**3GPP TSG-RAN4 Meeting #112 *Rev of* R4-2411252 (v1)**

**Maastricht, NL, 19th – 23rd August, 2024**

**Agenda item:** 8.12.2.3

**Source:** Keysight Technologies, Spirent Communications

**Title:** TP on Dynamic MIMO Aspects

**Document for:** Approval

# Introduction

This contribution is incorporating previous proposals and agreements from the previous meeting [1], [2] into the TR skeleton [3].

# Discussion

The draft TP included the following aspects:

* The test metric of CTMT, introduced in Clause 5, is aligned with CTIA. However, the final pass/fail criteria based on the CTMTs for different UE orientations and rotations is FFS
* The UE noise limited environmental condition was incorporated in Clause 6.2
* The system setup, ripple test, calibration procedure, introduced in Clause 6.3, is aligned with CTIA and FR1 MIMO OTA per 3GPP.
* The minimum range length is left FFS while the test zone size is defined as 30cm in Clause 6.3.2 and is aligned with CTIA and LTE MIMO OTA per 3GPP.
* The UE positioning and DUT positioning guidelines, introduced in Clauses 6.4 and B.2, are aligned with CTIA and FR1 MIMO OTA per 3GPP
* The channel models, including channel model definition and BS beamforming config introduced in Clause 7, are aligned with CTIA
* The channel model validation has been introduced in Clause 8 and is aligned with CTIA
* The gNodeB emulator settings in Clause 9.2 are aligned with CTIA
* The dynamic link adaptation, introduced in Clause 9.3, is aligned with CTIA for the most part; changes will be proposed in CTIA shortly to align with the text proposed here, i.e., reference the CSI configuration to Clause 6.4.3 of TS38.521-4 instead of A.10 of TR38.901-5.
* The reference coordinate system in Clause B.1 is aligned with FR1 MIMO OTA per 3GPP
* The environmental requirements in Annex D are aligned with FR1 MIMO OTA per 3GPP

It is proposed to approve the TP with the understanding that additional changes and modifications can be made.

Proposal 1: approve the TP with the understanding that additional changes and modifications can be made

Revision history:

r1: moved paragraph (“The communication tester…”) from Clause 8.2.1 to Clause 6.3.5, formatting of tables, corrected typos, removed SIR from Table 8.2.1-1

# Conclusion

The following observations and conclusions were made in this contribution.

**Proposal 1: approve the TP with the understanding that additional changes and modifications can be made**

# References

1. R4-2409769, On FR1 dynamic MIMO OTA methodology, Keysight Technologies, 3GPP TSG-RAN4 Meeting #111, May 2024
2. R4-2409931, WF for [111][338] TRP\_TRS\_MIMO\_OTA, vivo, 3GPP TSG-RAN WG4 Meeting #111, May 2024
3. R4-2407667, Skeleton of TR 38.xyz, Multiple Input Multiple Output (MIMO) Over-the-Air (OTA) dynamic test methodology for FR1 UEs, CAICT, 3GPP TSG-RAN WG4 Meeting #111, May 2024

**<<< START OF CHANGES >>>**

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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.

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 is a technical report for the Multiple Input Multiple Output (MIMO) Over-the-Air (OTA) dynamic test methodology for NR FR1 UEs developed in the work item TRP\_TRS\_MIMO\_OTA\_Ph3.

In Rel-16, Rel-17, and Rel-18, the static MIMO OTA test methodology for NR UEs was developed and enhanced. This TR targets to define dynamic test methodology and radiated metrics for multi-antenna reception performance of NR FR1 UEs.

# 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 37.977, Verification of radiated multi-antenna reception performance of User Equipment (UE)

[3] 3GPP TS 38.151, Multiple Input Multiple Output (MIMO) Over-the-Air (OTA) performance requirements

[4] 3GPP TR 38.827, Study on radiated metrics and test methodology for the verification of multi-antenna reception performance of NR User Equipment (UE)

[5] L. Hentilä, P. Kyösti and P. Heino, "Evaluation of beam forming and multi antenna techniques in non-stationary propagation scenarios with HW emulator," 2012 International ITG Workshop on Smart Antennas (WSA), Dresden, 2012, pp. 347-351. Online: <https://ieeexplore.ieee.org/document/6181232>

[6] 3GPP TR 38.901, Study on channel model for frequencies from 0.5 to 100 GHz

[7] 3GPP TS 38.151 Multiple Input Multiple Output (MIMO) Over-the-Air (OTA) performance requirements for NR UEs

[8] 3GPP TS 38.101-4 User Equipment (UE) radio transmission and reception; Part 4: Performance requirements

[9] 3GPP TS 38.214: "NR; Physical layer procedures for data"

[x] <doctype> <#>[ ([up to and including]{yyyy[-mm]|V<a[.b[.c]]>}[onwards])]: "<Title>".

# 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)

<ABBREVIATION> <Expansion>

# 4 General

## 4.1 Device types

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

## 4.2 Testing configurations

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

## 4.3 Testing bands

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

# 5 Performance metrics

Let the CDF of the Total Measured Throughput (CTMT) be the figure of merit for the MIMO OTA tests with link adaptation and dynamic channel models. The TP shall be recorded every 200 ms during the emulation of the route separately for each of the DUT orientations, defined in Clause B.2. The Total Measured Throughput (TMT) is defined as the combination/concatenation of all measured TP values for each channel model, i.e.,

and

Three separate CTMT values shall be determined from the TMT values, i.e., the 10%, 50%, and 90%-ile CDF

Whether and how to combine the CTMT metrics for different each device orientations, positions/rotations, routes/channel models is FFS.

# 6 Measurement methodology

## 6.1 General

*<Editor’s note: includes general aspects. >*

## 6.2 Environmental conditions

The test cases shall utilize the UE noise limit condition, i.e., UE throughput is characterized as a function of signal power incident to the DUT antennas.

Here, the signal power takes the full UMa/UMi path loss model into account, i.e., the path loss is modelled per Table 7.4.1-1 of [6]. The normalized signal power with gNB antenna effect would therefore be modelled as illustrated in Figure 6.2-1 for the UMa route/model and in Figure 6.2-2 for the UMi route/model.



Figure 6.2-1: Signal Power Profile with gNB antenna effect for UE Noise-Limited Environment using UMa Route with UMa path loss from Table 7.4.1-1 of [6]



Figure 6.2-2: Signal Power Profile with gNB antenna effect for UE Noise-Limited Environment using UMi Route with UMi path loss from Table 7.4.1-1 of [6]

## 6.3 Multi-Probe Anechoic Chamber (MPAC)

### 6.3.1 System setup

The Multi-Probe Anechoic Chamber is based on the anechoic boundary array concept used for LTE [2] and NR FR1 MIMO with static channel models [3].

Figure 6.3.1-1 illustrates a typical 16 element boundary array configuration with 32 channels of spatial channel emulation; the intention is to apply fading on the DL signals only while the separate UL signals are not faded, e.g., via a link antenna (not shown in Figure 6.3.1-1). Each output channel of the channel emulator typically requires amplification to provide enough signal level to propagate over the air to the DUT.

A turntable is normally used to provide azimuthal averaging of the device orientation within the test volume, although rotation of the channel model can also be used to accomplish a similar result, depending on the desired angular resolution. Rotation of the device within the test volume provides for determining a statistical average performance of the device in the specified spatial channel, as opposed to measuring a radiation pattern of the DUT. With dynamic channel models, time-variant angles of multipaths are rotated around the DUT, controlled by the channel emulator.



Figure 6.3.1-1 Block Diagram of a Typical Boundary Array RF Environment Simulation System

### 6.3.2 Minimum range length and test zone size

The minimum range length is FFS.

The minimum test zone size for the NR MIMO OTA test method with dynamic link adaptation is 30cm. The DUT shall be completely contained within the test zone.

### 6.3.3 Ripple test for quiet zone

For an azimuthal boundary array, the standard phi-axis ripple test described in Clause D.1 of [4] shall be used with a cylindrical quiet zone 300 mm in diameter around the phi axis and 300 mm tall.

### 6.3.4 Calibration procedure

Clause 6.2.1.1 of [4] applies in terms of system calibration.

### 6.3.5 Test procedure

*<Editor’s note: includes test procedures using MPAC system. >*

The communication tester shall record the TP in the required 200 ms increments throughout the entire duration of the model instead of the TP being queried periodically from the control PC. The TMT trace shall be recorded as a function of time, synchronized with the start of the channel model to reliably calculate the desired CDF and subsequently the CTMT metrics, as outlined in Clause 5. After the completion of the channel model, the recorded TP results shall be made available from the communication tester to the control PC, e.g., as comma separated value list over SCPI or as file via remote file system.

## 6.4 UE positioning in MPAC

In order to minimize measurement uncertainty, it is important that test house ensures the DUT is oriented within the chamber’s test zone in a standardized manner. The “black-box” testing approach is adopted for NR MIMO OTA testing, i.e., the physical centre of the DUT shall be placed in the centre of the test zone.

Two aspects are considered to determine the DUT antenna spacing and positioning guidelines. The maximum antenna spacing in the DUT shall be within the limit determined by the MPAC system’s ability to emulate the spatial correlation function and the power stability of the field incident on the DUT. The DUT shall wholly reside within the 300 mm test zone under all DUT positioning conditions. Clause B.2 provides a preliminary set of normative DUT orientation conditions.

The maximum antenna spacing in the DUT shall be defined as FFS wavelength at the centre frequency of the band under test. Testing is not required in any band where the maximum antenna spacing of any two antennas is greater than FFS wavelengths.

# 7 Channel models

## 7.1 Dynamic channel model definition

Dynamic, i.e., non-stationary, channel models shall be used for evaluation of the CTMT MIMO TP Metric defined in Clause 5. The modelling principle is described in [5]. A DUT route is defined by a number of way points. Each way point is assigned a different 3GPP CDL model, together with orientations, speed and direction of travel (DoT) of the DUT. Parameter sets for each way point are given in tables of Clause B. For smooth/continuous channel modeling, each parameter, such as DUT speed, orientation, path delays, powers, Ricean K-factor, etc., must be linearly interpolated between two successive way points. Angles and angle spreads are interpolated in degree units, delays in nanoseconds, cluster powers and K-factors in linear units, and path losses and XPRs in decibel units. The LOS direction is an exception, being determined by linearly interpolated DUT and BS coordinates. However, ZoA is always 90.

Parameters are interpolated between way points 𝑎 and 𝑏 as

|  |  |
| --- | --- |
|  | (1) |

where 𝜀(𝑡), 𝜀(𝑎), and 𝜀(𝑏) are the parameter values in the time instant 𝑡, way point 𝑎, and 𝑏, respectively, and 𝑇\_𝑎𝑏 is the total time from way point 𝑎 to 𝑏 in seconds, such that 𝑡=0 at way point 𝑎 and 𝑡=𝑇\_𝑎𝑏 at way point 𝑏.

To avoid discontinuities, the DoT does not follow the route geometry, but instead it is continuously interpolated according to eq. (1) where the DoT varies from the arrival direction of previous way-point to the arrival direction of the next way-point.[[1]](#footnote-2) Hence, the DoT is modelled to continuously change along a straight route segment. The DoT and UE orientation equate, i.e., the UE is oriented according to its interpolated DoT at each time instant.

Direction of the LOS path is quantized to the closest probe direction and the path will be radiated through one probe at a time. The instantaneous probe used for radiating the LOS path (when present) is determined by the interpolated LOS AoA and DoT as

|  |  |
| --- | --- |
|  | (2) |

where is the azimuth angle of the *k*th probe.

Different way point may have different number of clusters. Assume way point has and has clusters. For cluster power interpolation the power of non-existing cluster in way point is set dB and the power ramp is interpolated between and as defined by the equation. In LOS condition the power of LOS ray is determined by the Ricean K-factor. Transitions between LOS and NLOS conditions are handled by defining the power of LOS ray to −100 dB for NLOS way points. These 100 dB power values correspond to the cluster parameters in tables of Annex A, i.e., 100 dB is the power before adding the distance dependent path loss. For other parameter the following rule for void clusters is applied. Parameter denotes the parameter value of cluster at way point . If cluster is void and is not, then , i.e., the value of next way point is copied to the previous. The same applies if is void and is not, then . If both the previous and the next way point are void, then the closest non-void value is selected. Here closest means the closest in way point indices, not closest in time or distance. Notice that these clusters being void in both the previous and next way point have very low gain and will have only minimal contribution to the channel.

Unwanted randomness of channel models is removed by modifications defined in Clause 7.2 of [4]. It is, by specifying fixed 2×2 initial phases for each ray, as defined in Table 7.2-8 of [4] and introducing a uniformly distributed random scalar initial phase per path instead. Moreover, the coupling of ray angles is fixed as specified in Table 7.2-6 of [4]. Finally, after having interpolated propagation parameters, fixed randomness, and base station antenna configuration as defined in Clause 7.2 the fading channel coefficients are generated using the normal procedure defined in [6].

Overview of dynamic scenario geometry, K-factor and speed profile for UMa scenario is presented in Figures 7.1-1 and 7.1-2 and for UMi scenario in Figures 7.1-3 and 7.1-4.

