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| 3GPP TR 38.827 V16.8.0 (2022-09) | |
| Technical Report | |
| 3rd Generation Partnership Project;  Technical Specification Group Radio Access Network;  **Study on radiated metrics and test methodology for the verification of multi-antenna reception performance**  **of NR User Equipment (UE);**  (Release 16) | |
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# Foreword

This Technical Report 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;

3 or greater indicates TSG approved document under change control.

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.

# 1 Scope

The present document is the technical report for the study item on NR MIMO OTA, which was approved at TSG RAN#80 [2]. The scope of the SI is to define the radiated metrics and end-to-end test methodology for the verification of multi-antenna reception performance of NR UEs in FR1 and FR2 and the associated preliminary measurement uncertainty budgets.

# 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] RP-182691, “Revised SID: Study on radiated metrics and test methodology for the verification of multi-antenna reception performance of NR UEs,” CAICT, OPPO, Samsung, 3GPP RAN #82, December 2018.

[3] 3GPP TR 37.977: "Universal Terrestrial Radio Access (UTRA) and Evolved Universal Terrestrial Radio Access (E-UTRA); Verification of radiated multi-antenna reception performance of User Equipment (UE)".

[4] 3GPP TR 38.810: “Study on test methods for New Radio”.

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

[6] 3GPP TS 38.508-1: “User Equipment (UE) conformance specification; Part 1: Common test environment”.

[7] 3GPP TR 25.914: “Measurement of Radio Performances for UMTS terminals in speech mode”.

[8] 3GPP TS 34.114: "User Equipment (UE) / Mobile Station (MS) Over The Air (OTA) antenna performance; Conformance testing".

[9] 3GPP TS 38.521-2: “User Equipment (UE) conformance specification; Radio transmission and reception; Part 2: Range 2 Standalone”.

# 3 Definitions, symbols and abbreviations

## 3.1 Definitions

For the purposes of the present document, the terms and definitions given in 3GPP TR 21.905 [1] and the following apply. A term defined in the present document takes precedence over the definition of the same term, if any, in 3GPP TR 21.905 [1].

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

## 3.2 Symbols

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

*D*rad The diameter of the effective radiating aperture

*R*TZ The radius of the test zone

## 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].

3D three-dimensional

AOA Azimuth angle Of Arrival

AOD Azimuth angle Of Departure

AS Angular Spread

ASA Azimuth angle Spread of Arrival

ASD Azimuth angle Spread of Departure

BS Base Station

CDL Clustered Delay Line

D2D Device-to-Device

DML Data Mode Landscape

DMP Data Mode Portrait

DMSU Data Mode Screen Up

DS Delay Spread

EUT Equipment Under Test

FR1 Frequency Range 1

FR2 Frequency Range 2

FS Free Space

FWA Fixed wireless access

InO Indoor Office

LOS Line Of Sight

MIMO Multiple Input Multiple Output

MPAC Multi-Probe Anechoic Chamber

NLOS Non-LOS

OTA Over The Air

PAS Power Angular Spectrum

PDP Power Delay Profile

PSP PAS Similarity Percentage

RMS Root Mean Square

RTS Radiated Two Stage

TVD Total Variation Distance

UE User Equipment

UMa Urban Macro

UMi Urban Micro

XPR Cross-Polarization Ratio

ZOA Zenith angle Of Arrival

ZOD Zenith angle Of Departure

ZSA Zenith angle Spread of Arrival

ZSD Zenith angle Spread of Departure

# 4 General

## 4.1 Device types

The following device types are in the scope of this study:

- Smartphone

- Tablet

- Wearable device

- Fixed wireless access (FWA) terminal

- Other UE types are not precluded for discussion as a second priority

The development of test methodology aspects shall initially focus on the smartphone device type.

## 4.2 Testing configuration

Utilizing the free space (FS) testing configuration is the first priority. A second priority is the study of head/hand/body blocking and its impact on test methods – this will be in collaboration with CTIA who plan to study these aspects.

NR MIMO OTA testing should be performed under primary mechanical mode of UE for data mode usage. The primary mechanical mode for data mode usage for devices having multiple mechanical modes shall be declared by the manufacturers. Single primary mechanical mode for each device should be declared to test labs for NR MIMO OTA.

## 4.3 Testing Bands

The present technical report covers both FR1 and FR2 operating bands.

Table 4.3-1: Definition of frequency ranges

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

Table 4.3-2: NR operating bands in FR1

|  |  |  |  |
| --- | --- | --- | --- |
| NR operating band | Uplink (UL) *operating band* BS receive / UE transmit  FUL\_low  – FUL\_high | Downlink (DL) *operating band* BS transmit / UE receive  FDL\_low – FDL\_high | Duplex Mode |
| n1 | 1920 MHz – 1980 MHz | 2110 MHz – 2170 MHz | FDD |
| n2 | 1850 MHz – 1910 MHz | 1930 MHz – 1990 MHz | FDD |
| n3 | 1710 MHz – 1785 MHz | 1805 MHz – 1880 MHz | FDD |
| n5 | 824 MHz – 849 MHz | 869 MHz – 894 MHz | FDD |
| n7 | 2500 MHz – 2570 MHz | 2620 MHz – 2690 MHz | FDD |
| n8 | 880 MHz – 915 MHz | 925 MHz – 960 MHz | FDD |
| n12 | 699 MHz – 716 MHz | 729 MHz – 746 MHz | FDD |
| n20 | 832 MHz – 862 MHz | 791 MHz – 821 MHz | FDD |
| n25 | 1850 MHz – 1915 MHz | 1930 MHz – 1995 MHz | FDD |
| n28 | 703 MHz – 748 MHz | 758 MHz – 803 MHz | FDD |
| n34 | 2010 MHz – 2025 MHz | 2010 MHz – 2025 MHz | TDD |
| n38 | 2570 MHz – 2620 MHz | 2570 MHz – 2620 MHz | TDD |
| n39 | 1880 MHz – 1920 MHz | 1880 MHz – 1920 MHz | TDD |
| n40 | 2300 MHz – 2400 MHz | 2300 MHz – 2400 MHz | TDD |
| n41 | 2496 MHz – 2690 MHz | 2496 MHz – 2690 MHz | TDD |
| n50 | 1432 MHz – 1517 MHz | 1432 MHz – 1517 MHz | TDD1 |
| n51 | 1427 MHz – 1432 MHz | 1427 MHz – 1432 MHz | TDD |
| n66 | 1710 MHz – 1780 MHz | 2110 MHz – 2200 MHz | FDD |
| n70 | 1695 MHz – 1710 MHz | 1995 MHz – 2020 MHz | FDD |
| n71 | 663 MHz – 698 MHz | 617 MHz – 652 MHz | FDD |
| n74 | 1427 MHz – 1470 MHz | 1475 MHz – 1518 MHz | FDD |
| n75 | N/A | 1432 MHz – 1517 MHz | SDL |
| n76 | N/A | 1427 MHz – 1432 MHz | SDL |
| n77 | 3300 MHz – 4200 MHz | 3300 MHz – 4200 MHz | TDD |
| n78 | 3300 MHz – 3800 MHz | 3300 MHz – 3800 MHz | TDD |
| n79 | 4400 MHz – 5000 MHz | 4400 MHz – 5000 MHz | TDD |
| n80 | 1710 MHz – 1785 MHz | N/A | SUL |
| n81 | 880 MHz – 915 MHz | N/A | SUL |
| n82 | 832 MHz – 862 MHz | N/A | SUL |
| n83 | 703 MHz – 748 MHz | N/A | SUL |
| n84 | 1920 MHz – 1980 MHz | N/A | SUL |
| n86 | 1710 MHz – 1780MHz | N/A | SUL |

Table 4.3-3: NR operating bands in FR2

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Operating Band | Uplink (UL) operating band BS receive UE transmit | | | Downlink (DL) operating band BS transmit  UE receive | | | Duplex Mode |
| FUL\_low – FUL\_high | | | FDL\_low – FDL\_high | | |
| n257 | 26500 MHz | – | 29500 MHz | 26500 MHz | – | 29500 MHz | TDD |
| n258 | 24250 MHz | – | 27500 MHz | 24250 MHz | – | 27500 MHz | TDD |
| n260 | 37000 MHz | – | 40000 MHz | 37000 MHz | – | 40000 MHz | TDD |
| n261 | 27500 MHz | – | 28350 MHz | 27500 MHz | – | 28350 MHz | TDD |

# 5 Performance metrics

## 5.1 Figure of Merits

5.1.1 Definition of MIMO throughput

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 also FR2 static 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 a FRC during the measurement period. MeasurementTime is the total composed of successful slots (ACK), unsuccessful slots (NACK) and DTX-symbols.

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

## 5.2 Averaging of throughput curves

For FR1 MIMO OTA measurement, the throughput curves shall be averaged by:

The average TRMS of free space data mode portrait (FS DMP), free space data mode landscape (FSDML), and free space data mode screen up (FS DMSU), as defined in Annex A.3. The averaging shall be done in linear scale for the TRMS results at these DUT positions.



where



Such that *MODE* is one of {*FS\_DMP, FS\_DML, FS\_DMSU*}, *x* is one of throughput outage (for example {[*70%, 95%*]}), and {*PMODE,x,0, …, PMODE,x,11*} are the measured sensitivity values at each azimuth position.

For FR2 MIMO OTA measurement, the throughput curves shall be averaged by:

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

Such that {P70,1, …, P70,18} are the best 18 sensitivity values from all the 36 constant density measurement points, as defined in clause 6.2.3.2.

# 6 Measurement methodologies

## 6.1 Environmental conditions

UE-noise limited environmental condition is adopted for both FR1 and FR2 MIMO OTA testing, i.e., UE throughput characterized as a function of signal power incident to the DUT antennas.

## 6.2 Measurement setup

### 6.2.1 Multi-Probe Anechoic Chamber (MPAC) for FR1

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 6.2.1-1,signals propagate from the base station/communication tester to the EUT through a simulated multipath environment known as a spatial channel model, where appropriate channel impairments such as Doppler and fading are applied to each path prior to injecting all of the directional signals into the chamber simultaneously through the antenna array. The resulting field distribution in the test zone is then integrated by the EUT antenna(s) and processed by the receiver(s) just as it would do so in any non-simulated multipath environment. MPAC system with 16 uniformly-spaced dual-polarized probes is permitted for NR FR1 MIMO OTA testing.

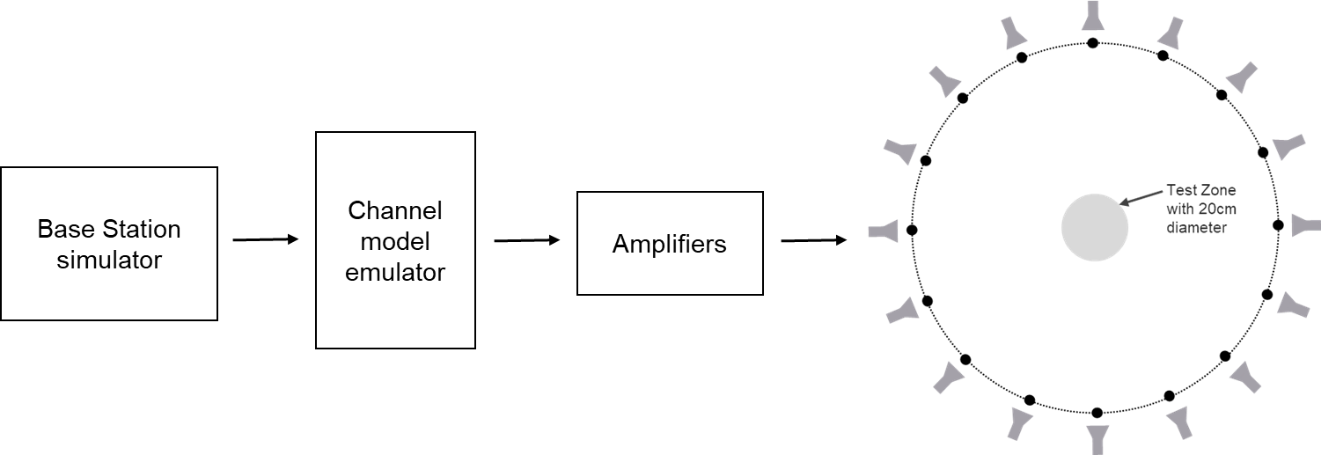


Figure 6.2.1-1: MPAC system layout for NR FR1 MIMO OTA testing

#### 6.2.1.1 Calibration procedure

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

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

1. Place a vertical reference dipole in the center of the test zone, connected to a VNA port, with the other VNA port connected to the input of the channel emulator unit – Figure 7.4.1.1-1.

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 center of test zone.

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

#### 6.2.1.2 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 C are met.

2. Configure the test system according to Clauses 8.2 and 7.2 for the applicable test case.

3. Verify the implementation of the channel model as specified in Clause 7.4.1.

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

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 is [-80dBm/15kHz (or equivalent -77dBm/30kHz)]. MIMO OTA throughput is the minimum downlink signal power resulting in a pre-defined throughput value (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 Annex A.3.

4. The postprocessing method to calculate the average MIMO Throughput is defined in 5.2.

Note 1: 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.

Note 2: For devices that exhibit non-linear TP behaviour and that achieve target throughput at multiple RF power levels, NR MIMO sensititivity level is chosen to be lowest measured DL power level which crosses the target throughput level.

Note 3: For saving measurement time, as soon as the measured TP drops below 70% of maximum theoretical throughput, the sensitivity level search can be stopped. In case non-linear TP behaviour presents, the TP cut-off point can be set lower, to find the lowest measured DL power level at target throughput level.

### 6.2.2 Radiated Two Stage (RTS) for FR1

RTS test method is the harmonized methodology for FR1 NR MIMO OTA testing, according to the applicability criteria.

#### 6.2.2.1 RTS system setup

One example RTS system layout suitable for 4x4 testing is shown in Figure 6.2.2.1-1 while Figure 6.2.2.1-2 illustrates the coordinate system and one example dual-probe antenna configuration. The Base Station emulator sends the downlink signals to the channel emulator, which could be integrated within the base station emulator or be external. The specified channel models are implemented in the channel emulator and the output signals from the channel emulator are fed to the probe antennas. The DUT is placed in the centre of the anechoic chamber and a separate communication antenna is used for the uplink connection with the Base Station emulator. Depending on chamber size and path losses, amplifiers may be needed for downlink and uplink.

To support the channel model scenarios in Clause 7.1, at least two cross-polarized probe antennas located at different positions are required for the 4x4 MIMO OTA RTS test methodology. The probe antennas can be placed on a circular arc around the DUT in the x-y plane as shown in Figure 6.2.2.1-1 or the y-z plane as shown in Figure 6.2.2.1-2 with each dual-polarized probe antenna placed arbitrarily on the arc. If more than two dual-polarized probe antennas are placed on the arc, electric switching could be used to select the required probe antenna.

The DUT is placed in the centre of the arc in the desired test condition and can be rotated in the x-y plane. The distributed axis system can perform 3D or 2D antenna pattern measurements which can then be used to determine the transmission paths between the probe antennas/polarizations and the DUT antennas. The transmission matrix, *H*, is then described by a 4 x 4 or 2 x 2 matrix depending on whether 4x4 or 2x2 MIMO OTA is tested. Changing the probe antenna positions and/or rotating the DUT alters the transmission matrix. To perform the second stage RTS test, it is only necessary to find one transmission matrix which can achieve sufficient isolation after applying an inverted channel matrix using the channel emulator. The minimum isolation level sufficient for the 2nd stage throughput is FFS.

Anechoic Chamber

DUT

Communication antenna

Uplink

Dual-polarized probe antenna

Base Station Emulator

Channel Emulator

Downlink

Figure 6.2.2.1-1: Example RTS system layout for 2x2 or 4x4 NR FR1 MIMO OTA testing



Figure 6.2.2.1-2: Coordination system and one probe antenna layout example for RTS NR FR1 MIMO OTA testing

#### 6.2.2.2 Test procedure

The RTS test method divides the test procedure into two stages: The First stage is to acquire the DUT’s antenna pattern, and the second stage is to calibrate the transmission matrix between probe antennas and the DUT’s receiver prior to performing the throughput tests.

**First stage: Antenna pattern measurement**

The first stage is to acquire the DUT’s antenna pattern. For this to be a non-intrusive antenna measurement, the DUT needs to have the capability of measuring the amplitude and relative phase of known signals incident at the DUT antennas. This functionality is commonly referred to as the Antenna Test Function (ATF) using the SS Reference Signal Received Power per Branch (SS-RSRPB) and SS Reference Signal Antenna Relative Phase (SS-RSARP) measurements. This capability is implemented as part of a test mode in the device. By rotating the DUT relative to the known incident signal it is possible to construct the 3D or 2D antenna patterns from the DUT amplitude measurements and relative phase measurements between the antennas. To fully characterize the antennas, measurements are made at two orthogonal probe antenna orientations, typically vertical and horizontal. This can be done by switching between two separate probe antennas or by rotating a single probe antenna polarization direction.

The absolute accuracy of the resulting antenna patterns is not primarily a function of the accuracy of the DUT measurements but is referenced to the calibration of the known incident signals in the anechoic chamber. The linearity of the DUT measurements for amplitude and relative phase can also be calibrated out if necessary. The measured amplitude and phase information should be transmitted over the uplink air interface which is active during the pattern measurements. This may take the form of an IP data connection with associated client application (depends on the support of chip vendors) or using a layer 3 signalling connection.

**Second stage: Wireless channel calibration and throughput measurements**

The second stage of the RTS MIMO OTA test method is illustrated in Figure 6.2.2.2-1 using a 2 x 2 MIMO configuration as an example. The specified base station antenna pattern from Table 7.2-7 is loaded into the channel emulator as the Tx antenna pattern, while the measured DUT’s antenna pattern obtained in the 1st stage is loaded into the channel emulator as the Rx antenna pattern and both are then convolved with the spatial channel model chosen to evaluate the DUT performance. This process generates the signals at the DUT receiver that would have been received by the DUT had it been placed in the chosen 2D or 3D spatial field.

Prior to the throughput test, a “wireless cable” connection needs to be established between the probe antennas and DUT’s receivers. The purpose of the wireless cable connection is to enable the signals generated by the channel emulator, which are already conditioned to include the effect of the device antennas, to be directly connected to the device receiver as if through a lossless cable connection. However, this can only be done by calibrating out the impact of the signal propagation in the anechoic chamber and the impact of the receive antennas in the device. To achieve this calibration, it is necessary to measure the propagation matrix inside the anechoic chamber (dotted lines in Figure 6.2.2.2-1) and modify the transmitted signals by multiplying by the inverse matrix of the propagation matrix. This approach will make the DUT receive signals equivalent to cable conducted conditions at the receiver but with radiated self-interference included.

The isolation between branches in the second stage can be measured by establishing a connection and measuring the difference in dB between the SS-RSRPB reported for each DUT receiver. For a DUT to be usable with the RTS method a minimum isolation of FFS has to be achieved averaged over sufficient number of SS-RSRPB measurements.

The choice of DUT orientation for the radiated second stage can be chosen from the measured antenna pattern to avoid any nulls in either antenna which would otherwise reduce the achievable isolation.

After the isolation has been confirmed, the throughput tests are performed for each rotation angle. During this second stage it is not necessary to alter the device orientation physically relative to the probe antennas since the rotation of the DUT relative to the chosen channel model is performed electrically within the channel emulator by rotating the measured DUT’s antenna pattern measured in the first stage.

Downlink faded signal

Channel Emulator

Base Station Emulator

Apply Antenna Pattern and Implement MIMO Channel Model

Apply Inverse Matrix of Radiated Channel

Chamber

DUT

PC with control software

Uplink signal

Main Antenna

Sub Antenna

Figure 6.2.2.2-1: Illustration of the 2x2 RTS Second Stage

The applicability criteria of RTS MIMO OTA test method are:

- The RTS method requires device support for the antenna test function (ATF)

- The RTS method is only applicable to devices which do not change their antenna pattern or configuration in response to the radio environment

- The RTS method can only be used if the isolation between channels is above FFS dB. Separate values might be required for 2x2 and 4x4.

### 6.2.3 3D Multi-Probe Anechoic Chamber (MPAC) for FR2

The 3D MPAC test method is the reference methodology for FR2 NR MIMO OTA testing. By arranging an array of antennas around the Equipment Under Test (EUT), a spatial distribution of angles of arrival in the 3D 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 6.2.3-1, 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 probe 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. The 3D MPAC system with 6 dual-polarized probes (illustrated with black dots in Figure 6.2.3-1) placed on a sector with minimum radius of 0.75m from the centre of the test zone is permitted for NR FR2 MIMO OTA testing.

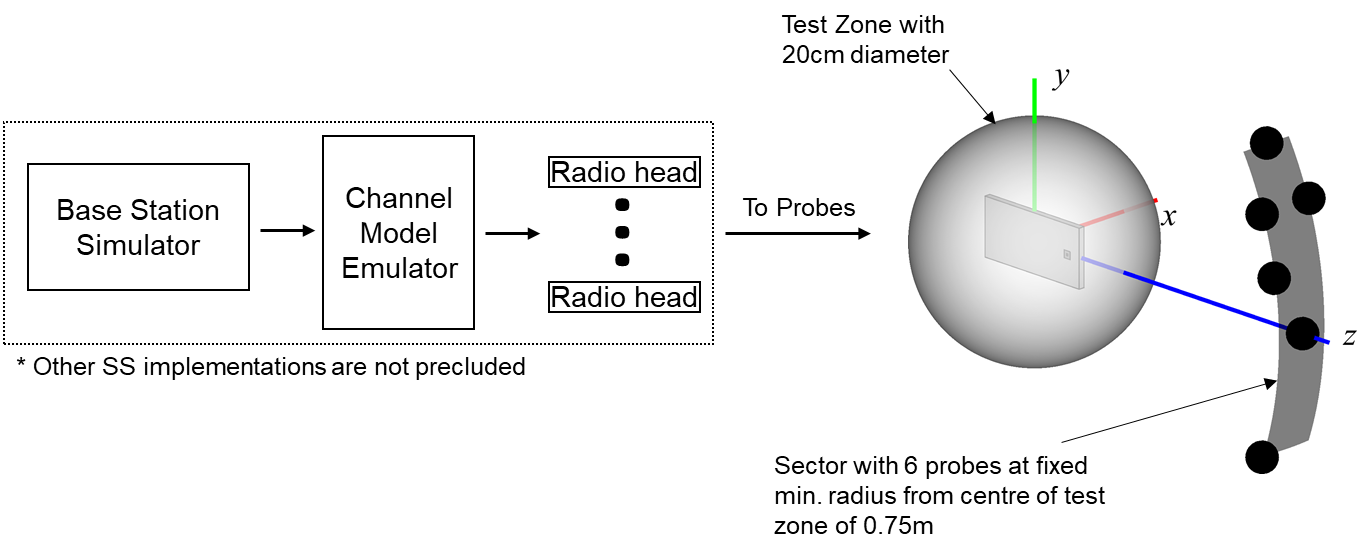


Figure 6.2.3-1: 3D MPAC system layout for NR FR2 MIMO OTA testing

The exact probe locations with respect to the OTA test system coordinate system are tabulated in Table 6.2.3-1.

Table 6.2.3-1. FR2 3D MPAC Probe Locations in OTA test system coordinate system

|  |  |  |
| --- | --- | --- |
| Probe Number | Theta [deg] | Phi  [deg] |
| 1 | 0.0 | 0.0 |
| 2 | 11.2 | 116.7 |
| 3 | 20.6 | -104.3 |
| 4 | 20.6 | 104.3 |
| 5 | 20.6 | 75.7 |
| 6 | 30.0 | 90.0 |

The 3D MPAC probes in Table 6.2.3-1 can be implemented using conventional millimetre-wave probes as well as IFF-based probes as long as the same probe configuration and same number of probes is used.

The channel model parameters and probe locations for channel model implementation are defined in a channel model coordinate system, which is illustrated in figure 6.2.3-2. The channel model coordinate axes *x*CM, *y*CM, and *z*CM correspond to the OTA test system coordinate axes *z*, *y*,and -*x*, respectively.

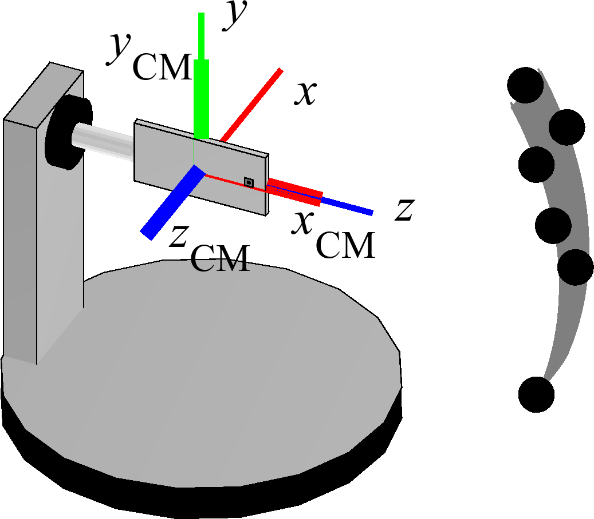


Figure 6.2.3-2: Channel Model Coordinate Axes

The probe locations with respect to channel model coordinate axes are tabulated in table 6.2.3-2.

