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# Foreword

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# 1 Scope

The present document specifies the coding, multiplexing and mapping to physical channels for 5G NR.

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## 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.
- For a specific reference, subsequent revisions do not apply.
- 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 38.201: "NR; Physical Layer – General Description"
- [3] 3GPP TS 38.202: "NR; Services provided by the physical layer"
- [4] 3GPP TS 38.211: "NR; Physical channels and modulation"
- [5] 3GPP TS 38.213: "NR; Physical layer procedures for control"
- [6] 3GPP TS 38.214: "NR; Physical layer procedures for data"
- [7] 3GPP TS 38.215: "NR; Physical layer measurements"
- [8] 3GPP TS 38.321: "NR; Medium Access Control (MAC) protocol specification"
- [9] 3GPP TS 38.331: "NR; Radio Resource Control (RRC) protocol specification"
- [10] 3GPP TS 38.473: "NG-RAN; F1 Application Protocol (F1AP)"
- [11] 3GPP TS 36.212: "Evolved Universal Terrestrial Radio Access (E-UTRA); Multiplexing and channel coding"
- [12] 3GPP TS 23.287: "Architecture enhancements for 5G System (5GS) to support Vehicle-to-Everything (V2X) services"

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## 3 Definitions, symbols and abbreviations

### 3.1 Definitions

For the purposes of the present document, the terms and definitions given in TR 21.905 [1] and the following apply. A term defined in the present document takes precedence over the definition of the same term, if any, in TR 21.905 [1].

### 3.2 Symbols

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



### 3.3 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].

BCH	Broadcast channel
CBG	Code block group
CBGTI	Code block group transmission information
CG	Configured grant
CG-DFI	CG downlink feedback information
CG-UCI	CG uplink control information
CORESET	Control resource set
COT	Channel occupancy time
CQI	Channel quality indicator
CRC	Cyclic redundancy check
CRI	CSI-RS resource indicator
CSI	Channel state information
CSI-RS	CSI reference signal
DAI	Downlink assignment index
DCI	Downlink control information
DL	Downlink
DL-SCH	Downlink shared channel
DMRS	Dedicated demodulation reference signal
HARQ	Hybrid automatic repeat request
HARQ-ACK	Hybrid automatic repeat request acknowledgement
LDPC	Low density parity check
LI	Layer indicator
MCS	Modulation and coding scheme
OFDM	Orthogonal frequency division multiplex
PBCH	Physical broadcast channel
PCH	Paging channel
PDCCH	Physical downlink control channel
PDSCH	Physical downlink shared channel
PMI	Precoding matrix indicator
PRB	Physical resource block
PRACH	Physical random access channel
PSBCH	Physical sidelink broadcast channel
PSCCH	Physical sidelink control channel
PSFCH	Physical sidelink feedback channel
PSSCH	Physical sidelink shared channel
PTRS	Phase-tracking reference signal
PUCCH	Physical uplink control channel
PUSCH	Physical uplink shared channel
RACH	Random access channel
RI	Rank indicator
RSRP	Reference signal received power
SCI	Sidelink control information
SFCI	Sidelink feedback control information
SFN	System frame number
SL	Sidelink
SL-BCH	Sidelink broadcast channel
SL-SCH	Sidelink shared channel
SR	Scheduling request
SRS	Sounding reference signal
SS	Synchronisation signal
SUL	Supplementary uplink
TPC	Transmit power control
TrCH	Transport channel
UCI	Uplink control information
UE	User equipment

UL	Uplink
UL-SCH	Uplink shared channel
VRB	Virtual resource block
ZP CSI-RS	Zero power CSI-RS

## 4 Mapping to physical channels

### 4.1 Uplink

Table 4.1-1 specifies the mapping of the uplink transport channels to their corresponding physical channels. Table 4.1-2 specifies the mapping of the uplink control channel information to its corresponding physical channel.

**Table 4.1-1**

TrCH	Physical Channel
UL-SCH	PUSCH
RACH	PRACH

**Table 4.1-2**

Control information	Physical Channel
UCI	PUCCH, PUSCH

### 4.2 Downlink

Table 4.2-1 specifies the mapping of the downlink transport channels to their corresponding physical channels. Table 4.2-2 specifies the mapping of the downlink control channel information to its corresponding physical channel.

**Table 4.2-1**

TrCH	Physical Channel
DL-SCH	PDSCH
BCH	PBCH
PCH	PDSCH

**Table 4.2-2**

Control information	Physical Channel
DCI	PDCCH

### 4.3 Sidelink

Table 4.3-1 specifies the mapping of the sidelink transport channels to their corresponding physical channels. Table 4.3-2 specifies the mapping of the sidelink control information and sidelink feedback control information to their corresponding physical channels.

**Table 4.3-1**

TrCH	Physical Channel
SL-SCH	PSSCH
SL-BCH	PSBCH

Table 4.3-2

Control information	Physical Channel
1 <sup>st</sup> -stage SCI	PSCCH
2 <sup>nd</sup> -stage SCI	PSSCH
SFCI	PSFCH

## 5 General procedures

Data and control streams from/to MAC layer are encoded /decoded to offer transport and control services over the radio transmission link. Channel coding scheme is a combination of error detection, error correcting, rate matching, interleaving and transport channel or control information mapping onto/splitting from physical channels.

### 5.1 CRC calculation

Denote the input bits to the CRC computation by  $a_0, a_1, a_2, a_3, \dots, a_{A-1}$ , and the parity bits by  $p_0, p_1, p_2, p_3, \dots, p_{L-1}$ , where  $A$  is the size of the input sequence and  $L$  is the number of parity bits. The parity bits are generated by one of the following cyclic generator polynomials:

- $g_{\text{CRC24A}}(D) = [D^{24} + D^{23} + D^{18} + D^{17} + D^{14} + D^{11} + D^{10} + D^7 + D^6 + D^5 + D^4 + D^3 + D + 1]$  for a CRC length  $L = 24$ ;
- $g_{\text{CRC24B}}(D) = [D^{24} + D^{23} + D^6 + D^5 + D + 1]$  for a CRC length  $L = 24$ ;
- $g_{\text{CRC24C}}(D) = [D^{24} + D^{23} + D^{21} + D^{20} + D^{17} + D^{15} + D^{13} + D^{12} + D^8 + D^4 + D^2 + D + 1]$  for a CRC length  $L = 24$ ;
- $g_{\text{CRC16}}(D) = [D^{16} + D^{12} + D^5 + 1]$  for a CRC length  $L = 16$ ;
- $g_{\text{CRC11}}(D) = [D^{11} + D^{10} + D^9 + D^5 + 1]$  for a CRC length  $L = 11$ ;
- $g_{\text{CRC6}}(D) = [D^6 + D^5 + 1]$  for a CRC length  $L = 6$ .

The encoding is performed in a systematic form, which means that in GF(2), the polynomial:

$$a_0 D^{A+L-1} + a_1 D^{A+L-2} + \dots + a_{A-1} D^L + p_0 D^{L-1} + p_1 D^{L-2} + \dots + p_{L-2} D^1 + p_{L-1}$$

yields a remainder equal to 0 when divided by the corresponding CRC generator polynomial.

The bits after CRC attachment are denoted by  $b_0, b_1, b_2, b_3, \dots, b_{B-1}$ , where  $B = A + L$ . The relation between  $a_k$  and  $b_k$  is:

$$b_k = a_k \quad \text{for } k = 0, 1, 2, \dots, A-1$$

$$b_k = p_{k-A} \quad \text{for } k = A, A+1, A+2, \dots, A+L-1.$$

## 5.2 Code block segmentation and code block CRC attachment

### 5.2.1 Polar coding

The input bit sequence to the code block segmentation is denoted by  $a_0, a_1, a_2, a_3, \dots, a_{A-1}$ , where  $A > 0$ .

if  $I_{\text{seg}} = 1$

Number of code blocks:  $C = 2$ ;

else

Number of code blocks:  $C = 1$

end if

$A' = \lceil A/C \rceil \cdot C$ ;

for  $i = 0$  to  $A' - A - 1$

$a'_i = 0$ ;

end for

for  $i = A' - A$  to  $A' - 1$

$a'_i = a_{i-(A'-A)}$ ;

end for

$s = 0$ ;

for  $r = 0$  to  $C - 1$

for  $k = 0$  to  $A'/C - 1$

$c_{rk} = a'_s$ ;

$s = s + 1$ ;

end for

The sequence  $c_{r0}, c_{r1}, c_{r2}, c_{r3}, \dots, c_{r(A'/C-1)}$  is used to calculate the CRC parity bits  $p_{r0}, p_{r1}, p_{r2}, \dots, p_{r(L-1)}$  according to Clause 5.1 with a generator polynomial of length  $L$ .

for  $k = A'/C$  to  $A'/C + L - 1$

$c_{rk} = p_{r(k-A'/C)}$ ;

end for

end for

The value of  $A$  is no larger than 1706.

## 5.2.2 Low density parity check coding

The input bit sequence to the code block segmentation is denoted by  $b_0, b_1, b_2, b_3, \dots, b_{B-1}$ , where  $B > 0$ . If  $B$  is larger than the maximum code block size  $K_{cb}$ , segmentation of the input bit sequence is performed and an additional CRC sequence of  $L = 24$  bits is attached to each code block.

For LDPC base graph 1, the maximum code block size is:

- $K_{cb} = 8448$ .

For LDPC base graph 2, the maximum code block size is:

- $K_{cb} = 3840$ .

Total number of code blocks  $C$  is determined by:

if  $B \leq K_{cb}$

$$L = 0$$

Number of code blocks:  $C = 1$

$$B' = B$$

else

$$L = 24$$

Number of code blocks:  $C = \lceil B / (K_{cb} - L) \rceil$ .

$$B' = B + C \cdot L$$

end if

The bits output from code block segmentation are denoted by  $c_{r0}, c_{r1}, c_{r2}, c_{r3}, \dots, c_{r(K_r-1)}$ , where  $0 \leq r < C$  is the code block number, and  $K_r = K$  is the number of bits for the code block number  $r$ .

The number of bits  $K$  in each code block is calculated as:

$$K' = B' / C ;$$

For LDPC base graph 1,

$$K_b = 22 .$$

For LDPC base graph 2,

if  $B > 640$

$$K_b = 10 ;$$

elseif  $B > 560$

$$K_b = 9 ;$$

elseif  $B > 192$

$$K_b = 8 ;$$

else

$$K_b = 6 ;$$

end if

find the minimum value of  $Z$  in all sets of lifting sizes in Table 5.3.2-1, denoted as  $Z_c$ , such that  $K_b \cdot Z_c \geq K'$ , and set  $K = 22Z_c$  for LDPC base graph 1 and  $K = 10Z_c$  for LDPC base graph 2;

The bit sequence  $c_{rk}$  is calculated as:

$$s = 0 ;$$

for  $r = 0$  to  $C - 1$

for  $k = 0$  to  $K' - L - 1$

```

 $c_{rk} = b_s;$ 

 $s = s + 1;$ 

end for

if  $C > 1$ 

The sequence  $c_{r0}, c_{r1}, c_{r2}, c_{r3}, \dots, c_{r(K'-L-1)}$  is used to calculate the CRC parity bits  $p_{r0}, p_{r1}, p_{r2}, \dots, p_{r(L-1)}$  according to Clause 5.1 with the generator polynomial  $g_{\text{CRC24B}}(D)$ .

for  $k = K' - L$  to  $K' - 1$ 

 $c_{rk} = P_{r(k+L-K')};$ 

end for

end if

for  $k = K'$  to  $K - 1$  -- Insertion of filler bits

 $c_{rk} = \langle \text{NULL} \rangle;$ 

end for

end for

```

## 5.3 Channel coding

Usage of coding scheme for the different types of TrCH is shown in table 5.3-1. Usage of coding scheme for the different control information types is shown in table 5.3-2.

**Table 5.3-1: Usage of channel coding scheme for TrCHs**

TrCH	Coding scheme
UL-SCH	LDPC
DL-SCH	
PCH	
BCH	Polar code

**Table 5.3-2: Usage of channel coding scheme for control information**

Control Information	Coding scheme
DCI	Polar code
UCI	Block code
	Polar code

### 5.3.1 Polar coding

The bit sequence input for a given code block to channel coding is denoted by  $c_0, c_1, c_2, c_3, \dots, c_{K-1}$ , where  $K$  is the number of bits to encode. After encoding the bits are denoted by  $d_0, d_1, d_2, \dots, d_{N-1}$ , where  $N = 2^n$  and the value of  $n$  is determined by the following:

Denote by  $E$  the rate matching output sequence length as given in Clause 5.4.1;

If  $E \leq (9/8) \cdot 2^{\lceil \log_2 E \rceil - 1}$  and  $K/E < 9/16$

```

 $n_1 = \lceil \log_2 E \rceil - 1;$ 
else
 $n_1 = \lceil \log_2 E \rceil;$ 
end if
 $R_{\min} = 1/8;$ 
 $n_2 = \lceil \log_2 (K / R_{\min}) \rceil;$ 
 $n = \max\{\min\{n_1, n_2, n_{\max}\}, n_{\min}\}$ 
where  $n_{\min} = 5$ .

```

UE is not expected to be configured with  $K + n_{PC} > E$ , where  $n_{PC}$  is the number of parity check bits defined in Clause 5.3.1.2.

### 5.3.1.1 Interleaving

The bit sequence  $c_0, c_1, c_2, c_3, \dots, c_{K-1}$  is interleaved into bit sequence  $c'_0, c'_1, c'_2, c'_3, \dots, c'_{K-1}$  as follows:

$$c'_k = c_{\Pi(k)}, \quad k = 0, 1, \dots, K-1$$

where the interleaving pattern  $\Pi(k)$  is given by the following:

```

if  $I_{IL} = 0$ 
 $\Pi(k) = k, \quad k = 0, 1, \dots, K-1$ 
else
 $k = 0;$ 
for  $m = 0$  to  $K_{IL}^{\max} - 1$ 
if  $\Pi_{IL}^{\max}(m) \geq K_{IL}^{\max} - K$ 
 $\Pi(k) = \Pi_{IL}^{\max}(m) - (K_{IL}^{\max} - K);$ 
 $k = k + 1;$ 
end if
end for
end if

```

where  $\Pi_{IL}^{\max}(m)$  is given by Table 5.3.1.1-1 and  $K_{IL}^{\max} = 164$ .

Table 5.3.1.1-1: Interleaving pattern  $\Pi_{LL}^{\max}(m)$ 

$m$	$\Pi_{LL}^{\max}(m)$	$m$	$\Pi_{LL}^{\max}(m)$	$m$	$\Pi_{LL}^{\max}(m)$	$m$	$\Pi_{LL}^{\max}(m)$	$m$	$\Pi_{LL}^{\max}(m)$	$m$	$\Pi_{LL}^{\max}(m)$
0	0	28	67	56	122	84	68	112	33	140	38
1	2	29	69	57	123	85	73	113	36	141	144
2	4	30	70	58	126	86	78	114	44	142	39
3	7	31	71	59	127	87	84	115	47	143	145
4	9	32	72	60	129	88	90	116	64	144	40
5	14	33	76	61	132	89	92	117	74	145	146
6	19	34	77	62	134	90	94	118	79	146	41
7	20	35	81	63	138	91	96	119	85	147	147
8	24	36	82	64	139	92	99	120	97	148	148
9	25	37	83	65	140	93	102	121	100	149	149
10	26	38	87	66	1	94	105	122	103	150	150
11	28	39	88	67	3	95	107	123	117	151	151
12	31	40	89	68	5	96	109	124	125	152	152
13	34	41	91	69	8	97	112	125	131	153	153
14	42	42	93	70	10	98	114	126	136	154	154
15	45	43	95	71	15	99	116	127	142	155	155
16	49	44	98	72	21	100	121	128	12	156	156
17	50	45	101	73	27	101	124	129	17	157	157
18	51	46	104	74	29	102	128	130	23	158	158
19	53	47	106	75	32	103	130	131	37	159	159
20	54	48	108	76	35	104	133	132	48	160	160
21	56	49	110	77	43	105	135	133	75	161	161
22	58	50	111	78	46	106	141	134	80	162	162
23	59	51	113	79	52	107	6	135	86	163	163
24	61	52	115	80	55	108	11	136	137		
25	62	53	118	81	57	109	16	137	143		
26	65	54	119	82	60	110	22	138	13		
27	66	55	120	83	63	111	30	139	18		

### 5.3.1.2 Polar encoding

The Polar sequence  $\mathbf{Q}_0^{N_{\max}-1} = \{Q_0^{N_{\max}}, Q_1^{N_{\max}}, \dots, Q_{N_{\max}-1}^{N_{\max}}\}$  is given by Table 5.3.1.2-1, where  $0 \leq Q_i^{N_{\max}} \leq N_{\max} - 1$  denotes a bit index before Polar encoding for  $i = 0, 1, \dots, N_{\max} - 1$  and  $N_{\max} = 1024$ . The Polar sequence  $\mathbf{Q}_0^{N_{\max}-1}$  is in ascending order of reliability  $W(Q_0^{N_{\max}}) < W(Q_1^{N_{\max}}) < \dots < W(Q_{N_{\max}-1}^{N_{\max}})$ , where  $W(Q_i^{N_{\max}})$  denotes the reliability of bit index  $Q_i^{N_{\max}}$ .

For any code block encoded to  $N$  bits, a same Polar sequence  $\mathbf{Q}_0^{N-1} = \{Q_0^N, Q_1^N, Q_2^N, \dots, Q_{N-1}^N\}$  is used. The Polar sequence  $\mathbf{Q}_0^{N-1}$  is a subset of Polar sequence  $\mathbf{Q}_0^{N_{\max}-1}$  with all elements  $Q_i^{N_{\max}}$  of values less than  $N$ , ordered in ascending order of reliability  $W(Q_0^N) < W(Q_1^N) < W(Q_2^N) < \dots < W(Q_{N-1}^N)$ .

Denote  $\overline{\mathbf{Q}}_I^N$  as a set of bit indices in Polar sequence  $\mathbf{Q}_0^{N-1}$ , and  $\overline{\mathbf{Q}}_F^N$  as the set of other bit indices in Polar sequence  $\mathbf{Q}_0^{N-1}$ , where  $\overline{\mathbf{Q}}_I^N$  and  $\overline{\mathbf{Q}}_F^N$  are given in Clause 5.4.1.1,  $|\overline{\mathbf{Q}}_I^N| = K + n_{PC}$ ,  $|\overline{\mathbf{Q}}_F^N| = N - |\overline{\mathbf{Q}}_I^N|$ , and  $n_{PC}$  is the number of parity check bits.

Denote  $\mathbf{G}_N = (\mathbf{G}_2)^{\otimes n}$  as the  $n$ -th Kronecker power of matrix  $\mathbf{G}_2$ , where  $\mathbf{G}_2 = \begin{bmatrix} 1 & 0 \\ 1 & 1 \end{bmatrix}$ .

For a bit index  $j$  with  $j = 0, 1, \dots, N - 1$ , denote  $\mathbf{g}_j$  as the  $j$ -th row of  $\mathbf{G}_N$  and  $w(\mathbf{g}_j)$  as the row weight of  $\mathbf{g}_j$ , where  $w(\mathbf{g}_j)$  is the number of ones in  $\mathbf{g}_j$ . Denote the set of bit indices for parity check bits as  $\mathbf{Q}_{PC}^N$ , where  $|\mathbf{Q}_{PC}^N| = n_{PC}$ . A number of  $(n_{PC} - n_{PC}^{wm})$  parity check bits are placed in the  $(n_{PC} - n_{PC}^{wm})$  least reliable bit indices in  $\overline{\mathbf{Q}}_I^N$ . A number of  $n_{PC}^{wm}$  other parity check bits are placed in the bit indices of minimum row weight in  $\tilde{\mathbf{Q}}_I^N$ , where  $\tilde{\mathbf{Q}}_I^N$  denotes the  $(|\overline{\mathbf{Q}}_I^N| - n_{PC})$  most reliable bit indices in  $\overline{\mathbf{Q}}_I^N$ ; if there are more than  $n_{PC}^{wm}$  bit indices of the same minimum row weight in  $\tilde{\mathbf{Q}}_I^N$ , the  $n_{PC}^{wm}$  other parity check bits are placed in the  $n_{PC}^{wm}$  bit indices of the highest reliability and the minimum row weight in  $\tilde{\mathbf{Q}}_I^N$ .

Generate  $\mathbf{u} = [u_0 \ u_1 \ u_2 \ \dots \ u_{N-1}]$  according to the following:

$$k = 0;$$



```

if  $n_{PC} > 0$ 
   $y_0 = 0; y_1 = 0; y_2 = 0; y_3 = 0; y_4 = 0;$ 
  for  $n=0$  to  $N-1$ 
     $y_t = y_0; y_0 = y_1; y_1 = y_2; y_2 = y_3; y_3 = y_4; y_4 = y_t;$ 
    if  $n \in \overline{\mathbf{Q}}_t^N$ 
      if  $n \in \mathbf{Q}_{PC}^N$ 
         $u_n = y_0;$ 
      else
         $u_n = c'_k;$ 
         $k = k + 1;$ 
         $y_0 = y_0 \oplus u_n;$ 
      end if
    else
       $u_n = 0;$ 
    end if
  end for
else
  for  $n=0$  to  $N-1$ 
    if  $n \in \overline{\mathbf{Q}}_t^N$ 
       $u_n = c'_k;$ 
       $k = k + 1;$ 
    else
       $u_n = 0;$ 
    end if
  end for
end if

```

The output after encoding  $\mathbf{d} = [d_0 \ d_1 \ d_2 \ \dots \ d_{N-1}]$  is obtained by  $\mathbf{d} = \mathbf{u}\mathbf{G}_N$ . The encoding is performed in GF(2).

**Table 5.3.1.2-1: Polar sequence  $Q_0^{N_{\max}-1}$  and its corresponding reliability  $W(Q_i^{N_{\max}})$**



87	27	215	197	343	585	471	595	599	682	727	905	855	701	983	766
88	97	216	116	344	299	472	189	600	573	728	795	856	931	984	511
89	39	217	170	345	354	473	566	601	411	729	473	857	756	985	988
90	259	218	61	346	211	474	676	602	803	730	634	858	860	986	1001
91	84	219	531	347	401	475	361	603	789	731	744	859	499	987	951
92	138	220	525	348	185	476	706	604	709	732	852	860	731	988	1002
93	145	221	642	349	396	477	589	605	365	733	960	861	823	989	893
94	261	222	281	350	344	478	215	606	440	734	865	862	922	990	975
95	29	223	278	351	586	479	786	607	628	735	693	863	874	991	894
96	43	224	526	352	645	480	647	608	689	736	797	864	918	992	1009
97	98	225	177	353	593	481	348	609	374	737	906	865	502	993	955
98	515	226	293	354	535	482	419	610	423	738	715	866	933	994	1004
99	88	227	388	355	240	483	406	611	466	739	807	867	743	995	1010
100	140	228	91	356	206	484	464	612	793	740	474	868	760	996	957
101	30	229	584	357	95	485	680	613	250	741	636	869	881	997	983
102	146	230	769	358	327	486	801	614	371	742	694	870	494	998	958
103	71	231	198	359	564	487	362	615	481	743	254	871	702	999	987
104	262	232	172	360	800	488	590	616	574	744	717	872	921	1000	1012
105	265	233	120	361	402	489	409	617	413	745	575	873	501	1001	999
106	161	234	201	362	356	490	570	618	603	746	913	874	876	1002	1016
107	576	235	336	363	307	491	788	619	366	747	798	875	847	1003	767
108	45	236	62	364	301	492	597	620	468	748	811	876	992	1004	989
109	100	237	282	365	417	493	572	621	655	749	379	877	447	1005	1003
110	640	238	143	366	213	494	219	622	900	750	697	878	733	1006	990
111	51	239	103	367	568	495	311	623	805	751	431	879	827	1007	1005
112	148	240	178	368	832	496	708	624	615	752	607	880	934	1008	959
113	46	241	294	369	588	497	598	625	684	753	489	881	882	1009	1011
114	75	242	93	370	186	498	601	626	710	754	866	882	937	1010	1013
115	266	243	644	371	646	499	651	627	429	755	723	883	963	1011	895
116	273	244	202	372	404	500	421	628	794	756	486	884	747	1012	1006
117	517	245	592	373	227	501	792	629	252	757	908	885	505	1013	1014
118	104	246	323	374	896	502	802	630	373	758	718	886	855	1014	1017
119	162	247	392	375	594	503	611	631	605	759	813	887	924	1015	1018
120	53	248	297	376	418	504	602	632	848	760	476	888	734	1016	991
121	193	249	770	377	302	505	410	633	690	761	856	889	829	1017	1020
122	152	250	107	378	649	506	231	634	713	762	839	890	965	1018	1007
123	77	251	180	379	771	507	688	635	632	763	725	891	938	1019	1015
124	164	252	151	380	360	508	653	636	482	764	698	892	884	1020	1019
125	768	253	209	381	539	509	248	637	806	765	914	893	506	1021	1021
126	268	254	284	382	111	510	369	638	427	766	752	894	749	1022	1022
127	274	255	648	383	331	511	190	639	904	767	868	895	945	1023	1023

### 5.3.2 Low density parity check coding

The bit sequence input for a given code block to channel coding is denoted by  $c_0, c_1, c_2, c_3, \dots, c_{K-1}$ , where  $K$  is the number of bits to encode as defined in Clause 5.2.2. After encoding the bits are denoted by  $d_0, d_1, d_2, \dots, d_{N-1}$ , where  $N = 66Z_c$  for LDPC base graph 1 and  $N = 50Z_c$  for LDPC base graph 2, and the value of  $Z_c$  is given in Clause 5.2.2.

For a code block encoded by LDPC, the following encoding procedure applies:

1) Find the set with index  $i_{LS}$  in Table 5.3.2-1 which contains  $Z_c$ .

2) for  $k = 2Z_c$  to  $K-1$

if  $c_k \neq \text{NULL}$

$d_{k-2Z_c} = c_k$ ;

else

$c_k = 0$ ;

$d_{k-2Z_c} = \text{NULL}$ ;

end if

end for

3) Generate  $N + 2Z_c - K$  parity bits  $\mathbf{w} = [w_0, w_1, w_2, \dots, w_{N+2Z_c-K-1}]^T$  such that  $\mathbf{H} \times \begin{bmatrix} \mathbf{c} \\ \mathbf{w} \end{bmatrix} = \mathbf{0}$ , where

$\mathbf{c} = [c_0, c_1, c_2, \dots, c_{K-1}]^T$ ;  $\mathbf{0}$  is a column vector of all elements equal to 0. The encoding is performed in GF(2).

For LDPC base graph 1, a matrix of  $\mathbf{H}_{\text{BG}}$  has 46 rows with row indices  $i = 0, 1, 2, \dots, 45$  and 68 columns with column indices  $j = 0, 1, 2, \dots, 67$ . For LDPC base graph 2, a matrix of  $\mathbf{H}_{\text{BG}}$  has 42 rows with row indices  $i = 0, 1, 2, \dots, 41$  and 52 columns with column indices  $j = 0, 1, 2, \dots, 51$ . The elements in  $\mathbf{H}_{\text{BG}}$  with row and column indices given in Table 5.3.2-2 (for LDPC base graph 1) and Table 5.3.2-3 (for LDPC base graph 2) are of value 1, and all other elements in  $\mathbf{H}_{\text{BG}}$  are of value 0.

The matrix  $\mathbf{H}$  is obtained by replacing each element of  $\mathbf{H}_{\text{BG}}$  with a  $Z_c \times Z_c$  matrix, according to the following:

- Each element of value 0 in  $\mathbf{H}_{\text{BG}}$  is replaced by an all zero matrix  $\mathbf{0}$  of size  $Z_c \times Z_c$ ;
- Each element of value 1 in  $\mathbf{H}_{\text{BG}}$  is replaced by a circular permutation matrix  $\mathbf{I}(P_{i,j})$  of size  $Z_c \times Z_c$ , where  $i$  and  $j$  are the row and column indices of the element, and  $\mathbf{I}(P_{i,j})$  is obtained by circularly shifting the identity matrix  $\mathbf{I}$  of size  $Z_c \times Z_c$  to the right  $P_{i,j}$  times. The value of  $P_{i,j}$  is given by  $P_{i,j} = \text{mod}(V_{i,j}, Z_c)$ . The value of  $V_{i,j}$  is given by Tables 5.3.2-2 and 5.3.2-3 according to the set index  $i_{LS}$  and LDPC base graph.

4) for  $k = K$  to  $N + 2Z_c - 1$

$$d_{k-2Z_c} = w_{k-K};$$

end for

**Table 5.3.2-1: Sets of LDPC lifting size  $Z$**

Set index ( $i_{LS}$ )	Set of lifting sizes ( $Z$ )
0	{2, 4, 8, 16, 32, 64, 128, 256}
1	{3, 6, 12, 24, 48, 96, 192, 384}
2	{5, 10, 20, 40, 80, 160, 320}
3	{7, 14, 28, 56, 112, 224}
4	{9, 18, 36, 72, 144, 288}
5	{11, 22, 44, 88, 176, 352}
6	{13, 26, 52, 104, 208}
7	{15, 30, 60, 120, 240}

**Table 5.3.2-2: LDPC base graph 1 ( $H_{BG}$ ) and its parity check matrices ( $V_{i,j}$ )**







**Table 5.3.2-3: LDPC base graph 2 ( $H_{BG}$ ) and its parity check matrices ( $V_{i,j}$ )**

$H_{BG}$		$V_{i,j}$							$H_{BG}$		$V_{i,j}$									
Row index $i$	Column index $j$	Set index $i_{LS}$							Row index $i$	Column index $j$	Set index $i_{LS}$									
		0	1	2	3	4	5	6			7	0	1	2	3	4	5	6	7	
0	0	9	174	0	72	3	156	143	145	16	26	0	0	0	0	48	120	134	57	196
	1	117	97	0	110	26	143	19	131	17	1	254	158	0	48	120	134	57	196	
	2	204	166	0	23	53	14	176	71	5	124	23	24	132	43	23	201	173		
	3	26	66	0	181	35	3	165	21	11	114	9	109	206	65	62	142	195		
	6	189	71	0	95	115	40	196	23	12	64	6	18	2	42	163	35	218		
	9	205	172	0	8	127	123	13	112	27	0	0	0	0	0	0	0	0	0	0
	10	0	0	0	1	0	0	0	1	0	220	186	0	68	17	173	129	128		
	11	0	0	0	0	0	0	0	0	6	194	6	18	16	106	31	203	211		
	0	167	27	137	53	19	17	18	142	7	50	46	86	156	142	22	140	210		
	3	166	36	124	156	94	65	27	174	28	0	0	0	0	0	0	0	0	0	0
	4	253	48	0	115	104	63	3	183	0	87	58	0	35	79	13	110	39		
5	125	92	0	156	66	1	102	27	1	20	42	158	138	28	135	124	84			
6	226	31	88	115	84	55	185	96	10	185	156	154	86	41	145	52	88			
7	156	187	0	200	98	37	17	23	29	0	0	0	0	0	0	0	0	0	0	
8	224	185	0	29	69	171	14	9	1	26	76	0	6	2	128	196	117			
9	252	3	55	31	50	133	180	167	4	105	61	148	20	103	52	35	227			
11	0	0	0	0	0	0	0	0	11	29	153	104	141	78	173	114	6			
12	0	0	0	0	0	0	0	0	30	0	0	0	0	0	0	0	0	0	0	
2	0	81	25	20	152	95	98	126	74	0	76	157	0	80	91	156	10	238		
	1	114	114	94	131	106	168	163	31	8	42	175	17	43	75	166	122	13		
	3	44	117	99	46	92	107	47	3	13	210	67	33	81	81	40	23	11		
	4	52	110	9	191	110	82	183	53	31	0	0	0	0	0	0	0	0	0	0
	8	240	114	108	91	111	142	132	155	1	222	20	0	49	54	18	202	195		
	10	1	1	1	0	1	1	1	0	2	63	52	4	1	132	163	126	44		
	12	0	0	0	0	0	0	0	0	32	0	0	0	0	0	0	0	0	0	0
	13	0	0	0	0	0	0	0	0	0	23	106	0	156	68	110	52	5		
	1	8	136	38	185	120	53	36	239	3	235	86	75	54	115	132	170	94		
	2	58	175	15	6	121	174	48	171	5	238	95	158	134	56	150	13	111		
	4	158	113	102	36	22	174	18	95	33	0	0	0	0	0	0	0	0	0	0
	5	104	72	146	124	4	127	111	110	1	46	182	0	153	30	113	113	81		
	6	209	123	12	124	73	17	203	159	2	139	153	69	88	42	108	161	19		
7	54	118	57	110	49	89	3	199	9	8	64	87	63	101	61	88	130			
8	18	28	53	156	128	17	191	43	34	0	0	0	0	0	0	0	0	0	0	
9	128	186	46	133	79	105	160	75	0	228	45	0	211	128	72	197	66			
10	0	0	0	1	0	0	0	1	5	156	21	65	94	63	136	194	95			
13	0	0	0	0	0	0	0	0	35	0	0	0	0	0	0	0	0	0	0	
4	0	179	72	0	200	42	86	43	29	2	29	67	0	90	142	36	164	146		
	1	214	74	136	16	24	67	27	140	7	143	137	100	6	28	38	172	66		
	11	71	29	157	101	51	83	117	180	12	160	55	13	221	100	53	49	190		
	14	0	0	0	0	0	0	0	0	13	122	85	7	6	133	145	161	86		
	0	231	10	0	185	40	79	136	121	36	0	0	0	0	0	0	0	0	0	0
5	1	41	44	131	138	140	84	49	41	0	8	103	0	27	13	42	168	64		
	5	194	121	142	170	84	35	36	169	6	151	50	32	118	10	104	193	181		
	7	159	80	141	219	137	103	132	88	37	0	0	0	0	0	0	0	0	0	0
	11	103	48	64	193	71	60	62	207	1	98	70	0	216	106	64	14	7		
	15	0	0	0	0	0	0	0	0	2	101	111	126	212	77	24	186	144		
6	0	155	129	0	123	109	47	7	137	5	135	168	110	193	43	149	46	16		
	5	228	92	124	55	87	154	34	72	38	0	0	0	0	0	0	0	0	0	0
	7	45	100	99	31	107	10	198	172	0	18	110	0	108	133	139	50	25		
	9	28	49	45	222	133	155	168	124	4	28	17	154	61	25	161	27	57		
	11	158	184	148	209	139	29	12	56	39	0	0	0	0	0	0	0	0	0	0
	16	0	0	0	0	0	0	0	0	2	71	120	0	106	87	84	70	37		
7	1	129	80	0	103	97	48	163	86	5	240	154	35	44	56	173	17	139		
	5	147	186	45	13	135	125	78	186	7	9	52	51	185	104	93	50	221		
	7	140	16	148	105	35	24	143	87	9	84	56	134	176	70	29	6	17		
	11	3	102	96	150	108	47	107	172	40	0	0	0	0	0	0	0	0	0	0
	13	116	143	78	181	65	55	58	154	1	106	3	0	147	80	117	115	201		
	17	0	0	0	0	0	0	0	0	13	1	170	20	182	139	148	189	46		
	0	142	118	0	147	70	53	101	176	41	0	0	0	0	0	0	0	0	0	0
8	1	94	70	65	43	69	31	177	169	0	242	84	0	108	32	116	110	179		
	12	230	152	87	152	88	161	22	225	5	44	8	20	21	89	73	0	14		
	18	0	0	0	0	0	0	0	0	12	166	17	122	110	71	142	163	116		
	1	203	28	0	2	97	104	186	167	42	0	0	0	0	0	0	0	0	0	0
	8	205	132	97	30	40	142	27	238	2	132	165	0	71	135	105	163	46		
9	10	61	185	51	184	24	99	205	48	7	164	179	88	12	6	137	173	2		
	11	247	178	85	83	49	64	81	68	10	235	124	13	109	2	29	179	106		
	19	0	0	0	0	0	0	0	0	43	0	0	0	0	0	0	0	0	0	0
	0	11	59	0	174	46	111	125	38	0	147	173	0	29	37	11	197	184		
	1	185	104	17	150	41	25	60	217	12	85	177	19	201	25	41	191	135		
10	6	0	22	156	8	101	174	208	13	36	12	78	69	114	162	193	141			
	7	117	52	20	56	96	23	51	232	44	0	0	0	0	0	0	0	0	0	0
	20	0	0	0	0	0	0	0	0	1	57	77	0	91	60	126	157	85		
	0	11	32	0	99	28	91	39	178	5	40	184	157	165	137	152	167	225		
	7	236	92	7	138	30	175	29	214	11	63	18	6	55	93	172	181	175		
	9	210	174	4	110	116	24	35	168	45	0	0	0	0	0	0	0	0	0	0
11	13	56	154	2	99	64	141	8	51	0	140	25	0	1	121	73	197	178		
	21	0	0	0	0	0	0	0	0	2	38	151	63	175	129	154	167	112		
	1	63	39	0	46	33	122	18	124	7	154	170	82	83	26	129	179	106		
	3	111	93	113	217	122	11	155	122	46	0	0	0	0	0	0	0	0	0	0
12	11	14	11	48	109	131	4	49	72	10	219	37	0	40	97	167	181	154		
	22	0	0	0	0	0	0	0	0	13	151	31	144	12	56	38	193	114		
	0	83	49	0	37	76	29	32	48	47	0	0	0	0	0	0	0	0	0	0
	1	2	125	112	113	37	91	53	57	38	1	31	84	0	37	1	112	157	42	

8	8	38	35	102	143	62	27	95	167	5	66	151	93	97	70	7	173	41
	13	222	166	26	140	47	127	186	219		11	38	190	19	46	1	19	191
14	23	0	0	0	0	0	0	0	0	48	0	0	0	0	0	0	0	0
	1	115	19	0	36	143	11	91	82	0	239	93	0	106	119	109	181	167
	6	145	118	138	95	51	145	20	232	7	172	132	24	181	32	6	157	45
	11	3	21	57	40	130	8	52	204	12	34	57	138	154	142	105	173	189
	13	232	163	27	116	97	166	109	162	49	0	0	0	0	0	0	0	0
	24	0	0	0	0	0	0	0	0	2	0	103	0	98	6	160	193	78
15	0	51	68	0	116	139	137	174	38	10	75	107	36	35	73	156	163	67
	10	175	63	73	200	96	103	108	217	13	120	163	143	36	102	82	179	180
	11	213	81	99	110	128	40	102	157	50	0	0	0	0	0	0	0	0
	25	0	0	0	0	0	0	0	0	1	129	147	0	120	48	132	191	53
	1	203	87	0	75	48	78	125	170	5	229	7	2	101	47	6	197	215
16	9	142	177	79	158	9	158	31	23	11	118	60	55	81	19	8	167	230
	11	8	135	111	134	28	17	54	175	51	0	0	0	0	0	0	0	0
	12	242	64	143	97	8	165	176	202									

### 5.3.3 Channel coding of small block lengths

The bit sequence input for a given code block to channel coding is denoted by  $c_0, c_1, c_2, c_3, \dots, c_{K-1}$ , where  $K$  is the number of bits to encode. After encoding the bits are denoted by  $d_0, d_1, d_2, \dots, d_{N-1}$ .

#### 5.3.3.1 Encoding of 1-bit information

For  $K = 1$ , the code block is encoded according to Table 5.3.3.1-1, where  $N = Q_m$  and  $Q_m$  is the modulation order for the code block.

**Table 5.3.3.1-1: Encoding of 1-bit information**

$Q_m$	Encoded bits $d_0, d_1, d_2, \dots, d_{N-1}$
1	$[c_0]$
2	$[c_0 y]$
4	$[c_0 y x x]$
6	$[c_0 y x x x x]$
8	$[c_0 y x x x x x x]$

The "x" and "y" in Table 5.3.3.1-1 are placeholders for Clause 6.3.1.1 of [4, TS 38.211] to scramble the information bits in a way that maximizes the Euclidean distance of the modulation symbols carrying the information bits.

#### 5.3.3.2 Encoding of 2-bit information

For  $K = 2$ , the code block is encoded according to Table 5.3.3-2, where  $c_2 = (c_0 + c_1) \bmod 2$ ,  $N = 3Q_m$ , and  $Q_m$  is the modulation order for the code block.

**Table 5.3.3.2-1: Encoding of 2-bit information**

$Q_m$	Encoded bits $d_0, d_1, d_2, \dots, d_{N-1}$
1	$[c_0 c_1 c_2]$
2	$[c_0 c_1 c_2 c_0 c_1 c_2]$
4	$[c_0 c_1 x x c_2 c_0 x x c_1 c_2 x x]$
6	$[c_0 c_1 x x x x c_2 c_0 x x x x c_1 c_2 x x x x]$
8	$[c_0 c_1 x x x x x x c_2 c_0 x x x x x x c_1 c_2 x x x x x x]$

The "x" in Table 5.3.3.2-1 are placeholders for Clause 6.3.1.1 of [4, TS 38.211] to scramble the information bits in a way that maximizes the Euclidean distance of the modulation symbols carrying the information bits.

### 5.3.3.3 Encoding of other small block lengths

For  $3 \leq K \leq 11$ , the code block is encoded by  $d_i = \left( \sum_{k=0}^{K-1} c_k \cdot M_{i,k} \right) \bmod 2$ , where  $i = 0, 1, \dots, N-1$ ,  $N = 32$ , and  $M_{i,k}$  represents the basis sequences as defined in Table 5.3.3.3-1.

**Table 5.3.3.3-1: Basis sequences for (32,  $K$ ) code**

$i$	$M_{i,0}$	$M_{i,1}$	$M_{i,2}$	$M_{i,3}$	$M_{i,4}$	$M_{i,5}$	$M_{i,6}$	$M_{i,7}$	$M_{i,8}$	$M_{i,9}$	$M_{i,10}$
0	1	1	0	0	0	0	0	0	0	0	1
1	1	1	1	0	0	0	0	0	0	1	1
2	1	0	0	1	0	0	1	0	1	1	1
3	1	0	1	1	0	0	0	0	1	0	1
4	1	1	1	1	0	0	0	1	0	0	1
5	1	1	0	0	1	0	1	1	1	0	1
6	1	0	1	0	1	0	1	0	1	1	1
7	1	0	0	1	1	0	0	1	1	0	1
8	1	1	0	1	1	0	0	1	0	1	1
9	1	0	1	1	1	0	1	0	0	1	1
10	1	0	1	0	0	1	1	1	0	1	1
11	1	1	1	0	0	1	1	0	1	0	1
12	1	0	0	1	0	1	0	1	1	1	1
13	1	1	0	1	0	1	0	1	0	1	1
14	1	0	0	0	1	1	0	1	0	0	1
15	1	1	0	0	1	1	1	1	0	1	1
16	1	1	1	0	1	1	1	0	0	1	0
17	1	0	0	1	1	1	0	0	1	0	0
18	1	1	0	1	1	1	1	1	0	0	0
19	1	0	0	0	0	1	1	0	0	0	0
20	1	0	1	0	0	0	1	0	0	0	1
21	1	1	0	1	0	0	0	0	0	1	1
22	1	0	0	0	1	0	0	1	1	0	1
23	1	1	1	0	1	0	0	0	1	1	1
24	1	1	1	1	1	0	1	1	1	1	0
25	1	1	0	0	0	1	1	1	0	0	1
26	1	0	1	1	0	1	0	0	1	1	0
27	1	1	1	1	0	1	0	1	1	1	0
28	1	0	1	0	1	1	1	0	1	0	0
29	1	0	1	1	1	1	1	1	1	0	0
30	1	1	1	1	1	1	1	1	1	1	1
31	1	0	0	0	0	0	0	0	0	0	0

## 5.4 Rate matching

### 5.4.1 Rate matching for Polar code

The rate matching for Polar code is defined per coded block and consists of sub-block interleaving, bit collection, and bit interleaving. The input bit sequence to rate matching is  $d_0, d_1, d_2, \dots, d_{N-1}$ . The output bit sequence after rate matching is denoted as  $f_0, f_1, f_2, \dots, f_{E-1}$ .

#### 5.4.1.1 Sub-block interleaving

The bits input to the sub-block interleaver are the coded bits  $d_0, d_1, d_2, \dots, d_{N-1}$ . The coded bits  $d_0, d_1, d_2, \dots, d_{N-1}$  are divided into 32 sub-blocks. The bits output from the sub-block interleaver are denoted as  $y_0, y_1, y_2, \dots, y_{N-1}$ , generated as follows:

for  $n=0$  to  $N-1$

$$i = \lfloor 32n / N \rfloor;$$

$$J(n) = P(i) \times (N/32) + \text{mod}(n, N/32);$$

$$y_n = d_{J(n)};$$

end for

where the sub-block interleaver pattern  $P(i)$  is given by Table 5.4.1.1-1.

**Table 5.4.1.1-1: Sub-block interleaver pattern  $P(i)$**

$i$	$P(i)$	$i$	$P(i)$	$i$	$P(i)$	$i$	$P(i)$	$i$	$P(i)$	$i$	$P(i)$	$i$	$P(i)$	$i$	$P(i)$
0	0	4	3	8	8	12	10	16	12	20	14	24	24	28	27
1	1	5	5	9	16	13	18	17	20	21	22	25	25	29	29
2	2	6	6	10	9	14	11	18	13	22	15	26	26	30	30
3	4	7	7	11	17	15	19	19	21	23	23	27	28	31	31

The sets of bit indices  $\overline{\mathbf{Q}}_I^N$  and  $\overline{\mathbf{Q}}_F^N$  are determined as follows, where  $K$ ,  $n_{PC}$ , and  $\mathbf{Q}_0^{N-1}$  are defined in Clause 5.3.1

$$\overline{\mathbf{Q}}_{F,imp}^N = \emptyset$$

if  $E < N$

if  $K/E \leq 7/16$  -- puncturing

for  $n=0$  to  $N-E-1$

$$\overline{\mathbf{Q}}_{F,imp}^N = \overline{\mathbf{Q}}_{F,imp}^N \cup \{J(n)\};$$

end for

if  $E \geq 3N/4$

$$\overline{\mathbf{Q}}_{F,imp}^N = \overline{\mathbf{Q}}_{F,imp}^N \cup \{0,1,\dots,\lceil 3N/4 - E/2 \rceil - 1\};$$

else

$$\overline{\mathbf{Q}}_{F,imp}^N = \overline{\mathbf{Q}}_{F,imp}^N \cup \{0,1,\dots,\lceil 9N/16 - E/4 \rceil - 1\};$$

end if

else -- shortening

for  $n=E$  to  $N-1$

$$\overline{\mathbf{Q}}_{F,imp}^N = \overline{\mathbf{Q}}_{F,imp}^N \cup \{J(n)\};$$

end for

end if

end if

$$\overline{\mathbf{Q}}_{I,imp}^N = \mathbf{Q}_0^{N-1} \setminus \overline{\mathbf{Q}}_{F,imp}^N;$$

$\overline{\mathbf{Q}}_I^N$  comprises  $(K + n_{PC})$  most reliable bit indices in  $\overline{\mathbf{Q}}_{I,imp}^N$ ;

$$\overline{\mathbf{Q}}_F^N = \mathbf{Q}_0^{N-1} \setminus \overline{\mathbf{Q}}_I^N;$$

### 5.4.1.2 Bit selection

The bit sequence after the sub-block interleaver  $y_0, y_1, y_2, \dots, y_{N-1}$  from Clause 5.4.1.1 is written into a circular buffer of length  $N$ .

Denoting by  $E$  the rate matching output sequence length, the bit selection output bit sequence  $e_k, k=0,1,2,\dots,E-1$ , is generated as follows:

```

if  $E \geq N$  -- repetition
  for  $k=0$  to  $E-1$ 
     $e_k = y_{\text{mod}(k,N)}$ ;
  end for
else
  if  $K/E \leq 7/16$  -- puncturing
    for  $k=0$  to  $E-1$ 
       $e_k = y_{k+N-E}$ ;
    end for
  else -- shortening
    for  $k=0$  to  $E-1$ 
       $e_k = y_k$ ;
    end for
  end if
end if

```

### 5.4.1.3 Interleaving of coded bits

The bit sequence  $e_0, e_1, e_2, \dots, e_{E-1}$  is interleaved into bit sequence  $f_0, f_1, f_2, \dots, f_{E-1}$ , as follows:

```

If  $I_{BL} = 1$ 
  Denote  $T$  as the smallest integer such that  $T(T+1)/2 \geq E$ ;
   $k=0$ ;
  for  $i=0$  to  $T-1$ 
    for  $j=0$  to  $T-1-i$ 
      if  $k < E$ 
         $v_{i,j} = e_k$ ;
      else
         $v_{i,j} = \langle \text{NULL} \rangle$ ;
      end if
    end for
  end for

```

```

        k = k + 1;
    end for
end for
k = 0;
for j = 0 to T - 1
    for i = 0 to T - 1 - j
        if vi,j ≠ < NULL >
            fk = vi,j;
            k = k + 1
        end if
    end for
end for
else
    for i = 0 to E - 1
        fi = ei;
    end for
end if

```

The value of  $E$  is no larger than 8192.

## 5.4.2 Rate matching for LDPC code

The rate matching for LDPC code is defined per coded block and consists of bit selection and bit interleaving. The input bit sequence to rate matching is  $d_0, d_1, d_2, \dots, d_{N-1}$ . The output bit sequence after rate matching is denoted as

$f_0, f_1, f_2, \dots, f_{E-1}$ .

### 5.4.2.1 Bit selection

The bit sequence after encoding  $d_0, d_1, d_2, \dots, d_{N-1}$  from Clause 5.3.2 is written into a circular buffer of length  $N_{cb}$  for the  $r$ -th coded block, where  $N$  is defined in Clause 5.3.2.

For the  $r$ -th code block, let  $N_{cb} = N$  if  $I_{LBRM} = 0$  and  $N_{cb} = \min(N, N_{ref})$  otherwise, where  $N_{ref} = \left\lfloor \frac{TBS_{LBRM}}{C \cdot R_{LBRM}} \right\rfloor$ ,

$R_{LBRM} = 2/3$ ,  $TBS_{LBRM}$  is determined according to Clause 6.1.4.2 in [6, TS 38.214] for UL-SCH and Clause 5.1.3.2 in [6, TS 38.214] for DL-SCH/PCH, assuming the following:

- maximum number of layers for one TB for UL-SCH is given by  $X$ , where
  - if the higher layer parameter *maxMIMO-Layers* of *PUSCH-ServingCellConfig* of the serving cell is configured,  $X$  is given by that parameter
  - elseif the higher layer parameter *maxRank* of *pusch-Config* of the serving cell is configured,  $X$  is given by the maximum value of *maxRank* across all BWPs of the serving cell
  - otherwise,  $X$  is given by the maximum number of layers for PUSCH supported by the UE for the serving cell

- maximum number of layers for one TB for DL-SCH/PCH is given by the minimum of  $X$  and 4, where
  - if the higher layer parameter *maxMIMO-Layers* of *PDSCH-ServingCellConfig* of the serving cell is configured,  $X$  is given by that parameter
  - otherwise,  $X$  is given by the maximum number of layers for PDSCH supported by the UE for the serving cell
- if the higher layer parameter *mcs-Table* or *mcs-TableDCI-1-2* given by a *pdsch-Config* for at least one DL BWP of the serving cell is set to 'qam256', maximum modulation order  $Q_m = 8$  is assumed for DL-SCH; otherwise a maximum modulation order  $Q_m = 6$  is assumed for DL-SCH;
- if the higher layer parameter *mcs-Table* or *mcs-TableTransformPrecoder* or *mcs-TableDCI-0-2* or *mcs-TableTransformPrecoderDCI-0-2* given by a *pusch-Config* or the higher layer parameter *mcs-Table* or *mcs-TableTransformPrecoder* given by *configuredGrantConfig* for at least one UL BWP of the serving cell is set to 'qam256', maximum modulation order  $Q_m = 8$  is assumed for UL-SCH; otherwise a maximum modulation order  $Q_m = 6$  is assumed for UL-SCH
- maximum coding rate of 948/1024;
- $n_{PRB} = n_{PRB,LBRM}$  is given by Table 5.4.2.1-1, where the value of  $n_{PRB,LBRM}$  for DL-SCH is determined according to the initial downlink bandwidth part if there is no other downlink bandwidth part configured to the UE;
- $N_{RE} = 156 \cdot n_{PRB}$ ;
- $C$  is the number of code blocks of the transport block determined according to Clause 5.2.2.

**Table 5.4.2.1-1: Value of  $n_{PRB,LBRM}$**

Maximum number of PRBs across all configured DL BWPs and UL BWPs of a carrier for DL-SCH and UL-SCH, respectively	$n_{PRB,LBRM}$
Less than 33	32
33 to 66	66
67 to 107	107
108 to 135	135
136 to 162	162
163 to 217	217
Larger than 217	273

Denoting by  $E_r$  the rate matching output sequence length for the  $r$ -th coded block, where the value of  $E_r$  is determined as follows:

Set  $j = 0$

for  $r = 0$  to  $C - 1$

if the  $r$ -th coded block is not scheduled for transmission as indicated by CBGTI according to Clause 5.1.7.2 for DL-SCH and 6.1.5.2 for UL-SCH in [6, TS 38.214]

$E_r = 0$ ;

else

if  $j \leq C' - \text{mod}(G / (N_L \cdot Q_m), C') - 1$

$$E_r = N_L \cdot Q_m \cdot \left\lfloor \frac{G}{N_L \cdot Q_m \cdot C'} \right\rfloor;$$



else

$$E_r = N_L \cdot Q_m \cdot \left\lceil \frac{G}{N_L \cdot Q_m \cdot C'} \right\rceil;$$

end if

$$j = j + 1;$$

end if

end for

where

- $N_L$  is the number of transmission layers that the transport block is mapped onto;
- $Q_m$  is the modulation order;
- $G$  is the total number of coded bits available for transmission of the transport block;
- $C' = C$  if CBGTI is not present in the DCI scheduling the transport block and  $C'$  is the number of scheduled code blocks of the transport block if CBGTI is present in the DCI scheduling the transport block.

Denote by  $rv_{id}$  the redundancy version number for this transmission ( $rv_{id} = 0, 1, 2$  or  $3$ ), the rate matching output bit sequence  $e_k$ ,  $k=0,1,2,\dots,E-1$ , is generated as follows, where  $k_0$  is given by Table 5.4.2.1-2 according to the value of  $rv_{id}$  and LDPC base graph:

$$k = 0;$$

$$j = 0;$$

while  $k < E$

if  $d_{(k_0+j) \bmod N_{cb}} \neq \langle NULL \rangle$

$$e_k = d_{(k_0+j) \bmod N_{cb}};$$

$$k = k + 1;$$

end if

$$j = j + 1;$$

end while

**Table 5.4.2.1-2: Starting position of different redundancy versions,  $k_0$**

$rv_{id}$	$k_0$	
	LDPC base graph 1	LDPC base graph 2
0	0	0
1	$\left\lfloor \frac{17N_{cb}}{66Z_c} \right\rfloor Z_c$	$\left\lfloor \frac{13N_{cb}}{50Z_c} \right\rfloor Z_c$
2	$\left\lfloor \frac{33N_{cb}}{66Z_c} \right\rfloor Z_c$	$\left\lfloor \frac{25N_{cb}}{50Z_c} \right\rfloor Z_c$
3	$\left\lfloor \frac{56N_{cb}}{66Z_c} \right\rfloor Z_c$	$\left\lfloor \frac{43N_{cb}}{50Z_c} \right\rfloor Z_c$

### 5.4.2.2 Bit interleaving

The bit sequence  $e_0, e_1, e_2, \dots, e_{E-1}$  is interleaved to bit sequence  $f_0, f_1, f_2, \dots, f_{E-1}$ , according to the following, where the value of  $Q_m$  is the modulation order.

for  $j = 0$  to  $E / Q_m - 1$

for  $i = 0$  to  $Q_m - 1$

$$f_{i+jQ_m} = e_{i+E/Q_m+j};$$

end for

end for

### 5.4.3 Rate matching for channel coding of small block lengths

The input bit sequence to rate matching is  $d_0, d_1, d_2, \dots, d_{N-1}$ . The output bit sequence after rate matching is denoted as  $f_0, f_1, f_2, \dots, f_{E-1}$ , where  $E$  is the rate matching output sequence length. The bit sequence  $f_0, f_1, f_2, \dots, f_{E-1}$  is obtained by the following:

for  $k = 0$  to  $E - 1$

$$f_k = d_{k \bmod N};$$

end for

## 5.5 Code block concatenation

The input bit sequence for the code block concatenation block are the sequences  $f_{rk}$ , for  $r = 0, \dots, C - 1$  and  $k = 0, \dots, E_r - 1$ , where  $E_r$  is the number of rate matched bits for the  $r$ -th code block. The output bit sequence from the code block concatenation block is the sequence  $g_k$  for  $k = 0, \dots, G - 1$ .

The code block concatenation consists of sequentially concatenating the rate matching outputs for the different code blocks. Therefore,

Set  $k = 0$  and  $r = 0$

while  $r < C$

Set  $j = 0$

while  $j < E_r$

$$g_k = f_{rj}$$

$$k = k + 1$$

$$j = j + 1$$

end while

$$r = r + 1$$

end while

## 6 Uplink transport channels and control information

### 6.1 Random access channel

The sequence index for the random access channel is received from higher layers and is processed according to [4, TS 38.211].

