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Contents

Foreword

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1 Scope

The present document specifies and establishes the characteristics of the physicals layer procedures in the FDD and TDD modes of E-UTRA.

2 References

The following documents contain provisions which, through reference in this text, constitute provisions of the present document.

- References are either specific (identified by date of publication, edition number, version number, etc.) or non-specific.
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- For a non-specific reference, the latest version applies. In the case of a reference to a 3GPP document (including a GSM document), a non-specific reference implicitly refers to the latest version of that document *in the same Release as the present document.*

[1] 3GPP TR 21.905: "Vocabulary for 3GPP Specifications".

[2] 3GPP TS 36.201: "Evolved Universal Terrestrial Radio Access (E-UTRA); Physical Layer – General Description".

[3] 3GPP TS 36.211: "Evolved Universal Terrestrial Radio Access (E-UTRA); Physical channels and modulation".

[4] 3GPP TS 36.212: "Evolved Universal Terrestrial Radio Access (E-UTRA); Multiplexing and channel coding".

[5] 3GPP TS 36.214: "Evolved Universal Terrestrial Radio Access (E-UTRA); Physical layer – Measurements".

[6] 3GPP TS 36.101: "Evolved Universal Terrestrial Radio Access (E-UTRA); User Equipment (UE) radio transmission and reception".

[7] 3GPP TS 36.104: "Evolved Universal Terrestrial Radio Access (E-UTRA); Base Station (BS) radio transmission and reception".

[8] 3GPP TS 36.321, "Evolved Universal Terrestrial Radio Access (E-UTRA); Medium Access Control (MAC) protocol specification".

[9] 3GPP TS 36.423, "Evolved Universal Terrestrial Radio Access (E-UTRA); X2 Application Protocol (X2AP)".

[10] 3GPP TS 36.133, "Evolved Universal Terrestrial Radio Access (E-UTRA); Requirements for support of radio resource management".

[11] 3GPP TS 36.331, "Evolved Universal Terrestrial Radio Access (E-UTRA); Radio Resource Control (RRC) protocol specification".

[12] 3GPP TS 36.306: "Evolved Universal Terrestrial Radio Access (E-UTRA); User Equipment (UE) radio access capabilities".

3 Symbols and abbreviations

3.1 Symbols

For the purposes of the present document, the following symbols apply:

n_f System frame number as defined in [3]

n_s	Slot number within a radio frame as defined in [3]
N_{cells}^{DL}	Number of configured cells
$N_{\mathrm{RB}}^{\mathrm{DL}}$	Downlink bandwidth configuration, expressed in units of $N_{\mathrm{sc}}^{\mathrm{RB}}$ as defined in [3]
$N_{\mathrm{RB}}^{\mathrm{UL}}$	Uplink bandwidth configuration, expressed in units of $N_{\mathrm{sc}}^{\mathrm{RB}}$ as defined in [3]
$N_{\mathrm{symb}}^{\mathrm{UL}}$	Number of SC-FDMA symbols in an uplink slot as defined in [3]
$N_{\mathrm{sc}}^{\mathrm{RB}}$	Resource block size in the frequency domain, expressed as a number of subcarriers as defined in [3]
T_s	Basic time unit as defined in [3]

3.2 Abbreviations

For the purposes of the present document, the abbreviations given in TR 21.905 [1] and the following apply.
An abbreviation defined in the present document takes precedence over the definition of the same abbreviation, if any, in TR 21.905 [1].

ACK	Acknowledgement
BCH	Broadcast Channel
CCE	Control Channel Element
CDD	Cyclic Delay Diversity
CG	Cell Group
CIF	Carrier Indicator Field
CQI	Channel Quality Indicator
CRC	Cyclic Redundancy Check
CRI	CSI-RS Resource Indicator
CSI	Channel State Information
CSI-IM	CSI-interference measurement
DAI	Downlink Assignment Index
DCI	Downlink Control Information
DL	Downlink
DL-SCH	Downlink Shared Channel
DTX	Discontinuous Transmission
EPDCCH	Enhanced Physical Downlink Control Channel
EPRE	Energy Per Resource Element
MCG	Master Cell Group
MCS	Modulation and Coding Scheme
NACK	Negative Acknowledgement
NPBCH	Narrowband Physical Broadcast CHannel
NPDCCH	Narrowband Physical Downlink Control CHannel
NPDSCH	Narrowband Physical Downlink Shared CHannel
NPRACH	Narrowband Physical Random Access CHannel
NPUSCH	Narrowband Physical Uplink Shared CHannel
NPSS	Narrowband Primary Synchronization Signal
NSSS	Narrowband Secondary Synchronization Signal
NRS	Narrowband Reference Signal
PBCH	Physical Broadcast Channel
PCFICH	Physical Control Format Indicator Channel
PDCCH	Physical Downlink Control Channel
PDSCH	Physical Downlink Shared Channel
PHICH	Physical Hybrid ARQ Indicator Channel
PMCH	Physical Multicast Channel
PMI	Precoding Matrix Indicator
PRACH	Physical Random Access Channel
PRS	Positioning Reference Signal
PRB	Physical Resource Block
PSBCH	Physical Sidelink Broadcast Channel
PSCCH	Physical Sidelink Control Channel
PSCell	Primary Secondary cell

PSDCH	Physical Sidelink Discovery Channel
PSSCH	Physical Sidelink Shared Channel
PSSS	Primary Sidelink Synchronisation Signal
PUCCH	Physical Uplink Control Channel
PUCCH-SCell	PUCCH SCell
PUSCH	Physical Uplink Shared Channel
PTI	Precoding Type Indicator
RBG	Resource Block Group
RE	Resource Element
RI	Rank Indication
RS	Reference Signal
SCG	Secondary Cell Group
SINR	Signal to Interference plus Noise Ratio
SPS C-RNTI	Semi-Persistent Scheduling C-RNTI
SR	Scheduling Request
SRS	Sounding Reference Symbol
SSSS	Secondary Sidelink Synchronisation Signal
TAG	Timing Advance Group
TBS	Transport Block Size
UCI	Uplink Control Information
UE	User Equipment
UL	Uplink
UL-SCH	Uplink Shared Channel
VRB	Virtual Resource Block

4 Synchronization procedures

4.1 Cell search

Cell search is the procedure by which a UE acquires time and frequency synchronization with a cell and detects the physical layer Cell ID of that cell. E-UTRA cell search supports a scalable overall transmission bandwidth corresponding to 6 resource blocks and upwards.

The following signals are transmitted in the downlink to facilitate cell search: the primary and secondary synchronization signals.

A UE may assume the antenna ports 0 – 3 and the antenna port for the primary/secondary synchronization signals of a serving cell are quasi co-located (as defined in [3]) with respect to Doppler shift and average delay.

4.2 Timing synchronization

4.2.1 Radio link monitoring

The downlink radio link quality of the primary cell shall be monitored by the UE for the purpose of indicating out-of-sync/in-sync status to higher layers.

If the UE is configured with a SCG [11] and the parameter *rlf-TimersAndConstantsSCG* is provided by the higher layers and is not set to release, the downlink radio link quality of the PSCell [11] of the SCG shall be monitored by the UE for the purpose of indicating out-of-sync/in-sync status to higher layers.

In non-DRX mode operation, the physical layer in the UE shall every radio frame assess the radio link quality, evaluated over the previous time period defined in [10], against thresholds (Q_{out} and Q_{in}) defined by relevant tests in [10].

In DRX mode operation, the physical layer in the UE shall at least once every DRX period assess the radio link quality, evaluated over the previous time period defined in [10], against thresholds (Q_{out} and Q_{in}) defined by relevant tests in [10].

If higher-layer signalling indicates certain subframes for restricted radio link monitoring, the radio link quality shall not be monitored in any subframe other than those indicated.

The physical layer in the UE shall in radio frames where the radio link quality is assessed indicate out-of-sync to higher layers when the radio link quality is worse than the threshold Q_{out}. When the radio link quality is better than the threshold Q_{in}, the physical layer in the UE shall in radio frames where the radio link quality is assessed indicate in-sync to higher layers.

4.2.2 Inter-cell synchronization

No functionality is specified in this subclause in this release.

4.2.3 Transmission timing adjustments

Upon reception of a timing advance command for a TAG containing the primary cell or PSCell, the UE shall adjust uplink transmission timing for PUCCH/PUSCH/SRS of the primary cell or PSCell based on the received timing advance command.

The UL transmission timing for PUSCH/SRS of a secondary cell is the same as the primary cell if the secondary cell and the primary cell belong to the same TAG. If the primary cell in a TAG has a frame structure type 1 and a secondary cell in the same TAG has a frame structure type 2, UE may assume that $N_{TA} \geq 624$.

If the UE is configured with a SCG, the UL transmission timing for PUSCH/SRS of a secondary cell other than the PSCell is the same as the PScell if the secondary cell and the PSCell belong to the same TAG.

Upon reception of a timing advance command for a TAG not containing the primary cell or PSCell, if all the serving cells in the TAG have the same frame structure type, the UE shall adjust uplink transmission timing for PUSCH/SRS of all the secondary cells in the TAG based on the received timing advance command where the UL transmission timing for PUSCH /SRS is the same for all the secondary cells in the TAG.

Upon reception of a timing advance command for a TAG not containing the primary cell or PSCell, if a serving cell in the TAG has a different frame structure type compared to the frame structure type of another serving cell in the same TAG, the UE shall adjust uplink transmission timing for PUSCH/SRS of all the secondary cells in the TAG by using $N_{TAoffset}$ = 624 regardless of the frame structure type of the serving cells and based on the received timing advance command where the UL transmission timing for PUSCH /SRS is the same for all the secondary cells in the TAG. $N_{TAoffset}$ is described in [3].

The timing advance command for a TAG indicates the change of the uplink timing relative to the current uplink timing for the TAG as multiples of $16\,T_s$. The start timing of the random access preamble is specified in [3].

In case of random access response, an 11-bit timing advance command [8], T_A, for a TAG indicates N_{TA} values by index values of T_A = 0, 1, 2, ..., 256 if the UE is configured with a SCG, and T_A = 0, 1, 2, ..., 1282 otherwise, where an amount of the time alignment for the TAG is given by $N_{TA} = T_A \times 16$. N_{TA} is defined in [3].

In other cases, a 6-bit timing advance command [8], T_A, for a TAG indicates adjustment of the current N_{TA} value, $N_{TA,old}$, to the new N_{TA} value, $N_{TA,new}$, by index values of T_A = 0, 1, 2,..., 63, where $N_{TA,new} = N_{TA,old} + (T_A - 31)\times 16$. Here, adjustment of N_{TA} value by a positive or a negative amount indicates advancing or delaying the uplink transmission timing for the TAG by a given amount respectively.

For a timing advance command received on subframe *n*, the corresponding adjustment of the uplink transmission timing shall apply from the beginning of subframe *n+6*. For serving cells in the same TAG, when the UE's uplink PUCCH/PUSCH/SRS transmissions in subframe *n* and subframe *n*+1 are overlapped due to the timing adjustment, the UE shall complete transmission of subframe *n* and not transmit the overlapped part of subframe *n*+1.

If the received downlink timing changes and is not compensated or is only partly compensated by the uplink timing adjustment without timing advance command as specified in [10], the UE changes N_{TA} accordingly.

4.3 Timing for Secondary Cell Activation / Deactivation

When a UE receives an activation command [8] for a secondary cell in subframe *n*, the corresponding actions in [8] shall be applied no later than the minimum requirement defined in [10] and no earlier than subframe n+8, except for the following:

- the actions related to CSI reporting on a serving cell which is active in subframe n+8
- the actions related to the *sCellDeactivationTimer* associated with the secondary cell [8]

which shall be applied in subframe *n+8*.

- the actions related to CSI reporting on a serving cell which is not active in subframe n+8

which shall be applied in the earliest subframe after n+8 in which the serving cell is active.

When a UE receives a deactivation command [8] for a secondary cell or the *sCellDeactivationTimer* associated with the secondary cell expires in subframe *n*, the corresponding actions in [8] shall apply no later than the minimum requirement defined in [10], except for the actions related to CSI reporting on a serving cell which is active which shall be applied in subframe *n+8*.

5 Power control

Downlink power control determines the Energy Per Resource Element (EPRE). The term resource element energy denotes the energy prior to CP insertion. The term resource element energy also denotes the average energy taken over all constellation points for the modulation scheme applied. Uplink power control determines the average power over a SC-FDMA symbol in which the physical channel is transmitted.

5.1 Uplink power control

Uplink power control controls the transmit power of the different uplink physical channels.

For PUSCH, the transmit power $\hat{P}_{\text{PUSCH},c}(i)$ defined in subclause 5.1.1, is first scaled by the ratio of the number of antennas ports with a non-zero PUSCH transmission to the number of configured antenna ports for the transmission scheme. The resulting scaled power is then split equally across the antenna ports on which the non-zero PUSCH is transmitted.

For PUCCH or SRS, the transmit power $\hat{P}_{\text{PUCCH}}(i)$, defined in subclause 5.1.1.1, or $\hat{P}_{\text{SRS,c}}(i)$ is split equally across the configured antenna ports for PUCCH or SRS. $\hat{P}_{\text{SRS,c}}(i)$ is the linear value of $P_{\text{SRS,c}}(i)$ defined in subclause 5.1.3.

A cell wide overload indicator (OI) and a High Interference Indicator (HII) to control UL interference are defined in [9].

For a serving cell with frame structure type 1, a UE is not expected to be configured with *UplinkPowerControlDedicated-v12x0*.

5.1.1 Physical uplink shared channel

If the UE is configured with a SCG, the UE shall apply the procedures described in this clause for both MCG and SCG

- When the procedures are applied for MCG, the terms 'secondary cell', 'secondary cells' , 'serving cell', 'serving cells' in this clause refer to secondary cell, secondary cells, serving cell, serving cells belonging to the MCG respectively.

- When the procedures are applied for SCG, the terms 'secondary cell', 'secondary cells', 'serving cell', 'serving cells' in this clause refer to secondary cell, secondary cells (not including PSCell), serving cell, serving cells belonging to the SCG respectively. The term 'primary cell' in this clause refers to the PSCell of the SCG.

If the UE is configured with a PUCCH-SCell, the UE shall apply the procedures described in this clause for both primary PUCCH group and secondary PUCCH group

- When the procedures are applied for primary PUCCH group, the terms 'secondary cell', 'secondary cells' , 'serving cell', 'serving cells' in this clause refer to secondary cell, secondary cells, serving cell, serving cells belonging to the primary PUCCH group respectively.

- When the procedures are applied for secondary PUCCH group, the terms 'secondary cell', 'secondary cells', 'serving cell', 'serving cells' in this clause refer to secondary cell, secondary cells, serving cell, serving cells belonging to the secondary PUCCH group respectively.

5.1.1.1 UE behaviour

The setting of the UE Transmit power for a Physical Uplink Shared Channel (PUSCH) transmission is defined as follows.

If the UE transmits PUSCH without a simultaneous PUCCH for the serving cell c, then the UE transmit power $P_{\text{PUSCH},c}(i)$ for PUSCH transmission in subframe i for the serving cell c is given by

$$P_{\text{PUSCH,c}}(i) = \min\begin{Bmatrix} P_{\text{CMAX},c}(i), \\ 10\log_{10}(M_{\text{PUSCH,c}}(i)) + P_{\text{O\_PUSCH,c}}(j) + \alpha_c(j)\cdot PL_c + \Delta_{\text{TF,c}}(i) + f_c(i) \end{Bmatrix} \quad \text{[dBm]}$$

If the UE transmits PUSCH simultaneous with PUCCH for the serving cell c, then the UE transmit power $P_{\mathrm{PUSCH},c}(i)$ for the PUSCH transmission in subframe *i* for the serving cell c is given by

$$P_{\mathrm{PUSCH,c}}(i) = \min\begin{Bmatrix} 10\log_{10}\left(\hat{P}_{\mathrm{CMAX},c}(i) - \hat{P}_{\mathrm{PUCCH}}(i)\right), \\ 10\log_{10}(M_{\mathrm{PUSCH,c}}(i)) + P_{\mathrm{O\_PUSCH,c}}(j) + \alpha_c(j)\cdot PL_c + \Delta_{\mathrm{TF,c}}(i) + f_c(i) \end{Bmatrix} \quad [\mathrm{dBm}]$$

If the UE is not transmitting PUSCH for the serving cell c, for the accumulation of TPC command received with DCI format 3/3A for PUSCH, the UE shall assume that the UE transmit power $P_{\mathrm{PUSCH},c}(i)$ for the PUSCH transmission in subframe *i* for the serving cell c is computed by

$$P_{\mathrm{PUSCH,c}}(i) = \min\left\{P_{\mathrm{CMAX,c}}(i), P_{\mathrm{O\_PUSCH,c}}(1) + \alpha_c(1)\cdot PL_c + f_c(i)\right\} \quad [\mathrm{dBm}]$$

where,

- $P_{\mathrm{CMAX,c}}(i)$ is the configured UE transmit power defined in [6] in subframe *i* for serving cell c and $\hat{P}_{\mathrm{CMAX,c}}(i)$ is the linear value of $P_{\mathrm{CMAX,c}}(i)$. If the UE transmits PUCCH without PUSCH in subframe i for the serving cell c, for the accumulation of TPC command received with DCI format 3/3A for PUSCH, the UE shall assume $P_{\mathrm{CMAX,c}}(i)$ as given by subclause 5.1.2.1. If the UE does not transmit PUCCH and PUSCH in subframe i for the serving cell c, for the accumulation of TPC command received with DCI format 3/3A for PUSCH, the UE shall compute $P_{\mathrm{CMAX,c}}(i)$ assuming MPR=0dB, A-MPR=0dB, P-MPR=0dB and ΔT_C =0dB, where MPR, A-MPR, P-MPR and ΔT_C are defined in [6].

- $\hat{P}_{\mathrm{PUCCH}}(i)$ is the linear value of $P_{\mathrm{PUCCH}}(i)$ defined in subclause 5.1.2.1

- $M_{\mathrm{PUSCH,c}}(i)$ is the bandwidth of the PUSCH resource assignment expressed in number of resource blocks valid for subframe *i* and serving cell c.

- If the UE is configured with higher layer parameter *UplinkPowerControlDedicated-v12x0* for serving cell c and if subframe i belongs to uplink power control subframe set 2 as indicated by the higher layer parameter *tpc-SubframeSet-r12*,

  - when j=0, $P_{\mathrm{O\_PUSCH,c}}(0) = P_{\mathrm{O\_UE\_PUSCH,c,2}}(0) + P_{\mathrm{O\_NOMINAL\_PUSCH,c,2}}(0)$, where j=0 is used for PUSCH (re)transmissions corresponding to a semi-persistent grant. $P_{\mathrm{O\_UE\_PUSCH,c,2}}(0)$ and $P_{\mathrm{O\_NOMINAL\_PUSCH,c,2}}(0)$ are the parameters *p0-UE-PUSCH-Persistent-SubframeSet2-r12 and p0-NominalPUSCH-Persistent -SubframeSet2-r12* respectively provided by higher layers, for each serving cell c.

  - when j=1, $P_{\mathrm{O\_PUSCH,c}}(1) = P_{\mathrm{O\_UE\_PUSCH,c,2}}(1) + P_{\mathrm{O\_NOMINAL\_PUSCH,c,2}}(1)$, where j=1 is used for PUSCH (re)transmissions corresponding to a dynamic scheduled grant. $P_{\mathrm{O\_UE\_PUSCH,c,2}}(1)$ and $P_{\mathrm{O\_NOMINAL\_PUSCH,c,2}}(1)$ are the parameters *p0-UE-PUSCH-SubframeSet2-r12 and p0-NominalPUSCH-SubframeSet2-r12* respectively, provided by higher layers for serving cell c.

  - when j=2, $P_{\mathrm{O\_PUSCH,c}}(2) = P_{\mathrm{O\_UE\_PUSCH,c}}(2) + P_{\mathrm{O\_NOMINAL\_PUSCH,c}}(2)$ where $P_{\mathrm{O\_UE\_PUSCH,c}}(2) = 0$ and $P_{\mathrm{O\_NOMINAL\_PUSCH,c}}(2) = P_{\mathrm{O\_PRE}} + \Delta_{PREAMBLE\_Msg3}$, where the parameter *preambleInitialReceivedTargetPower* [8] ($P_{\mathrm{O\_PRE}}$) and $\Delta_{PREAMBLE\_Msg3}$ are signalled from higher layers for serving cell c, where j=2 is used for PUSCH (re)transmissions corresponding to the random access response grant.

  Otherwise

  - $P_{\mathrm{O\_PUSCH,c}}(j)$ is a parameter composed of the sum of a component $P_{\mathrm{O\_NOMINAL\_PUSCH,c}}(j)$ provided from higher layers for *j=0* and *1* and a component $P_{\mathrm{O\_UE\_PUSCH,c}}(j)$ provided by higher layers for *j=0* and *1* for serving cell c. For PUSCH (re)transmissions corresponding to a semi-persistent grant then *j=0* , for

PUSCH (re)transmissions corresponding to a dynamic scheduled grant then *j=1* and for PUSCH (re)transmissions corresponding to the random access response grant then *j=2*. $P_{\text{O\_UE\_PUSCH,c}}(2) = 0$ and $P_{\text{O\_NOMINAL\_PUSCH,c}}(2) = P_{\text{O\_PRE}} + \Delta_{PREAMBLE\_Msg3}$, where the parameter *preambleInitialReceivedTargetPower* [8] ($P_{\text{O\_PRE}}$) and $\Delta_{PREAMBLE\_Msg3}$ are signalled from higher layers for serving cell c.

- If the UE is configured with higher layer parameter *UplinkPowerControlDedicated-v12x0* for serving cell c and if subframe i belongs to uplink power control subframe set 2 as indicated by the higher layer parameter *tpc-SubframeSet-r12*,
  - For *j*=0 or 1, $\alpha_c(j) = \alpha_{c,2} \in \{0, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9, 1\}$. $\alpha_{c,2}$ is the parameter *alpha-SubframeSet2-r12* provided by higher layers for each serving cell c.
  - For *j*=2, $\alpha_c(j) = 1$.

  Otherwise

  - For *j* =0 or *1*, $\alpha_c \in \{0, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9, 1\}$ is a 3-bit parameter provided by higher layers for serving cell c. For *j*=2, $\alpha_c(j) = 1$.

- PL_c is the downlink path loss estimate calculated in the UE for serving cell c in dB and PL_c = *referenceSignalPower* – higher layer filtered RSRP, where *referenceSignalPower* is provided by higher layers and RSRP is defined in [5] for the reference serving cell and the higher layer filter configuration is defined in [11] for the reference serving cell.
  - If serving cell c belongs to a TAG containing the primary cell then, for the uplink of the primary cell, the primary cell is used as the reference serving cell for determining *referenceSignalPower* and higher layer filtered RSRP. For the uplink of the secondary cell, the serving cell configured by the higher layer parameter *pathlossReferenceLinking* defined in [11] is used as the reference serving cell for determining *referenceSignalPower* and higher layer filtered RSRP.
  - If serving cell c belongs to a TAG containing the PSCell then, for the uplink of the PSCell, the PSCell is used as the reference serving cell for determining *referenceSignalPower* and higher layer filtered RSRP; for the uplink of the secondary cell other than PSCell, the serving cell configured by the higher layer parameter *pathlossReferenceLinking* defined in [11] is used as the reference serving cell for determining *referenceSignalPower* and higher layer filtered RSRP.
  - If serving cell c belongs to a TAG not containing the primary cell or PSCell then serving cell c is used as the reference serving cell for determining *referenceSignalPower* and higher layer filtered RSRP.

- $\Delta_{TF,c}(i) = 10\log_{10}\left(\left(2^{BPRE \cdot K_s} - 1\right) \cdot \beta_{offset}^{PUSCH}\right)$ for $K_S = 1.25$ and 0 for $K_S = 0$ where K_S is given by the parameter *deltaMCS-Enabled* provided by higher layers for each serving cell c. $BPRE$ and β_{offset}^{PUSCH}, for each serving cell c, are computed as below. $K_S = 0$ for transmission mode 2.
  - $BPRE = O_{\text{CQI}} / N_{\text{RE}}$ for control data sent via PUSCH without UL-SCH data and $\sum_{r=0}^{C-1} K_r / N_{\text{RE}}$ for other cases.
    - where C is the number of code blocks, K_r is the size for code block r, O_{CQI} is the number of CQI/PMI bits including CRC bits and N_{RE} is the number of resource elements determined as $N_{\text{RE}} = M_{sc}^{PUSCH-initial} \cdot N_{\text{symb}}^{\text{PUSCH-initial}}$, where C, K_r, $M_{sc}^{PUSCH-initial}$ and $N_{\text{symb}}^{\text{PUSCH-initial}}$ are defined in [4].
  - $\beta_{offset}^{PUSCH} = \beta_{offset}^{CQI}$ for control data sent via PUSCH without UL-SCH data and 1 for other cases.

- $\delta_{\mathrm{PUSCH,c}}$ is a correction value, also referred to as a TPC command and is included in PDCCH/EPDCCH with DCI format 0/4 or in MPDCCH with DCI format 6-0A for serving cell c or jointly coded with other TPC commands in PDCCH/MPDCCH with DCI format 3/3A whose CRC parity bits are scrambled with TPC-PUSCH-RNTI. If the UE is configured with higher layer parameter *UplinkPowerControlDedicated-v12x0* for serving cell c and if subframe i belongs to uplink power control subframe set 2 as indicated by the higher layer parameter *tpc-SubframeSet-r12,* the current PUSCH power control adjustment state for serving cell c is given by $f_{c,2}(i)$, and the UE shall use $f_{c,2}(i)$ instead of $f_c(i)$ to determine $P_{\mathrm{PUSCH},c}(i)$. Otherwise, the current PUSCH power control adjustment state for serving cell c is given by $f_c(i)$. $f_{c,2}(i)$ and $f_c(i)$ are defined by:
  - $f_c(i) = f_c(i-1) + \delta_{\mathrm{PUSCH,c}}(i - K_{\mathrm{PUSCH}})$ and $f_{c,2}(i) = f_{c,2}(i-1) + \delta_{\mathrm{PUSCH,c}}(i - K_{\mathrm{PUSCH}})$ if accumulation is enabled based on the parameter *Accumulation-enabled* provided by higher layers or if the TPC command $\delta_{\mathrm{PUSCH,c}}$ is included in a PDCCH/EPDCCH with DCI format 0 or in a MPDCCH with DCI format 6-0A for serving cell c where the CRC is scrambled by the Temporary C-RNTI
    - where $\delta_{\mathrm{PUSCH,c}}(i - K_{\mathrm{PUSCH}})$ was signalled on PDCCH/EPDCCH with DCI format 0/4 or MPDCCH with DCI format 6-0A or PDCCH/MPDCCH with DCI format 3/3A on subframe $i - K_{PUSCH}$, and where $f_c(0)$ is the first value after reset of accumulation. For a BL/CE UE configured with CEModeA, subframe $i - K_{PUSCH}$ is the last subframe in which the MPDCCH with DCI format 6-0A or MPDCCH with DCI format 3/3A is transmitted.
    - The value of K_{PUSCH} is
      - For FDD or FDD-TDD and serving cell frame structure type 1, K_{PUSCH} = 4
      - For TDD, if the UE is configured with more than one serving cell and the TDD UL/DL configuration of at least two configured serving cells is not the same, or if the UE is configured with the parameter *EIMTA-MainConfigServCell-r12* for at least one serving cell, or for FDD-TDD and serving cell frame structure type 2, the "TDD UL/DL configuration" refers to the UL-reference UL/DL configuration (defined in subclause 8.0) for serving cell c.
      - For TDD UL/DL configurations 1-6, K_{PUSCH} is given in Table 5.1.1.1-1
      - For TDD UL/DL configuration 0
        - If the PUSCH transmission in subframe *2* or *7* is scheduled with a PDCCH/EPDCCH of DCI format 0/4 or a MPDCCH of DCI format 6-0A in which the LSB of the UL index is set to 1, K_{PUSCH} = 7
        - For all other PUSCH transmissions, K_{PUSCH} is given in Table 5.1.1.1-1.
    - For serving cell c and a non-BL/CE UE, the UE attempts to decode a PDCCH/EPDCCH of DCI format 0/4 with the UE's C-RNTI or DCI format 0 for SPS C-RNTI and a PDCCH of DCI format 3/3A with this UE's TPC-PUSCH-RNTI in every subframe except when in DRX or where serving cell c is deactivated.
    - For serving cell c and a BL/CE UE configured with CEModeA, the UE attempts to decode a MPDCCH of DCI format 6-0A with the UE's C-RNTI or SPS C-RNTI and a MPDCCH of DCI format 3/3A with this UE's TPC-PUSCH-RNTI in every BL/CE downlink subframe except when in DRX
    - For a non-BL/CE UE, if DCI format 0/4 for serving cell c and DCI format 3/3A are both detected in the same subframe, then the UE shall use the $\delta_{\mathrm{PUSCH,c}}$ provided in DCI format 0/4.
    - For a BL/CE UE configured with CEModeA, if DCI format 6-0A for serving cell c and DCI format 3/3A are both detected in the same subframe, then the UE shall use the $\delta_{\mathrm{PUSCH,c}}$ provided in DCI format 6-0A.

- $\delta_{\mathrm{PUSCH,c}} = 0$ dB for a subframe where no TPC command is decoded for serving cell c or where DRX occurs or *i* is not an uplink subframe in TDD or FDD-TDD and serving cell c frame structure type 2.
- The $\delta_{\mathrm{PUSCH,c}}$ dB accumulated values signalled on PDCCH/EPDCCH with DCI format 0/4 or MPDCCH with DCI format 6-0A are given in Table 5.1.1.1-2. If the PDCCH/EPDCCH with DCI format 0 or MPDCCH with DCI format 6-0A is validated as a SPS activation or release PDCCH/EPDCCH/MPDCCH, then $\delta_{\mathrm{PUSCH,c}}$ is 0dB.
- The δ_{PUSCH} dB accumulated values signalled on PDCCH/MPDCCH with DCI format 3/3A are one of SET1 given in Table 5.1.1.1-2 or SET2 given in Table 5.1.1.1-3 as determined by the parameter *TPC-Index* provided by higher layers.
- If UE has reached $P_{\mathrm{CMAX,c}}(i)$ for serving cell c, positive TPC commands for serving cell c shall not be accumulated
- If UE has reached minimum power, negative TPC commands shall not be accumulated
- If the UE is not configured with higher layer parameter *UplinkPowerControlDedicated-v12x0* for serving cell c, the UE shall reset accumulation
  - For serving cell c, when $P_{\mathrm{O\_UE\_PUSCH,c}}$ value is changed by higher layers
  - For serving cell c, when the UE receives random access response message for serving cell c
- If the UE is configured with higher layer parameter *UplinkPowerControlDedicated-v12x0* for serving cell c,
  - the UE shall reset accumulation corresponding to $f_c(*)$ for serving cell c
    - when $P_{\mathrm{O\_UE\_PUSCH,c}}$ value is changed by higher layers
    - when the UE receives random access response message for serving cell c
  - the UE shall reset accumulation corresponding to $f_{c,2}(*)$ for serving cell c
    - when $P_{\mathrm{O\_UE\_PUSCH,c,2}}$ value is changed by higher layers
- If the UE is configured with higher layer parameter *UplinkPowerControlDedicated-v12x0* for serving cell c and
  - if subframe i belongs to uplink power control subframe set 2 as indicated by the higher layer parameter *tpc-SubframeSet-r12* $f_c(i) = f_c(i-1)$
  - if subframe i does not belong to uplink power control subframe set 2 as indicated by the higher layer parameter *tpc-SubframeSet-r12* $f_{c,2}(i) = f_{c,2}(i-1)$

- $f_c(i) = \delta_{\mathrm{PUSCH,c}}(i - K_{\mathrm{PUSCH}})$ and $f_{c,2}(i) = \delta_{\mathrm{PUSCH,c}}(i - K_{\mathrm{PUSCH}})$ if accumulation is not enabled for serving cell c based on the parameter *Accumulation-enabled* provided by higher layers
  - where $\delta_{\mathrm{PUSCH,c}}(i - K_{\mathrm{PUSCH}})$ was signalled on PDCCH/EPDCCH with DCI format 0/4 or MPDCCH with DCI format 6-0A for serving cell c on subframe $i - K_{PUSCH}$. For a BL/CE UE configured with CEModeA, subframe $i - K_{PUSCH}$ is the last subframe in which the MPDCCH with DCI format 6-0A or MPDCCH with DCI format 3/3A is transmitted.
  - The value of K_{PUSCH} is
    - For FDD or FDD-TDD and serving cell frame structure type 1, $K_{PUSCH} = 4$

- For TDD, if the UE is configured with more than one serving cell and the TDD UL/DL configuration of at least two configured serving cells is not the same, or if the UE is configured with the parameter *EIMTA-MainConfigServCell-r12* for at least one serving cell, or FDD-TDD and serving cell frame structure type 2, the "TDD UL/DL configuration" refers to the UL-reference UL/DL configuration (defined in subclause 8.0) for serving cell c.

- For TDD UL/DL configurations 1-6, K_{PUSCH} is given in Table 5.1.1.1-1.

- For TDD UL/DL configuration 0

  - If the PUSCH transmission in subframe *2* or *7* is scheduled with a PDCCH/EPDCCH of DCI format 0/4 or a MPDCCH with DCI format 6-0A in which the LSB of the UL index is set to 1, $K_{PUSCH} = 7$

  - For all other PUSCH transmissions, K_{PUSCH} is given in Table 5.1.1.1-1.

- The $\delta_{\mathrm{PUSCH,c}}$ dB absolute values signalled on PDCCH/EPDCCH with DCI format 0/4 or a MPDCCH with DCI format 6-0A are given in Table 5.1.1.1-2. If the PDCCH/EPDCCH with DCI format 0 or a MPDCCH with DCI format 6-0A is validated as a SPS activation or release PDCCH/EPDCCH/MPDCCH, then $\delta_{\mathrm{PUSCH,c}}$ is 0dB.

- for a non-BL/CE UE, $f_c(i) = f_c(i-1)$ and $f_{c,2}(i) = f_{c,2}(i-1)$ for a subframe where no PDCCH/EPDCCH with DCI format 0/4 is decoded for serving cell c or where DRX occurs or *i* is not an uplink subframe in TDD or FDD-TDD and serving cell c frame structure type 2.

- for a BL/CE UE configured with CEModeA, $f_c(i) = f_c(i-1)$ and $f_{c,2}(i) = f_{c,2}(i-1)$ for a subframe where no MPDCCH with DCI format 6-0A is decoded for serving cell c or where DRX occurs or *i* is not an uplink subframe in TDD.

- If the UE is configured with higher layer parameter *UplinkPowerControlDedicated-v12x0* for serving cell c and

  - if subframe i belongs to uplink power control subframe set 2 as indicated by the higher layer parameter *tpc-SubframeSet-r12* $f_c(i) = f_c(i-1)$

  - if subframe i does not belong to uplink power control subframe set 2 as indicated by the higher layer parameter *tpc-SubframeSet-r12* $f_{c,2}(i) = f_{c,2}(i-1)$

- For both types of $f_c(*)$ (accumulation or current absolute) the first value is set as follows:

  - If $P_{\mathrm{O\_UE\_PUSCH,c}}$ value is changed by higher layers and serving cell c is the primary cell or, if $P_{\mathrm{O\_UE\_PUSCH,c}}$ value is received by higher layers and serving cell c is a Secondary cell

    - $f_c(0) = 0$

  - Else

    - If the UE receives the random access response message for a serving cell c

      - $f_c(0) = \Delta P_{rampup,c} + \delta_{msg2,c}$, where

        - $\delta_{msg2,c}$ is the TPC command indicated in the random access response corresponding to the random access preamble transmitted in the serving cell c, see subclause 6.2, and

$$\Delta P_{rampup,c} = \min\left[\left\{\max\left(0, P_{CMAX,c} - \begin{pmatrix} 10\log_{10}(M_{PUSCH,c}(0)) \\ + P_{O\_PUSCH,c}(2) + \delta_{msg2} \\ + \alpha_c(2)\cdot PL + \Delta_{TF,c}(0) \end{pmatrix}\right)\right\}, \Delta P_{rampuprequested,c}\right]$$

and $\Delta P_{rampuprequested,c}$ is provided by higher layers and corresponds to the total power ramp-up requested by higher layers from the first to the last preamble in the serving cell c, $M_{\mathrm{PUSCH,c}}(0)$ is the bandwidth of the PUSCH resource assignment expressed in number of resource blocks valid for the subframe of first PUSCH transmission in the serving cell c, and $\Delta_{TF,c}(0)$ is the power adjustment of first PUSCH transmission in the serving cell *c*.

- If $P_{\mathrm{O\_UE\_PUSCH,c,2}}$ value is received by higher layers for a serving cell *c*.
  - $f_{c,2}(0) = 0$

Table 5.1.1.1-1: K_{PUSCH} for TDD configuration 0-6

TDD UL/DL Configuration	subframe number *i*									
	0	1	2	3	4	5	6	7	8	9
0	-	-	6	7	4	-	-	6	7	4
1	-	-	6	4	-	-	-	6	4	-
2	-	-	4	-	-	-	-	4	-	-
3	-	-	4	4	4	-	-	-	-	-
4	-	-	4	4	-	-	-	-	-	-
5	-	-	4	-	-	-	-	-	-	-
6	-	-	7	7	5	-	-	7	7	-

Table 5.1.1.1-2: Mapping of TPC Command Field in DCI format 0/3/4/6-0A to absolute and accumulated $\delta_{\mathrm{PUSCH,c}}$ values

TPC Command Field in DCI format 0/3/4/6-0A	Accumulated $\delta_{\mathrm{PUSCH,c}}$ [dB]	Absolute $\delta_{\mathrm{PUSCH,c}}$ [dB] only DCI format 0/4/6-0A
0	-1	-4
1	0	-1
2	1	1
3	3	4

Table 5.1.1.1-3: Mapping of TPC Command Field in DCI format 3A to accumulated $\delta_{\mathrm{PUSCH,c}}$ values

TPC Command Field in DCI format 3A	Accumulated $\delta_{\mathrm{PUSCH,c}}$ [dB]
0	-1
1	1

If the UE is not configured with an SCG or a PUCCH-SCell, and if the total transmit power of the UE would exceed $\hat{P}_{CMAX}(i)$, the UE scales $\hat{P}_{\mathrm{PUSCH},c}(i)$ for the serving cell c in subframe *i* such that the condition

$$\sum_c w(i)\cdot \hat{P}_{\mathrm{PUSCH},c}(i) \le \left(\hat{P}_{\mathrm{CMAX}}(i) - \hat{P}_{\mathrm{PUCCH}}(i)\right)$$

is satisfied where $\hat{P}_{\text{PUCCH}}(i)$ is the linear value of $P_{\text{PUCCH}}(i)$, $\hat{P}_{\text{PUSCH},c}(i)$ is the linear value of $P_{\text{PUSCH},c}(i)$, $\hat{P}_{CMAX}(i)$ is the linear value of the UE total configured maximum output power P_{CMAX} defined in [6] in subframe *i* and $w(i)$ is a scaling factor of $\hat{P}_{\text{PUSCH},c}(i)$ for serving cell c where $0 \le w(i) \le 1$. In case there is no PUCCH transmission in subframe *i* $\hat{P}_{\text{PUCCH}}(i) = 0$.

If the UE is not configured with an SCG or a PUCCH-Scell, and if the UE has PUSCH transmission with UCI on serving cell *j* and PUSCH without UCI in any of the remaining serving cells, and the total transmit power of the UE would exceed $\hat{P}_{CMAX}(i)$, the UE scales $\hat{P}_{\text{PUSCH},c}(i)$ for the serving cells without UCI in subframe *i* such that the condition

$$\sum_{c \neq j} w(i) \cdot \hat{P}_{\text{PUSCH},c}(i) \le \left(\hat{P}_{\text{CMAX}}(i) - \hat{P}_{\text{PUSCH},j}(i)\right)$$

is satisfied where $\hat{P}_{\text{PUSCH},j}(i)$ is the PUSCH transmit power for the cell with UCI and $w(i)$ is a scaling factor of $\hat{P}_{\text{PUSCH},c}(i)$ for serving cell c without UCI. In this case, no power scaling is applied to $\hat{P}_{\text{PUSCH},j}(i)$ unless $\sum_{c \neq j} w(i) \cdot \hat{P}_{\text{PUSCH},c}(i) = 0$ and the total transmit power of the UE still would exceed $\hat{P}_{CMAX}(i)$.

For a UE not configured with a SCG or a PUCCH-SCell, note that $w(i)$ values are the same across serving cells when $w(i) > 0$ but for certain serving cells $w(i)$ may be zero.

If the UE is not configured with an SCG or a PUCCH-SCell, and if the UE has simultaneous PUCCH and PUSCH transmission with UCI on serving cell j and PUSCH transmission without UCI in any of the remaining serving cells, and the total transmit power of the UE would exceed $\hat{P}_{CMAX}(i)$, the UE obtains $\hat{P}_{\text{PUSCH},c}(i)$ according to

$$\hat{P}_{\text{PUSCH},j}(i) = \min\left(\hat{P}_{\text{PUSCH},j}(i), \left(\hat{P}_{\text{CMAX}}(i) - \hat{P}_{\text{PUCCH}}(i)\right)\right)$$

and

$$\sum_{c \neq j} w(i) \cdot \hat{P}_{\text{PUSCH},c}(i) \le \left(\hat{P}_{\text{CMAX}}(i) - \hat{P}_{\text{PUCCH}}(i) - \hat{P}_{\text{PUSCH},j}(i)\right)$$

If the UE is not configured with a SCG or a PUCCH-SCell, and

- If the UE is configured with multiple TAGs, and if the PUCCH/PUSCH transmission of the UE on subframe i for a given serving cell in a TAG overlaps some portion of the first symbol of the PUSCH transmission on subframe $i+1$ for a different serving cell in another TAG the UE shall adjust its total transmission power to not exceed P_{CMAX} on any overlapped portion.

- If the UE is configured with multiple TAGs, and if the PUSCH transmission of the UE on subframe i for a given serving cell in a TAG overlaps some portion of the first symbol of the PUCCH transmission on subframe $i+1$ for a different serving cell in another TAG the UE shall adjust its total transmission power to not exceed P_{CMAX} on any overlapped portion.

- If the UE is configured with multiple TAGs, and if the SRS transmission of the UE in a symbol on subframe i for a given serving cell in a TAG overlaps with the PUCCH/PUSCH transmission on subframe i or subframe $i+1$ for a different serving cell in the same or another TAG the UE shall drop SRS if its total transmission power exceeds P_{CMAX} on any overlapped portion of the symbol.

- If the UE is configured with multiple TAGs and more than 2 serving cells, and if the SRS transmission of the UE in a symbol on subframe i for a given serving cell overlaps with the SRS transmission on subframe i for a different serving cell(s) and with PUSCH/PUCCH transmission on subframe i or subframe $i+1$ for another serving cell(s) the UE shall drop the SRS transmissions if the total transmission power exceeds P_{CMAX} on any overlapped portion of the symbol.

- If the UE is configured with multiple TAGs, the UE shall, when requested by higher layers, to transmit PRACH in a secondary serving cell in parallel with SRS transmission in a symbol on a subframe of a different serving cell belonging to a different TAG, drop SRS if the total transmission power exceeds P_{CMAX} on any overlapped portion in the symbol.
- If the UE is configured with multiple TAGs, the UE shall, when requested by higher layers, to transmit PRACH in a secondary serving cell in parallel with PUSCH/PUCCH in a different serving cell belonging to a different TAG, adjust the transmission power of PUSCH/PUCCH so that its total transmission power does not exceed P_{CMAX} on the overlapped portion.

For a BL/CE UE configured with CEModeA, if the PUSCH is transmitted in more than one subframe i_0, i_1, …, i_{N-1} where $i_0 < i_1 < \ldots < i_{N-1}$, the PUSCH transmit power in subframe i_k , k=0, 1, …, N-1, is determined by

$$P_{\mathrm{PUSCH},c}(i_k) = P_{\mathrm{PUSCH},c}(i_0)$$

For a BL/CE UE configured with CEModeB, the PUSCH transmit power in subframe i_k is determined by

$$P_{\mathrm{PUSCH},c}(i_k) = P_{\mathrm{CMAX},c}(i_0)$$

5.1.1.2 Power headroom

There are two types of UE power headroom reports defined. A UE power headroom PH is valid for subframe i for serving cell c .

If the UE is configured with a SCG, and if the higher layer parameter *phr-ModeOtherCG-r12* for a CG indicates 'virtual', for power headroom reports transmitted on that CG, the UE shall compute PH assuming that it does not transmit PUSCH/PUCCH on any serving cell of the other CG.

If the UE is configured with a SCG,

- For computing power headroom for cells belonging to MCG, the term 'serving cell' in this subclause refers to serving cell belonging to the MCG.
- For computing power headroom for cells belonging to SCG, the term 'serving cell' in this subclause refers to serving cell belonging to the SCG. The term 'primary cell' in this subclause refers to the PSCell of the SCG.

If the UE is configured with a PUCCH-SCell,

- For computing power headroom for cells belonging to primary PUCCH group, the term 'serving cell' in this subclause refers to serving cell belonging to the primary PUCCH group.
- For computing power headroom for cells belonging to secondary PUCCH group, the term 'serving cell' in this subclause refers to serving cell belonging to the secondary PUCCH group. The term 'primary cell' in this subclause refers to the PUCCH-SCell of the secondary PUCCH group.

Type 1:

If the UE transmits PUSCH without PUCCH in subframe i for serving cell c , power headroom for a Type 1 report is computed using

$$PH_{\mathrm{type1,c}}(i) = P_{\mathrm{CMAX},c}(i) - \left\{10\log_{10}(M_{\mathrm{PUSCH,c}}(i)) + P_{\mathrm{O\_PUSCH,c}}(j) + \alpha_c(j)\cdot PL_c + \Delta_{\mathrm{TF,c}}(i) + f_c(i)\right\} \quad \text{[dB]}$$

where, $P_{\mathrm{CMAX},c}(i)$, $M_{\mathrm{PUSCH,c}}(i)$, $P_{\mathrm{O\_PUSCH,c}}(j)$, $\alpha_c(j)$, PL_c, $\Delta_{\mathrm{TF},c}(i)$ and $f_c(i)$ are defined in subclause 5.1.1.1.

If the UE transmits PUSCH with PUCCH in subframe i for serving cell c, power headroom for a Type 1 report is computed using

$$PH_{\text{type1,c}}(i) = \tilde{P}_{\text{CMAX},c}(i) - \left\{10\log_{10}(M_{\text{PUSCH,c}}(i)) + P_{\text{O\_PUSCH,c}}(j) + \alpha_c(j)\cdot PL_c + \Delta_{\text{TF,c}}(i) + f_c(i)\right\} \text{ [dB]}$$

where, $M_{\text{PUSCH,c}}(i)$, $P_{\text{O\_PUSCH,c}}(j)$, $\alpha_c(j)$, PL_c, $\Delta_{\text{TF},c}(i)$ and $f_c(i)$ are defined in subclause 5.1.1.1. $\tilde{P}_{\text{CMAX},c}(i)$ is computed based on the requirements in [6] assuming a PUSCH only transmission in subframe i. For this case, the physical layer delivers $\tilde{P}_{\text{CMAX},c}(i)$ instead of $P_{\text{CMAX},c}(i)$ to higher layers.

If the UE does not transmit PUSCH in subframe i for serving cell c, power headroom for a Type 1 report is computed using

$$PH_{\text{type1,c}}(i) = \tilde{P}_{\text{CMAX},c}(i) - \left\{P_{\text{O\_PUSCH,c}}(1) + \alpha_c(1)\cdot PL_c + f_c(i)\right\} \text{ [dB]}$$

where, $\tilde{P}_{\text{CMAX,c}}(i)$ is computed assuming MPR=0dB, A-MPR=0dB, P-MPR=0dB and ΔT_C =0dB, where MPR , A-MPR, P-MPR and ΔT_C are defined in [6]. $P_{\text{O\_PUSCH,c}}(1)$, $\alpha_c(1)$, PL_c, and $f_c(i)$ are defined in subclause 5.1.1.1.

Type 2:

If the UE transmits PUSCH simultaneous with PUCCH in subframe i for the primary cell, power headroom for a Type 2 report is computed using

$$PH_{\text{type2}}(i) = P_{\text{CMAX},c}(i) - 10\log_{10}\left(\begin{array}{l}10^{\left(10\log_{10}(M_{\text{PUSCH,c}}(i)) + P_{\text{O\_PUSCH,c}}(j) + \alpha_c(j)\cdot PL_c + \Delta_{\text{TF,c}}(i) + f_c(i)\right)/10} \\ +\ 10^{\left(P_{\text{0\_PUCCH}} + PL_c + h(n_{CQI}, n_{HARQ}, n_{SR}) + \Delta_{\text{F\_PUCCH}}(F) + \Delta_{TxD}(F') + g(i)\right)/10}\end{array}\right) \text{ [dB]}$$

where, $P_{\text{CMAX,c}}$, $M_{\text{PUSCH,c}}(i)$, $P_{\text{O\_PUSCH,c}}(j)$, $\alpha_c(j)$, $\Delta_{\text{TF},c}(i)$ and $f_c(i)$ are the primary cell parameters as defined in subclause 5.1.1.1 and $P_{\text{O\_PUCCH}}$, PL_c, $h(n_{CQI}, n_{HARQ}, n_{SR})$, $\Delta_{\text{F\_PUCCH}}(F)$, $\Delta_{TxD}(F')$ and $g(i)$ are defined in subclause 5.1.2.1

If the UE transmits PUSCH without PUCCH in subframe i for the primary cell, power headroom for a Type 2 report is computed using

$$PH_{\text{type2}}(i) = P_{\text{CMAX},c}(i) - 10\log_{10}\left(\begin{array}{l}10^{\left(10\log_{10}(M_{\text{PUSCH,c}}(i)) + P_{\text{O\_PUSCH,c}}(j) + \alpha_c(j)\cdot PL_c + \Delta_{\text{TF,c}}(i) + f_c(i)\right)/10} \\ +\ 10^{\left(P_{\text{0\_PUCCH}} + PL_c + g(i)\right)/10}\end{array}\right) \text{ [dB]}$$

where, $P_{\text{CMAX,c}}(i)$, $M_{\text{PUSCH,c}}(i)$, $P_{\text{O\_PUSCH,c}}(j)$, $\alpha_c(j)$, $\Delta_{\text{TF},c}(i)$ and $f_c(i)$ are the primary cell parameters as defined in subclause 5.1.1.1 and $P_{\text{O\_PUCCH}}$, PL_c and $g(i)$ are defined in subclause 5.1.2.1.

If the UE transmits PUCCH without PUSCH in subframe i for the primary cell, power headroom for a Type 2 report is computed using

$$PH_{\text{type2}}(i) = P_{\text{CMAX},c}(i) - 10\log_{10}\left(\begin{array}{l}10^{\left(P_{\text{O\_PUSCH,c}}(1) + \alpha_c(1)\cdot PL_c + f_c(i)\right)/10} \\ +\ 10^{\left(P_{\text{0\_PUCCH}} + PL_c + h(n_{CQI}, n_{HARQ}, n_{SR}) + \Delta_{\text{F\_PUCCH}}(F) + \Delta_{TxD}(F') + g(i)\right)/10}\end{array}\right) \text{ [dB]}$$

where, $P_{\text{O\_PUSCH,c}}(1)$, $\alpha_c(1)$ and $f_c(i)$ are the primary cell parameters as defined in subclause 5.1.1.1, $P_{\text{CMAX,c}}(i)$, $P_{\text{O\_PUCCH}}$, PL_c, $h(n_{CQI}, n_{HARQ}, n_{SR})$, $\Delta_{\text{F\_PUCCH}}(F)$, $\Delta_{TxD}(F')$ and $g(i)$ are also defined in subclause 5.1.2.1.

If the UE does not transmit PUCCH or PUSCH in subframe i for the primary cell, power headroom for a Type 2 report is computed using

$$PH_{\text{type2}}(i) = \tilde{P}_{\text{CMAX},c}(i) - 10\log_{10}\left(\begin{array}{l}10^{\left(P_{\text{O\_PUSCH,c}}(1) + \alpha_c(1)\cdot PL_c + f_c(i)\right)/10} \\ +\ 10^{\left(P_{\text{0\_PUCCH}} + PL_c + g(i)\right)/10}\end{array}\right) \text{ [dB]}$$

where, $\tilde{P}_{CMAX,c}(i)$ is computed assuming MPR=0dB, A-MPR=0dB, P-MPR=0dB and ΔT_C =0dB, where MPR , A-MPR, P-MPR and ΔT_C are defined in [6], $P_{\text{O\_PUSCH,c}}(1)$, $\alpha_c(1)$ and $f_c(i)$ are the primary cell parameters as defined in subclause 5.1.1.1 and $P_{\text{O\_PUCCH}}$, PL_c and $g(i)$ are defined in subclause 5.1.2.1.

If the UE is unable to determine whether there is a PUCCH transmission corresponding to PDSCH transmission(s) or not, or which PUCCH resource is used, in subframe *i* for the primary cell, before generating power headroom for a Type 2 report, upon (E)PDCCH detection, with the following conditions:

- if both PUCCH format 1b with channel selection and *simultaneousPUCCH-PUSCH* are configured for the UE, or

- if PUCCH format 1b with channel selection is used for HARQ-ACK feedback for the UE configured with PUCCH format 3 and *simultaneousPUCCH-PUSCH* are configured,

then, UE is allowed to compute power headroom for a Type 2 using

$$PH_{\text{type2}}(i) = P_{\text{CMAX},c}(i) - 10\log_{10}\left(\begin{array}{l}10^{\left(10\log_{10}(M_{\text{PUSCH,c}}(i)) + P_{\text{O\_PUSCH,c}}(j) + \alpha_c(j)\cdot PL_c + \Delta_{\text{TF,c}}(i) + f_c(i)\right)/10} \\ +\ 10^{\left(P_{\text{0\_PUCCH}} + PL_c + g(i)\right)/10}\end{array}\right) \text{ [dB]}$$

where, $P_{\text{CMAX,c}}(i)$, $M_{\text{PUSCH,c}}(i)$, $P_{\text{O\_PUSCH,c}}(j)$, $\alpha_c(j)$, $\Delta_{\text{TF},c}(i)$ and $f_c(i)$ are the primary cell parameters as defined in subclause 5.1.1.1 and $P_{\text{O\_PUCCH}}$, PL_c and $g(i)$ are defined in subclause 5.1.2.1.

The power headroom shall be rounded to the closest value in the range [40; -23] dB with steps of 1 dB and is delivered by the physical layer to higher layers.

If the UE is configured with higher layer parameter *UplinkPowerControlDedicated-v12x0* for serving cell c and if subframe i belongs to uplink power control subframe set 2 as indicated by the higher layer parameter *tpc-SubframeSet-r12*, the UE shall use $f_{c,2}(i)$ instead of $f_c(i)$ to compute $PH_{\text{type1,c}}(i)$ and $PH_{\text{type2,c}}(i)$ for subframe *i* and serving cell c, where $f_{c,2}(i)$ is defined in subclause 5.1.1.1.

5.1.2 Physical uplink control channel

If the UE is configured with a SCG, the UE shall apply the procedures described in this subclause for both MCG and SCG.

- When the procedures are applied for MCG, the term 'serving cell' in this subclause refers to serving cell belonging to the MCG.

When the procedures are applied for SCG, the term 'serving cell' in this subclause refers to serving cell belonging to the SCG. The term 'primary cell' in this subclause refers to the PSCell of the SCG.If the UE is configured with a PUCCH-SCell, the UE shall apply the procedures described in this subclause for both primary PUCCH group and secondary PUCCH group.

- When the procedures are applied for the primary PUCCH group, the term 'serving cell' in this subclause refers to serving cell belonging to the primary PUCCH group.

- When the procedures are applied for the secondary PUCCH group, the term ‘serving cell’ in this subclause refers to serving cell belonging to the secondary PUCCH group. The term ‘primary cell’ in this subclause refers to the PUCCH-SCell of the secondary PUCCH group.

5.1.2.1 UE behaviour

If serving cell c is the primary cell, for PUCCH format 1/1a/1b/2/2a/2b/3, the setting of the UE Transmit power P_{PUCCH} for the physical uplink control channel (PUCCH) transmission in subframe i for serving cell c is defined by

$$P_{\text{PUCCH}}(i) = \min\left\{\begin{array}{l} P_{\text{CMAX,c}}(i), \\ P_{\text{0\_PUCCH}} + PL_c + h(n_{CQI}, n_{HARQ}, n_{SR}) + \Delta_{\text{F\_PUCCH}}(F) + \Delta_{TxD}(F') + g(i) \end{array}\right\} \quad \text{[dBm]}$$

If serving cell c is the primary cell, for PUCCH format 4/5, the setting of the UE Transmit power P_{PUCCH} for the physical uplink control channel (PUCCH) transmission in subframe i for serving cell c is defined by

$$P_{\text{PUCCH}}(i) = \min\left\{\begin{array}{l} P_{\text{CMAX,c}}(i), \\ P_{\text{0\_PUCCH}} + PL_c + 10\log_{10}(M_{\text{PUCCH,c}}(i)) + \Delta_{\text{TF,c}}(i) + \Delta_{\text{F\_PUCCH}}(F) + g(i) \end{array}\right\} \quad \text{[dBm]}$$

If the UE is not transmitting PUCCH for the primary cell, for the accumulation of TPC command for PUCCH, the UE shall assume that the UE transmit power P_{PUCCH} for PUCCH in subframe i is computed by

$$P_{\text{PUCCH}}(i) = \min\{P_{\text{CMAX,c}}(i), P_{\text{0\_PUCCH}} + PL_c + g(i)\} \quad \text{[dBm]}$$

where

- $P_{\text{CMAX,c}}(i)$ is the configured UE transmit power defined in [6] in subframe i for serving cell c. If the UE transmits PUSCH without PUCCH in subframe i for the serving cell c, for the accumulation of TPC command for PUCCH, the UE shall assume $P_{\text{CMAX,c}}(i)$ as given by subclause 5.1.1.1. If the UE does not transmit PUCCH and PUSCH in subframe i for the serving cell c, for the accumulation of TPC command for PUCCH, the UE shall compute $P_{\text{CMAX,c}}(i)$ assuming MPR=0dB, A-MPR=0dB, P-MPR=0dB and ΔT_C =0dB, where MPR, A-MPR, P-MPR and ΔT_C are defined in [6].
- The parameter $\Delta_{\text{F\_PUCCH}}(F)$ is provided by higher layers. Each $\Delta_{\text{F\_PUCCH}}(F)$ value corresponds to a PUCCH format (F) relative to PUCCH format 1a, where each PUCCH format (F) is defined in Table 5.4-1 of [3].
- If the UE is configured by higher layers to transmit PUCCH on two antenna ports, the value of $\Delta_{TxD}(F')$ is provided by higher layers where each PUCCH format F' is defined in Table 5.4-1 of [3] ; otherwise, $\Delta_{TxD}(F') = 0$.
- $h(n_{CQI}, n_{HARQ}, n_{SR})$ is a PUCCH format dependent value, where n_{CQI} corresponds to the number of information bits for the channel quality information defined in subclause 5.2.3.3 in [4]. n_{SR} = 1 if subframe i is configured for SR for the UE not having any associated transport block for UL-SCH, otherwise n_{SR} =0. If the UE is configured with more than one serving cell, or the UE is configured with one serving cell and transmitting using PUCCH format 3, the value of n_{HARQ} is defined in subclause 10.1; otherwise, n_{HARQ} is the number of HARQ-ACK bits sent in subframe i.
  - For PUCCH format 1,1a and 1b $h(n_{CQI}, n_{HARQ}, n_{SR}) = 0$
  - For PUCCH format 1b with channel selection, if the UE is configured with more than one serving cell, $h(n_{CQI}, n_{HARQ}, n_{SR}) = \frac{(n_{HARQ} - 1)}{2}$, otherwise, $h(n_{CQI}, n_{HARQ}, n_{SR}) = 0$
  - For PUCCH format 2, 2a, 2b and normal cyclic prefix

$$h(n_{CQI}, n_{HARQ}, n_{SR}) = \begin{cases} 10\log_{10}\left(\frac{n_{CQI}}{4}\right) & \text{if } n_{CQI} \geq 4 \\ 0 & \text{otherwise} \end{cases}$$

- For PUCCH format 2 and extended cyclic prefix

$$h(n_{CQI}, n_{HARQ}, n_{SR}) = \begin{cases} 10\log_{10}\left(\frac{n_{CQI} + n_{HARQ}}{4}\right) & \text{if } n_{CQI} + n_{HARQ} \geq 4 \\ 0 & \text{otherwise} \end{cases}$$

- For PUCCH format 3 and when UE transmits HARQ-ACK/SR without periodic CSI,
  - If the UE is configured by higher layers to transmit PUCCH format 3 on two antenna ports, or if the UE transmits more than 11 bits of HARQ-ACK/SR

$$h(n_{CQI}, n_{HARQ}, n_{SR}) = \frac{n_{HARQ} + n_{SR} - 1}{3}$$

  - Otherwise

$$h(n_{CQI}, n_{HARQ}, n_{SR}) = \frac{n_{HARQ} + n_{SR} - 1}{2}$$

- For PUCCH format 3 and when UE transmits HARQ-ACK/SR and periodic CSI,
  - If the UE is configured by higher layers to transmit PUCCH format 3 on two antenna ports, or if the UE transmits more than 11 bits of HARQ-ACK/SR and CSI

$$h(n_{CQI}, n_{HARQ}, n_{SR}) = \frac{n_{HARQ} + n_{SR} + n_{CQI} - 1}{3}$$

  - Otherwise

$$h(n_{CQI}, n_{HARQ}, n_{SR}) = \frac{n_{HARQ} + n_{SR} + n_{CQI} - 1}{2}$$

- For PUCCH format 4, $M_{\mathrm{PUCCH,c}}(i)$ is the bandwidth of the PUCCH format 4 expressed in number of resource blocks valid for subframe *i* and serving cell c. For PUCCH format 5, $M_{\mathrm{PUCCH,c}}(i) = 1$.
- $\Delta_{TF,c}(i) = 10\log_{10}\left(2^{1.25 \cdot BPRE(i)} - 1\right)$ where $BPRE(i) = O_{\mathrm{UCI}}(i) / N_{\mathrm{RE}}(i)$,
  - $O_{\mathrm{UCI}}(i)$ is the number of HARQ-ACK/SR/RI/CQI/PMI bits including CRC bits transmitted on PUCCH format 4/5 in subframe *i*;
  - $N_{\mathrm{RE}}(i) = M_{\mathrm{PUCCH,c}}(i) \cdot N_{sc}^{RB} \cdot N_{\mathrm{symb}}^{\mathrm{PUCCH}}$ for PUCCH format 4 and $N_{\mathrm{RE}}(i) = N_{sc}^{RB} \cdot N_{\mathrm{symb}}^{\mathrm{PUCCH}} / 2$ for PUCCH format 5;
  - $N_{\mathrm{symb}}^{\mathrm{PUCCH}} = 2 \cdot \left(N_{\mathrm{symb}}^{\mathrm{UL}} - 1\right) - 1$ if shortened PUCCH format 4 or shortened PUCCH format 5 is used in subframe *i* and $N_{\mathrm{symb}}^{\mathrm{PUCCH}} = 2 \cdot \left(N_{\mathrm{symb}}^{\mathrm{UL}} - 1\right)$ otherwise.

- $P_{\mathrm{O\_PUCCH}}$ is a parameter composed of the sum of a parameter $P_{\mathrm{O\_NOMINAL\_PUCCH}}$ provided by higher layers and a parameter $P_{\mathrm{O\_UE\_PUCCH}}$ provided by higher layers.

- δ_{PUCCH} is a UE specific correction value, also referred to as a TPC command, included in a PDCCH with DCI format 1A/1B/1D/1/2A/2/2B/2C/2D for the primary cell, or included in a MPDCCH with DCI format 6-1A, or included in an EPDCCH with DCI format 1A/1B/1D/1/2A/2/2B/2C/2D for the primary cell, or sent jointly coded with other UE specific PUCCH correction values on a PDCCH/MPDCCH with DCI format 3/3A whose CRC parity bits are scrambled with TPC-PUCCH-RNTI.

- For a non-BL/CE UE, if the UE is not configured for EPDCCH monitoring, the UE attempts to decode a PDCCH of DCI format 3/3A with the UE's TPC-PUCCH-RNTI and one or several PDCCHs of DCI format 1A/1B/1D/1/2A/2/2B/2C/2D with the UE's C-RNTI or SPS C-RNTI on every subframe except when in DRX.
- If a UE is configured for EPDCCH monitoring, the UE attempts to decode
  - a PDCCH of DCI format 3/3A with the UE's TPC-PUCCH-RNTI and one or several PDCCHs of DCI format 1A/1B/1D/1/2A/2/2B/2C/2D with the UE's C-RNTI or SPS C-RNTI as described in subclause 9.1.1, and
  - one or several EPDCCHs of DCI format 1A/1B/1D/1/2A/2/2B/2C/2D with the UE's C-RNTI or SPS C-RNTI, as described in subclause 9.1.4.
- For a BL/CE UE configured with CEModeA, the UE attempts to decode a MPDCCH of DCI format 3/3A with the UE's TPC-PUCCH-RNTI and MPDCCH of DCI format 6-1A with the UE's C-RNTI or SPS C-RNTI on every BL/CE downlink subframe except when in DRX.
- If the UE decodes
  - a PDCCH with DCI format 1A/1B/1D/1/2A/2/2B/2C/2D or
  - an EPDCCH with DCI format 1A/1B/1D/1/2A/2/2B/2C/2D or
  - an MPDCCH with DCI format 6-1A

  for the primary cell and the corresponding detected RNTI equals the C-RNTI or SPS C-RNTI of the UE and the TPC field in the DCI format is not used to determine the PUCCH resource as in subclause 10.1, the UE shall use the δ_{PUCCH} provided in that PDCCH/EPDCCH/MPDCCH.

  Else

  - if the UE decodes a PDCCH/MPDCCH with DCI format 3/3A, the UE shall use the δ_{PUCCH} provided in that PDCCH/MPDCCH

    else the UE shall set δ_{PUCCH} = 0 dB.

- $g(i) = g(i-1) + \sum_{m=0}^{M-1} \delta_{PUCCH}(i-k_m)$ where $g(i)$ is the current PUCCH power control adjustment state and where $g(0)$ is the first value after reset.
  - For FDD or FDD-TDD and primary cell frame structure type 1, $M = 1$ and $k_0 = 4$.
  - For TDD, values of M and k_m are given in Table 10.1.3.1-1, where the "UL/DL configuration" in Table 10.1.3.1-1 corresponds to the *eimta-HARQ-ReferenceConfig-r12* for the primary cell when the UE is configured with the parameter *EIMTA-MainConfigServCell-r12* for the primary cell.
  - The δ_{PUCCH} dB values signalled on PDCCH with DCI format 1A/1B/1D/1/2A/2/2B/2C/2D or EPDCCH with DCI format 1A/1B/1D/1/2A/2/2B/2C/2D or MPDCCH with DCI format 6-1A are given in Table 5.1.2.1-1. If the PDCCH with DCI format 1/1A/2/2A/2B/2C/2D or EPDCCH with DCI format 1/1A/2A/2/2B/2C/2D or MPDCCH with DCI format 6-1A is validated as an SPS activation PDCCH/EPDCCH/MPDCCH, or the PDCCH/EPDCCH with DCI format 1A or MPDCCH with DCI format 6-1A is validated as an SPS release PDCCH/EPDCCH/MPDCCH, then δ_{PUCCH} is 0dB.
  - The δ_{PUCCH} dB values signalled on PDCCH/MPDCCH with DCI format 3/3A are given in Table 5.1.2.1-1 or in Table 5.1.2.1-2 as semi-statically configured by higher layers.
  - If $P_{\mathrm{O\_UE\_PUCCH}}$ value is changed by higher layers,
    - $g(0) = 0$

- Else
  - $g(0) = \Delta P_{rampup} + \delta_{msg2}$, where
    - δ_{msg2} is the TPC command indicated in the random access response corresponding to the random access preamble transmitted in the primary cell, see subclause 6.2 and
    - if UE is transmitting PUCCH in subframe i,

$$\Delta P_{rampup} = \min\left[\left\{\max\left(0, P_{CMAX,c} - \begin{pmatrix} P_{0\_PUCCH} \\ + PL_c + h(n_{CQI}, n_{HARQ}, n_{SR}) \\ + \Delta_{F\_PUCCH}(F) + \Delta_{TxD}(F') \end{pmatrix}\right)\right\}, \Delta P_{rampuprequested}\right].$$

Otherwise,

$$\Delta P_{rampup} = \min\left[\left\{\max\left(0, P_{CMAX,c} - \left(P_{0\_PUCCH} + PL_c\right)\right)\right\}, \Delta P_{rampuprequested}\right]$$ and $\Delta P_{rampuprequested}$ is provided by higher layers and corresponds to the total power ramp-up requested by higher layers from the first to the last preamble in the primary cell.

- If UE has reached $P_{\mathrm{CMAX,c}}(i)$ for the primary cell, positive TPC commands for the primary cell shall not be accumulated.
- If UE has reached minimum power, negative TPC commands shall not be accumulated.
- UE shall reset accumulation
  - when $P_{\mathrm{O\_UE\_PUCCH}}$ value is changed by higher layers
  - when the UE receives a random access response message for the primary cell
  - $g(i) = g(i-1)$ if i is not an uplink subframe in TDD or FDD-TDD and primary cell frame structure type 2.

For a BL/CE UE configured with CEModeA, if the PUCCH is transmitted in more than one subframe i_0, i_1, …, i_{N-1} where $i_0 < i_1 < \ldots < i_{N-1}$, the PUCCH transmit power in subframe i_k , k=0, 1, …, N-1is determined by

$$P_{\mathrm{PUCCH},c}(i_k) = P_{\mathrm{PUCCH},c}(i_0)$$

For a BL/CE UE configured with CEModeB, the PUCCH transmit power in subframe i_k is determined by

$$P_{\mathrm{PUCCH},c}(i_k) = P_{\mathrm{CMAX},c}(i_0)$$

Table 5.1.2.1-1: Mapping of TPC Command Field in DCI format 1A/1B/1D/1/2A/2B/2C/2D/2/3/6-1A to δ_{PUCCH} values

TPC Command Field in DCI format 1A/1B/1D/1/2A/2B/2C/2D/2/3/6-1A	δ_{PUCCH} [dB]
0	-1
1	0
2	1
3	3

Table 5.1.2.1-2: Mapping of TPC Command Field in DCI format 3A to δ_{PUCCH} values

TPC Command Field in DCI format 3A	δ_{PUCCH} [dB]
0	-1
1	1

5.1.3 Sounding Reference Symbol (SRS)

5.1.3.1 UE behaviour

The setting of the UE Transmit power P_{SRS} for the SRS transmitted on subframe *i* for serving cell c is defined by

$$P_{\text{SRS,c}}(i) = \min\left\{ P_{\text{CMAX,c}}(i),\ P_{\text{SRS\_OFFSET,c}}(m) + 10\log_{10}(M_{\text{SRS,c}}) + P_{\text{O\_PUSCH,c}}(j) + \alpha_c(j)\cdot PL_c + f_c(i) \right\} \ \text{[dBm]}$$

where

- $P_{\text{CMAX,c}}(i)$ is the configured UE transmit power defined in [6] in subframe *i* for serving cell c.
- $P_{\text{SRS\_OFFSET,c}}(m)$ is semi-statically configured by higher layers for *m=0* and *m=1* for serving cell c. For SRS transmission given trigger type 0 then *m=0* and for SRS transmission given trigger type 1 then *m=1*.
- $M_{\text{SRS,c}}$ is the bandwidth of the SRS transmission in subframe *i* for serving cell c expressed in number of resource blocks.
- $f_c(i)$ is the current PUSCH power control adjustment state for serving cell c, see subclause 5.1.1.1.
- $P_{\text{O\_PUSCH,c}}(j)$ and $\alpha_c(j)$ are parameters as defined in subclause 5.1.1.1 for subframe i, where $j=1$.

If the UE is not configured with an SCG or a PUCCH-SCell, and if the total transmit power of the UE for the Sounding Reference Symbol in an SC-FDMA symbol would exceed $\hat{P}_{CMAX}(i)$, the UE scales $\hat{P}_{\text{SRS},c}(i)$ for the serving cell c and the SC-FDMA symbol in subframe *i* such that the condition

$$\sum_{c} w(i)\cdot \hat{P}_{\text{SRS},c}(i) \le \hat{P}_{CMAX}(i)$$

is satisfied where $\hat{P}_{\text{SRS},c}(i)$ is the linear value of $P_{\text{SRS},c}(i)$, $\hat{P}_{CMAX}(i)$ is the linear value of P_{CMAX} defined in [6] in subframe *i* and $w(i)$ is a scaling factor of $\hat{P}_{\text{SRS},c}(i)$ for serving cell c where $0 < w(i) \le 1$. Note that $w(i)$ values are the same across serving cells.

If the UE is not configured with an SCG or a PUCCH-SCell, and if the UE is configured with multiple TAGs and the SRS transmission of the UE in an SC-FDMA symbol for a serving cell in subframe i in a TAG overlaps with the SRS transmission in another SC-FDMA symbol in subframe i for a serving cell in another TAG, and if the total transmit power of the UE for the Sounding Reference Symbol in the overlapped portion would exceed $\hat{P}_{CMAX}(i)$, the UE scales

$\hat{P}_{\mathrm{SRS},c}(i)$ for the serving cell c and each of the overlapped SRS SC-FDMA symbols in subframe i such that the condition

$$\sum_{c} w(i) \cdot \hat{P}_{\mathrm{SRS},c}(i) \le \hat{P}_{CMAX}(i)$$

is satisfied where $\hat{P}_{\mathrm{SRS},c}(i)$ is the linear value of $P_{\mathrm{SRS},c}(i)$, $\hat{P}_{CMAX}(i)$ is the linear value of P_{CMAX} defined in [6] in subframe i and $w(i)$ is a scaling factor of $\hat{P}_{\mathrm{SRS},c}(i)$ for serving cell c where $0 < w(i) \le 1$. Note that $w(i)$ values are the same across serving cells.

If the UE is configured with higher layer parameter *UplinkPowerControlDedicated-v12x0* for serving cell c and if subframe i belongs to uplink power control subframe set 2 as indicated by the higher layer parameter *tpc-SubframeSet-r12*, the UE shall use $f_{c,2}(i)$ instead of $f_c(i)$ to determine $P_{\mathrm{SRS},c}(i)$ for subframe i and serving cell c, where $f_{c,2}(i)$ is defined in subclause 5.1.1.1.

5.1.4 Power allocation for dual connectivity

If a UE is configured with multiple cell groups,

- if the UE supports synchronous dual connectivity but does not support asynchronous dual connectivity, or if the UE supports both synchronous dual connectivity and asynchronous dual connectivity and if the higher layer parameter *powerControlMode* indicates dual connectivity power control mode 1
  - if the maximum uplink timing difference between transmitted signals to different serving cells including serving cells belonging to different CGs is equal to or less than the minimum requirement for maximum transmission timing difference for synchronous dual connectivity defined in [10].
    - The UE shall use the procedures described in sub clause 5.1.4.1.
    - If a PRACH transmission of the UE on the Pcell starting in subframe $i1$ of MCG overlaps in time domain with another PRACH transmission of the UE starting in subframe $i2$ of SCG, and if subframe $i1$ and subframe $i2$ overlap in time with more than one symbol, and if the total power of both the PRACH transmissions would exceed $\hat{P}_{\mathrm{CMAX}}(i1,i2)$, the UE shall transmit the PRACH on the Pcell using the preamble transmission power P_{PRACH} described in subclause 6.1. The UE may drop or adjust the power of the PRACH transmission in subframe $i2$ of SCG such that the total power does not exceed $\hat{P}_{\mathrm{CMAX}}(i1,i2)$, where $\hat{P}_{\mathrm{CMAX}}(i1,i2)$ is the linear value configured transmitted power for Dual Connectivity for the subframe pair $(i1,i2)$ as described in [6]. If the UE drops the PRACH transmission, it sends power ramping suspension indicator to the higher layers. If the UE adjusts the power of PRACH transmission, it may send power ramping suspension indicator to the higher layers.
- if the UE supports both synchronous dual connectivity and asynchronous dual connectivity and if the higher layer parameter *powerControlMode* does not indicate dual connectivity power control mode 1
  - The UE shall use the procedures described in sub clause 5.1.4.2 .
  - If a PRACH transmission on the Pcell in subframe $i1$ of MCG overlaps in time another PRACH transmission in subframe $i2$ of SCG, and if the time difference between the start of the two PRACH transmissions is less than $30720 \cdot T_s$, and if the transmission timing of the PRACH on the Pcell (according to subclause 6.1.1) is such that the UE is ready to transmit the PRACH on Pcell at least one subframe before subframe $i1$ of MCG, and if the total power of both the PRACH transmissions exceeds $\hat{P}_{\mathrm{CMAX}}(i1,i2)$, the UE shall transmit the PRACH on the Pcell using the preamble transmission power P_{PRACH} described in subclause 6.1. The UE may drop or adjust the power of the PRACH transmission in subframe $i2$ of SCG such that the total power does not exceed $\hat{P}_{\mathrm{CMAX}}(i1,i2)$, where $\hat{P}_{\mathrm{CMAX}}(i1,i2)$ is the linear value

configured transmitted power for Dual Connectivity for the subframe pair $(i1, i2)$ as described in [6]. If the UE drops the PRACH transmissions, it sends power ramping suspension indicator to the higher layers. If the UE adjusts the power of PRACH transmission, it may send power ramping suspension indicator to the higher layers.

5.1.4.1 Dual connectivity power control Mode 1

If the UE PUSCH/PUCCH transmission(s) in subframe $i1$ of CG1 overlap in time with PUSCH/PUCCH transmission(s) in more than one symbol of subframe $i2$ of CG2 or if at least the last symbol the UE PUSCH/PUCCH transmission(s) in subframe $i1$ of CG1 overlap in time with SRS transmission(s) of subframe $i2$, and

- if the UE has a PUCCH/PUSCH transmission with UCI including HARQ-ACK/SR in subframe $i1$ of CG1: If the UE has a PUCCH transmission with UCI including HARQ-ACK/SR in subframe $i1$ of CG1 and if $\hat{P}_{PUCCH\_CG1}(i1)$ would exceed $S1(i1)$, the UE scales $\hat{P}_{PUCCH\_CG1}(i1)$ such that the condition $\alpha 1(i1) \cdot \hat{P}_{PUCCH\_CG1}(i1) = \max\{0, S1(i1)\}$ is satisfied where $0 \le \alpha 1(i1) \le 1$ and $\hat{P}'_{PUCCH\_CG1}(i1) = \alpha 1(i1) \cdot \hat{P}_{PUCCH\_CG1}(i1)$. If $\hat{P}_{PUCCH\_CG1}(i1)$ would not exceed $S1(i1)$, $\hat{P}'_{PUCCH\_CG1}(i1) = \hat{P}_{PUCCH\_CG1}(i1)$. If the UE has a PUSCH transmission with UCI including HARQ-ACK in subframe $i1$ of serving cell $c_1 \in CG1$, and if $\hat{P}_{PUSCH,c_1}(i1)$ would exceed $S1(i1)$, the UE scales $\hat{P}_{PUSCH,c_1}(i1)$ such that the condition $\alpha 1(i1) \cdot \hat{P}_{PUSCH,c_1}(i1) = \max\{0, S1(i1)\}$ is satisfied where $0 \le \alpha 1(i1) \le 1$ and $\hat{P}'_{PUSCH,c_1}(i1) = \alpha 1(i1) \cdot \hat{P}_{PUSCH,c_1}(i1)$. If $\hat{P}_{PUSCH,c_1}(i1)$ would not exceed $S1(i1)$, $\hat{P}'_{PUSCH,c_1}(i1) = \hat{P}_{PUSCH,c_1}(i1)$.
  $S1(i1)$ is determined as follows

  $$S1(i1) = \hat{P}_{\text{CMAX}}(i1,i2) - \hat{P}_{u1}(i1) - \hat{P}_{q1}(i2) - \min\left\{ \begin{array}{l} \max\left\{ \begin{array}{l} 0, \\ \hat{P}_{\text{CMAX}}(i1,i2) \cdot \dfrac{\gamma_{CG2}}{100} - \hat{P}_{q1}(i2) \end{array} \right\}, \\ \hat{P}'_{q1}(i2) \end{array} \right\};$$

  where

  - $\hat{P}_{u1}(i1) = \hat{P}_{PRACH\_CG1}(i1)$;
  - if CG1 is MCG and CG2 is SCG,
    - $\hat{P}_{q1}(i2) = \hat{P}_{PRACH\_CG2}(i2)$;
    - $\hat{P}'_{q1}(i2) = \hat{P}_{PUCCH\_CG2}(i2) + \sum_{c_2 \in CG2} \left(\hat{P}_{PUSCH,c_2}(i2) + \hat{\hat{P}}_{SRS,c_2}(i2) \right)$;
  - if CG1 is SCG and CG2 is MCG
    - if the UE has a PUCCH transmission with UCI including HARQ-ACK/SR subframe $i2$ of CG2,
      - $\hat{P}_{q1}(i2) = \hat{P}_{PRACH\_CG2}(i2) + \hat{P}'_{PUCCH\_CG2}(i2)$;
      - $\hat{P}'_{q1}(i2) = \sum_{c_2 \in CG2} \left(\hat{P}_{PUSCH,c_2}(i2) + \hat{\hat{P}}_{SRS,c_2}(i2) \right)$
    - else if the UE has a PUSCH transmission with UCI including HARQ-ACK in subframe $i2$ of serving cell $j_2 \in CG2$,

- $\hat{P}_{q1}(i2) = \hat{P}_{PRACH\_CG2}(i2) + \hat{P}'_{PUSCH,j_2}(i2)$;

- $\hat{P}'_{q1}(i2) = \sum_{c_2 \in CG2, c_2 \neq j_2} \hat{P}_{PUSCH,c_2}(i2) + \sum_{c_2 \in CG2} \hat{\tilde{P}}_{SRS,c_2}(i2)$;

- otherwise,

  - $\hat{P}_{q1}(i2) = \hat{P}_{PRACH\_CG2}(i2)$;

  - $\hat{P}'_{q1}(i2) = \hat{P}_{PUCCH\_CG2}(i2) + \sum_{c_2 \in CG2} \left(\hat{P}_{PUSCH,c_2}(i2) + \hat{\tilde{P}}_{SRS,c_2}(i2) \right)$

- if the UE has a PUCCH/PUSCH transmission with UCI not including HARQ-ACK/SR in subframe $i1$ of CG1: If the UE has a PUCCH transmission with UCI not including HARQ-ACK/SR in subframe $i1$ of CG1 and if $\hat{P}_{PUCCH\_CG1}(i1)$ would exceed $S2(i1)$, the UE scales $\hat{P}_{PUCCH\_CG1}(i1)$ such that the condition $\alpha2(i1) \cdot \hat{P}_{PUCCH\_CG1}(i1) = \max\{0, S2(i1)\}$ is satisfied where $0 \le \alpha2(i1) \le 1$ and $\hat{P}'_{PUCCH\_CG1}(i1) = \alpha2(i1) \cdot \hat{P}_{PUCCH\_CG1}(i1)$. If $\hat{P}_{PUCCH\_CG1}(i1)$ would not exceed $S2(i1)$, $\hat{P}'_{PUCCH\_CG1}(i1) = \hat{P}_{PUCCH\_CG1}(i1)$. If the UE has a PUSCH transmission with UCI not including HARQ-ACK in subframe $i1$ of serving cell $c_1 \in CG1$, and if $\hat{P}_{PUSCH,c_1}(i1)$ would exceed $S2(i1)$, the UE scales $\hat{P}_{PUSCH,c_1}(i1)$ such that the condition $\alpha2(i1) \cdot \hat{P}_{PUSCH,c_1}(i1) = \max\{0, S2(i1)\}$ is satisfied where $0 \le \alpha2(i1) \le 1$ and $\hat{P}'_{PUSCH,c_1}(i1) = \alpha2(i1) \cdot \hat{P}_{PUSCH,c_1}(i1)$. If $\hat{P}_{PUSCH,c_1}(i1)$ would not exceed $S2(i1)$, $\hat{P}'_{PUSCH,c_1}(i1) = \hat{P}_{PUSCH,c_1}(i1)$.
  $S2(i1)$ is determined as follows

$$S2(i1) = \hat{P}_{\mathrm{CMAX}}(i1,i2) - \hat{P}_{u2}(i1) - \hat{P}_{q2}(i2) - \min\left\{ \begin{matrix} \max\left\{ \begin{matrix} 0, \\ \hat{P}_{\mathrm{CMAX}}(i1,i2) \cdot \frac{\gamma_{CG2}}{100} - \hat{P}_{q2}(i2) \end{matrix} \right\} \\ \hat{P}'_{q2}(i2) \end{matrix} \right\}$$

  where

  - $\hat{P}_{u2}(i1) = \hat{P}_{PRACH\_CG1}(i1) + \hat{P}'_{PUCCH\_CG1}(i1)$ if the UE has a PUCCH transmission with HARQ-ACK/SR and a PUSCH transmission with UCI not including HARQ-ACK in subframe $i1$ of CG1, otherwise, $\hat{P}_{u2}(i1) = \hat{P}_{PRACH\_CG1}(i1)$.

  - if CG1 is MCG and CG2 is SCG

    - if the UE has a PUCCH transmission with UCI including HARQ-ACK/SR in subframe $i2$ of CG2,

      - $\hat{P}_{q2}(i2) = \hat{P}_{PRACH\_CG2}(i2) + \hat{P}'_{PUCCH\_CG2}(i2)$

      - $\hat{P}'_{q2}(i2) = \sum_{c_2 \in CG2} \left(\hat{P}_{PUSCH,c_2}(i2) + \hat{\tilde{P}}_{SRS,c_2}(i2) \right)$;

    - else if the UE has a PUSCH transmission with UCI including HARQ-ACK in subframe $i2$ of serving cell $j_2 \in CG2$,

- $\hat{P}_{q2}(i2) = \hat{P}_{PRACH\_CG2}(i2) + \hat{P}'_{PUSCH,j_2}(i2)$
- $\hat{P}'_{q2}(i2) = \sum_{c_2 \in CG2, c_2 \neq j_2} \hat{P}_{PUSCH,c_2}(i2) + \sum_{c_2 \in CG2} \hat{\tilde{P}}_{SRS,c_2}(i2)$;

- otherwise,
  - $\hat{P}_{q2}(i2) = \hat{P}_{PRACH\_CG2}(i2)$
  - $\hat{P}'_{q2}(i2) = \hat{P}_{PUCCH\_CG2}(i2) + \sum_{c_2 \in CG2} \left(\hat{P}_{PUSCH,c_2}(i2) + \hat{\tilde{P}}_{SRS,c_2}(i2) \right)$

- if CG1 is SCG and CG2 is MCG
  - if the UE has a PUCCH transmission in subframe $i2$ of CG2 and/or a PUSCH transmission with UCI in in subframe $i2$ of serving cell $j_2 \in CG2$
    - $\hat{P}_{q2}(i2) = \hat{P}_{PRACH\_CG2}(i2) + \hat{P}'_{PUCCH\_CG2}(i2) + \hat{P}'_{PUSCH,j_2}(i2)$
    - $\hat{P}'_{q2}(i2) = \sum_{c_2 \in CG2, c_2 \neq j_2} \hat{P}_{PUSCH,c_2}(i2) + \sum_{c_2 \in CG2} \hat{\tilde{P}}_{SRS,c_2}(i2)$

    where, $\hat{P}_{PUCCH\_CG2}(i2) = 0$ if the UE does not have a PUCCH transmission in subframe $i2$ of CG2; $\hat{P}_{PUSCH,j_2}(i2) = 0$ if the UE does not have a PUSCH transmission with UCI in subframe $i2$ of CG2;
  - otherwise
    - $\hat{P}_{q2}(i2) = \hat{P}_{PRACH\_CG2}(i2)$
    - $\hat{P}'_{q2}(i2) = \sum_{c_2 \in CG2} \left(\hat{P}_{PUSCH,c_2}(i2) + \hat{\tilde{P}}_{SRS,c_2}(i2) \right)$

- If the UE has PUSCH transmission(s) without UCI in subframe $i1$ of CG1, the UE shall determine

$$S3(i1) = \hat{P}_{\mathrm{CMAX}}(i1,i2) - \hat{P}_{u3}(i1) - \hat{P}_{q3}(i2) - \min\left\{ \begin{matrix} \max\left\{ \begin{matrix} 0, \\ \hat{P}_{\mathrm{CMAX}}(i1,i2) \cdot \frac{\gamma_{CG2}}{100} - \hat{P}_{q3}(i2) \end{matrix} \right\} \\ \hat{P}'_{q3}(i2) \end{matrix} \right\}$$

  where

  - if the UE has a PUCCH transmission in subframe $i1$ of CG1 and/or a PUSCH transmission with UCI in in subframe $i1$ of serving cell $j_1 \in CG1$ $\hat{P}_{u3}(i1) = \hat{P}_{PRACH\_CG1}(i1) + \hat{P}'_{PUCCH\_CG1}(i1) + \hat{P}'_{PUSCH,j_1}(i1)$, where $\hat{P}_{PUCCH\_CG1}(i1) = 0$ if the UE does not have a PUCCH transmission in subframe $i1$ of CG1, $\hat{P}_{PUSCH,j_1}(i1) = 0$ if the UE does not have a PUSCH transmission with UCI in subframe $i1$ of CG1; otherwise $\hat{P}_{u3}(i1) = \hat{P}_{PRACH\_CG1}(i1)$;

  - if CG1 is MCG and CG2 is SCG

- if the UE has a PUCCH transmission in subframe $i2$ of CG2 and/or a PUSCH transmission with UCI in in subframe $i2$ of serving cell $j_2 \in CG2$

  - $\hat{P}_{q3}(i2) = \hat{P}_{PRACH\_CG2}(i2) + \hat{P}'_{PUCCH\_CG2}(i2) + \hat{P}'_{PUSCH,j_2}(i2)$

  - $\hat{P}'_{q3}(i2) = \sum_{c_2 \in CG2, c_2 \neq j_2} \hat{P}_{PUSCH,c_2}(i2) + \sum_{c_2 \in CG2} \hat{\hat{P}}_{SRS,c_2}(i2)$

    where, $\hat{P}_{PUCCH\_CG2}(i2) = 0$ if the UE does not have a PUCCH transmission in subframe $i2$ of CG2; $\hat{P}_{PUSCH,j_2}(i2) = 0$ if the UE does not have a PUSCH transmission with UCI in subframe $i2$ of CG2;

- otherwise

  - $\hat{P}_{q3}(i2) = \hat{P}_{PRACH\_CG2}(i2)$

  - $\hat{P}'_{q3}(i2) = \sum_{c_2 \in CG2} \left(\hat{P}_{PUSCH,c_2}(i2) + \hat{\hat{P}}_{SRS,c_2}(i2) \right)$;

- if CG1 is SCG and CG2 is MCG

  - $\hat{P}_{q3}(i2) = \hat{P}_{PRACH\_CG2}(i2) + \hat{P}'_{PUCCH\_CG2}(i2) + \sum_{c_2 \in CG2} \hat{P}'_{PUSCH,c_2}(i2)$

  - $\hat{P}'_{q3}(i2) = \sum_{c_2 \in CG2} \hat{\hat{P}}_{SRS,c_2}(i2)$;

- If the total transmit power of all the PUSCH transmission(s) without UCI in subframe $i1$ of CG1 would exceed $S3(i1)$, the UE scales $\hat{P}_{\text{PUSCH},c1}(i1)$ for each serving cell $c_1 \in CG1$ with a PUSCH transmission without UCI in subframe $i1$ such that the condition $\sum_{c_1 \in CG1} w(i1) \cdot \hat{P}_{\text{PUSCH},c_1}(i1) \leq \max\{0, S3(i1)\}$ is satisfied, where $\hat{P}'_{\text{PUSCH},c_1}(i1) = w(i1) \cdot \hat{P}_{\text{PUSCH},c_1}(i1)$, and where $w(i1)$ is a scaling factor of $\hat{P}_{\text{PUSCH},c_1}(i1)$ for serving cell c_1 where $0 \leq w(i1) \leq 1$. Note that $w(i1)$ values are the same across serving cells within a cell group when $w(i1) > 0$ but for certain serving cells within the cell group $w(i1)$ may be zero. If the total transmit power of all the PUSCH transmission(s) without UCI in subframe $i1$ of CG1 would not exceed $S3(i1)$, $\hat{P}'_{\text{PUSCH},c_1}(i1) = \hat{P}_{\text{PUSCH},c_1}(i1)$.

where

- $\hat{P}_{\text{CMAX}}(i1, i2)$ is the linear value of configured transmitted power for Dual Connectivity for the subframe pair $(i1, i2)$ as described in [6];

- if CG1 is MCG and CG2 is SCG

  - $\hat{P}_{\text{PUCCH\_CG1}}(i1)$ is the linear value of $P_{\text{PUCCH}}(i1)$ corresponding to PUCCH transmission on the primary cell ; $\hat{P}_{\text{PUCCH\_CG2}}(i2)$ is the linear value of $P_{\text{PUCCH}}(i2)$ corresponding to PUCCH transmission on the PSCell.

  - $\gamma_{CG1} = \gamma_{MCG}$;

- if CG1 is SCG and CG2 is MCG;
  - $\hat{P}_{\text{PUCCH\_CG1}}(i1)$ is the linear value of $P_{\text{PUCCH}}(i1)$ corresponding to PUCCH transmission on the PSCell; $\hat{P}_{\text{PUCCH\_CG2}}(i2)$ is the linear value of $P_{\text{PUCCH}}(i2)$ corresponding to PUCCH transmission on the primary cell.
  - $\gamma_{CG1} = \gamma_{SCG}$;
- $\hat{P}_{\text{PUSCH},c_1}(i1)$ is the linear value of $P_{\text{PUSCH},c_1}(i1)$ for subframe $i1$ of serving cell of serving cell $c_1 \in CG1$, and $\hat{P}_{\text{PUSCH},c_2}(i2)$ is the linear value of $P_{\text{PUSCH},c_2}(i2)$ for subframe $i2$ of serving cell of serving cell $c_2 \in CG2$.
- γ_{MCG} and γ_{SCG} are given by Table 5.1.4.2-1 according to higher layer parameters p-MeNB and p-SeNB respectively;
- If the UE has a PRACH transmission for CG1 overlapping with subframe $i1$ of CG1, $\hat{P}_{PRACH\_CG1}(i1)$ is the linear value of the transmission power of that PRACH transmission; otherwise, $\hat{P}_{PRACH\_CG1}(i1) = 0$;
- If the UE has a PRACH transmission for CG2 overlapping with subframe $i2$ of CG2, $\hat{P}_{PRACH\_CG2}(i2)$ is the linear value of the transmission power of that PRACH transmission; otherwise, $\hat{P}_{PRACH\_CG2}(i2) = 0$.
- $\hat{\tilde{P}}_{SRS,c_2}(i2)$ is determined as follows
  - if the PUSCH/PUCCH is not transmitted in the last symbol of subframe $i1$ of CG1, or if the UE does not have an SRS transmission in subframe $i2$ of serving cell $c_2 \in CG2$ or if the UE drops SRS transmission in subframe $i2$ of serving cell $c_2 \in CG2$ due to collision with PUCCH in subframe $i2$ of serving cell $c_2 \in CG2$
    - $\hat{\tilde{P}}_{SRS,c_2}(i2) = 0$;
  - if the UE has an SRS transmission and does not have a PUCCH/PUSCH transmission in subframe $i2$ of serving cell $c_2 \in CG2$
    - $\hat{\tilde{P}}_{SRS,c_2}(i2) = \hat{P}_{SRS,c_2}(i2)$;
  - if the UE has an SRS transmission and a has PUCCH transmission, and does not have a PUSCH transmission in subframe $i2$ of serving cell $c_2 \in CG2$
    - $$\hat{\tilde{P}}_{SRS,c_2}(i2) = \max\left\{\begin{matrix}0, \\ \hat{P}_{SRS,c_2}(i2) - \hat{P}_{PUCCH\_CG2}(i2)\end{matrix}\right\}$$
  - if the UE has an SRS transmission and a has PUSCH transmission, and does not have a PUCCH transmission in subframe $i2$ of serving cell $c_2 \in CG2$
    - $$\hat{\tilde{P}}_{SRS,c_2}(i2) = \max\left\{\begin{matrix}0, \\ \hat{P}_{SRS,c_2}(i2) - \hat{P}_{PUSCH,c_2}(i2)\end{matrix}\right\}$$

- if the UE has an SRS transmission and has a PUSCH transmission and a PUCCH transmission in in subframe $i2$ of serving cell $c_2 \in CG2$

- $$\hat{\tilde{P}}_{SRS,c_2}(i2) = \max\left\{\begin{matrix} 0, \\ \hat{P}_{SRS,c_2}(i2) - \hat{P}_{PUSCH,c_2}(i2) - \hat{P}_{PUCCH\_CG2}(i2) \end{matrix}\right\}$$

If the total transmit power for the Sounding Reference Symbol in an SC-FDMA symbol across all the serving cells within a TAG of a cell group CG1 would exceed $S4(i1)$, the UE scales $\hat{P}_{\mathrm{SRS},c_1}(i1)$ for the serving cell $c_1 \in CG1$ and the SC-FDMA symbol in subframe $i1$ such that the condition $\sum_{c_1 \in CG1} v(i1) \cdot \hat{P}_{\mathrm{SRS},c_1}(i1) \le S4(i1)$

is satisfied, where $\hat{P}'_{\mathrm{SRS},c_1}(i1) = v(i1) \cdot \hat{P}_{\mathrm{SRS},c_1}(i1)$ is the transmission power of SRS after scaling and where $\hat{P}_{\mathrm{SRS},c_1}(i1)$ is the linear value of $P_{\mathrm{SRS},c_1}(i1)$ described in section 5.1.3.1, and $v(i)$ is a scaling factor of $\hat{P}_{\mathrm{SRS},c_1}(i1)$ for serving cell $c_1 \in CG1$ where $0 < v(i) \le 1$. Note that $v(i)$ values are the same across serving cells within the same CG.

If the UE is configured with multiple TAGs within CG1 and the SRS transmission of the UE in an SC-FDMA symbol for a serving cell in subframe $i1$ in a TAG belonging to CG1 overlaps with the SRS transmission in another SC-FDMA symbol in subframe $i1$ for a serving cell in another TAG belonging to CG1, and if the total transmit power of the UE for the Sounding Reference Symbol in the overlapped portion would exceed $S4(i1)$, the UE scales $\hat{P}_{\mathrm{SRS},c_1}(i1)$ for the serving cell $c_1 \in CG1$ and each of the overlapped SRS SC-FDMA symbols in subframe $i1$ such that the condition $\sum_{c_1 \in CG1} v(i1) \cdot \hat{P}_{\mathrm{SRS},c_1}(i1) \le S4(i1)$ is satisfied, where $\hat{P}'_{\mathrm{SRS},c_1}(i1) = v(i1) \cdot \hat{P}_{\mathrm{SRS},c_1}(i1)$ is the transmission power of SRS after scaling, and where $v(i1)$ is a scaling factor of $\hat{P}_{\mathrm{SRS},c_1}(i1)$ for serving cell c_1 where $0 \le v(i1) \le 1$. Note that $v(i1)$ values are the same across serving cells within a cell group.

$S4(i1)$ is determined as follows

$$S4(i1) = \hat{P}_{\mathrm{CMAX}}(i1,i2) - \hat{P}_{q4}(i2) - \min\left\{\begin{matrix} \max\left\{\begin{matrix} 0, \\ \hat{P}_{\mathrm{CMAX}}(i1,i2) \cdot \frac{\gamma_{CG2}}{100} - \hat{P}_{q4}(i2) \end{matrix}\right\} \\ \hat{P}'_{q4}(i2) \end{matrix}\right\}$$

where

- if CG1 is MCG and CG2 is SCG

- $$\hat{P}_{q4}(i2) = \hat{\tilde{P}}_{PRACH\_CG2}(i2) + \hat{\tilde{P}}'_{PUCCH\_CG2}(i2) + \sum_{c_2 \in CG2} \hat{\tilde{P}}'_{PUSCH,c_2}(i2)$$

- $$\hat{P}'_{q4}(i2) = \sum_{c_2 \in CG2} \hat{P}_{SRS,c_2}(i2)$$

- if CG1 is SCG and CG2 is MCG

- $\hat{P}_{q4}(i2) = \hat{\hat{P}}_{PRACH\_CG2}(i2) + \hat{\hat{P}}'_{PUCCH\_CG2}(i2) + \sum_{c_2 \in CG2} \hat{\hat{P}}'_{PUSCH,c_2}(i2) + \sum_{c_2 \in CG2} \hat{P}'_{SRS,c_2}(i2)$

- $\hat{P}'_{q4}(i2) = 0$

- if the UE has no PUCCH transmission or has a shortened PUCCH transmission in subframe $i2$ of CG2, $\hat{\hat{P}}'_{PUCCH\_CG2}(i2) = 0$; otherwise $\hat{\hat{P}}'_{PUCCH\_CG2}(i2) = \hat{P}'_{PUCCH\_CG2}(i2)$

- if the UE has no PUSCH transmission in the last symbol of subframe $i2$ of serving cell $c_2 \in CG2$, $\hat{\hat{P}}'_{PUSCH,c_2}(i2) = 0$; otherwise $\hat{\hat{P}}'_{PUSCH,c_2}(i2) = \hat{P}'_{PUSCH,c_2}(i2)$

- if the UE has PRACH transmission in CG2 that overlaps with the last symbol of subframe $i2$ of CG2, $\hat{\hat{P}}_{PRACH\_CG2}(i2) = \hat{P}_{PRACH\_CG2}(i2)$; otherwise $\hat{\hat{P}}_{PRACH\_CG2}(i2) = 0$

For both cell groups

- if the PUCCH/PUSCH transmission of the UE on subframe $i1$ for a given serving cell in a TAG of CG1 overlaps some portion of the first symbol of the PUSCH transmission on subframe $i1+1$ for a different serving cell in another TAG of CG1 and/or overlaps with the PUCCH/PUSCH transmission on subframe $i2+1$ for a serving cell in another TAG of CG2, the UE shall adjust its total transmission power of all CGs such that the total transmission power of the UE across all CGs does not exceed P_{CMAX} on any overlapped portion.

- if the PUSCH transmission of the UE on subframe $i1$ for a given serving cell in a TAG of CG1 overlaps some portion of the first symbol of the PUCCH transmission on subframe $i1+1$ for a different serving cell in another TAG of CG1 and/or overlaps with the PUCCH/PUSCH transmission on subframe $i2+1$ for a serving cell in another TAG of CG2, the UE shall adjust its total transmission power of all CGs such that the total transmission power of the UE across all CGs does not exceed P_{CMAX} on any overlapped portion.

- if the SRS transmission of the UE in a symbol on subframe $i1$ for a given serving cell in a TAG of CG1 overlaps with the PUCCH/PUSCH transmission on subframe $i1$ or subframe $i1+1$ for a different serving cell in the same or another TAG of CG1 and/or overlaps with the PUCCH/PUSCH transmission on subframe $i2+1$ for a serving cell of CG2, the UE shall drop the SRS in CG1 if its total transmission power across all CGs exceeds P_{CMAX} on any overlapped portion of the symbol.

- if the SRS transmission of the UE in a symbol on subframe $i1$ for a given serving cell in CG1 overlaps with the SRS transmission on subframe $i1$ for a different serving cell(s) in CG1 or overlaps with SRS transmission on subframe $i2$ for a serving cell(s) in CG2, and if the SRS transmissions overlap with PUSCH/PUCCH transmission on subframe $i1$ or subframe $i1+1$ for another serving cell(s) in CG1, and/or if the SRS transmissions overlap with PUSCH/PUCCH transmission on subframe $i2+1$ for a serving cell of CG2, the UE shall drop the SRS transmissions in CG1 if its total transmission power across all CGs exceeds P_{CMAX} on any overlapped portion of the symbol.

- UE shall, when requested by higher layers, to transmit PRACH on subframe $i1$ or subframe $i1+1$ in a secondary serving cell in CG1 and/or to transmit PRACH on subframe $i2+1$ in a serving cell in CG2 in parallel with SRS transmission in a symbol on subframe $i1$ of a different serving cell belonging to a different TAG of CG1, drop SRS in CG1 if its total transmission power across all CGs exceeds P_{CMAX} on any overlapped portion of the symbol.

- UE shall, when requested by higher layers, to transmit PRACH on subframe $i1+1$ in a secondary serving cell in CG1 and/or to transmit PRACH on subframe $i2+1$ in a serving cell in CG2 in parallel with

PUSCH/PUCCH on subframe $i1$ in a different serving cell belonging to a different TAG of CG1, adjust the transmission power of PUSCH/PUCCH in CG1 so that the total transmission power of the UE across all CGs does not exceed P_{CMAX} on the overlapped portion.

5.1.4.2 Dual connectivity power control Mode 2

If subframe $i1$ of CG1 overlaps in time with subframe $i2-1$ and subframe $i2$ of CG2, and if the UE has transmission(s) in subframe $i1$ of CG1,

- if the UE determines based on higher layer signalling that transmission(s) in subframe $i1$ of CG1 cannot overlap in time with transmission(s) in subframe $i2$ of CG2, the UE shall determine

$$\hat{P}^{1}_{CG1}(i1) = \min\left\{\begin{matrix} \hat{P}_{\mathrm{q1}}(i1), \\ \hat{P}_{\mathrm{CMAX}}(i1, i2-1) - \hat{P}_{\mathrm{PRACH\_CG1}}(i1) - \hat{P}^{1}_{CG2}(i2-1) - \hat{P}_{\mathrm{PRACH\_CG2}}(i2-1) \end{matrix}\right\}$$

- Otherwise, the UE shall determine

$$\hat{P}^{1}_{CG1}(i1) = \min\left\{\begin{matrix} \hat{P}_{\mathrm{q1}}(i1), \\ \hat{P}_{\mathrm{CMAX}}(i1, i2-1) - \hat{P}_{\mathrm{PRACH\_CG1}}(i1) - \max\left\{\begin{matrix} \hat{P}_{\mathrm{CMAX}}(i1, i2-1)\cdot\frac{\gamma_{CG2}}{100}, \\ \hat{P}^{1}_{CG2}(i2-1) + \hat{P}_{\mathrm{PRACH\_CG2}}(i2-1), \\ \hat{P}_{\mathrm{PRACH\_CG2}}(i2) \end{matrix}\right\} \end{matrix}\right\}.$$

where,

- $\hat{P}_{q1}(i1) = \hat{P}_{PUCCH\_CG1}(i1) + \sum_{c \in CG1}\left(\hat{P}_{PUSCH,c}(i1) + \hat{\hat{P}}_{SRS,c}(i1)\right)$
- $\hat{P}_{\mathrm{CMAX}}(i1, i2-1)$ is the linear value of configured transmitted power for Dual Connectivity for the subframe pair $(i1, i2-1)$, as described in [6];
- $\hat{P}_{PUSCH,c}(i1) = 0$, if the UE does not have a PUSCH transmission in serving cell $c \in CG1$;
- $\hat{P}_{PUCCH\_CG1}(i1) = 0$ if the UE does not have a PUCCH transmission in CG1;
- $\hat{P}^{1}_{CG2}(i2-1) = 0$ if the UE has no transmission of PUCCH, PUSCH, or SRS in subframe $i2-1$ of CG2;
- $\gamma_{CG1} = \gamma_{MCG}$, and $\gamma_{CG2} = \gamma_{SCG}$ if CG1 is MCG and CG2 is SCG;
- $\gamma_{CG1} = \gamma_{SCG}$, and $\gamma_{CG2} = \gamma_{MCG}$, if CG1 is SCG and CG2 is MCG;
- γ_{MCG} and γ_{SCG} are given by Table 5.1.4.2-1 according to higher layer parameters *p-MeNB* and *p-SeNB* respectively;
- If the UE has a PRACH transmission for CG1 overlapping with subframe $i1$ of CG1, $\hat{P}_{PRACH\_CG1}(i1)$ is the linear value of the transmission power of that PRACH transmission; otherwise, $\hat{P}_{PRACH\_CG1}(i1) = 0$.

- If the UE has a PRACH transmission for CG2 overlapping with subframe $i2$ of CG2, and if the transmission timing of the PRACH transmission (according to subclause 6.1.1) is such that the UE is ready to transmit the PRACH at least one subframe before subframe $i2$ of CG2, $\hat{P}_{PRACH\_CG2}(i2)$ is the linear value of the transmission power of that PRACH transmission; otherwise, $\hat{P}_{PRACH\_CG2}(i2) = 0$.

- If the UE has a PRACH transmission for CG2 overlapping with subframe $i2-1$ of CG2, $\hat{P}_{\mathrm{PRACH\_CG2}}(i2-1)$ is the linear value of the transmission power of that PRACH transmission; otherwise, $\hat{P}_{\mathrm{PRACH\_CG2}}(i2-1) = 0$.

- $\hat{\tilde{P}}_{SRS,c}(i1)$ is determined as follows

  - if the UE does not have an SRS transmission in subframe $i1$ of serving cell $c \in CG1$ or if the UE drops the SRS transmission in subframe $i1$ of serving cell $c \in CG1$ due to collision with a PUCCH transmission in subframe $i1$ of serving cell $c \in CG1$

    - $\hat{\tilde{P}}_{SRS,c}(i1) = 0$;

  - if the UE has an SRS transmission and does not have a PUCCH/PUSCH transmission in subframe $i1$ of serving cell $c \in CG1$

    - $\hat{\tilde{P}}_{SRS,c}(i1) = \hat{P}_{SRS,c}(i1)$;

  - if the UE has an SRS transmission and a has PUCCH transmission, and does not have a PUSCH transmission in subframe $i1$ of serving cell $c \in CG1$

    - $\hat{\tilde{P}}_{SRS,c}(i1) = \max\left\{ \begin{matrix} 0, \\ \hat{P}_{SRS,c}(i1) - \hat{P}_{PUCCH\_CG1}(i1) \end{matrix} \right\}$

  - if the UE has an SRS transmission and a has PUSCH transmission, and does not have a PUCCH transmission in subframe $i1$ of serving cell $c \in CG1$

    - $\hat{\tilde{P}}_{SRS,c}(i1) = \max\left\{ \begin{matrix} 0, \\ \hat{P}_{SRS,c}(i1) - \hat{P}_{PUSCH,c}(i1) \end{matrix} \right\}$

  - if the UE has an SRS transmission and has a PUSCH transmission and a PUCCH transmission in subframe $i1$ of serving cell $c \in CG1$

    - $\hat{\tilde{P}}_{SRS,c}(i1) = \max\left\{ \begin{matrix} 0, \\ \hat{P}_{SRS,c}(i1) - \hat{P}_{PUSCH,c}(i1) - \hat{P}_{PUCCH\_CG1}(i1) \end{matrix} \right\}$

  where $\hat{P}_{SRS,c}(i1)$ is the linear value of $P_{SRS,c}(i1)$ described in section 5.1.3.1.

If $\hat{P}_{\mathrm{PUCCH\_CG1}}(i)$ would exceed $\hat{P}^{1}_{CG1}(i)$, the UE scales $\hat{P}_{PUCCH\_CG1}(i)$ such that the condition $\alpha 1(i) \cdot \hat{P}_{PUCCH\_CG1}(i) \le \hat{P}^{1}_{CG1}(i)$ is satisfied where

- if CG1 is MCG, $\hat{P}_{\mathrm{PUCCH\_CG1}}(i)$ is the linear value of $P_{\mathrm{PUCCH}}(i)$ corresponding to PUCCH transmission on the primary cell, in case there is no PUCCH transmission in subframe *i* on the primary cell $\hat{P}_{\mathrm{PUCCH\_CG1}}(i) = 0$.
- if CG1 is SCG , $\hat{P}_{\mathrm{PUCCH\_CG1}}(i)$ is the linear value of $P_{\mathrm{PUCCH}}(i)$ corresponding to PUCCH transmission on PSCell, in case there is no PUCCH transmission in subframe *i* on the PSCell $\hat{P}_{\mathrm{PUCCH\_CG1}}(i) = 0$. $\hat{P}_{\mathrm{PUSCH},c}(i)$ is the linear value of $P_{\mathrm{PUSCH},c}(i)$
- $0 \le \alpha 1(i) \le 1$ is a scaling factor of $\hat{P}_{\mathrm{PUCCH\_CG1}}(i)$.

If the UE has PUSCH transmission with UCI on serving cell $j \in CG1$, and $\hat{P}_{\mathrm{PUSCH},j}(i)$ would exceed $\hat{P}^{1}_{CG1}(i)$ the UE scales $\hat{P}_{\mathrm{PUSCH},j}(i)$ such that the condition $\alpha 2(i) \cdot \hat{P}_{\mathrm{PUSCH},j}(i) \le \hat{P}^{1}_{CG1}(i)$ is satisfied where $\hat{P}_{\mathrm{PUSCH},j}(i)$ is the linear value of the PUSCH transmit power for the cell with UCI, and $0 \le \alpha 2(i) \le 1$ is a scaling factor of $\hat{P}_{\mathrm{PUSCH},j}(i)$ for serving cell $j \in CG1$.

If the total transmit power across all the serving cells of a cell group CG1 would exceed $\hat{P}^{1}_{CG1}(i)$, the UE scales $\hat{P}_{\mathrm{PUSCH},c}(i)$ for the serving cell $c \in CG1$ in subframe *i* such that the condition $\sum_{c \in CG1} w(i) \cdot \hat{P}_{\mathrm{PUSCH},c}(i) \le \left(\hat{P}^{1}_{CG1}(i) - \hat{P}_{\mathrm{PUCCH\_CG1}}(i)\right)$ is satisfied; and $w(i)$ is a scaling factor of $\hat{P}_{\mathrm{PUSCH},c}(i)$ for serving cell c where $0 \le w(i) \le 1$.

If the UE has PUSCH transmission with UCI on serving cell $j \in CG1$ and PUSCH without UCI in any of the remaining serving cells belonging to CG1, and the total transmit power across all the serving cells of CG1 would exceed $\hat{P}^{1}_{CG1}(i)$, the UE scales $\hat{P}_{\mathrm{PUSCH},c}(i)$ for the serving cells belonging to CG1 without UCI in subframe *i* such that the condition $\sum_{c \in CG1,\, c \ne j} w(i) \cdot \hat{P}_{\mathrm{PUSCH},c}(i) \le \left(\hat{P}^{1}_{CG1}(i) - \hat{P}_{\mathrm{PUSCH},j}(i)\right)$ is satisfied;

where $\hat{P}_{\mathrm{PUSCH},j}(i)$ is the PUSCH transmit power for the cell with UCI and $w(i)$ is a scaling factor of $\hat{P}_{\mathrm{PUSCH},c}(i)$ for serving cell c without UCI. In this case, no power scaling is applied to $\hat{P}_{\mathrm{PUSCH},j}(i)$ unless $\sum_{c \in CG1, c \ne j} w(i) \cdot \hat{P}_{\mathrm{PUSCH},c}(i) = 0$ and the total transmit power across all of the serving cells of the CG1 still would exceed $\hat{P}^{1}_{CG1}(i)$.

If the UE has simultaneous PUCCH and PUSCH transmission with UCI on serving cell $j \in CG1$ and PUSCH transmission without UCI in any of the remaining serving cells belonging to CG1, and the total transmit power across all the serving cells of the CG1 would exceed $\hat{P}^{1}_{CG1}(i)$, the UE obtains $\hat{P}_{\mathrm{PUSCH},c}(i)$ according to

$$\hat{P}_{\mathrm{PUSCH},j}(i) = \min\left(\hat{P}_{\mathrm{PUSCH},j}(i), \left(\hat{P}^{1}_{CG1}(i) - \hat{P}_{\mathrm{PUCCH\_CG1}}(i)\right)\right)$$ and

$$\sum_{c \in CG1,\, c \ne j} w(i) \cdot \hat{P}_{\mathrm{PUSCH},c}(i) \le \left(\hat{P}^{1}_{CG1}(i) - \hat{P}_{\mathrm{PUCCH\_CG1}}(i) - \hat{P}_{\mathrm{PUSCH},j}(i)\right)$$

where

- if CG1 is MCG, $\hat{P}_{\mathrm{PUCCH\_CG1}}(i)$ is the linear value of $P_{\mathrm{PUCCH}}(i)$ corresponding to PUCCH transmission on the primary cell.

- if CG1 is SCG , $\hat{P}_{\text{PUCCH\_CG1}}(i)$ is the linear value of $P_{\text{PUCCH}}(i)$ corresponding to PUCCH transmission on PSCell.

Note that $w(i)$ values are the same across serving cells within a cell group when $w(i) > 0$ but for certain serving cells within the cell group $w(i)$ may be zero.

If the total transmit power for the Sounding Reference Symbol in an SC-FDMA symbol across all the serving cells within a TAG of a cell group CG1 would exceed $\hat{P}^{1}_{CG1}(i)$, the UE scales $\hat{P}_{\text{SRS},c}(i)$ for the serving cell $c \in CG1$ and the SC-FDMA symbol in subframe *i* such that the condition

$$\sum_{c \in CG1} v(i) \cdot \hat{P}_{\text{SRS},c}(i) \le \hat{P}^{1}_{CG1}(i)$$

is satisfied where $\hat{P}_{\text{SRS},c}(i)$ is the linear value of $P_{\text{SRS},c}(i)$ described in section 5.1.3.1, and $v(i)$ is a scaling factor of $\hat{P}_{\text{SRS},c}(i)$ for serving cell $c \in CG1$ where $0 < v(i) \le 1$. Note that $v(i)$ values are the same across serving cells within the same CG.

If the UE is configured with multiple TAGs within CG1 and the SRS transmission of the UE in an SC-FDMA symbol for a serving cell in subframe i in a TAG belonging to CG1 overlaps with the SRS transmission in another SC-FDMA symbol in subframe i for a serving cell in another TAG belonging to CG1, and if the total transmit power of the UE for the Sounding Reference Symbol in the overlapped portion would exceed $\hat{P}^{1}_{CG1}(i)$, the UE scales $\hat{P}_{\text{SRS},c}(i)$ for the serving cell $c \in CG1$ and each of the overlapped SRS SC-FDMA symbols in subframe i such that the condition

$$\sum_{c \in CG1} v(i) \cdot \hat{P}_{\text{SRS},c}(i) \le \hat{P}^{1}_{CG1}(i)$$

is satisfied where $\hat{P}_{\text{SRS},c}(i)$ is the linear value of $P_{\text{SRS},c}(i)$ described in section 5.1.3.1, and $v(i)$ is a scaling factor of $\hat{P}_{\text{SRS},c}(i)$ for serving cell $c \in CG1$ where $0 < v(i) \le 1$. Note that $v(i)$ values are the same across serving cells within the same CG.

For a cell group CG1

- if the UE is configured with multiple TAGs within CG1, and if the PUCCH/PUSCH transmission of the UE on subframe i for a given serving cell in a TAG of CG1 overlaps some portion of the first symbol of the PUSCH transmission on subframe $i+1$ for a different serving cell in another TAG of CG1, the UE shall adjust its total transmission power of CG1 to not exceed $\hat{P}^{1}_{CG1}$ on any overlapped portion.

- if the UE is configured with multiple TAGs within CG1, and if the PUSCH transmission of the UE on subframe i for a given serving cell in a TAG of CG1 overlaps some portion of the first symbol of the PUCCH transmission on subframe $i+1$ for a different serving cell in another TAG of CG1 the UE shall adjust its total transmission power of CG1 to not exceed $\hat{P}^{1}_{CG1}$ on any overlapped portion.

- if the UE is configured with multiple TAGs within CG1, and if the SRS transmission of the UE in a symbol on subframe i for a given serving cell in a TAG of CG1 overlaps with the PUCCH/PUSCH transmission on subframe i or subframe $i+1$ for a different serving cell in the same or another TAG of CG1 the UE shall drop SRS if its total transmission power of CG exceeds $\hat{P}^{1}_{CG1}$ on any overlapped portion of the symbol.

- if the UE is configured with multiple TAGs within CG1 and more than 2 serving cells within CG1, and if the SRS transmission of the UE in a symbol on subframe i for a given serving cell in the CG1 overlaps with the SRS transmission on subframe i for a different serving cell(s) in CG1 and with PUSCH/PUCCH transmission on subframe i or subframe $i+1$ for another serving cell(s) in CG1, the UE shall drop the SRS transmissions in CG1 if the total transmission power of CG1 exceeds $\hat{P}^{1}_{CG1}$ on any overlapped portion of the symbol.

- if the UE is configured with multiple TAGs within CG1, the UE shall, when requested by higher layers, to transmit PRACH in a secondary serving cell in CG1 in parallel with SRS transmission in a symbol on a subframe of a different serving cell belonging to a different TAG of CG1, drop SRS in CG1 if the total transmission power of CG1 exceeds $\hat{P}_{CG1}^{1}$ on any overlapped portion in the symbol.

- if the UE is configured with multiple TAGs within CG1, the UE shall, when requested by higher layers, to transmit PRACH in a secondary serving cell in CG1 in parallel with PUSCH/PUCCH in a different serving cell belonging to a different TAG in CG1, adjust the transmission power of PUSCH/PUCCH in CG1 so that its total transmission power of CG1 does not exceed $\hat{P}_{CG1}^{1}$ on the overlapped portion.

Table 5.1.4.2-1: γ_{MCG} (or γ_{SCG}) values for determining power allocation for dual connectivity

p-MeNB (or p-SeNB)	γ_{MCG} (or γ_{SCG}) Value (in %)
0	0
1	5
2	10
3	15
4	20
5	30
6	37
7	44
8	50
9	56
10	63
11	70
12	80
13	90
14	95
15	100

5.1.5 Power allocation for PUCCH-SCell

If a UE is configured with a PUCCH-SCell, power allocation for serving cells in the primary PUCCH group and secondary PUCCH group is performed according to section 5.1.4.1, with the following exceptions:

- the term 'MCG' is replaced by 'primary PUCCH group';

- the term 'SCG' is replaced by 'secondary PUCCH group';

- $i1 = i2 = i$ and $\hat{P}_{\mathrm{CMAX}}(i1, i2) = \hat{P}_{\mathrm{CMAX}}(i)$ is the linear value of the UE total configured maximum output power P_{CMAX} defined in [6] in subframe *i*; and

- $\gamma_{\mathrm{MCG}} = \gamma_{\mathrm{SCG}} = 0$.

5.2 Downlink power allocation

The eNodeB determines the downlink transmit energy per resource element.

For the purpose of RSRP and RSRQ measurements, the UE may assume downlink cell-specific RS EPRE is constant across the downlink system bandwidth and constant across all subframes with discovery signal transmissions until different cell-specific RS power information is received.

For a cell that is not a LAA Scell, the UE may assume downlink cell-specific RS EPRE is constant across the downlink system bandwidth and constant across all subframes until different cell-specific RS power information is received.

The downlink cell-specific reference-signal EPRE can be derived from the downlink reference-signal transmit power given by the parameter *referenceSignalPower* provided by higher layers. The downlink reference-signal transmit power is defined as the linear average over the power contributions (in [W]) of all resource elements that carry cell-specific reference signals within the operating system bandwidth.

For a LAA SCell, the UE may assume that the EPRE of downlink cell-specific RS in subframe n is same as the EPRE of downlink cell-specific RS in subframe n-1, if all OFDM symbols of at least the second slot of subframe n-1, are occupied.

The ratio of PDSCH EPRE to cell-specific RS EPRE among PDSCH REs (not applicable to PDSCH REs with zero EPRE) for each OFDM symbol is denoted by either ρ_A or ρ_B according to the OFDM symbol index as given by Table 5.2-2 and Table 5.2-3. In addition, ρ_A and ρ_B are UE-specific.

For a UE in transmission mode 8 - 10 when UE-specific RSs are not present in the PRBs upon which the corresponding PDSCH is mapped or in transmission modes 1 – 7, the UE may assume that for 16 QAM, 64 QAM, or 256QAM, spatial multiplexing with more than one layer or for PDSCH transmissions associated with the multi-user MIMO transmission scheme,

- ρ_A is equal to $\delta_{\text{power-offset}} + P_A + 10\log_{10}(2)$ [dB] when the UE receives a PDSCH data transmission using precoding for transmit diversity with 4 cell-specific antenna ports according to subclause 6.3.4.3 of [3];
- ρ_A is equal to $\delta_{\text{power-offset}} + P_A$ [dB] otherwise

where $\delta_{\text{power-offset}}$ is 0 dB for all PDSCH transmission schemes except multi-user MIMO and where P_A is a UE specific parameter provided by higher layers.

For a UE configured with higher layers parameter *servCellp-a-r12*, and the UE in transmission modes 8-10 when UE-specific RSs are not present in the PRBs upon which the corresponding PDSCH is mapped or in transmission modes 1-7, the UE may assume that for QPSK and transmission with single-antenna port or transmit diversity transmission schemes or spatial multiplexing using a single transmission layer, and the PDSCH transmission is not associated with the multi-user MIMO transmission scheme, and the PDSCH is scheduled by a PDCCH/EPDCCH with CRC scrambled by C-RNTI,

- ρ_A is equal to $P'_A + 10 \cdot \log_{10}(2)$ [dB] when the UE receives a PDSCH data transmission using precoding for transmit diversity with 4 cell-specific antenna ports according to subclause 6.3.4.3 of [3];
- ρ_A is equal to P'_A [dB] otherwise

and where P'_A is given by the parameter *servCellp-a-r12*.

For a cell supporting SC-PTM, the UE may assume that for the PDSCH scrambled by G-RNTI,

- ρ_A is equal to $P''_A + 10 \cdot \log_{10}(2)$ [dB] when the UE receives a PDSCH data transmission using precoding for transmit diversity with 4 cell-specific antenna ports according to subclause 6.3.4.3 of [3];
- ρ_A is equal to P''_A [dB] otherwise

where P''_A is configured per SC-MTCH and is given by higher layer parameter *p-a-r13*. If P''_A is not configured, the UE may assume that $P''_A = 0$ [dB].

For transmission mode 7, if UE-specific RSs are present in the PRBs upon which the corresponding PDSCH is mapped, the ratio of PDSCH EPRE to UE-specific RS EPRE within each OFDM symbol containing UE-specific RSs shall be a constant, and that constant shall be maintained over all the OFDM symbols containing the UE-specific RSs in the corresponding PRBs. In addition, the UE may assume that for 16QAM, 64QAM, or 256QAM, this ratio is 0 dB.

For transmission mode 8, if UE-specific RSs are present in the PRBs upon which the corresponding PDSCH is mapped, the UE may assume the ratio of PDSCH EPRE to UE-specific RS EPRE within each OFDM symbol containing UE-specific RSs is 0 dB.

For transmission mode 9 or 10, if UE-specific RSs are present in the PRBs upon which the corresponding PDSCH is mapped, the UE may assume the ratio of PDSCH EPRE to UE-specific RS EPRE within each OFDM symbol containing UE-specific RS is 0 dB for number of transmission layers less than or equal to two and -3 dB otherwise.

A UE may assume that downlink positioning reference signal EPRE is constant across the positioning reference signal bandwidth and across all OFDM symbols that contain positioning reference signals in a given positioning reference signal occasion [10].

For the purpose of RSRP and RSRQ measurements on CSI-RS of a discovery signal the UE may assume that the EPRE of CSI-RS is constant across the downlink system bandwidth and constant across all subframes with discovery signal transmissions for each CSI-RS resource.

If a serving cell is not configured for a UE as a LAA Scell, and if CSI-RS is configured in the serving cell then the UE shall assume downlink CSI-RS EPRE is constant across the downlink system bandwidth and constant across all subframes for each CSI-RS resource.

If a serving cell is configured for a UE as a LAA Scell, the UE may assume that EPRE of CSI-RS in subframe n2 is same as EPRE of CSI-RS in earlier subframe n1, if all OFDM symbols of subframe n1 and all subframes between subframe n1 and subframe n2, are occupied.

The cell-specific ratio ρ_B / ρ_A is given by Table 5.2-1 according to cell-specific parameter P_B signalled by higher layers and the number of configured eNodeB cell specific antenna ports. P_B is given by higher layer parameter *p-b-r13* for PDSCH scrambled by G-RNTI and by higher layer parameter *p-b* otherwise. In case PDSCH is scrambled by G-RNTI, if P_B is not configured, the UE may assume that $\rho_B / \rho_A = 1$.

Table 5.2-1: The cell-specific ratio ρ_B / ρ_A for 1, 2, or 4 cell specific antenna ports

P_B	ρ_B / ρ_A	
	One Antenna Port	**Two and Four Antenna Ports**
0	1	5/4
1	4/5	1
2	3/5	3/4
3	2/5	1/2

For PMCH with 16QAM, 64QAM, or 256QAM, the UE may assume that the ratio of PMCH EPRE to MBSFN RS EPRE is equal to 0 dB.

Table 5.2-2: OFDM symbol indices within a slot of a non-MBSFN subframe where the ratio of the corresponding PDSCH EPRE to the cell-specific RS EPRE is denoted by ρ_A or ρ_B

Number of antenna ports	OFDM symbol indices within a slot where the ratio of the corresponding PDSCH EPRE to the cell-specific RS EPRE is denoted by ρ_A		OFDM symbol indices within a slot where the ratio of the corresponding PDSCH EPRE to the cell-specific RS EPRE is denoted by ρ_B	
	Normal cyclic prefix	**Extended cyclic prefix**	**Normal cyclic prefix**	**Extended cyclic prefix**
One or two	1, 2, 3, 5, 6	1, 2, 4, 5	0, 4	0, 3
Four	2, 3, 5, 6	2, 4, 5	0, 1, 4	0, 1, 3

Table 5.2-3: OFDM symbol indices within a slot of an MBSFN subframe where the ratio of the corresponding PDSCH EPRE to the cell-specific RS EPRE is denoted by ρ_A or ρ_B

Number of antenna ports	OFDM symbol indices within a slot where the ratio of the corresponding PDSCH EPRE to the cell-specific RS EPRE is denoted by ρ_A				OFDM symbol indices within a slot where the ratio of the corresponding PDSCH EPRE to the cell-specific RS EPRE is denoted by ρ_B			
	Normal cyclic prefix		Extended cyclic prefix		Normal cyclic prefix		Extended cyclic prefix	
	n_s mod 2 = 0	n_s mod 2 = 1	n_s mod 2 = 0	n_s mod 2 = 1	n_s mod 2 = 0	n_s mod 2 = 1	n_s mod 2 = 0	n_s mod 2 = 1
One or two	1, 2, 3, 4, 5, 6	0, 1, 2, 3, 4, 5, 6	1, 2, 3, 4, 5	0, 1, 2, 3, 4, 5	0	-	0	-
Four	2, 3, 4, 5, 6	0, 1, 2, 3, 4, 5, 6	2, 4, 3, 5	0, 1, 2, 3, 4, 5	0, 1	-	0, 1	-

5.2.1 eNodeB Relative Narrowband TX Power (RNTP) restrictions

The determination of reported Relative Narrowband TX Power indication $RNTP(n_{PRB})$ is defined as follows:

$$RNTP(n_{PRB}) = \begin{cases} 0 & \text{if} \quad \dfrac{E_A(n_{PRB})}{E_{\max\_nom}^{(p)}} \le RNTP_{threshold} \\ 1 & \text{if} \quad \text{no promise about the upper limit of } \dfrac{E_A(n_{PRB})}{E_{\max\_nom}^{(p)}} \text{ is made} \end{cases}$$

where $E_A(n_{PRB})$ is the maximum intended EPRE of UE-specific PDSCH REs in OFDM symbols not containing RS in this physical resource block on antenna port *p* in the considered future time interval; n_{PRB} is the physical resource block number $n_{PRB} = 0,...,N_{RB}^{DL} - 1$; $RNTP_{threshold}$ takes on one of the following values $RNTP_{threshold} \in \{-\infty,-11,-10,-9,-8,-7,-6,-5,-4,-3,-2,-1,0,+1,+2,+3\}$ [dB] and

$$E_{\max\_nom}^{(p)} = \frac{P_{\max}^{(p)} \cdot \dfrac{1}{\Delta f}}{N_{RB}^{DL} \cdot N_{SC}^{RB}}$$

where $P_{\max}^{(p)}$ is the base station maximum output power described in [7], and Δf, N_{RB}^{DL} and N_{SC}^{RB} are defined in [3].

6 Random access procedure

If the UE is configured with a SCG, the UE shall apply the procedures described in this clause for both MCG and SCG

- When the procedures are applied for MCG, the terms 'secondary cell', 'secondary cells' , 'serving cell', 'serving cells' in this clause refer to secondary cell, secondary cells, serving cell, serving cells belonging to the MCG respectively.
- When the procedures are applied for SCG, the terms 'secondary cell', 'secondary cells', 'serving cell', 'serving cells' in this clause refer to secondary cell, secondary cells (not including PSCell), serving cell, serving cells belonging to the SCG respectively. The term 'primary cell' in this clause refers to the PSCell of the SCG

Prior to initiation of the non-synchronized physical random access procedure, Layer 1 shall receive the following information from the higher layers:

- Random access channel parameters (PRACH configuration and frequency position)
- Parameters for determining the root sequences and their cyclic shifts in the preamble sequence set for the primary cell (index to logical root sequence table, cyclic shift (N_{CS}), and set type (unrestricted or restricted set))

6.1 Physical non-synchronized random access procedure

From the physical layer perspective, the L1 random access procedure encompasses the transmission of random access preamble and random access response. The remaining messages are scheduled for transmission by the higher layer on the shared data channel and are not considered part of the L1 random access procedure. A random access channel occupies 6 resource blocks in a subframe or set of consecutive subframes reserved for random access preamble transmissions. The eNodeB is not prohibited from scheduling data in the resource blocks reserved for random access channel preamble transmission.

The following steps are required for the L1 random access procedure:

- Layer 1 procedure is triggered upon request of a preamble transmission by higher layers.
- A preamble index, a target preamble received power (PREAMBLE_RECEIVED_TARGET_POWER), a corresponding RA-RNTI and a PRACH resource are indicated by higher layers as part of the request.
- For a BL/CE UE, a number of PRACH repetitions for preamble transmission attempt is also indicated by higher layers as part of the request. For a non-BL/CE UE or for a BL/CE UE with the PRACH coverage enhancement level 0/1/2, a preamble transmission power P_{PRACH} is determined as
  $P_{\mathrm{PRACH}} = \min\{ P_{\mathrm{CMAX,c}}(i),\ \mathrm{PREAMBLE_RECEIVED_TARGET_POWER} + PL_c \}$_[dBm], where $P_{\mathrm{CMAX,c}}(i)$ is the configured UE transmit power defined in [6] for subframe i of serving cell c and PL_c is the downlink path loss estimate calculated in the UE for serving cell c . For a BL/CE UE, P_{PRACH} is set to $P_{\mathrm{CMAX,c}}(i)$ for the highest PRACH coverage enhancement level 3.
- A preamble sequence is selected from the preamble sequence set using the preamble index.
- A single preamble is transmitted using the selected preamble sequence with transmission power P_{PRACH} on the indicated PRACH resource. For a BL/CE UE, the single preamble is transmitted for the number of PRACH repetitions for the associated PRACH coverage enhancement level as indicated by higher layers.
- For non-BL/CE UEs, detection of a PDCCH with the indicated RA-RNTI is attempted during a window controlled by higher layers (see [8], subclause 5.1.4). If detected, the corresponding DL-SCH transport block is passed to higher layers. The higher layers parse the transport block and indicate the 20-bit uplink grant to the physical layer, which is processed according to subclause 6.2.
- For BL/CE UEs, detection of a MPDCCH with DCI scrambled by RA-RNTI is attempted during a window controlled by higher layers (see [8], subclause 5.1.4). If detected, the corresponding DL-SCH transport block is passed to higher layers. The higher layers parse the transport block and indicate the Nr-bit uplink grant to the physical layer, which is processed according to subclause 6.2.

6.1.1 Timing

For the L1 random access procedure, a non-BL/CE UE's uplink transmission timing after a random access preamble transmission is as follows.

a) If a PDCCH with associated RA-RNTI is detected in subframe *n*, and the corresponding DL-SCH transport block contains a response to the transmitted preamble sequence, the UE shall, according to the information in the response, transmit an UL-SCH transport block in the first subframe $n+k_1$, $k_1 \geq 6$, if the UL delay field in subclause 6.2 is set to zero where $n+k_1$ is the first available UL subframe for PUSCH transmission, where for TDD serving cell, the first UL subframe for PUSCH transmission is determined based on the UL/DL configuration (i.e., the parameter *subframeAssignment*) indicated by higher layers. The UE shall postpone the PUSCH transmission to the next available UL subframe after $n+k_1$ if the field is set to 1.

b) If a random access response is received in subframe *n*, and the corresponding DL-SCH transport block does not contain a response to the transmitted preamble sequence, the UE shall, if requested by higher layers, be ready to transmit a new preamble sequence no later than in subframe $n+5$.

c) If no random access response is received in subframe *n*, where subframe *n* is the last subframe of the random access response window, the UE shall, if requested by higher layers, be ready to transmit a new preamble sequence no later than in subframe $n+4$.

For the L1 random access procedure, a BL/CE UE's uplink transmission after a random access preamble transmission is as follows.

a) If a MPDCCH with associated RA-RNTI is detected and the corresponding DL-SCH transport block reception ending in subframe *n* contains a response to the transmitted preamble sequence, the UE shall, according to the information in the response, transmit an UL-SCH transport block in the first subframe $n+k_1$, $k_1 \geq 6$, if the UL delay field in subclause 6.2 is set to zero where the subframe $n+k_1$ is the first available UL subframe for PUSCH transmission, where for TDD serving cell, the first UL subframe for PUSCH transmission is determined based on the UL/DL configuration (i.e., the parameter *subframeAssignment*) indicated by higher layers.

   When the number of Msg3 PUSCH repetitions, Δ, as indicated in the random access response, is greater than 1, the subframe $n+k_1$ is the first available UL subframe in the set of BL/CE UL subframes. The UE shall postpone the PUSCH transmission to the next available UL subframe after $n+k_1+\Delta$, if the UL delay field is set to 1.

   When the number of Msg3 PUSCH repetitions, Δ, as indicated in the random access response, is equal to 1, the subframe $n+k_1$ is the first available UL subframe for PUSCH transmission determined by $k_1 = 6$ for FDD and the parameter *subframeAssignment* for TDD. The UE shall postpone the PUSCH transmission to the next available UL subframe after $n+k_1+\Delta$, if the UL delay field is set to 1.

b) If a random access response is received and its reception ends in subframe *n*, and the corresponding DL-SCH transport block does not contain a response to the transmitted preamble sequence, the UE shall, if requested by higher layers, be ready to transmit a new preamble sequence no later than in subframe $n+5$.

c) If no random access response is received in subframe *n*, where subframe *n* is the last subframe of the random access response window, the UE shall, if requested by higher layers, be ready to transmit a new preamble sequence no later than in subframe $n+4$.

In case a random access procedure is initiated by a "PDCCH order" in subframe *n* for non-BL/CE UEs, or "PDCCH order" reception ending in subframe *n* for BL/CE UEs, the UE shall, if requested by higher layers, transmit random access preamble in the first subframe $n+k_2$, $k_2 \geq 6$, where a PRACH resource is available.

If a UE is configured with multiple TAGs, and if the UE is configured with the carrier indicator field for a given serving cell, the UE shall use the carrier indicator field value from the detected "PDCCH order" to determine the serving cell for the corresponding random access preamble transmission.

6.2 Random Access Response Grant

The higher layers indicate the Nr-bit UL Grant to the physical layer, as defined in 3GPP TS 36.321 [8]. This is referred to the Random Access Response Grant in the physical layer.

If BL/CE UE then

- If the most recent PRACH coverage enhancement level for the UE is 0 or 1, the contents of the Random Access Response Grant are interpreted according to CEModeA.

- If the most recent PRACH coverage enhancement level for the UE is 2 or 3, the contents of the Random Access Response Grant are interpreted according to CEModeB.

- The content of these Nr bits starting with the MSB and ending with the LSB are given in Table 6-2 for CEmodeA and CEmodeB:

- where $N_{\mathrm{NB}} = \left\lfloor N_{\mathrm{RB}}^{\mathrm{UL}} / 6 \right\rfloor$ and $N_{\mathrm{NB}}^{index} = \left\lceil \log_2(N_{\mathrm{NB}}) \right\rceil$

Table 6-2: Random Access Response Grant Content field size

DCI contents	CEmodeA	CEmodeB
Msg3 PUSCH narrowband index	N_{NB}^{index}	2
Msg3 PUSCH Resource allocation	4	3
Number of Repetitions for Msg3 PUSCH	2	3
MCS	3	0
TBS	0	2
TPC	3	0
CSI request	1	0
UL delay	1	0
Msg3/4 MPDCCH narrowband index	2	2
Zero padding	4 - N_{NB}^{index}	0
Total Nr-bits	20	12

- For CEmodeB, the Msg3 PUSCH narrowband index indicates the narrowband to be used for first subframe of Msg3 PUSCH transmission as given in Table 6.2-A.

- NB_{RAR} given in Table 6.2-A and Table 6.2-B is the narrow band used for first subframe of MPDCCH for Random Access Response and is determined by higher layer parameter *mpdcch-NarrowbandsToMonitor-r13* if only one narrowband is configured, otherwise, it is determined by Table 6-2-E.

Table 6.2-A: Msg3 PUSCH Narrowband Value for CEmodeB.

Value of 'Msg3 narrowband index'	Msg3 PUSCH Narrowband
'00'	$NB_{RAR} \bmod N_{NB}$
'01'	$(NB_{RAR} + 1) \bmod N_{NB}$
'10'	$(NB_{RAR} + 2) \bmod N_{NB}$
'11'	$(NB_{RAR} + 3) \bmod N_{NB}$

- The Msg3/4 MPDCCH narrowband index indicates the narrowband used for first subframe of MPDCCH for Msg3 PUSCH retransmission and MPDCCH for Msg4 PDSCH transmission as given in Table 6.2-B. The number of downlink narrowbands is given by $N_{\mathrm{NB2}} = \left\lfloor N_{\mathrm{RB}}^{\mathrm{DL}} / 6 \right\rfloor$.

Table 6.2-B: Msg3/4 MPDCCH Narrowband Value for CEmodeA and CEmodeB.

Value of 'Msg3/4 MPDCCH narrowband index'	Msg3/4 MPDCCH Narrowband
'00'	$NB_{RAR} \bmod N_{NB2}$
'01'	$(NB_{RAR}+1) \bmod N_{NB2}$
'10'	$(NB_{RAR}+2) \bmod N_{NB2}$
'11'	$(NB_{RAR}+3) \bmod N_{NB2}$

- The repetition number field in the random access response grant configured by higher layers indicates the repetition level for Msg3 PUSCH as given in Table 6.2-C for CEmodeA and Table 6.2-D for CEmodeB, where
  - Y_A is determined by higher layer parameter *pusch-maxNumRepetitionCEmodeA-r13* if it is signaled, otherwise Y_A = 8,
  - Y_B is determined by higher layer parameter *pusch-maxNumRepetitionCEmodeB-r13* if it is signaled, otherwise Y_B = 512.

Table 6.2-C: Msg3 PUSCH Repetition Level Value for CEmodeA.

Value of 'Repetition number'	Msg3 PUSCH Repetition level
'00'	$Y_A/8$
'01'	$Y_A/4$
'10'	$Y_A/2$
'11'	Y_A

Table 6.2-D: Msg3 PUSCH Repetition Level Value for CEmodeB.

Value of 'Repetition number'	Msg3 PUSCH Repetition level
'000'	$Y_B/128$
'001'	$Y_B/64$
'010'	$Y_B/32$
'011'	$Y_B/16$
'100'	$Y_B/8$
'101'	$Y_B/4$
'110'	$Y_B/2$
'111'	Y_B

Table 6.2-E: Narrowband (NB_{RAR}) for MPDCCH RAR.

Mapped Preamble Index	NB_{RAR}
mod(Preamble Index, 2)=0	First narrowband configured by high layer parameter *mpdcch-NarrowbandsToMonitor-r13*
mod(Preamble Index, 2)=1	Second narrowband configured by high layer parameter *mpdcch-NarrowbandsToMonitor-r13*

- The resource allocation field is interpreted as follows:

  - For CEmodeA, insert one most significant bit with value set to '0', and interpret the expanded resource allocation using UL resource allocation type 0 within the indicated narrowband.

  - For CEmodeB, interpret the resource allocation using UL resource allocation type 2 within the indicated narrowband.

- The truncated modulation and coding scheme field is interpreted such that the modulation and coding scheme corresponding to the Random Access Response grant is determined from MCS indices 0 through 7 for CEmodeA in Table 8.6.1-1

The truncated TBS field is interpreted such that the TBS value corresponding to the Random Access Response grant is determined from TBS indices 0 through 3 for CEmodeB in Table 7.1.7.2.1-1

else,

- Nr=20, and the content of these 20 bits starting with the MSB and ending with the LSB are as follows:

- Hopping flag – 1 bit

- Fixed size resource block assignment – 10 bits

- Truncated modulation and coding scheme – 4 bits

- TPC command for scheduled PUSCH – 3 bits

- UL delay – 1 bit

- CSI request – 1 bit

- The UE shall use the single-antenna port uplink transmission scheme for the PUSCH transmission corresponding to the Random Access Response Grant and the PUSCH retransmission for the same transport block.

- The UE shall perform PUSCH frequency hopping if the single bit frequency hopping (FH) field in a corresponding Random Access Response Grant is set as 1 and the uplink resource block assignment is type 0, otherwise no PUSCH frequency hopping is performed. When the hopping flag is set, the UE shall perform PUSCH hopping as indicated via the fixed size resource block assignment detailed below.

- The fixed size resource block assignment field is interpreted as follows:

- if $N_{\mathrm{RB}}^{\mathrm{UL}} \leq 44$

  - Truncate the fixed size resource block assignment to its b least significant bits, where $b = \left\lceil \log_2 \left(N_{\mathrm{RB}}^{\mathrm{UL}} \cdot \left(N_{\mathrm{RB}}^{\mathrm{UL}} + 1 \right) / 2 \right) \right\rceil$, and interpret the truncated resource block assignment according to the rules for a regular DCI format 0

- else

  - Insert b most significant bits with value set to '0' after the N_{UL_hop} hopping bits in the fixed size resource block assignment, where the number of hopping bits N_{UL_hop} is zero when the hopping flag bit is not set to 1, and is defined in Table 8.4-1 when the hopping flag bit is set to 1, and $b = \left(\left\lceil \log_2 \left(N_{\mathrm{RB}}^{\mathrm{UL}} \cdot \left(N_{\mathrm{RB}}^{\mathrm{UL}} + 1 \right) / 2 \right) \right\rceil - 10 \right)$, and interpret the expanded resource block assignment according to the rules for a regular DCI format 0

- end if

- The truncated modulation and coding scheme field is interpreted such that the modulation and coding scheme corresponding to the Random Access Response grant is determined from MCS indices 0 through 15 in Table 8.6.1-1.

- The TPC command δ_{msg2} shall be used for setting the power of the PUSCH, and is interpreted according to Table 6.2-1.

end if

Table 6.2-1: TPC Command δ_{msg2} for Scheduled PUSCH

TPC Command	Value (in dB)
0	-6
1	-4
2	-2
3	0
4	2
5	4
6	6
7	8

In non-contention based random access procedure, the CSI request field is interpreted to determine whether an aperiodic CQI, PMI, RI, and CRI report is included in the corresponding PUSCH transmission according to subclause 7.2.1. In contention based random access procedure, the CSI request field is reserved.

The UL delay applies for TDD, FDD and FDD-TDD and this field can be set to 0 or 1 to indicate whether the delay of PUSCH is introduced as shown in subclause 6.1.1.

7 Physical downlink shared channel related procedures

If the UE is configured with a SCG, the UE shall apply the procedures described in this clause for both MCG and SCG unless stated otherwise

- When the procedures are applied for MCG, the terms ‘secondary cell’, ‘secondary cells’, ‘serving cell’, and ‘serving cells’ in this clause refer to secondary cell, secondary cells, serving cell or serving cells belonging to the MCG respectively unless stated otherwise. The terms ‘subframe’ and ‘subframes’ refer to subframe or subframes belonging to MCG.
- When the procedures are applied for SCG, the terms ‘secondary cell’, ‘secondary cells’, ‘serving cell’ and ‘serving cells’ in this clause refer to secondary cell, secondary cells (not including the PSCell), serving cell, serving cells belonging to the SCG respectively unless stated otherwise. The term ‘primary cell’ in this clause refers to the PSCell of the SCG. The terms ‘subframe’ and ‘subframes’ refer to subframe or subframes belonging to SCG

If a UE is configured with a LAA Scell, the UE shall apply the procedures described in this clause assuming frame structure type 1 for the LAA Scell unless stated otherwise.

For FDD, there shall be a maximum of 8 downlink HARQ processes per serving cell.

For FDD-TDD and primary cell frame structure type 1, there shall be a maximum of 8 downlink HARQ processes per serving cell.

For TDD and a UE not configured with the parameter *EIMTA-MainConfigServCell-r12* for any serving cell,, if the UE is configured with one serving cell, or if the UE is configured with more than one serving cell and the TDD UL/DL configuration of all the configured serving cells is the same, the maximum number of downlink HARQ processes per serving cell shall be determined by the UL/DL configuration (Table 4.2-2 of [3]), as indicated in Table 7-1.

For TDD, if a UE is configured with more than one serving cell and if the TDD UL/DL configuration of at least two configured serving cells is not the same, or if the UE is configured with the parameter *EIMTA-MainConfigServCell-r12* for at least one serving cell, or for FDD-TDD and primary cell frame structure type 2 and serving cell frame structure type 2, the maximum number of downlink HARQ processes for a serving cell shall be determined as indicated in Table 7-1, wherein the "TDD UL/DL configuration" in Table 7-1 refers to the DL-reference UL/DL configuration for the serving cell (as defined in subclause 10.2).

For FDD-TDD and primary cell frame structure type 2 and serving cell frame structure type 1, the maximum number of downlink HARQ processes for the serving cell shall be determined by the DL-reference UL/DL configuration for the serving cell (as defined in subclause 10.2), as indicated in Table 7-2.

A BL/CE UE configured with CEModeB is not expected to support more than 2 downlink HARQ processes.

For TDD and a BL/CE configured with CEModeA, the maximum number of downlink HARQ processes for a serving cell shall be determined as indicated in Table 7-3.

The dedicated broadcast HARQ process defined in [8] is not counted as part of the maximum number of HARQ processes for FDD, TDD and FDD-TDD.

Table 7-1: Maximum number of DL HARQ processes for TDD

TDD UL/DL configuration	Maximum number of HARQ processes
0	4
1	7
2	10
3	9
4	12
5	15
6	6

Table 7-2: Maximum number of DL HARQ processes for FDD-TDD, primary cell frame structure type 2, and serving cell frame structure type 1

DL-reference UL/DL Configuration	Maximum number of HARQ processes
0	10
1	11
2	12
3	15
4	16
5	16
6	12

Table 7-3: Maximum number of DL HARQ processes for TDD (UE configured with CEModeA)

TDD UL/DL configuration	Maximum number of HARQ processes
0	6
1	9
2	12
3	11
4	14
5	16
6	8

7.1 UE procedure for receiving the physical downlink shared channel

Except the subframes indicated by the higher layer parameter *mbsfn-SubframeConfigList* or by *mbsfn-SubframeConfigList-v12x0* or by *laa-SCellSubframeConfig* of serving cell c , a UE shall

- upon detection of a PDCCH of the serving cell with DCI format 1, 1A, 1B, 1C, 1D, 2, 2A, 2B, 2C, or 2D intended for the UE in a subframe, or

- upon detection of an EPDCCH of the serving cell with DCI format 1, 1A, 1B, 1D, 2, 2A, 2B, 2C, or 2D intended for the UE in a subframe

decode the corresponding PDSCH in the same subframe with the restriction of the number of transport blocks defined in the higher layers.

For BL/CE UEs , the higher layers indicate the set of BL/CE DL subframes according to *fdd-DownlinkOrTddSubframeBitmapBR* [11].

A BL/CE UE shall upon detection of a MPDCCH with DCI format 6-1A, 6-1B, 6-2 intended for the UE, decode the corresponding PDSCH in one more BL/CE DL subframes as described in subclause 7.1.11, with the restriction of the number of transport blocks defined in the higher layers.

For the purpose of decoding PDSCH containing *SystemInformationBlockType2,* a BL/CE UE shall assume that subframes in which *SystemInformationBlockType2* is scheduled are non-MBSFN subframes.

If a UE is configured with more than one serving cell and if the frame structure type of any two configured serving cells is different, then the UE is considered to be configured for FDD-TDD carrier aggregation.

Except for MBMS reception, the UE is not required to monitor PDCCH with CRC scrambled by the SI-RNTI on the PSCell.

A UE may assume that positioning reference signals are not present in resource blocks in which it shall decode PDSCH according to a detected PDCCH with CRC scrambled by the SI-RNTI or P-RNTI with DCI format 1A or 1C intended for the UE.

A UE configured with the carrier indicator field for a given serving cell shall assume that the carrier indicator field is not present in any PDCCH of the serving cell in the common search space that is described in subclause 9.1. Otherwise, the configured UE shall assume that for the given serving cell the carrier indicator field is present in PDCCH/EPDCCH located in the UE specific search space described in subclause 9.1 when the PDCCH/EPDCCH CRC is scrambled by C-RNTI or SPS C-RNTI.

If a UE is configured by higher layers to decode PDCCH with CRC scrambled by the SI-RNTI, the UE shall decode the PDCCH and the corresponding PDSCH according to any of the combinations defined in Table 7.1-1. The scrambling initialization of PDSCH corresponding to these PDCCHs is by SI-RNTI.

Table 7.1-1: PDCCH and PDSCH configured by SI-RNTI

DCI format	Search Space	Transmission scheme of PDSCH corresponding to PDCCH
DCI format 1C	Common	If the number of PBCH antenna ports is one, Single-antenna port, port 0 is used (see subclause 7.1.1), otherwise Transmit diversity (see subclause 7.1.2).
DCI format 1A	Common	If the number of PBCH antenna ports is one, Single-antenna port, port 0 is used (see subclause 7.1.1), otherwise Transmit diversity (see subclause 7.1.2).

For BL/CE UE, for PDSCH carrying *SystemInformationBlockType1-BR* and SI-messages, the UE shall decode PDSCH according to Table 7.1-1A. The scrambling initialization of PDSCH is by SI-RNTI.

Table 7.1-1A: PDSCH configured by SI-RNTI

Transmission scheme of PDSCH
If the number of PBCH antenna ports is one, Single-antenna port, port 0 is used (see subclause 7.1.1), otherwise Transmit diversity (see subclause 7.1.2).

If a UE is configured by higher layers to decode PDCCH with CRC scrambled by the P-RNTI, the UE shall decode the PDCCH and the corresponding PDSCH according to any of the combinations defined in Table 7.1-2.
The scrambling initialization of PDSCH corresponding to these PDCCHs is by P-RNTI.

If a UE is configured by higher layers to decode MPDCCH with CRC scrambled by the P-RNTI, the UE shall decode the MPDCCH and any corresponding PDSCH according to any of the combinations defined in Table 7.1-2A.
The scrambling initialization of PDSCH corresponding to these MPDCCHs is by P-RNTI.

The UE is not required to monitor PDCCH with CRC scrambled by the P-RNTI on the PSCell.

Table 7.1-2: PDCCH and PDSCH configured by P-RNTI

DCI format	Search Space	Transmission scheme of PDSCH corresponding to PDCCH
DCI format 1C	Common	If the number of PBCH antenna ports is one, Single-antenna port, port 0 is used (see subclause 7.1.1), otherwise Transmit diversity (see subclause 7.1.2)
DCI format 1A	Common	If the number of PBCH antenna ports is one, Single-antenna port, port 0 is used (see subclause 7.1.1), otherwise Transmit diversity (see subclause 7.1.2)

Table 7.1-2A: MPDCCH and PDSCH configured by P-RNTI

DCI format	Search Space	Transmission scheme of PDSCH corresponding to MPDCCH
6-2	Type1-common	If the number of PBCH antenna ports is one, Single-antenna port, port 0 is used (see subclause 7.1.1), otherwise Transmit diversity (see subclause 7.1.2)

If a UE is configured by higher layers to decode PDCCH with CRC scrambled by the RA-RNTI, the UE shall decode the PDCCH and the corresponding PDSCH according to any of the combinations defined in Table 7.1-3. The scrambling initialization of PDSCH corresponding to these PDCCHs is by RA-RNTI.

If a UE is configured by higher layers to decode MPDCCH with CRC scrambled by the RA-RNTI, the UE shall decode the MPDCCH and the corresponding PDSCH according to any of the combinations defined in Table 7.1-3A. The scrambling initialization of PDSCH corresponding to these MPDCCHs is by RA-RNTI.

When RA-RNTI and either C-RNTI or SPS C-RNTI are assigned in the same subframe, the UE is not required to decode a PDSCH on the primary cell indicated by a PDCCH/EPDCCH with a CRC scrambled by C-RNTI or SPS C-RNTI.

Table 7.1-3: PDCCH and PDSCH configured by RA-RNTI

DCI format	Search Space	Transmission scheme of PDSCH corresponding to PDCCH
DCI format 1C	Common	If the number of PBCH antenna ports is one, Single-antenna port, port 0 is used (see subclause 7.1.1), otherwise Transmit diversity (see subclause 7.1.2)
DCI format 1A	Common	If the number of PBCH antenna ports is one, Single-antenna port, port 0 is used (see subclause 7.1.1), otherwise Transmit diversity (see subclause 7.1.2)

Table 7.1-3A: MPDCCH and PDSCH configured by RA-RNTI

DCI format	Search Space	Transmission scheme of PDSCH corresponding to MPDCCH
6-1A or 6-1B	Type2-common	If the number of PBCH antenna ports is one, Single-antenna port, port 0 is used (see subclause 7.1.1), otherwise Transmit diversity (see subclause 7.1.2)

If a UE is configured by higher layers to decode PDCCH with CRC scrambled by the G-RNTI or SC-RNTI, the UE shall decode the PDCCH and the corresponding PDSCH according to any of the combinations defined in Table 7.1-4. The scrambling initialization of PDSCH corresponding to these PDCCHs is by G-RNTI or SC-RNTI.

Table 7.1-4: PDCCH and PDSCH configured by G-RNTI or SC-RNTI

DCI format	Search Space	Transmission scheme of PDSCH corresponding to PDCCH
DCI format 1C	Common	If the number of PBCH antenna ports is one, Single-antenna port, port 0 is used (see subclause 7.1.1), otherwise Transmit diversity (see subclause 7.1.2).
DCI format 1A	Common	If the number of PBCH antenna ports is one, Single-antenna port, port 0 is used (see subclause 7.1.1), otherwise Transmit diversity (see subclause 7.1.2).

If a UE is configured by higher layers to decode PDCCH with CRC scrambled by the SC-N-RNTI, the UE shall decode the PDCCH according to the combination defined in table 7.1-4A.

Table 7.1-4A: PDCCH configured by SC-N-RNTI

DCI format	Search Space
DCI format 1C	Common

The UE is semi-statically configured via higher layer signalling to receive PDSCH data transmissions signalled via PDCCH/EPDCCH according to one of the transmission modes, denoted mode 1 to mode 10.

For a BL/CE UE, the UE is semi-statically configured via higher layer signalling to receive PDSCH data transmissions signalled via MPDCCH according to one of the transmission modes: mode 1, mode 2, mode 6, and mode 9.

For LAA Scells, the UE is not expected to receive PDSCH data transmissions signalled via PDCCH/EPDCCH according to transmission modes 5,6,7.

For frame structure type 1,

- the UE is not expected to receive PDSCH resource blocks transmitted on antenna port 5 in any subframe in which the number of OFDM symbols for PDCCH with normal CP is equal to four;
- a non-BL/CE UE is not expected to receive PDSCH resource blocks transmitted on antenna port 5, 7, 8, 9, 10, 11, 12, 13 or 14 in the two PRBs to which a pair of VRBs is mapped if either one of the two PRBs overlaps in frequency with a transmission of either PBCH or primary or secondary synchronization signals in the same subframe;
- the UE is not expected to receive PDSCH resource blocks transmitted on antenna port 7 for which distributed VRB resource allocation is assigned.
- The UE may skip decoding the transport block(s) if it does not receive all assigned PDSCH resource blocks except if it is capable of receiving the non-colliding PDSCH resource blocks in an assignment which partly collides in frequency with a transmission of PBCH or primary synchronization signal or secondary synchronization signal in the same subframes and that capability is indicated by *pdsch-CollisionHandling* [12]. If the UE skips decoding, the physical layer indicates to higher layer that the transport block(s) are not successfully decoded.

For frame structure type 2,

- the UE is not expected to receive PDSCH resource blocks transmitted on antenna port 5 in any subframe in which the number of OFDM symbols for PDCCH with normal CP is equal to four;
- the UE is not expected to receive PDSCH resource blocks transmitted on antenna port 5 in the two PRBs to which a pair of VRBs is mapped if either one of the two PRBs overlaps in frequency with a transmission of PBCH in the same subframe;
- a non-BL/CE UE is not expected to receive PDSCH resource blocks transmitted on antenna port 7, 8, 9, 10, 11, 12, 13 or 14 in the two PRBs to which a pair of VRBs is mapped if either one of the two PRBs overlaps in frequency with a transmission of primary or secondary synchronization signals in the same subframe;
- with normal CP configuration, the UE is not expected to receive PDSCH on antenna port 5 for which distributed VRB resource allocation is assigned in the special subframe with configuration #1 or #6;
- the UE is not expected to receive PDSCH on antenna port 7 for which distributed VRB resource allocation is assigned;
- with normal cyclic prefix, the UE is not expected to receive PDSCH resource blocks transmitted on antenna port 5 in DwPTS when the UE is configured with special subframe configuration 9.
- The UE may skip decoding the transport block(s) if it does not receive all assigned PDSCH resource blocks except if it is capable of receiving the non-colliding PDSCH resource blocks in an assignment which partly collides in frequency with a transmission of PBCH or primary synchronization signal or secondary

synchronization signal in the same subframe and that capability is indicated by *pdsch-CollisionHandling* [12]. If the UE skips decoding, the physical layer indicates to higher layer that the transport block(s) are not successfully decoded.

If a UE is configured by higher layers to decode PDCCH with CRC scrambled by the C-RNTI, the UE shall decode the PDCCH and any corresponding PDSCH according to the respective combinations defined in Table 7.1-5. The scrambling initialization of PDSCH corresponding to these PDCCHs is by C-RNTI.

If a UE is configured by higher layers to decode EPDCCH with CRC scrambled by the C-RNTI, the UE shall decode the EPDCCH and any corresponding PDSCH according to the respective combinations defined in Table 7.1-5A. The scrambling initialization of PDSCH corresponding to these EPDCCHs is by C-RNTI.

If a BL/CE UE is configured by higher layers to decode MPDCCH with CRC scrambled by the C-RNTI, the UE shall decode the MPDCCH and any corresponding PDSCH according to the respective combinations defined in Table 7.1-5B. The scrambling initialization of PDSCH corresponding to these MPDCCHs is by C-RNTI.

If a UE is configured with CEModeA, the UE shall decode MPDCCH DCI Format 6-1A. If the UE is configured with CEModeB, the UE shall decode MPDCCH DCI Format 6-1B.

If the UE is configured with the carrier indicator field for a given serving cell and, if the UE is configured by higher layers to decode PDCCH/EPDCCH with CRC scrambled by the C-RNTI, then the UE shall decode PDSCH of the serving cell indicated by the carrier indicator field value in the decoded PDCCH/EPDCCH.

When a UE configured in transmission mode 3, 4, 8, 9 or 10 receives a DCI Format 1A assignment, it shall assume that the PDSCH transmission is associated with transport block 1 and that transport block 2 is disabled.

When a UE is configured in transmission mode 7, scrambling initialization of UE-specific reference signals corresponding to these PDCCHs/EPDCCHs is by C-RNTI.

The UE does not support transmission mode 8 if extended cyclic prefix is used in the downlink.

When a UE is configured in transmission mode 9 or 10, in the downlink subframes indicated by the higher layer parameter *mbsfn-SubframeConfigList* or by *mbsfn-SubframeConfigList-v12x0* or by *laa-SCellSubframeConfig* of serving cell c except in subframes for the serving cell

- indicated by higher layers to decode PMCH or,
- configured by higher layers to be part of a positioning reference signal occasion and the positioning reference signal occasion is only configured within MBSFN subframes and the cyclic prefix length used in subframe #0 is normal cyclic prefix,

the UE shall upon detection of a PDCCH with CRC scrambled by the C-RNTI with DCI format 1A/2C/2D intended for the UE or, upon detection of an EPDCCH with CRC scrambled by the C-RNTI with DCI format 1A/2C/2D intended for the UE, decode the corresponding PDSCH in the same subframe.

A UE configured in transmission mode 10 can be configured with scrambling identities, $n_{\mathrm{ID}}^{\mathrm{DMRS},i}$, $i=0,1$ by higher layers for UE-specific reference signal generation as defined in subclause 6.10.3.1 of [3] to decode PDSCH according to a detected PDCCH/EPDCCH with CRC scrambled by the C-RNTI with DCI format 2D intended for the UE.

Table 7.1-5: PDCCH and PDSCH configured by C-RNTI

Transmission mode	DCI format	Search Space	Transmission scheme of PDSCH corresponding to PDCCH
Mode 1	DCI format 1A	Common and UE specific by C-RNTI	Single-antenna port, port 0 (see subclause 7.1.1)
	DCI format 1	UE specific by C-RNTI	Single-antenna port, port 0 (see subclause 7.1.1)
Mode 2	DCI format 1A	Common and UE specific by C-RNTI	Transmit diversity (see subclause 7.1.2)
	DCI format 1	UE specific by C-RNTI	Transmit diversity (see subclause 7.1.2)
Mode 3	DCI format 1A	Common and UE specific by C-RNTI	Transmit diversity (see subclause 7.1.2)
	DCI format 2A	UE specific by C-RNTI	Large delay CDD (see subclause 7.1.3) or Transmit diversity (see subclause 7.1.2)
Mode 4	DCI format 1A	Common and UE specific by C-RNTI	Transmit diversity (see subclause 7.1.2)
	DCI format 2	UE specific by C-RNTI	Closed-loop spatial multiplexing (see subclause 7.1.4)or Transmit diversity (see subclause 7.1.2)
Mode 5	DCI format 1A	Common and UE specific by C-RNTI	Transmit diversity (see subclause 7.1.2)
	DCI format 1D	UE specific by C-RNTI	Multi-user MIMO (see subclause 7.1.5)
Mode 6	DCI format 1A	Common and UE specific by C-RNTI	Transmit diversity (see subclause 7.1.2)
	DCI format 1B	UE specific by C-RNTI	Closed-loop spatial multiplexing (see subclause 7.1.4) using a single transmission layer
Mode 7	DCI format 1A	Common and UE specific by C-RNTI	If the number of PBCH antenna ports is one, Single-antenna port, port 0 is used (see subclause 7.1.1), otherwise Transmit diversity (see subclause 7.1.2)
	DCI format 1	UE specific by C-RNTI	Single-antenna port, port 5 (see subclause 7.1.1)
Mode 8	DCI format 1A	Common and UE specific by C-RNTI	If the number of PBCH antenna ports is one, Single-antenna port, port 0 is used (see subclause 7.1.1), otherwise Transmit diversity (see subclause 7.1.2)
	DCI format 2B	UE specific by C-RNTI	Dual layer transmission, port 7 and 8 (see subclause 7.1.5A) or single-antenna port, port 7 or 8 (see subclause 7.1.1)
Mode 9	DCI format 1A	Common and UE specific by C-RNTI	• Non-MBSFN subframe: If the number of PBCH antenna ports is one, Single-antenna port, port 0 is used (see subclause 7.1.1), otherwise Transmit diversity (see subclause 7.1.2) • MBSFN subframe: Single-antenna port, port 7 (see subclause 7.1.1)
	DCI format 2C	UE specific by C-RNTI	Up to 8 layer transmission, ports 7-14 (see subclause 7.1.5B) or single-antenna port, port 7, 8, 11, or 13 (see subclause 7.1.1) if UE is configured with higher layer parameter *dmrs-tableAlt,* single-antenna port, port 7 or 8 (see subclause 7.1.1) otherwise
Mode 10	DCI format 1A	Common and UE specific by C-RNTI	• Non-MBSFN subframe: If the number of PBCH antenna ports is one, Single-antenna port, port 0 is used (see subclause 7.1.1), otherwise Transmit diversity (see subclause 7.1.2) • MBSFN subframe: Single-antenna port, port 7 (see subclause 7.1.1)
	DCI format 2D	UE specific by C-RNTI	Up to 8 layer transmission, ports 7-14 (see subclause 7.1.5B) or single-antenna port, port 7, 8, 11, or 13 (see subclause 7.1.1) if UE is configured with higher layer parameter *dmrs-tableAlt*, single-antenna port, port 7 or 8 (see subclause 7.1.1) otherwise

Table 7.1-5A: EPDCCH and PDSCH configured by C-RNTI

Transmission mode	DCI format	Search Space	Transmission scheme of PDSCH corresponding to EPDCCH
Mode 1	DCI format 1A	UE specific by C-RNTI	Single-antenna port, port 0 (see subclause 7.1.1)
	DCI format 1	UE specific by C-RNTI	Single-antenna port, port 0 (see subclause 7.1.1)
Mode 2	DCI format 1A	UE specific by C-RNTI	Transmit diversity (see subclause 7.1.2)
	DCI format 1	UE specific by C-RNTI	Transmit diversity (see subclause 7.1.2)
Mode 3	DCI format 1A	UE specific by C-RNTI	Transmit diversity (see subclause 7.1.2)
	DCI format 2A	UE specific by C-RNTI	Large delay CDD (see subclause 7.1.3) or Transmit diversity (see subclause 7.1.2)
Mode 4	DCI format 1A	UE specific by C-RNTI	Transmit diversity (see subclause 7.1.2)
	DCI format 2	UE specific by C-RNTI	Closed-loop spatial multiplexing (see subclause 7.1.4)or Transmit diversity (see subclause 7.1.2)
Mode 5	DCI format 1A	UE specific by C-RNTI	Transmit diversity (see subclause 7.1.2)
	DCI format 1D	UE specific by C-RNTI	Multi-user MIMO (see subclause 7.1.5)
Mode 6	DCI format 1A	UE specific by C-RNTI	Transmit diversity (see subclause 7.1.2)
	DCI format 1B	UE specific by C-RNTI	Closed-loop spatial multiplexing (see subclause 7.1.4) using a single transmission layer
Mode 7	DCI format 1A	UE specific by C-RNTI	If the number of PBCH antenna ports is one, Single-antenna port, port 0 is used (see subclause 7.1.1), otherwise Transmit diversity (see subclause 7.1.2)
	DCI format 1	UE specific by C-RNTI	Single-antenna port, port 5 (see subclause 7.1.1)
Mode 8	DCI format 1A	UE specific by C-RNTI	If the number of PBCH antenna ports is one, Single-antenna port, port 0 is used (see subclause 7.1.1), otherwise Transmit diversity (see subclause 7.1.2)
	DCI format 2B	UE specific by C-RNTI	Dual layer transmission, port 7 and 8 (see subclause 7.1.5A) or single-antenna port, port 7 or 8 (see subclause 7.1.1)
Mode 9	DCI format 1A	UE specific by C-RNTI	• Non-MBSFN subframe: If the number of PBCH antenna ports is one, Single-antenna port, port 0 is used (see subclause 7.1.1), otherwise Transmit diversity (see subclause 7.1.2) • MBSFN subframe: Single-antenna port, port 7 (see subclause 7.1.1)
	DCI format 2C	UE specific by C-RNTI	Up to 8 layer transmission, ports 7-14 (see subclause 7.1.5B) or single-antenna port, port 7, 8, 11, or 13 (see subclause 7.1.1) if UE is configured with higher layer parameter *dmrs-tableAlt*, single-antenna port, port 7 or 8 (see subclause 7.1.1) otherwise
Mode 10	DCI format 1A	UE specific by C-RNTI	• Non-MBSFN subframe: If the number of PBCH antenna ports is one, Single-antenna port, port 0 is used (see subclause 7.1.1), otherwise Transmit diversity (see subclause 7.1.2) • MBSFN subframe: Single-antenna port, port 7 (see subclause 7.1.1)
	DCI format 2D	UE specific by C-RNTI	Up to 8 layer transmission, ports 7-14 (see subclause 7.1.5B) or single-antenna port, port 7, 8, 11, or 13 (see subclause 7.1.1) if UE is configured with higher layer parameter *dmrs-tableAlt*, single-antenna port, port 7 or 8 (see subclause 7.1.1) otherwise

Table 7.1-5B: MPDCCH and PDSCH configured by C-RNTI

Transmission mode	DCI format	Search Space	Transmission scheme of PDSCH corresponding to MPDCCH
Mode 1	6-1A	Type0-Common	Single-antenna port, port 0 (see subclause 7.1.1)
	6-1A or 6-1B	UE specific by C-RNTI	
Mode 2	6-1A	Type0-Common	Transmit diversity (see subclause 7.1.2)
	6-1A or 6-1B	UE specific by C-RNTI	
Mode 6	6-1A	Type0-Common	Transmit diversity (see subclause 7.1.2)
	6-1A	UE specific by C-RNTI	Closed-loop spatial multiplexing (see subclause 7.1.4) using a single transmission layer
Mode 9	6-1A	Type0-Common	If the number of PBCH antenna ports is one, Single-antenna port, port 0 is used (see subclause 7.1.1), otherwise Transmit diversity (see subclause 7.1.2)
	6-1A	UE specific by C-RNTI	Single-antenna port, port 7 or 8 (see subclause 7.1.1)
	6-1B	UE specific by C-RNTI	Single-antenna port, port 7 (see subclause 7.1.1)

If a UE is configured by higher layers to decode PDCCH with CRC scrambled by the SPS C-RNTI, the UE shall decode the PDCCH on the primary cell and any corresponding PDSCH on the primary cell according to the respective combinations defined in Table 7.1-6. The same PDSCH related configuration applies in the case that a PDSCH is transmitted without a corresponding PDCCH. The scrambling initialization of PDSCH corresponding to these PDCCHs and PDSCH without a corresponding PDCCH is by SPS C-RNTI.

If a UE is configured by higher layers to decode EPDCCH with CRC scrambled by the SPS C-RNTI, the UE shall decode the EPDCCH on the primary cell and any corresponding PDSCH on the primary cell according to the respective combinations defined in Table 7.1-6A. The same PDSCH related configuration applies in the case that a PDSCH is transmitted without a corresponding EPDCCH. The scrambling initialization of PDSCH corresponding to these EPDCCHs and PDSCH without a corresponding EPDCCH is by SPS C-RNTI.

If a UE configured with CEModeA is configured by higher layers to decode MPDCCH with CRC scrambled by the SPS C-RNTI, the UE shall decode the MPDCCH on the primary cell and any corresponding PDSCH on the primary cell according to the respective combinations defined in Table 7.1-6B. The same PDSCH related configuration applies in the case that a PDSCH is transmitted without a corresponding MPDCCH. The scrambling initialization of PDSCH corresponding to these MPDCCHs and PDSCH without a corresponding MPDCCH is by SPS C-RNTI.

When a UE is configured in transmission mode 7, scrambling initialization of UE-specific reference signals for PDSCH corresponding to these PDCCHs/EPDCCHs and for PDSCH without a corresponding PDCCH/EPDCCH is by SPS C-RNTI.

When a UE is configured in transmission mode 9 or 10, in the downlink subframes indicated by the higher layer parameter *mbsfn-SubframeConfigList* or by *mbsfn-SubframeConfigList-v12x0* of serving cell c except in subframes for the serving cell

- indicated by higher layers to decode PMCH or,
- configured by higher layers to be part of a positioning reference signal occasion and the positioning reference signal occasion is only configured within MBSFN subframes and the cyclic prefix length used in subframe #0 is normal cyclic prefix,

the UE shall upon detection of a PDCCH with CRC scrambled by the SPS C-RNTI with DCI format 1A/2C/2D, or upon detection of a EPDCCH with CRC scrambled by the SPS C-RNTI with DCI format 1A/2C/2D, or for a configured PDSCH without PDCCH intended for the UE, decode the corresponding PDSCH in the same subframe.

A UE configured in transmission mode 10 can be configured with scrambling identities, $n_{\mathrm{ID}}^{\mathrm{DMRS},i}$, $i = 0,1$ by higher layers for UE-specific reference signal generation as defined in subclause 6.10.3.1 of [3] to decode PDSCH according to a detected PDCCH/EPDCCH with CRC scrambled by the SPS C-RNTI with DCI format 2D intended for the UE.

For PDSCH without a corresponding PDCCH/EPDCCH, the UE shall use the value of n_{SCID} and the scrambling identity of $n_{\mathrm{ID}}^{(n_{\mathrm{SCID}})}$ (as defined in subclause 6.10.3.1 of [3]) derived from the DCI format 2D corresponding to the associated SPS activation for UE-specific reference signal generation.