Table 6.2.3-2. FR2 3D MPAC Probe Locations in Channel Model Coordinate System

|  |  |  |
| --- | --- | --- |
| Probe Number | Theta [deg] | Phi [deg] |
| 1 | 90 | 0 |
| 2 | 85 | 10 |
| 3 | 85 | -20 |
| 4 | 85 | 20 |
| 5 | 95 | 20 |
| 6 | 90 | 30 |

The channel model rotations assumed for this probe configuration are tabulated in Table 6.2.3--3.

Table 6.2.3-3. Channel Model Rotations

|  |  |  |  |
| --- | --- | --- | --- |
| InO CDL-A | | UMi CDL-C | |
| Phi [deg] | Theta [deg] | Phi [deg] | Theta [deg] |
| -5 | -2.0 | 32 | 15.0 |

These channel model rotations assume the relative orientations of BS and UE antennas displayed in Figure 6.2.3-3, i.e., the DUT antenna is pointed towards the BS in channel model coordinate system.

In order to avoid positioning ambiguities, the turntable implementing the rotation in  shall match the intended DUT  for P0 Orientation 1 without the re-positioning approach, as defined in Annex A.3, applied. With the re-positioning approach applied, the relative orientation between the DUT and the probes for P0 Orientation 2 shall be the same the relative orientation between DUT and probes as for P0 Orientation 1.

Diagram

Description automatically generated

Figure 6.2.3-3: Relative orientations of BS and UE antennas.

Since the test points are uniformly spaced in 3D already, Table 6.2.3.2-1, there is no need to adjust/rotate the DUT rotations by the channel model rotations.

#### 6.2.3.1 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.

The path loss for each probe in the 3D MPAC system must be calibrated 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.

For the calibration measurement, the reference antenna is placed in the centre of the quiet zone, connected to a VNA port, with the other VNA port connected to the input of the channel emulator unit as illustrated schematically in Figure 7.4.1.1-1. For each probe antenna, the reference antenna needs to be aligned in polarization, i.e.,  or , and direction with the probe antenna that corresponds to the respective path to be calibrated. For each calibration measurement, the channel emulator needs to be configured in bypass mode. The calibration process determines the composite loss, Lpath,pol, of the entire receiver chain path gains (measurement antenna, amplification) and losses (switches, combiners, cables, path loss, etc.). The calibration measurement is repeated for each measurement path (two orthogonal polarizations and each signal path).

#### 6.2.3.2 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 C are met.

2. Configure the test system according to Clauses 8.2 and 7.2 for the applicable test case.

3. Verify the implementation of the channel model as specified in Clause 7.4.1.

4. Position the UE in the chamber according to Annex D.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. Position the DUT in the default P0 alignment option (Orientation 1), as defined in Section D.3

2. Measure MIMO OTA throughput, the maximum downlink power is [-79.1dBm/120kHz]. MIMO OTA throughput is the minimum downlink signal power resulting in a pre-defined throughput value (70%) 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.

3. Rotate the UE to the next test point. Table 6.2.3.2-1 lists 36 evenly spaced test points determined using the charged particle approach and with test point #1 centred at (0,0).

4. Repeat the test from step 2 for each specified test point. If the re-positioning concept is applied, the device needs to be positioned in P0 Orientation 2 (either option 1 or option 2).

5. he postprocessing method and the performance metric are defined in Clause 5.2.

Note: For step 2 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 the throughput curve curve can reach at least 70% of the maximum theoretical throughput.

Table 6.2.3.2-1. Evenly spaced FR2 test points with a constant density

|  |  |  |
| --- | --- | --- |
| Test Point Number | Theta [deg] | Phi [deg] |
| 1 | 0.0 | 0.0 |
| 2 | 33.5 | 139.7 |
| 3 | 33.9 | 49.7 |
| 4 | 35.5 | -142.9 |
| 5 | 35.5 | -76.9 |
| 6 | 37.6 | -17.2 |
| 7 | 52.3 | 94.7 |
| 8 | 56.9 | 175.7 |
| 9 | 62.5 | 20.4 |
| 10 | 63.7 | -99.8 |
| 11 | 67.1 | -55.0 |
| 12 | 69.3 | -139.5 |
| 13 | 69.5 | 130.1 |
| 14 | 70.3 | 60.8 |
| 15 | 72.1 | -16.2 |
| 16 | 88.7 | -167.5 |
| 17 | 88.7 | 98.5 |
| 18 | 89.3 | 157.0 |
| 19 | 93.9 | -78.9 |
| 20 | 94.6 | 31.6 |
| 21 | 95.3 | -115.6 |
| 22 | 99.6 | -38.3 |
| 23 | 103.8 | -1.1 |
| 24 | 104.4 | 66.3 |
| 25 | 110.1 | 127.5 |
| 26 | 115.1 | -145.6 |
| 27 | 120.8 | 171.9 |
| 28 | 125.3 | -60.7 |
| 29 | 128.2 | -104.1 |
| 30 | 128.8 | 91.3 |
| 31 | 129.9 | 35.8 |
| 32 | 136.0 | -13.4 |
| 33 | 145.8 | 138.1 |
| 34 | 150.2 | -153.3 |
| 35 | 160.6 | -67.4 |
| 36 | 161.7 | 59.1 |

## 6.3 Test methodology verification

For FR1 MPAC and FR2 3D-MPAC MIMO OTA system, the power verification is defined in subclause 7.4.1.5.

## 6.4 Test method applicability

For FR1 MIMO OTA, the MPAC system is applicable for up to 4x4 MIMO with device within 20cm. For FR2 MIMO OTA, the 3D-MPAC system is applicable for up to 2x2 MIMO with device within 20cm.

## 6.5 EUT positioning in the chamber

6.5.1 Minimum test zone size

The minimum test zone size for NR MIMO OTA test methods, both FR1 and FR2, is 20cm. Another test zone size larger than 20cm is FFS. “Black-box” testing approach is adopted for NR MIMO OTA testing, the physical center of the EUT shall be placed in the centre of the test zone, the EUT shall be completely contained within the test zone size defined by respective operation band. The detailed test zone size for each band is listed in Annex A.4.

6.5.2 EUT orientation within the test zone

In order to minimize measurement uncertainty, it’s important that test house ensure the EUT is oriented within the chamber’s test zone in a standardized manner. Annex A.3 provides a preliminary set of normative EUT orientation conditions.

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 flat (FS DMSU), the DUT azimuthal rotation shall be performed over 360 degrees per orientation in 30 degree steps (12 total positions). Fine angular steps at FR1 high frequency for rotation is FFS.

For FR2 MIMO OTA, the DUT shall be tested using a 3D scan. With the DUT positioned in the default P0 alignment option, as defined in Section A.3, measurements on 36 evenly spaced test points with a constant density shall be performed.

## 6.6 Minimum Range Length for FR1 MIMO OTA Systems

This sub-section specifies the minimum range lengths for NR FR1 MIMO OTA systems. The range length is defined as the distance from the centre of the test zone to the aperture of the measurement probes/antennas, as illustrated in Figure 6.6-1 for MPAC and Figure 6.6-2 for RTS.

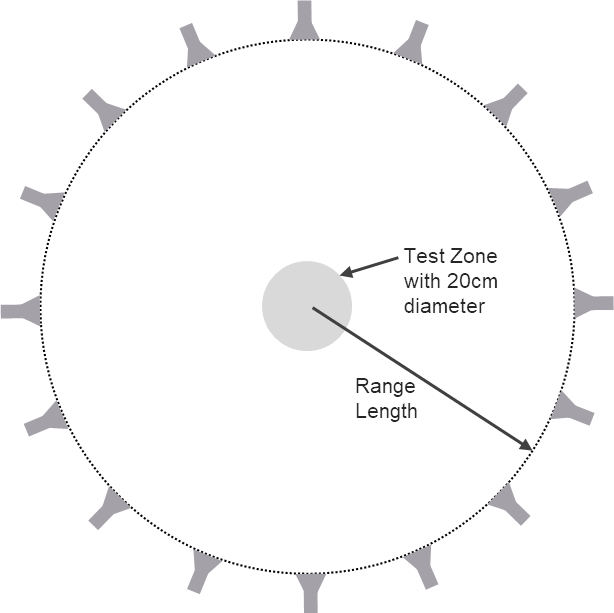


Figure 6.6-1: Illustration of range length definition of MPAC

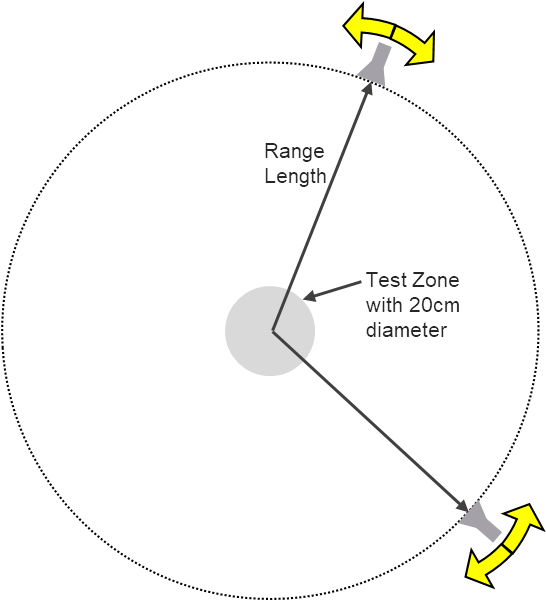


Figure 6.6-2: Illustration of range length definition of RTS

#### 6.6.1 MPAC

The minimum range length for NR FR1 MPAC OTA systems with 20cm test zone size is 1.2m. 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 1.2m.

#### 6.6.2 RTS

For RTS NR FR1 MIMO OTA systems, far-field conditions have to apply due to the pattern measurements in the first stage. The minimum range length shall be the maximum of the following three limits

- The phase uncertainty limit: *R*TZ+2*D*rad2/

- The amplitude uncertainty limit: 3*D*

- The reactive Near-Field limit: *R*TZ+2

where *R*TZ is defined as the radius of the test zone, i.e., *R*TZ=*D*/2, and *D*rad is the diameter of the effective radiating aperture., The minimum range length calculations for *D*=20cm test zone size RTS systems shall assume that *D*rad is 20cm below 1.5GHz and decrease linearly from 20cm to 5cm from 1.5GHz to 7.125GHz, respectively. The last column of Table 6.6.2-1 shall be considered the minimum range length for NR FR1 RTS MIMO systems with 20cm test zone size.

Table 6.6.2-1. Minimum Range Length for RTS Systems with 20cm test zone size.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| *f* [GHz] | Drad [m] | RTZ+2*Drad*²/λ | 3*D* = 6*R*TZ | RTZ+2λ | max(RTZ+2λ,3*D*,RTZ+2*D*²/λ) |
| 0.41 | 0.20 | 0.21 | 0.60 | 1.56 | 1.56 |
| 0.60 | 0.20 | 0.26 | 0.60 | 1.10 | 1.10 |
| 0.70 | 0.20 | 0.29 | 0.60 | 0.96 | 0.96 |
| 0.80 | 0.20 | 0.31 | 0.60 | 0.85 | 0.85 |
| 1.00 | 0.20 | 0.37 | 0.60 | 0.70 | 0.70 |
| 1.20 | 0.20 | 0.42 | 0.60 | 0.60 | 0.60 |
| 1.40 | 0.20 | 0.47 | 0.60 | 0.53 | 0.60 |
| 1.60 | 0.20 | 0.53 | 0.60 | 0.47 | 0.60 |
| 1.80 | 0.20 | 0.58 | 0.60 | 0.43 | 0.60 |
| 2.00 | 0.20 | 0.63 | 0.60 | 0.40 | 0.63 |
| 2.20 | 0.20 | 0.69 | 0.60 | 0.37 | 0.69 |
| 2.40 | 0.18 | 0.60 | 0.60 | 0.35 | 0.60 |
| 2.60 | 0.17 | 0.61 | 0.60 | 0.33 | 0.61 |
| 2.80 | 0.17 | 0.61 | 0.60 | 0.31 | 0.61 |
| 3.00 | 0.16 | 0.62 | 0.60 | 0.30 | 0.62 |
| 4.00 | 0.13 | 0.58 | 0.60 | 0.25 | 0.60 |
| 5.00 | 0.11 | 0.48 | 0.60 | 0.22 | 0.60 |
| 6.00 | 0.08 | 0.36 | 0.60 | 0.20 | 0.60 |
| 7.00 | 0.05 | 0.24 | 0.60 | 0.19 | 0.60 |
| 7.13 | 0.05 | 0.22 | 0.60 | 0.18 | 0.60 |

# 7 Channel Models

## 7.1 General

The different channel models are defined to create corresponding complex multipath radio propagation conditions for FR1 and FR2. The following scenarios are selected for NR MIMO OTA:

FR1 scenarios:

- For 2x2 MIMO: Urban Macro

- For 4x4 MIMO: Urban Micro

FR2 static testing scenarios:

- Urban Micro street canyon and Indoor

In order to describe unambiguously the procedure of generating realizations CDL channel models, various aspects need to be clarified, e.g., details of scaling procedure, inclusion of BS antenna arrays and beams to the model output, and removing unwanted randomness of model realizations.

The concept of angular scaling is based on rotating AoDs/ZoDs and scaling CDL model using the methods in TR 38.901 (section 7.7.5.1) to make them fit the median values in TR 38.901 Table 7.5-6 for the accepted scenarios.

For NR MIMO OTA testing, the following channel models are required to be measured: FR1 UMi CDL-A in table 7.2.1-1, FR1 UMa CDL-C in table 7.2.1-8; FR2 InO CDL-A in table 7.2.2-6, FR2 UMi CDL-C in table 7.2.2-3.

For NR FR1 and FR2 MIMO OTA testing, the number of samples for sequence length at each testing point is FFS.

## 7.2 Channel Models

This section describes amendments to the step-wise procedure of the CDL subclause 7.7.1 in TR 38.901 for generating fast fading radio channel realizations. This channel model methodology considers non-Jakes spectrum with the multi-path fading propagation conditions between the gNB emulator and test chamber probe modelled based on Clustered Delay Line (CDL) methodology.

First, the RMS delay spread values of CDL models are normalized first and they must be scaled in delay so that a desired RMS delay spread can be achieved. The scaled delays can be obtained according to the following equation:

, (7.2-1)

in which

-  is the normalized delay value of the *n*th cluster in a CDL in Tables 7.7.1.1 – 7.7.1.5 of [2]

-  is the new delay value (in [ns]) of the *n*th cluster

-  is the target delay spread (in [ns]).

Values of for FR1/FR2 and for different model scenarios are specified in Table 7.2-1.

Table 7.2-1. Target delay spread values.

|  |  |  |
| --- | --- | --- |
| Frequency | Scenario | DSdesired |
| FR1 | UMi | 100 ns |
| FR1 | UMa | 365 ns |
| FR2 | UMi | 60 ns |
| FR2 | InO | 30 ns |

Subsequently, the departure and arrival angles (based on subclause 7.7.1 step 1 in TR38.901 are generated by combining 7.7-5 and part of step 7 in subclause 7.5. The arrival angles of azimuth using are generated using the following equation

, (7.2-2)

where

*- n,*AOA and *c*ASA are the cluster AOA and the cluster-wise rms azimuth spread of arrival angles (cluster ASA), respectively, in Tables 7.7.1.1 – 7.7.1.5 of TR38.901

*- m* denotes the ray offset angles within a cluster given by Table 7.5-3,

*-*  is the mean angle of the original channel model table in NLOS case (equation is specified in Annex A.2 of TR38.901) and the LOS angle  in LOS case,

- Tables 7.2-2 and 7.2.-3 contain the non-circular angle spread values of the original CDL models of TR38.901 before any angular scaling, ASmodel are the angular spreads derived from the original CDL Tables 7.7.1.1 – 7.7.1.5 of TR38.901. TR25.996 describes :

, (7.2-3)

The values are calculated for the AOD, AOA, ZOD, and ZOA angles after removing the mean angle following the definition of rms angular spread in TR25.996, without finding the minimum over circular shifts. Here, the calculation is performed after removing the mean angle first and subsequently equation A-2 from Annex A of TR38.901

, (7.2-4)

is used to rotate  to zero (and also wrap AOAs within +/-180). Equations A-3

, (7.2-5)

and A-1 of TR 25.996

, (7.2-6)

are used to calculate the ASmodel. Note that equation A-2 of TR 25.996 is not applied to ASmodel calculations, the following equation is used instead

ASdesired is the target angular spread. Table 7.2-4 specifies ASdesired values for CDL-A,B,C,D,E UMi and UMa at FR1 and Table 7.2-5 specifies the corresponding ASdesired values at FR2. These target values are obtained by determining median angular spreads of Table 7.5-6 of TR38.901.

The angular scaling is applied to the ray angles and no further scaling is performed. The generation of AOD (), ZOA (), and ZOD () follows a procedure similar to AOA as described above. Here, the azimuth angles may need to be wrapped around to be within [0, 360] degrees, while the zenith angles may need to be clipped to be within [0, 180] degrees.

Each CDL parameter table of contains two sets of three rows, i.e., three clusters, with exactly same angular parameters. This is harmful for the statistical properties of the models as they become non-WSS across the ensemble of model realizations. Instead of making the angular parameters non-equal by introducing small offsets to angles of the three rows, the problematic clusters are treated as midpaths as intended when the CDLs where drawn from statistical distributions which works across all frequency ranges. For the clusters that look like midpaths, e.g., Cluster 2-4 and 5-7 for CDL-A and Cluster 2-4 and 6-8 for CDL-C, the powers for each of the three clusters are added and using the regular midpath power distribution of 0.5, 0.3, and 0.2 specified in Table 7.5-5 of TR38.901, the powers for the each of the midpaths are calculated. Notice that the intra cluster delay spread in Table 7.5-5 of TR38.901 is not followed, and the same delays as the original CDL are followed for the midpaths (aka Sub-Cluster). This helps keeping the rms DS of the modified CDL to 1s.

Table 7.2-2: Original (non-circular) angle spreads of CDL models UMi and UMa (K-factor 9 dB)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Model | ASmodel [deg] | | | |
| ASD | ASA | ZSD | ZSA |
| CDL-A | 73.6985 | 85.2676 | 28.5575 | 21.0831 |
| CDL-B | 41.5917 | 59.3326 | 5.9633 | 10.3818 |
| CDL-C | 39.0949 | 71.1175 | 4.0666 | 10.4245 |
| CDL-D | 15.6771 | 17.3604 | 2.4462 | 1.5362 |
| CDL-E | 13.1544 | 37.5640 | 1.4577 | 2.4601 |

Table 7.2-3: Original (non-circular) angle spreads of CDL-D and CDL-E models InO (K-factor 7 dB)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Model | ASmodel [deg] | | | |
| ASD | ASA | ZSD | ZSA |
| CDL-D | 18.9859 | 21.0747 | 2.9629 | 1.8735 |
| CDL-E | 15.7784 | 45.3434 | 1.7692 | 2.9982 |

Table 7.2-4: Desired AS for UMi and UMa at 3.5 GHz (FR1)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Model | ASdesired [deg] | | | |
| ASD | ASA | ZSD | ZSA |
| UMi NLOS (CDL-A, B, C) | 23.9751 | 57.2457 | 0.7762 | 7.8320 |
| UMi LOS (CDL-D, E) | 15.0432 | 47.6149 | 0.6166 | 4.6204 |
| UMa NLOS (CDL-A, B, C) | 25.7620 | 74.1138 | 4.8978 | 18.2050 |
| UMa LOS (CDL-D, E) | 14.0180 | 64.5654 | 3.4674 | 8.9125 |
| Note: For UMa frequency fc = 6 as stated in [2], and other parameters hUMa = 25, hUMi = 10, hUT = 1.5, and D2D = 100. | | | | |

Table 7.2-5: Desired AS for UMi and InO at 28 GHz (FR2)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Model | ASdesired [deg] | | | |
| ASD | ASA | ZSD | ZSA |
| UMi NLOS (CDL-A, B, C) | 15.6188 | 49.3183 | 0.7762 | 7.2695 |
| UMi LOS (CDL-D, E) | 13.7050 | 41.0212 | 0.6166 | 3.8350 |
| InO NLOS (CDL-A, B, C) | 41.6869 | 50.3659 | 12.0226 | 14.7109 |
| InO LOS (CDL-D, E) | 39.8107 | 31.8526 | 1.3702 | 11.4756 |

Subsequently, the AOD angles are coupled to AOA angles within a cluster *n*. Instead of random procedure, the coupling is performed using the fixed coupling pattern specified in Table 7.2-6. The same fixed coupling pattern is applied for all clusters *n.*

Table 7.2-6: Fixed coupling pattern of ray angles to be applied for each cluster

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | m | | | | | | | | | | | | | | | | | | | |
|  | 6 | 12 | 5 | 10 | 8 | 11 | 16 | 14 | 18 | 9 | 20 | 4 | 2 | 15 | 7 | 13 | 19 | 17 | 3 | 1 |
|  | 20 | 9 | 12 | 1 | 13 | 18 | 10 | 4 | 8 | 2 | 6 | 14 | 11 | 19 | 7 | 3 | 17 | 5 | 15 | 16 |
|  | 2 | 16 | 3 | 11 | 18 | 9 | 5 | 17 | 4 | 19 | 15 | 20 | 13 | 7 | 10 | 1 | 8 | 12 | 6 | 14 |
|  | 15 | 18 | 13 | 1 | 12 | 9 | 6 | 7 | 5 | 3 | 2 | 8 | 14 | 17 | 19 | 16 | 11 | 20 | 10 | 4 |

In the next steps, the linear cross polarization power ratios (XPR) **are calculated for each ray *m* of each cluster *n* as

, (7.2-7)

where *X* is the per-cluster XPR in dB from Tables 7.7.1.1 – 7.7.1.5 of TR38.901.

The gNB beam pattern including the assumptions for gNB antenna for definitions and symbols of subclause 7.3 of TR38.901 for FR1 and FR2 are summarized in Table 7.2-7.

Table 7.2-7: BS Antenna Parameters

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Parameter description | Symbol | Parameter value | | |
| FR1 ≤2.5GHz | FR1 >2.5GHz | FR2 |
| Antenna panels in vertical dimension | *Mg* | 1 | 1 | 1 |
| Antenna panels in horizontal dimension | *Ng* | 1 | 1 | 1 |
| Elements per panel in vertical dimension | *Me* | 4 | 8 | 8 |
| Elements per panel in horizontal dimension | *Ne* | 8 | 8 | 16 |
| Number of polarizations per panel | *P* | 2 | 2 | 2 |
| Element spacing in horizontal dimension (λ) | *dH* | 0.5 | 0.5 | 0.5 |
| Element spacing in vertical dimension (λ) | *dV* | 0.5 | 0.5 | 0.5 |

Antenna element radiation patterns, including orientation of the element main polarization components as well as orientation of the antenna array for both FR1 and FR2 are as in the example pattern in Table 7.3-1 of TR38.901. The antenna element has ±45 polarization components and the radiation pattern parameters are θ3dB = 65°, 3dB = 65°, Amax = 30dB,SLAv = 30dB, *GE,max* =8 dBi.

It is assumed the co-polarized elements of the array are combined to a single RF port, i.e. they compose an antenna array that can form beams by setting certain weights per element. Weight vector for the first polarization and for the second polarization is

, (7.2-8)



where is the location vector of transmit antenna element and , and is a spherical unit vector denoting the target beam direction. Determination of beam directions is

described in section 7.3..

Random initial phase  are not used for the different polarization combinations (*θθ, θϕ, ϕθ, ϕϕ*). Instead, a fixed and pre-defined set of initial phases of Table 7.2-8 and a scalar random initial phase term is used for each ray *m* of each cluster *n*.

The set of fixed initial phases can be same for all clusters, i.e. etc. for all four polarization combinations. These 20×4 initial phase values can be specified either by a table of values or by setting a random number generator and a fixed seed number. The distribution of scalar initial phases is uniform within . Its purpose is to enable generation of different fading sequences on different uses of the model, but still maintaining the power angular distribution of the model. The scalar initial phases can be fixed (or removed) if completely deterministic process, i.e. exactly same fading sequences at each model use, is aimed at.

