**3GPP TSG-WG4 Meeting #107 *R4-2309820***

**Incheon, South Korea, 22nd May – 26th May 2023**

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| *CR-Form-v12.2* | | | | | | | | |
| **CHANGE REQUEST** | | | | | | | | |
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|  |  | **CR** | **0012** | **rev** | **1** | **Current version:** |  |  |
|  | | | | | | | | |
| *For* [***HE******LP***](http://www.3gpp.org/3G_Specs/CRs.htm#_blank)*on using this form: comprehensive instructions can be found at* [*http://www.3gpp.org/Change-Requests*](http://www.3gpp.org/Change-Requests)*.* | | | | | | | | |
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| ***Proposed change affects:*** | UICC apps |  | ME | **X** | Radio Access Network |  | Core Network |  |

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| ***Title:*** | On TS 38.151 Annex C editorial updates | | | | | | | | | |
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| ***Source to WG:***  ***Source to TSG:*** | Apple Hungary kft.  R4 | | | | | | | | | |
|  |  | | | | | | | | | |
| ***Work item code:*** | NR\_MIMO\_OTA | | | | |  | ***Date:*** | | | 2023-05-23 |
|  |  | | | |  | |  | | |  |
| ***Category:*** | F |  | | | | | ***Release:*** | | | Rel-17 |
|  | *Use one of the following categories:* ***F*** *(correction)* ***A*** *(mirror corresponding to a change in an earlier release)* ***B*** *(addition of feature),* ***C*** *(functional modification of feature)* ***D*** *(editorial modification)*  Detailed explanations of the above categories can be found in 3GPP [TR 21.900](http://www.3gpp.org/ftp/Specs/html-info/21900.htm). | | | | | | | | *Use one of the following releases: Rel-8 (Release 8) Rel-9 (Release 9) Rel-10 (Release 10) Rel-11 (Release 11) … Rel-16 (Release 16) Rel-17 (Release 17) Rel-18 (Release 18) Rel-19 (Release 19)* | |
|  |  | | | | | | | | | |
| ***Reason for change:*** | | TS 38.151 editorial updates on Annex C | | | | | | | | |
|  | |  | | | | | | | | |
| ***Summary of change:*** | | Editorial clarification on Channel models and Validation procedures, into the TS 38.151 | | | | | | | | |
|  | |  | | | | | | | | |
| ***Consequences if not approved:*** | | Lack of editorial clarity on the specification | | | | | | | | |
|  | |  | | | | | | | | |
| ***Clauses affected:*** | | Annex C | | | | | | | | |
|  | |  | | | | | | | | |
|  | | **Y** | **N** |  | | | |  | | |
| ***Other specs*** | |  | **x** | Other core specifications | | | | TS/TR ... CR ... | | |
| ***affected:*** | |  | **x** | Test specifications | | | | TS/TR ... CR ... | | |
| ***(show related CRs)*** | |  | **x** | O&M Specifications | | | | TS/TR ... CR ... | | |
|  | |  | | | | | | | | |
| ***Other comments:*** | |  | | | | | | | | |
|  | |  | | | | | | | | |
| ***This CR's revision history:*** | | This is a revised CR from R4-2309744 | | | | | | | | |

# 

## **<Start of Change>**

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

# C.1 FR1 Channel models

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

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

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

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

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

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

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

# C.2 FR1 Base Station beam configuration

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

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

Table C.2-1: BS Antenna Parameters

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

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

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

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

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

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

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

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

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

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

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

# C.3 FR1 Channel model validation

## C.3.1 General

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

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

- Power Delay Profile (PDP)

- Doppler/Temporal correlation

- Spatial correlation

- Cross-polarization

- Power validation

Frequencies to be used to test for channel model validation:

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

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

Table C.3.1-2: Frequencies for Power validation

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

C.3.2 Power Delay Profile (PDP)

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

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

Shape

Description automatically generated with medium confidence

Figure C.3.2-1: Setup for PDP measurements

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

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

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

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

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

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

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

**Method of measurement result analysis:**

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



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

**Beam-Specific Block Diagram**

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

- Beam 1: Input 1 and Input 2

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

Shape

Description automatically generated with medium confidence

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

Shape

Description automatically generated with medium confidence

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

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

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

|  |  |  |
| --- | --- | --- |
| Combined Clusters index | Delay(ns) | Power(dB) |
| 1 | 0 | -34.3 |
| 2-5 | 80 | -19.5 |
| 6-8 | 235 | 0.0 |
| 9-10 | 290 | -33.0 |
| 11 | 450 | -35.8 |
| 12 | 480 | -34.0 |

