IMT-2020 Evaluation: Calibration of NOMOR's System Level Simulator

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Summary

ITU-R is committed to deliver a specification for an international mobile telecommunication system for 2020 and beyond (IMT-2020). ITU-R has asked for proposals for Radio Interface Technologies (RITs). Each submission has to include either an initial self evaluation or the proponents' endorsement of an initial evaluation according to the ITU-R guidelines. Currently, work is being performed on the IMT-2020 evaluation process. 3GPP as a proponent is performing a self evaluation. Nine organizations have indicated their intention to serve as independent evaluation groups to corroborate the self-evaluation results provided by the propoents. One of these was launched under the umbrella of the 5G Infrastructure Association (5G-IA), which colaborates with the European Commission in the context of the 5G-PPP sub-program of Horizon 2020 on 5G. Within this IMT-2020 Evaluation Group of 5G-IA, Nomor Research is responsible for conducting a major share of the required system level simulations. In this document, we introduce the considered scenarios including the main configuration settings. Our considerations are limited to the enhanced mobile broadband (eMBB) usage scenario. In the context of self evaluation, 3GPP is performing a calibration of system level simulators of different members considering Downlink Coupling Gain and Downlink Geometry as calibration metrics. We performed the calibration of our system level simulator against these results and observed that our results are well aligned.

1 Introduction

In 2012, ITU-R started to develop a vision of the international mobile telecommunication system for 2020 and beyond referred to as IMT-2020 [IRb]. To determine the international specification for 5G, which shall be presented in 2020, ITU-R has defined technical performance requirements in ITU-R M.2410-0 [IR17a] and service and spectrum aspect requirements have been summarized in ITU-R M.2411-0 [IR17b]. Furthermore, the ITU-R has specified evaluation guidelines in ITU-R M.2412-0 [IR17c] to evaluate the candidate IMT-2020 radio interface technologies (RITs) or Set of RITs (SRIT) for different test environments.

Based on the schedule presented by ITU-R WP5D, proposals for IMT-2020 can be submitted from October 2017 to July 2019. The ongoing evaluation of the candidates will end in February 2020 [IRa].

3GPP defined a work plan for its submissions according to this timetable. At the beginning of this year, the initial description was submitted [SA18a]. It includes two submissions: Submission 1 is an SRIT composed by two RITs, namely New Radio (NR) and LTE, where NR is the term 3GPP used for the standard specified from Release 15 onwards. Submission 2 is an NR RIT. An update, which contains the preliminary self-evaluation and link budget results and compliance templates in addition to the extended characteristics, was submitted in October 2018 [SA18b]. The final submission is planned for July 2019 [Ita17]. This will include further Release 16 enhancements.

ITU-R has registered nine different Independent Evaluation Groups (IEG) [IRa], commissioned to verify the performance of candidate proposals for 5G. Proponents, such as 3GPP, are required to perform self evaluation based on scenarios and constraints defined by the ITU-R in [IR17c].

The 5G Infrastructure Public Private Partnership (5G-PPP), a sub-program of the Horizon 2020 program addressed by the European Commission and the European information and communication technology industry, organized in the 5G Infrastructure Association (5G-IA) thereby representing the private side of 5G-PPP, has formed one of these registered IEG to evaluate 3GPP's proposal based on the IMT-2020 evaluation guidelines. This evaluation group mainly includes members of the EU funded Horizon 2020 phase-2 projects 5G-XCast, 5G-MoNArch, One5G and 5G-Essence. Nomor Research is part of it and responsible for many of the system-level simulations, specifically those related to enhanced mobile broadband (eMBB).

Recently, we participated the 3GPP Workshop on 5G NR IMT2020 evaluation in Brussels, Belgium. The workshop introduced the IEGs and the industry to the 5G mobile communication system developed by 3GPP. Additionally, the 3GPP submissions for IMT-2020 including the corresponding evaluations were explained and a short outlook was presented.