Table 7.1-6: PDCCH and PDSCH configured by SPS C-RNTI

Transmission mode	DCI format	Search Space	Transmission scheme of PDSCH corresponding to PDCCH
Mode 1	DCI format 1A	Common and UE specific by C-RNTI	Single-antenna port, port 0 (see subclause 7.1.1)
	DCI format 1	UE specific by C-RNTI	Single-antenna port, port 0 (see subclause 7.1.1)
Mode 2	DCI format 1A	Common and UE specific by C-RNTI	Transmit diversity (see subclause 7.1.2)
	DCI format 1	UE specific by C-RNTI	Transmit diversity (see subclause 7.1.2)
Mode 3	DCI format 1A	Common and UE specific by C-RNTI	Transmit diversity (see subclause 7.1.2)
	DCI format 2A	UE specific by C-RNTI	Transmit diversity (see subclause 7.1.2)
Mode 4	DCI format 1A	Common and UE specific by C-RNTI	Transmit diversity (see subclause 7.1.2)
	DCI format 2	UE specific by C-RNTI	Transmit diversity (see subclause 7.1.2)
Mode 5	DCI format 1A	Common and UE specific by C-RNTI	Transmit diversity (see subclause 7.1.2)
Mode 6	DCI format 1A	Common and UE specific by C-RNTI	Transmit diversity (see subclause 7.1.2)
Mode 7	DCI format 1A	Common and UE specific by C-RNTI	Single-antenna port, port 5 (see subclause 7.1.1)
	DCI format 1	UE specific by C-RNTI	Single-antenna port, port 5 (see subclause 7.1.1)
Mode 8	DCI format 1A	Common and UE specific by C-RNTI	Single-antenna port, port 7(see subclause 7.1.1)
	DCI format 2B	UE specific by C-RNTI	Single-antenna port, port 7 or 8 (see subclause 7.1.1)
Mode 9	DCI format 1A	Common and UE specific by C-RNTI	Single-antenna port, port 7 (see subclause 7.1.1)
	DCI format 2C	UE specific by C-RNTI	Single-antenna port, port 7, 8, 11, or 13 (see subclause 7.1.1) if UE is configured with higher layer parameter *dmrs-tableAlt*, Single-antenna port, port 7 or 8, (see subclause 7.1.1) otherwise
Mode 10	DCI format 1A	Common and UE specific by C-RNTI	Single-antenna port, port 7 (see subclause 7.1.1)
	DCI format 2D	UE specific by C-RNTI	Single-antenna port, port 7, 8, 11, or 13 (see subclause 7.1.1) if UE is configured with higher layer parameter *dmrs-tableAlt*, Single-antenna port, port 7 or 8, (see subclause 7.1.1) otherwise

Table 7.1-6A: EPDCCH and PDSCH configured by SPS C-RNTI

Transmission mode	DCI format	Search Space	Transmission scheme of PDSCH corresponding to EPDCCH
Mode 1	DCI format 1A	UE specific by C-RNTI	Single-antenna port, port 0 (see subclause 7.1.1)
	DCI format 1	UE specific by C-RNTI	Single-antenna port, port 0 (see subclause 7.1.1)
Mode 2	DCI format 1A	UE specific by C-RNTI	Transmit diversity (see subclause 7.1.2)
	DCI format 1	UE specific by C-RNTI	Transmit diversity (see subclause 7.1.2)
Mode 3	DCI format 1A	UE specific by C-RNTI	Transmit diversity (see subclause 7.1.2)
	DCI format 2A	UE specific by C-RNTI	Transmit diversity (see subclause 7.1.2)
Mode 4	DCI format 1A	UE specific by C-RNTI	Transmit diversity (see subclause 7.1.2)
	DCI format 2	UE specific by C-RNTI	Transmit diversity (see subclause 7.1.2)
Mode 5	DCI format 1A	UE specific by C-RNTI	Transmit diversity (see subclause 7.1.2)
Mode 6	DCI format 1A	UE specific by C-RNTI	Transmit diversity (see subclause 7.1.2)
Mode 7	DCI format 1A	UE specific by C-RNTI	Single-antenna port, port 5 (see subclause 7.1.1)
	DCI format 1	UE specific by C-RNTI	Single-antenna port, port 5 (see subclause 7.1.1)
Mode 8	DCI format 1A	UE specific by C-RNTI	Single-antenna port, port 7(see subclause 7.1.1)
	DCI format 2B	UE specific by C-RNTI	Single-antenna port, port 7 or 8 (see subclause 7.1.1)
Mode 9	DCI format 1A	UE specific by C-RNTI	Single-antenna port, port 7 (see subclause 7.1.1)
	DCI format 2C	UE specific by C-RNTI	Single-antenna port, port 7, 8, 11, or 13 (see subclause 7.1.1) if UE is configured with higher layer parameter *dmrs-tableAlt*, Single-antenna port, port 7 or 8, (see subclause 7.1.1) otherwise
Mode 10	DCI format 1A	UE specific by C-RNTI	Single-antenna port, port 7 (see subclause 7.1.1)
	DCI format 2D	UE specific by C-RNTI	Single-antenna port, port 7, 8, 11, or 13 (see subclause 7.1.1) if UE is configured with higher layer parameter *dmrs-tableAlt*, Single-antenna port, port 7 or 8, (see subclause 7.1.1) otherwise

Table 7.1-6B: MPDCCH and PDSCH configured by SPS C-RNTI

Transmission mode	DCI format	Search Space	Transmission scheme of PDSCH corresponding to MPDCCH
Mode 1	6-1A	UE specific by C-RNTI	Single-antenna port, port 0 (see subclause 7.1.1)
Mode 2	6-1A	UE specific by C-RNTI	Transmit diversity (see subclause 7.1.2)
Mode 6	6-1A	UE specific by C-RNTI	Transmit diversity (see subclause 7.1.2)
Mode 9	6-1A	UE specific by C-RNTI	Single-antenna port, port 7 or 8 (see subclause 7.1.1)

NOTE: For BL/CE UEs configured with transmission mode 6, and for DCI 6-1A mapped onto the UE specific search space and with CRC scrambled by the SPS C-RNTI, the bits corresponding to TPMI information for precoding and PMI information for precoding are set to zero.

If a UE is configured by higher layers to decode PDCCH with CRC scrambled by the Temporary C-RNTI and is not configured to decode PDCCH with CRC scrambled by the C-RNTI, the UE shall decode the PDCCH and the corresponding PDSCH according to the combination defined in Table 7.1-7. The scrambling initialization of PDSCH corresponding to these PDCCHs is by Temporary C-RNTI.

If a UE is configured by higher layers to decode MPDCCH with CRC scrambled by the Temporary C-RNTI and is not configured to decode MPDCCH with CRC scrambled by the C-RNTI during random access procedure, the UE shall decode the MPDCCH and the corresponding PDSCH according to the combination defined in Table 7.1-8. The scrambling initialization of PDSCH corresponding to these MPDCCHs is by Temporary C-RNTI.

If a UE is also configured by higher layers to decode MPDCCH with CRC scrambled by the C-RNTI during random access procedure, the UE shall decode the MPDCCH and the corresponding PDSCH according to the combination defined in Table 7.1-8. The scrambling initialization of PDSCH corresponding to these MPDCCHs is by C-RNTI.

Table 7.1-7: PDCCH and PDSCH configured by Temporary C-RNTI

DCI format	Search Space	Transmission scheme of PDSCH corresponding to PDCCH
DCI format 1A	Common and UE specific by Temporary C-RNTI	If the number of PBCH antenna port is one, Single-antenna port, port 0 is used (see subclause 7.1.1), otherwise Transmit diversity (see subclause 7.1.2)
DCI format 1	UE specific by Temporary C-RNTI	If the number of PBCH antenna port is one, Single-antenna port, port 0 is used (see subclause 7.1.1), otherwise Transmit diversity (see subclause 7.1.2)

Table 7.1-8: MPDCCH and PDSCH configured by Temporary C-RNTI and/or C-RNTI during random access procedure

DCI format	Search Space	Transmission scheme of PDSCH corresponding to MPDCCH
DCI format 6-1A	Type2-Common	If the number of PBCH antenna port is one, Single-antenna port, port 0 is used (see subclause 7.1.1), otherwise Transmit diversity (see subclause 7.1.2)
DCI format 6-1B	Type2-Common	If the number of PBCH antenna port is one, Single-antenna port, port 0 is used (see subclause 7.1.1), otherwise Transmit diversity (see subclause 7.1.2)

The transmission schemes of the PDSCH are described in the following sub-subclauses.

7.1.1 Single-antenna port scheme

For the single-antenna port transmission schemes (port 0/5/7/8/11/13) of the PDSCH, the UE may assume that an eNB transmission on the PDSCH would be performed according to subclause 6.3.4.1 of [3].

If the UE is not configured with higher layer parameter *dmrs-tableAlt* and in case an antenna port $p \in \{7,8\}$ is used, or if the higher layer parameter *dmrs-tableAlt* is set to 1 and in case an antenna port $p \in \{7,8\}$ corresponding to one codeword values 0-3 in Table 5.3.3.1.5C-2 [4] is used, the UE cannot assume that the other antenna port in the set $\{7,8\}$ is not associated with transmission of PDSCH to another UE.

If the UE is configured with higher layer parameter *dmrs-tableAlt*, and in case of single layer transmission scheme on antenna port $p \in \{7,8,11,13\}$ corresponding to one codeword values 4-11 in Table 5.3.3.1.5C-2 [4] is used, the UE cannot assume that the other antenna ports in the set $\{7,8,11,13\}$ is not associated with transmission of PDSCH to another UE.

7.1.2 Transmit diversity scheme

For the transmit diversity transmission scheme of the PDSCH, the UE may assume that an eNB transmission on the PDSCH would be performed according to subclause 6.3.4.3 of [3]

7.1.3 Large delay CDD scheme

For the large delay CDD transmission scheme of the PDSCH, the UE may assume that an eNB transmission on the PDSCH would be performed according to large delay CDD as defined in subclause 6.3.4.2.2 of [3].

7.1.4 Closed-loop spatial multiplexing scheme

For the closed-loop spatial multiplexing transmission scheme of the PDSCH, the UE may assume that an eNB transmission on the PDSCH would be performed according to the applicable number of transmission layers as defined in subclause 6.3.4.2.1 of [3].

7.1.5 Multi-user MIMO scheme

For the multi-user MIMO transmission scheme of the PDSCH, the UE may assume that an eNB transmission on the PDSCH would be performed on one layer and according to subclause 6.3.4.2.1 of [3]. The $\delta_{\text{power-offset}}$ dB value signalled on PDCCH/EPDCCH with DCI format 1D using the downlink power offset field is given in Table 7.1.5-1.

Table 7.1.5-1: Mapping of downlink power offset field in DCI format 1D to the $\delta_{\text{power-offset}}$ value.

Downlink power offset field	$\delta_{\text{power-offset}}$ [dB]
0	$-10\log_{10}(2)$
1	0

7.1.5A Dual layer scheme

For the dual layer transmission scheme of the PDSCH, the UE may assume that an eNB transmission on the PDSCH would be performed with two transmission layers on antenna ports 7 and 8 as defined in subclause 6.3.4.4 of [3].

7.1.5B Up to 8 layer transmission scheme

For the up to 8 layer transmission scheme of the PDSCH, the UE may assume that an eNB transmission on the PDSCH would be performed with up to 8 transmission layers on antenna ports 7 - 14 as defined in subclause 6.3.4.4 of [3].

If the UE is configured with higher layer parameter *dmrs-tableAlt*, and in case of dual layer transmission scheme on antenna ports $\{7,8\}$ or $\{11,13\}$ corresponding to two codewords values 2-5 in Table 5.3.3.1.5C-2 [4] is used, the UE cannot assume that the other antenna ports in the set $\{7,8,11,13\}$ is not associated with transmission of PDSCH to another UE.

7.1.6 Resource allocation

The UE shall interpret the resource allocation field depending on the PDCCH/EPDCCH DCI format detected. A resource allocation field in each PDCCH/EPDCCH includes two parts, a resource allocation header field and information consisting of the actual resource block assignment.

PDCCH DCI formats 1, 2, 2A, 2B, 2C and 2D with type 0 and PDCCH DCI formats 1, 2, 2A, 2B, 2C and 2D with type 1 resource allocation have the same format and are distinguished from each other via the single bit resource allocation header field which exists depending on the downlink system bandwidth (subclause 5.3.3.1 of [4]), where type 0 is indicated by 0 value and type 1 is indicated otherwise. PDCCH with DCI format 1A, 1B, 1C and 1D have a type 2 resource allocation while PDCCH with DCI format 1, 2, 2A, 2B, 2C and 2D have type 0 or type 1 resource allocation. PDCCH DCI formats with a type 2 resource allocation do not have a resource allocation header field.

EPDCCH DCI formats 1, 2, 2A, 2B, 2C and 2D with type 0 and EPDCCH DCI formats 1, 2, 2A, 2B, 2C and 2D with type 1 resource allocation have the same format and are distinguished from each other via the single bit resource allocation header field which exists depending on the downlink system bandwidth (subclause 5.3.3.1 of [4]), where type 0 is indicated by 0 value and type 1 is indicated otherwise. EPDCCH with DCI format 1A, 1B, and 1D have a type 2 resource allocation while EPDCCH with DCI format 1, 2, 2A, 2B, 2C and 2D have type 0 or type 1 resource allocation. EPDCCH DCI formats with a type 2 resource allocation do not have a resource allocation header field.

MPDCCH with DCI format 6-1A utilizes a type 2 resource allocation. Resource allocation for MPDCCH with DCI format 6-1B is given by the Resource block assignment field as described in [4]. MPDCCH with DCI format 6-2 assigns a set of six contiguously allocated localized virtual resource blocks within a narrowband. Localized virtual resource blocks are always used in case of MPDCCH with DCI format 6-1A, 6-1B, or 6-2.

A UE may assume, for any PDSCH transmission scheduled by a cell with physical cell identity given in *NAICS-AssistanceInfo-r12* and the PDSCH transmission mode belonging to *transmissionModeList-r12* associated with the cell except spatial multiplexing using up to 8 transmission layers in transmission mode 10, that the resource allocation granularity and precoding granularity in terms of PRB pairs in the frequency domain are both given by N, where N is given by the higher layer parameter *resAllocGranularity-r12* associated with the cell. The first set of N consecutive PRB pairs of the resource allocation starts from the lowest frequency of the system bandwidth and the UE may assume the same precoding applies to all PRB pairs within a set.

For a BL/CE UE, the resource allocation for PDSCH carrying *SystemInformationBlockType1-BR* and SI messages is a set of six contiguously allocated localized virtual resource blocks within a narrowband. The number of repetitions for the PDSCH carrying *SystemInformationBlockType1-BR* is determined based on the parameter *schedulingInfoSIB1-BR-r13* configured by higher-layers and according to Table 7.1.6-1. If the value of the parameter *schedulingInfoSIB1-BR-r13* configured by higher-layers is set to 0, UE assumes that *SystemInformationBlockType1-BR* is not transmitted.

Table 7.1.6-1: Number of repetitions for PDSCH carrying *SystemInformationBlockType1-BR* for BL/CE UE.

Value of *schedulingInfoSIB1-BR-r13*	Number of PDSCH repetitions
0	N/A
1	4
2	8
3	16
4	4
5	8
6	16
7	4
8	8
9	16
10	4
11	8
12	16
13	4
14	8
15	16
16	4
17	8
18	16
19-31	Reserved

7.1.6.1 Resource allocation type 0

In resource allocations of type 0, resource block assignment information includes a bitmap indicating the Resource Block Groups (RBGs) that are allocated to the scheduled UE where a RBG is a set of consecutive virtual resource blocks (VRBs) of localized type as defined in subclause 6.2.3.1 of [3]. Resource block group size (P) is a function of the system bandwidth as shown in Table 7.1.6.1-1. The total number of RBGs (N_{RBG}) for downlink system bandwidth of $N_{\mathrm{RB}}^{\mathrm{DL}}$ is given by $N_{RBG} = \lceil N_{\mathrm{RB}}^{\mathrm{DL}} / P \rceil$ where $\lfloor N_{\mathrm{RB}}^{\mathrm{DL}} / P \rfloor$ of the RBGs are of size P and if $N_{\mathrm{RB}}^{\mathrm{DL}} \bmod P > 0$ then one of the RBGs is of size $N_{\mathrm{RB}}^{\mathrm{DL}} - P \cdot \lfloor N_{\mathrm{RB}}^{\mathrm{DL}} / P \rfloor$. The bitmap is of size N_{RBG} bits with one bitmap bit per RBG such that each RBG is addressable. The RBGs shall be indexed in the order of increasing frequency and non-increasing RBG sizes starting at the lowest frequency. The order of RBG to bitmap bit mapping is in such way that RBG 0 to RBG $N_{\mathrm{RBG}} - 1$ are mapped to MSB to LSB of the bitmap. The RBG is allocated to the UE if the corresponding bit value in the bitmap is 1, the RBG is not allocated to the UE otherwise.

Table 7.1.6.1-1: Type 0 resource allocation RBG size vs. Downlink System Bandwidth

System Bandwidth $N_{\mathrm{RB}}^{\mathrm{DL}}$	RBG Size (*P*)
≤10	1
11 – 26	2
27 – 63	3
64 – 110	4

7.1.6.2 Resource allocation type 1

In resource allocations of type 1, a resource block assignment information of size N_{RBG} indicates to a scheduled UE the VRBs from the set of VRBs from one of P RBG subsets. The virtual resource blocks used are of localized type as defined in subclause 6.2.3.1 of [3]. Also P is the RBG size associated with the system bandwidth as shown in Table

7.1.6.1-1. A RBG subset p, where $0 \leq p < P$, consists of every P th RBG starting from RBG p. The resource block assignment information consists of three fields [4].

The first field with $\lceil \log_2(P) \rceil$ bits is used to indicate the selected RBG subset among P RBG subsets.

The second field with one bit is used to indicate a shift of the resource allocation span within a subset. A bit value of 1 indicates shift is triggered. Shift is not triggered otherwise.

The third field includes a bitmap, where each bit of the bitmap addresses a single VRB in the selected RBG subset in such a way that MSB to LSB of the bitmap are mapped to the VRBs in the increasing frequency order. The VRB is allocated to the UE if the corresponding bit value in the bit field is 1, the VRB is not allocated to the UE otherwise. The portion of the bitmap used to address VRBs in a selected RBG subset has size $N_{\mathrm{RB}}^{\mathrm{TYPE1}}$ and is defined as

$$N_{\mathrm{RB}}^{\mathrm{TYPE1}} = \left\lceil N_{\mathrm{RB}}^{\mathrm{DL}} / P \right\rceil - \left\lceil \log_2(P) \right\rceil - 1$$

The addressable VRB numbers of a selected RBG subset start from an offset, $\Delta_{\mathrm{shift}}(p)$ to the smallest VRB number within the selected RBG subset, which is mapped to the MSB of the bitmap. The offset is in terms of the number of VRBs and is done within the selected RBG subset. If the value of the bit in the second field for shift of the resource allocation span is set to 0, the offset for RBG subset p is given by $\Delta_{\mathrm{shift}}(p) = 0$. Otherwise, the offset for RBG subset p is given by $\Delta_{\mathrm{shift}}(p) = N_{\mathrm{RB}}^{\mathrm{RBG\,subset}}(p) - N_{\mathrm{RB}}^{\mathrm{TYPE1}}$, where the LSB of the bitmap is justified with the highest VRB number within the selected RBG subset. $N_{\mathrm{RB}}^{\mathrm{RBG\,subset}}(p)$ is the number of VRBs in RBG subset p and can be calculated by the following equation,

$$N_{\mathrm{RB}}^{\mathrm{RBG\ subset}}(p) = \begin{cases} \left\lfloor \frac{N_{\mathrm{RB}}^{\mathrm{DL}} - 1}{P^2} \right\rfloor \cdot P + P & , p < \left\lfloor \frac{N_{\mathrm{RB}}^{\mathrm{DL}} - 1}{P} \right\rfloor \bmod P \\ \left\lfloor \frac{N_{\mathrm{RB}}^{\mathrm{DL}} - 1}{P^2} \right\rfloor \cdot P + (N_{\mathrm{RB}}^{\mathrm{DL}} - 1) \bmod P + 1 & , p = \left\lfloor \frac{N_{\mathrm{RB}}^{\mathrm{DL}} - 1}{P} \right\rfloor \bmod P \\ \left\lfloor \frac{N_{\mathrm{RB}}^{\mathrm{DL}} - 1}{P^2} \right\rfloor \cdot P & , p > \left\lfloor \frac{N_{\mathrm{RB}}^{\mathrm{DL}} - 1}{P} \right\rfloor \bmod P \end{cases}$$

Consequently, when RBG subset p is indicated, bit i for $i = 0,1,\cdots, N_{\mathrm{RB}}^{\mathrm{TYPE1}} - 1$ in the bitmap field indicates VRB number,

$$n_{\mathrm{VRB}}^{\mathrm{RBG\ subset}}(p) = \left\lfloor \frac{i + \Delta_{\mathrm{shift}}(p)}{P} \right\rfloor P^2 + p \cdot P + \left(i + \Delta_{\mathrm{shift}}(p)\right) \bmod P .$$

7.1.6.3 Resource allocation type 2

For BL/CE UEs with resource allocation type 2 resource assignment, $N_{\mathrm{RB}}^{\mathrm{DL}} = 6$ and $N_{\mathrm{VRB}}^{\mathrm{DL}} = 6$ is used in the rest of this subclause.

In resource allocations of type 2, the resource block assignment information indicates to a scheduled UE a set of contiguously allocated localized virtual resource blocks or distributed virtual resource blocks. In case of resource allocation signalled with PDCCH DCI format 1A, 1B or 1D, or for resource allocation signalled with EPDCCH DCI format 1A, 1B, or 1D, one bit flag indicates whether localized virtual resource blocks or distributed virtual resource blocks are assigned (value 0 indicates Localized and value 1 indicates Distributed VRB assignment) while distributed virtual resource blocks are always assigned in case of resource allocation signalled with PDCCH DCI format 1C. Localized VRB allocations for a UE vary from a single VRB up to a maximum number of VRBs spanning the system bandwidth. For DCI format 1A the distributed VRB allocations for a UE vary from a single VRB up to $N_{\mathrm{VRB}}^{\mathrm{DL}}$ VRBs, where $N_{\mathrm{VRB}}^{\mathrm{DL}}$ is defined in [3], if the DCI CRC is scrambled by P-RNTI, RA-RNTI, or SI-RNTI. With PDCCH DCI format 1B, 1D with a CRC scrambled by C-RNTI, or with DCI format 1A with a CRC scrambled with C-RNTI, SPS C-

RNTI or Temporary C-RNTI distributed VRB allocations for a UE vary from a single VRB up to $N_{\mathrm{VRB}}^{\mathrm{DL}}$ VRBs if $N_{\mathrm{RB}}^{\mathrm{DL}}$ is 6-49 and vary from a single VRB up to 16 if $N_{\mathrm{RB}}^{\mathrm{DL}}$ is 50-110. With EPDCCH DCI format 1B, 1D with a CRC scrambled by C-RNTI, or with DCI format 1A with a CRC scrambled with C-RNTI, SPS C-RNTI distributed VRB allocations for a UE vary from a single VRB up to $N_{\mathrm{VRB}}^{\mathrm{DL}}$ VRBs if $N_{\mathrm{RB}}^{\mathrm{DL}}$ is 6-49 and vary from a single VRB up to 16 if $N_{\mathrm{RB}}^{\mathrm{DL}}$ is 50-110. With PDCCH DCI format 1C, distributed VRB allocations for a UE vary from $N_{\mathrm{RB}}^{\mathrm{step}}$ VRB(s) up to $\lfloor N_{\mathrm{VRB}}^{\mathrm{DL}} / N_{\mathrm{RB}}^{\mathrm{step}} \rfloor \cdot N_{\mathrm{RB}}^{\mathrm{step}}$ VRBs with an increment step of $N_{\mathrm{RB}}^{\mathrm{step}}$, where $N_{\mathrm{RB}}^{\mathrm{step}}$ value is determined depending on the downlink system bandwidth as shown in Table 7.1.6.3-1.

Table 7.1.6.3-1: $N_{\mathrm{RB}}^{\mathrm{step}}$ values vs. Downlink System Bandwidth

System BW ($N_{\mathrm{RB}}^{\mathrm{DL}}$)	$N_{\mathrm{RB}}^{\mathrm{step}}$
	DCI format 1C
6-49	2
50-110	4

For PDCCH DCI format 1A, 1B or 1D, or for EPDCCH DCI format 1A, 1B, or 1D, or for MPDCCH DCI format 6-1A, a type 2 resource allocation field consists of a resource indication value (*RIV*) corresponding to a starting resource block (RB_{start}) and a length in terms of virtually contiguously allocated resource blocks L_{CRBs}. The resource indication value is defined by

if $(L_{CRBs} - 1) \le \lfloor N_{RB}^{DL} / 2 \rfloor$ then

$$RIV = N_{RB}^{DL}(L_{CRBs} - 1) + RB_{start}$$

else

$$RIV = N_{RB}^{DL}(N_{RB}^{DL} - L_{CRBs} + 1) + (N_{RB}^{DL} - 1 - RB_{start})$$

where $L_{CRBs} \ge 1$ and shall not exceed $N_{VRB}^{DL} - RB_{start}$.

For PDCCH DCI format 1C, a type 2 resource block assignment field consists of a resource indication value (*RIV*) corresponding to a starting resource block ($RB_{start} = 0$, $N_{\mathrm{RB}}^{\mathrm{step}}$, $2N_{\mathrm{RB}}^{\mathrm{step}}, \ldots,$ $(\lfloor N_{\mathrm{VRB}}^{\mathrm{DL}} / N_{\mathrm{RB}}^{\mathrm{step}} \rfloor - 1) N_{\mathrm{RB}}^{\mathrm{step}}$) and a length in terms of virtually contiguously allocated resource blocks ($L_{CRBs} = N_{\mathrm{RB}}^{\mathrm{step}}$, $2N_{\mathrm{RB}}^{\mathrm{step}}, \ldots,$ $\lfloor N_{\mathrm{VRB}}^{\mathrm{DL}} / N_{\mathrm{RB}}^{\mathrm{step}} \rfloor \cdot N_{\mathrm{RB}}^{\mathrm{step}}$).
The resource indication value is defined by:

if $(L'_{CRBs} - 1) \le \lfloor N'^{DL}_{VRB} / 2 \rfloor$ then

$$RIV = N'^{DL}_{VRB}(L'_{CRBs} - 1) + RB'_{start}$$

else

$$RIV = N'^{DL}_{VRB}(N'^{DL}_{VRB} - L'_{CRBs} + 1) + (N'^{DL}_{VRB} - 1 - RB'_{start})$$

where $L'_{CRBs} = L_{CRBs} / N_{RB}^{step}$, $RB'_{start} = RB_{start} / N_{RB}^{step}$ and $N'^{DL}_{VRB} = \lfloor N_{VRB}^{DL} / N_{RB}^{step} \rfloor$. Here,

$L'_{CRBs} \ge 1$ and shall not exceed $N'^{DL}_{VRB} - RB'_{start}$.

7.1.6.4 PDSCH starting position

This subclause describes PDSCH starting position for UEs that are not BL/CE UEs.

PDSCH starting position for BL/CE UEs is described in subclause 7.1.6.4A.

The starting OFDM symbol for the PDSCH of each activated serving cell is given by index $l_{\text{DataStart}}$.

For a UE configured in transmission mode 1-9, for a given activated serving cell

- if the PDSCH is assigned by EPDCCH received in the same serving cell, or if the UE is configured to monitor EPDCCH in the subframe and the PDSCH is not assigned by a PDCCH/EPDCCH, and if the UE is configured with the higher layer parameter *epdcch-StartSymbol-r11*
  - $l_{\text{DataStart}}$ is given by the higher-layer parameter *epdcch-StartSymbol-r11*.
- else if PDSCH and the corresponding PDCCH/EPDCCH are received on different serving cells
  - $l_{\text{DataStart}}$ is given by the higher-layer parameter *pdsch-Start-r10* for the serving cell on which PDSCH is received,
- Otherwise
  - $l_{\text{DataStart}}$ is given by the CFI value in the subframe of the given serving cell when $N_{\text{RB}}^{\text{DL}} > 10$, and $l_{\text{DataStart}}$ is given by the CFI value + 1 in the subframe of the given serving cell when $N_{\text{RB}}^{\text{DL}} \leq 10$.

For a UE configured in transmission mode 10, for a given activated serving cell

- if the PDSCH is assigned by a PDCCH with DCI format 1C or by a PDCCH with DCI format 1A and with CRC scrambled with P-RNTI/RA-RNTI/SI-RNTI/Temporary C-RNTI
  - $l_{\text{DataStart}}$ is given by the span of the DCI given by the CFI value in the subframe of the given serving cell according to subclause 5.3.4 of [4].
- if the PDSCH is assigned by a PDCCH/EPDCCH with DCI format 1A and with CRC scrambled with C-RNTI and if the PDSCH transmission is on antenna ports 0 - 3
  - if the PDSCH is assigned by EPDCCH received in the same serving cell
    - $l_{\text{DataStart}}$ is given by $l_{\text{EPDCCHStart}}$ for the EPDCCH-PRB-set where EPDCCH with the DCI format 1A was received ($l_{\text{EPDCCHStart}}$ as defined in subclause 9.1.4.1),
  - else if PDSCH and the corresponding PDCCH/EPDCCH are received on different serving cells
    - $l_{\text{DataStart}}$ is given by the higher-layer parameter *pdsch-Start-r10* for the serving cell on which PDSCH is received.
  - otherwise
    - $l_{\text{DataStart}}$ is given by the CFI value in the subframe of the given serving cell when $N_{\text{RB}}^{\text{DL}} > 10$, and $l_{\text{DataStart}}$ is given by the CFI value+1 in the subframe of the given serving cell when $N_{\text{RB}}^{\text{DL}} \leq 10$.
- if the PDSCH is assigned by or semi-statically scheduled by a PDCCH/EPDCCH with DCI format 1A and if the PDSCH transmission is on antenna port 7
  - if the value of the higher layer parameter *pdsch-Start-r11* determined from parameter set 1 in table 7.1.9-1 for the serving cell on which PDSCH is received belongs to {1,2,3,4},
    - $l'_{\text{DataStart}}$ is given by the higher layer parameter *pdsch-Start-r11* determined from parameter set 1 in table 7.1.9-1 for the serving cell on which PDSCH is received.
  - else,
    - if PDSCH and the corresponding PDCCH/EPDCCH are received on different serving cells,

- $l'_{\mathrm{DataStart}}$ is given by the higher-layer parameter *pdsch-Start-r10* for the serving cell on which PDSCH is received

- otherwise

  - $l'_{\mathrm{DataStart}}$ is given by the CFI value in the subframe of the given serving cell when $N_{\mathrm{RB}}^{\mathrm{DL}} > 10$, and $l_{\mathrm{DataStart}}$ is given by the CFI value + 1 in the subframe of the given serving cell when $N_{\mathrm{RB}}^{\mathrm{DL}} \leq 10$.

- if the subframe on which PDSCH is received is indicated by the higher layer parameter *mbsfn-SubframeConfigList-r11* determined from parameter set 1 in table 7.1.9-1 for the serving cell on which PDSCH is received, or if the PDSCH is received on subframe 1 or 6 for the frame structure type 2,

  - $l_{\mathrm{DataStart}} = \min(2, l'_{\mathrm{DataStart}})$,

- otherwise

  - $l_{\mathrm{DataStart}} = l'_{\mathrm{DataStart}}$.

- if the PDSCH is assigned by or semi-persistently scheduled by a PDCCH/EPDCCH with DCI format 2D,

  - if the value of the higher layer parameter *pdsch-Start-r11* determined from the DCI (according to subclause 7.1.9) for the serving cell on which PDSCH is received belongs to {1,2,3,4},

    - $l'_{\mathrm{DataStart}}$ is given by parameter *pdsch-Start-r11* determined from the DCI (according to subclause 7.1.9) for the serving cell on which PDSCH is received

  - else,

    - if PDSCH and the corresponding PDCCH/EPDCCH are received on different serving cells,

      - $l'_{\mathrm{DataStart}}$ is given by the higher-layer parameter *pdsch-Start-r10* for the serving cell on which PDSCH is received

    - Otherwise

      - $l'_{\mathrm{DataStart}}$ is given by the CFI value in the subframe of the given serving cell when $N_{\mathrm{RB}}^{\mathrm{DL}} > 10$, and $l_{\mathrm{DataStart}}$ is given by the CFI value+1 in the subframe of the given serving cell when $N_{\mathrm{RB}}^{\mathrm{DL}} \leq 10$.

  - if the subframe on which PDSCH is received is indicated by the higher layer parameter *mbsfn-SubframeConfigList-r11* determined from the DCI (according to subclause 7.1.9) for the serving cell on which PDSCH is received, or if the PDSCH is received on subframe 1 or 6 for frame structure type 2,

    - $l_{\mathrm{DataStart}} = \min(2, l'_{\mathrm{DataStart}})$,

  - otherwise

    - $l_{\mathrm{DataStart}} = l'_{\mathrm{DataStart}}$.

7.1.6.4A PDSCH starting position for BL/CE UEs

The starting OFDM symbol for PDSCH is given by index $l_{\mathrm{DataStart}}$ in the first slot in a subframe k and is determined as follows

- for reception of SIB1-BR

  - $l_{\mathrm{DataStart}} = 3$ if $N_{\mathrm{RB}}^{\mathrm{DL}} > 10$ for the cell on which PDSCH is received

  - $l_{\mathrm{DataStart}} = 4$ if $N_{\mathrm{RB}}^{\mathrm{DL}} \leq 10$ for the cell on which PDSCH is received

- else
  - $l'_{\mathrm{DataStart}}$ is given by the higher layer parameter *startSymbolBR*
  - if subframe k is configured as an MBSFN subframe and if the BL/CE UE is configured in CEModeA
    - $l_{\mathrm{DataStart}} = \min\left(2, l'_{\mathrm{DataStart}}\right)$
  - else
    - $l_{\mathrm{DataStart}} = l'_{\mathrm{DataStart}}$.

7.1.6.5 Physical Resource Block (PRB) bundling

A UE configured for transmission mode 9 for a given serving cell *c* may assume that precoding granularity is multiple resource blocks in the frequency domain when PMI/RI reporting is configured.

For a given serving cell c, if a UE is configured for transmission mode 10

- if PMI/RI reporting is configured for all configured CSI processes for the serving cell *c*, the UE may assume that precoding granularity is multiple resource blocks in the frequency domain,
- otherwise, the UE shall assume the precoding granularity is one resource block in the frequency domain.

Fixed system bandwidth dependent Precoding Resource block Groups (PRGs) of size P' partition the system bandwidth and each PRG consists of consecutive PRBs. If $N_{\mathrm{RB}}^{\mathrm{DL}} \bmod P' > 0$ then one of the PRGs is of size $N_{\mathrm{RB}}^{\mathrm{DL}} - P'\left\lfloor N_{\mathrm{RB}}^{\mathrm{DL}} / P' \right\rfloor$. The PRG size is non-increasing starting at the lowest frequency. The UE may assume that the same precoder applies on all scheduled PRBs within a PRG.

If the UE is a BL/CE UE P' =3 otherwise the PRG size a UE may assume for a given system bandwidth is given by:

Table 7.1.6.5-1

System Bandwidth ($N_{\mathrm{RB}}^{\mathrm{DL}}$)	PRG Size (P') (PRBs)
≤10	1
11 – 26	2
27 – 63	3
64 – 110	2

7.1.7 Modulation order and transport block size determination

To determine the modulation order and transport block size(s) in the physical downlink shared channel, the UE shall first

- if the UE is a BL/CE UE
  - if PDSCH is assigned by MPDCCH DCI format 6-1A
    - read the 4-bit "modulation and coding scheme (I^1_{MCS})" field in the DCI
    - The UE is not expected to receive a DCI format 6-1A indicating $I^1_{\mathrm{MCS}} > 15$
- if PDSCH is assigned by MPDCCH DCI format 6-2
  - read the 3-bit "modulation and coding scheme (I^1_{MCS})" field in the DCI
  - The UE is not expected to receive a DCI format 6-2 indicating $I^1_{\mathrm{MCS}} > 7$
- else if PDSCH is assigned by MPDCCH DCI format 6-1B
  - read the 4-bit "modulation and coding scheme (I^1_{MCS})" field in the DCI and set $I^1_{\mathrm{TBS}} = I^1_{\mathrm{MCS}}$.
- else if the UE is a BL/CE UE and if PDSCH carriers *SystemInformationBlockType1-BR*
  - set I_{TBS} to the value of the parameter *schedulingInfoSIB1-BR-r13* configured by higher-layers
- otherwise
  - read the 5-bit "modulation and coding scheme" field (I_{MCS}) in the DCI

and second if the PDCCH DCI CRC is scrambled by P-RNTI, RA-RNTI, or SI-RNTI then

- for DCI format 1A:
  - set the Table 7.1.7.2.1-1 column indicator N_{PRB} to $N^{1\mathrm{A}}_{\mathrm{PRB}}$ from subclause 5.3.3.1.3 in [4]
- for DCI format 1C:
  - use Table 7.1.7.2.3-1 for determining its transport block size.

else

- if the UE is a BL/CE UE
  - if MPDCCH DCI CRC is scrambled by RA-RNTI and for DCI 6-1A
    - set the Table 7.1.7.2.1-1 column indicator N_{PRB} to $N^{1\mathrm{A}}_{\mathrm{PRB}}$ from subclause 5.3.3.1.12 in [4]
  - if PDSCH is assigned by MPDCCH DCI format 6-2
    - use Table 7.1.7.2.3-1 for determining its transport block size.
  - else if PDSCH carriers *SystemInformationBlockType1-BR*
    - use subclause 7.1.7.2.7 for determining its transport block size.
  - otherwise,
    - set N'_{PRB} to the total number of allocated PRBs based on the procedure defined in subclause 7.1.6.
    - set the Table 7.1.7.2.1-1 column indicator $N_{PRB} = N'_{PRB}$.

- if PDSCH is assigned by MPDCCH DCI format 6-1B
  - use subclause 7.1.7.2.6 for determining its transport block size.
- otherwise
  - set N'_{PRB} to the total number of allocated PRBs based on the procedure defined in subclause 7.1.6.

  if the transport block is transmitted in DwPTS of the special subframe in frame structure type 2, or is transmitted in the subframes with the same duration as the DwPTS duration of a special subframe configuration in frame structure type 3, then

  - for special subframe configuration 9 with normal cyclic prefix or special subframe configuration 7 with extended cyclic prefix:
    - set the Table 7.1.7.2.1-1 column indicator $N_{PRB} = \max\left\{\left\lfloor N'_{\mathrm{PRB}} \times 0.375 \right\rfloor, \quad 1\right\}$
  - for other special subframe configurations:
    - set the Table 7.1.7.2.1-1 column indicator $N_{PRB} = \max\left\{\left\lfloor N'_{\mathrm{PRB}} \times 0.75 \right\rfloor, \quad 1\right\}$,

  else, set the Table 7.1.7.2.1-1 column indicator $N_{PRB} = N'_{PRB}$.

The UE may skip decoding a transport block in an initial transmission if the effective channel code rate is higher than 0.931, where the effective channel code rate is defined as the number of downlink information bits (including CRC bits) divided by the number of physical channel bits on PDSCH. If the UE skips decoding, the physical layer indicates to higher layer that the transport block is not successfully decoded. For the special subframe configurations 0 and 5 with normal downlink CP or configurations 0 and 4 with extended downlink CP in frame structure type 2, or for subframes with the same duration as the DwPTS duration of the special subframe configuration 0 and 5 in frame structure type 3, with the special subframe configurations shown in Table 4.2-1 of [3], a non-BL/CE UE shall assume there is no PDSCH transmission in DwPTS of the special subframe.

For frame structure type 2 and those special subframes where the MPDCCH is not supported, if these special subframes are considered as BL/CE DL subframe according to subclause 6.8B.1 of [3], the BL/CE UE shall assume PDSCH is dropped in these special subframes.

7.1.7.1 Modulation order and redundancy version determination

For BL/CE UEs configured with CEModeA, I^1_{MCS} is used in place of I_{MCS} in the rest of this subclause.

The UE shall use Q_m = 2 if the DCI CRC is scrambled by P-RNTI, RA-RNTI, SI-RNTI, or SC-RNTI, or if PDSCH is assigned by MPDCCH DCI Format 6-1B, or if PDSCH carriers *SystemInformationBlockType1-BR*, or if PDSCH carries BL/CE SI messages, otherwise,

- if the higher layer parameter *altCQI-Table-r12* is configured, and if the PDSCH is assigned by a PDCCH/EPDCCH with DCI format 1/1B/1D/2/2A/2B/2C/2D with CRC scrambled by C-RNTI,
  - if the assigned PDSCH is transmitted only in the second slot of a subframe, the UE shall use I_{MCS} and Table 7.1.7.1-1A to determine the modulation order (Q'_m). The modulation order (Q_m) used in the physical downlink shared channel is set to $Q_m = Q'_m$;
  - otherwise, the UE shall use I_{MCS} and Table 7.1.7.1-1A to determine the modulation order (Q_m) used in the physical downlink shared channel.
- else

- if the assigned PDSCH is transmitted only in the second slot of a subframe, the UE shall use I_{MCS} and Table 7.1.7.1-1 to determine the modulation order ($Q_m^{'}$). The modulation order (Q_m) used in the physical downlink shared channel is set to $Q_m = Q_m^{'}$;

- otherwise, the UE shall use I_{MCS} and Table 7.1.7.1-1 to determine the modulation order (Q_m) used in the physical downlink shared channel.

Table 7.1.7.1-1: Modulation and TBS index table for PDSCH

MCS Index I_{MCS}	Modulation Order Q_m	Modulation Order $Q_m^{'}$	TBS Index I_{TBS}
0	2	2	0
1	2	2	1
2	2	2	2
3	2	2	3
4	2	2	4
5	2	4	5
6	2	4	6
7	2	4	7
8	2	4	8
9	2	4	9
10	4	6	9
11	4	6	10
12	4	6	11
13	4	6	12
14	4	6	13
15	4	6	14
16	4	6	15
17	6	6	15
18	6	6	16
19	6	6	17
20	6	6	18
21	6	6	19
22	6	6	20
23	6	6	21
24	6	6	22
25	6	6	23
26	6	6	24
27	6	6	25
28	6	6	26/26A
29	2	2	reserved
30	4	4	
31	6	6	

Table 7.1.7.1-1A. Modulation and TBS index table 2 for PDSCH

MCS Index I_{MCS}	Modulation Order Q_m	Modulation Order $Q_m^{'}$	TBS Index I_{TBS}
0	2	2	0
1	2	2	2
2	2	2	4
3	2	4	6
4	2	4	8
5	4	6	10
6	4	6	11
7	4	6	12
8	4	6	13

MCS Index I_{MCS}	Modulation Order Q_m	Modulation Order Q'_m	TBS Index I_{TBS}
9	4	6	14
10	4	8	15
11	6	8	16
12	6	8	17
13	6	8	18
14	6	8	19
15	6	8	20
16	6	8	21
17	6	8	22
18	6	8	23
19	6	8	24
20	8	8	25
21	8	8	27
22	8	8	28
23	8	8	29
24	8	8	30
25	8	8	31
26	8	8	32
27	8	8	33/33A
28	2	2	reserved
29	4	4	
30	6	6	
31	8	8	

For BL/CE UEs, the same redundancy version is applied to PDSCH transmitted in a given block of N_{acc} consecutive subframes, if the PDSCH is not carrying *SystemInformationBlockType1-BR* or SI message. The subframe number of the first subframe in each block of N_{acc} consecutive subframes, denoted as $n_{\text{abs},1}$, satisfies $\left(n_{\text{abs},1}-\delta\right)\bmod N_{\text{acc}}=0$, where $\delta=0$ for FDD and $\delta=2$ for TDD. Denote i_0 as the subframe number of the first downlink subframe intended for PDSCH. The PDSCH transmission spans $N_{\text{abs}}^{\text{PDSCH}}$ consecutive subframes including non-BL/CE subframes where the PDSCH transmission is postponed. Note that BL/CE subframe(s) refers to either BL/CE DL subframe(s) or BL/CE UL subframe(s). For the j^{th} block of N_{acc} consecutive subframes, the redundancy version (rv_{idx}) for PDSCH is determined according to Table 7.1.7.1-2 using $rv=\left(j+rv_{DCI}\right)\bmod 4$, where $j=0,1,\ldots,J^{\text{PDSCH}}-1$ if $(i_0-\delta)\bmod N_{\text{acc}}=0$, $j=0,1,\ldots,J^{\text{PDSCH}}$ if $(i_0-\delta)\bmod N_{\text{acc}}>0$, and $J^{\text{PDSCH}}=\left\lceil\frac{N_{\text{abs}}^{\text{PDSCH}}}{N_{\text{acc}}}\right\rceil$. The J^{PDSCH} blocks of subframes are sequential in time, starting with $j=0$ to which subframe i_0 belongs. For a BL/CE UE configured in CEModeA, $N_{\text{acc}}=1$ and rv_{DCI} is determined by the 'Redundancy version' field in DCI format 6-1A. For a BL/CE UE configured with CEModeB, or a BL/CE UE receiving PDSCH associated with P-RNTI, $N_{\text{acc}}=4$ for FDD and $N_{\text{acc}}=10$ for TDD, and $rv_{DCI}=0$.

Table 7.1.7.1-2: Redundancy version

Redundancy version Index rv	rv_{idx}
0	0
1	2
2	3
3	1

7.1.7.2 Transport block size determination

For BL/CE UEs configured with CEModeA, I^{1}_{MCS} is used in place of I_{MCS} in the rest of this subclause

If the DCI CRC is scrambled by P-RNTI, RA-RNTI, or SI-RNTI then

- for DCI format 1A or DCI format 6-1A:
  - the UE shall set the TBS index (I_{TBS}) equal to I_{MCS} and determine its TBS by the procedure in subclause 7.1.7.2.1 for $0 \le I_{\text{TBS}} \le 26$.
- for DCI format 1C and DCI format 6-2:
  - the UE shall set the TBS index (I_{TBS}) equal to I_{MCS} and determine its TBS from Table 7.1.7.2.3-1.

else if the higher layer parameter *altCQI-Table-r12* is configured, then

- for DCI format 1A with CRC scrambled by C-RNTI and for DCI format 1/1A/2/2A/2B/2C/2D with CRC scrambled by SPS C-RNTI:
  - for $0 \le I_{\text{MCS}} \le 28$, the UE shall first determine the TBS index (I_{TBS}) using I_{MCS} and Table 7.1.7.1-1 except if the transport block is disabled in DCI formats 2, 2A, 2B, 2C and 2D as specified below. For a transport block that is not mapped to more than single-layer spatial multiplexing, the TBS is determined by the procedure in subclause 7.1.7.2.1.
  - for $29 \le I_{\text{MCS}} \le 31$, the TBS is assumed to be as determined from DCI transported in the latest PDCCH/EPDCCH for the same transport block using $0 \le I_{\text{TBS}} \le 33$. If there is no PDCCH/EPDCCH for the same transport block using $0 \le I_{\text{TBS}} \le 26$, and if the initial PDSCH for the same transport block is semi-persistently scheduled, the TBS shall be determined from the most recent semi-persistent scheduling assignment PDCCH/EPDCCH.
  - In DCI formats 2, 2A, 2B, 2C and 2D a transport block is disabled if $I_{\text{MCS}} = 0$ and if rv_{idx} = 1 otherwise the transport block is enabled.
- for DCI format 1/1B/1D/2/2A/2B/2C/2D with CRC scrambled by C-RNTI
  - for $0 \le I_{\text{MCS}} \le 27$, the UE shall first determine the TBS index (I_{TBS}) using I_{MCS} and Table 7.1.7.1-1A except if the transport block is disabled in DCI formats 2, 2A, 2B, 2C and 2D as specified below. When $I_{\text{MCS}} = 27$, if the UE is scheduled by DCI formats 2C/2D and is configured with a33 in *tbsIndexAlt*, I_{TBS} is 33A; otherwise I_{TBS} is 33. For a transport block that is not mapped to more than single-layer spatial multiplexing, the TBS is determined by the procedure in subclause 7.1.7.2.1. For a transport block that is mapped to two-layer spatial multiplexing, the TBS is determined by the procedure in subclause 7.1.7.2.2. For a transport block that is mapped to three-layer spatial multiplexing, the TBS is determined by the procedure in subclause 7.1.7.2.4. For a transport block that is mapped to four-layer spatial multiplexing, the TBS is determined by the procedure in subclause 7.1.7.2.5.
  - for $28 \le I_{\text{MCS}} \le 31$, the TBS is assumed to be as determined from DCI transported in the latest PDCCH/EPDCCH for the same transport block using $0 \le I_{\text{MCS}} \le 27$.

- In DCI formats 2, 2A, 2B, 2C and 2D a transport block is disabled if $I_{\mathrm{MCS}} = 0$ and if $rv_{idx} = 1$ otherwise the transport block is enabled.

else

- for $0 \le I_{\mathrm{MCS}} \le 28$, the UE shall first determine the TBS index (I_{TBS}) using I_{MCS} and Table 7.1.7.1-1 except if the transport block is disabled in DCI formats 2, 2A, 2B, 2C and 2D as specified below. When $I_{\mathrm{MCS}} = 28$, if the UE is scheduled by DCI formats 2C/2D and is configured with a26 in *tbsIndexAlt*, I_{TBS} is 26A; otherwise I_{TBS} is 26. For a transport block that is not mapped to more than single-layer spatial multiplexing, the TBS is determined by the procedure in subclause 7.1.7.2.1. For a transport block that is mapped to two-layer spatial multiplexing, the TBS is determined by the procedure in subclause 7.1.7.2.2. For a transport block that is mapped to three-layer spatial multiplexing, the TBS is determined by the procedure in subclause 7.1.7.2.4. For a transport block that is mapped to four-layer spatial multiplexing, the TBS is determined by the procedure in subclause 7.1.7.2.5.

- for $29 \le I_{\mathrm{MCS}} \le 31$, the TBS is assumed to be as determined from DCI transported in the latest PDCCH/EPDCCH for the same transport block using $0 \le I_{\mathrm{MCS}} \le 28$. If there is no PDCCH/EPDCCH for the same transport block using $0 \le I_{\mathrm{MCS}} \le 28$, and if the initial PDSCH for the same transport block is semi-persistently scheduled, the TBS shall be determined from the most recent semi-persistent scheduling assignment PDCCH/EPDCCH.

- In DCI formats 2, 2A, 2B, 2C and 2D a transport block is disabled if $I_{\mathrm{MCS}} = 0$ and if $rv_{idx} = 1$ otherwise the transport block is enabled.

The NDI and HARQ process ID, as signalled on PDCCH/EPDCCH/MPDCCH, and the TBS, as determined above, shall be delivered to higher layers.

7.1.7.2.1 Transport blocks not mapped to two or more layer spatial multiplexing

For $1 \le N_{\mathrm{PRB}} \le 110$, the TBS is given by the (I_{TBS}, N_{PRB}) entry of Table 7.1.7.2.1-1.

Table 7.1.7.2.1-1: Transport block size table (dimension 34×110)

I_{TBS}	N_{PRB}									
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
0	16	32	56	88	120	152	176	208	224	256
1	24	56	88	144	176	208	224	256	328	344
2	32	72	144	176	208	256	296	328	376	424
3	40	104	176	208	256	328	392	440	504	568
4	56	120	208	256	328	408	488	552	632	696
5	72	144	224	328	424	504	600	680	776	872
6	328	176	256	392	504	600	712	808	936	1032
7	104	224	328	472	584	712	840	968	1096	1224
8	120	256	392	536	680	808	968	1096	1256	1384
9	136	296	456	616	776	936	1096	1256	1416	1544
10	144	328	504	680	872	1032	1224	1384	1544	1736
11	176	376	584	776	1000	1192	1384	1608	1800	2024
12	208	440	680	904	1128	1352	1608	1800	2024	2280
13	224	488	744	1000	1256	1544	1800	2024	2280	2536
14	256	552	840	1128	1416	1736	1992	2280	2600	2856
15	280	600	904	1224	1544	1800	2152	2472	2728	3112
16	328	632	968	1288	1608	1928	2280	2600	2984	3240
17	336	696	1064	1416	1800	2152	2536	2856	3240	3624
18	376	776	1160	1544	1992	2344	2792	3112	3624	4008
19	408	840	1288	1736	2152	2600	2984	3496	3880	4264
20	440	904	1384	1864	2344	2792	3240	3752	4136	4584
21	488	1000	1480	1992	2472	2984	3496	4008	4584	4968
22	520	1064	1608	2152	2664	3240	3752	4264	4776	5352
23	552	1128	1736	2280	2856	3496	4008	4584	5160	5736
24	584	1192	1800	2408	2984	3624	4264	4968	5544	5992
25	616	1256	1864	2536	3112	3752	4392	5160	5736	6200

26	712	1480	2216	2984	3752	4392	5160	5992	6712	7480
26A	632	1288	1928	2600	3240	3880	4584	5160	5992	6456

I_{TBS}	N_{PRB}									
	11	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
0	288	328	344	376	392	424	456	488	504	536
1	376	424	456	488	520	568	600	632	680	712
2	472	520	568	616	648	696	744	776	840	872
3	616	680	744	808	872	904	968	1032	1096	1160
4	776	840	904	1000	1064	1128	1192	1288	1352	1416
5	968	1032	1128	1224	1320	1384	1480	1544	1672	1736
6	1128	1224	1352	1480	1544	1672	1736	1864	1992	2088
7	1320	1480	1608	1672	1800	1928	2088	2216	2344	2472
8	1544	1672	1800	1928	2088	2216	2344	2536	2664	2792
9	1736	1864	2024	2216	2344	2536	2664	2856	2984	3112
10	1928	2088	2280	2472	2664	2792	2984	3112	3368	3496
11	2216	2408	2600	2792	2984	3240	3496	3624	3880	4008
12	2472	2728	2984	3240	3368	3624	3880	4136	4392	4584
13	2856	3112	3368	3624	3880	4136	4392	4584	4968	5160
14	3112	3496	3752	4008	4264	4584	4968	5160	5544	5736
15	3368	3624	4008	4264	4584	4968	5160	5544	5736	6200
16	3624	3880	4264	4584	4968	5160	5544	5992	6200	6456
17	4008	4392	4776	5160	5352	5736	6200	6456	6712	7224
18	4392	4776	5160	5544	5992	6200	6712	7224	7480	7992
19	4776	5160	5544	5992	6456	6968	7224	7736	8248	8504
20	5160	5544	5992	6456	6968	7480	7992	8248	8760	9144
21	5544	5992	6456	6968	7480	7992	8504	9144	9528	9912
22	5992	6456	6968	7480	7992	8504	9144	9528	10296	10680
23	6200	6968	7480	7992	8504	9144	9912	10296	11064	11448
24	6712	7224	7992	8504	9144	9912	10296	11064	11448	12216
25	6968	7480	8248	8760	9528	10296	10680	11448	12216	12576
26	8248	8760	9528	10296	11064	11832	12576	13536	14112	14688
26A	7224	7736	8504	9144	9912	10296	11064	11832	12576	12960

I_{TBS}	N_{PRB}									
	21	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**
0	568	600	616	648	680	712	744	776	776	808
1	744	776	808	872	904	936	968	1000	1032	1064
2	936	968	1000	1064	1096	1160	1192	1256	1288	1320
3	1224	1256	1320	1384	1416	1480	1544	1608	1672	1736
4	1480	1544	1608	1736	1800	1864	1928	1992	2088	2152
5	1864	1928	2024	2088	2216	2280	2344	2472	2536	2664
6	2216	2280	2408	2472	2600	2728	2792	2984	2984	3112
7	2536	2664	2792	2984	3112	3240	3368	3368	3496	3624
8	2984	3112	3240	3368	3496	3624	3752	3880	4008	4264
9	3368	3496	3624	3752	4008	4136	4264	4392	4584	4776
10	3752	3880	4008	4264	4392	4584	4776	4968	5160	5352
11	4264	4392	4584	4776	4968	5352	5544	5736	5992	5992
12	4776	4968	5352	5544	5736	5992	6200	6456	6712	6712
13	5352	5736	5992	6200	6456	6712	6968	7224	7480	7736
14	5992	6200	6456	6968	7224	7480	7736	7992	8248	8504
15	6456	6712	6968	7224	7736	7992	8248	8504	8760	9144
16	6712	7224	7480	7736	7992	8504	8760	9144	9528	9912
17	7480	7992	8248	8760	9144	9528	9912	10296	10296	10680
18	8248	8760	9144	9528	9912	10296	10680	11064	11448	11832
19	9144	9528	9912	10296	10680	11064	11448	12216	12576	12960
20	9912	10296	10680	11064	11448	12216	12576	12960	13536	14112
21	10680	11064	11448	12216	12576	12960	13536	14112	14688	15264
22	11448	11832	12576	12960	13536	14112	14688	15264	15840	16416
23	12216	12576	12960	13536	14112	14688	15264	15840	16416	16992
24	12960	13536	14112	14688	15264	15840	16416	16992	17568	18336
25	13536	14112	14688	15264	15840	16416	16992	17568	18336	19080
26	15264	16416	16992	17568	18336	19080	19848	20616	21384	22152
26A	13536	14112	15264	15840	16416	16992	17568	18336	19080	19848

I_{TBS}	N_{PRB}									
	31	**32**	**33**	**34**	**35**	**36**	**37**	**38**	**39**	**40**
0	840	872	904	936	968	1000	1032	1032	1064	1096
1	1128	1160	1192	1224	1256	1288	1352	1384	1416	1416
2	1384	1416	1480	1544	1544	1608	1672	1672	1736	1800
3	1800	1864	1928	1992	2024	2088	2152	2216	2280	2344

4	2216	2280	2344	2408	2472	2600	2664	2728	2792	2856
5	2728	2792	2856	2984	3112	3112	3240	3368	3496	3496
6	3240	3368	3496	3496	3624	3752	3880	4008	4136	4136
7	3752	3880	4008	4136	4264	4392	4584	4584	4776	4968
8	4392	4584	4584	4776	4968	4968	5160	5352	5544	5544
9	4968	5160	5160	5352	5544	5736	5736	5992	6200	6200
10	5544	5736	5736	5992	6200	6200	6456	6712	6712	6968
11	6200	6456	6712	6968	6968	7224	7480	7736	7736	7992
12	6968	7224	7480	7736	7992	8248	8504	8760	8760	9144
13	7992	8248	8504	8760	9144	9144	9528	9912	9912	10296
14	8760	9144	9528	9912	9912	10296	10680	11064	11064	11448
15	9528	9912	10296	10296	10680	11064	11448	11832	11832	12216
16	9912	10296	10680	11064	11448	11832	12216	12216	12576	12960
17	11064	11448	11832	12216	12576	12960	13536	13536	14112	14688
18	12216	12576	12960	13536	14112	14112	14688	15264	15264	15840
19	13536	13536	14112	14688	15264	15264	15840	16416	16992	16992
20	14688	14688	15264	15840	16416	16992	16992	17568	18336	18336
21	15840	15840	16416	16992	17568	18336	18336	19080	19848	19848
22	16992	16992	17568	18336	19080	19080	19848	20616	21384	21384
23	17568	18336	19080	19848	19848	20616	21384	22152	22152	22920
24	19080	19848	19848	20616	21384	22152	22920	22920	23688	24496
25	19848	20616	20616	21384	22152	22920	23688	24496	24496	25456
26	22920	23688	24496	25456	25456	26416	27376	28336	29296	29296
26A	20616	20616	21384	22152	22920	23688	24496	24496	25456	26416

I_{TBS}	N_{PRB}									
	41	**42**	**43**	**44**	**45**	**46**	**47**	**48**	**49**	**50**
0	1128	1160	1192	1224	1256	1256	1288	1320	1352	1384
1	1480	1544	1544	1608	1608	1672	1736	1736	1800	1800
2	1800	1864	1928	1992	2024	2088	2088	2152	2216	2216
3	2408	2472	2536	2536	2600	2664	2728	2792	2856	2856
4	2984	2984	3112	3112	3240	3240	3368	3496	3496	3624
5	3624	3752	3752	3880	4008	4008	4136	4264	4392	4392
6	4264	4392	4584	4584	4776	4776	4968	4968	5160	5160
7	4968	5160	5352	5352	5544	5736	5736	5992	5992	6200
8	5736	5992	5992	6200	6200	6456	6456	6712	6968	6968
9	6456	6712	6712	6968	6968	7224	7480	7480	7736	7992
10	7224	7480	7480	7736	7992	7992	8248	8504	8504	8760
11	8248	8504	8760	8760	9144	9144	9528	9528	9912	9912
12	9528	9528	9912	9912	10296	10680	10680	11064	11064	11448
13	10680	10680	11064	11448	11448	11832	12216	12216	12576	12960
14	11832	12216	12216	12576	12960	12960	13536	13536	14112	14112
15	12576	12960	12960	13536	13536	14112	14688	14688	15264	15264
16	13536	13536	14112	14112	14688	14688	15264	15840	15840	16416
17	14688	15264	15264	15840	16416	16416	16992	17568	17568	18336
18	16416	16416	16992	17568	17568	18336	18336	19080	19080	19848
19	17568	18336	18336	19080	19080	19848	20616	20616	21384	21384
20	19080	19848	19848	20616	20616	21384	22152	22152	22920	22920
21	20616	21384	21384	22152	22920	22920	23688	24496	24496	25456
22	22152	22920	22920	23688	24496	24496	25456	25456	26416	27376
23	23688	24496	24496	25456	25456	26416	27376	27376	28336	28336
24	25456	25456	26416	26416	27376	28336	28336	29296	29296	30576
25	26416	26416	27376	28336	28336	29296	29296	30576	31704	31704
26	30576	30576	31704	32856	32856	34008	35160	35160	36696	36696
26A	26416	27376	27376	29296	29296	29296	30576	30576	31704	32856

I_{TBS}	N_{PRB}									
	51	**52**	**53**	**54**	**55**	**56**	**57**	**58**	**59**	**60**
0	1416	1416	1480	1480	1544	1544	1608	1608	1608	1672
1	1864	1864	1928	1992	1992	2024	2088	2088	2152	2152
2	2280	2344	2344	2408	2472	2536	2536	2600	2664	2664
3	2984	2984	3112	3112	3240	3240	3368	3368	3496	3496
4	3624	3752	3752	3880	4008	4008	4136	4136	4264	4264
5	4584	4584	4776	4776	4776	4968	4968	5160	5160	5352
6	5352	5352	5544	5736	5736	5992	5992	5992	6200	6200
7	6200	6456	6456	6712	6712	6712	6968	6968	7224	7224
8	7224	7224	7480	7480	7736	7736	7992	7992	8248	8504
9	7992	8248	8248	8504	8760	8760	9144	9144	9144	9528
10	9144	9144	9144	9528	9528	9912	9912	10296	10296	10680
11	10296	10680	10680	11064	11064	11448	11448	11832	11832	12216
12	11832	11832	12216	12216	12576	12576	12960	12960	13536	13536
13	12960	13536	13536	14112	14112	14688	14688	14688	15264	15264

14	14688	14688	15264	15264	15840	15840	16416	16416	16992	16992
15	15840	15840	16416	16416	16992	16992	17568	17568	18336	18336
16	16416	16992	16992	17568	17568	18336	18336	19080	19080	19848
17	18336	19080	19080	19848	19848	20616	20616	20616	21384	21384
18	19848	20616	21384	21384	22152	22152	22920	22920	23688	23688
19	22152	22152	22920	22920	23688	24496	24496	25456	25456	25456
20	23688	24496	24496	25456	25456	26416	26416	27376	27376	28336
21	25456	26416	26416	27376	27376	28336	28336	29296	29296	30576
22	27376	28336	28336	29296	29296	30576	30576	31704	31704	32856
23	29296	29296	30576	30576	31704	31704	32856	32856	34008	34008
24	31704	31704	32856	32856	34008	34008	35160	35160	36696	36696
25	32856	32856	34008	34008	35160	35160	36696	36696	37888	37888
26	37888	37888	39232	40576	40576	40576	42368	42368	43816	43816
26A	32856	34008	34008	35160	36696	36696	36696	37888	37888	39232

I_{TBS}	N_{PRB}									
	61	**62**	**63**	**64**	**65**	**66**	**67**	**68**	**69**	**70**
0	1672	1736	1736	1800	1800	1800	1864	1864	1928	1928
1	2216	2280	2280	2344	2344	2408	2472	2472	2536	2536
2	2728	2792	2856	2856	2856	2984	2984	3112	3112	3112
3	3624	3624	3624	3752	3752	3880	3880	4008	4008	4136
4	4392	4392	4584	4584	4584	4776	4776	4968	4968	4968
5	5352	5544	5544	5736	5736	5736	5992	5992	5992	6200
6	6456	6456	6456	6712	6712	6968	6968	6968	7224	7224
7	7480	7480	7736	7736	7992	7992	8248	8248	8504	8504
8	8504	8760	8760	9144	9144	9144	9528	9528	9528	9912
9	9528	9912	9912	10296	10296	10296	10680	10680	11064	11064
10	10680	11064	11064	11448	11448	11448	11832	11832	12216	12216
11	12216	12576	12576	12960	12960	13536	13536	13536	14112	14112
12	14112	14112	14112	14688	14688	15264	15264	15264	15840	15840
13	15840	15840	16416	16416	16992	16992	16992	17568	17568	18336
14	17568	17568	18336	18336	18336	19080	19080	19848	19848	19848
15	18336	19080	19080	19848	19848	20616	20616	20616	21384	21384
16	19848	19848	20616	20616	21384	21384	22152	22152	22152	22920
17	22152	22152	22920	22920	23688	23688	24496	24496	24496	25456
18	24496	24496	24496	25456	25456	26416	26416	27376	27376	27376
19	26416	26416	27376	27376	28336	28336	29296	29296	29296	30576
20	28336	29296	29296	29296	30576	30576	31704	31704	31704	32856
21	30576	31704	31704	31704	32856	32856	34008	34008	35160	35160
22	32856	34008	34008	34008	35160	35160	36696	36696	36696	37888
23	35160	35160	36696	36696	37888	37888	37888	39232	39232	40576
24	36696	37888	37888	39232	39232	40576	40576	42368	42368	42368
25	39232	39232	40576	40576	40576	42368	42368	43816	43816	43816
26	45352	45352	46888	46888	48936	48936	48936	51024	51024	52752
26A	40576	40576	40576	40576	42368	42368	43816	43816	45352	45352

I_{TBS}	N_{PRB}									
	71	**72**	**73**	**74**	**75**	**76**	**77**	**78**	**79**	**80**
0	1992	1992	2024	2088	2088	2088	2152	2152	2216	2216
1	2600	2600	2664	2728	2728	2792	2792	2856	2856	2856
2	3240	3240	3240	3368	3368	3368	3496	3496	3496	3624
3	4136	4264	4264	4392	4392	4392	4584	4584	4584	4776
4	5160	5160	5160	5352	5352	5544	5544	5544	5736	5736
5	6200	6200	6456	6456	6712	6712	6712	6968	6968	6968
6	7480	7480	7736	7736	7736	7992	7992	8248	8248	8248
7	8760	8760	8760	9144	9144	9144	9528	9528	9528	9912
8	9912	9912	10296	10296	10680	10680	10680	11064	11064	11064
9	11064	11448	11448	11832	11832	11832	12216	12216	12576	12576
10	12576	12576	12960	12960	12960	13536	13536	13536	14112	14112
11	14112	14688	14688	14688	15264	15264	15840	15840	15840	16416
12	16416	16416	16416	16992	16992	17568	17568	17568	18336	18336
13	18336	18336	19080	19080	19080	19848	19848	19848	20616	20616
14	20616	20616	20616	21384	21384	22152	22152	22152	22920	22920
15	22152	22152	22152	22920	22920	23688	23688	23688	24496	24496
16	22920	23688	23688	24496	24496	24496	25456	25456	25456	26416
17	25456	26416	26416	26416	27376	27376	27376	28336	28336	29296
18	28336	28336	29296	29296	29296	30576	30576	30576	31704	31704
19	30576	30576	31704	31704	32856	32856	32856	34008	34008	34008
20	32856	34008	34008	34008	35160	35160	35160	36696	36696	36696
21	35160	36696	36696	36696	37888	37888	39232	39232	39232	40576
22	37888	39232	39232	40576	40576	40576	42368	42368	42368	43816
23	40576	40576	42368	42368	43816	43816	43816	45352	45352	45352

24	43816	43816	45352	45352	45352	46888	46888	46888	48936	48936
25	45352	45352	46888	46888	46888	48936	48936	48936	51024	51024
26	52752	52752	55056	55056	55056	55056	57336	57336	57336	59256
26A	45352	46888	46888	48936	48936	48936	51024	51024	51024	52752

I_{TBS}	N_{PRB}									
	81	**82**	**83**	**84**	**85**	**86**	**87**	**88**	**89**	**90**
0	2280	2280	2280	2344	2344	2408	2408	2472	2472	2536
1	2984	2984	2984	3112	3112	3112	3240	3240	3240	3240
2	3624	3624	3752	3752	3880	3880	3880	4008	4008	4008
3	4776	4776	4776	4968	4968	4968	5160	5160	5160	5352
4	5736	5992	5992	5992	5992	6200	6200	6200	6456	6456
5	7224	7224	7224	7480	7480	7480	7736	7736	7736	7992
6	8504	8504	8760	8760	8760	9144	9144	9144	9144	9528
7	9912	9912	10296	10296	10296	10680	10680	10680	11064	11064
8	11448	11448	11448	11832	11832	12216	12216	12216	12576	12576
9	12960	12960	12960	13536	13536	13536	13536	14112	14112	14112
10	14112	14688	14688	14688	14688	15264	15264	15264	15840	15840
11	16416	16416	16992	16992	16992	17568	17568	17568	18336	18336
12	18336	19080	19080	19080	19080	19848	19848	19848	20616	20616
13	20616	21384	21384	21384	22152	22152	22152	22920	22920	22920
14	22920	23688	23688	24496	24496	24496	25456	25456	25456	25456
15	24496	25456	25456	25456	26416	26416	26416	27376	27376	27376
16	26416	26416	27376	27376	27376	28336	28336	28336	29296	29296
17	29296	29296	30576	30576	30576	30576	31704	31704	31704	32856
18	31704	32856	32856	32856	34008	34008	34008	35160	35160	35160
19	35160	35160	35160	36696	36696	36696	37888	37888	37888	39232
20	37888	37888	39232	39232	39232	40576	40576	40576	42368	42368
21	40576	40576	42368	42368	42368	43816	43816	43816	45352	45352
22	43816	43816	45352	45352	45352	46888	46888	46888	48936	48936
23	46888	46888	46888	48936	48936	48936	51024	51024	51024	51024
24	48936	51024	51024	51024	52752	52752	52752	52752	55056	55056
25	51024	52752	52752	52752	55056	55056	55056	55056	57336	57336
26	59256	59256	61664	61664	61664	63776	63776	63776	66592	66592
26A	52752	52752	55056	55056	55056	55056	57336	57336	57336	59256

I_{TBS}	N_{PRB}									
	91	**92**	**93**	**94**	**95**	**96**	**97**	**98**	**99**	**100**
0	2536	2536	2600	2600	2664	2664	2728	2728	2728	2792
1	3368	3368	3368	3496	3496	3496	3496	3624	3624	3624
2	4136	4136	4136	4264	4264	4264	4392	4392	4392	4584
3	5352	5352	5352	5544	5544	5544	5736	5736	5736	5736
4	6456	6456	6712	6712	6712	6968	6968	6968	6968	7224
5	7992	7992	8248	8248	8248	8504	8504	8760	8760	8760
6	9528	9528	9528	9912	9912	9912	10296	10296	10296	10296
7	11064	11448	11448	11448	11448	11832	11832	11832	12216	12216
8	12576	12960	12960	12960	13536	13536	13536	13536	14112	14112
9	14112	14688	14688	14688	15264	15264	15264	15264	15840	15840
10	15840	16416	16416	16416	16992	16992	16992	16992	17568	17568
11	18336	18336	19080	19080	19080	19080	19848	19848	19848	19848
12	20616	21384	21384	21384	21384	22152	22152	22152	22920	22920
13	23688	23688	23688	24496	24496	24496	25456	25456	25456	25456
14	26416	26416	26416	27376	27376	27376	28336	28336	28336	28336
15	28336	28336	28336	29296	29296	29296	29296	30576	30576	30576
16	29296	30576	30576	30576	30576	31704	31704	31704	31704	32856
17	32856	32856	34008	34008	34008	35160	35160	35160	35160	36696
18	36696	36696	36696	37888	37888	37888	37888	39232	39232	39232
19	39232	39232	40576	40576	40576	40576	42368	42368	42368	43816
20	42368	42368	43816	43816	43816	45352	45352	45352	46888	46888
21	45352	46888	46888	46888	46888	48936	48936	48936	48936	51024
22	48936	48936	51024	51024	51024	51024	52752	52752	52752	55056
23	52752	52752	52752	55056	55056	55056	55056	57336	57336	57336
24	55056	57336	57336	57336	57336	59256	59256	59256	61664	61664
25	57336	59256	59256	59256	61664	61664	61664	61664	63776	63776
26	66592	68808	68808	68808	71112	71112	71112	73712	73712	75376
26A	59256	59256	59256	61664	61664	61664	63776	63776	63776	66592

I_{TBS}	N_{PRB}									
	101	**102**	**103**	**104**	**105**	**106**	**107**	**108**	**109**	**110**
0	2792	2856	2856	2856	2984	2984	2984	2984	2984	3112
1	3752	3752	3752	3752	3880	3880	3880	4008	4008	4008

2	4584	4584	4584	4584	4776	4776	4776	4776	4968	4968
3	5992	5992	5992	5992	6200	6200	6200	6200	6456	6456
4	7224	7224	7480	7480	7480	7480	7736	7736	7736	7992
5	8760	9144	9144	9144	9144	9528	9528	9528	9528	9528
6	10680	10680	10680	10680	11064	11064	11064	11448	11448	11448
7	12216	12576	12576	12576	12960	12960	12960	12960	13536	13536
8	14112	14112	14688	14688	14688	14688	15264	15264	15264	15264
9	15840	16416	16416	16416	16416	16992	16992	16992	16992	17568
10	17568	18336	18336	18336	18336	18336	19080	19080	19080	19080
11	20616	20616	20616	21384	21384	21384	21384	22152	22152	22152
12	22920	23688	23688	23688	23688	24496	24496	24496	24496	25456
13	26416	26416	26416	26416	27376	27376	27376	27376	28336	28336
14	29296	29296	29296	29296	30576	30576	30576	30576	31704	31704
15	30576	31704	31704	31704	31704	32856	32856	32856	34008	34008
16	32856	32856	34008	34008	34008	34008	35160	35160	35160	35160
17	36696	36696	36696	37888	37888	37888	39232	39232	39232	39232
18	40576	40576	40576	40576	42368	42368	42368	42368	43816	43816
19	43816	43816	43816	45352	45352	45352	46888	46888	46888	46888
20	46888	46888	48936	48936	48936	48936	48936	51024	51024	51024
21	51024	51024	51024	52752	52752	52752	52752	55056	55056	55056
22	55056	55056	55056	57336	57336	57336	57336	59256	59256	59256
23	57336	59256	59256	59256	59256	61664	61664	61664	61664	63776
24	61664	61664	63776	63776	63776	63776	66592	66592	66592	66592
25	63776	63776	66592	66592	66592	66592	68808	68808	68808	71112
26	75376	75376	75376	75376	75376	75376	75376	75376	75376	75376
26A	66592	66592	66592	68808	68808	68808	71112	71112	71112	71112

I_{TBS}	N_{PRB}									
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
27	648	1320	1992	2664	3368	4008	4584	5352	5992	6712
28	680	1384	2088	2792	3496	4264	4968	5544	6200	6968
29	712	1480	2216	2984	3752	4392	5160	5992	6712	7480
30	776	1544	2344	3112	3880	4776	5544	6200	6968	7736
31	808	1608	2472	3240	4136	4968	5736	6456	7480	8248
32	840	1672	2536	3368	4264	5160	5992	6712	7736	8504
33	968	1992	2984	4008	4968	5992	6968	7992	8760	9912
33A	840	1736	2600	3496	4392	5160	5992	6968	7736	8760

I_{TBS}	N_{PRB}									
	11	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
27	7224	7992	8504	9144	9912	10680	11448	11832	12576	12960
28	7736	8504	9144	9912	10680	11064	11832	12576	13536	14112
29	8248	8760	9528	10296	11064	11832	12576	13536	14112	14688
30	8504	9528	10296	11064	11832	12576	13536	14112	14688	15840
31	9144	9912	10680	11448	12216	12960	14112	14688	15840	16416
32	9528	10296	11064	11832	12960	13536	14688	15264	16416	16992
33	10680	11832	12960	13536	14688	15840	16992	17568	19080	19848
33A	9528	10296	11448	12216	12960	14112	14688	15840	16416	17568

I_{TBS}	N_{PRB}									
	21	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**
27	14112	14688	15264	15840	16416	16992	17568	18336	19080	19848
28	14688	15264	16416	16992	17568	18336	19080	19848	20616	21384
29	15840	16416	16992	17568	18336	19080	19848	20616	21384	22152
30	16416	16992	18336	19080	19848	20616	21384	22152	22920	23688
31	17568	18336	19080	19848	20616	21384	22152	22920	23688	24496
32	17568	19080	19848	20616	21384	22152	22920	23688	24496	25456
33	20616	21384	22920	23688	24496	25456	26416	27376	28336	29296
33A	18336	19080	19848	20616	22152	22920	23688	24496	25456	26416

I_{TBS}	N_{PRB}									
	31	**32**	**33**	**34**	**35**	**36**	**37**	**38**	**39**	**40**
27	20616	21384	22152	22920	22920	23688	24496	25456	25456	26416
28	22152	22152	22920	23688	24496	25456	26416	26416	27376	28336
29	22920	23688	24496	25456	26416	26416	27376	28336	29296	29296
30	24496	25456	25456	26416	27376	28336	29296	29296	30576	31704
31	25456	26416	27376	28336	29296	29296	30576	31704	31704	32856
32	26416	27376	28336	29296	29296	30576	31704	32856	32856	34008
33	30576	31704	32856	34008	35160	35160	36696	37888	39232	39232
33A	27376	27376	29296	29296	30576	30576	31704	32856	34008	35160

I_{TBS}	N_{PRB}									
	41	42	43	44	45	46	47	48	49	50
27	27376	27376	28336	29296	29296	30576	31704	31704	32856	32856
28	29296	29296	30576	30576	31704	32856	32856	34008	34008	35160
29	30576	31704	31704	32856	34008	34008	35160	35160	36696	36696
30	31704	32856	34008	34008	35160	36696	36696	37888	37888	39232
31	34008	35160	35160	36696	36696	37888	39232	39232	40576	40576
32	35160	35160	36696	37888	37888	39232	40576	40576	42368	42368
33	40576	40576	42368	43816	43816	45352	46888	46888	48936	48936
33A	35160	36696	36696	37888	39232	40576	40576	40576	42368	43816

I_{TBS}	N_{PRB}									
	51	52	53	54	55	56	57	58	59	60
27	34008	34008	35160	35160	36696	36696	37888	37888	39232	39232
28	35160	36696	36696	37888	39232	39232	40576	40576	42368	42368
29	37888	39232	39232	40576	40576	42368	42368	43816	43816	45352
30	40576	40576	42368	42368	43816	43816	45352	45352	46888	46888
31	42368	42368	43816	45352	45352	46888	46888	46888	48936	48936
32	43816	43816	45352	46888	46888	46888	48936	48936	51024	51024
33	51024	51024	52752	52752	55056	55056	57336	57336	59256	59256
33A	43816	45352	45352	46888	48936	48936	48936	51024	51024	52752

I_{TBS}	N_{PRB}									
	61	62	63	64	65	66	67	68	69	70
27	40576	40576	42368	42368	43816	43816	43816	45352	45352	46888
28	42368	43816	43816	45352	45352	46888	46888	46888	48936	48936
29	45352	45352	46888	46888	48936	48936	48936	51024	51024	52752
30	46888	48936	48936	51024	51024	51024	52752	52752	55056	55056
31	51024	51024	52752	52752	52752	55056	55056	55056	57336	57336
32	52752	52752	52752	55056	55056	57336	57336	57336	59256	59256
33	59256	61664	61664	63776	63776	63776	66592	66592	68808	68808
33A	52752	55056	55056	55056	57336	57336	57336	59256	59256	61664

I_{TBS}	N_{PRB}									
	71	72	73	74	75	76	77	78	79	80
27	46888	46888	48936	48936	48936	51024	51024	51024	52752	52752
28	48936	51024	51024	52752	52752	52752	55056	55056	55056	57336
29	52752	52752	55056	55056	55056	57336	57336	57336	59256	59256
30	55056	57336	57336	57336	59256	59256	59256	61664	61664	63776
31	59256	59256	59256	61664	61664	63776	63776	63776	66592	66592
32	61664	61664	61664	63776	63776	63776	66592	66592	66592	68808
33	71112	71112	71112	73712	75376	76208	76208	76208	78704	78704
33A	61664	61664	63776	63776	66592	66592	66592	68808	68808	68808

I_{TBS}	N_{PRB}									
	81	82	83	84	85	86	87	88	89	90
27	52752	55056	55056	55056	57336	57336	57336	59256	59256	59256
28	57336	57336	59256	59256	59256	61664	61664	61664	61664	63776
29	59256	61664	61664	61664	63776	63776	63776	66592	66592	66592
30	63776	63776	63776	66592	66592	66592	68808	68808	68808	71112
31	66592	68808	68808	68808	71112	71112	71112	73712	73712	73712
32	68808	71112	71112	71112	73712	73712	73712	75376	76208	76208
33	81176	81176	81176	81176	84760	84760	84760	87936	87936	87936
33A	71112	71112	71112	73712	75376	75376	76208	76208	78704	78704

I_{TBS}	N_{PRB}									
	91	92	93	94	95	96	97	98	99	100
27	59256	61664	61664	61664	63776	63776	63776	63776	66592	66592
28	63776	63776	66592	66592	66592	66592	68808	68808	68808	71112
29	66592	68808	68808	68808	71112	71112	71112	73712	73712	73712
30	71112	71112	73712	73712	75376	75376	76208	76208	78704	78704
31	75376	76208	76208	78704	78704	78704	81176	81176	81176	81176
32	78704	78704	78704	81176	81176	81176	84760	84760	84760	84760
33	90816	90816	90816	93800	93800	93800	93800	97896	97896	97896
33A	78704	81176	81176	81176	81176	84760	84760	84760	84760	87936

I_{TBS}	N_{PRB}									
	101	**102**	**103**	**104**	**105**	**106**	**107**	**108**	**109**	**110**
27	66592	66592	68808	68808	68808	71112	71112	71112	71112	73712
28	71112	71112	73712	73712	73712	75376	75376	76208	76208	76208
29	75376	76208	76208	76208	78704	78704	78704	81176	81176	81176
30	78704	81176	81176	81176	81176	84760	84760	84760	84760	87936
31	84760	84760	84760	84760	87936	87936	87936	87936	90816	90816
32	87936	87936	87936	87936	90816	90816	90816	93800	93800	93800
33	97896	97896	97896	97896	97896	97896	97896	97896	97896	97896
33A	87936	87936	87936	90816	90816	90816	93800	93800	93800	97896

7.1.7.2.2 Transport blocks mapped to two-layer spatial multiplexing

For $1 \le N_{\mathrm{PRB}} \le 55$, the TBS is given by the (I_{TBS} , $2 \cdot N_{\mathrm{PRB}}$) entry of Table 7.1.7.2.1-1.

For $56 \le N_{\mathrm{PRB}} \le 110$, a baseline TBS_L1 is taken from the (I_{TBS} , N_{PRB}) entry of Table 7.1.7.2.1-1, which is then translated into TBS_L2 using the mapping rule shown in Table 7.1.7.2.2-1. The TBS is given by TBS_L2.

Table 7.1.7.2.2-1: One-layer to two-layer TBS translation table

TBS_L1	TBS_L2	TBS_L1	TBS_L2	TBS_L1	TBS_L2	TBS_L1	TBS_L2
1544	3112	3752	7480	10296	20616	28336	57336
1608	3240	3880	7736	10680	21384	29296	59256
1672	3368	4008	7992	11064	22152	30576	61664
1736	3496	4136	8248	11448	22920	31704	63776
1800	3624	4264	8504	11832	23688	32856	66592
1864	3752	4392	8760	12216	24496	34008	68808
1928	3880	4584	9144	12576	25456	35160	71112
1992	4008	4776	9528	12960	25456	36696	73712
2024	4008	4968	9912	13536	27376	37888	76208
2088	4136	5160	10296	14112	28336	39232	78704
2152	4264	5352	10680	14688	29296	40576	81176
2216	4392	5544	11064	15264	30576	42368	84760
2280	4584	5736	11448	15840	31704	43816	87936
2344	4776	5992	11832	16416	32856	45352	90816
2408	4776	6200	12576	16992	34008	46888	93800
2472	4968	6456	12960	17568	35160	48936	97896
2536	5160	6712	13536	18336	36696	51024	101840
2600	5160	6968	14112	19080	37888	52752	105528
2664	5352	7224	14688	19848	39232	55056	110136
2728	5544	7480	14688	20616	40576	57336	115040
2792	5544	7736	15264	21384	42368	59256	119816
2856	5736	7992	15840	22152	43816	61664	124464
2984	5992	8248	16416	22920	45352	63776	128496
3112	6200	8504	16992	23688	46888	66592	133208
3240	6456	8760	17568	24496	48936	68808	137792
3368	6712	9144	18336	25456	51024	71112	142248
3496	6968	9528	19080	26416	52752	73712	146856
3624	7224	9912	19848	27376	55056	75376	149776
76208	152976	81176	161760	87936	175600	93800	187712
78704	157432	84760	169544	90816	181656	97896	195816

7.1.7.2.3 Transport blocks mapped for DCI Format 1C and DCI Format 6-2

The TBS is given by the I_{TBS} entry of Table 7.1.7.2.3-1. For DCI Format 6-2, $0 \le I_{\mathrm{TBS}} \le 7$.

Table 7.1.7.2.3-1: Transport Block Size (TBS) table for DCI format 1C and DCI Format 6-2

I_{TBS}	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
TBS	40	56	72	120	136	144	176	208	224	256	280	296	328	336	392	488
I_{TBS}	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
TBS	552	600	632	696	776	840	904	1000	1064	1128	1224	1288	1384	1480	1608	1736

7.1.7.2.4 Transport blocks mapped to three-layer spatial multiplexing

For $1 \le N_{\mathrm{PRB}} \le 36$, the TBS is given by the (I_{TBS}, $3 \cdot N_{\mathrm{PRB}}$) entry of Table 7.1.7.2.1-1.

For $37 \le N_{\mathrm{PRB}} \le 110$, a baseline TBS_L1 is taken from the (I_{TBS}, N_{PRB}) entry of Table 7.1.7.2.1-1, which is then translated into TBS_L3 using the mapping rule shown in Table 7.1.7.2.4-1. The TBS is given by TBS_L3.

Table 7.1.7.2.4-1: One-layer to three-layer TBS translation table

TBS_L1	TBS_L3	TBS_L1	TBS_L3	TBS_L1	TBS_L3	TBS_L1	TBS_L3
1032	3112	2664	7992	8248	24496	26416	78704
1064	3240	2728	8248	8504	25456	27376	81176
1096	3240	2792	8248	8760	26416	28336	84760
1128	3368	2856	8504	9144	27376	29296	87936
1160	3496	2984	8760	9528	28336	30576	90816
1192	3624	3112	9144	9912	29296	31704	93800
1224	3624	3240	9528	10296	30576	32856	97896
1256	3752	3368	9912	10680	31704	34008	101840
1288	3880	3496	10296	11064	32856	35160	105528
1320	4008	3624	10680	11448	34008	36696	110136
1352	4008	3752	11064	11832	35160	37888	115040
1384	4136	3880	11448	12216	36696	39232	119816
1416	4264	4008	11832	12576	37888	40576	119816
1480	4392	4136	12576	12960	39232	42368	128496
1544	4584	4264	12960	13536	40576	43816	133208
1608	4776	4392	12960	14112	42368	45352	137792
1672	4968	4584	13536	14688	43816	46888	142248
1736	5160	4776	14112	15264	45352	48936	146856
1800	5352	4968	14688	15840	46888	51024	152976
1864	5544	5160	15264	16416	48936	52752	157432
1928	5736	5352	15840	16992	51024	55056	165216
1992	5992	5544	16416	17568	52752	57336	171888
2024	5992	5736	16992	18336	55056	59256	177816
2088	6200	5992	18336	19080	57336	61664	185728
2152	6456	6200	18336	19848	59256	63776	191720
2216	6712	6456	19080	20616	61664	66592	199824
2280	6712	6712	19848	21384	63776	68808	205880
2344	6968	6968	20616	22152	66592	71112	214176
2408	7224	7224	21384	22920	68808	73712	221680
2472	7480	7480	22152	23688	71112	75376	226416
2536	7480	7736	22920	24496	73712		
2600	7736	7992	23688	25456	76208		
76208	230104	81176	245648	87936	266440	93800	284608
78704	236160	84760	254328	90816	275376	97896	293736

7.1.7.2.5 Transport blocks mapped to four-layer spatial multiplexing

For $1 \le N_{\mathrm{PRB}} \le 27$, the TBS is given by the (I_{TBS}, $4 \cdot N_{\mathrm{PRB}}$) entry of Table 7.1.7.2.1-1.

For $28 \le N_{\mathrm{PRB}} \le 110$, a baseline TBS_L1 is taken from the (I_{TBS}, N_{PRB}) entry of Table 7.1.7.2.1-1, which is then translated into TBS_L4 using the mapping rule shown in Table 7.1.7.2.5-1. The TBS is given by TBS_L4.

Table 7.1.7.2.5-1: One-layer to four-layer TBS translation table

TBS_L1	TBS_L4	TBS_L1	TBS_L4	TBS_L1	TBS_L4	TBS_L1	TBS_L4
776	3112	2280	9144	7224	29296	24496	97896
808	3240	2344	9528	7480	29296	25456	101840
840	3368	2408	9528	7736	30576	26416	105528
872	3496	2472	9912	7992	31704	27376	110136
904	3624	2536	10296	8248	32856	28336	115040
936	3752	2600	10296	8504	34008	29296	115040
968	3880	2664	10680	8760	35160	30576	124464
1000	4008	2728	11064	9144	36696	31704	128496
1032	4136	2792	11064	9528	37888	32856	133208
1064	4264	2856	11448	9912	39232	34008	137792
1096	4392	2984	11832	10296	40576	35160	142248
1128	4584	3112	12576	10680	42368	36696	146856
1160	4584	3240	12960	11064	43816	37888	151376
1192	4776	3368	13536	11448	45352	39232	157432
1224	4968	3496	14112	11832	46888	40576	161760
1256	4968	3624	14688	12216	48936	42368	169544
1288	5160	3752	15264	12576	51024	43816	175600
1320	5352	3880	15264	12960	51024	45352	181656
1352	5352	4008	15840	13536	55056	46888	187712
1384	5544	4136	16416	14112	57336	48936	195816
1416	5736	4264	16992	14688	59256	51024	203704
1480	5992	4392	17568	15264	61664	52752	211936
1544	6200	4584	18336	15840	63776	55056	220296
1608	6456	4776	19080	16416	66592	57336	230104
1672	6712	4968	19848	16992	68808	59256	236160
1736	6968	5160	20616	17568	71112	61664	245648
1800	7224	5352	21384	18336	73712	63776	254328
1864	7480	5544	22152	19080	76208	66592	266440
1928	7736	5736	22920	19848	78704	68808	275376
1992	7992	5992	23688	20616	81176	71112	284608
2024	7992	6200	24496	21384	84760	73712	293736
2088	8248	6456	25456	22152	87936	75376	299856
2152	8504	6712	26416	22920	90816		
2216	8760	6968	28336	23688	93800		
76208	305976	81176	324336	87936	351224	93800	375448
78704	314888	84760	339112	90816	363336	97896	391656

7.1.7.2.6 Transport blocks mapped for BL/CE UEs configured with CEModeB

The UE shall set $I_{\mathrm{TBS}} = I^{1}_{\mathrm{TBS}}$ and determine its TBS by the procedure in subclause 7.1.7.2.1 for $0 \le I_{\mathrm{TBS}} \le 9$, and N_{PRB} = 4 or N_{PRB} = 6.

7.1.7.2.7 Transport blocks mapped for BL/CE UEs *SystemInformationBlockType1-BR*

The TBS is given by the I_{TBS} entry of Table 7.1.7.2.7-1.

Table 7.1.7.2.7-1: Transport block size (TBS) table for PDSCH carrying *SystemInformationBlockType1-BR*

I_{TBS}	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
TBS	N/A	208	208	208	256	256	256	328	328	328	504	504	504	712	712	712
I_{TBS}	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
TBS	936	936	936	Reserved												

7.1.7.3 Redundancy Version determination for Format 1C

If the DCI Format 1C CRC is scrambled by P-RNTI or RA-RNTI, then

- the UE shall set the Redundancy Version to 0

Else if the DCI Format 1C CRC is scrambled by SI-RNTI, then

- the UE shall set the Redundancy Version as defined in [8].

7.1.8 Storing soft channel bits

For FDD, TDD and FDD-TDD, if the UE is configured with more than one serving cell or if the UE is configured with a SCG, then for each serving cell, for at least $K_{\mathrm{MIMO}} \cdot \min(M_{\mathrm{DL\_HARQ}}, M_{\mathrm{limit}})$ transport blocks, upon decoding failure of a code block of a transport block, the UE shall store received soft channel bits corresponding to a range of at least $w_k \; w_{k+1}, \ldots, w_{\mathrm{mod}(k+n_{SB}-1, N_{cb})}$, where:

$$n_{SB} = \min\left(N_{cb}, \left\lfloor \frac{N'_{soft}}{C \cdot N_{cells}^{DL} \cdot K_{\mathrm{MIMO}} \cdot \min(M_{\mathrm{DL\_HARQ}}, M_{\mathrm{limit}})} \right\rfloor\right),$$

w_k, C, N_{cb}, K_{MIMO}, ,and M_{limit} are defined in subclause 5.1.4.1.2 of [4].

$M_{\mathrm{DL\_HARQ}}$ is the maximum number of DL HARQ processes.

If the UE is configured with a SCG

- N_{cells}^{DL} is the number of configured serving cells across both MCG and SCG.

else

- N_{cells}^{DL} is the number of configured serving cells.

N'_{soft} is the maximum “Total number of soft channel bits” [12] among all the indicated UE categories [11] of this UE.

In determining *k*, the UE should give priority to storing soft channel bits corresponding to lower values of *k*. w_k shall correspond to a received soft channel bit. The range $w_k \; w_{k+1}, \ldots, w_{\mathrm{mod}(k+n_{SB}-1, N_{cb})}$ may include subsets not containing received soft channel bits.

7.1.9 PDSCH resource mapping parameters

A UE configured in transmission mode 10 for a given serving cell can be configured with up to 4 parameter sets by higher layer signaling to decode PDSCH according to a detected PDCCH/EPDCCH with DCI format 2D intended for the UE and the given serving cell. The UE shall use the parameter set according to the value of the 'PDSCH RE Mapping and Quasi-Co-Location indicator' field (mapping defined in Table 7.1.9-1) in the detected PDCCH/EPDCCH with DCI format 2D for determining the PDSCH RE mapping (defined in subclause 6.4 of [3]), and for determining PDSCH antenna port quasi co-location (defined in subclause 7.1.10) if the UE is configured with Type B quasi co-location type (defined in subclause 7.1.10). For PDSCH without a corresponding PDCCH/EPDCCH, the UE shall use the parameter set indicated in the PDCCH/EPDCCH with DCI format 2D corresponding to the associated SPS activation for determining the PDSCH RE mapping (defined in subclause 6.4 of [3]) and PDSCH antenna port quasi co-location (defined in subclause 7.1.10).

Table 7.1.9-1: PDSCH RE Mapping and Quasi-Co-Location Indicator field in DCI format 2D

Value of 'PDSCH RE Mapping and Quasi-Co-Location Indicator' field	Description
'00'	Parameter set 1 configured by higher layers
'01'	Parameter set 2 configured by higher layers
'10'	Parameter set 3 configured by higher layers
'11'	Parameter set 4 configured by higher layers

The following parameters for determining PDSCH RE mapping and PDSCH antenna port quasi co-location are configured via higher layer signaling for each parameter set:

- *crs-PortsCount-r11*.
- *crs-FreqShift-r11*.
- *mbsfn-SubframeConfigList-r11*.
- *csi-RS-ConfigZPId-r11*.
- *pdsch-Start-r11*.
- *qcl-CSI-RS-ConfigNZPId-r11*.
- *zeroTxPowerCSI-RS2-r12* if the UE is configured with higher layer parameter *eMIMO-Type* for TDD serving cell.

To decode PDSCH according to a detected PDCCH/EPDCCH with DCI format 1A with CRC scrambled with C-RNTI intended for the UE and the given serving cell and for PDSCH transmission on antenna port 7, a UE configured in transmission mode 10 for a given serving cell shall use the parameter set 1 in table 7.1.9-1 for determining the PDSCH RE mapping (defined in subclause 6.4 of [3]), and for determining PDSCH antenna port quasi co-location (defined in subclause 7.1.10) if the UE is configured with Type B quasi co-location type (defined in subclause 7.1.10).

To decode PDSCH corresponding to detected PDCCH/EPDCCH with DCI format 1A with CRC scrambled with SPS C-RNTI and PDSCH without a corresponding PDCCH/EPDCCH associated with SPS activation indicated in PDCCH/EPDCCH with DCI format 1A, a UE configured in transmission mode 10 for a given serving cell shall use the parameter set 1 in table 7.1.9-1 for determining the PDSCH RE mapping (defined in subclause 6.4 of [3]), and for determining PDSCH antenna port quasi co-location (defined in subclause 7.1.10) if the UE is configured with Type B quasi co-location type (defined in subclause 7.1.10).

To decode PDSCH according to a detected PDCCH/EPDCCH with DCI format 1A intended for the UE on a given serving cell and for PDSCH transmission on antenna port 0 – 3, a UE configured in transmission mode 10 for the given serving cell shall determine the PDSCH RE mapping (as described in subclause 6.4 of [3]) using the lowest indexed zero-power CSI-RS resource.

7.1.10 Antenna ports quasi co-location for PDSCH

A UE configured in transmission mode 8-10 for a serving cell may assume the antenna ports 7 – 14 of the serving cell are quasi co-located (as defined in [3]) for a given subframe with respect to delay spread, Doppler spread, Doppler shift, average gain, and average delay.

A UE configured in transmission mode 1-9 for a serving cell may assume the antenna ports 0 – 3, 5, 7 – 30 of the serving cell are quasi co-located (as defined in [3]) with respect to Doppler shift, Doppler spread, average delay, and delay spread.

A UE configured in transmission mode 10 for a serving cell is configured with one of two quasi co-location types for the serving cell by higher layer parameter *qcl-Operation* to decode PDSCH according to transmission scheme associated with antenna ports 7-14:

- Type A: The UE may assume the antenna ports 0 – 3, 7 – 30 of a serving cell are quasi co-located (as defined in [3]) with respect to delay spread, Doppler spread, Doppler shift, and average delay.

- Type B: The UE may assume the antenna ports 15 – 30 corresponding to the CSI-RS resource configuration identified by the higher layer parameter *qcl-CSI-RS-ConfigNZPId-r11* (defined in subclause 7.1.9) and the antenna ports 7 – 14 associated with the PDSCH are quasi co-located (as defined in [3]) with respect to Doppler shift, Doppler spread, average delay, and delay spread.

For a LAA Scell, the UE is not expected to be configured with quasi co-location type B.

7.1.11 PDSCH subframe assignment for BL/CE UE using MPDCCH

A BL/CE UE shall upon detection of a MPDCCH with DCI format 6-1A/6-1B/6-2 intended for the UE, decode the corresponding PDSCH in subframe(s) $n+k_i$ with $i = 0, 1, \ldots, N-1$ according to the MPDCCH, where

- subframe n is the last subframe in which the MPDCCH is transmitted and is determined from the starting subframe of MPDCCH transmission and the DCI subframe repetition number field in the corresponding DCI; and

- subframe(s) $n+k_i$ with $i=0,1,\ldots,N-1$ are N consecutive BL/CE DL subframe(s) where, $x=k_0<k_1<\ldots,k_{N-1}$ and the value of $N \in \{n1, n2, \ldots n_{\max}\}$ is determined by the repetition number field in the corresponding DCI, where $n1, n2, \ldots n_{\max}$ are given in Table 7.1.11-1, Table 7.1.11-2 and Table 7.1.11-3, respectively and subframe $n+x$ is the second BL/CE DL subframe after subframe n.

If PDSCH carrying *SystemInformationBlockType1-BR* is transmitted in one narrowband in subframe $n+k_i$, a BL/CE UE shall assume any other PDSCH in the same narrowband in the subframe $n+k_i$ is dropped. If PDSCH carrying SI message is transmitted in one narrowband in subframe $n+k_i$, a BL/CE UE shall assume any other PDSCH not carrying *SystemInformationBlockType1-BR* in the same narrowband in the subframe $n+k_i$ is dropped.

For single antenna port (port 0), transmit diversity and closed-loop spatial multiplexing transmission schemes, if a PDSCH is transmitted in BL/CE DL subframe $n+k_i$ and BL/CE DL subframe $n+k_i$ is configured as an MBSFN subframe, a BL/CE UE shall assume that the PDSCH in subframe $n+k_i$ is dropped.

Table 7.1.11-1: PDSCH repetition levels (DCI Format 6-1A)

Higher layer parameter '*pdsch-maxNumRepetitionCEmodeA*'	$\{n1, n2, n3, n4\}$
Not configured	{1,2,4,8}
16	{1,4,8,16}
32	{1,4,16,32}

Table 7.1.11-2: PDSCH repetition levels (DCI Format 6-1B)

Higher layer parameter '*pdsch-maxNumRepetitionCEmodeB*'	$\{n1, n2, \ldots, n8\}$
Not configured	{4,8,16,32,64,128,256,512}
192	{1,4,8,16,32,64,128,192}
256	{4,8,16,32,64,128,192,256}
384	{4,16,32,64,128,192,256,384}
512	{4,16,64,128,192,256,384,512}
768	{8,32,128,192,256,384,512,768}
1024	{4,8,16,64,128,256,512,1024}
1536	{4,16,64,256,512,768,1024,1536}
2048	{4,16,64,128,256,512,1024,2048}

Table 7.1.11-3: PDSCH repetition levels (DCI Format 6-2)

2-bit "DCI subframe repetition number" field in DCI Format 6-2	$\{n1, n2, \ldots, n8\}$
00	{1,2,4,8,16,32,64,128}
01	{4,8,16,32,64,128,192,256}
10	{32,64,128,192,256,384,512,768}
11	{192,256,384,512,768,1024,1536,2048}

7.2 UE procedure for reporting Channel State Information (CSI)

If the UE is configured with a PUCCH-SCell, the UE shall apply the procedures described in this clause for both primary PUCCH group and secondary PUCCH group unless stated otherwise

- When the procedures are applied for the primary PUCCH group, the terms 'secondary cell', 'secondary cells', 'serving cell', and 'serving cells' in this clause refer to secondary cell, secondary cells, serving cell or serving cells belonging to the primary PUCCH group respectively unless stated otherwise.
- When the procedures are applied for secondary PUCCH group, the terms 'secondary cell', 'secondary cells', 'serving cell' and 'serving cells' in this clause refer to secondary cell, secondary cells (not including the PUCCH-SCell), serving cell, serving cells belonging to the secondary PUCCH group respectively unless stated otherwise. The term 'primary cell' in this clause refers to the PUCCH-SCell of the secondary PUCCH group.

The time and frequency resources that can be used by the UE to report CSI which consists of Channel Quality Indicator (CQI), precoding matrix indicator (PMI), precoding type indicator (PTI), CSI-RS resource indicator (CRI), and/or rank indication (RI) are controlled by the eNB. For spatial multiplexing, as given in [3], the UE shall determine a RI corresponding to the number of useful transmission layers. For transmit diversity as given in [3], RI is equal to one.

A non-BL/CE UE in transmission mode 8 or 9 is configured with or without PMI/RI reporting by the higher layer parameter *pmi-RI-Report*.

A UE in transmission mode 10 can be configured with one or more CSI processes per serving cell by higher layers.

For a UE in transmission mode 10,

- If a UE is not configured with higher layer parameter *eMIMO-Type*, each CSI process is associated with a CSI-RS resource (defined in subclause 7.2.5) and a CSI-interference measurement (CSI-IM) resource (defined in subclause 7.2.6). A UE can be configured with up to two CSI-IM resources for a CSI process if the UE is configured with CSI subframe sets $C_{\text{CSI},0}$ and $C_{\text{CSI},1}$ by the higher layer parameter *csi-SubFramePatternConfig-r12* for the CSI process.
- If the UE is configured with higher layer parameter *eMIMO-Type*, and *eMIMO-Type* is set to 'CLASS A', each CSI process is associated with a CSI-RS resource (defined in subclause 7.2.5) and a CSI-interference measurement (CSI-IM) resource (defined in subclause 7.2.6). A UE can be configured with up to two CSI-IM resources for a CSI process if the UE is configured with CSI subframe sets $C_{\text{CSI},0}$ and $C_{\text{CSI},1}$ by the higher layer parameter *csi-SubFramePatternConfig-r12* for the CSI process.
- If the UE is configured with higher layer parameter *eMIMO-Type*, and *eMIMO-Type* is set to 'CLASS B', each CSI process is associated with one or more CSI-RS resource (defined in subclause 7.2.5) and one or more CSI-interference measurement (CSI-IM) resource (defined in subclause 7.2.6). Each CSI-RS resource is associated with a CSI-IM resource by higher layers. For a CSI process with one CSI-RS resource, a UE can be configured with CSI-IM resource for each CSI subframe sets if the UE is configured with CSI subframe sets $C_{\text{CSI},0}$ and $C_{\text{CSI},1}$ by the higher layer parameter *csi-SubFramePatternConfig-r12* for the CSI process.

For a UE in transmission mode 10, a CSI reported by the UE corresponds to a CSI process configured by higher layers. Each CSI process can be configured with or without PMI/RI reporting by higher layer signalling.

If a UE is configured with a serving cell with frame structure 3, the UE is not required to update measurements for more than 5 CSI processes in a subframe, in case the total number of serving cells is no more than 5. If a UE is configured with more than 5 serving cells, and if the UE is configured with a serving cell with frame structure 3, the UE is not required to update measurements for more than N_y CSI processes in a subframe, where the value of N_y is given by *maxNumberUpdatedCSI-Proc-r13*.

For UE in transmission mode 9 and the UE configured with higher layer parameter *eMIMO-Type*, the term 'CSI process' in this subclause refers to the CSI configured for the UE.

For a UE in transmission mode 9, and if the UE is configured with higher layer parameter *eMIMO-Type*, and,

- *eMIMO-Type* is set to 'CLASS A', each CSI process is associated with a CSI-RS resource (defined in subclause 7.2.5).

- *eMIMO-Type* is set to 'CLASS B', each CSI process is associated with one or more CSI-RS resource (defined in subclause 7.2.5).

For a CSI process, and if a UE is configured in transmission mode 9 or 10, and UE is not configured with higher layer parameter *pmi-RI-Report*, and UE is configured with higher layer parameter *eMIMO-Type*, and *eMIMO-Type* is set to 'CLASS B', and the number of CSI-RS antenna ports in at least one of the one or more configured CSI-RS resource is more than one, the UE is considered to be configured without PMI reporting.

A UE is configured with resource-restricted CSI measurements if the subframe sets $C_{\text{CSI},0}$ and $C_{\text{CSI},1}$ are configured by higher layers.

For a serving cell with frame structure type 1, a UE is not expected to be configured with *csi-SubframePatternConfig-r12*.

CSI reporting is periodic or aperiodic.

A BL/CE UE configured with CEModeB is not expected to be configured with either aperiodic CSI or periodic CSI reporting.

If the UE is configured with more than one serving cell, it transmits CSI for activated serving cell(s) only.

If a UE is not configured for simultaneous PUSCH and PUCCH transmission, it shall transmit periodic CSI reporting on PUCCH as defined hereafter in subframes with no PUSCH allocation.

If a UE is not configured for simultaneous PUSCH and PUCCH transmission, it shall transmit periodic CSI reporting on PUSCH of the serving cell with smallest *ServCellIndex* as defined hereafter in subframes with a PUSCH allocation, where the UE shall use the same PUCCH-based periodic CSI reporting format on PUSCH.

A UE shall transmit aperiodic CSI reporting on PUSCH if the conditions specified hereafter are met. For aperiodic CQI/PMI reporting, RI reporting is transmitted only if the configured CSI feedback type supports RI reporting.

Table 7.2-1: Void

In case both periodic and aperiodic CSI reporting would occur in the same subframe, the UE shall only transmit the aperiodic CSI report in that subframe.

If the higher layer parameter *altCQI-Table-r12* is configured and is set to *allSubframes-r12*,

- the UE shall report CQI according to Table 7.2.3-2.

Else if the higher layer parameter *altCQI-Table-r12* is configured and is set to *csi-SubframeSet1-r12* or *csi-SubframeSet2-r12*,

- the UE shall report CQI according to Table 7.2.3-2 for the corresponding CSI subframe set configured by *altCQI-Table-r12*

- the UE shall report CQI for the other CSI subframe set according to Table 7.2.3-1.

Else

- the UE shall report CQI according to Table 7.2.3-1.

For a non-BL/CE UE, when reporting RI the UE reports a single instance of the number of useful transmission layers. For each RI reporting interval when the UE is configured in transmission modes 4 or when the UE is configured in transmission mode 8, 9 or 10 with PMI/RI reporting, a UE shall determine a RI from the supported set of RI values as defined in subclause 5.2.2.6 of [4] and report the number in each RI report. For each RI reporting interval when the UE is configured in transmission mode 3, a UE shall determine RI as defined in subclause 5.2.2.6 of [4] in each reporting interval and report the detected number in each RI report to support selection between transmit diversity and large delay CDD.

For a UE configured in transmission mode 9 or 10, when reporting CRI the UE reports a single instance of a selected CSI-RS resource. For each CRI reporting interval when a UE is configured with higher layer parameter *eMIMO-Type*, and *eMIMO-Type* is set to 'CLASS B', and the number of configured CSI-RS resources is more than one for a CSI process, the UE shall determine a CRI from the supported set of CRI values as defined in subclause 5.2.2.6 of [4] and report the number in each CRI report, where CRI value 0 corresponds to the configured *csi-RS-ConfigNZPId*, first entry of *csi-IM-ConfigIdList*, first entry of *p-C-AndCBSR-PerResourceConfigList*, and *alternativeCodebookEnabledFor4TXProc*, and CRI value *k* (*k*>0) corresponds to the configured *k*-th entry of *csi-RS-ConfigNZPIdListExt*, (*k*+1)-th entry of *csi-IM-ConfigIdList*, (*k*+1)-th entry of *p-C-AndCBSR-PerResourceConfigList*, and *k*-th entry of *ace-For4Tx-PerResourceConfigList*.

For a non-BL/CE UE, when reporting PMI the UE reports either a single or a multiple PMI report. The number of RBs represented by a single UE PMI report can be $N_{\mathrm{RB}}^{\mathrm{DL}}$ or a smaller subset of RBs. The number of RBs represented by a single PMI report is semi-statically configured by higher layer signalling. A UE is restricted to report PMI, RI and PTI within a precoder codebook subset specified by one or more bitmap parameter(s) *codebookSubsetRestriction, codebookSubsetRestriction-1, codebookSubsetRestriction-2, codebookSubsetRestriction-3* configured by higher layer signalling.

For a UE configured in transmission mode 10 and the UE not configured with higher layer parameter *eMIMO-Type* for a CSI process, or for a UE configured in transmission mode 9 or 10 and the UE configured with higher layer parameter *eMIMO-Type*, and *eMIMO-Type* is set to 'CLASS B', and one CSI-RS resource configured and except with higher layer parameter *alternativeCodebookEnabledCLASSB_K1=TRUE* configured and except with higher layer parameter *alternativeCodebookEnabledCLASSB_K1=TRUE* configured for a CSI process, the bitmap parameter *codebookSubsetRestriction* is configured for each CSI process and each subframe sets (if subframe sets $C_{\mathrm{CSI},0}$ and $C_{\mathrm{CSI},1}$ are configured by higher layers) by higher layer signaling.

For a UE configured in transmission mode 9 or 10, and for a CSI process and UE configured with higher layer parameter *eMIMO-Type*, and *eMIMO-Type* is set to 'CLASS A', the bitmap parameters *codebookSubsetRestriction-1, codebookSubsetRestriction-2* is configured for the CSI process and each subframe sets (if subframe sets $C_{\mathrm{CSI},0}$ and $C_{\mathrm{CSI},1}$ are configured by higher layers) by higher layer signaling.

For a UE configured in transmission mode 9 or 10, and for a CSI process and UE configured with higher layer parameter *eMIMO-Type*, and *eMIMO-Type* is set to 'CLASS B', and one CSI-RS resource configured, and higher layer parameter *alternativeCodebookEnabledCLASSB_K1=TRUE*, the bitmap parameter *codebookSubsetRestriction-3* is configured for the CSI process and each subframe sets (if subframe sets $C_{\mathrm{CSI},0}$ and $C_{\mathrm{CSI},1}$ are configured by higher layers) by higher layer signaling.

For a UE configured in transmission mode 9 or 10, and for a CSI process and UE configured with higher layer parameter *eMIMO-Type*, and *eMIMO-Type* is set to 'CLASS B', and more than one CSI-RS resource configured, the bitmap parameter *codebookSubsetRestriction* is configured for each CSI-RS resource of the CSI process and each subframe sets (if subframe sets $C_{\mathrm{CSI},0}$ and $C_{\mathrm{CSI},1}$ are configured by higher layers) by higher layer signaling.

For a specific precoder codebook and associated transmission mode, the bitmap can specify all possible precoder codebook subsets from which the UE can assume the eNB may be using when the UE is configured in the relevant transmission mode. Codebook subset restriction is supported for transmission modes 3, 4, 5, 6 and for transmission modes 8, 9 and 10 with PMI/RI reporting, and transmission mode 9 and 10 without PMI reporting. The resulting number of bits for each transmission mode are given in Table 7.2-1b, Table 7.2-1d, Table 7.2-1e, and Table 7.2-1f. The bitmap parameter *codebookSubsetRestriction*, *codebookSubsetRestriction-1* or *codebookSubsetRestriction*-3 forms the bit sequence $a_{A_c-1},...,a_3,a_2,a_1,a_0$ where a_0 is the LSB and a_{A_c-1} is the MSB and where a bit value of zero indicates that the PMI and RI reporting is not allowed to correspond to precoder(s) associated with the bit. The bitmap parameter *codebookSubsetRestriction-2* forms the bit sequence $b_{B_c-1},...,b_3,b_2,b_1,b_0$ where b_0 is the LSB and b_{B_c-1} is the MSB and where a bit value of zero indicates that the PMI and RI reporting is not allowed to correspond to precoder(s) associated with the bit. The association of bits to precoders for the relevant transmission modes are given as follows:

1. Transmission mode 3

   a. 2 antenna ports: bit $a_{\upsilon-1}, \upsilon=2$ is associated with the precoder in Table 6.3.4.2.3-1 of [3] corresponding to υ layers and codebook index 0 while bit a_0 is associated with the precoder for 2 antenna ports in subclause 6.3.4.3 of [3].

b. 4 antenna ports: bit $a_{\upsilon-1}, \upsilon = 2,3,4$ is associated with the precoders in Table 6.3.4.2.3-2 of [3] corresponding to υ layers and codebook indices 12, 13, 14, and 15 while bit a_0 is associated with the precoder for 4 antenna ports in subclause 6.3.4.3 of [3].

2. Transmission mode 4

a. 2 antenna ports: see Table 7.2-1c

b. 4 antenna ports: bit $a_{16(\upsilon-1)+i_c}$ is associated with the precoder for υ layers and with codebook index i_c in Table 6.3.4.2.3-2 of [3].

3. Transmission modes 5 and 6

a. 2 antenna ports: bit a_{i_c} is associated with the precoder for $\upsilon = 1$ layer with codebook index i_c in Table 6.3.4.2.3-1 of [3].

b. 4 antenna ports: bit a_{i_c} is associated with the precoder for $\upsilon = 1$ layer with codebook index i_c in Table 6.3.4.2.3-2 of [3].

4. Transmission mode 8

a. 2 antenna ports: see Table 7.2-1c

b. 4 antenna ports except with *alternativeCodeBookEnabledFor4TX-r12=TRUE* configured: bit $a_{16(\upsilon-1)+i_c}$ is associated with the precoder for υ layers and with codebook index i_c in Table 6.3.4.2.3-2 of [3], $\upsilon = 1,2$.

c. 4 antenna ports with *alternativeCodeBookEnabledFor4TX-r12=TRUE* configured: bit $a_{16(\upsilon-1)+i_1}$ is associated with the precoder for υ layers ($\upsilon \in \{1,2\}$) and codebook index i_1 and bit $a_{32+16(\upsilon-1)+i_2}$ is associated with the precoder for υ layers ($\upsilon \in \{1,2\}$) and codebook index i_2. Codebook indices i_1 and i_2 are given in Table 7.2.4-0A or 7.2.4-0B, for υ=1 or 2 respectively.

5. Transmission modes 9 and 10

a. 2 antenna ports except when a UE configured with higher layer parameter *eMIMO-Type*, and *eMIMO-Type* is set to 'CLASS B', and one CSI-RS resource configured, and higher layer parameter *alternativeCodebookEnabledCLASSB_K1=TRUE* for a CSI process: see Table 7.2-1c

b. 4 antenna ports except with *alternativeCodeBookEnabledFor4TX-r12=TRUE* configured or for a CSI process the UE is configured with higher layer parameter *eMIMO-Type*, and *eMIMO-Type* is set to 'CLASS B', and one CSI-RS resource configured, and higher layer parameter *alternativeCodebookEnabledCLASSB_K1=TRUE*: bit $a_{16(\upsilon-1)+i_c}$ is associated with the precoder for υ layers and with codebook index i_c in Table 6.3.4.2.3-2 of [3].

c. 4 antenna ports with *alternativeCodeBookEnabledFor4TX-r12=TRUE* configured except when a UE configured with higher layer parameter *eMIMO-Type*, and *eMIMO-Type* is set to 'CLASS B', and one CSI-RS resource configured, and higher layer parameter *alternativeCodebookEnabledCLASSB_K1=TRUE* for a CSI process: bit $a_{16(\upsilon-1)+i_1}$ is associated with the precoder for υ layers ($\upsilon \in \{1,2\}$) and codebook index i_1 and bit $a_{32+16(\upsilon-1)+i_2}$ is associated with the precoder for υ layers ($\upsilon \in \{1,2,3,4\}$) and codebook index i_2. Codebook indices i_1 and i_2 are given in Table 7.2.4-0A, 7.2.4-0B, 7.2.4-0C or 7.2.4-0D, for υ=1,2,3 or 4 respectively.

d. 8 antenna ports except when a UE configured with higher layer parameter *eMIMO-Type*, and *eMIMO-Type* is set to 'CLASS A', or for when a UE configured with higher layer parameter *eMIMO-Type*, and *eMIMO-Type* is set to 'CLASS B', and one CSI-RS resource configured, and higher layer parameter *alternativeCodebookEnabledCLASSB_K1=TRUE* for a CSI process: bit $a_{f1(\upsilon-1)+i_1}$ is associated with the precoder for υ layers ($\upsilon \in \{1,2,3,4,5,6,7,8\}$) and codebook index i_1 where $f1(\cdot)=\{0,16,32,36,40,44,48,52\}$ and bit $a_{53+g1(\upsilon-1)+i_2}$ is associated with the precoder for υ layers ($\upsilon \in \{1,2,3,4\}$) and codebook index i_2 where $g1(\cdot)=\{0,16,32,48\}$. Codebook indices i_1 and i_2 are given in Table 7.2.4-1, 7.2.4-2, 7.2.4-3, 7.2.4-4, 7.2.4-5, 7.2.4-6, 7.2.4-7, or 7.2.4-8, for υ=1,2,3,4,5,6,7, or 8 respectively.

e. 8, 12, and 16 antenna ports and for a CSI process the UE is configured with higher layer parameter *eMIMO-Type*, and *eMIMO-Type* is set to 'CLASS A': bit $a_{N_2O_2l+m}$ is associated with the precoder based on the quantity $v_{l,m}$ $l=0,1,...,N_1O_1-1$, $m=0,1,...,N_2O_2-1$ and bit $a_{N_1O_1N_2O_2+\upsilon-1}$ is associated with the precoder for υ layers ($\upsilon \in \{1,2,3,4,5,6,7,8\}$). The quantity $v_{l,m}$ is defined in subclause 7.2.4. Bit $b_{g(\upsilon-1)+i_2}$ is associated with the precoder for υ layers ($\upsilon \in \{1,2,3,4\}$) and codebook index i_2 where $g(\cdot)$ is given in Table 7.2-1g. Codebook index i_2 is given in Table 7.2.4-10, 7.2.4-11, 7.2.4-12, 7.2.4-13, 7.2.4-14, 7.2.4-15, 7.2.4-16, or 7.2.4-17, for υ=1,2,3,4,5,6,7, or 8 respectively.

f. 2, 4, or 8 antenna ports and for a CSI process the UE is configured with higher layer parameter *eMIMO-Type*, and *eMIMO-Type* is set to 'CLASS B', and one CSI-RS resource configured, and higher layer parameter *alternativeCodebookEnabledCLASSB_K1=TRUE*: bit $a_{f(\upsilon-1)+i_c}$ is associated with the precoder for υ layers and codebook index i_c where $\upsilon \in \{1,2\}$ and $f(\cdot)=\{0,4\}$ for 2 antenna ports, $\upsilon \in \{1,2,3,4\}$ and $f(\cdot)=\{0,8,16,20\}$ for 4 antenna ports, and $\upsilon \in \{1,2,3,4,5,6,7,8\}$ and $f(\cdot)=\{0,16,32,48,56,57,58,59\}$ for 8 antenna ports. Codebook index i_c is given in Table 7.2.4-18, 7.2.4-19, or 7.2.4-20, for 2, 4, or 8 antenna ports respectively.

For a BL/CE UE, when reporting PMI the UE reports a single PMI report. A UE is restricted to report PMI within a precoder codebook subset specified by a bitmap parameter *codebookSubsetRestriction* configured by higher layer signalling. For a specific precoder codebook and associated transmission mode, the bitmap can specify all possible precoder codebook subsets from which the UE can assume the eNB may be using when the UE is configured in the relevant transmission mode. Codebook subset restriction is supported for transmission modes 6 and 9. The resulting number of bits for each transmission mode is given in Table 7.2-1b. The bitmap forms the bit sequence $a_{A_c-1},...,a_3,a_2,a_1,a_0$ where a_0 is the LSB and a_{A_c-1} is the MSB and where a bit value of zero indicates that the PMI reporting is not allowed to correspond to precoder(s) associated with the bit. The association of bits to precoders for the relevant transmission modes are given as follows:

- Transmission mode 6
  - 2 antenna ports: bit a_{i_c} is associated with the precoder for $\upsilon=1$ layer with codebook index i_c in Table 6.3.4.2.3-1 of [3].
  - 4 antenna ports: bit a_{i_c} is associated with the precoder for $\upsilon=1$ layer with codebook index i_c in Table 6.3.4.2.3-2 of [3].
- Transmission mode 9
  - 2 antenna ports: bit a_{i_c} is associated with the precoder for $\upsilon=1$ layer with codebook index i_c in Table 6.3.4.2.3-1 of [3].
  - 4 antenna ports: bit a_{i_c} is associated with the precoder for $\upsilon=1$ layer and with codebook index i_c in Table 6.3.4.2.3-2 of [3].

Table 7.2-1b: Number of bits in codebook subset restriction *codebookSubsetRestriction* bitmap for applicable transmission modes

	Number of bits A_c		
	2 antenna ports	4 antenna ports	8 antenna ports
Transmission mode 3	2	4	
Transmission mode 4	6	64	
Transmission mode 5	4	16	
Transmission mode 6	4	16	
Transmission mode 8	6	64 with *alternativeCodeBookEnabledFor4TX-r12=TRUE* configured, otherwise 32	
Transmission modes 9 and 10	6	96 with *alternativeCodeBookEnabledFor4TX-r12=TRUE* configured, otherwise 64	109

Table 7.2-1c: Association of bits in *codebookSubSetRestriction* bitmap to precoders in the 2 antenna port codebook of Table 6.3.4.2.3-1 in [3]

Codebook index i_c	Number of layers υ	
	1	2
0	a_0	-
1	a_1	a_4
2	a_2	a_5
3	a_3	-

Table 7.2-1d: Number of bits in codebook subset restriction *codebookSubsetRestriction1* bitmap for applicable transmission modes

	Number of bits A_c
Transmission modes 9 and 10	$N_1 O_1 N_2 O_2 + 8$

Table 7.2-1e: Number of bits in codebook subset restriction *codebookSubsetRestriction2* bitmap for applicable transmission modes

	Value of codebookConfig	Number of bits A_c
Transmission modes 9 and 10	1	12
	2	56
	3	56
	4	56

Table 7.2-1f: Number of bits in codebook subset restriction *codebookSubsetRestriction3* bitmap for applicable transmission modes

	Number of bits A_c		
	2 antenna ports	4 antenna ports	8 antenna ports
Transmission modes 9 and 10	6	22	60

Table 7.2-1g: $g(\cdot)$ for a CSI process with *eMIMO-Type* set to 'CLASS A'

Value of codebookConfig	$g(\cdot)$
1	$\{0,4,8,10\}$
2	$\{0,16,32,48\}$
3	$\{0,16,32,48\}$
4	$\{0,16,32,48\}$

For a non-BL/CE UE, the set of subbands (S) a UE shall evaluate for CQI reporting spans the entire downlink system bandwidth. A subband is a set of k contiguous PRBs where k is a function of system bandwidth. Note the last subband in set S may have fewer than k contiguous PRBs depending on N_{RB}^{DL} . The number of subbands for system bandwidth given by N_{RB}^{DL} is defined by $N = \lceil N_{RB}^{DL} / k \rceil$. The subbands shall be indexed in the order of increasing frequency and non-increasing sizes starting at the lowest frequency.

- For transmission modes 1, 2, 3 and 5, as well as transmission modes 8, 9 and 10 without PMI/RI reporting, transmission mode 4 with RI=1, transmission modes 8, 9 and 10 with PMI/RI reporting and RI=1, and transmission modes 9 and 10 without PMI reporting and RI=1, a single 4-bit wideband CQI is reported.

- For transmission modes 3 and 4, as well as transmission modes 8, 9 and 10 with PMI/RI reporting, and transmission modes 9 and 10 without PMI reporting, CQI is calculated assuming transmission of one codeword for RI=1 and two codewords for RI > 1.

- For RI > 1 with transmission mode 4, as well as transmission modes 8, 9 and 10 with PMI/RI reporting, and transmission modes 9 and 10 without PMI reporting, PUSCH based triggered reporting includes reporting a wideband CQI which comprises:

  - A 4-bit wideband CQI for codeword 0

  - A 4-bit wideband CQI for codeword 1

- For RI > 1 with transmission mode 4, as well as transmission modes 8, 9 and 10 with PMI/RI reporting, and transmission modes 9 and 10 without PMI reporting, PUCCH based reporting includes reporting a 4-bit wideband CQI for codeword 0 and a wideband spatial differential CQI. The wideband spatial differential CQI value comprises:

  - A 3-bit wideband spatial differential CQI value for codeword 1 offset level

    - Codeword 1 offset level = wideband CQI index for codeword 0 – wideband CQI index for codeword 1.

  - The mapping from the 3-bit wideband spatial differential CQI value to the offset level is shown in Table 7.2-2.

Table 7.2-2 Mapping spatial differential CQI value to offset level

Spatial differential CQI value	Offset level
0	0
1	1
2	2
3	≥3
4	≤-4
5	-3
6	-2
7	-1

7.2.1 Aperiodic CSI Reporting using PUSCH

The term "UL/DL configuration" in this subclause refers to the higher layer parameter *subframeAssignment* unless specified otherwise.

A non-BL/CE UE shall perform aperiodic CSI reporting using the PUSCH in subframe $n+k$ on serving cell c, upon decoding in subframe n either:

- an uplink DCI format [4], or
- a Random Access Response Grant,

for serving cell c if the respective CSI request field is set to trigger a report and is not reserved.

A BL/CE UE shall perform aperiodic CSI reporting using the PUSCH upon decoding either:

- an uplink DCI format [4], or
- a Random Access Response Grant,

for serving cell c if the respective CSI request field is set to trigger a report and is not reserved. The subframe(s) in which the PUSCH carrying the corresponding aperiodic CSI reporting triggered by an UL DCI format is transmitted is determined according to subclause 8.0.

If the CSI request field is 1 bit and the UE is configured in transmission mode 1-9 and the UE is not configured with *csi-SubframePatternConfig-r12* for any serving cell, a report is triggered for serving cell c, if the CSI request field is set to '1'.

If the CSI request field is 1 bit and the UE is configured in transmission mode 10 and the UE is not configured with *csi-SubframePatternConfig-r12* for any serving cell, a report is triggered for a set of CSI process(es) for serving cell c corresponding to the higher layer configured set of CSI process(es) associated with the value of CSI request field of '01' in Table 7.2.1-1B, if the CSI request field is set to '1'.

If the CSI request field size is 2 bits and the UE is configured in transmission mode 1-9 for all serving cells and the UE is not configured with *csi-SubframePatternConfig-r12* for any serving cell, a report is triggered according to the value in Table 7.2.1-1A corresponding to aperiodic CSI reporting.

If the CSI request field size is 2 bits and the UE is configured in transmission mode 10 for at least one serving cell and the UE is not configured with *csi-SubframePatternConfig-r12* for any serving cell, a report is triggered according to the value in Table 7.2.1-1B corresponding to aperiodic CSI reporting.

If the CSI request field is 1 bit and the UE is configured with the higher layer parameter *csi-SubframePatternConfig-r12* for at least one serving cell, a report is triggered for a set of CSI process(es) and/or {CSI process, CSI subframe set}-pair(s) for serving cell c corresponding to the higher layer configured set of CSI process(es) and/or {CSI process, CSI subframe set}-pair(s) associated with the value of CSI request field of '01' in Table 7.2.1-1C, if the CSI request field is set to '1'.

If the CSI request field size is 2 bits and the UE is configured with the higher layer parameter *csi-SubframePatternConfig-r12* for at least one serving cell, a report is triggered according to the value in Table 7.2.1-1C corresponding to aperiodic CSI reporting.

If the CSI request field size is 3 bits and the UE is not configured with the higher layer parameter *csi-SubframePatternConfig-r12* for any serving cell, a report is triggered according to the value in Table 7.2.1-1D corresponding to aperiodic CSI reporting.

If the CSI request field size is 3 bits and the UE is configured with the higher layer parameter *csi-SubframePatternConfig-r12* for at least one serving cell, a report is triggered according to the value in Table 7.2.1-1E corresponding to aperiodic CSI reporting.

For a given serving cell, if the UE is configured in transmission modes 1-9, the "CSI process" in Table 7.2.1-1B, Table 7.2.1-1C, Table 7.2.1-1D, and Table 7.2.1-1E refers to the aperiodic CSI configured for the UE on the given serving cell. A UE is not expected to be configured by higher layers with more than 5 CSI processes in each of the 1^{st} and 2^{nd} set of CSI process(es) in Table 7.2.1-1B. A UE is not expected to be configured by higher layers with more than 5 CSI processes and/or {CSI process, CSI subframe set}-pair(s) in each of the 1^{st} and 2^{nd} set of CSI process(es) and/or {CSI process, CSI subframe set}-pair(s) in Table 7.2.1-1C. A UE is not expected to be configured by higher layers with more than one instance of the same CSI process in each of the higher layer configured sets associated with the value of CSI request field of '01', '10', and '11' in Table 7.2.1-1B and Table 7.2.1-1C respectively. A UE is not expected to be configured by higher layers with more than 32 CSI processes in each of the 1^{st} to 6^{th} set of CSI process(es) in Table 7.2.1-1D. A UE is not expected to be configured by higher layers with more than 32 CSI processes and/or {CSI process, CSI subframe set}-pair(s) in each of the 1^{st} to 6^{th} set of CSI process(es) and/or {CSI process, CSI subframe set}-pair(s) in Table 7.2.1-1E. A UE is not expected to be configured by higher layers with more than one instance of the same CSI process in each of the higher layer configured sets associated with the value of CSI request field of '001', '010', '011', '100', '101', '110' and '111' in Table 7.2.1-1D and Table 7.2.1-1E respectively.

A UE is not expected to receive more than one aperiodic CSI report request for a given subframe.

If a UE is configured with more than one CSI process for a serving cell, the UE on reception of an aperiodic CSI report request triggering a CSI report according to Table 7.2.1-1B is not expected to update CSI corresponding to the CSI reference resource (defined in subclause 7.2.3) for all CSI processes except the $\max(N_x - N_u, 0)$ lowest-indexed CSI processes for the serving cell associated with the request when the UE has N_u unreported CSI processes associated with other aperiodic CSI requests for the serving cell, where a CSI process associated with a CSI request shall only be counted as unreported in a subframe before the subframe where the PUSCH carrying the corresponding CSI is transmitted, and N_{CSI-P} is the maximum number of CSI processes supported by the UE for the serving cell and:

- for FDD serving cell $N_x = N_{CSI-P}$;
- for TDD serving cell
  - if the UE is configured with four CSI processes for the serving cell , $N_x = N_{CSI-P}$
  - if the UE is configured with two or three CSI processes for the serving cell, $N_x = 3$.

If more than one value of N_{CSI-P} is included in the *UE-EUTRA-Capability*, the UE assumes a value of N_{CSI-P} that is consistent with its CSI process configuration. If more than one consistent value of N_{CSI-P} exists, the UE may assume any one of the consistent values.

If a UE is configured with multiple cell groups, and if the UE receives multiple aperiodic CSI report requests in a subframe for different cell groups triggering more than one CSI report, the UE is not required to update CSI for more than 5 CSI processes from the CSI processes corresponding to all the triggered CSI reports.

If a UE is configured with a PUCCH-SCell, and if the UE receives multiple aperiodic CSI report requests in a subframe for both the primary PUCCH group and the secondary PUCCH group triggering more than one CSI report, the UE is not required to update CSI for more than 5 CSI processes from the CSI processes corresponding to all the triggered CSI reports, in case the total number of serving cells in the primary and secondary PUCCH group is no more than 5. If a UE is configured with more than 5 serving cells, and if the UE receives aperiodic CSI report request in a subframe triggering more than N_y CSI reports, the UE is not required to update CSI for more than N_y CSI processes from the CSI processes corresponding to all the triggered CSI reports, where the value of N_y is given by *maxNumberUpdatedCSI-Proc-r13*.

Table 7.2.1-1A: CSI Request field for PDCCH/EPDCCH with uplink DCI format in UE specific search space

Value of CSI request field	Description
'00'	No aperiodic CSI report is triggered
'01'	Aperiodic CSI report is triggered for serving cell c
'10'	Aperiodic CSI report is triggered for a 1st set of serving cells configured by higher layers
'11'	Aperiodic CSI report is triggered for a 2nd set of serving cells configured by higher layers

Table 7.2.1-1B: CSI Request field for PDCCH/EPDCCH with uplink DCI format in UE specific search space

Value of CSI request field	Description
'00'	No aperiodic CSI report is triggered
'01'	Aperiodic CSI report is triggered for a set of CSI process(es) configured by higher layers for serving cell c
'10'	Aperiodic CSI report is triggered for a 1st set of CSI process(es) configured by higher layers
'11'	Aperiodic CSI report is triggered for a 2nd set of CSI process(es) configured by higher layers

Table 7.2.1-1C: CSI Request field for PDCCH/EPDCCH/MPDCCH with uplink DCI format in UE specific search space

Value of CSI request field	Description
'00'	No aperiodic CSI report is triggered
'01'	Aperiodic CSI report is triggered for a set of CSI process(es) and/or {CSI process, CSI subframe set}-pair(s) configured by higher layers for serving cell c
'10'	Aperiodic CSI report is triggered for a 1st set of CSI process(es) and/or {CSI process, CSI subframe set}-pair(s) configured by higher layers
'11'	Aperiodic CSI report is triggered for a 2nd set of CSI process(es) and/or {CSI process, CSI subframe set}-pair(s) configured by higher layers

Table 7.2.1-1D: CSI Request field for PDCCH/EPDCCH with uplink DCI format in UE specific search space

Value of CSI request field	Description
'000'	No aperiodic CSI report is triggered
'001'	Aperiodic CSI report is triggered for a set of CSI process(es) configured by higher layers for serving cell c
'010'	Aperiodic CSI report is triggered for a 1st set of CSI process(es) configured by higher layers
'011'	Aperiodic CSI report is triggered for a 2nd set of CSI process(es) configured by higher layers
'100'	Aperiodic CSI report is triggered for a 3rd set of CSI process(es) configured by higher layers
'101'	Aperiodic CSI report is triggered for a 4th set of CSI process(es) configured by higher layers
'110'	Aperiodic CSI report is triggered for a 5th set of CSI process(es) configured by higher layers
'111'	Aperiodic CSI report is triggered for a 6th set of CSI process(es) configured by higher layers

Table 7.2.1-1E: CSI Request field for PDCCH/EPDCCH with uplink DCI format in UE specific search space

Value of CSI request field	Description
'000'	No aperiodic CSI report is triggered
'001'	Aperiodic CSI report is triggered for a set of CSI process(es) and/or {CSI process, CSI subframe set}-pair(s) configured by higher layers for serving cell c
'010'	Aperiodic CSI report is triggered for a 1st set of CSI process(es) and/or {CSI process, CSI subframe set}-pair(s) configured by higher layers
'011'	Aperiodic CSI report is triggered for a 2nd set of CSI process(es) and/or {CSI process, CSI subframe set}-pair(s) configured by higher layers
'100'	Aperiodic CSI report is triggered for a 3rd set of CSI process(es) and/or {CSI process, CSI subframe set}-pair(s) configured by higher layers
'101'	Aperiodic CSI report is triggered for a 4th set of CSI process(es) and/or {CSI process, CSI subframe set}-pair(s) configured by higher layers
'110'	Aperiodic CSI report is triggered for a 5th set of CSI process(es) and/or {CSI process, CSI subframe set}-pair(s) configured by higher layers
'111'	Aperiodic CSI report is triggered for a 6th set of CSI process(es) and/or {CSI process, CSI subframe set}-pair(s) configured by higher layers

NOTE: PDCCH/EPDCCH/MPDCCH with DCI formats used to grant PUSCH transmissions as given by DCI format 0, DCI format 4 and DCI format 6-0A are herein referred to as uplink DCI format when common behaviour is addressed.

For a non-BL/CE UE, when the CSI request field from an uplink DCI format is set to trigger a report, for FDD $k=4$, and for TDD UL/DL configuration 1-6, k is given in Table 8-2. For TDD UL/DL configuration 0, if the MSB of the UL index is set to 1 and LSB of the UL index is set to 0, k is given in Table 8-2; or if MSB of the UL index is set to 0 and LSB of the UL index is set to 1, k is equal to 7; or if both MSB and LSB of the UL index is set to 1, k is given in Table 8-2.

For TDD, if a UE is configured with more than one serving cell and if the UL/DL configurations of at least two serving cells are different, or if the UE is configured with the parameter *EIMTA-MainConfigServCell-r12* for at least one serving cell, or for FDD-TDD and serving cell frame structure type 2, the "TDD UL/DL Configuration" given in Table 8-2 refers to the UL-reference UL/DL configuration (defined in subclause 8.0).

For a non-BL/CE UE, when the CSI request field from a Random Access Response Grant is set to trigger a report and is not reserved, k is equal to k_1 if the UL delay field in subclause 6.2 is set to zero, where k_1 is given in subclause 6.1.1. The UE shall postpone aperiodic CSI reporting to the next available UL subframe if the UL delay field is set to 1.

For a BL/CE UE, when the CSI request field from a Random Access Response Grant is set to trigger a report and is not reserved, the subframe(s) in which the corresponding aperiodic CSI reporting is transmitted is determined according to subclause 6.1.1.

The minimum reporting interval for aperiodic reporting of CQI and PMI and RI and CRI is 1 subframe. The subband size for CQI shall be the same for transmitter-receiver configurations with and without precoding.

If a UE is not configured for simultaneous PUSCH and PUCCH transmission, when aperiodic CSI report with no transport block associated as defined in subclause 8.6.2 and positive SR is transmitted in the same subframe, the UE shall transmit SR, and, if applicable, HARQ-ACK, on PUCCH resources as described in subclause 10.1

A UE is semi-statically configured by higher layers to feed back CQI and PMI and corresponding RI and CRI on the same PUSCH using one of the following CSI reporting modes given in Table 7.2.1-1 and described below. For a BL/CE UE the UE shall not transmit the RI for any CSI reporting mode in Table 7.2.1-1.

Table 7.2.1-1: CQI and PMI Feedback Types for PUSCH CSI reporting Modes

		PMI Feedback Type		
		No PMI	**Single PMI**	**Multiple PMI**
PUSCH CQI Feedback Type	**Wideband (wideband CQI)**	Mode 1-0	Mode 1-1	Mode 1-2
	UE Selected (subband CQI)	Mode 2-0		Mode 2-2
	Higher Layer-configured (subband CQI)	Mode 3-0	Mode 3-1	Mode 3-2

For non-BL/CE UE and for each of the transmission modes defined in subclause 7.1, the following reporting modes are supported on PUSCH:

Transmission mode 1 : Modes 2-0, 3-0, 1-0
Transmission mode 2 : Modes 2-0, 3-0, 1-0
Transmission mode 3 : Modes 2-0, 3-0, 1-0
Transmission mode 4 : Modes 1-2, 2-2, 3-1, 3-2, 1-1
Transmission mode 5 : Mode 3-1, 1-1
Transmission mode 6 : Modes 1-2, 2-2, 3-1, 3-2, 1-1
Transmission mode 7 : Modes 2-0, 3-0, 1-0
Transmission mode 8 : Modes 1-2, 2-2, 3-1, 3-2, 1-1 if the UE is configured with PMI/RI reporting; modes 2-0, 3-0, 1-0 if the UE is configured without PMI/RI reporting
Transmission mode 9 : Modes 1-2, 2-2, 3-1, 3-2, 1-1 if the UE is configured with PMI/RI reporting and number of CSI-RS ports > 1; modes 2-0, 3-0, 1-0 if the UE is configured without PMI/RI reporting or without PMI reporting or number of CSI-RS ports=1 or the number of CSI-RS ports in each of one or more CSI-RS resources in a CSI process is one when *eMIMO-Type* is set to 'CLASS B'.

Transmission mode 10 : Modes 1-2, 2-2, 3-1, 3-2, 1-1 if the UE is configured with PMI/RI reporting and number of CSI-RS ports > 1; modes 2-0, 3-0, 1-0 if the UE is configured without PMI/RI reporting or without PMI reporting or number of CSI-RS ports=1 or the number of CSI-RS ports in each of one or more CSI-RS resources in a CSI process is one when *eMIMO-Type* is set to 'CLASS B'.

For a BL/CE UE configured with CEModeA, the following reporting modes are supported on PUSCH:

Transmission mode 1 : Mode 2-0
Transmission mode 2 : Mode 2-0
Transmission mode 6 : Mode 2-0
Transmission mode 9 : Mode 2-0

For Transmission mode 6 and a BL/CE UE configured with a C-RNTI, the BL/CE UE reports CQI for the closed-loop with spatial multiplexing PDSCH transmission scheme.

The aperiodic CSI reporting mode is given by the parameter *cqi-ReportModeAperiodic* which is configured by higher-layer signalling.

For a serving cell with $N_{\mathrm{RB}}^{\mathrm{DL}} \leq 7$, PUSCH reporting modes are not supported for that serving cell.
For a non-BL/CE UE, RI is only reported for transmission modes 3 and 4, as well as transmission modes 8, 9 and 10 with PMI/RI reporting, and transmission modes 9 and 10 without PMI reporting.
For a BL/CE UE, RI is not reported.

For serving cell c, a UE configured in transmission mode 10 with PMI/RI reporting or without PMI reporting for a CSI process can be configured with a 'RI-reference CSI process' for the CSI process. If the UE is configured with a 'RI-reference CSI process' for the CSI process, the reported RI for the CSI process shall be the same as the reported RI for the configured 'RI-reference CSI process'. The RI for the 'RI-reference CSI process' is not based on any other configured CSI process other than the 'RI-reference CSI process'. The UE is not expected to receive an aperiodic CSI report request for a given subframe triggering a CSI report including CSI associated with the CSI process and not including CSI associated with the configured 'RI-reference CSI process'. If the UE is configured with a 'RI-reference CSI process' for a CSI process and if subframe sets $C_{\mathrm{CSI,0}}$ and $C_{\mathrm{CSI,1}}$ are configured by higher layers for only one of the CSI processes then the UE is not expected to receive configuration for the CSI process configured with the subframe subsets that have a different set of restricted RIs with precoder codebook subset restriction between the two subframe sets. The UE is not expected to receive configurations for the CSI process and the 'RI-reference CSI process' that have a different:

- Aperiodic CSI reporting mode, and/or
- number of CSI-RS antenna ports, and/or
- set of restricted RIs with precoder codebook subset restriction if subframe sets $C_{\mathrm{CSI,0}}$ and $C_{\mathrm{CSI,1}}$ are not configured by higher layers for both CSI processes, and/or
- set of restricted RIs with precoder codebook subset restriction for each subframe set if subframe sets $C_{\mathrm{CSI,0}}$ and $C_{\mathrm{CSI,1}}$ are configured by higher layers for both CSI processes, and/or
- set of restricted RIs with precoder codebook subset restriction if subframe sets $C_{\mathrm{CSI,0}}$ and $C_{\mathrm{CSI,1}}$ are configured by higher layers for only one of the CSI processes, and the set of restricted RIs for the two subframe sets are the same, and/or
- number of CSI-RS antenna ports for any two CSI-RS resources for the two CSI processes, if a UE is configured with higher layer parameter *eMIMO-Type*, and *eMIMO-Type* is set to 'CLASS B', and the number of configured CSI-RS resources is more than one for at least one of the two CSI processes, and/or
- set of restricted RIs with precoder codebook subset restriction for any two CSI-RS resources for the two CSI processes, if a UE is configured with higher layer parameter *eMIMO-Type*, and *eMIMO-Type* is set to 'CLASS

B', and the number of configured CSI-RS resources is more than one for at least one of the two CSI processes and if subframe sets $C_{\text{CSI},0}$ and $C_{\text{CSI},1}$ are not configured by higher layers for both CSI processes, and/or

- set of restricted RIs with precoder codebook subset restriction for each subframe set and for any two CSI-RS resources for the two CSI processes, if a UE is configured with higher layer parameter *eMIMO-Type*, and *eMIMO-Type* is set to 'CLASS B', and the number of configured CSI-RS resources is more than one for at least one of the two CSI processes and if subframe sets $C_{\text{CSI},0}$ and $C_{\text{CSI},1}$ are configured by higher layers for both CSI processes, and/or
- set of restricted RIs with precoder codebook subset restriction for any two CSI-RS resources for the two CSI processes, if a UE is configured with higher layer parameter *eMIMO-Type*, and *eMIMO-Type* is set to 'CLASS B', and the number of configured CSI-RS resources is more than one for at least one of the two CSI processes and if subframe sets $C_{\text{CSI},0}$ and $C_{\text{CSI},1}$ are configured by higher layers for only one of the CSI processes, and the set of restricted RIs for the two subframe sets are the same.

For a non-BL/CE UE, a RI report for a serving cell on an aperiodic reporting mode is valid only for CQI/PMI report or CQI report without PMI reporting for that serving cell on that aperiodic reporting mode.

For a UE configured in transmission mode 9 or 10, and for a CSI process, if a UE is configured with parameter *eMIMO-Type* configured by higher layers, and *eMIMO-Type* is set to 'CLASS B' and the number of configured CSI-RS resources is more than one, and the total number of antenna ports across all configured CSI-RS resources is more than 15, the UE on reception of an aperiodic CSI report request triggering a CSI report in uplink subframe n is not expected to update CRI corresponding to the CSI process if CRI for the CSI process has been reported and updated on or after subframe $n-5$.

- Wideband feedback
  - Mode 1-2 description:
    - For a UE configured in transmission mode 9 or 10, and for a CSI process, if a UE is configured with higher layer parameter *eMIMO-Type*, and *eMIMO-Type* is set to 'CLASS B', and the number of configured CSI-RS resources is more than one, the UE shall report one wideband CRI which is calculated assuming transmission on set *S* subbands.
    - For each subband a preferred precoding matrix is selected from the codebook subset assuming transmission only in the subband
    - A UE shall report one wideband CQI value per codeword which is calculated assuming the use of the corresponding selected precoding matrix in each subband and transmission on set *S* subbands.The UE shall report the selected precoding matrix indicator for each set *S* subband except with
      - 8 CSI-RS ports configured for transmission modes 9 and 10 or with *alternativeCodeBookEnabledFor4TX-r12=TRUE* configured for transmission modes 8, 9 and 10, in which case a first precoding matrix indicator i_1 is reported for the set *S* subbands and a second precoding matrix indicator i_2 is reported for each set *S* subband, if the UE is not configured with higher layer parameter *eMIMO-Type*, or UE reports CRI, or UE is configured in transmission mode 9 or 10, and with higher layer parameter *eMIMO-Type*, and *eMIMO-Type* is set to 'CLASS B', and one CSI-RS resource configured, and except with higher layer parameter *alternativeCodebookEnabledCLASSB_K1=TRUE* configured.
      - UE is configured in transmission mode 9 or 10, and with higher layer parameter *eMIMO-Type*, and *eMIMO-Type* is set to 'CLASS A', in which case a first precoding matrix indicator i_1 is reported for the set *S* subbands and a second precoding matrix indicator i_2 is reported for each set *S* subband.
    - Subband size is given by Table 7.2.1-3.
    - For transmission modes 4, 8, 9 and 10, the reported PMI and CQI values are calculated conditioned on the reported RI. For other transmission modes they are reported conditioned on rank 1. If CRI is reported, the reported PMI, CQI, and RI values are calculated conditioned on the reported CRI.
  - Mode 1-1 description:

- For a UE configured in transmission mode 9 or 10, and for a CSI process, if a UE is configured with higher layer parameter *eMIMO-Type*, and *eMIMO-Type* is set to 'CLASS B', and the number of configured CSI-RS resources is more than one, the UE shall report one wideband CRI which is calculated assuming transmission on set *S* subbands.
- A single precoding matrix is selected from the codebook subset assuming transmission on set S subbands
- A UE shall report a wideband CQI value per codeword which is calculated assuming the use of the single precoding matrix in all subbands and transmission on set *S* subbands
- The UE shall report the selected single precoding matrix indicator except with
  - 8 CSI-RS ports configured for transmission modes 9 and 10 or with *alternativeCodeBookEnabledFor4TX-r12=TRUE* configured for transmission modes 8, 9 and 10, in which case a first and second precoding matrix indicator are reported corresponding to the selected single precoding matrix, if the UE is not configured with higher layer parameter *eMIMO-Type*, or UE reports CRI, or UE is configured in transmission mode 9 or 10, and with higher layer parameter *eMIMO-Type*, and *eMIMO-Type* is set to 'CLASS B', and one CSI-RS resource configured, and except with higher layer parameter *alternativeCodebookEnabledCLASSB_K1=TRUE* configured.
  - UE is configured in transmission mode 9 or 10, and with higher layer parameter *eMIMO-Type*, and *eMIMO-Type* is set to 'CLASS A', in which case a first and second precoding matrix indicator are reported corresponding to the selected single precoding matrix.
- For transmission modes 4, 8, 9 and 10, the reported PMI and CQI values are calculated conditioned on the reported RI. For other transmission modes they are reported conditioned on rank 1. If CRI is reported, the reported PMI, CQI, and RI values are calculated conditioned on the reported CRI.

o Mode 1-0 description:

o If a UE is configured in transmission mode 9 or 10, and UE is configured with higher layer parameter *eMIMO-Type* for a CSI process, and *eMIMO-Type* is set to 'CLASS B', and the number of CSI-RS antenna ports in at least one of the one or more configured CSI-RS resource is more than one,

- If the number of configured CSI-RS resources is more than one, the UE shall report one wideband CRI which is calculated assuming transmission on set *S* subbands.
- A single precoding matrix is selected from the codebook subset assuming transmission on set S subbands
- A UE shall report a wideband CQI value per codeword which is calculated assuming the use of the single precoding matrix in all subbands and transmission on set *S* subbands
- The selected precoding matrix, and reported CQI values are calculated conditioned on the reported RI. If CRI is reported, the selected precoding matrix, reported CQI, and RI values are calculated conditioned on the reported CRI

otherwise,

- For a UE configured in transmission mode 9 or 10, and for a CSI process, if a UE is configured with higher layer parameter *eMIMO-Type*, and *eMIMO-Type* is set to 'CLASS B', and the number of configured CSI-RS resources is more than one, the UE shall report one wideband CRI which is calculated assuming transmission on set *S* subbands.

- A UE shall report a wideband CQI value which is calculated assuming transmission on set *S* subbands
- The wideband CQI represents channel quality for the first codeword, even when RI>1.
- For transmission mode 3 the reported CQI value is calculated conditioned on the reported RI. For other transmission modes they are reported conditioned on rank 1. If CRI is reported, the reported CQI values are calculated conditioned on the reported CRI.

- Higher Layer-configured subband feedback
  - Mode 3-0 description:
  - If a UE is configured in transmission mode 9 or 10, and UE is configured with higher layer parameter *eMIMO-Type* for a CSI process, and *eMIMO-Type* is set to 'CLASS B', and the number of CSI-RS antenna ports in at least one of the one or more configured CSI-RS resource is more than one,
    - If the number of configured CSI-RS resources is more than one, the UE shall report one wideband CRI which is calculated assuming transmission on set *S* subbands.
    - A single precoding matrix is selected from the codebook subset assuming transmission on set S subbands
    - A UE shall report one subband CQI value per codeword for each set *S* subband which are calculated assuming the use of the single precoding matrix in all subbands and assuming transmission in the corresponding subband.
    - A UE shall report a wideband CQI value per codeword which is calculated assuming the use of the single precoding matrix in all subbands and transmission on set *S* subbands
    - The selected precoding matrix, and reported CQI values are calculated conditioned on the reported RI. If CRI is reported, the selected precoding matrix, reported CQI, and RI values are calculated conditioned on the reported CRI

  otherwise,

    - For a UE configured in transmission mode 9 or 10, and for a CSI process, if a UE is configured with higher layer parameter *eMIMO-Type*, and *eMIMO-Type* is set to 'CLASS B', and the number of configured CSI-RS resources is more than one, the UE shall report one wideband CRI which is calculated assuming transmission on set *S* subbands.
    - A UE shall report a wideband CQI value which is calculated assuming transmission on set *S* subbands
    - The UE shall also report one subband CQI value for each set *S* subband. The subband CQI value is calculated assuming transmission only in the subband
    - Both the wideband and subband CQI represent channel quality for the first codeword, even when RI>1.
    - For transmission mode 3 the reported CQI values are calculated conditioned on the reported RI. For other transmission modes they are reported conditioned on rank 1. If CRI is reported, the reported CQI values are calculated conditioned on the reported CRI.
  - Mode 3-1 description:
    - For a UE configured in transmission mode 9 or 10, and for a CSI process, if a UE is configured with higher layer parameter *eMIMO-Type*, and *eMIMO-Type* is set to 'CLASS B', and the number of configured CSI-RS resources is more than one, the UE

shall report one wideband CRI which is calculated assuming transmission on set *S* subbands.

- A single precoding matrix is selected from the codebook subset assuming transmission on set S subbands
- A UE shall report one subband CQI value per codeword for each set *S* subband which are calculated assuming the use of the single precoding matrix in all subbands and assuming transmission in the corresponding subband.
- A UE shall report a wideband CQI value per codeword which is calculated assuming the use of the single precoding matrix in all subbands and transmission on set *S* subbands
- The UE shall report the selected single precoding matrix indicator except with,
  - 8 CSI-RS ports configured for transmission modes 9 and 10 or with *alternativeCodeBookEnabledFor4TX-r12=TRUE* configured for transmission modes 8, 9 and 10, in which case a first and second precoding matrix indicator are reported corresponding to the selected single precoding matrix, if the UE is not configured with higher layer parameter *eMIMO-Type*, or UE reports CRI, or UE is configured in transmission mode 9 or 10, and with higher layer parameter *eMIMO-Type*, and *eMIMO-Type* is set to 'CLASS B', and one CSI-RS resource configured, and except with higher layer parameter *alternativeCodebookEnabledCLASSB_K1=TRUE* configured.
  - UE is configured in transmission mode 9 or 10, and with higher layer parameter *eMIMO-Type*, and *eMIMO-Type* is set to 'CLASS A', in which case a first and second precoding matrix indicator are reported corresponding to the selected single precoding matrix.
- For transmission modes 4, 8, 9 and 10, the reported PMI and CQI values are calculated conditioned on the reported RI. For other transmission modes they are reported conditioned on rank 1. If CRI is reported, the reported PMI, CQI, and RI values are calculated conditioned on the reported CRI.

o Mode 3-2 description:

- For a UE configured in transmission mode 9 or 10, and for a CSI process, if a UE is configured with higher layer parameter *eMIMO-Type*, and *eMIMO-Type* is set to 'CLASS B', and the number of configured CSI-RS resources is more than one, the UE shall report one wideband CRI which is calculated assuming transmission on set *S* subbands.
- For each subband a preferred precoding matrix is selected from the codebook subset assuming transmission only in the subband
- A UE shall report one wideband CQI value per codeword which is calculated assuming the use of the corresponding selected precoding matrix in each subband and transmission on set *S* subbands.
- A UE shall report the selected single precoding matrix indicator for each set *S* subband except with,
  - 8 CSI-RS ports configured for transmission mode 9 and 10, or with *alternativeCodeBookEnabledFor4TX-r12=TRUE* configured for transmission modes 8, 9 and 10, in which case the UE shall report a first precoding matrix indicator for all set *S* subbands and also report a second precoding matrix indicator for each set S subband, if the UE is not configured with higher layer parameter *eMIMO-Type*, or UE reports CRI, or UE is configured in transmission mode 9 or 10, and with higher layer parameter *eMIMO-Type*, and *eMIMO-Type* is set to 'CLASS B', and one CSI-RS resource configured, and except with higher layer parameter *alternativeCodebookEnabledCLASSB_K1=TRUE* configured.

- UE is configured in transmission mode 9 or 10, and with higher layer parameter *eMIMO-Type*, and *eMIMO-Type* is set to 'CLASS A', in which case a first precoding matrix indicator i_1 is reported for the set *S* subbands and a second precoding matrix indicator i_2 is reported for each set *S* subband.

  - A UE shall report one subband CQI value per codeword for each set *S* subband reflecting transmission over the single subband and using the selected precoding matrix in the corresponding subband.

  - For transmission modes 4, 8, 9 and 10, the reported PMI and CQI values are calculated conditioned on the reported RI. For transmission mode 6 they are reported conditioned on rank 1. If CRI is reported, the reported PMI, CQI, and RI values are calculated conditioned on the reported CRI.

- Subband CQI value for each codeword are encoded differentially with respect to their respective wideband CQI using 2-bits as defined by

  - Subband differential CQI offset level = subband CQI index – wideband CQI index. The mapping from the 2-bit subband differential CQI value to the offset level is shown in Table 7.2.1-2.

Table 7.2.1-2: Mapping subband differential CQI value to offset level

Subband differential CQI value	Offset level
0	0
1	1
2	≥2
3	≤-1

- Supported subband size (*k*) is given in Table 7.2.1-3.

Table 7.2.1-3: Subband Size (*k*) vs. System Bandwidth

System Bandwidth $N_{\mathrm{RB}}^{\mathrm{DL}}$	Subband Size (*k*)
6 - 7	NA
8 - 10	4
11 - 26	4
27 - 63	6
64 - 110	8

- UE-selected subband feedback

  - Mode 2-0 description:

    - If a UE is configured in transmission mode 9 or 10, and UE is configured with higher layer parameter *eMIMO-Type* for a CSI process,, and *eMIMO-Type* is set to 'CLASS B', and the number of CSI-RS antenna ports in at least one of the one or more configured CSI-RS resource is more than one,

      - If the number of configured CSI-RS resources is more than one, the UE shall report one wideband CRI which is calculated assuming transmission on set *S* subbands.

      - The UE shall perform joint selection of the set of *M* preferred subbands of size *k* within the set of subbands *S* and a preferred single precoding matrix selected from the codebook subset that is preferred to be used for transmission over the *M* selected subbands.

      - The UE shall report one CQI value per codeword reflecting transmission only over the selected *M* preferred subbands and using the same selected single precoding matrix in each of the *M* subbands.

        - A single precoding matrix is selected from the codebook subset assuming transmission on set S subbands
        - A UE shall report a wideband CQI value per codeword which is calculated assuming the use of the single precoding matrix in all subbands and transmission on set *S* subbands
        - The selected precoding matrix, and reported CQI values are calculated conditioned on the reported RI. If CRI is reported, the selected precoding matrix, reported CQI, and RI values are calculated conditioned on the reported CRI.
    - otherwise,
        - For a UE configured in transmission mode 9 or 10, and for a CSI process, if a UE is configured with higher layer parameter *eMIMO-Type*, and *eMIMO-Type* is set to 'CLASS B', and the number of configured CSI-RS resources is more than one, the UE shall report one wideband CRI which is calculated assuming transmission on set *S* subbands.
        - The UE shall select a set of *M* preferred subbands of size *k* (where *k* and *M* are given in Table 7.2.1-5 for each system bandwidth range) within the set of subbands *S*.
        - The UE shall also report one CQI value reflecting transmission only over the *M* selected subbands determined in the previous step. The CQI represents channel quality for the first codeword, even when RI>1.
        - Additionally, the UE shall also report one wideband CQI value which is calculated assuming transmission on set *S* subbands. The wideband CQI represents channel quality for the first codeword, even when RI>1.
        - For transmission mode 3 the reported CQI values are calculated conditioned on the reported RI. For other transmission modes they are reported conditioned on rank 1. If CRI is reported, the reported CQI values are calculated conditioned on the reported CRI.
- Mode 2-2 description:
        - For a UE configured in transmission mode 9 or 10, and for a CSI process, if a UE is configured with higher layer parameter *eMIMO-Type*, and *eMIMO-Type* is set to 'CLASS B', and the number of configured CSI-RS resources is more than one, the UE shall report one wideband CRI which is calculated assuming transmission on set *S* subbands.
        - The UE shall perform joint selection of the set of *M* preferred subbands of size *k* within the set of subbands *S* and a preferred single precoding matrix selected from the codebook subset that is preferred to be used for transmission over the *M* selected subbands.
        - The UE shall report one CQI value per codeword reflecting transmission only over the selected *M* preferred subbands and using the same selected single precoding matrix in each of the *M* subbands.
        - A single precoding matrix is selected from the codebook subset assuming transmission on set S subbands
        - A UE shall report a wideband CQI value per codeword which is calculated assuming the use of the single precoding matrix in all subbands and transmission on set *S* subbands
        - The UE shall report the selected single precoding matrix indicator preferred for the *M* selected subbands and the selected single precoding matrix indicator for all set *S* subbands except with,
            - 8 CSI-RS ports configured for transmission modes 9 and 10 or with *alternativeCodeBookEnabledFor4TX-r12=TRUE* configured for transmission modes 8, 9 and 10, in which case the UE shall report a first precoding matrix

indicator for all set S subbands, a second precoding matrix indicator for all set S subbands and another second precoding matrix indicator for the M selected subbands, if the UE is not configured with higher layer parameter *eMIMO-Type*, or UE reports CRI, or UE is configured in transmission mode 9 or 10, and with higher layer parameter *eMIMO-Type*, and *eMIMO-Type* is set to 'CLASS B', and one CSI-RS resource configured, and except with higher layer parameter *alternativeCodebookEnabledCLASSB_K1=TRUE* configured.

- UE is configured in transmission mode 9 or 10, and with higher layer parameter *eMIMO-Type*, and *eMIMO-Type* is set to 'CLASS A', in which case the UE shall report a first precoding matrix indicator i_1 for all set S subbands, a second precoding matrix indicator i_2 for all set S subbands and another second precoding matrix indicator i_2 for or the M selected subbands.

- For transmission modes 4, 8, 9 and 10, the reported PMI and CQI values are calculated conditioned on the reported RI. For other transmission modes they are reported conditioned on rank 1. If CRI is reported, the reported PMI, CQI, and RI values are calculated conditioned on the reported CRI.

- For all UE-selected subband feedback modes the UE shall report the positions of the M selected subbands using a combinatorial index r defined as

  - $r = \sum_{i=0}^{M-1} \left\langle \begin{matrix} N - s_i \\ M - i \end{matrix} \right\rangle$

  - where the set $\{s_i\}_{i=0}^{M-1}$, $(1 \le s_i \le N, \quad s_i < s_{i+1})$ contains the M sorted subband indices and $\left\langle \begin{matrix} x \\ y \end{matrix} \right\rangle = \begin{cases} \binom{x}{y} & x \ge y \\ 0 & x < y \end{cases}$ is the extended binomial coefficient, resulting in unique label $r \in \left\{ 0, \cdots, \binom{N}{M} - 1 \right\}$.

- The CQI value for the M selected subbands for each codeword is encoded differentially using 2-bits relative to its respective wideband CQI as defined by

  - Differential CQI offset level = M selected subbands CQI index – wideband CQI index

  - The mapping from the 2-bit differential CQI value to the offset level is shown in Table 7.2.1-4.

Table 7.2.1-4: Mapping differential CQI value to offset level

Differential CQI value	Offset level
0	≤1
1	2
2	3
3	≥4

- Supported subband size k and M values include those shown in Table 7.2.1-5. In Table 7.2.1-5 the k and M values are a function of system bandwidth.

- The number of bits to denote the position of the M selected subbands is $L = \left\lceil \log_2 \binom{N}{M} \right\rceil$.

For a BL/CE UE, the reported CQI values are calculated conditioned on rank 1.

- UE-selected subband feedback
  - Mode 2-0 description:
    - The UE shall report one wideband CQI value which is calculated assuming transmission on all narrowband(s) in the CSI reference resource.
    - If frequency hopping is configured for MPDCCH,
      - the UE shall select M=1 preferred narrowband defined in subclause 6.2.7 of [3] within the set of narrowband(s) in which MPDCCH is monitored.
      - the UE shall also report one CQI value reflecting transmission only over the selected narrowband determined in the previous step.
      - The CQI value for the M=1 selected narrowband is encoded differentially using 2-bits relative to its respective wideband CQI as defined by
        - Differential CQI offset level = selected narrowband CQI index – wideband CQI index
        - The mapping from the 2-bit differential CQI value to the offset level is shown in Table 7.2.1-4.
      - the UE shall report the positions of the M=1 selected narrowband according to Table 7.2.1-6.
    - otherwise,
      - the UE shall report a Differential CQI value = 0 and a position of the M=1 selected narrowband according to Table 7.2.1-6.

Table 7.2.1-5: Subband Size (*k*) and Number of Subbands (*M*) in S vs. Downlink System Bandwidth

System Bandwidth N_{RB}^{DL}	Subband Size *k* (RBs)	*M*
6 – 7	NA	NA
8 – 10	2	1
11 – 26	2	3
27 – 63	3	5
64 – 110	4	6

Table 7.2.1-6: Reporting UE selected narrowband position for BL/CE UEs

Number of narrowbands for MPDCCH monitoring	UE reported bit(s) for narrowband position (MSB, LSB)	MPDCCH Narrowband Reported
1	0	The narrowband used for MPDCCH monitoring
2	0	Narrowband with lowest narrowband index
	1	Narrowband with highest narrowband index
4	00	Narrowband with lowest narrowband index
	01	Narrowband with second lowest narrowband index
	10	Narrowband with third lowest narrowband index
	11	Narrowband with highest narrowband index

7.2.2 Periodic CSI Reporting using PUCCH

A UE is semi-statically configured by higher layers to periodically feed back different CSI components (CQI, PMI, PTI, CRI, and/or RI) on the PUCCH using the reporting modes given in Table 7.2.2-1 and described below. A UE in transmission mode 10 can be configured by higher layers for multiple periodic CSI reports corresponding to one or more CSI processes per serving cell on PUCCH.

A BL/CE UE configured with CEModeB is not expected to be configured with periodic CSI report.

Table 7.2.2-1: CQI and PMI Feedback Types for PUCCH CSI reporting Modes

		PMI Feedback Type	
		No PMI	**Single PMI**
PUCCH CQI Feedback Type	**Wideband (wideband CQI)**	Mode 1-0	Mode 1-1
	UE Selected (subband CQI)	Mode 2-0	Mode 2-1

For a non-BL/CE UE and for each of the transmission modes defined in subclause 7.1, the following periodic CSI reporting modes are supported on PUCCH:

Transmission mode 1 : Modes 1-0, 2-0
Transmission mode 2 : Modes 1-0, 2-0
Transmission mode 3 : Modes 1-0, 2-0
Transmission mode 4 : Modes 1-1, 2-1
Transmission mode 5 : Modes 1-1, 2-1
Transmission mode 6 : Modes 1-1, 2-1
Transmission mode 7 : Modes 1-0, 2-0
Transmission mode 8 : Modes 1-1, 2-1 if the UE is configured with PMI/RI reporting; modes 1-0, 2-0 if the UE is configured without PMI/RI reporting
Transmission mode 9 : Modes 1-1, 2-1 if the UE is configured with PMI/RI reporting and number of CSI-RS ports>1; modes 1-0, 2-0 if the UE is configured without PMI/RI reporting or without PMI reporting or number of CSI-RS ports=1 or the number of CSI-RS ports in each of one or more CSI-RS resources in a CSI process is one when *eMIMO-Type* is set to be 'CLASS B'.
Transmission mode 10 : Modes 1-1, 2-1 if the UE is configured with PMI/RI reporting and number of CSI-RS ports>1; modes 1-0, 2-0 if the UE is configured without PMI/RI reporting or without PMI reporting or number of CSI-RS ports=1 or the number of CSI-RS ports in each of one or more CSI-RS resources in a CSI process is one when *eMIMO-Type* is set to be 'CLASS B'.

For a BL/CE UE configured with CEModeA, the following periodic CSI reporting modes are supported on PUCCH:

Transmission mode 1 : Mode 1-0
Transmission mode 2 : Mode 1-0
Transmission mode 6 : Mode 1-1
Transmission mode 9 : Modes 1-1, 1-0.

For a UE configured in transmission mode 1-9, one periodic CSI reporting mode for each serving cell is configured by higher-layer signalling.

For a UE configured in transmission mode 10, one or more periodic CSI reporting modes for each serving cell are configured by higher-layer signalling.

For UE in transmission mode 9 and the UE configured with higher layer parameter *eMIMO-Type*, the term 'CSI process' in this subclause refers to the CSI configured for the UE.

For a UE configured with transmission mode 9 or 10, and with 8 CSI-RS ports, if the UE is not configured with parameter *eMIMO-Type* by higher layers , or UE is configured with parameter *eMIMO-Type* by higher layers, and *eMIMO-Type* is set to 'CLASS B', and one CSI-RS resource configured, and except with higher layer parameter *alternativeCodebookEnabledCLASSB_K1=TRUE* configured, or UE is configured with parameter *eMIMO-Type* by higher layers, and *eMIMO-Type* is set to 'CLASS B', and more than one CSI-RS resource configured, and at least one CSI-RS resource with 8 CSI-RS ports, mode 1-1 is configured to be either submode 1 or submode 2 via higher-layer signaling using the parameter *PUCCH_format1-1_CSI_reporting_mode*.

For a UE configured with transmission mode 8, 9 or 10, and with *alternativeCodeBookEnabledFor4TX-r12=TRUE* configured, if the UE is not configured with higher layer parameter *eMIMO-Type*, or UE is configured with parameter *eMIMO-Type* by higher layers, and *eMIMO-Type* is set to 'CLASS B', and one CSI-RS resource configured, and except with higher layer parameter *alternativeCodebookEnabledCLASSB_K1=TRUE* configured, or UE is configured with parameter *eMIMO-Type* by higher layers, and *eMIMO-Type* is set to 'CLASS B', and more than one CSI-RS resource configured, and at least one CSI-RS resource with 4 CSI-RS ports, mode 1-1 is configured to be either submode 1 or submode 2 via higher-layer signaling using the parameter *PUCCH_format1-1_CSI_reporting_mode*.

For the UE-selected subband CQI, a CQI report in a certain subframe of a certain serving cell describes the channel quality in a particular part or in particular parts of the bandwidth of that serving cell described subsequently as bandwidth part (BP) or parts. The bandwidth parts shall be indexed in the order of increasing frequency and non-increasing sizes starting at the lowest frequency.

For each serving cell

- There are a total of *N* subbands for a serving cell system bandwidth given by $N_{\mathrm{RB}}^{\mathrm{DL}}$ where $\lfloor N_{\mathrm{RB}}^{\mathrm{DL}} / k \rfloor$ subbands are of size *k*. If $\lceil N_{\mathrm{RB}}^{\mathrm{DL}} / k \rceil - \lfloor N_{\mathrm{RB}}^{\mathrm{DL}} / k \rfloor > 0$ then one of the subbands is of size $N_{\mathrm{RB}}^{\mathrm{DL}} - k \cdot \lfloor N_{\mathrm{RB}}^{\mathrm{DL}} / k \rfloor$.

- A bandwidth part *j* is frequency-consecutive and consists of N_{j} subbands where *J* bandwidth parts span *S* or $N_{\mathrm{RB}}^{\mathrm{DL}}$ as given in Table 7.2.2-2. If $J = 1$ then N_{j} is $\lceil N_{\mathrm{RB}}^{\mathrm{DL}} / k / J \rceil$. If *J>1* then N_{j} is either $\lceil N_{\mathrm{RB}}^{\mathrm{DL}} / k / J \rceil$ or $\lceil N_{\mathrm{RB}}^{\mathrm{DL}} / k / J \rceil - 1$, depending on $N_{\mathrm{RB}}^{\mathrm{DL}}$, *k* and *J*.

- Each bandwidth part *j*, where $0 \le j \le J$-1, is scanned in sequential order according to increasing frequency.

- For UE selected subband feedback a single subband out of N_{j} subbands of a bandwidth part is selected along with a corresponding *L*-bit label indexed in the order of increasing frequency, where $L = \lceil \log_2 \lceil N_{\mathrm{RB}}^{\mathrm{DL}} / k / J \rceil \rceil$.

The CQI and PMI payload sizes of each PUCCH CSI reporting mode are given in Table 7.2.2-3.

The following CQI/PMI and RI reporting types with distinct periods and offsets are supported for the PUCCH CSI reporting modes given in Table 7.2.2-3:

- Type 1 report supports CQI feedback for the UE selected sub-bands
- Type 1a report supports subband CQI and second PMI feedback
- Type 2, Type 2b, and Type 2c report supports wideband CQI and PMI feedback
- Type 2a report supports wideband PMI feedback
- Type 3 report supports RI feedback
- Type 4 report supports wideband CQI
- Type 5 report supports RI and wideband PMI feedback
- Type 6 report supports RI and PTI feedback
- Type 7 report support CRI and RI feedback
- Type 8 report supports CRI, RI and wideband PMI feedback
- Type 9 report supports CRI, RI and PTI feedback
- Type 10 report supports CRI feedback

For a UE configured in transmission mode 1-9 and for each serving cell, or for a UE configured in transmission mode 10 and for each CSI process in each serving cell, the periodicity N_{pd} (in subframes) and offset $N_{OFFSET,CQI}$ (in subframes) for CQI/PMI reporting are determined based on the parameter *cqi-pmi-ConfigIndex* ($I_{CQI/PMI}$) given in Table 7.2.2-1A for FDD or for FDD-TDD with primary cell frame structure 1 and Table 7.2.2-1C for TDD or for FDD-TDD and primary cell frame structure type 2. The periodicity M_{RI} and relative offset $N_{OFFSET,RI}$ for RI reporting are determined based on the parameter *ri-ConfigIndex* (I_{RI}) given in Table 7.2.2-1B. For a UE configured in transmission mode 9 and for each serving cell, or for a UE configured in transmission mode 10 and for each CSI process in each serving cell, if the UE is configured with parameter *eMIMO-Type* by higher layers, and *eMIMO-Type* is set to 'CLASS B', and the number of configured CSI-RS resources is more than one, when RI reporting is configured, the periodicity M_{CRI} for CRI reporting is determined based on the parameter *cri-ConfigIndex* (I_{CRI}) given in Table 7.2.2-1J. When the number of antenna ports in each configured CSI-RS resource is one, the periodicity M_{CRI} and relative offset $N_{OFFSET,CRI}$ for CRI reporting are determined based on the parameter *cri-ConfigIndex* (I_{CRI}) given in Table 7.2.2-1K. The parameters *cqi-pmi-ConfigIndex*, *ri-ConfigIndex* , and *cri-ConfigIndex* are configured by higher layer signalling. The relative reporting offset for RI $N_{OFFSET,RI}$ takes values from the set $\{0,-1,...,-(N_{pd}-1)\}$. If a UE is configured to report for more than one CSI subframe set then parameter *cqi-pmi-ConfigIndex*, *ri-ConfigIndex* and *cri-ConfigIndex* respectively correspond to the CQI/PMI, RI, and CRI periodicity and relative reporting offset for subframe set 1 and *cqi-pmi-ConfigIndex2*, *ri-ConfigIndex*2 and *cri-ConfigIndex*2 respectively correspond to the CQI/PMI, RI, and CRI periodicity and relative reporting offset for subframe set 2. For a UE configured with transmission mode 10, the parameters *cqi-pmi-ConfigIndex* , *ri-ConfigIndex*, *cri-ConfigIndex*, *cqi-pmi-ConfigIndex2*, *ri-ConfigIndex*2, and *cri-ConfigIndex*2 can be configured for each CSI process. A BL/CE UE is not expected to be configured with the parameter *ri-ConfigIndex*.

