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TECHNICAL SPECIFICATION

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Contents

Foreword

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

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z the third digit is incremented when editorial only changes have been incorporated in the document.

In the present document, modal verbs have the following meanings:

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The constructions "shall" and "shall not" are confined to the context of normative provisions, and do not appear in Technical Reports.

The constructions "must" and "must not" are not used as substitutes for "shall" and "shall not". Their use is avoided insofar as possible, and they are not used in a normative context except in a direct citation from an external, referenced, non-3GPP document, or so as to maintain continuity of style when extending or modifying the provisions of such a referenced document.

should indicates a recommendation to do something

should not indicates a recommendation not to do something

may indicates permission to do something

need not indicates permission not to do something

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can indicates that something is possible

cannot indicates that something is impossible

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will indicates that something is certain or expected to happen as a result of action taken by an agency the behaviour of which is outside the scope of the present document

will not indicates that something is certain or expected not to happen as a result of action taken by an agency the behaviour of which is outside the scope of the present document

might indicates a likelihood that something will happen as a result of action taken by some agency the behaviour of which is outside the scope of the present document

might not indicates a likelihood that something will not happen as a result of action taken by some agency the behaviour of which is outside the scope of the present document

In addition:

is (or any other verb in the indicative mood) indicates a statement of fact

is not (or any other negative verb in the indicative mood) indicates a statement of fact

The constructions "is" and "is not" do not indicate requirements.

1 Scope

The present document establishes the Multiple Input Multiple Output (MIMO) Over-the-Air (OTA) performance requirements for NR UEs operating on frequency Range 1 and frequency rang 2, for NR standalone (SA) and NR non-standalone (NSA) operation mode. The corresponding test methodologies are also presented in the Annex of this Technical Specification.

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 TR 38.827: “Study on radiated metrics and test methodology for the verification of multi-antenna reception performance of NR User Equipment (UE)”.

[3] 3GPP TS 38.101-1: "NR; User Equipment (UE) radio transmission and reception; Part 1: Range 1 Standalone"

[4] 3GPP TS 38.101-2: "NR; User Equipment (UE) radio transmission and reception; Part 2: Range 2 Standalone"

[5] 3GPP TS 38.101-3: "NR; User Equipment (UE) radio transmission and reception; Part 3: Range 1 and Range 2 Interworking operation with other radios"

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

[7] 3GPP TS 38.508-1: "5GS; User Equipment (UE) conformance specification; Part 1: Common test environment"

[8] 3GPP TR 38.901: "Study on channel model for frequencies from 0.5 to 100 GHz"

[9] F. Zhang, L. Hentilä, P. Kyösti and W. Fan, "Millimeter-wave New Radio Test Zone Validation for MIMO Over-the-air Testing," in IEEE Transactions on Antennas and Propagation, doi: 10.1109/TAP.2021.3111326.

[10] 3GPP TS 38.101-4: "NR; User Equipment (UE) radio transmission and reception; Part 4: Performance requirements"

[11] 3GPP TS 38.551: "NR; User Equipment (UE) Multiple Input Multiple Output (MIMO) Over-the-Air (OTA) performance; Conformance testing"

3 Definitions of terms, symbols and abbreviations

3.1 Terms

For the purposes of the present document, the terms given in 3GPP 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 3GPP TR 21.905 [1].

FS: UE used in a free space configuration.

Handheld UE: A UE intended to be used in hand held scenario.

MIMO Average Spherical Coverage: An averaged sensitivity of best 18 FR2 MIMO OTA sensitivity values within the 3D sphere with constant-density points for PC3 device.

Primary mechanical mode: The mode that is most often used for a specific user scenario. Every terminal has at least one primary mechanical mode, if multiple modes are supported, different primary mechanical modes may be applicable for different user scenarios, e.g., different primary mechanical modes for Free Space and Hand phantom usage for the same UE.

PSP (PAS Similarity Percentage): The similarity of the PAS produced by the OTA system and the reference PAS, which is presented by the Total Variation Distance (TVD) of power angular spectrum (PAS). PSP is defined as (1-TVD)*100%. PSP=100% denotes full similarity and PSP=0% denotes full dissimilarity.

3.2 Symbols

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

$P_{RS\text{-}EPRE\text{-}MAX}$ Maximum downlink RS-EPRE

3.3 Abbreviations

For the purposes of the present document, the abbreviations given in 3GPP 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 3GPP TR 21.905 [1].

