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Technical Specification

3rd Generation Partnership Project;
Technical Specification Group Radio Access Network;
NR;
Multiple Input Multiple Output (MIMO) Over-the-Air (OTA) performance requirements for NR UEs
(Release 17)

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Contents

Foreword

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

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

Version x.y.z

where:

x the first digit:

1 presented to TSG for information;

2 presented to TSG for approval;

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.

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

shall indicates a mandatory requirement to do something

shall not indicates an interdiction (prohibition) to do something

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

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

should indicates a recommendation to do something

should not indicates a recommendation not to do something

may indicates permission to do something

need not indicates permission not to do something

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

can indicates that something is possible

cannot indicates that something is impossible

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

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

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

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

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

In addition:

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

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

1 Scope

The present document establishes the Multiple Input Multiple Output (MIMO) Over-the-Air (OTA) performance requirements for NR UEs operating on frequency Range 1 and frequency rang 2, for NR standalone (SA) and NR non-standalone (NSA) operation mode.

2 References

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

- References are either specific (identified by date of publication, edition number, version number, etc.) or non-specific.
- For a specific reference, subsequent revisions do not apply.
- For a non-specific reference, the latest version applies. In the case of a reference to a 3GPP document (including a GSM document), a non-specific reference implicitly refers to the latest version of that document *in the same Release as the present document*.

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

[2] 3GPP TR 38.827: “Study on radiated metrics and test methodology for the verification of multi-antenna reception performance of NR User Equipment (UE)”.

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

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

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

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

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

3 Definitions of terms, symbols and abbreviations

3.1 Terms

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

Definition format (Normal)

<defined term>: *<definition>.*

example: text used to clarify abstract rules by applying them literally.

3.2 Symbols

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

Symbol format (EW)

<symbol> <Explanation>

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].

Abbreviation format (EW)

DML Data Mode Landscape
DMP Data Mode Portrait
DMSU Data Mode Screen Up
EUT Equipment Under Test
FR1 Frequency Range 1
FR2 Frequency Range 2
FS Free Space
MIMO Multiple Input Multiple Output
MPAC Multi-Probe Anechoic Chamber
NR New Radio
NSA Non-Standalone, a mode of operation where operation of an other radio is assisted with an other radio
OTA Over The Air
PDP Power Delay Profile
PSP PAS Similarity Percentage
UE User Equipment
UMa Urban Macro
UMi Urban Micro

4 General

4.1 Relationship between minimum requirements and test requirements

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

4.2 Applicability of minimum requirements

<Editor's note: Detailed structure of the subclause is TBD. >

5 Frequency bands

5.1 General

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

Table 5.1-1: Definition of frequency ranges

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

The present specification covers both FR1 and FR2 operating bands.

5.2 Operating bands

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

6 FR1 MIMO OTA requirements

6.1 General

<Editor's note: Detailed structure of the subclause is TBD. Include FoM of TRMS for FR1. >

6.1.1 Definition of MIMO throughput

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

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

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

Hence the MIMO (OTA) throughput can be calculated as

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

Where Transmitted TBS is the Transport Block Size transmitted by the SS, which is fixed for 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.

6.1.2 Total Radiated Multi-antenna Sensitivity (TRMS)

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

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

where

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

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

If 1 azimuth position does not result in a defined measured sensitivity at 70% throughput, $S_{MODE,70}$ is calculated using the 11 measured sensitivities and the maximum downlink RS-EPRE $P_{RS\text{-}EPRE\text{-}MAX}$ (substitution approach) for the one missing result. $P_{RS\text{-}EPRE\text{-}MAX}$ is the maximum downlink RS-EPRE supported by the test system, and is defined as below:

- For FR1 band frequency <3GHz, the $P_{RS\text{-}EPRE\text{-}MAX}$ is [-80dBm/15kHz (or equivalent 77dBm/30kHz)]
- For FR1 band frequency >3GHz, the $P_{RS\text{-}EPRE\text{-}MAX}$ is TBD.

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

The additional criterion in azimuthal orientations shall be met:

- For 10 MHz and 40MHz testing, the EUT must meet 70% throughput in 11 of total 12 azimuthal orientations. If the EUT fails to meet this criterion even under maximum downlink power condition (i.e. $P_{RS\text{-}EPRE\text{-}MAX}$), the EUT shall fail the FR1 MIMO OTA test.
- For 10 MHz and 40MHz testing, the EUT must meet 90% throughput in [TBD] of total 12 azimuthal orientations. If the EUT fails to meet this criterion even under maximum downlink power condition (i.e. $P_{RS\text{-}EPRE\text{-}MAX}$), the EUT shall fail the FR1 MIMO OTA test.

6.2 Minimum requirement

<Editor's note: Detailed structure of the subclause is TBD. Subclause for SA and EN-DC bands can be added>

7 FR2 MIMO OTA requirements

7.1 General

<Editor's note: Detailed structure of the subclause is TBD. Include FoM of and data processing for FR2. >

7.1.1 MIMO Average Spherical Coverage (MASC)

The MIMO Average Spherical Coverage (MASC) is the Figure of Merit of FR2 MIMO OTA requirement. FR2 MIMO OTA is measured with 36 constant-density points within the 3D sphere, the MASC is determined by the averaging of all the values better than 50% percentile of CCDF. The averaging shall be done in linear scale for the MASC result according to the formula:

$$MASC_{50\%-tile,70} = 10\log\left[N \Big/ \left(\frac{1}{10^{P_{50\%-tile,70,0}/10}} + \frac{1}{10^{P_{50\%-tile,70,1}/10}} + \cdots + \frac{1}{10^{P_{50\%-tile,70,N}/10}} \right) \right]$$

Such that $\{P_{50\%\text{-}tile,70,0}, \ldots, P_{50\%\text{-}tile,70,N}\}$ are the N sensitivity values better than 50%-tile of the CCDF. The CCDF are the sensitive values at 70% maximum throughput outage measured from all the 36 constant density points, as defined in Annex B.2.3.

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

If the UE can not meet 70% maximum throughput outage at any direction, then how to handle this test point is FFS.

Other criteria for FR2 are FFS.

7.2 Minimum requirement

<Editor's note: Detailed structure of the subclause is TBD. >

Annex A (normative): <FR1 Test methodology>

<Editor's note: Detailed structure of the subclause is TBD.