In the case where wideband CQI/PMI reporting is configured:

- The reporting instances for wideband CQI/PMI are subframes satisfying $\left(10\times n_f+\lfloor n_s/2\rfloor-N_{OFFSET,CQI}\right)\bmod\left(N_{pd}\right)=0$.

- For a UE configured in transmission mode 9 or 10, and UE configured with the parameter *eMIMO-Type* by higher layers, and *eMIMO-Type* set to 'CLASS A', the reporting interval of wideband first PMI reporting is an integer multiple H' of period N_{pd} (in subframes).

  - The reporting instances for wideband first PMI are subframes satisfying $\left(10\times n_f+\lfloor n_s/2\rfloor-N_{OFFSET,CQI}\right)\bmod\left(H'\cdot N_{pd}\right)=0$.

- In case RI reporting is configured, the reporting interval of the RI reporting is an integer multiple M_{RI} of period N_{pd} (in subframes).

  - The reporting instances for RI are subframes satisfying $\left(10\times n_f+\lfloor n_s/2\rfloor-N_{OFFSET,CQI}-N_{OFFSET,RI}\right)\bmod\left(N_{pd}\cdot M_{RI}\right)=0$.

- In case CRI reporting is configured,

  - if the number of antenna ports in each configured CSI-RS resource is one,

    - the reporting interval of the CRI reporting is an integer multiple M_{CRI} of period N_{pd} (in subframes)

    - The reporting instances for CRI are subframes satisfying $\left(10\times n_f+\lfloor n_s/2\rfloor-N_{OFFSET,CQI}-N_{OFFSET,CRI}\right)\bmod\left(N_{pd}\cdot M_{CRI}\right)=0$.

  - otherwise

    - the reporting interval of the CRI reporting is an integer multiple M_{CRI} of period $N_{pd}\cdot M_{RI}$ (in subframes).

    - The reporting instances for CRI are subframes satisfying $\left(10\times n_f+\lfloor n_s/2\rfloor-N_{OFFSET,CQI}-N_{OFFSET,RI}\right)\bmod\left(N_{pd}\cdot M_{RI}\cdot M_{CRI}\right)=0$.

In the case where both wideband CQI/PMI and subband CQI (or subband CQI/second PMI for transmission modes 9 and 10) reporting are configured:

- The reporting instances for wideband CQI/PMI and subband CQI (or subband CQI/second PMI for transmission modes 9 and 10) are subframes satisfying $\left(10 \times n_f + \lfloor n_s / 2 \rfloor - N_{OFFSET,CQI}\right) \bmod N_{pd} = 0$.

  - When PTI is not transmitted (due to not being configured) or the most recently transmitted PTI is equal to 1 for a UE configured in transmission modes 8 and 9, or for a UE configured in transmission mode 10 without a 'RI-reference CSI process' for a CSI process, or the transmitted PTI is equal to 1 reported in the most recent RI reporting instance for a CSI process when a UE is configured in transmission mode 10 with a 'RI-reference CSI process' for the CSI process, or the transmitted PTI is equal to 1 for a 'RI-reference CSI process' reported in the most recent RI reporting instance for a CSI process when a UE is configured in transmission mode 10 with the 'RI-reference CSI process' for the CSI process, and the most recent type 6 report for the CSI process is dropped:

    - The wideband CQI/ wideband PMI (or wideband CQI/wideband second PMI for transmission modes 8, 9 and 10) report has period $H \cdot N_{pd}$, and is reported on the subframes satisfying $\left(10 \times n_f + \lfloor n_s / 2 \rfloor - N_{OFFSET,CQI}\right) \bmod \left(H \cdot N_{pd}\right) = 0$. The integer H is defined as $H = J \cdot K + 1$, where J is the number of bandwidth parts.

    - Between every two consecutive wideband CQI/ wideband PMI (or wideband CQI/wideband second PMI for transmission modes 8, 9 and 10) reports, the remaining $J \cdot K$ reporting instances are used in sequence for subband CQI (or subband CQI/second PMI for transmission modes 9 and 10) reports on K full cycles of bandwidth parts except when the gap between two consecutive wideband CQI/PMI reports contains less than $J \cdot K$ reporting instances due to a system frame number transition to 0, in which case the UE shall not transmit the remainder of the subband CQI (or subband CQI/second PMI for transmission modes 9 and 10) reports which have not been transmitted before the second of the two wideband CQI/ wideband PMI (or wideband CQI/wideband second PMI for transmission modes 8, 9 and 10) reports. Each full cycle of bandwidth parts shall be in increasing order starting from bandwidth part 0 to bandwidth part $J - 1$. The parameter K is configured by higher-layer signalling.

  - When the most recently transmitted PTI is 0 for a UE configured in transmission modes 8 and 9 or for a UE configured in transmission mode 10 without a 'RI-reference CSI process' for a CSI process, or the transmitted PTI is 0 reported in the most recent RI reporting instance for a CSI process when a UE is configured in transmission mode 10 with a 'RI-reference CSI process' for the CSI process, or the transmitted PTI is 0 for a 'RI-reference CSI process' reported in the most recent RI reporting instance for a CSI process when a UE is configured in transmission mode 10 with the 'RI-reference CSI process' for the CSI process, and the most recent type 6 report for the CSI process is dropped:

    - The wideband first precoding matrix indicator report has period $H' \cdot N_{pd}$, and is reported on the subframes satisfying $\left(10 \times n_f + \lfloor n_s / 2 \rfloor - N_{OFFSET,CQI}\right) \bmod \left(H' \cdot N_{pd}\right) = 0$, where H' is signalled by higher layers.

    - Between every two consecutive wideband first precoding matrix indicator reports, the remaining reporting instances are used for a wideband second precoding matrix indicator with wideband CQI as described below

- In case RI reporting is configured, the reporting interval of RI is M_{RI} times the wideband CQI/PMI period $H \cdot N_{pd}$, and RI is reported on the same PUCCH cyclic shift resource as both the wideband CQI/PMI and subband CQI reports.

  - The reporting instances for RI are subframes satisfying $\left(10 \times n_f + \lfloor n_s / 2 \rfloor - N_{OFFSET,CQI} - N_{OFFSET,RI}\right) \bmod \left(H \cdot N_{pd} \cdot M_{RI}\right) = 0$

- In case CRI reporting is configured,

  - if the number of antenna ports in each configured CSI-RS resource is one,

    - the reporting interval of the CRI reporting is M_{CRI} times the wideband CQI/PMI period $H \cdot N_{pd}$,

- The reporting instances for CRI are subframes satisfying $\left(10\times n_f+\lfloor n_s/2\rfloor-N_{OFFSET,CQI}-N_{OFFSET,CRI}\right)\mathrm{mod}\left(H\cdot N_{pd}\cdot M_{CRI}\right)=0$.

- otherwise
  - the reporting interval of the CRI reporting is M_{CRI} times the RI period $H.N_{pd}\cdot M_{RI}$ (in subframes).
  - The reporting instances for CRI are subframes satisfying $\left(10\times n_f+\lfloor n_s/2\rfloor-N_{OFFSET,CQI}-N_{OFFSET,RI}\right)\mathrm{mod}\left(H\cdot N_{pd}\cdot M_{RI}\cdot M_{CRI}\right)=0$

If a UE is not configured with higher layer parameter *eMIMO-Type*, or for a CSI process a UE is configured with higher layer parameter *eMIMO-Type* and *eMIMO-Type* is set to 'CLASS A', or for a CSI process a UE is configured with higher layer parameter *eMIMO-Type* and *eMIMO-Type* is set to 'CLASS B', and one configured CSI-RS resource, in case of collision of a CSI report with PUCCH reporting type 3, 5, or 6 of one serving cell with a CSI report with PUCCH reporting type 1, 1a, 2, 2a, 2b, 2c, or 4 of the same serving cell the latter CSI report with PUCCH reporting type (1, 1a, 2, 2a, 2b, 2c, or 4) has lower priority and is dropped.
For a CSI process, if a UE is configured with higher layer parameter *eMIMO-Type* and *eMIMO-Type* is set to 'CLASS B', and more than one configured CSI-RS resources, in case of collision of a CSI report with PUCCH reporting type 7, 8, 9, or 10 of one serving cell with a CSI report with PUCCH reporting type 1, 1a, 2, 2a, 2b, 2c, 3, 4, 5, or 6 of the same serving cell the latter CSI report with PUCCH reporting type (1, 1a, 2, 2a, 2b, 2c, 3, 4, 5, or 6) has lower priority and is dropped.

For a serving cell and UE configured in transmission mode 10, in case of collision between CSI reports of same serving cell with PUCCH reporting type of the same priority, and the CSI reports corresponding to different CSI processes, the CSI reports corresponding to all CSI processes except the CSI process with the lowest *csi-ProcessId-r11* are dropped.

For a serving cell and UE configured in transmission mode 1-9 and configured with CSI subframe sets $C_{\mathrm{CSI},0}$ and $C_{\mathrm{CSI},1}$ by the higher layer parameter *csi-SubframePatternConfig-r12* for the serving cell, in case of collision between CSI reports of same serving cell with PUCCH reporting type of the same priority, the CSI report corresponding to CSI subframe set $C_{\mathrm{CSI},1}$ is dropped.

For a serving cell and UE configured in transmission mode 10 and configured with CSI subframe sets $C_{\mathrm{CSI},0}$ and $C_{\mathrm{CSI},1}$ by the higher layer parameter *csi-SubframePatternConfig-r12* for the serving cell, in case of collision between CSI reports of same serving cell with PUCCH reporting type of the same priority and the CSI reports corresponding to CSI processes with same *csi-ProcessId-r11*, the CSI report corresponding to CSI subframe set $C_{\mathrm{CSI},1}$ is dropped.

If a UE is not configured with higher layer parameter *format4-MultiCSI-resourceConfiguration* or *format5-MultiCSI-resourceConfiguration*,and if the UE is configured with more than one serving cell, the UE transmits a CSI report of only one serving cell in any given subframe. For a given subframe, in case of collision of a CSI report with PUCCH reporting type 7, 8, 9, or 10 of one serving cell with a CSI report with PUCCH reporting type 1, 1a, 2, 2a, 2b, 2c, 3, 4, 5 or 6 of another serving cell, the latter CSI with PUCCH reporting type (1, 1a, 2, 2a, 2b, 2c, 3, 4, 5 or 6) has lower priority and is dropped. For a given subframe, in case of collision of a CSI report with PUCCH reporting type 3, 5, 6, or 2a of one serving cell with a CSI report with PUCCH reporting type 1, 1a, 2, 2b, 2c, or 4 of another serving cell, the latter CSI with PUCCH reporting type (1, 1a, 2, 2b, 2c, or 4) has lower priority and is dropped. For a given subframe, in case of collision of CSI report with PUCCH reporting type 2, 2b, 2c, or 4 of one serving cell with CSI report with PUCCH reporting type 1 or 1a of another serving cell, the latter CSI report with PUCCH reporting type 1, or 1a has lower priority and is dropped.
For a given subframe and serving cells with UE configured in transmission mode 1-9, in case of collision between CSI reports of these different serving cells with PUCCH reporting type of the same priority, the CSI reports for all these serving cells except the serving cell with lowest *ServCellIndex* are dropped.

If a UE is not configured with higher layer parameter *format4-MultiCSI-resourceConfiguration* or *format5-MultiCSI-resourceConfiguration*, for a given subframe and serving cells with UE configured in transmission mode 10, in case of collision between CSI reports of different serving cells with PUCCH reporting type of the same priority and the CSI reports corresponding to CSI processes with same *csi-ProcessId-r11*, the CSI reports of all serving cells except the serving cell with lowest *ServCellIndex* are dropped.

If a UE is not configured with higher layer parameter *format4-MultiCSI-resourceConfiguration* or *format5-MultiCSI-resourceConfiguration*, for a given subframe and serving cells with UE configured in transmission mode 10, in case of collision between CSI reports of different serving cells with PUCCH reporting type of the same priority and the CSI reports corresponding to CSI processes with different *csi-ProcessId-r11*, the CSI reports of all serving cells except the serving cell with CSI reports corresponding to CSI process with the lowest *csi-ProcessId-r11* are dropped.

If a UE is not configured with higher layer parameter *format4-MultiCSI-resourceConfiguration* or *format5-MultiCSI-resourceConfiguration*, for a given subframe, in case of collision between CSI report of a given serving cell with UE configured in transmission mode 1-9, and CSI report(s) corresponding to CSI process(es) of a different serving cell with the UE configured in transmission mode 10, and the CSI reports of the serving cells with PUCCH reporting type of the same priority, the CSI report(s) corresponding to CSI process(es) with *csi-ProcessId-r11* > 1 of the different serving cell are dropped.

If a UE is not configured with higher layer parameter *format4-MultiCSI-resourceConfiguration* or *format5-MultiCSI-resourceConfiguration*, for a given subframe, in case of collision between CSI report of a given serving cell with UE configured in transmission mode 1-9, and CSI report corresponding to CSI process with *csi-ProcessId-r11* = 1 of a different serving cell with the UE configured in transmission mode 10, and the CSI reports of the serving cells with PUCCH reporting type of the same priority, the CSI report of the serving cell with highest *ServCellIndex* is dropped.

See subclause 10.1 for UE behaviour regarding collision between CSI and HARQ-ACK and the corresponding PUCCH format assignment.

If a UE is not configured with higher layer parameter *format4-MultiCSI-resourceConfiguration* or *format5-MultiCSI-resourceConfiguration*, the CSI report of a given PUCCH reporting type shall be transmitted on the PUCCH resource $n_{\mathrm{PUCCH}}^{(2,\tilde{p})}$ as defined in [3], where $n_{\mathrm{PUCCH}}^{(2,\tilde{p})}$ is UE specific and configured by higher layers for each serving cell.

If a UE is not configured with higher layer parameter *format4-MultiCSI-resourceConfiguration* or *format5-MultiCSI-resourceConfiguration*, and

- if the UE is not configured for simultaneous PUSCH and PUCCH transmission or,
- if the UE is configured for simultaneous PUSCH and PUCCH transmission and not transmitting PUSCH,

in case of collision between CSI and positive SR in a same subframe, CSI is dropped.

If a UE is configured with *format4-MultiCSI-resourceConfiguration* or *format5-MultiCSI-resourceConfiguration*, for a subframe in which only periodic CSI and SR (if any) is transmitted,

- if there is only one CSI report in the subframe,
    - o the CSI report of a given PUCCH reporting type shall be transmitted on the PUCCH resource $n_{\mathrm{PUCCH}}^{(2,\tilde{p})}$ as defined in [3], where $n_{\mathrm{PUCCH}}^{(2,\tilde{p})}$ is UE specific and configured by higher layers for each serving cell;
    - o In case of collision between CSI and positive SR in a same subframe, if the UE is not configured for simultaneous PUSCH and PUCCH transmission, or if the UE is configured for simultaneous PUSCH and PUCCH transmission and not transmitting PUSCH, CSI is dropped.
- if there are more than one CSI reports in the subframe,
    - o if the parameter *simultaneousAckNackAndCQI-Format4-Format5-r13* provided by higher layers is set TRUE, when a PUCCH format 4/5 transmission of CSI reports coincides with a sub-frame configured to the UE by higher layers for transmission of a scheduling request, the UE shall transmit the CSI and SR on the PUCCH; Otherwise, CSI is dropped;
    - o if the UE is configured with a single PUCCH format 4 resource $n_{\mathrm{PUCCH}}^{(4)}$ according to higher layer parameter *format4-MultiCSI-resourceConfiguration*, the PUCCH format 4 resource $n_{\mathrm{PUCCH}}^{(4)}$ is used for transmission of the CSI reports and SR (if any);
    - o if the UE is configured with a PUCCH format 5 resource $n_{\mathrm{PUCCH}}^{(5)}$ according to higher layer parameter *format5-MultiCSI-resourceConfiguration*, the PUCCH format 5 resource $n_{\mathrm{PUCCH}}^{(5)}$ is used for transmission of the CSI reports and SR (if any);

- if the UE is configured with two PUCCH format 4 resources $n^{(4)}_{\text{PUCCH},1}$ and $n^{(4)}_{\text{PUCCH},2}$ according to higher layer parameter *format4-MultiCSI-resourceConfiguration*, if $\left(O^{SR}+O_{\text{P-CSI}}+O_{CRC}\right)\leq \min\left(M^{\text{PUCCH4}}_{\text{RB},1}, M^{\text{PUCCH4}}_{\text{RB},2}\right)\cdot N^{RB}_{sc}\cdot N^{\text{PUCCH4}}_{\text{symb}}\cdot 2\cdot r$, the PUCCH format 4 resource with the smaller $M^{\text{PUCCH4}}_{\text{RB},i}$ between $n^{(4)}_{\text{PUCCH},1}$ and $n^{(4)}_{\text{PUCCH},2}$ is used for transmission of the CSI reports; otherwise, the PUCCH format 4 resource with the larger $M^{\text{PUCCH4}}_{\text{RB},i}$ between $n^{(4)}_{\text{PUCCH},1}$ and $n^{(4)}_{\text{PUCCH},2}$ is used for transmission of the CSI reports, where
  - $O_{\text{P-CSI}}$ is the total number of CSI report bits in the subframe;
  - O_{CRC} is the number of CRC bits;
  - $O^{SR}=0$ if there is no scheduling request bit in the subframe and $O^{SR}=1$ otherwise;
  - $M^{\text{PUCCH4}}_{\text{RB},i}$, $i=1,2$, is the number of PRBs for $n^{(4)}_{\text{PUCCH},1}$ and $n^{(4)}_{\text{PUCCH},2}$ respectively, according to higher layer parameter *numberOfPRB-format4-r13* according to Table 10.1.1-2;
  - $N^{\text{PUCCH4}}_{\text{symb}}=2\cdot\left(N^{\text{UL}}_{\text{symb}}-1\right)-1$ if shortened PUCCH format 4 is used in the subframe and $N^{\text{PUCCH4}}_{\text{symb}}=2\cdot\left(N^{\text{UL}}_{\text{symb}}-1\right)$ otherwise; and
  - r is the code rate given by higher layer parameter *maximumPayloadCoderate-r13* according to Table 10.1.1-1.

If a UE transmits only periodic CSI and SR (if any) using either a PUCCH format 4 $n^{(4)}_{\text{PUCCH}}$ or PUCCH format 5 $n^{(5)}_{\text{PUCCH}}$ in a subframe and if $\left(O^{SR}+O_{\text{P-CSI}}+O_{CRC}\right)>2\cdot N_{\text{RE}}\cdot r$, the UE shall select the SR (if any) and $N_{\text{CSI,reported}}$ CSI report(s) for transmission in ascending order of $\text{Pri}_{CSI}(y,s,c,t)$, where:

- $O_{\text{P-CSI}}$ is the total number of CSI report bits in the subframe;
- O_{CRC} is the number of CRC bits
- $O^{SR}=0$ if there is no scheduling request bit in the subframe and $O^{SR}=1$ otherwise;
- $N_{\text{RE}}=M^{\text{PUCCH4}}_{\text{RB}}\cdot N^{RB}_{sc}\cdot N^{\text{PUCCH}}_{\text{symb}}$ for PUCCH format 4 and $N_{\text{RE}}=N^{RB}_{sc}\cdot N^{\text{PUCCH}}_{\text{symb}}/2$ for PUCCH format 5, where $N^{\text{PUCCH}}_{\text{symb}}=2\cdot\left(N^{\text{UL}}_{\text{symb}}-1\right)-1$ if shortened PUCCH format 4 or shortened PUCCH format 5 is used in the subframe and $N^{\text{PUCCH}}_{\text{symb}}=2\cdot\left(N^{\text{UL}}_{\text{symb}}-1\right)$ otherwise;
- r is the code rate given by higher layer parameter *maximumPayloadCoderate-r13* according to Table 10.1.1-1;
- for a CSI report of a serving cell, $\text{Pri}_{CSI}(y,s,c,t)$ for the CSI report is defined as $\text{Pri}_{CSI}(y,s,c,t)=y\cdot 4\cdot 32\cdot 2+s\cdot 32\cdot 2+c\cdot 2+t$, where
  - $y=0$ for CSI report type 3/5/6/2a, $y=1$ for CSI report type 2/2b/2c/4, and $y=2$ for CSI report type 1/1a;
  - s is the CSI process ID according to *csi-ProcessId-r11* if the serving cell is configured with transmission mode 10, and $s=1$ if the serving cell configured with transmission mode 1-9;
  - c is the serving cell index;
  - $t=0$ and $t=1$ for CSI subframe sets $C_{\text{CSI},0}$ and $C_{\text{CSI},1}$ respectively if CSI subframe sets are configured for the serving cell, and $t=0$ otherwise.

- The value of $N_{\text{CSI,reported}}$ satisfies $\left(O^{SR}+\sum_{n=1}^{N_{\text{CSI,reported}}} O_{P-CSI,n}+O_{CRC}\right)\le 2\cdot N_{\text{RE}}\cdot r$ and $\left(O^{SR}+\sum_{n=1}^{N_{\text{CSI,reported}}+1} O_{P-CSI,n}+O_{CRC}\right)> 2\cdot N_{\text{RE}}\cdot r$, where $O^{SR}=0$ if there no scheduling request bit in the subframe and $O^{SR}=1$ otherwise. $O_{P-CSI,n}$ is the number of CSI report bits for the *n*th CSI report in ascending order of $\text{Pri}_{CSI}(y,s,c,t)$.

If a UE is configured with *format4-MultiCSI-resourceConfiguration* or *format5-MultiCSI-resourceConfiguratio* and if the UE is configured with more than N_y periodic CSI reports in a subframe, the UE is not required to update CSI for more than N_y CSI processes from the CSI processes corresponding to all the configured CSI reports, where the value of N_y is given by *maxNumberUpdatedCSI-Proc-r13*.

Table 7.2.2-1A: Mapping of $I_{CQI/PMI}$ to N_{pd} and $N_{OFFSET,CQI}$ for FDD or for FDD-TDD and primary cell frame structure type 1

$I_{CQI/PMI}$	Value of N_{pd}	Value of $N_{OFFSET,CQI}$
0 ≤ $I_{CQI/PMI}$ ≤ 1	2	$I_{CQI/PMI}$
2 ≤ $I_{CQI/PMI}$ ≤ 6	5	$I_{CQI/PMI}$ – 2
7 ≤ $I_{CQI/PMI}$ ≤ 16	10	$I_{CQI/PMI}$ – 7
17 ≤ $I_{CQI/PMI}$ ≤ 36	20	$I_{CQI/PMI}$ – 17
37 ≤ $I_{CQI/PMI}$ ≤ 76	40	$I_{CQI/PMI}$ – 37
77 ≤ $I_{CQI/PMI}$ ≤ 156	80	$I_{CQI/PMI}$ – 77
157 ≤ $I_{CQI/PMI}$ ≤ 316	160	$I_{CQI/PMI}$ – 157
$I_{CQI/PMI}$ = 317	Reserved	
318 ≤ $I_{CQI/PMI}$ ≤ 349	32	$I_{CQI/PMI}$ – 318
350 ≤ $I_{CQI/PMI}$ ≤ 413	64	$I_{CQI/PMI}$ – 350
414 ≤ $I_{CQI/PMI}$ ≤ 541	128	$I_{CQI/PMI}$ – 414
542 ≤ $I_{CQI/PMI}$ ≤ 601	60	$I_{CQI/PMI}$ – 542
602 ≤ $I_{CQI/PMI}$ ≤ 1023	Reserved	

Table 7.2.2-1B: Mapping of I_{RI} to M_{RI} and $N_{OFFSET,RI}$.

I_{RI}	Value of M_{RI}	Value of $N_{OFFSET,RI}$
0 ≤ I_{RI} ≤ 160	1	$-I_{RI}$
161 ≤ I_{RI} ≤ 321	2	− (I_{RI} – 161)
322 ≤ I_{RI} ≤ 482	4	− (I_{RI} – 322)
483 ≤ I_{RI} ≤ 643	8	− (I_{RI} – 483)
644 ≤ I_{RI} ≤ 804	16	− (I_{RI} – 644)
805 ≤ I_{RI} ≤ 965	32	− (I_{RI} – 805)
966 ≤ I_{RI} ≤ 1023	Reserved	

Table 7.2.2-1C: Mapping of $I_{CQI/PMI}$ to N_{pd} and $N_{OFFSET,CQI}$ for TDD or for FDD-TDD and primary cell frame structure type 2

$I_{CQI/PMI}$	Value of N_{pd}	Value of $N_{OFFSET,CQI}$
$I_{CQI/PMI} = 0$	1	$I_{CQI/PMI}$
$1 \le I_{CQI/PMI} \le 5$	5	$I_{CQI/PMI} - 1$
$6 \le I_{CQI/PMI} \le 15$	10	$I_{CQI/PMI} - 6$
$16 \le I_{CQI/PMI} \le 35$	20	$I_{CQI/PMI} - 16$
$36 \le I_{CQI/PMI} \le 75$	40	$I_{CQI/PMI} - 36$
$76 \le I_{CQI/PMI} \le 155$	80	$I_{CQI/PMI} - 76$
$156 \le I_{CQI/PMI} \le 315$	160	$I_{CQI/PMI} - 156$
$316 \le I_{CQI/PMI} \le 375$	60	$I_{CQI/PMI} - 316$
$376 \le I_{CQI/PMI} \le 1023$	Reserved	

Table 7.2.2-1J: Mapping of I_{CRI} to M_{CRI} when RI reporting is configured

I_{CRI}	Value of M_{CRI}
0	1
1	2
2	4
3	8
4	16
5	32
6	64
7	128
$7 < I_{CRI} \le 1023$	Reserved

Table 7.2.2-1K: Mapping of I_{CRI} to M_{CRI} and $N_{OFFSET,CRI}$ when the number of antenna ports in each configured CSI-RS resource is one

I_{CRI}	Value of M_{CRI}	Value of $N_{OFFSET,CRI}$
$0 \le I_{CRI} \le 160$	1	$-I_{CRI}$
$161 \le I_{CRI} \le 321$	2	$-(I_{CRI} - 161)$
$322 \le I_{CRI} \le 482$	4	$-(I_{CRI} - 322)$
$483 \le I_{CRI} \le 643$	8	$-(I_{CRI} - 483)$
$644 \le I_{CRI} \le 804$	16	$-(I_{CRI} - 644)$
$805 \le I_{CRI} \le 965$	32	$-(I_{CRI} - 805)$
$966 \le I_{CRI} \le 1023$	*Reserved*	

For TDD or FDD-TDD and primary cell frame structure type 2 periodic CQI/PMI reporting, the following periodicity values apply for a serving cell *c* depending on the TDD UL/DL configuration of the primary cell [3], where the UL/DL configuration corresponds to the *eimta-HARQ-ReferenceConfig-r12* for the primary cell if the UE is configured with the parameter *EIMTA-MainConfigServCell-r12* for the primary cell:

- The reporting period of $N_{pd} = 1$ is applicable for the serving cell *c* only if TDD UL/DL configuration of the primary cell belongs to {0, 1, 3, 4, 6}, and where all UL subframes of the primary cell in a radio frame are used for CQI/PMI reporting.

- The reporting period of $N_{pd} = 5$ is applicable for the serving cell *c* only if TDD UL/DL configuration of the primary cell belongs to {0, 1, 2, 6}.
- The reporting periods of $N_{pd} = \{10,20,40,80,160\}$ are applicable for the serving cell c for any TDD UL/DL configuration of the primary cell.

For a serving cell with $N_{\mathrm{RB}}^{\mathrm{DL}} \le 7$, Mode 2-0 and Mode 2-1 are not supported for that serving cell.

The sub-sampled codebook for PUCCH mode 1-1 submode 2 for 8 CSI-RS ports is defined in Table 7.2.2-1D for first and second precoding matrix indicator i_1 and i_2. Joint encoding of rank and first precoding matrix indicator i_1 for PUCCH mode 1-1 submode 1 for 8 CSI-RS ports is defined in Table 7.2.2-1E. The sub-sampled codebook for PUCCH mode 2-1 for 8 CSI-RS ports is defined in Table 7.2.2-1F for PUCCH Reporting Type 1a.

For a UE configured with transmission mode 9 or 10, , and the UE configured with parameter *eMIMO-Type* by higher layers, and *eMIMO-Type* is set to 'CLASS A', and PUCCH Reporting Type 1a, the sub-sampled codebook for PUCCH mode 2-1 for value of parameter *codebookConfig* set to 2, 3, or 4 is defined in Table 7.2.2-1F, for value of parameter *codebookConfig* set to 1, the value of the second PMI, I_{PMI2}, is set to i_2.

Table 7.2.2-1D: PUCCH mode 1-1 submode 2 codebook subsampling

RI	Relationship between the first PMI value and codebook index i_1		Relationship between the second PMI value and codebook index i_2		total
	Value of the first PMI I_{PMI1}	Codebook index i_1	Value of the second PMI I_{PMI2}	Codebook index i_2	#bits
1	0-7	$2I_{PMI1}$	0-1	$2I_{PMI2}$	4
2	0-7	$2I_{PMI1}$	0-1	I_{PMI2}	4
3	0-1	$2I_{PMI1}$	0-7	$4\lfloor I_{PMI2}/4 \rfloor + I_{PMI2}$	4
4	0-1	$2I_{PMI1}$	0-7	I_{PMI2}	4
5	0-3	I_{PMI1}	0	0	2
6	0-3	I_{PMI1}	0	0	2
7	0-3	I_{PMI1}	0	0	2
8	0	0	0	0	0

Table 7.2.2-1E: Joint encoding of RI and i_1 for PUCCH mode 1-1 submode 1

Value of joint encoding of RI and the first PMI $I_{RI/PMI1}$	RI	Codebook index i_1
0-7	1	$2I_{RI/PMI1}$
8-15	2	2($I_{RI/PMI1}$-8)
16-17	3	2($I_{RI/PMI1}$-16)
18-19	4	2($I_{RI/PMI1}$-18)
20-21	5	2($I_{RI/PMI1}$-20)
22-23	6	2($I_{RI/PMI1}$-22)
24-25	7	2($I_{RI/PMI1}$-24)
26	8	0
27-31	reserved	NA

Table 7.2.2-1F: PUCCH mode 2-1 codebook subsampling

RI	Relationship between the second PMI value and codebook index i_2	
	Value of the second PMI I_{PMI2}	Codebook index i_2
1	0-15	I_{PMI2}
2	0-3	$2I_{PMI2}$
3	0-3	$8\cdot\lfloor I_{PMI2}/2\rfloor+(I_{PMI2} \bmod 2)+2$
4	0-3	$2I_{PMI2}$
5	0	0
6	0	0
7	0	0
8	0	0

The sub-sampled codebook for PUCCH mode 1-1 submode 2 for transmission modes 8, 9 and 10 configured with *alternativeCodeBookEnabledFor4TX-r12=TRUE* is defined in Table 7.2.2-G for first and second precoding matrix indicator i_1 and i_2. Joint encoding of rank and first precoding matrix indicator i_1 for PUCCH mode 1-1 submode 1 for transmission modes 8, 9 and 10 configured with *alternativeCodeBookEnabledFor4TX-r12=TRUE* is defined in Table 7.2.2-1H. The sub-sampled codebook for PUCCH mode 2-1 for transmission modes 8, 9 and 10 configured with *alternativeCodeBookEnabledFor4TX-r12=TRUE* is defined in Table 7.2.2-1I for PUCCH Reporting Type 1a.

Table 7.2.2-1G: PUCCH mode 1-1 submode 2 codebook subsampling with 4 antenna ports

	Relationship between the first PMI value and codebook index i_1		Relationship between the second PMI value and codebook index i_2		total
RI	Value of the first PMI I_{PMI1}	Codebook index i_1	Value of the second PMI I_{PMI2}	Codebook index i_2	#bits
1	0-3	$4I_{PMI1}$	0-3	$2I_{PMI2}+4\cdot\lfloor I_{PMI2}/2\rfloor$	4
2	0-3	$4I_{PMI1}$	0-3	$I_{PMI2}+2\cdot\lfloor I_{PMI2}/2\rfloor$	4
3	0	0	0-15	I_{PMI2}	4
4	0	0	0-15	I_{PMI2}	4

Table 7.2.2-1 H: Joint encoding of RI and for PUCCH mode 1-1 submode 1 with 4 antenna ports

Value of joint encoding of RI and the first PMI $I_{RI/PMI1}$	RI	Codebook index i_1
0-7	1	$I_{RI/PMI1}$
8-15	2	$I_{RI/PMI1}-8$
16	3	0
17	4	0
18-31	reserved	NA

Table 7.2.2-1 I: PUCCH mode 2-1 codebook subsampling with 4 antenna ports

RI	Relationship between the second PMI value and codebook index i_2	
	Value of the second PMI I_{PMI2}	Codebook index i_2
1	0-15	I_{PMI2}
2	0-3	$I_{PMI2} + 2 \cdot \lfloor I_{PMI2} / 2 \rfloor$
3	0-3	$2I_{PMI2} + 4 \cdot \lfloor I_{PMI2} / 2 \rfloor$
4	0-3	$2I_{PMI2} + 4 \cdot \lfloor I_{PMI2} / 2 \rfloor$

An CRI or RI or PTI or any precoding matrix indicator reported for a serving cell in a periodic reporting mode is valid only for CSI reports for that serving cell on that periodic CSI reporting mode.

For serving cell c, a UE configured in transmission mode 10 with PMI/RI reporting or without PMI reporting for a CSI process can be configured with a 'RI-reference CSI process'. The RI for the 'RI-reference CSI process' is not based on any other configured CSI process other than the 'RI-reference CSI process'. If the UE is configured with a 'RI-reference CSI process' for a CSI process and if subframe sets $C_{\text{CSI},0}$ and $C_{\text{CSI},1}$ are configured by higher layers for only one of the CSI processes then the UE is not expected to receive configuration for the CSI process configured with the subframe subsets that have a different set of restricted RIs with precoder codebook subset restriction between the two subframe sets.The UE is not expected to receive configurations for the CSI process and the 'RI-reference CSI process' that have a different:

- periodic CSI reporting mode (including sub-mode if configured), and/or
- number of CSI-RS antenna ports, and/or
- set of restricted RIs with precoder codebook subset restriction if subframe sets $C_{\text{CSI},0}$ and $C_{\text{CSI},1}$ are not configured by higher layers for both CSI processes, and/or
- set of restricted RIs with precoder codebook subset restriction for each subframe set if subframe sets $C_{\text{CSI},0}$ and $C_{\text{CSI},1}$ are configured by higher layers for both CSI processes, and/or
- set of restricted RIs with precoder codebook subset restriction if subframe sets $C_{\text{CSI},0}$ and $C_{\text{CSI},1}$ are configured by higher layers for only one of the CSI processes, and the set of restricted RIs for the two subframe sets are the same, and/or
- number of CSI-RS antenna ports for any two CSI-RS resources for the two CSI processes, if a UE is configured with higher layer parameter *eMIMO-Type*, and *eMIMO-Type* is set to ‘CLASS B’, and the number of configured CSI-RS resources is more than one for at least one of the two CSI processes, and/or
- set of restricted RIs with precoder codebook subset restriction for any two CSI-RS resources for the two CSI processes, if a UE is configured with higher layer parameter *eMIMO-Type*, and *eMIMO-Type* is set to ‘CLASS B’, and the number of configured CSI-RS resources is more than one for at least one of the two CSI processes and if subframe sets $C_{\text{CSI},0}$ and $C_{\text{CSI},1}$ are not configured by higher layers for both CSI processes, and/or
- set of restricted RIs with precoder codebook subset restriction for each subframe set and for any two CSI-RS resources for the two CSI processes, if a UE is configured with higher layer parameter *eMIMO-Type*, and *eMIMO-Type* is set to ‘CLASS B’, and the number of configured CSI-RS resources is more than one for at least one of the two CSI processes and if subframe sets $C_{\text{CSI},0}$ and $C_{\text{CSI},1}$ are configured by higher layers for both CSI processes, and/or
- set of restricted RIs with precoder codebook subset restriction for any two CSI-RS resources for the two CSI processes, if a UE is configured with higher layer parameter *eMIMO-Type*, and *eMIMO-Type* is set to ‘CLASS B’, and the number of configured CSI-RS resources is more than one for at least one of the two CSI processes

and if subframe sets $C_{\text{CSI},0}$ and $C_{\text{CSI},1}$ are configured by higher layers for only one of the CSI processes, and the set of restricted RIs for the two subframe sets are the same.

If a UE is configured for CRI reporting,

- For the calculation of CQI/PMI/RI conditioned on the last reported CRI, in the absence of a last reported CRI the UE shall conduct the CQI/PMI/RI calculation conditioned on the lowest possible CRI. If reporting for more than one CSI subframe set is configured, CQI/PMI/RI is conditioned on the last reported CRI linked to the same subframe set as the CSI report.
- For the calculation of CQI/PMI conditioned on the last reported RI and CRI, in the absence of a last reported RI and CRI, the UE shall conduct the CQI/PMI calculation conditioned on the lowest possible RI associated with the lowest possible CRI and as given by the bitmap parameter *codebookSubsetRestriction* and the parameter *alternativeCodeBookEnabledFor4TX-r12* if configured. If reporting for more than one CSI subframe set is configured, CQI/PMI is conditioned on the last reported RI associated with the last reported CRI and linked to the same subframe set as the CSI report

otherwise,

- For the calculation of CQI/PMI conditioned on the last reported RI, in the absence of a last reported RI the UE shall conduct the CQI/PMI calculation conditioned on the lowest possible RI as given by the bitmap parameter *codebookSubsetRestriction* and the parameter *alternativeCodeBookEnabledFor4TX-r12* if configured. If reporting for more than one CSI subframe set is configured, CQI/PMI is conditioned on the last reported RI linked to the same subframe set as the CSI report.

- For a non-BL/CE UE, the periodic CSI reporting modes are described as following:
  - Wideband feedback
    - Mode 1-0 description:
      - In the subframe where RI is reported (only for transmission mode 3, and transmission mode 9 or 10 without PMI reporting with one configured CSI-RS resource or with more than one configured CSI-RS resource and the number of CSI-RS ports of the selected CSI-RS resource is more than one):
        - If a UE is configured in transmission mode 10 with a 'RI-reference CSI process' for a CSI process, the RI for the CSI process shall be the same as the RI in the most recent CSI report comprising RI for the configured 'RI-reference CSI process' irrespective of subframe sets if configured; otherwise, for transmission mode 3 the UE shall determine a RI assuming transmission on set *S* subbands, and for transmission mode 9 or 10 without PMI reporting, the UE shall determine a RI assuming transmission on set *S* subbands conditioned on the last reported periodic CRI.
        - The UE shall report a type 3 report consisting of one RI.
      - In the subframe where RI and CRI is reported (only for transmission mode 9 or 10 without PMI reporting and number of configured CSI-RS resources more than one):
        - A UE shall determine a CRI assuming transmission on set *S* subbands.
        - If a UE is configured in transmission mode 10 with a 'RI-reference CSI process' for a CSI process, the RI for the CSI process shall be the same as the RI in the most recent CSI report comprising RI for the configured 'RI-reference CSI process' irrespective of subframe sets if configured; otherwise, the UE shall determine a RI assuming transmission on set *S* subbands conditioned on the reported CRI.
        - The UE shall report a type 7 report consisting of one RI and one CRI.
      - In the subframe where CRI is reported (only for transmission mode 9 or 10 with CRI reporting and the number of antenna ports in each of configured CSI-RS resources is one):

- A UE shall determine a CRI assuming transmission on set *S* subbands.
- The UE shall report a type10 report consisting of one CRI.

▪ In the subframe where CQI is reported:

- If the UE is configured without PMI reporting (only for transmission mode 9 or 10):
  - o A single precoding matrix is selected from the codebook subset assuming transmission on set *S* subbands.
  - o A UE shall report a type 4 report consisting of
    - ▪ A single wideband CQI value which is calculated assuming the use of a single precoding matrix in all subbands and transmission on set *S* subbands.
    - ▪ When RI>1, an additional 3-bit wideband spatial differential CQI, which is shown in Table 7.2-2.
  - o If the UE is configured with CRI reporting,
    - ▪ If a UE is configured in transmission mode 10 with a ''RI-reference CSI process'' for a CSI process, and the most recent type 3 report for the CSI process is dropped, and a type 3 report for the ''RI-reference CSI process'' is reported in the most recent RI reporting instance for the CSI process, the selected precoding matrix and CQI for the CSI process are calculated conditioned on the reported periodic RI for the configured ''RI-reference CSI process'' in the most recent RI reporting instance for the CSI process and last reported periodic CRI for the CSI process; otherwise the selected precoding matrix and CQI are calculated conditioned on the last reported periodic RI and the last reported periodic CRI.
  - o otherwise,
    - ▪ If a UE is configured in transmission mode 10 with a ''RI-reference CSI process'' for a CSI process, and the most recent type 3 report for the CSI process is dropped, and a type 3 report for the ''RI-reference CSI process'' is reported in the most recent RI reporting instance for the CSI process, the selected precoding matrix and CQI for the CSI process are calculated conditioned on the reported periodic RI for the configured ''RI-reference CSI process'' in the most recent RI reporting instance for the CSI process; otherwise the selected precoding matrix and CQI are calculated conditioned on the last reported periodic RI.
- otherwise,
  - o A UE shall report a type 4 report consisting of one wideband CQI value which is calculated assuming transmission on set *S* subbands. The wideband CQI represents channel quality for the first codeword, even when RI>1.
  - o For transmission mode 3 the CQI is calculated conditioned on the last reported periodic RI. For other transmission modes it is calculated conditioned on transmission rank 1. If the UE is configured with CRI reporting, the CQI is calculated conditioned on the last reported periodic CRI.

o Mode 1-1 description:

▪ In the subframe where RI is reported (only for transmission modes 4, 8, 9 and 10):

- If the UE is configured with CRI reporting,

      - If a UE is configured in transmission mode 10 with a 'RI-reference CSI process' for a CSI process, the RI for the CSI process shall be the same as the RI in the most recent CSI report comprising RI for the configured 'RI-reference CSI process' irrespective of subframe sets if configured; otherwise, the UE shall determine a RI assuming transmission on set *S* subbands conditioned on the last reported periodic CRI.
    - otherwise,
      - If a UE is configured in transmission mode 10 with a 'RI-reference CSI process' for a CSI process, the RI for the CSI process shall be the same as the RI in the most recent CSI report comprising RI for the configured 'RI-reference CSI process' irrespective of subframe sets if configured; otherwise, the UE shall determine a RI assuming transmission on set *S* subbands.
    - The UE shall report a type 3 report consisting of one RI.
  - In the subframe where RI and CRI is reported for transmission modes 9 and 10:
    - A UE shall determine a CRI assuming transmission on set *S* subbands.
    - If a UE is configured in transmission mode 10 with a 'RI-reference CSI process' for a CSI process, the RI for the CSI process shall be the same as the RI in the most recent CSI report comprising RI for the configured 'RI-reference CSI process' irrespective of subframe sets if configured; otherwise, the UE shall determine a RI assuming transmission on set *S* subbands conditioned on the reported CRI for the CSI process.
    - The UE shall report a type 7 report consisting of one RI and one CRI.
  - In the subframe where RI and a first PMI are reported for transmission modes 9 and 10 configured with submode 1 and 8 CSI-RS ports without CRI reporting or 8 CSI-RS ports or 4 CSI-RS ports with *alternativeCodeBookEnabledFor4TX-r12=TRUE* in the selected CSI-RS resource and UE is configured with CRI reporting, and for transmission modes 8, 9 and 10 configured with submode 1 and *alternativeCodeBookEnabledFor4TX-r12=TRUE* without CRI reporting:
    - If the UE is configured with CRI reporting,
      - If a UE is configured in transmission mode 10 with a 'RI-reference CSI process' for a CSI process, the RI for the CSI process shall be the same as the RI in the most recent CSI report comprising RI for the configured 'RI-reference CSI process' irrespective of subframe sets if configured; otherwise, the UE shall determine a RI assuming transmission on set *S* subbands conditioned on the last reported periodic CRI.
    - otherwise,
      - If a UE is configured in transmission mode 10 with a 'RI-reference CSI process' for a CSI process, the RI for the CSI process shall be the same as the RI in the most recent CSI report comprising RI for the configured 'RI-reference CSI process' irrespective of subframe sets if configured; otherwise, the UE shall determine a RI assuming transmission on set *S* subbands.
    - The UE shall report a type 5 report consisting of jointly coded RI and a first PMI corresponding to a set of precoding matrices selected from the codebook subset assuming transmission on set *S* subbands.
    - If the UE is configured with CRI reporting,
      - If the UE is configured in transmission mode 10 with a 'RI-reference CSI process' for a CSI process and in case of collision of type 5 report for the CSI process with type 5 report for the 'RI-reference CSI

process', the wideband first PMI for the CSI process shall be the same as the wideband first PMI in the most recent type 5 report for the configured 'RI-reference CSI process'; otherwise, the wideband first PMI value is calculated conditioned on the reported periodic RI and last reported periodic CRI.

- otherwise,
  - o If the UE is configured in transmission mode 10 with a 'RI-reference CSI process' for a CSI process and in case of collision of type 5 report for the CSI process with type 5 report for the 'RI-reference CSI process', the wideband first PMI for the CSI process shall be the same as the wideband first PMI in the most recent type 5 report for the configured 'RI-reference CSI process'; otherwise, the wideband first PMI value is calculated conditioned on the reported periodic RI.

- ▪ In the subframe where CRI, RI and a first PMI are reported for transmission modes 9, and 10 configured with submode 1 and 8 CSI-RS ports in at least one of the configured CSI-RS resources, or for transmission modes 8, 9 and 10 configured with submode 1 and *alternativeCodeBookEnabledFor4TX-r12=TRUE* and 4 CSI-RS ports in at least one of configured CSI-RS resources:
  - A UE shall determine a CRI assuming transmission on set *S* subbands.
  - If a UE is configured in transmission mode 10 with a 'RI-reference CSI process' for a CSI process, the RI for the CSI process shall be the same as the RI in the most recent CSI report comprising RI for the configured 'RI-reference CSI process' irrespective of subframe sets if configured; otherwise, the UE shall determine a RI assuming transmission on set *S* subbands conditioned on the reported CRI.
  - If the configured CSI-RS resource corresponding to the determined CRI comprises 8 CSI-RS ports or 4 CSI-RS ports with *alternativeCodeBookEnabledFor4TX-r12=TRUE*, the UE shall report a type 8 report consisting of jointly coded CRI, RI and a first PMI corresponding to a set of precoding matrices selected from the codebook subset assuming transmission on set *S* subbands. Otherwise, the UE shall report a type 8 report consisting of jointly coded CRI, RI and a first PMI fixed to zero.
  - If the UE is configured in transmission mode 10 with a 'RI-reference CSI process' for a CSI process and in case of collision of type 5 report for the CSI process with type 5 report for the 'RI-reference CSI process', the wideband first PMI for the CSI process shall be the same as the wideband first PMI in the most recent type 5 report for the configured 'RI-reference CSI process'; otherwise, the wideband first PMI value is calculated conditioned on the reported periodic RI and last reported periodic CRI conditioned on the reported CRI.

- ▪ In the subframe where the wideband first PMI is reported, for transmission modes 9 and 10 with higher layer parameter *eMIMO-Type* configured, and *eMIMO-Type* set to 'CLASS A',
  - A set of precoding matrices corresponding to the wideband first PMI is selected from the codebook assuming transmission on set *S* subbands.
  - A UE shall report a type 2a report consisting of the wideband first PMI corresponding to the selected set of precoding matrices.
  - If a UE is configured in transmission mode 10 with a 'RI-reference CSI process' for a CSI process, and the most recent type 3 report for the CSI process is dropped, and a type 3 report for the 'RI-reference CSI process' is reported in the most recent RI reporting instance for the CSI process, the wideband first PMI value for the CSI process is calculated conditioned on the reported periodic RI for the configured 'RI-reference CSI process' in the most

recent RI reporting instance for the CSI process; otherwise the wideband first PMI value is calculated conditioned on the last reported periodic RI.

- In the subframe where CQI/PMI is reported for all transmission modes except with,
  - UE is configured with higher layer parameter *eMIMO-Type*, and *eMIMO-Type* is set to 'CLASS A', or
  - 8 CSI-RS ports configured for transmission modes 9 and 10, or with *alternativeCodeBookEnabledFor4TX-r12=TRUE* configured for transmission modes 8, 9 and 10, if the UE is not configured with higher layer parameter *eMIMO-Type*, or UE configured with CRI reporting, or UE is configured with higher layer parameter *eMIMO-Type*, and *eMIMO-Type* is set to 'CLASS B', and one CSI-RS resource configured, and except with higher layer parameter *alternativeCodebookEnabledCLASSB_K1=TRUE* configured:
    - o A single precoding matrix is selected from the codebook subset assuming transmission on set *S* subbands.
    - o A UE shall report a type 2 report consisting of
      - A single wideband CQI value which is calculated assuming the use of a single precoding matrix in all subbands and transmission on set *S* subbands.
      - The selected single PMI (wideband PMI).
      - When RI>1, an additional 3-bit wideband spatial differential CQI, which is shown in Table 7.2-2.
    - o If the UE is configured with CRI reporting,
      - If a UE is configured in transmission mode 10 with a ''RI-reference CSI process'' for a CSI process, and the most recent type 3 report for the CSI process is dropped, and a type 3 report for the ''RI-reference CSI process'' is reported in the most recent RI reporting instance for the CSI process, the PMI and CQI for the CSI process are calculated conditioned on the reported periodic RI for the configured ''RI-reference CSI process'' in the most recent RI reporting instance for the CSI process; otherwise the PMI and CQI are calculated conditioned on the last reported periodic RI and the last reported periodic CRI.
    - o otherwise,
      - For transmission modes 4, 8, 9 and 10,
        - If a UE is configured in transmission mode 10 with a ''RI-reference CSI process'' for a CSI process, and the most recent type 3 report for the CSI process is dropped, and a type 3 report for the ''RI-reference CSI process'' is reported in the most recent RI reporting instance for the CSI process, the PMI and CQI for the CSI process are calculated conditioned on the reported periodic RI for the configured ''RI-reference CSI process'' in the most recent RI reporting instance for the CSI process; otherwise the PMI and CQI are calculated conditioned on the last reported periodic RI.
      - For other transmission modes the PMI and CQI are calculated conditioned on transmission rank 1.
- In the subframe where wideband CQI/second PMI is reported for transmission modes 9 and 10 with 8 CSI-RS ports and submode 1 without CRI reporting, or for 8 CSI-RS ports or 4 CSI-RS ports with *alternativeCodeBookEnabledFor4TX-r12=TRUE* in the selected CSI-RS resource and UE is configured with CRI reporting, or for transmission modes 8, 9 and 10 with submode 1 and *alternativeCodeBookEnabledFor4TX-*

r12=TRUE without CRI reporting, or for transmission modes 9 and 10 with higher layer parameter *eMIMO-Type* configured, and *eMIMO-Type* set to 'CLASS A':

- A single precoding matrix is selected from the codebook subset assuming transmission on set *S* subbands.
- A UE shall report a type 2b report consisting of
  - A single wideband CQI value which is calculated assuming the use of the single precoding matrix in all subbands and transmission on set *S* subbands.
  - The wideband second PMI corresponding to the selected single precoding matrix.
  - When RI>1, an additional 3-bit wideband spatial differential CQI, which is shown in Table 7.2-2.
- If the UE is configured with CRI reporting,
  - If a UE is configured in transmission mode 10 with a 'RI-reference CSI process' for a CSI process, and the most recent type 5 report for the CSI process is dropped, and a type 5 report for the 'RI-reference CSI process' is reported in the most recent RI reporting instance for the CSI process,
    - The wideband second PMI value for the CSI process is calculated conditioned on the reported periodic RI and the wideband first PMI for the configured 'RI-reference CSI process' in the most recent RI reporting instance for the CSI process and the last reported periodic CRI for the CSI process.
    - The wideband CQI value is calculated conditioned on the selected precoding matrix for the CSI process and the reported periodic RI for the configured 'RI-reference CSI process' in the most recent RI reporting instance for the CSI process and the last reported periodic CRI for the CSI process.
  - Otherwise,
    - The wideband second PMI value is calculated conditioned on the last reported periodic RI and the wideband first PMI and the last reported periodic CRI.
    - The wideband CQI value is calculated conditioned on the selected precoding matrix and the last reported periodic RI and the last reported periodic CRI.
- .otherwise,
  - If a UE is configured in transmission mode 10 with a 'RI-reference CSI process' for a CSI process, and the most recent type 5 report for the CSI process is dropped, and a type 5 report for the 'RI-reference CSI process' is reported in the most recent RI reporting instance for the CSI process,
    - The wideband second PMI value for the CSI process is calculated conditioned on the reported periodic RI and the wideband first PMI for the configured 'RI-reference CSI process' in the most recent RI reporting instance for the CSI process.
    - The wideband CQI value is calculated conditioned on the selected precoding matrix for the CSI process and the reported periodic RI for the configured 'RI-reference CSI process' in the most recent RI reporting instance for the CSI process.
  - Otherwise,

- The wideband second PMI value is calculated conditioned on the last reported periodic RI and the wideband first PMI.
- The wideband CQI value is calculated conditioned on the selected precoding matrix and the last reported periodic RI.

- In the subframe where wideband CQI/first PMI/second PMI is reported for transmission modes 9 and 10 with submode 2 and 8 CSI-RS ports configured without CRI reporting or 8 CSI-RS ports or 4 CSI-RS ports with *alternativeCodeBookEnabledFor4TX-r12=TRUE* in the selected CSI-RS resource and UE is configured with CRI reporting, and for transmission modes 8, 9 and 10 with submode 2 and *alternativeCodeBookEnabledFor4TX-r12=TRUE* configured without CRI reporting:
  - A single precoding matrix is selected from the codebook subset assuming transmission on set *S* subbands.
  - A UE shall report a type 2c report consisting of
    - A single wideband CQI value which is calculated assuming the use of a single precoding matrix in all subbands and transmission on set *S* subbands.
    - The wideband first PMI and the wideband second PMI corresponding to the selected single precoding matrix as defined in subclause 7.2.4.
    - When RI>1, an additional 3-bit wideband spatial differential CQI, which is shown in Table 7.2-2.
  - If the UE is configured with CRI reporting,
    - If a UE is configured in transmission mode 10 with a 'RI-reference CSI process' for a CSI process, and the most recent type 3 report for the CSI process is dropped, and a type 3 report for the 'RI-reference CSI process' is reported in the most recent RI reporting instance for the CSI process, the wideband first PMI, the wideband second PMI and the wideband CQI for the CSI process are calculated conditioned on the reported periodic RI for the configured 'RI-reference CSI process' in the most recent RI reporting instance for the CSI process and the last reported periodic CRI for the CSI process; otherwise the wideband first PMI, the wideband second PMI and the wideband CQI are calculated conditioned on the last reported periodic RI and the last reported periodic CRI.
  - otherwise
    - If a UE is configured in transmission mode 10 with a 'RI-reference CSI process' for a CSI process, and the most recent type 3 report for the CSI process is dropped, and a type 3 report for the 'RI-reference CSI process' is reported in the most recent RI reporting instance for the CSI process, the wideband first PMI, the wideband second PMI and the wideband CQI for the CSI process are calculated conditioned on the reported periodic RI for the configured 'RI-reference CSI process' in the most recent RI reporting instance for the CSI process; otherwise the wideband first PMI, the wideband second PMI and the wideband CQI are calculated conditioned on the last reported periodic RI.

- UE Selected subband feedback
  - Mode 2-0 description:
    - In the subframe where RI is reported (only for transmission mode 3, and transmission mode 9 or 10 without PMI reporting with one configured CSI-RS resource or with more than one configured CSI-RS resource and the number of CSI-RS ports of the selected CSI-RS is more than one):

- If a UE is configured in transmission mode 10 with a 'RI-reference CSI process' for a CSI process, the RI for the CSI process shall be the same as the RI in the most recent CSI report comprising RI for the configured 'RI-reference CSI process' irrespective of subframe sets if configured; otherwise, for transmission mode 3 the UE shall determine a RI assuming transmission on set *S* subbands, and for transmission mode 9 or 10 without PMI reporting, the UE shall determine a RI assuming transmission on set *S* subbands conditioned on the last reported periodic CRI.

- The UE shall report a type 3 report consisting of one RI.

▪ In the subframe where RI and CRI is reported (only for transmission mode 9 or 10 without PMI reporting and number of configured CSI-RS resources more than one and the number of antenna ports in at least one of the configured CSI-RS resources is more than one):

  - A UE shall determine a CRI assuming transmission on set *S* subbands.

  - If a UE is configured in transmission mode 10 with a 'RI-reference CSI process' for a CSI process, the RI for the CSI process shall be the same as the RI in the most recent CSI report comprising RI for the configured 'RI-reference CSI process' irrespective of subframe sets if configured; otherwise, the UE shall determine a RI assuming transmission on set *S* subbands conditioned on the reported CRI.
  - The UE shall report a type 7 report consisting of one RI and one CRI.

▪ In the subframe where CRI is reported (only for transmission mode 9 or 10 with CRI reporting and the number of antenna ports in each of configured CSI-RS resources is one):

  - A UE shall determine a CRI assuming transmission on set *S* subbands.

  - The UE shall report a type10 report consisting of one CRI.

▪ In the subframe where wideband CQI is reported:

  - If the UE is configured without PMI reporting (only for transmission mode 9 or 10):

    o A single precoding matrix is selected from the codebook subset assuming transmission on set *S* subbands.
    o A UE shall report a type 4 report on each respective successive reporting opportunity consisting of

      ▪ A single wideband CQI value which is calculated assuming the use of a single precoding matrix in all subbands and transmission on set *S* subbands.

      ▪ When RI>1, an additional 3-bit wideband spatial differential CQI, which is shown in Table 7.2-2.
    o If the UE is configured with CRI reporting,
      ▪ If a UE is configured in transmission mode 10 with a ‘'RI-reference CSI process'’ for a CSI process, and the most recent type 3 report for the CSI process is dropped, and a type 3 report for the ‘'RI-reference CSI process'’ is reported in the most recent RI reporting instance for the CSI process, the subband selection, selected precoding matrix and CQI for the CSI process are calculated conditioned on the reported periodic RI for the configured ‘'RI-reference CSI process'’ in the most recent RI reporting instance for the CSI process and the last reported periodic CRI for the CSI process; otherwise the subband selection, selected precoding matrix and CQI are

calculated conditioned on the last reported periodic RI and the last reported periodic CRI.

- o otherwise
  - ▪ If a UE is configured in transmission mode 10 with a ‘'RI-reference CSI process’' for a CSI process, and the most recent type 3 report for the CSI process is dropped, and a type 3 report for the ‘'RI-reference CSI process’' is reported in the most recent RI reporting instance for the CSI process, the subband selection, selected precoding matrix and CQI for the CSI process are calculated conditioned on the reported periodic RI for the configured ‘'RI-reference CSI process’' in the most recent RI reporting instance for the CSI process; otherwise the subband selection, selected precoding matrix and CQI are calculated conditioned on the last reported periodic RI.

- • otherwise,
  - o The UE shall report a type 4 report on each respective successive reporting opportunity consisting of one wideband CQI value which is calculated assuming transmission on set *S* subbands. The wideband CQI represents channel quality for the first codeword, even when RI>1.
  - o For transmission mode 3 the CQI is calculated conditioned on the last reported periodic RI. For other transmission modes it is calculated conditioned on transmission rank 1. If the UE is configured with CRI reporting, the CQI is calculated conditioned on the last reported periodic CRI.

- ▪ In the subframe where CQI for the selected subbands is reported:
  - • If the UE is configured without PMI reporting (only for transmission mode 9 or 10):
    - o The UE shall select the preferred subband within the set of N_j subbands in each of the *J* bandwidth parts where *J* is given in Table 7.2.2-2.
    - o A single precoding matrix is selected from the codebook subset assuming transmission on on the selected subband within the applicable bandwidth part.
    - o The UE shall report a type 1 report per bandwidth part on each respective successive reporting opportunity consisting of:
      - ▪ CQI value for codeword 0 reflecting transmission only over the selected subband of a bandwidth part determined in the previous step along with the corresponding preferred subband *L*-bit label.
      - ▪ When RI>1, an additional 3-bit subband spatial differential CQI value for codeword 1 offset level
        - • Codeword 1 offset level = subband CQI index for codeword 0 – subband CQI index for codeword 1.
      - ▪ The mapping from the 3-bit subband spatial differential CQI value to the offset level is shown in Table 7.2-2.
    - o If the UE is configured with CRI reporting,
      - ▪ If a UE is configured in transmission mode 10 with a ‘'RI-reference CSI process’' for a CSI process, and the most recent type 3 report for the CSI process is dropped, and a type 3 report for the ‘'RI-reference CSI process’' is reported

in the most recent RI reporting instance for the CSI process, the selected precoding matrix and CQI for the CSI process are calculated conditioned on the reported periodic RI for the configured ‘'RI-reference CSI process’' in the most recent RI reporting instance for the CSI process and the last reported periodic CRI for the CSI process; otherwise the selected precoding matrix and CQI are calculated conditioned on the last reported periodic RI and the last reported periodic CRI.

- o otherwise,
  - ▪ If a UE is configured in transmission mode 10 with a ‘'RI-reference CSI process’' for a CSI process, and the most recent type 3 report for the CSI process is dropped, and a type 3 report for the ‘'RI-reference CSI process’' is reported in the most recent RI reporting instance for the CSI process, the selected precoding matrix and CQI for the CSI process are calculated conditioned on the reported periodic RI for the configured ‘'RI-reference CSI process’' in the most recent RI reporting instance for the CSI process; otherwise the selected precoding matrix and CQI are calculated conditioned on the last reported periodic RI.

- otherwise,
  - o The UE shall select the preferred subband within the set of N_j subbands in each of the *J* bandwidth parts where *J* is given in Table 7.2.2-2.
  - o The UE shall report a type 1 report consisting of one CQI value reflecting transmission only over the selected subband of a bandwidth part determined in the previous step along with the corresponding preferred subband *L*-bit label. A type 1 report for each bandwidth part will in turn be reported in respective successive reporting opportunities. The CQI represents channel quality for the first codeword, even when RI>1.
  - o For transmission mode 3 the preferred subband selection and CQI values are calculated conditioned on the last reported periodic RI. For other transmission modes they are calculated conditioned on transmission rank 1. If the UE is configured with CRI reporting, the preferred subband selection and CQI values are calculated conditioned on the last reported periodic CRI.

o Mode 2-1 description:

- ▪ In the subframe where RI is reported for transmission mode 4, transmission mode 8 except with *alternativeCodeBookEnabledFor4TX-r12=TRUE* configured, transmission modes 9 and 10 with 2 CSI-RS ports, and transmission modes 9 and 10 with 4 CSI-RS ports except with *alternativeCodeBookEnabledFor4TX-r12=TRUE* configured, and for transmission modes 9 and 10 with higher layer parameter *eMIMO-Type* configured, *eMIMO-Type* set to ‘CLASS B’, one CSI-RS resource configured, with higher layer parameter *alternativeCodebookEnabledCLASSB_K1=TRUE*:
  - If a UE is configured with CRI reporting,
    - o If a UE is configured in transmission mode 10 with a 'RI-reference CSI process' for a CSI process, the RI for the CSI process shall be the same as the RI in the most recent CSI report comprising RI for the configured 'RI-reference CSI process' irrespective of subframe sets if configured; otherwise, the UE shall determine a RI assuming transmission on set *S* subbands conditioned on the last reported periodic CRI.
  - otherwise,

        - If a UE is configured in transmission mode 10 with a 'RI-reference CSI process' for a CSI process, the RI for the CSI process shall be the same as the RI in the most recent CSI report comprising RI for the configured 'RI-reference CSI process' irrespective of subframe sets if configured; otherwise, the UE shall determine a RI assuming transmission on set *S* subbands.
    - The UE shall report a type 3 report consisting of one RI.
- In the subframe where RI and PTI are reported, for transmission modes 9 and 10 with 8 CSI-RS ports configured and higher layer parameter *eMIMO-Type* not configured, or for transmission modes 9 and 10 with 8 CSI-RS ports or 4 CSI-RS ports with *alternativeCodeBookEnabledFor4TX-r12=TRUE* in the selected CSI-RS resource and UE is configured with CRI reporting, or for transmission modes 9 and 10 with 8 CSI-RS ports configured and UE is configured with higher layer parameter *eMIMO-Type*, and *eMIMO-Type* is set to 'CLASS B', and one CSI-RS resource configured, and except with higher layer parameter *alternativeCodebookEnabledCLASSB_K1=TRUE* configured, or for transmission modes 9 and 10 with higher layer parameter *eMIMO-Type* configured, and *eMIMO-Type* set to 'CLASS A',or for transmission modes 8, 9 and 10 with *alternativeCodeBookEnabledFor4TX-r12=TRUE* configured without CRI reporting then:
    - If a UE is configured with CRI reporting,
        - If a UE is configured in transmission mode 10 with a 'RI-reference CSI process' for a CSI process, the RI for the CSI process shall be the same as the RI in the most recent CSI report comprising RI for the configured 'RI-reference CSI process' irrespective of subframe sets if configured; otherwise, the UE shall determine a RI assuming transmission on set *S* subbands conditioned on the last reported periodic CRI.
        - If a UE is configured in transmission mode 10 with a 'RI-reference CSI process' for a CSI process, the PTI for the CSI process shall be the same as the PTI in the most recent type 6 report for the configured 'RI-reference CSI process'; otherwise, the UE shall determine a precoder type indication (PTI) conditioned on the last reported periodic CRI.
    - otherwise,
        - If a UE is configured in transmission mode 10 with a 'RI-reference CSI process' for a CSI process, the RI for the CSI process shall be the same as the RI in the most recent CSI report comprising RI for the configured 'RI-reference CSI process' irrespective of subframe sets if configured; otherwise, the UE shall determine a RI assuming transmission on set *S* subbands.
        - If a UE is configured in transmission mode 10 with a 'RI-reference CSI process' for a CSI process, the PTI for the CSI process shall be the same as the PTI in the most recent type 6 report for the configured 'RI-reference CSI process'; otherwise, the UE shall determine a precoder type indication (PTI).
    - The PTI for the CSI process shall be equal to 1 if the RI reported jointly with the PTI is greater than 2 for transmission modes 8, 9, 10 with *alternativeCodeBookEnabledFor4TX-r12=TRUE* configured.
    - The UE shall report a type 6 report consisting of one RI and the PTI.
- In the subframe where RI and CRI is reported for transmission modes 9 and 10 with parameter *eMIMO-Type* configured by higher layers, and *eMIMO-Type* is set to 'CLASS B', and the number of configured CSI-RS resources is more than one:
    - A UE shall determine a CRI assuming transmission on set *S* subbands.
    - If a UE is configured in transmission mode 10 with a 'RI-reference CSI process' for a CSI process, the RI for the CSI process shall be the same as the RI in the most recent CSI report comprising RI for the configured 'RI-reference CSI process' irrespective of subframe sets if configured; otherwise, the UE

shall determine a RI assuming transmission on set *S* subbands conditioned on the reported CRI for the CSI process.

- If each of the maximum number of ports in the configured CSI-RS resources is 2, or 4 except with *alternativeCodeBookEnabledFor4TX-r12=TRUE* configured,
  - The UE shall report a type 7 report consisting of one RI and one CRI.
- otherwise,
  - If a UE is configured in transmission mode 10 with a 'RI-reference CSI process' for a CSI process, the PTI for the CSI process shall be the same as the PTI in the most recent type 6 report for the configured 'RI-reference CSI process'; otherwise, the UE shall determine a precoder type indication (PTI) conditioned on the reported CRI for the CSI process.
  - If the configured CSI-RS resource corresponding to the determined CRI comprises 2 CSI-RS ports or 4 CSI-RS ports except with alternativeCodeBookEnabledFor4TX-r12=TRUE configured, PTI is fixed to zero.
  - The PTI for the CSI process shall be equal to 1 if the RI reported jointly with the PTI is greater than 2 for transmission modes 9, 10 with *alternativeCodeBookEnabledFor4TX-r12=TRUE* configured.
  - The UE shall report a type 9 report consisting of one CRI, RI, and the PTI.

- In the subframe where wideband CQI/PMI is reported for all transmission modes except with
  - UE is configured with higher layer parameter *eMIMO-Type*, and *eMIMO-Type* is set to ‘CLASS A’, or
  - 8 CSI-RS ports configured for transmission modes 9 and 10, or with *alternativeCodeBookEnabledFor4TX-r12=TRUE* configured for transmission modes 8, 9 and 10, if the UE is not configured with higher layer parameter *eMIMO-Type*, or UE is configured with CRI reporting, or UE is configured with higher layer parameter *eMIMO-Type*, and *eMIMO-Type* is set to ‘CLASS B’, and one CSI-RS resource configured, and except with higher layer parameter *alternativeCodebookEnabledCLASSB_K1=TRUE* configured:
    - A single precoding matrix is selected from the codebook subset assuming transmission on set *S* subbands.
    - A UE shall report a type 2 report on each respective successive reporting opportunity consisting of:
      - A wideband CQI value which is calculated assuming the use of a single precoding matrix in all subbands and transmission on set *S* subbands.
      - The selected single PMI (wideband PMI).
      - When RI>1, an additional 3-bit wideband spatial differential CQI, which is shown in Table 7.2-2.
  - If the UE is configured with CRI reporting,
    - If a UE is configured in transmission mode 10 with a 'RI-reference CSI process' for a CSI process, and the most recent type 3 report for the CSI process is dropped, and a type 3 report for the 'RI-reference CSI process' is reported in the most recent RI reporting instance for the CSI process, the PMI and CQI values for the CSI process are calculated conditioned on the reported periodic RI for the configured 'RI-reference CSI process' in the most recent RI reporting instance for the CSI process and the last reported periodic CRI for the CSI

process; otherwise the PMI and CQI values are calculated conditioned on the last reported periodic RI and the last reported periodic CRI.

- otherwise,
  - o For transmission modes 4, 8, 9 and 10,
    - ▪ If a UE is configured in transmission mode 10 with a 'RI-reference CSI process' for a CSI process, and the most recent type 3 report for the CSI process is dropped, and a type 3 report for the 'RI-reference CSI process' is reported in the most recent RI reporting instance for the CSI process, the PMI and CQI values for the CSI process are calculated conditioned on the reported periodic RI for the configured 'RI-reference CSI process' in the most recent RI reporting instance for the CSI process; otherwise the PMI and CQI values are calculated conditioned on the last reported periodic RI.
  - o For other transmission modes the PMI and CQI values are calculated conditioned on transmission rank 1.

▪ In the subframe where the wideband first PMI is reported for transmission modes 9 and 10 with 8 CSI-RS ports configured and higher layer parameter *eMIMO-Type* not configured, or for transmission modes 9 and 10 with 8 CSI-RS ports or 4 CSI-RS ports with *alternativeCodeBookEnabledFor4TX-r12=TRUE* in the selected CSI-RS resource and UE is configured with CRI reporting, or for transmission modes 9 and 10 with 8 CSI-RS ports configured and UE is configured with higher layer parameter *eMIMO-Type*, and *eMIMO-Type* is set to 'CLASS B', and one CSI-RS resource configured, and except with higher layer parameter *alternativeCodebookEnabledCLASSB_K1=TRUE* configured, or for transmission modes 9 and 10 with higher layer parameter *eMIMO-Type* configured, and *eMIMO-Type* set to 'CLASS A', or for transmission modes 8, 9 and 10 with *alternativeCodeBookEnabledFor4TX-r12=TRUE* configured without CRI reporting:

- A set of precoding matrices corresponding to the wideband first PMI is selected from the codebook subset assuming transmission on set *S* subbands.
- A UE shall report a type 2a report on each respective successive reporting opportunity consisting of the wideband first PMI corresponding to the selected set of precoding matrices.
- If the UE is configured with CRI reporting,
  - o If a UE is configured in transmission mode 10 with a 'RI-reference CSI process' for a CSI process, and the most recent type 6 report for the CSI process is dropped, and a type 6 report for the 'RI-reference CSI process' with PTI=0 is reported in the most recent RI reporting instance for the CSI process, the wideband first PMI value for the CSI process is calculated conditioned on the reported periodic RI for the configured 'RI-reference CSI process' in the most recent RI reporting instance for the CSI process and the last reported periodic CRI for the CSI process; otherwise with the last reported PTI=0, the wideband first PMI value is calculated conditioned on the last reported periodic RI and the last reported periodic CRI.
- otherwise,
  - o If a UE is configured in transmission mode 10 with a 'RI-reference CSI process' for a CSI process, and the most recent type 6 report for the CSI process is dropped, and a type 6 report for the 'RI-reference CSI process' with PTI=0 is reported in the most recent RI reporting instance for the CSI process, the wideband first PMI value for the CSI process is calculated conditioned on the reported periodic RI for the

configured 'RI-reference CSI process' in the most recent RI reporting instance for the CSI process; otherwise with the last reported PTI=0, the wideband first PMI value is calculated conditioned on the last reported periodic RI.

- In the subframe where wideband CQI/second PMI is reported, for transmission modes 9 and 10 with 8 CSI-RS ports configured and higher layer parameter *eMIMO-Type* not configured, or for transmission modes 9 and 10 with 8 CSI-RS ports or 4 CSI-RS ports with *alternativeCodeBookEnabledFor4TX-r12=TRUE* in the selected CSI-RS resource and UE is configured with CRI reporting, or for transmission modes 9 and 10 with 8 CSI-RS ports configured and UE is configured with higher layer parameter *eMIMO-Type*, and *eMIMO-Type* is set to 'CLASS B', and one CSI-RS resource configured, and except with higher layer parameter *alternativeCodebookEnabledCLASSB_K1=TRUE* configured, or for transmission modes 9 and 10 with higher layer parameter *eMIMO-Type* configured, and *eMIMO-Type* set to 'CLASS A',or for transmission modes 8,9, and 10 with *alternativeCodeBookEnabledFor4TX-r12=TRUE* configured without CRI reporting:
  - A single precoding matrix is selected from the codebook subset assuming transmission on set *S* subbands.
  - A UE shall report a type 2b report on each respective successive reporting opportunity consisting of:
    - A wideband CQI value which is calculated assuming the use of the selected single precoding matrix in all subbands and transmission on set *S* subbands.
    - The wideband second PMI corresponding to the selected single precoding matrix.
    - When RI>1, an additional 3-bit wideband spatial differential CQI, which is shown in Table 7.2-2.
  - If the UE is configured with CRI reporting,
    - If a UE is configured in transmission mode 10 with a 'RI-reference CSI process' for a CSI process, and the most recent type 6 report for the CSI process is dropped, and a type 6 report for the 'RI-reference CSI process' with PTI=1 is reported in the most recent RI reporting instance for the CSI process,
      - The wideband second PMI value for the CSI process is calculated conditioned on the reported periodic RI for the configured 'RI-reference CSI process' in the most recent RI reporting instance for the CSI process and the last reported wideband first PMI for the CSI process and the last reported periodic CRI for the CSI process,
      - The wideband CQI value is calculated conditioned on the selected precoding matrix for the CSI process and the reported periodic RI for the configured 'RI-reference CSI process' in the most recent RI reporting instance for the CSI process and the last reported periodic CRI for the CSI process.
    - Otherwise, with the last reported PTI=1,
      - The wideband second PMI value is calculated conditioned on the last reported periodic RI and the wideband first PMI and the last reported periodic CRI.
      - The wideband CQI value is calculated conditioned on the selected precoding matrix and the last reported periodic RI and the last reported periodic CRI.

- otherwise,
  - o If a UE is configured in transmission mode 10 with a 'RI-reference CSI process' for a CSI process, and the most recent type 6 report for the CSI process is dropped, and a type 6 report for the 'RI-reference CSI process' with PTI=1 is reported in the most recent RI reporting instance for the CSI process,
    - ▪ The wideband second PMI value for the CSI process is calculated conditioned on the reported periodic RI for the configured 'RI-reference CSI process' in the most recent RI reporting instance for the CSI process and the last reported wideband first PMI for the CSI process,
    - ▪ The wideband CQI value is calculated conditioned on the selected precoding matrix for the CSI process and the reported periodic RI for the configured 'RI-reference CSI process' in the most recent RI reporting instance for the CSI process.
  - o Otherwise, with the last reported PTI=1,
    - ▪ The wideband second PMI value is calculated conditioned on the last reported periodic RI and the wideband first PMI.
    - ▪ The wideband CQI value is calculated conditioned on the selected precoding matrix and the last reported periodic RI.
- If the last reported first PMI was computed under an RI assumption that differs from the last reported periodic RI, or in the absence of a last reported first PMI, the conditioning of the second PMI value is not specified.

▪ In the subframe where CQI for the selected subband is reported for all transmission modes except with

- UE is configured with higher layer parameter *eMIMO-Type*, and *eMIMO-Type* is set to ‘CLASS A’, or
- 8 CSI-RS ports configured for transmission modes 9 and 10, or with *alternativeCodeBookEnabledFor4TX-r12=TRUE* configured for transmission modes 8, 9 and 10, if the UE is not configured with higher layer parameter *eMIMO-Type*, or UE is configured with CRI reporting, or UE is configured with higher layer parameter *eMIMO-Type*, and *eMIMO-Type* is set to ‘CLASS B’, and one CSI-RS resource configured, and except with higher layer parameter *alternativeCodebookEnabledCLASSB_K1=TRUE* configured:
  - o The UE shall select the preferred subband within the set of N_j subbands in each of the J bandwidth parts where J is given in Table 7.2.2-2.
  - o The UE shall report a type 1 report per bandwidth part on each respective successive reporting opportunity consisting of:
    - ▪ CQI value for codeword 0 reflecting transmission only over the selected subband of a bandwidth part determined in the previous step along with the corresponding preferred subband L-bit label.
    - ▪ When RI>1, an additional 3-bit subband spatial differential CQI value for codeword 1 offset level
      - Codeword 1 offset level = subband CQI index for codeword 0 – subband CQI index for codeword 1.
      - Assuming the use of the most recently reported single precoding matrix in all subbands and

transmission on the selected subband within the applicable bandwidth part.

- The mapping from the 3-bit subband spatial differential CQI value to the offset level is shown in Table 7.2-2.

- If the UE is configured with CRI reporting,
  - F If a UE is configured in transmission mode 10 with a 'RI-reference CSI process' for a CSI process, and the most recent type 3 report for the CSI process is dropped, and a type 3 report for the 'RI-reference CSI process' is reported in the most recent RI reporting instance for the CSI process, the subband selection and CQI values for the CSI process are calculated conditioned on the last reported periodic wideband PMI for the CSI process and the reported periodic RI for the configured 'RI-reference CSI process' in the most recent RI reporting instance for the CSI process and the last reported periodic CRI for the CSI process; otherwise the subband selection and CQI values are calculated conditioned on the last reported periodic wideband PMI, RI and CRI.
- otherwise,
  - For transmission modes 4, 8, 9 and 10,
    - If a UE is configured in transmission mode 10 with a 'RI-reference CSI process' for a CSI process, and the most recent type 3 report for the CSI process is dropped, and a type 3 report for the 'RI-reference CSI process' is reported in the most recent RI reporting instance for the CSI process, the subband selection and CQI values for the CSI process are calculated conditioned on the last reported periodic wideband PMI for the CSI process and the reported periodic RI for the configured 'RI-reference CSI process' in the most recent RI reporting instance for the CSI process; otherwise the subband selection and CQI values are calculated conditioned on the last reported periodic wideband PMI and RI.
  - For other transmission modes the subband selection and CQI values are calculated conditioned on the last reported PMI and transmission rank 1.

- In the subframe where wideband CQI/second PMI is reported, for transmission modes 9 and 10 with 8 CSI-RS ports configured and higher layer parameter *eMIMO-Type* not configured, or for transmission modes 9 and 10 with 8 CSI-RS ports or 4 CSI-RS ports with *alternativeCodeBookEnabledFor4TX-r12=TRUE* in the selected CSI-RS resource and UE is configured with CRI reporting, or for transmission modes 9 and 10 with 8 CSI-RS ports configured and UE is configured with higher layer parameter *eMIMO-Type*, and *eMIMO-Type* is set to 'CLASS B', and one CSI-RS resource configured, and except with higher layer parameter *alternativeCodebookEnabledCLASSB_K1=TRUE* configured, or for transmission modes 9 and 10 with higher layer parameter *eMIMO-Type* configured, and *eMIMO-Type* set to 'CLASS A',or for transmission modes 8, 9 and 10 with *alternativeCodeBookEnabledFor4TX-r12=TRUE* configured without CRI reporting:
  - A single precoding matrix is selected from the codebook subset assuming transmission on set *S* subbands.
  - The UE shall report a type 2b report on each respective successive reporting opportunity consisting of:

- A wideband CQI value which is calculated assuming the use of the selected single precoding matrix in all subbands and transmission on set *S* subbands.
- The wideband second PMI corresponding to the selected single precoding matrix.
- When RI>1, an additional 3-bit wideband spatial differential CQI, which is shown in Table 7.2-2.

- If the UE is configured with CRI reporting,
  - If a UE is configured in transmission mode 10 with a 'RI-reference CSI process' for a CSI process, and the most recent type 6 report for the CSI process is dropped, and a type 6 report for the 'RI-reference CSI process' with PTI=0 is reported in the most recent RI reporting instance for the CSI process,
    - The wideband second PMI value for the CSI process is calculated conditioned on the reported periodic RI for the configured 'RI-reference CSI process' in the most recent RI reporting instance for the CSI process and the last reported wideband first PMI for the CSI process and the last reported periodic CRI for the CSI process.
    - The wideband CQI value is calculated conditioned on the selected precoding matrix for the CSI process and the reported periodic RI for the configured 'RI-reference CSI process' in the most recent RI reporting instance for the CSI process and the last reported periodic CRI for the CSI process.
  - otherwise, with the last reported PTI=0,
    - The wideband second PMI value is calculated conditioned on the last reported periodic RI and the wideband first PMI and the last reported periodic CRI.
    - The wideband CQI value is calculated conditioned on the selected precoding matrix and the last reported periodic RI process and the last reported periodic CRI.
- otherwise,
  - If a UE is configured in transmission mode 10 with a 'RI-reference CSI process' for a CSI process, and the most recent type 6 report for the CSI process is dropped, and a type 6 report for the 'RI-reference CSI process' with PTI=0 is reported in the most recent RI reporting instance for the CSI process,
    - The wideband second PMI value for the CSI process is calculated conditioned on the reported periodic RI for the configured 'RI-reference CSI process' in the most recent RI reporting instance for the CSI process and the last reported wideband first PMI for the CSI process.
    - The wideband CQI value is calculated conditioned on the selected precoding matrix for the CSI process and the reported periodic RI for the configured 'RI-reference CSI process' in the most recent RI reporting instance for the CSI process.
  - Otherwise, with the last reported PTI=0,

  - The wideband second PMI value is calculated conditioned on the last reported periodic RI and the wideband first PMI.
  - The wideband CQI value is calculated conditioned on the selected precoding matrix and the last reported periodic RI.
- If the last reported first PMI was computed under an RI assumption that differs from the last reported periodic RI, or in the absence of a last reported first PMI, the conditioning of the second PMI value is not specified.

- In the subframe where subband CQI/second PMI for the selected subband is reported, for transmission modes 9 and 10 with 8 CSI-RS ports configured and higher layer parameter *eMIMO-Type* not configured, or for transmission modes 9 and 10 with 8 CSI-RS ports or 4 CSI-RS ports with alternativeCodeBookEnabledFor4TX-r12=TRUE in the selected CSI-RS resource and UE is configured with CRI reporting, or for transmission modes 9 and 10 with 8 CSI-RS ports configured and UE is configured with higher layer parameter *eMIMO-Type*, and *eMIMO-Type* is set to 'CLASS B', and one CSI-RS resource configured, and except with higher layer parameter *alternativeCodebookEnabledCLASSB_K1=TRUE* configured, or for transmission modes 9 and 10 with higher layer parameter *eMIMO-Type* configured, and *eMIMO-Type* set to 'CLASS A',or for transmission modes 8, 9 and 10 with *alternativeCodeBookEnabledFor4TX-r12=TRUE* configured without CRI reporting:
  - The UE shall select the preferred subband within the set of N_j subbands in each of the J bandwidth parts where J is given in Table 7.2.2-2.
  - The UE shall report a type 1a report per bandwidth part on each respective successive reporting opportunity consisting of:
    - o CQI value for codeword 0 reflecting transmission only over the selected subband of a bandwidth part determined in the previous step along with the corresponding preferred subband L-bit label.
    - o When RI>1, an additional 3-bit subband spatial differential CQI value for codeword 1 offset level
      - Codeword 1 offset level = subband CQI index for codeword 0 – subband CQI index for codeword 1.
      - Assuming the use of the precoding matrix corresponding to the selected second PMI and the most recently reported first PMI and transmission on the selected subband within the applicable bandwidth part.
    - o The mapping from the 3-bit subband spatial differential CQI value to the offset level is shown in Table 7.2-2.
    - o A second PMI of the preferred precoding matrix selected from the codebook subset assuming transmission only over the selected subband within the applicable bandwidth part determined in the previous step.
  - If the UE is configured with CRI reporting,
    - o If a UE is configured in transmission mode 10 with a 'RI-reference CSI process' for a CSI process, and the most recent type 6 report for the CSI process is dropped, and a type 6 report for the 'RI-reference CSI process' with PTI=1 is reported in the most recent RI reporting instance for the CSI process,
      - The subband second PMI values for the CSI process are calculated conditioned on the reported periodic RI for the configured 'RI-reference CSI process' in the most recent RI reporting instance for the CSI process and the last reported

wideband first PMI for the CSI process and the last reported periodic CRI for the CSI process.

        - The subband selection and CQI values are calculated conditioned on the selected precoding matrix for the CSI process and the reported periodic RI for the configured 'RI-reference CSI process' in the most recent RI reporting instance for the CSI process and the last reported periodic CRI for the CSI process.

    - Otherwise, with the last reported PTI=1

        - The subband second PMI values are calculated conditioned on the last reported periodic RI and the wideband first PMI and the last reported periodic CRI.

        - The subband selection and CQI values are calculated conditioned on the selected precoding matrix and the last reported periodic RI and the last reported periodic CRI.

- otherwise,

    - If a UE is configured in transmission mode 10 with a 'RI-reference CSI process' for a CSI process, and the most recent type 6 report for the CSI process is dropped, and a type 6 report for the 'RI-reference CSI process' with PTI=1 is reported in the most recent RI reporting instance for the CSI process,

        - The subband second PMI values for the CSI process are calculated conditioned on the reported periodic RI for the configured 'RI-reference CSI process' in the most recent RI reporting instance for the CSI process and the last reported wideband first PMI for the CSI process.

        - The subband selection and CQI values are calculated conditioned on the selected precoding matrix for the CSI process and the reported periodic RI for the configured 'RI-reference CSI process' in the most recent RI reporting instance for the CSI process.

    - Otherwise, with the last reported PTI=1

        - The subband second PMI values are calculated conditioned on the last reported periodic RI and the wideband first PMI.

        - The subband selection and CQI values are calculated conditioned on the selected precoding matrix and the last reported periodic RI.

- If the last reported first PMI was computed under an RI assumption that differs from the last reported periodic RI, or in the absence of a last reported first PMI, the conditioning of the second PMI value is not specified.

Table 7.2.2-2: Subband Size (*k*) and Bandwidth Parts *(J)* vs. Downlink System Bandwidth

System Bandwidth $N_{\mathrm{RB}}^{\mathrm{DL}}$	Subband Size *k* (RBs)	Bandwidth Parts (*J*)
6 – 7	NA	NA
8 – 10	4	1
11 – 26	4	2
27 – 63	6	3
64 – 110	8	4

For a BL/CE UE, the periodic CSI reporting modes are described as following:

- Wideband feedback
  - Mode 1-0 description:
    - In the subframe where CQI is reported:
      - A UE shall report a type 4 report consisting of one wideband CQI value which is calculated assuming transmission on all narrowband(s) in the CSI reference resource. The wideband CQI is calculated conditioned on transmission rank 1.
  - Mode 1-1 description:
    - In the subframe where CQI/PMI is reported:
      - A single precoding matrix is selected from the codebook subset assuming transmission on all narrowband(s) in the CSI reference resource. The PMI is calculated conditioned on transmission rank 1.
      - A UE shall report a type 2 report consisting of
        - A single wideband CQI value which is calculated assuming the use of a single precoding matrix in all narrowband(s) in the CSI reference resource and transmission on all narrowband(s) in the CSI reference resource. The wideband CQI is calculated conditioned on transmission rank 1.
        - The selected single PMI (wideband PMI).

If parameter *ttiBundling* provided by higher layers is set to *TRUE* and if an UL-SCH in subframe bundling operation collides with a periodic CSI reporting instance, then the UE shall drop the periodic CSI report of a given PUCCH reporting type in that subframe and shall not multiplex the periodic CSI report payload in the PUSCH transmission in that subframe. A UE is not expected to be configured with simultaneous PUCCH and PUSCH transmission when UL-SCH subframe bundling is configured.

Table 7.2.2-3: PUCCH Reporting Type Payload size per PUCCH Reporting Mode and Mode State

PUCCH Reporting Type	Reported	Mode State	PUCCH Reporting Modes			
			Mode 1-1 (bits/BP[*])	Mode 2-1 (bits/BP[*])	Mode 1-0 (bits/BP[*])	Mode 2-0 (bits/BP[*])
1	**Sub-band CQI**	RI = 1	NA	4+L	NA	4+L
		RI > 1	NA	7+L	NA	4+L[1] 7+L[2]
1a	**Sub-band CQI / second PMI**	8 antenna ports or 8/12/16 antenna ports with *codebookConfig*={2,3,4}, RI = 1	NA	8+L	NA	NA
		8 antenna ports or 8/12/16 antenna ports with *codebookConfig*={2,3,4}, 1 < RI < 5	NA	9+L	NA	NA
		8 antenna ports or 8/12/16 antenna ports with *codebookConfig*={1,2,3,4} RI > 4	NA	7+L	NA	NA
		8/12/16 antenna ports with *codebookConfig*=1, RI = 1	NA	6+L	NA	NA
		8/12/16 antenna ports with *codebookConfig*=1, RI = 2	NA	9+L	NA	NA
		8/12/16 antenna ports with *codebookConfig*=1, 2<RI<5	NA	8+L	NA	NA
		4 antenna ports RI=1	NA	8+L	NA	NA
		4 antenna ports 1<RI≤4	NA	9+L	NA	NA
2	**Wideband CQI/PMI**	2 antenna ports RI = 1	6	6	NA	NA
		4 antenna ports RI = 1, Note[5]	8	8	NA	NA
		2 antenna ports RI > 1	8	8	NA	NA
		4 antenna ports RI > 1, Note[5]	11	11	NA	NA
		4 antenna ports RI = 1, Note[6]	7	7	NA	NA
		4 antenna ports RI = 2, Note[6]	10	10	NA	NA
		4 antenna ports RI = 3, Note[6]	9	9	NA	NA
		4 antenna ports RI = 4, Note[6]	8	8	NA	NA
		8 antenna ports RI = 1	8	8	NA	NA
		8 antenna ports 1<RI<4	11	11	NA	NA
		8 antenna ports RI = 4	10	10	NA	NA
		8 antenna ports RI > 4	7	7	NA	NA
2a	**Wideband first PMI**	8 antenna ports RI < 3	NA	4	NA	NA
		8 antenna ports 2 < RI < 8	NA	2	NA	NA
		8 antenna ports RI = 8	NA	0	NA	NA
		4 antenna ports 1≤RI≤2	NA	4	NA	NA
		4 antenna ports 2≤RI≤4	NA	NA	NA	NA
		8/12/16 antenna ports with *codebookConfig*=1, 1≤RI≤8	Note[3]	Note[3]	NA	NA
		8/12/16 antenna ports with *codebookConfig*={2,3,4}	Note[4]	Note[4]	NA	NA
2b	**Wideband CQI / second PMI**	8 antenna ports or 8/12/16 antenna ports with *codebookConfig* = {2,3,4}, RI = 1	8	8	NA	NA
		8 antenna ports or 8/12/16 antenna ports with *codebookConfig* = {2,3,4}, 1 < RI < 4	11	11	NA	NA
		8 antenna ports or 8/12/16 antenna ports with *codebookConfig* = {2,3,4}, RI = 4	10	10	NA	NA
		8 antenna ports or 8/12/16 antenna ports with *codebookConfig* = {1,2,3,4}, RI > 4	7	7	NA	NA
		4 antenna ports RI=1	8	8	NA	NA
		4 antenna port 1<RI≤4	11	11	NA	NA
		8/12/16 antenna ports with *codebookConfig*=1, RI = 1	6	6	NA	NA
		8/12/16 antenna ports with *codebookConfig*=1, RI = 2	9	9	NA	NA
		8/12/16 antenna ports with *codebookConfig*=1, 2<RI<5	8	8	NA	NA
2c	**Wideband CQI / first PMI / second PMI**	8 antenna ports RI = 1	8	NA	NA	NA
		8 antenna ports 1 < RI ≤ 4	11	NA	NA	NA
		8 antenna ports 4 < RI ≤ 7	9	NA	NA	NA
		8 antenna ports RI = 8	7	NA	NA	NA
		4 antenna ports RI=1	8	NA	NA	NA
		4 antenna port 1<RI≤4	11	NA	NA	NA
3	**RI**	2/4 antenna ports, 2-layer spatial multiplexing	1	1	1	1
		8 antenna ports, 2-layer spatial multiplexing	1	NA	NA[1] 1[2]	NA[1] 1[2]
		4 antenna ports, 4-layer spatial multiplexing	2	2	2	2
		8 antenna ports, 4-layer spatial multiplexing	2	NA	NA[1] 2[2]	NA[1] 2[2]

		8-layer spatial multiplexing	3	NA	NA[1] 3[2]	NA[1] 3[2]
		12/16 antenna ports, 2-layer spatial multiplexing	1	NA	NA	NA
		12/16 antenna ports, 4-layer spatial multiplexing	2	NA	NA	NA
		12/16 antenna ports, 8-layer spatial multiplexing	3	NA	NA	NA
4	**Wideband CQI**	RI = 1 or RI>1, without PMI/RI reporting	NA	NA	4	4
		RI = 1 without PMI reporting	NA	NA	4	4
		RI>1 without PMI reporting	NA	NA	7	7
5	**RI/ first PMI**	8 antenna ports, 2-layer spatial multiplexing	4	NA	NA	NA
		8 antenna ports, 4 and 8-layer spatial multiplexing	5			
		4 antenna ports, 2-layer spatial multiplexing	4			
		4 antenna ports, 4-layer spatial multiplexing	5			
6	**RI/PTI**	8 antenna ports, 2-layer spatial multiplexing	NA	2	NA	NA
		8 antenna ports, 4-layer spatial multiplexing	NA	3	NA	NA
		8 antenna ports, 8-layer spatial multiplexing	NA	4	NA	NA
		4 antenna ports, 2-layer spatial multiplexing	NA	2	NA	NA
		4 antenna ports, 4-layer spatial multiplexing	NA	3	NA	NA
7	CRI/RI	2-layer spatial multiplexing	*k*+1	*k*+1	*k*+1	*k*+1
		4-layer spatial multiplexing	*k*+2	*k*+2	*k*+2	*k*+2
		8-layer spatial multiplexing	*k*+3	*k*+3	*k*+3	*k*+3
8	CRI/RI/first PMI	2-layer spatial multiplexing	*k*+4	NA	NA	NA
		4 and 8-layer spatial multiplexing	*k*+5	NA	NA	NA
9	CRI/RI/PTI	2-layer spatial multiplexing	NA	*k*+2	NA	NA
		4-layer spatial multiplexing	NA	*k*+3	NA	NA
		8-layer spatial multiplexing	NA	*k*+4	NA	NA
10	CRI	Without PMI/RI reporting	NA	NA	*k*	*k*

NOTE *: For wideband CQI reporting types, the stated payload size applies to the full bandwidth.
NOTE 1: Without PMI/RI reporting
NOTE 2: Without PMI reporting $k=\lceil \log_2(K) \rceil$ where K is the number of configured CSI-RS resources
NOTE 3: Sum of Wideband first PMI i1,1 bit width and Wideband first PMI i1,2 bit width in Table 5.2.3.3.2-3B-1 of [4] with PTI=0
NOTE 4: Sum of Wideband first PMI i1,1 bit width and Wideband first PMI i1,2 bit width in Table 5.2.3.3.2-3B-2 of [4] with PTI=0
NOTE 5: Not configured with parameter *eMIMO-Type* by higher-layers
NOTE 6: Configured with parameter *eMIMO-Type* by higher-layers

7.2.3 Channel Quality Indicator (CQI) definition

The CQI indices and their interpretations are given in Table 7.2.3-1 for reporting CQI based on QPSK, 16QAM and 64QAM. The CQI indices and their interpretations are given in Table 7.2.3-2 for reporting CQI based on QPSK, 16QAM, 64QAM and 256QAM. The CQI indices and their interpretations are given in Table 7.2.3-3 for reporting CQI based on QPSK and 16QAM.

For a non-BL/CE UE, based on an unrestricted observation interval in time unless specified otherwise in this subclause, and an unrestricted observation interval in frequency, the UE shall derive for each CQI value reported in uplink subframe *n* the highest CQI index between 1 and 15 in Table 7.2.3-1 or Table 7.2.3-2 which satisfies the following condition, or CQI index 0 if CQI index 1 does not satisfy the condition:

- A single PDSCH transport block with a combination of modulation scheme and transport block size corresponding to the CQI index, and occupying a group of downlink physical resource blocks termed the CSI reference resource, could be received with a transport block error probability not exceeding 0.1.

For a BL/CE UE, based on an unrestricted observation interval in time and frequency, the UE shall derive for each CQI value the highest CQI index between 1 and 10 in Table 7.2.3-3 which satisfies the following condition, or CQI index 0 if CQI index 1 does not satisfy the condition:

- A single PDSCH transport block with a combination of modulation scheme and transport block size corresponding to the CQI index, and occupying a group of downlink physical resource blocks termed the CSI reference resource, could be received with a transport block error probability not exceeding 0.1.

If CSI subframe sets $C_{\text{CSI},0}$ and $C_{\text{CSI},1}$ are configured by higher layers, each CSI reference resource belongs to either $C_{\text{CSI},0}$ or $C_{\text{CSI},1}$ but not to both. When CSI subframe sets $C_{\text{CSI},0}$ and $C_{\text{CSI},1}$ are configured by higher layers a UE is not expected to receive a trigger for which the CSI reference resource is in subframe that does not belong to either subframe set. For a UE in transmission mode 10 and periodic CSI reporting, the CSI subframe set for the CSI reference resource is configured by higher layers for each CSI process.

For a UE in transmission mode 9 when parameter *pmi-RI-Report* is configured by higher layers and parameter *eMIMO-Type* is not configured by higher layers, the UE shall derive the channel measurements for computing the CQI value reported in uplink subframe *n* based on only the Channel-State Information (CSI) reference signals (CSI-RS) defined in [3] for which the UE is configured to assume non-zero power for the CSI-RS. For a non-BL/CE UE in transmission mode 9 when the parameter *pmi-RI-Report* is not configured by higher layers or in transmission modes 1-8 the UE shall derive the channel measurements for computing CQI based on CRS. For a BL/CE UE the UE shall derive the channel measurements for computing CQI based on CRS.

For a UE in transmission mode 10, when parameter *eMIMO-Type* is not configured by higher layers, the UE shall derive the channel measurements for computing the CQI value reported in uplink subframe *n* and corresponding to a CSI process, based on only the non-zero power CSI-RS (defined in [3]) within a configured CSI-RS resource associated with the CSI process.

For a UE in transmission mode 9 and the UE configured with parameter *eMIMO-Type* by higher layers, the term 'CSI process' in this clause refers to the CSI configured for the UE.

For a UE in transmission mode 9 or 10 and for a CSI process, if the UE is configured with parameter *eMIMO-Type* by higher layers, and *eMIMO-Type* is set to 'CLASS A', and one CSI-RS resource configured, or the UE is configured with parameter *eMIMO-Type* by higher layers, and *eMIMO-Type* is set to 'CLASS B', and parameter *channelMeasRestriction* is not configured by higher layers, the UE shall derive the channel measurements for computing the CQI value reported in uplink subframe *n* and corresponding to the CSI process, based on only the non-zero power CSI-RS (defined in [3]) within a configured CSI-RS resource associated with the CSI process. If the UE is configured with parameter *eMIMO-Type* by higher layers, and *eMIMO-Type* is set to 'CLASS B' and the number of configured CSI-RS resources is K>1, and parameter *channelMeasRestriction* is not configured by higher layers, the UE shall derive the channel measurements for computing the CQI value using only the configured CSI-RS resource indicated by the CRI.

For a UE in transmission mode 9 or 10 and for a CSI process, if the UE is configured with parameter *eMIMO-Type* by higher layers, and *eMIMO-Type* is set to 'CLASS B', and parameter *channelMeasRestriction* is configured by higher layers, the UE shall derive the channel measurements for computing the CQI value reported in uplink subframe *n* and corresponding to the CSI process, based on only the most recent, no later than the CSI reference resource, non-zero power CSI-RS (defined in [3]) within a configured CSI-RS resource associated with the CSI process. If the UE is configured with parameter *eMIMO-Type* by higher layers, and *eMIMO-Type* is set to 'CLASS B' and the number of configured CSI-RS resources is K>1, and parameter *channelMeasRestriction* is configured by higher layers, the UE shall derive the channel measurements for computing the CQI value using only the most recent, no later than the CSI reference resource, non-zero power CSI-RS within the configured CSI-RS resource indicated by the CRI.

For a UE in transmission mode 10, when parameter *eMIMO-Type* is not configured by higher layers, the UE shall derive the interference measurements for computing the CQI value reported in uplink subframe *n* and corresponding to a CSI process, based on only the configured CSI-IM resource associated with the CSI process.

For a UE in transmission mode 10 and for a CSI process, when parameters *eMIMO-Type* and *interferenceMeasRestriction* is configured by higher layers, the UE shall derive the interference measurements for computing the CQI value reported in uplink subframe *n* and corresponding to the CSI process, based on only the most recent, no later than the CSI reference resource, configured CSI-IM resource associated with the CSI process. If the UE is configured with parameter *eMIMO-Type* by higher layers, and *eMIMO-Type* is set to 'CLASS B' and the number of configured CSI-RS resources is K>1, and *interferenceMeasRestriction* is configured, the UE shall derive interference measurement for computing the CQI value based on only the most recent, no later than the CSI reference resource, the configured CSI-IM resource associated with the CSI-RS resource indicated by the CRI. If *interferenceMeasRestriction* is not configured, the UE shall derive the interference measurement for computing the CQI value based on the CSI-IM associated with the CSI-RS resource indicated by the CRI.

If the UE in transmission mode 10 is configured by higher layers for CSI subframe sets $C_{\text{CSI},0}$ and $C_{\text{CSI},1}$ for the CSI process, the configured CSI-IM resource within the subframe subset belonging to the CSI reference resource is used to derive the interference measurement.

For a UE configured with the parameter *EIMTA-MainConfigServCell-r12* for a serving cell, configured CSI-IM resource(s) within only downlink subframe(s) of a radio frame that are indicated by UL/DL configuration of the serving cell can be used to derive the interference measurement for the serving cell.

For a LAA Scell,

- for channel measurements, if the UE averages CRS/CSI-RS measurements from multiple subframes
    - the UE should not average CSI-RS measurement in subframe n1 with CSI-RS measurement in a later subframe n2, if any OFDM symbol of subframe n1 or any subframe from subframe n1+1 to subframe n2, is not occupied.
    - the UE should not average CRS measurement in subframe n1 with CRS measurement in a later subframe n2, if any OFDM symbol of the second slot of subframe n1 or any OFDM symbol of any subframe from subframe n1+1 to subframe n2-1, or any of the first 3 OFDM symbols in subframe n2, is not occupied.
- for interference measurements, the UE shall derive the interference measurements for computing the CQI value based on only measurements in subframes with occupied OFDM symbols.

A combination of modulation scheme and transport block size corresponds to a CQI index if:

- the combination could be signalled for transmission on the PDSCH in the CSI reference resource according to the relevant Transport Block Size table, and
- the modulation scheme is indicated by the CQI index, and
- the combination of transport block size and modulation scheme when applied to the reference resource results in the effective channel code rate which is the closest possible to the code rate indicated by the CQI index. If more than one combination of transport block size and modulation scheme results in an effective channel code rate equally close to the code rate indicated by the CQI index, only the combination with the smallest of such transport block sizes is relevant.

The CSI reference resource for a serving cell is defined as follows:

- For a non-BL/CE UE, in the frequency domain, the CSI reference resource is defined by the group of downlink physical resource blocks corresponding to the band to which the derived CQI value relates. For a BL/CE UE, in the frequency domain, the CSI reference resource includes all downlink physical resource blocks for any of the narrowband to which the derived CQI value relates.
- In the time domain and for a non-BL/CE UE,

- for a UE configured in transmission mode 1-9 or transmission mode 10 with a single configured CSI process for the serving cell, the CSI reference resource is defined by a single downlink or special subframe $n\text{-}n_{CQI\_ref}$,
  - where for periodic CSI reporting or for LAA Scell and aperiodic CSI reporting, n_{CQI_ref} is the smallest value greater than or equal to 4, such that it corresponds to a valid downlink or valid special subframe,
  - where for FDD serving cell or TDD serving cell and aperiodic CSI reporting, if the UE is not configured with the higher layer parameter *csi-SubframePatternConfig-r12*,.
    - n_{CQI_ref} is such that the reference resource is in the same valid downlink or valid special subframe as the corresponding CSI request in an uplink DCI format.
    - n_{CQI_ref} is equal to 4 and subframe $n\text{-}n_{CQI\_ref}$ corresponds to a valid downlink or valid special subframe, where subframe $n\text{-}n_{CQI\_ref}$ is received after the subframe with the corresponding CSI request in a Random Access Response Grant.
  - where for aperiodic CSI reporting, and the UE configured with the higher layer parameter *csi-SubframePatternConfig-r12*,
    - for the UE configured in transmission mode 1-9,
      - n_{CQI_ref} is the smallest value greater than or equal to 4 and subframe $n\text{-}n_{CQI\_ref}$ corresponds to a valid downlink or valid special subframe, where subframe $n\text{-}n_{CQI\_ref}$ is received on or after the subframe with the corresponding CSI request in an uplink DCI format;
      - n_{CQI_ref} is the smallest value greater than or equal to 4, and subframe $n\text{-}n_{CQI\_ref}$ corresponds to a valid downlink or valid special subframe, where subframe $n\text{-}n_{CQI\_ref}$ is received after the subframe with the corresponding CSI request in an Random Access Response Grant;
      - if there is no valid value for n_{CQI_ref} based on the above conditions, then n_{CQI_ref} is the smallest value such that the reference resource is in a valid downlink or valid special subframe $n\text{-}n_{CQI\_ref}$ prior to the subframe with the corresponding CSI request, where subframe $n\text{-}n_{CQI\_ref}$ is the lowest indexed valid downlink or valid special subframe within a radio frame;
    - for the UE configured in transmission mode 10,
      - n_{CQI_ref} is the smallest value greater than or equal to 4, such that it corresponds to a valid downlink or valid special subframe, and the corresponding CSI request is in an uplink DCI format;
      - n_{CQI_ref} is the smallest value greater than or equal to 4, and subframe $n\text{-}n_{CQI\_ref}$ corresponds to a valid downlink or valid special subframe, where subframe $n\text{-}n_{CQI\_ref}$ is received after the subframe with the corresponding CSI request in a Random Access Response Grant;
- for a UE configured in transmission mode 10 with multiple configured CSI processes for the serving cell, the CSI reference resource for a given CSI process is defined by a single downlink or special subframe $n\text{-}n_{CQI\_ref}$,
  - where for FDD serving cell or LAA Scell and periodic or aperiodic CSI reporting n_{CQI_ref} is the smallest value greater than or equal to 5, such that it corresponds to a valid downlink or valid special subframe, and for aperiodic CSI reporting the corresponding CSI request is in an uplink DCI format;
  - where for FDD serving cell and aperiodic CSI reporting n_{CQI_ref} is equal to 5 and subframe $n\text{-}n_{CQI\_ref}$ corresponds to a valid downlink or valid special subframe, where subframe $n\text{-}n_{CQI\_ref}$ is received after the subframe with the corresponding CSI request in a Random Access Response Grant.
  - where for TDD serving cell, and 2 or 3 configured CSI processes, and periodic or aperiodic CSI reporting, n_{CQI_ref} is the smallest value greater than or equal to 4, such that it corresponds to a valid downlink or valid special subframe, and for aperiodic CSI reporting the corresponding CSI request is in an uplink DCI format;
  - where for TDD serving cell, and 2 or 3 configured CSI processes, and aperiodic CSI reporting, n_{CQI_ref} is equal to 4 and subframe $n\text{-}n_{CQI\_ref}$ corresponds to a valid downlink or valid special subframe, where subframe $n\text{-}n_{CQI\_ref}$ is received after the subframe with the corresponding CSI request in a Random Access Response Grant;
  - where for TDD serving cell, and 4 configured CSI processes, and periodic or aperiodic CSI reporting, n_{CQI_ref} is the smallest value greater than or equal to 5, such that it corresponds to a valid downlink or

valid special subframe, and for aperiodic CSI reporting the corresponding CSI request is in an uplink DCI format;

- where for TDD serving cell, and 4 configured CSI processes, and aperiodic CSI reporting, n_{CQI_ref} is equal to 5 and subframe $n\text{-}n_{CQI\_ref}$ corresponds to a valid downlink or valid special subframe, where subframe $n\text{-}n_{CQI\_ref}$ is received after the subframe with the corresponding CSI request in a Random Access Response Grant.

- In the time domain and for a BL/CE UE, the CSI reference resource is defined by a set of BL/CE downlink or special subframes where the last subframe is subframe $n\text{-}n_{CQI\_ref}$,
  - where for periodic CSI reporting n_{CQI_ref} is ≥ 4;
  - where for aperiodic CSI reporting n_{CQI_ref} is ≥ 4;

  where each subframe in the CSI reference resource is a valid downlink or valid special subframe;

  - where for wideband CSI reports:
    - The set of BL/CE downlink or special subframes is the set of the last $\mathrm{ceil}\left(R^{\mathrm{CSI}} / N_{\mathrm{NB,hop}}^{\mathrm{ch,DL}}\right)$ subframes before $n\text{-}n_{CQI\_ref}$ used for MPDCCH monitoring by the BL/CE UE in each of the narrowbands where the BL/CE UE monitors MPDCCH, where $N_{\mathrm{NB,hop}}^{\mathrm{ch,DL}}$ is the number of narrowbands where the BL/CE UE monitors MPDCCH.
  - where for subband CSI reports:
    - The set of BL/CE downlink or special subframes is the set of the last R^{CSI} subframes used for MPDCCH monitoring by the BL/CE UE in the corresponding narrowband before $n\text{-}n_{CQI\_ref}$;
  - where R^{CSI} is given by the higher layer parameter *csi-NumRepetitionCE*.

A subframe in a serving cell shall be considered to be a valid downlink or a valid special subframe if:

- it is configured as a downlink subframe or a special subframe for that UE, and
- in case multiple cells with different uplink-downlink configurations are aggregated and the UE is not capable of simultaneous reception and transmission in the aggregated cells, the subframe in the primary cell is a downlink subframe or a special subframe with the length of DwPTS more than $7680 \cdot T_{\mathrm{s}}$, and
- except for a non-BL/CE UE in transmission mode 9 or 10, it is not an MBSFN subframe, and
- it does not contain a DwPTS field in case the length of DwPTS is $7680 \cdot T_{\mathrm{s}}$ and less, and
- it does not fall within a configured measurement gap for that UE, and
- for periodic CSI reporting, it is an element of the CSI subframe set linked to the periodic CSI report when that UE is configured with CSI subframe sets, and
- for a UE configured in transmission mode 10 with multiple configured CSI processes, and aperiodic CSI reporting for a CSI process, it is an element of the CSI subframe set linked to the downlink or special subframe with the corresponding CSI request in an uplink DCI format, when that UE is configured with CSI subframe sets for the CSI process and UE is not configured with the higher layer parameter *csi-SubframePatternConfig-r12*, and
- for a UE configured in transmission mode 1-9, and aperiodic CSI reporting, it is an element of the CSI subframe set associated with the corresponding CSI request in an uplink DCI format, when that UE is configured with CSI subframe sets by the higher layer parameter *csi-SubframePatternConfig-r12*, and
- for a UE configured in transmission mode 10, and aperiodic CSI reporting for a CSI process, it is an element of the CSI subframe set associated with the corresponding CSI request in an uplink DCI format, when that UE is configured with CSI subframe sets by the higher layer parameter *csi-SubframePatternConfig-r12* for the CSI process.

- except if the serving cell is a LAA Scell, and at least one OFDM symbol in the subframe is not occupied.
- except if the serving cell is a LAA Scell, and $n'_{\mathrm{s}} \neq n_{\mathrm{s}}$ as described in sub clause 6.10.1.1 in [3].
- except if the serving cell is a LAA Scell, and for a UE configured in transmission mode 9 or 10, the configured CSI-RS resource associated with the CSI process is not in the subframe.

For a non-BL/CE UE, if there is no valid downlink or no valid special subframe for the CSI reference resource in a serving cell, CSI reporting is omitted for the serving cell in uplink subframe *n*.

- In the layer domain, the CSI reference resource is defined by any RI and PMI on which the CQI is conditioned.

In the CSI reference resource, the UE shall assume the following for the purpose of deriving the CQI index, and if also configured, PMI and RI:

- The first 3 OFDM symbols are occupied by control signalling
- No resource elements used by primary or secondary synchronization signals or PBCH or EPDCCH
- CP length of the non-MBSFN subframes
- Redundancy Version 0
- If CSI-RS is used for channel measurements, the ratio of PDSCH EPRE to CSI-RS EPRE is as given in subclause 7.2.5
- For transmission mode 9 CSI reporting of a non-BL/CE UE:
  - CRS REs are as in non-MBSFN subframes;
  - If the UE is configured for PMI/RI reporting or without PMI reporting, the UE-specific reference signal overhead is consistent with the most recent reported rank if more than one CSI-RS port is configured, and is consistent with rank 1 transmission if only one CSI-RS port is configured; and PDSCH signals on antenna ports $\{7\ldots 6+\upsilon\}$ for υ layers would result in signals equivalent to corresponding symbols transmitted on antenna ports $\{15\ldots 14+P\}$, as given by $\begin{bmatrix} y^{(15)}(i) \\ \vdots \\ y^{(14+P)}(i) \end{bmatrix} = W(i)\begin{bmatrix} x^{(0)}(i) \\ \vdots \\ x^{(\upsilon-1)}(i) \end{bmatrix}$, where $x(i) = \begin{bmatrix} x^{(0)}(i) & \ldots & x^{(\upsilon-1)}(i) \end{bmatrix}^T$ is a vector of symbols from the layer mapping in subclause 6.3.3.2 of [3], $P \in \{1,2,4,8,12,16\}$ is the number of CSI-RS ports configured, and if only one CSI-RS port is configured, $W(i)$ is 1, otherwise for UE configured for PMI/RI reporting $W(i)$ is the precoding matrix corresponding to the reported PMI applicable to $x(i)$ and for UE configured without PMI reporting $W(i)$ is the selected precoding matrix corresponding to the reported CQI applicable to $x(i)$. The corresponding PDSCH signals transmitted on antenna ports $\{15\ldots 14+P\}$ would have a ratio of EPRE to CSI-RS EPRE equal to the ratio given in subclause 7.2.5.
- For transmission mode 10 CSI reporting, if a CSI process is configured without PMI/RI reporting:
  - If the number of antenna ports of the associated CSI-RS resource is one, a PDSCH transmission is on single-antenna port, port 7. The channel on antenna port {7} is inferred from the channel on antenna port {15} of the associated CSI-RS resource.
    - CRS REs are as in non-MBSFN subframes. The CRS overhead is assumed to be the same as the CRS overhead corresponding to the number of CRS antenna ports of the serving cell;
    - The UE-specific reference signal overhead is 12 REs per PRB pair.
  - Otherwise,
    - If the number of antenna ports of the associated CSI-RS resource is 2, the PDSCH transmission scheme assumes the transmit diversity scheme defined in subclause 7.1.2 on antenna ports {0,1} except that the

channels on antenna ports {0,1} are inferred from the channels on antenna port {15, 16} of the associated CSI resource respectively.

- If the number of antenna ports of the associated CSI-RS resource is 4, the PDSCH transmission scheme assumes the transmit diversity scheme defined in subclause 7.1.2 on antenna ports {0,1,2,3} except that the channels on antenna ports {0,1,2,3} are inferred from the channels on antenna ports {15, 16, 17, 18} of the associated CSI-RS resource respectively.

- The UE is not expected to be configured with more than 4 antenna ports for the CSI-RS resource associated with the CSI process configured without PMI/RI reporting.

- The overhead of CRS REs is assuming the same number of antenna ports as that of the associated CSI-RS resource.

- UE-specific reference signal overhead is zero.

- For transmission mode 10 CSI reporting, if a CSI process is configured with PMI/RI reporting or without PMI reporting:

  - CRS REs are as in non-MBSFN subframes. The CRS overhead is assumed to be the same as the CRS overhead corresponding to the number of CRS antenna ports of the serving cell;

  - The UE-specific reference signal overhead is consistent with the most recent reported rank for the CSI process if more than one CSI-RS port is configured, and is consistent with rank 1 transmission if only one CSI-RS port is configured; and PDSCH signals on antenna ports $\{7\ldots 6+\upsilon\}$ for υ layers would result in signals equivalent to corresponding symbols transmitted on antenna ports $\{15\ldots 14+P\}$, as given by $\begin{bmatrix} y^{(15)}(i) \\ \vdots \\ y^{(14+P)}(i) \end{bmatrix} = W(i)\begin{bmatrix} x^{(0)}(i) \\ \vdots \\ x^{(\upsilon-1)}(i) \end{bmatrix}$, where $x(i)=\begin{bmatrix} x^{(0)}(i) & \ldots & x^{(\upsilon-1)}(i) \end{bmatrix}^T$ is a vector of symbols from the layer mapping in subclause 6.3.3.2 of [3], $P \in \{1,2,4,8,12,16\}$ is the number of antenna ports of the associated CSI-RS resource, and if P=1, $W(i)$ is 1, otherwise for UE configured for PMI/RI reporting $W(i)$ is the precoding matrix corresponding to the reported PMI applicable to $x(i)$ and for UE configured without PMI reporting $W(i)$ is the selected precoding matrix corresponding to the reported CQI applicable to $x(i)$. The corresponding PDSCH signals transmitted on antenna ports $\{15\ldots 14+P\}$ would have a ratio of EPRE to CSI-RS EPRE equal to the ratio given in subclause 7.2.5

- Assume no REs allocated for CSI-RS and zero-power CSI-RS

- Assume no REs allocated for PRS

  - The PDSCH transmission scheme given by Table 7.2.3-0 depending on the transmission mode currently configured for the UE (which may be the default mode).

  - If CRS is used for channel measurements, the ratio of PDSCH EPRE to cell-specific RS EPRE is as given in subclause 5.2 with the exception of ρ_A which shall be assumed to be

    - $\rho_A = P_A + \Delta_{offset} + 10\log_{10}(2)$ [dB] for any modulation scheme, if the UE is configured with transmission mode 2 with 4 cell-specific antenna ports, or transmission mode 3 with 4 cell-specific antenna ports and the associated RI is equal to one;

    - $\rho_A = P_A + \Delta_{offset}$ [dB] for any modulation scheme and any number of layers, otherwise.

The shift Δ_{offset} is given by the parameter *nomPDSCH-RS-EPRE-Offset* which is configured by higher-layer signalling.

Table 7.2.3-0: PDSCH transmission scheme assumed for CSI reference resource

Transmission mode	Transmission scheme of PDSCH
1	Single-antenna port, port 0
2	Transmit diversity
3	Transmit diversity if the associated rank indicator is 1, otherwise large delay CDD
4	Closed-loop spatial multiplexing
5	Multi-user MIMO
6	Closed-loop spatial multiplexing with a single transmission layer
7	If the number of PBCH antenna ports is one, Single-antenna port, port 0; otherwise Transmit diversity
8	If the UE is configured without PMI/RI reporting: if the number of PBCH antenna ports is one, single-antenna port, port 0; otherwise transmit diversity If the UE is configured with PMI/RI reporting: closed-loop spatial multiplexing
9	For a non-BL/CE UE, if the UE is configured without PMI/RI reporting: if the number of PBCH antenna ports is one, single-antenna port, port 0; otherwise transmit diversity For a non-BL/CE UE, if the UE is configured with PMI/RI reporting or without PMI reporting: if the number of CSI-RS ports is one, single-antenna port, port 7; otherwise up to 8 layer transmission, ports 7-14 (see subclause 7.1.5B) For a BL/CE UE, if the UE is not configured with periodic CSI reporting mode 1-1: if the number of PBCH antenna ports is one, single-antenna port, port 0; otherwise transmit diversity For a BL/CE UE, if the UE is configured with periodic CSI reporting mode 1-1: if the number of PBCH antenna ports is one, single-antenna port, port 0; otherwise closed-loop spatial multiplexing with a single transmission layer
10	If a CSI process of the UE is configured without PMI/RI reporting: if the number of CSI-RS ports is one, single-antenna port, port7; otherwise transmit diversity If a CSI process of the UE is configured with PMI/RI reporting or without PMI reporting: if the number of CSI-RS ports is one, single-antenna port, port 7; otherwise up to 8 layer transmission, ports 7-14 (see subclause 7.1.5B)

Table 7.2.3-1: 4-bit CQI Table

CQI index	modulation	code rate x 1024	efficiency
0	out of range		
1	QPSK	78	0.1523
2	QPSK	120	0.2344
3	QPSK	193	0.3770
4	QPSK	308	0.6016
5	QPSK	449	0.8770
6	QPSK	602	1.1758
7	16QAM	378	1.4766
8	16QAM	490	1.9141
9	16QAM	616	2.4063
10	64QAM	466	2.7305
11	64QAM	567	3.3223
12	64QAM	666	3.9023
13	64QAM	772	4.5234
14	64QAM	873	5.1152
15	64QAM	948	5.5547

Table 7.2.3-2: 4-bit CQI Table 2

CQI index	modulation	code rate x 1024	efficiency
0	out of range		
1	QPSK	78	0.1523
2	QPSK	193	0.3770
3	QPSK	449	0.8770
4	16QAM	378	1.4766
5	16QAM	490	1.9141
6	16QAM	616	2.4063
7	64QAM	466	2.7305
8	64QAM	567	3.3223
9	64QAM	666	3.9023
10	64QAM	772	4.5234
11	64QAM	873	5.1152
12	256QAM	711	5.5547
13	256QAM	797	6.2266
14	256QAM	885	6.9141
15	256QAM	948	7.4063

Table 7.2.3-3: 4-bit CQI Table 3

CQI index	modulation	code rate x 1024 x R^{CSI}	efficiency x R^{CSI}
0	out of range		
1	QPSK	40	0.0781
2	QPSK	78	0.1523
3	QPSK	120	0.2344
4	QPSK	193	0.3770
5	QPSK	308	0.6016
6	QPSK	449	0.8770
7	QPSK	602	1.1758
8	16QAM	378	1.4766
9	16QAM	490	1.9141
10	16QAM	616	2.4063
11	Reserved	Reserved	Reserved
12	Reserved	Reserved	Reserved
13	Reserved	Reserved	Reserved
14	Reserved	Reserved	Reserved
15	Reserved	Reserved	Reserved

7.2.4 Precoding Matrix Indicator (PMI) definition

For transmission modes 4, 5 and 6, precoding feedback is used for channel dependent codebook based precoding and relies on UEs reporting precoding matrix indicator (PMI). For transmission mode 8, the UE shall report PMI if configured with PMI/RI reporting. For transmission modes 9 and 10, the non-BL/CE UE shall report PMI if configured with PMI/RI reporting and the number of CSI-RS ports is larger than 1. For transmission modes 9, the BL/CE UE shall report PMI based on CRS. A UE shall report PMI based on the feedback modes described in 7.2.1 and 7.2.2. For other transmission modes, PMI reporting is not supported.

For 2 antenna ports, except with UE configured with higher layer parameter *eMIMO-Type*, and *eMIMO-Type* is set to 'CLASS B', and one CSI-RS resource configured, and higher layer parameter *alternativeCodebookEnabledCLASSB_K1=TRUE*, each PMI value corresponds to a codebook index given in Table 6.3.4.2.3-1 of [3] as follows:

- For 2 antenna ports $\{0,1\}$ or {15,16} and an associated RI value of 1, a PMI value of $n \in \{0,1,2,3\}$ corresponds to the codebook index n given in Table 6.3.4.2.3-1 of [3] with $\upsilon = 1$.
- For 2 antenna ports $\{0,1\}$ or {15,16} and an associated RI value of 2, a PMI value of $n \in \{0,1\}$ corresponds to the codebook index $n+1$ given in Table 6.3.4.2.3-1 of [3] with $\upsilon = 2$.

For 4 antenna ports $\{0,1,2,3\}$ or {15,16,17,18}, except with UE configured with higher layer parameter *eMIMO-Type*, and *eMIMO-Type* is set to 'CLASS B', and one CSI-RS resource configured, and higher layer parameter *alternativeCodebookEnabledCLASSB_K1=TRUE* configured, each PMI value corresponds to a codebook index given in Table 6.3.4.2.3-2 of [3] or a pair of codebook indices given in Table 7.2.4-0A, 7.2.4-0B, 7.2.4-0C, or 7.2.4-0D as follows:

- A PMI value of $n \in \{0,1,\cdots,15\}$ corresponds to the codebook index n given in Table 6.3.4.2.3-2 of [3] with υ equal to the associated RI value except with *alternativeCodeBookEnabledFor4TX-r12=TRUE* configured.
- If *alternativeCodeBookEnabledFor4TX-r12=TRUE* is configured, each PMI value corresponds to a pair of codebook indices given in Table 7.2.4-0A, 7.2.4-0B, 7.2.4-0C, or 7.2.4-0D, where the quantities φ_n, φ'_n and v'_m in Table 7.2.4-0A and Table 7.2.4-0B are given by

$$\varphi_n = e^{j\pi n/2}$$
$$\varphi'_n = e^{j2\pi n/32}$$
$$v'_m = \begin{bmatrix}1 & e^{j2\pi m/32}\end{bmatrix}^{\mathrm{T}}$$

  - A first PMI value of $i_1 \in \{0,1,\cdots,f(\upsilon)-1\}$ and a second PMI value of $i_2 \in \{0,1,\cdots,g(\upsilon)-1\}$ correspond to the codebook indices i_1 and i_2 respectively given in Table 7.2.4-0*j* with υ equal to the associated RI value and where *j* ={A,B,C,D} respectively when $\upsilon = \{1,2,3,4\}$, $f(\upsilon) = \{16,16,1,1\}$ and $g(\upsilon) = \{16,16,16,16\}$.
  - The quantity $W_n^{\{s\}}$ in Table 7.2.4-0C and Table 7.2.4-0D denotes the matrix defined by the columns given by the set $\{s\}$ from the expression $W_n = I - 2u_n u_n^H / u_n^H u_n$ where I is the 4×4 identity matrix and the vector u_n is given by Table 6.3.4.2.3-2 in [3] and $n = i_2$.
  - In some cases codebook subsampling is supported. The sub-sampled codebook for PUCCH mode 1-1 submode 2 is defined in Table 7.2.2-1G for first and second precoding matrix indicators i_1 and i_2. Joint encoding of rank and first precoding matrix indicator i_1 for PUCCH mode 1-1 submode 1 is defined in Table 7.2.2-1H. The sub-sampled codebook for PUCCH mode 2-1 is defined in Table 7.2.2-1I for PUCCH Reporting Type 1a.

Table 7.2.4-0A: Codebook for 1-layer CSI reporting using antenna ports 0 to 3 or 15 to 18

i_1	i_2							
	0	**1**	**2**	**3**	**4**	**5**	**6**	**7**
0 – 15	$W_{i_1,0}^{(1)}$	$W_{i_1,8}^{(1)}$	$W_{i_1,16}^{(1)}$	$W_{i_1,24}^{(1)}$	$W_{i_1+8,2}^{(1)}$	$W_{i_1+8,10}^{(1)}$	$W_{i_1+8,18}^{(1)}$	$W_{i_1+8,26}^{(1)}$
i_1	i_2							
	8	**9**	**10**	**11**	**12**	**13**	**14**	**15**

0 - 15	$W^{(1)}_{i_1+16,4}$	$W^{(1)}_{i_1+16,12}$	$W^{(1)}_{i_1+16,20}$	$W^{(1)}_{i_1+16,28}$	$W^{(1)}_{i_1+24,6}$	$W^{(1)}_{i_1+24,14}$	$W^{(1)}_{i_1+24,22}$	$W^{(1)}_{i_1+24,30}$
where $W^{(1)}_{m,n} = \frac{1}{2}\begin{bmatrix} v'_m \\ \varphi'_n v'_m \end{bmatrix}$								

Table 7.2.4-0B: Codebook for 2-layer CSI reporting using antenna ports 0 to 3 or 15 to 18

i_1	i_2			
	0	**1**	**2**	**3**
0 – 15	$W^{(2)}_{i_1,i_1,0}$	$W^{(2)}_{i_1,i_1,1}$	$W^{(2)}_{i_1+8,i_1+8,0}$	$W^{(2)}_{i_1+8,i_1+8,1}$
i_1	i_2			
	4	**5**	**6**	**7**
0 – 15	$W^{(2)}_{i_1+16,i_1+16,0}$	$W^{(2)}_{i_1+16,i_1+16,1}$	$W^{(2)}_{i_1+24,i_1+24,0}$	$W^{(2)}_{i_1+24,i_1+24,1}$
i_1	i_2			
	8	**9**	**10**	**11**
0 – 15	$W^{(2)}_{i_1,i_1+8,0}$	$W^{(2)}_{i_1,i_1+8,1}$	$W^{(2)}_{i_1+8,i_1+16,0}$	$W^{(2)}_{i_1+8,i_1+16,1}$
i_1	i_2			
	12	**13**	**14**	**15**
0 – 15	$W^{(2)}_{i_1,i_1+24,0}$	$W^{(2)}_{i_1,i_1+24,1}$	$W^{(2)}_{i_1+8,i_1+24,0}$	$W^{(2)}_{i_1+8,i_1+24,1}$
where $W^{(2)}_{m,m',n} = \frac{1}{\sqrt{8}}\begin{bmatrix} v'_m & v'_{m'} \\ \varphi_n v'_m & -\varphi_n v'_{m'} \end{bmatrix}$				

Table 7.2.4-0C: Codebook for 3-layer CSI reporting using antenna ports 15 to 18

i_1	i_2							
	0	**1**	**2**	**3**	**4**	**5**	**6**	**7**
0	$W_0^{\{124\}}/\sqrt{3}$	$W_1^{\{123\}}/\sqrt{3}$	$W_2^{\{123\}}/\sqrt{3}$	$W_3^{\{123\}}/\sqrt{3}$	$W_4^{\{124\}}/\sqrt{3}$	$W_5^{\{124\}}/\sqrt{3}$	$W_6^{\{134\}}/\sqrt{3}$	$W_7^{\{134\}}/\sqrt{3}$
i_1	i_2							
	8	**9**	**10**	**11**	**12**	**13**	**14**	**15**
0	$W_8^{\{124\}}/\sqrt{3}$	$W_9^{\{134\}}/\sqrt{3}$	$W_{10}^{\{123\}}/\sqrt{3}$	$W_{11}^{\{134\}}/\sqrt{3}$	$W_{12}^{\{123\}}/\sqrt{3}$	$W_{13}^{\{123\}}/\sqrt{3}$	$W_{14}^{\{123\}}/\sqrt{3}$	$W_{15}^{\{123\}}/\sqrt{3}$

Table 7.2.4-0D: Codebook for 4-layer CSI reporting using antenna ports 15 to 18

i_1	i_2							
	0	**1**	**2**	**3**	**4**	**5**	**6**	**7**
0	$W_0^{\{1234\}}/2$	$W_1^{\{1234\}}/2$	$W_2^{\{3214\}}/2$	$W_3^{\{3214\}}/2$	$W_4^{\{1234\}}/2$	$W_5^{\{1234\}}/2$	$W_6^{\{1324\}}/2$	$W_7^{\{1324\}}/2$
i_1	i_2							
	8	**9**	**10**	**11**	**12**	**13**	**14**	**15**
0	$W_8^{\{1234\}}/2$	$W_9^{\{1234\}}/2$	$W_{10}^{\{1324\}}/2$	$W_{11}^{\{1324\}}/2$	$W_{12}^{\{1234\}}/2$	$W_{13}^{\{1324\}}/2$	$W_{14}^{\{3214\}}/2$	$W_{15}^{\{1234\}}/2$

For a non-BL/CE UE, the UE is not expected to receive the configuration of *alternativeCodeBookEnabledFor4TX-r12* except for transmission mode 8 configured with 4 CRS ports, and transmission modes 9 and 10 configured with 4 CSI-RS ports. For a UE configured in transmission mode 10, the parameter *alternativeCodeBookEnabledFor4TX-r12* may be configured for each CSI process.
For a BL/CE UE, the UE is not expected to receive the configuration of *alternativeCodeBookEnabledFor4TX-r12*.

For 8 antenna ports, except with,

- UE is configured with higher layer parameter *eMIMO-Type*, and *eMIMO-Type* is set to 'CLASS A', or
- UE is configured with higher layer parameter *eMIMO-Type*, and *eMIMO-Type* is set to 'CLASS B', and one CSI-RS resource configured, and higher layer parameter *alternativeCodebookEnabledCLASSB_K1=TRUE* configured,

each PMI value corresponds to a pair of codebook indices given in Table 7.2.4-1, 7.2.4-2, 7.2.4-3, 7.2.4-4, 7.2.4-5, 7.2.4-6, 7.2.4-7, or 7.2.4-8, where the quantities φ_n and v_m are given by

$$\varphi_n = e^{j\pi n/2}$$
$$v_m = \begin{bmatrix} 1 & e^{j2\pi m/32} & e^{j4\pi m/32} & e^{j6\pi m/32} \end{bmatrix}^{\mathrm{T}}$$

- as follows:For 8 antenna ports $\{15,16,17,18,19,20,21,22\}$, a first PMI value of $i_1 \in \{0,1,\cdots,f(\upsilon)-1\}$ and a second PMI value of $i_2 \in \{0,1,\cdots,g(\upsilon)-1\}$ corresponds to the codebook indices i_1 and i_2 given in Table 7.2.4-*j* with υ equal to the associated RI value and where *j* = υ, $f(\upsilon)=\{16,16,4,4,4,4,4,1\}$ and $g(\upsilon)=\{16,16,16,8,1,1,1,1\}$.
- In some cases codebook subsampling is supported. The sub-sampled codebook for PUCCH mode 1-1 submode 2 is defined in Table 7.2.2-1D for first and second precoding matrix indicator i_1 and i_2. Joint encoding of rank and first precoding matrix indicator i_1 for PUCCH mode 1-1 submode 1 is defined in Table 7.2.2-1E. The sub-sampled codebook for PUCCH mode 2-1 is defined in Table 7.2.2-1F for PUCCH Reporting Type 1a.

Table 7.2.4-1: Codebook for 1-layer CSI reporting using antenna ports 15 to 22

i_1	i_2							
	0	**1**	**2**	**3**	**4**	**5**	**6**	**7**
0 – 15	$W^{(1)}_{2i_1,0}$	$W^{(1)}_{2i_1,1}$	$W^{(1)}_{2i_1,2}$	$W^{(1)}_{2i_1,3}$	$W^{(1)}_{2i_1+1,0}$	$W^{(1)}_{2i_1+1,1}$	$W^{(1)}_{2i_1+1,2}$	$W^{(1)}_{2i_1+1,3}$
i_1	i_2							
	8	**9**	**10**	**11**	**12**	**13**	**14**	**15**
0 - 15	$W^{(1)}_{2i_1+2,0}$	$W^{(1)}_{2i_1+2,1}$	$W^{(1)}_{2i_1+2,2}$	$W^{(1)}_{2i_1+2,3}$	$W^{(1)}_{2i_1+3,0}$	$W^{(1)}_{2i_1+3,1}$	$W^{(1)}_{2i_1+3,2}$	$W^{(1)}_{2i_1+3,3}$
where $W^{(1)}_{m,n} = \frac{1}{\sqrt{8}}\begin{bmatrix} v_m \\ \varphi_n v_m \end{bmatrix}$								

Table 7.2.4-2: Codebook for 2-layer CSI reporting using antenna ports 15 to 22

i_1	i_2			
	0	**1**	**2**	**3**
0 – 15	$W^{(2)}_{2i_1,2i_1,0}$	$W^{(2)}_{2i_1,2i_1,1}$	$W^{(2)}_{2i_1+1,2i_1+1,0}$	$W^{(2)}_{2i_1+1,2i_1+1,1}$
i_1	i_2			
	4	**5**	**6**	**7**
0 – 15	$W^{(2)}_{2i_1+2,2i_1+2,0}$	$W^{(2)}_{2i_1+2,2i_1+2,1}$	$W^{(2)}_{2i_1+3,2i_1+3,0}$	$W^{(2)}_{2i_1+3,2i_1+3,1}$
i_1	i_2			
	8	**9**	**10**	**11**
0 – 15	$W^{(2)}_{2i_1,2i_1+1,0}$	$W^{(2)}_{2i_1,2i_1+1,1}$	$W^{(2)}_{2i_1+1,2i_1+2,0}$	$W^{(2)}_{2i_1+1,2i_1+2,1}$
i_1	i_2			
	12	**13**	**14**	**15**
0 – 15	$W^{(2)}_{2i_1,2i_1+3,0}$	$W^{(2)}_{2i_1,2i_1+3,1}$	$W^{(2)}_{2i_1+1,2i_1+3,0}$	$W^{(2)}_{2i_1+1,2i_1+3,1}$
where $W^{(2)}_{m,m',n} = \frac{1}{4}\begin{bmatrix} v_m & v_{m'} \\ \varphi_n v_m & -\varphi_n v_{m'} \end{bmatrix}$				

Table 7.2.4-3: Codebook for 3-layer CSI reporting using antenna ports 15 to 22

i_1	i_2			
	0	**1**	**2**	**3**
0 - 3	$W^{(3)}_{8i_1,8i_1,8i_1+8}$	$W^{(3)}_{8i_1+8,8i_1,8i_1+8}$	$\tilde{W}^{(3)}_{8i_1,8i_1+8,8i_1+8}$	$\tilde{W}^{(3)}_{8i_1+8,8i_1,8i_1}$
i_1	i_2			
	4	**5**	**6**	**7**
0 - 3	$W^{(3)}_{8i_1+2,8i_1+2,8i_1+10}$	$W^{(3)}_{8i_1+10,8i_1+2,8i_1+10}$	$\tilde{W}^{(3)}_{8i_1+2,8i_1+10,8i_1+10}$	$\tilde{W}^{(3)}_{8i_1+10,8i_1+2,8i_1+2}$
i_1	i_2			
	8	**9**	**10**	**11**
0 - 3	$W^{(3)}_{8i_1+4,8i_1+4,8i_1+12}$	$W^{(3)}_{8i_1+12,8i_1+4,8i_1+12}$	$\tilde{W}^{(3)}_{8i_1+4,8i_1+12,8i_1+12}$	$\tilde{W}^{(3)}_{8i_1+12,8i_1+4,8i_1+4}$
i_1	i_2			
	12	**13**	**14**	**15**
0 - 3	$W^{(3)}_{8i_1+6,8i_1+6,8i_1+14}$	$W^{(3)}_{8i_1+14,8i_1+6,8i_1+14}$	$\tilde{W}^{(3)}_{8i_1+6,8i_1+14,8i_1+14}$	$\tilde{W}^{(3)}_{8i_1+14,8i_1+6,8i_1+6}$
where $W^{(3)}_{m,m',m''} = \frac{1}{\sqrt{24}}\begin{bmatrix} v_m & v_{m'} & v_{m''} \\ v_m & -v_{m'} & -v_{m''} \end{bmatrix}$, $\tilde{W}^{(3)}_{m,m',m''} = \frac{1}{\sqrt{24}}\begin{bmatrix} v_m & v_{m'} & v_{m''} \\ v_m & v_{m'} & -v_{m''} \end{bmatrix}$				

Table 7.2.4-4: Codebook for 4-layer CSI reporting using antenna ports 15 to 22

i_1	i_2			
	0	**1**	**2**	**3**
0 - 3	$W^{(4)}_{8i_1,8i_1+8,0}$	$W^{(4)}_{8i_1,8i_1+8,1}$	$W^{(4)}_{8i_1+2,8i_1+10,0}$	$W^{(4)}_{8i_1+2,8i_1+10,1}$
i_1	i_2			
	4	**5**	**6**	**7**
0 - 3	$W^{(4)}_{8i_1+4,8i_1+12,0}$	$W^{(4)}_{8i_1+4,8i_1+12,1}$	$W^{(4)}_{8i_1+6,8i_1+14,0}$	$W^{(4)}_{8i_1+6,8i_1+14,1}$
where $W^{(4)}_{m,m',n} = \frac{1}{\sqrt{32}}\begin{bmatrix} v_m & v_{m'} & v_m & v_{m'} \\ \varphi_n v_m & \varphi_n v_{m'} & -\varphi_n v_m & -\varphi_n v_{m'} \end{bmatrix}$				

Table 7.2.4-5: Codebook for 5-layer CSI reporting using antenna ports 15 to 22.

i_1	i_2
	0
0 - 3	$W_{i_1}^{(5)} = \frac{1}{\sqrt{40}}\begin{bmatrix} v_{2i_1} & v_{2i_1} & v_{2i_1+8} & v_{2i_1+8} & v_{2i_1+16} \\ v_{2i_1} & -v_{2i_1} & v_{2i_1+8} & -v_{2i_1+8} & v_{2i_1+16} \end{bmatrix}$

Table 7.2.4-6: Codebook for 6-layer CSI reporting using antenna ports 15 to 22.

i_1	i_2
	0
0 - 3	$W_{i_1}^{(6)} = \frac{1}{\sqrt{48}}\begin{bmatrix} v_{2i_1} & v_{2i_1} & v_{2i_1+8} & v_{2i_1+8} & v_{2i_1+16} & v_{2i_1+16} \\ v_{2i_1} & -v_{2i_1} & v_{2i_1+8} & -v_{2i_1+8} & v_{2i_1+16} & -v_{2i_1+16} \end{bmatrix}$

Table 7.2.4-7: Codebook for 7-layer CSI reporting using antenna ports 15 to 22.

i_1	i_2
	0
0 - 3	$W_{i_1}^{(7)} = \frac{1}{\sqrt{56}}\begin{bmatrix} v_{2i_1} & v_{2i_1} & v_{2i_1+8} & v_{2i_1+8} & v_{2i_1+16} & v_{2i_1+16} & v_{2i_1+24} \\ v_{2i_1} & -v_{2i_1} & v_{2i_1+8} & -v_{2i_1+8} & v_{2i_1+16} & -v_{2i_1+16} & v_{2i_1+24} \end{bmatrix}$

Table 7.2.4-8: Codebook for 8-layer CSI reporting using antenna ports 15 to 22.

i_1	i_2
	0
0	$W_{i_1}^{(8)} = \frac{1}{8}\begin{bmatrix} v_{2i_1} & v_{2i_1} & v_{2i_1+8} & v_{2i_1+8} & v_{2i_1+16} & v_{2i_1+16} & v_{2i_1+24} & v_{2i_1+24} \\ v_{2i_1} & -v_{2i_1} & v_{2i_1+8} & -v_{2i_1+8} & v_{2i_1+16} & -v_{2i_1+16} & v_{2i_1+24} & -v_{2i_1+24} \end{bmatrix}$

For 8 antenna ports $\{15,16,17,18,19,20,21,22\}$, 12 antenna ports $\{15,16,17,18,19,20,21,22,23,24,25,26\}$, 16 antenna ports $\{15,16,17,18,19,20,21,22,23,24,25,26,27,28,29,30\}$, and UE configured with higher layer parameter *eMIMO-Type*, and *eMIMO-Type* is set to 'CLASS A', each PMI value corresponds to three codebook indices given in Table 7.2.4-10, 7.2.4-11, 7.2.4-12, 7.2.4-13, 7.2.4-14, 7.2.4-15, 7.2.4-16, or 7.2.4-17, where the quantities φ_n, u_m and $v_{l,m}$ are given by

$$\varphi_n = e^{j\pi n/2}$$

$$u_m = \begin{bmatrix} 1 & e^{j\frac{2\pi m}{O_2 N_2}} & \dots & e^{j\frac{2\pi m(N_2-1)}{O_2 N_2}} \end{bmatrix}$$

$$v_{l,m} = \begin{bmatrix} u_m & e^{j\frac{2\pi l}{O_1 N_1}} u_m & \dots & e^{j\frac{2\pi l(N_1-1)}{O_1 N_1}} u_m \end{bmatrix}^T$$

- The values of N_1, N_2, O_1, and O_2 are configured with the higher-layer parameter *codebookConfigig-N1*, *codebookConfig-N2*, *codebook-Over-Sampling-RateConfig-O1*, and *codebook-Over-Sampling-RateConfig-O2*, respectively. The supported configurations of (O_1, O_2) and (N_1, N_2) for a given number of CSI-RS ports are given in Table 7.2.4-17. The number of CSI-RS ports, *P*, is $2N_1N_2$.

- UE is not expected to be configured with value of CodebookConfig set to 2 or 3, if the value of codebookConfigN2 is set to 1.
- UE shall only use $i_{1,2} = 0$ and shall not report $i_{1,2}$ if the value of codebookConfigN2 is set to 1.
- A first PMI value i_1 corresponds to the codebook indices pair $\{i_{1,1}, i_{1,2}\}$, and a second PMI value i_2 corresponds to the codebook index i_2 given in Table 7.2.4-*j* with υ equal to the associated RI value and where *j* = $\upsilon + 9$.
- In some cases codebook subsampling is supported. The sub-sampled codebook for PUCCH mode 2-1 for value of parameter *codebookConfig* set to 2, 3, or 4 is defined in Table 7.2.2-1F for PUCCH Reporting Type 1a.

Table 7.2.4-9: Supported configurations of (O_1, O_2) and (N_1, N_2)

Number of CSI-RS antenna ports, *P*	(N_1, N_2)	(O_1, O_2)
8	**(2,2)**	**(4,4), (8,8)**
12	**(2,3)**	**(8,4), (8,8)**
	(3,2)	**(8,4), (4,4)**
16	**(2,4)**	**(8,4), (8,8)**
	(4,2)	**(8,4), (4,4)**
	(8,1)	**(4,-), (8,-)**

Table 7.2.4-10: Codebook for 1-layer CSI reporting using antenna ports 15 to 14+*P*

Value of *Codebook-Config*	$i_{1,1}$	$i_{1,2}$	i_2			
			0	**1**	**2**	**3**
1	$0,1,\cdots,O_1N_1-1$	$0,1,\cdots,O_2N_2-1$	$W^{(1)}_{i_{1,1},i_{1,2},0}$	$W^{(1)}_{i_{1,1},i_{1,2},1}$	$W^{(1)}_{i_{1,1},i_{1,2},2}$	$W^{(1)}_{i_{1,1},i_{1,2},3}$
where $W^{(1)}_{l,m,n}=\frac{1}{\sqrt{P}}\begin{bmatrix}v_{l,m}\\ \varphi_n v_{l,m}\end{bmatrix}$						

Value of *Codebook-Config*	$i_{1,1}$	$i_{1,2}$	i_2			
			0	**1**	**2**	**3**
2	$0,1,...,\frac{N_1O_1}{2}-1$	$0,1,...,\frac{N_2O_2}{2}-1$	$W^{(1)}_{2i_{1,1},2i_{1,2},0}$	$W^{(1)}_{2i_{1,1},2i_{1,2},1}$	$W^{(1)}_{2i_{1,1},2i_{1,2},2}$	$W^{(1)}_{2i_{1,1},2i_{1,2},3}$
Value of *Codebook-Config*	$i_{1,1}$	$i_{1,2}$	i_2			
			4	**5**	**6**	**7**
2	$0,1,...,\frac{N_1O_1}{2}-1$	$0,1,...,\frac{N_2O_2}{2}-1$	$W^{(1)}_{2i_{1,1}+1,2i_{1,2},0}$	$W^{(1)}_{2i_{1,1}+1,2i_{1,2},1}$	$W^{(1)}_{2i_{1,1}+1,2i_{1,2},2}$	$W^{(1)}_{2i_{1,1}+1,2i_{1,2},3}$
Value of *Codebook-Config*	$i_{1,1}$	$i_{1,2}$	i_2			
			8	**9**	**10**	**11**
2	$0,1,...,\frac{N_1O_1}{2}-1$	$0,1,...,\frac{N_2O_2}{2}-1$	$W^{(1)}_{2i_{1,1},2i_{1,2}+1,0}$	$W^{(1)}_{2i_{1,1},2i_{1,2}+1,1}$	$W^{(1)}_{2i_{1,1},2i_{1,2}+1,2}$	$W^{(1)}_{2i_{1,1},2i_{1,2}+1,3}$
Value of Codebook-Config	$i_{1,1}$	$i_{1,2}$	i_2			
			12	**13**	**14**	**15**
2	$0,1,...,\frac{N_1O_1}{2}-1$	$0,1,...,\frac{N_2O_2}{2}-1$	$W^{(1)}_{2i_{1,1}+1,2i_{1,2}+1,0}$	$W^{(1)}_{2i_{1,1}+1,2i_{1,2}+1,1}$	$W^{(1)}_{2i_{1,1}+1,2i_{1,2}+1,2}$	$W^{(1)}_{2i_{1,1}+1,2i_{1,2}+1,3}$
where $W^{(1)}_{l,m,n}=\frac{1}{\sqrt{P}}\begin{bmatrix}v_{l,m}\\ \varphi_n v_{l,m}\end{bmatrix}$						

Value of *Codebook-Config*	$i_{1,1}$	$i_{1,2}$	i_2			
			0	**1**	**2**	**3**
3	$0,1,...,\frac{N_1O_1}{2}-1$	$0,1,...,\frac{N_2O_2}{2}-1$	$W^{(1)}_{2x,2y,0}$	$W^{(1)}_{2x,2y,1}$	$W^{(1)}_{2x,2y,2}$	$W^{(1)}_{2x,2y,3}$
Value of *Codebook-Config*	$i_{1,1}$	$i_{1,2}$	i_2			
			4	**5**	**6**	**7**
3	$0,1,...,\frac{N_1O_1}{2}-1$	$0,1,...,\frac{N_2O_2}{2}-1$	$W^{(1)}_{2x+2,2y,0}$	$W^{(1)}_{2x+2,2y,1}$	$W^{(1)}_{2x+2,2y,2}$	$W^{(1)}_{2x+2,2y,3}$
Value of *Codebook-Config*	$i_{1,1}$	$i_{1,2}$	i_2			
			8	**9**	**10**	**11**
3	$0,1,...,\frac{N_1O_1}{2}-1$	$0,1,...,\frac{N_2O_2}{2}-1$	$W^{(1)}_{2x+1,2y+1,0}$	$W^{(1)}_{2x+1,2y+1,1}$	$W^{(1)}_{2x+1,2y+1,2}$	$W^{(1)}_{2x+1,2y+1,3}$
Value of *Codebook-Config*	$i_{1,1}$	$i_{1,2}$	i_2			
			12	**13**	**14**	**15**
3	$0,1,...,\frac{N_1O_1}{2}-1$	$0,1,...,\frac{N_2O_2}{2}-1$	$W^{(1)}_{2x+3,2y+1,0}$	$W^{(1)}_{2x+3,2y+1,1}$	$W^{(1)}_{2x+3,2y+1,2}$	$W^{(1)}_{2x+3,2y+1,3}$
where $x=i_{1,1},\quad y=i_{1,2},\quad W^{(1)}_{l,m,n}=\frac{1}{\sqrt{P}}\begin{bmatrix}v_{l,m}\\ \varphi_n v_{l,m}\end{bmatrix}$, if $N_1\geq N_2$ $x=i_{1,2},\quad y=i_{1,1},\quad W^{(1)}_{l,m,n}=\frac{1}{\sqrt{P}}\begin{bmatrix}v_{m,l}\\ \varphi_n v_{m,l}\end{bmatrix}$, if $N_1 < N_2$						

Value of *Codebook-Config*	$i_{1,1}$	$i_{1,2}$	i_2			
			0	**1**	**2**	**3**
4	$0,1,...,\frac{N_1O_1}{2}-1$	$0,1,...,\frac{N_2O_2}{2}-1$	$W^{(1)}_{2x,2y,0}$	$W^{(1)}_{2x,2y,1}$	$W^{(1)}_{2x,2y,2}$	$W^{(1)}_{2x,2y,3}$
Value of *Codebook-Config*	$i_{1,1}$	$i_{1,2}$	i_2			
			4	**5**	**6**	**7**
4	$0,1,...,\frac{N_1O_1}{2}-1$	$0,1,...,\frac{N_2O_2}{2}-1$	$W^{(1)}_{2x+1,2y,0}$	$W^{(1)}_{2x+1,2y,1}$	$W^{(1)}_{2x+1,2y,2}$	$W^{(1)}_{2x+1,2y,3}$
Value of *Codebook-Config*	$i_{1,1}$	$i_{1,2}$	i_2			
			8	**9**	**10**	**11**
4	$0,1,...,\frac{N_1O_1}{2}-1$	$0,1,...,\frac{N_2O_2}{2}-1$	$W^{(1)}_{2x+2,2y,0}$	$W^{(1)}_{2x+2,2y,1}$	$W^{(1)}_{2x+2,2y,2}$	$W^{(1)}_{2x+2,2y,3}$
Value of Codebook-Config	$i_{1,1}$	$i_{1,2}$	i_2			
			12	**13**	**14**	**15**
4	$0,1,...,\frac{N_1O_1}{2}-1$	$0,1,...,\frac{N_2O_2}{2}-1$	$W^{(1)}_{2x+3,2y,0}$	$W^{(1)}_{2x+3,2y,1}$	$W^{(1)}_{2x+3,2y,2}$	$W^{(1)}_{2x+3,2y,3}$
where $x=i_{1,1},\quad y=i_{1,2},\quad W^{(1)}_{l,m,n}=\frac{1}{\sqrt{P}}\begin{bmatrix} v_{l,m} \\ \varphi_n v_{l,m}\end{bmatrix}$, if $N_1 \geq N_2$ $x=i_{1,2},\quad y=i_{1,1},\quad W^{(1)}_{l,m,n}=\frac{1}{\sqrt{P}}\begin{bmatrix} v_{m,l} \\ \varphi_n v_{m,l}\end{bmatrix}$, if $N_1 < N_2$						

Table 7.2.4-11: Codebook for 2-layer CSI reporting using antenna ports 15 to 14+*P*

***2 Layers, Codebook-Config* = 1**				
$i_{1,2}=0,\cdots,N_2O_2-1$				
$i_{1,1}$	i_2			
	0	**1**	**2**	**3**
$0,\cdots,N_1O_1-1$	$W^{(2)}_{i_{1,1},i_{1,1},i_{1,2},i_{1,2},0}$	$W^{(2)}_{i_{1,1},i_{1,1},i_{1,2},i_{1,2},1}$	$W^{(2)}_{i_{1,1},i_{1,1},i_{1,2},i_{1,2},2}$	$W^{(2)}_{i_{1,1},i_{1,1},i_{1,2},i_{1,2},3}$
where $W^{(2)}_{l,l',m,m',n}=\frac{1}{\sqrt{2P}}\begin{bmatrix} v_{l,m} & v_{l',m'} \\ \varphi_n v_{l,m} & -\varphi_n v_{l',m'}\end{bmatrix}$.				

***2 Layers, Codebook-Config* = 2**				
If $N_1 > N_2, p=1$ otherwise $p=O_1$				
$i_{1,2}=0,\cdots,N_2O_2/2-1$				
$i_{1,1}$	i_2			
	0	**1**	**2**	**3**
$0,\cdots,\frac{N_1O_1}{2}-1$	$W^{(2)}_{2i_{1,1},2i_{1,1},2i_{1,2},2i_{1,2},0}$	$W^{(2)}_{2i_{1,1},2i_{1,1},2i_{1,2},2i_{1,2},1}$	$W^{(2)}_{2i_{1,1}+p,2i_{1,1}+p,2i_{1,2},2i_{1,2},0}$	$W^{(2)}_{2i_{1,1}+p,2i_{1,1}+p,2i_{1,2},2i_{1,2},1}$
$i_{1,1}$	i_2			
	4	5	6	7
$0,\cdots,\frac{N_1O_1}{2}-1$	$W^{(2)}_{2i_{1,1}+p,2i_{1,1}+p,2i_{1,2}+1,2i_{1,2}+1,0}$	$W^{(2)}_{2i_{1,1}+p,2i_{1,1}+p,2i_{1,2}+1,2i_{1,2}+1,1}$	$W^{(2)}_{2i_{1,1},2i_{1,1},2i_{1,2}+1,2i_{1,2}+1,0}$	$W^{(2)}_{2i_{1,1},2i_{1,1},2i_{1,2}+1,2i_{1,2}+1,1}$
$i_{1,1}$	i_2			
	8	9	10	11

$0,\cdots,\frac{N_1O_1}{2}-1$	$W^{(2)}_{2i_{1,1},2i_{1,1}+p,2i_{1,2},2i_{1,2},0}$	$W^{(2)}_{2i_{1,1},2i_{1,1}+p,2i_{1,2},2i_{1,2},1}$	$W^{(2)}_{2i_{1,1},2i_{1,1}+p,2i_{1,2}+1,2i_{1,2}+1,0}$	$W^{(2)}_{2i_{1,1},2i_{1,1}+p,2i_{1,2}+1,2i_{1,2}+1,1}$
$i_{1,1}$	i_2			
	12	13	14	15
$0,\cdots,\frac{N_1O_1}{2}-1$	$W^{(2)}_{2i_{1,1},2i_{1,1},2i_{1,2},2i_{1,2}+1,0}$	$W^{(2)}_{2i_{1,1},2i_{1,1},2i_{1,2},2i_{1,2}+1,1}$	$W^{(2)}_{2i_{1,1}+p,2i_{1,1}+p,2i_{1,2},2i_{1,2}+1,0}$	$W^{(2)}_{2i_{1,1}+p,2i_{1,1}+p,2i_{1,2},2i_{1,2}+1,1}$.
where $W^{(2)}_{l,l',m,m',n}=\frac{1}{\sqrt{2P}}\begin{bmatrix} v_{l,m} & v_{l',m'} \\ \varphi_n v_{l,m} & -\varphi_n v_{l',m'} \end{bmatrix}$.				