Table 7.2-8: Fixed initial phases for 2x2 polarization matrices. These values are drawn from uniform distribution

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| *m* | [rad] | [rad] | [rad] | [rad] |
| 1 | 1.7609 | -0.6928 | -1.6230 | -0.6037 |
| 2 | -2.5356 | -2.3124 | 2.7775 | 2.8660 |
| 3 | 0.4725 | -2.7660 | -1.6664 | -0.9226 |
| 4 | 2.0181 | -3.0448 | -2.8713 | -2.0798 |
| 5 | 0.9369 | 1.4560 | 0.9283 | -0.3084 |
| 6 | 0.2954 | -1.2798 | 1.5375 | -1.9544 |
| 7 | 1.1735 | -1.9886 | -0.8263 | 0.7893 |
| 8 | 1.7607 | -2.6319 | 2.6979 | 1.7324 |
| 9 | -0.0830 | -0.4030 | -0.3344 | -1.2167 |
| 10 | 0.0535 | 0.0677 | 1.9957 | 1.8525 |
| 11 | 0.9068 | -0.7627 | 1.9577 | 0.2062 |
| 12 | -0.9379 | 2.7583 | 2.3621 | 0.3151 |
| 13 | 0.7695 | 0.5469 | -1.8363 | -1.2488 |
| 14 | -0.1827 | -1.6934 | 2.1634 | -1.9179 |
| 15 | -1.7221 | -2.0690 | -1.7111 | -0.4040 |
| 16 | -1.1869 | 2.6602 | -0.4385 | -1.9804 |
| 17 | 2.5439 | 3.0143 | -0.3841 | -2.4434 |
| 18 | -1.5201 | -0.5735 | 0.5962 | -1.4941 |
| 19 | 0.6462 | 1.3271 | -1.7483 | -2.4038 |
| 20 | -1.2775 | -1.1386 | -0.4765 | 0.0494 |

To determine the channel all clusters are treated as "weaker cluster", i.e., no further sub-clusters in delay should be generated. The BS beamforming weights defined in Equation 7.2-8for antenna elements are used and the BS antenna signals are summed for BS beamforming. The BS transmits downlink signals with *S* beams. Index denotes the formed beam index. Each beam may have different and thus the beamforming weight of eq. (7.2-8) becomes specific for index *s* as ; it should be noted though that there are always two orthogonally polarized beams to the same direction. Here, the random initial phases are used for sub-paths, but not for the different polarization combinations (*θθ*, *θϕ,* *ϕθ,* *ϕϕ*). The channel coefficient for time instant *t*, Rx antenna/beam *u*, Tx beam *s*, and cluster *n* is defined by the following equations. They apply for the NLOS clusters and the LOS path, respectively:

, (7.2-9)

, (7.2-10)

where , , and are the theta and phi polarized radiation patterns and the position vector of the BS antenna element of sub-array *s*, respectively.Symbols *Frx,u,θ* , *Frx,u,ϕ*, , , and , are determined as in TR 38.901. UE velocity vector is determined as

 (7.2-11)

UE velocity *v* is defined as follows: 30km/h for FR1 vs 3 km/h (Indoor Office) and 12 km/h (UMi) for FR2. The UE travelling direction (**v, **v) are as follows for FR1:

- (135°,90o) for UMi CDL A channel model

- ([127.0455°],90o) for UMi CDL C channel model

- ([182.1659°],90o) for UMa CDL A channel model

- (65°,90o) for UMa CDL C channel model

The UE travelling direction (**v, **v) are as follows for FR2:

- (112.51°,90°) for InO CDL-A channel model

- (74.11°,90°) for UMi CDL-C channel model

### 7.2.1 Channel Models for FR1

The Channel model parameter tables for CDL-A, B, C, D, and E for UMa and UMi at 3.5 GHz are presented in this subclause without the effect of base station antenna filtering.

For FR1, the baseline emulated propagation environment for FR1 MIMO OTA is 2D without elevation modelling, i.e., all ZOA are set 90° and ZSA is 0° in the following tables.

Tables 7.2.1-1—7.2.1-5 show the model parameters, UMi CDL-A—CDL-E models, respectively. For the determination of desired zenith spread of departure (ZSDdesired) from table 7.5-8 of TR38.901, the following parameters are used hBS = 10 m, hUT = 1.5 m, and d2d = 100 m.

Table 7.2.1-1: Channel model parameters for UMi CDL-A at 3.5 GHz

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Cluster # | Absolute Delay [ns] | Power in [dB] | AOD in [°] | AOA in [°] | ZOD in [°] | ZOA in [°] |
| 1 | 0 | -13.4014 | -59.324 | 98.721 | 95.9936 | 90 |
| 2 | 38.19 | 0 | -2.752 | -156.546 | 97.1624 | 90 |
| 3 | 40.25 | -2.2185 | -2.752 | -156.546 | 97.1624 | 90 |
| 4 | 58.68 | -3.9794 | -2.752 | -156.546 | 97.1624 | 90 |
| 5 | 46.1 | -5.9799 | 27.9576 | 115.7066 | 97.9452 | 90 |
| 6 | 53.75 | -8.1984 | 27.9576 | 115.7066 | 97.9452 | 90 |
| 7 | 67.08 | -9.9593 | 27.9576 | 115.7066 | 97.9452 | 90 |
| 8 | 57.5 | -10.5014 | 38.1399 | -55.2369 | 98.7118 | 90 |
| 9 | 76.18 | -7.5014 | -27.9638 | -82.1587 | 96.1295 | 90 |
| 10 | 153.75 | -15.9014 | 50.144 | 127.5226 | 95.3467 | 90 |
| 11 | 189.78 | -6.6014 | -28.3867 | 99.1238 | 98.0648 | 90 |
| 12 | 222.42 | -16.7014 | 42.4666 | -131.84 | 99.2935 | 90 |
| 13 | 217.18 | -12.4014 | -51.1586 | 82.1383 | 98.7444 | 90 |
| 14 | 249.42 | -15.2014 | -57.3396 | 115.7066 | 98.902 | 90 |
| 15 | 251.19 | -10.8014 | -43.6439 | -58.728 | 95.912 | 90 |
| 16 | 305.82 | -11.3014 | -45.6283 | -69.4699 | 95.7272 | 90 |
| 17 | 408.1 | -12.7014 | 52.4212 | -85.7169 | 95.806 | 90 |
| 18 | 445.79 | -16.2014 | 46.8909 | 138.3987 | 99.0271 | 90 |
| 19 | 456.95 | -18.3014 | 41.7835 | 161.2923 | 94.9226 | 90 |
| 20 | 479.66 | -18.9014 | -39.9679 | 168.543 | 95.083 | 90 |
| 21 | 500.66 | -16.6014 | -51.5165 | 132.7593 | 99.2962 | 90 |
| 22 | 530.43 | -19.9014 | 39.7665 | -155.942 | 95.2461 | 90 |
| 23 | 965.86 | -29.7014 | -19.6683 | 101.3393 | 98.5677 | 90 |
| Per-Cluster Parameters | | | | | | |
| Parameter | CASD in [°] | CASA in [°] | CZSD in [°] | CZSA in [°] | XPR in [dB] |  |
| Value | 1.6266 | 7.385 | 0.0815 | 0 | 10 |  |

Table 7.2.1-2: Channel model parameters for UMi CDL-B at 3.5 GHz

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Cluster # | Absolute Delay [ns] | Power in [dB] | AOD in [°] | AOA in [°] | ZOD in [°] | ZOA in [°] |
| 1 | 0 | 0 | 3.2594 | -173.655 | 105.6621 | 90 |
| 2 | 10.72 | -2.2185 | 3.2594 | -173.655 | 105.6621 | 90 |
| 3 | 21.55 | -3.9794 | 3.2594 | -173.655 | 105.6621 | 90 |
| 4 | 20.95 | -3.2014 | -21.7581 | 127.2975 | 106.8987 | 90 |
| 5 | 28.7 | -9.8014 | -39.8007 | -91.3552 | 107.4194 | 90 |
| 6 | 29.86 | -1.2 | -8.6729 | 155.8564 | 105.3237 | 90 |
| 7 | 37.52 | -3.4185 | -8.6729 | 155.8564 | 105.3237 | 90 |
| 8 | 50.55 | -5.1794 | -8.6729 | 155.8564 | 105.3237 | 90 |
| 9 | 36.81 | -7.6014 | -40.8383 | -93.0919 | 107.2762 | 90 |
| 10 | 36.97 | -3.0014 | 28.1617 | 133.6653 | 105.1674 | 90 |
| 11 | 57 | -8.9014 | -43.6052 | -87.11 | 104.9592 | 90 |
| 12 | 52.83 | -9.0014 | 40.7281 | 98.1597 | 104.6858 | 90 |
| 13 | 110.21 | -4.8014 | -32.1917 | 106.2642 | 105.3497 | 90 |
| 14 | 127.56 | -5.7014 | -31.2117 | -91.1623 | 105.2325 | 90 |
| 15 | 154.74 | -7.5014 | 33.292 | -95.697 | 105.0893 | 90 |
| 16 | 178.42 | -1.9014 | 15.5376 | -140.658 | 105.2976 | 90 |
| 17 | 201.69 | -7.6014 | -43.8934 | -93.8638 | 104.9071 | 90 |
| 18 | 282.94 | -12.2014 | -54.327 | 62.7505 | 106.8857 | 90 |
| 19 | 302.19 | -9.8014 | -46.8333 | -82.6718 | 104.9722 | 90 |
| 20 | 361.87 | -11.4014 | -49.7155 | 69.6972 | 107.4584 | 90 |
| 21 | 410.67 | -14.9014 | -61.8207 | 57.058 | 107.3413 | 90 |
| 22 | 427.9 | -9.2014 | 41.4774 | 91.7918 | 107.2241 | 90 |
| 23 | 478.34 | -11.3014 | -46.8333 | -64.726 | 106.9508 | 90 |
| Per-Cluster Parameters | | | | | | |
| Parameter | CASD in [°] | CASA in [°] | CZSD in [°] | CZSA in [°] | XPR in [dB] |  |
| Value | 5.7644 | 21.2262 | 0.3905 | 0 | 8 |  |

Table 7.2.1-3: 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 7.2.1-4: Channel model parameters for UMi CDL-D at 3.5 GHz

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Cluster # | Cluster PAS | Absolute Delay [ns] | Power in [dB] | AOD in [°] | AOA in [°] | ZOD in [°] | ZOA in [°] |
| 1 | Specular (LOS path) | 0 | -0.2 | 0 | 180 | 98.5 | 90 |
| Laplacian | 0 | -13.8303 | 0 | -180 | 98.5 | 90 |
| 2 | Laplacian | 3.5275 | -19.1289 | 85.5931 | -69.0402 | 95.2232 | 90 |
| 3 | Laplacian | 61.6807 | -21.3474 | 85.5931 | -69.0402 | 95.2232 | 90 |
| 4 | Laplacian | 137.3705 | -23.1083 | 85.5931 | -69.0402 | 95.2232 | 90 |
| 5 | Laplacian | 141.6035 | -18.2289 | 12.4743 | 133.3735 | 98.2479 | 90 |
| 6 | Laplacian | 181.8169 | -20.4474 | 12.4743 | 133.3735 | 98.2479 | 90 |
| 7 | Laplacian | 261.6389 | -22.2083 | 12.4743 | 133.3735 | 98.2479 | 90 |
| 8 | Laplacian | 178.8941 | -23.2303 | 33.2009 | -62.0624 | 98.5 | 90 |
| 9 | Laplacian | 407.3746 | -28.1303 | -61.8919 | -109.358 | 95.9542 | 90 |
| 10 | Laplacian | 799.9337 | -23.9303 | -31.5697 | 36.555 | 96.6852 | 90 |
| 11 | Laplacian | 949.8016 | -25.1303 | 50.4731 | -14.3389 | 99.8359 | 90 |
| 12 | Laplacian | 978.4246 | -30.3303 | -126.759 | -71.2668 | 93.9125 | 90 |
| 13 | Laplacian | 1262.337 | -28.0303 | 74.0784 | 83.851 | 95.4753 | 90 |
| Per-Cluster Parameters | | | | | | | |
| Parameter |  | CASD in [°] | CASA in [°] | CZSD in [°] | CZSA in [°] | XPR in [dB] |  |
| Value |  | 4.7978 | 21.9419 | 0.7562 | 0 | 11 |  |

Table 7.2.1-5: Channel model parameters for UMi CDL-E at 3.5 GHz

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Cluster # | Cluster PAS | Absolute Delay [ns] | Power in [dB] | AOD in [°] | AOA in [°] | ZOD in [°] | ZOA in [°] |
| 1 | Specular (LOS path) | 0 | -0.03 | 0 | 180 | 99.6 | 90 |
| Laplacian | 0 | -22.2442 | 0 | -180 | 99.6 | 90 |
| 2 | Laplacian | 49.9706 | -16.0427 | 65.756 | -25.0925 | 101.5457 | 90 |
| 3 | Laplacian | 52.9593 | -18.2612 | 65.756 | -25.0925 | 101.5457 | 90 |
| 4 | Laplacian | 54.8089 | -20.0221 | 65.756 | -25.0925 | 101.5457 | 90 |
| 5 | Laplacian | 52.9593 | -23.1142 | -22.986 | 80.8762 | 99.5154 | 90 |
| 6 | Laplacian | 69.2365 | -22.6142 | 18.526 | 94.9462 | 100.1076 | 90 |
| 7 | Laplacian | 185.8637 | -18.8128 | 10.6353 | -148.945 | 99.2616 | 90 |
| 8 | Laplacian | 187.8204 | -21.0313 | 10.6353 | -148.945 | 99.2616 | 90 |
| 9 | Laplacian | 190.702 | -22.7922 | 10.6353 | -148.945 | 99.2616 | 90 |
| 10 | Laplacian | 257.2613 | -22.5142 | 21.7281 | -133.48 | 100.1076 | 90 |
| 11 | Laplacian | 361.5249 | -25.8142 | 37.3951 | -71.8765 | 98.2465 | 90 |
| 12 | Laplacian | 530.7998 | -20.4142 | 0.5718 | 138.1703 | 99.3039 | 90 |
| 13 | Laplacian | 1168.55 | -30.0142 | 63.9262 | 2.2763 | 97.9081 | 90 |
| 14 | Laplacian | 2009.522 | -29.4142 | 65.8703 | 15.2055 | 101.7149 | 90 |
| Per-Cluster Parameters | | | | | | | |
| Parameter |  | CASD in [°] | CASA in [°] | CZSD in [°] | CZSA in [°] | XPR in [dB] |  |
| Value |  | 5.7179 | 13.9432 | 1.2689 | 0 | 8 |  |

Tables 7.2.1-6—7.2.1-10 tabulate channel model parameters for UMa CDL-A—CDL-E models at 3.5 GHz, respectively.

In the determination of desired angle spreads (ASdesired), frequency is set 6 GHz as stated in Table 7.5-6 Part-1 of TR38.901.

For the determination of desired zenith spread of departure (ZSDdesired) from table 7.5-7 of TR38.901, the following parameters are used hUT = 1.5 m, and d2d = 100 m.

Table 7.2.1-6: Channel model parameters for UMa CDL-A at 3.5 GHz

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Cluster # | Absolute Delay [ns] | Power in [dB] | AOD in [°] | AOA in [°] | ZOD in [°] | ZOA in [°] |
| 1 | 0 | -13.4014 | -63.5923 | 70.1754 | 89.1998 | 90 |
| 2 | 139.3935 | 0 | -2.804 | -154.231 | 96.5746 | 90 |
| 3 | 146.9125 | -2.2185 | -2.804 | -154.231 | 96.5746 | 90 |
| 4 | 214.182 | -3.9794 | -2.804 | -154.231 | 96.5746 | 90 |
| 5 | 168.265 | -5.9799 | 30.1944 | 92.1659 | 101.5139 | 90 |
| 6 | 196.1875 | -8.1984 | 30.1944 | 92.1659 | 101.5139 | 90 |
| 7 | 244.842 | -9.9593 | 30.1944 | 92.1659 | 101.5139 | 90 |
| 8 | 209.875 | -10.5014 | 41.1356 | -23.0699 | 106.3504 | 90 |
| 9 | 278.057 | -7.5014 | -29.8948 | -57.9245 | 90.0573 | 90 |
| 10 | 561.1875 | -15.9014 | 54.0343 | 107.4637 | 85.1179 | 90 |
| 11 | 692.697 | -6.6014 | -30.3493 | 70.6969 | 102.2686 | 90 |
| 12 | 811.833 | -16.7014 | 45.7847 | -122.245 | 110.0206 | 90 |
| 13 | 792.707 | -12.4014 | -54.8184 | 48.7064 | 106.5562 | 90 |
| 14 | 910.383 | -15.2014 | -61.46 | 92.1659 | 107.551 | 90 |
| 15 | 916.8435 | -10.8014 | -46.7436 | -27.5897 | 88.6853 | 90 |
| 16 | 1116.243 | -11.3014 | -48.8759 | -41.4968 | 87.519 | 90 |
| 17 | 1489.565 | -12.7014 | 56.4812 | -62.5312 | 88.0164 | 90 |
| 18 | 1627.1335 | -16.2014 | 50.5387 | 121.5446 | 108.3399 | 90 |
| 19 | 1667.8675 | -18.3014 | 45.0506 | 151.184 | 82.4424 | 90 |
| 20 | 1750.759 | -18.9014 | -42.7936 | 160.5712 | 83.4543 | 90 |
| 21 | 1827.409 | -16.6014 | -55.2029 | 114.2434 | 110.0378 | 90 |
| 22 | 1936.0695 | -19.9014 | 42.8834 | -153.449 | 84.4834 | 90 |
| 23 | 3525.389 | -29.7014 | -20.9811 | 73.5652 | 105.4414 | 90 |
| Per-Cluster Parameters | | | | | | |
| Parameter | CASD in [°] | CASA in [°] | CZSD in [°] | CZSA in [°] | XPR in [dB] |  |
| Value | 1.7478 | 9.5611 | 0.5145 | 0 | 10 |  |

Table 7.2.1-7: Channel model parameters for UMa CDL-B at 3.5 GHz

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Cluster # | Absolute Delay [ns] | Power in [dB] | AOD in [°] | AOA in [°] | ZOD in [°] | ZOA in [°] |
| 1 | 0 | 0 | 3.8721 | -170.785 | 105.7717 | 90 |
| 2 | 39.128 | -2.2185 | 3.8721 | -170.785 | 105.7717 | 90 |
| 3 | 78.6575 | -3.9794 | 3.8721 | -170.785 | 105.7717 | 90 |
| 4 | 76.4675 | -3.2014 | -23.0099 | 112.7684 | 113.5742 | 90 |
| 5 | 104.755 | -9.8014 | -42.3972 | -64.2347 | 116.8595 | 90 |
| 6 | 108.989 | -1.2 | -8.9495 | 149.7425 | 103.6362 | 90 |
| 7 | 136.948 | -3.4185 | -8.9495 | 149.7425 | 103.6362 | 90 |
| 8 | 184.5075 | -5.1794 | -8.9495 | 149.7425 | 103.6362 | 90 |
| 9 | 134.3565 | -7.6014 | -43.5122 | -66.4831 | 115.956 | 90 |
| 10 | 134.9405 | -3.0014 | 30.6303 | 121.0127 | 102.6507 | 90 |
| 11 | 208.05 | -8.9014 | -46.4853 | -58.7386 | 101.3365 | 90 |
| 12 | 192.8295 | -9.0014 | 44.1333 | 75.0448 | 99.6118 | 90 |
| 13 | 402.2665 | -4.8014 | -34.2211 | 85.5375 | 103.8005 | 90 |
| 14 | 465.594 | -5.7014 | -33.1681 | -63.9849 | 103.0613 | 90 |
| 15 | 564.801 | -7.5014 | 36.143 | -69.8558 | 102.1579 | 90 |
| 16 | 651.233 | -1.9014 | 17.0654 | -128.065 | 103.472 | 90 |
| 17 | 736.1685 | -7.6014 | -46.795 | -67.4824 | 101.008 | 90 |
| 18 | 1032.731 | -12.2014 | -58.0062 | 29.2019 | 113.4921 | 90 |
| 19 | 1102.994 | -9.8014 | -49.9539 | -52.9926 | 101.4187 | 90 |
| 20 | 1320.826 | -11.4014 | -53.051 | 38.1956 | 117.1059 | 90 |
| 21 | 1498.946 | -14.9014 | -66.0584 | 21.8321 | 116.3667 | 90 |
| 22 | 1561.835 | -9.2014 | 44.9385 | 66.8006 | 115.6275 | 90 |
| 23 | 1745.941 | -11.3014 | -49.9539 | -29.7588 | 113.9027 | 90 |
| Per-Cluster Parameters | | | | | | |
| Parameter | CASD in [°] | CASA in [°] | CZSD in [°] | CZSA in [°] | XPR in [dB] |  |
| Value | 6.194 | 27.4808 | 2.464 | 0 | 8 |  |

Table 7.2.1-8: 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 |  |

Table 7.2.1-9: Channel model parameters for UMa CDL-D at 3.5 GHz

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Cluster # | Cluster PAS | Absolute Delay [ns] | Power in [dB] | AOD in [°] | AOA in [°] | ZOD in [°] | ZOA in [°] |
| 1 | Specular (LOS path) | 0 | -0.2 | 0 | 180 | 98.5 | 90 |
| Laplacian | 0 | -13.8303 | 0 | -180 | 98.5 | 90 |
| 2 | Laplacian | 12.8753 | -19.1289 | 79.7601 | -157.697 | 80.0732 | 90 |
| 3 | Laplacian | 225.1344 | -21.3474 | 79.7601 | -157.697 | 80.0732 | 90 |
| 4 | Laplacian | 501.4023 | -23.1083 | 79.7601 | -157.697 | 80.0732 | 90 |
| 5 | Laplacian | 516.8527 | -18.2289 | 11.6242 | 116.7749 | 97.0826 | 90 |
| 6 | Laplacian | 663.6315 | -20.4474 | 11.6242 | 116.7749 | 97.0826 | 90 |
| 7 | Laplacian | 954.9819 | -22.2083 | 11.6242 | 116.7749 | 97.0826 | 90 |
| 8 | Laplacian | 652.9634 | -23.2303 | 30.9383 | -20.0777 | 98.5 | 90 |
| 9 | Laplacian | 1486.917 | -28.1303 | -57.6741 | 147.6324 | 84.1838 | 90 |
| 10 | Laplacian | 2919.758 | -23.9303 | -29.4182 | -14.5102 | 88.2944 | 90 |
| 11 | Laplacian | 3466.776 | -25.1303 | 47.0334 | 44.6351 | 106.0125 | 90 |
| 12 | Laplacian | 3571.25 | -30.3303 | -118.12 | 95.5983 | 72.7025 | 90 |
| 13 | Laplacian | 4607.53 | -28.0303 | 69.03 | 177.7798 | 81.4907 | 90 |
| Per-Cluster Parameters | | | | | | | |
| Parameter |  | CASD in [°] | CASA in [°] | CZSD in [°] | CZSA in [°] | XPR in [dB] |  |
| Value |  | 4.4709 | 29.753 | 4.2523 | 0 | 11 |  |

Table 7.2.1-10: Channel model parameters for UMa CDL-E at 3.5 GHz

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Cluster # | Cluster PAS | Absolute Delay [ns] | Power in [dB] | AOD in [°] | AOA in [°] | ZOD in [°] | ZOA in [°] |
| 1 | Specular (LOS path) | 0 | -0.03 | 0 | 180 | 99.6 | 90 |
| Laplacian | 0 | -22.2442 | 0 | -180 | 99.6 | 90 |
| 2 | Laplacian | 182.3926 | -16.0427 | 61.2748 | -98.1037 | 110.5415 | 90 |
| 3 | Laplacian | 193.3013 | -18.2612 | 61.2748 | -98.1037 | 110.5415 | 90 |
| 4 | Laplacian | 200.0527 | -20.0221 | 61.2748 | -98.1037 | 110.5415 | 90 |
| 5 | Laplacian | 193.3013 | -23.1142 | -21.4195 | 45.5889 | 99.1243 | 90 |
| 6 | Laplacian | 252.7131 | -22.6142 | 17.2635 | 64.6678 | 102.4543 | 90 |
| 7 | Laplacian | 678.4024 | -18.8128 | 9.9105 | -137.889 | 97.6971 | 90 |
| 8 | Laplacian | 685.5446 | -21.0313 | 9.9105 | -137.889 | 97.6971 | 90 |
| 9 | Laplacian | 696.0624 | -22.7922 | 9.9105 | -137.889 | 97.6971 | 90 |
| 10 | Laplacian | 939.0038 | -22.5142 | 20.2473 | -116.92 | 102.4543 | 90 |
| 11 | Laplacian | 1319.566 | -25.8142 | 34.8467 | -33.3854 | 91.9885 | 90 |
| 12 | Laplacian | 1937.419 | -20.4142 | 0.5328 | 123.2792 | 97.935 | 90 |
| 13 | Laplacian | 4265.208 | -30.0142 | 59.5698 | 67.1651 | 90.0856 | 90 |
| 14 | Laplacian | 7334.755 | -29.4142 | 61.3814 | 84.697 | 111.493 | 90 |
| Per-Cluster Parameters | | | | | | | |
| Parameter |  | CASD in [°] | CASA in [°] | CZSD in [°] | CZSA in [°] | XPR in [dB] |  |
| Value |  | 5.3282 | 18.9069 | 7.1358 | 0 | 8 |  |

### 7.2.2 Channel Models for FR2

Channel model parameter tables for CDL-A and C for UMi and InO at 28 GHz are presented in this subclause. The channel model tables presented here are only the propagation parameters, i.e., without the effect of base station antenna filtering.

Tables 7.2.2-1—7.2.2.5 show the model parameters, UMi CDL-A—CDL-E models, respectively. For the determination of desired zenith spread of departure (ZSDdesired) from table 7.5-8 of TR38.901, the following parameters are used hBS = 10 m, hUT = 1.5 m, and d2d = 100 m.

