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Foreword

This Technical Specification has been produced by the 3rd Generation Partnership Project (3GPP).

The contents of the present document are subject to continuing work within the TSG and may change following formal TSG approval. Should the TSG modify the contents of the present document, it will be re-released by the TSG with an identifying change of release date and an increase in version number as follows:

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1 Scope

The present document describes the physical layer measurements for NR.

2 References

The following documents contain provisions which, through reference in this text, constitute provisions of 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 38.211: "NR; Physical channels and modulation"

[4] 3GPP TS 38.212: "NR; Multiplexing and channel coding"

[5] 3GPP TS 38.213: "NR; Physical layer procedures for control channels"

[6] 3GPP TS 38.214: "NR; Physical layer procedures for data channels"

[7] 3GPP TS 38.321: "NR; Medium Access Control (MAC) protocol specification"

[8] 3GPP TS 38.331: "NR; Radio Resource Control (RRC); Protocol specification"

[9] 3GPP TS 38.104: "NR; Base Station (BS) radio transmission and reception"

[10] 3GPP TS 36.331: "Evolved Universal Terrestrial Radio Access (E-UTRA); Radio Resource Control (RRC); Protocol specification"

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

[12] 3GPP TS 38.133: "NR; Requirements for support of radio resource management"

[13] 3GPP TS 36.211: "Evolved Universal Terrestrial Radio Access (E-UTRA); Physical channels and modulation"

[14] 3GPP TS 38.901: "Study on channel model for frequencies from 0.5 to 100 GHz"

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].

ARFCN	Absolute Radio-Frequency Channel Number
CLI	Cross Link Interference
CSI-RSRP	CSI Reference Signal Received Power

CSI-RSRQ	CSI Reference Signal Received Quality
E-UTRAN	Evolved UTRAN
GNSS	Global Navigation Satellite System
GSM	Global System for Mobile communication
LBT	Listen before Talk
SRS	Sounding Reference Signal
SS-RSRP	Synchronization Signal Reference Signal Received Power
SS-RSRQ	Synchronization Signal Reference Signal Received Quality
UTRAN	Universal Terrestrial Radio Access Network

4 Control of UE/NG-RAN 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 NG-RAN. These measurements can be classified in different reported measurement types: intra-frequency, inter-frequency, inter-system, traffic volume, quality and UE internal measurements.

In the L1 measurement definitions, see chapter 5, the measurements are categorised as measurements in the UE or measurements in the NG-RAN.

5 Measurement capabilities for NR

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_INACTIVE; 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 SS reference signal received power (SS-RSRP)

Definition	SS reference signal received power (SS-RSRP) is defined as the linear average over the power contributions (in [W]) of the resource elements that carry secondary synchronization signals. The measurement time resource(s) for SS-RSRP are confined within SS/PBCH Block Measurement Time Configuration (SMTC) window duration. If SS-RSRP is used for L1-RSRP as configured by reporting configurations as defined in TS 38.214 [6], the measurement time resources(s) restriction by SMTC window duration is not applicable. For SS-RSRP determination demodulation reference signals for physical broadcast channel (PBCH) and, if indicated by higher layers, CSI reference signals in addition to secondary synchronization signals may be used. SS-RSRP using demodulation reference signal for PBCH or CSI reference signal 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 TS 38.213 [5]. If SS-RSRP is not used for L1-RSRP, the additional use of CSI reference signals for SS-RSRP determination is not applicable. 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 SS-RSRP is not used for L1-RSRP and higher-layers indicate certain SS/PBCH blocks for performing SS-RSRP measurements, then SS-RSRP is measured only from the indicated set of SS/PBCH block(s). For frequency range 1, the reference point for the SS-RSRP shall be the antenna connector of the UE. For frequency range 2, 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 SS-RSRP value shall not be lower than the corresponding SS-RSRP of any of the individual receiver branches.
Applicable for	If SS-RSRP is used for L1-RSRP, RRC_CONNECTED intra-frequency. Otherwise, RRC_IDLE intra-frequency, RRC_IDLE inter-frequency, RRC_INACTIVE intra-frequency, RRC_INACTIVE inter-frequency, RRC_CONNECTED intra-frequency, RRC_CONNECTED inter-frequency

NOTE 1: The number of resource elements within the measurement period that are used by the UE to determine 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.