### 6.2 Uplink shared channel

#### 6.2.1 Transport block CRC attachment

Error detection is provided on each UL-SCH transport block through a Cyclic Redundancy Check (CRC).

The entire transport block is used to calculate the CRC parity bits. Denote the bits in a transport block delivered to layer 1 by  $a_0, a_1, a_2, a_3, \dots, a_{A-1}$ , and the parity bits by  $p_0, p_1, p_2, p_3, \dots, p_{L-1}$ , where  $A$  is the payload size and  $L$  is the number of parity bits. The lowest order information bit  $a_0$  is mapped to the most significant bit of the transport block as defined in Clause 6.1.1 of [TS38.321].

The parity bits are computed and attached to the UL-SCH transport block according to Clause 5.1, by setting  $L$  to 24 bits and using the generator polynomial  $g_{\text{CRC24A}}(D)$  if  $A > 3824$ ; and by setting  $L$  to 16 bits and using the generator polynomial  $g_{\text{CRC16}}(D)$  otherwise.

The bits after CRC attachment are denoted by  $b_0, b_1, b_2, b_3, \dots, b_{B-1}$ , where  $B = A + L$ .

#### 6.2.2 LDPC base graph selection

For initial transmission of a transport block with coding rate  $R$  indicated by the MCS index according to Clause 6.1.4.1 in [6, TS 38.214] and subsequent re-transmission of the same transport block, each code block of the transport block is encoded with either LDPC base graph 1 or 2 according to the following:

- if  $A \leq 292$ , or if  $A \leq 3824$  and  $R \leq 0.67$ , or if  $R \leq 0.25$ , LDPC base graph 2 is used;
- otherwise, LDPC base graph 1 is used,

where  $A$  is the payload size as described in Clause 6.2.1.

#### 6.2.3 Code block segmentation and code block CRC attachment

The bits input to the code block segmentation are denoted by  $b_0, b_1, b_2, b_3, \dots, b_{B-1}$  where  $B$  is the number of bits in the transport block (including CRC).

Code block segmentation and code block CRC attachment are performed according to Clause 5.2.2.

The bits after code block segmentation are denoted by  $c_{r0}, c_{r1}, c_{r2}, c_{r3}, \dots, c_{r(K_r-1)}$ , where  $r$  is the code block number and  $K_r$  is the number of bits for code block number  $r$  according to Clause 5.2.2.

#### 6.2.4 Channel coding of UL-SCH

Code blocks are delivered to the channel coding block. The bits in a code block are denoted by  $c_{r0}, c_{r1}, c_{r2}, c_{r3}, \dots, c_{r(K_r-1)}$ , where  $r$  is the code block number, and  $K_r$  is the number of bits in code block number  $r$ .

The total number of code blocks is denoted by  $C$  and each code block is individually LDPC encoded according to Clause 5.3.2.

After encoding the bits are denoted by  $d_{r0}, d_{r1}, d_{r2}, d_{r3}, \dots, d_{r(N_r-1)}$ , where the values of  $N_r$  is given in Clause 5.3.2.

## 6.2.5 Rate matching

Coded bits for each code block, denoted as  $d_{r0}, d_{r1}, d_{r2}, d_{r3}, \dots, d_{r(N_r-1)}$ , are delivered to the rate match block, where  $r$  is the code block number, and  $N_r$  is the number of encoded bits in code block number  $r$ . The total number of code blocks is denoted by  $C$  and each code block is individually rate matched according to Clause 5.4.2 by setting  $I_{LBRM} = 1$  if higher layer parameter *rateMatching* is set to *limitedBufferRM* and by setting  $I_{LBRM} = 0$  otherwise.

After rate matching, the bits are denoted by  $f_{r0}, f_{r1}, f_{r2}, f_{r3}, \dots, f_{r(E_r-1)}$ , where  $E_r$  is the number of rate matched bits for code block number  $r$ .

## 6.2.6 Code block concatenation

The input bit sequence for the code block concatenation block are the sequences  $f_{r0}, f_{r1}, f_{r2}, f_{r3}, \dots, f_{r(E_r-1)}$ , for  $r = 0, \dots, C-1$  and where  $E_r$  is the number of rate matched bits for the  $r$ -th code block.

Code block concatenation is performed according to Clause 5.5.

The bits after code block concatenation are denoted by  $g_0, g_1, g_2, g_3, \dots, g_{G-1}$ , where  $G$  is the total number of coded bits for transmission.

## 6.2.7 Data and control multiplexing

Denote the coded bits for UL-SCH as  $g_0^{\text{UL-SCH}}, g_1^{\text{UL-SCH}}, g_2^{\text{UL-SCH}}, g_3^{\text{UL-SCH}}, \dots, g_{G^{\text{UL-SCH}}-1}^{\text{UL-SCH}}$ .

Denote the coded bits for HARQ-ACK or jointly coded bits for HARQ-ACK and CG-UCI when the high layer parameter *cg-UCI-Multiplexing* is configured, if any, as  $g_0^{\text{ACK}}, g_1^{\text{ACK}}, g_2^{\text{ACK}}, g_3^{\text{ACK}}, \dots, g_{G^{\text{ACK}}-1}^{\text{ACK}}$ .

Denote the coded bits for CSI part 1, if any, as  $g_0^{\text{CSI-part1}}, g_1^{\text{CSI-part1}}, g_2^{\text{CSI-part1}}, g_3^{\text{CSI-part1}}, \dots, g_{G^{\text{CSI-part1}}-1}^{\text{CSI-part1}}$ .

Denote the coded bits for CSI part 2, if any, as  $g_0^{\text{CSI-part2}}, g_1^{\text{CSI-part2}}, g_2^{\text{CSI-part2}}, g_3^{\text{CSI-part2}}, \dots, g_{G^{\text{CSI-part2}}-1}^{\text{CSI-part2}}$ .

Denote the coded bits for CG-UCI without HARQ-ACK, if any, as  $g_0^{\text{CG-UCI}}, g_1^{\text{CG-UCI}}, g_2^{\text{CG-UCI}}, g_3^{\text{CG-UCI}}, \dots, g_{G^{\text{CG-UCI}}-1}^{\text{CG-UCI}}$ .

Denote the multiplexed data and control coded bit sequence as  $g_0, g_1, g_2, g_3, \dots, g_{G-1}$ .

Denote  $l$  as the OFDM symbol index of the scheduled PUSCH, starting from 0 to  $N_{\text{sym,all}}^{\text{PUSCH}} - 1$ , where  $N_{\text{sym,all}}^{\text{PUSCH}}$  is the total number of OFDM symbols of the PUSCH, including all OFDM symbols used for DMRS.

Denote  $k$  as the subcarrier index of the scheduled PUSCH, starting from 0 to  $M_{\text{sc}}^{\text{PUSCH}} - 1$ , where  $M_{\text{sc}}^{\text{PUSCH}}$  is expressed as a number of subcarriers.

Denote  $\Phi_l^{\text{UL-SCH}}$  as the set of resource elements, in ascending order of indices  $k$ , available for transmission of data in OFDM symbol  $l$ , for  $l = 0, 1, 2, \dots, N_{\text{sym,all}}^{\text{PUSCH}} - 1$ .

Denote  $M_{\text{sc}}^{\text{UL-SCH}}(l) = |\Phi_l^{\text{UL-SCH}}|$  as the number of elements in set  $\Phi_l^{\text{UL-SCH}}$ . Denote  $\Phi_l^{\text{UL-SCH}}(j)$  as the  $j$ -th element in  $\Phi_l^{\text{UL-SCH}}$ .

Denote  $\Phi_l^{\text{UCI}}$  as the set of resource elements, in ascending order of indices  $k$ , available for transmission of UCI in OFDM symbol  $l$ , for  $l = 0, 1, 2, \dots, N_{\text{symb.all}}^{\text{PUSCH}} - 1$ . Denote  $M_{\text{sc}}^{\text{UCI}}(l) = |\Phi_l^{\text{UCI}}|$  as the number of elements in set  $\Phi_l^{\text{UCI}}$ . Denote  $\Phi_l^{\text{UCI}}(j)$  as the  $j$ -th element in  $\Phi_l^{\text{UCI}}$ . For any OFDM symbol that carries DMRS of the PUSCH,  $\Phi_l^{\text{UCI}} = \emptyset$ . For any OFDM symbol that does not carry DMRS of the PUSCH,  $\Phi_l^{\text{UCI}} = \Phi_l^{\text{UL-SCH}}$ .

If frequency hopping is configured for the PUSCH,

- denote  $l^{(1)}$  as the OFDM symbol index of the first OFDM symbol after the first set of consecutive OFDM symbol(s) carrying DMRS in the first hop;
- denote  $l^{(2)}$  as the OFDM symbol index of the first OFDM symbol after the first set of consecutive OFDM symbol(s) carrying DMRS in the second hop.
- denote  $l_{\text{CSI}}^{(1)}$  as the OFDM symbol index of the first OFDM symbol that does not carry DMRS in the first hop;
- denote  $l_{\text{CSI}}^{(2)}$  as the OFDM symbol index of the first OFDM symbol that does not carry DMRS in the second hop;
- if HARQ-ACK is present for transmission on the PUSCH with UL-SCH or if both HARQ-ACK and CG-UCI are present on the same PUSCH with UL-SCH, let
  - $G^{\text{ACK}}(1) = N_L \cdot Q_m \cdot \lceil G^{\text{ACK}} / (2 \cdot N_L \cdot Q_m) \rceil$  and  $G^{\text{ACK}}(2) = N_L \cdot Q_m \cdot \lceil G^{\text{ACK}} / (2 \cdot N_L \cdot Q_m) \rceil$ ;
- if CSI is present for transmission on the PUSCH with UL-SCH, let
  - $G^{\text{CSI-part1}}(1) = N_L \cdot Q_m \cdot \lceil G^{\text{CSI-part1}} / (2 \cdot N_L \cdot Q_m) \rceil$ ;
  - $G^{\text{CSI-part1}}(2) = N_L \cdot Q_m \cdot \lceil G^{\text{CSI-part1}} / (2 \cdot N_L \cdot Q_m) \rceil$ ;
  - $G^{\text{CSI-part2}}(1) = N_L \cdot Q_m \cdot \lceil G^{\text{CSI-part2}} / (2 \cdot N_L \cdot Q_m) \rceil$ ; and
  - $G^{\text{CSI-part2}}(2) = N_L \cdot Q_m \cdot \lceil G^{\text{CSI-part2}} / (2 \cdot N_L \cdot Q_m) \rceil$ ;
- if CG-UCI is present for transmission on the PUSCH with UL-SCH and without HARQ-ACK, let
  - $G^{\text{CG-UCI}}(1) = N_L \cdot Q_m \cdot \lceil G^{\text{CG-UCI}} / (2 \cdot N_L \cdot Q_m) \rceil$  and  $G^{\text{CG-UCI}}(2) = N_L \cdot Q_m \cdot \lceil G^{\text{CG-UCI}} / (2 \cdot N_L \cdot Q_m) \rceil$
- if only HARQ-ACK and CSI part 1 are present for transmission on the PUSCH without UL-SCH, let
  - $G^{\text{ACK}}(1) = \min\left(N_L \cdot Q_m \cdot \lceil G^{\text{ACK}} / (2 \cdot N_L \cdot Q_m) \rceil, M_3 \cdot N_L \cdot Q_m\right)$ ;
  - $G^{\text{ACK}}(2) = G^{\text{ACK}} - G^{\text{ACK}}(1)$  ;
  - $G^{\text{CSI-part1}}(1) = M_1 \cdot N_L \cdot Q_m - G^{\text{ACK}}(1)$ ; and
  - $G^{\text{CSI-part1}}(2) = G^{\text{CSI-part1}} - G^{\text{CSI-part1}}(1)$  ;
- if HARQ-ACK, CSI part 1 and CSI part 2 are present for transmission on the PUSCH without UL-SCH, let
  - $G^{\text{ACK}}(1) = \min\left(N_L \cdot Q_m \cdot \lceil G^{\text{ACK}} / (2 \cdot N_L \cdot Q_m) \rceil, M_3 \cdot N_L \cdot Q_m\right)$ ;
  - $G^{\text{ACK}}(2) = G^{\text{ACK}} - G^{\text{ACK}}(1)$  ;

- if the number of HARQ-ACK information bits is more than 2 or if both HARQ-ACK and CG-UCI are present on the same PUSCH with UL-SCH,  $G^{\text{CSI-part1}}(1) = \min(N_L \cdot Q_m \cdot \lfloor G^{\text{CSI-part1}} / (2 \cdot N_L \cdot Q_m) \rfloor, M_1 \cdot N_L \cdot Q_m - G^{\text{ACK}}(1))$ ;  
otherwise,  $G^{\text{CSI-part1}}(1) = \min(N_L \cdot Q_m \cdot \lfloor G^{\text{CSI-part1}} / (2 \cdot N_L \cdot Q_m) \rfloor, M_1 \cdot N_L \cdot Q_m - G_{\text{rvd}}^{\text{ACK}}(1))$
- $G^{\text{CSI-part1}}(2) = G^{\text{CSI-part1}} - G^{\text{CSI-part1}}(1)$  ;
- $G^{\text{CSI-part2}}(1) = M_1 \cdot N_L \cdot Q_m - G^{\text{CSI-part1}}(1)$  if the number of HARQ-ACK information bits is no more than 2, and  
 $G^{\text{CSI-part2}}(1) = M_1 \cdot N_L \cdot Q_m - G^{\text{ACK}}(1) - G^{\text{CSI-part1}}(1)$  otherwise; and
- $G^{\text{CSI-part2}}(2) = M_2 \cdot N_L \cdot Q_m - G^{\text{CSI-part1}}(2)$  if the number of HARQ-ACK information bits is no more than 2, and  
 $G^{\text{CSI-part2}}(2) = M_2 \cdot N_L \cdot Q_m - G^{\text{ACK}}(2) - G^{\text{CSI-part1}}(2)$  otherwise;
- if CG-UCI is present for transmission on the PUSCH with UL-SCH and without HARQ-ACK, let
  - $G^{\text{CSI-part1}}(1) = \min(N_L \cdot Q_m \cdot \lfloor G^{\text{CSI-part1}} / (2 \cdot N_L \cdot Q_m) \rfloor, M_1 \cdot N_L \cdot Q_m - G^{\text{CG-UCI}}(1))$ ;
  - $G^{\text{CSI-part1}}(2) = G^{\text{CSI-part1}} - G^{\text{CSI-part1}}(1)$ ;
  - $G^{\text{CSI-part2}}(1) = M_1 \cdot N_L \cdot Q_m - G^{\text{CG-UCI}}(1) - G^{\text{CSI-part1}}(1)$ ; and
  - $G^{\text{CSI-part2}}(2) = M_2 \cdot N_L \cdot Q_m - G^{\text{CG-UCI}}(2) - G^{\text{CSI-part1}}(2)$ ;
- if CSI part 1 and CSI part 2 are present for transmission on the PUSCH without UL-SCH, let
  - $G^{\text{CSI-part1}}(1) = \min(N_L \cdot Q_m \cdot \lfloor G^{\text{CSI-part1}} / (2 \cdot N_L \cdot Q_m) \rfloor, M_1 \cdot N_L \cdot Q_m - G_{\text{rvd}}^{\text{ACK}}(1))$ ;
  - $G^{\text{CSI-part1}}(2) = G^{\text{CSI-part1}} - G^{\text{CSI-part1}}(1)$  ;
  - $G^{\text{CSI-part2}}(1) = M_1 \cdot N_L \cdot Q_m - G^{\text{CSI-part1}}(1)$ ; and
  - $G^{\text{CSI-part2}}(2) = M_2 \cdot N_L \cdot Q_m - G^{\text{CSI-part1}}(2)$ ;
- let  $N_{\text{hop}}^{\text{PUSCH}} = 2$ , and denote  $N_{\text{sybm,hop}}^{\text{PUSCH}}(1)$ ,  $N_{\text{sybm,hop}}^{\text{PUSCH}}(2)$  as the number of OFDM symbols of the PUSCH in the first and second hop, respectively;
- $N_L$  is the number of transmission layers of the PUSCH;
- $Q_m$  is the modulation order of the PUSCH;
- $M_1 = \sum_{l=0}^{N_{\text{sybm,hop}}^{\text{PUSCH}}(1)-1} M_{\text{SC}}^{\text{UCI}}(l)$ ;
- $M_2 = \sum_{l=N_{\text{sybm,hop}}^{\text{PUSCH}}(1)}^{N_{\text{sybm,hop}}^{\text{PUSCH}}(1)+N_{\text{sybm,hop}}^{\text{PUSCH}}(2)-1} M_{\text{SC}}^{\text{UCI}}(l)$
- $M_3 = \sum_{l=l_{\text{CSI}}^{(1)}}^{N_{\text{sybm,hop}}^{\text{PUSCH}}(1)-1} M_{\text{SC}}^{\text{UCI}}(l)$ .

If frequency hopping is not configured for the PUSCH,

- denote  $l^{(1)}$  as the OFDM symbol index of the first OFDM symbol after the first set of consecutive OFDM symbol(s) carrying DMRS;
- denote  $l_{\text{CSI}}^{(1)}$  as the OFDM symbol index of the first OFDM symbol that does not carry DMRS;
- if HARQ-ACK is present for transmission on the PUSCH or if both HARQ-ACK and CG-UCI are present on the same PUSCH with UL-SCH, let  $G^{\text{ACK}}(1) = G^{\text{ACK}}$ ;

- if CSI is present for transmission on the PUSCH, let  $G^{\text{CSI-part1}}(1) = G^{\text{CSI-part1}}$  and  $G^{\text{CSI-part2}}(1) = G^{\text{CSI-part2}}$ ;
- if CG-UCI is present for transmission on the PUSCH without HARQ-ACK, let  $G^{\text{CG-UCI}}(1) = G^{\text{CG-UCI}}$ ;
- let  $N_{\text{hop}}^{\text{PUSCH}} = 1$  and  $N_{\text{symp,hop}}^{\text{PUSCH}}(1) = N_{\text{symp,all}}^{\text{PUSCH}}$ .

The multiplexed data and control coded bit sequence  $g_0, g_1, g_2, g_3, \dots, g_{G-1}$  is obtained according to the following:

**Step 1:**

Set  $\bar{\Phi}_l^{\text{UL-SCH}} = \Phi_l^{\text{UL-SCH}}$  for  $l = 0, 1, 2, \dots, N_{\text{symp,all}}^{\text{PUSCH}} - 1$ ;

Set  $\bar{M}_{\text{sc}}^{\text{UL-SCH}}(l) = |\bar{\Phi}_l^{\text{UL-SCH}}|$  for  $l = 0, 1, 2, \dots, N_{\text{symp,all}}^{\text{PUSCH}} - 1$ ;

Set  $\bar{\Phi}_l^{\text{UCI}} = \Phi_l^{\text{UCI}}$  for  $l = 0, 1, 2, \dots, N_{\text{symp,all}}^{\text{PUSCH}} - 1$ ;

Set  $\bar{M}_{\text{sc}}^{\text{UCI}}(l) = |\bar{\Phi}_l^{\text{UCI}}|$  for  $l = 0, 1, 2, \dots, N_{\text{symp,all}}^{\text{PUSCH}} - 1$ ;

if the number of HARQ-ACK information bits to be transmitted on PUSCH is 0, 1 or 2 bits and without CG-UCI

the number of reserved resource elements for potential HARQ-ACK transmission is calculated according to Clause 6.3.2.4.2.1, by setting  $O_{\text{ACK}} = 2$ ;

denote  $G_{\text{rvd}}^{\text{ACK}}$  as the number of coded bits for potential HARQ-ACK transmission using the reserved resource elements;

if frequency hopping is configured for the PUSCH, let  $G_{\text{rvd}}^{\text{ACK}}(1) = N_L \cdot Q_m \cdot \lfloor G_{\text{rvd}}^{\text{ACK}} / (2 \cdot N_L \cdot Q_m) \rfloor$  and

$$G_{\text{rvd}}^{\text{ACK}}(2) = N_L \cdot Q_m \cdot \lceil G_{\text{rvd}}^{\text{ACK}} / (2 \cdot N_L \cdot Q_m) \rceil;$$

if frequency hopping is not configured for the PUSCH, let  $G_{\text{rvd}}^{\text{ACK}}(1) = G_{\text{rvd}}^{\text{ACK}}$ ;

denote  $\bar{\Phi}_l^{\text{rvd}}$  as the set of reserved resource elements for potential HARQ-ACK transmission, in OFDM symbol  $l$ , for  $l = 0, 1, 2, \dots, N_{\text{symp,all}}^{\text{PUSCH}} - 1$ ;

Set  $m_{\text{count}}^{\text{ACK}}(1) = 0$ ;

Set  $m_{\text{count}}^{\text{ACK}}(2) = 0$ ;

$\bar{\Phi}_l^{\text{rvd}} = \emptyset$  for  $l = 0, 1, 2, \dots, N_{\text{symp,all}}^{\text{PUSCH}} - 1$ ;

for  $i = 1$  to  $N_{\text{hop}}^{\text{PUSCH}}$

$$l = l^{(i)};$$

while  $m_{\text{count}}^{\text{ACK}}(i) < G_{\text{rvd}}^{\text{ACK}}(i)$

if  $\bar{M}_{\text{sc}}^{\text{UCI}}(l) > 0$

if  $G_{\text{rvd}}^{\text{ACK}}(i) - m_{\text{count}}^{\text{ACK}}(i) \geq \bar{M}_{\text{sc}}^{\text{UCI}}(l) \cdot N_L \cdot Q_m$

$$d = 1;$$

$$m_{\text{count}}^{\text{RE}} = \bar{M}_{\text{sc}}^{\text{UL-SCH}}(l);$$

end if

if  $G_{\text{rvd}}^{\text{ACK}}(i) - m_{\text{count}}^{\text{ACK}}(i) < \bar{M}_{\text{sc}}^{\text{UCI}}(l) \cdot N_L \cdot Q_m$

$$d = \left\lfloor \bar{M}_{\text{sc}}^{\text{UCI}}(l) \cdot N_L \cdot Q_m / (G_{\text{rvd}}^{\text{ACK}}(i) - m_{\text{count}}^{\text{ACK}}(i)) \right\rfloor;$$

$$m_{\text{count}}^{\text{RE}} = \left\lceil (G_{\text{rvd}}^{\text{ACK}}(i) - m_{\text{count}}^{\text{ACK}}(i)) / (N_L \cdot Q_m) \right\rceil;$$

end if

for  $j = 0$  to  $m_{\text{count}}^{\text{RE}} - 1$

$$\bar{\Phi}_l^{\text{rvd}} = \bar{\Phi}_l^{\text{rvd}} \cup \{\bar{\Phi}_l^{\text{UL-SCH}}(j \cdot d)\}$$

$$m_{\text{count}}^{\text{ACK}}(i) = m_{\text{count}}^{\text{ACK}}(i) + N_L \cdot Q_m;$$

end for

end if

$l = l + 1$ ;

end while

end for

else

$$\bar{\Phi}_l^{\text{rvd}} = \emptyset \text{ for } l = 0, 1, 2, \dots, N_{\text{symb,all}}^{\text{PUSCH}} - 1;$$

end if

Denote  $\bar{M}_{\text{sc,rvd}}^{\bar{\Phi}}(l) = |\bar{\Phi}_l^{\text{rvd}}|$  as the number of elements in  $\bar{\Phi}_l^{\text{rvd}}$ .

### **Step 2:**

if HARQ-ACK is present for transmission on the PUSCH and the number of HARQ-ACK information bits is more than 2 or if both HARQ-ACK and CG-UCI are present on the same PUSCH with UL-SCH,

Set  $m_{\text{count}}^{\text{ACK}}(1) = 0$ ;

Set  $m_{\text{count}}^{\text{ACK}}(2) = 0$ ;

Set  $m_{\text{countall}}^{\text{ACK}} = 0$ ;

for  $i = 1$  to  $N_{\text{hop}}^{\text{PUSCH}}$

$l = l^{(i)}$ ;

while  $m_{\text{count}}^{\text{ACK}}(i) < G^{\text{ACK}}(i)$

if  $\bar{M}_{\text{sc}}^{\text{UCI}}(l) > 0$

if  $G^{\text{ACK}}(i) - m_{\text{count}}^{\text{ACK}}(i) \geq \bar{M}_{\text{sc}}^{\text{UCI}}(l) \cdot N_L \cdot Q_m$

$d = 1$ ;



$$m_{\text{count}}^{\text{RE}} = \bar{M}_{\text{sc}}^{\text{UCI}}(l);$$

end if

if  $G^{\text{ACK}}(i) - m_{\text{count}}^{\text{ACK}}(i) < \bar{M}_{\text{sc}}^{\text{UCI}}(l) \cdot N_L \cdot Q_m$

$$d = \left\lfloor \frac{\bar{M}_{\text{sc}}^{\text{UCI}}(l) \cdot N_L \cdot Q_m}{(G^{\text{ACK}}(i) - m_{\text{count}}^{\text{ACK}}(i))} \right\rfloor;$$

$$m_{\text{count}}^{\text{RE}} = \left\lceil \frac{(G^{\text{ACK}}(i) - m_{\text{count}}^{\text{ACK}}(i))}{(N_L \cdot Q_m)} \right\rceil;$$

end if

for  $j = 0$  to  $m_{\text{count}}^{\text{RE}} - 1$

$$k = \bar{\Phi}_l^{\text{UCI}}(j \cdot d);$$

for  $v = 0$  to  $N_L \cdot Q_m - 1$

$$\bar{g}_{l,k,v} = g_{m_{\text{count,all}}^{\text{ACK}}};$$

$$m_{\text{count,all}}^{\text{ACK}} = m_{\text{count,all}}^{\text{ACK}} + 1;$$

$$m_{\text{count}}^{\text{ACK}}(i) = m_{\text{count}}^{\text{ACK}}(i) + 1;$$

end for

end for

$$\bar{\Phi}_{l,\text{tmp}}^{\text{UCI}} = \emptyset;$$

for  $j = 0$  to  $m_{\text{count}}^{\text{RE}} - 1$

$$\bar{\Phi}_{l,\text{tmp}}^{\text{UCI}} = \bar{\Phi}_{l,\text{tmp}}^{\text{UCI}} \cup \bar{\Phi}_l^{\text{UCI}}(j \cdot d);$$

end for

$$\bar{\Phi}_l^{\text{UCI}} = \bar{\Phi}_l^{\text{UCI}} \setminus \bar{\Phi}_{l,\text{tmp}}^{\text{UCI}};$$

$$\bar{\Phi}_l^{\text{UL-SCH}} = \bar{\Phi}_l^{\text{UL-SCH}} \setminus \bar{\Phi}_{l,\text{tmp}}^{\text{UCI}};$$

$$\bar{M}_{\text{sc}}^{\text{UCI}}(l) = |\bar{\Phi}_l^{\text{UCI}}|;$$

$$\bar{M}_{\text{sc}}^{\text{UL-SCH}}(l) = |\bar{\Phi}_l^{\text{UL-SCH}}|;$$

end if

$$l = l + 1;$$

end while

end for

end if

**Step 2A:**

If CG-UCI is present for transmission on the PUSCH without HARQ-ACK,

Set  $m_{count}^{CG-UCI}(1) = 0$ ;

Set  $m_{count}^{CG-UCI}(2) = 0$ ;

Set  $m_{count,all}^{CG-UCI} = 0$ ;

for  $i = 1$  to  $N_{hop}^{PUSCH}$

$l = l^{(i)}$ ;

while  $m_{count}^{CG-UCI}(i) < G^{CG-UCI}(i)$

if  $\bar{M}_{sc}^{UCI}(l) > 0$

if  $G^{CG-UCI}(i) - m_{count}^{CG-UCI}(1) \geq \bar{M}_{sc}^{UCI}(l) \cdot N_L \cdot Q_m$

$d = 1$ ;

$m_{count}^{RE} = \bar{M}_{sc}^{UCI}(l)$ ;

end if

if  $G^{CG-UCI}(i) - m_{count}^{CG-UCI}(1) < \bar{M}_{sc}^{UCI}(l) \cdot N_L \cdot Q_m$

$d = \lceil \bar{M}_{sc}^{UCI}(l) \cdot N_L \cdot Q_m / (G^{CG-UCI}(i) - m_{count}^{CG-UCI}(i)) \rceil$ ;

$m_{count}^{RE} = \lceil (G^{CG-UCI}(i) - m_{count}^{CG-UCI}(i)) / (N_L \cdot Q_m) \rceil$ ;

end if

for  $j = 0$  to  $m_{count}^{RE} - 1$

$k = \bar{\Phi}_l^{UCI}(j, d)$ ;

for  $v = 0$  to  $N_L \cdot Q_m - 1$

$\bar{g}_{l,k,v} = g_{m_{count,all}^{CG-UCI}}^{CG-UCI}$ ;

$m_{count,all}^{CG-UCI} = m_{count,all}^{CG-UCI} + 1$ ;

$m_{count}^{CG-UCI}(i) = m_{count}^{CG-UCI}(i) + 1$ ;

end for

end for

$\bar{\Phi}_{l,tmp}^{UCI} = \emptyset$ ;

for  $j = 0$  to  $m_{count}^{RE} - 1$

$\bar{\Phi}_{l,tmp}^{UCI} = \bar{\Phi}_{l,tmp}^{UCI} \cup \bar{\Phi}_l^{UCI}(j, d)$ ;

end for

$\bar{\Phi}_l^{UCI} = \bar{\Phi}_l^{UCI} \setminus \bar{\Phi}_{l,tmp}^{UCI}$ ;

$\bar{\Phi}_l^{UL-SCH} = \bar{\Phi}_l^{UL-SCH} \setminus \bar{\Phi}_{l,tmp}^{UCI}$ ;

$\bar{M}_{sc}^{UCI}(l) = |\bar{\Phi}_l^{UCI}|$ ;

$\bar{M}_{sc}^{UL-SCH}(l) = |\bar{\Phi}_l^{UL-SCH}|$ ;

end if  
 $l = l + 1$ ;  
end while  
end for  
end if

**Step 3:**

if CSI is present for transmission on the PUSCH,

Set  $m_{\text{count}}^{\text{CSI-part1}}(1) = 0$ ;

Set  $m_{\text{count}}^{\text{CSI-part1}}(2) = 0$ ;

Set  $m_{\text{count,all}}^{\text{CSI-part1}} = 0$ ;

for  $i = 1$  to  $N_{\text{hop}}^{\text{PUSCH}}$

$l = l_{\text{CSI}}^{(i)}$ ;

while  $\bar{M}_{\text{sc}}^{\text{UCI}}(l) - \bar{M}_{\text{sc,rvd}}^{\bar{\Phi}}(l) \leq 0$

$l = l + 1$ ;

end while

while  $m_{\text{count}}^{\text{CSI-part1}}(i) < G^{\text{CSI-part1}}(i)$

if  $\bar{M}_{\text{sc}}^{\text{UCI}}(l) - \bar{M}_{\text{sc,rvd}}^{\bar{\Phi}}(l) > 0$

if  $G^{\text{CSI-part1}}(i) - m_{\text{count}}^{\text{CSI-part1}}(i) \geq (\bar{M}_{\text{sc}}^{\text{UCI}}(l) - \bar{M}_{\text{sc,rvd}}^{\bar{\Phi}}(l)) \cdot N_L \cdot Q_m$

$d = 1$ ;

$m_{\text{count}}^{\text{RE}} = \bar{M}_{\text{sc}}^{\text{UCI}}(l) - \bar{M}_{\text{sc,rvd}}^{\bar{\Phi}}(l)$ ;

end if

if  $G^{\text{CSI-part1}}(i) - m_{\text{count}}^{\text{CSI-part1}}(i) < (\bar{M}_{\text{sc}}^{\text{UCI}}(l) - \bar{M}_{\text{sc,rvd}}^{\bar{\Phi}}(l)) \cdot N_L \cdot Q_m$

$d = \left\lceil \frac{(\bar{M}_{\text{sc}}^{\text{UCI}}(l) - \bar{M}_{\text{sc,rvd}}^{\bar{\Phi}}(l)) \cdot N_L \cdot Q_m}{(G^{\text{CSI-part1}}(i) - m_{\text{count}}^{\text{CSI-part1}}(i))} \right\rceil$ ;

$m_{\text{count}}^{\text{RE}} = \left\lceil \frac{(G^{\text{CSI-part1}}(i) - m_{\text{count}}^{\text{CSI-part1}}(i))}{(N_L \cdot Q_m)} \right\rceil$ ;

end if

$\bar{\Phi}_l^{\text{temp}} = \bar{\Phi}_l^{\text{UCI}} \setminus \bar{\Phi}_l^{\text{rvd}}$ ;

for  $j = 0$  to  $m_{\text{count}}^{\text{RE}} - 1$

$k = \bar{\Phi}_l^{\text{temp}}(j \cdot d)$ ;

for  $v=0$  to  $N_L \cdot Q_m - 1$

$$\bar{g}_{l,k,v} = g_{m_{\text{count,all}}^{\text{CSI-part1}}}^{\text{CSI-part1}};$$

$$m_{\text{count,all}}^{\text{CSI-part1}} = m_{\text{count,all}}^{\text{CSI-part1}} + 1;$$

$$m_{\text{count}}^{\text{CSI-part1}}(i) = m_{\text{count}}^{\text{CSI-part1}}(i) + 1;$$

end for

end for

$$\bar{\Phi}_{l,\text{tmp}}^{\text{UCI}} = \emptyset;$$

for  $j=0$  to  $m_{\text{count}}^{\text{RE}} - 1$

$$\bar{\Phi}_{l,\text{tmp}}^{\text{UCI}} = \bar{\Phi}_{l,\text{tmp}}^{\text{UCI}} \cup \bar{\Phi}_l^{\text{temp}}(j \cdot d);$$

end for

$$\bar{\Phi}_l^{\text{UCI}} = \bar{\Phi}_l^{\text{UCI}} \setminus \bar{\Phi}_{l,\text{tmp}}^{\text{UCI}};$$

$$\bar{\Phi}_l^{\text{UL-SCH}} = \bar{\Phi}_l^{\text{UL-SCH}} \setminus \bar{\Phi}_{l,\text{tmp}}^{\text{UCI}};$$

$$\bar{M}_{\text{sc}}^{\text{UCI}}(l) = |\bar{\Phi}_l^{\text{UCI}}|;$$

$$\bar{M}_{\text{sc}}^{\text{UL-SCH}}(l) = |\bar{\Phi}_l^{\text{UL-SCH}}|;$$

end if

$$l = l + 1;$$

end while

end for

Set  $m_{\text{count}}^{\text{CSI-part2}}(1) = 0$ ;

Set  $m_{\text{count}}^{\text{CSI-part2}}(2) = 0$ ;

Set  $m_{\text{count,all}}^{\text{CSI-part2}} = 0$ ;

for  $i=1$  to  $N_{\text{hop}}^{\text{PUSCH}}$

$$l = l_{\text{CSI}}^{(i)};$$

while  $\bar{M}_{\text{sc}}^{\text{UCI}}(l) \leq 0$

$$l = l + 1;$$

end while

while  $m_{\text{count}}^{\text{CSI-part2}}(i) < G^{\text{CSI-part2}}(i)$

if  $\bar{M}_{sc}^{UCI}(l) > 0$

if  $G^{CSI-part2}(i) - m_{count}^{CSI-part2}(i) \geq \bar{M}_{sc}^{UCI}(l) \cdot N_L \cdot Q_m$

$d = 1$ ;

$m_{count}^{RE} = \bar{M}_{sc}^{UCI}(l)$ ;

end if

if  $G^{CSI-part2}(i) - m_{count}^{CSI-part2}(i) < \bar{M}_{sc}^{UCI}(l) \cdot N_L \cdot Q_m$

$d = \left\lfloor \frac{\bar{M}_{sc}^{UCI}(l) \cdot N_L \cdot Q_m}{G^{CSI-part2}(i) - m_{count}^{CSI-part2}(i)} \right\rfloor$ ;

$m_{count}^{RE} = \left\lceil \frac{G^{CSI-part2}(i) - m_{count}^{CSI-part2}(i)}{N_L \cdot Q_m} \right\rceil$ ;

end if

for  $j = 0$  to  $m_{count}^{RE} - 1$

$k = \bar{\Phi}_l^{UCI}(j \cdot d)$ ;

for  $v = 0$  to  $N_L \cdot Q_m - 1$

$\bar{g}_{l,k,v} = g_{m_{count.all}^{CSI-part2}}^{CSI-part2}$ ;

$m_{count.all}^{CSI-part2} = m_{count.all}^{CSI-part2} + 1$ ;

$m_{count}^{CSI-part2}(i) = m_{count}^{CSI-part2}(i) + 1$ ;

end for

end for

$\bar{\Phi}_{l,mp}^{UCI} = \emptyset$ ;

for  $j = 0$  to  $m_{count}^{RE} - 1$

$\bar{\Phi}_{l,mp}^{UCI} = \bar{\Phi}_{l,mp}^{UCI} \cup \bar{\Phi}_l^{UCI}(j \cdot d)$ ;

end for

$\bar{\Phi}_l^{UCI} = \bar{\Phi}_l^{UCI} \setminus \bar{\Phi}_{l,mp}^{UCI}$ ;

$\bar{\Phi}_l^{UL-SCH} = \bar{\Phi}_l^{UL-SCH} \setminus \bar{\Phi}_{l,mp}^{UCI}$ ;

$\bar{M}_{sc}^{UCI}(l) = |\bar{\Phi}_l^{UCI}|$ ;

$\bar{M}_{sc}^{UL-SCH}(l) = |\bar{\Phi}_l^{UL-SCH}|$ ;

end if

$l = l + 1$ ;

end while

end for

end if

**Step 4:**

if UL-SCH is present for transmission on the PUSCH,

Set  $m_{\text{count}}^{\text{UL-SCH}} = 0$ ;

for  $l = 0$  to  $N_{\text{sym,all}}^{\text{PUSCH}} - 1$

if  $\bar{M}_{\text{sc}}^{\text{UL-SCH}}(l) > 0$

for  $j = 0$  to  $\bar{M}_{\text{sc}}^{\text{UL-SCH}}(l) - 1$

$k = \bar{\Phi}_l^{\text{UL-SCH}}(j)$ ;

for  $v = 0$  to  $N_L \cdot Q_m - 1$

$\bar{g}_{l,k,v} = g_{m_{\text{count}}}^{\text{UL-SCH}}$ ;

$m_{\text{count}}^{\text{UL-SCH}} = m_{\text{count}}^{\text{UL-SCH}} + 1$ ;

end for

end for

end if

end for

end if

**Step 5:**

if HARQ-ACK is present for transmission on the PUSCH without CG-UCI and the number of HARQ-ACK information bits is no more than 2,

Set  $m_{\text{count}}^{\text{ACK}}(1) = 0$ ;

Set  $m_{\text{count}}^{\text{ACK}}(2) = 0$ ;

Set  $m_{\text{count,all}}^{\text{ACK}} = 0$ ;

for  $i = 1$  to  $N_{\text{hop}}^{\text{PUSCH}}$

$l = l^{(i)}$ ;

while  $m_{\text{count}}^{\text{ACK}}(i) < G^{\text{ACK}}(i)$

if  $\bar{M}_{\text{sc,rvid}}^{\bar{\Phi}}(l) > 0$

if  $G^{\text{ACK}}(i) - m_{\text{count}}^{\text{ACK}}(i) \geq \bar{M}_{\text{sc,rvid}}^{\bar{\Phi}}(l) \cdot N_L \cdot Q_m$

$d = 1;$

$$m_{\text{count}}^{\text{RE}} = \bar{M}_{\text{sc,rvd}}^{\bar{\Phi}}(l);$$

end if

if  $G^{\text{ACK}}(i) - m_{\text{count}}^{\text{ACK}}(i) < \bar{M}_{\text{sc,rvd}}^{\bar{\Phi}}(l) \cdot N_L \cdot Q_m$

$$d = \left\lceil \bar{M}_{\text{sc,rvd}}^{\bar{\Phi}}(l) \cdot N_L \cdot Q_m / (G^{\text{ACK}}(i) - m_{\text{count}}^{\text{ACK}}(i)) \right\rceil;$$

$$m_{\text{count}}^{\text{RE}} = \left\lceil (G^{\text{ACK}}(i) - m_{\text{count}}^{\text{ACK}}(i)) / (N_L \cdot Q_m) \right\rceil;$$

end if

for  $j = 0$  to  $m_{\text{count}}^{\text{RE}} - 1$

$$k = \bar{\Phi}_l^{\text{rvd}}(j \cdot d);$$

for  $v = 0$  to  $N_L \cdot Q_m - 1$

$$\bar{g}_{l,k,v} = g_{m_{\text{count,all}}^{\text{ACK}}};$$

$$m_{\text{count,all}}^{\text{ACK}} = m_{\text{count,all}}^{\text{ACK}} + 1;$$

$$m_{\text{count}}^{\text{ACK}}(i) = m_{\text{count}}^{\text{ACK}}(i) + 1;$$

end for

end for

end if

$$l = l + 1;$$

end while

end for

end if

### **Step 6:**

Set  $t = 0;$

for  $l = 0$  to  $N_{\text{symb,all}}^{\text{PUSCH}} - 1$

for  $j = 0$  to  $M_{\text{sc}}^{\text{UL-SCH}}(l) - 1$

$$k = \Phi_l^{\text{UL-SCH}}(j);$$

for  $v = 0$  to  $N_L \cdot Q_m - 1$

$$g_t = \bar{g}_{l,k,v};$$

$$t = t + 1;$$

end for

end for

end for

## 6.3 Uplink control information

### 6.3.1 Uplink control information on PUCCH

The procedure in this clause applies to PUCCH formats 2/3/4.

#### 6.3.1.1 UCI bit sequence generation

##### 6.3.1.1.1 HARQ-ACK/SR only

If only HARQ-ACK bits are transmitted on a PUCCH, the UCI bit sequence  $a_0, a_1, a_2, a_3, \dots, a_{A-1}$  is determined by setting  $a_i = \tilde{o}_i^{ACK}$  for  $i = 0, 1, \dots, O^{ACK} - 1$  and  $A = O^{ACK}$ , where the HARQ-ACK bit sequence  $\tilde{o}_0^{ACK}, \tilde{o}_1^{ACK}, \dots, \tilde{o}_{O^{ACK}-1}^{ACK}$  is given by Clause 9.1 of [5, TS38.213].

If only HARQ-ACK and SR bits are transmitted on a PUCCH, the UCI bit sequence  $a_0, a_1, a_2, a_3, \dots, a_{A-1}$  is determined by setting  $a_i = \tilde{o}_i^{ACK}$  for  $i = 0, 1, \dots, O^{ACK} - 1$ ,  $a_i = \tilde{o}_{i-O^{ACK}}^{SR}$  for  $i = O^{ACK}, O^{ACK} + 1, \dots, O^{ACK} + O^{SR} - 1$ , and  $A = O^{ACK} + O^{SR}$ , where the HARQ-ACK bit sequence  $\tilde{o}_0^{ACK}, \tilde{o}_1^{ACK}, \dots, \tilde{o}_{O^{ACK}-1}^{ACK}$  is given by Clause 9.1 of [5, TS 38.213], and the SR bit sequence  $\tilde{o}_0^{SR}, \tilde{o}_1^{SR}, \dots, \tilde{o}_{O^{SR}-1}^{SR}$  is given by Clause 9.2.5.1 of [5, TS 38.213].

##### 6.3.1.1.2 CSI only

The bitwidth for PMI of *codebookType=typeI-SinglePanel* with 2 CSI-RS ports is 2 for Rank=1 and 1 for Rank=2, according to Clause 5.2.2.2.1 in [6, TS 38.214].

The bitwidth for PMI of *codebookType=typeI-SinglePanel* with more than 2 CSI-RS ports is provided in Tables 6.3.1.1.2-1, where the values of  $(N_1, N_2)$  and  $(O_1, O_2)$  are given by Clause 5.2.2.2.1 in [6, TS 38.214].

**Table 6.3.1.1.2-1: PMI of *codebookType=typeI-SinglePanel***

	Information field $X_1$ for wideband PMI			Information field $X_2$ for wideband PMI or per subband PMI	
	$(i_{1,1}, i_{1,2})$		$i_{1,3}$	$i_2$	
	<i>codebookMode</i> =1	<i>codebookMode</i> =2		<i>codebookMode</i> =1	<i>codebookMode</i> =2
Rank = 1 with >2 CSI-RS ports, $N_2 > 1$	$(\lceil \log_2 N_1 O_1 \rceil, \lceil \log_2 N_2 O_2 \rceil)$	$(\lceil \log_2 \frac{N_1 O_1}{2} \rceil, \lceil \log_2 \frac{N_2 O_2}{2} \rceil)$	N/A	2	4
Rank = 1 with >2 CSI-RS ports, $N_2 = 1$	$(\lceil \log_2 N_1 O_1 \rceil, \lceil \log_2 N_2 O_2 \rceil)$	$(\lceil \log_2 (\frac{N_1 O_1}{2}) \rceil, 0)$	N/A	2	4



Rank=2 with 4 CSI-RS ports, $N_2 = 1$	$(\lceil \log_2 N_1 O_1 \rceil, \lceil \log_2 N_2 O_2 \rceil)$	$(\lceil \log_2 \left(\frac{N_1 O_1}{2}\right) \rceil, 0)$	1	1	3
Rank=2 with >4 CSI-RS ports, $N_2 > 1$	$(\lceil \log_2 N_1 O_1 \rceil, \lceil \log_2 N_2 O_2 \rceil)$	$(\lceil \log_2 \frac{N_1 O_1}{2} \rceil, \lceil \log_2 \frac{N_2 O_2}{2} \rceil)$	2	1	3
Rank=2 with >4 CSI-RS ports, $N_2 = 1$	$(\lceil \log_2 N_1 O_1 \rceil, \lceil \log_2 N_2 O_2 \rceil)$	$(\lceil \log_2 \left(\frac{N_1 O_1}{2}\right) \rceil, 0)$	2	1	3
Rank=3 or 4, with 4 CSI-RS ports	$(\lceil \log_2 N_1 O_1 \rceil, \lceil \log_2 N_2 O_2 \rceil)$		0		1
Rank=3 or 4, with 8 or 12 CSI-RS ports	$(\lceil \log_2 N_1 O_1 \rceil, \lceil \log_2 N_2 O_2 \rceil)$		2		1
Rank=3 or 4, with $\geq 16$ CSI-RS ports	$(\lceil \log_2 \frac{N_1 O_1}{2} \rceil, \lceil \log_2 N_2 O_2 \rceil)$		2		1
Rank=5 or 6	$(\lceil \log_2 N_1 O_1 \rceil, \lceil \log_2 N_2 O_2 \rceil)$		N/A		1
Rank=7 or 8, $N_1 = 4, N_2 = 1$	$(\lceil \log_2 \frac{N_1 O_1}{2} \rceil, \lceil \log_2 N_2 O_2 \rceil)$		N/A		1
Rank=7 or 8, $N_1 > 2, N_2 = 2$	$(\lceil \log_2 N_1 O_1 \rceil, \lceil \log_2 \frac{N_2 O_2}{2} \rceil)$		N/A		1
Rank=7 or 8, with $N_1 > 4, N_2 = 1$ or $N_1 = 2, N_2 = 2$ or $N_1 > 2, N_2 > 2$	$(\lceil \log_2 N_1 O_1 \rceil, \lceil \log_2 N_2 O_2 \rceil)$		N/A		1

The bandwidth for PMI of *codebookType= typeI-MultiPanel* is provided in Tables 6.3.1.1.2-2, where the values of  $(N_g, N_1, N_2)$  and  $(O_1, O_2)$  are given by Clause 5.2.2.2.2 in [6, TS 38.214].

**Table 6.3.1.1.2-2: PMI of *codebookType= typeI-MultiPanel***

	Information fields $X_1$ for wideband					Information fields $X_2$ for wideband or per subband			
	$(i_{1,1}, i_{1,2})$	$i_{1,3}$	$i_{1,4,1}$	$i_{1,4,2}$	$i_{1,4,3}$	$i_2$	$i_{2,0}$	$i_{2,1}$	$i_{2,2}$

Rank=1 with $N_g = 2$ <i>codebookMode=1</i>	$(\lceil \log_2 N_1 O_1 \rceil,$ $\lceil \log_2 N_2 O_2 \rceil)$	N/A	2	N/A	N/A	2	N/A	N/A	N/A
Rank=1 with $N_g = 4$ <i>codebookMode=1</i>	$(\lceil \log_2 N_1 O_1 \rceil,$ $\lceil \log_2 N_2 O_2 \rceil)$	N/A	2	2	2	2	N/A	N/A	N/A
Rank=2 with $N_g = 2,$ $N_1 N_2 = 2$ <i>codebookMode=1</i>	$(\lceil \log_2 N_1 O_1 \rceil,$ $\lceil \log_2 N_2 O_2 \rceil)$	1	2	N/A	N/A	1	N/A	N/A	N/A
Rank=3 or 4 with $N_g = 2,$ $N_1 N_2 = 2$ <i>codebookMode=1</i>	$(\lceil \log_2 N_1 O_1 \rceil,$ $\lceil \log_2 N_2 O_2 \rceil)$	0	2	N/A	N/A	1	N/A	N/A	N/A
Rank=2 or 3 or 4 with $N_g = 2,$ $N_1 N_2 > 2$ <i>codebookMode=1</i>	$(\lceil \log_2 N_1 O_1 \rceil,$ $\lceil \log_2 N_2 O_2 \rceil)$	2	2	N/A	N/A	1	N/A	N/A	N/A
Rank=2 with $N_g = 4,$ $N_1 N_2 = 2$ <i>codebookMode=1</i>	$(\lceil \log_2 N_1 O_1 \rceil,$ $\lceil \log_2 N_2 O_2 \rceil)$	1	2	2	2	1	N/A	N/A	N/A
Rank=3 or 4 with $N_g = 4,$ $N_1 N_2 = 2$ <i>codebookMode=1</i>	$(\lceil \log_2 N_1 O_1 \rceil,$ $\lceil \log_2 N_2 O_2 \rceil)$	0	2	2	2	1	N/A	N/A	N/A
Rank=2 or 3 or 4 with $N_g = 4,$ $N_1 N_2 > 2$ <i>codebookMode=1</i>	$(\lceil \log_2 N_1 O_1 \rceil,$ $\lceil \log_2 N_2 O_2 \rceil)$	2	2	2	2	1	N/A	N/A	N/A
Rank=1 with $N_g = 2$ <i>codebookMode=2</i>	$(\lceil \log_2 N_1 O_1 \rceil,$ $\lceil \log_2 N_2 O_2 \rceil)$	N/A	2	2	N/A	N/A	2	1	1
Rank=2 with $N_g = 2,$ $N_1 N_2 = 2$ <i>codebookMode=2</i>	$(\lceil \log_2 N_1 O_1 \rceil,$ $\lceil \log_2 N_2 O_2 \rceil)$	1	2	2	N/A	N/A	1	1	1
Rank=3 or 4 with $N_g = 2,$ $N_1 N_2 = 2$ <i>codebookMode=2</i>	$(\lceil \log_2 N_1 O_1 \rceil,$ $\lceil \log_2 N_2 O_2 \rceil)$	0	2	2	N/A	N/A	1	1	1
Rank=2 or 3 or 4 with $N_g = 2,$ $N_1 N_2 > 2$ <i>codebookMode=2</i>	$(\lceil \log_2 N_1 O_1 \rceil,$ $\lceil \log_2 N_2 O_2 \rceil)$	2	2	2	N/A	N/A	1	1	1

The bitwidth for PMI with 1 CSI-RS port is 0.

The bitwidth for RI/LI/CQI/CRI of *codebookType=typeI-SinglePanel* is provided in Tables 6.3.1.1.2-3.

**Table 6.3.1.1.2-3: RI, LI, CQI, and CRI of *codebookType=typeI-SinglePanel***

Field	Bitwidth				
	1 antenna port	2 antenna ports	4 antenna ports	>4 antenna ports	
				Rank1~4	Rank5~8
Rank Indicator	0	$\min(1, \lceil \log_2 n_{\text{RI}} \rceil)$	$\min(2, \lceil \log_2 n_{\text{RI}} \rceil)$	$\lceil \log_2 n_{\text{RI}} \rceil$	$\lceil \log_2 n_{\text{RI}} \rceil$
Layer Indicator	0	$\lceil \log_2 v \rceil$	$\min(2, \lceil \log_2 v \rceil)$	$\min(2, \lceil \log_2 v \rceil)$	$\min(2, \lceil \log_2 v \rceil)$
Wide-band CQI for the first TB	4	4	4	4	4
Wideband CQI for the second TB	0	0	0	0	4
Subband differential CQI for the first TB	2	2	2	2	2
Subband differential CQI for the second TB	0	0	0	0	2
CRI	$\lceil \log_2 (K_s^{\text{CSI-RS}}) \rceil$	$\lceil \log_2 (K_s^{\text{CSI-RS}}) \rceil$	$\lceil \log_2 (K_s^{\text{CSI-RS}}) \rceil$	$\lceil \log_2 (K_s^{\text{CSI-RS}}) \rceil$	$\lceil \log_2 (K_s^{\text{CSI-RS}}) \rceil$

$n_{\text{RI}}$  in Table 6.3.1.1.2-3 is the number of allowed rank indicator values according to Clause 5.2.2.2.1 [6, TS 38.214].

$v$  is the value of the rank. The value of  $K_s^{\text{CSI-RS}}$  is the number of CSI-RS resources in the corresponding resource set. The values of the rank indicator field are mapped to allowed rank indicator values with increasing order, where '0' is mapped to the smallest allowed rank indicator value.

The bitwidth for RI/LI/CQI/CRI of *codebookType=typeI-MultiPanel* is provided in Table 6.3.1.1.2-4.

**Table 6.3.1.1.2-4: RI, LI, CQI, and CRI of *codebookType=typeI-MultiPanel***

Field	Bitwidth
Rank Indicator	$\min(2, \lceil \log_2 n_{\text{RI}} \rceil)$
Layer Indicator	$\min(2, \lceil \log_2 v \rceil)$
Wide-band CQI	4
Subband differential CQI	2
CRI	$\lceil \log_2 (K_s^{\text{CSI-RS}}) \rceil$

where  $n_{\text{RI}}$  is the number of allowed rank indicator values according to Clause 5.2.2.2.2 [6, TS 38.214],  $v$  is the value of the rank, and  $K_s^{\text{CSI-RS}}$  is the number of CSI-RS resources in the corresponding resource set. The values of the rank indicator field are mapped to allowed rank indicator values with increasing order, where '0' is mapped to the smallest allowed rank indicator value.

The bitwidth for RI/LI/CQI of *codebookType=typeII* or *codebookType=typeII-PortSelection* is provided in Table 6.3.1.1.2-5.

**Table 6.3.1.1.2-5: RI, LI, and CQI of *codebookType=typell* or *typell-PortSelection***

Field	Bitwidth
Rank Indicator	$\min(1, \lceil \log_2 n_{\text{RI}} \rceil)$
Layer Indicator	$\min(2, \lceil \log_2 v \rceil)$
Wide-band CQI	4
Subband differential CQI	2
Indicator of the number of non-zero wideband amplitude coefficients $M_l$ for layer $l$	$\lceil \log_2(2L-1) \rceil$

where  $n_{\text{RI}}$  is the number of allowed rank indicator values according to Clauses 5.2.2.2.3 and 5.2.2.2.4 [6, TS 38.214] and  $v$  is the value of the rank. The values of the rank indicator field are mapped to allowed rank indicator values with increasing order, where '0' is mapped to the smallest allowed rank indicator value.

The bitwidth for CRI, SSBRI, RSRP, and differential RSRP are provided in Table 6.3.1.1.2-6.

**Table 6.3.1.1.2-6: CRI, SSBRI, and RSRP**

Field	Bitwidth
CRI	$\lceil \log_2(K_s^{\text{CSI-RS}}) \rceil$
SSBRI	$\lceil \log_2(K_s^{\text{SSB}}) \rceil$
RSRP	7
Differential RSRP	4

where  $K_s^{\text{CSI-RS}}$  is the number of CSI-RS resources in the corresponding resource set, and  $K_s^{\text{SSB}}$  is the configured number of SS/PBCH blocks in the corresponding resource set for reporting 'ssb-Index-RSRP'.

The bitwidth for CRI, SSBRI, SINR, and differential SINR are provided in Table 6.3.1.1.2-6A.

**Table 6.3.1.1.2-6A: CRI, SSBRI, and SINR**

Field	Bitwidth
CRI	$\lceil \log_2(K_s^{\text{CSI-RS}}) \rceil$
SSBRI	$\lceil \log_2(K_s^{\text{SSB}}) \rceil$
SINR	7
Differential SINR	4

where  $K_s^{\text{CSI-RS}}$  is the number of CSI-RS resources in the corresponding resource set, and  $K_s^{\text{SSB}}$  is the configured number of SS/PBCH blocks in the corresponding resource set for reporting 'ssb-Index-SINR'.

