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Contents

Foreword

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1 Scope

The present document contains the description and definition of the measurements done at the UE and network in order to support operation in idle mode and connected mode.

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 36.201: "Evolved Universal Terrestrial Radio Access (E-UTRA); Physical Layer – General Description ".

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

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

[5] 3GPP TS 36.213: "Evolved Universal Terrestrial Radio Access (E-UTRA); Physical layer procedures ".

[6] 3GPP TS 36.321: "Evolved Universal Terrestrial Radio Access (E-UTRA); Medium Access Control (MAC) protocol specification".

[7] 3GPP TS 36.331: "Evolved Universal Terrestrial Radio Access (E-UTRA); Radio Resource Control (RRC); Protocol specification ".

[8] 3GPP2 CS.0005-D v1.0 "Upper Layer (Layer 3) Signaling Standard for CDMA2000 Spread Spectrum Systems Release D".

[9] 3GPP2 CS.0024-A v3.0 "cdma2000 High Rate Packet Data Air Interface Specification"

[10] 3GPP TS 36.104: "Evolved Universal Terrestrial Radio Access (E-UTRA); Base Station (BS) radio transmission and reception ".

[11] 3GPP TS 36.355: "Evolved Universal Terrestrial Radio Access (E-UTRA); LTE Positioning Protocol (LPP)"

[12] 3GPP TS 36.455: "Evolved Universal Terrestrial Radio Access (E-UTRA); LTE Positioning Protocol A (LPPa)"

[13] 3GPP TS 36.459: "Evolved Universal Terrestrial Radio Access (E-UTRA); SLm Application Protocol (SLmAP)"

[14] 3GPP TS 36.111: "Evolved Universal Terrestrial Radio Access (E-UTRA); Location Measurement Unit (LMU) performance specification; Network Based Positioning Systems in E-UTRAN"

[15] IEEE 802.11, Part 11: "Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) specifications, IEEE Std.".

[16] 3GPP TS 36.304: "Evolved Universal Terrestrial Radio Access (E-UTRA); User Equipment (UE) procedures in idle mode ".

[17] 3GPP TS 38.213: "NR; Physical layer procedures for control".

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:

Ec/No Received energy per chip divided by the power density in the band

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].

1x RTT	CDMA2000 1x Radio Transmission Technology
CPICH	Common Pilot Channel
E-SMLC	Enhanced Serving Mobile Location Centre
E-UTRA	Evolved UTRA
E-UTRAN	Evolved UTRAN
FDD	Frequency Division Duplex
GNSS	Global Navigation Satellite System
GSM	Global System for Mobile communication
HRPD	CDMA2000 High Rate Packet Data
LMU	Location Measurement Unit
P-CCPCH	Primary Common Control Physical Channel
RSCP	Received Signal Code Power
RSRP	Reference Signal Received Power
RSRQ	Reference Signal Received Quality
RSSI	Received Signal Strength Indicator
RSTD	Reference Signal Time Difference
SRS	Sounding Reference Signal
TDD	Time Division Duplex
UTRA	Universal Terrestrial Radio Access
UTRAN	Universal Terrestrial Radio Access Network

4 Control of UE/E-UTRAN measurements

In this chapter the general measurement control concept of the higher layers is briefly described to provide an understanding on how L1 measurements are initiated and controlled by higher layers.

With the measurement specifications L1 provides measurement capabilities for the UE and E-UTRAN. These measurements can be classified in different reported measurement types: intra-frequency, inter-frequency, inter-system, traffic volume, quality and UE internal measurements (see the RRC Protocol [7]).

In the L1 measurement definitions, see chapter 5, the measurements are categorised as measurements in the UE (the messages for these will be described in the MAC Protocol [6] or RRC Protocol [7] or LPP Protocol [11]) or measurements in the E-UTRAN (the messages for these will be described in the Frame Protocol or LPPa Protocol [12]).

To initiate a specific measurement, the E-UTRAN transmits a 'RRC connection reconfiguration message' to the UE including a measurement ID and type, a command (setup, modify, release), the measurement objects, the measurement quantity, the reporting quantities and the reporting criteria (periodical/event-triggered), see [7] or E-SMLC transmits an 'LPP Request Location Information message' to UE, see [11].

When the reporting criteria are fulfilled the UE shall answer with a 'measurement report message' to the E-UTRAN including the measurement ID and the results or an 'LPP Provide Location Information message' to the E-SMLC, see [11].

For idle mode, the measurement information elements are broadcast in the System Information.

5 Measurement capabilities for E-UTRA

In this chapter the physical layer measurements reported to higher layers are defined.

5.1 UE measurement capabilities

The structure of the table defining a UE measurement quantity is shown below.

Column field	Comment
Definition	Contains the definition of the measurement.
Applicable for	States in which state(s) it shall be possible to perform this measurement. The following terms are used in the tables: RRC_IDLE; RRC_CONNECTED; Intra-frequency appended to the RRC state: Shall be possible to perform in the corresponding RRC state on an intra-frequency cell; Inter-frequency appended to the RRC state: Shall be possible to perform in the corresponding RRC state on an inter-frequency cell Inter-RAT appended to the RRC state: Shall be possible to perform in the corresponding RRC state on an inter-RAT cell.

5.1.1 Reference Signal Received Power (RSRP)

Definition	Reference signal received power (RSRP), is defined as the linear average over the power contributions (in [W]) of the resource elements that carry cell-specific reference signals within the considered measurement frequency bandwidth. For RSRP determination the cell-specific reference signals R_0 according to TS 36.211 [3] shall be used. If the UE can reliably detect that R_1 is available, it may use R_1 in addition to R_0 to determine RSRP. If higher layers indicate measurements based on discovery signals, the UE shall measure RSRP in the subframes in the configured discovery signal occasions. For frame structure 1 and 2, if the UE can reliably detect that cell-specific reference signals are present in other subframes, the UE may use those subframes in addition to determine RSRP. The reference point for the RSRP shall be the antenna connector of the UE. If receiver diversity is in use by the UE, the reported value shall not be lower than the corresponding RSRP of any of the individual diversity branches.
Applicable for	RRC_IDLE intra-frequency, RRC_IDLE inter-frequency, RRC_CONNECTED intra-frequency, RRC_CONNECTED inter-frequency

NOTE 1: The number of resource elements within the considered measurement frequency bandwidth and within the measurement period that are used by the UE to determine RSRP is left up to the UE implementation with the limitation that corresponding measurement accuracy requirements have to be fulfilled.

