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Part 2: New Radio (NR)

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Foreword

This Technical Report (TR) has been produced by ETSI Technical Committee Railway Telecommunications (RT).

The present document is part 2 of a multi-part deliverable covering radio performance simulations and evaluations in rail environment, as identified below:

Part 1: "Long Term Evolution (LTE)";

Part 2: "New Radio (NR)".

Modal verbs terminology

In the present document "**should**", "**should not**", "**may**", "**need not**", "**will**", "**will not**", "**can**" and "**cannot**" are to be interpreted as described in clause 3.2 of the ETSI Drafting Rules (Verbal forms for the expression of provisions).

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Executive summary

In order to assess 3GPP NR radio performance in a rail environment, several scenarios have been defined representing various radio conditions typical to rail environment in the 900 MHz with FDD of 5 MHz bandwidth and the 1 900 - 1 910 MHz band with TDD. Intersite distances between 2 km and 8 km were evaluated in system simulations by 3 companies, noted as Company A, Company B and Company C. The tables in clause 6 summarize the data throughputs simulated by each company in each scenario.

Introduction

3GPP NR radio access is one of the candidates for the radio access technology to be used for the Future Rail Mobile Communications System (FRMCS). In the present document, the term FRMCS refers -unless stated otherwise- to the radio part of the communication system.

Radio performance evaluation of NR system could be done by simulation, through software and processing resources only, or through a test bench incorporating pieces of equipment emulating parts of the chain, e.g. the RF. In both cases, it is important to align the parameters and the assumptions made in the simulation and in the evaluation chain to be able to better reflect a deployment in a rail environment, and to better compare and understand the simulation and the evaluation results.

The present document reports the assumptions and results conducted within TC RT of NR radio performance simulations and evaluations in rail environment.

The purpose of the present document is to summarize the results of the system simulations for a railway environment in both urban and rural scenarios given typical inter-site distances for each scenario. The main bulk of the present document is devoted to the results and analysis of an extensive system simulation campaign that was performed by 3 companies using similar input assumptions but with varying system simulation methodologies.

1 Scope

The present document is intended to:

- Define the simulation parameters relevant to rail environment relating to 3GPP NR radio performance in the 900 MHz (FDD) and 1 900 MHZ (TDD) frequency band. This includes operating frequency bands, bandwidths, deployment scenario (inter-site distance) and antenna characteristics, transmit powers and channel models, along with relevant metrics to be evaluated.
- Collect and analyse the simulation results of an NR system in the rail environment.
- Identify potential limitations of NR system in the rail environment.

2 References

2.1 Normative references

Normative references are not applicable in the present document.

2.2 Informative references

References are either specific (identified by date of publication and/or edition number or version number) or non-specific. For specific references, only the cited version applies. For non-specific references, the latest version of the referenced document (including any amendments) applies.

NOTE: While any hyperlinks included in this clause were valid at the time of publication, ETSI cannot guarantee their long term validity.

The following referenced documents are not necessary for the application of the present document, but they assist the user with regard to a particular subject area.

[i.1] ETSI TR 103 554-1: "Rail Telecommunications (RT); Next Generation Communication System; LTE radio performance simulations and evaluations in rail environment; Part 1: Long Term Evolution (LTE)".

[i.2] Recommendation ITU-R M.2135-1 (12/2009): "Guidelines for evaluation of radio interface technologies for IMT-Advanced".

[i.3] 3GPP TR 36.873: "Study on 3D channel model for LTE".

[i.4] ETSI TS 138 213: "5G; NR; Physical layer procedures for control (3GPP TS 38.213)".

[i.5] ETSI TR 138 901: "5G; Study on channel model for frequencies from 0.5 to 100 GHz (3GPP TR 38.901)".

[i.6] Kathrein model no. 80010991.

[i.7] ETSI TS 138 214: "5G; NR; Physical layer procedures for data (3GPP TS 38.214)".

[i.8] ETSI TS 138 211: "5G; NR; Physical channels and modulation (3GPP TS 38.211)".

[i.9] 3GPP TR 36.884: "Performance requirements of MMSE-IRC receiver for LTE BS".

[i.10] Recommendation ITU-R F.1336-5: "Reference radiation patterns of omnidirectional, sectoral and other antennas for the fixed and mobile service for use in sharing studies in the frequency range from 400 MHz to about 70 GHz".

[i.11] Erik Dahlman, Stefan Parkvall, Johan Sköld: "5G NR: The Next Generation Wireless Access Technology", Elsevier/Academic Press, 2018.

[i.12] 3GPP TR 36.878: "Study on performance enhancements for high speed scenario in LTE".

[i.13] 3GPP 36.814: "Evolved Universal Terrestrial Radio Access (E-UTRA); Further advancements for E-UTRA physical layer aspects".

3 Definition of terms, symbols and abbreviations

3.1 Terms

Void.

3.2 Symbols

Void.

3.3 Abbreviations

For the purposes of the present document, the following abbreviations apply:

3GPP	3rd Generation Partnership Project
5G	Fifth Generation Mobile Networks
AWGN	Additive White Gauss Noise
BLER	BLock Error Rate
BS	Base Station
BTS	Base Transceiver Station
BW	BandWidth
CDF	Cumulative Distribution Function
CDL	Clustered Delay Line
CDL-C	Cluster Delay Line -C Profile
CDM	Code Division Multiplexing
COST	Cooperation of Scientific and Technical
CQI	Channel Quality Information
CSI	Channel State Information
CSI-RS	Channel State Information- Reference Signal
DL	DownLink
DMRS	Demodulation Reference Signal
DM-RS	Demodulation Reference Signal
DS	Delay Spread
EESM	Exponential Effective SNR Mapping
EIRENE	European Integrated Radio Enhanced NEtwork
EIRP	Equivalent Isotropically Radiated Power
EPRE	Emitted Power per Resource Element
FDD	Frequency Division Duplex
FRMCS	Future Rail Mobile Communications System
GSM	Global System for Mobile Communications
HARQ	Hybrid Automatic Repeat Request
HD	High Density
HPBW	Half-Power BeamWidth
INR	Interference-to-Noise Ratio
IRC	Idle Receiver Control
ISD	Inter-Site Distance
KM	Kilometer
KPI	Key Performance Indicator
LDPC	Low Density Parity Check
LOS	Line of Sight
LTE	Long Term Evolution
MCL	Minimum Coupling Loss

MCS	Modulation and Coding scheme
MIMO	Multiple Input Multiple Output
MMSE	Minimum Mean Square Error
MMSE-IRC	Minimum Mean Square Error - Interference Rejection Combining
NLOS	Near Line of Sight
NR	New Radio
NR_X	Number of Receive Antennas
NT_X	Number or Transmit Antennas
OFDM	Orthogonal Frequency Division Multiplexing
PC	Power Control
PDCCH	Physical Downlink Control CHannel
PDSCH	Physical Downlink Shared Channel
PER	Packet Error Rate
PHY	Physical Layer
PRB	Physical Resource Block
PTRS	Phase Tracking Reference Signal
PUCCH	Physical Uplink Control CHannel
PUSCH	Physical Uplink Shared Channel
QAM	Quadrature Amplitude Modulation
QoS	Quality of Service
QPSK	Quadrature Phase Shift Keying
RB	Resource Block
RF	Radio Frequency
RHS	Right Hand Side
RMS	Root Mean Square
RSRP	Reference Signal Received Power
RX	Receive
SC	Subcarrier Spacing
SCS	SubCarrier Spacing
SE	Spectrum Engineering
SINR	Signal-to-Interference-and-Noise Ratio
SIR	Signal to Interference Ratio
SNR	Signal-to-Noise Ratio
SRS	Sounding Reference Signal
SSB	Synchronization Signal Block
SVD	Singular Value Decomposition
TC	Technical Committee
TDD	Time Division Duplex
TDL	Tapped Delay Line
TPMI	Transmit Precoding Matrix Index
TPUT	Throughput
TTI	Transmission Time Interval
TX	Transmission
UE	User Equipment
UE/BS	User Equipment/Base Station
UIC	Union Internationale des Chemins de Fer
UL	UpLink
WI	Work Item

4 Assumptions and Parameters for Simulations and Evaluations

4.1 Introduction

Assumption and Parameters used by all Companies for the simulations and evaluations are summarized in clause A.3.3.1.

4.2 Scenarios

The objective is to define the minimum number of scenarios which cover most of the radio environment:

- Rural scenario:
  - High-speed segment at 350 km/h.
- Urban scenario:
  - High-density segment at 80 km/h.
  - Low-density segment at 80 km/h.
- Hilly scenario:
  - hilly will be investigated in a subsequent study.

4.3 System-related Parameters

4.3.1 Spectrum, system bandwidths and operation modes

4.3.1.1 900 MHz FDD

- 5 MHz channel bandwidth within 875 MHz to 880 MHz/920 MHz to 925 MHz frequency range.
- Subcarrier spacing 15 kHz.

4.3.1.2 1 900 MHz TDD

- 10 MHz channel bandwidth within 1 900 MHz to 1 910 MHz frequency range.
- Two UL/DL configurations to be considered: 50/50 and 90/10.
- Subcarrier spacing 15 kHz.

4.3.2 Transmit power assumptions

4.3.2.1 Downlink case

- BTS EIRP 900 MHz: 63 dBm (include feeder losses and antenna gain).
- BTS EIRP 1 900 MHz: 40 dBm and 63 dBm (include feeder losses and antenna gain).

4.3.2.2 Uplink case

- UE max. power classes:1 maximum output power of 31 dBm is considered.
- UE power class 2 maximum output power of 26 dBm might be considered (optional).
- UE power class 3 maximum output power of 23 dBm is considered.
- UE power control; open loop power control. Details are to be found in clause 4.6.2.3.11.

4.3.3 Antenna parametrization

4.3.3.1 Trackside/BS

As per parameters outlined in clause A.3.3.1:

- 900 MHz Antenna peak gain: 17 dBi
- 900 MHz BS feeder loss: 3 dB, [i.1]
- 1 900 MHz Antenna peak gain: 18 dBi
- 1 900 MHz BS feeder loss: 4 dB
- Horizontal polarization/3 dBm BW azimuth plane: 65°, [i.1]
- Vertical polarization/3 dBm BW elevation plane 8,5° ± 1,5°
- Downtilt: 0° - 3°
- Examples for antenna model used for parametrization:
  - Recommendation ITU-R F.1336-5 [i.10]
  - 3GPP 38 series reference antenna pattern

4.3.3.2 Train side/UE

- Within the present document, it is assumed that the UE antenna gain compensates the cable/feeder losses.

4.3.4 Multi-antenna/MIMO configurations under consideration

- Potential MIMO schemes 900 MHz:
  - Downlink: 2x1, 2x2, 4x1, 4x2
  - Uplink: 1x2, 2x2, 1x4, 2x4
- Potential MIMO schemes 1 900 MHz:
  - Downlink: 2x1, 2x2, 4x1, 4x2, 8x1, 8x2
  - Uplink: 1x2, 2x2, 1x4, 2x4, 1x8, 2x8
- Transmission diversity mode to be defined

4.3.5 Inter-site Interference mitigation method

- Baseline configuration is noted in each company approach.
- Constant frequency approach (Reuse Factor 1):
  In 3GPP, the baseline receiver agreed to be used for the simulations on the performance requirements is Minimum Mean Square Error (MMSE) - Interference Rejection Combining (IRC) receiver. The MMSE-IRC receiver has the capability to 'reject' the interference by creating a 'null' in the spatial domain towards the most dominant interferer, Company A and Company B are using MMSE-IRC receiver in both the BS and UE (see 3GPP TR 36.884 [i.9] Performance requirements of MMSE-IRC receiver for LTE BS).

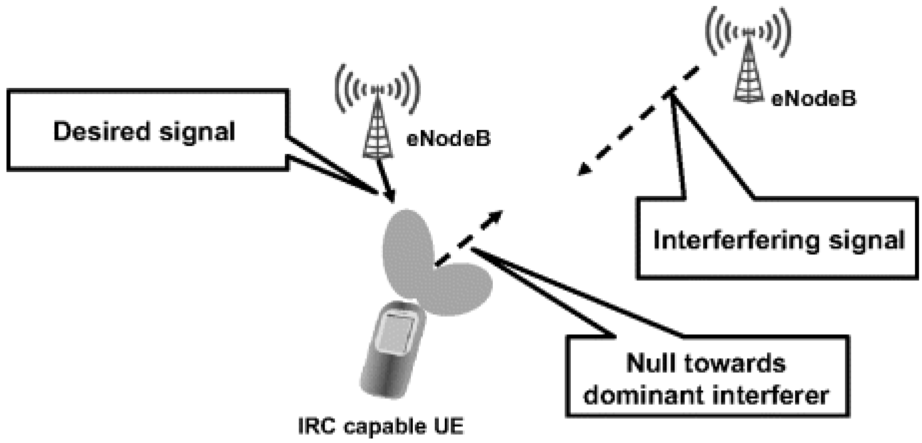


Figure 1: The MMSE-IRC receiver principle in the LTE context

- Fractional Frequency Reuse:
  COMPANY C is using this method.

4.4 Deployment-Related Parameters

4.4.1 Cellular layout

As per parameters outlined in clause A.5:

- Considered inter-site distances (ISD) using 900 MHz band:
  - Rural scenario: 8 km
  - Urban scenario: 2 km and 4 km
- Considered inter-site distances (ISD) using 1 900 MHz band:
  - Rural scenario: 4, 6 and 8 km
  - Urban scenario: 2 and 4 km
- BS antenna height:
  - Rural: 35 m
    (Company A has used 30 m for rural scenario)
  - Urban: 20 m
    (Company A has used 18 m for urban scenario)
- UE/Train antenna height: 4 m
- Tower to track distance: 15 m

4.4.2 Neighbour cell interference models

- To be documented for each simulation

4.4.3 Train and railway track assumptions

4.4.3.1 Common assumptions to all scenarios

- Two parallel tracks with specified inter-track distance of 3,5 m
- The following train densities are defined globally for 2 tracks

4.4.3.2 Rural scenario - High-speed segment

- Train speed: 350 km/h (since 2 tracks are used the density per track is 0,25/km/track)
- Train density (for 2 tracks): 0,5 trains/km

4.4.3.3 Urban scenario - High-density segment

- Train speed: 80 km/h
- Train density (for 2 tracks): up to 1 trains/km

4.4.3.4 Urban scenario - Low-density segment

- Train speed: 80 km/h
- Train density (for 2 tracks): 0,5 trains/km

4.5 Additional Conditions to be Documented

- Mitigation of Doppler effect, when applied to be documented by each Company
- Channel estimation method to be documented by each Company
- Interference mitigation to be documented by each Company

4.6 Simulation Methodology and Propagation Model Aspects

4.6.1 Common link- and system level assumptions

4.6.2 Specific link- and system level assumptions and simulator tools

4.6.2.1 Company A

4.6.2.1.1 Simulator Introduction

The system-level simulator models a multi-link PHY layer and evaluates certain performance metrics under a BLER target. The BLER is one PHY-layer specific parameter that influences the reliability and availability of an end-to-end application. To align with currently used 3GPP approaches, it is proposed to use a BLER of 10^{-1} for the purpose of the present document.

The simulator drops train positions according to the desired deployment layout as well as large scale channel parameters. It calculates complex MIMO channels for each link and the SINR per layer after multi-antenna receiver. The time-dynamic behaviour of the MIMO channels caused by the train movement is captured by the channel models described further below. The link-to-system level interface is derived from a mutual information link quality model, which constrain separate modulation and coding models. The modulation model maps the received SNR to the mutual information symbol-by-symbol and the coding mode maps the sum or average of the mutual information to decoding performance for each coding block. The calculated BLER is used in a random experiment to determine if a packet is correctly decoded. If the packet was not correctly decoded, packet retransmission will occur using a HARQ model. The throughput is then calculated by the aggregated correctly decoded bits during the simulation time. Besides the implementation of 3GPP compliant HARQ schemes, the system simulator incorporates models for link adaption and CSI feedback delay.

The simulations are time-dynamic Monte Carlo simulations consisting of many drops. In each drop, train positions, slow and fast fading parameters are drawn randomly according to specified distributions. In a drop, several time slots are simulated and during this time these parameters are fixed and only the fast fading is varying between slots. A slot is 1 ms for 15 kHz subcarrier spacing. In a drop, 2 000 slots are simulated. While the train position is fixed during a drop, the train speed will cause a time-varying channel which is reflected by the utilized geometry-based stochastic channel generation model. The interference will also vary over the slots in a drop since different UEs are scheduled in different slots and the interferers' precoder will vary with the fading variations of the channel.

Some challenges related to high-speed train scenarios are not captured by the system simulation models. E.g. the impact of Doppler on synchronization, intercarrier interference, and channel estimation is not modelled. However, the impact of fast variations in the small-scale fading on multi-antenna transmission performance is captured via the used channel models and delays in Channel State Information (CSI) reports. Mobility issues, such as handover between cells, and aspects related to reliability and latency are not considered in the present document.

Furthermore, channel estimation errors and hardware impairments are not modelled. Only data channels (PUSCH and PDSCH) are evaluated in the simulations, but the impact of control channel overhead on the data channel throughput is considered. It has been assumed in the simulations that the receiver has perfect channel knowledge.

4.6.2.1.2 Channel model

For system-level MIMO simulations, geometry-based stochastic models, sometimes also referred to a double directional channel models [i.2], are appropriate. Such models include stochastic modelling of large-scale channel properties such as path loss and shadowing as well as small-scale, frequency-selective fading and spatial properties. In the system simulations presented in the present document, well established channel models standardized by ITU and 3GPP are used. In the used channel models, multi-path propagation is modelled using randomly generated scattering clusters for the multi-antenna transmissions.

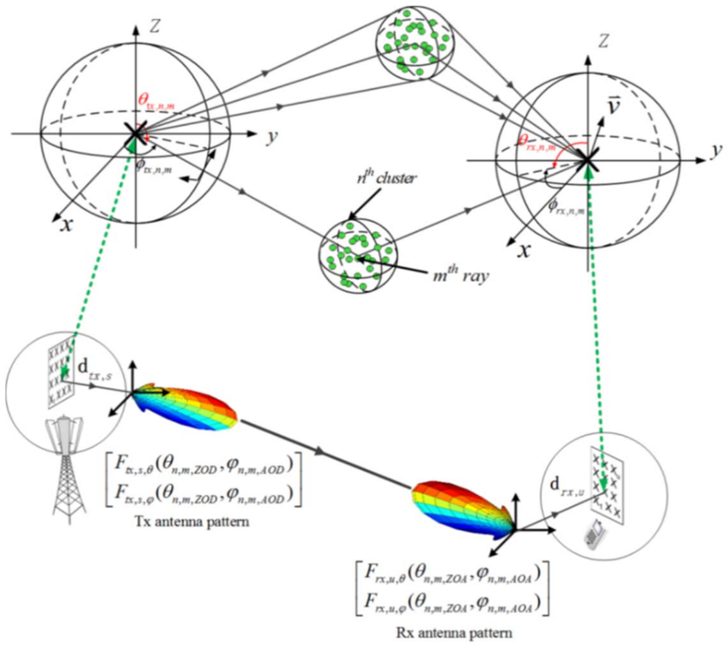


Figure 2: Multi-antenna multi-path generation using clusters of scatterers

For the rural scenario, the ITU Rural Macro (RMa) channel model in [i.2] is used. This model is designed for macro-cell scenarios with large ISDs, low building density and BS antennas mounted higher than the average rooftop height. Since train antennas are mounted outside the train hull, the car penetration loss present in the ITU RMa model is removed in the system simulations.

For the high-density urban scenario, the 3GPP Urban Macro (UMa) channel model in 3GPP TR 36.873 [i.3] is used. The UMa model is supposed to model an environment with higher average building height compared to the RMa model, but the BS antenna is still assumed to be mounted above the rooftop level of surrounding buildings. This model has a similar structure as the ITU RMa model but has other settings of channel model parameters to model an urban scenario. A difference compared to the ITU RMa and ITU UMa models is that the latter model is a 3D model that distributes channel clusters in both azimuth and elevation, hence taking elevation angular spread into account. The UMa model in 3GPP TR 36.873 [i.3] is like the corresponding 5G UMa model in ETSI TR 138 901 [i.5], but the 5G UMa path loss model has some simplifications, e.g. the BS antenna height has been set to 25 m. Using the UMa model the antenna is set to a height of 18 m.

4.6.2.1.3 Deployment Aspects

Company A has studied the following scenarios:

- Rural scenario - High-speed segment at 350 km/h with 8 km ISD at 900 MHz and 4, 6, 8 km ISD for 1 900 MHz antenna height of 30 m.
- Urban scenario - High-density segment at 80 km/h with 4 km ISD at 900 MHz and 2,4 km ISD for 1 900 MHz.

In both scenarios, the railway track is modelled as two parallel straight tracks with 3,5 m separation. 20 sites are placed equidistantly along the tracks and each site has two sectors with directional antennas pointing in opposite directions along the tracks. Each sector is a cell with a unique physical cell identity and its own scheduler. Figure 3 shows an illustration of the cellular network layout. The dashed vertical lines indicate the geometrical border between cells. Note that these are only "geometrical" cell borders since the actual cell associations are determined from the path gain between a UE and all cells. A UE is attached to the cell with the highest path gain, which may not be the closest cell since the shadow fading can be different to different sites. Path gain is calculated as the path loss multiplied by the antenna gain between the first UE antenna and the first antenna port on the BS antenna, herein referred to as antenna port 0. All UE antennas and all BS antenna ports have the same gain, so it does not matter which antenna port is selected for the path gain calculation. The path loss includes shadow fading and is averaged over the small-scale fading.

The Base Station (BS) tower is placed 15 m from the closest track and the BS antennas are mounted at a height which is referred to as the antenna height in the present document. The antenna height is 18 m for high-density urban tracks and 30 m for rural tracks. The UE antenna is mounted 4 m above ground, which is referred to as the UE antenna height. The length of the analyzed reference track is 20 × ISD, where ISD is the intersite distance.

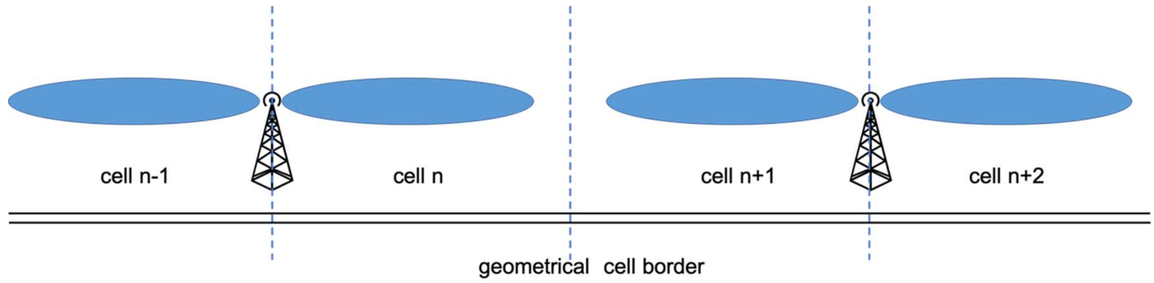


Figure 3: Illustration of the cellular network layout

Train positions are generated with a Monte-Carlo technique using drops. In each drop, train positions for the two tracks are generated independently. Trains on the same track travel in the same direction with a specified minimum train separation, while trains on different tracks travel in opposite directions. The minimum train separation is 3 km for the rural scenario and 1 km for the high-density urban scenario. The positions on one track are drawn from a uniform distribution such that the required train density and minimum train separation requirements are fulfilled. The minimum train separation is achieved by sequentially drawing samples from a uniform distribution of train positions and rejecting positions that do not fulfil the minimum separation requirement. An example of generated trains positions on the two tracks together with the site locations are illustrated in Figure 4 for a case with 8 km ISD and a train density of 0,25 trains/km/track. For a 2-track scenario this is equivalent to 0,5 trains/km.

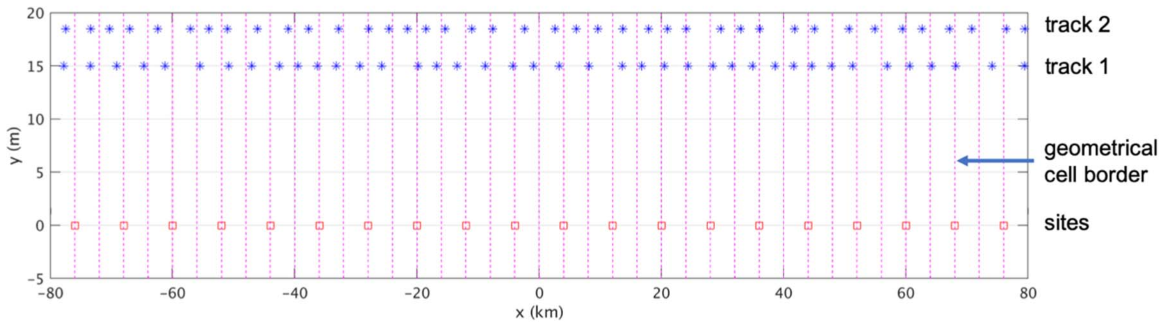


Figure 4: Location of sites and a sample realization of generated train positions on the two tracks for 8 km ISD

In the performance evaluation, the UEs connected to the BSs in the sites at each edge of the network are discarded from the performance calculations to mitigate the border effects of simulating a finite network. Hence, the 18 centre sites (36 cells) are used in the performance calculations.

4.6.2.1.4 Traffic model

A full buffer user traffic model is used in the evaluations, i.e. the number of trains is constant for a given scenario and each train requests unlimited amount of data throughout the simulation. Each UE is allocated the entire bandwidth in a slot and the UEs are scheduled in a round-robin manner without taking the channel conditions into account.

Only open loop power control (i.e. no closed loop power control) for the UL is used. The parameter α controls the level of pathloss compensation and is chosen to be 1, which means that full pathloss compensation is performed. Details on optimization of the path loss compensation factor are given in Annex A.

NOTE: α = 1 means full path loss compensation, α < 1 fractional path loss compensation and α = 0 means no path loss compensation.

The simulator does currently not support TDD DL/UL partitioning, but UL and DL are simulated in separate simulations. The impact of a particular TDD pattern is estimated by scaling of the throughput from an UL or DL simulation.

For the DL, SVD-based precoding in accordance with ideal CSI is used. For the UL, codebook- in accordance with precoding derived from the 3GPP Rel. 15 codebook is used.

4.6.2.1.5 BS Tx power/EIRP

The maximum transmit (Tx) power at the BS is assumed to be 46 dBm for the 900 MHz band. This power is the total power from the BS before the feeder. The power available at an individual antenna port is given by dividing this power between the antenna ports and subtracting the feeder loss. The feeder loss is assumed to be 3 dBm at 900 MHz.

For the 1 900 MHz band, two different options on maximum EIRP are considered, 40 dBm/10 MHz and 63 dBm/10 MHz and 3,5 dB feeder loss:

1) Case of maximum effective isotropic radiated power (EIRP) of 40 dBm/10 MHz:

   - It assumed that beamforming gain is included in the EIRP. The relation between total power at the BS, P_{tot}, and EIRP has been calculated as $P_{tot} = EIRP + L - G_0 - G_{BF}$, where L is the feeder loss, G_0 is the antenna gain per antenna port, and G_{BF} is the beamforming gain. Ideal beamforming gain is assumed in the EIRP calculations, i.e. 3 dBm and 6 dBm when beamforming over two and four ports having the same polarization, respectively. The maximum total Tx power therefore depends on the number of antenna ports according to:

     - 2 ports: $P_{tot} = 40 + 3{,}5 - 18 - 0 = 25{,}5$ dBm
     - 4 ports: $P_{tot} = 40 + 3{,}5 - 18 - 3 = 22{,}5$ dBm
     - 8 ports: $P_{tot} = 40 + 3{,}5 - 16 - 6 = 19{,}5$ dBm

2) Case of maximum effective isotropic radiated power (EIRP) of 63 dBm/10 MHz:

- EIRP was achieved by using 4 ports with 45,5 dBm total power according to:

  - 4 ports: $P_{tot} = 63 + 3{,}5 - 18 - 3 = 45{,}5$ dBm

Remark: In 1 900 MHz only MIMO 4x24 port configuration allows the maximum EIRP of 63 dBm/10 MHz.

4.6.2.1.6 UE Tx power

The maximum Tx power at the UE is assumed to be 23 dBm or 31 dBm for both 900 MHz and 1 900 MHz. This is the total power that should be divided between the Tx antennas. Regarding feeder loss at the UE, the same assumption is made as in ETSI TR 103 554-1 [i.1] that the UE antenna gain compensates the feeder loss. Therefore, both the antenna gain and the feeder loss at the UE is set to 0 dB.

4.6.2.1.7 Multi-antenna transmission and reception

4.6.2.1.7.1 Uplink (UL)

In the UL, codebook-based precoding at the UE according to NR Release 15 [i.7] is evaluated. In codebook-based precoding, the BS selects the best precoder from a set of pre-defined precoding matrices in a so-called codebook. The BS then signals the selected precoder to the UE, so the UE knows which precoder to use in the data transmission. The codebook in NR release 15 [i.8] supports up to rank-4 transmissions. In the simulations, the BS evaluates all precoders for all ranks and selects the rank and precoder that gives the highest estimated throughput. The precoder is wideband, i.e. the same precoder is applied on all resource blocks in the frequency domain. A delay of 5 ms between the channel measurement and the data transmission is modelled in the simulations to take channel ageing effects into account.

In the UL data reception, the BS uses an MMSE-IRC receiver [i.10]. It is assumed that the BS has perfect channel knowledge when calculating the receiver weights.

Only single-user UL MIMO is evaluated in this simulation.