**Table 6.3.1.1.2-7: Mapping order of CSI fields of one CSI report, *pmi-FormatIndicator=widebandPMI* and *cqi-FormatIndicator=widebandCQI***

CSI report number	CSI fields
CSI report #n	CRI as in Tables 6.3.1.1.2-3/4, if reported
	Rank Indicator as in Tables 6.3.1.1.2-3/4, if reported
	Layer Indicator as in Tables 6.3.1.1.2-3/4, if reported
	Zero padding bits $O_p$ , if needed
	PMI wideband information fields $X_1$ , from left to right as in Tables 6.3.1.1.2-1/2, if reported
	PMI wideband information fields $X_2$ , from left to right as in Tables 6.3.1.1.2-1/2, or codebook index for 2 antenna ports according to Clause 5.2.2.2.1 in [6, TS38.214], if reported
	Wideband CQI for the first TB as in Tables 6.3.1.1.2-3/4, if reported
	Wideband CQI for the second TB as in Tables 6.3.1.1.2-3/4, if reported

The number of zero padding bits  $O_p$  in Table 6.3.1.1.2-7 is 0 for 1 CSI-RS port and  $O_p = N_{\max} - N_{\text{reported}}$  for more than 1 CSI-RS port, where

- $N_{\max} = \max_{r \in S_{\text{Rank}}} B(r)$  and  $S_{\text{Rank}}$  is the set of rank values  $r$  that are allowed to be reported;
- $N_{\text{reported}} = B(R)$ , where  $R$  is the reported rank;
- For 2 CSI-RS ports,  $B(r) = N_{\text{PMI}}(r) + N_{\text{CQI}}(r) + N_{\text{LI}}(r)$ ;
- For more than 2 CSI-RS ports,  $B(r) = N_{\text{PMI}_{i1}}(r) + N_{\text{PMI}_{i2}}(r) + N_{\text{CQI}}(r) + N_{\text{LI}}(r)$ ;
- if PMI is reported,  $N_{\text{PMI}}(1) = 2$  and  $N_{\text{PMI}}(2) = 1$ ; otherwise,  $N_{\text{PMI}}(r) = 0$ ;
- if PMI  $i_1$  is reported,  $N_{\text{PMI}_{i1}}(r)$  is obtained according to Tables 6.3.1.1.2-1/2; otherwise,  $N_{\text{PMI}_{i1}}(r) = 0$ ;
- if PMI  $i_2$  is reported,  $N_{\text{PMI}_{i2}}(r)$  is obtained according to Tables 6.3.1.1.2-1/2; otherwise,  $N_{\text{PMI}_{i2}}(r) = 0$ ;
- if CQI is reported,  $N_{\text{CQI}}(r)$  is obtained according to Tables 6.3.1.1.2-3/4; otherwise,  $N_{\text{CQI}}(r) = 0$ ;
- if LI is reported,  $N_{\text{LI}}(r)$  is obtained according to Tables 6.3.1.1.2-3/4; otherwise,  $N_{\text{LI}}(r) = 0$ .

**Table 6.3.1.1.2-8: Mapping order of CSI fields of one report for CRI/RSRP or SSBRI/RSRP reporting**

CSI report number	CSI fields
CSI report #n	CRI or SSBRI #1 as in Table 6.3.1.1.2-6, if reported
	CRI or SSBRI #2 as in Table 6.3.1.1.2-6, if reported
	CRI or SSBRI #3 as in Table 6.3.1.1.2-6, if reported
	CRI or SSBRI #4 as in Table 6.3.1.1.2-6, if reported
	RSRP #1 as in Table 6.3.1.1.2-6, if reported
	Differential RSRP #2 as in Table 6.3.1.1.2-6, if reported
	Differential RSRP #3 as in Table 6.3.1.1.2-6, if reported
	Differential RSRP #4 as in Table 6.3.1.1.2-6, if reported

Table 6.3.1.1.2-8A: Mapping order of CSI fields of one report for CRI/SINR or SSBRI/SINR reporting

CSI report number	CSI fields
CSI report #n	CRI or SSBRI #1 as in Table 6.3.1.1.2-6A, if reported
	CRI or SSBRI #2 as in Table 6.3.1.1.2-6A, if reported
	CRI or SSBRI #3 as in Table 6.3.1.1.2-6A, if reported
	CRI or SSBRI #4 as in Table 6.3.1.1.2-6A, if reported
	SINR #1 as in Table 6.3.1.1.2-6A, if reported
	Differential SINR #2 as in Table 6.3.1.1.2-6A, if reported
	Differential SINR #3 as in Table 6.3.1.1.2-6A, if reported
	Differential SINR #4 as in Table 6.3.1.1.2-6A, if reported

Table 6.3.1.1.2-9: Mapping order of CSI fields of one CSI report, CSI part 1, *pmi-FormatIndicator= subbandPMI* or *cqi-FormatIndicator=subbandCQI*

CSI report number	CSI fields
CSI report #n CSI part 1	CRI as in Tables 6.3.1.1.2-3/4, if reported
	Rank Indicator as in Tables 6.3.1.1.2-3/4/5, if reported
	Wideband CQI for the first TB as in Tables 6.3.1.1.2-3/4/5, if reported
	Subband differential CQI for the first TB with increasing order of subband number as in Tables 6.3.1.1.2-3/4/5, if reported
	Indicator of the number of non-zero wideband amplitude coefficients $M_0$ for layer 0 as in Table 6.3.1.1.2-5, if reported
	Indicator of the number of non-zero wideband amplitude coefficients $M_1$ for layer 1 as in Table 6.3.1.1.2-5 (if the rank according to the reported RI is equal to one, this field is set to all zeros), if 2-layer PMI reporting is allowed according to the rank restriction in Clauses 5.2.2.2.3 and 5.2.2.2.4 [6, TS 38.214] and if reported
Note:	Subbands for given CSI report $n$ indicated by the higher layer parameter <i>csi-ReportingBand</i> are numbered continuously in the increasing order with the lowest subband of <i>csi-ReportingBand</i> as subband 0.

Table 6.3.1.1.2-10: Mapping order of CSI fields of one CSI report, CSI part 2 wideband, *pmi-FormatIndicator= subbandPMI* or *cqi-FormatIndicator=subbandCQI*

CSI report number	CSI fields
CSI report #n CSI part 2 wideband	Wideband CQI for the second TB as in Tables 6.3.1.1.2-3/4/5, if present and reported
	Layer Indicator as in Tables 6.3.1.1.2-3/4/5, if reported
	PMI wideband information fields $X_1$ , from left to right as in Tables 6.3.1.1.2-1/2, if reported
	PMI wideband information fields $X_2$ , from left to right as in Tables 6.3.1.1.2-1/2, or codebook index for 2 antenna ports according to Clause 5.2.2.2.1 in [6, TS38.214], if <i>pmi-FormatIndicator= widebandPMI</i> and if reported

**Table 6.3.1.1.2-11: Mapping order of CSI fields of one CSI report, CSI part 2 subband, *pmi-FormatIndicator= subbandPMI* or *cqi-FormatIndicator=subbandCQI***

CSI report #n Part 2 subband	Subband differential CQI for the second TB of all even subbands with increasing order of subband number, as in Tables 6.3.1.1.2-3/4/5, if <i>cqi-FormatIndicator=subbandCQI</i> and if reported
	PMI subband information fields $X_2$ of all even subbands with increasing order of subband number, from left to right as in Tables 6.3.1.1.2-1/2, or codebook index for 2 antenna ports according to Clause 5.2.2.2.1 in [6, TS38.214] of all even subbands with increasing order of subband number, if <i>pmi-FormatIndicator= subbandPMI</i> and if reported
	Subband differential CQI for the second TB of all odd subbands with increasing order of subband number, as in Tables 6.3.1.1.2-3/4/5, if <i>cqi-FormatIndicator=subbandCQI</i> and if reported
	PMI subband information fields $X_2$ of all odd subbands with increasing order of subband number, from left to right as in Tables 6.3.1.1.2-1/2, or codebook index for 2 antenna ports according to Clause 5.2.2.2.1 in [6, TS38.214] of all odd subbands with increasing order of subband number, if <i>pmi-FormatIndicator= subbandPMI</i> and if reported

Note: Subbands for given CSI report  $n$  indicated by the higher layer parameter *csi-ReportingBand* are numbered continuously in the increasing order with the lowest subband of *csi-ReportingBand* as subband 0.

If none of the CSI reports for transmission on a PUCCH is of two parts, the CSI fields of all CSI reports, in the order from upper part to lower part in Table 6.3.1.1.2-12, are mapped to the UCI bit sequence  $a_0, a_1, a_2, a_3, \dots, a_{A-1}$  starting with  $a_0$ . The most significant bit of each field is mapped to the lowest order information bit for that field, e.g. the most significant bit of the first field is mapped to  $a_0$ .

**Table 6.3.1.1.2-12: Mapping order of CSI reports to UCI bit sequence  $a_0, a_1, a_2, a_3, \dots, a_{A-1}$ , without two-part CSI report(s)**

UCI bit sequence	CSI report number
$a_0$	CSI report #1 as in Table 6.3.1.1.2-7/8
$a_1$	
$a_2$	CSI report #2 as in Table 6.3.1.1.2-7/8
$a_3$	...
$\vdots$	
$a_{A-1}$	CSI report #n as in Table 6.3.1.1.2-7/8

If at least one of the CSI reports for transmission on a PUCCH is of two parts, two UCI bit sequences are generated,  $a_0^{(1)}, a_1^{(1)}, a_2^{(1)}, a_3^{(1)}, \dots, a_{A^{(1)}-1}^{(1)}$  and  $a_0^{(2)}, a_1^{(2)}, a_2^{(2)}, a_3^{(2)}, \dots, a_{A^{(2)}-1}^{(2)}$ . The CSI fields of all CSI reports, in the order from upper part to lower part in Table 6.3.1.1.2-13, are mapped to the UCI bit sequence  $a_0^{(1)}, a_1^{(1)}, a_2^{(1)}, a_3^{(1)}, \dots, a_{A^{(1)}-1}^{(1)}$  starting with  $a_0^{(1)}$ . The most significant bit of each field is mapped to the lowest order information bit for that field, e.g. the most significant bit of the first field is mapped to  $a_0^{(1)}$ . The CSI fields of all CSI reports, in the order from upper part to lower part in Table 6.3.1.1.2-14, are mapped to the UCI bit sequence  $a_0^{(2)}, a_1^{(2)}, a_2^{(2)}, a_3^{(2)}, \dots, a_{A^{(2)}-1}^{(2)}$  starting with  $a_0^{(2)}$ . The most significant bit of each field is mapped to the lowest order information bit for that field, e.g. the most significant bit of the first field is mapped to  $a_0^{(2)}$ . If the length of UCI bit sequence  $a_0^{(2)}, a_1^{(2)}, a_2^{(2)}, a_3^{(2)}, \dots, a_{A^{(2)}-1}^{(2)}$  is less than 3 bits, zeros shall be appended to the UCI bit sequence until its length equals 3.

**Table 6.3.1.1.2-13: Mapping order of CSI reports to UCI bit sequence  $a_0^{(1)}, a_1^{(1)}, a_2^{(1)}, a_3^{(1)}, \dots, a_{A^{(1)}-1}^{(1)}$ , with two-part CSI report(s)**

UCI bit sequence	CSI report number
$a_0^{(1)}$	CSI report #1 if CSI report #1 is not of two parts, or CSI report #1, CSI part 1, if CSI report #1 is of two parts, as in Table 6.3.1.1.2-7/8/9
$a_1^{(1)}$	CSI report #2 if CSI report #2 is not of two parts, or CSI report #2, CSI part 1, if CSI report #2 is of two parts, as in Table 6.3.1.1.2-7/8/9
$a_2^{(1)}$	...
$a_3^{(1)}$	...
$\vdots$	...
$a_{A^{(1)}-1}^{(1)}$	CSI report #n if CSI report #n is not of two parts, or CSI report #n, CSI part 1, if CSI report #n is of two parts, as in Table 6.3.1.1.2-7/8/9

where CSI report #1, CSI report #2, ..., CSI report #n in Table 6.3.1.1.2-13 correspond to the CSI reports in increasing order of CSI report priority values according to Clause 5.2.5 of [6, TS38.214].

**Table 6.3.1.1.2-14: Mapping order of CSI reports to UCI bit sequence  $a_0^{(2)}, a_1^{(2)}, a_2^{(2)}, a_3^{(2)}, \dots, a_{A^{(2)}-1}^{(2)}$ , with two-part CSI report(s)**

UCI bit sequence	CSI report number
$a_0^{(2)}$	CSI report #1, CSI part 2 wideband, as in Table 6.3.1.1.2-10 if CSI part 2 exists for CSI report #1
	CSI report #2, CSI part 2 wideband, as in Table 6.3.1.1.2-10 if CSI part 2 exists for CSI report #2
	...
	CSI report #n, CSI part 2 wideband, as in Table 6.3.1.1.2-10 if CSI part 2 exists for CSI report #n
	CSI report #1, CSI part 2 subband, as in Table 6.3.1.1.2-11 if CSI part 2 exists for CSI report #1
	CSI report #2, CSI part 2 subband, as in Table 6.3.1.1.2-11 if CSI part 2 exists for CSI report #2
	...
$a_1^{(2)}$	CSI report #n, CSI part 2 subband, as in Table 6.3.1.1.2-11 if CSI part 2 exists for CSI report #n
$a_2^{(2)}$	...
$a_3^{(2)}$	...
$\vdots$	...
$a_{A^{(2)}-1}^{(2)}$	...
	CSI report #n, CSI part 2 subband, as in Table 6.3.1.1.2-11 if CSI part 2 exists for CSI report #n

where CSI report #1, CSI report #2, ..., CSI report #n in Table 6.3.1.1.2-14 correspond to the CSI reports in increasing order of CSI report priority values according to Clause 5.2.5 of [6, TS38.214].

### 6.3.1.1.3 HARQ-ACK/SR and CSI

If none of the CSI reports for transmission on a PUCCH is of two parts, the UCI bit sequence  $a_0, a_1, a_2, a_3, \dots, a_{A-1}$  is generated according to the following, where  $A = O^{\text{ACK}} + O^{\text{SR}} + O^{\text{CSI}}$ :

- if there is HARQ-ACK for transmission on the PUCCH, the HARQ-ACK bits are mapped to the UCI bit sequence  $a_0, a_1, a_2, a_3, \dots, a_{O^{\text{ACK}}-1}$ , where  $a_i = \tilde{o}_i^{\text{ACK}}$  for  $i = 0, 1, \dots, O^{\text{ACK}} - 1$ , the HARQ-ACK bit sequence  $\tilde{o}_0^{\text{ACK}}, \tilde{o}_1^{\text{ACK}}, \dots, \tilde{o}_{O^{\text{ACK}}-1}^{\text{ACK}}$  is given by Clause 9.1 of [5, TS38.213], and  $O^{\text{ACK}}$  is number of HARQ-ACK bits; if there is no HARQ-ACK for transmission on the PUCCH, set  $O^{\text{ACK}} = 0$ ;



- if there is SR for transmission on the PUCCH, set  $a_i = \tilde{o}_{i-O^{\text{ACK}}}^{\text{SR}}$  for  $i = O^{\text{ACK}}, O^{\text{ACK}} + 1, \dots, O^{\text{ACK}} + O^{\text{SR}} - 1$ , where the SR bit sequence  $\tilde{o}_0^{\text{SR}}, \tilde{o}_1^{\text{SR}}, \dots, \tilde{o}_{O^{\text{SR}}-1}^{\text{SR}}$  is given by Clause 9.2.5.1 of [5, TS 38.213]; if there is no SR for transmission on the PUCCH, set  $O^{\text{SR}} = 0$ ;
- the CSI fields of all CSI reports, in the order from upper part to lower part in Table 6.3.1.1.2-12, are mapped to the UCI bit sequence  $a_{O^{\text{ACK}}+O^{\text{SR}}}, a_{O^{\text{ACK}}+O^{\text{SR}}+1}, \dots, a_{O^{\text{ACK}}+O^{\text{SR}}+O^{\text{CSI}}-1}$  starting with  $a_{O^{\text{ACK}}+O^{\text{SR}}}$ , where  $O^{\text{CSI}}$  is the number of CSI bits.

If at least one of the CSI reports for transmission on a PUCCH is of two parts, two UCI bit sequences are generated,  $a_0^{(1)}, a_1^{(1)}, a_2^{(1)}, a_3^{(1)}, \dots, a_{A^{(1)}-1}^{(1)}$  and  $a_0^{(2)}, a_1^{(2)}, a_2^{(2)}, a_3^{(2)}, \dots, a_{A^{(2)}-1}^{(2)}$ , according to the following, where

$A^{(1)} = O^{\text{ACK}} + O^{\text{SR}} + O^{\text{CSI-part1}}$  and  $A^{(2)} = O^{\text{CSI-part2}}$ :

- if there is HARQ-ACK for transmission on the PUCCH, the HARQ-ACK bits are mapped to the UCI bit sequence  $a_0^{(1)}, a_1^{(1)}, a_2^{(1)}, a_3^{(1)}, \dots, a_{O^{\text{ACK}}-1}^{(1)}$ , where  $a_i^{(1)} = \tilde{o}_i^{\text{ACK}}$  for  $i = 0, 1, \dots, O^{\text{ACK}} - 1$ , the HARQ-ACK bit sequence  $\tilde{o}_0^{\text{ACK}}, \tilde{o}_1^{\text{ACK}}, \dots, \tilde{o}_{O^{\text{ACK}}-1}^{\text{ACK}}$  is given by Clause 9.1 of [5, TS38.213], and  $O^{\text{ACK}}$  is number of HARQ-ACK bits; if there is no HARQ-ACK for transmission on the PUCCH, set  $O^{\text{ACK}} = 0$ ;
- if there is SR for transmission on the PUCCH, set  $a_i = \tilde{o}_{i-O^{\text{ACK}}}^{\text{SR}}$  for  $i = O^{\text{ACK}}, O^{\text{ACK}} + 1, \dots, O^{\text{ACK}} + O^{\text{SR}} - 1$ , where the SR bit sequence  $\tilde{o}_0^{\text{SR}}, \tilde{o}_1^{\text{SR}}, \dots, \tilde{o}_{O^{\text{SR}}-1}^{\text{SR}}$  is given by Clause 9.2.5.1 of [5, TS 38.213]; if there is no SR for transmission on the PUCCH, set  $O^{\text{SR}} = 0$ ;
- the CSI fields of all CSI reports, in the order from upper part to lower part in Table 6.3.1.1.2-13, are mapped to the UCI bit sequence  $a_{O^{\text{ACK}}+O^{\text{SR}}}, a_{O^{\text{ACK}}+O^{\text{SR}}+1}, \dots, a_{O^{\text{ACK}}+O^{\text{SR}}+O^{\text{CSI-part1}}-1}^{(1)}$  starting with  $a_{O^{\text{ACK}}+O^{\text{SR}}}^{(1)}$ , where  $O^{\text{CSI-part1}}$  is the number of CSI bits in CSI part 1 of all CSI reports;
- the CSI fields of all CSI reports, in the order from upper part to lower part in Table 6.3.1.1.2-14, are mapped to the UCI bit sequence  $a_0^{(2)}, a_1^{(2)}, a_2^{(2)}, a_3^{(2)}, \dots, a_{A^{(2)}-1}^{(2)}$  starting with  $a_0^{(2)}$ , where  $O^{\text{CSI-part2}}$  is the number of CSI bits in CSI part 2 of all CSI reports. If the length of UCI bit sequence  $a_0^{(2)}, a_1^{(2)}, a_2^{(2)}, a_3^{(2)}, \dots, a_{A^{(2)}-1}^{(2)}$  is less than 3 bits, zeros shall be appended to the UCI bit sequence until its length equals 3.

### 6.3.1.2 Code block segmentation and CRC attachment

The UCI bit sequence from clause 6.3.1.1 is denoted by  $a_0, a_1, a_2, a_3, \dots, a_{A-1}$ , where  $A$  is the payload size. The procedure in 6.3.1.2.1 applies for  $A \geq 12$  and the procedure in Clause 6.3.1.2.2 applies for  $A \leq 11$ .

#### 6.3.1.2.1 UCI encoded by Polar code

If the payload size  $A \geq 12$ , code block segmentation and CRC attachment is performed according to Clause 5.2.1. If ( $A \geq 360$  and  $E \geq 1088$ ) or if  $A \geq 1013$ ,  $I_{\text{seg}} = 1$ ; otherwise  $I_{\text{seg}} = 0$ , where  $E$  is the rate matching output sequence length as given in Clause 6.3.1.4.1.

If  $12 \leq A \leq 19$ , the parity bits  $p_{r0}, p_{r1}, p_{r2}, \dots, p_{r(L-1)}$  in Clause 5.2.1 are computed by setting  $L$  to 6 bits and using the generator polynomial  $g_{\text{CRC6}}(D)$  in Clause 5.1, resulting in the sequence  $c_{r0}, c_{r1}, c_{r2}, c_{r3}, \dots, c_{r(K_r-1)}$  where  $r$  is the code block number and  $K_r$  is the number of bits for code block number  $r$ .

If  $A \geq 20$ , the parity bits  $p_{r0}, p_{r1}, p_{r2}, \dots, p_{r(L-1)}$  in Clause 5.2.1 are computed by setting  $L$  to 11 bits and using the generator polynomial  $g_{\text{CRC11}}(D)$  in Clause 5.1, resulting in the sequence  $c_{r0}, c_{r1}, c_{r2}, c_{r3}, \dots, c_{r(K_r-1)}$  where  $r$  is the code block number and  $K_r$  is the number of bits for code block number  $r$ .

### 6.3.1.2.2 UCI encoded by channel coding of small block lengths

If the payload size  $A \leq 11$ , CRC bits are not attached.

The output bit sequence is denoted by  $c_0, c_1, c_2, c_3, \dots, c_{K-1}$ , where  $c_i = a_i$  for  $i=0, 1, \dots, A-1$  and  $K = A$ .

### 6.3.1.3 Channel coding of UCI

#### 6.3.1.3.1 UCI encoded by Polar code

Information bits are delivered to the channel coding block. They are denoted by  $c_{r0}, c_{r1}, c_{r2}, c_{r3}, \dots, c_{r(K_r-1)}$ , where  $r$  is the code block number, and  $K_r$  is the number of bits in code block number  $r$ . The total number of code blocks is denoted by  $C$  and each code block is individually encoded by the following:

If  $18 \leq K_r \leq 25$ , the information bits are encoded via Polar coding according to Clause 5.3.1, by setting  $n_{\max} = 10$ ,  $I_{LL} = 0$ ,  $n_{PC} = 3$ ,  $n_{PC}^{wm} = 1$  if  $E_r - K_r + 3 > 192$  and  $n_{PC}^{wm} = 0$  if  $E_r - K_r + 3 \leq 192$ , where  $E_r$  is the rate matching output sequence length as given in Clause 6.3.1.4.1.

If  $K_r > 30$ , the information bits are encoded via Polar coding according to Clause 5.3.1, by setting  $n_{\max} = 10$ ,  $I_{LL} = 0$ ,  $n_{PC} = 0$ , and  $n_{PC}^{wm} = 0$ .

After encoding the bits are denoted by  $d_{r0}, d_{r1}, d_{r2}, d_{r3}, \dots, d_{r(N_r-1)}$ , where  $N_r$  is the number of coded bits in code block number  $r$ .

#### 6.3.1.3.2 UCI encoded by channel coding of small block lengths

Information bits are delivered to the channel coding block. They are denoted by  $c_0, c_1, c_2, c_3, \dots, c_{K-1}$ , where  $K$  is the number of bits.

The information bits are encoded according to Clause 5.3.3.

After encoding the bits are denoted by  $d_0, d_1, d_2, d_3, \dots, d_{N-1}$ , where  $N$  is the number of coded bits.

### 6.3.1.4 Rate matching

For PUCCH formats 2/3/4, the total rate matching output sequence length  $E_{\text{tot}}$  is given by Table 6.3.1.4-1, where  $N_{\text{symb,UCI}}^{\text{PUCCH2}}$ ,  $N_{\text{symb,UCI}}^{\text{PUCCH3}}$ , and  $N_{\text{symb,UCI}}^{\text{PUCCH4}}$  are the number of symbols carrying UCI for PUCCH formats 2/3/4 respectively;  $N_{\text{PRB}}^{\text{PUCCH2}}$  and  $N_{\text{PRB}}^{\text{PUCCH3}}$  are the number of PRBs that are determined by the UE for PUCCH formats 2/3 transmission respectively according to Clause 9.2 of [5, TS38.213]; and  $N_{\text{SF}}^{\text{PUCCH2}}$ ,  $N_{\text{SF}}^{\text{PUCCH3}}$ , and  $N_{\text{SF}}^{\text{PUCCH4}}$  are the spreading factors for PUCCH format 2, PUCCH format 3, and PUCCH format 4, respectively.

**Table 6.3.1.4-1: Total rate matching output sequence length  $E_{\text{tot}}$**

PUCCH format	Modulation order	
	QPSK	$\pi/2$ -BPSK
PUCCH format 2	$16 \cdot N_{\text{symb,UCI}}^{\text{PUCCH2}} \cdot N_{\text{PRB}}^{\text{PUCCH2}} / N_{\text{SF}}^{\text{PUCCH2}}$	N/A
PUCCH format 3	$24 \cdot N_{\text{symb,UCI}}^{\text{PUCCH3}} \cdot N_{\text{PRB}}^{\text{PUCCH3}} / N_{\text{SF}}^{\text{PUCCH3}}$	$12 \cdot N_{\text{symb,UCI}}^{\text{PUCCH3}} \cdot N_{\text{PRB}}^{\text{PUCCH3}} / N_{\text{SF}}^{\text{PUCCH3}}$
PUCCH format 4	$24 \cdot N_{\text{symb,UCI}}^{\text{PUCCH4}} / N_{\text{SF}}^{\text{PUCCH4}}$	$12 \cdot N_{\text{symb,UCI}}^{\text{PUCCH4}} / N_{\text{SF}}^{\text{PUCCH4}}$

### 6.3.1.4.1 UCI encoded by Polar code

The input bit sequence to rate matching is  $d_{r_0}, d_{r_1}, d_{r_2}, d_{r_3}, \dots, d_{r(N_r-1)}$  where  $r$  is the code block number, and  $N_r$  is the number of coded bits in code block number  $r$ .

**Table 6.3.1.4.1-1: Rate matching output sequence length  $E_{\text{UCI}}$**

UCI(s) for transmission on a PUCCH	UCI for encoding	Value of $E_{\text{UCI}}$
HARQ-ACK	HARQ-ACK	$E_{\text{UCI}} = E_{\text{tot}}$
HARQ-ACK, SR	HARQ-ACK, SR	$E_{\text{UCI}} = E_{\text{tot}}$
CSI (CSI not of two parts)	CSI	$E_{\text{UCI}} = E_{\text{tot}}$
HARQ-ACK, CSI (CSI not of two parts)	HARQ-ACK, CSI	$E_{\text{UCI}} = E_{\text{tot}}$
HARQ-ACK, SR, CSI (CSI not of two parts)	HARQ-ACK, SR, CSI	$E_{\text{UCI}} = E_{\text{tot}}$
CSI (CSI of two parts)	CSI part 1	$E_{\text{UCI}} = \min(E_{\text{tot}}, \lceil (O^{\text{CSI-part1}} + L) / R_{\text{UCI}}^{\text{max}} / Q_m \rceil \cdot Q_m)$
	CSI part 2	$E_{\text{UCI}} = E_{\text{tot}} - \min(E_{\text{tot}}, \lceil (O^{\text{CSI-part1}} + L) / R_{\text{UCI}}^{\text{max}} / Q_m \rceil \cdot Q_m)$
HARQ-ACK, CSI (CSI of two parts)	HARQ-ACK, CSI part 1	$E_{\text{UCI}} = \min(E_{\text{tot}}, \lceil (O^{\text{ACK}} + O^{\text{CSI-part1}} + L) / R_{\text{UCI}}^{\text{max}} / Q_m \rceil \cdot Q_m)$
	CSI part 2	$E_{\text{UCI}} = E_{\text{tot}} - \min(E_{\text{tot}}, \lceil (O^{\text{ACK}} + O^{\text{CSI-part1}} + L) / R_{\text{UCI}}^{\text{max}} / Q_m \rceil \cdot Q_m)$
HARQ-ACK, SR, CSI (CSI of two parts)	HARQ-ACK, SR, CSI part 1	$E_{\text{UCI}} = \min(E_{\text{tot}}, \lceil (O^{\text{ACK}} + O^{\text{SR}} + O^{\text{CSI-part1}} + L) / R_{\text{UCI}}^{\text{max}} / Q_m \rceil \cdot Q_m)$
	CSI part 2	$E_{\text{UCI}} = E_{\text{tot}} - \min(E_{\text{tot}}, \lceil (O^{\text{ACK}} + O^{\text{SR}} + O^{\text{CSI-part1}} + L) / R_{\text{UCI}}^{\text{max}} / Q_m \rceil \cdot Q_m)$

Rate matching is performed according to Clause 5.4.1 by setting  $I_{\text{BL}} = 1$  and the rate matching output sequence length to  $E_r = \lfloor E_{\text{UCI}} / C_{\text{UCI}} \rfloor$ , where  $C_{\text{UCI}}$  is the number of code blocks for UCI determined according to Clause 6.3.1.2.1 and the value of  $E_{\text{UCI}}$  is given by Table 6.3.1.4.1-1:

- $O^{\text{ACK}}$  is the number of bits for HARQ-ACK for transmission on the current PUCCH;
- $O^{\text{SR}}$  is the number of bits for SR for transmission on the current PUCCH;
- $O^{\text{CSI-part1}}$  is the number of bits for CSI part 1 for transmission on the current PUCCH;
- $O^{\text{CSI-part2}}$  is the number of bits for CSI part 2 for transmission on the current PUCCH;
- if  $A \geq 360$ ,  $L = 11$ ; otherwise,  $L$  is the number of CRC bits determined according to clause 6.3.1.2.1, where  $A$  equals  $O^{\text{CSI-part1}}$  for "CSI (CSI of two parts)", equals  $O^{\text{ACK}} + O^{\text{CSI-part1}}$  for "HARQ-ACK, CSI (CSI of two parts)", and equals  $O^{\text{ACK}} + O^{\text{SR}} + O^{\text{CSI-part1}}$  for "HARQ-ACK, SR, CSI (CSI of two parts)" respectively in Table 6.3.1.4.1-1;
- $R_{\text{UCI}}^{\text{max}}$  is the configured maximum PUCCH coding rate;
- $E_{\text{tot}}$  is given by Table 6.3.1.4-1.

The output bit sequence after rate matching is denoted as  $f_{r_0}, f_{r_1}, f_{r_2}, \dots, f_{r(E_r-1)}$  where  $E_r$  is the length of rate matching output sequence in code block number  $r$ .

### 6.3.1.4.2 UCI encoded by channel coding of small block lengths

The input bit sequence to rate matching is  $d_0, d_1, d_2, \dots, d_{N-1}$ .

The value of  $E_{UCI}$  is determined according to Table 6.3.1.4.1-1 by setting  $L = 0$ .

Rate matching is performed according to Clause 5.4.3 by setting the rate matching output sequence length  $E = E_{UCI}$ .

The output bit sequence after rate matching is denoted as  $f_0, f_1, f_2, \dots, f_{E-1}$ .

### 6.3.1.5 Code block concatenation

The input bit sequence for the code block concatenation block are the sequences  $f_{r0}, f_{r1}, f_{r2}, \dots, f_{r(E_r-1)}$ , for  $r = 0, \dots, C-1$  and where  $E_r$  is the number of rate matched bits for the  $r$ -th code block.

Code block concatenation is performed according to Clause 5.5.

The bits after code block concatenation are denoted by  $g_0, g_1, g_2, g_3, \dots, g_{G'-1}$ , where  $G' = \lfloor E_{UCI} / C_{UCI} \rfloor \cdot C_{UCI}$  with the values of  $E_{UCI}$  and  $C_{UCI}$  given in Clause 6.3.1.4.1. Let  $G$  be the total number of coded bits for transmission and  $G = G' + \text{mod}(E_{UCI}, C_{UCI})$ . Set  $g_i = 0$  for  $i = G', G'+1, \dots, G-1$ .

### 6.3.1.6 Multiplexing of coded UCI bits to PUCCH

If CSI of two parts are transmitted on a PUCCH, the coded bits corresponding to UCI bit sequence  $a_0^{(1)}, a_1^{(1)}, a_2^{(1)}, a_3^{(1)}, \dots, a_{A^{(1)}-1}^{(1)}$  is denoted by  $g_0^{(1)}, g_1^{(1)}, g_2^{(1)}, g_3^{(1)}, \dots, g_{G^{(1)}-1}^{(1)}$  and the coded bits corresponding to UCI bit sequence  $a_0^{(2)}, a_1^{(2)}, a_2^{(2)}, a_3^{(2)}, \dots, a_{A^{(2)}-1}^{(2)}$  is denoted by  $g_0^{(2)}, g_1^{(2)}, g_2^{(2)}, g_3^{(2)}, \dots, g_{G^{(2)}-1}^{(2)}$ . The coded bit sequence  $g_0, g_1, g_2, g_3, \dots, g_{G-1}$ , where  $G = G^{(1)} + G^{(2)}$ , is generated according to the following.

**Table 6.3.1.6-1: PUCCH DMRS and UCI symbols**

PUCCH duration (symbols)	PUCCH DMRS symbol indices	Number of UCI symbol indices sets $N_{UCI}^{set}$	1 <sup>st</sup> UCI symbol indices set $S_{UCI}^{(1)}$	2 <sup>nd</sup> UCI symbol indices set $S_{UCI}^{(2)}$	3 <sup>rd</sup> UCI symbol indices set $S_{UCI}^{(3)}$
4	{1}	2	{0,2}	{3}	-
4	{0,2}	1	{1,3}	-	-
5	{0, 3}	1	{1, 2, 4}	-	-
6	{1, 4}	1	{0, 2, 3, 5}	-	-
7	{1, 4}	2	{0, 2, 3, 5}	{6}	-
8	{1, 5}	2	{0, 2, 4, 6}	{3, 7}	-
9	{1, 6}	2	{0, 2, 5, 7}	{3, 4, 8}	-
10	{2, 7}	2	{1, 3, 6, 8}	{0, 4, 5, 9}	-
10	{1, 3, 6, 8}	1	{0,2,4,5,7,9}	-	-
11	{2, 7}	3	{1,3,6,8}	{0,4,5,9}	{10}
11	{1,3,6,9}	1	{0,2,4,5,7,8,10}	-	-
12	{2, 8}	3	{1,3,7,9}	{0,4,6,10}	{5, 11}
12	{1,4,7,10}	1	{0,2,3,5,6,8,9,11}	-	-
13	{2, 9}	3	{1,3,8,10}	{0,4,7,11}	{5,6,12}
13	{1,4,7,11}	2	{0,2,3,5,6,8,10,12}	{9}	-
14	{3, 10}	3	{2,4,9,11}	{1,5,8,12}	{0,6,7,13}
14	{1,5,8,12}	2	{0,2,4,6,7,9,11,13}	{3, 10}	-

Denote  $s_i$  as UCI OFDM symbol index. Denote  $N_{UCI}^{(i)}$  as the number of elements in UCI symbol indices set  $S_{UCI}^{(i)}$  for  $i = 1, \dots, N_{UCI}^{set}$ , where  $S_{UCI}^{(i)}$  and  $N_{UCI}^{set}$  are given by Table 6.3.1.6-1 according to the PUCCH duration and the PUCCH

DMRS configuration. Denote  $N_{\text{symb, UCI}}^{PUCCH} = \sum_{i=1}^{N_{UCI}^{set}} N_{UCI}^{(i)}$  as the number of OFDM symbols carrying UCI in the PUCCH.

Denote  $Q_m$  as the modulation order of the PUCCH.

For PUCCH format 3, set  $N_{\text{UCI}}^{\text{symbol}} = 12 \cdot N_{\text{PRB}}^{\text{PUCCH},3} / N_{\text{SF}}^{\text{PUCCH},3}$ , where  $N_{\text{PRB}}^{\text{PUCCH},3}$  is the number of PRBs that is determined by the UE for PUCCH format 3 transmission according to Clause 9.2 of [5, TS 38.213], and  $N_{\text{SF}}^{\text{PUCCH},3}$  is the spreading factor for PUCCH format 3 [4, TS 38.211].

For PUCCH format 4, set  $N_{\text{UCI}}^{\text{symbol}} = 12 / N_{\text{SF}}^{\text{PUCCH},4}$ , where  $N_{\text{SF}}^{\text{PUCCH},4}$  is the spreading factor for PUCCH format 4.

Find the smallest  $j > 0$  such that  $\left( \sum_{i=1}^j N_{\text{UCI}}^{(i)} \right) \cdot N_{\text{UCI}}^{\text{symbol}} \cdot Q_m \geq G^{(1)}$ .

Set  $n_1 = 0$ ;

Set  $n_2 = 0$ ;

Set  $\bar{N}_{\text{UCI}}^{\text{symbol}} = \left\lceil \left( G^{(1)} - \left( \sum_{i=1}^{j-1} N_{\text{UCI}}^{(i)} \right) \cdot N_{\text{UCI}}^{\text{symbol}} \cdot Q_m \right) / \left( N_{\text{UCI}}^{(j)} \cdot Q_m \right) \right\rceil$ ;

Set  $M = \text{mod} \left( \left( G^{(1)} - \left( \sum_{i=1}^{j-1} N_{\text{UCI}}^{(i)} \right) \cdot N_{\text{UCI}}^{\text{symbol}} \cdot Q_m \right) / Q_m, N_{\text{UCI}}^{(j)} \right)$ ;

for  $l = 0$  to  $N_{\text{symb,UCI}}^{\text{PUCCH}} - 1$

if  $s_l \in \bigcup_{i=1}^{j-1} S_{\text{UCI}}^{(i)}$

for  $k = 0$  to  $N_{\text{UCI}}^{\text{symbol}} - 1$

for  $v = 0$  to  $Q_m - 1$

$\bar{g}_{l,k,v} = g_{n_1}^{(1)}$ ;

$n_1 = n_1 + 1$ ;

end for

end for

elseif  $s_l \in S_{\text{UCI}}^{(j)}$

if  $M > 0$

$\gamma = 1$ ;

else

$\gamma = 0$ ;

end if

$M = M - 1$ ;

for  $k = 0$  to  $\bar{N}_{\text{UCI}}^{\text{symbol}} + \gamma - 1$

for  $v = 0$  to  $Q_m - 1$

$\bar{g}_{l,k,v} = g_{n_1}^{(1)}$ ;

```

         $n_1 = n_1 + 1;$ 
    end for
end for
for  $k = \bar{N}_{\text{UCI}}^{\text{symbol}} + \gamma$  to  $N_{\text{UCI}}^{\text{symbol}} - 1$ 
    for  $v = 0$  to  $Q_m - 1$ 
         $\bar{g}_{l,k,v} = g_{n_2}^{(2)};$ 
         $n_2 = n_2 + 1;$ 
    end for
end for
else
    for  $k = 0$  to  $N_{\text{UCI}}^{\text{symbol}} - 1$ 
        for  $v = 0$  to  $Q_m - 1$ 
             $\bar{g}_{l,k,v} = g_{n_2}^{(2)};$ 
             $n_2 = n_2 + 1;$ 
        end for
    end for
end if
end for
Set  $n = 0$ 
for  $l = 0$  to  $N_{\text{symp,UCI}}^{\text{PUCCH}} - 1$ 
    for  $k = 0$  to  $N_{\text{UCI}}^{\text{symbol}} - 1$ 
        for  $v = 0$  to  $Q_m - 1$ 
             $g_n = \bar{g}_{l,k,v};$ 
             $n = n + 1;$ 
        end for
    end for
end for
end for

```

### 6.3.2 Uplink control information on PUSCH

#### 6.3.2.1 UCI bit sequence generation

##### 6.3.2.1.1 HARQ-ACK

If HARQ-ACK bits are transmitted on a PUSCH, the UCI bit sequence  $a_0, a_1, a_2, a_3, \dots, a_{A-1}$  is determined as follows:

- If UCI is transmitted on PUSCH without UL-SCH and the UCI includes CSI part 1 without CSI part 2,
- if there is no HARQ-ACK bit given by Clause 9.1 of [5, TS 38.213], set  $a_0 = 0$ ,  $a_1 = 0$ , and  $A = 2$ ;
- if there is only one HARQ-ACK bit  $\tilde{o}_0^{ACK}$  given by Clause 9.1 of [5, TS 38.213], set  $a_0 = \tilde{o}_0^{ACK}$ ,  $a_1 = 0$ , and  $A = 2$ ;
- otherwise, set  $a_i = \tilde{o}_i^{ACK}$  for  $i = 0, 1, \dots, O^{ACK} - 1$  and  $A = O^{ACK}$ , where the HARQ-ACK bit sequence  $\tilde{o}_0^{ACK}, \tilde{o}_1^{ACK}, \dots, \tilde{o}_{O^{ACK}-1}^{ACK}$  is given by Clause 9.1 of [5, TS 38.213].

##### 6.3.2.1.2 CSI

The bitwidth for PMI of *codebookType=typeI-SinglePanel* and *codebookType=typeI-MultiPanel* is specified in Clause 6.3.1.1.2.

The bitwidth for RI/LI/CQI/CRI of *codebookType=typeI-SinglePanel* and *codebookType=typeI-MultiPanel* is specified in Clause 6.3.1.1.2.

The bitwidth for PMI of *codebookType=typeII* is provided in Tables 6.3.2.1.2-1, where the values of  $(N_1, N_2)$ ,  $(O_1, O_2)$ ,  $L$ ,  $N_{PSK}$ ,  $M_1$ ,  $M_2$ , and  $K^{(2)}$  are given by Clause 5.2.2.2.3 in [6, TS 38.214].

**Table 6.3.2.1.2-1: PMI of *codebookType= typeII***

	Information fields $X_1$ for wideband PMI						Information fields $X_2$ for wideband PMI or per subband PMI			
	$i_{1,1}$	$i_{1,2}$	$i_{1,3,1}$	$i_{1,4,1}$	$i_{1,3,2}$	$i_{1,4,2}$	$i_{2,1,1}$	$i_{2,1,2}$	$i_{2,2,1}$	$i_{2,2,2}$
Rank=1 SBAmpp off	$\lceil \log_2(O_1 O_2) \rceil$	$\lceil \log_2 \left( \frac{N_1 N_2}{L} \right) \rceil$	$\lceil \log_2(2L) \rceil$	$3(2L-1)$	N/A	N/A	$(M_1 - 1) \cdot \log_2 N_{PSK}$	N/A	N/A	N/A
Rank=2 SBAmpp off	$\lceil \log_2(O_1 O_2) \rceil$	$\lceil \log_2 \left( \frac{N_1 N_2}{L} \right) \rceil$	$\lceil \log_2(2L) \rceil$	$3(2L-1)$	$\lceil \log_2(2L) \rceil$	$3(2L-1)$	$(M_1 - 1) \cdot \log_2 N_{PSK}$	$(M_2 - 1) \cdot \log_2 N_{PSK}$	N/A	N/A
Rank=1 SBAmpp on	$\lceil \log_2(O_1 O_2) \rceil$	$\lceil \log_2 \left( \frac{N_1 N_2}{L} \right) \rceil$	$\lceil \log_2(2L) \rceil$	$3(2L-1)$	N/A	N/A	$\min(M_1, K^{(2)}) \cdot \log_2 N_{PSK} - \log_2 N_{PSK} + 2 \cdot (M_1 - \min(M_1, K^{(2)}))$	N/A	$\min(M_1, K^{(2)}) - 1$	N/A
Rank=2 SBAmpp on	$\lceil \log_2(O_1 O_2) \rceil$	$\lceil \log_2 \left( \frac{N_1 N_2}{L} \right) \rceil$	$\lceil \log_2(2L) \rceil$	$3(2L-1)$	$\lceil \log_2(2L) \rceil$	$3(2L-1)$	$\min(M_1, K^{(2)}) \cdot \log_2 N_{PSK} - \log_2 N_{PSK} + 2 \cdot (M_1 - \min(M_1, K^{(2)}))$	$\min(M_2, K^{(2)}) \cdot \log_2 N_{PSK} - \log_2 N_{PSK} + 2 \cdot (M_2 - \min(M_2, K^{(2)}))$	$\min(M_1, K^{(2)}) - 1$	$\min(M_2, K^{(2)}) - 1$

The bitwidth for PMI of *codebookType=typeII-r16* is provided in Tables 6.3.2.1.2-1A, where the values of  $(N_1, N_2)$ ,  $(O_1, O_2)$ ,  $L$ ,  $K^{NZ}$ ,  $N_3$ , and  $\{M_l\}_{l=1, \dots, v}$  are given by Clause 5.2.2.2.5 in [6, TS 38.214].

Table 6.3.2.1.2-1A: PMI of *codebookType= type1-r16*

	Information fields $X_1$											
	$i_{1,1}$	$i_{1,2}$	$i_{1,8,1}$	$i_{1,8,2}$	$i_{1,8,3}$	$i_{1,8,4}$						
Rank=1 $N_3 \leq 19$	$\lceil \log_2(O_1 O_2) \rceil$	$\lceil \log_2 \left( \frac{N_1 N_2}{L} \right) \rceil$	$\lceil \log_2 K^{NZ} \rceil$	N/A	N/A	N/A						
Rank=2 $N_3 \leq 19$	$\lceil \log_2(O_1 O_2) \rceil$	$\lceil \log_2 \left( \frac{N_1 N_2}{L} \right) \rceil$	$\lceil \log_2(2L) \rceil$	$\lceil \log_2(2L) \rceil$	N/A	N/A						
Rank=3 $N_3 \leq 19$	$\lceil \log_2(O_1 O_2) \rceil$	$\lceil \log_2 \left( \frac{N_1 N_2}{L} \right) \rceil$	$\lceil \log_2(2L) \rceil$	$\lceil \log_2(2L) \rceil$	$\lceil \log_2(2L) \rceil$	N/A						
Rank=4 $N_3 \leq 19$	$\lceil \log_2(O_1 O_2) \rceil$	$\lceil \log_2 \left( \frac{N_1 N_2}{L} \right) \rceil$	$\lceil \log_2(2L) \rceil$	$\lceil \log_2(2L) \rceil$	$\lceil \log_2(2L) \rceil$	$\lceil \log_2(2L) \rceil$						
Rank=1 $N_3 > 19$	$\lceil \log_2(O_1 O_2) \rceil$	$\lceil \log_2 \left( \frac{N_1 N_2}{L} \right) \rceil$	$\lceil \log_2 K^{NZ} \rceil$	N/A	N/A	N/A						
Rank=2 $N_3 > 19$	$\lceil \log_2(O_1 O_2) \rceil$	$\lceil \log_2 \left( \frac{N_1 N_2}{L} \right) \rceil$	$\lceil \log_2(2L) \rceil$	$\lceil \log_2(2L) \rceil$	N/A	N/A						
Rank=3 $N_3 > 19$	$\lceil \log_2(O_1 O_2) \rceil$	$\lceil \log_2 \left( \frac{N_1 N_2}{L} \right) \rceil$	$\lceil \log_2(2L) \rceil$	$\lceil \log_2(2L) \rceil$	$\lceil \log_2(2L) \rceil$	N/A						
Rank=4 $N_3 > 19$	$\lceil \log_2(O_1 O_2) \rceil$	$\lceil \log_2 \left( \frac{N_1 N_2}{L} \right) \rceil$	$\lceil \log_2(2L) \rceil$	$\lceil \log_2(2L) \rceil$	$\lceil \log_2(2L) \rceil$	$\lceil \log_2(2L) \rceil$						
	Information fields $X_2$											
	$i_{2,3,1}$	$i_{2,3,2}$	$i_{2,3,3}$	$i_{2,3,4}$	$i_{1,5}$	$i_{1,6,1}$	$i_{1,6,2}$	$i_{1,6,3}$	$i_{1,6,4}$	$\{i_{2,4,i}\}_{i=1,\dots,v}$	$\{i_{2,5,i}\}_{i=1,\dots,v}$	$\{i_{1,7,i}\}_{i=1,\dots,v}$
Rank=1 $N_3 \leq 19$	4	N/A	N/A	N/A	N/A	$\lceil \log_2 \left( \frac{N_3 - 1}{M_1 - 1} \right) \rceil$	N/A	N/A	N/A	$3(K^{NZ} - 1)$	$4(K^{NZ} - 1)$	$2LM_1$
Rank=2 $N_3 \leq 19$	4	4	N/A	N/A	N/A	$\lceil \log_2 \left( \frac{N_3 - 1}{M_2 - 1} \right) \rceil$	$\lceil \log_2 \left( \frac{N_3 - 1}{M_2 - 1} \right) \rceil$	N/A	N/A	$3(K^{NZ} - 2)$	$4(K^{NZ} - 2)$	$4LM_2$
Rank=3 $N_3 \leq 19$	4	4	4	N/A	N/A	$\lceil \log_2 \left( \frac{N_3 - 1}{M_3 - 1} \right) \rceil$	$\lceil \log_2 \left( \frac{N_3 - 1}{M_3 - 1} \right) \rceil$	$\lceil \log_2 \left( \frac{N_3 - 1}{M_3 - 1} \right) \rceil$	N/A	$3(K^{NZ} - 3)$	$4(K^{NZ} - 3)$	$6LM_3$
Rank=4 $N_3 \leq 19$	4	4	4	4	N/A	$\lceil \log_2 \left( \frac{N_3 - 1}{M_4 - 1} \right) \rceil$	$\lceil \log_2 \left( \frac{N_3 - 1}{M_4 - 1} \right) \rceil$	$\lceil \log_2 \left( \frac{N_3 - 1}{M_4 - 1} \right) \rceil$	$\lceil \log_2 \left( \frac{N_3 - 1}{M_4 - 1} \right) \rceil$	$3(K^{NZ} - 4)$	$4(K^{NZ} - 4)$	$8LM_4$
Rank=1 $N_3 > 19$	4	N/A	N/A	N/A	$\lceil \log_2(2M_1) \rceil$	$\lceil \log_2 \left( \frac{2M_1 - 1}{M_1 - 1} \right) \rceil$	N/A	N/A	N/A	$3(K^{NZ} - 1)$	$4(K^{NZ} - 1)$	$2LM_1$
Rank=2 $N_3 > 19$	4	4	N/A	N/A	$\lceil \log_2(2M_2) \rceil$	$\lceil \log_2 \left( \frac{2M_2 - 1}{M_2 - 1} \right) \rceil$	$\lceil \log_2 \left( \frac{2M_2 - 1}{M_2 - 1} \right) \rceil$	N/A	N/A	$3(K^{NZ} - 2)$	$4(K^{NZ} - 2)$	$4LM_2$



Rank=3 $N_3 > 19$	4	4	4	N/A	$\lceil \log_2(2M_3) \rceil$	$\lceil \log_2 \binom{2M_3-1}{M_3-1} \rceil$	$\lceil \log_2 \binom{2M_3-1}{M_3-1} \rceil$	$\lceil \log_2 \binom{2M_3-1}{M_3-1} \rceil$	N/A	$3(K^{NZ} - 3)$	$4(K^{NZ} - 3)$	$6LM_3$
Rank=4 $N_3 > 19$	4	4	4	4	$\lceil \log_2(2M_4) \rceil$	$\lceil \log_2 \binom{2M_4-1}{M_4-1} \rceil$	$\lceil \log_2 \binom{2M_4-1}{M_4-1} \rceil$	$\lceil \log_2 \binom{2M_4-1}{M_4-1} \rceil$	$\lceil \log_2 \binom{2M_4-1}{M_4-1} \rceil$	$3(K^{NZ} - 4)$	$4(K^{NZ} - 4)$	$8LM_4$

Note: the bandwidth for  $\{i_{1,7,l}\}_{l=1,\dots,v}$ ,  $\{i_{2,4,l}\}_{l=1,\dots,v}$  and  $\{i_{2,5,l}\}_{l=1,\dots,v}$  shown in Table 6.3.2.1.2-1A is the total bandwidth of  $\{i_{1,7,l}\}$ ,  $\{i_{2,4,l}\}$  and  $\{i_{2,5,l}\}$  up to Rank =  $v$ , respectively, and the corresponding per layer bandwidths are  $2LM_v$ ,  $3(K_l^{NZ} - 1)$ , and  $4(K_l^{NZ} - 1)$ , (i.e., 1, 3, and 4 bits for each respective indicator elements  $k_{l,i,f}^{(3)}$ ,  $k_{l,i,f}^{(2)}$ , and  $c_{l,i,f}$ , respectively), where  $K_l^{NZ}$  as defined in Clause 5.2.2.2.5 in [6, TS 38.214] is the number of nonzero coefficients for layer  $l$  such that  $K^{NZ} = \sum_{l=1}^v K_l^{NZ}$ .

The bandwidth for PMI of *codebookType=typeII-PortSelection* is provided in Tables 6.3.2.1.2-2, where the values of  $P_{CSI-RS}$ ,  $d$ ,  $L$ ,  $N_{PSK}$ ,  $M_1$ ,  $M_2$ , and  $K^{(2)}$  are given by Clause 5.2.2.2.4 in [6, TS 38.214].

**Table 6.3.2.1.2-2: PMI of *codebookType=typeII-PortSelection***

	Information fields $X_1$ for wideband PMI					Information fields $X_2$ for wideband PMI or per subband PMI			
	$i_{1,1}$	$i_{1,3,1}$	$i_{1,4,1}$	$i_{1,3,2}$	$i_{1,4,2}$	$i_{2,1,1}$	$i_{2,1,2}$	$i_{2,2,1}$	$i_{2,2,2}$
Rank=1 SBAmpon off	$\lceil \log_2 \left\lceil \frac{P_{CSI-RS}}{2d} \right\rceil \rceil$	$\lceil \log_2(2L) \rceil$	$3(2L-1)$	N/A	N/A	$(M_1-1) \cdot \log_2 N_{PSK}$	N/A	N/A	N/A
Rank=2 SBAmpon off	$\lceil \log_2 \left\lceil \frac{P_{CSI-RS}}{2d} \right\rceil \rceil$	$\lceil \log_2(2L) \rceil$	$3(2L-1)$	$\lceil \log_2(2L) \rceil$	$3(2L-1)$	$(M_1-1) \cdot \log_2 N_{PSK}$	$(M_2-1) \cdot \log_2 N_{PSK}$	N/A	N/A
Rank=1 SBAmpon on	$\lceil \log_2 \left\lceil \frac{P_{CSI-RS}}{2d} \right\rceil \rceil$	$\lceil \log_2(2L) \rceil$	$3(2L-1)$	N/A	N/A	$\min(M_1, K^{(2)}) \cdot \log_2 N_{PSK} - \log_2 N_{PSK} + 2 \cdot (M_1 - \min(M_1, K^{(2)}))$	N/A	$\min(M_1, K^{(2)}) - 1$	N/A
Rank=2 SBAmpon on	$\lceil \log_2 \left\lceil \frac{P_{CSI-RS}}{2d} \right\rceil \rceil$	$\lceil \log_2(2L) \rceil$	$3(2L-1)$	$\lceil \log_2(2L) \rceil$	$3(2L-1)$	$\min(M_1, K^{(2)}) \cdot \log_2 N_{PSK} - \log_2 N_{PSK} + 2 \cdot (M_1 - \min(M_1, K^{(2)}))$	$\min(M_2, K^{(2)}) \cdot \log_2 N_{PSK} - \log_2 N_{PSK} + 2 \cdot (M_2 - \min(M_2, K^{(2)}))$	$\min(M_1, K^{(2)}) - 1$	$\min(M_2, K^{(2)}) - 1$

The bandwidth for PMI of *codebookType=typeII-PortSelection-r16* is provided in Tables 6.3.2.1.2-2A, where the values of  $P_{CSI-RS}$ ,  $d$ ,  $L$ ,  $K^{NZ}$ ,  $N_3$ , and  $\{M_l\}_{l=1,\dots,v}$  are given by Clause 5.2.2.2.6 in [6, TS 38.214].

