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| 3GPP TS 38.551 V17.1.0 (2024-03) | |
| Technical Specification | |
| 3rd Generation Partnership Project;  Technical Specification Group Radio Access Network;  NR;  User Equipment (UE) Multiple Input Multiple Output (MIMO)  Over‑the-Air (OTA) performance  Conformance testing  (Release 17) | |
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| ***3GPP***  Postal address  3GPP support office address  650 Route des Lucioles - Sophia Antipolis  Valbonne - FRANCE  Tel.: +33 4 92 94 42 00 Fax: +33 4 93 65 47 16  Internet  http://www.3gpp.org |
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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:

Version x.y.z

where:

x the first digit:

1 presented to TSG for information;

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

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

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

# 1 Scope

The present document specifies details of conformance testing of UE Multiple Input Multiple Output (MIMO) Over-the-Air (OTA) requirements and test methodologies for FR1 (NR SA and NSA). The correspondent testing methodologies are also presented in the Annex A of the present document.

# 2 References

The following documents contain provisions which, through reference in this text, constitute provisions of the present document.

- References are either specific (identified by date of publication, edition number, version number, etc.) or non‑specific.

- For a specific reference, subsequent revisions do not apply.

- For a non-specific reference, the latest version applies. In the case of a reference to a 3GPP document (including a GSM document), a non-specific reference implicitly refers to the latest version of that document *in the same Release as the present document*.

[1] 3GPP TR 21.905: "Vocabulary for 3GPP Specifications".

[2] 3GPP TS 38.101-1: "NR; User Equipment (UE) radio transmission and reception; Part 1: Range 1 Standalone".

[3] 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".

[4] 3GPP TS 38.508-1: "5GS; User Equipment (UE) conformance specification; Part 1: Common test environment".

[5] 3GPP TR 38.901: "Study on channel model for frequencies from 0.5 to 100 GHz".

[6] 3GPP TS 38.101-4: "NR; User Equipment (UE) radio transmission and reception; Part 4: Performance requirements".

[7] 3GPP TS 38.151: "NR; User Equipment (UE) Multiple Input Multiple Output (MIMO) Over-the-Air (OTA) performance requirements".

[8] 3GPP TS 38.561: "UE TRP (Total Radiated Power) and TRS (Total Radiated Sensitivity) requirements and test methodologies for FR1 (NR SA and EN-DC); User Equipment (UE) conformance specification".

[9] IEEE Std 149: "IEEE Standard Test Procedures for Antennas", IEEE.

# 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].

**Free Space (FS):** UE used in a free space configuration

**Handheld UE:** UE intended to be used in hand held scenario

**primary mechanical mode:** mode that is most often used for a specific user scenario.

**PAS Similarity Percentage (PSP):** similarity of the PAS produced by the OTA system and the reference 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:

*PRS-EPRE-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].

ACK Acknowledgment

AOA Azimuth angle Of Arrival

AOD Azimuth angle Of Departure

ASA Azimuth Spread of Arrival angles

ASD Azimuth Spread of Departure angles

BS Base Station

CASA Cluster ASA

CASD Cluster ASD

CDL Clustered Delay Line

CIR Channel Impulse Response

CSI Channel state information

CSI-RS CSI reference signal

CW Continuous Wave

CZSA Cluster ZSA

CZSD Cluster ZSD

DML Data Mode Landscape

DMP Data Mode Portrait

DMRS Demodulation reference signal

DMSU Data Mode Screen Up

DUT Device Under Test

EUT Equipment Under Test

EVM Error Vector Magnitude

FR1 Frequency Range 1

FRC Fixed Reference Measurement Channel

FS Free Space

gNB Next Generation Node B

HARQ Hybrid automatic repeat request

MIMO Multiple Input Multiple Output

MPAC Multi-Probe Anechoic Chamber

MU Measurement Uncertainty

NACK Not Acknowledged

NR New Radio

NSA Non-Standalone a mode of operation where operation of another radio is assisted with another radio

OCNG OFDMA Channel Noise Generator

OTA Over The Air

PAS Power Angular Spectrum

PDP Power Delay Profile

PDSCH Physical downlink shared channel

PRB Physical resource block

PSP PAS Similarity Percentage

RE Resource Element

RS-EPRE Reference Signal-Energy Per Resource Element

SCS Subcarrier spacing

SNR Signal to Noise Ratio

SS System Simulator

SSS Secondary Synchronization Signal

TBS Transport Block Size

TCI Transmission Configuration Indicator

TRMS Total Radiated Multi-antenna Sensitivity

UE User Equipment

UMa Urban Macro

UMi Urban Micro

VNA Vector Network Analyser

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

Editor's Note: Intended to capture additional general information to be used within this test specification, such as follows:

4.3 Specification suffix information

4.4 Test point analysis

4.5 Applicability and test coverage rules

4.6 Pass fail decisions rule of test case based on Test Tolerance definitions.

## 4.1 Relationship between minimum requirements and test requirements

The Minimum Requirements given in 3GPP TS 38.151 [7] make no allowance for Measurement Uncertainty (MU). The present document defines the MU and Test Tolerances in Annex B for FR1 MIMO OTA. The test tolerances are used to relax the Minimum Requirements in 3GPP TS 38.151 [7] to create the 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 E.

## 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.

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.

# 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 FR1 operating bands.

## 5.2 Operating bands

NR is designed to operate in FR1 operating bands defined in 3GPP TS 38.101-1 [3]. NSA band combinations are defined in 3GPP TS 38.101-3 [3].

# 6 FR1 MIMO OTA Performance

## 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:



Where Transmitted TBS is the Transport Block Size transmitted by the SS, which is fixed for an FRC during the measurement period. Measurement Time 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)

Editor’s note: The test case is incomplete. TT is pending further analysis. 6.1.2.1 Test Purpose

The purpose of this test is to ensure that the UE meets the TRMS minimum performance requirements.

6.1.2.2 Test Applicability

This test case applies to all types of NR UE release 17 and forward. See clause 4.2 for additional applicability.

6.1.2.3 Minimum Conformance Requirements

Editor's Note: TRMS values for n28/n79 are pending in RAN4 spec TS38.151.

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:



where



Such that *MODE* is one of {*FS\_DMP, FS\_DML, FS\_DMSU*}, and {*PMODE,70,0, …, PMODE,70,11*} are the measured sensitivity values at each azimuth position at the 70% throughput outage.

The reported TRMS value shall be corrected by of the final power step search and the correction shall be noted in the test report.

If 1 azimuth position does not result in a defined measured sensitivity at 70 % throughput, SMODE,70 is calculated using the 11 measured sensitivities and the maximum downlink RS-EPRE PRS-EPRE-MAX (substitution approach) for the one missing result. PRS-EPRE-MAX is the maximum downlink RS-EPRE supported by the test system, and is defined as -80 dBm/15 kHz (or equivalent -77 dBm/30 kHz) for FR1 MIMO OTA.

The TRMS shall be measured at the mid channel as specified in 3GPP TS 38.508-1 [4], subclause 4.3.1.

The additional criterion in azimuthal orientations shall be met:

- The EUT has to 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. PRS-EPRE-MAX), the EUT shall fail the FR1 MIMO OTA test.

- The EUT has to 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. PRS-EPRE-MAX), the EUT shall fail the FR1 MIMO OTA test.

FR1 TRMS minimum performance requirements for NR handheld UEs operating in 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 clause C.1 and clause E.1 are defined in Table 6.1.2.3-1.

Table 6.1.2.3-1: 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 | TRMSaverage,70 |
| n28 | 10 | 2x2 | FR1 UMi CDL-C | R.PDSCH.1-3.1 FDD | […] 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 | […] dBm/30kHz |

6.1.2.4 Test Description

6.1.2.4.1 Initial Conditions

Initial conditions are a set of test configurations the UE needs to be tested in and the steps for the SS to take with the UE to reach the correct measurement state.

A radio communications tester or a corresponding device is used as a gNB simulator to setup calls to the DUT according to Clause D.1.

Channel model shall be set according to Clause C.1 and the emulated BS beam configuration shall be set according to Clause C.2.

Chamber environment constraints shall be the same as described in Clause A.2.1. The coordinate system shall match that of Clause A.3.

Environmental conditions from Annex E shall apply.

The positioning of the device under test within the test volume shall be set as defined in Clause A.3.

The calibration procedure is specified in Clause A.2.2.

Initial conditions are a set of test configurations the UE shall be tested in and the steps for the SS to take with the UE to reach the correct measurement state for each test case.

1) Ensure environmental requirements of Annex E are met.

2) Configure the test system according to Annexes C and D for the applicable test case.

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

4) Position the UE in the chamber according to clause 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.

6.1.2.4.2 Test Procedure

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 PRS-EPRE-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.

3) Repeat the test from step 1 for each specified device orientation. A list of orientations is given in clause A.3.

4) The postprocessing method to calculate the average MIMO Throughput is defined in clause 6.

NOTE: For step 1 of throughput testing, the measurement is not needed to start from maximum downlink power each time. To save testing time, the starting downlink power can be set as a proper value (lower than maximum downlink power supported by test system) as long as all the throughput curve curves at 12 different UE azimuth rotations can reach at least 90% of the maximum theoretical throughput.

6.1.2.4 Test Requirements

Editor's Note: TRMS values for n28/n79 are pending in RAN4 spec TS38.151.

The test requirements are shown in Table 6.1.2.4-1.

Table 6.1.2.4-1: FR1 TRMS test 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 | TRMSaverage,70 |
| n28 | 10 | 2x2 | FR1 UMi CDL-C | R.PDSCH.1-3.1 FDD | […] dBm/15kHz |
| n41 | 40 | 4x4 | FR1 UMa CDL-C | R.PDSCH.2-2.4 TDD | -93.3 dBm/30kHz + TT |
| n78 | 40 | 4x4 | FR1 UMa CDL-C | R.PDSCH.2-2.4 TDD | -94.8 dBm/30kHz +TT |
| n79 | 40 | 4x4 | FR1 UMa CDL-C | R.PDSCH.2-2.4 TDD | […] dBm/30kHz |

## 6.2 VOID



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 geometric 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)

## 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.

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.

A picture containing device, gauge, control panel

Description automatically generated

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

For the selected environmental conditions modelled by the FR1 CDL channel models, the minimum setup configuration can be described as in Table A.2.1-1:

Table A.2.1-1: Example of a minimum setup for MPAC

|  |  |
| --- | --- |
|  | MPAC |
| Minimum number of antenna positions | 16 |
| Antenna spacing | 22.5 |
| Applicable channel model | FR1 UMi/UMa CDL-C |

The setup of OTA chamber antennas with sixteen antenna positions is depicted in Figure A.2.1-2. The DUT is at the centre, and the antennas are aligned on a circle around the DUT with uniform spacing (e.g. 22.5° with 32 elements arranged in 16 positions, where each position contains a vertically and horizontally polarized antenna pair). Denoting directions of *K* OTA antennas with *fk*, *k* = 1… *K*, and antenna spacing of 22.5°. Each antenna is connected to a single fading emulator output port. In the figure, for example, antenna *A*1V denotes the first OTA antenna position and Vertically (V) polarized element, *A*8H denotes the eight OTA antenna position and horizontally (H) polarized element, etc.

A diagram of a device with arrows and directions

Description automatically generated with medium confidence

Figure A.2.1-2: OTA chamber antenna setup with sixteen uniformly spaced dual polarized chamber antennas

## 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 has to 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.

## 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 E are met.

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

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

4) Position the UE in the chamber according to clause 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 PRS-EPRE-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.

3) Repeat the test from step 1 for each specified device orientation. A list of orientations is given in clause A.3.

4) The postprocessing method to calculate the average MIMO Throughput is defined in clause 6.

NOTE: For step 1 of throughput testing, the measurement is not needed to start from maximum downlink power each time. To save testing time, the starting downlink power can be set as a proper value (lower than maximum downlink power supported by test system) as long as all the throughput curve curves at 12 different UE azimuth rotations can reach at least 90% of the maximum theoretical throughput.

## A.2.4 Minimum Range Length

The minimum range length of FR1 MPAC system is defined as the distance from the centre of the test zone to the aperture of the measurement probes/antennas, as illustrated in Figure A.2.4-1.

A picture containing schematic

Description automatically generated

Figure A.2.4-1: Illustration of range length definition of FR1 MPAC

The minimum range length for NR FR1 MPAC OTA systems with 20cm test zone size is 1.2 m. While for MPAC systems, the far-field requirements do not have to apply, it was shown that the spatial correlation can be impacted significantly for distances below 1.2 m.

# A.3 EUT positioning

This Clause defines the measurement coordinate system for the NR MIMO OTA.

1. For FR1 MIMO OTA, the DUT shall be tested under Free Space Data Mode Portrait (FS DMP), Free Space Data Mode Landscape (FS DML), and Free Space Data Mode Screen Up (FS DMSU), the DUT azimuthal rotation shall be performed over 360 degrees per orientation. The three different test and environment conditions for handsets are summarized in Table A.3-1.
2. The geometric centre of the DUT shall be aligned with the centre of the test zone/coordinate system and the DUT shall be fully contained within the test zone, i.e., a sphere with 20 cm diameter.
3. Table A.3-1: Summary of testing environment conditions for devices supporting DL MIMO data reception

|  |  |  |  |
| --- | --- | --- | --- |
| DUT type | Testing condition | DUT orientation angles | Diagram |
| Handset | FS DMP | Ψ=0° Θ=−45° Φ=0° |  |
| Handset | FS DML – Left Tilt | Ψ=90° Θ=−45° Φ=0° |  |
| Handset | FS DMSU | Ψ=0° Θ=−90° Φ=0° |  |
| NOTE: Rotation angles defined in Figure A.4-2 with the reference coordinate system defined in Clause A.4. | | | |

# A.4 Reference coordinate system

This clause defines the measurement coordinate system for the NR UE. The reference coordinate system as defined in IEEE Std 149 [9] is provided in Figure A.4-1 below while Figure A.4-2 shows an example DUT in the default alignment, i.e., the DUT and the reference coordinate systems are aligned with α = 0o and β = 0o and γ = 0o where α, β, and γ describe the relative angles between the two coordinate systems.