4.6.2.1.7.2 Downlink (DL)

In the DL simulations, the BS uses a frequency-selective precoder with a Singular Value Decomposition (SVD) of the channel matrix. A precoder is calculated per resource block and rank hypothesis. The rank that maximizes the wideband throughput is selected and then used for all resource blocks. The best precoder per resource block for the selected rank is then applied in the data transmission. It is assumed that the BS has perfect channel knowledge when calculating the precoder weights, but a 5 ms delay is applied between the precoder calculation and data transmission.

For TDD, frequency selective SVD precoding is a feasible approach since the channel can be assumed to be reciprocal. Hence, the DL channel can be estimated from UL sounding. For FDD, however, the small-scale fading of the channel is not reciprocal and the BS therefore needs to rely on CSI feedback from the UE to estimate the DL channel. Such feedback-based precoding has not been modelled for the DL in the present document. Therefore, the performance of the frequency selective SVD precoder should be an upper bound on performance when used in FDD simulations.

Only single-user DL MIMO is evaluated in the present document.

In the DL data reception, it is assumed that the UE uses an MMSE-IRC receiver with perfect channel knowledge.

4.6.2.1.8 Link adaptation

In the link adaptation, the BS selects a Modulation and Coding Scheme (MCS) from the MCS index tables in ETSI TS 138 214 [i.7] that will give 10^{-1} BLER using an estimated SINR. An outer loop link adaptation is also used that adjusts the estimated SINR by an offset related to whether a packet has been received correctly or not. Modulation order up to 256QAM is supported for both the DL and the UL.

4.6.2.1.9 Frequency bands and duplex modes

Performance is evaluated for the 900 MHz FDD band at and for the 1 900 MHz to 1 910 MHz TDD band for which the European Commission has given a mandate to study the feasibility for FRMCS operation. In the 900 MHz band, 5 MHz system bandwidth (including guard band) is evaluated in the frequency range 875 MHz to 880 MHz/920 MHz to 925 MHz. In the 1 900 MHz band, 10 MHz system bandwidth within 1 900 MHz to 1 910 MHz using 15 kHz subcarrier spacing is evaluated.

The following restriction is applied: UL and DL are simulated in separate simulations. Therefore, any potential coupling between UL and DL in TDD is not captured by the simulations. The net throughput for a given UL/DL ratio is estimated by scaling the throughput from obtained from the simulation according to the UL/DL ratio. Two different UL/DL ratios, 90/10 and 50/50, are evaluated. In NR, these UL/DL ratios can be achieved by the following TDD patterns:

- 90/10: SUUUUSUUUU
- 50/50: DSUUDDSUUD

Here, S denotes a special slot, D a DL slot, and U a UL slot. A special slot is here assumed to consist of 6 DL symbols, 2 guard symbols, and 6 UL symbols. The TDD patterns are not explicitly simulated in the system simulator but are used for estimating the overhead for different UL/DL ratios.

Since UL and DL are simulated separately and only data channels are modelled, any impact of the DL signalling on the UL, and vice versa, is not captured by the system simulations. For example, the latency with UL heavy TDD patterns may be negatively affected by the fact that there are only a few symbols available for DL control signalling like scheduling grants and ACK/NACKs. These issues need to be studied by link simulations but is beyond the scope of the present document.

4.6.2.1.10 Overhead

Reference signals and control signals are needed to support successful communication between a BS and a UE, but at the cost of leaving less resource for data transmission. Reference signals, e.g. SSB, SRS, CSI-RS, DMRS, are transmitted with certain density in time and frequency for purposes such as synchronization, channel measurement and demodulation. Control signals, on the other hand, are used to carry scheduling grants, assignments, feedback, etc. In the present document, reference signals and control signals are not modelled explicitly. However, the overhead that they have caused will be roughly estimated, in terms of number of occupied resource elements for a given TDD configuration and system bandwidth.

The first order impact of increased overhead is that the resource elements for data transmission will be proportionally fewer, resulting in reduced user throughput. However, the reduction in throughput may not be exactly linear with respect to overhead. The fundamental reason lies in the fact that data is transmitted in transport blocks, while the transport block size can only be selected from a set of quantized values, depending on the MCS being used. Additionally, scheduling, link adaptation, transmission rank etc., may also vary once the available number of resource elements for data changes. In clause A.3.1.5, it is shown that in most cases it is accurate enough to scale the throughput using the calculated overhead in order to obtain the net throughput. In cases this is not accurate enough, separate simulations for different overhead values are performed.

The estimated DL and UL overhead for TDD at 1 900 MHz are summarized in Table 1 together with the overhead for 900 MHz FDD. The overhead numbers are calculated as the number of overhead resource elements divided by the total number of used resource elements, i.e. the frequency guard band is not included in the overhead numbers. The given overhead numbers are only rough estimates and the same overhead has been assumed for all antenna configurations.

Table 1: Estimated overhead for different UL/DL ratios and bandwidths for the TDD simulations at 1 900 MHz and FDD simulations at 900 MHz

	1 900 MHz		900 MHz
UL/DL ratio	90/10	50/50	-
Nominal bandwidth (MHz)	10	10	5
Occupied bandwidth (MHz)	9,36	9,36	4,68
DL overhead ( )	40	12	30
UL overhead ( )	11	14	23

The estimated overhead numbers are attributed to certain assumptions on how control channels and reference signals have been configured. Since the system simulator only models data transmissions (PDSCH/PUSCH), the assumed configuration has no impact on the simulation results other than overhead.

4.6.2.1.11 Uplink power control

In the UL, the UE can adjust the transmit power to get desired received signal power at BS. In principle, the transmit power for PUSCH can be determined by the UE via the following expression [i.11]:

$$P_{PUSCH} = min(P_{CMAX}, P_O - \alpha \cdot PG + 10 \cdot log_{10}(2^{\mu} \cdot M_{RB}) + \Delta_{TF} + \delta),$$

where:

- P_{PUSCH} is the PUSCH transmit power.
- P_{CMAX} is the maximum allowed transmit power per carrier, it is either 23 dBm or 31 dBm in the present document.
- P_O is a network-configurable parameter that can be mapped to a desired received signal power at the BS.
- α is a network-configurable path loss compensation parameter.
- PG is the path gain between a UE antenna and BS antenna port 0.
- The term $10 \cdot log_{10}(2^{\mu} \cdot M_{RB})$, where M_{RB} is the number of RBs assigned for PUSCH transmission while μ relates to the subcarrier spacing via $\mathrm{SCS} = 2^{\mu} \cdot 15\ kHz$, reflects the fact that the transmit power should be proportional to the bandwidth assigned for the PUSCH transmission, in order to maintain a given received power.
- Δ_{TF} is an MCS-dependent power term, which is disabled in the present document.
- δ is the closed-loop power adjustment that can be included in the UL scheduling grant, its value is referring to network measurement of received power. However, closed-loop power control is not considered in the present document, thus $\delta = 0$ dB.

Company A simulation only considers open-loop power control, which is adjusted according to the expression $P_O + \alpha \cdot PL$. Closed-loop power control is not modelled in the simulations. The quantity P_O, which is related to target received power or SNR, is provided as part of the power control configuration by the network. Herein, P_O is parameterized as in the present document and only considers open-loop power control, which is adjusted according to the expression $P_O + \alpha \cdot PL$. Closed-loop power control is not modelled in the simulations. The quantity P_O, which is related to target received power or SNR, is provided as part of the power control configuration by the network. Herein, P_O is parameterized as:

$$P_O ==== \alpha \cdot \left(SNR_{target} + P_n\right) + (1 - \alpha) \cdot P_{CMAX},$$

where P_n is the receiver noise per antenna and RB, while SNR_{target} is the desired SNR at a BS receiver antenna.

The path loss compensation factor α is set to 1 in the simulations, which means that full path loss compensation is performed. The target SNR, SNR_{target}, is set to 7 dBm per UE Tx and BS Rx antenna port. Although α and SNR_{target} could be optimized for each MIMO configuration and scenario, the same values are used for all cases in the simulations. The discussion in the Appendix shows results that motivate the chosen settings for these parameters. Note that since the target SNR has been defined per antenna port in the simulations, it will mean that UEs that have enough drop power to reach the target SNR will transmit with lower power if the gain per BS antenna port is reduced. Furthermore, increasing the number of UE antennas can increase the SNR at the BS above the target SNR thanks to the potential Tx beamforming gain.

For UEs that do not have enough Tx power to reach the target SNR, an option is to reduce the bandwidth to increase the power spectral density. This is however not used in the simulations; UEs always transmit over the entire system bandwidth.

4.6.2.1.12 Aspects on resource sharing and scheduling

When there is more than one UE in a cell the available time-frequency radio resources need to be shared between the UEs, leading to reduced net throughput for each UE. The average number of UEs per cell is given by the UE density and cell size and are shown in Table 2 for selected scenarios.

Table 2: Average number of UEs per cell for different scenarios in a two-track layout

Scenario and frequency band	Average number of UEs per cell
Rural, 900 MHz (ISD 8 km)	2
Rural, 1 900 MHz (ISD 4 km)	1
High-Density Urban, 900 MHz (ISD 4 km)	2
High Density Urban, 1 900 MHz (ISD 2 km)	1

Since the UEs are dropped randomly as described in clause 4.4.1 the actual number of UEs per cell will vary. Figure 5 shows histograms of the number of UEs per cell for the different scenarios. The number of UEs per cell can vary from 0 up to 5 UEs per cell in the urban 900 MHz case. This is one source of the random variations in the user throughput. Note that the spectral efficiency, as defined in clause 5.1.2.1 removes the effect of resource sharing since only the scheduled resources are accounted for in this metric.

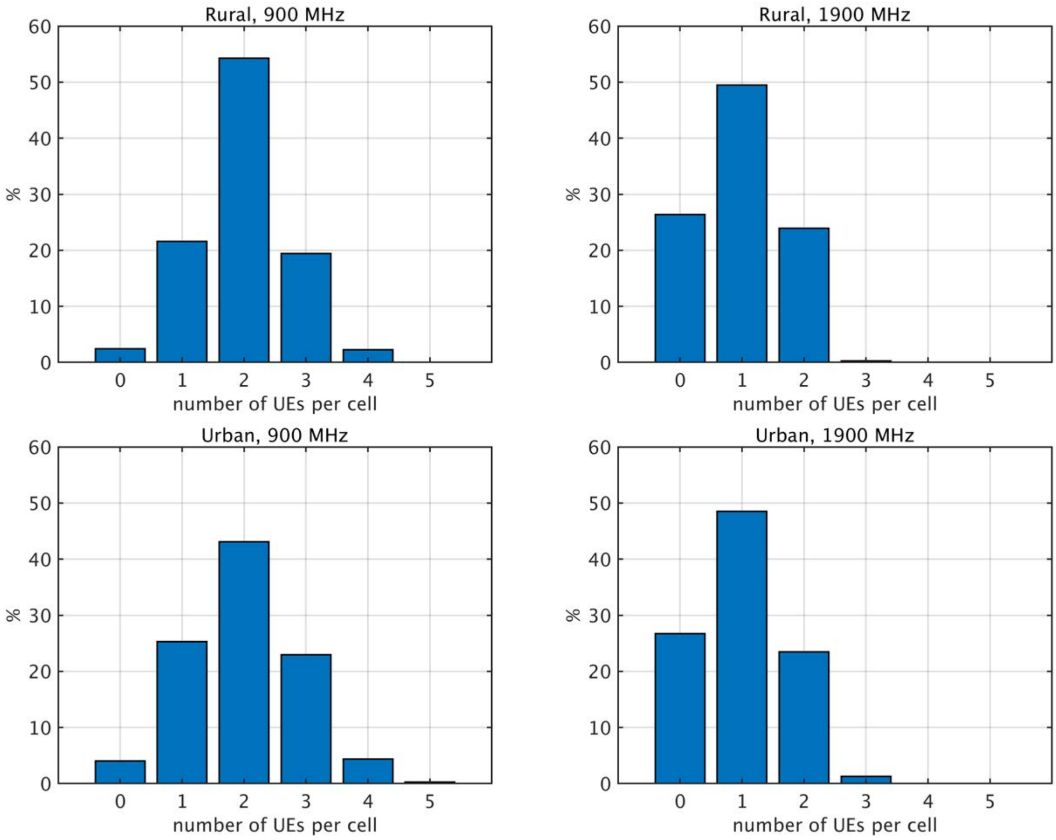


Figure 5: Histogram of number of UEs per cell for different scenarios of Table 2

The assumptions on full buffer traffic and round robin scheduling have some implications on performance. The round robin scheduler assigns equal amount of resources to each UE, regardless of their channel quality or performance requirements. The full buffer traffic model implies that there is no limit on the throughput that a UE needs. Therefore, a UE close to the BS and/or with high channel quality can achieve a much higher throughput than what it needs while, at the same time, a UE far away from the BS and/or with low channel quality cannot achieve the required throughput. A way to solve this problem could be to assign more time-frequency radio resources to the bad UE and less resources to the good UE. In this way, cell-edge throughput can be further improved at the expense of reduced peak throughput. However, such a scheduling strategy has not been investigated in the Company A report. In this way, cell-edge throughput can be increased at the expense of reduced peak throughput. However, such a scheduling strategy has not been investigated in the present document.

4.6.2.2 Company B

4.6.2.2.1 Simulator Introduction

The system level simulator sets up a simulated environment where the trains (or user equipment, these terms can be used interchangeably in this chapter) move along a predefined route in the environment. In this environment it simulates the radio properties of each train's link at the Physical layer.

The simulator focuses on SINR modelling, and calculating throughput based on the SINR value. It takes the SINR value and matches it to a Block Error Rate (BLER) value, taken from detailed link level simulations. The used link level parameters and results can be found in annex A. This link-to-system interface is based on the Exponential Effective SNR Mapping (EESM) approach. This calculates the SINR value for each symbol, which is then mapped to a BLER value. Then, using this value the packet decode success is randomly decided. If it was unsuccessful, then packet retransmission is done using Hybrid Automatic Repeat Request (HARQ). The overall throughput for each train is based on the overall successfully decoded packets.

A BLER target of 10^{-1} was specified in the simulations.

The used traffic model is full buffer, with each train and base station generating more data than it can transmit.

4.6.2.2.2 Short summary of simulation workflow

1) Randomize initial slow/fast fading:
    a) Slow fading is correlated over 50 metres, with a factor of 0,37:
        i) Slow fading can be visualized as a square grid overlaid on the simulation environment. One square is 50x50 metres. The current slow fading value corresponds to the value in the current square.
2) Place UEs/trains randomly along the tracks, defined the by the following distance limits:
    a) Equal distribution, not normal/gaussian.
3) Start the simulation:
    a) 1 step = 1 OFDM symbol, 14 000 steps per 1 second.
    b) UEs start cell selection measurement for the cell selection (5 ms/60 steps is the cell selection measurement interval, measurement length is 14 steps/1 TTI, condition is best RSRP).
    c) Associate with the best cell after each measurement:
        i) new measurement interval starts immediately after the previous and keeps going until the end.
    d) UEs start to move along the direction of the tracks:
        i) two parallel horizontal lines, upper line goes left, lower line goes right:
            1) movement locations are updated every 14 steps.
        ii) fast fading values are updated according to ETSI TR 138 901 [i.5] fast fading spatial consistency Model B:
            1) fast fading values updated every 10 metres;
            2) consistency model updated every 1 000 steps.
    e) BSs start Round Robin resource sharing between their UEs:
        i) switching interval: 1 ms, 14 steps;
        ii) newly associated UEs will only be scheduled in the next round;

iii) how it works: when the BSs are started, they query the associated UEs, and start a round of scheduling on these. Assuming that the BS has 3 UEs associated, it will run round-robin on these, and after it is over it will query the associated UE list again, and start it over. The newly associated UEs will be scheduled after the current scheduling period is over, and the UE list is queried again.

f) Calculate SINR, and then based on the link-to-system mapper data the packet error probability for each MCS.

g) Pick the highest MCS, where the packet error probability satisfies the requirement:

i) DL to DL and UL to UL interference is calculated/estimated in the respective receivers.

4) Simulation stops after 240 × 14 000 steps (4 minutes of real-world time).

4.6.2.2.3 Channel model

In the simulations the 3GPP rural macro and urban macro propagation models were used from ETSI TR 138 901 [i.5], for the rural and urban cases respectively. These channel models were designed for use in 5G simulations. Slow fading is correlated between the sites. Fast fading is set up according to use 5G spatial channel model, with the correct values for each scenario, with spatial consistency Procedure B. After several steps, the values for slow and fast fading is updated.

Slow fading is set up according to ETSI TR 138 901 [i.5]. Used slow fading standard deviation values:

- 6 dB for rural macro.
- 6 dB for urban macro.

Depending on the selected simulation case, some or all devices were equipped with multiple receive and/or multiple transmit antennas. This enabled them to have higher gain. However, the number of transmitted streams was fixed at one.

The rural channel model uses fixed LOS propagation, while the urban channel model uses fixed NLOS propagation.

4.6.2.2.4 Deployment

The simulated environment is similar in all cases: 24 km long, 300-metre-wide, and 50-metre-high rectangular shape, with wraparound at the edges. Two parallel tracks are placed, 3,5 metre from each other, and the base stations are 15 metres away from the track located closer to them. The trains move in one direction on each of the tracks, and trains head in opposite direction compared to the other track.

The placement of the train in the environment was based on the following distance from the previous train. One train was randomly placed on each track, and then the following distance was calculated from the previously placed train. The distribution of the random values was uniform. The distribution of each track was independent of the other track.

The distance limits used for each scenario was the following:

- Rural: 3 000 to 5 000 metres
- Urban (both low and high density): 1 000 to 3 000 metres

At each base station location two cells are placed, pointing in opposite directions along the tracks. Each cell has its own identity and scheduler. The height of the base station is 35 metres in the rural case and 20 metres in both urban cases.

4.6.2.2.5 Antenna models

The reference train antenna is an ideal omnidirectional antenna, with a total gain of 0 dBi. It was previously established that an example antenna has 5,6 dBi of gain, while hardware losses can go up to 6 dB. Assuming the worst-case scenario, the hardware losses can zero out the antenna gain. The maximum transmit power was 23 dBm or 31 dBm, depending on the case. In MIMO cases, this is the total transmit power, and this was scaled down to each antenna element.

The base station antennas are modelled with the antenna model from 3GPP TR 36.814 [i.13], with the antenna parameters aligned with an example antenna. This antenna has 65° Half Power Beam Width (HPBW) in the horizontal plane, 8,5° HPBW in the vertical plane, with a peak gain of 17 dBi. No down tilt was specified. The base station output power was 23 or 46 dBm depending on the case. In MIMO cases, this is the total transmit power, and this was scaled down to each antenna element. With different MIMO configurations the number of antennas were changed according to the scheme, however, the size of the antenna array has remained the same. Thereby only some extra combination gain is observed.

Both the downlink and uplink receivers use MMSE-IRC receivers to mitigate the effects of interference.

4.6.2.2.6 Link adaptation

Using the calculated SINR the base station chooses a Modulation and Coding Scheme (MCS) that will satisfy the BLER target (10^{-1}). The same MCS list is used for DL and UL. The modulations used are QPSK, 16QAM and 64QAM. The coding rates are 1/6, 1/4, 1/3, 1/2, 2/3, 3/4 and 5/6. The reference to the performance of each of these MCSs can be found in Annex A.

4.6.2.2.7 Duplex modes

The used frequency bands in 900 MHz correspond to the (E)R-GSM FDD band, and the 1 900 MHz to 1 910 MHz TDD band in 1 900 MHz. The used bandwidths are 5 MHz for 900 MHz, and 10 MHz for 1 900 MHz. Subcarrier spacing is 15 kHz in both cases.

One simulation encompasses both the DL and UL direction for that given case. The simulator is capable of modelling DL to DL and UL to UL interference, however, due to the chosen scheduling method this is not needed.

Two ratios were agreed for TDD: 90/10 and 50/50, for UL/DL respectively. These ratios were modelled with the following TDD pattern:

- 90/10: SUUUUSUUUU
- 50/50: DSUUDDSUUD

Here, S denotes a special slot, D a DL slot, and U a UL slot. A special slot is here assumed to consist of 6 DL symbols, 2 guard symbols, and 6 UL symbols. This setup was also chosen to align with the other companies in the present document.

4.6.2.2.8 Power control

In downlink no Power Control (PC) was used.

In uplink, pathloss based power control was used. The following equation is used for pathloss based PC in these simulations:

$$TxPow\ (dBm) = \min(MaxTxPow, P_0\ (dBm) + \alpha * Pathloss\ (dB))$$

In this equation:

- $TxPow$ is the used transmit power.
- $MaxTxPow$ is the maximum allowed transmit power. This can be set to 23 or 31 dBm, per the current case.
- P_0 is a network configuration parameter. This represents the target for the received power at the base station. In these simulations this value is set to -95 dBm.
- α is the path loss compensation factor. In these simulations only full path loss compensation is used, so this parameter is set to 1.
- $Pathloss$ is the path loss between the train and the base station. Another way to express this parameter is to multiply path gain with -1.

Only open loop power control is used in these simulations.

4.6.2.2.9 Overhead

In mobile networks, control signals are needed for controlling the device's behaviour (e.g. when and on which frequency to transmit), while reference signals are needed to provide information about the channel conditions.

These signals encompass the SS block, DMRS, PTRS, SRS, PUCCH, PDCCH, etc. In these simulations the overhead caused by these signals, which is traffic that is not carrying data counting towards the throughput, is not accurately modelled by the simulator. The signal with the largest impact is the DMRS signal, 3 out of 14 OFDM symbols are allocated to DMRS, with further details in Annex A.

CQI measurement period is 10 ms, with a reporting delay of 5 ms.

4.6.2.2.10 Scheduling

Since the cells can have multiple trains assigned to them, scheduling is needed between the users. Round robin scheduling is used, with a new UE scheduled every 1 millisecond. When a user equipment is scheduled it has access to the full bandwidth, so practically a time division multiplexing scheme is used. Each base station runs its own scheduling on the associated UEs. There is no coordination between them.

This scheduling method was chosen to make comparison with other companies' results easier. This method does not reach optimal throughput or latency. For the throughput it favours the cell centre UEs, against the cell edge UEs. For the latency it does not give priority to higher Quality of Service (QoS) classes, although in these simulations only one QoS class was used. It also has effects on the power control: for cell edge UEs which do not reach the target power, a possibility would be to reduce the used transmission bandwidth, so that power density can be increased. This is not an option in these simulations.

Since the number of trains is not deterministic, multiple simulation were started until a total of 100 trains (overall, counting both directions) were simulated. Each simulation's length was equivalent to four minutes of real-world time, during which the trains were moving, and all trains and base stations were receiving and transmitting data.

No frequency reuse scheme was enabled (frequency reuse factor of 1).

4.6.2.3 Company C

4.6.2.3.1 Simulator Introduction

The simulator used for this study uses Monte-Carlo statistical approach. It considers multiple cells in a linear deployment along the track and encompasses link-level simulation as well as system-level simulation.

Link level simulations allow to compute the Block Error Rate (BLER) of the radio transmission scheme, including multiple modulation and coding and MIMO schemes, channel estimation, small-scale fading effects, Doppler as well as normalized antenna patterns.

Step 1: Link level simulation:

1) Computation of the PERi vs. Signal-to-Interference-plus-Noise Ratio (SINR) for N different transmission schemes (characterized by a specific modulation, coding rate, speed and MIMO scheme) that results in link level throughputs Ti, i=1,…,N (assuming AWGN interference).

2) For each transmission scheme i and each SINR value, computation of the resulting throughput Tres,i (SINR) considering PER as:

$$T_{res,i} = T_i \times \left(1 - PER_i\left(SINR\right)\right)$$

3) For each SINR, storage in a look-up table of the maximum resulting throughput as shown in Figure 6 among all transmission schemes (modulation, coding rate, MIMO) as a result of ideal link adaptation to large-scale channel properties:

$$T_{\max}\left(SINR\right) = \arg\max_i \left(T_{res,i}\left(SINR\right)\right)$$

System level simulation includes effect of large-scale fading (i.e. distance-dependent path-loss and shadowing), antenna patterns, inter-cell interference and other deployment aspects.

Step 2: System level simulation:

1) 1 000 drops for each train position and associated large-scale channel realizations are performed to obtain resulting SINR. A drop is a realization of UE positions within the cells. These positions are randomly drawn under the constraints of the scenario of interest (UE distribution depends on UE density in a cell).

2) From all the drops, computation of the Cumulative Density Function (CDF) of the throughput by using the obtained SINR values as inputs in the look-up table Tmax(SINR) obtained in the link-level evaluation step.

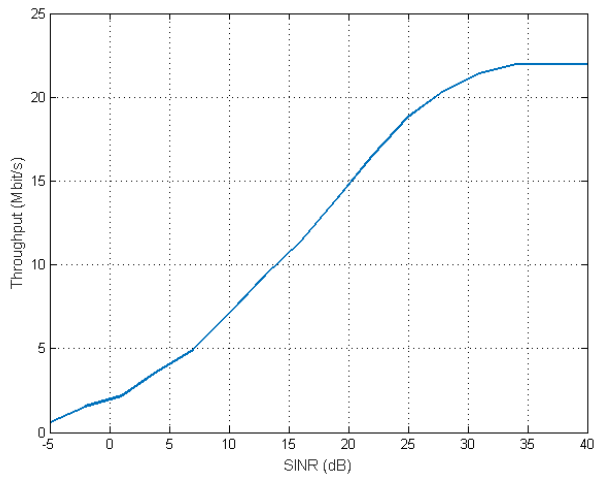


Figure 6: Maximum resulting throughput example for a given transmission scheme

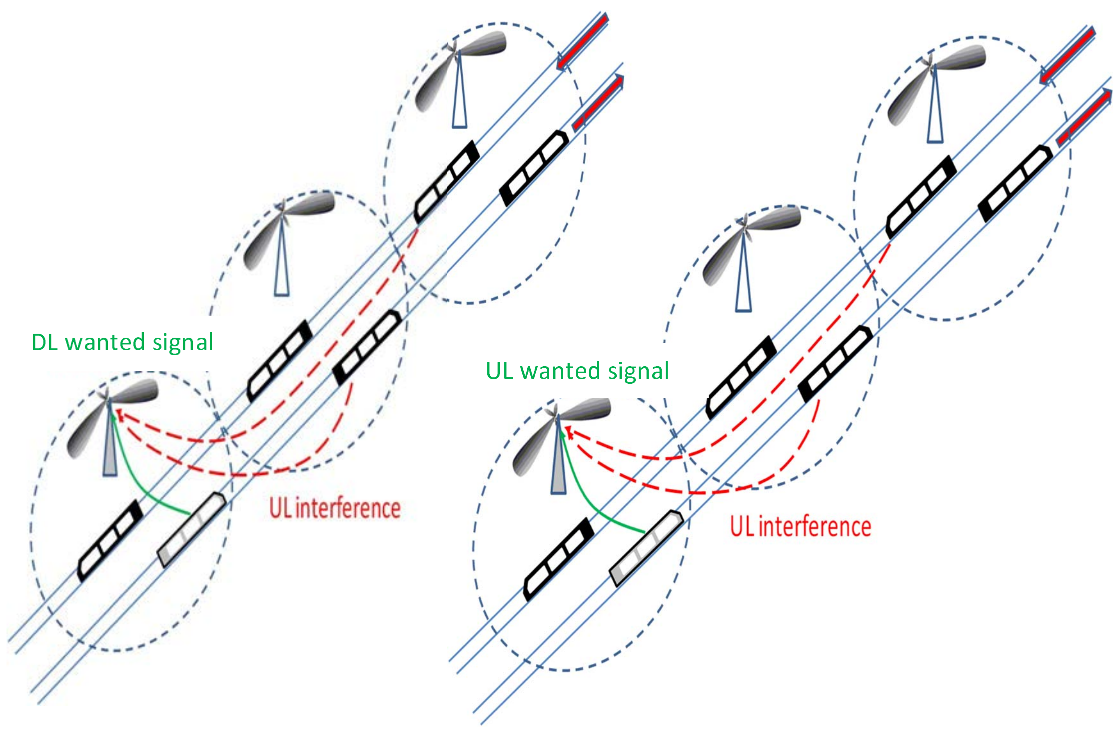


Figure 7: Railway line configuration and inter-cell interference

4.6.2.3.2 Channel model

As for FRMCS evaluation in ETSI TR 103 554-1 [i.1], CDL MIMO channel models have been used. The channel generation makes use of the methodology described in Recommendation ITU-R M.2135-1 [i.2] to derive the MIMO channel impulse response. Intrinsically channel correlation on both transmitter and receiver are included. This method is based on clusters where each cluster is characterized by relative delay and power as well as average departure and arrival angle.

COST 231 channel models are Tapped Delay Line (TDL) models (no mention of spatial distribution) which have been widely used for railway communication networks design. The spatial aspect (not covered by COST231) has been adapted from Recommendation ITU-R M.2135-1 [i.2] (Angles of Arrival and Departure) and combined with COST231 TDL to have more representative models (propagation delays and spatial distribution) mainly in terms of Doppler effect which is better evaluated when a realistic angular distribution is used so that channel variations are simulated.

Therefore, as for ETSI TR 103 554-1 [i.1], the channel models used in these simulations are CDL models and the channel impulse response generation is compliant with Recommendation ITU-R M.2135-1 [i.2] and ETSI TR 138 901 [i.5] methodology.

