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TECHNICAL SPECIFICATION

5G;
NR;
User Equipment (UE) Multiple Input Multiple Output (MIMO) Over-the-Air (OTA) performance requirements
(3GPP TS 38.151 version 17.2.0 Release 17)

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Modal verbs terminology

In the present document "**shall**", "**shall not**", "**should**", "**should not**", "**may**", "**need not**", "**will**", "**will not**", "**can**" and "**cannot**" are to be interpreted as described in clause 3.2 of the ETSI Drafting Rules (Verbal forms for the expression of provisions).

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2 presented to TSG for approval;

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y the second digit is incremented for all changes of substance, i.e. technical enhancements, corrections, updates, etc.

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:

shall indicates a mandatory requirement to do something

shall not indicates an interdiction (prohibition) to do something

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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

The construction "may not" is ambiguous and is not used in normative elements. The unambiguous constructions "might not" or "shall not" are used instead, depending upon the meaning intended.

can indicates that something is possible

cannot indicates that something is impossible

The constructions "can" and "cannot" are not substitutes for "may" and "need not".

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

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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"

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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].

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

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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.

5 Frequency bands

5.1 General

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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

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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].

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)

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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:

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

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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, and is defined as -80dBm/15kHz (or equivalent -77dBm/30kHz) 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. 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	$TRMS_{average,70}$
n28	10	2x2	FR1 UMi CDL-C	R.PDSCH.1-3.1 FDD	TBD 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	TBD dBm/30kHz

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:

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

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 shall be measured at the mid channel as specified in TS 38.508-1 subclause 4.3.1 [7]. The MASC shall be lower than the requirements specified in Clause 7.2.

For FR2 MIMO OTA, $P_{RS\text{-}EPRE\text{-}MAX}$, i.e., the maximum downlink RS-EPRE supported by the test system, is defined as [-79.1dBm/120kHz].

If the number of test points where the UE can meet 70% maximum throughput outage even under maximum downlink power condition (i.e., [-79.1dBm/120kHz]) is less than [18], then UE fails the test.

Other criteria for FR2 are FFS.

7.2 Minimum requirement

FR2 MASC minimum performance requirements for power class 3 NR handheld UEs in free space and the primary mechanical mode for averaging of the best 18 sensitivity values for 70% DL throughput with the corresponding measurement configurations (i.e., channel model and gNB configuration) specified in Annex D.1 and Annex E.2 are defined in Table 7.2-1.

Table 7.2-1: FR2 MASC minimum performance requirements for NR handheld UEs in free space and the primary mechanical mode

NR bands	Bandwidth (MHz)	MIMO layer	Channel model	Reference channel	$MASC_{70}$ [dBm/120kHz]
n257	100	2x2	FR2 UMi CDL-C	R.PDSCH.5-2.2 TDD	TBD
n258	100	2x2	FR2 UMi CDL-C	R.PDSCH.5-2.2 TDD	TBD
n260	100	2x2	FR2 UMi CDL-C	R.PDSCH.5-2.2 TDD	TBD
n261	100	2x2	FR2 UMi CDL-C	R.PDSCH.5-2.2 TDD	TBD

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Annex A (normative): <FR1 Test methodology>

A.1 General

FR1 MIMO OTA requirement testing is based on UE-noise limited environmental condition, i.e., UE throughput characterized as a function of signal power incident to the DUT antennas.

The minimum test zone size for FR1 MIMO OTA test methods is 20cm. “Black-box” testing approach is adopted for NR MIMO OTA testing, the physical centre of the EUT shall be placed in the centre of the test zone, the EUT shall be completely contained within the minimum test zone size.

FR1 MIMO OTA requirement testing should be performed under primary mechanical mode. The primary mechanical mode for devices having multiple mechanical modes shall be declared by the manufacturers. Single primary mechanical mode for each device should be declared for MIMO OTA conformance testing.

A.2 Multi-Probe Anechoic Chamber (MPAC)

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A.2.1 System setup

MPAC test method is the reference methodology for FR NR MIMO OTA testing. By arranging an array of antennas around the Equipment Under Test (EUT), a spatial distribution of angles of arrival in MPAC system may be simulated to expose the EUT to a near field environment that appears to have originated from a complex multipath far field environment.

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As illustrated schematically in Figure A.2.1-1, signals propagate from the base station/communication tester to the EUT through a simulated multipath environment known as a spatial channel model, where appropriate channel impairments such as Doppler and fading are applied to each path prior to injecting all of the directional signals into the chamber simultaneously through the antenna array. The resulting field distribution in the test zone is then integrated by the EUT antenna(s) and processed by the receiver(s) just as it would do so in any non-simulated multipath environment. MPAC system with 16 uniformly-spaced dual-polarized probes is permitted for NR FR1 MIMO OTA testing.