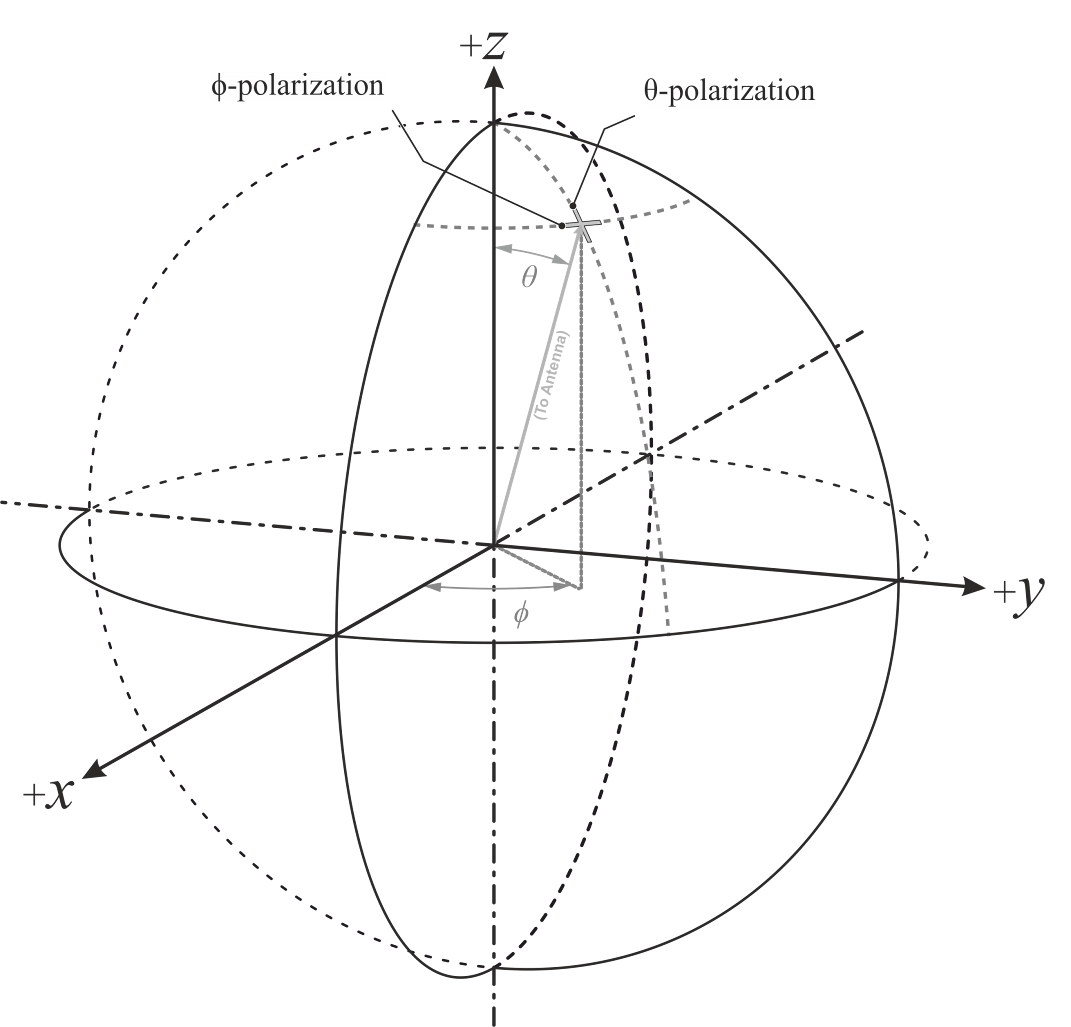


Figure A.4-1: Reference coordinate system



Figure A.4-2: DUT default alignment of example smartphone UE to coordinate system

The following aspects are necessary:

- A basic understanding of the top and bottom of the device is needed in order to define unambiguous DUT positioning requirements for the test, e.g., in the drawings used in this annex, the three buttons are on the bottom of the device (front) and the camera is on the top of the device (back).

- An understanding of the origin and alignment the coordinate system inside the test system i.e. the directions in which the *x*, *y*, *z* -axes points inside the test chamber is needed in order to define unambiguous DUT orientation, DUT beam, signal, interference, and measurement angles

Annex B (informative):  
Estimation of measurement uncertainty

# B.1 MU budget of FR1 MPAC system

This clause defines the measurement uncertainty (MU) for FR1 MPAC system, as shown in Table B.1-1.

Table B.1-1: Preliminary measurement uncertainty budget for FR1 MPAC system

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| UID | Description of uncertainty contribution | Example value (410 MHz <f ≤ 3 GHz) [dB] | Example value (3 GHz < f ≤ 7.125GHz) [dB] | Distribution of the probability | Std Uncertainty (410 MHz < f ≤ 3 GHz) [dB] | Std Uncertainty (3 GHz < f ≤ 7.125GHz) [dB] |
| Stage 2: DUT measurement | | | | | |  |
| 1 | Mismatch for measurement process | 0 | 0 | U-Shaped | 0 | 0 |
| 2 | Measure distance uncertainty | 0 | 0 | Normal | 0 | 0 |
| 3 | Quality of quiet zone | 0.5 | 0.5 | Actual | 0.5 | 0.5 |
| 4 | Base Station simulator | 1.3 | 1.3 | Normal | 0.65 | 0.65 |
| 5 | Channel Emulator  - absolute output power  - output signal stability  - output stability with temperature | 1.5  0.5  0.4 | 1.5  0.5  0.4 | Actual  (Normal - power;  rect-stability) | 0.84 | 0.84 |
| 6 | Amplifier uncertainties | 0.7 | 0.7 | Rectangular | 0.40 | 0.40 |
| 7 | Random uncertainty | 0.4 | 0.4 | Normal | 0.20 | 0.20 |
| 8 | Throughput measurement: output level step resolution | 0 | 0 | Rectangular | 0 | 0 |
| 9 | Signal flatness | 0 | 0 | Normal | 0 | 0 |
| Stage 1: Calibration measurement | | | | | |  |
| 10 | Mismatch for calibration process  - loopback cable path  - system input path  - reference antenna | 0.2 | 0.2 | U-Shaped | 0.14 | 0.14 |
| 11 | Reference antenna positioning misalignment | 0 | 0 | Normal | 0 | 0 |
| 12 | Quality of quiet zone | 0.5 | 0.5 | Rectangular | 0.29 | 0.20 |
| 13 | Total uncertainty of the Network Analyzer | 0.2 | 0.5 | Normal | 0.10 | 0.25 |
| 14 | Uncertainty of an absolute gain of the calibration antenna | 0.58 | 0.58 | Normal | 0.29 | 0.29 |
| 15 | Offset of the Phase Center of the Reference Antenna | 0 | 0 | Normal | 0 | 0 |
| **Total Expanded Uncertainty, U, with 95 % Confidence Interval** | | | | | **2.61** | **2.65** |

The detailed descriptions of each measurement uncertainty contributor are defined in in clause B.2.

# B.2 Measurement error contribution descriptions for MPAC

## B.2.1 Mismatch for measurement process

This term comes from the mismatch between the system input cables connecting to the base station simulator output port. For more information, see clause A.4.2.1 of 3GPP TS 38.561 [8].

## B.2.2 Measurement distance uncertainty

The cause of this uncertainty contributor is due to the reduction of distance between the measurement antenna and the DUT. Given that 1.2 m is defined as the minimum range length for FR1 MPAC system and the device is not offset from the axis(es) of rotation, this term could be set as 0 dB.

## B.2.3 Quality of quiet zone

The quality of the quiet zone procedure characterizes the quiet zone performance of the anechoic chamber, specifically the effect of reflections within the anechoic chamber including any positioners and support structures. For FR1 quality of quiet zone measurements, reference antennas of sleeve dipole or magnetic loop are used. For more information, see clause A.4.2.8 of 3GPP TS 38.561 [8] with the exception that only the phi-axis ripple test is performed for MIMO OTA.

## B.2.4 Base Station simulator

gNB emulator is used to drive a signal to the channel emulator and then to the device under test. Generally there occurs uncertainty contribution from absolute level accuracy, non-linearity and frequency characteristic of the gNB emulator.

For practical reasons, in a case that a VNA is used as a calibration equipment, gNB emulator is connected to the system after the calibration measurement is performed by the VNA. Hence, the uncertainty on the absolute level of gNB emulator (transmitter device) cannot be assumed as systematic. This uncertainty will be determined from the manufacturer's datasheet and the distribution used shall match that provided in the datasheet which are commonly quoting MUs/accuracies with a "95 % confidence level" and/or a "coverage factor of 2". In the absence of a declared distribution in the datasheet, the rectangular distribution should be used. Furthermore, the uncertainty of the non-linearity is included in the absolute level uncertainty.

## B.2.5 Channel Emulator

The channel emulator is also working as a signal source in the NR MIMO OTA system, therefore there occurs uncertainty contribution from absolute level accuracy, non-linearity, frequency characteristic and stability of the channel emulator. These uncertainty contributions shall be taken from the manufacturer's data sheet.

## B.2.6 Amplifier uncertainties

Any components in the setup can potentially introduce measurement uncertainty. It is then needed to determine the uncertainty contributors associated with the use of such components. For the case of external amplifiers, the following uncertainties should be considered but the applicability is contingent to the measurement implementation and calibration procedure:

- Stability:

- An uncertainty contribution comes from the output level stability of the amplifier. Even if the amplifier is part of the system for both measurement and calibration, the uncertainty due to the stability shall be considered. This uncertainty can be either measured or determined by the manufacturers' data sheet for the operating conditions in which the system will be required to operate.

- Linearity:

- An uncertainty contribution comes from the linearity of the amplifier since in most cases calibration and measurements are performed at two different input/output power levels. This uncertainty can be either measured or determined by the manufacturers' data sheet.

- Noise Figure:

- When the signal goes into an amplifier, noise is added so that the SNR at the output is reduced with regard to the SNR of the signal at the input. This added noise introduces error on the signal which affects the Error Rate of the receiver thus the EVM (Error Vector Magnitude). An uncertainty can be calculated through the following formula:



- Where SNR is the signal to noise ratio in dB at the signal level used during the sensitivity measurement.

- Mismatch:

- If the external amplifier is used for both stages, measurement and calibration the uncertainty contribution associated with it can be considered systematic and constant -> 0dB. If it is not the case, the mismatch uncertainty at its input and output shall be either measured or determined by the method described in 3GPP TR 38.901 [5].

- Gain:

- If the external amplifier is used for both stages, measurement and calibration the uncertainty contribution associated with it can be considered systematic and constant -> 0 dB. If it is not the case, this uncertainty shall be considered.

## B.2.7 Random uncertainty

This contribution is used to account for all the unknown, unquantifiable, etc. uncertainties associated with the measurements.

Random uncertainty MU contributions are normally distributed. The random uncertainty term, by definition, cannot be measured, or even isolated completely. A fixed value of 0.4 dB is suggested for TRMS measurements to include a digital error rate uncertainty and is aligned with the random uncertainty for TRS for NR FR1 (3GPP TS 38.561 [8]).

## B.2.8 Throughput measurement: output level step resolution

When output power of the communication tester is swept to reach the throughput target that defines the sensitivity threshold, the final power step resolution represents an asymmetric uncertainty contribution that can be corrected since this uncertainty is device and test system independent. The lab shall correct the TRMS results by ‑0,5  of the final power step search and note the correction in the test report. If the alternate DL signal power search procedure with linearization, detailed in clause A.2.3 is applied to assess the DL signal power at each grid point, no correction of TRMS shall be applied and no additional MU shall be considered.

## B.2.9 Signal flatness

For wireless technologies with wide channel bandwidths, the test system might not have a flat frequency response across the entire channel. While the range calibration corrects for any variation of frequency response as a function of the centre frequency of the channel, the broadband delivered to the test zone will be a function of the entire channel bandwidth as opposed to just the centre frequency. For more information, see clause A.4.2.14 of 3GPP TS 38.561 [8].

## B.2.10 Mismatch for calibration process

During calibration stage, there will be impendence mismatch between the various RF cables and components used within the system. Standing waves are created by the reflections between any two components and uncertainty in the signal level will be generated. In general, three mismatch for calibration process should be considered:

- Loopback cable path: This item comes from the mismatch between the reference cable and the loopback cable during the loopback cable measurement step.

- System input path: This item comes from the mismatch between the loopback cable and the system input cable (generally the output cable after BS simulator). The reflectivity of the source output port is measured at the end of the loopback cable connecting to the system input cable.

- Reference antenna: This item comes from the mismatch between the VNA input port and the reference antenna. The reflectivity of the VNA input port is measured at the end of the reference cable connecting to the reference antenna.

For more information, see clause A.4.2.1 of 3GPP TS 38.561 [8].

## B.2.11 Reference antenna positioning misalignment

This contribution originates from reference antenna alignment and pointing error. In this measurement if the maximum gain directions of the reference antenna and the receiving antenna are aligned to each other, this contribution can be considered negligible and therefore set to zero.

## B.2.12 Total Uncertainty of the Network Analyzer

This contribution originates from all uncertainties involved transmission magnitude measurement (including drift and frequency flatness) with a network analyser. will be determined from the manufacturer's datasheet which is now commonly quoting MUs/accuracies with a "95 % confidence level" and/or a "coverage factor of 2"and the distribution used shall match that provided in the datasheet. In the absence of a declared distribution in the datasheet, the rectangular distribution should be used.

## B.2.13 Uncertainty of an absolute gain of the calibration antenna

The calibration antenna only appears in calibration phase (Stage 1). Therefore, the gain uncertainty has to be taken into account.

This uncertainty shall come from a calibration report (which is now commonly quoting MUs/accuracies with a "95 % confidence level" and/or a "coverage factor of 2") with traceability to a National Metrology Institute with measurement uncertainty budgets generated following the guidelines outlined in internationally accepted standards. In the absence of a declared distribution in the present document, the rectangular distribution should be used.

## B.2.14 Offset of the Phase Center of the Reference Antenna

During range reference measurement, if a directional antenna is used, the uncertainty in the accuracy of positioning its phase center on the axis of rotation will directly generate an uncertainty in this part of the measurement. In practical measurement, sleeve dipoles and loops are used for FR1 calibration, then the uncertainty of this element should be 0 dB, since the phase center offset is negligible.

Annex C (normative):  
FR1 Channel models and Validation procedure

# C.1 FR1 Channel models

The following channel models are required for FR1 MIMO OTA measurement.

The generic models are Table C.1-1 FR1 UMi CDL-C and Table C.1-2 FR1 UMa CDL-C, which do not include base station antenna filtering. UMi CDL-C and UMa CDL-C are selected to define 2x2 and 4x4 MIMO OTA requirements, respectively.

Therefore, in addition, the BS beam filtering effect defined in clause C.2 also apply when emulating the channel models.

Table C.1-1: Channel model parameters for UMi CDL-C at 3.5 GHz

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Cluster # | Absolute Delay [ns] | Power in [dB] | AOD in [°] | AOA in [°] | ZOD in [°] | ZOA in [°] |
| 1 | 0 | -4.4215 | -36.1891 | -122.2815 | 98.9242 | 90 |
| 2 | 20.99 | -1.25 | -21.5937 | 125.831 | 99.1915 | 90 |
| 3 | 22.19 | -3.4684 | -21.5937 | 125.831 | 99.1915 | 90 |
| 4 | 23.29 | -5.2294 | -21.5937 | 125.831 | 99.1915 | 90 |
| 5 | 21.76 | -2.5215 | -32.5709 | -143.6126 | 99.5732 | 90 |
| 6 | 63.66 | 0 | -7.4275 | 166.4003 | 99.306 | 90 |
| 7 | 64.48 | -2.2185 | -7.4275 | 166.4003 | 99.306 | 90 |
| 8 | 65.6 | -3.9794 | -7.4275 | 166.4003 | 99.306 | 90 |
| 9 | 65.84 | -7.4215 | 37.2175 | 73.8315 | 100.4513 | 90 |
| 10 | 79.35 | -7.1215 | -47.1664 | 82.7664 | 98.5616 | 90 |
| 11 | 82.13 | -10.7215 | 41.5716 | -79.6999 | 100.6231 | 90 |
| 12 | 93.36 | -11.1215 | -67.1585 | 66.9895 | 98.218 | 90 |
| 13 | 122.85 | -5.1215 | -41.5244 | 84.0543 | 100.165 | 90 |
| 14 | 130.83 | -6.8215 | -47.0437 | -96.2818 | 100.2604 | 90 |
| 15 | 217.04 | -8.7215 | -55.7519 | 94.8406 | 98.1225 | 90 |
| 16 | 271.05 | -13.2215 | 55.3698 | 53.9494 | 100.2604 | 90 |
| 17 | 425.89 | -13.9215 | 53.2234 | 16.0364 | 98.4852 | 90 |
| 18 | 460.03 | -13.9215 | 46.8456 | 32.2963 | 98.1416 | 90 |
| 19 | 549.02 | -15.8215 | -70.1021 | 18.2098 | 97.9698 | 90 |
| 20 | 560.77 | -17.1215 | 48.9306 | 37.0455 | 100.7376 | 90 |
| 21 | 630.65 | -16.0215 | 49.6052 | 33.7452 | 98.1225 | 90 |
| 22 | 663.74 | -15.7215 | 57.7615 | 29.801 | 98.1034 | 90 |
| 23 | 704.27 | -21.6215 | 65.6725 | 11.6092 | 100.4513 | 90 |
| 24 | 865.23 | -22.8215 | -83.5324 | 56.2837 | 100.9476 | 90 |
| Per-Cluster Parameters | | | | | | |
| Parameter | CASD in [°] | CASA in [°] | CZSD in [°] | CZSA in [°] | XPR in [dB] |  |
| Value | 1.2265 | 12.0742 | 0.5726 | 0 | 7 |  |