***2 Layers, Codebook-Config* = 3**				
$i_{1,2}=0,\cdots,N_2O_2/2-1$				
$i_{1,1}$	i_2			
	0	1	2	3
$0,\cdots,\frac{N_1O_1}{2}-1$	$W^{(2)}_{2x,2x,2y,2y,0}$	$W^{(2)}_{2x,2x,2y,2y,1}$	$W^{(2)}_{2x+1,2x+1,2y+1,2y+1,0}$	$W^{(2)}_{2x+1,2x+1,2y+1,2y+1,1}$
$i_{1,1}$	i_2			
	4	5	6	7
$0,\cdots,\frac{N_1O_1}{2}-1$	$W^{(2)}_{2x+2,2x+2,2y,2y,0}$	$W^{(2)}_{2x+2,2x+2,2y,2y,1}$	$W^{(2)}_{2x+3,2x+3,2y+1,2y+1,0}$	$W^{(2)}_{2x+3,2x+3,2y+1,2y+1,1}$
$i_{1,1}$	i_2			
	8	9	10	11
$0,\cdots,\frac{N_1O_1}{2}-1$	$W^{(2)}_{2x,2x+1,2y,2y+1,0}$	$W^{(2)}_{2x,2x+1,2y,2y+1,1}$	$W^{(2)}_{2x+1,2x+2,2y+1,2y,0}$	$W^{(2)}_{2x+1,2x+2,2y+1,2y,1}$
$i_{1,1}$	i_2			
	12	13	14	15
$0,\cdots,\frac{N_1O_1}{2}-1$	$W^{(2)}_{2x,2x+3,2y,2y+1,0}$	$W^{(2)}_{2x,2x+3,2y,2y+1,1}$	$W^{(2)}_{2x+1,2x+3,2y+1,2y+1,0}$	$W^{(2)}_{2x+1,2x+3,2y+1,2y+1,1}$
where $x=i_{1,1},\quad y=i_{1,2},\quad W^{(2)}_{l,l',m,m',n}=\frac{1}{\sqrt{2P}}\begin{bmatrix} v_{l,m} & v_{l',m'} \\ \varphi_n v_{l,m} & -\varphi_n v_{l',m'} \end{bmatrix}$ if $N_1 \geq N_2$ and $x=i_{1,2},\quad y=i_{1,1},\quad W^{(2)}_{l,l',m,m',n}=\frac{1}{\sqrt{2P}}\begin{bmatrix} v_{m,l} & v_{m',l'} \\ \varphi_n v_{m,l} & -\varphi_n v_{m',l'} \end{bmatrix}$, if $N_1 < N_2$				

***2 Layers, Codebook-Config* = 4**				
$i_{1,2}=0,\cdots,N_2O_2/2-1$				
$i_{1,1}$	i_2			
	0	**1**	**2**	**3**
$0,\cdots,\frac{N_1O_1}{2}-1$	$W^{(2)}_{2x,2x,2y,2y,0}$	$W^{(2)}_{2x,2x,2y,2y,1}$	$W^{(2)}_{2x+1,2x+1,2y,2y,0}$	$W^{(2)}_{2x+1,2x+1,2y,2y,1}$
$i_{1,1}$	i_2			
	4	**5**	**6**	**7**

$0,\cdots,\frac{N_1O_1}{2}-1$	$W^{(2)}_{2x+2,2x+2,2y,2y,0}$	$W^{(2)}_{2x+2,2x+2,2y,2y,1}$	$W^{(2)}_{2x+3,2x+3,2y,2y,0}$	$W^{(2)}_{2x+3,2x+3,2y,2y,1}$
$i_{1,1}$	i_2			
	8	**9**	**10**	**11**
$0,\cdots,\frac{N_1O_1}{2}-1$	$W^{(2)}_{2x,2x+1,2y,2y,0}$	$W^{(2)}_{2x,2x+1,2y,2y,1}$	$W^{(2)}_{2x+1,2x+2,2y,2y,0}$	$W^{(2)}_{2x+1,2x+2,2y,2y,1}$
$i_{1,1}$	i_2			
	12	**13**	**14**	**15**
$0,\cdots,\frac{N_1O_1}{2}-1$	$W^{(2)}_{2x,2x+3,2y,2y,0}$	$W^{(2)}_{2x,2x+3,2y,2y,1}$	$W^{(2)}_{2x+1,2x+3,2y,2y,0}$	$W^{(2)}_{2x+1,2x+3,2y,2y,1}$
where $x=i_{1,1},\quad y=i_{1,2},\quad W^{(2)}_{l,l',m,m',n}=\frac{1}{\sqrt{2P}}\begin{bmatrix} v_{l,m} & v_{l',m'} \\ \varphi_n v_{l,m} & -\varphi_n v_{l',m'} \end{bmatrix}$ if $N_1 \geq N_2$ and $x=i_{1,2},\quad y=i_{1,1},\quad W^{(2)}_{l,l',m,m',n}=\frac{1}{\sqrt{2P}}\begin{bmatrix} v_{m,l} & v_{m',l'} \\ \varphi_n v_{m,l} & -\varphi_n v_{m',l'} \end{bmatrix}$, if $N_1 < N_2$				

Table 7.2.4-12: Codebook for 3-layer CSI reporting using antenna ports 15 to 14+*P*

***3 Layers, Codebook-Config* = 1,** $N_1>1,\ N_2>1$		
$i_{1,2}=0,1,\cdots,N_2O_2-1$		
$i_{1,1}$	i_2	
	0	**1**
$0,\cdots,O_1N_1-1$	$W^{(3)}_{i_{1,1},i_{1,1}+O_1,i_{1,2},i_{1,2}}$	$\tilde{W}^{(3)}_{i_{1,1},i_{1,1}+O_1,i_{1,2},i_{1,2}}$
$O_1N_1,\cdots,2O_1N_1-1$	$W^{(3)}_{i_{1,1},i_{1,1},i_{1,2},i_{1,2}+O_2}$	$\tilde{W}^{(3)}_{i_{1,1},i_{1,1},i_{1,2},i_{1,2}+O_2}$
where $W^{(3)}_{l,l',m,m'}=\frac{1}{\sqrt{3P}}\begin{bmatrix} v_{l,m} & v_{l,m} & v_{l',m'} \\ v_{l,m} & -v_{l,m} & -v_{l',m'} \end{bmatrix}$, $\tilde{W}^{(3)}_{l,l',m,m'}=\frac{1}{\sqrt{3P}}\begin{bmatrix} v_{l,m} & v_{l',m'} & v_{l',m'} \\ v_{l,m} & v_{l',m'} & -v_{l',m'} \end{bmatrix}$		

***3 Layers, Codebook-Config* = 1,** $N_2=1$		
$i_{1,2}=0$		
$i_{1,1}$	i_2	
	0	**1**
$0,\cdots,O_1N_1-1$	$W^{(3)}_{i_{1,1},i_{1,1}+O_1,0,0}$	$\tilde{W}^{(3)}_{i_{1,1},i_{1,1}+O_1,0,0}$
$O_1N_1,\cdots,2O_1N_1-1$	$W^{(3)}_{i_{1,1},i_{1,1}+2O_1,0,0}$	$\tilde{W}^{(3)}_{i_{1,1},i_{1,1}+2O_1,0,0}$
$2O_1N_1,\cdots,3O_1N_1-1$	$W^{(3)}_{i_{1,1},i_{1,1}+3O_1,0,0}$	$\tilde{W}^{(3)}_{i_{1,1},i_{1,1}+3O_1,0,0}$
where $W^{(3)}_{l,l',m,m'}=\frac{1}{\sqrt{3P}}\begin{bmatrix} v_{l,m} & v_{l,m} & v_{l',m'} \\ v_{l,m} & -v_{l,m} & -v_{l',m'} \end{bmatrix}$, $\tilde{W}^{(3)}_{l,l',m,m'}=\frac{1}{\sqrt{3P}}\begin{bmatrix} v_{l,m} & v_{l',m'} & v_{l',m'} \\ v_{l,m} & v_{l',m'} & -v_{l',m'} \end{bmatrix}$		

***3 Layers, Codebook-Config* = 2**				
$i_{1,2}=0,1,\cdots,2N_2-1$				
$i_{1,1}$	i_2			
	0	**1**	**2**	**3**

$0,\cdots,2N_1-1$	$W^{(3)}_{2i_{1,1},2i_{1,1}+4,2i_{1,2},2i_{1,2}}$	$W^{(3)}_{2i_{1,1}+4,2i_{1,1},2i_{1,2},2i_{1,2}}$	$\tilde{W}^{(3)}_{2i_{1,1},2i_{1,1}+4,2i_{1,2},2i_{1,2}}$	$\tilde{W}^{(3)}_{2i_{1,1}+4,2i_{1,1},2i_{1,2},2i_{1,2}}$
$2N_1,\cdots,4N_1-1$	$W^{(3)}_{2i_{1,1},2i_{1,1},2i_{1,2},2i_{1,2}+4}$	$W^{(3)}_{2i_{1,1},2i_{1,1},2i_{1,2}+4,2i_{1,2}}$	$\tilde{W}^{(3)}_{2i_{1,1},2i_{1,1},2i_{1,2},2i_{1,2}+4}$	$\tilde{W}^{(3)}_{2i_{1,1},2i_{1,1},2i_{1,2}+4,2i_{1,2}}$
$i_{1,1}$	i_2			
	4	**5**	**6**	**7**
$0,\cdots,2N_1-1$	$W^{(3)}_{2i_{1,1}+1,2i_{1,1}+5,2i_{1,2},2i_{1,2}}$	$W^{(3)}_{2i_{1,1}+5,2i_{1,1}+1,2i_{1,2},2i_{1,2}}$	$\tilde{W}^{(3)}_{2i_{1,1}+1,2i_{1,1}+5,2i_{1,2},2i_{1,2}}$	$\tilde{W}^{(3)}_{2i_{1,1}+5,2i_{1,1}+1,2i_{1,2},2i_{1,2}}$
$2N_1,\cdots,4N_1-1$	$W^{(3)}_{2i_{1,1}+1,2i_{1,1}+1,2i_{1,2},2i_{1,2}+4}$	$W^{(3)}_{2i_{1,1}+1,2i_{1,1}+1,2i_{1,2}+4,2i_{1,2}}$	$\tilde{W}^{(3)}_{2i_{1,1}+1,2i_{1,1}+1,2i_{1,2},2i_{1,2}+4}$	$\tilde{W}^{(3)}_{2i_{1,1}+1,2i_{1,1}+1,2i_{1,2}+4,2i_{1,2}}$
$i_{1,1}$	i_2			
	8	**9**	**10**	**11**
$0,\cdots,2N_1-1$	$W^{(3)}_{2i_{1,1},2i_{1,1}+4,2i_{1,2}+1,2i_{1,2}+1}$	$W^{(3)}_{2i_{1,1}+4,2i_{1,1},2i_{1,2}+1,2i_{1,2}+1}$	$\tilde{W}^{(3)}_{2i_{1,1},2i_{1,1}+4,2i_{1,2}+1,2i_{1,2}+1}$	$\tilde{W}^{(3)}_{2i_{1,1}+4,2i_{1,1},2i_{1,2}+1,2i_{1,2}+1}$
$2N_1,\cdots,4N_1-1$	$W^{(3)}_{2i_{1,1},2i_{1,1},2i_{1,2}+1,2i_{1,2}+5}$	$W^{(3)}_{2i_{1,1},2i_{1,1},2i_{1,2}+5,2i_{1,2}+1}$	$\tilde{W}^{(3)}_{2i_{1,1},2i_{1,1},2i_{1,2}+1,2i_{1,2}+5}$	$\tilde{W}^{(3)}_{2i_{1,1},2i_{1,1},2i_{1,2}+5,2i_{1,2}+1}$
$i_{1,1}$	i_2			
	12	**13**	**14**	**15**
$0,\cdots,2N_1-1$	$W^{(3)}_{2i_{1,1}+1,2i_{1,1}+5,2i_{1,2}+1,2i_{1,2}+1}$	$W^{(3)}_{2i_{1,1}+5,2i_{1,1}+1,2i_{1,2}+1,2i_{1,2}+1}$	$\tilde{W}^{(3)}_{2i_{1,1}+1,2i_{1,1}+5,2i_{1,2}+1,2i_{1,2}+1}$	$\tilde{W}^{(3)}_{2i_{1,1}+5,2i_{1,1}+1,2i_{1,2}+1,2i_{1,2}+1}$
$2N_1,\cdots,4N_1-1$	$W^{(3)}_{2i_{1,1}+1,2i_{1,1}+1,2i_{1,2}+1,2i_{1,2}+5}$	$W^{(3)}_{2i_{1,1}+1,2i_{1,1}+1,2i_{1,2}+5,2i_{1,2}+1}$	$\tilde{W}^{(3)}_{2i_{1,1}+1,2i_{1,1}+1,2i_{1,2}+1,2i_{1,2}+5}$	$\tilde{W}^{(3)}_{2i_{1,1}+1,2i_{1,1}+1,2i_{1,2}+5,2i_{1,2}+1}$
where $W^{(3)}_{l,l',m,m'} = \frac{1}{\sqrt{3P}}\begin{bmatrix} v_{\frac{O_1}{4}l,\frac{O_2}{4}m} & v_{\frac{O_1}{4}l,\frac{O_2}{4}m} & v_{\frac{O_1}{4}l',\frac{O_2}{4}m'} \\ v_{\frac{O_1}{4}l,\frac{O_2}{4}m} & -v_{\frac{O_1}{4}l,\frac{O_2}{4}m} & -v_{\frac{O_1}{4}l',\frac{O_2}{4}m'} \end{bmatrix}$, $\tilde{W}^{(3)}_{l,l',m,m'} = \frac{1}{\sqrt{3P}}\begin{bmatrix} v_{\frac{O_1}{4}l,\frac{O_2}{4}m} & v_{\frac{O_1}{4}l',\frac{O_2}{4}m'} & v_{\frac{O_1}{4}l',\frac{O_2}{4}m'} \\ v_{\frac{O_1}{4}l,\frac{O_2}{4}m} & v_{\frac{O_1}{4}l',\frac{O_2}{4}m'} & -v_{\frac{O_1}{4}l',\frac{O_2}{4}m'} \end{bmatrix}$				

3 Layers, Codebook-Config =3				
$i_{1,2}=0,1,\cdots,2N_2-1$				
$i_{1,1}$	i_2			
	0	**1**	**2**	**3**
$0,\cdots,N_1-1$	$W^{(3)}_{4i_{1,1}+2,4i_{1,1}+6,2i_{1,2},2i_{1,2}}$	$W^{(3)}_{4i_{1,1}+6,4i_{1,1}+2,2i_{1,2},2i_{1,2}}$	$\tilde{W}^{(3)}_{4i_{1,1}+2,4i_{1,1}+6,2i_{1,2},2i_{1,2}}$	$\tilde{W}^{(3)}_{4i_{1,1}+6,4i_{1,1}+2,2i_{1,2},2i_{1,2}}$
$N_1,\cdots,2N_1-1$	$W^{(3)}_{4i_{1,1}+2,4i_{1,1}+2,2i_{1,2},2i_{1,2}+4}$	$W^{(3)}_{4i_{1,1}+2,4i_{1,1}+2,2i_{1,2}+4,2i_{1,2}}$	$\tilde{W}^{(3)}_{4i_{1,1}+2,4i_{1,1}+2,2i_{1,2},2i_{1,2}+4}$	$\tilde{W}^{(3)}_{4i_{1,1}+2,4i_{1,1}+2,2i_{1,2}+4,2i_{1,2}}$
$i_{1,1}$	i_2			
	4	**5**	**6**	**7**
$0,\cdots,N_1-1$	$W^{(3)}_{4i_{1,1}+3,4i_{1,1}+7,2i_{1,2},2i_{1,2}}$	$W^{(3)}_{4i_{1,1}+7,4i_{1,1}+3,2i_{1,2},2i_{1,2}}$	$\tilde{W}^{(3)}_{4i_{1,1}+3,4i_{1,1}+7,2i_{1,2},2i_{1,2}}$	$\tilde{W}^{(3)}_{4i_{1,1}+7,4i_{1,1}+3,2i_{1,2},2i_{1,2}}$
$N_1,\cdots,2N_1-1$	$W^{(3)}_{4i_{1,1}+3,4i_{1,1}+3,2i_{1,2},2i_{1,2}+4}$	$W^{(3)}_{4i_{1,1}+3,4i_{1,1}+3,2i_{1,2}+4,2i_{1,2}}$	$\tilde{W}^{(3)}_{4i_{1,1}+3,4i_{1,1}+3,2i_{1,2},2i_{1,2}+4}$	$\tilde{W}^{(3)}_{4i_{1,1}+3,4i_{1,1}+3,2i_{1,2}+4,2i_{1,2}}$
$i_{1,1}$	i_2			
	8	**9**	**10**	**11**
$0,\cdots,N_1-1$	$W^{(3)}_{4i_{1,1},4i_{1,1}+4,2i_{1,2}+1,2i_{1,2}+1}$	$W^{(3)}_{4i_{1,1}+4,4i_{1,1},2i_{1,2}+1,2i_{1,2}+1}$	$\tilde{W}^{(3)}_{4i_{1,1},4i_{1,1}+4,2i_{1,2}+1,2i_{1,2}+1}$	$\tilde{W}^{(3)}_{4i_{1,1}+4,4i_{1,1},2i_{1,2}+1,2i_{1,2}+1}$
$N_1,\cdots,2N_1-1$	$W^{(3)}_{4i_{1,1},4i_{1,1},2i_{1,2}+1,2i_{1,2}+5}$	$W^{(3)}_{4i_{1,1},4i_{1,1},2i_{1,2}+5,2i_{1,2}+1}$	$\tilde{W}^{(3)}_{4i_{1,1},4i_{1,1},2i_{1,2}+1,2i_{1,2}+5}$	$\tilde{W}^{(3)}_{4i_{1,1},4i_{1,1},2i_{1,2}+5,2i_{1,2}+1}$
$i_{1,1}$	i_2			
	12	**13**	**14**	**15**

$0,\cdots,N_1-1$	$W^{(3)}_{4i_{1,1}+1,4i_{1,1}+5,2i_{1,2}+1,2i_{1,2}+1}$	$W^{(3)}_{4i_{1,1}+5,4i_{1,1}+1,2i_{1,2}+1,2i_{1,2}+1}$	$\tilde{W}^{(3)}_{4i_{1,1}+1,4i_{1,1}+5,2i_{1,2}+1,2i_{1,2}+1}$	$\tilde{W}^{(3)}_{4i_{1,1}+5,4i_{1,1}+1,2i_{1,2}+1,2i_{1,2}+1}$
$N_1,\cdots,2N_1-1$	$W^{(3)}_{4i_{1,1}+1,4i_{1,1}+1,2i_{1,2}+1,2i_{1,2}+5}$	$W^{(3)}_{4i_{1,1}+1,4i_{1,1}+1,2i_{1,2}+5,2i_{1,2}+1}$	$\tilde{W}^{(3)}_{4i_{1,1}+1,4i_{1,1}+1,2i_{1,2}+1,2i_{1,2}+5}$	$\tilde{W}^{(3)}_{4i_{1,1}+1,4i_{1,1}+1,2i_{1,2}+5,2i_{1,2}+1}$
where $W^{(3)}_{l,l',m,m'}=\frac{1}{\sqrt{3P}}\begin{bmatrix} v_{\frac{O_1 l}{4},\frac{O_2 m}{4}} & v_{\frac{O_1 l}{4},\frac{O_2 m}{4}} & v_{\frac{O_1 l'}{4},\frac{O_2 m'}{4}} \\ v_{\frac{O_1 l}{4},\frac{O_2 m}{4}} & -v_{\frac{O_1 l}{4},\frac{O_2 m}{4}} & -v_{\frac{O_1 l'}{4},\frac{O_2 m'}{4}} \end{bmatrix}$, $\tilde{W}^{(3)}_{l,l',m,m'}=\frac{1}{\sqrt{3P}}\begin{bmatrix} v_{\frac{O_1 l}{4},\frac{O_2 m}{4}} & v_{\frac{O_1 l'}{4},\frac{O_2 m'}{4}} & v_{\frac{O_1 l'}{4},\frac{O_2 m'}{4}} \\ v_{\frac{O_1 l}{4},\frac{O_2 m}{4}} & v_{\frac{O_1 l'}{4},\frac{O_2 m'}{4}} & -v_{\frac{O_1 l'}{4},\frac{O_2 m'}{4}} \end{bmatrix}$				

3 Layers, Codebook-Config =4, $N_1>1,\ N_2>1$				
$i_{1,2}=0,1,\cdots,4N_2-1$				
$i_{1,1}$	i_2			
	0	**1**	**2**	**3**
$0,\cdots,N_1-1$	$W^{(3)}_{4i_{1,1},4i_{1,1}+4,i_{1,2},i_{1,2}}$	$W^{(3)}_{4i_{1,1}+4,4i_{1,1},i_{1,2},i_{1,2}}$	$\tilde{W}^{(3)}_{4i_{1,1},4i_{1,1}+4,i_{1,2},i_{1,2}}$	$\tilde{W}^{(3)}_{4i_{1,1}+4,4i_{1,1},i_{1,2},i_{1,2}}$
$N_1,\cdots,2N_1-1$	$W^{(3)}_{4i_{1,1},4i_{1,1},i_{1,2},i_{1,2}+4}$	$W^{(3)}_{4i_{1,1},4i_{1,1},i_{1,2}+4,i_{1,2}}$	$\tilde{W}^{(3)}_{4i_{1,1},4i_{1,1},i_{1,2},i_{1,2}+4}$	$\tilde{W}^{(3)}_{4i_{1,1},4i_{1,1},i_{1,2}+4,i_{1,2}}$
$i_{1,1}$	i_2			
	4	**5**	**6**	**7**
$0,\cdots,N_1-1$	$W^{(3)}_{4i_{1,1}+1,4i_{1,1}+5,i_{1,2},i_{1,2}}$	$W^{(3)}_{4i_{1,1}+5,4i_{1,1}+1,i_{1,2},i_{1,2}}$	$\tilde{W}^{(3)}_{4i_{1,1}+1,4i_{1,1}+5,i_{1,2},i_{1,2}}$	$\tilde{W}^{(3)}_{4i_{1,1}+5,4i_{1,1}+1,i_{1,2},i_{1,2}}$
$N_1,\cdots,2N_1-1$	$W^{(3)}_{4i_{1,1}+1,4i_{1,1}+1,i_{1,2},i_{1,2}+4}$	$W^{(3)}_{4i_{1,1}+1,4i_{1,1}+1,i_{1,2}+4,i_{1,2}}$	$\tilde{W}^{(3)}_{4i_{1,1}+1,4i_{1,1}+1,i_{1,2},i_{1,2}+4}$	$\tilde{W}^{(3)}_{4i_{1,1}+1,4i_{1,1}+1,i_{1,2}+4,i_{1,2}}$
$i_{1,1}$	i_2			
	8	**9**	**10**	**11**
$0,\cdots,N_1-1$	$W^{(3)}_{4i_{1,1}+2,4i_{1,1}+6,i_{1,2},i_{1,2}}$	$W^{(3)}_{4i_{1,1}+6,4i_{1,1}+2,i_{1,2},i_{1,2}}$	$\tilde{W}^{(3)}_{4i_{1,1}+2,4i_{1,1}+6,i_{1,2},i_{1,2}}$	$\tilde{W}^{(3)}_{4i_{1,1}+6,4i_{1,1}+2,i_{1,2},i_{1,2}}$
$N_1,\cdots,2N_1-1$	$W^{(3)}_{4i_{1,1}+2,4i_{1,1}+2,i_{1,2},i_{1,2}+4}$	$W^{(3)}_{4i_{1,1}+2,4i_{1,1}+2,i_{1,2}+4,i_{1,2}}$	$\tilde{W}^{(3)}_{4i_{1,1}+2,4i_{1,1}+2,i_{1,2},i_{1,2}+4}$	$\tilde{W}^{(3)}_{4i_{1,1}+2,4i_{1,1}+2,i_{1,2}+4,i_{1,2}}$
$i_{1,1}$	i_2			
	12	**13**	**14**	**15**
$0,\cdots,N_1-1$	$W^{(3)}_{4i_{1,1}+3,4i_{1,1}+7,i_{1,2},i_{1,2}}$	$W^{(3)}_{4i_{1,1}+7,4i_{1,1}+3,i_{1,2},i_{1,2}}$	$\tilde{W}^{(3)}_{4i_{1,1}+3,4i_{1,1}+7,i_{1,2},i_{1,2}}$	$\tilde{W}^{(3)}_{4i_{1,1}+7,4i_{1,1}+3,i_{1,2},i_{1,2}}$
$N_1,\cdots,2N_1-1$	$W^{(3)}_{4i_{1,1}+3,4i_{1,1}+3,i_{1,2},i_{1,2}+4}$	$W^{(3)}_{4i_{1,1}+3,4i_{1,1}+3,i_{1,2}+4,i_{1,2}}$	$\tilde{W}^{(3)}_{4i_{1,1}+3,4i_{1,1}+3,i_{1,2},i_{1,2}+4}$	$\tilde{W}^{(3)}_{4i_{1,1}+3,4i_{1,1}+3,i_{1,2}+4,i_{1,2}}$
where $W^{(3)}_{l,l',m,m'}=\frac{1}{\sqrt{3P}}\begin{bmatrix} v_{\frac{O_1 l}{4},\frac{O_2 m}{4}} & v_{\frac{O_1 l}{4},\frac{O_2 m}{4}} & v_{\frac{O_1 l'}{4},\frac{O_2 m'}{4}} \\ v_{\frac{O_1 l}{4},\frac{O_2 m}{4}} & -v_{\frac{O_1 l}{4},\frac{O_2 m}{4}} & -v_{\frac{O_1 l'}{4},\frac{O_2 m'}{4}} \end{bmatrix}$, $\tilde{W}^{(3)}_{l,l',m,m'}=\frac{1}{\sqrt{3P}}\begin{bmatrix} v_{\frac{O_1 l}{4},\frac{O_2 m}{4}} & v_{\frac{O_1 l'}{4},\frac{O_2 m'}{4}} & v_{\frac{O_1 l'}{4},\frac{O_2 m'}{4}} \\ v_{\frac{O_1 l}{4},\frac{O_2 m}{4}} & v_{\frac{O_1 l'}{4},\frac{O_2 m'}{4}} & -v_{\frac{O_1 l'}{4},\frac{O_2 m'}{4}} \end{bmatrix}$				

3 Layers, Codebook-Config =4, $N_2=1$				
$i_{1,2}=0$				
$i_{1,1}$	i_2			
	0	**1**	**2**	**3**
$0,\cdots,N_1-1$	$W^{(3)}_{4i_{1,1},4i_{1,1}+4,0,0}$	$W^{(3)}_{4i_{1,1}+4,4i_{1,1},0,0}$	$\tilde{W}^{(3)}_{4i_{1,1},4i_{1,1}+4,0,0}$	$\tilde{W}^{(3)}_{4i_{1,1}+4,4i_{1,1},0,0}$
$N_1,\cdots,2N_1-1$	$W^{(3)}_{4i_{1,1},4i_{1,1}+8,0,0}$	$W^{(3)}_{4i_{1,1}+8,4i_{1,1},0,0}$	$\tilde{W}^{(3)}_{4i_{1,1},4i_{1,1}+8,0,0}$	$\tilde{W}^{(3)}_{4i_{1,1}+8,4i_{1,1},0,0}$
$2N_1,\cdots,3N_1-1$	$W^{(3)}_{4i_{1,1},4i_{1,1}+12,0,0}$	$W^{(3)}_{4i_{1,1}+12,4i_{1,1},0,0}$	$\tilde{W}^{(3)}_{4i_{1,1},4i_{1,1}+12,0,0}$	$\tilde{W}^{(3)}_{4i_{1,1}+12,4i_{1,1},0,0}$
$i_{1,1}$	i_2			
	4	**5**	**6**	**7**

$0,\cdots,N_1-1$	$W^{(3)}_{4i_{1,1}+1,4i_{1,1}+5,0,0}$	$W^{(3)}_{4i_{1,1}+5,4i_{1,1}+1,0,0}$	$\tilde{W}^{(3)}_{4i_{1,1}+1,4i_{1,1}+5,0,0}$	$\tilde{W}^{(3)}_{4i_{1,1}+5,4i_{1,1}+1,0,0}$
$N_1,\cdots,2N_1-1$	$W^{(3)}_{4i_{1,1}+1,4i_{1,1}+9,0,0}$	$W^{(3)}_{4i_{1,1}+9,4i_{1,1}+1,0,0}$	$\tilde{W}^{(3)}_{4i_{1,1}+1,4i_{1,1}+9,0,0}$	$\tilde{W}^{(3)}_{4i_{1,1}+9,4i_{1,1}+1,0,0}$
$2N_1,\cdots,3N_1-1$	$W^{(3)}_{4i_{1,1}+1,4i_{1,1}+13,0,0}$	$W^{(3)}_{4i_{1,1}+13,4i_{1,1}+1,0,0}$	$\tilde{W}^{(3)}_{4i_{1,1}+1,4i_{1,1}+13,0,0}$	$\tilde{W}^{(3)}_{4i_{1,1}+13,4i_{1,1}+1,0,0}$
$i_{1,1}$	i_2			
	8	**9**	**10**	**11**
$0,\cdots,N_1-1$	$W^{(3)}_{4i_{1,1}+2,4i_{1,1}+6,0,0}$	$W^{(3)}_{4i_{1,1}+6,4i_{1,1}+2,0,0}$	$\tilde{W}^{(3)}_{4i_{1,1}+2,4i_{1,1}+6,0,0}$	$\tilde{W}^{(3)}_{4i_{1,1}+6,4i_{1,1}+2,0,0}$
$N_1,\cdots,2N_1-1$	$W^{(3)}_{4i_{1,1}+2,4i_{1,1}+10,0,0}$	$W^{(3)}_{4i_{1,1}+10,4i_{1,1}+2,0,0}$	$\tilde{W}^{(3)}_{4i_{1,1}+2,4i_{1,1}+10,0,0}$	$\tilde{W}^{(3)}_{4i_{1,1}+10,4i_{1,1}+2,0,0}$
$2N_1,\cdots,3N_1-1$	$W^{(3)}_{4i_{1,1}+2,4i_{1,1}+14,0,0}$	$W^{(3)}_{4i_{1,1}+14,4i_{1,1}+2,0,0}$	$\tilde{W}^{(3)}_{4i_{1,1}+2,4i_{1,1}+14,0,0}$	$\tilde{W}^{(3)}_{4i_{1,1}+14,4i_{1,1}+2,0,0}$
$i_{1,1}$	i_2			
	12	**13**	**14**	**15**
$0,\cdots,N_1-1$	$W^{(3)}_{4i_{1,1}+3,4i_{1,1}+7,0,0}$	$W^{(3)}_{4i_{1,1}+7,4i_{1,1}+3,0,0}$	$\tilde{W}^{(3)}_{4i_{1,1}+3,4i_{1,1}+7,0,0}$	$\tilde{W}^{(3)}_{4i_{1,1}+7,4i_{1,1}+3,0,0}$
$N_1,\cdots,2N_1-1$	$W^{(3)}_{4i_{1,1}+3,4i_{1,1}+11,0,0}$	$W^{(3)}_{4i_{1,1}+11,4i_{1,1}+3,0,0}$	$\tilde{W}^{(3)}_{4i_{1,1}+3,4i_{1,1}+11,0,0}$	$\tilde{W}^{(3)}_{4i_{1,1}+11,4i_{1,1}+3,0,0}$
$2N_1,\cdots,3N_1-1$	$W^{(3)}_{4i_{1,1}+3,4i_{1,1}+15,0,0}$	$W^{(3)}_{4i_{1,1}+15,4i_{1,1}+3,0,0}$	$\tilde{W}^{(3)}_{4i_{1,1}+3,4i_{1,1}+15,0,0}$	$\tilde{W}^{(3)}_{4i_{1,1}+15,4i_{1,1}+3,0,0}$
where $W^{(3)}_{l,l',m,m'}=\frac{1}{\sqrt{3P}}\begin{bmatrix} v_{\frac{O_1 l}{4},\frac{O_2 m}{4}} & v_{\frac{O_1 l}{4},\frac{O_2 m}{4}} & v_{\frac{O_1 l'}{4},\frac{O_2 m'}{4}} \\ v_{\frac{O_1 l}{4},\frac{O_2 m}{4}} & -v_{\frac{O_1 l}{4},\frac{O_2 m}{4}} & -v_{\frac{O_1 l'}{4},\frac{O_2 m'}{4}} \end{bmatrix}$, $\tilde{W}^{(3)}_{l,l',m,m'}=\frac{1}{\sqrt{3P}}\begin{bmatrix} v_{\frac{O_1 l}{4},\frac{O_2 m}{4}} & v_{\frac{O_1 l'}{4},\frac{O_2 m'}{4}} & v_{\frac{O_1 l'}{4},\frac{O_2 m'}{4}} \\ v_{\frac{O_1 l}{4},\frac{O_2 m}{4}} & v_{\frac{O_1 l'}{4},\frac{O_2 m'}{4}} & -v_{\frac{O_1 l'}{4},\frac{O_2 m'}{4}} \end{bmatrix}$				

Table 7.2.4-13: Codebook for 4-layer CSI reporting using antenna ports 15 to 14+*P*

***4 Layers, Codebook-Config* = 1**, $N_1>1$, $N_2>1$		
$i_{1,2}=0,1,\cdots,N_2O_2-1$		
$i_{1,1}$	i_2	
	0	**1**
$0,\cdots,N_1O_1-1$	$W^{(4)}_{i_{1,1},i_{1,1}+O_1,i_{1,2},i_{1,2},0}$	$W^{(4)}_{i_{1,1},i_{1,1}+O_1,i_{1,2},i_{1,2},1}$
$O_1N_1,\cdots,2O_1N_1-1$	$W^{(4)}_{i_{1,1},i_{1,1},i_{1,2},i_{1,2}+O_2,0}$	$W^{(4)}_{i_{1,1},i_{1,1},i_{1,2},i_{1,2}+O_2,1}$
where $W^{(4)}_{l,l',m,m',n}=\frac{1}{\sqrt{4P}}\begin{bmatrix} v_{l,m} & v_{l',m'} & v_{l,m} & v_{l',m'} \\ \varphi_n v_{l,m} & \varphi_n v_{l',m'} & -\varphi_n v_{l,m} & -\varphi_n v_{l',m'} \end{bmatrix}$		

***4 Layers**, **Codebook-Config* = 1,** $N_2 = 1$		
$i_{1,2} = 0$		
$i_{1,1}$	i_2	
	0	1
$0,\cdots,O_1N_1-1$	$W^{(4)}_{i_{1,1},i_{1,1}+O_1,0,0,0}$	$W^{(4)}_{i_{1,1},i_{1,1}+O_1,0,0,1}$
$O_1N_1,\cdots,2O_1N_1-1$	$W^{(4)}_{i_{1,1},i_{1,1}+2O_1,0,0,0}$	$W^{(4)}_{i_{1,1},i_{1,1}+2O_1,0,0,1}$
$2O_1N_1,\cdots,3O_1N_1-1$	$W^{(4)}_{i_{1,1},i_{1,1}+3O_1,0,0,0}$	$W^{(4)}_{i_{1,1},i_{1,1}+3O_1,0,0,1}$
$W^{(4)}_{l,l',m,m',n} = \frac{1}{\sqrt{4P}}\begin{bmatrix} v_{l,m} & v_{l',m'} & v_{l,m} & v_{l',m'} \\ \varphi_n v_{l,m} & \varphi_n v_{l',m'} & -\varphi_n v_{l,m} & -\varphi_n v_{l',m'} \end{bmatrix}$		

***4 Layers, Codebook-Config* = 2**				
$i_{1,2} = 0,1,\cdots,2N_2-1$				
$i_{1,1}$	i_2			
	0	**1**	**2**	**3**
$0,\cdots,2N_1-1$	$W^{(4)}_{2i_{1,1},2i_{1,1}+4,2i_{1,2},2i_{1,2},0}$	$W^{(4)}_{2i_{1,1},2i_{1,1}+4,2i_{1,2},2i_{1,2},1}$	$W^{(4)}_{2i_{1,1}+1,2i_{1,1}+5,2i_{1,2},2i_{1,2},0}$	$W^{(4)}_{2i_{1,1}+1,2i_{1,1}+5,2i_{1,2},2i_{1,2},1}$
$2N_1,\cdots,4N_1-1$	$W^{(4)}_{2i_{1,1},2i_{1,1},2i_{1,2},2i_{1,2}+4,0}$	$W^{(4)}_{2i_{1,1},2i_{1,1},2i_{1,2},2i_{1,2}+4,1}$	$W^{(4)}_{2i_{1,1}+1,2i_{1,1}+1,2i_{1,2},2i_{1,2}+4,0}$	$W^{(4)}_{2i_{1,1}+1,2i_{1,1}+1,2i_{1,2},2i_{1,2}+4,1}$
$i_{1,1}$	i_2			
	4	5	6	7
$0,\cdots,2N_1-1$	$W^{(4)}_{2i_{1,1},2i_{1,1}+4,2i_{1,2}+1,2i_{1,2}+1,0}$	$W^{(4)}_{2i_{1,1},2i_{1,1}+4,2i_{1,2}+1,2i_{1,2}+1,1}$	$W^{(4)}_{2i_{1,1}+1,2i_{1,1}+5,2i_{1,2}+1,2i_{1,2}+1,0}$	$W^{(4)}_{2i_{1,1}+1,2i_{1,1}+5,2i_{1,2}+1,2i_{1,2}+1,1}$
$2N_1,\cdots,4N_1-1$	$W^{(4)}_{2i_{1,1},2i_{1,1},2i_{1,2}+1,2i_{1,2}+5,0}$	$W^{(4)}_{2i_{1,1},2i_{1,1},2i_{1,2}+1,2i_{1,2}+5,1}$	$W^{(4)}_{2i_{1,1}+1,2i_{1,1}+1,2i_{1,2}+1,2i_{1,2}+5,0}$	$W^{(4)}_{2i_{1,1}+1,2i_{1,1}+1,2i_{1,2}+1,2i_{1,2}+5,1}$
$W^{(4)}_{l,l',m,m',n} = \frac{1}{\sqrt{4P}}\begin{bmatrix} v_{\frac{O_1}{4}l,\frac{O_2}{4}m} & v_{\frac{O_1}{4}l',\frac{O_2}{4}m'} & v_{\frac{O_1}{4}l,\frac{O_2}{4}m} & v_{\frac{O_1}{4}l',\frac{O_2}{4}m'} \\ \varphi_n v_{\frac{O_1}{4}l,\frac{O_2}{4}m} & \varphi_n v_{\frac{O_1}{4}l',\frac{O_2}{4}m'} & -\varphi_n v_{\frac{O_1}{4}l,\frac{O_2}{4}m} & -\varphi_n v_{\frac{O_1}{4}l',\frac{O_2}{4}m'} \end{bmatrix}$				

***4 Layers, Codebook-Config* =3**				
$i_{1,2} = 0,1,\cdots,2N_2-1$				
$i_{1,1}$	i_2			
	0	**1**	**2**	**3**
$0,\cdots,N_1-1$	$W^{(4)}_{4i_{1,1}+2,4i_{1,1}+6,2i_{1,2},2i_{1,2},0}$	$W^{(4)}_{4i_{1,1}+2,4i_{1,1}+6,2i_{1,2},2i_{1,2},1}$	$W^{(4)}_{4i_{1,1}+3,4i_{1,1}+7,2i_{1,2},2i_{1,2},0}$	$W^{(4)}_{4i_{1,1}+3,4i_{1,1}+7,2i_{1,2},2i_{1,2},1}$
$N_1,\cdots,2N_1-1$	$W^{(4)}_{4i_{1,1}+2,4i_{1,1}+2,2i_{1,2},2i_{1,2}+4,0}$	$W^{(4)}_{4i_{1,1}+2,4i_{1,1}+2,2i_{1,2},2i_{1,2}+4,1}$	$W^{(4)}_{4i_{1,1}+3,4i_{1,1}+3,2i_{1,2},2i_{1,2}+4,0}$	$W^{(4)}_{4i_{1,1}+3,4i_{1,1}+3,2i_{1,2},2i_{1,2}+4,1}$
$i_{1,1}$	i_2			
	4	5	6	7

$0,\cdots,N_1-1$	$W^{(4)}_{4i_{1,1},4i_{1,1}+4,2i_{1,2}+1,2i_{1,2}+1,0}$	$W^{(4)}_{4i_{1,1},4i_{1,1}+4,2i_{1,2}+1,2i_{1,2}+1,1}$	$W^{(4)}_{4i_{1,1}+1,4i_{1,1}+5,2i_{1,2}+1,2i_{1,2}+1,0}$	$W^{(4)}_{4i_{1,1}+1,4i_{1,1}+5,2i_{1,2}+1,2i_{1,2}+1,1}$
$N_1,\cdots,2N_1-1$	$W^{(4)}_{4i_{1,1},4i_{1,1},2i_{1,2}+1,2i_{1,2}+5,0}$	$W^{(4)}_{4i_{1,1},4i_{1,1},2i_{1,2}+1,2i_{1,2}+5,1}$	$W^{(4)}_{4i_{1,1}+1,4i_{1,1}+1,2i_{1,2}+1,2i_{1,2}+5,0}$	$W^{(4)}_{4i_{1,1}+1,4i_{1,1}+1,2i_{1,2}+1,2i_{1,2}+5,1}$

$$W^{(4)}_{l,l',m,m',n}=\frac{1}{\sqrt{4P}}\begin{bmatrix} v_{\frac{O_1}{4}l,\frac{O_2}{4}m} & v_{\frac{O_1}{4}l',\frac{O_2}{4}m'} & v_{\frac{O_1}{4}l,\frac{O_2}{4}m} & v_{\frac{O_1}{4}l',\frac{O_2}{4}m'} \\ \varphi_n v_{\frac{O_1}{4}l,\frac{O_2}{4}m} & \varphi_n v_{\frac{O_1}{4}l',\frac{O_2}{4}m'} & -\varphi_n v_{\frac{O_1}{4}l,\frac{O_2}{4}m} & -\varphi_n v_{\frac{O_1}{4}l',\frac{O_2}{4}m'} \end{bmatrix}$$

4 Layers, Codebook-Config =4, $N_1>1,\ N_2>1$				
$i_{1,2}=0,1,\cdots,4N_2-1$				
$i_{1,1}$	i_2			
	0	**1**	**2**	**3**
$0,\cdots,N_1-1$	$W^{(4)}_{4i_{1,1},4i_{1,1}+4,i_{1,2},i_{1,2},0}$	$W^{(4)}_{4i_{1,1},4i_{1,1}+4,i_{1,2},i_{1,2},1}$	$W^{(4)}_{4i_{1,1}+1,4i_{1,1}+5,i_{1,2},i_{1,2},0}$	$W^{(4)}_{4i_{1,1}+1,4i_{1,1}+5,i_{1,2},i_{1,2},1}$
$N_1,\cdots,2N_1-1$	$W^{(4)}_{4i_{1,1},4i_{1,1},i_{1,2},i_{1,2}+4,0}$	$W^{(4)}_{4i_{1,1},4i_{1,1},i_{1,2},i_{1,2}+4,1}$	$W^{(4)}_{4i_{1,1}+1,4i_{1,1}+1,i_{1,2},i_{1,2}+4,0}$	$W^{(4)}_{4i_{1,1}+1,4i_{1,1}+1,i_{1,2},i_{1,2}+4,1}$
$i_{1,1}$	i_2			
	4	5	6	7
$0,\cdots,N_1-1$	$W^{(4)}_{4i_{1,1}+2,4i_{1,1}+6,2i_{1,2},2i_{1,2},0}$	$W^{(4)}_{4i_{1,1}+2,4i_{1,1}+6,2i_{1,2},2i_{1,2},1}$	$W^{(4)}_{4i_{1,1}+3,4i_{1,1}+7,2i_{1,2},2i_{1,2},0}$	$W^{(4)}_{4i_{1,1}+3,4i_{1,1}+7,2i_{1,2},2i_{1,2},1}$
$N_1,\cdots,2N_1-1$	$W^{(4)}_{4i_{1,1}+2,4i_{1,1}+2,2i_{1,2},2i_{1,2}+4,0}$	$W^{(4)}_{4i_{1,1}+2,4i_{1,1}+2,2i_{1,2},2i_{1,2}+4,1}$	$W^{(4)}_{4i_{1,1}+3,4i_{1,1}+3,2i_{1,2},2i_{1,2}+4,0}$	$W^{(4)}_{4i_{1,1}+3,4i_{1,1}+3,2i_{1,2},2i_{1,2}+4,1}$

$$W^{(4)}_{l,l',m,m',n}=\frac{1}{\sqrt{4P}}\begin{bmatrix} v_{\frac{O_1}{4}l,\frac{O_2}{4}m} & v_{\frac{O_1}{4}l',\frac{O_2}{4}m'} & v_{\frac{O_1}{4}l,\frac{O_2}{4}m} & v_{\frac{O_1}{4}l',\frac{O_2}{4}m'} \\ \varphi_n v_{\frac{O_1}{4}l,\frac{O_2}{4}m} & \varphi_n v_{\frac{O_1}{4}l',\frac{O_2}{4}m'} & -\varphi_n v_{\frac{O_1}{4}l,\frac{O_2}{4}m} & -\varphi_n v_{\frac{O_1}{4}l',\frac{O_2}{4}m'} \end{bmatrix}$$

4 Layers, Codebook-Config =4, $N_2=1$				
$i_{1,2}=0$				
$i_{1,1}$	i_2			
	0	**1**	**2**	**3**
$0,\cdots,N_1-1$	$W^{(4)}_{4i_{1,1},4i_{1,1}+4,0,0,0}$	$W^{(4)}_{4i_{1,1},4i_{1,1}+4,0,0,1}$	$W^{(4)}_{4i_{1,1}+1,4i_{1,1}+5,0,0,0}$	$W^{(4)}_{4i_{1,1}+1,4i_{1,1}+5,0,0,1}$
$N_1,\cdots,2N_1-1$	$W^{(4)}_{4i_{1,1},4i_{1,1}+8,0,0,0}$	$W^{(4)}_{4i_{1,1},4i_{1,1}+8,0,0,1}$	$W^{(4)}_{4i_{1,1}+1,4i_{1,1}+9,0,0,0}$	$W^{(4)}_{4i_{1,1}+1,4i_{1,1}+9,0,0,1}$
$2N_1,\cdots,3N_1-1$	$W^{(4)}_{4i_{1,1},4i_{1,1}+12,0,0,0}$	$W^{(4)}_{4i_{1,1},4i_{1,1}+12,0,0,1}$	$W^{(4)}_{4i_{1,1}+1,4i_{1,1}+13,0,0,0}$	$W^{(4)}_{4i_{1,1}+1,4i_{1,1}+13,0,0,1}$
$i_{1,1}$	i_2			
	4	**5**	**6**	**7**
$0,\cdots,N_1-1$	$W^{(4)}_{4i_{1,1}+2,4i_{1,1}+6,0,0,0}$	$W^{(4)}_{4i_{1,1}+2,4i_{1,1}+6,0,0,1}$	$W^{(4)}_{4i_{1,1}+3,4i_{1,1}+7,0,0,0}$	$W^{(4)}_{4i_{1,1}+3,4i_{1,1}+7,0,0,1}$
$N_1,\cdots,2N_1-1$	$W^{(4)}_{4i_{1,1}+2,4i_{1,1}+10,0,0,0}$	$W^{(4)}_{4i_{1,1}+2,4i_{1,1}+10,0,0,1}$	$W^{(4)}_{4i_{1,1}+3,4i_{1,1}+11,0,0,0}$	$W^{(4)}_{4i_{1,1}+3,4i_{1,1}+11,0,0,1}$
$2N_1,\cdots,3N_1-1$	$W^{(4)}_{4i_{1,1}+2,4i_{1,1}+14,0,0,0}$	$W^{(4)}_{4i_{1,1}+2,4i_{1,1}+14,0,0,1}$	$W^{(4)}_{4i_{1,1}+3,4i_{1,1}+15,0,0,0}$	$W^{(4)}_{4i_{1,1}+3,4i_{1,1}+15,0,0,1}$

$$W^{(4)}_{l,l',m,m',n}=\frac{1}{\sqrt{4P}}\begin{bmatrix} v_{\frac{O_1}{4}l,\frac{O_2}{4}m} & v_{\frac{O_1}{4}l',\frac{O_2}{4}m'} & v_{\frac{O_1}{4}l,\frac{O_2}{4}m} & v_{\frac{O_1}{4}l',\frac{O_2}{4}m'} \\ \varphi_n v_{\frac{O_1}{4}l,\frac{O_2}{4}m} & \varphi_n v_{\frac{O_1}{4}l',\frac{O_2}{4}m'} & -\varphi_n v_{\frac{O_1}{4}l,\frac{O_2}{4}m} & -\varphi_n v_{\frac{O_1}{4}l',\frac{O_2}{4}m'} \end{bmatrix}$$

Table 7.2.4-14: Codebook for 5-layer CSI reporting using antenna ports 15 to 14+*P*

5 Layers, $P=8$, $N_1=N_2$			
Value of *Codebook-Config*	$i_{1,1}$	$i_{1,2}$	
1	$0,1,\cdots,O_1N_1-1$	$0,1,\cdots,O_2N_2-1$	$W^{(5)}_{i_{1,1},i_{1,1}+O_1,i_{1,1}+O_1,i_{1,2},i_{1,2},i_{1,2}+O_2}$
2-4	$0,1,\cdots,4N_1-1$	$0,1,\cdots,4N_2-1$	$W^{(5)}_{i_{1,1},i_{1,1}+4,i_{1,1}+4,i_{1,2},i_{1,2},i_{1,2}+4}$
$W^{(5)}_{l,l',l'',m,m',m''}=\frac{1}{\sqrt{5P}}\begin{bmatrix} v_{\frac{O_1}{4}l,\frac{O_2}{4}m} & v_{\frac{O_1}{4}l,\frac{O_2}{4}m} & v_{\frac{O_1}{4}l',\frac{O_2}{4}m'} & v_{\frac{O_1}{4}l',\frac{O_2}{4}m'} & v_{\frac{O_1}{4}l'',\frac{O_2}{4}m''} \\ v_{\frac{O_1}{4}l,\frac{O_2}{4}m} & -v_{\frac{O_1}{4}l,\frac{O_2}{4}m} & v_{\frac{O_1}{4}l',\frac{O_2}{4}m'} & -v_{\frac{O_1}{4}l',\frac{O_2}{4}m'} & v_{\frac{O_1}{4}l'',\frac{O_2}{4}m''} \end{bmatrix}$ for *Codebook-Config* = 2-4 $W^{(5)}_{l,l',l'',m,m',m''}=\frac{1}{\sqrt{5P}}\begin{bmatrix} v_{l,m} & v_{l,m} & v_{l',m'} & v_{l',m'} & v_{l'',m''} \\ v_{l,m} & -v_{l,m} & v_{l',m'} & -v_{l',m'} & v_{l'',m''} \end{bmatrix}$ for *Codebook-Config* = 1			

5 Layers, $P=12$				
Value of *Codebook-Config*	**Configuration**	$i_{1,1}$	$i_{1,2}$	
1	$N_1>1,\ N_2\geq 1$	$0,1,\cdots,O_1N_1-1$	$0,1,\cdots,O_2N_2-1$	$W^{(5)}_{i_{1,1},i_{1,1}+O_1,i_{1,1}+O_1,i_{1,2},i_{1,2},i_{1,2}+O_2}$
2	$N_1>1,\ N_2>1$	$0,1,\cdots,4N_1-1$	$0,1,\cdots,4N_2-1$	$W^{(5)}_{i_{1,1},i_{1,1}+4,i_{1,1}+4,i_{1,2},i_{1,2},i_{1,2}+4}$
3	$N_1\geq N_2$	$0,1,\cdots,4N_1-1$	$0,1,\cdots,4N_2-1$	$W^{(5)}_{i_{1,1},i_{1,1}+4,i_{1,1}+8,i_{1,2},i_{1,2},i_{1,2}+4}$
	$N_1<N_2$	$0,1,\cdots,4N_1-1$	$0,1,\cdots,4N_2-1$	$W^{(5)}_{i_{1,1},i_{1,1},i_{1,1}+4,i_{1,2},i_{1,2}+4,i_{1,2}+8}$
4	$N_1\geq N_2$	$0,1,\cdots,4N_1-1$	$0,1,\cdots,4N_2-1$	$W^{(5)}_{i_{1,1},i_{1,1}+4,i_{1,1}+8,i_{1,2},i_{1,2},i_{1,2}}$
	$N_1<N_2$	$0,1,\cdots,4N_1-1$	$0,1,\cdots,4N_2-1$	$W^{(5)}_{i_{1,1},i_{1,1},i_{1,1},i_{1,2},i_{1,2}+4,i_{1,2}+8}$
where $W^{(5)}_{l,l',l'',m,m',m''}=\frac{1}{\sqrt{5P}}\begin{bmatrix} v_{\frac{O_1}{4}l,\frac{O_2}{4}m} & v_{\frac{O_1}{4}l,\frac{O_2}{4}m} & v_{\frac{O_1}{4}l',\frac{O_2}{4}m'} & v_{\frac{O_1}{4}l',\frac{O_2}{4}m'} & v_{\frac{O_1}{4}l'',\frac{O_2}{4}m''} \\ v_{\frac{O_1}{4}l,\frac{O_2}{4}m} & -v_{\frac{O_1}{4}l,\frac{O_2}{4}m} & v_{\frac{O_1}{4}l',\frac{O_2}{4}m'} & -v_{\frac{O_1}{4}l',\frac{O_2}{4}m'} & v_{\frac{O_1}{4}l'',\frac{O_2}{4}m''} \end{bmatrix}$ for *Codebook-Config* = 2-4 $W^{(5)}_{l,l',l'',m,m',m''}=\frac{1}{\sqrt{5P}}\begin{bmatrix} v_{l,m} & v_{l,m} & v_{l',m'} & v_{l',m'} & v_{l'',m''} \\ v_{l,m} & -v_{l,m} & v_{l',m'} & -v_{l',m'} & v_{l'',m''} \end{bmatrix}$ for *Codebook-Config* = 1				

5 Layers, $P=16$				
Value of *Codebook-Config*	**Configuration**	$i_{1,1}$	$i_{1,2}$	
1	$N_1>1, N_2>1$	$0,1,\cdots,O_1N_1-1$	$0,1,\cdots,O_2N_2-1$	$W^{(5)}_{i_{1,1},i_{1,1}+O_1,i_{1,1}+O_1,i_{1,2},i_{1,2},i_{1,2}+O_2}$
	$N_2=1$	$0,1,\cdots,O_1N_1-1$	0	$W^{(5)}_{i_{1,1},i_{1,1}+O_1,i_{1,1}+2O_1,i_{1,2},i_{1,2},i_{1,2}}$
2	$N_1>1,\ N_2>1$	$0,1,\cdots,4N_1-1$	$0,1,\cdots,4N_2-1$	$W^{(5)}_{i_{1,1},i_{1,1}+4,i_{1,1}+4,i_{1,2},i_{1,2},i_{1,2}+4}$
3	$N_1 \geq N_2$	$0,1,\cdots,4N_1-1$	$0,1,\cdots,4N_2-1$	$W^{(5)}_{i_{1,1},i_{1,1}+4,i_{1,1}+8,i_{1,2},i_{1,2},i_{1,2}+4}$
	$N_1 < N_2$	$0,1,\cdots,4N_1-1$	$0,1,\cdots,4N_2-1$	$W^{(5)}_{i_{1,1},i_{1,1},i_{1,1}+4,i_{1,2},i_{1,2}+4,i_{1,2}+8}$
4	$N_1 > N_2, N_2 > 1$	$0,1,\cdots,4N_1-1$	$0,1,\cdots,4N_2-1$	$W^{(5)}_{i_{1,1},i_{1,1}+4,i_{1,1}+8,i_{1,2},i_{1,2},i_{1,2}}$
	$N_2=1$	$0,1,\cdots,4N_1-1$	0	$W^{(5)}_{i_{1,1},i_{1,1}+4,i_{1,1}+8,i_{1,2},i_{1,2},i_{1,2}}$
	$N_1 < N_2$	$0,1,\cdots,4N_1-1$	$0,1,\cdots,4N_2-1$	$W^{(5)}_{i_{1,1},i_{1,1},i_{1,1},i_{1,2},i_{1,2}+4,i_{1,2}+8}$

where

$$W^{(5)}_{l,l',l'',m,m',m''} = \frac{1}{\sqrt{5P}}\begin{bmatrix} v_{\frac{O_1}{4}l,\frac{O_2}{4}m} & v_{\frac{O_1}{4}l,\frac{O_2}{4}m} & v_{\frac{O_1}{4}l',\frac{O_2}{4}m'} & v_{\frac{O_1}{4}l',\frac{O_2}{4}m'} & v_{\frac{O_1}{4}l'',\frac{O_2}{4}m''} \\ v_{\frac{O_1}{4}l,\frac{O_2}{4}m} & -v_{\frac{O_1}{4}l,\frac{O_2}{4}m} & v_{\frac{O_1}{4}l',\frac{O_2}{4}m'} & -v_{\frac{O_1}{4}l',\frac{O_2}{4}m'} & v_{\frac{O_1}{4}l'',\frac{O_2}{4}m''} \end{bmatrix} \text{ for } \textit{Codebook-Config} = 2\text{-}4$$

$$W^{(5)}_{l,l',l'',m,m',m''} = \frac{1}{\sqrt{5P}}\begin{bmatrix} v_{l,m} & v_{l,m} & v_{l',m'} & v_{l',m'} & v_{l'',m''} \\ v_{l,m} & -v_{l,m} & v_{l',m'} & -v_{l',m'} & v_{l'',m''} \end{bmatrix} \text{ for } \textit{Codebook-Config} = 1$$

Table 7.2.4-15: Codebook for 6-layer CSI reporting using antenna ports 15 to 14+*P*

6 Layers, $P=8$, $N_1=N_2$			
Value of *Codebook-Config*	$i_{1,1}$	$i_{1,2}$	
1	$0,1,\cdots,O_1N_1-1$	$0,1,\cdots,O_2N_2-1$	$W^{(6)}_{i_{1,1},i_{1,1}+O_1,i_{1,1}+O_1,i_{1,2},i_{1,2},i_{1,2}+O_2}$
2-4	$0,1,\cdots,4N_1-1$	$0,1,\cdots,4N_2-1$	$W^{(6)}_{i_{1,1},i_{1,1}+4,i_{1,1}+4,i_{1,2},i_{1,2},i_{1,2}+4}$

where

$$W^{(6)}_{l,l',l'',m,m',m''} = \frac{1}{\sqrt{6P}}\begin{bmatrix} v_{\frac{O_1}{4}l,\frac{O_2}{4}m} & v_{\frac{O_1}{4}l,\frac{O_2}{4}m} & v_{\frac{O_1}{4}l',\frac{O_2}{4}m'} & v_{\frac{O_1}{4}l',\frac{O_2}{4}m'} & v_{\frac{O_1}{4}l'',\frac{O_2}{4}m''} & v_{\frac{O_1}{4}l'',\frac{O_2}{4}m''} \\ v_{\frac{O_1}{4}l,\frac{O_2}{4}m} & -v_{\frac{O_1}{4}l,\frac{O_2}{4}m} & v_{\frac{O_1}{4}l',\frac{O_2}{4}m'} & -v_{\frac{O_1}{4}l',\frac{O_2}{4}m'} & v_{\frac{O_1}{4}l'',\frac{O_2}{4}m''} & -v_{\frac{O_1}{4}l'',\frac{O_2}{4}m''} \end{bmatrix} \text{ for } \textit{Codebook-Config} = 2\text{-}4$$

$$W^{(6)}_{l,l',l'',m,m',m''} = \frac{1}{\sqrt{6P}}\begin{bmatrix} v_{l,m} & v_{l,m} & v_{l',m'} & v_{l',m'} & v_{l'',m''} & v_{l'',m''} \\ v_{l,m} & -v_{l,m} & v_{l',m'} & -v_{l',m'} & v_{l'',m''} & -v_{l'',m''} \end{bmatrix} \text{ for } \textit{Codebook-Config} = 1$$

6 Layers, *P=12*				
Value of *Codebook-Config*	**Configuration**	$i_{1,1}$	$i_{1,2}$	
1	$N_1>1,\ N_2\geq 1$	$0,1,\cdots,O_1N_1-1$	$0,1,\cdots,O_2N_2-1$	$W^{(6)}_{i_{1,1},i_{1,1}+O_1,i_{1,1}+O_1,i_{1,2},i_{1,2},i_{1,2}+O_2}$
2	$N_1>1,\ N_2>1$	$0,1,\cdots,4N_1-1$	$0,1,\cdots,4N_2-1$	$W^{(6)}_{i_{1,1},i_{1,1}+4,i_{1,1}+4,i_{1,2},i_{1,2},i_{1,2}+4}$
3	$N_1\geq N_2$	$0,1,\cdots,4N_1-1$	$0,1,\cdots,4N_2-1$	$W^{(6)}_{i_{1,1},i_{1,1}+4,i_{1,1}+8,i_{1,2},i_{1,2},i_{1,2}+4}$
	$N_1<N_2$	$0,1,\cdots,4N_1-1$	$0,1,\cdots,4N_2-1$	$W^{(6)}_{i_{1,1},i_{1,1},i_{1,1}+4,i_{1,2},i_{1,2}+4,i_{1,2}+8}$
4	$N_1\geq N_2$	$0,1,\cdots,4N_1-1$	$0,1,\cdots,4N_2-1$	$W^{(6)}_{i_{1,1},i_{1,1}+4,i_{1,1}+8,i_{1,2},i_{1,2},i_{1,2}}$
	$N_1<N_2$	$0,1,\cdots,4N_1-1$	$0,1,\cdots,4N_2-1$	$W^{(6)}_{i_{1,1},i_{1,1},i_{1,1},i_{1,2},i_{1,2}+4,i_{1,2}+8}$

where

$$W^{(6)}_{l,l',l'',m,m',m''}=\frac{1}{\sqrt{6P}}\begin{bmatrix} v_{\frac{O_1}{4}l,\frac{O_2}{4}m} & v_{\frac{O_1}{4}l,\frac{O_2}{4}m} & v_{\frac{O_1}{4}l',\frac{O_2}{4}m'} & v_{\frac{O_1}{4}l',\frac{O_2}{4}m'} & v_{\frac{O_1}{4}l'',\frac{O_2}{4}m''} & v_{\frac{O_1}{4}l'',\frac{O_2}{4}m''} \\ v_{\frac{O_1}{4}l,\frac{O_2}{4}m} & -v_{\frac{O_1}{4}l,\frac{O_2}{4}m} & v_{\frac{O_1}{4}l',\frac{O_2}{4}m'} & -v_{\frac{O_1}{4}l',\frac{O_2}{4}m'} & v_{\frac{O_1}{4}l'',\frac{O_2}{4}m''} & -v_{\frac{O_1}{4}l'',\frac{O_2}{4}m''} \end{bmatrix}$$ for *Codebook-Config* = 2-4

$$W^{(6)}_{l,l',l'',m,m',m''}=\frac{1}{\sqrt{6P}}\begin{bmatrix} v_{l,m} & v_{l,m} & v_{l',m'} & v_{l',m'} & v_{l'',m''} & v_{l'',m''} \\ v_{l,m} & -v_{l,m} & v_{l',m'} & -v_{l',m'} & v_{l'',m''} & -v_{l'',m''} \end{bmatrix}$$ for *Codebook-Config* = 1

6 Layers, *P=16*				
Value of *Codebook-Config*	**Configuration**	$i_{1,1}$	$i_{1,2}$	
1	$N_1>1, N_2>1$	$0,1,\cdots,O_1N_1-1$	$0,1,\cdots,O_2N_2-1$	$W^{(6)}_{i_{1,1},i_{1,1}+O_1,i_{1,1}+O_1,i_{1,2},i_{1,2},i_{1,2}+O_2}$
	$N_2=1$	$0,1,\cdots,O_1N_1-1$	0	$W^{(6)}_{i_{1,1},i_{1,1}+O_1,i_{1,1}+2O_1,i_{1,2},i_{1,2},i_{1,2}}$
2	$N_1>1,\ N_2>1$	$0,1,\cdots,4N_1-1$	$0,1,\cdots,4N_2-1$	$W^{(6)}_{i_{1,1},i_{1,1}+4,i_{1,1}+4,i_{1,2},i_{1,2},i_{1,2}+4}$
3	$N_1\geq N_2$	$0,1,\cdots,4N_1-1$	$0,1,\cdots,4N_2-1$	$W^{(6)}_{i_{1,1},i_{1,1}+4,i_{1,1}+8,i_{1,2},i_{1,2},i_{1,2}+4}$
	$N_1<N_2$	$0,1,\cdots,4N_1-1$	$0,1,\cdots,4N_2-1$	$W^{(6)}_{i_{1,1},i_{1,1},i_{1,1}+4,i_{1,2},i_{1,2}+4,i_{1,2}+8}$
4	$N_1>N_2, N_2>1$	$0,1,\cdots,4N_1-1$	$0,1,\cdots,4N_2-1$	$W^{(6)}_{i_{1,1},i_{1,1}+4,i_{1,1}+8,i_{1,2},i_{1,2},i_{1,2}}$
	$N_2=1$	$0,1,\cdots,4N_1-1$	0	$W^{(6)}_{i_{1,1},i_{1,1}+4,i_{1,1}+8,i_{1,2},i_{1,2},i_{1,2}}$
	$N_1<N_2$	$0,1,\cdots,4N_1-1$	$0,1,\cdots,4N_2-1$	$W^{(6)}_{i_{1,1},i_{1,1},i_{1,1},i_{1,2},i_{1,2}+4,i_{1,2}+8}$

where

$$W^{(6)}_{l,l',l'',m,m',m''}=\frac{1}{\sqrt{6P}}\begin{bmatrix} v_{\frac{O_1}{4}l,\frac{O_2}{4}m} & v_{\frac{O_1}{4}l,\frac{O_2}{4}m} & v_{\frac{O_1}{4}l',\frac{O_2}{4}m'} & v_{\frac{O_1}{4}l',\frac{O_2}{4}m'} & v_{\frac{O_1}{4}l'',\frac{O_2}{4}m''} & v_{\frac{O_1}{4}l'',\frac{O_2}{4}m''} \\ v_{\frac{O_1}{4}l,\frac{O_2}{4}m} & -v_{\frac{O_1}{4}l,\frac{O_2}{4}m} & v_{\frac{O_1}{4}l',\frac{O_2}{4}m'} & -v_{\frac{O_1}{4}l',\frac{O_2}{4}m'} & v_{\frac{O_1}{4}l'',\frac{O_2}{4}m''} & -v_{\frac{O_1}{4}l'',\frac{O_2}{4}m''} \end{bmatrix}$$ for *Codebook-Config* = 2-4

$$W^{(6)}_{l,l',l'',m,m',m''}=\frac{1}{\sqrt{6P}}\begin{bmatrix} v_{l,m} & v_{l,m} & v_{l',m'} & v_{l',m'} & v_{l'',m''} & v_{l'',m''} \\ v_{l,m} & -v_{l,m} & v_{l',m'} & -v_{l',m'} & v_{l'',m''} & -v_{l'',m''} \end{bmatrix}$$ and for *Codebook-Config* = 1

Table 7.2.4-16: Codebook for 7-layer CSI reporting using antenna ports 15 to 14+*P*

7 Layers $P=8$, $N_1=N_2$			
Value of *Codebook-Config*	$i_{1,1}$	$i_{1,2}$	
1	$0,1,\cdots,O_1N_1-1$	$0,1,\cdots,O_2N_2-1$	$W^{(7)}_{i_{1,1},i_{1,1}+O_1,i_{1,1}+O_1,i_{1,1},i_{1,2},i_{1,2},i_{1,2}+O_2,i_{1,2}+O_2}$
2-4	$0,1,\cdots,4N_1-1$	$0,1,\cdots,4N_2-1$	$W^{(7)}_{i_{1,1},i_{1,1}+4,i_{1,1}+4,i_{1,1},i_{1,2},i_{1,2},i_{1,2}+4,i_{1,2}+4}$

where

$$W^{(7)}_{l,l',l'',l''',m,m',m'',m'''}=\frac{1}{\sqrt{7P}}\begin{bmatrix} v_{\frac{O_1}{4}l,\frac{O_2}{4}m} & v_{\frac{O_1}{4}l,\frac{O_2}{4}m} & v_{\frac{O_1}{4}l',\frac{O_2}{4}m'} & v_{\frac{O_1}{4}l',\frac{O_2}{4}m'} & v_{\frac{O_1}{4}l'',\frac{O_2}{4}m''} & v_{\frac{O_1}{4}l'',\frac{O_2}{4}m''} & v_{\frac{O_1}{4}l''',\frac{O_2}{4}m'''} \\ v_{\frac{O_1}{4}l,\frac{O_2}{4}m} & -v_{\frac{O_1}{4}l,\frac{O_2}{4}m} & v_{\frac{O_1}{4}l',\frac{O_2}{4}m'} & -v_{\frac{O_1}{4}l',\frac{O_2}{4}m'} & v_{\frac{O_1}{4}l'',\frac{O_2}{4}m''} & -v_{\frac{O_1}{4}l'',\frac{O_2}{4}m''} & v_{\frac{O_1}{4}l''',\frac{O_2}{4}m'''} \end{bmatrix}$$ for *Codebook-Config* = 2-4

$$W^{(7)}_{l,l',l'',l''',m,m',m'',m'''}=\frac{1}{\sqrt{7P}}\begin{bmatrix} v_{l,m} & v_{l,m} & v_{l',m'} & v_{l',m'} & v_{l'',m''} & v_{l'',m''} & v_{l''',m'''} \\ v_{l,m} & -v_{l,m} & v_{l',m'} & -v_{l',m'} & v_{l'',m''} & -v_{l'',m''} & v_{l''',m'''} \end{bmatrix}$$ for *Codebook-Config* = 1

7 Layers, $P=12$				
Value of *Codebook-Config*	**Configuration**	$i_{1,1}$	$i_{1,2}$	
1	$N_1>1,\ N_2\geq 1$	$0,1,\cdots,O_1N_1-1$	$0,1,\cdots,O_2N_2-1$	$W^{(7)}_{i_{1,1},i_{1,1}+O_1,i_{1,1}+O_1,i_{1,1},i_{1,2},i_{1,2},i_{1,2}+O_2,i_{1,2}+O_2}$
2	$N_1>1,\ N_2>1$	$0,1,\cdots,4N_1-1$	$0,1,\cdots,4N_2-1$	$W^{(7)}_{i_{1,1},i_{1,1}+4,i_{1,1}+4,i_{1,1},i_{1,2},i_{1,2},i_{1,2}+4,i_{1,2}+4}$
3	$N_1\geq N_2$	$0,1,\cdots,4N_1-1$	$0,1,\cdots,4N_2-1$	$W^{(7)}_{i_{1,1},i_{1,1}+4,i_{1,1}+8,i_{1,1}+4,i_{1,2},i_{1,2},i_{1,2}+4,i_{1,2}+4}$
	$N_1<N_2$	$0,1,\cdots,4N_1-1$	$0,1,\cdots,4N_2-1$	$W^{(7)}_{i_{1,1},i_{1,1},i_{1,1}+4,i_{1,1}+4,i_{1,2},i_{1,2}+4,i_{1,2}+8,i_{1,2}+4}$
4	$N_1\geq N_2$	$0,1,\cdots,4N_1-1$	$0,1,\cdots,4N_2-1$	$W^{(7)}_{i_{1,1},i_{1,1}+4,i_{1,1}+8,i_{1,1},i_{1,2},i_{1,2},i_{1,2},i_{1,2}+4}$
	$N_1<N_2$	$0,1,\cdots,4N_1-1$	$0,1,\cdots,4N_2-1$	$W^{(7)}_{i_{1,1},i_{1,1},i_{1,1},i_{1,1}+4,i_{1,2},i_{1,2}+4,i_{1,2}+8,i_{1,2}}$

where

$$W^{(7)}_{l,l',l'',l''',m,m',m'',m'''}=\frac{1}{\sqrt{7P}}\begin{bmatrix} v_{l,m} & v_{l,m} & v_{l',m'} & v_{l',m'} & v_{l'',m''} & v_{l'',m''} & v_{l''',m'''} \\ v_{l,m} & -v_{l,m} & v_{l',m'} & -v_{l',m'} & v_{l'',m''} & -v_{l'',m''} & v_{l''',m'''} \end{bmatrix}$$ for *Codebook-Config* = 2-4

$$W^{(7)}_{l,l',l'',l''',m,m',m'',m'''}=\frac{1}{\sqrt{7P}}\begin{bmatrix} v_{l,m} & v_{l,m} & v_{l',m'} & v_{l',m'} & v_{l'',m''} & v_{l'',m''} & v_{l''',m'''} \\ v_{l,m} & -v_{l,m} & v_{l',m'} & -v_{l',m'} & v_{l'',m''} & -v_{l'',m''} & v_{l''',m'''} \end{bmatrix}$$ for *Codebook-Config* = 1

7 Layers, $P=16$				
Value of *Codebook-Config*	**Configuration**	$i_{1,1}$	$i_{1,2}$	
1	$N_1>1, N_2>1$	$0,1,\cdots,O_1N_1-1$	$0,1,\cdots,O_2N_2-1$	$W^{(7)}_{i_{1,1},i_{1,1}+O_1,i_{1,1}+O_1,i_{1,1},i_{1,2},i_{1,2},i_{1,2}+O_2,i_{1,2}+O_2}$
	$N_2=1$	$0,1,\cdots,O_1N_1-1$	0	$W^{(7)}_{i_{1,1},i_{1,1}+O_1,i_{1,1}+2O_1,i_{1,1}+3O_1,i_{1,2},i_{1,2},i_{1,2},i_{1,2}}$
2	$N_1>1,\ N_2>1$	$0,1,\cdots,4N_1-1$	$0,1,\cdots,4N_2-1$	$W^{(7)}_{i_{1,1},i_{1,1}+4,i_{1,1}+4,i_{1,1},i_{1,2},i_{1,2},i_{1,2}+4,i_{1,2}+4}$
3	$N_1 \ge N_2$	$0,1,\cdots,4N_1-1$	$0,1,\cdots,4N_2-1$	$W^{(7)}_{i_{1,1},i_{1,1}+4,i_{1,1}+8,i_{1,1}+12,i_{1,2},i_{1,2},i_{1,2}+4,i_{1,2}+4}$
	$N_1 < N_2$	$0,1,\cdots,4N_1-1$	$0,1,\cdots,4N_2-1$	$W^{(7)}_{i_{1,1},i_{1,1},i_{1,1}+4,i_{1,1}+4,i_{1,2},i_{1,2}+4,i_{1,2}+8,i_{1,2}+12}$
4	$N_1>N_2, N_2>1$	$0,1,\cdots,4N_1-1$	$0,1,\cdots,4N_2-1$	$W^{(7)}_{i_{1,1},i_{1,1}+4,i_{1,1}+8,i_{1,1}+12,i_{1,2},i_{1,2},i_{1,2},i_{1,2}}$
	$N_2=1$	$0,1,\cdots,4N_1-1$	0	$W^{(7)}_{i_{1,1},i_{1,1}+4,i_{1,1}+8,i_{1,1}+12,i_{1,2},i_{1,2},i_{1,2},i_{1,2}}$
	$N_1 < N_2$	$0,1,\cdots,4N_1-1$	$0,1,\cdots,4N_2-1$	$W^{(7)}_{i_{1,1},i_{1,1},i_{1,1},i_{1,1},i_{1,2},i_{1,2}+4,i_{1,2}+8,i_{1,2}+12}$

where

$$W^{(7)}_{l,l',l'',l''',m,m',m'',m'''}=\frac{1}{\sqrt{7P}}\begin{bmatrix} v_{\frac{O_1}{4}l,\frac{O_2}{4}m} & v_{\frac{O_1}{4}l,\frac{O_2}{4}m} & v_{\frac{O_1}{4}l',\frac{O_2}{4}m'} & v_{\frac{O_1}{4}l',\frac{O_2}{4}m'} & v_{\frac{O_1}{4}l'',\frac{O_2}{4}m''} & v_{\frac{O_1}{4}l'',\frac{O_2}{4}m''} & v_{\frac{O_1}{4}l''',\frac{O_2}{4}m'''} \\ v_{\frac{O_1}{4}l,\frac{O_2}{4}m} & -v_{\frac{O_1}{4}l,\frac{O_2}{4}m} & v_{\frac{O_1}{4}l',\frac{O_2}{4}m'} & -v_{\frac{O_1}{4}l',\frac{O_2}{4}m'} & v_{\frac{O_1}{4}l'',\frac{O_2}{4}m''} & -v_{\frac{O_1}{4}l'',\frac{O_2}{4}m''} & v_{\frac{O_1}{4}l''',\frac{O_2}{4}m'''} \end{bmatrix}$$ for *Codebook-Config* = 2-4

$$W^{(7)}_{l,l',l'',l''',m,m',m'',m'''}=\frac{1}{\sqrt{7P}}\begin{bmatrix} v_{l,m} & v_{l,m} & v_{l',m'} & v_{l',m'} & v_{l'',m''} & v_{l'',m''} & v_{l''',m'''} \\ v_{l,m} & -v_{l,m} & v_{l',m'} & -v_{l',m'} & v_{l'',m''} & -v_{l'',m''} & v_{l''',m'''} \end{bmatrix}$$ and for *Codebook-Config* = 1

Table 7.2.4-17: Codebook for 8-layer CSI reporting using antenna ports 15 to 14+*P*

8 Layers, $P=8$, $N_1=N_2$			
Value of *Codebook-Config*	$i_{1,1}$	$i_{1,2}$	
1	$0,1,\cdots,O_1N_1-1$	$0,1,\cdots,O_2N_2-1$	$W^{(8)}_{i_{1,1},i_{1,1}+O_1,i_{1,1}+O_1,i_{1,1},i_{1,2},i_{1,2},i_{1,2}+O_2,i_{1,2}+O_2}$
2-4	$0,1,\cdots,4N_1-1$	$0,1,\cdots,4N_2-1$	$W^{(8)}_{i_{1,1},i_{1,1}+4,i_{1,1}+4,i_{1,1},i_{1,2},i_{1,2},i_{1,2}+4,i_{1,2}+4}$

where $$W^{(8)}_{l,l',l'',l''',m,m',m'',m'''}=\frac{1}{\sqrt{8P}}\begin{bmatrix} v_{\frac{O_1}{4}l,\frac{O_2}{4}m} & v_{\frac{O_1}{4}l,\frac{O_2}{4}m} & v_{\frac{O_1}{4}l',\frac{O_2}{4}m'} & v_{\frac{O_1}{4}l',\frac{O_2}{4}m'} & v_{\frac{O_1}{4}l'',\frac{O_2}{4}m''} & v_{\frac{O_1}{4}l'',\frac{O_2}{4}m''} & v_{\frac{O_1}{4}l''',\frac{O_2}{4}m'''} & v_{\frac{O_1}{4}l''',\frac{O_2}{4}m'''} \\ v_{\frac{O_1}{4}l,\frac{O_2}{4}m} & -v_{\frac{O_1}{4}l,\frac{O_2}{4}m} & v_{\frac{O_1}{4}l',\frac{O_2}{4}m'} & -v_{\frac{O_1}{4}l',\frac{O_2}{4}m'} & v_{\frac{O_1}{4}l'',\frac{O_2}{4}m''} & -v_{\frac{O_1}{4}l'',\frac{O_2}{4}m''} & v_{\frac{O_1}{4}l''',\frac{O_2}{4}m'''} & -v_{\frac{O_1}{4}l''',\frac{O_2}{4}m'''} \end{bmatrix}$$ for *Codebook-Config* = 2-4

$$W^{(8)}_{l,l',l'',l''',m,m',m'',m'''}=\frac{1}{\sqrt{8P}}\begin{bmatrix} v_{l,m} & v_{l,m} & v_{l',m'} & v_{l',m'} & v_{l'',m''} & v_{l'',m''} & v_{l''',m'''} & v_{l''',m'''} \\ v_{l,m} & -v_{l,m} & v_{l',m'} & -v_{l',m'} & v_{l'',m''} & -v_{l'',m''} & v_{l''',m'''} & -v_{l''',m'''} \end{bmatrix}$$

for *Codebook-Config* = 1

8 Layers, $P=12$				
Value of *Codebook-Config*	**Configuration**	$i_{1,1}$	$i_{1,2}$	
1	$N_1>1,\ N_2\geq 1$	$0,1,\cdots,O_1N_1-1$	$0,1,\cdots,O_2N_2-1$	$W^{(8)}_{i_{1,1},i_{1,1}+O_1,i_{1,1}+O_1,i_{1,1},i_{1,2},i_{1,2},i_{1,2}+O_2,i_{1,2}+O_2}$
2	$N_1>1,\ N_2>1$	$0,1,\cdots,4N_1-1$	$0,1,\cdots,4N_2-1$	$W^{(8)}_{i_{1,1},i_{1,1}+4,i_{1,1}+4,i_{1,1},i_{1,2},i_{1,2},i_{1,2}+4,i_{1,2}+4}$
3	$N_1\geq N_2$	$0,1,\cdots,4N_1-1$	$0,1,\cdots,4N_2-1$	$W^{(8)}_{i_{1,1},i_{1,1}+4,i_{1,1}+8,i_{1,1}+4,i_{1,2},i_{1,2},i_{1,2}+4,i_{1,2}+4}$
	$N_1<N_2$	$0,1,\cdots,4N_1-1$	$0,1,\cdots,4N_2-1$	$W^{(8)}_{i_{1,1},i_{1,1},i_{1,1}+4,i_{1,1}+4,i_{1,2},i_{1,2}+4,i_{1,2}+8,i_{1,2}+4}$
4	$N_1\geq N_2$	$0,1,\cdots,4N_1-1$	$0,1,\cdots,4N_2-1$	$W^{(8)}_{i_{1,1},i_{1,1}+4,i_{1,1}+8,i_{1,1},i_{1,2},i_{1,2},i_{1,2},i_{1,2}+4}$
	$N_1<N_2$	$0,1,\cdots,4N_1-1$	$0,1,\cdots,4N_2-1$	$W^{(8)}_{i_{1,1},i_{1,1},i_{1,1},i_{1,1}+4,i_{1,2},i_{1,2}+4,i_{1,2}+8,i_{1,2}}$

where $W^{(8)}_{l,l',l'',l''',m,m',m'',m'''}=\frac{1}{\sqrt{8P}}\begin{bmatrix} v_{\frac{O_1}{4}l,\frac{O_2}{4}m} & v_{\frac{O_1}{4}l,\frac{O_2}{4}m} & v_{\frac{O_1}{4}l',\frac{O_2}{4}m'} & v_{\frac{O_1}{4}l',\frac{O_2}{4}m'} & v_{\frac{O_1}{4}l'',\frac{O_2}{4}m''} & v_{\frac{O_1}{4}l'',\frac{O_2}{4}m''} & v_{\frac{O_1}{4}l''',\frac{O_2}{4}m'''} & v_{\frac{O_1}{4}l''',\frac{O_2}{4}m'''} \\ v_{\frac{O_1}{4}l,\frac{O_2}{4}m} & -v_{\frac{O_1}{4}l,\frac{O_2}{4}m} & v_{\frac{O_1}{4}l',\frac{O_2}{4}m'} & -v_{\frac{O_1}{4}l',\frac{O_2}{4}m'} & v_{\frac{O_1}{4}l'',\frac{O_2}{4}m''} & -v_{\frac{O_1}{4}l'',\frac{O_2}{4}m''} & v_{\frac{O_1}{4}l''',\frac{O_2}{4}m'''} & -v_{\frac{O_1}{4}l''',\frac{O_2}{4}m'''} \end{bmatrix}$ for *Codebook-Config* = 2-4

$W^{(8)}_{l,l',l'',l''',m,m',m'',m'''}=\frac{1}{\sqrt{8P}}\begin{bmatrix} v_{l,m} & v_{l,m} & v_{l',m'} & v_{l',m'} & v_{l'',m''} & v_{l'',m''} & v_{l''',m'''} & v_{l''',m'''} \\ v_{l,m} & -v_{l,m} & v_{l',m'} & -v_{l',m'} & v_{l'',m''} & -v_{l'',m''} & v_{l''',m'''} & -v_{l''',m'''} \end{bmatrix}$ for *Codebook-Config* = 1

8 Layers, $P=16$				
Value of *Codebook-Config*	**Configuration**	$i_{1,1}$	$i_{1,2}$	
1	$N_1>1, N_2>1$	$0,1,\cdots,O_1N_1-1$	$0,1,\cdots,O_2N_2-1$	$W^{(8)}_{i_{1,1},i_{1,1}+O_1,i_{1,1}+O_1,i_{1,1},i_{1,2},i_{1,2},i_{1,2}+O_2,i_{1,2}+O_2}$
	$N_2=1$	$0,1,\cdots,O_1N_1-1$	0	$W^{(8)}_{i_{1,1},i_{1,1}+O_1,i_{1,1}+2O_1,i_{1,1}+3O_1,i_{1,2},i_{1,2},i_{1,2},i_{1,2}}$
2	$N_1>1,\ N_2>1$	$0,1,\cdots,4N_1-1$	$0,1,\cdots,4N_2-1$	$W^{(8)}_{i_{1,1},i_{1,1}+4,i_{1,1}+4,i_{1,1},i_{1,2},i_{1,2},i_{1,2}+4,i_{1,2}+4}$
3	$N_1\geq N_2$	$0,1,\cdots,4N_1-1$	$0,1,\cdots,4N_2-1$	$W^{(8)}_{i_{1,1},i_{1,1}+4,i_{1,1}+8,i_{1,1}+12,i_{1,2},i_{1,2},i_{1,2}+4,i_{1,2}+4}$
	$N_1<N_2$	$0,1,\cdots,4N_1-1$	$0,1,\cdots,4N_2-1$	$W^{(8)}_{i_{1,1},i_{1,1},i_{1,1}+4,i_{1,1}+4,i_{1,2},i_{1,2}+4,i_{1,2}+8,i_{1,2}+12}$
4	$N_1>N_2, N_2>1$	$0,1,\cdots,4N_1-1$	$0,1,\cdots,4N_2-1$	$W^{(8)}_{i_{1,1},i_{1,1}+4,i_{1,1}+8,i_{1,1}+12,i_{1,2},i_{1,2},i_{1,2},i_{1,2}}$
	$N_2=1$	$0,1,\cdots,4N_1-1$	0	$W^{(8)}_{i_{1,1},i_{1,1}+4,i_{1,1}+8,i_{1,1}+12,i_{1,2},i_{1,2},i_{1,2},i_{1,2}}$
	$N_1<N_2$	$0,1,\cdots,4N_1-1$	$0,1,\cdots,4N_2-1$	$W^{(8)}_{i_{1,1},i_{1,1},i_{1,1},i_{1,1},i_{1,2},i_{1,2}+4,i_{1,2}+8,i_{1,2}+12}$

where $W^{(8)}_{l,l',l'',l''',m,m',m'',m'''}=\frac{1}{\sqrt{8P}}\begin{bmatrix} v_{\frac{O_1}{4}l,\frac{O_2}{4}m} & v_{\frac{O_1}{4}l,\frac{O_2}{4}m} & v_{\frac{O_1}{4}l',\frac{O_2}{4}m'} & v_{\frac{O_1}{4}l',\frac{O_2}{4}m'} & v_{\frac{O_1}{4}l'',\frac{O_2}{4}m''} & v_{\frac{O_1}{4}l'',\frac{O_2}{4}m''} & v_{\frac{O_1}{4}l''',\frac{O_2}{4}m'''} & v_{\frac{O_1}{4}l''',\frac{O_2}{4}m'''} \\ v_{\frac{O_1}{4}l,\frac{O_2}{4}m} & -v_{\frac{O_1}{4}l,\frac{O_2}{4}m} & v_{\frac{O_1}{4}l',\frac{O_2}{4}m'} & -v_{\frac{O_1}{4}l',\frac{O_2}{4}m'} & v_{\frac{O_1}{4}l'',\frac{O_2}{4}m''} & -v_{\frac{O_1}{4}l'',\frac{O_2}{4}m''} & v_{\frac{O_1}{4}l''',\frac{O_2}{4}m'''} & -v_{\frac{O_1}{4}l''',\frac{O_2}{4}m'''} \end{bmatrix}$ for *Codebook-Config* = 1

$W^{(8)}_{l,l',l'',l''',m,m',m'',m'''}=\frac{1}{\sqrt{8P}}\begin{bmatrix} v_{l,m} & v_{l,m} & v_{l',m'} & v_{l',m'} & v_{l'',m''} & v_{l'',m''} & v_{l''',m'''} & v_{l''',m'''} \\ v_{l,m} & -v_{l,m} & v_{l',m'} & -v_{l',m'} & v_{l'',m''} & -v_{l'',m''} & v_{l''',m'''} & -v_{l''',m'''} \end{bmatrix}$ *Codebook-Config* = 2-4

For a UE configured with higher layer parameter *eMIMO-Type*, and *eMIMO-Type* is set to 'CLASS B', and one CSI-RS resource configured, and higher layer parameter *alternativeCodebookEnabledCLASSB_K1=TRUE* configured,

- For 2 antenna ports $\{15,16\}$, a PMI value corresponds to the codebook index n given in Table 7.2.4-18 with υ equal to the associated RI value.
- For 4 antenna ports $\{15,16,17,18\}$, a PMI corresponds to the codebook index n given in Table 7.2.4-19 with υ equal to the associated RI value.
- For 8 antenna ports $\{15,16,17,18,19,20,21,22\}$, a PMI value corresponds to the codebook index n given in Table 7.2.4-20 with υ equal to the associated RI value.

where $e_k^{(N)}$ is a length-*N* column-vector where its *l*-th element is 1 for *k*=*l* ($k,l \in \{0,1,\cdots,N-1\}$), and 0 otherwise.

Table 7.2.4-18: Codebook for υ-layer CSI reporting using antenna ports $\{15,16\}$

Codebook index, *n*	Number of layers υ	
	1	**2**
0	$\frac{1}{\sqrt{2}}\begin{bmatrix}1\\1\end{bmatrix}$	$\frac{1}{2}\begin{bmatrix}1 & 1\\1 & -1\end{bmatrix}$
1	$\frac{1}{\sqrt{2}}\begin{bmatrix}1\\-1\end{bmatrix}$	$\frac{1}{2}\begin{bmatrix}1 & 1\\j & -j\end{bmatrix}$
2	$\frac{1}{\sqrt{2}}\begin{bmatrix}1\\j\end{bmatrix}$	-
3	$\frac{1}{\sqrt{2}}\begin{bmatrix}1\\-j\end{bmatrix}$	-

Table 7.2.4-19: Codebook for υ-layer CSI reporting using antenna ports $\{15,16,17,18\}$

Codebook index, *n*	Number of layers υ			
	1	**2**	**3**	**4**
0	$\frac{1}{\sqrt{2}}\begin{bmatrix} e_0^{(2)} \\ e_0^{(2)} \end{bmatrix}$	$\frac{1}{2}\begin{bmatrix} e_0^{(2)} & e_0^{(2)} \\ e_0^{(2)} & -e_0^{(2)} \end{bmatrix}$	$\frac{1}{\sqrt{6}}\begin{bmatrix} e_0^{(2)} & e_0^{(2)} & e_1^{(2)} \\ e_0^{(2)} & -e_0^{(2)} & -e_1^{(2)} \end{bmatrix}$	$\frac{1}{2\sqrt{2}}\begin{bmatrix} e_0^{(2)} & e_1^{(2)} & e_0^{(2)} & e_1^{(2)} \\ e_0^{(2)} & e_1^{(2)} & -e_0^{(2)} & -e_1^{(2)} \end{bmatrix}$
1	$\frac{1}{\sqrt{2}}\begin{bmatrix} e_0^{(2)} \\ -e_0^{(2)} \end{bmatrix}$	$\frac{1}{2}\begin{bmatrix} e_0^{(2)} & e_0^{(2)} \\ je_0^{(2)} & -je_0^{(2)} \end{bmatrix}$	$\frac{1}{\sqrt{6}}\begin{bmatrix} e_1^{(2)} & e_0^{(2)} & e_1^{(2)} \\ e_1^{(2)} & -e_0^{(2)} & -e_1^{(2)} \end{bmatrix}$	$\frac{1}{2\sqrt{2}}\begin{bmatrix} e_0^{(2)} & e_1^{(2)} & e_0^{(2)} & e_1^{(2)} \\ je_0^{(2)} & je_1^{(2)} & -je_0^{(2)} & -je_1^{(2)} \end{bmatrix}$
2	$\frac{1}{\sqrt{2}}\begin{bmatrix} e_0^{(2)} \\ j\cdot e_0^{(2)} \end{bmatrix}$	$\frac{1}{2}\begin{bmatrix} e_1^{(2)} & e_1^{(2)} \\ e_1^{(2)} & -e_1^{(2)} \end{bmatrix}$	$\frac{1}{\sqrt{6}}\begin{bmatrix} e_0^{(2)} & e_1^{(2)} & e_1^{(2)} \\ e_0^{(2)} & e_1^{(2)} & -e_1^{(2)} \end{bmatrix}$	-
3	$\frac{1}{\sqrt{2}}\begin{bmatrix} e_0^{(2)} \\ -j\cdot e_0^{(2)} \end{bmatrix}$	$\frac{1}{2}\begin{bmatrix} e_1^{(2)} & e_1^{(2)} \\ je_1^{(2)} & -je_1^{(2)} \end{bmatrix}$	$\frac{1}{\sqrt{6}}\begin{bmatrix} e_1^{(2)} & e_0^{(2)} & e_0^{(2)} \\ e_1^{(2)} & e_0^{(2)} & -e_0^{(2)} \end{bmatrix}$	-
4	$\frac{1}{\sqrt{2}}\begin{bmatrix} e_1^{(2)} \\ e_1^{(2)} \end{bmatrix}$	$\frac{1}{2}\begin{bmatrix} e_0^{(2)} & e_1^{(2)} \\ e_0^{(2)} & -e_1^{(2)} \end{bmatrix}$	-	-
5	$\frac{1}{\sqrt{2}}\begin{bmatrix} e_1^{(2)} \\ -e_1^{(2)} \end{bmatrix}$	$\frac{1}{2}\begin{bmatrix} e_0^{(2)} & e_1^{(2)} \\ je_0^{(2)} & -je_1^{(2)} \end{bmatrix}$	-	-
6	$\frac{1}{\sqrt{2}}\begin{bmatrix} e_1^{(2)} \\ j\cdot e_1^{(2)} \end{bmatrix}$	$\frac{1}{2}\begin{bmatrix} e_1^{(2)} & e_0^{(2)} \\ e_1^{(2)} & -e_0^{(2)} \end{bmatrix}$	-	-
7	$\frac{1}{\sqrt{2}}\begin{bmatrix} e_1^{(2)} \\ -j\cdot e_1^{(2)} \end{bmatrix}$	$\frac{1}{2}\begin{bmatrix} e_1^{(2)} & e_0^{(2)} \\ je_1^{(2)} & -je_0^{(2)} \end{bmatrix}$	-	-

Table 7.2.4-20: Codebook for υ-layer CSI reporting using antenna ports $\{15,16,17,18,19,20,21,22\}$

Codebook index, *n*	Number of layers υ			
	1	2	3	4
0	$\frac{1}{\sqrt{2}}\begin{bmatrix} e_0^{(4)} \\ e_0^{(4)} \end{bmatrix}$	$\frac{1}{2}\begin{bmatrix} e_0^{(4)} & e_0^{(4)} \\ e_0^{(4)} & -e_0^{(4)} \end{bmatrix}$	$\frac{1}{\sqrt{6}}\begin{bmatrix} e_0^{(4)} & e_0^{(4)} & e_1^{(4)} \\ e_0^{(4)} & -e_0^{(4)} & -e_1^{(4)} \end{bmatrix}$	$\frac{1}{2\sqrt{2}}\begin{bmatrix} e_0^{(4)} & e_1^{(4)} & e_0^{(4)} & e_1^{(4)} \\ e_0^{(4)} & e_1^{(4)} & -e_0^{(4)} & -e_1^{(4)} \end{bmatrix}$
1	$\frac{1}{\sqrt{2}}\begin{bmatrix} e_0^{(4)} \\ -e_0^{(4)} \end{bmatrix}$	$\frac{1}{2}\begin{bmatrix} e_0^{(4)} & e_0^{(4)} \\ je_0^{(4)} & -je_0^{(4)} \end{bmatrix}$	$\frac{1}{\sqrt{6}}\begin{bmatrix} e_1^{(4)} & e_0^{(4)} & e_1^{(4)} \\ e_1^{(4)} & -e_0^{(4)} & -e_1^{(4)} \end{bmatrix}$	$\frac{1}{2\sqrt{2}}\begin{bmatrix} e_0^{(4)} & e_1^{(4)} & e_0^{(4)} & e_1^{(4)} \\ je_0^{(4)} & je_1^{(4)} & -je_0^{(4)} & -je_1^{(4)} \end{bmatrix}$
2	$\frac{1}{\sqrt{2}}\begin{bmatrix} e_0^{(4)} \\ j\cdot e_0^{(4)} \end{bmatrix}$	$\frac{1}{2}\begin{bmatrix} e_1^{(4)} & e_1^{(4)} \\ e_1^{(4)} & -e_1^{(4)} \end{bmatrix}$	$\frac{1}{\sqrt{6}}\begin{bmatrix} e_0^{(4)} & e_1^{(4)} & e_1^{(4)} \\ e_0^{(4)} & e_1^{(4)} & -e_1^{(4)} \end{bmatrix}$	$\frac{1}{2\sqrt{2}}\begin{bmatrix} e_1^{(4)} & e_2^{(4)} & e_1^{(4)} & e_2^{(4)} \\ e_1^{(4)} & e_2^{(4)} & -e_1^{(4)} & -e_2^{(4)} \end{bmatrix}$
3	$\frac{1}{\sqrt{2}}\begin{bmatrix} e_0^{(4)} \\ -j\cdot e_0^{(4)} \end{bmatrix}$	$\frac{1}{2}\begin{bmatrix} e_1^{(4)} & e_1^{(4)} \\ je_1^{(4)} & -je_1^{(4)} \end{bmatrix}$	$\frac{1}{\sqrt{6}}\begin{bmatrix} e_1^{(4)} & e_0^{(4)} & e_0^{(4)} \\ e_1^{(4)} & e_0^{(4)} & -e_0^{(4)} \end{bmatrix}$	$\frac{1}{2\sqrt{2}}\begin{bmatrix} e_1^{(4)} & e_2^{(4)} & e_1^{(4)} & e_2^{(4)} \\ je_1^{(4)} & je_2^{(4)} & -je_1^{(4)} & -je_2^{(4)} \end{bmatrix}$
4	$\frac{1}{\sqrt{2}}\begin{bmatrix} e_1^{(4)} \\ e_1^{(4)} \end{bmatrix}$	$\frac{1}{2}\begin{bmatrix} e_2^{(4)} & e_2^{(4)} \\ e_2^{(4)} & -e_2^{(4)} \end{bmatrix}$	$\frac{1}{\sqrt{6}}\begin{bmatrix} e_1^{(4)} & e_1^{(4)} & e_2^{(4)} \\ e_1^{(4)} & -e_1^{(4)} & -e_2^{(4)} \end{bmatrix}$	$\frac{1}{2\sqrt{2}}\begin{bmatrix} e_2^{(4)} & e_3^{(4)} & e_2^{(4)} & e_3^{(4)} \\ e_2^{(4)} & e_3^{(4)} & -e_2^{(4)} & -e_3^{(4)} \end{bmatrix}$
5	$\frac{1}{\sqrt{2}}\begin{bmatrix} e_1^{(4)} \\ -e_1^{(4)} \end{bmatrix}$	$\frac{1}{2}\begin{bmatrix} e_2^{(4)} & e_2^{(4)} \\ je_2^{(4)} & -je_2^{(4)} \end{bmatrix}$	$\frac{1}{\sqrt{6}}\begin{bmatrix} e_2^{(4)} & e_1^{(4)} & e_2^{(4)} \\ e_2^{(4)} & -e_1^{(4)} & -e_2^{(4)} \end{bmatrix}$	$\frac{1}{2\sqrt{2}}\begin{bmatrix} e_2^{(4)} & e_3^{(4)} & e_2^{(4)} & e_3^{(4)} \\ je_2^{(4)} & je_3^{(4)} & -je_2^{(4)} & -je_3^{(4)} \end{bmatrix}$
6	$\frac{1}{\sqrt{2}}\begin{bmatrix} e_1^{(4)} \\ j\cdot e_1^{(4)} \end{bmatrix}$	$\frac{1}{2}\begin{bmatrix} e_3^{(4)} & e_3^{(4)} \\ e_3^{(4)} & -e_3^{(4)} \end{bmatrix}$	$\frac{1}{\sqrt{6}}\begin{bmatrix} e_1^{(4)} & e_2^{(4)} & e_2^{(4)} \\ e_1^{(4)} & e_2^{(4)} & -e_2^{(4)} \end{bmatrix}$	$\frac{1}{2\sqrt{2}}\begin{bmatrix} e_3^{(4)} & e_0^{(4)} & e_3^{(4)} & e_0^{(4)} \\ e_3^{(4)} & e_0^{(4)} & -e_3^{(4)} & -e_0^{(4)} \end{bmatrix}$
7	$\frac{1}{\sqrt{2}}\begin{bmatrix} e_1^{(4)} \\ -j\cdot e_1^{(4)} \end{bmatrix}$	$\frac{1}{2}\begin{bmatrix} e_3^{(4)} & e_3^{(4)} \\ je_3^{(4)} & -je_3^{(4)} \end{bmatrix}$	$\frac{1}{\sqrt{6}}\begin{bmatrix} e_2^{(4)} & e_1^{(4)} & e_1^{(4)} \\ e_2^{(4)} & e_1^{(4)} & -e_1^{(4)} \end{bmatrix}$	$\frac{1}{2\sqrt{2}}\begin{bmatrix} e_3^{(4)} & e_0^{(4)} & e_3^{(4)} & e_0^{(4)} \\ je_3^{(4)} & je_0^{(4)} & -je_3^{(4)} & -je_0^{(4)} \end{bmatrix}$
8	$\frac{1}{\sqrt{2}}\begin{bmatrix} e_2^{(4)} \\ e_2^{(4)} \end{bmatrix}$	$\frac{1}{2}\begin{bmatrix} e_0^{(4)} & e_1^{(4)} \\ e_0^{(4)} & -e_1^{(4)} \end{bmatrix}$	$\frac{1}{\sqrt{6}}\begin{bmatrix} e_2^{(4)} & e_2^{(4)} & e_3^{(4)} \\ e_2^{(4)} & -e_2^{(4)} & -e_3^{(4)} \end{bmatrix}$	-
9	$\frac{1}{\sqrt{2}}\begin{bmatrix} e_2^{(4)} \\ -e_2^{(4)} \end{bmatrix}$	$\frac{1}{2}\begin{bmatrix} e_0^{(4)} & e_1^{(4)} \\ je_0^{(4)} & -je_1^{(4)} \end{bmatrix}$	$\frac{1}{\sqrt{6}}\begin{bmatrix} e_3^{(4)} & e_2^{(4)} & e_3^{(4)} \\ e_3^{(4)} & -e_2^{(4)} & -e_3^{(4)} \end{bmatrix}$	-
10	$\frac{1}{\sqrt{2}}\begin{bmatrix} e_2^{(4)} \\ j\cdot e_2^{(4)} \end{bmatrix}$	$\frac{1}{2}\begin{bmatrix} e_1^{(4)} & e_2^{(4)} \\ e_1^{(4)} & -e_2^{(4)} \end{bmatrix}$	$\frac{1}{\sqrt{6}}\begin{bmatrix} e_2^{(4)} & e_3^{(4)} & e_3^{(4)} \\ e_2^{(4)} & e_3^{(4)} & -e_3^{(4)} \end{bmatrix}$	-
11	$\frac{1}{\sqrt{2}}\begin{bmatrix} e_2^{(4)} \\ -j\cdot e_2^{(4)} \end{bmatrix}$	$\frac{1}{2}\begin{bmatrix} e_1^{(4)} & e_2^{(4)} \\ je_1^{(4)} & -je_2^{(4)} \end{bmatrix}$	$\frac{1}{\sqrt{6}}\begin{bmatrix} e_3^{(4)} & e_2^{(4)} & e_2^{(4)} \\ e_3^{(4)} & e_2^{(4)} & -e_2^{(4)} \end{bmatrix}$	-
12	$\frac{1}{\sqrt{2}}\begin{bmatrix} e_3^{(4)} \\ e_3^{(4)} \end{bmatrix}$	$\frac{1}{2}\begin{bmatrix} e_0^{(4)} & e_3^{(4)} \\ e_0^{(4)} & -e_3^{(4)} \end{bmatrix}$	$\frac{1}{\sqrt{6}}\begin{bmatrix} e_3^{(4)} & e_3^{(4)} & e_0^{(4)} \\ e_3^{(4)} & -e_3^{(4)} & -e_0^{(4)} \end{bmatrix}$	-
13	$\frac{1}{\sqrt{2}}\begin{bmatrix} e_3^{(4)} \\ -e_3^{(4)} \end{bmatrix}$	$\frac{1}{2}\begin{bmatrix} e_0^{(4)} & e_3^{(4)} \\ je_0^{(4)} & -je_3^{(4)} \end{bmatrix}$	$\frac{1}{\sqrt{6}}\begin{bmatrix} e_0^{(4)} & e_3^{(4)} & e_0^{(4)} \\ e_0^{(4)} & -e_3^{(4)} & -e_0^{(4)} \end{bmatrix}$	-

14	$\frac{1}{\sqrt{2}}\begin{bmatrix} e_3^{(4)} \\ j \cdot e_3^{(4)} \end{bmatrix}$	$\frac{1}{2}\begin{bmatrix} e_1^{(4)} & e_3^{(4)} \\ e_1^{(4)} & -e_3^{(4)} \end{bmatrix}$	$\frac{1}{\sqrt{6}}\begin{bmatrix} e_3^{(4)} & e_0^{(4)} & e_0^{(4)} \\ e_3^{(4)} & e_0^{(4)} & -e_0^{(4)} \end{bmatrix}$	-
15	$\frac{1}{\sqrt{2}}\begin{bmatrix} e_3^{(4)} \\ -j \cdot e_3^{(4)} \end{bmatrix}$	$\frac{1}{2}\begin{bmatrix} e_1^{(4)} & e_3^{(4)} \\ je_1^{(4)} & -je_3^{(4)} \end{bmatrix}$	$\frac{1}{\sqrt{6}}\begin{bmatrix} e_0^{(4)} & e_3^{(4)} & e_3^{(4)} \\ e_0^{(4)} & e_3^{(4)} & -e_3^{(4)} \end{bmatrix}$	-

Codebook index, *n*	**Number of layers υ**	
	5	**6**
0	$\frac{1}{\sqrt{10}}\begin{bmatrix} e_0^{(4)} & e_0^{(4)} & e_1^{(4)} & e_1^{(4)} & e_2^{(4)} \\ e_0^{(4)} & -e_0^{(4)} & e_1^{(4)} & -e_1^{(4)} & e_2^{(4)} \end{bmatrix}$	$\frac{1}{2\sqrt{3}}\begin{bmatrix} e_0^{(4)} & e_0^{(4)} & e_1^{(4)} & e_1^{(4)} & e_2^{(4)} & e_2^{(4)} \\ e_0^{(4)} & -e_0^{(4)} & e_1^{(4)} & -e_1^{(4)} & e_2^{(4)} & -e_2^{(4)} \end{bmatrix}$
1-15	-	-

Codebook index, *n*	**Number of layers υ**	
	7	**8**
0	$\frac{1}{\sqrt{14}}\begin{bmatrix} e_0^{(4)} & e_0^{(4)} & e_1^{(4)} & e_1^{(4)} & e_2^{(4)} & e_2^{(4)} & e_3^{(4)} \\ e_0^{(4)} & -e_0^{(4)} & e_1^{(4)} & -e_1^{(4)} & e_2^{(4)} & -e_2^{(4)} & e_3^{(4)} \end{bmatrix}$	$\frac{1}{4}\begin{bmatrix} e_0^{(4)} & e_0^{(4)} & e_1^{(4)} & e_1^{(4)} & e_2^{(4)} & e_2^{(4)} & e_3^{(4)} & e_3^{(4)} \\ e_0^{(4)} & -e_0^{(4)} & e_1^{(4)} & -e_1^{(4)} & e_2^{(4)} & -e_2^{(4)} & e_3^{(4)} & -e_3^{(4)} \end{bmatrix}$
1-15	-	-

7.2.5 Channel-State Information – Reference Signal (CSI-RS) definition

For a serving cell and UE configured in transmission mode 9 and not configured with higher layer parameter *eMIMO-Type*, the UE can be configured with one CSI-RS resource configuration.

For a serving cell and UE configured in transmission mode 9 and configured with higher layer parameter *eMIMO-Type*, and *eMIMO-Type* is set to 'CLASS A', the UE can be configured with one CSI-RS resource configuration.

For a serving cell and UE configured in transmission mode 9 and configured with higher layer parameter *eMIMO-Type*, and *eMIMO-Type* is set to 'CLASS B', the UE can be configured with one or more CSI-RS resource configuration(s).

For a serving cell and UE configured in transmission mode 10, the UE can be configured with one or more CSI-RS resource configuration(s). The following parameters for which the UE shall assume non-zero transmission power for CSI-RS are configured via higher layer signaling for each CSI-RS resource configuration:

- CSI-RS resource configuration identity, if the UE is configured in transmission mode 9 and configured with higher layer parameter *eMIMO-Type*, and *eMIMO-Type* is set to 'CLASS B', the UE is configured with more than one CSI-RS resource configurations, or if the UE is configured in transmission mode 10,
- Number of CSI-RS ports. The allowable values and port mapping are given in subclause 6.10.5 of [3].
- CSI RS Configuration (see Table 6.10.5.2-1 and Table 6.10.5.2-2 in [3])
- CSI RS subframe configuration $I_{\mathrm{CSI-RS}}$. The allowable values are given in subclause 6.10.5.3 of [3].
- UE assumption on reference PDSCH transmitted power for CSI feedback P_c, if the UE is configured in transmission mode 9.
- UE assumption on reference PDSCH transmitted power for CSI feedback P_c for each CSI process, if the UE is configured in transmission mode 10. If CSI subframe sets $C_{\mathrm{CSI},0}$ and $C_{\mathrm{CSI},1}$ are configured by higher layers for a CSI process, P_c is configured for each CSI subframe set of the CSI process.
- Pseudo-random sequence generator parameter, n_{ID}. The allowable values are given in [11].
- CDM type parameter, if the UE is configured with higher layer parameter *eMIMO-Type*, and *eMIMO-Type* is set to 'CLASS A' for a CSI process. The allowable values are given in subclause 6.10.5.3 of [3].
- Higher layer parameter *qcl-CRS-Info-r11* for Quasi co-location type B UE assumption of CRS antenna ports and CSI-RS antenna ports with the following parameters, if the UE is configured in transmission mode 10:
  - *qcl-ScramblingIdentity-r11*.
  - *crs-PortsCount-r11*.
  - *mbsfn-SubframeConfigList-r11*.

P_c is the assumed ratio of PDSCH EPRE to CSI-RS EPRE when UE derives CSI feedback and takes values in the range of [-8, 15] dB with 1 dB step size, where the PDSCH EPRE corresponds to the symbols for which the ratio of the PDSCH EPRE to the cell-specific RS EPRE is denoted by ρ_A, as specified in Table 5.2-2 and Table 5.2-3.

A UE should not expect the configuration of CSI-RS and PMCH in the same subframe of a serving cell.

For frame structure type 2 serving cell and 4 CRS ports, the UE is not expected to receive a CSI RS Configuration index (see Table 6.10.5.2-1 and Table 6.10.5.2-2 in [3]) belonging to the set [20-31] for the normal CP case or the set [16-27] for the extended CP case.

A UE may assume the CSI-RS antenna ports of a CSI-RS resource configuration are quasi co-located (as defined in [3]) with respect to delay spread, Doppler spread, Doppler shift, average gain, and average delay.

A UE configured in transmission mode 10 and with quasi co-location type B, may assume the antenna ports 0 – 3 associated with *qcl-CRS-Info-r11* corresponding to a CSI-RS resource configuration and antenna ports 15 – 30 corresponding to the CSI-RS resource configuration are quasi co-located (as defined in [3]) with respect to Doppler shift, and Doppler spread.

A UE configured in transmission mode 10, and configured with higher layer parameter *eMIMO-Type*, and *eMIMO-Type* is set to 'CLASS B', and the number of configured CSI-RS resources is more than one for a CSI process, and with quasi co-location type B, is not expected to receive CSI-RS resource configurations for the CSI process that have different values of the higher layer parameter *qcl-CRS-Info-r11*.

A BL/CE UE configured with CEModeA or CEModeB is not expected to be configured with non-zero transmission power CSI-RS.

7.2.6 Channel-State Information – Interference Measurement (CSI-IM) Resource definition

For a serving cell and UE configured in transmission mode 10, the UE can be configured with one or more CSI-IM resource configuration(s). The following parameters are configured via higher layer signaling for each CSI-IM resource configuration:

- Zero-power CSI RS Configuration (see Table 6.10.5.2-1 and Table 6.10.5.2-2 in [3])
- Zero-power CSI RS subframe configuration $I_{\mathrm{CSI-RS}}$. The allowable values are given in subclause 6.10.5.3 of [3].

For a serving cell, if a UE is not configured with the higher layer parameter *csi-SubframePatternConfig-r12*, the UE is not expected to receive CSI-IM resource configuration(s) that are not all completely overlapping with one zero-power CSI-RS resource configuration which can be configured for the UE.

A UE is not expected to receive a CSI-IM resource configuration that is not completely overlapping with one of the zero-power CSI-RS resource configurations defined in subclause 7.2.7.

For a serving cell, if a UE is not configured with CSI subframe sets $C_{\mathrm{CSI},0}$ and $C_{\mathrm{CSI},1}$ for any CSI process, and the UE is configured with four CSI-IM resources, then the UE is not expected to be configured with CSI processes that are associated with all of the four CSI-IM resources.

A UE should not expect the configuration of CSI-IM resource and PMCH in the same subframe of a serving cell.

7.2.7 Zero Power CSI-RS Resource definition

For a serving cell and UE configured in transmission mode 1-9 and UE not configured with *csi-SubframePatternConfig-r12* for the serving cell, the UE can be configured with one zero-power CSI-RS resource configuration. For a serving cell and UE configured in transmission mode 1-9 and UE configured with *csi-SubframePatternConfig-r12* for the serving cell, the UE can be configured with up to two zero-power CSI-RS resource configurations. For a serving cell and UE configured in transmission mode 10, the UE can be configured with one or more zero-power CSI-RS resource configuration(s).

For a serving cell, the UE can be configured with up to 5 additional zero-power CSI-RS resource configurations according to the higher layer parameter *ds-ZeroTxPowerCSI-RS-r12*.

The following parameters are configured via higher layer signaling for each zero-power CSI-RS resource configuration:

- Zero-power CSI RS Configuration list (16-bit bitmap *ZeroPowerCSI-RS* in [3])
- Zero-power CSI RS subframe configuration $I_{\mathrm{CSI-RS}}$. *T*he allowable values are given in subclause 6.10.5.3 of [3].

A UE should not expect the configuration of zero-power CSI-RS and PMCH in the same subframe of a serving cell.

For frame structure type 1 serving cell, the UE is not expected to receive the 16-bit bitmap *ZeroPowerCSI-RS* with any one of the 6 LSB bits set to 1 for the normal CP case, or with any one of the 8 LSB bits set to 1 for the extended CP case.

For frame structure type 2 serving cell and 4 CRS ports, the UE is not expected to receive the 16-bit bitmap *ZeroPowerCSI-RS* with any one of the 6 LSB bits set to 1 for the normal CP case, or with any one of the 8 LSB bits set to 1 for the extended CP case.

A BL/CE UE configured with CEModeA or CEModeB is not expected to be configured with zero-power CSI-RS.

7.3 UE procedure for reporting HARQ-ACK

If the UE is configured with a PUCCH-SCell, the UE shall apply the procedures described in this clause for both primary PUCCH group and secondary PUCCH group unless stated otherwise

- When the procedures are applied for the primary PUCCH group, the terms 'secondary cell', 'secondary cells', 'serving cell', and 'serving cells' in this clause refer to secondary cell, secondary cells, serving cell or serving cells belonging to the primary PUCCH group respectively unless stated otherwise.
- When the procedures are applied for secondary PUCCH group, the terms 'secondary cell', 'secondary cells', 'serving cell' and 'serving cells' in this clause refer to secondary cell, secondary cells (not including the PUCCH-SCell), serving cell, serving cells belonging to the secondary PUCCH group respectively unless stated otherwise. The term 'primary cell' in this clause refers to the PUCCH-SCell of the secondary PUCCH group.

If each of the serving cell(s) configured for the UE has frame structure type 1, the UE procedure for HARQ-ACK reporting for frame structure type 1 is given in subclause 7.3.1.

If each of the serving cell(s) configured for the UE has frame structure type 2, the UE procedure for HARQ-ACK reporting for frame structure type 2 is given in subclause 7.3.2.

If the UE is configured with more than one serving cell, and if the frame structure type of any two configured serving cells is different, and if the primary cell is frame structure type 1, UE procedure for HARQ-ACK reporting is given in subclause 7.3.3.

If the UE is configured for more than one serving cell, and if the frame structure type of any two configured serving cells is different, and if the primary cell is frame structure type 2, UE procedure for HARQ-ACK reporting is given in subclause 7.3.4.

7.3.1 FDD HARQ-ACK reporting procedure

For FDD with PUCCH format 1a/1b transmission, when both HARQ-ACK and SR are transmitted in the same sub-frame, a UE shall transmit the HARQ-ACK on its assigned HARQ-ACK PUCCH format 1a/1b resource for a negative SR transmission and transmit the HARQ-ACK on its assigned SR PUCCH resource for a positive SR transmission.

For FDD with PUCCH format 1b with channel selection, when both HARQ-ACK and SR are transmitted in the same sub-frame a UE shall transmit the HARQ-ACK on its assigned HARQ-ACK PUCCH resource with channel selection as defined in subclause 10.1.2.2.1 for a negative SR transmission and transmit one HARQ-ACK bit per serving cell on its assigned SR PUCCH resource for a positive SR transmission according to the following:

- if only one transport block or a PDCCH/EPDCCH indicating downlink SPS release is detected on a serving cell, the HARQ-ACK bit for the serving cell is the HARQ-ACK bit corresponding to the transport block or the PDCCH/EPDCCH indicating downlink SPS release;
- if two transport blocks are received on a serving cell, the HARQ-ACK bit for the serving cell is generated by spatially bundling the HARQ-ACK bits corresponding to the transport blocks;
- if neither PDSCH transmission for which HARQ-ACK response shall be provided nor PDCCH/EPDCCH indicating downlink SPS release is detected for a serving cell, the HARQ-ACK bit for the serving cell is set to NACK;

and the HARQ-ACK bits for the primary cell and the secondary cell are mapped to $b(0)$ and $b(1)$, respectively, where $b(0)$ and $b(1)$ are specified in subclause 5.4.1 in [3].

For FDD, when a PUCCH format 3/4/5 transmission of HARQ-ACK coincides with a sub-frame configured to the UE by higher layers for transmission of a scheduling request, the UE shall multiplex HARQ-ACK and SR bits on HARQ-ACK PUCCH resource as defined in subclause 5.2.3.1 in [4], unless the HARQ-ACK corresponds to a PDSCH transmission on the primary cell only or a PDCCH/EPDCCH indicating downlink SPS release on the primary cell only, in which case the SR shall be transmitted as for FDD with PUCCH format 1a/1b.

For a non-BL/CE UE for FDD and for a PUSCH transmission, a UE shall not transmit HARQ-ACK on PUSCH in subframe *n* if the UE does not receive PDSCH or PDCCH indicating downlink SPS release in subframe *n-4*.

For a BL/CE UE, for FDD and for a PUSCH transmission scheduled by an MPDCCH where the last transmission of the MPDCCH is in subframe *n-4*, a UE shall not transmit HARQ-ACK on PUSCH in subframe *n* if there is no PDSCH or MPDCCH indicating downlink SPS release transmitted to the UE in subframe *n-4* where the last transmission of the PDSCH or MPDCCH indicating downlink SPS release is in subframe *n-4*.

When only a positive SR is transmitted, a UE shall use PUCCH Format 1 for the SR resource as defined in subclause 5.4.1 in [3].

If a UE is configured with higher layer parameter *codebooksizeDetermination-r13 = dai*, for FDD and a subframe *n*, the value of the counter Downlink Assignment Indicator (DAI) in DCI format 1/1A/1B/1D/2/2A/2B/2C/2D denotes the accumulative number of serving cell(s) with PDSCH transmission(s) associated with PDCCH/EPDCCH and serving cell with PDCCH/EPDCCH indicating downlink SPS release, up to the present serving cell in increasing order of serving cell index; the value of the total DAI in DCI format 1/1A/1B/1D/2/2A/2B/2C/2D denotes the total number of serving cell(s) with PDSCH transmission(s) associated with PDCCH/EPDCCH(s) and serving cell with PDCCH/EPDCCH indicating downlink SPS release. Denote $V_{C-DAI,c}^{DL}$ as the value of the counter DAI in DCI format 1/1A/1B/1D/2/2A/2B/2C/2D scheduling PDSCH transmission or indicating downlink SPS release for serving cell *c*, according to table 7.3.1-1. Denote V_{T-DAI}^{DL} as the value of the total DAI, according to Table 7.3.1-1. The UE shall assume a same value of total DAI in all PDCCH/EPDCCH scheduling PDSCH transmission(s) and PDCCH/EPDCCH indicating downlink SPS release in a subframe.

If a UE is configured with higher layer parameter *codebooksizeDetermination-r13 = dai* and if the UE transmits HARQ-ACK using PUCCH format 3 or PUCCH format 4 or PUCCH format 5 in subframe *n*, the UE shall determine the $\tilde{o}_0^{ACK}, \tilde{o}_1^{ACK}, ..., \tilde{o}_{O^{ACK}-1}^{ACK}$ according to the following pseudo-code:

Set $c = 0$ – cell index: lower indices correspond to lower RRC indices of corresponding cell

Set $j = 0$

Set $V_{temp} = 0$

Set $V_s = \varnothing$

Set N_{cells}^{DL} to the number of cells configured by higher layers for the UE

while $c <$ N_{cells}^{DL}

if there is a PDSCH on serving cell *c* associated with PDCCH/EPDCCH or there is a PDCCH/EPDCCH indicating downlink SPS release on serving cell *c*,

if $V_{C-DAI,c}^{DL} = \varnothing$

$V_{C-DAI,c}^{DL} = \mathrm{mod}(V_{temp}, 4) + 1$

end if

if $V_{C-DAI,c}^{DL} \leq V_{temp}$

$j = j+1$

end if

$V_{temp} = V_{C-DAI,c}^{DL}$

if the higher layer parameter *spatialBundlingPUCCH* is set *FALSE* and the UE is configured with a transmission mode supporting two transport blocks in at least one configured serving cell,

$\tilde{o}_{8j+2(V_{C-DAI,c}^{DL}-1)}^{ACK}$ = HARQ-ACK bit corresponding to the first codeword of this cell

$\tilde{o}_{8j+2(V_{C-DAI,c}^{DL}-1)+1}^{ACK}$ = HARQ-ACK bit corresponding to the second codeword of this cell

$V_s = V_s \cup \{8j + 2(V_{C-DAI,c}^{DL} - 1), 8j + 2(V_{C-DAI,c}^{DL} - 1) + 1\}$

elseif the higher layer parameter *spatialBundlingPUCCH* is set *TRUE* and the UE is configured with a transmission mode supporting two transport blocks in at least one configured serving cell,

$\tilde{o}^{ACK}_{4j+V^{DL}_{C-DAI,c}-1}$ = binary AND operation of the HARQ-ACK bits corresponding to the first and second codewords of this cell

$V_s = V_s \bigcup \{4j + V^{DL}_{C-DAI,c} - 1\}$

else

$\tilde{o}^{ACK}_{4j+V^{DL}_{C-DAI,c}-1}$ = HARQ-ACK bit of this cell

$V_s = V_s \bigcup \{4j + V^{DL}_{C-DAI,c} - 1\}$

end if

end if

$c = c + 1$

end while

if $V^{DL}_{T-DAI} < V_{temp}$

$j = j+1$

end if

if the higher layer parameter *spatialBundlingPUCCH* is set *FALSE* and the UE is configured with a transmission mode supporting two transport blocks in at least one configured serving cell,

$O^{ACK} = 2 \cdot (4 \cdot j + V^{DL}_{T-DAI})$

else

$O^{ACK} = 4 \cdot j + V^{DL}_{T-DAI}$

end if

$\tilde{o}^{ACK}_i = \text{NACK}$ for any $i \in \{0,1,...,O^{ACK} - 1\} \setminus V_s$

if SPS PDSCH transmission is activated for a UE and the UE is configured to receive SPS PDSCH in subframe *n*-4

$O^{ACK} = O^{ACK} + 1$

$o^{ACK}_{O^{ACK}-1}$ = HARQ-ACK bit associated with the SPS PDSCH transmission

end if

For a UE configured with higher layer parameter *codebooksizeDetermination-r13 = dai*, if the UE transmits HARQ-ACK on PUSCH in a subframe, the UE shall determine the $\tilde{o}^{ACK}_0, \tilde{o}^{ACK}_1, ..., \tilde{o}^{ACK}_{O^{ACK}-1}$ according to the above procedure as if the UE transmits HARQ-ACK using PUCCH format 3 or PUCCH format 4 or PUCCCH format 5, except that the higher layer parameter *spatialBundlingPUCCH* is replaced by *spatialBundlingPUSCH*.

Table 7.3.1-1: Value of counter DAI and total DAI

DAI MSB, LSB	$V_{C-DAI,c}^{DL}$ or V_{T-DAI}^{DL}	Number of serving cells with PDSCH transmission associated with PDCCH/EPDCCH and serving cell with PDCCH/EPDCCH indicating DL SPS release
0,0	1	1 or 5 or 9 or 13 or 17 or 21 or 25 or 29
0,1	2	2 or 6 or 10 or 14 or 18 or 22 or 26 or 30
1,0	3	3 or 7 or 11 or 15 or 19 or 23 or 27 or 31
1,1	4	0 or 4 or 8 or 12 or 16 or 20 or 24 or 28 or 32

If a UE is configured with higher layer parameter *codebooksizeDetermination-r13 = cc* and if the UE transmits HARQ-ACK using PUCCH format 4 or PUCCH format 5 in subframe *n*, the UE shall determine the $\tilde{o}_0^{ACK}, \tilde{o}_1^{ACK}, \ldots, \tilde{o}_{O^{ACK}-1}^{ACK}$ according to the pseudo-code in subclause 5.2.3.1 in [4].

For a UE configured with higher layer parameter *codebooksizeDetermination-r13 = cc*, if the UE transmits HARQ-ACK on PUSCH in a subframe, the UE shall determine the $\tilde{o}_0^{ACK}, \tilde{o}_1^{ACK}, \ldots, \tilde{o}_{O^{ACK}-1}^{ACK}$ according to the pseudo-code in subclause 5.2.2.6 in [4].

7.3.2 TDD HARQ-ACK reporting procedure

For TDD and a UE not configured with the parameter *EIMTA-MainConfigServCell-r12* for any serving cell, if the UE is configured with one serving cell, or if the UE is configured with more than one serving cell and the TDD UL/DL configuration of all the configured serving cells is the same, UE procedure for reporting HARQ-ACK is given in subclause 7.3.2.1.

For TDD, if a UE is configured with more than one serving cell and the TDD UL/DL configuration of at least two configured serving cells is not the same, or if the UE is configured with the parameter *EIMTA-MainConfigServCell-r12* for at least one serving cell, UE procedure for reporting HARQ-ACK is given in subclause 7.3.2.2.

When only a positive SR is transmitted, a UE shall use PUCCH Format 1 for the SR resource as defined in subclause 5.4.1 in [3].

7.3.2.1 TDD HARQ-ACK reporting procedure for same UL/DL configuration

Unless otherwise stated, the procedure in this section applies to non-BL/CE UEs.

For TDD, the UE shall upon detection of a PDSCH transmission or a PDCCH/EPDCCH indicating downlink SPS release (defined in subclause 9.2) within subframe(s) $n-k$, where $k \in K$ and K is defined in Table 10.1.3.1-1 intended for the UE and for which HARQ-ACK response shall be provided, transmit the HARQ-ACK response in UL subframe *n*.

For TDD, when PUCCH format 3/4/5 is configured for transmission of HARQ-ACK, for special subframe configurations 0 and 5 with normal downlink CP or configurations 0 and 4 with extended downlink CP in a serving cell, shown in table 4.2-1 [3], the special subframe of the serving cell is excluded from the HARQ-ACK codebook size determination. In this case, if the serving cell is the primary cell, there is no PDCCH/EPDCCH indicating downlink SPS release in the special subframe.

For TDD UL/DL configurations 1-6 and one configured serving cell, if the UE is not configured with PUCCH format 3, the value of the Downlink Assignment Index (DAI) in DCI format 0/4, V_{DAI}^{UL}, detected by the UE according to Table 7.3-X in subframe $n-k'$, where k' is defined in Table 7.3-Y, represents the total number of subframes with PDSCH transmissions and with PDCCH/EPDCCH indicating downlink SPS release to the corresponding UE within all the subframe(s) $n-k$, where $k \in K$. The value V_{DAI}^{UL} includes all PDSCH transmission with and without corresponding PDCCH/EPDCCH within all the subframe(s) $n-k$. In case neither PDSCH transmission, nor PDCCH/EPDCCH indicating the downlink SPS resource release is intended to the UE, the UE can expect that the value of the DAI in DCI format 0/4, V_{DAI}^{UL}, if transmitted, is set to 4.

For TDD UL/DL configuration 1-6 and a UE configured with more than one serving cell, or for TDD UL/DL configuration 1-6 and a UE configured with one serving cell and PUCCH format 3, a value W_{DAI}^{UL} is determined by the

Downlink Assignment Index (DAI) in DCI format 0/4 according to Table 7.3-Z in subframe $n-k'$, where k' is defined in Table 7.3-Y. In case neither PDSCH transmission, nor PDCCH/EPDCCH indicating the downlink SPS resource release is intended to the UE, the UE can expect that the value of W_{DAI}^{UL} is set to 4 by the DAI in DCI format 0/4 if transmitted.

If a UE is not configured with higher layer parameter *codebooksizeDetermination-r13 = dai*, for TDD UL/DL configurations 1-6, the value of the DAI in DCI format 1/1A/1B/1D/2/2A/2B/2C/2D denotes the accumulative number of PDCCH/EPDCCH (s) with assigned PDSCH transmission(s) and PDCCH/EPDCCH indicating downlink SPS release up to the present subframe within subframe(s) $n-k$ of each configured serving cell, where $k \in K$, and shall be updated from subframe to subframe. Denote $V_{DAI,c}^{DL}$ as the value of the DAI in PDCCH/EPDCCH with DCI format 1/1A/1B/1D/2/2A/2B/2C/2D detected by the UE according to Table 7.3-X in subframe $n-k_m$ in serving cell c, where k_m is the smallest value in the set K (defined in Table 10.1.3.1-1) such that the UE detects a DCI format 1/1A/1B/1D/2/2A/2B/2C/2D. When configured with one serving cell, the subscript of c in $V_{DAI,c}^{DL}$ can be omitted.

For all TDD UL/DL configurations, denote $U_{DAI,c}$ as the total number of PDCCH/EPDCCH (s) with assigned PDSCH transmission(s) and PDCCH/EPDCCH indicating downlink SPS release detected by the UE within the subframe(s) $n-k$ in serving cell c, where $k \in K$. When configured with one serving cell, the subscript of c in $U_{DAI,c}$ can be omitted. Denote N_{SPS}, which can be zero or one, as the number of PDSCH transmissions without a corresponding PDCCH/EPDCCH within the subframe(s) $n-k$, where $k \in K$.

For TDD HARQ-ACK bundling or HARQ-ACK multiplexing and a subframe n with $M=1$, the UE shall generate one or two HARQ-ACK bits by performing a logical AND operation per codeword across M downlink and special subframes associated with a single UL subframe, of all the corresponding $U_{DAI} + N_{SPS}$ individual PDSCH transmission HARQ-ACKs and individual ACK in response to received PDCCH/EPDCCH indicating downlink SPS release, where M is the number of elements in the set K defined in Table 10.1.3.1-1. The UE shall detect if at least one downlink assignment has been missed, and for the case that the UE is transmitting on PUSCH the UE shall also determine the parameter N_{bundled}.

- For TDD UL/DL configuration 0, N_{bundled} shall be 1 if the UE detects the PDSCH transmission with or without corresponding PDCCH/EPDCCH, or detects PDCCH indicating downlink SPS release within the subframe $n-k$, where $k \in K$. The UE shall not transmit HARQ-ACK on PUSCH if the UE does not receive PDSCH or PDCCH indicating downlink SPS release within the subframe(s) $n-k$, where $k \in K$.
- For the case that the UE is not transmitting on PUSCH in subframe *n* and TDD UL/DL configurations 1-6, if $U_{DAI} > 0$ and $V_{DAI}^{DL} \neq (U_{DAI} - 1) \bmod 4 + 1$, the UE detects that at least one downlink assignment has been missed.
- For the case that the UE is transmitting on PUSCH and the PUSCH transmission is adjusted based on a detected PDCCH/EPDCCH with DCI format 0/4 intended for the UE and TDD UL/DL configurations 1-6, if $V_{DAI}^{UL} \neq (U_{DAI} + N_{SPS} - 1) \bmod 4 + 1$ the UE detects that at least one downlink assignment has been missed and the UE shall generate NACK for all codewords where N_{bundled} is determined by the UE as $N_{\text{bundled}} = V_{DAI}^{UL} + 2$. If the UE does not detect any downlink assignment missing, N_{bundled} is determined by the UE as $N_{\text{bundled}} = V_{DAI}^{UL}$. UE shall not transmit HARQ-ACK if $U_{DAI} + N_{SPS} = 0$ and $V_{DAI}^{UL} = 4$.
- For the case that the UE is transmitting on PUSCH, and the PUSCH transmission is not based on a detected PDCCH/EPDCCH with DCI format 0/4 intended for the UE and TDD UL/DL configurations 1-6, if $U_{DAI} > 0$ and $V_{DAI}^{DL} \neq (U_{DAI} - 1) \bmod 4 + 1$, the UE detects that at least one downlink assignment has been missed and the UE shall generate NACK for all codewords. The UE determines $N_{\text{bundled}} = (U_{DAI} + N_{SPS})$ as the number of assigned subframes. The UE shall not transmit HARQ-ACK if $U_{DAI} + N_{SPS} = 0$.

For TDD, when PUCCH format 3 is configured for transmission of HARQ-ACK without PUCCH format 4 or PUCCH format 5 configured for transmission of HARQ-ACK, the HARQ-ACK feedback bits $o_{c,0}^{ACK}\ o_{c,1}^{ACK},...,o_{c,O_c^{ACK}-1}^{ACK}$ for the *c*-th serving cell configured by RRC are constructed as follows, where *c*≥0, $O_c^{ACK}=B_c^{DL}$ if transmission mode configured in the *c*-th serving cell supports one transport block or spatial HARQ-ACK bundling is applied and $O_c^{ACK}=2B_c^{DL}$ otherwise, where B_c^{DL} is the number of downlink and special subframes for which the UE needs to feedback HARQ-ACK bits for the *c*-th serving cell.

- For the case that the UE is transmitting on PUCCH, $B_c^{DL}=M$ where M is the number of elements in the set K defined in Table 10.1.3.1-1 associated with subframe *n* and the set K does not include a special subframe of configurations 0 and 5 with normal downlink CP or of configurations 0 and 4 with extended downlink CP; otherwise $B_c^{DL}=M-1$.

- For TDD UL/DL configuration 0 or for a PUSCH transmission not adjusted based on a detected PDCCH/EPDCCH with DCI format 0/4, the UE shall assume $B_c^{DL}=M$ where M is the number of elements in the set K defined in Table 10.1.3.1-1 associated with subframe *n* and the set K does not include a special subframe of configurations 0 and 5 with normal downlink CP or of configurations 0 and 4 with extended downlink CP; otherwise $B_c^{DL}=M-1$. The UE shall not transmit HARQ-ACK on PUSCH if the UE does not receive PDSCH or PDCCH/EPDCCH indicating downlink SPS release in subframe(s) $n-k$, where $k\in K$.

- For TDD UL/DL configurations {1, 2, 3, 4, 6} and a PUSCH transmission adjusted based on a detected PDCCH/EPDCCH with DCI format 0/4, the UE shall assume $B_c^{DL}=W_{DAI}^{UL}$. The UE shall not transmit HARQ-ACK on PUSCH if the UE does not receive PDSCH or PDCCH/EPDCCH indicating downlink SPS release in subframe(s) $n-k$ where $k\in K$ and $W_{DAI}^{UL}=4$.

- For TDD UL/DL configurations 5 and a PUSCH transmission adjusted based on a detected PDCCH/EPDCCH with DCI format 0/4, the UE shall assume $B_c^{DL}=W_{DAI}^{UL}+4\left\lceil \left(U-W_{DAI}^{UL}\right)/4\right\rceil$, where U denotes the maximum value of U_c among all the configured serving cells, U_c is the total number of received PDSCHs and PDCCH/EPDCCH indicating downlink SPS release in subframe(s) $n-k$ on the *c*-th serving cell, $k\in K$. The UE shall not transmit HARQ-ACK on PUSCH if the UE does not receive PDSCH or PDCCH/EPDCCH indicating downlink SPS release in subframe(s) $n-k$ where $k\in K$ and $W_{DAI}^{UL}=4$.

For TDD, when PUCCH format 4/5 is configured for transmission of HARQ-ACK and if the UE is configured with higher layer parameter *codebooksizeDetermination-r13 = cc*, the HARQ-ACK feedback bits $o_{c,0}^{ACK}\ o_{c,1}^{ACK},...,o_{c,O_c^{ACK}-1}^{ACK}$ for the *c*-th serving cell configured by RRC are constructed as follows, where *c*≥0, $O_c^{ACK}=B_c^{DL}$ if transmission mode configured in the *c*-th serving cell supports one transport block or spatial HARQ-ACK bundling is applied and $O_c^{ACK}=2B_c^{DL}$ otherwise, where B_c^{DL} is the number of downlink and special subframes for which the UE needs to feedback HARQ-ACK bits for the *c*-th serving cell.

- For the case that the UE is transmitting on PUCCH, $B_c^{DL}=M$ where M is the number of elements in the set K defined in Table 10.1.3.1-1 associated with subframe *n* and the set K does not include a special subframe of configurations 0 and 5 with normal downlink CP or of configurations 0 and 4 with extended downlink CP; otherwise $B_c^{DL}=M-1$.

- For the case that UE is transmitting on PUSCH not adjusted based on a detected PDCCH/EPDCCH with DCI format 0/4, the UE shall assume $B_c^{DL}=M$ where M is the number of elements in the set K defined in Table 10.1.3.1-1 associated with subframe *n* and the set K does not include a special subframe of configurations 0 and 5 with normal downlink CP or of configurations 0 and 4 with extended downlink CP; otherwise $B_c^{DL}=M-1$. The UE shall not transmit HARQ-ACK on PUSCH if the UE does not receive PDSCH or PDCCH/EPDCCH indicating downlink SPS release in subframe(s) $n-k$, where $k\in K$.

For TDD, when PUCCH format 3/4/5 is configured for transmission of HARQ-ACK and if the UE is not configured with higher layer parameter *codebooksizeDetermination-r13 = dai*,

- for TDD UL/DL configurations 1-6, the HARQ-ACK for a PDSCH transmission with a corresponding PDCCH/EPDCCH or for a PDCCH/EPDCCH indicating downlink SPS release in subframe $n-k$ is associated with $o^{ACK}_{c,DAI(k)-1}$ if transmission mode configured in the *c*-th serving cell supports one transport block or spatial HARQ-ACK bundling is applied, or associated with $o^{ACK}_{c,2DAI(k)-2}$ and $o^{ACK}_{c,2DAI(k)-1}$ otherwise, where *DAI(k)* is the value of DAI in DCI format 1A/1B/1D/1/2/2A/2B/2C/2D detected in subframe $n-k$, $o^{ACK}_{c,2DAI(k)-2}$ and $o^{ACK}_{c,2DAI(k)-1}$ are the HARQ-ACK feedback for codeword 0 and codeword 1, respectively. For the case with $N_{SPS}>0$, the HARQ-ACK associated with a PDSCH transmission without a corresponding PDCCH/EPDCCH is mapped to o^{ACK}_{c,O^{ACK}_c-1} The HARQ-ACK feedback bits without any detected PDSCH transmission or without detected PDCCH/EPDCCH indicating downlink SPS release are set to NACK;
- for TDD UL/DL configuration 0, the HARQ-ACK for a PDSCH transmission or for a PDCCH/EPDCCH indicating downlink SPS release in subframe $n-k$ is associated with $o^{ACK}_{c,0}$ if transmission mode configured in the *c*-th serving cell supports one transport block or associated with $o^{ACK}_{c,0}$ and $o^{ACK}_{c,1}$ otherwise, where $o^{ACK}_{c,0}$ and $o^{ACK}_{c,1}$ are the HARQ-ACK feedback for codeword 0 and codeword 1, respectively. The HARQ-ACK feedback bits without any detected PDSCH transmission or without detected PDCCH/EPDCCH indicating downlink SPS release are set to NACK.

For TDD when format 1b with channel selection is configured for transmission of HARQ-ACK and for 2 configured serving cells, the HARQ-ACK feedback bits $o^{ACK}_0\ o^{ACK}_1,...,o^{ACK}_{O^{ACK}-1}$ on PUSCH are constructed as follows.

- For TDD UL/DL configuration 0, o^{ACK}_j = HARQ-ACK(*j*), $0\le j\le A-1$ as defined in subclause 10.1.3.2.1. The UE shall not transmit HARQ-ACK on PUSCH if the UE does not receive PDSCH or PDCCH/EPDCCH indicating downlink SPS release in subframe(s) $n-k$ where $k\in K$.
- For TDD UL/DL configurations {1, 2, 3, 4, 6} and a PUSCH transmission adjusted based on a detected PDCCH/EPDCCH with DCI format 0/4 with W^{UL}_{DAI} =1 or 2, o^{ACK}_j is determined as if PUCCH format 3 is configured for transmission of HARQ-ACK, except that spatial HARQ-ACK bundling across multiple codewords within a downlink or special subframe is performed for all serving cells configured with a downlink transmission mode that supports up to two transport blocks in case W^{UL}_{DAI} =2.
- For TDD UL/DL configurations {1, 2, 3, 4, 6} and a PUSCH transmission adjusted based on a detected PDCCH/EPDCCH with DCI format 0/4 with W^{UL}_{DAI} =3 or 4, $o^{ACK}_j=o(j)$, $0\le j\le 3$ as defined in Table 10.1.3.2-5 or in Table 10.1.3.2-6 respectively, where the value of M is replaced by W^{UL}_{DAI}. The UE shall not transmit HARQ-ACK on PUSCH if the UE does not receive PDSCH or PDCCH/EPDCCH indicating downlink SPS release in subframe(s) $n-k$ where $k\in K$ and $W^{UL}_{DAI}=4$.
- For TDD UL/DL configurations {1, 2, 3, 4, 6} and a PUSCH transmission not adjusted based on a detected PDCCH/EPDCCH with DCI format 0/4 and a subframe n with M =1 or 2, o^{ACK}_j = HARQ-ACK(*j*), $0\le j\le A-1$ as defined in subclause 10.1.3.2.1. The UE shall not transmit HARQ-ACK on PUSCH if the UE does not receive PDSCH or PDCCH/EPDCCH indicating downlink SPS release in subframe(s) $n-k$ where $k\in K$.
- For TDD UL/DL configurations {1, 2, 3, 4, 6} and a PUSCH transmission not adjusted based on a detected PDCCH/EPDCCH with DCI format 0/4 and a subframe n with M =3 or 4, $o^{ACK}_j=o(j)$, $0\le j\le 3$ as defined in Table 10.1.3.2-5 or in Table 10.1.3.2-6 respectively. The UE shall not transmit HARQ-ACK on

PUSCH if the UE does not receive PDSCH or PDCCH/EPDCCH indicating downlink SPS release in subframe(s) $n-k$ where $k \in K$.

For TDD HARQ-ACK bundling, when the UE is configured by transmission mode 3, 4, 8, 9 or 10 defined in subclause 7.1 and HARQ-ACK bits are transmitted on PUSCH, the UE shall always generate 2 HARQ-ACK bits assuming both codeword 0 and 1 are enabled. For the case that the UE detects only the PDSCH transmission associated with codeword 0 within the bundled subframes, the UE shall generate NACK for codeword 1.

Table 7.3-X: Value of Downlink Assignment Index

DAI MSB, LSB	V_{DAI}^{UL} or V_{DAI}^{DL}	Number of subframes with PDSCH transmission and with PDCCH/EPDCCH indicating DL SPS release
0,0	1	1 or 5 or 9
0,1	2	2 or 6 or 10
1,0	3	3 or 7
1,1	4	0 or 4 or 8

Table 7.3-Y: Uplink association index *k*' for TDD

TDD UL/DL Configuration	subframe number *n*									
	0	1	2	3	4	5	6	7	8	9
1			6	4				6	4	
2			4					4		
3			4	4	4					
4			4	4						
5			4							
6			7	7	5			7	7	

Table 7.3-Z: Value of W_{DAI}^{UL} determined by the DAI field in DCI format 0/4

DAI MSB, LSB	W_{DAI}^{UL}
0,0	1
0,1	2
1,0	3
1,1	4

For TDD HARQ-ACK multiplexing and a subframe n with $M > 1$, spatial HARQ-ACK bundling across multiple codewords within a downlink or special subframe is performed by a logical AND operation of all the corresponding individual HARQ-ACKs. In case the UE is transmitting on PUSCH, the UE shall determine the number of HARQ-ACK feedback bits O^{ACK} and the HARQ-ACK feedback bits o_n^{ACK} , $n = 0,\ldots,O^{ACK}-1$ to be transmitted in subframe *n*.

- If the PUSCH transmission is adjusted based on a detected PDCCH/EPDCCH with DCI format 0/4 intended for the UE, then $O^{ACK} = V_{DAI}^{UL}$ unless $V_{DAI}^{UL} = 4$ and $U_{DAI} + N_{SPS} = 0$ in which case the UE shall not transmit HARQ-ACK. The spatially bundled HARQ-ACK for a PDSCH transmission with a corresponding PDCCH/EPDCCH or for a PDCCH/EPDCCH indicating downlink SPS release in subframe $n-k$ is associated with $o_{DAI(k)-1}^{ACK}$ where *DAI(k)* is the value of DAI in DCI format 1A/1B/1D/1/2/2A/2B/2C/2D detected in subframe $n-k$. For the case with $N_{SPS} > 0$, the HARQ-ACK associated with a PDSCH transmission without a corresponding PDCCH/EPDCCH is mapped to $o_{O^{ACK}-1}^{ACK}$. The HARQ-ACK feedback bits without any detected PDSCH transmission or without detected PDCCH/EPDCCH indicating downlink SPS release are set to NACK.

- If the PUSCH transmission is not adjusted based on a detected PDCCH/EPDCCH with DCI format 0/4 intended for the UE, $O^{ACK} = M$, and o_i^{ACK} is associated with the spatially bundled HARQ-ACK for downlink or special subframe $n-k_i$, where $k_i \in K$. The HARQ-ACK feedback bits without any detected PDSCH transmission or without detected PDCCH/EPDCCH indicating downlink SPS release are set to NACK. The UE shall not transmit HARQ-ACK if $U_{DAI} + N_{SPS} = 0$.

If a UE is configured with higher layer parameter *codebooksizeDetermination-r13 = dai*, the value of the counter Downlink Assignment Indicator (DAI) in DCI format 1/1A/1B/1D/2/2A/2B/2C/2D denotes the accumulative number of {serving cell, subframe}-pair(s) in which PDSCH transmission(s) associated with PDCCH/EPDCCH or PDCCH/EPDCCH indicating downlink SPS release is present, up to the present serving cell and present subframe, first in increasing order of serving cell index and then in increasing order of subframe index within subframe(s) $n-k$ where $k \in K$; the value of the total DAI in DCI format 1/1A/1B/1D/2/2A/2B/2C/2D denotes the total number of {serving cell, subframe}-pair(s) in which PDSCH transmission(s) associated with PDCCH/EPDCCH(s) or PDCCH/EPDCCH indicating downlink SPS release is present, up to the present subframe within subframe(s) $n-k$ where $k \in K$, and shall be updated from subframe to subframe. Denote $V_{C-DAI,c,k}^{DL}$ as the value of the counter DAI in DCI format 1/1A/1B/1D/2/2A/2B/2C/2D scheduling PDSCH transmission or indicating downlink SPS release for serving cell *c* in subframe $n-k$ where $k \in K$ according to table 7.3.2.1-1. Denote $V_{T-DAI,k}^{DL}$ as the value of the total DAI in subframe $n-k$ where $k \in K$, according to Table 7.3.2.1-1. The UE shall assume a same value of total DAI in all PDCCH/EPDCCH scheduling PDSCH transmission(s) and PDCCH/EPDCCH indicating downlink SPS release in a subframe.

If a UE is configured with higher layer parameter *codebooksizeDetermination-r13 = dai* and if the UE transmits HARQ-ACK using PUCCH format 3 or PUCCH format 4 or PUCCH format 5 in subframe *n*, the UE shall determine the $\tilde{o}_0^{ACK}, \tilde{o}_1^{ACK}, ..., \tilde{o}_{O^{ACK}-1}^{ACK}$ according to the following pseudo-code:

Set *c = 0* – cell index: lower indices correspond to lower RRC indices of corresponding cell

Set *m = 0* – subframe index: lower index corresponds to earlier subframe within subframe(s) $n-k$ where $k \in K$

Set *j = 0*

Set $V_{temp} = 0$

Set $V_{temp2} = 0$

Set $V_s = \varnothing$

Set N_{cells}^{DL} to the number of cells configured by higher layers for the UE

Set *M* to the number of subframes within subframe(s) $n-k$ where $k \in K$

while *m* < *M*

  while *c* < N_{cells}^{DL}

    if there is a PDSCH on serving cell *c* in subframe *m* associated with PDCCH/EPDCCH or there is a PDCCH/EPDCCH indicating downlink SPS release on serving cell *c* in subframe *m*,

      if $V_{C-DAI,c,m}^{DL} \le V_{temp}$

        j = j+1

      end if

$V_{temp} = V^{DL}_{C-DAI,c,m}$

if $V^{DL}_{T-DAI,m} = \varnothing$

$V_{temp2} = V^{DL}_{C-DAI,c,m}$

else

$V_{temp2} = V^{DL}_{T-DAI,m}$

end if

if the higher layer parameter *spatialBundlingPUCCH* is set *FALSE* and the UE is configured with a transmission mode supporting two transport blocks in at least one configured serving cell,

$\tilde{o}^{ACK}_{8j+2\left(V^{DL}_{C-DAI,c,m}-1\right)}$ = HARQ-ACK bit corresponding to the first codeword of this cell

$\tilde{o}^{ACK}_{8j+2\left(V^{DL}_{C-DAI,c,m}-1\right)+1}$ = HARQ-ACK bit corresponding to the second codeword of this cell

$V_s = V_s \cup \left\{8j + 2\left(V^{DL}_{C-DAI,c,m} - 1\right), 8j + 2\left(V^{DL}_{C-DAI,c,m} - 1\right) + 1\right\}$

elseif the higher layer parameter *spatialBundlingPUCCH* is set *TRUE* and the UE is configured with a transmission mode supporting two transport blocks in at least one configured serving cell,

$\tilde{o}^{ACK}_{4j+V^{DL}_{C-DAI,c,m}-1}$ = binary AND operation of the HARQ-ACK bits corresponding to the first and second codewords of this cell

$V_s = V_s \cup \left\{4j + V^{DL}_{C-DAI,c,m} - 1\right\}$

else

$\tilde{o}^{ACK}_{4j+V^{DL}_{C-DAI,c,m}-1}$ = HARQ-ACK bit of this cell

$V_s = V_s \cup \left\{4j + V^{DL}_{C-DAI,c,m} - 1\right\}$

end if

c = *c* + 1

end while

m = m + 1

end while

if $V_{temp2} < V_{temp}$

j = j+1

end if

if the higher layer parameter *spatialBundlingPUCCH* is set *FALSE* and the UE is configured with a transmission mode supporting two transport blocks in at least one configured serving cell,

$O^{ACK} = 2 \cdot \left(4 \cdot j + V_{temp2}\right)$

else

$$O^{ACK} = 4 \cdot j + V_{temp2}$$

$$\tilde{o}_i^{ACK} = \text{NACK} \text{ for any } i \in \{0,1,...,O^{ACK}-1\} \backslash V_s$$

if SPS PDSCH transmission is activated for a UE and the UE is configured to receive SPS PDSCH in a subframe $n-k$ where $k \in K$

$$O^{ACK} = O^{ACK} + 1$$

$o_{O^{ACK}-1}^{ACK}$ = HARQ-ACK bit associated with the SPS PDSCH transmission

end if

For a UE configured with higher layer parameter *codebooksizeDetermination-r13 = dai*, if the UE transmits HARQ-ACK on PUSCH in a subframe, the UE shall determine the $\tilde{o}_0^{ACK}, \tilde{o}_1^{ACK}, ..., \tilde{o}_{O^{ACK}-1}^{ACK}$ according to the above procedure as if the UE transmits HARQ-ACK using PUCCH format 3 or PUCCH format 4 or PUCCCH format 5, except that the higher layer parameter *spatialBundlingPUCCH* is replaced by *spatialBundlingPUSCH*.

Table 7.3.2.1-1: Value of counter DAI and total DAI

DAI MSB, LSB	$V_{C-DAI,c,k}^{DL}$ or $V_{T-DAI,k}^{DL}$	Number of {serving cell, subframe}-pair(s) in which PDSCH transmission(s) associated with PDCCH/EPDCCH or PDCCH/EPDCCH indicating downlink SPS release is present, denoted as Y and $Y \geq 1$
0,0	1	$\text{mod}(Y-1,4)+1=1$
0,1	2	$\text{mod}(Y-1,4)+1=2$
1,0	3	$\text{mod}(Y-1,4)+1=3$
1,1	4	$\text{mod}(Y-1,4)+1=4$

If a UE is configured with higher layer parameter *codebooksizeDetermination-r13 = cc* and if the UE transmits HARQ-ACK using PUCCH format 4 or PUCCH format 5 in subframe *n*, the UE shall determine the $\tilde{o}_0^{ACK}, \tilde{o}_1^{ACK}, ..., \tilde{o}_{O^{ACK}-1}^{ACK}$ according to the pseudo-code in subclause 5.2.3.1 in [4].

For a UE configured with higher layer parameter *codebooksizeDetermination-r13 = cc*, if the UE transmits HARQ-ACK on PUSCH in a subframe, the UE shall determine the $\tilde{o}_0^{ACK}, \tilde{o}_1^{ACK}, ..., \tilde{o}_{O^{ACK}-1}^{ACK}$ according to the pseudo-code in subclause 5.2.2.6 in [4].

For TDD when a PUCCH format 3 or a PUCCH format 4/5 configured with higher layer parameter *codebooksizeDetermination-r13 =cc* transmission of HARQ-ACK coincides with a sub-frame configured to the UE by higher layers for transmission of a scheduling request, the UE shall multiplex HARQ-ACK and SR bits on HARQ-ACK PUCCH resource as defined in subclause 5.2.3.1 in [4], unless the HARQ-ACK corresponds to one of the following cases

- a single PDSCH transmission only on the primary cell indicated by the detection of a corresponding PDCCH/EPDCCH in subframe $n-k_m$, where $k_m \in K$, and for TDD UL/DL configurations 1-6 the DAI value in the PDCCH/EPDCCH is equal to '1' (defined in Table 7.3-X), or a PDCCH/EPDCCH indicating downlink SPS release (defined in subclause 9.2) in subframe $n-k_m$, where $k_m \in K$, and for TDD UL/DL configurations 1-6 the DAI value in the PDCCH/EPDCCH is equal to '1', or
- a single PDSCH transmission only on the primary cell where there is not a corresponding PDCCH/EPDCCH detected within subframe(s) $n-k$, where $k \in K$ and no PDCCH/EPDCCH indicating downlink SPS release (defined in subclause 9.2) within subframe(s) $n-k$, where $k \in K$, or

- a PDSCH transmission only on the primary cell where there is not a corresponding PDCCH/EPDCCH detected within subframe(s) $n-k$, where $k \in K$ and an additional PDSCH transmission only on the primary cell indicated by the detection of a corresponding PDCCH/EPDCCH in subframe $n-k_m$, where $k_m \in K$ with the DAI value in the PDCCH/EPDCCH equal to '1' (defined in Table 7.3-X) or a PDCCH/EPDCCH indicating downlink SPS release (defined in subclause 9.2) in the subframe $n-k_m$, where $k_m \in K$ with the DAI value in the PDCCH/EPDCCH equal to '1',

in which case the UE shall transmit the HARQ-ACK and scheduling request according to the procedure for PUCCH format 1b with channel selection in TDD.

For TDD when a PUCCH format 4/5 configured with higher layer parameter *codebooksizeDetermination-r13 = dai* transmission of HARQ-ACK coincides with a sub-frame configured to the UE by higher layers for transmission of a scheduling request, the UE shall multiplex HARQ-ACK and SR bits on HARQ-ACK PUCCH resource as defined in subclause 5.2.3.1 in [4], unless the HARQ-ACK corresponds to one of the following cases

- a single PDSCH transmission only on the primary cell indicated by the detection of a corresponding PDCCH/EPDCCH in subframe $n-k_m$, where $k_m \in K$, and both the counter DAI value and the total DAI value in the PDCCH/EPDCCH is equal to '1' (defined in Table 7.3.2.1-1), or a single PDCCH/EPDCCH indicating downlink SPS release (defined in subclause 9.2) in subframe $n-k_m$, where $k_m \in K$, and both the counter DAI value and the total DAI value in the PDCCH/EPDCCH is equal to '1' (defined in Table 7.3.2.1-1), or

- a single PDSCH transmission only on the primary cell where there is not a corresponding PDCCH/EPDCCH detected within subframe(s) $n-k$, where $k \in K$ and no PDCCH/EPDCCH indicating downlink SPS release (defined in subclause 9.2) within subframe(s) $n-k$, where $k \in K$, or

- a PDSCH transmission only on the primary cell where there is not a corresponding PDCCH/EPDCCH detected within subframe(s) $n-k$, where $k \in K$ and an additional PDSCH transmission only on the primary cell indicated by the detection of a corresponding PDCCH/EPDCCH in subframe $n-k_m$, where $k_m \in K$ with both the counter DAI value and the total DAI value in the PDCCH/EPDCCH is equal to '1' (defined in Table 7.3.2.1-1) or an additional PDCCH/EPDCCH indicating downlink SPS release (defined in subclause 9.2) in the subframe $n-k_m$, where $k_m \in K$ with both the counter DAI value and the total DAI value in the PDCCH/EPDCCH is equal to '1' (defined in Table 7.3.2.1-1),

in which case the UE shall transmit the HARQ-ACK and scheduling request according to the procedure for PUCCH format 1b with channel selection in TDD.

For TDD when the UE is configured with HARQ-ACK bundling, HARQ-ACK multiplexing or PUCCH format 1b with channel selection, and when both HARQ-ACK and SR are transmitted in the same sub-frame, a UE shall transmit the bundled HARQ-ACK or the multiple HARQ-ACK responses (according to subclause 10.1) on its assigned HARQ-ACK PUCCH resources for a negative SR transmission. For a positive SR, the UE shall transmit $b(0),b(1)$ on its assigned SR PUCCH resource using PUCCH format 1b according to subclause 5.4.1 in [3]. The value of $b(0),b(1)$ are generated according to Table 7.3-1 from the $N_{SPS} + \sum_{c=0}^{N_{cells}^{DL}-1} U_{DAI,c}$ HARQ-ACK responses including ACK in response to PDCCH/EPDCCH indicating downlink SPS release by spatial HARQ-ACK bundling across multiple codewords within each PDSCH transmission for all serving cells N_{cells}^{DL}. For TDD UL/DL configurations 1-6, if $\sum_{c=0}^{N_{cells}^{DL}-1} U_{DAI,c} > 0$ and $V_{DAI,c}^{DL} \neq (U_{DAI,c} - 1) \bmod 4 + 1$ for a serving cell c, the UE detects that at least one downlink assignment has been missed.

Table 7.3-1: Mapping between multiple HARQ-ACK responses and $b(0), b(1)$

Number of ACK among multiple ($N_{SPS} + \sum_{c=0}^{N_{cells}^{DL}-1} U_{DAI,c}$) HARQ-ACK responses	$b(0), b(1)$
0 or None (UE detect at least one DL assignment is missed)	0, 0
1	1, 1
2	1, 0
3	0, 1
4	1, 1
5	1, 0
6	0, 1
7	1, 1
8	1, 0
9	0, 1

For TDD if the parameter *simultaneousAckNackAndCQI* provided by higher layers is set *TRUE,* and if the UE is configured with HARQ-ACK bundling, HARQ-ACK multiplexing or PUCCH format 1b with channel selection, and if the UE receives PDSCH and/or PDCCH/EPDCCH indicating downlink SPS release only on the primary cell within subframe(s) $n-k$, where $k \in K$, a UE shall transmit the CSI and $b(0), b(1)$ using PUCCH format 2b for normal CP or PUCCH format 2 for extended CP, according to subclause 5.2.3.4 in [4] with a_0'', a_1'' replaced by $b(0), b(1)$. The value of $b(0), b(1)$ are generated according to Table 7.3-1 from the $N_{SPS} + \sum_{c=0}^{N_{cells}^{DL}-1} U_{DAI,c}$ HARQ-ACK responses including ACK in response to PDCCH/EPDCCH indicating downlink SPS release by spatial HARQ-ACK bundling across multiple codewords within each PDSCH transmission for all serving cells N_{cells}^{DL}. For TDD UL/DL configurations 1-6, if $\sum_{c=0}^{N_{cells}^{DL}-1} U_{DAI,c} > 0$ and $V_{DAI,c}^{DL} \neq (U_{DAI,c} - 1) \bmod 4 + 1$ for a serving cell c, the UE detects that at least one downlink assignment has been missed.

For TDD if the parameter *simultaneousAckNackAndCQI* provided by higher layers is set *TRUE,* and if the UE is configured with PUCCH format 1b with channel selection and receives at least one PDSCH on the secondary cell within subframe(s) $n-k$, where $k \in K$, the UE shall drop the CSI and transmit HARQ-ACK according to subclause 10.1.3.

For TDD and a UE is configured with PUCCH format 3,

if the parameter *simultaneousAckNackAndCQI* is set *TRUE* and if the UE receives,

- a single PDSCH transmission only on the primary cell indicated by the detection of a corresponding PDCCH/EPDCCH in subframe $n-k_m$, where $k_m \in K$, and for TDD UL/DL configurations 1-6 the DAI value in the PDCCH/EPDCCH is equal to '1' (defined in Table 7.3-X), or a PDCCH/EPDCCH indicating downlink SPS release (defined in subclause 9.2) in subframe $n-k_m$, where $k_m \in K$, and for TDD UL/DL configurations 1-6 the DAI value in the PDCCH/EPDCCH is equal to '1', or
- a single PDSCH transmission only on the primary cell where there is not a corresponding PDCCH/EPDCCH detected within subframe(s) $n-k$, where $k \in K$ and no PDCCH/EPDCCH indicating downlink SPS release (defined in subclause 9.2) within subframe(s) $n-k$, where $k \in K$,

then the UE shall transmit the CSI and HARQ-ACK using PUCCH format 2/2a/2b according to subclause 5.2.3.4 in [4]; else if

- the parameter *simultaneousAckNackAndCQI-Format3-r11* is set *TRUE* and if PUCCH format 3 resource is determined according to subclause 10.1.3.1 or subclause 10.1.3.2.2 and
  - if the total number of bits in the subframe corresponding to HARQ-ACKs, SR (if any), and the CSI is not larger than 22, or

- if the total number of bits in the subframe corresponding to spatially bundled HARQ-ACKs, SR (if any), and the CSI is not larger than 22

then the UE shall transmit the HARQ-ACKs, SR (if any) and the CSI using the determined PUCCH format 3 resource according to [4];

else,

- the UE shall drop the CSI and transmit the HARQ-ACK according to subclause 10.1.3.

For TDD and a UE configured with PUCCH format 4 or PUCCH format 5, and if the UE has HARQ-ACK/SR and periodic CSI reports to transmit in a subframe,

- if a PUCCH format 3 is determined to transmit the HARQ-ACK/SR according to subclause 10.1.3.2.3 or 10.1.3.2.4, the UE shall use the determined PUCCH format 3 for transmission of the HARQ-ACK/SR and periodic CSI report(s) if the parameter *simultaneousAckNackAndCQI-Format3-r11* provided by higher layers is set *TRUE*; otherwise, the UE shall drop the periodic CSI report(s) and transmit only HARQ-ACK/SR;
- if a PUCCH format 4 is determined to transmit the HARQ-ACK/SR according to subclause 10.1.3.2.3 or a PUCCH format 5 is determined to transmit the HARQ-ACK/SR according to 10.1.3.2.4, the UE shall use the determined PUCCH format 4 or PUCCH format 5 for transmission of the HARQ-ACK/SR and periodic CSI report(s) if the parameter *simultaneousAckNackAndCQI-Format4-Format5-r13* provided by higher layers is set *TRUE*; otherwise, the UE shall drop the periodic CSI report(s) and transmit only HARQ-ACK/SR;
- if there is no PUCCH format 3 or 4 determined to transmit the HARQ-ACK/SR according to subclause 10.1.3.2.3 and there is no PUCCH format 3 or 5 determined to transmit the HARQ-ACK/SR according to subclause 10.1.3.2.4 and there are more than one periodic CSI report(s) in the subframe,
  - o if the parameter *simultaneousAckNackAndCQI-Format4-Format5-r13* provided by higher layers is set *TRUE* and if the UE is configured with a single PUCCH format 4 resource $n_{\text{PUCCH}}^{(4)}$ according to higher layer parameter *format4-MultiCSI-resourceConfiguration*, the PUCCH format 4 resource $n_{\text{PUCCH}}^{(4)}$ is used for transmission of the HARQ-ACK/SR and periodic CSI report(s);
  - o if the parameter *simultaneousAckNackAndCQI-Format4-Format5-r13* provided by higher layers is set *TRUE* and if the UE is configured with a PUCCH format 5 resource $n_{\text{PUCCH}}^{(5)}$ according to higher layer parameter *format5-MultiCSI-resourceConfiguration*, the PUCCH format 5 resource $n_{\text{PUCCH}}^{(5)}$ is used for transmission of the HARQ-ACK/SR and periodic CSI report(s);
  - o if the parameter *simultaneousAckNackAndCQI-Format4-Format5-r13* provided by higher layers is set *TRUE* and if the UE is configured with two PUCCH format 4 resources $n_{\text{PUCCH},1}^{(4)}$ and $n_{\text{PUCCH},2}^{(4)}$ according to higher layer parameter *format4-MultiCSI-resourceConfiguration*, if $\left(O^{ACK} + O^{SR} + O_{\text{P-CSI}} + O_{CRC}\right) \le \min\left(M_{\text{RB},1}^{\text{PUCCH4}}, M_{\text{RB},2}^{\text{PUCCH4}}\right) \cdot N_{sc}^{RB} \cdot N_{\text{symb}}^{\text{PUCCH4}} \cdot 2 \cdot r$, the PUCCH format 4 resource with the smaller $M_{\text{RB},i}^{\text{PUCCH4}}$ between $n_{\text{PUCCH},1}^{(4)}$ and $n_{\text{PUCCH},2}^{(4)}$ is used for transmission of the HARQ-ACK/SR and periodic CSI report(s); otherwise, the PUCCH format 4 resource with the larger $M_{\text{RB},i}^{\text{PUCCH4}}$ between $n_{\text{PUCCH},1}^{(4)}$ and $n_{\text{PUCCH},2}^{(4)}$ is used for transmission of the HARQ-ACK/SR periodic CSI report(s), where
    - O^{ACK} is the total number of HARQ-ACK bits in the subframe;
    - $O^{SR} = 0$ if there is no scheduling request bit in the subframe and $O^{SR} = 1$ otherwise
    - $O_{\text{P-CSI}}$ is the total number of CSI report bits in the subframe;
    - O_{CRC} is the number of CRC bits;
    - $M_{\text{RB},i}^{\text{PUCCH4}}$, $i = 1,2$, is the number of PRBs for $n_{\text{PUCCH},1}^{(4)}$ and $n_{\text{PUCCH},2}^{(4)}$ respectively, according to higher layer parameter *numberOfPRB-format4-r13* according to Table 10.1.1-2;

  - $N_{\text{symb}}^{\text{PUCCH4}} = 2 \cdot \left(N_{\text{symb}}^{\text{UL}} - 1\right) - 1$ if shortened PUCCH format 4 is used in the subframe and $N_{\text{symb}}^{\text{PUCCH4}} = 2 \cdot \left(N_{\text{symb}}^{\text{UL}} - 1\right)$ otherwise; and
  - r is the code rate given by higher layer parameter *maximumPayloadCoderate-r13* according to Table 10.1.1-1.
- o otherwise, the UE shall drop the periodic CSI reports and transmit only HARQ-ACK/SR.

- if there is no PUCCH format 3 or 4 determined to transmit the HARQ-ACK/SR according to subclause 10.1.3.2.3 and there is no PUCCH format 3 or 5 determined to transmit the HARQ-ACK/SR according to subclause 10.1.3.2.4 and there is only one periodic CSI report in the subframe,
  - o if there is no positive SR and the parameter *simultaneousAckNackAndCQI* is set *TRUE* and if the UE receives,
    - a single PDSCH transmission only on the primary cell indicated by the detection of a corresponding PDCCH/EPDCCH in subframe $n - k_m$, where $k_m \in K$, and the counter DAI value in the PDCCH/EPDCCH is equal to '1' (defined in Table 7.3-X), or a PDCCH/EPDCCH indicating downlink SPS release (defined in subclause 9.2) in subframe $n - k_m$, where $k_m \in K$, and the counter DAI value in the PDCCH/EPDCCH is equal to '1', or
    - a single PDSCH transmission only on the primary cell where there is not a corresponding PDCCH/EPDCCH detected within subframe(s) $n - k$, where $k \in K$ and no PDCCH/EPDCCH indicating downlink SPS release (defined in subclause 9.2) within subframe(s) $n - k$, where $k \in K$,

    then the UE shall transmit the CSI and HARQ-ACK using PUCCH format 2/2a/2b according to subclause 5.2.3.4 in [4];
  - o else,

    the UE shall drop the CSI and transmit the HARQ-ACK according to subclause 10.1.3.2.3 or 10.1.3.2.4 when UE shall transmit HARQ-ACK only or UE shall drop the CSI and transmit the HARQ-ACK and SR according to the procedure for PUCCH format 1b with channel selection in TDD when there is positive SR.

- If a UE transmits HARQ-ACK/SR and periodic CSI report(s) using either a PUCCH format 4 $n_{\text{PUCCH}}^{(4)}$ or PUCCH format 5 $n_{\text{PUCCH}}^{(5)}$ in a subframe
  - o if $\left(O^{ACK} + O^{SR} + O_{\text{P-CSI}} + O_{\text{CRC}}\right) \le 2 \cdot N_{\text{RE}} \cdot r$, the UE shall transmit the HARQ-ACK/SR and periodic CSI bits using the PUCCH format 4 $n_{\text{PUCCH}}^{(4)}$ or the PUCCH format 5 $n_{\text{PUCCH}}^{(5)}$;
  - o if $\left(O^{ACK} + O^{SR} + O_{\text{P-CSI}} + O_{\text{CRC}}\right) > 2 \cdot N_{\text{RE}} \cdot r$, the UE shall select $N_{\text{CSI,reported}}$ CSI report(s) for transmission together with HARQ-ACK/SR in ascending order of $\text{Pri}_{CSI}(y,s,c,t)$, where $\text{Pri}_{CSI}(y,s,c,t)$, N_{RE} and r are determined according to subclause 7.2.2; the value of $N_{\text{CSI,reported}}$ satisfies $\left(O^{ACK} + O^{SR} + \sum_{n=1}^{N_{\text{CSI,reported}}} O_{\text{P-CSI},n} + O_{\text{CRC}}\right) \le 2 \cdot N_{\text{RE}} \cdot r$ and $\left(O^{ACK} + O^{SR} + \sum_{n=1}^{N_{\text{CSI,reported}}+1} O_{\text{P-CSI},n} + O_{\text{CRC}}\right) > 2 \cdot N_{\text{RE}} \cdot r$, and $O_{P-CSI,n}$ is the number of CSI report bits for the *n*th CSI report in ascending order of $\text{Pri}_{CSI}(y,s,c,t)$.

For TDD and a BL/CE UE,

- if the UE is configured with *csi-NumRepetitionCE* equal to 1 and *mPDCCH-NumRepetition* equal to 1,

- the UE behaviour for HARQ-ACK reporting is the same as that of a non-BL/CE UE with TDD, except:
    - PDCCH/EPDCCH is replaced by MPDCCH; and
    - DCI format 1/1A/1B/1D/2/2A/2B/2C/2D is replaced by DCI format 6-1A; and
    - DCI format 0/4 is replaced by DCI format 6-0A; and
    - PUCCH is transmitted in a set of BL/CE UL subframe(s) according to section 10.2 for TDD and BL/CE UEs;
- else
    - the UE is not expected to receive more than one PDSCH transmission, or more than one of PDSCH and MPDCCH indicating downlink SPS releases, with transmission ending within subframe(s) $n-k$, where $k \in K$ and K is defined in Table 10.1.3.1-1 intended for the UE;
    - The UE behavior for HARQ-ACK reporting is the same as that of a BL/CE UE with FDD, except:
        - PUCCH resource is determined according to section 10.1.3.1; and
        - PUCCH is transmitted in a set of BL/CE UL subframe(s) according to section 10.2 for TDD and BL/CE UEs.

If the BL/CE UE is configured in CEModeA, and if the PDSCH is assigned by or semi-statically scheduled by a MPDCCH with DCI format 6-1A, the UE shall assume no PDSCH repetition if the higher layer parameter *csi-NumRepetitionCE-r13* indicates one subframe.

7.3.2.2 TDD HARQ-ACK reporting procedure for different UL/DL configurations

For a configured serving cell, the DL-reference UL/DL configuration as defined in subclause 10.2 is referred to as the "DL-reference UL/DL configuration" in the rest of this subclause.

For a configured serving cell, if a UE is not configured with higher layer parameter *codebooksizeDetermination-r13 = dai* and if the DL-reference UL/DL configuration is 0, then the DAI in DCI format 1/1A/1B/1D/2/2A/2B/2C/2D is not used.

The UE shall upon detection of a PDSCH transmission or a PDCCH/EPDCCH indicating downlink SPS release (defined in subclause 9.2) within subframe(s) $n-k$ for serving cell *c*, where $k \in K_c$ intended for the UE and for which HARQ-ACK response shall be provided, transmit the HARQ-ACK response in UL subframe *n*, wherein set K_c contains values of $k \in K$ such that subframe *n-k* corresponds to a downlink subframe or a special subframe for serving cell *c*, where DL subframe or special subframe of serving cell *c* is according to the higher layer parameter *eimta-HARQ-ReferenceConfig-r12* if the UE is configured with the higher layer parameter *EIMTA-MainConfigServCell-r12* for serving cell *c;* K defined in Table 10.1.3.1-1 (where "UL/DL configuration" in Table 10.1.3.1-1 refers to the DL-reference UL/DL configuration) is associated with subframe *n.* M_c is the number of elements in set K_c associated with subframe *n* for serving cell *c*.

For the remainder of this subclause $K = K_c$.

If the UE is configured with the parameter *EIMTA-MainConfigServCell-r12* for the primary cell, “UL/DL configuration of the primary cell” in the rest of this subclause refers to “DL-reference UL/DL configuration of the primary cell”.

When PUCCH format 3/4/5 is configured for transmission of HARQ-ACK, for special subframe configurations 0 and 5 with normal downlink CP or configurations 0 and 4 with extended downlink CP in a serving cell, shown in table 4.2-1 [3], the special subframe of the serving cell is excluded from the HARQ-ACK codebook size determination. In this case, if the serving cell is the primary cell, there is no PDCCH/EPDCCH indicating downlink SPS release in the special subframe.

If the UL-reference UL/DL configuration (defined in Sec 8.0) belongs to {1,2,3,4,5,6} for a serving cell, a value W_{DAI}^{UL} is determined by the Downlink Assignment Index (DAI) in DCI format 0/4 corresponding to a PUSCH on the serving cell according to Table 7.3-Z in subframe $n-k'$, where k' is defined in Table 7.3-Y and the "TDD UL/DL Configuration" in Table 7.3-Y refers to the UL-reference UL/DL configuration (defined in subclause 8.0) for the serving cell. In case neither PDSCH transmission, nor PDCCH/EPDCCH indicating the downlink SPS resource release is intended to the UE, the UE can expect that the value of W_{DAI}^{UL} is set to 4 by the DAI in DCI format 0/4 if transmitted.

If a UE is not configured with higher layer parameter *codebooksizeDetermination-r13 = dai* and if the DL-reference UL/DL configuration belongs to {1,2,3,4,5,6}, the value of the DAI in DCI format 1/1A/1B/1D/2/2A/2B/2C/2D denotes the accumulative number of PDCCH/EPDCCH (s) with assigned PDSCH transmission(s) and PDCCH/EPDCCH indicating downlink SPS release up to the present subframe within subframe(s) $n-k$ of each configured serving cell, where $k \in K$, and shall be updated from subframe to subframe. Denote $V_{DAI,c}^{DL}$ as the value of the DAI in PDCCH/EPDCCH with DCI format 1/1A/1B/1D/2/2A/2B/2C/2D detected by the UE according to Table 7.3-X in subframe $n-k_m$ in serving cell c, where k_m is the smallest value in the set K such that the UE detects a DCI format 1/1A/1B/1D/2/2A/2B/2C/2D.

For all TDD UL/DL configurations, denote $U_{DAI,c}$ as the total number of PDCCH/EPDCCH (s) with assigned PDSCH transmission(s) and PDCCH/EPDCCH indicating downlink SPS release detected by the UE within the subframe(s) $n-k$ in serving cell c, where $k \in K$. Denote N_{SPS}, which can be zero or one, as the number of PDSCH transmissions without a corresponding PDCCH/EPDCCH within the subframe(s) $n-k$, where $k \in K$.

If PUCCH format 3 is configured for transmission of HARQ-ACK without PUCCH format 4/5 configured for transmission of HARQ-ACK, the HARQ-ACK feedback bits $o_{c,0}^{ACK}\, o_{c,1}^{ACK},...,o_{c,O_c^{ACK}-1}^{ACK}$ for the *c*-th serving cell configured by RRC are constructed as follows, where *c*≥0, $O_c^{ACK} = B_c^{DL}$ if transmission mode configured in the *c*-th serving cell supports one transport block or spatial HARQ-ACK bundling is applied and $O_c^{ACK} = 2B_c^{DL}$ otherwise, where B_c^{DL} is the number of downlink and special subframes for which the UE needs to feedback HARQ-ACK bits for the *c*-th serving cell.

- For the case that the UE is transmitting in subframe *n* on PUCCH or a PUSCH transmission not adjusted based on a detected DCI format 0/4 or a PUSCH transmission adjusted based on an associated detected DCI format 0/4 with UL-reference UL/DL configuration 0 (defined in Sec 8.0), then $B_c^{DL} = M_c$. The UE shall not transmit HARQ-ACK on PUSCH if the UE does not receive PDSCH or PDCCH/EPDCCH indicating downlink SPS release in subframe(s) $n-k$, where $k \in K$.
- If DL-reference UL/DL configuration of each of the configured serving cells belongs to {0, 1, 2, 3, 4, 6} and for a PUSCH transmission in a subframe *n* adjusted based on a detected PDCCH/EPDCCH with DCI format 0/4 using UL-reference UL/DL configuration belonging to {1,2,3,4,5,6} (defined in Sec 8.0), the UE shall assume $B_c^{DL} = \min\left(W_{DAI}^{UL}, M_c\right)$. The UE shall not transmit HARQ-ACK on PUSCH if the UE does not receive PDSCH or PDCCH/EPDCCH indicating downlink SPS release in subframe(s) $n-k$ where $k \in K$ and $W_{DAI}^{UL} = 4$.
- If DL-reference UL/DL configuration of at least one configured serving cell belongs to {5} and for a PUSCH transmission adjusted based on an associated detected PDCCH/EPDCCH with DCI format 0/4 using UL-reference UL/DL configuration belonging to {1,2,3,4,5,6} (defined in Sec 8.0), the UE shall assume $B_c^{DL} = \min\left(W_{DAI}^{UL} + 4\left\lceil \left(U - W_{DAI}^{UL}\right)/4 \right\rceil, M_c\right)$, where U denotes the maximum value of U_c among all the configured serving cells, U_c is the total number of received PDSCHs and PDCCH/EPDCCH indicating downlink SPS release in subframe(s) $n-k$ for the *c*-th serving cell, $k \in K$. The UE shall not transmit HARQ-ACK on PUSCH if the UE does not receive PDSCH or PDCCH/EPDCCH indicating downlink SPS release in subframe(s) $n-k$ where $k \in K$ and $W_{DAI}^{UL} = 4$.

If PUCCH format 4/5 is configured for transmission of HARQ-ACK and higher layer parameter *codebooksizeDetermination-r13 = cc* is not configured, the HARQ-ACK feedback bits $o_{c,0}^{ACK}\, o_{c,1}^{ACK},...,o_{c,O_c^{ACK}-1}^{ACK}$ for the *c*-th serving cell configured by RRC are constructed as follows, where *c*≥0, $O_c^{ACK} = B_c^{DL}$ if transmission mode configured in the *c*-th serving cell supports one transport block or spatial HARQ-ACK bundling is applied and

$O_c^{ACK} = 2B_c^{DL}$ otherwise, where B_c^{DL} is the number of downlink and special subframes for which the UE needs to feedback HARQ-ACK bits for the *c*-th serving cell.

- For the case that the UE is transmitting in subframe *n* on PUCCH or a PUSCH transmission not adjusted based on a detected DCI format 0/4 or a PUSCH transmission adjusted based on an associated detected DCI format 0/4, then $B_c^{DL} = M_c$. The UE shall not transmit HARQ-ACK on PUSCH if the UE does not receive PDSCH or PDCCH/EPDCCH indicating downlink SPS release in subframe(s) $n-k$, where $k \in K$.

When PUCCH format 3/4/5 is configured for transmission of HARQ-ACK and if the UE is not configured with higher layer parameter *codebooksizeDetermination-r13 = cc*,

- if DL-reference UL/DL configuration belongs to {1,2,3,4,5,6}, the HARQ-ACK for a PDSCH transmission with a corresponding PDCCH/EPDCCH or for a PDCCH/EPDCCH indicating downlink SPS release in subframe $n-k$ is associated with $o_{c,DAI(k)-1}^{ACK}$ if transmission mode configured in the *c*-th serving cell supports one transport block or spatial HARQ-ACK bundling is applied, or associated with $o_{c,2DAI(k)-2}^{ACK}$ and $o_{c,2DAI(k)-1}^{ACK}$ otherwise, where *DAI(k)* is the value of DAI in DCI format 1A/1B/1D/1/2/2A/2B/2C/2D detected in subframe $n-k$, $o_{c,2DAI(k)-2}^{ACK}$ and $o_{c,2DAI(k)-1}^{ACK}$ are the HARQ-ACK feedback for codeword 0 and codeword 1, respectively. For the case with $N_{SPS} > 0$, the HARQ-ACK associated with a PDSCH transmission without a corresponding PDCCH/EPDCCH is mapped to $o_{c,O_c^{ACK}-1}^{ACK}$ The HARQ-ACK feedback bits without any detected PDSCH transmission or without detected PDCCH/EPDCCH indicating downlink SPS release are set to NACK;

- if DL-reference UL/DL configuration is 0, the HARQ-ACK for a PDSCH transmission or for a PDCCH/EPDCCH indicating downlink SPS release in subframe $n-k$ is associated with $o_{c,0}^{ACK}$ if transmission mode configured in the *c*-th serving cell supports one transport block or spatial HARQ-ACK bundling is applied, or associated with $o_{c,0}^{ACK}$ and $o_{c,1}^{ACK}$ otherwise, where $o_{c,0}^{ACK}$ and $o_{c,1}^{ACK}$ are the HARQ-ACK feedback for codeword 0 and codeword 1, respectively. The HARQ-ACK feedback bits without any detected PDSCH transmission or without detected PDCCH/EPDCCH indicating downlink SPS release are set to NACK.

If DL-reference UL/DL configuration of each of the serving cells belongs to {0,1,2,3,4,6} and if PUCCH format 1b with channel selection is configured for transmission of HARQ-ACK and for two configured serving cells, the HARQ-ACK feedback bits o_0^{ACK} o_1^{ACK} $,...,o_{O^{ACK}-1}^{ACK}$ on PUSCH are constructed as follows

- if UL-reference UL/DL configuration (defined in Sec 8.0) belongs to {1, 2, 3, 4, 6}, for a PUSCH transmission adjusted based on a detected PDCCH/EPDCCH with DCI format 0/4 with W_{DAI}^{UL} =1 or 2, o_j^{ACK} is determined as if PUCCH format 3 is configured for transmission of HARQ-ACK, except that spatial HARQ-ACK bundling across multiple codewords within a downlink or special subframe is performed for all serving cells configured with a downlink transmission mode that supports up to two transport blocks in case W_{DAI}^{UL} =2, where the UL-reference UL/DL configuration is the UL-reference UL/DL configuration of the serving cell corresponding to the PUSCH transmission.

- if UL-reference UL/DL configuration (defined in Sec 8.0) belongs to {1, 2, 3, 4, 6}, for a PUSCH transmission adjusted based on a detected PDCCH/EPDCCH with DCI format 0/4 with W_{DAI}^{UL} =3 or 4, $o_j^{ACK} = o(j)$, $0 \le j \le 3$ as defined in Table 10.1.3.2-5 or in Table 10.1.3.2-6 respectively, where the value of M is replaced by W_{DAI}^{UL} where the UL-reference UL/DL configuration is the UL-reference UL/DL configuration of the serving cell corresponding to the PUSCH transmission. The UE shall not transmit HARQ-ACK on PUSCH if the UE does not receive PDSCH or PDCCH/EPDCCH indicating downlink SPS release in subframe(s) $n-k$ where $k \in K$ and $W_{DAI}^{UL} = 4$.

- if UL-reference UL/DL configuration (defined in Sec 8.0) is 0, or if UL-reference UL/DL configuration (defined in Sec 8.0) belongs to {1, 2, 3, 4, 6}, for a PUSCH transmission not adjusted based on a detected PDCCH/EPDCCH with DCI format 0/4, for a subframe n with M =1 or 2 (M defined in Sec 10.1.3.2.1),

o_j^{ACK} = HARQ-ACK(j), $0 \le j \le A-1$ as defined in subclause 10.1.3.2.1, where the UL-reference UL/DL configuration is the UL-reference UL/DL configuration of the serving cell corresponding to the PUSCH transmission. The UE shall not transmit HARQ-ACK on PUSCH if the UE does not receive PDSCH or PDCCH/EPDCCH indicating downlink SPS release in subframe(s) $n-k$ where $k \in K$.

- if UL-reference UL/DL configuration (defined in Sec 8.0) is 0, or if UL-reference UL/DL configuration (defined in Sec 8.0) belongs to {1, 2, 3, 4, 6} and, for a PUSCH transmission not adjusted based on a detected PDCCH/EPDCCH with DCI format 0/4, for a subframe n with M =3 or 4 (M defined in Sec 10.1.3.2.1), $o_j^{ACK} = o(j)$, $0 \le j \le 3$ as defined in Table 10.1.3.2-5 or in Table 10.1.3.2-6 respectively, where the UL-reference UL/DL configuration is the UL-reference UL/DL configuration of the serving cell corresponding to the PUSCH transmission. The UE shall not transmit HARQ-ACK on PUSCH if the UE does not receive PDSCH or PDCCH/EPDCCH indicating downlink SPS release in subframe(s) $n-k$ where $k \in K$.

If a UE is configured with higher layer parameter *codebooksizeDetermination-r13 = dai*, the value of the counter Downlink Assignment Indicator (DAI) in DCI format 1/1A/1B/1D/2/2A/2B/2C/2D denotes the accumulative number of {serving cell, subframe}-pair(s) in which PDSCH transmission(s) associated with PDCCH/EPDCCH or PDCCH/EPDCCH indicating downlink SPS release is present, up to the present serving cell and present subframe, first in increasing order of serving cell index and then in increasing order of subframe index within subframe(s) $n-k$ where $k \in \bigcup_{i \in C} K_i$ and C is the set of configured serving cells; the value of the total DAI in DCI format 1/1A/1B/1D/2/2A/2B/2C/2D denotes the total number of {serving cell, subframe}-pair(s) in which PDSCH transmission(s) associated with PDCCH/EPDCCH(s) or PDCCH/EPDCCH indicating downlink SPS release is present, up to the present subframe within subframe(s) $n-k$ where $k \in \bigcup_{i \in C} K_i$ and C is the set of configured serving cells, and shall be updated from subframe to subframe. Denote $V_{C-DAI,c,k}^{DL}$ as the value of the counter DAI in DCI format 1/1A/1B/1D/2/2A/2B/2C/2D scheduling PDSCH transmission or indicating downlink SPS release for serving cell c in subframe $n-k$ where $k \in \bigcup_{i \in C} K_i$ according to table 7.3.2.1-1. Denote $V_{T-DAI,k}^{DL}$ as the value of the total DAI in subframe $n-k$ where $k \in \bigcup_{i \in C} K_i$, according to Table 7.3.2.1-1. The UE shall assume a same value of total DAI in all PDCCH/EPDCCH scheduling PDSCH transmission(s) and PDCCH/EPDCCH indicating downlink SPS release in a subframe. For a serving cell c and a value $k \in \bigcup_{i \in C} K_i$ but $k \notin K_c$, the {serving cell, subframe}-pair {c, $n-k$ } is excluded when determining the values of counter DAI and total DAI for HARQ-ACK transmission in subframe n.

If a UE is configured with higher layer parameter *codebooksizeDetermination-r13 = dai* and if the UE transmits HARQ-ACK using PUCCH format 3 or PUCCH format 4 or PUCCH format 5 in subframe n, the UE shall determine the $\tilde{o}_0^{ACK}, \tilde{o}_1^{ACK}, ..., \tilde{o}_{O^{ACK}-1}^{ACK}$ according to the following pseudo-code:

Set $c = 0$ – cell index: lower indices correspond to lower RRC indices of corresponding cell

Set $m = 0$ – subframe index: lower index corresponds to earlier subframe within subframe(s) $n-k$ where $k \in \bigcup_{i \in C} K_i$

Set $j = 0$

Set $V_{temp} = 0$

Set $V_{temp2} = 0$

Set $V_s = \emptyset$

Set N_{cells}^{DL} to the number of cells configured by higher layers for the UE

Set *M* to the number of subframes within subframe(s) $n-k$ where $k \in \bigcup_{i \in C} K_i$

while *m* < *M*

while *c* < N_{cells}^{DL}

if there is a PDSCH on serving cell *c* in subframe *m* associated with PDCCH/EPDCCH or there is a PDCCH/EPDCCH indicating downlink SPS release on serving cell *c* in subframe *m*, and if subframe *m* belongs to the set of subframe(s) $n-k$ where $k \in K_c$,

if $V_{C-DAI,c,m}^{DL} \le V_{temp}$

$j = j+1$

end if

$V_{temp} = V_{C-DAI,c,m}^{DL}$

if $V_{T-DAI,m}^{DL} = \varnothing$

$V_{temp2} = V_{C-DAI,c,m}^{DL}$

else

$V_{temp2} = V_{T-DAI,m}^{DL}$

end if

if the higher layer parameter *spatialBundlingPUCCH* is set *FALSE* and the UE is configured with a transmission mode supporting two transport blocks in at least one configured serving cell,

$\tilde{o}_{8j+2\left(V_{C-DAI,c,m}^{DL}-1\right)}^{ACK}$ = HARQ-ACK bit corresponding to the first codeword of this cell

$\tilde{o}_{8j+2\left(V_{C-DAI,c,m}^{DL}-1\right)+1}^{ACK}$ = HARQ-ACK bit corresponding to the second codeword of this cell

$$V_s = V_s \cup \left\{8j + 2\left(V_{C-DAI,c,m}^{DL} - 1\right), 8j + 2\left(V_{C-DAI,c,m}^{DL} - 1\right) + 1\right\}$$

elseif the higher layer parameter *spatialBundlingPUCCH* is set *TRUE* and the UE is configured with a transmission mode supporting two transport blocks in at least one configured serving cell,

$\tilde{o}_{4j+V_{C-DAI,c,m}^{DL}-1}^{ACK}$ = binary AND operation of the HARQ-ACK bits corresponding to the first and second codewords of this cell

$$V_s = V_s \cup \left\{4j + V_{C-DAI,c,m}^{DL} - 1\right\}$$

else

$\tilde{o}_{4j+V_{C-DAI,c,m}^{DL}-1}^{ACK}$ = HARQ-ACK bit of this cell

$$V_s = V_s \cup \left\{4j + V_{C-DAI,c,m}^{DL} - 1\right\}$$

end if

end if

$c = c + 1$

end while

m = m + 1

end while

if $V_{temp2} < V_{temp}$

j = j+1

end if

if the higher layer parameter *spatialBundlingPUCCH* is set *FALSE* and the UE is configured with a transmission mode supporting two transport blocks in at least one configured serving cell,

$$O^{ACK} = 2 \cdot \left(4 \cdot j + V_{temp2}\right)$$

else

$$O^{ACK} = 4 \cdot j + V_{temp2}$$

end if

$\tilde{o}_i^{ACK} = \text{NACK}$ for any $i \in \{0,1,...,O^{ACK}-1\} \backslash V_s$

if SPS PDSCH transmission is activated for a UE and the UE is configured to receive SPS PDSCH in a subframe $n-k$ where $k \in \bigcup_{i \in C} K_i$

$$O^{ACK} = O^{ACK} + 1$$

$o_{O^{ACK}-1}^{ACK}$ = HARQ-ACK bit associated with the SPS PDSCH transmission

end if

For a UE configured with higher layer parameter *codebooksizeDetermination-r13 = dai*, if the UE transmits HARQ-ACK on PUSCH in a subframe, the UE shall determine the $\tilde{o}_0^{ACK}, \tilde{o}_1^{ACK}, ..., \tilde{o}_{O^{ACK}-1}^{ACK}$ according to the above procedure as if the UE transmits HARQ-ACK using PUCCH format 3 or PUCCH format 4 or PUCCCH format 5, except that the higher layer parameter *spatialBundlingPUCCH* is replaced by *spatialBundlingPUSCH*.