**Table 6.3.2.1.2-2A: PMI of *codebookType=typeII-PortSelection-r16***

	Information fields $X_1$				
	$i_{1,1}$	$i_{1,8,1}$	$i_{1,8,2}$	$i_{1,8,3}$	$i_{1,8,4}$
Rank=1 $N_3 \leq 19$	$\lceil \log_2 \left\lceil \frac{P_{CSI-RS}}{2d} \right\rceil \rceil$	$\lceil \log_2 K^{NZ} \rceil$	N/A	N/A	N/A
Rank=2 $N_3 \leq 19$	$\lceil \log_2 \left\lceil \frac{P_{CSI-RS}}{2d} \right\rceil \rceil$	$\lceil \log_2(2L) \rceil$	$\lceil \log_2(2L) \rceil$	N/A	N/A

Rank=3 $N_3 \leq 19$	$\left\lceil \log_2 \left[ \frac{P_{CSI-RS}}{2d} \right] \right\rceil$				$\lceil \log_2(2L) \rceil$	$\lceil \log_2(2L) \rceil$	$\lceil \log_2(2L) \rceil$	$\lceil \log_2(2L) \rceil$	N/A			
Rank=4 $N_3 \leq 19$	$\left\lceil \log_2 \left[ \frac{P_{CSI-RS}}{2d} \right] \right\rceil$				$\lceil \log_2(2L) \rceil$	$\lceil \log_2(2L) \rceil$	$\lceil \log_2(2L) \rceil$	$\lceil \log_2(2L) \rceil$	$\lceil \log_2(2L) \rceil$			
Rank=1 $N_3 > 19$	$\left\lceil \log_2 \left[ \frac{P_{CSI-RS}}{2d} \right] \right\rceil$				$\lceil \log_2 K^{NZ} \rceil$	N/A	N/A	N/A	N/A			
Rank=2 $N_3 > 19$	$\left\lceil \log_2 \left[ \frac{P_{CSI-RS}}{2d} \right] \right\rceil$				$\lceil \log_2(2L) \rceil$	$\lceil \log_2(2L) \rceil$	N/A	N/A	N/A			
Rank=3 $N_3 > 19$	$\left\lceil \log_2 \left[ \frac{P_{CSI-RS}}{2d} \right] \right\rceil$				$\lceil \log_2(2L) \rceil$	$\lceil \log_2(2L) \rceil$	$\lceil \log_2(2L) \rceil$	$\lceil \log_2(2L) \rceil$	N/A			
Rank=4 $N_3 > 19$	$\left\lceil \log_2 \left[ \frac{P_{CSI-RS}}{2d} \right] \right\rceil$				$\lceil \log_2(2L) \rceil$	$\lceil \log_2(2L) \rceil$	$\lceil \log_2(2L) \rceil$	$\lceil \log_2(2L) \rceil$	$\lceil \log_2(2L) \rceil$			
Information fields $X_2$												
	$i_{2,3,1}$	$i_{2,3,2}$	$i_{2,3,3}$	$i_{2,3,4}$	$i_{1,5}$	$i_{1,6,1}$	$i_{1,6,2}$	$i_{1,6,3}$	$i_{1,6,4}$	$\{i_{2,4,i}\}_{i=1,\dots,v}$	$\{i_{2,5,i}\}_{i=1,\dots,v}$	$\{i_{1,7,i}\}_{i=1,\dots,v}$
Rank=1 $N_3 \leq 19$	4	N/A	N/A	N/A	N/A	$\left\lceil \log_2 \binom{N_3-1}{M_1-1} \right\rceil$	N/A	N/A	N/A	$3(K^{NZ}-1)$	$4(K^{NZ}-1)$	$2LM_1$
Rank=2 $N_3 \leq 19$	4	4	N/A	N/A	N/A	$\left\lceil \log_2 \binom{N_3-1}{M_2-1} \right\rceil$	$\left\lceil \log_2 \binom{N_3-1}{M_2-1} \right\rceil$	N/A	N/A	$3(K^{NZ}-2)$	$4(K^{NZ}-2)$	$4LM_2$
Rank=3 $N_3 \leq 19$	4	4	4	N/A	N/A	$\left\lceil \log_2 \binom{N_3-1}{M_3-1} \right\rceil$	$\left\lceil \log_2 \binom{N_3-1}{M_3-1} \right\rceil$	$\left\lceil \log_2 \binom{N_3-1}{M_3-1} \right\rceil$	N/A	$3(K^{NZ}-3)$	$4(K^{NZ}-3)$	$6LM_3$
Rank=4 $N_3 \leq 19$	4	4	4	4	N/A	$\left\lceil \log_2 \binom{N_3-1}{M_4-1} \right\rceil$	$\left\lceil \log_2 \binom{N_3-1}{M_4-1} \right\rceil$	$\left\lceil \log_2 \binom{N_3-1}{M_4-1} \right\rceil$	$\left\lceil \log_2 \binom{N_3-1}{M_4-1} \right\rceil$	$3(K^{NZ}-4)$	$4(K^{NZ}-4)$	$8LM_4$
Rank=1 $N_3 > 19$	4	N/A	N/A	N/A	$\lceil \log_2(2M_1) \rceil$	$\left\lceil \log_2 \binom{2M_1-1}{M_1-1} \right\rceil$	N/A	N/A	N/A	$3(K^{NZ}-1)$	$4(K^{NZ}-1)$	$2LM_1$
Rank=2 $N_3 > 19$	4	4	N/A	N/A	$\lceil \log_2(2M_2) \rceil$	$\left\lceil \log_2 \binom{2M_2-1}{M_2-1} \right\rceil$	$\left\lceil \log_2 \binom{2M_2-1}{M_2-1} \right\rceil$	N/A	N/A	$3(K^{NZ}-2)$	$4(K^{NZ}-2)$	$4LM_2$
Rank=3 $N_3 > 19$	4	4	4	N/A	$\lceil \log_2(2M_3) \rceil$	$\left\lceil \log_2 \binom{2M_3-1}{M_3-1} \right\rceil$	$\left\lceil \log_2 \binom{2M_3-1}{M_3-1} \right\rceil$	$\left\lceil \log_2 \binom{2M_3-1}{M_3-1} \right\rceil$	N/A	$3(K^{NZ}-3)$	$4(K^{NZ}-3)$	$6LM_3$
Rank=4 $N_3 > 19$	4	4	4	4	$\lceil \log_2(2M_4) \rceil$	$\left\lceil \log_2 \binom{2M_4-1}{M_4-1} \right\rceil$	$\left\lceil \log_2 \binom{2M_4-1}{M_4-1} \right\rceil$	$\left\lceil \log_2 \binom{2M_4-1}{M_4-1} \right\rceil$	$\left\lceil \log_2 \binom{2M_4-1}{M_4-1} \right\rceil$	$3(K^{NZ}-4)$	$4(K^{NZ}-4)$	$8LM_4$

Note: the bitwidth for  $\{i_{1,7,l}\}_{l=1,\dots,v}$ ,  $\{i_{2,4,l}\}_{l=1,\dots,v}$  and  $\{i_{2,5,l}\}_{l=1,\dots,v}$  shown in Table 6.3.2.1.2-2A is the total bitwidth of  $\{i_{1,7,l}\}$ ,  $\{i_{2,4,l}\}$  and  $\{i_{2,5,l}\}$  up to Rank =  $v$ , respectively, and the corresponding per layer bitwidths are  $2LM_v$ ,  $3(K_l^{NZ} - 1)$ , and  $4(K_l^{NZ} - 1)$ , (i.e., 1, 3, and 4 bits for each respective indicator elements  $k_{l,i,f}^{(3)}$ ,  $k_{l,i,f}^{(2)}$ , and  $c_{l,i,f}$ , respectively), where  $K_l^{NZ}$  as defined in Clause 5.2.2.2.5 in [6, TS 38.214] is the number of nonzero coefficients for layer  $l$  such that  $K^{NZ} = \sum_{l=1}^v K_l^{NZ}$ .

For CSI on PUSCH, two UCI bit sequences are generated,  $a_0^{(1)}, a_1^{(1)}, a_2^{(1)}, a_3^{(1)}, \dots, a_{A^{(1)}-1}^{(1)}$  and  $a_0^{(2)}, a_1^{(2)}, a_2^{(2)}, a_3^{(2)}, \dots, a_{A^{(2)}-1}^{(2)}$ . The CSI fields of all CSI reports, in the order from upper part to lower part in Table 6.3.2.1.2-6, are mapped to the UCI bit sequence  $a_0^{(1)}, a_1^{(1)}, a_2^{(1)}, a_3^{(1)}, \dots, a_{A^{(1)}-1}^{(1)}$  starting with  $a_0^{(1)}$ . The CSI fields of all CSI reports, in the order from upper part to lower part in Table 6.3.2.1.2-7, are mapped to the UCI bit sequence  $a_0^{(2)}, a_1^{(2)}, a_2^{(2)}, a_3^{(2)}, \dots, a_{A^{(2)}-1}^{(2)}$  starting with  $a_0^{(2)}$ .

The mapping order of CSI fields of one report for CRI/RSRP or SSBRI/RSRP reporting is provided in Table 6.3.1.1.2-8. The mapping order of CSI fields of one report for CRI/SINR or SSBRI/SINR reporting is provided in Table 6.3.1.1.2-8A. The procedure in clause 6.3.2 described for CSI part 1 is also applicable for one report for CRI/RSRP, SSBRI/RSRP, CRI/SINR, or SSBRI/SINR reporting.

**Table 6.3.2.1.2-3: Mapping order of CSI fields of one CSI report, CSI part 1**

CSI report number	CSI fields
CSI report #n CSI part 1	CRI as in Tables 6.3.1.1.2-3/4/6, if reported
	Rank Indicator as in Tables 6.3.1.1.2-3/4/5 or 6.3.2.1.2-8, if reported
	Wideband CQI for the first TB as in Tables 6.3.1.1.2-3/4/5 or 6.3.2.1.2-8, if reported
	Subband differential CQI for the first TB with increasing order of subband number as in Tables 6.3.1.1.2-3/4/5 or 6.3.2.1.2-8, if reported
	Indicator of the number of non-zero wideband amplitude coefficients $M_0$ for layer 0 as in Table 6.3.1.1.2-5, if reported
	Indicator of the number of non-zero wideband amplitude coefficients $M_1$ for layer 1 as in Table 6.3.1.1.2-5 (if the rank according to the reported RI is equal to one, this field is set to all zeros), if 2-layer PMI reporting is allowed according to the rank restriction in Clauses 5.2.2.2.3 and 5.2.2.2.4 [6, TS 38.214] and if reported
	Indicator of the total number of non-zero coefficients summed across all layers $K^{NZ}$ as in Table 6.3.2.1.2-8, if reported
Note:	Subbands for given CSI report $n$ indicated by the higher layer parameter <i>csi-ReportingBand</i> are numbered continuously in the increasing order with the lowest subband of <i>csi-ReportingBand</i> as subband 0.

**Table 6.3.2.1.2-4: Mapping order of CSI fields of one CSI report, CSI part 2 wideband**

CSI report number	CSI fields
CSI report #n CSI part 2 wideband	Wideband CQI for the second TB as in Tables 6.3.1.1.2-3/4/5, if present and reported
	Layer Indicator as in Tables 6.3.1.1.2-3/4/5, if reported
	PMI wideband information fields $X_1$ , from left to right as in Tables 6.3.1.1.2-1/2 or 6.3.2.1.2-1/2, if reported
	PMI wideband information fields $X_2$ , from left to right as in Tables 6.3.1.1.2-1/2 or 6.3.2.1.2-1/2, or codebook index for 2 antenna ports according to Clause 5.2.2.2.1 in [6, TS38.214], if <i>pmi-FormatIndicator</i> = <i>widebandPMI</i> and if reported

**Table 6.3.2.1.2-5: Mapping order of CSI fields of one CSI report, CSI part 2 subband**

CSI report #n Part 2 subband	Subband differential CQI for the second TB of all even subbands with increasing order of subband number, as in Tables 6.3.1.1.2-3/4/5, if <i>cqi-FormatIndicator=subbandCQI</i> and if reported
	PMI subband information fields $X_2$ of all even subbands with increasing order of subband number, from left to right as in Tables 6.3.1.1.2-1/2 or 6.3.2.1.2-1/2, or codebook index for 2 antenna ports according to Clause 5.2.2.2.1 in [6, TS38.214] of all even subbands with increasing order of subband number, if <i>pmi-FormatIndicator= subbandPMI</i> and if reported
	Subband differential CQI for the second TB of all odd subbands with increasing order of subband number, as in Tables 6.3.1.1.2-3/4/5, if <i>cqi-FormatIndicator=subbandCQI</i> and if reported
	PMI subband information fields $X_2$ of all odd subbands with increasing order of subband number, from left to right as in Tables 6.3.1.1.2-1/2 or 6.3.2.1.2-1/2, or codebook index for 2 antenna ports according to Clause 5.2.2.2.1 in [6, TS38.214] of all odd subbands with increasing order of subband number, if <i>pmi-FormatIndicator= subbandPMI</i> and if reported

Note: Subbands for given CSI report  $n$  indicated by the higher layer parameter *csi-ReportingBand* are numbered continuously in the increasing order with the lowest subband of *csi-ReportingBand* as subband 0.

**Table 6.3.2.1.2-5A: Mapping order of CSI fields of one CSI report, CSI part 2 of *codebookType=typell-r16* or *typell-PortSelection-r16***

CSI report number	CSI fields
CSI report #n CSI part 2, group 0	PMI fields $X_1$ , from left to right as in Tables 6.3.2.1.2-1A/2A, if reported
CSI report #n CSI part 2, group 1	The following PMI fields $X_2$ , from left to right, as in Tables 6.3.2.1.2-1A/2A: $\{i_{2,3,l}: l = 1, \dots, v\}$ , $i_{1,5}$ , $\{i_{1,6,l}: l = 1, \dots, v\}$ and $(\lfloor \frac{K^{NZ}}{2} \rfloor - v) \times 3$ highest priority bits of $\{i_{2,4,l}: l = 1, \dots, v\}$ , $(\lfloor \frac{K^{NZ}}{2} \rfloor - v) \times 4$ highest priority bits of $\{i_{2,5,l}: l = 1, \dots, v\}$ and $v * 2LM_v - \lfloor \frac{K^{NZ}}{2} \rfloor$ highest priority bits of $\{i_{1,7,l}: l = 1, \dots, v\}$ , in decreasing order of priority based on function $\text{Pri}(l, i, f)$ defined in clause 5.2.3 of TS38.214, if reported
CSI report #n CSI part 2, group 2	The following PMI fields $X_2$ , from left to right, as in Tables 6.3.2.1.2-1A/2A: $\lfloor \frac{K^{NZ}}{2} \rfloor \times 3$ lowest priority bits of $\{i_{2,4,l}: l = 1, \dots, v\}$ , $\lfloor \frac{K^{NZ}}{2} \rfloor \times 4$ lowest priority bits of $\{i_{2,5,l}: l = 1, \dots, v\}$ and $\lfloor \frac{K^{NZ}}{2} \rfloor$ lowest priority bits of $\{i_{1,7,l}: l = 1, \dots, v\}$ , in decreasing order of priority based on function $\text{Pri}(l, i, f)$ defined in clause 5.2.3 of TS38.214, if reported

**Table 6.3.2.1.2-6: Mapping order of CSI reports to UCI bit sequence  $a_0^{(1)}, a_1^{(1)}, a_2^{(1)}, a_3^{(1)}, \dots, a_{A^{(1)}-1}^{(1)}$ , with two-part CSI report(s)**

UCI bit sequence	CSI report number
$a_0^{(1)}$	CSI part 1 of CSI report #1 as in Table 6.3.2.1.2-3 or Table 6.3.1.1.2-8 or Table 6.3.1.1.2-8A
$a_1^{(1)}$	CSI part 1 of CSI report #2 as in Table 6.3.2.1.2-3 or Table 6.3.1.1.2-8 or Table 6.3.1.1.2-8A
$a_2^{(1)}$	
$a_3^{(1)}$	...
$\vdots$	
$a_{A^{(1)}-1}^{(1)}$	CSI part 1 of CSI report #n as in Table 6.3.2.1.2-3 or Table 6.3.1.1.2-8 or Table 6.3.1.1.2-8A

where CSI report #1, CSI report #2, ..., CSI report #n in Table 6.3.2.1.2-6 correspond to the CSI reports in increasing order of CSI report priority values according to Clause 5.2.5 of [6, TS38.214].

**Table 6.3.2.1.2-7: Mapping order of CSI reports to UCI bit sequence  $a_0^{(2)}, a_1^{(2)}, a_2^{(2)}, a_3^{(2)}, \dots, a_{A^{(2)}-1}^{(2)}$ , with two-part CSI report(s)**

UCI bit sequence	CSI report number
$a_0^{(2)}$ $a_1^{(2)}$ $a_2^{(2)}$ $a_3^{(2)}$ $\vdots$ $a_{A^{(2)}-1}^{(2)}$	CSI report #1, CSI part 2 wideband, as in Table 6.3.2.1.2-4, or CSI part 2 with group 0, as in Table 6.3.2.1.2-5A, if CSI part 2 exists for CSI report #1
	CSI report #2, CSI part 2 wideband, as in Table 6.3.2.1.2-4, or CSI part 2 with group 0, as in Table 6.3.2.1.2-5A, if CSI part 2 exists for CSI report #2
	...
	CSI report #n, CSI part 2 wideband, as in Table 6.3.2.1.2-4, or CSI part 2 with group 0, as in Table 6.3.2.1.2-5A, if CSI part 2 exists for CSI report #n
	CSI report #1, CSI part 2 subband, as in Table 6.3.2.1.2-5, or CSI part 2 with group 1 and 2, as in Table 6.3.2.1.2-5A, if CSI part 2 exists for CSI report #1
	CSI report #2, CSI part 2 subband, as in Table 6.3.2.1.2-5, or CSI part 2 with group 1 and 2, as in Table 6.3.2.1.2-5A, if CSI part 2 exists for CSI report #2
	...
	CSI report #n, CSI part 2 subband, as in Table 6.3.2.1.2-5, or CSI part 2 with group 1 and 2, as in Table 6.3.2.1.2-5A, if CSI part 2 exists for CSI report #n

where CSI report #1, CSI report #2, ..., CSI report #n in Table 6.3.2.1.2-7 correspond to the CSI reports in increasing order of CSI report priority values according to Clause 5.2.5 of [6, TS38.214].

The bandwidth for RI/CQI of *codebookType= typeII-r16* or *codebookType=typeII-PortSelection-r16* is provided in Table 6.3.2.1.2-8.

**Table 6.3.2.1.2-8: RI and CQI of *codebookType=typeII-r16* or *typeII-PortSelection-r16***

Field	Bitwidth
Rank Indicator	$\min(2, \lceil \log_2 n_{RI} \rceil)$
Wide-band CQI	4
Subband differential CQI	2
Indicator of the total number of non-zero coefficients summed across all layers $K^{NZ}$	$\lceil \log_2(K_0) \rceil$ if max allowed rank is 1; $\lceil \log_2(2K_0) \rceil$ otherwise

where  $n_{RI}$  is the number of allowed rank indicator values according to Clauses 5.2.2.2.5 and 5.2.2.2.6 [6, TS 38.214],  $K_0 = \left\lceil 2L \left[ p_1 \times \frac{N_3}{R} \right] \beta \right\rceil$ , where  $p_1$ ,  $N_3$ ,  $R$ , and  $\beta$  are given by Clause 5.2.2.2.5 and 5.2.2.2.6 in [6, TS 38.214]. The values of the rank indicator field are mapped to allowed rank indicator values with increasing order, where '0' is mapped to the smallest allowed rank indicator value.

### 6.3.2.1.3 CG-UCI

For CG-UCI bits transmitted on a CG PUSCH, the CG-UCI bit sequence  $a_0, a_1, a_2, a_3, \dots, a_{A-1}$  is determined as follows:

- set  $a_i = \tilde{o}_i^{CG-UCI}$  for  $i = 0, 1, \dots, O^{CG-UCI} - 1$  and  $A = O^{CG-UCI}$ , where the CG-UCI bit sequence  $\tilde{o}_0^{CG-UCI}, \tilde{o}_1^{CG-UCI}, \dots, \tilde{o}_{O^{CG-UCI}-1}^{CG-UCI}$  is given by Table 6.3.2.1.3-1, mapped in the order from upper part to lower part.

Table 6.3.2.1.3-1: Mapping order of CG-UCI fields

Field	Bitwidth
HARQ process number	4
Redundancy version	2
New data indicator	1
Channel Occupancy Time (COT) sharing information	<p><math>\lceil \log_2 C \rceil</math> if both higher layer parameter <i>ul-toDL-COT-SharingED-Threshold</i> and higher layer parameter <i>cg-COT-SharingList</i> are configured, where <i>C</i> is the number of combinations configured in <i>cg-COT-SharingList</i>;</p> <p>1 if higher layer parameter <i>ul-toDL-COT-SharingED-Threshold</i> is not configured and higher layer parameter <i>cg-COT-SharingOffset</i> is configured;</p> <p>0 otherwise;</p> <p>If a UE indicates COT sharing other than "no sharing" in a CG PUSCH within the UE's initiated COT, the UE should provide consistent COT sharing information in all the subsequent CG PUSCHs, if any, occurring within the same UE's initiated COT such that the same DL starting point and duration are maintained.</p>

#### 6.3.2.1.4 HARQ-ACK and CG-UCI

When higher layer parameter *cg-UCI-Multiplexing* is configured, the UCI bit sequence  $a_0, a_1, a_2, a_3, \dots, a_{A-1}$  is determined as follows, where  $A = O^{CG-UCI} + O^{ACK}$ .

- The CG-UCI bits are mapped to the UCI bit sequence  $a_0, a_1, a_2, a_3, \dots, a_{O^{CG-UCI}-1}$ , where  $a_i = \tilde{d}_i^{CG-UCI}$  for  $i = 0, 1, \dots, O^{CG-UCI} - 1$ . The CG-UCI bit sequence  $\tilde{d}_0^{CG-UCI}, \tilde{d}_1^{CG-UCI}, \dots, \tilde{d}_{O^{CG-UCI}-1}^{CG-UCI}$  is given by Table 6.3.2.1.3-1 mapped in the order from upper part to lower part, and  $O^{CG-UCI}$  is number of CG-UCI bits;
- The HARQ-ACK bits are mapped to the UCI bit sequence  $a_{O^{CG-UCI}}, a_{O^{CG-UCI}+1}, \dots, a_{O^{CG-UCI}+O^{ACK}-1}$ , where  $a_{i+O^{CG-UCI}} = \tilde{d}_i^{ACK}$  for  $i = 0, 1, \dots, O^{ACK} - 1$ . The HARQ-ACK bit sequence  $\tilde{d}_0^{ACK}, \tilde{d}_1^{ACK}, \dots, \tilde{d}_{O^{ACK}-1}^{ACK}$  is given by Clause 9.1 of [5, TS38.213], and  $O^{ACK}$  is number of HARQ-ACK bits.

#### 6.3.2.2 Code block segmentation and CRC attachment

Denote the bits of the payload by  $a_0, a_1, a_2, a_3, \dots, a_{A-1}$ , where  $A$  is the payload size. The procedure in 6.3.2.2.1 applies for  $A \geq 12$  and the procedure in Clause 6.3.2.2.2 applies for  $A \leq 11$ .

##### 6.3.2.2.1 UCI encoded by Polar code

Code block segmentation and CRC attachment is performed according to Clause 6.3.1.2.1.

##### 6.3.2.2.2 UCI encoded by channel coding of small block lengths

The procedure in Clause 6.3.1.2.2 applies.

#### 6.3.2.3 Channel coding of UCI

##### 6.3.2.3.1 UCI encoded by Polar code

Channel coding is performed according to Clause 6.3.1.3.1, except that the rate matching output sequence length  $E_r$  is given in Clause 6.3.2.4.1.

### 6.3.2.3.2 UCI encoded by channel coding of small block lengths

Information bits are delivered to the channel coding block. They are denoted by  $c_0, c_1, c_2, c_3, \dots, c_{K-1}$ , where  $K$  is the number of bits.

The information bits are encoded according to Clause 5.3.3.

After encoding the bits are denoted by  $d_0, d_1, d_2, d_3, \dots, d_{N-1}$ , where  $N$  is the number of coded bits.

### 6.3.2.4 Rate matching

#### 6.3.2.4.1 UCI encoded by Polar code

##### 6.3.2.4.1.1 HARQ-ACK

For HARQ-ACK transmission on PUSCH not using repetition type B with UL-SCH, the number of coded modulation symbols per layer for HARQ-ACK transmission, denoted as  $Q'_{\text{ACK}}$ , is determined as follows:

$$Q'_{\text{ACK}} = \min \left\{ \left[ \frac{(O_{\text{ACK}} + L_{\text{ACK}}) \cdot \beta_{\text{offset}}^{\text{PUSCH}} \cdot \sum_{l=0}^{N_{\text{sym,all}}^{\text{PUSCH}}-1} M_{\text{sc}}^{\text{UCI}}(l)}{\sum_{r=0}^{C_{\text{UL-SCH}}-1} K_r} \right], \left\lceil \alpha \cdot \sum_{l=l_0}^{N_{\text{sym,all}}^{\text{PUSCH}}-1} M_{\text{sc}}^{\text{UCI}}(l) \right\rceil \right\}$$

where

- $O_{\text{ACK}}$  is the number of HARQ-ACK bits;
- if  $O_{\text{ACK}} \geq 360$ ,  $L_{\text{ACK}} = 11$ ; otherwise  $L_{\text{ACK}}$  is the number of CRC bits for HARQ-ACK determined according to Clause 6.3.1.2.1;
- $\beta_{\text{offset}}^{\text{PUSCH}} = \beta_{\text{offset}}^{\text{HARQ-ACK}}$ ;
- $C_{\text{UL-SCH}}$  is the number of code blocks for UL-SCH of the PUSCH transmission;
- if the DCI format scheduling the PUSCH transmission includes a CBGTI field indicating that the UE shall not transmit the  $r$ -th code block,  $K_r = 0$ ; otherwise,  $K_r$  is the  $r$ -th code block size for UL-SCH of the PUSCH transmission;
- $M_{\text{sc}}^{\text{PUSCH}}$  is the scheduled bandwidth of the PUSCH transmission, expressed as a number of subcarriers;
- $M_{\text{sc}}^{\text{PT-RS}}(l)$  is the number of subcarriers in OFDM symbol  $l$  that carries PTRS, in the PUSCH transmission;
- $M_{\text{sc}}^{\text{UCI}}(l)$  is the number of resource elements that can be used for transmission of UCI in OFDM symbol  $l$ , for  $l = 0, 1, 2, \dots, N_{\text{sym,all}}^{\text{PUSCH}} - 1$ , in the PUSCH transmission and  $N_{\text{sym,all}}^{\text{PUSCH}}$  is the total number of OFDM symbols of the PUSCH, including all OFDM symbols used for DMRS;
  - for any OFDM symbol that carries DMRS of the PUSCH,  $M_{\text{sc}}^{\text{UCI}}(l) = 0$ ;
  - for any OFDM symbol that does not carry DMRS of the PUSCH,  $M_{\text{sc}}^{\text{UCI}}(l) = M_{\text{sc}}^{\text{PUSCH}} - M_{\text{sc}}^{\text{PT-RS}}(l)$ ;
- $\alpha$  is configured by higher layer parameter *scaling*;

- $l_0$  is the symbol index of the first OFDM symbol that does not carry DMRS of the PUSCH, after the first DMRS symbol(s), in the PUSCH transmission.

For HARQ-ACK transmission on an actual repetition of a PUSCH with repetition Type B with UL-SCH, the number of coded modulation symbols per layer for HARQ-ACK transmission, denoted as  $Q'_{ACK}$ , is determined as follows:

$$Q'_{ACK} = \min \left\{ \left[ \frac{(O_{ACK} + L_{ACK}) \cdot \beta_{\text{offset}}^{\text{PUSCH}} \cdot \sum_{l=0}^{N_{\text{symb,nominal}}^{\text{PUSCH}} - 1} M_{\text{sc,nominal}}^{\text{UCI}}(l)}{\sum_{r=0}^{C_{\text{UL-SCH}} - 1} K_r} \right], \left[ \alpha \cdot \sum_{l=0}^{N_{\text{symb,nominal}}^{\text{PUSCH}} - 1} M_{\text{sc,nominal}}^{\text{UCI}}(l) \right], \left[ \sum_{l=0}^{N_{\text{symb,actual}}^{\text{PUSCH}} - 1} M_{\text{sc,actual}}^{\text{UCI}}(l) \right] \right\}$$

where

- $M_{\text{sc,nominal}}^{\text{UCI}}(l)$  is the number of resource elements that can be used for transmission of UCI in OFDM symbol  $l$ , for  $l = 0, 1, 2, \dots, N_{\text{symb,nominal}}^{\text{PUSCH}} - 1$ , in the PUSCH transmission assuming a nominal repetition without segmentation, and  $N_{\text{symb,nominal}}^{\text{PUSCH}}$  is the total number of OFDM symbols in a nominal repetition of the PUSCH, including all OFDM symbols used for DMRS;
  - for any OFDM symbol that carries DMRS of the PUSCH assuming a nominal repetition without segmentation,  $M_{\text{sc,nominal}}^{\text{UCI}}(l) = 0$ ;
  - for any OFDM symbol that does not carry DMRS of the PUSCH assuming a nominal repetition without segmentation,  $M_{\text{sc,nominal}}^{\text{UCI}}(l) = M_{\text{sc}}^{\text{PUSCH}} - M_{\text{sc,nominal}}^{\text{PT-RS}}(l)$  where  $M_{\text{sc,nominal}}^{\text{PT-RS}}(l)$  is the number of subcarriers in OFDM symbol  $l$  that carries PTRS, in the PUSCH transmission assuming a nominal repetition without segmentation;
- $M_{\text{sc,actual}}^{\text{UCI}}(l)$  is the number of resource elements that can be used for transmission of UCI in OFDM symbol  $l$ , for  $l = 0, 1, 2, \dots, N_{\text{symb,actual}}^{\text{PUSCH}} - 1$ , in the actual repetition of the PUSCH transmission, and  $N_{\text{symb,actual}}^{\text{PUSCH}}$  is the total number of OFDM symbols in the actual repetition of the PUSCH transmission, including all OFDM symbols used for DMRS;
  - for any OFDM symbol that carries DMRS of the actual repetition of the PUSCH transmission,  $M_{\text{sc,actual}}^{\text{UCI}}(l) = 0$ ;
  - for any OFDM symbol that does not carry DMRS of the actual repetition of the PUSCH transmission,  $M_{\text{sc,actual}}^{\text{UCI}}(l) = M_{\text{sc}}^{\text{PUSCH}} - M_{\text{sc,actual}}^{\text{PT-RS}}(l)$  where  $M_{\text{sc,actual}}^{\text{PT-RS}}(l)$  is the number of subcarriers in OFDM symbol  $l$  that carries PTRS, in the actual repetition of the PUSCH transmission;
- and all the other notations in the formula are defined the same as for PUSCH not using repetition type B.

For HARQ-ACK transmission on PUSCH without UL-SCH, the number of coded modulation symbols per layer for HARQ-ACK transmission, denoted as  $Q'_{ACK}$ , is determined as follows:

$$Q'_{ACK} = \min \left\{ \left[ \frac{(O_{ACK} + L_{ACK}) \cdot \beta_{\text{offset}}^{\text{PUSCH}}}{R \cdot Q_m} \right], \left[ \alpha \cdot \sum_{l=l_0}^{N_{\text{symb,all}}^{\text{PUSCH}} - 1} M_{\text{sc}}^{\text{UCI}}(l) \right] \right\}$$

where

- $O_{ACK}$  is the number of HARQ-ACK bits;
- if  $O_{ACK} \geq 360$ ,  $L_{ACK} = 11$ ; otherwise  $L_{ACK}$  is the number of CRC bits for HARQ-ACK defined according to Clause 6.3.1.2.1.1;



- $\beta_{\text{offset}}^{\text{PUSCH}} = \beta_{\text{offset}}^{\text{HARQ-ACK}}$  ;
- $M_{\text{sc}}^{\text{PUSCH}}$  is the scheduled bandwidth of the PUSCH transmission, expressed as a number of subcarriers;
- $M_{\text{sc}}^{\text{PT-RS}}(l)$  is the number of subcarriers in OFDM symbol  $l$  that carries PTRS, in the PUSCH transmission;
- $M_{\text{sc}}^{\text{UCI}}(l)$  is the number of resource elements that can be used for transmission of UCI in OFDM symbol  $l$ , for  $l = 0, 1, 2, \dots, N_{\text{sym,all}}^{\text{PUSCH}} - 1$ , in the PUSCH transmission and  $N_{\text{sym,all}}^{\text{PUSCH}}$  is the total number of OFDM symbols of the PUSCH, including all OFDM symbols used for DMRS;
- for any OFDM symbol that carries DMRS of the PUSCH,  $M_{\text{sc}}^{\text{UCI}}(l) = 0$ ;
- for any OFDM symbol that does not carry DMRS of the PUSCH,  $M_{\text{sc}}^{\text{UCI}}(l) = M_{\text{sc}}^{\text{PUSCH}} - M_{\text{sc}}^{\text{PT-RS}}(l)$ ;
- $l_0$  is the symbol index of the first OFDM symbol that does not carry DMRS of the PUSCH, after the first DMRS symbol(s), in the PUSCH transmission;
- $R$  is the code rate of the PUSCH, determined according to Clause 6.1.4.1 of [6, TS38.214];
- $Q_m$  is the modulation order of the PUSCH;
- $\alpha$  is configured by higher layer parameter *scaling*.

The input bit sequence to rate matching is  $d_{r0}, d_{r1}, d_{r2}, d_{r3}, \dots, d_{r(N_r-1)}$  where  $r$  is the code block number, and  $N_r$  is the number of coded bits in code block number  $r$ .

Rate matching is performed according to Clause 5.4.1 by setting  $I_{\text{BL}} = 1$  and the rate matching output sequence length to  $E_r = \lfloor E_{\text{UCI}} / C_{\text{UCI}} \rfloor$ , where

- $C_{\text{UCI}}$  is the number of code blocks for UCI determined according to Clause 5.2.1;
- $N_L$  is the number of transmission layers of the PUSCH;
- $Q_m$  is the modulation order of the PUSCH;
- $E_{\text{UCI}} = N_L \cdot Q'_{\text{ACK}} \cdot Q_m$ .

The output bit sequence after rate matching is denoted as  $f_{r0}, f_{r1}, f_{r2}, \dots, f_{r(E_r-1)}$  where  $E_r$  is the length of rate matching output sequence in code block number  $r$ .

#### 6.3.2.4.1.2 CSI part 1

For CSI part 1 transmission on PUSCH not using repetition type B with UL-SCH, the number of coded modulation symbols per layer for CSI part 1 transmission, denoted as  $Q'_{\text{CSI-part1}}$ , is determined as follows:

$$Q'_{\text{CSI-1}} = \min \left\{ \left\lceil \frac{(O_{\text{CSI-1}} + L_{\text{CSI-1}}) \cdot \beta_{\text{offset}}^{\text{PUSCH}} \cdot \sum_{l=0}^{N_{\text{sym,all}}^{\text{PUSCH}} - 1} M_{\text{sc}}^{\text{UCI}}(l)}{\sum_{r=0}^{C_{\text{UL-SCH}} - 1} K_r} \right\rceil, \left\lceil \alpha \cdot \sum_{l=0}^{N_{\text{sym,all}}^{\text{PUSCH}} - 1} M_{\text{sc}}^{\text{UCI}}(l) \right\rceil - Q'_{\text{ACK/CG-UCI}} \right\}$$

where

- $O_{\text{CSI-1}}$  is the number of bits for CSI part 1;

- if  $O_{\text{CSI-1}} \geq 360$ ,  $L_{\text{CSI-1}} = 11$ ; otherwise  $L_{\text{CSI-1}}$  is the number of CRC bits for CSI part 1 determined according to Clause 6.3.1.2.1;
- $\beta_{\text{offset}}^{\text{PUSCH}} = \beta_{\text{offset}}^{\text{CSI-part1}}$ ;
- $C_{\text{UL-SCH}}$  is the number of code blocks for UL-SCH of the PUSCH transmission;
- if the DCI format scheduling the PUSCH transmission includes a CBGTI field indicating that the UE shall not transmit the  $r$ -th code block,  $K_r = 0$ ; otherwise,  $K_r$  is the  $r$ -th code block size for UL-SCH of the PUSCH transmission;
- $M_{\text{sc}}^{\text{PUSCH}}$  is the scheduled bandwidth of the PUSCH transmission, expressed as a number of subcarriers;
- $M_{\text{sc}}^{\text{PT-RS}}(l)$  is the number of subcarriers in OFDM symbol  $l$  that carries PTRS, in the PUSCH transmission;
- $Q'_{\text{ACK/CG-UCI}} = Q'_{\text{ACK}}$  if HARQ-ACK is present for transmission on the same PUSCH with UL-SCH and without CG-UCI, where  $Q'_{\text{ACK}}$  is the number of coded modulation symbols per layer for HARQ-ACK transmitted on the PUSCH as defined in clause 6.3.2.4.1.1 if number of HARQ-ACK information bits is more than 2, and
 
$$Q'_{\text{ACK}} = \sum_{l=0}^{N_{\text{symb,all}}^{\text{PUSCH}}-1} \bar{M}_{\text{sc,rvd}}^{\text{ACK}}(l)$$
 if the number of HARQ-ACK information bits is no more than 2 bits, where  $\bar{M}_{\text{sc,rvd}}^{\text{ACK}}(l)$  is the number of reserved resource elements for potential HARQ-ACK transmission in OFDM symbol  $l$ , for  $l = 0, 1, 2, \dots, N_{\text{symb,all}}^{\text{PUSCH}} - 1$ , in the PUSCH transmission, defined in Clause 6.2.7; or
- $Q'_{\text{ACK/CG-UCI}} = Q'_{\text{ACK}}$  if both HARQ-ACK and CG-UCI are present on the same PUSCH with UL-SCH, where  $Q'_{\text{ACK}}$  is the number of coded modulation symbols per layer for HARQ-ACK and CG-UCI transmitted on the PUSCH as defined in clause 6.3.2.4.1.5; or
- $Q'_{\text{ACK/CG-UCI}} = Q'_{\text{CG-UCI}}$  if CG-UCI is present on the same PUSCH with UL-SCH and without HARQ-ACK, where  $Q'_{\text{CG-UCI}}$  is the number of coded modulation symbols per layer for CG-UCI transmitted on the PUSCH as defined in clause 6.3.2.4.1.4;
- $M_{\text{sc}}^{\text{UCI}}(l)$  is the number of resource elements that can be used for transmission of UCI in OFDM symbol  $l$ , for  $l = 0, 1, 2, \dots, N_{\text{symb,all}}^{\text{PUSCH}} - 1$ , in the PUSCH transmission and  $N_{\text{symb,all}}^{\text{PUSCH}}$  is the total number of OFDM symbols of the PUSCH, including all OFDM symbols used for DMRS;
  - for any OFDM symbol that carries DMRS of the PUSCH,  $M_{\text{sc}}^{\text{UCI}}(l) = 0$ ;
  - for any OFDM symbol that does not carry DMRS of the PUSCH,  $M_{\text{sc}}^{\text{UCI}}(l) = M_{\text{sc}}^{\text{PUSCH}} - M_{\text{sc}}^{\text{PT-RS}}(l)$ ;
- $\alpha$  is configured by higher layer parameter *scaling*.

For CSI part 1 transmission on an actual repetition of a PUSCH with repetition Type B with UL-SCH, the number of coded modulation symbols per layer for CSI part 1 transmission, denoted as  $Q'_{\text{CSI-part1}}$ , is determined as follows:

$$Q'_{\text{CSI-1}} = \min \left\{ \left[ \frac{(O_{\text{CSI-1}} + L_{\text{CSI-1}}) \cdot \beta_{\text{offset}}^{\text{PUSCH}} \cdot \sum_{l=0}^{N_{\text{symb,nominal}}^{\text{PUSCH}}-1} M_{\text{sc,nominal}}^{\text{UCI}}(l)}{\sum_{r=0}^{C_{\text{UL-SCH}}-1} K_r} \right], \left[ \alpha \cdot \sum_{l=0}^{N_{\text{symb,nominal}}^{\text{PUSCH}}-1} M_{\text{sc,nominal}}^{\text{UCI}}(l) \right] \right. \\ \left. - Q'_{\text{ACK/CG-UCI}}, \sum_{l=0}^{N_{\text{symb,actual}}^{\text{PUSCH}}-1} M_{\text{sc,actual}}^{\text{UCI}}(l) - Q'_{\text{ACK/CG-UCI}} \right\}$$

where

- $M_{sc,nominal}^{UCI}(l)$  is the number of resource elements that can be used for transmission of UCI in OFDM symbol  $l$ , for  $l = 0, 1, 2, \dots, N_{symb,nominal}^{PUSCH} - 1$ , in the PUSCH transmission assuming a nominal repetition without segmentation, and  $N_{symb,nominal}^{PUSCH}$  is the total number of OFDM symbols in a nominal repetition of the PUSCH, including all OFDM symbols used for DMRS;
  - for any OFDM symbol that carries DMRS of the PUSCH assuming a nominal repetition without segmentation,  $M_{sc,nominal}^{UCI}(l) = 0$ ;
  - for any OFDM symbol that does not carry DMRS of the PUSCH assuming a nominal repetition without segmentation,  $M_{sc,nominal}^{UCI}(l) = M_{sc}^{PUSCH} - M_{sc,nominal}^{PT-RS}(l)$  where  $M_{sc,nominal}^{PT-RS}(l)$  is the number of subcarriers in OFDM symbol  $l$  that carries PTRS, in the PUSCH transmission assuming a nominal repetition without segmentation;
- $M_{sc,actual}^{UCI}(l)$  is the number of resource elements that can be used for transmission of UCI in OFDM symbol  $l$ , for  $l = 0, 1, 2, \dots, N_{symb,actual}^{PUSCH} - 1$ , in the actual repetition of the PUSCH transmission, and  $N_{symb,actual}^{PUSCH}$  is the total number of OFDM symbols in the actual repetition of the PUSCH transmission, including all OFDM symbols used for DMRS;
  - for any OFDM symbol that carries DMRS of the actual repetition of the PUSCH transmission,  $M_{sc,actual}^{UCI}(l) = 0$ ;
  - for any OFDM symbol that does not carry DMRS of the actual repetition of the PUSCH transmission,  $M_{sc,actual}^{UCI}(l) = M_{sc}^{PUSCH} - M_{sc,actual}^{PT-RS}(l)$  where  $M_{sc,actual}^{PT-RS}(l)$  is the number of subcarriers in OFDM symbol  $l$  that carries PTRS, in the actual repetition of the PUSCH transmission;
- and all the other notations in the formula are defined the same as for PUSCH not using repetition type B.

For CSI part 1 transmission on PUSCH without UL-SCH, the number of coded modulation symbols per layer for CSI part 1 transmission, denoted as  $Q'_{CSI-part1}$ , is determined as follows:

if there is CSI part 2 to be transmitted on the PUSCH,

$$Q'_{CSI-1} = \min \left\{ \left[ \frac{(O_{CSI-1} + L_{CSI-1}) \cdot \beta_{offset}^{PUSCH}}{R \cdot Q_m} \right], \sum_{l=0}^{N_{symb,all}^{PUSCH}-1} M_{sc}^{UCI}(l) - Q'_{ACK} \right\}$$

else

$$Q'_{CSI-1} = \sum_{l=0}^{N_{symb,all}^{PUSCH}-1} M_{sc}^{UCI}(l) - Q'_{ACK}$$

end if

where

- $O_{CSI-1}$  is the number of bits for CSI part 1;
- if  $O_{CSI-1} \geq 360$ ,  $L_{CSI-1} = 11$ ; otherwise  $L_{CSI-1}$  is the number of CRC bits for CSI part 1 determined according to Clause 6.3.1.2.1;
- $\beta_{offset}^{PUSCH} = \beta_{offset}^{CSI-part1}$ ;
- $M_{sc}^{PUSCH}$  is the scheduled bandwidth of the PUSCH transmission, expressed as a number of subcarriers;
- $M_{sc}^{PT-RS}(l)$  is the number of subcarriers in OFDM symbol  $l$  that carries PTRS, in the PUSCH transmission;

- $Q'_{ACK}$  is the number of coded modulation symbols per layer for HARQ-ACK transmitted on the PUSCH if number of HARQ-ACK information bits is more than 2, and  $Q'_{ACK} = \sum_{l=0}^{N_{\text{symb,all}}^{\text{PUSCH}}-1} \bar{M}_{\text{sc,rvd}}^{\text{ACK}}(l)$  if the number of HARQ-ACK information bits is no more than 2 bits, where  $\bar{M}_{\text{sc,rvd}}^{\text{ACK}}(l)$  is the number of reserved resource elements for potential HARQ-ACK transmission in OFDM symbol  $l$ , for  $l = 0, 1, 2, \dots, N_{\text{symb,all}}^{\text{PUSCH}} - 1$ , in the PUSCH transmission, defined in Clause 6.2.7;
- $M_{\text{sc}}^{\text{UCI}}(l)$  is the number of resource elements that can be used for transmission of UCI in OFDM symbol  $l$ , for  $l = 0, 1, 2, \dots, N_{\text{symb,all}}^{\text{PUSCH}} - 1$ , in the PUSCH transmission and  $N_{\text{symb,all}}^{\text{PUSCH}}$  is the total number of OFDM symbols of the PUSCH, including all OFDM symbols used for DMRS;
  - for any OFDM symbol that carries DMRS of the PUSCH,  $M_{\text{sc}}^{\text{UCI}}(l) = 0$ ;
  - for any OFDM symbol that does not carry DMRS of the PUSCH,  $M_{\text{sc}}^{\text{UCI}}(l) = M_{\text{sc}}^{\text{PUSCH}} - M_{\text{sc}}^{\text{PT-RS}}(l)$ ;
- $R$  is the code rate of the PUSCH, determined according to Clause 6.1.4.1 of [6, TS38.214];
- $Q_m$  is the modulation order of the PUSCH.

The input bit sequence to rate matching is  $d_{r0}, d_{r1}, d_{r2}, d_{r3}, \dots, d_{r(N_r-1)}$  where  $r$  is the code block number, and  $N_r$  is the number of coded bits in code block number  $r$ .

Rate matching is performed according to Clause 5.4.1 by setting  $I_{\text{BL}} = 1$  and the rate matching output sequence length to  $E_r = \lfloor E_{\text{UCI}} / C_{\text{UCI}} \rfloor$ , where

- $C_{\text{UCI}}$  is the number of code blocks for UCI determined according to Clause 5.2.1;
- $N_L$  is the number of transmission layers of the PUSCH;
- $Q_m$  is the modulation order of the PUSCH;
- $E_{\text{UCI}} = N_L \cdot Q'_{\text{CSI-1}} \cdot Q_m$ .

The output bit sequence after rate matching is denoted as  $f_{r0}, f_{r1}, f_{r2}, \dots, f_{r(E_r-1)}$  where  $E_r$  is the length of rate matching output sequence in code block number  $r$ .

### 6.3.2.4.1.3 CSI part 2

For CSI part 2 transmission on PUSCH not using repetition type B with UL-SCH, the number of coded modulation symbols per layer for CSI part 2 transmission, denoted as  $Q'_{\text{CSI-part2}}$ , is determined as follows:

$$Q'_{\text{CSI-2}} = \min \left\{ \left\lceil \frac{(O_{\text{CSI-2}} + L_{\text{CSI-2}}) \cdot \beta_{\text{offset}}^{\text{PUSCH}} \cdot \sum_{l=0}^{N_{\text{symb,all}}^{\text{PUSCH}}-1} M_{\text{sc}}^{\text{UCI}}(l)}{\sum_{r=0}^{C_{\text{UL-SCH}}-1} K_r} \right\rceil, \left\lfloor \alpha \cdot \sum_{l=0}^{N_{\text{symb,all}}^{\text{PUSCH}}-1} M_{\text{sc}}^{\text{UCI}}(l) \right\rfloor - Q'_{\text{ACK/CG-UCI}} - Q'_{\text{CSI-1}} \right\}$$

where

- $O_{\text{CSI-2}}$  is the number of bits for CSI part 2;
- if  $O_{\text{CSI-2}} \geq 360$ ,  $L_{\text{CSI-2}} = 11$ ; otherwise  $L_{\text{CSI-2}}$  is the number of CRC bits for CSI part 2 determined according to Clause 6.3.1.2.1;

- $\beta_{\text{offset}}^{\text{PUSCH}} = \beta_{\text{offset}}^{\text{CSI-part2}}$ ;
- $C_{\text{UL-SCH}}$  is the number of code blocks for UL-SCH of the PUSCH transmission;
- if the DCI format scheduling the PUSCH transmission includes a CBGTI field indicating that the UE shall not transmit the  $r$ -th code block,  $K_r=0$ ; otherwise,  $K_r$  is the  $r$ -th code block size for UL-SCH of the PUSCH transmission;
- $M_{\text{sc}}^{\text{PUSCH}}$  is the scheduled bandwidth of the PUSCH transmission, expressed as a number of subcarriers;
- $M_{\text{sc}}^{\text{PT-RS}}(l)$  is the number of subcarriers in OFDM symbol  $l$  that carries PTRS, in the PUSCH transmission;
- $Q'_{\text{ACK/CG-UCI}} = Q'_{\text{ACK}}$  if HARQ-ACK is present for transmission on the same PUSCH with UL-SCH and without CG-UCI, where  $Q'_{\text{ACK}}$  is the number of coded modulation symbols per layer for HARQ-ACK transmitted on the PUSCH as defined in clause 6.3.2.4.1.1 if number of HARQ-ACK information bits is more than 2, and  $Q'_{\text{ACK}} = 0$  if the number of HARQ-ACK information bits is 1 or 2 bits; or
- $Q'_{\text{ACK/CG-UCI}} = Q'_{\text{ACK}}$  if both HARQ-ACK and CG-UCI are present on the same PUSCH with UL-SCH, where  $Q'_{\text{ACK}}$  is the number of coded modulation symbols per layer for HARQ-ACK and CG-UCI transmitted on the PUSCH as defined in clause 6.3.2.4.1.5; or
- $Q'_{\text{ACK/CG-UCI}} = Q'_{\text{CG-UCI}}$  if CG-UCI is present on the same PUSCH with UL-SCH and without HARQ-ACK, where  $Q'_{\text{CG-UCI}}$  is the number of coded modulation symbols per layer for CG-UCI transmitted on the PUSCH as defined in clause 6.3.2.4.1.4;
- $Q'_{\text{CSI-1}}$  is the number of coded modulation symbols per layer for CSI part 1 transmitted on the PUSCH;
- $M_{\text{sc}}^{\text{UCI}}(l)$  is the number of resource elements that can be used for transmission of UCI in OFDM symbol  $l$ , for  $l = 0, 1, 2, \dots, N_{\text{sym,all}}^{\text{PUSCH}} - 1$ , in the PUSCH transmission and  $N_{\text{sym,all}}^{\text{PUSCH}}$  is the total number of OFDM symbols of the PUSCH, including all OFDM symbols used for DMRS;
  - for any OFDM symbol that carries DMRS of the PUSCH,  $M_{\text{sc}}^{\text{UCI}}(l) = 0$ ;
  - for any OFDM symbol that does not carry DMRS of the PUSCH,  $M_{\text{sc}}^{\text{UCI}}(l) = M_{\text{sc}}^{\text{PUSCH}} - M_{\text{sc}}^{\text{PT-RS}}(l)$ .
- $\alpha$  is configured by higher layer parameter *scaling*.

For CSI part 2 transmission on an actual repetition of a PUSCH with repetition Type B with UL-SCH, the number of coded modulation symbols per layer for CSI part 2 transmission, denoted as  $Q'_{\text{CSI-part2}}$ , is determined as follows:

$$Q'_{\text{CSI-2}} = \min \left\{ \left[ \frac{(O_{\text{CSI-2}} + L_{\text{CSI-2}}) \cdot \beta_{\text{offset}}^{\text{PUSCH}} \cdot \sum_{l=0}^{N_{\text{sym,nominal}}^{\text{PUSCH}} - 1} M_{\text{sc,nominal}}^{\text{UCI}}(l)}{\sum_{r=0}^{C_{\text{UL-SCH}} - 1} K_r} \right], \left[ \alpha \cdot \sum_{l=0}^{N_{\text{sym,nominal}}^{\text{PUSCH}} - 1} M_{\text{sc,nominal}}^{\text{UCI}}(l) \right] \right. \\ \left. - Q'_{\text{ACK/CG-UCI}} - Q'_{\text{CSI-1}}, \sum_{l=0}^{N_{\text{sym,actual}}^{\text{PUSCH}} - 1} M_{\text{sc,actual}}^{\text{UCI}}(l) - Q'_{\text{ACK/CG-UCI}} - Q'_{\text{CSI-1}} \right\}$$

where

- $M_{\text{sc,nominal}}^{\text{UCI}}(l)$  is the number of resource elements that can be used for transmission of UCI in OFDM symbol  $l$ , for  $l = 0, 1, 2, \dots, N_{\text{sym,nominal}}^{\text{PUSCH}} - 1$ , in the PUSCH transmission assuming a nominal repetition without segmentation, and  $N_{\text{sym,nominal}}^{\text{PUSCH}}$  is the total number of OFDM symbols in a nominal repetition of the PUSCH, including all OFDM symbols used for DMRS;

- for any OFDM symbol that carries DMRS of the PUSCH assuming a nominal repetition without segmentation,  $M_{sc,nominal}^{UCI}(l) = 0$ ;
- for any OFDM symbol that does not carry DMRS of the PUSCH assuming a nominal repetition without segmentation,  $M_{sc,nominal}^{UCI}(l) = M_{sc}^{PUSCH} - M_{sc,nominal}^{PT-RS}(l)$  where  $M_{sc,nominal}^{PT-RS}(l)$  is the number of subcarriers in OFDM symbol  $l$  that carries PTRS, in the PUSCH transmission assuming a nominal repetition without segmentation;
- $M_{sc,actual}^{UCI}(l)$  is the number of resource elements that can be used for transmission of UCI in OFDM symbol  $l$ , for  $l = 0, 1, 2, \dots, N_{symb,actual}^{PUSCH} - 1$ , in the actual repetition of the PUSCH transmission, and  $N_{symb,actual}^{PUSCH}$  is the total number of OFDM symbols in the actual repetition of the PUSCH transmission, including all OFDM symbols used for DMRS;
  - for any OFDM symbol that carries DMRS of the actual repetition of the PUSCH transmission,  $M_{sc,actual}^{UCI}(l) = 0$ ;
  - for any OFDM symbol that does not carry DMRS of the actual repetition of the PUSCH transmission,  $M_{sc,actual}^{UCI}(l) = M_{sc}^{PUSCH} - M_{sc,actual}^{PT-RS}(l)$  where  $M_{sc,actual}^{PT-RS}(l)$  is the number of subcarriers in OFDM symbol  $l$  that carries PTRS, in the actual repetition of the PUSCH transmission;
- and all the other notations in the formula are defined the same as for PUSCH not using repetition type B.

For CSI part 2 transmission on PUSCH without UL-SCH, the number of coded modulation symbols per layer for CSI part 2 transmission, denoted as  $Q'_{CSI-part2}$ , is determined as follows:

$$Q'_{CSI-2} = \sum_{l=0}^{N_{symb,all}^{PUSCH}-1} M_{sc}^{UCI}(l) - Q'_{ACK} - Q'_{CSI-1}$$

where

- $M_{sc}^{PUSCH}$  is the scheduled bandwidth of the PUSCH transmission, expressed as a number of subcarriers;
- $M_{sc}^{PT-RS}(l)$  is the number of subcarriers in OFDM symbol  $l$  that carries PTRS, in the PUSCH transmission;
- $Q'_{ACK}$  is the number of coded modulation symbols per layer for HARQ-ACK transmitted on the PUSCH if number of HARQ-ACK information bits is more than 2, and  $Q'_{ACK} = 0$  if the number of HARQ-ACK information bits is 1 or 2 bits;
- $Q'_{CSI-1}$  is the number of coded modulation symbols per layer for CSI part 1 transmitted on the PUSCH;
- $M_{sc}^{UCI}(l)$  is the number of resource elements that can be used for transmission of UCI in OFDM symbol  $l$ , for  $l = 0, 1, 2, \dots, N_{symb,all}^{PUSCH} - 1$ , in the PUSCH transmission and  $N_{symb,all}^{PUSCH}$  is the total number of OFDM symbols of the PUSCH, including all OFDM symbols used for DMRS;
  - for any OFDM symbol that carries DMRS of the PUSCH,  $M_{sc}^{UCI}(l) = 0$ ;
  - for any OFDM symbol that does not carry DMRS of the PUSCH,  $M_{sc}^{UCI}(l) = M_{sc}^{PUSCH} - M_{sc}^{PT-RS}(l)$ .

The input bit sequence to rate matching is  $d_{r0}, d_{r1}, d_{r2}, d_{r3}, \dots, d_{r(N_r-1)}$  where  $r$  is the code block number, and  $N_r$  is the number of coded bits in code block number  $r$ .

Rate matching is performed according to Clause 5.4.1 by setting  $I_{BL} = 1$  and the rate matching output sequence length to  $E_r = \lfloor E_{UCI} / C_{UCI} \rfloor$ , where

- $C_{UCI}$  is the number of code blocks for UCI determined according to Clause 5.2.1;
- $N_L$  is the number of transmission layers of the PUSCH;
- $Q_m$  is the modulation order of the PUSCH;
- $E_{UCI} = N_L \cdot Q'_{CSI,2} \cdot Q_m$ .

The output bit sequence after rate matching is denoted as  $f_{r0}, f_{r1}, f_{r2}, \dots, f_{r(E_r-1)}$  where  $E_r$  is the length of rate matching output sequence in code block number  $r$ .