AOA	Azimuth angle Of Arrival
AOD	Azimuth angle Of Departure
BS	Base Station
CDL	Clustered Delay Line
CW	Continuous Wave
DML	Data Mode Landscape
DMP	Data Mode Portrait
DMSU	Data Mode Screen Up
DUT	Device Under Test
EUT	Equipment Under Test
FR1	Frequency Range 1
FR2	Frequency Range 2
FS	Free Space
MASC	MIMO Average Spherical Coverage
MIMO	Multiple Input Multiple Output
MPAC	Multi-Probe Anechoic Chamber
NR	New Radio
NSA	Non-Standalone, a mode of operation where operation of an other radio is assisted with an other radio
OTA	Over The Air
PAS	Power Angular Spectrum
PDP	Power Delay Profile

PSP	PAS Similarity Percentage
RS-EPRE	Reference Signal-Energy Per Resource Element
SS	System Simulator
SSS	Secondary Synchronization Signal
TRMS	Total Radiated Multi-antenna Sensitivity
UE	User Equipment
UMa	Urban Macro
UMi	Urban Micro
XPR	Cross-Polarization Ratio
ZOA	Zenith angle Of Arrival
ZOD	Zenith angle Of Departure
ZSA	Zenith angle Spread of Arrival
ZSD	Zenith angle Spread of Departure

4 General

4.1 Relationship between minimum requirements and test requirements

The Minimum Requirements given in this specification make no allowance for measurement uncertainty. The test specification in RAN5 will define test tolerances for FR1 and FR2 MIMO OTA. The test tolerances are used to relax the minimum requirements in this specification to create test requirements.

4.2 Applicability of minimum requirements

The MIMO OTA minimum requirements apply only to the primary mechanical mode of UE which is declared by the manufacturer if the UE can support multiple mechanical modes.

The minimum requirements apply only to the UE under normal environmental conditions specified in Annex F.

4.3 Applicability rules for testing of SA and NSA UEs

The applicability and test coverage rules for Non-Standalone (NSA) only capable UEs shall include the following:

- For FR1 NSA (EN-DC) only capable UEs, testing is not required.
- For FR2 NSA (EN-DC) only capable UEs, for each FR2 NR band supported by the device, test the UE in EN-DC mode using any one example configuration containing that NR band or configuration declaration decision tree as per recommended MIMO OTA test procedures in this specification.

The applicability and test coverage rules for Standalone (SA) and NSA (EN-DC) capable UEs shall include the following:

- For FR1 UEs, for each NR band in a device, test the UE in Standalone Mode as per the TRMS test procedures in this specification. This shall also fulfil coverage for all EN-DC minimum performance requirements for that NR band and need not be retested in EN-DC mode.
- For FR2 UEs, for each FR2 NR band supported by the device, test the UE in any of SA modes including FR2 only mode, FR1+FR2 NR-DC mode and FR1+FR2 NR-CA mode using any one example configuration containing that NR band. This shall fulfil coverage for FR2 MIMO OTA requirements for that NR band and need not be retested in EN-DC mode.

5 Frequency bands

5.1 General

NR MIMO OTA Requirements are defined separately for different frequency ranges (FR). The frequency ranges in which NR can operate according to this version of the specification are identified as described in Table 5.1-1.

Table 5.1-1: Definition of frequency ranges

Frequency range designation	Corresponding frequency range
FR1	410 MHz – 7125 MHz
FR2	24250 MHz – 52600 MHz

The present specification covers both FR1 and FR2 operating bands. For FR2, only FR2-1 bands are applicable.

5.2 Operating bands

NR is designed to operate in FR1 operating bands defined in TS 38.101-1 [3] and FR2 operating bands defined in TS 38.101-2 [4]. NSA band combinations are defined in TS 38.101-3 [5]. E-UTRA is designed to operate in operating bands defined in TS 36.101 [6].

For FR2 EN-DC capable UEs, principle of EN-DC band combinations selection for FR2 MIMO OTA testing is as following:

1) Focus on the performance of the NR carrier and do not consider multiple permutations between different LTE bands and NR band under test, i.e., for each NR band, only select one EN-DC band combination.

2) For UE supporting multiple EN-DC band combinations for the same NR band, consider only those EN-DC configurations which have no MSD impact on either LTE or NR.