Chart, line chart

Description automatically generated

Figure 7.1-1 Base station and the UE route in the UMa case. The base station location is on left and DUT route starts from the rightmost way point and continues counterclockwise back to the starting point. UE is always oriented towards its direction of travel (DoT).

A diagram of a graph

Description automatically generated

Figure 7.1-2 DUT speed and maximum Doppler frequency (top). LOS AoA as observed in the DUT coordinate system (middle). Narrowband Ricean K-factor (bottom). Way points are shown by vertical dotted lines. Top figure contains the CDL model scenario label A, C, D, E on the time axis. Graphs are for the UMa scenario.

A picture containing sky, colorful, line

Description automatically generated

Figure 7.1-3 Base station and the UE route in the UMi case. The base station location is on left and UE route starts from the rightmost way point and continues clockwise back to the starting point. UE is always oriented towards its direction of travel (DoT).

A diagram of a graph

Description automatically generated with medium confidence

Figure 7.1-4 UE speed and maximum Doppler frequency (top). LOS AoA as observed in the UE coordinate system (middle). Narrowband Ricean K-factor (bottom). Way points are shown by vertical dotted lines. Top figure contains the CDL model scenario label A, C, D, E on the time axis. Graphs are for the UMi scenario.

The cross-polarization power ratio in a propagation channel is defined as:

where

and

*- SVV* is the coefficient for scattered/reflected power on V-polarization and incident power on V-polarization

*- SVH* is the coefficient for scattered/reflected power on V-polarization and incident power on H-polarization

*- SHV* is the coefficient for scattered/reflected power on H-polarization and incident power on V-polarization

*- SHH* is the coefficient for scattered/reflected power on H-polarization and incident power on H-polarization

## 7.2 Emulation of base station beamforming configuration

In geometry-based channel models, the antennas and propagation are specified separately. Hence, the propagation parameters specified in the annex are not dependent on the BS antenna or beam definitions. The single BS antenna element has 65 HPBW with 8 dBi gain and it is as specified in Table 7.3-1 of [6]. Moreover, no specific beamforming is included in the antenna radiation pattern. The beamforming for the PDSCH transmission is realized by the PMI-feedback based MIMO precoding by the BS emulator when the test case is configured with a dynamic link adaptation for rank and MIMO precoding. The antenna array geometry and physical antenna element mapping to logical CSI-RS antenna ports is defined and implemented in channel emulation, such that each logical CSI-RS antenna port is mapped to one channel emulation input port. The number of CSI-RS antenna ports is 4 and the CSI-RSs are non-beamformed. Therefore, only BS element radiation pattern is considered for each channel model input port. Antenna array elements are dual-polarized following polarization model 2 from [6] and the element spacing is 0.5 wavelengths. The array configuration for 4 CSI-RS antenna ports is shown in Figure 7.2-1.

Blue x and x on a black background

Description automatically generated

Figure 7.2-1 Base station antenna array configuration.

# 8 Channel model validation

## 8.1 General

Editor’s Note: Additional frequencies for validation measurements are not precluded.

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

The following validation measurements shall be performed at 2450 MHz:

* Path Loss (PL)
* Power Delay Profile (PDP)
* Doppler/Temporal correlation (TCF)
* Spatial Correlation (SCF)
* Cross-polarization (XPO)

The target values of validation items defined in following clauses are obtained computationally from propagation parameters of Annex A using the specified antennas. The reference channel model is ideal and primarily does not consider multi-probe OTA limitations. The only exception is the LOS path, which is quantized to the closest probe of MPAC configuration as defined in Clause 7.1. This quantization affects the target statistical values of spatial correlation in Clause 8.2.5.

## 8.2 Validation of the dynamic channel models

### 8.2.1 Measurement Setup

The measurement setup includes the following equipment listed in Table 8.2.1-1.

Table 8.2.1-1 Required Measurement Equipment

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Item | Quantity | Item | PL | PDP | TCF | SCF | XPO |
| 1 | 1 | Channel Emulator (CE) | x | x | x | x | x |
| 2 | 1 | Signal Generator (SG) (Optional, Note 1-2) | x | (x) | x | (x) | x |
| 3 | 1 | Signal Analyzer (SAN) | x | (x) | x | (x) | x |
| 4 | 1 | Vector Network Analyzer (VNA) (Note 3) | - | (x) | - | (x) | - |
| 5 | 1 | Dipole | x | x | x | x | x |
| 6 | 1 | Loop | - | - | - | - | x |
| Note 1. VNA can typically generate CW.  Note 2. Some gNB emulators can generate NR/AWGN signals in non-signaling mode.  Note 3. Frequency domain method uses VNA and time domain method SG + SAN. | | | | | | | |

#### 8.2.1.1 Network Analyser (VNA) Setup

Figure 8.2.1.1-1 shows a typical network analyser setup for channel model validation purposes.

A black background with a black square

Description automatically generated with medium confidence

Figure 8.2.1.1-1 Setup for Anechoic Chamber VNA Measurements

#### 8.2.1.2 Signal Analyzer (SAN) Setup

Figure 8.2.1.2-1 shows a typical network analyser setup for channel model validation purposes.

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Description automatically generated with medium confidence

Figure 8.2.1.2-1 Setup for Spectrum Analyzer Measurements

### 8.2.2 Validation of dynamic path loss

The intention of this validation measurement is to capture the emulated dynamic path loss (PL) as it is realized in the centre of the test zone. Measurement antenna is a vertical dipole.

#### 8.2.2.1 PL Method of Measurement

The measurement antenna is placed in the centre of the test zone. Time domain technique depicted in Figure 8.2.1.2-1 is used. Table 8.2.2.1-1 outlines the settings for the channel emulator, signal generator, and signal analyser respectively.

The time domain technique (time sweep) is used for the validation. A signal generator transmits a CW signal through the test system. The CW signal is split to two input ports of fading emulator that correspond to the two first signal streams of the gNB emulator, i.e., two orthogonally polarized co-located gNB antennas. The signal is received by a test antenna within the test area. Finally, the signal is collected by a signal analyser and the measured signal is stored. Signal generator and signal analyser settings are listed in Tables 8.2.2.1-2 and 8.2.2.1-3, respectively. The measurement is triggered to start with the time instant 0 of the channel model and to stop at the last time instant of the channel model.

Table 8.2.2.1-1 MPAC Dynamic Channel Model Specification

| Item | Unit | Value |
| --- | --- | --- |
| Centre frequency | MHz | 2450 |
| Channel emulator mode | N/A | Triggered start and stop |
| Channel model |  | As specified in Clause 7.1 |
| Mobile speed | km/h | Dynamic, as specified in Clause 7.1 |

Table 8.2.2.1-2 MPAC Path Loss Signal Generator Settings

| Item | Unit | Value |
| --- | --- | --- |
| Centre frequency | MHz | 2450 |
| Output Power | dBm | Function of the CE. Sufficiently above Noise Floor |

Table 8.2.2.1-3 MPAC Path Loss Signal Analyzer Settings

| Item | Unit | Value |
| --- | --- | --- |
| Centre frequency | MHz | 2450 |
| Sampling | Hz | At least 15 times bigger than the max Doppler spread (*fd=v/λ)* |
| Observation time | s | One full duration of the channel model route. |

The channel emulator should issue a trigger signal when the channel model is started. When the channel model is run to the end, another trigger signal is issued. A time domain trace with the SAN is collected. Data recording is synchronized with the channel emulator trigger.

#### 8.2.2.2 PL Measurement Antenna

The measurement antenna shall be a vertically-oriented dipole.

#### 8.2.2.3 PL Measurement Results Analysis

The measured channel gains (inverse of path loss) are averaged over time segments and normalized such that the maximum value across all segments is 0 dB. The resulting normalized channel gains are the target values.

Lengths of time segment and time increment between segments in seconds are specified separately for both models. Example values for start and end time of UMa route segments are given in Table 8.2.2.3-1 and of the UMi route segments are given in Table 8.2.2.3-2.

Table 8.2.2.3-1 Start and end times of time segments for UMa route

|  |  |  |
| --- | --- | --- |
| Segment number | Start time [s] | End time [s] |
| 1 | 1 | 5 |
| 2 | 10 | 15 |
| 3 | 21 | 42 |
| 4 | 47 | 52 |
| 5 | 62 | 67 |
| 6 | 82 | 87 |
| 7 | 90 | 95 |
| 8 | 102 | 107 |
| 9 | 115 | 120 |

Table 8.2.2.3-2 Start and end times of time segments for UMi route

|  |  |  |
| --- | --- | --- |
| Segment number | Start time [s] | End time [s] |
| 1 | FFS | FFS |
| 2 | FFS | FFS |
| 3 | FFS | FFS |
| 4 | FFS | FFS |
| 5 | FFS | FFS |
| 6 | FFS | FFS |
| 7 | FFS | FFS |
| 8 | FFS | FFS |
| … |  |  |

#### 8.2.2.4 PL Target Values

FFS

### 8.2.3 Validation of Power Delay Profile (PDP)

The purpose of this item is to validate the slow variation of power delay profile as observed by the DUT due to the dynamic channel model. PDP can be measured either by using the frequency sweep method and a network analyser or alternatively the time domain method with wideband signal transmitted through the test system. In both options the test signal is received by a test antenna in the test zone. The variation of PDP in the reference channel model is caused by the change of path delays and powers along the route. There are two categories of channel segments (defined in Tables 8.2.2.3-1 and 8.2.2.3-2) in the UMa and UMi dynamic models. Firstly, those with same CDL model throughout the segment, meaning that only the initial delay changes during the segment but excess delays remain unchanged, i.e., quasi time invariant. Secondly, some segments have different CDL models on preceding and subsequent way-points, meaning that both the initial delay and excess delays are time variant during the segment. Channel segments with quasi time invariant and time variant excess delays are validated differently.

In the UMa dynamic model the channel segments 1, 2, 6, 7, and 9 are in the first category and segments 3, 4, 5, and 8 in the second. In the UMi dynamic model, the categories are FFS.

The validation is done by observing the measured channel impulse responses and averaging them to a PDP estimate. PDP can be evaluated either by using the frequency sweep method and a network analyser or alternatively the time domain method with wideband signal transmitted through the test system. In both options the test signal is received by a test antenna in the test zone.

#### 8.2.3.1 PDP Method of Measurement using Frequency-Domain Technique

A network analyser transmits frequency tones through the test system when the frequency sweep technique is used in the validation. See Figure 8.2.1.1-1 for the block diagram. The signal is received by a test antenna within the test area. During each frequency sweep the channel model is paused by the channel emulator. After the sweep, channel model is stepped to the next time instant and paused again for the next frequency sweep. The time increment between consecutive frequency sweeps measuring the frequency responses of channel model instances is defined in Table 8.2.3.1-1. It is at most the inverse of twice the maximum Doppler frequency, i.e., .

Channel model segments are specified in Tables 8.2.2.3-1 and 8.2.2.3-2. At the first time instant of a segment the model is paused and the complex channel frequency response is measured and stored. This is repeated with the specified time increment until the whole time segment is covered. The sequence of measured channel responses of the segment is analysed as defined in clause 8.2.3-4. The subsequent channel segments are measured then correspondingly. Network analyser settings are defined in Table 8.2.3.1-1. The measured channel frequency response of channel model segment at frequency and channel model time instant is

where is the lowest frequency point, is the index of frequency point, is the spacing between frequency points, is the first time instant of segment , is the index of time instants, and is the increment between measured time instants.

Table 8.2.3.1-1 MPAC PDP Network Analyzer Settings

| Item | Unit | Value |
| --- | --- | --- |
| Bandwidth | MHz | 200 |
| Number of frequency points | - | 1101 |
| Number of traces | - | One per every CIR within the segment |

#### 8.2.3.2 PDP Method of Measurement using Time-Domain Technique

FFS

#### 8.2.3.3 PDP Measurement Antenna

The measurement antenna shall be a vertically-oriented dipole

#### 8.2.3.4 PDP Measurement Results Analysis using Frequency-Domain Technique

The first operation is to remove the quasi time-variant initial delay from measured responses . The initial delay at each time instant is calculated by dividing the instantaneous link distance with the speed of light (in vacuum). It is removed from each frequency response by time shifting in frequency domain and a new delay shifted response is

These responses are then transformed to impulse responses

By the inverse Fourier transformation, where = 5 ns is the width of a delay bin and is the index of the delay bin. Note that due to different cable lengths, calibration etc. of test setups the resulting measured PDPs must be further shifted such that the first path component of PDPs is set on zero excess delay. This can be done either by visual observation or by correlating the resulting dynamic PDPs with theoretical reference PDPs and choosing the delay shift yielding best correlation.

Segments with quasi time invariant excess delays for UMa: 1, 2, 6, 7, and 9 and for UMi: FFS:

Power delay profile for each segment is determined by the time average

Finally, the normalized PDP is

All values of below −40 dB are neglected in validation. Peaks, i.e., local maxima of (in dB scale) are identified and chosen as the target value of the time segment.