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

|  |  |  |
| --- | --- | --- |
| Combined Clusters index | Delay(ns) | Power(dB) |
| 1 | 0 | -27.9 |
| 2-5 | 80 | 0.0 |
| 6-8 | 235 | -18.4 |
| 9-10 | 290 | -27.8 |
| 11 | 450 | -27.9 |
| 12 | 480 | -28.0 |

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

|  |  |  |
| --- | --- | --- |
| Combined Clusters index | Delay(ns) | Power(dB) |
| 1 | 0 | -34.2 |
| 2-5 | 80 | -19.3 |
| 6-8 | 235 | 0.0 |
| 9 | 290 | -34.7 |
| 10 | 450 | -35.8 |
| 11 | 480 | -34.7 |

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

|  |  |  |
| --- | --- | --- |
| Combined Clusters index | delay(ns) | power(dB) |
| 1 | 0 | -27.8 |
| 2-5 | 80 | 0.0 |
| 6-8 | 235 | -18.3 |
| 9-10 | 290 | -28.9 |
| 11 | 450 | -28.1 |
| 12 | 480 | -28.8 |

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

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

## C.3.3 Doppler/Temporal correlation

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

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

**Method of measurement:**

A picture containing shape

Description automatically generated

Figure C.3.3-1: Setup for Doppler measurements

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

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

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

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

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

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

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

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

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

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

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

**Time Domain Alternate Method**

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

A screenshot of a computer

Description automatically generated with medium confidence

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

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

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

Table C.3.3-4: Signal Analyser Settings

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

**Beam-Specific Block Diagram**

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

- Beam 1: Input 1 and Input 2

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

Shape

Description automatically generated with medium confidence

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

Shape

Description automatically generated with medium confidence

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

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

Table C.3.3-5: Autocorrelation Targets

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

## C.3.4 Spatial correlation

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

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

The measurement and analysis procedure are as follows:

Set the target channel model to fading emulator.

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



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



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



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



5.