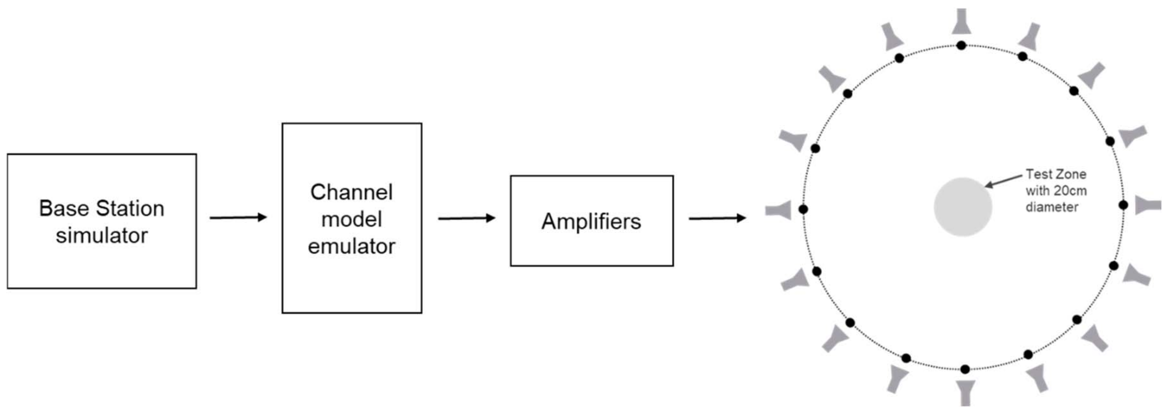

Figure A.2.1-1: MPAC system layout for NR FR1 MIMO OTA testing

A.2.2 Calibration procedure

The system needs to be calibrated by using a reference calibration antenna with known gain values in order to ensure that the downlink signal power is correct. In non-standalone (NSA) mode, the LTE link antenna provides a stable LTE signal without precise path loss or polarization control.

Unlike traditional TRP/TRS testing where the path loss corrections can all be applied as a post processing step to the measured data, the path loss for each probe in the MPAC system must be balanced at test time in order to generate the desired channel model environment within the test zone of the chamber. The imbalance of each path during testing would result in an alteration of the angular dependence of the channel model (i.e. varied characteristics of generated channel model) within the test zone of the chamber.

1. Place a vertical reference dipole in the centre of the test zone, connected to a VNA port, with the other VNA port connected to the input of the channel emulator unit.

2. Configure the channel emulator for bypass mode.

3. Measure the response of each path from each vertical polarization probe to the reference antenna in the centre of test zone.

4. Adjust the power on all vertical polarization branches of the channel emulator so that the powers received at the centre are equal.

5. Repeat the steps 1 to 4 with the magnetic loop or horizontally polarized reference dipole instead, and adjust the horizontal polarization branches of the channel emulator.

6. The worst-case path loss becomes the reference path loss of the entire system, this loss is used to compute the power in the centre of the test zone relative to the output power of the Base Station simulator. Besides, based on the reference path loss, the relative offset of each path loss shall be corrected.

Note: Calibration based on other antennas, e.g., horn antennas is not precluded.

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A.2.3 Test procedure

Before throughput testing, the initial conditions shall be confirmed to reach the correct measurement state for each test case.

1. Ensure environmental requirements of Annex F are met.

2. Configure the test system according to Annex C, D and E for the applicable test case.

3. Verify the implementation of the channel model as specified in Annex C.3.

4. Position the UE in the chamber according to Annex A.3.

5. Power on the UE.

6. Set up the connection.

Note: For step 3, the verification of the channel model implementation is usually performed once for each channel model as part of the laboratory accreditation process, and will remain valid as long as the setup and instruments remain unchanged. Otherwise the channel model validation may need to be performed prior to starting each throughput test.

For throughput testing, the following steps shall be followed in order to evaluate NR MIMO OTA performance of the DUT:

1. Measure MIMO OTA throughput from one measurement point, the maximum downlink power $P_{RS\text{-}EPRE\text{-}MAX}$ is defined in Clause 6.1.2. MIMO OTA throughput is the minimum downlink signal power resulting in a pre-defined throughput value, i.e., 70% and 90% of the maximum theoretical throughput. The downlink signal power step size shall be no more than 0.5 dB when RF power level is near the NR MIMO sensitivity level.

2. Rotate the UE around vertical axis of the test system by 30 degrees and repeat from step 1 until one complete rotation has been measured i.e. 12 different UE azimuth rotations.