3GPP 3D Channel Model Package User Manual and Documentation

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Abstract

This document explains the use of the 3rd Generation Partnership Project (3GPP) 3-dimensional (3D) channel model package. It was developed based on the 3GPP TR 36.873 [1], and was originally built as an integral part of the Vienna LTE-A System Level Simulator (v1.9 Q2-2016). For this reason, the nomenclature of the code follows the one used in the simulator. This code package only includes those programming objects necessary to generate channel coefficients according to the 3GPP 3D channel model.

CONTENTS

I. 3GPP 3D Channel Model

The 3rd Generation Partnership Project (3GPP) 3-dimensional (3D) channel model package is implemented in MATLAB using an object oriented framework. As it was originally developed with the Vienna LTE-A System Level Simulator, the parameter naming follows the one used in the simulator. The specific 3D model parameter naming is self-explanatory and very easy to follow from 3GPP TR 36.873, e.g., `cl_power_LOS` (cluster power for LOS propagation condition), `cl_power_NLOS` (cluster power for NLOS propagation condition), `azimuth_angle_of_arrival_LOS`, `zenith_angle_of_arrival_LOS`, etc.

Naming nomenclature inherited from the Vienna LTE-A System Level Simulator (Q2-2016):

- `eNodeB_site` denotes the eNodeB class
- `eNodeB` denotes the sector eNodeB
- `UE` denotes the user class
- `config` denotes the input simulation parameter class

II. Running the Code

The code is started from a *main launcher file*. In this package three demo launcher files are available:

- `Sim_main_launcher_3D_model_hexagonal_grid.m` - simulates a hexagonal grid of three-sectorized eNodeB sites.
- `Sim_main_launcher_3D_model_single_eNodeB_single_UE.m` - simulates a single eNodeB - single UE scenario.
- `Sim_main_launcher_3D_model_single_link.m` - simulates a single link, used for the link- level simulation.

III. Channel Generation Procedure

The implementation of the 3GPP 3D model is based on the step-vise procedure shown in Figure 1.

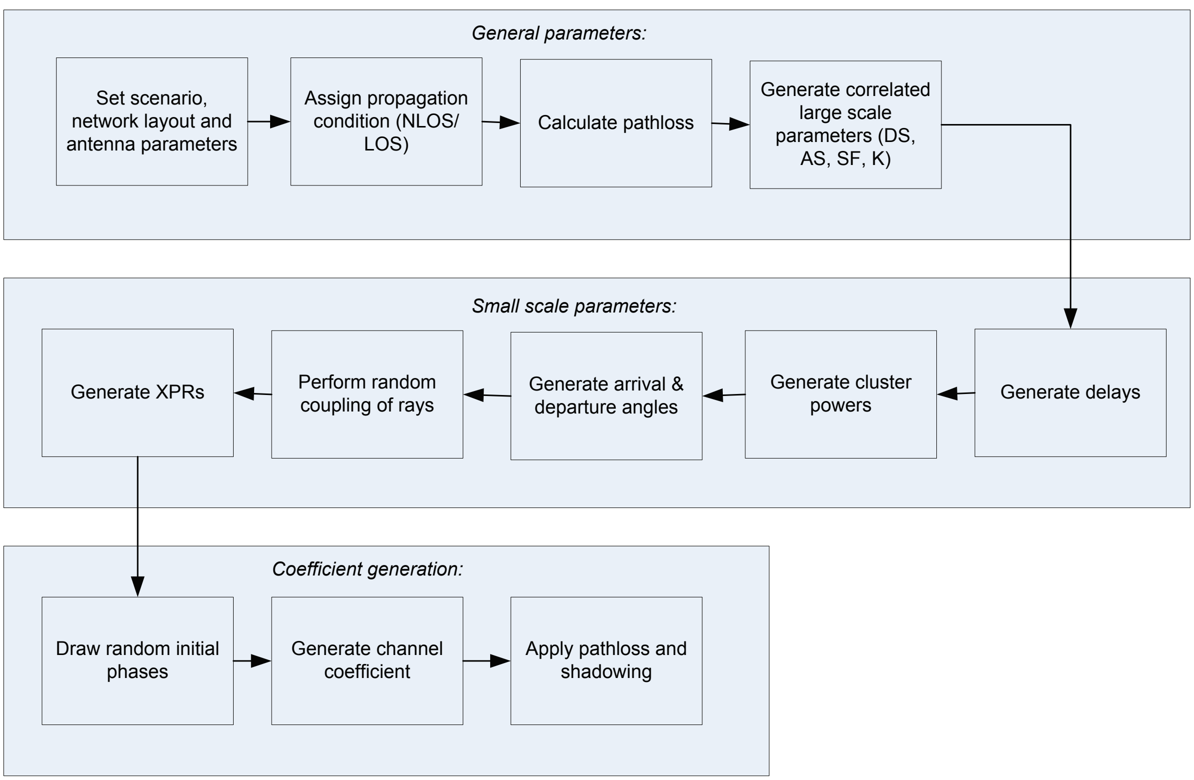


Fig. 1: Channel coefficient generation procedure [1]