If a UE is configured with higher layer parameter *codebooksizeDetermination-r13 = cc* and if the UE transmits HARQ-ACK using PUCCH format 4 or PUCCH format 5 in subframe *n*, the UE shall determine the $\tilde{o}_0^{ACK}, \tilde{o}_1^{ACK}, ..., \tilde{o}_{O^{ACK}-1}^{ACK}$ according to the pseudo-code in subclause 5.2.3.1 in [4].

For a UE configured with higher layer parameter *codebooksizeDetermination-r13 = cc*, if the UE transmits HARQ-ACK on PUSCH in a subframe, the UE shall determine the $\tilde{o}_0^{ACK}, \tilde{o}_1^{ACK}, ..., \tilde{o}_{O^{ACK}-1}^{ACK}$ according to the pseudo-code in subclause 5.2.2.6 in [4].

When a PUCCH format 3 transmission of HARQ-ACK coincides with a sub-frame configured to the UE by higher layers for transmission of a scheduling request, the UE shall multiplex HARQ-ACK and SR bits on HARQ-ACK PUCCH resource as defined in subclause 5.2.3.1 in [4], unless the HARQ-ACK corresponds to one of the following cases

- a single PDSCH transmission only on the primary cell indicated by the detection of a corresponding PDCCH/EPDCCH in subframe $n-k_m$, where $k_m \in K$, and for UL/DL configuration of the primary cell belonging to {1,2,3,4,5,6}, the DAI value in the PDCCH/EPDCCH is equal to '1' (defined in Table 7.3-X), or a

PDCCH/EPDCCH indicating downlink SPS release (defined in subclause 9.2) in subframe $n-k_m$, where $k_m \in K$, and for UL/DL configuration of the primary cell belonging to {1,2,3,4,5,6} the DAI value in the PDCCH/EPDCCH is equal to '1', or

- a single PDSCH transmission only on the primary cell where there is not a corresponding PDCCH/EPDCCH detected within subframe(s) $n-k$, where $k \in K$ and no PDCCH/EPDCCH indicating downlink SPS release (defined in subclause 9.2) within subframe(s) $n-k$, where $k \in K$, or

- a PDSCH transmission only on the primary cell where there is not a corresponding PDCCH/EPDCCH detected within subframe(s) $n-k$, where $k \in K$ and an additional PDSCH transmission only on the primary cell indicated by the detection of a corresponding PDCCH/EPDCCH in subframe $n-k_m$, where $k_m \in K$ with the DAI value in the PDCCH/EPDCCH equal to '1' (defined in Table 7.3-X) or a PDCCH/EPDCCH indicating downlink SPS release (defined in subclause 9.2) in the subframe $n-k_m$, where $k_m \in K$ with the DAI value in the PDCCH/EPDCCH equal to '1',

in which case the UE shall transmit the HARQ-ACK and scheduling request according to the procedure for PUCCH format 1b with channel selection in TDD.

When a PUCCH format 4/5 transmission of HARQ-ACK coincides with a sub-frame configured to the UE by higher layers for transmission of a scheduling request, the UE shall follow the same procedure described in subclause 7.3.2.1.

If the parameter *simultaneousAckNackAndCQI* provided by higher layers is set *TRUE,* and if the UE is configured with PUCCH format 1b with channel selection, and if the UE receives PDSCH and/or PDCCH/EPDCCH indicating downlink SPS release only on the primary cell within subframe(s) $n-k$, where $k \in K$, a UE shall transmit the CSI and $b(0),b(1)$ using PUCCH format 2b for normal CP or PUCCH format 2 for extended CP, according to subclause 5.2.3.4 in [4] with a_0'', a_1'' replaced by $b(0),b(1)$. The value of $b(0),b(1)$ are generated according to Table 7.3-1 from the $N_{SPS} + \sum_{c=0}^{N_{cells}^{DL}-1} U_{DAI,c}$ HARQ-ACK responses including ACK in response to PDCCH/EPDCCH indicating downlink SPS release by spatial HARQ-ACK bundling across multiple codewords within each PDSCH transmission for all serving cells N_{cells}^{DL}. If DL-reference UL/DL configuration belongs to {1,2,3,4,5,6} and, if $\sum_{c=0}^{N_{cells}^{DL}-1} U_{DAI,c} > 0$ and $V_{DAI,c}^{DL} \neq (U_{DAI,c}-1) \bmod 4 + 1$ for a serving cell c, the UE detects that at least one downlink assignment has been missed.

If the parameter *simultaneousAckNackAndCQI* provided by higher layers is set *TRUE,* and if the UE is configured with PUCCH format 1b with channel selection and receives at least one PDSCH on the secondary cell within subframe(s) $n-k$, where $k \in K$, the UE shall drop the CSI and transmit HARQ-ACK according to subclause 10.1.3.

When both HARQ-ACK and CSI are configured to be transmitted in the same sub-frame and if a UE is configured with PUCCH format 3 and not configured with PUCCH format 4/5,

if the parameter *simultaneousAckNackAndCQI* is set *TRUE* and if the UE receives

- a single PDSCH transmission only on the primary cell indicated by the detection of a corresponding PDCCH/EPDCCH in subframe $n-k_m$, where $k_m \in K$, and for UL/DL configuration of the primary cell belonging to {1,2,3,4,5,6} the DAI value in the PDCCH/EPDCCH is equal to '1' (defined in Table 7.3-X), or a PDCCH/EPDCCH indicating downlink SPS release (defined in subclause 9.2) in subframe $n-k_m$, where $k_m \in K$, and for UL/DL configuration of the primary cell belonging to {1,2,3,4,5,6} the DAI value in the PDCCH/EPDCCH is equal to '1', or

- a single PDSCH transmission only on the primary cell where there is not a corresponding PDCCH detected within subframe(s) $n-k$, where $k \in K$ and no PDCCH/EPDCCH indicating downlink SPS release (defined in subclause 9.2) within subframe(s) $n-k$, where $k \in K$,

then the UE shall transmit the CSI and HARQ-ACK using PUCCH format 2/2a/2b according to subclause 5.2.3.4 in [4];

else if

- the parameter *simultaneousAckNackAndCQI-Format3-r11* is set *TRUE* and if PUCCH format 3 resource is determined according to subclause 10.1.3.1 or subclause 10.1.3.2.2 and
  - if the total number of bits in the subframe corresponding to HARQ-ACKs, SR (if any), and the CSI is not larger than 22, or
  - if the total number of bits in the subframe corresponding to spatially bundled HARQ-ACKs, SR (if any), and the CSI is not larger than 22

then the UE shall transmit the HARQ-ACKs, SR (if any) and the CSI using the determined PUCCH format 3 resource according to [4];

else,

- the UE shall drop the CSI and transmit the HARQ-ACK according to subclause 10.1.3.

For TDD and a UE configured with PUCCH format 4 or PUCCH format 5, if the parameter *simultaneousAckNackAndCQI-Format4-Format5-r13* provided by higher layers is set *TRUE*, and if the UE has HARQ-ACK/SR and periodic CSI reports to transmit in a subframe, the UE HARQ-ACK/SR and periodic CSI reporting procedure follow the procedure described in subclause 7.3.2.1 with the parameter *simultaneousAckNackAndCQI-Format4-Format5-r13* provided by higher layers is set *TRUE*.

7.3.3 FDD-TDD HARQ-ACK reporting procedure for primary cell frame structure type 1

For FDD-TDD and the primary cell is frame structure type 1, with PUCCH format 1b with channel selection,

- for a negative SR transmission,
  - UE shall transmit the HARQ-ACK on its assigned HARQ-ACK PUCCH resource with channel selection as defined in subclause 10.1.2A.
- for a positive SR transmission,
  - if one transport block or two transport blocks or a PDCCH/EPDCCH indicating downlink SPS release is detected on the primary cell in subframe i, and if subframe i is an uplink or a special subframe of configurations 0 and 5 with normal downlink CP or of configurations 0 and 4 with extended downlink CP for the secondary cell according to the higher layer parameter subframeAssignment for UE not configured with the higher layer parameter *EIMTA-MainConfigServCell-r12* and according to the higher layer parameter *eimta-HARQ-ReferenceConfig-r12* for UE configured with the higher layer parameter *EIMTA-MainConfigServCell-r12*,
    - UE shall transmit the HARQ-ACK and SR as for FDD with PUCCH format 1a/1b as described in subclause 7.3.1.
  - otherwise
    - UE shall transmit the HARQ-ACK and SR as for FDD with PUCCH format 1b with channel selection as described in subclause 7.3.1.

For FDD-TDD and the primary cell is frame structure type 1, when PUCCH format 3/4/5 is configured for transmission of HARQ-ACK, for special subframe configurations 0 and 5 with normal downlink CP or configurations 0 and 4 with extended downlink CP in a serving cell, shown in table 4.2-1 [3], the special subframe of the serving cell is excluded from the HARQ-ACK codebook size determination.

For FDD-TDD and the primary cell is frame structure type 1, when a PUCCH format 3/4/5 transmission of HARQ-ACK coincides with a sub-frame configured to the UE by higher layers for transmission of a scheduling request, the UE shall multiplex HARQ-ACK and SR bits on HARQ-ACK PUCCH resource as defined in subclause 5.2.3.1 in [4], unless the HARQ-ACK corresponds to a PDSCH transmission on the primary cell only or a PDCCH/EPDCCH indicating downlink SPS release on the primary cell only, in which case the SR shall be transmitted as for FDD with PUCCH format 1a/1b as described in subclause 7.3.1.

For FDD-TDD and for a PUSCH transmission, a UE shall not transmit HARQ-ACK on PUSCH in subframe *n* if the UE does not receive PDSCH or PDCCH indicating downlink SPS release in subframe *n-4*.

When only a positive SR is transmitted, a UE shall use PUCCH Format 1 for the SR resource as defined in subclause 5.4.1 in [3].

If a UE is configured with higher layer parameter *codebooksizeDetermination-r13 = dai*, the FDD-TDD HARQ-ACK reporting procedure follows the HARQ-ACK procedure described in subclause 7.3.1 for a UE configured with higher layer parameter *codebooksizeDetermination-r13 = dai*.

If a UE is configured with higher layer parameter *codebooksizeDetermination-r13 = cc*, the FDD-TDD HARQ-ACK reporting procedure follows the HARQ-ACK procedure described in subclause 7.3.1 for a UE configured with higher layer parameter *codebooksizeDetermination-r13 = cc*.

7.3.4 FDD-TDD HARQ-ACK reporting procedure for primary cell frame structure type 2

When only a positive SR is transmitted, a UE shall use PUCCH Format 1 for the SR resource as defined in subclause 5.4.1 in [3].

The FDD-TDD HARQ-ACK reporting procedure follows the HARQ-ACK procedure described in subclause 7.3.2.2 with the following exceptions:

- for a serving cell with frame structure type 1, and a UE not configured to monitor PDCCH/EPDCCH in another serving cell for scheduling the serving cell, K is defined in Table 10.1.3A-1, otherwise K is defined in Table 10.1.3.1-1.
- for a serving cell with frame structure type 1 and a UE not configured to monitor PDCCH/EPDCCH in another serving cell for scheduling the serving cell, if the DL-reference UL/DL configuration of the serving cell in Table 10.1.3A-1 belongs to {2,3,4}, B_c^{DL} is determined as in subclause 7.3.2.2 for a serving cell with DL-reference UL/DL configuration {5}.
- for a serving cell with frame structure type 1, and if PUCCH format 3 is configured for transmission of HARQ-ACK, and for a PUSCH transmission in a subframe *n* adjusted based on a detected PDCCH/EPDCCH with DCI format 0/4, the UE shall assume the UL-reference UL/DL configuration of the serving cell belongs to {1,2,3,4,5,6}.
- for a serving cell with frame structure type 1, and if DL-reference UL/DL configuration of each of the serving cells belongs to {0,1,2,3,4,6}, and if PUCCH format 1b with channel selection is configured for transmission of HARQ-ACK and for two configured serving cells, the UE shall assume the UL-reference UL/DL configuration of the serving cell belongs to {1,2,3,4,6}.
- for a serving cell with frame structure type 1, a value W_{DAI}^{UL} is determined by the Downlink Assignment Index (DAI) in DCI format 0/4 corresponding to a PUSCH on the serving cell according to Table 7.3-Z in subframe $n-k'$, where k'=4.
- for a serving cell with frame structure type 1, when PUCCH format 3 is configured for transmission of HARQ-ACK, if the DL-reference UL/DL configuration of the serving cell is 0, the HARQ-ACK for a PDSCH transmission with a corresponding PDCCH/EPDCCH in subframe $n-k$ is associated with $o_{c,DAI(k)-1}^{ACK}$ if transmission mode configured in the *c*-th serving cell supports one transport block or spatial HARQ-ACK bundling is applied, or associated with $o_{c,2DAI(k)-2}^{ACK}$ and $o_{c,2DAI(k)-1}^{ACK}$ otherwise, where *DAI(k)* is the value of DAI in DCI format 1A/1B/1D/1/2/2A/2B/2C/2D detected in subframe $n-k$, $o_{c,2DAI(k)-2}^{ACK}$ and $o_{c,2DAI(k)-1}^{ACK}$ are the HARQ-ACK feedback for codeword 0 and codeword 1, respectively. For the case with $N_{SPS} > 0$, the HARQ-ACK associated with a PDSCH transmission without a corresponding PDCCH/EPDCCH is mapped to $o_{c,O_c^{ACK}-1}^{ACK}$. The HARQ-ACK feedback bits without any detected PDSCH transmission are set to NACK.

8 Physical uplink shared channel related procedures

If the UE is configured with a SCG, the UE shall apply the procedures described in this clause for both MCG and SCG

- When the procedures are applied for MCG, the terms 'secondary cell', 'secondary cells' , 'serving cell', 'serving cells' in this clause refer to secondary cell, secondary cells, serving cell, serving cells belonging to the MCG respectively.
- When the procedures are applied for SCG, the terms 'secondary cell', 'secondary cells', 'serving cell', 'serving cells' in this clause refer to secondary cell, secondary cells (not including PSCell), serving cell, serving cells belonging to the SCG respectively. The term 'primary cell' in this clause refers to the PSCell of the SCG.

For a non-BL/CE UE, and for FDD and transmission mode 1, there shall be 8 uplink HARQ processes per serving cell for non-subframe bundling operation, i.e. normal HARQ operation, and 3 uplink HARQ processes for subframe bundling operation when parameter *e-HARQ-Pattern-r12* is set to *TRUE* and 4 uplink HARQ processes for subframe bundling operation otherwise. For a non-BL/CE UE, and for FDD and transmission mode 2, there shall be 16 uplink HARQ processes per serving cell for non-subframe bundling operation and there are two HARQ processes associated with a given subframe as described in [8]. The subframe bundling operation is configured by the parameter *ttiBundling* provided by higher layers.

For FDD and a BL/CE UE configured with CEModeA, there shall be at most 8 uplink HARQ processes per serving cell.

For FDD and a BL/CE UE configured with CEModeB, there shall be at most 2 uplink HARQ processes per serving cell.

In case higher layers configure the use of subframe bundling for FDD and TDD, the subframe bundling operation is only applied to UL-SCH, such that four consecutive uplink subframes are used.

A BL/CE UE is not expected to be configured with simultaneous PUSCH and PUCCH transmission.

8.0 UE procedure for transmitting the physical uplink shared channel

The term "UL/DL configuration" in this subclause refers to the higher layer parameter *subframeAssignment* unless specified otherwise.

For FDD and normal HARQ operation, the UE shall upon detection on a given serving cell of a PDCCH/EPDCCH with DCI format 0/4 and/or a PHICH transmission in subframe n intended for the UE, adjust the corresponding PUSCH transmission in subframe $n+4$ according to the PDCCH/EPDCCH and PHICH information.

For FDD-TDD and normal HARQ operation and a PUSCH for serving cell c with frame structure type 1, the UE shall upon detection of a PDCCH/EPDCCH with DCI format 0/4 and/or a PHICH transmission in subframe n intended for the UE, adjust the corresponding PUSCH transmission for serving cell c in subframe $n+4$ according to the PDCCH/EPDCCH and PHICH information.

For normal HARQ operation, if the UE detects a PHICH transmission and if the most recent PUSCH transmission for the same transport block was using spatial multiplexing according to subclause 8.0.2 and the UE does not detect a PDCCH/EPDCCH with DCI format 4 in subframe n intended for the UE, the UE shall adjust the corresponding PUSCH retransmission in the associated subframe according to the PHICH information, and using the number of transmission layers and precoding matrix according to the most recent PDCCH/EPDCCH, if the number of negatively acknowledged transport blocks is equal to the number of transport blocks indicated in the most recent PDCCH/EPDCCH associated with the corresponding PUSCH.

For normal HARQ operation, if the UE detects a PHICH transmission and if the most recent PUSCH transmission for the same transport block was using spatial multiplexing according to subclause 8.0.2 and the UE does not detect a PDCCH/EPDCCH with DCI format 4 in subframe n intended for the UE, and if the number of negatively acknowledged transport blocks is not equal to the number of transport blocks indicated in the most recent PDCCH/EPDCCH associated with the corresponding PUSCH then the UE shall adjust the corresponding PUSCH retransmission in the associated subframe according to the PHICH information, using the precoding matrix with codebook index 0 and the number of transmission layers equal to number of layers corresponding to the negatively acknowledged transport block from the most recent PDCCH/EPDCCH. In this case, the UL DMRS resources are calculated according to the cyclic shift field for DMRS [3] in the most recent PDCCH/EPDCCH with DCI format 4 associated with the corresponding PUSCH transmission and number of layers corresponding to the negatively acknowledged transport block.

If a UE is configured with the carrier indicator field for a given serving cell, the UE shall use the carrier indicator field value from the detected PDCCH/EPDCCH with uplink DCI format to determine the serving cell for the corresponding PUSCH transmission.

For FDD and normal HARQ operation, if a PDCCH/EPDCCH with CSI request field set to trigger an aperiodic CSI report, as described in subclause 7.2.1, is detected by a UE on subframe *n*, then on subframe *n+4* UCI is mapped on the corresponding PUSCH transmission, when simultaneous PUSCH and PUCCH transmission is not configured for the UE.

For FDD and a BL/CE UE configured with CEModeA, if an MPDCCH with CSI request field set to trigger an aperiodic CSI report, as described in subclause 7.2.1, is detected by a UE on subframe *n*, then on subframe *n+4* UCI is mapped on the corresponding PUSCH transmission, including all subframe repetitions of the PUSCH transmission.

For FDD-TDD and normal HARQ operation, for a serving cell with frame structure type 1, if a PDCCH/EPDCCH with CSI request field set to trigger an aperiodic CSI report, as described in subclause 7.2.1, is detected by a UE on subframe *n*, then on subframe *n+4* UCI is mapped on the corresponding PUSCH transmission, when simultaneous PUSCH and PUCCH transmission is not configured for the UE.

For TDD, if a UE is configured with the parameter *EIMTA-MainConfigServCell-r12* for at least one serving cell, if the UE is configured with one serving cell or if the UE is configured with more than one serving cell and the TDD UL/DL configuration of all the configured serving cells is the same, then for a given serving cell, the serving cell UL/DL configuration is the UL-reference UL/DL configuration.

For TDD, if a UE is configured with more than one serving cell and if the UL/DL configurations of at least two serving cells are different, if the serving cell is a primary cell or if the UE is not configured to monitor PDCCH/EPDCCH in another serving cell for scheduling the serving cell, the serving cell UL/DL configuration is the UL-reference UL/DL configuration.

For TDD, if a UE is configured with more than one serving cell and if the UL/DL configurations of at least two serving cells are different and if the serving cell is a secondary cell and if the UE is configured to monitor PDCCH/EPDCCH in another serving cell for scheduling the serving cell, then for the serving cell, the UL reference UL/DL configuration is given in Table 8-0A corresponding to the pair formed by (other serving cell UL/DL configuration, serving cell UL/DL configuration).

For FDD-TDD and primary cell frame structure type 2, if a serving cell is a primary cell, the serving cell UL/DL configuration is the UL-reference UL/DL configuration for the serving cell.

For FDD-TDD if the UE is not configured to monitor PDCCH/EPDCCH in another serving cell for scheduling a secondary serving cell with frame structure type 2, the serving cell UL/DL configuration is the UL-reference UL/DL configuration for the serving cell.

For FDD-TDD, and for secondary serving cell *c* with frame structure type 2, if the UE is configured to monitor PDCCH/EPDCCH in another serving cell with frame structure type 1 for scheduling the serving cell, the serving cell UL/DL configuration is the UL-reference UL/DL configuration for the serving cell.

For FDD-TDD, if a UE is configured with more than one serving cell with frame structure type 2, and if the serving cell is a secondary cell with frame structure type 2 and if the UE is configured to monitor PDCCH/EPDCCH in another serving cell with frame structure type 2 for scheduling the serving cell, then for the serving cell, the UL reference UL/DL configuration is given in Table 8-0A corresponding to the pair formed by (other serving cell UL/DL configuration, serving cell UL/DL configuration).

Table 8-0A: UL-reference UL/DL Configuration for serving cell based on the pair formed by (other serving cell UL/DL configuration, serving cell UL/DL configuration)

Set #	(other serving cell UL/DL configuration, serving cell UL/DL configuration)	UL-reference UL/DL configuration
Set 1	(1,1),(1,2),(1,4),(1,5)	1

	(2,2),(2,5)	2
	(3,3),(3,4),(3,5)	3
	(4,4),(4,5)	4
	(5,5)	5
Set 2	(1,0),(2,0),(3,0),(4,0),(5,0)	0
	(2,1),(4,1),(5,1)	1
	(5,2)	2
	(4,3),(5,3)	3
	(5,4)	4
	(1,6),(2,6),(3,6),(4,6),(5,6)	6
Set 3	(3,1)	1
	(3,2),(4,2)	2
	(1,3),(2,3)	3
	(2,4)	4
Set 4	(0,0),(6,0)	0
	(0,1),(0,2),(0,4),(0,5),(6,1),(6,2),(6,5)	1
	(0,3),(6,3)	3
	(6,4)	4
	(0,6),(6,6)	6

If a UE is configured with the parameter *EIMTA-MainConfigServCell-r12* for a serving cell, for a radio frame of the serving cell, PUSCH transmissions can occur only in subframes that are indicated by eIMTA-UL/DL-configuration as uplink subframe(s) for the serving cell unless specified otherwise.

For TDD and normal HARQ operation, if a PDCCH/EPDCCH with CSI request field set to trigger an aperiodic CSI report, as described in subclause 7.2.1, is detected by a UE on subframe *n*, then on subframe *n+k* UCI is mapped on the corresponding PUSCH transmission where *k* is given by Table 8-2, when simultaneous PUSCH and PUCCH transmission is not configured for the UE.

For TDD and a BL/CE UE configured with CEModeA, if an MPDCCH with CSI request field set to trigger an aperiodic CSI report, as described in subclause 7.2.1, is detected by a UE on subframe *n*, then on subframe *n+k* UCI is mapped on the corresponding PUSCH transmission, including all subframe repetitions of the PUSCH transmission, where *k* is given by Table 8-2..
For FDD-TDD normal HARQ operation, for a serving cell with frame structure type 2, if a PDCCH/EPDCCH with CSI request field set to trigger an aperiodic CSI report on the serving cell, as described in subclause 7.2.1, is detected by a UE on subframe *n*, then on subframe *n+k* UCI is mapped on the corresponding PUSCH transmission where *k* is given by Table 8-2 and the "TDD UL/DL configuration" refers to the UL-reference UL/DL configuration for the serving cell, when simultaneous PUSCH and PUCCH transmission is not configured for the UE.

When a UE is configured with higher layer parameter *ttiBundling* and configured with higher layer parameter *e-HARQ-Pattern-r12* set to *FALSE* or not configured, for FDD and subframe bundling operation, the UE shall upon detection of a PDCCH/EPDCCH with DCI format 0 in subframe *n* intended for the UE, and/or a PHICH transmission in subframe *n-5* intended for the UE, adjust the corresponding first PUSCH transmission in the bundle in subframe *n+4* according to the PDCCH/EPDCCH and PHICH information.

When a UE is configured with higher layer parameter *ttiBundling* and configured with higher layer parameter *e-HARQ-Pattern-r12* set to *TRUE*, for FDD and subframe bundling operation, the UE shall upon detection of a PDCCH/EPDCCH with DCI format 0 in subframe *n* intended for the UE, and/or a PHICH transmission in subframe *n-1* intended for the UE, adjust the corresponding first PUSCH transmission in the bundle in subframe *n+4* according to the PDCCH/EPDCCH and PHICH information.

For both FDD and TDD serving cells, the NDI as signalled on PDCCH/EPDCCH, the RV as determined in subclause 8.6.1, and the TBS as determined in subclause 8.6.2, shall be delivered to higher layers.

For a non-BL/CE UE, for TDD and transmission mode 1, the number of HARQ processes per serving cell shall be determined by the UL/DL configuration (Table 4.2-2 of [3]), as indicated in Table 8-1. For TDD and transmission mode 2, the number of HARQ processes per serving cell for non-subframe bundling operation shall be twice the number determined by the UL/DL configuration (Table 4.2-2 of [3]) as indicated in Table 8-1 and there are two HARQ processes associated with a given subframe as described in [8]. For TDD and both transmission mode 1 and transmission mode 2, the "TDD UL/DL configuration" in Table 8-1 refers to the UL-reference UL/DL configuration for the serving cell if UL-reference UL/DL configuration is defined for the serving cell and refers to the serving cell UL/DL configuration otherwise.

For a BL/CE UE configured with CEModeA and for TDD, the maximum number of HARQ processes per serving cell shall be determined by the UL/DL configuration (Table 4.2-2 of [3]) according to the normal HARQ operation in Table 8-1. For TDD a BL/CE UE configured with CEModeB is not expected to support more than 2 uplink HARQ processes per serving cell.

Table 8-1: Number of synchronous UL HARQ processes for TDD

TDD UL/DL configuration	Number of HARQ processes for normal HARQ operation	Number of HARQ processes for subframe bundling operation
0	7	3
1	4	2
2	2	N/A
3	3	N/A
4	2	N/A
5	1	N/A
6	6	3

For TDD, if the UE is not configured with *EIMTA-MainConfigServCell-r12* for any serving cell, and if a UE is configured with one serving cell, or if the UE is configured with more than one serving cell and the TDD UL/DL configuration of all the configured serving cells is the same,

- For TDD UL/DL configurations 1-6 and normal HARQ operation, the UE shall upon detection of a PDCCH/EPDCCH with uplink DCI format and/or a PHICH transmission in subframe *n* intended for the UE, adjust the corresponding PUSCH transmission in subframe *n+k*, with *k* given in Table 8-2, according to the PDCCH/EPDCCH and PHICH information.

- For TDD UL/DL configuration 0 and normal HARQ operation the UE shall upon detection of a PDCCH/EPDCCH with uplink DCI format and/or a PHICH transmission in subframe *n* intended for the UE, adjust the corresponding PUSCH transmission in subframe *n+k* if the MSB of the UL index in the PDCCH/EPDCCH with uplink DCI format is set to 1 or PHICH is received in subframe *n*=0 or 5 in the resource corresponding to $I_{PHICH} = 0$, as defined in subclause 9.1.2, with *k* given in Table 8-2. If, for TDD UL/DL configuration 0 and normal HARQ operation, the LSB of the UL index in the DCI format 0/4 is set to 1 in subframe *n* or a PHICH is received in subframe *n*=0 or 5 in the resource corresponding to $I_{PHICH} = 1$, as defined in subclause 9.1.2, or PHICH is received in subframe *n*=1 or 6, the UE shall adjust the corresponding PUSCH transmission in subframe *n+7*. If, for TDD UL/DL configuration 0, both the MSB and LSB of the UL index in the PDCCH/EPDCCH with uplink DCI format are set in subframe *n*, the UE shall adjust the corresponding PUSCH transmission in both subframes *n+ k* and *n+7*, with *k* given in Table 8-2.

For TDD, if a UE is configured with more than one serving cell and the TDD UL/DL configuration of at least two configured serving cells is not the same or if the UE is configured with *EIMTA-MainConfigServCell-r12* for at least one serving cell, or FDD-TDD,

- For a serving cell with an UL-reference UL/DL configurations belonging to {1,2,3,4,5,6} and normal HARQ operation, the UE shall upon detection of a PDCCH/EPDCCH with uplink DCI format and/or a PHICH transmission in subframe *n* intended for the UE, adjust the corresponding PUSCH transmission in subframe *n+k* for the serving cell, with *k* given in Table 8-2, according to the PDCCH/EPDCCH and PHICH information, where the "TDD UL/DL Configuration" given in Table 8-2 refers to the UL-reference UL/DL configuration.

- For a serving cell with UL-reference UL/DL configuration 0 and normal HARQ operation the UE shall upon detection of a PDCCH/EPDCCH with uplink DCI format and/or a PHICH transmission in subframe *n* intended for the UE, adjust the corresponding PUSCH transmission in subframe *n+k* for the serving cell if the MSB of the UL index in the PDCCH/EPDCCH with uplink DCI format is set to 1 or PHICH is received in subframe *n*=0 or 5 in the resource corresponding to $I_{PHICH} = 0$, as defined in subclause 9.1.2, with *k* given in Table 8-2. If, for a serving cell with UL-reference UL/DL configuration 0 and normal HARQ operation, the LSB of the UL index in the DCI format 0/4 is set to 1 in subframe *n* or a PHICH is received in subframe *n*=0 or 5 in the resource corresponding to $I_{PHICH} = 1$, as defined in subclause 9.1.2, or PHICH is received in subframe *n*=1 or 6, the UE shall adjust the corresponding PUSCH transmission in subframe *n+7* for the serving cell. If, for a serving cell with UL-reference UL/DL configuration 0, both the MSB and LSB of the UL index in the PDCCH/EPDCCH with uplink DCI format are set in subframe *n*, the UE shall adjust the corresponding PUSCH transmission in both subframes *n+ k* and *n+7* for the serving cell, with *k* given in Table 8-2, where the TDD UL/DL Configuration" given in Table 8-2 refers to the UL-reference UL/DL configuration.

For TDD UL/DL configurations 1 and 6 and subframe bundling operation, the UE shall upon detection of a PDCCH/EPDCCH with DCI format 0 in subframe *n* intended for the UE, and/or a PHICH transmission intended for the UE in subframe *n-l* with *l* given in Table 8-2a, adjust the corresponding first PUSCH transmission in the bundle in subframe *n+k*, with *k* given in Table 8-2, according to the PDCCH/EPDCCH and PHICH information.

For TDD UL/DL configuration 0 and subframe bundling operation, the UE shall upon detection of a PDCCH/EPDCCH with DCI format 0 in subframe *n* intended for the UE, and/or a PHICH transmission intended for the UE in subframe *n-l* with *l* given in Table 8-2a, adjust the corresponding first PUSCH transmission in the bundle in subframe *n+k*, if the MSB of the UL index in the DCI format 0 is set to 1 or if $I_{PHICH} = 0$, as defined in subclause 9.1.2, with *k* given in Table 8-2, according to the PDCCH/EPDCCH and PHICH information. If, for TDD UL/DL configuration 0 and subframe bundling operation, the LSB of the UL index in the PDCCH/EPDCCH with DCI format 0 is set to 1 in subframe *n* or if $I_{PHICH} = 1$, as defined in subclause 9.1.2, the UE shall adjust the corresponding first PUSCH transmission in the bundle in subframe *n+7*, according to the PDCCH/EPDCCH and PHICH information.

Table 8-2: *k* for TDD configurations 0-6

TDD UL/DL Configuration	subframe number *n*									
	0	1	2	3	4	5	6	7	8	9
0	4	6				4	6			
1		6			4		6			4
2				4					4	
3	4								4	4
4									4	4
5									4	
6	7	7				7	7			5

Table 8-2a: *l* for TDD configurations 0, 1 and 6

TDD UL/DL Configuration	subframe number *n*									
	0	1	2	3	4	5	6	7	8	9
0	9	6				9	6			
1		2			3		2			3
6	5	5				6	6			8

For BL/CE UEs, the higher layers indicate the set of BL/CE UL subframes according to *fdd-DownlinkOrTddSubframeBitmapBR* and *fdd-UplinkSubframeBitmapBR* [11].

A BL/CE UE shall upon detection on a given serving cell of an MPDCCH with DCI format 6-0A/6-0B intended for the UE, adjust the corresponding PUSCH transmission in subframe(s) $n+k_i$ with $i = 0, 1, \ldots, N-1$ according to the MPDCCH, where

- subframe *n* is the last subframe in which the MPDCCH is transmitted; and
- $x \le k_0 < k_1 < \ldots, k_{N-1}$ and the value of $N \in \{n1, n2, \ldots n_{\max}\}$ is determined by the *repetition number* field in the corresponding DCI, where $n1, n2, \ldots n_{\max}$ are given in Table 8-2b and Table 8-2c; and
- in case $N>1$, subframe(s) $n+k_i$ with $i=0,1,\ldots,N-1$ are *N* consecutive BL/CE UL subframe(s) starting with subframe *n+x*, and in case $N=1$, $k_0=x$;
- for FDD, $x = 4$;
- for TDD UL/DL configurations 1-6, or for TDD UL/DL configuration 0 and a BL/CE UE in CEModeB, the value of *x* is given as the value of *k* in Table 8-2 for the corresponding TDD UL/DL configuration; If the value x is not given in Table 8-2 for subframe *n*, denote subframe *n'* as the first downlink/special subframe which has a

value in Table 8-2 after subframe *n*, and substitute *n* with *n'* in the above procedure for adjusting the PUSCH transmission.

- for TDD UL/DL configuration 0 and a BL/CE UE in CEModeA and N=1, if the MSB of the UL index in the MPDCCH with DCI format 6-0A is set to 1, the value of *x* is given as the value of *k* in Table 8-2 for the corresponding TDD UL/DL configuration; if the LSB of the UL index in the MPDCCH with DCI format 6-0A is set to 1, $x = 7$. The UE is not expected to receive DCI format 6-0A with both the MSB and LSB of the UL index set to 1 when $N>1$. In case both the MSB and LSB of the UL index are set to 1, the HARQ process number of the PUSCH corresponding the MSB of the UL index is $n_{\text{HARQ\_ID}}$ and the HARQ process number of the PUSCH corresponding the LSB of the UL index is $(n_{\text{HARQ\_ID}}+1) \bmod 7$, where $n_{\text{HARQ\_ID}}$ is determined according to the *HARQ process number* field in DCI format 6-0A
- The higher layer parameter *ttiBundling* is not applicable to BL/CE UEs.
- For a BL/CE UE, in case a PUSCH transmission with a corresponding MPDCCH collides with a PUSCH transmission without a corresponding MPDCCH in a subframe *n*, the PUSCH transmission without a corresponding MPDCCH is dropped from subframe *n*.
- For a BL/CE UE, in case of collision between at least one physical resource block to be used for PUSCH transmission and physical resource blocks corresponding to configured PRACH resources for BL/CE UEs or non-BL/CE UEs (defined in [3]) in a same subframe, the PUSCH transmission is dropped in that subframe.
- For a BL/CE UE in half-duplex FDD operation, in case a PUSCH transmission including half-duplex guard subframe without a corresponding MPDCCH collides partially or fully with a PDSCH transmission with a corresponding MPDCCH, the PUSCH transmission without a corresponding MPDCCH is dropped.

Table 8.2b: PUSCH repetition levels (DCI Format 6-0A)

Higher layer parameter '*pusch-maxNumRepetitionCEmodeA*'	$\{n1, n2, n3, n4\}$
Not configured	{1,2,4,8}
16	{1,4,8,16}
32	{1,4,16,32 }

Table 8.2c: PUSCH repetition levels (DCI Format 6-0B)

Higher layer parameter '*pusch-maxNumRepetitionCEmodeB*'	$\{n1, n2, \ldots, n8\}$
Not configured	{4,8,16,32,64,128,256,512}
192	{1,4,8,16,32,64,128,192}
256	{4,8,16,32,64,128,192,256}
384	{4,16,32,64,128,192,256,384}
512	{4,16,64,128,192,256,384,512}
768	{8,32,128,192,256,384,512,768}
1024	{4,8,16,64,128,256,512,1024}
1536	{4,16,64,256,512,768,1024,1536}
2048	{4,16,64,128,256,512,1024,2048}

A UE is semi-statically configured via higher layer signalling to transmit PUSCH transmissions signalled via PDCCH/EPDCCH according to one of two uplink transmission modes, denoted mode 1 - 2.

If a UE is configured by higher layers to decode PDCCHs with the CRC scrambled by the C-RNTI, the UE shall decode the PDCCH according to the combination defined in Table 8-3 and transmit the corresponding PUSCH. The scrambling initialization of this PUSCH corresponding to these PDCCHs and the PUSCH retransmission for the same transport block is by C-RNTI.

If a UE is configured by higher layers to decode EPDCCHs with the CRC scrambled by the C-RNTI, the UE shall decode the EPDCCH according to the combination defined in Table 8-3A and transmit the corresponding PUSCH. The scrambling initialization of this PUSCH corresponding to these EPDCCHs and the PUSCH retransmission for the same transport block is by C-RNTI.

If a UE is configured by higher layers to decode MPDCCHs with the CRC scrambled by the C-RNTI, the UE shall decode the MPDCCH according to the combination defined in Table 8-3B and transmit the corresponding PUSCH. The scrambling initialization of this PUSCH corresponding to these MPDCCHs and the PUSCH retransmission for the same transport block is by C-RNTI.

Transmission mode 1 is the default uplink transmission mode for a UE until the UE is assigned an uplink transmission mode by higher layer signalling.

When a UE configured in transmission mode 2 receives a DCI Format 0 uplink scheduling grant, it shall assume that the PUSCH transmission is associated with transport block 1 and that transport block 2 is disabled.

Table 8-3: PDCCH and PUSCH configured by C-RNTI

Transmission mode	DCI format	Search Space	Transmission scheme of PUSCH corresponding to PDCCH
Mode 1	DCI format 0	Common and UE specific by C-RNTI	Single-antenna port, port 10 (see subclause 8.0.1)
Mode 2	DCI format 0	Common and UE specific by C-RNTI	Single-antenna port, port 10 (see subclause 8.0.1)
	DCI format 4	UE specific by C-RNTI	Closed-loop spatial multiplexing (see subclause 8.0.2)

Table 8-3A: EPDCCH and PUSCH configured by C-RNTI

Transmission mode	DCI format	Search Space	Transmission scheme of PUSCH corresponding to EPDCCH
Mode 1	DCI format 0	UE specific by C-RNTI	Single-antenna port, port 10 (see subclause 8.0.1)
Mode 2	DCI format 0	UE specific by C-RNTI	Single-antenna port, port 10 (see subclause 8.0.1)
	DCI format 4	UE specific by C-RNTI	Closed-loop spatial multiplexing (see subclause 8.0.2)

Table 8-3B: MPDCCH and PUSCH configured by C-RNTI

Transmission mode	DCI format	Search Space	Transmission scheme of PUSCH corresponding to MPDCCH
Mode 1	DCI format 6-0A or 6-0B	Type0-common (only for 6-0A) and UE specific by C-RNTI	Single-antenna port, port 10 (see subclause 8.0.1)

If a UE is configured by higher layers to decode PDCCHs with the CRC scrambled by the C-RNTI and is also configured to receive random access procedures initiated by "PDCCH orders", the UE shall decode the PDCCH according to the combination defined in Table 8-4.

If a UE is configured by higher layers to decode EPDCCHs with the CRC scrambled by the C-RNTI and is also configured to receive random access procedures initiated by "PDCCH orders", the UE shall decode the EPDCCH according to the combination defined in Table 8-4A.

If a UE is configured by higher layers to decode MPDCCHs with the CRC scrambled by the C-RNTI and is also configured to receive random access procedures initiated by "PDCCH orders", the UE shall decode the MPDCCH according to the combination defined in Table 8-4B.

Table 8-4: PDCCH configured as "PDCCH order" to initiate random access procedure

DCI format	Search Space
DCI format 1A	Common and UE specific by C-RNTI

Table 8-4A: EPDCCH configured as "PDCCH order" to initiate random access procedure

DCI format	Search Space
DCI format 1A	UE specific by C-RNTI

Table 8-4B: MPDCCH configured as "PDCCH order" to initiate random access procedure

DCI format	Search Space
DCI format 6-1A or 6-1B	Type0-common (only for 6-1A) and UE specific by C-RNTI

If a UE is configured by higher layers to decode PDCCHs with the CRC scrambled by the SPS C-RNTI, the UE shall decode the PDCCH according to the combination defined in Table 8-5 and transmit the corresponding PUSCH. The scrambling initialization of this PUSCH corresponding to these PDCCHs and PUSCH retransmission for the same transport block is by SPS C-RNTI. The scrambling initialization of initial transmission of this PUSCH without a corresponding PDCCH and the PUSCH retransmission for the same transport block is by SPS C-RNTI.

If a UE is configured by higher layers to decode EPDCCHs with the CRC scrambled by the SPS C-RNTI, the UE shall decode the EPDCCH according to the combination defined in Table 8-5A and transmit the corresponding PUSCH. The scrambling initialization of this PUSCH corresponding to these EPDCCHs and PUSCH retransmission for the same transport block is by SPS C-RNTI. The scrambling initialization of initial transmission of this PUSCH without a corresponding EPDCCH and the PUSCH retransmission for the same transport block is by SPS C-RNTI.

If a UE is configured by higher layers to decode MPDCCHs with the CRC scrambled by the SPS C-RNTI, the UE shall decode the MPDCCH according to the combination defined in Table 8-5B and transmit the corresponding PUSCH. The scrambling initialization of this PUSCH corresponding to these MPDCCHs and PUSCH retransmission for the same transport block is by SPS C-RNTI. The scrambling initialization of initial transmission of this PUSCH without a corresponding MPDCCH and the PUSCH retransmission for the same transport block is by SPS C-RNTI.

Table 8-5: PDCCH and PUSCH configured by SPS C-RNTI

Transmission mode	DCI format	Search Space	Transmission scheme of PUSCH corresponding to PDCCH
Mode 1	DCI format 0	Common and UE specific by C-RNTI	Single-antenna port, port 10 (see subclause 8.0.1)
Mode 2	DCI format 0	Common and UE specific by C-RNTI	Single-antenna port, port 10 (see subclause 8.0.1)

Table 8-5A: EPDCCH and PUSCH configured by SPS C-RNTI

Transmission mode	DCI format	Search Space	Transmission scheme of PUSCH corresponding to PDCCH
Mode 1	DCI format 0	UE specific by C-RNTI	Single-antenna port, port 10 (see subclause 8.0.1)
Mode 2	DCI format 0	UE specific by C-RNTI	Single-antenna port, port 10 (see subclause 8.0.1)

Table 8-5B: MPDCCH and PUSCH configured by SPS C-RNTI

Transmission mode	DCI format	Search Space	Transmission scheme of PUSCH corresponding to PDCCH
Mode 1	DCI format 6-0A	Type0-common (only for 6-0A) and UE specific by C-RNTI	Single-antenna port, port 10 (see subclause 8.0.1)

If a UE is configured by higher layers to decode PDCCHs with the CRC scrambled by the Temporary C-RNTI regardless of whether UE is configured or not configured to decode PDCCHs with the CRC scrambled by the C-RNTI, the UE shall decode the PDCCH according to the combination defined in Table 8-6 and transmit the corresponding PUSCH. The scrambling initialization of PUSCH corresponding to these PDCCH is by Temporary C-RNTI.

If a UE is configured by higher layers to decode MPDCCHs with the CRC scrambled by the Temporary C-RNTI regardless of whether UE is configured or not configured to decode MPDCCHs with the CRC scrambled by the C-RNTI during random access procedure, the UE shall decode the MPDCCH according to the combination defined in

Table 8-6A and transmit the corresponding PUSCH. The scrambling initialization of PUSCH corresponding to these MPDCCH is by Temporary C-RNTI.

If a Temporary C-RNTI is set by higher layers, the scrambling of PUSCH corresponding to the Random Access Response Grant in subclause 6.2 and the PUSCH retransmission for the same transport block is by Temporary C-RNTI. Else, the scrambling of PUSCH corresponding to the Random Access Response Grant in subclause 6.2 and the PUSCH retransmission for the same transport block is by C-RNTI.

If a UE is also configured by higher layers to decode MPDCCH with CRC scrambled by the C-RNTI during random access procedure, the UE shall decode the MPDCCH according to the combination defined in Table 8-6A and transmit the corresponding PUSCH. The scrambling initialization of PUSCH corresponding to these MPDCCH is by C-RNTI.

Table 8-6: PDCCH configured by Temporary C-RNTI

DCI format	Search Space
DCI format 0	Common

Table 8-6A: MPDCCH configured by Temporary C-RNTI and/or C-RNTI during random access procedure

DCI format	Search Space
DCI format 6-0A, 6-0B	Type2-Common

If a UE is configured by higher layers to decode PDCCHs with the CRC scrambled by the TPC-PUCCH-RNTI, the UE shall decode the PDCCH according to the combination defined in table 8-7. The notation 3/3A implies that the UE shall receive either DCI format 3 or DCI format 3A depending on the configuration.

If a UE is configured by higher layers to decode MPDCCHs with the CRC scrambled by the TPC-PUCCH-RNTI, the UE shall decode the MPDCCH according to the combination defined in table 8-7A. The notation 3/3A implies that the UE shall receive either DCI format 3 or DCI format 3A depending on the configuration.

Table 8-7: PDCCH configured by TPC-PUCCH-RNTI

DCI format	Search Space
DCI format 3/3A	Common

Table 8-7A: MPDCCH configured by TPC-PUCCH-RNTI

DCI format	Search Space
DCI format 3/3A	Type0-Common (for CEModeA only)

If a UE is configured by higher layers to decode PDCCHs with the CRC scrambled by the TPC-PUSCH-RNTI, the UE shall decode the PDCCH according to the combination defined in table 8.8. The notation 3/3A implies that the UE shall receive either DCI format 3 or DCI format 3A depending on the configuration.

If a UE is configured by higher layers to decode MPDCCHs with the CRC scrambled by the TPC-PUSCH-RNTI, the UE shall decode the MPDCCH according to the combination defined in table 8.8A. The notation 3/3A implies that the UE shall receive either DCI format 3 or DCI format 3A depending on the configuration.

Table 8-8: PDCCH configured by TPC-PUSCH-RNTI

DCI format	Search Space
DCI format 3/3A	Common

Table 8-8A: MPDCCH configured by TPC-PUSCH-RNTI

DCI format	Search Space
DCI format 3/3A	Type0-Common (for CEModeA only)

8.0.1 Single-antenna port scheme

For the single-antenna port transmission schemes (port 10) of the PUSCH, the UE transmission on the PUSCH is performed according to subclause 5.3.2A.1 of [3].

8.0.2 Closed-loop spatial multiplexing scheme

For the closed-loop spatial multiplexing transmission scheme of the PUSCH, the UE transmission on the PUSCH is performed according to the applicable number of transmission layers as defined in subclause 5.3.2A.2 of [3].

8.1 Resource allocation for PDCCH/EPDCCH with uplink DCI format

Two resource allocation schemes Type 0 and Type 1 are supported for PDCCH/EPDCCH with uplink DCI format.

Resource allocation scheme Type 0 or Type 2 are supported for MPDCCH with uplink DCI format.

If the resource allocation type bit is not present in the uplink DCI format, only resource allocation type 0 is supported.

If the resource allocation type bit is present in the uplink DCI format, the selected resource allocation type for a decoded PDCCH/EPDCCH is indicated by a resource allocation type bit where type 0 is indicated by 0 value and type 1 is indicated otherwise. The UE shall interpret the resource allocation field depending on the resource allocation type bit in the PDCCH/EPDCCH with uplink DCI format detected.

8.1.1 Uplink resource allocation type 0

The resource allocation information for uplink resource allocation type 0 indicates to a scheduled UE a set of contiguously allocated virtual resource block indices denoted by n_{VRB}. A resource allocation field in the scheduling grant consists of a resource indication value (*RIV*) corresponding to a starting resource block (RB_{START}) and a length in terms of contiguously allocated resource blocks ($L_{\mathrm{CRBs}} \geq 1$). For a BL/CE UE, uplink resource allocation type 0 is only applicable for UE configured with CEModeA and $N_{\mathrm{RB}}^{\mathrm{UL}} = 6$ in this subclause. The resource indication value is defined by

if $(L_{\mathrm{CRBs}} - 1) \leq \left\lfloor N_{\mathrm{RB}}^{\mathrm{UL}} / 2 \right\rfloor$ then

$$RIV = N_{\mathrm{RB}}^{\mathrm{UL}}(L_{\mathrm{CRBs}} - 1) + RB_{\mathrm{START}}$$

else

$$RIV = N_{\mathrm{RB}}^{\mathrm{UL}}(N_{\mathrm{RB}}^{\mathrm{UL}} - L_{\mathrm{CRBs}} + 1) + (N_{\mathrm{RB}}^{\mathrm{UL}} - 1 - RB_{\mathrm{START}})$$

8.1.2 Uplink resource allocation type 1

The resource allocation information for uplink resource allocation type 1 indicates to a scheduled UE two sets of resource blocks with each set including one or more consecutive resource block groups of size *P* as given in table 7.1.6.1-1 assuming $N_{\mathrm{RB}}^{\mathrm{UL}}$ as the system bandwidth. A combinatorial index *r* consists of $\left\lceil \log_2\left(\binom{\left\lceil N_{RB}^{UL} / P + 1 \right\rceil}{4}\right)\right\rceil$ bits.

The bits from the resource allocation field in the scheduling grant represent *r* unless the number of bits in the resource allocation field in the scheduling grant is

- smaller than required to fully represent *r*, in which case the bits in the resource allocation field in the scheduling grant occupy the LSBs of *r* and the value of the remaining bits of *r* shall be assumed to be 0; or

- larger than required to fully represent *r*, in which case *r* occupies the LSBs of the resource allocation field in the scheduling grant.

The combinatorial index *r* corresponds to a starting and ending RBG index of resource block set 1, s_0 and $s_1 - 1$, and resource block set 2, s_2 and $s_3 - 1$ respectively, where *r* is given by equation $r = \sum_{i=0}^{M-1} \left\langle \begin{matrix} N - s_i \\ M - i \end{matrix} \right\rangle$ defined in subclause 7.2.1 with *M*=4 and $N = \left\lceil N_{\mathrm{RB}}^{\mathrm{UL}} / P \right\rceil + 1$. subclause 7.2.1 also defines ordering properties and range of values that s_i (RBG indices) map to. Only a single RBG is allocated for a set at the starting RBG index if the corresponding ending RBG index equals the starting RBG index.

8.1.3 Uplink resource allocation type 2

Uplink resource allocation type 2 is only applicable for BL/CE UE configured with CEModeB. The resource allocation information for uplink resource allocation type 2 indicates to a scheduled UE a set of contiguously allocated resource blocks within a narrowband as given in Table 8.1.3-1

Table 8.1.3-1: Resource block(s) allocation for BL/CE UE configured with CEModeB.

Value of resource allocation field	Allocated resource blocks
‘000’	0
‘001’	1
‘010’	2
‘011’	3
‘100’	4
‘101’	5
‘110’	0 and 1
‘111’	2 and 3

8.2 UE sounding procedure

If the UE is configured with a PUCCH-SCell, the UE shall apply the procedures described in this clause for both primary PUCCH group and secondary PUCCH group unless stated otherwise

- When the procedures are applied for the primary PUCCH group, the terms 'secondary cell', 'secondary cells', 'serving cell', and 'serving cells' in this clause refer to secondary cell, secondary cells, serving cell or serving cells belonging to the primary PUCCH group respectively unless stated otherwise.

- When the procedures are applied for secondary PUCCH group, the terms 'secondary cell', 'secondary cells', 'serving cell' and 'serving cells' in this clause refer to secondary cell, secondary cells (not including the PUCCH-SCell), serving cell, serving cells belonging to the secondary PUCCH group respectively unless stated otherwise. The term 'primary cell' in this clause refers to the PUCCH-SCell of the secondary PUCCH group.

A UE shall transmit Sounding Reference Symbol (SRS) on per serving cell SRS resources based on two trigger types:

- trigger type 0: higher layer signalling

- trigger type 1: DCI formats 0/4/1A/6-0A/6-1A for FDD and TDD and DCI formats 2B/2C/2D for TDD.

In case both trigger type 0 and trigger type 1 SRS transmissions would occur in the same subframe in the same serving cell, the UE shall only transmit the trigger type 1 SRS transmission.

A UE may be configured with SRS parameters for trigger type 0 and trigger type 1 on each serving cell. A BL/CE UE configured with CEModeB is not expected to be configured with SRS parameters for trigger type 0 and trigger type 1. The following SRS parameters are serving cell specific and semi-statically configurable by higher layers for trigger type 0 and for trigger type 1.

- Number of combs K_{TC} as defined in subclause 5.5.3.2 of [3] for trigger type 0 and each configuration of trigger type 1, if configured

- srs-UpPtsAdd: two or four additional SC-FDMA symbols in UpPTS as defined in [11] for trigger type 0 and trigger type 1, if configured

- Transmission comb $\bar{k}_{TC}$, as defined in subclause 5.5.3.2 of [3] for trigger type 0 and each configuration of trigger type 1

- Starting physical resource block assignment n_{RRC}, as defined in subclause 5.5.3.2 of [3] for trigger type 0 and each configuration of trigger type 1

- *duration*: single or indefinite (until disabled), as defined in [11] for trigger type 0

- *srs-ConfigIndex* $\mathrm{I}_{\mathrm{SRS}}$ for SRS periodicity T_{SRS} and SRS subframe offset T_{offset}, as defined in Table 8.2-1 and Table 8.2-2 for trigger type 0 and SRS periodicity $T_{\mathrm{SRS,1}}$ and SRS subframe offset $T_{offset,1}$, as defined in Table 8.2-4 and Table 8.2-5 trigger type 1

- SRS bandwidth B_{SRS}, as defined in subclause 5.5.3.2 of [3] for trigger type 0 and each configuration of trigger type 1

- Frequency hopping bandwidth, b_{hop}, as defined in subclause 5.5.3.2 of [3] for trigger type 0

- Cyclic shift n_{SRS}^{cs}, as defined in subclause 5.5.3.1 of [3] for trigger type 0 and each configuration of trigger type 1

- Number of antenna ports N_p for trigger type 0 and each configuration of trigger type 1

For trigger type 0, if *SoundingRS-UL-ConfigDedicatedUpPTsExt* is configured, the SRS parameters in *SoundingRS-UL-ConfigDedicatedUpPTsExt* shall be used; otherwise, *SoundingRS-UL-ConfigDedicated* shall be used.

For trigger type 1, if *SoundingRS-UL-ConfigDedicatedAperiodicUpPTsExt* is configured, the SRS parameters in *SoundingRS-UL-ConfigDedicatedAperiodicUpPTsExt* shall be used; otherwise, *SoundingRS-UL-ConfigDedicatedAperiodic* shall be used.

For trigger type 1 and DCI format 4 three sets of SRS parameters, *srs-ConfigApDCI-Format4*, are configured by higher layer signalling. The 2-bit SRS request field [4] in DCI format 4 indicates the SRS parameter set given in Table 8.1-1. For trigger type 1 and DCI format 0/6-0A, a single set of SRS parameters, *srs-ConfigApDCI-Format0*, is configured by higher layer signalling. For trigger type 1 and DCI formats 1A/2B/2C/2D/6-1A, a single common set of SRS parameters, *srs-ConfigApDCI-Format1a2b2c*, is configured by higher layer signalling. The SRS request field is 1 bit [4] for DCI formats 0/1A/2B/2C/2D/6-0A/6-1A, with a type 1 SRS triggered if the value of the SRS request field is set to '1'.
A 1-bit SRS request field shall be included in DCI formats 0/1A for frame structure type 1 and 0/1A/2B/2C/2D for frame structure type 2 if the UE is configured with SRS parameters for DCI formats 0/1A/2B/2C/2D by higher-layer signalling. A 1-bit SRS request field shall be included in DCI formats 6-0A/6-1A, the value of which is reserved if the UE is not configured with SRS parameters for DCI formats 6-0A/6-1A by higher layer signalling.

Table 8.1-1: SRS request value for trigger type 1 in DCI format 4

Value of SRS request field	Description
'00'	No type 1 SRS trigger
'01'	The 1st SRS parameter set configured by higher layers
'10'	The 2nd SRS parameter set configured by higher layers
'11'	The 3rd SRS parameter set configured by higher layers

The serving cell specific SRS transmission bandwidths C_{SRS} are configured by higher layers. The allowable values are given in subclause 5.5.3.2 of [3].

The serving cell specific SRS transmission sub-frames are configured by higher layers. The allowable values are given in subclause 5.5.3.3 of [3].

For a TDD serving cell, SRS transmissions can occur in UpPTS and uplink subframes of the UL/DL configuration indicated by the higher layer parameter *subframeAssignment* for the serving cell.

When closed-loop UE transmit antenna selection is enabled for a given serving cell for a UE that supports transmit antenna selection, the index $a(n_{SRS})$, of the UE antenna that transmits the SRS at time n_{SRS} is given by

$a(n_{SRS}) = n_{SRS} \bmod 2$, for both partial and full sounding bandwidth, and when frequency hopping is disabled (i.e., $b_{hop} \geq B_{SRS}$),

$$a(n_{SRS}) = \begin{cases} \left(n_{SRS} + \lfloor n_{SRS}/2 \rfloor + \beta \cdot \lfloor n_{SRS}/K \rfloor\right) \bmod 2 & \text{when } K \text{ is even} \\ n_{SRS} \bmod 2 & \text{when } K \text{ is odd} \end{cases}, \quad \beta = \begin{cases} 1 & \text{where } K \bmod 4 = 0 \\ 0 & \text{otherwise} \end{cases}$$

when frequency hopping is enabled (i.e., $b_{hop} < B_{SRS}$),

where values B_{SRS}, b_{hop}, N_b, and n_{SRS} are given in subclause 5.5.3.2 of [3], and $K = \prod_{b'=b_{hop}}^{B_{SRS}} N_{b'}$ (where $N_{b_{hop}} = 1$ regardless of the N_b value), except when a single SRS transmission is configured for the UE. If a UE is configured with more than one serving cell, the UE is not expected to transmit SRS on different antenna ports simultaneously.

A UE may be configured to transmit SRS on N_p antenna ports of a serving cell where N_p may be configured by higher layer signalling. For PUSCH transmission mode 1 $N_p \in \{0,1,2,4\}$ and for PUSCH transmission mode 2 $N_p \in \{0,1,2\}$ with two antenna ports configured for PUSCH and $N_p \in \{0,1,4\}$ with 4 antenna ports configured for PUSCH. A UE configured for SRS transmission on multiple antenna ports of a serving cell shall transmit SRS for all the configured transmit antenna ports within one SC-FDMA symbol of the same subframe of the serving cell.
The SRS transmission bandwidth and starting physical resource block assignment are the same for all the configured

antenna ports of a given serving cell. The UE does not support a value of K_{TC} set to '4', if the UE is configured for SRS transmission on 4 antenna ports of a serving cell.

If a UE is not configured with multiple TAGs and the UE not is configured with the parameter *srs-UpPtsAdd* for trigger type 1, or if a UE is not configured with multiple TAGs and the UE is not configured with more than one serving cell of different CPs, the UE shall not transmit SRS in a symbol whenever SRS and PUSCH transmissions happen to overlap in the same symbol.

For TDD serving cell, and UE not configured with additional SC-FDMA symbols in UpPTS, when one SC-FDMA symbol exists in UpPTS of the given serving cell, it can be used for SRS transmission, when two SC-FDMA symbols exist in UpPTS of the given serving cell, both can be used for SRS transmission and for trigger type 0 SRS both can be assigned to the same UE. For TDD serving cell, and if the UE is configured with two or four additional SC-FDMA symbols in UpPTS of the given serving cell, all can be used for SRS transmission and for trigger type 0 SRS at most two SC-FDMA symbols out of the configured additional SC-FDMA symbols in UpPTS can be assigned to the same UE.

If a UE is not configured with multiple TAGs and the UE not is configured with the parameter *srs-UpPtsAdd* for trigger type 1, or if a UE is not configured with multiple TAGs and the UE is not configured with more than one serving cell of different CPs, or if a UE is configured with multiple TAGs and SRS and PUCCH format 2/2a/2b happen to coincide in the same subframe in the same serving cell,

- The UE shall not transmit type 0 triggered SRS whenever type 0 triggered SRS and PUCCH format 2/2a/2b transmissions happen to coincide in the same subframe;

- The UE shall not transmit type 1 triggered SRS whenever type 1 triggered SRS and PUCCH format 2a/2b or format 2 with HARQ-ACK transmissions happen to coincide in the same subframe;

- The UE shall not transmit PUCCH format 2 without HARQ-ACK whenever type 1 triggered SRS and PUCCH format 2 without HARQ-ACK transmissions happen to coincide in the same subframe.

If a UE is not configured with multiple TAGs and the UE not is configured with the parameter *srs-UpPtsAdd* for trigger type 1, or if a UE is not configured with multiple TAGs and the UE is not configured with more than one serving cell of different CPs, or if a UE is configured with multiple TAGs and SRS and PUCCH happen to coincide in the same subframe in the same serving cell,

- The UE shall not transmit SRS whenever SRS transmission and PUCCH transmission carrying HARQ-ACK and/or positive SR happen to coincide in the same subframe if the parameter *ackNackSRS-SimultaneousTransmission* is *FALSE*;

- For FDD-TDD and primary cell frame structure 1, the UE shall not transmit SRS in a symbol whenever SRS transmission and PUCCH transmission carrying HARQ-ACK and/or positive SR using shortened format as defined in subclauses 5.4.1, 5.4.2A, 5.4.2B, and 5.4.2C of [3] happen to overlap in the same symbol if the parameter *ackNackSRS-SimultaneousTransmission* is *TRUE.*

- Unless otherwise prohibited, the UE shall transmit SRS whenever SRS transmission and PUCCH transmission carrying HARQ-ACK and/or positive SR using shortened format as defined in subclauses 5.4.1 and 5.4.2A of [3] happen to coincide in the same subframe if the parameter *ackNackSRS-SimultaneousTransmission* is *TRUE*.

If a UE is not configured with multiple TAGs and the UE not is configured with the parameter *srs-UpPtsAdd* for trigger type 1, or if a UE is not configured with multiple TAGs and the UE is not configured with more than one serving cell of different CPs, the UE shall not transmit SRS whenever SRS transmission on any serving cells and PUCCH transmission carrying HARQ-ACK and/or positive SR using normal PUCCH format as defined in subclauses 5.4.1 and 5.4.2A of [3] happen to coincide in the same subframe.

In UpPTS, whenever SRS transmission instance overlaps with the PRACH region for preamble format 4 or exceeds the range of uplink system bandwidth configured in the serving cell, the UE shall not transmit SRS.

The parameter *ackNackSRS-SimultaneousTransmission* provided by higher layers determines if a UE is configured to support the transmission of HARQ-ACK on PUCCH and SRS in one subframe. If it is configured to support the transmission of HARQ-ACK on PUCCH and SRS in one subframe, then in the cell specific SRS subframes of the primary cell,

- if the UE transmits PUCCH format 1/1a/1b/3, the UE shall transmit HARQ-ACK and SR using the shortened PUCCH format as defined in subclauses 5.4.1 and 5.4.2A of [3], where the HARQ-ACK or the SR symbol corresponding to the SRS location is punctured.

- If the UE transmits PUCCH format 4/5 partly or fully overlapping with the cell specific SRS bandwidth in the cell specific SRS subframes of the primary cell, then UE shall transmit UCI using the shortened PUCCH format as defined in subclauses 5.4.2B and 5.4.2C of [3].

For PUCCH format 1/1a/1b/3, this shortened PUCCH format shall be used in a cell specific SRS subframe of the primary cell even if the UE does not transmit SRS in that subframe. For PUCCH format 4/5, this shortened PUCCH format shall be used if the PUCCH transmission partly or fully overlaps with the cell-specific SRS bandwidth in the cell specific SRS subframes of the primary cell even if the UE does not transmit SRS in that subframe.The cell specific SRS subframes are defined in subclause 5.5.3.3 of [3]. Otherwise, the UE shall use the normal PUCCH format 1/1a/1b as defined in subclause 5.4.1 of [3] or normal PUCCH format 3 as defined in subclause 5.4.2A or normal PUCCH format 4 as defined in subclause 5.4.2B or normal PUCCH format 5 as defined in subclause 5.4.2C of [3].

For a BL/CE UE, for a SRS transmission in subframe *n* and if the UE transmits PUSCH/PUCCH in subframe *n* and/or *n+1*, the UE shall not transmit the SRS in subframe *n* if the SRS transmission bandwidth in subframe *n* is not completely within the narrowband of PUSCH/PUCCH in subframe *n* and/or *n+1*

A BL/CE UE shall not transmit SRS in UpPTS if SRS frequency location is different from DwPTS reception narrowband in the same special subframe.

Trigger type 0 SRS configuration of a UE in a serving cell for SRS periodicity, T_{SRS}, and SRS subframe offset, T_{offset}, is defined in Table 8.2-1 and Table 8.2-2, for FDD and TDD serving cell, respectively. The periodicity T_{SRS} of the SRS transmission is serving cell specific and is selected from the set {2, 5, 10, 20, 40, 80, 160, 320} ms or subframes.
For the SRS periodicity T_{SRS} of 2 ms in TDD serving cell, two SRS resources are configured in a half frame containing UL subframe(s) of the given serving cell.

Type 0 triggered SRS transmission instances in a given serving cell for TDD serving cell with $T_{\mathrm{SRS}} > 2$ and for FDD serving cell are the subframes satisfying $(10 \cdot n_f + k_{\mathrm{SRS}} - T_{offset}) \bmod T_{\mathrm{SRS}} = 0$, where for FDD $k_{\mathrm{SRS}} = \{0,1,...,9\}$ is the subframe index within the frame, for TDD serving cell, if the UE is configured with the parameter *srs-UpPtsAdd* for trigger type 0, k_{SRS} is defined in Table 8.2-6; otherwise k_{SRS} is defined in Table 8.2-3. The SRS transmission instances for TDD serving cell with $T_{\mathrm{SRS}} = 2$ are the subframes satisfying $(k_{\mathrm{SRS}} - T_{offset}) \bmod 5 = 0$.

For TDD serving cell, and a UE configured for type 0 triggered SRS transmission in serving cell *c*, and the UE configured with the parameter *EIMTA-MainConfigServCell-r12* for serving cell *c*, if the UE does not detect an UL/DL configuration indication for radio frame *m* (as described in section 13.1), the UE shall not transmit trigger type 0 SRS in a subframe of radio frame *m* that is indicated by the parameter *eimta-HARQ-ReferenceConfig-r12* as a downlink subframe unless the UE transmits PUSCH in the same subframe.

Trigger type 1 SRS configuration of a UE in a serving cell for SRS periodicity, $T_{\mathrm{SRS},1}$, and SRS subframe offset, $T_{offset,1}$, is defined in Table 8.2-4 and Table 8.2-5, for FDD and TDD serving cell, respectively. The periodicity $T_{\mathrm{SRS},1}$ of the SRS transmission is serving cell specific and is selected from the set {2, 5, 10} ms or subframes.
For the SRS periodicity $T_{\mathrm{SRS},1}$ of 2 ms in TDD serving cell, two SRS resources are configured in a half frame containing UL subframe(s) of the given serving cell.

For TDD serving cell, and a UE configured for type 1 triggered SRS transmission in serving cell *c* and configured with the parameter *srs-UpPtsAdd*, the UE is not expected to receive trigger type 1 SRS configurations with SRS periodicity $T_{\mathrm{SRS},1}$ of 2 ms.

A UE configured for type 1 triggered SRS transmission in serving cell *c* and not configured with a carrier indicator field shall transmit SRS on serving cell *c* upon detection of a positive SRS request in PDCCH/EPDCCH/MPDCCH scheduling PUSCH/PDSCH on serving cell *c*.

A UE configured for type 1 triggered SRS transmission in serving cell *c* and configured with a carrier indicator field shall transmit SRS on serving cell *c* upon detection of a positive SRS request in PDCCH/EPDCCH scheduling PUSCH/PDSCH with the value of carrier indicator field corresponding to serving cell *c*.

A non-BL/CE UE configured for type 1 triggered SRS transmission on serving cell *c* upon detection of a positive SRS request in subframe *n* of serving cell *c* shall commence SRS transmission in the first subframe satisfying $n+k, k \geq 4$ and

$(10 \cdot n_f + k_{\text{SRS}} - T_{offset,1}) \bmod T_{\text{SRS},1} = 0$ for TDD serving cell *c* with $T_{\text{SRS},1} > 2$ and for FDD serving cell *c*,

$(k_{\text{SRS}} - T_{offset,1}) \bmod 5 = 0$ for TDD serving cell *c* with $T_{\text{SRS},1} = 2$

where for FDD serving cell *c* $k_{\text{SRS}} = \{0,1,...,9\}$ is the subframe index within the frame n_f, for TDD serving cell *c*, if the UE is configured with the parameter *srs-UpPtsAdd* for trigger type 1, k_{SRS} is defined in Table 8.2-6; otherwise k_{SRS} is defined in Table 8.2-3.

A BL/CE UE configured for type 1 triggered SRS transmission on serving cell *c* upon detection of a positive SRS request of serving cell *c* shall commence SRS transmission in the first subframe satisfying $n+k, k \geq 4$, where subframe *n* is the last subframe in which the DCI format 6-0A/6-1A with the positive SRS request is transmitted, and

$(10 \cdot n_f + k_{\text{SRS}} - T_{offset,1}) \bmod T_{\text{SRS},1} = 0$ for TDD serving cell *c* with $T_{\text{SRS},1} > 2$ and for FDD serving cell *c*,

$(k_{\text{SRS}} - T_{offset,1}) \bmod 5 = 0$ for TDD serving cell *c* with $T_{\text{SRS},1} = 2$ where for FDD serving cell *c* $k_{\text{SRS}} = \{0,1,...,9\}$ is the subframe index within the frame n_f, for TDD serving cell *c* k_{SRS} is defined in Table 8.2-3.

A UE configured for type 1 triggered SRS transmission is not expected to receive type 1 SRS triggering events associated with different values of trigger type 1 SRS transmission parameters, as configured by higher layer signalling, for the same subframe and the same serving cell.

For TDD serving cell *c*, and a UE configured with *EIMTA-MainConfigServCell-r12* for a serving cell *c*, the UE shall not transmit SRS in a subframe of a radio frame that is indicated by the corresponding eIMTA-UL/DL-configuration as a downlink subframe.

A UE shall not transmit SRS whenever SRS and a PUSCH transmission corresponding to a Random Access Response Grant or a retransmission of the same transport block as part of the contention based random access procedure coincide in the same subframe.

Table 8.2-1: UE Specific SRS Periodicity T_{SRS} and Subframe Offset Configuration T_{offset} for trigger type 0, FDD

SRS Configuration Index I_{SRS}	SRS Periodicity T_{SRS} (ms)	SRS Subframe Offset T_{offset}
0 – 1	2	I_{SRS}
2 – 6	5	I_{SRS} – 2
7 – 16	10	I_{SRS} – 7
17 – 36	20	I_{SRS} – 17
37 – 76	40	I_{SRS} – 37
77 – 156	80	I_{SRS} – 77
157 – 316	160	I_{SRS} – 157
317 – 636	320	I_{SRS} – 317
637 – 1023	reserved	reserved

Table 8.2-2: UE Specific SRS Periodicity T_{SRS} and Subframe Offset Configuration T_{offset} for trigger type 0, TDD

SRS Configuration Index I_SRS	SRS Periodicity T_{SRS} (ms)	SRS Subframe Offset T_{offset}
0	2	0, 1
1	2	0, 2
2	2	1, 2
3	2	0, 3
4	2	1, 3
5	2	0, 4
6	2	1, 4
7	2	2, 3
8	2	2, 4
9	2	3, 4
10 – 14	5	I_{SRS} – 10
15 – 24	10	I_{SRS} – 15
25 – 44	20	I_{SRS} – 25
45 – 84	40	I_{SRS} – 45
85 – 164	80	I_{SRS} – 85
165 – 324	160	I_{SRS} – 165
325 – 644	320	I_{SRS} – 325
645 – 1023	reserved	reserved

Table 8.2-3: k_{SRS} for TDD

<table>
<tr><th rowspan="3"></th><th colspan="12">subframe index n</th></tr>
<tr><th rowspan="2">0</th><th colspan="2">1</th><th rowspan="2">2</th><th rowspan="2">3</th><th rowspan="2">4</th><th rowspan="2">5</th><th colspan="2">6</th><th rowspan="2">7</th><th rowspan="2">8</th><th rowspan="2">9</th></tr>
<tr><th>1st symbol of UpPTS</th><th>2nd symbol of UpPTS</th><th>1st symbol of UpPTS</th><th>2nd symbol of UpPTS</th></tr>
<tr><td>k_{SRS} in case UpPTS length of 2 symbols</td><td></td><td>0</td><td>1</td><td>2</td><td>3</td><td>4</td><td></td><td>5</td><td>6</td><td>7</td><td>8</td><td>9</td></tr>
<tr><td>k_{SRS} in case UpPTS length of 1 symbol</td><td></td><td>1</td><td></td><td>2</td><td>3</td><td>4</td><td></td><td>6</td><td></td><td>7</td><td>8</td><td>9</td></tr>
</table>

Table 8.2-4: UE Specific SRS Periodicity $T_{\mathrm{SRS},1}$ and Subframe Offset Configuration $T_{offset,1}$ for trigger type 1, FDD

SRS Configuration Index I_SRS	SRS Periodicity $T_{\mathrm{SRS},1}$ (ms)	SRS Subframe Offset $T_{offset,1}$
0 – 1	2	I_{SRS}
2 – 6	5	I_{SRS} – 2
7 – 16	10	I_{SRS} – 7
17 – 31	reserved	reserved

Table 8.2-5: UE Specific SRS Periodicity $T_{\mathrm{SRS},1}$ and Subframe Offset Configuration $T_{offset,1}$ for trigger type 1, TDD

SRS Configuration Index I_{SRS}	SRS Periodicity $T_{\mathrm{SRS},1}$ (ms)	SRS Subframe Offset $T_{offset,1}$
0	reserved	reserved
1	2	0, 2
2	2	1, 2
3	2	0, 3
4	2	1, 3
5	2	0, 4
6	2	1, 4
7	2	2, 3
8	2	2, 4
9	2	3, 4
10 – 14	5	I_{SRS} – 10
15 – 24	10	I_{SRS} – 15
25 – 31	reserved	reserved

Table 8.2-6: k_{SRS} for TDD and UE configured with two or four additional SC-FDMA symbols in UpPTS

	subframe index *n*															
	0	1				2	3	4	5	6				7	8	9
		1st symbol of UpPTS	2nd symbol of UpPTS	3rd symbol of UpPTS	4th symbol of UpPTS					1st symbol of UpPTS	2nd symbol of UpPTS	3rd symbol of UpPTS	4th symbol of UpPTS			
k_{SRS} in case UpPTS length of 4 symbols		0	1	2	3					5	6	7	8			
k_{SRS} in case UpPTS length of 2 symbols		2	3							7	8					

8.3 UE HARQ-ACK procedure

For FDD, and serving cell with frame structure type 1, an HARQ-ACK received on the PHICH assigned to a UE in subframe *i* is associated with the PUSCH transmission in subframe *i*-4.

For FDD-TDD, and serving cell with frame structure type 1, and UE not configured to monitor PDCCH/EPDCCH in another serving cell with frame structure type 2 for scheduling the serving cell, an HARQ-ACK received on the PHICH assigned to a UE in subframe *i* is associated with the PUSCH transmission in subframe *i*-4.

For FDD-TDD, if a serving cell is a secondary cell with frame structure type 1 and if the UE is configured to monitor PDCCH/EPDCCH in another serving cell with frame structure type 2 for scheduling the serving cell, then an HARQ-ACK received on the PHICH assigned to a UE in subframe *i* is associated with PUSCH transmission on the serving cell in subframe *i*-6.

For TDD, if the UE is not configured with *EIMTA-MainConfigServCell-r12* for any serving cell and, if a UE is configured with one serving cell, or if the UE is configured with more than one serving cell and the TDD UL/DL configuration of all the configured serving cells is the same,

- For frame structure type 2 UL/DL configuration 1-6, an HARQ-ACK received on the PHICH assigned to a UE in subframe *i* is associated with the PUSCH transmission in the subframe *i-k* as indicated by the following Table 8.3-1.

- For frame structure type 2 UL/DL configuration 0, an HARQ-ACK received on the PHICH in the resource corresponding to $I_{PHICH} = 0$, as defined in subclause 9.1.2, assigned to a UE in subframe *i* is associated with the PUSCH transmission in the subframe *i-k* as indicated by the following Table 8.3-1. For frame structure type 2 UL/DL configuration 0, an HARQ-ACK received on the PHICH in the resource corresponding to $I_{PHICH} = 1$, as defined in subclause 9.1.2, assigned to a UE in subframe *i* is associated with the PUSCH transmission in the subframe *i*-6.

For TDD, if a UE is configured with more than one serving cell and the TDD UL/DL configuration of at least two configured serving cells is not the same, or if the UE is configured with *EIMTA-MainConfigServCell-r12* for at least one serving cell, or FDD-TDD and serving cell is frame structure type 2,

- For serving cell with an UL-reference UL/DL configuration (defined in subclause 8.0) belonging to {1,2,3,4,5,6}, an HARQ-ACK received on the PHICH assigned to a UE in subframe *i* is associated with the PUSCH transmission in the subframe *i-k* for the serving cell as indicated by the following Table 8.3-1, where "TDD UL/DL Configuration" in Table 8.3-1 refers to the UL-reference UL/DL Configuration.

- For a serving cell with UL-reference UL/DL configuration 0 (defined in subclause 8.0), an HARQ-ACK received on the PHICH in the resource corresponding to $I_{PHICH} = 0$, as defined in subclause 9.1.2, assigned to a UE in subframe *i* is associated with the PUSCH transmission in the subframe *i-k* for the serving cell as indicated by the following Table 8.3-1, where "TDD UL/DL Configuration" in Table 8.3-1 refers to the UL-reference UL/DL configuration. For a serving cell with UL-reference UL/DL configuration 0, an HARQ-ACK received on the PHICH in the resource corresponding to $I_{PHICH} = 1$, as defined in subclause 9.1.2, assigned to a UE in subframe *i* is associated with the PUSCH transmission in the subframe *i*-6 for the serving cell.

- For FDD-TDD, if a serving cell is a secondary cell with UL-reference UL/DL configuration 0 and if the UE is configured to monitor PDCCH/EPDCCH in another serving cell with frame structure type 1 for scheduling the serving cell, for downlink subframe *i*, if a transport block was transmitted in the associated PUSCH subframe *i*-6 for the serving cell then PHICH resource corresponding to that transport block is not present in subframe *i*.

For a BL/CE UE, the UE is not expected to receive PHICH corresponding to a transport block.

Table 8.3-1: *k* for TDD configurations 0-6

TDD UL/DL Configuration	subframe number *i*									
	0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
0	7	4				7	4			
1		4			6		4			6
2				6					6	
3	6								6	6
4									6	6
5									6	
6	6	4				7	4			6

For a non-BL/CE UE, the physical layer in the UE shall deliver indications to the higher layers as follows:

For FDD, and for TDD with a UE configured with one serving cell, and for TDD with a UE configured with more than one serving cell and with TDD UL/DL configuration of all configured serving cells the same, and UE is not configured with *EIMTA-MainConfigServCell-r12* for any serving cell, for downlink or special subframe *i*, if a transport block was transmitted in the associated PUSCH subframe then:

if ACK is decoded on the PHICH corresponding to that transport block in subframe *i*, or if that transport block is disabled by PDCCH/EPDCCH received in downlink or special subframe *i*, ACK for that transport block shall be delivered to the higher layers; else NACK for that transport block shall be delivered to the higher layers.

For TDD, if the UE is configured with more than one serving cell, and if at least two serving cells have different UL/DL configurations, or the UE is configured with *EIMTA-MainConfigServCell-r12* for at least one serving cell, or for FDD-TDD, for downlink or special subframe *i*, if a transport block was transmitted in the associated PUSCH subframe then:

if ACK is decoded on the PHICH corresponding to that transport block in subframe *i*, or if that transport block is disabled by PDCCH/EPDCCH received in downlink or special subframe *i*, ACK for that transport block shall be delivered to the higher layers; or

if a PHICH resource corresponding to that transport block is not present in subframe *i* or if UE is not expected to receive PHICH corresponding to that transport block in subframe *i*, ACK for that transport block shall be delivered to the higher layers.

else NACK for that transport block shall be delivered to the higher layers.

8.4 UE PUSCH hopping procedure

The UE shall perform PUSCH frequency hopping if the single bit Frequency Hopping (FH) field in a corresponding PDCCH/EPDCCH with DCI format 0 is set to 1 and the uplink resource block assignment is type 0 otherwise no PUSCH frequency hopping is performed.

A UE performing PUSCH frequency hopping shall determine its PUSCH Resource Allocation (RA) for the first slot of a subframe (*S1*) including the lowest index PRB ($n_{PRB}^{S1}(n)$) in subframe *n* from the resource allocation field in the latest PDCCH/EPDCCH with DCI format 0 for the same transport block. If there is no PDCCH/EPDCCH for the same transport block, the UE shall determine its hopping type based on

- the hopping information in the most recent semi-persistent scheduling assignment PDCCH/EPDCCH, when the initial PUSCH for the same transport block is semi-persistently scheduled or
- the random access response grant for the same transport block, when the PUSCH is initiated by the random access response grant.

The resource allocation field in DCI format 0 excludes either 1 or 2 bits used for hopping information as indicated by Table 8.4-1 below where the number of PUSCH resource blocks is defined as

$$N_{RB}^{PUSCH} = \begin{cases} N_{RB}^{UL} - \tilde{N}_{RB}^{HO} - \left(N_{RB}^{UL} \bmod 2\right) & \text{Type 1 PUSCH hopping} \\ N_{RB}^{UL} & \text{Type 2 } \mathrm{N_{sb}} = 1 \text{ PUSCH hopping} \\ N_{RB}^{UL} - \tilde{N}_{RB}^{HO} & \text{Type 2 } \mathrm{N_{sb}} > 1 \text{ PUSCH hopping} \end{cases}$$

For type 1 and type 2 PUSCH hopping, $\tilde{N}_{\mathrm{RB}}^{\mathrm{HO}} = N_{\mathrm{RB}}^{\mathrm{HO}} + 1$ if $N_{\mathrm{RB}}^{\mathrm{HO}}$ is an odd number where $N_{\mathrm{RB}}^{\mathrm{HO}}$ defined in [3]. $\tilde{N}_{\mathrm{RB}}^{\mathrm{HO}} = N_{\mathrm{RB}}^{\mathrm{HO}}$ in other cases. The size of the resource allocation field in DCI format 0 after excluding either 1 or 2 bits shall be $y = \left\lceil \log_2 (N_{\mathrm{RB}}^{\mathrm{UL}} (N_{\mathrm{RB}}^{\mathrm{UL}} + 1)/2) \right\rceil - N_{UL\_hop}$, where N_{UL_hop} = 1 or 2 bits. The number of contiguous RBs that can be assigned to a type-1 hopping user is limited to $\left\lfloor 2^y / N_{\mathrm{RB}}^{\mathrm{UL}} \right\rfloor$. The number of contiguous RBs that can be assigned to a type-2 hopping user is limited to min($\left\lfloor 2^y / N_{\mathrm{RB}}^{\mathrm{UL}} \right\rfloor, \left\lfloor N_{\mathrm{RB}}^{\mathrm{PUSCH}} / N_{sb} \right\rfloor$), where the number of sub-bands N_{sb} is given by higher layers.

A UE performing PUSCH frequency hopping shall use one of two possible PUSCH frequency hopping types based on the hopping information. PUSCH hopping type 1 is described in subclause 8.4.1 and type 2 is described in subclause 8.4.2.

Table 8.4-1: Number of Hopping Bits N_{UL_hop} vs. System Bandwidth

System BW N_{RB}^{UL}	#Hopping bits for 2nd slot RA (N_{UL_hop})
6-49	1
50-110	2

The parameter *Hopping-mode* provided by higher layers determines if PUSCH frequency hopping is "inter-subframe" or "intra and inter-subframe".

8.4.1 Type 1 PUSCH hopping

For PUSCH hopping type 1 the hopping bit or bits indicated in Table 8.4-1 determine $\tilde{n}_{PRB}(i)$ as defined in Table 8.4-2. The lowest index PRB ($n_{PRB}^{S1}(i)$) of the 1st slot RA in subframe *i* is defined as $n_{PRB}^{S1}(i) = \tilde{n}_{PRB}^{S1}(i) + \tilde{N}_{\mathrm{RB}}^{\mathrm{HO}}/2$, where $n_{PRB}^{S1}(i) = RB_{START}$, and RB_{START} is obtained from the uplink scheduling grant as in subclause 8.4 and subclause 8.1.

The lowest index PRB ($n_{PRB}(i)$) of the 2nd slot RA in subframe *i* is defined as $n_{PRB}(i) = \tilde{n}_{PRB}(i) + \tilde{N}_{\mathrm{RB}}^{\mathrm{HO}}/2$.

The set of physical resource blocks to be used for PUSCH transmission are L_{CRBs} contiguously allocated resource blocks from PRB index $n_{PRB}^{S1}(i)$ for the 1st slot, and from PRB index $n_{PRB}(i)$ for the 2nd slot, respectively, where L_{CRBs} is obtained from the uplink scheduling grant as in subclause 8.4 and subclause 8.1.

If the *Hopping-mode* is "inter-subframe", the 1st slot RA is applied to even CURRENT_TX_NB, and the 2nd slot RA is applied to odd CURRENT_TX_NB, where CURRENT_TX_NB is defined in [8].

8.4.2 Type 2 PUSCH hopping

In PUSCH hopping type 2 the set of physical resource blocks to be used for transmission in slot n_{s} is given by the scheduling grant together with a predefined pattern according to [3] subclause 5.3.4.
If the system frame number is not acquired by the UE yet, the UE shall not transmit PUSCH with type-2 hopping and $N_{sb} > 1$ for TDD, where N_{sb} is defined in [3].

Table 8.4-2: PDCCH/EPDCCH DCI format 0 hopping bit definition

System BW N_{RB}^{UL}	Number of Hopping bits	Information in hopping bits	$\tilde{n}_{PRB}(i)$
6 – 49	1	0	$\left(\left\lfloor N_{RB}^{PUSCH}/2\right\rfloor + \tilde{n}_{PRB}^{S1}(i)\right) \bmod N_{RB}^{PUSCH}$,
		1	Type 2 PUSCH Hopping
50 – 110	2	00	$\left(\left\lfloor N_{RB}^{PUSCH}/4\right\rfloor + \tilde{n}_{PRB}^{S1}(i)\right) \bmod N_{RB}^{PUSCH}$
		01	$\left(-\left\lfloor N_{RB}^{PUSCH}/4\right\rfloor + \tilde{n}_{PRB}^{S1}(i)\right) \bmod N_{RB}^{PUSCH}$
		10	$\left(\left\lfloor N_{RB}^{PUSCH}/2\right\rfloor + \tilde{n}_{PRB}^{S1}(i)\right) \bmod N_{RB}^{PUSCH}$
		11	Type 2 PUSCH Hopping

8.5 UE Reference Symbol (RS) procedure

If UL sequence-group hopping or sequence hopping is configured in a serving cell, it applies to all Reference Symbols (SRS, PUSCH and PUCCH RS). If disabling of the sequence-group hopping and sequence hopping is configured for the UE in the serving cell through the higher-layer parameter *Disable-sequence-group-hopping*, the sequence-group hopping and sequence hopping for PUSCH RS are disabled.

8.6 Modulation order, redundancy version and transport block size determination

To determine the modulation order, redundancy version and transport block size for the physical uplink shared channel, the UE shall first

- read the "modulation and coding scheme and redundancy version" field (I_{MCS}) if the UE is a non-BL/CE UEs and read the “modulation and coding scheme” field (I_{MCS}) if the UE is a BL/CE UE, and
- check the "CSI request" bit field, and
- compute the total number of allocated PRBs (N_{PRB}) based on the procedure defined in subclause 8.1, and
- compute the number of coded symbols for control information.

8.6.1 Modulation order and redundancy version determination

For a non-BL/CE UE and for $0 \le I_{\text{MCS}} \le 28$, the modulation order (Q_m) is determined as follows:

- If the UE is capable of supporting 64QAM in PUSCH and has not been configured by higher layers to transmit only QPSK and 16QAM, the modulation order is given by $Q_m^{'}$ in Table 8.6.1-1.
- If the UE is not capable of supporting 64QAM in PUSCH or has been configured by higher layers to transmit only QPSK and 16QAM, $Q_m^{'}$ is first read from Table 8.6.1-1. The modulation order is set to $Q_m = \min(4, Q_m^{'})$.
- If the parameter *ttiBundling* provided by higher layers is set to *TRUE*, then the modulation order is set to $Q_m = 2$. Resource allocation size is restricted to $N_{\text{PRB}} \le 3$ applies in this case if the UE does not indicate support by higher layers to operate without it.

For a non-BL/CE UE and for $29 \le I_{\text{MCS}} \le 31$ the modulation order (Q_m) is determined as follows:

- if DCI format 0 is used and $I_{\text{MCS}} = 29$ or, if DCI format 4 is used and only 1 TB is enabled and $I_{\text{MCS}} = 29$ for the enabled TB and the signalled number of transmission layers is 1, and if
  - the "CSI request" bit field is 1 bit and the bit is set to trigger an aperiodic report and, $N_{\text{PRB}} \le 4$ or,
  - the "CSI request" bit field is 2 bits and is triggering an aperiodic CSI report for one serving cell according to Table 7.2.1-1A, and, $N_{\text{PRB}} \le 4$ or,
  - the "CSI request" bit field is 2 bits and is triggering an aperiodic CSI report for more than one serving cell according to Table 7.2.1-1A and, $N_{\text{PRB}} \le 20$ or,
  - the "CSI request" bit field is 2 bits and is triggering an aperiodic CSI report for one CSI process according to Table 7.2.1-1B and $N_{\text{PRB}} \le 4$ or,
  - the "CSI request" bit field is 2 bits and is triggering an aperiodic CSI report for more than one CSI process according to Table 7.2.1-1B and $N_{\text{PRB}} \le 20$ or,
  - the "CSI request" bit field is 2 bits and is triggering an aperiodic CSI report for one CSI process or {CSI process, CSI subframe set}-pair according to Table 7.2.1-1C and $N_{\text{PRB}} \le 4$ or,
  - the "CSI request" bit field is 2 bits and is triggering an aperiodic CSI report for more than one CSI process and/or {CSI process, CSI subframe set}-pair according to Table 7.2.1-1C and $N_{\text{PRB}} \le 20$, or

- the "CSI request" bit field is 3 bits and is triggering an aperiodic CSI report for one CSI process according to Table 7.2.1-1D or Table 7.2.1-1E and $N_{\mathrm{PRB}} \leq 4$, or
- the "CSI request" bit field is 3 bits and is triggering an aperiodic CSI report for 2 to 5 CSI processes according to Table 7.2.1-1D or Table 7.2.1-1E and $N_{\mathrm{PRB}} \leq 20$, or
- the "CSI request" bit field is 3 bits and is triggering an aperiodic CSI report for more than 5 CSI processes according to Table 7.2.1-1D or Table 7.2.1-1E,

then the modulation order is set to $Q_m = 2$.

- Otherwise, the modulation order shall be determined from the DCI transported in the latest PDCCH/EPDCCH with DCI format 0/4 for the same transport block using $0 \leq I_{\mathrm{MCS}} \leq 28$. If there is no PDCCH/EPDCCH with DCI format 0/4 for the same transport block using $0 \leq I_{\mathrm{MCS}} \leq 28$, the modulation order shall be determined from
  - the most recent semi-persistent scheduling assignment PDCCH/EPDCCH, when the initial PUSCH for the same transport block is semi-persistently scheduled, or,
  - the random access response grant for the same transport block, when the PUSCH is initiated by the random access response grant.

For a non-BL/CE UE, the UE shall use I_{MCS} and Table 8.6.1-1 to determine the redundancy version (rv_{idx}) to use in the physical uplink shared channel.

Table 8.6.1-1: Modulation, TBS index and redundancy version table for PUSCH

MCS Index I_{MCS}	Modulation Order $Q_m^{'}$	TBS Index I_{TBS}	Redundancy Version rv_{idx}
0	2	0	0
1	2	1	0
2	2	2	0
3	2	3	0
4	2	4	0
5	2	5	0
6	2	6	0
7	2	7	0
8	2	8	0
9	2	9	0
10	2	10	0
11	4	10	0
12	4	11	0
13	4	12	0
14	4	13	0
15	4	14	0
16	4	15	0
17	4	16	0
18	4	17	0
19	4	18	0
20	4	19	0
21	6	19	0
22	6	20	0
23	6	21	0
24	6	22	0
25	6	23	0
26	6	24	0
27	6	25	0
28	6	26	0
29	reserved		1
30			2
31			3

For a BL/CE UE, the modulation order is determined according to table 8.6.1-2. A BL/CE UE configured with CEModeB is not expected to receive a DCI format 6-0B indicating $I_{\mathrm{MCS}} > 10$.

For BL/CE UEs, the same redundancy version is applied to PUSCH transmitted in a given block of N_{acc} consecutive subframes. The subframe number of the first subframe in each block of N_{acc} consecutive subframes, denoted as $n_{\mathrm{abs},1}$, satisfies $n_{\mathrm{abs},1} \bmod N_{\mathrm{acc}} = 0$. Denote i_0 as the subframe number of the first uplink subframe intended for PUSCH. The PUSCH transmission spans $N_{\mathrm{abs}}^{\mathrm{PUSCH}}$ consecutive subframes including non-BL/CE subframes where the PUSCH transmission is postponed. For the j^{th} block of N_{acc} consecutive subframes, the redundancy version (rv_{idx}) for PUSCH is determined according to Table 7.1.7.1-2 using $rv = (j + rv_{DCI}) \bmod 4$, where $j = 0,1,..., J^{\mathrm{PUSCH}} - 1$ if $i_0 \bmod N_{\mathrm{acc}} = 0$, $j = 0,1,..., J^{\mathrm{PUSCH}}$ if $i_0 \bmod N_{\mathrm{acc}} > 0$, and $J^{\mathrm{PUSCH}} = \left\lceil \frac{N_{\mathrm{abs}}^{\mathrm{PUSCH}}}{N_{\mathrm{acc}}} \right\rceil$. The J^{PUSCH} blocks of subframes are sequential in time, starting with $j = 0$ to which subframe i_0 belongs. For a BL/CE UE configured in CEModeA, $N_{\mathrm{acc}} = 1$ and rv_{DCI} is determined by the 'Redundancy version' field in DCI format 6-0A. For a BL/CE UE configured with CEModeB, $N_{\mathrm{acc}} = 4$ for FDD and $N_{\mathrm{acc}} = 5$ for TDD, and $rv_{DCI} = 0$.

Table 8.6.1-2: Modulation and TBS index table for PUSCH

MCS Index I_{MCS}	Modulation Order Q_m	TBS Index I_{TBS}
0	2	0
1	2	1
2	2	2
3	2	3
4	2	4
5	2	5
6	2	6
7	2	7
8	2	8
9	2	9
10	2	10
11	4	10
12	4	11
13	4	12
14	4	13
15	4	14

8.6.2 Transport block size determination

For a non-BL/CE UE and for $0 \le I_{\mathrm{MCS}} \le 28$, the UE shall first determine the TBS index (I_{TBS}) using I_{MCS} and Table 8.6.1-1 except if the transport block is disabled in DCI format 4 as specified below. For a transport block that is not mapped to two-layer spatial multiplexing, the TBS is determined by the procedure in subclause 7.1.7.2.1. For a transport block that is mapped to two-layer spatial multiplexing, the TBS is determined by the procedure in subclause 7.1.7.2.2.

For a non-BL/CE UE and for $29 \le I_{\mathrm{MCS}} \le 31$,

- if DCI format 0 is used and $I_{\mathrm{MCS}} = 29$ or, if DCI format 4 is used and only 1 TB is enabled and $I_{\mathrm{MCS}} = 29$ for the enabled TB and the number of transmission layers is 1, and if
    - the "CSI request" bit field is 1 bit and is set to trigger an aperiodic CSI report and $N_{\mathrm{PRB}} \le 4$ or,

- the "CSI request" bit field is 2 bits and is triggering an aperiodic CSI report for one serving cell according to Table 7.2.1-1A, and , $N_{\mathrm{PRB}} \leq 4$ or,
- the "CSI request" bit field is 2 bits and is triggering aperiodic CSI report for more than one serving cell according to Table 7.2.1-1A and, $N_{\mathrm{PRB}} \leq 20$ or,
- the "CSI request" bit field is 2 bits and is triggering an aperiodic CSI report for one CSI process according to Table 7.2.1-1B and $N_{\mathrm{PRB}} \leq 4$ or,
- the "CSI request" bit field is 2 bits and is triggering an aperiodic CSI report for more than one CSI process according to Table 7.2.1-1B and, $N_{\mathrm{PRB}} \leq 20$ or,
- the "CSI request" bit field is 2 bits and is triggering an aperiodic CSI report for one CSI process or {CSI process, CSI subframe set}-pair according to Table 7.2.1-1C and $N_{\mathrm{PRB}} \leq 4$ or,
- the "CSI request" bit field is 2 bits and is triggering an aperiodic CSI report for more than one CSI process and/or {CSI process, CSI subframe set}-pair according to Table 7.2.1-1C and $N_{\mathrm{PRB}} \leq 20$,, or
- the "CSI request" bit field is 3 bits and is triggering an aperiodic CSI report for one CSI process according to Table 7.2.1-1D or Table 7.2.1-1E and $N_{\mathrm{PRB}} \leq 4$, or
- the "CSI request" bit field is 3 bits and is triggering an aperiodic CSI report for 2 to 5 CSI processes according to Table 7.2.1-1D or Table 7.2.1-1E and $N_{\mathrm{PRB}} \leq 20$, or
- the "CSI request" bit field is 3 bits and is triggering an aperiodic CSI report for more than 5 CSI processes according to Table 7.2.1-1D or Table 7.2.1-1E,

then there is no transport block for the UL-SCH and only the control information feedback for the current PUSCH reporting mode is transmitted by the UE.

- Otherwise, the transport block size shall be determined from the initial PDCCH/EPDCCH for the same transport block using $0 \leq I_{\mathrm{MCS}} \leq 28$. If there is no initial PDCCH/EPDCCH with an uplink DCI format for the same transport block using $0 \leq I_{\mathrm{MCS}} \leq 28$, the transport block size shall be determined from
  - the most recent semi-persistent scheduling assignment PDCCH/EPDCCH, when the initial PUSCH for the same transport block is semi-persistently scheduled, or,
  - the random access response grant for the same transport block, when the PUSCH is initiated by the random access response grant.

In DCI format 4 a transport block is disabled if either the combination of $I_{\mathrm{MCS}} = 0$ and $N_{\mathrm{PRB}} > 1$ or the combination of $I_{\mathrm{MCS}} = 28$ and $N_{\mathrm{PRB}} = 1$ is signalled, otherwise the transport block is enabled.

For a BL/CE UE configured with CEModeA and a PUSCH transmission not scheduled by the Random Access Response Grant, the UE shall first determine the TBS index (I_{TBS}) using I_{MCS} and Table 8.6.1-2. For a BL/CE UE the TBS is determined by the procedure in subclause 7.1.7.2.1.

For a BL/CE UE configured with CEModeA and a PUSCH transmission scheduled by the Random Access Response Grant, the UE shall determine the TBS index by the procedure in subclause 6.2.

For a BL/CE UE configured with CEModeB, the TBS is determined according to the procedure in subclause 7.1.7.2.1 for $0 \leq I_{\mathrm{TBS}} \leq 10$, and N_{PRB} =6 when resource allocation field is '110' or '111' otherwise N_{PRB} = 3.

8.6.3 Control information MCS offset determination

Offset values are defined for single codeword PUSCH transmission and multiple codeword PUSCH transmission. Single codeword PUSCH transmission offsets $\beta_{offset}^{HARQ-ACK}$, β_{offset}^{RI} and β_{offset}^{CQI} shall be configured to values according to Table 8.6.3-1,2,3 with the higher layer signalled indexes $I_{offset}^{HARQ-ACK}$ if the UE transmits no more than 22 HARQ-ACK bits on a PUSCH, I_{offset}^{RI}, and I_{offset}^{CQI}, respectively. Single codeword PUSCH transmission offset $\beta_{offset}^{HARQ-ACK}$ shall be configured to values according to [Table 8.6.3-1] with the higher layer signalled index $I_{offset,X}^{HARQ-ACK}$ if the UE transmits more than 22 HARQ-ACK bits on a PUSCH. Multiple codeword PUSCH transmission offsets $\beta_{offset}^{HARQ-ACK}$, β_{offset}^{RI} and β_{offset}^{CQI} shall be configured to values according to Table 8.6.3-1,2,3 with the higher layer signalled indexes $I_{offset,MC}^{HARQ-ACK}$ if the UE transmits no more than 22 HARQ-ACK bits on a PUSCH, $I_{offset,MC}^{RI}$ and $I_{offset,MC}^{CQI}$, respectively. Multiple codeword PUSCH transmission offset $\beta_{offset}^{HARQ-ACK}$ shall be configured to values according to [Table 8.6.3-1] with the higher layer signalled index $I_{offset,MC,X}^{HARQ-ACK}$ if the UE transmits more than 22 HARQ-ACK bits on a PUSCH.

If the UE is configured with higher layer parameter *UplinkPowerControlDedicated-v12x0* for serving cell c, and if a subframe belongs to uplink power control subframe set 2 as indicated by the higher layer parameter *tpc-SubframeSet-r12*, then for that subframe, the UE shall use

- the higher layer indexes $I_{offset,set2}^{HARQ-ACK}$, $I_{offset,set2,X}^{HARQ-ACK}$, $I_{offset,set2}^{RI}$ and $I_{offset,set2}^{CQI}$ in place of $I_{offset}^{HARQ-ACK}$, $I_{offset,X}^{HARQ-ACK}$, I_{offset}^{RI}, and I_{offset}^{CQI} respectively in Tables 8.6.3-1,2,3, to determine $\beta_{offset}^{HARQ-ACK}$, β_{offset}^{RI} and β_{offset}^{CQI} respectively for single codeword PUSCH transmissions, and

- the higher layer indexes $I_{offset,MC,set2}^{HARQ-ACK}$, $I_{offset,MC,set2,X}^{HARQ-ACK}$, $I_{offset,MC,set2}^{RI}$ and $I_{offset,MC,set2}^{CQI}$ in place of $I_{offset,MC}^{HARQ-ACK}$, $I_{offset,MC,X}^{HARQ-ACK}$, $I_{offset,MC}^{RI}$ and $I_{offset,MC}^{CQI}$ respectively in Tables 8.6.3-1,2,3, to determine $\beta_{offset}^{HARQ-ACK}$, β_{offset}^{RI} and β_{offset}^{CQI} respectively for multiple codeword PUSCH transmissions.

Table 8.6.3-1: Mapping of HARQ-ACK offset values and the index signalled by higher layers

$I_{offset}^{HARQ-ACK}$ or $I_{offset,MC}^{HARQ-ACK}$	$\beta_{offset}^{HARQ-ACK}$
0	2.000
1	2.500
2	3.125
3	4.000
4	5.000
5	6.250
6	8.000
7	10.000
8	12.625
9	15.875
10	20.000
11	31.000
12	50.000
13	80.000
14	126.000
15	1.0

Table 8.6.3-2: Mapping of RI offset values and the index signalled by higher layers

I_{offset}^{RI} or $I_{offset,MC}^{RI}$	β_{offset}^{RI}
0	1.250
1	1.625
2	2.000
3	2.500
4	3.125
5	4.000
6	5.000
7	6.250
8	8.000
9	10.000
10	12.625
11	15.875
12	20.000
13	reserved
14	reserved
15	reserved

Table 8.6.3-3: Mapping of CQI offset values and the index signalled by higher layers

I_{offset}^{CQI} or $I_{offset,MC}^{CQI}$	β_{offset}^{CQI}
0	reserved
1	reserved
2	1.125
3	1.250
4	1.375
5	1.625
6	1.750
7	2.000
8	2.250
9	2.500
10	2.875
11	3.125
12	3.500
13	4.000
14	5.000
15	6.250

8.7 UE transmit antenna selection

UE transmit antenna selection is configured by higher layers via parameter *ue-TransmitAntennaSelection*.

A UE configured with transmit antenna selection for a serving cell is not expected to

- be configured with more than one antenna port for any uplink physical channel or signal for any configured serving cell, or
- be configured with trigger type 1 SRS transmission on any configured serving cell, or
- be configured with simultaneous PUCCH and PUSCH transmission, or
- be configured with demodulation reference signal for PUSCH with OCC for any configured serving cell (see [3], subclause 5.5.2.1.1), or
- receive DCI Format 0 indicating uplink resource allocation type 1 for any serving cell, or
- be configured with a SCG.

If UE transmit antenna selection is disabled or not supported by the UE, the UE shall transmit from UE port 0.

If closed-loop UE transmit antenna selection is enabled by higher layers the UE shall perform transmit antenna selection for PUSCH in response to the most recent command received via DCI Format 0 in subclause 5.3.3.2 of [4].
If a UE is configured with more than one serving cell, the UE may assume the same transmit antenna port value is indicated in each PDCCH/EPDCCH with DCI format 0 in a given subframe.

If open-loop UE transmit antenna selection is enabled by higher layers, the transmit antenna for PUSCH/SRS to be selected by the UE is not specified.

9 Physical downlink control channel procedures

If the UE is configured with a SCG, the UE shall apply the procedures described in this clause for both MCG and SCG

- When the procedures are applied for MCG, the terms 'secondary cell', 'secondary cells' , 'serving cell', 'serving cells' in this clause refer to secondary cell, secondary cells, serving cell, serving cells belonging to the MCG respectively.
- When the procedures are applied for SCG, the terms 'secondary cell', 'secondary cells', 'serving cell', 'serving cells' in this clause refer to secondary cell, secondary cells (not including PSCell), serving cell, serving cells belonging to the SCG respectively. The term 'primary cell' in this clause refers to the PSCell of the SCG.

If a UE is configured with a LAA Scell, the UE shall apply the procedures described in this clause assuming frame structure type 1 for the LAA Scell unless stated otherwise.

9.1 UE procedure for determining physical downlink control channel assignment

9.1.1 PDCCH assignment procedure

The control region of each serving cell consists of a set of CCEs, numbered from 0 to $N_{\mathrm{CCE},k}-1$ according to subclause 6.8.1 in [3], where $N_{\mathrm{CCE},k}$ is the total number of CCEs in the control region of subframe k.
The UE shall monitor a set of PDCCH candidates on one or more activated serving cells as configured by higher layer signalling for control information, where monitoring implies attempting to decode each of the PDCCHs in the set according to all the monitored DCI formats.

A BL/CE UE is not required to monitor PDCCH.

The set of PDCCH candidates to monitor are defined in terms of search spaces, where a search space $S_k^{(L)}$ at aggregation level $L \in \{1,2,4,8\}$ is defined by a set of PDCCH candidates. For each serving cell on which PDCCH is monitored, the CCEs corresponding to PDCCH candidate *m* of the search space $S_k^{(L)}$ are given by

$$L \left\{ (Y_k + m') \bmod \lfloor N_{\mathrm{CCE},k} / L \rfloor \right\} + i$$

where Y_k is defined below, $i = 0, \cdots, L-1$. For the common search space $m' = m$. For the PDCCH UE specific search space, for the serving cell on which PDCCH is monitored, if the monitoring UE is configured with carrier indicator field then $m' = m + M_{full}^{(L)} \cdot n_{CI}$ where n_{CI} is the carrier indicator field value, else if the monitoring UE is not configured with carrier indicator field then $m' = m$, where $m = 0, \cdots, M^{(L)} - 1$. $M^{(L)}$ is the number of PDCCH candidates to monitor in the given search space for the scheduled serving cell. $M_{full}^{(L)}$ is determined according to Table 9.1.1-1 by replacing $M^{(L)}$ with $M_{full}^{(L)}$.

If a UE is configured with higher layer parameter *cif-InSchedulingCell-r13*, the carrier indicator field value corresponds to *cif-InSchedulingCell-r13*, otherwise, the carrier indicator field value is the same as *ServCellIndex* given in [11].

The UE shall monitor one common search space in every non-DRX subframe at each of the aggregation levels 4 and 8 on the primary cell.

A UE shall monitor common search space on a cell to decode the PDCCHs necessary to receive MBMS on that cell when configured by higher layers.

If a UE is not configured for EPDCCH monitoring, and if the UE is not configured with a carrier indicator field, then the UE shall monitor one PDCCH UE-specific search space at each of the aggregation levels 1, 2, 4, 8 on each activated serving cell in every non-DRX subframe.

If a UE is not configured for EPDCCH monitoring, and if the UE is configured with a carrier indicator field, then the UE shall monitor one or more UE-specific search spaces at each of the aggregation levels 1, 2, 4, 8 on one or more activated serving cells as configured by higher layer signalling in every non-DRX subframe.

If a UE is configured for EPDCCH monitoring on a serving cell, and if that serving cell is activated, and if the UE is not configured with a carrier indicator field, then the UE shall monitor one PDCCH UE-specific search space at each of the aggregation levels 1, 2, 4, 8 on that serving cell in all non-DRX subframes where EPDCCH is not monitored on that serving cell.

If a UE is configured for EPDCCH monitoring on a serving cell, and if that serving cell is activated, and if the UE is configured with a carrier indicator field, then the UE shall monitor one or more PDCCH UE-specific search spaces at each of the aggregation levels 1, 2, 4, 8 on that serving cell as configured by higher layer signalling in all non-DRX subframes where EPDCCH is not monitored on that serving cell.

The common and PDCCH UE-specific search spaces on the primary cell may overlap.

A UE configured with the carrier indicator field associated with monitoring PDCCH on serving cell *c* shall monitor PDCCH configured with carrier indicator field and with CRC scrambled by C-RNTI in the PDCCH UE specific search space of serving cell *c*.

A UE configured with the carrier indicator field associated with monitoring PDCCH on the primary cell shall monitor PDCCH configured with carrier indicator field and with CRC scrambled by SPS C-RNTI in the PDCCH UE specific search space of the primary cell.

The UE shall monitor the common search space for PDCCH without carrier indicator field.

For the serving cell on which PDCCH is monitored, if the UE is not configured with a carrier indicator field, it shall monitor the PDCCH UE specific search space for PDCCH without carrier indicator field, if the UE is configured with a carrier indicator field it shall monitor the PDCCH UE specific search space for PDCCH with carrier indicator field.

If the UE is not configured with a LAA Scell, the UE is not expected to monitor the PDCCH of a secondary cell if it is configured to monitor PDCCH with carrier indicator field corresponding to that secondary cell in another serving cell.

If the UE is configured with a LAA Scell, the UE is not expected to monitor the PDCCH UE specific space of the LAA SCell if it is configured to monitor PDCCH with carrier indicator field corresponding to that LAA Scell in another serving cell,

- where the UE is not expected to be configured to monitor PDCCH with carrier indicator field in an LAA Scell;
- where the UE is not expected to be scheduled with PDSCH starting in the second slot in a subframe in an LAA Scell if the UE is configured to monitor PDCCH with carrier indicator field corresponding to that LAA Scell in another serving cell.

For the serving cell on which PDCCH is monitored, the UE shall monitor PDCCH candidates at least for the same serving cell.

A UE configured to monitor PDCCH candidates with CRC scrambled by C-RNTI or SPS C-RNTI with a common payload size and with the same first CCE index n_{CCE} (as described in subclause 10.1) but with different sets of DCI information fields as defined in [4] in the

common search space

PDCCH UE specific search space

on the primary cell shall assume that for the PDCCH candidates with CRC scrambled by C-RNTI or SPS C-RNTI,

if the UE is configured with the carrier indicator field associated with monitoring the PDCCH on the primary cell, only the PDCCH in the common search space is transmitted by the primary cell;

otherwise, only the PDCCH in the UE specific search space is transmitted by the primary cell.

A UE configured to monitor PDCCH candidates in a given serving cell with a given DCI format size with CIF, and CRC scrambled by C- RNTI, where the PDCCH candidates may have one or more possible values of CIF for the given DCI format size, shall assume that a PDCCH candidate with the given DCI format size may be transmitted in the given serving cell in any PDCCH UE specific search space corresponding to any of the possible values of CIF for the given DCI format size.

If a serving cell is a LAA Scell, and if the higher layer parameter *subframeStartPosition* for the Scell indicates ‘s07’,

- The UE monitors PDCCH UE-specific search space candidates on the Scell in both the first and second slots of a subframe, and the aggregation levels defining the search spaces are listed in Table 9.1.1-1A;

otherwise,

- The aggregation levels defining the search spaces are listed in Table 9.1.1-1.

If a serving cell is a LAA Scell, the UE may receive PDCCH with DCI CRC scrambled by CC-RNTI as described in subclause 13A on the LAA Scell.

The DCI formats that the UE shall monitor depend on the configured transmission mode per each serving cell as defined in subclause 7.1.

If a UE is configured with higher layer parameter *skipMonitoringDCI-format0-1A* for a serving cell, the UE is not required to monitor the PDCCH with DCI Format 0/1A in the UE specific search space for that serving cell.

If a UE is configured with higher layer parameter *pdcch-candidateReductions* for a UE specific search space at aggregation level L for a serving cell, the corresponding number of PDCCH candidates is given by $M^{(L)} = \mathrm{round}\left(a \times M_{full}^{(L)}\right)$, where the value of a is determined according to Table 9.1.1-2 and $M_{full}^{(L)}$ is determined according to Table 9.1.1-1 by replacing $M^{(L)}$ with $M_{full}^{(L)}$.

Table 9.1.1-1: PDCCH candidates monitored by a UE

Search space $S_k^{(L)}$			Number of PDCCH candidates $M^{(L)}$
Type	Aggregation level L	Size [in CCEs]	
UE-specific	1	6	6
	2	12	6
	4	8	2
	8	16	2
Common	4	16	4
	8	16	2

Table 9.1.1-1A: PDCCH UE-specific search space candidates monitored by a UE on LAA Scell

Search space $S_k^{(L)}$			Number of PDCCH candidates $M^{(L)}$ in first slot	Number of PDCCH candidates $M^{(L)}$ in second slot
Type	Aggregation level L	Size [in CCEs]		
UE-specific	1	6	6	6
	2	12	6	6
	4	8	2	2
	8	16	2	2

Table 9.1.1-2: Scaling factor for PDCCH candidates reduction

pdcch-candidateReductions	Value of a
0	0
1	0.33
2	0.66
3	1

For the common search spaces, Y_k is set to 0 for the two aggregation levels $L=4$ and $L=8$.

For the UE-specific search space $S_k^{(L)}$ at aggregation level L, the variable Y_k is defined by

$$Y_k = \left(A \cdot Y_{k-1}\right) \bmod D$$

where $Y_{-1} = n_{\mathrm{RNTI}} \neq 0$, $A = 39827$, $D = 65537$ and $k = \lfloor n_s/2 \rfloor$, n_s is the slot number within a radio frame. The RNTI value used for n_{RNTI} is defined in subclause 7.1 in downlink and subclause 8 in uplink.

9.1.2 PHICH assignment procedure

If a UE is not configured with multiple TAGs, or if a UE is configured with multiple TAGs and PUSCH transmissions scheduled from serving cell c in subframe n are not scheduled by a Random Access Response Grant corresponding to a random access preamble transmission for a secondary cell

- For PUSCH transmissions scheduled from serving cell c in subframe n, the UE shall determine the corresponding PHICH resource of serving cell c in subframe $n + k_{PHICH}$, where
  - k_{PHICH} is always 4 for FDD.
  - k_{PHICH} is 6 for FDD-TDD and serving cell c frame structure type 2 and the PUSCH transmission is for another serving cell with frame structure type 1.
  - k_{PHICH} is 4 for FDD-TDD and serving cell c frame structure type 1and the PUSCH transmission is for a serving cell with frame structure type 1.
  - k_{PHICH} is given in table 9.1.2-1 for FDD-TDD and serving cell c frame structure type 1 and the PUSCH transmission is for another serving cell with frame structure type 2.

- For TDD, if the UE is not configured with *EIMTA-MainConfigServCell-r12* for any serving cell and, if the UE is configured with one serving cell, or if the UE is configured with more than one serving cell and the TDD UL/DL configuration of all the configured serving cells is the same, for PUSCH transmissions scheduled from serving cell c in subframe *n*, the UE shall determine the corresponding PHICH resource of serving cell c in subframe $n+k_{PHICH}$, where k_{PHICH} is given in table 9.1.2-1.

- For TDD, if the UE is configured with more than one serving cell and the TDD UL/DL configuration of at least two configured serving cells is not the same, or if the UE is configured with *EIMTA-MainConfigServCell-r12* for at least one serving cell , or for FDD-TDD and serving cell c frame structure type 2, for PUSCH transmissions scheduled from serving cell c in subframe *n*, the UE shall determine the corresponding PHICH resource of serving cell c in subframe $n+k_{PHICH}$, where k_{PHICH} is given in table 9.1.2-1, where the "TDD UL/DL Configuration" in the rest of this subclause refers to the UL-reference UL/DL configuration (defined in subclause 8.0) of the serving cell corresponding to the PUSCH transmission.

If a UE is configured with multiple TAGs, for PUSCH transmissions on subframe *n* for a secondary cell c scheduled by a Random Access Response grant corresponding to a random access preamble transmission for the secondary cell c,

- For TDD, if the UE is configured with more than one serving cell and the TDD UL/DL configuration of at least two configured serving cells is not the same, or if the UE is configured with *EIMTA-MainConfigServCell-r12* for at least one serving cell, or for FDD-TDD and serving cell c frame structure type 2, the "TDD UL/DL Configuration" in the rest of this subclause refers to the UL-reference UL/DL configuration (defined in subclause 8.0) of secondary cell c.

- If the UE is not configured to monitor PDCCH/EPDCCH with carrier indicator field corresponding to secondary cell c in another serving cell, the UE shall determine the corresponding PHICH resource on the secondary cell c in subframe $n+k_{PHICH}$, where

  - k_{PHICH} is always 4 for FDD and where k_{PHICH} is given in table 9.1.2-1 for TDD.

  - k_{PHICH} is 4 for FDD-TDD and secondary cell c frame structure type 1.

  - k_{PHICH} is given in table 9.1.2-1 for FDD-TDD and secondary cell c frame structure type 2

- If the UE is configured to monitor PDCCH/EPDCCH with carrier indicator field corresponding to secondary cell c in another serving cell $c1$, the UE configured with multiple TAGs shall determine the corresponding PHICH resource on the serving cell $c1$ in subframe $n+k_{PHICH}$, where

  - k_{PHICH} is always 4 for FDD and where k_{PHICH} is given in table 9.1.2-1 for TDD.

  - k_{PHICH} is 4 for FDD-TDD and primary cell frame structure type 1 and frame structure type 1 for secondary cell c and serving cell $c1$

  - k_{PHICH} is given in table 9.1.2-1 for FDD-TDD and serving cell c frame structure type 2

  - k_{PHICH} is 6 for FDD-TDD and serving cell c frame structure type 1 and serving cell $c1$ frame structure type 2

For subframe bundling operation, the corresponding PHICH resource is associated with the last subframe in the bundle.

Table 9.1.2-1: k_{PHICH} for TDD

TDD UL/DL Configuration	subframe index *n*									
	0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
0			4	7	6			4	7	6
1			4	6				4	6	
2			6					6		
3			6	6	6					
4			6	6						
5			6							
6			4	6	6			4	7	

The PHICH resource is identified by the index pair $(n_{PHICH}^{group}, n_{PHICH}^{seq})$ where n_{PHICH}^{group} is the PHICH group number and n_{PHICH}^{seq} is the orthogonal sequence index within the group as defined by:

$$n_{PHICH}^{group} = (I_{PRB\_RA} + n_{DMRS}) \bmod N_{PHICH}^{group} + I_{PHICH} N_{PHICH}^{group}$$
$$n_{PHICH}^{seq} = (\lfloor I_{PRB\_RA} / N_{PHICH}^{group} \rfloor + n_{DMRS}) \bmod 2N_{SF}^{PHICH}$$

where

- n_{DMRS} is mapped from the cyclic shift for DMRS field (according to Table 9.1.2-2) in the most recent PDCCH/EPDCCH with uplink DCI format [4] for the transport block(s) associated with the corresponding PUSCH transmission. n_{DMRS} shall be set to zero, if there is no PDCCH/EPDCCH with uplink DCI format for the same transport block, and
    - if the initial PUSCH for the same transport block is semi-persistently scheduled, or
    - if the initial PUSCH for the same transport block is scheduled by the random access response grant .
- N_{SF}^{PHICH} is the spreading factor size used for PHICH modulation as described in subclause 6.9.1 in [3].
- $$I_{PRB\_RA} = \begin{cases} I_{PRB\_RA}^{lowest\_index} & \text{for the first TB of a PUSCH with associated PDCCH/EPDCCH or for the case of no associated PDCCH/EPDCCH when the number of negatively acknowledged TBs is not equal to the number of TBs indicated in the most recent PDCCH/EPDCCH associated with the corresponding PUSCH} \\ I_{PRB\_RA}^{lowest\_index} + 1 & \text{for a second TB of a PUSCH with associated PDCCH/EPDCCH} \end{cases}$$

  where $I_{PRB\_RA}^{lowest\_index}$ is the lowest PRB index in the first slot of the corresponding PUSCH transmission
- N_{PHICH}^{group} is the number of PHICH groups configured by higher layers as described in subclause 6.9 of [3],
- $$I_{PHICH} = \begin{cases} 1 & \text{for TDD UL/DL configuration 0 with PUSCH transmission in subframe } n = 4 \text{ or } 9 \\ 0 & \text{otherwise} \end{cases}$$

Table 9.1.2-2: Mapping between n_{DMRS} and the cyclic shift for DMRS field in PDCCH/EPDCCH with uplink DCI format in [4]

Cyclic Shift for DMRS Field in PDCCH/EPDCCH with uplink DCI format in [4]	n_{DMRS}
000	0
001	1
010	2
011	3
100	4
101	5
110	6
111	7

9.1.3 Control Format Indicator (CFI) assignment procedure

PHICH duration is signalled by higher layers according to Table 6.9.3-1 in [3]. The duration signalled puts a lower limit on the size of the control region determined from the control format indicator (CFI). When $N_{\mathrm{RB}}^{\mathrm{DL}} > 10$, if extended PHICH duration is indicated by higher layers then the UE shall assume that CFI is equal to PHICH duration.

In subframes indicated by higher layers to decode PMCH, when $N_{\mathrm{RB}}^{\mathrm{DL}} > 10$, a UE may assume that CFI is equal to the value of the higher layer parameter *non-MBSFNregionLength* [11].

9.1.4 EPDCCH assignment procedure

For each serving cell, higher layer signalling can configure a UE with one or two EPDCCH-PRB-sets for EPDCCH monitoring. The PRB-pairs corresponding to an EPDCCH-PRB-set are indicated by higher layers as described in subclause 9.1.4.4. Each EPDCCH-PRB-set consists of set of ECCEs numbered from 0 to $N_{\mathrm{ECCE},p,k} - 1$ where $N_{\mathrm{ECCE},p,k}$ is the number of ECCEs in EPDCCH-PRB-set p of subframe k. Each EPDCCH-PRB-set can be configured for either localized EPDCCH transmission or distributed EPDCCH transmission.

The UE shall monitor a set of EPDCCH candidates on one or more activated serving cells as configured by higher layer signalling for control information, where monitoring implies attempting to decode each of the EPDCCHs in the set according to the monitored DCI formats.

A BL/CE UE is not required to monitor EPDCCH.

The set of EPDCCH candidates to monitor are defined in terms of EPDCCH UE-specific search spaces.

For each serving cell, the subframes in which the UE monitors EPDCCH UE-specific search spaces are configured by higher layers.

The UE shall not monitor EPDCCH

- For TDD and normal downlink CP, in special subframes for the special subframe configurations 0 and 5, or for frame structure type 3, in the subframe with the same duration as the DwPTS duration of the special subframe configurations 0 and 5, shown in Table 4.2-1 of [3].
- For TDD and extended downlink CP, in special subframes for the special subframe configurations 0, 4 and 7 shown in Table 4.2-1 of [3].
- In subframes indicated by higher layers to decode PMCH.
- For TDD and if the UE is configured with different UL/DL configurations for the primary and a secondary cell, in a downlink subframe on the secondary cell when the same subframe on the primary cell is a special subframe and the UE is not capable of simultaneous reception and transmission on the primary and secondary cells.

An EPDCCH UE-specific search space $ES_k^{(L)}$ at aggregation level $L \in \{1,2,4,8,16,32\}$ is defined by a set of EPDCCH candidates.

For an EPDCCH-PRB-set p, the ECCEs corresponding to EPDCCH candidate *m* of the search space $ES_k^{(L)}$ are given by

$$L\left\{\left(Y_{p,k}+\left\lfloor\frac{m\cdot N_{\mathrm{ECCE},p,k}}{L\cdot M_{p,full}^{(L)}}\right\rfloor+b\right)\bmod\left\lfloor N_{\mathrm{ECCE},p,k}/L\right\rfloor\right\}+i$$

where

$Y_{p,k}$ is defined below,

$i=0,\cdots,L-1$

$b=n_{CI}$ if the UE is configured with a carrier indicator field for the serving cell on which EPDCCH is monitored, otherwise $b=0$

n_{CI} is the carrier indicator field value,

$M_{p,full}^{(L)}$ is the nominal number of EPDCCH candidates to monitor at aggregation level *L* in EPDCCH-PRB-set *p* determined according to Tables 9.1.4-1a to 9.1.4-5b by replacing $M_p^{(L)}$ with $M_{p,full}^{(L)}$,

$m=0,1,\ldots M_p^{(L)}-1$.

If the UE is not configured with a carrier indicator field for the serving cell on which EPDCCH is monitored, $M_p^{(L)}$ is the number of EPDCCH candidates to monitor at aggregation level L in EPDCCH-PRB-set p for the serving cell on which EPDCCH is monitored, as given in Tables 9.1.4-1a, 9.1.4-1b, 9.1.4-2a, 9.1.4-2b, 9.1.4-3a, 9.1.4-3b, 9.1.4-4a, 9.4.4-4b, 9.1.4-5a, 9.1.4-5b below; otherwise, $M_p^{(L)}$ is the number of EPDCCH candidates to monitor at aggregation level L in EPDCCH-PRB-set p for the serving cell indicated by n_{CI}.

If a UE is configured with higher layer parameter *pdcch-candidateReductions* for a specific search space at aggregation level *L* in EPDCCH-PRB-set p for a serving cell, the corresponding number of EPDCCH candidates is given by $M_p^{(L)}=\mathrm{round}\left(a\times M_{p,full}^{(L)}\right)$, where the value of a is determined according to Table 9.1.1-2 and $M_{p,full}^{(L)}$ is determined according to Tables 9.1.4-1a to 9.1.4-5b by replacing $M_p^{(L)}$ with $M_{p,full}^{(L)}$.

If a UE is configured with higher layer parameter *cif-InSchedulingCell-r13*, the carrier indicator field value corresponds to *cif-InSchedulingCell-r13*, otherwise the carrier indicator field value is the same as *ServCellIndex* given in [11].

A UE is not expected to monitor an EPDCCH candidate, if an ECCE corresponding to that EPDCCH candidate is mapped to a PRB pair that overlaps in frequency with a transmission of either PBCH or primary or secondary synchronization signals in the same subframe.

If a UE is configured with two EPDCCH-PRB-sets with the same $n_{\mathrm{ID},i}^{\mathrm{EPDCCH}}$ value (where $n_{\mathrm{ID},i}^{\mathrm{EPDCCH}}$ is defined in subclause 6.10.3A.1 in [3]), if the UE receives an EPDCCH candidate with a given DCI payload size corresponding to one of the EPDCCH-PRB-sets and mapped only to a given set of REs (as described in subclause 6.8A.5 in [3]), and if the UE is also configured to monitor an EPDCCH candidate with the same DCI payload size and corresponding to the other EPDCCH-PRB-set and which is mapped only to the same set of REs, and if the number of the first ECCE of the received EPDCCH candidate is used for determining PUCCH resource for HARQ-ACK transmission (as described in subclause 10.1.2 and subclause 10.1.3), the number of the first ECCE shall be determined based on EPDCCH-PRB-set $p=0$.

The variable $Y_{p,k}$ is defined by

$$Y_{p,k}=\left(A_p\cdot Y_{p,k-1}\right)\bmod D$$

where $Y_{p,-1} = n_{\mathrm{RNTI}} \neq 0$, $A_0 = 39827$, $A_1 = 39829$, $D = 65537$ and $k = \lfloor n_s/2 \rfloor$, n_s is the slot number within a radio frame. The RNTI value used for n_{RNTI} is defined in subclause 7.1 in downlink and subclause 8 in uplink. The DCI formats that the UE shall monitor depend on the configured transmission mode per each serving cell as defined in subclause 7.1.

If a UE is configured with higher layer parameter *skipMonitoringDCI-format0-1A* for a serving cell, the UE is not required to monitor the EPDCCH with DCI Format 0/1A in the UE specific search space for that serving cell.

If a serving cell is a LAA Scell, and if the higher layer parameter *subframeStartPosition* for the Scell indicates 's07'

- the UE monitors EPDCCH UE-specific search space candidates on the Scell assuming they start in both the first slot and the second slot of a subframe.

The aggregation levels defining the search spaces and the number of monitored EPDCCH candidates is given as follows

- For a UE configured with only one EPDCCH-PRB-set for distributed transmission, the aggregation levels defining the search spaces and the number of monitored EPDCCH candidates are listed in Table 9.1.4-1a, Table 9.1.4-1b.
- For a UE configured with only one EPDCCH-PRB-set for localized transmission, the aggregation levels defining the search spaces and the number of monitored EPDCCH candidates are listed in Table 9.1.4-2a, Table 9.1.4-2b.
- For a UE configured with two EPDCCH-PRB-sets for distributed transmission, the aggregation levels defining the search spaces and the number of monitored EPDCCH candidates are listed in Table 9.1.4-3a, 9.1.4-3b.
- For a UE configured with two EPDCCH-PRB-sets for localized transmission, the aggregation levels defining the search spaces and the number of monitored EPDCCH candidates are listed in Table 9.1.4-4a, 9.4.4-4b.
- For a UE configured with one EPDCCH-PRB-set for distributed transmission, and one EPDCCH-PRB-set for localized transmission, the aggregation levels defining the search spaces and the number of monitored EPDCCH candidates are listed in Table 9.1.4-5a, 9.1.4-5b.

If the UE is not configured with a carrier indicator field for the serving cell on which EPDCCH is monitored, $\hat{N}_{\mathrm{RB}}^{\mathrm{DL}} = N_{\mathrm{RB}}^{\mathrm{DL}}$ of the serving cell on which EPDCCH is monitored. If the UE is configured with a carrier indicator field for the serving cell on which EPDCCH is monitored, $\hat{N}_{\mathrm{RB}}^{\mathrm{DL}} = N_{\mathrm{RB}}^{\mathrm{DL}}$ of the serving cell indicated by n_{CI}.

For Tables 9.1.4-1a, 9.1.4-1b, 9.1.4-2a, 9.1.4-2b, 9.1.4-3a, 9.1.4-3b, 9.1.4-4a, 9.4.4-4b, 9.1.4-5a, 9.1.4-5b

- Case 1 applies
    - for normal subframes and normal downlink CP when DCI formats 2/2A/2B/2C/2D are monitored and $\hat{N}_{\mathrm{RB}}^{\mathrm{DL}} \geq 25$, or
    - for frame structure type 3, for downlink subframes with PDSCH transmissions starting in the second slot,
    - for special subframes with special subframe configuration 3,4,8 for frame structure type 2 or the subframes with the same duration as the DwPTS duration of a special subframe configuration 3,4,8 for frame structure type 3, and normal downlink CP when DCI formats 2/2A/2B/2C/2D are monitored and $\hat{N}_{\mathrm{RB}}^{\mathrm{DL}} \geq 25$, or
    - for normal subframes and normal downlink CP when DCI formats 1A/1B/1D/1/2/2A/2B/2C/2D/0/4/5/6-0A/6-0B/6-1A/6-1B are monitored, and when $n_{\mathrm{EPDCCH}} < 104$ (n_{EPDCCH} defined in subclause 6.8A.1 in [3]), or
    - for special subframes with special subframe configuration 3, 4, 8 for frame structure type 2 or the subframes with the same duration as the DwPTS duration of a special subframe configuration 3,4,8 for frame structure type 3, and normal downlink CP when DCI formats 1A/1B/1D/1/2A/2/2B/2C/2D/0/4/5/6-0A/6-0B/6-1A/6-1B are monitored, and when $n_{\mathrm{EPDCCH}} < 104$ (n_{EPDCCH} defined in subclause 6.8A.1 in [3]);
- Case 2 applies

- for normal subframes and extended downlink CP when DCI formats 1A/1B/1D/1/2A/2/2B/2C/2D/0/4/5/6-0A/6-0B/6-1A/6-1B are monitored or,
- for special subframes with special subframe configuration 1,2,6,7,9 for frame structure type 2 or the subframes with the same duration as the DwPTS duration of a special subframe configuration 1,2,6,7,9 for frame structure type 3, and normal downlink CP when DCI formats 1A/1B/1D/1/2A/2/2B/2C/2D/0/4/5/6-0A/6-0B/6-1A/6-1B are monitored , or
- for special subframes with special subframe configuration 1,2,3,5,6 and extended downlink CP when DCI formats 1A/1B/1D/1/2A/2/2B/2C/2D/0/4/5/6-0A/6-0B/6-1A/6-1B are monitored;

- otherwise
  - Case 3 is applied.

$N_{\mathrm{RB}}^{X_p}$ is the number of PRB-pairs constituting EPDCCH-PRB-set p .

Table 9.1.4-1a: EPDCCH candidates monitored by a UE (One Distributed EPDCCH-PRB-set - Case1, Case 2)

$N_{\mathrm{RB}}^{X_p}$	Number of EPDCCH candidates $M_p^{(L)}$ for Case 1					Number of EPDCCH candidates $M_p^{(L)}$ for Case 2				
	L=2	L=4	L=8	L=16	L=32	L=1	L=2	L=4	L=8	L=16
2	4	2	1	0	0	4	2	1	0	0
4	8	4	2	1	0	8	4	2	1	0
8	6	4	3	2	1	6	4	3	2	1

Table 9.1.4-1b: EPDCCH candidates monitored by a UE (One Distributed EPDCCH-PRB-set – Case 3)

$N_{\mathrm{RB}}^{X_p}$	Number of EPDCCH candidates $M_p^{(L)}$ for Case 3				
	L=1	L=2	L=4	L=8	L=16
2	8	4	2	1	0
4	4	5	4	2	1
8	4	4	4	2	2

Table 9.1.4-2a: EPDCCH candidates monitored by a UE (One Localized EPDCCH-PRB-set - Case1, Case 2)

$N_{\mathrm{RB}}^{X_p}$	Number of EPDCCH candidates $M_p^{(L)}$ for Case 1				Number of EPDCCH candidates $M_p^{(L)}$ for Case 2			
	L=2	L=4	L=8	L=16	L=1	L=2	L=4	L=8
2	4	2	1	0	4	2	1	0
4	8	4	2	1	8	4	2	1
8	6	6	2	2	6	6	2	2

Table 9.1.4-2b: EPDCCH candidates monitored by a UE (One Localized EPDCCH-PRB-set – Case 3)

$N_{\mathrm{RB}}^{X_p}$	Number of EPDCCH candidates $M_p^{(L)}$ for Case 3			
	L=1	L=2	L=4	L=8
2	8	4	2	1
4	6	6	2	2
8	6	6	2	2

.

Table 9.1.4-3a: EPDCCH candidates monitored by a UE (Two Distributed EPDCCH-PRB-sets - Case1, Case 2)

$N_{\mathrm{RB}}^{Xp_1}$	$N_{\mathrm{RB}}^{Xp_2}$	Number of EPDCCH candidates $\left[M_{p1}^{(L)}, M_{p2}^{(L)}\right]$ for Case 1					Number of EPDCCH candidates $\left[M_{p1}^{(L)}, M_{p2}^{(L)}\right]$ for Case 2				
		L=2	L=4	L=8	L=16	L=32	L=1	L=2	L=4	L=8	L=16
2	2	4,4	2,2	1,1	0,0	0,0	4,4	2,2	1,1	0,0	0,0
4	4	3,3	3,3	1,1	1,1	0,0	3,3	3,3	1,1	1,1	0,0
8	8	3,3	2,2	1,1	1,1	1,1	3,3	2,2	1,1	1,1	1,1
4	2	5,3	3,2	1,1	1,0	0,0	5,3	3,2	1,1	1,0	0,0
8	2	4,2	4,2	1,1	1,0	1,0	4,2	4,2	1,1	1,0	1,0
8	4	3,3	2,2	2,1	1,1	1,0	3,3	2,2	2,1	1,1	1,0

Table 9.1.4-3b: EPDCCH candidates monitored by a UE (Two Distributed EPDCCH-PRB-sets – Case 3)

$N_{\mathrm{RB}}^{Xp_1}$	$N_{\mathrm{RB}}^{Xp_2}$	Number of EPDCCH candidates $\left[M_{p1}^{(L)}, M_{p2}^{(L)}\right]$ for Case 3				
		L=1	L=2	L=4	L=8	L=16
2	2	2,2	3,3	2,2	1,1	0,0
4	4	2,2	2,2	2,2	1,1	1,1
8	8	2,2	2,2	2,2	1,1	1,1
4	2	3,1	3,2	3,1	1,1	1,0
8	2	3,1	4,1	3,1	1,1	1,0
8	4	2,2	2,2	2,2	1,1	1,1

Table 9.1.4-4a: EPDCCH candidates monitored by a UE (Two Localized EPDCCH-PRB-sets - Case1, Case 2)

$N_{\mathrm{RB}}^{Xp_1}$	$N_{\mathrm{RB}}^{Xp_2}$	Number of EPDCCH candidates $\left[M_{p1}^{(L)}, M_{p2}^{(L)}\right]$ for Case 1				Number of EPDCCH candidates $\left[M_{p1}^{(L)}, M_{p2}^{(L)}\right]$ for Case 2			
		L=2	L=4	L=8	L=16	L=1	L=2	L=4	L=8
2	2	4,4	2,2	1,1	0,0	4,4	2,2	1,1	0,0
4	4	3,3	3,3	1,1	1,1	3,3	3,3	1,1	1,1
8	8	3,3	3,3	1,1	1,1	3,3	3,3	1,1	1,1
4	2	4,3	4,2	1,1	1,0	4,3	4,2	1,1	1,0
8	2	5,2	4,2	1,1	1,0	5,2	4,2	1,1	1,0
8	4	3,3	3,3	1,1	1,1	3,3	3,3	1,1	1,1

Table 9.1.4-4b: EPDCCH candidates monitored by a UE (Two Localized EPDCCH-PRB-sets – Case 3)

$N_{\mathrm{RB}}^{Xp_1}$	$N_{\mathrm{RB}}^{Xp_2}$	Number of EPDCCH candidates $\left[M_{p1}^{(L)}, M_{p2}^{(L)}\right]$ for Case 3			
		L=1	L=2	L=4	L=8
2	2	3,3	3,3	1,1	1,1
4	4	3,3	3,3	1,1	1,1
8	8	3,3	3,3	1,1	1,1
4	2	4,2	4,2	1,1	1,1
8	2	4,2	4,2	1,1	1,1
8	4	3,3	3,3	1,1	1,1

Table 9.1.4-5a: EPDCCH candidates monitored by a UE (NOTE)

$N_{\mathrm{RB}}^{Xp_1}$	$N_{\mathrm{RB}}^{Xp_2}$	Number of EPDCCH candidates $\left[M_{p1}^{(L)}, M_{p2}^{(L)}\right]$ for Case 1					Number of EPDCCH candidates $\left[M_{p1}^{(L)}, M_{p2}^{(L)}\right]$ for Case 2				
		L=2	L=4	L=8	L=16	L=32	L=1	L=2	L=4	L=8	L=16
2	2	4,4	2,2	1,1	0,0	0,0	4,4	2,2	1,1	0,0	0,0
4	4	4,2	4,3	0,2	0,1	0,0	4,2	4,3	0,2	0,1	0,0
8	8	4,1	4,2	0,2	0,2	0,1	4,1	4,2	0,2	0,2	0,1
2	4	4,3	2,4	0,2	0,1	0,0	4,3	2,4	0,2	0,1	0,0
2	8	4,1	2,2	0,4	0,2	0,1	4,1	2,2	0,4	0,2	0,1
4	2	5,2	4,2	1,1	1,0	0,0	5,2	4,2	1,1	1,0	0,0
4	8	4,1	4,2	0,2	0,2	0,1	4,1	4,2	0,2	0,2	0,1
8	2	5,1	4,2	2,1	1,0	0,0	5,1	4,2	2,1	1,0	0,0
8	4	6,1	4,2	0,2	0,1	0,0	6,1	4,2	0,2	0,1	0,0

NOTE: One localized EPDCCH-PRB-set and one distributed EPDCCH-PRB-set, - Case1, Case 2;
p_1 is the identity of the localized EPDCCH-PRB-set,
p_2 is the identity of the distributed EPDCCH-PRB-set

Table 9.1.4-5b: EPDCCH candidates monitored by a UE (NOTE)

$N_{\mathrm{RB}}^{Xp_1}$	$N_{\mathrm{RB}}^{Xp_2}$	Number of EPDCCH candidates $\left[M_{p1}^{(L)}, M_{p2}^{(L)}\right]$ for Case 3				
		L=1	L=2	L=4	L=8	L=16
2	2	4,1	4,2	2,2	0,1	0,0
4	4	4,1	4,1	2,2	0,1	0,1
8	8	4,1	4,1	2,2	0,1	0,1
2	4	4,1	4,1	2,2	0,1	0,1
2	8	4,1	4,1	2,2	0,1	0,1
4	2	4,1	4,1	2,2	1,1	0,0
4	8	4,1	4,1	2,2	0,1	0,1
8	2	4,1	4,1	4,1	0,1	0,0
8	4	4,1	4,1	2,2	0,1	0,1

NOTE: One localized EPDCCH-PRB-set and one distributed EPDCCH-PRB-set - Case 3);
p_1 is the identity of the localized EPDCCH-PRB-set,
p_2 is the identity of the distributed EPDCCH-PRB-set)

If the UE is not configured with a carrier indicator field, then the UE shall monitor one EPDCCH UE-specific search space at each of the aggregation levels given by Tables 9.1.4-1a to 9.1.4-5b on each activated serving cell for which it is configured to monitor EPDCCH.

If a UE is configured for EPDCCH monitoring, and if the UE is configured with a carrier indicator field, then the UE shall monitor one or more EPDCCH UE-specific search spaces at each of the aggregation levels given by Tables 9.1.4-1a to 9.1.4-5b on one or more activated serving cells as configured by higher layer signalling.

A UE configured with the carrier indicator field associated with monitoring EPDCCH on serving cell c shall monitor EPDCCH configured with carrier indicator field and with CRC scrambled by C-RNTI in the EPDCCH UE specific search space of serving cell c.

A UE configured with the carrier indicator field associated with monitoring EPDCCH on the primary cell shall monitor EPDCCH configured with carrier indicator field and with CRC scrambled by SPS C-RNTI in the EPDCCH UE specific search space of the primary cell.

A UE is not expected to be configured to monitor EPDCCH with carrier indicator field in an LAA Scell

A UE is not expected to be scheduled with PDSCH starting in the second slot in a subframe in an LAA Scell if the UE is configured to monitor EPDCCH with carrier indicator field corresponding to that LAA Scell in another serving cell

For the serving cell on which EPDCCH is monitored, if the UE is not configured with a carrier indicator field, it shall monitor the EPDCCH UE specific search space for EPDCCH without carrier indicator field, if the UE is configured with a carrier indicator field it shall monitor the EPDCCH UE specific search space for EPDCCH with carrier indicator field.

A UE is not expected to monitor the EPDCCH of a secondary cell if it is configured to monitor EPDCCH with carrier indicator field corresponding to that secondary cell in another serving cell. For the serving cell on which EPDCCH is monitored, the UE shall monitor EPDCCH candidates at least for the same serving cell.

A UE configured to monitor EPDCCH candidates in a given serving cell with a given DCI format size with CIF, and CRC scrambled by C- RNTI, where the EPDCCH candidates may have one or more possible values of CIF for the given DCI format size, shall assume that an EPDCCH candidate with the given DCI format size may be transmitted in the given serving cell in any EPDCCH UE specific search space corresponding to any of the possible values of CIF for the given DCI format size.

For the serving cell on which EPDCCH is monitored, a UE is not required to monitor the EPDCCH in a subframe which is configured by higher layers to be part of a positioning reference signal occasion if the positioning reference signal occasion is only configured within MBSFN subframes and the cyclic prefix length used in subframe #0 is normal cyclic prefix.

A UE may assume the same c_{init} value (described in subclause 6.10.3A.1 of [3]) is used for antenna ports 107,108 while monitoring an EPDCCH candidate associated with either antenna port 107 or antenna port 108.
A UE may assume the same c_{init} value (described in subclause 6.10.3A.1 of [3]) is used for antenna ports 109,110 while monitoring an EPDCCH candidate associated with either antenna port 109 or antenna port 110.

9.1.4.1 EPDCCH starting position

For a given serving cell, if the UE is configured via higher layer signalling to receive PDSCH data transmissions according to transmission modes 1-9,

- if the UE is configured with a higher layer parameter *epdcch-StartSymbol-r11*,
  - o the starting OFDM symbol for EPDCCH given by index $l_{\text{EPDCCHStart}}$ is determined from the higher layer parameter,
- otherwise
  - o the starting OFDM symbol for EPDCCH given by index $l_{\text{EPDCCHStart}}$ is given by the CFI value in the subframe of the given serving cell when $N_{\text{RB}}^{\text{DL}} > 10$, and $l_{\text{EPDCCHStart}}$ is given by the CFI value+1 in the subframe of the given serving cell when $N_{\text{RB}}^{\text{DL}} \le 10$

For a given serving cell, if the UE is configured via higher layer signalling to receive PDSCH data transmissions according to transmission mode 10, for each EPDCCH-PRB-set, the starting OFDM symbol for monitoring EPDCCH in subframe k is determined from the higher layer parameter *pdsch-Start-r11* (defined in subclause 9.1.4.3) as follows

- if the value of the parameter *pdsch-Start-r11* belongs to {1,2,3,4},
  - o $l'_{EPDCCHStart}$ is given by the higher layer parameter *pdsch-Start-r11*
- otherwise
  - o $l'_{EPDCCHStart}$ is given by the CFI value in subframe k of the given serving cell when $N_{\text{RB}}^{\text{DL}} > 10$, and $l'_{EPDCCHStart}$ is given by the CFI value+1 in subframe k of the given serving cell when $N_{\text{RB}}^{\text{DL}} \le 10$
- if subframe k is indicated by the higher layer parameter *mbsfn-SubframeConfigList-r11* (defined in subclause 9.1.4.3), or if subframe k is subframe 1 or 6 for frame structure type 2,
  - o $l_{EPDCCHStart} = \min(2, l'_{EPDCCHStart})$,
- otherwise

- o $l_{\text{EPDCCHStart}} = l'_{\text{EPDCCHStart}}$.

If a serving cell is a LAA Scell, and if the higher layer parameter *subframeStartPosition* for the Scell indicates 's07'

- for monitoring EPDCCH candidates starting in the first slot of the subframe, the starting OFDM symbol for EPDCCH is given by index $l_{\text{EPDCCHStart}}$ in the first slot in a subframe;
- for monitoring EPDCCH candidates starting in the second slot of the subframe, the starting OFDM symbol for EPDCCH is given by index $l_{\text{EPDCCHStart}}$ in the second slot in a subframe;

otherwise

- the starting OFDM symbol for EPDCCH is given by index $l_{\text{EPDCCHStart}}$ in the first slot in a subframe.

9.1.4.2 Antenna ports quasi co-location for EPDCCH

For a given serving cell, if the UE is configured via higher layer signalling to receive PDSCH data transmissions according to transmission modes 1-9, and if the UE is configured to monitor EPDCCH,

- the UE may assume the antenna ports 0 – 3, 107 – 110 of the serving cell are quasi co-located (as defined in [3]) with respect to Doppler shift, Doppler spread, average delay, and delay spread.

For a given serving cell, if the UE is configured via higher layer signalling to receive PDSCH data transmissions according to transmission mode 10, and if the UE is configured to monitor EPDCCH, for each EPDCCH-PRB-set,

- if the UE is configured by higher layers to decode PDSCH according to quasi co-location Type-A as described in subclause 7.1.10
  - the UE may assume the antenna ports 0 – 3, 107 – 110 of the serving cell are quasi co-located (as defined in [3]) with respect to Doppler shift, Doppler spread, average delay, and delay spread.
- if the UE is configured by higher layers to decode PDSCH according to quasi co-location Type-B as described in subclause 7.1.10
  - the UE may assume antenna ports 15 – 22 corresponding to the higher layer parameter *qcl-CSI-RS-ConfigNZPId-r11* (defined in subclause 9.1.4.3) and antenna ports 107-110 are quasi co-located (as defined in [3]) with respect to Doppler shift, Doppler spread, average delay, and delay spread.

9.1.4.3 Resource mapping parameters for EPDCCH

For a given serving cell, if the UE is configured via higher layer signalling to receive PDSCH data transmissions according to transmission mode 10, and if the UE is configured to monitor EPDCCH, for each EPDCCH-PRB-set, the UE shall use the parameter set indicated by the higher layer parameter *re-MappingQCL-ConfigId-r11* for determining the EPDCCH RE mapping (defined in subclause 6.8A.5 of [3]) and EPDCCH antenna port quasi co-location. The following parameters for determining EPDCCH RE mapping (as described in subclause 6.8A.5 of [3]) and EPDCCH antenna port quasi co-location are included in the parameter set:

- *crs-PortsCount-r11*.
- *crs-FreqShift-r11*.
- *mbsfn-SubframeConfigList-r11*.
- *csi-RS-ConfigZPId-r11*.
- *pdsch-Start-r11*.
- *qcl-CSI-RS-ConfigNZPId-r11*.
- *csi-RS-ConfigZPId2-r12* if the UE is configured with CSI subframe sets $C_{\text{CSI},0}$ and $C_{\text{CSI},1}$ by the higher layer parameter *csi-SubframePatternConfig-r12* for the serving cell or the UE is configured with higher layer parameter *eMIMO-Type* for TDD serving cell.

9.1.4.4 PRB-pair indication for EPDCCH

For BL/CE UEs and USS, following is applied in the rest of this subclause.

- $N'^{X_p}_{\mathrm{RB}}$ is used in place of $N^{X_p}_{\mathrm{RB}}$.
- If $N'^{X_p}_{\mathrm{RB}}$ =2+4, PRB-pairs of the 2 PRB set is obtained using *resourceBlockAssignment-r11* and the procedure described in the rest of this subclause. PRB-pairs of the 4 PRB set is the remaining 4 PRB-pairs in PRB-pairs in MPDCCH-PRB-set p . If $N'^{X_p}_{\mathrm{RB}}$ =2, PRB-pairs of the 2 PRB set is obtained using *resourceBlockAssignment-r11* and the procedure described in the rest of this subclause. If $N'^{X_p}_{\mathrm{RB}}$ =4, PRB-pairs of the 4 PRB set is obtained using *resourceBlockAssignment-r11* and the procedure described in the rest of this subclause.
- N^{DL}_{RB} is set to 6.

For a given serving cell, for each EPDCCH-PRB-pair set/MPDCCH-PRB-pair set p , the UE is configured with a higher layer parameter *resourceBlockAssignment-r11* indicating a combinatorial index r corresponding to the PRB index $\{k_i\}_{i=0}^{N_{RB}^{X_p}-1}$, $(1 \le k_i \le N_{RB}^{DL},\quad k_i < k_{i+1})$ and given by equation $r = \sum_{i=0}^{N_{RB}^{X_p}-1} \left\langle \begin{matrix} N_{RB}^{DL} - k_i \\ N_{RB}^{X_p} - i \end{matrix} \right\rangle$, where N_{RB}^{DL} is the number of PRB pairs associated with the downlink bandwidth, $N^{X_p}_{\mathrm{RB}}$ is the number of PRB-pairs constituting EPDCCH-PRB-set/MPDCCH-PRB-pair set p , and is configured by the higher layer parameter *numberPRBPairs-r11*, and $\left\langle \begin{matrix} x \\ y \end{matrix} \right\rangle = \begin{cases} \binom{x}{y} & x \ge y \\ 0 & x < y \end{cases}$ is the extended binomial coefficient, resulting in unique label $r \in \left\{ 0,\ldots,\binom{N_{RB}^{DL}}{N_{RB}^{X_p}} - 1 \right\}$.

9.1.5 MPDCCH assignment procedure

A BL/CE UE shall monitor a set of MPDCCH candidates on one or more Narrowbands (described in subclause 6.2.7 of [3]) as configured by higher layer signalling for control information, where monitoring implies attempting to decode each of the MPDCCHs in the set according to all the monitored DCI formats. The Narrowband in a subframe used for MPDCCH monitoring is determined as described in [3].

A UE that is not a BL/CE UE is not required to monitor MPDCCH.

A BL/CE UE can derive the configuration of one or two MPDCCH-PRB-sets for MPDCCH monitoring from higher layer signalling. The PRB-pairs corresponding to an MPDCCH-PRB-set are indicated by higher layers. Each MPDCCH-PRB-set consists of set of ECCEs numbered from 0 to $N'_{ECCE,p,k} - 1$ where $N'_{ECCE,p,k}$ is the number of ECCEs in MPDCCH-PRB-set p of subframe k .

The MPDCCH-PRB-set(s) can be configured by higher layers for either localized MPDCCH transmission or distributed MPDCCH transmission.

The set of MPDCCH candidates to monitor are defined in terms of MPDCCH search spaces.

The BL/CE UE shall monitor one or more of the following search spaces

- a Type0-MPDCCH common search space if configured with CEmodeA,
- a Type1-MPDCCH common search space,
- a Type2-MPDCCH common search space, and
- a MPDCCH UE-specific search space.

A BL/CE UE configured with CEModeB is not required to monitor Type0-MPDCCH common search space.

The BL/CE UE is not required to simultaneously monitor MPDCCH UE-specific search space and Type1-MPDCCH common search space.

The BL/CE UE is not required to simultaneously monitor MPDCCH UE-specific search space and Type2-MPDCCH common search space.

A BL/CE UE is not expected to monitor an MPDCCH candidate, if an ECCE corresponding to that MPDCCH candidate is mapped to a PRB pair that overlaps with a transmission of PDSCH scheduled previously in the same subframe. For aggregation level $L'=24$ or $L'=12$ ECCEs, the number of ECCEs refers to the MPDCCH mapping to the REs of the 2+4 PRB set as defined in [3]. An MPDCCH search space $MS_k^{(L',R)}$ at aggregation level $L'\in\{1,2,4,8,16,12,24\}$ and repetition level $R\in\{1,2,4,8,16,32,64,128,256\}$ is defined by a set of MPDCCH candidates where each candidate is repeated in a set of R consecutive BL/CE downlink subframes starting with subframe k. For an MPDCCH-PRB-set p, the ECCEs corresponding to MPDCCH candidate *m* of the search space $MS_k^{(L',R)}$ are given by

$$L'\left\{ \left(Y_{p,k} + \left\lfloor \frac{m \cdot N'_{ECCE,p,k}}{L' \cdot M'^{(L')}_p} \right\rfloor \right) \bmod \left\lfloor N'_{\mathrm{ECCE},p,k} / L' \right\rfloor \right\} + i$$

where

$i = 0,\ldots,L'-1$

$m = 0,1,\ldots M'^{(L')}_p - 1$,

$M'^{(L')}_p$ is the number of MPDCCH candidates to monitor at aggregation level L' in MPDCCH-PRB-set p in each subframe in the set of R consecutive subframes.

$Y_{p,k}$ for MPDCCH UE-specific search space is determined as described in subclause 9.1.4, and $Y_{p,k} = 0$ for Type0-MPDCCH common search space, Type1-MPDCCH common search space and Type2-MPDCCH common search space.

A BL/CE UE is not expected to monitor MPDCCH in subframes that are not BL/CE DL subframes.

Until BL/CE UE receives higher layer configuration of MPDCCH UE-specific search space, the BL/CE UE monitors MPDCCH according to the same configuration of MPDCCH search space and Narrowband as that for MPDCCH scheduling Msg4.

The aggregation and repetition levels defining the MPDCCH search spaces and the number of monitored MPDCCH candidates are given as follows:

For MPDCCH UE-specific search space

- if the BL/CE UE is configured with $N'^{X_p}_{\mathrm{RB}}$=2 or $N'^{X_p}_{\mathrm{RB}}$=4 PRB-pairs, and *mPDCCH-NumRepetition*=1, and
    - if the MPDCCH-PRB-set is configured for distributed transmission, the aggregation levels defining the search spaces and the number of monitored MPDCCH candidates are listed in Table 9.1.4-1a and Table 9.1.4-1b, where L is substituted with L' for $L \le$24, and $N^{X_p}_{\mathrm{RB}}$ is substituted with $N'^{X_p}_{\mathrm{RB}}$.
    - if the MPDCCH-PRB-set is configured for localized transmission, the aggregation levels defining the search spaces and the number of monitored MPDCCH candidates are listed in Table 9.1.4-2a and Table 9.1.4-2b, where L is substituted with L' and $N^{X_p}_{\mathrm{RB}}$ is substituted with $N'^{X_p}_{\mathrm{RB}}$.
- otherwise
    - if the UE is configured with CEModeA, and $N'^{X_p}_{\mathrm{RB}}$=2 or $N'^{X_p}_{\mathrm{RB}}$=4, the aggregation and repetition levels defining the search spaces and the number of monitored MPDCCH candidates are listed in Table 9.1.5-1a

- if the UE is configured with CEModeA, and $N'^{X_p}_{\mathrm{RB}}$ =2+4 , the aggregation and repetition levels defining the search spaces and the number of monitored MPDCCH candidates are listed in Table 9.1.5-1b
- if the UE is configured with CEModeB, and $N'^{X_p}_{\mathrm{RB}}$ =2 or $N'^{X_p}_{\mathrm{RB}}$ =4, the aggregation and repetition levels defining the search spaces and the number of monitored MPDCCH candidates are listed in Table 9.1.5-2a
- if the UE is configured with CEModeB, and $N'^{X_p}_{\mathrm{RB}}$ =2+4 , the aggregation and repetition levels defining the search spaces and the number of monitored MPDCCH candidates are listed in Table 9.1.5-2b

$N'^{X_p}_{\mathrm{RB}}$ is the number of PRB-pairs configured for MPDCCH UE-specific search space. When $N'^{X_p}_{\mathrm{RB}}$ =2+4, it is given by the higher layer parameter *numberPRB-Pairs-r13*, and when $N'^{X_p}_{\mathrm{RB}}$ =2 or $N'^{X_p}_{\mathrm{RB}}$ =4, it is given by the higher layer parameter *numberPRB-Pairs-r11*.

$r1,\ r2,\ r3,\ r4$ are determined from Table 9.1.5-3 by substituting the value of $r_{\max}$ with the value of higher layer parameter *mPDCCH-NumRepetition*.

The PRB-pairs within a Narrowband corresponding to an MPDCCH-PRB-set are indicated by higher layers and are determined using the description given in subclause 9.1.4.4.

If higher layer configuration *numberPRB-Pairs-r13* for MPDCCH-PRB-set p is 6, $N'^{X_p}_{\mathrm{RB}}$ =2+4, and the number of PRB-pairs in an MPDCCH-PRB-set p = 2+4.

If Type2-MPDCCH common search space,

- PRB-pairs of the 2 PRB set in the 2+4 PRB set correspond to PRB-pairs with the largest two PRB indices in MPDCCH-PRB-set p .
- PRB-pairs of the4 PRB set in the 2+4 PRB set correspond to PRB-pairs with the smallest 4 PRB indices in MPDCCH-PRB-set p .
- PRB-pairs of the 2+4 PRB set in the 2+4 PRB set correspond to all PRB-pairs in MPDCCH-PRB-set p

Table 9.1.5-1a: MPDCCH candidates monitored by a BL/CE UE (CEModeA, MPDCCH-PRB-set size – 2PRBs or 4PRBs)

$N'^{X_p}_{\mathrm{RB}}$	R	$M'^{(L')}_p$				
		L'=2	L'=4	L'=8	L'=16	L'=24
2	r1	2	1	1	0	0
4		1	1	1	1	0
2	r2	2	1	1	0	0
4		1	1	1	1	0
2	r3	2	1	1	0	0
4		1	1	1	1	0
2	r4	2	1	1	0	0
4		1	1	1	1	0

Table 9.1.5-1b: MPDCCH candidates monitored by a BL/CE UE (CEModeA, MPDCCH-PRB-set size – 2+4PRBs)

MPDCCH PRB set	R	$M'^{(L')}_p$				
		L'=2	L'=4	L'=8	L'=16	L'=24
2 PRB set in 2+4 PRB set	r1	1	1	0	0	0
4 PRB set in 2+4 PRB set		0	0	2	1	0
Both PRB sets in 2+4 PRB set		0	0	0	0	1
2 PRB set in 2+4 PRB set	r2	0	1	1	0	0
4 PRB set in 2+4 PRB set		0	0	2	1	0
Both PRB sets in 2+4 PRB set		0	0	0	0	1
2 PRB set in 2+4 PRB set	r3	0	0	0	0	0
4 PRB set in 2+4 PRB set		0	0	1	1	0
Both PRB sets in 2+4 PRB set		0	0	0	0	1
2 PRB set in 2+4 PRB set	r4	0	0	0	0	0
4 PRB set in 2+4 PRB set		0	0	0	0	0
Both PRB sets in 2+4 PRB set		0	0	0	0	1

Table 9.1.5-2a: MPDCCH candidates monitored by a BL/CE UE (CEModeB, MPDCCH-PRB-set size – 2PRBs or 4PRBs)

$N'^{X_p}_{\mathrm{RB}}$	R	$M'^{(L')}_p$				
		L'=2	L'=4	L'=8	L'=16	L'=24
2	r1	0	0	1	0	0
4		0	0	1	1	0
2	r2	0	0	1	0	0
4		0	0	1	1	0
2	r3	0	0	1	0	0
4		0	0	1	1	0
2	r4	0	0	1	0	0
4		0	0	1	1	0

Table 9.1.5-2b: MPDCCH candidates monitored by a BL/CE UE (CEModeB, MPDCCH-PRB-set size – 2+4PRBs)

MPDCCH PRB set	R	$M'^{(L')}_p$				
		L'=2	L'=4	L'=8	L'=16	L'=24
2 PRB set in 2+4 PRB set	r1	0	0	1	0	0
4 PRB set in 2+4 PRB set		0	0	0	1	0
Both PRB sets in 2+4 PRB set		0	0	0	0	1
2 PRB set in 2+4 PRB set	r2	0	0	1	0	0
4 PRB set in 2+4 PRB set		0	0	0	1	0
Both PRB sets in 2+4 PRB set		0	0	0	0	1
2 PRB set in 2+4 PRB set	r3	0	0	1	0	0
4 PRB set in 2+4 PRB set		0	0	0	1	0
Both PRB sets in 2+4 PRB set		0	0	0	0	1
2 PRB set in 2+4 PRB set	r4	0	0	1	0	0
4 PRB set in 2+4 PRB set		0	0	0	1	0
Both PRB sets in 2+4 PRB set		0	0	0	0	1

Table 9.1.5-3: Determination of repetition levels

$r_{\max}$	$r1$	$r2$	$r3$	$r4$
1	1	-	-	-
2	1	2	-	-
4	1	2	4	-
>=8	$r_{\max}/8$	$r_{\max}/4$	$r_{\max}/2$	$r_{\max}$

Table 9.1.5-4: Repetition levels for Type1-MPDCCH common search space

r_{max}	$r1$	$r2$	$r3$	$r4$
256	2	16	64	256
128	2	16	64	128
64	2	8	32	64
32	1	4	16	32
16	1	4	8	16
8	1	2	4	8
4	1	2	4	-
2	1	2	-	-
1	1	-	-	-

For Type0-MPDCCH common search space, the narrowband location and the MPDCCH-PRB-set p are the same as for MPDCCH UE-specific search space, and

- if $N'^{X_p}_{RB}$=2,
  - $M'^{(L')}_p$=1 for L'=8 and repetition levels $r1, r2$, $r3$, $r4$ given in Table 9.1.5.-3. For all other cases, $M'^{(L')}_p$=0
- if $N'^{X_p}_{RB}$=4,
  - $M'^{(L')}_p$=1 for L'=16 and repetition levels $r1, r2$, $r3$, $r4$ given in Table 9.1.5.-3. For all other cases, $M'^{(L')}_p$=0
- if $N'^{X_p}_{RB}$=2+4,
  - $M'^{(L')}_p$=1 for L'=24 and repetition levels $r1, r2$, $r3$, $r4$ given in Table 9.1.5.-3. For all other cases, $M'^{(L')}_p$=0

where $r1$, $r2$, $r3$, $r4$ are determined from Table 9.1.5-3 by substituting the value of r_{max} with the value of higher layer parameter *mPDCCH-NumRepetition*.

For Type1-MPDCCH common search space, the number of PRB-pairs in MPDCCH-PRB-set p is 2+4 PRB-pairs, and

- $M'^{(L')}_p$=1 for L'=24 and repetition levels $r1, r2$, $r3$, $r4$ where the repetition levels are determined from Table 9.1.5-4 by substituting the value of r_{max} with higher layer *parameter mPDCCH-NumRepetition-Paging*.
- For all other cases, $M'^{(L')}_p$=0

For Type2-MPDCCH common search space, the number of PRB-pairs in MPDCCH-PRB-set p is 2+4 PRB-pairs, and

- If the most recent coverage enhancement level used for PRACH is coverage enhancement level 0 and 1, the aggregation and repetition levels defining the search spaces and the number of monitored MPDCCH candidates are determined from Table 9.1.5-1b, by assuming that the number of candidates for L'<8 as zero.
- If the most recent coverage enhancement level used for PRACH is coverage enhancement level 2 and 3, the aggregation and repetition levels defining the search spaces and the number of monitored MPDCCH candidates are determined from Table 9.1.5-2b.

where $r1$, $r2$, $r3$, $r4$ are determined from Table 9.1.5-3 by substituting the value of r_{max} with the value of higher layer parameter *mPDCCH-NumRepetition-RA*.

In tables 9.1.5-1a, 9.1.5-1b, 9.1.5-2a, 9.1.5-2b, and for Type0, Type1, Type2 MPDCCH common search space, L' is applied for $N_{\text{EREG}}^{\text{ECCE}}$=4, and L'' is applied for $N_{\text{EREG}}^{\text{ECCE}}$=8 wherein $L''=L'/2$ substituting the values of L'.

For Type1-MPDCCH common search space and Type2-MPDCCH common search space, distributed MPDCCH transmission is used.

For MPDCCH UE-specific search space, Type0-MPDCCH common search space, and Type2-MPDCCH common search space locations of starting subframe k are given by $k = k_b$ where k_b is the b^{th} consecutive BL/CE DL subframe from subframe $k0$, and $b = u \cdot rj$, and $u = 0,1,\ldots \frac{r_{\max}}{rj} - 1$, and $j \in \{1,2,3,4\}$, where

- subframe $k0$ is a subframe satisfying the condition $(10n_{\text{f}} + \lfloor n_{\text{s}}/2 \rfloor) \bmod T = 0$, where $T = r_{\max} \cdot G$
    - For MPDCCH UE-specific search space, and Type0-MPDCCH common search space, G is given by the higher layer parameter *mPDCCH-startSF-UESS*,
    - For Type2-MPDCCH common search space, G is given by the higher layer parameter *mPDCCH-startSF-CSS-RA-r13*
- $r_{\max}$ is given by higher layer parameter *mPDCCH-NumRepetition* for MPDCCH UE-specific search space and Type0-MPDCCH common search space, and *mPDCCH-NumRepetition-RA* for Type2-MPDCCH common search space, and
- $r1$, $r2$, $r3$, $r4$ are given in Table 9.1.5-3.

A BL/CE UE is not expected to be configured with values of $r_{\max}$ and G that result in non-integer values of T.

For Type1-MPDCCH common search space, $k = k0$ and is determined from locations of paging opportunity subframes,

If *SystemInformationBlockType1-BR* or SI message is transmitted in one narrowband in subframe k, a BL/CE UE shall assume MPDCCH in the same narrowband in the subframe k is dropped.

The BL/CE UE is not required to monitor an MPDCCH search space if any ECCEs corresponding to any of its MPDCCH candidates occur within a frame before $n_f = 0$ and also occur within frame $n_f \geq 0$.

The BL/CE UE is not expected to be configured with overlapping MPDCCH search spaces.

For MPDCCH UE-specific search space or for Type0-MPDCCH common search space if the higher layer parameter *mPDCCH-NumRepetition* is set to 1; or for Type2-MPDCCH common search space if the higher layer parameter *mPDCCH-NumRepetition-RA* is set to 1;

- The BL/CE UE is not required to monitor MPDCCH
    - For TDD and normal downlink CP, in special subframes for the special subframe configurations 0 and 5 shown in Table 4.2-1 of [3]
    - For TDD and extended downlink CP, in special subframes for the special subframe configurations 0, 4 and 7 shown in Table 4.2-1 of [3];

otherwise

- The BL/CE UE is not required to monitor MPDCCH
    - For TDD, in special subframes, if the BL/CE UE is configured with CEModeB
    - For TDD and normal downlink CP, in special subframes for the special subframe configurations 0, 1, 2,5,6,7 and 9 shown in Table 4.2-1 of [3], if the BL/CE UE is configured with CEModeA
    - For TDD and extended downlink CP, in special subframes for the special subframe configurations 0, 4, 7, 8 and 9 shown in Table 4.2-1 of [3], if the BL/CE UE is configured with CEModeA.

- For TDD, in special subframes, for MPDCCH in Type1-MPDCCH common search space.

The number of MPDCCH repetitions is indicated in the 'DCI subframe repetition number' field in the DCI according to the mapping in Table 9.1.5-5.

Table 9.1.5-5: Mapping for DCI subframe repetition number

R	DCI subframe repetition number
$r1$	00
$r2$	01
$r3$	10
$r4$	11

9.1.5.1 MPDCCH starting position

The starting OFDM symbol for MPDCCH given by index $l_{MPDCCHStart}$ in the first slot in a subframe k and is determined as follows

- $l'_{MPDCCHStart}$ is given by the higher layer parameter *startSymbolBR*
- if subframe k is configured as an MBSFN subframe and if the BL/CE UE is configured in CEModeA
  - $l_{MPDCCHStart} = \min\left(2, l'_{MPDCCHStart}\right)$
- else
  - $l_{MPDCCHStart} = l'_{MPDCCHStart}$.

9.1.5.2 Antenna ports quasi co-location for MPDCCH

Regardless of transmission modes configuration of PDSCH data transmissions, the BL/CE UE may assume the antenna ports 0 – 3, 107 – 110 of the serving cell are quasi co-located (as defined in [3]) with respect to Doppler shift, Doppler spread, average delay, and delay spread.

9.2 PDCCH/EPDCCH/MPDCCH validation for semi-persistent scheduling

A UE shall validate a Semi-Persistent Scheduling assignment PDCCH only if all the following conditions are met:

- the CRC parity bits obtained for the PDCCH payload are scrambled with the Semi-Persistent Scheduling C-RNTI
- the new data indicator field is set to '0'. In case of DCI formats 2, 2A, 2B, 2C and 2D, the new data indicator field refers to the one for the enabled transport block.

A UE shall validate a Semi-Persistent Scheduling assignment EPDCCH only if all the following conditions are met:

- the CRC parity bits obtained for the EPDCCH payload are scrambled with the Semi-Persistent Scheduling C-RNTI
- the new data indicator field is set to '0'. In case of DCI formats 2, 2A, 2B, 2C and 2D, the new data indicator field refers to the one for the enabled transport block.

A UE shall validate a Semi-Persistent Scheduling assignment MPDCCH only if all the following conditions are met:

- the CRC parity bits obtained for the MPDCCH payload are scrambled with the Semi-Persistent Scheduling C-RNTI
- the new data indicator field is set to '0'.

Validation is achieved if all the fields for the respective used DCI format are set according to Table 9.2-1 or Table 9.2-1A, 9.2-1B, 9.2-1C.

If validation is achieved, the UE shall consider the received DCI information accordingly as a valid semi-persistent activation or release.

If validation is not achieved, the received DCI format shall be considered by the UE as having been received with a non-matching CRC.

Table 9.2-1: Special fields for Semi-Persistent Scheduling Activation PDCCH/EPDCCH Validation

	DCI format 0	DCI format 1/1A	DCI format 2/2A/2B/2C/2D
TPC command for scheduled PUSCH	set to '00'	N/A	N/A
Cyclic shift DM RS	set to '000'	N/A	N/A
Modulation and coding scheme and redundancy version	MSB is set to '0'	N/A	N/A
HARQ process number	N/A	FDD: set to '000' TDD: set to '0000'	FDD: set to '000' TDD: set to '0000'
Modulation and coding scheme	N/A	MSB is set to '0'	For the enabled transport block: MSB is set to '0'
Redundancy version	N/A	set to '00'	For the enabled transport block: set to '00'

Table 9.2-1A: Special fields for Semi-Persistent Scheduling Release PDCCH/EPDCCH Validation

	DCI format 0	DCI format 1A
TPC command for scheduled PUSCH	set to '00'	N/A
Cyclic shift DM RS	set to '000'	N/A
Modulation and coding scheme and redundancy version	set to '11111'	N/A
Resource block assignment and hopping resource allocation	Set to all '1's	N/A
HARQ process number	N/A	FDD: set to '000' TDD: set to '0000'
Modulation and coding scheme	N/A	set to '11111'
Redundancy version	N/A	set to '00'
Resource block assignment	N/A	Set to all '1's

Table 9.2-1B: Special fields for Semi-Persistent Scheduling Activation MPDCCH Validation

	DCI format 6-0A	DCI format 6-1A
HARQ process number	set to '000'	FDD: set to '000' TDD: set to '0000
Redundancy version	set to '00'	set to '00'
TPC command for scheduled PUSCH	set to '00'	N/A
TPC command for scheduled PUCCH	N/A	set to '00'

Table 9.2-1C: Special fields for Semi-Persistent Scheduling Release MPDCCH Validation

	DCI format 6-0A	DCI format 6-1A
HARQ process number	set to '000'	FDD: set to '000' TDD: set to '0000
Redundancy version	set to '00'	set to '00'
Repetition number	set to '00'	set to '00'
Modulation and coding scheme	set to '1111'	set to '1111'
TPC command for scheduled PUSCH	set to '00'	N/A
Resource block assignment	Set to all '1's	Set to all '1's

For the case that the DCI format indicates a semi-persistent downlink scheduling activation, the TPC command for PUCCH field shall be used as an index to one of the four PUCCH resource values configured by higher layers, with the mapping defined in Table 9.2-2

Table 9.2-2: PUCCH resource value for downlink semi-persistent scheduling

Value of 'TPC command for PUCCH'	$n_{\mathrm{PUCCH}}^{(1,p)}$
'00'	The first PUCCH resource value configured by the higher layers
'01'	The second PUCCH resource value configured by the higher layers
'10'	The third PUCCH resource value configured by the higher layers
'11'	The fourth PUCCH resource value configured by the higher layers

9.3 PDCCH/EPDCCH/MPDCCH control information procedure

A UE shall discard the PDCCH/EPDCCH/MPDCCH if consistent control information is not detected.