Segments with time variant excess delays for UMa are 3, 4, 5, and 8 and for UMi are FFS:

These validation segment must be treated differently since straightforward averaging of the power per delay bin over the time domain would provide erroneous result. Therefore, PDPs are evaluated per cluster (tap) index not per delay bin in the case of time variant excess delays. The procedure is as follows. First, the excess delay at the first and the last measured time instant of the segment is determined from time interpolated model parameters for each cluster . The excess delay of th cluster is linearly interpolated for each time sample of the measurement and then quantized to the delay resolution supported by the measurement. The resulting quantized cluster excess delay at th time sample is . Then dynamic powers of clusters on segment are calculated as the sum of powers over time samples in delay bins determined by . Since cluster powers are dispersed across neighbouring delay bins due to limited measurement bandwidth, also the previous and the successive delay bin are included in the summation. This is expressed by the formula

Finally, the measured power per cluster is normalized such that the maximum cluster power per segment becomes unity

#### 8.2.3.5 PDP Measurement Results Analysis using Time-Domain Technique

FFS

#### 8.2.3.6 PDP Target Values

FFS

### 8.2.4 Validation of Doppler/Temporal Correlation

The purpose of this item is to validate the slow variation of Doppler effect due of the dynamic channel model. This is done indirectly by observing the temporal correlation function (TCF). TCF at a few time lags are evaluated from the measured narrowband signal transmitted through the test system.

#### 8.2.4.1 TCF Method of Measurement

The time domain technique (time sweep) is used for the validation. See the block diagram of the setup in Figure 8.2.1.2-1. A signal generator transmits a CW signal through the test system. The signal is received by a test antenna within the test area. Finally, the signal is collected by a signal analyser and the measured signal is stored. Signal analyser and signal generator settings are defined in Tables 8.2.4.1-1 and 8.2.4.1-2. The measurement is triggered to start with the time instant 0 of the channel model and to stop at the last time instant of the channel model.

Table 8.2.4.1-1 MPAC TCF Signal Generator Settings

| Item | Unit | Value |
| --- | --- | --- |
| Centre frequency | MHz | 2450 |
| Output Power | dBm | Function of the CE. Sufficiently above Noise Floor |

Table 8.2.4.1-2 MPAC TCF Signal Analyzer Settings

| Item | Unit | Value |
| --- | --- | --- |
| Centre frequency | MHz | 2450 |
| Sampling | Hz | At least 15 times bigger than the max Doppler spread (fd=v/λ) |
| Observation time | s | One full duration of the channel model route. |

The signal analyser records I/Q samples at the rate of 15 times the maximum Doppler frequency (72.24 Hz). The full model length is measured at once.

#### 8.2.4.2 TCF Measurement Antenna

The measurement antenna shall be a vertically-oriented dipole.

#### 8.2.4.3 TCF Measurement Results Analysis

Segments of recorded I/Q samples are selected, autocorrelation of I/Q samples of a segment is calculated, and a few samples of the resulting temporal correlation function are picked for the validation. Time lags to be picked for TFC are 4.6 ms and 20.2 ms.

#### 8.2.4.5 TCF Target Values

FFS

### 8.2.5 Validation of Spatial Correlation

The purpose of this item is to validate the slow variation of angular power distribution as observed by the DUT due of the dynamic channel model. The variation of PAS in the reference channel model is caused by the change of path angles, path powers, and UE orientation along the route. The validation is done indirectly by observing the spatial correlation function (SCF). SCF is evaluated from the measured narrowband signal transmitted through the test system and received by a test antenna in a few spatial positions within the test zone.

#### 8.2.5.1 SCF Method of Measurement

The time domain technique (time sweep) is used for the validation. See the block diagram of the setup in Figure 8.2.1.2-1. A signal generator transmits a CW signal through the test system. The CW signal is split to two input ports of fading emulator that correspond to the two first signal streams of the gNB emulator. The signal is received by a test antenna in a specific position within the test area. Finally, the signal is collected by a signal analyser and the measured signal is stored. Signal analyser and signal generator settings are defined in Tables 4.2.3.1-1 and 4.2.3.1-2. The measurement is triggered to start with the time instant 0 of the channel model and to stop at the last time instant of the channel model. The position of test antenna is changed and the measurement is repeated. All spatial positions are illustrated in Figure 8.2.5.1-1.

Table 8.2.5.1-1 MPAC SCF Signal Generator Settings

| Item | Unit | Value |
| --- | --- | --- |
| Centre frequency | MHz | 2450 |
| Output Power | dBm | Function of the CE. Sufficiently above Noise Floor |

Table 8.2.5.1-2 MPAC SCF Signal Analyzer Settings

| Item | Unit | Value |
| --- | --- | --- |
| Centre frequency | MHz | 2450 |
| Sampling | Hz | At least 15 times bigger than the max Doppler spread (fd=v/λ) |
| Observation time | s | One full duration of the channel model route. |

The full model length is measured at once.



Figure 8.2.5.1-1 Spatial sampling points within the test zone at 2450 MHz.

Table 8.2.5.1-3 Spatial sample points, i.e., positions of test antenna for the SCF validation at 2450 MHz.

| Point number | x [mm] | y [mm] | z [mm] |
| --- | --- | --- | --- |
| #1 (reference point) | 0 | -150 | 0 |
| #2 | -22.9 | -148.3 | 0 |
| #3 | -86.3 | -122.7 | 0 |
| #4 | -149.9 | -5.7 | 0 |

#### 8.2.5.2 SCF Measurement Antenna

The measurement antenna shall be a vertically-oriented dipole

#### 8.2.5.3 SCF Measurement Results Analysis

Time segments of recorded I/Q samples are selected. For each time segment the cross correlation (with zero time lag) of I/Q samples measured in different spatial sample points is calculated. Spatial sample points picked for SFC have at maximum distance 1.7 wavelength to the reference sample point. Absolute values of estimated complex spatial correlations per time segment are chosen as the target SCF values.

#### 8.2.5.4 Target Values

FFS

### 8.2.6 Validation of Cross-Polarization

This measurement checks how well the measured vertically or horizontally polarized power levels follow expected values of cross polarization (XPO).

#### 8.2.6.1 XPO Method of Measurement

The time domain technique (time sweep) is used for the validation. See the block diagram of the setup in Figure 8.2.1.2-1. A signal generator transmits a CW signal through the test system. The CW signal is split to two input ports of fading emulator that correspond to the two first signal streams of the gNB emulator, i.e., that correspond to two co-located ±45° slanted linearly polarized elements. The signal is received by a vertically polarized test antenna within the test area. Finally, the signal is collected by a signal analyser and the measured signal is stored. Signal generator and signal analyser settings are listed in Tables 8.2.6.1-1 and 8.2.6.1-2. The measurement is triggered to start with the time instant 0 of the channel model and to stop at the last time instant of the channel model. The measurement is repeated with a horizontally polarized test antenna, placed in the same position. The result is a stored sequence of channel gains of segment received with the vertically and horizontally polarized test antennas are denoted and , respectively, where Note that the time increment and correspondingly the number of stored time samples is different in this measurement as compared to the PDP measurement.

Table 8.2.6.1-1 MPAC path loss Signal Generator Settings

| Item | Unit | Value |
| --- | --- | --- |
| Centre frequency | MHz | 2450 |
| Output Power | dBm | Function of the CE. Sufficiently above Noise Floor |

Table 8.2.6.1-2 MPAC path loss Signal Analyzer Settings

| Item | Unit | Value |
| --- | --- | --- |
| Centre frequency | MHz | 2450 |
| Sampling | Hz | At least 15 times bigger than the max Doppler spread (fd=v/λ) |
| Observation time | s | One full duration of the channel model route. |

#### 8.2.6.2 XPO Measurement Antenna

Measurement antennas shall be a vertically-oriented dipole and a loop.

#### 8.2.6.3 XPO Measurement Results Analysis

The measured channel gains (inverse of path loss) are averaged over each time segment to obtain average powers

The resulting V/H power ratios

of time segments are the target values.

#### 8.2.6.4 XPO Target Values

FFS

## 8.3 Validation pass/fail criteria

<Editor’s note: includes pass/fail criteria for dynamic channel model validation. >

The validation pass/fail criteria are FFS.

# 9 gNodeB configurations

## 9.1 General

<Editor’s note: includes general aspects of gNodeB emulator configurations. >

## 9.2 gNodeB emulator settings

The gNB emulator used to execute tests at FR1 frequencies described in this document shall be configured according to the common configuration parameters in Table 9.2-1. The 4x4 FDD specific configuration are provided in Tables 9.2-2 and 9.2-3, while the 4x4 TDD specific configuration are provided in Tables 9.2-4 and 9.2-5. The proposed gNB parameters in are based on 3GPP MIMO OTA gNB configuration parameters in [7] and the subsequent reference channels in [8].

Table 9.2-1: FR1 Common test parameters for gNB emulator configuration.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| 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, 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 [8] 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 [8] | |
| Minimum Number of Slots per Stream | | |  | 20000 for 15kHz SCS  40000 for 30kHz SCS |
| 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. | | | | | |

Table 9.2-2: Test Parameters for FR1 4x4 FDD

|  |  |  |  |
| --- | --- | --- | --- |
| Parameter | | Unit | Value |
| Duplex mode | |  | FDD |
| Modulation DL | |  | CQI based |
| 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 |
| Number of HARQ Processes | |  | 4 |
| The number of slots between PDSCH and corresponding HARQ-ACK information | |  | 2 |

Table 9.2-3: NR band specific parameters for FR1 4x4 FDD

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Parameters | | 5G NR band | | | | | | | | | |
| n2 | n5 | n12 | n14 | n25 | n26 | n30 | n66 | n70 | n71 |
| Bandwidth (MHz) | | 10 | 10 | 10 | 10 | 20 | 10 | 10 | 20 | 15 | 10 |
| SCS | | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 30 |
| Reference channel measurement | Number of allocated resource blocks | 52 | 52 | 52 | 52 | 106 | 52 | 52 | 106 | 79 | 24 |
| Number of consecutive PDSCH symbols | 12 | 12 | 12 | 12 | 12 | 12 | 12 | 12 | 12 | 12 |
| Allocated slots per 2 frames | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 |
| Overhead for TBS determination | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Number of DMRS REs | 12 | 12 | 12 | 12 | 12 | 12 | 12 | 12 | 12 | 12 |
| Number of MIMO layers | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 |

Table 9.2-4: Test Parameters for FR1 4x4 TDD

|  |  |  |  |
| --- | --- | --- | --- |
| Parameter | | Unit | Value |
| Duplex mode | |  | TDD |
| Modulation DL | |  | CQI based/VRMC |
| Modulation UL | |  | QPSK |
| Active DL BWP index | |  | 1 |
| PDSCH configuration | Mapping type |  | Type A |
| k0 |  | 0 |
| Starting symbol (S) |  | 2 |
| Length (L) |  | Specific to the 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 |
| Number of HARQ Processes | |  | 8 |
| TDD UL-DL pattern | |  | FR1.30-1 as defined in Annex A.1.2 of TS 38.101-4 [8] for 30 kHz  Table A.1.2-1: TDD UL-DL configuration for SCS 15 kHz |
| CSI-RS for tracking | 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 |
| CSI-RS periodicity | Slots | 40 |
| CSI-RS offset | Slots | 20 for CSI-RS resource 1 and 2  21 for CSI-RS resource 3 and 4 |

Table 9.2-5: NR band specific parameters for FR1 4x4 TDD

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Parameters | | 5G NR band | | | |
| n41 | n48 | n77 | n78 |
| Bandwidth (MHz) | | 100 | 100 | 100 | 100 |
| SCS | | 30 | 30 | 30 | 30 |
| Reference channel measurement | Allocated resource bocks | 273 | 273 | 273 | 273 |
| For 30 kHz  For Slot i, if mod(i, 10) = 7 for i from {0,…,39} | 4 | 4 | 4 | 4 |
| For 15 kHz  For Slot i, if mod(i, 5) = 3 for i from {0,…,19} |  |  |  |  |
| For 15 kHz  For Slot i, if mod(i, 5) = {0,1,2} for i from {1,…,19} |  |  |  |  |
| For 30 kHz  For Slot i, if mod(i, 10) = {0,1,2,3,4,5,6} for i from {1,…,39} | 12 | 12 | 12 | 12 |
| Allocated slots per 2 frames | 31 | 31 | 31 | 31 |
| Number of MIMO layers | 4 | 4 | 4 | 4 |
| Overhead for TBS determination | 0 | 0 | 0 | 0 |

The gNB emulator used to execute the Spatial Multiplexing (SM) tests at FR1 frequencies for 2x2 MIMO configuration described in this document shall be configured according to the common configuration parameters in Table 9.2-1. The FDD and TDD specific configurations for 2x2 FDD and 2x2 TDD tests are given in Table 9.2-6 and 9.2-8 respectively. The NR band specific configurations are given in Tables 9.2-7 and Table 9.2-9 respectively.