5.1.2 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 of the antenna port(s) that carry CSI reference signals configured for RSRP measurements within the considered measurement frequency bandwidth in the configured CSI-RS occasions. For CSI-RSRP determination CSI reference signals transmitted on antenna port 3000 according to TS 38.211 [4] shall be used. If CSI-RSRP is used for L1-RSRP, CSI reference signals transmitted on antenna ports 3000, 3001 can be used for CSI-RSRP determination. For intra-frequency CSI-RSRP measurements, if the measurement gap is not configured, UE is not expected to measure the CSI-RS resource(s) outside of the active downlink bandwidth part. For frequency range 1, the reference point for the CSI-RSRP shall be the antenna connector of the UE. For frequency range 2, CSI-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 CSI-RSRP value shall not be lower than the corresponding CSI-RSRP of any of the individual receiver branches.
Applicable for	If CSI-RSRP is used for L1-RSRP, RRC_CONNECTED intra-frequency. Otherwise, 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.

5.1.3 SS reference signal received quality (SS-RSRQ)

Definition

Secondary synchronization signal reference signal received quality (SS-RSRQ) is defined as the ratio of N×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. For cell selection, according to Clause 4.1 of TS 38.211 [12], the measurement time resources(s) for NR Carrier RSSI are not constrained. Otherwise, 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, if measurement gap is not used, the NR Carrier RSSI is measured in slots within the SMTC window duration that are indicated by the higher layer parameter *measurementSlots* and in OFDM symbols given by Table 5.1.3-1 and, if measurement gap is used, the NR Carrier RSSI is measured in slots within the SMTC window duration that are indicated by the higher layer parameter *measurementSlots* and in OFDM symbols given by Table 5.1.3-1 that are overlapped with the measurement gap, which is defined in TS38.133 [12].

- For intra-frequency measurements, NR Carrier RSSI is measured with timing reference corresponding to the serving cell in the frequency layer
- For inter-frequency measurements, NR Carrier RSSI is measured with timing reference corresponding to any cell in the target frequency layer

Otherwise not indicated by higher-layers, 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 the measurement gap.

Table 5.1.3-1: NR Carrier RSSI measurement symbols

OFDM signal indication *endSymbol*	Symbol indexes
0	{0,1}
1	{0,1,2,..,10,11}
2	{0,1,2,…, 5}
3	{0,1,2,…, 7}

If higher-layers indicate certain SS/PBCH blocks for performing SS-RSRQ measurements, then SS-RSRP is measured only from the indicated set of SS/PBCH block(s).

For frequency range 1, the reference point for the 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 SS-RSRP measurements. For frequency range 1 and 2, if receiver diversity is in use by the UE, the reported SS-RSRQ value shall not be lower than the corresponding SS-RSRQ of any of the individual receiver branches.

Applicable for

RRC_IDLE intra-frequency,
RRC_IDLE inter-frequency,
RRC_INACTIVE intra-frequency,
RRC_INACTIVE inter-frequency,
RRC_CONNECTED intra-frequency,
RRC_CONNECTED inter-frequency

5.1.4 CSI reference signal received quality (CSI-RSRQ)

Definition	CSI reference signal received quality (CSI-RSRQ) is defined as the ratio of N×CSI-RSRP to CSI-RSSI, where N is the number of resource blocks in the CSI-RSSI measurement bandwidth. The measurements in the numerator and denominator shall be made over the same set of resource blocks. CSI Received Signal Strength Indicator (CSI-RSSI), comprises the linear average of the total received power (in [W]) observed only in 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 CSI-RSSI corresponds to OFDM symbols containing configured CSI-RS occasions. For CSI-RSRQ determination CSI reference signals transmitted on antenna port 3000 according to TS 38.211 [4] shall be used. For intra-frequency CSI-RSRQ measurements, if the measurement gap is not configured, UE is not expected to measure the CSI-RS resource(s) outside of the active downlink bandwidth part. For frequency range 1, the reference point for the CSI-RSRQ shall be the antenna connector of the UE. For frequency range 2, CSI-RSSI shall be measured based on the combined signal from antenna elements corresponding to a given receiver branch, where the combining for CSI-RSSI shall be the same as the one used for CSI-RSRP measurements. For frequency range 1 and 2, if receiver diversity is in use by the UE, the reported CSI-RSRQ value shall not be lower than the corresponding CSI-RSRQ of any of the individual receiver branches.
Applicable for	RRC_CONNECTED intra-frequency, RRC_CONNECTED inter-frequency