NOTE 2: The power per resource element is determined from the energy received during the useful part of the symbol, excluding the CP.

5.1.2 Void

5.1.3 Reference Signal Received Quality (RSRQ)

Definition	Reference Signal Received Quality (RSRQ) is defined as the ratio *N*×RSRP/(E-UTRA carrier RSSI), where *N* is the number of RB's of the E-UTRA carrier RSSI measurement bandwidth. The measurements in the numerator and denominator shall be made over the same set of resource blocks. E-UTRA Carrier Received Signal Strength Indicator (RSSI), comprises the linear average of the total received power (in [W]) observed only in certain OFDM symbols of measurement subframes, in the measurement bandwidth, over *N* number of resource blocks by the UE from all sources, including co-channel serving and non-serving cells, adjacent channel interference, thermal noise etc. Unless indicated otherwise by higher layers, RSSI is measured only from OFDM symbols containing reference symbols for antenna port 0 of measurement subframes. If higher layers indicate all OFDM symbols for performing RSRQ measurements, then RSSI is measured from all OFDM symbols of the DL part of measurement subframes. If higher-layers indicate certain subframes for performing RSRQ measurements, then RSSI is measured from all OFDM symbols of the DL part of the indicated subframes. If higher layers indicate measurements based on discovery signals, RSSI is measured from all OFDM symbols of the DL part of the subframes in the configured discovery signal occasions. The reference point for the RSRQ shall be the antenna connector of the UE. If receiver diversity is in use by the UE, the reported value shall not be lower than the corresponding RSRQ of any of the individual diversity branches.
Applicable for	RRC_IDLE intra-frequency, RRC_IDLE inter-frequency, RRC_CONNECTED intra-frequency, RRC_CONNECTED inter-frequency

5.1.4 UTRA FDD CPICH RSCP

Definition	Received Signal Code Power, the received power on one code measured on the Primary CPICH. The reference point for the RSCP shall be the antenna connector of the UE. If Tx diversity is applied on the Primary CPICH the received code power from each antenna shall be separately measured and summed together in [W] to a total received code power on the Primary CPICH. If receiver diversity is in use by the UE, the reported value shall not be lower than the corresponding CPICH RSCP of any of the individual receive antenna branches.
Applicable for	RRC_IDLE inter-RAT, RRC_CONNECTED inter-RAT

5.1.5 UTRA FDD carrier RSSI

Definition	The received wide band power, including thermal noise and noise generated in the receiver, within the bandwidth defined by the receiver pulse shaping filter. The reference point for the measurement shall be the antenna connector of the UE. If receiver diversity is in use by the UE, the reported value shall not be lower than the corresponding UTRA carrier RSSI of any of the individual receive antenna branches.
Applicable for	RRC_IDLE inter-RAT, RRC_CONNECTED inter-RAT

NOTE: This definition does not correspond to a reported measurement. This definition is just an intermediate definition used in the definition of UTRA FDD CPICH Ec/No.

5.1.6 UTRA FDD CPICH Ec/No

Definition	The received energy per chip divided by the power density in the band. If receiver diversity is not in use by the UE, the CPICH Ec/No is identical to CPICH RSCP/UTRA Carrier RSSI. Measurement shall be performed on the Primary CPICH. The reference point for the CPICH Ec/No shall be the antenna connector of the UE. If Tx diversity is applied on the Primary CPICH the received energy per chip (Ec) from each antenna shall be separately measured and summed together in [Ws] to a total received chip energy per chip on the Primary CPICH, before calculating the Ec/No. If receiver diversity is in use by the UE, the measured CPICH Ec/No value shall not be lower than the corresponding CPICH $RSCP_i$/UTRA Carrier $RSSI_i$ of receive antenna branch *i* .
Applicable for	RRC_IDLE inter-RAT, RRC_CONNECTED inter-RAT

5.1.7 GSM carrier RSSI

Definition	Received Signal Strength Indicator, the wide-band received power within the relevant channel bandwidth. Measurement shall be performed on a GSM BCCH carrier. The reference point for the RSSI shall be the antenna connector of the UE.
Applicable for	RRC_IDLE inter-RAT, RRC_CONNECTED inter-RAT

5.1.8 Void

5.1.9 UTRA TDD P-CCPCH RSCP

Definition	Received Signal Code Power, the received power on P-CCPCH of a neighbour UTRA TDD cell. The reference point for the RSCP shall be the antenna connector of the UE.
Applicable for	RRC_IDLE inter-RAT, RRC_CONNECTED inter-RAT

5.1.10 CDMA2000 1x RTT Pilot Strength

Definition	CDMA2000 1x RTT Pilot Strength measurement is defined in section 2.6.6.2.2 of [8]
Applicable for	RRC_IDLE inter-RAT, RRC_CONNECTED inter-RAT

5.1.11 CDMA2000 HRPD Pilot Strength

Definition	CDMA2000 HRPD Pilot Strength Measurement is defined in section 8.7.6.1.2.3 of [9]
Applicable for	RRC_IDLE inter-RAT, RRC_CONNECTED inter-RAT