10 Physical uplink control channel procedures

If the UE is configured with a SCG, the UE shall apply the procedures described in this clause for both MCG and SCG

- When the procedures are applied for MCG, the terms 'secondary cell', 'secondary cells' , 'serving cell', 'serving cells' in this clause refer to secondary cell, secondary cells, serving cell, serving cells belonging to the MCG respectively.
- When the procedures are applied for SCG, the terms 'secondary cell', 'secondary cells', 'serving cell', 'serving cells' in this clause refer to secondary cell, secondary cells (not including PSCell), serving cell, serving cells belonging to the SCG respectively. The term 'primary cell' in this clause refers to the PSCell of the SCG.

If the UE is configured with a PUCCH-SCell, the UE shall apply the procedures described in this clause for both primary PUCCH group and secondary PUCCH group

- When the procedures are applied for the primary PUCCH group, the terms 'secondary cell', 'secondary cells' , 'serving cell', 'serving cells' in this clause refer to secondary cell, secondary cells, serving cell, serving cells belonging to the primary PUCCH group respectively.
- When the procedures are applied for secondary PUCCH group, the terms 'secondary cell', 'secondary cells', 'serving cell', 'serving cells' in this clause refer to secondary cell, secondary cells (not including the PUCCH-SCell), serving cell, serving cells belonging to the secondary PUCCH group respectively. The term 'primary cell' in this clause refers to the PUCCH-SCell of the secondary PUCCH group.

If a UE is configured with a LAA Scell, the UE shall apply the procedures described in this clause assuming frame structure type 1 for the LAA Scell unless stated otherwise.

10.1 UE procedure for determining physical uplink control channel assignment

If a non-BL/CE UE is configured for a single serving cell and is not configured for simultaneous PUSCH and PUCCH transmissions, then in subframe n uplink control information (UCI) shall be transmitted

- on PUCCH using format 1/1a/1b/3 or 2/2a/2b if the UE is not transmitting PUSCH
- on PUSCH if the UE is transmitting PUSCH in subframe n unless the PUSCH transmission corresponds to a Random Access Response Grant or a retransmission of the same transport block as part of the contention based random access procedure, in which case UCI is not transmitted

If the UE is configured for a single serving cell and simultaneous PUSCH and PUCCH transmission, then in subframe n UCI shall be transmitted

- on PUCCH using format 1/1a/1b/3 if the UCI consists only of HARQ-ACK and/or SR
- on PUCCH using format 2 if the UCI consists only of periodic CSI
- on PUCCH using format 2/2a/2b/3 if the UCI consists of periodic CSI and HARQ-ACK and if the UE is not transmitting PUSCH
- on PUCCH and PUSCH if the UCI consists of HARQ-ACK/HARQ-ACK+SR/positive SR and periodic/aperiodic CSI and if the UE is transmitting PUSCH in subframe n, in which case the HARQ-ACK/HARQ-ACK+SR/positive SR is transmitted on PUCCH using format 1/1a/1b/3 and the periodic/aperiodic CSI transmitted on PUSCH unless the PUSCH transmission corresponds to a Random Access Response Grant or a retransmission of the same transport block as part of the contention based random access procedure, in which case periodic/aperiodic CSI is not transmitted

If the UE is configured with more than one serving cell and is not configured for simultaneous PUSCH and PUCCH transmission, then in subframe n UCI shall be transmitted

- on PUCCH using format 1/1a/1b/3/4/5 or 2/2a/2b if the UE is not transmitting PUSCH

- on PUSCH of the serving cell given in subclause 7.2.1 if the UCI consists of aperiodic CSI or aperiodic CSI and HARQ-ACK
- on primary cell PUSCH if the UCI consists of periodic CSI and/or HARQ-ACK and if the UE is transmitting on the primary cell PUSCH in subframe n unless the primary cell PUSCH transmission corresponds to a Random Access Response Grant or a retransmission of the same transport block as part of the contention based random access procedure, in which case UCI is not transmitted
- on PUSCH of the secondary cell with smallest *SCellIndex* if the UCI consists of periodic CSI and/or HARQ-ACK and if the UE is not transmitting PUSCH on primary cell but is transmitting PUSCH on at least one secondary cell

If the UE is configured with more than one serving cell and simultaneous PUSCH and PUCCH transmission, then in subframe n UCI shall be transmitted

- on PUCCH using format 1/1a/1b/3 if the UCI consists only of HARQ-ACK and/or SR
- on PUCCH using format 4/5 if the UCI consists only of HARQ-ACK and/or SR and/or periodic CSI
- on PUCCH using format 2 if the UCI consists only of periodic CSI corresponding to one serving cell
- as described in subclause 10.1.1, if the UCI consists of periodic CSI and HARQ-ACK and if the UE is not transmitting on PUSCH
- on PUCCH and primary cell PUSCH if the UCI consists of HARQ-ACK and periodic CSI and the UE is transmitting PUSCH on the primary cell, in which case the HARQ-ACK is transmitted on PUCCH using format 1a/1b/3 and the periodic CSI is transmitted on PUSCH unless the primary cell PUSCH transmission corresponds to a Random Access Response Grant or a retransmission of the same transport block as part of the contention based random access procedure, in which case periodic CSI is not transmitted
- on PUCCH and PUSCH of the secondary cell with the smallest *SCellIndex* if the UCI consists of HARQ-ACK and periodic CSI and if the UE is not transmitting PUSCH on primary cell but is transmitting PUSCH on at least one secondary cell, in which case, the HARQ-ACK is transmitted on PUCCH using format 1a/1b/3 and the periodic CSI is transmitted on PUSCH
- on PUCCH and PUSCH if the UCI consists of HARQ-ACK/HARQ-ACK+SR/positive SR and aperiodic CSI in which case the HARQ-ACK/HARQ-ACK+SR/positive SR is transmitted on PUCCH using format 1/1a/1b/3 and the aperiodic CSI is transmitted on PUSCH of the serving cell given in subclause 7.2.1

For a BL/CE UE, uplink control information (UCI) shall be transmitted in subframe n

- on PUCCH using PUCCH formats 1, 1a, 2, 2a for FDD and a UE configured with CEModeA if the UE is not transmitting PUSCH in subframe n, or if the UE is transmitting PUSCH in subframe n and the number of PUCCH repetitions defined for the UCI in [3] is larger than 1, or if the UE is transmitting PUSCH in subframe n and the indicated PUSCH repetition number in DCI format 6-0A/6-0B is larger than 1
- on PUCCH using PUCCH formats 1, 1a, 1b, 2, 2a, 2b for TDD and a UE configured with CEModeA if the UE is not transmitting PUSCH in subframe n, or if the UE is transmitting PUSCH in subframe n and the number of PUCCH repetitions defined for the UCI in [3] is larger than 1, or if the UE is transmitting PUSCH in subframe n and the indicated PUSCH repetition number in DCI format 6-0A/6-0B is larger than 1
- on PUCCH formats 1, 1a for a UE configured with CEModeB
- on PUSCH if the UE is transmitting PUSCH in subframe n and the number of PUCCH repetitions defined for the UCI in [3] is equal to 1, and the indicated PUSCH repetition number in DCI format 6-0A/6-0B is equal to 1 unless the PUSCH transmission corresponds to a Random Access Response Grant or a retransmission of the same transport block as part of the contention based random access procedure, in which case UCI is not transmitted

If the UE is configured with more than one serving cell, then reporting prioritization and collision handling of periodic CSI reports of a certain PUCCH reporting type is given in subclause 7.2.2.

A UE transmits PUCCH only on the primary cell.

A UE is configured by higher layers to transmit PUCCH on one antenna port $(p = p_0)$ or two antenna ports $(p \in [p_0, p_1])$. PUCCH format 4 and PUCCH format 5 can only be transmitted on one antenna port $(p = p_0)$.

For FDD or FDD-TDD and primary cell frame structure 1, with two configured serving cells and PUCCH format 1b with channel selection or for FDD with two or more configured serving cells and PUCCH format 3 and without PUCCH format 4/5 configured, $n_{\text{HARQ}} = \sum_{c=0}^{N_{cells}^{DL}-1} N_c^{\text{received}}$ where N_{cells}^{DL} is the number of configured cells and N_c^{received} is the number of transport blocks or the SPS release PDCCH/EPDCCH, if any, received in subframe $n-4$ in serving cell c.

For TDD and a UE not configured with the parameter *EIMTA-MainConfigServCell-r12* for any serving cell, if a UE is configured with one serving cell, or the UE is configured with more than one serving cell and the UL/DL configurations of all serving cells are the same, then

- For TDD with two configured serving cells and PUCCH format 1b with channel selection and a subframe *n* with *M = 1*, or for TDD UL/DL configuration 0 and PUCCH format 3, $n_{\text{HARQ}} = \sum_{c=0}^{N_{cells}^{DL}-1} \sum_{k \in K} N_{k,c}^{\text{received}}$, where $N_{k,c}^{\text{received}}$ is the number of transport blocks or the SPS release PDCCH/EPDCCH, if any, received in subframe $n-k$ in serving cell c, where $k \in K$, and *M* is the number of elements in *K.*

- For TDD UL/DL configurations 1-6 and PUCCH format 3 and without PUCCH format 4/5 configured, or for TDD with two configured serving cells and PUCCH format 1b with channel selection and *M* = 2, $n_{\text{HARQ}} = \sum_{c=0}^{N_{cells}^{DL}-1} \left(\left(\left(V_{\text{DAI},c}^{\text{DL}} - U_{\text{DAI},c} \right) \bmod 4 \right) \cdot n_c^{\text{ACK}} + \sum_{k \in K} N_{k,c}^{\text{received}} \right)$ where $V_{\text{DAI,c}}^{\text{DL}}$ is the $V_{\text{DAI}}^{\text{DL}}$ in serving cell c, $U_{\text{DAI,c}}$ is the U_{DAI} in serving cell c, and n_c^{ACK} is the number of HARQ-ACK bits corresponding to the configured DL transmission mode on serving cell c. In case spatial HARQ-ACK bundling is applied, $n_c^{\text{ACK}} = 1$ and $N_{k,c}^{\text{received}}$ is the number of PDCCH/EPDCCH or PDSCH without a corresponding PDCCH/EPDCCH received in subframe $n-k$ and serving cell c, where $k \in K$ and *M* is the number of elements in *K*. In case spatial HARQ-ACK bundling is not applied, $N_{k,c}^{\text{received}}$ is the number of transport blocks received or the SPS release PDCCH/EPDCCH received in subframe $n-k$ in serving cell c, where $k \in K$ and *M* is the number of elements in *K*. $V_{\text{DAI,c}}^{\text{DL}}$ =0 if no transport block or SPS release PDCCH/EPDCCH is detected in subframe(s) $n-k$ in serving cell c, where $k \in K$.

- For TDD with two configured serving cells and PUCCH format 1b with channel selection and *M* = 3 or 4, $n_{\text{HARQ}} = 2$ if UE receives PDSCH or PDCCH/EPDCCH indicating downlink SPS release only on one serving cell within subframes $n-k$,where $k \in K$;otherwise $n_{\text{HARQ}} = 4$.

For TDD if the UE is configured with more than one serving cell and if at least two serving cells have different UL/DL configurations, or if the UE is configured with the parameter *EIMTA-MainConfigServCell-r12* for at least one serving cell, or for FDD-TDD and primary cell frame structure 2, then

- For PUCCH format 3 without PUCCH format 4/5 configured, or for two configured serving cells and PUCCH format 1b with channel selection and $M \leq 2$ (defined in subclause 10.1.3.2.1 for TDD and subclause 10.1.3A for FDD-TDD), $n_{\text{HARQ}} = \sum_{c=0}^{N_{cells}^{DL}-1} \left(\left(\left(V_{\text{DAI},c}^{\text{DL}} - U_{\text{DAI},c} \right) \bmod 4 \right) \cdot n_c^{\text{ACK}} + \sum_{k \in K} N_{k,c}^{\text{received}} \right)$ where $V_{\text{DAI,c}}^{\text{DL}}$ is the $V_{\text{DAI}}^{\text{DL}}$ in serving cell c, $U_{\text{DAI,c}}$ is the U_{DAI} in serving cell c, and n_c^{ACK} is the number of HARQ-ACK bits corresponding to the configured DL transmission mode on serving cell c. In case spatial HARQ-ACK bundling is applied, $n_c^{\text{ACK}} = 1$ and $N_{k,c}^{\text{received}}$ is the number of PDCCH/EPDCCH or PDSCH without a corresponding PDCCH/EPDCCH received in subframe $n-k$ and serving cell c, where $k \in K$ and

$K = K_c$ (defined in subclause 7.3.2.2 for TDD and subclause 7.3.4 for FDD-TDD). In case spatial HARQ-ACK bundling is not applied, $N_{k,c}^{\text{received}}$ is the number of transport blocks received or the SPS release PDCCH/EPDCCH received in subframe $n-k$ in serving cell c, where $k \in K$ and $K = K_c$ (defined in subclause 7.3.2.2 for TDD and subclause 7.3.4 for FDD-TDD). $V_{\text{DAI, c}}^{\text{DL}}$ =0 if no transport block or SPS release PDCCH/EPDCCH is detected in subframe(s) $n-k$ in serving cell c, where $k \in K$ and $K = K_c$ (defined in subclause 7.3.2.2 for TDD and subclause 7.3.4 for FDD-TDD). For a serving cell c, set $V_{\text{DAI, c}}^{\text{DL}} = U_{\text{DAI, c}}$ if the DL-reference UL/DL configuration (defined in subclause 10.2) for serving cell c is TDD UL/DL configuration 0,

- For two configured serving cells and PUCCH format 1b with channel selection and M = 3 or 4 (defined in subclause 10.1.3.2.1 for TDD and subclause 10.1.3A for FDD-TDD), $n_{\text{HARQ}} = 2$ if UE receives PDSCH or PDCCH/EPDCCH indicating downlink SPS release only on one serving cell within subframes $n-k$,where $k \in K$ and $K = K_c$ (defined in subclause 7.3.2.2 for TDD and subclause 7.3.4 for FDD-TDD); otherwise $n_{\text{HARQ}} = 4$.

Throughout the following subclauses, subframes are numbered in monotonically increasing order; if the last subframe of a radio frame is denoted as k , the first subframe of the next radio frame is denoted as $k+1$.

Throughout the following subclauses for a non-BL/CE UE, if the UE is configured with higher layer parameter *n1PUCCH-AN-r11* then $N_{\text{PUCCH}}^{(1)}$ is given by *n1PUCCH-AN-r11*, else $N_{\text{PUCCH}}^{(1)}$ is given by higher layer parameter *n1PUCCH-AN* .

10.1.1 PUCCH format information

Using the PUCCH formats defined in subclause 5.4.1 and 5.4.2 in [3], the following combinations of UCI on PUCCH are supported:

- Format 1a for 1-bit HARQ-ACK or in case of FDD or FDD-TDD primary cell frame structure type 1 for 1-bit HARQ-ACK with positive SR.
- Format 1b for 2-bit HARQ-ACK or for 2-bit HARQ-ACK with positive SR.
- Format 1b for up to 4-bit HARQ-ACK with channel selection when the UE is configured with more than one serving cell or, in the case of TDD, when the UE is configured with a single serving cell.
- Format 1 for positive SR.
- Format 2 for a CSI report when not multiplexed with HARQ-ACK.
- Format 2a for a CSI report multiplexed with 1-bit HARQ-ACK for normal cyclic prefix.
- Format 2b for a CSI report multiplexed with 2-bit HARQ-ACK for normal cyclic prefix.
- Format 2 for a CSI report multiplexed with HARQ-ACK for extended cyclic prefix.
- Format 3 for up to 10-bit HARQ-ACK for FDD or FDD-TDD primary cell frame structure type 1 and for up to 20-bit HARQ-ACK for TDD and for up to 21 bit HARQ-ACK for FDD-TDD primary cell frame structure type 2.
- Format 3 for up to 11-bit corresponding to 10-bit HARQ-ACK and 1-bit positive/negative SR for FDD or FDD-TDD and for up to 21-bit corresponding to 20-bit HARQ-ACK and 1-bit positive/negative SR for TDD and for up to 22-bit corresponding to 21-bit HARQ-ACK and 1-bit positive/negative SR for FDD-TDD primary cell frame structure type 2.
- Format 3 for HARQ-ACK, 1-bit positive/negative SR (if any) and CSI report(s).
- Format 4 for more than 22 bits of UCI including HARQ-ACK, SR (if any) and periodic CSI report(s) (if any).
- Format 5 for more than 22 bits of UCI including HARQ-ACK, SR (if any) and periodic CSI report(s) (if any).

- Format 4 for more than one CSI report and SR (if any).

- Format 5 for more than one CSI report and SR (if any).

For a UE configured with PUCCH format 3, not configured with PUCCH format 4/5, and for HARQ-ACK transmission on PUSCH or using PUCCH format 3, or for a UE configured with two serving cells and PUCCH format 1b with channel selection and HARQ-ACK transmission on PUSCH, or for a non BL/CE UE configured with one serving cell and PUCCH format 1b with channel selection according to Tables 10.1.3-5, 10.1.3-6, 10.1.3-7 and HARQ-ACK transmission on PUSCH or for a UE configured with PUCCH format 4/5 and HARQ-ACK transmission on PUSCH or using PUCCH format 3/4/5:

- if the configured downlink transmission mode for a serving cell supports up to 2 transport blocks and only one transport block is received in a subframe, the UE shall generate a NACK for the other transport block if spatial HARQ-ACK bundling is not applied.

- if neither PDSCH nor PDCCH/EPDCCH indicating downlink SPS release is detected in a subframe for a serving cell, the UE shall generate two NACKs when the configured downlink transmission mode supports up to 2 transport blocks and the UE shall generate a single NACK when the configured downlink transmission mode supports a single transport block.

For a UE configured with PUCCH format 4/5 and with a transmission mode supporting two transport blocks in at least one serving cell, the HARQ-ACK response for a serving cell configured with a transmission mode supporting one transport blockis associated with the first codeword. The UE shall generate a NACK for the second codeword if spatial bundling is not applied, and shall generate the same HARQ-ACK response for the second codeword as that for the first codeword if spatial bundling is applied.

For a BL/CE UE configured with PUCCH format 1b with channel selection according to Tables 10.1.3-5, 10.1.3-6, 10.1.3-7, if neither PDSCH nor MPDCCH indicating downlink SPS release is detected in a subframe for a serving cell, the UE shall generate a single NACK.

The scrambling initialization of PUCCH format 2, 2a, 2b, 3, 4 and 5 is by C-RNTI.

For a non-BL/CE UE that is configured with a single serving cell and is not configured with PUCCH format 3, in case of collision between a periodic CSI report and an HARQ-ACK in a same subframe without PUSCH, the periodic CSI report is multiplexed with HARQ-ACK on PUCCH if the parameter *simultaneousAckNackAndCQI* provided by higher layers is set *TRUE*, otherwise the CSI is dropped.

For a BL/CE UE,

- if both *pucch-NumRepetitionCE-format1* and *pucch-NumRepetitionCE-format2* equal 1, in case of collision among two or more of a periodic CSI report, an HARQ-ACK and a SR in a same subframe without PUSCH, the UE behavior follows that of a non-BL/CE UE.

- if at least one of *pucch-NumRepetitionCE-format1* and *pucch-NumRepetitionCE-format2* is larger than 1, in case of collision among two or more of a periodic CSI report, an HARQ-ACK, and a SR in a same subframe without PUSCH, the highest priority UCI is transmitted, where the priority of HARQ-ACK is higher than SR and the priority of SR is higher than periodic CSI report.

For TDD and for a UE that is configured with a single serving cell and with PUCCH format 3, in case of collision between a periodic CSI report and an HARQ-ACK in a same subframe without PUSCH, if the parameter *simultaneousAckNackAndCQI* provided by higher layers is set *TRUE* or if the parameter *simultaneousAckNackAndCQI-Format3-r11* provided by higher layers is set *TRUE*, the periodic CSI report is multiplexed with HARQ-ACK or dropped as described in subclause 7.3, otherwise the CSI is dropped.

For FDD or for FDD-TDD and primary cell frame structure type 1 and for a UE that is configured with more than one serving cell and is not configured with PUCCH format 4/5, in case of collision between a periodic CSI report and an HARQ-ACK in a same subframe without PUSCH,

- if the parameter simultaneousAckNackAndCQI provided by higher layers is set TRUE and if the HARQ-ACK corresponds to a PDSCH transmission or PDCCH/EPDCCH indicating downlink SPS release only on the primary cell,

  then the periodic CSI report is multiplexed with HARQ-ACK on PUCCH using PUCCH format 2/2a/2b

- else if the UE is configured with PUCCH format 3 and if the parameter *simultaneousAckNackAndCQI-Format3-r11* provided by higher layers is set *TRUE*, and if PUCCH resource is determined according to subclause 10.1.2.2.2, and
  - if the total number of bits in the subframe corresponding to HARQ-ACKs, SR (if any), and the CSI is not larger than 22 or
  - if the total number of bits in the subframe corresponding to spatially bundled HARQ-ACKs, SR (if any), and the CSI is not larger than 22

  then the periodic CSI report is multiplexed with HARQ-ACK on PUCCH using the determined PUCCH format 3 resource according to [4]
- otherwise,

  CSI is dropped.

For FDD or for FDD-TDD and primary cell frame structure type 1, for a UE configured with PUCCH format 4 or PUCCH format 5, and if the UE has HARQ-ACK/SR and periodic CSI reports to transmit in a subframe,

- if a PUCCH format 3 is determined to transmit the HARQ-ACK/SR according to subclause 10.1.2.2.3 or 10.1.2.2.4, the UE shall use the determined PUCCH format 3 for transmission of the HARQ-ACK/SR and periodic CSI report(s) if the parameter *simultaneousAckNackAndCQI-Format3-r11* provided by higher layers is set *TRUE*; otherwise, the UE shall drop the periodic CSI report(s) and transmit only HARQ-ACK/SR;
- if a PUCCH format 4 is determined to transmit the HARQ-ACK/SR according to subclause 10.1.2.2.3 or a PUCCH format 5 is determined to transmit the HARQ-ACK/SR according to 10.1.2.2.4, the UE shall used the determined PUCCH format 4 or PUCCH format 5 for transmission of the HARQ-ACK/SR and periodic CSI report(s) if the parameter *simultaneousAckNackAndCQI-Format4-Format5-r13* provided by higher layers is set *TRUE*; otherwise, the UE shall drop the periodic CSI report(s) and transmit only HARQ-ACK/SR;
- if there is no PUCCH format 3 or 4 determined to transmit the HARQ-ACK/SR according to subclause 10.1.2.2.3 and there is no PUCCH format 3 or 5 determined to transmit the HARQ-ACK/SR according to subclause 10.1.2.2.4 and there are more than one periodic CSI report(s) in the subframe,
  - if the parameter *simultaneousAckNackAndCQI-Format4-Format5-r13* provided by higher layers is set *TRUE* and if the UE is configured with a single PUCCH format 4 resource $n_{\text{PUCCH}}^{(4)}$ according to higher layer parameter *format4-MultiCSI-resourceConfiguration*, the PUCCH format 4 resource $n_{\text{PUCCH}}^{(4)}$ is used for transmission of the HARQ-ACK/SR and periodic CSI report(s);
  - if the parameter *simultaneousAckNackAndCQI-Format4-Format5-r13* provided by higher layers is set *TRUE* and if the UE is configured with a PUCCH format 5 resource $n_{\text{PUCCH}}^{(5)}$ according to higher layer parameter *format5-MultiCSI-resourceConfiguration*, the PUCCH format 5 resource $n_{\text{PUCCH}}^{(5)}$ is used for transmission of the HARQ-ACK/SR and periodic CSI report(s);
  - if the parameter *simultaneousAckNackAndCQI-Format4-Format5-r13* provided by higher layers is set *TRUE* and if the UE is configured with two PUCCH format 4 resources $n_{\text{PUCCH},1}^{(4)}$ and $n_{\text{PUCCH},2}^{(4)}$ according to higher layer parameter *format4-MultiCSI-resourceConfiguration*, if $\left(O^{ACK} + O^{SR} + O_{\text{P-CSI}} + O_{\text{CRC}}\right) \le \min\left(M_{\text{RB},1}^{\text{PUCCH4}}, M_{\text{RB},2}^{\text{PUCCH4}}\right) \cdot N_{sc}^{RB} \cdot N_{\text{symb}}^{\text{PUCCH4}} \cdot 2 \cdot r$, the PUCCH format 4 resource with the smaller $M_{\text{RB},i}^{\text{PUCCH4}}$ between $n_{\text{PUCCH},1}^{(4)}$ and $n_{\text{PUCCH},2}^{(4)}$ is used for transmission of the HARQ-ACK/SR and periodic CSI report(s); otherwise, the PUCCH format 4 resource with the larger $M_{\text{RB},i}^{\text{PUCCH4}}$ between $n_{\text{PUCCH},1}^{(4)}$ and $n_{\text{PUCCH},2}^{(4)}$ is used for transmission of the HARQ-ACK/SR and periodic CSI report(s), where
    - O^{ACK} is the total number of HARQ-ACK bits in the subframe;
    - $O^{SR} = 0$ if there no scheduling request bit in the subframe and $O^{SR} = 1$ otherwise
    - $O_{\text{P-CSI}}$ is the total number of CSI report bits in the subframe;
    - O_{CRC} is the number of CRC bits;

- $M_{\mathrm{RB},i}^{\mathrm{PUCCH4}}$, $i = 1,2$, is the number of PRBs for $n_{\mathrm{PUCCH},1}^{(4)}$ and $n_{\mathrm{PUCCH},2}^{(4)}$ respectively, according to higher layer parameter *numberOfPRB-format4-r13* according to Table 10.1.1-2;
- $N_{\mathrm{symb}}^{\mathrm{PUCCH4}} = 2 \cdot \left(N_{\mathrm{symb}}^{\mathrm{UL}} - 1\right) - 1$ if shortened PUCCH format 4 is used in the subframe and $N_{\mathrm{symb}}^{\mathrm{PUCCH4}} = 2 \cdot \left(N_{\mathrm{symb}}^{\mathrm{UL}} - 1\right)$ otherwise; and
- r is the code rate given by higher layer parameter *maximumPayloadCoderate-r13* according to Table 10.1.1-2*;*

- otherwise, the UE shall drop the periodic CSI report(s) and transmit only HARQ-ACK/SR;

- if there is no PUCCH format 3 or 4 determined to transmit the HARQ-ACK/SR according to subclause 10.1.2.2.3 and there is no PUCCH format 3 or 5 determined to transmit the HARQ-ACK/SR according to subclause 10.1.2.2.4 and there are only one periodic CSI report in the subframe,
  - if there is no positive SR and the parameter *simultaneousAckNackAndCQI* provided by higher layers is set *TRUE* and if the HARQ-ACK corresponds to a PDSCH transmission or PDCCH/EPDCCH indicating downlink SPS release only on the primary cell, then the periodic CSI report is multiplexed with HARQ-ACK on PUCCH using PUCCH format 2/2a/2b
  - else, the UE shall drop the CSI and transmit the HARQ-ACK according to subclause 10.1.2.2.3 or 10.1.2.2.4 when UE shall transmit HARQ-ACK only or UE shall drop the CSI and transmit the HARQ-ACK and SR according to the procedure for FDD with PUCCH format 1a/1b when there is positive SR.

- If a UE transmits HARQ-ACK/SR and periodic CSI report(s) using either a PUCCH format 4 $n_{\mathrm{PUCCH}}^{(4)}$ or PUCCH format 5 $n_{\mathrm{PUCCH}}^{(5)}$ in a subframe
  - if $\left(O^{ACK} + O^{SR} + O_{\mathrm{P-CSI}} + O_{\mathrm{CRC}}\right) \le 2 \cdot N_{\mathrm{RE}} \cdot r$, the UE shall transmit the HARQ-ACK/SR and periodic CSI bits using the PUCCH format 4 $n_{\mathrm{PUCCH}}^{(4)}$ or the PUCCH format 5 $n_{\mathrm{PUCCH}}^{(5)}$;
  - if $\left(O^{ACK} + O^{SR} + O_{\mathrm{P-CSI}} + O_{\mathrm{CRC}}\right) > 2 \cdot N_{\mathrm{RE}} \cdot r$, the UE shall select $N_{\mathrm{CSI,reported}}$ CSI report(s) for transmission together with HARQ-ACK/SR in ascending order of $\mathrm{Pri}_{CSI}(y,s,c,t)$, where $\mathrm{Pri}_{CSI}(y,s,c,t)$, N_{RE} and r are determined according to subclause 7.2.2; the value of $N_{\mathrm{CSI,reported}}$ satisfies $\left(O^{ACK} + O^{SR} + \sum_{n=1}^{N_{\mathrm{CSI,reported}}} O_{\mathrm{P-CSI},n} + O_{\mathrm{CRC}}\right) \le 2 \cdot N_{\mathrm{RE}} \cdot r$ and $\left(O^{ACK} + O^{SR} + \sum_{n=1}^{N_{\mathrm{CSI,reported}}+1} O_{\mathrm{P-CSI},n} + O_{\mathrm{CRC}}\right) > 2 \cdot N_{\mathrm{RE}} \cdot r$, and $O_{P-CSI,n}$ is the number of CSI report bits for the *n*th CSI report in ascending order of $\mathrm{Pri}_{CSI}(y,s,c,t)$.

For TDD or for FDD-TDD and primary cell frame structure type 2 and for a UE that is configured with more than one serving cell, in case of collision between a periodic CSI report and an HARQ-ACK in a same subframe without PUSCH, if the parameter *simultaneousAckNackAndCQI* provided by higher layers is set *TRUE* or if the parameter *simultaneousAckNackAndCQI-Format3-r11* provided by higher layers is set *TRUE* or if the parameter *simultaneousAckNackAndCQI-Format4-Format5-r13* provided by higher layers is set *TRUE*, the periodic CSI report is multiplexed with HARQ-ACK or dropped as described in subclause 7.3, otherwise the CSI is dropped.

In case of collision between a periodic CSI report and an HARQ-ACK in a same subframe with PUSCH, the periodic CSI is multiplexed with the HARQ-ACK in the PUSCH transmission in that subframe if the UE is not configured by higher layers for simultaneous PUCCH and PUSCH transmissions or if the UE is provided by higher layers a parameter *simultaneousAckNackAndCQI-Format4-Format5-r13* that is set *FALSE*. If the UE is configured by higher layers for simultaneous PUCCH and PUSCH transmissions, and if the UE does not determine PUCCH format 4/5 for periodic CSI and HARQ-ACK transmission or if the UE is provided by higher layers a parameter *simultaneousAckNackAndCQI-Format4-Format5-r13* that is set *FALSE*, the HARQ-ACK is transmitted in the PUCCH and the periodic CSI is transmitted in the PUSCH. If the UE is configured by higher layers for simultaneous PUCCH and PUSCH transmissions and if the UE determines PUCCH format 4/5 for periodic CSI and HARQ-ACK transmission and if the

UE is provided by higher layers a parameter *simultaneousAckNackAndCQI-Format4-Format5-r13* that is set *TRUE*, the periodic CSI and HARQ-ACK is transmitted in PUCCH format 4/5.

For a BL/CE UE, in case of collision between a UCI and a PUSCH transmission in a same subframe, if the number of PUCCH repetitions defined for the UCI in [3] is larger than 1 or if the indicated PUSCH repetition number in DCI format 6-0A/6-0B is larger than 1, the PUSCH transmission is dropped in that subframe.

For a BL/CE UE in half-duplex FDD operation, in case of collision between a PUCCH format 2 transmission including half-duplex guard subframe and a PDSCH reception with repetitions, the PUCCH format 2 transmission is dropped.

For a BL/CE UE, in case of collision between at least one physical resource block to be used for transmission of UCI on PUCCH (defined in [3]) and physical resource blocks corresponding to configured PRACH resources for BL/CE UEs or non-BL/CE UEs (defined in [3]) in a same subframe, the PUCCH is dropped in that subframe.

If each of the serving cells configured for the UE has frame structure type 1, UE procedures for HARQ-ACK feedback are given in subclause 10.1.2.

If each of the serving cells configured for the UE has frame structure type 2, UE procedures for HARQ-ACK feedback are given in subclause 10.1.3.

If the UE is configured for more than one serving cell, and if the frame structure type of any two configured serving cells is different, and if the primary cell is frame structure type 1, UE procedure for HARQ-ACK feedback is given in subclause 10.1.2A.

If the UE is configured for more than one serving cell, and if the frame structure type of any two configured serving cells is different, and if the primary cell is frame structure type 2, UE procedure for HARQ-ACK feedback is given in subclause 10.1.3A.

Table 10.1.1-1: code rate r corresponding to higher layer parameter *maximumPayloadCoderate-r13*

Value of *maximumPayloadCoderate-r13*	Code rate r
0	0.08
1	0.15
2	0.25
3	0.35
4	0.45
5	0.60
6	0.80
7	Reserved

Table 10.1.1-2: Number of PRBs for PUCCCH format 4 $M_{\text{RB}}^{\text{PUCCH4}}$ corresponding to higher layer parameter *numberOfPRB-format4-r13*

Value of *numberOfPRB-format4-r13*	$M_{\text{RB}}^{\text{PUCCH4}}$
0	1
1	2
2	3
3	4
4	5
5	6
6	8
7	Reserved

10.1.2 FDD HARQ-ACK feedback procedures

For FDD and for a UE not configured with PUCCH format 4/5 and transmitting HARQ-ACK using PUCCH format 1b with channel selection or PUCCH format 3, the UE shall determine the number of HARQ-ACK bits, O, based on the number of configured serving cells and the downlink transmission modes configured for each serving cell. The UE shall use two HARQ-ACK bits for a serving cell configured with a downlink transmission mode that support up to two transport blocks; and one HARQ-ACK bit otherwise.

A UE that supports aggregating at most 2 serving cells with frame structure type 1 shall use PUCCH format 1b with channel selection for transmission of HARQ-ACK when configured with more than one serving cell with frame structure type 1.

A UE that supports aggregating more than 2 serving cells with frame structure type 1 is configured by higher layers to use either PUCCH format 1b with channel selection or PUCCH format 3/4/5 for transmission of HARQ-ACK when configured with more than one serving cell with frame structure type 1.

The FDD HARQ-ACK feedback procedure for one configured serving cell is given in subclause 10.1.2.1 and procedures for more than one configured serving cell are given in subclause 10.1.2.2.

10.1.2.1 FDD HARQ-ACK procedure for one configured serving cell

HARQ-ACK transmission on two antenna ports $(p \in [p_0, p_1])$ is supported for PUCCH format 1a/1b.

For FDD and one configured serving cell, the UE shall use PUCCH resource $n_{\text{PUCCH}}^{(1,\tilde{p})}$ for transmission of HARQ-ACK in subframe n for $\tilde{p}$ mapped to antenna port *p* for PUCCH format 1a/1b [3], where

- for a PDSCH transmission indicated by the detection of a corresponding PDCCH in subframe $n-4$, or for a PDCCH indicating downlink SPS release (defined in subclause 9.2) in subframe $n-4$, the UE shall use $n_{\text{PUCCH}}^{(1,\tilde{p}_0)} = n_{\text{CCE}} + N_{\text{PUCCH}}^{(1)}$ for antenna port p_0, where n_{CCE} is the number of the first CCE (i.e. lowest CCE index used to construct the PDCCH) used for transmission of the corresponding DCI assignment and $N_{\text{PUCCH}}^{(1)}$ is configured by higher layers. For two antenna port transmission the PUCCH resource for antenna port p_1 is given by $n_{\text{PUCCH}}^{(1,\tilde{p}_1)} = n_{\text{CCE}} + 1 + N_{\text{PUCCH}}^{(1)}$.

- for a non-BL/CE UE, and for a PDSCH transmission on the primary cell where there is not a corresponding PDCCH/EPDCCH detected in subframe $n-4$, the value of $n_{\text{PUCCH}}^{(1,\tilde{p})}$ is determined according to higher layer configuration and Table 9.2-2. For a UE configured for two antenna port transmission, a PUCCH resource value in Table 9.2-2 maps to two PUCCH resources with the first PUCCH resource $n_{\text{PUCCH}}^{(1,\tilde{p}_0)}$ for antenna port p_0 and the second PUCCH resource $n_{\text{PUCCH}}^{(1,\tilde{p}_1)}$ for antenna port p_1, otherwise, the PUCCH resource value maps to a single PUCCH resource $n_{\text{PUCCH}}^{(1,\tilde{p}_0)}$ for antenna port p_0.

- for a PDSCH transmission indicated by the detection of a corresponding EPDCCH in subframe $n-4$, or for an EPDCCH indicating downlink SPS release (defined in subclause 9.2) in subframe $n-4$, the UE shall use

    - o if EPDCCH-PRB-set q is configured for distributed transmission
      $n_{\text{PUCCH}}^{(1,\tilde{p}_0)} = n_{\text{ECCE,q}} + \Delta_{ARO} + N_{\text{PUCCH,q}}^{(\text{e1})}$

    - o if EPDCCH-PRB-set q is configured for localized transmission

$$n_{\text{PUCCH}}^{(1,\tilde{p}_0)} = \left\lfloor \frac{n_{\text{ECCE,q}}}{N_{RB}^{ECCE,q}} \right\rfloor \cdot N_{RB}^{ECCE,q} + n' + \Delta_{ARO} + N_{\text{PUCCH,q}}^{(\text{e1})}$$

  for antenna port p_0, where $n_{\text{ECCE,q}}$ is the number of the first ECCE (i.e. lowest ECCE index used to construct the EPDCCH) used for transmission of the corresponding DCI assignment in EPDCCH-PRB-set q, Δ_{ARO} is determined from the HARQ-ACK resource offset field in the DCI format of the corresponding EPDCCH as given in Table 10.1.2.1-1, $N_{\text{PUCCH,q}}^{(\text{e1})}$ for EPDCCH-PRB-set q is configured by the higher layer parameter *pucch-ResourceStartOffset-r11* , $N_{RB}^{ECCE,q}$ for EPDCCH-PRB-set q is given in subclause 6.8A.1 in [3], n' is determined from the antenna port used for localized EPDCCH transmission which is described in subclause 6.8A.5 in [3]. For two antenna port transmission the PUCCH resource for antenna port p_1 is given by

- o if EPDCCH-PRB-set q is configured for distributed transmission
  $$n_{\text{PUCCH}}^{(1,\tilde{p}_1)} = n_{\text{ECCE,q}} + 1 + \Delta_{ARO} + N_{\text{PUCCH,q}}^{(\text{e1})}$$
- o if EPDCCH-PRB-set q is configured for localized transmission
  $$n_{\text{PUCCH}}^{(1,\tilde{p}_1)} = \left\lfloor \frac{n_{\text{ECCE,q}}}{N_{RB}^{ECCE,q}} \right\rfloor \cdot N_{RB}^{ECCE,q} + 1 + n' + \Delta_{ARO} + N_{\text{PUCCH,q}}^{(\text{e1})}$$

- for a BL/CE UE, and for a PDSCH on the primary cell where there is not a corresponding MPDCCH detected and subframe $n-k$ is the last subframe in which the PDSCH is transmitted, the value of $n_{\text{PUCCH}}^{(1,p_0)}$ is determined according to higher layer configuration and Table 9.2-2.
- for a PDSCH transmission indicated by the detection of a corresponding MPDCCH, or for an MPDCCH indicating downlink SPS release (defined in subclause 9.2) where subframe $n-k$ is the last subframe in which the PDSCH is transmitted, the UE shall use
  - o if MPDCCH-PRB-set q is configured for distributed transmission
    $$n_{\text{PUCCH}}^{(1,p_0)} = n_{\text{ECCE,q}} + \Delta_{ARO} + N_{\text{PUCCH,q}}^{(m1)}$$
  - o if EPDCCH-PRB-set q is configured for localized transmission
    $$n_{\text{PUCCH}}^{(1,p_0)} = \left\lfloor \frac{n_{\text{ECCE,q}}}{N_{RB}^{ECCE,q}} \right\rfloor \cdot N_{RB}^{ECCE,q} + n' + \Delta_{ARO} + N_{\text{PUCCH,q}}^{(m1)}$$

  for antenna port p_0, where $n_{\text{ECCE,q}}$ is the number of the first ECCE (i.e. lowest ECCE index used to construct the MPDCCH) used for transmission of the corresponding DCI assignment in MPDCCH-PRB-set q, Δ_{ARO} is determined from the HARQ-ACK resource offset field in the DCI format of the corresponding MPDCCH as given in Table 10.1.2.1-1, $N_{\text{PUCCH,q}}^{(m1)}$ for MPDCCH-PRB-set q is configured

  - o by the higher layer parameter *n1PUCCH-AN-r13*, if configured; otherwise:
  - o by the higher layer parameter *n1PUCCH-AN-InfoList-r13* for the corresponding CE level,

$N_{RB}^{ECCE,q}$ for MPDCCH-PRB-set q is given in subclause 6.8A.1 in [3] where the same $N_{RB}^{ECCE,q}$ value is used for each subframe containing a repeat of a MPDCCH transmission, n' is determined from the antenna port used for localized MPDCCH transmission which is described in subclause 6.8A.5 in [3]. When an MPDCCH-PRB-set p is 2+4, following procedures is applied.

- o if the detected MPDCCH is located within 2 PRB set, $n_{\text{PUCCH}}^{(1,p_0)}$ is obtained by above procedure.
- o if the detected MPDCCH is located within 4 PRB set, $n_{\text{PUCCH}}^{(1,p_0)}$ is the sum between $2N_{RB}^{ECCE,q}$ and the value obtained by above procedure.
- o if the detected MPDCCH is MPDCCH format 5, $n_{\text{PUCCH}}^{(1,p_0)}$ is obtained by the above procedure with $n_{\text{ECCE,q}}$ = 0.

Table 10.1.2.1-1: Mapping of ACK/NACK Resource offset Field in DCI format 1A/1B/1D/1/2A/2/2B/2C/2D/6-1A/6-1B to Δ_{ARO} values

ACK/NACK Resource offset field in DCI format 1A/1B/1D/1/2A/2/2B/2C/2D	Δ_{ARO}
0	0
1	-1
2	-2
3	2

10.1.2.2 FDD HARQ-ACK procedures for more than one configured serving cell

The FDD HARQ-ACK feedback procedures for more than one configured serving cell are either based on a PUCCH format 1b with channel selection HARQ-ACK procedure as described in subclause 10.1.2.2.1 or a PUCCH format 3 HARQ-ACK procedure as described in subclause 10.1.2.2.2 or a PUCCH format 4 HARQ-ACK procedure as described in subclause 10.1.2.2.3 or a PUCCH format 5 HARQ-ACK procedure as described in subclause 10.1.2.2.4.

HARQ-ACK transmission on two antenna ports $(p \in [p_0, p_1])$ is supported for PUCCH format 3.

HARQ-ACK transmission on two antenna ports $(p \in [p_0, p_1])$ is supported for PUCCH format 1b with channel selection and FDD with two configured serving cells.

10.1.2.2.1 PUCCH format 1b with channel selection HARQ-ACK procedure

For two configured serving cells and PUCCH format 1b with channel selection, the UE shall transmit $b(0)b(1)$ on PUCCH resource $n_{\text{PUCCH}}^{(1,\tilde{p})}$ for $\tilde{p}$ mapped to antenna port *p* using PUCCH format 1b where

- $n_{\text{PUCCH}}^{(1,\tilde{p}_0)} = n_{\text{PUCCH}}^{(1)}$ for antenna port p_0 where $n_{\text{PUCCH}}^{(1)}$ is selected from A PUCCH resources, $n_{\text{PUCCH},j}^{(1)}$ where $0 \le j \le A-1$ and $A \in \{2,3,4\}$, according to Table 10.1.2.2.1-3, Table 10.1.2.2.1-4, Table 10.1.2.2.1-5 in subframe n. HARQ-ACK(*j*) denotes the ACK/NACK/DTX response for a transport block or SPS release PDCCH/EPDCCH associated with serving cell c, where the transport block and serving cell for HARQ-ACK(*j*) and A PUCCH resources are given by Table 10.1.2.2.1-1.

- $n_{\text{PUCCH}}^{(1,\tilde{p}_1)}$ for antenna port p_1, where $n_{\text{PUCCH}}^{(1,\tilde{p}_1)}$ is selected from A PUCCH resources, $n_{\text{PUCCH},j}^{(1,\tilde{p}_1)}$ configured by higher layers where $0 \le j \le A-1$ and $A \in \{2,3,4\}$, according to Table 10.1.2.2.1-3, Table 10.1.2.2.1-4, Table 10.1.2.2.1-5 by replacing $n_{\text{PUCCH}}^{(1)}$ with $n_{\text{PUCCH}}^{(1,\tilde{p}_1)}$ and replacing $n_{\text{PUCCH},i}^{(1)}$ with $n_{\text{PUCCH},i}^{(1,\tilde{p}_1)}$ in subframe n, when the UE is configured with two antenna port transmission for PUCCH format 1b with channel selection.

A UE configured with a transmission mode that supports up to two transport blocks on serving cell, c, shall use the same HARQ-ACK response for both the transport blocks in response to a PDSCH transmission with a single transport block or a PDCCH/EPDCCH indicating downlink SPS release associated with the serving cell c.

Table 10.1.2.2.1-1: Mapping of Transport Block and Serving Cell to HARQ-ACK(*j*) for PUCCH format 1b HARQ-ACK channel selection

A	*HARQ-ACK(j)*			
	HARQ-ACK(0)	**HARQ-ACK(1)**	**HARQ-ACK(2)**	**HARQ-ACK(3)**
2	TB1 Primary cell	TB1 Secondary cell	NA	NA
3	TB1 Serving cell1	TB2 Serving cell1	TB1 Serving cell2	NA
4	TB1 Primary cell	TB2 Primary cell	TB1 Secondary cell	TB2 Secondary cell

The UE shall determine the A PUCCH resources, $n_{\text{PUCCH},j}^{(1)}$ associated with HARQ-ACK(*j*) where $0 \le j \le A-1$ in Table 10.1.2.2.1-1, according to

- for a PDSCH transmission indicated by the detection of a corresponding PDCCH in subframe $n-4$ on the primary cell, or for a PDCCH indicating downlink SPS release (defined in subclause 9.2) in subframe $n-4$ on the primary cell, the PUCCH resource is $n^{(1)}_{\mathrm{PUCCH,j}} = n_{\mathrm{CCE}} + N^{(1)}_{\mathrm{PUCCH}}$, and for transmission mode that supports up to two transport blocks, the PUCCH resource $n^{(1)}_{\mathrm{PUCCH},j+1}$ is given by $n^{(1)}_{\mathrm{PUCCH},j+1} = n_{\mathrm{CCE}} + 1 + N^{(1)}_{\mathrm{PUCCH}}$ where n_{CCE} is the number of the first CCE used for transmission of the corresponding PDCCH and $N^{(1)}_{\mathrm{PUCCH}}$ is configured by higher layers.

- for a PDSCH transmission on the primary cell where there is not a corresponding PDCCH/EPDCCH detected in subframe $n-4$, the value of $n^{(1)}_{\mathrm{PUCCH},j}$ is determined according to higher layer configuration and Table 9.2-2. For transmission mode that supports up to two transport blocks, the PUCCH resource $n^{(1)}_{\mathrm{PUCCH},j+1}$ is given by $n^{(1)}_{\mathrm{PUCCH},j+1} = n^{(1)}_{\mathrm{PUCCH},j} + 1$

- for a PDSCH transmission indicated by the detection of a corresponding PDCCH/EPDCCH in subframe $n-4$ on the secondary cell, the value of $n^{(1)}_{\mathrm{PUCCH},j}$, and the value of $n^{(1)}_{\mathrm{PUCCH},j+1}$ for the transmission mode that supports up to two transport blocks is determined according to higher layer configuration and Table 10.1.2.2.1-2. The TPC field in the DCI format of the corresponding PDCCH/EPDCCH shall be used to determine the PUCCH resource values from one of the four resource values configured by higher layers, with the mapping defined in Table 10.1.2.2.1-2. For a UE configured for a transmission mode that supports up to two transport blocks a PUCCH resource value in Table 10.1.2.2.1-2 maps to two PUCCH resources $(n^{(1)}_{\mathrm{PUCCH},j}, n^{(1)}_{\mathrm{PUCCH},j+1})$, otherwise, the PUCCH resource value maps to a single PUCCH resource $n^{(1)}_{\mathrm{PUCCH},j}$.

- for a PDSCH transmission indicated by the detection of a corresponding EPDCCH in subframe $n-4$ on the primary cell, or for an EPDCCH indicating downlink SPS release (defined in subclause 9.2) in subframe $n-4$ on the primary cell, the PUCCH resource is given by

  - if EPDCCH-PRB-set q is configured for distributed transmission

$$n^{(1)}_{\mathrm{PUCCH,j}} = n_{\mathrm{ECCE,q}} + \Delta_{ARO} + N^{(\mathrm{e1})}_{\mathrm{PUCCH,q}}$$

  - if EPDCCH-PRB-set q is configured for localized transmission

$$n^{(1)}_{\mathrm{PUCCH,j}} = \left\lfloor \frac{n_{\mathrm{ECCE,q}}}{N_{RB}^{ECCE,q}} \right\rfloor \cdot N_{RB}^{ECCE,q} + n' + \Delta_{ARO} + N^{(\mathrm{e1})}_{\mathrm{PUCCH,q}}$$

where $n_{\mathrm{ECCE,q}}$ is the number of the first ECCE (i.e. lowest ECCE index used to construct the EPDCCH) used for transmission of the corresponding DCI assignment in EPDCCH-PRB-set q, Δ_{ARO} is determined from the HARQ-ACK resource offset field in the DCI format of the corresponding EPDCCH as given in Table 10.1.2.1-1, $N^{(\mathrm{e1})}_{\mathrm{PUCCH,q}}$ for EPDCCH-PRB-set q is configured by the higher layer parameter *pucch-ResourceStartOffset-r11*, $N_{RB}^{ECCE,q}$ for EPDCCH-PRB-set q is given in subclause 6.8A.1 in [3], n' is determined from the antenna port used for localized EPDCCH transmission which is described in subclause 6.8A.5 in [3].

For transmission mode that supports up to two transport blocks, the PUCCH resource $n^{(1)}_{\mathrm{PUCCH},j+1}$ is given by

  - if EPDCCH-PRB-set q is configured for distributed transmission

$$n^{(1)}_{\mathrm{PUCCH,j+1}} = n_{\mathrm{ECCE,q}} + 1 + \Delta_{ARO} + N^{(\mathrm{e1})}_{\mathrm{PUCCH,q}}$$

  - if EPDCCH-PRB-set q is configured for localized transmission

$$n^{(1)}_{\mathrm{PUCCH,j+1}} = \left\lfloor \frac{n_{ECCE,q}}{N^{ECCE,q}_{RB}} \right\rfloor \cdot N^{ECCE,q}_{RB} + 1 + n' + \Delta_{ARO} + N^{(e1)}_{\mathrm{PUCCH,q}}$$

Table 10.1.2.2.1-2: PUCCH Resource Value for HARQ-ACK Resource for PUCCH

Value of 'TPC command for PUCCH'	$n^{(1)}_{\mathrm{PUCCH},j}$ **or** $(n^{(1)}_{\mathrm{PUCCH},j}, n^{(1)}_{\mathrm{PUCCH},j+1})$
'00'	The 1st PUCCH resource value configured by the higher layers
'01'	The 2nd PUCCH resource value configured by the higher layers
'10'	The 3rd PUCCH resource value configured by the higher layers
'11'	The 4th PUCCH resource value configured by the higher layers
NOTE: $(n^{(1)}_{\mathrm{PUCCH},j}, n^{(1)}_{\mathrm{PUCCH},j+1})$ are determined from the first and second PUCCH resource lists configured by *n1PUCCH-AN-CS-List-r10* in [11], respectively.	

Table 10.1.2.2.1-3: Transmission of Format 1b HARQ-ACK channel selection for $A = 2$

HARQ-ACK(0)	HARQ-ACK(1)	$n^{(1)}_{\mathrm{PUCCH}}$	$b(0)b(1)$
ACK	ACK	$n^{(1)}_{\mathrm{PUCCH},1}$	1,1
ACK	NACK/DTX	$n^{(1)}_{\mathrm{PUCCH},0}$	1,1
NACK/DTX	ACK	$n^{(1)}_{\mathrm{PUCCH},1}$	0,0
NACK	NACK/DTX	$n^{(1)}_{\mathrm{PUCCH},0}$	0,0
DTX	NACK/DTX	No Transmission	

Table 10.1.2.2.1-4: Transmission of Format 1b HARQ-ACK channel selection for $A = 3$

HARQ-ACK(0)	HARQ-ACK(1)	HARQ-ACK(2)	$n^{(1)}_{\mathrm{PUCCH}}$	$b(0)b(1)$
ACK	ACK	ACK	$n^{(1)}_{\mathrm{PUCCH},1}$	1,1
ACK	NACK/DTX	ACK	$n^{(1)}_{\mathrm{PUCCH},1}$	1,0
NACK/DTX	ACK	ACK	$n^{(1)}_{\mathrm{PUCCH},1}$	0,1
NACK/DTX	NACK/DTX	ACK	$n^{(1)}_{\mathrm{PUCCH},2}$	1,1
ACK	ACK	NACK/DTX	$n^{(1)}_{\mathrm{PUCCH},0}$	1,1
ACK	NACK/DTX	NACK/DTX	$n^{(1)}_{\mathrm{PUCCH},0}$	1,0
NACK/DTX	ACK	NACK/DTX	$n^{(1)}_{\mathrm{PUCCH},0}$	0,1
NACK/DTX	NACK/DTX	NACK	$n^{(1)}_{\mathrm{PUCCH},2}$	0,0
NACK	NACK/DTX	DTX	$n^{(1)}_{\mathrm{PUCCH},0}$	0,0
NACK/DTX	NACK	DTX	$n^{(1)}_{\mathrm{PUCCH},0}$	0,0
DTX	DTX	DTX	No Transmission	

Table 10.1.2.2.1-5: Transmission of Format 1b HARQ-ACK channel selection for $A = 4$

HARQ-ACK(0)	HARQ-ACK(1)	HARQ-ACK(2)	HARQ-ACK(3)	$n^{(1)}_{\text{PUCCH}}$	$b(0)b(1)$
ACK	ACK	ACK	ACK	$n^{(1)}_{\text{PUCCH},1}$	1,1
ACK	NACK/DTX	ACK	ACK	$n^{(1)}_{\text{PUCCH},2}$	0,1
NACK/DTX	ACK	ACK	ACK	$n^{(1)}_{\text{PUCCH},1}$	0,1
NACK/DTX	NACK/DTX	ACK	ACK	$n^{(1)}_{\text{PUCCH},3}$	1,1
ACK	ACK	ACK	NACK/DTX	$n^{(1)}_{\text{PUCCH},1}$	1,0
ACK	NACK/DTX	ACK	NACK/DTX	$n^{(1)}_{\text{PUCCH},2}$	0,0
NACK/DTX	ACK	ACK	NACK/DTX	$n^{(1)}_{\text{PUCCH},1}$	0,0
NACK/DTX	NACK/DTX	ACK	NACK/DTX	$n^{(1)}_{\text{PUCCH},3}$	1,0
ACK	ACK	NACK/DTX	ACK	$n^{(1)}_{\text{PUCCH},2}$	1,1
ACK	NACK/DTX	NACK/DTX	ACK	$n^{(1)}_{\text{PUCCH},2}$	1,0
NACK/DTX	ACK	NACK/DTX	ACK	$n^{(1)}_{\text{PUCCH},3}$	0,1
NACK/DTX	NACK/DTX	NACK/DTX	ACK	$n^{(1)}_{\text{PUCCH},3}$	0,0
ACK	ACK	NACK/DTX	NACK/DTX	$n^{(1)}_{\text{PUCCH},0}$	1,1
ACK	NACK/DTX	NACK/DTX	NACK/DTX	$n^{(1)}_{\text{PUCCH},0}$	1,0
NACK/DTX	ACK	NACK/DTX	NACK/DTX	$n^{(1)}_{\text{PUCCH},0}$	0,1
NACK/DTX	NACK	NACK/DTX	NACK/DTX	$n^{(1)}_{\text{PUCCH},0}$	0,0
NACK	NACK/DTX	NACK/DTX	NACK/DTX	$n^{(1)}_{\text{PUCCH},0}$	0,0
DTX	DTX	NACK/DTX	NACK/DTX	No Transmission	

10.1.2.2.2 PUCCH format 3 HARQ-ACK procedure

For PUCCH format 3, the UE shall use PUCCH resource $n^{(3,\tilde{p})}_{\text{PUCCH}}$ or $n^{(1,\tilde{p})}_{\text{PUCCH}}$ for transmission of HARQ-ACK in subframe n for $\tilde{p}$ mapped to antenna port *p* where

- for a PDSCH transmission only on the primary cell indicated by the detection of a corresponding PDCCH in subframe $n-4$, or for a PDCCH indicating downlink SPS release (defined in subclause 9.2) in subframe $n-4$ on the primary cell, the UE shall use PUCCH format 1a/1b and PUCCH resource $n^{(1,\tilde{p})}_{\text{PUCCH}}$ with $n^{(1,\tilde{p}_0)}_{\text{PUCCH}} = n_{\text{CCE}} + N^{(1)}_{\text{PUCCH}}$ for antenna port p_0, where n_{CCE} is the number of the first CCE (i.e. lowest CCE index used to construct the PDCCH) used for transmission of the corresponding PDCCH and $N^{(1)}_{\text{PUCCH}}$ is configured by higher layers. When two antenna port transmission is configured for PUCCH format 1a/1b, the PUCCH resource for antenna port p_1 is given by $n^{(1,\tilde{p}_1)}_{\text{PUCCH}} = n_{\text{CCE}} + 1 + N^{(1)}_{\text{PUCCH}}$.

- for a PDSCH transmission only on the primary cell where there is not a corresponding PDCCH/EPDCCH detected in subframe $n-4$, the UE shall use PUCCH format 1a/1b and PUCCH resource $n^{(1,\tilde{p})}_{\text{PUCCH}}$ where the value of $n^{(1,\tilde{p})}_{\text{PUCCH}}$ is determined according to higher layer configuration and Table 9.2-2. For a UE configured for two antenna port transmission for PUCCH format 1a/1b, a PUCCH resource value in Table 9.2-2 maps to two PUCCH resources with the first PUCCH resource $n^{(1,\tilde{p}_0)}_{\text{PUCCH}}$ for antenna port p_0 and the second PUCCH resource $n_{\text{PUCCH}}^{(1,\tilde{p}_1)}$ for antenna port p_1, otherwise, the PUCCH resource value maps to a single PUCCH resource $n_{\text{PUCCH}}^{(1,\tilde{p}_0)}$ for antenna port p_0.

- for a PDSCH transmission on the secondary cell indicated by the detection of a corresponding PDCCH/EPDCCH in subframe $n-4$, the UE shall use PUCCH format 3 and PUCCH resource $n_{\text{PUCCH}}^{(3,\tilde{p})}$ where the value of $n_{\text{PUCCH}}^{(3,\tilde{p})}$ is determined according to higher layer configuration and Table 10.1.2.2.2-1. The TPC field in the DCI format of the corresponding PDCCH/EPDCCH shall be used to determine the PUCCH resource values from one of the four resource values configured by higher layers, with the mapping defined in Table 10.1.2.2.2-1. For a UE configured for two antenna port transmission for PUCCH format 3, a PUCCH resource value in Table 10.1.2.2.2-1 maps to two PUCCH resources with the first PUCCH resource $n_{\text{PUCCH}}^{(3,\tilde{p}_0)}$ for antenna port p_0 and the second PUCCH resource $n_{\text{PUCCH}}^{(3,\tilde{p}_1)}$ for antenna port p_1, otherwise, the PUCCH resource value maps to a single PUCCH resource $n_{\text{PUCCH}}^{(3,\tilde{p}_0)}$ for antenna port p_0. A UE shall assume that the same HARQ-ACK PUCCH resource value is transmitted in each DCI format of the corresponding secondary cell PDCCH/EPDCCH assignments in a given subframe.

- for a PDSCH transmission only on the primary cell indicated by the detection of a corresponding EPDCCH in subframe $n-4$, or for a EPDCCH indicating downlink SPS release (defined in subclause 9.2) in subframe $n-4$ on the primary cell, the UE shall use PUCCH format 1a/1b and PUCCH resource $n_{\text{PUCCH}}^{(1,\tilde{p})}$ given by

  - if EPDCCH-PRB-set q is configured for distributed transmission

$$n_{\text{PUCCH}}^{(1,\tilde{p}_0)} = n_{\text{ECCE,q}} + \Delta_{ARO} + N_{\text{PUCCH,q}}^{(\text{e1})}$$

  - if EPDCCH-PRB-set q is configured for localized transmission

$$n_{\text{PUCCH}}^{(1,\tilde{p}_0)} = \left\lfloor \frac{n_{\text{ECCE,q}}}{N_{RB}^{ECCE,q}} \right\rfloor \cdot N_{RB}^{ECCE,q} + n' + \Delta_{ARO} + N_{\text{PUCCH,q}}^{(\text{e1})}$$

for antenna port p_0, where $n_{\text{ECCE,q}}$ is the number of the first ECCE (i.e. lowest ECCE index used to construct the EPDCCH) used for transmission of the corresponding DCI assignment in EPDCCH-PRB-set q, Δ_{ARO} is determined from the HARQ-ACK resource offset field in the DCI format of the corresponding EPDCCH as given in Table 10.1.2.1-1, $N_{\text{PUCCH,q}}^{(\text{e1})}$ for EPDCCH-PRB-set q is configured by the higher layer parameter *pucch-ResourceStartOffset-r11*, $N_{RB}^{ECCE,q}$ for EPDCCH-PRB-set q is given in subclause 6.8A.1 in [3], n' is determined from the antenna port used for localized EPDCCH transmission which is described in subclause 6.8A.5 in [3]. When two antenna port transmission is configured for PUCCH format 1a/1b, the PUCCH resource for antenna port p_1 is given by.

  - if EPDCCH-PRB-set q is configured for distributed transmission

$$n_{\text{PUCCH}}^{(1,\tilde{p}_1)} = n_{\text{ECCE,q}} + 1 + \Delta_{ARO} + N_{\text{PUCCH,q}}^{(\text{e1})}$$

  - if EPDCCH-PRB-set q is configured for localized transmission

$$n_{\text{PUCCH}}^{(1,\tilde{p}_1)} = \left\lfloor \frac{n_{\text{ECCE,q}}}{N_{RB}^{ECCE,q}} \right\rfloor \cdot N_{RB}^{ECCE,q} + 1 + n' + \Delta_{ARO} + N_{\text{PUCCH,q}}^{(\text{e1})}$$

Table 10.1.2.2.2-1: PUCCH Resource Value for HARQ-ACK Resource for PUCCH

Value of 'TPC command for PUCCH' or 'HARQ-ACK resource offset'	$n_{\text{PUCCH}}^{(3,\tilde{p})}$
'00'	The 1st PUCCH resource value configured by the higher layers
'01'	The 2nd PUCCH resource value configured by the higher layers
'10'	The 3rd PUCCH resource value configured by the higher layers
'11'	The 4th PUCCH resource value configured by the higher layers

10.1.2.2.3 PUCCH format 4 HARQ-ACK procedure

For PUCCH format 4, the UE shall use PUCCH resource $n_{\text{PUCCH}}^{(4)}$ or $n_{\text{PUCCH}}^{(3,\tilde{p})}$ or $n_{\text{PUCCH}}^{(1,\tilde{p})}$ for transmission of HARQ-ACK and scheduling request (if any) and periodic CSI (if any) in subframe n for $\tilde{p}$ mapped to antenna port p where

- for a PDSCH transmission only on the primary cell indicated by the detection of a corresponding PDCCH in subframe $n-4$, or for a PDCCH indicating downlink SPS release (defined in subclause 9.2) in subframe $n-4$ on the primary cell, the UE shall use PUCCH format 1a/1b and PUCCH resource $n_{\text{PUCCH}}^{(1,\tilde{p})}$ with $n_{\text{PUCCH}}^{(1,\tilde{p}_0)} = n_{\text{CCE}} + N_{\text{PUCCH}}^{(1)}$ for antenna port p_0, where n_{CCE} is the number of the first CCE (i.e. lowest CCE index used to construct the PDCCH) used for transmission of the corresponding PDCCH and $N_{\text{PUCCH}}^{(1)}$ is configured by higher layers. When two antenna port transmission is configured for PUCCH format 1a/1b, the PUCCH resource for antenna port p_1 is given by $n_{\text{PUCCH}}^{(1,\tilde{p}_1)} = n_{\text{CCE}} + 1 + N_{\text{PUCCH}}^{(1)}$.

- for a PDSCH transmission only on the primary cell where there is not a corresponding PDCCH/EPDCCH detected in subframe $n-4$, the UE shall use PUCCH format 1a/1b and PUCCH resource $n_{\text{PUCCH}}^{(1,\tilde{p})}$ where the value of $n_{\text{PUCCH}}^{(1,\tilde{p})}$ is determined according to higher layer configuration and Table 9.2-2. For a UE configured for two antenna port transmission for PUCCH format 1a/1b, a PUCCH resource value in Table 9.2-2 maps to two PUCCH resources with the first PUCCH resource $n_{\text{PUCCH}}^{(1,\tilde{p}_0)}$ for antenna port p_0 and the second PUCCH resource $n_{\text{PUCCH}}^{(1,\tilde{p}_1)}$ for antenna port p_1, otherwise, the PUCCH resource value maps to a single PUCCH resource $n_{\text{PUCCH}}^{(1,\tilde{p}_0)}$ for antenna port p_0.

- for a PDSCH transmission on the secondary cell indicated by the detection of a corresponding PDCCH/EPDCCH in subframe $n-4$,

  - if the UE is configured with *codebooksizeDetermination-r13 = cc*, or if the UE is configured with *codebooksizeDetermination-r13 = dai* and the total number of HARQ-ACK bits O^{ACK} and scheduling request bit O^{SR} (if any) and periodic CSI bits $O_{\text{P-CSI}}$ (if any) is more than 22, the UE shall use PUCCH format 4 and PUCCH resource $n_{\text{PUCCH}}^{(4)}$ where the value of $n_{\text{PUCCH}}^{(4)}$ is determined according to higher layer configuration and Table 10.1.2.2.3-1.
    The TPC field in the DCI format of the corresponding PDCCH/EPDCCH shall be used to determine the PUCCH resource values from one of the four resource values configured by higher layers, with the mapping defined in Table 10.1.2.2.3-1. A UE shall assume that the same HARQ-ACK PUCCH resource value is transmitted in each DCI format of the corresponding secondary cell PDCCH assignments in a given subframe.

  - If the UE is configured with *codebooksizeDetermination-r13 = dai* and if the total number of HARQ-ACK bits O^{ACK} and scheduling request bit O^{SR} (if any) and periodic CSI bits $O_{\text{P-CSI}}$ (if any) is no more than 22, the UE shall use PUCCH format 3 and PUCCH resource $n_{\text{PUCCH}}^{(3,\tilde{p})}$ where the value of $n_{\text{PUCCH}}^{(3,\tilde{p})}$ is determined according to higher layer configuration and Table 10.1.2.2.2-1. The TPC field in the DCI format of the corresponding PDCCH/EPDCCH shall be used to determine the PUCCH resource values from one of the four resource values configured by higher layers, with the mapping defined in Table 10.1.2.2.2-1. . For a UE configured for two antenna port transmission for PUCCH format 3, a PUCCH resource value in Table 10.1.2.2.2-1 maps to two PUCCH resources with the first PUCCH resource $n_{\text{PUCCH}}^{(3,\tilde{p})}$ for antenna port p_0 and the second PUCCH resource $n_{\text{PUCCH}}^{(3,\tilde{p})}$ for antenna port p_1, otherwise, the PUCCH resource value maps to a single PUCCH resource $n_{\text{PUCCH}}^{(3,\tilde{p})}$ for antenna port p_0. A UE shall assume that the same HARQ-ACK PUCCH resource value is transmitted in each DCI format of the corresponding secondary cell PDCCH assignments in a given subframe.

- for a PDSCH transmission only on the primary cell indicated by the detection of a corresponding EPDCCH in subframe $n-4$, or for a EPDCCH indicating downlink SPS release (defined in subclause 9.2) in subframe $n-4$ on the primary cell, the UE shall use PUCCH format 1a/1b and PUCCH resource $n_{\text{PUCCH}}^{(1,\tilde{p})}$ given by

  - if EPDCCH-PRB-set q is configured for distributed transmission

$$n_{\text{PUCCH}}^{(1,\tilde{p}_0)} = n_{\text{ECCE,q}} + \Delta_{ARO} + N_{\text{PUCCH,q}}^{(\text{e1})}$$

  - if EPDCCH-PRB-set q is configured for localized transmission

$$n_{\text{PUCCH}}^{(1,\tilde{p}_0)} = \left\lfloor \frac{n_{\text{ECCE,q}}}{N_{RB}^{ECCE,q}} \right\rfloor \cdot N_{RB}^{ECCE,q} + n' + \Delta_{ARO} + N_{\text{PUCCH,q}}^{(\text{e1})}$$

for antenna port p_0, where $n_{\text{ECCE,q}}$ is the number of the first ECCE (i.e. lowest ECCE index used to construct the EPDCCH) used for transmission of the corresponding DCI assignment in EPDCCH-PRB-set q, Δ_{ARO} is determined from the HARQ-ACK resource offset field in the DCI format of the corresponding EPDCCH as given in Table 10.1.2.1-1, $N_{\text{PUCCH,q}}^{(\text{e1})}$ for EPDCCH-PRB-set q is configured by the higher layer parameter *pucch-ResourceStartOffset-r11*, $N_{RB}^{ECCE,q}$ for EPDCCH-PRB-set q is given in subclause 6.8A.1 in [3], n' is determined from the antenna port used for localized EPDCCH transmission which is described in subclause 6.8A.5 in [3]. When two antenna port transmission is configured for PUCCH format 1a/1b, the PUCCH resource for antenna port p_1 is given by.

  - if EPDCCH-PRB-set q is configured for distributed transmission $n_{\text{PUCCH}}^{(1,\tilde{p}_1)} = n_{\text{ECCE,q}} + 1 + \Delta_{ARO} + N_{\text{PUCCH,q}}^{(\text{e1})}$

  - if EPDCCH-PRB-set q is configured for localized transmission

$$n_{\text{PUCCH}}^{(1,\tilde{p}_1)} = \left\lfloor \frac{n_{\text{ECCE,q}}}{N_{RB}^{ECCE,q}} \right\rfloor \cdot N_{RB}^{ECCE,q} + 1 + n' + \Delta_{ARO} + N_{\text{PUCCH,q}}^{(\text{e1})}$$

Table 10.1.2.2.3-1: PUCCH Resource Value for HARQ-ACK Resource for PUCCH

Value of 'TPC command for PUCCH' or 'HARQ-ACK resource offset'	$n_{\text{PUCCH}}^{(4,\tilde{p})}$
'00'	The 1st PUCCH resource value configured by the higher layers
'01'	The 2nd PUCCH resource value configured by the higher layers
'10'	The 3rd PUCCH resource value configured by the higher layers
'11'	The 4th PUCCH resource value configured by the higher layers

10.1.2.2.4 PUCCH format 5 HARQ-ACK procedure

The HARQ-ACK feedback procedure for PUCCH format 5 HARQ-ACK procedure is as described in subclause 10.1.2.2.3, by replacing $n_{\text{PUCCH}}^{(4)}$ with $n_{\text{PUCCH}}^{(5)}$.

10.1.2A FDD-TDD HARQ-ACK feedback procedures for primary cell frame structure type 1

For a UE transmitting HARQ-ACK using PUCCH format 1b with channel selection, the UE shall determine the number of HARQ-ACK bits, O in subframe n, based on the number of configured serving cells with subframe $n-4$ configured as a downlink or special subframe according to the DL-reference UL/DL configuration (defined in subclause 10.2) of each serving cell and the downlink transmission modes configured for each serving cell. For a UE not configured with PUCCH format 4/5 and transmitting HARQ-ACK using PUCCH format 3, the UE shall determine the number of HARQ-ACK bits, O in subframe n, based on the number of configured serving cells with subframe $n-4$ configured as a downlink or special subframe except a special subframe of configurations 0 and 5 with normal downlink CP or of configurations 0 and 4 with extended downlink CP according to the DL-reference UL/DL configuration (defined in subclause 10.2) of each serving cell and the downlink transmission modes configured for each serving cell. The UE shall use two HARQ-ACK bits for a serving cell configured with a downlink transmission mode that support up to two transport blocks; and one HARQ-ACK bit otherwise.

A UE that supports aggregating at most 2 serving cells shall use PUCCH format 1b with channel selection for transmission of HARQ-ACK when configured with primary cell frame structure type 1 and secondary cell frame structure type 2.

A UE that supports aggregating more than 2 serving cells with primary cell frame structure type 1 is configured by higher layers to use either PUCCH format 1b with channel selection or PUCCH format 3/4/5 for transmission of HARQ-ACK when configured with more than one serving cell and primary cell frame structure type 1 and at least one secondary cell with frame structure type 2.

For HARQ-ACK transmission in subframe n with PUCCH format 1b with channel selection, the FDD-TDD HARQ-ACK procedure follows HARQ-ACK procedure described in subclause 10.1.2.1 if subframe $n-4$ is an uplink or a special subframe of configurations 0 and 5 with normal downlink CP or of configurations 0 and 4 with extended downlink CP for the secondary cell according to the higher layer parameter *subframeAssignment* for UE not configured with the higher layer parameter *EIMTA-MainConfigServCell-r12*, and according to the higher layer parameter *eimta-HARQ-ReferenceConfig-r12* for UE configured with the higher layer parameter *EIMTA-MainConfigServCell-r12*, and HARQ-ACK procedure described in subclause 10.1.2.2.1 otherwise.

The FDD-TDD HARQ-ACK feedback procedure for PUCCH format 3 HARQ-ACK procedure as described in subclause 10.1.2.2.2.

The FDD-TDD HARQ-ACK feedback procedure for PUCCH format 4 HARQ-ACK procedure is as described in subclause 10.1.2.2.3.

The FDD-TDD HARQ-ACK feedback procedure for PUCCH format 5 HARQ-ACK procedure is as described in subclause 10.1.2.2.4.

HARQ-ACK transmission on two antenna ports $(p \in [p_0, p_1])$ is supported for PUCCH format 3.

HARQ-ACK transmission on two antenna ports $(p \in [p_0, p_1])$ is supported for PUCCH format 1b with channel selection and with two configured serving cells.

10.1.3 TDD HARQ-ACK feedback procedures

For TDD and a UE that does not support aggregating more than one serving cell with frame structure type 2, two HARQ-ACK feedback modes are supported by higher layer configuration.

- HARQ-ACK bundling and
- HARQ-ACK multiplexing

For TDD and a BL/CE UE,

- if the UE is configured with *csi-NumRepetitionCE* equal to 1 and *mPDCCH-NumRepetition* equal to 1,
    - the UE may be configured with HARQ-ACK bundling or HARQ-ACK multiplexing;
    - HARQ-ACK multiplexing can be configured only if *pucch-NumRepetitionCE-format1* equal 1 and HARQ-ACK multiplexing is performed according to the set of Tables 10.1.3-5/6/7

- else
  - the UE is not expected to receive more than one PDSCH transmission, or more than one of PDSCH and MPDCCH indicating downlink SPS releases, with transmission ending within subframe(s) $n-k$, where $k \in K$ and K is defined in Table 10.1.3.1-1 intended for the UE;

For TDD UL/DL configuration 5 and a UE that does not support aggregating more than one serving cell with frame structure type 2 and the UE is not configured with *EIMTA-MainConfigServCell-r12* for the serving cell, only HARQ-ACK bundling is supported.

A UE that supports aggregating more than one serving cell with frame structure type 2 is configured by higher layers to use either PUCCH format 1b with channel selection or PUCCH format 3/4/5 for transmission of HARQ-ACK when configured with more than one serving cell with frame structure type 2.

A UE that supports aggregating more than one serving cell with frame structure type 2 and is not configured with the parameter *EIMTA-MainConfigServCell-r12* for any serving cell is configured by higher layers to use HARQ-ACK bundling, PUCCH format 1b with channel selection according to the set of Tables 10.1.3-2/3/4 or according to the set of Tables 10.1.3-5/6/7, or PUCCH format 3 for transmission of HARQ-ACK when configured with one serving cell with frame structure type 2.

A UE that is configured with the parameter *EIMTA-MainConfigServCell-r12* and configured with one serving cell is configured by higher layers to use PUCCH format 1b with channel selection according to the set of Tables 10.1.3-5/6/7, or PUCCH format 3 for transmission of HARQ-ACK. A UE that is configured with the parameter *EIMTA-MainConfigServCell-r12* for at least one serving cell and configured with more than one serving cell is configured by higher layers to use PUCCH format 1b with channel selection according to the set of Tables 10.1.3-5/6/7, or PUCCH format 3/4/5 for transmission of HARQ-ACK.

PUCCH format 1b with channel selection according to the set of Tables 10.1.3-2/3/4 or according to the set of Tables 10.1.3-5/6/7 is not supported for TDD UL/DL configuration 5.

TDD HARQ-ACK bundling is performed per codeword across M multiple downlink or special subframes associated with a single UL subframe *n*, where M is the number of elements in the set K defined in Table 10.1.3.1-1, by a logical AND operation of all the individual PDSCH transmission (with and without corresponding PDCCH/EPDCCH/MPDCCH) HARQ-ACKs and ACK in response to PDCCH/EPDCCH/MPDCCH indicating downlink SPS release. For one configured serving cell the bundled 1 or 2 HARQ-ACK bits are transmitted using PUCCH format 1a or PUCCH format 1b, respectively.

For TDD HARQ-ACK multiplexing and a subframe *n* with $M > 1$, where M is the number of elements in the set K defined in Table 10.1.3.1-1, spatial HARQ-ACK bundling across multiple codewords within a downlink or special subframe is performed by a logical AND operation of all the corresponding individual HARQ-ACKs. PUCCH format 1b with channel selection is used in case of one configured serving cell. For TDD HARQ-ACK multiplexing and a subframe *n* with $M = 1$, spatial HARQ-ACK bundling across multiple codewords within a downlink or special subframe is not performed, 1 or 2 HARQ-ACK bits are transmitted using PUCCH format 1a or PUCCH format 1b, respectively for one configured serving cell.

In the case of TDD and more than one configured serving cell with PUCCH format 1b with channel selection and more than 4 HARQ-ACK bits for M multiple downlink or special subframes associated with a single UL subframe *n*, where M is defined in subclause 10.1.3.2.1, and for the configured serving cells, spatial HARQ-ACK bundling across multiple codewords within a downlink or special subframe for all configured cells is performed and the bundled HARQ-ACK bits for each configured serving cell is transmitted using PUCCH format 1b with channel selection. For TDD and more than one configured serving cell with PUCCH format 1b with channel selection and up to 4 HARQ-ACK bits for M multiple downlink or special subframes associated with a single UL subframe *n*, where M is defined in subclause 10.1.3.2.1, and for the configured serving cells, spatial HARQ-ACK bundling is not performed and the HARQ-ACK bits are transmitted using PUCCH format 1b with channel selection.

In the case of TDD and more than one configured serving cell with PUCCH format 3 and without PUCCH format 4/5 configured and more than 20 HARQ-ACK bits for M multiple downlink or special subframes associated with a single UL subframe *n*, where M is the number of elements in the set K defined in subclause 10.1.3.2.2 and for the configured serving cells, spatial HARQ-ACK bundling across multiple codewords within a downlink or special subframe is performed for each serving cell by a logical AND operation of all of the corresponding individual HARQ-ACKs and PUCCH format 3 is used. For TDD and more than one configured serving cell with PUCCH format 3 and up to 20 HARQ-ACK bits for M multiple downlink or special subframes associated with a single UL subframe *n*, where

M is the number of elements in the set K defined in subclause 10.1.3.2.2 and for the configured serving cells, spatial HARQ-ACK bundling is not performed and the HARQ-ACK bits are transmitted using PUCCH format 3.

For TDD with PUCCH format 3 without PUCCH format 4/5 configured, a UE shall determine the number of HARQ-ACK bits, O, associated with an UL subframe *n*

according to $O=\sum_{c=1}^{N_{cells}^{DL}} O_c^{ACK}$ where N_{cells}^{DL} is the number of configured cells, and O_c^{ACK} is the number of HARQ-bits for the *c*-th serving cell defined in subclause 7.3.

TDD HARQ-ACK feedback procedures for one configured serving cell are given in subclause 10.1.3.1 and procedures for more than one configured serving cell are given in subclause 10.1.3.2.

10.1.3.1 TDD HARQ-ACK procedure for one configured serving cell

HARQ-ACK transmission on two antenna ports $(p \in [p_0, p_1])$ is supported for PUCCH format 1a/1b with TDD HARQ-ACK bundling feedback mode and for PUCCH format 3.

A UE that supports aggregating more than one serving cell with frame structure type 2 can be configured by higher layers for HARQ-ACK transmission on two antenna ports $(p \in [p_0, p_1])$ for PUCCH format 1b with channel selection.

The TDD HARQ-ACK procedure for a UE configured with PUCCH format 3 is as described in subclause 10.1.3.2.2 when the UE receives PDSCH and/or SPS release PDCCH/EPDCCH only on the primary cell.

If the UE is not configured with the higher layer parameter *EIMTA-MainConfigServCell-r12,* for TDD HARQ-ACK bundling or TDD HARQ-ACK multiplexing for one configured serving cell and a subframe *n* with $M=1$ where M is the number of elements in the set K defined in Table 10.1.3.1-1, the UE shall use PUCCH resource $n_{\text{PUCCH}}^{(1,\tilde{p})}$ for transmission of HARQ-ACK in subframe n for $\tilde{p}$ mapped to antenna port *p* for PUCCH format 1a/1b, where

- If there is PDSCH transmission indicated by the detection of corresponding PDCCH/EPDCCH or there is PDCCH/EPDCCH indicating downlink SPS release within subframe(s) $n-k$, where $k \in K$ and K (defined in Table 10.1.3.1-1) is a set of *M* elements $\{k_0, k_1, \cdots k_{M-1}\}$ depending on the subframe *n* and the UL/DL configuration (defined in Table 4.2-2 in [3]), and if PDCCH indicating PDSCH transmission or downlink SPS release is detected in subframe $n-k_m$, where k_m is the smallest value in set K such that UE detects a PDCCH/EPDCCH indicating PDSCH transmission or downlink SPS release within subframe(s) $n-k$ and $k \in K$, the UE first selects a c value out of {0, 1, 2, 3} which makes $N_c \le n_{\text{CCE}} < N_{c+1}$ and shall use $n_{\text{PUCCH}}^{(1,\tilde{p}_0)} = (M-m-1)\cdot N_c + m \cdot N_{c+1} + n_{\text{CCE}} + N_{\text{PUCCH}}^{(1)}$ for antenna port p_0, where $N_{\text{PUCCH}}^{(1)}$ is configured by higher layers, $N_c = \max\left\{0, \left\lfloor [N_{\text{RB}}^{\text{DL}} \cdot (N_{\text{sc}}^{\text{RB}} \cdot c - 4)]/36 \right\rfloor\right\}$, and n_{CCE} is the number of the first CCE used for transmission of the corresponding PDCCH in subframe $n-k_m$ and the corresponding *m*. When two antenna port transmission is configured for PUCCH format 1a/1b, the PUCCH resource for HARQ-ACK bundling for antenna port p_1 is given by $n_{\text{PUCCH}}^{(1,\tilde{p}_1)} = (M-m-1)\cdot N_c + m \cdot N_{c+1} + n_{\text{CCE}} + 1 + N_{\text{PUCCH}}^{(1)}$.

- For a non-BL/CE UE and if there is only a PDSCH transmission where there is not a corresponding PDCCH/EPDCCH detected within subframe(s) $n-k$, where $k \in K$ and K is defined in Table 10.1.3.1-1, the UE shall use PUCCH format 1a/1b and PUCCH resource $n_{\text{PUCCH}}^{(1,\tilde{p})}$ with the value of $n_{\text{PUCCH}}^{(1,\tilde{p})}$ is determined according to higher layer configuration and Table 9.2-2. For a UE configured for two antenna port transmission for PUCCH format 1a/1b and HARQ-ACK bundling, a PUCCH resource value in Table 9.2-2 maps to two PUCCH resources with the first PUCCH resource $n_{\text{PUCCH}}^{(1,\tilde{p}_0)}$ for antenna port p_0 and the second PUCCH resource $n_{\text{PUCCH}}^{(1,\tilde{p}_1)}$ for antenna port p_1, otherwise, the PUCCH resource value maps to a single PUCCH resource $n_{\text{PUCCH}}^{(1,\tilde{p}_0)}$ for antenna port p_0.

- If there is PDSCH transmission indicated by the detection of corresponding PDCCH/EPDCCH or there is PDCCH/EPDCCH indicating downlink SPS release within subframe(s) $n-k$, where $k \in K$ and K (defined in Table 10.1.3.1-1) is a set of *M* elements $\{k_0, k_1, \cdots k_{M-1}\}$ depending on the subframe *n* and the UL/DL configuration (defined in Table 4.2-2 in [3]), and if EPDCCH indicating PDSCH transmission or downlink SPS release is detected in subframe $n-k_m$, where k_m is the smallest value in set K such that UE detects a PDCCH/EPDCCH indicating PDSCH transmission or downlink SPS release within subframe(s) $n-k$ and $k \in K$, the UE shall use
  - if EPDCCH-PRB-set q is configured for distributed transmission

$$n_{\text{PUCCH}}^{(1,\tilde{p}_0)} = n_{\text{ECCE,q}} + \sum_{i1=0}^{m-1} N_{ECCE,q,n-k_{i1}} + \Delta_{ARO} + N_{\text{PUCCH,q}}^{(\text{e1})}$$

  - if EPDCCH-PRB-set q is configured for localized transmission

$$n_{\text{PUCCH}}^{(1,\tilde{p}_0)} = \left\lfloor \frac{n_{\text{ECCE,q}}}{N_{RB}^{ECCE,q}} \right\rfloor \cdot N_{RB}^{ECCE,q} + \sum_{i1=0}^{m-1} N_{ECCE,q,n-k_{i1}} + n' + \Delta_{ARO} + N_{\text{PUCCH,q}}^{(\text{e1})}$$

  for antenna port p_0, where $n_{\text{ECCE,q}}$ is the number of the first ECCE (i.e. lowest ECCE index used to construct the EPDCCH) used for transmission of the corresponding DCI assignment in EPDCCH-PRB-set q in subframe $n-k_m$ and the corresponding *m*, $N_{\text{PUCCH,q}}^{(\text{e1})}$ for EPDCCH-PRB-set q is configured by the higher layer parameter *pucch-ResourceStartOffset-r11* , $N_{RB}^{ECCE,q}$ for EPDCCH-PRB-set q in subframe $n-k_m$ is given in subclause 6.8A.1 in [3], n' is determined from the antenna port used for EPDCCH transmission in subframe $n-k_m$ which is described in subclause 6.8A.5 in [3]. If $m=0$, Δ_{ARO} is determined from the HARQ-ACK resource offset field in the DCI format of the corresponding EPDCCH as given in Table 10.1.2.1-1. If $m>0$, Δ_{ARO} is determined from the HARQ-ACK resource offset field in the DCI format of the corresponding EPDCCH as given in Table 10.1.3.1-2. If the UE is configured to monitor EPDCCH in subframe $n-k_{i1}$, $N_{ECCE,q,n-k_{i1}}$ is equal to the number of ECCEs in EPDCCH-PRB-set q configured for that UE in subframe $n-k_{i1}$. If the UE is not configured to monitor EPDCCH in subframe $n-k_{i1}$, $N_{ECCE,q,n-k_{i1}}$ is equal to the number of ECCEs computed assuming EPDCCH-PRB-set q is configured for that UE in subframe $n-k_{i1}$. For normal downlink CP, if subframe $n-k_{i1}$ is a special subframe with special subframe configuration 0 or 5, $N_{ECCE,q,n-k_{i1}}$ is equal to 0. For extended downlink CP, if subframe $n-k_{i1}$ is a special subframe with special subframe configuration 0 or 4 or 7, $N_{ECCE,q,n-k_{i1}}$ is equal to 0. When two antenna port transmission is configured for PUCCH format 1a/1b, the PUCCH resource for HARQ-ACK bundling for antenna port p_1 is given by

  - if EPDCCH-PRB-set q is configured for distributed transmission

$$n_{\text{PUCCH}}^{(1,\tilde{p}_1)} = n_{\text{ECCE,q}} + 1 + \sum_{i1=0}^{m-1} N_{ECCE,q,n-k_{i1}} + \Delta_{ARO} + N_{\text{PUCCH,q}}^{(\text{e1})}$$

  - if EPDCCH-PRB-set q is configured for localized transmission

$$n_{\text{PUCCH}}^{(1,\tilde{p}_1)} = \left\lfloor \frac{n_{\text{ECCE,q}}}{N_{RB}^{ECCE,q}} \right\rfloor \cdot N_{RB}^{ECCE,q} + 1 + \sum_{i1=0}^{m-1} N_{ECCE,q,n-k_{i1}} + n' + \Delta_{ARO} + N_{\text{PUCCH,q}}^{(\text{e1})}$$

- For a BL/CE UE, if there is only a PDSCH transmission within one or more consecutive BL/CE downlink subframe(s) where subframe $n-k$, is the last subframe in which the PDSCH is transmitted where $k \in K$ and K is defined in Table 10.1.3.1-1 and there is not a corresponding MPDCCH, the UE shall use PUCCH format

1a and PUCCH resource $n_{\mathrm{PUCCH}}^{(1,\mathrm{p}_0)}$ where the value of $n_{\mathrm{PUCCH}}^{(1,\mathrm{p}_0)}$ is determined according to higher layer configuration and Table 9.2-2.

- If there is PDSCH transmission indicated by the detection of corresponding MPDCCH or there is MPDCCH indicating downlink SPS release within subframe(s) $n-k$, where $k \in K$ and K (defined in Table 10.1.3.1-1) is a set of *M* elements $\{k_0, k_1, \cdots k_{M-1}\}$ depending on the subframe *n* and the UL/DL configuration (defined in Table 4.2-2 in [3]) and subframe $n-k_m$ is the last subframe in which the PDSCH or MPDCCH indicating downlink SPS release is transmitted and there is no $k_{m'} \in K$ where $k_{m'} < k_m$ and subframe $n-k_{m'}$ is the last subframe in which a PDSCH indicated by the detection of corresponding MPDCCH or MPDCCH indicating downlink SPS release is transmitted, the UE shall use

  - if MPDCCH-PRB-set q is configured for distributed transmission

$$n_{\mathrm{PUCCH}}^{(1,\mathrm{p}_0)} = n_{\mathrm{ECCE,q}} + \sum_{i1=0}^{m-1} N_{ECCE,q,n-k_{i1}} + \Delta_{ARO} + N_{\mathrm{PUCCH,q}}^{(m1)}$$

  - if MPDCCH-PRB-set q is configured for localized transmission

$$n_{\mathrm{PUCCH}}^{(1,\mathrm{p}_0)} = \left\lfloor \frac{n_{\mathrm{ECCE,q}}}{N_{RB}^{ECCE,q}} \right\rfloor \cdot N_{RB}^{ECCE,q} + \sum_{i1=0}^{m-1} N_{ECCE,q,n-k_{i1}} + n' + \Delta_{ARO} + N_{\mathrm{PUCCH,q}}^{(m1)}$$

for antenna port p_0, where $n_{\mathrm{ECCE,q}}$ is the number of the first ECCE (i.e. lowest ECCE index used to construct the MPDCCH) used for transmission of the corresponding DCI assignment in MPDCCH-PRB-set q, $N_{\mathrm{PUCCH,q}}^{(m1)}$ for MPDCCH-PRB-set q is configured

- o by the higher layer parameter *n1PUCCH-AN-r13*, if configured; otherwise:
- o by the higher layer parameter *n1PUCCH-AN-InfoList-r13* for the corresponding CE level,

$N_{RB}^{ECCE,q}$ for MPDCCH-PRB-set q is given in subclause 6.8A.1 in [3], n' is determined from the antenna port used for the MPDCCH transmission which is described in subclause 6.8A.5 in [3]. If $m=0$, Δ_{ARO} is determined from the HARQ-ACK resource offset field in the DCI format of the corresponding MPDCCH as given in Table 10.1.2.1-1. If $m>0$, Δ_{ARO} is determined from the HARQ-ACK resource offset field in the DCI format of the corresponding MPDCCH as given in Table 10.1.3.1-2. If subframe $n-k_{i1}$ is a BL/CE downlink subframe, $N_{ECCE,q,n-k_{i1}}$ is equal to the number of ECCEs in MPDCCH-PRB-set q configured for that UE in subframe $n-k_{i1}$. If subframe $n-k_{i1}$ is not a BL/CE downlink subframe, $N_{ECCE,q,n-k_{i1}}$ is equal to 0. For normal downlink CP, if subframe $n-k_{i1}$ is a special subframe with special subframe configuration 0 or 5, $N_{ECCE,q,n-k_{i1}}$ is equal to 0. For extended downlink CP, if subframe $n-k_{i1}$ is a special subframe with special subframe configuration 0 or 4 or 7, $N_{ECCE,q,n-k_{i1}}$ is equal to 0. When an MPDCCH-PRB-set p is 2+4, following procedures is applied.

- o if the detected MPDCCH is located within 2 PRB set, $n_{\mathrm{PUCCH}}^{(1,\mathrm{p}_0)}$ is obtained by above procedure.
- o if the detected MPDCCH is located within 4 PRB set, $n_{\mathrm{PUCCH}}^{(1,\mathrm{p}_0)}$ is the sum between $2N_{RB}^{ECCE,q}$ and the value obtained by above procedure.
- o if the detected MPDCCH is MPDCCH format 5, $n_{\mathrm{PUCCH}}^{(1,\mathrm{p}_0)}$ is obtained by the above procedure with $n_{\mathrm{ECCE,q}} = 0$.

Table 10.1.3.1-1: Downlink association set K : $\{k_0, k_1, \cdots k_{M-1}\}$ for TDD

UL/DL Configuration	Subframe *n*									
	0	1	2	3	4	5	6	7	8	9
0	-	-	6	-	4	-	-	6	-	4
1	-	-	7, 6	4	-	-	-	7, 6	4	-
2	-	-	8, 7, 4, 6	-	-	-	-	8, 7, 4, 6	-	-
3	-	-	7, 6, 11	6, 5	5, 4	-	-	-	-	-
4	-	-	12, 8, 7, 11	6, 5, 4, 7	-	-	-	-	-	-
5	-	-	13, 12, 9, 8, 7, 5, 4, 11, 6	-	-	-	-	-	-	-
6	-	-	7	7	5	-	-	7	7	-

Table 10.1.3.1-1A: eIMTA downlink association set K^A : $\{k_0^A, k_1^A, \ldots, k_{M^A-1}^A\}$ for TDD

Higher layer parameter '*eimta-HARQ-ReferenceConfig-r12*'	Higher layer parameter '*subframeAssignment*'	Subframe *n*									
		0	1	2	3	4	5	6	7	8	9
2	0	-	-	7,8,4	-	-	-	-	7,8,4	-	-
	1	-	-	8,4	-	-	-	-	8,4	-	-
	6	-	-	6,8,4	-	-	-	-	8,6,4	-	-
4	0	-	-	12,7,11,8	7,4,5,6	-	-	-	-	-	-
	1	-	-	12,8,11	7,5,6	-	-	-	-	-	-
	3	-	-	12,8	4,7	-	-	-	-	-	-
	6	-	-	12,11,8	4,5,6	-	-	-	-	-	-
5	0	-	-	12,7,11,13,8,4,9,5	-	-	-	-	-	-	-
	1	-	-	13,12,8,11,4,9,5	-	-	-	-	-	-	-
	2	-	-	13,12,9,11,5	-	-	-	-	-	-	-
	3	-	-	13,12,5,4,8,9	-	-	-	-	-	-	-
	4	-	-	13,5,4,6,9	-	-	-	-	-	-	-
	6	-	-	13,12,11,6,8,4,9,5	-	-	-	-	-	-	-

Table 10.1.3.1-2: Mapping of ACK/NACK Resource offset Field in DCI format 1A/1B/1D/1/2A/2/2B/2C/2D/6-1A/6-1B to Δ_{ARO} values for TDD when $m > 0$

ACK/NACK Resource offset field in DCI format 1A/1B/1D/1/2A/2/2B/2C/2D	Δ_{ARO}
0	0
1	$-\sum_{i1=0}^{m-1} N_{ECCE,q,n-k_{i1}} - 2$
2	$-\sum_{i1=m-\lceil m/3 \rceil}^{m-1} N_{ECCE,q,n-k_{i1}} - 1$
3	2

Table 10.1.3.1-3: Mapping of ACK/NACK Resource offset Field in DCI format 1A/1B/1D/1/2A/2/2B/2C/2D to Δ'_{ARO} values for TDD when $i4 = M'$ and $i5 \neq 0$

ACK/NACK Resource offset field in DCI format 1A/1B/1D/1/2A/2/2B/2C/2D	Δ'_{ARO}
0	0
1	$-\sum_{i1=0}^{i4-1} N'_{ECCE,q,n-k'_{i1}} - \sum_{i1=0}^{i5-1} N'_{ECCE,q,n-k^A_{i1}} - 2$
2	$-\sum_{i1=\min(i4,\, i4-\delta+i5)}^{i4-1} N'_{ECCE,q,n-k'_{i1}} - \sum_{i1=\max(0,\, i5-\delta)}^{i5-1} N'_{ECCE,q,n-k^A_{i1}} - 1 \quad , \delta = \left\lceil \frac{(i4+i5)}{3} \right\rceil$
3	2

If the UE is not configured with the higher layer parameter *EIMTA-MainConfigServCell-r12*, for TDD HARQ-ACK multiplexing and sub-frame n with $M > 1$ and one configured serving cell, where M is the number of elements in the set K defined in Table 10.1.3.1-1, denote $n^{(1)}_{\mathrm{PUCCH},i}$ as the PUCCH resource derived from sub-frame $n-k_i$ and HARQ-ACK(i) as the ACK/NACK/DTX response from sub-frame $n-k_i$, where $k_i \in K$ (defined in Table 10.1.3.1-1) and $0 \le i \le M-1$.

- For a PDSCH transmission indicated by the detection of corresponding PDCCH or a PDCCH indicating downlink SPS release in sub-frame $n-k_i$ where $k_i \in K$, the PUCCH resource $n^{(1)}_{\mathrm{PUCCH},i} = (M-i-1)\cdot N_c + i \cdot N_{c+1} + n_{\mathrm{CCE},i} + N^{(1)}_{\mathrm{PUCCH}}$, where c is selected from {0, 1, 2, 3} such that $N_c \le n_{\mathrm{CCE},i} < N_{c+1}$, $N_c = \max\left\{0, \left\lfloor [N^{\mathrm{DL}}_{\mathrm{RB}} \cdot (N^{\mathrm{RB}}_{\mathrm{sc}} \cdot c - 4)]/36 \right\rfloor\right\}$, $n_{\mathrm{CCE},i}$ is the number of the first CCE used for transmission of the corresponding PDCCH in subframe $n-k_i$, and $N^{(1)}_{\mathrm{PUCCH}}$ is configured by higher layers.

- For a PDSCH transmission where there is not a corresponding PDCCH/EPDCCH detected in subframe $n-k_i$, the value of $n^{(1)}_{\mathrm{PUCCH},i}$ is determined according to higher layer configuration and Table 9.2-2.

- For a non-BL/CE UE and for a PDSCH transmission indicated by the detection of corresponding EPDCCH or a EPDCCH indicating downlink SPS release in sub-frame $n-k_i$ where $k_i \in K$, the UE shall use

  - if EPDCCH-PRB-set q is configured for distributed transmission

$$n^{(1)}_{\mathrm{PUCCH,i}} = n_{\mathrm{ECCE,q}} + \sum_{i1=0}^{i-1} N_{ECCE,q,n-k_{i1}} + \Delta_{ARO} + N^{(\mathrm{e1})}_{\mathrm{PUCCH,q}}$$

  - if EPDCCH-PRB-set q is configured for localized transmission

$$n^{(1)}_{\mathrm{PUCCH,i}} = \left\lfloor \frac{n_{\mathrm{ECCE,q}}}{N^{ECCE,q}_{RB}} \right\rfloor \cdot N^{ECCE,q}_{RB} + \sum_{i1=0}^{i-1} N_{ECCE,q,n-k_{i1}} + n' + \Delta_{ARO} + N^{(\mathrm{e1})}_{\mathrm{PUCCH,q}}$$

  where $n_{\mathrm{ECCE,q}}$ is the number of the first ECCE (i.e. lowest ECCE index used to construct the EPDCCH) used for transmission of the corresponding DCI assignment in EPDCCH-PRB-set q in subframe $n-k_i$, $N^{(\mathrm{e1})}_{\mathrm{PUCCH,q}}$ for EPDCCH-PRB-set q is configured by the higher layer parameter *pucch-ResourceStartOffset-r11* , $N^{ECCE,q}_{RB}$ for EPDCCH-PRB-set q in subframe $n-k_i$ is given in subclause 6.8A.1 in [3], n' is determined from the antenna port used for EPDCCH transmission in subframe $n-k_i$ which is described in subclause 6.8A.5 in [3]. If $i = 0$, Δ_{ARO} is determined from the HARQ-ACK resource offset field in the DCI format of the corresponding EPDCCH as given in Table 10.1.2.1-1. If $i > 0$, Δ_{ARO} is determined from the HARQ-ACK resource offset field in the DCI format of the corresponding EPDCCH as given in Table 10.1.3.1-2, where the variable m in the table is substituted with i. If the UE is configured to monitor EPDCCH in subframe $n-k_{i1}$, $N_{ECCE,q,n-k_{i1}}$ is equal to the number of ECCEs in EPDCCH-PRB-set q configured for that UE in subframe $n-k_{i1}$. If the UE is not configured to monitor EPDCCH in subframe $n-k_{i1}$, $N_{ECCE,q,n-k_{i1}}$ is equal to the number of ECCEs computed assuming EPDCCH-PRB-set q is configured for that UE in subframe $n-k_{i1}$. For normal downlink CP, if subframe $n-k_{i1}$ is a special subframe with special subframe configuration 0 or 5, $N_{ECCE,q,n-k_{i1}}$ is equal to 0. For extended downlink CP, if subframe $n-k_{i1}$ is a special subframe with special subframe configuration 0 or 4 or 7, $N_{ECCE,q,n-k_{i1}}$ is equal to 0.

- For a BL/CE UE, for a PDSCH transmission detected in subframe $n-k_i$ without a corresponding MPDCCH, the value of $n^{(1)}_{\mathrm{PUCCH},i}$ is determined according to higher layer configuration and Table 9.2-2.

- For a BL/CE UE, for a PDSCH transmission in sub-frame $n-k_i$ where $k_i \in K$ indicated by the detection of corresponding MPDCCH or a MPDCCH indicating downlink SPS release in sub-frame $n-k_i$ where $k_i \in K$, the UE shall use

  - if MPDCCH-PRB-set q is configured for distributed transmission

$$n^{(1)}_{\mathrm{PUCCH,i}} = n_{\mathrm{ECCE,q}} + \sum_{i1=0}^{i-1} N_{ECCE,q,n-k_{i1}} + \Delta_{ARO} + N^{(m1)}_{\mathrm{PUCCH,q}}$$

  - if MPDCCH-PRB-set q is configured for localized transmission

$$n^{(1)}_{\mathrm{PUCCH,i}} = \left\lfloor \frac{n_{\mathrm{ECCE,q}}}{N_{RB}^{ECCE,q}} \right\rfloor \cdot N_{RB}^{ECCE,q} + \sum_{i1=0}^{i-1} N_{ECCE,q,n-k_{i1}} + n' + \Delta_{ARO} + N^{(m1)}_{\mathrm{PUCCH,q}}$$

where $n_{\mathrm{ECCE,q}}$ is the number of the first ECCE (i.e. lowest ECCE index used to construct the MPDCCH) used for transmission of the corresponding DCI assignment in MPDCCH-PRB-set q, $N^{(m1)}_{\mathrm{PUCCH,q}}$ for MPDCCH-PRB-set q is configured by the higher layer parameter *n1PUCCH-AN-InfoList-r13* for the corresponding CE level, $N_{RB}^{ECCE,q}$ for MPDCCH-PRB-set q is given in subclause 6.8A.1 in [3], n' is determined from the antenna port used for the MPDCCH transmission which is described in subclause 6.8A.5 in [3]. If $i = 0$, Δ_{ARO} is determined from the HARQ-ACK resource offset field in the DCI format of the corresponding MPDCCH as given in Table 10.1.2.1-1. If $i > 0$, Δ_{ARO} is determined from the HARQ-ACK resource offset field in the DCI format of the corresponding MPDCCH as given in Table 10.1.3.1-2, where the variable m in the table is substituted with i. If subframe $n-k_{i1}$ is a BL/CE downlink subframe, $N_{ECCE,q,n-k_{i1}}$ is equal to the number of ECCEs in MPDCCH-PRB-set q configured for that UE in subframe $n-k_{i1}$. If subframe $n-k_{i1}$ is not a BL/CE downlink subframe, $N_{ECCE,q,n-k_{i1}}$ is equal to 0. For normal downlink CP, if subframe $n-k_{i1}$ is a special subframe with special subframe configuration 0 or 5, $N_{ECCE,q,n-k_{i1}}$ is equal to 0. For extended downlink CP, if subframe $n-k_{i1}$ is a special subframe with special subframe configuration 0 or 4 or 7, $N_{ECCE,q,n-k_{i1}}$ is equal to 0. When an MPDCCH-PRB-set p is 2+4, following procedures is applied.

  - o if the detected MPDCCH is located within 2 PRB set, $n^{(1,\mathrm{p}_0)}_{\mathrm{PUCCH}}$ is obtained by above procedure.

  - o if the detected MPDCCH is located within 4 PRB set, $n^{(1,\mathrm{p}_0)}_{\mathrm{PUCCH}}$ is the sum between $2N_{RB}^{ECCE,q}$ and the value obtained by above procedure.

- o if the detected MPDCCH is MPDCCH format 5, $n_{\text{PUCCH}}^{(1,p_0)}$ is obtained by the above procedure with $n_{\text{ECCE,q}} = 0$.

If a UE is configured with the higher layer parameter *EIMTA-MainConfigServCell-r12*, then $K' = K$ where the set K is defined in Table 10.1.3.1-1 (where "UL/DL configuration" in the table refers to the higher layer parameter *subframeAsssignment*), and M' is the number of elements in set K'.

If a UE is configured with the higher layer parameter *EIMTA-MainConfigServCell-r12*, then the set K for the rest of this subclause is as defined in Sec 10.2, and M is the number of elements for subframe *n* in the set K

If the UE is configured with the higher layer parameter *EIMTA-MainConfigServCell-r12*, for TDD HARQ-ACK multiplexing and sub-frame n, denote $n_{\text{PUCCH},i0}^{(1)}$ as the PUCCH resource derived from sub-frame $n-k_i$ and HARQ-ACK(i0) as the ACK/NACK/DTX response from sub-frame $n-k_i$, where $k_i \in K$, and $0 \le i \le M-1$.

- $i0$ corresponding to each subframe $n-k_i, \forall i, 0 \le i \le M-1$ is determined as follows

    Set $b = 0$;

    for $i2 = 0,1,\ldots M' - 1$

        if the value of k'_{i2} is the same as the value of an element k_i in set K, where $k'_{i2} \in K'$,

            $i0$ corresponding to subframe $n-k_i = b$;

            $b = b+1$

        end if

    end for

        for $i3 = 0,1,...,M^A - 1$

            if the value of k_{i3}^A is same as the value of an element k_i in set K, where $k_{i3}^A \in K^A$ (defined in Table 10.1.3.1-1A)

                $i0$ corresponding to subframe $n-k_i = b$;

                $b = b+1$

            end if

    end for

- For a PDSCH transmission indicated by the detection of corresponding PDCCH or a PDCCH indicating downlink SPS release in sub-frame $n-k_i$,

    - if the value of k_i is same as the value of an element k'_{i2} in set K', the PUCCH resource $n_{\text{PUCCH},i0}^{(1)}$ is given by $n_{\text{PUCCH},i0}^{(1)} = (M' - i2 - 1)\cdot N_c + i2 \cdot N_{c+1} + n_{\text{CCE},i} + N_{\text{PUCCH}}^{(1)}$;

    - otherwise, if the value of k_i is same as the value of an element k_{i3}^A in set K^A, where $k_{i3}^A \in K^A$ (defined in Table 10.1.3.1-1A), the UE shall set, the PUCCH resource $n_{\text{PUCCH},i0}^{(1)}$ is given by $n_{PUCCH,i0}^{(1)} = (M^A - i3 - 1)\cdot N_c + i3 \cdot N_{c+1} + n_{CCE,i} + N_{PUCCH}^{K^A}$;

where M^A is the number of elements in the set K^A defined in Table 10.1.3.1-1A , c is selected from {0, 1, 2, 3} such that $N_c \le n_{\text{CCE},i} < N_{c+1}$, $N_c = \max\left\{0, \left\lfloor [N_{\text{RB}}^{\text{DL}} \cdot (N_{\text{sc}}^{\text{RB}} \cdot c - 4)]/36 \right\rfloor\right\}$, $n_{\text{CCE},i}$ is the number of the first CCE used for transmission of the corresponding PDCCH in subframe $n-k_i$, and $N_{\text{PUCCH}}^{\text{K}^A}$, $N_{\text{PUCCH}}^{(1)}$, are configured by higher layers.

- For a PDSCH transmission where there is not a corresponding PDCCH/EPDCCH detected in subframe $n-k_i$, the value of $n_{\text{PUCCH},i0}^{(1)}$ is determined according to higher layer configuration and Table 9.2-2.

- For a PDSCH transmission indicated by the detection of corresponding EPDCCH or a EPDCCH indicating downlink SPS release in sub-frame $n-k_i$ where $k_i \in K$, the UE shall use

  - if EPDCCH-PRB-set q is configured for distributed transmission
  $$n_{\text{PUCCH,i0}}^{(1)} = n_{\text{ECCE,q}} + \sum_{i1=0}^{i4-1} N'_{ECCE,q,n-k'_{i1}} + \sum_{i1=0}^{i5-1} N'_{ECCE,q,n-k^A_{i1}} + \Delta'_{ARO} + N_{\text{PUCCH,q}}^{(\text{e1})}$$

  - if EPDCCH-PRB-set q is configured for localized transmission
  $$n_{\text{PUCCH,i0}}^{(1)} = \left\lfloor \frac{n_{\text{ECCE,q}}}{N_{RB}^{ECCE,q}} \right\rfloor \cdot N_{RB}^{ECCE,q} + \sum_{i1=0}^{i4-1} N'_{ECCE,q,n-k'_{i1}} + \sum_{i1=0}^{i5-1} N'_{ECCE,q,n-k^A_{i1}} + n' + \Delta'_{ARO} + N_{\text{PUCCH,q}}^{(\text{e1})}$$

  where

  - if the value of k_i is same as the value of an index k'_{i2}, where $k'_{i2} \in K'$, then $i4 = i2$ and $i5 = 0$;

  - otherwise, if the value of k_i is same as the value of an index k^A_{i3}, where $k^A_{i3} \in K^A$, then $i4 = M'$ and $i5 = i3$;

, and where $n_{\text{ECCE,q}}$ is the number of the first ECCE (i.e. lowest ECCE index used to construct the EPDCCH) used for transmission of the corresponding DCI assignment in EPDCCH-PRB-set q in subframe $n-k_i$, $N_{\text{PUCCH,q}}^{(\text{e1})}$ for EPDCCH-PRB-set q is configured by the higher layer parameter *pucch-ResourceStartOffset-r11* , $N_{RB}^{ECCE,q}$ for EPDCCH-PRB-set q in subframe $n-k_i$ is given in subclause 6.8A.1 in [3], n' is determined from the antenna port used for EPDCCH transmission in subframe $n-k_i$ which is described in subclause 6.8A.5 in [3].

Δ'_{ARO} is determined as follows

- If $i4 = 0$ and $i5 = 0$, Δ'_{ARO} is determined from the HARQ-ACK resource offset field in the DCI format of the corresponding EPDCCH as given in Table 10.1.2.1-1.

- If $0 < i4 < M'$ and $i5 = 0$, Δ'_{ARO} is determined from the HARQ-ACK resource offset field in the DCI format of the corresponding EPDCCH as given in Table 10.1.3.1-2, where the variable Δ_{ARO} in the table is substituted with Δ'_{ARO}, the variable m in the table is substituted with $i4$, the variable N in the table is substituted with N' and the variable k_{i1} in the table is substituted with k'_{i1}.

- If $i4 = M'$ and $i5 \ne 0$, Δ'_{ARO} is determined from the HARQ-ACK resource offset field in the DCI format of the corresponding EPDCCH as given in Table 10.1.3.1-3,

For a given subframe u, $N'_{ECCE,q,u}$ is determined as follows

- If the UE is configured to monitor EPDCCH in subframe u, $N'_{ECCE,q,u}$ is equal to the number of ECCEs in EPDCCH-PRB-set q configured for that UE in subframe u.

- If the UE is not configured to monitor EPDCCH in subframe u, $N'_{ECCE,q,u}$ is equal to the number of ECCEs computed assuming EPDCCH-PRB-set q is configured for that UE in subframe u.
- For normal downlink CP, if subframe u is a special subframe with special subframe configuration 0 or 5, $N'_{ECCE,q,u}$ is equal to 0.
- For extended downlink CP, if subframe u is a special subframe with special subframe configuration 0 or 4 or 7, $N'_{ECCE,q,u}$ is equal to 0.

For a non-BL/CE UE, if the UE is not configured with two antenna port transmission for PUCCH format 1b with channel selection, and if the UE is not configured with the higher layer parameter *EIMTA-MainConfigServCell-r12*, based on higher layer signalling the UE configured with a single serving cell will perform channel selection either according to the set of Tables 10.1.3-2, 10.1.3-3, and 10.1.3-4 or according to the set of Tables 10.1.3-5, 10.1.3-6, and 10.1.3-7.

If a UE is configured with two antenna port transmission for PUCCH format 1b with channel selection, and if the UE is not configured with the higher layer parameter *EIMTA-MainConfigServCell-r12*, then the UE will perform channel selection according to the set of Tables 10.1.3-5, 10.1.3-6, and 10.1.3-7.

If the UE is configured with the higher layer parameter *EIMTA-MainConfigServCell-r12*, the UE configured with a single serving cell will perform channel selection according to the set of Tables 10.1.3-5, 10.1.3-6, and 10.1.3-7.

For the selected table set, the UE shall transmit $b(0),b(1)$ on PUCCH resource $n^{(1,\tilde{p})}_{\text{PUCCH}}$ in sub-frame n for $\tilde{p}$ mapped to antenna port p using PUCCH format 1b according to subclause 5.4.1 in [3] where

- $n^{(1,\tilde{p})}_{\text{PUCCH}} = n^{(1)}_{\text{PUCCH}}$ for antenna port p_0 and the value of $b(0),b(1)$ and the PUCCH resource $n^{(1)}_{\text{PUCCH}}$ are generated by channel selection according to the selected set of Tables for M = 2, 3, and 4 respectively
- $n^{(1,\tilde{p}_1)}_{\text{PUCCH}}$ for antenna port p_1, where $n^{(1,\tilde{p}_1)}_{\text{PUCCH}}$ is selected from PUCCH resources $n^{(1,\tilde{p}_1)}_{\text{PUCCH},i}$ configured by higher layers where $0 \le i \le M-1$, according to selected set of Tables for M = 2, 3, and 4 respectively by replacing $n^{(1)}_{\text{PUCCH}}$ with $n^{(1,\tilde{p}_1)}_{\text{PUCCH}}$ and replacing $n^{(1)}_{\text{PUCCH},i}$ with $n^{(1,\tilde{p}_1)}_{\text{PUCCH},i}$, when the UE is configured with two antenna port transmission for PUCCH format 1b with channel selection.

Table 10.1.3-2: Transmission of HARQ-ACK multiplexing for *M* = 2

HARQ-ACK(0), HARQ-ACK(1)	$n^{(1)}_{\text{PUCCH}}$	$b(0),b(1)$
ACK, ACK	$n^{(1)}_{\text{PUCCH},1}$	1, 1
ACK, NACK/DTX	$n^{(1)}_{\text{PUCCH},0}$	0, 1
NACK/DTX, ACK	$n^{(1)}_{\text{PUCCH},1}$	0, 0
NACK/DTX, NACK	$n^{(1)}_{\text{PUCCH},1}$	1, 0
NACK, DTX	$n^{(1)}_{\text{PUCCH},0}$	1, 0
DTX, DTX	No transmission	

Table 10.1.3-3: Transmission of HARQ-ACK multiplexing for *M* = 3

HARQ-ACK(0), HARQ-ACK(1), HARQ-ACK(2)	$n_{\mathrm{PUCCH}}^{(1)}$	$b(0), b(1)$
ACK, ACK, ACK	$n_{\mathrm{PUCCH},2}^{(1)}$	1, 1
ACK, ACK, NACK/DTX	$n_{\mathrm{PUCCH},1}^{(1)}$	1, 1
ACK, NACK/DTX, ACK	$n_{\mathrm{PUCCH},0}^{(1)}$	1, 1
ACK, NACK/DTX, NACK/DTX	$n_{\mathrm{PUCCH},0}^{(1)}$	0, 1
NACK/DTX, ACK, ACK	$n_{\mathrm{PUCCH},2}^{(1)}$	1, 0
NACK/DTX, ACK, NACK/DTX	$n_{\mathrm{PUCCH},1}^{(1)}$	0, 0
NACK/DTX, NACK/DTX, ACK	$n_{\mathrm{PUCCH},2}^{(1)}$	0, 0
DTX, DTX, NACK	$n_{\mathrm{PUCCH},2}^{(1)}$	0, 1
DTX, NACK, NACK/DTX	$n_{\mathrm{PUCCH},1}^{(1)}$	1, 0
NACK, NACK/DTX, NACK/DTX	$n_{\mathrm{PUCCH},0}^{(1)}$	1, 0
DTX, DTX, DTX	No transmission	

Table 10.1.3-4: Transmission of HARQ-ACK multiplexing for *M* = 4

HARQ-ACK(0), HARQ-ACK(1), HARQ-ACK(2), HARQ-ACK(3)	$n^{(1)}_{\mathrm{PUCCH}}$	$b(0), b(1)$
ACK, ACK, ACK, ACK	$n^{(1)}_{\mathrm{PUCCH},1}$	1, 1
ACK, ACK, ACK, NACK/DTX	$n^{(1)}_{\mathrm{PUCCH},1}$	1, 0
NACK/DTX,NACK/DTX,NACK,DTX	$n^{(1)}_{\mathrm{PUCCH},2}$	1, 1
ACK, ACK, NACK/DTX, ACK	$n^{(1)}_{\mathrm{PUCCH},1}$	1, 0
NACK, DTX, DTX, DTX	$n^{(1)}_{\mathrm{PUCCH},0}$	1, 0
ACK, ACK, NACK/DTX, NACK/DTX	$n^{(1)}_{\mathrm{PUCCH},1}$	1, 0
ACK, NACK/DTX, ACK, ACK	$n^{(1)}_{\mathrm{PUCCH},3}$	0, 1
NACK/DTX, NACK/DTX, NACK/DTX, NACK	$n^{(1)}_{\mathrm{PUCCH},3}$	1, 1
ACK, NACK/DTX, ACK, NACK/DTX	$n^{(1)}_{\mathrm{PUCCH},2}$	0, 1
ACK, NACK/DTX, NACK/DTX, ACK	$n^{(1)}_{\mathrm{PUCCH},0}$	0, 1
ACK, NACK/DTX, NACK/DTX, NACK/DTX	$n^{(1)}_{\mathrm{PUCCH},0}$	1, 1
NACK/DTX, ACK, ACK, ACK	$n^{(1)}_{\mathrm{PUCCH},3}$	0, 1
NACK/DTX, NACK, DTX, DTX	$n^{(1)}_{\mathrm{PUCCH},1}$	0, 0
NACK/DTX, ACK, ACK, NACK/DTX	$n^{(1)}_{\mathrm{PUCCH},2}$	1, 0
NACK/DTX, ACK, NACK/DTX, ACK	$n^{(1)}_{\mathrm{PUCCH},3}$	1, 0
NACK/DTX, ACK, NACK/DTX, NACK/DTX	$n^{(1)}_{\mathrm{PUCCH},1}$	0, 1
NACK/DTX, NACK/DTX, ACK, ACK	$n^{(1)}_{\mathrm{PUCCH},3}$	0, 1
NACK/DTX, NACK/DTX, ACK, NACK/DTX	$n^{(1)}_{\mathrm{PUCCH},2}$	0, 0
NACK/DTX, NACK/DTX, NACK/DTX, ACK	$n^{(1)}_{\mathrm{PUCCH},3}$	0, 0
DTX, DTX, DTX, DTX	No transmission	

Table 10.1.3-5: Transmission of HARQ-ACK multiplexing for *M* = 2

HARQ-ACK(0), HARQ-ACK(1)	$n^{(1)}_{\mathrm{PUCCH}}$	$b(0)b(1)$
ACK, ACK	$n^{(1)}_{\mathrm{PUCCH},1}$	1, 0
ACK, NACK/DTX	$n^{(1)}_{\mathrm{PUCCH},0}$	1, 1
NACK/DTX, ACK	$n^{(1)}_{\mathrm{PUCCH},1}$	0, 1
NACK, NACK/DTX	$n^{(1)}_{\mathrm{PUCCH},0}$	0, 0
DTX, NACK/DTX	No Transmission	

Table 10.1.3-6: Transmission of HARQ-ACK multiplexing for *M* = 3

HARQ-ACK(0), HARQ-ACK(1), HARQ-ACK(2)	$n^{(1)}_{\text{PUCCH}}$	$b(0)b(1)$
ACK, ACK, ACK	$n^{(1)}_{\text{PUCCH},2}$	1, 1
ACK, ACK, NACK/DTX	$n^{(1)}_{\text{PUCCH},1}$	1, 0
ACK, NACK/DTX, ACK	$n^{(1)}_{\text{PUCCH},2}$	1, 0
ACK, NACK/DTX, NACK/DTX	$n^{(1)}_{\text{PUCCH},0}$	1, 1
NACK/DTX, ACK, ACK	$n^{(1)}_{\text{PUCCH},2}$	0, 1
NACK/DTX, ACK, NACK/DTX	$n^{(1)}_{\text{PUCCH},1}$	0, 1
NACK/DTX, NACK/DTX, ACK	$n^{(1)}_{\text{PUCCH},2}$	0, 0
NACK, NACK/DTX, NACK/DTX	$n^{(1)}_{\text{PUCCH},0}$	0, 0
DTX, NACK/DTX, NACK/DTX	No Transmission	

Table 10.1.3-7: Transmission of HARQ-ACK multiplexing for *M* = 4

HARQ-ACK(0), HARQ-ACK(1), HARQ-ACK(2), HARQ-ACK(3)	$n^{(1)}_{\text{PUCCH}}$	$b(0)b(1)$
ACK, ACK, ACK, ACK	$n^{(1)}_{\text{PUCCH},1}$	1, 1
ACK, ACK, ACK, NACK/DTX	$n^{(1)}_{\text{PUCCH},2}$	1, 1
ACK, ACK, NACK/DTX, ACK	$n^{(1)}_{\text{PUCCH},0}$	1, 0
ACK, ACK, NACK/DTX, NACK/DTX	$n^{(1)}_{\text{PUCCH},1}$	1, 0
ACK, NACK/DTX, ACK, ACK	$n^{(1)}_{\text{PUCCH},3}$	1, 1
ACK, NACK/DTX, ACK, NACK/DTX	$n^{(1)}_{\text{PUCCH},2}$	1, 0
ACK, NACK/DTX, NACK/DTX, ACK	$n^{(1)}_{\text{PUCCH},0}$	0, 1
ACK, NACK/DTX, NACK/DTX, NACK/DTX	$n^{(1)}_{\text{PUCCH},0}$	1, 1
NACK/DTX, ACK, ACK, ACK	$n^{(1)}_{\text{PUCCH},1}$	0, 0
NACK/DTX, ACK, ACK, NACK/DTX	$n^{(1)}_{\text{PUCCH},2}$	0, 1
NACK/DTX, ACK, NACK/DTX, ACK	$n^{(1)}_{\text{PUCCH},3}$	1, 0
NACK/DTX, ACK, NACK/DTX, NACK/DTX	$n^{(1)}_{\text{PUCCH},1}$	0, 1
NACK/DTX, NACK/DTX, ACK, ACK	$n^{(1)}_{\text{PUCCH},3}$	0, 1
NACK/DTX, NACK/DTX, ACK, NACK/DTX	$n^{(1)}_{\text{PUCCH},2}$	0, 0
NACK/DTX, NACK/DTX, NACK/DTX, ACK	$n^{(1)}_{\text{PUCCH},3}$	0, 0
NACK, NACK/DTX, NACK/DTX, NACK/DTX	$n^{(1)}_{\text{PUCCH},0}$	0, 0
DTX, NACK/DTX, NACK/DTX, NACK/DTX	No Transmission	

10.1.3.2 TDD HARQ-ACK procedure for more than one configured serving cell

If a UE configured with *EIMTA-MainConfigServCell-r12* for a serving cell, "UL/DL configuration" of the serving cell in the rest of this subclause refers to the UL/DL configuration given by the parameter *eimta-HARQ-ReferenceConfig-r12* for the serving cell unless specified otherwise.

The TDD HARQ-ACK feedback procedures for more than one configured serving cell are either based on a PUCCH format 1b with channel selection HARQ-ACK procedure as described in subclause 10.1.3.2.1 or a PUCCH format 3 HARQ-ACK procedure as described in subclause 10.1.3.2.2 or a PUCCH format 4 HARQ-ACK procedure as described in subclause 10.1.3.2.3 or a PUCCH format 5 HARQ-ACK procedure as described in subclause 10.1.3.2.4.

HARQ-ACK transmission on two antenna ports $(p \in [p_0, p_1])$ is supported for PUCCH format 3 and TDD with more than one configured serving cell.

If a UE is configured with more than one serving cell and the TDD UL/DL configurations of all serving cells are the same, TDD UL/DL configuration 5 with PUCCH format 3 is only supported for up to two configured serving cells. If a UE is configured with two serving cells and the TDD UL/DL configuration of the two serving cells is the same, TDD UL/DL configuration 5 with PUCCH format 1b with channel selection for two configured serving cells is not supported. If a UE is configured with two serving cells and if the TDD UL/DL configuration of the two serving cells are not the same and if the DL-reference UL/DL configuration (as defined in subclause 10.2) of at least one serving cell is TDD UL/DL Configuration 5, PUCCH format 1b with channel selection is not supported.

If a UE is configured with the parameter *EIMTA-MainConfigServCell-r12* for at least one serving cell and is configured with PUCCH format 3 without PUCCH format 4/5 configured, the UE is not expected to be configured with more than two serving cells having UL/DL Configuration 5 as a DL-reference UL/DL configuration.

HARQ-ACK transmission on two antenna ports $(p \in [p_0, p_1])$ is supported for PUCCH format 1b with channel selection and TDD with two configured serving cells.

10.1.3.2.1 PUCCH format 1b with channel selection HARQ-ACK procedure

If a UE is configured with the higher layer parameter *EIMTA-MainConfigServCell-r12*, then $K' = K$ where the set K is defined in Table 10.1.3.1-1 (where "UL/DL configuration" in the table refers to the higher layer parameter *subframeAssignment*), and M' is the number of elements in set K'.

If a UE is configured with two serving cells with the same UL/DL configurations, then in the rest of this subcaluse, K is as defined in Sec 10.2 and M is the number of elements for subframe *n* in the set K , and $M_{primary} = M$.

If a UE is configured with two serving cells with different UL/DL configurations,

- then the UE shall determine M for a subframe *n* in this subclause as $M = \max(M_{primary}, M_{secondary})$, where
  - $M_{primary}$ denotes the number of elements for subframe *n* in the set K for the primary cell (as defined in subclause 10.2)
  - $M_{secondary}$ denotes the number of elements for subframe *n* in the set K_c for the secondary serving cell (as defined in subclause 10.2)
- if $M_{secondary} < M$, then the UE shall, for the secondary serving cell, set HARQ-ACK(j) to DTX for *j* = $M_{secondary}$ to $M-1$.
- if $M_{primary} < M$, then the UE shall, for the primary cell, set HARQ-ACK(j) to DTX for *j* = $M_{primary}$ to $M-1$

If the UE is configured with two serving cells with different UL/DL configurations, then in the rest of this subclause, $K = K_c$ where K_c is defined in subclause 10.2.

For TDD HARQ-ACK multiplexing with PUCCH format 1b with channel selection and two configured serving cells and a subframe *n* with $M = 1$, a UE shall determine the number of HARQ-ACK bits, O, based on the number of configured serving cells and the downlink transmission modes configured for each serving cell. The UE shall use two HARQ-ACK bits for a serving cell configured with a downlink transmission mode that supports up to two transport blocks; and one HARQ-ACK bit otherwise.

For TDD HARQ-ACK multiplexing with PUCCH format 1b with channel selection and two configured serving cells and a subframe *n* with $M \le 2$, the UE shall transmit $b(0)b(1)$ on PUCCH resource $n_{\mathrm{PUCCH}}^{(1,\tilde{p})}$ for $\tilde{p}$ mapped to antenna port *p* using PUCCH format 1b where

- $n_{\mathrm{PUCCH}}^{(1,\tilde{p})} = n_{\mathrm{PUCCH}}^{(1)}$ for antenna port p_0, where $n_{\mathrm{PUCCH}}^{(1)}$ selected from A PUCCH resources, $n_{\mathrm{PUCCH},j}^{(1)}$ where $0 \le j \le A-1$ and $A \in \{2,3,4\}$, according to Tables 10.1.3.2-1, 10.1.3.2-2, and 10.1.3.2-3 in subframe n using PUCCH format 1b.
- $n_{\mathrm{PUCCH}}^{(1,\tilde{p}_1)}$ for antenna port p_1, where $n_{\mathrm{PUCCH}}^{(1,\tilde{p}_1)}$ selected from A PUCCH resources, $n_{\mathrm{PUCCH},j}^{(1,\tilde{p}_1)}$ configured by higher layers where $0 \le j \le A-1$ and $A \in \{2,3,4\}$, according to Tables 10.1.3.2-1, 10.1.3.2-2, and 10.1.3.2-3 by replacing $n_{\mathrm{PUCCH}}^{(1)}$ with $n_{\mathrm{PUCCH}}^{(1,\tilde{p}_1)}$ and replacing $n_{\mathrm{PUCCH},i}^{(1)}$ with $n_{\mathrm{PUCCH},i}^{(1,\tilde{p}_1)}$ in subframe n, when the UE is configured with two antenna port transmission for PUCCH format 1b with channel selection,

and for a subframe *n* with $M = 1$, HARQ-ACK(*j*) denotes the ACK/NACK/DTX response for a transport block or SPS release PDCCH/EPDCCH associated with serving cell, where the transport block and serving cell for HARQ-ACK(*j*) and A PUCCH resources are given by Table 10.1.2.2.1-1. For a subframe *n* with $M = 2$, HARQ-ACK(*j*) denotes the ACK/NACK/DTX response for a PDSCH transmission or SPS release PDCCH/EPDCCH within subframe(s) given by set K on each serving cell, where the subframes on each serving cell for HARQ-ACK(*j*) and A PUCCH resources are given by Table 10.1.3.2-4.

If the UE is not configured with the higher layer parameter *EIMTA-MainConfigServCell-r12*, the UE shall determine the A PUCCH resources, $n_{\mathrm{PUCCH},j}^{(1)}$ associated with HARQ-ACK(*j*) where $0 \le j \le A-1$ in Table 10.1.2.2.1-1 for $M = 1$ and Table 10.1.3.2-4 for $M = 2$, according to

- for a PDSCH transmission indicated by the detection of a corresponding PDCCH in subframe $n-k_m$, where $k_m \in K$ on the primary cell, or for a PDCCH indicating downlink SPS release (defined in subclause 9.2) in subframe $n-k_m$, where $k_m \in K$ on the primary cell, the PUCCH resource is $n_{\mathrm{PUCCH},j}^{(1)} = \left(M_{primary} - m - 1\right) \cdot N_c + m \cdot N_{c+1} + n_{\mathrm{CCE},m} + N_{\mathrm{PUCCH}}^{(1)}$, where c is selected from {0, 1, 2, 3} such that $N_c \le n_{\mathrm{CCE},m} < N_{c+1}$, $N_c = \max\left\{0, \left\lfloor [N_{\mathrm{RB}}^{\mathrm{DL}} \cdot (N_{\mathrm{sc}}^{\mathrm{RB}} \cdot c - 4)] / 36 \right\rfloor\right\}$ where $N_{\mathrm{RB}}^{\mathrm{DL}}$ is determined from the primary cell, and for a subframe *n* with $M = 1$ and a transmission mode that supports up to two transport blocks on the serving cell where the corresponding PDSCH transmission occurs, the PUCCH resource $n_{\mathrm{PUCCH},j+1}^{(1)}$ is given by $n_{\mathrm{PUCCH},j+1}^{(1)} = \left(M_{primary} - m - 1\right) \cdot N_c + m \cdot N_{c+1} + n_{\mathrm{CCE},m} + 1 + N_{\mathrm{PUCCH}}^{(1)}$ where $n_{\mathrm{CCE,m}}$ is the number of the first CCE used for transmission of the corresponding DCI assignment and $N_{\mathrm{PUCCH}}^{(1)}$ is configured by higher layers.
- for a PDSCH transmission on the primary cell where there is not a corresponding PDCCH/EPDCCH detected within subframe(s) $n-k$, where $k \in K$, the value of $n_{\mathrm{PUCCH},j}^{(1)}$ is determined according to higher layer configuration and Table 9.2-2.
- For a PDSCH transmission indicated by the detection of corresponding EPDCCH or a EPDCCH indicating downlink SPS release in sub-frame $n-k_m$ where $k_m \in K$ on the primary cell, the PUCCH resource $n_{\mathrm{PUCCH},j}^{(1)}$ is given by
  - if EPDCCH-PRB-set q is configured for distributed transmission

$$n_{\mathrm{PUCCH,j}}^{(1)} = n_{\mathrm{ECCE,q}} + \sum_{i1=0}^{m-1} N_{ECCE,q,n-k_{i1}} + \Delta_{ARO} + N_{\mathrm{PUCCH,q}}^{(\mathrm{e1})}$$

- if EPDCCH-PRB-set q is configured for localized transmission

$$n^{(1)}_{\mathrm{PUCCH,j}} = \left\lfloor \frac{n_{\mathrm{ECCE,q}}}{N^{ECCE,q}_{RB}} \right\rfloor \cdot N^{ECCE,q}_{RB} + \sum_{i1=0}^{m-1} N_{ECCE,q,n-k_{i1}} + n' + \Delta_{ARO} + N^{(e1)}_{\mathrm{PUCCH,q}}$$

where $n_{\mathrm{ECCE,q}}$ is the number of the first ECCE (i.e. lowest ECCE index used to construct the EPDCCH) used for transmission of the corresponding DCI assignment in EPDCCH-PRB-set q in subframe $n-k_m$, $N^{(e1)}_{\mathrm{PUCCH,q}}$ for EPDCCH-PRB-set q is configured by the higher layer parameter *pucch-ResourceStartOffset-r11* , $N^{ECCE,q}_{RB}$ for EPDCCH-PRB-set q in subframe $n-k_m$ is given in subclause 6.8A.1 in [3], n' is determined from the antenna port used for EPDCCH transmission in subframe $n-k_m$ which is described in subclause 6.8A.5 in [3]. If $m=0$, Δ_{ARO} is determined from the HARQ-ACK resource offset field in the DCI format of the corresponding EPDCCH as given in Table 10.1.2.1-1. If $m>0$, Δ_{ARO} is determined from the HARQ-ACK resource offset field in the DCI format of the corresponding EPDCCH as given in Table 10.1.3.1-2. If the UE is configured to monitor EPDCCH in subframe $n-k_{i1}$, $N_{ECCE,q,n-k_{i1}}$ is equal to the number of ECCEs in EPDCCH-PRB-set q configured for that UE in subframe $n-k_{i1}$. If the UE is not configured to monitor EPDCCH in subframe $n-k_{i1}$, $N_{ECCE,q,n-k_{i1}}$ is equal to the number of ECCEs computed assuming EPDCCH-PRB-set q is configured for that UE in subframe $n-k_{i1}$. For normal downlink CP, if subframe $n-k_{i1}$ is a special subframe with special subframe configuration 0 or 5, $N_{ECCE,q,n-k_{i1}}$ is equal to 0. For extended downlink CP, if subframe $n-k_{i1}$ is a special subframe with special subframe configuration 0 or 4 or 7, $N_{ECCE,q,n-k_{i1}}$ is equal to 0. For a subframe *n* with $M=1$ and a transmission mode that supports up to two transport blocks on the serving cell where the corresponding PDSCH transmission occurs, the PUCCH resource $n^{(1)}_{\mathrm{PUCCH},j+1}$ is given by

- if EPDCCH-PRB-set q is configured for distributed transmission

$$n^{(1,\tilde{p}_1)}_{\mathrm{PUCCH}} = n_{\mathrm{ECCE,q}} + 1 + \sum_{i1=0}^{m-1} N_{ECCE,q,n-k_{i1}} + \Delta_{ARO} + N^{(e1)}_{\mathrm{PUCCH,q}}$$

- if EPDCCH-PRB-set q is configured for localized transmission

$$n^{(1,\tilde{p}_1)}_{\mathrm{PUCCH}} = \left\lfloor \frac{n_{\mathrm{ECCE,q}}}{N^{ECCE,q}_{RB}} \right\rfloor \cdot N^{ECCE,q}_{RB} + 1 + \sum_{i1=0}^{m-1} N_{ECCE,q,n-k_{i1}} + n' + \Delta_{ARO} + N^{(e1)}_{\mathrm{PUCCH,q}}$$

- for a PDSCH transmission indicated by the detection of a corresponding PDCCH/EPDCCH within subframe(s) $n-k$, where $k \in K$ on the secondary cell, the value of $n^{(1)}_{\mathrm{PUCCH},j}$, and the value of $n^{(1)}_{\mathrm{PUCCH},j+1}$ for a subframe *n* with $M=2$ or for a subframe *n* with $M=1$ and a transmission mode on the secondary cell that supports up to two transport blocks is determined according to higher layer configuration and Table 10.1.2.2.1-2. The TPC field in the DCI format of the corresponding PDCCH/EPDCCH shall be used to determine the PUCCH resource values from one of the four resource values configured by higher layers, with the mapping defined in Table 10.1.2.2.1-2. For a UE configured for a transmission mode on the secondary cell that supports up to two transport blocks and a subframe *n* with $M=1$, or for a subframe *n* with $M=2$, a PUCCH resource value in Table 10.1.2.2.1-2 maps to two PUCCH resources $(n^{(1)}_{\mathrm{PUCCH},j}, n^{(1)}_{\mathrm{PUCCH},j+1})$, otherwise, the PUCCH resource value maps to a single PUCCH resource $n^{(1)}_{\mathrm{PUCCH},j}$. A UE shall assume that the same HARQ-ACK PUCCH resource value is transmitted in the TPC field on all PDCCH/EPDCCH assignments on the secondary cell within subframe(s) $n-k$, where $k \in K$.

Table 10.1.3.2-1: Transmission of HARQ-ACK multiplexing for *A* = 2

HARQ-ACK(0), HARQ-ACK(1)	$n_{\text{PUCCH}}^{(1)}$	$b(0)b(1)$
ACK, ACK	$n_{\text{PUCCH},1}^{(1)}$	1, 0
ACK, NACK/DTX	$n_{\text{PUCCH},0}^{(1)}$	1, 1
NACK/DTX, ACK	$n_{\text{PUCCH},1}^{(1)}$	0, 1
NACK, NACK/DTX	$n_{\text{PUCCH},0}^{(1)}$	0, 0
DTX, NACK/DTX	No Transmission	

Table 10.1.3.2-2: Transmission of HARQ-ACK multiplexing for *A* = 3

HARQ-ACK(0), HARQ-ACK(1), HARQ-ACK(2)	$n_{\text{PUCCH}}^{(1)}$	$b(0)b(1)$
ACK, ACK, ACK	$n_{\text{PUCCH},2}^{(1)}$	1, 1
ACK, ACK, NACK/DTX	$n_{\text{PUCCH},1}^{(1)}$	1, 0
ACK, NACK/DTX, ACK	$n_{\text{PUCCH},2}^{(1)}$	1, 0
ACK, NACK/DTX, NACK/DTX	$n_{\text{PUCCH},0}^{(1)}$	1, 1
NACK/DTX, ACK, ACK	$n_{\text{PUCCH},2}^{(1)}$	0, 1
NACK/DTX, ACK, NACK/DTX	$n_{\text{PUCCH},1}^{(1)}$	0, 1
NACK/DTX, NACK/DTX, ACK	$n_{\text{PUCCH},2}^{(1)}$	0, 0
NACK, NACK/DTX, NACK/DTX	$n_{\text{PUCCH},0}^{(1)}$	0, 0
DTX, NACK/DTX, NACK/DTX	No Transmission	

Table 10.1.3.2-3: Transmission of HARQ-ACK multiplexing for *A* = 4

HARQ-ACK(0), HARQ-ACK(1), HARQ-ACK(2), HARQ-ACK(3)	$n_{\text{PUCCH}}^{(1)}$	$b(0)b(1)$
ACK, ACK, ACK, ACK	$n_{\text{PUCCH},1}^{(1)}$	1, 1
ACK, ACK, ACK, NACK/DTX	$n_{\text{PUCCH},2}^{(1)}$	1, 1
ACK, ACK, NACK/DTX, ACK	$n_{\text{PUCCH},0}^{(1)}$	1, 0
ACK, ACK, NACK/DTX, NACK/DTX	$n_{\text{PUCCH},1}^{(1)}$	1, 0
ACK, NACK/DTX, ACK, ACK	$n_{\text{PUCCH},3}^{(1)}$	1, 1
ACK, NACK/DTX, ACK, NACK/DTX	$n_{\text{PUCCH},2}^{(1)}$	1, 0
ACK, NACK/DTX, NACK/DTX, ACK	$n_{\text{PUCCH},0}^{(1)}$	0, 1
ACK, NACK/DTX, NACK/DTX, NACK/DTX	$n_{\text{PUCCH},0}^{(1)}$	1, 1
NACK/DTX, ACK, ACK, ACK	$n_{\text{PUCCH},1}^{(1)}$	0, 0
NACK/DTX, ACK, ACK, NACK/DTX	$n_{\text{PUCCH},2}^{(1)}$	0, 1
NACK/DTX, ACK, NACK/DTX, ACK	$n_{\text{PUCCH},3}^{(1)}$	1, 0
NACK/DTX, ACK, NACK/DTX, NACK/DTX	$n_{\text{PUCCH},1}^{(1)}$	0, 1
NACK/DTX, NACK/DTX, ACK, ACK	$n_{\text{PUCCH},3}^{(1)}$	0, 1
NACK/DTX, NACK/DTX, ACK, NACK/DTX	$n_{\text{PUCCH},2}^{(1)}$	0, 0
NACK/DTX, NACK/DTX, NACK/DTX, ACK	$n_{\text{PUCCH},3}^{(1)}$	0, 0
NACK, NACK/DTX, NACK/DTX, NACK/DTX	$n_{\text{PUCCH},0}^{(1)}$	0, 0
DTX, NACK/DTX, NACK/DTX, NACK/DTX	No Transmission	

Table 10.1.3.2-4: Mapping of subframes on each serving cell to HARQ-ACK(*j*) for PUCCH format 1b HARQ-ACK channel selection for TDD with $M = 2$

A	HARQ-ACK(j)			
	HARQ-ACK(0)	HARQ-ACK(1)	HARQ-ACK(2)	HARQ-ACK(3)
4	The first subframe of Primary cell	The second subframe of Primary cell	The first subframe of Secondary cell	The second subframe of Secondary cell

For TDD HARQ-ACK multiplexing with PUCCH format 1b with channel selection and sub-frame n with $M > 2$ and two configured serving cells, denotes $n_{\text{PUCCH},i}^{(1)}$ $0 \le i \le 3$ as the PUCCH resource derived from the transmissions in M downlink or special sub-frames associated with the UL subframe n . $n_{\text{PUCCH},0}^{(1)}$ and $n_{\text{PUCCH},1}^{(1)}$ are associated with the PDSCH transmission(s) or a PDCCH/EPDCCH indicating downlink SPS release (defined in subclause 9.2) on the primary cell and $n_{\text{PUCCH},2}^{(1)}$ and $n_{\text{PUCCH},3}^{(1)}$ are associated with the PDSCH transmission(s) on the secondary cell.

For Primary cell:

- If the UE is not configured with the higher layer parameter *EIMTA-MainConfigServCell-r12* on the primary cell, and if there is a PDSCH transmission on the primary cell without a corresponding PDCCH/EPDCCH detected within the subframe(s) $n-k$, where $k \in K$,
  - the value of $n_{\text{PUCCH},0}^{(1)}$ is determined according to higher layer configuration and Table 9.2-2.

- for a PDSCH transmission on the primary cell indicated by the detection of a corresponding PDCCH in subframe $n-k_m$, where $k_m \in K$ with the DAI value in the PDCCH equal to '1' (defined in Table 7.3-X) or a PDCCH indicating downlink SPS release (defined in subclause 9.2) in subframe $n-k_m$, where $k_m \in K$ with the DAI value in the PDCCH equal to '1', the PUCCH resource $n^{(1)}_{\mathrm{PUCCH},1} = (M_{primary} - m - 1) \cdot N_c + m \cdot N_{c+1} + n_{\mathrm{CCE},m} + N^{(1)}_{\mathrm{PUCCH}}$ where c is selected from {0, 1, 2, 3} such that $N_c \le n_{\mathrm{CCE},m} < N_{c+1}$, $N_c = \max\{0, \lfloor [N^{\mathrm{DL}}_{\mathrm{RB}} \cdot (N^{\mathrm{RB}}_{\mathrm{sc}} \cdot c - 4)]/36 \rfloor\}$, where $n_{\mathrm{CCE,m}}$ is the number of the first CCE used for transmission of the corresponding PDCCH in subframe $n-k_m$ and $N^{(1)}_{\mathrm{PUCCH}}$ is configured by higher layers.

- for a PDSCH transmission on the primary cell indicated by the detection of a corresponding EPDCCH in subframe $n-k_m$, where $k_m \in K$ with the DAI value in the EPDCCH equal to '1' (defined in Table 7.3-X) or an EPDCCH indicating downlink SPS release (defined in subclause 9.2) in subframe $n-k_m$, where $k_m \in K$ with the DAI value in the EPDCCH equal to '1', the PUCCH resource is given by

  - If EPDCCH-PRB-set q is configured for distributed transmission

$$n^{(1)}_{\mathrm{PUCCH},1} = n_{\mathrm{ECCE,q}} + \sum_{i1=0}^{m-1} N_{ECCE,q,n-k_{i1}} + \Delta_{ARO} + N^{(e1)}_{\mathrm{PUCCH,q}}$$

  - If EPDCCH-PRB-set q is configured for localized transmission

$$n^{(1)}_{\mathrm{PUCCH},1} = \left\lfloor \frac{n_{\mathrm{ECCE,q}}}{N^{ECCE,q}_{RB}} \right\rfloor \cdot N^{ECCE,q}_{RB} + \sum_{i1=0}^{m-1} N_{ECCE,q,n-k_{i1}} + n' + \Delta_{ARO} + N^{(e1)}_{\mathrm{PUCCH,q}}$$

  where $n_{\mathrm{ECCE,q}}$ is the number of the first ECCE (i.e. lowest ECCE index used to construct the EPDCCH) used for transmission of the corresponding DCI assignment in EPDCCH-PRB-set q in subframe $n-k_m$, $N^{(e1)}_{\mathrm{PUCCH,q}}$ for EPDCCH-PRB-set q is configured by the higher layer parameter *pucch-ResourceStartOffset-r11*, $N^{ECCE,q}_{RB}$ for EPDCCH-PRB-set q in subframe $n-k_m$ is given in subclause 6.8A.1 in [3], n' is determined from the antenna port used for EPDCCH transmission in subframe $n-k_m$ which is described in subclause 6.8A.5 in [3]. If $m = 0$, Δ_{ARO} is determined from the HARQ-ACK resource offset field in the DCI format of the corresponding EPDCCH as given in Table 10.1.2.1-1. If $m > 0$, Δ_{ARO} is determined from the HARQ-ACK resource offset field in the DCI format of the corresponding EPDCCH as given in Table 10.1.3.1-2. If the UE is configured to monitor EPDCCH in subframe $n-k_{i1}$, $N_{ECCE,q,n-k_{i1}}$ is equal to the number of ECCEs in EPDCCH-PRB-set q configured for that UE in subframe $n-k_{i1}$. If the UE is not configured to monitor EPDCCH in subframe $n-k_{i1}$, $N_{ECCE,q,n-k_{i1}}$ is equal to the number of ECCEs computed assuming EPDCCH-PRB-set q is configured for that UE in subframe $n-k_{i1}$. For normal downlink CP, if subframe $n-k_{i1}$ is a special subframe with special subframe configuration 0 or 5, $N_{ECCE,q,n-k_{i1}}$ is equal to 0. For extended downlink CP, if subframe $n-k_{i1}$ is a special subframe with special subframe configuration 0 or 4 or 7, $N_{ECCE,q,n-k_{i1}}$ is equal to 0.

- If the UE is configured with the higher layer parameter *EIMTA-MainConfigServCell-r12* on the primary cell, and if there is a PDSCH transmission on the primary cell without a corresponding PDCCH/EPDCCH detected within the subframe(s) $n-k$, where $k \in K$,

  - the value of $n^{(1)}_{\mathrm{PUCCH},0}$ is determined according to higher layer configuration and Table 9.2-2.

- for a PDSCH transmission on the primary cell indicated by the detection of a corresponding PDCCH in subframe $n-k_i$, where $k_i \in K$ with the DAI value in the PDCCH equal to '1' (defined in Table 7.3-X) or a PDCCH indicating downlink SPS release (defined in subclause 9.2) in subframe $n-k_i$, where $k_i \in K$ with the DAI value in the PDCCH equal to '1',

  - if the value of k_i is same as the value of an element k'_{i2} , where $k'_{i2} \in K'$, the PUCCH resource $n^{(1)}_{\mathrm{PUCCH},1}$ is given by $n^{(1)}_{\mathrm{PUCCH},1} = (M'-i2-1)\cdot N_c + i2\cdot N_{c+1} + n_{\mathrm{CCE},i} + N^{(1)}_{\mathrm{PUCCH}}$;

  - otherwise, if the value of k_i is same as the value of an element k^A_{i3} in set K^A, where $k^A_{i3} \in K^A$(defined in Table 10.1.3.1-1A), the PUCCH resource $n^{(1)}_{\mathrm{PUCCH},1}$ is given by $n^{(1)}_{\mathrm{PUCCH},1} = (M^A - i3 - 1)\cdot N_c + i3\cdot N_{c+1} + n_{\mathrm{CCE},i} + N^{\mathrm{K^A}}_{\mathrm{PUCCH}}$;

  where M^A is the number of elements in the set K^A defined in Table 10.1.3.1-1A , where c is selected from {0, 1, 2, 3} such that $N_c \le n_{\mathrm{CCE},i} < N_{c+1}$, $N_c = \max\left\{0, \left\lfloor [N^{\mathrm{DL}}_{\mathrm{RB}}\cdot(N^{\mathrm{RB}}_{\mathrm{sc}}\cdot c-4)]/36 \right\rfloor\right\}$ where $N^{\mathrm{DL}}_{\mathrm{RB}}$ is determined from the primary cell, $n_{\mathrm{CCE},i}$ is the number of the first CCE used for transmission of the corresponding PDCCH in subframe $n-k_i$, and $N^{\mathrm{K^A}}_{\mathrm{PUCCH}}$, $N^{(1)}_{\mathrm{PUCCH}}$, are configured by higher layers .

- for a PDSCH transmission on the primary cell indicated by the detection of a corresponding EPDCCH in subframe $n-k_i$, where $k_i \in K$ with the DAI value in the EPDCCH equal to '1' (defined in Table 7.3-X) or an EPDCCH indicating downlink SPS release (defined in subclause 9.2) in subframe $n-k_i$, where $k_i \in K$ with the DAI value in the EPDCCH equal to '1', the PUCCH resource is given by

  - If EPDCCH-PRB-set q is configured for distributed transmission

$$n^{(1)}_{\mathrm{PUCCH},1} = n_{\mathrm{ECCE,q}} + \sum_{i1=0}^{i4-1} N'_{ECCE,q,n-k'_{i1}} + \sum_{i1=0}^{i5-1} N'_{ECCE,q,n-k^A_{i1}} + \Delta'_{ARO} + N^{(\mathrm{e1})}_{\mathrm{PUCCH,q}}$$

  - If EPDCCH-PRB-set q is configured for localized transmission

$$n^{(1)}_{\mathrm{PUCCH},1} = \left\lfloor \frac{n_{\mathrm{ECCE,q}}}{N^{ECCE,q}_{RB}} \right\rfloor \cdot N^{ECCE,q}_{RB} + \sum_{i1=0}^{i4-1} N'_{ECCE,q,n-k'_{i1}} + \sum_{i1=0}^{i5-1} N'_{ECCE,q,n-k^A_{i1}} + n' + \Delta'_{ARO} + N^{(\mathrm{e1})}_{\mathrm{PUCCH,q}}$$

  where

  - if the value of k_i is same as the value of an index k'_{i2} , where $k'_{i2} \in K'$, then $i4 = i2$ and $i5 = 0$;

  - otherwise, if the value of k_i is same as the value of an index k^A_{i3}, where $k^A_{i3} \in K^A$, then $i4 = M'$ and $i5 = i3$;

  , and where $n_{\mathrm{ECCE,q}}$ is the number of the first ECCE (i.e. lowest ECCE index used to construct the EPDCCH) used for transmission of the corresponding DCI assignment in EPDCCH-PRB-set q in subframe $n-k_i$, $N^{(\mathrm{e1})}_{\mathrm{PUCCH,q}}$ for EPDCCH-PRB-set q is configured by the higher layer parameter *pucch-ResourceStartOffset-r11* , $N^{ECCE,q}_{RB}$ for EPDCCH-PRB-set q in subframe $n-k_i$ is given in subclause 6.8A.1 in [3], n' is determined from the antenna port used for EPDCCH transmission in subframe $n-k_m$ which is described in subclause 6.8A.5 in [3]. Δ'_{ARO} , $N'_{ECCE,q,n-k'_{i1}}$, $N'_{ECCE,q,n-k^A_{i1}}$ are determined as described in section 10.1.3.1.

- HARQ-ACK(0) is the ACK/NACK/DTX response for the PDSCH transmission without a corresponding PDCCH/EPDCCH. For $1 \le j \le M-1$, if a PDSCH transmission with a corresponding PDCCH/EPDCCH and DAI value in the PDCCH/EPDCCH equal to 'j' or a PDCCH/EPDCCH indicating downlink SPS release and with DAI value in the PDCCH/EPDCCH equal to 'j' is received, HARQ-ACK(j) is the corresponding ACK/NACK/DTX response; otherwise HARQ-ACK(j) shall be set to DTX.

- Otherwise,

  - If the UE is not configured with the higher layer parameter *EIMTA-MainConfigServCell-r12* on the primary cell, for a PDSCH transmission on the primary cell indicated by the detection of a corresponding PDCCH in subframe $n-k_m$, where $k_m \in K$ and for TDD UL/DL configuration of the primary cell belonging to {1,2,3,4,6} the DAI value in the PDCCH equal to either '1' or '2' or a PDCCH indicating downlink SPS release (defined in subclause 9.2) in subframe $n-k_m$, where $k_m \in K$ and for TDD UL/DL configuration of the primary cell belonging to {1,2,3,4,6} the DAI value in the PDCCH equal to either '1' or '2', the PUCCH resource $n^{(1)}_{\mathrm{PUCCH},i} = \left(M_{primary} - m - 1\right) \cdot N_c + m \cdot N_{c+1} + n_{\mathrm{CCE},m} + N^{(1)}_{\mathrm{PUCCH}}$, where c is selected from {0, 1, 2, 3} such that $N_c \le n_{\mathrm{CCE},m} < N_{c+1}$, $N_c = \max\left\{0, \left\lfloor [N^{\mathrm{DL}}_{\mathrm{RB}} \cdot (N^{\mathrm{RB}}_{\mathrm{sc}} \cdot c - 4)]/36 \right\rfloor\right\}$, where $n_{\mathrm{CCE,m}}$ is the number of the first CCE used for transmission of the corresponding PDCCH in subframe $n-k_m$, $N^{(1)}_{\mathrm{PUCCH}}$ is configured by higher layers and for TDD UL/DL configuration of the primary cell belonging to {1,2,3,4,6}, $i=0$ for the corresponding PDCCH with the DAI value equal to '1' and $i=1$ for the corresponding PDCCH with the DAI value equal to '2', and for the primary cell with TDD UL/DL configuration 0 $i=0$ for the corresponding PDCCH.

  - If the UE is configured with the higher layer parameter *EIMTA-MainConfigServCell-r12* on the primary cell, for a PDSCH transmission on the primary cell indicated by the detection of a corresponding PDCCH in subframe $n-k_m$, where $k_m \in K$ and for TDD UL/DL configuration of the primary cell belonging to {1,2,3,4,6} the DAI value in the PDCCH equal to either '1' or '2' or a PDCCH indicating downlink SPS release (defined in subclause 9.2) in subframe $n-k_m$, where $k_m \in K$ and for TDD UL/DL configuration of the primary cell belonging to {1,2,3,4,6} the DAI value in the PDCCH equal to either '1' or '2',

    - if the value of k_m is same as the value of an element k'_{i2}, where $k'_{i2} \in K'$, the PUCCH resource $n^{(1)}_{\mathrm{PUCCH},i}$ is given by $n^{(1)}_{\mathrm{PUCCH},i} = (M' - i2 - 1) \cdot N_c + i2 \cdot N_{c+1} + n_{\mathrm{CCE},m} + N^{(1)}_{\mathrm{PUCCH}}$;

    - otherwise, if the value of k_m is same as the value of an element k^A_{i3} in set K^A, where $k^A_{i3} \in K^A$(defined in Table 10.1.3.1-1A), the PUCCH resource $n^{(1)}_{\mathrm{PUCCH},i}$ is given by $n^{(1)}_{\mathrm{PUCCH},i} = (M^A - i3 - 1) \cdot N_c + i3 \cdot N_{c+1} + n_{\mathrm{CCE},m} + N^{\mathrm{K^A}}_{\mathrm{PUCCH}}$;

    where M^A is the number of elements in the set K^A, where c is selected from {0, 1, 2, 3} such that $N_c \le n_{\mathrm{CCE},m} < N_{c+1}$, $N_c = \max\left\{0, \left\lfloor [N^{\mathrm{DL}}_{\mathrm{RB}} \cdot (N^{\mathrm{RB}}_{\mathrm{sc}} \cdot c - 4)]/36 \right\rfloor\right\}$ where $N^{\mathrm{DL}}_{\mathrm{RB}}$ is determined from the primary cell, $n_{CCE,m}$ is the number of the first CCE used for transmission of the corresponding PDCCH in subframe $n-k_m$, and $N^{\mathrm{K^A}}_{\mathrm{PUCCH}}$, $N^{(1)}_{\mathrm{PUCCH}}$, are configured by higher layers. Here, for TDD UL/DL configuration of the primary cell belonging to {1,2,3,4,6}, $i=0$ for the corresponding PDCCH with the DAI value equal to '1' and $i=1$ for the corresponding PDCCH with the DAI value equal to '2', and for the primary cell with TDD UL/DL configuration 0 $i=0$ for the corresponding PDCCH.

  - If the UE is not configured with the higher layer parameter *EIMTA-MainConfigServCell-r12* on the primary cell for a PDSCH transmission on the primary cell indicated by the detection of a corresponding EPDCCH in subframe $n-k_m$, where $k_m \in K$ and for TDD UL/DL configuration of the primary cell belonging to {1,2,3,4,6} the DAI value in the EPDCCH equal to either '1' or '2' or an EPDCCH indicating downlink SPS release (defined in subclause 9.2) in subframe $n-k_m$, where $k_m \in K$ and for TDD UL/DL configuration of the primary cell belonging to {1,2,3,4,6}the DAI value in the EPDCCH equal to either '1' or '2', the PUCCH resource is given by

- If EPDCCH-PRB-set q is configured for distributed transmission

$$n_{\mathrm{PUCCH,i}}^{(1)} = n_{\mathrm{ECCE,q}} + \sum_{i1=0}^{m-1} N_{ECCE,q,n-k_{i1}} + \Delta_{ARO} + N_{\mathrm{PUCCH,q}}^{(\mathrm{e1})}$$

- If EPDCCH-PRB-set q is configured for localized transmission

$$n_{\mathrm{PUCCH,i}}^{(1)} = \left\lfloor \frac{n_{\mathrm{ECCE,q}}}{N_{RB}^{ECCE,q}} \right\rfloor \cdot N_{RB}^{ECCE,q} + \sum_{i1=0}^{m-1} N_{ECCE,q,n-k_{i1}} + n' + \Delta_{ARO} + N_{\mathrm{PUCCH,q}}^{(\mathrm{e1})}$$

where $n_{\mathrm{ECCE,q}}$ is the number of the first ECCE (i.e. lowest ECCE index used to construct the EPDCCH) used for transmission of the corresponding DCI assignment in EPDCCH-PRB-set q in subframe $n-k_m$, $N_{\mathrm{PUCCH,q}}^{(\mathrm{e1})}$ for EPDCCH-PRB-set q is configured by the higher layer parameter *pucch-ResourceStartOffset-r11*, $N_{RB}^{ECCE,q}$ for EPDCCH-PRB-set q in subframe $n-k_m$ is given in subclause 6.8A.1 in [3], n' is determined from the antenna port used for EPDCCH transmission in subframe $n-k_m$ which is described in subclause 6.8A.5 in [3]. If $m=0$, Δ_{ARO} is determined from the HARQ-ACK resource offset field in the DCI format of the corresponding EPDCCH as given in Table 10.1.2.1-1. If $m>0$, Δ_{ARO} is determined from the HARQ-ACK resource offset field in the DCI format of the corresponding EPDCCH as given in Table 10.1.3.1-2. If the UE is configured to monitor EPDCCH in subframe $n-k_{i1}$, $N_{ECCE,q,n-k_{i1}}$ is equal to the number of ECCEs in EPDCCH-PRB-set q configured for that UE in subframe $n-k_{i1}$. If the UE is not configured to monitor EPDCCH in subframe $n-k_{i1}$, $N_{ECCE,q,n-k_{i1}}$ is equal to the number of ECCEs computed assuming EPDCCH-PRB-set q is configured for that UE in subframe $n-k_{i1}$. For normal downlink CP, if subframe $n-k_{i1}$ is a special subframe with special subframe configuration 0 or 5, $N_{ECCE,q,n-k_{i1}}$ is equal to 0. For extended downlink CP, if subframe $n-k_{i1}$ is a special subframe with special subframe configuration 0 or 4 or 7, $N_{ECCE,q,n-k_{i1}}$ is equal to 0. Here, for TDD UL/DL configuration of the primary cell belonging to {1,2,3,4,6} $i=0$ for the corresponding EPDCCH with the DAI value equal to '1' and $i=1$ for the corresponding EPDCCH with the DAI value equal to '2', and for the primary cell with TDD UL/DL configuration 0 $i=0$ for the corresponding EPDCCH.

- If the UE is configured with the higher layer parameter *EIMTA-MainConfigServCell-r12* on the primary cell for a PDSCH transmission on the primary cell indicated by the detection of a corresponding EPDCCH in subframe $n-k_m$, where $k_m \in K$ and for TDD UL/DL configuration of the primary cell belonging to {1,2,3,4,6} the DAI value in the EPDCCH equal to either '1' or '2' or an EPDCCH indicating downlink SPS release (defined in subclause 9.2) in subframe $n-k_m$, where $k_m \in K$ and for TDD UL/DL configuration of the primary cell belonging to {1,2,3,4,6}the DAI value in the EPDCCH equal to either '1' or '2', the PUCCH resource is given by

  - If EPDCCH-PRB-set q is configured for distributed transmission

$$n_{\mathrm{PUCCH,i}}^{(1)} = n_{\mathrm{ECCE,q}} + \sum_{i1=0}^{i4-1} N_{ECCE,q,n-k'_{i1}} + \sum_{i1=0}^{i5-1} N_{ECCE,q,n-k_{i1}^{A}} + \Delta_{ARO} + N_{\mathrm{PUCCH,q}}^{(\mathrm{e1})}$$

  - If EPDCCH-PRB-set q is configured for localized transmission

$$n^{(1)}_{\mathrm{PUCCH,i}} = \left\lfloor \frac{n_{\mathrm{ECCE,q}}}{N_{RB}^{ECCE,q}} \right\rfloor \cdot N_{RB}^{ECCE,q} + \sum_{i1=0}^{i4-1} N_{ECCE,q,n-k'_{i1}} + \sum_{i1=0}^{i5-1} N_{ECCE,q,n-k^A_{i1}} + n' + \Delta_{ARO} + N^{(e1)}_{\mathrm{PUCCH,q}}$$

where

- if the value of k_m is same as the value of an index k'_{i2}, where $k'_{i2} \in K'$, then $i4 = i2$;
- otherwise, if the value of k_m is same as the value of an index k^A_{i3}, where $k^A_{i3} \in K^A$, then $i4 = i3$;

, and where $n_{\mathrm{ECCE,q}}$ is the number of the first ECCE (i.e. lowest ECCE index used to construct the EPDCCH) used for transmission of the corresponding DCI assignment in EPDCCH-PRB-set q in subframe $n-k_m$, $N^{(e1)}_{\mathrm{PUCCH,q}}$ for EPDCCH-PRB-set q is configured by the higher layer parameter *pucch-ResourceStartOffset-r11*, $N_{RB}^{ECCE,q}$ for EPDCCH-PRB-set q in subframe $n-k_m$ is given in subclause 6.8A.1 in [3], n' is determined from the antenna port used for EPDCCH transmission in subframe $n-k_m$ which is described in subclause 6.8A.5 in [3].. Δ'_{ARO}, $N_{ECCE,q,n-k'_{i1}}$, $N_{ECCE,q,n-k^A_{i1}}$ are determined as described in section 10.1.3.1. Here, for TDD UL/DL configuration of the primary cell belonging to {1,2,3,4,6} $i=0$ for the corresponding EPDCCH with the DAI value equal to '1' and $i=1$ for the corresponding EPDCCH with the DAI value equal to '2', and for the primary cell with TDD UL/DL configuration 0 $i=0$ for the corresponding EPDCCH.

- For $0 \le j \le M-1$ and TDD UL/DL configuration of the primary cell belonging to {1,2,3,4,6}, if a PDSCH transmission with a corresponding PDCCH/EPDCCH and DAI value in the PDCCH/EPDCCH equal to '$j+1$' or a PDCCH/EPDCCH indicating downlink SPS release and with DAI value in the PDCCH/EPDCCH equal to '$j+1$' is received, HARQ-ACK(j) is the corresponding ACK/NACK/DTX response; otherwise HARQ-ACK(j) shall be set to DTX. For $0 \le j \le M-1$ and the primary cell with TDD UL/DL configuration 0, if a PDSCH transmission with a corresponding PDCCH/EPDCCH or a PDCCH/EPDCCH indicating downlink SPS release is received, HARQ-ACK(0) is the corresponding ACK/NACK/DTX response; otherwise HARQ-ACK(j) shall be set to DTX.

For Secondary cell:

- If the UE is not configured with the higher layer parameter *EIMTA-MainConfigServCell-r12* on the primary cell, for a PDSCH transmission on the secondary cell indicated by the detection of a corresponding PDCCH on the primary cell in subframe $n-k_m$, where $k_m \in K$ with the DAI value in the PDCCH equal to either '1' or '2', the PUCCH resources $n^{(1)}_{\mathrm{PUCCH},i} = \left(M_{primary} - m - 1\right) \cdot N_c + m \cdot N_{c+1} + n_{\mathrm{CCE},m} + N^{(1)}_{\mathrm{PUCCH}}$, where c is selected from {0, 1, 2, 3} such that $N_c \le n_{\mathrm{CCE,m}} < N_{c+1}$, $N_c = \max\left\{0, \left\lfloor [N^{\mathrm{DL}}_{\mathrm{RB}} \cdot (N^{\mathrm{RB}}_{\mathrm{sc}} \cdot c - 4)]/36 \right\rfloor\right\}$, where $N^{\mathrm{DL}}_{\mathrm{RB}}$ is determined from the primary cell, $n_{\mathrm{CCE,m}}$ is the number of the first CCE used for transmission of the corresponding PDCCH in subframe $n-k_m$, $N^{(1)}_{\mathrm{PUCCH}}$ is configured by higher layers, $i=2$ for the corresponding PDCCH with the DAI value equal to '1' and $i=3$ for the corresponding PDCCH with the DAI value equal to '2'.
- If the UE is configured with the higher layer parameter *EIMTA-MainConfigServCell-r12* on the primary cell, for a PDSCH transmission on the secondary cell indicated by the detection of a corresponding PDCCH on the primary cell in subframe $n-k_m$, where $k_m \in K$ with the DAI value in the PDCCH equal to either '1' or '2',
  - if the value of k_m is same as the value of an element k'_{i2}, where $k'_{i2} \in K'$, the PUCCH resource $n^{(1)}_{\mathrm{PUCCH},i}$ is given by $n^{(1)}_{\mathrm{PUCCH},i} = (M' - i2 - 1) \cdot N_c + i2 \cdot N_{c+1} + n_{\mathrm{CCE},m} + N^{(1)}_{\mathrm{PUCCH}}$;
  - otherwise, if the value of k_m is same as the value of an element k^A_{i3} in set K^A, where $k^A_{i3} \in K^A$(defined in Table 10.1.3.1-1A, where "UL/DL configuration" in the table refers to the higher layer parameter

subframeAssignment), the PUCCH resource $n^{(1)}_{\text{PUCCH},i}$ is given by

$n^{(1)}_{\text{PUCCH},i} = (M^{A} - i3 - 1)\cdot N_c + i3\cdot N_{c+1} + n_{\text{CCE},m} + N^{\text{K}^{\text{A}}}_{\text{PUCCH}}$;

where M^{A} is the number of elements in the set K^{A} defined in Table 10.1.3.1-1A , where c is selected from {0, 1, 2, 3} such that $N_c \le n_{\text{CCE},m} < N_{c+1}$, $N_c = \max\left\{0, \left\lfloor [N^{\text{DL}}_{\text{RB}}\cdot(N^{\text{RB}}_{\text{sc}}\cdot c - 4)]/36 \right\rfloor\right\}$ where $N^{\text{DL}}_{\text{RB}}$ is determined from the primary cell, $n_{CCE,m}$ is the number of the first CCE used for transmission of the corresponding PDCCH in subframe $n-k_m$, and $N^{\text{K}^{\text{A}}}_{\text{PUCCH}}$, $N^{(1)}_{\text{PUCCH}}$, are configured by higher layers. Here, $i=2$ for the corresponding PDCCH with the DAI value equal to '1' and $i=3$ for the corresponding PDCCH the DAI value in the PDCCH equal to either '1' or '2'.

- If the UE is not configured with the higher layer parameter *EIMTA-MainConfigServCell-r12* on the primary cell, for a PDSCH transmission on the secondary cell indicated by the detection of a corresponding EPDCCH on the primary cell in subframe $n-k_m$, where $k_m \in K$ with the DAI value in the PDCCH equal to either '1' or '2', the PUCCH resources are given by

  - If EPDCCH-PRB-set q is configured for distributed transmission

$$n^{(1)}_{\text{PUCCH,i}} = n_{\text{ECCE,q}} + \sum_{i1=0}^{m-1} N_{ECCE,q,n-k_{i1}} + \Delta_{ARO} + N^{(\text{e1})}_{\text{PUCCH,q}}$$

  - If EPDCCH-PRB-set q is configured for localized transmission

$$n^{(1)}_{\text{PUCCH,i}} = \left\lfloor \frac{n_{\text{ECCE,q}}}{N^{ECCE,q}_{RB}} \right\rfloor \cdot N^{ECCE,q}_{RB} + \sum_{i1=0}^{m-1} N_{ECCE,q,n-k_{i1}} + n' + \Delta_{ARO} + N^{(\text{e1})}_{\text{PUCCH,q}}$$

where $n_{\text{ECCE,q}}$ is the number of the first ECCE (i.e. lowest ECCE index used to construct the EPDCCH) used for transmission of the corresponding DCI assignment in EPDCCH-PRB-set q in subframe $n-k_m$, $N^{(\text{e1})}_{\text{PUCCH,q}}$ for EPDCCH-PRB-set q is configured by the higher layer parameter *pucch-ResourceStartOffset-r11* , $N^{ECCE,q}_{RB}$ for EPDCCH-PRB-set q in subframe $n-k_m$ is given in subclause 6.8A.1 in [3], n' is determined from the antenna port used for EPDCCH transmission in subframe $n-k_m$ which is described in subclause 6.8A.5 in [3]. If $m=0$, Δ_{ARO} is determined from the HARQ-ACK resource offset field in the DCI format of the corresponding EPDCCH as given in Table 10.1.2.1-1. If $m>0$, Δ_{ARO} is determined from the HARQ-ACK resource offset field in the DCI format of the corresponding EPDCCH as given in Table 10.1.3.1-2. If the UE is configured to monitor EPDCCH in subframe $n-k_{i1}$, $N_{ECCE,q,n-k_{i1}}$ is equal to the number of ECCEs in EPDCCH-PRB-set q configured for that UE in subframe $n-k_{i1}$. If the UE is not configured to monitor EPDCCH in subframe $n-k_{i1}$, $N_{ECCE,q,n-k_{i1}}$ is equal to the number of ECCEs computed assuming EPDCCH-PRB-set q is configured for that UE in subframe $n-k_{i1}$. For normal downlink CP, if subframe $n-k_{i1}$ is a special subframe with special subframe configuration 0 or 5, $N_{ECCE,q,n-k_{i1}}$ is equal to 0. For extended downlink CP, if subframe $n-k_{i1}$ is a special subframe with special subframe configuration 0 or 4 or 7, $N_{ECCE,q,n-k_{i1}}$ is equal to 0. Here, $i=2$ for the corresponding EPDCCH with the DAI value equal to '1' and $i=3$ for the corresponding EPDCCH with the DAI value equal to '2'.

- If the UE is configured with the higher layer parameter *EIMTA-MainConfigServCell-r12* on the primary cell, for a PDSCH transmission on the secondary cell indicated by the detection of a corresponding EPDCCH on the primary cell in subframe $n-k_m$, where $k_m \in K$ with the DAI value in the PDCCH to either '1' or '2', the PUCCH resources are given by

  - If EPDCCH-PRB-set q is configured for distributed transmission

$$n^{(1)}_{\text{PUCCH,i}} = n_{\text{ECCE,q}} + \sum_{i1=0}^{i4-1} N'_{ECCE,q,n-k'_{i1}} + \sum_{i1=0}^{i5-1} N'_{ECCE,q,n-k^A_{i1}} + \Delta'_{ARO} + N^{(e1)}_{\text{PUCCH,q}}$$

- If EPDCCH-PRB-set q is configured for localized transmission

$$n^{(1)}_{\text{PUCCH,i}} = \left\lfloor \frac{n_{\text{ECCE,q}}}{N^{ECCE,q}_{RB}} \right\rfloor \cdot N^{ECCE,q}_{RB} + \sum_{i1=0}^{i4-1} N'_{ECCE,q,n-k'_{i1}} + \sum_{i1=0}^{i5-1} N'_{ECCE,q,n-k^A_{i1}} + n' + \Delta'_{ARO} + N^{(e1)}_{\text{PUCCH,q}}$$

where

- if the value of k_m is same as the value of an index k'_{i2}, where $k'_{i2} \in K'$, then $i4 = i2$;
- otherwise, if the value of k_m is same as the value of an index k^A_{i3}, where $k^A_{i3} \in K^A$, then $i4 = i3$;

and where $n_{\text{ECCE,q}}$ is the number of the first ECCE (i.e. lowest ECCE index used to construct the EPDCCH) used for transmission of the corresponding DCI assignment in EPDCCH-PRB-set q in subframe $n-k_m$, $N^{(e1)}_{\text{PUCCH,q}}$ for EPDCCH-PRB-set q is configured by the higher layer parameter *pucch-ResourceStartOffset-r11*, $N^{ECCE,q}_{RB}$ for EPDCCH-PRB-set q in subframe $n-k_m$ is given in subclause 6.8A.1 in [3], n' is determined from the antenna port used for EPDCCH transmission in subframe $n-k_m$ which is described in subclause 6.8A.5 in [3]. Δ'_{ARO}, $N'_{ECCE,q,n-k'_{i1}}$, $N'_{ECCE,q,n-k^A_{i1}}$ are determined as described in subclause 10.1.3.1. For extended downlink CP, if subframe $n-k_{i1}$ is a special subframe with special subframe configuration 0 or 4 or 7, $N_{ECCE,q,n-k_{i1}}$ is equal to 0. Here, $i=2$ for the corresponding EPDCCH with the DAI value equal to '1' and $i=3$ for the corresponding EPDCCH with the DAI value equal to '2'.