The first step of the evaluation process is to calibrate the system level simulator in simplified reference scenarios. Chapter II of this document introduces the considered scenarios and the main calibration parameters including the configuration settings and calibration metrics. The calibration results of Nomor Research's system level simulator are compared against the 3GPP results in Chapter III. Chapter IV concludes with a summary of the observations and gives an outlook regarding the next steps.

II Scenarios and Calibration Parameters

3GPP's calibration scenarios are largely based on the test environments defined by ITU-R in [IR17c]. [IR17c] also specifies channel models, one of which in turn coincides with that defined by 3GPP in [3GP17].

II.A Test Environments

For the IMT-2020 evaluation, the ITU-R defined different usage scenarios [IR17c], namely enhanced mobile broadband (eMBB), massive machine type communications (mMTC) and ultra-reliable and low latency communications (URLLC), and combines each of them with one or several geographic environment(s) resulting in five different test environments, see Table 1. These give the possibility to investigate the critical aspects in system design and performance.

Scenario	Test Environment
eMBB	Indoor Hotspot – eMBB Dense Urban – eMBB Rural – eMBB
mMTC	Urban Macro – mMTC
URLLC	Urban Macro – URLLC

Table 1: Test environments defined by ITU

In this document we restrict ourselves to the three test environments related to the eMBB usage scenario.

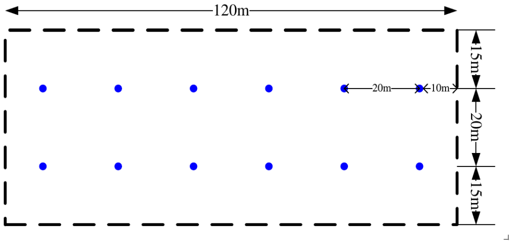

Figure 1: Layout for Indoor Hotspot – eMBB [IR17c]

II.B Network Layout

For the network layout no specific topography is taken into account, instead base stations are placed in regular grids [IR17c].

For the Indoor Hotspot – eMBB test environment, 12 sites are placed at a height of 3 m and with an inter-site distance of 20 m in a confined and isolated area of $120\,\mathrm{m} \times 50\,\mathrm{m}$, see Figure 1. The scenario represents one floor of a building which has a height of 3 m with ceiling mounted base stations. Internal walls are modeled via the stochastic LOS probability model. In two variants of this scenario one site can be configured with one or three sectors or cells, respectively.

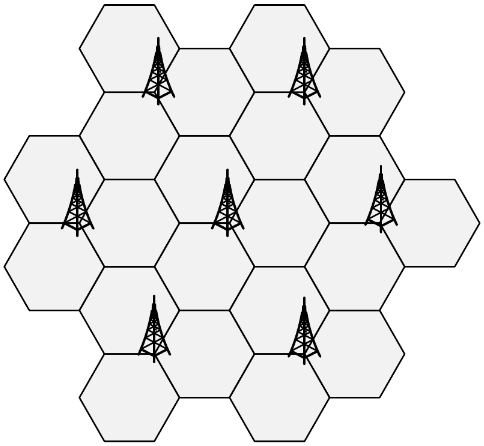

Figure 2: Hexagonal site layout for Dense Urban – eMBB and Rural – eMBB [IR17c]

The Dense Urban – eMBB test environment consists of a macro and a micro layer. For the macro layer, a regular hexagonal layout is used, where each site has three sectors, see Figure 2. In each macro cell area three micro sites are randomly dropped for the micro layer. For the purpose of calibration, 3GPP and therefore also we herein only consider the macro layer.

For the Rural – eMBB test environment the network deployment is the same as the macro layer of the Dense Urban – eMBB test environment, but differs in terms of inter-site distance and height of the base stations.

II.C Parameter Settings

In Table 5 of [IR17c] the ITU-R defines evaluation configurations for each test environment. For several parameters as the number of antenna elements or the bandwidth, a range is given. 3GPP specified these parameters for its calibration within the framework of the self evaluation. An overview of all parameters used is given in e. g. [Hua18]. We applied these 3GPP parameter settings for our calibration.