#### 6.3.2.4.1.4 CG-UCI

For CG-UCI transmission on PUSCH with UL-SCH, the number of coded modulation symbols per layer for CG-UCI transmission, denoted as  $Q'_{CG-UCI}$ , is determined as follows:

$$Q'_{CG-UCI} = \min \left\{ \left\lfloor \frac{(O_{CG-UCI} + L_{CG-UCI}) \cdot \beta_{offset}^{PUSCH} \cdot \sum_{l=0}^{N_{symb,all}^{PUSCH}-1} M_{sc}^{UCI}(l)}{\sum_{r=0}^{C_{UL-SCH}} K_r} \right\rfloor, \left\lfloor \alpha \cdot \sum_{l=l_0}^{N_{symb,all}^{PUSCH}-1} M_{sc}^{UCI}(l) \right\rfloor \right\}$$

where

- $O_{CG-UCI}$  is the number of CG-UCI bits;
- $L_{CG-UCI}$  is the number of CRC bits for CG-UCI determined according to Clause 6.3.1.2.1;
- $\beta_{offset}^{PUSCH} = \beta_{offset}^{CG-UCI}$ ;
- $C_{UL-SCH}$  is the number of code blocks for UL-SCH of the PUSCH transmission;
- $K_r$  is the  $r$ -th code block size for UL-SCH of the PUSCH transmission;
- $M_{sc}^{PUSCH}$  is the scheduled bandwidth of the PUSCH transmission, expressed as a number of subcarriers;
- $M_{sc}^{PT-RS}(l)$  is the number of subcarriers in OFDM symbol  $l$  that carries PTRS, in the PUSCH transmission;
- $M_{sc}^{UCI}(l)$  is the number of resource elements that can be used for transmission of UCI in OFDM symbol  $l$ , for  $l=0,1,2,\dots,N_{symb,all}^{PUSCH}-1$ , in the PUSCH transmission and  $N_{symb,all}^{PUSCH}$  is the total number of OFDM symbols of the PUSCH, including all OFDM symbols used for DMRS;
  - for any OFDM symbol that carries DMRS of the PUSCH,  $M_{sc}^{UCI}(l) = 0$ ;
  - for any OFDM symbol that does not carry DMRS of the PUSCH,  $M_{sc}^{UCI}(l) = M_{sc}^{PUSCH} - M_{sc}^{PT-RS}(l)$ ;
- $\alpha$  is configured by higher layer parameter *scaling*;
- $l_0$  is the symbol index of the first OFDM symbol that does not carry DMRS of the PUSCH, after the first DMRS symbol(s), in the PUSCH transmission.

The input bit sequence to rate matching is  $d_{r0}, d_{r1}, d_{r2}, d_{r3}, \dots, d_{r(N_r-1)}$  where  $r$  is the code block number, and  $N_r$  is the number of coded bits in code block number  $r$ .

Rate matching is performed according to Clause 5.4.1 by setting  $I_{BL} = 1$  and the rate matching output sequence length to  $E_r = \lfloor E_{UCI} / C_{UCI} \rfloor$ , where

- $C_{UCI}$  is the number of code blocks for UCI determined according to Clause 5.2.1;
- $N_L$  is the number of transmission layers of the PUSCH;
- $Q_m$  is the modulation order of the PUSCH;

$$- E_{UCI} = N_L \cdot Q'_{CG-UCI} \cdot Q_m.$$

The output bit sequence after rate matching is denoted as  $f_{r0}, f_{r1}, f_{r2}, \dots, f_{r(E_r-1)}$  where  $E_r$  is the length of rate matching output sequence in code block number  $r$ .

### 6.3.2.4.1.5 HARQ-ACK and CG-UCI

For HARQ-ACK and CG-UCI transmission on PUSCH with UL-SCH, the number of coded modulation symbols per layer for HARQ-ACK and CG-UCI transmission, denoted as  $Q'_{ACK}$ , is determined as follows:

$$Q'_{ACK} = \min \left\{ \left\lceil \frac{(O_{ACK} + O_{CG-UCI} + L_{ACK}) \cdot \beta_{\text{offset}}^{\text{PUSCH}} \cdot \sum_{l=0}^{N_{\text{symb,all}}^{\text{PUSCH}} - 1} M_{\text{sc}}^{\text{UCI}}(l)}{\sum_{r=0}^{C_{UL-SCH} - 1} K_r} \right\rceil, \left\lceil \alpha \cdot \sum_{l=l_0}^{N_{\text{symb,all}}^{\text{PUSCH}} - 1} M_{\text{sc}}^{\text{UCI}}(l) \right\rceil \right\}$$

where

- $O_{ACK}$  is the number of HARQ-ACK bits;
- $O_{CG-UCI}$  is the number of CG-UCI bits;
- if  $O_{ACK} + O_{CG-UCI} > 360$ ,  $L_{ACK} = 11$ ; otherwise  $L_{ACK}$  is the number of CRC bits for HARQ-ACK and CG-UCI determined according to Clause 6.3.1.2.1;
- $\beta_{\text{offset}}^{\text{PUSCH}} = \beta_{\text{offset}}^{\text{HARQ-ACK}}$ ;
- $C_{UL-SCH}$  is the number of code blocks for UL-SCH of the PUSCH transmission;
- $K_r$  is the  $r$ -th code block size for UL-SCH of the PUSCH transmission;
- $M_{\text{sc}}^{\text{PUSCH}}$  is the scheduled bandwidth of the PUSCH transmission, expressed as a number of subcarriers;
- $M_{\text{sc}}^{\text{PT-RS}}(l)$  is the number of subcarriers in OFDM symbol  $l$  that carries PTRS, in the PUSCH transmission;
- $M_{\text{sc}}^{\text{UCI}}(l)$  is the number of resource elements that can be used for transmission of UCI in OFDM symbol  $l$ , for  $l=0,1,2,\dots, N_{\text{symb,all}}^{\text{PUSCH}} - 1$ , in the PUSCH transmission and  $N_{\text{symb,all}}^{\text{PUSCH}}$  is the total number of OFDM symbols of the PUSCH, including all OFDM symbols used for DMRS;
  - for any OFDM symbol that carries DMRS of the PUSCH,  $M_{\text{sc}}^{\text{UCI}}(l) = 0$ ;
  - for any OFDM symbol that does not carry DMRS of the PUSCH,  $M_{\text{sc}}^{\text{UCI}}(l) = M_{\text{sc}}^{\text{PUSCH}} - M_{\text{sc}}^{\text{PT-RS}}(l)$ ;
- $\alpha$  is configured by higher layer parameter *scaling*;
- $l_0$  is the symbol index of the first OFDM symbol that does not carry DMRS of the PUSCH, after the first DMRS symbol(s), in the PUSCH transmission.

The input bit sequence to rate matching is  $d_{r0}, d_{r1}, d_{r2}, d_{r3}, \dots, d_{r(N_r-1)}$  where  $r$  is the code block number, and  $N_r$  is the number of coded bits in code block number  $r$ .

Rate matching is performed according to Clause 5.4.1 by setting  $I_{\text{BIL}} = 1$  and the rate matching output sequence length to  $E_r = \lfloor E_{\text{UCI}} / C_{\text{UCI}} \rfloor$ , where

- $C_{\text{UCI}}$  is the number of code blocks for UCI determined according to Clause 5.2.1;
- $N_L$  is the number of transmission layers of the PUSCH;
- $Q_m$  is the modulation order of the PUSCH;
- $E_{\text{UCI}} = N_L \cdot Q'_{ACK} \cdot Q_m$ .

The output bit sequence after rate matching is denoted as  $f_{r0}, f_{r1}, f_{r2}, \dots, f_{r(E_r-1)}$  where  $E_r$  is the length of rate matching output sequence in code block number  $r$ .



### 6.3.2.4.2 UCI encoded by channel coding of small block lengths

#### 6.3.2.4.2.1 HARQ-ACK

For HARQ-ACK transmission on PUSCH, the number of coded modulation symbols per layer for HARQ-ACK transmission, denoted as  $Q'_{\text{ACK}}$ , is determined according to Clause 6.3.2.4.1.1, by setting the number of CRC bits  $L = 0$ .

The input bit sequence to rate matching is  $d_0, d_1, d_2, \dots, d_{N-1}$ .

Rate matching is performed according to Clause 5.4.3, by setting the rate matching output sequence length  $E = N_L \cdot Q'_{\text{ACK}} \cdot Q_m$ , where

- $N_L$  is the number of transmission layers of the PUSCH;
- $Q_m$  is the modulation order of the PUSCH.

The output bit sequence after rate matching is denoted as  $f_0, f_1, f_2, \dots, f_{E-1}$ .

#### 6.3.2.4.2.2 CSI part 1

For CSI part 1 transmission on PUSCH, the number of coded modulation symbols per layer for CSI part 1 transmission, denoted as  $Q'_{\text{CSI,1}}$ , is determined according to Clause 6.3.2.4.1.2, by setting the number of CRC bits  $L = 0$ .

Rate matching is performed according to Clause 5.4.3, by setting the rate matching output sequence length  $E = N_L \cdot Q'_{\text{CSI,1}} \cdot Q_m$ , where

- $N_L$  is the number of transmission layers of the PUSCH;
- $Q_m$  is the modulation order of the PUSCH.

The output bit sequence after rate matching is denoted as  $f_0, f_1, f_2, \dots, f_{E-1}$ .

#### 6.3.2.4.2.3 CSI part 2

For CSI part 2 transmission on PUSCH, the number of coded modulation symbols per layer for CSI part 2 transmission, denoted as  $Q'_{\text{CSI,2}}$ , is determined according to Clause 6.3.2.4.1.3, by setting the number of CRC bits  $L = 0$ .

Rate matching is performed according to Clause 5.4.3, by setting the rate matching output sequence length  $E = N_L \cdot Q'_{\text{CSI,2}} \cdot Q_m$ , where

- $N_L$  is the number of transmission layers of the PUSCH;
- $Q_m$  is the modulation order of the PUSCH.

The output bit sequence after rate matching is denoted as  $f_0, f_1, f_2, \dots, f_{E-1}$ .

#### 6.3.2.4.2.4 CG-UCI

For CG-UCI transmission on PUSCH, the number of coded modulation symbols per layer for CG-UCI transmission, denoted as  $Q'_{\text{CG-UCI}}$ , is determined according to Clause 6.3.2.4.1.4, by setting the number of CRC bits  $L_{\text{CG-UCI}} = 0$ .

The input bit sequence to rate matching is  $d_0, d_1, d_2, \dots, d_{N-1}$ .

Rate matching is performed according to Clause 5.4.3, by setting the rate matching output sequence length

$E = N_L \cdot Q'_{\text{CG-UCI}} \cdot Q_m$ , where

- $N_L$  is the number of transmission layers of the PUSCH;
- $Q_m$  is the modulation order of the PUSCH.

The output bit sequence after rate matching is denoted as  $f_0, f_1, f_2, \dots, f_{E-1}$ .

#### 6.3.2.4.2.5 HARQ-ACK and CG-UCI

For HARQ-ACK and CG-UCI transmission on PUSCH, the number of coded modulation symbols per layer for HARQ-ACK and CG-UCI transmission, denoted as  $Q'_{ACK}$ , is determined according to Clause 6.3.2.4.1.5, by setting the number of CRC bits  $L_{ACK} = 0$ .

The input bit sequence to rate matching is  $d_0, d_1, d_2, \dots, d_{N-1}$ .

Rate matching is performed according to Clause 5.4.3, by setting the rate matching output sequence length  $E = N_L \cdot Q'_{ACK} \cdot Q_m$ , where

- $N_L$  is the number of transmission layers of the PUSCH;
- $Q_m$  is the modulation order of the PUSCH.

The output bit sequence after rate matching is denoted as  $f_0, f_1, f_2, \dots, f_{E-1}$ .

#### 6.3.2.5 Code block concatenation

Code block concatenation is performed according to Clause 6.3.1.5, except that the values of  $E_{UCI}$  and  $C_{UCI}$  given in Clause 6.3.2.4.1.

#### 6.3.2.6 Multiplexing of coded UCI bits to PUSCH

The coded UCI bits are multiplexed onto PUSCH according to the procedures in Clause 6.2.7.

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## 7 Downlink transport channels and control information

### 7.1 Broadcast channel

Data arrives to the coding unit in the form of a maximum of one transport block every 80ms. The following coding steps can be identified:

- Payload generation
- Scrambling
- Transport block CRC attachment
- Channel coding
- Rate matching

#### 7.1.1 PBCH payload generation

Denote the bits in a transport block delivered to layer 1 by  $\bar{a}_0, \bar{a}_1, \bar{a}_2, \bar{a}_3, \dots, \bar{a}_{\bar{A}-1}$ , where  $\bar{A}$  is the payload size generated by higher layers. The lowest order information bit  $\bar{a}_0$  is mapped to the most significant bit of the transport block as defined in Clause 6.1.1 of [8, TS 38.321].

Generate the following additional timing related PBCH payload bits  $\bar{a}_{\bar{A}}, \bar{a}_{\bar{A}+1}, \bar{a}_{\bar{A}+2}, \bar{a}_{\bar{A}+3}, \dots, \bar{a}_{\bar{A}+7}$ , where:

- $\bar{a}_{\bar{A}}, \bar{a}_{\bar{A}+1}, \bar{a}_{\bar{A}+2}, \bar{a}_{\bar{A}+3}$  are the 4<sup>th</sup>, 3<sup>rd</sup>, 2<sup>nd</sup>, and 1<sup>st</sup> LSB of SFN, respectively;
- $\bar{a}_{\bar{A}+4}$  is the half frame bit  $\bar{a}_{\text{HRF}}$ ;
- if  $\bar{L}_{max} = 10$  as defined in Clause 4.1 of [5, TS38.213],  
 $\bar{a}_{\bar{A}+5}$  is the MSB of  $k_{\text{SSB}}$  as defined in Clause 7.4.3.1 of [4, TS 38.211].  
 $\bar{a}_{\bar{A}+6}$  is reserved.  
 $\bar{a}_{\bar{A}+7}$  is the MSB of candidate SS/PBCH block index.
- else if  $\bar{L}_{max} = 20$  as defined in Clause 4.1 of [5, TS38.213],  
 $\bar{a}_{\bar{A}+5}$  is the MSB of  $k_{\text{SSB}}$  as defined in Clause 7.4.3.1 of [4, TS 38.211].  
 $\bar{a}_{\bar{A}+6}, \bar{a}_{\bar{A}+7}$  are the 5<sup>th</sup> and 4<sup>th</sup> bits of the candidate SS/PBCH block index, respectively.
- else if  $\bar{L}_{max} = 64$  as defined in Clause 4.1 of [5, TS38.213],  
 $\bar{a}_{\bar{A}+5}, \bar{a}_{\bar{A}+6}, \bar{a}_{\bar{A}+7}$  are the 6<sup>th</sup>, 5<sup>th</sup>, and 4<sup>th</sup> bits of the candidate SS/PBCH block index, respectively.
- else  
 $\bar{a}_{\bar{A}+5}$  is the MSB of  $k_{\text{SSB}}$  as defined in Clause 7.4.3.1 of [4, TS 38.211].  
 $\bar{a}_{\bar{A}+6}, \bar{a}_{\bar{A}+7}$  are reserved.
- end if

Let  $A = \bar{A} + 8$ ;  $j_{\text{SFN}} = 0$ ;  $j_{\text{HRF}} = 10$ ;  $j_{\text{SSB}} = 11$ ;  $j_{\text{other}} = 14$ ;

for  $i = 0$  to  $A - 1$

if  $\bar{a}_i$  is an SFN bit

$$a_{G(j_{\text{SFN}})} = \bar{a}_i;$$

$$j_{\text{SFN}} = j_{\text{SFN}} + 1;$$

elseif  $\bar{a}_i$  is the half radio frame bit

$$a_{G(j_{\text{HRF}})} = \bar{a}_i$$

elseif  $\bar{A} + 5 \leq i \leq \bar{A} + 7$

$$a_{G(j_{\text{SSB}})} = \bar{a}_i;$$

$$j_{\text{SSB}} = j_{\text{SSB}} + 1;$$

else

$$a_{G(j_{\text{Other}})} = \bar{a}_i;$$

$$j_{\text{Other}} = j_{\text{Other}} + 1;$$

end if

end for

where  $\bar{L}_{max}$  is the number of candidate SS/PBCH blocks in a half frame according to Clause 4.1 of [5, TS38.213], and the value of  $G(j)$  is given by Table 7.1.1-1.

**Table 7.1.1-1: Value of PBCH payload interleaver pattern  $G(j)$**

$j$	$G(j)$	$j$	$G(j)$	$j$	$G(j)$	$j$	$G(j)$	$j$	$G(j)$	$j$	$G(j)$	$j$	$G(j)$	$j$	$G(j)$
0	16	4	8	8	24	12	3	16	9	20	14	24	21	28	27
1	23	5	30	9	7	13	2	17	11	21	15	25	22	29	28
2	18	6	10	10	0	14	1	18	12	22	19	26	25	30	29
3	17	7	6	11	5	15	4	19	13	23	20	27	26	31	31

## 7.1.2 Scrambling

For PBCH transmission in a frame, the bit sequence  $a_0, a_1, a_2, a_3, \dots, a_{A-1}$  is scrambled into a bit sequence  $a'_0, a'_1, a'_2, a'_3, \dots, a'_{A-1}$ , where  $a'_i = (a_i + s_i) \bmod 2$  for  $i=0,1,\dots,A-1$  and  $s_0, s_1, s_2, s_3, \dots, s_{A-1}$  is generated according to the following:

$i = 0$ ;

$j = 0$ ;

while  $i < A$

if  $a_i$  corresponds to any one of the bits belonging to the candidate SS/PBCH block index, the half frame index, and 2<sup>nd</sup> and 3<sup>rd</sup> least significant bits of the system frame number

$s_i = 0$ ;

else

$s_i = c(j + vM)$ ;

$j = j + 1$ ;

end if

$i = i + 1$ ;

end while

The scrambling sequence  $c(i)$  is given by Clause 5.2.1 of [4, TS38.211] and initialized with  $c_{init} = N_{ID}^{cell}$  at the start of each SFN satisfying  $\text{mod}(SFN, 8) = 0$ ;  $M = A - 3$  for  $\bar{L}_{max} = 4$  or  $\bar{L}_{max} = 8$ ,  $M = A - 4$  for  $\bar{L}_{max} = 10$ ,  $M = A - 5$  for  $\bar{L}_{max} = 20$ , and  $M = A - 6$  for  $\bar{L}_{max} = 64$ , where  $\bar{L}_{max}$  is the number of candidate SS/PBCH blocks in a half frame according to Clause 4.1 of [5, TS38.213]; and  $v$  is determined according to Table 7.1.2-1 using the 3<sup>rd</sup> and 2<sup>nd</sup> LSB of the SFN in which the PBCH is transmitted.

**Table 7.1.2-1: Value of  $v$  for PBCH scrambling**

(3 <sup>rd</sup> LSB of SFN, 2 <sup>nd</sup> LSB of SFN)	Value of $v$
(0, 0)	0
(0, 1)	1
(1, 0)	2
(1, 1)	3

### 7.1.3 Transport block CRC attachment

Error detection is provided on BCH transport blocks through a Cyclic Redundancy Check (CRC).

The entire transport block is used to calculate the CRC parity bits. The input bit sequence is denoted by  $a'_0, a'_1, a'_2, a'_3, \dots, a'_{A-1}$ , and the parity bits by  $p_0, p_1, p_2, p_3, \dots, p_{L-1}$ , where  $A$  is the payload size and  $L$  is the number of parity bits.

The parity bits are computed and attached to the BCH transport block according to Clause 5.1 by setting  $L$  to 24 bits and using the generator polynomial  $g_{\text{CRC24C}}(D)$ , resulting in the sequence  $b_0, b_1, b_2, b_3, \dots, b_{B-1}$ , where  $B = A + L$ .

The bit sequence  $b_0, b_1, b_2, b_3, \dots, b_{B-1}$  is the input bit sequence  $c_0, c_1, c_2, c_3, \dots, c_{K-1}$  to the channel encoder, where  $c_i = b_i$  for  $i = 0, 1, \dots, B-1$  and  $K = B$ .

### 7.1.4 Channel coding

Information bits are delivered to the channel coding block. They are denoted by  $c_0, c_1, c_2, c_3, \dots, c_{K-1}$ , where  $K$  is the number of bits, and they are encoded via Polar coding according to Clause 5.3.1, by setting  $n_{\text{max}} = 9$ ,  $I_{\text{IL}} = 1$ ,  $n_{\text{PC}} = 0$ , and  $n_{\text{PC}}^{\text{wm}} = 0$ .

After encoding the bits are denoted by  $d_0, d_1, d_2, d_3, \dots, d_{N-1}$ , where  $N$  is the number of coded bits.

### 7.1.5 Rate matching

The input bit sequence to rate matching is  $d_0, d_1, d_2, \dots, d_{N-1}$ .

The rate matching output sequence length  $E = 864$ .

Rate matching is performed according to Clause 5.4.1 by setting  $I_{\text{BL}} = 0$ .

The output bit sequence after rate matching is denoted as  $f_0, f_1, f_2, \dots, f_{E-1}$ .

## 7.2 Downlink shared channel and paging channel

### 7.2.1 Transport block CRC attachment

Error detection is provided on each transport block through a Cyclic Redundancy Check (CRC).

The entire transport block is used to calculate the CRC parity bits. Denote the bits in a transport block delivered to layer 1 by  $a_0, a_1, a_2, a_3, \dots, a_{A-1}$ , and the parity bits by  $p_0, p_1, p_2, p_3, \dots, p_{L-1}$ , where  $A$  is the payload size and  $L$  is the number of parity bits. The lowest order information bit  $a_0$  is mapped to the most significant bit of the transport block as defined in Clause 6.1.1 of [TS38.321].

The parity bits are computed and attached to the DL-SCH transport block according to Clause 5.1, by setting  $L$  to 24 bits and using the generator polynomial  $g_{\text{CRC24A}}(D)$  if  $A > 3824$ ; and by setting  $L$  to 16 bits and using the generator polynomial  $g_{\text{CRC16}}(D)$  otherwise.

The bits after CRC attachment are denoted by  $b_0, b_1, b_2, b_3, \dots, b_{B-1}$ , where  $B = A + L$ .

## 7.2.2 LDPC base graph selection

For initial transmission of a transport block with coding rate  $R$  indicated by the MCS index according to Clause 5.1.3.1 in [6, TS 38.214] and subsequent re-transmission of the same transport block, each code block of the transport block is encoded with either LDPC base graph 1 or 2 according to the following:

- if  $A \leq 292$ , or if  $A \leq 3824$  and  $R \leq 0.67$ , or if  $R \leq 0.25$ , LDPC base graph 2 is used;
- otherwise, LDPC base graph 1 is used,

where  $A$  is the payload size in Clause 7.2.1.

## 7.2.3 Code block segmentation and code block CRC attachment

The bits input to the code block segmentation are denoted by  $b_0, b_1, b_2, b_3, \dots, b_{B-1}$  where  $B$  is the number of bits in the transport block (including CRC).

Code block segmentation and code block CRC attachment are performed according to Clause 5.2.2.

The bits after code block segmentation are denoted by  $c_{r0}, c_{r1}, c_{r2}, c_{r3}, \dots, c_{r(K_r-1)}$ , where  $r$  is the code block number and  $K_r$  is the number of bits for code block number  $r$  according to Clause 5.2.2.

## 7.2.4 Channel coding

Code blocks are delivered to the channel coding block. The bits in a code block are denoted by  $c_{r0}, c_{r1}, c_{r2}, c_{r3}, \dots, c_{r(K_r-1)}$ , where  $r$  is the code block number, and  $K_r$  is the number of bits in code block number  $r$ .

The total number of code blocks is denoted by  $C$  and each code block is individually LDPC encoded according to Clause 5.3.2.

After encoding the bits are denoted by  $d_{r0}, d_{r1}, d_{r2}, d_{r3}, \dots, d_{r(N_r-1)}$ , where the values of  $N_r$  is given in Clause 5.3.2.

## 7.2.5 Rate matching

Coded bits for each code block, denoted as  $d_{r0}, d_{r1}, d_{r2}, d_{r3}, \dots, d_{r(N_r-1)}$ , are delivered to the rate match block, where  $r$  is the code block number, and  $N_r$  is the number of encoded bits in code block number  $r$ . The total number of code blocks is denoted by  $C$  and each code block is individually rate matched according to Clause 5.4.2 by setting  $I_{LBRM} = 1$ .

After rate matching, the bits are denoted by  $f_{r0}, f_{r1}, f_{r2}, f_{r3}, \dots, f_{r(E_r-1)}$ , where  $E_r$  is the number of rate matched bits for code block number  $r$ .

## 7.2.6 Code block concatenation

The input bit sequence for the code block concatenation block are the sequences  $f_{r0}, f_{r1}, f_{r2}, f_{r3}, \dots, f_{r(E_r-1)}$ , for  $r = 0, \dots, C-1$  and where  $E_r$  is the number of rate matched bits for the  $r$ -th code block.

Code block concatenation is performed according to Clause 5.5.

The bits after code block concatenation are denoted by  $g_0, g_1, g_2, g_3, \dots, g_{G-1}$ , where  $G$  is the total number of coded bits for transmission.

## 7.3 Downlink control information

A DCI transports downlink control information for one or more cells with one RNTI.

The following coding steps can be identified:

- Information element multiplexing
- CRC attachment
- Channel coding
- Rate matching

### 7.3.1 DCI formats

The DCI formats defined in table 7.3.1-1 are supported.

**Table 7.3.1-1: DCI formats**

DCI format	Usage
0_0	Scheduling of PUSCH in one cell
0_1	Scheduling of one or multiple PUSCH in one cell, or indicating downlink feedback information for configured grant PUSCH (CG-DFI)
0_2	Scheduling of PUSCH in one cell
1_0	Scheduling of PDSCH in one cell
1_1	Scheduling of PDSCH in one cell, and/or triggering one shot HARQ-ACK codebook feedback
1_2	Scheduling of PDSCH in one cell
2_0	Notifying a group of UEs of the slot format, available RB sets, COT duration and search space set group switching
2_1	Notifying a group of UEs of the PRB(s) and OFDM symbol(s) where UE may assume no transmission is intended for the UE
2_2	Transmission of TPC commands for PUCCH and PUSCH
2_3	Transmission of a group of TPC commands for SRS transmissions by one or more UEs
2_4	Notifying a group of UEs of the PRB(s) and OFDM symbol(s) where UE cancels the corresponding UL transmission from the UE
2_5	Notifying the availability of soft resources as defined in Clause 9.3.1 of [10, TS 38.473]
2_6	Notifying the power saving information outside DRX Active Time for one or more UEs
3_0	Scheduling of NR sidelink in one cell
3_1	Scheduling of LTE sidelink in one cell

The fields defined in the DCI formats below are mapped to the information bits  $a_0$  to  $a_{A-1}$  as follows.

Each field is mapped in the order in which it appears in the description, including the zero-padding bit(s), if any, with the first field mapped to the lowest order information bit  $a_0$  and each successive field mapped to higher order information bits. The most significant bit of each field is mapped to the lowest order information bit for that field, e.g. the most significant bit of the first field is mapped to  $a_0$ .

If the number of information bits in a DCI format is less than 12 bits, zeros shall be appended to the DCI format until the payload size equals 12.

The size of each DCI format is determined by the configuration of the corresponding active bandwidth part of the scheduled cell and shall be adjusted as described in clause 7.3.1.0 if necessary.

If a UE is configured with *pdsch-HARQ-ACK-CodebookList-r16*, *pdsch-HARQ-ACK-Codebook* is replaced by the relevant entry in *pdsch-HARQ-ACK-CodebookList-r16* in this clause.

### 7.3.1.0 DCI size alignment

If necessary, padding or truncation shall be applied to the DCI formats according to the following steps executed in the order below:

Step 0:

- Determine DCI format 0\_0 monitored in a common search space according to clause 7.3.1.1.1 where  $N_{RB}^{UL,BWP}$  is the size of the initial UL bandwidth part.
- Determine DCI format 1\_0 monitored in a common search space according to clause 7.3.1.2.1 where  $N_{RB}^{DL,BWP}$  is given by
  - the size of CORESET 0 if CORESET 0 is configured for the cell; and
  - the size of initial DL bandwidth part if CORESET 0 is not configured for the cell.
- If DCI format 0\_0 is monitored in common search space and if the number of information bits in the DCI format 0\_0 prior to padding is less than the payload size of the DCI format 1\_0 monitored in common search space for scheduling the same serving cell, a number of zero padding bits are generated for the DCI format 0\_0 until the payload size equals that of the DCI format 1\_0.
- If DCI format 0\_0 is monitored in common search space and if the number of information bits in the DCI format 0\_0 prior to truncation is larger than the payload size of the DCI format 1\_0 monitored in common search space for scheduling the same serving cell, the bitwidth of the frequency domain resource assignment field in the DCI format 0\_0 is reduced by truncating the first few most significant bits such that the size of DCI format 0\_0 equals the size of the DCI format 1\_0.

Step 1:

- Determine DCI format 0\_0 monitored in a UE-specific search space according to clause 7.3.1.1.1 where  $N_{RB}^{UL,BWP}$  is the size of the active UL bandwidth part.
- Determine DCI format 1\_0 monitored in a UE-specific search space according to clause 7.3.1.2.1 where  $N_{RB}^{DL,BWP}$  is the size of the active DL bandwidth part.
- For a UE configured with *supplementaryUplink* in *ServingCellConfig* in a cell, if PUSCH is configured to be transmitted on both the SUL and the non-SUL of the cell and if the number of information bits in DCI format 0\_0 in UE-specific search space for the SUL is not equal to the number of information bits in DCI format 0\_0 in UE-specific search space for the non-SUL, a number of zero padding bits are generated for the smaller DCI format 0\_0 until the payload size equals that of the larger DCI format 0\_0.
- If DCI format 0\_0 is monitored in UE-specific search space and if the number of information bits in the DCI format 0\_0 prior to padding is less than the payload size of the DCI format 1\_0 monitored in UE-specific search space for scheduling the same serving cell, a number of zero padding bits are generated for the DCI format 0\_0 until the payload size equals that of the DCI format 1\_0.
- If DCI format 1\_0 is monitored in UE-specific search space and if the number of information bits in the DCI format 1\_0 prior to padding is less than the payload size of the DCI format 0\_0 monitored in UE-specific search space for scheduling the same serving cell, zeros shall be appended to the DCI format 1\_0 until the payload size equals that of the DCI format 0\_0.

Step 2:

- Determine DCI format 0\_1 monitored in a UE-specific search space according to clause 7.3.1.1.2.
- Determine DCI format 1\_1 monitored in a UE-specific search space according to clause 7.3.1.2.2.
- For a UE configured with *supplementaryUplink* in *ServingCellConfig* in a cell, if PUSCH is configured to be transmitted on both the SUL and the non-SUL of the cell and if the number of information bits in format 0\_1 for the SUL is not equal to the number of information bits in format 0\_1 for the non-SUL, zeros shall be appended to smaller format 0\_1 until the payload size equals that of the larger format 0\_1.



- If the size of DCI format 0\_1 monitored in a UE-specific search space equals that of a DCI format 0\_0/1\_0 monitored in another UE-specific search space, one bit of zero padding shall be appended to DCI format 0\_1.
- If the size of DCI format 1\_1 monitored in a UE-specific search space equals that of a DCI format 0\_0/1\_0 monitored in another UE-specific search space, one bit of zero padding shall be appended to DCI format 1\_1.

## Step 2A:

- Determine DCI format 0\_2 monitored in a UE-specific search space according to clause 7.3.1.1.3.
- Determine DCI format 1\_2 monitored in a UE-specific search space according to clause 7.3.1.2.3.
- For a UE configured with *supplementaryUplink* in *ServingCellConfig* in a cell, if PUSCH is configured to be transmitted on both the SUL and the non-SUL of the cell and if the number of information bits in format 0\_2 for the SUL is not equal to the number of information bits in format 0\_2 for the non-SUL, zeros shall be appended to smaller format 0\_2 until the payload size equals that of the larger format 0\_2.

## Step 3:

- If both of the following conditions are fulfilled the size alignment procedure is complete
  - the total number of different DCI sizes configured to monitor is no more than 4 for the cell
  - the total number of different DCI sizes with C-RNTI configured to monitor is no more than 3 for the cell

## Step 4:

- Otherwise

## Step 4A:

- Remove the padding bit (if any) introduced in step 2 above.
- Determine DCI format 1\_0 monitored in a UE-specific search space according to clause 7.3.1.2.1 where  $N_{RB}^{DL,BWP}$  is given by
  - the size of CORESET 0 if CORESET 0 is configured for the cell; and
  - the size of initial DL bandwidth part if CORESET 0 is not configured for the cell.
- Determine DCI format 0\_0 monitored in a UE-specific search space according to clause 7.3.1.1.1 where  $N_{RB}^{UL,BWP}$  is the size of the initial UL bandwidth part.
- If the number of information bits in the DCI format 0\_0 monitored in a UE-specific search space prior to padding is less than the payload size of the DCI format 1\_0 monitored in UE-specific search space for scheduling the same serving cell, a number of zero padding bits are generated for the DCI format 0\_0 monitored in a UE-specific search space until the payload size equals that of the DCI format 1\_0 monitored in a UE-specific search space.
- If the number of information bits in the DCI format 0\_0 monitored in a UE-specific search space prior to truncation is larger than the payload size of the DCI format 1\_0 monitored in UE-specific search space for scheduling the same serving cell, the bitwidth of the frequency domain resource assignment field in the DCI format 0\_0 is reduced by truncating the first few most significant bits such that the size of DCI format 0\_0 monitored in a UE-specific search space equals the size of the DCI format 1\_0 monitored in a UE-specific search space.

## Step 4B:

- If the total number of different DCI sizes configured to monitor is more than 4 for the cell after applying the above steps, or if the total number of different DCI sizes with C-RNTI configured to monitor is more than 3 for the cell after applying the above steps
  - If the number of information bits in the DCI format 0\_2 prior to padding is less than the payload size of the DCI format 1\_2 for scheduling the same serving cell, a number of zero padding bits are generated for the DCI format 0\_2 until the payload size equals that of the DCI format 1\_2.

- If the number of information bits in the DCI format 1\_2 prior to padding is less than the payload size of the DCI format 0\_2 for scheduling the same serving cell, zeros shall be appended to the DCI format 1\_2 until the payload size equals that of the DCI format 0\_2.

Step 4C:

- If the total number of different DCI sizes configured to monitor is more than 4 for the cell after applying the above steps, or if the total number of different DCI sizes with C-RNTI configured to monitor is more than 3 for the cell after applying the above steps
  - If the number of information bits in the DCI format 0\_1 prior to padding is less than the payload size of the DCI format 1\_1 for scheduling the same serving cell, a number of zero padding bits are generated for the DCI format 0\_1 until the payload size equals that of the DCI format 1\_1.
  - If the number of information bits in the DCI format 1\_1 prior to padding is less than the payload size of the DCI format 0\_1 for scheduling the same serving cell, zeros shall be appended to the DCI format 1\_1 until the payload size equals that of the DCI format 0\_1.

The UE is not expected to handle a configuration that, after applying the above steps, results in

- the total number of different DCI sizes configured to monitor is more than 4 for the cell; or
- the total number of different DCI sizes with C-RNTI configured to monitor is more than 3 for the cell; or
- the size of DCI format 0\_0 in a UE-specific search space is equal to DCI format 0\_1 in another UE-specific search space; or
- the size of DCI format 1\_0 in a UE-specific search space is equal to DCI format 1\_1 in another UE-specific search space; or
- the size of DCI format 0\_0 in a UE-specific search space is equal to DCI format 0\_2 in another UE-specific search space when at least one pair of the corresponding PDCCH candidates of DCI formats 0\_0 and 0\_2 are mapped to the same resource; or
- the size of DCI format 1\_0 in a UE-specific search space is equal to DCI format 1\_2 in another UE-specific search space when at least one pair of the corresponding PDCCH candidates of DCI formats 1\_0 and 1\_2 are mapped to the same resource; or
- the size of DCI format 0\_1 in a UE-specific search space is equal to DCI format 0\_2 in the same or another UE-specific search space when at least one pair of the corresponding PDCCH candidates of DCI formats 0\_1 and 0\_2 are mapped to the same resource; or
- the size of DCI format 1\_1 in a UE-specific search space is equal to DCI format 1\_2 in the same or another UE-specific search space when at least one pair of the corresponding PDCCH candidates of DCI formats 1\_1 and 1\_2 are mapped to the same resource.

#### 7.3.1.0.1 DCI size alignment for DCI formats for scheduling of sidelink

If DCI format 3\_0 or DCI format 3\_1 is monitored on a cell, DCI size alignment for DCI format 3\_0 and DCI format 3\_1 is performed as described in this clause after performing the DCI size alignment described in Clause 7.3.1.0. The size(s) of the DCI formats configured to monitor for a cell in this clause refers to that after performing the DCI size alignment described in Clause 7.3.1.0.

If DCI format 3\_0 or DCI format 3\_1 is monitored on a cell and the total number of DCI sizes of the DCI formats configured to monitor for the cell and DCI format 3\_0 or DCI format 3\_1 is more than 4, zeros shall be appended to DCI format 3\_0 if configured and DCI format 3\_1 if configured, until the payload size of DCI format 3\_0 or DCI format 3\_1 equals that of the smallest DCI format configured to monitor for the cell that is larger than DCI format 3\_0 or DCI format 3\_1.

The UE is not expected to handle a configuration that results in:

- the total number of different DCI sizes configured to monitor for the cell and DCI format 3\_0 or DCI format 3\_1 is more than 4; and

- the payload size of DCI format 3\_0 or DCI format 3\_1 is larger than the payload size of all other DCI formats configured to monitor for the cell.

### 7.3.1.1 DCI formats for scheduling of PUSCH

#### 7.3.1.1.1 Format 0\_0

DCI format 0\_0 is used for the scheduling of PUSCH in one cell.

The following information is transmitted by means of the DCI format 0\_0 with CRC scrambled by C-RNTI or CS-RNTI or MCS-C-RNTI:

- Identifier for DCI formats – 1 bit
  - The value of this bit field is always set to 0, indicating an UL DCI format
- Frequency domain resource assignment – number of bits determined by the following:
  - $\lceil \log_2(N_{RB}^{UL,BWP}(N_{RB}^{UL,BWP} + 1)/2) \rceil$  bits if neither of the higher layer parameters *useInterlacePUCCH-PUSCH* in *BWP-UplinkCommon* and *useInterlacePUCCH-PUSCH* in *BWP-UplinkDedicated* is configured, where  $N_{RB}^{UL,BWP}$  is defined in clause 7.3.1.0
  - For PUSCH hopping with resource allocation type 1:
    - $N_{UL\_hop}$  MSB bits are used to indicate the frequency offset according to Clause 6.3 of [6, TS 38.214], where  $N_{UL\_hop} = 1$  if the higher layer parameter *frequencyHoppingOffsetLists* contains two offset values and  $N_{UL\_hop} = 2$  if the higher layer parameter *frequencyHoppingOffsetLists* contains four offset values
    - $\lceil \log_2(N_{RB}^{UL,BWP}(N_{RB}^{UL,BWP} + 1)/2) \rceil - N_{UL\_hop}$  bits provide the frequency domain resource allocation according to Clause 6.1.2.2.2 of [6, TS 38.214]
  - For non-PUSCH hopping with resource allocation type 1:
    - $\lceil \log_2(N_{RB}^{UL,BWP}(N_{RB}^{UL,BWP} + 1)/2) \rceil$  bits provide the frequency domain resource allocation according to Clause 6.1.2.2.2 of [6, TS 38.214]
- If any of the higher layer parameters *useInterlacePUCCH-PUSCH* in *BWP-UplinkCommon* and *useInterlacePUCCH-PUSCH* in *BWP-UplinkDedicated* is configured
  - 5+Y bits provide the frequency domain resource allocation according to Clause 6.1.2.2.3 of [6, TS 38.214] if the subcarrier spacing for the active UL bandwidth part is 30 kHz.
  - 6+Y bits provide the frequency domain resource allocation according to Clause 6.1.2.2.3 of [6, TS 38.214] if the subcarrier spacing for the active UL bandwidth part is 15 kHz.

If the DCI format 0\_0 is monitored in a UE-specific search space, the value of Y is determined by

$\lceil \log_2 \left( \frac{N_{RB-set,UL}^{BWP}(N_{RB-set,UL}^{BWP} + 1)}{2} \right) \rceil$  where  $N_{RB-set,UL}^{BWP}$  is the number of RB sets contained in the active UL BWP as defined in clause 7 of [6, TS38.214]. If the DCI 0\_0 is monitored in a common search space Y = 0.

- Time domain resource assignment – 4 bits as defined in Clause 6.1.2.1 of [6, TS 38.214]
- Frequency hopping flag – 1 bit according to Table 7.3.1.1.1-3, as defined in Clause 6.3 of [6, TS 38.214]
- Modulation and coding scheme – 5 bits as defined in Clause 6.1.4.1 of [6, TS 38.214]
- New data indicator – 1 bit
- Redundancy version – 2 bits as defined in Table 7.3.1.1.1-2
- HARQ process number – 4 bits

- TPC command for scheduled PUSCH – 2 bits as defined in Clause 7.1.1 of [5, TS 38.213]
- ChannelAccess-CPext – 2 bits indicating combinations of channel access type and CP extension as defined in Table 7.3.1.1.1-4, or Table 7.3.1.1.1.4A, if *ChannelAccessMode-r16* = "semistatic" is provided for operation in a cell with shared spectrum channel access; 0 bit otherwise.
- Padding bits, if required.
- UL/SUL indicator – 1 bit for UEs configured with *supplementaryUplink* in *ServingCellConfig* in the cell as defined in Table 7.3.1.1.1-1 and the number of bits for DCI format 1\_0 before padding is larger than the number of bits for DCI format 0\_0 before padding; 0 bit otherwise. The UL/SUL indicator, if present, locates in the last bit position of DCI format 0\_0, after the padding bit(s).
  - If the UL/SUL indicator is present in DCI format 0\_0 and the higher layer parameter *pusch-Config* is not configured on both UL and SUL the UE ignores the UL/SUL indicator field in DCI format 0\_0, and the corresponding PUSCH scheduled by the DCI format 0\_0 is for the UL or SUL for which high layer parameter *pucch-Config* is configured;
  - If the UL/SUL indicator is not present in DCI format 0\_0 and *pucch-Config* is configured, the corresponding PUSCH scheduled by the DCI format 0\_0 is for the UL or SUL for which high layer parameter *pucch-Config* is configured.
  - If the UL/SUL indicator is not present in DCI format 0\_0 and *pucch-Config* is not configured, the corresponding PUSCH scheduled by the DCI format 0\_0 is for the uplink on which the latest PRACH is transmitted.

The following information is transmitted by means of the DCI format 0\_0 with CRC scrambled by TC-RNTI:

- Identifier for DCI formats – 1 bit
  - The value of this bit field is always set to 0, indicating an UL DCI format
- Frequency domain resource assignment – number of bits determined by the following:
  - $\left\lceil \log_2(N_{RB}^{UL,BWP}(N_{RB}^{UL,BWP} + 1)/2) \right\rceil$  bits if the higher layer parameter *useInterlacePUCCH-PUSCH* in *BWP-UplinkCommon* is not configured, where
    - $N_{RB}^{UL,BWP}$  is the size of the initial UL bandwidth part.
    - For PUSCH hopping with resource allocation type 1:
      - $N_{UL\_hop}$  MSB bits are used to indicate the frequency offset according to Table 8.3-1 in Clause 8.3 of [5, TS 38.213], where  $N_{UL\_hop} = 1$  if  $N_{RB}^{UL,BWP} < 50$  and  $N_{UL\_hop} = 2$  otherwise
      - $\left\lceil \log_2(N_{RB}^{UL,BWP}(N_{RB}^{UL,BWP} + 1)/2) \right\rceil - N_{UL\_hop}$  bits provide the frequency domain resource allocation according to Clause 6.1.2.2.2 of [6, TS 38.214]
    - For non-PUSCH hopping with resource allocation type 1:
      - $\left\lceil \log_2(N_{RB}^{UL,BWP}(N_{RB}^{UL,BWP} + 1)/2) \right\rceil$  bits provide the frequency domain resource allocation according to Clause 6.1.2.2.2 of [6, TS 38.214]
  - If the higher layer parameter *useInterlacePUCCH-PUSCH* in *BWP-UplinkCommon* is configured
    - 5 bits provide the frequency domain resource allocation according to Clause 6.1.2.2.3 of [6, TS 38.214] if the subcarrier spacing for the active UL bandwidth part is 30 kHz
    - 6 bits provide the frequency domain resource allocation according to Clause 6.1.2.2.3 of [6, TS 38.214] if the subcarrier spacing for the active UL bandwidth part is 15 kHz
- Time domain resource assignment – 4 bits as defined in Clause 6.1.2.1 of [6, TS 38.214]

- Frequency hopping flag – 1 bit according to Table 7.3.1.1.1-3, as defined in Clause 6.3 of [6, TS 38.214]
- Modulation and coding scheme – 5 bits as defined in Clause 6.1.4.1 of [6, TS 38.214]
- New data indicator – 1 bit, reserved
- Redundancy version – 2 bits as defined in Table 7.3.1.1.1-2
- HARQ process number – 4 bits, reserved
- TPC command for scheduled PUSCH – 2 bits as defined in Clause 7.1.1 of [5, TS 38.213]
- ChannelAccess-CPext – 2 bits indicating combinations of channel access type and CP extension as defined in Table 7.3.1.1.1-4, or Table 7.3.1.1.1.4A, if *ChannelAccessMode-r16* = "semistatic" is provided for operation in a cell with shared spectrum channel access; 0 bit otherwise
- Padding bits, if required.
- UL/SUL indicator – 1 bit if the cell has two ULs and the number of bits for DCI format 1\_0 before padding is larger than the number of bits for DCI format 0\_0 before padding; 0 bit otherwise. The UL/SUL indicator, if present, locates in the last bit position of DCI format 0\_0, after the padding bit(s).
- If 1 bit, reserved, and the corresponding PUSCH is always on the same UL carrier as the previous transmission of the same TB

**Table 7.3.1.1.1-1: UL/SUL indicator**

Value of UL/SUL indicator	Uplink
0	The non-supplementary uplink
1	The supplementary uplink

**Table 7.3.1.1.1-2: Redundancy version**

Value of the Redundancy version field	Value of $rv_{id}$ to be applied
00	0
01	1
10	2
11	3

**Table 7.3.1.1.1-3: Frequency hopping indication**

Bit field mapped to index	PUSCH frequency hopping
0	Disabled
1	Enabled

**Table 7.3.1.1.1-4: Channel access type & CP extension for DCI format 0\_0 and DCI format 1\_0**

Bit field mapped to index	Channel Access Type	The CP extension T_"ext" index defined in Clause 5.3.1 of [4, TS 38.211]
0	Type2C-ULChannelAccess defined in [clause 4.2.1.2.3 in 37.213]	2
1	Type2A-ULChannelAccess defined in [clause 4.2.1.2.1 in 37.213]	3
2	Type2A-ULChannelAccess defined in [clause 4.2.1.2.1 in 37.213]	1
3	Type1-ULChannelAccess defined in [clause 4.2.1.1 in 37.213]	0

**Table 7.3.1.1.1-4A: Channel access type & CP extension if *ChannelAccessMode-r16* = "semistatic" is provided**

Bit field mapped to index	Channel Access Type	The CP extension T_"ext" index defined in Clause 5.3.1 of [4, TS 38.211]
0	No sensing as defined in Clause 4.3 in TS 37.213	0
1	No sensing as defined in Clause 4.3 in TS 37.213	2
2	9us sensing within a 25us interval as defined in Clause 4.3 in TS 37.213	0
3	-	-

### 7.3.1.1.2 Format 0\_1

DCI format 0\_1 is used for the scheduling of one or multiple PUSCH in one cell, or indicating CG downlink feedback information (CG-DFI) to a UE.

The following information is transmitted by means of the DCI format 0\_1 with CRC scrambled by C-RNTI or CS-RNTI or SP-CSI-RNTI or MCS-C-RNTI:

- Identifier for DCI formats – 1 bit
  - The value of this bit field is always set to 0, indicating an UL DCI format
- Carrier indicator – 0 or 3 bits, as defined in Clause 10.1 of [5, TS38.213].
- DFI flag – 0 or 1 bit
  - 1 bit if the UE is configured to monitor DCI format 0\_1 with CRC scrambled by CS-RNTI and for operation in a cell with shared spectrum channel access. For a DCI format 0\_1 with CRC scrambled by CS-RNTI, the bit value of 0 indicates activating type 2 CG transmission and the bit value of 1 indicates CG-DFI. For a DCI format 0\_1 with CRC scrambled by C-RNTI/SP-CSI-RNTI/MCS-C-RNTI and for operation in a cell with shared spectrum channel access, the bit is reserved.
  - 0 bit otherwise;

If DCI format 0\_1 is used for indicating CG-DFI, all the remaining fields are set as follows:

- HARQ-ACK bitmap – 16 bits, where the order of the bitmap to HARQ process index mapping is such that HARQ process indices are mapped in ascending order from MSB to LSB of the bitmap. For each bit of the bitmap, value 1 indicates ACK, and value 0 indicates NACK.
- TPC command for scheduled PUSCH – 2 bits as defined in Clause 7.1.1 of [5, TS38.213]

- All the remaining bits in format 0\_1 are set to zero.

Otherwise, all the remaining fields are set as follows:

- UL/SUL indicator – 0 bit for UEs not configured with *supplementaryUplink* in *ServingCellConfig* in the cell or UEs configured with *supplementaryUplink* in *ServingCellConfig* in the cell but only one carrier in the cell is configured for PUSCH transmission; otherwise, 1 bit as defined in Table 7.3.1.1.1-1.
- Bandwidth part indicator – 0, 1 or 2 bits as determined by the number of UL BWPs  $n_{\text{BWP,RRC}}$  configured by higher layers, excluding the initial UL bandwidth part. The bitwidth for this field is determined as  $\lceil \log_2(n_{\text{BWP}}) \rceil$  bits, where
  - $n_{\text{BWP}} = n_{\text{BWP,RRC}} + 1$  if  $n_{\text{BWP,RRC}} \leq 3$ , in which case the bandwidth part indicator is equivalent to the ascending order of the higher layer parameter *BWP-Id*;
  - otherwise  $n_{\text{BWP}} = n_{\text{BWP,RRC}}$ , in which case the bandwidth part indicator is defined in Table 7.3.1.1.2-1;

If a UE does not support active BWP change via DCI, the UE ignores this bit field.

- Frequency domain resource assignment – number of bits determined by the following, where  $N_{\text{RB}}^{\text{UL,BWP}}$  is the size of the active UL bandwidth part:
  - If higher layer parameter *useInterlacePUCCH-PUSCH* in *BWP-UplinkDedicated* is not configured
    - $N_{\text{RBG}}$  bits if only resource allocation type 0 is configured, where  $N_{\text{RBG}}$  is defined in Clause 6.1.2.2.1 of [6, TS 38.214],
    - $\lceil \log_2(N_{\text{RB}}^{\text{UL,BWP}}(N_{\text{RB}}^{\text{UL,BWP}} + 1)/2) \rceil$  bits if only resource allocation type 1 is configured, or  $\max(\lceil \log_2(N_{\text{RB}}^{\text{UL,BWP}}(N_{\text{RB}}^{\text{UL,BWP}} + 1)/2) \rceil, N_{\text{RBG}}) + 1$  bits if *resourceAllocation* is configured as '*dynamicSwitch*'.
    - If *resourceAllocation* is configured as '*dynamicSwitch*', the MSB bit is used to indicate resource allocation type 0 or resource allocation type 1, where the bit value of 0 indicates resource allocation type 0 and the bit value of 1 indicates resource allocation type 1.
    - For resource allocation type 0, the  $N_{\text{RBG}}$  LSBs provide the resource allocation as defined in Clause 6.1.2.2.1 of [6, TS 38.214].
    - For resource allocation type 1, the  $\lceil \log_2(N_{\text{RB}}^{\text{UL,BWP}}(N_{\text{RB}}^{\text{UL,BWP}} + 1)/2) \rceil$  LSBs provide the resource allocation as follows:
      - For PUSCH hopping with resource allocation type 1:
        - $N_{\text{UL,hop}}$  MSB bits are used to indicate the frequency offset according to Clause 6.3 of [6, TS 38.214], where  $N_{\text{UL,hop}} = 1$  if the higher layer parameter *frequencyHoppingOffsetLists* contains two offset values and  $N_{\text{UL,hop}} = 2$  if the higher layer parameter *frequencyHoppingOffsetLists* contains four offset values
        - $\lceil \log_2(N_{\text{RB}}^{\text{UL,BWP}}(N_{\text{RB}}^{\text{UL,BWP}} + 1)/2) \rceil - N_{\text{UL,hop}}$  bits provide the frequency domain resource allocation according to Clause 6.1.2.2.2 of [6, TS 38.214]
      - For non-PUSCH hopping with resource allocation type 1:
        - $\lceil \log_2(N_{\text{RB}}^{\text{UL,BWP}}(N_{\text{RB}}^{\text{UL,BWP}} + 1)/2) \rceil$  bits provide the frequency domain resource allocation according to Clause 6.1.2.2.2 of [6, TS 38.214]

If "Bandwidth part indicator" field indicates a bandwidth part other than the active bandwidth part and if *resourceAllocation* is configured as '*dynamicSwitch*' for the indicated bandwidth part, the UE assumes resource allocation type 0 for the indicated bandwidth part if the bitwidth of the "Frequency domain resource

assignment" field of the active bandwidth part is smaller than the bitwidth of the "Frequency domain resource assignment" field of the indicated bandwidth part.

- If the higher layer parameter *useInterlacePUCCH-PUSCH* in *BWP-UplinkDedicated* is configured
  - 5 + Y bits provide the frequency domain resource allocation according to Clause 6.1.2.2.3 of [6, TS 38.214] if the subcarrier spacing for the active UL bandwidth part is 30 kHz. The 5 MSBs provide the interlace allocation and the Y LSBs provide the RB set allocation.
  - 6 + Y bits provide the frequency domain resource allocation according to Clause 6.1.2.2.3 of [6, TS 38.214] if the subcarrier spacing for the active UL bandwidth part is 15 kHz. The 6 MSBs provide the interlace allocation and the Y LSBs provide the RB set allocation.

The value of Y is determined by  $\left\lceil \log_2 \left( \frac{N_{\text{RB-set,UL}}^{\text{BWP}} (N_{\text{RB-set,UL}}^{\text{BWP}} + 1)}{2} \right) \right\rceil$  where  $N_{\text{RB-set,UL}}^{\text{BWP}}$  is the number of RB sets contained in the active UL BWP as defined in clause 7 of [6, TS38.214].

- Time domain resource assignment – 0, 1, 2, 3, 4, 5, or 6 bits
  - If the higher layer parameter *pusch-TimeDomainAllocationListDCI-0-1* is not configured and if the higher layer parameter *pusch-TimeDomainAllocationListForMultiPUSCH* is not configured and if the higher layer parameter *pusch-TimeDomainAllocationList* is configured, 0, 1, 2, 3, or 4 bits as defined in Clause 6.1.2.1 of [6, TS38.214]. The bitwidth for this field is determined as  $\lceil \log_2(I) \rceil$  bits, where  $I$  is the number of entries in the higher layer parameter *pusch-TimeDomainAllocationList*;
  - If the higher layer parameter *pusch-TimeDomainAllocationListDCI-0-1* is configured or if the higher layer parameter *pusch-TimeDomainAllocationListForMultiPUSCH* is configured, 0, 1, 2, 3, 4, 5 or 6 bits as defined in Clause 6.1.2.1 of [6, TS38.214]. The bitwidth for this field is determined as  $\lceil \log_2(I) \rceil$  bits, where  $I$  is the number of entries in the higher layer parameter *pusch-TimeDomainAllocationListDCI-0-1* or *pusch-TimeDomainAllocationListForMultiPUSCH*;
  - otherwise the bitwidth for this field is determined as  $\lceil \log_2(I) \rceil$  bits, where  $I$  is the number of entries in the default table.
- Frequency hopping flag – 0 or 1 bit:
  - 0 bit if only resource allocation type 0 is configured, or if the higher layer parameter *frequencyHopping* is not configured and the higher layer parameter *pusch-RepTypeIndicatorDCI-0-1* is not configured to *pusch-RepTypeB*, or if the higher layer parameter *frequencyHoppingDCI-0-1* is not configured and *pusch-RepTypeIndicatorDCI-0-1* is configured to *pusch-RepTypeB*, or if only resource allocation type 2 is configured;
  - 1 bit according to Table 7.3.1.1.1-3 otherwise, only applicable to resource allocation type 1, as defined in Clause 6.3 of [6, TS 38.214].
- Modulation and coding scheme – 5 bits as defined in Clause 6.1.4.1 of [6, TS 38.214]
- New data indicator – 1 bit if the number of scheduled PUSCH indicated by the Time domain resource assignment field is 1; otherwise 2, 3, 4, 5, 6, 7 or 8 bits determined based on the maximum number of schedulable PUSCH among all entries in the higher layer parameter *pusch-TimeDomainAllocationListForMultiPUSCH*, where each bit corresponds to one scheduled PUSCH as defined in clause 6.1.4 in [6, TS 38.214].
- Redundancy version – number of bits determined by the following:
  - 2 bits as defined in Table 7.3.1.1.1-2 if the number of scheduled PUSCH indicated by the Time domain resource assignment field is 1;
  - otherwise 2, 3, 4, 5, 6, 7 or 8 bits determined by the maximum number of schedulable PUSCHs among all entries in the higher layer parameter *pusch-TimeDomainAllocationListForMultiPUSCH*, where each bit corresponds to one scheduled PUSCH as defined in clause 6.1.4 in [6, TS 38.214] and redundancy version is determined according to Table 7.3.1.1.2-34.
- HARQ process number – 4 bits



- 1<sup>st</sup> downlink assignment index – 1, 2 or 4 bits:
  - 1 bit for semi-static HARQ-ACK codebook;
  - 2 bits for dynamic HARQ-ACK codebook, or for enhanced dynamic HARQ-ACK codebook without *UL-TotalDAI-Included* configured;
  - 4 bits for enhanced dynamic HARQ-ACK codebook and with *UL-TotalDAI-Included = true*.