5.1.5 SS signal-to-noise and interference ratio (SS-SINR)

Definition	SS signal-to-noise and interference ratio (SS-SINR), is defined as the linear average over the power contribution (in [W]) of the resource elements carrying secondary synchronisation signals divided by the linear average of the noise and interference power contribution (in [W]). If SS-SINR is used for L1-SINR reporting, the interference and noise is measured over resource(s) indicated by higher layers as described in TS 38.214 [6]. Otherwise, the interference and noise are measured over the resource elements carrying secondary synchronisation signals within the same frequency bandwidth. The measurement time resource(s) for SS-SINR are confined within SS/PBCH Block Measurement Time Configuration (SMTC) window duration. If SS-SINR is used for L1-SINR as configured by reporting configurations defined in TS 38.214 [6], the measurement time resources(s) restriction by SMTC window duration is not applicable. For SS-SINR determination demodulation reference signals for physical broadcast channel (PBCH) in addition to secondary synchronization signals may be used. If SS-SINR is not used for L1-SINR and higher-layers indicate certain SS/PBCH blocks for performing SS-SINR measurements, then SS-SINR is measured only from the indicated set of SS/PBCH block(s). For frequency range 1, the reference point for the SS-SINR shall be the antenna connector of the UE. For frequency range 2, SS-SINR 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 SS-SINR value shall not be lower than the corresponding SS-SINR of any of the individual receiver branches.
Applicable for	If SS-SINR is used for L1-SINR, RRC_CONNECTED intra-frequency. Otherwise, RRC_CONNECTED intra-frequency, RRC_CONNECTED inter-frequency

5.1.6 CSI signal-to-noise and interference ratio (CSI-SINR)

Definition	CSI signal-to-noise and interference ratio (CSI-SINR), is defined as the linear average over the power contribution (in [W]) of the resource elements carrying CSI reference signals divided by the linear average of the noise and interference power contribution (in [W]). If CSI-SINR is used for L1-SINR reporting, the interference and noise is measured over resource(s) indicated by higher layers as described in TS 38.214 [6]. Otherwise, the interference and noise are measured over the resource elements carrying CSI reference signals reference signals within the same frequency bandwidth. For CSI-SINR determination CSI reference signals transmitted on antenna port 3000 according to TS 38.211 [4] shall be used. For intra-frequency CSI-SINR measurements not used for L1-SINR reporting, if the measurement gap is not configured, UE is not expected to measure the CSI-RS resource(s) outside of the active downlink bandwidth part. For frequency range 1, the reference point for the CSI-SINR shall be the antenna connector of the UE. For frequency range 2, CSI-SINR 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 CSI-SINR value shall not be lower than the corresponding CSI-SINR of any of the individual receiver branches.
Applicable for	If CSI-SINR is used for L1-SINR, RRC_CONNECTED intra-frequency. Otherwise, RRC_CONNECTED intra-frequency, RRC_CONNECTED inter-frequency

5.1.7 Void

5.1.8 Void

5.1.9 UE GNSS Timing of Cell Frames for UE positioning for E-UTRA

Definition	The timing between E-UTRA cell j and a GNSS-specific reference time for a given GNSS (e.g., GPS/Galileo/Glonass system time). $T_{UE\text{-}GNSS}$ is defined as the time of occurrence of a specified NG-RAN event according to GNSS time for a given GNSS Id. The specified NG-RAN 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 $T_{UE\text{-}GNSSj}$ shall be the antenna connector of the UE.
Applicable for	RRC_CONNECTED inter-RAT

5.1.10 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 NG-RAN/E-UTRAN/UTRAN/GSM signals; its applicability is therefore independent of the UE RRC state)

5.1.11 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 NG-RAN/E-UTRAN/UTRAN/GSM signals; its applicability is therefore independent of the UE RRC state)