5.1.12 Reference signal time difference (RSTD)

Definition	The relative timing difference between the neighbour cell j and the reference cell i, defined as $T_{SubframeRxj} – T_{SubframeRxi}$, where: $T_{SubframeRxj}$ is the time when the UE receives the start of one subframe from cell j $T_{SubframeRxi}$ is the time when the UE receives the corresponding start of one subframe from cell i that is closest in time to the subframe received from cell j. The reference point for the observed subframe time difference shall be the antenna connector of the UE.
Applicable for	RRC_CONNECTED intra-frequency RRC_CONNECTED inter-frequency RRC_IDLE intra-frequency only applicable for NB-IoT UEs RRC_IDLE inter-frequency only applicable for NB-IoT UEs

5.1.13 UE GNSS Timing of Cell Frames for UE positioning

Definition	The timing between cell j and a GNSS-specific reference time for a given GNSS (e.g., GPS/Galileo/Glonass system time). $T_{UE-GNSS}$ is defined as the time of occurrence of a specified E-UTRAN event according to GNSS time for a given GNSS Id. The specified E-UTRAN event is the beginning of a particular frame (identified through its SFN) in the first detected path (in time) of the cell-specific reference signals of the cell j, where cell j is a cell chosen by the UE. The reference point for $T_{UE-GNSSj}$ shall be the antenna connector of the UE.
Applicable for	RRC_CONNECTED intra-frequency

5.1.14 UE GNSS code measurements

Definition	The GNSS code phase (integer and fractional parts) of the spreading code of the i^{th} GNSS satellite signal. The reference point for the GNSS code phase shall be the antenna connector of the UE.
Applicable for	Void (this measurement is not related to E-UTRAN/UTRAN/GSM signals; its applicability is therefore independent of the UE RRC state)

5.1.14A UE GNSS carrier phase measurements

Definition	The number of carrier-phase cycles (integer and fractional parts) of the i^{th} GNSS satellite signal, measured since locking onto the signal. Also called Accumulated Delta Range (ADR). The reference point for the GNSS carrier phase shall be the antenna connector of the UE.
Applicable for	Void (this measurement is not related to E-UTRAN/UTRAN/GSM signals; its applicability is therefore independent of the UE RRC state)

5.1.15 UE Rx – Tx time difference

Definition	The UE Rx – Tx time difference is defined as $T_{UE-RX} - T_{UE-TX}$ Where: T_{UE-RX} is the UE received timing of downlink radio frame #i from the serving cell, defined by the first detected path in time. T_{UE-TX} is the UE transmit timing of uplink radio frame #i. The reference point for the UE Rx – Tx time difference measurement shall be the UE antenna connector. For a HD-FDD UE, if the UE does not receive any DL transmission in radio frame #i, it shall compensate for the difference in the received timing of radio frame #i and the radio frame in which it did receive a DL transmission used for T_{UE-RX} estimation.
Applicable for	RRC_CONNECTED intra-frequency Not applicable for NB-IoT UEs

5.1.16 IEEE 802.11 WLAN RSSI

Definition	The IEEE 802.11 WLAN RSSI as used in RRC specification [7] refers to RSSI as defined in IEEE 802.11 specification [15], measured from Beacon, DMG Beacon or FILS discovery frames (in passive scanning mode) or from probe response frames (in active scanning mode).
Applicable for	RRC_CONNECTED inter-RAT, RRC_IDLE inter-RAT

5.1.17 MBSFN Reference Signal Received Power (MBSFN RSRP)

Definition	MBSFN Reference signal received power (MBSFN RSRP), is defined as the linear average over the power contributions (in [W]) of the resource elements that carry MBSFN reference signals within the considered measurement frequency bandwidth. For MBSFN RSRP determination the MBSFN reference signals R_4 according to TS 36.211 [3] shall be used. The reference point for the MBSFN RSRP shall be the antenna connector of the UE. If receiver diversity is in use by the UE, the reported value shall not be lower than the corresponding MBSFN RSRP of any of the individual diversity branches.
Applicable for	RRC_IDLE intra-frequency, RRC_IDLE inter-frequency, RRC_CONNECTED intra-frequency, RRC_CONNECTED inter-frequency

NOTE 1: The number of resource elements within the considered measurement frequency bandwidth and within the measurement period that are used by the UE to determine MBSFN RSRP is left up to the UE implementation with the limitation that corresponding measurement accuracy requirements have to be fulfilled.

NOTE 2: The power per resource element is determined from the energy received during the useful part of the symbol, excluding the CP.

NOTE 3: The measurement is made only in subframes and on carriers where the UE is decoding PMCH.

5.1.18 MBSFN Reference Signal Received Quality (MBSFN RSRQ)

Definition	MBSFN Reference Signal Received Quality (RSRQ) is defined as the ratio N× MBSFN RSRP/(MBSFN carrier RSSI), where N is the number of RBs of the MBSFN carrier RSSI measurement bandwidth. The measurements in the numerator and denominator shall be made over the same set of resource blocks. MBSFN Carrier Received Signal Strength Indicator (MBSFN carrier RSSI), comprises the linear average of the total received power (in [W]) observed only in OFDM symbols containing reference symbols for antenna port 4, in the measurement bandwidth, over N number of resource blocks by the UE from all sources, including co-channel serving and non-serving cells, adjacent channel interference, thermal noise etc. The reference point for the MBSFN RSRQ shall be the antenna connector of the UE. If receiver diversity is in use by the UE, the reported value shall not be lower than the corresponding MBSFN RSRQ of any of the individual diversity branches.
Applicable for	RRC_IDLE intra-frequency, RRC_IDLE inter-frequency, RRC_CONNECTED intra-frequency, RRC_CONNECTED inter-frequency

NOTE 1: The measurement is made only in subframes and on carriers where the UE is decoding PMCH.

5.1.19 Multicast Channel Block Error Rate (MCH BLER)

Definition	Multicast channel block error rate (MCH BLER) estimation shall be based on evaluating the CRC of MCH transport blocks. The BLER shall be computed over the measurement period as the ratio between the number of received MCH transport blocks resulting in a CRC error and the total number of received MCH transport blocks of an MCH. The MCH BLER estimation shall only consider MCH transport blocks using the same MCS.
Applicable for	RRC_IDLE intra-frequency, RRC_IDLE inter-frequency, RRC_CONNECTED intra-frequency, RRC_CONNECTED inter-frequency

NOTE 1: The measurement is made only in subframes and on carriers where the UE is decoding PMCH.