Table C.1-2: Channel model parameters for UMa CDL-C at 3.5 GHz

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Cluster # | Absolute Delay [ns] | Power in [dB] | AOD in [°] | AOA in [°] | ZOD in [°] | ZOA in [°] |
| 1 | 0 | -4.4215 | -37.4195 | -96.4031 | 96.7645 | 90 |
| 2 | 76.6135 | -1.25 | -21.7362 | 118.7405 | 98.4506 | 90 |
| 3 | 80.9935 | -3.4684 | -21.7362 | 118.7405 | 98.4506 | 90 |
| 4 | 85.0085 | -5.2294 | -21.7362 | 118.7405 | 98.4506 | 90 |
| 5 | 79.424 | -2.5215 | -33.5316 | -124.0196 | 100.8594 | 90 |
| 6 | 232.359 | 0 | -6.5142 | 171.2639 | 99.1732 | 90 |
| 7 | 235.352 | -2.2185 | -6.5142 | 171.2639 | 99.1732 | 90 |
| 8 | 239.44 | -3.9794 | -6.5142 | 171.2639 | 99.1732 | 90 |
| 9 | 240.316 | -7.4215 | 41.4581 | 51.4188 | 106.3995 | 90 |
| 10 | 289.6275 | -7.1215 | -49.2149 | 62.9864 | 94.4761 | 90 |
| 11 | 299.7745 | -10.7215 | 46.1367 | -41.2744 | 107.4834 | 90 |
| 12 | 340.764 | -11.1215 | -70.697 | 42.5606 | 92.3083 | 90 |
| 13 | 448.4025 | -5.1215 | -43.1524 | 64.6538 | 104.5929 | 90 |
| 14 | 477.5295 | -6.8215 | -49.0831 | -62.7423 | 105.1951 | 90 |
| 15 | 792.196 | -8.7215 | -58.4403 | 78.6184 | 91.7061 | 90 |
| 16 | 989.3325 | -13.2215 | 60.9633 | 25.6781 | 105.1951 | 90 |
| 17 | 1554.4985 | -13.9215 | 58.6569 | -23.4063 | 93.9944 | 90 |
| 18 | 1679.1095 | -13.9215 | 51.8037 | -2.3553 | 91.8265 | 90 |
| 19 | 2003.923 | -15.8215 | -73.86 | -20.5926 | 90.7426 | 90 |
| 20 | 2046.8105 | -17.1215 | 54.0442 | 3.7933 | 108.2061 | 90 |
| 21 | 2301.8725 | -16.0215 | 54.7691 | -0.4794 | 91.7061 | 90 |
| 22 | 2422.651 | -15.7215 | 63.5332 | -5.5859 | 91.5856 | 90 |
| 23 | 2570.5855 | -21.6215 | 72.0338 | -29.1381 | 106.3995 | 90 |
| 24 | 3158.0895 | -22.8215 | -88.2912 | 28.7003 | 109.5309 | 90 |
| Per-Cluster Parameters | | | | | | |
| Parameter | CASD in [°] | CASA in [°] | CZSD in [°] | CZSA in [°] | XPR in [dB] |  |
| Value | 1.3179 | 15.632 | 3.6131 | 0 | 7 |  |

# C.2 FR1 Base Station beam configuration

The emulated BS beam configuration to be used for all emulation of channel models defined in Annex C.1 is specified in this clause.

The Base Station beam configuration includes basic antenna parameters and beamforming characteristic. The basic BS antenna parameters is defined in Table C.2-1.

Table C.2-1: BS Antenna Parameters

|  |  |  |  |
| --- | --- | --- | --- |
| Parameter description | Symbol | Parameter value | |
| FR1 ≤ 2.5GHz | FR1 > 2.5GHz |
| Antenna panels in vertical dimension | *Mg* | 1 | 1 |
| Antenna panels in horizontal dimension | *Ng* | 1 | 1 |
| Elements per panel in vertical dimension | *Me* | 4 | 8 |
| Elements per panel in horizontal dimension | *Ne* | 8 | 8 |
| Number of polarizations per panel | *P* | 2 | 2 |
| Element spacing in horizontal dimension (λ) | *dH* | 0.5 | 0.5 |
| Element spacing in vertical dimension (λ) | *dV* | 0.5 | 0.5 |

Antenna element radiation patterns, including orientation of the element main polarization components as well as orientation of the antenna array are as in the example pattern in Table 7.3-1 of 3GPP TR 38.901 [5]. The antenna element has ±45 polarization components and the radiation pattern parameters are 3dB = 65, 3dB = 65, Amax = 30dB,SLAv = 30dB, *GE,max* =8 dBi.

The beamforming characteristic of the FR1 BS pattern is defined as follow:

- A code book of 60 fixed beams is constructed to a grid of five elevation angles from -20° to +20° with 10° steps and 12 azimuth angles from -80° to +80° with ~15° steps.

- For 4x4 MIMO OTA, two strongest transmitting beams are selected from the pre-defined beam grid based on their proximity to the strong clusters of each FR1 channel model. These beams should have different azimuth directions and can provide the highest receive power for UE.

- For 2x2 MIMO OTA, 1 strongest transmitting beam is selected from the pre-defined beam grid which provides the highest received power for UE based on the FR1 channel model.

- Beam directions for channels model given in clause C.1 are:

- For UMa CDL-C, the beam directions are:

- Strongest beam: AoD: -7.27°, ZoD: 100°

- 2nd strongest beam: AoD: -21.82°, ZoD: 100°

- For UMi CDL-C, the strongest beam direction is: AoD: -7.27°, ZoD: 100°.

# C.3 FR1 Channel model validation

## C.3.1 General

This clause describes the MIMO OTA validation measurements, in order to ensure that the channel models are correctly implemented and hence capable of generating the propagation environment, as described by the model, within the test zone.

The following measurements shall be done for FR1 channel model validation:

- Power Delay Profile (PDP).

- Doppler/Temporal correlation.

- Spatial correlation.

- Cross-polarization.

- Power validation.

Frequencies to be used to test for channel model validation.

Table C.3.1-1: Frequencies for PDP, Doppler, Spatial correlation and  
Cross-polarization validation

|  |  |  |
| --- | --- | --- |
| NR FR1 Bands | Range | Test frequency (MHz) |
| n71 | Low | 617 MHz |
| n12, n17, n29, n14, n28 | 722 MHz |
| n5, n8, n18, n20 | 836.5 MHz |
| n50, n51, n74 | Mid | 1575.42 MHz |
| n3, n2, n25, n39 | 1880 MHz |
| n1, n34, n65 | 2132.5 MHz |
| n7, n30, n41, n40, n38, [n90] | 2450 MHz |
| n77,n78 | High | 3600 MHz |
| n79 | [4700 MHz] |

Table C.3.1-2: Frequencies for Power validation

|  |  |  |
| --- | --- | --- |
| NR FR1 Bands | Range | Test frequency (centre frequency of each band) |
| n71 | Low | n71 |
| n12, n17, n29, n14, n28 | n28 |
| n5, n8, n18, n20 | n8 |
| n50, n51, n74 | Mid | n51 |
| n3, n2, n25, n39 | n3 |
| n1, n34, n65 | n1 |
| n7, n30, n41, n40, n38, [n90] | n41 |
| n77, n78 | High | n78 |
| n79 | n79 |

## C.3.2 Power Delay Profile (PDP)

This measurement checks that the resulting power delay profile (PDP) is in-line with the PDP defined for the channel model. For PDP validation measurement, only Vertical validation is required.

The PDP measurement is performed with a Vector Network Analyser (VNA). An example setup for PDP measurement is shown in Figure C.3.2-1. VNA transmits frequency sweep signals thorough the NR MIMO OTA test system. A reference antenna (i.e. dipole antenna), within the centre of the test zone, receives the signal and VNA analyses the frequency response of the system. A number of traces (frequency responses) are measured and recorded by VNA and analysed by a post processing SW, e.g. Matlab. Special care has to be taken into account to keep the fading conditions unchanged, i.e. frozen, during the short period of time of a single trace measurement. The fading may proceed only in between traces.

Shape

Description automatically generated with medium confidence

Figure C.3.2-1: Setup for PDP measurements

Step the emulation and store traces from VNA, i.e. run the emulation to CIR number 1, pause, measure VNA trace, run the emulation to CIR number 10, pause, measure VNA trace. Continue until 1000 VNA traces are measured.

VNA settings for PDP measurements are presented in Table C.3.2-1.

Table C.3.2-1: VNA settings for PDP measurements

|  |  |  |
| --- | --- | --- |
| Item | Unit | Value |
| Centre frequency | MHz | Downlink centre frequency  in Table C.3.1-1 |
| Span | MHz | 200 |
| Number of traces |  | 1000 |
| Number of points |  | 1101 |
| Averaging |  | 1 |

Channel model specification for PDP measurements is presented in Table C.3.2-2.

Table C.3.2-2: Channel model specification for PDP measurements

| Item | Unit | Value |
| --- | --- | --- |
| Centre frequency | MHz | Downlink centre frequency  in Table C.3.1-1 |
| Distance between traces in channel model | wavelength (note) | > 2 |
| Channel model |  | As specified in clause C.1 |
| NOTE: Time [s] = distance [λ] / MS speed [λ/s].  MS speed [λ/s] = MS speed [m/s] / Speed of light [m/s] \* Centre frequency [Hz]. | | |

**Method of measurement result analysis:**

Measured VNA traces (frequency responses H(t,f)) are saved into a hard drive. The data is read into, e.g. Matlab.   
The analysis is performed by taking the Fourier transform of each FR. The resulting impulse responses h(t,) are averaged in power over time:



Finally the resulting PDP is shifted in delay, such that the first tap is on delay zero.

**Beam-Specific Block Diagram**

It is assumed that the beams are mapped to the inputs of the channel emulator as follows:

- Beam 1: Input 1 and Input 2.

- Beam 2: Input 3 and Input 4 (CDL-C UMa only).

Shape

Description automatically generated with medium confidence

Figure C.3.2-2: Setup for Beam-Specific PDP measurements (Beam 1)

Shape

Description automatically generated with medium confidence

Figure C.3.2-3: Setup for Beam-Specific PDP measurements (Beam 2 CDL-C UMa only)

The detailed PDP reference value for CDL-C UMa and CDL-C UMi validation are defined in the following tables:

Table C.3.2-3: PDP Targets for CDL-C UMa beam 1 at ≤ 2.5 GHz

|  |  |  |
| --- | --- | --- |
| Combined Clusters index | Delay(ns) | Power(dB) |
| 1 | 0 | -34.3 |
| 2-5 | 80 | -19.5 |
| 6-8 | 235 | 0 |
| 9-10 | 290 | -33.0 |
| 11 | 450 | -35.8 |
| 12 | 480 | -34.0 |

Table C.3.2-4: PDP Targets for CDL-C UMa beam 2 at ≤ 2.5 GHz

|  |  |  |
| --- | --- | --- |
| Combined Clusters index | Delay(ns) | Power(dB) |
| 1 | 0 | -27.9 |
| 2-5 | 80 | 0 |
| 6-8 | 235 | -18.4 |
| 9-10 | 290 | -27.8 |
| 11 | 450 | -27.9 |
| 12 | 480 | -28.0 |

Table C.3.2-5: PDP Targets for CDL-C UMa beam 1 at > 2.5 GHz

|  |  |  |
| --- | --- | --- |
| Combined Clusters index | Delay(ns) | Power(dB) |
| 1 | 0 | -34.2 |
| 2-5 | 80 | -19.3 |
| 6-8 | 235 | 0 |
| 9 | 290 | -34.7 |
| 10 | 450 | -35.8 |
| 11 | 480 | -34.7 |

Table C.3.2-6: PDP Targets for CDL-C UMa beam 2 at > 2.5 GHz

|  |  |  |
| --- | --- | --- |
| Combined Clusters index | delay(ns) | power(dB) |
| 1 | 0 | -27.8 |
| 2-5 | 80 | 0 |
| 6-8 | 235 | -18.3 |
| 9-10 | 290 | -28.9 |
| 11 | 450 | -28.1 |
| 12 | 480 | -28.8 |

Table C.3.2-7: PDP Targets for CDL-C UMi at ≤ 2.5 GHz and > 2.5 GHz

|  |  |  |
| --- | --- | --- |
| Combined Clusters index | Delay(ns) | Power(dB) |
| 1 | 0 | -30.7 |
| 2-5 | 20 | -19.2 |
| 6-10 | 65 | 0 |
| 11-12 | 130 | -31.4 |

## C.3.3 Doppler/Temporal correlation

This measurement checks the Doppler/temporal correlation. For Doppler/Temporal correlation validation measurement, only Vertical validation is required.

The Doppler spectrum is measured with a spectrum analyser as shown in Figure C.3.3-1. In this case a signal generator transmits CW signal through the NR MIMO OTA test system. The signal is received by a test antenna within the test area. Finally, the signal is analysed by a spectrum analyser and the measured spectrum is compared to the target spectrum. This setup can be used to measure Doppler Spectrum of the Channel models defined in clause C.1.

**Method of measurement:**

A picture containing shape

Description automatically generated

Figure C.3.3-1: Setup for Doppler measurements

Sine wave (CW, carrier wave) signal is transmitted from the signal generator. The signal is connected from the signal generator to fading emulator via cables. The fading emulator output signals are connected to power amplifier boxes via cables. The amplified signals are then transferred via cables to the probe antennas. The probe antennas radiate the signals over the air to the test antenna. The Doppler spectrum is measured by the spectrum analyser and the trace is saved.

Signal generator settings for Doppler/Temporal correlation measurements are presented in Table C.3.3-1.

Table C.3.3-1: Signal generator settings for Doppler/Temporal correlation measurements

| Item | Unit | Value |
| --- | --- | --- |
| Centre frequency | MHz | Downlink centre frequency in Table C.3.1-1 |
| Modulation |  | OFF |

Spectrum analyser settings for Doppler/Temporal correlation measurements are presented in Table C.3.3-2.

Table C.3.3-2: Spectrum analyser settings for Doppler/Temporal correlation measurements

| Item | Unit | Value |
| --- | --- | --- |
| Centre frequency | MHz | Downlink centre frequency in Table C.3.1-1 |
| Minimum Span | Hz | 4 kHz |
| RBW | Hz | 1 |
| VBW | Hz | 1 |
| Number of points |  | 16002 |
| Averaging |  | 100 |

Channel model specification for Doppler/Temporal correlation measurements is presented in Table C.3.3-3.

Table C.3.3-3: Channel model specification for Doppler/Temporal correlation measurements

| Item | Unit | Value |
| --- | --- | --- |
| Centre frequency | MHz | Downlink centre frequency in Table C.3.1-1 |
| Channel model |  | As specified in clause C.1 |
| Mobile speed | km/h | 100 |

Method of measurement result analysis: Measurement data file (Doppler power spectrum) is saved into hard drive. The data is read into, e.g. Matlab. The analysis is performed by taking the Fourier transformation of the Doppler spectrum. The resulting temporal correlation function Rt(∆*t*) is normalized such that max(abs(*Rt*(∆*t*)))=1. Then the function values left from the maximum i.e. the negative lags are cut out. Further on the function values after five periods are cut out.

**Time Domain Alternate Method**

Time domain techniques can also be used to validate the temporal correlation. The temporal correlation validation measurement setup is illustrated in Figure C.3.3-2. In this case a Signal generator transmits a CW signal through the MIMO test system. The signal is received by a test antenna within the test area. Finally, the signal is collected by a signal analyser and the measured signal is stored as IQ data format for postprocessing.