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

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

Diagram

Description automatically generated

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

**Beam-Specific Block Diagram**

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

- Beam 1: Input 1 and Input 2

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

Shape

Description automatically generated with medium confidence

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

Shape

Description automatically generated with medium confidence

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

**Time and frequency samples**

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

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

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

Table C.3.4-2: Channel model specification

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

**Spatial samples**

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

Table C.3.4-3: Spacing of Spatial Samples

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

A red moon in a black sky

Description automatically generated with medium confidence

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



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

**Reference Spatial Correlation Curves**

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

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

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | |  | |  | |  | |  | |
| Azim [] | || beam 1 | Azim [] | || beam 1 | Azim [] | || beam 1 | Azim [] | || beam 1 | Azim [] | || beam 1 |
| 617 MHz | | 722 MHz | | 836.5 MHz | | 1575.42 MHz | | 1800 MHz | |
| 270.0 | 1.00 | 270.0 | 1.00 | 270.0 | 1.00 | 270.0 | 1.00 | 270.0 | 1.00 |
| 251.4 | 1.00 | 254.1 | 1.00 | 256.3 | 1.00 | 262.7 | 1.00 | 260.9 | 1.00 |
| 232.9 | 1.00 | 238.3 | 1.00 | 242.6 | 1.00 | 255.5 | 1.00 | 251.7 | 1.00 |
| 214.3 | 0.99 | 222.4 | 1.00 | 228.9 | 1.00 | 248.2 | 1.00 | 242.6 | 0.99 |
| 195.8 | 0.99 | 206.6 | 0.99 | 215.2 | 0.99 | 240.9 | 0.99 | 233.5 | 0.99 |
| 110.4 | 0.87 | 190.7 | 0.98 | 201.6 | 0.98 | 233.7 | 0.99 | 224.3 | 0.98 |
| 40.8 | 0.87 | 120.5 | 0.84 | 187.9 | 0.96 | 226.4 | 0.99 | 215.2 | 0.97 |
| 331.2 | 0.98 | 61.1 | 0.80 | 128.7 | 0.82 | 219.1 | 0.98 | 206.0 | 0.95 |
|  |  | 1.6 | 0.91 | 77.3 | 0.73 | 211.9 | 0.97 | 196.9 | 0.92 |
|  |  | 302.1 | 0.99 | 26.0 | 0.81 | 204.6 | 0.96 | 187.8 | 0.87 |
|  |  |  |  | 334.7 | 0.95 | 197.3 | 0.94 | 134.3 | 0.39 |
|  |  |  |  | 283.3 | 1.00 | 190.0 | 0.91 | 88.6 | 0.15 |