For each test environment different configurations are available. The considered scenarios with the characterizing configurations are summarized in Table 2.

Considering Indoor Hotspot – eMBB and Dense Urban – eMBB, carrier frequencies f_c of 4 GHz and 30 GHz are used. Meaning two different frequency ranges are investigated, namely frequency range 1, i. e. frequencies below or equal 6 GHz and frequency range 2, i. e. frequencies above 6 GHz. For the Rural – eMBB scenario, there are two configurations in frequency range 1, one with 700 MHz and one with 4 GHz carrier frequency.

In case of Indoor Hotspot – eMBB Config A, 32 antenna elements are configured at the base station and 4 antenna elements at the UE. All antenna elements are controlled individually meaning we have a one-to-one mapping between transceiver units (TXRUs) and antenna elements.

Indoor Hotspot – eMBB		
	Config A	Config B
f_c	4 GHz	30 GHz
Tx × Rx	32×4	64×32
GoB	–	$\surd$
Dense Urban – eMBB		
	Config A	Config B
f_c	4 GHz	30 GHz
Tx × Rx	128×4	256×32
GoB	$\surd$	
Rural – eMBB		
	Config A	Config B
f_c	700 MHz	4 GHz
Tx × Rx	64×2	128×4
GoB	fixed downtilt	

Table 2: Scenario Parameters

We performed the calibration of all Indoor Hotspot – eMBB scenarios with one sector per site as well as with three sectors. As mentioned in Section II.B the configuration can be selected by the proponent.

A grid of beam (GoB) with 8 or 12 different directions is applied at the gNB in the Indoor Hotspot – eMBB Config B scenario or in the two Dense Urban – eMBB scenarios, respectively, i. e. the antenna elements are grouped as disjoint sets into sub-array partitions served by different TXRUs. Within the TXRUs analog beamforming is applied on the individual antenna elements, while for the combination of the different TXRUs digital precoding is used. In the Indoor Hotspot – eMBB Config B scenario the 64 antenna elements are grouped into 8 partitions each connected to an TXRU. Each partition has 4 columns and 2 rows of antenna elements. The TXRUs of the two Dense Urban – eMBB scenarios each feed partitions of 32 antenna elements arranged in 8 columns and 4 rows. While for Config A 4 TXRUs are used, Config B uses 8 TXRUs.

At the UE 4 antenna elements with a one-to-one mapping are configured for Config A both of Indoor Hotspot – eMBB and Dense Urban – eMBB. Considering the appropriate configurations of frequency range 2, GoB with 8 different directions is applied at the UE. 32 antenna elements are grouped into 4 partitions. Each partition has 4 columns and 2 rows of antenna elements. While for the gNB, the TXRUs or antenna elements are positioned such that the beams or patterns look all into the same direction, the partitions of the latter configurations are as separate panels positioned back-to-back to allow a reception of all different directions.

For Rural – eMBB we have a fixed downtilt at the base station for all TXRUs. 8 antenna elements spaced in one column are fed by one TXRU. For Config A $(f_c = 700\,\mathrm{MHz})$ there are 8 TXRUs, for Config B $(f_c = 4\,\mathrm{GHz})$ 16 TXRUs, resulting in a total number of antenna elements of 64 or 128, respectively. On the UE side, 2 antenna elements are used for Config A, whereas 4 antenna elements are used for Config B.

At the gNB cross polarization with an orientation of $+45^\circ$ and -45° is applied. The orientation of the antenna elements at the UE is 0° and $+90^\circ$.

For all simulations we apply a bandwidth of 10 MHz and IMT channel model B [IR17c] which corresponds to the 3GPP channel model for frequencies from 0.5 GHz to 100 GHz specified in TR 38.901 [3GP17].

Further parameter settings can be found in [Hua18].