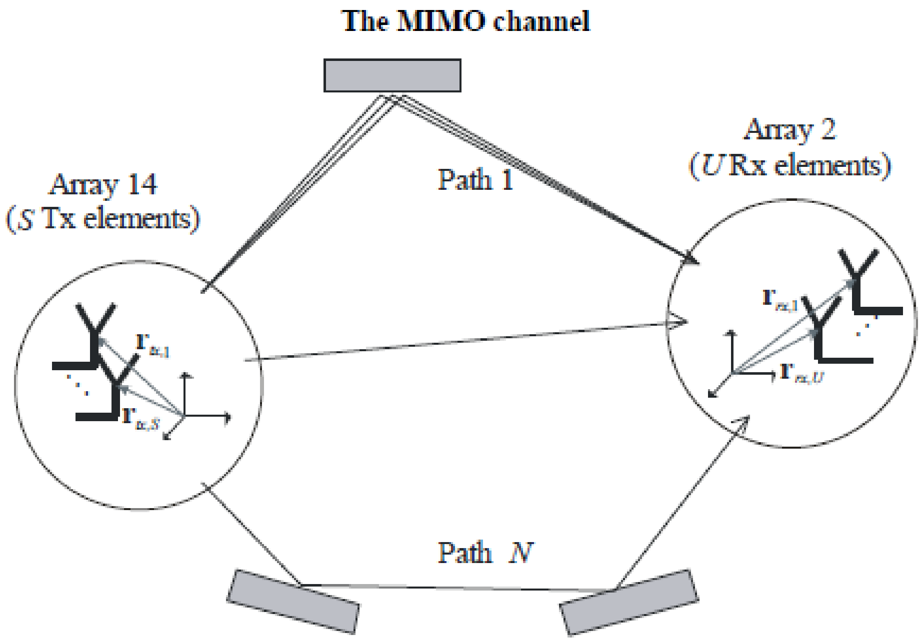


Figure 8: Clustered Delay Lines modelling

The channel models that are taken cover multiple propagation environments: Rural, Urban and Hilly. In Rural area, probability to experience a LOS path is high while this is not the case for Urban and Hilly environments. The delay spread depends also on the propagation environment; the models cover these cases from very short delay spread to high delay spread. Table 3 summarizes these aspects.

Table 3: Propagation characteristics for Urban, Rural and Hilly environments

	Propagation environment		
	Typical Rural Area	Typical Urban Area	Typical Hilly Terrain
Covered scenario	Short delay spread in LOS - high speed	Medium delay spread in NLOS - low speed	High delay spread in NLOS - high speed
RMS delay (µs)	0,1	1	5
Max delay (µs)	0,5	5	20
Rice Factor (dB)	0	N.A (NLOS only)	N.A (NLOS only)
LOS probability	1	0	0
AoS/AoD spatial distribution is taken from Recommendation ITU-R M.2135-1 [i.2].			

Accordingly, the models cover scenarios ranging from short delay spread scenario with LOS to high delay spread without LOS.

In absence of compensation mechanism, the signal received in downlink by the UE is shifted in frequency and this shifted signal is reused for uplink transmission time synchronization. At the base station receiver, this is then equivalent to having the UE moving at twice its actual speed (double Doppler assumption). To consider this effect, uplink performance is evaluated with mobile speeds up to the double of train maximum speed.

4.6.2.3.3 Deployment aspects

The inter-site distances given above in clause 4.4.1 for each environment are used. Each site includes one bi-sectored cell with two antenna patterns pointing in the opposite directions but transmitting the same signal on the same frequency. By default, all cells use the same frequency bandwidth (reuse factor = 1). To mitigate interference, hard frequency reuse can be deployed (reuse factor > 1), where every two neighbouring cells use different chunks of the bandwidth. Performance are evaluated for reuse factors varying from 1 to 3, as illustrated in Figure 9. Indeed, soft frequency reuse schemes can be used, it offers better spectral efficiency in cell centre while at cell edge hard and soft frequency reuse are expected to offer similar performance.

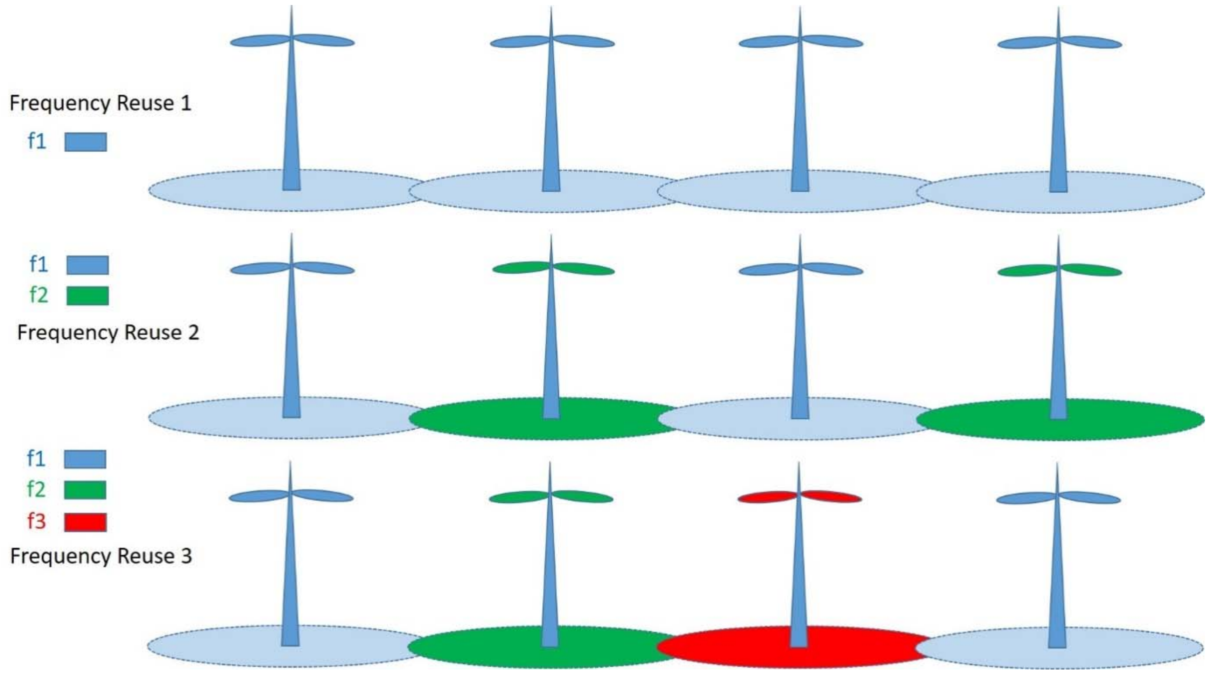


Figure 9: Illustration of hard frequency reuse and cells deployment

4.6.2.3.4 Traffic model

Full buffer is assumed in all the simulations.

4.6.2.3.5 BS Tx power

As required in clause 4.3.2, for 900 MHz band the BS transmission power is defined per antenna connector (46 dBm). For the 1 900 MHz, the power is defined in terms of maximum EIRP, which intrinsically includes transmitting antenna gain. Two maximum EIRP values (40 dBm and 63 dBm) are used.

4.6.2.3.6 UE Tx power

Three UE transmission power values are evaluated 23 dBm, 26 dBm and 31 dBm as required in clause 4.3.2. These values affect the received wanted signal but also the interference power.

4.6.2.3.7 Multi-antenna transmission and reception

In these simulations, it is assumed a single layer 2x2 MIMO transmission with digital beamforming in both uplink and downlink.

4.6.2.3.8 Link adaptation

NR modulation and coding schemes are evaluated ranging from (QPSK, 1/8) up to (64QAM, 5/6) using the standard LDPC codes. At high speed the 64QAM-modulated signals with high code rates cannot resist to channel variations therefore modulation order higher than 64QAM are not considered for high speeds.

4.6.2.3.9 Frequency bands and duplex modes

For the 900 MHz UIC band, 5 MHz bandwidth is assumed in FDD duplex mode. For the 1 900 MHz band, 10 MHz bandwidth is assumed in TDD mode.

4.6.2.3.10 Overhead

- Demodulation reference signals (DMRS) has the highest overhead and is intrinsically included in achievable throughput evaluation. Three DMRS symbols out of 14 were considered (21,4 % overhead) in the results which is a good trade-off between performance and overhead. Indeed, in case of moderate or low speed, it is possible to reduce this overhead to 7,14 % or 14,29 % by allocating one or two symbols for DMRS instead of three.

- Control channel overhead.

	FDD 5 MHz - 900 MHz	
Slot configuration	UL UUUUUUUUUUUUUUU	DL DDDDDDDDDDDDDD
Overhead	8 %	14 %

	TDD 10 MHz - 1 900 MHz	
Slot configuration	UL	DL
DFUUUUUUUUUUUU DDDDDDFFUUUUUU	8 %	14 %

The total overhead is 35 % in downlink and 29 % in uplink.

4.6.2.3.11 Uplink power control

Full path loss compensation is used for in the serving cell and in the neighbouring cells.

4.6.2.3.12 Aspects on resource sharing and scheduling

At each position in a cell, a train is allocated the whole bandwidth. This is equivalent a Round Robin time multiplexing. Indeed, a more realistic scheduling strategy can be used but this scheduling is useful for the sake of evaluating the achievable throughput per position. Otherwise, throughput per position would depend on the positions of other trains. In practice and especially in some scenarios such as rural environment (high speed) it is frequent to see only one train in a cell while in urban environments and especially in railway stations neighbourhood higher number of trains per cell can be observed and a more sophisticated scheduling could be required.

5 Evaluation

5.1 Evaluation Methodology

5.1.1 Common evaluation and analysis criteria

The analysis of performance should be according to the system simulations methodologies and assumption as per clause A.3.3.

5.1.2 Specific evaluation and analysis criteria

5.1.2.1 Company A

User throughput is used as the main Key Performance Indicator (KPI) in the present document. User throughput is calculated as the total number of correctly decoded bits divided by the total simulation time for each UE. It includes the effects of overhead, re-transmissions and scheduling of multiple UEs in a cell. Latency and packet reliability are not considered in the present document.

To understand how performance depends on the position along the track, user throughput and other metrics are calculated as a function of the distance between a UE and the closest BS. Since the system simulations are Monte Carlo-based with random generation of UE positions, performance as a function of distance is not obtained explicitly from the simulations. Therefore, to obtain performance as a function of distance, the following binning approach is taken:

1) For each UE, the distance to the closest BS is calculated.

2) All UEs in all cells and drops are grouped into distance bins so that the UEs in the same distance bin have roughly the same distance to its closest BS.

3) For each distance bin, a CDF of the performance metric, e.g. user throughput, over all UEs in the distance bin is calculated.

4) The 5 - and 50 - percentiles are extracted from the CDF in each distance bin. These percentiles are plotted as a function of the average distance of each distance bin.

Note that the closest BS may not be the serving BS since the shadow fading can be different to different sites. UEs in the same distance bin can have quite large difference in performance since UEs from different cells and drops can experience different channel conditions (e.g. LoS/NLoS, shadow fading, angular spread, delay spread, etc.) and interference. The 5 -percentile represents the worst performance (excluding outliers) and the 50 -percentile represents typical performance in each distance bin.

Particular attention is paid to cell-edge performance in the network. This is defined herein as the performance in the last distance bin, i.e. the distance bin closest to the geometrical cell border. Due to the high requirements on reliability, the 5 -percentile in the last distance bin is of special interest. This corresponds to a UE in a bad position, having poor channel conditions and/or high interference. Note that this 5 -percentile cell-edge performance is a much more pessimistic KPI than what is typically used in system simulations of cellular networks, where often the 5 -percentile over all UE positions in the network is used, not just the ones close to the geometrical cell border. Figure 10 illustrates how 5 -percentile cell-edge user throughput is obtained. The plot shows 5 -percentile throughput as a function of distance for 4, 6 and 8 km ISD, respectively. The 5 -percentile cell-edge throughput, i.e. the value in the last distance bin, is indicated in Figure 10.

The size of the distance bin is a trade-off between statistical accuracy (i.e. the number of UEs in each bin) and the distance resolution. Typically, 200 m distance bins are used, but for cases with small ISD, the distance bins are smaller. With 200 m distance bins the number of UEs in each bin is in the order of 1 000.

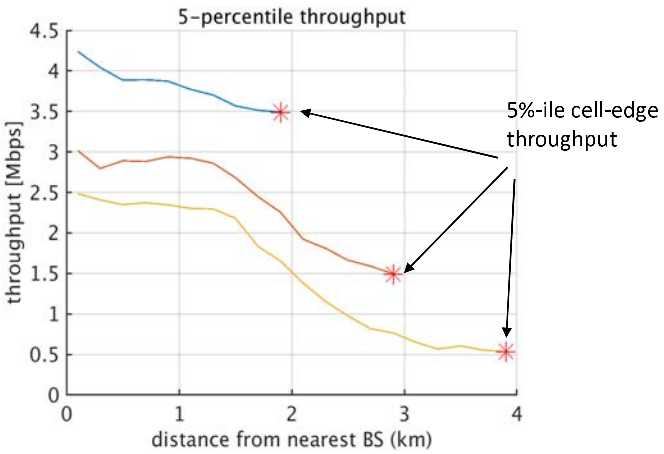


Figure 10: Illustration of how 5 -percentile cell-edge throughput is obtained

Other metrics that are considered in the present document are:

- ***Spectral efficiency***. This is calculated as the total number of correctly decoded bits divided by the scheduled time and nominal system bandwidth. Hence, only the slots in which a UE has been scheduled is considered. Therefore, it does not capture the effect that the time-frequency radio resources have to be shared between UEs when there is more than one UE in a cell. Overhead is not included in the spectral efficiency.
- ***Signal-to-noise ratio (SNR), signal-to-interference-and-noise ratio (SINR), and interference-to-noise ratio (INR).*** Unless otherwise stated, this is calculated from the received signal and interference power on UE/BS antenna port 0, i.e. before the receiver. This means that transmit precoding is included in the calculation but not the receiver combining. The received power is averaged over the system bandwidth and the entire simulation time.

5.1.2.2 Company B

In the simulation time and movement of the trains is simulated. The trains are randomly placed along each track, according to the following distance limits between each train. Four minutes of real-world time and movement is simulated.

Due to the way the simulator works, two kinds of statistics gathering is used: location based (e.g. SINR at a location), and time based (e.g. user throughput in kbps). The location-based statistics are set up for 100 metre sampling size and are aggregated based on the inter-site distance. 100 metre grouping is set up along the inter-site distance, and the values are aggregated into those. For the time based, these are, again, matched to location based on the inter-site distance and aggregated into 100 metre grouping in post-processing of the simulation results. This is done to conform to the 100 metre EIRENE recommendation.

The main Key Performance Indicator (KPI) is the number of successfully transmitted (i.e. correctly decoded) bits per each user equipment on the cell edge. Within the previously mentioned 100 metre groupings a CDF of the samples is generated, and the 5^{th} and 50^{th} percentile values are taken from each of these CDFs to be plotted. The usual definition of cell edge throughput, 5^{th} percentile value of the throughput CDF generated for the whole cell, is not used here, instead from the furthest grouping the 5^{th} percentile value is used to show the worst case results, and the 50^{th} percentile is used to show the general expected values. As mentioned before, this is much more pessimistic than general, and yields a significantly worse value.

Other statistics:

- Signal to Interference and Noise Ratio (SINR) values.
- Interference to Noise Ratio (INR) values are also shown for the whole cell, cell centre (within 30 metres from the base station location) and cell edge (30 metre from the ISD/2 location, or the geometric cell edge). Only the 5^{th}, 50^{th} and 95^{th} percentile values are shown from these CDFs for the sake of space.

Where applicable and unless mentioned otherwise, the statistics were taken at the receiver.

5.1.2.3 Company C

Link level evaluations are given in terms of Block Error Rate (BLER) per modulation and coding scheme. BLER, which is mapped to throughput considering Demodulation Reference Signals (DMRS) overhead, (three symbols out of 14 are allocated for DMRS ~ 21,5 % overhead). The maximum achievable throughput is then obtained from the MCS offering the highest throughput.

System level simulations accounts for interference from neighbouring cells. Interference is captured through Cumulative Density Function of interference power as well the Interference over Noise ratio (INR) per position.

Signal to interference and noise ratio (SINR) is accounted according to the channel models described above in clause 4.6.2.1.1 and SINR 5 %-ile and 50/-ile are calculated over a 100 metre sliding window with a step of 10 m, which makes performance non-sensitive to small changes in train position.

Net throughput performance is provided including both reference signals (DMRS) and control channels overheads.

Frequency reuse for interference mitigation:

- For comparison with results from companies A and B (deploying frequency reuse 1), results of frequency reuse 1 from the tables in clause 6.1.3 should be used.

- For evaluation of achievable performance, hard frequency reuse 2 and 3 are considered together with frequency reuse 1 in a case-by-case manner (especially on cell edge) as a potential interference mitigation technique. Indeed, the drawback of hard frequency reuse can be seen in cell centre where the throughput is limited by the reduced allocated bandwidth. In practice, this can be avoided by using soft frequency reuse scheme, interference coordination and appropriate scheduling.

6 Simulation Results

6.1 Results description for 900 MHz

6.1.1 Company A

6.1.1.1 Rural UL 8 km ISD/2 cells site

6.1.1.1.1 Analysis of Results

Figure 11 shows 5 - and 50 -percentile throughput as a function of distance for the rural scenario at 900 MHz with 5 MHz bandwidth, 31 dBm max UE Tx power, and different MIMO configurations. It shows the 5 - and 50 -percentile cell-edge throughput for 23 dBm and 31 dBm max UE TX power. The maximum UE Tx power has a strong impact on performance, especially on the 5 -percentile cell-edge throughput. It can also be seen that increasing the number BS Rx antenna ports from 2 to 4 gives a significant increase in performance. This is mainly due to that the BS effective antenna area is increased when going from 2 to 4 antenna ports, leading to more received energy. It also increases the possibilities for higher transmission rank. This can be seen in Figure 13 which shows the CDF of the average transmission rank for each UE. Increasing the number UE Tx antennas also improves performance, but not as much as increasing the number BS Rx antennas. This is expected since the transmitter has less detailed channel knowledge than the receiver.

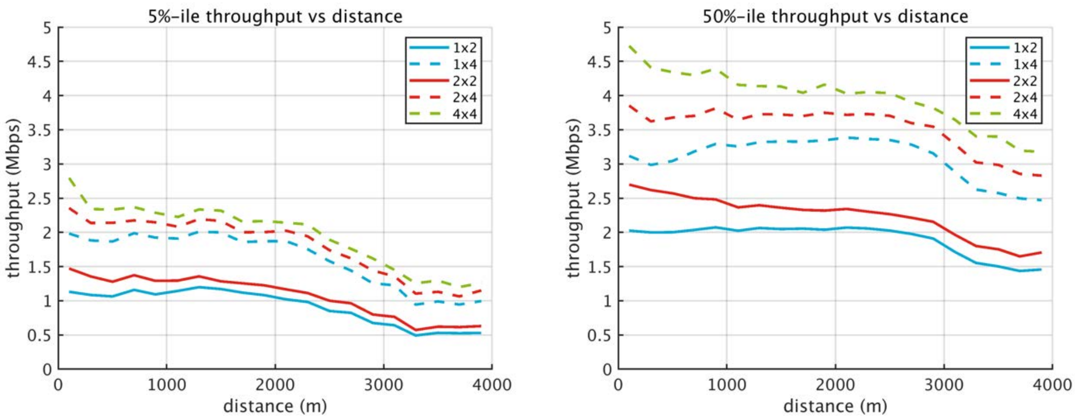


Figure 11: 5 - and 50 -percentile throughput as a function of distance for 31 dBm max UE Tx power and different MIMO configurations, 5 MHz bandwidth

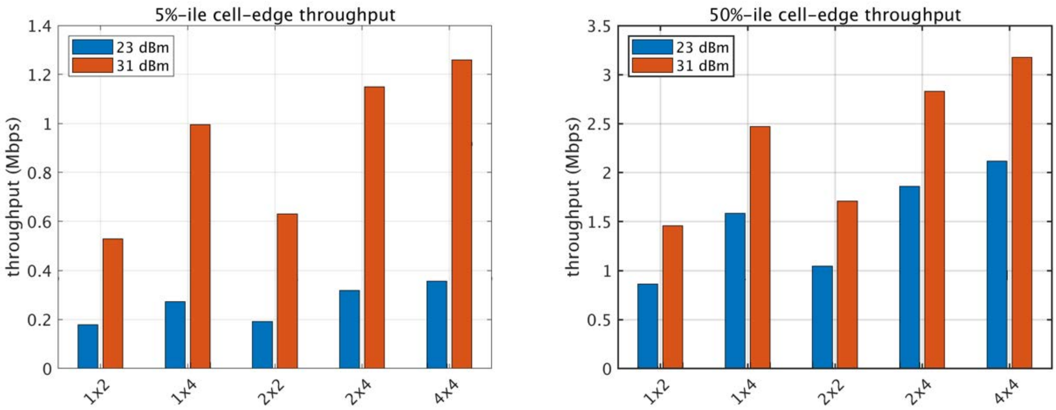


Figure 12: 5 - and 50 -percentile cell-edge throughput for 5 MHz bandwidth and different MIMO configurations ISD 8 km

Figure 13 shows the SNR, SINR, and INR for BS antenna port 0 as a function of distance for the 2x2 MIMO configuration. These are calculated from the power received from the desired UE and the interfering UEs scheduled in other cells. It is the received power on a single antenna port before the receiver. Therefore, any interference suppression in the receiver is not considered in this SINR metric. The SNR and INR for each UE is first calculated for each time slot and then averaged over all time slots The UEs are then put into 200 m distance bins and a CDF over all UEs in each distance bin is calculated. The SNR plot shows the 5 - and 50 -percentile in the CDF for each distance bin while the INR plots shows the 95 - and 50 -percentile to illustrate worst-case and typical behaviour. These plots can be used to investigate whether performance is mainly limited by noise or by interference. However, this is only a rough estimate since the interference suppression in the receiver is not seen here. The SINR improvement by the receiver is investigated in clause A.3.1.2. Furthermore, an overall comparison of SNR, SINR, and INR distributions between different scenarios are summarized in clause A.3.1.1. It should also be noted that the antenna gain per port can be different for different frequency bands and antenna configurations and this will have an impact on the SNR, SINR, and INR plots shown here.

For 23 dBm UE Tx power the signal power is well above both noise and interference for short distances. For longer distances, the 5 -percentile signal power is more than 5 dBm lower than the noise level. The median interference level is around 10 dBm below the noise level for all distances. For a typical UE, the performance is therefore noise limited. However, for the worst interfered UEs (95 -percentile), the interference level is around the same level as the thermal noise. Increasing the UE Tx power to 31 dBm improves the SNR and SINR significantly for UEs far away from the BS. It also increases the interference level by approximately 5 dBm over all distances. More UEs are therefore interference limited compared to the 23 dBm case. The SNR for short distances is not improved by the increase in UE Tx power since those UEs achieved their target SNR already with 23 dBm power. However, since other UEs that could not achieve their target SNR with max 23 dBm power will transmit with higher power when the max power increases to 31 dBm and thereby generate more interference. Therefore, the SINR for the UEs close to the BS will decrease when the max UE power is increased.

It can be seen in Figure 13 that the received interference power does not have a strong dependence on distance. This is expected since the locations and strengths of the interferers in the other cells are in principle not dependent on the position of the UE that has been scheduled in the own cell. However, there is an indirect dependence between the locations of trains in adjacent cells since there is a constraint on the minimum distance between trains on the same track.

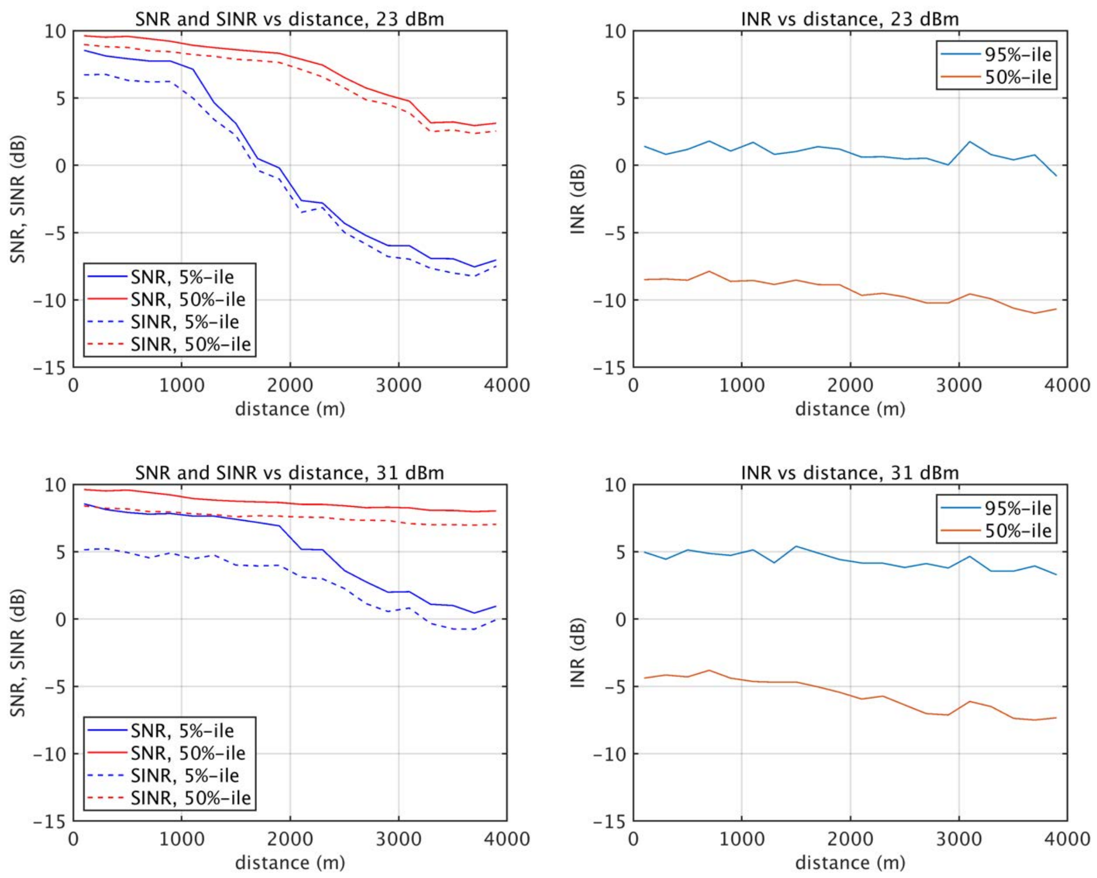


Figure 13: SNR, SINR, and INR for BS antenna port 0 (before the receiver) as a function of distance for 2x2 MIMO configuration and 30 m antenna height. Top: 23 dBm max UE Tx power. Bottom: 31 dBm max UE Tx power

6.1.1.1.2 Table Summary of Results for 8 km ISD Rural UL 900 MHz in kbps

MIMO	23 dBm 5 -percentile	23 dBm 50 -percentile	31 dBm 5 -percentile	31 dBm 50 -percentile
2x2	191	1 043	630	1 706
2x4	318	1 856	1 150	2 824
1x2	179	859	523	1 458
1x4	273	1 584	995	2 470
4x4	356	2 116	1 259	3 176

6.1.1.2 High Density Urban UL 4 km ISD/2 cells/site

6.1.1.2.1 Analysis of Results

Figure 14 shows 5 - and 50 -percentile cell-edge throughput for the urban scenario at 900 MHz with 5 MHz bandwidth for different MIMO configurations and maximum UE Tx power. Comparing to the corresponding results for the rural scenario at 900 MHz in clause 6.1.1.1.1, it can be seen that performance is lower for the urban scenario despite that the ISD has been reduced to 4 km compared to 8 km in the rural scenario. One reason for this is that the path loss is higher for the urban scenario. This is caused by several effects:

- The LoS probability is lower in the UMa channel model compared to the RMa channel model. This is shown in Figure 15. The LoS path loss is higher for the urban scenario for distances beyond 600 m. This can be seen in the left plot in Figure 14. This is due to that the break point distance is at 600 m for the urban scenario and at 2,3 km for the rural scenario. The shorter break point distance in the urban scenario is due to that the antenna height is lower and that the break point distance occurs at a shorter distance in the UMa channel model compared to the RMa channel model.

- The NLoS path loss is higher for the urban scenario. This can be seen in the right plot in Figure 16. This is partly due to that the lower antenna height in the urban scenario gives higher NLoS path loss. Another reason for the higher path loss is that the average building height is higher in the UMa channel model. The path loss for RMa at 4 km is actually 6,5 dBm lower than the path loss for UMa at 2 km distance, so UEs at the geometrical cell-edge have a better link budget in the rural scenario even though the ISD is twice that of the ISD in the urban scenario.