- for a PDSCH transmission indicated by the detection of a corresponding PDCCH/EPDCCH within the subframe(s) $n-k$, where $k \in K$ on the secondary cell, the value of $n^{(1)}_{\text{PUCCH,2}}$ and $n^{(1)}_{\text{PUCCH,3}}$ is determined according to higher layer configuration and Table 10.1.2.2.1-2. The TPC field in the DCI format of the corresponding PDCCH/EPDCCH shall be used to determine the PUCCH resource values from one of the four resource values configured by higher layers, with the mapping defined in Table 10.1.2.2.1-2. A UE shall assume that the same HARQ-ACK PUCCH resource value is transmitted in the TPC field on all PDCCH/EPDCCH assignments on the secondary cell within subframe(s) $n-k$, where $k \in K$.

- For $0 \le j \le M-1$, if a PDSCH transmission with a corresponding PDCCH/EPDCCH and DAI value in the PDCCH/EPDCCH equal to '$j+1$' is received, HARQ-ACK(j) is the corresponding ACK/NACK/DTX response; otherwise HARQ-ACK(j) shall be set to DTX.

A UE shall perform channel selection according to the Tables 10.1.3.2-5, and 10.1.3.2-6 and transmit $b(0), b(1)$ on PUCCH resource $n^{(1,\tilde{p})}_{\text{PUCCH}}$ for $\tilde{p}$ mapped to antenna port *p* using PUCCH format 1b according to subclause 5.4.1 in [3] where

- $n^{(1,\tilde{p}_0)}_{\text{PUCCH}} = n^{(1)}_{\text{PUCCH}}$ in sub-frame n for $\tilde{p}$ mapped to antenna port p_0 where "any" in Tables 10.1.3.2-5, and 10.1.3.2-6 represents any response of ACK, NACK, or DTX. The value of $b(0), b(1)$ and the PUCCH resource $n^{(1)}_{\text{PUCCH}}$ are generated by channel selection according to Tables 10.1.3.2-5, and 10.1.3.2-6 for *M* = 3, and 4 respectively.

- $n^{(1,\tilde{p}_1)}_{\text{PUCCH}}$ for antenna port p_1, where $n^{(1,\tilde{p}_1)}_{\text{PUCCH}}$ selected from PUCCH resources, $n^{(1,\tilde{p}_1)}_{\text{PUCCH},i}$ configured by higher layers where $0 \le i \le 3$ according Tables 10.1.3.2-5, and 10.1.3.2-6 for *M* = 3, and 4 respectively by replacing $n^{(1)}_{\text{PUCCH}}$ with $n^{(1,\tilde{p}_1)}_{\text{PUCCH}}$ and replacing $n^{(1)}_{\text{PUCCH},i}$ with $n^{(1,\tilde{p}_1)}_{\text{PUCCH},i}$, where "any" in Tables 10.1.3.2-5, and 10.1.3.2-6 represents any response of ACK, NACK, or DTX, when the UE is configured with two antenna port transmission for PUCCH format 1b with channel selection.

Table 10.1.3.2-5: Transmission of HARQ-ACK multiplexing for *M* = 3

Primary Cell	Secondary Cell	Resource	Constellation	RM Code Input Bits
HARQ-ACK(0), HARQ-ACK(1), HARQ-ACK(2)	**HARQ-ACK(0), HARQ-ACK(1), HARQ-ACK(2)**	$n^{(1)}_{\mathrm{PUCCH}}$	$b(0), b(1)$	$o(0), o(1), o(2), o(3)$
ACK, ACK, ACK	ACK, ACK, ACK	$n^{(1)}_{\mathrm{PUCCH},1}$	1, 1	1,1,1,1
ACK, ACK, NACK/DTX	ACK, ACK, ACK	$n^{(1)}_{\mathrm{PUCCH},1}$	0, 0	1,0,1,1
ACK, NACK/DTX, any	ACK, ACK, ACK	$n^{(1)}_{\mathrm{PUCCH},3}$	1, 1	0,1,1,1
NACK/DTX, any, any	ACK, ACK, ACK	$n^{(1)}_{\mathrm{PUCCH},3}$	0, 1	0,0,1,1
ACK, ACK, ACK	ACK, ACK, NACK/DTX	$n^{(1)}_{\mathrm{PUCCH},0}$	1, 0	1,1,1,0
ACK, ACK, NACK/DTX	ACK, ACK, NACK/DTX	$n^{(1)}_{\mathrm{PUCCH},3}$	1, 0	1,0,1,0
ACK, NACK/DTX, any	ACK, ACK, NACK/DTX	$n^{(1)}_{\mathrm{PUCCH},0}$	0, 1	0,1,1,0
NACK/DTX, any, any	ACK, ACK, NACK/DTX	$n^{(1)}_{\mathrm{PUCCH},3}$	0, 0	0,0,1,0
ACK, ACK, ACK	ACK, NACK/DTX, any	$n^{(1)}_{\mathrm{PUCCH},2}$	1, 1	1, 1, 0, 1
ACK, ACK, NACK/DTX	ACK, NACK/DTX, any	$n^{(1)}_{\mathrm{PUCCH},2}$	0, 1	1, 0, 0, 1
ACK, NACK/DTX, any	ACK, NACK/DTX, any	$n^{(1)}_{\mathrm{PUCCH},2}$	1, 0	0, 1, 0, 1
NACK/DTX, any, any	ACK, NACK/DTX, any	$n^{(1)}_{\mathrm{PUCCH},2}$	0, 0	0, 0, 0, 1
ACK, ACK, ACK	NACK/DTX, any, any	$n^{(1)}_{\mathrm{PUCCH},1}$	1, 0	1, 1, 0, 0
ACK, ACK, NACK/DTX	NACK/DTX, any, any	$n^{(1)}_{\mathrm{PUCCH},1}$	0, 1	1, 0, 0, 0
ACK, NACK/DTX, any	NACK/DTX, any, any	$n^{(1)}_{\mathrm{PUCCH},0}$	1, 1	0, 1, 0, 0
NACK, any, any	NACK/DTX, any, any	$n^{(1)}_{\mathrm{PUCCH},0}$	0, 0	0, 0, 0, 0
DTX, any, any	NACK/DTX, any, any	No Transmission		0, 0, 0, 0

Table 10.1.3.2-6: Transmission of HARQ-ACK multiplexing for *M* = 4

Primary Cell	Secondary Cell	Resource	Constellation	RM Code Input Bits
HARQ-ACK(0), HARQ-ACK(1), HARQ-ACK(2), HARQ-ACK(3)	**HARQ-ACK(0), HARQ-ACK(1), HARQ-ACK(2), HARQ-ACK(3)**	$n^{(1)}_{\text{PUCCH}}$	$b(0), b(1)$	$o(0), o(1), o(2), o(3)$
ACK, ACK, ACK, NACK/DTX	ACK, ACK, ACK, NACK/DTX	$n^{(1)}_{\text{PUCCH},1}$	1, 1	1, 1, 1, 1
ACK, ACK, NACK/DTX, any	ACK, ACK, ACK, NACK/DTX	$n^{(1)}_{\text{PUCCH},1}$	0, 0	1, 0, 1, 1
ACK, DTX, DTX, DTX	ACK, ACK, ACK, NACK/DTX	$n^{(1)}_{\text{PUCCH},3}$	1, 1	0, 1, 1, 1
ACK, ACK, ACK, ACK	ACK, ACK, ACK, NACK/DTX	$n^{(1)}_{\text{PUCCH},3}$	1, 1	0, 1, 1, 1
NACK/DTX, any, any, any	ACK, ACK, ACK, NACK/DTX	$n^{(1)}_{\text{PUCCH},3}$	0, 1	0, 0, 1, 1
(ACK, NACK/DTX, any, any), except for (ACK, DTX, DTX, DTX)	ACK, ACK, ACK, NACK/DTX	$n^{(1)}_{\text{PUCCH},3}$	0, 1	0, 0, 1, 1
ACK, ACK, ACK, NACK/DTX	ACK, ACK, NACK/DTX, any	$n^{(1)}_{\text{PUCCH},0}$	1, 0	1, 1, 1, 0
ACK, ACK, NACK/DTX, any	ACK, ACK, NACK/DTX, any	$n^{(1)}_{\text{PUCCH},3}$	1, 0	1, 0, 1, 0
ACK, DTX, DTX, DTX	ACK, ACK, NACK/DTX, any	$n^{(1)}_{\text{PUCCH},0}$	0, 1	0, 1, 1, 0
ACK, ACK, ACK, ACK	ACK, ACK, NACK/DTX, any	$n^{(1)}_{\text{PUCCH},0}$	0, 1	0, 1, 1, 0
NACK/DTX, any, any, any	ACK, ACK, NACK/DTX, any	$n^{(1)}_{\text{PUCCH},3}$	0, 0	0, 0, 1, 0
(ACK, NACK/DTX, any, any), except for (ACK, DTX, DTX, DTX)	ACK, ACK, NACK/DTX, any	$n^{(1)}_{\text{PUCCH},3}$	0, 0	0, 0, 1, 0
ACK, ACK, ACK, NACK/DTX	ACK, DTX, DTX, DTX	$n^{(1)}_{\text{PUCCH},2}$	1, 1	1, 1, 0, 1
ACK, ACK, ACK, NACK/DTX	ACK, ACK, ACK, ACK	$n^{(1)}_{\text{PUCCH},2}$	1, 1	1, 1, 0, 1
ACK, ACK, NACK/DTX, any	ACK, DTX, DTX, DTX	$n^{(1)}_{\text{PUCCH},2}$	0, 1	1, 0, 0, 1
ACK, ACK, NACK/DTX, any	ACK, ACK, ACK, ACK	$n^{(1)}_{\text{PUCCH},2}$	0, 1	1, 0, 0, 1
ACK, DTX, DTX, DTX	ACK, DTX, DTX, DTX	$n^{(1)}_{\text{PUCCH},2}$	1, 0	0, 1, 0, 1
ACK, DTX, DTX, DTX	ACK, ACK, ACK, ACK	$n^{(1)}_{\text{PUCCH},2}$	1, 0	0, 1, 0, 1
ACK, ACK, ACK, ACK	ACK, DTX, DTX, DTX	$n^{(1)}_{\text{PUCCH},2}$	1, 0	0, 1, 0, 1
ACK, ACK, ACK, ACK	ACK, ACK, ACK, ACK	$n^{(1)}_{\text{PUCCH},2}$	1, 0	0, 1, 0, 1
NACK/DTX, any, any, any	ACK, DTX, DTX, DTX	$n^{(1)}_{\text{PUCCH},2}$	0, 0	0, 0, 0, 1
NACK/DTX, any, any, any	ACK, ACK, ACK, ACK	$n^{(1)}_{\text{PUCCH},2}$	0, 0	0, 0, 0, 1
(ACK, NACK/DTX, any, any), except for (ACK, DTX, DTX, DTX)	ACK, DTX, DTX, DTX	$n^{(1)}_{\text{PUCCH},2}$	0, 0	0, 0, 0, 1
(ACK, NACK/DTX, any, any), except for (ACK, DTX, DTX, DTX)	ACK, ACK, ACK, ACK	$n^{(1)}_{\text{PUCCH},2}$	0, 0	0, 0, 0, 1
ACK, ACK, ACK, NACK/DTX	NACK/DTX, any, any, any	$n^{(1)}_{\text{PUCCH},1}$	1, 0	1, 1, 0, 0
ACK, ACK, ACK, NACK/DTX	(ACK, NACK/DTX, any, any), except for (ACK, DTX, DTX, DTX)	$n^{(1)}_{\text{PUCCH},1}$	1, 0	1, 1, 0, 0
ACK, ACK, NACK/DTX, any	NACK/DTX, any, any, any	$n^{(1)}_{\text{PUCCH},1}$	0, 1	1, 0, 0, 0

ACK, ACK, NACK/DTX, any	(ACK, NACK/DTX, any, any), except for (ACK, DTX, DTX, DTX)	$n^{(1)}_{\text{PUCCH},1}$	0, 1	1, 0, 0, 0
ACK, DTX, DTX, DTX	NACK/DTX, any, any, any	$n^{(1)}_{\text{PUCCH},0}$	1, 1	0, 1, 0, 0
ACK, DTX, DTX, DTX	(ACK, NACK/DTX, any, any), except for (ACK, DTX, DTX, DTX)	$n^{(1)}_{\text{PUCCH},0}$	1, 1	0, 1, 0, 0
ACK, ACK, ACK, ACK	NACK/DTX, any, any, any	$n^{(1)}_{\text{PUCCH},0}$	1, 1	0, 1, 0, 0
ACK, ACK, ACK, ACK	(ACK, NACK/DTX, any, any), except for (ACK, DTX, DTX, DTX)	$n^{(1)}_{\text{PUCCH},0}$	1, 1	0, 1, 0, 0
NACK, any, any, any	NACK/DTX, any, any, any	$n^{(1)}_{\text{PUCCH},0}$	0, 0	0, 0, 0, 0
NACK, any, any, any	(ACK, NACK/DTX, any, any), except for (ACK, DTX, DTX, DTX)	$n^{(1)}_{\text{PUCCH},0}$	0, 0	0, 0, 0, 0
(ACK, NACK/DTX, any, any), except for (ACK, DTX, DTX, DTX)	NACK/DTX, any, any, any	$n^{(1)}_{\text{PUCCH},0}$	0, 0	0, 0, 0, 0
(ACK, NACK/DTX, any, any), except for (ACK, DTX, DTX, DTX)	(ACK, NACK/DTX, any, any), except for (ACK, DTX, DTX, DTX)	$n^{(1)}_{\text{PUCCH},0}$	0, 0	0, 0, 0, 0
DTX, any, any, any	NACK/DTX, any, any, any	No Transmission		0, 0, 0, 0
DTX, any, any, any	(ACK, NACK/DTX, any, any), except for (ACK, DTX, DTX, DTX)	No Transmission		0, 0, 0, 0

10.1.3.2.2 PUCCH format 3 HARQ-ACK procedure

If a UE is configured with the higher layer parameter *EIMTA-MainConfigServCell-r12*, then $K' = K$ where the set K is defined in Table 10.1.3.1-1 (where "UL/DL configuration" in the table refers to the higher layer parameter *subframeAssignment*), and M' is the number of elements in set K'.

If a UE is configured with one serving cell, or if a UE is configured with more than one serving cells and the UL/DL configuration of all serving cells is same, then in the rest of this subclause K is as defined in Sec 10.2, and M is the number of elements in the set K.

If a UE is configured with more than one serving cell and if at least two cells have different UL/DL configurations, then K in this subclause refers to K_c (as defined in subclause 10.2) , and M is the number of elements in the set K.

For TDD HARQ-ACK transmission with PUCCH format 3 and sub-frame n with $M \geq 1$ and more than one configured serving cell, where M is the number of elements in the set K, the UE shall use PUCCH resource $n_{\mathrm{PUCCH}}^{(3,\tilde{p})}$ or $n_{\mathrm{PUCCH}}^{(1,\tilde{p})}$ for transmission of HARQ-ACK in subframe n for $\tilde{p}$ mapped to antenna port *p* where

- If the UE is not configured with the higher layer parameter *EIMTA-MainConfigServCell-r12* on the primary cell,
  - for a single PDSCH transmission only on the primary cell indicated by the detection of a corresponding PDCCH in subframe $n - k_m$, where $k_m \in K$, and for a TDD UL/DL configuration of the primary cell belonging to {1,2,3,4,5,6} the DAI value in the PDCCH is equal to '1' (defined in Table 7.3-X), or
  - for a single PDCCH indicating downlink SPS release (defined in subclause 9.2) in subframe $n - k_m$, where $k_m \in K$, and for a TDD UL/DL configuration of the primary cell belonging to {1,2,3,4,5,6} the DAI value in the PDCCH is equal to '1',
    - the UE shall use PUCCH format 1a/1b and PUCCH resource $n_{\mathrm{PUCCH}}^{(1,\tilde{p})}$ with $n_{\mathrm{PUCCH}}^{(1,\tilde{p}_0)} = (M - m - 1) \cdot N_c + m \cdot N_{c+1} + n_{\mathrm{CCE},m} + N_{\mathrm{PUCCH}}^{(1)}$ for antenna port p_0, where $N_{\mathrm{PUCCH}}^{(1)}$ is configured by higher layers, c is selected from {0, 1, 2, 3} such that $N_c \leq n_{\mathrm{CCE},m} < N_{c+1}$, $N_c = \max\left\{0, \left\lfloor [N_{\mathrm{RB}}^{\mathrm{DL}} \cdot (N_{\mathrm{sc}}^{\mathrm{RB}} \cdot c - 4)]/36 \right\rfloor\right\}$, and $n_{\mathrm{CCE,m}}$ is the number of the first CCE used for transmission of the corresponding PDCCH in subframe $n - k_m$ where $k_m \in K$. When two antenna port transmission is configured for PUCCH format 1a/1b, the PUCCH resource for antenna port p_1 is given by $n_{\mathrm{PUCCH}}^{(1,\tilde{p}_1)} = n_{\mathrm{PUCCH}}^{(1,\tilde{p}_0)} + 1$
- If the UE is configured with the higher layer parameter *EIMTA-MainConfigServCell-r12* on the primary cell,
  - for a single PDSCH transmission only on the primary cell indicated by the detection of a corresponding PDCCH in subframe $n - k_m$, where $k_m \in K$, and for a TDD UL/DL configuration of the primary cell belonging to {1,2,3,4,5,6} the DAI value in the PDCCH is equal to '1' (defined in Table 7.3-X), or
  - for a single PDCCH indicating downlink SPS release (defined in subclause 9.2) in subframe $n - k_m$, where $k_m \in K$, and for a TDD UL/DL configuration of the primary cell belonging to {1,2,3,4,5,6} the DAI value in the PDCCH is equal to '1',
    - the UE shall use PUCCH format 1a/1b, and
      - if the value of k_m is same as the value of an element k'_{i2}, where $k'_{i2} \in K'$, the PUCCH resource $n_{\mathrm{PUCCH}}^{(1,\tilde{p})}$ is given by $n_{\mathrm{PUCCH}}^{(1,\tilde{p})} = (M' - i2 - 1) \cdot N_c + i2 \cdot N_{c+1} + n_{\mathrm{CCE},m} + N_{\mathrm{PUCCH}}^{(1)}$;
      - otherwise, if the value of k_m is same as the value of an element k_{i3}^A in set K^A, where $k_{i3}^A \in K^A$ (defined in Table 10.1.3.1-1A, where "UL/DL configuration" in the table refers to the higher

layer parameter *subframeAssignment*), the PUCCH resource $n^{(1,\tilde{p})}_{\text{PUCCH}}$ is given by
$n^{(1,\tilde{p})}_{\text{PUCCH}} = (M^A - i3 - 1)\cdot N_c + i3\cdot N_{c+1} + n_{\text{CCE},m} + N^{\text{K}^\text{A}}_{\text{PUCCH}}$;

where M^A is the number of elements in the set K^A defined in Table 10.1.3.1-1A , where c is selected from {0, 1, 2, 3} such that $N_c \le n_{\text{CCE},m} < N_{c+1}$,
$N_c = \max\left\{0, \left\lfloor [N^{\text{DL}}_{\text{RB}}\cdot(N^{\text{RB}}_{\text{sc}}\cdot c - 4)]/36 \right\rfloor\right\}$ where $N^{\text{DL}}_{\text{RB}}$ is determined from the primary cell, $n_{CCE,m}$ is the number of the first CCE used for transmission of the corresponding PDCCH in subframe $n-k_m$, and $N^{\text{K}^\text{A}}_{\text{PUCCH}}$, $N^{(1)}_{\text{PUCCH}}$, are configured by higher layers. When two antenna port transmission is configured for PUCCH format 1a/1b, the PUCCH resource for antenna port p_1 is given by $n^{(1,\tilde{p}_1)}_{\text{PUCCH}} = n^{(1,\tilde{p}_0)}_{\text{PUCCH}} + 1$

- If the UE is not configured with the higher layer parameter *EIMTA-MainConfigServCell-r12* on the primary cell,
  - for a single PDSCH transmission only on the primary cell indicated by the detection of a corresponding EPDCCH in subframe $n-k_m$, where $k_m \in K$, and for a TDD UL/DL configuration of the primary cell belonging to {1,2,3,4,5,6} the DAI value in the EPDCCH is equal to '1' (defined in Table 7.3-X), or
  - for a single PDCCH indicating downlink SPS release (defined in subclause 9.2) in subframe $n-k_m$, where $k_m \in K$, and for a TDD UL/DL configuration of the primary cell belonging to {1,2,3,4,5,6} the DAI value in the EPDCCH is equal to '1',
    - the UE shall use PUCCH format 1a/1b and PUCCH resource $n^{(1,\tilde{p})}_{\text{PUCCH}}$ given by
      - If EPDCCH-PRB-set q is configured for distributed transmission

$$n^{(1,\tilde{p})}_{\text{PUCCH}} = n_{\text{ECCE,q}} + \sum_{i1=0}^{m-1} N_{ECCE,q,n-k_{i1}} + \Delta_{ARO} + N^{(\text{e1})}_{\text{PUCCH,q}}$$

      - If EPDCCH-PRB-set q is configured for localized transmission

$$n^{(1,\tilde{p})}_{\text{PUCCH}} = \left\lfloor \frac{n_{\text{ECCE,q}}}{N^{ECCE,q}_{RB}} \right\rfloor \cdot N^{ECCE,q}_{RB} + \sum_{i1=0}^{m-1} N_{ECCE,q,n-k_{i1}} + n' + \Delta_{ARO} + N^{(\text{e1})}_{\text{PUCCH,q}}$$

where $n_{\text{ECCE,q}}$ is the number of the first ECCE (i.e. lowest ECCE index used to construct the EPDCCH) used for transmission of the corresponding DCI assignment in EPDCCH-PRB-set q in subframe $n-k_m$, $N^{(\text{e1})}_{\text{PUCCH,q}}$ for EPDCCH-PRB-set q is configured by the higher layer parameter pucch-ResourceStartOffset-r11 , $N^{ECCE,q}_{RB}$ for EPDCCH-PRB-set q in subframe $n-k_m$ is given in subclause 6.8A.1 in [3], n' is determined from the antenna port used for EPDCCH transmission in subframe $n-k_m$ which is described in subclause 6.8A.5 in [3]. If $m=0$, Δ_{ARO} is determined from the HARQ-ACK resource offset field in the DCI format of the corresponding EPDCCH as given in Table 10.1.2.1-1. If $m>0$, Δ_{ARO} is determined from the HARQ-ACK resource offset field in the DCI format of the corresponding EPDCCH as given in Table 10.1.3.1-2. If the UE is configured to monitor EPDCCH in subframe $n-k_{i1}$, $N_{ECCE,q,n-k_{i1}}$ is equal to the number of ECCEs in EPDCCH-PRB-set q configured for that UE in subframe $n-k_{i1}$. If the UE is not configured to monitor EPDCCH in subframe $n-k_{i1}$, $N_{ECCE,q,n-k_{i1}}$ is equal to the number of ECCEs computed assuming EPDCCH-PRB-set q is configured for that UE in subframe $n-k_{i1}$. For normal downlink CP, if subframe $n-k_{i1}$ is a special subframe with special subframe configuration 0 or 5,

$N_{ECCE,q,n-k_{i1}}$ is equal to 0. For extended downlink CP, if subframe $n-k_{i1}$ is a special subframe with special subframe configuration 0 or 4 or 7, $N_{ECCE,q,n-k_{i1}}$ is equal to 0. When two antenna port transmission is configured for PUCCH format 1a/1b, the PUCCH resource for antenna port p_1 is given by $n_{\text{PUCCH}}^{(1,\tilde{p}_1)} = n_{\text{PUCCH}}^{(1,\tilde{p}_0)} + 1$.

- If the UE is configured with the higher layer parameter *EIMTA-MainConfigServCell-r12* on the primary cell,
  - for a single PDSCH transmission only on the primary cell indicated by the detection of a corresponding EPDCCH in subframe $n-k_m$, where $k_m \in K$, and for a TDD UL/DL configuration of the primary cell belonging to {1,2,3,4,5,6} the DAI value in the EPDCCH is equal to '1' (defined in Table 7.3-X), or
  - for a single PDCCH indicating downlink SPS release (defined in subclause 9.2) in subframe $n-k_m$, where $k_m \in K$, and for a TDD UL/DL configuration of the primary cell belonging to {1,2,3,4,5,6} the DAI value in the EPDCCH is equal to '1',
    - the UE shall use PUCCH format 1a/1b and PUCCH resource $n_{\text{PUCCH}}^{(1,\tilde{p})}$ given by
      - if EPDCCH-PRB-set q is configured for distributed transmission

$$n_{\text{PUCCH}}^{(1,\tilde{p})} = n_{\text{ECCE,q}} + \sum_{i1=0}^{i4-1} N'_{ECCE,q,n-k'_{i1}} + \sum_{i1=0}^{i5-1} N'_{ECCE,q,n-k^A_{i1}} + \Delta'_{ARO} + N_{\text{PUCCH,q}}^{(\text{e1})}$$

      - if EPDCCH-PRB-set q is configured for localized transmission

$$n_{\text{PUCCH}}^{(1,\tilde{p})} = \left\lfloor \frac{n_{\text{ECCE,q}}}{N_{RB}^{ECCE,q}} \right\rfloor \cdot N_{RB}^{ECCE,q} + \sum_{i1=0}^{i4-1} N'_{ECCE,q,n-k'_{i1}} + \sum_{i1=0}^{i5-1} N'_{ECCE,q,n-k^A_{i1}} + n' + \Delta'_{ARO} + N_{\text{PUCCH,q}}^{(\text{e1})}$$

      where

        - if the value of k_m is same as the value of an index k'_{i2}, where $k'_{i2} \in K'$, then $i4 = i2$;
        - otherwise, if the value of k_m is same as the value of an index k^A_{i3}, where $k^A_{i3} \in K^A$, then $i4 = i3$;

        and where $n_{\text{ECCE,q}}$ is the number of the first ECCE (i.e. lowest ECCE index used to construct the EPDCCH) used for transmission of the corresponding DCI assignment in EPDCCH-PRB-set q in subframe $n-k_m$, $N_{\text{PUCCH,q}}^{(\text{e1})}$ for EPDCCH-PRB-set q is configured by the higher layer parameter *pucch-ResourceStartOffset-r11* , $N_{RB}^{ECCE,q}$ for EPDCCH-PRB-set q in subframe $n-k_m$ is given in subclause 6.8A.1 in [3], n' is determined from the antenna port used for EPDCCH transmission in subframe $n-k_m$ which is described in subclause 6.8A.5 in [3]. Δ'_{ARO}, $N'_{ECCE,q,n-k'_{i1}}$, $N'_{ECCE,q,n-k^A_{i1}}$ are determined as described in section 10.1.3.1. When two antenna port transmission is configured for PUCCH format 1a/1b, the PUCCH resource for antenna port p_1 is given by $n_{\text{PUCCH}}^{(1,\tilde{p}_1)} = n_{\text{PUCCH}}^{(1,\tilde{p}_0)} + 1$.

- for a single PDSCH transmission only on the primary cell where there is not a corresponding PDCCH/EPDCCH detected within subframe(s) $n-k$, where $k \in K$ and no PDCCH/EPDCCH indicating downlink SPS release (defined in subclause 9.2) within subframe(s) $n-k$, where $k \in K$, the UE shall use PUCCH format 1a/1b and PUCCH resource $n_{\text{PUCCH}}^{(1,\tilde{p})}$ with the value of $n_{\text{PUCCH}}^{(1,\tilde{p})}$ is determined according to higher layer configuration and Table 9.2-2. For a UE configured for two antenna port transmission for PUCCH format 1a/1b, a PUCCH resource value in Table 9.2-2 maps to two PUCCH resources with the first PUCCH resource $n_{\text{PUCCH}}^{(1,\tilde{p}_0)}$ for antenna port p_0 and the second PUCCH resource $n_{\mathrm{PUCCH}}^{(1,\tilde{p}_1)}$ for antenna port p_1, otherwise, the PUCCH resource value maps to a single PUCCH resource $n_{\mathrm{PUCCH}}^{(1,\tilde{p}_0)}$ for antenna port p_0.

- for $M > 1$, and
  - for a PDSCH transmission only on the primary cell where there is not a corresponding PDCCH detected within subframe(s) $n-k$, where $k \in K$, and
    - for an additional PDSCH transmission only on the primary cell indicated by the detection of a corresponding PDCCH in subframe $n-k_m$, where $k_m \in K$ with the DAI value in the PDCCH equal to '1' (defined in Table 7.3-X), or
    - for an additional PDCCH indicating downlink SPS release (defined in subclause 9.2) in subframe $n-k_m$, where $k_m \in K$ with the DAI value in the PDCCH equal to '1',
      - the UE shall transmit $b(0), b(1)$ in subframe n using PUCCH format 1b on PUCCH resource $n_{\mathrm{PUCCH}}^{(1)}$ selected from A PUCCH resources $n_{\mathrm{PUCCH},i}^{(1)}$ where $0 \le i \le A-1$, according to Table 10.1.3.2-1 and Table 10.1.3.2-2 for $A = 2$ and $A = 3$, respectively. For a UE configured with a transmission mode that supports up to two transport blocks on the primary cell, $A = 3$; otherwise, $A = 2$.
        - If the UE is not configured with the higher layer parameter *EIMTA-MainConfigServCell-r12* on the primary cell, the PUCCH resource $n_{\mathrm{PUCCH},0}^{(1)}$ is determined according to higher layer configuration and Table 9.2-2. The PUCCH resource $n_{\mathrm{PUCCH},1}^{(1)}$ is determined as $n_{\mathrm{PUCCH},1}^{(1)} = (M - m - 1) \cdot N_c + m \cdot N_{c+1} + n_{\mathrm{CCE},m} + N_{\mathrm{PUCCH}}^{(1)}$, where $N_{\mathrm{PUCCH}}^{(1)}$ is configured by higher layers, c is selected from {0, 1, 2, 3} such that $N_c \le n_{\mathrm{CCE},m} < N_{c+1}$, $N_c = \max\left\{0, \left\lfloor [N_{\mathrm{RB}}^{\mathrm{DL}} \cdot (N_{\mathrm{sc}}^{\mathrm{RB}} \cdot c - 4)]/36 \right\rfloor\right\}$, and $n_{\mathrm{CCE,m}}$ is the number of the first CCE used for transmission of the corresponding PDCCH in subframe $n-k_m$ where $k_m \in K$.
        - If the UE is configured with the higher layer parameter *EIMTA-MainConfigServCell-r12* on the primary cell, the PUCCH resource $n_{\mathrm{PUCCH},0}^{(1)}$ is determined according to higher layer configuration and Table 9.2-2. The PUCCH resource $n_{\mathrm{PUCCH},1}^{(1)}$ is determined as
          - if the value of k_m is same as the value of an element k'_{i2}, where $k'_{i2} \in K'$, the PUCCH resource $n_{\mathrm{PUCCH},1}^{(1)}$ is given by $n_{\mathrm{PUCCH},1}^{(1)} = (M' - i2 - 1) \cdot N_c + i2 \cdot N_{c+1} + n_{\mathrm{CCE},m} + N_{\mathrm{PUCCH}}^{(1)}$;
          - otherwise, if the value of k_m is same as the value of an element k_{i3}^{A} in set K^A, where $k_{i3}^{A} \in K^A$ (defined in Table 10.1.3.1-1A, where "UL/DL configuration" in the table refers to the higher layer parameter *subframeAssignment*), the PUCCH resource $n_{\mathrm{PUCCH},1}^{(1)}$ is given by $n_{\mathrm{PUCCH},1}^{(1)} = (M^A - i3 - 1) \cdot N_c + i3 \cdot N_{c+1} + n_{\mathrm{CCE},m} + N_{\mathrm{PUCCH}}^{\mathrm{K^A}}$;

            where M^A is the number of elements in the set K^A defined in Table 10.1.3.1-1A , where c is selected from {0, 1, 2, 3} such that $N_c \le n_{\mathrm{CCE},m} < N_{c+1}$, $N_c = \max\left\{0, \left\lfloor [N_{\mathrm{RB}}^{\mathrm{DL}} \cdot (N_{\mathrm{sc}}^{\mathrm{RB}} \cdot c - 4)]/36 \right\rfloor\right\}$, $n_{CCE,m}$ is the number of the first CCE used for transmission of the corresponding PDCCH in subframe $n-k_m$, and $N_{\mathrm{PUCCH}}^{\mathrm{K^A}}$, $N_{\mathrm{PUCCH}}^{(1)}$, are configured by higher layers.

- For a UE configured with a transmission mode that supports up to two transport blocks on the primary cell, the PUCCH resource $n^{(1)}_{\mathrm{PUCCH},2}$ is determined as $n^{(1)}_{\mathrm{PUCCH},2} = n^{(1)}_{\mathrm{PUCCH},1} + 1$.HARQ-ACK(0) is the ACK/NACK/DTX response for the PDSCH without a corresponding PDCCH detected. HARQ-ACK(1) is the ACK/NACK/DTX response for the first transport block of the PDSCH indicated by the detection of a corresponding PDCCH for which the value of the DAI field in the corresponding DCI format is equal to '1' or for the PDCCH indicating downlink SPS release for which the value of the DAI field in the corresponding DCI format is equal to '1'. HARQ-ACK(2) is the ACK/NACK/DTX response for the second transport block of the PDSCH indicated by the detection of a corresponding PDCCH for which the value of the DAI field in the corresponding DCI format is equal to '1'.

- for $M > 1$, and
  - for a PDSCH transmission only on the primary cell where there is not a corresponding EPDCCH detected within subframe(s) $n-k$, where $k \in K$, and
    - for an additional PDSCH transmission only on the primary cell indicated by the detection of a corresponding EPDCCH in subframe $n-k_m$, where $k_m \in K$ with the DAI value in the EPDCCH equal to '1' (defined in Table 7.3-X), or
    - for an additional EPDCCH indicating downlink SPS release (defined in subclause 9.2) in subframe $n-k_m$, where $k_m \in K$ with the DAI value in the EPDCCH equal to '1',
      - the UE shall transmit $b(0), b(1)$ in subframe n using PUCCH format 1b on PUCCH resource $n^{(1)}_{\mathrm{PUCCH}}$ selected from A PUCCH resources $n^{(1)}_{\mathrm{PUCCH},i}$ where $0 \le i \le A-1$, according to Table 10.1.3.2-1 and Table 10.1.3.2-2 for $A = 2$ and $A = 3$, respectively. For a UE configured with a transmission mode that supports up to two transport blocks on the primary cell, $A = 3$; otherwise, $A = 2$.
        - If the UE is not configured with the higher layer parameter *EIMTA-MainConfigServCell-r12* on the primary cell, the PUCCH resource $n^{(1)}_{\mathrm{PUCCH},0}$ is determined according to higher layer configuration and Table 9.2-2. The PUCCH resource $n^{(1)}_{\mathrm{PUCCH},1}$ is determined as
          - If EPDCCH-PRB-set q is configured for distributed transmission

$$n^{(1)}_{\mathrm{PUCCH},1} = n_{\mathrm{ECCE,q}} + \sum_{i1=0}^{m-1} N_{ECCE,q,n-k_{i1}} + \Delta_{ARO} + N^{(e1)}_{\mathrm{PUCCH,q}}$$

          - If EPDCCH-PRB-set q is configured for localized transmission

$$n^{(1)}_{\mathrm{PUCCH},1} = \left\lfloor \frac{n_{\mathrm{ECCE,q}}}{N^{ECCE,q}_{RB}} \right\rfloor \cdot N^{ECCE,q}_{RB} + \sum_{i1=0}^{m-1} N_{ECCE,q,n-k_{i1}} + n' + \Delta_{ARO} + N^{(e1)}_{\mathrm{PUCCH,q}}$$

where $n_{\mathrm{ECCE,q}}$ is the number of the first ECCE (i.e. lowest ECCE index used to construct the EPDCCH) used for transmission of the corresponding DCI assignment in EPDCCH-PRB-set q in subframe $n-k_m$, $N^{(e1)}_{\mathrm{PUCCH,q}}$ for EPDCCH-PRB-set q is configured by the higher layer parameter pucch-ResourceStartOffset-r11 , $N^{ECCE,q}_{RB}$ for EPDCCH-PRB-set q in subframe $n-k_m$ is given in subclause 6.8A.1 in [3], n' is determined from the antenna port used for EPDCCH transmission in subframe $n-k_m$ which is described in subclause 6.8A.5 in [3]. If $m = 0$, Δ_{ARO} is determined from the HARQ-ACK resource offset field in the DCI format of the corresponding EPDCCH as given in Table 10.1.2.1-1. If $m > 0$, Δ_{ARO} is determined from the HARQ-ACK resource offset field in the DCI format of the corresponding EPDCCH as given in Table 10.1.3.1-2. If the UE is configured to monitor EPDCCH in subframe $n-k_{i1}$,

$N_{ECCE,q,n-k_{i1}}$ is equal to the number of ECCEs in EPDCCH-PRB-set q configured for that UE in subframe $n-k_{i1}$. If the UE is not configured to monitor EPDCCH in subframe $n-k_{i1}$, $N_{ECCE,q,n-k_{i1}}$ is equal to the number of ECCEs computed assuming EPDCCH-PRB-set q is configured for that UE in subframe $n-k_{i1}$. For normal downlink CP, if subframe $n-k_{i1}$ is a special subframe with special subframe configuration 0 or 5, $N_{ECCE,q,n-k_{i1}}$ is equal to 0. For extended downlink CP, if subframe $n-k_{i1}$ is a special subframe with special subframe configuration 0 or 4 or 7, $N_{ECCE,q,n-k_{i1}}$ is equal to 0.

- If the UE is configured with the higher layer parameter *EIMTA-MainConfigServCell-r12* on the primary cell, the PUCCH resource $n^{(1)}_{\mathrm{PUCCH},0}$ is determined according to higher layer configuration and Table 9.2-2. The PUCCH resource $n^{(1)}_{\mathrm{PUCCH},1}$ is determined as

  - If EPDCCH-PRB-set q is configured for distributed transmission

$$n^{(1)}_{\mathrm{PUCCH,i}} = n_{\mathrm{ECCE,q}} + \sum_{i1=0}^{i4-1} N'_{ECCE,q,n-k'_{i1}} + \sum_{i1=0}^{i5-1} N'_{ECCE,q,n-k^A_{i1}} + \Delta'_{ARO} + N^{(e1)}_{\mathrm{PUCCH,q}}$$

  - If EPDCCH-PRB-set q is configured for localized transmission

$$n^{(1)}_{\mathrm{PUCCH,i}} = \left\lfloor \frac{n_{\mathrm{ECCE,q}}}{N_{RB}^{ECCE,q}} \right\rfloor \cdot N_{RB}^{ECCE,q} + \sum_{i1=0}^{i4-1} N'_{ECCE,q,n-k'_{i1}} + \sum_{i1=0}^{i5-1} N'_{ECCE,q,n-k^A_{i1}} + n' + \Delta'_{ARO} + N^{(e1)}_{\mathrm{PUCCH,q}}$$

  where

    - if the value of k_m is same as the value of an index k'_{i2}, where $k'_{i2} \in K'$, then $i4 = i2$;
    - otherwise, if the value of k_m is same as the value of an index k^A_{i3}, where $k^A_{i3} \in K^A$, then $i4 = i3$;

  - and where $n_{\mathrm{ECCE,q}}$ is the number of the first ECCE (i.e. lowest ECCE index used to construct the EPDCCH) used for transmission of the corresponding DCI assignment in EPDCCH-PRB-set q in subframe $n-k_m$, $N^{(e1)}_{\mathrm{PUCCH,q}}$ for EPDCCH-PRB-set q is configured by the higher layer parameter *pucch-ResourceStartOffset-r11*, $N_{RB}^{ECCE,q}$ for EPDCCH-PRB-set q in subframe $n-k_m$ is given in subclause 6.8A.1 in [3], n' is determined from the antenna port used for EPDCCH transmission in subframe $n-k_m$ which is described in subclause 6.8A.5 in [3]. Δ'_{ARO}, $N'_{ECCE,q,n-k'_{i1}}$, $N'_{ECCE,q,n-k^A_{i1}}$ are determined as described in section 10.1.3.1.

- For a UE configured with a transmission mode that supports up to two transport blocks on the primary cell, the PUCCH resource $n^{(1)}_{\mathrm{PUCCH},2}$ is determined as $n^{(1)}_{\mathrm{PUCCH},2} = n^{(1)}_{\mathrm{PUCCH},1} + 1$.HARQ-ACK(0) is the ACK/NACK/DTX response for the PDSCH without a corresponding EPDCCH detected. HARQ-ACK(1) is the ACK/NACK/DTX response for the first transport block of the PDSCH indicated by the detection of a corresponding EPDCCH for which the value of the DAI field in the corresponding DCI format is equal to '1' or for the EPDCCH indicating downlink SPS release for which the value of the DAI field in the corresponding DCI format is equal to '1'. HARQ-ACK(2) is the ACK/NACK/DTX response for the second transport block of the PDSCH indicated by the detection of a corresponding EPDCCH for which the value of the DAI field in the corresponding DCI format is equal to '1'.

- for $M > 1$, and

  - for a PDSCH transmission only on the primary cell indicated by the detection of a corresponding PDCCH in subframe $n-k_m$, where $k_m \in K$ with the DAI value in the PDCCH greater than '1' (defined in Table 7.3-X), or

  - for a PDCCH indicating downlink SPS release (defined in subclause 9.2) in subframe $n-k_m$, where $k_m \in K$ with the DAI value in the PDCCH greater than '1', or

  - for $M = 9$ and for a PDSCH transmission only on the primary cell indicated by the detection of a corresponding PDCCH in subframe $n-k_m$, where $k_m \in K$ with the DAI value in the PDCCH equal to '1' (defined in Table 7.3-X) not being the first PDCCH/EPDCCH transmission in subframe(s) $n-k$, where $k \in K$ with the DAI value equal to '1', or

  - for $M = 9$ and for a PDCCH indicating downlink SPS release (defined in subclause 9.2) in subframe $n-k_m$, where $k_m \in K$ with the DAI value in the PDCCH equal to '1' (defined in Table 7.3-X) not being the first PDCCH/EPDCCH transmission in subframe(s) $n-k$, where $k \in K$ with the DAI value equal to '1',

    - the UE shall use PUCCH format 3 and PUCCH resource $n_{\text{PUCCH}}^{(3,\tilde{p})}$ where the value of $n_{\text{PUCCH}}^{(3,\tilde{p})}$ is determined according to higher layer configuration and Table 10.1.2.2.2-1 and the TPC field in a PDCCH assignment with DAI value greater than '1' (defined in Table 7.3-X) or with DAI value equal to '1', not being the first PDCCH/EPDCCH assignment in subframe(s) $n-k$, where $k \in K$ with the DAI value equal to '1', shall be used to determine the PUCCH resource value from one of the four PUCCH resource values configured by higher layers, with the mapping defined in Table 10.1.2.2.2-1. A UE shall assume that the same HARQ-ACK PUCCH resource value is transmitted on all PDCCH assignments used to determine the PUCCH resource values within the subframe(s) $n-k$, where $k \in K$.

- for $M > 1$, and

  - for a PDSCH transmission only on the primary cell indicated by the detection of a corresponding EPDCCH in subframe $n-k_m$, where $k_m \in K$ with the DAI value in the EPDCCH greater than '1' (defined in Table 7.3-X), or

  - for an EPDCCH indicating downlink SPS release (defined in subclause 9.2) in subframe $n-k_m$, where $k_m \in K$ with the DAI value in the EPDCCH greater than '1', or

  - for $M = 9$ and for a PDSCH transmission only on the primary cell indicated by the detection of a corresponding EPDCCH in subframe $n-k_m$, where $k_m \in K$ with the DAI value in the EPDCCH equal to '1' (defined in Table 7.3-X) not being the first PDCCH/EPDCCH transmission in subframe(s) $n-k$, where $k \in K$ with the DAI value equal to '1', or

  - for $M = 9$ and for an EPDCCH indicating downlink SPS release (defined in subclause 9.2) in subframe $n-k_m$, where $k_m \in K$ with the DAI value in the EPDCCH equal to '1' (defined in Table 7.3-X) not being the first PDCCH/EPDCCH transmission in subframe(s) $n-k$, where $k \in K$ with the DAI value equal to '1',

    - the UE shall use PUCCH format 3 and PUCCH resource $n_{\text{PUCCH}}^{(3,\tilde{p})}$ where the value of $n_{\text{PUCCH}}^{(3,\tilde{p})}$ is determined according to higher layer configuration and Table 10.1.2.2.2-1 and the HARQ-ACK resource offset field in the DCI format of the corresponding EPDCCH assignment with DAI value greater than '1' or with DAI value equal to '1' (defined in Table 7.3-X), not being the first PDCCH/EPDCCH assignment in subframe(s) $n-k$, where $k \in K$ with the DAI value equal to '1', shall be used to determine the PUCCH resource value from one of the four PUCCH resource values configured by higher layers, with the mapping defined in Table 10.1.2.2.2-1. A UE shall assume that the same HARQ-ACK PUCCH resource value is transmitted on all EPDCCH assignments used to determine the PUCCH resource values within the subframe(s) $n-k$, where $k \in K$.

- If the UL/DL configurations of all serving cells are the same, for a PDSCH transmission on the secondary cell indicated by the detection of a corresponding PDCCH/EPDCCH within subframe(s) $n-k$, where $k \in K$, the UE shall use PUCCH format 3 and PUCCH resource $n_{\text{PUCCH}}^{(3,\tilde{p})}$ where the value of $n_{\text{PUCCH}}^{(3,\tilde{p})}$ is determined according to higher layer configuration and Table 10.1.2.2.2-1 and the TPC field in the corresponding

PDCCH/EPDCCH shall be used to determine the PUCCH resource value from one of the four resource values configured by higher layers, with the mapping defined in Table 10.1.2.2.2-1. For TDD UL/DL configurations 1-6, if a PDCCH corresponding to a PDSCH on the primary cell within subframe(s) $n-k$, where $k \in K$, or a PDCCH indicating downlink SPS release (defined in subclause 9.2) within subframe(s) $n-k$, where $k \in K$, is detected, the TPC field in the PDCCH with the DAI value greater than '1' or with DAI value equal to '1', not being the first PDCCH/EPDCCH transmission in subframe(s) $n-k$, where $k \in K$ with the DAI value equal to '1' (defined in Table 7.3-X), shall be used to determine the PUCCH resource value from one of the four resource values configured by higher layers, with the mapping defined in Table 10.1.2.2.2-1. A UE shall assume that the same HARQ-ACK PUCCH resource value is transmitted on all PDCCH assignments in the primary cell and in each secondary cell that are used to determined the PUCCH resource value within the subframe(s) $n-k$, where $k \in K$. For TDD UL/DL configurations 1-6, if an EPDCCH corresponding to a PDSCH on the primary cell within subframe(s) $n-k$, where $k \in K$, or an EPDCCH indicating downlink SPS release (defined in subclause 9.2) within subframe(s) $n-k$, where $k \in K$, is detected, the HARQ-ACK resource offset field in the DCI format of the corresponding EPDCCH assignment with the DAI value greater than '1' (defined in Table 7.3-X) or with DAI value equal to '1', not being the first PDCCH/EPDCCH transmission in subframe(s) $n-k$, where $k \in K$ with the DAI value equal to '1', shall be used to determine the PUCCH resource value from one of the four resource values configured by higher layers, with the mapping defined in Table 10.1.2.2.2-1. A UE shall assume that the same HARQ-ACK PUCCH resource value is transmitted on all EPDCCH assignments in the primary cell and in each secondary cell that are used to determined the PUCCH resource value within the subframe(s) $n-k$, where $k \in K$.

- If the UL/DL configurations of at least two serving cells are different, for a PDSCH transmission on the secondary cell indicated by the detection of a corresponding PDCCH/EPDCCH within subframe(s) $n-k$, where $k \in K$, the UE shall use PUCCH format 3 and PUCCH resource $n_{\mathrm{PUCCH}}^{(3,\tilde{p})}$ where the value of $n_{\mathrm{PUCCH}}^{(3,\tilde{p})}$ is determined according to higher layer configuration and Table 10.1.2.2.2-1 and the TPC field in the corresponding PDCCH/EPDCCH shall be used to determine the PUCCH resource value from one of the four resource values configured by higher layers, with the mapping defined in Table 10.1.2.2.2-1. For a UL/DL configuration of the primary cell belonging to {1,2,3,4,5,6} as defined in subclause 10.2, if a PDCCH corresponding to a PDSCH on the primary cell within subframe(s) $n-k$, where $k \in K$, or a PDCCH indicating downlink SPS release (defined in subclause 9.2) within subframe(s) $n-k$, where $k \in K$, is detected, the TPC field in the PDCCH with the DAI value greater than '1' (defined in Table 7.3-X) or with DAI value equal to '1', not being the first PDCCH/EPDCCH transmission in subframe(s) $n-k$, where $k \in K$ with the DAI value equal to '1', shall be used to determine the PUCCH resource value from one of the four resource values configured by higher layers, with the mapping defined in Table 10.1.2.2.2-1. A UE shall assume that the same HARQ-ACK PUCCH resource value is transmitted on all PDCCH assignments in the primary cell and in each secondary cell that are used to determined the PUCCH resource value within the subframe(s) $n-k$, where $k \in K$. For a UL/DL configuration of the primary cell belonging to {1,2,3,4,5,6} as defined in subclause 10.2, if an EPDCCH corresponding to a PDSCH on the primary cell within subframe(s) $n-k$, where $k \in K$, or an EPDCCH indicating downlink SPS release (defined in subclause 9.2) within subframe(s) $n-k$, where $k \in K$, is detected, the HARQ-ACK resource offset field in the DCI format of the corresponding EPDCCH assignment with the DAI value greater than '1' or with DAI value equal to '1', not being the first PDCCH/EPDCCH transmission in subframe(s) $n-k$, where $k \in K$ with the DAI value equal to '1', shall be used to determine the PUCCH resource value from one of the four resource values configured by higher layers, with the mapping defined in Table 10.1.2.2.2-1. A UE shall assume that the same HARQ-ACK PUCCH resource value is transmitted on all EPDCCH assignments in the primary cell and in each secondary cell that are used to determined the PUCCH resource value within the subframe(s) $n-k$, where $k \in K$.

- For PUCCH format 3 and PUCCH resource $n_{\mathrm{PUCCH}}^{(3,\tilde{p})}$ and a UE configured for two antenna port transmission, a PUCCH resource value in Table 10.1.2.2.2-1 maps to two PUCCH resources with the first PUCCH resource $n_{\mathrm{PUCCH}}^{(3,\tilde{p}_0)}$ for antenna port p_0 and the second PUCCH resource $n_{\mathrm{PUCCH}}^{(3,\tilde{p}_1)}$ for antenna port p_1, otherwise, the PUCCH resource value maps to a single PUCCH resource $n_{\mathrm{PUCCH}}^{(3,\tilde{p}_0)}$ for antenna port p_0.

10.1.3.2.3 PUCCH format 4 HARQ-ACK procedure

TDD HARQ-ACK feedback procedures for a UE configured with PUCCH format 4 and *codebooksizeDetermination-r13 = cc* is described in section 10.1.3.2.3.1.

TDD HARQ-ACK feedback procedures for a UE configured with PUCCH format 4 and *codebooksizeDetermination-r13 = dai* is described in section 10.1.3.2.3.2.

10.1.3.2.3.1 PUCCH format 4 HARQ-ACK procedure without adaptive codebook

The procedure in this subclause applies to a UE configured with PUCCH format 4 and *codebooksizeDetermination-r13 = cc*.

If a UE is configured with the higher layer parameter *EIMTA-MainConfigServCell-r12*, then $K' = K$ where the set K is defined in Table 10.1.3.1-1 (where "UL/DL configuration" in the table refers to the higher layer parameter *subframeAssignment*), and M' is the number of elements in set K'.

If a UE is configured with more than one serving cells and the UL/DL configuration of all serving cells is same, then in the rest of this subclause K is as defined in Sec 10.2, and M is the number of elements in the set K.

If a UE is configured with more than one serving cell and if at least two cells have different UL/DL configurations, then K in this subclause refers to K_c (as defined in subclause 10.2) , and M is the number of elements in the set K.

For TDD HARQ-ACK transmission with PUCCH format 4 and sub-frame n with $M \geq 1$ and more than one configured serving cell, where M is the number of elements in the set K, the UE shall use PUCCH resource $n_{\text{PUCCH}}^{(5)}$ or $n_{\text{PUCCH}}^{(1,\tilde{p})}$ for transmission of HARQ-ACK and scheduling request (if any) and periodic CSI (if any) in subframe n for $\tilde{p}$ mapped to antenna port *p* where

- If the UE is not configured with the higher layer parameter *EIMTA-MainConfigServCell-r12* on the primary cell,
  - for a single PDSCH transmission only on the primary cell indicated by the detection of a corresponding PDCCH in subframe $n - k_m$, where $k_m \in K$, and for a TDD UL/DL configuration of the primary cell belonging to {1,2,3,4,5,6} the DAI value in the PDCCH is equal to '1' (defined in Table 7.3-X), or
  - for a single PDCCH indicating downlink SPS release (defined in subclause 9.2) in subframe $n - k_m$, where $k_m \in K$, and for a TDD UL/DL configuration of the primary cell belonging to {1,2,3,4,5,6} the DAI value in the PDCCH is equal to '1',
    - the UE shall use PUCCH format 1a/1b and PUCCH resource $n_{\text{PUCCH}}^{(1,\tilde{p})}$ with $n_{\text{PUCCH}}^{(1,\tilde{p}_0)} = (M - m - 1) \cdot N_c + m \cdot N_{c+1} + n_{\text{CCE},m} + N_{\text{PUCCH}}^{(1)}$ for antenna port p_0, where $N_{\text{PUCCH}}^{(1)}$ is configured by higher layers, c is selected from {0, 1, 2, 3} such that $N_c \leq n_{\text{CCE},m} < N_{c+1}$, $N_c = \max\left\{0, \left\lfloor [N_{\text{RB}}^{\text{DL}} \cdot (N_{\text{sc}}^{\text{RB}} \cdot c - 4)]/36 \right\rfloor\right\}$, and $n_{\text{CCE,m}}$ is the number of the first CCE used for transmission of the corresponding PDCCH in subframe $n - k_m$ where $k_m \in K$. When two antenna port transmission is configured for PUCCH format 1a/1b, the PUCCH resource for antenna port p_1 is given by $n_{\text{PUCCH}}^{(1,\tilde{p}_1)} = n_{\text{PUCCH}}^{(1,\tilde{p}_0)} + 1$
- If the UE is configured with the higher layer parameter *EIMTA-MainConfigServCell-r12* on the primary cell,
  - for a single PDSCH transmission only on the primary cell indicated by the detection of a corresponding PDCCH in subframe $n - k_m$, where $k_m \in K$, and for a TDD UL/DL configuration of the primary cell belonging to {1,2,3,4,5,6} the DAI value in the PDCCH is equal to '1' (defined in Table 7.3-X), or
  - for a single PDCCH indicating downlink SPS release (defined in subclause 9.2) in subframe $n - k_m$, where $k_m \in K$, and for a TDD UL/DL configuration of the primary cell belonging to {1,2,3,4,5,6} the DAI value in the PDCCH is equal to '1',
    - the UE shall use PUCCH format 1a/1b, and
      - if the value of k_m is same as the value of an element k'_{i2}, where $k'_{i2} \in K'$, the PUCCH resource $n_{\text{PUCCH}}^{(1,\tilde{p})}$ is given by $n_{\text{PUCCH}}^{(1,\tilde{p})} = (M' - i2 - 1) \cdot N_c + i2 \cdot N_{c+1} + n_{\text{CCE},m} + N_{\text{PUCCH}}^{(1)}$;

- otherwise, if the value of k_m is same as the value of an element k_{i3}^A in set K^A, where $k_{i3}^A \in K^A$ (defined in Table 10.1.3.1-1A, where "UL/DL configuration" in the table refers to the higher layer parameter *subframeAssignment*), the PUCCH resource $n_{\text{PUCCH}}^{(1,\tilde{p})}$ is given by $n_{\text{PUCCH}}^{(1,\tilde{p})} = (M^A - i3 - 1) \cdot N_c + i3 \cdot N_{c+1} + n_{\text{CCE},m} + N_{\text{PUCCH}}^{\text{K}^\text{A}}$;

  where M^A is the number of elements in the set K^A defined in Table 10.1.3.1-1A , where c is selected from {0, 1, 2, 3} such that $N_c \le n_{\text{CCE},m} < N_{c+1}$, $N_c = \max\left\{0, \left\lfloor [N_{\text{RB}}^{\text{DL}} \cdot (N_{\text{sc}}^{\text{RB}} \cdot c - 4)]/36 \right\rfloor\right\}$ where $N_{\text{RB}}^{\text{DL}}$ is determined from the primary cell, $n_{CCE,m}$ is the number of the first CCE used for transmission of the corresponding PDCCH in subframe $n - k_m$, and $N_{\text{PUCCH}}^{\text{K}^\text{A}}$, $N_{\text{PUCCH}}^{(1)}$, are configured by higher layers. When two antenna port transmission is configured for PUCCH format 1a/1b, the PUCCH resource for antenna port p_1 is given by $n_{\text{PUCCH}}^{(1,\tilde{p}_1)} = n_{\text{PUCCH}}^{(1,\tilde{p}_0)} + 1$

- If the UE is not configured with the higher layer parameter *EIMTA-MainConfigServCell-r12* on the primary cell,
  - for a single PDSCH transmission only on the primary cell indicated by the detection of a corresponding EPDCCH in subframe $n - k_m$, where $k_m \in K$, and for a TDD UL/DL configuration of the primary cell belonging to {1,2,3,4,5,6} the DAI value in the EPDCCH is equal to '1' (defined in Table 7.3-X), or
  - for a single PDCCH indicating downlink SPS release (defined in subclause 9.2) in subframe $n - k_m$, where $k_m \in K$, and for a TDD UL/DL configuration of the primary cell belonging to {1,2,3,4,5,6} the DAI value in the EPDCCH is equal to '1',
    - the UE shall use PUCCH format 1a/1b and PUCCH resource $n_{\text{PUCCH}}^{(1,\tilde{p})}$ given by
      - If EPDCCH-PRB-set q is configured for distributed transmission

$$n_{\text{PUCCH}}^{(1,\tilde{p})} = n_{\text{ECCE,q}} + \sum_{i1=0}^{m-1} N_{ECCE,q,n-k_{i1}} + \Delta_{ARO} + N_{\text{PUCCH,q}}^{(\text{e1})}$$

      - If EPDCCH-PRB-set q is configured for localized transmission

$$n_{\text{PUCCH}}^{(1,\tilde{p})} = \left\lfloor \frac{n_{\text{ECCE,q}}}{N_{RB}^{ECCE,q}} \right\rfloor \cdot N_{RB}^{ECCE,q} + \sum_{i1=0}^{m-1} N_{ECCE,q,n-k_{i1}} + n' + \Delta_{ARO} + N_{\text{PUCCH,q}}^{(\text{e1})}$$

  where $n_{\text{ECCE,q}}$ is the number of the first ECCE (i.e. lowest ECCE index used to construct the EPDCCH) used for transmission of the corresponding DCI assignment in EPDCCH-PRB-set q in subframe $n - k_m$, $N_{\text{PUCCH,q}}^{(\text{e1})}$ for EPDCCH-PRB-set q is configured by the higher layer parameter pucch-ResourceStartOffset-r11 , $N_{RB}^{ECCE,q}$ for EPDCCH-PRB-set q in subframe $n - k_m$ is given in subclause 6.8A.1 in [3], n' is determined from the antenna port used for EPDCCH transmission in subframe $n - k_m$ which is described in subclause 6.8A.5 in [3]. If $m = 0$, Δ_{ARO} is determined from the HARQ-ACK resource offset field in the DCI format of the corresponding EPDCCH as given in Table 10.1.2.1-1. If $m > 0$, Δ_{ARO} is determined from the HARQ-ACK resource offset field in the DCI format of the corresponding EPDCCH as given in Table 10.1.3.1-2. If the UE is configured to monitor EPDCCH in subframe $n - k_{i1}$, $N_{ECCE,q,n-k_{i1}}$ is equal to the number of ECCEs in EPDCCH-PRB-set q configured for that UE in subframe $n - k_{i1}$. If the UE is not configured to monitor EPDCCH in subframe $n - k_{i1}$, $N_{ECCE,q,n-k_{i1}}$ is equal to the number of ECCEs computed assuming EPDCCH-PRB-set q is configured for that UE in subframe $n-k_{i1}$. For normal downlink CP, if subframe $n-k_{i1}$ is a special subframe with special subframe configuration 0 or 5, $N_{ECCE,q,n-k_{i1}}$ is equal to 0. For extended downlink CP, if subframe $n-k_{i1}$ is a special subframe with special subframe configuration 0 or 4 or 7, $N_{ECCE,q,n-k_{i1}}$ is equal to 0. When two antenna port transmission is configured for PUCCH format 1a/1b, the PUCCH resource for antenna port p_1 is given by $n_{\text{PUCCH}}^{(1,\tilde{p}_1)} = n_{\text{PUCCH}}^{(1,\tilde{p}_0)} + 1$.

- If the UE is configured with the higher layer parameter *EIMTA-MainConfigServCell-r12* on the primary cell,
  - for a single PDSCH transmission only on the primary cell indicated by the detection of a corresponding EPDCCH in subframe $n-k_m$, where $k_m \in K$, and for a TDD UL/DL configuration of the primary cell belonging to {1,2,3,4,5,6} the DAI value in the EPDCCH is equal to '1' (defined in Table 7.3-X), or
  - for a single PDCCH indicating downlink SPS release (defined in subclause 9.2) in subframe $n-k_m$, where $k_m \in K$, and for a TDD UL/DL configuration of the primary cell belonging to {1,2,3,4,5,6} the DAI value in the EPDCCH is equal to '1',
    - the UE shall use PUCCH format 1a/1b and PUCCH resource $n_{\text{PUCCH}}^{(1,\tilde{p})}$ given by
      - if EPDCCH-PRB-set q is configured for distributed transmission

$$n_{\text{PUCCH}}^{(1,\tilde{p})} = n_{\text{ECCE,q}} + \sum_{i1=0}^{i4-1} N'_{ECCE,q,n-k'_{i1}} + \sum_{i1=0}^{i5-1} N'_{ECCE,q,n-k^A_{i1}} + \Delta'_{ARO} + N_{\text{PUCCH,q}}^{(\text{e1})}$$

      - if EPDCCH-PRB-set q is configured for localized transmission

$$n_{\text{PUCCH}}^{(1,\tilde{p})} = \left\lfloor \frac{n_{\text{ECCE,q}}}{N_{RB}^{ECCE,q}} \right\rfloor \cdot N_{RB}^{ECCE,q} + \sum_{i1=0}^{i4-1} N'_{ECCE,q,n-k'_{i1}} + \sum_{i1=0}^{i5-1} N'_{ECCE,q,n-k^A_{i1}} + n' + \Delta'_{ARO} + N_{\text{PUCCH,q}}^{(\text{e1})}$$

where

- if the value of k_m is same as the value of an index k'_{i2}, where $k'_{i2} \in K'$, then $i4 = i2$;
- otherwise, if the value of k_m is same as the value of an index k^A_{i3}, where $k^A_{i3} \in K^A$, then $i4 = i3$;

and where $n_{\text{ECCE,q}}$ is the number of the first ECCE (i.e. lowest ECCE index used to construct the EPDCCH) used for transmission of the corresponding DCI assignment in EPDCCH-PRB-set q in subframe $n-k_m$, $N_{\text{PUCCH,q}}^{(\text{e1})}$ for EPDCCH-PRB-set q is configured by the higher layer parameter *pucch-ResourceStartOffset-r11*, $N_{RB}^{ECCE,q}$ for EPDCCH-PRB-set q in subframe $n-k_m$ is given in subclause 6.8A.1 in [3], n' is determined from the antenna port used for EPDCCH transmission in subframe $n-k_m$ which is described in subclause 6.8A.5 in [3]. Δ'_{ARO}, $N'_{ECCE,q,n-k'_{i1}}$, $N'_{ECCE,q,n-k^A_{i1}}$ are determined as described in section 10.1.3.1. When two antenna port transmission is configured for PUCCH format 1a/1b, the PUCCH resource for antenna port p_1 is given by $n_{\text{PUCCH}}^{(1,\tilde{p}_1)} = n_{\text{PUCCH}}^{(1,\tilde{p}_0)} + 1$.

- for a single PDSCH transmission only on the primary cell where there is not a corresponding PDCCH/EPDCCH detected within subframe(s) $n-k$, where $k \in K$ and no PDCCH/EPDCCH indicating downlink SPS release (defined in subclause 9.2) within subframe(s) $n-k$, where $k \in K$, the UE shall use PUCCH format 1a/1b and PUCCH resource $n_{\text{PUCCH}}^{(1,\tilde{p})}$ with the value of $n_{\text{PUCCH}}^{(1,\tilde{p})}$ is determined according to higher layer configuration and Table 9.2-2. For a UE configured for two antenna port transmission for PUCCH format 1a/1b, a PUCCH resource value in Table 9.2-2 maps to two PUCCH resources with the first PUCCH resource $n_{\text{PUCCH}}^{(1,\tilde{p}_0)}$ for antenna port p_0 and the second PUCCH resource $n_{\text{PUCCH}}^{(1,\tilde{p}_1)}$ for antenna port p_1, otherwise, the PUCCH resource value maps to a single PUCCH resource $n_{\text{PUCCH}}^{(1,\tilde{p}_0)}$ for antenna port p_0.

- for $M > 1$, and
  - for a PDSCH transmission only on the primary cell where there is not a corresponding PDCCH detected within subframe(s) $n-k$, where $k \in K$, and
    - for an additional PDSCH transmission only on the primary cell indicated by the detection of a corresponding PDCCH in subframe $n-k_m$, where $k_m \in K$ with the DAI value in the PDCCH equal to '1' (defined in Table 7.3-X), or
    - for an additional PDCCH indicating downlink SPS release (defined in subclause 9.2) in subframe $n-k_m$, where $k_m \in K$ with the DAI value in the PDCCH equal to '1',
      - the UE shall transmit $b(0), b(1)$ in subframe n using PUCCH format 1b on PUCCH resource $n_{\text{PUCCH}}^{(1)}$ selected from A PUCCH resources $n_{\text{PUCCH},i}^{(1)}$ where $0 \le i \le A-1$, according to Table 10.1.3.2-1 and Table 10.1.3.2-2 for $A=2$ and $A=3$, respectively. For a UE configured with a transmission mode that supports up to two transport blocks on the primary cell, $A=3$; otherwise, $A=2$.
        - If the UE is not configured with the higher layer parameter *EIMTA-MainConfigServCell-r12* on the primary cell, the PUCCH resource $n_{\text{PUCCH},0}^{(1)}$ is determined according to higher layer configuration and Table 9.2-2. The PUCCH resource $n_{\text{PUCCH},1}^{(1)}$ is determined as $n_{\text{PUCCH},1}^{(1)} = (M-m-1)\cdot N_c + m \cdot N_{c+1} + n_{\text{CCE},m} + N_{\text{PUCCH}}^{(1)}$, where $N_{\text{PUCCH}}^{(1)}$ is configured by higher layers, c is selected from {0, 1, 2, 3} such that $N_c \le n_{\text{CCE},m} < N_{c+1}$, $N_c = \max\left\{0, \left\lfloor [N_{\text{RB}}^{\text{DL}} \cdot (N_{\text{sc}}^{\text{RB}} \cdot c - 4)]/36 \right\rfloor\right\}$, and $n_{\text{CCE,m}}$ is the number of the first CCE used for transmission of the corresponding PDCCH in subframe $n-k_m$ where $k_m \in K$.
        - If the UE is configured with the higher layer parameter *EIMTA-MainConfigServCell-r12* on the primary cell, the PUCCH resource $n_{\text{PUCCH},0}^{(1)}$ is determined according to higher layer configuration and Table 9.2-2. The PUCCH resource $n_{\text{PUCCH},1}^{(1)}$ is determined as
          - if the value of k_m is same as the value of an element k'_{i2}, where $k'_{i2} \in K'$, the PUCCH resource $n_{\text{PUCCH},1}^{(1)}$ is given by $n_{\text{PUCCH},1}^{(1)} = (M'-i2-1)\cdot N_c + i2 \cdot N_{c+1} + n_{\text{CCE},m} + N_{\text{PUCCH}}^{(1)}$;
          - otherwise, if the value of k_m is same as the value of an element k_{i3}^A in set K^A, where $k_{i3}^A \in K^A$ (defined in Table 10.1.3.1-1A, where "UL/DL configuration" in the table refers to the higher layer parameter *subframeAssignment*), the PUCCH resource $n_{\text{PUCCH},1}^{(1)}$ is given by $n_{\text{PUCCH},1}^{(1)} = (M^A - i3 - 1)\cdot N_c + i3 \cdot N_{c+1} + n_{\text{CCE},m} + N_{\text{PUCCH}}^{\text{K}^\text{A}}$;

          where M^A is the number of elements in the set K^A defined in Table 10.1.3.1-1A , where c is selected from {0, 1, 2, 3} such that $N_c \le n_{\text{CCE},m} < N_{c+1}$, $N_c = \max\left\{0, \left\lfloor [N_{\text{RB}}^{\text{DL}} \cdot (N_{\text{sc}}^{\text{RB}} \cdot c - 4)]/36 \right\rfloor\right\}$, $n_{CCE,m}$ is the number of the first CCE used for transmission of the corresponding PDCCH in subframe $n-k_m$, and $N_{\text{PUCCH}}^{\text{K}^\text{A}}$, $N_{\text{PUCCH}}^{(1)}$, are configured by higher layers.

- For a UE configured with a transmission mode that supports up to two transport blocks on the primary cell, the PUCCH resource $n^{(1)}_{\mathrm{PUCCH},2}$ is determined as $n^{(1)}_{\mathrm{PUCCH},2} = n^{(1)}_{\mathrm{PUCCH},1} + 1$.HARQ-ACK(0) is the ACK/NACK/DTX response for the PDSCH without a corresponding PDCCH detected. HARQ-ACK(1) is the ACK/NACK/DTX response for the first transport block of the PDSCH indicated by the detection of a corresponding PDCCH for which the value of the DAI field in the corresponding DCI format is equal to '1' or for the PDCCH indicating downlink SPS release for which the value of the DAI field in the corresponding DCI format is equal to '1'. HARQ-ACK(2) is the ACK/NACK/DTX response for the second transport block of the PDSCH indicated by the detection of a corresponding PDCCH for which the value of the DAI field in the corresponding DCI format is equal to '1'.

- for $M > 1$, and

  - for a PDSCH transmission only on the primary cell where there is not a corresponding EPDCCH detected within subframe(s) $n-k$, where $k \in K$, and

    - for an additional PDSCH transmission only on the primary cell indicated by the detection of a corresponding EPDCCH in subframe $n-k_m$, where $k_m \in K$ with the DAI value in the EPDCCH equal to '1' (defined in Table 7.3-X), or

    - for an additional EPDCCH indicating downlink SPS release (defined in subclause 9.2) in subframe $n-k_m$, where $k_m \in K$ with the DAI value in the EPDCCH equal to '1',

      - the UE shall transmit $b(0), b(1)$ in subframe n using PUCCH format 1b on PUCCH resource $n^{(1)}_{\mathrm{PUCCH}}$ selected from A PUCCH resources $n^{(1)}_{\mathrm{PUCCH},i}$ where $0 \le i \le A-1$, according to Table 10.1.3.2-1 and Table 10.1.3.2-2 for $A = 2$ and $A = 3$, respectively. For a UE configured with a transmission mode that supports up to two transport blocks on the primary cell, $A = 3$; otherwise, $A = 2$.

        - If the UE is not configured with the higher layer parameter *EIMTA-MainConfigServCell-r12* on the primary cell, the PUCCH resource $n^{(1)}_{\mathrm{PUCCH},0}$ is determined according to higher layer configuration and Table 9.2-2. The PUCCH resource $n^{(1)}_{\mathrm{PUCCH},1}$ is determined as

          - If EPDCCH-PRB-set q is configured for distributed transmission

$$n^{(1)}_{\mathrm{PUCCH},1} = n_{\mathrm{ECCE,q}} + \sum_{i1=0}^{m-1} N_{ECCE,q,n-k_{i1}} + \Delta_{ARO} + N^{(e1)}_{\mathrm{PUCCH,q}}$$

          - If EPDCCH-PRB-set q is configured for localized transmission

$$n^{(1)}_{\mathrm{PUCCH},1} = \left\lfloor \frac{n_{\mathrm{ECCE,q}}}{N^{ECCE,q}_{RB}} \right\rfloor \cdot N^{ECCE,q}_{RB} + \sum_{i1=0}^{m-1} N_{ECCE,q,n-k_{i1}} + n' + \Delta_{ARO} + N^{(e1)}_{\mathrm{PUCCH,q}}$$

          where $n_{\mathrm{ECCE,q}}$ is the number of the first ECCE (i.e. lowest ECCE index used to construct the EPDCCH) used for transmission of the corresponding DCI assignment in EPDCCH-PRB-set q in subframe $n-k_m$, $N^{(e1)}_{\mathrm{PUCCH,q}}$ for EPDCCH-PRB-set q is configured by the higher layer parameter pucch-ResourceStartOffset-r11 , $N^{ECCE,q}_{RB}$ for EPDCCH-PRB-set q in subframe $n-k_m$ is given in subclause 6.8A.1 in [3], n' is determined from the antenna port used for EPDCCH transmission in subframe $n-k_m$ which is described in subclause 6.8A.5 in [3]. If $m = 0$, Δ_{ARO} is determined from the HARQ-ACK resource offset field in the DCI format of the corresponding EPDCCH as given in Table 10.1.2.1-1. If $m > 0$, Δ_{ARO} is determined from the HARQ-ACK resource offset field in the DCI format of the corresponding EPDCCH as given in Table 10.1.3.1-2. If the UE is configured to monitor EPDCCH in subframe $n-k_{i1}$,

$N_{ECCE,q,n-k_{i1}}$ is equal to the number of ECCEs in EPDCCH-PRB-set q configured for that UE in subframe $n-k_{i1}$. If the UE is not configured to monitor EPDCCH in subframe $n-k_{i1}$, $N_{ECCE,q,n-k_{i1}}$ is equal to the number of ECCEs computed assuming EPDCCH-PRB-set q is configured for that UE in subframe $n-k_{i1}$. For normal downlink CP, if subframe $n-k_{i1}$ is a special subframe with special subframe configuration 0 or 5, $N_{ECCE,q,n-k_{i1}}$ is equal to 0. For extended downlink CP, if subframe $n-k_{i1}$ is a special subframe with special subframe configuration 0 or 4 or 7, $N_{ECCE,q,n-k_{i1}}$ is equal to 0.

- If the UE is configured with the higher layer parameter *EIMTA-MainConfigServCell-r12* on the primary cell, the PUCCH resource $n^{(1)}_{\text{PUCCH},0}$ is determined according to higher layer configuration and Table 9.2-2. The PUCCH resource $n^{(1)}_{\text{PUCCH},1}$ is determined as

  - If EPDCCH-PRB-set q is configured for distributed transmission

$$n^{(1)}_{\text{PUCCH,i}} = n_{\text{ECCE,q}} + \sum_{i1=0}^{i4-1} N'_{ECCE,q,n-k'_{i1}} + \sum_{i1=0}^{i5-1} N'_{ECCE,q,n-k^A_{i1}} + \Delta'_{ARO} + N^{(e1)}_{\text{PUCCH,q}}$$

  - If EPDCCH-PRB-set q is configured for localized transmission

$$n^{(1)}_{\text{PUCCH,i}} = \left\lfloor \frac{n_{\text{ECCE,q}}}{N^{ECCE,q}_{RB}} \right\rfloor \cdot N^{ECCE,q}_{RB} + \sum_{i1=0}^{i4-1} N'_{ECCE,q,n-k'_{i1}} + \sum_{i1=0}^{i5-1} N'_{ECCE,q,n-k^A_{i1}} + n' + \Delta'_{ARO} + N^{(e1)}_{\text{PUCCH,q}}$$

  where

    - if the value of k_m is same as the value of an index k'_{i2}, where $k'_{i2} \in K'$, then $i4 = i2$;
    - otherwise, if the value of k_m is same as the value of an index k^A_{i3}, where $k^A_{i3} \in K^A$, then $i4 = i3$;

  - and where $n_{\text{ECCE,q}}$ is the number of the first ECCE (i.e. lowest ECCE index used to construct the EPDCCH) used for transmission of the corresponding DCI assignment in EPDCCH-PRB-set q in subframe $n-k_m$, $N^{(e1)}_{\text{PUCCH,q}}$ for EPDCCH-PRB-set q is configured by the higher layer parameter *pucch-ResourceStartOffset-r11*, $N^{ECCE,q}_{RB}$ for EPDCCH-PRB-set q in subframe $n-k_m$ is given in subclause 6.8A.1 in [3], n' is determined from the antenna port used for EPDCCH transmission in subframe $n-k_m$ which is described in subclause 6.8A.5 in [3]. Δ'_{ARO}, $N'_{ECCE,q,n-k'_{i1}}$, $N'_{ECCE,q,n-k^A_{i1}}$ are determined as described in section 10.1.3.1.

- For a UE configured with a transmission mode that supports up to two transport blocks on the primary cell, the PUCCH resource $n^{(1)}_{\text{PUCCH},2}$ is determined as $n^{(1)}_{\text{PUCCH},2} = n^{(1)}_{\text{PUCCH},1} + 1$.HARQ-ACK(0) is the ACK/NACK/DTX response for the PDSCH without a corresponding EPDCCH detected. HARQ-ACK(1) is the ACK/NACK/DTX response for the first transport block of the PDSCH indicated by the detection of a corresponding EPDCCH for which the value of the DAI field in the corresponding DCI format is equal to '1' or for the EPDCCH indicating downlink SPS release for which the value of the DAI field in the corresponding DCI format is equal to '1'. HARQ-ACK(2) is the ACK/NACK/DTX response for the second transport block of the PDSCH indicated by the detection of a corresponding EPDCCH for which the value of the DAI field in the corresponding DCI format is equal to '1'.

- for $M > 1$, and

- for a PDSCH transmission only on the primary cell indicated by the detection of a corresponding PDCCH in subframe $n-k_m$, where $k_m \in K$ with the DAI value in the PDCCH greater than '1' (defined in Table 7.3-X), or
- for a PDCCH indicating downlink SPS release (defined in subclause 9.2) in subframe $n-k_m$, where $k_m \in K$ with the DAI value in the PDCCH greater than '1', or
- for $M = 9$ and for a PDSCH transmission only on the primary cell indicated by the detection of a corresponding PDCCH in subframe $n-k_m$, where $k_m \in K$ with the DAI value in the PDCCH equal to '1' (defined in Table 7.3-X) not being the first PDCCH/EPDCCH transmission in subframe(s) $n-k$, where $k \in K$ with the DAI value equal to '1', or
- for $M = 9$ and for a PDCCH indicating downlink SPS release (defined in subclause 9.2) in subframe $n-k_m$, where $k_m \in K$ with the DAI value in the PDCCH equal to ‘1’ (defined in Table 7.3-X) not being the first PDCCH/EPDCCH transmission in subframe(s) $n-k$, where $k \in K$ with the DAI value equal to '1',
  - the UE shall use PUCCH format 4 and PUCCH resource $n_{\mathrm{PUCCH}}^{(4)}$ where the value of $n_{\mathrm{PUCCH}}^{(4)}$ is determined according to higher layer configuration and Table 10.1.2.2.3-1 and the TPC field in a PDCCH assignment with DAI value greater than '1' (defined in Table 7.3-X) or with DAI value equal to ‘1’, not being the first PDCCH/EPDCCH assignment in subframe(s) $n-k$, where $k \in K$ with the DAI value equal to '1', shall be used to determine the PUCCH resource value from one of the four PUCCH resource values configured by higher layers, with the mapping defined in Table 10.1.2.2.3-1. A UE shall assume that the same HARQ-ACK PUCCH resource value is transmitted on all PDCCH assignments used to determine the PUCCH resource values within the subframe(s) $n-k$, where $k \in K$.

- for $M > 1$, and
  - for a PDSCH transmission only on the primary cell indicated by the detection of a corresponding EPDCCH in subframe $n-k_m$, where $k_m \in K$ with the DAI value in the EPDCCH greater than '1' (defined in Table 7.3-X), or
  - for an EPDCCH indicating downlink SPS release (defined in subclause 9.2) in subframe $n-k_m$, where $k_m \in K$ with the DAI value in the EPDCCH greater than '1', or
  - for $M = 9$ and for a PDSCH transmission only on the primary cell indicated by the detection of a corresponding EPDCCH in subframe $n-k_m$, where $k_m \in K$ with the DAI value in the EPDCCH equal to '1' (defined in Table 7.3-X) not being the first PDCCH/EPDCCH transmission in subframe(s) $n-k$, where $k \in K$ with the DAI value equal to '1', or
  - for $M = 9$ and for an EPDCCH indicating downlink SPS release (defined in subclause 9.2) in subframe $n-k_m$, where $k_m \in K$ with the DAI value in the EPDCCH equal to ‘1’ (defined in Table 7.3-X) not being the first PDCCH/EPDCCH transmission in subframe(s) $n-k$, where $k \in K$ with the DAI value equal to '1',
    - the UE shall use PUCCH format 4 and PUCCH resource $n_{\mathrm{PUCCH}}^{(4)}$ where the value of $n_{\mathrm{PUCCH}}^{(4)}$ is determined according to higher layer configuration and Table 10.1.2.2.3-1 and the HARQ-ACK resource offset field in the DCI format of the corresponding EPDCCH assignment with DAI value greater than '1' or with DAI value equal to ‘1’ (defined in Table 7.3-X), not being the first PDCCH/EPDCCH assignment in subframe(s) $n-k$, where $k \in K$ with the DAI value equal to '1', shall be used to determine the PUCCH resource value from one of the four PUCCH resource values configured by higher layers, with the mapping defined in Table 10.1.2.2.3-1. A UE shall assume that the same HARQ-ACK PUCCH resource value is transmitted on all EPDCCH assignments used to determine the PUCCH resource values within the subframe(s) $n-k$, where $k \in K$.

- If the UL/DL configurations of all serving cells are the same, for a PDSCH transmission on the secondary cell indicated by the detection of a corresponding PDCCH/EPDCCH within subframe(s) $n-k$, where $k \in K$, the UE shall use PUCCH format 4 and PUCCH resource $n_{\mathrm{PUCCH}}^{(4)}$ where the value of $n_{\mathrm{PUCCH}}^{(4)}$ is determined according to higher layer configuration and Table 10.1.2.2.3-1 and the TPC field in the corresponding PDCCH/EPDCCH shall be used to determine the PUCCH resource value from one of the four resource values configured by higher layers, with the mapping defined in Table 10.1.2.2.3-1. For TDD UL/DL configurations 1-6, if a PDCCH corresponding to a PDSCH on the primary cell within subframe(s) $n-k$, where $k \in K$, or a PDCCH indicating downlink SPS release (defined in subclause 9.2) within subframe(s) $n-k$, where $k \in K$, is detected, the TPC field in the PDCCH with the DAI value greater than '1' or with DAI value equal to '1', not being the first PDCCH/EPDCCH transmission in subframe(s) $n-k$, where $k \in K$ with the DAI value equal to '1' (defined in Table 7.3-X), shall be used to determine the PUCCH resource value from one of the four resource values configured by higher layers, with the mapping defined in Table 10.1.2.2.3-1. A UE shall assume that the same HARQ-ACK PUCCH resource value is transmitted on all PDCCH assignments in the primary cell and in each secondary cell that are used to determined the PUCCH resource value within the subframe(s) $n-k$, where $k \in K$. For TDD UL/DL configurations 1-6, if an EPDCCH corresponding to a PDSCH on the primary cell within subframe(s) $n-k$, where $k \in K$, or an EPDCCH indicating downlink SPS release (defined in subclause 9.2) within subframe(s) $n-k$, where $k \in K$, is detected, the HARQ-ACK resource offset field in the DCI format of the corresponding EPDCCH assignment with the DAI value greater than '1' (defined in Table 7.3-X) or with DAI value equal to '1', not being the first PDCCH/EPDCCH transmission in subframe(s) $n-k$, where $k \in K$ with the DAI value equal to '1', shall be used to determine the PUCCH resource value from one of the four resource values configured by higher layers, with the mapping defined in Table 10.1.2.2.3-1. A UE shall assume that the same HARQ-ACK PUCCH resource value is transmitted on all EPDCCH assignments in the primary cell and in each secondary cell that are used to determined the PUCCH resource value within the subframe(s) $n-k$, where $k \in K$.

- If the UL/DL configurations of at least two serving cells are different, for a PDSCH transmission on the secondary cell indicated by the detection of a corresponding PDCCH/EPDCCH within subframe(s) $n-k$, where $k \in K$, the UE shall use PUCCH format 4 and PUCCH resource $n_{\text{PUCCH}}^{(4)}$ where the value of $n_{\text{PUCCH}}^{(4)}$ is determined according to higher layer configuration and Table 10.1.2.2.3-1 and the TPC field in the corresponding PDCCH/EPDCCH shall be used to determine the PUCCH resource value from one of the four resource values configured by higher layers, with the mapping defined in Table 10.1.2.2.3-1. For a UL/DL configuration of the primary cell belonging to {1,2,3,4,5,6} as defined in subclause 10.2, if a PDCCH corresponding to a PDSCH on the primary cell within subframe(s) $n-k$, where $k \in K$, or a PDCCH indicating downlink SPS release (defined in subclause 9.2) within subframe(s) $n-k$, where $k \in K$, is detected, the TPC field in the PDCCH with the DAI value greater than '1' (defined in Table 7.3-X) or with DAI value equal to '1', not being the first PDCCH/EPDCCH transmission in subframe(s) $n-k$, where $k \in K$ with the DAI value equal to '1', shall be used to determine the PUCCH resource value from one of the four resource values configured by higher layers, with the mapping defined in Table 10.1.2.2.3-1. A UE shall assume that the same HARQ-ACK PUCCH resource value is transmitted on all PDCCH assignments in the primary cell and in each secondary cell that are used to determined the PUCCH resource value within the subframe(s) $n-k$, where $k \in K$. For a UL/DL configuration of the primary cell belonging to {1,2,3,4,5,6} as defined in subclause 10.2, if an EPDCCH corresponding to a PDSCH on the primary cell within subframe(s) $n-k$, where $k \in K$, or an EPDCCH indicating downlink SPS release (defined in subclause 9.2) within subframe(s) $n-k$, where $k \in K$, is detected, the HARQ-ACK resource offset field in the DCI format of the corresponding EPDCCH assignment with the DAI value greater than '1' or with DAI value equal to '1', not being the first PDCCH/EPDCCH transmission in subframe(s) $n-k$, where $k \in K$ with the DAI value equal to '1', shall be used to determine the PUCCH resource value from one of the four resource values configured by higher layers, with the mapping defined in Table 10.1.2.2.3-1. A UE shall assume that the same HARQ-ACK PUCCH resource value is transmitted on all EPDCCH assignments in the primary cell and in each secondary cell that are used to determined the PUCCH resource value within the subframe(s) $n-k$, where $k \in K$.

10.1.3.2.3.2 PUCCH format 4 HARQ-ACK procedure with adaptive codebook

The procedure in this subclause applies to a UE configured with PUCCH format 4 and *codebooksizeDetermination-r13 = dai*.

If a UE is configured with the higher layer parameter *EIMTA-MainConfigServCell-r12*, then $K' = K$ where the set K is defined in Table 10.1.3.1-1 (where "UL/DL configuration" in the table refers to the higher layer parameter *subframeAssignment*), and M' is the number of elements in set K'.

If a UE is configured with more than one serving cells and the UL/DL configuration of all serving cells is same, then in the rest of this subclause K is as defined in Sec 10.2, and M is the number of elements in the set K.

If a UE is configured with more than one serving cell and if at least two cells have different UL/DL configurations, then K in this subclause refers to K_c (as defined in subclause 10.2) , and M is the number of elements in the set K .

For TDD HARQ-ACK transmission with PUCCH format 4 and sub-frame n with $M \geq 1$ and more than one configured serving cell, where M is the number of elements in the set K , the UE shall use PUCCH resource $n_{\text{PUCCH}}^{(4)}$ or $n_{\text{PUCCH}}^{(3,\tilde{p})}$ or $n_{\text{PUCCH}}^{(1,\tilde{p})}$ for transmission of HARQ-ACK and scheduling request (if any) and periodic CSI (if any) in subframe n for $\tilde{p}$ mapped to antenna port p where

- If the UE is not configured with the higher layer parameter *EIMTA-MainConfigServCell-r12* on the primary cell,
  - for a single PDSCH transmission only on the primary cell indicated by the detection of a corresponding PDCCH in subframe $n-k_m$, where $k_m \in K$, and both the counter DAI value and the total DAI value in the PDCCH are equal to '1' (defined in Table 7.3.2.1-1), or
  - for a single PDCCH indicating downlink SPS release (defined in subclause 9.2) in subframe $n-k_m$, where $k_m \in K$, and both the counter DAI value and the total DAI value in the PDCCH are equal to '1',
    - the UE shall use PUCCH format 1a/1b and PUCCH resource $n_{\text{PUCCH}}^{(1,\tilde{p})}$ with $n_{\text{PUCCH}}^{(1,\tilde{p}_0)} = (M-m-1)\cdot N_c + m\cdot N_{c+1} + n_{\text{CCE},m} + N_{\text{PUCCH}}^{(1)}$ for antenna port p_0, where $N_{\text{PUCCH}}^{(1)}$ is configured by higher layers, c is selected from {0, 1, 2, 3} such that $N_c \leq n_{\text{CCE},m} < N_{c+1}$, $N_c = \max\left\{0, \left\lfloor [N_{\text{RB}}^{\text{DL}}\cdot(N_{\text{sc}}^{\text{RB}}\cdot c-4)]/36 \right\rfloor\right\}$, and $n_{\text{CCE,m}}$ is the number of the first CCE used for transmission of the corresponding PDCCH in subframe $n-k_m$ where $k_m \in K$. When two antenna port transmission is configured for PUCCH format 1a/1b, the PUCCH resource for antenna port p_1 is given by $n_{\text{PUCCH}}^{(1,\tilde{p}_1)} = n_{\text{PUCCH}}^{(1,\tilde{p}_0)} + 1$
- If the UE is configured with the higher layer parameter *EIMTA-MainConfigServCell-r12* on the primary cell,
  - for a single PDSCH transmission only on the primary cell indicated by the detection of a corresponding PDCCH in subframe $n-k_m$, where $k_m \in K$, and both the counter DAI value and the total DAI value in the PDCCH are equal to '1' (defined in Table 7.3.2.1-1), or
  - for a single PDCCH indicating downlink SPS release (defined in subclause 9.2) in subframe $n-k_m$, where $k_m \in K$, and both the counter DAI value and the total DAI value in the PDCCH are equal to '1',
    - the UE shall use PUCCH format 1a/1b, and
      - if the value of k_m is same as the value of an element k'_{i2}, where $k'_{i2} \in K'$, the PUCCH resource $n_{\text{PUCCH}}^{(1,\tilde{p})}$ is given by $n_{\text{PUCCH}}^{(1,\tilde{p})} = (M'-i2-1)\cdot N_c + i2\cdot N_{c+1} + n_{\text{CCE},m} + N_{\text{PUCCH}}^{(1)}$;
      - otherwise, if the value of k_m is same as the value of an element k_{i3}^A in set K^A, where $k_{i3}^A \in K^A$(defined in Table 10.1.3.1-1A, where "UL/DL configuration" in the table refers to the higher layer parameter *subframeAssignment*), the PUCCH resource $n_{\text{PUCCH}}^{(1,\tilde{p})}$ is given by $n_{\text{PUCCH}}^{(1,\tilde{p})} = (M^A - i3 - 1)\cdot N_c + i3\cdot N_{c+1} + n_{\text{CCE},m} + N_{\text{PUCCH}}^{\text{K}^\text{A}}$;

        where M^A is the number of elements in the set K^A defined in Table 10.1.3.1-1A , where c is selected from {0, 1, 2, 3} such that $N_c \leq n_{\text{CCE},m} < N_{c+1}$, $N_c = \max\left\{0, \left\lfloor [N_{\text{RB}}^{\text{DL}}\cdot(N_{\text{sc}}^{\text{RB}}\cdot c-4)]/36 \right\rfloor\right\}$ where $N_{\text{RB}}^{\text{DL}}$ is determined from the primary cell, $n_{CCE,m}$ is the number of the first CCE used for transmission of the corresponding PDCCH in subframe $n-k_m$, and $N_{\mathrm{PUCCH}}^{\mathrm{K}^{\mathrm{A}}}$, $N_{\mathrm{PUCCH}}^{(1)}$, are configured by higher layers. When two antenna port transmission is configured for PUCCH format 1a/1b, the PUCCH resource for antenna port p_1 is given by $n_{\mathrm{PUCCH}}^{(1,\tilde{p}_1)} = n_{\mathrm{PUCCH}}^{(1,\tilde{p}_0)} + 1$

- If the UE is not configured with the higher layer parameter *EIMTA-MainConfigServCell-r12* on the primary cell,
  - for a single PDSCH transmission only on the primary cell indicated by the detection of a corresponding EPDCCH in subframe $n-k_m$, where $k_m \in K$, and both the counter DAI value and the total DAI value in the EPDCCH are equal to '1' (defined in Table 7.3.2.1-1), or
  - for a single EPDCCH indicating downlink SPS release (defined in subclause 9.2) in subframe $n-k_m$, where $k_m \in K$, and both the counter DAI value and the total DAI value in the EPDCCH are equal to '1',
    - the UE shall use PUCCH format 1a/1b and PUCCH resource $n_{\mathrm{PUCCH}}^{(1,\tilde{p})}$ given by
      - If EPDCCH-PRB-set q is configured for distributed transmission

$$n_{\mathrm{PUCCH}}^{(1,\tilde{p})} = n_{\mathrm{ECCE,q}} + \sum_{i1=0}^{m-1} N_{ECCE,q,n-k_{i1}} + \Delta_{ARO} + N_{\mathrm{PUCCH,q}}^{(\mathrm{e1})}$$

      - If EPDCCH-PRB-set q is configured for localized transmission

$$n_{\mathrm{PUCCH}}^{(1,\tilde{p})} = \left\lfloor \frac{n_{\mathrm{ECCE,q}}}{N_{RB}^{ECCE,q}} \right\rfloor \cdot N_{RB}^{ECCE,q} + \sum_{i1=0}^{m-1} N_{ECCE,q,n-k_{i1}} + n' + \Delta_{ARO} + N_{\mathrm{PUCCH,q}}^{(\mathrm{e1})}$$

where $n_{\mathrm{ECCE,q}}$ is the number of the first ECCE (i.e. lowest ECCE index used to construct the EPDCCH) used for transmission of the corresponding DCI assignment in EPDCCH-PRB-set q in subframe $n-k_m$, $N_{\mathrm{PUCCH,q}}^{(\mathrm{e1})}$ for EPDCCH-PRB-set q is configured by the higher layer parameter pucch-ResourceStartOffset-r11 , $N_{RB}^{ECCE,q}$ for EPDCCH-PRB-set q in subframe $n-k_m$ is given in subclause 6.8A.1 in [3], n' is determined from the antenna port used for EPDCCH transmission in subframe $n-k_m$ which is described in subclause 6.8A.5 in [3]. If $m=0$, Δ_{ARO} is determined from the HARQ-ACK resource offset field in the DCI format of the corresponding EPDCCH as given in Table 10.1.2.1-1. If $m>0$, Δ_{ARO} is determined from the HARQ-ACK resource offset field in the DCI format of the corresponding EPDCCH as given in Table 10.1.3.1-2. If the UE is configured to monitor EPDCCH in subframe $n-k_{i1}$, $N_{ECCE,q,n-k_{i1}}$ is equal to the number of ECCEs in EPDCCH-PRB-set q configured for that UE in subframe $n-k_{i1}$. If the UE is not configured to monitor EPDCCH in subframe $n-k_{i1}$, $N_{ECCE,q,n-k_{i1}}$ is equal to the number of ECCEs computed assuming EPDCCH-PRB-set q is configured for that UE in subframe $n-k_{i1}$. For normal downlink CP, if subframe $n-k_{i1}$ is a special subframe with special subframe configuration 0 or 5, $N_{ECCE,q,n-k_{i1}}$ is equal to 0. For extended downlink CP, if subframe $n-k_{i1}$ is a special subframe with special subframe configuration 0 or 4 or 7, $N_{ECCE,q,n-k_{i1}}$ is equal to 0. When two antenna port transmission is configured for PUCCH format 1a/1b, the PUCCH resource for antenna port p_1 is given by $n_{\mathrm{PUCCH}}^{(1,\tilde{p}_1)} = n_{\mathrm{PUCCH}}^{(1,\tilde{p}_0)} + 1$.

- If the UE is configured with the higher layer parameter *EIMTA-MainConfigServCell-r12* on the primary cell,
  - for a single PDSCH transmission only on the primary cell indicated by the detection of a corresponding EPDCCH in subframe $n-k_m$, where $k_m \in K$, and both the counter DAI value and the total DAI value in the EPDCCH are equal to '1' (defined in Table 7.3.2.1-1), or

- for a single EPDCCH indicating downlink SPS release (defined in subclause 9.2) in subframe $n-k_m$, where $k_m \in K$, and both the counter DAI value and the total DAI value in the EPDCCH are equal to '1',
  - the UE shall use PUCCH format 1a/1b and PUCCH resource $n_{\text{PUCCH}}^{(1,\tilde{p})}$ given by
    - if EPDCCH-PRB-set q is configured for distributed transmission

$$n_{\text{PUCCH}}^{(1,\tilde{p})} = n_{\text{ECCE,q}} + \sum_{i1=0}^{i4-1} N'_{ECCE,q,n-k'_{i1}} + \sum_{i1=0}^{i5-1} N'_{ECCE,q,n-k^A_{i1}} + \Delta'_{ARO} + N_{\text{PUCCH,q}}^{(\text{e1})}$$

    - if EPDCCH-PRB-set q is configured for localized transmission

$$n_{\text{PUCCH}}^{(1,\tilde{p})} = \left\lfloor \frac{n_{\text{ECCE,q}}}{N_{RB}^{ECCE,q}} \right\rfloor \cdot N_{RB}^{ECCE,q} + \sum_{i1=0}^{i4-1} N'_{ECCE,q,n-k'_{i1}} + \sum_{i1=0}^{i5-1} N'_{ECCE,q,n-k^A_{i1}} + n' + \Delta'_{ARO} + N_{\text{PUCCH,q}}^{(\text{e1})}$$

    where

      - if the value of k_m is same as the value of an index k'_{i2}, where $k'_{i2} \in K'$, then $i4 = i2$;
      - otherwise, if the value of k_m is same as the value of an index k^A_{i3}, where $k^A_{i3} \in K^A$, then $i4 = i3$;

      and where $n_{\text{ECCE,q}}$ is the number of the first ECCE (i.e. lowest ECCE index used to construct the EPDCCH) used for transmission of the corresponding DCI assignment in EPDCCH-PRB-set q in subframe $n-k_m$, $N_{\text{PUCCH,q}}^{(\text{e1})}$ for EPDCCH-PRB-set q is configured by the higher layer parameter *pucch-ResourceStartOffset-r11* , $N_{RB}^{ECCE,q}$ for EPDCCH-PRB-set q in subframe $n-k_m$ is given in subclause 6.8A.1 in [3], n' is determined from the antenna port used for EPDCCH transmission in subframe $n-k_m$ which is described in subclause 6.8A.5 in [3]. Δ'_{ARO}, $N'_{ECCE,q,n-k'_{i1}}$, $N'_{ECCE,q,n-k^A_{i1}}$ are determined as described in section 10.1.3.1. When two antenna port transmission is configured for PUCCH format 1a/1b, the PUCCH resource for antenna port p_1 is given by $n_{\text{PUCCH}}^{(1,\tilde{p}_1)} = n_{\text{PUCCH}}^{(1,\tilde{p}_0)} + 1$.

- for a single PDSCH transmission only on the primary cell where there is not a corresponding PDCCH/EPDCCH detected within subframe(s) $n-k$, where $k \in K$ and no PDCCH/EPDCCH indicating downlink SPS release (defined in subclause 9.2) within subframe(s) $n-k$, where $k \in K$, the UE shall use PUCCH format 1a/1b and PUCCH resource $n_{\text{PUCCH}}^{(1,\tilde{p})}$ with the value of $n_{\text{PUCCH}}^{(1,\tilde{p})}$ is determined according to higher layer configuration and Table 9.2-2. For a UE configured for two antenna port transmission for PUCCH format 1a/1b, a PUCCH resource value in Table 9.2-2 maps to two PUCCH resources with the first PUCCH resource $n_{\text{PUCCH}}^{(1,\tilde{p}_0)}$ for antenna port p_0 and the second PUCCH resource $n_{\text{PUCCH}}^{(1,\tilde{p}_1)}$ for antenna port p_1, otherwise, the PUCCH resource value maps to a single PUCCH resource $n_{\text{PUCCH}}^{(1,\tilde{p}_0)}$ for antenna port p_0.
- for $M > 1$, and
  - for a PDSCH transmission only on the primary cell where there is not a corresponding PDCCH detected within subframe(s) $n-k$, where $k \in K$, and
    - for an additional PDSCH transmission only on the primary cell indicated by the detection of a corresponding PDCCH in subframe $n-k_m$, where $k_m \in K$ with both the counter DAI value and the total DAI value in the PDCCH equal to '1' (defined in Table 7.3.2.1-1), or
    - for an additional PDCCH indicating downlink SPS release (defined in subclause 9.2) in subframe $n-k_m$, where $k_m \in K$ with both the counter DAI value and the total DAI value in the PDCCH equal to '1',

- the UE shall transmit $b(0), b(1)$ in subframe n using PUCCH format 1b on PUCCH resource $n^{(1)}_{\text{PUCCH}}$ selected from A PUCCH resources $n^{(1)}_{\text{PUCCH},i}$ where $0 \le i \le A-1$, according to Table 10.1.3.2-1 and Table 10.1.3.2-2 for $A=2$ and $A=3$, respectively. For a UE configured with a transmission mode that supports up to two transport blocks on the primary cell, $A=3$; otherwise, $A=2$.
  - If the UE is not configured with the higher layer parameter *EIMTA-MainConfigServCell-r12* on the primary cell, the PUCCH resource $n^{(1)}_{\text{PUCCH},0}$ is determined according to higher layer configuration and Table 9.2-2. The PUCCH resource $n^{(1)}_{\text{PUCCH},1}$ is determined as $n^{(1)}_{\text{PUCCH},1} = (M-m-1)\cdot N_c + m \cdot N_{c+1} + n_{\text{CCE},m} + N^{(1)}_{\text{PUCCH}}$, where $N^{(1)}_{\text{PUCCH}}$ is configured by higher layers, c is selected from {0, 1, 2, 3} such that $N_c \le n_{\text{CCE},m} < N_{c+1}$, $N_c = \max\left\{0, \left\lfloor [N^{\text{DL}}_{\text{RB}} \cdot (N^{\text{RB}}_{\text{sc}} \cdot c - 4)]/36 \right\rfloor\right\}$, and $n_{\text{CCE,m}}$ is the number of the first CCE used for transmission of the corresponding PDCCH in subframe $n-k_m$ where $k_m \in K$.
  - If the UE is configured with the higher layer parameter *EIMTA-MainConfigServCell-r12* on the primary cell, the PUCCH resource $n^{(1)}_{\text{PUCCH},0}$ is determined according to higher layer configuration and Table 9.2-2. The PUCCH resource $n^{(1)}_{\text{PUCCH},1}$ is determined as
    - if the value of k_m is same as the value of an element k'_{i2}, where $k'_{i2} \in K'$, the PUCCH resource $n^{(1)}_{\text{PUCCH},1}$ is given by $n^{(1)}_{\text{PUCCH},1} = (M'-i2-1)\cdot N_c + i2 \cdot N_{c+1} + n_{\text{CCE},m} + N^{(1)}_{\text{PUCCH}}$;
    - otherwise, if the value of k_m is same as the value of an element k^A_{i3} in set K^A, where $k^A_{i3} \in K^A$(defined in Table 10.1.3.1-1A, where "UL/DL configuration" in the table refers to the higher layer parameter *subframeAssignment*), the PUCCH resource $n^{(1)}_{\text{PUCCH},1}$ is given by $n^{(1)}_{\text{PUCCH},1} = (M^A - i3 - 1)\cdot N_c + i3 \cdot N_{c+1} + n_{\text{CCE},m} + N^{\text{K}^{\text{A}}}_{\text{PUCCH}}$;

      where M^A is the number of elements in the set K^A defined in Table 10.1.3.1-1A , where c is selected from {0, 1, 2, 3} such that $N_c \le n_{\text{CCE},m} < N_{c+1}$, $N_c = \max\left\{0, \left\lfloor [N^{\text{DL}}_{\text{RB}} \cdot (N^{\text{RB}}_{\text{sc}} \cdot c - 4)]/36 \right\rfloor\right\}$, $n_{CCE,m}$ is the number of the first CCE used for transmission of the corresponding PDCCH in subframe $n-k_m$, and $N^{\text{K}^{\text{A}}}_{\text{PUCCH}}$, $N^{(1)}_{\text{PUCCH}}$, are configured by higher layers.
- For a UE configured with a transmission mode that supports up to two transport blocks on the primary cell, the PUCCH resource $n^{(1)}_{\text{PUCCH},2}$ is determined as $n^{(1)}_{\text{PUCCH},2} = n^{(1)}_{\text{PUCCH},1} + 1$.HARQ-ACK(0) is the ACK/NACK/DTX response for the PDSCH without a corresponding PDCCH detected. HARQ-ACK(1) is the ACK/NACK/DTX response for the first transport block of the PDSCH indicated by the detection of a corresponding PDCCH for which the value of both the counter DAI field and total DAI field in the corresponding DCI format is equal to '1' or for the PDCCH indicating downlink SPS release for which the value of both the counter DAI field and total DAI field in the corresponding DCI format is equal to '1'. HARQ-ACK(2) is the ACK/NACK/DTX response for the second transport block of the PDSCH indicated by the detection of a corresponding PDCCH for which the value of both the counter DAI field and the total DAI field in the corresponding DCI format is equal to '1'.

- for $M > 1$, and
  - for a PDSCH transmission only on the primary cell where there is not a corresponding EPDCCH detected within subframe(s) $n-k$, where $k \in K$, and

- for an additional PDSCH transmission only on the primary cell indicated by the detection of a corresponding EPDCCH in subframe $n-k_m$, where $k_m \in K$ with both the counter DAI value and the total DAI value in the EPDCCH equal to '1' (defined in Table 7.3.2.1-1), or

- for an additional EPDCCH indicating downlink SPS release (defined in subclause 9.2) in subframe $n-k_m$, where $k_m \in K$ with both the counter DAI value and the total DAI value in the EPDCCH equal to '1',

  - the UE shall transmit $b(0),b(1)$ in subframe n using PUCCH format 1b on PUCCH resource $n^{(1)}_{\text{PUCCH}}$ selected from A PUCCH resources $n^{(1)}_{\text{PUCCH},i}$ where $0 \le i \le A-1$, according to Table 10.1.3.2-1 and Table 10.1.3.2-2 for $A=2$ and $A=3$, respectively. For a UE configured with a transmission mode that supports up to two transport blocks on the primary cell, $A=3$; otherwise, $A=2$.

    - If the UE is not configured with the higher layer parameter *EIMTA-MainConfigServCell-r12* on the primary cell, the PUCCH resource $n^{(1)}_{\text{PUCCH},0}$ is determined according to higher layer configuration and Table 9.2-2. The PUCCH resource $n^{(1)}_{\text{PUCCH},1}$ is determined as

      - If EPDCCH-PRB-set q is configured for distributed transmission

$$n^{(1)}_{\text{PUCCH},1} = n_{\text{ECCE,q}} + \sum_{i1=0}^{m-1} N_{ECCE,q,n-k_{i1}} + \Delta_{ARO} + N^{(e1)}_{\text{PUCCH,q}}$$

      - If EPDCCH-PRB-set q is configured for localized transmission

$$n^{(1)}_{\text{PUCCH},1} = \left\lfloor \frac{n_{\text{ECCE,q}}}{N_{RB}^{ECCE,q}} \right\rfloor \cdot N_{RB}^{ECCE,q} + \sum_{i1=0}^{m-1} N_{ECCE,q,n-k_{i1}} + n' + \Delta_{ARO} + N^{(e1)}_{\text{PUCCH,q}}$$

where $n_{\text{ECCE,q}}$ is the number of the first ECCE (i.e. lowest ECCE index used to construct the EPDCCH) used for transmission of the corresponding DCI assignment in EPDCCH-PRB-set q in subframe $n-k_m$, $N^{(e1)}_{\text{PUCCH,q}}$ for EPDCCH-PRB-set q is configured by the higher layer parameter pucch-ResourceStartOffset-r11 , $N_{RB}^{ECCE,q}$ for EPDCCH-PRB-set q in subframe $n-k_m$ is given in subclause 6.8A.1 in [3], n' is determined from the antenna port used for EPDCCH transmission in subframe $n-k_m$ which is described in subclause 6.8A.5 in [3]. If $m=0$, Δ_{ARO} is determined from the HARQ-ACK resource offset field in the DCI format of the corresponding EPDCCH as given in Table 10.1.2.1-1. If $m>0$, Δ_{ARO} is determined from the HARQ-ACK resource offset field in the DCI format of the corresponding EPDCCH as given in Table 10.1.3.1-2. If the UE is configured to monitor EPDCCH in subframe $n-k_{i1}$, $N_{ECCE,q,n-k_{i1}}$ is equal to the number of ECCEs in EPDCCH-PRB-set q configured for that UE in subframe $n-k_{i1}$. If the UE is not configured to monitor EPDCCH in subframe $n-k_{i1}$, $N_{ECCE,q,n-k_{i1}}$ is equal to the number of ECCEs computed assuming EPDCCH-PRB-set q is configured for that UE in subframe $n-k_{i1}$. For normal downlink CP, if subframe $n-k_{i1}$ is a special subframe with special subframe configuration 0 or 5, $N_{ECCE,q,n-k_{i1}}$ is equal to 0. For extended downlink CP, if subframe $n-k_{i1}$ is a special subframe with special subframe configuration 0 or 4 or 7, $N_{ECCE,q,n-k_{i1}}$ is equal to 0.

- If the UE is configured with the higher layer parameter *EIMTA-MainConfigServCell-r12* on the primary cell, the PUCCH resource $n^{(1)}_{\text{PUCCH},0}$ is determined according to higher layer configuration and Table 9.2-2. The PUCCH resource $n^{(1)}_{\text{PUCCH},1}$ is determined as

  - If EPDCCH-PRB-set q is configured for distributed transmission

$$n^{(1)}_{\text{PUCCH,i}} = n_{\text{ECCE,q}} + \sum_{i1=0}^{i4-1} N'_{ECCE,q,n-k'_{i1}} + \sum_{i1=0}^{i5-1} N'_{ECCE,q,n-k^A_{i1}} + \Delta'_{ARO} + N^{(\text{e1})}_{\text{PUCCH,q}}$$

  - If EPDCCH-PRB-set q is configured for localized transmission

$$n^{(1)}_{\text{PUCCH,i}} = \left\lfloor \frac{n_{\text{ECCE,q}}}{N^{ECCE,q}_{RB}} \right\rfloor \cdot N^{ECCE,q}_{RB} + \sum_{i1=0}^{i4-1} N'_{ECCE,q,n-k'_{i1}} + \sum_{i1=0}^{i5-1} N'_{ECCE,q,n-k^A_{i1}} + n' + \Delta'_{ARO} + N^{(\text{e1})}_{\text{PUCCH,q}}$$

  where

    - if the value of k_m is same as the value of an index k'_{i2}, where $k'_{i2} \in K'$, then $i4 = i2$;

    - otherwise, if the value of k_m is same as the value of an index k^A_{i3}, where $k^A_{i3} \in K^A$, then $i4 = i3$;

  - and where $n_{\text{ECCE,q}}$ is the number of the first ECCE (i.e. lowest ECCE index used to construct the EPDCCH) used for transmission of the corresponding DCI assignment in EPDCCH-PRB-set q in subframe $n-k_m$, $N^{(\text{e1})}_{\text{PUCCH,q}}$ for EPDCCH-PRB-set q is configured by the higher layer parameter *pucch-ResourceStartOffset-r11*, $N^{ECCE,q}_{RB}$ for EPDCCH-PRB-set q in subframe $n-k_m$ is given in subclause 6.8A.1 in [3], n' is determined from the antenna port used for EPDCCH transmission in subframe $n-k_m$ which is described in subclause 6.8A.5 in [3]. Δ'_{ARO}, $N'_{ECCE,q,n-k'_{i1}}$, $N'_{ECCE,q,n-k^A_{i1}}$ are determined as described in section 10.1.3.1.

- For a UE configured with a transmission mode that supports up to two transport blocks on the primary cell, the PUCCH resource $n^{(1)}_{\text{PUCCH},2}$ is determined as $n^{(1)}_{\text{PUCCH},2} = n^{(1)}_{\text{PUCCH},1} + 1$.HARQ-ACK(0) is the ACK/NACK/DTX response for the PDSCH without a corresponding EPDCCH detected. HARQ-ACK(1) is the ACK/NACK/DTX response for the first transport block of the PDSCH indicated by the detection of a corresponding EPDCCH for which the value of both the counter DAI field and the total DAI field in the corresponding DCI format is equal to '1' or for the EPDCCH indicating downlink SPS release for which the value of both the counter DAI field and the total DAI field in the corresponding DCI format is equal to '1'. HARQ-ACK(2) is the ACK/NACK/DTX response for the second transport block of the PDSCH indicated by the detection of a corresponding EPDCCH for which the value of both the counter DAI field and the total DAI field in the corresponding DCI format is equal to '1'.

- if a PDSCH transmission is indicated by the detection of a corresponding PDCCH/EPDCCH in subframe $n-k_m$, where $k_m \in K$ with either the counter DAI value or the total DAI value in the PDCCH/EPDCCH greater than '1' (defined in Table 7.3.2.1-1) on the primary cell, or

- if a PDCCH/EPDCCH indicating downlink SPS release (defined in subclause 9.2) is detected in subframe $n-k_m$, where $k_m \in K$ with either the counter DAI value or the total DAI value in the PDCCH/EPDCCH greater than '1' on the primary cell, or

- if a PDSCH transmission is indicated by the detection of a corresponding PDCCH/EPDCCH in subframe $n-k$, where $k \in K$ on a secondary cell,

- if the total number of HARQ-ACK bits O^{ACK} and scheduling request bit O^{SR} (if any) and periodic CSI bits $O_{\mathrm{P-CSI}}$ (if any) is more than 22, the UE shall use PUCCH format 4 and PUCCCH resource $n_{\mathrm{PUCCH}}^{(4)}$ where the value of $n_{\mathrm{PUCCH}}^{(4)}$ is determined according to higher layer configuration and Table 10.1.2.2.3-1. Denote C as the set of configured serving cells for the UE. Denote $k_{smallest}$ is the smallest value in $\bigcup_{c\in C} K_c$ such that PDCCH/EPDCCH scheduling PDSCH or indicating DL SPS release is detected in subframe $n-k_{smallest}$ on serving cell $\tilde{c}$ and $k_{smallest} \in K_{\tilde{c}}$. The TPC field in a PDCCH/EPDCCH scheduling PDSCH or indicating downlink SPS release in subframe $n-k_{smallest}$ on a serving cell c satisfying $k_{smallest} \in K_c$ shall be used to determine the PUCCH resource value from one of the four resource values configured by higher layers, with the mapping defined in Table 10.1.2.2.3-1. A UE shall assume that the same HARQ-ACK PUCCH resource value is transmitted on any PDCCH/EPDCCH scheduling PDSCH or indicating downlink SPS release in subframe $n-k_{smallest}$ on any serving cell c satisfying $k_{smallest} \in K_c$.

- if the total number of HARQ-ACK bits O^{ACK} and scheduling request bit O^{SR} (if any) and periodic CSI bits $O_{\mathrm{P-CSI}}$ (if any) is no more than 22, the UE shall use PUCCH format 3 and PUCCH resource $n_{\mathrm{PUCCH}}^{(3,\tilde{p})}$ where the value of $n_{\mathrm{PUCCH}}^{(3,\tilde{p})}$ is determined according to higher layer configuration and Table 10.1.2.2.2-1. Denote C as the set of configured serving cells for the UE. Denote $k_{smallest}$ is the smallest value in $\bigcup_{c\in C} K_c$ such that PDCCH/EPDCCH scheduling PDSCH or indicating DL SPS release is detected in subframe $n-k_{smallest}$ on serving cell $\tilde{c}$ and $k_{smallest} \in K_{\tilde{c}}$. The TPC field in a PDCCH/EPDCCH scheduling PDSCH or indicating downlink SPS release in subframe $n-k_{smallest}$ on a serving cell c satisfying $k_{smallest} \in K_c$ shall be used to determine the PUCCH resource value from one of the four resource values configured by higher layers, with the mapping defined in Table 10.1.2.2.2-1. A UE shall assume that the same HARQ-ACK PUCCH resource value is transmitted on any PDCCH/EPDCCH scheduling PDSCH or indicating downlink SPS release in subframe $n-k_{smallest}$ on any serving cell c satisfying $k_{smallest} \in K_c$. If a UE is configured for two antenna port transmission for PUCCH format 3, a PUCCH resource value in Table 10.1.2.2.2-1 maps to two PUCCH resources with the first PUCCH resource $n_{\mathrm{PUCCH}}^{(3,\tilde{p}_0)}$ for antenna port p_0 and the second PUCCH resource $n_{\mathrm{PUCCH}}^{(3,\tilde{p}_1)}$ for antenna port p_1, otherwise, the PUCCH resource value maps to a single PUCCH resource $n_{\mathrm{PUCCH}}^{(3,\tilde{p}_0)}$ for antenna port p_0.

10.1.3.2.4 PUCCH format 5 HARQ-ACK procedure

TDD HARQ-ACK feedback procedures for a UE configured with PUCCH format 5 and *codebooksizeDetermination-r13 = cc* is described in section 10.1.3.2.4.1.

TDD HARQ-ACK feedback procedures for a UE configured with PUCCH format 5 and *codebooksizeDetermination-r13 = dai* is described in section 10.1.3.2.4.2.

10.1.3.2.4.1 PUCCH format 5 HARQ-ACK procedure without adaptive codebook

The HARQ-ACK feedback procedure for PUCCH format 5 HARQ-ACK procedure is as described in subclause 10.1.3.2.3.1, by replacing $n_{\mathrm{PUCCH}}^{(4)}$ with $n_{\mathrm{PUCCH}}^{(5)}$.

10.1.3.2.4.2 PUCCH format 5 HARQ-ACK procedure with adaptive codebook

The HARQ-ACK feedback procedure for PUCCH format 5 HARQ-ACK procedure is as described in subclause 10.1.3.2.3.2, by replacing $n_{\mathrm{PUCCH}}^{(4)}$ with $n_{\mathrm{PUCCH}}^{(5)}$.

10.1.3A FDD-TDD HARQ-ACK feedback procedures for primary cell frame structure type 2

A UE is configured by higher layers to use either PUCCH format 1b with channel selection or PUCCH format 3/4/5 for transmission of HARQ-ACK.

For a serving cell, if the serving cell is frame structure type 1, and a UE is not configured to monitor PDCCH/EPDCCH in another serving cell for scheduling the serving cell, set K is defined in Table 10.1.3A-1, otherwise set K is defined in Table 10.1.3.1-1.

PUCCH format 1b with channel selection is not supported if a UE is configured with more than two serving cells, or if the DL-reference UL/DL configuration 5 (as defined in subclause 10.2) is defined for any serving cell, or if the DL-reference UL/DL configuration of a serving cell with frame structure type 1 belongs to {2, 3, 4} and the UE is not configured to monitor PDCCH/EPDCCH in another serving cell for scheduling the serving cell.

If a UE is configured with the parameter *EIMTA-MainConfigServCell-r12* for at least one serving cell and is configured with PUCCH format 3 without PUCCH format 4/5 configured, the UE is not expected to be configured with more than two serving cells having DL-reference UL/DL configuration 5.

If a UE is configured to use PUCCH format 1b with channel selection for HARQ-ACK transmission, for the serving cells,

- if more than 4 HARQ-ACK bits for M multiple downlink and special subframes associated with a single UL subframe *n*, where M is as defined in subclause 10.1.3.2.1 for case where the UE is configured with two serving cells with different UL/DL configurations,
  - spatial HARQ-ACK bundling across multiple codewords within a downlink or special subframe is performed for each serving cell by a logical AND operation of all the corresponding individual HARQ-ACKs, and the bundled HARQ-ACK bits for each serving cell is transmitted using PUCCH format 1b with channel selection,
- otherwise,
  - spatial HARQ-ACK bundling is not performed, and the HARQ-ACK bits are transmitted using PUCCH format 1b with channel selection.

If a UE is configured to use PUCCH format 3 without PUCCH format 4/5 configured for HARQ-ACK transmission, for the serving cells,

- if more than 21 HARQ-ACK bits for M multiple downlink and special subframes associated with a single UL subframe *n*, where M as defined in subclause 10.1.3.2.2 for the case of UE configured with more than one serving cell and if at least two cells have different UL/DL configurations,
  - spatial HARQ-ACK bundling across multiple codewords within a downlink or special subframe is performed for each serving cell by a logical AND operation of all of the corresponding individual HARQ-ACKs, and PUCCH format 3 is used,
- otherwise,
  - spatial HARQ-ACK bundling is not performed, and the HARQ-ACK bits are transmitted using PUCCH format 3.
- UE shall determine the number of HARQ-ACK bits, O, associated with an UL subframe *n* according to $O = \sum_{c=1}^{N_{cells}^{DL}} O_c^{ACK}$ where N_{cells}^{DL} is the number of configured cells, and O_c^{ACK} is the number of HARQ-bits for the *c*-th serving cell defined in subclause 7.3.4. If a UE is not configured to monitor PDCCH/EPDCCH in another serving cell for scheduling a serving cell with frame structure type 1, and the DL-reference UL/DL configuration of the serving cell belongs to {2, 3, 4, 5}, then the UE is not expected to be configured with N_{cells}^{DL} which result in $O > 21$.

HARQ-ACK transmission on two antenna ports $(p \in [p_0, p_1])$ is supported for PUCCH format 3.

HARQ-ACK transmission on two antenna ports $(p \in [p_0, p_1])$ is supported for PUCCH format 1b with channel selection and with two configured serving cells.

The FDD-TDD HARQ-ACK feedback procedure for PUCCH format 1b with channel selection follows the HARQ-ACK procedure described in subclause 10.1.3.2.1 for the case of UE configured with two serving cells with different UL/DL configurations, and for PUCCH format 3/4/5 follows the HARQ-ACK procedure described in subclause 10.1.3.2.2/10.1.3.2.3/10.2.3.2.4 for the case of UE configured with more than one serving cell and if at least two cells have different UL/DL configurations.

Table 10.1.3A-1: Downlink association set $K:\ \{k_0, k_1, \cdots k_{M-1}\}$ for FDD-TDD and serving cell frame structure type 1

DL-reference UL/DL Configuration	Subframe *n*									
	0	1	2	3	4	5	6	7	8	9
0	-	-	6, 5	5, 4	4	-	-	6, 5	5, 4	4
1	-	-	7, 6	6, 5, 4	-	-	-	7, 6	6, 5, 4	-
2	-	-	8, 7, 6, 5, 4	-	-	-	-	8, 7, 6, 5, 4	-	-
3	-	-	11, 10, 9, 8, 7, 6	6, 5	5, 4	-	-	-	-	-
4	-	-	12, 11, 10, 9, 8, 7	7, 6, 5, 4	-	-	-	-	-	-
5	-	-	13, 12, 11, 10, 9, 8, 7, 6, 5, 4	-	-	-	-	-	-	-
6	-	-	8, 7	7, 6	6, 5	-	-	7	7, 6, 5	-

10.1.4 HARQ-ACK Repetition procedure

For a non-BL/CE UE, HARQ-ACK repetition is enabled or disabled by a UE specific parameter *ackNackRepetition* configured by higher layers. Once enabled, the UE shall repeat any HARQ-ACK transmission with a repetition factor N_{ANRep}, where N_{ANRep} is provided by higher layers and includes the initial HARQ-ACK transmission, until HARQ-ACK repetition is disabled by higher layers. For a PDSCH transmission without a corresponding PDCCH/EPDCCH detected, the UE shall transmit the corresponding HARQ-ACK response N_{ANRep} times using PUCCH resource $n_{\text{PUCCH}}^{(1,\tilde{p})}$ configured by higher layers. For a PDSCH transmission with a corresponding PDCCH/EPDCCH detected, or for a PDCCH/EPDCCH indicating downlink SPS release, the UE shall first transmit the corresponding HARQ-ACK response once using PUCCH resource derived from the corresponding PDCCH CCE index or EPDCCH ECCE index (as described in subclauses 10.1.2 and 10.1.3), and repeat the transmission of the corresponding HARQ-ACK response $N_{\text{ANRep}} - 1$ times always using PUCCH resource $n_{\text{PUCCH,ANRep}}^{(1,\tilde{p})}$, where $n_{\text{PUCCH,ANRep}}^{(1,\tilde{p})}$ is configured by higher layers.

HARQ-ACK repetition is only applicable for UEs configured with one serving cell for FDD and TDD. For TDD, HARQ-ACK repetition is only applicable for HARQ-ACK bundling.

HARQ-ACK repetition can be enabled with PUCCH format 1a/1b on two antenna ports. For a UE configured for two antenna port transmission for HARQ-ACK repetition with PUCCH format 1a/1b, a PUCCH resource value $n_{\text{PUCCH,ANRep}}^{(1,\tilde{p})}$ maps to two PUCCH resources with the first PUCCH resource $n_{\text{PUCCH,ANRep}}^{(1,\tilde{p}_0)}$ for antenna port p_0 and the second PUCCH resource $n_{\text{PUCCH,ANRep}}^{(1,\tilde{p}_1)}$ for antenna port p_1, otherwise, the PUCCH resource value maps to a single PUCCH resource $n_{\text{PUCCH,ANRep}}^{(1,\tilde{p}_0)}$ for antenna port p_0.

10.1.5 Scheduling Request (SR) procedure

A non-BL/CE UE is configured by higher layers to transmit the SR on one antenna port or two antenna ports. For a non-BL/CE UE, the scheduling request shall be transmitted on the PUCCH resource(s) $n_{\mathrm{PUCCH}}^{(1,\tilde{p})} = n_{\mathrm{PUCCH,SRI}}^{(1,\tilde{p})}$ for $\tilde{p}$ mapped to antenna port *p* as defined in [3], where $n_{\mathrm{PUCCH,SRI}}^{(1,\tilde{p})}$ is configured by higher layers unless the SR coincides in time with the transmission of HARQ-ACK using PUCCH Format 3/4/5 in which case the SR is multiplexed with HARQ-ACK according to subclause 5.2.3.1 of [4]. The SR configuration for SR transmission periodicity $SR_{\mathrm{PERIODICITY}}$ and SR subframe offset $N_{\mathrm{OFFSET,SR}}$ is defined in Table 10.1.5-1 by the parameter *sr-ConfigIndex* I_{SR} given by higher layers.

SR transmission instances are the uplink subframes satisfying $\left(10 \times n_f + \lfloor n_s / 2 \rfloor - N_{\mathrm{OFFSET,SR}}\right) \bmod SR_{\mathrm{PERIODICITY}} = 0$.

For a BL/CE UE, the scheduling request shall be transmitted on the PUCCH resource(s) $n_{\mathrm{PUCCH}}^{(1)} = n_{\mathrm{PUCCH,\,SRI}}^{(1)}$ mapped to antenna port p_0 as defined in [3], where $n_{\mathrm{PUCCH,\,SRI}}^{(1)}$ is configured by higher layers. The SR configuration for SR transmission periodicity $SR_{\mathrm{PERIODICITY}}$ and SR subframe offset $N_{\mathrm{OFFSET,SR}}$ is defined in Table 10.1.5-1 by the parameter *sr-ConfigIndex* I_{SR} given by higher layers. The SR transmission instances are $N_{\mathrm{PUCCH,\,rep}}^{(\mathrm{m})}$ consecutive BL/CE uplink subframes starting from a subframe satisfying $\left(10 \times n_f + \lfloor n_s / 2 \rfloor - N_{\mathrm{OFFSET,SR}}\right) \bmod SR_{\mathrm{PERIODICITY}} = 0$, where $N_{\mathrm{PUCCH,\,rep}}^{(\mathrm{m})}$ is provided by higher layer parameter *NumRepetitionCE-format1*.

Table 10.1.5-1: UE-specific SR periodicity and subframe offset configuration

SR configuration Index I_{SR}	SR periodicity (ms) $SR_{\mathrm{PERIODICITY}}$	SR subframe offset $N_{\mathrm{OFFSET,SR}}$
0 – 4	5	I_{SR}
5 – 14	10	$I_{SR}-5$
15 – 34	20	$I_{SR}-15$
35 – 74	40	$I_{SR}-35$
75 – 154	80	$I_{SR}-75$
155 – 156	2	$I_{SR}-155$
157	1	$I_{SR}-157$

10.2 Uplink HARQ-ACK timing

For TDD or for FDD-TDD and primary cell frame structure type 2 or for FDD-TDD and primary cell frame structure type 1, if a UE configured with *EIMTA-MainConfigServCell-r12* for a serving cell, "UL/DL configuration" of the serving cell in subclause 10.2 refers to the UL/DL configuration given by the parameter *eimta-HARQ-ReferenceConfig-r12* for the serving cell unless specified otherwise.

For a non-BL/CE UE, for FDD or for FDD-TDD and primary cell frame structure type 1, the UE shall upon detection of a PDSCH transmission in subframe *n-4* intended for the UE and for which an HARQ-ACK shall be provided, transmit the HARQ-ACK response in subframe *n*. If HARQ-ACK repetition is enabled, upon detection of a PDSCH transmission in subframe *n-4* intended for the UE and for which HARQ-ACK response shall be provided, and if the UE is not repeating the transmission of any HARQ-ACK in subframe n corresponding to a PDSCH transmission in subframes $n-N_{\text{ANRep}}-3, \ldots, n-5$, the UE:

- shall transmit only the HARQ-ACK response (corresponding to the detected PDSCH transmission in subframe $n-4$) on PUCCH in subframes n, $n+1, \ldots, n+N_{\text{ANRep}}-1$;

- shall not transmit any other signal/channel in subframes n, $n+1, \ldots, n+N_{\text{ANRep}}-1$; and

- shall not transmit any HARQ-ACK response repetitions corresponding to any detected PDSCH transmission in subframes $n-3, \ldots, n+N_{\text{ANRep}}-5$.

For TDD and a UE configured with *EIMTA-MainConfigServCell-r12* for at least one serving cell, if the UE is configured with one serving cell or if the UE is configured with more than one serving cell and the TDD UL/DL configuration of all the configured serving cells is the same, the DL-reference UL/DL configuration for a serving cell is the UL/DL configuration of the serving cell.

For FDD-TDD and primary cell frame structure type 1, if a serving cell is a secondary serving cell with frame structure type 2, the DL-reference UL/DL configuration for the serving cell is the UL/DL configuration of the serving cell.

For TDD, if the UE is configured with more than one serving cell and if at least two serving cells have different UL/DL configurations and if a serving cell is a primary cell, then the primary cell UL/DL configuration is the DL-reference UL/DL configuration for the serving cell.

For FDD-TDD and primary cell frame structure type 2, if a serving cell is a primary cell or if a serving cell is a secondary cell with frame structure type 1, then the primary cell UL/DL configuration is the DL-reference UL/DL configuration for the serving cell.

For TDD and if the UE is configured with more than one serving cell and if at least two serving cells have different UL/DL configurations and if the UE is not configured with *harqTimingTDD = TRUE* and if a serving cell is a secondary cell, or for FDD-TDD and primary cell frame structure type 2 and if the UE is not configured with *harqTimingTDD = TRUE* and if a serving cell is a secondary cell with frame structure type 2

- if the pair formed by (primary cell UL/DL configuration, serving cell UL/DL configuration) belongs to Set 1 in Table 10.2-1 or

- if the UE is not configured to monitor PDCCH/EPDCCH in another serving cell for scheduling the serving cell, and if the pair formed by (primary cell UL/DL configuration, serving cell UL/DL configuration) belongs to Set 2 or Set 3 in Table 10.2-1 or

- if the UE is configured to monitor PDCCH/EPDCCH in another serving cell for scheduling the serving cell, and if the pair formed by (primary cell UL/DL configuration, serving cell UL/DL configuration) belongs to Set 4 or Set 5 in Table 10.2-1

then the DL-reference UL/DL configuration for the serving cell is defined in the corresponding Set in Table 10.2-1.

For TDD and if the UE is configured with more than one serving cell and if at least two serving cells have different UL/DL configurations and if the UE is configured with *harqTimingTDD = TRUE* and if a serving cell is a secondary cell, or for FDD-TDD and primary cell frame structure type 2 and if the UE is configured with *harqTimingTDD = TRUE* and if a serving cell is a secondary cell with frame structure type 2

- if the UE is configured to monitor PDCCH/EPDCCH in another serving cell for scheduling the serving cell, and if the pair formed by (primary cell UL/DL configuration, serving cell UL/DL configuration) belongs to Set 1 or

Set 4 or Set 5 in Table 10.2-1, then the DL-reference UL/DL configuration for the serving cell is defined in the corresponding Set in Table 10.2-1;

- if the UE is not configured to monitor PDCCH/EPDCCH in another serving cell for scheduling the serving cell, and then the primary cell UL/DL configuration is the DL-reference UL/DL configuration for the serving cell.

For a UE not configured with PUCCH format 4 or PUCCH format 5, for TDD and if a UE is configured with more than one serving cell and if at least two serving cells have different UL/DL configurations or for FDD-TDD and primary cell frame structure type 2, if the DL-reference UL/DL configuration for at least one serving cell is TDD UL/DL Configuration 5, then the UE is not expected to be configured with more than two serving cells.

For TDD and a non-BL/CE UE not configured with *EIMTA-MainConfigServCell-r12* for any serving cell, if the UE is configured with one serving cell, or the UE is configured with more than one serving cell and the UL/DL configurations of all serving cells is same, then the UE shall upon detection of a PDSCH transmission within subframe(s) $n-k$, where $k \in K$ and K is defined in Table 10.1.3.1-1 intended for the UE and for which HARQ-ACK response shall be provided, transmit the HARQ-ACK response in UL subframe *n*.

For a UE not configured with *harqTimingTDD = TRUE*, for TDD and if a UE is configured with more than one serving cell and if at least two serving cells have different UL/DL configurations, or if a UE is configured with *EIMTA-MainConfigServCell-r12* for at least one serving cell, or for FDD-TDD and primary cell frame structure type 2 and if a serving cell *c* is frame structure type 2, then the UE shall upon detection of a PDSCH transmission within subframe(s) $n-k$ for serving cell c, where $k \in K_c$ intended for the UE and for which HARQ-ACK response shall be provided, transmit the HARQ-ACK response in UL subframe *n*, wherein set K_c contains values of $k \in K$ such that subframe *n-k* corresponds to a DL subframe or a special subframe for serving cell c, where DL subframe or special subframe of serving cell c is according to the higher layer parameter *eimta-HARQ-ReferenceConfig-r12* if the UE is configured with the higher layer parameter *EIMTA-MainConfigServCell-r12* for serving cell c; K defined in Table 10.1.3.1-1 (where "UL/DL configuration" in Table 10.1.3.1-1 refers to the "DL-reference UL/DL configuration") is associated with subframe *n*.

For a UE configured with *harqTimingTDD = TRUE*, for TDD and if a UE is configured with more than one serving cell and if at least two serving cells have different UL/DL configurations, or for FDD-TDD and primary cell frame structure type 2 and if a serving cell *c* is frame structure type 2,

- if the UE is configured to monitor PDCCH/EPDCCH in another serving cell for scheduling the serving cell c, then the UE shall upon detection of a PDSCH transmission within subframe(s) $n-k$ for serving cell c, where $k \in K_c$ intended for the UE and for which HARQ-ACK response shall be provided, transmit the HARQ-ACK response in UL subframe *n*, wherein set K_c contains values of $k \in K$ such that subframe *n-k* corresponds to a DL subframe or a special subframe for serving cell c, where K is defined in Table 10.1.3.1-1 (where "UL/DL configuration" in Table 10.1.3.1-1 refers to the "DL-reference UL/DL configuration") is associated with subframe *n.*

- if the UE is not configured to monitor PDCCH/EPDCCH in another serving cell for scheduling the serving cell c, then the UE shall upon detection of a PDSCH transmission within subframe(s) $n-k$ for serving cell c, where $k \in K_c$ intended for the UE and for which HARQ-ACK response shall be provided, transmit the HARQ-ACK response in UL subframe *n*, wherein set K_c contains values of $k \in K$ such that subframe *n-k* corresponds to a DL subframe or a special subframe for serving cell c, where K is defined in Table 10.1.3A-1 (where "UL/DL configuration" in Table 10.1.3A-1 refers to the "DL-reference UL/DL configuration") is associated with subframe *n.*

For a non-BL/CE UE, and for FDD-TDD and primary cell frame structure type 2, if a serving cell c is frame structure type 1 and a UE is not configured to monitor PDCCH/EPDCCH in another serving cell for scheduling the serving cell c, then the UE shall upon detection of a PDSCH transmission within subframe(s) $n-k$ for serving cell c, where $k \in K_c$, $K_c = K$ and K is defined in Table 10.1.3A-1 intended for the UE and for which HARQ-ACK response shall be provided, transmit the HARQ-ACK response in subframe *n*.

For FDD-TDD and primary cell frame structure type 2, if a serving cell c is frame structure type 1 and a UE is configured to monitor PDCCH/EPDCCH in another serving cell for scheduling serving cell c, then the UE shall upon detection of a PDSCH transmission within subframe(s) $n-k$ for serving cell c, where $k \in K_c$, $K_c = K$ and K is defined in Table 10.1.3.1-1, intended for the UE and for which HARQ-ACK response shall be provided, transmit the HARQ-ACK response in subframe *n*, where "UL/DL configuration" in Table 10.1.3.1-1 refers to the "DL-reference UL/DL configuration" of serving cell c.

For TDD, if HARQ-ACK repetition is enabled, upon detection of a PDSCH transmission within subframe(s) $n-k$, where $k \in K$ and K is defined in Table 10.1.3.1-1 intended for the UE and for which HARQ-ACK response shall be provided, and if the UE is not repeating the transmission of any HARQ-ACK in subframe n corresponding to a PDSCH transmission in a downlink or special subframe earlier than subframe $n-k$, the UE:

- shall transmit only the HARQ-ACK response (corresponding to the detected PDSCH transmission in subframe $n-k$) on PUCCH in UL subframe n and the next $N_{\text{ANRep}}-1$ UL subframes denoted as n_1, …, $n_{N_{\text{ANRep}}-1}$;
- shall not transmit any other signal/channel in UL subframe n, n_1, …, $n_{N_{\text{ANRep}}-1}$; and
- shall not transmit any HARQ-ACK response repetitions corresponding to any detected PDSCH transmission in subframes $n_i - k$, where $k \in K_i$, K_i is the set defined in Table 10.1.3.1-1 corresponding to UL subframe n_i, and $1 \le i \le N_{\text{ANRep}} - 1$.

For TDD, HARQ-ACK bundling, if the UE detects that at least one downlink assignment has been missed as described in subclause 7.3, the UE shall not transmit HARQ-ACK on PUCCH if HARQ-ACK is the only UCI present in a given subframe.

For FDD, a BL/CE UE shall upon detection of a PDSCH intended for the UE and for which an HARQ-ACK shall be provided, transmit the HARQ-ACK response using the same $n_{\text{PUCCH}}^{(1,\text{p}_0)}$ derived according to section 10.1.2.1 in subframe(s) $n+k_i$ with $i = 0,1, \ldots, N-1$, where

- subframe *n-4* is the last subframe in which the PDSCH is transmitted; and
- $0 \le k_0 < k_1 < \ldots, k_{N-1}$ and the value of $N = N_{\text{PUCCH, rep}}^{(\text{m})}$ and $N_{\text{PUCCH, rep}}^{(\text{m})}$ is provided by higher layer parameter *pucch-NumRepetitionCE-format1* if the PDSCH does not contain a contention resolution or *RRCConnectionSetup*, otherwise it is provided by higher layer parameter *pucch-NumRepetitionCE Msg4-Level0-r13, pucch-NumRepetitionCE-Msg4-Level1-r13, pucch-NumRepetitionCE-Msg4-Level2-r13* or *pucch-NumRepetitionCE-Msg4-Level3-r13* depending on whether the most recent PRACH coverage enhancement level for the UE is 0, 1, 2 or 3, respectively; and

  if $N>1$

  - subframe(s) $n+k_i$ with $i=0,1,\ldots,N-1$ are N consecutive BL/CE UL subframe(s) immediately after subframe *n-1*, and the set of BL/CE UL subframes are configured by higher layers;

  otherwise

  - $k_0 = 0$

For TDD, a BL/CE UE shall upon detection of a PDSCH within subframe(s) $n-k$, where $k \in K$ and K is defined in Table 10.1.3.1-1 intended for the UE and for which HARQ-ACK response shall be provided, transmit the HARQ-ACK response using the same $n_{\text{PUCCH}}^{(1,\text{p}_0)}$ derived according to section 10.1.3.1 in subframe(s) $n+k_i$ with $i = 0,1, \ldots, N-1$, where

- subframe *n-k* is the last subframe in which the PDSCH is transmitted; and
- $0 \le k_0 < k_1 < \ldots, k_{N-1}$ and the value of $N = N_{\text{PUCCH, rep}}^{(\text{m})}$ and $N_{\text{PUCCH, rep}}^{(\text{m})}$ is provided by higher layers parameter *pucch-NumRepetitionCE-format1* if the PDSCH does not contain a contention resolution or *RRCConnectionSetup*, otherwise it is provided by higher layer parameter *pucch-NumRepetitionCE Msg4-Level0-r13, pucch-NumRepetitionCE-Msg4-Level1-r13, pucch-NumRepetitionCE-Msg4-Level2-r13* or *pucch-*

NumRepetitionCE-Msg4-Level3-r13 depending on whether the most recent PRACH coverage enhancement level for the UE is 0, 1, 2 or 3, respectively; and

if $N>1$

- subframe(s) $n+k_i$ with $i=0,1,\ldots,N-1$ are N consecutive BL/CE UL subframe(s) immediately after subframe $n-1$, and the set of BL/CE UL subframes are configured by higher layers;

otherwise

- $k_0=0$

The uplink timing for the ACK corresponding to a detected PDCCH/EPDCCH indicating downlink SPS release shall be the same as the uplink timing for the HARQ-ACK corresponding to a detected PDSCH, as defined above.

For a BL/CE UE, the uplink timing for the ACK corresponding to a detected MPDCCH indicating downlink SPS release shall be the same as the uplink timing for the HARQ-ACK corresponding to a detected PDSCH, as defined above.

Table 10.2-1: DL-reference UL/DL configuration for serving cell based on pair formed by (primary cell UL/DL configuration, secondary cell UL/DL configuration)

Set #	(Primary cell UL/DL configuration, Secondary cell UL/DL configuration)	DL-reference UL/DL configuration
Set 1	(0,0)	0
	(1,0),(1,1),(1,6)	1
	(2,0),(2,2),(2,1),(2,6)	2
	(3,0),(3,3),(3,6)	3
	(4,0),(4,1),(4,3),(4,4),(4,6)	4
	(5,0),(5,1),(5,2),(5,3),(5,4),(5,5),(5,6)	5
	(6,0),(6,6)	6
Set 2	(0,1),(6,1)	1
	(0,2),(1,2),(6,2)	2
	(0,3),(6,3)	3
	(0,4),(1,4),(3,4),(6,4)	4
	(0,5),(1,5),(2,5),(3,5),(4,5),(6,5)	5
	(0,6)	6
Set 3	(3,1),(1,3)	4
	(3,2),(4,2),(2,3),(2,4)	5
Set 4	(0,1),(0,2),(0,3),(0,4),(0,5),(0,6)	0
	(1,2),(1,4),(1,5)	1
	(2,5)	2
	(3,4),(3,5)	3
	(4,5)	4
	(6,1),(6,2),(6,3),(6,4),(6,5)	6
Set 5	(1,3)	1
	(2,3),(2,4)	2
	(3,1),(3,2)	3
	(4,2)	4

11 Physical Multicast Channel (PMCH) related procedures

11.1 UE procedure for receiving the PMCH

The UE shall decode the PMCH when configured by higher layers. The UE may assume that an eNB transmission on the PMCH is performed according to subclause 6.5 of [3].

The I_{MCS} for the PMCH is configured by higher layers. If the UE is configured by higher layers to decode the PMCH based on QPSK, 16QAM, 64QAM, and 256QAM then the UE shall use I_{MCS} and Table 7.1.7.1-1A to determine the modulation order (Q_m) and TBS index (I_{TBS}) used in the PMCH. Else the UE shall use I_{MCS} for the PMCH and Table 7.1.7.1-1 to determine the modulation order (Q_m) and TBS index (I_{TBS}) used in the PMCH.
The UE shall then follow the procedure in subclause 7.1.7.2.1 to determine the transport block size, assuming N_{PRB} is equal to $N_{\text{RB}}^{\text{DL}}$. The UE shall set the redundancy version to 0 for the PMCH.

11.2 UE procedure for receiving MCCH change notification

If a UE is configured by higher layers to decode PDCCHs with the CRC scrambled by the M-RNTI, the UE shall decode the PDCCH according to the combination defined in Table 11.2-1.

Table 11.2-1: PDCCH configured by M-RNTI

DCI format	Search Space
DCI format 1C	Common

The 8-bit information for MCCH change notification [11], as signalled on the PDCCH, shall be delivered to higher layers.

12 Assumptions independent of physical channel

A UE shall not assume that two antenna ports are quasi co-located unless specified otherwise.

A UE may assume the antenna ports 0 – 3 of a serving cell are quasi co-located (as defined in [3]) with respect to delay spread, Doppler spread, Doppler shift, average gain, and average delay.

For the purpose of discovery-signal-based measurements, a UE shall not assume any other signals or physical channels are present other than the discovery signal.

If a UE supports *discoverySignalsInDeactSCell-r12*, and if the UE is configured with discovery-signal-based RRM measurements on a carrier frequency applicable for a secondary cell on the same carrier frequency, and if the secondary cell is deactivated, and if the UE is not configured by higher layers to receive MBMS on the secondary cell, the UE shall, except for discovery-signal transmissions, assume that PSS, SSS, PBCH, CRS, PCFICH, PDSCH, PDCCH, EPDCCH, PHICH, DMRS and CSI-RS may be not transmitted by the secondary cell until the subframe where an activation command is received for the secondary cell.

For BL/CE UE, if CEModeA or CEModeB is not configured, UE shall assume the following configuration:

- For a BL/CE UE with the PRACH coverage enhancement level 0/1, UE shall assume CEModeA.
- For a BL/CE UE with the PRACH coverage enhancement level 2/3, UE shall assume CEModeB.

13 Uplink/Downlink configuration determination procedure for Frame Structure Type 2

If the UE is configured with a SCG, the UE shall apply the procedures described in this clause for both MCG and SCG

- When the procedures are applied for MCG, the terms ‘secondary cell’, ‘secondary cells’ , ‘serving cell’, ‘serving cells’ in this clause refer to secondary cell, secondary cells, serving cell, serving cells belonging to the MCG respectively.
- When the procedures are applied for SCG, the terms ‘secondary cell’, ‘secondary cells’, ‘serving cell’, ‘serving cells’ in this clause refer to secondary cell, secondary cells (not including PSCell), serving cell, serving cells belonging to the SCG respectively. The term ‘primary cell’ in this clause refers to the PSCell of the SCG.

For each serving cell

If the UE is not configured with the higher layer parameter *EIMTA-MainConfigServCell-r12*,

- the UE shall set the UL/DL configuration equal to the UL/DL configuration (i.e., the parameter *subframeAssignment*) indicated by higher layers.

If the UE is configured by higher layers with the parameter *EIMTA-MainConfigServCell-r12*, then for each radio frame,

- the UE shall determine eIMTA-UL/DL-configuration as described in subclause 13.1.
- the UE shall set the UL/DL configuration for each radio frame equal to the eIMTA-UL/DL-configuration of that radio frame.

13.1 UE procedure for determining eIMTA-uplink/downlink configuration

If a UE is configured by higher layers to decode PDCCHs with the CRC scrambled by the eIMTA-RNTI, the UE shall decode the PDCCH according to the combination defined in Table 13.1-1.

Table 13.1-1: PDCCH configured by eIMTA-RNTI

DCI format	Search Space
DCI format 1C	Common

The subframes in which the UE monitors PDCCH with CRC scrambled by eIMTA-RNTI are configured by higher layers.

For each serving cell,

- if T= 10,
  - if the UE detects PDCCH with CRC scrambled by eIMTA-RNTI in subframe 0 of a radio frame m or if the UE detects PDCCH with CRC scrambled by eIMTA-RNTI in a subframe other than subframe 0 of a radio frame m-1,
    - the eIMTA-UL/DL-configuration for radio frame m is given by the UL/DL configuration indication signalled on the PDCCH as described in [4],
    - the UE may assume that the same UL/DL configuration indication is indicated by PDCCH with CRC scrambled by eIMTA-RNTI in subframe 0 of radio frame m and in all the subframes other than subframe 0 of radio frame m-1 in which PDCCH with CRC scrambled by eIMTA-RNTI is monitored,
  - otherwise
    - the eIMTA-UL/DL-configuration for radio frame m is same as the UL/DL configuration (i.e., the parameter *subframeAssignment*) indicated by higher layers;

- if T is a value other than 10,
  - if the UE detects PDCCH with CRC scrambled by eIMTA-RNTI in a subframe in radio frame $mT/10$,
    - the eIMTA-UL/DL-configuration for radio frames {$mT/10+1$, $mT/10+2$,…. $(m + 1)T/10$} is given by the UL/DL configuration indication signalled on the PDCCH as described [4],
    - the UE may assume that the same UL/DL configuration indication is indicated by PDCCH with CRC scrambled by eIMTA-RNTI in all the subframes of radio frame $mT/10$ in which PDCCH with CRC scrambled by eIMTA-RNTI is monitored,
  - otherwise
    - the eIMTA-UL/DL-configuration for radio frames {$mT/10+1$, $mT/10+2$,…. $(m +1) T/10$} is same as the UL/DL configuration (i.e., the parameter *subframeAssignment*) indicated by higher layers.

where T denotes the value of parameter *eimta-CommandPeriodicity-r12*.

For a serving cell c , if subframe i is indicated as uplink subframe or a special subframe by higher layer parameter *eimta-HARQ-ReferenceConfig-r12*, the UE is not expected to receive a PDCCH with CRC scrambled by eIMTA-RNTI containing an UL/DL configuration for serving cell c that would indicate subframe i as a downlink subframe.

For a serving cell c , if subframe i is indicated as downlink subframe or a special subframe by higher layer parameter *subframeAssignment*, the UE is not expected to receive a PDCCH with CRC scrambled by eIMTA-RNTI containing an UL/DL configuration for serving cell c that would indicate subframe i as an uplink subframe.

For a serving cell c , a UE is not expected to be configured with parameter *eimta-HARQ-ReferenceConfig-r12* if a subframe indicated as an uplink subframe by *eimta-HARQ-ReferenceConfig-r12* is not indicated as an uplink subframe by the UL-reference UL/DL configuration.

If UE is not configured with the parameter *EIMTA-MainConfigServCell-r12* for any activated serving cell, the UE is not expected to monitor PDCCH with CRC scrambled by eIMTA-RNTI.

If the UE is configured with the parameter *EIMTA-MainConfigServCell-r12* for at least one serving cell, the UE is not expected to monitor PDCCH with CRC scrambled by eIMTA-RNTI outside of the Active Time defined in [8] in order to determine the configured CSI-RS or CSI-IM REs in subframe 6 for CSI reporting purposes. If the UE doesn't detect an UL/DL configuration indication for radio frame m, the UE determines the configured CSI-RS and CSI-IM REs in subframe 6 according to the UL/DL configuration indicated by higher layer parameter *subframeAssignment* for the serving cell.

13A Subframe configuration for Frame Structure Type 3

If a UE detects PDCCH with DCI CRC scrambled by CC-RNTI in subframe n-1 or subframe n of a LAA Scell, the UE may assume the configuration of occupied OFDM symbols in subframe n of the LAA Scell according to the 'Subframe configuration for LAA' field in the detected DCI in subframe n-1 or subframe n.

The 'Subframe configuration for LAA' field indicates the configuration of occupied OFDM symbols (i.e., OFDM symbols used for transmission of downlink physical channels and/or physical signals) in current and/or next subframe according to Table 13A-1.

If the configuration of occupied OFDM symbols for subframe n is indicated by the Subframe configuration for LAA field in both subframe n-1 and subframe n, the UE may assume that the same configuration of occupied OFDM symbols is indicated in both subframe n-1 and subframe n.

If a UE detects PDCCH with DCI CRC scrambled by CC-RNTI in subframe n, and the UE does not detect PDCCH with DCI CRC scrambled by CC-RNTI in subframe n-1, and if the number of occupied OFDM symbols for subframe n indicated by the Subframe configuration for LAA field in subframe n is less than 14, the UE is not required to receive any other physical channels in subframe n.

If a UE does not detect PDCCH with DCI CRC scrambled by CC-RNTI containing 'Subframe Configuration for LAA' field set to other than '1110' and '1111' in subframe n and the UE does not detect PDCCH with DCI CRC scrambled by CC-RNTI containing 'Subframe Configuration for LAA' field set to other than '1110' and '1111' in subframe n-1, the UE is not required to use subframe n for updating CSI measurement.

The UE may detect PDCCH with DCI CRC scrambled by CC-RNTI by monitoring the following PDCCH candidates according to DCI Format 1C.

- one PDCCH candidate at aggregation level L=4 with the CCEs corresponding to the PDCCH candidate given by CCEs numbered 0,1,2,3
- one PDCCH candidate at aggregation level L=8 with the CCEs corresponding to the PDCCH candidate given by CCEs numbered 0,1,2,3,4,5,6,7

If a serving cell is a LAA Scell, and if the higher layer parameter *subframeStartPosition* for the Scell indicates 's07', and if the UE detects PDCCH/EPDCCH intended for the UE starting in the second slot of a subframe, the UE may assume that OFDM symbols in the first slot of the subframe are not occupied, and all OFDM symbols in the second slot of the subframe are occupied,

If subframe n is a subframe in which OFDM symbols in the first slot are not occupied, the UE may assume that all the OFDM symbols are occupied in subframe n+1.

Table 13A-1: Subframe configuration for LAA in current and next subframe

Value of 'Subframe configuration for LAA' field in current subframe	Configuration of occupied OFDM symbols (current subframe, next subframe)
0000	(-,14)
0001	(-,12)
0010	(-,11)
0011	(-,10)
0100	(-,9)
0101	(-,6)
0110	(-,3)
0111	(14,*)
1000	(12,-)
1001	(11,-)
1010	(10,-)
1011	(9,-)
1100	(6,-)
1101	(3,-)
1110	reserved
1111	reserved
NOTE: - (-, Y) means UE may assume the first Y symbols are occupied in next subframe and other symbols in the next subframe are not occupied. - (X,-) means UE may assume the first X symbols are occupied in current subframe and other symbols in the current subframe are not occupied. - (X,*) means UE may assume the first X symbols are occupied in current subframe, and at least the first OFDM symbol of the next subframe is not occupied.	

14 UE procedures related to Sidelink

A UE can be configured by higher layers with one or more PSSCH resource configuration(s). A PSSCH resource configuration can be for reception of PSSCH, or for transmission of PSSCH. The physical sidelink shared channel related procedures are described in subclause 14.1.

A UE can be configured by higher layers with one or more PSCCH resource configuration(s). A PSCCH resource configuration can be for reception of PSCCH, or for transmission of PSCCH and the PSCCH resource configuration is associated with either sidelink transmission mode 1 or sidelink transmission mode 2. The physical sidelink control channel related procedures are described in subclause 14.2.

A UE can be configured by higher layers with one or more PSDCH resource configuration(s). A PSDCH resource configuration can be for reception of PSDCH, or for transmission of PSDCH. The transmissions of PSDCH according to a PSDCH resource configuration are associated with either sidelink discovery type 1 or sidelink discovery type 2B. The physical sidelink discovery channel related procedures are described in subclause 14.3.

The physical sidelink synchronization related procedures are described in subclause 14.4.

Except in the case of secondary sidelink synchronization signal transmission, sidelink transmission power shall not change during a sidelink subframe. For a UE transmitting PSBCH, the transmit power of PSBCH (P_{PSBCH}) is same as the transmit power of primary sidelink synchronisation signal P_{PSSS}.

A UE is not expected to be configured with PSCCH resource configuration(s) such that, in a given subframe, the total number of resource blocks across the resource block pools (as described in subclause 14.2.3) indicated by the PSCCH resource configuration(s) exceeds 50.

If a UE uplink transmission that is not a PRACH transmission in subframe n+1 of a serving cell overlaps in time domain with a PSDCH transmission or a SLSS transmission for PSDCH by the UE in subframe n and subframe n+1 is included in *discTxGapConfig* [11], then the UE shall drop the uplink transmission in subframe n+1. Else, if a UE uplink transmission in subframe n+1 of a serving cell overlaps in time domain with sidelink transmission/reception by the UE in subframe n of the serving cell, then the UE shall drop the sidelink transmission/reception in subframe n.

For a given carrier frequency, a UE is not expected to receive sidelink physical channels/signals with different cyclic prefix lengths in the same sidelink subframe.

For a given carrier frequency, in a sidelink subframe, if a UE has a sidelink transmission, the sidelink transmission shall occur only in contiguous physical resource blocks.

If a UE's sidelink transmission does not occur on a serving cell with its uplink transmission(s), and if the UE's sidelink transmission in a subframe overlaps in time with its uplink transmission(s), the UE shall adjust the sidelink transmission power such that its total transmission power does not exceed P_{CMAX} defined in [6] on any overlapped portion. In this case, calculation of the adjustment to the sidelink transmission power is not specified.

14.1 Physical Sidelink Shared Channel related procedures

14.1.1 UE procedure for transmitting the PSSCH

If the UE transmits SCI format 0 on PSCCH according to a PSCCH resource configuration in subframe n belonging to a PSCCH period (described in subclause 14.2.3), then for the corresponding PSSCH transmissions

- the transmissions occur in a set of subframes in the PSCCH period and in a set of resource blocks within the set of subframes. The first PSSCH transport block is transmitted in the first four subframes in the set, the second transport block is transmitted in the next four subframes in the set, and so on.
    - for sidelink transmission mode 1,
        - the set of subframes is determined using the subframe pool indicated by the PSSCH resource configuration (described in subclause 14.1.4) and using time resource pattern (I_{TRP}) in the SCI format 0 as described in subclause 14.1.1.1.

    - the set of resource blocks is determined using Resource block assignment and hopping allocation in the SCI format 0 as described in subclause 14.1.1.2.

  - for sidelink transmission mode 2,

    - the set of subframes is determined using the subframe pool indicated by the PSSCH resource configuration (described in subclause 14.1.3) and using time resource pattern (I_{TRP}) in the SCI format 0 as described in subclause 14.1.1.3.

    - the set of resource blocks is determined using the resource block pool indicated by the PSSCH resource configuration (described in subclause 14.1.3) and using Resource block assignment and hopping allocation in the SCI format 0 as described in subclause 14.1.1.4.

- the modulation order is determined using the "modulation and coding scheme " field (I_{MCS}) in SCI format 0. For $0 \le I_{\mathrm{MCS}} \le 28$, the modulation order is set to $Q' = \min(4, Q'_{\mathrm{m}})$, where Q'_{m} is determined from Table 8.6.1-1.

- the TBS index (I_{TBS}) is determined based on I_{MCS} and Table 8.6.1-1, and the transport block size is determined using I_{TBS} and the number of allocated resource blocks (N_{PRB}) using the procedure in subclause 7.1.7.2.1.

14.1.1.1 UE procedure for determining subframes for transmitting PSSCH for sidelink transmission mode 1

Within the PSCCH period (described in subclause 14.2.3), the subframes used for PSSCH are determined as follows:

- a subframe indicator bitmap $\left(b'_0, b'_1, \ldots b'_{N_{TRP}-1}\right)$ and N_{TRP} are determined using the procedure described in subclause 14.1.1.1.1.

- a bitmap $\left(b_0, b_1, \ldots b_{L_{PSSCH}-1}\right)$ is determined using $b_j = b'_{j \bmod N_{TRP}}$ and a subframe l_j^{PSSCH} in the subframe pool is used for PSSCH if $b_j = 1$, otherwise the subframe l_j^{PSSCH} is not used for PSSCH, where $\left(l_0^{PSSCH}, l_1^{PSSCH}, \ldots, l_{L_{PSSCH}-1}^{PSSCH}\right)$ and L_{PSSCH} are described in subclause 14.1.4. The subframes used for PSSCH are denoted by $\left(n_0^{PSSCH}, n_1^{PSSCH}, \ldots, n_{N_{PSSCH}-1}^{PSSCH}\right)$ arranged in increasing order of subframe index and where N_{PSSCH} is the number of subframes that can be used for PSSCH transmission in a PSCCH period and is a multiple of 4.

14.1.1.1.1 Determination of subframe indicator bitmap

For FDD and TDD with UL/DL configuration belonging to {1,2,4,5}, N_{TRP} is 8, and the mapping between Time Resource pattern Index (I_{TRP}) and subframe indicator bitmap $\left(b'_0, b'_1, \ldots b'_{N_{TRP}-1}\right)$ is given by table 14.1.1.1.1-1.

For TDD with UL/DL configuration 0, N_{TRP} is 7, and the mapping between Time Resource pattern Index (I_{TRP}) and subframe indicator bitmap $\left(b'_0, b'_1, \ldots b'_{N_{TRP}-1}\right)$ is given by table 14.1.1.1.1-2.

For TDD with UL/DL configuration belonging to {3,6}, N_{TRP} is 6, and the mapping between Time Resource pattern Index (I_{TRP}) and subframe indicator bitmap $\left(b'_0, b'_1, \ldots b'_{N_{TRP}-1}\right)$ is given by table 14.1.1.1.1-3.

Table 14.1.1.1.1-1: Time Resource pattern Index mapping for $N_{TRP} = 8$

I_{TRP}	k_{TRP}	$\left(b'_0, b'_1, \ldots b'_{N_{TRP}-1}\right)$	I_{TRP}	k_{TRP}	$\left(b'_0, b'_1, \ldots b'_{N_{TRP}-1}\right)$	I_{TRP}	k_{TRP}	$\left(b'_0, b'_1, \ldots b'_{N_{TRP}-1}\right)$
0	1	(1,0,0,0,0,0,0,0)	37	4	(1,1,1,0,1,0,0,0)	74	4	(0,1,1,1,0,0,0,1)
1	1	(0,1,0,0,0,0,0,0)	38	4	(1,1,0,1,1,0,0,0)	75	4	(1,1,0,0,1,0,0,1)
2	1	(0,0,1,0,0,0,0,0)	39	4	(1,0,1,1,1,0,0,0)	76	4	(1,0,1,0,1,0,0,1)

3	1	(0,0,0,1,0,0,0,0)	40	4	(0,1,1,1,1,0,0,0)	77	4	(0,1,1,0,1,0,0,1)
4	1	(0,0,0,0,1,0,0,0)	41	4	(1,1,1,0,0,1,0,0)	78	4	(1,0,0,1,1,0,0,1)
5	1	(0,0,0,0,0,1,0,0)	42	4	(1,1,0,1,0,1,0,0)	79	4	(0,1,0,1,1,0,0,1)
6	1	(0,0,0,0,0,0,1,0)	43	4	(1,0,1,1,0,1,0,0)	80	4	(0,0,1,1,1,0,0,1)
7	1	(0,0,0,0,0,0,0,1)	44	4	(0,1,1,1,0,1,0,0)	81	4	(1,1,0,0,0,1,0,1)
8	2	(1,1,0,0,0,0,0,0)	45	4	(1,1,0,0,1,1,0,0)	82	4	(1,0,1,0,0,1,0,1)
9	2	(1,0,1,0,0,0,0,0)	46	4	(1,0,1,0,1,1,0,0)	83	4	(0,1,1,0,0,1,0,1)
10	2	(0,1,1,0,0,0,0,0)	47	4	(0,1,1,0,1,1,0,0)	84	4	(1,0,0,1,0,1,0,1)
11	2	(1,0,0,1,0,0,0,0)	48	4	(1,0,0,1,1,1,0,0)	85	4	(0,1,0,1,0,1,0,1)
12	2	(0,1,0,1,0,0,0,0)	49	4	(0,1,0,1,1,1,0,0)	86	4	(0,0,1,1,0,1,0,1)
13	2	(0,0,1,1,0,0,0,0)	50	4	(0,0,1,1,1,1,0,0)	87	4	(1,0,0,0,1,1,0,1)
14	2	(1,0,0,0,1,0,0,0)	51	4	(1,1,1,0,0,0,1,0)	88	4	(0,1,0,0,1,1,0,1)
15	2	(0,1,0,0,1,0,0,0)	52	4	(1,1,0,1,0,0,1,0)	89	4	(0,0,1,0,1,1,0,1)
16	2	(0,0,1,0,1,0,0,0)	53	4	(1,0,1,1,0,0,1,0)	90	4	(0,0,0,1,1,1,0,1)
17	2	(0,0,0,1,1,0,0,0)	54	4	(0,1,1,1,0,0,1,0)	91	4	(1,1,0,0,0,0,1,1)
18	2	(1,0,0,0,0,1,0,0)	55	4	(1,1,0,0,1,0,1,0)	92	4	(1,0,1,0,0,0,1,1)
19	2	(0,1,0,0,0,1,0,0)	56	4	(1,0,1,0,1,0,1,0)	93	4	(0,1,1,0,0,0,1,1)
20	2	(0,0,1,0,0,1,0,0)	57	4	(0,1,1,0,1,0,1,0)	94	4	(1,0,0,1,0,0,1,1)
21	2	(0,0,0,1,0,1,0,0)	58	4	(1,0,0,1,1,0,1,0)	95	4	(0,1,0,1,0,0,1,1)
22	2	(0,0,0,0,1,1,0,0)	59	4	(0,1,0,1,1,0,1,0)	96	4	(0,0,1,1,0,0,1,1)
23	2	(1,0,0,0,0,0,1,0)	60	4	(0,0,1,1,1,0,1,0)	97	4	(1,0,0,0,1,0,1,1)
24	2	(0,1,0,0,0,0,1,0)	61	4	(1,1,0,0,0,1,1,0)	98	4	(0,1,0,0,1,0,1,1)
25	2	(0,0,1,0,0,0,1,0)	62	4	(1,0,1,0,0,1,1,0)	99	4	(0,0,1,0,1,0,1,1)
26	2	(0,0,0,1,0,0,1,0)	63	4	(0,1,1,0,0,1,1,0)	100	4	(0,0,0,1,1,0,1,1)
27	2	(0,0,0,0,1,0,1,0)	64	4	(1,0,0,1,0,1,1,0)	101	4	(1,0,0,0,0,1,1,1)
28	2	(0,0,0,0,0,1,1,0)	65	4	(0,1,0,1,0,1,1,0)	102	4	(0,1,0,0,0,1,1,1)
29	2	(1,0,0,0,0,0,0,1)	66	4	(0,0,1,1,0,1,1,0)	103	4	(0,0,1,0,0,1,1,1)
30	2	(0,1,0,0,0,0,0,1)	67	4	(1,0,0,0,1,1,1,0)	104	4	(0,0,0,1,0,1,1,1)
31	2	(0,0,1,0,0,0,0,1)	68	4	(0,1,0,0,1,1,1,0)	105	4	(0,0,0,0,1,1,1,1)
32	2	(0,0,0,1,0,0,0,1)	69	4	(0,0,1,0,1,1,1,0)	106	8	(1,1,1,1,1,1,1,1)
33	2	(0,0,0,0,1,0,0,1)	70	4	(0,0,0,1,1,1,1,0)	107-127	reserved	reserved
34	2	(0,0,0,0,0,1,0,1)	71	4	(1,1,1,0,0,0,0,1)			
35	2	(0,0,0,0,0,0,1,1)	72	4	(1,1,0,1,0,0,0,1)			
36	4	(1,1,1,1,0,0,0,0)	73	4	(1,0,1,1,0,0,0,1)			

Table 14.1.1.1.1-2: Time Resource pattern Index mapping for $N_{TRP} = 7$

I_{TRP}	k_{TRP}	$\left(b'_0, b'_1, \ldots b'_{N_{TRP}-1}\right)$	I_{TRP}	k_{TRP}	$\left(b'_0, b'_1, \ldots b'_{N_{TRP}-1}\right)$	I_{TRP}	k_{TRP}	$\left(b'_0, b'_1, \ldots b'_{N_{TRP}-1}\right)$
0	reserved	reserved	44	3	(0,0,1,1,0,1,0)	88	3	(0,0,0,1,1,0,1)
1	1	(1,0,0,0,0,0,0)	45	4	(1,0,1,1,0,1,0)	89	4	(1,0,0,1,1,0,1)
2	1	(0,1,0,0,0,0,0)	46	4	(0,1,1,1,0,1,0)	90	4	(0,1,0,1,1,0,1)
3	2	(1,1,0,0,0,0,0)	47	5	(1,1,1,1,0,1,0)	91	5	(1,1,0,1,1,0,1)
4	1	(0,0,1,0,0,0,0)	48	2	(0,0,0,0,1,1,0)	92	4	(0,0,1,1,1,0,1)
5	2	(1,0,1,0,0,0,0)	49	3	(1,0,0,0,1,1,0)	93	5	(1,0,1,1,1,0,1)
6	2	(0,1,1,0,0,0,0)	50	3	(0,1,0,0,1,1,0)	94	5	(0,1,1,1,1,0,1)

7	3	(1,1,1,0,0,0,0)	51	4	(1,1,0,0,1,1,0)	95	6	(1,1,1,1,1,0,1)
8	1	(0,0,0,1,0,0,0)	52	3	(0,0,1,0,1,1,0)	96	2	(0,0,0,0,0,1,1)
9	2	(1,0,0,1,0,0,0)	53	4	(1,0,1,0,1,1,0)	97	3	(1,0,0,0,0,1,1)
10	2	(0,1,0,1,0,0,0)	54	4	(0,1,1,0,1,1,0)	98	3	(0,1,0,0,0,1,1)
11	3	(1,1,0,1,0,0,0)	55	5	(1,1,1,0,1,1,0)	99	4	(1,1,0,0,0,1,1)
12	2	(0,0,1,1,0,0,0)	56	3	(0,0,0,1,1,1,0)	100	3	(0,0,1,0,0,1,1)
13	3	(1,0,1,1,0,0,0)	57	4	(1,0,0,1,1,1,0)	101	4	(1,0,1,0,0,1,1)
14	3	(0,1,1,1,0,0,0)	58	4	(0,1,0,1,1,1,0)	102	4	(0,1,1,0,0,1,1)
15	4	(1,1,1,1,0,0,0)	59	5	(1,1,0,1,1,1,0)	103	5	(1,1,1,0,0,1,1)
16	1	(0,0,0,0,1,0,0)	60	4	(0,0,1,1,1,1,0)	104	3	(0,0,0,1,0,1,1)
17	2	(1,0,0,0,1,0,0)	61	5	(1,0,1,1,1,1,0)	105	4	(1,0,0,1,0,1,1)
18	2	(0,1,0,0,1,0,0)	62	5	(0,1,1,1,1,1,0)	106	4	(0,1,0,1,0,1,1)
19	3	(1,1,0,0,1,0,0)	63	6	(1,1,1,1,1,1,0)	107	5	(1,1,0,1,0,1,1)
20	2	(0,0,1,0,1,0,0)	64	1	(0,0,0,0,0,0,1)	108	4	(0,0,1,1,0,1,1)
21	3	(1,0,1,0,1,0,0)	65	2	(1,0,0,0,0,0,1)	109	5	(1,0,1,1,0,1,1)
22	3	(0,1,1,0,1,0,0)	66	2	(0,1,0,0,0,0,1)	110	5	(0,1,1,1,0,1,1)
23	4	(1,1,1,0,1,0,0)	67	3	(1,1,0,0,0,0,1)	111	6	(1,1,1,1,0,1,1)
24	2	(0,0,0,1,1,0,0)	68	2	(0,0,1,0,0,0,1)	112	3	(0,0,0,0,1,1,1)
25	3	(1,0,0,1,1,0,0)	69	3	(1,0,1,0,0,0,1)	113	4	(1,0,0,0,1,1,1)
26	3	(0,1,0,1,1,0,0)	70	3	(0,1,1,0,0,0,1)	114	4	(0,1,0,0,1,1,1)
27	4	(1,1,0,1,1,0,0)	71	4	(1,1,1,0,0,0,1)	115	5	(1,1,0,0,1,1,1)
28	3	(0,0,1,1,1,0,0)	72	2	(0,0,0,1,0,0,1)	116	4	(0,0,1,0,1,1,1)
29	4	(1,0,1,1,1,0,0)	73	3	(1,0,0,1,0,0,1)	117	5	(1,0,1,0,1,1,1)
30	4	(0,1,1,1,1,0,0)	74	3	(0,1,0,1,0,0,1)	118	5	(0,1,1,0,1,1,1)
31	5	(1,1,1,1,1,0,0)	75	4	(1,1,0,1,0,0,1)	119	6	(1,1,1,0,1,1,1)
32	1	(0,0,0,0,0,1,0)	76	3	(0,0,1,1,0,0,1)	120	4	(0,0,0,1,1,1,1)
33	2	(1,0,0,0,0,1,0)	77	4	(1,0,1,1,0,0,1)	121	5	(1,0,0,1,1,1,1)
34	2	(0,1,0,0,0,1,0)	78	4	(0,1,1,1,0,0,1)	122	5	(0,1,0,1,1,1,1)
35	3	(1,1,0,0,0,1,0)	79	5	(1,1,1,1,0,0,1)	123	6	(1,1,0,1,1,1,1)
36	2	(0,0,1,0,0,1,0)	80	2	(0,0,0,0,1,0,1)	124	5	(0,0,1,1,1,1,1)
37	3	(1,0,1,0,0,1,0)	81	3	(1,0,0,0,1,0,1)	125	6	(1,0,1,1,1,1,1)
38	3	(0,1,1,0,0,1,0)	82	3	(0,1,0,0,1,0,1)	126	6	(0,1,1,1,1,1,1)
39	4	(1,1,1,0,0,1,0)	83	4	(1,1,0,0,1,0,1)	127	7	(1,1,1,1,1,1,1)
40	2	(0,0,0,1,0,1,0)	84	3	(0,0,1,0,1,0,1)			
41	3	(1,0,0,1,0,1,0)	85	4	(1,0,1,0,1,0,1)			
42	3	(0,1,0,1,0,1,0)	86	4	(0,1,1,0,1,0,1)			
43	4	(1,1,0,1,0,1,0)	87	5	(1,1,1,0,1,0,1)			

Table 14.1.1.1.1-3: Time Resource pattern Index mapping for $N_{TRP} = 6$

I_{TRP}	k_{TRP}	$\left(b'_0, b'_1, \ldots b'_{N_{TRP}-1}\right)$	I_{TRP}	k_{TRP}	$\left(b'_0, b'_1, \ldots b'_{N_{TRP}-1}\right)$	I_{TRP}	k_{TRP}	$\left(b'_0, b'_1, \ldots b'_{N_{TRP}-1}\right)$
0	reserved	reserved	22	3	(0,1,1,0,1,0)	44	3	(0,0,1,1,0,1)
1	1	(1,0,0,0,0,0)	23	4	(1,1,1,0,1,0)	45	4	(1,0,1,1,0,1)
2	1	(0,1,0,0,0,0)	24	2	(0,0,0,1,1,0)	46	4	(0,1,1,1,0,1)
3	2	(1,1,0,0,0,0)	25	3	(1,0,0,1,1,0)	47	5	(1,1,1,1,0,1)

4	1	(0,0,1,0,0,0)	26	3	(0,1,0,1,1,0)	48	2	(0,0,0,0,1,1)
5	2	(1,0,1,0,0,0)	27	4	(1,1,0,1,1,0)	49	3	(1,0,0,0,1,1)
6	2	(0,1,1,0,0,0)	28	3	(0,0,1,1,1,0)	50	3	(0,1,0,0,1,1)
7	3	(1,1,1,0,0,0)	29	4	(1,0,1,1,1,0)	51	4	(1,1,0,0,1,1)
8	1	(0,0,0,1,0,0)	30	4	(0,1,1,1,1,0)	52	3	(0,0,1,0,1,1)
9	2	(1,0,0,1,0,0)	31	5	(1,1,1,1,1,0)	53	4	(1,0,1,0,1,1)
10	2	(0,1,0,1,0,0)	32	1	(0,0,0,0,0,1)	54	4	(0,1,1,0,1,1)
11	3	(1,1,0,1,0,0)	33	2	(1,0,0,0,0,1)	55	5	(1,1,1,0,1,1)
12	2	(0,0,1,1,0,0)	34	2	(0,1,0,0,0,1)	56	3	(0,0,0,1,1,1)
13	3	(1,0,1,1,0,0)	35	3	(1,1,0,0,0,1)	57	4	(1,0,0,1,1,1)
14	3	(0,1,1,1,0,0)	36	2	(0,0,1,0,0,1)	58	4	(0,1,0,1,1,1)
15	4	(1,1,1,1,0,0)	37	3	(1,0,1,0,0,1)	59	5	(1,1,0,1,1,1)
16	1	(0,0,0,0,1,0)	38	3	(0,1,1,0,0,1)	60	4	(0,0,1,1,1,1)
17	2	(1,0,0,0,1,0)	39	4	(1,1,1,0,0,1)	61	5	(1,0,1,1,1,1)
18	2	(0,1,0,0,1,0)	40	2	(0,0,0,1,0,1)	62	5	(0,1,1,1,1,1)
19	3	(1,1,0,0,1,0)	41	3	(1,0,0,1,0,1)	63	6	(1,1,1,1,1,1)
20	2	(0,0,1,0,1,0)	42	3	(0,1,0,1,0,1)	64-127	reserved	reserved
21	3	(1,0,1,0,1,0)	43	4	(1,1,0,1,0,1)			

14.1.1.2 UE procedure for determining resource blocks for transmitting PSSCH for sidelink transmission mode 1

The set of resource blocks is determined using the procedure described in subclause 14.1.1.2.1 and 14.1.1.2.2.