Refer to TR38.827 Include: General (environmental condition, test zone size), measurement methodology (setup, procedure, minimum range length), EUT positioning:

Exception or additional decisions can be added. >

A.1 General

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

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

A.2 Multi-Probe Anechoic Chamber (MPAC)

A.2.1 system setup

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

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

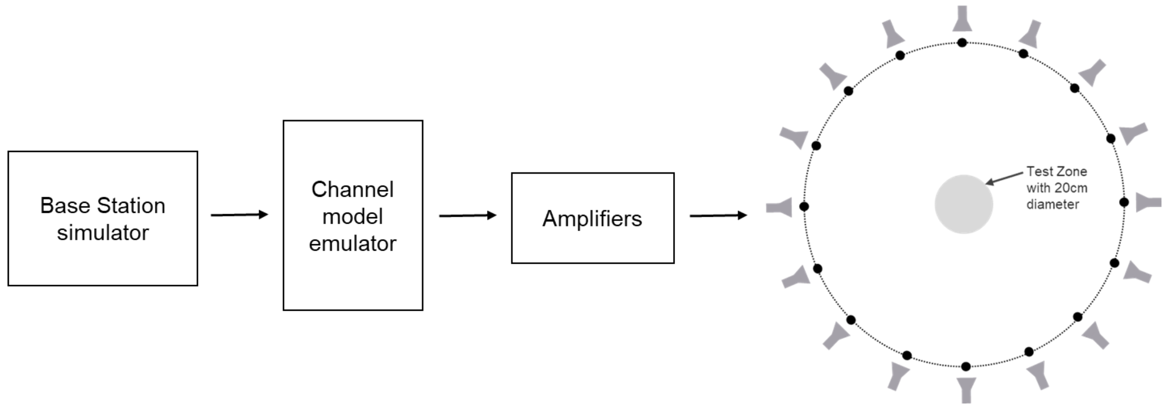

Figure A.2.1-1: MPAC system layout for NR FR1 MIMO OTA testing

A.2.2 Calibration procedure

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

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

1. Place a vertical reference dipole in the center of the test zone, connected to a VNA port, with the other VNA port connected to the input of the channel emulator unit.
2. Configure the channel emulator for bypass mode.
3. Measure the response of each path from each vertical polarization probe to the reference antenna in the 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 and horizontally polarized probes 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.

A.2.3 Test procedure

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

1. Ensure environmental requirements of Annex F are met.
2. Configure the test system according to Annex C, D and E for the applicable test case.
3. Verify the implementation of the channel model as specified in Annex C.3.
4. Position the UE in the chamber according to Annex A.3.
5. Power on the UE.
6. Set up the connection.

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

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

1. Measure MIMO OTA throughput from one measurement point, the maximum downlink power is TBD. MIMO OTA throughput is the minimum downlink signal power resulting in a pre-defined throughput value, i.e., 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.
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 Clause 6.

A.2.4 Minimum Range Length

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

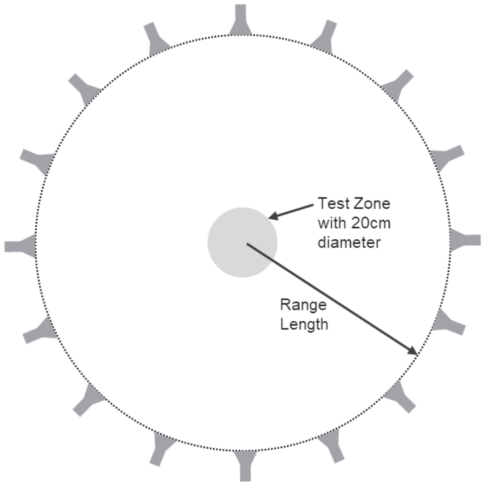

Figure A.2.4-1: Illustration of range length definition of FR1 MPAC

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

A.3 EUT positioning

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

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).

Annex B (normative): <FR2 Test methodology>

B.1 General

FR2 MIMO OTA requirement testing is based on UE-noise limited environmental condition, i.e., UE throughput characterized as a function of signal power incident to the DUT antennas.

The minimum test zone size for FR2 MIMO OTA 3D-MPAC system is 20cm. “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 completely contained within the minimum test zone size.

B.2 FR2 3D Multi-Probe Anechoic Chamber (3D-MPAC)

B.2.1 system setup

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 B.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 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 B.2.1-1) 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.

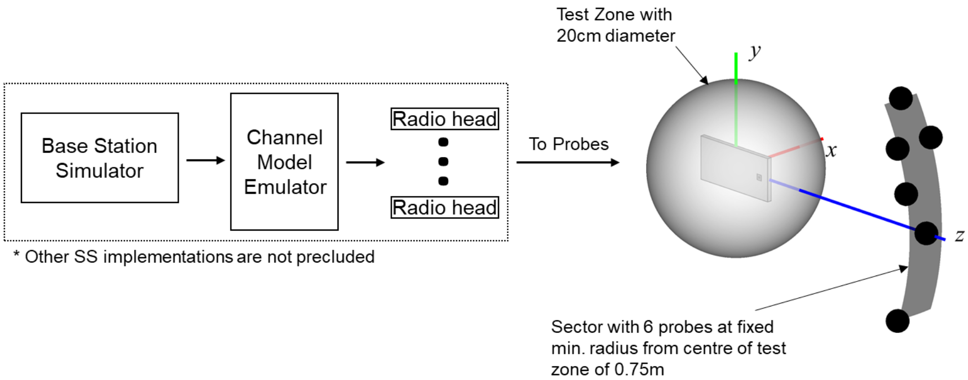

Figure B.2.1-1: 3D MPAC system layout for NR FR2 MIMO OTA testing

The exact probe locations with respect to the OTA test system coordinate system are tabulated in Table B.2.1-1.

Table B.2.1-1. 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 B.2.1-1 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 B.2.1-2. 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.

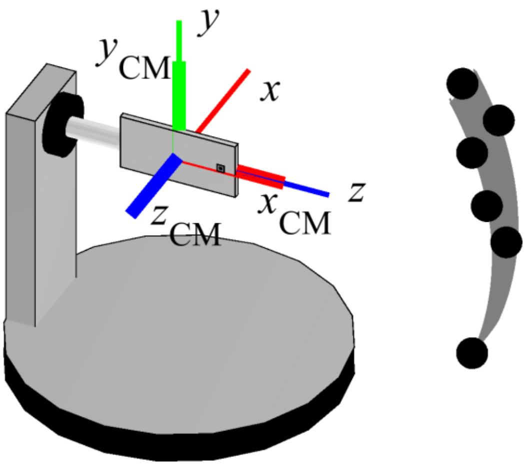

Figure B.2.1-2: Channel Model Coordinate Axes in FR2 3D-MPAC system

The probe locations with respect to channel model coordinate axes are tabulated in table B.2.1-2.

Table B.2.1-2. 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 B.2.1-3.