Table 7.2.2-1: Channel model parameters for UMi CDL-A at 28 GHz

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Cluster # | Absolute Delay [ns] | Power in [dB] | AOD in [°] | AOA in [°] | ZOD in [°] | ZOA in [°] |
| 1 | 0 | -13.4014 | -39.363 | 112.1365 | 95.9936 | 100.6889 |
| 2 | 22.914 | 0 | -2.5086 | -157.634 | 97.1624 | 88.9311 |
| 3 | 24.15 | -2.2185 | -2.5086 | -157.634 | 97.1624 | 88.9311 |
| 4 | 35.208 | -3.9794 | -2.5086 | -157.634 | 97.1624 | 88.9311 |
| 5 | 27.66 | -5.9799 | 17.4974 | 126.7698 | 97.9452 | 89.8621 |
| 6 | 32.25 | -8.1984 | 17.4974 | 126.7698 | 97.9452 | 89.8621 |
| 7 | 40.248 | -9.9593 | 17.4974 | 126.7698 | 97.9452 | 89.8621 |
| 8 | 34.5 | -10.5014 | 24.1308 | -70.3543 | 98.7118 | 73.6909 |
| 9 | 45.708 | -7.5014 | -18.9331 | -93.5479 | 96.1295 | 76.7596 |
| 10 | 92.25 | -15.9014 | 31.951 | 136.9496 | 95.3467 | 67.8293 |
| 11 | 113.868 | -6.6014 | -19.2086 | 112.4835 | 98.0648 | 77.7251 |
| 12 | 133.452 | -16.7014 | 26.9494 | -136.349 | 99.2935 | 66.4156 |
| 13 | 130.308 | -12.4014 | -34.0436 | 97.8501 | 98.7444 | 74.415 |
| 14 | 149.652 | -15.2014 | -38.0703 | 126.7698 | 98.902 | 106.7919 |
| 15 | 150.714 | -10.8014 | -29.1481 | -73.3619 | 95.912 | 97.9305 |
| 16 | 183.492 | -11.3014 | -30.4408 | -82.6162 | 95.7272 | 99.7579 |
| 17 | 244.86 | -12.7014 | 33.4345 | -96.6134 | 95.806 | 99.9303 |
| 18 | 267.474 | -16.2014 | 29.8317 | 146.3196 | 99.0271 | 68.6913 |
| 19 | 274.17 | -18.3014 | 26.5044 | 166.0428 | 94.9226 | 66.8293 |
| 20 | 287.796 | -18.9014 | -26.7533 | 172.2895 | 95.083 | 62.6917 |
| 21 | 300.396 | -16.6014 | -34.2767 | 141.4611 | 99.2962 | 107.7918 |
| 22 | 318.258 | -19.9014 | 25.1904 | -157.113 | 95.2461 | 109.4124 |
| 23 | 579.516 | -29.7014 | -13.5289 | 114.3922 | 98.5677 | 111.2743 |
| Per-Cluster Parameters | | | | | | |
| Parameter | CASD in [°] | CASA in [°] | CZSD in [°] | CZSA in [°] | XPR in [dB] |  |
| Value | 1.0596 | 6.3623 | 0.0815 | 1.0344 | 10 |  |

Table 7.2.2-2: Channel model parameters for UMi CDL-B at 28 GHz

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Cluster # | Absolute Delay [ns] | Power in [dB] | AOD in [°] | AOA in [°] | ZOD in [°] | ZOA in [°] |
| 1 | 0 | 0 | 0.3941 | -175.004 | 105.6621 | 76.7603 |
| 2 | 6.432 | -2.2185 | 0.3941 | -175.004 | 105.6621 | 76.7603 |
| 3 | 12.93 | -3.9794 | 0.3941 | -175.004 | 105.6621 | 76.7603 |
| 4 | 12.57 | -3.2014 | -15.9038 | 134.1256 | 106.8987 | 65.837 |
| 5 | 17.22 | -9.8014 | -27.6578 | -104.101 | 107.4194 | 63.4563 |
| 6 | 17.916 | -1.2 | -7.3793 | 158.7297 | 105.3237 | 68.7779 |
| 7 | 22.512 | -3.4185 | -7.3793 | 158.7297 | 105.3237 | 68.7779 |
| 8 | 30.33 | -5.1794 | -7.3793 | 158.7297 | 105.3237 | 68.7779 |
| 9 | 22.086 | -7.6014 | -28.3337 | -105.597 | 107.2762 | 79.3511 |
| 10 | 22.182 | -3.0014 | 16.6169 | 139.6116 | 105.1674 | 67.9377 |
| 11 | 34.2 | -8.9014 | -30.1363 | -100.444 | 104.9592 | 64.6467 |
| 12 | 31.698 | -9.0014 | 24.8034 | 109.0228 | 104.6858 | 62.1259 |
| 13 | 66.126 | -4.8014 | -22.7008 | 116.0051 | 105.3497 | 76.2702 |
| 14 | 76.536 | -5.7014 | -22.0624 | -103.935 | 105.2325 | 78.931 |
| 15 | 92.844 | -7.5014 | 19.9591 | -107.841 | 105.0893 | 65.2068 |
| 16 | 107.052 | -1.9014 | 8.3929 | -146.576 | 105.2976 | 76.1301 |
| 17 | 121.014 | -7.6014 | -30.324 | -106.262 | 104.9071 | 64.1565 |
| 18 | 169.764 | -12.2014 | -37.1211 | 78.5171 | 106.8857 | 79.5612 |
| 19 | 181.314 | -9.8014 | -32.2392 | -96.62 | 104.9722 | 64.0865 |
| 20 | 217.122 | -11.4014 | -34.1169 | 84.5019 | 107.4584 | 61.6358 |
| 21 | 246.402 | -14.9014 | -42.0029 | 73.6129 | 107.3413 | 63.4563 |
| 22 | 256.74 | -9.2014 | 25.2916 | 103.5368 | 107.2241 | 63.5964 |
| 23 | 287.004 | -11.3014 | -32.2392 | -81.1593 | 106.9508 | 65.1368 |
| Per-Cluster Parameters | | | | | | |
| Parameter | CASD in [°] | CASA in [°] | CZSD in [°] | CZSA in [°] | XPR in [dB] |  |
| Value | 3.7533 | 18.2868 | 0.3905 | 4.9015 | 8 |  |

Table 7.2.2-3: Channel model parameters for UMi CDL-C at 28 GHz

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Cluster # | Absolute Delay [ns] | Power in [dB] | AOD in [°] | AOA in [°] | ZOD in [°] | ZOA in [°] |
| 1 | 0 | -4.4215 | -30.4353 | -134.4434 | 98.9242 | 83.3318 |
| 2 | 12.594 | -1.25 | -20.9269 | 129.1633 | 99.1915 | 72.5229 |
| 3 | 13.314 | -3.4684 | -20.9269 | 129.1633 | 99.1915 | 72.5229 |
| 4 | 13.974 | -5.2294 | -20.9269 | 129.1633 | 99.1915 | 72.5229 |
| 5 | 13.056 | -2.5215 | -28.0782 | -152.8206 | 99.5732 | 71.1282 |
| 6 | 38.196 | 0 | -11.6982 | 164.1145 | 99.306 | 74.7544 |
| 7 | 38.688 | -2.2185 | -11.6982 | 164.1145 | 99.306 | 74.7544 |
| 8 | 39.36 | -3.9794 | -11.6982 | 164.1145 | 99.306 | 74.7544 |
| 9 | 39.504 | -7.4215 | 17.3861 | 84.3647 | 100.4513 | 69.2454 |
| 10 | 47.61 | -7.1215 | -37.5865 | 92.0623 | 98.5616 | 66.7349 |
| 11 | 49.278 | -10.7215 | 20.2226 | -97.7585 | 100.6231 | 72.0348 |
| 12 | 56.016 | -11.1215 | -50.6106 | 78.4702 | 98.218 | 64.4337 |
| 13 | 73.71 | -5.1215 | -33.911 | 93.1719 | 100.165 | 85.4238 |
| 14 | 78.498 | -6.8215 | -37.5066 | -112.0441 | 100.2604 | 64.1548 |
| 15 | 130.224 | -8.7215 | -43.1797 | 102.4645 | 98.1225 | 64.7824 |
| 16 | 162.63 | -13.2215 | 29.2116 | 67.2359 | 100.2604 | 92.467 |
| 17 | 255.534 | -13.9215 | 27.8133 | 34.5731 | 98.4852 | 65.6889 |
| 18 | 276.018 | -13.9215 | 23.6584 | 48.5813 | 98.1416 | 68.7572 |
| 19 | 329.412 | -15.8215 | -52.5282 | 36.4455 | 97.9698 | 59.1339 |
| 20 | 336.462 | -17.1215 | 25.0168 | 52.6729 | 100.7376 | 65.3402 |
| 21 | 378.39 | -16.0215 | 25.4562 | 49.8296 | 98.1225 | 58.4365 |
| 22 | 398.244 | -15.7215 | 30.7697 | 46.4316 | 98.1034 | 65.2705 |
| 23 | 422.562 | -21.6215 | 35.9234 | 30.759 | 100.4513 | 62.6903 |
| 24 | 519.138 | -22.8215 | -61.2775 | 69.2469 | 100.9476 | 61.993 |
| Per-Cluster Parameters | | | | | | |
| Parameter | CASD in [°] | CASA in [°] | CZSD in [°] | CZSA in [°] | XPR in [dB] |  |
| Value | 0.799 | 10.4021 | 0.5726 | 4.8814 | 7 |  |

Table 7.2.2-4: Channel model parameters for UMi CDL-D at 28 GHz

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Cluster # | Cluster PAS | Absolute Delay [ns] | Power in [dB] | AOD in [°] | AOA in [°] | ZOD in [°] | ZOA in [°] |
| 1 | Specular (LOS path) | 0 | -0.2 | 0 | 180 | 98.5 | 81.5 |
| Laplacian | 0 | -13.8303 | 0 | -180 | 98.5 | 81.5 |
| 2 | Laplacian | 2.1165 | -19.1289 | 77.9794 | -34.5531 | 95.2232 | 94.9807 |
| 3 | Laplacian | 37.0084 | -21.3474 | 77.9794 | -34.5531 | 95.2232 | 94.9807 |
| 4 | Laplacian | 82.4223 | -23.1083 | 77.9794 | -34.5531 | 95.2232 | 94.9807 |
| 5 | Laplacian | 84.9621 | -18.2289 | 11.3647 | 139.8304 | 98.2479 | 76.2575 |
| 6 | Laplacian | 109.0901 | -20.4474 | 11.3647 | 139.8304 | 98.2479 | 76.2575 |
| 7 | Laplacian | 156.9833 | -22.2083 | 11.3647 | 139.8304 | 98.2479 | 76.2575 |
| 8 | Laplacian | 107.3364 | -23.2303 | 30.2476 | -78.3945 | 98.5 | 73.2618 |
| 9 | Laplacian | 244.4247 | -28.1303 | -56.3864 | -69.288 | 95.9542 | 61.7782 |
| 10 | Laplacian | 479.9602 | -23.9303 | -28.7614 | 56.4193 | 96.6852 | 73.5114 |
| 11 | Laplacian | 569.8809 | -25.1303 | 45.9833 | -37.2797 | 99.8359 | 95.2304 |
| 12 | Laplacian | 587.0548 | -30.3303 | -115.483 | -136.177 | 93.9125 | 54.2889 |
| 13 | Laplacian | 757.4022 | -28.0303 | 67.4889 | 47.3128 | 95.4753 | 60.0307 |
| Per-Cluster Parameters | | | | | | | |
| Parameter |  | CASD in [°] | CASA in [°] | CZSD in [°] | CZSA in [°] | XPR in [dB] |  |
| Value |  | 4.371 | 18.9034 | 0.7562 | 7.4893 | 11 |  |

Table 7.2.2-5: Channel model parameters for UMi CDL-E at 28 GHz

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Cluster # | Cluster PAS | Absolute Delay [ns] | Power in [dB] | AOD in [°] | AOA in [°] | ZOD in [°] | ZOA in [°] |
| 1 | Specular (LOS path) | 0 | -0.03 | 0 | 180 | 99.6 | 80.4 |
| Laplacian | 0 | -22.2442 | 0 | -180 | 99.6 | 80.4 |
| 2 | Laplacian | 29.9823 | -16.0427 | 59.9068 | 3.3088 | 101.5457 | 80.4 |
| 3 | Laplacian | 31.7756 | -18.2612 | 59.9068 | 3.3088 | 101.5457 | 80.4 |
| 4 | Laplacian | 32.8854 | -20.0221 | 59.9068 | 3.3088 | 101.5457 | 80.4 |
| 5 | Laplacian | 31.7756 | -23.1142 | -20.9413 | 94.6029 | 99.5154 | 81.0235 |
| 6 | Laplacian | 41.5419 | -22.6142 | 16.8781 | 106.7245 | 100.1076 | 89.5973 |
| 7 | Laplacian | 111.5182 | -18.8128 | 9.6893 | -153.245 | 99.2616 | 83.9854 |
| 8 | Laplacian | 112.6923 | -21.0313 | 9.6893 | -153.245 | 99.2616 | 83.9854 |
| 9 | Laplacian | 114.4212 | -22.7922 | 9.6893 | -153.245 | 99.2616 | 83.9854 |
| 10 | Laplacian | 154.3568 | -22.5142 | 19.7953 | -139.922 | 100.1076 | 84.2971 |
| 11 | Laplacian | 216.9149 | -25.8142 | 34.0687 | -86.8495 | 98.2465 | 92.2473 |
| 12 | Laplacian | 318.4799 | -20.4142 | 0.5209 | 143.9629 | 99.3039 | 81.3353 |
| 13 | Laplacian | 701.1301 | -30.0142 | 58.2398 | -22.9654 | 97.9081 | 93.1826 |
| 14 | Laplacian | 1205.713 | -29.4142 | 60.011 | -11.8267 | 101.7149 | 77.1264 |
| Per-Cluster Parameters | | | | | | | |
| Parameter |  | CASD in [°] | CASA in [°] | CZSD in [°] | CZSA in [°] | XPR in [dB] |  |
| Value |  | 5.2093 | 12.0124 | 1.2689 | 10.912 | 8 |  |

Tables 7.2.2-6—7.2.2.10 tabulate channel model parameters for InO CDL-A—CDL-E models at 28 GHz, respectively.

Table 7.2.2-6: Channel model parameters for InO CDL-A at 28 GHz

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Cluster # | Absolute Delay [ns] | Power in [dB] | AOD in [°] | AOA in [°] | ZOD in [°] | ZOA in [°] |
| 1 | 0 | -13.4014 | -101.633 | 110.3637 | 77.4554 | 114.0008 |
| 2 | 11.457 | 0 | -3.2678 | -157.49 | 95.5583 | 90.2073 |
| 3 | 12.075 | -2.2185 | -3.2678 | -157.49 | 95.5583 | 90.2073 |
| 4 | 17.604 | -3.9794 | -3.2678 | -157.49 | 95.5583 | 90.2073 |
| 5 | 13.83 | -5.9799 | 50.1288 | 125.3079 | 107.6831 | 92.0912 |
| 6 | 16.125 | -8.1984 | 50.1288 | 125.3079 | 107.6831 | 92.0912 |
| 7 | 20.124 | -9.9593 | 50.1288 | 125.3079 | 107.6831 | 92.0912 |
| 8 | 17.25 | -10.5014 | 67.8333 | -68.3566 | 119.5552 | 59.3663 |
| 9 | 22.854 | -7.5014 | -47.105 | -92.0429 | 79.5604 | 65.5763 |
| 10 | 46.125 | -15.9014 | 88.7055 | 135.7039 | 67.4357 | 47.5044 |
| 11 | 56.934 | -6.6014 | -47.8403 | 110.7181 | 109.5355 | 67.5301 |
| 12 | 66.726 | -16.7014 | 75.3564 | -135.753 | 128.5646 | 44.6436 |
| 13 | 65.154 | -12.4014 | -87.4352 | 95.7739 | 120.0604 | 60.8316 |
| 14 | 74.826 | -15.2014 | -98.1824 | 125.3079 | 122.5022 | 126.3512 |
| 15 | 75.357 | -10.8014 | -74.3689 | -71.4282 | 76.1924 | 108.4188 |
| 16 | 91.746 | -11.3014 | -77.8193 | -80.879 | 73.3297 | 112.1169 |
| 17 | 122.43 | -12.7014 | 92.665 | -95.1735 | 74.5505 | 112.4658 |
| 18 | 133.737 | -16.2014 | 83.0491 | 145.2729 | 124.4388 | 49.2488 |
| 19 | 137.085 | -18.3014 | 74.1685 | 165.4151 | 60.8681 | 45.4809 |
| 20 | 143.898 | -18.9014 | -67.9771 | 171.7944 | 63.352 | 37.1078 |
| 21 | 150.198 | -16.6014 | -88.0574 | 140.3112 | 128.6067 | 128.3747 |
| 22 | 159.129 | -19.9014 | 70.6615 | -156.959 | 65.878 | 131.6542 |
| 23 | 289.758 | -29.7014 | -32.6811 | 112.6674 | 117.3239 | 135.4221 |
| Per-Cluster Parameters | | | | | | |
| Parameter | CASD in [°] | CASA in [°] | CZSD in [°] | CZSA in [°] | XPR in [dB] |  |
| Value | 2.8282 | 6.4975 | 1.263 | 2.0933 | 10 |  |

Table 7.2.2-7: Channel model parameters for InO CDL-B at 28 GHz

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Cluster # | Absolute Delay [ns] | Power in [dB] | AOD in [°] | AOA in [°] | ZOD in [°] | ZOA in [°] |
| 1 | 0 | 0 | 9.3327 | -174.826 | 105.9611 | 81.8761 |
| 2 | 3.216 | -2.2185 | 9.3327 | -174.826 | 105.9611 | 81.8761 |
| 3 | 6.465 | -3.9794 | 9.3327 | -174.826 | 105.9611 | 81.8761 |
| 4 | 6.285 | -3.2014 | -34.1667 | 133.2233 | 125.1141 | 59.7711 |
| 5 | 8.61 | -9.8014 | -65.5384 | -102.417 | 133.1785 | 54.9534 |
| 6 | 8.958 | -1.2 | -11.4147 | 158.35 | 100.7192 | 65.7225 |
| 7 | 11.256 | -3.4185 | -11.4147 | 158.35 | 100.7192 | 65.7225 |
| 8 | 15.165 | -5.1794 | -11.4147 | 158.35 | 100.7192 | 65.7225 |
| 9 | 11.043 | -7.6014 | -67.3425 | -103.945 | 130.9608 | 87.119 |
| 10 | 11.091 | -3.0014 | 52.6316 | 138.8259 | 98.2999 | 64.0221 |
| 11 | 17.1 | -8.9014 | -72.1535 | -98.6816 | 95.0741 | 57.3623 |
| 12 | 15.849 | -9.0014 | 74.4815 | 107.5873 | 90.8403 | 52.2611 |
| 13 | 33.063 | -4.8014 | -52.3082 | 114.7179 | 101.1224 | 80.8842 |
| 14 | 38.268 | -5.7014 | -50.6043 | -102.247 | 99.308 | 86.2688 |
| 15 | 46.422 | -7.5014 | 61.552 | -106.237 | 97.0902 | 58.4959 |
| 16 | 53.526 | -1.9014 | 30.6814 | -145.794 | 100.316 | 80.6008 |
| 17 | 60.507 | -7.6014 | -72.6547 | -104.624 | 94.2677 | 56.3704 |
| 18 | 84.882 | -12.2014 | -90.7961 | 76.4337 | 124.9125 | 87.5441 |
| 19 | 90.657 | -9.8014 | -77.7663 | -94.7768 | 95.2758 | 56.2287 |
| 20 | 108.561 | -11.4014 | -82.7778 | 82.5456 | 133.7833 | 51.2692 |
| 21 | 123.201 | -14.9014 | -103.826 | 71.4253 | 131.9688 | 54.9534 |
| 22 | 128.37 | -9.2014 | 75.7845 | 101.9848 | 130.1543 | 55.2368 |
| 23 | 143.502 | -11.3014 | -77.7663 | -78.9878 | 125.9205 | 58.3542 |
| Per-Cluster Parameters | | | | | | |
| Parameter | CASD in [°] | CASA in [°] | CZSD in [°] | CZSA in [°] | XPR in [dB] |  |
| Value | 10.0229 | 18.6752 | 6.0483 | 9.9189 | 8 |  |

Table 7.2.2-8: Channel model parameters for InO CDL-C at 28 GHz

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Cluster # | Absolute Delay [ns] | Power in [dB] | AOD in [°] | AOA in [°] | ZOD in [°] | ZOA in [°] |
| 1 | 0 | -4.4215 | -48.3848 | -132.8363 | 93.0309 | 93.3988 |
| 2 | 6.297 | -1.25 | -23.0068 | 128.723 | 97.1699 | 71.5254 |
| 3 | 6.657 | -3.4684 | -23.0068 | 128.723 | 97.1699 | 71.5254 |
| 4 | 6.987 | -5.2294 | -23.0068 | 128.723 | 97.1699 | 71.5254 |
| 5 | 6.528 | -2.5215 | -42.0936 | -151.6038 | 103.0827 | 68.703 |
| 6 | 19.098 | 0 | 1.6247 | 164.4166 | 98.9437 | 76.0412 |
| 7 | 19.344 | -2.2185 | 1.6247 | 164.4166 | 98.9437 | 76.0412 |
| 8 | 19.68 | -3.9794 | 1.6247 | 164.4166 | 98.9437 | 76.0412 |
| 9 | 19.752 | -7.4215 | 79.2514 | 82.9728 | 116.6821 | 64.8928 |
| 10 | 23.805 | -7.1215 | -67.4716 | 90.8339 | 87.4138 | 59.8126 |
| 11 | 24.639 | -10.7215 | 86.8222 | -95.3722 | 119.3429 | 70.5376 |
| 12 | 28.008 | -11.1215 | -102.233 | 76.9531 | 82.0922 | 55.1556 |
| 13 | 36.855 | -5.1215 | -57.6616 | 91.9671 | 112.2475 | 97.6324 |
| 14 | 39.249 | -6.8215 | -67.2583 | -109.9613 | 113.7257 | 54.5912 |
| 15 | 65.112 | -8.7215 | -82.3998 | 101.457 | 80.614 | 55.8612 |
| 16 | 81.315 | -13.2215 | 110.8139 | 65.4801 | 113.7257 | 111.8854 |
| 17 | 127.767 | -13.9215 | 107.0819 | 32.1236 | 86.2312 | 57.6958 |
| 18 | 138.009 | -13.9215 | 95.9924 | 46.4294 | 80.9097 | 63.905 |
| 19 | 164.706 | -15.8215 | -107.3512 | 34.0358 | 78.2489 | 44.4306 |
| 20 | 168.231 | -17.1215 | 99.6178 | 50.6078 | 121.1167 | 56.9902 |
| 21 | 189.195 | -16.0215 | 100.7907 | 47.7042 | 80.614 | 43.0194 |
| 22 | 199.122 | -15.7215 | 114.9725 | 44.234 | 80.3184 | 56.8491 |
| 23 | 211.281 | -21.6215 | 128.7278 | 28.2285 | 116.6821 | 51.6277 |
| 24 | 259.569 | -22.8215 | -130.7032 | 67.5339 | 124.3688 | 50.2165 |
| Per-Cluster Parameters | | | | | | |
| Parameter | CASD in [°] | CASA in [°] | CZSD in [°] | CZSA in [°] | XPR in [dB] |  |
| Value | 2.1326 | 10.6231 | 8.8692 | 9.8783 | 7 |  |

Table 7.2.2-9: Channel model parameters for InO CDL-D at 28 GHz

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Cluster # | Cluster PAS | Absolute Delay [ns] | Power in [dB] | AOD in [°] | AOA in [°] | ZOD in [°] | ZOA in [°] |
| 1 | Specular (LOS path) | 0 | -0.2 | 0 | 180 | 98.5 | 81.5 |
| Laplacian | 0 | -12.1055 | 0 | -180 | 98.5 | 81.5 |
| 2 | Laplacian | 0.8738 | -17.404 | -172.96 | 42.7638 | 92.4883 | 114.5755 |
| 3 | Laplacian | 15.2798 | -19.6225 | -172.96 | 42.7638 | 92.4883 | 114.5755 |
| 4 | Laplacian | 34.0301 | -21.3834 | -172.96 | 42.7638 | 92.4883 | 114.5755 |
| 5 | Laplacian | 35.0787 | -16.504 | 27.2592 | 154.306 | 98.0376 | 68.6373 |
| 6 | Laplacian | 45.0405 | -18.7225 | 27.2592 | 154.306 | 98.0376 | 68.6373 |
| 7 | Laplacian | 64.8144 | -20.4834 | 27.2592 | 154.306 | 98.0376 | 68.6373 |
| 8 | Laplacian | 44.3165 | -21.5055 | 72.5514 | -115.009 | 98.5 | 61.2872 |
| 9 | Laplacian | 100.9167 | -26.4055 | -135.248 | 20.546 | 93.8293 | 33.1118 |
| 10 | Laplacian | 198.1633 | -22.2055 | -68.9868 | 100.9531 | 95.1704 | 61.8997 |
| 11 | Laplacian | 235.2893 | -23.4055 | 110.295 | -88.7107 | 100.9509 | 115.188 |
| 12 | Laplacian | 242.3799 | -28.6055 | 83.0045 | 78.3003 | 90.0836 | 14.7365 |
| 13 | Laplacian | 312.7121 | -26.3055 | 161.8778 | -34.6022 | 92.9507 | 28.8242 |
| Per-Cluster Parameters | | | | | | | |
| Parameter |  | CASD in [°] | CASA in [°] | CZSD in [°] | CZSA in [°] | XPR in [dB] |  |
| Value |  | 10.4843 | 12.0913 | 1.3873 | 18.3753 | 11 |  |

Table 7.2.2-10: Channel model parameters for InO CDL-E at 28 GHz

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Cluster # | Cluster PAS | Absolute Delay [ns] | Power in [dB] | AOD in [°] | AOA in [°] | ZOD in [°] | ZOA in [°] |
| 1 | Specular (LOS path) | 0 | -0.03 | 0 | 180 | 99.6 | 80.4 |
| Laplacian | 0 | -20.5194 | 0 | -180 | 99.6 | 80.4 |
| 2 | Laplacian | 12.3987 | -14.3178 | 145.0787 | 66.3397 | 103.1625 | 80.4 |
| 3 | Laplacian | 13.1402 | -16.5363 | 145.0787 | 66.3397 | 103.1625 | 80.4 |
| 4 | Laplacian | 13.5992 | -18.2972 | 145.0787 | 66.3397 | 103.1625 | 80.4 |
| 5 | Laplacian | 13.1402 | -21.3894 | -50.7145 | 125.0665 | 99.4451 | 81.931 |
| 6 | Laplacian | 17.1789 | -20.8894 | 40.8743 | 132.864 | 100.5293 | 102.9826 |
| 7 | Laplacian | 46.1165 | -17.0879 | 23.4649 | -162.789 | 98.9804 | 89.2034 |
| 8 | Laplacian | 46.602 | -19.3064 | 23.4649 | -162.789 | 98.9804 | 89.2034 |
| 9 | Laplacian | 47.317 | -21.0673 | 23.4649 | -162.789 | 98.9804 | 89.2034 |
| 10 | Laplacian | 63.8316 | -20.7894 | 47.939 | -154.219 | 100.5293 | 89.9689 |
| 11 | Laplacian | 89.7015 | -24.0894 | 82.5056 | -120.079 | 97.1217 | 109.4894 |
| 12 | Laplacian | 131.7019 | -18.6894 | 1.2616 | 156.8183 | 99.0579 | 82.6965 |
| 13 | Laplacian | 289.9404 | -28.2894 | 141.0417 | -78.9842 | 96.5022 | 111.7859 |
| 14 | Laplacian | 498.6022 | -27.6894 | 145.331 | -71.819 | 103.4723 | 72.3621 |
| Per-Cluster Parameters | | | | | | | |
| Parameter |  | CASD in [°] | CASA in [°] | CZSD in [°] | CZSA in [°] | XPR in [dB] |  |
| Value |  | 12.6155 | 7.7272 | 2.3234 | 26.7929 | 8 |  |

### 7.3 Channel Model emulation of the Base Station beamforming configuration

The basic parameters of NR BS antenna is specified in table 7.2-7. The propagation environment generated in the test zone is channel model defined in section 7.2 with base station antenna filtering effect. For the channel model emulation in the chamber, the beamforming characteristic of the BS pattern is defined as follow:

- For FR1: 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 FR2: A code book of 128 fixed beams is constructed to a grid of eight elevation angles from –25° to +25° with ~7.1° step size and 16° azimuth angles from –60° to +60° with 8° step size；

For NR FR1 MIMO OTA, 2 strongest transmitting beams are selected from the pre-defined beam grid based on their proximity to the strong clusters of each FR1 channel model.