5.1.20 CSI Reference Signal Received Power (CSI-RSRP)

Definition	CSI reference signal received power (CSI-RSRP), is defined as the linear average over the power contributions (in [W]) of the resource elements that carry CSI reference signals configured for discovery signal measurements within the considered measurement frequency bandwidth in the subframes in the configured discovery signal occasions. For CSI-RSRP determination CSI reference signals R_{15} according to TS 36.211 [3] shall be used. The reference point for the CSI-RSRP shall be the antenna connector of the UE. If receiver diversity is in use by the UE, the reported value shall not be lower than the corresponding CSI-RSRP of any of the individual diversity branches.
Applicable for	RRC_CONNECTED intra-frequency, RRC_CONNECTED inter-frequency

NOTE 1: The number of resource elements within the considered measurement frequency bandwidth and within the measurement period that are used by the UE to determine CSI-RSRP is left up to the UE implementation with the limitation that corresponding measurement accuracy requirements have to be fulfilled.

NOTE 2: The power per resource element is determined from the energy received during the useful part of the symbol, excluding the CP.

5.1.21 Sidelink Reference Signal Received Power (S-RSRP)

Definition	Sidelink Reference Signal Received Power (S-RSRP) is defined as the linear average over the power contributions (in [W]) of the resource elements that carry demodulation reference signals associated with PSBCH, within the central 6 PRBs of the applicable subframes. The reference point for the S-RSRP shall be the antenna connector of the UE. If receiver diversity is in use by the UE, the reported value shall not be lower than the corresponding S-RSRP of any of the individual diversity branches.
Applicable for	RRC_IDLE intra-frequency, RRC_IDLE inter-frequency, RRC_CONNECTED inter-frequency

NOTE 1: The number of resource elements within the considered measurement frequency bandwidth and within the measurement period that are used by the UE to determine S-RSRP is left up to the UE implementation with the limitation that corresponding measurement accuracy requirements have to be fulfilled.

NOTE 2: The power per resource element is determined from the energy received during the useful part of the symbol, excluding the CP.

NOTE 3: For RRC_IDLE intra-frequency, S-RSRP is only applicable to the Any Cell Selection state[16].

5.1.22 Sidelink Discovery Reference Signal Received Power (SD-RSRP)

Definition	Sidelink Discovery Reference Signal Received Power (SD-RSRP) is defined as the linear average over the power contributions (in [W]) of the resource elements that carry demodulation reference signals associated with PSDCH for which CRC has been validated. The reference point for the SD-RSRP shall be the antenna connector of the UE. If receiver diversity is in use by the UE, the reported value shall not be lower than the corresponding SD-RSRP of any of the individual diversity branches.
Applicable for	RRC_IDLE intra-frequency, RRC_IDLE inter-frequency, RRC_CONNECTED intra-frequency RRC_CONNECTED inter-frequency

NOTE 1: The number of resource elements within the considered measurement frequency bandwidth and within the measurement period that are used by the UE to determine SD-RSRP is left up to the UE implementation with the limitation that corresponding measurement accuracy requirements have to be fulfilled.

NOTE 2: The power per resource element is determined from the energy received during the useful part of the symbol, excluding the CP.

5.1.23 Reference signal-signal to noise and interference ratio (RS-SINR)

Definition	Reference signal-signal to noise and interference ratio (RS-SINR), is defined as the linear average over the power contribution (in [W]) of the resource elements carrying cell-specific reference signals divided by the linear average of the noise and interference power contribution (in [W]) over the resource elements carrying cell-specific reference signals within the same frequency bandwidth. For RS-SINR determination, the cell-specific reference signals R_0 according TS 36.211 [3] shall be used. The reference point for the RS-SINR shall be the antenna connector of the UE. If receiver diversity is in use by the UE, the reported value shall not be lower than the corresponding RS-SINR of any of the individual diversity branches. If higher-layer signalling indicates certain subframes for performing RS-SINR measurements, then RS-SINR is measured in the indicated subframes.
Applicable for	RRC_CONNECTED intra-frequency, RRC_CONNECTED inter-frequency

5.1.24 Received Signal Strength Indicator (RSSI)

Definition	E-UTRA Received Signal Strength Indicator (RSSI), comprises the linear average of the total received power (in [W]) observed only in the configured OFDM symbol and in the measurement bandwidth over *N* number of resource blocks, by the UE from all sources, including co-channel serving and non-serving cells, adjacent channel interference, thermal noise etc. Higher layers indicate the measurement duration and which OFDM symbol(s) should be measured by the UE. The reference point for the RSSI shall be the antenna connector of the UE. If receiver diversity is in use by the UE, the reported value shall not be lower than the corresponding RSSI of any of the individual diversity branches
Applicable for	RRC_CONNECTED intra-frequency, RRC_CONNECTED inter-frequency

5.1.25 SFN and subframe timing difference (SSTD)

Definition	The observed SFN and subframe timing difference (SSTD) between a PCell and a PSCell is defined as consisting of the following three components; - SFN offset = (SFN_{PCell} - SFN_{PSCell}) mod 1024, where SFN_{PCell} is the SFN of a PCell radio frame and SFN_{PSCell} is the SFN of the PSCell radio frame of which the UE receives the start closest in time to the time when it receives the start of the PCell radio frame. - Frame boundary offset = $\lfloor (T_{FrameBoundaryPCell} - T_{FrameBoundaryPSCell})/1000 \rfloor$, where $T_{FrameBoundaryPCell}$ is the time when the UE receives the start of a radio frame from the PCell and $T_{FrameBoundaryPSCell}$ is the time when the UE receives the start of the radio frame of PSCell that is closest in time to the radio frame received from the PCell. The unit of ($T_{FrameBoundaryPCell}$ - $T_{FrameBoundaryPSCell}$) is [µs]. - Subframe boundary offset = $T_{SubframePCell}$ - $T_{SubframePSCell}$, where $T_{SubframePCell}$ is the time when the UE receives the start of a subframe from the PCell and $T_{SubframePSCell}$ is the time when the UE receives the start of the subframe from the PSCell that is closest in time to the subframe received from the PCell. The reference point for the observed SFN and subframe time difference shall be the antenna connector of the UE.
Applicable for	RRC_CONNECTED intra-frequency