Table 5.2-1: Measurement parameters for example inter-band EN-DC band combinations (LTE + FR2, two bands)

EN-DC configuration	E-UTRA configurations	NR FR2 configurations
DC_66A_n261A	Mid channel	Mid channel

Table 5.2-2: Measurement parameters for example inter-band NR-DC band combinations (FR1 + FR2, two bands)

NR-DC configuration	NR FR1 configurations	NR FR2 configurations
DC_n66A_n261A	Mid channel	Mid channel

Table 5.2-3: Measurement parameters for example inter-band NR-CA band combinations (FR1 + FR2, two bands)

NR-CA configuration	NR FR1 configurations	NR FR2 configurations
CA-n66A_n261A	Mid channel	Mid channel

With the above basic principle and example band combination, the selection logic for testing is defined by the decision trees shown in Figure 5.2-1 and Figure 5.2-2.

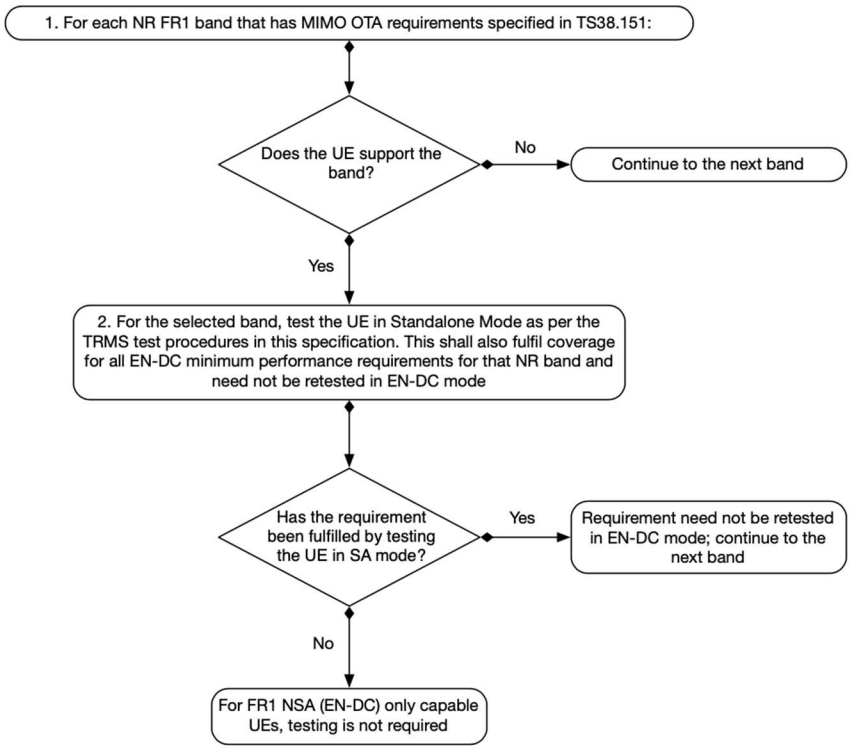

Figure 5.2-1: Decision tree for FR1 MIMO OTA testing

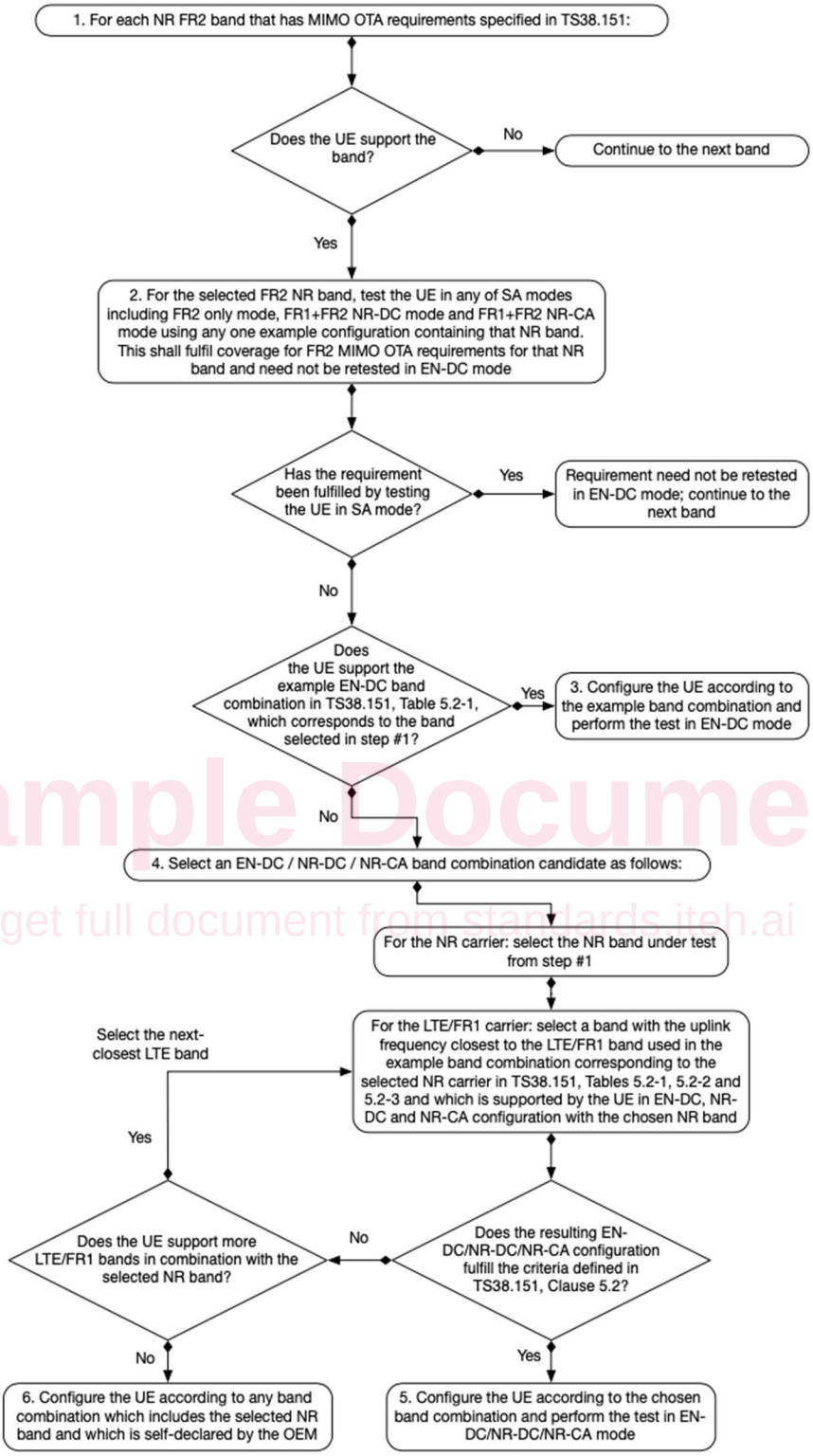

Figure 5.2-2: Decision tree for FR2 MIMO OTA testing

6 FR1 MIMO OTA requirements

6.1 General

6.1.1 Definition of MIMO throughput

The MIMO throughput is defined here as the time-averaged number of correctly received transport blocks in a communication system running an application, where a Transport Block is defined in the reference measurement channel. From OTA perspective, this is also called MIMO OTA throughput. It will be used as the baseline figure of merit for FR1 and FR2 MIMO OTA testing.

The MIMO OTA throughput is measured at the top of physical layer of NR system under the use of FRC, the SS transmit fixed-size payload bits to the DUT. The DUT signals back either ACK or NACK to the SS. The SS then records the following:

- Number of ACKs,
- Number of NACKs, and
- Number of DTX slots

Hence the MIMO (OTA) throughput can be calculated as

$$MIMO\ (OTA)\ Throughput = \frac{Transmitted\ TBS \times Num\ of\ \ ACKs}{MeasurementTime}$$

Where Transmitted TBS is the Transport Block Size transmitted by the SS, which is fixed for an FRC during the measurement period. MeasurementTime is the total composed of successful slots (ACK), unsuccessful slots (NACK) and DTX-symbols.

The time-averaging is to be taken over a time period sufficiently long to average out the variations due to the fading channel. Therefore, this is also called the average MIMO OTA throughput. The throughput should be measured at a time when eventual start-up transients in the system have evanesced.

6.1.2 Total Radiated Multi-antenna Sensitivity (TRMS)

The average TRMS of free space data mode portrait (FS DMP), free space data mode landscape (FS DML), and free space data mode screen up (FS DMSU), is defined as the FR1 MIMO OTA requirement. The averaging shall be done in linear scale for the TRMS results at these DUT positions, according to the formula:

$$TRMS_{average,70} = 10\log\left[3\Big/\left(\frac{1}{10^{S_{FS\_DMP,70}/10}} + \frac{1}{10^{S_{FS\_DML,70}/10}} + \frac{1}{10^{S_{FS\_DMSU,70}/10}}\right)\right]$$

where

$$S_{MODE,70} = 10\log\left[12\Big/\left(\frac{1}{10^{P_{MODE,70,0}/10}} + \frac{1}{10^{P_{MODE,70,1}/10}} + \cdots + \frac{1}{10^{P_{MODE,70,11}/10}}\right)\right]$$

Such that *MODE* is one of {*FS_DMP*, *FS_DML*, *FS_DMSU*}, and {$P_{MODE,70,0}$, …, $P_{MODE,70,11}$} are the measured sensitivity values at each azimuth position at the 70% throughput outage.