When two HARQ-ACK codebooks are configured for the same serving cell and if higher layer parameter *priorityIndicatorDCI-0-1* is configured, if the bit width of the 1<sup>st</sup> downlink assignment index in DCI format 0\_1 for one HARQ-ACK codebook is not equal to that of the 1<sup>st</sup> downlink assignment index in DCI format 0\_1 for the other HARQ-ACK codebook, a number of most significant bits with value set to '0' are inserted to smaller 1<sup>st</sup> downlink assignment index until the bit width of the 1<sup>st</sup> downlink assignment index in DCI format 0\_1 for the two HARQ-ACK codebooks are the same.

- 2<sup>nd</sup> downlink assignment index – 0, 2 or 4 bits:
  - 2 bits for dynamic HARQ-ACK codebook with two HARQ-ACK sub-codebooks, or for enhanced dynamic HARQ-ACK codebook with two HARQ-ACK sub-codebooks and without *UL-TotalDAI-Included* configured;
  - 4 bits for enhanced dynamic HARQ-ACK codebook with two HARQ-ACK sub-codebooks and with *UL-TotalDAI-Included = true*;
  - 0 bit otherwise.

When two HARQ-ACK codebooks are configured for the same serving cell and if higher layer parameter *priorityIndicatorDCI-0-1* is configured, if the bit width of the 2<sup>nd</sup> downlink assignment index in DCI format 0\_1 for one HARQ-ACK codebook is not equal to that of the 2<sup>nd</sup> downlink assignment index in DCI format 0\_1 for the other HARQ-ACK codebook, a number of most significant bits with value set to '0' are inserted to smaller 2<sup>nd</sup> downlink assignment index until the bit width of the 2<sup>nd</sup> downlink assignment index in DCI format 0\_1 for the two HARQ-ACK codebooks are the same.

- TPC command for scheduled PUSCH – 2 bits as defined in Clause 7.1.1 of [5, TS38.213]

- SRS resource indicator –  $\left\lceil \log_2 \left( \sum_{k=1}^{\min\{L_{\max}, N_{\text{SRS}}\}} \binom{N_{\text{SRS}}}{k} \right) \right\rceil$  or  $\lceil \log_2(N_{\text{SRS}}) \rceil$  bits, where  $N_{\text{SRS}}$  is the number of

configured SRS resources in the SRS resource set configured by higher layer parameter *srs-ResourceSetToAddModList*, and associated with the higher layer parameter *usage* of value 'codeBook' or 'nonCodeBook',

- $\left\lceil \log_2 \left( \sum_{k=1}^{\min\{L_{\max}, N_{\text{SRS}}\}} \binom{N_{\text{SRS}}}{k} \right) \right\rceil$  bits according to Tables 7.3.1.1.2-28/29/30/31 if the higher layer parameter

*txConfig = nonCodebook*, where  $N_{\text{SRS}}$  is the number of configured SRS resources in the SRS resource set configured by higher layer parameter *srs-ResourceSetToAddModList*, and associated with the higher layer parameter *usage* of value 'nonCodeBook' and

- if UE supports operation with *maxMIMO-Layers* and the higher layer parameter *maxMIMO-Layers of PUSCH-ServingCellConfig* of the serving cell is configured,  $L_{\max}$  is given by that parameter
- otherwise,  $L_{\max}$  is given by the maximum number of layers for PUSCH supported by the UE for the serving cell for non-codebook based operation.
- $\lceil \log_2(N_{\text{SRS}}) \rceil$  bits according to Tables 7.3.1.1.2-32, 7.3.1.1.2-32A and 7.3.1.1.2-32B if the higher layer parameter *txConfig = codebook*, where  $N_{\text{SRS}}$  is the number of configured SRS resources in the SRS resource set configured by higher layer parameter *srs-ResourceSetToAddModList*, and associated with the higher layer parameter *usage* of value 'codeBook'.
- Precoding information and number of layers – number of bits determined by the following:
  - 0 bits if the higher layer parameter *txConfig = nonCodeBook*;

- 0 bits for 1 antenna port and if the higher layer parameter  $txConfig = codebook$ ;
- 4, 5, or 6 bits according to Table 7.3.1.1.2-2 for 4 antenna ports, if  $txConfig = codebook$ ,  $ul-FullPowerTransmission$  is not configured or configured to  $fullpowerMode2$  or configured to  $fullpower$ , and according to whether transform precoder is enabled or disabled, and the values of higher layer parameters  $maxRank$ , and  $codebookSubset$ ;
- 4 or 5 bits according to Table 7.3.1.1.2-2A for 4 antenna ports, if  $txConfig = codebook$ ,  $ul-FullPowerTransmission = fullpowerMode1$ ,  $maxRank=2$ , transform precoder is disabled, and according to the values of higher layer parameter  $codebookSubset$ ;
- 4 or 6 bits according to Table 7.3.1.1.2-2B for 4 antenna ports, if  $txConfig = codebook$ ,  $ul-FullPowerTransmission = fullpowerMode1$ ,  $maxRank=3$  or  $4$ , transform precoder is disabled, and according to the values of higher layer parameter  $codebookSubset$ ;
- 2, 4, or 5 bits according to Table 7.3.1.1.2-3 for 4 antenna ports, if  $txConfig = codebook$ ,  $ul-FullPowerTransmission$  is not configured or configured to  $fullpowerMode2$  or configured to  $fullpower$ , and according to whether transform precoder is enabled or disabled, and the values of higher layer parameters  $maxRank$ , and  $codebookSubset$ ;
- 3 or 4 bits according to Table 7.3.1.1.2-3A for 4 antenna ports, if  $txConfig = codebook$ ,  $ul-FullPowerTransmission = fullpowerMode1$ ,  $maxRank=1$ , and according to whether transform precoder is enabled or disabled, and the values of higher layer parameter  $codebookSubset$ ;
- 2 or 4 bits according to Table 7.3.1.1.2-4 for 2 antenna ports, if  $txConfig = codebook$ ,  $ul-FullPowerTransmission$  is not configured or configured to  $fullpowerMode2$  or configured to  $fullpower$ , and according to whether transform precoder is enabled or disabled, and the values of higher layer parameters  $maxRank$  and  $codebookSubset$ ;
- 2 bits according to Table 7.3.1.1.2-4A for 2 antenna ports, if  $txConfig = codebook$ ,  $ul-FullPowerTransmission = fullpowerMode1$ , transform precoder is disabled,  $maxRank=2$ , and  $codebookSubset=nonCoherent$ ;
- 1 or 3 bits according to Table 7.3.1.1.2-5 for 2 antenna ports, if  $txConfig = codebook$ ,  $ul-FullPowerTransmission$  is not configured or configured to  $fullpowerMode2$  or configured to  $fullpower$ , and according to whether transform precoder is enabled or disabled, and the values of higher layer parameters  $maxRank$  and  $codebookSubset$ ;
- 2 bits according to Table 7.3.1.1.2-5A for 2 antenna ports, if  $txConfig = codebook$ ,  $ul-FullPowerTransmission = fullpowerMode1$ ,  $maxRank=1$ , and according to whether transform precoder is enabled or disabled, and the values of higher layer parameter  $codebookSubset$ ;

For the higher layer parameter  $txConfig=codebook$ , if  $ul-FullPowerTransmission$  is configured to  $fullpowerMode2$ ,  $maxRank$  is configured to be larger than 2, and at least one SRS resource with 4 antenna ports is configured in an SRS resource set with usage set to 'codebook' and an SRS resource with 2 antenna ports is indicated via SRI in the same SRS resource set, then Table 7.3.1.1.2-4 is used.

For the higher layer parameter  $txConfig = codebook$ , if different SRS resources with different number of antenna ports are configured, the bitwidth is determined according to the maximum number of ports in an SRS resource among the configured SRS resources in an SRS resource set with usage set to 'codebook'. If the number of ports for a configured SRS resource in the set is less than the maximum number of ports in an SRS resource among the configured SRS resources, a number of most significant bits with value set to '0' are inserted to the field.

- Antenna ports – number of bits determined by the following
  - 2 bits as defined by Tables 7.3.1.1.2-6, if transform precoder is enabled,  $dmrs-Type=1$ , and  $maxLength=1$ , except that  $dmrs-UplinkTransformPrecoding$  and  $tp-pi2BPSK$  are both configured and  $\pi/2$  BPSK modulation is used;
  - 2 bits as defined by Tables 7.3.1.1.2-6A, if transform precoder is enabled and  $dmrs-UplinkTransformPrecoding$  and  $tp-pi2BPSK$  are both configured,  $\pi/2$  BPSK modulation is used,  $dmrs-Type=1$ , and  $maxLength=1$ , where  $n_{SCID}$  is the scrambling identity for antenna ports defined in [Clause 6.4.1.1.1.2, TS38.211];

- 4 bits as defined by Tables 7.3.1.1.2-7, if transform precoder is enabled,  $dmrs\text{-}Type=1$ , and  $maxLength=2$ , except that  $dmrs\text{-}UplinkTransformPrecoding$  and  $tp\text{-}pi2BPSK$  are both configured and  $\pi/2$  BPSK modulation is used;
- 4 bits as defined by Tables 7.3.1.1.2-7A, if transform precoder is enabled and  $dmrs\text{-}UplinkTransformPrecoding$  and  $tp\text{-}pi2BPSK$  are both configured,  $\pi/2$  BPSK modulation is used,  $dmrs\text{-}Type=1$ , and  $maxLength=2$ , where  $n_{SCID}$  is the scrambling identity for antenna ports defined in [Clause 6.4.1.1.1.2, TS38.211];
- 3 bits as defined by Tables 7.3.1.1.2-8/9/10/11, if transform precoder is disabled,  $dmrs\text{-}Type=1$ , and  $maxLength=1$ , and the value of rank is determined according to the SRS resource indicator field if the higher layer parameter  $txConfig = nonCodebook$  and according to the Precoding information and number of layers field if the higher layer parameter  $txConfig = codebook$ ;
- 4 bits as defined by Tables 7.3.1.1.2-12/13/14/15, if transform precoder is disabled,  $dmrs\text{-}Type=1$ , and  $maxLength=2$ , and the value of rank is determined according to the SRS resource indicator field if the higher layer parameter  $txConfig = nonCodebook$  and according to the Precoding information and number of layers field if the higher layer parameter  $txConfig = codebook$ ;
- 4 bits as defined by Tables 7.3.1.1.2-16/17/18/19, if transform precoder is disabled,  $dmrs\text{-}Type=2$ , and  $maxLength=1$ , and the value of rank is determined according to the SRS resource indicator field if the higher layer parameter  $txConfig = nonCodebook$  and according to the Precoding information and number of layers field if the higher layer parameter  $txConfig = codebook$ ;
- 5 bits as defined by Tables 7.3.1.1.2-20/21/22/23, if transform precoder is disabled,  $dmrs\text{-}Type=2$ , and  $maxLength=2$ , and the value of rank is determined according to the SRS resource indicator field if the higher layer parameter  $txConfig = nonCodebook$  and according to the Precoding information and number of layers field if the higher layer parameter  $txConfig = codebook$ .

where the number of CDM groups without data of values 1, 2, and 3 in Tables 7.3.1.1.2-6 to 7.3.1.1.2-23 refers to CDM groups  $\{0\}$ ,  $\{0,1\}$ , and  $\{0, 1,2\}$  respectively.

If a UE is configured with both  $dmrs\text{-}UplinkForPUSCH\text{-}MappingTypeA$  and  $dmrs\text{-}UplinkForPUSCH\text{-}MappingTypeB$ , the bitwidth of this field equals  $\max\{x_A, x_B\}$ , where  $x_A$  is the "Antenna ports" bitwidth derived according to  $dmrs\text{-}UplinkForPUSCH\text{-}MappingTypeA$  and  $x_B$  is the "Antenna ports" bitwidth derived according to  $dmrs\text{-}UplinkForPUSCH\text{-}MappingTypeB$ . A number of  $|x_A - x_B|$  zeros are padded in the MSB of this field, if the mapping type of the PUSCH corresponds to the smaller value of  $x_A$  and  $x_B$ .

- SRS request – 2 bits as defined by Table 7.3.1.1.2-24 for UEs not configured with  $supplementaryUplink$  in  $ServingCellConfig$  in the cell; 3 bits for UEs configured with  $supplementaryUplink$  in  $ServingCellConfig$  in the cell where the first bit is the non-SUL/SUL indicator as defined in Table 7.3.1.1.1-1 and the second and third bits are defined by Table 7.3.1.1.2-24. This bit field may also indicate the associated CSI-RS according to Clause 6.1.1.2 of [6, TS 38.214].
- CSI request – 0, 1, 2, 3, 4, 5, or 6 bits determined by higher layer parameter  $reportTriggerSize$ .
- CBG transmission information (CBGTI) – 0 bit if higher layer parameter  $codeBlockGroupTransmission$  for PUSCH is not configured or if the number of scheduled PUSCH indicated by the Time domain resource assignment field is larger than 1; otherwise, 2, 4, 6, or 8 bits determined by higher layer parameter  $maxCodeBlockGroupsPerTransportBlock$  for PUSCH.
- PTRS-DMRS association – number of bits determined as follows
  - 0 bit if  $PTRS\text{-}UplinkConfig$  is not configured in either  $dmrs\text{-}UplinkForPUSCH\text{-}MappingTypeA$  or  $dmrs\text{-}UplinkForPUSCH\text{-}MappingTypeB$  and transform precoder is disabled, or if transform precoder is enabled, or if  $maxRank=1$ ;
  - 2 bits otherwise, where Table 7.3.1.1.2-25 and 7.3.1.1.2-26 are used to indicate the association between PTRS port(s) and DMRS port(s) when one PT-RS port and two PT-RS ports are configured by  $maxNrofPorts$  in  $PTRS\text{-}UplinkConfig$  respectively, and the DMRS ports are indicated by the Antenna ports field.

If "Bandwidth part indicator" field indicates a bandwidth part other than the active bandwidth part and the "PTRS-DMRS association" field is present for the indicated bandwidth part but not present for the active bandwidth part, the UE assumes the "PTRS-DMRS association" field is not present for the indicated bandwidth part.

- beta\_offset indicator – 0 if the higher layer parameter *betaOffsets* = *semiStatic*; otherwise 2 bits as defined by Table 9.3-3 in [5, TS 38.213].

When two HARQ-ACK codebooks are configured for the same serving cell and if higher layer parameter *priorityIndicatorDCI-0-1* is configured, if the bit width of the beta\_offset indicator in DCI format 0\_1 for one HARQ-ACK codebook is not equal to that of the beta\_offset indicator in DCI format 0\_1 for the other HARQ-ACK codebook, a number of most significant bits with value set to '0' are inserted to smaller beta\_offset indicator until the bit width of the beta\_offset indicator in DCI format 0\_1 for the two HARQ-ACK codebooks are the same.

- DMRS sequence initialization – 0 bit if transform precoder is enabled; 1 bit if transform precoder is disabled.
- UL-SCH indicator – 0 or 1 bit as follows
  - 0 bit if the number of scheduled PUSCH indicated by the Time domain resource assignment field is larger than 1;
  - 1 bit otherwise. A value of "1" indicates UL-SCH shall be transmitted on the PUSCH and a value of "0" indicates UL-SCH shall not be transmitted on the PUSCH. Except for DCI format 0\_1 with CRC scrambled by SP-CSI-RNTI, a UE is not expected to receive a DCI format 0\_1 with UL-SCH indicator of "0" and CSI request of all zero(s).
- ChannelAccess-CPext-CAPC – 0, 1, 2, 3, 4, 5 or 6 bits. The bitwidth for this field is determined as  $\lceil \log_2(I) \rceil$  bits, where  $I$  is the number of entries in the higher layer parameter *ul-AccessConfigListDCI-0-1* or in Table 7.3.1.1.1-4A if *ChannelAccessMode-r16* = "*semistatic*" is provided for operation in a cell with shared spectrum channel access; otherwise 0 bit. One or more entries from Table 7.3.1.1.2-35 are configured by the higher layer parameter *ul-AccessConfigListDCI-0-1*.
- Open-loop power control parameter set indication – 0 or 1 or 2 bits.
  - 0 bit if the higher layer parameter *p0-PUSCH-SetList* is not configured;
  - 1 or 2 bits otherwise,
    - 1 bit if SRS resource indicator is present in the DCI format 0\_1;
    - 1 or 2 bits as determined by higher layer parameter *olpc-ParameterSetDCI-0-1* if SRS resource indicator is not present in the DCI format 0\_1.
- Priority indicator – 0 bit if higher layer parameter *priorityIndicatorDCI-0-1* is not configured; otherwise 1 bit as defined in Clause 9 in [5, TS 38.213].
- Invalid symbol pattern indicator – 0 bit if higher layer parameter *invalidSymbolPatternIndicatorDCI-0-1* is not configured; otherwise 1 bit as defined in Clause 6.1.2.1 in [6, TS 38.214].
- Minimum applicable scheduling offset indicator – 0 or 1 bit
  - 0 bit if higher layer parameter *minimumSchedulingOffsetK2* is not configured;
  - 1 bit if higher layer parameter *minimumSchedulingOffsetK2* is configured. The 1 bit indication is used to determine the minimum applicable K2 for the active UL BWP and the minimum applicable K0 value for the active DL BWP, if configured respectively, according to Table 7.3.1.1.2-33. If the minimum applicable K0 is indicated, the minimum applicable value of the aperiodic CSI-RS triggering offset for an active DL BWP shall be the same as the minimum applicable K0 value.
- SCell dormancy indication – 0 bit if higher layer parameter *dormancyGroupWithinActiveTime* is not configured; otherwise 1, 2, 3, 4 or 5 bits bitmap determined according to higher layer parameter *dormancyGroupWithinActiveTime*, where each bit corresponds to one of the SCell group(s) configured by higher layers parameter *dormancyGroupWithinActiveTime*, with MSB to LSB of the bitmap corresponding to the first to last configured SCell group. The field is only present when this format is carried by PDCCH on the primary cell within DRX Active Time and the UE is configured with at least two DL BWPs for an SCell.

- Sidelink assignment index – 0, 1 or 2 bits:
  - 1 bit if the UE is configured with *pdsch-HARQ-ACK-Codebook* = *semi-static* and, in addition, the UE is configured with a SL configured grant type 1 or to monitor DCI format 3\_0 with CRC scrambled by SL-RNTI or SL-CS-RNTI;
  - 2 bits if the UE is configured with *pdsch-HARQ-ACK-Codebook* = *dynamic* and, in addition, the UE is configured with a SL configured grant type 1 or to monitor DCI format 3\_0 with CRC scrambled by SL-RNTI or SL-CS-RNTI;
  - 0 bit otherwise.

A UE does not expect that the bit width of a field in DCI format 0\_1 with CRC scrambled by CS-RNTI is larger than corresponding bit width of same field in DCI format 0\_1 with CRC scrambled by C-RNTI for the same serving cell. If the bit width of a field in the DCI format 0\_1 with CRC scrambled by CS-RNTI is not equal to that of the corresponding field in the DCI format 0\_1 with CRC scrambled by C-RNTI for the same serving cell, a number of most significant bits with value set to '0' are inserted to the field in DCI format 0\_1 with CRC scrambled by CS-RNTI until the bit width equals that of the corresponding field in the DCI format 0\_1 with CRC scrambled by C-RNTI for the same serving cell.

If the number of information bits in DCI format 0\_1 scheduling a single PUSCH prior to padding is not equal to the number of information bits in DCI format 0\_1 scheduling multiple PUSCHs for the same serving cell, zeros shall be appended to the DCI format 0\_1 with smaller size until the payload size is the same for scheduling a single PUSCH and multiple PUSCHs.

**Table 7.3.1.1.2-1: Bandwidth part indicator**

Value of BWP indicator field 2 bits	Bandwidth part
00	Configured BWP with BWP-Id = 1
01	Configured BWP with BWP-Id = 2
10	Configured BWP with BWP-Id = 3
11	Configured BWP with BWP-Id = 4

**Table 7.3.1.1.2-2: Precoding information and number of layers, for 4 antenna ports, if transform precoder is disabled, *maxRank* = 2 or 3 or 4, and *ul-FullPowerTransmission* is not configured or configured to *fullpowerMode2* or configured to *fullpower***

Bit field mapped to index	<i>codebookSubset = fullyAndPartialAndNonCoherent</i>	Bit field mapped to index	<i>codebookSubset = partialAndNonCoherent</i>	Bit field mapped to index	<i>codebookSubset = nonCoherent</i>
0	1 layer: TPMI=0	0	1 layer: TPMI=0	0	1 layer: TPMI=0
1	1 layer: TPMI=1	1	1 layer: TPMI=1	1	1 layer: TPMI=1
...	...	...	...	...	...
3	1 layer: TPMI=3	3	1 layer: TPMI=3	3	1 layer: TPMI=3
4	2 layers: TPMI=0	4	2 layers: TPMI=0	4	2 layers: TPMI=0
...	...	...	...	...	...
9	2 layers: TPMI=5	9	2 layers: TPMI=5	9	2 layers: TPMI=5
10	3 layers: TPMI=0	10	3 layers: TPMI=0	10	3 layers: TPMI=0
11	4 layers: TPMI=0	11	4 layers: TPMI=0	11	4 layers: TPMI=0
12	1 layer: TPMI=4	12	1 layer: TPMI=4	12-15	reserved
...	...	...	...	...	...
19	1 layer: TPMI=11	19	1 layer: TPMI=11		
20	2 layers: TPMI=6	20	2 layers: TPMI=6		
...	...	...	...		
27	2 layers: TPMI=13	27	2 layers: TPMI=13		
28	3 layers: TPMI=1	28	3 layers: TPMI=1		
29	3 layers: TPMI=2	29	3 layers: TPMI=2		
30	4 layers: TPMI=1	30	4 layers: TPMI=1		
31	4 layers: TPMI=2	31	4 layers: TPMI=2		
32	1 layer: TPMI=12				
...	...				
47	1 layers: TPMI=27				
48	2 layers: TPMI=14				
...	...				
55	2 layers: TPMI=21				
56	3 layers: TPMI=3				
...	...				
59	3 layers: TPMI=6				
60	4 layers: TPMI=3				
61	4 layers: TPMI=4				
62-63	reserved				

**Table 7.3.1.1.2-2A: Precoding information and number of layers for 4 antenna ports, if transform precoder is disabled, *maxRank* = 2, and *ul-FullPowerTransmission* = *fullpowerMode1***

Bit field mapped to index	<i>codebookSubset = partialAndNonCoherent</i>	Bit field mapped to index	<i>codebookSubset = nonCoherent</i>
0	1 layer: TPMI=0	0	1 layer: TPMI=0
1	1 layer: TPMI=1	1	1 layer: TPMI=1
...	...	...	...
3	1 layer: TPMI=3	3	1 layer: TPMI=3
4	2 layers: TPMI=0	4	2 layers: TPMI=0
...	...	...	...
9	2 layers: TPMI=5	9	2 layers: TPMI=5
10	1 layer: TPMI=13	10	1 layer: TPMI=13
11	2 layer: TPMI=6	11	2 layer: TPMI=6
12	1 layer: TPMI=4	12-15	Reserved
...	...		
20	1 layer: TPMI=12		
21	1 layer: TPMI=14		
22	1 layer: TPMI=15		
23	2 layers: TPMI=7		
...	...		
29	2 layers: TPMI=13		
30-31	Reserved		

**Table 7.3.1.1.2-2B: Precoding information and number of layers for 4 antenna ports, if transform precoder is disabled, *maxRank* = 3 or 4, and *ul-FullPowerTransmission* = *fullpowerMode1***

Bit field mapped to index	<i>codebookSubset</i> = <i>partialAndNonCoherent</i>	Bit field mapped to index	<i>codebookSubset</i> = <i>nonCoherent</i>
0	1 layer: TPMI=0	0	1 layer: TPMI=0
1	1 layer: TPMI=1	1	1 layer: TPMI=1
...	...	...	...
3	1 layer: TPMI=3	3	1 layer: TPMI=3
4	2 layers: TPMI=0	4	2 layers: TPMI=0
...	...	...	...
9	2 layers: TPMI=5	9	2 layers: TPMI=5
10	3 layers: TPMI=0	10	3 layers: TPMI=0
11	4 layers: TPMI=0	11	4 layers: TPMI=0
12	1 layer: TPMI=13	12	1 layer: TPMI=13
13	2 layer: TPMI=6	13	2 layer: TPMI=6
14	3 layer: TPMI=1	14	3 layer: TPMI=1
15	1 layer: TPMI=4	15	Reserved
...	...		
23	1 layer: TPMI=12		
24	1 layer: TPMI=14		
25	1 layer: TPMI=15		
26	2 layers: TPMI=7		
...	...		
32	2 layers: TPMI=13		
33	3 layers: TPMI=2		
34	4 layers: TPMI=1		
35	4 layers: TPMI=2		
36-63	Reserved		

**Table 7.3.1.1.2-3: Precoding information and number of layers for 4 antenna ports, if transform precoder is enabled and *ul-FullPowerTransmission* is either not configured or configured to *fullpowerMode2*, or if transform precoder is disabled, *maxRank* = 1, and *ul-FullPowerTransmission* is not configured or configured to *fullpowerMode2* or configured to *fullpower***

Bit field mapped to index	<i>codebookSubset</i> = <i>fullyAndPartialAndNonCoherent</i>	Bit field mapped to index	<i>codebookSubset</i> = <i>partialAndNonCoherent</i>	Bit field mapped to index	<i>codebookSubset</i> = <i>nonCoherent</i>
0	1 layer: TPMI=0	0	1 layer: TPMI=0	0	1 layer: TPMI=0
1	1 layer: TPMI=1	1	1 layer: TPMI=1	1	1 layer: TPMI=1
...	...	...	...	...	...
3	1 layer: TPMI=3	3	1 layer: TPMI=3	3	1 layer: TPMI=3
4	1 layer: TPMI=4	4	1 layer: TPMI=4		
...	...	...	...		
11	1 layer: TPMI=11	11	1 layer: TPMI=11		
12	1 layers: TPMI=12	12-15	reserved		
...	...				
27	1 layers: TPMI=27				
28-31	reserved				

**Table 7.3.1.1.2-3A: Precoding information and number of layers for 4 antenna ports, if transform precoder is enabled and *ul-FullPowerTransmission* = *fullpowerMode1*, or if transform precoder is disabled, *maxRank* = 1, and *ul-FullPowerTransmission* = *fullpowerMode1***

Bit field mapped to index	<i>codebookSubset=partialAndNonCoherent</i>	Bit field mapped to index	<i>codebookSubset=nonCoherent</i>
0	1 layer: TPMI=0	0	1 layer: TPMI=0
1	1 layer: TPMI=1	1	1 layer: TPMI=1
...	...	...	...
3	1 layer: TPMI=3	3	1 layer: TPMI=3
4	1 layer: TPMI=13	4	1 layer: TPMI=13
5	1 layer: TPMI=4	5-7	Reserved
...	...		
13	1 layer: TPMI=12		
14	1 layer: TPMI=14		
15	1 layer: TPMI=15		

**Table 7.3.1.1.2-4: Precoding information and number of layers, for 2 antenna ports, if transform precoder is disabled, *maxRank* = 2, and *ul-FullPowerTransmission* is not configured or configured to *fullpowerMode2* or configured to *fullpower***

Bit field mapped to index	<i>codebookSubset=fullyAndPartialAndNonCoherent</i>	Bit field mapped to index	<i>codebookSubset=nonCoherent</i>
0	1 layer: TPMI=0	0	1 layer: TPMI=0
1	1 layer: TPMI=1	1	1 layer: TPMI=1
2	2 layers: TPMI=0	2	2 layers: TPMI=0
3	1 layer: TPMI=2	3	reserved
4	1 layer: TPMI=3		
5	1 layer: TPMI=4		
6	1 layer: TPMI=5		
7	2 layers: TPMI=1		
8	2 layers: TPMI=2		
9-15	reserved		

**Table 7.3.1.1.2-4A: Precoding information and number of layers, for 2 antenna ports, if transform precoder is disabled, *maxRank* = 2, and *ul-FullPowerTransmission* = *fullpowerMode1***

Bit field mapped to index	<i>codebookSubset=nonCoherent</i>
0	1 layer: TPMI=0
1	1 layer: TPMI=1
2	2 layers: TPMI=0
3	1 layer: TPMI=2



**Table 7.3.1.1.2-5: Precoding information and number of layers, for 2 antenna ports, if transform precoder is enabled and *ul-FullPowerTransmission* is not configured or configured to *fullpowerMode2* or configured to *fullpower*, or if transform precoder is disabled, *maxRank* = 1, and *ul-FullPowerTransmission* is not configured or configured to *fullpowerMode2* or configured to *fullpower***

Bit field mapped to index	<i>codebookSubset = fullyAndPartialAndNonCoherent</i>	Bit field mapped to index	<i>codebookSubset = nonCoherent</i>
0	1 layer: TPMI=0	0	1 layer: TPMI=0
1	1 layer: TPMI=1	1	1 layer: TPMI=1
2	1 layer: TPMI=2		
3	1 layer: TPMI=3		
4	1 layer: TPMI=4		
5	1 layer: TPMI=5		
6-7	reserved		

**Table 7.3.1.1.2-5A: Precoding information and number of layers, for 2 antenna ports, if transform precoder is enabled and *ul-FullPowerTransmission = fullpowerMode1*, or if transform precoder is disabled, *maxRank* = 1, and *ul-FullPowerTransmission = fullpowerMode1***

Bit field mapped to index	<i>codebookSubset = nonCoherent</i>
0	1 layer: TPMI=0
1	1 layer: TPMI=1
2	1 layer: TPMI=2
3	Reserved

**Table 7.3.1.1.2-6: Antenna port(s), transform precoder is enabled, *dmrs-Type=1*, *maxLength=1*, except that *dmrs-UplinkTransformPrecoding* and *tp-pi2BPSK* are both configured and  $\pi/2$ -BPSK modulation is used**

Value	Number of DMRS CDM group(s) without data	DMRS port(s)
0	2	0
1	2	1
2	2	2
3	2	3

**Table 7.3.1.1.2-6A: Antenna port(s), transform precoder is enabled, *dmrs-UplinkTransformPrecoding* and *tp-pi2BPSK* are both configured,  $\pi/2$ -BPSK modulation is used, *dmrs-Type=1*, *maxLength=1***

Value	Number of DMRS CDM group(s) without data	DMRS port(s)
0	2	0, $n_{SCID} = 0$
1	2	0, $n_{SCID} = 1$
2	2	2, $n_{SCID} = 0$
3	2	2, $n_{SCID} = 1$

**Table 7.3.1.1.2-7: Antenna port(s), transform precoder is enabled, *dmrs-Type=1*, *maxLength=2*, except that *dmrs-UplinkTransformPrecoding* and *tp-pi2BPSK* are both configured and  $\pi/2$ -BPSK modulation is used**

Value	Number of DMRS CDM group(s) without data	DMRS port(s)	Number of front-load symbols
0	2	0	1
1	2	1	1
2	2	2	1
3	2	3	1
4	2	0	2
5	2	1	2
6	2	2	2
7	2	3	2
8	2	4	2
9	2	5	2
10	2	6	2
11	2	7	2
12-15	Reserved	Reserved	Reserved

**Table 7.3.1.1.2-7A: Antenna port(s), transform precoder is enabled, *dmrs-UplinkTransformPrecoding* and *tp-pi2BPSK* are both configured,  $\pi/2$ -BPSK modulation is used, *dmrs-Type=1*, *maxLength=2***

Value	Number of DMRS CDM group(s) without data	DMRS port(s)	Number of front-load symbols
0	2	0, $n_{\text{SCID}}=0$	1
1	2	0, $n_{\text{SCID}}=1$	1
2	2	2, $n_{\text{SCID}}=0$	1
3	2	2, $n_{\text{SCID}}=1$	1
4	2	0, $n_{\text{SCID}}=0$	2
5	2	0, $n_{\text{SCID}}=1$	2
6	2	2, $n_{\text{SCID}}=0$	2
7	2	2, $n_{\text{SCID}}=1$	2
8	2	4, $n_{\text{SCID}}=0$	2
9	2	4, $n_{\text{SCID}}=1$	2
10	2	6, $n_{\text{SCID}}=0$	2
11	2	6, $n_{\text{SCID}}=1$	2
12-15	Reserved	Reserved	Reserved

**Table 7.3.1.1.2-8: Antenna port(s), transform precoder is disabled, *dmrs-Type=1*, *maxLength=1*, rank = 1**

Value	Number of DMRS CDM group(s) without data	DMRS port(s)
0	1	0
1	1	1
2	2	0
3	2	1
4	2	2
5	2	3
6-7	Reserved	Reserved

**Table 7.3.1.1.2-9: Antenna port(s), transform precoder is disabled, *dmrs-Type=1*, *maxLength=1*, rank = 2**

Value	Number of DMRS CDM group(s) without data	DMRS port(s)
0	1	0,1
1	2	0,1
2	2	2,3
3	2	0,2
4-7	Reserved	Reserved

Table 7.3.1.1.2-10: Antenna port(s), transform precoder is disabled, *dmrs-Type=1*, *maxLength=1*, rank = 3

Value	Number of DMRS CDM group(s) without data	DMRS port(s)
0	2	0-2
2-7	Reserved	Reserved

Table 7.3.1.1.2-11: Antenna port(s), transform precoder is disabled, *dmrs-Type=1*, *maxLength=1*, rank = 4

Value	Number of DMRS CDM group(s) without data	DMRS port(s)
0	2	0-3
2-7	Reserved	Reserved

Table 7.3.1.1.2-12: Antenna port(s), transform precoder is disabled, *dmrs-Type=1*, *maxLength=2*, rank = 1

Value	Number of DMRS CDM group(s) without data	DMRS port(s)	Number of front-load symbols
0	1	0	1
1	1	1	1
2	2	0	1
3	2	1	1
4	2	2	1
5	2	3	1
6	2	0	2
7	2	1	2
8	2	2	2
9	2	3	2
10	2	4	2
11	2	5	2
12	2	6	2
13	2	7	2
14-15	Reserved	Reserved	Reserved

Table 7.3.1.1.2-13: Antenna port(s), transform precoder is disabled, *dmrs-Type=1*, *maxLength=2*, rank = 2

Value	Number of DMRS CDM group(s) without data	DMRS port(s)	Number of front-load symbols
0	1	0,1	1
1	2	0,1	1
2	2	2,3	1
3	2	0,2	1
4	2	0,1	2
5	2	2,3	2
6	2	4,5	2
7	2	6,7	2
8	2	0,4	2
9	2	2,6	2
10-15	Reserved	Reserved	Reserved

Table 7.3.1.1.2-14: Antenna port(s), transform precoder is disabled, *dmrs-Type=1*, *maxLength=2*, rank = 3

Value	Number of DMRS CDM group(s) without data	DMRS port(s)	Number of front-load symbols
0	2	0-2	1
1	2	0,1,4	2
2	2	2,3,6	2
3-15	Reserved	Reserved	Reserved

**Table 7.3.1.1.2-15: Antenna port(s), transform precoder is disabled, *dmrs-Type=1*, *maxLength=2*, rank = 4**

Value	Number of DMRS CDM group(s) without data	DMRS port(s)	Number of front-load symbols
0	2	0-3	1
1	2	0,1,4,5	2
2	2	2,3,6,7	2
3	2	0,2,4,6	2
4-15	Reserved	Reserved	Reserved

**Table 7.3.1.1.2-16: Antenna port(s), transform precoder is disabled, *dmrs-Type=2*, *maxLength=1*, rank=1**

Value	Number of DMRS CDM group(s) without data	DMRS port(s)
0	1	0
1	1	1
2	2	0
3	2	1
4	2	2
5	2	3
6	3	0
7	3	1
8	3	2
9	3	3
10	3	4
11	3	5
12-15	Reserved	Reserved

**Table 7.3.1.1.2-17: Antenna port(s), transform precoder is disabled, *dmrs-Type=2*, *maxLength=1*, rank=2**

Value	Number of DMRS CDM group(s) without data	DMRS port(s)
0	1	0,1
1	2	0,1
2	2	2,3
3	3	0,1
4	3	2,3
5	3	4,5
6	2	0,2
7-15	Reserved	Reserved

**Table 7.3.1.1.2-18: Antenna port(s), transform precoder is disabled, *dmrs-Type=2*, *maxLength=1*, rank =3**

Value	Number of DMRS CDM group(s) without data	DMRS port(s)
0	2	0-2
1	3	0-2
2	3	3-5
3-15	Reserved	Reserved

**Table 7.3.1.1.2-19: Antenna port(s), transform precoder is disabled, *dmrs-Type=2*, *maxLength=1*, rank =4**

Value	Number of DMRS CDM group(s) without data	DMRS port(s)
0	2	0-3
1	3	0-3
2-15	Reserved	Reserved

**Table 7.3.1.1.2-20: Antenna port(s), transform precoder is disabled, *dmrs-Type=2*, *maxLength=2*, *rank=1***

Value	Number of DMRS CDM group(s) without data	DMRS port(s)	Number of front-load symbols
0	1	0	1
1	1	1	1
2	2	0	1
3	2	1	1
4	2	2	1
5	2	3	1
6	3	0	1
7	3	1	1
8	3	2	1
9	3	3	1
10	3	4	1
11	3	5	1
12	3	0	2
13	3	1	2
14	3	2	2
15	3	3	2
16	3	4	2
17	3	5	2
18	3	6	2
19	3	7	2
20	3	8	2
21	3	9	2
22	3	10	2
23	3	11	2
24	1	0	2
25	1	1	2
26	1	6	2
27	1	7	2
28-31	Reserved	Reserved	Reserved

**Table 7.3.1.1.2-21: Antenna port(s), transform precoder is disabled, *dmrs-Type=2*, *maxLength=2*, *rank=2***

Value	Number of DMRS CDM group(s) without data	DMRS port(s)	Number of front-load symbols
0	1	0,1	1
1	2	0,1	1
2	2	2,3	1
3	3	0,1	1
4	3	2,3	1
5	3	4,5	1
6	2	0,2	1
7	3	0,1	2
8	3	2,3	2
9	3	4,5	2
10	3	6,7	2
11	3	8,9	2
12	3	10,11	2
13	1	0,1	2
14	1	6,7	2
15	2	0,1	2
16	2	2,3	2
17	2	6,7	2
18	2	8,9	2
19-31	Reserved	Reserved	Reserved

**Table 7.3.1.1.2-22: Antenna port(s), transform precoder is disabled, *dmrs-Type=2*, *maxLength=2*, *rank=3***

Value	Number of DMRS CDM group(s) without data	DMRS port(s)	Number of front-load symbols
0	2	0-2	1
1	3	0-2	1
2	3	3-5	1
3	3	0,1,6	2
4	3	2,3,8	2
5	3	4,5,10	2
6-31	Reserved	Reserved	Reserved

**Table 7.3.1.1.2-23: Antenna port(s), transform precoder is disabled, *dmrs-Type=2*, *maxLength=2*, *rank=4***

Value	Number of DMRS CDM group(s) without data	DMRS port(s)	Number of front-load symbols
0	2	0-3	1
1	3	0-3	1
2	3	0,1,6,7	2
3	3	2,3,8,9	2
4	3	4,5,10,11	2
5-31	Reserved	Reserved	Reserved

**Table 7.3.1.1.2-24: SRS request**

Value of SRS request field	Triggered aperiodic SRS resource set(s) for DCI format 0_1, 0_2, 1_1, 1_2, and 2_3 configured with higher layer parameter <i>srs-TPC-PDCCH-Group</i> set to 'typeB'	Triggered aperiodic SRS resource set(s) for DCI format 2_3 configured with higher layer parameter <i>srs-TPC-PDCCH-Group</i> set to 'typeA'
00	No aperiodic SRS resource set triggered	No aperiodic SRS resource set triggered
01	SRS resource set(s) configured by <i>SRS-ResourceSet</i> with higher layer parameter <i>aperiodicSRS-ResourceTrigger</i> set to 1 or an entry in <i>aperiodicSRS-ResourceTriggerList</i> set to 1  SRS resource set(s) configured by <i>SRS-PosResourceSet</i> with an entry in <i>aperiodicSRS-ResourceTriggerList</i> set to 1 when triggered by DCI formats 0_1, 0_2, 1_1, and 1_2	SRS resource set(s) configured with higher layer parameter <i>usage</i> in <i>SRS-ResourceSet</i> set to 'antennaSwitching' and <i>resourceType</i> in <i>SRS-ResourceSet</i> set to 'aperiodic' for a 1 <sup>st</sup> set of serving cells configured by higher layers
10	SRS resource set(s) configured by <i>SRS-ResourceSet</i> with higher layer parameter <i>aperiodicSRS-ResourceTrigger</i> set to 2 or an entry in <i>aperiodicSRS-ResourceTriggerList</i> set to 2  SRS resource set(s) configured by <i>SRS-PosResourceSet</i> with an entry in <i>aperiodicSRS-ResourceTriggerList</i> set to 2 when triggered by DCI formats 0_1, 0_2, 1_1, and 1_2	SRS resource set(s) configured with higher layer parameter <i>usage</i> in <i>SRS-ResourceSet</i> set to 'antennaSwitching' and <i>resourceType</i> in <i>SRS-ResourceSet</i> set to 'aperiodic' for a 2 <sup>nd</sup> set of serving cells configured by higher layers
11	SRS resource set(s) configured by <i>SRS-ResourceSet</i> with higher layer parameter <i>aperiodicSRS-ResourceTrigger</i> set to 3 or an entry in <i>aperiodicSRS-ResourceTriggerList</i> set to 3  SRS resource set(s) configured by <i>SRS-PosResourceSet</i> with an entry in <i>aperiodicSRS-ResourceTriggerList</i> set to 3 when triggered by DCI formats 0_1, 0_2, 1_1, and 1_2	SRS resource set(s) configured with higher layer parameter <i>usage</i> in <i>SRS-ResourceSet</i> set to 'antennaSwitching' and <i>resourceType</i> in <i>SRS-ResourceSet</i> set to 'aperiodic' for a 3 <sup>rd</sup> set of serving cells configured by higher layers

**Table 7.3.1.1.2-25: PTRS-DMRS association for UL PTRS port 0**

Value	DMRS port
0	1 <sup>st</sup> scheduled DMRS port
1	2 <sup>nd</sup> scheduled DMRS port
2	3 <sup>rd</sup> scheduled DMRS port
3	4 <sup>th</sup> scheduled DMRS port

**Table 7.3.1.1.2-26: PTRS-DMRS association for UL PTRS ports 0 and 1**

Value of MSB	DMRS port		Value of LSB	DMRS port
0	1 <sup>st</sup> DMRS port which shares PTRS port 0		0	1 <sup>st</sup> DMRS port which shares PTRS port 1
1	2 <sup>nd</sup> DMRS port which shares PTRS port 0		1	2 <sup>nd</sup> DMRS port which shares PTRS port 1

Table 7.3.1.1.2-27: void

Table 7.3.1.1.2-28: SRI indication for non-codebook based PUSCH transmission,  $L_{\max} = 1$ 

Bit field mapped to index	SRI(s), $N_{\text{SRS}} = 2$	Bit field mapped to index	SRI(s), $N_{\text{SRS}} = 3$	Bit field mapped to index	SRI(s), $N_{\text{SRS}} = 4$
0	0	0	0	0	0
1	1	1	1	1	1
		2	2	2	2
		3	reserved	3	3

Table 7.3.1.1.2-29: SRI indication for non-codebook based PUSCH transmission,  $L_{\max} = 2$ 

Bit field mapped to index	SRI(s), $N_{\text{SRS}} = 2$	Bit field mapped to index	SRI(s), $N_{\text{SRS}} = 3$	Bit field mapped to index	SRI(s), $N_{\text{SRS}} = 4$
0	0	0	0	0	0
1	1	1	1	1	1
2	0,1	2	2	2	2
3	reserved	3	0,1	3	3
		4	0,2	4	0,1
		5	1,2	5	0,2
		6-7	reserved	6	0,3
				7	1,2
				8	1,3
				9	2,3
				10-15	reserved

Table 7.3.1.1.2-30: SRI indication for non-codebook based PUSCH transmission,  $L_{\max} = 3$ 

Bit field mapped to index	SRI(s), $N_{\text{SRS}} = 2$	Bit field mapped to index	SRI(s), $N_{\text{SRS}} = 3$	Bit field mapped to index	SRI(s), $N_{\text{SRS}} = 4$
0	0	0	0	0	0
1	1	1	1	1	1
2	0,1	2	2	2	2
3	reserved	3	0,1	3	3
		4	0,2	4	0,1
		5	1,2	5	0,2
		6	0,1,2	6	0,3
		7	reserved	7	1,2
				8	1,3
				9	2,3
				10	0,1,2
				11	0,1,3
				12	0,2,3
				13	1,2,3
				14-15	reserved



**Table 7.3.1.1.2-31: SRI indication for non-codebook based PUSCH transmission,  $L_{\max} = 4$**

Bit field mapped to index	SRI(s), $N_{SRS} = 2$	Bit field mapped to index	SRI(s), $N_{SRS} = 3$	Bit field mapped to index	SRI(s), $N_{SRS} = 4$
0	0	0	0	0	0
1	1	1	1	1	1
2	0,1	2	2	2	2
3	reserved	3	0,1	3	3
		4	0,2	4	0,1
		5	1,2	5	0,2
		6	0,1,2	6	0,3
		7	reserved	7	1,2
				8	1,3
				9	2,3
				10	0,1,2
				11	0,1,3
				12	0,2,3
				13	1,2,3
				14	0,1,2,3
				15	reserved

**Table 7.3.1.1.2-32: SRI indication for codebook based PUSCH transmission, if *ul-FullPowerTransmission* is not configured, or *ul-FullPowerTransmission* = *fullpowerMode1*, or *ul-FullPowerTransmission* = *fullpowerMode2*, or *ul-FullPowerTransmission* = *fullpower* and  $N_{SRS} = 2$**

Bit field mapped to index	SRI(s), $N_{SRS} = 2$
0	0
1	1

**Table 7.3.1.1.2-32A: SRI indication for codebook based PUSCH transmission, if *ul-FullPowerTransmission* = *fullpowerMode2* and  $N_{SRS} = 3$**

Bit field mapped to index	SRI(s), $N_{SRS} = 3$
0	0
1	1
2	2
3	Reserved

**Table 7.3.1.1.2-32B: SRI indication for codebook based PUSCH transmission, if *ul-FullPowerTransmission* = *fullpowerMode2* and  $N_{SRS} = 4$**

Bit field mapped to index	SRI(s), $N_{SRS} = 4$
0	0
1	1
2	2
3	3

**Table 7.3.1.1.2-33: Joint indication of minimum applicable scheduling offset K0/K2**

Bit field mapped to index	Minimum applicable K0 for the active DL BWP, if <i>minimumSchedulingOffsetK0</i> is configured for the DL BWP	Minimum applicable K2 for the active UL BWP, if <i>minimumSchedulingOffsetK2</i> is configured for the UL BWP
0	The first value configured by <i>minimumSchedulingOffsetK0</i> for the active DL BWP	The first value configured by <i>minimumSchedulingOffsetK2</i> for the active UL BWP
1	The second value configured by <i>minimumSchedulingOffsetK0</i> for the active DL BWP if the second value is configured; 0 otherwise	The second value configured by <i>minimumSchedulingOffsetK2</i> for the active UL BWP if the second value is configured; 0 otherwise

**Table 7.3.1.1.2-34: Redundancy version**

Value of the Redundancy version field	Value of $rv_{id}$ to be applied
0	0
1	2

**Table 7.3.1.1.2-35: Allowed entries for DCI format 0\_1, configured by higher layer parameter *ul-AccessConfigListDCI-0-1***

Entry index	Channel Access Type	The CP extension T_"ext" index defined in Clause 5.3.1 of [4, 38.211]	CAPC
0	Type2C-ULChannelAccess defined in [clause 4.2.1.2.3 in 37.213]	0	1
1	Type2C-ULChannelAccess defined in [clause 4.2.1.2.3 in 37.213]	0	2
2	Type2C-ULChannelAccess defined in [clause 4.2.1.2.3 in 37.213]	0	3
3	Type2C-ULChannelAccess defined in [clause 4.2.1.2.3 in 37.213]	0	4
4	Type2C-ULChannelAccess defined in [clause 4.2.1.2.3 in 37.213]	2	1
5	Type2C-ULChannelAccess defined in [clause 4.2.1.2.3 in 37.213]	2	2
6	Type2C-ULChannelAccess defined in [clause 4.2.1.2.3 in 37.213]	2	3
7	Type2C-ULChannelAccess defined in [clause 4.2.1.2.3 in 37.213]	2	4
8	Type2B-ULChannelAccess defined in [clause 4.2.1.2.3 in 37.213]	0	1
9	Type2B-ULChannelAccess defined in [clause 4.2.1.2.3 in 37.213]	0	2
10	Type2B-ULChannelAccess defined in [clause 4.2.1.2.3 in 37.213]	0	3
11	Type2B-ULChannelAccess defined in [clause 4.2.1.2.3 in 37.213]	0	4
12	Type2B-ULChannelAccess defined in [clause 4.2.1.2.3 in 37.213]	2	1
13	Type2B-ULChannelAccess defined in [clause 4.2.1.2.3 in 37.213]	2	2
14	Type2B-ULChannelAccess defined in [clause 4.2.1.2.3 in 37.213]	2	3
15	Type2B-ULChannelAccess defined in [clause 4.2.1.2.3 in 37.213]	2	4
16	Type2A-ULChannelAccess defined in [clause 4.2.1.2.1 in 37.213]	0	1
17	Type2A-ULChannelAccess defined in [clause 4.2.1.2.1 in 37.213]	0	2
18	Type2A-ULChannelAccess defined in [clause 4.2.1.2.1 in 37.213]	0	3
19	Type2A-ULChannelAccess defined in [clause 4.2.1.2.1 in 37.213]	0	4
20	Type2A-ULChannelAccess defined in [clause 4.2.1.2.1 in 37.213]	1	1
21	Type2A-ULChannelAccess defined in [clause 4.2.1.2.1 in 37.213]	1	2
22	Type2A-ULChannelAccess defined in [clause 4.2.1.2.1 in 37.213]	1	3
23	Type2A-ULChannelAccess defined in [clause 4.2.1.2.1 in 37.213]	1	4
24	Type2A-ULChannelAccess defined in [clause 4.2.1.2.1 in 37.213]	3	1
25	Type2A-ULChannelAccess defined in [clause 4.2.1.2.1 in 37.213]	3	2
26	Type2A-ULChannelAccess defined in [clause 4.2.1.2.1 in 37.213]	3	3
27	Type2A-ULChannelAccess defined in [clause 4.2.1.2.1 in 37.213]	3	4
28	Type1-ULChannelAccess defined in [clause 4.2.1.1 in 37.213]	0	1
29	Type1-ULChannelAccess defined in [clause 4.2.1.1 in 37.213]	0	2
30	Type1-ULChannelAccess defined in [clause 4.2.1.1 in 37.213]	0	3
31	Type1-ULChannelAccess defined in [clause 4.2.1.1 in 37.213]	0	4
32	Type1-ULChannelAccess defined in [clause 4.2.1.1 in 37.213]	1	1
33	Type1-ULChannelAccess defined in [clause 4.2.1.1 in 37.213]	1	2
34	Type1-ULChannelAccess defined in [clause 4.2.1.1 in 37.213]	1	3
35	Type1-ULChannelAccess defined in [clause 4.2.1.1 in 37.213]	1	4
36	Type1-ULChannelAccess defined in [clause 4.2.1.1 in 37.213]	2	1
37	Type1-ULChannelAccess defined in [clause 4.2.1.1 in 37.213]	2	2
38	Type1-ULChannelAccess defined in [clause 4.2.1.1 in 37.213]	2	3
39	Type1-ULChannelAccess defined in [clause 4.2.1.1 in 37.213]	2	4
40	Type1-ULChannelAccess defined in [clause 4.2.1.1 in 37.213]	3	1
41	Type1-ULChannelAccess defined in [clause 4.2.1.1 in 37.213]	3	2
42	Type1-ULChannelAccess defined in [clause 4.2.1.1 in 37.213]	3	3
43	Type1-ULChannelAccess defined in [clause 4.2.1.1 in 37.213]	3	4

### 7.3.1.1.3 Format 0\_2

DCI format 0\_2 is used for the scheduling of PUSCH in one cell.

The following information is transmitted by means of the DCI format 0\_2 with CRC scrambled by C-RNTI or CS-RNTI or SP-CSI-RNTI or MCS-C-RNTI:

- Identifier for DCI formats – 1 bit
  - The value of this bit field is always set to 0, indicating an UL DCI format
- Carrier indicator – 0, 1, 2 or 3 bits determined by higher layer parameter *carrierIndicatorSizeDCI-0-2*, as defined in Clause 10.1 of [5, TS38.213].
- UL/SUL indicator – 0 bit for UEs not configured with *supplementaryUplink* in *ServingCellConfig* in the cell or UEs configured with *supplementaryUplink* in *ServingCellConfig* in the cell but only one carrier in the cell is configured for PUSCH transmission; otherwise, 1 bit as defined in Table 7.3.1.1.1-1.

- Bandwidth part indicator – 0, 1 or 2 bits as determined by the number of UL BWPs  $n_{BWP,RRC}$  configured by higher layers, excluding the initial UL bandwidth part. The bitwidth for this field is determined as  $\lceil \log_2(n_{BWP}) \rceil$  bits, where
  - $n_{BWP} = n_{BWP,RRC} + 1$  if  $n_{BWP,RRC} \leq 3$ , in which case the bandwidth part indicator is equivalent to the ascending order of the higher layer parameter *BWP-Id*;
  - otherwise  $n_{BWP} = n_{BWP,RRC}$ , in which case the bandwidth part indicator is defined in Table 7.3.1.1.2-1;

If a UE does not support active BWP change via DCI, the UE ignores this bit field.

- Frequency domain resource assignment – number of bits determined by the following:
  - $N_{RBG}$  bits if only resource allocation type 0 is configured, where  $N_{RBG}$  is defined in Clause 6.1.2.2.1 of [6, TS 38.214]
  - $\lceil \log_2(N_{RBG,K1}(N_{RBG,K1} + 1)/2) \rceil$  bits if only resource allocation type 1 is configured, or  $\max(\lceil \log_2(N_{RBG,K1}(N_{RBG,K1} + 1)/2) \rceil, N_{RBG}) + 1$  bits if *resourceAllocationDCI-0-2-r16* is configured as 'dynamicSwitch', where  $N_{RBG,K1} = \lceil (N_{RB}^{UL,BWP} + (N_{UL,BWP}^{start} \bmod K1)) / K1 \rceil$ ,  $N_{RB}^{UL,BWP}$  is the size of the active UL bandwidth part,  $N_{UL,BWP}^{start}$  is defined as in clause 4.4.4.4 of [4, TS 38.211] and  $K1$  is given by higher layer parameter *resourceAllocationType1GranularityDCI-0-2*. If the higher layer parameter *resourceAllocationType1GranularityDCI-0-2* is not configured,  $K1$  is equal to 1.
  - If *resourceAllocationDCI-0-2-r16* is configured as 'dynamicSwitch', the MSB bit is used to indicate resource allocation type 0 or resource allocation type 1, where the bit value of 0 indicates resource allocation type 0 and the bit value of 1 indicates resource allocation type 1.
  - For resource allocation type 0, the  $N_{RBG}$  LSBs provide the resource allocation as defined in Clause 6.1.2.2.1 of [6, TS 38.214].
  - For resource allocation type 1, the  $\lceil \log_2(N_{RBG,K1}(N_{RBG,K1} + 1)/2) \rceil$  LSBs provide the resource allocation as follows:
    - For PUSCH hopping with resource allocation type 1:
      - $N_{UL,hop}$  MSB bits are used to indicate the frequency offset according to Clause 6.3 of [6, TS 38.214], where  $N_{UL,hop} = 1$  if the higher layer parameter *frequencyHoppingOffsetListsDCI-0-2* contains two offset values and  $N_{UL,hop} = 2$  if the higher layer parameter *frequencyHoppingOffsetListsDCI-0-2* contains four offset values
      - $\lceil \log_2(N_{RBG,K1}(N_{RBG,K1} + 1)/2) \rceil - N_{UL,hop}$  bits provide the frequency domain resource allocation according to Clause 6.1.2.2.2 of [6, TS 38.214]
    - For non-PUSCH hopping with resource allocation type 1:
      - $\lceil \log_2(N_{RBG,K1}(N_{RBG,K1} + 1)/2) \rceil$  bits provide the frequency domain resource allocation according to Clause 6.1.2.2.2 of [6, TS 38.214]

If "Bandwidth part indicator" field indicates a bandwidth part other than the active bandwidth part and if *resourceAllocationDCI-0-2-r16* is configured as 'dynamicSwitch' for the indicated bandwidth part, the UE assumes resource allocation type 0 for the indicated bandwidth part if the bitwidth of the "Frequency domain resource assignment" field of the active bandwidth part is smaller than the bitwidth of the "Frequency domain resource assignment" field of the indicated bandwidth part.