Table B.2.1-3. Channel Model Rotations

UMi CDL-C	
Phi [deg]	Theta [deg]
32	15.0

This channel model rotation assumes the relative orientations of BS and UE antennas displayed in Figure B.2.1-3, i.e., the DUT antenna is pointed towards the BS in channel model coordinate system.

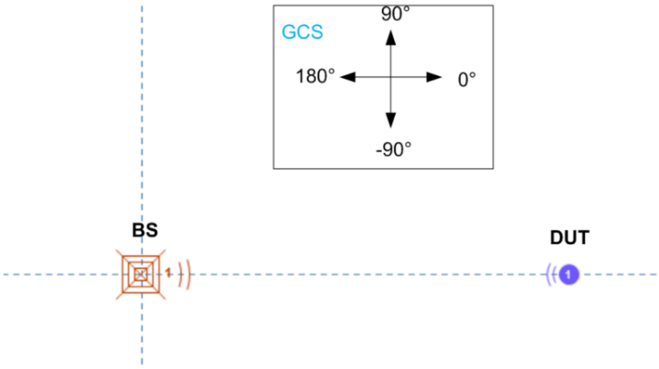

Figure B.2.1-3: Relative orientations of BS and UE antennas.

Since the test points are uniformly spaced in 3D already, Table B.2.3-1, there is no need to adjust/rotate the DUT rotations by the channel model rotations.

B.2.2 Calibration procedure

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

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 D.3.2-1. For each probe antenna, the reference antenna needs to be aligned in polarization, i.e., θ or ϕ, 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, $L_{path,pol}$, 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).

B.2.3 Test procedure

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

1. Ensure environmental requirements of Annex F are met.
2. Configure the test system according to Annex E.2 and Annex D.1 for the applicable test case.
3. Verify the implementation of the channel model as specified in Annex D.3.
4. Position the UE in the chamber according to Annex B.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 FR2 MIMO OTA performance of the DUT:

1. Position the DUT in the default P0 alignment option (Orientation 1), as defined in Annex A.3 in TR38.827 [2].

2. Measure MIMO OTA throughput, the maximum downlink power is TBD. 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 B.2.3-1 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. The postprocessing method and the performance metric are FFS.

Table B.2.3-1. 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

B.2.4 Minimum Range Length

The minimum range length of FR2 MPAC system is defined as the distance from the centre of the test zone to the aperture of the measurement probes/antennas, as illustrated in Figure B.2.4-1.

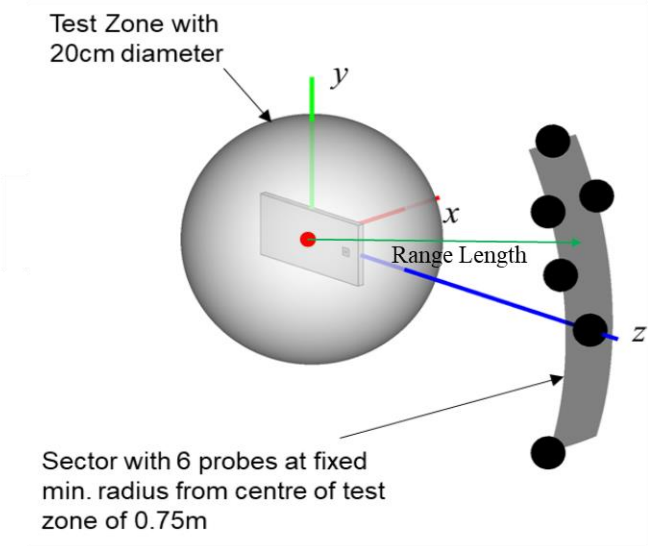

Figure B.2.4-1: Illustration of range length definition of FR2 3D-MPAC

The minimum range length for NR FR2 MPAC OTA systems with 20cm test zone size is 0.75m. It was shown that the PSP can be reduced significantly for distances below 0.75m.

B.3 EUT positioning

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

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 Annex A.3 in [2], measurements on 36 evenly spaced test points with a constant density shall be performed.

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

<Editor's note: Detailed structure of the subclause is TBD.

Include FR1 channel model tables after down-selection for requirement, FR1 channel model validation procedure, and validation pass/fail requirement. >

C.1 FR1 Channel models

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

The generic models are Table C.1-1 FR1 UMi CDL-A and Table C.1-2 FR1 UMa CDL-C, which do not include base station antenna filtering.

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

Table C.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	C_{ASD} in [°]	C_{ASA} in [°]	C_{ZSD} in [°]	C_{ZSA} in [°]	XPR in [dB]	
Value	1.6266	7.385	0.0815	0	10	

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

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

C.2 FR1 Base Station beam configuration

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

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

Table C.2-1: BS Antenna Parameters

Parameter description	Symbol	Parameter value		
		FR1 ≤2.5GHz	FR1 >2.5GHz	FR2
Antenna panels in vertical dimension	M_g	1	1	1
Antenna panels in horizontal dimension	N_g	1	1	1
Elements per panel in vertical dimension	M_e	4	8	8
Elements per panel in horizontal dimension	N_e	8	8	16
Number of polarizations per panel	P	2	2	2
Element spacing in horizontal dimension (λ)	d_H	0.5	0.5	0.5
Element spacing in vertical dimension (λ)	d_V	0.5	0.5	0.5

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

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

- 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.

C.3 FR1 Channel model validation

C.3.1 General

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

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

Power Delay Profile (PDP)

Doppler/Temporal correlation

Spatial correlation

Cross-polarization

Power validation

Frequencies to be used to test for channel model validation:

Table C.3.1-1: Channel model validation frequencies

NR FR1 Bands	Range	Test frequency (MHz)
n71	Low	617MHz
n12, n17, n29, n14, n28, [n29]		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]

C.3.2 Power Delay Profile (PDP)

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

The PDP measurement is performed with a Vector Network Analyzer (VNA). An example setup for PDP measurement is shown in Figure C.3.2-1. VNA transmits frequency sweep signals thorough the NR MIMO OTA test system. A reference antenna (i.e dipole antenna), within the 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.