II.D Metrics for Calibration

3GPP's calibration process is based on two metrics, namely Dowlink Coupling Gain and Downlink Geometry.

The Dowlink Coupling Gain includes pathloss, antenna gains and average fast fading gains. Any processing gains at transmitter or receiver like beamforming or maximum ratio combining gain are excluded, except for analog beamforming gains of the TXRUs where applicable.

The Downlink Geometry is the ratio of received signal power to the sum of interference and noise power where all signals are averaged individually over the used bandwidth. Like the Downlink Coupling Gain, it does not include any processing gain at transmitter or receiver except with analog beamforming where applicable. As such the Downlink Geometry is a kind of wideband SINR.

III Calibration Results

We calibrated our system-level simulator against the various simulators used in 3GPP, cf. [Hua18]. The calibration results, regarding the metrics Downlink Coupling Gain and Downlink Geometry, are presented in Figure 3 to 18. The results of the various 3GPP simulators are included in the figures tagged with legend entries "3GPP $\#i$", the index i being that specfied in [Hua18].

The figures show a very good match of our results with the 3GPP results regarding Downlink Coupling Gain as well as Downlink Geometry. Only in Rural – eMBB, Config A ($f_c = 700\,\mathrm{MHz}$) our results indicate a slightly increased probability of the Downlink Geometry in the range below -3 dB, cf. Figure 16.

IV Conclusions

In this paper, the IMT-2020 evaluation process was shortly introduced and considered scenarios, the main calibration parameters and configuration settings are explained. As a member of the 5G-IA independent evaluation group responsible for the system level simulation, we presented our calibration results against the ones provided by 3GPP. We concluded that our results match very well with the 3GPP results.

In the next step we will perform the actual performance evaluation following the methodology of [IR17c].