A. General Parameters

1) Configuration: The file `load_specific_params.m` specifies the physical parameters of an LTE network, e.g., number of resource blocks, bandwidth per resource block, etc. The parameters specific for the 3GPP 3D channel model are given in two separate files `load_UMa_parameters.m`, `load_UMi_parameters.m` for network scenarios 3D-urban macro cell (UMa) and 3D-urban micro cell (UMi), respectively.

2) Antenna Pattern: The antenna gain and polarized antenna element field pattern are specified in `+antennas/TR36873_3DAntenna.m`. The function `gain(theta, phi)` generates the antenna gain of a single antenna element as given in [1, Table 7.1-1]. The function `calculate_array_single_column_field_pattern` generates the gain of one column antenna array (vertical direction) and it is possible to use for the sector assignment. To generate the channel coefficients only the antenna element gain is used.

3) Propagation Conditions and Pathloss Calculation: The path loss is calculated in `+macroscopic_pathloss_models/TR36873PathlossModel.m` based on the scenario specified in the configuration file. Before calculating the pathloss, the probability of being in line-of-sight (LOS) is calculated, as defined in [1, Table 7.2-2]. A map called `LOS_positions` is saved for each eNodeB-sector, where the LOS points are denoted by *ones* and non line-of-sight (NLOS) points by *zeros* . The map `LOS_positions` is generated for each pixel, thus having the same size as the pathloss map. After defining the `LOS_positions` map, three other maps are generated:

- `UE_indoor_map`: Specifies the indoor/outdoor User Equipment (UE) fraction with 80 % indoor UEs [1, Table 6-1].
- `UE_height_map`: Specifies the UE height in m as defined in [1, Table 6-1].
- `UE_indoor_dist_map`: Specifies the indoor distance for indoor UEs, which is assumed to be uniformly distributed between 0 and 25 [1, Table 7.2-1].

According to these maps, the pathloss is calculated based on LOS/NLOS and indoor/outdoor specific conditions [1, Table 7.2-1]. At the UE object, the following properties are saved:

- `is_LOS`: denotes whether the UE is LOS or NLOS (type `boolean`). It contains a vector of values defined with respect to the serving eNodeB and to the interfering eNodeBs, where the first value of the vector denotes the serving eNodeB.
- `is_indoor`: denotes whether the UE is indoor or outdoor (type `boolean`).
- `rx_height`: denotes the UE height.
- `dist_indoor`: denotes the indoor distance.

4) Shadow Fading Maps: In this package shadow fading maps based on the *Claussen method*[1] are generated for determining the large-scale pathloss and to perform a more realistic UE association. Regarding the 3GPP 3D model, a shadow fading value is necessary only when generating the channel coefficients. In this case we use the shadow fading value from correlated large scale parameters, while the shadow fading maps are only used for determining the UE association and large-scale pathloss.

5) Large Scale Parameters Generation: Large scale parameters are generated in the main launcher file `Sim_main_launcher_3D_model_hexagonal_grid.m`. The corresponding function to generate the Large Scale parameters are included in the file `calculate_correlations.m` and in `+network_elements/eNodeB.m`. It follows a two-step procedure: autocorrelation and cross correlation that are calculated according to [1, Table 7.3-6] and the procedure described in [1]. In the UE object, a property named: `all_large_scale_params` is saved, denoting a matrix of large scale parameters for the desired channel(first row) and interfering channels (each row corresponds to one interferer). Each row of `all_large_scale_params` represents a vector with values corresponding to parameters in the following order: [SF, K, DS, ASD, ASA, ZSD, ZSA], denoting shadow fading, K-Ricean factor, delay spread, azimuth spread of departure, azimuth spread of arrival, zenith spread of departure and zenith spread of arrival. Large scale parameters are generated for each eNodeB-sector and saved for each user.