For FR1 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 FR1 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.

- In detail, beam directions for channels model given in Clause 7.2.1 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°.

For NR FR2 MIMO OTA, 1 strongest transmitting beam is generated from BS, the direction of this beam towards the strongest cluster of each FR2 channel model. In detail, the directions in CDL-A InO and CDL-C UMi models are (-4.0°, 93.6°) and (-12.0°, 100.7°), respectively.

## 7.4 Verification of Channel Model implementation

### 7.4.1 Channel Models validation

This clause describe 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

The following measurements shall be done for FR2 channel model validation:

Power Delay Profile (PDP)

Doppler/Temporal correlation

PAS similarity percentage (PSP)

Cross-polarization

Power validation

Frequencies to be used to test for channel model validation and quality of quiet zone validation:

Table 7.4.1-1: Frequencies for PDP, Doppler, Spatial correlation, Cross-polarization validation, and Quality of Quiet Zone validation

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

Table 7.4.1-2: Channel model validation and Quality of Quiet Zone validation frequencies

|  |  |  |
| --- | --- | --- |
| NR FR2 Bands | Range | Test Frequency (MHz) |
| n257 | Low | 27750 |
| n260 | High | 38500 |
| n258 | Low | 25875 |
| n261 | Low | 27925 |

Table 7.4.1-3: Frequencies for FR1 power validation

|  |  |  |
| --- | --- | --- |
| NR FR1 Bands | Range | Test frequency (center 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 |

#### 7.4.1.1 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.

**FR1 PDP validation procedure for MPAC system:**

The PDP measurement is performed with a Vector Network Analyzer (VNA). An example setup for PDP measurement is shown in Figure 7.4.1.1-1. VNA transmits frequency sweep signals thorough the NR MIMO OTA test system. A reference antenna (i.e dipole antenna), within the center 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 analyzed 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.

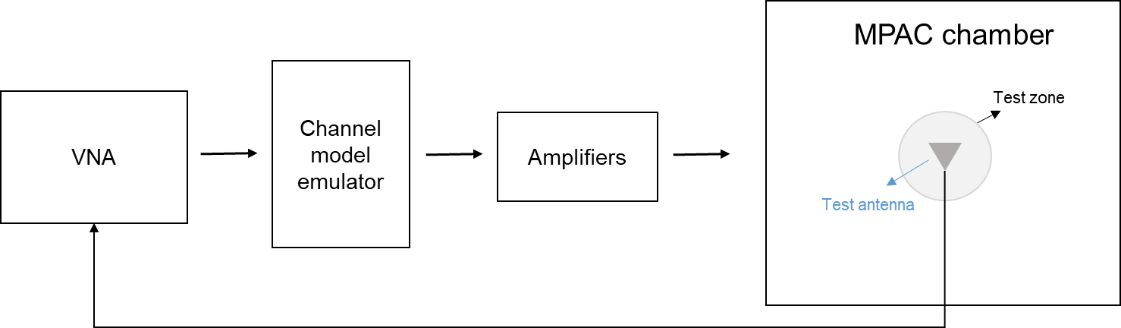


Figure 7.4.1.1-1: Setup for PDP measurements

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:**

Table 7.4.1.1-1: VNA settings for PDP measurements

|  |  |  |
| --- | --- | --- |
| Item | Unit | Value |
| Center frequency | MHz | Downlink center frequency  in Table 7.4.1-1 |
| Span | MHz | 200 |
| Number of traces |  | 1000 |
| Number of points |  | 1101 |
| Averaging |  | 1 |

**Channel model specification:**

Table 7.4.1.1-2: Channel model specification for PDP measurements

| Item | Unit | Value |
| --- | --- | --- |
| Center frequency | MHz | Downlink center frequency  in Table 7.4.1-1 |
| Distance between traces in channel model | wavelength (Note) | > 2 |
| Channel model |  | As specified in Clause 7.2 |
| NOTE: Time [s] = distance [λ] / MS speed [λ/s]  MS speed [λ/s] = MS speed [m/s] / Speed of light [m/s] \* Center 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.

**FR2 PDP validation procedure for 3D-MPAC system:**

The PDP measurement is performed with a Vector Network Analyzer (VNA). An example setup for PDP measurement is shown in Figure 7.4.1.1-2. VNA transmits frequency sweep signals thorough the NR MIMO OTA test system. A reference 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 analyzed 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.

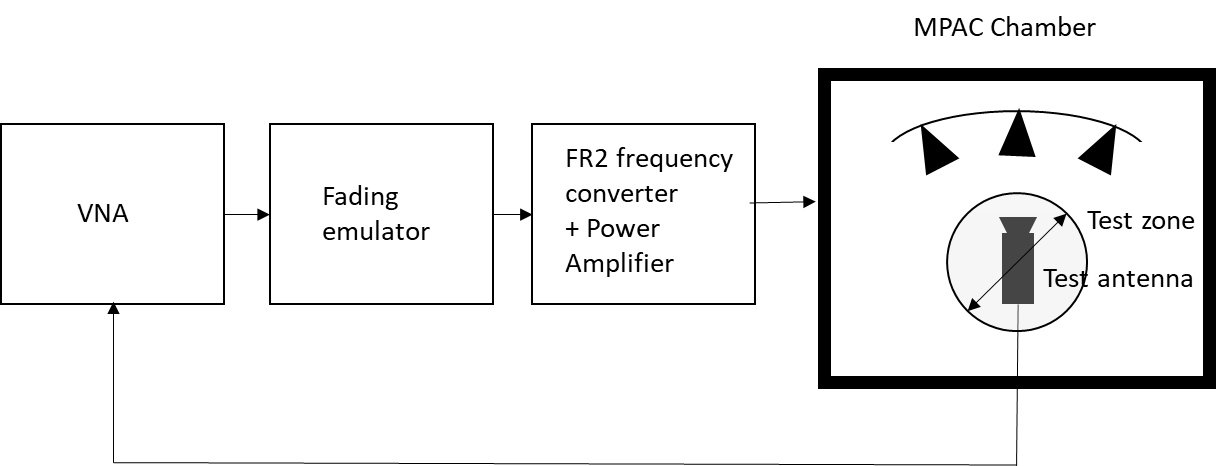


Figure 7.4.1.1-2: Setup for PDP measurements (FR2)

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:**

Table 7.4.1.1-1: VNA settings for PDP measurements

|  |  |  |
| --- | --- | --- |
| Item | Unit | Value |
| Center frequency | MHz | Downlink center frequency  in Table 7.4.1-2 |
| Span | MHz | 200 |
| Number of traces |  | 1000 |
| Number of points |  | 1101 |
| Averaging |  | 1 |

**Channel model specification:**

Table 7.4.1.1-3: Channel model specification for FR2 PDP measurements

| Item | Unit | Value |
| --- | --- | --- |
| Center frequency | MHz | Downlink center frequency  in Table 7.4.1-2 |
| Distance between traces in channel model | wavelength (Note) | > 2 |
| Channel model |  | As specified in Clause 7.2 |
| NOTE: Time [s] = distance [λ] / MS speed [λ/s]  MS speed [λ/s] = MS speed [m/s] / Speed of light [m/s] \* Center 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 Inverse Fourier transform of each trace. 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.

#### 7.4.1.2 Doppler/Temporal correlation

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

**FR1 Doppler/Temporal correlation validation procedure for MPAC system:**

The Doppler spectrum is measured with a spectrum analyzer as shown in Figure 7.4.1.2-1. 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 analyzed by a spectrum analyzer 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 7.2.

**Method of measurement:**

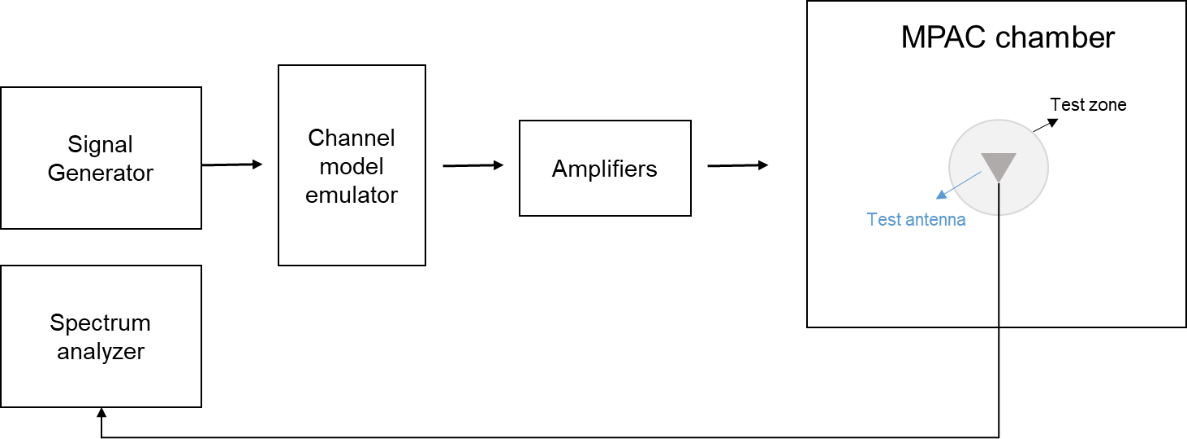


Figure 7.4.1.2-1: Setup for Doppler measurements

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 analyzer and the trace is saved.

**Signal generator settings:**

Table 7.4.1.2-1: Signal generator settings for Doppler/Temporal correlation measurements

| Item | Unit | Value |
| --- | --- | --- |
| Center frequency | MHz | Downlink center frequency  in Table 7.4.1-1 |
| Modulation |  | OFF |

**Spectrum analyzer settings:**

Table 7.4.1.2-2: Spectrum analyzer settings for Doppler/Temporal correlation measurements

| Item | Unit | Value |
| --- | --- | --- |
| Center frequency | MHz | Downlink center frequency  in Table 7.4.1-1 |
| Minimum Span | Hz | 4 kHz |
| RBW | Hz | 1 |
| VBW | Hz | 1 |
| Number of points |  | 16002 |
| Averaging |  | 100 |

**Channel model specification:**

Table 7.4.1.2-3: Channel model specification for Doppler/Temporal correlation measurements

| Item | Unit | Value |
| --- | --- | --- |
| Center frequency | MHz | Downlink center frequency  in Table 7.4.1-1 |
| Channel model |  | As specified in Clause 7.2 |
| 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  is normalized such that . Then the function values left from the maximum is cut out. Further on the function values after, e.g. seven periods is cut out.

**FR2 Doppler/Temporal correlation validation procedure for 3D-MPAC system:**

The Doppler spectrum is measured with a spectrum analyzer as shown in Figure 7.4.1.2-2. 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 7.2.

**Method of measurement:**

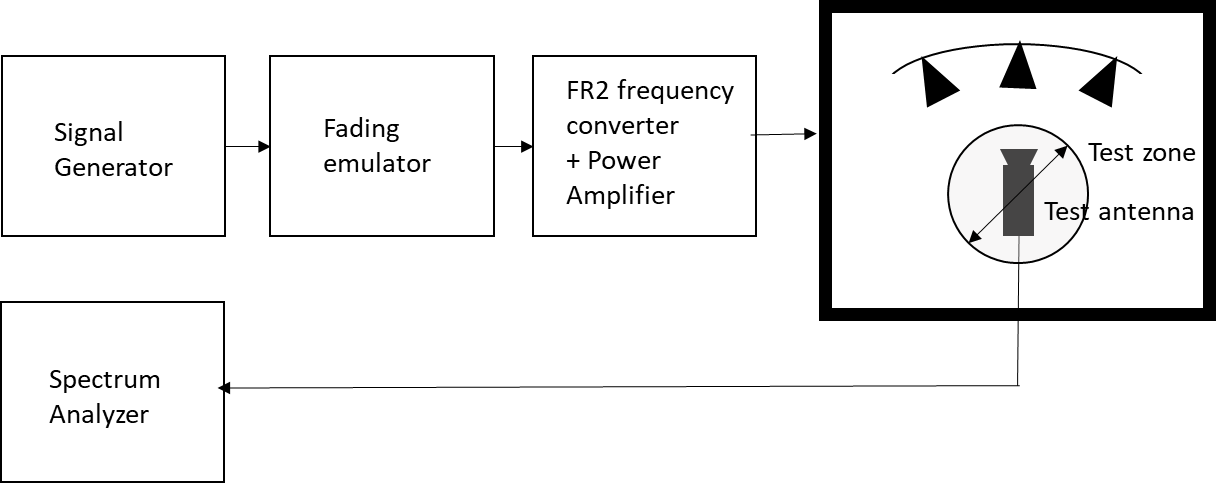


Figure 7.4.1.2-2: Setup for Doppler measurements

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 frequency converter and 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 analyzer and the trace is saved.

**Signal generator settings:**

Table 7.4.1.2-2: Signal generator settings for Doppler/Temporal correlation measurements

| Item | Unit | Value |
| --- | --- | --- |
| Center frequency | MHz | Downlink center frequency  in Table 7.4.1-2 |
| Modulation |  | OFF |

**Spectrum analyzer settings:**

Table 7.4.1.2-2: Spectrum analyzer settings for Doppler/Temporal correlation measurements

| Item | Unit | Value |
| --- | --- | --- |
| Center frequency | MHz | Downlink center frequency  in Table 7.4.1-2 |
| Minimum Span | Hz | 4 kHz |
| RBW | Hz | 1 |
| VBW | Hz | 1 |
| Number of points |  | 16002 |
| Averaging |  | 100 |

**Channel model specification:**

Table 7.4.1.2-3: Channel model specification for Doppler/Temporal correlation measurements

| Item | Unit | Value |
| --- | --- | --- |
| Center frequency | MHz | Downlink center frequency  in Table 7.4.1-2 |
| Channel model |  | As specified in Clause 7.2 |
| Mobile speed | km/h | 3 |

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  is normalized such that . Then the function values left from the maximum is cut out. Further on the function values after, e.g. seven periods is cut out.

#### 7.4.1.3 Spatial correlation

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

The spatial correlation validation measurement setup is illustrated in Figure 7.4.1.3-1. 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 is as follows:

1 Set the target channel model to fading emulator.

2 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.

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

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

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

6

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

8 Calculate the weighted RMS correlation error between the measured and the reference.



Figure 7.4.1.3-1: Configuration for spatial correlation validation

**Time and frequency samples**

The number of temporal snapshots *N* and frequency samples *M* is TBD. They must be chosen to minimize the validation measurement time, but sufficiently high to keep an adequate correlation estimation accuracy. It is beneficial to choose the time sampling interval larger than the coherence time of the channel model. such that the recorded time samples represent independent fading occasions. The same principle applies also to frequency sampling interval and the channel coherence bandwidth.

**Spatial samples**

The spatial samples for the correlation validation measurement are on the circumference of the quiet zone, as illustrated in Figure 7.4.1.3-2. 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-A and CDL-C 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 must 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 7.4.1.3-1 for test frequencies less than 1800 MHz and equal to or greater than 1800 MHz.

Table 7.4.1.3-1: 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 |

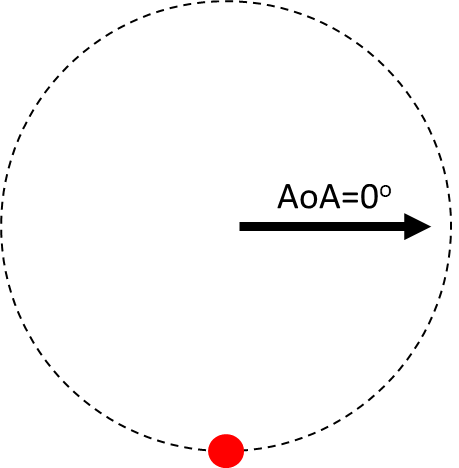




Figure 7.4.1.3-2: Spatial sampling for spatial correlation validation measurement for test frequencies less than and equal to or greater than 1800 MHz: 617 MHz spatial sampling (left) and 4700 MHz spatial sampling (right).

**Reference Spatial Correlation Curves**

The spatial correlation validation reference curves are tabulated in Tables 7.4.1.3-2 and 7.4.1.3-3 for CDL-A UMi and in Tables 7.4.1.3-4 and 7.4.1.3-5 for CDL-C UMa for a vertically polarized MPAC OTA setup with 16 uniformly spaced probes.

Table 7.4.1.3-2: Spatial correlation reference curves for CDL-A UMi model for a vertically polarized MPAC OTA setup with 16 uniformly spaced probes at FR1 test frequencies below 1800 MHz

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| 617 MHz | | 722 MHz | | 836.5 MHz | | 1575.42 MHz | |
| Azimuth [o] | ref | Azimuth [o] | ref | Azimuth [o] | ref | Azimuth [o] | ref |
| 270.0 | 1.000 | 270.0 | 1.000 | 270.0 | 1.000 | 270.0 | 1.000 |
| 251.4 | 0.999 | 254.1 | 0.999 | 256.3 | 0.999 | 262.7 | 0.999 |
| 232.9 | 0.997 | 238.3 | 0.997 | 242.6 | 0.996 | 255.5 | 0.996 |
| 214.3 | 0.992 | 222.4 | 0.993 | 228.9 | 0.993 | 248.2 | 0.992 |
| 195.8 | 0.981 | 206.6 | 0.984 | 215.2 | 0.987 | 240.9 | 0.987 |
| 110.40 | 0.809 | 190.7 | 0.969 | 201.6 | 0.975 | 233.7 | 0.982 |
| 40.80 | 0.823 | 120.52 | 0.778 | 187.9 | 0.955 | 226.4 | 0.977 |
| 331.21 | 0.96 | 61.05 | 0.731 | 128.66 | 0.751 | 219.1 | 0.971 |
|  |  | 1.57 | 0.88 | 77.33 | 0.645 | 211.9 | 0.962 |
|  |  | 302.09 | 0.99 | 25.99 | 0.762 | 204.6 | 0.949 |
|  |  |  |  | 334.66 | 0.928 | 197.3 | 0.929 |
|  |  |  |  | 283.32 | 0.998 | 190.0 | 0.903 |
|  |  |  |  |  |  | 182.8 | 0.868 |
|  |  |  |  |  |  | 152.74 | 0.620 |
|  |  |  |  |  |  | 125.48 | 0.363 |
|  |  |  |  |  |  | 98.23 | 0.299 |
|  |  |  |  |  |  | 70.97 | 0.364 |
|  |  |  |  |  |  | 43.71 | 0.460 |
|  |  |  |  |  |  | 16.45 | 0.58 |
|  |  |  |  |  |  | 349.20 | 0.71 |
|  |  |  |  |  |  | 321.94 | 0.86 |
|  |  |  |  |  |  | 294.68 | 0.97 |

Table 7.4.1.3-3: Spatial correlation reference curves for CDL-A UMi model for a vertically polarized MPAC OTA setup with 16 uniformly spaced probes at FR1 test frequencies equal to or greater than 1800 MHz

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 1800 MHz | | 2132.5 MHz | | 2450 MHz | | 3600 MHz | | 4700 MHz | |
| Azimuth [o] | ref | Azimuth [o] | ref | Azimuth [o] | ref | Azimuth [o] | ref | Azimuth [o] | ref |
| 270.0 | 1.000 | 270.0 | 1.000 | 270.0 | 1.000 | 270.0 | 1.000 | 270.0 | 1.000 |
| 260.9 | 0.998 | 261.9 | 0.998 | 263.0 | 0.997 | 265.2 | 0.997 | 266.3 | 0.997 |
| 251.7 | 0.991 | 253.9 | 0.990 | 256.0 | 0.990 | 260.5 | 0.990 | 262.7 | 0.990 |
| 242.6 | 0.981 | 245.8 | 0.980 | 249.0 | 0.979 | 255.7 | 0.979 | 259.0 | 0.979 |
| 233.5 | 0.967 | 237.8 | 0.967 | 242.0 | 0.966 | 250.9 | 0.966 | 255.4 | 0.969 |
| 224.3 | 0.951 | 229.7 | 0.952 | 234.9 | 0.951 | 246.1 | 0.950 | 251.7 | 0.956 |
| 215.2 | 0.932 | 221.7 | 0.933 | 227.9 | 0.932 | 241.4 | 0.932 | 248.1 | 0.942 |
| 206.0 | 0.906 | 213.6 | 0.911 | 220.9 | 0.913 | 236.6 | 0.908 | 244.4 | 0.922 |
| 196.9 | 0.877 | 205.6 | 0.883 | 213.9 | 0.888 | 231.8 | 0.881 | 240.8 | 0.896 |
| 187.8 | 0.845 | 197.5 | 0.854 | 206.9 | 0.862 | 227.1 | 0.857 | 237.1 | 0.872 |
| 134.3 | 0.748 | 189.5 | 0.823 | 199.9 | 0.833 | 222.3 | 0.832 | 233.5 | 0.842 |
| 88.6 | 0.729 | 181.4 | 0.795 | 192.9 | 0.805 | 217.5 | 0.815 | 229.8 | 0.817 |
| 43.0 | 0.833 | 139.7 | 0.737 | 185.9 | 0.783 | 212.7 | 0.800 | 226.1 | 0.792 |
| 357.3 | 0.953 | 99.5 | 0.725 | 144.9 | 0.742 | 208.0 | 0.792 | 222.5 | 0.775 |
| 311.6 | 0.978 | 59.2 | 0.753 | 109.9 | 0.754 | 203.2 | 0.785 | 218.8 | 0.760 |
|  |  | 18.9 | 0.884 | 74.8 | 0.727 | 198.4 | 0.782 | 215.2 | 0.753 |
|  |  | 338.6 | 0.970 | 39.8 | 0.778 | 193.7 | 0.781 | 211.5 | 0.750 |
|  |  | 298.4 | 0.982 | 4.7 | 0.901 | 188.9 | 0.786 | 207.9 | 0.753 |
|  |  |  |  | 329.7 | 0.974 | 184.1 | 0.795 | 204.2 | 0.760 |
|  |  |  |  | 294.6 | 0.980 | 156.1 | 0.886 | 200.6 | 0.775 |
|  |  |  |  |  |  | 132.3 | 0.952 | 196.9 | 0.792 |
|  |  |  |  |  |  | 108.4 | 0.949 | 193.3 | 0.817 |
|  |  |  |  |  |  | 84.6 | 0.906 | 189.6 | 0.840 |
|  |  |  |  |  |  | 60.7 | 0.830 | 185.9 | 0.865 |
|  |  |  |  |  |  | 36.9 | 0.741 | 182.3 | 0.888 |
|  |  |  |  |  |  | 13.0 | 0.774 | 161.7 | 0.978 |
|  |  |  |  |  |  | 349.1 | 0.894 | 143.5 | 0.945 |
|  |  |  |  |  |  | 325.3 | 0.966 | 125.2 | 0.926 |
|  |  |  |  |  |  | 301.4 | 0.969 | 106.9 | 0.926 |
|  |  |  |  |  |  | 277.6 | 0.994 | 88.6 | 0.948 |
|  |  |  |  |  |  |  |  | 70.4 | 0.948 |
|  |  |  |  |  |  |  |  | 52.1 | 0.896 |
|  |  |  |  |  |  |  |  | 33.8 | 0.747 |
|  |  |  |  |  |  |  |  | 15.5 | 0.682 |
|  |  |  |  |  |  |  |  | 357.3 | 0.799 |
|  |  |  |  |  |  |  |  | 339.0 | 0.912 |
|  |  |  |  |  |  |  |  | 320.7 | 0.956 |
|  |  |  |  |  |  |  |  | 302.4 | 0.968 |
|  |  |  |  |  |  |  |  | 284.2 | 0.973 |