|  |  |  |  |  |  | 182.8 | 0.87 | 43.0 | 0.24 |
|  |  |  |  |  |  | 152.7 | 0.66 | 357.3 | 0.62 |
|  |  |  |  |  |  | 125.5 | 0.44 | 311.6 | 0.94 |
|  |  |  |  |  |  | 98.2 | 0.30 |  |  |
|  |  |  |  |  |  | 71.0 | 0.28 |  |  |
|  |  |  |  |  |  | 43.7 | 0.37 |  |  |
|  |  |  |  |  |  | 16.5 | 0.54 |  |  |
|  |  |  |  |  |  | 349.2 | 0.75 |  |  |
|  |  |  |  |  |  | 321.9 | 0.91 |  |  |
|  |  |  |  |  |  | 294.7 | 0.99 |  |  |
|  | |  | |  | |  | |
| Azim [] | || beam 1 | Azim [] | || beam 1 | Azim [] | || beam 1 | Azim [] | || beam 1 |
| 2132.5 MHz | | 2450 MHz | | 3600 MHz | | 4700 MHz | |
| 270.0 | 1.00 | 270.0 | 1.00 | 270.0 | 1.00 | 270.0 | 1.00 |
| 261.9 | 1.00 | 263.0 | 1.00 | 265.2 | 1.00 | 266.3 | 1.00 |
| 253.9 | 1.00 | 256.0 | 1.00 | 260.5 | 1.00 | 262.7 | 1.00 |
| 245.8 | 0.99 | 249.0 | 0.99 | 255.7 | 0.99 | 259.0 | 0.99 |
| 237.8 | 0.99 | 242.0 | 0.99 | 250.9 | 0.99 | 255.4 | 0.99 |
| 229.7 | 0.98 | 234.9 | 0.99 | 246.1 | 0.99 | 251.7 | 0.99 |
| 221.7 | 0.97 | 227.9 | 0.98 | 241.4 | 0.98 | 248.1 | 0.98 |
| 213.6 | 0.96 | 220.9 | 0.97 | 236.6 | 0.98 | 244.4 | 0.98 |
| 205.6 | 0.93 | 213.9 | 0.95 | 231.8 | 0.97 | 240.8 | 0.98 |
| 197.5 | 0.89 | 206.9 | 0.92 | 227.1 | 0.97 | 237.1 | 0.97 |
| 189.5 | 0.84 | 199.9 | 0.88 | 222.3 | 0.95 | 233.5 | 0.97 |
| 181.4 | 0.77 | 192.9 | 0.83 | 217.5 | 0.93 | 229.8 | 0.96 |
| 139.7 | 0.27 | 185.9 | 0.76 | 212.7 | 0.90 | 226.1 | 0.95 |
| 99.5 | 0.14 | 144.9 | 0.19 | 208.0 | 0.86 | 222.5 | 0.93 |
| 59.2 | 0.14 | 109.9 | 0.26 | 203.2 | 0.81 | 218.8 | 0.91 |
| 18.9 | 0.26 | 74.8 | 0.37 | 198.4 | 0.75 | 215.2 | 0.87 |
| 338.6 | 0.71 | 39.8 | 0.19 | 193.7 | 0.68 | 211.5 | 0.83 |
| 298.4 | 0.97 | 4.7 | 0.29 | 188.9 | 0.59 | 207.9 | 0.78 |
|  |  | 329.7 | 0.74 | 184.1 | 0.49 | 204.2 | 0.72 |
|  |  | 294.6 | 0.97 | 156.1 | 0.23 | 200.6 | 0.64 |
|  |  |  |  | 132.3 | 0.62 | 196.9 | 0.56 |
|  |  |  |  | 108.4 | 0.85 | 193.3 | 0.47 |
|  |  |  |  | 84.6 | 0.93 | 189.6 | 0.37 |
|  |  |  |  | 60.7 | 0.92 | 185.9 | 0.27 |
|  |  |  |  | 36.9 | 0.79 | 182.3 | 0.18 |
|  |  |  |  | 13.0 | 0.42 | 161.7 | 0.51 |
|  |  |  |  | 349.1 | 0.15 | 143.5 | 0.83 |
|  |  |  |  | 325.3 | 0.60 | 125.2 | 0.95 |
|  |  |  |  | 301.4 | 0.90 | 106.9 | 0.89 |
|  |  |  |  | 277.6 | 1.00 | 88.6 | 0.80 |
|  |  |  |  |  |  | 70.4 | 0.78 |
|  |  |  |  |  |  | 52.1 | 0.88 |
|  |  |  |  |  |  | 33.8 | 0.98 |
|  |  |  |  |  |  | 15.5 | 0.91 |
|  |  |  |  |  |  | 357.3 | 0.53 |
|  |  |  |  |  |  | 339.0 | 0.09 |
|  |  |  |  |  |  | 320.7 | 0.50 |
|  |  |  |  |  |  | 302.4 | 0.82 |
|  |  |  |  |  |  | 284.2 | 0.97 |