A screenshot of a computer

Description automatically generated with medium confidence

Figure C.3.3-2: Setup for Doppler measurements based on time domain technique

The time domain doppler spectrum is measured by the signal analyser and the trace in IQ format is saved. Follow the same procedure to post process the data and calculate the temporal correlation curve. Data recording is synchronized with the channel emulator trigger.

The settings for the signal analyser are in Table C.3.3-4.

Table C.3.3-4: Signal Analyser Settings

|  |  |  |
| --- | --- | --- |
| Item | Unit | Value |
| Centre frequency | MHz | Downlink centre frequency in Table C.3.1-1 |
| Sampling | Hz | At least 15 times bigger than the max Doppler spread (*fd=v/λ)* |
| Observation time | s | At least 16 s.  Channel Model length should be the same or greater than the observation time |

Beam-Specific Block Diagram

It is assumed that the beams are mapped to the inputs of the channel emulator as follows:

- Beam 1: Input 1 and Input 2.

- Beam 2: Input 3 and Input 4 (CDL-C UMa only).

Shape

Description automatically generated with medium confidence

Figure C.3.3-3: Setup for Beam-Specific Doppler measurements (Beam 1)

Shape

Description automatically generated with medium confidence

Figure C.3.3-4: Setup for Beam-Specific Doppler measurements (Beam 2 CDL-C UMa only)

The detailed Temporal correlation reference value for CDL-C UMa and CDL-C UMi channel model validation is defined is Table C.3.3-5.

Table C.3.3-5: Autocorrelation Targets

| Lambda Separation | CDL-C UMa beam 1 at  ≤ 2.5 GHz | CDL-C UMa beam 2 at ≤ 2.5 GHz | CDL-C UMa beam 1 at > 2.5 GHz | CDL-C UMa beam 2 at > 2.5 GHz | CDL-C UMi beam 1 at  ≤ 2.5 GHz | CDL-C UMi beam 1 at > 2.5 GHz |
| --- | --- | --- | --- | --- | --- | --- |
| 0.0 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 |
| 0.1 | 0.986 | 0.974 | 0.985 | 0.973 | 0.995 | 0.995 |
| 0.2 | 0.945 | 0.907 | 0.942 | 0.904 | 0.982 | 0.982 |
| 0.3 | 0.882 | 0.832 | 0.874 | 0.825 | 0.962 | 0.961 |
| 0.4 | 0.801 | 0.776 | 0.787 | 0.765 | 0.936 | 0.935 |
| 0.5 | 0.709 | 0.738 | 0.689 | 0.723 | 0.906 | 0.905 |
| 0.6 | 0.613 | 0.695 | 0.586 | 0.675 | 0.872 | 0.871 |
| 0.7 | 0.518 | 0.623 | 0.486 | 0.599 | 0.834 | 0.834 |
| 0.8 | 0.430 | 0.525 | 0.394 | 0.496 | 0.793 | 0.793 |
| 0.9 | 0.353 | 0.426 | 0.315 | 0.391 | 0.750 | 0.749 |
| 1.0 | 0.289 | 0.360 | 0.252 | 0.319 | 0.705 | 0.704 |
| 1.1 | 0.240 | 0.335 | 0.206 | 0.290 | 0.659 | 0.658 |
| 1.2 | 0.204 | 0.320 | 0.174 | 0.273 | 0.614 | 0.612 |
| 1.3 | 0.181 | 0.287 | 0.154 | 0.239 | 0.569 | 0.568 |
| 1.4 | 0.167 | 0.233 | 0.143 | 0.185 | 0.527 | 0.525 |
| 1.5 | 0.159 | 0.176 | 0.137 | 0.129 | 0.487 | 0.485 |
| 1.6 | 0.155 | 0.141 | 0.135 | 0.096 | 0.450 | 0.448 |
| 1.7 | 0.153 | 0.135 | 0.134 | 0.092 | 0.417 | 0.415 |
| 1.8 | 0.150 | 0.137 | 0.134 | 0.095 | 0.387 | 0.385 |
| 1.9 | 0.144 | 0.132 | 0.130 | 0.093 | 0.361 | 0.358 |
| 2.0 | 0.135 | 0.117 | 0.122 | 0.089 | 0.337 | 0.335 |
| 2.1 | 0.121 | 0.097 | 0.109 | 0.086 | 0.316 | 0.313 |
| 2.2 | 0.105 | 0.076 | 0.090 | 0.076 | 0.296 | 0.293 |
| 2.3 | 0.085 | 0.062 | 0.069 | 0.064 | 0.277 | 0.274 |
| 2.4 | 0.065 | 0.071 | 0.047 | 0.067 | 0.258 | 0.255 |
| 2.5 | 0.048 | 0.090 | 0.031 | 0.088 | 0.239 | 0.236 |
| 2.6 | 0.039 | 0.099 | 0.033 | 0.103 | 0.219 | 0.216 |
| 2.7 | 0.038 | 0.088 | 0.046 | 0.099 | 0.198 | 0.195 |
| 2.8 | 0.042 | 0.058 | 0.057 | 0.073 | 0.178 | 0.175 |
| 2.9 | 0.043 | 0.037 | 0.062 | 0.038 | 0.158 | 0.154 |
| 3.0 | 0.041 | 0.067 | 0.060 | 0.045 | 0.138 | 0.135 |
| 3.1 | 0.037 | 0.103 | 0.050 | 0.080 | 0.120 | 0.116 |
| 3.2 | 0.036 | 0.120 | 0.036 | 0.100 | 0.103 | 0.100 |
| 3.3 | 0.044 | 0.115 | 0.019 | 0.099 | 0.089 | 0.085 |
| 3.4 | 0.056 | 0.097 | 0.010 | 0.081 | 0.076 | 0.073 |
| 3.5 | 0.068 | 0.082 | 0.019 | 0.061 | 0.066 | 0.063 |
| 3.6 | 0.075 | 0.083 | 0.029 | 0.053 | 0.057 | 0.055 |
| 3.7 | 0.076 | 0.090 | 0.034 | 0.060 | 0.051 | 0.049 |
| 3.8 | 0.068 | 0.089 | 0.036 | 0.073 | 0.046 | 0.044 |
| 3.9 | 0.051 | 0.079 | 0.044 | 0.091 | 0.042 | 0.041 |
| 4.0 | 0.027 | 0.068 | 0.062 | 0.111 | 0.039 | 0.038 |
| 4.1 | 0.007 | 0.063 | 0.090 | 0.127 | 0.037 | 0.035 |
| 4.2 | 0.036 | 0.062 | 0.123 | 0.133 | 0.036 | 0.034 |
| 4.3 | 0.067 | 0.057 | 0.155 | 0.129 | 0.038 | 0.036 |
| 4.4 | 0.093 | 0.052 | 0.182 | 0.126 | 0.043 | 0.040 |
| 4.5 | 0.111 | 0.055 | 0.200 | 0.131 | 0.051 | 0.048 |
| 4.6 | 0.119 | 0.063 | 0.207 | 0.139 | 0.061 | 0.058 |
| 4.7 | 0.116 | 0.066 | 0.200 | 0.138 | 0.073 | 0.070 |
| 4.8 | 0.101 | 0.058 | 0.180 | 0.117 | 0.085 | 0.082 |
| 4.9 | 0.078 | 0.047 | 0.149 | 0.079 | 0.096 | 0.093 |
| 5.0 | 0.051 | 0.048 | 0.110 | 0.034 | 0.107 | 0.104 |

## C.3.4 Spatial correlation

This measurement checks whether the measured correlation curve follows the theoretical curve. For spatial correlation validation measurement, only Vertical validation measurement is required. Spatial correlation validation is only adopted for FR1 MIMO OTA.

The spatial correlation validation measurement setup is illustrated in Figure C.3.4-1. The network analyser transmits signals through the fading emulator and probes. The 16 probes radiate the signals within the anechoic chamber and a receiving test antenna is placed within the test zone. The test antenna is attached to a positioner that can move the antenna to pre-defined spatial locations on a fixed radius from the centre of the quiet zone. The received signal is measured with the network analyser.

The measurement and analysis procedure are as follows:

Set the target channel model to fading emulator:

1) For each position of the test antenna in the test zone, step & pause the emulator to different time instances. Measure the frequency responses for all stepped channel snapshots , where the interval between frequency and time samples is and , respectively. The number of channel snapshots and frequency samples should be sufficiently high so that the matrix can be estimated reliably.



2) Move the measurement antenna with a positioner to another location and repeat step 2 to record frequency responses of all stepped channel snapshots.



3) Repeat step 3 to record frequency responses at all spatial sample points.



4) Stack measured time and frequency samples to a vector and calculate correlation between the first spatial sample point (i.e. ) and other spatial points .



5) .



6) Take the theoretical reference spatial correlation of the corresponding spatial sample points. Plot both the measured and theoretical curves.

7) Calculate the weighted RMS correlation error between the measured and the reference.

Diagram

Description automatically generated

Figure C.3.4-1: Configuration for spatial correlation validation

Beam-Specific Block Diagram

It is assumed that the beams are mapped to the inputs of the channel emulator as follows:

- Beam 1: Input 1 and Input 2.

- Beam 2: Input 3 and Input 4 (CDL-C UMa only).

Shape

Description automatically generated with medium confidence

Figure C.3.4-2: Configuration for spatial correlation validation (CDL-C UMi)

Shape

Description automatically generated with medium confidence

Figure C.3.4-3: Configuration for spatial correlation validation (CDL-C UMa)

Time and frequency samples

The number of temporal snapshots *N* and frequency samples *M* is shown in Table C.3.4-1. The channel model specification is presented in Table C.3.4-2.

Table C.3.4-1: VNA settings for spatial correlation

|  |  |  |
| --- | --- | --- |
| Item | Unit | Value |
| Center frequency | MHz | Downlink centre frequency  in Table C.3.1-1 |
| Span | MHz | 0 (see note 2) |
| RF output level | dBm | -15 |
| Number of traces |  | 1000 |
| Distance between traces in channel model | Wavelength (see note 1) | > 2 |
| Number of points |  | 1 (or the smallest possible)  (see note 2) |
| Averaging |  | 1 |
| NOTE1: Time in seconds = distance [] / MS speed [/s].  MS speed [/s] = MS speed [m /s] / Speed of light [m/s] \* Center frequency [Hz].  NOTE 2: Span and number of points may be increased to estimate reliably. | | |

Table C.3.4-2: Channel model specification

|  |  |  |
| --- | --- | --- |
| Item | Unit | Value |
| Center frequency | MHz | Downlink centre frequency  in Table C.3.1-1 |
| Channel model samples | Wavelength | > 2000 |
| Channel model |  | As specified in clause C.1 |
| Mobile speed | km/h | 30 |

Spatial samples

The spatial samples for the correlation validation measurement are on the circumference of the quiet zone, as illustrated in Figure C.3.4-4. The test zone is a circle with 20 cm diameter in the horizontal plane. The reference point (denoted by a red marker) is in AoA 270°. The mean AoAs of the CDL-C UMi and CDL-C UMa models are slightly different, but the underlying geometry for the CDL model indicates that the mean AoA (or assumed LoS direction) of the model is 180°. The reference point orientation of the validation measurement is proposed to be with 90° offset to the channel model reference AoA to enable accurate sampling of the main lobe of the spatial correlation curve. The reference point orientation has to be defined in the channel model coordinate system instead of the chamber/probe coordinate system to enable optimization of OTA model implementation to achieve better alignment with the cluster AoAs and probe directions. In order to have spatial samples that yield reasonable measurement times and adequately capture the main lobe of the correlation curve, a non-uniform sampling is used where the first quadrant i.e. 270°-180°, is sampled with dense sampling compared to the rest of the circle. The spacing of the spatial samples is summarized in Table C.3.4-3 for test frequencies less than 1800 MHz and equal to or greater than 1800 MHz.

Table C.3.4-3: Spacing of Spatial Samples

| Test Frequencies [MHz] | First quadrant of test zone circumference (270o-180o) | Remaining quadrants |
| --- | --- | --- |
| 617, 722, 836.5 1575.42 | /15 | /4 |
| 1800, 2132.50, 2450, 3600, 4700 | /10 | /2 |

A red moon in a black sky

Description automatically generated with medium confidence

Figure C.3.4-4: Test zone interpretation with Angle of Arrival reference orientation



Figure C.3.4-5: Spatial sampling for spatial correlation validation measurement for  
test frequencies less than and equal to or greater than 1800 MHz:  
617 MHz spatial sampling (left) and 4700 MHz spatial sampling (right)

Reference Spatial Correlation Curves

The spatial correlation validation reference curves are tabulated in Tables C.3.4-4 and C.3.4-5 for CDL-C UMi and CDL-C UMa, respectively, for a vertically polarized MPAC OTA setup with 16 uniformly spaced probes.

Table C.3.4-4: Spatial correlation reference curves for CDL-C UMi model for  
a vertically polarized MPAC OTA setup with 16 uniformly spaced probes at FR1 test frequencies

| Azim [] | || beam 1 | Azim [] | || beam 1 | Azim [] | || beam 1 | Azim [] | || beam 1 | Azim [] | || beam 1 |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 617 MHz | | 722 MHz | | 836.5 MHz | | 1575.42 MHz | | 1800 MHz | |
| 270.0 | 1.00 | 270.0 | 1.00 | 270.0 | 1.00 | 270.0 | 1.00 | 270.0 | 1.00 |
| 251.4 | 1.00 | 254.1 | 1.00 | 256.3 | 1.00 | 262.7 | 1.00 | 260.9 | 1.00 |
| 232.9 | 1.00 | 238.3 | 1.00 | 242.6 | 1.00 | 255.5 | 1.00 | 251.7 | 1.00 |
| 214.3 | 0.99 | 222.4 | 1.00 | 228.9 | 1.00 | 248.2 | 1.00 | 242.6 | 0.99 |
| 195.8 | 0.99 | 206.6 | 0.99 | 215.2 | 0.99 | 240.9 | 0.99 | 233.5 | 0.99 |
| 110.4 | 0.87 | 190.7 | 0.98 | 201.6 | 0.98 | 233.7 | 0.99 | 224.3 | 0.98 |
| 40.8 | 0.87 | 120.5 | 0.84 | 187.9 | 0.96 | 226.4 | 0.99 | 215.2 | 0.97 |
| 331.2 | 0.98 | 61.1 | 0.80 | 128.7 | 0.82 | 219.1 | 0.98 | 206.0 | 0.95 |
|  |  | 1.6 | 0.91 | 77.3 | 0.73 | 211.9 | 0.97 | 196.9 | 0.92 |
|  |  | 302.1 | 0.99 | 26.0 | 0.81 | 204.6 | 0.96 | 187.8 | 0.87 |
|  |  |  |  | 334.7 | 0.95 | 197.3 | 0.94 | 134.3 | 0.39 |
|  |  |  |  | 283.3 | 1.00 | 190.0 | 0.91 | 88.6 | 0.15 |
|  |  |  |  |  |  | 182.8 | 0.87 | 43.0 | 0.24 |
|  |  |  |  |  |  | 152.7 | 0.66 | 357.3 | 0.62 |
|  |  |  |  |  |  | 125.5 | 0.44 | 311.6 | 0.94 |
|  |  |  |  |  |  | 98.2 | 0.30 |  |  |
|  |  |  |  |  |  | 71.0 | 0.28 |  |  |
|  |  |  |  |  |  | 43.7 | 0.37 |  |  |
|  |  |  |  |  |  | 16.5 | 0.54 |  |  |
|  |  |  |  |  |  | 349.2 | 0.75 |  |  |
|  |  |  |  |  |  | 321.9 | 0.91 |  |  |
|  |  |  |  |  |  | 294.7 | 0.99 |  |  |