- Time domain resource assignment – 0, 1, 2, 3, 4, 5 or 6 bits as defined in Clause 6.1.2.1 of [6, TS38.214]. The bitwidth for this field is determined as  $\lceil \log_2(I) \rceil$  bits, where  $I$  is the number of entries in the higher layer parameter *pusch-TimeDomainAllocationListDCI-0-2* if the higher layer parameter is configured, or  $I$  is the number of entries in the higher layer parameter *PUSCH-TimeDomainResourceAllocationList* if the higher layer parameter *PUSCH-TimeDomainResourceAllocationList* is configured and the higher layer parameter *pusch-TimeDomainAllocationListDCI-0-2* is not configured; otherwise  $I$  is the number of entries in the default table.
- Frequency hopping flag – 0 or 1 bit:

- 0 bit if the higher layer parameter *frequencyHoppingDCI-0-2* is not configured;
- 1 bit according to Table 7.3.1.1.1-3 otherwise, only applicable to resource allocation type 1, as defined in Clause 6.3 of [6, TS 38.214].
- Modulation and coding scheme – 5 bits as defined in Clause 6.1.4.1 of [6, TS 38.214]
- New data indicator – 1 bit
- Redundancy version – 0, 1 or 2 bits determined by higher layer parameter *numberOfBitsForRV-DCI-0-2*
  - If 0 bit is configured, *rv<sub>id</sub>* to be applied is 0;
  - 1 bit according to Table 7.3.1.2.3-1;
  - 2 bits according to Table 7.3.1.1.1-2.
- HARQ process number – 0, 1, 2, 3 or 4 bits determined by higher layer parameter *harq-ProcessNumberSizeDCI-0-2*
- Downlink assignment index – 0, 1, 2 or 4 bits
  - 0 bit if the higher layer parameter *downlinkAssignmentIndexDCI-0-2* is not configured;
  - 1, 2 or 4 bits otherwise,
    - 1<sup>st</sup> downlink assignment index – 1 or 2 bits:
      - 1 bit for semi-static HARQ-ACK codebook;
      - 2 bits for dynamic HARQ-ACK codebook.
    - 2<sup>nd</sup> downlink assignment index – 0 or 2 bits
      - 2 bits for dynamic HARQ-ACK codebook with two HARQ-ACK sub-codebooks;
      - 0 bit otherwise.

When two HARQ-ACK codebooks are configured for the same serving cell and if higher layer parameter *priorityIndicatorDCI-0-2* is configured, if the bit width of the Downlink assignment index in DCI format 0\_2 for one HARQ-ACK codebook is not equal to that of the Downlink assignment index in DCI format 0\_2 for the other HARQ-ACK codebook, a number of most significant bits with value set to '0' are inserted to smaller Downlink assignment index until the bit width of the Downlink assignment index in DCI format 0\_2 for the two HARQ-ACK codebooks are the same.

- TPC command for scheduled PUSCH – 2 bits as defined in Clause 7.1.1 of [5, TS38.213]
- SRS resource indicator –  $\left\lceil \log_2 \left( \sum_{k=1}^{\min\{L_{max}, N_{SRS,0,2}\}} \binom{N_{SRS,0,2}}{k} \right) \right\rceil$  or  $\left\lceil \log_2 N_{SRS,0,2} \right\rceil$  bits, where  $N_{SRS,0,2}$  is the number of configured SRS resources in the SRS resource set configured by higher layer parameter *srs-ResourceSetToAddModListDCI-0-2*, and associated with the higher layer parameter *usage* of value 'codeBook' or 'nonCodeBook', where the SRS resource set is composed of the first  $N_{SRS,0,2}$  SRS resources together with other configurations in the SRS resource set configured by higher layer parameter *srs-ResourceSetToAddModList*, if any, and associated with the higher layer parameter *usage* of value 'codeBook' or 'nonCodeBook', respectively
- $\left\lceil \log_2 \left( \sum_{k=1}^{\min\{L_{max}, N_{SRS,0,2}\}} \binom{N_{SRS,0,2}}{k} \right) \right\rceil$  bits according to Tables 7.3.1.1.2-28/29/30/31 if the higher layer parameter *txConfig = nonCodebook*, where  $N_{SRS,0,2}$  is the number of configured SRS resources in the SRS resource set configured by higher layer parameter *srs-ResourceSetToAddModListDCI-0-2*, and associated with the higher layer parameter *usage* of value 'nonCodeBook', where the SRS resource set is composed of the first  $N_{SRS,0,2}$  SRS resources together with other configurations in the SRS resource set configured by higher layer parameter *srs-ResourceSetToAddModList*, if any, and associated with the higher layer parameter *usage* of value 'nonCodeBook', and
  - if UE supports operation with *maxMIMO-LayersDCI-0-2* and the higher layer parameter *maxMIMO-LayersDCI-0-2* of *PUSCH-ServingCellConfig* of the serving cell is configured,  $L_{max}$  is given by that parameter

- otherwise,  $L_{max}$  is given by the maximum number of layers for PUSCH supported by the UE for the serving cell for non-codebook based operation.
- $\lceil \log_2 N_{SRS,0,2} \rceil$  bits according to Tables 7.3.1.1.2-32 if the higher layer parameter  $txConfig = codebook$ , where  $N_{SRS,0,2}$  is the number of configured SRS resources in the SRS resource set configured by higher layer parameter  $srs-ResourceSetToAddModListDCI-0-2$ , and associated with the higher layer parameter  $usage$  of value 'codeBook', where the SRS resource set is composed of the first  $N_{SRS,0,2}$  SRS resources together with other configurations in the SRS resource set configured by higher layer parameter  $srs-ResourceSetToAddModList$ , if any, and associated with the higher layer parameter  $usage$  of value 'codeBook'.
- Precoding information and number of layers – number of bits determined by the following:
  - 0 bits if the higher layer parameter  $txConfig = nonCodeBook$ ;
  - 0 bits for 1 antenna port and if the higher layer parameter  $txConfig = codebook$ ;
  - 4, 5, or 6 bits according to Table 7.3.1.1.2-2 for 4 antenna ports, if  $txConfig = codebook$ ,  $ul-FullPowerTransmission$  is not configured or configured to  $fullpowerMode2$  or configured to  $fullpower$ , and according to whether transform precoder is enabled or disabled, and the values of higher layer parameters  $maxRankDCI-0-2$ , and  $codebookSubsetDCI-0-2$ ;
  - 4 or 5 bits according to Table 7.3.1.1.2-2A for 4 antenna ports, if  $txConfig = codebook$ ,  $ul-FullPowerTransmission = fullpowerMode1$ , the values of higher layer parameters  $maxRankDCI-0-2=2$ , transform precoder is disabled, and according to the value of higher layer parameter  $codebookSubsetDCI-0-2$ ;
  - 4 or 6 bits according to Table 7.3.1.1.2-2B for 4 antenna ports, if  $txConfig = codebook$ ,  $ul-FullPowerTransmission = fullpowerMode1$ , the values of higher layer parameters  $maxRankDCI-0-2=3$  or  $4$ , transform precoder is disabled, and according to the value of higher layer parameter  $codebookSubsetDCI-0-2$ ;
  - 2, 4, or 5 bits according to Table 7.3.1.1.2-3 for 4 antenna ports, if  $txConfig = codebook$ ,  $ul-FullPowerTransmission$  is not configured or configured to  $fullpowerMode2$  or configured to  $fullpower$ , and according to whether transform precoder is enabled or disabled, and the values of higher layer parameters  $maxRankDCI-0-2$  and  $codebookSubsetDCI-0-2$ ;
  - 3 or 4 bits according to Table 7.3.1.1.2-3A for 4 antenna ports, if  $txConfig = codebook$ ,  $ul-FullPowerTransmission = fullpowerMode1$ ,  $maxRankDCI-0-2=1$ , and according to whether transform precoder is enabled or disabled, and the value of higher layer parameter  $codebookSubsetDCI-0-2$ ;
  - 2 or 4 bits according to Table 7.3.1.1.2-4 for 2 antenna ports, if  $txConfig = codebook$ ,  $ul-FullPowerTransmission$  is not configured or configured to  $fullpowerMode2$  or configured to  $fullpower$ , and according to whether transform precoder is enabled or disabled, and the values of higher layer parameters  $maxRankDCI-0-2$  and  $codebookSubsetDCI-0-2$ ;
  - 2 bits according to Table 7.3.1.1.2-4A for 2 antenna ports, if  $txConfig = codebook$ ,  $ul-FullPowerTransmission = fullpowerMode1$ , transform precoder is disabled, the  $maxRankDCI-0-2=2$ , and  $codebookSubsetDCI-0-2=nonCoherent$ ;
  - 1 or 3 bits according to Table 7.3.1.1.2-5 for 2 antenna ports, if  $txConfig = codebook$ ,  $ul-FullPowerTransmission$  is not configured or configured to  $fullpowerMode2$  or configured to  $fullpower$ , and according to whether transform precoder is enabled or disabled, and the values of higher layer parameters  $maxRankDCI-0-2$  and  $codebookSubsetDCI-0-2$ ;
  - 2 bits according to Table 7.3.1.1.2-5A for 2 antenna ports, if  $txConfig = codebook$ ,  $ul-FullPowerTransmission = fullpowerMode1$ ,  $maxRankDCI-0-2=1$ , and according to whether transform precoder is enabled or disabled, and the value of higher layer parameter  $codebookSubsetDCI-0-2$ .

For the higher layer parameter  $txConfig=codebook$ , if  $ul-FullPowerTransmission$  is configured to  $fullpowerMode2$ , the values of higher layer parameters  $maxRankDCI-0-2$  is configured to be larger than 2, and at least one SRS resource with 4 antenna ports is configured in an SRS resource set with usage set to 'codebook' and an SRS resource with 2 antenna ports is indicated via SRI in the same SRS resource set, then Table 7.3.1.1.2-4 is used.

For the higher layer parameter  $txConfig = codebook$ , if different SRS resources with different number of antenna ports are configured, the bitwidth is determined according to the maximum number of ports in an SRS resource among the configured SRS resources in an SRS resource set with usage set to 'codebook'. If the number of ports for

a configured SRS resource in the set is less than the maximum number of ports in an SRS resource among the configured SRS resources, a number of most significant bits with value set to '0' are inserted to the field.

- Antenna ports – number of bits determined by the following:
  - 0 bit if higher layer parameter *antennaPortsFieldPresenceDCI-0-2* is not configured;
  - 2, 3, 4, or 5 bits otherwise,
    - 2 bits as defined by Tables 7.3.1.1.2-6, if transform precoder is enabled, *dmrs-Type=1*, and *maxLength=1*, except that *dmrs-UplinkTransformPrecoding* and *tp-pi2BPSK* are both configured and  $\pi/2$  BPSK modulation is used;
    - 2 bits as defined by 7.3.1.1.2-6A, if transform precoder is enabled, and *dmrs-UplinkTransformPrecoding* and *tp-pi2BPSK* are both configured,  $\pi/2$  BPSK modulation is used, *dmrs-Type=1*, and *maxLength=1*, where  $n_{SCID}$  is the scrambling identity for antenna ports defined in Clause 6.4.1.1.1.2, in [4, TS38.211];
    - 4 bits as defined by Tables 7.3.1.1.2-7, if transform precoder is enabled, *dmrs-Type=1*, and *maxLength=2*, except that *dmrs-UplinkTransformPrecoding* and *tp-pi2BPSK* are both configured and  $\pi/2$  BPSK modulation is used;
    - 4 bits as defined by Tables 7.3.1.1.2-7A, if transform precoder is enabled, and *dmrs-UplinkTransformPrecoding* and *tp-pi2BPSK* are both configured,  $\pi/2$  BPSK modulation is used, *dmrs-Type=1*, and *maxLength=2*, where  $n_{SCID}$  is the scrambling identity for antenna ports defined in Clause 6.4.1.1.1.2, in [4, TS38.211];
    - 3 bits as defined by Tables 7.3.1.1.2-8/9/10/11, if transform precoder is disabled, *dmrs-Type=1*, and *maxLength=1*, and the value of rank is determined according to the SRS resource indicator field if the higher layer parameter *txConfig = nonCodebook* and according to the Precoding information and number of layers field if the higher layer parameter *txConfig = codebook*;
    - 4 bits as defined by Tables 7.3.1.1.2-12/13/14/15, if transform precoder is disabled, *dmrs-Type=1*, and *maxLength=2*, and the value of rank is determined according to the SRS resource indicator field if the higher layer parameter *txConfig = nonCodebook* and according to the Precoding information and number of layers field if the higher layer parameter *txConfig = codebook*;
    - 4 bits as defined by Tables 7.3.1.1.2-16/17/18/19, if transform precoder is disabled, *dmrs-Type=2*, and *maxLength=1*, and the value of rank is determined according to the SRS resource indicator field if the higher layer parameter *txConfig = nonCodebook* and according to the Precoding information and number of layers field if the higher layer parameter *txConfig = codebook*;
    - 5 bits as defined by Tables 7.3.1.1.2-20/21/22/23, if transform precoder is disabled, *dmrs-Type=2*, and *maxLength=2*, and the value of rank is determined according to the SRS resource indicator field if the higher layer parameter *txConfig = nonCodebook* and according to the Precoding information and number of layers field if the higher layer parameter *txConfig = codebook*.

where the number of CDM groups without data of values 1, 2, and 3 in Tables 7.3.1.1.2-6 to 7.3.1.1.2-23 refers to CDM groups {0}, {0,1}, and {0, 1,2} respectively.

If a UE is configured with both *dmrs-UplinkForPUSCH-MappingTypeA-DCI-0-2* and *dmrs-UplinkForPUSCH-MappingTypeB-DCI-0-2* and is configured with *antennaPortsFieldPresenceDCI-0-2*, the bitwidth of this field equals  $\max\{x_A, x_B\}$ , where  $x_A$  is the "Antenna ports" bitwidth derived according to *dmrs-UplinkForPUSCH-MappingTypeA-DCI-0-2* and  $x_B$  is the "Antenna ports" bitwidth derived according to *dmrs-UplinkForPUSCH-MappingTypeB-DCI-0-2*. A number of  $|x_A - x_B|$  zeros are padded in the MSB of this field, if the mapping type of the PUSCH corresponds to the smaller value of  $x_A$  and  $x_B$ .

If a UE is not configured with higher layer parameter *antennaPortsFieldPresenceDCI-0-2*, antenna port(s) are defined assuming bit field index value 0 in Tables 7.3.1.1.2-6 to 7.3.1.1.2-23.

- SRS request – 0, 1, 2 or 3 bits
  - 0 bit if the higher layer parameter *srs-RequestDCI-0-2* is not configured;
  - 1 bit as defined by Table 7.3.1.1.3-1 if higher layer parameter *srs-RequestDCI-0-2 = 1* and for UEs not configured with *supplementaryUplink* in *ServingCellConfig* in the cell;

- 2 bits if higher layer parameter *srs-RequestDCI-0-2* = 1 and for UEs configured with *supplementaryUplink* in *ServingCellConfig* in the cell, where the first bit is the non-SUL/SUL indicator as defined in Table 7.3.1.1.1-1 and the second bit is defined by Table 7.3.1.1.3-1;
- 2 bits as defined by Table 7.3.1.1.2-24 if higher layer parameter *srs-RequestDCI-0-2* = 2 and for UEs not configured with *supplementaryUplink* in *ServingCellConfig* in the cell;
- 3 bits if higher layer parameter *srs-RequestDCI-0-2* = 2 and for UEs configured with *supplementaryUplink* in *ServingCellConfig* in the cell, where the first bit is the non-SUL/SUL indicator as defined in Table 7.3.1.1.1-1 and the second and third bits are defined by Table 7.3.1.1.2-24;
- CSI request – 0, 1, 2, 3, 4, 5, or 6 bits determined by higher layer parameter *reportTriggerSizeDCI-0-2*.
- PTRS-DMRS association – number of bits determined as follows
  - 0 bit if *PTRS-UplinkConfig* is not configured in either *dmrs-UplinkForPUSCH-MappingTypeA* or *dmrs-UplinkForPUSCH-MappingTypeB* and transform precoder is disabled, or if transform precoder is enabled, or if *maxRankDCI-0-2*=1;
  - 2 bits otherwise, where Table 7.3.1.1.2-25 and 7.3.1.1.2-26 are used to indicate the association between PTRS port(s) and DMRS port(s) when one PT-RS port and two PT-RS ports are configured by *maxNrofPorts* in *PTRS-UplinkConfig* respectively, and the DMRS ports are indicated by the Antenna ports field.

If "Bandwidth part indicator" field indicates a bandwidth part other than the active bandwidth part and the "PTRS-DMRS association" field is present for the indicated bandwidth part but not present for the active bandwidth part, the UE assumes the "PTRS-DMRS association" field is not present for the indicated bandwidth part.

- *beta\_offset* indicator – 0 bit if the higher layer parameter *betaOffsets* = *semiStatic*; otherwise 1 bit if 2 offset indexes are configured by higher layer parameter *dynamicDCI-0-2* as defined by Table 9.3-3A in [5, TS 38.213], and 2 bits if 4 offset indexes are configured by higher layer parameter *dynamicDCI-0-2* as defined by Table 9.3-3 in [5, TS 38.213].

When two HARQ-ACK codebooks are configured for the same serving cell and if higher layer parameter *priorityIndicatorDCI-0-2* is configured, if the bit width of the *beta\_offset* indicator in DCI format 0\_2 for one HARQ-ACK codebook is not equal to that of the *beta\_offset* indicator in DCI format 0\_2 for the other HARQ-ACK codebook, a number of most significant bits with value set to '0' are inserted to smaller *beta\_offset* indicator until the bit width of the *beta\_offset* indicator in DCI format 0\_2 for the two HARQ-ACK codebooks are the same.

- DMRS sequence initialization – 0 or 1 bit
  - 0 bit if the higher layer parameter *dmrs-SequenceInitializationDCI-0-2* is not configured or if transform precoder is enabled;
  - 1 bit if transform precoder is disabled and the higher layer parameter *dmrs-SequenceInitializationDCI-0-2* is configured.
- UL-SCH indicator – 1 bit. A value of "1" indicates UL-SCH shall be transmitted on the PUSCH and a value of "0" indicates UL-SCH shall not be transmitted on the PUSCH. Except for DCI format 0\_2 with CRC scrambled by SP-CSI-RNTI, a UE is not expected to receive a DCI format 0\_2 with UL-SCH indicator of "0" and CSI request of all zero(s).
- Open-loop power control parameter set indication – 0 or 1 or 2 bits.
  - 0 bit if the higher layer parameter *p0-PUSCH-SetList* is not configured;
  - 1 or 2 bits otherwise,
    - 1 bit if SRS resource indicator is present in the DCI format 0\_2;
    - 1 or 2 bits as determined by higher layer parameter *olpc-ParameterSetDCI-0-2* if SRS resource indicator is not present in the DCI format 0\_2;



- Priority indicator – 0 bit if higher layer parameter *priorityIndicatorDCI-0-2* is not configured; otherwise 1 bit as defined in Clause 9 in [5, TS 38.213].
- Invalid symbol pattern indicator – 0 bit if higher layer parameter *invalidSymbolPatternIndicatorDCI-0-2* is not configured; otherwise 1 bit as defined in Clause 6.1.2.1 in [6, TS 38.214].

A UE does not expect that the bit width of a field in DCI format 0\_2 with CRC scrambled by CS-RNTI is larger than corresponding bit width of same field in DCI format 0\_2 with CRC scrambled by C-RNTI for the same serving cell. If the bit width of a field in the DCI format 0\_2 with CRC scrambled by CS-RNTI is not equal to that of the corresponding field in the DCI format 0\_2 with CRC scrambled by C-RNTI for the same serving cell, a number of most significant bits with value set to '0' are inserted to the field in DCI format 0\_2 with CRC scrambled by CS-RNTI until the bit width equals that of the corresponding field in the DCI format 0\_2 with CRC scrambled by C-RNTI for the same serving cell.

**Table 7.3.1.1.3-1: 1 bit SRS request in DCI format 0\_2 and DCI format 1\_2**

Value of SRS request field	Triggered aperiodic SRS resource set(s) for DCI format 0_2 and 1_2
0	No aperiodic SRS resource set triggered
1	SRS resource set(s) configured with higher layer parameter <i>aperiodicSRS-ResourceTrigger</i> set to 1 or an entry in <i>aperiodicSRS-ResourceTriggerList</i> set to 1

## 7.3.1.2 DCI formats for scheduling of PDSCH

### 7.3.1.2.1 Format 1\_0

DCI format 1\_0 is used for the scheduling of PDSCH in one DL cell.

The following information is transmitted by means of the DCI format 1\_0 with CRC scrambled by C-RNTI or CS-RNTI or MCS-C-RNTI:

- Identifier for DCI formats – 1 bits
  - The value of this bit field is always set to 1, indicating a DL DCI format
- Frequency domain resource assignment –  $\lceil \log_2(N_{RB}^{DL,BWP}(N_{RB}^{DL,BWP} + 1)/2) \rceil$  bits where  $N_{RB}^{DL,BWP}$  is given by clause 7.3.1.0

If the CRC of the DCI format 1\_0 is scrambled by C-RNTI and the "Frequency domain resource assignment" field are of all ones, the DCI format 1\_0 is for random access procedure initiated by a PDCCH order, with all remaining fields set as follows:

- Random Access Preamble index – 6 bits according to *ra-PreambleIndex* in Clause 5.1.2 of [8, TS38.321]
- UL/SUL indicator – 1 bit. If the value of the "Random Access Preamble index" is not all zeros and if the UE is configured with *supplementaryUplink* in *ServingCellConfig* in the cell, this field indicates which UL carrier in the cell to transmit the PRACH according to Table 7.3.1.1.1-1; otherwise, this field is reserved
- SS/PBCH index – 6 bits. If the value of the "Random Access Preamble index" is not all zeros, this field indicates the SS/PBCH that shall be used to determine the RACH occasion for the PRACH transmission; otherwise, this field is reserved.
- PRACH Mask index – 4 bits. If the value of the "Random Access Preamble index" is not all zeros, this field indicates the RACH occasion associated with the SS/PBCH indicated by "SS/PBCH index" for the PRACH transmission, according to Clause 5.1.1 of [8, TS38.321]; otherwise, this field is reserved
- Reserved bits – 12 bits for operation in a cell with shared spectrum channel access; otherwise 10 bits

Otherwise, all remaining fields are set as follows:

- Time domain resource assignment – 4 bits as defined in Clause 5.1.2.1 of [6, TS 38.214]
- VRB-to-PRB mapping – 1 bit according to Table 7.3.1.2.2-5
- Modulation and coding scheme – 5 bits as defined in Clause 5.1.3 of [6, TS 38.214]
- New data indicator – 1 bit
- Redundancy version – 2 bits as defined in Table 7.3.1.1.1-2
- HARQ process number – 4 bits
- Downlink assignment index – 2 bits as defined in Clause 9.1.3 of [5, TS 38.213], as counter DAI
- TPC command for scheduled PUCCH – 2 bits as defined in Clause 7.2.1 of [5, TS 38.213]
- PUCCH resource indicator – 3 bits as defined in Clause 9.2.3 of [5, TS 38.213]
- PDSCH-to-HARQ\_feedback timing indicator – 3 bits as defined in Clause 9.2.3 of [5, TS38.213]
- ChannelAccess-CPext – 2 bits indicating combinations of channel access type and CP extension as defined in Table 7.3.1.1.1-4, or Table 7.3.1.1.1.4A, if *ChannelAccessMode-r16* = "semistatic" is provided for operation in a cell with shared spectrum channel access; 0 bits otherwise

The following information is transmitted by means of the DCI format 1\_0 with CRC scrambled by P-RNTI:

- Short Messages Indicator – 2 bits according to Table 7.3.1.2.1-1.
- Short Messages – 8 bits, according to Clause 6.5 of [9, TS38.331]. If only the scheduling information for Paging is carried, this bit field is reserved.
- Frequency domain resource assignment –  $\left\lceil \log_2 (N_{RB}^{DL,BWP} (N_{RB}^{DL,BWP} + 1) / 2) \right\rceil$  bits. If only the short message is carried, this bit field is reserved.
  - $N_{RB}^{DL,BWP}$  is the size of CORESET 0
- Time domain resource assignment – 4 bits as defined in Clause 5.1.2.1 of [6, TS38.214]. If only the short message is carried, this bit field is reserved.
- VRB-to-PRB mapping – 1 bit according to Table 7.3.1.2.2-5. If only the short message is carried, this bit field is reserved.
- Modulation and coding scheme – 5 bits as defined in Clause 5.1.3 of [6, TS38.214], using Table 5.1.3.1-1. If only the short message is carried, this bit field is reserved.
- TB scaling – 2 bits as defined in Clause 5.1.3.2 of [6, TS38.214]. If only the short message is carried, this bit field is reserved.
- Reserved bits – 8 bits for operation in a cell with shared spectrum channel access; otherwise 6 bits

The following information is transmitted by means of the DCI format 1\_0 with CRC scrambled by SI-RNTI:

- Frequency domain resource assignment –  $\left\lceil \log_2 (N_{RB}^{DL,BWP} (N_{RB}^{DL,BWP} + 1) / 2) \right\rceil$  bits
  - $N_{RB}^{DL,BWP}$  is the size of CORESET 0
- Time domain resource assignment – 4 bits as defined in Clause 5.1.2.1 of [6, TS38.214]
- VRB-to-PRB mapping – 1 bit according to Table 7.3.1.2.2-5

- Modulation and coding scheme – 5 bits as defined in Clause 5.1.3 of [6, TS38.214], using Table 5.1.3.1-1
- Redundancy version – 2 bits as defined in Table 7.3.1.1.1-2
- System information indicator – 1 bit as defined in Table 7.3.1.2.1-2
- Reserved bits – 17 bits for operation in a cell with shared spectrum channel access; otherwise 15 bits

The following information is transmitted by means of the DCI format 1\_0 with CRC scrambled by RA-RNTI or MsgB-RNTI:

- Frequency domain resource assignment –  $\lceil \log_2(N_{RB}^{DL,BWP}(N_{RB}^{DL,BWP} + 1)/2) \rceil$  bits
  - $N_{RB}^{DL,BWP}$  is the size of CORESET 0 if CORESET 0 is configured for the cell and  $N_{RB}^{DL,BWP}$  is the size of initial DL bandwidth part if CORESET 0 is not configured for the cell
- Time domain resource assignment – 4 bits as defined in Clause 5.1.2.1 of [6, TS38.214]
- VRB-to-PRB mapping – 1 bit according to Table 7.3.1.2.2-5
- Modulation and coding scheme – 5 bits as defined in Clause 5.1.3 of [6, TS38.214], using Table 5.1.3.1-1
- TB scaling – 2 bits as defined in Clause 5.1.3.2 of [6, TS38.214]
- LSBs of SFN – 2 bits for the DCI format 1\_0 with CRC scrambled by MsgB-RNTI as defined in Clause 8.2A of [5, TS 38.213] if *msgB-responseWindow* is configured to be larger than 10 ms; or 2 bits for the DCI format 1\_0 with CRC scrambled by RA-RNTI as defined in Clause 8.2 of [5, TS 38.213] for operation in a cell with shared spectrum channel access if *ra-ResponseWindow* or *ra-ResponseWindow-v1610* is configured to be larger than 10 ms; 0 bit otherwise
- Reserved bits – (16 – A) bits for operation in a cell without shared spectrum access, (18 – A) for operation in a cell with shared spectrum access, where the value of A is the number of bits for the field 'LSBs of SFN' as defined above

The following information is transmitted by means of the DCI format 1\_0 with CRC scrambled by TC-RNTI:

- Identifier for DCI formats – 1 bit
  - The value of this bit field is always set to 1, indicating a DL DCI format
- Frequency domain resource assignment –  $\lceil \log_2(N_{RB}^{DL,BWP}(N_{RB}^{DL,BWP} + 1)/2) \rceil$  bits
  - $N_{RB}^{DL,BWP}$  is the size of CORESET 0
- Time domain resource assignment – 4 bits as defined in Clause 5.1.2.1 of [6, TS38.214]
- VRB-to-PRB mapping – 1 bit according to Table 7.3.1.2.2-5
- Modulation and coding scheme – 5 bits as defined in Clause 5.1.3 of [6, TS38.214], using Table 5.1.3.1-1
- New data indicator – 1 bit
- Redundancy version – 2 bits as defined in Table 7.3.1.1.1-2
- HARQ process number – 4 bits
- Downlink assignment index – 2 bits, reserved
- TPC command for scheduled PUCCH – 2 bits as defined in Clause 7.2.1 of [5, TS38.213]
- PUCCH resource indicator – 3 bits as defined in Clause 9.2.3 of [5, TS38.213]
- PDSCH-to-HARQ\_feedback timing indicator – 3 bits as defined in Clause 9.2.3 of [5, TS38.213]

- ChannelAccess-CPext – 2 bits indicating combinations of channel access type and CP extension as defined in Table 7.3.1.1.1-4, or Table 7.3.1.1.1.4A, if *ChannelAccessMode-r16* = "semistatic" is provided for operation in a cell with shared spectrum channel access; otherwise 0 bit

**Table 7.3.1.2.1-1: Short Message indicator**

Bit field	Short Message indicator
00	Reserved
01	Only scheduling information for Paging is present in the DCI
10	Only short message is present in the DCI
11	Both scheduling information for Paging and short message are present in the DCI

**Table 7.3.1.2.1-2: System information indicator**

Bit field	System information indicator
0	SIB1 [9, TS38.331, Clause 5.2.1]
1	SI message [9, TS38.331, Clause 5.2.1]

### 7.3.1.2.2 Format 1\_1

DCI format 1\_1 is used for the scheduling of PDSCH in one cell.

The following information is transmitted by means of the DCI format 1\_1 with CRC scrambled by C-RNTI or CS-RNTI or MCS-C-RNTI:

- Identifier for DCI formats – 1 bits
  - The value of this bit field is always set to 1, indicating a DL DCI format
- Carrier indicator – 0 or 3 bits as defined in Clause 10.1 of [5, TS 38.213].
- Bandwidth part indicator – 0, 1 or 2 bits as determined by the number of DL BWPs  $n_{\text{BWP,RRC}}$  configured by higher layers, excluding the initial DL bandwidth part. The bitwidth for this field is determined as  $\lceil \log_2(n_{\text{BWP}}) \rceil$  bits, where
  - $n_{\text{BWP}} = n_{\text{BWP,RRC}} + 1$  if  $n_{\text{BWP,RRC}} \leq 3$ , in which case the bandwidth part indicator is equivalent to the ascending order of the higher layer parameter *BWP-Id*;
  - otherwise  $n_{\text{BWP}} = n_{\text{BWP,RRC}}$ , in which case the bandwidth part indicator is defined in Table 7.3.1.1.2-1;

If a UE does not support active BWP change via DCI, the UE ignores this bit field.

- Frequency domain resource assignment – number of bits determined by the following, where  $N_{\text{RB}}^{\text{DL,BWP}}$  is the size of the active DL bandwidth part:
  - $N_{\text{RBG}}$  bits if only resource allocation type 0 is configured, where  $N_{\text{RBG}}$  is defined in Clause 5.1.2.2.1 of [6, TS38.214],
  - $\lceil \log_2(N_{\text{RB}}^{\text{DL,BWP}}(N_{\text{RB}}^{\text{DL,BWP}} + 1)/2) \rceil$  bits if only resource allocation type 1 is configured, or
  - $\max\left(\lceil \log_2(N_{\text{RB}}^{\text{DL,BWP}}(N_{\text{RB}}^{\text{DL,BWP}} + 1)/2) \rceil, N_{\text{RBG}}\right) + 1$  bits if *resourceAllocation* is configured as 'dynamicSwitch'.
  - If *resourceAllocation* is configured as 'dynamicSwitch', the MSB bit is used to indicate resource allocation type 0 or resource allocation type 1, where the bit value of 0 indicates resource allocation type 0 and the bit value of 1 indicates resource allocation type 1.

- For resource allocation type 0, the  $N_{\text{RBG}}$  LSBs provide the resource allocation as defined in Clause 5.1.2.2.1 of [6, TS 38.214].
- For resource allocation type 1, the  $\lceil \log_2(N_{\text{RB}}^{\text{DL,BWP}}(N_{\text{RB}}^{\text{DL,BWP}} + 1)/2) \rceil$  LSBs provide the resource allocation as defined in Clause 5.1.2.2.2 of [6, TS 38.214]

If "Bandwidth part indicator" field indicates a bandwidth part other than the active bandwidth part and if *resourceAllocation* is configured as 'dynamicSwitch' for the indicated bandwidth part, the UE assumes resource allocation type 0 for the indicated bandwidth part if the bitwidth of the "Frequency domain resource assignment" field of the active bandwidth part is smaller than the bitwidth of the "Frequency domain resource assignment" field of the indicated bandwidth part.

- Time domain resource assignment – 0, 1, 2, 3, or 4 bits as defined in Clause 5.1.2.1 of [6, TS 38.214]. The bitwidth for this field is determined as  $\lceil \log_2(I) \rceil$  bits, where  $I$  is the number of entries in the higher layer parameter *pdsch-TimeDomainAllocationList* if the higher layer parameter is configured; otherwise  $I$  is the number of entries in the default table.
- VRB-to-PRB mapping – 0 or 1 bit:
  - 0 bit if only resource allocation type 0 is configured or if interleaved VRB-to-PRB mapping is not configured by high layers;
  - 1 bit according to Table 7.3.1.2.2-5 otherwise, only applicable to resource allocation type 1, as defined in Clause 7.3.1.6 of [4, TS 38.211].
- PRB bundling size indicator – 0 bit if the higher layer parameter *prb-BundlingType* is not configured or is set to 'staticBundling', or 1 bit if the higher layer parameter *prb-BundlingType* is set to 'dynamicBundling' according to Clause 5.1.2.3 of [6, TS 38.214].
- Rate matching indicator – 0, 1, or 2 bits according to higher layer parameters *rateMatchPatternGroup1* and *rateMatchPatternGroup2*, where the MSB is used to indicate *rateMatchPatternGroup1* and the LSB is used to indicate *rateMatchPatternGroup2* when there are two groups.
- ZP CSI-RS trigger – 0, 1, or 2 bits as defined in Clause 5.1.4.2 of [6, TS 38.214]. The bitwidth for this field is determined as  $\lceil \log_2(n_{\text{ZP}} + 1) \rceil$  bits, where  $n_{\text{ZP}}$  is the number of aperiodic ZP CSI-RS resource sets configured by higher layer.

For transport block 1:

- Modulation and coding scheme – 5 bits as defined in Clause 5.1.3.1 of [6, TS 38.214]
- New data indicator – 1 bit
- Redundancy version – 2 bits as defined in Table 7.3.1.1.1-2

For transport block 2 (only present if *maxNrofCodeWordsScheduledByDCI* equals 2):

- Modulation and coding scheme – 5 bits as defined in Clause 5.1.3.1 of [6, TS 38.214]
- New data indicator – 1 bit
- Redundancy version – 2 bits as defined in Table 7.3.1.1.1-2

If "Bandwidth part indicator" field indicates a bandwidth part other than the active bandwidth part and the value of *maxNrofCodeWordsScheduledByDCI* for the indicated bandwidth part equals 2 and the value of *maxNrofCodeWordsScheduledByDCI* for the active bandwidth part equals 1, the UE assumes zeros are padded when interpreting the "Modulation and coding scheme", "New data indicator", and "Redundancy version" fields of transport block 2 according to Clause 12 of [5, TS38.213], and the UE ignores the "Modulation and coding scheme", "New data indicator", and "Redundancy version" fields of transport block 2 for the indicated bandwidth part.

- HARQ process number – 4 bits
- Downlink assignment index – number of bits as defined in the following

- 6 bits if more than one serving cell are configured in the DL and the higher layer parameter *nfi-TotalDAI-Included* is configured. The 4 MSB bits are the counter DAI and the total DAI for the scheduled PDSCH group, and the 2 LSB bits are the total DAI for the non-scheduled PDSCH group.
- 4 bits if only one serving cell is configured in the DL and the higher layer parameter *nfi-TotalDAI-Included* is configured. The 2 MSB bits are the counter DAI for the scheduled PDSCH group, and the 2 LSB bits are the total DAI for the non-scheduled PDSCH group;
- 4 bits if more than one serving cell are configured in the DL, the higher layer parameter *pdsch-HARQ-ACK-Codebook=dynamic* or *pdsch-HARQ-ACK-Codebook-r16=enhancedDynamic*, and *nfi-TotalDAI-Included* is not configured, where the 2 MSB bits are the counter DAI and the 2 LSB bits are the total DAI;
- 4 bits if one serving cell is configured in the DL, and the higher layer parameter *pdsch-HARQ-ACK-Codebook=dynamic*, and the UE is not provided *coresetPoolIndex* or is provided *coresetPoolIndex* with value 0 for one or more first CORESETs and is provided *coresetPoolIndex* with value 1 for one or more second CORESETs, and is provided *ackNackFeedbackMode = joint*, where the 2 MSB bits are the counter DAI and the 2 LSB bits are the total DAI;
- 2 bits if only one serving cell is configured in the DL, the higher layer parameter *pdsch-HARQ-ACK-Codebook=dynamic* or *pdsch-HARQ-ACK-Codebook-r16=enhancedDynamic*, and *nfi-TotalDAI-Included* is not configured, when the UE is not configured with *coresetPoolIndex* or the value of *coresetPoolIndex* is the same for all CORESETs if *coresetPoolIndex* is provided or the UE is not configured with *ackNackFeedbackMode = joint*, where the 2 bits are the counter DAI;
- 0 bits otherwise.

If the UE is configured with a PUCCH-SCell, the number of serving cells is determined within a PUCCH group.

If the UE is configured with a PUCCH-SCell, *pdsch-HARQ-ACK-Codebook* is replaced by *pdsch-HARQ-ACK-Codebook-secondaryPUCCHgroup-r16* if present for the secondary PUCCH group.

If higher layer parameter *priorityIndicatorDCI-1-1* is configured, if the bit width of the Downlink assignment index in DCI format 1\_1 for one HARQ-ACK codebook is not equal to that of the Downlink assignment index in DCI format 1\_1 for the other HARQ-ACK codebook, a number of most significant bits with value set to '0' are inserted to smaller Downlink assignment index until the bit width of the Downlink assignment index in DCI format 1\_1 for the two HARQ-ACK codebooks are the same.

- TPC command for scheduled PUCCH – 2 bits as defined in Clause 7.2.1 of [5, TS 38.213]
- PUCCH resource indicator – 3 bits as defined in Clause 9.2.3 of [5, TS 38.213]
- PDSCH-to-HARQ\_feedback timing indicator – 0, 1, 2, or 3 bits as defined in Clause 9.2.3 of [5, TS 38.213]. The bitwidth for this field is determined as  $\lceil \log_2(I) \rceil$  bits, where  $I$  is the number of entries in the higher layer parameter *dl-DataToUL-ACK*.

If higher layer parameter *priorityIndicatorDCI-1-1* is configured, if the bit width of the PDSCH-to-HARQ\_feedback timing indicator in DCI format 1\_1 for one HARQ-ACK codebook is not equal to that of the PDSCH-to-HARQ\_feedback timing indicator in DCI format 1\_1 for the other HARQ-ACK codebook, a number of most significant bits with value set to '0' are inserted to smaller PDSCH-to-HARQ\_feedback timing indicator until the bit width of the PDSCH-to-HARQ\_feedback timing indicator in DCI format 1\_1 for the two HARQ-ACK codebooks are the same.

- One-shot HARQ-ACK request – 0 or 1 bit.
  - 1 bit if higher layer parameter *pdsch-HARQ-ACK-OneShotFeedback-r16* is configured;
  - 0 bit otherwise.
- PDSCH group index – 0 or 1 bit.
  - 1 bit if the higher layer parameter *pdsch-HARQ-ACK-Codebook-r16=enhancedDynamic*;
  - 0 bit otherwise.
- New feedback indicator – 0, 1 or 2 bits.

- 1 bit if the higher layer parameter *pdsch-HARQ-ACK-Codebook-r16*= *enhancedDynamic* and the higher layer parameter *nfi-TotalDAI-Included* is not configured;
- 2 bits if the higher layer parameter *pdsch-HARQ-ACK-Codebook-r16*= *enhancedDynamic* and the higher layer parameter *nfi-TotalDAI-Included*=*true*; the MSB corresponds to the scheduled PDSCH group, and the LSB corresponds to the non-scheduled PDSCH group, as defined in [TS38.213] clause 9.1.3.3
- 0 bit otherwise.
- Number of requested PDSCH group(s) – 0 or 1 bit.
  - 1 bit if the higher layer parameter *pdsch-HARQ-ACK-Codebook-r16*= *enhancedDynamic*;
  - 0 bit otherwise.
- Antenna port(s) – 4, 5, or 6 bits as defined by Tables 7.3.1.2.2-1/2/3/4 and Tables 7.3.1.2.2-1A/2A/3A/4A, where the number of CDM groups without data of values 1, 2, and 3 refers to CDM groups {0}, {0,1}, and {0, 1,2} respectively. The antenna ports  $\{p_0, \dots, p_{v-1}\}$  shall be determined according to the ordering of DMRS port(s) given by Tables 7.3.1.2.2-1/2/3/4 or Tables 7.3.1.2.2-1A/2A/3A/4A. When a UE receives an activation command that maps at least one codepoint of DCI field '*Transmission Configuration Indication*' to two TCI states, the UE shall use Table 7.3.1.2.2-1A/2A/3A/4A; otherwise, it shall use Tables 7.3.1.2.2-1/2/3/4. The UE can receive an entry with DMRS ports equals to 1000, 1002, 1003 when two TCI states are indicated in a codepoint of DCI field '*Transmission Configuration Indication*'.

If a UE is configured with both *dmrs-DownlinkForPDSCH-MappingTypeA* and *dmrs-DownlinkForPDSCH-MappingTypeB*, the bitwidth of this field equals  $\max\{x_A, x_B\}$ , where  $x_A$  is the "Antenna ports" bitwidth derived according to *dmrs-DownlinkForPDSCH-MappingTypeA* and  $x_B$  is the "Antenna ports" bitwidth derived according to *dmrs-DownlinkForPDSCH-MappingTypeB*. A number of  $|x_A - x_B|$  zeros are padded in the MSB of this field, if the mapping type of the PDSCH corresponds to the smaller value of  $x_A$  and  $x_B$ .

- Transmission configuration indication – 0 bit if higher layer parameter *tci-PresentInDCI* is not enabled; otherwise 3 bits as defined in Clause 5.1.5 of [6, TS38.214].
- If "Bandwidth part indicator" field indicates a bandwidth part other than the active bandwidth part,
- if the higher layer parameter *tci-PresentInDCI* is not enabled for the CORESET used for the PDCCH carrying the DCI format 1\_1,
    - the UE assumes *tci-PresentInDCI* is not enabled for all CORESETs in the indicated bandwidth part;
  - otherwise,
    - the UE assumes *tci-PresentInDCI* is enabled for all CORESETs in the indicated bandwidth part.
  - SRS request – 2 bits as defined by Table 7.3.1.1.2-24 for UEs not configured with *supplementaryUplink* in *ServingCellConfig* in the cell; 3 bits for UEs configured with *supplementaryUplink* in *ServingCellConfig* in the cell where the first bit is the non-SUL/SUL indicator as defined in Table 7.3.1.1.1-1 and the second and third bits are defined by Table 7.3.1.1.2-24. This bit field may also indicate the associated CSI-RS according to Clause 6.1.1.2 of [6, TS 38.214].
  - CBG transmission information (CBGTI) – 0 bit if higher layer parameter *codeBlockGroupTransmission* for PDSCH is not configured, otherwise, 2, 4, 6, or 8 bits as defined in Clause 5.1.7 of [6, TS38.214], determined by the higher layer parameters *maxCodeBlockGroupsPerTransportBlock* and *maxNrofCodeWordsScheduledByDCI* for the PDSCH.

If higher layer parameter *priorityIndicatorDCI-1-1* is configured, if the bit width of the CBG transmission information in DCI format 1\_1 for one HARQ-ACK codebook is not equal to that of the CBG transmission information in DCI format 1\_1 for the other HARQ-ACK codebook, a number of most significant bits with value set to '0' are inserted to smaller CBG transmission information until the bit width of the CBG transmission information in DCI format 1\_1 for the two HARQ-ACK codebooks are the same.

- CBG flushing out information (CBGFI) – 1 bit if higher layer parameter *codeBlockGroupFlushIndicator* is configured as "TRUE", 0 bit otherwise.

If higher layer parameter *priorityIndicatorDCI-1-1* is configured, if the bit width of the CBG flushing out information in DCI format 1\_1 for one HARQ-ACK codebook is not equal to that of the CBG flushing out information in DCI format 1\_1 for the other HARQ-ACK codebook, a number of most significant bits with value set to '0' are inserted to smaller CBG flushing out information until the bit width of the CBG flushing out information in DCI format 1\_1 for the two HARQ-ACK codebooks are the same.

- DMRS sequence initialization – 1 bit.
- Priority indicator – 0 bit if higher layer parameter *priorityIndicatorDCI-1-1* is not configured; otherwise 1 bit as defined in Clause 9 in [5, TS 38.213].
- ChannelAccess-CPext – 0, 1, 2, 3 or 4 bits. The bitwidth for this field is determined as  $\lceil \log_2(I) \rceil$  bits, where  $I$  is the number of entries in the higher layer parameter *ul-AccessConfigListDCI-1-1* or in Table 7.3.1.1.1-4A if *ChannelAccessMode-r16* = "semistatic" is provided for operation in a cell with shared spectrum channel access; otherwise 0 bit. One or more entries from Table 7.3.1.2.2-6 are configured by the higher layer parameter *ul-AccessConfigListDCI-1-1*.
- Minimum applicable scheduling offset indicator – 0 or 1 bit
  - 0 bit if higher layer parameter *minimumSchedulingOffsetK0* is not configured;
  - 1 bit if higher layer parameter *minimumSchedulingOffsetK0* is configured. The 1 bit indication is used to determine the minimum applicable K0 for the active DL BWP and the minimum applicable K2 value for the active UL BWP, if configured respectively, according to Table 7.3.1.1.2-33. If the minimum applicable K0 is indicated, the minimum applicable value of the aperiodic CSI-RS triggering offset for an active DL BWP shall be the same as the minimum applicable K0 value.
- SCell dormancy indication – 0 bit if higher layer parameter *dormancyGroupWithinActiveTime* is not configured; otherwise 1, 2, 3, 4 or 5 bits bitmap determined according to higher layer parameter *dormancyGroupWithinActiveTime*, where each bit corresponds to one of the SCell group(s) configured by higher layers parameter *dormancyGroupWithinActiveTime*, with MSB to LSB of the bitmap corresponding to the first to last configured SCell group. The field is only present when this format is carried by PDCCH on the primary cell within DRX Active Time and the UE is configured with at least two DL BWPs for an SCell.

If one-shot HARQ-ACK request is not present or set to '0', and all bits of frequency domain resource assignment are set to 0 for resource allocation type 0 or set to 1 for resource allocation type 1 or set to 0 or 1 for dynamic switch resource allocation type, this field is reserved and the following fields among the fields above are used for SCell dormancy indication, where each bit corresponds to one of the configured SCell(s), with MSB to LSB of the following fields concatenated in the order below corresponding to the SCell with lowest to highest SCell index

- Modulation and coding scheme of transport block 1
- New data indicator of transport block 1
- Redundancy version of transport block 1
- HARQ process number
- Antenna port(s)
- DMRS sequence initialization

If DCI formats 1\_1 are monitored in multiple search spaces associated with multiple CORESETs in a BWP for scheduling the same serving cell, zeros shall be appended until the payload size of the DCI formats 1\_1 monitored in the multiple search spaces equal to the maximum payload size of the DCI format 1\_1 monitored in the multiple search spaces.



Table 7.3.1.2.2-1: Antenna port(s) (1000 + DMRS port), *dmrs-Type=1*, *maxLength=1*

One Codeword: Codeword 0 enabled, Codeword 1 disabled		
Value	Number of DMRS CDM group(s) without data	DMRS port(s)
0	1	0
1	1	1
2	1	0,1
3	2	0
4	2	1
5	2	2
6	2	3
7	2	0,1
8	2	2,3
9	2	0-2
10	2	0-3
11	2	0,2
12-15	Reserved	Reserved

Table 7.3.1.2.2-1A: Antenna port(s) (1000 + DMRS port), *dmrs-Type=1*, *maxLength=1*

One Codeword: Codeword 0 enabled, Codeword 1 disabled		
Value	Number of DMRS CDM group(s) without data	DMRS port(s)
0	1	0
1	1	1
2	1	0,1
3	2	0
4	2	1
5	2	2
6	2	3
7	2	0,1
8	2	2,3
9	2	0-2
10	2	0-3
11	2	0,2
12	2	0,2,3
13-15	Reserved	Reserved

Table 7.3.1.2.2-2: Antenna port(s) (1000 + DMRS port), *dmrs-Type=1*, *maxLength=2*

One Codeword: Codeword 0 enabled, Codeword 1 disabled				Two Codewords: Codeword 0 enabled, Codeword 1 enabled			
Value	Number of DMRS CDM group(s) without data	DMRS port(s)	Number of front-load symbols	Value	Number of DMRS CDM group(s) without data	DMRS port(s)	Number of front-load symbols
0	1	0	1	0	2	0-4	2
1	1	1	1	1	2	0,1,2,3,4,6	2
2	1	0,1	1	2	2	0,1,2,3,4,5,6	2
3	2	0	1	3	2	0,1,2,3,4,5,6,7	2
4	2	1	1	4-31	reserved	reserved	reserved
5	2	2	1				
6	2	3	1				
7	2	0,1	1				
8	2	2,3	1				
9	2	0-2	1				
10	2	0-3	1				
11	2	0,2	1				
12	2	0	2				
13	2	1	2				
14	2	2	2				
15	2	3	2				
16	2	4	2				
17	2	5	2				
18	2	6	2				
19	2	7	2				
20	2	0,1	2				
21	2	2,3	2				
22	2	4,5	2				
23	2	6,7	2				
24	2	0,4	2				
25	2	2,6	2				
26	2	0,1,4	2				
27	2	2,3,6	2				
28	2	0,1,4,5	2				
29	2	2,3,6,7	2				
30	2	0,2,4,6	2				
31	Reserved	Reserved	Reserved				

Table 7.3.1.2.2-2A: Antenna port(s) (1000 + DMRS port), *dmrs-Type=1*, *maxLength=2*

One Codeword: Codeword 0 enabled, Codeword 1 disabled				Two Codewords: Codeword 0 enabled, Codeword 1 enabled			
Value	Number of DMRS CDM group(s) without data	DMRS port(s)	Number of front-load symbols	Value	Number of DMRS CDM group(s) without data	DMRS port(s)	Number of front-load symbols
0	1	0	1	0	2	0-4	2
1	1	1	1	1	2	0,1,2,3,4,6	2
2	1	0,1	1	2	2	0,1,2,3,4,5,6	2
3	2	0	1	3	2	0,1,2,3,4,5,6,7	2
4	2	1	1	4-31	reserved	reserved	reserved
5	2	2	1				
6	2	3	1				
7	2	0,1	1				
8	2	2,3	1				
9	2	0-2	1				
10	2	0-3	1				
11	2	0,2	1				
12	2	0	2				
13	2	1	2				
14	2	2	2				
15	2	3	2				
16	2	4	2				
17	2	5	2				
18	2	6	2				
19	2	7	2				
20	2	0,1	2				
21	2	2,3	2				
22	2	4,5	2				
23	2	6,7	2				
24	2	0,4	2				
25	2	2,6	2				
26	2	0,1,4	2				
27	2	2,3,6	2				
28	2	0,1,4,5	2				
29	2	2,3,6,7	2				
30	2	0,2,4,6	2				
31	2	0,2,3	1				

Table 7.3.1.2.2-3: Antenna port(s) (1000 + DMRS port), *dmrs-Type=2*, *maxLength=1*

One codeword: Codeword 0 enabled, Codeword 1 disabled			Two codewords: Codeword 0 enabled, Codeword 1 enabled		
Value	Number of DMRS CDM group(s) without data	DMRS port(s)	Value	Number of DMRS CDM group(s) without data	DMRS port(s)
0	1	0	0	3	0-4
1	1	1	1	3	0-5
2	1	0,1	2-31	reserved	reserved
3	2	0			
4	2	1			
5	2	2			
6	2	3			
7	2	0,1			
8	2	2,3			
9	2	0-2			
10	2	0-3			
11	3	0			
12	3	1			
13	3	2			
14	3	3			
15	3	4			
16	3	5			
17	3	0,1			
18	3	2,3			
19	3	4,5			
20	3	0-2			
21	3	3-5			
22	3	0-3			
23	2	0,2			
24-31	Reserved	Reserved			

Table 7.3.1.2.2-3A: Antenna port(s) (1000 + DMRS port), *dmrs-Type=2*, *maxLength=1*

One codeword: Codeword 0 enabled, Codeword 1 disabled			Two codewords: Codeword 0 enabled, Codeword 1 enabled		
Value	Number of DMRS CDM group(s) without data	DMRS port(s)	Value	Number of DMRS CDM group(s) without data	DMRS port(s)
0	1	0	0	3	0-4
1	1	1	1	3	0-5
2	1	0,1	2-31	reserved	reserved
3	2	0			
4	2	1			
5	2	2			
6	2	3			
7	2	0,1			
8	2	2,3			
9	2	0-2			
10	2	0-3			
11	3	0			
12	3	1			
13	3	2			
14	3	3			
15	3	4			
16	3	5			
17	3	0,1			
18	3	2,3			
19	3	4,5			
20	3	0-2			
21	3	3-5			
22	3	0-3			
23	2	0,2			
24	2	0,2,3			
25-31	Reserved	Reserved			

**Table 7.3.1.2.2-4: Antenna port(s) (1000 + DMRS port), *dmrs-Type=2*, *maxLength=2***

One codeword: Codeword 0 enabled, Codeword 1 disabled				Two Codewords: Codeword 0 enabled, Codeword 1 enabled			
Value	Number of DMRS CDM group(s) without data	DMRS port(s)	Number of front-load symbols	Value	Number of DMRS CDM group(s) without data	DMRS port(s)	Number of front-load symbols
0	1	0	1	0	3	0-4	1
1	1	1	1	1	3	0-5	1
2	1	0,1	1	2	2	0,1,2,3,6	2
3	2	0	1	3	2	0,1,2,3,6,8	2
4	2	1	1	4	2	0,1,2,3,6,7,8	2
5	2	2	1	5	2	0,1,2,3,6,7,8,9	2
6	2	3	1	6-63	Reserved	Reserved	Reserved
7	2	0,1	1				
8	2	2,3	1				
9	2	0-2	1				
10	2	0-3	1				
11	3	0	1				
12	3	1	1				
13	3	2	1				
14	3	3	1				
15	3	4	1				
16	3	5	1				
17	3	0,1	1				
18	3	2,3	1				
19	3	4,5	1				
20	3	0-2	1				
21	3	3-5	1				
22	3	0-3	1				
23	2	0,2	1				
24	3	0	2				
25	3	1	2				
26	3	2	2				
27	3	3	2				
28	3	4	2				
29	3	5	2				
30	3	6	2				
31	3	7	2				
32	3	8	2				
33	3	9	2				
34	3	10	2				
35	3	11	2				
36	3	0,1	2				
37	3	2,3	2				
38	3	4,5	2				
39	3	6,7	2				
40	3	8,9	2				
41	3	10,11	2				
42	3	0,1,6	2				
43	3	2,3,8	2				
44	3	4,5,10	2				
45	3	0,1,6,7	2				
46	3	2,3,8,9	2				
47	3	4,5,10,11	2				
48	1	0	2				
49	1	1	2				
50	1	6	2				
51	1	7	2				
52	1	0,1	2				
53	1	6,7	2				
54	2	0,1	2				
55	2	2,3	2				
56	2	6,7	2				

57	2	8,9	2				
58-63	Reserved	Reserved	Reserved				



**Table 7.3.1.2.2-4A: Antenna port(s) (1000 + DMRS port), *dmrs-Type=2*, *maxLength=2***

One codeword: Codeword 0 enabled, Codeword 1 disabled				Two Codewords: Codeword 0 enabled, Codeword 1 enabled			
Value	Number of DMRS CDM group(s) without data	DMRS port(s)	Number of front-load symbols	Value	Number of DMRS CDM group(s) without data	DMRS port(s)	Number of front-load symbols
0	1	0	1	0	3	0-4	1
1	1	1	1	1	3	0-5	1
2	1	0,1	1	2	2	0,1,2,3,6	2
3	2	0	1	3	2	0,1,2,3,6,8	2
4	2	1	1	4	2	0,1,2,3,6,7,8	2
5	2	2	1	5	2	0,1,2,3,6,7,8,9	2
6	2	3	1	6-63	Reserved	Reserved	Reserved
7	2	0,1	1				
8	2	2,3	1				
9	2	0-2	1				
10	2	0-3	1				
11	3	0	1				
12	3	1	1				
13	3	2	1				
14	3	3	1				
15	3	4	1				
16	3	5	1				
17	3	0,1	1				
18	3	2,3	1				
19	3	4,5	1				
20	3	0-2	1				
21	3	3-5	1				
22	3	0-3	1				
23	2	0,2	1				
24	3	0	2				
25	3	1	2				
26	3	2	2				
27	3	3	2				
28	3	4	2				
29	3	5	2				
30	3	6	2				
31	3	7	2				
32	3	8	2				
33	3	9	2				
34	3	10	2				
35	3	11	2				
36	3	0,1	2				
37	3	2,3	2				
38	3	4,5	2				
39	3	6,7	2				
40	3	8,9	2				
41	3	10,11	2				
42	3	0,1,6	2				
43	3	2,3,8	2				
44	3	4,5,10	2				
45	3	0,1,6,7	2				
46	3	2,3,8,9	2				
47	3	4,5,10,11	2				
48	1	0	2				
49	1	1	2				
50	1	6	2				
51	1	7	2				
52	1	0,1	2				
53	1	6,7	2				
54	2	0,1	2				
55	2	2,3	2				
56	2	6,7	2				

57	2	8,9	2				
58	2	0,2,3	1				
59-63	Reserved	Reserved	Reserved				

Table 7.3.1.2.2-5: VRB-to-PRB mapping

Bit field mapped to index	VRB-to-PRB mapping
0	Non-interleaved
1	Interleaved

Table 7.3.1.2.2-6: Allowed entries for DCI format 1\_1, configured by higher layer parameter *ul-AccessConfigListDCI-1-1*

Entry index	Channel Access Type	The CP extension Text index defined in Clause 5.3.1 of [4, TS 38.211]
0	Type2C-ULChannelAccess defined in [clause 4.2.1.2.3 in 37.213]	0
1	Type2C-ULChannelAccess defined in [clause 4.2.1.2.3 in 37.213]	2
2	Type2B-ULChannelAccess defined in [clause 4.2.1.2.3 in 37.213]	0
3	Type2B-ULChannelAccess defined in [clause 4.2.1.2.3 in 37.213]	2
4	Type2A-ULChannelAccess defined in [clause 4.2.1.2.1 in 37.213]	0
5	Type2A-ULChannelAccess defined in [clause 4.2.1.2.1 in 37.213]	1
6	Type2A-ULChannelAccess defined in [clause 4.2.1.2.1 in 37.213]	3
7	Type1-ULChannelAccess defined in [clause 4.2.1.1 in 37.213]	0
8	Type1-ULChannelAccess defined in [clause 4.2.1.1 in 37.213]	1
9	Type1-ULChannelAccess defined in [clause 4.2.1.1 in 37.213]	2
10	Type1-ULChannelAccess defined in [clause 4.2.1.1 in 37.213]	3

### 7.3.1.2.3 Format 1\_2

DCI format 1\_2 is used for the scheduling of PDSCH in one cell.