5.1.26 Narrowband Reference Signal Received Power (NRSRP)

Definition	Unless indicated otherwise by higher layers, narrowband reference signal received power (NRSRP), is defined as the linear average over the power contributions (in [W]) of the resource elements that carry narrowband specific reference signals within the considered measurement frequency bandwidth. For NRS based NRSRP determination, the narrowband reference signals for the first antenna port (R_{2000}) according to TS 36.211 [3] shall be used. If the UE can reliably detect that a second antenna port (R_{2001}) is available, it may use the second antenna port in addition to the first antenna port to determine NRSRP. If higher layers indicate measurements based on narrow band secondary synchronization signal (NSSS), NRSRP is defined as the linear average over the power contributions (in [W]) of the resource elements that carry NSSS in the NSSS occasions that the UE measures. The NRSRP is adjusted by the NSSS to NRS EPRE ratio as indicated by higher layers [7]. For NSSS based NRSRP determination, the UE may take the signalled precoder information applied at the antenna ports into account [7]. The reference point for the NRSRP shall be the antenna connector of the UE.
Applicable for	RRC_IDLE intra-frequency, RRC_IDLE inter-frequency, RRC_CONNECTED intra-frequency (only applicable for NRS based NRSRP)

5.1.27 Narrowband Reference Signal Received Quality (NRSRQ)

Definition	Narrowband Reference Signal Received Quality (NRSRQ) is defined as the ratio NRSRP/NRSSI. The measurements in the numerator and denominator shall be made over the same set of resource blocks. Narrowband Received Signal Strength Indicator (NRSSI), comprises the linear average of the total received power (in [W]) observed OFDM symbols of measurement subframes, in the measurement bandwidth by the UE from all sources, including co-channel serving and non-serving cells, adjacent channel interference, thermal noise etc. NRSSI is measured from all OFDM symbols of measurement subframes. The reference point for the NRSRQ shall be the antenna connector of the UE.
Applicable for	RRC_IDLE intra-frequency, RRC_IDLE inter-frequency

5.1.28 Sidelink Received Signal Strength Indicator (S-RSSI)

Definition	Sidelink RSSI (S-RSSI) is defined as the linear average of the total received power (in [W]) per SC-FDMA symbol observed by the UE only in the configured sub-channel in SC-FDMA symbols 1, 2, …, 6 of the first slot and SC-FDMA symbols 0,1,…, 5 of the second slot of a subframe The reference point for the S-RSSI shall be the antenna connector of the UE. If receiver diversity is in use by the UE, the reported value shall not be lower than the corresponding S-RSSI of any of the individual diversity branches
Applicable for	RRC_IDLE intra-frequency, RRC_IDLE inter-frequency, RRC_CONNECTED intra-frequency, RRC_CONNECTED inter-frequency

5.1.29 PSSCH Reference Signal Received Power (PSSCH-RSRP)

Definition	PSSCH Reference Signal Received Power (PSSCH-RSRP) is defined as the linear average over the power contributions (in [W]) of the resource elements that carry demodulation reference signals associated with PSSCH, within the PRBs indicated by the associated PSCCH. The reference point for the PSSCH-RSRP shall be the antenna connector of the UE. If receiver diversity is in use by the UE, the reported value shall not be lower than the corresponding PSSCH-RSRP of any of the individual diversity branches
Applicable for	RRC_IDLE intra-frequency, RRC_IDLE inter-frequency, RRC_CONNECTED intra-frequency, RRC_CONNECTED inter-frequency

NOTE: The power per resource element is determined from the energy received during the useful part of the symbol, excluding the CP.

5.1.30 Channel busy ratio (CBR)

Definition	Channel busy ratio (CBR) measured in subframe *n* is defined as follows: - For PSSCH, the portion of sub-channels in the resource pool whose S-RSSI measured by the UE exceed a (pre-)configured threshold sensed over subframes [*n-100*, *n-1*]; - For PSCCH, in a pool (pre)configured such that PSCCH may be transmitted with its corresponding PSSCH in non-adjacent resource blocks, the portion of the resources of the PSCCH pool whose S-RSSI measured by the UE exceed a (pre-)configured threshold sensed over subframes [*n-100, n-1*], assuming that the PSCCH pool is composed of resources with a size of two consecutive PRB pairs in the frequency domain.
Applicable for	RRC_IDLE intra-frequency, RRC_IDLE inter-frequency, RRC_CONNECTED intra-frequency, RRC_CONNECTED inter-frequency

NOTE: The subframe index is based on physical subframe index

5.1.31 Channel occupancy ratio (CR)

Definition	Channel occupancy ratio (CR) evaluated at subframe *n* is defined as the total number of sub-channels used for its transmissions in subframes [*n-a*, *n-1*] and granted in subframes [*n*, *n+b*] divided by the total number of configured sub-channels in the transmission pool over [*n-a*, *n+b*].
Applicable for	RRC_IDLE intra-frequency, RRC_IDLE inter-frequency, RRC_CONNECTED intra-frequency, RRC_CONNECTED inter-frequency

NOTE 1: *a* is a positive integer and *b* is 0 or a positive integer; *a* and *b* are determined by UE implementation with $a+b+1 = 1000$, a >= 500, and n+b should not exceed the last transmission opportunity of the grant for the current transmission.