| Azim [] | || beam 1 | Azim [] | || beam 1 | Azim [] | || beam 1 | Azim [] | || beam 1 |
| --- | --- | --- | --- | --- | --- | --- | --- |
| 2132.5 MHz | | 2450 MHz | | 3600 MHz | | 4700 MHz | |
| 270.0 | 1.00 | 270.0 | 1.00 | 270.0 | 1.00 | 270.0 | 1.00 |
| 261.9 | 1.00 | 263.0 | 1.00 | 265.2 | 1.00 | 266.3 | 1.00 |
| 253.9 | 1.00 | 256.0 | 1.00 | 260.5 | 1.00 | 262.7 | 1.00 |
| 245.8 | 0.99 | 249.0 | 0.99 | 255.7 | 0.99 | 259.0 | 0.99 |
| 237.8 | 0.99 | 242.0 | 0.99 | 250.9 | 0.99 | 255.4 | 0.99 |
| 229.7 | 0.98 | 234.9 | 0.99 | 246.1 | 0.99 | 251.7 | 0.99 |
| 221.7 | 0.97 | 227.9 | 0.98 | 241.4 | 0.98 | 248.1 | 0.98 |
| 213.6 | 0.96 | 220.9 | 0.97 | 236.6 | 0.98 | 244.4 | 0.98 |
| 205.6 | 0.93 | 213.9 | 0.95 | 231.8 | 0.97 | 240.8 | 0.98 |
| 197.5 | 0.89 | 206.9 | 0.92 | 227.1 | 0.97 | 237.1 | 0.97 |
| 189.5 | 0.84 | 199.9 | 0.88 | 222.3 | 0.95 | 233.5 | 0.97 |
| 181.4 | 0.77 | 192.9 | 0.83 | 217.5 | 0.93 | 229.8 | 0.96 |
| 139.7 | 0.27 | 185.9 | 0.76 | 212.7 | 0.90 | 226.1 | 0.95 |
| 99.5 | 0.14 | 144.9 | 0.19 | 208.0 | 0.86 | 222.5 | 0.93 |
| 59.2 | 0.14 | 109.9 | 0.26 | 203.2 | 0.81 | 218.8 | 0.91 |
| 18.9 | 0.26 | 74.8 | 0.37 | 198.4 | 0.75 | 215.2 | 0.87 |
| 338.6 | 0.71 | 39.8 | 0.19 | 193.7 | 0.68 | 211.5 | 0.83 |
| 298.4 | 0.97 | 4.7 | 0.29 | 188.9 | 0.59 | 207.9 | 0.78 |
|  |  | 329.7 | 0.74 | 184.1 | 0.49 | 204.2 | 0.72 |
|  |  | 294.6 | 0.97 | 156.1 | 0.23 | 200.6 | 0.64 |
|  |  |  |  | 132.3 | 0.62 | 196.9 | 0.56 |
|  |  |  |  | 108.4 | 0.85 | 193.3 | 0.47 |
|  |  |  |  | 84.6 | 0.93 | 189.6 | 0.37 |
|  |  |  |  | 60.7 | 0.92 | 185.9 | 0.27 |
|  |  |  |  | 36.9 | 0.79 | 182.3 | 0.18 |
|  |  |  |  | 13.0 | 0.42 | 161.7 | 0.51 |
|  |  |  |  | 349.1 | 0.15 | 143.5 | 0.83 |
|  |  |  |  | 325.3 | 0.60 | 125.2 | 0.95 |
|  |  |  |  | 301.4 | 0.90 | 106.9 | 0.89 |
|  |  |  |  | 277.6 | 1.00 | 88.6 | 0.80 |
|  |  |  |  |  |  | 70.4 | 0.78 |
|  |  |  |  |  |  | 52.1 | 0.88 |
|  |  |  |  |  |  | 33.8 | 0.98 |
|  |  |  |  |  |  | 15.5 | 0.91 |
|  |  |  |  |  |  | 357.3 | 0.53 |
|  |  |  |  |  |  | 339.0 | 0.09 |
|  |  |  |  |  |  | 320.7 | 0.50 |
|  |  |  |  |  |  | 302.4 | 0.82 |
|  |  |  |  |  |  | 284.2 | 0.97 |

Table C.3.4-5: Spatial correlation reference curves for CDL-C UMa model for a vertically polarized MPAC OTA setup with 16 uniformly spaced probes at FR1 test frequencies

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Azim [] | || comb | Azim [] | || comb | Azim [] | || comb | Azim [] | || comb | Azim [] | || comb |
| 617 MHz | | 722 MHz | | 836.5 MHz | | 1575.42 MHz | | 1800 MHz | |
| 270.0 | 1.00 | 270.0 | 1.00 | 270.0 | 1.00 | 270.0 | 1.00 | 270.0 | 1.00 |
| 251.4 | 0.99 | 254.1 | 0.99 | 256.3 | 0.99 | 262.7 | 0.99 | 260.9 | 0.99 |
| 232.9 | 0.99 | 238.3 | 0.98 | 242.6 | 0.98 | 255.5 | 0.98 | 251.7 | 0.96 |
| 214.3 | 0.98 | 222.4 | 0.97 | 228.9 | 0.97 | 248.2 | 0.96 | 242.6 | 0.93 |
| 195.8 | 0.96 | 206.6 | 0.96 | 215.2 | 0.96 | 240.9 | 0.94 | 233.5 | 0.90 |
| 110.4 | 0.61 | 190.7 | 0.94 | 201.6 | 0.95 | 233.7 | 0.92 | 224.3 | 0.89 |
| 40.8 | 0.47 | 120.5 | 0.58 | 187.9 | 0.92 | 226.4 | 0.91 | 215.2 | 0.88 |
| 331.2 | 0.85 | 61.1 | 0.30 | 128.7 | 0.56 | 219.1 | 0.90 | 206.0 | 0.87 |
|  |  | 1.6 | 0.56 | 77.3 | 0.19 | 211.9 | 0.89 | 196.9 | 0.84 |
|  |  | 302.1 | 0.95 | 26.0 | 0.27 | 204.6 | 0.88 | 187.8 | 0.79 |
|  |  |  |  | 334.7 | 0.70 | 197.3 | 0.87 | 134.3 | 0.16 |
|  |  |  |  | 283.3 | 0.99 | 190.0 | 0.84 | 88.6 | 0.30 |
|  |  |  |  |  |  | 182.8 | 0.79 | 43.0 | 0.22 |
|  |  |  |  |  |  | 152.7 | 0.42 | 357.3 | 0.36 |
|  |  |  |  |  |  | 125.5 | 0.13 | 311.6 | 0.57 |
|  |  |  |  |  |  | 98.2 | 0.30 |  |  |
|  |  |  |  |  |  | 71.0 | 0.31 |  |  |
|  |  |  |  |  |  | 43.7 | 0.29 |  |  |
|  |  |  |  |  |  | 16.5 | 0.33 |  |  |
|  |  |  |  |  |  | 349.2 | 0.29 |  |  |
|  |  |  |  |  |  | 321.9 | 0.48 |  |  |
|  |  |  |  |  |  | 294.7 | 0.88 |  |  |

| Azim [] | || comb | Azim [] | || comb | Azim [] | || comb | Azim [] | || comb |
| --- | --- | --- | --- | --- | --- | --- | --- |
| 2132.5 MHz | | 2450 MHz | | 3600 MHz | | 4700 MHz | |
| 270.0 | 1.00 | 270.0 | 1.00 | 270.0 | 1.00 | 270.0 | 1.00 |
| 261.9 | 0.99 | 263.0 | 0.99 | 265.2 | 0.98 | 266.3 | 0.98 |
| 253.9 | 0.95 | 256.0 | 0.95 | 260.5 | 0.95 | 262.7 | 0.94 |
| 245.8 | 0.92 | 249.0 | 0.91 | 255.7 | 0.90 | 259.0 | 0.89 |
| 237.8 | 0.89 | 242.0 | 0.87 | 250.9 | 0.84 | 255.4 | 0.83 |
| 229.7 | 0.86 | 234.9 | 0.85 | 246.1 | 0.80 | 251.7 | 0.78 |
| 221.7 | 0.85 | 227.9 | 0.83 | 241.4 | 0.77 | 248.1 | 0.73 |
| 213.6 | 0.85 | 220.9 | 0.82 | 236.6 | 0.75 | 244.4 | 0.70 |
| 205.6 | 0.83 | 213.9 | 0.82 | 231.8 | 0.73 | 240.8 | 0.68 |
| 197.5 | 0.80 | 206.9 | 0.80 | 227.1 | 0.72 | 237.1 | 0.66 |
| 189.5 | 0.75 | 199.9 | 0.77 | 222.3 | 0.71 | 233.5 | 0.65 |
| 181.4 | 0.67 | 192.9 | 0.73 | 217.5 | 0.70 | 229.8 | 0.64 |
| 139.7 | 0.22 | 185.9 | 0.66 | 212.7 | 0.69 | 226.1 | 0.63 |
| 99.5 | 0.24 | 144.9 | 0.26 | 208.0 | 0.67 | 222.5 | 0.62 |
| 59.2 | 0.03 | 109.9 | 0.23 | 203.2 | 0.64 | 218.8 | 0.61 |
| 18.9 | 0.16 | 74.8 | 0.19 | 198.4 | 0.61 | 215.2 | 0.60 |
| 338.6 | 0.37 | 39.8 | 0.13 | 193.7 | 0.56 | 211.5 | 0.59 |
| 298.4 | 0.73 | 4.7 | 0.15 | 188.9 | 0.49 | 207.9 | 0.57 |
|  |  | 329.7 | 0.38 | 184.1 | 0.41 | 204.2 | 0.55 |
|  |  | 294.6 | 0.74 | 156.1 | 0.42 | 200.6 | 0.52 |
|  |  |  |  | 132.3 | 0.19 | 196.9 | 0.48 |
|  |  |  |  | 108.4 | 0.64 | 193.3 | 0.42 |
|  |  |  |  | 84.6 | 0.47 | 189.6 | 0.35 |
|  |  |  |  | 60.7 | 0.44 | 185.9 | 0.26 |
|  |  |  |  | 36.9 | 0.28 | 182.3 | 0.18 |
|  |  |  |  | 13.0 | 0.16 | 161.7 | 0.59 |
|  |  |  |  | 349.1 | 0.16 | 143.5 | 0.26 |
|  |  |  |  | 325.3 | 0.41 | 125.2 | 0.79 |
|  |  |  |  | 301.4 | 0.40 | 106.9 | 0.43 |
|  |  |  |  | 277.6 | 0.95 | 88.6 | 0.68 |
|  |  |  |  |  |  | 70.4 | 0.63 |
|  |  |  |  |  |  | 52.1 | 0.75 |
|  |  |  |  |  |  | 33.8 | 0.87 |
|  |  |  |  |  |  | 15.5 | 0.67 |
|  |  |  |  |  |  | 357.3 | 0.09 |
|  |  |  |  |  |  | 339.0 | 0.25 |
|  |  |  |  |  |  | 320.7 | 0.32 |
|  |  |  |  |  |  | 302.4 | 0.42 |
|  |  |  |  |  |  | 284.2 | 0.73 |

Time Domain Alternative Method:

Time domain techniques can also be used to validate the spatial correlation. The spatial correlation validation measurement setup is illustrated in Figure C.3.4-3. In this case a Signal generator transmits a CW signal through the MIMO test system. The signal is received by a test antenna within the test area. Finally, the signal is collected by a signal analyser and the measured signal is stored for postprocessing.

Diagram

Description automatically generated

Figure C.3.4-6: Configuration for spatial correlation validation based on time domain techniques

For each spatial point, the channel emulator should issue a trigger signal each time fading is started. For each point collect a time domain trace with the signal analyser, when done, stop fading. Data recording is synchronized with the channel emulator trigger.

Follow the same procedure to postprocess the data and calculate the spatial correlation by setting *m* to 1. The settings for the Signal Generator and Signal Analyser are in Tables C.3.4-6 and C.3.4-7 respectively.

Table C.3.4-6: Signal Generator Settings

|  |  |  |
| --- | --- | --- |
| Item | Unit | Value |
| Centre frequency | MHz | Downlink centre frequency in Table C.3.1-1 |
| Output power | dBm | Function of the CE. Sufficiently above Noise Floor |

Table C.3.4-7: Signal Analyser Settings

|  |  |  |
| --- | --- | --- |
| Item | Unit | Value |
| Centre frequency | MHz | Downlink centre frequency in Table C.3.1-1 |
| Sampling | Hz | At least 15 times bigger than the max Doppler spread (*fd=v/λ)* |
| Observation time | s | At least 16 s. Channel Model length should be the same or greater than the observation time |

**Beam-Simultaneous Block Diagram**

It is assumed that the beams are mapped to the inputs of the channel emulator as follows:

- Beam 1: Input 1 and Input 2.

- Beam 2: Input 3 and Input 4 (CDL-C UMa only).

Shape

Description automatically generated with medium confidence

Figure C.3.4-7: Configuration for spatial correlation validation based on  
time domain techniques (CDL-C UMi)

Shape

Description automatically generated with medium confidence

Figure C.3.4-8: Configuration for spatial correlation validation based on  
time domain techniques (CDL-C UMa)

## C.3.5 Cross-polarization

This measurement checks how well the measured vertically or horizontally polarized power levels follow expected values. The test setup for cross-polarization is the same as PDP validation in Figure C.3.2-1.

**Method of measurement:** Step the emulation and store traces from VNA.

VNA settings for cross-polarization measurements are presented in Table C.3.5-1.

Table C.3.5-1: VNA settings for cross-polarization

| Item | Unit | Value |
| --- | --- | --- |
| Centre frequency | MHz | Downlink Centre Frequency in Table C.3.1-1 |
| Span | MHz | 40 |
| Number of traces |  | 1000 |
| Number of points |  | 802 |
| Averaging |  | 1 |

Channel model specification for cross-polarization measurements is presented in Table C.3.5-2.

Table C.3.5-2: Channel model specification for cross-polarization

|  |  |  |
| --- | --- | --- |
| Item | Unit | Value |
| Centre frequency | MHz | Downlink centre frequency in Table C.3.1-1 |
| Distance between traces in channel model | wavelength (see note 1) | > 2 |
| Channel model |  | As specified in clause C.1 |
| Mobile speed (see note 2) | km/h | 30 |
| NOTE 1: Time [s] = distance [λ] / MS speed [λ/s]. MS speed [λ/s] = MS speed [m /s] / Speed of light [m/s] \* Centre frequency [Hz].  NOTE 2: The mobile speed is valid for the Time Domain Alternative method only. | | |

**Measurement Procedure:**

Step the emulation and store traces from VNA. i.e. run the emulation to CIR number 1, pause, measure VNA trace, run the emulation to CIR number 10, pause, measure VNA trace. Continue until 1000 VNA traces are measured:

a. Use a vertically polarized sleeve dipole to measure the V component.

b. Use a horizontally polarized (vertically oriented) magnetic loop dipole, or a horizontally polarized sleeve dipole measured in four orthogonal horizontal positions and summed to measure the H component.

**Method of measurement result analysis:**

Measured VNA traces (frequency responses and are saved into a hard drive. The data is read into, e.g. Matlab. The frequency responses are averaged in power over time and frequency and the V/H ratio calculated as follows:

**Beam-Specific Block Diagram**

It is assumed that the beams are mapped to the inputs of the channel emulator as follows:

- Beam 1: Input 1 and Input 2

- Beam 2: Input 3 and Input 4 (CDL-C UMa only)

Shape

Description automatically generated with medium confidence

Figure C.3.5-1: Setup for Beam-Specific V/H measurements (Beam 1)

Shape

Description automatically generated with medium confidence

Figure C.3.5-2: Setup for Beam-Specific V/H measurements (Beam 2 CDL-C UMa only)

Time Domain Alternative Method:

The power in the Vertical and Horizontal polarizations can also be measured in time domain. The measurement setup for Beam-Specific are presented in Figures C.3.5-3, and C.3.5-4.