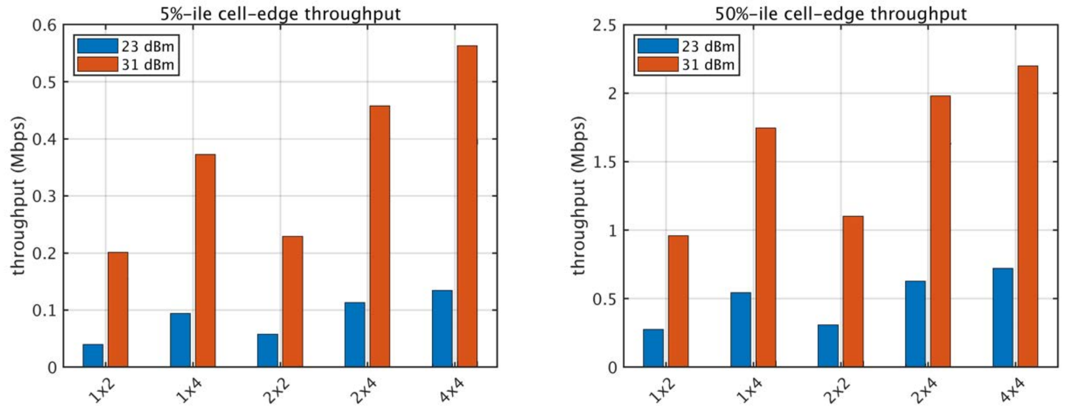


Figure 14: 5 - and 50 -percentile cell-edge throughput for 5 MHz bandwidth and 18 m antenna height

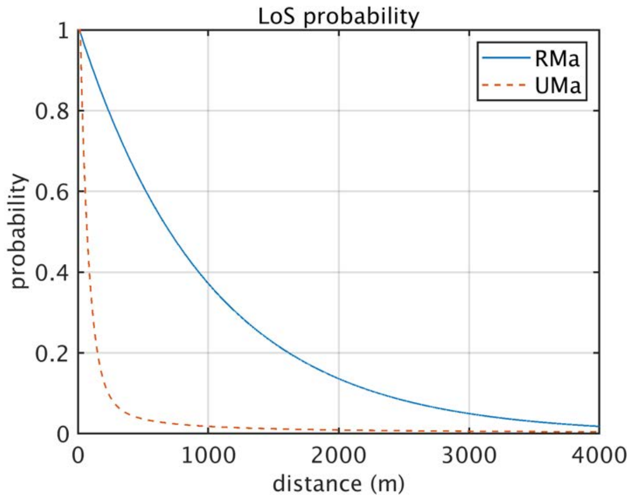


Figure 15: LoS probability as a function of distance for the RMa and UMa channel models, respectively

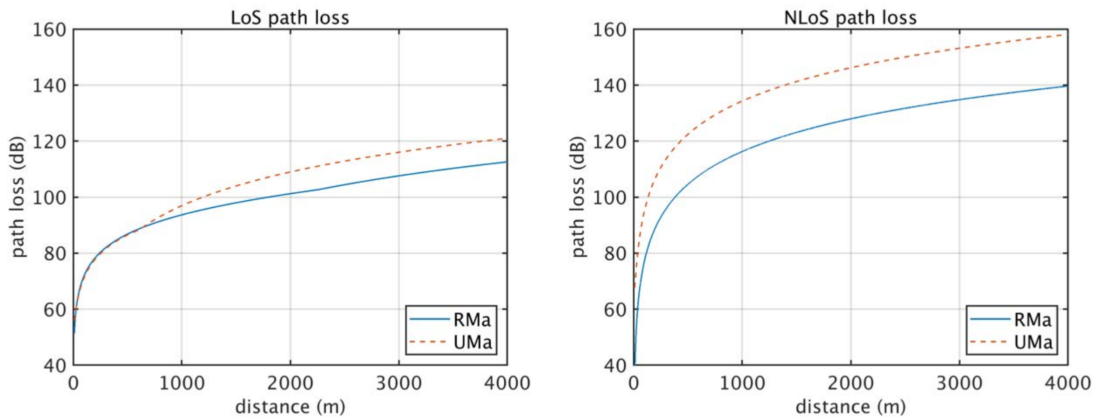


Figure 16: LoS (left) and NLoS (right) path loss as a function of distance for RMa and UMa

Figure 17 shows CDFs of path gain for the rural and urban scenarios obtained from system simulations using a 1x2 MIMO configuration. Most UEs have a significantly higher path gain in the rural scenario despite that the ISD is 8 km in the rural scenario compared to 4 km in the urban scenario.

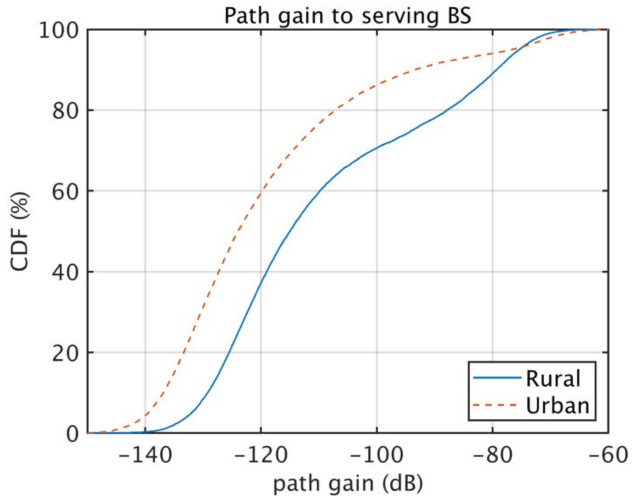


Figure 17: CDFs of path gain for the rural and urban scenario, 1x2 MIMO configuration. Antenna height = 30 m in rural and 18 m in urban

Figure 18 shows SNR, SINR, and INR as a function of distance for 18 m antenna height and 2x2 MIMO. The urban scenario is even more noise limited than the corresponding rural scenario. The received signal power from UEs at the cell-edge is very low with 23 dBm power, explaining the poor cell-edge performance for this case.

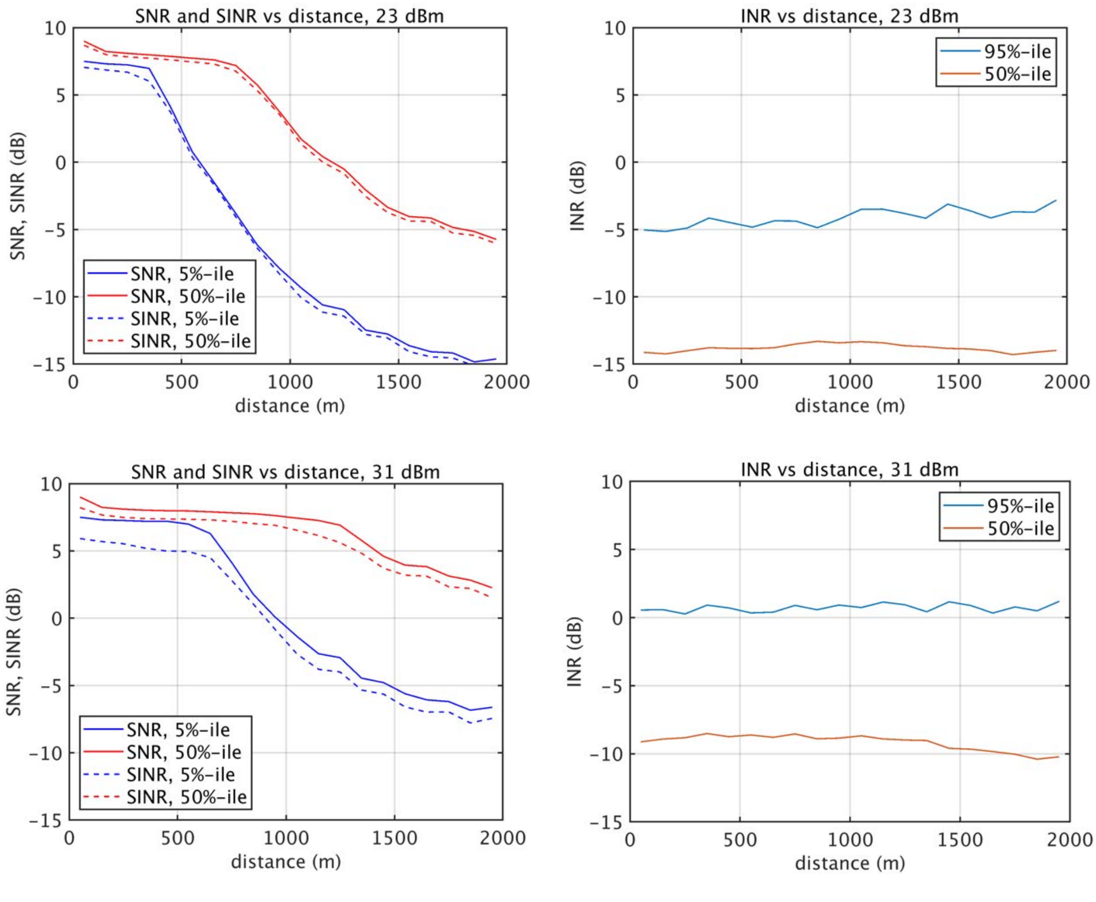


Figure 18: SNR, SINR and INR for BS antenna port 0 (before the receiver) as a function of distance for 2x2 MIMO configuration and 18 m antenna height

Figure 19 shows a comparison of the SINR as function of distance for the rural and urban scenarios at 900 MHz. The SINR decreases more rapidly with distance in the urban scenario due to the higher path loss. A physical interpretation of this model property is that the propagation is more obstructed by buildings in the urban scenario.

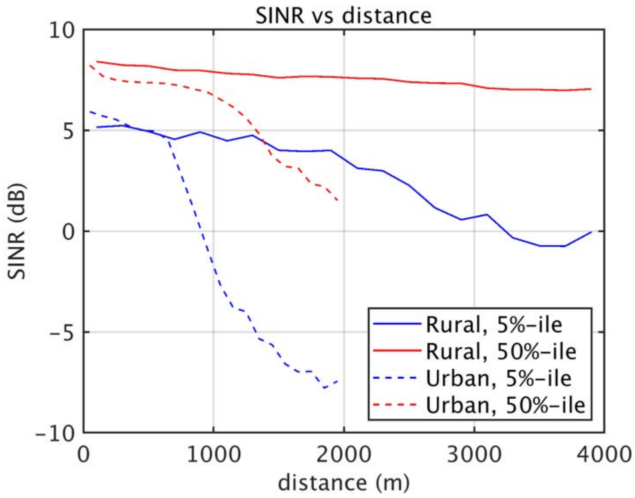


Figure 19: SINR for BS antenna port 0 as a function of distance to closest BS for 2x2 MIMO configuration and 31 dBm UE Tx power. Comparison of the rural and urban scenarios at 900 MHz

6.1.1.2.2 Urban Uplink 4 km ISD UL power Summary of Results in kbps

MIMO	23 dBm 5 -percentile	23 dBm 50 -percentile	31 dBm 5 -percentile	31 dBm 50 -percentile
2x2	57	307	229	1 100
2x4	112	626	457	1 978
1x2	39	273	200	957
1x4	93	542	372	1 744

6.1.1.2.3 High Density Urban UL 2 km ISD/2 cells/site

MIMO	23 dBm 5 -percentile	23 dBm 50 -percentile	31 dBm 5 -percentile	31 dBm 50 -percentile
2x2	822	2 845	1 982	3 431
2x4	1 764	4 981	3 626	5 980
1x2	700	2 573	1 826	3 117
1x4	1 442	4 072	3 275	4 642

6.1.1.3 Rural DL 8km ISD/2 cells/site

6.1.1.3.1 Analysis of Results

In order to investigate the interference and noise situation in this scenario for the DL, the SNR, SINR and INR for port 0 are compared as a function of distance for the 2x2 MIMO configuration with 5 MHz bandwidth in Figure 20. Note again that the signal, interference and noise power is measured at UE antenna port 0, therefore, receiver combining and interference suppression is not considered. These metrics are calculated with the same binning approach as described in the UL analysis.

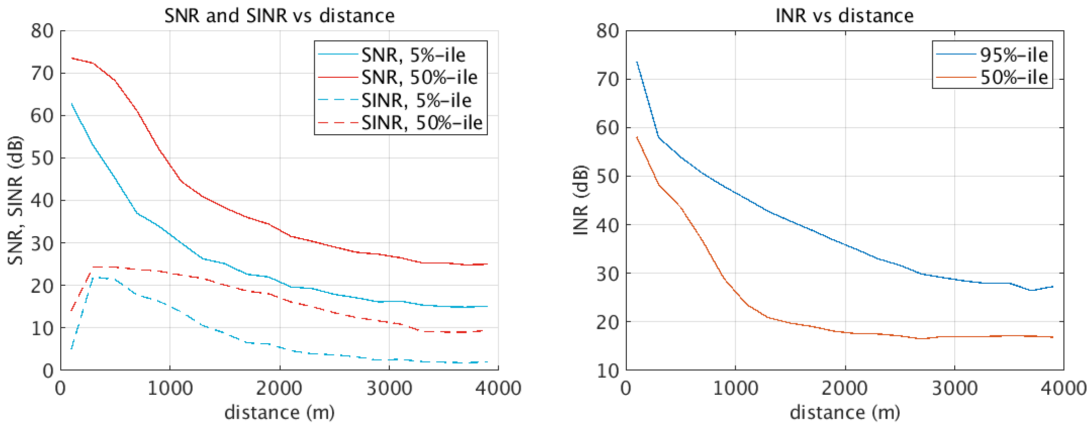


Figure 20: SNR, SINR, and INR for UE antenna port 0 (before the receiver) as a function of distance for 2x2 MIMO configuration and 30 m BS height

Unlike in the UL, where the INR has relatively small variation over distance, the INR in DL has a strong dependence on distance. Interference is stronger when close to the BS and gradually gets weaker as distance increases. In general, the DL scenario is interference-limited, even for cell-edge where interference is around 20 dB higher than noise. One major reason is that in DL the BSs constantly transmit with full power, which is different from UL where power control is applied. It can also be seen that the strongest interference happens for trains with short distance to BS. Such interference comes from the back lobe of the co-sited BS, which has similar propagation condition as the serving BS. As distance increases, this dominating co-sited interferer gets weaker and thus the INR decreases. Then, the INR flattens when the train gets closer to the cell-edge, this is because the secondary interferer which comes from opposite-facing BS will get stronger, compensating the weakening co-sited interferer.

The SNR in this scenario becomes lower when the train is farther away from the BS. This is mainly due to path gain's dependence on distance. However, the SINR shows a different behaviour for the first few hundred meters. More specifically, the SINR firstly increases and then decreases as distance increases. The increase for the first few hundred meters is caused by the difference in antenna gains for signal and interference. To explain this, the trajectories of signal and interference gain is plotted in the 2-D antenna pattern in Figure 21 as a train moves from x = 0 to x = 500 m, where 0 dBm corresponds to the antenna peak gain. It is noted that signal and interference experience different antenna gain variations within this distance interval, which is more visible to the left in Figure 22. For desired signal, it firstly comes from the quadrant sidelobe floor and then gradually switches to the main lobe peak. For interference, it firstly comes from the quadrant sidelobe floor and then gradually switches to the backlobe. The relative gain variation in signal and interference makes the effective signal-to-interference ratio, excluding path loss, as seen to the right in Figure 22. As interference is dominating over noise for short distances to the BS, the SINR behaves similar as SIR, therefore there is an increase when train is close the BS.

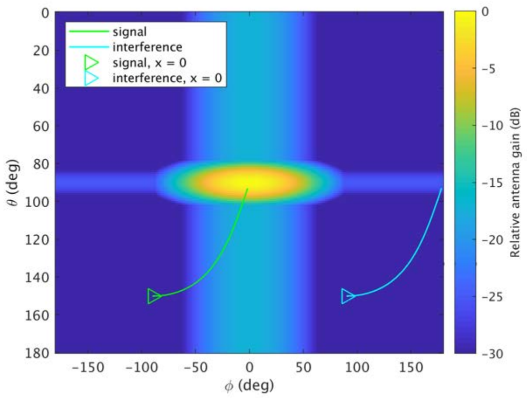


Figure 21: The trajectories of signal and interference gain in the 2-D antenna pattern as a train moves from x = 0 to x = 500 m

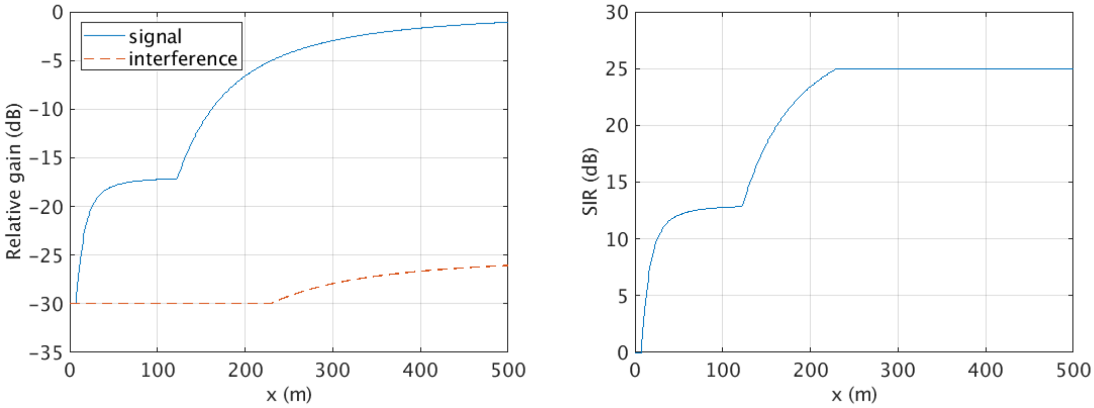


Figure 22: Relative antenna gain of signal and interference (left) and the SIR without path loss (right) as a train moves from x = 0 to x = 500 m

Figure 23 shows the 5 - and 50 -percentile throughput as a function of distance between a train and its closest BS, for the rural scenario at 900 MHz with 5 MHz bandwidth and 46 dBm Tx power. The legend "4x2" denotes 4 antenna ports at the BS and 2 antenna ports at the train. It is noted that the throughput will first increase and then decrease as a train is moving away from the BS. This is basically the same behaviour as seen for the SINR. It is also observed that increasing the number of Tx antenna ports from 2 to 4 at the BS side only provides marginal gain, while increasing the number of receive antennas at the train can improve the throughput significantly. Note that the 4x4 MIMO configuration in this clause is provided as reference and not intended for comparison purposes. Not all rolling stock can be fitted with four UE antennas. In DL, when increasing the number of transmit antenna ports, both the serving and the interfering BSs will get the same number of additional ports, moreover, as most trains are served and interfered from the main lobe of the serving and interfering BSs, respectively, both signal and interference will get roughly the same order of enhancement. Lastly, this scenario is interference-limited in the DL, thus, increasing only the number of Tx antenna ports does not help improving throughput. On the other hand, having more receive antenna ports at the train can be very helpful for interference rejection. Furthermore, having more Rx antenna ports will also help improve spatial multiplexing by supporting higher transmission ranks.

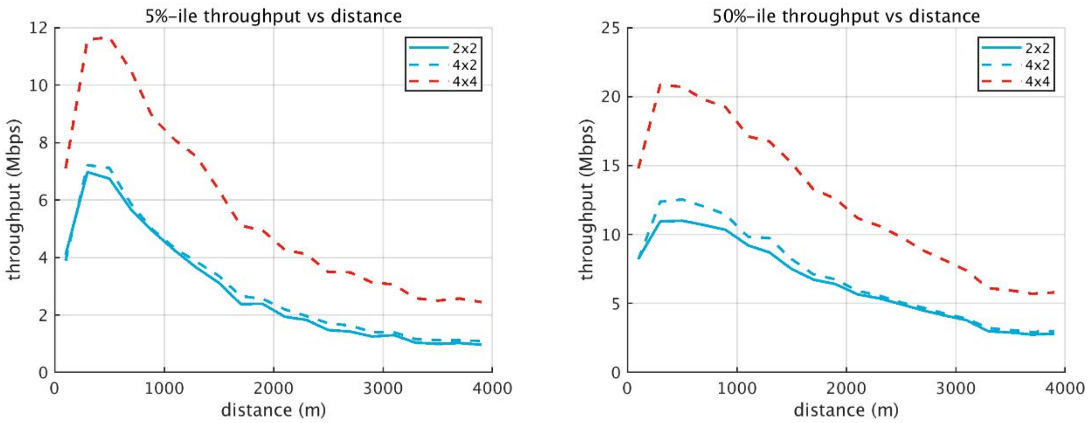


Figure 23: 5 - and 50 -percentile throughput as a function of the distance between train and the closest BS for different MIMO configurations

6.1.1.3.2 46 dBm Rural DL 900 MHz 8 km ISD

MIMO	5 -percentile	50 -percentile
2x2	964	2 820
4x2	1 097	3 007

6.1.1.4 High-Density Urban DL 4 km ISD/2 cells/site

6.1.1.4.1 Analysis of Results

The INR, SNR and SINR for the urban scenario with 900 MHz and the 2x2 MIMO configuration is plotted in Figure 24. Comparing the INR in the urban scenario with the INR in the rural scenario in Figure 20 it can be seen that the interference level is a bit lower for the urban scenario near cell-edge, despite the ISD is reduced from 8 km to 4 km. As explained in the UL analysis, this is due to that the path loss in the urban scenario is higher. Overall, however, DL in the urban scenario is still dominated by interference. The SNR and SINR demonstrate a similar behaviour as seen in the rural 900 MHz scenario. The SNR drops monotonically, while the SINR first increases and then decreases, as distance to BS increases. The increase in the first few hundred meters in SINR is due to a shift from a train being served by the side lobe to being served by the main lobe, whereas the decrease for both SNR and SINR is due to increased path loss. This is the same as in the rural scenario.

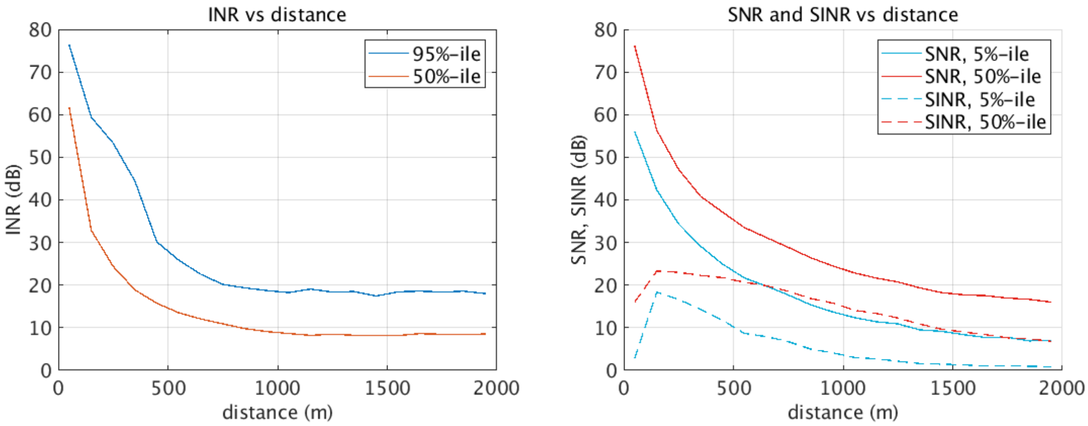


Figure 24: INR, SNR and SINR for UE antenna port 0 (before the receiver) as a function of distance for 2x2 MIMO configuration and 30 m antenna height

Figure 25 shows the 5 - and 50 -percentile throughput as a function of distance for the 900 MHz urban scenario with 46 dBm transmit power and different MIMO configurations. Like the rural scenario, doubling the number of transmit antennas provides only marginal improvement in throughput. This is because the interference may also be increased due to beamforming, as a train is most likely served and interfered from 0° angle in elevation. Doubling the number of receive antennas, as also seen in the rural scenario, can almost double the throughput, thanks to more spatial multiplexing layers and additional gain in interference suppression.

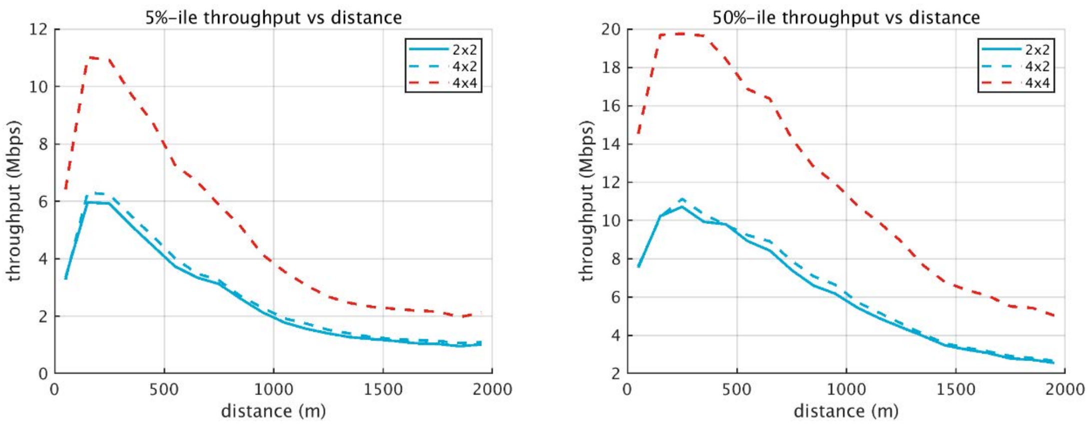


Figure 25: 5 - and 50 -percentile throughput as a function of the distance between train and the closest BS for different MIMO configurations

6.1.1.4.2 Table Summary of Results 900 MHz DL 4km ISD in kbps

MIMO	5 -percentile	50 -percentile
2x2	1 015	2 555
4x2	1 094	2 654

6.1.1.4.3 Table Summary of Results 900 MHz DL 2 km ISD in kbps

MIMO	5 -percentile	50 -percentile
2x2	2 000	6 000
4x2	2 100	6 100

6.1.2 Company B

6.1.2.1 Rural scenario: 8 KM ISD, 2 cells/site

As mentioned previously, these are the cell edge 5th and 50th percentile values.

Downlink

MIMO setup	5th percentile (kbps)	50th percentile (kbps)
2x1	1 210	2 100
2x2	1 400	2 300
4x1	1 330	2 350
4x2	1 450	2 500

Uplink, 23 dBm transmit power

MIMO setup	5th percentile (kbps)	50th percentile (kbps)
1x2	1 100	1 650
2x2	1 400	1 850
1x4	1 410	1 930
2x4	1 450	1 990

Uplink, 31 dBm transmit power

MIMO setup	5th percentile (kbps)	50th percentile (kbps)
1x2	1 400	1 830
2x2	1 500	1 950
1x4	1 590	2 100
2x4	1 630	2 230

6.1.2.2 Urban scenario: 2 KM ISD, 2 cells/site

Downlink

MIMO setup	5th percentile (kbps)	50th percentile (kbps)
2x1	530	1 830
2x2	700	2 400
4x1	590	1 930
4x2	810	2 560

Uplink, 23 dBm transmit power

MIMO setup	5th percentile (kbps)	50th percentile (kbps)
1x2	950	2 000
2x2	950	2 100
1x4	1 100	2 410
2x4	1 070	2 530

Uplink, 31 dBm transmit power

MIMO setup	5th percentile (kbps)	50th percentile (kbps)
1x2	1 380	2 300
2x2	1 370	2 370
1x4	1 550	2 510
2x4	1 580	2 580

6.1.2.3 Urban scenario: 4 KM ISD, 2 cells/site

Downlink

MIMO setup	5th percentile (kbps)	50th percentile (kbps)
2x1	170	610
2x2	300	970
4x1	250	830
4x2	410	1 040

Uplink, 23 dBm transmit power

MIMO setup	5th percentile (kbps)	50th percentile (kbps)
1x2	60	250
2x2	70	300
1x4	100	380
2x4	110	410

Uplink, 31 dBm transmit power

MIMO setup	5th percentile (kbps)	50th percentile (kbps)
1x2	180	620
2x2	170	690
1x4	210	740
2x4	230	770

6.1.3 Company C

6.1.3.1 Analysis of Results

In the following, results for 900 MHz FDD band with 5 MHz bandwidth are presented. The orange column corresponds to the 5 %-ile on cell edge which is the main criterion (worst-case performance). For every UL/DL power value, the underlined bolded row shows the frequency reuse scheme achieving best performance while keeping all the other simulation assumptions. For the cases where a higher reuse factor does not bring significant throughput gain on cell edge, lower reuse factor is preferred so that throughput reduction in cell centre is avoided. For a better understanding of the following, refer to the associated link level performance and interference statistics in Annex A of the present document.

6.1.3.2 Rural Area - ISD 8 Km - Uplink

2x2 MIMO						With potential HARQ gain	
Speed (km/h)	Freq Reuse factor	Max UL Power (dBm)	Cell Centre (Mbps)	Cell Edge 50 %-ile (Mbps)	Cell Edge 5 %-ile (Mbps)	Cell Edge 50 %-ile (Mbps)	Cell Edge 5 %-ile (Mbps)
350	1	23	11,84	8,61	1,33	11,01	3,87
700			5,89	5,89	1,18	5,89	3,59
350	2		5,92	5,92	5,03	5,92	5,92
700			**2,94**	**2,94**	**2,94**	**2,94**	**2,94**
350	3		3,95	3,95	3,87	3,95	3,95
700			1,96	1,96	1,96	1,96	1,96
350	1	26	11,84	9,47	1,84	11,60	5,03
700			5,89	5,89	1,81	5,89	4,27
350	2		5,92	5,92	5,77	5,92	5,92
700			**2,94**	**2,94**	**2,94**	**2,94**	**2,94**
350	3		3,95	3,95	3,95	3,95	3,95
700			1,96	1,96	1,96	1,96	1,96
350	1	31	11,84	9,81	3,50	11,84	6,22
700			**5,89**	**5,89**	**3,08**	**5,89**	**5,60**
350	2		5,92	5,92	5,92	5,92	5,92
700			2,94	2,94	2,94	2,94	2,94
350	3		3,95	3,95	3,95	3,95	3,95
700			1,96	1,96	1,96	1,96	1,96

Figure 26 shows how the different Reuse factors impact UL SINR, the cell edge 5 %-ile SINR in increased from -9 to 11 and 13,7 with respective reuse factor 1, 2 and 3. Similar observation can be made for 50 %-ile. The gain brought by reuse 3 is minor since most of the interference has been avoided.