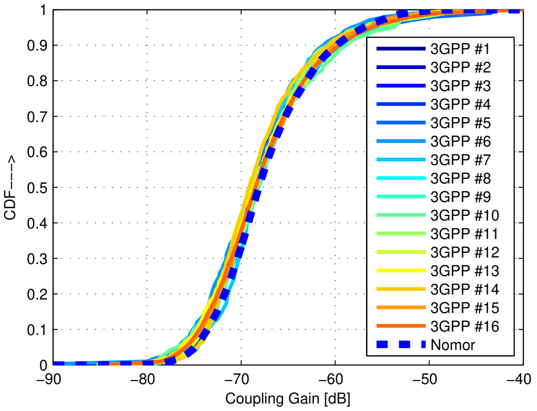

Figure 3: Coupling Gain, Indoor Hotspot – eMBB, Config A, 1 sector

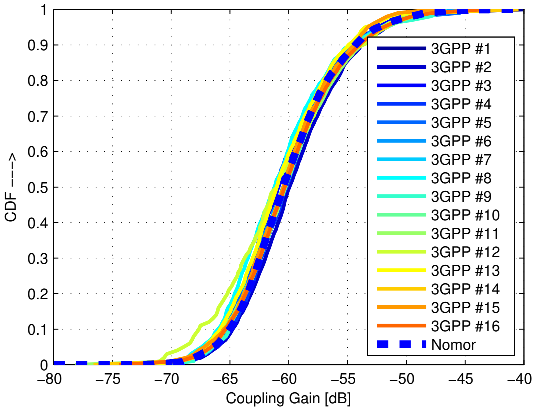

Figure 5: Coupling Gain, Indoor Hotspot – eMBB, Config A, 3 sectors

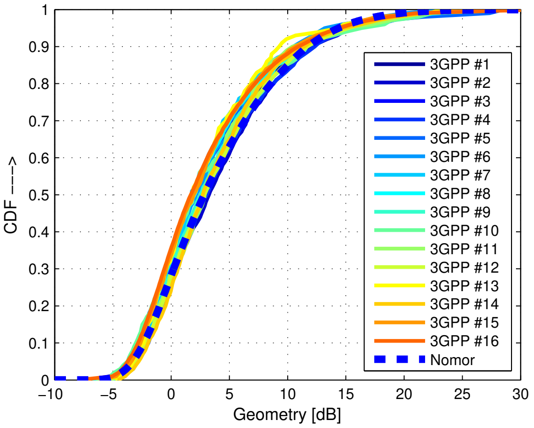

Figure 4: Geometry, Indoor Hotspot – eMBB, Config A, 1 sector

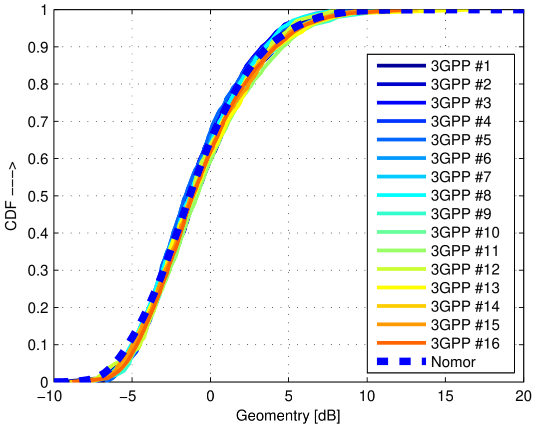

Figure 6: Geometry, Indoor Hotspot – eMBB, Config A, 3 sectors

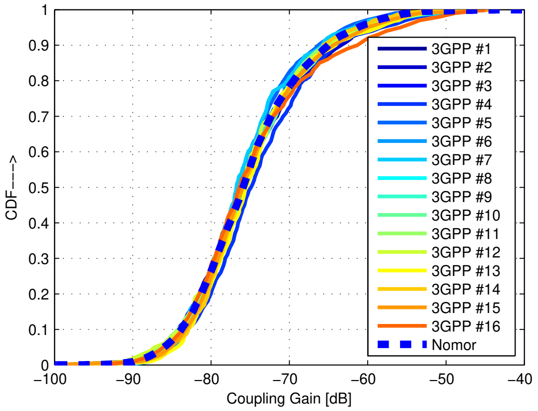

Figure 7: Coupling Gain, Indoor Hotspot – eMBB, Config B, 1 sector