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

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

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

**Time Domain Alternative Method:**

Time domain techniques can also be used to validate the spatial correlation. The spatial correlation validation measurement setup is illustrated in Figure C.3.4-6. In this case a Signal generator transmits a CW signal through the MIMO test system. The signal is received by a test antenna within the test area. Finally, the signal is collected by a signal analyser and the measured signal is stored for postprocessing.

Diagram

Description automatically generated

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

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

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

Table C.3.4-6: Signal Generator Settings

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

Table C.3.4-7: Signal Analyser Settings

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

**Beam-Simultaneous Block Diagram**

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

- Beam 1: Input 1 and Input 2

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

Shape

Description automatically generated with medium confidence

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

Shape

Description automatically generated with medium confidence

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

## C.3.5 Cross-polarization

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

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

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

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

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

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

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

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

**Measurement Procedure:**

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

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

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

**Method of measurement result analysis:**

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

**Beam-Specific Block Diagram**

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

- Beam 1: Input 1 and Input 2

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

Shape

Description automatically generated with medium confidence

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

Shape

Description automatically generated with medium confidence

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

**Time Domain Alternative Method:**

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

Shape

Description automatically generated with medium confidence

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

Shape

Description automatically generated with medium confidence

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

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

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

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

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

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

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

## C.3.6 Power validation

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

A picture containing shape

Description automatically generated

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

Spectrum analyser settings for power validation measurements are presented in Table C.3.6-1.

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

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

**Measurement Procedure:**

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

2. Record the cable and reference dipole gains.

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

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

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

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

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

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

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

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

Shape

Description automatically generated with medium confidence

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

Shape

Description automatically generated with medium confidence

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

# C.4 Validation Pass/fail limit

## C.4.1 General

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

## C.4.2 Pass/Fail Criteria of PDP

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

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

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

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

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

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

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

For the detailed pass/fail limits, the values are defined in the Table C.4.3-1.

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

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

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

     