Table 9.2-6: Test Parameters for FR1 2x2 FDD

|  |  |  |  |
| --- | --- | --- | --- |
| Parameter | | Unit | Value |
| Duplex mode | |  | FDD |
| Modulation DL | |  | CQI based |
| 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 |
| Number of HARQ Processes | |  | 4 |
| The number of slots between PDSCH and corresponding HARQ-ACK information | |  | 2 |

Table 9.2-7: NR band specific parameters for FR1 2x2 FDD

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Parameters | | 5G NR band | | | | | | | | | |
| n2 | n5 | n12 | n14 | n25 | n26 | n30 | n66 | n70 | n71 |
| Bandwidth (MHz) | | 10 | 10 | 10 | 10 | 20 | 10 | 10 | 20 | 15 | 10 |
| SCS | | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 30 |
| Reference channel measurement | Number of allocated resource blocks | 52 | 52 | 52 | 52 | 106 | 52 | 52 | 106 | 79 | 24 |
| Number of consecutive PDSCH symbols | 12 | 12 | 12 | 12 | 12 | 12 | 12 | 12 | 12 | 12 |
| Allocated slots per 2 frames | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 |
| Overhead for TBS determination | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Number of DMRS REs | 12 | 12 | 12 | 12 | 12 | 12 | 12 | 12 | 12 | 12 |
| Number of MIMO layers | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |

Table 9.2-8: Test Parameters for FR1 2x2 TDD

|  |  |  |  |
| --- | --- | --- | --- |
| Parameter | | Unit | Value |
| Duplex mode | |  | TDD |
| Modulation DL | |  | CQI based |
| Modulation UL | |  | QPSK |
| Active DL BWP index | |  | 1 |
| PDSCH configuration | Mapping type |  | Type A |
| k0 |  | 0 |
| Starting symbol (S) |  | 2 |
| Length (L) |  | Specific to the 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 |
| Number of HARQ Processes | |  | 8 |
| TDD UL-DL pattern | |  | FR1.30-1 as defined in Annex A.1.2 of TS 38.101-4 [8] for 30 kHz  Table A.1.2-1 of TS 38.101-4 [8]: TDD UL-DL configuration for SCS 15 kHz |

Table 9.2-9: NR band specific parameters for FR1 2x2 TDD

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Parameters | | 5G NR band | | | |
| n41 | n48 | n77 | n78 |
| Bandwidth (MHz) | | 100 | 100 | 100 | 100 |
| SCS | | 30 | 30 | 30 | 30 |
| Reference channel measurement | Allocated resource bocks | 273 | 273 | 273 | 273 |
| For 30 kHz  For Slot i, if mod(i, 10) = 7 for i from {0,…,39} | 4 | 4 | 4 | 4 |
| For 15 kHz  For Slot i, if mod(i, 5) = 3 for i from {0,…,19} |  |  |  |  |
| For 15 kHz  For Slot i, if mod(i, 5) = {0,1,2} for i from {1,…,19} |  |  |  |  |
| For 30 kHz  For Slot i, if mod(i, 10) = {0,1,2,3,4,5,6} for i from {1,…,39} | 12 | 12 | 12 | 12 |
| Allocated slots per 2 frames | 31 | 31 | 31 | 31 |
| Number of MIMO layers | 2 | 2 | 2 | 2 |
| Overhead for TBS determination | 0 | 0 | 0 | 0 |

## 9.3 Dynamic link adaptation for MCS, rank and MIMO precoding

In the 5G NR dynamic scenario, the DUT is moving and hence link adaptation as well as the PDSCH MIMO precoding and beam alignment needs to be considered. The dynamic scheduling for MCS and rank adaptation follows Clause 6.4.2 of [8], where the gNB emulator adjusts the MCS and Rank based on the DUT’s reporting (CQI/RI reporting). The PDCCH DCI 1\_1 and PDCCH DCI\_1\_0 transmitted by the gNB contains the link adaptation parameter for the DUT.

The PDSCH MIMO precoding and beam alignment by the gNB is configured by modifying the precoding matrix by the gNB based the PMI reporting from the DUT. Hence, the gNB emulator should adjust the MCS/RI/Precoding matrix based on the CQI/RI/PMI reporting from the DUT. The configuration for CSI configurations given in Table 9.3-1.

Table 9.3-1: CSI configuration

|  |  |  |  |
| --- | --- | --- | --- |
| Parameter | | Unit | Test |
| TDD Slot Configuration (Note 1) | |  | FR1.30-1 |
| SNR | | dB | 22 |
| Beamforming Model | |  | As defined in Clause B.4.1 in TS 38.101-4 [8] |
| CSI-IM configuration | CSI-IM resource Type |  | Periodic |
| CSI-IM RE pattern |  | Pattern 0 |
| CSI-IM Resource Mapping  (kCSI-IM,lCSI-IM) |  | (4,9) |
| CSI-IM timeConfig-periodicity and offset | slot | 10/1 |
| ReportConfigType | |  | Periodic |
| CQI-table (Note 3) | |  | Table 2 |
| reportQuantity | |  | cri-RI-PMI-CQI |
| timeRestrictionForChannelMeasurements | |  | not configured |
| timeRestrictionForInterferenceMeasurements | |  | not configured |
| cqi-FormatIndicator | |  | Wideband |
| pmi-FormatIndicator | |  | Wideband |
| Sub-band Size | | RB | 16 |
| csi-ReportingBand | |  | 1111111 |
| CSI-Report periodicity and offset | | slot | 10/9 |
| Codebook configuration | Codebook Type |  | typeI-SinglePanel |
| Codebook Mode |  | 1 |
| (CodebookConfig-N1, CodebookConfig-N2) |  | 2-1 |
| CodebookSubsetRestriction |  | 11111111 |
| RI Restriction |  | 00000010 for fixed Rank 2 and 00001111 for follow RI |
| Physical channel for CSI report | |  | PUCCH |
| CQI/RI/PMI delay (Note 2) | | ms | 9.5 |
| Maximum number of HARQ transmission | |  | 1 |
| Note 1: FR1.30-1 is defined in Clause A.1.2 of TS 38.101-4 [8]  Note:2: Let CQI/RI/PMI delay corresponds to ‘k’ slots. Then, if the UE reports in an available uplink reporting instance at slot#n based on PMI estimation at a downlink slot not later than slot#[(n-k/2)], this reported PMI cannot be applied at the gNB downlink before slot#[(n+k/2)].  Note 3: CQI table to use for CQI calculation (see clause 5.2.2.1 of [9]) | | | |

The gNB emulator used to execute tests at FR1 frequencies described in this document shall be configured according to the common configuration parameters