NOTE 2: CR is evaluated for each (re)transmission.

NOTE 3: In evaluating CR, the UE shall assume the transmission parameter used at subframe *n* is reused according to the existing grant(s) in subframes [*n+1*, *n+b*] without packet dropping.

NOTE 4: The subframe index is based on physical subframe index.

NOTE 5: CR can be computed per priority level

5.1.32 NR SS reference signal received power (NR-SS-RSRP)

Definition	NR SS reference signal received power (NR-SS-RSRP) is defined as the linear average over the power contributions (in [W]) of the resource elements that carry secondary synchronization signals (SS). The measurement time resource(s) for NR-SS-RSRP are confined within SS/PBCH Block Measurement Time Configuration (SMTC) window duration. For NR-SS-RSRP determination demodulation reference signals for physical broadcast channel (PBCH) in addition to secondary synchronization signals may be used. NR-SS-RSRP using demodulation reference signal for PBCH shall be measured by linear averaging over the power contributions of the resource elements that carry corresponding reference signals taking into account power scaling for the reference signals as defined in 3GPP TS 38.213 [17]. NR-SS-RSRP shall be measured only among the reference signals corresponding to SS/PBCH blocks with the same SS/PBCH block index and the same physical-layer cell identity. If higher-layers indicate certain SS/PBCH blocks for performing NR-SS-RSRP measurements, then NR-SS-RSRP is measured only from the indicated set of SS/PBCH block(s). For frequency range 1, the reference point for the NR-SS-RSRP shall be the antenna connector of the UE. For frequency range 2, NR-SS-RSRP shall be measured based on the combined signal from antenna elements corresponding to a given receiver branch. For frequency range 1 and 2, if receiver diversity is in use by the UE, the reported NR-SS-RSRP value shall not be lower than the corresponding NR-SS-RSRP of any of the individual receiver branches.
Applicable for	RRC_IDLE inter-RAT, RRC_CONNECTED inter-RAT

NOTE 1: The number of resource elements within the measurement period that are used by the UE to determine NR-SS-RSRP is left up to the UE implementation with the limitation that corresponding measurement accuracy requirements have to be fulfilled.

NOTE 2: The power per resource element is determined from the energy received during the useful part of the symbol, excluding the CP.

5.1.33 NR SS reference signal received quality (NR-SS-RSRQ)

<table>
<tr><td>Definition</td><td>NR Secondary synchronization signal reference signal received quality (NR-SS-RSRQ) is defined as the ratio of N× NR-SS-RSRP / NR carrier RSSI, where N is the number of resource blocks in the NR carrier RSSI measurement bandwidth. The measurements in the numerator and denominator shall be made over the same set of resource blocks.

NR carrier Received Signal Strength Indicator (NR carrier RSSI), comprises the linear average of the total received power (in [W]) observed only in certain OFDM symbols of measurement time resource(s), in the measurement bandwidth, over N number of resource blocks from all sources, including co-channel serving and non-serving cells, adjacent channel interference, thermal noise etc. The measurement time resource(s) for NR Carrier RSSI are confined within SS/PBCH Block Measurement Time Configuration (SMTC) window duration.

If indicated by higher-layers, for a half-frame with SS/PBCH blocks the NR Carrier RSSI is measured from OFDM symbols of the indicated slots and the OFDM symbol are given by Table 5.1.33-1. Otherwise, if measurement gap is not used, NR Carrier RSSI is measured from OFDM symbols within SMTC window duration and, if measurement gap is used, NR Carrier RSSI is measured from OFDM symbols corresponding to overlapped time span between SMTC window duration and minimum measurement time within the measurement gap.

Table 5.1.33-1: NR Carrier RSSI measurement symbols
<table>
<tr><th>OFDM signal indication
SS-RSSI-MeasurementSymbolConfig</th><th>Symbol indexes</th></tr>
<tr><td>0</td><td>{0,1}</td></tr>
<tr><td>1</td><td>{0,1,2,..,10,11}</td></tr>
<tr><td>2</td><td>{0,1,2,…, 5}</td></tr>
<tr><td>3</td><td>{0,1,2,…, 7}</td></tr>
</table>
If higher-layers indicate certain SS/PBCH blocks for performing NR-SS-RSRQ measurements, then NR-SS-RSRP is measured only from the indicated set of SS/PBCH block(s).

For frequency range 1, the reference point for the NR-SS-RSRQ shall be the antenna connector of the UE. For frequency range 2, NR Carrier RSSI shall be measured based on the combined signal from antenna elements corresponding to a given receiver branch, where the combining for NR Carrier RSSI shall be the same as the one used for NR-SS-RSRP measurements. For frequency range 1 and 2, if receiver diversity is in use by the UE, the reported NR-SS-RSRQ value shall not be lower than the corresponding NR-SS-RSRQ of any of the individual receiver branches.</td></tr>
<tr><td>Applicable for</td><td>RRC_IDLE inter-RAT,
RRC_CONNECTED inter-RAT</td></tr>
</table>

5.1.34 SFN and frame timing difference (SFTD)

Definition	The observed SFN and frame timing difference (SFTD) between an E-UTRA PCell and an NR PSCell is defined as comprising the following two components: - SFN offset = (SFN_{PCell} - SFN_{PSCell}) mod 1024, where SFN_{PCell} is the SFN of a E-UTRA PCell radio frame and SFN_{PSCell} is the SFN of the NR PSCell radio frame of which the UE receives the start closest in time to the time when it receives the start of the PCell radio frame. - Frame boundary offset = $\lfloor (T_{FrameBoundaryPCell} - T_{FrameBoundaryPSCell})/5 \rfloor$, where $T_{FrameBoundaryPCell}$ is the time when the UE receives the start of a radio frame from the PCell, $T_{FrameBoundaryPSCell}$ is the time when the UE receives the start of the radio frame, from the PSCell, that is closest in time to the radio frame received from the PCell. The unit of ($T_{FrameBoundaryPCell}$ - $T_{FrameBoundaryPSCell}$) is Ts.
Applicable for	RRC_CONNECTED intra-frequency

5.2 E-UTRAN measurement abilities

The structure of the table defining a E-UTRAN measurement quantity is shown below.