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

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

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

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

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

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

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | |  | |  | |  | |  | |
| Lower | Upper | Lower | Upper | Lower | Upper | Lower | Upper | Lower | Upper |
| 617 MHz | | 722 MHz | | 836.5 MHz | | 1575.42 MHz | | 1880 MHz | |
| 0.90 | 1.00 | 0.90 | 1.00 | 0.90 | 1.00 | 0.90 | 1.00 | 0.90 | 1.00 |
| 0.90 | 1.00 | 0.90 | 1.00 | 0.90 | 1.00 | 0.90 | 1.00 | 0.90 | 1.00 |
| 0.90 | 1.00 | 0.90 | 1.00 | 0.90 | 1.00 | 0.90 | 1.00 | 0.90 | 1.00 |
| 0.90 | 1.00 | 0.90 | 1.00 | 0.90 | 1.00 | 0.90 | 1.00 | 0.89 | 1.00 |
| 0.89 | 1.00 | 0.89 | 1.00 | 0.89 | 1.00 | 0.89 | 1.00 | 0.89 | 1.00 |
| 0.88 | 1.00 | 0.88 | 1.00 | 0.88 | 1.00 | 0.89 | 1.00 | 0.88 | 1.00 |
| 0.74 | 0.94 | 0.74 | 0.94 | 0.86 | 1.00 | 0.89 | 1.00 | 0.87 | 1.00 |
| 0.70 | 0.90 | 0.70 | 0.90 | 0.72 | 0.92 | 0.88 | 1.00 | 0.85 | 1.00 |
|  |  | 0.81 | 1.00 | 0.63 | 0.83 | 0.87 | 1.00 | 0.82 | 1.00 |
|  |  | 0.89 | 1.00 | 0.71 | 0.91 | 0.86 | 1.00 | 0.77 | 0.97 |
|  |  |  |  | 0.85 | 1.00 | 0.84 | 1.00 | 0.29 | 0.49 |
|  |  |  |  | 0.90 | 1.00 | 0.81 | 1.00 | 0.00 | 0.35 |
|  |  |  |  |  |  | 0.77 | 0.97 | 0.04 | 0.44 |
|  |  |  |  |  |  | 0.56 | 0.76 | 0.52 | 0.72 |
|  |  |  |  |  |  | 0.34 | 0.54 | 0.84 | 1.00 |
|  |  |  |  |  |  | 0.10 | 0.50 |  |  |
|  |  |  |  |  |  | 0.08 | 0.48 |  |  |
|  |  |  |  |  |  | 0.27 | 0.47 |  |  |
|  |  |  |  |  |  | 0.44 | 0.64 |  |  |
|  |  |  |  |  |  | 0.65 | 0.85 |  |  |
|  |  |  |  |  |  | 0.81 | 1.00 |  |  |
|  |  |  |  |  |  | 0.89 | 1.00 |  |  |
|  | |  | |  | |  | |
| Lower | Upper | Lower | Upper | Lower | Upper | Lower | Upper |
| 2132.5 MHz | | 2450 MHz | | 3600 MHz | | 4700 MHz | |
| 0.90 | 1.00 | 0.90 | 1.00 | 0.90 | 1.00 | 0.90 | 1.00 |
| 0.90 | 1.00 | 0.90 | 1.00 | 0.90 | 1.00 | 0.90 | 1.00 |
| 0.90 | 1.00 | 0.90 | 1.00 | 0.90 | 1.00 | 0.90 | 1.00 |
| 0.89 | 1.00 | 0.89 | 1.00 | 0.89 | 1.00 | 0.89 | 1.00 |
| 0.89 | 1.00 | 0.89 | 1.00 | 0.89 | 1.00 | 0.89 | 1.00 |
| 0.88 | 1.00 | 0.89 | 1.00 | 0.89 | 1.00 | 0.89 | 1.00 |
| 0.87 | 1.00 | 0.88 | 1.00 | 0.88 | 1.00 | 0.88 | 1.00 |
| 0.85 | 1.00 | 0.87 | 1.00 | 0.88 | 1.00 | 0.88 | 1.00 |
| 0.82 | 1.00 | 0.85 | 1.00 | 0.87 | 1.00 | 0.88 | 1.00 |
| 0.77 | 0.97 | 0.82 | 1.00 | 0.87 | 1.00 | 0.87 | 1.00 |
| 0.29 | 0.49 | 0.78 | 0.98 | 0.85 | 1.00 | 0.87 | 1.00 |
| 0.00 | 0.35 | 0.73 | 0.93 | 0.83 | 1.00 | 0.86 | 1.00 |
| 0.04 | 0.44 | 0.66 | 0.86 | 0.80 | 1.00 | 0.85 | 1.00 |
| 0.52 | 0.72 | 0.00 | 0.39 | 0.76 | 0.96 | 0.83 | 1.00 |
| 0.84 | 1.00 | 0.06 | 0.46 | 0.71 | 0.91 | 0.81 | 1.00 |
| 0.90 | 1.00 | 0.27 | 0.47 | 0.65 | 0.85 | 0.77 | 0.97 |
| 0.90 | 1.00 | 0.00 | 0.39 | 0.58 | 0.78 | 0.73 | 0.93 |
| 0.90 | 1.00 | 0.09 | 0.49 | 0.49 | 0.69 | 0.68 | 0.88 |
|  |  | 0.64 | 0.84 | 0.39 | 0.59 | 0.62 | 0.82 |
|  |  | 0.87 | 1.00 | 0.03 | 0.43 | 0.54 | 0.74 |
|  |  |  |  | 0.52 | 0.72 | 0.46 | 0.66 |
|  |  |  |  | 0.75 | 0.95 | 0.37 | 0.57 |
|  |  |  |  | 0.83 | 1.00 | 0.27 | 0.47 |
|  |  |  |  | 0.82 | 1.00 | 0.07 | 0.47 |
|  |  |  |  | 0.69 | 0.89 | 0.00 | 0.38 |
|  |  |  |  | 0.32 | 0.52 | 0.41 | 0.61 |
|  |  |  |  | 0.00 | 0.35 | 0.73 | 0.93 |
|  |  |  |  | 0.50 | 0.70 | 0.85 | 1.00 |
|  |  |  |  | 0.80 | 1.00 | 0.79 | 0.99 |
|  |  |  |  | 0.90 | 1.00 | 0.70 | 0.90 |
|  |  |  |  |  |  | 0.68 | 0.88 |
|  |  |  |  |  |  | 0.78 | 0.98 |
|  |  |  |  |  |  | 0.88 | 1.00 |
|  |  |  |  |  |  | 0.81 | 1.00 |
|  |  |  |  |  |  | 0.43 | 0.63 |
|  |  |  |  |  |  | 0.00 | 0.29 |
|  |  |  |  |  |  | 0.40 | 0.60 |
|  |  |  |  |  |  | 0.72 | 0.92 |
|  |  |  |  |  |  | 0.87 | 1.00 |