Annex A:  
Channel model parameters

Table A-1 Parameter Table for Dynamic UMa Channel Model

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Way point | 1 |  |  |  |  |  |
| Cluster# | Power [dB] | Excess delay [ns] | AoA [°] | AoD [°] | ASA [°] | ZoD [°] |
| LOS | -0.51 | 0 | 179.99 | -0.01 | 0 | 93.09 |
| 1 | -13.83 | 0 | 179.99 | -0.01 | 29.75 | 93.09 |
| 2 | -19.13 | 3 | -157.71 | 79.75 | 29.75 | 89.46 |
| 3 | -21.33 | 58 | -157.71 | 79.75 | 26.775 | 89.46 |
| 4 | -23.13 | 128 | -157.71 | 79.75 | 23.8 | 89.46 |
| 5 | -18.23 | 132 | 116.76 | 11.61 | 29.75 | 92.81 |
| 6 | -23.23 | 167 | -20.09 | 30.93 | 29.75 | 93.09 |
| 7 | -20.43 | 170 | 116.76 | 11.61 | 26.775 | 92.81 |
| 8 | -22.23 | 244 | 116.76 | 11.61 | 23.8 | 92.81 |
| 9 | -28.13 | 380 | 147.62 | -57.68 | 29.75 | 90.27 |
| 10 | -23.93 | 747 | -14.52 | -29.43 | 29.75 | 91.08 |
| 11 | -25.13 | 887 | 44.63 | 47.02 | 29.75 | 94.57 |
| 12 | -30.33 | 913 | 95.59 | -118.13 | 29.75 | 88 |
| 13 | -28.03 | 1178 | 177.77 | 69.02 | 29.75 | 89.74 |
| Ini. delay [ns] | XPR [dB] | PL [dB] | ZoA [°] | ASD [°] | ZSA [°] | ZSD [°] |
| 1456 | 11 | 94.69 | 90 | 4.47 | 0 | 0.84 |
| UE speed [m/s] | UE DoT Az [°] | UE coordinates (x,y,z) [m] | BS coordinates (x,y,z) [m] | K-factor [dB] |  |  |
| 8.33 | 125.17 | (435.78,-0.11,1.5) | (0,0,25) | 9 |  |  |
|  |  |  |  |  |  |  |
| Way point | 2 |  |  |  |  |  |
| Cluster# | Power [dB] | Excess delay [ns] | AoA [°] | AoD [°] | ASA [°] | ZoD [°] |
| LOS | -0.51 | 0 | -162.14 | 17.86 | 0 | 93.6 |
| 1 | -13.83 | 0 | -162.14 | 17.86 | 29.75 | 93.6 |
| 2 | -19.13 | 3 | -139.84 | 97.62 | 29.75 | 88.68 |
| 3 | -21.33 | 58 | -139.84 | 97.62 | 26.775 | 88.68 |
| 4 | -23.13 | 128 | -139.84 | 97.62 | 23.8 | 88.68 |
| 5 | -18.23 | 132 | 134.63 | 29.48 | 29.75 | 93.22 |
| 6 | -23.23 | 167 | -2.22 | 48.8 | 29.75 | 93.6 |
| 7 | -20.43 | 170 | 134.63 | 29.48 | 26.775 | 93.22 |
| 8 | -22.23 | 244 | 134.63 | 29.48 | 23.8 | 93.22 |
| 9 | -28.13 | 380 | 165.49 | -39.81 | 29.75 | 89.78 |
| 10 | -23.93 | 747 | 3.35 | -11.56 | 29.75 | 90.87 |
| 11 | -25.13 | 887 | 62.5 | 64.89 | 29.75 | 95.61 |
| 12 | -30.33 | 913 | 113.46 | -100.26 | 29.75 | 86.71 |
| 13 | -28.03 | 1178 | -164.36 | 86.89 | 29.75 | 89.06 |
| Ini. delay [ns] | XPR [dB] | PL [dB] | ZoA [°] | ASD [°] | ZSA [°] | ZSD [°] |
| 1247 | 11 | 92.38 | 90 | 4.47 | 0 | 1.14 |
| UE speed [m/s] | UE DoT Az [°] | UE coordinates (x,y,z) [m] | BS coordinates (x,y,z) [m] | K-factor [dB] |  |  |
| 8.33 | 112.77 | (355.11,114.39,1.5) | (0,0,25) | 9 |  |  |
|  |  |  |  |  |  |  |
| Way point | 3 |  |  |  |  |  |
| Cluster# | Power [dB] | Excess delay [ns] | AoA [°] | AoD [°] | ASA [°] | ZoD [°] |
| 1 | -12.09 | 0 | -77.57 | -18.59 | 15.63 | 102.25 |
| 2 | -8.89 | 76 | 137.57 | -2.91 | 15.63 | 102.71 |
| 3 | -10.19 | 79 | -105.19 | -14.7 | 15.63 | 103.35 |
| 4 | -11.19 | 81 | 137.57 | -2.91 | 14.067 | 102.71 |
| 5 | -12.89 | 85 | 137.57 | -2.91 | 12.504 | 102.71 |
| 6 | -7.69 | 232 | -169.91 | 12.32 | 15.63 | 102.9 |
| 7 | -9.89 | 235 | -169.91 | 12.32 | 14.067 | 102.9 |
| 8 | -11.59 | 239 | -169.91 | 12.32 | 12.504 | 102.9 |
| 9 | -15.09 | 240 | 70.25 | 60.29 | 15.63 | 104.83 |
| 10 | -14.79 | 289 | 81.82 | -30.38 | 15.63 | 101.64 |
| 11 | -18.39 | 299 | -22.44 | 64.97 | 15.63 | 105.12 |
| 12 | -18.79 | 340 | 61.39 | -51.87 | 15.63 | 101.06 |
| 13 | -12.79 | 447 | 83.48 | -24.32 | 15.63 | 104.35 |
| 14 | -14.49 | 476 | -43.91 | -30.25 | 15.63 | 104.51 |
| 15 | -16.39 | 790 | 97.45 | -39.61 | 15.63 | 100.9 |
| 16 | -20.89 | 987 | 44.51 | 79.79 | 15.63 | 104.51 |
| 17 | -21.59 | 1551 | -4.58 | 77.49 | 15.63 | 101.51 |
| 18 | -21.59 | 1675 | 16.47 | 70.63 | 15.63 | 100.93 |
| 19 | -23.49 | 1999 | -1.76 | -55.03 | 15.63 | 100.64 |
| 20 | -24.79 | 2042 | 22.62 | 72.87 | 15.63 | 105.32 |
| 21 | -23.69 | 2296 | 18.35 | 73.6 | 15.63 | 100.9 |
| 22 | -23.39 | 2417 | 13.24 | 82.36 | 15.63 | 100.87 |
| 23 | -29.29 | 2564 | -10.31 | 90.86 | 15.63 | 104.83 |
| 24 | -30.49 | 3151 | 47.53 | -69.46 | 15.63 | 105.67 |
| Ini. delay [ns] | XPR [dB] | PL [dB] | ZoA [°] | ASD [°] | ZSA [°] | ZSD [°] |
| 1245 | 7 | 121.84 | 90 | 1.32 | 0 | 0.97 |
| UE speed [m/s] | UE DoT Az [°] | UE coordinates (x,y,z) [m] | BS coordinates (x,y,z) [m] | K-factor [dB] |  |  |
| 0.833 | 161.92 | (352.65,120.25,1.5) | (0,0,25) | - |  |  |
|  |  |  |  |  |  |  |
| Way point | 4 |  |  |  |  |  |
| Cluster# | Power [dB] | Excess delay [ns] | AoA [°] | AoD [°] | ASA [°] | ZoD [°] |
| 1 | -18.8 | 0 | 91.07 | -42.7 | 9.56 | 98.71 |
| 2 | -5.4 | 139 | -133.34 | 18.09 | 9.56 | 100.85 |
| 3 | -7.6 | 147 | -133.34 | 18.09 | 8.604 | 100.85 |
| 4 | -11.4 | 168 | 113.06 | 51.08 | 9.56 | 102.28 |
| 5 | -13.6 | 196 | 113.06 | 51.08 | 8.604 | 102.28 |
| 6 | -15.9 | 209 | -2.18 | 62.03 | 9.56 | 103.69 |
| 7 | -9.4 | 214 | -133.34 | 18.09 | 7.648 | 100.85 |
| 8 | -15.3 | 244 | 113.06 | 51.08 | 7.648 | 102.28 |
| 9 | -12.9 | 277 | -37.03 | -9 | 9.56 | 98.96 |
| 10 | -21.3 | 560 | 128.35 | 74.92 | 9.56 | 97.52 |
| 11 | -12 | 691 | 91.59 | -9.46 | 9.56 | 102.5 |
| 12 | -17.8 | 791 | 69.6 | -33.93 | 9.56 | 103.75 |
| 13 | -22.1 | 810 | -101.35 | 66.67 | 9.56 | 104.75 |
| 14 | -20.6 | 908 | 113.06 | -40.57 | 9.56 | 104.04 |
| 15 | -16.2 | 915 | -6.7 | -25.85 | 9.56 | 98.56 |
| 16 | -16.7 | 1114 | -20.61 | -27.99 | 9.56 | 98.22 |
| 17 | -18.1 | 1486 | -41.64 | 77.37 | 9.56 | 98.37 |
| 18 | -21.6 | 1623 | 142.43 | 71.43 | 9.56 | 104.27 |
| 19 | -23.7 | 1664 | 172.07 | 65.94 | 9.56 | 96.75 |
| 20 | -24.3 | 1747 | -178.54 | -21.9 | 9.56 | 97.04 |
| 21 | -22 | 1823 | 135.13 | -34.31 | 9.56 | 104.76 |
| 22 | -25.3 | 1931 | -132.56 | 63.77 | 9.56 | 97.34 |
| 23 | -35.1 | 3517 | 94.46 | -0.09 | 9.56 | 103.42 |
| Ini. delay [ns] | XPR [dB] | PL [dB] | ZoA [°] | ASD [°] | ZSA [°] | ZSD [°] |
| 1189 | 10 | 121.06 | 90 | 1.75 | 0 | 0.15 |
| UE speed [m/s] | UE DoT Az [°] | UE coordinates (x,y,z) [m] | BS coordinates (x,y,z) [m] | K-factor [dB] |  |  |
| 0.833 | 155.87 | (332.43,126.85,1.5) | (0,0,25) | - |  |  |
|  |  |  |  |  |  |  |
| Way point | 5 |  |  |  |  |  |
| Cluster# | Power [dB] | Excess delay [ns] | AoA [°] | AoD [°] | ASA [°] | ZoD [°] |
| 1 | -18.8 | 0 | 92.44 | -41.33 | 9.56 | 98.7 |
| 2 | -5.4 | 139 | -131.97 | 19.46 | 9.56 | 100.93 |
| 3 | -7.6 | 147 | -131.97 | 19.46 | 8.604 | 100.93 |
| 4 | -11.4 | 168 | 114.43 | 52.45 | 9.56 | 102.42 |
| 5 | -13.6 | 196 | 114.43 | 52.45 | 8.604 | 102.42 |
| 6 | -15.9 | 209 | -0.81 | 63.4 | 9.56 | 103.89 |
| 7 | -9.4 | 214 | -131.97 | 19.46 | 7.648 | 100.93 |
| 8 | -15.3 | 244 | 114.43 | 52.45 | 7.648 | 102.42 |
| 9 | -12.9 | 277 | -35.66 | -7.63 | 9.56 | 98.96 |
| 10 | -21.3 | 560 | 129.72 | 76.29 | 9.56 | 97.47 |
| 11 | -12 | 691 | 92.96 | -8.09 | 9.56 | 102.65 |
| 12 | -17.8 | 791 | 70.97 | -32.56 | 9.56 | 103.95 |
| 13 | -22.1 | 810 | -99.98 | 68.04 | 9.56 | 104.99 |
| 14 | -20.6 | 908 | 114.43 | -39.2 | 9.56 | 104.25 |
| 15 | -16.2 | 915 | -5.33 | -24.48 | 9.56 | 98.55 |
| 16 | -16.7 | 1114 | -19.24 | -26.62 | 9.56 | 98.2 |
| 17 | -18.1 | 1486 | -40.27 | 78.74 | 9.56 | 98.35 |
| 18 | -21.6 | 1623 | 143.8 | 72.8 | 9.56 | 104.49 |
| 19 | -23.7 | 1664 | 173.44 | 67.31 | 9.56 | 96.66 |
| 20 | -24.3 | 1747 | -177.17 | -20.53 | 9.56 | 96.97 |
| 21 | -22 | 1823 | 136.5 | -32.94 | 9.56 | 105 |
| 22 | -25.3 | 1931 | -131.19 | 65.14 | 9.56 | 97.28 |
| 23 | -35.1 | 3517 | 95.83 | 1.28 | 9.56 | 103.61 |
| Ini. delay [ns] | XPR [dB] | PL [dB] | ZoA [°] | ASD [°] | ZSA [°] | ZSD [°] |
| 1162 | 10 | 120.67 | 90 | 1.75 | 0 | 0.16 |
| UE speed [m/s] | UE DoT Az [°] | UE coordinates (x,y,z) [m] | BS coordinates (x,y,z) [m] | K-factor [dB] |  |  |
| 8.33 | -130.59 | (321.65,131.68,1.5) | (0,0,25) | - |  |  |
|  |  |  |  |  |  |  |
| Way point | 6 |  |  |  |  |  |
| Cluster# | Power [dB] | Excess delay [ns] | AoA [°] | AoD [°] | ASA [°] | ZoD [°] |
| 1 | -12.09 | 0 | -96.5 | -37.52 | 15.63 | 104.24 |
| 2 | -8.89 | 76 | 118.64 | -21.84 | 15.63 | 105.24 |
| 3 | -10.19 | 79 | -124.12 | -33.63 | 15.63 | 106.67 |
| 4 | -11.19 | 81 | 118.64 | -21.84 | 14.067 | 105.24 |
| 5 | -12.89 | 85 | 118.64 | -21.84 | 12.504 | 105.24 |
| 6 | -7.69 | 232 | 171.16 | -6.61 | 15.63 | 105.67 |
| 7 | -9.89 | 235 | 171.16 | -6.61 | 14.067 | 105.67 |
| 8 | -11.59 | 239 | 171.16 | -6.61 | 12.504 | 105.67 |
| 9 | -15.09 | 240 | 51.32 | 41.36 | 15.63 | 109.94 |