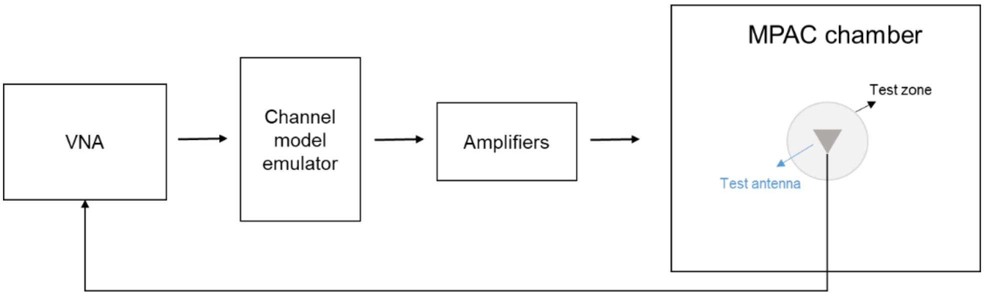

Figure C.3.2-1: Setup for PDP measurements

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

VNA settings:

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

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

Channel model specification:

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

Item	Unit	Value
Center frequency	MHz	Downlink center frequency in Table C.3.1-1
Distance between traces in channel model	wavelength (Note)	> 2
Channel model		As specified in Annex C.1
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,τ) are averaged in power over time:

$$P(\tau) = \frac{1}{T}\sum_{t=1}^{T} \left| h(t,\tau) \right|^2$$

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

C.3.3 Doppler/Temporal correlation

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

The Doppler spectrum is measured with a spectrum analyzer as shown in Figure C.3.3-1. In this case a signal generator transmits CW signal through the NR MIMO OTA test system. The signal is received by a test antenna within the test area. Finally, the signal is 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 Annex C.1.

Method of measurement:

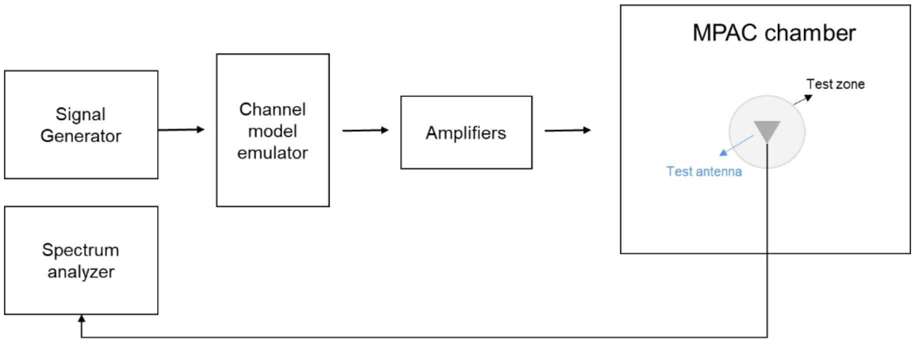

Figure C.3.3-1: Setup for Doppler measurements

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

Signal generator settings:

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

Item	Unit	Value
Center frequency	MHz	Downlink center frequency in Table C.3.1-1
Modulation		OFF

Spectrum analyzer settings:

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

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

Channel model specification:

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

Item	Unit	Value
Center frequency	MHz	Downlink center frequency in Table C.3.1-1
Channel model		As specified in Annex C.1
Mobile speed	km/h	100

Method of measurement result analysis: Measurement data file (Doppler power spectrum) is saved into hard drive. The data is read into, e.g., Matlab. The analysis is performed by taking the Fourier transformation of the Doppler spectrum.

The resulting temporal correlation function $R_t(\Delta t)$ is normalized such that $\max(\mathrm{Re}(R_t(\Delta t)))=1$. Then the function values left from the maximum is cut out. Further on the function values after, e.g. seven periods is cut out.

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

The measurement and analysis procedure 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 $H(f,t) = H(m\Delta f, n\Delta \mathrm{T}), m = 0, \dots, M-1$ for all stepped channel snapshots $n = 0, \dots, N-1$, where the interval between frequency and time samples is Δf and $\Delta \mathrm{T}$, respectively. The number of channel snapshots N and frequency samples M should be sufficiently high so that the matrix can be estimated reliably.

3. Move the measurement antenna with a positioner to another location k and repeat step 2 to record frequency responses $H_k(m\Delta f, n\Delta \mathrm{T})$ of all stepped channel snapshots.

4. Repeat step 3 to record frequency responses at all $k = 1, \dots, K$ spatial sample points.

5. Stack measured time and frequency samples to a vector and calculate correlation between the first spatial sample point (i.e. $k = 1$) and other spatial points $k = 1, \dots K$

6. $\rho_k = \mathrm{corr}\left[\mathrm{vec}\left(H_1(m\Delta f, n\Delta \mathrm{T})\right), \mathrm{vec}\left(H_k(m\Delta f, n\Delta \mathrm{T})\right)\right]$

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.

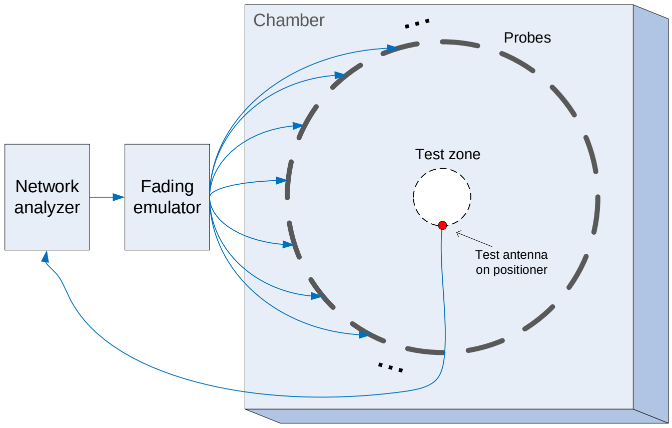

Figure C.3.4-1: Configuration for spatial correlation validation

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 $\Delta \mathrm{T}$ 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 Δf 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 C.3.4-2. 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 C.3.4-1 for test frequencies less than 1800 MHz and equal to or greater than 1800 MHz.