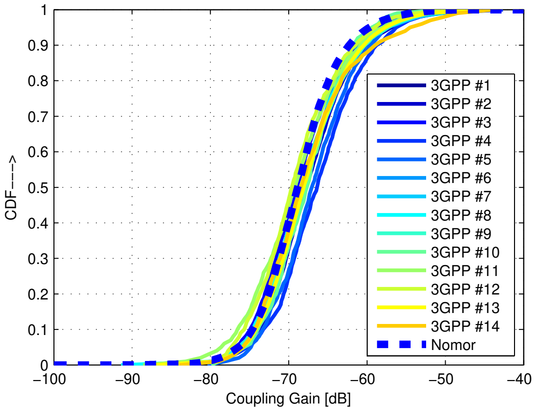

Figure 9: Coupling Gain, Indoor Hotspot – eMBB, Config B, 3 sectors

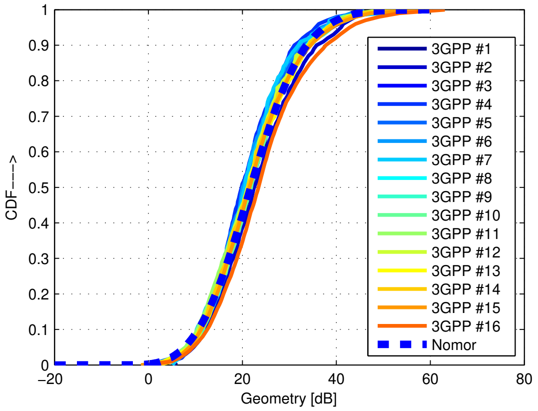

Figure 8: Geometry, Indoor Hotspot – eMBB, Config B, 1 sector

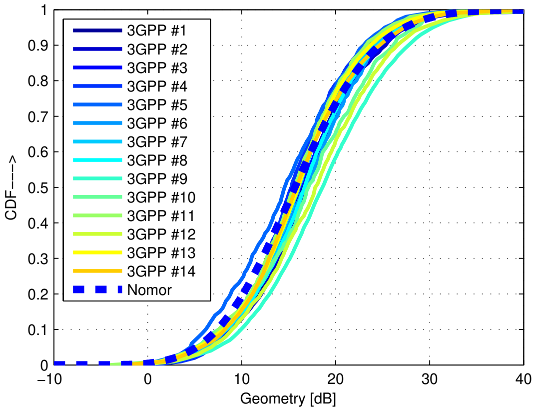

Figure 10: Geometry, Indoor Hotspot – eMBB, Config B, 3 sectors

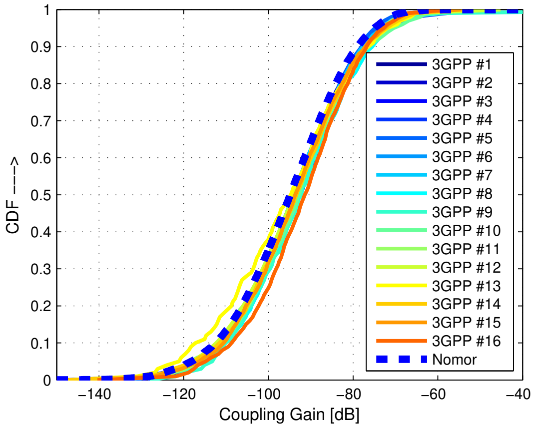

Figure 11: Coupling Gain, Dense Urban – eMBB, Config A

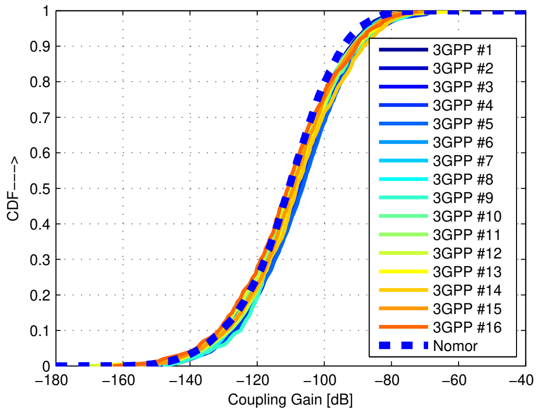

Figure 13: Coupling Gain, Dense Urban – eMBB, Config B

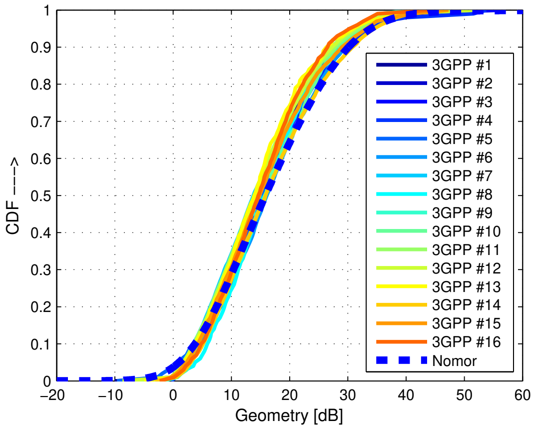