Shape

Description automatically generated with medium confidence

Figure C.3.5-3: Setup for Beam-Specific V/H measurements (Beam 1)

Shape

Description automatically generated with medium confidence

Figure C.3.5-4: Setup for Beam-Specific V/H measurements (Beam 2 CDL-C UMa only)

The instruments settings are the same as those in Tables C.3.4-6 and C.3.4-7. The measurement analysis is the same as that of the frequency domain method setting the summation over *f* to a single point.

The reference V/H-ratios for CDL-C UMa and CDL-C UMi channel model validation are defined in Tables C.3.5-3 and C.3.5-4, respectively.

Table C.3.5-3: Reference V/H-ratios for CDL-C UMa

|  |  |  |
| --- | --- | --- |
| UMa C, fc ≤ 2.5 GHz | Beam 1 | Input 1+2: V/H = 0 dB |
| Beam 2 | Input 3+4: V/H = 0 dB |
| UMa C, fc > 2.5 GHz | Beam 1 | Input 1+2: V/H = 0 dB |
| Beam 2 | Input 3+4: V/H = 0 dB |

Table C.3.5-4: Reference V/H-ratios for CDL-C UMi

|  |  |  |
| --- | --- | --- |
| UMi C, fc ≤ 2.5 GHz | Beam 1 | Inputs 1+2: V/H = 0 dB |
| UMi C, fc > 2.5 GHz | Beam 1 | Inputs 1+2: V/H = 0 dB |

## C.3.6 Power validation

This measurement checks the total power in the centre of the test zone. The power validation is measured with a spectrum analyser as shown in Figure C.3.6-1.

A picture containing shape

Description automatically generated

Figure C.3.6-1: Setup for power validation measurements

Table C.3.6-1: Spectrum analyser settings for power validation measurements

| Item | Unit | Value |
| --- | --- | --- |
| Centre frequency | MHz | Downlink centre frequency in Table C.3.1-2 |
| Integrated Channel Span | Hz | 40MHz |
| RBW | Hz | 30 kHz |
| VBW | Hz | ≥10MHz |
| Number of points |  | ≥400 |
| Averaging |  | ≥100 |
| Detector |  | RMS |

**Measurement Procedure:**

1) Place a vertical reference dipole in the centre of the test zone connected to a spectrum analyser (or power meter) via a cable.

2) Record the cable and reference dipole gains.

3) Load the target channel model into the channel emulator and play the model.

4) Start the NR FR1 signalling in the base station emulator with the required parameter identical to the measurements conditions.

5) Average the power received by the spectrum analyser for a sufficient amount of time to account for the fading channel - one full channel simulation might be unnecessary.

6) Repeat steps 1 to 4 with a magnetic loop for the horizontal polarization, or a horizontally polarized sleeve dipole measured in at least four orthogonal horizontal positions and average the summed orientations to get the H component.

7) Calculate the total power received at the test area as the sum of the power in the two polarizations.

NOTE: In step 6, if horizontally polarized sleeve dipole is used, the reference gain correction should be the average of the theta gain pattern cut of the dipole. Besides, more horizontal positions for averaging will improve the measurement accuracy but increase the total measurement time.

The power validation result is considered as systematic offset, which needs to be corrected on the UE final sensitivity value to further reduce measurement uncertainty.

The detailed power validation setup for CDL-C UMi and CDL-C UMa channel models are illustrated in Figure C.3.6‑2 and Figure C.3.6-3.

Shape

Description automatically generated with medium confidence

Figure C.3.6-2: Setup for power validation measurements for CDL-C UMi

Shape

Description automatically generated with medium confidence

Figure C.3.6-3: Setup for power validation measurements for CDL-C Uma

# C.4 Validation Pass/fail limit

## C.4.1 General

This clause defines the pass/fail limit of FR1 MPAC system for FR1 channel model validation.

## C.4.2 Pass/Fail Criteria of PDP

This clause defines the pass/fail criteria of PDP, this pass/fail limits apply for all FR1 frequency bands, for both combined and individual beams.

The detailed pass/fail limits for each cluster of CDL-C UMa and CDL-C UMi are defined in Table C.4.2-1.

Table C.4.2-1: PDP pass/fail limits for CDL-C UMa and CDL-C UMi channel model validation

|  |  |  |
| --- | --- | --- |
|  | Power Tolerance | Delay Tolerance |
| Paths from 0 dB to 10 dB | ±1 dB | ±6 ns |
| Paths from 10 dB to 20 dB | ±2.5 dB | ±6 ns |
| Paths from 20 dB to 30 dB | ±5 dB | ±6 ns |
| Paths from 30 dB to 40 dB | ±10 dB | ±6 ns |

## C.4.3 Pass/Fail Criteria of Doppler/Temporal correlation

This clause defines the pass/fail criteria of doppler/temporal correlation, this pass/fail limits apply for all channel models in all FR1 frequency bands, for both combined and individual beams.

The pass/fail limits for theoretical temporal correlation defined in clause C.3.3 above 0.3 are formed as bands of ±0.1 of correlation capped at 1 at the high end. Additionally, when the theoretical temporal correlation drops below 0.3, the limits are formed at bands of ±0.3 of correlation capped at 0 at the low end.

Table C.4.3-1: pass/fail limits for temporal correlation

| CDL-C UMa beam 1 at ≤ 2.5 GHz | | CDL-C UMa beam 2 at ≤ 2.5 GHz | | CDL-C UMa beam 1 at > 2.5 GHz | | CDL-C UMa beam 2 at > 2.5 GHz | | CDL-C UMi beam 1 at ≤ 2.5 GHz | | CDL-C UMi beam 1 at > 2.5 GHz | |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Lower | Upper | Lower | Upper | Lower | Upper | Lower | Upper | Lower | Upper | Lower | Upper |
| 0.9 | 1 | 0.9 | 1 | 0.9 | 1 | 0.9 | 1 | 0.9 | 1 | 0.9 | 1 |
| 0.886 | 1 | 0.874 | 1 | 0.885 | 1 | 0.873 | 1 | 0.895 | 1 | 0.895 | 1 |
| 0.845 | 1 | 0.807 | 1 | 0.842 | 1 | 0.804 | 1 | 0.882 | 1 | 0.882 | 1 |
| 0.782 | 0.982 | 0.732 | 0.932 | 0.774 | 0.974 | 0.725 | 0.925 | 0.862 | 1 | 0.861 | 1 |
| 0.701 | 0.901 | 0.676 | 0.876 | 0.687 | 0.887 | 0.665 | 0.865 | 0.836 | 1 | 0.835 | 1 |
| 0.609 | 0.809 | 0.638 | 0.838 | 0.589 | 0.789 | 0.623 | 0.823 | 0.806 | 1 | 0.805 | 1 |
| 0.513 | 0.713 | 0.595 | 0.795 | 0.486 | 0.686 | 0.575 | 0.775 | 0.772 | 0.972 | 0.771 | 0.971 |
| 0.418 | 0.618 | 0.523 | 0.723 | 0.386 | 0.586 | 0.499 | 0.699 | 0.734 | 0.934 | 0.734 | 0.934 |
| 0.33 | 0.53 | 0.425 | 0.625 | 0.294 | 0.494 | 0.396 | 0.596 | 0.693 | 0.893 | 0.693 | 0.893 |
| 0.253 | 0.453 | 0.326 | 0.526 | 0.215 | 0.415 | 0.291 | 0.491 | 0.65 | 0.85 | 0.649 | 0.849 |
| 0.189 | 0.389 | 0.26 | 0.46 | 0.152 | 0.352 | 0.219 | 0.419 | 0.605 | 0.805 | 0.604 | 0.804 |
| 0.14 | 0.34 | 0.235 | 0.435 | 0.106 | 0.306 | 0.19 | 0.39 | 0.559 | 0.759 | 0.558 | 0.758 |
| 0.104 | 0.304 | 0.22 | 0.42 | 0 | 0.3 | 0.173 | 0.373 | 0.514 | 0.714 | 0.512 | 0.712 |
| 0 | 0.3 | 0.187 | 0.387 | 0 | 0.3 | 0.139 | 0.339 | 0.469 | 0.669 | 0.468 | 0.668 |
| 0 | 0.3 | 0.133 | 0.333 | 0 | 0.3 | 0 | 0.3 | 0.427 | 0.627 | 0.425 | 0.625 |
| 0 | 0.3 | 0 | 0.3 | 0 | 0.3 | 0 | 0.3 | 0.387 | 0.587 | 0.385 | 0.585 |
| 0 | 0.3 | 0 | 0.3 | 0 | 0.3 | 0 | 0.3 | 0.35 | 0.55 | 0.348 | 0.548 |
| 0 | 0.3 | 0 | 0.3 | 0 | 0.3 | 0 | 0.3 | 0.317 | 0.517 | 0.315 | 0.515 |
| 0 | 0.3 | 0 | 0.3 | 0 | 0.3 | 0 | 0.3 | 0.287 | 0.487 | 0.285 | 0.485 |
| 0 | 0.3 | 0 | 0.3 | 0 | 0.3 | 0 | 0.3 | 0.261 | 0.461 | 0.258 | 0.458 |
| 0 | 0.3 | 0 | 0.3 | 0 | 0.3 | 0 | 0.3 | 0.237 | 0.437 | 0.235 | 0.435 |
| 0 | 0.3 | 0 | 0.3 | 0 | 0.3 | 0 | 0.3 | 0.216 | 0.416 | 0.213 | 0.413 |
| 0 | 0.3 | 0 | 0.3 | 0 | 0.3 | 0 | 0.3 | 0.196 | 0.396 | 0.193 | 0.393 |
| 0 | 0.3 | 0 | 0.3 | 0 | 0.3 | 0 | 0.3 | 0.177 | 0.377 | 0.174 | 0.374 |
| 0 | 0.3 | 0 | 0.3 | 0 | 0.3 | 0 | 0.3 | 0.158 | 0.358 | 0.155 | 0.355 |
| 0 | 0.3 | 0 | 0.3 | 0 | 0.3 | 0 | 0.3 | 0.139 | 0.339 | 0.136 | 0.336 |
| 0 | 0.3 | 0 | 0.3 | 0 | 0.3 | 0 | 0.3 | 0.119 | 0.319 | 0.116 | 0.316 |
| 0 | 0.3 | 0 | 0.3 | 0 | 0.3 | 0 | 0.3 | 0 | 0.3 | 0 | 0.3 |
| 0 | 0.3 | 0 | 0.3 | 0 | 0.3 | 0 | 0.3 | 0 | 0.3 | 0 | 0.3 |
| 0 | 0.3 | 0 | 0.3 | 0 | 0.3 | 0 | 0.3 | 0 | 0.3 | 0 | 0.3 |
| 0 | 0.3 | 0 | 0.3 | 0 | 0.3 | 0 | 0.3 | 0 | 0.3 | 0 | 0.3 |
| 0 | 0.3 | 0 | 0.3 | 0 | 0.3 | 0 | 0.3 | 0 | 0.3 | 0 | 0.3 |
| 0 | 0.3 | 0 | 0.3 | 0 | 0.3 | 0 | 0.3 | 0 | 0.3 | 0 | 0.3 |
| 0 | 0.3 | 0 | 0.3 | 0 | 0.3 | 0 | 0.3 | 0 | 0.3 | 0 | 0.3 |
| 0 | 0.3 | 0 | 0.3 | 0 | 0.3 | 0 | 0.3 | 0 | 0.3 | 0 | 0.3 |
| 0 | 0.3 | 0 | 0.3 | 0 | 0.3 | 0 | 0.3 | 0 | 0.3 | 0 | 0.3 |
| 0 | 0.3 | 0 | 0.3 | 0 | 0.3 | 0 | 0.3 | 0 | 0.3 | 0 | 0.3 |
| 0 | 0.3 | 0 | 0.3 | 0 | 0.3 | 0 | 0.3 | 0 | 0.3 | 0 | 0.3 |
| 0 | 0.3 | 0 | 0.3 | 0 | 0.3 | 0 | 0.3 | 0 | 0.3 | 0 | 0.3 |
| 0 | 0.3 | 0 | 0.3 | 0 | 0.3 | 0 | 0.3 | 0 | 0.3 | 0 | 0.3 |
| 0 | 0.3 | 0 | 0.3 | 0 | 0.3 | 0 | 0.3 | 0 | 0.3 | 0 | 0.3 |
| 0 | 0.3 | 0 | 0.3 | 0 | 0.3 | 0 | 0.3 | 0 | 0.3 | 0 | 0.3 |
| 0 | 0.3 | 0 | 0.3 | 0 | 0.3 | 0 | 0.3 | 0 | 0.3 | 0 | 0.3 |
| 0 | 0.3 | 0 | 0.3 | 0 | 0.3 | 0 | 0.3 | 0 | 0.3 | 0 | 0.3 |
| 0 | 0.3 | 0 | 0.3 | 0 | 0.3 | 0 | 0.3 | 0 | 0.3 | 0 | 0.3 |
| 0 | 0.3 | 0 | 0.3 | 0 | 0.3 | 0 | 0.3 | 0 | 0.3 | 0 | 0.3 |
| 0 | 0.3 | 0 | 0.3 | 0 | 0.3 | 0 | 0.3 | 0 | 0.3 | 0 | 0.3 |
| 0 | 0.3 | 0 | 0.3 | 0 | 0.3 | 0 | 0.3 | 0 | 0.3 | 0 | 0.3 |
| 0 | 0.3 | 0 | 0.3 | 0 | 0.3 | 0 | 0.3 | 0 | 0.3 | 0 | 0.3 |
| 0 | 0.3 | 0 | 0.3 | 0 | 0.3 | 0 | 0.3 | 0 | 0.3 | 0 | 0.3 |
| 0 | 0.3 | 0 | 0.3 | 0 | 0.3 | 0 | 0.3 | 0 | 0.3 | 0 | 0.3 |

Based on the value defined in Table C.4.3-1, Figure C.4.3-1 shows the pass/fail and reference curve of temporal correlation.

Figure C.4.3-1: Pass/fail limits and targets of Temporal correlation for CDL-C UMa and CDL-C UMi channel model: red curve (reference), blue (upper limit) and green (lower limit)

## C.4.4 Pass/Fail Criteria of Spatial correlation

This clause defines the pass/fail criteria of spatial correlation, this general pass/fail limits principle apply for all channel models in all FR1 frequency bands, for both combined and individual beams.

The pass/fail limits for spatial correlation are formed as bands of ±10% of correlation capped at 100 % for the upper limit for target correlation defined in clause C.3.4 of 35 % (for CDL-C UMa @3600MHz, this value is 65 %) and above. For target correlations below 35 % (for CDL-C UMa @3600MHz, this value is 65 %), the band is widened to ±20 % capped at 0 %.

For the detailed pass/fail limit, the values are defined in the Table C.4.4-1 and Table C.4.4-2, for CDL-C UMi and CDL-C UMa channel model, respectively.