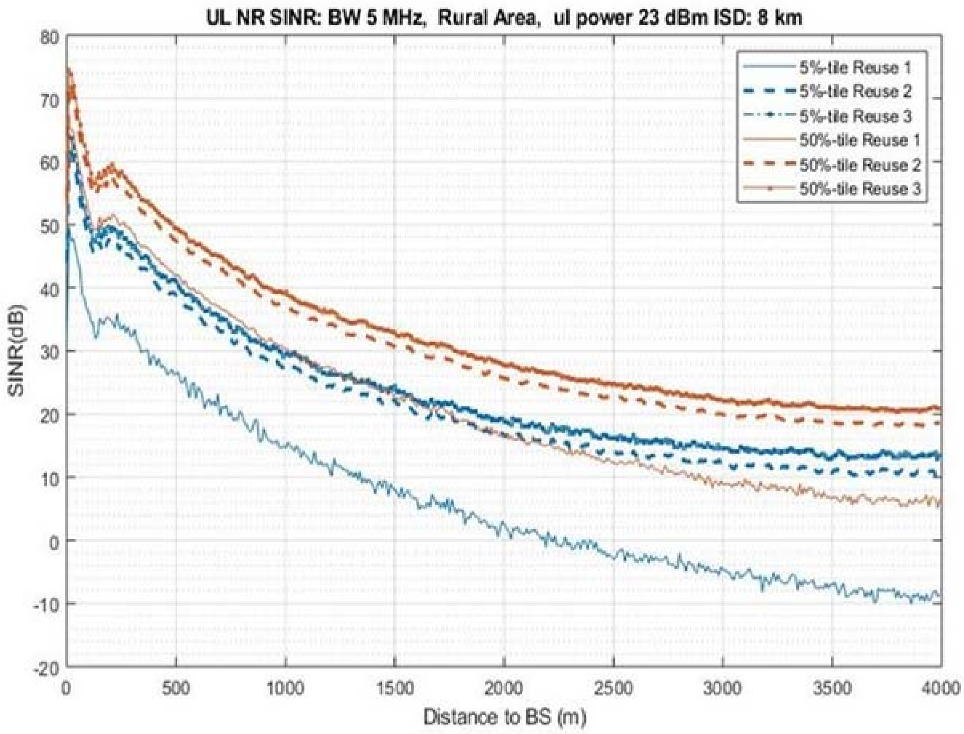


Figure 26: SINR variation with distance for different reuse factors, uplink Tx power 23 dBm

Observing final throughput, it can be seen that for reuse 2 and 3, the throughput is flat with distance. This is because of SINR saturation. In other words, even if the SINR drops with distance, with appropriate interference mitigation, SINR remains above the saturation SINR. Saturation SINR is the SINR above which maximum achievable throughput for a given scenario and configuration is reached. In this specific the achievable throughput is around 6,5 dBm (see Figure 28). Consequently, no variation with distance can be seen for reuse 2 and 3 (seeFigure 27).

The very low variation in throughput observed with distance and the very low variance between 5 %-ile and 50 %ile is then caused by the hard frequency reuse scheme. It can be observed in several other configurations for the same reason.

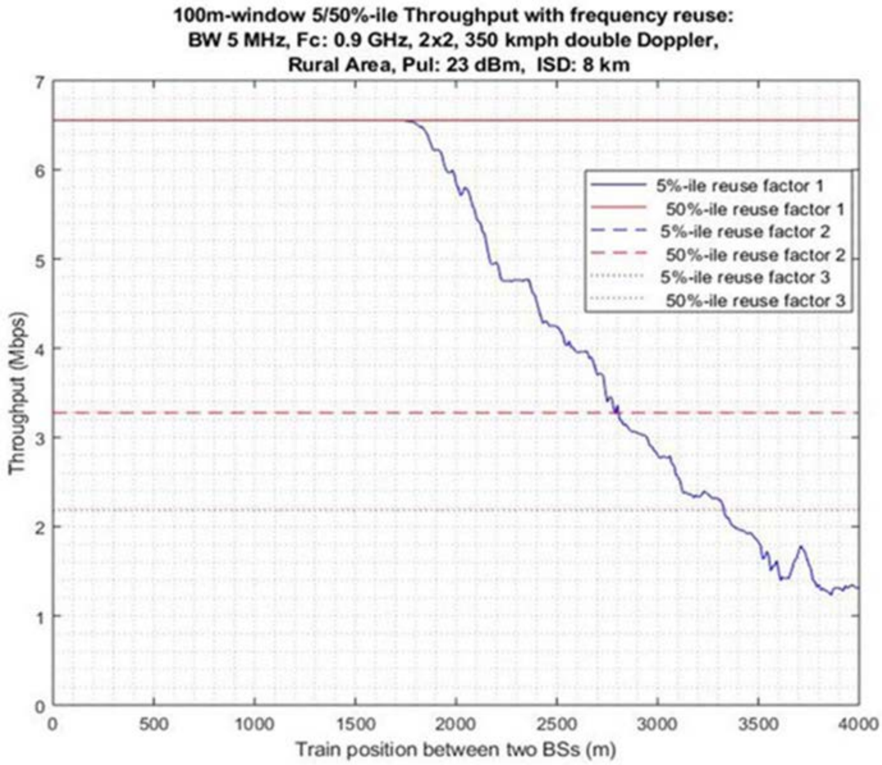


Figure 27: Throughput variation with distance for different reuse factors, uplink Tx power 23 dBm

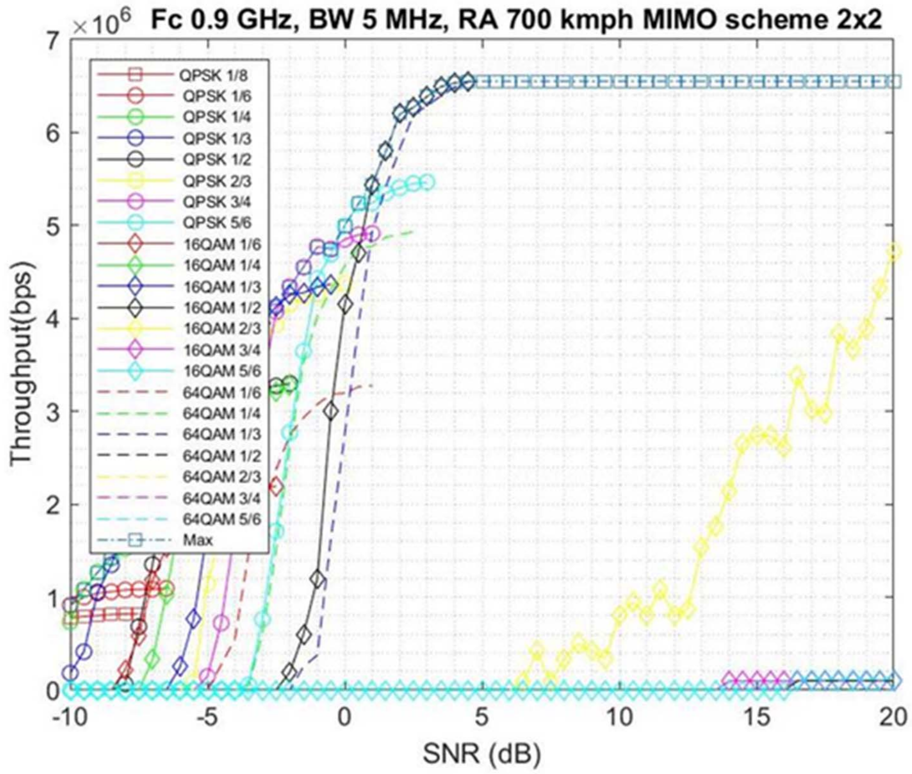


Figure 28: Link level performance and maximum achievable throughput in rural area with double Doppler 350 Km/h speed

6.1.3.3 Rural Area - ISD 8Km - downlink

2x2 MIMO						With potential HARQ gain	
Speed (Km/h)	Frequency reuse factor	Max DL power (dBm)	Cell Centre (Mbps)	Cell Edge 50 %-ile (Mbps)	Cell Edge 5 %-ile (Mbps)	Cell Edge 50 %-ile (Mbps)	Cell Edge 5 %-ile (Mbps)
350	1	46 dBm per antenna connector	10,84	5,45	0,55	8,83	2,62
350	**2**		**5,42**	**5,42**	**5,38**	**5,42**	**5,42**
350	3		3,61	3,61	3,61	3,61	3,61

6.1.3.4 Hilly Terrain - ISD 8Km - Uplink

2x2 MIMO						With potential HARQ gain	
Speed (km/h)	Frequency reuse factor	Max UL Power (dBm)	Cell Centre (Mbps)	Cell Edge 50 %-ile (Mbps)	Cell Edge 5 %-ile (Mbps)	Cell Edge 50 %-ile (Mbps)	Cell Edge 5 %-ile (Mbps)
350	1	23	11,82	2,15	0,00	4,51	0,00
700			7,78	1,90	0,00	4,13	0,00
350	2		5,91	4,21	1,80	5,85	2,95
700			**3,89**	**3,12**	**1,67**	**3,86**	**2,84**
350	3		3,94	3,14	1,47	3,94	2,49
700			2,59	2,46	1,36	2,56	1,97
350	1	26	11,82	2,75	0,00	5,42	0,27
700			7,78	2,60	0,00	4,64	0,20
350	2		5,91	4,62	2,08	5,91	3,65
700			**3,89**	**3,54**	**1,98**	**3,87**	**2,95**
350	3		3,94	3,63	1,88	3,94	2,89
700			2,59	2,53	1,66	2,59	2,21

2x2 MIMO						With potential HARQ gain	
Speed (km/h)	Frequency reuse factor	Max UL Power (dBm)	Cell Centre (Mbps)	Cell Edge 50 %-ile (Mbps)	Cell Edge 5 %-ile (Mbps)	Cell Edge 50 %-ile (Mbps)	Cell Edge 5 %-ile (Mbps)
350	1	31	11,82	3,76	0,00	6,40	0,95
700			7,78	3,65	0,00	5,84	0,90
350	2		5,91	5,66	2,94	5,91	4,65
700			**3,89**	**3,79**	**2,75**	**3,89**	**3,57**
350	3		3,94	3,93	2,41	3,94	3,71
700			2,59	2,56	1,97	2,59	2,52

6.1.3.5 Hilly Terrain - ISD 8 Km - downlink

2x2 MIMO						With potential HARQ gain	
Speed (Km/h)	Frequency reuse factor	Max DL power (dBm)	Cell Centre (Mbps)	Cell Edge 50 %-ile (Mbps)	Cell Edge 5 %-ile (Mbps)	Cell Edge 50 %-ile (Mbps)	Cell Edge 5 %-ile (Mbps)
350	1	46 dBm per antenna connector	10,81	1,22	0,00	3,26	0,00
350	**2**		**5,41**	**5,41**	**2,68**	**5,41**	**4,23**
350	3		3,60	3,60	2,87	3,60	3,60

6.1.3.6 Urban Area - ISD 2Km - Uplink

2x2 MIMO						With potential HARQ gain	
Speed (km/h)	Freq Reuse factor	Max UL Power (dBm)	Cell Centre (Mbps)	Cell Edge 50 %-ile (Mbps)	Cell Edge 5 %-ile (Mbps)	Cell Edge 50 %-ile (Mbps)	Cell Edge 5 %-ile (Mbps)
80	1	23	14,76	11,30	2,53	14,66	5,40
160			14,73	11,15	2,50	14,43	5,36
80	2		7,38	7,38	4,45	7,38	6,80
160			**7,36**	**7,36**	**4,37**	**7,36**	**6,40**
80	3		4,92	4,92	4,50	4,92	4,92
160			4,91	4,91	4,20	4,91	4,91
80	1	26	14,76	11,87	3,26	14,76	5,87
160			14,73	11,67	3,26	14,73	5,83
80	2		7,38	7,38	5,31	7,38	7,13
160			**7,36**	**7,36**	**5,24**	**7,36**	**7,07**
80	3		4,92	4,92	4,78	4,92	4,92
160			4,91	4,91	4,72	4,91	4,91
80	1	31	14,76	14,07	4,62	14,76	7,93
160			14,73	13,68	4,59	14,73	7,84
80	2		7,38	7,38	6,29	7,38	7,38
160			**7,36**	**7,36**	**6,05**	**7,36**	**7,36**
80	3		4,92	4,92	4,92	4,92	4,92
160			4,91	4,91	4,91	4,91	4,91

6.1.3.7 Urban Area - ISD 2Km - Downlink

2x2 MIMO						With potential HARQ gain	
Speed (Km/h)	Frequency reuse factor	Max DL power (dBm)	Cell Centre (Mbps)	Cell Edge 50 %-ile (Mbps)	Cell Edge 5 %-ile (Mbps)	Cell Edge 50 %-ile (Mbps)	Cell Edge 5 %-ile (Mbps)
80	1	46 dBm per antenna connector	13,50	2,53	0,00	5,16	0,50
80	2		6,75	5,20	1,67	6,73	2,95
80	**3**		**4,50**	**4,50**	**2,19**	**4,50**	**3,48**

6.1.3.8 Urban Area High Density - ISD 4Km - Uplink

2x2 MIMO						With potential HARQ gain	
Speed (km/h)	Freq Reuse factor	Max UL Power (dBm)	Cell Centre (Mbps)	Cell Edge 50 %-ile (Mbps)	Cell Edge 5 %-ile (Mbps)	Cell Edge 50 %-ile (Mbps)	Cell Edge 5 %-ile (Mbps)
80	1	23	14,76	6,55	0,80	10,93	2,77
160			14,73	6,48	0,80	10,68	2,77
80	2		7,38	5,81	2,22	7,38	3,94
160			**7,36**	**5,80**	**2,21**	**7,36**	**3,85**
80	3		4,92	4,72	2,28	4,92	3,77
160			4,91	4,58	2,22	4,91	3,72
80	1	26	14,76	5,90	0,64	10,24	2,38
160			14,73	5,84	0,64	10,04	2,38
80	2		7,38	5,82	2,16	7,38	3,88
160			**7,36**	**5,81**	**2,15**	**7,36**	**3,79**
80	3		4,92	4,78	2,43	4,92	3,86
160			4,91	4,72	2,42	4,91	3,86
80	1	31	14,76	5,32	0,31	8,64	1,72
160			14,73	5,30	0,28	8,43	1,71
80	2		7,38	5,77	1,98	7,38	3,60
160			**7,36**	**5,76**	**1,96**	**7,34**	**3,59**
80	3		4,92	4,88	2,45	4,92	3,87
160			4,91	4,79	2,43	4,91	3,86

6.1.3.9 Urban Area High Density - ISD 4Km - Downlink

2x2 MIMO						With potential HARQ gain	
Speed (Km/h)	Frequency reuse factor	Max DL power (dBm)	Cell Centre (Mbps)	Cell Edge 50 %-ile (Mbps)	Cell Edge 5 %-ile (Mbps)	Cell Edge 50 %-ile (Mbps)	Cell Edge 5 %-ile (Mbps)
80	1	46 dBm per antenna connector	13,50	2,49	0,00	5,12	0,41
80	2		6,75	5,12	1,64	6,69	2,90
80	**3**		**4,50**	**4,50**	**2,10**	**4,50**	**3,45**

6.2 Results description for 1 900 MHz

6.2.1 Company A

6.2.1.1 Rural UL

6.2.1.1.1 Analysis of Results

Figure 29 shows 5 - and 50 -percentile throughput as a function of distance for the rural scenario at 1 900 MHz with 10 MHz bandwidth, 31 dBm max UE Tx power, 30 m antenna height, 15 kHz subcarrier spacing, 90/10 UL/DL ratio and different MIMO configurations. Figure 29 shows the 5 - and 50 -percentile cell-edge throughput for 23 and 31 dBm max UE TX power. Increasing the number of Rx antennas gives a high increase in both 5 - and 50 -percentile throughput. However, doubling the number of Rx antennas from 4 to 8 does not give as much gain as doubling from 2 to 4. This is due to that the effective antenna area is not increased when going from 4 to 8 antenna ports. A possible explanation for the performance increase in this case can be that more Rx antenna ports can improve the interference suppression. The max UE Tx power has a strong impact on the 5 -percentile but not so much on the 50 -percentile throughput. This is because this scenario is not as power limited as the Rural 900 scenario which has 4 km ISD compared to 2 km in the Rural 1 900 scenario.

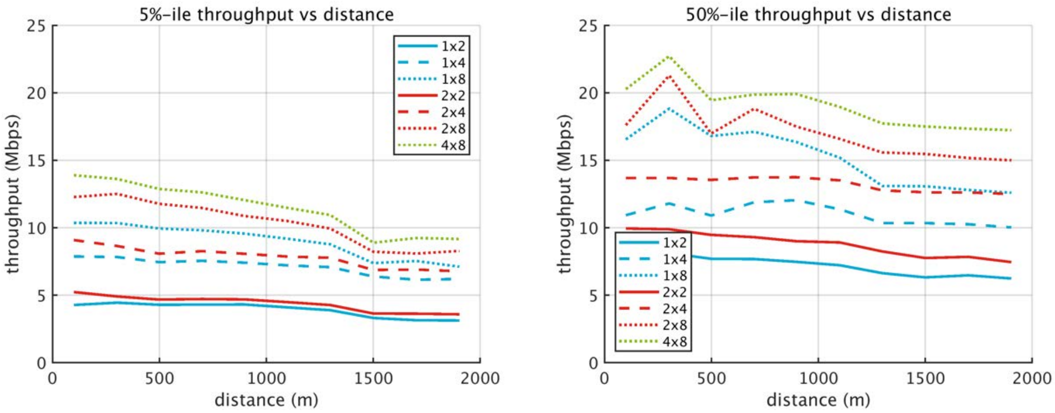


Figure 29: 5 - and 50 -percentile throughput as a function of distance for 10 MHz bandwidth, 31 dBm max UE Tx power, 30 m antenna height, 15 kHz subcarrier spacing, 90/10 UL/DL ratio and different MIMO configurations

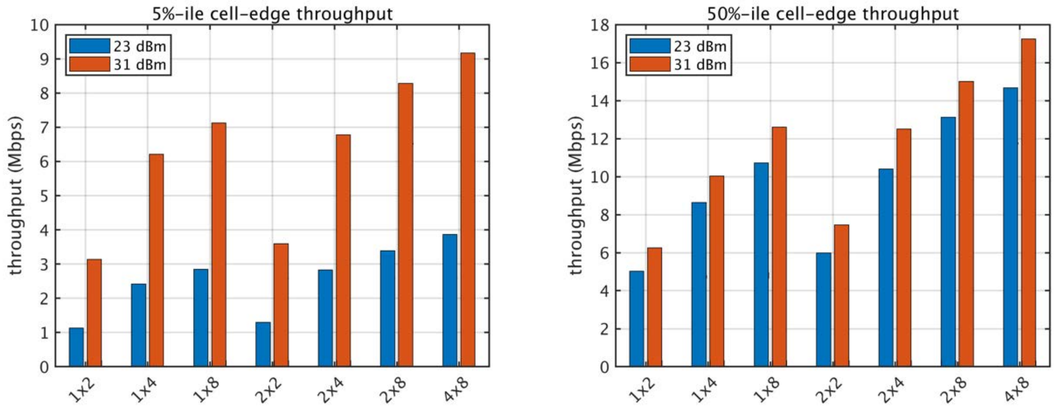


Figure 30: 5 - and 50 -percentile cell-edge throughput for 10 MHz bandwidth, 30 m antenna height, 15 kHz SC spacing, and 90/10 UL/DL ratio

To dwell further upon this, Figure 31 shows the NLoS and LoS path loss for the RMa channel model at 900 and 1 900 MHz, respectively. The frequency dependence of the path loss in the RMa channel model is $20\log_{10}(f)$, i.e. the same dependence as free-space path loss. The frequency dependence of free-space path loss here is however not due to that free-space wave propagation frequency dependency. It is due to that the path loss model is assuming isotropic Tx and Rx antennas and the effective antenna area is frequency dependent. An isotropic Rx antenna will receive less power at a higher frequency because its effective antenna area is smaller. There is another frequency dependence in the RMa path loss model; the break point distance in the LoS path loss model. This distance depends linearly on frequency and is in the rural scenario at 2,3 km for 900 MHz and at 4,8 km for 1 900 MHz. Therefore, for distances larger than 2,3 km, the difference between the 900 and 1 900 MHz LoS path loss will be smaller than given by the $20\log_{10}(f)$ dependence.

At the cell-edge, path loss is mainly determined by the NLoS path loss since the LoS probability in the RMa channel model is low at large distances (14 at 2 km and 2 at 4 km). Comparing the NLoS path loss at the geometrical cell-edge (4 km) for 900 MHz with the geometrical cell-edge (2 km) for 1 900 MHz, Figure 31 shows that the path loss is 5 dBm higher at the cell-edge for the 900 MHz scenario than at the cell-edge for the 1 900 MHz scenario. For 30 m antenna height, the path loss exponent in the RMa NLoS path loss model is 3,9. Reducing the ISD from 4 to 2 km for fixed frequency will therefore decrease the path loss at the geometrical cell-edge by $39\log_{10}(4/2) = 11{,}7$ dB. Increasing the frequency from 900 to 1 900 MHz for fixed distance will increase the path loss by $20\log_{10}(1\ 900/900) = 6{,}5$ dB. Hence, the cell-edge path loss will be 11,7 - 6,5 = 5,2 dB lower for the 1 900 MHz scenario. Furthermore, the antenna gain per port is 2 dB higher at 1 900 MHz for the 2- and 4-port BS antenna which will give additional gain to UEs that are sufficiently far away from the BS (so that they are close to the main lobe peak in elevation). The 8-port BS antenna at 1 900 MHz can apply elevation beamforming and gain 3 dBm over the 4-port BS antenna at 900 MHz.

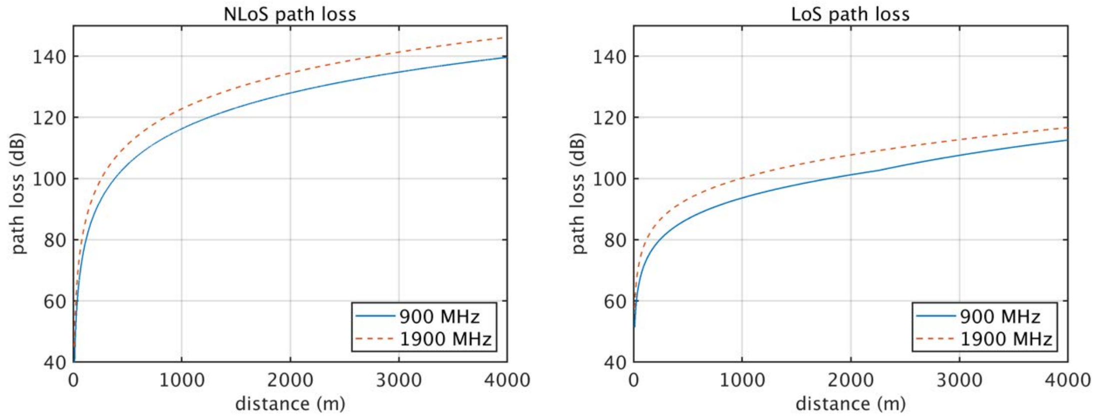


Figure 31: NLoS (left) and LoS (right) path loss as a function of distance for the RMa channel model at 900 MHz and 1 900 MHz, respectively

In order to compare with results from system simulations, Figure 32 shows CDFs of path gain to the serving BS for 900 and 1 900 MHz, respectively. Most UEs have higher path gain at 1 900 MHz. At the 5 -percentile the difference is approximately 7 dB. This agrees with the calculations above since the UEs around the 5 -percentile are likely to be close to the geometrical cell-edge where the path loss is 5 dBm lower and the antenna gain is 2 dB higher for 1 900 MHz. Of course, not all UEs will have higher path gain at 1 900 MHz since for a given position and shadow fading realization, the path loss will be higher at 1 900 MHz. Note that the serving BS is not necessarily the closest BS since the shadow fading can be different to different BSs. These results show that the Rural 900 scenario is more power-limited than the Rural 1900 scenario.

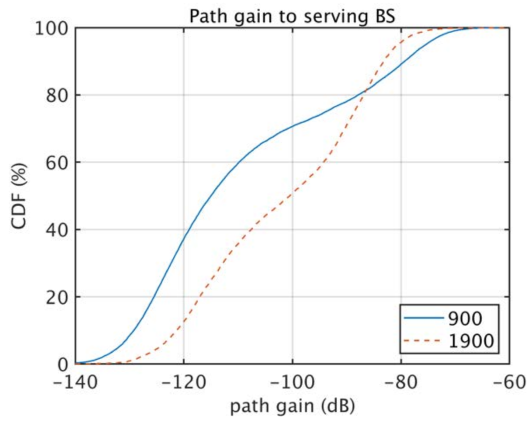


Figure 32: CDFs of path gain for 900 and 1 900 MHz, respectively. 1x2 MIMO, 30 m antenna height, 5 MHz bandwidth

Figure 33 shows SNR, SINR and INR for BS antenna port 0 as a function of distance for 30 m antenna height, and 2x2 MIMO. Like the results for 900 MHz in the overall system performance is mainly noise limited also in this case, although the worst interfered UEs can receive significant interference power. It can also be seen that the cell-edge UEs have higher SNR at 1 900 MHz due to the shorter ISD.

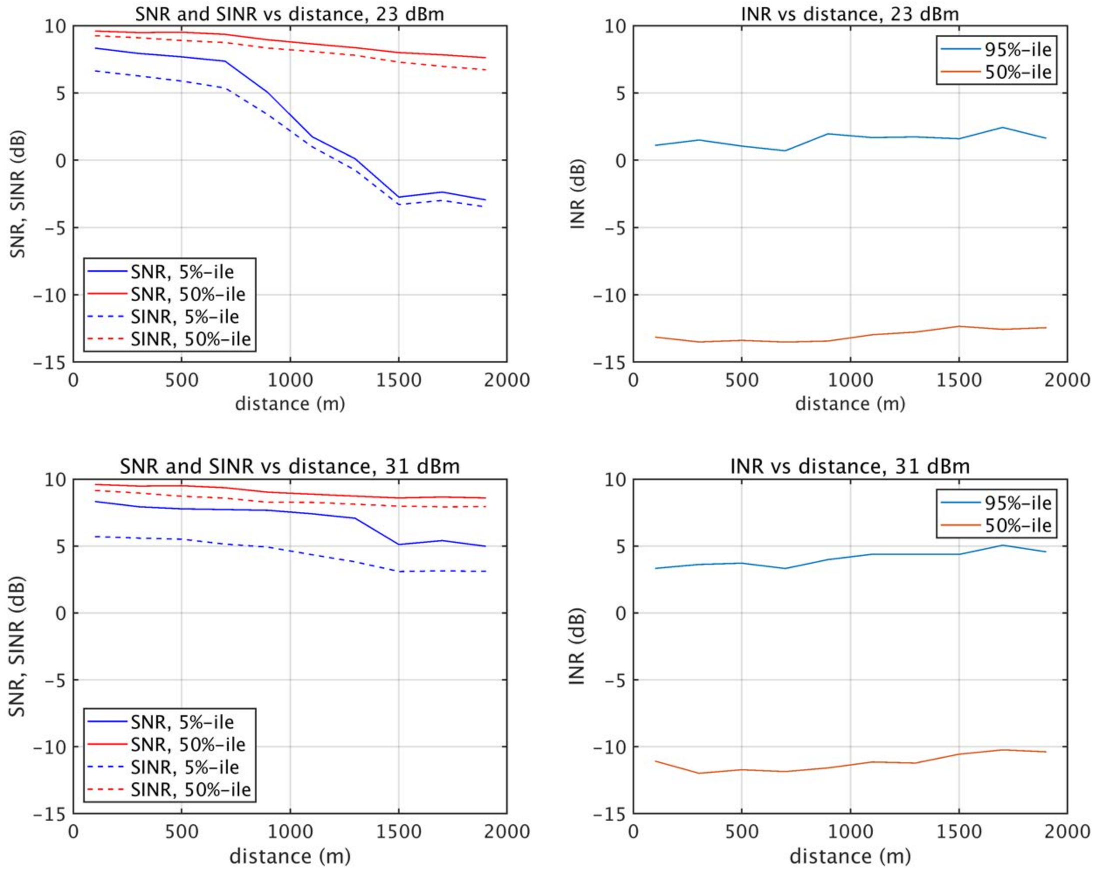


Figure 33: SNR, SINR, and INR for BS antenna port 0 (before the receiver) as a function of distance for 2x2 MIMO configuration, and 30 m antenna height

Figure 34 which shows the LoS and NLoS path loss vs distance for the ITU RMa channel model. The LoS path loss value does not depend on the antenna height for distances shorter than the break point distance. i.e. the distance at which the path loss exponent changes from 2 to 4 (The path loss depends on the distance, x, according to 〖Cx〗 ^α, where C is a constant and α is the path loss exponent). This change in path loss exponent is due to ground reflection or objects (e.g. buildings) within the first Fresnel zone. The break point distance in the ITU RMa channel model depends on the antenna height according to $d_{BP} = 2\pi h_{BS} h_{UE} f_c / c$, where h_{BS} is the antenna height, h_{UE} is the UE height, f_c is the carrier frequency, and c is the speed of light. The LoS probability as a function of distance for the ITU RMa channel model is shown in Figure 35.