Specifically for the zenith spread of departure, as given in [1, Table 7.3-7, 7.3-8], the generated offset parameters are saved as UE property named `all_ZOD_params`, following the same structure as `all_large_scale_params`.

B. Small Scale Parameters

The calculation of small scale parameters is done in `TR36873_Fading_3D_channel.m` containing steps 5 to 11 as specified in [1, Sec. 7.3].

C. Channel Coefficient Generation

The final channel matrix for the desired and interfering links is generated in the main launcher file `Sim_main_launcher_3D_model_*.m`. See [3] for more details on the channel coefficient generation procedure.

[1]This method generates a lognormal-distributed 2D space-correlated shadow map, as in [2].

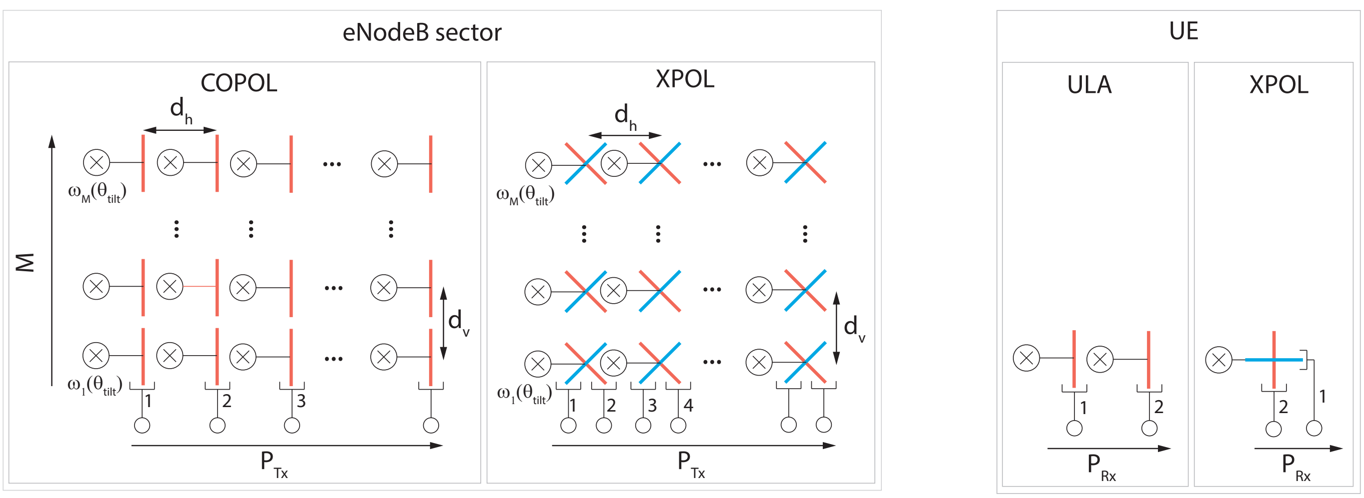
IV. 2D Antenna Array Configuration

With the 3D channel model, a 2-dimensional (2D) antenna array can be configured. The 3D antenna element gain pattern and the polarization function are generated in `+antennas/TR36873_3DAntenna`. The structure of the planar antenna array is illustrated in Figure 2.

- Polarization mode: 'COPOL' or 'XPOL' is set by `config.antenna.antenna_polarization`.
- Polarization slant angle is set by `config.antenna.slant_angle`. In the case of 'COPOL', the parameter is set to $0°$, and for 'XPOL' it is set to $45°$.
- Spacing between antenna elements in vertical direction $\mathrm{d_v}$, is set by `config.antenna_element_vertical_spacing`.
- Spacing between antenna elements in horizontal direction $\mathrm{d_h}$, is set by `config.antenna_element_horizontal_spacing` .
- Number of antenna elements in vertical direction M is set by `config.nr_of_antenna_elements_in_each_column`. Note that the number of antenna elements in vertical direction is not limited.
- The electrical downtilt angle as used to generate the weights for each antenna element is set by the parameter `config.electrical_downtilt`.

Figure 2 shows the antenna element-to-port mapping for two polarization modes. The antenna array configuration at the eNodeB sector is illustrated in Figure 2a.