Table C.4.4-1: Spatial correlation pass/fail limits for CDL-C UMi channel model

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Lower | Upper | Lower | Upper | Lower | Upper | Lower | Upper | Lower | Upper |
| 617 MHz | | 722 MHz | | 836.5 MHz | | 1575.42 MHz | | 1880 MHz | |
| 0.90 | 1.00 | 0.90 | 1.00 | 0.90 | 1.00 | 0.90 | 1.00 | 0.90 | 1.00 |
| 0.90 | 1.00 | 0.90 | 1.00 | 0.90 | 1.00 | 0.90 | 1.00 | 0.90 | 1.00 |
| 0.90 | 1.00 | 0.90 | 1.00 | 0.90 | 1.00 | 0.90 | 1.00 | 0.90 | 1.00 |
| 0.90 | 1.00 | 0.90 | 1.00 | 0.90 | 1.00 | 0.90 | 1.00 | 0.89 | 1.00 |
| 0.89 | 1.00 | 0.89 | 1.00 | 0.89 | 1.00 | 0.89 | 1.00 | 0.89 | 1.00 |
| 0.88 | 1.00 | 0.88 | 1.00 | 0.88 | 1.00 | 0.89 | 1.00 | 0.88 | 1.00 |
| 0.74 | 0.94 | 0.74 | 0.94 | 0.86 | 1.00 | 0.89 | 1.00 | 0.87 | 1.00 |
| 0.70 | 0.90 | 0.70 | 0.90 | 0.72 | 0.92 | 0.88 | 1.00 | 0.85 | 1.00 |
|  |  | 0.81 | 1.00 | 0.63 | 0.83 | 0.87 | 1.00 | 0.82 | 1.00 |
|  |  | 0.89 | 1.00 | 0.71 | 0.91 | 0.86 | 1.00 | 0.77 | 0.97 |
|  |  |  |  | 0.85 | 1.00 | 0.84 | 1.00 | 0.29 | 0.49 |
|  |  |  |  | 0.90 | 1.00 | 0.81 | 1.00 | 0.00 | 0.35 |
|  |  |  |  |  |  | 0.77 | 0.97 | 0.04 | 0.44 |
|  |  |  |  |  |  | 0.56 | 0.76 | 0.52 | 0.72 |
|  |  |  |  |  |  | 0.34 | 0.54 | 0.84 | 1.00 |
|  |  |  |  |  |  | 0.10 | 0.50 |  |  |
|  |  |  |  |  |  | 0.08 | 0.48 |  |  |
|  |  |  |  |  |  | 0.27 | 0.47 |  |  |
|  |  |  |  |  |  | 0.44 | 0.64 |  |  |
|  |  |  |  |  |  | 0.65 | 0.85 |  |  |
|  |  |  |  |  |  | 0.81 | 1.00 |  |  |
|  |  |  |  |  |  | 0.89 | 1.00 |  |  |

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Lower | Upper | Lower | Upper | Lower | Upper | Lower | Upper |
| 2132.5 MHz | | 2450 MHz | | 3600 MHz | | 4700 MHz | |
| 0.90 | 1.00 | 0.90 | 1.00 | 0.90 | 1.00 | 0.90 | 1.00 |
| 0.90 | 1.00 | 0.90 | 1.00 | 0.90 | 1.00 | 0.90 | 1.00 |
| 0.90 | 1.00 | 0.90 | 1.00 | 0.90 | 1.00 | 0.90 | 1.00 |
| 0.89 | 1.00 | 0.89 | 1.00 | 0.89 | 1.00 | 0.89 | 1.00 |
| 0.89 | 1.00 | 0.89 | 1.00 | 0.89 | 1.00 | 0.89 | 1.00 |
| 0.88 | 1.00 | 0.89 | 1.00 | 0.89 | 1.00 | 0.89 | 1.00 |
| 0.87 | 1.00 | 0.88 | 1.00 | 0.88 | 1.00 | 0.88 | 1.00 |
| 0.86 | 1.00 | 0.87 | 1.00 | 0.88 | 1.00 | 0.88 | 1.00 |
| 0.83 | 1.00 | 0.85 | 1.00 | 0.87 | 1.00 | 0.88 | 1.00 |
| 0.79 | 0.99 | 0.82 | 1.00 | 0.87 | 1.00 | 0.87 | 1.00 |
| 0.74 | 0.94 | 0.78 | 0.98 | 0.85 | 1.00 | 0.87 | 1.00 |
| 0.67 | 0.87 | 0.73 | 0.93 | 0.83 | 1.00 | 0.86 | 1.00 |
| 0.07 | 0.47 | 0.66 | 0.86 | 0.80 | 1.00 | 0.85 | 1.00 |
| 0 | 0.34 | 0.00 | 0.39 | 0.76 | 0.96 | 0.83 | 1.00 |
| 0 | 0.34 | 0.06 | 0.46 | 0.71 | 0.91 | 0.81 | 1.00 |
| 0.06 | 0.46 | 0.27 | 0.47 | 0.65 | 0.85 | 0.77 | 0.97 |
| 0.61 | 0.81 | 0.00 | 0.39 | 0.58 | 0.78 | 0.73 | 0.93 |
| 0.87 | 1.00 | 0.09 | 0.49 | 0.49 | 0.69 | 0.68 | 0.88 |
|  |  | 0.64 | 0.84 | 0.39 | 0.59 | 0.62 | 0.82 |
|  |  | 0.87 | 1.00 | 0.03 | 0.43 | 0.54 | 0.74 |
|  |  |  |  | 0.52 | 0.72 | 0.46 | 0.66 |
|  |  |  |  | 0.75 | 0.95 | 0.37 | 0.57 |
|  |  |  |  | 0.83 | 1.00 | 0.27 | 0.47 |
|  |  |  |  | 0.82 | 1.00 | 0.07 | 0.47 |
|  |  |  |  | 0.69 | 0.89 | 0.00 | 0.38 |
|  |  |  |  | 0.32 | 0.52 | 0.41 | 0.61 |
|  |  |  |  | 0.00 | 0.35 | 0.73 | 0.93 |
|  |  |  |  | 0.50 | 0.70 | 0.85 | 1.00 |
|  |  |  |  | 0.80 | 1.00 | 0.79 | 0.99 |
|  |  |  |  | 0.90 | 1.00 | 0.70 | 0.90 |
|  |  |  |  |  |  | 0.68 | 0.88 |
|  |  |  |  |  |  | 0.78 | 0.98 |
|  |  |  |  |  |  | 0.88 | 1.00 |
|  |  |  |  |  |  | 0.81 | 1.00 |
|  |  |  |  |  |  | 0.43 | 0.63 |
|  |  |  |  |  |  | 0.00 | 0.29 |
|  |  |  |  |  |  | 0.40 | 0.60 |
|  |  |  |  |  |  | 0.72 | 0.92 |
|  |  |  |  |  |  | 0.87 | 1.00 |

Table C.4.4-2: Spatial correlation pass/fail limits for CDL-C UMa channel model

| Lower | Upper | Lower | Upper | Lower | Upper | Lower | Upper | Lower | Upper |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 617 MHz | | 722 MHz | | 836.5 MHz | | 1575.42 MHz | | 1800 MHz | |
| 0.90 | 1.00 | 0.90 | 1.00 | 0.90 | 1.00 | 0.90 | 1.00 | 0.90 | 1.00 |
| 0.89 | 1.00 | 0.89 | 1.00 | 0.89 | 1.00 | 0.89 | 1.00 | 0.89 | 1.00 |
| 0.89 | 1.00 | 0.88 | 1.00 | 0.88 | 1.00 | 0.88 | 1.00 | 0.86 | 1.00 |
| 0.88 | 1.00 | 0.87 | 1.00 | 0.87 | 1.00 | 0.86 | 1.00 | 0.83 | 1.00 |
| 0.86 | 1.00 | 0.86 | 1.00 | 0.86 | 1.00 | 0.84 | 1.00 | 0.80 | 1.00 |
| 0.51 | 0.71 | 0.84 | 1.00 | 0.85 | 1.00 | 0.82 | 1.00 | 0.79 | 0.99 |
| 0.37 | 0.57 | 0.48 | 0.68 | 0.82 | 1.00 | 0.81 | 1.00 | 0.78 | 0.98 |
| 0.75 | 0.95 | 0.20 | 0.40 | 0.46 | 0.66 | 0.80 | 1.00 | 0.77 | 0.97 |
|  |  | 0.46 | 0.66 | 0.09 | 0.29 | 0.79 | 0.99 | 0.74 | 0.94 |
|  |  | 0.85 | 1.00 | 0.17 | 0.37 | 0.78 | 0.98 | 0.69 | 0.89 |
|  |  |  |  | 0.60 | 0.80 | 0.77 | 0.97 | 0.00 | 0.36 |
|  |  |  |  | 0.89 | 1.00 | 0.74 | 0.94 | 0.10 | 0.50 |
|  |  |  |  |  |  | 0.69 | 0.89 | 0.02 | 0.42 |
|  |  |  |  |  |  | 0.32 | 0.52 | 0.26 | 0.46 |
|  |  |  |  |  |  | 0.00 | 0.33 | 0.47 | 0.67 |
|  |  |  |  |  |  | 0.10 | 0.50 |  |  |
|  |  |  |  |  |  | 0.11 | 0.51 |  |  |
|  |  |  |  |  |  | 0.09 | 0.49 |  |  |
|  |  |  |  |  |  | 0.13 | 0.53 |  |  |
|  |  |  |  |  |  | 0.09 | 0.49 |  |  |
|  |  |  |  |  |  | 0.38 | 0.58 |  |  |
|  |  |  |  |  |  | 0.78 | 0.98 |  |  |

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Lower | Upper | Lower | Upper | Lower | Upper | Lower | Upper |
| 2132.5 MHz | | 2450 MHz | | 3600 MHz | | 4700 MHz | |
| 0.90 | 1.00 | 0.90 | 1.00 | 0.90 | 1.00 | 0.90 | 1.00 |
| 0.89 | 1.00 | 0.89 | 1.00 | 0.88 | 1.00 | 0.88 | 1.00 |
| 0.86 | 1.00 | 0.85 | 1.00 | 0.85 | 1.00 | 0.84 | 1.00 |
| 0.83 | 1.00 | 0.81 | 1.00 | 0.80 | 1.00 | 0.79 | 0.99 |
| 0.80 | 1.00 | 0.77 | 0.97 | 0.74 | 0.94 | 0.73 | 0.93 |
| 0.79 | 0.99 | 0.75 | 0.95 | 0.70 | 0.90 | 0.68 | 0.88 |
| 0.78 | 0.98 | 0.73 | 0.93 | 0.67 | 0.87 | 0.63 | 0.83 |
| 0.77 | 0.97 | 0.72 | 0.92 | 0.65 | 0.85 | 0.60 | 0.80 |
| 0.74 | 0.94 | 0.72 | 0.92 | 0.63 | 0.83 | 0.58 | 0.78 |
| 0.69 | 0.89 | 0.70 | 0.90 | 0.62 | 0.82 | 0.56 | 0.76 |
| 0.00 | 0.36 | 0.67 | 0.87 | 0.61 | 0.81 | 0.55 | 0.75 |
| 0.10 | 0.50 | 0.63 | 0.83 | 0.60 | 0.80 | 0.54 | 0.74 |
| 0.02 | 0.42 | 0.56 | 0.76 | 0.59 | 0.79 | 0.53 | 0.73 |
| 0.26 | 0.46 | 0.06 | 0.46 | 0.57 | 0.77 | 0.52 | 0.72 |
| 0.47 | 0.67 | 0.03 | 0.43 | 0.44 | 0.84 | 0.51 | 0.71 |
| 0.90 | 1.00 | 0.00 | 0.39 | 0.41 | 0.81 | 0.50 | 0.70 |
| 0.89 | 1.00 | 0.00 | 0.33 | 0.36 | 0.76 | 0.49 | 0.69 |
| 0.86 | 1.00 | 0.00 | 0.35 | 0.29 | 0.69 | 0.47 | 0.67 |
|  |  | 0.28 | 0.48 | 0.21 | 0.61 | 0.45 | 0.65 |
|  |  | 0.64 | 0.84 | 0.22 | 0.62 | 0.42 | 0.62 |
|  |  |  |  | 0.00 | 0.49 | 0.38 | 0.58 |
|  |  |  |  | 0.44 | 0.84 | 0.32 | 0.52 |
|  |  |  |  | 0.27 | 0.67 | 0.15 | 0.55 |
|  |  |  |  | 0.24 | 0.64 | 0.06 | 0.46 |
|  |  |  |  | 0.08 | 0.58 | 0.00 | 0.38 |
|  |  |  |  | 0.00 | 0.46 | 0.49 | 0.69 |
|  |  |  |  | 0.00 | 0.46 | 0.06 | 0.46 |
|  |  |  |  | 0.21 | 0.61 | 0.69 | 0.89 |
|  |  |  |  | 0.20 | 0.60 | 0.33 | 0.53 |
|  |  |  |  | 0.85 | 1.00 | 0.58 | 0.78 |
|  |  |  |  |  |  | 0.53 | 0.73 |
|  |  |  |  |  |  | 0.65 | 0.85 |
|  |  |  |  |  |  | 0.77 | 0.97 |
|  |  |  |  |  |  | 0.57 | 0.77 |
|  |  |  |  |  |  | 0.00 | 0.29 |
|  |  |  |  |  |  | 0.05 | 0.45 |
|  |  |  |  |  |  | 0.12 | 0.52 |
|  |  |  |  |  |  | 0.32 | 0.52 |
|  |  |  |  |  |  | 0.63 | 0.83 |

## C.4.5 Pass/Fail Criteria of Cross-polarization

This clause defines the pass/fail criteria of cross-polarization, this pass/fail limits apply for all channel models in all FR1 frequency bands, for both combined and individual beams.

The cross-polarization ratio pass/fail limit is specified as ±1dB.

## C.4.6 Pass/Fail Criteria of Power validation

This clause defines the pass/fail criteria of power validation, this pass/fail limits apply for all channel models.

The power validation pass/fail limit is specified as ±1.5 dB.

Annex D (normative):  
gNB configurations

# D.1 FR1 gNB configurations

The gNodeB emulator parameters shall be set according to Table D.1-1 for FR1 common parameters, Table D.1-2 for FR1 FDD 2x2 test parameters, Table D.1-3 for FR1 TDD 2x2 test parameters, Table D.1-4 for FR1 FDD 4x4 test parameters, and Table D.1-5 for FR1 TDD 4x4 test parameters.