The following information is transmitted by means of the DCI format 1\_2 with CRC scrambled by C-RNTI or CS-RNTI or MCS-C-RNTI:

- Identifier for DCI formats – 1 bits
  - The value of this bit field is always set to 1, indicating a DL DCI format.
- Carrier indicator – 0, 1, 2 or 3 bits determined by higher layer parameter *carrierIndicatorSizeDCI-1-2*, as defined in Clause 10.1 of [5, TS38.213].
- Bandwidth part indicator – 0, 1 or 2 bits as determined by the number of DL BWPs  $n_{BWP,RRC}$  configured by higher layers, excluding the initial DL bandwidth part. The bitwidth for this field is determined as  $\lceil \log_2(n_{BWP}) \rceil$  bits, where
  - $n_{BWP} = n_{BWP,RRC} + 1$  if  $n_{BWP,RRC} \leq 3$ , in which case the bandwidth part indicator is equivalent to the ascending order of the higher layer parameter *BWP-Id*;
  - otherwise  $n_{BWP} = n_{BWP,RRC}$ , in which case the bandwidth part indicator is defined in Table 7.3.1.1.2-1;

If a UE does not support active BWP change via DCI, the UE ignores this bit field.

- Frequency domain resource assignment – number of bits determined by the following:
  - $N_{RBG}$  bits if only resource allocation type 0 is configured, where  $N_{RBG}$  is defined in Clause 5.1.2.2.1 of [6, TS 38.214];
  - $\lceil \log_2(N_{RBG,K2}(N_{RBG,K2} + 1)/2) \rceil$  bits if only resource allocation type 1 is configured, or  $\max(\lceil \log_2(N_{RBG,K2}(N_{RBG,K2} + 1)/2) \rceil, N_{RBG}) + 1$  bits if *resourceAllocationDCI-1-2-r16* is configured as

'dynamicSwitch', where  $N_{RBG,K2} = \left[ \left( N_{RB}^{DL,BWP} + (N_{DL,BWP}^{start} \bmod K2) \right) / K2 \right]$ ,  $N_{RB}^{DL,BWP}$  is the size of the active DL bandwidth part,  $N_{DL,BWP}^{start}$  is defined as in clause 4.4.4.4 of [4, TS 38.211] and  $K2$  is determined by higher layer parameter *resourceAllocationType1GranularityDCI-1-2*. If the higher layer parameter *resourceAllocationType1GranularityDCI-1-2* is not configured,  $K2$  is equal to 1.

- If *resourceAllocationDCI-1-2-r16* is configured as 'dynamicSwitch', the MSB bit is used to indicate resource allocation type 0 or resource allocation type 1, where the bit value of 0 indicates resource allocation type 0 and the bit value of 1 indicates resource allocation type 1.
- For resource allocation type 0, the  $N_{RBG}$  LSBs provide the resource allocation as defined in Clause 5.1.2.2.1 of [6, TS 38.214].
- For resource allocation type 1, the  $\lceil \log_2(N_{RBG,K2}(N_{RBG,K2} + 1)/2) \rceil$  LSBs provide the resource allocation as defined in Clause 5.1.2.2.2 of [6, TS 38.214]

If "Bandwidth part indicator" field indicates a bandwidth part other than the active bandwidth part and if *resourceAllocationDCI-1-2-r16* is configured as 'dynamicSwitch' for the indicated bandwidth part, the UE assumes resource allocation type 0 for the indicated bandwidth part if the bitwidth of the "Frequency domain resource assignment" field of the active bandwidth part is smaller than the bitwidth of the "Frequency domain resource assignment" field of the indicated bandwidth part.

- Time domain resource assignment – 0, 1, 2, 3, or 4 bits as defined in Clause 5.1.2.1 of [6, TS 38.214]. The bitwidth for this field is determined as  $\lceil \log_2(I) \rceil$  bits, where  $I$  is the number of entries in the higher layer parameter *pdsch-TimeDomainAllocationListDCI-1-2* if the higher layer parameter is configured, or  $I$  is the number of entries in the higher layer parameter *pdsch-TimeDomainAllocationList* if the higher layer parameter *pdsch-TimeDomainAllocationListDCI-1-2* is not configured; otherwise  $I$  is the number of entries in the default table.
- VRB-to-PRB mapping – 0 or 1 bit:
  - 0 bit if the higher layer parameter *vrB-ToPRB-InterleaverDCI-1-2* is not configured;
  - 1 bit according to Table 7.3.1.2.2-5 otherwise, only applicable to resource allocation type 1, as defined in Clause 7.3.1.6 of [4, TS 38.211].
- PRB bundling size indicator – 0 bit if the higher layer parameter *prB-BundlingTypeDCI-1-2* is not configured or is set to 'static', or 1 bit if the higher layer parameter *prB-BundlingTypeDCI-1-2* is set to 'dynamic' according to Clause 5.1.2.3 of [6, TS 38.214].
- Rate matching indicator – 0, 1, or 2 bits according to higher layer parameters *rateMatchPatternGroup1DCI-1-2* and *rateMatchPatternGroup2DCI-1-2*, where the MSB is used to indicate *rateMatchPatternGroup1DCI-1-2* and the LSB is used to indicate *rateMatchPatternGroup2DCI-1-2* when there are two groups.
- ZP CSI-RS trigger – 0, 1, or 2 bits as defined in Clause 5.1.4.2 of [6, TS 38.214]. The bitwidth for this field is determined as  $\lceil \log_2(n_{ZP} + 1) \rceil$  bits, where  $n_{ZP}$  is the number of aperiodic ZP CSI-RS resource sets configured by higher layer parameter *aperiodicZP-CSI-RS-ResourceSetsToAddModListDCI-1-2*.
- Modulation and coding scheme – 5 bits as defined in Clause 5.1.3.1 of [6, TS 38.214]
- New data indicator – 1 bit
- Redundancy version – 0, 1 or 2 bits determined by higher layer parameter *numberOfBitsForRV-DCI-1-2*
  - If 0 bit is configured,  $rv_{id}$  to be applied is 0;
  - 1 bit according to Table 7.3.1.2.3-1;
  - 2 bits according to Table 7.3.1.1.1-2.
- HARQ process number – 0, 1, 2, 3 or 4 bits determined by higher layer parameter *harq-ProcessNumberSizeDCI-1-2*
- Downlink assignment index – 0, 1, 2 or 4 bits
  - 0 bit if the higher layer parameter *downlinkAssignmentIndexDCI-1-2* is not configured;

- 1, 2 or 4 bits determined by higher layer parameter *downlinkAssignmentIndexDCI-1-2* otherwise,
- 4 bits if more than one serving cell are configured in the DL and the higher layer parameter *pdsch-HARQ-ACK-Codebook=dynamic*, where the 2 MSB bits are the counter DAI and the 2 LSB bits are the total DAI
- 4 bits if only one serving cell is configured in the DL and the higher layer parameter *pdsch-HARQ-ACK-Codebook=dynamic*, and the UE is not provided *coresetPoolIndex* or is provided *coresetPoolIndex* with value 0 for one or more first CORESETs and is provided *coresetPoolIndex* with value 1 for one or more second CORESETs, and is provided *ackNackFeedbackMode = joint*, where the 2 MSB bits are the counter DAI and the 2 LSB bits are the total DAI.
- 1 or 2 bits if only one serving cell is configured in the DL and the higher layer parameter *pdsch-HARQ-ACK-Codebook=dynamic*, when the UE is not configured with *coresetPoolIndex* or the value of *coresetPoolIndex* is the same for all CORESETs if *coresetPoolIndex* is provided or the UE is not configured with *ackNackFeedbackMode = joint*, where the 1 bit or 2 bits are the counter DAI.

If the UE is configured with a PUCCH-SCell, the number of serving cells is determined within a PUCCH group.

If the UE is configured with a PUCCH-SCell, *pdsch-HARQ-ACK-Codebook* is replaced by *pdsch-HARQ-ACK-Codebook-secondaryPUCCHgroup-r16* if present for the secondary PUCCH group.

If higher layer parameter *priorityIndicatorDCI-1-2* is configured, if the bit width of the Downlink assignment index in DCI format 1\_2 for one HARQ-ACK codebook is not equal to that of the Downlink assignment index in DCI format 1\_2 for the other HARQ-ACK codebook, a number of most significant bits with value set to '0' are inserted to smaller Downlink assignment index until the bit width of the Downlink assignment index in DCI format 1\_2 for the two HARQ-ACK codebooks are the same.

- TPC command for scheduled PUCCH – 2 bits as defined in Clause 7.2.1 of [5, TS 38.213]
- PUCCH resource indicator – 0 or 1 or 2 or 3 bits determined by higher layer parameter *numberOfBitsForPUCCH-ResourceIndicatorDCI-1-2*
- PDSCH-to-HARQ\_feedback timing indicator – 0, 1, 2, or 3 bits as defined in Clause 9.2.3 of [5, TS 38.213]. The bitwidth for this field is determined as  $\lceil \log_2(I) \rceil$  bits, where  $I$  is the number of entries in the higher layer parameter *DL-DataToUL-ACK-DCI-1-2*.

If higher layer parameter *priorityIndicatorDCI-1-2* is configured, if the bit width of the PDSCH-to-HARQ\_feedback timing indicator in DCI format 1\_2 for one HARQ-ACK codebook is not equal to that of the PDSCH-to-HARQ\_feedback timing indicator in DCI format 1\_2 for the other HARQ-ACK codebook, a number of most significant bits with value set to '0' are inserted to smaller PDSCH-to-HARQ\_feedback timing indicator until the bit width of the PDSCH-to-HARQ\_feedback timing indicator in DCI format 1\_2 for the two HARQ-ACK codebooks are the same.

- Antenna port(s) – 0, 4, 5, or 6 bits
  - 0 bit if higher layer parameter *antennaPortsFieldPresenceDCI-1-2* is not configured;
  - Otherwise 4, 5 or 6 bits as defined by Tables 7.3.1.2.2-1/2/3/4, where the number of CDM groups without data of values 1, 2, and 3 refers to CDM groups {0}, {0,1}, and {0, 1,2} respectively. The antenna ports  $\{p_0, \dots, p_{v-1}\}$  shall be determined according to the ordering of DMRS port(s) given by Tables 7.3.1.2.2-1/2/3/4. If a UE is configured with both *dmrs-DownlinkForPDSCH-MappingTypeA-DCI-1-2* and *dmrs-DownlinkForPDSCH-MappingTypeB-DCI-1-2* and is configured with higher layer parameter *antennaPortsFieldPresenceDCI-1-2*, the bitwidth of this field equals  $\max\{x_A, x_B\}$ , where  $x_A$  is the "Antenna ports" bitwidth derived according to *dmrs-DownlinkForPDSCH-MappingTypeA-DCI-1-2* and  $x_B$  is the "Antenna ports" bitwidth derived according to *dmrs-DownlinkForPDSCH-MappingTypeB-DCI-1-2*. A number of  $|x_A - x_B|$  zeros are padded in the MSB of this field, if the mapping type of the PDSCH corresponds to the smaller value of  $x_A$  and  $x_B$ .

If a UE is not configured with higher layer parameter *antennaPortsFieldPresenceDCI-1-2*, antenna port(s) are defined assuming bit field index value 0 in Tables 7.3.1.2.2-1/2/3/4.

- Transmission configuration indication – 0 bit if higher layer parameter *tci-PresentDCI-1-2* is not configured; otherwise 1 or 2 or 3 bits determined by higher layer parameter *tci-PresentDCI-1-2* as defined in Clause 5.1.5 of [6, TS38.214].

If "Bandwidth part indicator" field indicates a bandwidth part other than the active bandwidth part,

- if the higher layer parameter *tci-PresentDCI-1-2* is not configured for the CORESET used for the PDCCH carrying the DCI format 1\_2,
  - the UE assumes *tci-PresentDCI-1-2* is not configured for all CORESETs in the indicated bandwidth part;
- otherwise,
  - the UE assumes *tci-PresentDCI-1-2* is configured for all CORESETs in the indicated bandwidth part with the same value configured for the CORESET used for the PDCCH carrying the DCI format 1\_2.
- SRS request – 0, 1, 2 or 3 bits
  - 0 bit if the higher layer parameter *srs-RequestDCI-1-2* is not configured;
  - 1 bit as defined by Table 7.3.1.1.3-1 if the higher layer parameter *srs-RequestDCI-1-2* = 1 and for UEs not configured with *supplementaryUplink* in *ServingCellConfig* in the cell;
  - 2 bits if the higher layer parameter *srs-RequestDCI-1-2* = 1 and for UEs configured with *supplementaryUplink* in *ServingCellConfig* in the cell, where the first bit is the non-SUL/SUL indicator as defined in Table 7.3.1.1.1-1 and the second bit is defined by Table 7.3.1.1.3-1;
  - 2 bits as defined by Table 7.3.1.1.2-24 if the higher layer parameter *srs-RequestDCI-1-2* = 2 and for UEs not configured with *supplementaryUplink* in *ServingCellConfig* in the cell;
  - 3 bits if the higher layer parameter *srs-RequestDCI-1-2* = 2 and for UEs configured with *supplementaryUplink* in *ServingCellConfig* in the cell, where the first bit is the non-SUL/SUL indicator as defined in Table 7.3.1.1.1-1 and the second and third bits are defined by Table 7.3.1.1.2-24;
- DMRS sequence initialization – 0 or 1 bit
  - 0 bit if the higher layer parameter *dmrs-SequenceInitializationDCI-1-2* is not configured;
  - 1 bit otherwise.
- Priority indicator – 0 bit if higher layer parameter *priorityIndicatorDCI-1-2* is not configured; otherwise 1 bit as defined in Clause 9 in [5, TS 38.213].

If DCI formats 1\_2 are monitored in multiple search spaces associated with multiple CORESETs in a BWP for scheduling the same serving cell, zeros shall be appended until the payload size of the DCI formats 1\_2 monitored in the multiple search spaces equal to the maximum payload size of the DCI format 1\_2 monitored in the multiple search spaces.

**Table 7.3.1.2.3-1: Redundancy version**

Value of the Redundancy version field	Value of $rv_{id}$ to be applied
0	0
1	3

### 7.3.1.3 DCI formats for other purposes

#### 7.3.1.3.1 Format 2\_0

DCI format 2\_0 is used for notifying the slot format, COT duration, available RB set, and search space set group switching.

The following information is transmitted by means of the DCI format 2\_0 with CRC scrambled by SFI-RNTI:

- If the higher layer parameter *slotFormatCombToAddModList* is configured,
  - Slot format indicator 1, Slot format indicator 2, ..., Slot format indicator *N*,
- If the higher layer parameter *availableRB-SetsToAddModList* is configured,
  - Available RB set Indicator 1, Available RB set Indicator 2, ..., Available RB set Indicator *NI*,
- If the higher layer parameter *co-DurationsPerCellToAddModList* is configured
  - COT duration indicator 1, COT duration indicator 2, ..., COT duration indicator *N2*.
- If the higher layer parameter *switchTriggerToAddModList* is configured
  - Search space set group switching flag 1, Search space set group switching flag 2, ..., Search space set group switching flag *M*.

The size of DCI format 2\_0 is configurable by higher layers up to 128 bits, according to Clause 11.1.1 of [5, TS 38.213].

### 7.3.1.3.2 Format 2\_1

DCI format 2\_1 is used for notifying the PRB(s) and OFDM symbol(s) where UE may assume no transmission is intended for the UE.

The following information is transmitted by means of the DCI format 2\_1 with CRC scrambled by INT-RNTI:

- Pre-emption indication 1, Pre-emption indication 2, ..., Pre-emption indication *N*.

The size of DCI format 2\_1 is configurable by higher layers up to 126 bits, according to Clause 11.2 of [5, TS 38.213]. Each pre-emption indication is 14 bits.

### 7.3.1.3.3 Format 2\_2

DCI format 2\_2 is used for the transmission of TPC commands for PUCCH and PUSCH.

The following information is transmitted by means of the DCI format 2\_2 with CRC scrambled by TPC-PUSCH-RNTI or TPC-PUCCH-RNTI:

- block number 1, block number 2, ..., block number *N*

The parameter *tpc-PUSCH* or *tpc-PUCCH* provided by higher layers determines the index to the block number for an UL of a cell, with the following fields defined for each block:

- Closed loop indicator – 0 or 1 bit.
  - For DCI format 2\_2 with TPC-PUSCH-RNTI, 0 bit if the UE is not configured with high layer parameter *twoPUSCH-PC-AdjustmentStates*, in which case UE assumes each block in the DCI format 2\_2 is of 2 bits; 1 bit otherwise, in which case UE assumes each block in the DCI format 2\_2 is of 3 bits;
  - For DCI format 2\_2 with TPC-PUCCH-RNTI, 0 bit if the UE is not configured with high layer parameter *twoPUCCH-PC-AdjustmentStates*, in which case UE assumes each block in the DCI format 2\_2 is of 2 bits; 1 bit otherwise, in which case UE assumes each block in the DCI format 2\_2 is of 3 bits;
- TPC command – 2 bits

The number of information bits in format 2\_2 shall be equal to or less than the payload size of format 1\_0 monitored in common search space in the same serving cell. If the number of information bits in format 2\_2 is less than the payload size of format 1\_0 monitored in common search space in the same serving cell, zeros shall be appended to format 2\_2 until the payload size equals that of format 1\_0 monitored in common search space in the same serving cell.

### 7.3.1.3.4 Format 2\_3

DCI format 2\_3 is used for the transmission of a group of TPC commands for SRS transmissions by one or more UEs. Along with a TPC command, a SRS request may also be transmitted.

The following information is transmitted by means of the DCI format 2\_3 with CRC scrambled by TPC-SRS-RNTI:

- block number 1, block number 2, ..., block number  $B$

where the starting position of a block is determined by the parameter *startingBitOfFormat2-3* or *startingBitOfFormat2-3SUL-v1530* provided by higher layers for the UE configured with the block.

If the UE is configured with higher layer parameter *srs-TPC-PDCCH-Group = typeA* for an UL without PUCCH and PUSCH or an UL on which the SRS power control is not tied with PUSCH power control, one block is configured for the UE by higher layers, with the following fields defined for the block:

- SRS request – 0 or 2 bits. The presence of this field is according to the definition in Clause 11.4 of [5, TS38.213]. If present, this field is interpreted as defined by Table 7.3.1.1.2-24.
- TPC command number 1, TPC command number 2, ..., TPC command number  $N$ , where each TPC command applies to a respective UL carrier provided by higher layer parameter *cc-IndexInOneCC-Set*

If the UE is configured with higher layer parameter *srs-TPC-PDCCH-Group = typeB* for an UL without PUCCH and PUSCH or an UL on which the SRS power control is not tied with PUSCH power control, one block or more blocks is configured for the UE by higher layers where each block applies to an UL carrier, with the following fields defined for each block:

- SRS request – 0 or 2 bits. The presence of this field is according to the definition in Clause 11.4 of [5, TS38.213]. If present, this field is interpreted as defined by Table 7.3.1.1.2-24.
- TPC command –2 bits

The number of information bits in format 2\_3 shall be equal to or less than the payload size of format 1\_0 monitored in common search space in the same serving cell. If the number of information bits in format 2\_3 is less than the payload size of format 1\_0 monitored in common search space in the same serving cell, zeros shall be appended to format 2\_3 until the payload size equals that of format 1\_0 monitored in common search space in the same serving cell.

#### 7.3.1.3.5 Format 2\_4

DCI format 2\_4 is used for notifying the PRB(s) and OFDM symbol(s) where UE cancels the corresponding UL transmission from the UE according to Clause 11.2A of [5, TS 38.213].

The following information is transmitted by means of the DCI format 2\_4 with CRC scrambled by ci-RNTI:

- Cancellation indication 1, Cancellation indication 2, ..., Cancellation indication  $N$ .

The size of DCI format 2\_4 is configurable by higher layers parameter *dci-PayloadSizeForCI* up to 126 bits, according to Clause 11.2A of [5, TS 38.213]. The number of bits for each cancellation indication is configurable by higher layer parameter *ci-PayloadSize*. For a UE, there is at most one cancellation indication for an UL carrier.

#### 7.3.1.3.6 Format 2\_5

DCI format 2\_5 is used for notifying the availability of soft resources as defined in Clause 9.3.1 of [10, TS 38.473]

The following information is transmitted by means of the DCI format 2\_5 with CRC scrambled by AI-RNTI:

- Availability indicator 1, Availability indicator 2, ..., Availability indicator  $N$ .

The size of DCI format 2\_5 is configurable by higher layers up to 128 bits, according to Clause 14 of [5, TS 38.213].

#### 7.3.1.3.7 Format 2\_6

DCI format 2\_6 is used for notifying the power saving information outside DRX Active Time for one or more UEs.

The following information is transmitted by means of the DCI format 2\_6 with CRC scrambled by PS-RNTI:

- block number 1, block number 2, ..., block number  $N$

where the starting position of a block is determined by the parameter *ps-PositionDCI-2-6* provided by higher layers for the UE configured with the block.



If the UE is configured with higher layer parameter *ps-RNTI* and *dci-Format2-6*, one block is configured for the UE by higher layers, with the following fields defined for the block:

- Wake-up indication - 1 bit
- SCell dormancy indication – 0 bit if higher layer parameter *dormancyGroupOutsideActiveTime* is not configured; otherwise 1, 2, 3, 4 or 5 bits bitmap determined according to higher layer parameter *dormancyGroupOutsideActiveTime*, where each bit corresponds to one of the SCell group(s) configured by higher layers parameter *dormancyGroupOutsideActiveTime*, with MSB to LSB of the bitmap corresponding to the first to last configured SCell group.

The size of DCI format 2\_6 is indicated by the higher layer parameter *sizeDCI-2-6*, according to Clause 10.3 of [5, TS 38.213].

### 7.3.1.4 DCI formats for scheduling of sidelink

#### 7.3.1.4.1 Format 3\_0

DCI format 3\_0 is used for scheduling of NR PSCCH and NR PSSCH in one cell.

The following information is transmitted by means of the DCI format 3\_0 with CRC scrambled by SL-RNTI or SL-CS-RNTI:

- Resource pool index  $-\lceil \log_2 I \rceil$  bits, where  $I$  is the number of resource pools for transmission configured by the higher layer parameter *sl-TxPoolScheduling*.
- Time gap – 3 bits determined by higher layer parameter *sl-DCI-ToSL-Trans*, as defined in clause 8.1.2.1 of [6, TS 38.214]
- HARQ process number – 4 bits as defined in clause 16.4 of [5, TS 38.213]
- New data indicator – 1 bit as defined in clause 16.4 of [5, TS 38.213]
- Lowest index of the subchannel allocation to the initial transmission  $-\lceil \log_2 (N_{\text{subChannel}}^{\text{SL}}) \rceil$  bits as defined in clause 8.1.2.2 of [6, TS 38.214]
- SCI format 1-A fields according to clause 8.3.1.1:
  - Frequency resource assignment.
  - Time resource assignment.
- PSFCH-to-HARQ feedback timing indicator  $-\lceil \log_2 N_{\text{fb,timing}} \rceil$  bits, where  $N_{\text{fb,timing}}$  is the number of entries in the higher layer parameter *sl-PSFCH-ToPUCCH*, as defined in clause 16.5 of [5, TS 38.213]
- PUCCH resource indicator – 3 bits as defined in clause 16.5 of [5, TS 38.213].
- Configuration index – 0 bit if the UE is not configured to monitor DCI format 3\_0 with CRC scrambled by SL-CS-RNTI; otherwise 3 bits as defined in clause 8.1.2 of [6, TS 38.214]. If the UE is configured to monitor DCI format 3\_0 with CRC scrambled by SL-CS-RNTI, this field is reserved for DCI format 3\_0 with CRC scrambled by SL-RNTI.
- Counter sidelink assignment index – 2 bits
  - 2 bits as defined in clause 16.5.2 of [5, TS 38.213] if the UE is configured with *pdsch-HARQ-ACK-Codebook = dynamic*
  - 2 bits as defined in clause 16.5.1 of [5, TS 38.213] if the UE is configured with *pdsch-HARQ-ACK-Codebook = semi-static*
- Padding bits, if required

If multiple transmit resource pools are provided in *sl-TxPoolScheduling*, zeros shall be appended to the DCI format 3\_0 until the payload size is equal to the size of a DCI format 3\_0 given by a configuration of the transmit resource pool resulting in the largest number of information bits for DCI format 3\_0.

If the UE is configured to monitor DCI format 3\_1 and the number of information bits in DCI format 3\_0 is less than the payload of DCI format 3\_1, zeros shall be appended to DCI format 3\_0 until the payload size equals that of DCI format 3\_1.

#### 7.3.1.4.2 Format 3\_1

DCI format 3\_1 is used for scheduling of LTE PSCCH and LTE PSSCH in one cell.

The following information is transmitted by means of the DCI format 3\_1 with CRC scrambled by SL Semi-Persistent Scheduling V-RNTI:

- Timing offset – 3 bits determined by higher layer parameter *sl-TimeOffsetEUTRA*, as defined in clause 16.6 of [5, TS 38.213]
- Carrier indicator – 3 bits as defined in 5.3.3.1.9A of [11, TS 36.212].
- Lowest index of the subchannel allocation to the initial transmission -  $\lceil \log_2(N_{\text{subchannel}}^{\text{SL}}) \rceil$  bits as defined in 5.3.3.1.9A of [11, TS 36.212].
- Frequency resource location of initial transmission and retransmission, as defined in 5.3.3.1.9A of [11, TS 36.212]
- Time gap between initial transmission and retransmission, as defined in 5.3.3.1.9A of [11, TS 36.212]
- SL index – 2 bits as defined in 5.3.3.1.9A of [11, TS 36.212]
- SL SPS configuration index – 3 bits as defined in clause 5.3.3.1.9A of [11, TS 36.212].
- Activation/release indication – 1 bit as defined in clause 5.3.3.1.9A of [11, TS 36.212].

If the UE is configured to monitor DCI format 3\_0 and the number of information bits in DCI format 3\_1 is less than the payload of DCI format 3\_0, zeros shall be appended to DCI format 3\_1 until the payload size equals that of DCI format 3\_0.

### 7.3.2 CRC attachment

Error detection is provided on DCI transmissions through a Cyclic Redundancy Check (CRC).

The entire payload is used to calculate the CRC parity bits. Denote the bits of the payload by  $a_0, a_1, a_2, a_3, \dots, a_{A-1}$ , and the parity bits by  $p_0, p_1, p_2, p_3, \dots, p_{L-1}$ , where  $A$  is the payload size and  $L$  is the number of parity bits. Let  $a'_0, a'_1, a'_2, a'_3, \dots, a'_{A+L-1}$  be a bit sequence such that  $a'_i = 1$  for  $i = 0, 1, \dots, L-1$  and  $a'_i = a_{i-L}$  for  $i = L, L+1, \dots, A+L-1$ . The parity bits are computed with input bit sequence  $a'_0, a'_1, a'_2, a'_3, \dots, a'_{A+L-1}$  and attached according to Clause 5.1 by setting  $L$  to 24 bits and using the generator polynomial  $g_{\text{CRC24C}}(D)$ . The output bit  $b_0, b_1, b_2, b_3, \dots, b_{K-1}$  is

$$b_k = a_k \quad \text{for } k = 0, 1, 2, \dots, A-1$$

$$b_k = p_{k-A} \quad \text{for } k = A, A+1, A+2, \dots, A+L-1,$$

where  $K = A + L$ .

After attachment, the CRC parity bits are scrambled with the corresponding RNTI  $x_{\text{rnti},0}, x_{\text{rnti},1}, \dots, x_{\text{rnti},15}$ , where  $x_{\text{rnti},0}$  corresponds to the MSB of the RNTI, to form the sequence of bits  $c_0, c_1, c_2, c_3, \dots, c_{K-1}$ . The relation between  $c_k$  and  $b_k$  is:

$$c_k = b_k \quad \text{for } k = 0, 1, 2, \dots, A+7$$

$$c_k = (b_k + x_{\text{rnti},k-A-8}) \bmod 2 \quad \text{for } k = A+8, A+9, A+10, \dots, A+23.$$

### 7.3.3 Channel coding

Information bits are delivered to the channel coding block. They are denoted by  $c_0, c_1, c_2, c_3, \dots, c_{K-1}$ , where  $K$  is the number of bits, and they are encoded via Polar coding according to Clause 5.3.1, by setting  $n_{\max} = 9$ ,  $I_{IL} = 1$ ,  $n_{PC} = 0$ , and  $n_{PC}^{wm} = 0$ .

After encoding the bits are denoted by  $d_0, d_1, d_2, d_3, \dots, d_{N-1}$ , where  $N$  is the number of coded bits.

### 7.3.4 Rate matching

The input bit sequence to rate matching is  $d_0, d_1, d_2, \dots, d_{N-1}$ .

Rate matching is performed according to Clause 5.4.1 by setting  $I_{BL} = 0$ .

The output bit sequence after rate matching is denoted as  $f_0, f_1, f_2, \dots, f_{E-1}$ .

---

## 8 Sidelink transport channels and control information

### 8.1 Sidelink broadcast channel

The processing for SL-BCH transport channel follows the BCH according to clause 7.1, with the following changes:

- In Clause 7.1, 'maximum of one transport block every 80ms' is replaced with 'maximum of one transport block'.
- Clause 7.1.1 for PBCH payload generation is not performed.
- Clause 7.1.2 for scrambling is not performed.
- In clause 7.1.5, the rate matching output sequence length  $E = 1386$  when higher layer parameter *cyclicPrefix* is configured, otherwise,  $E = 1782$ .

#### 8.1.1 (void)

### 8.2 Sidelink shared channel

The processing for SL-SCH transport channel follows the UL-SCH according to clause 6.2, with the following changes:

- Rate matching of SL-SCH follows the rate matching according to clause 6.2.5 by setting  $I_{LBRM} = 0$
- Clause 6.2.7 is replaced by clause 8.2.1

#### 8.2.1 Data and control multiplexing

Denote the coded bits for SL-SCH as  $g_0^{SL-SCH}, g_1^{SL-SCH}, g_2^{SL-SCH}, g_3^{SL-SCH}, \dots, g_{G^{SL-SCH}-1}^{SL-SCH}$ .

Denote the coded bits for the 2<sup>nd</sup>-stage SCI, as  $g_0^{SCI2}, g_1^{SCI2}, g_2^{SCI2}, g_3^{SCI2}, \dots, g_{G^{SCI2}-1}^{SCI2}$ .

Denote the multiplexed data and control coded bit sequence as  $g_0, g_1, \dots, g_{G-1}$ , where  $G$  is the total number of coded bits for transmission.

Assuming that  $N_L$  is the number of layers onto which the SL-SCH transport block is mapped, the multiplexed data and control coded bit sequence  $g_0, g_1, \dots, g_{G-1}$  is obtained as follows:

Denote  $Q_m^{SCI2}$  is modulation order of the 2<sup>nd</sup>-stage SCI.

if  $N_L = 1$ ,

```

for  $i = 0$  to  $G^{SCI2} + G^{SL-SCH} - 1$ 
  if  $0 \leq i < G^{SCI2}$ 
     $g_i = g_i^{SCI2}$ 
  end if
  if  $G^{SCI2} \leq i \leq G^{SCI2} + G^{SL-SCH} - 1$ 
     $g_i = g_{i-G^{SCI2}}^{SL-SCH}$ 
  end if
end for
end if
if  $N_L = 2$ ,
  let  $M_{count,SCI2}^{RE} = G^{SCI2} / Q_m^{SCI2}$ 
  set  $m_{count}^{RE} = 0$ 
  for  $i = 0$  to  $M_{count,SCI2}^{RE} - 1$ 
    for  $v = 0$  to  $N_L - 1$ 
      for  $q = 0$  to  $Q_m^{SCI2} - 1$ 
        if  $v = 0$ 
           $g_{m_{count}^{RE}} = g_{i \cdot Q_m^{SCI2} + q}^{SCI2}$ 
        else
           $g_{m_{count}^{RE}} = x$  // placeholder bit
        end if
         $m_{count}^{RE} = m_{count}^{RE} + 1$ 
      end for
    end for
  end for
end for
for  $i = 0$  to  $G^{SL-SCH} - 1$ 
   $g_{m_{count}^{RE}} = g_i^{SL-SCH}$ 
   $m_{count}^{RE} = m_{count}^{RE} + 1$ 
end for
end if

```

### 8.3 Sidelink control information on PSCCH

SCI carried on PSCCH is a 1<sup>st</sup>-stage SCI, which transports sidelink scheduling information.

### 8.3.1 1<sup>st</sup>-stage SCI formats

The fields defined in each of the 1<sup>st</sup>-stage SCI formats below are mapped to the information bits  $a_0$  to  $a_{A-1}$  as follows:

Each field is mapped in the order in which it appears in the description, with the first field mapped to the lowest order information bit  $a_0$  and each successive field mapped to higher order information bits. The most significant bit of each field is mapped to the lowest order information bit for that field, e.g. the most significant bit of the first field is mapped to  $a_0$ .

#### 8.3.1.1 SCI format 1-A

SCI format 1-A is used for the scheduling of PSSCH and 2<sup>nd</sup>-stage-SCI on PSSCH

The following information is transmitted by means of the SCI format 1-A:

- Priority – 3 bits as specified in clause 5.4.3.3 of [12, TS 23.287] and clause 5.22.1.3.1 of [8, TS 38.321].
- Frequency resource assignment –  $\left\lceil \log_2 \left( \frac{N_{\text{subChannel}}^{\text{SL}} (N_{\text{subChannel}}^{\text{SL}} + 1)}{2} \right) \right\rceil$  bits when the value of the higher layer parameter *sl-MaxNumPerReserve* is configured to 2; otherwise  $\left\lceil \log_2 \left( \frac{N_{\text{subChannel}}^{\text{SL}} (N_{\text{subChannel}}^{\text{SL}} + 1) (2N_{\text{subChannel}}^{\text{SL}} + 1)}{6} \right) \right\rceil$  bits when the value of the higher layer parameter *sl-MaxNumPerReserve* is configured to 3, as defined in clause 8.1.5 of [6, TS 38.214].
- Time resource assignment – 5 bits when the value of the higher layer parameter *sl-MaxNumPerReserve* is configured to 2; otherwise 9 bits when the value of the higher layer parameter *sl-MaxNumPerReserve* is configured to 3, as defined in clause 8.1.5 of [6, TS 38.214].
- Resource reservation period –  $\lceil \log_2 N_{\text{rsv\_period}} \rceil$  bits as defined in clause 16.4 of [5, TS 38.213], where  $N_{\text{rsv\_period}}$  is the number of entries in the higher layer parameter *sl-ResourceReservePeriodList*, if higher layer parameter *sl-MultiReserveResource* is configured; 0 bit otherwise.
- DMRS pattern –  $\lceil \log_2 N_{\text{pattern}} \rceil$  bits as defined in clause 8.4.1.1.2 of [4, TS 38.211], where  $N_{\text{pattern}}$  is the number of DMRS patterns configured by higher layer parameter *sl-PSSCH-DMRS-TimePatternList*.
- 2<sup>nd</sup>-stage SCI format – 2 bits as defined in Table 8.3.1.1-1.
- Beta\_offset indicator – 2 bits as provided by higher layer parameter *sl-BetaOffsets2ndSCI* and Table 8.3.1.1-2.
- Number of DMRS port – 1 bit as defined in Table 8.3.1.1-3.
- Modulation and coding scheme – 5 bits as defined in clause 8.1.3 of [6, TS 38.214].
- Additional MCS table indicator – as defined in clause 8.1.3.1 of [6, TS 38.214]: 1 bit if one MCS table is configured by higher layer parameter *sl-Additional-MCS-Table*; 2 bits if two MCS tables are configured by higher layer parameter *sl-Additional-MCS-Table*; 0 bit otherwise.
- PSFCH overhead indication – 1 bit as defined clause 8.1.3.2 of [6, TS 38.214] if higher layer parameter *sl-PSFCH-Period* = 2 or 4; 0 bit otherwise.
- Reserved – a number of bits as determined by higher layer parameter *sl-NumReservedBits*, with value set to zero.

**Table 8.3.1.1-1: 2<sup>nd</sup>-stage SCI formats**

Value of 2nd-stage SCI format field	2nd-stage SCI format
00	SCI format 2-A
01	SCI format 2-B
10	Reserved
11	Reserved

**Table 8.3.1.1-2: Mapping of Beta\_offset indicator values to indexes in Table 9.3-2 of [5, TS38.213]**

Value of Beta_offset indicator	Beta_offset index in Table 9.3-2 of [5, TS38.213]
00	1st index provided by higher layer parameter <i>sl-BetaOffsets2ndSCI</i>
01	2nd index provided by higher layer parameter <i>sl-BetaOffsets2ndSCI</i>
10	3rd index provided by higher layer parameter <i>sl-BetaOffsets2ndSCI</i>
11	4th index provided by higher layer parameter <i>sl-BetaOffsets2ndSCI</i>

**Table 8.3.1.1-3: Number of DMRS port(s)**

Value of the Number of DMRS port field	Antenna ports
0	1000
1	1000 and 1001

### 8.3.2 CRC attachment

CRC attachment is performed according to clause 7.3.2 except that scrambling is not performed.

### 8.3.3 Channel coding

Channel coding is performed according to clause 7.3.3.

### 8.3.4 Rate Matching

Rate matching is performed according to clause 7.3.4.

## 8.4 Sidelink control information on PSSCH

SCI carried on PSSCH is a 2<sup>nd</sup>-stage SCI, which transports sidelink scheduling information.

### 8.4.1 2<sup>nd</sup>-stage SCI formats

The fields defined in each of the 2<sup>nd</sup>-stage SCI formats below are mapped to the information bits  $a_0$  to  $a_{A-1}$  as follows:

Each field is mapped in the order in which it appears in the description, with the first field mapped to the lowest order information bit  $a_0$  and each successive field mapped to higher order information bits. The most significant bit of each field is mapped to the lowest order information bit for that field, e.g. the most significant bit of the first field is mapped to  $a_0$ .

#### 8.4.1.1 SCI format 2-A

SCI format 2-A is used for the decoding of PSSCH, with HARQ operation when HARQ-ACK information includes ACK or NACK, when HARQ-ACK information includes only NACK, or when there is no feedback of HARQ-ACK information.

The following information is transmitted by means of the SCI format 2-A:

- HARQ process number – 4 bits.
- New data indicator – 1 bit.
- Redundancy version – 2 bits as defined in Table 7.3.1.1.1-2.
- Source ID – 8 bits as defined in clause 8.1 of [6, TS 38.214].

- Destination ID – 16 bits as defined in clause 8.1 of [6, TS 38.214].
- HARQ feedback enabled/disabled indicator – 1 bit as defined in clause 16.3 of [5, TS 38.213].
- Cast type indicator – 2 bits as defined in Table 8.4.1.1-1 and in clause 8.1 of [6, TS 38.214].
- CSI request – 1 bit as defined in clause 8.2.1 of [6, TS 38.214] and in clause 8.1 of [6, TS 38.214].

**Table 8.4.1.1-1: Cast type indicator**

Value of Cast type indicator	Cast type
00	Broadcast
01	Groupcast when HARQ-ACK information includes ACK or NACK
10	Unicast
11	Groupcast when HARQ-ACK information includes only NACK

### 8.4.1.2 SCI format 2-B

SCI format 2-B is used for the decoding of PSSCH, with HARQ operation when HARQ-ACK information includes only NACK, or when there is no feedback of HARQ-ACK information.

The following information is transmitted by means of the SCI format 2-B:

- HARQ process number – 4 bits.
- New data indicator – 1 bit.
- Redundancy version – 2 bits as defined in Table 7.3.1.1.1-2.
- Source ID – 8 bits as defined in clause 8.1 of [6, TS 38.214].
- Destination ID – 16 bits as defined in clause 8.1 of [6, TS 38.214].
- HARQ feedback enabled/disabled indicator – 1 bit as defined in clause 16.3 of [5, TS 38.213].
- Zone ID – 12 bits as defined in clause 5.8.11 of [9, TS 38.331].
- Communication range requirement – 4 bits determined by higher layer parameter *sl-ZoneConfigMCR-Index*.

### 8.4.2 CRC attachment

CRC attachment is performed according to clause 7.3.2 except that scrambling is not performed.

### 8.4.3 Channel coding

Channel coding is performed according to clause 7.3.3.

### 8.4.4 Rate Matching

For 2<sup>nd</sup>-stage SCI transmission on PSSCH with SL-SCH, the number of coded modulation symbols generated for 2<sup>nd</sup>-stage SCI transmission prior to duplication for the 2nd layer if present, denoted as  $Q'_{SC12}$ , is determined as follows:

$$Q'_{SC12} = \min \left\{ \left\lceil \frac{(O_{SC12} + L_{SC12}) \cdot \beta_{offset}^{SC12}}{Q_m^{SC12} \cdot R} \right\rceil, \left\lceil \alpha \sum_{l=0}^{N_{symbol}^{PSSCH}-1} M_{sc}^{SC12}(l) \right\rceil \right\} + \gamma$$

where

- $O_{SCI2}$  is the number of the 2<sup>nd</sup>-stage SCI bits
- $L_{SCI2}$  is the number of CRC bits for the 2<sup>nd</sup>-stage SCI, which is 24 bits.
- $\beta_{offset}^{SCI2}$  is indicated in the corresponding 1<sup>st</sup>-stage SCI.
- $M_{sc}^{PSSCH}(l)$  is the scheduled bandwidth of PSSCH transmission, expressed as a number of subcarriers.
- $M_{sc}^{PSCCH}(l)$  is the number of subcarriers in OFDM symbol  $l$  that carry PSCCH and PSCCH DMRS associated with the PSSCH transmission.
- $M_{sc}^{SCI2}(l)$  is the number of resource elements that can be used for transmission of the 2<sup>nd</sup>-stage SCI in OFDM symbol  $l$ , for  $l = 0, 1, 2, \dots, N_{symbol}^{PSSCH} - 1$  and for  $N_{symbol}^{PSSCH} = N_{symbol}^{sh} - N_{symbol}^{PSFCH}$ , in PSSCH transmission, where  $N_{symbol}^{sh} = sl-lengthSymbols - 2$ , where  $sl-lengthSymbols$  is the number of sidelink symbols within the slot provided by higher layers as defined in [6, TS 38.214]. If higher layer parameter  $sl-PSFCH-Period = 2$  or  $4$ ,  $N_{symbol}^{PSFCH} = 3$  if "PSFCH overhead indication" field of SCI format 1-A indicates "1", and  $N_{symbol}^{PSFCH} = 0$  otherwise. If higher layer parameter  $sl-PSFCH-Period = 0$ ,  $N_{symbol}^{PSFCH} = 0$ . If higher layer parameter  $sl-PSFCH-Period$  is 1,  $N_{symbol}^{PSFCH} = 3$ .
- $M_{sc}^{SCI2}(l) = M_{sc}^{PSSCH}(l) - M_{sc}^{PSCCH}(l)$
- $\gamma$  is the number of vacant resource elements in the resource block to which the last coded symbol of the 2<sup>nd</sup>-stage SCI belongs.
- $R$  is the coding rate as indicated by "Modulation and coding scheme" field in SCI format 1-A.
- $\alpha$  is configured by higher layer parameter  $sl-Scaling$ .

The input bit sequence to rate matching is  $d_0, d_1, d_2, d_3, \dots, d_{N-1}$ , where  $N$  is the number of coded bits.

Rate matching is performed according to Clause 5.4.1 by setting  $I_{BL} = 1$ .

The output bit sequence after rate matching is denoted as  $g_0^{SCI2}, g_1^{SCI2}, g_2^{SCI2}, g_3^{SCI2}, \dots, g_{G^{SCI2}-1}^{SCI2}$ , where  $G^{SCI2} = Q'_{SCI2} \cdot Q_m^{SCI2}$  and  $Q_m^{SCI2}$  is modulation order of the 2<sup>nd</sup>-stage SCI. A UE is not expected to have  $G^{SCI2} > 4096$ .

### 8.4.5 Multiplexing of coded 2<sup>nd</sup>-stage SCI bits to PSSCH

The coded 2<sup>nd</sup>-stage SCI bits are multiplexed onto PSSCH according to the procedures in Clause 8.2.1.



## Annex A: Change history

Change history							
Date	Meeting	TDoc	CR	Rev	Cat	Subject/Comment	New version
2017-05	RAN1#89	R1-1707082				Draft skeleton	0.0.0
2017-07	AH_NR2	R1-1712014				Inclusion of LDPC related agreements	0.0.1
2017-08	RAN1#90	R1-1714564				Inclusion of Polar coding related agreements	0.0.2
2017-08	RAN1#90	R1-1714659				Endorsed version by RAN1#90 as basis for further updates	0.1.0
2017-09	RAN1#90	R1-1715322				Capturing additional agreements on LDPC and Polar code from RAN1 #90	0.1.1
2017-09	RAN#77	RP-171991				For information to plenary	1.0.0
2017-09	RAN1#90b	R1-1716928				Capturing additional agreements on LDPC and Polar code from RAN1 NR AH#3	1.0.1
2017-10	RAN1#90b	R1-1719106				Endorsed as v1.1.0	1.1.0
2017-11	RAN1#91	R1-1719225				Capturing additional agreements on channel coding, etc.	1.1.1
2017-11	RAN1#91	R1-1719245				Capturing additional agreements on DCI format, channel coding, etc.	1.1.2
2017-11	RAN1#91	R1-1721049				Endorsed as v1.2.0	1.2.0
2017-12	RAN1#91	R1-1721342				Capturing additional agreements on UCI, DCI, channel coding, etc.	1.2.1
2017-12	RAN#78	RP-172668				Endorsed version for approval by plenary.	2.0.0
2017-12	RAN#78					Approved by plenary – Rel-15 spec under change control	15.0.0
2018-03	RAN#79	RP-180200	0001	-	F	CR capturing the Jan18 ad-hoc and RAN1#92 meeting agreements	15.1.0
2018-04	RAN#79					MCC: correction of typo in DCI format 0_1 (time domain resource assignment) – higher layer parameter should be <i>pusch-AllocationList</i>	15.1.1
2018-06	RAN#80	RP-181172	0002	1	F	CR to 38.212 capturing the RAN1#92bis and RAN1#93 meeting agreements	15.2.0
2018-06	RAN#80	RP-181257	0003	-	B	CR to 38.212 capturing the RAN1#92bis and RAN1#93 meeting agreements related to URLLC	15.2.0
2018-09	RAN#81	RP-181789	0004	-	F	CR to 38.212 capturing the RAN1#94 meeting agreements	15.3.0
2018-12	RAN#82	RP-182523	0005	3	F	Combined CR of all essential corrections to 38.212 from RAN1#94bis and RAN1#95	15.4.0
2019-03	RAN#83	RP-190448	0006	-	F	Correction of wrong implementation on frequency domain resource assignment bandwidth	15.5.0
2019-03	RAN#83	RP-190448	0008	-	F	Correction to UCI multiplexing	15.5.0
2019-03	RAN#83	RP-190448	0009	-	F	Correction on DCI format 2_3 for SUL cell in TS 38.212	15.5.0
2019-03	RAN#83	RP-190448	0010	-	F	Corrections to TS38.212	15.5.0
2019-03	RAN#83	RP-190448	0011	-	F	On bandwidth calculation for DCI fields using RRC parameter indicating maximum number of MIMO layers per serving cell	15.5.0
2019-03	RAN#83	RP-190448	0012	-	F	CR on zero-padding of DCI 1_1 in cross-carrier scheduling case	15.5.0
2019-03	RAN#83	RP-190448	0013	-	F	Clarification on UL_SUL indicator field and SRS request field	15.5.0
2019-06	RAN#84	RP-191282	0014	-	F	CR on correction to bandwidth of NNZC indicator	15.6.0
2019-06	RAN#84	RP-191282	0015	-	F	Correction on DCI size alignment in TS 38.212	15.6.0
2019-06	RAN#84	RP-191282	0016	-	F	Correction on UL/SUL indicator in DCI format 0_0	15.6.0
2019-06	RAN#84	RP-191282	0017	-	F	Corrections to 38.212 including alignment of terminology across specifications	15.6.0
2019-06	RAN#84	RP-191282	0018	-	F	CR on maximum modulation order configured for serving cell	15.6.0
2019-06	RAN#84	RP-191282	0019	1	F	Corrections to 38.212 including alignment of terminology across specifications from RAN1#97	15.6.0
2019-09	RAN#85	RP-191941	0020	-	F	Corrections to 38.212 including alignment of terminology across specifications in RAN1#98	15.7.0
2019-12	RAN#86	RP-192625	0021	-	F	CR on UL/SUL indicator in DCI format 0_1	15.8.0
2019-12	RAN#86	RP-192625	0022	-	F	Corrections to 38.212 including alignment of terminology across specifications in RAN1#98bis and RAN1#99	15.8.0
2019-12	RAN#86	RP-192636	0023	-	B	Introduction of NR based access to unlicensed spectrum into 38.212	16.0.0
2019-12	RAN#86	RP-192637	0024	-	B	Introduction of IAB into 38.212	16.0.0
2019-12	RAN#86	RP-192638	0025	-	B	Introduction of 5G V2X sidelink features into TS 38.212	16.0.0
2019-12	RAN#86	RP-192639	0026	-	B	Introduction of Physical Layer Enhancements for NR URLLC	16.0.0
2019-12	RAN#86	RP-192641	0027	-	B	Introduction of Enhancements on NR MIMO	16.0.0
2019-12	RAN#86	RP-192642	0028	-	B	Introduction of power saving in 38.212	16.0.0
2019-12	RAN#86	RP-192645	0029	-	B	Introduction of MR DC/CA	16.0.0
2019-12	RAN#86	RP-192643	0030	-	B	Introduction of NR positioning support	16.0.0
2019-12	RAN#86	RP-192635	0031	-	B	Introduction of two-step RACH	16.0.0
2020-03	RAN#87-e	RP-200185	0032	-	F	Corrections for Rel-16 NR-U after RAN1#100-e	16.1.0

2020-03	RAN#87-e	RP-200190	0033	-	F	Corrections for NR MIMO after RAN1#100-e	16.1.0
2020-03	RAN#87-e	RP-200188	0034	-	F	Corrections for URLLC after RAN1#100-e	16.1.0
2020-03	RAN#87-e	RP-200191	0035	-	F	Corrections for power saving after RAN1#100-e	16.1.0
2020-03	RAN#87-e	RP-200187	0036	-	F	Corrections on 5G V2X sidelink features after RAN1#100-e	16.1.0
2020-06	RAN#88-e	RP-200683	0038	-	A	CR on L1-RSRP report on PUSCH	16.2.0
2020-06	RAN#88-e	RP-200693	0039	1	F	Corrections for power saving	16.2.0
2020-06	RAN#88-e	RP-200689	0040	1	F	Corrections on 5G V2X sidelink features after RAN1#100bis-e and RAN1#101-e	16.2.0
2020-06	RAN#88-e	RP-200694	0041	1	F	Corrections in TS 38.212 for NR positioning	16.2.0
2020-06	RAN#88-e	RP-200692	0042	1	F	Corrections in TS 38.212 for NR MIMO	16.2.0
2020-06	RAN#88-e	RP-200696	0043	-	F	Corrections for Rel-16 MR-DC/CA after RAN1#100bis-e	16.2.0
2020-06	RAN#88-e	RP-200690	0044	1	F	Corrections on NR eURLLC	16.2.0
2020-06	RAN#88-e	RP-200687	0045	1	F	Corrections for Rel-16 NR-U	16.2.0
2020-06	RAN#88-e	RP-200688	0046	-	F	Corrections for NR IAB	16.2.0
2020-09	RAN#89-e	RP-201814	0047	-	F	Correction on UCI bit sequence generation	16.3.0
2020-09	RAN#89-e	RP-201803	0049	-	A	CR on PTRS for TS 38.212	16.3.0
2020-09	RAN#89-e	RP-201810	0050	-	F	Alignment of RRC parameter <i>ps-RNTI</i>	16.3.0
2020-09	RAN#89-e	RP-201813	0051	-	F	CR to 38.212 on RRC parameter alignment for SCell dormancy	16.3.0
2020-09	RAN#89-e	RP-201807	0052	-	F	Corrections on 5G V2X sidelink features	16.3.0
2020-09	RAN#89-e	RP-201809	0053	-	F	Corrections to MIMO enhancements	16.3.0
2020-09	RAN#89-e	RP-201805	0054	-	F	Corrections to MIMO enhancements	16.3.0
2020-09	RAN#89-e	RP-201808	0055	-	F	Corrections on NR eURLLC	16.3.0
2020-12	RAN#90-e	RP-202390	0056	-	F	RRC IE name fix to dynamic frequency domain resource allocation type selection (Rel-15 origin)	16.4.0
2020-12	RAN#90-e	RP-202384	0057	-	F	Correction on Transmission configuration indication in DCI format 1_2	16.4.0
2020-12	RAN#90-e	RP-202398	0058	-	F	Alignment CR for TS 38.212	16.4.0
2021-03	RAN#91-e	RP-210052	0059	-	F	CR on DMRS	16.5.0
2021-03	RAN#91-e	RP-210049	0060	-	F	Correction to description of FDRA field size in DCI 0_0	16.5.0
2021-03	RAN#91-e	RP-210049	0061	-	F	Correction to description of FDRA field interpretation in DCI 0_1	16.5.0
2021-03	RAN#91-e	RP-210050	0062	-	F	Correction on Sidelink Broadcast channel	16.5.0
2021-03	RAN#91-e	RP-210049	0063	-	F	Correction on LBT Type and CP Extension Indication for Semi-Static Channel Occupancy	16.5.0
2021-03	RAN#91-e	RP-210059	0064	-	F	Alignment CR for TS 38.212	16.5.0
2021-06	RAN#92-e	RP-211252	0066	-	F	38.212 CR on DAI size determination for DCI format 1_1/1-2 in CA	16.6.0
2021-06	RAN#92-e	RP-211236	0067	-	F	Corrections on parameter of MCS table set to qam256	16.6.0
2021-06	RAN#92-e	RP-211234	0068	-	D	Alignment CR for TS 38.212 (post RAN1#104bis-e)	16.6.0
2021-06	RAN#92-e	RP-211234	0069	-	F	Correction on HARQ-ACK codebook RRC parameter	16.6.0
2021-06	RAN#92-e	RP-211236	0070	-	F	Correction on SRS resource set configuration in TS 38.212	16.6.0

2021-06	RAN#92-e	RP-211243	0071	-	F	Alignment CR for TS 38.212 (post RAN1#105-e)	16.6.0
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# History

<b>Document history</b>		
V16.2.0	July 2020	Publication
V16.3.0	November 2020	Publication
V16.4.0	January 2021	Publication
V16.5.0	April 2021	Publication
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