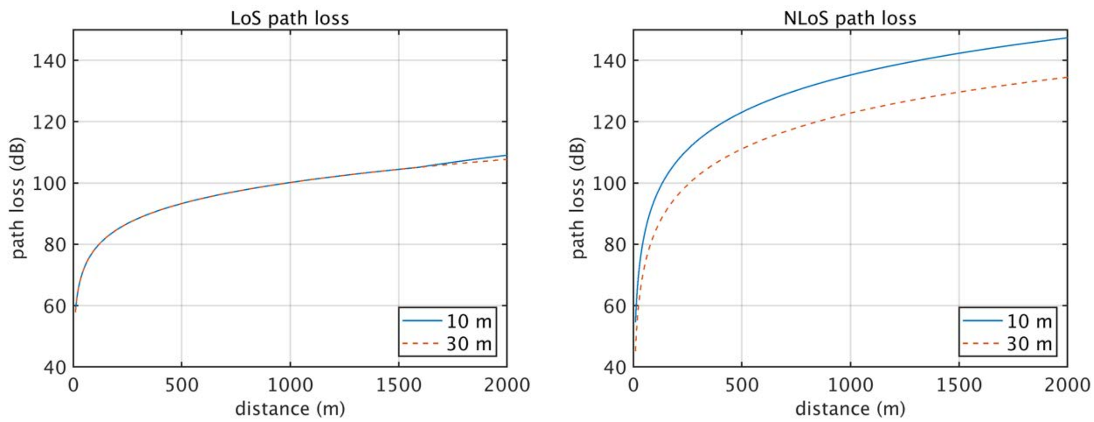


Figure 34: Path loss as a function of distance for LoS (left) and NLoS (right) in the ITU RMa channel model

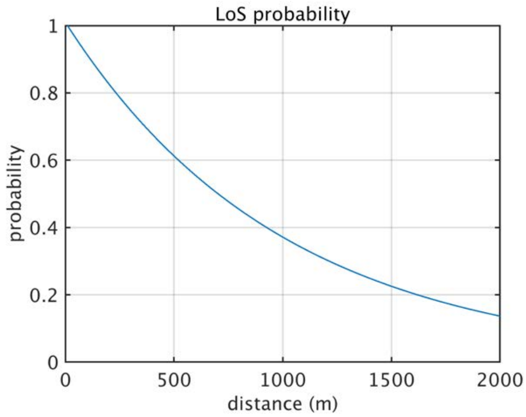


Figure 35: LoS probability as a function of distance in the ITU RMa channel model

6.2.1.1.2 Table Summary of Results Rural UL 4 km ISD 50:50 in kbps

MIMO	5 -percentile 23 dBm	50 -percentile 23 dBm	5 -percentile 31 dBm	50 -percentile 31 dBm
1x2	605	2 697	1 681	3 351
1x4	1 297	4 630	3 332	5 381
1x8	1 525	5 752	3 820	6 763
2x2	690	3 209	1 296	4 002
2x4	1 517	5 582	3 639	6 711
2x8	1 818	7 043	4 444	8 049

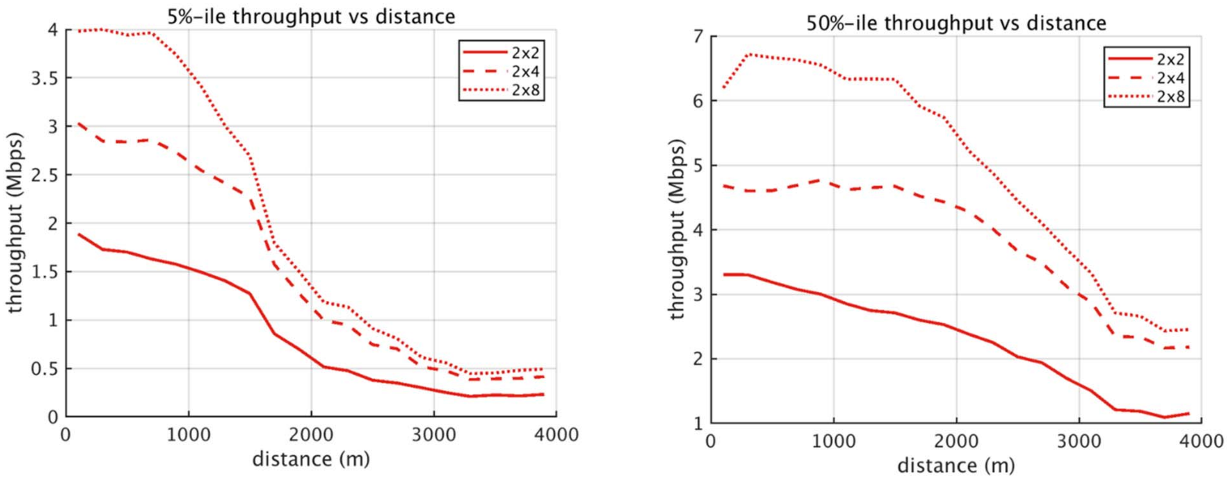


Figure 36: Rural Uplink 23 dBm 50:50 (UL:DL) 4 km ISD

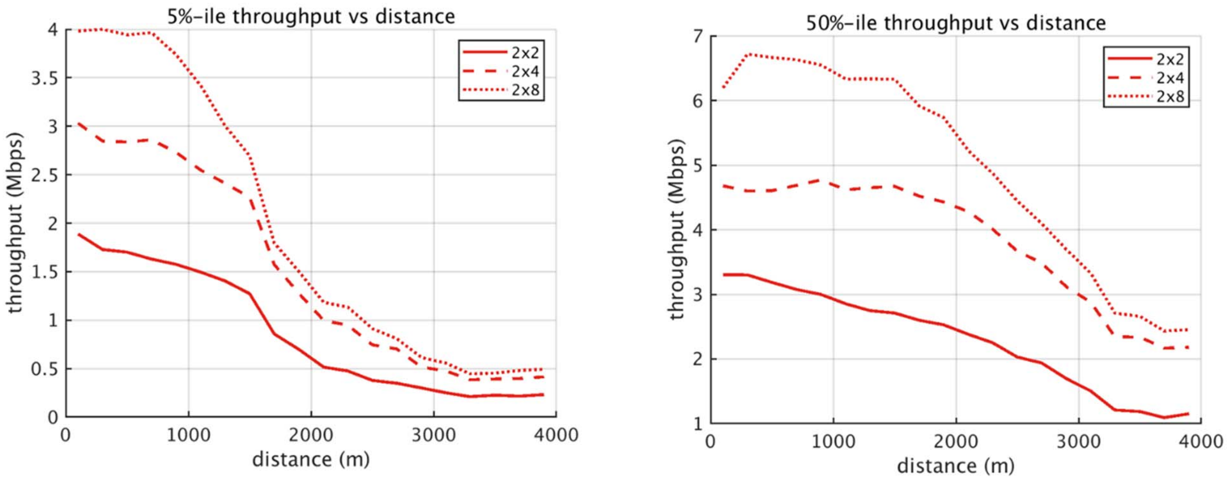


Figure 37: Rural UL Throughput vs Distance 50:50 UL:DL 31 dBm

6.2.1.1.3 Table Summary of Results 1 900 MHz UL 4km ISD 90:10 in kbps

MIMO	23 dBm 5 -percentile	23 dBm 50 -percentile	31 dBm 5 -percentile	31 dBm 50 -percentile
1x2	1 128	2 065	3 131	6 242
1x4	2 417	4 000	6 206	10 020
1x8	2 841	4 746	7 116	12 600
2x2	1 295	2 287	3 587	7 455
2x4	2 826	4 437	6 778	12 500
2x8	3 387	5 409	8 276	14 990

6.2.1.1.4 Table Summary of Results 1 900 MHz UL 8km ISD 50:50 in kbps

MIMO	31 dBm 5 -percentile	31 dBm 50 -percentile
2x2	232	1 152
2x4	414	218
2x8	493	2 452

6.2.1.2 Rural DL

6.2.1.2.1 Analysis of Results

In 1900 DL the 2x2 MIMO appears to perform better than 8x2 MIMO. This is mainly due to increasing the number of transmit ports reduces the total transmit power, as beamforming gain needs to be considered when using EIRP constraint. For example, the transmit power with 4x2 is 3 dBm lower than that of 2x2, while the beamforming gain with 4x2 comparing to that with 2x2 is at most 3 dB, which can only be achieved in theory. Therefore, taking practical impairments into account, 2x2 can give better performance than 4x2.

6.2.1.2.2 Table Summary of Results 1 900 MHz DL 40 dBm EIRP 90:10 in kbps

MIMO	4 km 5 -percentile	4 km 50 -percentile	6 km 5 -percentile	50 -percentile 6 km	5 -percentile 8 km	50 -percentile 8 km
2x1	434	2 122	142	595	34	247
4x1	396	2 066	108	512	15	218
8x1	407	2 226	111	525	17	221
2x2	1 073	4 860	265	1 447	101	459
4x2	879	4 443	217	1 223	77	383
8x2	917	4 608	219	1 257	78	386

6.2.1.2.3 Table Summary of Results 1 900 MHz DL 40 dBm EIRP 50:50 in kbps

MIMO	4 km 5 -percentile	4 km 50 -percentile	6 km 5 -percentile	6 km 50 -percentile	8 km 5 -percentile	8 km 50 -percentile
2x1	72	290	18	90	2	38
4x1	65	282	12	83	1	33
8x1	68	300	13	83	1	34
2x2	152	645	42	197	13	69
4x2	127	580	32	171	7	58
8x2	132	595	32	176	8	59

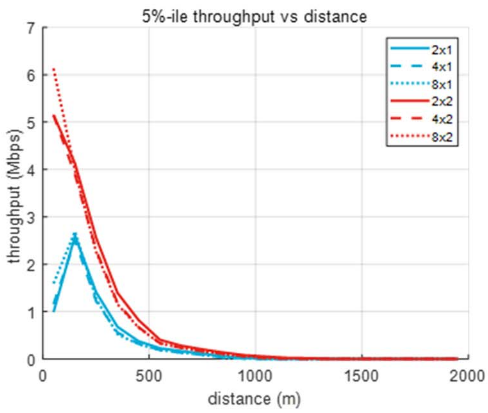
6.2.1.2.4 Table Summary of Results 63 dBm EIRP 50:50 8 km ISD in kbps 50:50 8 km ISD

MIMO	5 -percentile 8 km	50 -percentile 8 km
4x2(63 dBm EIRP)	**1 175**	**3 277**

6.2.1.3 Urban DL ISD 2 km and 4 km/2 cells/site

6.2.1.3.1 Analysis of Results

As in Rural DL above in 1 900 DL the 2x2 MIMO appears to perform better than 8x2 MIMO. This is mainly due to increasing the number of transmit ports reduces the total transmit power, as beamforming gain needs to be considered when using EIRP constraint. For example, the transmit power with 4x2 is 3 dBm lower than that of 2x2, while the beamforming gain with 4x2 comparing to with 2x2 is at most 3 dB, which can only be achieved in theory. Therefore, taking practical impairments into account, 2x2 can give better performance than 4x2.



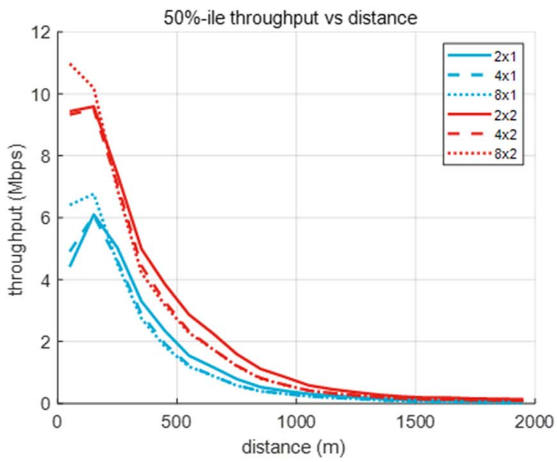


Figure 38: Urban DL Throughput vs Distance 40 dBm EIRP 50:50 UL:DL

6.2.1.3.2 Table Summary of Results 1 900 MHz DL 40 dBm EIRP 50:50 in kbps

MIMO	2 km 5 -percentile	2 km 50 -percentile	4 km 5 -percentile	4 km 50 -percentile
2x1	196	812	0	55
4x1	142	633	0	15
8x1	140	628	0	14
2x2	355	1 737	0	130
4x2	263	1 285	0	83
8x2	264	1 291	0	82

6.2.1.3.3 Table: Urban Downlink 1 900 MHz 40 dBm 90:10 in kbps

MIMO	2 km 5 -percentile	2 km 50 -percentile	4 km 5 -percentile	4 km 50 -percentile
2x1	12	27	0	0
4x1	9	16	0	0
8x1	9	17	0	0
2x2	23	52	0	18
4x2	17	39	0	0
8x2	17	39	0	0

6.2.1.4 High Density Urban UL 2 km ISD

6.2.1.4.1 Analysis of Results

Figure 39 shows 5 - and 50 -percentile throughput for the urban scenario at 1 900 MHz with 10 MHz bandwidth, 31 dBm max UE TX power, and 18 m antenna height for different MIMO configuration. Figure 40 shows 5 - and 50 -percentile cell-edge throughput for 23 and 31 dBm max UE Tx power. As for 900 MHz, the urban scenario has significantly lower performance than the rural scenario, except the 50 -percentile throughput with 31 dBm power which is almost as good as in the rural scenario. The max UE Tx power has a strong impact on both 5 - and 50 -percentile throughput.

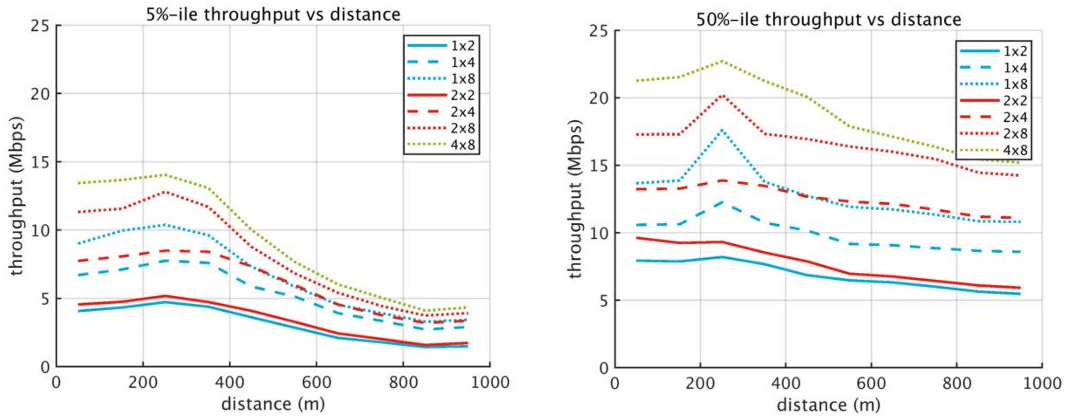


Figure 39: 5 - and 50 -percentile throughput as a function of distance for 10 MHz bandwidth, 18 m antenna height, 31 dBm max UE Tx power, 15 kHz SC spacing and 90/10 UL/DL ratio

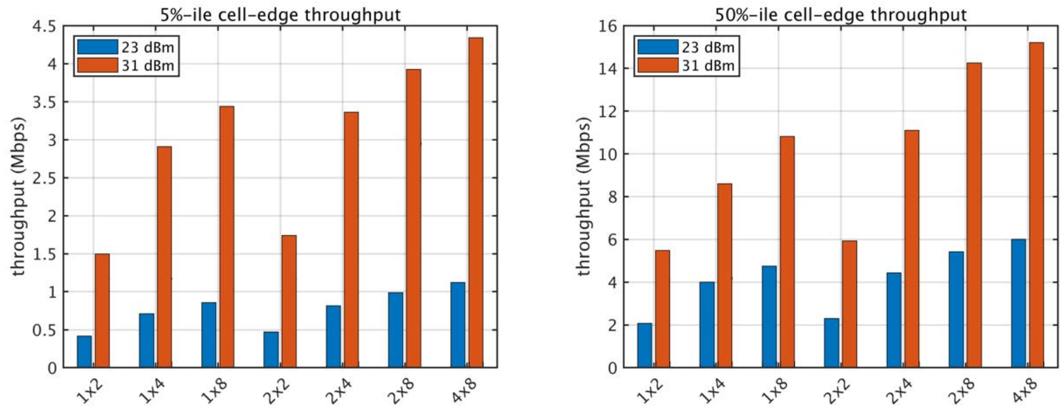


Figure 40: 5 - and 50 -percentile cell-edge throughput for 10 MHz bandwidth, 18 m antenna height, 15 kHz SC spacing, and 90/10 UL/DL ratio

The "bump" in the 50 -percentile throughput vs. distance curve at around 250 m is due to that small random variations can, in some cases, have a significant impact on throughput. This is caused by the distance binning and that different cells can have different number of attached UEs. This is illustrated in Figure 41, which shows CDFs of spectral efficiency and user throughput for the UEs in two adjacent distance bins, 150 m and 250 m, for the 2x8 MIMO configuration. The spectral efficiency for 150 m is higher than for 250 m over the entire CDF, as expected. In the user throughput CDFs, there is a sharp "knee" around the 50 -percentile between two "groups" of UEs. This "grouping" of UEs is caused by that some UEs are alone in the cell and get all the time-frequency radio resources, while some UEs are in a cell where there is also another connected UE. In the latter case, the available radio resources are shared equally between the two UEs in the cell, thereby reducing the throughput by a factor of two. Since there is a sharp knee at the 50 -percentile in this case, small changes in the distance binning can make this knee being slightly above or below the 50 -percentile. In this case the knee is slightly above the 50 -percentile at 150 m and slightly below at 250 m. Therefore, the 50 -percentile user throughput is significantly higher at 250 m than at 150 m even though the spectral efficiency is slightly lower.

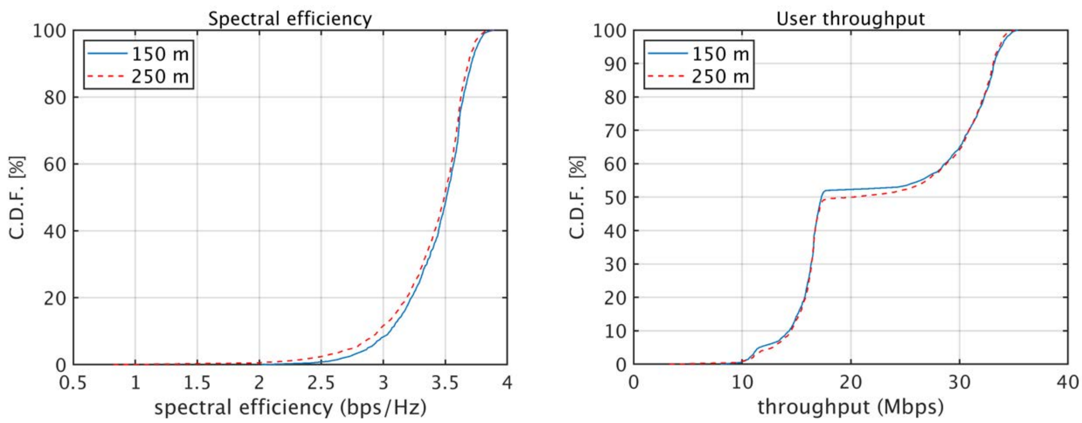


Figure 41: CDFs of spectral efficiency and user throughput for UEs in the 150 m and 250 m distance bins for the 2x8 MIMO configuration

Figure 42 shows SNR, SINR and INR for BS antenna port 0 as a function of distance for 2x2 MIMO configuration, and 18 m antenna height. The 50 -percentile SINR for 31 dBm UE Tx power is relatively high which explains the good performance for this case. These results also show that performance is mainly limited by noise in this case.

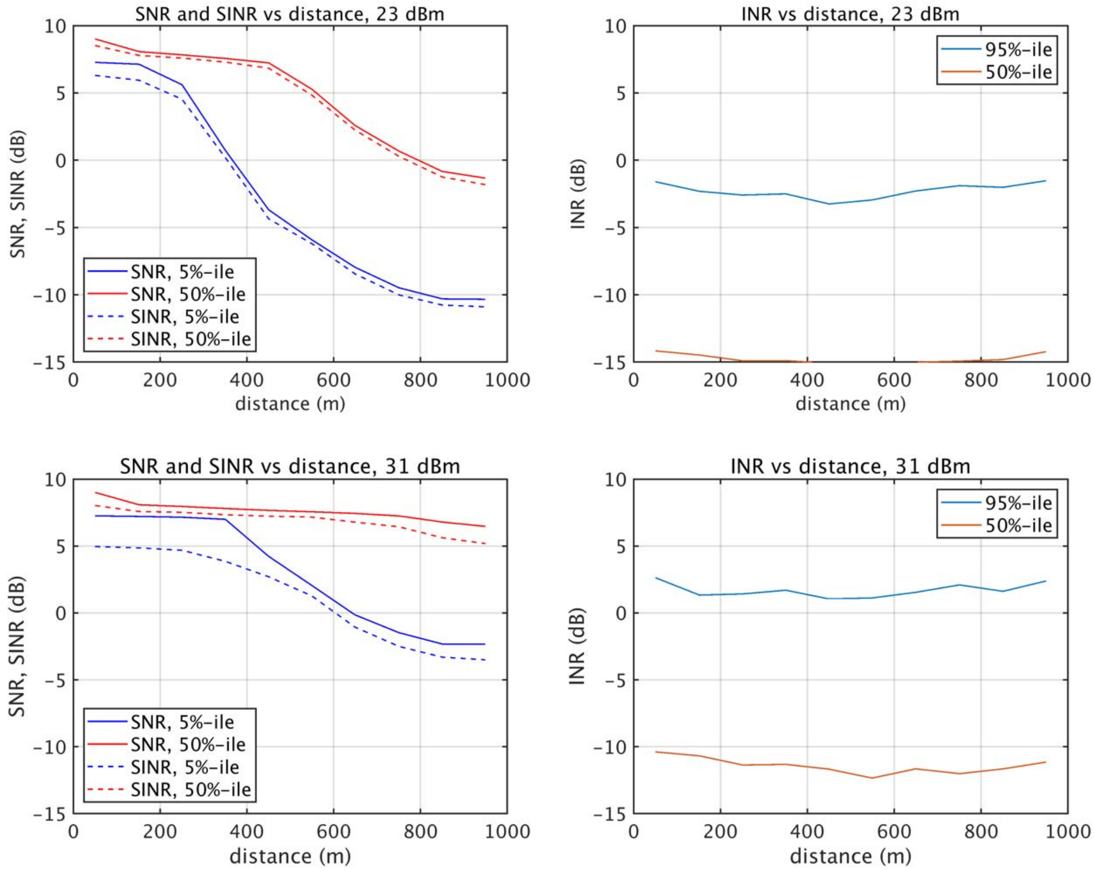


Figure 42: SNR, SINR and INR for BS antenna port 0 as a function of distance for 2x2 MIMO configuration, and 18 m antenna height

6.2.1.4.2 Table Summary of Results 1 900 MHz UL 2 km ISD 50:50 in kbps

MIMO	23 dBm 5 -percentile	23 dBm 50 -percentile	31 dBm 5 -percentile	31 dBm 50 -percentile
1x2	222	1 109	801	2 939
1x4	380	2 147	1 561	4 612
1x8	460	2 548	1 845	5 801
2x2	250	1 228	933	3 180
2x4	435	2 382	1 804	5 958
2x8	527	2 904	2 106	7 645

6.2.1.4.3 Table Summary of Results 1 900 MHz UL 2 km ISD 90:10 in kbps

MIMO	23 dBm 5 -percentile	23 dBm 50 -percentile	31 dBm 5 -percentile	31 dBm 50 -percentile
1x2	414	2 065	1 494	5 474
1x4	708	4 000	2 907	8 591
1x8	856	4 746	3 837	10 810
2x2	466	2 287	1 739	5 924
2x4	811	4 437	3 360	11 100
2x8	983	5 409	3 924	14 240

6.2.2 Company B

6.2.2.1 Rural scenario: 8 KM ISD, 2 cells/site

As mentioned previously, these are the cell edge 5th and 50th percentile values.

Downlink, 63 dBm EIRP

50/50 UL/DL TDD ratio

MIMO setup	5th percentile (kbps)	50th percentile (kbps)
2x1	500	980
2x2	660	1 090
4x1	580	1 030
4x2	800	1 170
8x1	780	1 500
8x2	1 000	1 700

90/10 UL/DL TDD ratio

MIMO setup	5th percentile (kbps)	50th percentile (kbps)
2x1	100	195
2x2	130	220
4x1	115	205
4x2	160	235
8x1	155	300
8x2	200	340

Downlink, 40 dBm EIRP

50/50 UL/DL TDD ratio

MIMO setup	5th percentile (kbps)	50th percentile (kbps)
2x1	190	450
2x2	240	570
4x1	230	550
4x2	245	570
8x1	220	580
8x2	290	630

90/10 UL/DL TDD ratio

MIMO setup	5th percentile (kbps)	50th percentile (kbps)
2x1	40	90
2x2	50	115
4x1	45	110
4x2	50	115
8x1	45	115
8x2	60	125

Uplink, 23 dBm transmit power

50/50 UL/DL TDD ratio

MIMO setup	5^{th} percentile (kbps)	50^{th} percentile (kbps)
1x2	530	730
2x2	510	700
1x4	570	790
2x4	530	760
1x8	610	820
2x8	600	790

90/10 UL/DL TDD ratio

MIMO setup	5^{th} percentile (kbps)	50^{th} percentile (kbps)
1x2	930	1 280
2x2	890	1 230
1x4	1 000	1 380
2x4	930	1 330
1x8	1 070	1 440
2x8	1 050	1 380

Uplink, 31 dBm transmit power

50/50 UL/DL TDD ratio

MIMO setup	5^{th} percentile (kbps)	50^{th} percentile (kbps)
1x2	670	1 180
2x2	670	1 100
1x4	790	1 300
2x4	760	1 280
1x8	810	1 370
2x8	800	1 370

90/10 UL/DL TDD ratio

MIMO setup	5^{th} percentile (kbps)	50^{th} percentile (kbps)
1x2	1 170	2 070
2x2	1 170	1 930
1x4	1 380	2 280
2x4	1 330	2 240
1x8	1 420	2 400
2x8	1 400	2 400

6.2.2.2 Rural scenario: 6 KM ISD, 2 cells/site

Downlink, 63 dBm EIRP

50/50 UL/DL TDD ratio

MIMO setup	5^{th} percentile (kbps)	50^{th} percentile (kbps)
2x1	810	1 530
2x2	860	1 600
4x1	900	1 660
4x2	930	1 700
8x1	950	1 720
8x2	960	1 750

90/10 UL/DL TDD ratio

MIMO setup	5^{th} percentile (kbps)	50^{th} percentile (kbps)
2x1	160	305
2x2	170	320
4x1	180	330
4x2	185	340
8x1	190	345
8x2	190	350

Downlink, 40 dBm EIRP

50/50 UL/DL TDD ratio

MIMO setup	5^{th} percentile (kbps)	50^{th} percentile (kbps)
2x1	650	1 150
2x2	730	1 260
4x1	750	1 280
4x2	810	1 350
8x1	820	1 370
8x2	880	1 440

90/10 UL/DL TDD ratio

MIMO setup	5^{th} percentile (kbps)	50^{th} percentile (kbps)
2x1	130	230
2x2	145	250
4x1	150	255
4x2	160	270
8x1	165	275
8x2	175	290

Uplink, 23 dBm transmit power

50/50 UL/DL TDD ratio

MIMO setup	5^{th} percentile (kbps)	50^{th} percentile (kbps)
1x2	930	1 500
2x2	990	1 580
1x4	990	1 600
2x4	1 010	1 650
1x8	1 050	1 670
2x8	1 030	1 700

90/10 UL/DL TDD ratio

MIMO setup	5^{th} percentile (kbps)	50^{th} percentile (kbps)
1x2	1 630	2 630
2x2	1 730	2 770
1x4	1 730	2 800
2x4	1 770	2 890
1x8	1 840	2 920
2x8	1 800	2 980

Uplink, 31 dBm transmit power

50/50 UL/DL TDD ratio

MIMO setup	5th percentile (kbps)	50th percentile (kbps)
1x2	1 400	1 660
2x2	1 400	1 700
1x4	1 450	1 770
2x4	1 480	1 790
1x8	1 470	1 800
2x8	1 510	1 830

90/10 UL/DL TDD ratio

MIMO setup	5th percentile (kbps)	50th percentile (kbps)
1x2	2 450	2 910
2x2	2 450	2 980
1x4	2 540	3 100
2x4	2 590	3 130
1x8	2 570	3 150
2x8	2 640	3 200

6.2.2.3 Rural scenario: 4 KM ISD, 2 cells/site

Downlink, 63 dBm EIRP

50/50 UL/DL TDD ratio

MIMO setup	5th percentile (kbps)	50th percentile (kbps)
2x1	1 580	5 650
2x2	1 700	6 010
4x1	1 670	5 830
4x2	1 760	6 020
8x1	1 730	6 090
8x2	1 790	6 150

90/10 UL/DL TDD ratio

MIMO setup	5th percentile (kbps)	50th percentile (kbps)
2x1	315	1 130
2x2	340	1 200
4x1	335	1 165
4x2	350	1 205
8x1	345	1 220
8x2	360	1 230

Downlink, 40 dBm EIRP

50/50 UL/DL TDD ratio

MIMO setup	5th percentile (kbps)	50th percentile (kbps)
2x1	1 620	4 800
2x2	1 750	5 000
4x1	1 770	5 030
4x2	1 770	5 050
8x1	1 800	5 100
8x2	1 810	5 100

90/10 UL/DL TDD ratio

MIMO setup	5th percentile (kbps)	50th percentile (kbps)
2x1	325	960
2x2	350	1 000
4x1	355	1 005
4x2	355	1 010
8x1	360	1 020
8x2	360	1 020

Uplink, 23 dBm transmit power

50/50 UL/DL TDD ratio

MIMO setup	5th percentile (kbps)	50th percentile (kbps)
1x2	2 850	4 240
2x2	2 830	4 250
1x4	2 850	4 300
2x4	2 870	4 300
1x8	2 900	4 400
2x8	2 900	4 370

90/10 UL/DL TDD ratio

MIMO setup	5th percentile (kbps)	50th percentile (kbps)
1x2	4 990	7 420
2x2	4 950	7 440
1x4	4 990	7 530
2x4	5 020	7 530
1x8	5 080	7 700
2x8	5 080	7 650

Uplink, 31 dBm transmit power

50/50 UL/DL TDD ratio

MIMO setup	5th percentile (kbps)	50th percentile (kbps)
1x2	2 830	4 300
2x2	2 820	4 280
1x4	2 850	4 330
2x4	2 830	4 340
1x8	2 910	4 410
2x8	2 890	4 400

90/10 UL/DL TDD ratio

MIMO setup	5th percentile (kbps)	50th percentile (kbps)
1x2	4 950	7 530
2x2	4 940	7 490
1x4	4 990	7 580
2x4	4 950	7 600
1x8	5 090	7 720
2x8	5 060	7 700

6.2.2.4 Urban scenario: 2 KM ISD, 2 cells/site

Downlink, 63 dBm EIRP

50/50 UL/DL TDD ratio

MIMO setup	5th percentile (kbps)	50th percentile (kbps)
2x1	1 220	2 020
2x2	1 250	2 140
4x1	1 280	2 150
4x2	1 310	2 200
8x1	1 360	2 260
8x2	1 400	2 290