5.1.12 IEEE 802.11 WLAN RSSI

Definition	The IEEE 802.11 WLAN RSSI as used in RRC specification [10] refers to RSSI as defined in IEEE 802.11 specification [11] , 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_INACTIVE inter-RAT, RRC_IDLE inter-RAT

5.1.13 Reference signal time difference (RSTD) for E-UTRA

Definition	The relative timing difference between the E-UTRA neighbour cell j and the E-UTRA 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 E-UTRA cell j $T_{SubframeRxi}$ is the time when the UE receives the corresponding start of one subframe from E-UTRA cell i that is closest in time to the subframe received from E-UTRA cell j. The reference point for the observed subframe time difference shall be the antenna connector of the UE.
Applicable for	RRC_CONNECTED inter-RAT

5.1.14 SFN and frame timing difference (SFTD)

Definition	The observed SFN and frame timing difference (SFTD) between an E-UTRA PCell and an NR PSCell (for EN-DC), or an NR PCell and an E-UTRA PSCell (for NE-DC), or an NR PCell and an NR PSCell (for NR-DC), or an NR PCell and NR neighbour cell (for UEs with NR PCell but no E-UTRA/NR PSCell) is defined as comprising the following two components: - SFN offset = $(SFN_{PCell} - SFN_{TRGCell}) \bmod 1024$, where SFN_{PCell} is the SFN of a PCell radio frame and $SFN_{TRGCell}$ is the SFN of the target cell 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 = $\lfloor (T_{FrameBoundaryPCell} - T_{FrameBoundaryTRGCell}) / 5 \rfloor$, where $T_{FrameBoundaryPCell}$ is the time when the UE receives the start of a radio frame from the PCell, $T_{FrameBoundaryTRGCell}$ is the time when the UE receives the start of the radio frame, from the target cell, that is closest in time to the radio frame received from the PCell. The unit of $(T_{FrameBoundaryPCell} - T_{FrameBoundaryTRGCell})$ is Ts.
Applicable for	RRC_CONNECTED intra-frequency for EN-DC, NE-DC, NR-DC RRC_CONNECTED inter-frequency for UEs with NR PCell but no E-UTRA/NR PSCell

5.1.15 E-UTRA RSRP

Definition	E-UTRA Reference signal received power (E-UTRA 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 E-UTRA RSRP determination the cell-specific reference signals R0 according to TS 36.211 [3] shall be used. If the UE can reliably detect that R1 is available it may use R_1 in addition to R_0 to determine E-UTRA RSRP. If higher layers indicate measurements based on discovery signals, the UE shall measure E-UTRA 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 E-UTRA RSRP. The reference point for the E-UTRA 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 E-UTRA RSRP of any of the individual diversity branches.
Applicable for	RRC_IDLE inter-RAT, RRC_INACTIVE inter-RAT, RRC_CONNECTED inter-RAT

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 E-UTRA 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.

5.1.16 E-UTRA RSRQ

Definition	E-UTRA Reference Signal Received Quality (E-UTRA RSRQ) is defined as the ratio N×E-UTRA RSRP/(E-UTRA carrier RSSI), where N is the number of RBs 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 (E-UTRA 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, E-UTRA 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 E-UTRA RSRQ measurements, then E-UTRA RSSI is measured from all OFDM symbols of the DL part of measurement subframes. If higher-layers indicate certain subframes for performing E-UTRA RSRQ measurements, then E-UTRA RSSI is measured from all OFDM symbols of the DL part of the indicated subframes. If higher layers indicate measurements based on discovery signals, E-UTRA 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 E-UTRA 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 E-UTRA RSRQ of any of the individual diversity branches.
Applicable for	RRC_IDLE inter-RAT, RRC_INACTIVE inter-RAT, RRC_CONNECTED inter-RAT

5.1.17 E-UTRA RS-SINR

Definition	E-UTRA reference signal-signal to noise and interference ratio (E-UTRA 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 E-UTRA RS-SINR determination, the E-UTRA cell-specific reference signals R_0 according TS 36.211 [13] shall be used. The reference point for the E-UTRA 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 E-UTRA RS-SINR of any of the individual diversity branches. If higher-layer signalling indicates certain subframes for performing E-UTRA RS-SINR measurements, then E-UTRA RS-SINR is measured in the indicated subframes.
Applicable for	RRC_CONNECTED inter-RAT