Table C.3.4-1: Spacing of Spatial Samples

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

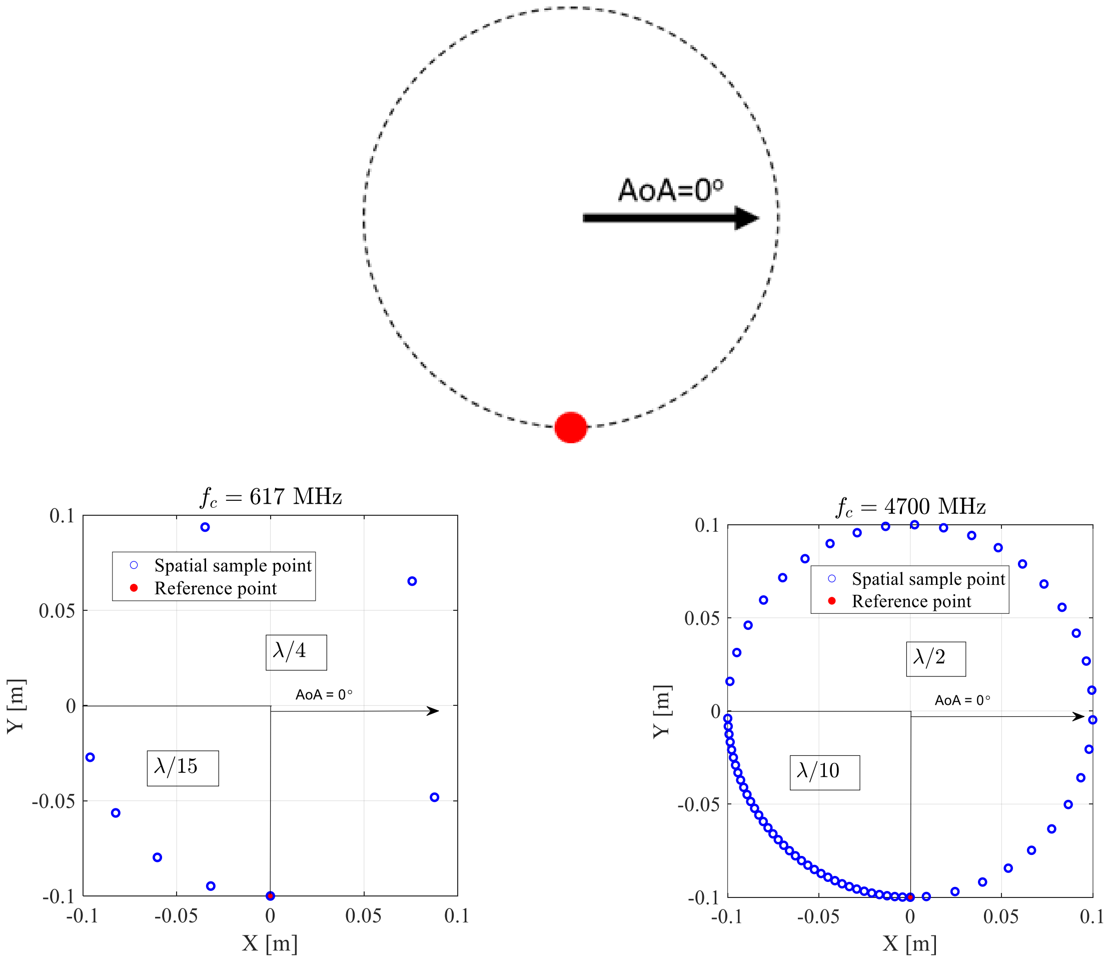

Figure C.3.4-2: Spatial sampling for spatial correlation validation measurement for test frequencies less than and equal to or greater than 1800 MHz: 617 MHz spatial sampling (left) and 4700 MHz spatial sampling (right).

Reference Spatial Correlation Curves

The spatial correlation validation reference curves are tabulated in Tables C.3.4-2 and C.3.4-3 for CDL-A UMi and in Tables C.3.4-4 and C.3.4-5 for CDL-C UMa for a vertically polarized MPAC OTA setup with 16 uniformly spaced probes.

Table C.3.4-2: 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]	ρ_{ref}	Azimuth [º]	ρ_{ref}	Azimuth [º]	ρ_{ref}	Azimuth [º]	ρ_{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 C.3.4-3: 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]	ρ_{ref}	Azimuth [º]	ρ_{ref}	Azimuth [º]	ρ_{ref}	Azimuth [º]	ρ_{ref}	Azimuth [º]	ρ_{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 C.3.4-4: 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]	ρ_{ref}	Azimuth [º]	ρ_{ref}	Azimuth [º]	ρ_{ref}	Azimuth [º]	ρ_{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 C.3.4-5: Spatial correlation reference curves for CDL-C UMa model for a vertically polarized MPAC OTA setup with 16 uniformly spaced probes at FR1 test frequencies equal to or greater than 1800 MHz

1800 MHz		2132.5 MHz		2450 MHz		3600 MHz		4700 MHz	
Azimuth [º]	ρ_{ref}	Azimuth [º]	ρ_{ref}	Azimuth [º]	ρ_{ref}	Azimuth [º]	ρ_{ref}	Azimuth [º]	ρ_{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 C.3.4-3. In this case a Signal generator transmits a CW signal through the MIMO test system. The signal is received by a test antenna within the test area. Finally, the signal is collected by a signal analyzer and the measured signal is stored for postprocessing.

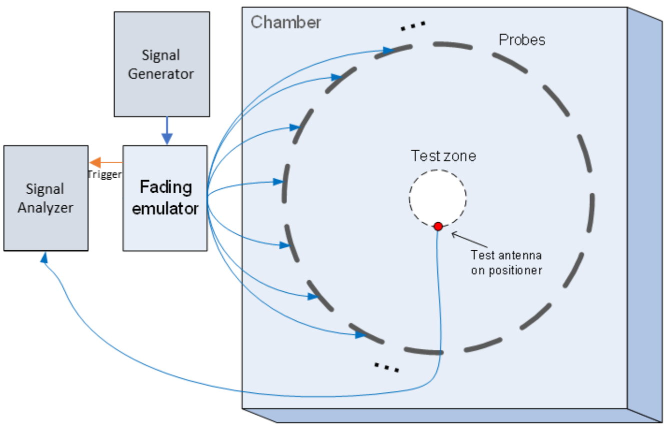

Figure C.3.4-3: Configuration for spatial correlation validation based on time domain techniques

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 C.3.4-6 and C.3.4-7 respectively.

Table C.3.4-6: Signal Generator Settings

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

Table C.3.4-7: Signal Analyzer Settings

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

C.3.5 Cross-polarization

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

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

VNA settings:

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

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

Channel model specification:

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

Item	Unit	Value
Center frequency	MHz	Downlink center frequency in Table C.3.1-1
Distance between traces in channel model	wavelength (Note)	> 2
Channel model		As specified in Annex C.1
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 Annex C.1.

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.

C.3.6 Power validation

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 C.3.6-1.

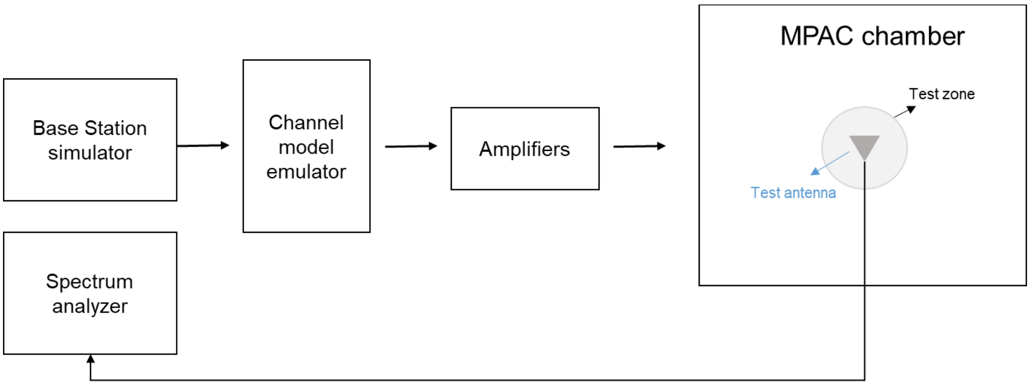

Figure C.3.6-1: Setup for power validation measurements

Spectrum analyzer settings:

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

Item	Unit	Value
Center frequency	MHz	Downlink center frequency in Table C.3.1-1
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 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.