| 10 | -14.79 | 289 | 62.89 | -49.31 | 15.63 | 102.89 |
| 11 | -18.39 | 299 | -41.37 | 46.04 | 15.63 | 110.59 |
| 12 | -18.79 | 340 | 42.46 | -70.8 | 15.63 | 101.61 |
| 13 | -12.79 | 447 | 64.55 | -43.25 | 15.63 | 108.87 |
| 14 | -14.49 | 476 | -62.84 | -49.18 | 15.63 | 109.23 |
| 15 | -16.39 | 790 | 78.52 | -58.54 | 15.63 | 101.25 |
| 16 | -20.89 | 987 | 25.58 | 60.86 | 15.63 | 109.23 |
| 17 | -21.59 | 1551 | -23.51 | 58.56 | 15.63 | 102.6 |
| 18 | -21.59 | 1675 | -2.46 | 51.7 | 15.63 | 101.32 |
| 19 | -23.49 | 1999 | -20.69 | -73.96 | 15.63 | 100.68 |
| 20 | -24.79 | 2042 | 3.69 | 53.94 | 15.63 | 111.01 |
| 21 | -23.69 | 2296 | -0.58 | 54.67 | 15.63 | 101.25 |
| 22 | -23.39 | 2417 | -5.69 | 63.43 | 15.63 | 101.18 |
| 23 | -29.29 | 2564 | -29.24 | 71.93 | 15.63 | 109.94 |
| 24 | -30.49 | 3151 | 28.6 | -88.39 | 15.63 | 111.8 |
| Ini. delay [ns] | XPR [dB] | PL [dB] | ZoA [°] | ASD [°] | ZSA [°] | ZSD [°] |
| 700 | 7 | 112.06 | 90 | 1.32 | 0 | 2.14 |
| UE speed [m/s] | UE DoT Az [°] | UE coordinates (x,y,z) [m] | BS coordinates (x,y,z) [m] | K-factor [dB] |  |  |
| 8.33 | -51.25 | (208.50,-0.36,1.5) | (0,0,25) | - |  |  |
|  |  |  |  |  |  |  |
| Way point | 7 |  |  |  |  |  |
| Cluster# | Power [dB] | Excess delay [ns] | AoA [°] | AoD [°] | ASA [°] | ZoD [°] |
| 1 | -12.09 | 0 | -119.5 | -60.52 | 15.63 | 102.45 |
| 2 | -8.89 | 76 | 95.64 | -44.84 | 15.63 | 102.97 |
| 3 | -10.19 | 79 | -147.12 | -56.63 | 15.63 | 103.71 |
| 4 | -11.19 | 81 | 95.64 | -44.84 | 14.067 | 102.97 |
| 5 | -12.89 | 85 | 95.64 | -44.84 | 12.504 | 102.97 |
| 6 | -7.69 | 232 | 148.16 | -29.61 | 15.63 | 103.19 |
| 7 | -9.89 | 235 | 148.16 | -29.61 | 14.067 | 103.19 |
| 8 | -11.59 | 239 | 148.16 | -29.61 | 12.504 | 103.19 |
| 9 | -15.09 | 240 | 28.32 | 18.36 | 15.63 | 105.41 |
| 10 | -14.79 | 289 | 39.89 | -72.31 | 15.63 | 101.75 |
| 11 | -18.39 | 299 | -64.37 | 23.04 | 15.63 | 105.74 |
| 12 | -18.79 | 340 | 19.46 | -93.8 | 15.63 | 101.09 |
| 13 | -12.79 | 447 | 41.55 | -66.25 | 15.63 | 104.86 |
| 14 | -14.49 | 476 | -85.84 | -72.18 | 15.63 | 105.04 |
| 15 | -16.39 | 790 | 55.52 | -81.54 | 15.63 | 100.9 |
| 16 | -20.89 | 987 | 2.58 | 37.86 | 15.63 | 105.04 |
| 17 | -21.59 | 1551 | -46.51 | 35.56 | 15.63 | 101.6 |
| 18 | -21.59 | 1675 | -25.46 | 28.7 | 15.63 | 100.94 |
| 19 | -23.49 | 1999 | -43.69 | -96.96 | 15.63 | 100.6 |
| 20 | -24.79 | 2042 | -19.31 | 30.94 | 15.63 | 105.97 |
| 21 | -23.69 | 2296 | -23.58 | 31.67 | 15.63 | 100.9 |
| 22 | -23.39 | 2417 | -28.69 | 40.43 | 15.63 | 100.86 |
| 23 | -29.29 | 2564 | -52.24 | 48.93 | 15.63 | 105.41 |
| 24 | -30.49 | 3151 | 5.6 | -111.39 | 15.63 | 106.37 |
| Ini. delay [ns] | XPR [dB] | PL [dB] | ZoA [°] | ASD [°] | ZSA [°] | ZSD [°] |
| 1151 | 7 | 120.5 | 90 | 1.32 | 0 | 1.11 |
| UE speed [m/s] | UE DoT Az [°] | UE coordinates (x,y,z) [m] | BS coordinates (x,y,z) [m] | K-factor [dB] |  |  |
| 8.33 | 45.03 | (316.65,-135.09,1.5) | (0,0,25) | - |  |  |
|  |  |  |  |  |  |  |
| Way point | 8 |  |  |  |  |  |
| Cluster# | Power [dB] | Excess delay [ns] | AoA [°] | AoD [°] | ASA [°] | ZoD [°] |
| LOS | -0.51 | 0 | 158.87 | -21.13 | 0 | 93.85 |
| 1 | -22.24 | 0 | 158.87 | -21.13 | 18.91 | 93.85 |
| 2 | -16.01 | 47 | -119.23 | 40.14 | 18.91 | 97.13 |
| 3 | -18.31 | 49 | -119.23 | 40.14 | 17.019 | 97.13 |
| 4 | -23.11 | 49 | 24.46 | -42.55 | 18.91 | 93.71 |
| 5 | -20.01 | 51 | -119.23 | 40.14 | 15.128 | 97.13 |
| 6 | -22.61 | 65 | 43.54 | -3.87 | 18.91 | 94.71 |
| 7 | -18.81 | 173 | -159.02 | -11.22 | 18.91 | 93.28 |
| 8 | -21.01 | 175 | -159.02 | -11.22 | 17.019 | 93.28 |
| 9 | -22.81 | 178 | -159.02 | -11.22 | 15.128 | 93.28 |
| 10 | -22.51 | 240 | -138.05 | -0.88 | 18.91 | 94.71 |
| 11 | -25.81 | 337 | -54.52 | 13.72 | 18.91 | 91.57 |
| 12 | -20.41 | 495 | 102.15 | -20.6 | 18.91 | 93.35 |
| 13 | -30.01 | 1091 | 46.04 | 38.44 | 18.91 | 91 |
| 14 | -29.41 | 1876 | 63.57 | 40.25 | 18.91 | 97.41 |
| Ini. delay [ns] | XPR [dB] | PL [dB] | ZoA [°] | ASD [°] | ZSA [°] | ZSD [°] |
| 1168 | 8 | 91. 76 | 90 | 5.33 | 0 | 2.14 |
| UE speed [m/s] | UE DoT Az [°] | UE coordinates (x,y,z) [m] | BS coordinates (x,y,z) [m] | K-factor [dB] |  |  |
| 8.33 | 5.64 | (325.81,-125.92,1.5) | (0,0,25) | 9 |  |  |
|  |  |  |  |  |  |  |
| Way point | 9 |  |  |  |  |  |
| Cluster# | Power [dB] | Excess delay [ns] | AoA [°] | AoD [°] | ASA [°] | ZoD [°] |
| LOS | -0.51 | 0 | 163.96 | -16.04 | 0 | 93.16 |
| 1 | -22.24 | 0 | 163.96 | -16.04 | 18.91 | 93.16 |
| 2 | -16.01 | 47 | -114.14 | 45.23 | 18.91 | 95.42 |
| 3 | -18.31 | 49 | -114.14 | 45.23 | 17.019 | 95.42 |
| 4 | -23.11 | 49 | 29.55 | -37.46 | 18.91 | 93.06 |
| 5 | -20.01 | 51 | -114.14 | 45.23 | 15.128 | 95.42 |
| 6 | -22.61 | 65 | 48.63 | 1.22 | 18.91 | 93.75 |
| 7 | -18.81 | 173 | -153.93 | -6.13 | 18.91 | 92.77 |
| 8 | -21.01 | 175 | -153.93 | -6.13 | 17.019 | 92.77 |
| 9 | -22.81 | 178 | -153.93 | -6.13 | 15.128 | 92.77 |
| 10 | -22.51 | 240 | -132.96 | 4.21 | 18.91 | 93.75 |
| 11 | -25.81 | 337 | -49.43 | 18.81 | 18.91 | 91.58 |
| 12 | -20.41 | 495 | 107.24 | -15.51 | 18.91 | 92.82 |
| 13 | -30.01 | 1091 | 51.13 | 43.53 | 18.91 | 91.19 |
| 14 | -29.41 | 1876 | 68.66 | 45.34 | 18.91 | 95.62 |
| Ini. delay [ns] | XPR [dB] | PL [dB] | ZoA [°] | ASD [°] | ZSA [°] | ZSD [°] |
| 1422 | 8 | 94.28 | 90 | 5.33 | 0 | 1.48 |
| UE speed [m/s] | UE DoT Az [°] | UE coordinates (x,y,z) [m] | BS coordinates (x,y,z) [m] | K-factor [dB] |  |  |
| 8.33 | 142.83 | (409.22,-117.68,1.5) | (0,0,25) | 9 |  |  |
|  |  |  |  |  |  |  |
| Way point | 10 |  |  |  |  |  |
| Cluster# | Power [dB] | Excess delay [ns] | AoA [°] | AoD [°] | ASA [°] | ZoD [°] |
| 1 | -18.8 | 0 | 56.01 | -77.76 | 9.56 | 98.73 |
| 2 | -5.4 | 139 | -168.4 | -16.97 | 9.56 | 100.52 |
| 3 | -7.6 | 147 | -168.4 | -16.97 | 8.604 | 100.52 |
| 4 | -11.4 | 168 | 78 | 16.02 | 9.56 | 101.72 |
| 5 | -13.6 | 196 | 78 | 16.02 | 8.604 | 101.72 |
| 6 | -15.9 | 209 | -37.24 | 26.97 | 9.56 | 102.9 |
| 7 | -9.4 | 214 | -168.4 | -16.97 | 7.648 | 100.52 |
| 8 | -15.3 | 244 | 78 | 16.02 | 7.648 | 101.72 |
| 9 | -12.9 | 277 | -72.09 | -44.06 | 9.56 | 98.94 |
| 10 | -21.3 | 560 | 93.29 | 39.86 | 9.56 | 97.74 |
| 11 | -12 | 691 | 56.53 | -44.52 | 9.56 | 101.91 |
| 12 | -17.8 | 791 | 34.54 | -68.99 | 9.56 | 102.95 |
| 13 | -22.1 | 810 | -136.41 | 31.61 | 9.56 | 103.79 |
| 14 | -20.6 | 908 | 78 | -75.63 | 9.56 | 103.19 |
| 15 | -16.2 | 915 | -41.76 | -60.91 | 9.56 | 98.61 |
| 16 | -16.7 | 1114 | -55.67 | -63.05 | 9.56 | 98.33 |
| 17 | -18.1 | 1486 | -76.7 | 42.31 | 9.56 | 98.45 |
| 18 | -21.6 | 1623 | 107.37 | 36.37 | 9.56 | 103.38 |
| 19 | -23.7 | 1664 | 137.01 | 30.88 | 9.56 | 97.09 |
| 20 | -24.3 | 1747 | 146.4 | -56.96 | 9.56 | 97.34 |
| 21 | -22 | 1823 | 100.07 | -69.37 | 9.56 | 103.79 |
| 22 | -25.3 | 1931 | -167.62 | 28.71 | 9.56 | 97.59 |
| 23 | -35.1 | 3517 | 59.4 | -35.15 | 9.56 | 102.68 |
| Ini. delay [ns] | XPR [dB] | PL [dB] | ZoA [°] | ASD [°] | ZSA [°] | ZSD [°] |
| 1312 | 10 | 122.73 | 90 | 1.75 | 0 | 0.12 |
| UE speed [m/s] | UE DoT Az [°] | UE coordinates (x,y,z) [m] | BS coordinates (x,y,z) [m] | K-factor [dB] |  |  |
| 0.833 | 34.08 | (380.81,-96.14,1.5) | (0,0,25) | - |  |  |
|  |  |  |  |  |  |  |
| Way point | 11 |  |  |  |  |  |
| Cluster# | Power [dB] | Excess delay [ns] | AoA [°] | AoD [°] | ASA [°] | ZoD [°] |
| LOS | -0.51 | 0 | 167.81 | -12.19 | 0 | 93.32 |
| 1 | -13.83 | 0 | 167.81 | -12.19 | 29.75 | 93.32 |
| 2 | -19.13 | 3 | -169.89 | 67.57 | 29.75 | 89.11 |
| 3 | -21.33 | 58 | -169.89 | 67.57 | 26.775 | 89.11 |
| 4 | -23.13 | 128 | -169.89 | 67.57 | 23.8 | 89.11 |
| 5 | -18.23 | 132 | 104.58 | -0.57 | 29.75 | 93 |
| 6 | -23.23 | 167 | -32.27 | 18.75 | 29.75 | 93.32 |
| 7 | -20.43 | 170 | 104.58 | -0.57 | 26.775 | 93 |
| 8 | -22.23 | 244 | 104.58 | -0.57 | 23.8 | 93 |
| 9 | -28.13 | 380 | 135.44 | -69.86 | 29.75 | 90.05 |
| 10 | -23.93 | 747 | -26.7 | -41.61 | 29.75 | 90.99 |
| 11 | -25.13 | 887 | 32.45 | 34.84 | 29.75 | 95.03 |
| 12 | -30.33 | 913 | 83.41 | -130.31 | 29.75 | 87.43 |
| 13 | -28.03 | 1178 | 165.59 | 56.84 | 29.75 | 89.44 |
| Ini. delay [ns] | XPR [dB] | PL [dB] | ZoA [°] | ASD [°] | ZSA [°] | ZSD [°] |
| 1355 | 11 | 93.44 | 90 | 4.47 | 0 | 0.97 |
| UE speed [m/s] | UE DoT Az [°] | UE coordinates (x,y,z) [m] | BS coordinates (x,y,z) [m] | K-factor [dB] |  |  |
| 8.33 | 65.26 | (396.39,-85.60,1.5) | (0,0,25) | 9 |  |  |