Table D.1-1: FR1 Common test parameters

| **Parameter** | | | **Unit** | **Value** | |
| --- | --- | --- | --- | --- | --- |
| PDSCH transmission scheme | | |  | Transmission scheme 1 | |
| Carrier configuration | Offset between Point A and the lowest usable subcarrier on this carrier (Note 2) | | RBs | 0 | |
| Subcarrier spacing | | kHz | 15 or 30 | |
| DL BWP configuration #1 | Cyclic prefix | |  | Normal | |
| RB offset | | RBs | 0 | |
| Number of contiguous PRB | | PRBs | Maximum transmission bandwidth configuration as specified in clause 5.3.2 of 3GPP TS 38.101-1 [2] for tested channel bandwidth and subcarrier spacing | |
| Common serving cell parameters | Physical Cell ID | |  | 0 | |
| SSB position in burst | |  | First SSB in Slot #0 | |
| SSB periodicity | | ms | 20 | |
| First DMRS position for Type A PDSCH mapping | |  | 2 | |
| PDCCH configuration | Slots for PDCCH monitoring | |  | Each slot | |
| Symbols with PDCCH | | Symbols | 0, 1 | |
| Number of PRBs in CORESET | |  | Table 5.2-2 of 3GPP TS 38.101-4 [6] for tested channel bandwidth and subcarrier spacing | |
| Number of PDCCH candidates and aggregation levels | |  | 1/AL8 | |
| CCE-to-REG mapping type | |  | Non-interleaved | |
| DCI format | |  | 1\_1 | |
| TCI state | |  | TCI state #1 | |
| Cross carrier scheduling | | |  | Not configured | |
| CSI-RS for tracking | First subcarrier index in the PRB used for CSI-RS | |  | k0=0 for CSI-RS resource 1,2,3,4 | |
| First OFDM symbol in the PRB used for CSI-RS | |  | l0 = 6 for CSI-RS resource 1 and 3  l0 = 10 for CSI-RS resource 2 and 4 | |
| Number of CSI-RS ports (X) | |  | 1 for CSI-RS resource 1,2,3,4 | |
| CDM Type | |  | 'No CDM' for CSI-RS resource 1,2,3,4 | |
| Density (ρ) | |  | 3 for CSI-RS resource 1,2,3,4 | |
| CSI-RS periodicity | | Slots | 15 kHz SCS: 20 for CSI-RS resource 1,2,3,4  30 kHz SCS: 40 for CSI-RS resource 1,2,3,4 | |
| CSI-RS offset | | Slots | 15 kHz SCS:  10 for CSI-RS resource 1 and 2  11 for CSI-RS resource 3 and 4  30 kHz SCS:  20 for CSI-RS resource 1 and 2  21 for CSI-RS resource 3 and 4 | |
| Frequency Occupation | |  | Start PRB 0  Number of PRB = BWP size | |
| QCL info | |  | TCI state #0 | |
| NZP CSI-RS for CSI acquisition | First subcarrier index in the PRB used for CSI-RS | |  | k0 = 0 | |
| First OFDM symbol in the PRB used for CSI-RS | |  | l0 = 12 | |
| Number of CSI-RS ports (X) | |  | Same as number of transmit antenna | |
| CDM Type | |  | 'FD-CDM2' | |
| Density (ρ) | |  | 1 | |
| CSI-RS periodicity | | Slots | 15 kHz SCS: 20  30 kHz SCS: 40 | |
| CSI-RS offset | | Slots | 0 | |
| Frequency Occupation | |  | Start PRB 0  Number of PRB = BWP size | |
| QCL info | |  | TCI state #1 | |
| ZP CSI-RS for CSI acquisition | First subcarrier index in the PRB used for CSI-RS | |  | k0 = 4 | |
| First OFDM symbol in the PRB used for CSI-RS | |  | l0 = 12 | |
| Number of CSI-RS ports (X) | |  | 4 | |
| CDM Type | |  | 'FD-CDM2' | |
| Density (ρ) | |  | 1 | |
| CSI-RS periodicity | | Slots | 15 kHz SCS: 20  30 kHz SCS: 40 | |
| CSI-RS offset | | Slots | 0 | |
| Frequency Occupation | |  | Start PRB 0  Number of PRB = BWP size | |
| PDSCH DMRS configuration | Antenna ports indexes | |  | {1000, 1001} for Rank 2 tests  {1000-1003} for Rank 4 tests | |
| Number of PDSCH DMRS CDM group(s) without data | |  | 1 for Rank 2 tests  2 for Rank 4 tests | |
| TCI state #0 | Type 1 QCL information | SSB index |  | SSB #0 | |
| QCL Type |  | Type C | |
| Type 2 QCL information | SSB index |  | N/A | |
| QCL Type |  | N/A | |
| TCI state #1 | Type 1 QCL information | CSI-RS resource |  | CSI-RS resource 1 from 'CSI-RS for tracking' configuration | |
| QCL Type |  | Type A | |
| Type 2 QCL information | CSI-RS resource |  | N/A | |
| QCL Type |  | N/A | |
| PT-RS configuration | | |  | PT-RS is not configured | |
| Maximum number of code block groups for ACK/NACK feedback | | |  | 1 | |
| Maximum number of HARQ transmission | | |  | 1 | |
| HARQ ACK/NACK bundling | | |  | Multiplexed | |
| Redundancy version coding sequence | | |  | N.A | |
| Precoding configuration | | |  | SP Type I, Random per slot with PRB bundling granularity | |
| Symbols for all unused REs | | |  | OCNG clause A.5 of 3GPP TS 38.101‑4 [9] | |
| Minimum Number of Slots per Stream | | |  | 20000 for 15kHz SCS  40000 for 30kHz SCS  (Note 3) |
| Transmit Power Control | | | dBm | 13 |
| DL power level  (RS EPRE of SSS) | | | dBm / SCS | Set at gNodeB simulator  with correction from calibration |
| EPRE ratio of PDSCH to SSS | | | dB | 0 |
| NOTE 1: UE assumes that the TCI state for the PDSCH is identical to the TCI state applied for the PDCCH transmission.  NOTE 2: Point A coincides with minimum guard band as specified in Table 5.3.3-1 from 3GPP TS 38.101-1 [2] for tested channel bandwidth and subcarrier spacing.  NOTE 3: For FR1 MIMO OTA test lab alignments and FR1 MIMO OTA UE performance requirements, the following values can be used: For FR1 bands >1GHz: 20k for 30kHz SCS, 10k for 15kHz SCS; For FR1 bands <1GHz: [20k] for 15kHz SCS; | | | | | |

Table D.1-2: Test parameters for FR1 FDD 2x2

|  |  |  |  |
| --- | --- | --- | --- |
| Parameter | | Unit | Value |
| Duplex mode | |  | FDD |
| Reference channel | |  | R.PDSCH.1-3.1 FDD (Note) |
| Bandwidth | | MHz | 10 |
| SCS | | kHz | 15 |
| Modulation DL | |  | 64QAM |
| Modulation UL | |  | QPSK |
| Active DL BWP index | |  | 1 |
| PDSCH configuration | Mapping type |  | Type A |
| k0 |  | 0 |
| Starting symbol (S) |  | 2 |
| Length (L) |  | 12 |
| PDSCH aggregation factor |  | 1 |
| PRB bundling type |  | Static |
| PRB bundling size |  | 2 |
| Resource allocation type |  | Type 0 |
| RBG size |  | Config2 |
| VRB-to-PRB mapping type |  | Non-interleaved |
| VRB-to-PRB mapping interleave bundle size |  | N/A |
| PDSCH DMRS configuration | DMRS Type |  | Type 1 |
| Number of additional DMRS |  | 1 |
| Maximum number of OFDM symbols for DL front loaded DMRS |  | 1 |
| CSI-RS for tracking | CSI-RS periodicity | Slots | 20 |
| CSI-RS offset | Slots | Table 5.2-1 [3] |
| Number of HARQ Processes | |  | 4 |
| The number of slots between PDSCH and corresponding HARQ-ACK information | |  | 2 |
| NOTE: "R.PDSCH.1-3.1 FDD" is defined in Table A.3.2.1.1-3 of 3GPP TS 38.101-4 [6]. | | | |

Table D.1-3: Test parameters for FR1 TDD 2x2

| **Parameter** | | **Unit** | **Value** |
| --- | --- | --- | --- |
| Duplex mode | |  | TDD |
| Reference channel | |  | R.PDSCH.2-3.1 TDD (Note 1) |
| Bandwidth | | MHz | 40 |
| SCS | | kHz | 30 |
| Modulation DL | |  | 64QAM |
| Modulation UL | |  | QPSK |
| Active DL BWP index | |  | 1 |
| PDSCH configuration | Mapping type |  | Type A |
| k0 |  | 0 |
| Starting symbol (S) |  | 2 |
| Length (L) |  | Specific to each Reference channel |
| PDSCH aggregation factor |  | 1 |
| PRB bundling type |  | Static |
| PRB bundling size |  | 2 |
| Resource allocation type |  | Type 0 |
| RBG size |  | Config2 |
| VRB-to-PRB mapping type |  | Non-interleaved |
| VRB-to-PRB mapping interleave bundle size |  | N/A |
| PDSCH DMRS configuration | DMRS Type |  | Type 1 |
| Number of additional DMRS |  | 1 |
| Maximum number of OFDM symbols for DL front loaded DMRS |  | 1 |
| CSI-RS for tracking | First OFDM symbol in the PRB used for CSI-RS |  | Table 5.2-1 [3] |
| CSI-RS periodicity | Slots | 40 |
| CSI-RS offset | Slots | Table 5.2-1 [3] |
| Number of HARQ Processes | |  | 8 |
| TDD UL-DL pattern | |  | FR1.30-1 (Note 2) |
| NOTE 1: "R.PDSCH.2-3.1 TDD" is defined in Table A.3.2.2.2-3 of 3GPP TS 38.101-4 [6].  NOTE 2: "FR1.30-1" is defined in Annex A.1.2 of 3GPP TS 38.101-4 [6]. | | | |

Table D.1-4: Test parameters for FR1 FDD 4x4

|  |  |  |  |
| --- | --- | --- | --- |
| Parameter | | Unit | Value |
| Duplex mode | |  | FDD |
| Reference channel | |  | R.PDSCH.1-2.4 FDD (Note) |
| Bandwidth | | MHz | 10 |
| SCS | | kHz | 15 |
| Modulation DL | |  | 16QAM |
| Modulation UL | |  | QPSK |
| Active DL BWP index | |  | 1 |
| PDSCH configuration | Mapping type |  | Type A |
| k0 |  | 0 |
| Starting symbol (S) |  | 2 |
| Length (L) |  | 12 |
| PDSCH aggregation factor |  | 1 |
| PRB bundling type |  | Static |
| PRB bundling size |  | 2 |
| Resource allocation type |  | Type 0 |
| RBG size |  | Config2 |
| VRB-to-PRB mapping type |  | Non-interleaved |
| VRB-to-PRB mapping interleave bundle size |  | N/A |
| PDSCH DMRS configuration | DMRS Type |  | Type 1 |
| Number of additional DMRS |  | 1 |
| Maximum number of OFDM symbols for DL front loaded DMRS |  | 1 |
| CSI-RS for tracking | CSI-RS periodicity | Slots | 20 |
| CSI-RS offset | Slots | Table 5.2-1 [3] |
| Number of HARQ Processes | |  | 4 |
| The number of slots between PDSCH and corresponding HARQ-ACK information | |  | 2 |
| NOTE: "R.PDSCH.1-2.4 FDD" is defined in Table A.3.2.1.1-2 of 3GPP TS 38.101-4 [6]. | | | |

Table D.1-5: Test parameters for FR1 TDD 4x4

| Parameter | | Unit | Value |
| --- | --- | --- | --- |
| Duplex mode | |  | TDD |
| Reference channel | |  | R.PDSCH.2-2.4 TDD (Note 1) |
| Bandwidth | | MHz | 40 |
| SCS | | kHz | 30 |
| Modulation DL | |  | 16QAM |
| Modulation UL | |  | QPSK |
| Active DL BWP index | |  | 1 |
| PDSCH configuration | Mapping type |  | Type A |
| k0 |  | 0 |
| Starting symbol (S) |  | 2 |
| Length (L) |  | Specific to each Reference channel |
| PDSCH aggregation factor |  | 1 |
| PRB bundling type |  | Static |
| PRB bundling size |  | 2 |
| Resource allocation type |  | Type 0 |
| RBG size |  | Config2 |
| VRB-to-PRB mapping type |  | Non-interleaved |
| VRB-to-PRB mapping interleave bundle size |  | N/A |
| PDSCH DMRS configuration | DMRS Type |  | Type 1 |
| Number of additional DMRS |  | 1 |
| Maximum number of OFDM symbols for DL front loaded DMRS |  | 1 |
| CSI-RS for tracking | First OFDM symbol in the PRB used for CSI-RS |  | Table 5.2-1 [3] |
| CSI-RS periodicity | Slots | 40. |
| CSI-RS offset | Slots | Table 5.2-1 [3] |
| Number of HARQ Processes | |  | 8 |
| TDD UL-DL pattern | |  | FR1.30-1 (Note 2) |
| NOTE 1: "R.PDSCH.2-2.4 TDD" is defined in Table A.3.2.2.2-2 of 3GPP TS 38.101-4 [6].  NOTE 2: "FR1.30-1" is defined in clause A.1.2 of 3GPP TS 38.101-4 [6]. | | | |

Annex E (normative):  
Environmental requirements

# E.1 Scope

The requirements in this clause apply to all types of UE(s) in FR1.

# E.2 Ambient temperature

All the MIMO OTA requirements are applicable in room temperature e.g. 25°C.

# E.3 Operating voltage

For FR1 MIMO OTA, all nominal voltage test cases shall be performed with the DUT operated in stand-alone battery powered mode.

Annex F (normative): Maximum uncertainty of test system and test tolerance

# F.1 Maximum uncertainty of test system

1. The maximum acceptable uncertainty of the Test System is specified in Table F.1-1 for each test, where appropriate. The Test System shall enable each test to be measured with an uncertainty not exceeding the specified values. All ranges and uncertainties are absolute values and are valid for a confidence level of 95 %.
2. In Annex B, the estimation of measurement uncertainty is defined.
3. Table F.1-1: Maximum Test System uncertainties for MIMO OTA tests

|  |  |  |
| --- | --- | --- |
| 1. Clause | 1. Maximum Test System Uncertainty | 1. Derivation of Test System Uncertainty |
| 1. 6.1.2 Total Radiated Multi-Antenna Sensitivity (TRMS) | 1. ±2.61 dB for ≤3GHz 2. ±2.65 dB for >3GHz | 1. Refer to Annex B |

# F.2 Test tolerances

1. Test tolerances in Table F.2-1 are used to relax the Minimum Requirements in the present document and to derive the Test Requirements.
2. Table F.2-1: Test Tolerances for OTA tests

|  |  |
| --- | --- |
| 1. Clause | 1. Test Tolerance |
| 1. 6.1.2 Total Radiated Multi-Antenna Sensitivity (TRMS) | 1dB for ≤3GHz  1dB for >3GHz |

Annex G (informative):  
Change history

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Change history** | | | | | | | |
| Date | Meeting | TDoc | CR | Rev | Cat | Subject/Comment | New version |
| 2022-11 | RAN5#97 | R5-227308 | - | - | - | Initial Skeleton | 0.0.1 |
| 2023-03 | RAN5#98 | R5-230842  R5-230843  R5-230844  R5-231803  R5-230847  R5-230848  R5-231804 | - | - | - | Implementation of pCRs into TS 38.551 V0.1.0 | 0.1.0 |
| 2023-05 | RAN5#99 | R5-232699  R5-232701  R5-232702  R5-232703  R5-232704 | - | - | - | Implementation of pCRs into TS 38.551 V0.2.0 | 0.2.0 |
| 2023-08 | RAN5#100 | R5-234597  R5-234598  R5-234599  R5-234600  R5-234601  R5-234602  R5-234603  R5-234604 | - | - | - | Implementation of pCRs into TS 38.551 V0.3.0 | 0.3.0 |
| 2023-11 | RAN5#101 | R5-237844  R5-237846  R5-236788  R5-237845 | - | - | - | Implementation of pCRs into TS 38.551 V0.4.0 | 0.4.0 |
| 2023-12 | RAN#102 | RP-233639 | - | - | - | presented at RAN#102 for 1-step approval | 1.0.0 |
| 2023-12 | RAN#102 | - | - | - | - | put under revision control as v17.0.0 with small editorial changes | 17.0.0 |
| 2024-03 | RAN#103 | R5-240598 | 0002 | - | F | Correction and alignment of Annex B title | 17.1.0 |
| 2024-03 | RAN#103 | R5-240599 | 0003 | - | F | Further clarifications in Annex A such as MPAC description and coordinate system | 17.1.0 |
| 2024-03 | RAN#103 | R5-241416 | 0009 | - | F | Add missing abbreviations | 17.1.0 |
| 2024-03 | RAN#103 | R5-241934 | 0001 | 1 | F | Introduce Annex for maximum uncertainty of test system and test tolerance | 17.1.0 |
| 2024-03 | RAN#103 | R5-241935 | 0004 | 1 | F | Align Test Case Structure to typical RAN5 spec | 17.1.0 |
| 2024-03 | RAN#103 | R5-241936 | 0005 | 1 | F | Editorial update on Annex C | 17.1.0 |
| 2024-03 | RAN#103 | R5-241937 | 0006 | 1 | F | Editorial update on Annex E | 17.1.0 |
| 2024-03 | RAN#103 | R5-241938 | 0007 | 1 | F | Editorial update on clause 3 | 17.1.0 |
| 2024-03 | RAN#103 | R5-241939 | 0008 | 1 | F | Editorial update on clause 4 | 17.1.0 |