The parameter N_{Tx} refers to the physical antenna ports and can be specified by the parameter `config.nTX`. With the current release of LTE-Advanced (LTE-A) this number is limited to 8 antenna ports. Each column with M antenna elements is mapped to one antenna port p_{Tx}. For the 'XPOL' polarization mode, each polarization dimension is mapped to one port p_{Tx}, meaning that for the first two columns, the antenna elements slanted by $+45°$ (blue color) are mapped to port $p_{\mathrm{Tx}} = 1$, and antenna elements slanted by $-45°$ (red color) are mapped to port $p_{\mathrm{Tx}} = 2$. The antenna configuration at the UE is illustrated in 2b. The number of receive antennas is denoted by N_{Rx} which can be set by the parameter `config.nRX`. For the 'XPOL' polarization mode, again each polarization dimension is mapped to one port p_{Rx}, such that the antenna elements slanted by $90°$ (blue color) are mapped to port $p_{\mathrm{Rx}} = 1$ and antenna elements slanted by $0°$ (red color) are mapped to port $p_{\mathrm{Rx}} = 2$.



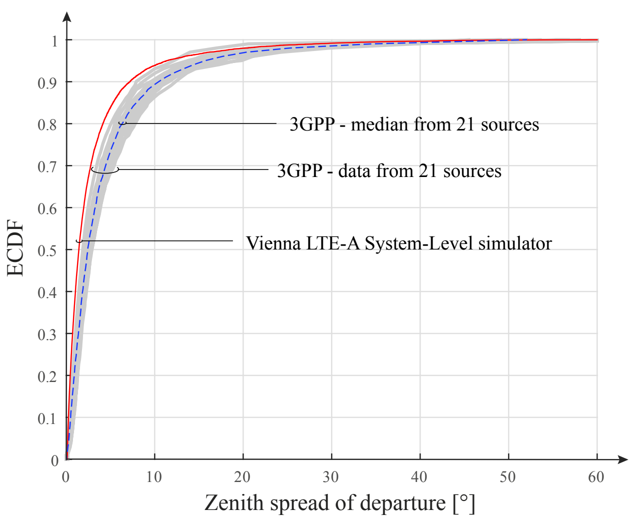
(a) 2D Antenna array at eNodeB sector

(b) Antenna at UE

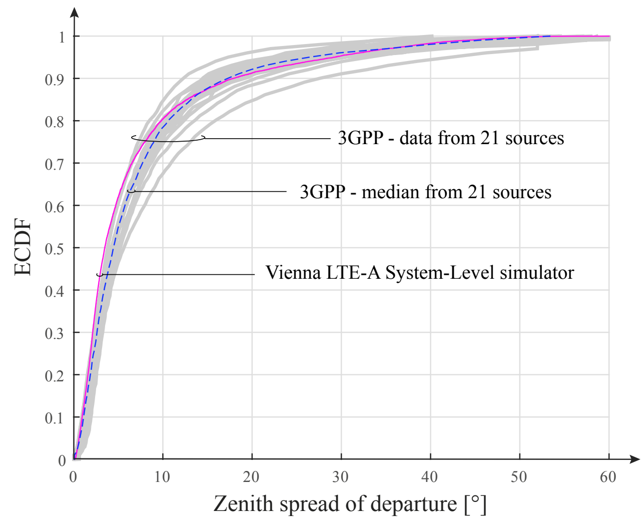
Fig. 2: Antenna configuration and polarization modes at eNodeB sector and at UE.

V. 3GPP 3D Channel Model Calibration

This section presents the calibration results by comparing the 3D channel model with 3GPP Phase-2 calibration results reported in [1, Sec. 8.2]. The calibration includes the results for zenith spread of departure- and arrival, as well as smallest- and largest singular value Empirical Cumulative Distribution Function (CDF)s (ECDFs). To reproduce the plots for angle spreads, you will need to run the simulations by using the files given in
`calibration`, and by saving all angles of arrival- and departure as UE properties. The extracted files reported in 3GPP R1-143469 are included in the `calibration/Extracted_calibration_values_3GPP_R1_143469`. Finally, to produce the plots for angular spreads, you will need to run the script `calibration/Angle_Spread_Calibration`. The resulting plots[2] are shown in Figure 3 and Figure 4.