Table A-2 Parameter Table for Dynamic UMi Channel Model

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Way point | 1 |  |  |  |  |  |
| Cluster# | Power [dB] | Excess delay [ns] | AoA [°] | AoD [°] | ASA [°] | ZoD [°] |
| 1 | -12.09 | 0 | -120.63 | -36.99 | 12.29 | 100.34 |
| 2 | -8.89 | 23 | 125.47 | -21.62 | 12.29 | 100.44 |
| 3 | -10.19 | 24 | -142.34 | -33.18 | 12.29 | 100.6 |
| 4 | -11.19 | 24 | 125.47 | -21.62 | 11.061 | 100.44 |
| 5 | -12.89 | 25 | 125.47 | -21.62 | 9.832 | 100.44 |
| 6 | -7.69 | 69 | 166.77 | -6.71 | 12.29 | 100.49 |
| 7 | -9.89 | 70 | 166.77 | -6.71 | 11.061 | 100.49 |
| 8 | -11.59 | 71 | 166.77 | -6.71 | 9.832 | 100.49 |
| 9 | -15.09 | 72 | 72.53 | 40.28 | 12.29 | 100.96 |
| 10 | -14.79 | 86 | 81.63 | -48.54 | 12.29 | 100.19 |
| 11 | -18.39 | 89 | -77.28 | 44.87 | 12.29 | 101.03 |
| 12 | -18.79 | 102 | 65.57 | -69.59 | 12.29 | 100.05 |
| 13 | -12.79 | 134 | 82.94 | -42.6 | 12.29 | 100.84 |
| 14 | -14.49 | 142 | -94.16 | -48.41 | 12.29 | 100.88 |
| 15 | -16.39 | 236 | 93.92 | -57.58 | 12.29 | 100.01 |
| 16 | -20.89 | 295 | 52.29 | 59.39 | 12.29 | 100.88 |
| 17 | -21.59 | 463 | 13.7 | 57.13 | 12.29 | 100.16 |
| 18 | -21.59 | 500 | 30.25 | 50.42 | 12.29 | 100.02 |
| 19 | -23.49 | 597 | 15.91 | -72.69 | 12.29 | 99.95 |
| 20 | -24.79 | 610 | 35.08 | 52.61 | 12.29 | 101.07 |
| 21 | -23.69 | 686 | 31.72 | 53.32 | 12.29 | 100.01 |
| 22 | -23.39 | 722 | 27.71 | 61.91 | 12.29 | 100 |
| 23 | -29.29 | 766 | 9.19 | 70.24 | 12.29 | 100.96 |
| 24 | -30.49 | 941 | 54.67 | -86.82 | 12.29 | 101.16 |
| Ini. delay [ns] | XPR [dB] | PL [dB] | ZoA [°] | ASD [°] | ZSA [°] | ZSD [°] |
| 1389 | 7 | 123.16 | 90 | 1.29 | 0 | 0.23 |
| UE speed [m/s] | UE DoT Az [°] | UE coordinates (x,y,z) [m] | BS coordinates (x,y,z) [m] | K-factor [dB] |  |  |
| 0.833 | -39.55 | (416.41,0.53,1.5) | (0,0,10) | - |  |  |
|  |  |  |  |  |  |  |
| Way point | 2 |  |  |  |  |  |
| Cluster# | Power [dB] | Excess delay [ns] | AoA [°] | AoD [°] | ASA [°] | ZoD [°] |
| LOS | -0.51 | 0 | 178.36 | -1.64 | 0 | 91.13 |
| 1 | -13.83 | 0 | 178.36 | -1.64 | 22.34 | 91.13 |
| 2 | -19.13 | 2 | -75.17 | 84.91 | 22.34 | 87.85 |
| 3 | -21.33 | 33 | -75.17 | 84.91 | 20.106 | 87.85 |
| 4 | -23.13 | 73 | -75.17 | 84.91 | 17.872 | 87.85 |
| 5 | -18.23 | 75 | 130.89 | 10.97 | 22.34 | 90.88 |
| 6 | -23.23 | 95 | -61.58 | 31.93 | 22.34 | 91.13 |
| 7 | -20.43 | 97 | 130.89 | 10.97 | 20.106 | 90.88 |
| 8 | -22.23 | 139 | 130.89 | 10.97 | 17.872 | 90.88 |
| 9 | -28.13 | 217 | -116.21 | -64.23 | 22.34 | 88.58 |
| 10 | -23.93 | 426 | 32.33 | -33.56 | 22.34 | 89.32 |
| 11 | -25.13 | 506 | -13 | 49.4 | 22.34 | 92.47 |
| 12 | -30.33 | 521 | -64.46 | -129.82 | 22.34 | 86.54 |
| 13 | -28.03 | 672 | 86.96 | 73.27 | 22.34 | 88.11 |
| Ini. delay [ns] | XPR [dB] | PL [dB] | ZoA [°] | ASD [°] | ZSA [°] | ZSD [°] |
| 1442 | 11 | 104.42 | 90 | 4.85 | 0 | 0.76 |
| UE speed [m/s] | UE DoT Az [°] | UE coordinates (x,y,z) [m] | BS coordinates (x,y,z) [m] | K-factor [dB] |  |  |
| 8.33 | -123.94 | (432.02,-12.36,1.5) | (0,0,10) | 9 |  |  |
|  |  |  |  |  |  |  |
| Way point | 3 |  |  |  |  |  |
| Cluster# | Power [dB] | Excess delay [ns] | AoA [°] | AoD [°] | ASA [°] | ZoD [°] |
| LOS | -0.51 | 0 | 155.21 | -24.79 | 0 | 91.32 |
| 1 | -13.83 | 0 | 155.21 | -24.79 | 22.34 | 91.32 |
| 2 | -19.13 | 2 | -98.32 | 61.76 | 22.34 | 88.04 |
| 3 | -21.33 | 33 | -98.32 | 61.76 | 20.106 | 88.04 |
| 4 | -23.13 | 73 | -98.32 | 61.76 | 17.872 | 88.04 |
| 5 | -18.23 | 75 | 107.74 | -12.18 | 22.34 | 91.07 |
| 6 | -23.23 | 95 | -84.73 | 8.78 | 22.34 | 91.32 |
| 7 | -20.43 | 97 | 107.74 | -12.18 | 20.106 | 91.07 |
| 8 | -22.23 | 139 | 107.74 | -12.18 | 17.872 | 91.07 |
| 9 | -28.13 | 217 | -139.36 | -87.38 | 22.34 | 88.77 |
| 10 | -23.93 | 426 | 9.18 | -56.71 | 22.34 | 89.51 |
| 11 | -25.13 | 506 | -36.15 | 26.25 | 22.34 | 92.66 |
| 12 | -30.33 | 521 | -87.61 | -152.97 | 22.34 | 86.73 |
| 13 | -28.03 | 672 | 63.81 | 50.12 | 22.34 | 88.3 |
| Ini. delay [ns] | XPR [dB] | PL [dB] | ZoA [°] | ASD [°] | ZSA [°] | ZSD [°] |
| 1235 | 11 | 101.72 | 90 | 4.85 | 0 | 0.76 |
| UE speed [m/s] | UE DoT Az [°] | UE coordinates (x,y,z) [m] | BS coordinates (x,y,z) [m] | K-factor [dB] |  |  |
| 8.33 | -174.45 | (335.93,-155.15,1.5) | (0,0,10) | 9 |  |  |
|  |  |  |  |  |  |  |
| Way point | 4 |  |  |  |  |  |
| Cluster# | Power [dB] | Excess delay [ns] | AoA [°] | AoD [°] | ASA [°] | ZoD [°] |
| 1 | -18.8 | 0 | 71.19 | -88.13 | 7.52 | 98.1 |
| 2 | -5.4 | 42 | 177.81 | -28.58 | 7.52 | 98.58 |
| 3 | -7.6 | 44 | 177.81 | -28.58 | 6.768 | 98.58 |
| 4 | -11.4 | 50 | 88.48 | 3.75 | 7.52 | 98.9 |
| 5 | -13.6 | 58 | 88.48 | 3.75 | 6.768 | 98.9 |
| 6 | -15.9 | 63 | -79.06 | 14.47 | 7.52 | 99.21 |
| 7 | -9.4 | 64 | 177.81 | -28.58 | 6.016 | 98.58 |
| 8 | -15.3 | 73 | 88.48 | 3.75 | 6.016 | 98.9 |
| 9 | -12.9 | 83 | -106.47 | -55.12 | 7.52 | 98.16 |
| 10 | -21.3 | 167 | 100.51 | 27.1 | 7.52 | 97.84 |
| 11 | -12 | 206 | 71.6 | -55.56 | 7.52 | 98.95 |
| 12 | -17.8 | 236 | 54.3 | -79.53 | 7.52 | 99.22 |
| 13 | -22.1 | 242 | -157.04 | 19.02 | 7.52 | 99.45 |
| 14 | -20.6 | 271 | 88.48 | -86.04 | 7.52 | 99.29 |
| 15 | -16.2 | 273 | -82.61 | -71.62 | 7.52 | 98.07 |
| 16 | -16.7 | 333 | -93.55 | -73.71 | 7.52 | 97.99 |
| 17 | -18.1 | 444 | -110.09 | 29.5 | 7.52 | 98.03 |
| 18 | -21.6 | 485 | 111.58 | 23.68 | 7.52 | 99.34 |
| 19 | -23.7 | 497 | 134.88 | 18.3 | 7.52 | 97.67 |
| 20 | -24.3 | 522 | 142.27 | -67.75 | 7.52 | 97.73 |
| 21 | -22 | 545 | 105.84 | -79.91 | 7.52 | 99.45 |
| 22 | -25.3 | 577 | 178.42 | 16.18 | 7.52 | 97.8 |
| 23 | -35.1 | 1051 | 73.85 | -46.39 | 7.52 | 99.15 |
| Ini. delay [ns] | XPR [dB] | PL [dB] | ZoA [°] | ASD [°] | ZSA [°] | ZSD [°] |
| 1199 | 10 | 120.9 | 90 | 1.71 | 0 | 0.03 |
| UE speed [m/s] | UE DoT Az [°] | UE coordinates (x,y,z) [m] | BS coordinates (x,y,z) [m] | K-factor [dB] |  |  |
| 8.33 | 120.08 | (323.58,-156.35,1.5) | (0,0,10) | - |  |  |
|  |  |  |  |  |  |  |
| Way point | 5 |  |  |  |  |  |
| Cluster# | Power [dB] | Excess delay [ns] | AoA [°] | AoD [°] | ASA [°] | ZoD [°] |
| 1 | -12.09 | 0 | -124.81 | -41.17 | 12.29 | 101.17 |
| 2 | -8.89 | 23 | 121.29 | -25.8 | 12.29 | 101.27 |
| 3 | -10.19 | 24 | -146.52 | -37.36 | 12.29 | 101.43 |
| 4 | -11.19 | 24 | 121.29 | -25.8 | 11.061 | 101.27 |
| 5 | -12.89 | 25 | 121.29 | -25.8 | 9.832 | 101.27 |
| 6 | -7.69 | 69 | 162.59 | -10.89 | 12.29 | 101.32 |
| 7 | -9.89 | 70 | 162.59 | -10.89 | 11.061 | 101.32 |
| 8 | -11.59 | 71 | 162.59 | -10.89 | 9.832 | 101.32 |
| 9 | -15.09 | 72 | 68.35 | 36.1 | 12.29 | 101.79 |
| 10 | -14.79 | 86 | 77.45 | -52.72 | 12.29 | 101.02 |
| 11 | -18.39 | 89 | -81.46 | 40.69 | 12.29 | 101.86 |
| 12 | -18.79 | 102 | 61.39 | -73.77 | 12.29 | 100.88 |
| 13 | -12.79 | 134 | 78.76 | -46.78 | 12.29 | 101.67 |
| 14 | -14.49 | 142 | -98.34 | -52.59 | 12.29 | 101.71 |
| 15 | -16.39 | 236 | 89.74 | -61.76 | 12.29 | 100.84 |
| 16 | -20.89 | 295 | 48.11 | 55.21 | 12.29 | 101.71 |
| 17 | -21.59 | 463 | 9.52 | 52.95 | 12.29 | 100.99 |
| 18 | -21.59 | 500 | 26.07 | 46.24 | 12.29 | 100.85 |
| 19 | -23.49 | 597 | 11.73 | -76.87 | 12.29 | 100.78 |
| 20 | -24.79 | 610 | 30.9 | 48.43 | 12.29 | 101.9 |
| 21 | -23.69 | 686 | 27.54 | 49.14 | 12.29 | 100.84 |
| 22 | -23.39 | 722 | 23.53 | 57.73 | 12.29 | 100.83 |
| 23 | -29.29 | 766 | 5.01 | 66.06 | 12.29 | 101.79 |
| 24 | -30.49 | 941 | 50.49 | -91 | 12.29 | 101.99 |
| Ini. delay [ns] | XPR [dB] | PL [dB] | ZoA [°] | ASD [°] | ZSA [°] | ZSD [°] |
| 814 | 7 | 114.96 | 90 | 1.29 | 0 | 0.23 |
| UE speed [m/s] | UE DoT Az [°] | UE coordinates (x,y,z) [m] | BS coordinates (x,y,z) [m] | K-factor [dB] |  |  |
| 8.33 | 98.5 | (243.15,-17.48,1.5) | (0,0,10) | - |  |  |
|  |  |  |  |  |  |  |
| Way point | 6 |  |  |  |  |  |
| Cluster# | Power [dB] | Excess delay [ns] | AoA [°] | AoD [°] | ASA [°] | ZoD [°] |
| 1 | -18.8 | 0 | 96.83 | -62.49 | 7.52 | 98.77 |
| 2 | -5.4 | 42 | -156.55 | -2.94 | 7.52 | 99.25 |
| 3 | -7.6 | 44 | -156.55 | -2.94 | 6.768 | 99.25 |
| 4 | -11.4 | 50 | 114.12 | 29.39 | 7.52 | 99.57 |
| 5 | -13.6 | 58 | 114.12 | 29.39 | 6.768 | 99.57 |
| 6 | -15.9 | 63 | -53.42 | 40.11 | 7.52 | 99.88 |
| 7 | -9.4 | 64 | -156.55 | -2.94 | 6.016 | 99.25 |
| 8 | -15.3 | 73 | 114.12 | 29.39 | 6.016 | 99.57 |
| 9 | -12.9 | 83 | -80.83 | -29.48 | 7.52 | 98.83 |
| 10 | -21.3 | 167 | 126.15 | 52.74 | 7.52 | 98.51 |
| 11 | -12 | 206 | 97.24 | -29.92 | 7.52 | 99.62 |
| 12 | -17.8 | 236 | 79.94 | -53.89 | 7.52 | 99.89 |
| 13 | -22.1 | 242 | -131.4 | 44.66 | 7.52 | 100.12 |
| 14 | -20.6 | 271 | 114.12 | -60.4 | 7.52 | 99.96 |
| 15 | -16.2 | 273 | -56.97 | -45.98 | 7.52 | 98.74 |
| 16 | -16.7 | 333 | -67.91 | -48.07 | 7.52 | 98.66 |
| 17 | -18.1 | 444 | -84.45 | 55.14 | 7.52 | 98.7 |
| 18 | -21.6 | 485 | 137.22 | 49.32 | 7.52 | 100.01 |
| 19 | -23.7 | 497 | 160.52 | 43.94 | 7.52 | 98.34 |
| 20 | -24.3 | 522 | 167.91 | -42.11 | 7.52 | 98.4 |
| 21 | -22 | 545 | 131.48 | -54.27 | 7.52 | 100.12 |
| 22 | -25.3 | 577 | -155.94 | 41.82 | 7.52 | 98.47 |
| 23 | -35.1 | 1051 | 99.49 | -20.75 | 7.52 | 99.82 |
| Ini. delay [ns] | XPR [dB] | PL [dB] | ZoA [°] | ASD [°] | ZSA [°] | ZSD [°] |
| 803 | 10 | 114.76 | 90 | 1.71 | 0 | 0.03 |
| UE speed [m/s] | UE DoT Az [°] | UE coordinates (x,y,z) [m] | BS coordinates (x,y,z) [m] | K-factor [dB] |  |  |
| 0.833 | 81.43 | (240.63,-0.61,1.5) | (0,0,10) | - |  |  |
|  |  |  |  |  |  |  |
| Way point | 7 |  |  |  |  |  |
| Cluster# | Power [dB] | Excess delay [ns] | AoA [°] | AoD [°] | ASA [°] | ZoD [°] |
| 1 | -12.09 | 0 | -117.19 | -33.55 | 12.29 | 101.17 |
| 2 | -8.89 | 23 | 128.91 | -18.18 | 12.29 | 101.27 |
| 3 | -10.19 | 24 | -138.9 | -29.74 | 12.29 | 101.43 |
| 4 | -11.19 | 24 | 128.91 | -18.18 | 11.061 | 101.27 |
| 5 | -12.89 | 25 | 128.91 | -18.18 | 9.832 | 101.27 |
| 6 | -7.69 | 69 | 170.21 | -3.27 | 12.29 | 101.32 |
| 7 | -9.89 | 70 | 170.21 | -3.27 | 11.061 | 101.32 |
| 8 | -11.59 | 71 | 170.21 | -3.27 | 9.832 | 101.32 |
| 9 | -15.09 | 72 | 75.97 | 43.72 | 12.29 | 101.79 |
| 10 | -14.79 | 86 | 85.07 | -45.1 | 12.29 | 101.02 |
| 11 | -18.39 | 89 | -73.84 | 48.31 | 12.29 | 101.86 |
| 12 | -18.79 | 102 | 69.01 | -66.15 | 12.29 | 100.88 |
| 13 | -12.79 | 134 | 86.38 | -39.16 | 12.29 | 101.67 |
| 14 | -14.49 | 142 | -90.72 | -44.97 | 12.29 | 101.71 |
| 15 | -16.39 | 236 | 97.36 | -54.14 | 12.29 | 100.84 |
| 16 | -20.89 | 295 | 55.73 | 62.83 | 12.29 | 101.71 |
| 17 | -21.59 | 463 | 17.14 | 60.57 | 12.29 | 100.99 |
| 18 | -21.59 | 500 | 33.69 | 53.86 | 12.29 | 100.85 |
| 19 | -23.49 | 597 | 19.35 | -69.25 | 12.29 | 100.78 |
| 20 | -24.79 | 610 | 38.52 | 56.05 | 12.29 | 101.9 |
| 21 | -23.69 | 686 | 35.16 | 56.76 | 12.29 | 100.84 |
| 22 | -23.39 | 722 | 31.15 | 65.35 | 12.29 | 100.83 |
| 23 | -29.29 | 766 | 12.63 | 73.68 | 12.29 | 101.79 |
| 24 | -30.49 | 941 | 58.11 | -83.38 | 12.29 | 101.99 |
| Ini. delay [ns] | XPR [dB] | PL [dB] | ZoA [°] | ASD [°] | ZSA [°] | ZSD [°] |
| 812 | 7 | 114.94 | 90 | 1.29 | 0 | 0.23 |
| UE speed [m/s] | UE DoT Az [°] | UE coordinates (x,y,z) [m] | BS coordinates (x,y,z) [m] | K-factor [dB] |  |  |
| 8.33 | 54.64 | (242.97,14.91,1.5) | (0,0,10) | - |  |  |
|  |  |  |  |  |  |  |
| Way point | 8 |  |  |  |  |  |
| Cluster# | Power [dB] | Excess delay [ns] | AoA [°] | AoD [°] | ASA [°] | ZoD [°] |
| 1 | -18.8 | 0 | 122.37 | -36.95 | 7.52 | 98.01 |
| 2 | -5.4 | 42 | -131.01 | 22.6 | 7.52 | 98.49 |
| 3 | -7.6 | 44 | -131.01 | 22.6 | 6.768 | 98.49 |
| 4 | -11.4 | 50 | 139.66 | 54.93 | 7.52 | 98.81 |
| 5 | -13.6 | 58 | 139.66 | 54.93 | 6.768 | 98.81 |
| 6 | -15.9 | 63 | -27.88 | 65.65 | 7.52 | 99.12 |
| 7 | -9.4 | 64 | -131.01 | 22.6 | 6.016 | 98.49 |
| 8 | -15.3 | 73 | 139.66 | 54.93 | 6.016 | 98.81 |
| 9 | -12.9 | 83 | -55.29 | -3.94 | 7.52 | 98.07 |
| 10 | -21.3 | 167 | 151.69 | 78.28 | 7.52 | 97.75 |
| 11 | -12 | 206 | 122.78 | -4.38 | 7.52 | 98.86 |
| 12 | -17.8 | 236 | 105.48 | -28.35 | 7.52 | 99.13 |
| 13 | -22.1 | 242 | -105.86 | 70.2 | 7.52 | 99.36 |
| 14 | -20.6 | 271 | 139.66 | -34.86 | 7.52 | 99.2 |
| 15 | -16.2 | 273 | -31.43 | -20.44 | 7.52 | 97.98 |
| 16 | -16.7 | 333 | -42.37 | -22.53 | 7.52 | 97.9 |
| 17 | -18.1 | 444 | -58.91 | 80.68 | 7.52 | 97.94 |
| 18 | -21.6 | 485 | 162.76 | 74.86 | 7.52 | 99.25 |
| 19 | -23.7 | 497 | -173.94 | 69.48 | 7.52 | 97.58 |
| 20 | -24.3 | 522 | -166.55 | -16.57 | 7.52 | 97.64 |
| 21 | -22 | 545 | 157.02 | -28.73 | 7.52 | 99.36 |
| 22 | -25.3 | 577 | -130.4 | 67.36 | 7.52 | 97.71 |
| 23 | -35.1 | 1051 | 125.03 | 4.79 | 7.52 | 99.06 |
| Ini. delay [ns] | XPR [dB] | PL [dB] | ZoA [°] | ASD [°] | ZSA [°] | ZSD [°] |
| 1294 | 10 | 122.07 | 90 | 1.71 | 0 | 0.03 |
| UE speed [m/s] | UE DoT Az [°] | UE coordinates (x,y,z) [m] | BS coordinates (x,y,z) [m] | K-factor [dB] |  |  |
| 8.33 | -23.54 | (350.59,166.27,1.5) | (0,0,10) | - |  |  |
|  |  |  |  |  |  |  |
| Way point | 9 |  |  |  |  |  |
| Cluster# | Power [dB] | Excess delay [ns] | AoA [°] | AoD [°] | ASA [°] | ZoD [°] |
| LOS | -0.51 | 0 | -156.01 | 23.99 | 0 | 91.23 |
| 1 | -22.24 | 0 | -156.01 | 23.99 | 14.19 | 91.23 |
| 2 | -16.01 | 27 | -4.8 | 90.48 | 14.19 | 93.18 |
| 3 | -18.31 | 28 | -4.8 | 90.48 | 12.771 | 93.18 |
| 4 | -23.11 | 28 | 103.08 | 0.75 | 14.19 | 91.15 |
| 5 | -20.01 | 29 | -4.8 | 90.48 | 11.352 | 93.18 |
| 6 | -22.61 | 37 | 117.4 | 42.72 | 14.19 | 91.74 |
| 7 | -18.81 | 99 | -124.4 | 34.74 | 14.19 | 90.89 |
| 8 | -21.01 | 100 | -124.4 | 34.74 | 12.771 | 90.89 |
| 9 | -22.81 | 102 | -124.4 | 34.74 | 11.352 | 90.89 |
| 10 | -22.51 | 137 | -108.65 | 45.96 | 14.19 | 91.74 |
| 11 | -25.81 | 193 | -45.94 | 61.8 | 14.19 | 89.88 |
| 12 | -20.41 | 283 | 161.41 | 24.57 | 14.19 | 90.93 |
| 13 | -30.01 | 622 | 29.55 | 88.63 | 14.19 | 89.54 |
| 14 | -29.41 | 1070 | 42.71 | 90.6 | 14.19 | 93.34 |
| Ini. delay [ns] | XPR [dB] | PL [dB] | ZoA [°] | ASD [°] | ZSA [°] | ZSD [°] |
| 1322 | 8 | 102.91 | 90 | 5.78 | 0 | 1.27 |
| UE speed [m/s] | UE DoT Az [°] | UE coordinates (x,y,z) [m] | BS coordinates (x,y,z) [m] | K-factor [dB] |  |  |
| 8.33 | -66.12 | (362.14,161.15,1.5) | (0,0,10) | 9 |  |  |
|  |  |  |  |  |  |  |
| Way point | 10 |  |  |  |  |  |
| Cluster# | Power [dB] | Excess delay [ns] | AoA [°] | AoD [°] | ASA [°] | ZoD [°] |
| LOS | -0.51 | 0 | -178.47 | 1.53 | 0 | 91.14 |
| 1 | -22.24 | 0 | -178.47 | 1.53 | 14.19 | 91.14 |
| 2 | -16.01 | 27 | -27.26 | 68.02 | 14.19 | 93.09 |
| 3 | -18.31 | 28 | -27.26 | 68.02 | 12.771 | 93.09 |
| 4 | -23.11 | 28 | 80.62 | -21.71 | 14.19 | 91.06 |
| 5 | -20.01 | 29 | -27.26 | 68.02 | 11.352 | 93.09 |
| 6 | -22.61 | 37 | 94.94 | 20.26 | 14.19 | 91.65 |
| 7 | -18.81 | 99 | -146.86 | 12.28 | 14.19 | 90.8 |
| 8 | -21.01 | 100 | -146.86 | 12.28 | 12.771 | 90.8 |
| 9 | -22.81 | 102 | -146.86 | 12.28 | 11.352 | 90.8 |
| 10 | -22.51 | 137 | -131.11 | 23.5 | 14.19 | 91.65 |
| 11 | -25.81 | 193 | -68.4 | 39.34 | 14.19 | 89.79 |
| 12 | -20.41 | 283 | 138.95 | 2.11 | 14.19 | 90.84 |
| 13 | -30.01 | 622 | 7.09 | 66.17 | 14.19 | 89.45 |
| 14 | -29.41 | 1070 | 20.25 | 68.14 | 14.19 | 93.25 |
| Ini. delay [ns] | XPR [dB] | PL [dB] | ZoA [°] | ASD [°] | ZSA [°] | ZSD [°] |
| 1430 | 8 | 104.27 | 90 | 5.78 | 0 | 1.27 |
| UE speed [m/s] | UE DoT Az [°] | UE coordinates (x,y,z) [m] | BS coordinates (x,y,z) [m] | K-factor [dB] |  |  |
| 8.33 | -137.72 | (428.41,11.4,1.5) | (0,0,10) | 9 |  |  |