If 1 azimuth position does not result in a defined measured sensitivity at 70% throughput, $S_{MODE,70}$ is calculated using the 11 measured sensitivities and the maximum downlink RS-EPRE $P_{RS\text{-}EPRE\text{-}MAX}$ (substitution approach) for the one missing result. $P_{RS\text{-}EPRE\text{-}MAX}$ is the maximum downlink RS-EPRE supported by the test system. For bands > 1 GHz, $P_{RS\text{-}EPRE\text{-}MAX}$ is defined as -80dBm/15kHz (or equivalent -77dBm/30kHz) for FR1 MIMO OTA; for bands < 1 GHz, $P_{RS\text{-}EPRE\text{-}MAX}$ is defined as -78dBm/15kHz for FR1 MIMO OTA.

The TRMS shall be measured at the mid channel as specified in TS 38.508-1 subclause 4.3.1 [7]. The average TRMS shall be lower than the average TRMS requirements specified in Clause 6.2.

The additional criterion in azimuthal orientations shall be met:

- The EUT must meet 70% throughput in 11 of total 12 azimuthal orientations. If the EUT fails to meet this criterion even under maximum downlink power condition (i.e. $P_{RS\text{-}EPRE\text{-}MAX}$), the EUT shall fail the FR1 MIMO OTA test.

- The EUT must meet 90% throughput in 10 of total 12 azimuthal orientations for bands > 1 GHz, and 8 of total 12 azimuthal orientations for bands < 1 GHz. If the EUT fails to meet this criterion even under maximum downlink power condition (i.e. $P_{RS\text{-}EPRE\text{-}MAX}$), the EUT shall fail the FR1 MIMO OTA test.

6.2 Minimum requirement

FR1 TRMS minimum performance requirements for NR handheld UEs operating on SA mode in free space and the primary mechanical mode for 70% DL throughput with the corresponding measurement configurations (i.e., channel model and gNB configuration) specified in Annex C.1 and Annex E.1 are defined in Table 6.2-1.

Table 6.2-1: FR1 TRMS minimum performance requirements for NR handheld UEs operating on SA mode in free space and the primary mechanical mode

NR bands	Bandwidth [MHz]	MIMO layer	Channel model	Reference channel	$TRMS_{average,70}$
n1	10	4x4	FR1 UMa CDL-C	R.PDSCH.1-2.4 FDD	-96.0 dBm/15kHz
n5	10	2x2	FR1 UMi CDL-C	R.PDSCH.1-3.1 FDD	-88.0 dBm/15kHz
n28	10	2x2	FR1 UMi CDL-C	R.PDSCH.1-3.1 FDD	-84.6 dBm/15kHz
n41	40	4x4	FR1 UMa CDL-C	R.PDSCH.2-2.4 TDD	-93.3 dBm/30kHz
n78	40	4x4	FR1 UMa CDL-C	R.PDSCH.2-2.4 TDD	-94.8 dBm/30kHz
n79	40	4x4	FR1 UMa CDL-C	R.PDSCH.2-2.4 TDD	

7 FR2 MIMO OTA requirements

7.1 General

7.1.1 MIMO Average Spherical Coverage (MASC)

The MIMO Average Spherical Coverage (MASC) is the Figure of Merit of FR2 MIMO OTA requirement. FR2 MIMO OTA is measured with 36 constant-density points within the 3D sphere. The MASC is determined by the averaging of the best 18 sensitivity values for power class 3 UE. The averaging shall be done in linear scale for the MASC result according to the formula:

$$MASC_{70} = 10\,log\left[\frac{18}{\left(\frac{1}{10^{\frac{P_{70,1}}{10}}} + \frac{1}{10^{\frac{P_{70,2}}{10}}} + \cdots + \frac{1}{10^{\frac{P_{70,18}}{10}}}\right)}\right]$$

Such that $\{P_{70,1}, \ldots, P_{70,18}\}$ are the best 18 sensitivity values from all the 36 constant density measurement points, as defined in Annex B.2.3.

The MASC is determined by the averaging of the best 5 sensitivity values for power class 1 UE. The averaging shall be done in linear scale for the MASC result according to the formula:

$$MASC_{70} = 10\,log\left[\frac{5}{\left(\frac{1}{10^{\frac{P_{70,1}}{10}}} + \frac{1}{10^{\frac{P_{70,2}}{10}}} + \cdots + \frac{1}{10^{\frac{P_{70,5}}{10}}}\right)}\right]$$