**3GPP T****SG-RAN WG4 Meeting #114bis R4-2503555**

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**Source: Nokia**

**Title: Simulation Results and CDL Implementation for Spatial Channel Model for Demodulation Performance Requirements**

**Agenda item: 7.16.2**

**Document for: Information**

1. Introduction

This informative contribution is intended to help other interested parties to implement a TS 38.827 based CDL channel model and enable alignment with our version.

It also contains attachments to deliver our simulation results in the expected results collection format.   
The following spreadsheets are attached:

* Spreadsheet 1 – Results collection table for NR SCM A1, Nokia V01.xlsx
* Spreadsheet 2 – Results collection table for NR SCM A2, Nokia V01.xlsx
* Spreadsheet 3 – Results collection table for NR SCM A3, Nokia V01.xlsx

No observations nor proposals are made in this simulation contribution.

1. TP for 38.827 based CDL channel model (SU version)

This section gives a description of a TR38.827 based SU CDL channel model (often referred to as “CDL” or “827 CDL”) in the form of a potential TP for 38.101-4, which was used to derive all our results in our contributions. Note that explanatory parts of TR38.827, that are not needed for implementation, have been removed, and the extension for conducted/virtual cable test setup have been added.   
Minor modifications based on discussions and agreements in prior meetings have been included, where appropriate

Interested contributors are encouraged to implement 827 CDL based on the following TP and exchange with Nokia to achieve alignment.

*<Start of TP>*

B.2.X1 Cluster Delay Line Channel Model

B.2.X1.Y1 General

The channel model is based on the description and clarifications given in TR 38.827.

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

B.2.X1.Y1 Channel Models

This section describes amendments to the stepwise procedure of the CDL subclause 7.7.1 in TR38.901 for generating fast fading radio channel realizations. This channel model methodology considers non-Jakes spectrum with the multi-path fading propagation conditions between the gNB emulator and DUT modelled based on Clustered Delay Line (CDL) methodology.

The tables provided in section B.2.X1.Y1 are to be used directly in the procedure in TR38.901 for generating fast fading radio channel realizations. The given coefficients have been scaled to achieve the following target delay spread values

Table 7.2-1. Target delay spread values.

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

Similarly, the cluster-wise rms azimuth spread of arrival angles (cluster ASA, *c*ASA), and similar spreads in the tables, are scaled to achieve the following desired AS, for the given cluster AOA (*n,*AOA) and similar azimuth/zenith angles (Tables 7.7.1.1 – 7.7.1.5 of TR 38.901).

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

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

Once the channel realization procedure arrives at the step of coupling the AOD angles to AOA angles within a cluster *n* (step 2). Instead of random procedure, the coupling shall be performed using the fixed coupling pattern specified in Table 7.2-6. The same fixed coupling pattern is applied for all clusters *n.*

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

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

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

, (7.2-7)

where *X* is the per-cluster XPR in dB from the tables provided in section B.2.X1.Y1.

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

Table 7.2-7: BS Antenna Parameters

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

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

Note this chosen AE pattern may impact the RMS delay spread scaling and necessitates coordinate transformations as defined in TR 38.901 section 7.3.2, but this has not been taken into account for deriving the tables provided in section B.2.X1.Y1.

The BS antenna panel is oriented to have 10 of mechanical tilt with respect to the horizon (10 rotation around the y-axis).

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

(7.2-8)

where is the location vector of transmit antenna element and , and is a spherical unit vector denoting the target beam direction. Note that the target beam directions, directions of departure (DoD) angles of the transmitter array, i.e., ZoD and AoD, and the locations of antenna elements, are referenced to the global coordinate system (GCS). Determination of beam directions is done as follows:

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

For FR1 8x8, the four 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.

In detail, beam directions for channels model given in Section B.2.X1.Y1 are

- For UMa CDL-C, the beam directions in the global coordinate system are:

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

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

- 3rd strongest beam: AoD: -36.36°, ZoD: 100°

- 4th strongest beam: AoD: -50.91°, ZoD: 100°

For the UE it is assumed that RF ports map directly to receive antenna elements, where is the location vector of receive antenna elements, which are configured as a ULA with Cross-pol (1, n/2, 2), i.e. [+ + + +] for n=8, antenna elements with omni radiation pattern, 0.5λ spacing, and the AE slant is rotated 45deg to the transmitter polarizations. Note that “n” is the number of Rx elements, and the directions of arrival (DoA) angles of the receiver array, i.e., ZoA and AoA, are referenced to the GCS.

The UE antenna panel is oriented to point towards the front of the BS panel without any mechanical tilt with respect to the horizon (no rotation around the y-axis).

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

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

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

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

, (7.2-9)

where , , and are the theta and phi polarized radiation patterns and the position vector of the BS antenna element of sub-array *s*, respectively.Symbols *Frx,u,θ* , *Frx,u,ϕ*, , , and , are determined as in TR 38.901, which includes the generation of AOA (), AOD (), ZOA (), and ZOD () to derive  and . The velocity vector is determined as

 (7.2-11)

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

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

- (127.05°],90o) for UMi CDL C channel model

- (182.17°,90o) for UMa CDL A channel model

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

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

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

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

Note: the FR2 cases may be mixed up in 38.827, though this has no impact in the CDL-C UMa case we are focusing on.

B.2.X1.Y1 Channel Model Parameters for FR1

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

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

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

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

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

Table 7.2.1-8: Channel model parameters for UMa CDL-C at 3.5 GHz

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

*<End of TP>*

1. Conclusion

Within this contribution we have provided simulation results and CDL implementation reference for use in the Spatial Channel Model for Demodulation Performance Requirements study.

References

1. None.