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

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | |  | |  | |  | |  | |
| Lower | Upper | Lower | Upper | Lower | Upper | Lower | Upper | Lower | Upper |
| 617 MHz | | 722 MHz | | 836.5 MHz | | 1575.42 MHz | | 1800 MHz | |
| 0.90 | 1.00 | 0.90 | 1.00 | 0.90 | 1.00 | 0.90 | 1.00 | 0.90 | 1.00 |
| 0.89 | 1.00 | 0.89 | 1.00 | 0.89 | 1.00 | 0.89 | 1.00 | 0.89 | 1.00 |
| 0.89 | 1.00 | 0.88 | 1.00 | 0.88 | 1.00 | 0.88 | 1.00 | 0.86 | 1.00 |
| 0.88 | 1.00 | 0.87 | 1.00 | 0.87 | 1.00 | 0.86 | 1.00 | 0.83 | 1.00 |
| 0.86 | 1.00 | 0.86 | 1.00 | 0.86 | 1.00 | 0.84 | 1.00 | 0.80 | 1.00 |
| 0.51 | 0.71 | 0.84 | 1.00 | 0.85 | 1.00 | 0.82 | 1.00 | 0.79 | 0.99 |
| 0.37 | 0.57 | 0.48 | 0.68 | 0.82 | 1.00 | 0.81 | 1.00 | 0.78 | 0.98 |
| 0.75 | 0.95 | 0.20 | 0.40 | 0.46 | 0.66 | 0.80 | 1.00 | 0.77 | 0.97 |
|  |  | 0.46 | 0.66 | 0.09 | 0.29 | 0.79 | 0.99 | 0.74 | 0.94 |
|  |  | 0.85 | 1.00 | 0.17 | 0.37 | 0.78 | 0.98 | 0.69 | 0.89 |
|  |  |  |  | 0.60 | 0.80 | 0.77 | 0.97 | 0.00 | 0.36 |
|  |  |  |  | 0.89 | 1.00 | 0.74 | 0.94 | 0.10 | 0.50 |
|  |  |  |  |  |  | 0.69 | 0.89 | 0.02 | 0.42 |
|  |  |  |  |  |  | 0.32 | 0.52 | 0.26 | 0.46 |
|  |  |  |  |  |  | 0.00 | 0.33 | 0.47 | 0.67 |
|  |  |  |  |  |  | 0.10 | 0.50 |  |  |
|  |  |  |  |  |  | 0.11 | 0.51 |  |  |
|  |  |  |  |  |  | 0.09 | 0.49 |  |  |
|  |  |  |  |  |  | 0.13 | 0.53 |  |  |
|  |  |  |  |  |  | 0.09 | 0.49 |  |  |
|  |  |  |  |  |  | 0.38 | 0.58 |  |  |
|  |  |  |  |  |  | 0.78 | 0.98 |  |  |
|  | |  | |  | |  | |
| Lower | Upper | Lower | Upper | Lower | Upper | Lower | Upper |
| 2132.5 MHz | | 2450 MHz | | 3600 MHz | | 4700 MHz | |
| 0.90 | 1.00 | 0.90 | 1.00 | 0.90 | 1.00 | 0.90 | 1.00 |
| 0.89 | 1.00 | 0.89 | 1.00 | 0.88 | 1.00 | 0.88 | 1.00 |
| 0.86 | 1.00 | 0.85 | 1.00 | 0.85 | 1.00 | 0.84 | 1.00 |
| 0.83 | 1.00 | 0.81 | 1.00 | 0.80 | 1.00 | 0.79 | 0.99 |
| 0.80 | 1.00 | 0.77 | 0.97 | 0.74 | 0.94 | 0.73 | 0.93 |
| 0.79 | 0.99 | 0.75 | 0.95 | 0.70 | 0.90 | 0.68 | 0.88 |
| 0.78 | 0.98 | 0.73 | 0.93 | 0.67 | 0.87 | 0.63 | 0.83 |
| 0.77 | 0.97 | 0.72 | 0.92 | 0.65 | 0.85 | 0.60 | 0.80 |
| 0.74 | 0.94 | 0.72 | 0.92 | 0.63 | 0.83 | 0.58 | 0.78 |
| 0.69 | 0.89 | 0.70 | 0.90 | 0.62 | 0.82 | 0.56 | 0.76 |
| 0.00 | 0.36 | 0.67 | 0.87 | 0.61 | 0.81 | 0.55 | 0.75 |
| 0.10 | 0.50 | 0.63 | 0.83 | 0.60 | 0.80 | 0.54 | 0.74 |
| 0.02 | 0.42 | 0.56 | 0.76 | 0.59 | 0.79 | 0.53 | 0.73 |
| 0.26 | 0.46 | 0.06 | 0.46 | 0.57 | 0.77 | 0.52 | 0.72 |
| 0.47 | 0.67 | 0.03 | 0.43 | 0.44 | 0.84 | 0.51 | 0.71 |
| 0.90 | 1.00 | 0.00 | 0.39 | 0.41 | 0.81 | 0.50 | 0.70 |
| 0.89 | 1.00 | 0.00 | 0.33 | 0.36 | 0.76 | 0.49 | 0.69 |
| 0.86 | 1.00 | 0.00 | 0.35 | 0.29 | 0.69 | 0.47 | 0.67 |
|  |  | 0.28 | 0.48 | 0.21 | 0.61 | 0.45 | 0.65 |
|  |  | 0.64 | 0.84 | 0.22 | 0.62 | 0.42 | 0.62 |
|  |  |  |  | 0.00 | 0.49 | 0.38 | 0.58 |
|  |  |  |  | 0.44 | 0.84 | 0.32 | 0.52 |
|  |  |  |  | 0.27 | 0.67 | 0.15 | 0.55 |
|  |  |  |  | 0.24 | 0.64 | 0.06 | 0.46 |
|  |  |  |  | 0.08 | 0.58 | 0.00 | 0.38 |
|  |  |  |  | 0.00 | 0.46 | 0.49 | 0.69 |
|  |  |  |  | 0.00 | 0.46 | 0.06 | 0.46 |
|  |  |  |  | 0.21 | 0.61 | 0.69 | 0.89 |
|  |  |  |  | 0.20 | 0.60 | 0.33 | 0.53 |
|  |  |  |  | 0.85 | 1.00 | 0.58 | 0.78 |
|  |  |  |  |  |  | 0.53 | 0.73 |
|  |  |  |  |  |  | 0.65 | 0.85 |
|  |  |  |  |  |  | 0.77 | 0.97 |
|  |  |  |  |  |  | 0.57 | 0.77 |
|  |  |  |  |  |  | 0.00 | 0.29 |
|  |  |  |  |  |  | 0.05 | 0.45 |
|  |  |  |  |  |  | 0.12 | 0.52 |
|  |  |  |  |  |  | 0.32 | 0.52 |
|  |  |  |  |  |  | 0.63 | 0.83 |

## 

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

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

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

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

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

The power validation pass/fail limit is specified as [TBD].

## **<End of Change>**