Table 7.4.1.3-4: 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 below 1800 MHz

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| 617 MHz | | 722 MHz | | 836.5 MHz | | 1575.42 MHz | |
| Azimuth [o] | ref | Azimuth [o] | ref | Azimuth [o] | ref | Azimuth [o] | ref |
| 270.0 | 1.000 | 270.0 | 1.000 | 270.0 | 1.000 | 270.0 | 1.000 |
| 251.4 | 0.999 | 254.1 | 0.999 | 256.3 | 0.999 | 262.7 | 0.999 |
| 232.9 | 0.997 | 238.3 | 0.997 | 242.6 | 0.996 | 255.5 | 0.996 |
| 214.3 | 0.992 | 222.4 | 0.993 | 228.9 | 0.993 | 248.2 | 0.992 |
| 195.8 | 0.981 | 206.6 | 0.984 | 215.2 | 0.987 | 240.9 | 0.987 |
| 110.40 | 0.809 | 190.7 | 0.969 | 201.6 | 0.975 | 233.7 | 0.982 |
| 40.80 | 0.823 | 120.52 | 0.778 | 187.9 | 0.955 | 226.4 | 0.977 |
| 331.21 | 0.96 | 61.05 | 0.731 | 128.66 | 0.751 | 219.1 | 0.971 |
|  |  | 1.57 | 0.88 | 77.33 | 0.645 | 211.9 | 0.962 |
|  |  | 302.09 | 0.99 | 25.99 | 0.762 | 204.6 | 0.949 |
|  |  |  |  | 334.66 | 0.928 | 197.3 | 0.929 |
|  |  |  |  | 283.32 | 0.998 | 190.0 | 0.903 |
|  |  |  |  |  |  | 182.8 | 0.868 |
|  |  |  |  |  |  | 152.74 | 0.620 |
|  |  |  |  |  |  | 125.48 | 0.363 |
|  |  |  |  |  |  | 98.23 | 0.299 |
|  |  |  |  |  |  | 70.97 | 0.364 |
|  |  |  |  |  |  | 43.71 | 0.460 |
|  |  |  |  |  |  | 16.45 | 0.58 |
|  |  |  |  |  |  | 349.20 | 0.71 |
|  |  |  |  |  |  | 321.94 | 0.86 |
|  |  |  |  |  |  | 294.68 | 0.97 |

Table 7.4.1.3-5: 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 equal to or greater than 1800 MHz

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 1800 MHz | | 2132.5 MHz | | 2450 MHz | | 3600 MHz | | 4700 MHz | |
| Azimuth [o] | ref | Azimuth [o] | ref | Azimuth [o] | ref | Azimuth [o] | ref | Azimuth [o] | ref |
| 270.0 | 1.000 | 270.0 | 1.000 | 270.0 | 1.000 | 270.0 | 1.000 | 270.0 | 1.000 |
| 260.9 | 0.998 | 261.9 | 0.998 | 263.0 | 0.997 | 265.2 | 0.997 | 266.3 | 0.996 |
| 251.7 | 0.991 | 253.9 | 0.991 | 256.0 | 0.992 | 260.5 | 0.989 | 262.7 | 0.988 |
| 242.6 | 0.984 | 245.8 | 0.984 | 249.0 | 0.983 | 255.7 | 0.979 | 259.0 | 0.976 |
| 233.5 | 0.976 | 237.8 | 0.975 | 242.0 | 0.975 | 250.9 | 0.969 | 255.4 | 0.966 |
| 224.3 | 0.967 | 229.7 | 0.966 | 234.9 | 0.965 | 246.1 | 0.960 | 251.7 | 0.957 |
| 215.2 | 0.955 | 221.7 | 0.955 | 227.9 | 0.953 | 241.4 | 0.954 | 248.1 | 0.951 |
| 206.0 | 0.936 | 213.6 | 0.940 | 220.9 | 0.939 | 236.6 | 0.947 | 244.4 | 0.945 |
| 196.9 | 0.908 | 205.6 | 0.918 | 213.9 | 0.921 | 231.8 | 0.937 | 240.8 | 0.940 |
| 187.8 | 0.863 | 197.5 | 0.888 | 206.9 | 0.898 | 227.1 | 0.925 | 237.1 | 0.935 |
| 134.3 | 0.309 | 189.5 | 0.846 | 199.9 | 0.867 | 222.3 | 0.903 | 233.5 | 0.928 |
| 88.6 | 0.269 | 181.4 | 0.793 | 192.9 | 0.829 | 217.5 | 0.876 | 229.8 | 0.918 |
| 43.0 | 0.396 | 139.7 | 0.280 | 185.9 | 0.786 | 212.7 | 0.837 | 226.1 | 0.902 |
| 357.3 | 0.619 | 99.5 | 0.252 | 144.9 | 0.245 | 208.0 | 0.798 | 222.5 | 0.882 |
| 311.6 | 0.879 | 59.2 | 0.257 | 109.9 | 0.299 | 203.2 | 0.753 | 218.8 | 0.851 |
|  |  | 18.9 | 0.471 | 74.8 | 0.215 | 198.4 | 0.708 | 215.2 | 0.816 |
|  |  | 338.6 | 0.661 | 39.8 | 0.251 | 193.7 | 0.669 | 211.5 | 0.767 |
|  |  | 298.4 | 0.937 | 4.7 | 0.489 | 188.9 | 0.624 | 207.9 | 0.708 |
|  |  |  |  | 329.7 | 0.652 | 184.1 | 0.580 | 204.2 | 0.651 |
|  |  |  |  | 294.6 | 0.946 | 156.1 | 0.175 | 200.6 | 0.580 |
|  |  |  |  |  |  | 132.3 | 0.565 | 196.9 | 0.516 |
|  |  |  |  |  |  | 108.4 | 0.745 | 193.3 | 0.444 |
|  |  |  |  |  |  | 84.6 | 0.820 | 189.6 | 0.383 |
|  |  |  |  |  |  | 60.7 | 0.750 | 185.9 | 0.310 |
|  |  |  |  |  |  | 36.9 | 0.493 | 182.3 | 0.229 |
|  |  |  |  |  |  | 13.0 | 0.120 | 161.7 | 0.445 |
|  |  |  |  |  |  | 349.1 | 0.272 | 143.5 | 0.750 |
|  |  |  |  |  |  | 325.3 | 0.498 | 125.2 | 0.879 |
|  |  |  |  |  |  | 301.4 | 0.843 | 106.9 | 0.813 |
|  |  |  |  |  |  | 277.6 | 0.991 | 88.6 | 0.733 |
|  |  |  |  |  |  |  |  | 70.4 | 0.740 |
|  |  |  |  |  |  |  |  | 52.1 | 0.873 |
|  |  |  |  |  |  |  |  | 33.8 | 0.944 |
|  |  |  |  |  |  |  |  | 15.5 | 0.643 |
|  |  |  |  |  |  |  |  | 357.3 | 0.250 |
|  |  |  |  |  |  |  |  | 339.0 | 0.178 |
|  |  |  |  |  |  |  |  | 320.7 | 0.375 |
|  |  |  |  |  |  |  |  | 302.4 | 0.726 |
|  |  |  |  |  |  |  |  | 284.2 | 0.929 |

**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 7.4.1.3-3. 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 analyzer and the measured signal is stored for postprocessing.

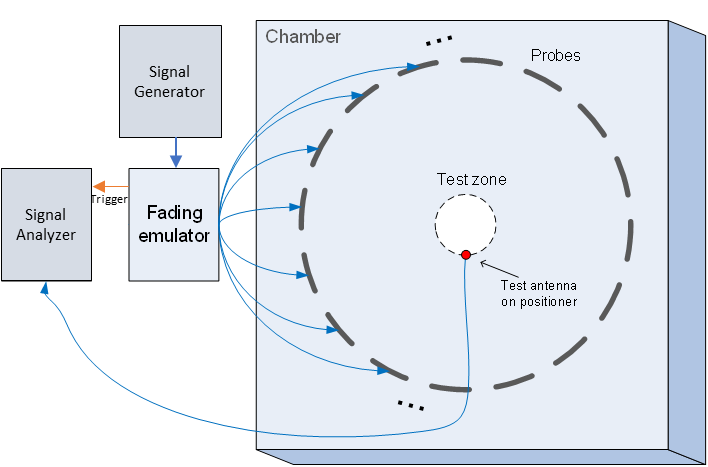


Figure 7.4.1.3-3: Configuration for spatial correlation validation based on time domain techniques

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 analyzer, when done, stop fading. Data recording is synchronized with the channel emulator trigger.

Follow the same procedure to postprocess the data and calcalate the spatial correlation by setting *m* to 1. The settings for the Signal Generator and Signal Analyzer are in Table 7.4.1.3-6 and 7.4.1.3-7 respectively.

Table 7.4.1.3-6: Signal Generator Settings

|  |  |  |
| --- | --- | --- |
| Item | Unit | Value |
| Center frequency | MHz | Downlink center frequency in Table 7.4.1-1 |
| Output power | dBm | Function of the CE. Sufficiently above Noise Floor |

Table 7.4.1.3-7: Signal Analyzer Settings

|  |  |  |
| --- | --- | --- |
| Item | Unit | Value |
| Center frequency | MHz | Downlink center frequency in Table 7.4.1-1 |
| Sampling | Hz | At least 15 times bigger than the max Doppler spread (*fd=v/λ)* |
| Observation time | s | At least 16s. Channel Model length should be the same or greater than the observation time. |

#### 7.4.1.4 Cross-polarization

**FR1 Cross polarization validation procedure for MPAC system:**

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 7.4.1.1-1.

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

**VNA settings:**

Table 7.4.1.4-1: VNA settings for cross-polarization

| Item | Unit | Value |
| --- | --- | --- |
| Center frequency | MHz | Downlink Center Frequency  in Table 7.4.1-1 |
| Span | MHz | 40 |
| Number of traces |  | 1000 |
| Number of points |  | 802 |
| Averaging |  | 1 |

**Channel model specification:**

Table 7.4.1.4-2: Channel model specification for cross-polarization.

|  |  |  |
| --- | --- | --- |
| Item | Unit | Value |
| Center frequency | MHz | Downlink center frequency  in Table 7.4.1-1 |
| Distance between traces in channel model | wavelength (Note) | > 2 |
| Channel model |  | As specified in Clause 7.2 |
| Mobile speed | km/h | 30 |
| NOTE: Time [s] = distance [λ] / MS speed [λ/s]  MS speed [λ/s] = MS speed [m /s] / Speed of light [m/s] \* Center frequency [Hz] | | |

**Measurement Procedure:**

1. Play or step through the channel model listed in clause 7.2.

2. Measure the absolute power received at the center of the test zone, averaged over a statistically significant number of fades.

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.

3. Calculate the V/H ratio.

4. Compare it with the theory value.

**FR2 Cross polarization validation procedure for 3D-MPAC system:**

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 7.4.1.1-2.

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

**VNA settings:**

Table 7.4.1.4-1: VNA settings for cross-polarization

| Item | Unit | Value |
| --- | --- | --- |
| Center frequency | MHz | Downlink Center Frequency  in Table 7.4.1-2 |
| Span | MHz | 40 |
| Number of traces |  | 1000 |
| Number of points |  | 802 |
| Averaging |  | 1 |

**Channel model specification:**

Table 7.4.1.4-2: Channel model specification for cross-polarization.

|  |  |  |
| --- | --- | --- |
| Item | Unit | Value |
| Center frequency | MHz | Downlink center frequency  in Table 7.4.1-2 |
| Distance between traces in channel model | wavelength (Note) | > 2 |
| Channel model |  | As specified in Clause 7.2 |
| Mobile speed | km/h | 3 |
| NOTE: Time [s] = distance [λ] / MS speed [λ/s]  MS speed [λ/s] = MS speed [m /s] / Speed of light [m/s] \* Center frequency [Hz] | | |

**Measurement Procedure:**

1. Play or step through the channel model listed in clause 7.2.

2. Measure the absolute power received at the center of the test zone, averaged over a statistically significant number of fades.

a. Use a dual polarized horn antenna and by terminating the H branch of antenna to measure the V component.

b. Use a dual polarized horn antenna and by terminating the V branch of antenna to measure the H component.

3. Calculate the V/H ratio.

4. Compare it with the theory value.

#### 7.4.1.5 Power validation

**FR1 power validation procedure for MPAC system:**

This measurement checks the total power in the center of the test zone. The power validation is measured with a spectrum analyzer as shown in Figure 7.4.1.5-1.

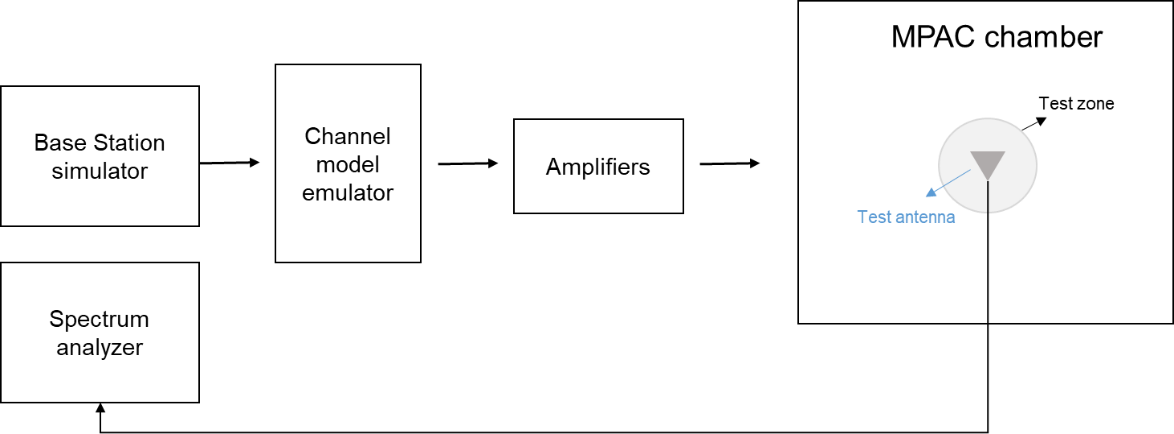


Figure 7.4.1.5-1: Setup for power validation measurements

**Spectrum analyzer settings:**

Table 7.4.1.5-1: Spectrum analyzer settings for Power validation measurements

| Item | Unit | Value |
| --- | --- | --- |
| Center frequency | MHz | Downlink center frequency  in Table 7.4.1-1 |
| Integrated Channel Span | Hz | 20MHz |
| 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 center of the test zone connected to a spectrum analyzer (or power meter) via a cable.

2. Record the cable and reference dipole gains.

3. Load the target channel model into the channel emulator.

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

5. Average the power received by the spectrum analyzer 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.

**FR2 power validation procedure for 3D-MPAC system:**

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 7.4.1.5-2.

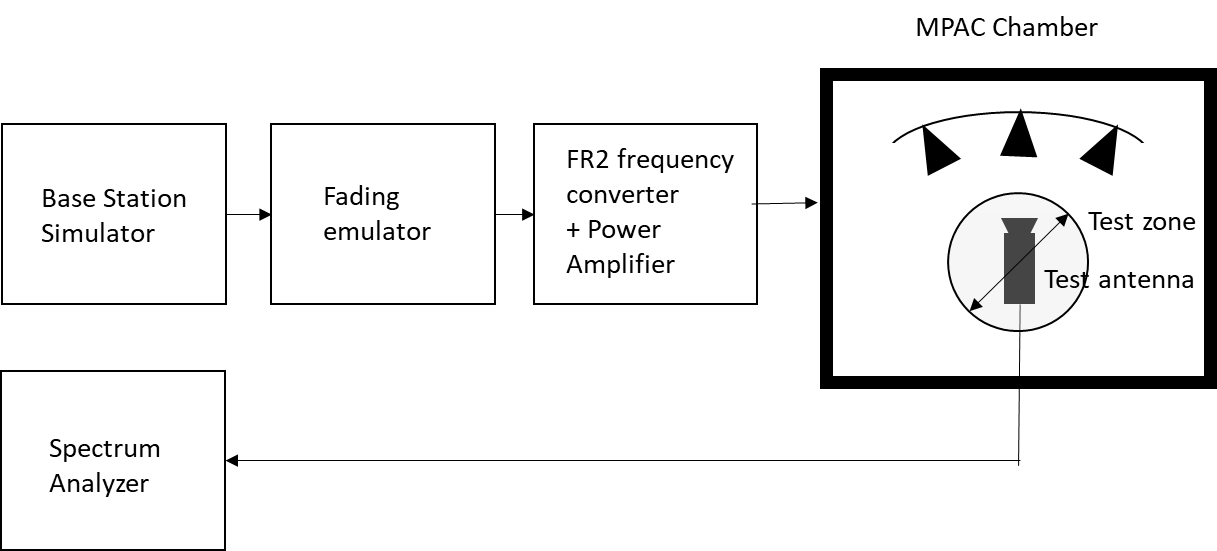


Figure 7.4.1.5-2: Setup for power validation measurements

**Spectrum analyzer settings:**

Table 7.4.1.5-2: Spectrum analyzer settings for Power validation measurements

| Item | Unit | Value |
| --- | --- | --- |
| Center frequency | MHz | Downlink center frequency  in Table 7.4.1-2 |
| Integrated Channel Span | Hz | 20MHz |
| RBW | Hz | 30 kHz |
| VBW | Hz | ≥10MHz |
| Number of points |  | ≥400 |
| Averaging |  | ≥100 |
| Detector |  | RMS |

**Measurement Procedure:**

1. Place a horn antenna with H polarization terminated in the centre of the test zone connected to a spectrum analyzer (or power meter) via a cable.

2. Record the cable and horn antenna gains.

3. Load the target channel model into the channel emulator.

4. Start the NR FR2 signalling in the base station emulator with the required parameter identical to the measurements conditions.

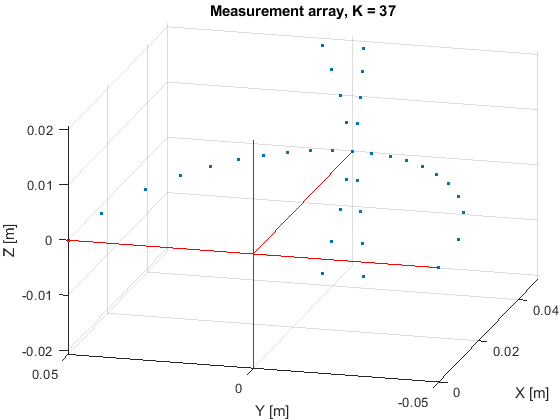
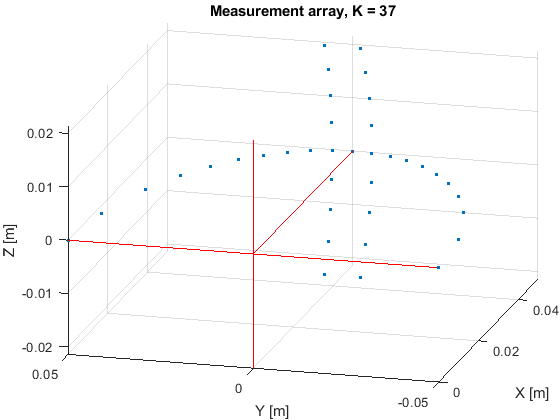
5. Average the power received by the spectrum analyzer for a sufficient amount of time to account for the fading channel – one full channel simulation might be unnecessary.

6. Repeat steps 1 to 4 with a horn antenna V polarization terminated for the horizontal polarization, in four orthogonal horizontal positions and summed to measure the H component.

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

#### 7.4.1.6 PAS similarity percentage (PSP)

The PSP validation measurements aim at evaluating PAS similarity percentage (PSP), which is one of the validation metrics for characterizing FR2 channel model under test in the quite zone of 3D-MPAC. For PSP validation measurement, only vertical polarization validation is required. The measurement array is essentially a virtual array configuration realized in 3D-MPAC through a -θ positioning system. The measurement array is a semi-circle and sectored array configuration illustrated in Figure 7.4.1.6-1 where complex channel frequency response is measured at each antenna location 0.5 λ apart using a vector network analyser (VNA) setup. The vertical sectors of the measurement array are limited to 60 (±30) and the horizontal sector to 180 (±90) with the broad side direction points towards the probes. Depending of the turntable architecture/implementation, the virtual array configuration for the PSP validation is composed of two alternative semi-circle arrangements (1 x horizontal and either 2 x crossed vertical or 2 x parallel vertical). The radius of the array element locations with respect to the centre of the test zone is 5 cm, which is equivalent to the half of the test zone radius at 28 GHz. For different frequency bands, the radius of the measurement array sectored semi-circles remains fixed at 5 cm while the spatial sampling of the array varies. This measurement validates the proper angular behaviour in the test zone*.*

**Figure 7.4.1.6-1: Semi-circle measurement array configurations with K = 37 elements (at 28 GHz). On the left with two crossed vertical sectors, on the right with two parallel vertical sectors.**

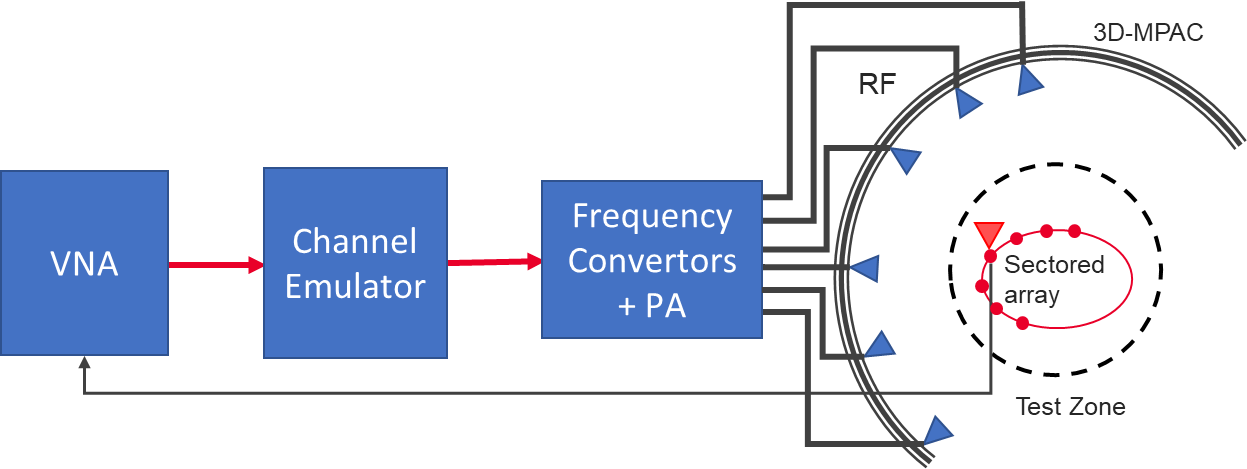


Figure 7.4.1.6-2: Setup for PSP validation measurements

The PSP validation is measured with a vector network analyser as shown in Figure 7.4.1.6-2 illustrating the PSP measurement setup. Port 1 of the VNA transmits signals through the fading emulator and radiate them through L probes within the anechoic chamber. The radiated signals are then received at the test antenna that is positioned inside the test zone. The test antenna is mounted on a -θ positioner which is capable of moving the antenna to pre-defined spatial locations on a fixed radius from the centre of the quiet zone according the measurement array configuration. Finally, the signal is received at port 2 of the VNA. The most suitable approach for the PSP validation is based on an omnidirectional antenna (omnidirectional pattern in AZ and wide BW in EL) as the test can be automated easily. Alternatively, a directional antenna could be used but requires frequent re-positioning.

The measurement and analysis procedure are given as follows:

1 Set the target channel model in the Channel Emulator.

2 For each position of the test antenna on the measurement array configuration in the test zone, step & pause the emulator to different time instances. Measure the complex 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 .