5.1.18 SS reference signal received power per branch (SS-RSRPB)

Definition	SS reference signal received power per branch (SS-RSRPB) 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 SS-RSRPB are confined within SS/PBCH Block Measurement Time Configuration (SMTC) window duration. For SS-RSRPB determination demodulation reference signals for physical broadcast channel (PBCH) and, if indicated by higher layers, CSI reference signals in addition to secondary synchronization signals may be used. SS-RSRPB using demodulation reference signal for PBCH or CSI reference signal 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 TS 38.213 [5]. SS-RSRPB 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 SS-RSRPB measurements, then SS-RSRPB is measured only from the indicated set of SS/PBCH block(s). For frequency range 1, SS-RSRPB is not defined. For frequency range 2, SS-RSRPB shall be measured for each receiver branch based on the combined signal from antenna elements corresponding to the receiver branch.
Applicable for	RRC_CONNECTED intra-frequency

NOTE 1: The number of resource elements within the measurement period that are used by the UE to determine SS-RSRPB 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.

5.1.19 SRS reference signal received power (SRS-RSRP)

Definition	SRS reference signal received power (SRS-RSRP) is defined as linear average of the power contributions (in [W]) of the resource elements carrying sounding reference signals (SRS). SRS-RSRP shall be measured over the configured resource elements within the considered measurement frequency bandwidth in the configured measurement time occasions. For frequency range 1, the reference point for the SRS-RSRP shall be the antenna connector of the UE. For frequency range 2, SRS-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 SRS-RSRP value shall not be lower than the corresponding SRS-RSRP of any of the individual receiver branches.
Applicable for	RRC_CONNECTED intra-frequency, RRC_CONNECTED inter-frequency

5.1.20 CLI Received signal strength indicator (CLI-RSSI)

Definition	CLI Received Signal Strength Indicator (CLI-RSSI), is defined as linear average of the total received power (in [W]) observed only in the configured OFDM symbols of the configured measurement time resource(s), in the configured measurement bandwidth from all sources, including co-channel serving and non-serving cells, adjacent channel interference, thermal noise etc. For frequency range 1, the reference point for the RSSI shall be the antenna connector of the UE. For frequency range 2, CLI-RSSI 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 CLI-RSSI value shall not be lower than the corresponding CLI-RSSI of any of the individual receiver branches.
Applicable for	RRC_CONNECTED intra-frequency, RRC_CONNECTED inter-frequency

5.1.21 Received Signal Strength Indicator (RSSI)

Definition	Received Signal Strength Indicator (RSSI), comprises the linear average of the total received power (in [W]) observed only in configured OFDM symbols and in the configured measurement bandwidth over *N* number of resource blocks corresponding to LBT bandwidth with the center frequency of configured ARFCN, by the UE from all sources, including co-channel serving and non-serving cells, adjacent channel interference, thermal noise etc. Higher layers configure the measurement bandwidth, measurement duration and which OFDM symbol(s) should be measured by the UE. For frequency range 1, 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 RSSI value shall not be lower than the corresponding RSSI of any of the individual receiver branches.
Applicable for	RRC_CONNECTED intra-frequency, RRC_CONNECTED inter-frequency

5.1.22 PSBCH reference signal received power (PSBCH-RSRP)

Definition	PSBCH Reference Signal Received Power (PSBCH-RSRP) is defined as the linear average over the power contributions (in [W]) of the resource elements that carry demodulation reference signals associated with physical sidelink broadcast channel (PSBCH). For frequency range 1, the reference point for the PSBCH RSRP shall be the antenna connector of the UE. For frequency range 2, PSBCH-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 PSBCH-RSRP value shall not be lower than the corresponding PSBCH-RSRP of any of the individual receiver 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 PSBCH-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 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 physical sidelink shared channel (PSSCH). For frequency range 1, the reference point for the PSSCH-RSRP shall be the antenna connector of the UE. For frequency range 2, PSSCH-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 PSSCH-RSRP value shall not be lower than the corresponding PSSCH-RSRP of any of the individual receiver branches.
Applicable for	RRC_IDLE intra-frequency, RRC_IDLE inter-frequency, RRC_CONNECTED inter-frequency

NOTE 1: The power per resource element is determined from the energy received during the useful part of the symbol, excluding the CP.