90/10 UL/DL TDD ratio

MIMO setup	5th percentile (kbps)	50th percentile (kbps)
2x1	245	405
2x2	250	430
4x1	255	430
4x2	260	440
8x1	270	450
8x2	280	460

Downlink, 40 dBm EIRP

50/50 UL/DL TDD ratio

MIMO setup	5th percentile (kbps)	50th percentile (kbps)
2x1	450	1 590
2x2	490	1 730
4x1	500	1 750
4x2	540	1 790
8x1	550	1 800
8x2	560	1 800

90/10 UL/DL TDD ratio

MIMO setup	5th percentile (kbps)	50th percentile (kbps)
2x1	90	320
2x2	100	345
4x1	100	350
4x2	110	360
8x1	110	360
8x2	110	360

Uplink, 23 dBm transmit power

50/50 UL/DL TDD ratio

MIMO setup	5th percentile (kbps)	50th percentile (kbps)
1x2	100	400
2x2	100	420
1x4	130	440
2x4	140	430
1x8	160	460
2x8	190	470

90/10 UL/DL TDD ratio

MIMO setup	5th percentile (kbps)	50th percentile (kbps)
1x2	180	700
2x2	180	740
1x4	230	770
2x4	250	750
1x8	280	810
2x8	330	820

Uplink, 31 dBm transmit power

50/50 UL/DL TDD ratio

MIMO setup	5th percentile (kbps)	50th percentile (kbps)
1x2	480	1 350
2x2	500	1 390
1x4	510	1 420
2x4	540	1 450
1x8	570	1 500
2x8	580	1 510

90/10 UL/DL TDD ratio

MIMO setup	5th percentile (kbps)	50th percentile (kbps)
1x2	840	2 360
2x2	880	2 430
1x4	890	2 490
2x4	950	2 540
1x8	1 000	2 630
2x8	1 020	2 640

6.2.2.5 Urban scenario: 4 KM ISD, 2 cells/site

Downlink, 63 dBm EIRP

50/50 UL/DL TDD ratio

MIMO setup	5th percentile (kbps)	50th percentile (kbps)
2x1	60	120
2x2	100	180
4x1	90	180
4x2	120	200
8x1	110	220
8x2	140	230

90/10 UL/DL TDD ratio

MIMO setup	5th percentile (kbps)	50th percentile (kbps)
2x1	10	25
2x2	20	35
4x1	20	35
4x2	25	40
8x1	20	45
8x2	30	45

Downlink, 40 dBm EIRP

50/50 UL/DL TDD ratio

MIMO setup	5th percentile (kbps)	50th percentile (kbps)
2x1	0	10
2x2	0	50
4x1	0	40
4x2	0	60
8x1	0	90
8x2	0	100

90/10 UL/DL TDD ratio

MIMO setup	5th percentile (kbps)	50th percentile (kbps)
2x1	0	0
2x2	0	10
4x1	0	10
4x2	0	10
8x1	0	20
8x2	0	20

Uplink, 23 dBm transmit power

50/50 UL/DL TDD ratio

MIMO setup	5th percentile (kbps)	50th percentile (kbps)
1x2	0	110
2x2	0	210
1x4	0	170
2x4	0	200
1x8	0	240
2x8	0	220

90/10 UL/DL TDD ratio

MIMO setup	5th percentile (kbps)	50th percentile (kbps)
1x2	0	190
2x2	0	370
1x4	0	300
2x4	0	350
1x8	0	420
2x8	0	390

Uplink, 31 dBm transmit power

50/50 UL/DL TDD ratio

MIMO setup	5th percentile (kbps)	50th percentile (kbps)
1x2	200	380
2x2	240	450
1x4	280	430
2x4	270	480
1x8	290	500
2x8	300	500

90/10 UL/DL TDD ratio

MIMO setup	5th percentile (kbps)	50th percentile (kbps)
1x2	350	670
2x2	420	790
1x4	490	750
2x4	470	840
1x8	510	880
2x8	530	880

6.2.3 Company C

6.2.3.1 Rural Area - ISD 8Km - Uplink - Analysis

In the following, results for 900 MHz FDD band with 5 MHz bandwidth are presented. The orange column corresponds to the 5 %-ile on cell edge which is the main criterion (worst-case performance). For every UL/DL power value, the underlined bolded row shows the frequency reuse scheme achieving best performance while keeping all the other simulation assumptions. For the cases where a higher reuse factor does not bring significant throughput gain on cell edge, lower reuse factor is preferred so that throughput reduction in cell centre is avoided. For a better understanding of the following, refer to the associated link level performance and interference statistics in Annex A.

6.2.3.2 Rural Area - ISD 8Km - Uplink - Results

2x2 MIMO			Full UL			TDD 50/50		TDD 90/10	
Speed (km/h)	Freq Reuse factor	Max UL Power (dBm)	Cell Centre (Mbps)	Cell Edge 50 %-ile (Mbps)	Cell Edge 5 %-ile (Mbps)	Cell Edge 50 %-ile (Mbps)	Cell Edge 5 %-ile (Mbps)	Cell Edge 50 %-ile (Mbps)	Cell Edge 5 %-ile (Mbps)
350	1	23	12,29	11,99	3,90	5,99	1,95	10,79	3,51
700			**4,06**	**4,06**	**1,86**	**2,03**	**0,93**	**3,65**	**1,68**
350	2		6,15	6,15	5,31	3,07	2,65	5,53	4,78
700			2,03	2,03	2,03	1,01	1,01	1,83	1,83
350	3		4,10	4,10	3,96	2,05	1,98	3,69	3,57
700			1,35	1,35	1,35	0,68	0,68	1,22	1,22
350	1	26	12,29	12,24	3,73	6,12	1,86	11,02	3,36
700			4,06	4,06	1,60	2,03	0,80	3,65	1,44
350	2		6,15	6,15	6,04	3,07	3,02	5,53	5,44
700			**2,03**	**2,03**	**2,03**	**1,01**	**1,01**	**1,83**	**1,83**
350	3		4,10	4,10	4,10	2,05	2,05	3,69	3,69
700			1,35	1,35	1,35	0,68	0,68	1,22	1,22
350	1	31	12,29	12,29	2,25	6,15	1,12	11,06	2,02
700			4,06	4,06	0,72	2,03	0,36	3,65	0,65
350	2		6,15	6,15	6,15	3,07	3,07	5,53	5,53
700			**2,03**	**2,03**	**2,03**	**1,01**	**1,01**	**1,83**	**1,83**
350	3		4,10	4,10	4,10	2,05	2,05	3,69	3,69
700			1,35	1,35	1,35	0,68	0,68	1,22	1,22

6.2.3.3 Rural Area - ISD 8Km - downlink

2x2 MIMO			FULL DL			TDD 50/50		TDD 90/10	
Speed (km/h)	Frequency reuse factor	Max DL EIRP (dBm)	Cell Centre (Mbps)	Cell Edge 50 %-ile (Mbps)	Cell Edge 5 %-ile (Mbps)	Cell Edge 50 %-ile (Mbps)	Cell Edge 5 %-ile (Mbps)	Cell Edge 50 %-ile (Mbps)	Cell Edge 5 %-ile (Mbps)
350	1	40	11,25	8,55	0,74	4,28	0,37	0,86	0,07
350	**2**		**5,62**	**5,62**	**4,60**	**2,81**	**2,30**	**0,56**	**0,46**
350	3		3,75	3,75	3,61	1,87	1,80	0,37	0,36
350	1	63	11,25	10,90	0,90	5,45	0,45	1,09	0,09
350	**2**		**5,62**	**5,62**	**5,62**	**2,81**	**2,81**	**0,56**	**0,56**
350	3		3,75	3,75	3,75	1,87	1,87	0,37	0,37

6.2.3.4 Rural Area - ISD 6Km - Uplink

2x2 MIMO+C209:L228			Full UL			TDD 50/50		TDD 90/10	
Speed (km/h)	F factor	Max UL Power (dBm)	Cell Centre (Mbps)	Cell Edge 50 %-ile (Mbps)	Cell Edge 5 %-ile (Mbps)	Cell Edge 50 %-ile (Mbps)	Cell Edge 5 %-ile (Mbps)	Cell Edge 50 %-ile (Mbps)	Cell Edge 5 %-ile (Mbps)
350	1	23	12,29	12,29	5,83	6,15	2,92	11,06	5,25
700			**4,06**	**4,06**	**2,98**	**2,03**	**1,49**	**3,65**	**2,68**
350	2		6,15	6,15	6,15	3,07	3,07	5,53	5,53
700			2,03	2,03	2,03	1,01	1,01	1,83	1,83
350	3		4,10	4,10	4,10	2,05	2,05	3,69	3,69
700			1,35	1,35	1,35	0,68	0,68	1,22	1,22
350	1	26	12,29	12,29	5,19	6,15	2,60	11,06	4,68
700			**4,06**	**4,06**	**2,78**	**2,03**	**1,39**	**3,65**	**2,51**
350	2		6,15	6,15	6,15	3,07	3,07	5,53	5,53
700			2,03	2,03	2,03	1,01	1,01	1,83	1,83
350	3		4,10	4,10	4,10	2,05	2,05	3,69	3,69
700			1,35	1,35	1,35	0,68	0,68	1,22	1,22
350	1	31	12,29	12,29	3,58	6,15	1,79	11,06	3,23
700			4,06	4,06	1,51	2,03	0,76	3,65	1,36
350	2		6,15	6,15	6,15	3,07	3,07	5,53	5,53
700			**2,03**	**2,03**	**2,03**	**1,01**	**1,01**	**1,83**	**1,83**
350	3		4,10	4,10	4,10	2,05	2,05	3,69	3,69
700			1,35	1,35	1,35	0,68	0,68	1,22	1,22

6.2.3.5 Rural Area - ISD 6Km - downlink

2x2 MIMO			FULL DL			TDD 50/50		TDD 90/10	
Speed (km/h)	Frequency reuse factor	Max DL EIRP (dBm)	Cell Centre (Mbps)	Cell Edge 50 %-ile (Mbps)	Cell Edge 5 %-ile (Mbps)	Cell Edge 50 %-ile (Mbps)	Cell Edge 5 %-ile (Mbps)	Cell Edge 50 %-ile (Mbps)	Cell Edge 5 %-ile (Mbps)
350	1	40	11,25	10,45	0,89	5,23	0,45	1,05	0,09
	2		**5,62**	**5,62**	**5,62**	**2,81**	**2,81**	**0,56**	**0,56**
	3		3,75	3,75	3,75	1,87	1,87	0,37	0,37
	1	63	11,25	10,90	0,78	5,45	0,39	1,09	0,08
	2		**5,62**	**5,62**	**5,62**	**2,81**	**2,81**	**0,56**	**0,56**
	3		3,75	3,75	3,75	1,87	1,87	0,37	0,37

6.2.3.6 Rural Area - ISD 4Km - Uplink

2x2 MIMO			Full UL			TDD 50/50		TDD 90/10	
Speed (km/h)	Frequency Reuse factor	Max UL Power (dBm)	Cell Centre (Mbps)	Cell Edge 50 %-ile (Mbps)	Cell Edge 5 %-ile (Mbps)	Cell Edge 50 %-ile (Mbps)	Cell Edge 5 %-ile (Mbps)	Cell Edge 50 %-ile (Mbps)	Cell Edge 5 %-ile (Mbps)
350	1	23	12,29	12,29	8,88	6,15	4,44	11,06	7,99
700			**4,06**	**4,06**	**4,01**	**2,03**	**2,00**	**3,65**	**3,61**
350	2		6,15	6,15	6,15	3,07	3,07	5,53	5,53
700			2,03	2,03	2,03	1,01	1,01	1,83	1,83
350	3		4,10	4,10	4,10	2,05	2,05	3,69	3,69
700			1,35	1,35	1,35	0,68	0,68	1,22	1,22
350	1	26	12,29	12,29	8,81	6,15	4,40	11,06	7,93
700			**4,06**	**4,06**	**3,99**	**2,03**	**2,00**	**3,65**	**3,59**
350	2		6,15	6,15	6,15	3,07	3,07	5,53	5,53
700			2,03	2,03	2,03	1,01	1,01	1,83	1,83
350	3		4,10	4,10	4,10	2,05	2,05	3,69	3,69
700			1,35	1,35	1,35	0,68	0,68	1,22	1,22
350	1	31	12,29	12,29	7,53	6,15	3,76	11,06	6,77
700			**4,06**	**4,06**	**3,63**	**2,03**	**1,82**	**3,65**	**3,27**
350	2		6,15	6,15	6,15	3,07	3,07	5,53	5,53
700			2,03	2,03	2,03	1,01	1,01	1,83	1,83

2x2 MIMO			Full UL			TDD 50/50		TDD 90/10	
Speed (km/h)	Frequency Reuse factor	Max UL Power (dBm)	Cell Centre (Mbps)	Cell Edge 50 %-ile (Mbps)	Cell Edge 5 %-ile (Mbps)	Cell Edge 50 %-ile (Mbps)	Cell Edge 5 %-ile (Mbps)	Cell Edge 50 %-ile (Mbps)	Cell Edge 5 %-ile (Mbps)
350	3		4,10	4,10	4,10	2,05	2,05	3,69	3,69
700			1,35	1,35	1,35	0,68	0,68	1,22	1,22

6.2.3.7 Rural Area - ISD 4Km - downlink

2x2 MIMO			FULL DL			TDD 50/50		TDD 90/10	
Speed (km/h)	Frequency reuse factor	Max DL EIRP (dBm)	Cell Centre (Mbps)	Cell Edge 50 %-ile (Mbps)	Cell Edge 5 %-ile (Mbps)	Cell Edge 50 %-ile (Mbps)	Cell Edge 5 %-ile (Mbps)	Cell Edge 50 %-ile (Mbps)	Cell Edge 5 %-ile (Mbps)
350	1	40	11,25	10,45	0,83	5,23	0,42	1,05	0,08
	2		**5,62**	**5,62**	**5,54**	**2,81**	**2,77**	**0,56**	**0,55**
	3		3,75	3,75	3,75	1,87	1,87	0,37	0,37
	1	63	11,25	10,44	0,66	5,22	0,33	1,04	0,07
	2		**5,62**	**5,62**	**5,60**	**2,81**	**2,80**	**0,56**	**0,56**
	3		3,75	3,75	3,75	1,87	1,87	0,37	0,37

6.2.3.8 Hilly Terrain - ISD 8Km - Uplink

2x2 MIMO			Full UL			TDD 50/50		TDD 90/11	
Speed (km/h)	Frequency reuse factor	Max UL Power (dBm)	Cell Centre (Mbps)	Cell Edge 50 %-ile (Mbps)	Cell Edge 5 %-ile (Mbps)	Cell Edge 50 %-ile (Mbps)	Cell Edge 5 %-ile (Mbps)	Cell Edge 50 %-ile (Mbps)	Cell Edge 5 %-ile (Mbps)
350	1	23	12,29	5,77	0,00	2,88	0,00	5,19	0,00
700			4,06	2,95	0,00	1,47	0,00	2,65	0,00
350	2		6,15	4,46	0,94	2,23	0,47	4,01	0,84
700			**2,03**	**2,01**	**0,25**	**1,00**	**0,13**	**1,81**	**0,23**
350	3		4,10	3,66	0,98	1,83	0,49	3,29	0,88
700			1,35	1,35	0,38	0,68	0,19	1,22	0,34
350	1	26	12,29	5,92	0,00	2,96	0,00	5,33	0,00
700			4,06	3,03	0,00	1,52	0,00	2,73	0,00
350	2		6,15	5,27	1,55	2,64	0,78	4,74	1,40
700			**2,03**	**2,03**	**0,61**	**1,01**	**0,31**	**1,83**	**0,55**
350	3		4,10	3,96	1,33	1,98	0,67	3,56	1,20
700			1,35	1,35	0,70	0,68	0,35	1,22	0,63
350	1	31	12,29	7,29	0,00	3,64	0,00	6,56	0,00
700			4,06	3,50	0,00	1,75	0,00	3,15	0,00
350	2		6,15	6,10	2,90	3,05	1,45	5,49	2,61
700			**2,03**	**2,03**	**1,48**	**1,01**	**0,74**	**1,83**	**1,33**
350	3		4,10	4,10	2,52	2,05	1,26	3,69	2,27
700			1,35	1,35	1,22	0,68	0,61	1,22	1,10

6.2.3.9 Hilly Terrain - ISD 8Km - downlink

2x2 MIMO			FULL DL			TDD 50/50		TDD 90/10	
Speed (km/h)	Frequency reuse factor	Max DL EIRP (dBm)	Cell Centre (Mbps)	Cell Edge 50 %-ile (Mbps)	Cell Edge 5 %-ile (Mbps)	Cell Edge 50 %-ile (Mbps)	Cell Edge 5 %-ile (Mbps)	Cell Edge 50 %-ile (Mbps)	Cell Edge 5 %-ile (Mbps)
350	1	40	14,62	1,71	0,00	0,85	0,00	0,17	0,00
	2		**7,31**	**3,46**	**0,28**	**1,73**	**0,14**	**0,35**	**0,03**
	3		4,87	2,62	0,51	1,31	0,26	0,26	0,05
	1	63	14,62	3,00	0,00	1,50	0,00	0,30	0,00
	2		**7,31**	**7,14**	**5,01**	**3,57**	**2,51**	**0,71**	**0,50**
	3		4,87	4,87	4,02	2,44	2,01	0,49	0,40

6.2.3.10 Urban Area - ISD 2Km - Uplink

2x2 MIMO			Full UL			TDD 50/50		TDD 90/10	
Speed (km/h)	Frequency reuse factor	Max UL Power (dBm)	Cell Centre (Mbps)	Cell Edge 50 %-ile (Mbps)	Cell Edge 5 %-ile (Mbps)	Cell Edge 50 %-ile (Mbps)	Cell Edge 5 %-ile (Mbps)	Cell Edge 50 %-ile (Mbps)	Cell Edge 5 %-ile (Mbps)
80	1	23	30,79	11,99	0,82	6,00	0,41	10,79	0,73
160			24,53	11,96	0,76	5,98	0,38	10,77	0,68
80	2		15,39	11,40	4,20	5,70	2,10	10,26	3,78
160			**12,27**	**10,40**	**4,00**	**5,20**	**2,00**	**9,36**	**3,60**
80	3		10,26	8,63	4,09	4,31	2,04	7,76	3,68
160			8,18	7,95	4,01	3,97	2,01	7,15	3,61
80	1	26	30,79	11,62	0,00	5,81	0,00	10,46	0,00
160			24,53	11,53	0,00	5,77	0,00	10,38	0,00
80	2		15,39	11,68	4,26	5,84	2,13	10,52	3,84
160			**12,27**	**10,60**	**4,04**	**5,30**	**2,02**	**9,54**	**3,63**
80	3		10,26	9,43	4,57	4,71	2,28	8,48	4,11
160			8,18	7,94	4,30	3,97	2,15	7,14	3,87
80	1	31	30,79	10,30	0,00	5,15	0,00	9,27	0,00
160			24,53	9,98	0,00	4,99	0,00	8,99	0,00
80	2		15,39	11,69	4,07	5,84	2,03	10,52	3,66
160			12,27	10,57	3,97	5,29	1,98	9,52	3,57
80	3		10,26	9,49	4,85	4,74	2,43	8,54	4,37
160			**8,18**	**8,12**	**4,71**	**4,06**	**2,35**	**7,30**	**4,24**

6.2.3.11 Urban Area - ISD 2Km - Downlink

2x2 MIMO			FULL DL			TDD 50/50		TDD 90/10	
Speed (km/h)	Frequency reuse factor	Max DL EIRP (dBm)	Cell Centre (Mbps)	Cell Edge 50 %-ile (Mbps)	Cell Edge 5 %-ile (Mbps)	Cell Edge 50 %-ile (Mbps)	Cell Edge 5 %-ile (Mbps)	Cell Edge 50 %-ile (Mbps)	Cell Edge 5 %-ile (Mbps)
80	1	40	28,17	6,00	0,00	3,00	0,00	0,60	0,00
	2		14,09	8,95	2,88	4,47	1,44	0,89	0,29
	3		**9,39**	**7,49**	**3,36**	**3,75**	**1,68**	**0,75**	**0,34**
	1	63	28,17	6,40	0,00	3,20	0,00	0,64	0,00
	2		14,09	10,70	3,01	5,35	1,50	1,07	0,30
	3		**9,39**	**9,17**	**4,28**	**4,58**	**2,14**	**0,92**	**0,43**

6.2.3.12 Urban Area High Density - ISD 4Km - Uplink

2x2 MIMO			Full UL			TDD 50/50		TDD 90/10	
Speed (km/h)	Frequency reuse factor	Max UL Power (dBm)	Cell Centre (Mbps)	Cell Edge 50 %-ile (Mbps)	Cell Edge 5 %-ile (Mbps)	Cell Edge 50 %-ile (Mbps)	Cell Edge 5 %-ile (Mbps)	Cell Edge 50 %-ile (Mbps)	Cell Edge 5 %-ile (Mbps)
80	1	23	30,79	6,20	0,00	3,10	0,00	5,58	0,00
160			24,53	6,07	0,00	3,03	0,00	5,46	0,00
80	2		15,39	5,17	0,88	2,59	0,44	4,65	0,79
160			**12,27**	**5,02**	**0,86**	**2,51**	**0,43**	**4,52**	**0,77**
80	3		10,26	3,94	1,07	1,97	0,53	3,54	0,96
160			8,18	3,89	1,06	1,94	0,53	3,50	0,96
80	1	26	30,79	6,49	0,00	3,24	0,00	5,84	0,00
160			24,53	6,39	0,00	3,19	0,00	5,75	0,00
80	2		15,39	5,67	1,43	2,83	0,71	5,10	1,28
160			**12,27**	**5,65**	**1,41**	**2,83**	**0,71**	**5,09**	**1,27**
80	3		10,26	4,67	1,59	2,34	0,79	4,21	1,43
160			8,18	4,47	1,57	2,24	0,79	4,02	1,42
80	1	31	30,79	6,57	0,00	3,29	0,00	5,91	0,00
160			24,53	6,47	0,00	3,24	0,00	5,82	0,00
80	2		15,39	6,30	1,83	3,15	0,92	5,67	1,65
160			**12,27**	**6,02**	**1,80**	**3,01**	**0,90**	**5,42**	**1,62**

2x2 MIMO			Full UL			TDD 50/50		TDD 90/10	
Speed (km/h)	Frequency reuse factor	Max UL Power (dBm)	Cell Centre (Mbps)	Cell Edge 50 %-ile (Mbps)	Cell Edge 5 %-ile (Mbps)	Cell Edge 50 %-ile (Mbps)	Cell Edge 5 %-ile (Mbps)	Cell Edge 50 %-ile (Mbps)	Cell Edge 5 %-ile (Mbps)
80	3		10,26	5,53	2,20	2,76	1,10	4,97	1,98
160			8,18	5,30	2,16	2,65	1,08	4,77	1,95

6.2.3.13 Urban Area High Density - ISD 4Km - Downlink

2x2 MIMO			FULL DL			TDD 50/50		TDD 90/10	
Speed (km/h)	Frequency reuse factor	Max DL EIRP (dBm)	Cell Centre (Mbps)	Cell Edge 50 %-ile (Mbps)	Cell Edge 5 %-ile (Mbps)	Cell Edge 50 %-ile (Mbps)	Cell Edge 5 %-ile (Mbps)	Cell Edge 50 %-ile (Mbps)	Cell Edge 5 %-ile (Mbps)
80	1	40	28,17	3,69	0,00	1,85	0,00	0,37	0,00
	2		**14,09**	**4,96**	**0,94**	**2,48**	**0,47**	**0,50**	**0,09**
	3		9,39	3,93	1,11	1,97	0,55	0,39	0,11
	1	63	28,17	5,98	0,00	2,99	0,00	0,60	0,00
	2		14,09	10,59	2,90	5,29	1,45	1,06	0,29
	3		**9,39**	**9,04**	**3,81**	**4,52**	**1,90**	**0,90**	**0,38**

6.2.3.14 Summary

Following tables summarizes the frequency reuse factors achieving best performance given above for each deployment.

	900 MHz				
	Power (dBm)	Rural ISD 8 Km	Hilly ISD 8 Km	Urban ISD 2 Km	Urban HD ISD 4 Km
UL power	23	2	2	2	2
	26	2	2	2	2
	31	1	2	2	2
DL Tx power	46 (antenna connector)	2	2	3	3

	1 900 MHz						
	Power (dBm)	Rural ISD (Km)			Hilly ISD 8 Km	Urban ISD 2 Km	Urban High Density ISD 4 Km
		4	6	8			
UL power	23	1	1	1	2	2	2
	26	1	1	2	2	2	2
	31	1	2	2	2	3	2
DL EIRP	40	2	2	2	2	3	2
	63	2	2	2	2	3	3

6.3 Comparison Cell Edge Throughput Companies A, B and C

6.3.1 Comparison Overview

Companies A and B simulators include a round-robin scheduler and assume several trains on the serving cell depending on the scenario. The throughput results correspond to what a UE could expect in the given scenario. Company C simulator does not include a scheduler. Results corresponds then to the available throughput in the serving cell at a given position. This throughput is reduced when the resources (RBs) are shared in a cell with more than one train.

To be able to compare the results between the two approaches, an evaluation of the impact of the scheduler has been done. The evaluation is based on spectral efficiency (*Se*) results provided by Company A. Indeed, in their results, the spectral efficiency is computed on the bandwidth allocated to a UE, and thus does not depend on the number of UEs that are to be served in the cell by the scheduler. Then an apparent spectral efficiency (*Sa*) has been computed, corresponding to the throughput per UE after the scheduling divided by the total bandwidth. The ratio between the two spectral efficiency values (*Se/Sa*) provides an evaluation of the impact of the scheduler for a given scenario. See clause A.3.4.1.3 for more information.

The correction tables *Se/Sa* for results of Company C are provided in Table 4 for 900 MHz band and in Table 5 for 1 900 MHz band.

Table 4: Scheduler impact alignment at 900 MHz

Scenario	Average (Se/Sa)
900 MHz Urban ISD = 4 km	2,70
900 MHz Urban ISD = 2 km	1,42
900 MHz Rural ISD = 8 km	2,75

Table 5: Scheduler impact alignment at 1 900 MHz

Scenario	Average (Se/Sa)
1 900 MHz Urban ISD = 2 km	1,42
1 900 MHz Urban ISD = 4 km	2,70
1 900 MHz Rural ISD = 6 km	2,06
1 900 MHz Rural ISD = 8 km	2,75
1 900 MHz Rural ISD = 4 km	1,38

Table 6 and Table 7 summarize a comparison between Companies A, B and C results in 900 MHz. *Se/Sa* alignment for Company C results is included.

For company C's results, (Rx) indicates the reuse factor used to get the value, with x in {1, 2, 3}. For the cases where company C results show low or no variance in throughput(distance) or 5/50 percentile are equal, refer to clause 6.1.3.1 where an example is provided. For interference-limited scenarios, cell edge performance with frequency reuse factors greater than 1 usually outperforms other schemes (MMSE-IRC frequency reuse 1) on the expenses of lower cell centre throughput. In the following the highest bounds of the cell edge performance range correspond to a reduced cell centre performance, while lower bounds cell edge performance corresponds to a higher cell centre performance. In practice, trade-off can be achieved by implementing soft or partial frequency reuse scheme (e.g. Inter-cell coordination).

6.3.2 900 MHz Rural scenario 8 km ISD

Downlink

5 Percentile

Table 6

MIMO Setting	No Mitigation	Interference Mitigation of MMSE-IRC scheme as per 3GPP TR 36.884 [i.9]		Hard Reuse of Frequencies	
	Company C	Company A	Company B	Company C	Company C
	Reuse 1	Reuse 1	Reuse 1	Reuse 2	Reuse 3
2x1			1 210		
2x2	200	964	1 400	1 956	1 313
4x1			1 330		
4x2		1 097	1 450		

50 Percentile

Table 7

MIMO Setting	No Mitigation	Interference Mitigation of MMSE-IRC scheme as per 3GPP TR 36.884 [i.9]		Hard Reuse of Frequencies	
	Company C	Company A	Company B	Company C	Company C
	Reuse 1	Reuse 1	Reuse 1	Reuse 2	Reuse 3
2x1			2 100		
2x2	1 982	2 820	2 300	1 971	1 313
4x1			2 350		
4x2		3 007	2 500		

Observation:

In Figure 35 Company A shows that INR has a strong dependence on distance and throughput at the cell edge is interference limited. This is because the BSs are constantly transmitting at full power. Also increasing the number of transmit antenna from 2 to 4 only helps marginally due to the interference limitation at cell edge. Company A did not consider Doppler; therefore 5 % and 50 % range may be lower.

Uplink, 23 dBm transmit power

5 Percentile

Table 8

MIMO Setting	No Mitigation	Interference Mitigation of MMSE-IRC scheme as per 3GPP TR 36.884 [i.9]		Hard Reuse of Frequencies	
	Company C	Company A	Company B	Company C	Company C
	Reuse 1	Reuse 1	Reuse 1	Reuse 2	Reuse 3
1x2		179	1 100		
2x2	429	191	1 400	1 069	713
1x4		273	1 410		
2x4		318	1 450		

50 Percentile

Table 9

MIMO Setting	No Mitigation	Interference Mitigation of MMSE-IRC scheme as per 3GPP TR 36.884 [i.9]		Hard Reuse of Frequencies	
	Company C	Company A	Company B	Company C	Company C
	Reuse 1	Reuse 1	Reuse 1	Reuse 2	Reuse 3
1x2		859	1 650		
2x2	2 142	1 043	1 850	1 069	713
1x4		1 548	1 930		
2x4		1 856	1 990		

Company C results show similar results for both 5 and 50 percentiles and for differing uplink power scenarios. This is explained in Figure 29 above and in its accompanying text above.