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

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

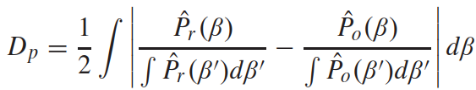
5 Estimate the measured PAS through the following two-step processing:

a In the first step, calculate the discrete azimuth and elevation angles (DoA) for the measurement array configuration by applying the MUSIC algorithm. Estimate the powers from the DoA and auto-covariance matrix of the received signal acquired through VNA complex frequency response data. A near field to far-field conversion is then applied to the transfer function between probes and measurement array positions.

b In the second step, use the angle and power estimates, i.e. the discrete PAS of N azimuth and elevation directions and power values in conjunction with a 4x4 DUT sampling array for beamforming with the conventional Bartlett beamformer to estimate the “measured PAS seen by DUT” for PSP calculation.

6 Evaluate the reference OTA PAS for the 4x4 DUT array by applying the conventional Bartlett beamformer to the OTA probe weights and the strongest beam from the code book of 128 beam-grid with 4x4 DUT sampling array.

7 Calculate total variation distance (*D*p) from the reference and measured PAS. Mathematically,



8 Calculate PSP values as PSP = (1-*Dp*) x 100%.

**VNA settings:**

Table 7.4.1.6-1: VNA settings for FR2 PSPmeasurements

|  |  |  |
| --- | --- | --- |
| Item | Unit | Value |
| Center frequency | MHz | Downlink center frequency  in Table 7.4.1-2 |
| Span | MHz | 0 (or the minimum) |
| Number of traces |  | 1000 |
| Number of points |  | 1 |

**Channel model specification:**

Table 7.4.1.6-2: Channel model specification for FR2 PSP measurements

| Item | Unit | Value |
| --- | --- | --- |
| Center frequency | MHz | Downlink center frequency  in Table 7.4.1-2 |
| Distance between traces in channel model | wavelength (Note) | > 2 |
| Channel model |  | As specified in Clause 7.2 |
| NOTE: Time [s] = distance [λ] / MS speed [λ/s]  MS speed [λ/s] = MS speed [m/s] / Speed of light [m/s] \* Center frequency [Hz] | | |

**Time Domain Alternative Method:**

PSP validation can also be implemented using time-domain techniques using the testing setup presented in Figure 7.4.1.6-3. The VNA is substituted by a signal generator, and a signal analyser.

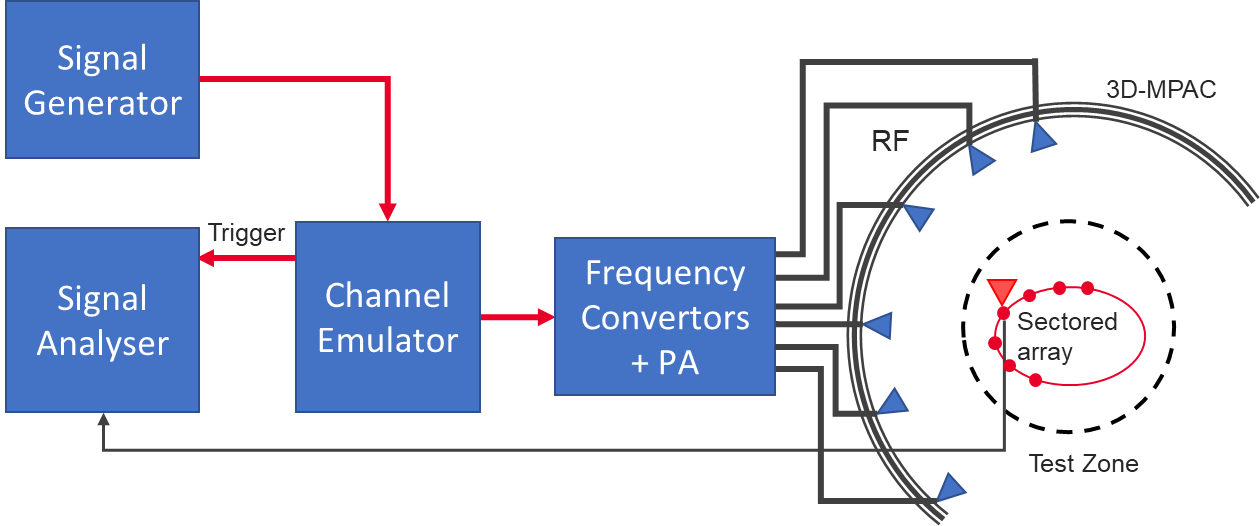


Figure 7.4.1.6-3: Setup for PSP validation measurements based on time domain

Table 7.4.1.6-3: Signal Generator Settings

|  |  |  |
| --- | --- | --- |
| Item | Unit | Value |
| Center frequency | MHz | Downlink centre frequency in 3GPP as required per band |
| Output power | dBm | Function of the CE. Sufficiently above Noise Floor |

Table 7.4.1.6-4: Signal Analyzer Settings

|  |  |  |
| --- | --- | --- |
| Item | Unit | Value |
| Center frequency | MHz | Downlink centre frequency in 3GPP as required per band |
| Sampling | Hz | At least 10 times bigger than the max Doppler spread (*fd=v/λ)* |
| Observation time | s | At least 32s |

The measurement and analysis procedure are given as follows:

Follow the same procedure as before, but M is set to 1. The Channel Emulator is not stepped, but it is allowed to play in free run mode for each of the K spatial points.

### 7.4.2 Pass/Fail Criteria

The Pass/Fail Criteria of channel model validation for FR1 and FR2 is FFS.

# 8 Base station configuration

## 8.1 General

In this part, Base station configuration for NR MIMO OTA testing is defined.

## 8.2 gNodeB emulator settings

Editor’s note: Further down selecting of parameters (FR1 TDD Bandwidth and FR2 DL Modulation) for RMC will be done in WI phase

The gNodeB emulator parameters shall be set according to Table 8.2-1 for FR1 common parameters, Table 8.2-2 for FR1 FDD 2x2 test parameters, Table 8.2-3 for FR1 TDD 2x2 test parameters, Table 8.2-4 for FR1 FDD 4x4 test parameters, Table 8.2-5 for FR1 TDD 4x4 test parameters, and Table 8.2-6 for FR2 common parameters, Table 8.2-7 and Table 8.2-8 for FR2 TDD 2x2 test parameters.

Table 8.2-1: 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 TS 38.101-1 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 TS 38.101-4 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 Annex A.5 of TS 38.101-4 |
| Minimum Number of Slots per Stream | | |  | 20000 for 15kHz SCS  40000 for 30kHz SCS  (Note 3) |
| Transmit Power Control | | | dBm | 13 dBm |
| 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 TS 38.101-1 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 8.2-2: Test parameters for FR1 FDD 2x2

|  |  |  |  |
| --- | --- | --- | --- |
| Parameter | | Unit | Value |
| Duplex mode | |  | FDD |
| Reference channel | |  | R.PDSCH.1-3.1 FDD (Note 1) |
| 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 interleaver 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 8.2-1. |
| Number of HARQ Processes | |  | 4 |
| The number of slots between PDSCH and corresponding HARQ-ACK information | |  | 2 |
| Note 1: “R.PDSCH.1-3.1 FDD” is defined in Table A.3.2.1.1-3 of TS 38.101-4 | | | |

Table 8.2-3: 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, [20] |
| 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 interleaver 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 8.2-1. |
| CSI-RS periodicity | Slots | 40 |
| CSI-RS offset | Slots | Table 8.2-1. |
| 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 TS 38.101-4  Note 2: “FR1.30-1” is defined in Annex A.1.2 of TS 38.101-4 | | | |

Table 8.2-4: Test parameters for FR1 FDD 4x4

|  |  |  |  |
| --- | --- | --- | --- |
| Parameter | | Unit | Value |
| Duplex mode | |  | FDD |
| Reference channel | |  | R.PDSCH.1-2.4 FDD (Note 1) |
| 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 interleaver 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 8.2-1. |
| Number of HARQ Processes | |  | 4 |
| The number of slots between PDSCH and corresponding HARQ-ACK information | |  | 2 |
| Note 1: “R.PDSCH.1-2.4 FDD” is defined in Table A.3.2.1.1-2 of TS 38.101-4 | | | |

Table 8.2-5: 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, [20] |
| 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 interleaver 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 8.2-1. |
| CSI-RS periodicity | Slots | 40. |
| CSI-RS offset | Slots | Table 8.2-1. |
| 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 TS 38.101-4  Note 2: “FR1.30-1” is defined in Annex A.1.2 of TS 38.101-4 | | | |

Table 8.2-6: FR2 Common Parameters

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Parameter | | | Unit | Value |
| PDSCH transmission scheme | | |  | Transmission scheme 1 |
| PTRS *epre-Ratio* | | |  | 0 |
| Actual carrier configuration | Offset between Point A and the lowest usable subcarrier on this carrier (Note 2) | | RBs | 0 |
| Subcarrier spacing | | kHz | 120 |
| 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 TS 38.101-2 for tested channel bandwidth and subcarrier spacing |
| Common serving cell parameters | Physical Cell ID | |  | 0 |
| SSB position in burst | |  | 1 |
| SSB periodicity | | ms | 20 |
| First DMRS position for Type A PDSCH mapping | |  | 2 |
| PDCCH configuration | Slots for PDCCH monitoring | |  | Each slot |
| Symbols with PDCCH | |  | 0 |
| Number of PRBs in CORESET | |  | Table 7.2-2 of TS 38.101-4 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 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 | 120 kHz SCS: 160 for CSI-RS resource 1,2,3,4 |
| CSI-RS offset | | Slots | 120 kHz SCS:  80 for CSI-RS resource 1 and 2  81 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*) | |  | 2 |
| CDM Type | |  | FD-CDM2 |
| Density (*ρ*) | |  | 1 |
| CSI-RS periodicity | | Slots | 120 kHz SCS: 160 |
| CSI-RS offset | |  | 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 | 120 kHz SCS: 160 |
| CSI-RS offset | |  | 0 |
| Frequency Occupation | |  | Start PRB 0  Number of PRB = BWP size |
| CSI-RS for beam refinement | First subcarrier index in the PRB used for CSI-RS | |  | k0=0 for CSI-RS resource 1,2 |
| First OFDM symbol in the PRB used for CSI-RS | |  | l0 = 8 for CSI-RS resource 1  l0 = 9 for CSI-RS resource 2 |
| Number of CSI-RS ports (X) | |  | 1 for CSI-RS resource 1,2 |
| CDM Type | |  | ‘No CDM’ for CSI-RS resource 1,2 |
| Density (ρ) | |  | 3 for CSI-RS resource 1,2 |
| CSI-RS periodicity | | Slots | 60 kHz SCS: 80 for CSI-RS resource 1,2  120 kHz SCS: 160 for CSI-RS resource 1,2 |
| CSI-RS offset | | Slots | 0 for CSI-RS resource 1,2 |
| QCL info | |  | TCI state #1 |
| PDSCH DMRS configuration | Antenna ports indexes | |  | {1000} for Rank 1 tests {1000, 1001} for Rank 2 tests |
| Number of PDSCH DMRS CDM group(s) without data | |  | 1 |
| TCI state #0 | Type 1 QCL information | SSB index |  | SSB #0 |
| QCL Type |  | Type C |
| Type 2 QCL information | SSB index |  | SSB #0 |
| QCL Type |  | Type D |
| 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 |  | CSI-RS resource 1 from ‘CSI-RS for tracking’ configuration |
| QCL Type |  | Type D |
| PTRS configuration | Frequency density (*KPT-RS*) | |  | 2 |
| Time density (*LPT-RS*) | |  | 1 |
| 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 | | |  | {0,2,3,1} |
| Precoding configuration | | |  | SP Type I, Random per slot with PRB bundling granularity |
| Symbols for all unused Res | | |  | OCNG in Annex A.5 of TS 38.101-4 |
| Minimum Number of Slots per Stream | | |  | 20000 for FR2 UMi models in Tables 7.2.2-1—7.2.2.5    75000 for FR2 InO models in Tables 7.2.2-6—7.2.2.10 |
| Transmit Power Control | | | dBm | 13 dBm |
| 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 TS 38.101-2 for tested channel bandwidth and subcarrier spacing. | | | | |

Table 8.2-7: Test Parameters for FR2 TDD 2x2 (16QAM)

|  |  |  |  |
| --- | --- | --- | --- |
| Parameter | | Unit | Value |
| Duplex mode | |  | TDD |
| Reference channel | |  | R.PDSCH.5-2.2 TDD (Note 1) |
| Bandwidth | | MHz | 100 |
| SCS | | kHz | 120 |
| Modulation DL | |  | 16QAM |
| Modulation UL | |  | QPSK |
| Active DL BWP index | |  | 1 |
| CSI-RS for tracking | First OFDM symbol in the PRB used for CSI-RS (*l0*) |  | Table 8.2-6 |
| CSI-RS offset | Slots | Table 8.2-6 |
| PDCCH configuration | Number of PDCCH candidates and aggregation levels |  | 1/AL8 |
| PDSCH configuration | Mapping type |  | Type A |
| *k0* |  | 0 |
| Starting symbol (S) |  | 1 |
| Length (L) |  | Specific to each Reference channel as defined in A.3.2.2 of TS 38.101-4 |
| PDSCH aggregation factor |  | 1 |
| PRB bundling type |  | Static |
| PRB bundling size |  | WB for Test 1-1,  2 for other tests |
| Resource allocation type |  | Type 0 |
| RBG size |  | config2 |
| VRB-to-PRB mapping type |  | Non-interleaved |
| VRB-to-PRB mapping interleaver 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 |
| Number of HARQ Processes | |  | 8 |
| TDD UL-DL pattern | |  | FR2.120-1 (Note2) |
| Note 1: “R.PDSCH.5-2.2 TDD” is defined in Table A.3.2.2.5-2 of TS 38.101-4  Note 2: “FR2.120-1” is defined in Annex A.1.3 of TS 38.101-4 | | | |

Table 8.2-8: Test Parameters for FR2 TDD 2x2 (64QAM)

|  |  |  |  |
| --- | --- | --- | --- |
| **Parameter** | | **Unit** | **Value** |
| Duplex mode | |  | TDD |
| Reference channel | |  | R.PDSCH.5-6.1 TDD (Note 1) |
| Bandwidth | | MHz | 100 |
| SCS | | kHz | 120 |
| Modulation DL | |  | 64QAM |
| Modulation UL | |  | QPSK |
| Active DL BWP index | |  | 1 |
| CSI-RS for tracking | First OFDM symbol in the PRB used for CSI-RS (*l0*) |  | Table 8.2-6 |
| CSI-RS offset | Slots | Table 8.2-6 |
| PDCCH configuration | Number of PDCCH candidates and aggregation levels |  | 1/AL8 |
| PDSCH configuration | Mapping type |  | Type A |
| *k0* |  | 0 |
| Starting symbol (S) |  | 1 |
| Length (L) |  | Specific to each Reference channel as defined in A.3.2.2 of TS 38.101-4 |
| 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 interleaver 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 |
| Number of HARQ Processes | |  | 8 |
| TDD UL-DL pattern | |  | FR2.120-1 (Note2) |
| Note 1: “R.PDSCH.5-2.2 TDD” is defined in Table A.3.2.2.5-6 of TS 38.101-4  Note 2: “FR2.120-1” is defined in Annex A.1.3 of TS 38.101-4 | | | |

Annex A:  
UE coordinate system

# A.1 Reference coordinate system

This annex defines the measurement coordinate system for the NR MIMO OTA. The reference coordinate system, as defined in [5] is provided in Figure A.1-1 below while A.1-2 shows the DUT in the default alignment.

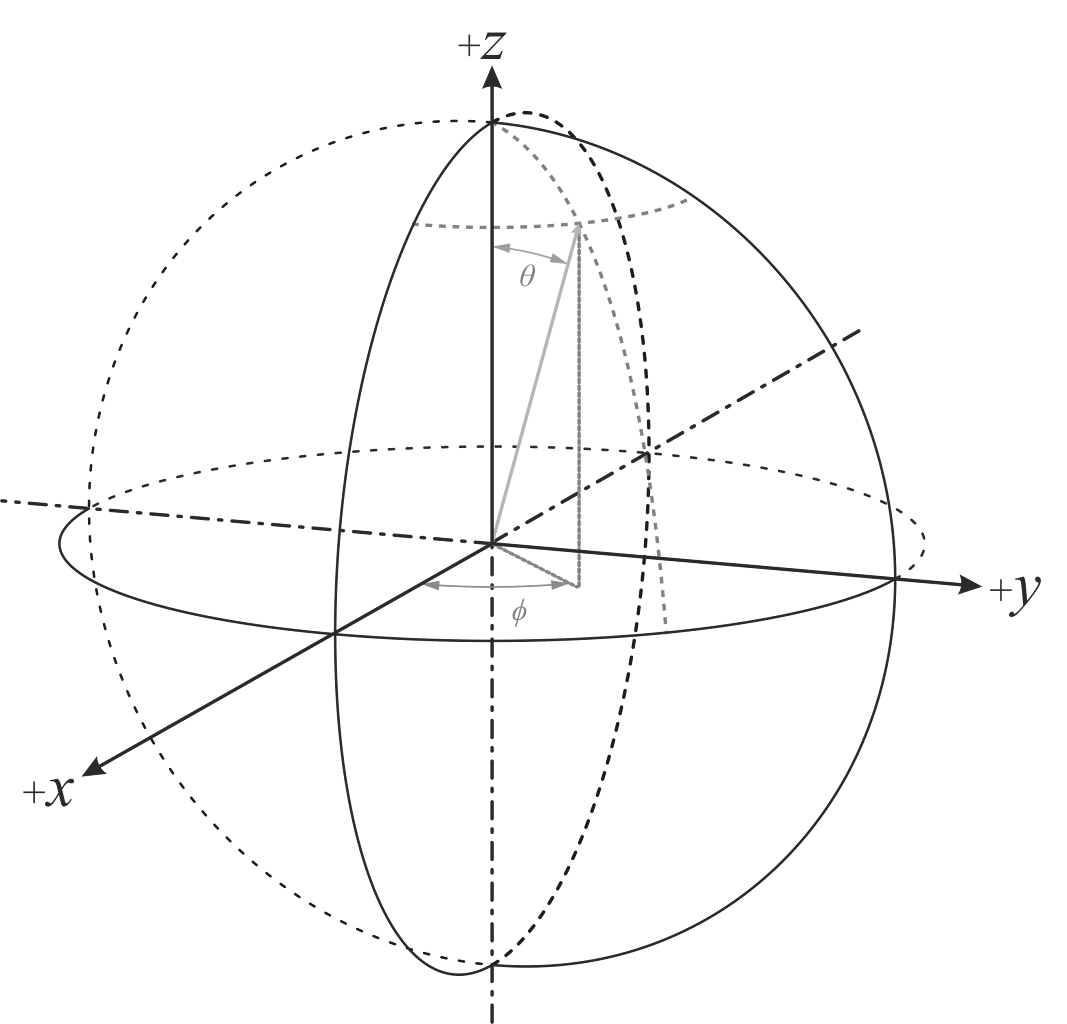


Figure A.1-1: Reference coordinate system

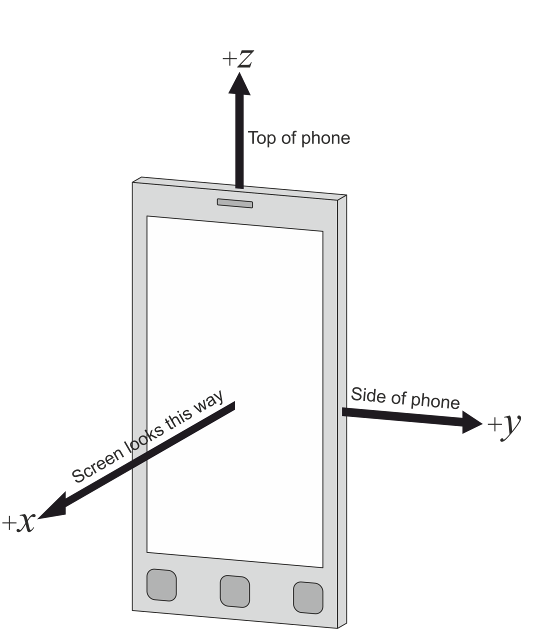


Figure A.1-2: DUT default alignment to coordinate system

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

# A.2 Test conditions and angle definitions

Free space is the test condition for both FR1 and FR2 MIMO OTA testing. The angle definition of the DUT orientation is specified in A.3.

In order to achieve the FR2 test points tabulated in Table 6.2.3.2-1, the UE is rotated so that the test point w.r.t. to the UE coordinate system is aligned with the test system z axis.

# A.3 DUT positioning guidelines

Table A.3-1 below lists the DUT positioning conditions along with a diagram. The XY plane or P0 condition is just shown for information as a reference to the coordinate system defined in Annex A.1.

Table A.3-1: Summary of possible DUT positioning options

|  |  |  |
| --- | --- | --- |
| Testing condition | DUT orientation angles | Diagram |
| XY plane or P0 Orientation 1 (default) | α=0; β=0; γ=0 |  |
| P0 Orientation 2 – Option 1  (based on re-positioning approach) | α=180o; β=0; γ=0 |  |
| P0 Orientation 2 – Option 2  (based on re-positioning approach) | α=0; β=180o; γ=0 |  |
| Free space data mode screen up (FS DMSU) | α=0; β=-90; γ=0 |  |
| Free space data mode portrait (FS DMP) | α=0; β=-45; γ=0 |  |
| Free space data mode landscape (FS DML) | α=90 (left tilt); β=-45; γ=0 |  |
| Note: the repositioning concept is applicable to FR2 only. | | |

Near-field coupling effects between the antenna and the pedestals/positioners/fixtures generally cause increased signal ripples. Re-positioning the DUT by directing the beam peak away from those areas can reduce the effect of signal ripple on TP measurements. The images on the left of Figure A.3-1 illustrate how to reposition the DUT when the near field coupling effects likely originate from the left, while the images on the right Figure A.3-1 illustrate how to reposition the DUT when the near field coupling effects likely originate from the bottom. In either case, Orientation 1 is used for the measurement of one hemisphere while Orientation 2 is used for the measurement of the opposite hemisphere. This re-positioning approach is applicable to FR2 only.

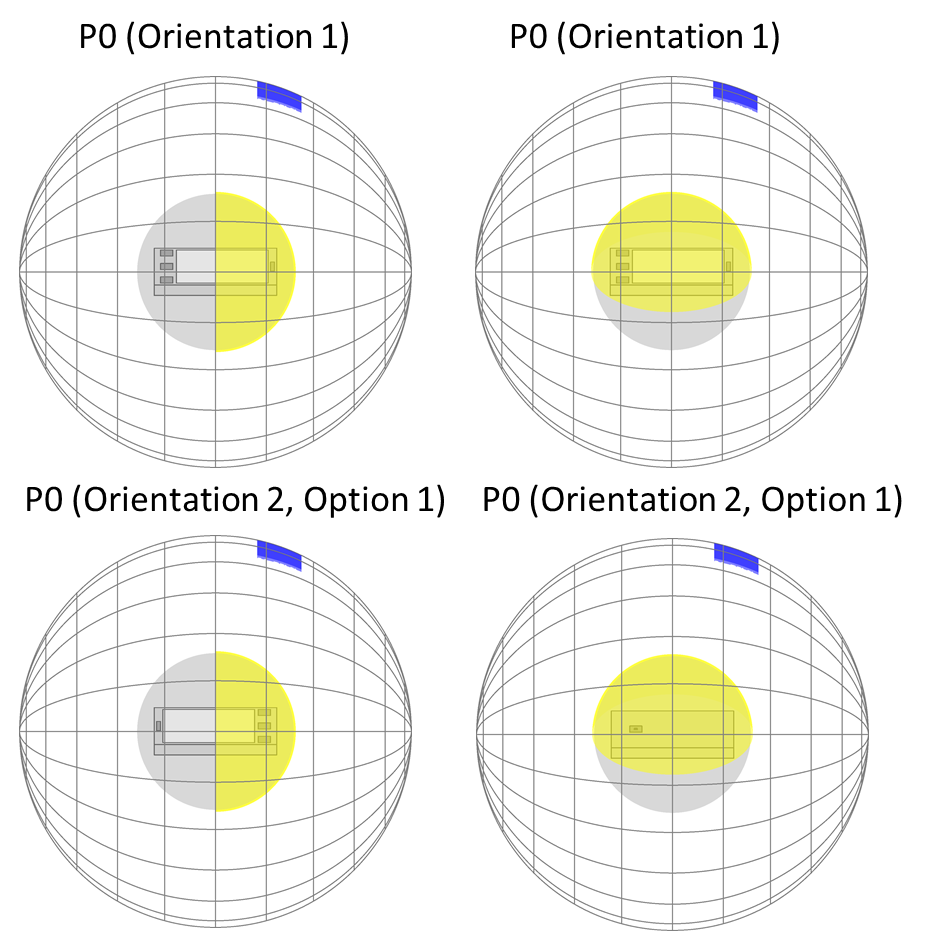


Figure A.3-1: Illustration of DUT re-positioning. The region with reduces signal ripple is illustrated in yellow. The sector which contains the probes is highlighted in blue.

Due to the non-commutative nature of rotations, the order of rotations is important and needs to be defined when multiple DUT orientations are tested.