C.4 Validation Pass/fail limit

Annex D (normative): <FR2 Channel models and Validation procedure >

D.1 FR2 Channel models

The following channel model is required for FR2 MIMO OTA measurement.

The generic model is Table D.1-1 FR2 UMi CDL-C, which does not include base station antenna filtering. Therefore, in addition, the BS beam filtering effect defined in Annex D.2 also apply when emulating the channel models.

Table D.1-1: 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	

D.2 FR2 Base Station beam configuration

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

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

Table D.2-1: FR2 BS Antenna Parameters

Parameter description	Symbol	Parameter value
		FR2
Antenna panels in vertical dimension	M_g	1
Antenna panels in horizontal dimension	N_g	1
Elements per panel in vertical dimension	M_e	8
Elements per panel in horizontal dimension	N_e	16
Number of polarizations per panel	P	2
Element spacing in horizontal dimension (λ)	d_H	0.5
Element spacing in vertical dimension (λ)	d_V	0.5

The beamforming characteristic of the FR2 BS pattern is defined as follow:

- 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；
- 1 strongest transmitting beam is generated from BS, the direction of this beam towards the strongest cluster of the FR2 channel model.

D.3 FR2 Channel model validation

D.3.1 General

This clause describes the FR2 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 of the 3D-MPAC system.

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 FR2 channel model validation:

Table D.3.1-1: FR2 Channel model validation frequencies

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

D.3.2 FR2 Power Delay Profile (PDP)

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

The PDP measurement is performed with a Vector Network Analyzer (VNA). An example setup for PDP measurement is shown in Figure D.3.2-1. 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.

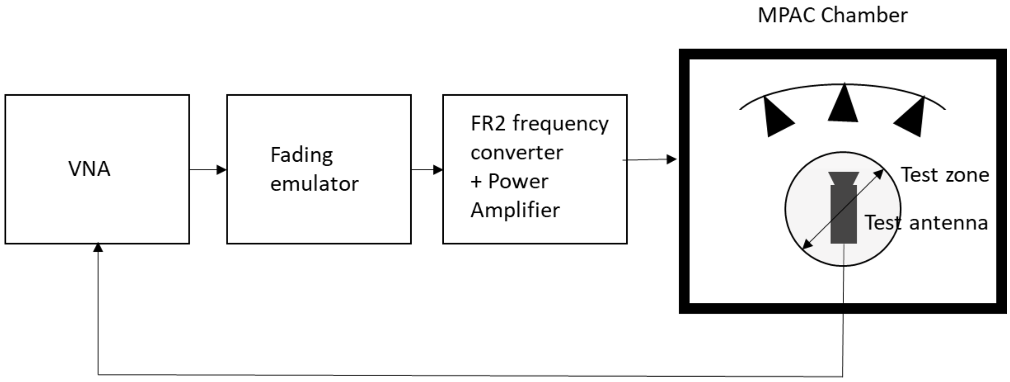

Figure D.3.2-1: Setup for PDP measurements (FR2)

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 D.3.2-1: VNA settings for FR2 PDP measurements

Item	Unit	Value
Center frequency	MHz	Downlink center frequency in Table D.3.1-1
Span	MHz	200
Number of traces		1000
Number of points		1101
Averaging		1

Channel model specification:

Table D.3.2-2: Channel model specification for FR2 PDP measurements

Item	Unit	Value
Center frequency	MHz	Downlink center frequency in Table D.3.1-1
Distance between traces in channel model	wavelength (Note)	> 2
Channel model		As specified in Annex D.1
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 trace. The resulting impulse responses h(t,τ) are averaged in power over time:

$$P(\tau) = \frac{1}{T} \sum_{t=1}^{T} \left| h(t, \tau) \right|^2$$

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

D.3.3 FR2 Doppler/Temporal correlation

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

The Doppler spectrum is measured with a spectrum analyzer as shown in Figure D.3.3-1. In this case a signal generator transmits CW signal through the NR MIMO OTA test system. The signal is received by a test antenna within the test area. Finally, the signal is analysed by a spectrum analyser and the measured spectrum is compared to the target spectrum. This setup can be used to measure Doppler Spectrum of the Channel models defined in Annex D.2.

Method of measurement:

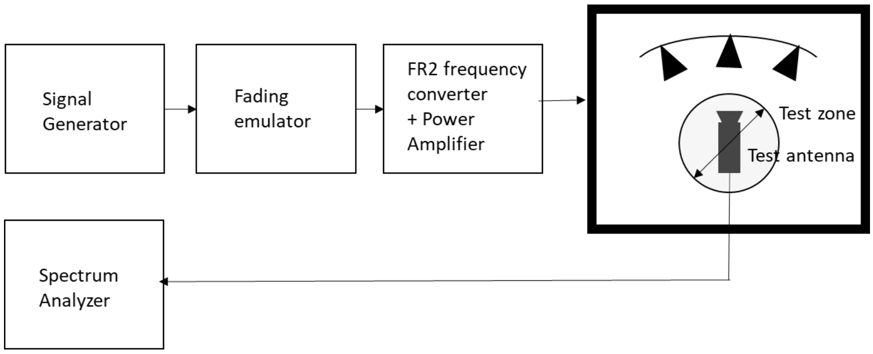

Figure D.3.3-1: Setup for FR2 Doppler measurements

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 D.3.3-1: Signal generator settings for FR2 Doppler/Temporal correlation measurements

Item	Unit	Value
Center frequency	MHz	Downlink center frequency in Table D.3.1-1
Modulation		OFF

Spectrum analyzer settings:

Table D.3.3-2: Spectrum analyzer settings for FR2 Doppler/Temporal correlation measurements

Item	Unit	Value
Center frequency	MHz	Downlink center frequency in Table D.3.1-1
Minimum Span	Hz	4 kHz
RBW	Hz	1
VBW	Hz	1
Number of points		16002
Averaging		100

Channel model specification:

Table D.3.3-3: Channel model specification for FR2 Doppler/Temporal correlation measurements

Item	Unit	Value
Center frequency	MHz	Downlink center frequency in Table D.3.1-1
Channel model		As specified in Annex D.1
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 $R_t(\Delta t)$ is normalized such that $\max(\mathrm{Re}(R_t(\Delta t)))=1$. Then the function values left from the maximum is cut out. Further on the function values after, e.g. seven periods is cut out.