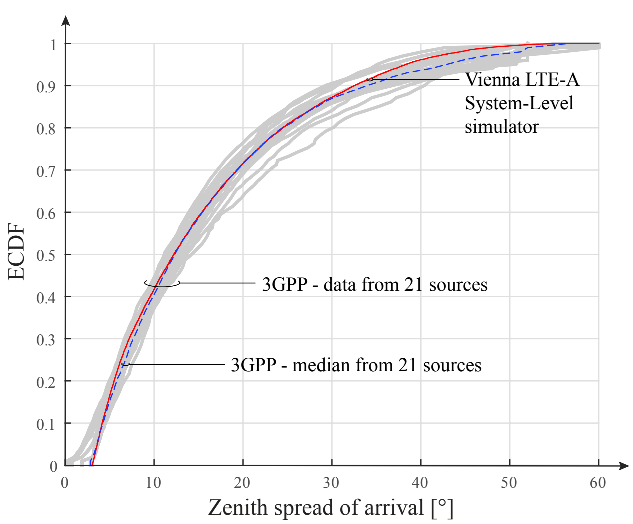


(a) 3D-UMa scenario

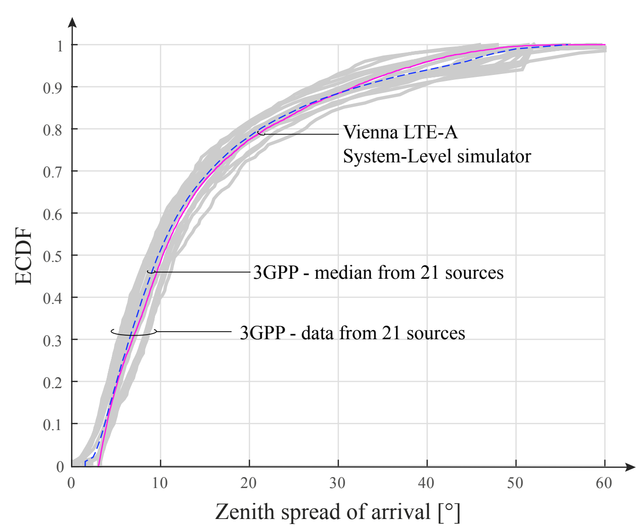


(b) 3D-UMi scenario

Fig. 3: Zenith spread of departure statistics. Gray lines refer to results reported by 21 sources from [4]. Dashed curves denote the 3GPP reference results from [1, Figure 8.2-11, Figure 8.2-13].



(a) 3D-UMa scenario

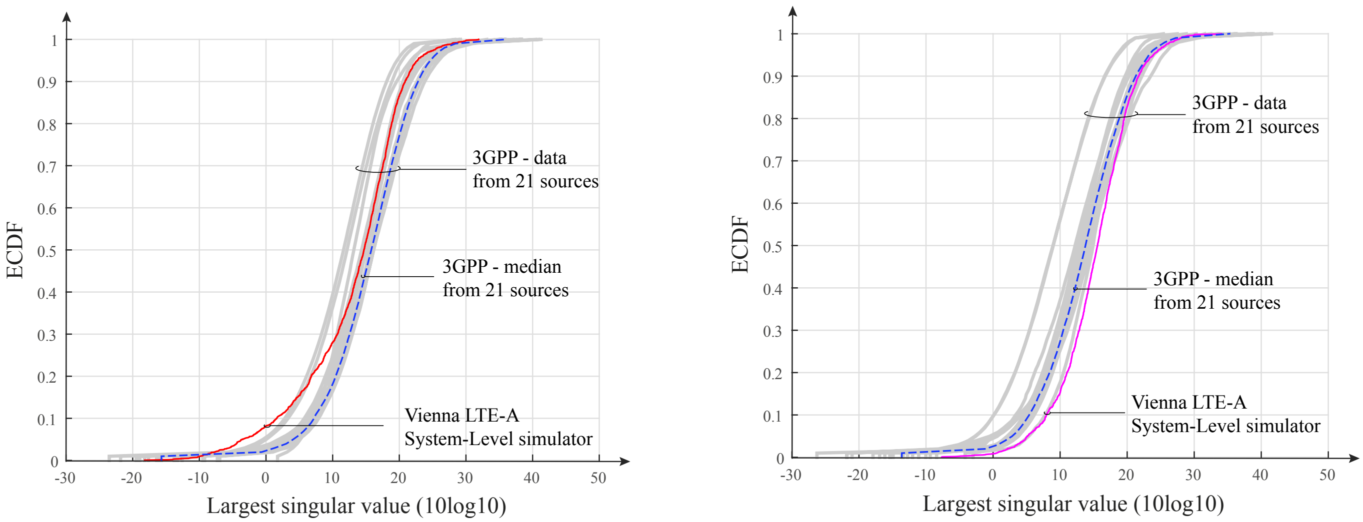


(b) 3D-UMi scenario

Fig. 4: Zenith spread of arrival statistics. Gray lines refer to results reported by 21 sources from [4]. Dashed curves denote the 3GPP reference results from [1, Figure 8.2-11, Figure 8.2-13].