5.1.24 PSCCH reference signal received power (PSCCH-RSRP)

Definition	PSCCH Reference Signal Received Power (PSCCH-RSRP) is defined as the linear average over the power contributions (in [W]) of the resource elements that carry demodulation reference signals associated with physical sidelink control channel (PSCCH). For frequency range 1, the reference point for the PSCCH-RSRP shall be the antenna connector of the UE. For frequency range 2, PSCCH-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 PSCCH-RSRP value shall not be lower than the corresponding PSCCH-RSRP of any of the individual receiver branches.
Applicable for	RRC_IDLE intra-frequency, RRC_IDLE inter-frequency, RRC_CONNECTED inter-frequency

NOTE 1: The power per resource element is determined from the energy received during the useful part of the symbol, excluding the CP.

5.1.25 Sidelink received signal strength indicator (SL RSSI)

Definition	Sidelink Received Signal Strength Indicator (SL RSSI) is defined as the linear average of the total received power (in [W]) observed in the configured sub-channel in OFDM symbols of a slot configured for PSCCH and PSSCH, starting from the 2nd OFDM symbol. For frequency range 1, the reference point for the SL RSSI shall be the antenna connector of the UE. For frequency range 2, SL RSSI 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 SL RSSI value shall not be lower than the corresponding SL RSSI of any of the individual receiver branches.
Applicable for	RRC_IDLE intra-frequency, RRC_IDLE inter-frequency, RRC_CONNECTED intra-frequency, RRC_CONNECTED inter-frequency

5.1.26 Sidelink channel occupancy ratio (SL CR)

Definition	Sidelink Channel Occupancy Ratio (SL CR) evaluated at slot *n* is defined as the total number of sub-channels used for its transmissions in slots [*n-a*, *n-1*] and granted in slots [*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 TBD; *a* and *b* are determined by UE implementation with $a+b+1 = 1000$ or $1000 \cdot 2^{\mu}$ slots, according to higher layer parameter *timeWindowSize-CR*, a >= TBD, and n+b should not exceed the last transmission opportunity of the grant for the current transmission.

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

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

[NOTE 4: The slot index is based on physical slot index.]

NOTE 5: SL CR can be computed per priority level

5.1.27 Sidelink channel busy ratio (SL CBR)

Definition	SL Channel Busy Ratio (SL CBR) measured in slot *n* is defined as the portion of sub-channels in the resource pool whose SL RSSI measured by the UE exceed a (pre-)configured threshold sensed over a CBR measurement window [*n-a*, *n*-1], wherein *a* is equal to 100 or $100 \cdot 2^{\mu}$ slots, according to higher layer parameter *timeWindowSize-CBR*.
Applicable for	RRC_IDLE intra-frequency, RRC_IDLE inter-frequency, RRC_CONNECTED intra-frequency, RRC_CONNECTED inter-frequency

5.1.28 DL PRS reference signal received power (DL PRS-RSRP)

Definition	DL PRS reference signal received power (DL PRS-RSRP), is defined as the linear average over the power contributions (in [W]) of the resource elements that carry DL PRS reference signals configured for RSRP measurements within the considered measurement frequency bandwidth. For frequency range 1, the reference point for the DL PRS-RSRP shall be the antenna connector of the UE. For frequency range 2, DL PRS-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 DL PRS-RSRP value shall not be lower than the corresponding DL PRS-RSRP of any of the individual receiver branches.
Applicable for	RRC_CONNECTED intra-frequency, RRC_CONNECTED inter-frequency

5.1.29 DL relative signal time difference (DL RSTD)

Definition	DL relative timing difference (DL RSTD) between the positioning node *j* and the reference positioning node *i*, is defined as $T_{SubframeRxj} - T_{SubframeRxi}$, Where: $T_{SubframeRxj}$ is the time when the UE receives the start of one subframe from positioning node *j*. $T_{SubframeRxi}$ is the time when the UE receives the corresponding start of one subframe from positioning node *i* that is closest in time to the subframe received from positioning node *j*. Multiple DL PRS resources can be used to determine the start of one subframe from a positioning node. For frequency range 1, the reference point for the DL RSTD shall be the antenna connector of the UE. For frequency range 2, the reference point for the DL RSTD shall be the antenna of the UE.
Applicable for	RRC_CONNECTED intra-frequency RRC_CONNECTED inter-frequency