Annex B:  
UE coordinate system

# B.1 Reference coordinate system

There are three sets of coordinate systems used for FR1 MIMO OTA measurements. They are aligned with the following instructions to avoid misalignment and ambiguity.

The coordinate system for UE positioning is the guidance to specify the UE orientation in Annex A of [4]. The default position of DUT aligned to coordinate system is illustrated in Figure B.1-1. For convenience, name the coordinate axis of DUT coordinate system as xDUT, yDUT and zDUT.

A white cell phone with black text

Description automatically generated

Figure B.1-1: Illustration of DUT coordinate system

The coordinate system for channel model, which is used to specify channel models for FR1 MIMO OTA, is defined in Clause 7 of [6]. Similarly, the coordinate axes of channel model coordinate system are named as *x*CM, *y*CM and *z*CM. The channel model coordinate system is illustrated in Figure B.1-2.

A diagram of a mathematical equation

Description automatically generated

Figure B.1-2: Illustration of channel model coordinate system

The coordinate system of anechoic chamber is also applied where the 16 measurement probes are evenly located in the azimuth plane. To avoid any chamber implementation flexibility/ambiguity, the *x*-axis of the chamber shall be aligned with one of the 16 probes. The OTA/channel model coordinate systems and probe placement are further clarified in Figure B.1-3. The *x*-axis of the coordinate system is aligned with the centre of a probe and the *x*, *y*, and *z* axes of the OTA coordinate system are aligned with the *xCM*, *yCM*, and *zCM* axes of the channel model coordinate system.

A diagram of a device

Description automatically generated

Figure B.1-3: Illustration of aligned OTA and channel model coordinate systems

# B.2 DUT positioning guidelines

To assess the MIMO OTA performance for representative device orientations and orientations, four device orientations are tested, i.e., DMP, DML (both left and right tilt), and DMSU as defined in Clause A.3 of [4] and as illustrated in Figure B.2-1.

A diagram of a custom alignment option

Description automatically generated A diagram of a custom alignment option

Description automatically generatedA diagram of a custom alignment option

Description automatically generated A diagram of a custom alignment option

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Figure B.2-1: Test Conditions: FS DMP (top left), FS DML-left tilt (top right), FS DML-right tilt (bottom left), FS DMSU (bottom right)

Four rotations, i.e., 0°, 90°, 180°, 270°, of the device (per orientation) within the test volume account for determining a statistical typical performance of the device in the specified spatial channel. Those 4 rotations are illustrated in Figure 6.3-2 for the DMP orientation.

A diagram of a custom alignment option

Description automatically generated A diagram of a custom alignment option

Description automatically generatedA diagram of a device

Description automatically generated A diagram of a device

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Figure B.2-2: Four Rotations for the DMP Orientation: 0°, 90°, 180°, 270°

Annex C:  
Measurement uncertainty

<Editor’s note: This Annex can be modified by RAN5 outcome. >

# C.1 MU assessment for MPAC

<Editor’s note: includes preliminary measurement uncertainty budget for the MPAC system. >

# C.2 MU contribution descriptions for MPAC

<Editor’s note: includes MU contribution descriptions for MPAC. >

Annex D:  
Environmental requirements

# D.1 Ambient temperature

All MIMO OTA requirements are applicable at nominal temperature, i.e., room temperature (25C).

# D.2 Operating voltage

All test cases shall be performed in the normal voltage condition with the DUT operated in stand-alone battery powered mode, i.e., no extreme voltage testing is required. No extreme voltage testing is required. It is recommended to start the testing with a fully charged battery and conclude and/or pause testing before the battery has completely lost its charge.

**<<< END OF CHANGES >>>**

1. DoT affects Doppler shifts and consequently the temporal correlation of the emulated channel model. DUT orientation in the internal coordinate system of the channel model affects the PAS and consequently the mapping of clusters (multi-paths of the model) onto probes. Continuous and smooth change of them both prevents discontinuities in way-point instances that would cause instantaneous spreading of Doppler spectrum, immediate obsolescence of channel estimates, and possibly artificial bursts of bit errors in the received signal. An example of interpolation: Say DoT is +30° in the location of way-point *a* and -10° in way-point *b*, then even though the route from WP*a* to WP*b* is straight, the DoT and correspondingly the orientation of UE in the model continuously and linearly changes from +30° to -10° along the route between way-points. [↑](#footnote-ref-2)