D.3.4 FR2 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 ϕ-θ positioning system. The measurement array is a semi-circle and sectored array configuration illustrated in Figure D.3.4-1 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.

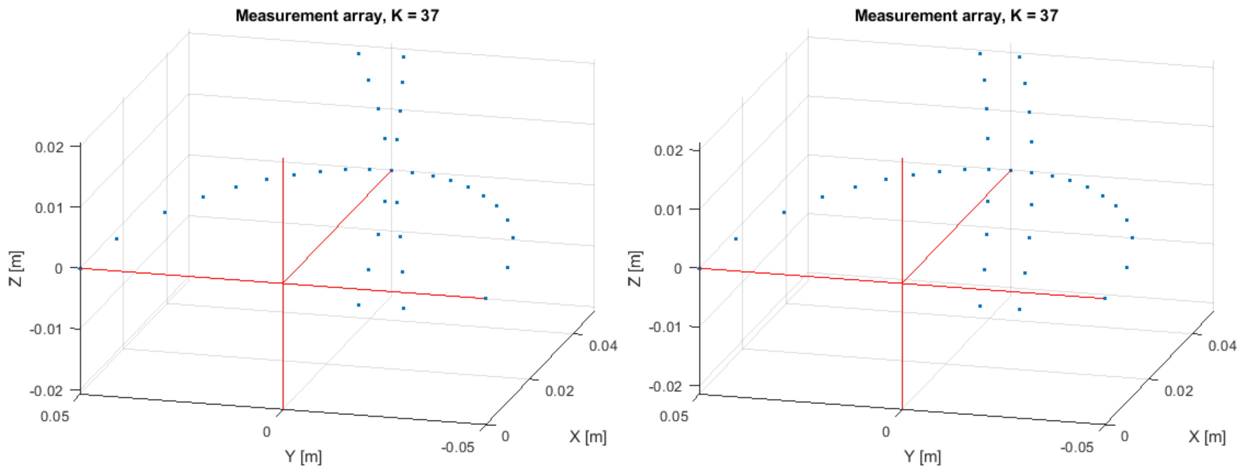

Figure D.3.4-1: Semi-circle measurement array configurations with K = 37 elements (at 28 GHz). On the left with two crossed vertical sectors, on the right with two parallel vertical sectors.

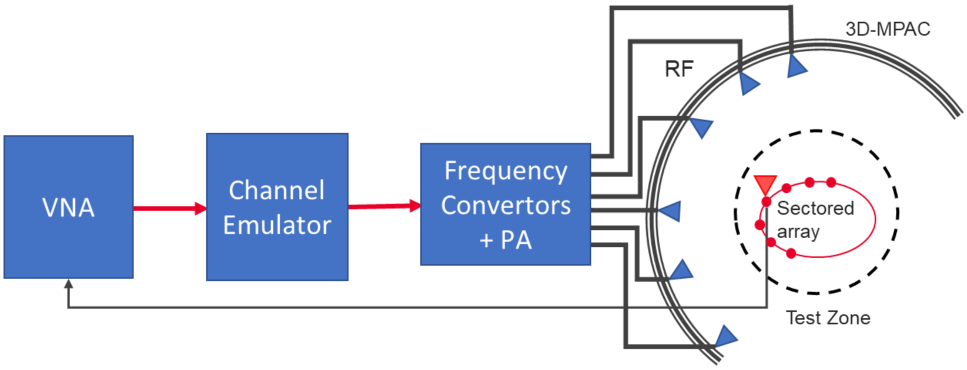

Figure D.3.4-2: Setup for FR2 PSP validation measurements

The PSP validation is measured with a vector network analyser as shown in Figure D.3.4-2 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 ϕ-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 $H(f,t) = H(m\Delta f, n\Delta T), m = 0,\dots,M-1$ for all stepped channel snapshots $n = 0,\dots,N-1$, where the interval between frequency and time samples is Δf and ΔT, respectively. The number of channel snapshots N and frequency samples M.

3. Move the measurement antenna with a positioner to another location k and repeat step 2 to record frequency responses$H_k(m\Delta f, n\Delta T)$ of all stepped channel snapshots.

4. Repeat step 3 to record frequency responses at all $k = 0,\dots,K$ 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,

$$D_p = \frac{1}{2}\int \left| \frac{\hat{P}_r(\beta)}{\int \hat{P}_r(\beta')d\beta'} - \frac{\hat{P}_o(\beta)}{\int \hat{P}_o(\beta')d\beta'} \right| d\beta$$

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

VNA settings:

Table D.3.4-1: VNA settings for FR2 PSP measurements

Item	Unit	Value
Center frequency	MHz	Downlink center frequency in Table D.3.1-1
Span	MHz	0 (or the minimum)
Number of traces		1000
Number of points		1

Channel model specification:

Table D.3.4-2: Channel model specification for FR2 PSP measurements

Item	Unit	Value
Center frequency	MHz	Downlink center frequency in Table D.3.1-1
Distance between traces in channel model	wavelength (Note)	> 2
Channel model		As specified in Annex D.1
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 D.3.4-3. The VNA is substituted by a signal generator, and a signal analyser.

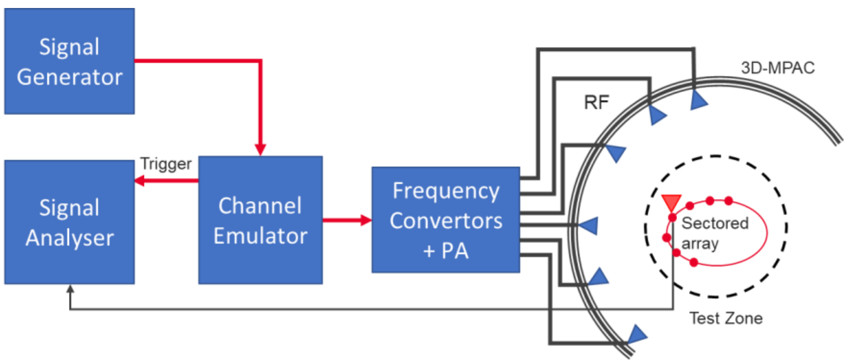

Figure D.3.4-3: Setup for FR2 PSP validation measurements based on time domain

Table D.3.4-3: Signal Generator Settings for FR2 PSP measurements based on time domain

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

Table D.3.4-4: Signal Analyzer Settings for FR2 PSP measurements based on time domain

Item	Unit	Value
Center frequency	MHz	Downlink centre frequency in Table D.3.1-1
Sampling	Hz	At least 10 times bigger than the max Doppler spread (f_d=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.