5.1.30 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 subframe #*i* from a positioning node, defined by the first detected path in time. T_{UE-TX} is the UE transmit timing of uplink subframe #*j* that is closest in time to the subframe #i received from the positioning node. Multiple DL PRS resources can be used to determine the start of one subframe of the first arrival path of the positioning node. For frequency range 1, the reference point for T_{UE-RX} measurement shall be the Rx antenna connector of the UE and the reference point for T_{UE-TX} measurement shall be the Tx antenna connector of the UE. For frequency range 2, the reference point for T_{UE-RX} measurement shall be the Rx antenna of the UE and the reference point for T_{UE-TX} measurement shall be the Tx antenna of the UE.
Applicable for	RRC_CONNECTED intra-frequency RRC_CONNECTED inter-frequency

5.2 NG-RAN measurement abilities

The structure of the table defining a NG-RAN measurement quantity is shown below.

Column field	Comment
Definition	Contains the definition of the measurement.

5.2.1 SSS transmit power

Definition	SSS transmit power is determined as the linear average over the power contributions (in [W]) of the resource elements that carry secondary synchronization signals within the secondary synchronization signal (SSS) bandwidth. For downlink reference signal transmit power determination the secondary synchronization signal according TS 38.211 [4] can be used. For frequency range 1, the reference point for the downlink reference signal power measurement shall be the transmit antenna connector.

5.2.2 UL Relative Time of Arrival ($T_{UL-RTOA}$)

Definition	[The UL Relative Time of Arrival ($T_{UL-RTOA}$) is the beginning of subframe *i* containing SRS received in positioning node *j*, relative to the configurable reference time.] Multiple SRS resources for positioning can be used to determine the beginning of one subframe containing SRS received at a positioning node. The reference point for $T_{UL-RTOA}$ shall be: - for type 1-C base station TS 38.104 [9]: the Rx antenna connector, - for type 1-O or 2-O base station TS 38.104 [9]: the Rx antenna, - for type 1-H base station TS 38.104 [9]: the Rx Transceiver Array Boundary connector.

5.2.3 gNB Rx – Tx time difference

Definition	The gNB Rx – Tx time difference is defined as $T_{gNB-RX} - T_{gNB-TX}$ Where: T_{gNB-RX} is the positioning node received timing of uplink subframe #*i* containing SRS associated with UE, defined by the first detected path in time. T_{gNB-TX} is the positioning node transmit timing of downlink subframe #*j* that is closest in time to the subframe #*i* received from the UE. Multiple SRS resources for positioning can be used to determine the start of one subframe containing SRS. The reference point for T_{gNB-RX} shall be: - for type 1-C base station TS 38.104 [9]: the Rx antenna connector, - for type 1-O or 2-O base station TS 38.104 [9]: the Rx antenna, - for type 1-H base station TS 38.104 [9]: the Rx Transceiver Array Boundary connector. The reference point for T_{gNB-TX} shall be: - for type 1-C base station TS 38.104 [9]: the Tx antenna connector, - for type 1-O or 2-O base station TS 38.104 [9]: the Tx antenna, - for type 1-H base station TS 38.104 [9]: the Tx Transceiver Array Boundary connector.

5.2.4 UL Angle of Arrival (UL AoA)

Definition	UL Angle of Arrival (UL AoA) is defined as the estimated azimuth angle and vertical angle of a UE with respect to a reference direction, wherein the reference direction is defined: - In the global coordinate system (GCS), wherein estimated azimuth angle is measured relative to geographical North and is positive in a counter-clockwise direction and estimated vertical angle is measured relative to zenith and positive to horizontal direction - In the local coordinate system (LCS), wherein estimated azimuth angle is measured relative to x-axis of LCS and positive in a counter-clockwise direction and estimated vertical angle is measured relatize to z-axis of LCS and positive to x-y plane direction. The bearing, downtilt and slant angles of LCS are defined according to TS 38.901 [14]. The UL AoA is determined at the gNB antenna for an UL channel corresponding to this UE.