Column field	Comment
Definition	Contains the definition of the measurement.

The term "antenna connector" used in this sub-clause to define the reference point for the E-UTRAN measurements refers to the "BS antenna connector" test port A and test port B as described in [10]. The term "antenna connector" refers to Rx or Tx antenna connector as described in the respective measurement definitions.

5.2.1 DL RS TX power

Definition	Downlink reference signal transmit power is determined for a considered cell as the linear average over the power contributions (in [W]) of the resource elements that carry cell-specific reference signals which are transmitted by the eNode B within its operating system bandwidth. For DL RS TX power determination the cell-specific reference signals R_0 and if available R_1 according TS 36.211 [3] can be used. The reference point for the DL RS TX power measurement shall be the TX antenna connector.

5.2.2 Received Interference Power

Definition	The uplink received interference power, including thermal noise, within one physical resource block's bandwidth of $N_{\mathrm{sc}}^{\mathrm{RB}}$ resource elements as defined in TS 36.211 [3]. The reported value shall contain a set of Received Interference Powers of physical resource blocks $n_{\mathrm{PRB}} = 0,..., N_{RB}^{UL} - 1$ as defined in TS 36.211 [3]. The reference point for the measurement shall be the RX antenna connector. In case of receiver diversity, the reported value shall be linear average of the power in the diversity branches.

5.2.3 Thermal noise power

Definition	The uplink thermal noise power within the UL system bandwidth consisting of N_{RB}^{UL} resource blocks as defined in [3]. It is defined as (N_o x *W*), where N_o denotes the white noise power spectral density on the uplink carrier frequency and $W = N_{RB}^{UL} \cdot N_{sc}^{RB} \cdot \Delta f$ denotes the UL system bandwidth. The measurement is optionally reported together with the Received Interference Power measurement, it shall be determined over the same time period as the Received Interference Power measurement, The reference point for the measurement shall be the RX antenna connector. In case of receiver diversity, the reported value shall be linear average of the power in the diversity branches.

5.2.4 Timing advance (T_{ADV})

Definition	Type1: Timing advance (T_{ADV}) type 1 is defined as the time difference T_{ADV} = (eNB Rx – Tx time difference) + (UE Rx – Tx time difference), where the eNB Rx – Tx time difference corresponds to the same UE that reports the UE Rx – Tx time difference. Type2: Timing advance (T_{ADV}) type 2 is defined as the time difference T_{ADV} = (eNB Rx – Tx time difference), where the eNB Rx – Tx time difference corresponds to a received uplink radio frame containing PRACH from the respective UE or similarly NPRACH from the respective NB-IoT UE..

5.2.5 eNB Rx – Tx time difference

Definition	The eNB Rx – Tx time difference is defined as $T_{\text{eNB-RX}} - T_{\text{eNB-TX}}$ Where: $T_{\text{eNB-RX}}$ is the eNB received timing of uplink radio frame #i, defined by the first detected path in time. The reference point for $T_{\text{eNB-RX}}$ shall be the Rx antenna connector. $T_{\text{eNB-TX}}$ is the eNB transmit timing of downlink radio frame #i. The reference point for $T_{\text{eNB-TX}}$ shall be the Tx antenna connector.

5.2.6 E-UTRAN GNSS Timing of Cell Frames for UE positioning

Definition	$T_{E\text{-}UTRAN\text{-}GNSS}$ is defined as the time of the occurrence of a specified LTE event according to a GNSS-specific reference time for a given GNSS (e.g., GPS/Galileo/Glonass system time). The specified LTE event is the beginning of the transmission of a particular frame (identified through its SFN) in the cell. The reference point for $T_{E\text{-}UTRAN\text{-}GNSS}$ shall be the Tx antenna connector.

5.2.7 Angle of Arrival (AoA)

Definition	AoA defines the estimated angle of a user with respect to a reference direction. The reference direction for this measurement shall be the geographical North, positive in a counter-clockwise direction. The AoA is determined at the eNB antenna for an UL channel corresponding to this UE.

5.2.8 UL Relative Time of Arrival ($T_{UL\text{-}RTOA}$)

Definition	The UL Relative Time of Arrival ($T_{UL\text{-}RTOA}$) is the beginning of subframe *i* containing SRS received in LMU *j*, relative to the configurable reference time [13], [14]. The reference point [14] for the UL relative time of arrival shall be the RX antenna connector of the LMU node when LMU has a separate RX antenna or shares RX antenna with eNB and the eNB antenna connector when LMU is integrated in eNB.