The rotations around the x, y, and z axes can be defined with the following rotation matrices





and

.

with the respective angles of rotation, **, **, ** and



Additionally, any translation of the DUT can be defined with the translation matrix

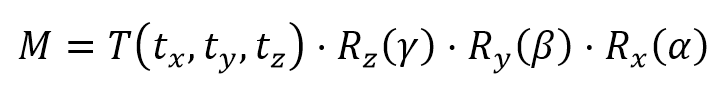


with offsets tx, ty, tz in x, y, and z, respectively and with



The combination of rotations and translation is captured by the multiplication of rotation and translation matrices.

For instance, the matrix M



describes an initial rotation of the DUT around the x axis with angle *α*, a subsequent rotation around the y axis with angle *β*, and a final rotation around the z axis with angle *γ*. After those rotations, the DUT is translated by tx, ty, tz in x, y, and z, respectively.

# A.4 Test Zone dimensions

The test zone size is 20cm for both FR1 and FR2 MIMO OTA testing. Larger test zone size is FFS.

Annex B:  
Measurement uncertainty

# B.1 Measurement uncertainty budget for FR1

## B.1.1 Measurement Uncertainty assessment for MPAC

Table B.1.1-1: Measurement uncertainty budget for MPAC

| UID | Description of uncertainty contribution | Example value (410MHz<f≤3GHz) | Example value (3GHz <f≤7.125GHz) | Distribution of the probability | Details in |
| --- | --- | --- | --- | --- | --- |
| Stage 2: DUT measurement | | | | | |
| 1 | Mismatch for measurement process |  |  | U-Shaped | B.1.2.1 |
| 2 | Measure distance uncertainty |  |  | Normal | B.1.2.2 |
| 3 | Quality of quiet zone |  |  | Rectangular | B.1.2.3 |
| 4 | Base Station simulator |  |  | Rectangular | B.1.2.4 |
| 5 | Channel Emulator  -absolute value  -stability |  |  | Normal | B.1.2.5 |
| 6 | Amplifier uncertainties |  |  | Rectangular | B.1.2.6 |
| 7 | Random uncertainty |  |  | Normal | B.1.2.7 |
| 8 | Throughput measurement: output level step resolution |  |  | Rectangular | B.1.2.8 |
| 9 | DUT sensitivity drift |  |  | Rectangular | B.1.2.9 |
| 10 | Signal flatness |  |  | Normal | B.1.2.10 |
| Stage 1: Calibration measurement | | | | | |
| 11 | Mismatch for calibration process  - loopback cable path  - system input path  - reference antenna |  |  | U-Shaped | B.1.2.11 |
| 12 | Reference antenna positioning misalignment |  |  | Normal | B.1.2.12 |
| 13 | Quality of quiet zone |  |  | Rectangular | B.1.2.3 |
| 14 | Total uncertainty of the Network Analyzer |  |  | Rectangular | B.1.2.13 |
| 15 | Uncertainty of an absolute gain of the calibration antenna |  |  | Normal | B.1.2.14 |
| 16 | Offset of the Phase Center of the Reference Antenna |  |  | Normal | B.1.2.15 |

## B.1.2 Measurement error contribution descriptions for MPAC

#### B.1.2.1 Mismatch for measurement process

This term comes from the mismatch between the system input cables connecting to the base station simulator output port.

#### B.1.2.2 Measure distance uncertainty

The cause of this uncertainty contributor is due to the reduction of distance between the measurement antenna and the DUT. Given that 1.2m is defined as the minimum range length for FR1 MPAC system, this term could be set as 0 dB.

#### B.1.2.3 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 measurement, reference antenna of sleeve dipole or magnetic loop is always used. The standard uncertainty shall be calculated by dividing the maximum ripple by √3, as measured in a volume greater than half a wavelength in diameter. This element is considered to be rectangularly distributed.

#### B.1.2.4 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 should be calculated from the manufacturer’s data in logs with a rectangular distribution, unless otherwise informed. Furthermore, the uncertainty of the non-linearity is included in the absolute level uncertainty.

#### B.1.2.5 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.1.2.6 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 [7].

- 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 -> 0dB. If it is not the case, this uncertainty shall be considered.

#### B.1.2.7 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 value of 0.2dB aligned with LTE is suggested.

#### B.1.2.8 Throughput measurement: output level step resolution

The cause of this uncertainty contributor is due to the step size in the power level used in the throughput measurement stage. Depending on the system provider implementation, the power level adjustment is based on changing the output power of BS simulator or channel model emulator. Fixed 0.5dB step is defined for NR MIMO OTA testing, an uncertainty contribution of 0.25dB with a rectangular distribution should be reported.

#### B.1.2.9 DUT sensitivity drift

Due to statistical uncertainty of throughput measurement, drift in the TRMS can not be monitored. An uncertainty value of 0.2dB can be used, or the TRMS drift should be measured, with a setup corresponding to the actual MIMO OTA measurement.

#### B.1.2.10 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 center frequency of the channel, the broadband radiated power measured or delivered to the test zone will be a function of the entire channel bandwidth as opposed to just the center frequency. Thus, any deviation of the rest of the channel from the signal level at the center frequency will result in an error in the measured result. The determination of the MU element is FFS.

#### B.1.2.11 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.

#### B.1.2.12 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.1.2.13 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. The uncertainty value will be indicated in the manufacturer's data sheet. It needs to be ensured that appropriate manufacturer's uncertainty contribution is specified for the absolute levels measured.

#### B.1.2.14 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 will come from a calibration report with traceability to a National Metrology Institute with measurement uncertainty budgets generated following the guidelines outlined in internationally accepted standards.

#### B.1.2.15 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.

# B.2 Measurement uncertainty budget for FR2

## B.2.1 Measurement Uncertainty assessment

Table B.2.1-1: Measurement uncertainty budget for FR2 3D-MPAC

| UID | Description of uncertainty contribution | Example value (26.5GHz≤f≤29.5GHz) | Example value (37GHz ≤f≤40GHz) | Distribution of the probability | Details in |
| --- | --- | --- | --- | --- | --- |
| Stage 2: DUT measurement | | | | | |
| 1 | Mismatch for measurement process |  |  | U-Shaped | B.2.2.1 |
| 2 | Measure distance uncertainty |  |  | Normal | B.2.2.2 |
| 3 | Quality of quiet zone |  |  | Rectangular | B.2.2.3 |
| 4 | Base Station simulator |  |  | Rectangular | B.2.2.4 |
| 5 | Channel Emulator  -absolute value  -stability  -linearity |  |  | Normal | B.2.2.5 |
| 6 | Amplifier uncertainties |  |  | Rectangular | B.2.2.6 |
| 7 | Random uncertainty |  |  | Normal | B.2.2.7 |
| 8 | Throughput measurement: output level step resolution |  |  | Rectangular | B.2.2.8 |
| 9 | DUT sensitivity drift |  |  | Rectangular | B.2.2.9 |
| 10 | Signal flatness |  |  | Normal | B.2.2.10 |
| Stage 1: Calibration measurement | | | | | |
| 11 | Mismatch for calibration process  - loopback cable path  - system input path  - reference antenna |  |  | U-Shaped | B.2.2.11 |
| 12 | Reference antenna positioning misalignment |  |  | Normal | B.2.2.12 |
| 13 | Quality of quiet zone |  |  | Rectangular | B.2.2.3 |
| 14 | Total uncertainty of the Network Analyzer |  |  | Rectangular | B.2.2.13 |
| 15 | Uncertainty of an absolute gain of the calibration antenna |  |  | Normal | B.2.2.14 |
| 16 | Offset of the Phase Center of the Reference Antenna |  |  | Normal | B.2.2.16 |

## B.2.2 Measurement error contribution descriptions

#### B.2.2.1 Mismatch for measurement process

This term comes from the mismatch between the system input cables connecting to the base station simulator output port.

#### B.2.2.2 Measure distance uncertainty

The cause of this uncertainty contributor is due to the reduction of distance between the measurement antenna and the DUT. Given that 0.75m is defined as the minimum range length for FR2 3D-MPAC system, this term could be set as 0 dB.

#### B.2.2.3 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.

#### B.2.2.4 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 should be calculated from the manufacturer’s data in logs with a rectangular distribution, unless otherwise informed. Furthermore, the uncertainty of the non-linearity is included in the absolute level uncertainty.

#### B.2.2.5 Channel Emulator

The channel emulator is also working as a signal source in the FR2 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. This uncertainty value shall be the final value after mmWave radio head.

#### B.2.2.6 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 [7].

- 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 -> 0dB. If it is not the case, this uncertainty shall be considered.

#### B.2.2.7 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 value of 0.2dB aligned with FR1 is suggested.

#### B.2.2.8 Throughput measurement: output level step resolution

The cause of this uncertainty contributor is due to the step size in the power level used in the throughput measurement stage. Depending on the system provider implementation, the power level adjustment is based on changing the output power of BS simulator or channel model emulator. Fixed 0.5dB step is defined for NR MIMO OTA testing, an uncertainty contribution of 0.25dB with a rectangular distribution should be reported.

#### B.2.2.9 DUT sensitivity drift

Due to statistical uncertainty of throughput measurement, drift in the TRMS can not be monitored. An uncertainty value of 0.2dB can be used, or the TRMS drift should be measured, with a setup corresponding to the actual MIMO OTA measurement.

#### B.2.2.10 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 center frequency of the channel, the broadband radiated power measured or delivered to the test zone will be a function of the entire channel bandwidth as opposed to just the center frequency. Thus, any deviation of the rest of the channel from the signal level at the center frequency will result in an error in the measured result. The determination of the MU element is FFS.

#### B.2.2.11 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.

#### B.2.2.12 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.2.2.13 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. The uncertainty value will be indicated in the manufacturer's data sheet. It needs to be ensured that appropriate manufacturer's uncertainty contribution is specified for the absolute levels measured.

#### B.2.2.14 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 will come from a calibration report with traceability to a National Metrology Institute with measurement uncertainty budgets generated following the guidelines outlined in internationally accepted standards.

#### B.2.2.15 Offset of the Phase Center of the Reference Antenna

Gain is defined at the phase centre of the antenna. If the phase centre of the calibration antenna is not aligned at the centre of the set up during the calibration, then there will be uncertainty related to the measurement distance.

Annex C:  
Environmental requirements

# C.1 Scope

The requirements in this clause apply to all types of UE(s) in FR1 and FR2.

# C.2 Ambient temperature

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

# C.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.

For FR2 MIMO OTA, all nominal voltage test cases shall be performed with the DUT operated in stand-alone battery powered mode or external power source. It shall be demonstrated that the impact of external power source to device performance is negligible comparing to stand-alone battery powered mode.

Annex D:  
Procedure to characterize the quality of the quiet zone

# D.1 FR1 quality of the quiet zone

Unwanted reflections and support structure blockage cause a volumetric ripple to the field magnitude seen from each measurement antenna as shown in Figure D1-1. By rotating an omnidirectional antenna through the test volume as illustrated by the red line, this volumetric ripple may be probed to obtain an estimate of the measurement uncertainty due to this volumetric error. The quality of the quiet zone test consists of a phi-axis ripple test that covers a cylindrical quiet zone 20 cm in diameter around the phi axis and 20 cm tall. Each reference antenna is oriented with its axis parallel to the phi axis at a total of three positions offset 10 cm perpendicular to the phi with 0 cm and ±10 cm offsets parallel to the phi axis. At each position, the phi axis is rotated 360°o record the ripple. Each position is labeled by its radial and axial offset from the center position, (*R*,*Z*), using 0, +, or – to represent the appropriate offset in each direction. See Figure D1-2 for additional information.



Figure D1-1: Volumetric ripple and 20cm Phi axis cut

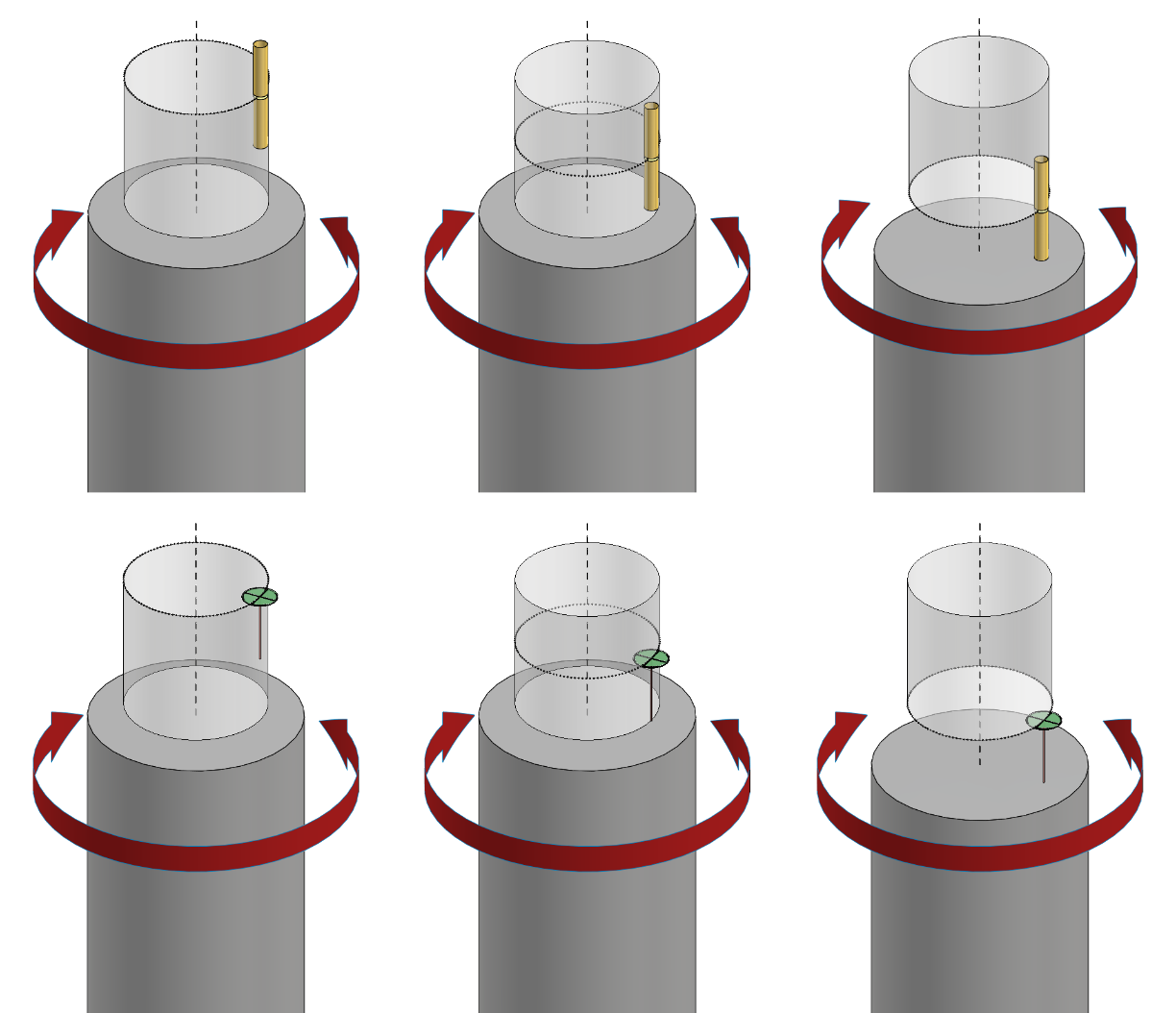


Figure D1-2: Phi-axis test geometry

For each polarization and band, repeat the following steps:

1 Place the Measurement Antenna and any associated theta-axis positioner at theta = 90° such that the Measurement Antenna is boresight with the center of the quiet zone. The Measurement Antenna should be at the same separation distance to be used for actual pattern measurements. This distance must be at least *R* (the minimum measurement distance is defined in clause 6.6) meters away from the center of the quiet zone. Select the polarization of the Measurement Antenna to correspond to the polarization (V or H) to be tested.

2 Mount the reference antenna to the phi-axis positioner using a low permittivity dielectric support. Use the sleeve dipole for the V polarization and the loop for the H polarization. At each of the six offset positions, ensure that the axis of the reference antenna is parallel to the phi axis of rotation.

3 Attach a signal source to a coaxial cable feeding the Measurement Antenna and set the frequency to the appropriate channel. Set the amplitude to a level appropriate for the measurement receiver. Connect a measurement receiver to the reference antenna. The received signal during the ripple test measurement should be at least 40 dB above the noise floor or noise errors greater than 0.1 dB will result. Ensure that all coaxial cables are dressed to minimize effects upon the measurement results.

4 Rotate the reference antenna about the phi axis and record the signal received by the Measurement Antenna at resolution sufficient to ensure smoothly varying curves for a total of 360°.

5 Record the measurement results to a file that can be imported into a spreadsheet.

6 Record test parameters including: (a) the distance between the measurement and reference antennas, (b) cable losses and other losses associated with the measurement setup, (c) the power of the signal source at the reference antenna connector, and (d) the noise level of the receiver with no signal applied.

7 Repeat steps 1 through 6 above for each reference antenna (polarization and band) for each of the 6 test positions, offsetting 100 mm ±2 mm from the center of the quiet zone in each direction along the phi axis and radially from the center. In order to accommodate reference positioning in the lower portion of the quiet zone, support materials with a dielectric constant less than 1.2 may be removed to a maximum distance of 250 mm outside the quiet zone for the tests that require additional clearance.

# D.2 FR2 quality of the quiet zone

The FR2 quality of quiet zone validation test characterizes the quiet zone performance of the anechoic chamber, specifically the effect of reflections within the anechoic chamber including any positioners and support structures. The spherical test zone with 20 cm diameter to be validated with the FR2 quality of quiet zone procedure is illustrated in Figure D.2-1.

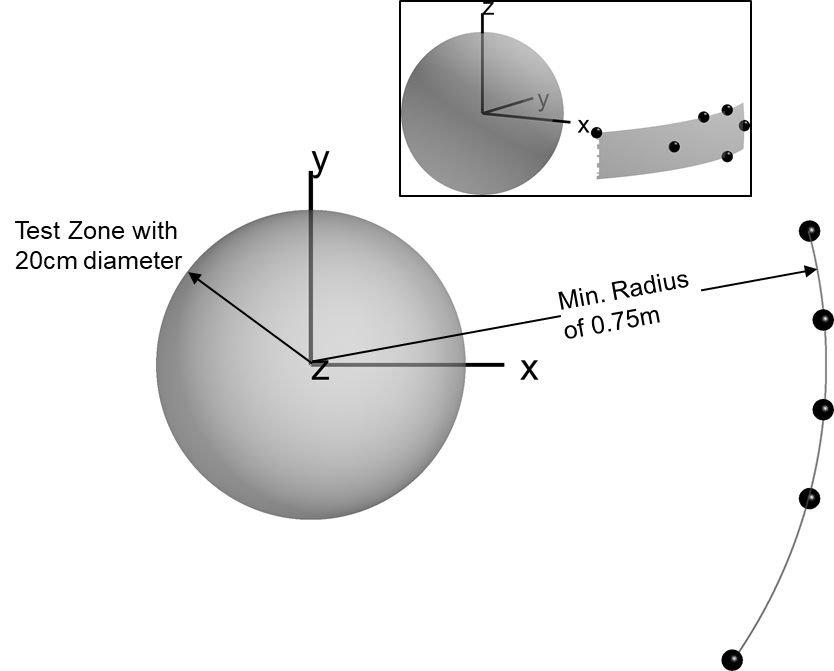


Figure D.2-1: Illustration of spherical 20 cm test zone validated using quality of quiet zone procedure

The quality of quiet zone test procedure, equipment, and test frequencies are defined in Annex O.2 of TS 38.521-2 [9]. For NR FR2 MIMO OTA, only the single-directional EIRP and EIS metrics need to be assessed and the procedure needs to be performed using just a single 3D MPAC probe.

Annex E:  
Change history

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| --- | --- | --- | --- | --- | --- | --- | --- |
| **Change history** | | | | | | | |
| **Date** | **Meeting** | **TDoc** | **CR** | **Rev** | **Cat** | **Subject/Comment** | **New version** |
| 2018-10 | R4#88bis | R4-1813566 |  |  |  | Skeleton of TR38.827 on NR MIMO OTA test methods | 0.0.1 |
| 2019-02 | R4#90 | R4-1901362 |  |  |  | R4-1815935, R4-1816656  Updated TR scope and FoM | 0.1.0 |
| 2019-05 | R4#91 | R4-1906127 |  |  |  | R4-1905103  Reference coordinate system | 0.2.0 |
| 2019-08 | R4#92 | R4-1909936 |  |  |  | R4-1907609  Test methods, EUT orientations, and Channel model validation | 0.3.0 |
| 2019-10 | R4#92bis | R4-1911619 |  |  |  | R4-1910396, R4-1909938, R4-1910399  DUT positioning guidelines, Abbreviations, Channel Models | 0.4.0 |
| 2019-11 | R4#93 | R4-1913689 |  |  |  | R4-1912899, R4-1912900, R4-1912902  Temperature and voltage conditions, RMC for MIMO OTA, Base Station beamforming configuration | 0.5.0 |
| 2019-11 | R4#93 | R4-1916173 |  |  |  | R4-1916010, R4-1916011, R4-1916012, R4-1916013, R4-1915073, R4-1916176  DoT for FR1; test methods, calibration and channel model validation for FR1; 64QAM RMC | 0.6.0 |
| 2019-12 | RP#86 | RP-192415 |  |  |  | Submitted for information to RAN | 1.0.0 |
| 2020-02 | R4#94-e | R4-2000894 |  |  |  | R4-1916014  RTS system, calibration and test proceudre | 1.1.0 |
| 2020-03 | R4#94-e | R4-2002482 |  |  |  | R4-2002481, R4-2002472, R4-2002473, R4-2002474, R4-2002475, R4-2002476, R4-2002152, R4-2002480, R4-2002533  spatial sampling points, general part, MU assessment, DoT for FR2, , FR2 channel model validation procedure, calibration and test procedure, EUT orientations for FR2, initial phase of channel model | 1.2.0 |
| 2020-04 | R4#94-e-bis | R4-2003640 |  |  |  | R4-2003639, R4-2005559  General part, FR2 3D-MPAC system probes location | 1.3.0 |
| 2020-06 | R4#95-e | R4-2006307 |  |  |  | R4-2006308, R4-2006740, R4-2006742, R4-2008273  RMC correction, FR2 QoQZ procedure, FR2 PSP validation procedure, FR2 system correction to avoid ambiguities. Editor’s editorial correction. | 1.4.0 |
| 2020-06 | RP#88-e | RP-201068 |  |  |  | Submitted to RAN for approval  Editorial correction of Figure 7.4.1.6-1. | 2.0.0 |

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| --- | --- | --- | --- | --- | --- | --- | --- |
| **Change history** | | | | | | | |
| **Date** | **Meeting** | **TDoc** | **CR** | **Rev** | **Cat** | **Subject/Comment** | **New version** |
| 2020-06 | RAN#88 |  |  |  |  | Approved by plenary – Rel-16 spec under change control | 16.0.0 |
| 2020-12 | RAN#90 | RP-202426 | 0002 | 2 | B | Addition of Time Domain Alternative for Spatial Correlation Validation | 16.1.0 |
| 2020-12 | RAN#90 | RP-202426 | 0003 |  | F | Update of FR2 probe configuration | 16.1.0 |
| 2020-12 | RAN#90 | RP-202426 | 0004 | 1 | F | Number of Slots for NR MIMO OTA testing | 16.1.0 |
| 2020-12 | RAN#90 | RP-202426 | 0007 | 1 | F | CR for 38.827 on corrections | 16.1.0 |
| 2021-03 | RAN#91 | RP-210069 | 0008 |  | F | Uplink Power Control for NR MIMO OTA test | 16.2.0 |
| 2021-03 | RAN#91 | RP-210069 | 0010 |  | F | CR on Channel Model Topics | 16.2.0 |
| 2021-03 | RAN#91 | RP-210069 | 0013 |  | F | CR to TR38.827 on the direction of the BS strongest beams | 16.2.0 |
| 2021-06 | RAN#92 | RP-211099 | 0014 |  | F | FR2 measurement data processing | 16.3.0 |
| 2021-06 | RAN#92 | RP-211099 | 0015 |  | F | Adding clarification of number of slots for FR1 MIMO OTA test | 16.3.0 |
| 2021-06 | RAN#92 | RP-211099 | 0016 |  | F | Calibration procedure and Test procedure Correction | 16.3.0 |
| 2021-09 | RAN#93 | RP-211894 | 0017 |  | F | Big CR for TR 38.827 maintenance (Rel-16, CAT F) | 16.4.0 |
| 2021-12 | RAN#94 | RP-212852 | 0018 |  | F | Big CR for TR 38.827 maintenance (Rel-16, CAT F) | 16.5.0 |
| 2022-03 | RAN#95 | RP-220340 | 0019 |  | F | Big CR for TR 38.827 maintenance (Rel-16, CAT F) | 16.6.0 |
| 2022-06 | RAN#96 | RP-221658 | 0020 |  | F | Big CR for TR 38.827 maintenance (Rel-16, CAT F) | 16.7.0 |
| 2022-09 | RAN#97 | RP-222024 | 0022 |  | F | Big CR for TR 38.827 maintenance (Rel-16, CAT F) | 16.8.0 |