14.1.1.2.1 PSSCH resource allocation for sidelink transmission mode 1

The resource allocation and hopping field of the SCI format 0 is used to determine a set of indices denoted by n'_{VRB} ($0 \le n'_{\text{VRB}} < N_{\text{RB}}^{\text{SL}}$), a starting index RB'_{START}, and a number of allocated PRBs L'_{CRBs} and $N_{\text{RB}}^{\text{PSSCH}}$ using the procedure in subclause 8.1.1, and 8.4 (for sidelink frequency hopping with type 1 or type 2 hopping) with the following exceptions:

- the term 'PUSCH' in subclauses 8.1.1 and 8.4 is replaced with 'PSSCH'.
- the quantity n_{VRB} in subclause 8.1.1 is replaced with n'_{VRB} .
- the quantity $N_{\text{RB}}^{\text{UL}}$ in subclauses 8.1.1 and 8.4 is replaced with $N_{\text{RB}}^{\text{SL}}$.
- the quantity RB_{START} in subclauses 8.1.1and 8.4 is replaced with RB'_{START}.
- the quantity L_{CRBs} in subclauses 8.1.1 and 8.4 is replaced with L'_{CRBs} .
- the quantity $N_{\text{RB}}^{\text{PUSCH}}$ in subclause 8.4 is replaced with $N_{\text{RB}}^{\text{PSSCH}}$.
- the quantity $N_{\text{RB}}^{\text{HO}}$ is given by higher layer parameter *rb-Offset-r12* associated with the corresponding PSSCH resource configuration.
- the quantity N_{sb} is given by higher layer parameter *numSubbands-r12* associated with the corresponding PSSCH resource configuration.

14.1.1.2.2 PSSCH frequency hopping for sidelink transmission mode 1

If sidelink frequency hopping with type 1 hopping is enabled, the set of physical resource blocks for PSSCH transmission is determined using subclause 8.4 with the following exceptions:

- the term 'PUSCH' is replaced with 'PSSCH'.
- only inter-subframe hopping shall be used.
- the quantity RB_{START} is replaced with RB'_{START}.
- the quantity $N_{\text{RB}}^{\text{UL}}$ is replaced with $N_{\text{RB}}^{\text{SL}}$.
- the quantity $N_{\text{RB}}^{\text{PUSCH}}$ is replaced with $N_{\text{RB}}^{\text{PSSCH}}$.
- the quantity $N_{\text{RB}}^{\text{HO}}$ is given by higher layer parameter *rb-Offset-r12* associated with the PSSCH resource configuration.
- the frequency hopping field in the SCI format 0 is used instead of DCI format 0.
- the quantity $n_{\text{PRB}}^{\text{S1}}(i)$ is replaced with $n_{\text{PRB}}^{\text{SL0}}$.
- the quantity $n_{\text{PRB}}(i)$ is replaced with $n_{\text{PRB}}^{\text{SL1}}$.
- for odd $n_{\text{ssf}}^{\text{PSSCH}}$ (described in subclause 9.2.4 of [3]), the set of physical resource blocks for PSSCH transmission are L'_{CRBs} contiguous resource blocks starting from PRB with index $n_{\text{PRB}}^{\text{SL0}}$.
- for even $n_{\text{ssf}}^{\text{PSSCH}}$ (described in subclause 9.2.4 of [3]), the set of physical resource blocks for PSSCH transmission are L'_{CRBs} contiguous resource blocks starting from PRB with index $n_{\text{PRB}}^{\text{SL1}}$.

14.1.1.3 UE procedure for determining subframes for transmitting PSSCH for sidelink transmission mode 2

For FDD or for TDD, and the UE not configured with the higher layer parameter *trpt-Subset-r12*

- The allowed values of I_{TRP} correspond to the values of k_{TRP} satisfying $k_{TRP} = k_i$, for a value of i in $0 \le i < X_{TRP}$, where k_i and X_{TRP} are determined from table 14.1.1.3-1.

For FDD or for TDD with UL/DL configuration belonging to {0,1,2,3,4,6}, and the UE configured with the higher layer parameter *trpt-Subset-r12*

- The allowed values of I_{TRP} correspond to the values of k_{TRP} satisfying $k_{TRP} = k_i$, for values of i in $0 \le i < X_{TRP}$ satisfying $a_i = 1$, $0 \le i < X_{TRP}$ and where k_i and X_{TRP} are determined from table 14.1.1.3-1, and $(a_0, a_1, ..., a_{X_{TRP}-1})$ is the bitmap indicated by *trpt-Subset-r12*.

Table 14.1.1.3-1: Determination of X_{TRP} and k_i for sidelink transmission mode 2

	X_{TRP}	k_0	k_1	k_2	k_3	k_4
FDD and TDD with UL/DL configuration 1,2,4,5	3	1	2	4	-	-
TDD with UL/DL configuration 0	5	1	2	3	4	5
TDD with UL/DL configuration 3,6	4	1	2	3	4	-

Within a PSCCH period, the subframes used for PSSCH are determined as follows:

- a subframe indicator bitmap $\left(b'_0, b'_1, \ldots b'_{N_{TRP}-1}\right)$ and N_{TRP} are determined using the procedure described in subclause 14.1.1.1.1 from the allowed values of I_{TRP} described in this subclause.
- a bitmap $\left(b_0, b_1, \ldots b_{L_{PSSCH}-1}\right)$ is determined using $b_j = b'_{j \bmod N_{TRP}}$ and a subframe l_j^{PSSCH} in the subframe pool is used for PSSCH if $b_j = 1$, otherwise the subframe l_j^{PSSCH} is not used for PSSCH, where $\left(l_0^{PSSCH}, l_1^{PSSCH}, \ldots, l_{L_{PSSCH}-1}^{PSSCH}\right)$ and L_{PSSCH} are described in subclause 14.1.3. The subframes used for PSSCH are denoted by $\left(n_0^{PSSCH}, n_1^{PSSCH}, \ldots, n_{N_{PSSCH}-1}^{PSSCH}\right)$ arranged in increasing order of subframe index and where N_{PSSCH} is the number of subframes that can be used for PSSCH transmission in a PSCCH period and is a multiple of 4.

14.1.1.4 UE procedure for determining resource blocks for transmitting PSSCH for sidelink transmission mode 2

The set of resource blocks within the resource block pool (defined in 14.1.3) is determined using the subclause 14.1.1.2.1 .

If sidelink frequency hopping with type 1 hopping is enabled, the set of physical resource blocks for PSSCH transmission is determined using subclause 14.1.1.2.2 with the following exceptions

- the quantity $N_{\mathrm{RB}}^{\mathrm{UL}}$ is replaced with $M_{RB}^{PSSCH\_RP}$ (defined in 14.1.3).
- for odd $n_{\mathrm{ssf}}^{\mathrm{PSSCH}}$, the set of physical resource blocks for PSSCH transmission are given by L'_{CRBs} contiguous resource blocks $m_x, m_{x+1}, \ldots m_{x+L'_{CRBs}-1}$ belonging to the resource block pool, where $x = n_{\mathrm{PRB}}^{\mathrm{SL0}}$.
- for even $n_{\mathrm{ssf}}^{\mathrm{PSSCH}}$, the set of physical resource blocks for PSSCH transmission are given by L'_{CRBs} contiguous resource blocks $m_x, m_{x+1}, \ldots m_{x+L'_{CRBs}-1}$ belonging to the resource block pool, where $x = n_{\mathrm{PRB}}^{\mathrm{SL1}}$.

14.1.1.5 UE procedure for PSSCH power control

For sidelink transmission mode 1 and PSCCH period *i*, the UE transmit power P_{PSSCH} for PSSCH transmission is given by the following

- if the TPC command field in configured sidelink grant (described in [8]) for PSCCH period *i* is set to 0
  - $P_{\mathrm{PSSCH}} = P_{\mathrm{CMAX},PSSCH}$
- if the TPC command field in configured sidelink grant (described in [8]) for PSCCH period *i* is set to 1
  - $P_{\mathrm{PSSCH}} = \min\left\{P_{\mathrm{CMAX},PSSCH},\ 10\log_{10}(M_{\mathrm{PSSCH}}) + P_{\mathrm{O\_PSSCH,1}} + \alpha_{PSSCH,1} \cdot PL\right\}$ [dBm]

where $P_{\mathrm{CMAX},PSSCH}$ is defined in [6], and M_{PSSCH} is the bandwidth of the PSSCH resource assignment expressed in number of resource block and $PL = PL_c$ where PL_c is defined in subclause 5.1.1.1. $P_{\mathrm{O\_PSSCH,1}}$ and $\alpha_{PSSCH,1}$ are provided by higher layer parameters *p0-r12* and *alpha-r12*, respectively and that are associated with the corresponding PSSCH resource configuration.

For sidelink transmission mode 2, the UE transmit power P_{PSSCH} for PSSCH transmission is given by

$$P_{\mathrm{PSSCH}} = \min\left\{P_{\mathrm{CMAX},PSSCH},\ 10\log_{10}(M_{\mathrm{PSSCH}}) + P_{\mathrm{O\_PSSCH,2}} + \alpha_{PSSCH,2} \cdot PL\right\} \text{ [dBm]},$$

where $P_{\mathrm{CMAX},PSSCH}$ is defined in [6], and M_{PSSCH} is the bandwidth of the PSSCH resource assignment expressed in number of resource blocks and $PL = PL_c$ where PL_c is defined in subclause 5.1.1.1. $P_{\mathrm{O\_PSSCH},2}$ and $\alpha_{PSSCH,2}$ are provided by higher layer parameter *p0-r12* and *alpha-r12*, respectively and that are associated with the corresponding PSSCH resource configuration.

14.1.2 UE procedure for receiving the PSSCH

For sidelink transmission mode 1, a UE upon detection of SCI format 0 on PSCCH can decode PSSCH according to the detected SCI format 0.

For sidelink transmission mode 2, a UE upon detection of SCI format 0 on PSCCH can decode PSSCH according to the detected SCI format 0, and associated PSSCH resource configuration configured by higher layers.

14.1.3 UE procedure for determining resource block pool and subframe pool for sidelink transmission mode 2

For a PSCCH period associated with the PSCCH resource configuration (determined in subclause 14.2.3) which is also associated with the PSSCH resource configuration, the UE determines a PSSCH pool consisting of a subframe pool and resource block pool as follows.

- For TDD, if the parameter *tdd-Config-r12* is indicated by the PSCCH resource configuration, the TDD UL/DL configuration used for determining the subframe pool is given by the parameter *tdd-Config-r12*, otherwise, the TDD UL/DL configuration used for determining the subframe pool is given by the UL/DL configuration (i.e. parameter *subframeAssignment*) for the serving cell.
- Within the PSCCH period, the uplink subframes with subframe index greater than or equal to $j_{begin} + O_2$ are denoted by $\left(l_0, l_1, ..., l_{N'-1}\right)$ arranged in increasing order of subframe index, where j_{begin} is described in subclause 14.2.3 and O_2 is the *offsetIndicator-r12* indicated by the PSSCH resource configuration, where N' denotes the number of uplink subframes within the PSCCH period with subframe index greater than or equal to $j_{begin} + O_2$.
- A bitmap $b_0, b_1, b_2, ..., b_{N'-1}$ is determined using $b_j = a_{j \bmod N_B}$, for $0 \le j < N'$, where $a_0, a_1, a_2, ..., a_{N_B-1}$ and N_B are the bitmap and the length of the bitmap indicated by *subframeBitmap-r12*, respectively.
- A subframe l_j $(0 \le j < N')$ belongs to the subframe pool if $b_j = 1$. The subframes in the subframe pool are denoted by $\left(l_0^{PSSCH}, l_1^{PSSCH}, ..., l_{L_{PSSCH}-1}^{PSSCH}\right)$ arranged in increasing order of subframe index and L_{PSSCH} denotes the number of subframes in the subframe pool.
- A PRB with index q $(0 \le q < N_{RB}^{SL})$ belongs to the resource block pool if $S1 \le q < S1 + M$ or if $S2 - M < q \le S2$, where *S1*, *S2*, and *M* denote the *prb-Start-r12*, *prb-End-r12* and *prb-Num-r12* indicated by the PSSCH resource configuration respectively.
- The resource blocks in the resource block pool are denoted by $\left(m_0^{PSSCH}, m_1^{PSSCH}, ..., m_{M_{RB}^{PSSCH\_RP}-1}^{PSSCH}\right)$ arranged in increasing order of resource block indices and $M_{RB}^{PSSCH\_RP}$ is the number of resource blocks in the resource block pool.

14.1.4 UE procedure for determining subframe pool for sidelink transmission mode 1

For a PSCCH period associated with the PSCCH resource configuration (described in subclause 14.2.3) which is also associated with the PSSCH resource configuration, the UE determines a PSSCH pool consisting of a subframe pool as follows.

- For TDD, if the parameter *tdd-Config-r12* is indicated by the PSCCH resource configuration, the TDD UL/DL configuration used for determining the subframe pool is given by the parameter *tdd-Config-r12*, otherwise, the TDD UL/DL configuration used for determining the subframe pool is given by the UL/DL configuration (i.e. parameter *subframeAssignment*) for the serving cell.

- Each uplink subframe with subframe index greater than or equal to $l^{PSCCH}_{L_{PSCCH}-1}+1$ belongs to the subframe pool for PSSCH, where $l^{PSCCH}_{L_{PSCCH}-1}+1$ and L_{PSCCH} are described in subclause 14.2.3.

- The subframes in the subframe pool for PSSCH are denoted by $\left(l_0^{PSSCH}, l_1^{PSSCH}, ..., l^{PSSCH}_{L_{PSSCH}-1}\right)$ arranged in increasing order of subframe index and L_{PSSCH} denotes the number of subframes in the subframe pool.

14.2 Physical Sidelink Control Channel related procedures

For sidelink transmission mode 1, if a UE is configured by higher layers to receive DCI format 5 with the CRC scrambled by the SL-RNTI, the UE shall decode the PDCCH/EPDCCH according to the combination defined in Table 14.2-1.

Table 14.2-1: PDCCH/EPDCCH configured by SL-RNTI

DCI format	Search Space
DCI format 5	For PDCCH: Common and UE specific by C-RNTI For EPDCCH: UE specific by C-RNTI

14.2.1 UE procedure for transmitting the PSCCH

For sidelink transmission mode 1and PSCCH period *i*,

- the UE shall determine the subframes and resource blocks for transmitting SCI format 0 as follows.
  - SCI format 0 is transmitted in two subframes in the subframe pool and one physical resource block per slot in each of the two subframes, wherein the physical resource blocks belong to the resource block pool, where the subframe pool and the resource block pool are indicated by the PSCCH resource configuration (as defined in subclause 14.2.3)
  - the two subframes and the resource blocks are determined using “Resource for PSCCH” field (n_{PSCCH}) in the configured sidelink grant (described in [8]) as described in subclause 14.2.1.1.
- the UE shall set the contents of the SCI format 0 as follows:
  - the UE shall set the Modulation and coding scheme field according to the Modulation and coding scheme indicated by the higher layer parameter *mcs-r12* if the parameter is configured by higher layers.
  - the UE shall set the Frequency hopping flag according to the “Frequency hopping flag” field in the configured sidelink grant.
  - the UE shall set the Resource block assignment and hopping resource allocation according to the “Resource block assignment and hopping resource allocation” field in the configured sidelink grant.
  - the UE shall set the Time resource pattern according to the “Time resource pattern” field in the configured sidelink grant .
  - the UE shall set the eleven-bit Timing advance indication to $I_{TAI}=\left\lfloor \frac{N_{TA}}{16} \right\rfloor$ to indicate sidelink reception timing adjustment value using the N_{TA} (defined in [3]) value for the UE in the subframe that is no earlier than subframe $l_{b1}^{PSCCH}-4$ (l_{b1}^{PSCCH} described in subclause 14.2.1.1).

For sidelink transmission mode 2,

- SCI format 0 is transmitted in two subframes in the subframe pool and one physical resource block per slot in each of the two subframes, wherein the physical resource blocks belongs to the resource block pool, where the subframe pool and the resource block pool are indicated by the PSCCH resource configuration (as defined in subclause 14.2.3)
  - the two subframes and the resource blocks are determined using the procedure described in subclause 14.2.1.2
  - the UE shall set the eleven-bit Timing advance indication I_{TAI} in the SCI format 0 to zero.

14.2.1.1 UE procedure for determining subframes and resource blocks for transmitting PSCCH for sidelink transmission mode 1

For $0 \le n_{PSCCH} < \lfloor M_{RB}^{PSCCH\_RP} / 2 \rfloor \cdot L_{PSCCH}$,

- one transmission of the PSCCH is in resource block m_{a1}^{PSCCH} of subframe l_{b1}^{PSCCH} of the PSCCH period, where $a1 = \lfloor n_{PSCCH} / L_{PSCCH} \rfloor$ and $b1 = n_{PSCCH} \bmod L_{PSCCH}$.
- the other transmission of the PSCCH is in resource block m_{a2}^{PSCCH} of subframe l_{b2}^{PSCCH} of the PSCCH period, where $a2 = \lfloor n_{PSCCH} / L_{PSCCH} \rfloor + \lfloor M_{RB}^{PSCCH\_RP} / 2 \rfloor$ and $b2 = \left(n_{PSCCH} + 1 + \lfloor n_{PSCCH} / L_{PSCCH} \rfloor \bmod (L_{PSCCH} - 1)\right) \bmod L_{PSCCH}$.

where $\left(l_0^{PSCCH}, l_1^{PSCCH}, ..., l_{L_{PSCCH}-1}^{PSCCH}\right)$, $\left(m_0^{PSCCH}, m_1^{PSCCH}, ..., m_{M_{RB}^{PSCCH\_RP}-1}^{PSCCH}\right)$, L_{PSCCH} and $M_{RB}^{PSCCH\_RP}$ are described in subclause 14.2.3.

14.2.1.2 UE procedure for determining subframes and resource blocks for transmitting PSCCH for sidelink transmission mode 2

The allowed values for PSCCH resource selection are given by 0,1… $\left(\lfloor M_{RB}^{PSCCH\_RP} / 2 \rfloor \cdot L_{PSCCH} - 1\right)$ where L_{PSCCH} and $M_{RB}^{PSCCH\_RP}$ described in subclause 14.2.3. The two subframes and the resource blocks are determined using selected resource value n_{PSCCH} (described in [8]) and the procedure described in subclause 14.2.1.1.

14.2.1.3 UE procedure for PSCCH power control

For sidelink transmission mode 1 and PSCCH period *i*, the UE transmit power P_{PSCCH} for PSCCH transmission is given by the following

- if the TPC command field in the configured sidelink grant (described in [8]) for PSCCH period *i* is set to 0
  - $P_{\mathrm{PSCCH}} = P_{\mathrm{CMAX},PSCCH}$
- if the TPC command field in the configured sidelink grant (described in [8]) for PSCCH period *i* is set to 1
  - $P_{\mathrm{PSCCH}} = \min\left\{P_{\mathrm{CMAX},PSCCH},\ 10\log_{10}(M_{\mathrm{PSCCH}}) + P_{\mathrm{O\_PSCCH},1} + \alpha_{PSCCH,1} \cdot PL\right\}$ [dBm]

where $P_{\mathrm{CMAX},PSCCH}$ is defined in [6], and M_{PSCCH} =1 and $PL = PL_c$ where PL_c is defined in subclause 5.1.1.1. $P_{\mathrm{O\_PSCCH},1}$ and $\alpha_{PSCCH,1}$ are provided by higher layer parameters *p0-r12* and *alpha-r12*, respectively and are associated with the corresponding PSCCH resource configuration.

For sidelink transmission mode 2, the UE transmit power P_{PSCCH} for PSCCH transmission is given by

$$P_{\mathrm{PSCCH}} = \min\left\{P_{\mathrm{CMAX},PSCCH},\ 10\log_{10}(M_{\mathrm{PSCCH}}) + P_{\mathrm{O\_PSCCH},2} + \alpha_{PSCCH,2} \cdot PL\right\} \text{ [dBm]},$$

where $P_{\mathrm{CMAX},PSCCH}$ is the $P_{\mathrm{CMAX},c}$ configured by higher layers and M_{PSCCH} =1 and $PL = PL_c$ where PL_c is defined in subclause 5.1.1.1. $P_{\mathrm{O\_PSCCH},2}$ and $\alpha_{PSCCH,2}$ are provided by higher layer parameters *p0-r12* and *alpha-r12*, respectively and are associated with the corresponding PSCCH resource configuration.

14.2.2 UE procedure for receiving the PSCCH

For each PSCCH resource configuration associated with sidelink transmission mode 1, a UE configured by higher layers to detect SCI format 0 on PSCCH shall attempt to decode the PSCCH according to the PSCCH resource configuration, and using the Group destination IDs indicated by higher layers.

For each PSCCH resource configuration associated with sidelink transmission mode 2, a UE configured by higher layers to detect SCI format 0 on PSCCH shall attempt to decode the PSCCH according to the PSCCH resource configuration, and using the Group destination IDs indicated by higher layers.

14.2.3 UE procedure for determining resource block pool and subframe pool for PSCCH

A PSCCH resource configuration for transmission/reception is associated with a set of periodically occurring time-domain periods (known as PSCCH periods). The *i*-th PSCCH period begins at subframe with subframe index $j_{begin} = O + i \cdot P$ and ends in subframe with subframe index $j_{end} = O + (i+1) \cdot P - 1$, where

- $0 \le j_{begin}, j_{end} < 10240$,
- the subframe index is relative to subframe#0 of the radio frame corresponding to SFN 0 of the serving cell or DFN 0 (described in [11]),
- O is the *offsetIndicator-r12* indicated by the PSCCH resource configuration,
- P is the *sc-Period-r12* indicated by the PSCCH resource configuration.

For a PSCCH period, the UE determines a PSCCH pool consisting of a subframe pool and a resource block pool as follows.

- For TDD, if the parameter *tdd-Config-r12* is indicated by the PSCCH resource configuration, the TDD UL/DL configuration used for determining the subframe pool is given by the parameter *tdd-Config-r12*, otherwise, the TDD UL/DL configuration used for determining the subframe pool is given by the UL/DL configuration (i.e. parameter *subframeAssignment*) for the serving cell.
- The first N' uplink subframes are denoted by $(l_0, l_1, ..., l_{N'-1})$ arranged in increasing order of subframe index, where N' is the length of the bitmap *subframeBitmap-r12* indicated by the PSCCH resource configuration.
- A subframe l_j $(0 \le j < N')$ belongs to the subframe pool if $a_j = 1$, where $(a_0, a_1, a_2, ..., a_{N'-1})$ is the bitmap *subframeBitmap-r12* indicated by the PSCCH resource configuration. The subframes in the subframe pool are denoted by $(l_0^{PSCCH}, l_1^{PSCCH}, ..., l_{L_{PSCCH}-1}^{PSCCH})$ arranged in increasing order of subframe index and L_{PSCCH} is the number of subframes in the subframe pool. A PRB with index q $(0 \le q < N_{RB}^{SL})$ belongs to the resource block pool if $S1 \le q < S1 + M$ or if $S2 - M < q \le S2$, where *S1*, *S2*, and *M* denote the *prb-Start-r12*, *prb-End-r12 and prb-Num-r12* indicated by the PSCCH resource configuration respectively.
- The resource blocks in the resource block pool are denoted by $(m_0^{PSCCH}, m_1^{PSCCH}, ..., m_{M_{RB}^{PSCCH\_RP}-1}^{PSCCH})$ arranged in increasing order of resource block indices and $M_{RB}^{PSCCH\_RP}$ is the number of resource blocks in the resource block pool.

14.3 Physical Sidelink Discovery Channel related procedures

14.3.1 UE procedure for transmitting the PSDCH

If a UE is configured by higher layers to transmit PSDCH according to a PSDCH resource configuration, in a PSDCH period i,

- the number of transmissions for a transport block on PSDCH is $N_{\text{SLD}}^{\text{TX}} = n+1$ where n is given by the higher layer parameter *numRetx-r12*, and each transmission corresponds to one subframe belonging to a set of subframes, and in each subframe, the PSDCH is transmitted on two physical resource blocks per slot.
  - for sidelink discovery type 1,
    - the allowed values for PSDCH resource selection are given by 0,1… $(N_t \cdot N_f - 1)$, where $N_t = \lfloor L_{PSDCH} / N_{\text{SLD}}^{\text{TX}} \rfloor$ and $N_f = \lfloor M_{RB}^{PSDCH\_RP} / 2 \rfloor$, and
    - the *j*-th transmission ($1 \le j \le N_{\text{SLD}}^{\text{TX}}$) for the transport block occurs in contiguous resource blocks $m_{2\cdot a_j^{(i)}}^{PSDCH}$ and $m_{2\cdot a_j^{(i)}+1}^{PSDCH}$ of subframe $l_{N_{\text{SLD}}^{\text{TX}} \cdot b_1^{(i)} + j-1}^{PSDCH}$ of the PSDCH period, where
      - $a_j^{(i)} = \left((j-1)\cdot \lfloor N_f / N_{SLD}^{TX} \rfloor + \lfloor n_{PSDCH} / N_t \rfloor\right) \bmod N_f$ and $b_1^{(i)} = n_{PSDCH} \bmod N_t$ and using selected resource value n_{PSDCH} (described in [8]).
      - $\left(l_0^{PSDCH}, l_1^{PSDCH}, ..., l_{L_{PSDCH}-1}^{PSDCH}\right)$, $\left(m_0^{PSDCH}, m_1^{PSDCH}, ..., m_{M_{RB}^{PSDCH\_RP}-1}^{PSDCH}\right)$, L_{PSDCH} and $M_{RB}^{PSDCH\_RP}$ are described in subclause 14.3.3.
  - for sidelink discovery type 2B,
    - The *j*-th transmission ($1 \le j \le N_{\text{SLD}}^{\text{TX}}$) for the transport block occurs in contiguous resource blocks $m_{2\cdot a_j^{(i)}}^{PSDCH}$ and $m_{2\cdot a_j^{(i)}+1}^{PSDCH}$ of subframe $l_{N_{\text{SLD}}^{\text{TX}} \cdot b_1^{(i)} + j-1}^{PSDCH}$ of the PSDCH period, where
      - $a_1^{(i)} = \left((N_{PSDCH}^{(2)} + n') \bmod 10 + \left\lfloor \left(a_1^{(i-1)} + N_f \cdot b_1^{(i-1)}\right) / N_t \right\rfloor\right) \bmod N_f$
      - $b_1^{(i)} = \left(N_{PSDCH}^{(1)} + N_{PSDCH}^{(3)} \cdot a_1^{(i-1)} + N_f \cdot b_1^{(i-1)}\right) \bmod N_t$
      - $a_j^{(i)} = \left((j-1)\cdot \lfloor N_f / N_{SLD}^{TX} \rfloor + a_1^{(i)}\right) \bmod N_f$ for $1 < j \le N_{\text{SLD}}^{\text{TX}}$
      - $N_t = \lfloor L_{PSDCH} / N_{\text{SLD}}^{\text{TX}} \rfloor$ and $N_f = \lfloor M_{RB}^{PSDCH\_RP} / 2 \rfloor$, and $\left(l_0^{PSDCH}, l_1^{PSDCH}, ..., l_{L_{PSDCH}-1}^{PSDCH}\right)$, $\left(m_0^{PSDCH}, m_1^{PSDCH}, ..., m_{M_{RB}^{PSDCH\_RP}-1}^{PSDCH}\right)$, L_{PSDCH} and $M_{RB}^{PSDCH\_RP}$ are described in subclause 14.3.3.
      - $a_1^{(0)}$ and $b_1^{(0)}$ are given by higher layer parameters *discPRB-Index* and *discSF-Index*, respectively and that associated with the PSDCH resource configuration.
      - $N_{PSDCH}^{(1)}$, $N_{PSDCH}^{(2)}$ and $N_{PSDCH}^{(3)}$ are given by higher layer parameters *a-r12*, *b-r12*, and *c-r12*, repectively and that are associated with the PSDCH resource configuration.
      - n' is the number of PSDCH periods since $N_{PSDCH}^{(2)}$ was received.
- the transport block size is 232

For sidelink discovery, the UE transmit power P_{PSDCH} for PSDCH transmission is given by the following

$$P_{\text{PSDCH}} = \min\left\{P_{\text{CMAX},PSDCH},\quad 10\log_{10}(M_{\text{PSDCH}}) + P_{\text{O\_PSDCH},1} + \alpha_{PSDCH,1}\cdot PL\right\} \text{ [dBm]}$$

where $P_{\text{CMAX},PSDCH}$ is defined in [6], and M_{PSDCH} =2 and $PL = PL_c$ where PL_c is defined in subclause 5.1.1.1 where c

is the serving cell if the sidelink discovery transmission occurs on the uplink carrier frequency of a serving cell, or

is the cell indicated by higher layers on downlink carrier frequency indicated by *discCarrierRef-r13*[11] if sidelink discovery transmission does not occur on the uplink carrier frequency of a serving cell.

$P_{\text{O\_PSDCH},1}$ and $\alpha_{PSDCH,1}$ are provided by higher layer parameters *p0-r12* and *alpha-r12*, respectively and are associated with the corresponding PSDCH resource configuration.

A UE shall drop any PSDCH transmissions that are associated with sidelink discovery type 1 in a sidelink subframe if the UE has a PSDCH transmission associated with sidelink discovery type 2B in that subframe.

14.3.2 UE procedure for receiving the PSDCH

For sidelink discovery type 1, for each PSDCH resource configuration associated with reception of PSDCH, a UE configured by higher layers to detect a transport block on PSDCH can decode the PSDCH according to the PSDCH resource configuration.

For sidelink discovery type 2B, for each PSDCH resource configuration associated with reception of PSDCH, a UE configured by higher layers to detect a transport block on PSDCH can decode the PSDCH according to the PSDCH resource configuration.

14.3.3 UE procedure for determining resource block pool and subframe pool for sidelink discovery

A PSDCH resource configuration for transmission/reception is associated with a set of periodically occurring time-domain periods (known as PSDCH periods). The *i*-th PSDCH period begins at subframe with subframe index $j_{begin} = O_3 + i \cdot P$ and ends in subframe with subframe index $j_{end} = O_3 + (i+1)\cdot P - 1$, where

- $0 \le j_{begin} < 10240$,
- the subframe index is relative to subframe#0 of a radio frame corresponding to SFN 0 of the serving cell or DFN 0 (described in [11]),
- O_3 is the *offsetIndicator-r12* indicated by the PSDCH resource configuration
- P is the *discPeriod-r12* indicated by the PSDCH resource configuration.

For a PSDCH period, the UE determines a discovery pool consisting of a subframe pool and a resource block pool for PSDCH as follows.

- For TDD, if the parameter *tdd-Config-r12* is indicated by the PSDCH resource configuration, the TDD UL/DL configuration used for determining the subframe pool is given by the parameter *tdd-Config-r12*, otherwise, the TDD UL/DL configuration used for determining the subframe pool is given by the UL/DL configuration (i.e. parameter *subframeAssignment*) for the serving cell.
- A bitmap $b_0, b_1, b_2, ..., b_{N'-1}$ is obtained using $b_j = a_{j \bmod N_B}$, for $0 \le j < N'$, where

  $a_0, a_1, a_2, ..., a_{N_B-1}$ and N_B are the bitmap and the length of the bitmap indicated by *subframeBitmap-r12*, respectively, and $N' = N_B \cdot N_R$, where N_R is the *numRepetition-r12* indicated by the PSDCH resource configuration.
- The first N' uplink subframes are denoted by $(l_0, l_1, ..., l_{N'-1})$ arranged in increasing order of subframe index.

- A subframe l_j $(0 \le j < N')$ belongs to the subframe pool if $b_j = 1$. The subframes in the subframe pool are denoted by $\left(l_0^{PSDCH}, l_1^{PSDCH}, ..., l_{L_{PSDCH}-1}^{PSDCH}\right)$ arranged in increasing order of subframe index and L_{PSDCH} denotes the number of subframes in the subframe pool.

- A PRB with index q $(0 \le q < N_{RB}^{SL})$ belongs to the resource block pool if $S1 \le q < S1 + M$ or if $S2 - M < q \le S2$, where *S1*, *S2*, and *M* denote the *prb-Start-r12*, *prb-End-r12* and *prb-Num-r12* indicated by the PSDCH resource configuration respectively.

- The resource blocks in the resource block pool are denoted by $\left(m_0^{PSDCH}, m_1^{PSDCH}, ..., m_{M_{RB}^{PSDCH\_RP}-1}^{PSDCH}\right)$ arranged in increasing order of resource block indices and $M_{RB}^{PSDCH\_RP}$ is the number of resource blocks in the resource block pool.

14.4 Physical Sidelink Synchronization related procedures

The synchronization resource configuration(s) for the UE are given by the higher layer parameter *SL-SyncConfig-r12*.

A UE shall transmit sidelink synchronisation signals according to subclause 5.10.7 in [11].

A UE may assume that sidelink synchronization signals are signals transmitted by an eNB as described in subclause 6.11 of [3] or are signals transmitted by a UE as described in [11].

A UE is not expected to blindly detect the cyclic prefix length of sidelink synchronization signals transmitted by another UE.

For a sidelink synchronization resource configuration associated with PSDCH reception, if cell *c* is indicated by the parameter *physCellId-r12* and if the parameter *discSyncWindow-r12* is configured with value *w1* for cell *c*, the UE may assume that sidelink synchronization signals are transmitted in cell *c* and that they are received within a reference synchronization window of size +/-*w1* ms with respect to the sidelink synchronization resource of cell *c* indicated by higher layers. The sidelink synchronization identity associated with the sidelink synchronization resource is indicated by higher layers.

For PSDCH reception, if cell *c* is indicated by the parameter *physCellId-r12* and if the parameter *discSyncWindow-r12* is configured with value *w2* for cell *c*, the UE may assume that PSDCH of UE in cell *c* is received within a reference synchronization window of size +/-*w2* ms with respect to the discovery resource of cell *c* indicated by higher layers.

The UE transmit power of primary sidelink synchronization signal P_{PSSS} and the UE transmit power of secondary synchronization signal P_{SSSS} are given by

- If the UE is configured with sidelink transmission mode 1, and if the UE transmits sidelink synchronization signals in PSCCH period *i*, and if the TPC command field in the configured sidelink grant (described in [8]) for the PSCCH period *i* is set to 0
  - $P_{\text{PSSS}} = P_{\text{CMAX},PSBCH}$
  - $P_{\text{SSSS}} = P_{\text{CMAX},SSSS}$
- otherwise
  - $P_{\text{PSSS}} = \min\left\{P_{\text{CMAX},PSBCH},\quad 10\log_{10}(M_{\text{PSSS}}) + P_{\text{O\_PSSS}} + \alpha_{PSSS} \cdot PL\right\}$ [dBm] ,
  - $P_{\text{SSSS}} = \min\left\{P_{\text{CMAX},SSSS},\quad 10\log_{10}(M_{\text{PSSS}}) + P_{\text{O\_PSSS}} + \alpha_{PSSS} \cdot PL\right\}$ [dBm] ,

where $P_{\text{CMAX},PSBCH}$ and $P_{\text{CMAX},SSSS}$ are defined in [6]. $M_{\text{PSSS}} = 6$ and $PL = PL_c$ where PL_c is defined in subclause 5.1.1.1. $P_{\text{O\_PSSS}}$ and α_{PSSS} are provided by higher layer parameters associated with the corresponding sidelink synchronization signal resource configuration.

If sidelink synchronization signals are transmitted for PSDCH, and if the PSDCH transmission does not occur on any serving cell configured for the UE, c is the cell indicated by higher layers on downlink carrier frequency indicated by *discCarrierRef* [11]. Otherwise, c is the serving cell on which the sidelink synchronization signals are transmitted. If sidelink synchronization signals are transmitted for PSDCH, then PSDCH and sidelink synchronization signal transmission occur on the same carrier frequency.

15 Channel access procedures for LAA

15.1 Downlink channel access procedures

An eNB operating LAA Scell(s) shall perform the channel access procedures described in this sub clause for accessing the channel(s) on which the LAA Scell(s) transmission(s) are performed.

15.1.1 Channel access procedure for transmission(s) including PDSCH

The eNB may transmit a transmission including PDSCH on a carrier on which LAA Scell(s) transmission(s) are performed , after first sensing the channel to be idle during the slot durations of a defer duration T_d ; and after the counter N is zero in step 4. The counter N is adjusted by sensing the channel for additional slot duration(s) according to the steps below:

1) set $N = N_{init}$, where N_{init} is a random number uniformly distributed between 0 and CW_p , and go to step 4;

2) if $N > 0$ and the eNB chooses to decrement the counter, set $N = N - 1$;

3) sense the channel for an additional slot duration, and if the additional slot duration is idle, go to step 4; else, go to step 5;

4) if $N = 0$, stop; else, go to step 2.

5) sense the channel until either a busy slot is detected within an additional defer duration T_d or all the slots of the additional defer duration T_d are detected to be idle;

6) if the channel is sensed to be idle during all the slot durations of the additional defer duration T_d , go to step 4; else, go to step 5;

If an eNB has not transmitted a transmission including PDSCH on a carrier on which LAA Scell(s) transmission(s) are performed after step 4 in the procedure above, the eNB may transmit a transmission including PDSCH on the carrier, if the channel is sensed to be idle at least in a slot duration T_{sl} when the eNB is ready to transmit PDSCH and if the channel has been sensed to be idle during all the slot durations of a defer duration T_d immediately before this transmission. If the channel has not been sensed to be idle in a slot duration T_{sl} when the eNB first senses the channel after it is ready to transmit or if the channel has been sensed to be not idle during any of the slot durations of a defer duration T_d immediately before this intended transmission, the eNB proceeds to step 1 after sensing the channel to be idle during the slot durations of a defer duration T_d ..

The defer duration T_d consists of duration $T_f = 16us$ immediately followed by m_p consecutive slot durations where each slot duration is $T_{sl} = 9us$, and T_f includes an idle slot duration T_{sl} at start of T_f ;

A slot duration T_{sl} is considered to be idle if the eNB senses the channel during the slot duration, and the power detected by the eNB for at least $4us$ within the slot duration is less than energy detection threshold X_{Thresh} . Otherwise, the slot duration T_{sl} is considered to be busy.

$CW_{\min,p} \le CW_p \le CW_{\max,p}$ is the contention window. CW_p adjustment is described in sub clause 15.1.3.

$CW_{\min,p}$ and $CW_{\max,p}$ are chosen before step 1 of the procedure above.

m_p, $CW_{\min,p}$, and $CW_{\max,p}$ are based on channel access priority class associated with the eNB transmission, as shown in Table 15.1.1-1.

X_{Thresh} adjustment is described in sub clause 15.1.4

If the eNB transmits discovery signal transmission(s) not including PDSCH when $N > 0$ in the procedure above, the eNB shall not decrement N during the slot duration(s) overlapping with discovery signal transmission.

The eNB shall not continuously transmit on a carrier on which the LAA Scell(s) transmission(s) are performed, for a period exceeding $T_{m\cot,p}$ as given in Table 15.1.1-1.

For $p = 3$ and $p = 4$, if the absence of any other technology sharing the carrier can be guaranteed on a long term basis (e.g. by level of regulation), $T_{m\cot,p} = 10ms$, otherwise, $T_{m\cot,p} = 8ms$.

Table 15.1.1-1: Channel Access Priority Class

Channel Access Priority Class (p)	m_p	$CW_{\min,p}$	$CW_{\max,p}$	$T_{m\cot,p}$	allowed CW_p sizes
1	1	3	7	2 ms	{3,7}
2	1	7	15	3 ms	{7,15}
3	3	15	63	8 or 10 ms	{15,31,63}
4	7	15	1023	8 or 10 ms	{15,31,63,127,255,511,1023}

For LAA operation in Japan, if the eNB has transmitted a transmission after $N = 0$ in step 4 of the procedure above, the eNB may transmit the next continuous transmission, for duration of maximum T_j =4 msec, immediately after sensing the channel to be idle for at least a sensing interval of T_{js} =34usec and if the total sensing and transmission time is not more than $1000 \cdot T_{mcot} + \lceil T_{mcot} / T_j - 1 \rceil \cdot T_{js}$ μsec. T_{js} consists of duration $T_f = 16us$ immediately followed by two slot durations $T_{sl} = 9us$ each and T_f includes an idle slot duration T_{sl} at start of T_f. The channel is considered to be idle for T_{js} if it is sensed to be idle during the during the slot durations of T_{js}.

15.1.2 Channel access procedure for transmissions including discovery signal transmission(s) and not including PDSCH

An eNB may transmit a transmission including discovery signal but not including PDSCH on a carrier on which LAA Scell(s) transmission(s) are performed immediately after sensing the channel to be idle for at least a sensing interval $T_{\text{drs}} = 25us$ and if the duration of the transmission is less than 1 ms. T_{drs} consists of a duration $T_f = 16us$ immediately followed by one slot duration $T_{sl} = 9us$ and T_f includes an idle slot duration T_{sl} at start of T_f. The channel is considered to be idle for T_{drs} if it is sensed to be idle during the slot durations of T_{drs}.

15.1.3 Contention window adjustment procedure

If the eNB transmits transmissions that are associated with channel access priority class p on a carrier, the eNB maintains the contention window value CW_p and adjusts CW_p before step 1 of the procedure described in sub clause 15.1.1 for those transmissions using the following steps:

1) for every priority class $p \in \{1,2,3,4\}$ set $CW_p = CW_{\min,p}$

2) if at least $Z = 80\%$ of HARQ-ACK values corresponding to PDSCH transmission(s) in reference subframe k are determined as NACK, increase CW_p for every priority class $p \in \{1,2,3,4\}$ to the next higher allowed value and remain in step 2; otherwise, go to step 1.

Reference subframe k is the starting subframe of the most recent transmission on the carrier made by the eNB, for which at least some HARQ-ACK feedback is expected to be available.

The eNB shall adjust the value of CW_p for every priority class $p \in \{1,2,3,4\}$ based on a given reference subframe k only once.

If $CW_p = CW_{\max,p}$, the next higher allowed value for adjusting CW_p is $CW_{\max,p}$.

For determining Z,

- if the eNB transmission(s) for which HARQ-ACK feedback is available start in the second slot of subframe k, HARQ-ACK values corresponding to PDSCH transmission(s) in subframe $k+1$ are also used in addition to the HARQ-ACK values corresponding to PDSCH transmission(s) in subframe k.

- if the HARQ-ACK values correspond to PDSCH transmission(s) on an LAA SCell that are assigned by (E)PDCCH transmitted on the same LAA SCell,

  - if no HARQ-ACK feedback is detected for a PDSCH transmission by the eNB, or if the eNB detects 'DTX', 'NACK/DTX' or 'any' state, it is counted as NACK.

- if the HARQ-ACK values correspond to PDSCH transmission(s) on an LAA SCell that are assigned by (E)PDCCH transmitted on another serving cell,

  - if the HARQ-ACK feedback for a PDSCH transmission is detected by the eNB, 'NACK/DTX' or 'any' state is counted as NACK, and 'DTX' state is ignored.

  - if no HARQ-ACK feedback is detected for a PDSCH transmission by the eNB

    - if PUCCH format 1b with channel selection is expected to be used by the UE, 'NACK/DTX' state corresponding to 'no transmission' as described in subclauses 10.1.2.2.1, 10.1.3.1 and 10.1.3.2.1 is counted as NACK, and 'DTX' state corresponding to 'no transmission' is ignored.- Otherwise, the HARQ-ACK for the PDSCH transmission is ignored.

- if a PDSCH transmission has two codewords, the HARQ-ACK value of each codeword is considered separately

- bundled HARQ-ACK across M subframes is considered as M HARQ-ACK responses.

If the $CW_p = CW_{\max,p}$ is consecutively used K times for generation of N_{init}, CW_p is reset to $CW_{\min,p}$ only for that priority class p for which $CW_p = CW_{\max,p}$ is consecutively used K times for generation of N_{init}. K is selected by eNB from the set of values {1, 2, …,8} for each priority class $p \in \{1,2,3,4\}$.

15.1.4 Energy detection threshold adaptation procedure

An eNB accessing a carrier on which LAA Scell(s) transmission(s) are performed, shall set the energy detection threshold (X_{Thresh}) to be less than or equal to the maximum energy detection threshold $X_{\text{Thresh\_max}}$.

$X_{\text{Thresh\_max}}$ is determined as follows:

- If the absence of any other technology sharing the carrier can be guaranteed on a long term basis (e.g. by level of regulation) then:

- $$X_{\text{Thresh\_max}} = \min \begin{Bmatrix} T_{\max} + 10\,dB, \\ X_r \end{Bmatrix}$$

  - X_r is Maximum energy detection threshold defined by regulatory requirements in dBm when such requirements are defined, otherwise $X_r = T_{\max} + 10\,dB$

- Otherwise,

- $$X_{\text{Thres\_max}} = \max \begin{Bmatrix} -72 + 10 \cdot \log 10(BWMHz / 20MHz)\ dBm, \\ \min \begin{Bmatrix} T_{\max}, \\ T_{\max} - T_A + \left(P_H + 10 \cdot \log 10(BWMHz / 20MHz) - P_{TX}\right) \end{Bmatrix} \end{Bmatrix}$$

- Where:

  - T_A = 10dB for transmission(s) including PDSCH;

  - T_A = 5dB for transmissions including discovery signal transmission(s) and not including PDSCH;

  - P_H = 23 dBm;

  - P_{TX} is the set maximum eNB output power in dBm for the carrier;

    - eNB uses the set maximum transmission power over a single carrier irrespective of whether single carrier or multi-carrier transmission is employed

  - $T_{\max}(\text{dBm}) = 10 \cdot \log 10\left(3.16228 \cdot 10^{-8}\,(mW / MHz) \cdot BWMHz\ (MHz)\right)$;

  - BWMHz is the single carrier bandwidth in MHz.

15.1.5 Channel access procedure for transmission(s) on multiple carriers

An eNB can access multiple carriers on which LAA Scell(s) transmission(s) are performed, according to one of the Type A or Type B procedures described in this subclause.

15.1.5.1 Type A multi-carrier access procedures

The eNB shall perform channel access on each carrier $c_i \in C$, according to the procedures described in subclause 15.1.1, where C is a set of carriers on which the eNB intends to transmit, and $i = 0,1,\ldots q-1$, and q is the number of carriers on which the eNB intends to transmit.

The counter N described in subclause 15.1.1 is determined for each carrier c_i and is denoted as N_{c_i}. N_{c_i} is maintained according to subclause 15.1.5.1.1or 15.1.5.1.2.

15.1.5.1.1 Type A1

Counter N as described in subclause 15.1.1 is independently determined for each carrier c_i and is denoted as N_{c_i}.

If the absence of any other technology sharing the carrier cannot be guaranteed on a long term basis (e.g. by level of regulation), when the eNB ceases transmission on any one carrier $c_j \in C$, for each carrier $c_i \neq c_j$, the eNB can resume decrementing N_{c_i} when idle slots are detected either after waiting for a duration of $4 \cdot T_{sl}$, or after reinitialising N_{c_i}.

15.1.5.1.2 Type A2

Counter N is determined as described in subclause 15.1.1 for carrier $c_j \in C$, and is denoted as N_{c_j}, where c_j is the carrier that has the largest CW_p value. For each carrier c_i, $N_{c_i} = N_{c_j}$.

When the eNB ceases transmission on any one carrier for which N_{c_i} is determined, the eNB shall reinitialise N_{c_i} for all carriers.

15.1.5.2 Type B multi-carrier access procedure

A carrier $c_j \in C$ is selected by the eNB as follows

- the eNB selects c_j by uniformly randomly choosing c_j from C before each transmission on multiple carriers $c_i \in C$, or

- the eNB selects c_j no more frequently than once every 1 second,

where C is a set of carriers on which the eNB intends to transmit, $i = 0,1,\ldots q-1$, and q is the number of carriers on which the eNB intends to transmit.

To transmit on carrier c_j

- the eNB shall perform channel access on carrier c_j according to the procedures described in subclause 15.1.1 with the modifications described in 15.1.5.2.1 or 15.1.5.2.2.

To transmit on carrier $c_i \neq c_j$, $c_i \in C$

- for each carrier c_i, the eNB shall sense the carrier c_i for at least a sensing interval $T_{\mathrm{mc}} = 25us$ immediately before the transmitting on carrier c_j, and the eNB may transmit on carrier c_i immediately after sensing the carrier c_i to be idle for at least the sensing interval T_{mc}. The carrier c_i is considered to be idle for T_{mc} if the channel is sensed to be idle during all the time durations in which such idle sensing is performed on the carrier c_j in given interval T_{mc}.

The eNB shall not continuously transmit on a carrier $c_i \neq c_j$, $c_i \in C$, for a period exceeding $T_{m\cot,p}$ as given in Table 15.1.1-1, where the value of $T_{m\cot,p}$ is determined using the channel access parameters used for carrier c_j.

15.1.5.2.1 Type B1

A single CW_p value is maintained for the set of carriers C.

For determining CW_p for channel access on carrier c_j, step 2 of the procedure described in sub clause 15.1.3 is modified as follows

- if at least $Z = 80\%$ of HARQ-ACK values corresponding to PDSCH transmission(s) in reference subframe k of all carriers $c_i \in C$ are determined as NACK, increase CW_p for every priority class $p \in \{1,2,3,4\}$ to the next higher allowed value; otherwise, go to step 1.

15.1.5.2.2 Type B2

A CW_p value is maintained independently for each carrier $c_i \in C$ using the procedure described in subclause 15.1.3.

For determining N_{init} for carrier c_j, CW_p value of carrier $c_{j1} \in C$ is used, where c_{j1} is the carrier with largest CW_p among all carriers in set C.

16 UE Procedures related to narrowband IoT

16.1 Synchronization procedures

16.1.1 Cell search

Cell search is the procedure by which a UE acquires time and frequency synchronization with a cell and detects the narrowband physical layer Cell ID.

If the higher layer parameter *operationModeInfo* indicates '*inband-SamePCI*' or *samePCI-Indicator* indicates '*samePCI*'' for a cell, the UE may assume that the physical layer cell ID is same as the narrowband physical layer cell ID for the cell.

The following signals are transmitted in the downlink to facilitate cell search for Narrowband IoT: the narrowband primary and narrowband secondary synchronization signals.

A UE may assume the antenna ports 2000 – 2001 and the antenna port for the narrowband primary/secondary synchronization signals of a serving cell are quasi co-located (as defined in [3]) with respect to Doppler shift and average delay.

16.1.2 Timing synchronization

Upon reception of a timing advance command, the UE shall adjust uplink transmission timing for NPUSCH based on the received timing advance command.

The timing advance command indicates the change of the uplink timing relative to the current uplink timing as multiples of $16\,T_s$. The start timing of the random access preamble is specified in [3].

In case of random access response, an 11-bit timing advance command [8], T_A, indicates N_{TA} values by index values of T_A = 0, 1, 2, ..., 1282, where an amount of the time alignment is given by $N_{TA} = T_A \times 16$. N_{TA} is defined in [3].

In other cases, a 6-bit timing advance command [8], T_A, indicates adjustment of the current N_{TA} value, $N_{TA,old}$, to the new N_{TA} value, $N_{TA,new}$, by index values of T_A = 0, 1, 2,..., 63, where $N_{TA,new} = N_{TA,old} + (T_A - 31)\times 16$. Here, adjustment of N_{TA} value by a positive or a negative amount indicates advancing or delaying the uplink transmission timing by a given amount respectively.

For a timing advance command reception ending in DL subframe *n*, the corresponding adjustment of the uplink transmission timing shall apply from the first available NB-IoT uplink slot following the end of *n+12* DL subframe and the first available NB-IoT uplink slot is the first slot of a NPUSCH transmission. When the UE's uplink NPUSCH transmissions in NB-IoT uplink slot *n* and NB-IoT uplink slot *n*+1 are overlapped due to the timing adjustment, the UE shall complete transmission of NB-IoT uplink slot *n* and not transmit the overlapped part of NB-IoT uplink slot *n*+1.

If the received downlink timing changes and is not compensated or is only partly compensated by the uplink timing adjustment without timing advance command as specified in [10], the UE changes N_{TA} accordingly.

16.2 Power control

16.2.1 Uplink power control

Uplink power control controls the transmit power of the different uplink physical channels.

16.2.1.1 Narrowband physical uplink shared channel

16.2.1.1.1 UE behaviour

The setting of the UE Transmit power for a Narrowband Physical Uplink Shared Channel (NPUSCH) transmission is defined as follows.

The UE transmit power $P_{\text{NPUSCH},c}(i)$ for NPUSCH transmission in NB-IoT UL slot *i* for the serving cell c is given by

If the number of repetitions of the allocated NPUSCH RUs is greater than 2

$$P_{\text{NPUSCH,c}}(i) = P_{\text{CMAX},c}(i) \text{ [dBm]}$$

otherwise

$$P_{\text{NPUSCH,c}}(i) = \min\begin{Bmatrix} P_{\text{CMAX},c}(i), \\ 10\log_{10}(M_{\text{NPUSCH,c}}(i)) + P_{\text{O\_NPUSCH,c}}(j) + \alpha_c(j)\cdot PL_c \end{Bmatrix} \text{ [dBm]}$$

where,

- $P_{\text{CMAX,c}}(i)$ is the configured UE transmit power defined in [6] in NB-IoT UL slot *i* for serving cell c.
- $M_{\text{NPUSCH,c}}(i)$ is {1/4} for 3.75 kHz subcarrier spacing and {1, 3, 6, 12}for 15kHz subcarrier spacing
- $P_{\text{O\_NPUSCH,c}}(j)$ is a parameter composed of the sum of a component $P_{\text{O\_NOMINAL\_NPUSCH,c}}(j)$ provided from higher layers and a component $P_{\text{O\_UE\_NPUSCH,c}}(j)$ provided by higher layers for *j=1* and for serving cell c where $j \in \{1,2\}$. For NPUSCH (re)transmissions corresponding to a dynamic scheduled grant then *j=1* and for NPUSCH (re)transmissions corresponding to the random access response grant then *j=2*. $P_{\text{O\_UE\_NPUSCH,c}}(2) = 0$ and $P_{\text{O\_NORMINAL\_NPUSCH,c}}(2) = P_{\text{O\_PRE}} + \Delta_{\text{PREAMBLE\_Msg3}}$, where the parameter *preambleInitialReceivedTargetPower* [8] ($P_{\text{O\_PRE}}$) and $\Delta_{\text{PREAMBLE\_Msg3}}$ are signalled from higher layers for serving cell c.
- For *j=1*, for NPUSCH format 2, $\alpha_c(j)$ =1; for NPUSCH format 1, $\alpha_c(j)$ is provided by higher layers for serving cell c. For *j*=2, $\alpha_c(j) = 1$.
- PL_c is the downlink path loss estimate calculated in the UE for serving cell c in dB and PL_c = *nrs-Power* + *nrs-PowerOffsetNonAnchor* – higher layer filtered NRSRP, where *nrs-Power* is provided by higher layers and *nrs-powerOffsetNonAnchor* is set to zero if it is not provided by higher layers and NRSRP is defined in [5] for serving cell c and the higher layer filter configuration is defined in [11] for serving cell c.

16.2.1.1.2 Power headroom

If the UE transmits NPUSCH in NB-IoT UL slot i for serving cell c, power headroom is computed using

$$PH_{\text{c}}(i) = P_{\text{CMAX},c}(i) - \left\{ P_{\text{O\_NPUSCH,c}}(1) + \alpha_c(1)\cdot PL_c \right\} \text{ [dB]}$$

where, $P_{\text{CMAX},c}(i)$, $P_{\text{O\_NPUSCH,c}}(1)$, $\alpha_c(1)$, and PL_c, are defined in subclause 16.2.1.1.1.

The power headroom shall be rounded down to the closest value in the set [PH1, PH2, PH3, PH4] dB as defined in [10] and is delivered by the physical layer to higher layers.

16.2.2 Downlink power allocation

The eNodeB determines the downlink transmit energy per resource element.

For an NB-IoT cell, the UE may assume NRS EPRE is constant across the downlink NB-IoT system bandwidth and constant across all subframes that contain NRS, until different NRS power information is received.

The downlink NRS EPRE can be derived from the downlink narrowband reference-signal transmit power given by *nrs-Power* + *nrs-PowerOffsetNonAnchor,* where the parameter *nrs-Power* is provided by higher layers and *nrs-powerOffsetNonAnchor* is zero if it is not provided by higher layers. The downlink narrowband reference-signal transmit power is defined as the linear average over the power contributions (in [W]) of all resource elements that carry narrowband reference signals within the operating NB-IoT system bandwidth.

A UE may assume the ratio of NPDSCH EPRE to NRS EPRE among NPDSCH REs (not applicable to NPDSCH REs with zero EPRE) is 0 dB for an NB-IoT cell with one NRS antenna port and -3 dB for an NB-IoT cell with two NRS antenna ports.

A UE may assume the ratio of NPBCH EPRE to NRS EPRE among NPBCH REs (not applicable to NPBCH REs with zero EPRE) is 0 dB for an NB-IoT cell with one NRS antenna port and -3 dB for an NB-IoT cell with two NRS antenna ports.

A UE may assume the ratio of NPDCCH EPRE to NRS EPRE among NPDCCH REs (not applicable to NPDCCH REs with zero EPRE) is 0 dB for an NB-IoT cell with one NRS antenna port and -3 dB for an NB-IoT cell with two NRS antenna ports.

If higher layer parameter *operationModeInfo* indicates '00' for a cell, the ratio of NRS EPRE to CRS EPRE is given by the parameter *nrs-CRS-PowerOffset* if the parameter *nrs-CRS-PowerOffset* is provided by higher layers, and the ratio of NRS EPRE to CRS EPRE may be assumed to be 0 dB if the parameter *nrs-CRS-PowerOffset* is not provided by higher layers.

16.3 Random access procedure

Prior to initiation of the non-synchronized physical random access procedure, Layer 1 shall receive the following information from the higher layers:

- Narrowband Random access channel parameters (NPRACH configuration)

16.3.1 Physical non-synchronized random access procedure

From the physical layer perspective, the L1 random access procedure encompasses the transmission of narrowband random access preamble and narrowband random access response. The remaining messages are scheduled for transmission by the higher layer on the shared data channel and are not considered part of the L1 random access procedure. A random access channel occupies one subcarrier per set of consecutive symbols reserved for narrowband random access preamble transmissions.

The following steps are required for the L1 random access procedure:

- Layer 1 procedure is triggered upon request of a narrowband preamble transmission by higher layers.
- A target narrowband preamble received power (NARROWBAND_PREAMBLE_RECEIVED_TARGET_POWER), a corresponding RA-RNTI and a NPRACH resource are indicated by higher layers as part of the request.
- For the lowest configured repetition level, a narrowband preamble transmission power P_{NPRACH} is determined as P_{NPRACH} = min{ $P_{\text{CMAX,c}}(i)$, NARROWBAND_PREAMBLE_RECEIVED_TARGET_POWER + PL_c }_[dBm], where $P_{\text{CMAX,c}}(i)$ is the configured UE transmit power for narrowband IoT transmission defined in [6] for subframe *i* of serving cell c and PL_c is the downlink path loss estimate calculated in the UE for serving cell c. For a repetition level other than the lowest configured repetition level, P_{NPRACH} is set to $P_{\text{CMAX,c}}(i)$.
- The narrowband preamble is transmitted with transmission power P_{NPRACH} commencing on the indicated NPRACH resource. The narrowband preamble is transmitted for the number of NPRACH repetitions for the associated NPRACH repetition level as indicated by higher layers.
- Detection of a NPDCCH with DCI scrambled by RA-RNTI is attempted during a window controlled by higher layers (see [8], subclause 5.1.4). If detected, the corresponding DL-SCH transport block is passed to higher

layers. The higher layers parse the transport block and indicate the Nr-bit uplink grant to the physical layer, which is processed according to subclause 16.3.3

16.3.2 Timing

For the L1 random access procedure, UE's uplink transmission timing after a random access preamble transmission is as follows.

a) If a NPDCCH with associated RA-RNTI is detected and the corresponding DL-SCH transport block ending in subframe *n* contains a response to the transmitted preamble sequence, the UE shall, according to the information in the response, transmit an UL-SCH transport block according to section 16.3.3.

b) If a random access response is received and the corresponding DL-SCH transport block ending in subframe *n* does not contain a response to the transmitted preamble sequence, the UE shall, if requested by higher layers, be ready to transmit a new preamble sequence no later than the NB-IoT UL slot starting 12 milliseconds after the end of subframe *n*.

c) If no random access response is received in subframe *n*, where subframe *n* is the last subframe of the random access response window, the UE shall, if requested by higher layers, be ready to transmit a new preamble sequence no later than the NB-IoT UL slot starting 12 milliseconds after the end of subframe *n*.

In case a random access procedure is initiated by a "PDCCH order" ending in subframe *n*, the UE shall, if requested by higher layers, start transmission of random access preamble at the end of the first subframe $n+k_2$, $k_2 \geq 8$, where a NPRACH resource is available. The "PDCCH order" in DCI format N1 indicates to the UE,

- allocated subcarrier for NPRACH, $n_{\mathrm{sc}} = I_{sc}$ where I_{sc} is the subcarrier indication field in the corresponding DCI, $I_{sc} = 48,49,...,63$ is reserved.

- a repetition number (N_{Rep}) for NPRACH determined by the repetition number field (I_{Rep}) in the corresponding DCI according to Table 16.3.2-1 where R_1, R_2 (if any) and R_3 (if any) are given by the higher layer parameter *numRepetitionsPerPreambleAttempt* for each NPRACH resource, respectively. $R_1 < R_2 < R_3$.

Table 16.3.2-1: Number of repetitions (N_{Rep}) for NPRACH following a "PDCCH order"

I_{Rep}	N_{Rep}
0	R_1
1	R_2
2	R_3
3	Reserved

16.3.3 Narrowband random access response grant

The higher layers indicate the Nr-bit UL Grant to the physical layer, as defined in 3GPP TS 36.321 [8]. This is referred to as the Narrowband Random Access Response Grant in the physical layer.

Nr-bit =15, and the content of these 15 bits starting with the MSB and ending with the LSB are as follows:

- Uplink subcarrier spacing Δf is '0'=3.75 kHz or '1'=15 kHz – 1 bit

- Subcarrier indication field I_{sc} as determined in subclause 16.5.1.1 – 6 bits

- Scheduling delay field (I_{Delay}) as determined in subclause 16.5.1 with k_0 = 12 for $I_{\mathrm{Delay}} = 0$, where NB-IoT DL subframe *n* is the last subframe in which the NPDSCH associated with the Narrowband Random Access Response Grant is transmitted – 2 bits

- Msg3 repetition number N_{Rep} as determine in subclause 16.5.1.1 – 3 bits

- MCS index indicating TBS, modulation, and number of RUs for Msg3 according to Table 16.3.3-1 – 3 bits

The redundancy version for the first transmission of Msg3 is 0.

Table 16.3.3-1: MCS index for Msg3 NPUSCH

MCS Index I_{MCS}	Modulation $\Delta f = 3.75\,\mathrm{kHz}$ or $\Delta f = 15\,\mathrm{kHz}$ and $I_{sc} = 0,1,...,11$	Modulation $\Delta f = 15\,\mathrm{kHz}$ and $I_{sc} > 11$	Number of RUs N_{RU}	TBS
‘000’	pi/2 BPSK	QPSK	4	88 bits
‘001’	pi/4 QPSK	QPSK	3	88 bits
‘010’	pi/4 QPSK	QPSK	1	88 bits
‘011’	reserved	reserved	reserved	reserved
‘100’	reserved	reserved	reserved	reserved
‘101’	reserved	reserved	reserved	reserved
‘110’	reserved	reserved	reserved	reserved
‘111’	reserved	reserved	reserved	reserved

16.4 Narrowband physical downlink shared channel related procedures

A NB-IoT UE shall assume a subframe as a NB-IoT DL subframe if

- the UE determines that the subframe does not contain NPSS/NSSS/NPBCH/NB-SIB1 transmission, and
- the subframe is configured as NB-IoT DL subframe after the UE has obtained *SystemInformationBlockType1-NB*.

16.4.1 UE procedure for receiving the narrowband physical downlink shared channel

A UE shall upon detection on a given serving cell of a NPDCCH with DCI format N1, N2 ending in subframe *n* intended for the UE, decode, starting in *n+5* DL subframe, the corresponding NPDSCH transmission in *N* consecutive NB-IoT DL subframe(s) n_i with $i = 0, 1, \ldots, N-1$ according to the NPDCCH information, where

- subframe *n* is the last subframe in which the NPDCCH is transmitted and is determined from the starting subframe of NPDCCH transmission and the DCI subframe repetition number field in the corresponding DCI;
- subframe(s) n_i with $i=0,1,\ldots,N-1$ are *N* consecutive NB-IoT DL subframe(s) excluding subframes used for SI messages where, $n_0<n_1<\ldots,n_{N-1}$,,
- $N = N_{\mathrm{Rep}} N_{\mathrm{SF}}$, where the value of N_{Rep} is determined by the repetition number field in the corresponding DCI (see subclause 16.4.1.3), and the value of N_{SF} is determined by the resource assignment field in the corresponding DCI (see subclause 16.4.1.3), and
- k_0 is the number of NB-IoT DL subframe(s) starting in DL subframe *n*+5 until DL subframe n_0, where k_0 is determined by the scheduling delay field (I_{Delay}) for DCI format N1 according to Table 16.4.1-1, and k_0 = 0 for DCI format N2. The value of $R_{\max}$ is according to subclause 16.6 for the corresponding DCI format N1.

Table 16.4.1-1: k_0 for DCI format N1.

I_{Delay}	k_0	
	$R_{\max} < 128$	$R_{\max} \geq 128$
0	0	0
1	4	16
2	8	32
3	12	64
4	16	128
5	32	256
6	64	512
7	128	1024

A UE is not expected to receive transmissions in 3 DL subframes following the end of a NPUSCH transmission by the UE.

If a UE is configured by higher layers to decode NPDCCH with CRC scrambled by the P-RNTI, the UE shall decode the NPDCCH and the corresponding NPDSCH according to any of the combinations defined in Table 16.4.1-2. The scrambling initialization of NPDSCH corresponding to these NPDCCHs is by P-RNTI.

Table 16.4.1-2: NPDCCH and NPDSCH configured by P-RNTI

DCI format	Search Space	Transmission scheme of NPDSCH corresponding to NPDCCH
DCI format N2	Type-1 Common	If the number of NPBCH antenna ports is one, Single-antenna port, port 2000 is used (see subclause 16.4.1.1), otherwise Transmit diversity (see subclause 16.4.1.2).

If a UE is configured by higher layers to decode NPDCCH with CRC scrambled by the RA-RNTI, the UE shall decode the NPDCCH and the corresponding NPDSCH according to any of the combinations defined in Table 16.4.1-3. The scrambling initialization of NPDSCH corresponding to these NPDCCHs is by RA-RNTI.

Table 16.4.1-3: NPDCCH and NPDSCH configured by RA-RNTI

DCI format	Search Space	Transmission scheme of NPDSCH corresponding to NPDCCH
DCI format N1	Type-2 Common	If the number of NPBCH antenna ports is one, Single-antenna port, port 2000 is used (see subclause 16.4.1.1), otherwise Transmit diversity (see subclause 16.4.1.2).

If a UE is configured by higher layers to decode NPDCCH with CRC scrambled by the C-RNTI except during random access procedure, the UE shall decode the NPDCCH and the corresponding NPDSCH according to any of the combinations defined in Table 16.4.1-4. The scrambling initialization of NPDSCH corresponding to these NPDCCHs is by C-RNTI.

Table 16.4.1-4: NPDCCH and NPDSCH configured by C-RNTI

DCI format	Search Space	Transmission scheme of NPDSCH corresponding to NPDCCH
DCI format N1	UE specific by C-RNTI	If the number of NPBCH antenna ports is one, Single-antenna port, port 2000 is used (see subclause 16.4.1.1), otherwise Transmit diversity (see subclause 16.4.1.2).

If a UE is configured by higher layers to decode NPDCCH with CRC scrambled by the Temporary C-RNTI and is not configured to decode NPDCCH with CRC scrambled by the C-RNTI during random access procedure, the UE shall decode the NPDCCH and the corresponding NPDSCH according to the combination defined in Table 16.4.1-5. The scrambling initialization of NPDSCH corresponding to these NPDCCHs is by Temporary C-RNTI.

If a UE is also configured by higher layers to decode NPDCCH with CRC scrambled by the C-RNTI during random access procedure, the UE shall decode the NPDCCH and the corresponding NPDSCH according to the combination defined in Table 16.4.1-5. The scrambling initialization of NPDSCH corresponding to these NPDCCHs is by C-RNTI.

Table 16.4.1-5: NPDCCH and NPDSCH configured by Temporary C-RNTI and/or C-RNTI during random access procedure

DCI format	Search Space	Transmission scheme of NPDSCH corresponding to NPDCCH
DCI format N1	Type-2 Common	If the number of NPBCH antenna ports is one, Single-antenna port, port 2000 is used (see subclause 16.4.1.1), otherwise Transmit diversity (see subclause 16.4.1.2).

For NPDSCH carrying *SystemInformationBlockType1-NB* and SI-messages, the UE shall decode NPDSCH according to the transmission scheme defined in Table 16.4.1-6. The scrambling initialization of NPDSCH is by SI-RNTI.

Table 16.4.1-6: NPDSCH configured by SI-RNTI

Transmission scheme of NPDSCH
If the number of NPBCH antenna ports is one, Single-antenna port, port 0 is used (see subclause 16.4.1.1), otherwise Transmit diversity (see subclause 16.4.1.2).

The transmission schemes for NPDSCH are defined in the following subclauses.

16.4.1.1 Single-antenna port scheme

For the single-antenna port transmission schemes (port 2000) of the NPDSCH, the UE may assume that an eNB transmission on the NPDSCH would be performed according to subclause 6.3.4.1 of [3].

16.4.1.2 Transmit diversity scheme

For the transmit diversity transmission scheme of the NPDSCH, the UE may assume that an eNB transmission on the NPDSCH would be performed according to subclause 6.3.4.3 of [3]

16.4.1.3 Resource allocation

The resource allocation information in DCI format N1, N2 (paging) for NPDSCH indicates to a scheduled UE

- a number of subframes (N_{SF}) determined by the resource assignment field (I_{SF}) in the corresponding DCI according to Table 16.4.1.3-1.
- a repetition number (N_{Rep}) determined by the repetition number field (I_{Rep}) in the corresponding DCI according to Table 16.4.1.3-2.

Table 16.4.1.3-1: Number of subframes (N_{SF}) for NPDSCH.

I_{SF}	N_{SF}
0	1
1	2
2	3
3	4
4	5
5	6
6	8
7	10

Table 16.4.1.3-2: Number of repetitions (N_{Rep}) for NPDSCH.

I_{Rep}	N_{Rep}
0	1
1	2
2	4
3	8
4	16
5	32
6	64
7	128
8	192
9	256
10	384
11	512
12	768
13	1024
14	1536
15	2048

The number of repetitions for the NPDSCH carrying *SystemInformationBlockType1-NB* is determined based on the parameter *schedulingInfoSIB1* configured by higher-layers and according to Table 16.4.1.3-3.

Table 16.4.1.3-3: Number of repetitions for NPDSCH carrying *SystemInformationBlockType1-NB*.

Value of *schedulingInfoSIB1*	Number of NPDSCH repetitions
0	4
1	8
2	16
3	4
4	8
5	16
6	4
7	8
8	16
9	4
10	8
11	16
12-15	Reserved

The starting radio frame for the first transmission of the NPDSCH carrying *SystemInformationBlockType1-NB* is determined according to Table 16.4.1.3-4.

Table 16.4.1.3-4: Starting radio frame for the first transmission of the NPDSCH carrying *SystemInformationBlockType1-NB*.

Number of NPDSCH repetitions	$N_{\text{ID}}^{\text{Ncell}}$	Starting radio frame number for NB-SIB1 repetitions (n_f *mod 256*)
4	$N_{\text{ID}}^{\text{Ncell}}$ mod 4 = 0	0
	$N_{\text{ID}}^{\text{Ncell}}$ mod 4 = 1	16
	$N_{\text{ID}}^{\text{Ncell}}$ mod 4 = 2	32
	$N_{\text{ID}}^{\text{Ncell}}$ mod 4 = 3	48

8	$N_{\text{ID}}^{\text{Ncell}}$ mod 2 = 0	0
	$N_{\text{ID}}^{\text{Ncell}}$ mod 2 = 1	16
16	$N_{\text{ID}}^{\text{Ncell}}$ mod 2 = 0	0
	$N_{\text{ID}}^{\text{Ncell}}$ mod 2 = 1	1

16.4.1.4 NPDSCH starting position

The starting OFDM symbol for NPDSCH is given by index $l_{\text{DataStart}}$ in the first slot in a subframe k and is determined as follows

- if subframe k is a subframe used for receiving SIB1-NB
  - $l_{\text{DataStart}} = 3$ if the value of the higher layer parameter *operationModeInfo* is set to '00' or '01'
  - $l_{\text{DataStart}} = 0$ otherwise
- else
  - $l_{\text{DataStart}}$ is given by the higher layer parameter *eutraControlRegionSize* if the value of the higher layer parameter *eutraControlRegionSize* is present
  - $l_{\text{DataStart}} = 0$ otherwise

16.4.1.5 Modulation order and transport block size determination

The UE shall use modulation order, $Q_m = 2$.

To determine the transport block size in the NPDSCH, the UE shall first,

- if NPDSCH carries SystemInformationBlockType1-NB
  - set I_{TBS} to the value of the parameter schedulingInfoSIB1 configured by higher-layers
- otherwise
  - read the 4-bit "modulation and coding scheme" field (I_{MCS}) in the DCI and set $I_{\text{TBS}} = I_{\text{MCS}}$.

and second,

- if NPDSCH carries SystemInformationBlockType1-NB
  - use subclause 16.4.1.5.2 for determining its transport block size.
- otherwise,
  - read the 3-bit "resource assignment" field (I_{SF}) in the DCI and determine its TBS by the procedure in subclause 16.4.1.5.1.

The NDI as signalled on NPDCCH, and the TBS, as determined above, shall be delivered to higher layers.

16.4.1.5.1 Transport blocks not mapped for *SystemInformationBlockType1-NB*

The TBS is given by the (I_{TBS}, I_{SF}) entry of Table 16.4.1.5.1-1. For the value of the higher layer parameter *operationModeInfo* set to '00' or '01', $0 \le I_{\text{TBS}} \le 10$.

Table 16.4.1.5.1-1: Transport block size (TBS) table.

I_{TBS}	I_{SF}							
	0	**1**	**2**	**3**	**4**	**5**	**6**	**7**
0	16	32	56	88	120	152	208	256
1	24	56	88	144	176	208	256	344
2	32	72	144	176	208	256	328	424
3	40	104	176	208	256	328	440	568
4	56	120	208	256	328	408	552	680
5	72	144	224	328	424	504	680	
6	88	176	256	392	504	600		
7	104	224	328	472	584	680		
8	120	256	392	536	680			
9	136	296	456	616				
10	144	328	504	680				
11	176	376	584					
12	208	440	680					

16.4.1.5.2 Transport blocks mapped for *SystemInformationBlockType1-NB*

The TBS is given by the I_{TBS} entry of Table 16.4.1.5.2-1.

Table 16.4.1.5.2-1: Transport block size (TBS) table for NPDSCH carrying *SystemInformationBlockType1-NB*

I_{TBS}	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
TBS	208	208	208	328	328	328	440	440	440	680	680	680	Reserved			

16.4.2 UE procedure for reporting ACK/NACK

The UE shall upon detection of a NPDSCH transmission ending in NB-IoT subframe *n* intended for the UE and for which an ACK/NACK shall be provided, start, at the end of $n+k_0-1$ DL subframe transmission of the NPUSCH carrying ACK/NACK response using NPUSCH format 2 in *N* consecutive NB-IoT UL slots, where

- $N = N_{\text{Rep}}^{AN} N_{\text{slots}}^{UL}$, where the value of N_{Rep}^{AN} is given by the higher layer parameter *ack-NACK-NumRepetitions-Msg4* configured for the associated NPRACH resource for Msg4 NPDSCH transmission, and higher layer parameter *ack-NACK-NumRepetitions* otherwise, and the value of N_{slots}^{UL} is the number of slots of the resource unit (defined in clause 10.1.2.3 of [3]),
- allocated subcarrier for ACK/NACK and value of k_0 is determined by the ACK/NACK resource field in the DCI format of the corresponding NPDCCH according to Table 16.4.2-1, and Table 16.4.2-2.

Table 16.4.2-1: ACK/NACK subcarrier and k_0 for NPUSCH with subcarrier spacing $\Delta f = 3.75\,\text{kHz}$.

ACK/NACK resource field	ACK/NACK subcarrier	k_0
0	38	13
1	39	13
2	40	13
3	41	13
4	42	13
5	43	13
6	44	13
7	45	13
8	38	21
9	39	21
10	40	21
11	41	21
12	42	21
13	43	21
14	44	21
15	45	21

Table 16.4.2-2: ACK/NACK subcarrier and k_0 for NPUSCH with subcarrier spacing $\Delta f = 15\,\text{kHz}$.

ACK/NACK resource field	ACK/NACK subcarrier	k_0
0	0	13
1	1	13
2	2	13
3	3	13
4	0	15
5	1	15
6	2	15
7	3	15
8	0	17
9	1	17
10	2	17
11	3	17
12	0	18
13	1	18
14	2	18
15	3	18

16.5 Narrowband physical uplink shared channel related procedures

16.5.1 UE procedure for transmitting format 1 narrowband physical uplink shared channel

A UE shall upon detection on a given serving cell of a NPDCCH with DCI format N0 ending in NB-IoT DL subframe *n* intended for the UE, adjust, at the end of $n+k_0$ DL subframe, the corresponding NPUSCH transmission using NPUSCH format 1 in *N* consecutive NB-IoT UL slots n_i with $i = 0, 1, \ldots, N-1$ according to the NPDCCH information where

- subframe *n* is the last subframe in which the NPDCCH is transmitted and is determined from the starting subframe of NPDCCH transmission and the DCI subframe repetition number field in the corresponding DCI; and

- $N = N_{\text{Rep}} N_{\text{RU}} N_{\text{slots}}^{UL}$, where the value of N_{Rep} is determined by the repetition number field in the corresponding DCI (see subclause 16.5.1.1), the value of N_{RU} is determined by the resource assignment field in the corresponding DCI (see subclause 16.5.1.1), and the value of N_{slots}^{UL} is the number of NB-IoT UL slots of the resource unit (defined in clause 10.1.2.3 of [3]) corresponding to the allocated number of subcarriers (as determined in subclause 16.5.1.1) in the corresponding DCI,

- n_0 is the first NB-IoT UL slot starting after the end of subframe $n+k_0$
- value of k_0 is determined by the scheduling delay field (I_{Delay}) in the corresponding DCI according to Table 16.5.1-1.

Table 16.5.1-1: k_0 for DCI format N0.

I_{Delay}	k_0
0	8
1	16
2	32
3	64

If a UE is configured by higher layers to decode NPDCCHs with the CRC scrambled by the C-RNTI, the UE shall decode the NPDCCH according to the combination defined in Table 16.5.1-2 and transmit the corresponding NPUSCH. The scrambling initialization of this NPUSCH corresponding to these NPDCCHs and the NPUSCH retransmission for the same transport block is by C-RNTI.

Table 16.5.1-2: NPDCCH and NPUSCH configured by C-RNTI

DCI format	Search Space
DCI format N0	UE specific by C-RNTI

If a UE is configured to receive random access procedures initiated by "PDCCH orders", the UE shall decode the NPDCCH according to the combination defined in Table 16.5.1-3.

Table 16.5.1-3: NPDCCH configured as "PDCCH order" to initiate random access procedure

DCI format	Search Space
DCI format N1	UE specific by C-RNTI

If a UE is configured by higher layers to decode NPDCCHs with the CRC scrambled by the Temporary C-RNTI regardless of whether UE is configured or not configured to decode NPDCCH with the CRC scrambled by the C-RNTI during random access procedure, the UE shall decode the NPDCCH according to the combination defined in Table 16.5.1-4 and transmit the corresponding NPUSCH. The scrambling initialization of NPUSCH corresponding to these NPDCCHs is by Temporary C-RNTI.

If a Temporary C-RNTI is set by higher layers, the scrambling initialization of NPUSCH corresponding to the Narrowband Random Access Response Grant in subclause 16.3.3 and any NPUSCH retransmission(s) for the same transport block is by Temporary C-RNTI. Otherwise, the scrambling initialization of NPUSCH corresponding to the Narrowband Random Access Response Grant in subclause 16.3.3 and any NPUSCH retransmission(s) for the same transport block is by C-RNTI.

If a UE is also configured by higher layers to decode NPDCCH with CRC scrambled by the C-RNTI during random access procedure, the UE shall decode the NPDCCH according to the combination defined in Table 16.5.1-4 and transmit the corresponding NPUSCH. The scrambling initialization of NPUSCH corresponding to these NPDCCH is by C-RNTI.

Table 16.5.1-4: NPDCCH and NPUSCH configured by Temporary C-RNTI and/or C-RNTI during random access procedure

DCI format	Search Space
DCI format N0	Type-2 Common

16.5.1.1 Resource allocation

The resource allocation information in uplink DCI format N0 for NPUSCH transmission indicates to a scheduled UE

- a set of contiguously allocated subcarriers (n_{sc}) of a resource unit determined by the Subcarrier indication field in the corresponding DCI,
- a number of resource units (N_{RU}) determined by the resource assignment field in the corresponding DCI according to Table 16.5.1.1-2,
- a repetition number (N_{Rep}) determined by the repetition number field in the corresponding DCI according to Table 16.5.1.1-3.

The subcarrier spacing Δf of NPUSCH transmission is determined by the uplink subcarrier spacing field in the Narrowband Random Access Response Grant according to subclause 16.3.3.

For NPUSCH transmission with subcarrier spacing $\Delta f = 3.75\,\text{kHz}$, $n_{sc} = I_{sc}$ where I_{sc} is the subcarrier indication field in the DCI. $I_{sc} = 48,49,...,63$ is reserved.

For NPUSCH transmission with subcarrier spacing $\Delta f = 15\,\text{kHz}$, the subcarrier indication field (I_{sc}) in the DCI determines the set of contiguously allocated subcarriers (n_{sc}) according to Table 16.5.1.1-1.

Table 16.5.1.1-1: Allocated subcarriers for NPUSCH with $\Delta f = 15\,\text{kHz}$.

Subcarrier indication field (I_{sc})	Set of Allocated subcarriers (n_{sc})
0 – 11	I_{sc}
12-15	$3(I_{sc} - 12) + \{0,1,2\}$
16-17	$6(I_{sc} - 16) + \{0,1,2,3,4,5\}$
18	$\{0,1,2,3,4,5,6,7,8,9,10,11\}$
19-63	Reserved

Table 16.5.1.1-2: Number of resource units (N_{RU}) for NPUSCH.

I_{RU}	N_{RU}
0	1
1	2
2	3
3	4
4	5
5	6
6	8
7	10

Table 16.5.1.1-3: Number of repetitions (N_{Rep}) for NPUSCH.

I_{Rep}	N_{Rep}
0	1
1	2
2	4
3	8
4	16
5	32
6	64
7	128

16.5.1.2 Modulation order, redundancy version and transport block size determination

To determine the modulation order, redundancy version and transport block size for the NPUSCH, the UE shall first

- read the "modulation and coding scheme" field (I_{MCS}) in the DCI, and
- read the "redundancy version" field (rv_{DCI}) in the DCI, and
- read the "resource assignment" field (I_{RU}) in the DCI, and
- compute the total number of allocated subcarriers ($N_{\text{sc}}^{\text{RU}}$), number of resource units (N_{RU}), and repetition number (N_{Rep}) according to subclause 16.5.1.1.

The UE shall use modulation order, $Q_m = 2$ if $N_{\text{sc}}^{\text{RU}} > 1$. The UE shall use I_{MCS} and Table 16.5.1.2-1 to determine the modulation order to use for NPUSCH if $N_{\text{sc}}^{\text{RU}} = 1$.

Table 16.5.1.2-1: Modulation and TBS index table for NPUSCH with $N_{\text{sc}}^{\text{RU}} = 1$.

MCS Index I_{MCS}	Modulation Order Q_m	TBS Index I_{TBS}
0	1	0
1	1	2
2	2	1
3	2	3
4	2	4
5	2	5
6	2	6
7	2	7
8	2	8
9	2	9
10	2	10

NPUSCH is transmitted in N consecutive NB-IoT UL slots, n_i , $i=0,1,\ldots,N-1$. The redundancy version $rv_{\text{idx}}(j)$ of the NPUSCH transmission in j^{th} block of B consecutive NB-IoT UL slots

n_i , $i = jB + b,\ b = 0,1,\ldots,B-1,\ j = 0,1,\ldots,\frac{N_{\text{Rep}}}{L} - 1,\quad B = L N_{\text{RU}} N_{\text{slots}}^{UL}$ is determined by,

$rv_{\text{idx}}(j) = 2 \cdot \text{mod}\left(rv_{\text{DCI}} + j, 2\right)$, where $L = 1$ if $N_{\text{sc}}^{\text{RU}} = 1$, $L = \min\left(4, \left\lceil N_{\text{Rep}} / 2 \right\rceil\right)$ otherwise. Portion of NPUSCH codeword with $rv_{\text{idx}}(j)$ as defined in clause 6.3.2 in [4] mapped to slot $\left\lfloor \frac{b}{L} \right\rfloor$ of allocated N_{RU} resource unit(s) is transmitted in NB-IoT UL slots n_i $i = jB + L\left\lfloor \frac{b}{L} \right\rfloor + l,\ l = 0,1,\ldots,L-1$ for $\Delta f = 3.75kHz$ and

$$i = jB + 2L\left\lfloor \frac{b}{2L} \right\rfloor + 2l + \mathrm{mod}(\left\lfloor \frac{b}{L} \right\rfloor,\quad 2), l = 0,1,\ldots L-1 \text{ for } \Delta f = 15kHz$$

The UE shall use (I_{TBS} , I_{RU}) and Table 16.5.1.2-2 to determine the TBS to use for the NPUSCH. I_{TBS} is given in Table 16.5.1.2.1-1 if $N_{\mathrm{sc}}^{\mathrm{RU}} = 1$, $I_{\mathrm{TBS}} = I_{\mathrm{MCS}}$ otherwise.

Table 16.5.1.2-2: Transport block size (TBS) table for NPUSCH.

I_{TBS}	I_{RU}							
	0	**1**	**2**	**3**	**4**	**5**	**6**	**7**
0	16	32	56	88	120	152	208	256
1	24	56	88	144	176	208	256	344
2	32	72	144	176	208	256	328	424
3	40	104	176	208	256	328	440	568
4	56	120	208	256	328	408	552	680
5	72	144	224	328	424	504	680	872
6	88	176	256	392	504	600	808	1000
7	104	224	328	472	584	712	1000	
8	120	256	392	536	680	808		
9	136	296	456	616	776	936		
10	144	328	504	680	872	1000		
11	176	376	584	776	1000			
12	208	440	680	1000				

The NDI as signalled on NPDCCH, and the RV and TBS, as determined above, shall be delivered to higher layers.

16.5.2 UE procedure for receiving ACK/NACK

For a NPUSCH transmission ending in NB-IoT DL subframe *n-4,* the UE shall monitor the corresponding ACK/NACK response starting from NB-IoT DL subframe *n*.

16.6 Narrowband physical downlink control channel related procedures

A UE shall monitor a set of NPDCCH candidates (described in subclause 10.2.5.1 of [3]) as configured by higher layer signalling for control information, where monitoring implies attempting to decode each of the NPDCCHs in the set according to all the monitored DCI formats.

The set of NPDCCH candidates to monitor are defined in terms of NPDCCH search spaces.

The UE shall monitor one or more of the following search spaces

- a Type1-NPDCCH common search space,
- a Type2-NPDCCH common search space, and
- a NPDCCH UE-specific search space.

A UE is not required to simultaneously monitor a NPDCCH UE-specific search space and a Type-1-NPDCCH common search space.

A UE is not required to simultaneously monitor a NPDCCH UE-specific search space and a Type2-NPDCCH common search space.

A UE is not required to simultaneously monitor a Type-1-NPDCCH common search space and a Type2-NPDCCH common search space.

An NPDCCH search space $NS_k^{(L',R)}$ at aggregation level $L' \in \{1,2\}$ and repetition level $R \in \{1,2,4,8,16,32,64,128,256,512,1024,2048\}$ is defined by a set of NPDCCH candidates where each candidate is repeated in a set of R consecutive NB-IoT downlink subframes excluding subframes used for transmission of SI messages starting with subframe k.

For NPDCCH UE-specific search space, the aggregation and repetition levels defining the search spaces and the corresponding NPDCCH candidates are listed in Table 16.6-1 by substituting the value of $R_{\max}$ with the higher layer configured parameter *npdcch-NumRepetitions*.

For Type1-NPDCCH common search space, the aggregation and repetition levels defining the search spaces are listed in Table 16.6-2 by substituting the value of $R_{\max}$ with the higher layer configured parameter *npdcch-NumRepetitionPaging*.

For Type2-NPDCCH common search space, the aggregation and repetition levels defining the search spaces and the corresponding monitored NPDCCH candidates are listed in Table 16.6-3 by substituting the value of $R_{\max}$ with the higher layer configured parameter *npdcch-NumRepetitions-RA*.

The locations of starting subframe k are given by $k = k_b$ where k_b is the b^{th} consecutive NB-IoT DL subframe from subframe $k0$, and $b = u \cdot R$, and $u = 0,1,\ldots \frac{R_{\max}}{R} - 1$, and where

- subframe $k0$ is a subframe satisfying the condition $(10n_{\text{f}} + \lfloor n_{\text{s}}/2 \rfloor) \bmod T = \alpha_{offset} \cdot T$, where $T = R_{\max} \cdot G$, $T \geq 4$.
  - for NPDCCH UE-specific search space,
    - G is given by the higher layer parameter *npdcch-StartSF-USS*,
    - α_{offset} is given by the higher layer parameter *npdcch-Offset-USS*,
  - for NPDCCH Type2-NPDCCH common search space,
    - G is given by the higher layer parameter *npdcch-StartSF-CSS-RA*,
    - α_{offset} is given by the higher layer parameter *npdcch-Offset-RA*,

For Type1-NPDCCH common search space, $k = k0$ and is determined from locations of NB-IoT paging opportunity subframes.

If the UE is configured by high layers with a NB-IoT carrier for monitoring of NPDCCH UE-specific search space,

- the UE shall monitor the NPDCCH UE-specific search space on the higher layer configured NB-IoT carrier,
- the UE is not expected to receive NPSS, NSSS, NPBCH on the higher layer configured NB-IoT carrier.

otherwise,

- the UE shall monitor the NPDCCH UE-specific search space on the same NB-IoT carrier on which NPSS/NSSS/NPBCH are detected.

Table 16.6-1: NPDCCH UE- specific search space candidates

R_{max}	R	DCI subframe repetition number	NCCE indices of monitored NPDCCH candidates	
			L'=1	L'=2
1	1	00	{0},{1}	{0,1}
2	1	00	{0},{1}	{0,1}
	2	01	-	{0,1}
4	1	00	-	{0,1}
	2	01	-	{0,1}
	4	10	-	{0,1}
>=8	$R_{max}/8$	00	-	{0,1}
	$R_{max}/4$	01	-	{0,1}
	$R_{max}/2$	10	-	{0,1}
	R_{max}	11	-	{0,1}

Note 1: {x}, {y} denotes NPDCCH Format 0 candidate with NCCE index 'x', and NPDCCH Format 0 candidate with NCCE index 'y' are monitored
Note 2: {x,y} denotes NPDCCH Format1 candidate corresponding to NCCEs 'x' and 'y' is monitored.

Table 16.6-2: Type 1- NPDCCH common search space candidates

R_{max}	R								NCCE indices of monitored NPDCCH candidates	
									L'=1	L'=2
1	1	-	-	-	-	-	-	-	-	{0,1}
2	1	2	-	-	-	-	-	-	-	{0,1}
4	1	2	4	-	-	-	-	-	-	{0,1}
8	1	2	4	8	-	-	-	-	-	{0,1}
16	1	2	4	8	16	-	-	-	--	{0,1}
32	1	2	4	8	16	32	-	-	-	{0,1}
64	1	2	4	8	16	32	64	-	-	{0,1}
128	1	2	4	8	16	32	64	128	-	{0,1}
256	1	4	8	16	32	64	128	256	-	{0,1}
512	1	4	16	32	64	128	256	512	-	{0,1}
1024	1	8	32	64	128	256	512	1024	-	{0,1}
2048	1	8	64	128	256	512	1024	2048	-	{0,1}
DCI subframe repetition number	000	001	010	011	100	101	110	111		
Note 1: {x,y} denotes NPDCCH Format1 candidate corresponding to NCCEs 'x' and 'y' is monitored.										

Table 16.6-3: Type 2- NPDCCH common search space candidates

R_{max}	R	DCI subframe repetition number	NCCE indices of monitored NPDCCH candidates	
			L'=1	L'=2
1	1	00	-	{0,1}
2	1	00	-	{0,1}
	2	01	-	{0,1}
4	1	00	-	{0,1}
	2	01	-	{0,1}
	4	10	-	{0,1}
>=8	$R_{max}/8$	00	-	{0,1}
	$R_{max}/4$	01	-	{0,1}
	$R_{max}/2$	10	-	{0,1}
	R_{max}	11	-	{0,1}
Note 1: {x,y} denotes NPDCCH Format1 candidate corresponding to NCCEs 'x' and 'y' is monitored.				

If a NB-IoT UE detects NPDCCH with DCI Format N0 ending in subframe n, and if the corresponding NPUSCH format 1 transmission starts from *n+k*, the UE is not required to monitor NPDCCH in any subframe starting from subframe *n+1* to subframe *n+k-1*.

If a NB-IoT UE detects NPDCCH with DCI Format N1 or N2 ending in subframe *n*, and if the corresponding NPDSCH transmission starts from *n+k*, the UE is not required to monitor NPDCCH in any subframe starting from subframe *n+1* to subframe *n+k-1*.

If a NB-IoT UE detects NPDCCH with DCI Format N1 ending in subframe *n*, and if the corresponding NPUSCH format 2 transmission starts from subframe *n+k*, the UE is not required to monitor NPDCCH in any subframe starting from subframe *n+1* to subframe *n+k-1*.

If a NB-IoT UE detects NPDCCH with DCI Format N1 for "PDCCH order" ending in subframe *n*, and if the corresponding NPRACH transmission starts from subframe *n+k*, the UE is not required to monitor NPDCCH in any subframe starting from subframe *n+1* to subframe *n+k-1*.

If a NB-IoT UE has a NPUSCH transmission ending in subframe *n* , the UE is not required to monitor NPDCCH in any subframe starting from subframe *n+1* to subframe *n+3*.

A NB-IoT UE is not required to monitor NPDCCH candidates of an NPDCCH search space if an NPDCCH candidate of the NPDCCH search space ends in subframe *n*, and if the UE is configured to monitor NPDCCH candidates of another NPDCCH search space having starting subframe k0 before subframe *n+5*.

An NB-IoT UE is not required to monitor NPDCCH candidates of an NPDCCH search space during an NPUSCH UL gap.

16.6.1 NPDCCH starting position

The starting OFDM symbol for NPDCCH given by index $l_{\mathrm{NPDCCHStart}}$ in the first slot in a subframe k and is determined as follows

- if higher layer parameter *eutraControlRegionSize* is present
  - $l_{\mathrm{NPDCCHStart}}$ is given by the higher layer parameter *eutraControlRegionSize*
- otherwise
  - $l_{\mathrm{NPDCCHStart}} = 0$

16.6.2 NPDCCH control information procedure

A UE shall discard the NPDCCH if consistent control information is not detected.

16.7 Assumptions independent of physical channel related to narrowband IoT

A UE may assume the antenna ports 2000 – 2001 of a serving cell are quasi co-located (as defined in [3]) with respect to delay spread, Doppler spread, Doppler shift, average gain, and average delay.

16.8 UE procedure for acquiring cell-specific reference signal sequence and raster offset

If the higher layer parameter *operationModeInfo* indicates *inband-SamePCI* for a cell, the UE may derive cell-specific reference signal sequence and raster offset from the higher layer parameter *eutra-CRS-SequenceInfo* according to Table 16.8-1, where E-UTRA PRB index n'_{PRB} is defined as $n'_{\mathrm{PRB}} = n_{\mathrm{PRB}} - \lfloor N_{\mathrm{RB}}^{\mathrm{DL}} / 2 \rfloor$.

Table 16.8-1: Definition of *eutra-CRS-SequenceInfo*

eutra-CRS-SequenceInfo	E-UTRA PRB index n'_{PRB} for odd number of $N_{\text{RB}}^{\text{DL}}$	Raster offset	*eutra-CRS-SequenceInfo*	E-UTRA PRB index n'_{PRB} for even number of $N_{\text{RB}}^{\text{DL}}$	Raster offset
0	-35	-7.5 kHz	14	-46	+2.5 kHz
1	-30		15	-41	
2	-25		16	-36	
3	-20		17	-31	
4	-15		18	-26	
5	-10		19	-21	
6	-5		20	-16	
7	5	+7.5 kHz	21	-11	
8	10		22	-6	
9	15		23	5	-2.5 kHz
10	20		24	10	
11	25		25	15	
12	30		26	20	
13	35		27	25	
			28	30	
			29	35	
			30	40	
			31	45	

Annex A (informative): Change history

Change history							
Date	**TSG #**	**TSG Doc.**	**CR**	**Rev**	**Subject/Comment**	**Old**	**New**
2006-09					Draft version created		0.0.0
2006-10					Endorsed by RAN1	0.0.0	0.1.0
2007-01					Inclusion of decisions from RAN1#46bis and RAN1#47	0.1.0	0.1.1
2007-01					Endorsed by RAN1	0.1.1	0.2.0
2007-02					Inclusion of decisions from RAN1#47bis	0.2.0	0.2.1
2007-02					Endorsed by RAN1	0.2.1	0.3.0
2007-02					Editor's version including decisions from RAN1#48 & RAN1#47bis	0.3.0	0.3.1
2007-03					Updated Editor's version	0.3.1	0.3.2
2007-03	RAN-35	RP-070171			For information at RAN#35	0.3.2	1.0.0
2007-03					Random access text modified to better reflect RAN1 scope	1.0.0	1.0.1
2007-03					Updated Editor's version	1.0.1	1.0.2
2007-03					Endorsed by RAN1	1.0.2	1.1.0
2007-05					Updated Editor's version	1.1.0	1.1.1
2007-05					Updated Editor's version	1.1.1	1.1.2
2007-05					Endorsed by RAN1	1.1.2	1.2.0
2007-08					Updated Editor's version	1.2.0	1.2.1
2007-08					Updated Editor's version – uplink power control from RAN1#49bis	1.2.1	1.2.2
2007-08					Endorsed by RAN1	1.2.2	1.3.0
2007-09					Updated Editor's version reflecting RAN#50 decisions	1.3.0	1.3.1
2007-09					Updated Editor's version reflecting comments	1.3.1	1.3.2
2007-09					Updated Editor's version reflecting further comments	1.3.2	1.3.3
2007-09					Updated Editor's version reflecting further comments	1.3.3	1.3.4
2007-09					Updated Edtior's version reflecting further comments	1.3.4	1.3.5
2007-09	RAN-37	RP-070731			Endorsed by RAN1	1.3.5	2.0.0
2007-09	RAN-37	RP-070737			For approval at RAN#37	2.0.0	2.1.0
12/09/07	RP-37	RP-070737	-	-	Approved version	2.1.0	8.0.0
28/11/07	RP-38	RP-070949	0001	2	Update of 36.213	8.0.0	8.1.0
05/03/08	RP-39	RP-080145	0002	-	Update of TS 36.213 according to changes listed in cover sheet	8.1.0	8.2.0
28/05/08	RP-40	RP-080434	0003	1	PUCCH timing and other formatting and typo corrections	8.2.0	8.3.0
28/05/08	RP-40	RP-080434	0006	1	PUCCH power control for non-unicast information	8.2.0	8.3.0
28/05/08	RP-40	RP-080434	0008	-	UE ACK/NACK Procedure	8.2.0	8.3.0
28/05/08	RP-40	RP-080434	0009	-	UL ACK/NACK timing for TDD	8.2.0	8.3.0
28/05/08	RP-40	RP-080434	0010	-	Specification of UL control channel assignment	8.2.0	8.3.0
28/05/08	RP-40	RP-080434	0011	-	Precoding Matrix for 2Tx Open-loop SM	8.2.0	8.3.0
28/05/08	RP-40	RP-080434	0012	-	Clarifications on UE selected CQI reports	8.2.0	8.3.0
28/05/08	RP-40	RP-080434	0013	1	UL HARQ Operation and Timing	8.2.0	8.3.0
28/05/08	RP-40	RP-080434	0014	-	SRS power control	8.2.0	8.3.0
28/05/08	RP-40	RP-080434	0015	1	Correction of UE PUSCH frequency hopping procedure	8.2.0	8.3.0
28/05/08	RP-40	RP-080434	0017	4	Blind PDCCH decoding	8.2.0	8.3.0
28/05/08	RP-40	RP-080434	0019	1	Tx Mode vs DCI format is clarified	8.2.0	8.3.0
28/05/08	RP-40	RP-080434	0020	-	Resource allocation for distributed VRB	8.2.0	8.3.0
28/05/08	RP-40	RP-080434	0021	2	Power Headroom	8.2.0	8.3.0
28/05/08	RP-40	RP-080434	0022	-	Clarification for RI reporting in PUCCH and PUSCH reporting modes	8.2.0	8.3.0
28/05/08	RP-40	RP-080434	0025	-	Correction of the description of PUSCH power control for TDD	8.2.0	8.3.0
28/05/08	RP-40	RP-080434	0026	-	UL ACK/NACK procedure for TDD	8.2.0	8.3.0
28/05/08	RP-40	RP-080434	0027	-	Indication of radio problem detection	8.2.0	8.3.0
28/05/08	RP-40	RP-080434	0028	-	Definition of Relative Narrowband TX Power Indicator	8.2.0	8.3.0
28/05/08	RP-40	RP-080434	0029	-	Calculation of $\Delta_{TF}(i)$ for UL-PC	8.2.0	8.3.0
28/05/08	RP-40	RP-080434	0030	-	CQI reference and set S definition, CQI mode removal, and Miscellanious	8.2.0	8.3.0
28/05/08	RP-40	RP-080434	0031	-	Modulation order and TBS determination for PDSCH and PUSCH	8.2.0	8.3.0
28/05/08	RP-40	RP-080434	0032	-	On Sounding RS	8.2.0	8.3.0
28/05/08	RP-40	RP-080426	0033	-	Multiplexing of rank and CQI/PMI reports on PUCCH	8.2.0	8.3.0
28/05/08	RP-40	RP-080466	0034	-	Timing advance command responding time	8.2.0	8.3.0
09/09/08	RP-41	RP-080670	37	2	SRS hopping pattern for closed loop antenna selection	8.3.0	8.4.0
09/09/08	RP-41	RP-080670	39	2	Clarification on uplink power control	8.3.0	8.4.0
09/09/08	RP-41	RP-080670	41	-	Clarification on DCI formats using resource allocation type 2	8.3.0	8.4.0

Change history							
Date	TSG #	TSG Doc.	CR	Rev	Subject/Comment	Old	New
09/09/08	RP-41	RP-080670	43	2	Clarification on tree structure of CCE aggregations	8.3.0	8.4.0
09/09/08	RP-41	RP-080670	46	2	Correction of the description of PUCCH power control for TDD	8.3.0	8.4.0
09/09/08	RP-41	RP-080670	47	1	Removal of CR0009	8.3.0	8.4.0
09/09/08	RP-41	RP-080670	48	1	Correction of mapping of cyclic shift value to PHICH modifier	8.3.0	8.4.0
09/09/08	RP-41	RP-080670	49	-	TBS disabling for DCI formats 2 and 2A	8.3.0	8.4.0
09/09/08	RP-41	RP-080670	50	-	Correction of maximum TBS sizes	8.3.0	8.4.0
09/09/08	RP-41	RP-080670	51	-	Completion of the table specifying the number of bits for the periodic feedback	8.3.0	8.4.0
09/09/08	RP-41	RP-080670	54	-	Clarification of RNTI for PUSCH/PUCCH power control with DCI formats 3/3A	8.3.0	8.4.0
09/09/08	RP-41	RP-080670	55	1	Clarification on mapping of Differential CQI fields	8.3.0	8.4.0
09/09/08	RP-41	RP-080670	59	1	PUSCH Power Control	8.3.0	8.4.0
09/09/08	RP-41	RP-080670	60	-	RB restriction and modulation order for CQI-only transmission on PUSCH	8.3.0	8.4.0
09/09/08	RP-41	RP-080670	61	-	Modulation order determination for uplink retransmissions	8.3.0	8.4.0
09/09/08	RP-41	RP-080670	62	2	Introducing missing L1 parameters into 36.213	8.3.0	8.4.0
09/09/08	RP-41	RP-080670	63	2	Correcting the range and representation of delta_TF_PUCCH	8.3.0	8.4.0
09/09/08	RP-41	RP-080670	64	1	Adjusting TBS sizes to for VoIP	8.3.0	8.4.0
09/09/08	RP-41	RP-080670	67	-	Correction to the downlink resource allocation	8.3.0	8.4.0
09/09/08	RP-41	RP-080670	68	-	Removal of special handling for PUSCH mapping in PUCCH region	8.3.0	8.4.0
09/09/08	RP-41	RP-080670	69	-	Correction to the formulas for uplink power control	8.3.0	8.4.0
09/09/08	RP-41	RP-080670	70	1	Definition of Bit Mapping for DCI Signalling	8.3.0	8.4.0
09/09/08	RP-41	RP-080670	71	-	Clarification on PUSCH TPC commands	8.3.0	8.4.0
09/09/08	RP-41	RP-080670	72	1	Reference for CQI/PMI Reporting Offset	8.3.0	8.4.0
09/09/08	RP-41	RP-080670	74	-	Correction to the downlink/uplink timing	8.3.0	8.4.0
09/09/08	RP-41	RP-080670	75	-	Correction to the time alignment command	8.3.0	8.4.0
09/09/08	RP-41	RP-080670	77	1	Correction of offset signalling of UL Control information MCS	8.3.0	8.4.0
09/09/08	RP-41	RP-080670	78	2	DCI format1C	8.3.0	8.4.0
09/09/08	RP-41	RP-080670	80	-	Correction to Precoder Cycling for Open-loop Spatial Multiplexing	8.3.0	8.4.0
09/09/08	RP-41	RP-080670	81	1	Clarifying Periodic CQI Reporting using PUCCH	8.3.0	8.4.0
09/09/08	RP-41	RP-080670	84	1	CQI reference measurement period	8.3.0	8.4.0
09/09/08	RP-41	RP-080670	86	-	Correction on downlink multi-user MIMO	8.3.0	8.4.0
09/09/08	RP-41	RP-080670	87	-	PUCCH Reporting	8.3.0	8.4.0
09/09/08	RP-41	RP-080670	88	1	Handling of Uplink Grant in Random Access Response	8.3.0	8.4.0
09/09/08	RP-41	RP-080670	89	-	Correction to UL Hopping operation	8.3.0	8.4.0
09/09/08	RP-41	RP-080670	90	-	DRS EPRE	8.3.0	8.4.0
09/09/08	RP-41	RP-080670	92	-	Uplink ACK/NACK mapping for TDD	8.3.0	8.4.0
09/09/08	RP-41	RP-080670	93	-	UL SRI Parameters Configuration	8.3.0	8.4.0
09/09/08	RP-41	RP-080670	94	-	Miscellaneous updates for 36.213	8.3.0	8.4.0
09/09/08	RP-41	RP-080670	95	-	Clarifying Requirement for Max PDSCH Coding Rate	8.3.0	8.4.0
09/09/08	RP-41	RP-080670	96	-	UE Specific SRS Configuration	8.3.0	8.4.0
09/09/08	RP-41	RP-080670	97	-	DCI Format 1A changes needed for scheduling Broadcast Control	8.3.0	8.4.0
09/09/08	RP-41	RP-080670	98	-	Processing of TPC bits in the random access response	8.3.0	8.4.0
09/09/08	RP-41	RP-080670	100	1	Support of multi-bit ACK/NAK transmission in TDD	8.3.0	8.4.0
03/12/08	RP-42	RP-081075	82	3	Corrections to RI for CQI reporting	8.4.0	8.5.0
03/12/08	RP-42	RP-081075	83	2	Moving description of large delay CDD to 36.211	8.4.0	8.5.0
03/12/08	RP-42	RP-081075	102	3	Reception of DCI formats	8.4.0	8.5.0
03/12/08	RP-42	RP-081075	105	8	Alignment of RAN1/RAN2 specification	8.4.0	8.5.0
03/12/08	RP-42	RP-081075	107	1	General correction of reset of power control and random access response message	8.4.0	8.5.0
03/12/08	RP-42	RP-081075	108	2	Final details on codebook subset restrictions	8.4.0	8.5.0
03/12/08	RP-42	RP-081075	109	-	Correction on the definition of Pmax	8.4.0	8.5.0
03/12/08	RP-42	RP-081075	112	2	CQI/PMI reference measurement periods	8.4.0	8.5.0
03/12/08	RP-42	RP-081075	113	-	Correction of introduction of shortened SR	8.4.0	8.5.0
03/12/08	RP-42	RP-081075	114	-	RAN1/2 specification alignment on HARQ operation	8.4.0	8.5.0
03/12/08	RP-42	RP-081075	115	-	Introducing other missing L1 parameters in 36.213	8.4.0	8.5.0
03/12/08	RP-42	RP-081075	116	-	PDCCH blind decoding	8.4.0	8.5.0
03/12/08	RP-42	RP-081075	117	-	PDCCH search space	8.4.0	8.5.0
03/12/08	RP-42	RP-081075	119	-	Delta_TF for PUSCH	8.4.0	8.5.0
03/12/08	RP-42	RP-081075	120	-	Delta_preamble_msg3 parameter values and TPC command in RA response	8.4.0	8.5.0
03/12/08	RP-42	RP-081075	122	1	Correction of offset signaling of uplink control information MCS	8.4.0	8.5.0
03/12/08	RP-42	RP-081075	124	-	Miscellaneous Corrections	8.4.0	8.5.0
03/12/08	RP-42	RP-081075	125	-	Clarification of the uplink index in TDD mode	8.4.0	8.5.0
03/12/08	RP-42	RP-081075	126	-	Clarification of the uplink transmission configurations	8.4.0	8.5.0
03/12/08	RP-42	RP-081075	127	2	Correction to the PHICH index assignment	8.4.0	8.5.0
03/12/08	RP-42	RP-081075	128	-	Clarification of type-2 PDSCH resource allocation for format 1C	8.4.0	8.5.0

Change history							
Date	**TSG #**	**TSG Doc.**	**CR**	**Rev**	**Subject/Comment**	**Old**	**New**
03/12/08	RP-42	RP-081075	129	-	Clarification of uplink grant in random access response	8.4.0	8.5.0
03/12/08	RP-42	RP-081075	130	-	UE sounding procedure	8.4.0	8.5.0
03/12/08	RP-42	RP-081075	134	-	Change for determining DCI format 1A TBS table column indicator for broadcast control	8.4.0	8.5.0
03/12/08	RP-42	RP-081075	135	-	Clarifying UL VRB Allocation	8.4.0	8.5.0
03/12/08	RP-42	RP-081075	136	1	Correction for Aperiodic CQI	8.4.0	8.5.0
03/12/08	RP-42	RP-081075	137	1	Correction for Aperiodic CQI Reporting	8.4.0	8.5.0
03/12/08	RP-42	RP-081075	138	1	Correction to PUCCH CQI reporting mode for N^DL_RB <= 7	8.4.0	8.5.0
03/12/08	RP-42	RP-081075	140	1	On sounding procedure in TDD	8.4.0	8.5.0
03/12/08	RP-42	RP-081075	141	1	Alignment of RAN1/RAN3 specification	8.4.0	8.5.0
03/12/08	RP-42	RP-081075	143	1	TTI bundling	8.4.0	8.5.0
03/12/08	RP-42	RP-081075	144	1	ACK/NACK transmission on PUSCH for LTE TDD	8.4.0	8.5.0
03/12/08	RP-42	RP-081075	145	1	Timing relationship between PHICH and its associated PUSCH	8.4.0	8.5.0
03/12/08	RP-42	RP-081075	147	1	Definition of parameter for downlink reference signal transmit power	8.4.0	8.5.0
03/12/08	RP-42	RP-081075	148	1	Radio link monitoring	8.4.0	8.5.0
03/12/08	RP-42	RP-081075	149	1	Correction in 36.213 related to TDD downlink HARQ processes	8.4.0	8.5.0
03/12/08	RP-42	RP-081075	151	-	Nominal PDSCH-to-RS EPRE Offset for CQI Reporting	8.4.0	8.5.0
03/12/08	RP-42	RP-081075	152	1	Support of UL ACK/NAK repetition in Rel-8	8.4.0	8.5.0
03/12/08	RP-42	RP-081075	155	-	Clarification of misconfiguration of aperiodic CQI and SR	8.4.0	8.5.0
03/12/08	RP-42	RP-081075	156	1	Correction of control information multiplexing in subframe bundling mode	8.4.0	8.5.0
03/12/08	RP-42	RP-081075	157	-	Correction to the PHICH index assignment	8.4.0	8.5.0
03/12/08	RP-42	RP-081075	158	1	UE transmit antenna selection	8.4.0	8.5.0
03/12/08	RP-42	RP-081075	159	-	Clarification of spatial different CQI for CQI reporting Mode 2-1	8.4.0	8.5.0
03/12/08	RP-42	RP-081075	160	1	Corrections for TDD ACK/NACK bundling and multiplexing	8.4.0	8.5.0
03/12/08	RP-42	RP-081075	161	-	Correction to RI for Open-Loop Spatial Multiplexing	8.4.0	8.5.0
03/12/08	RP-42	RP-081075	162	-	Correction of differential CQI	8.4.0	8.5.0
03/12/08	RP-42	RP-081075	163	-	Inconsistency between PMI definition and codebook index	8.4.0	8.5.0
03/12/08	RP-42	RP-081075	164	-	PDCCH validation for semi-persistent scheduling	8.4.0	8.5.0
03/12/08	RP-42	RP-081075	165	1	Correction to the UE behavior of PUCCH CQI piggybacked on PUSCH	8.4.0	8.5.0
03/12/08	RP-42	RP-081075	166	-	Correction on SRS procedure when shortened PUCCH format is used	8.4.0	8.5.0
03/12/08	RP-42	RP-081075	167	1	Transmission overlapping of physical channels/signals with PDSCH for transmission mode 7	8.4.0	8.5.0
03/12/08	RP-42	RP-081075	169	-	Clarification of SRS and SR transmission	8.4.0	8.5.0
03/12/08	RP-42	RP-081075	171	-	Clarification on UE behavior when skipping decoding	8.4.0	8.5.0
03/12/08	RP-42	RP-081075	172	1	PUSCH Hopping operation corrections	8.4.0	8.5.0
03/12/08	RP-42	RP-081075	173	-	Clarification on message 3 transmission timing	8.4.0	8.5.0
03/12/08	RP-42	RP-081075	174	-	MCS handling for DwPTS	8.4.0	8.5.0
03/12/08	RP-42	RP-081075	175	-	Clarification of UE-specific time domain position for SR transmission	8.4.0	8.5.0
03/12/08	RP-42	RP-081075	176	1	Physical layer parameters for CQI reporting	8.4.0	8.5.0
03/12/08	RP-42	RP-081075	177	-	A-periodic CQI clarification for TDD UL/DL configuration 0	8.4.0	8.5.0
03/12/08	RP-42	RP-081075	179	1	Correction to the definitions of rho_A and rho_B (downlink power allocation)	8.4.0	8.5.0
03/12/08	RP-42	RP-081075	180	-	Clarification of uplink A/N resource indication	8.4.0	8.5.0
03/12/08	RP-42	RP-081075	181	-	PDCCH format 0 for message 3 adaptive retransmission and transmission of control information in message 3 during contention based random access procedure	8.4.0	8.5.0
03/12/08	RP-42	RP-081075	182	-	To Fix the Discrepancy of Uplink Power Control and Channel Coding of Control Information in PUSCH	8.4.0	8.5.0
03/12/08	RP-42	RP-081122	183	1	CQI reporting for antenna port 5	8.4.0	8.5.0
03/12/08	RP-42	RP-081110	168	1	Clarification on path loss definition	8.4.0	8.5.0
04/03/09	RP-43	RP-090236	184	1	Corrections to Transmitted Rank Indication	8.5.0	8.6.0
04/03/09	RP-43	RP-090236	185	4	Corrections to transmission modes	8.5.0	8.6.0
04/03/09	RP-43	RP-090236	186	2	Delta_TF configuration for control only PUSCH	8.5.0	8.6.0
04/03/09	RP-43	RP-090236	187	1	Correction to concurrent SRS and ACK/NACK transmission	8.5.0	8.6.0
04/03/09	RP-43	RP-090236	191	1	PDCCH release for semi-persistent scheduling	8.5.0	8.6.0
04/03/09	RP-43	RP-090236	192	1	Correction on ACKNACK transmission on PUSCH for LTE TDD	8.5.0	8.6.0
04/03/09	RP-43	RP-090236	193	-	Correction to subband differential CQI value to offset level mapping for aperiodic CQI reporting	8.5.0	8.6.0
04/03/09	RP-43	RP-090236	194	-	Correction for DRS Collision handling	8.5.0	8.6.0
04/03/09	RP-43	RP-090236	196	2	Alignment of RAN1/RAN4 specification on UE maximum output power	8.5.0	8.6.0
04/03/09	RP-43	RP-090236	197	-	Transmission scheme for transmission mode 7 with SPS C-RNTI	8.5.0	8.6.0
04/03/09	RP-43	RP-090236	198	-	Clarifying bandwidth parts for periodic CQI reporting and CQI refererence period	8.5.0	8.6.0

Change history							
Date	TSG #	TSG Doc.	CR	Rev	Subject/Comment	Old	New
04/03/09	RP-43	RP-090236	199	2	Correction to the ACK/NACK bundling in case of transmission mode 3 and 4	8.5.0	8.6.0
04/03/09	RP-43	RP-090236	200	-	ACK/NAK repetition for TDD ACK/NAK multiplexing	8.5.0	8.6.0
04/03/09	RP-43	RP-090236	201	-	Clarifying UL ACK/NAK transmission in TDD	8.5.0	8.6.0
04/03/09	RP-43	RP-090236	202	-	Corrections to UE Transmit Antenna Selection	8.5.0	8.6.0
04/03/09	RP-43	RP-090236	203	-	Correction to UE PUSCH hopping procedure	8.5.0	8.6.0
04/03/09	RP-43	RP-090236	204	-	Correction to PHICH resource association in TTI bundling	8.5.0	8.6.0
04/03/09	RP-43	RP-090236	205	-	Clarification of the length of resource assignment	8.5.0	8.6.0
04/03/09	RP-43	RP-090236	206	-	Correction on ACK/NACK transmission for downlink SPS resource release	8.5.0	8.6.0
04/03/09	RP-43	RP-090236	207	-	Introduction of additional values of wideband CQI/PMI periodicities	8.5.0	8.6.0
04/03/09	RP-43	RP-090236	208	2	Correction to CQI/PMI/RI reporting field	8.5.0	8.6.0
04/03/09	RP-43	RP-090236	209	2	Correction to rho_A definition for CQI calculation	8.5.0	8.6.0
04/03/09	RP-43	RP-090236	210	-	Correction to erroneous cases in PUSCH linear block codes	8.5.0	8.6.0
04/03/09	RP-43	RP-090236	211	1	Removing RL monitoring start and stop	8.5.0	8.6.0
04/03/09	RP-43	RP-090236	214	1	Correction to type-1 and type-2 PUSCH hopping	8.5.0	8.6.0
04/03/09	RP-43	RP-090236	215	-	Contradicting statements on determination of CQI subband size	8.5.0	8.6.0
04/03/09	RP-43	RP-090236	216	-	Corrections to SRS	8.5.0	8.6.0
04/03/09	RP-43	RP-090236	219	2	Miscellaneous corrections on TDD ACKNACK	8.5.0	8.6.0
04/03/09	RP-43	RP-090236	221	1	CR for Redundancy Version mapping function for DCI 1C	8.5.0	8.6.0
04/03/09	RP-43	RP-090236	223	-	Scrambling of PUSCH corresponding to Random Access Response Grant	8.5.0	8.6.0
04/03/09	RP-43	RP-090236	225	-	Removal of SRS with message 3	8.5.0	8.6.0
04/03/09	RP-43	RP-090236	226	3	PRACH retransmission timing	8.5.0	8.6.0
04/03/09	RP-43	RP-090236	227	-	Clarifying error handling of PDSCH and PUSCH assignments	8.5.0	8.6.0
04/03/09	RP-43	RP-090236	228	-	Clarify PHICH index mapping	8.5.0	8.6.0
04/03/09	RP-43	RP-090236	229	-	Correction of CQI timing	8.5.0	8.6.0
04/03/09	RP-43	RP-090236	230	-	Alignment of CQI parameter names with RRC	8.5.0	8.6.0
04/03/09	RP-43	RP-090236	231	1	Removal of 'Off' values for periodic reporting in L1	8.5.0	8.6.0
04/03/09	RP-43	RP-090236	232	-	Default value of RI	8.5.0	8.6.0
04/03/09	RP-43	RP-090236	233	1	Clarification of uplink timing adjustments	8.5.0	8.6.0
04/03/09	RP-43	RP-090236	234	-	Clarification on ACK/NAK repetition	8.5.0	8.6.0
27/05/09	RP-44	RP-090529	235	1	Correction to the condition of resetting accumulated uplink power correction	8.6.0	8.7.0
27/05/09	RP-44	RP-090529	236	-	Correction to the random access channel parameters received from higher layer	8.6.0	8.7.0
27/05/09	RP-44	RP-090529	237	-	Correction on TDD ACKNACK	8.6.0	8.7.0
27/05/09	RP-44	RP-090529	238	1	Correction on CQI reporting	8.6.0	8.7.0
27/05/09	RP-44	RP-090529	239	-	Correction on the HARQ process number	8.6.0	8.7.0
27/05/09	RP-44	RP-090529	241	1	CR correction of the description on TTI-bundling	8.6.0	8.7.0
27/05/09	RP-44	RP-090529	242	1	Clarify latest and initial PDCCH for PDSCH and PUSCH transmisisons, and NDI for SPS activation	8.6.0	8.7.0
27/05/09	RP-44	RP-090529	243	-	Clarify DRS EPRE	8.6.0	8.7.0
27/05/09	RP-44	RP-090529	244	1	Clarification on TPC commands for SPS	8.6.0	8.7.0
15/09/09	RP-45	RP-090888	245	1	Correction to PUSCH hopping and PHICH mapping procedures	8.7.0	8.8.0
15/09/09	RP-45	RP-090888	246	-	Clarification on subband indexing in periodic CQI reporting	8.7.0	8.8.0
15/09/09	RP-45	RP-090888	247	2	Correction to DVRB operation in TDD transmission mode 7	8.7.0	8.8.0
15/09/09	RP-45	RP-090888	249	-	Clarification of concurrent ACKNACK and periodic PMI/RI transmission on PUCCH for TDD	8.7.0	8.8.0
15/09/09	RP-45	RP-090888	250	-	Clarify Inter-cell synchronization text	8.7.0	8.8.0
01/12/09	RP-46	RP-091172	248	1	Introduction of LTE positioning	8.8.0	9.0.0
01/12/09	RP-46	RP-091172	254	-	Clarification of PDSCH and PRS in combination for LTE positioning	8.8.0	9.0.0
01/12/09	RP-46	RP-091177	255	5	Editorial corrections to 36.213	8.8.0	9.0.0
01/12/09	RP-46	RP-091257	256	1	Introduction of enhanced dual layer transmission	8.8.0	9.0.0
01/12/09	RP-46	RP-091177	257	1	Add shorter SR periodicity	8.8.0	9.0.0
01/12/09	RP-46	RP-091256	258	-	Introduction of LTE MBMS	8.8.0	9.0.0
17/12/09	RP-46	RP-091257	256	1	Correction by MCC due to wrong implementation of CR0256r1 – Sentence is added to Single-antenna port scheme subclause 7.1.1	9.0.0	9.0.1
16/03/10	RP-47	RP-100211	259	3	UE behavior when collision of antenna port 7/8 with PBCH or SCH happened and when distributed VRB is used with antenna port 7	9.0.1	9.1.0
16/03/10	RP-47	RP-100210	260	1	MCCH change notification using DCI format 1C	9.0.1	9.1.0
16/03/10	RP-47	RP-100211	263	-	Correction on PDSCH EPRE and UE-specific RS EPRE for Rel-9 enhanced DL transmissions	9.0.1	9.1.0
01/06/10	RP-48	RP-100589	265	-	Clarification for TDD when multiplexing ACK/NACK with SR of ACK/NACK with CQI/PMI or RI	9.1.0	9.2.0
01/06/10	RP-48	RP-100590	268	1	Clarification of PRS EPRE	9.1.0	9.2.0

Change history							
Date	**TSG #**	**TSG Doc.**	**CR**	**Rev**	**Subject/Comment**	**Old**	**New**
14/09/10	RP-49	RP-100900	269	-	Clarification on Extended CP support with Transmission Mode 8	9.2.0	9.3.0
07/12/10	RP-50	RP-101320	270	-	Introduction of Rel-10 LTE-Advanced features in 36.213	9.3.0	10.0.0
27/12/10	-	-	-	-	Editorial change to correct a copy/past error in subclause 7.2.2	10.0.0	10.0.1
15/03/11	RP-51	RP-110255	271	1	A clarification for redundancy version of PMCH	10.0.1	10.1.0
15/03/11	RP-51	RP-110258	272	-	RLM Procedure with restricted measurements	10.0.1	10.1.0
15/03/11	RP-51	RP-110256	273	-	Corrections to Rel-10 LTE-Advanced features in 36.213	10.0.1	10.1.0
01/06/11	RP-52	RP-110819	274	3	Correction to HARQ-ACK procedure for TDD mode b with M=2	10.1.0	10.2.0
01/06/11	RP-52	RP-110819	275	3	Determination of PUSCH A/N codebook size for TDD	10.1.0	10.2.0
01/06/11	RP-52	RP-110823	276	-	The triggering of aperiodic SRS in DCI formats 2B and 2C	10.1.0	10.2.0
01/06/11	RP-52	RP-110819	278	3	Corrections to power headroom	10.1.0	10.2.0
01/06/11	RP-52	RP-110819	279	1	Removal of square brackets for PUCCH format 3 ACK/NACK	10.1.0	10.2.0
01/06/11	RP-52	RP-110819	281	1	Correction of AN repetition and PUCCH format 3	10.1.0	10.2.0
01/06/11	RP-52	RP-110819	282	2	Correction to timing for secondary cell activation and deactivation	10.1.0	10.2.0
01/06/11	RP-52	RP-110823	283	1	Correction to MCS offset for multiple TBs	10.1.0	10.2.0
01/06/11	RP-52	RP-110820	286	1	Miscellaneous Corrections	10.1.0	10.2.0
01/06/11	RP-52	RP-110819	288	1	Corrections on UE procedure for determining PUCCH Assignment	10.1.0	10.2.0
01/06/11	RP-52	RP-110819	289	2	Correction to Multi-cluster flag in DCI format 0	10.1.0	10.2.0
01/06/11	RP-52	RP-110819	290	2	Joint transmission of ACK/NACK and SR with PUCCH format 3	10.1.0	10.2.0
01/06/11	RP-52	RP-110819	291	3	Correction of uplink resource allocation type 1	10.1.0	10.2.0
01/06/11	RP-52	RP-110821	292	1	Correction on CSI-RS configuration	10.1.0	10.2.0
01/06/11	RP-52	RP-110818	294	-	ACK/NACK and CQI simultaneous transmission in ACK/NACK bundling in TDD	10.1.0	10.2.0
01/06/11	RP-52	RP-110823	295	-	UE specific disabling of UL DMRS sequence hopping	10.1.0	10.2.0
01/06/11	RP-52	RP-110821	296	-	PDSCH transmission in MBSFN subframes	10.1.0	10.2.0
01/06/11	RP-52	RP-110819	297	-	Introduction of PCMAX for PUSCH power scaling	10.1.0	10.2.0
01/06/11	RP-52	RP-110819	298	-	Power control for SR and ACK/NACK with PUCCH format 3	10.1.0	10.2.0
01/06/11	RP-52	RP-110819	299	2	CR on power control for HARQ-ACK transmission on PUCCH	10.1.0	10.2.0
01/06/11	RP-52	RP-110819	300	2	Correction to handling of search space overlap	10.1.0	10.2.0
01/06/11	RP-52	RP-110819	301	1	Correction to simultaneous transmission of SRS and PUCCH format 2/2a/2b	10.1.0	10.2.0
01/06/11	RP-52	RP-110819	302	1	Correction for Simultaneous PUCCH and SRS Transmissions on CA	10.1.0	10.2.0
01/06/11	RP-52	RP-110821	303	-	Correction on 8Tx Codebook Sub-sampling for PUCCH Mode 1-1	10.1.0	10.2.0
01/06/11	RP-52	RP-110821	304	1	Corrections on CQI type in PUCCH mode 2-1 and clarification on simultaneous PUCCH and PUSCH transmission for UL-SCH subframe bundling	10.1.0	10.2.0
01/06/11	RP-52	RP-110818	305	1	Correction on UE behaviour upon reporting periodic CSI using PUCCH Mode1-1	10.1.0	10.2.0
01/06/11	RP-52	RP-110818	306	-	Clarification for the definition of CQI	10.1.0	10.2.0
01/06/11	RP-52	RP-110818	307	-	Clarification for the definition of Precoding Matrix Indicator	10.1.0	10.2.0
01/06/11	RP-52	RP-110819	308	-	Simultaneous SRS transmissions in more than one cell	10.1.0	10.2.0
01/06/11	RP-52	RP-110819	310	1	Miscellaneous Corrections for TS 36.213	10.1.0	10.2.0
01/06/11	RP-52	RP-110821	311	1	Configuration of pmi-RI-Report	10.1.0	10.2.0
01/06/11	RP-52	RP-110819	312	1	Correction on the support of PUCCH format 3 and channel selection	10.1.0	10.2.0
01/06/11	RP-52	RP-110821	313	-	Correction on UE behaviour during DM-RS transmission on subframes carrying synchronization signals	10.1.0	10.2.0
01/06/11	RP-52	RP-110820	314	1	36.213 CR on antenna selection	10.1.0	10.2.0
01/06/11	RP-52	RP-110823	316	1	Number of HARQ process for UL spatial multiplexing	10.1.0	10.2.0
01/06/11	RP-52	RP-110819	317	-	PUCCH format 3 Fallback procedure in TDD	10.1.0	10.2.0
01/06/11	RP-52	RP-110819	318	-	Clarification on CSI reporting under an invalid downlink subframe	10.1.0	10.2.0
01/06/11	RP-52	RP-110819	320	-	Multiple Aperiodic SRS Triggers for Same Configuration	10.1.0	10.2.0
01/06/11	RP-52	RP-110823	321	-	UE antenna switch in UL MIMO	10.1.0	10.2.0
01/06/11	RP-52	RP-110819	322	-	UE behaviour for PDSCH reception with limited soft buffer in CA	10.1.0	10.2.0
01/06/11	RP-52	RP-110859	323	-	Joint transmission of ACK/NACK and SR or CSI with PUCCH format 3 and channel selection	10.1.0	10.2.0
15/09/11	RP-53	RP-111229	277	1	Correction to reception of PRS in MBSFN subframes	10.2.0	10.3.0
15/09/11	RP-53	RP-111230	325	3	Corrections on UE procedure for reporting HARQ-ACK	10.2.0	10.3.0
15/09/11	RP-53	RP-111230	326	2	Corrections on Physical Uplink Control Channel Procedure	10.2.0	10.3.0
15/09/11	RP-53	RP-111231	331	1	Correction to uplink transmission scheme usage for random access response and PHICH-triggered retransmissions	10.2.0	10.3.0
15/09/11	RP-53	RP-111229	336	-	Corrections on transmission mode 9	10.2.0	10.3.0
15/09/11	RP-53	RP-111230	339	-	Corrections on HARQ-ACK codebook size determination	10.2.0	10.3.0
15/09/11	RP-53	RP-111230	340	-	Corrections on TDD PUCCH format 1b with channel selection and HARQ-ACK transmission on PUSCH	10.2.0	10.3.0
15/09/11	RP-53	RP-111230	341	-	Corrections on NACK generation	10.2.0	10.3.0

Change history							
Date	**TSG #**	**TSG Doc.**	**CR**	**Rev**	**Subject/Comment**	**Old**	**New**
15/09/11	RP-53	RP-111230	342	-	Corrections on power headroom reporting	10.2.0	10.3.0
15/09/11	RP-53	RP-111229	346	-	Correction on TBS translation table	10.2.0	10.3.0
15/09/11	RP-53	RP-111229	347	2	Correction to the condition of enabling PMI feedback	10.2.0	10.3.0
15/09/11	RP-53	RP-111232	348	-	Miscellaneous corrections to 36.213	10.2.0	10.3.0
15/09/11	RP-53	RP-111229	349	-	Corrections on PUSCH and PUCCH modes	10.2.0	10.3.0
15/09/11	RP-53	RP-111231	350	1	CR on UL HARQ ACK determination	10.2.0	10.3.0
15/09/11	RP-53	RP-111231	351	1	Correction on UL DMRS resources for PHICH-triggered retransmission	10.2.0	10.3.0
15/09/11	RP-53	RP-111230	352	-	Clarification on the common search space description	10.2.0	10.3.0
15/09/11	RP-53	RP-111232	353	1	Clarification on ambiguous DCI information between UE-specific search space and common search space for DCI formats 0 and 1A	10.2.0	10.3.0
15/09/11	RP-53	RP-111229	354	-	Clarification of Reference PDSCH Power for CSI-RS based CSI Feedback	10.2.0	10.3.0
15/09/11	RP-53	RP-111230	355	2	Corrections on reporting Channel State Information	10.2.0	10.3.0
05/12/11	RP-54	RP-111669	324	3	Accumulation of power control commands from DCI format 3/3A	10.3.0	10.4.0
05/12/11	RP-54	RP-111666	357	1	Miscellaneous corrections on uplink power control	10.3.0	10.4.0
05/12/11	RP-54	RP-111666	358	-	Corrections on N_c^{received}	10.3.0	10.4.0
05/12/11	RP-54	RP-111666	359	-	Corrections on TDD PUCCH format 1b with channel selection and two configured serving cells	10.3.0	10.4.0
05/12/11	RP-54	RP-111666	360	-	Corrections on the notation of k and k_m	10.3.0	10.4.0
05/12/11	RP-54	RP-111668	361	1	Corrections on PUCCH mode 2-1	10.3.0	10.4.0
05/12/11	RP-54	RP-111668	362	3	A correction to PDSCH transmission assumption for CQI calculation	10.3.0	10.4.0
05/12/11	RP-54	RP-111666	363	1	Corrections on PUCCH Resource Notation	10.3.0	10.4.0
05/12/11	RP-54	RP-111667	364	-	Correction on the notation of SRS transmission comb	10.3.0	10.4.0
05/12/11	RP-54	RP-111666	365	-	Clarification on the HARQ-ACK procedure of TDD UL-DL configuration 5	10.3.0	10.4.0
05/12/11	RP-54	RP-111666	366	2	Clarification on the determination of resource for PUCCH Format 1b with channel selection in TDD mode	10.3.0	10.4.0
05/12/11	RP-54	RP-111666	367	1	Correction on HARQ-ACK procedure	10.3.0	10.4.0
05/12/11	RP-54	RP-111666	368	-	Correction for A/N on PUSCH with W=1,2 in case of TDD channel selection	10.3.0	10.4.0
05/12/11	RP-54	RP-111668	369	-	Clarification of PUCCH 2-1 Operation	10.3.0	10.4.0
05/12/11	RP-54	RP-111668	370	1	Correction on PMI index	10.3.0	10.4.0
05/12/11	RP-54	RP-111666	371	2	Correction to periodic CSI reports for carrier aggregation	10.3.0	10.4.0
05/12/11	RP-54	RP-111666	373	1	Removal of square bracket in HARQ-ACK procedure	10.3.0	10.4.0
05/12/11	RP-54	RP-111666	374	1	Clarification on UE's capability of supporting PUCCH format 3	10.3.0	10.4.0
05/12/11	RP-54	RP-111666	375	1	Clarifications of UE behavior on PUSCH power control	10.3.0	10.4.0
28/02/12	RP-55	RP-120286	376	1	RNTI Configuration associated with DL Resource Allocation Type 2	10.4.0	10.5.0
28/02/12	RP-55	RP-120283	377	2	Correction for ACK/NACK related procedure in case of TDD UL-DL configuration 0	10.4.0	10.5.0
13/06/12	RP-56	RP-120737	378	3	Correction of FDD channel selection HARQ-ACK and SR transmission	10.5.0	10.6.0
13/06/12	RP-56	RP-120738	379	-	Removal of description with square brackets	10.5.0	10.6.0
13/06/12	RP-56	RP-120738	381	-	Correction on transmission mode 9 with a single antenna port transmission	10.5.0	10.6.0
04/09/12	RP-57	RP-121265	382	-	Clarification of codebook subsampling for PUCCH 2-1	10.6.0	10.7.0
04/09/12	RP-57	RP-121266	383	-	Correction to UE transmit antenna selection	10.6.0	10.7.0
04/09/12	RP-57	RP-121264	384	-	TDD HARQ-ACK procedure for PUCCH format 1b with channel selection in carrier aggregation	10.6.0	10.7.0
04/09/12	RP-57	RP-121265	385	-	Corrections for Handling CSI-RS patterns	10.6.0	10.7.0
04/09/12	RP-57	RP-121264	386	1	Reference serving cell for pathloss estimation	10.6.0	10.7.0
04/09/12	RP-57	RP-121264	387	-	Power control for PUCCH format 3 with single configured cell	10.6.0	10.7.0
04/09/12	RP-57	RP-121264	388	-	ACK/NACK resource in case of channel selection	10.6.0	10.7.0
04/09/12	RP-57	RP-121274	380	4	Introduction of an additional special subframe configuration	10.7.0	11.0.0
04/09/12	RP-57	RP-121272	389	-	Introduction of Rel-11 features	10.7.0	11.0.0
04/12/12	RP-58	RP-121839	393	-	Correction to the parameter ue-Category-v10xy	11.0.0	11.1.0
04/12/12	RP-58	RP-121837	395	-	Correction of reference signal scrambling sequence initialization for SPS in transmission mode 7	11.0.0	11.1.0
04/12/12	RP-58	RP-121846	396	-	Finalisation for introducing Rel-11 features	11.0.0	11.1.0
26/02/13	RP-59	RP-130254	398	-	Correction on UE procedure for reporting HARQ-ACK	11.1.0	11.2.0
26/02/13	RP-59	RP-130252	400	-	Corrections for SRS power scaling in UpPTS	11.1.0	11.2.0
26/02/13	RP-59	RP-130252	403	-	CR on UE specific search and Common search space overlap on PDCCH	11.1.0	11.2.0
26/02/13	RP-59	RP-130358	404	-	Additional clarifications/corrections for introducing Rel-11 features	11.1.0	11.2.0
11/06/13	RP-60	RP-130752	405	-	Correction to EPDCCH monitoring in case of cross-carrier scheduling	11.2.0	11.3.0

Change history							
Date	**TSG #**	**TSG Doc.**	**CR**	**Rev**	**Subject/Comment**	**Old**	**New**
11/06/13	RP-60	RP-130751	407	1	Correction on the RI bit width	11.2.0	11.3.0
11/06/13	RP-60	RP-130750	408	-	Correction on parallel reception of PDSCH and Msg 2	11.2.0	11.3.0
11/06/13	RP-60	RP-130747	409	-	Correction on zero power CSI-RS resource configuration	11.2.0	11.3.0
11/06/13	RP-60	RP-130750	410	1	Corrections on different TDD UL-DL configurations on different bands	11.2.0	11.3.0
11/06/13	RP-60	RP-130752	411	-	Correction on EPDCCH PRB pair indication	11.2.0	11.3.0
11/06/13	RP-60	RP-130752	412	-	Correction on EPDCCH hashing function	11.2.0	11.3.0
11/06/13	RP-60	RP-130752	413	-	Correction on PUCCH resource determination for FDD EPDCCH	11.2.0	11.3.0
11/06/13	RP-60	RP-130752	414	2	CR on ambiguity in EPDCCH decoding candidates under two overlapped EPDCCH resource sets	11.2.0	11.3.0
11/06/13	RP-60	RP-130749	415	-	Removal of the case for spatial domain bundling in TDD UL/DL configuration 0	11.2.0	11.3.0
11/06/13	RP-60	RP-130752	416	-	Corrections to EPDCCH PRB pair indication	11.2.0	11.3.0
11/06/13	RP-60	RP-130753	417	1	Correction to PUSCH/PUCCH transmit power after PRACH power ramping	11.2.0	11.3.0
11/06/13	RP-60	RP-130747	418	-	CR on RI-Reference CSI Process with Subframe Sets	11.2.0	11.3.0
11/06/13	RP-60	RP-130747	420	-	Correction on UE-specific RS scrambling for SPS PDSCH in TM10	11.2.0	11.3.0
11/06/13	RP-60	RP-130747	421	-	CR on resolving ambiguous UE capability signaling for CoMP	11.2.0	11.3.0
11/06/13	RP-60	RP-130750	422	-	Correction of valid downlink subframe	11.2.0	11.3.0
11/06/13	RP-60	RP-130749	424	-	Correction on HARQ-ACK transmission for a UE configured with PUCCH format 3	11.2.0	11.3.0
11/06/13	RP-60	RP-130750	425	-	Correction of PHICH resource for half duplex TDD UE	11.2.0	11.3.0
11/06/13	RP-60	RP-130750	426	-	Correction on n_{HARQ} for TDD CA with different UL-DL configurations	11.2.0	11.3.0
11/06/13	RP-60	RP-130750	427	-	Correction on implicit HARQ-ACK resource determination for PUCCH format 1b with channel selection for TDD CA with different UL-DL configurations	11.2.0	11.3.0
11/06/13	RP-60	RP-130750	428	-	Correction on SRS power scaling with multiple TAGs	11.2.0	11.3.0
11/06/13	RP-60	RP-130747	429	-	Correction on MBSFN subframe configuration	11.2.0	11.3.0
11/06/13	RP-60	RP-130749	430	-	CR on SCell activation timing	11.2.0	11.3.0
03/09/13					MCC clean-up	11.3.0	11.4.0
03/09/13	RP-61	RP-131249	432	-	Correction for EPDCCH Search Space	11.3.0	11.4.0
03/09/13	RP-61	RP-131250	433	-	Correction to QCL behaviour on CRS	11.3.0	11.4.0
03/09/13	RP-61	RP-131250	434	-	Correction on PUCCH power control	11.3.0	11.4.0
03/09/13	RP-61	RP-131248	435	-	Correction on the ratio of PDSCH EPRE to CRS EPRE for TM10	11.3.0	11.4.0
03/09/13	RP-61	RP-131249	436	-	CR on EPDCCH Search Space for Cross-Carrier Scheduling	11.3.0	11.4.0
03/09/13	RP-61	RP-131249	437	-	Correction to the UE behaviour in case of collision between PRS and EPDCCH in different CP case	11.3.0	11.4.0
03/09/13	RP-61	RP-131249	438	-	On correction to higher layer parameter name for EPDCCH resource mapping	11.3.0	11.4.0
03/09/13	RP-61	RP-131248	439	-	Correction to PDSCH mapping for CoMP	11.3.0	11.4.0
03/12/13	RP-62	RP-131893	440	1	Correction on parameter ue-Category	11.4.0	11.5.0
03/12/13	RP-62	RP-131892	442	1	Correction on determination of modulation order and transport block size	11.4.0	11.5.0
03/12/13	RP-62	RP-132024	445	3	Correction on CSI reporting type and parameters	11.4.0	11.5.0
03/12/13	RP-62	RP-131894	446	-	Correction on deriving the length of the non-MBSFN region	11.4.0	11.5.0
03/12/13	RP-62	RP-131896	431	5	Introduction of Rel 12 feature for Downlink MIMO Enhancement	11.5.0	12.0.0
03/03/14	RP-63	RP-140286	447	-	Correction to CSI Reporting	12.0.0	12.1.0
03/03/14	RP-63	RP-140291	448	-	Clarification on PUCCH Mode 1-1 for 4Tx Dual Codebook	12.0.0	12.1.0
03/03/14	RP-63	RP-140287	450	1	Common search space monitoring for MBMS	12.0.0	12.1.0
03/03/14	RP-63	RP-140290	452	-	Introduction of new UE categories	12.0.0	12.1.0
03/03/14	RP-63	RP-140288	455	1	Modification to I_SRS = 0 for trigger type 1 SRS and TDD	12.0.0	12.1.0
03/03/14	RP-63	RP-140289	458	-	Correction to CSI processing in TM10	12.0.0	12.1.0
10/06/14	RP-64	RP-140858	459	1	Clarification on PUCCH reporting type payload size	12.1.0	12.2.0
10/06/14	RP-64	RP-140858	461	-	Clarification on SRS colliding with PUCCH in the same cell when the UE is configured with multiple TAGs	12.1.0	12.2.0
10/06/14	RP-64	RP-140858	462	1	Clarification on SRS antenna switching	12.1.0	12.2.0
10/06/14	RP-64	RP-140862	463	-	Introduction of Rel-12 LTE-Advanced features in 36.213	12.1.0	12.2.0
10/09/14	RP-65	RP-141479	464	-	Correction on SRS transmission for TDD-FDD CA	12.2.0	12.3.0
10/09/14	RP-65	RP-141478	465	-	Correction on beta_{offset}^{HARQ-ACK} determination for a UE configured with two uplink power control subframe sets	12.2.0	12.3.0
10/09/14	RP-65	RP-141478	466	-	Corrections for TDD eIMTA	12.2.0	12.3.0
10/09/14	RP-65	RP-141479	467	3	CR on HARQ-ACK Multiplexing in PUSCH for TDD-FDD CA	12.2.0	12.3.0
10/09/14	RP-65	RP-141474	469	-	Correction to UCI embedding in case of a single serving cell and simultaneous PUSCH and PUCCH transmission	12.2.0	12.3.0
10/09/14	RP-65	RP-141478	470	-	Corrections on UL-reference UL/DL configuration	12.2.0	12.3.0
10/09/14	RP-65	RP-141473	471	-	CR for Clarification of special subframe and usage alignment	12.2.0	12.3.0

Change history							
Date	**TSG #**	**TSG Doc.**	**CR**	**Rev**	**Subject/Comment**	**Old**	**New**
10/09/14	RP-65	RP-141485	472	-	Introduction of low-cost MTC and 256QAM features	12.2.0	12.3.0
08/12/14	RP-66	RP-142104	482	5	Introduction of Dual Connectivity, Small Cell Enhancements, NAICS, eIMTA, and TDD-FDD CA features	12.3.0	12.4.0
08/12/14	RP-66	RP-142097	487	1	Clarification of periodic CSI feedback for subband CQI and PMI	12.3.0	12.4.0
08/12/14	RP-66	RP-142100	491	-	Correction of the parameter CSIProcessIndex	12.3.0	12.4.0
09/03/15	RP-67	RP-150366	492	2	Introduction of D2D feature into 36.213	12.4.0	12.5.0
09/03/15	RP-67	RP-150363	494	1	Correction to PUCCH procedures in case of FDD Pcell and TDD Scell in TDD-FDD CA	12.4.0	12.5.0
09/03/15	RP-67	RP-150364	498	-	Correction on higher layer parameter names for 256QAM	12.4.0	12.5.0
09/03/15	RP-67	RP-150359	500	-	TM10 CSI-IM Interference Measurements	12.4.0	12.5.0
09/03/15	RP-67	RP-150358	502	-	Clarification on common search reception related to MBMS	12.4.0	12.5.0
09/03/15	RP-67	RP-150364	503	-	Correction to Discovery in Small Cell Enhancement feature	12.4.0	12.5.0
09/03/15	RP-67	RP-150365	504	1	Corrections to Dual Connectivity feature	12.4.0	12.5.0
15/06/15	RP-68	RP-150931	493	2	Clarification on HARQ-ACK repetition	12.5.0	12.6.0
15/06/15	RP-68	RP-150932	497	3	Clarification on PUCCH Format 3 Resource Derivation for TDD UL/DL Configuration 5	12.5.0	12.6.0
15/06/15	RP-68	RP-150933	506	-	Clarification on the PRACH power in subframe i2-1 for PCM2	12.5.0	12.6.0
15/06/15	RP-68	RP-150933	507	-	Clarification on the MTA operation in PCM1	12.5.0	12.6.0
15/06/15	RP-68	RP-150933	512	-	Correction of higher layer parameter names in dual connectivity	12.5.0	12.6.0
15/06/15	RP-68	RP-150935	513	1	Correction on UE procedure of determining subframe pool for PSCCH and PSSCH in ProSe	12.5.0	12.6.0
15/06/15	RP-68	RP-150935	514	1	Correction on UE procedure of transmitting PSCCH in ProSe	12.5.0	12.6.0
15/06/15	RP-68	RP-150933	515	1	Correction on UL Power Control for Synchronous Dual Connectivity	12.5.0	12.6.0
15/06/15	RP-68	RP-150933	516	1	Correction on UL Power Control for Asynchronous Dual Connectivity	12.5.0	12.6.0
15/06/15	RP-68	RP-150937	517	-	Correction to Rel-12 UE category signal name	12.5.0	12.6.0
15/06/15	RP-68	RP-150936	520	-	Corrections on eIMTA RRC parameter naming	12.5.0	12.6.0
15/06/15	RP-68	RP-150933	521	-	Correction on Closed Loop Antenna Selection for Dual Connectivity	12.5.0	12.6.0
15/06/15	RP-68	RP-150935	523	-	Alignment of Prose parameter names	12.5.0	12.6.0
14/09/15	RP-69	RP-151470	525	-	UE processing time relaxation on Type 2 Power Headroom Reporting	12.6.0	12.7.0
14/09/15	RP-69	RP-151468	527	-	Correction of ProSe parameters	12.6.0	12.7.0
14/09/15	RP-69	RP-151471	528	2	Clarification on power control for PCM2	12.6.0	12.7.0
07/12/15	RP-70	RP-152034	530	1	Clarification of PUCCH resource allocation related to EPDCCH SCells	12.7.0	12.8.0
07/12/15	RP-70	RP-152037	531	-	Clarification on the parameter notations for eIMTA	12.7.0	12.8.0
07/12/15	RP-70	RP-152037	534	-	Correction on aperiodic CSI transmission without UL-SCH according to table 7.2.1-1C	12.7.0	12.8.0
07/12/15	RP-70	RP-152038	535	1	Introduction of new maximum TBS for TM9/10	12.7.0	12.8.0
07/12/15	RP-70	RP-152034	542	-	Clarification of PHICH resource assignement related to EPDCCH scheduled PUSCH	12.7.0	12.8.0
07/12/15	RP-70	RP-152036	543	1	Modify max TA for dual connectivity	12.7.0	12.8.0
07/12/15	RP-70	RP-152125	533	3	eD2D CR for 36.213	12.8.0	13.0.0
07/12/15	RP-70	RP-152031	536	-	Introduction of Rel 13 features for SC-PTM	12.8.0	13.0.0
07/12/15	RP-70	RP-152026	537	2	Introduction of LAA (PHY layer aspects)	12.8.0	13.0.0
07/12/15	RP-70	RP-152026	538	5	Introduction of LAA (eNB Channel Access Procedures)	12.8.0	13.0.0
07/12/15	RP-70	RP-152027	539	1	Introduction of Enhanced CA in Release 13	12.8.0	13.0.0
07/12/15	RP-70	RP-152025	541	1	Introduction of EB/FD-MIMO	12.8.0	13.0.0
26/01/16	Post RP-70				MCC update to show correct version of the spec in the headers of all subparts and get all of them aligned with coversheet	13.0.0	13.0.1

Change history							
Date	Meeting	TDoc	CR	Rev	Cat	Subject/Comment	New version
2016-03	RAN#71	RP-160359	546	-	F	Alignment eD2D CR for 36.213	13.1.0
2016-03	RAN#71	RP-160549	548	3	F	Clarification on PDSCH collision with PSS/SSS/PBCH	13.1.0
2016-03	RAN#71	RP-160357	550	1	F	Clarification on number of PRBs for PUCCH format 4	13.1.0
2016-03	RAN#71	RP-160357	554	2	F	Clarification on code rate for periodic CSI transmission on PUCCH format 4 and 5	13.1.0
2016-03	RAN#71	RP-160360	555	1	F	Clarification on Averaging of CSI Measurements in LAA	13.1.0
2016-03	RAN#71	RP-160357	559	-	F	Limit on number of periodic CSI reports	13.1.0
2016-03	RAN#71	RP-160357	560	1	F	Correction on Transmission Code Rate Determination	13.1.0
2016-03	RAN#71	RP-160360	562	-	F	CR on LAA defer and sensing duration	13.1.0
2016-03	RAN#71	RP-160357	563	-	F	Correction on aperiodic CSI only PUSCH without UL-SCH	13.1.0
2016-03	RAN#71	RP-160357	564	-	F	Correction on HARQ-ACK and periodic CSI transmission	13.1.0
2016-03	RAN#71	RP-160357	565	-	F	Correction on Simultaneous HARQ-ACK and P-CSI Transmission	13.1.0
2016-03	RAN#71	RP-160358	566	1	F	CR on MR support in TM9	13.1.0
2016-03	RAN#71	RP-160358	568	-	F	Correction on Subsampling of Class A Codebook	13.1.0
2016-03	RAN#71	RP-160360	569	-	F	CR on definition of LAA idle sensing for periods longer than one CCA slot	13.1.0
2016-03	RAN#71	RP-160360	570	-	F	Correction on total sensing and transmission time for Japan	13.1.0
2016-03	RAN#71	RP-160360	571	-	F	Correction on common DCI detection of LAA in 36.213	13.1.0
2016-03	RAN#71	RP-160360	572	-	F	CR on valid downlink subframe definition for TM9/10	13.1.0
2016-03	RAN#71	RP-160360	573	-	F	CR on eCCE of EPDCCH for partial subframe	13.1.0
2016-03	RAN#71	RP-160360	576	-	F	Correction on cross-carrier scheduling in LAA	13.1.0
2016-03	RAN#71	RP-160360	577	-	F	Correction on QCL type B for LAA	13.1.0
2016-03	RAN#71	RP-160358	578	-	F	Correction on Class B CSI reporting	13.1.0
2016-03	RAN#71	RP-160358	579	-	F	CR on CRI reporting for one CSI-RS ports (36.213)	13.1.0
2016-03	RAN#71	RP-160358	580	-	F	Correction to the condition of CRI updating restriction	13.1.0
2016-03	RAN#71	RP-160358	581	-	F	Correction to the additional UpPTS symbols for SRS	13.1.0
2016-03	RAN#71	RP-160358	582	-	F	Clarification on PUCCH mode 1-1 configuration	13.1.0
2016-03	RAN#71	RP-160360	584	-	F	Correction on EPDCCH assignment in LAA	13.1.0
2016-03	RAN#71	RP-160360	585	-	F	CR for LAA CW reset per AC in case of K attempts at CWmax	13.1.0
2016-03	RAN#71	RP-160358	586	-	F	Corrections to RI-inheritance	13.1.0
2016-03	RAN#71	RP-160358	587	-	F	CR on CSI-RS resource in 36.213	13.1.0
2016-03	RAN#71	RP-160358	588	-	F	CR on mismatch between 36.213 and 36.331	13.1.0
2016-03	RAN#71	RP-160357	589	-	F	Correction on CSI transmission for eCA in 36.213	13.1.0
2016-03	RAN#71	RP-160358	590	-	F	Clarification on joint reports of CRI	13.1.0
2016-03	RAN#71	RP-160358	591	-	F	Correction to RI reference CSI process	13.1.0
2016-03	RAN#71	RP-160358	592	-	F	Corrections to Class B CSI reporting on PUCCH	13.1.0
2016-03	RAN#71	RP-160357	594	-	F	Correction on PUCCH transmission and (E)PDCCH disabling in eCA	13.1.0
2016-03	RAN#71	RP-160358	595	-	F	CSI-RS in DwPTS	13.1.0
2016-03	RAN#71	RP-160357	596	1	F	Correction on shortened PUCCH format for Rel-13 CA	13.1.0
2016-03	RAN#71	RP-160357	598	-	F	Correction on HARQ-ACK bit concatenation for PUCCH format 4 and 5	13.1.0
2016-03	RAN#71	RP-160360	599	-	F	Corrections for LAA Energy Detection Threshold	13.1.0
2016-03	RAN#71	RP-160360	0600	-	F	Correction on channel access procedure for DL LBT	13.1.0
2016-03	RAN#71	RP-160360	0601	-	F	Correction on CWS adjustment in LAA	13.1.0
2016-03	RAN#71	RP-160360	0602	-	F	Corrections for Type B Multi-channel access procedure for an LAA SCell	13.1.0
2016-03	RAN#71	RP-160358	0603	-	F	CR on Class B CQI measurement correction	13.1.0
2016-03	RAN#71	RP-160360	0604	1	F	Corrections for PDCCH and EPDCCH monitoring on an LAA SCell in 36.213	13.1.0
2016-03	RAN#71	RP-160363	0605	-	A	Clarification on T_threshold in dual connectivity	13.1.0
2016-03	RAN#71	RP-160361	0540	6	B	Introduction of further LTE Physical Layer Enhancements for MTC	13.1.0
2016-03	Post RAN#71					MCC update to show correct version of the spec in the headers of all subparts and get all of them aligned with coversheet	13.1.1
2016-06	RAN#72	RP-161062	0575	2	F	Correction on SPS HARQ-ACK bit handling in case of dynamic codebook configuration of eCA in 36.213	13.2.0
2016-06	RAN#72	RP-161063	0593	1	F	Correction to the UE's assumption on DMRS ports	13.2.0
2016-06	RAN#72	RP-161062	0608	1	F	Correction on HARQ-ACK ordering in case of semi-static codebook configuration of eCA	13.2.0
2016-06	RAN#72	RP-161062	0610	1	F	Correction on timing for secondary cell activation/deactivation for eCA in 36.213	13.2.0
2016-06	RAN#72	RP-161068	0611	-	A	Correction on RRC parameter for configuring new TBSs	13.2.0
2016-06	RAN#72	RP-161063	0614	-	F	Correction to rank 5-8 FD-MIMO CSI feedback	13.2.0
2016-06	RAN#72	RP-161062	0615	-	F	Correction on aperiodic CSI reporting mode 1-0 and 1-1	13.2.0
2016-06	RAN#72	RP-161066	0616	-	F	Correction of paging PDSCH transmission for MTC UE	13.2.0
2016-06	RAN#72	RP-161066	0618	-	F	Update RRC parameter names for MTC	13.2.0
2016-06	RAN#72	RP-161066	0619	-	F	PUCCH repetition for Msg4 for MTC	13.2.0

Change history							
Date	Meeting	TDoc	CR	Rev	Cat	Subject/Comment	New version
2016-06	RAN#72	RP-161066	0620	-	F	MPDCCH repetition for paging and random access for MTC	13.2.0
2016-06	RAN#72	RP-161066	0621	1	F	MCS field in DCI format 6-2 for paging for MTC	13.2.0
2016-06	RAN#72	RP-161062	0622	-	F	Coding of higher layer parameter codebooksizeDetermination-r13	13.2.0
2016-06	RAN#72	RP-161062	0623	1	F	Corrections on Simultaneous HARQ-ACK and P-CSI in 36.213	13.2.0
2016-06	RAN#72	RP-161069	0624	-	F	Corrections SRS dropping in CA in 36.213	13.2.0
2016-06	RAN#72	RP-161065	0625	-	D	Correction to the usage of undefined terminology "channel"	13.2.0
2016-06	RAN#72	RP-161065	0626	-	F	Correction on channel access procedure after an additional defer duration for DL LBT	13.2.0
2016-06	RAN#72	RP-161284	0627	1	F	Clarification for LAA CSI processing	13.2.0
2016-06	RAN#72	RP-161065	0628	-	F	MCS Table for Initial Partial TTI in LAA	13.2.0
2016-06	RAN#72	RP-161063	0629	-	F	Correction on the linkage between CSI-RS and CSI-IM for Class B	13.2.0
2016-06	RAN#72	RP-161062	0630	-	F	Correction for HARQ-ACK Codebook Determination in eCA	13.2.0
2016-06	RAN#72	RP-161065	0631	-	F	Clarification on "special subframe" for frame structure type 3 in 36.213	13.2.0
2016-06	RAN#72	RP-161062	0632	-	F	Corrections on simultaneous transmission of HARQ-ACK and SR in 36.213	13.2.0
2016-06	RAN#72	RP-161066	0633	2	F	MDPCCH candidate overflow monitoring correction for eMTC	13.2.0
2016-06	RAN#72	RP-161066	0634	-	F	Correction to TS 36.213 for eMTC	13.2.0
2016-06	RAN#72	RP-161066	0635	1	F	Correction on M-PDCCH case definition	13.2.0
2016-06	RAN#72	RP-161066	0636	-	F	Correction on CSS for MPDCCH configured by temporary C-RNTI and Type0 MPDCCH CSS resource	13.2.0
2016-06	RAN#72	RP-161066	0637	2	F	Correction on collision of dynamically scheduled data and semi-statically scheduled data for Rel-13 eMTC	13.2.0
2016-06	RAN#72	RP-161066	0638	1	F	Correction on PDSCH transmission timing for Rel-13 eMTC	13.2.0
2016-06	RAN#72	RP-161066	0639	-	F	On the collision between eMTC SIB and MPDCCH/PDSCH in TS 36.213	13.2.0
2016-06	RAN#72	RP-161066	0639	-	F	On the collision between eMTC SIB and MPDCCH/PDSCH in TS 36.213	13.2.0
2016-06	RAN#72	RP-161066	0640	-	F	Collision between PUCCH format 2 and PDSCH with repetitions	13.2.0
2016-06	RAN#72	RP-161066	0641	-	F	Clarification of TM1/2/6 on MBSFN subframes	13.2.0
2016-06	RAN#72	RP-161066	0642	-	F	Correction of fallback behavior for TM9	13.2.0
2016-06	RAN#72	RP-161066	0643	-	F	Correction on RV and MPDCCH starting position	13.2.0
2016-06	RAN#72	RP-161066	0644	1	F	Collision between PSS/SSS/PBCH and PDSCH for MTC	13.2.0
2016-06	RAN#72	RP-161065	0645	-	F	CR for 36.213 on multi-channel access procedure Type A2 in LAA	13.2.0
2016-06	RAN#72	RP-161066	0646	-	F	CR for TS36.213 related to 2+4 PRB set	13.2.0
2016-06	RAN#72	RP-161063	0647	-	F	CR on CSI-RS ID configuration for TM9 in TS 36.213	13.2.0
2016-06	RAN#72	RP-161065	0649	-	F	Initial CCA Behaviour in the Channel Access Procedure	13.2.0
2016-06	RAN#72	RP-161065	0650	-	F	CR on clarification for channel sensing	13.2.0
2016-06	RAN#72	RP-161065	0651	-	F	CR for the contention window adjustment procedure in LAA downlink channel access	13.2.0
2016-06	RAN#72	RP-161066	0653	1	F	eMTC MPDCCH corrections for 36.213	13.2.0
2016-06	RAN#72	RP-161064	0654	-	F	Correction on search space to decode the PDCCH configured by the SC-N-RNTI	13.2.0
2016-06	RAN#72	RP-161067	0656	1	B	Introduction of NB-IoT	13.2.0
2016-06	RAN#72	RP-161066	0657	-	F	Starting OFDM symbol for SIB1-BR for BL/CE UE	13.2.0
2016-06	RAN#72	RP-161066	0658	-	F	Collision between SIB1-BR and SI message for BL/CE UE	13.2.0
2016-06	RAN#72	RP-161066	0660	3	F	MPDCCH search space for random access in connected mode for BL/CE UE	13.2.0
2016-06	RAN#72	RP-161066	0662	-	F	Definition of number of MPDCCH repetitions for BL/CE UE	13.2.0
2016-06	RAN#72	RP-161066	0663	-	F	PRB locations for Type0 MPDCCH search space for BL/CE UE	13.2.0
2016-06	RAN#72	RP-161063	0666	-	F	CR on FD-MIMO codebooks (36.213)	13.2.0
2016-06	RAN#72	RP-161063	0667	-	F	CR on CSI-Reporting-Type in TS 36.213	13.2.0
2016-06	RAN#72	RP-161070	0668	-	B	Introduction of 60ms periodicity for wideband CQI/PMI reporting	13.2.0
2016-06	RAN#72	RP-161066	0669	-	F	Introduction of 60ms periodicity for wideband CQI/PMI reporting	13.2.0
2016-06	RAN#72	RP-161066	0670	-	F	On MPDCCH AL and search space for 8 EREGs per ECCE in TS 36.213	13.2.0
2016-06	RAN#72	RP-161066	0671	-	F	CR on MPDCCH quasi co-location	13.2.0
2016-06	RAN#72	RP-161063	0672	-	F	Correction on UE assumption on DMRS ports	13.2.0
2016-06	RAN#72	RP-161066	0673	-	F	A-CSI Reporting for TM6	13.2.0
2016-06	RAN#72	RP-161066	0674	-	F	Corrections on CSI Reporting	13.2.0
2016-06	RAN#72	RP-161066	0675	-	F	Correction on RV determination for PUSCH in TS 36.213	13.2.0
2016-06	RAN#72	RP-161066	0677	-	F	Clarification on Msg3 PUSCH repetition level in TS 36.213	13.2.0
2016-06	RAN#72	RP-161066	0678	-	F	Correction on SRS frequency location in TS 36.213	13.2.0
2016-06	RAN#72	RP-161066	0679	-	F	Correction on PDSCH reception timing for eMTC	13.2.0
2016-06	RAN#72	RP-161066	0680	1	F	Correcting configuration parameter for number of PRB-pairs	13.2.0
2016-06	RAN#72	RP-161066	0681	-	F	Clarification on starting subframe for MPDCCH	13.2.0
2016-06	RAN#72	RP-161066	0682	-	F	MCS for Random Access Response Grant	13.2.0
2016-06	RAN#72	RP-161066	0683	2	F	Correction on UCI multiplexing on PUSCH	13.2.0
2016-06	RAN#72	RP-161061	0684	-	F	Correction on RLM for PSCell in dual connectivity	13.2.0

Change history							
Date	Meeting	TDoc	CR	Rev	Cat	Subject/Comment	New version
2016-06	RAN#72	RP-161066	0685	-	F	Correction on PDSCH transmission scheme assumed for TM9 CSI reference resource in TS 36.213	13.2.0
2016-06	RAN#72	RP-161065	0686	-	F	CR on clarification for channel sensing	13.2.0
2016-06	RAN#72	RP-161065	0687	-	F	CR on CWp adjustment	13.2.0
2016-06	RAN#72	RP-161066	0688	-	F	Clarification of CSI measurements	13.2.0
2016-09	RAN#73	RP-161563	0689	1	F	Correction on random access procedure for NB-IoT on TS 36.213	13.3.0
2016-09	RAN#73	RP-161563	0690	-	F	Correction on NPDCCH related procedure on TS 36.213	13.3.0
2016-09	RAN#73	RP-161563	0691	-	F	Corrections to RRC parameter names for NB-IoT in TS 36.213	13.3.0
2016-09	RAN#73	RP-161563	0692	1	F	Corrections on NPDSCH related procedure in TS 36.213	13.3.0
2016-09	RAN#73	RP-161560	0693	-	F	Correction on FD-MIMO codebook in 36.213	13.3.0
2016-09	RAN#73	RP-161560	0694	-	F	Correction on RRC paremeters for SRS enhancement in 36.213	13.3.0
2016-09	RAN#73	RP-161562	0695	-	F	Transport block size determination for Msg2	13.3.0
2016-09	RAN#73	RP-161563	0696	-	F	Correction on NPUSCH related procedure on TS 36.213	13.3.0
2016-09	RAN#73	RP-161562	0698	-	F	Correction on the reference of narrowband definition in TS 36.213	13.3.0
2016-09	RAN#73	RP-161562	0699	-	F	Correction on the relationship between IMCS and ITBS for DCI format 6-1A in TS 36.213	13.3.0
2016-09	RAN#73	RP-161562	0700	1	F	Correction on the scrambling initialization for SIB1-BR and SI for eMTC in TS 36.213	13.3.0
2016-09	RAN#73	RP-161563	0701	-	F	Corrections on NPDCCH search space for random access in connected mode in TS 36.213	13.3.0
2016-09	RAN#73	RP-161558	0706	1	A	Correction on storing soft channel bits for different UE categories in Rel-13	13.3.0
2016-09	RAN#73	RP-161560	0708	-	F	Correction on the citation of table indexs for mapping of ICRI to MCRI	13.3.0
2016-09	RAN#73	RP-161560	0710	-	F	Corrections on Codebooks in 36.213	13.3.0
2016-09	RAN#73	RP-161562	0711	-	F	Default max number of PUSCH repetitions for Msg3 for BL/CE UE	13.3.0
2016-09	RAN#73	RP-161562	0714	1	F	PDSCH start subframe in TDD for BL/CE UE	13.3.0
2016-09	RAN#73	RP-161562	0715	-	F	Repetition with aperiodic CSI for BL/CE UE	13.3.0
2016-09	RAN#73	RP-161561	0718	-	F	Correction on "special subframe" for frame structure type 3 in 36.213 for Rel-13 LAA	13.3.0
2016-09	RAN#73	RP-161559	0719	-	F	Clarification on HARQ-ACK transmission	13.3.0
2016-09	RAN#73	RP-161562	0720	1	F	Correction for UL grant size in RAR	13.3.0
2016-09	RAN#73	RP-161562	0721	2	F	MBSFN subframes and SIB2 decoding	13.3.0
2016-09	RAN#73	RP-161562	0722	1	F	Overriding of invalid subframe for msg3 PUSCH when R=1	13.3.0
2016-09	RAN#73	RP-161562	0723	-	F	On the mapping of TPC command field to power correction values in TS 36.213	13.3.0
2016-09	RAN#73	RP-161562	0724	-	F	Correction on the MPDCCH scheduling Paging in special subframe in TS 36.213	13.3.0
2016-09	RAN#73	RP-161562	0725	1	F	Clarification of valid subframe in eMTC	13.3.0
2016-09	RAN#73	RP-161563	0726	-	F	Quasi-colocation of NB-IoT antenna ports	13.3.0
2016-09	RAN#73	RP-161562	0728	1	F	PUCCH resource allocation	13.3.0
2016-09	RAN#73	RP-161562	0729	1	F	RV version for PDSCH carrying paging	13.3.0
2016-09	RAN#73	RP-161735	0730	1	F	Missing definition of higher layer parameter eutra-CRS-SequenceInfo	13.3.0
2016-09	RAN#73	RP-161563	0731	-	F	PUSCH timing delay for NB-IoT	13.3.0
2016-09	RAN#73	RP-161562	0732	-	F	RV Cycling for PUSCH and PDSCH	13.3.0
2016-09	RAN#73	RP-161563	0734	-	F	Clarification of scheduling delay	13.3.0
2016-09	RAN#73	RP-161562	0736	-	F	Clarification on MPDCCH monitoring on SFN rollover and search space overlap	13.3.0
2016-09	RAN#73	RP-161562	0737	-	F	PUCCH transmission and invalid subframes	13.3.0
2016-09	RAN#73	RP-161562	0738	-	F	SRS bit in DCI	13.3.0
2016-09	RAN#73	RP-161563	0739	-	F	Clarification of NB-IoT DL subframe configuration	13.3.0
2016-09	RAN#73	RP-161560	0740	-	F	Correction on FD-MIMO codebooks	13.3.0
2016-09	RAN#73	RP-161561	0741	1	F	CR on LAA post transmission backoff	13.3.0
2016-09	RAN#73	RP-161797	0745	1	F	CR to remove the incorrect implementation of LAA defer and sensing duration introduced by the unapproved CR R1-161166	13.3.0
2016-12	RAN#74	RP-162359	0746	-	F	Correction on the determination of NPDCCH candidates	13.4.0
2016-12	RAN#74	RP-162361	0749	2	F	Correction on downlink power allocation for SC-PTM	13.4.0
2016-12	RAN#74	RP-162355	0753	-	F	Correction on PDCCH candidate configuration	13.4.0
2016-12	RAN#74	RP-162357	0754	-	F	Correction on CWp adjustment on Type B1 multi-carrier access procedure for Rel-13 LAA	13.4.0
2016-12	RAN#74	RP-162356	0755	-	F	Correction to PUCCH reporting mode 2-1	13.4.0
2016-12	RAN#74	RP-162356	0756	-	F	Correction to PUCCH reporting mode 1-1	13.4.0
2016-12	RAN#74	RP-162358	0763	-	F	Clarification on spectral efficiency	13.4.0
2016-12	RAN#74	RP-162358	0764	2	F	Aperiodic CSI without MPDCCH frequency hopping	13.4.0
2016-12	RAN#74	RP-162358	0767	1	F	Correction on equation for MPDCCH search space and starting subframe position	13.4.0
2016-12	RAN#74	RP-162358	0769	-	F	Clarification of number of repetitions of PUCCH	13.4.0
2016-12	RAN#74	RP-162359	0770	-	F	Clarification on nrs-Power related description	13.4.0

Change history							
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2016-12	RAN#74	RP-162357	0780	-	F	Correction on CSI reference resource definition in LAA	13.4.0
2016-12	RAN#74	RP-162357	0782	-	F	Correction on CSI measurement in LAA	13.4.0
2016-12	RAN#74	RP-162359	0789	-	F	Corrections on the description of carrier for NB-IoT in TS 36.213	13.4.0
2016-12	RAN#74	RP-162359	0791	2	F	Corrections on the Table 16.6-2: Type 1- NPDCCH common search space candidates for NB-IoT in TS 36.213	13.4.0
2016-12	RAN#74	RP-162359	0796	-	F	Control information inconsistent handling for NB-IoT in 36.213	13.4.0
2016-12	RAN#74	RP-162357	0800	-	F	Rel-13 CR on MCOT limits for carriers on which eNB performs Type B LBT	13.4.0
2016-12	RAN#74	RP-162357	0801	-	F	Correction on DL CWS adjustment for LAA	13.4.0
2016-12	RAN#74	RP-162358	0806	-	F	CR on RV Cycling for PDSCH	13.4.0
2016-12	RAN#74	RP-162355	0808	-	F	Correction on EPDCCH candidate configuration	13.4.0
2016-12	RAN#74	RP-162358	0812	-	F	PDSCH transmission on special subframe for eMTC	13.4.0
2016-12	RAN#74	RP-162358	0817	-	F	DCI for SPS	13.4.0
2016-12	RAN#74	RP-162358	0819	-	F	Number of MPDCCH-PRB sets	13.4.0
2016-12	RAN#74	RP-162359	0825	-	F	Correction on NPDCCH and NPDSCH start symbol	13.4.0

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