Annex A (informative): Change history

Change history							
Date	**TSG #**	**TSG Doc.**	**CR**	**Rev**	**Subject/Comment**	**Old**	**New**
02/10/06	-	-	-		Draft version created	-	0.0.0
11/10/06	-	-	-		Minor editorial updates for RAN1#46bis	0.0.0	0.0.1
13/10/06	-	-	-		Endorsed skeleton	0.0.1	0.1.0
27/02/07	-	-	-		Update after 3GPP TSG RAN WG1 #48	0.1.0	0.1.1
05/03/07	-	-	-		RAN1 endorsed version	0.1.1	0.2.0
03/05/07	-	-	-		Update after 3GPP TSG RAN WG1#48bis	0.2.0	0.2.1
08/03/07	-	-	-		RAN WG1#49 endorsed version	0.2.1	0.3.0
31/05/07	RAN#36	RP-070490	-		Presented for information at RAN#36	0.3.0	1.0.0
21/06/07	-	-	-		Update after 3GPP TSG RAN #36	1.0.0	1.0.1
25/06/07	-	-	-		3GPP TSG RAN WG1#49bis endorsed version	1.0.1	1.1.0
17/08/07	-	-	-		Update after 3GPP TSG RAN WG1#48bis	1.1.0	1.1.1
20/08/07	-	-	-		3GPP TSG RAN WG1#50 endorsed version	1.1.1	1.2.0
10/09/07	RAN#37	RP-070732	-		For approval at RAN#37	1.2.0	2.0.0
12/09/07	RAN_37	RP-070732	-	-	Approved version	2.0.0	8.0.0
28/11/07	RAN_38	RP-070949	0001	1	RRC state correction for LTE UE measurements	8.0.0	8.1.0
05/03/08	RAN_39	RP-080145	0003	1	Inclusion of agreements from RAN1#51bis and RAN1#52	8.1.0	8.2.0
28/05/08	RAN_40	RP-080435	0004	-	Introduction of eNode B Measurement of Received Interference Power	8.2.0	8.3.0
28/05/08	RAN_40	RP-080435	0005	-	Introduction of eNode B Measurement of Thermal Noise Power	8.2.0	8.3.0
09/09/08	RAN_41	RP-080671	0006	-	Modification to the RSRP definition	8.3.0	8.4.0
09/09/08	RAN_41	RP-080671	0007	-	Modification of RSRQ definition and removal of RSSI	8.3.0	8.4.0
03/12/08	RAN_42	RP-080985	0008	-	RSRQ Measurement Definition	8.4.0	8.5.0
04/03/09	RAN_43	RP-090237	0009	-	RSRP and RSRQ Definitions with Receiver Diversity	8.5.0	8.6.0
15/09/09	RAN_45	RP-090888	0010		Clarification on reference point of RSRP and RSRQ for EUTRA	8.6.0	8.7.0
01/12/09	RAN_46	RP-091172	0011	1	Introduction of LTE positioning	8.7.0	9.0.0
16/03/10	RAN_47	RP-100205	0012	1	Modification of RSRQ definition	9.0.0	9.1.0
01/06/10	RAN_48	RP-100590	0014	-	On alignment of RAN1/2 positioning specification	9.1.0	9.2.0
01/06/10	RAN_48	RP-100590	0015	1	Clarification of RSTD measurement	9.1.0	9.2.0
07/12/10	RAN_50	-	-	-	Creation of Rel-10 specification	9.2.0	10.0.0
15/03/11	RAN_51	RP-110258	0016	-	RSRQ Measurement with ABS	10.0.0	10.1.0
04/09/12	RAN_57	RP-121273	0018	4	UL Relative Time of Arrival	10.1.0	11.0.0
04/12/12	RAN_58	RP-121837	0019	1	Correcting inconsistency between inter-RAT UTRA measurements and requirements	11.0.0	11.1.0
10/09/14	RAN_65	RP-141484	0022	2	Inclusion of definition of WLAN Beacon RSSI in LTE specifications	11.1.0	12.0.0
08/12/14	RAN_66	RP-142105	0020	1	Introduction of MBSFN radio measurement	12.0.0	12.1.0
08/12/14	RAN_66	RP-142106	0023	3	Measurement definitions for measurements with discovery signals	12.0.0	12.1.0
09/03/15	RAN_67	RP-150361	0021	2	New E-UTRA RSRQ measurement definition	12.1.0	12.2.0
09/03/15	RAN_67	RP-150366	0026	2	Inclusion of measurement for ProSe	12.1.0	12.2.0
07/12/15	RAN_70	RP-152125	0027	1	eD2D CR for 36.214	12.2.0	13.0.0
07/12/15	RAN_70	RP-152035	0028	2	Introduction of RS-SINR measurement for Multicarrier Load Distribution	12.2.0	13.0.0
07/12/15	RAN_70	RP-152026	0029	1	Introduction of LAA	12.2.0	13.0.0
07/12/15	RAN_70	RP-152032	0030	-	Introduction of SSTD for dual connectivity enhancement	12.2.0	13.0.0

Change history							
Date	**Meeting**	**TDoc**	**CR**	**Rev**	**Cat**	**Subject/Comment**	**New version**
2016-03	RAN#71	RP-160364	0031	1	B	Introduction of WLAN RSSI measurements to support WLAN/LTE Radio Interworking	13.1.0
2016-03	RAN#71	RP-160360	0032	-	F	Correction on RSSI definition of LAA in 36.214	13.1.0
2016-06	RAN#72	RP-161067	0033	2	B	Introduction of NB-IoT	13.2.0
2016-09	RAN#73	RP-161567	0035	-	F	Correction to the WLAN RSSI definition	13.3.0
2016-09	RAN#73	RP-161563	0036	-	F	Correction on NRS port number mapping	13.3.0
2016-09	RAN#73	RP-161563	0037	-	F	Correction on NRSRQ applicability	13.3.0
2016-09	RAN#73	RP-161570	0038	1	B	Introduction of V2V support	14.0.0
2016-12	RAN#74	RP-162360	0040	-	A	Correction on SSTD definition	14.1.0
2017-03	RAN#75	RP-170622	0042	-	B	Introduction of V2X	14.2.0
2017-03	RAN#75	RP-170624	0043	-	B	Introduction of NB-IoT enhancements	14.2.0
2017-09	RAN#77	RP-171651	0046	-	A	Clarification CR for LAA RRM measurements within the DRS transmisison window	14.3.0
2017-09	RAN#77	RP-171641	0044	-	B	CR on 36.214 for UE carrier phase measurements	15.0.0
2018-01						MCC to correct missing 5G logo on spec cover sheet	15.0.1
2018-03	RAN#79	RP-180201	0048	1	B	Inter-RAT Measurements of NR	15.1.0
2018-03	RAN#79	RP-180193	0049	-	A	Revision of UE measurement report definitions considering NB-IoT UEs	15.1.0
2018-06	RAN#80	RP-181166	0050	1	B	Introduction Rel-15 Further NB-IoT enhancements	15.2.0

History

Document history		
V15.2.0	July 2018	Publication