5.2.5 UL SRS reference signal received power (UL SRS-RSRP)

Definition	UL SRS reference signal received power (UL SRS-RSRP) is defined as linear average of the power contributions (in [W]) of the resource elements carrying sounding reference signals (SRS). UL SRS-RSRP shall be measured over the configured resource elements within the considered measurement frequency bandwidth in the configured measurement time occasions. For frequency range 1, the reference point for the UL SRS-RSRP shall be the antenna connector of the gNB. For frequency range 2, UL SRS-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 gNB, the reported UL SRS-RSRP value shall not be lower than the corresponding UL SRS-RSRP of any of the individual receiver branches.

Annex A:
Change history

Change history							
Date	**Meeting**	**TDoc**	**CR**	**Rev**	**Cat**	**Subject/Comment**	**New version**
2017-05	RAN1#89	R1-1709124				Draft skeleton	0.0.0
2017-07	AH_NR2	R1-1712017				Inclusion of agreements up to and including RAN1 NR Ad-Hoc #2	0.0.1
2017-08	RAN1#90	R1-1714100				Updates according to email discussion " [NRAH2-03-215] TS 38.215	0.0.2
2017-08	RAN1#90	R1-1714660				Clean version	0.1.0
2017-08	RAN1#90	R1-1715325				Inclusion of agreements from RAN1#90	0.1.1
2017-08	RAN1#90	R1-1715333				Updates according to email discussion " [90-23-215] TS 38.215"	0.1.2
2017-09	RAN#77	RP-171999				For information to plenary	1.0.0
2017-09	AH_NR3	R1-1716931				Inclusion of agreements up to and including RAN1 NR Ad-Hoc #3	1.0.1
2017-09	RAN1#90 bis	R1-1719108				Clean version	1.1.0
2017-11	RAN1#90 bis	R1-1719228				Inclusion of agreements up to and including RAN1#90bis	1.1.1
2017-11	RAN1#90 bis	R1-1719244				Updates according to email discussion " [90b-NR-01-38.215] "	1.1.2
2017-11	RAN1#91	R1-1721052				Clean version	1.2.0
2017-12	RAN1#91	R1-1721345				Inclusion of agreements up to and including RAN1#91	1.3.0
2017-12	RAN#78	RP-172296				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	0002	-	F	CR capturing the Jan18 ad-hoc and RAN1#92 meeting agreements	15.1.0
2018-06	RAN#80	RP-181172	0003	1	F	CR to 38.215 capturing the RAN1#92bis and RAN1#93 meeting agreements	15.2.0
2018-09	RAN#81	RP-181789	0004	-	F	CR to 38.215 capturing the RAN1#94 meetings agreements	15.3.0
2018-12	RAN#82	RP-182523	0005	3	F	Combined CR of all essential corrections to 38.215 from RAN1#94bis and RAN1#95	15.4.0
2019-06	RAN#84	RP-191278	0006	-	F	CR on SFTD measurements for NE-DC	15.5.0
2019-06	RAN#84	RP-191278	0007	-	F	Correction on SFTD measurement for NR-DC (Late drop)	15.5.0
2019-12	RAN#86	RP-192628	0010	-	F	Correction of RSTD measurement for E-UTRA	15.6.0
2019-12	RAN#86	RP-192628	0012	-	F	Corrections to SFTD measurement	15.6.0
2019-12	RAN#86	RP-192634	0008	1	B	Introduction of cross layer interference measurements	16.0.0
2019-12	RAN#86	RP-192636	0013	-	B	Introduction of NR-based access to unlicensed spectrum	16.0.0
2019-12	RAN#86	RP-192638	0014	-	B	Introduction of V2X support	16.0.0
2019-12	RAN#86	RP-192641	0015	-	B	Introduction of MIMO enhancements	16.0.0
2019-12	RAN#86	RP-192643	0016	-	B	Introduction of NR positioning support	16.0.0
2020-01						MCC clean-up fixing font issue in clauses 5.2.2/5.2.3 and 5.2.4.	16.0.1