D.3.5 FR2 Cross-polarization

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

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

VNA settings:

Table D.3.5-1: VNA settings for FR2 cross-polarization

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

Channel model specification:

Table D.3.5-2: Channel model specification for FR2 cross-polarization.

Item	Unit	Value
Center frequency	MHz	Downlink center frequency in Table D.3.1-1
Distance between traces in channel model	wavelength (Note)	> 2
Channel model		As specified in Annex D.1
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 Annex D.1.
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.

D.3.6 FR2 Power validation

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 D.3.6-1.

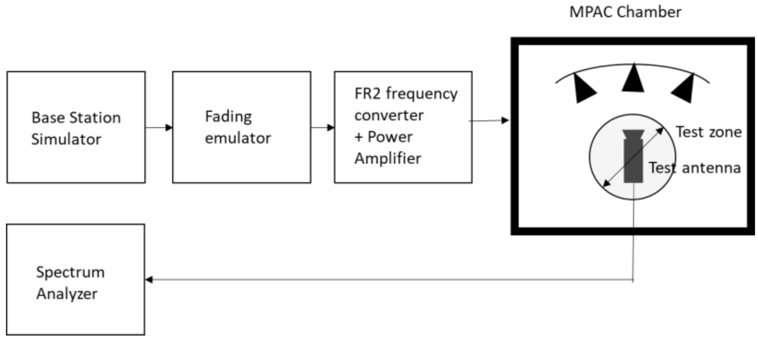

Figure D.3.6-1: Setup for FR2 power validation measurements

Spectrum analyzer settings:

Table D.3.6-1: Spectrum analyzer settings for FR2 power validation measurements

Item	Unit	Value
Center frequency	MHz	Downlink center frequency in Table D.3.1-1
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 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.

D.4 Validation Pass/fail limit

TBD

Annex E (normative): <gNB configurations>

< Editor's note: Detailed structure of the subclause is TBD.

Final RMC after down-selection for requirement, both FR1 and FR2. >

E.1 FR1 gNB configurations

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

Table E.1-1: FR1 Common test parameters

Parameter		Unit	Value
PDSCH transmission scheme			Transmission scheme 1
Carrier configuration	Offset between Point A and the lowest usable subcarrier on this carrier (Note 2)	RBs	0
	Subcarrier spacing	kHz	15 or 30
DL BWP configuration #1	Cyclic prefix		Normal
	RB offset	RBs	0
	Number of contiguous PRB	PRBs	Maximum transmission bandwidth configuration as specified in clause 5.3.2 of 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		k_0=0 for CSI-RS resource 1,2,3,4
	First OFDM symbol in the PRB used for CSI-RS		l_0 = 6 for CSI-RS resource 1 and 3 l_0 = 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			$k_0 = 0$
	First OFDM symbol in the PRB used for CSI-RS			$l_0 = 12$
	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			$k_0 = 4$
	First OFDM symbol in the PRB used for CSI-RS			$l_0 = 12$
	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 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.				

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

Parameter		Unit	Value
Duplex mode			TDD
Reference channel			R.PDSCH.2-3.1 TDD (Note 1)
Bandwidth		MHz	40
SCS		kHz	30
Modulation DL			64QAM
Modulation UL			QPSK
Active DL BWP index			1
PDSCH configuration	Mapping type		Type A
	k0		0
	Starting symbol (S)		2
	Length (L)		Specific to each Reference channel
	PDSCH aggregation factor		1
	PRB bundling type		Static
	PRB bundling size		2
	Resource allocation type		Type 0
	RBG size		Config2
	VRB-to-PRB mapping type		Non-interleaved
	VRB-to-PRB mapping 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			1

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

Parameter		Unit	Value
Duplex mode			TDD
Reference channel			R.PDSCH.2-2.4 TDD (Note 1)
Bandwidth		MHz	40
SCS		kHz	30
Modulation DL			16QAM
Modulation UL			QPSK
Active DL BWP index			1
PDSCH configuration	Mapping type		Type A
	k0		0
	Starting symbol (S)		2
	Length (L)		Specific to each Reference channel
	PDSCH aggregation factor		1
	PRB bundling type		Static
	PRB bundling size		2
	Resource allocation type		Type 0
	RBG size		Config2
	VRB-to-PRB mapping type		Non-interleaved
	VRB-to-PRB mapping 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			1
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			

E.2 FR2 gNB configurations

The gNodeB emulator parameters for FR2 MIMO OTA testing shall be set according to Table E.2-1 for FR2 common parameters and Table E.2-2 for FR2 TDD 2x2 test parameters.

Table E.2-1: FR2 Common test 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 (k_0)		0 for CSI-RS resource 1,2,3,4
	First OFDM symbol in the PRB used for CSI-RS (l_0)		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 (k_0)		0
	First OFDM symbol in the PRB used for CSI-RS (l_0)		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 (k_0)		4

	First OFDM symbol in the PRB used for CSI-RS (l_0)			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			k_0=0 for CSI-RS resource 1,2
	First OFDM symbol in the PRB used for CSI-RS			l_0 = 8 for CSI-RS resource 1 l_0 = 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 (K_{PT-RS})			2
	Time density (L_{PT-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 CDL-C
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 E.2-2: Test parameters for FR2 TDD 2x2

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 (l_0)		Table E.2-1
	CSI-RS offset	Slots	Table E.2-1
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			1
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			

Annex F (normative): <Environmental requirements>

F.1 Scope

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

F.2 Ambient temperature

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

F.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 G (informative): Change history

Change history							
Date	**Meeting**	**TDoc**	**CR**	**Rev**	**Cat**	**Subject/Comment**	**New version**
2020-08	RAN4#96-e	R4-2012709				Initial Skeleton	0.0.1
2020-11	RAN4#97-e	R4-2016216				R4-2016218, TP to TS 38.151 v0.0.1 on general part R4-2016222, TP to TS 38.151 v0.0.1 on FR1 test system for requirements R4-2017584, TP to TS 38.151 v0.0.1 on FR1 Channel model and RMC	0.1.0
2021-02	RAN4#98-e	R4-2101822				R4-2103969 TP to TS38.151 v0.1.0 on FR2 Channel model and RMC R4-2103970 TP to TS38.151 v0.1.0 on FR2 test system for requirements R4-2103971 TP to TS38.151 v0.1.0 on Performance metrics for NR MIMO OTA requirements	0.2.0