[2]NOTE: The calibration results shown in this section are performed with the Vienna LTE-A System level simulator (v1.9 Q2-2016).

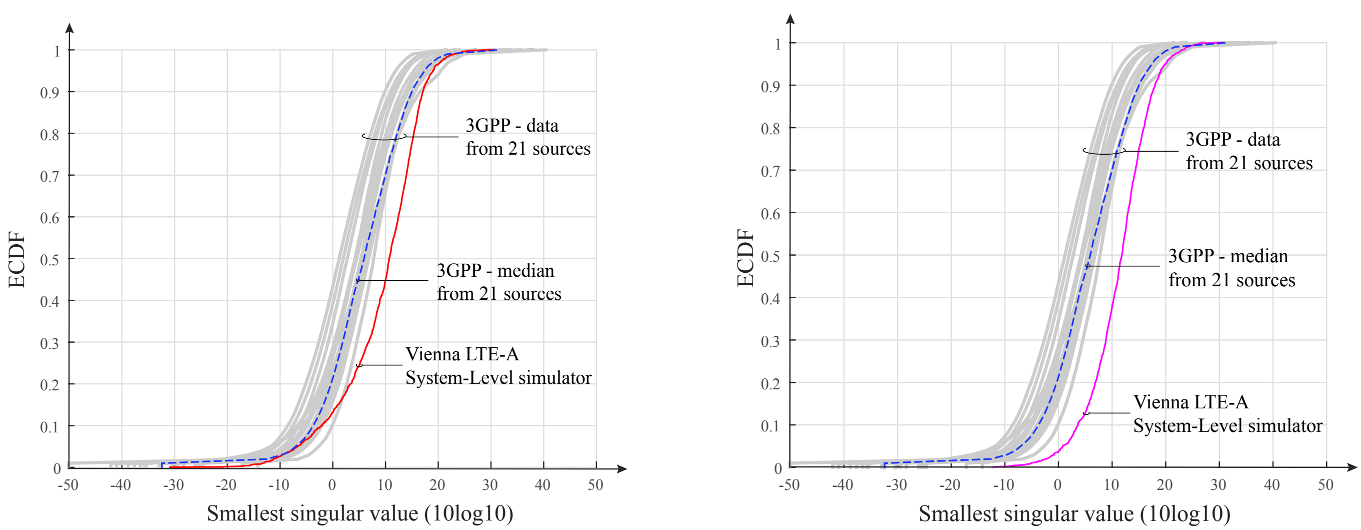
To reproduce the plots for largest and smallest singular values, you will need to run the simulations by using the specific antenna parameters as given
`calibration/LTE_main_launcher_parameters`. To produce the plots for channel singular values, you will need to run the script
`calibration/Plot_singular_values_calibration`. The resulting plots are shown in Figure 5 and Figure 6.



(a) 3D-UMa scenario

(b) 3D-UMi scenario

Fig. 5: Largest singular value ECDF in logarithmic scale for UMa and UMi scenario. Gray lines refer to results reported by 21 sources from [4]. Dashed curves denote the 3GPP reference results from [1, Figure 8.2-17, Figure 8.2-19].



(a) 3D-UMa scenario

(b) 3D-UMi scenario

Fig. 6: Smallest singular value ECDF in logarithmic scale for UMa and UMi scenario. Gray lines refer to results reported by 21 sources from [4]. Dashed curves denote the 3GPP reference results from [1, Figure 8.2-17, Figure 8.2-19].

REFERENCES

[1] 3rd Generation Partnership Project (3GPP), "Study on 3D channel model for LTE," 3rd Generation Partnership Project (3GPP), TR 36.873, Sept. 2014.

[2] H. Claussen, "Efficient modelling of channel maps with correlated shadow fading in mobile radio systems," in *2005 IEEE 16th International Symposium on Personal, Indoor and Mobile Radio Communications*, vol. 1, Sept 2005, pp. 512–516.

[3] F. Ademaj, M. Taranetz, and M. Rupp, "3GPP 3D MIMO Channel Model: A Holistic Implementation Guideline for Open Source SImulation Tools," *EURASIP Journal on Wireless Communication Networks 2016. doi:10.1186/s13638-016-0549-9*.

[4] 3GPP TSG RAN WG-1, "R1-143469: Summary of 3D-channel model calibration results," 3rd Generation Partnership Project (3GPP), Tech. Rep., August 2014.

List of Figures