Figure 12: Geometry, Dense Urban – eMBB, Config A

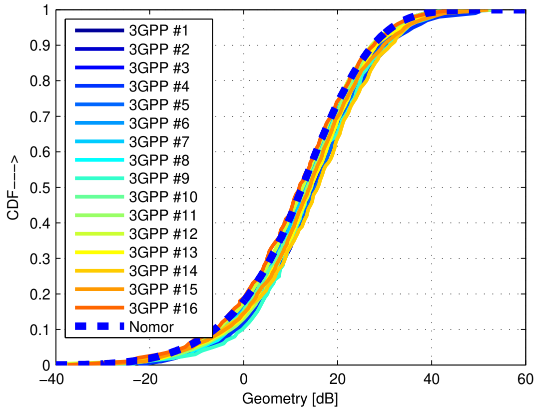

Figure 14: Geometry, Dense Urban – eMBB, Config B

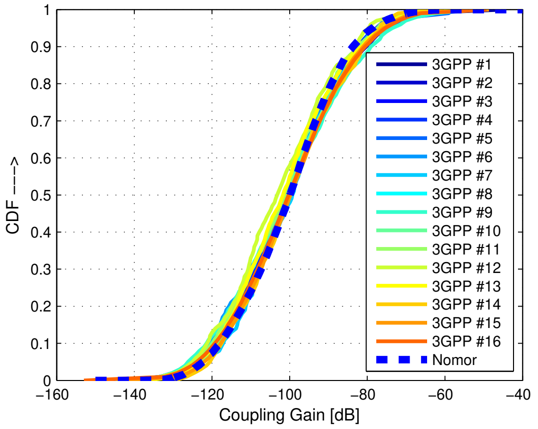

Figure 15: Coupling Gain, Rural – eMBB, Config A

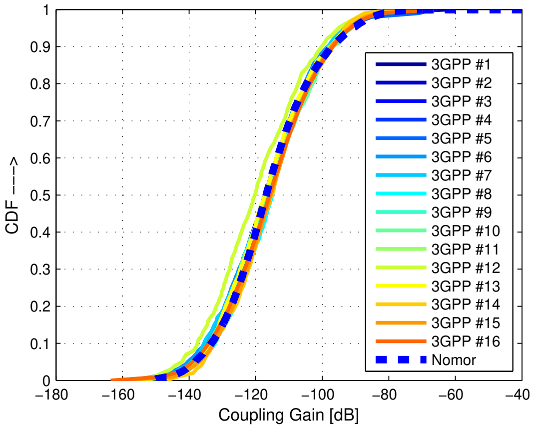

Figure 17: Coupling Gain, Rural – eMBB, Config B

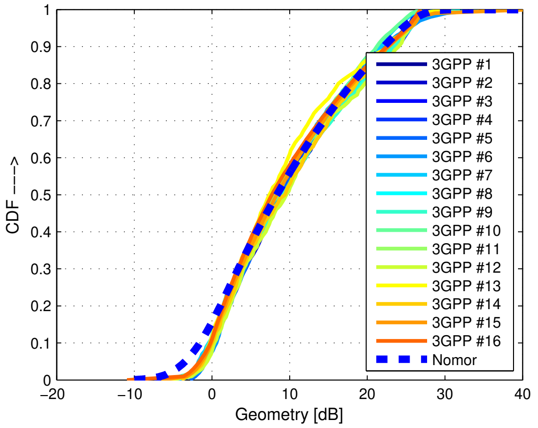

Figure 16: Geometry, Rural – eMBB, Config A

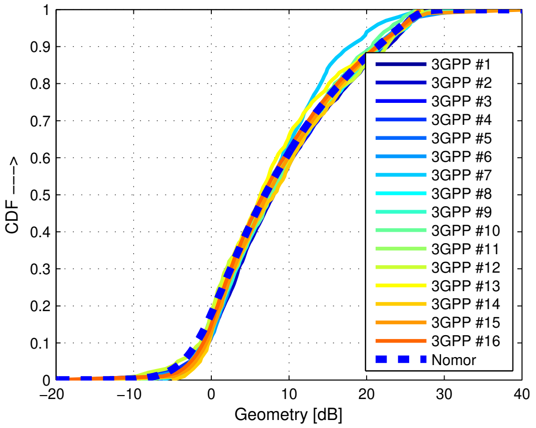

Figure 18: Geometry, Rural – eMBB, Config B

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