It can also be seen that increasing the number BS Rx antenna ports from 2 to 4 gives a significant increase in performance as well as a beamforming gain of 3 dB. This is mainly due to that the BS effective antenna area is increased when going from 2 to 4 antenna ports leading to more received energy. It also increases the possibilities for higher transmission rank. This can be seen in Figure 13 which shows the CDF of the average transmission rank for each UE. Increasing the number UE Tx antennas also improves performance, but not as much as increasing the number BS Rx antennas. This is expected since the transmitter has less detailed channel knowledge than the receiver.

For 23 dBm UE at longer distances, the 5 -percentile signal power is more than 5 dBm lower than the noise level. The median interference level is around 10 dBm below the noise level for all distances. For a typical UE, the performance is therefore noise limited. However, for the worst interfered UEs (5 -percentile), the interference level is around the same level as the thermal noise. Increasing the UE Tx power to 31 dBm improves the SNR and SINR significantly for UEs far away from the BS. It also increases the interference level by approximately 5 dBm over all distances. More UEs are therefore interference limited compared to the 23 dBm case. At this distance the received interference power does not have a strong dependence on distance. This is expected since the locations and strengths of the interferers in the other cells are in principle not dependent on the position of the UE that has been scheduled in the own cell. However, there is an indirect dependence between the locations of trains in adjacent cells since there is a constraint on the minimum distance between trains on the same track.

Uplink, 31 dBm transmit power

5 Percentile

Table 10

MIMO Setting	No Mitigation	Interference Mitigation of MMSE-IRC scheme as per 3GPP TR 36.884 [i.9]		Hard Reuse of Frequencies	
	Company C	Company A	Company B	Company C	Company C
	Reuse 1	Reuse 1	Reuse 1	Reuse 2	Reuse 3
1x2		523	1 400		
2x2	1 120	630	1 500	1 069	713
1x4		990	1 590		
2x4		1 150	1 630		

Company C reuse 1 value is higher than reuse 2 since the cell-edge SINR is high enough and no reuse interference mitigation is needed at the edge. If reuse is used then it utilizes fewer resource blocks leading to lower throughput.

50 Percentile

Table 11

MIMO Setting	No Mitigation	Interference Mitigation of MMSE-IRC scheme as per 3GPP TR 36.884 [i.9]		Hard Reuse of Frequencies	
	Company C	Company A	Company B	Company C	Company C
	Reuse 1	Reuse 1	Reuse 1	Reuse 2	Reuse 3
1x2		1 458	1 830		
2x2	2 142	1 706	1 950	1 069	713
1x4		2 470	2 100		
2x4		2 824	2 230		

The maximum UE Tx power has a strong impact on performance, especially on the 5 -percentile cell-edge throughput. It can also be seen that increasing the number BS Rx antenna ports from 2 to 4 gives a significant increase in performance. This is mainly due to that the BS effective antenna area is increased when going from 2 to 4 antenna ports leading to more received energy.

5 percentile range is 1 000 kbps to 1 150 kbps while 50 percentile range is around 1 300 - 2 000 kbps.

6.3.3 900 MHz High Density Urban scenario 2 km ISD

Downlink

5 Percentile

Table 12

MIMO Setting	No Mitigation	Interference Mitigation of MMSE-IRC scheme as per 3GPP TR 36.884 [i.9]		Hard Reuse of Frequencies	
	Company C	Company A	Company B	Company C	Company C
	Reuse 1	Reuse 1	Reuse 1	Reuse 2	Reuse 3
2x1			530		
2x2	0	2 000	700	1 176	1 542
4x1			590		
4x2		2 100	810		

50 Percentile

Table 13

MIMO Setting	No Mitigation	Interference Mitigation of MMSE-IRC scheme as per 3GPP TR 36.884 [i.9]		Hard Reuse of Frequencies	
	Company C	Company A	Company B	Company C	Company C
	Reuse 1	Reuse 1	Reuse 1	Reuse 2	Reuse 3
2x1			1 830		
2x2	1 782	6 000	2 400	3 662	3 169
4x1			1 930		
4x2		6 100	2 560		

Company A: Possible to get 2 ranks and NR MCS with 256QAM at these conditions for higher throughput

Uplink, 23 dBm transmit power

5 Percentile

Table 14

MIMO Setting	No Mitigation	Interference Mitigation of MMSE-IRC scheme as per 3GPP TR 36.884 [i.9]		Hard Reuse of Frequencies	
	Company C	Company A	Company B	Company C	Company C
	Reuse 1	Reuse 1	Reuse 1	Reuse 2	Reuse 3
1x2		700	950		
2x2	1 761	822	950	3 077	2 958
1x4		1 442	1 100		
2x4		1 764	1 070		

50 Percentile

Table 15

MIMO Setting	No Mitigation	Interference Mitigation of MMSE-IRC scheme as per 3GPP TR 36.884 [i.9]		Hard Reuse of Frequencies	
	Company C	Company A	Company B	Company C	Company C
	Reuse 1	Reuse 1	Reuse 1	Reuse 2	Reuse 3
1x2		2 573	2 000		
2x2	7 852	2 845	2 100	5 183	3 458
1x4		4 072	2 410		
2x4		4 981	2 530		

Increasing number BS Rx antenna ports from 2 to 4 gives a significant increase in performance. This is mainly due to that the BS effective antenna area is increased when going from 2 to 4 antenna ports, leading to more received energy.

Uplink, 31 dBm transmit power

5 Percentile

Table 16

MIMO Setting	No Mitigation	Interference Mitigation of MMSE-IRC scheme as per 3GPP TR 36.884 [i.9]		Hard Reuse of Frequencies	
	Company C	Company A	Company B	Company C	Company C
	Reuse 1	Reuse 1	Reuse 1	Reuse 2	Reuse 3
1x2		1 826	1 380		
2x2	3254	1 982	1 370	4 261	3 458
1x4		3 275	1 550		
2x4		3 626	1 580		

50 Percentile

Table 17

MIMO Setting	No Mitigation	Interference Mitigation of MMSE-IRC scheme as per 3GPP TR 36.884 [i.9]		Hard Reuse of Frequencies	
	Company C	Company A	Company B	Company C	Company C
	Reuse 1	Reuse 1	Reuse 1	Reuse 2	Reuse 3
1x2		3 117	2 300		
2x2	9 634	3 431	2 370	5 183	3 458
1x4		4 642	2 510		
2x4		5 980	2 580		

6.3.4 900 MHz High Density Urban scenario 4 km ISD

Downlink

5 Percentile

Table 18

MIMO Setting	No Mitigation	Interference Mitigation of MMSE-IRC scheme as per 3GPP TR 36.884 [i.9]		Hard Reuse of Frequencies	
	Company C	Company A	Company B	Company C	Company C
	Reuse 1	Reuse 1	Reuse 1	Reuse 2	Reuse 3
2x1			170		
2x2	0	1 015	300	607	778
4x1			250		
4x2		1 094	410		

50 Percentile

Table 19

MIMO Setting	No Mitigation	Interference Mitigation of MMSE-IRC scheme as per 3GPP TR 36.884 [i.9]		Hard Reuse of Frequencies	
	Company C	Company A	Company B	Company C	Company C
	Reuse 1	Reuse 1	Reuse 1	Reuse 2	Reuse 3
2x1			610		
2x2	922	2 555	970	1 896	1 667
4x1			830		
4x2		2 654	1 040		

Uplink, 23 dBm transmit power

5 Percentile

Table 20

MIMO Setting	No Mitigation	Interference Mitigation of MMSE-IRC scheme as per 3GPP TR 36.884 [i.9]		Hard Reuse of Frequencies	
	Company C	Company A	Company B	Company C	Company C
	Reuse 1	Reuse 1	Reuse 1	Reuse 2	Reuse 3
1x2		39	60		
2x2	296	57	70	819	822
1x4		93	100		
2x4		112	110		

50 Percentile

Table 21

MIMO Setting	No Mitigation	Interference Mitigation of MMSE-IRC scheme as per 3GPP TR 36.884 [i.9]		Hard Reuse of Frequencies	
	Company C	Company A	Company B	Company C	Company C
	Reuse 1	Reuse 1	Reuse 1	Reuse 2	Reuse 3
1x2		273	250		
2x2	2 400	307	300	2 148	1 696
1x4		542	380		
2x4		626	410		

5 percentile range 0 to 50 at 4 km 2x2 the SINR drops quickly at 1 km.

Uplink, 31 dBm transmit power

5 Percentile

Table 22

MIMO Setting	No Mitigation	Interference Mitigation of MMSE-IRC scheme as per 3GPP TR 36.884 [i.9]		Hard Reuse of Frequencies	
	Company C	Company A	Company B	Company C	Company C
	Reuse 1	Reuse 1	Reuse 1	Reuse 2	Reuse 3
1x2		200	180		
2x2	104	229	170	726	900
1x4		372	210		
2x4		457	230		

50 Percentile

Table 23

MIMO Setting	No Mitigation	Interference Mitigation of MMSE-IRC scheme as per 3GPP TR 36.884 [i.9]		Hard Reuse of Frequencies	
	Company C	Company A	Company B	Company C	Company C
	Reuse 1	Reuse 1	Reuse 1	Reuse 2	Reuse 3
1x2		957	620		
2x2	1 963	1 100	690	2 133	1 774
1x4		1 744	740		
2x4		1 978	770		

6.3.5 1 900 MHz Rural Scenario - 8 km ISD UL 50:50 in kbps

5 percentile 23 dBm

Table 24

MIMO Setting	No Mitigation	Interference Mitigation of MMSE-IRC scheme as per 3GPP TR 36.884 [i.9]		Hard Reuse of Frequencies	
	Company C	Company A	Company B	Company C	Company C
	Reuse 1	Reuse 1	Reuse 1	Reuse 2	Reuse 3
1x2			530		
1x4			570		
1x8			610		
2x2	338		510	367	247
2x4			530		
2x8			600		

50 percentile 23 dBm

Table 25

MIMO Setting	No Mitigation	Interference Mitigation of MMSE-IRC scheme as per 3GPP TR 36.884 [i.9]		Hard Reuse of Frequencies	
	Company C	Company A	Company B	Company C	Company C
	Reuse 1	Reuse 1	Reuse 1	Reuse 2	Reuse 3
1x2			730		
1x4			790		
1x8			820		
2x2	738		700	367	247
2x4			760		
2x8			790		

5 percentile 31 dBm

Table 26

MIMO Setting	No Mitigation	Interference Mitigation of MMSE-IRC scheme as per 3GPP TR 36.884 [i.9]		Hard Reuse of Frequencies	
	Company C	Company A	Company B	Company C	Company C
	Reuse 1	Reuse 1	Reuse 1	Reuse 2	Reuse 3
1x2			670		
1x4			790		
1x8			810		
2x2	131	232	670	367	247
2x4		414	760		
2x8		493	800		

50 percentile 31 dBm

Table 27

MIMO Setting	No Mitigation	Interference Mitigation of MMSE-IRC scheme as per 3GPP TR 36.884 [i.9]		Hard Reuse of Frequencies	
	Company C	Company A	Company B	Company C	Company C
	Reuse 1	Reuse 1	Reuse 1	Reuse 2	Reuse 3
1x2			1 180		
1x4			1 300		
1x8			1 370		
2x2	738	1 152	1 100	367	247
2x4		2 180	1 280		
2x8		2 452	1 370		

6.3.6 1 900 MHz Rural Scenario - 8 km ISD UL 90:10 in kbps

5 percentile 23 dBm

Table 28

MIMO Setting	No Mitigation	Interference Mitigation of MMSE-IRC scheme as per 3GPP TR 36.884 [i.9]		Hard Reuse of Frequencies	
	Company C	Company A	Company B	Company C	Company C
	Reuse 1	Reuse 1	Reuse 1	Reuse 2	Reuse 3
1x2			930		
1x4			1 000		
1x8			1 070		
2x2	611		890	665	444
2x4			930		
2x8			1 050		

50 percentile 23 dBm

Table 29

MIMO Setting	No Mitigation	Interference Mitigation of MMSE-IRC scheme as per 3GPP TR 36.884 [i.9]		Hard Reuse of Frequencies	
	Company C	Company A	Company B	Company C	Company C
	Reuse 1	Reuse 1	Reuse 1	Reuse 2	Reuse 3
1x2			1 280		
1x4			1 380		
1x8			1 440		
2x2	1 327		1 230	665	444
2x4			1 330		
2x8			1 380		

5 percentile 31 dBm

Table 30

MIMO Setting	No Mitigation	Interference Mitigation of MMSE-IRC scheme as per 3GPP TR 36.884 [i.9]		Hard Reuse of Frequencies	
	Company C	Company A	Company B	Company C	Company C
	Reuse 1	Reuse 1	Reuse 1	Reuse 2	Reuse 3
1x2			1 170		
1x4			1 380		
1x8			1 420		
2x2	236		1 170	665	444
2x4			1 330		
2x8			1 400		

50 percentile 31 dBm

Table 31

MIMO Setting	No Mitigation	Interference Mitigation of MMSE-IRC scheme as per 3GPP TR 36.884 [i.9]		Hard Reuse of Frequencies	
	Company C	Company A	Company B	Company C	Company C
	Reuse 1	Reuse 1	Reuse 1	Reuse 2	Reuse 3
1x2			2 070		
1x4			2 280		
1x8			2 400		
2x2	1 327		1 930	665	444
2x4			2 240		
2x8			2 400		

6.3.7 1 900 MHz Rural Scenario - 6 km ISD UL 50:50 in kbps

5 percentile 23 dBm

Table 32

MIMO Setting	No Mitigation	Interference Mitigation of MMSE-IRC scheme as per 3GPP TR 36.884 [i.9]		Hard Reuse of Frequencies	
	Company C	Company A	Company B	Company C	Company C
	Reuse 1	Reuse 1	Reuse 1	Reuse 2	Reuse 3
1x2			930		
1x4			990		
1x8			1 050		
2x2	723		990	490	330
2x4			1 010		
2x8			1 030		

50 percentile 23 dBm

Table 33

MIMO Setting	No Mitigation	Interference Mitigation of MMSE-IRC scheme as per 3GPP TR 36.884 [i.9]		Hard Reuse of Frequencies	
	Company C	Company A	Company B	Company C	Company C
	Reuse 1	Reuse 1	Reuse 1	Reuse 2	Reuse 3
1x2			1 500		
1x4			1 600		
1x8			1 670		
2x2	985		1 580	490	330
2x4			1 650		
2x8			1 700		

5 percentile 31 dBm

Table 34

MIMO Setting	No Mitigation	Interference Mitigation of MMSE-IRC scheme as per 3GPP TR 36.884 [i.9]		Hard Reuse of Frequencies	
	Company C	Company A	Company B	Company C	Company C
	Reuse 1	Reuse 1	Reuse 1	Reuse 2	Reuse 3
1x2			1 400		
1x4			1 450		
1x8			1 470		
2x2	369		1 400	490	330
2x4			1 480		
2x8			1 510		

50 percentile 31 dBm

Table 35

MIMO Setting	No Mitigation	Interference Mitigation of MMSE-IRC scheme as per 3GPP TR 36.884 [i.9]		Hard Reuse of Frequencies	
	Company C	Company A	Company B	Company C	Company C
	Reuse 1	Reuse 1	Reuse 1	Reuse 2	Reuse 3
1x2			1 660		
1x4			1 770		
1x8			1 800		
2x2	985		1 700	490	330
2x4			1 790		
2x8			1 830		

6.3.8 1 900 MHz Rural Scenario - 6 km ISD UL 90:10 in kbps

5 percentile 23 dBm

Table 36

MIMO Setting	No Mitigation	Interference Mitigation of MMSE-IRC scheme as per 3GPP TR 36.884 [i.9]		Hard Reuse of Frequencies	
	Company C	Company A	Company B	Company C	Company C
	Reuse 1	Reuse 1	Reuse 1	Reuse 2	Reuse 3
1x2			1 630		
1x4			1 730		
1x8			1 840		
2x2	1 301		1 730	888	592
2x4			1 770		
2x8			1 800		

50 percentile 23 dBm

Table 37

MIMO Setting	No Mitigation	Interference Mitigation of MMSE-IRC scheme as per 3GPP TR 36.884 [i.9]		Hard Reuse of Frequencies	
	Company C	Company A	Company B	Company C	Company C
	Reuse 1	Reuse 1	Reuse 1	Reuse 2	Reuse 3
1x2			2 630		
1x4			2 800		
1x8			2 920		
2x2	1 772		2 770	888	592
2x4			2 890		
2x8			2 980		

5 percentile 31 dBm

Table 38

MIMO Setting	No Mitigation	Interference Mitigation of MMSE-IRC scheme as per 3GPP TR 36.884 [i.9]		Hard Reuse of Frequencies	
	Company C	Company A	Company B	Company C	Company C
	Reuse 1	Reuse 1	Reuse 1	Reuse 2	Reuse 3
1x2			2 450		
1x4			2 540		
1x8			2 570		
2x2	660		2 450	888	592
2x4			2 590		
2x8			2 640		

50 percentile 31 dBm

Table 39

MIMO Setting	No Mitigation	Interference Mitigation of MMSE-IRC scheme as per 3GPP TR 36.884 [i.9]		Hard Reuse of Frequencies	
	Company C	Company A	Company B	Company C	Company C
	Reuse 1	Reuse 1	Reuse 1	Reuse 2	Reuse 3
1x2			2 910		
1x4			3 100		
1x8			3 150		
2x2	1 772		2 980	888	592
2x4			3 130		
2x8			3 200		

6.3.9 1 900 MHz Rural Scenario - 4 km ISD UL 50:50 in kbps

5 percentile 23 dBm

Table 40

MIMO Setting	No Mitigation	Interference Mitigation of MMSE-IRC scheme as per 3GPP TR 36.884 [i.9]		Hard Reuse of Frequencies	
	Company C	Company A	Company B	Company C	Company C
	Reuse 1	Reuse 1	Reuse 1	Reuse 2	Reuse 3
1x2		605	2 850		
1x4		1 297	2 850		
1x8		1 525	2 900		
2x2	1 449	690	2 830	732	493
2x4		1 517	2 870		
2x8		1 818	2 900		

50 percentile 23 dBm

Table 41

MIMO Setting	No Mitigation	Interference Mitigation of MMSE-IRC scheme as per 3GPP TR 36.884 [i.9]		Hard Reuse of Frequencies	
	Company C	Company A	Company B	Company C	Company C
	Reuse 1	Reuse 1	Reuse 1	Reuse 2	Reuse 3
1x2		2 697	4 240		
1x4		4 630	4 300		
1x8		5 752	4 400		
2x2	1 471	3 209	4 250	732	493
2x4		5 582	4 300		
2x8		7 043	4 370		

5 percentile 31 dBm

Table 42

MIMO Setting	No Mitigation	Interference Mitigation of MMSE-IRC scheme as per 3GPP TR 36.884 [i.9]		Hard Reuse of Frequencies	
	Company C	Company A	Company B	Company C	Company C
	Reuse 1	Reuse 1	Reuse 1	Reuse 2	Reuse 3
1x2		1 681	2 830		
1x4		3 332	2 850		
1x8		3 820	2 910		
2x2	1319	1 296	2 820	732	493
2x4		3 639	2 830		
2x8		4 444	2 890		

50 percentile 31 dBm

Table 43

MIMO Setting	No Mitigation	Interference Mitigation of MMSE-IRC scheme as per 3GPP TR 36.884 [i.9]		Hard Reuse of Frequencies	
	Company C	Company A	Company B	Company C	Company C
	Reuse 1	Reuse 1	Reuse 1	Reuse 2	Reuse 3
1x2		3 351	4 300		
1x4		5 381	4 330		
1x8		6 763	4 410		
2x2	1 471	4 002	4 280	732	493
2x4		6 711	4 340		
2x8		8 049	4 400		

6.3.10 1 900 MHz Rural Scenario - 4km ISD UL 90:10 in kbps

5 percentile 23 dBm

Table 44

MIMO Setting	No Mitigation	Interference Mitigation of MMSE-IRC scheme as per 3GPP TR 36.884 [i.9]		Hard Reuse of Frequencies	
	Company C	Company A	Company B	Company C	Company C
	Reuse 1	Reuse 1	Reuse 1	Reuse 2	Reuse 3
1x2		1 128	4 990		
1x4		2 417	4 990		
1x8		2 841	5 080		
2x2	2 616	1 295	4 950	1 326	884
2x4		2 826	5 020		
2x8		3 387	5 080		

50 percentile 23 dBm

Table 45

MIMO Setting	No Mitigation	Interference Mitigation of MMSE-IRC scheme as per 3GPP TR 36.884 [i.9]		Hard Reuse of Frequencies	
	Company C	Company A	Company B	Company C	Company C
	Reuse 1	Reuse 1	Reuse 1	Reuse 2	Reuse 3
1x2		2 065	7 420		
1x4		4 000	7 530		
1x8		4 746	7 700		
2x2	2 645	2 287	7 440	1 326	884
2x4		4 437	7 530		
2x8		5 409	7 650		

5 percentile 31 dBm

Table 46

MIMO Setting	No Mitigation	Interference Mitigation of MMSE-IRC scheme as per 3GPP TR 36.884 [i.9]		Hard Reuse of Frequencies	
	Company C	Company A	Company B	Company C	Company C
	Reuse 1	Reuse 1	Reuse 1	Reuse 2	Reuse 3
1x2		3 131	4 950		
1x4		6 206	4 990		
1x8		7 116	5 090		
2x2	2 370	3 587	4 940	1 326	884
2x4		6 778	4 950		
2x8		8 276	5 060		

50 percentile 31 dBm

Table 47

MIMO Setting	No Mitigation	Interference Mitigation of MMSE-IRC scheme as per 3GPP TR 36.884 [i.9]		Hard Reuse of Frequencies	
	Company C	Company A	Company B	Company C	Company C
	Reuse 1	Reuse 1	Reuse 1	Reuse 2	Reuse 3
1x2		6 242	7 530		
1x4		10 020	7 580		
1x8		12 600	7 720		
2x2	2 645	7 455	7 490	1 326	884
2x4		12 500	7 600		
2x8		14 990	7 700		

6.3.11 1 900 MHz Rural Scenario - DL 40 dBm EIRP 90:10 in kbps

Company A: Possible to use higher MCs for this scenario at 4 km

5 percentile 4 km ISD

Table 48

MIMO Setting	No Mitigation	Interference Mitigation of MMSE-IRC scheme as per 3GPP TR 36.884 [i.9]		Hard Reuse of Frequencies	
	Company C	Company A	Company B	Company C	Company C
	Reuse 1	Reuse 1	Reuse 1	Reuse 2	Reuse 3
2x1		72	325		
4x1		65	355		
8x1		68	360		
2x2	58	151	350	399	268
4x2		127	355		
8x2		132	360		

50 percentile 4 km ISD

Table 49

MIMO Setting	No Mitigation	Interference Mitigation of MMSE-IRC scheme as per 3GPP TR 36.884 [i.9]		Hard Reuse of Frequencies	
	Company C	Company A	Company B	Company C	Company C
	Reuse 1	Reuse 1	Reuse 1	Reuse 2	Reuse 3
2x1		290	960		
4x1		282	1 005		
8x1		300	1 020		
2x2	761	645	1 000	406	268
4x2		580	1 010		
8x2		595	1 020		

5 percentile6 km ISD

Table 50

MIMO Setting	No Mitigation	Interference Mitigation of MMSE-IRC scheme as per 3GPP TR 36.884 [i.9]		Hard Reuse of Frequencies	
	Company C	Company A	Company B	Company C	Company C
	Reuse 1	Reuse 1	Reuse 1	Reuse 2	Reuse 3
2x1		18	130		
4x1		12	150		
8x1		13	165		
2x2	44	42	145	272	180
4x2		32	160		
8x2		32	170		

50 percentile 6 km ISD

Table 51

MIMO Setting	No Mitigation	Interference Mitigation of MMSE-IRC scheme as per 3GPP TR 36.884 [i.9]		Hard Reuse of Frequencies	
	Company C	Company A	Company B	Company C	Company C
	Reuse 1	Reuse 1	Reuse 1	Reuse 2	Reuse 3
2x1		90	230		
4x1		82	255		
8x1		83	275		
2x2	510	197	250	272	180
4x2		171	270		
8x2		176	290		

5 percentile 8 km ISD

Table 52

MIMO Setting	No Mitigation	Interference Mitigation of MMSE-IRC scheme as per 3GPP TR 36.884 [i.9]		Hard Reuse of Frequencies	
	Company C	Company A	Company B	Company C	Company C
	Reuse 1	Reuse 1	Reuse 1	Reuse 2	Reuse 3
2x1		2	40		
4x1		0	45		
8x1		0	45		
2x2	25	13	50	167	131
4x2		7	50		
8x2		8	60		

50 percentile 8 km ISD

Table 53

MIMO Setting	No Mitigation	Interference Mitigation of MMSE-IRC scheme as per 3GPP TR 36.884 [i.9]		Hard Reuse of Frequencies	
	Company C	Company A	Company B	Company C	Company C
	Reuse 1	Reuse 1	Reuse 1	Reuse 2	Reuse 3
2x1		38	90		
4x1		33	110		
8x1		34	115		
2x2	313	69	115	204	135
4x2		58	115		
8x2		59	125		

6.3.12 1 900 MHz Rural Scenario - DL 40 dBm EIRP 50:50 in kbps

5 percentile 4 km ISD

Table 54

MIMO Setting	No Mitigation	Interference Mitigation of MMSE-IRC scheme as per 3GPP TR 36.884 [i.9]		Hard Reuse of Frequencies	
	Company C	Company A	Company B	Company C	Company C
	Reuse 1	Reuse 1	Reuse 1	Reuse 2	Reuse 3
2x1		434	1 620		
4x1		396	1 770		
8x1		407	1 880		
2x2	239	1 073	1 750	2 029	1 355
4x2		878	1 770		
8x2		917	1 810		

50 percentile 4 km ISD

Table 55

MIMO Setting	No Mitigation	Interference Mitigation of MMSE-IRC scheme as per 3GPP TR 36.884 [i.9]		Hard Reuse of Frequencies	
	Company C	Company A	Company B	Company C	Company C
	Reuse 1	Reuse 1	Reuse 1	Reuse 2	Reuse 3
2x1		2 121	4 800		
4x1		2 066	5 030		
8x1		2 226	5 100		
2x2	3 783	4 859	5 000	2 036	1 355
4x2		4 443	5 050		
8x2		4 608	5 100		

5 percentile 6 km ISD

Table 56

MIMO Setting	No Mitigation	Interference Mitigation of MMSE-IRC scheme as per 3GPP TR 36.884 [i.9]		Hard Reuse of Frequencies	
	Company C	Company A	Company B	Company C	Company C
	Reuse 1	Reuse 1	Reuse 1	Reuse 2	Reuse 3
2x1		142	650		
4x1		108	750		
8x1		111	820		
2x2	189	265	730	1 364	908
4x2		217	810		
8x2		219	880		

50 percentile 6 km ISD

Table 57

MIMO Setting	No Mitigation	Interference Mitigation of MMSE-IRC scheme as per 3GPP TR 36.884 [i.9]		Hard Reuse of Frequencies	
	Company C	Company A	Company B	Company C	Company C
	Reuse 1	Reuse 1	Reuse 1	Reuse 2	Reuse 3
2x1		595	1 150		
4x1		512	1 280		
8x1		525	1 370		
2x2	2 646	1 446	1 260	1 364	908
4x2		1 222	1 350		
8x2		1 256	1 440		

5 percentile 8 km ISD

Table 58

MIMO Setting	No Mitigation	Interference Mitigation of MMSE-IRC scheme as per 3GPP TR 36.884 [i.9]		Hard Reuse of Frequencies	
	Company C	Company A	Company B	Company C	Company C
	Reuse 1	Reuse 1	Reuse 1	Reuse 2	Reuse 3
2x1		34	190		
4x1		15	230		
8x1		17	220		
2x2	135	101	240	836	655
4x2		77	245		
8x2		78	290		

50 percentile 8 km ISD

Table 59

MIMO Setting	No Mitigation	Interference Mitigation of MMSE-IRC scheme as per 3GPP TR 36.884 [i.9]		Hard Reuse of Frequencies	
	Company C	Company A	Company B	Company C	Company C
	Reuse 1	Reuse 1	Reuse 1	Reuse 2	Reuse 3
2x1		247	450		
4x1		218	550		
8x1		221	580		
2x2	1 556	459	570	1 022	680
4x2		383	570		
8x2		386	630		

6.3.13 1 900 MHz Rural Scenario - DL 63 dBm EIRP 50:50 in kbps

5 percentile 4 km ISD

Table 60

MIMO Setting	No Mitigation	Interference Mitigation of MMSE-IRC scheme as per 3GPP TR 36.884 [i.9]		Hard Reuse of Frequencies	
	Company C	Company A	Company B	Company C	Company C
	Reuse 1	Reuse 1	Reuse 1	Reuse 2	Reuse 3
2x1			1 580		
4x1			1 700		
8x1	330		1 670	2 800	1870
2x2			1 760		
4x2			1 730		
8x2			1 790		

50 percentile 4 km ISD

Table 61

MIMO Setting	No Mitigation	Interference Mitigation of MMSE-IRC scheme as per 3GPP TR 36.884 [i.9]		Hard Reuse of Frequencies	
	Company C	Company A	Company B	Company C	Company C
	Reuse 1	Reuse 1	Reuse 1	Reuse 2	Reuse 3
2x1			5 650		
4x1			6 010		
8x1			5 830		
2x2	5 220		6 020	2 810	1 870
4x2			6 090		
8x2			6 150		

5 percentile 6 km ISD

Table 62

MIMO Setting	No Mitigation	Interference Mitigation of MMSE-IRC scheme as per 3GPP TR 36.884 [i.9]		Hard Reuse of Frequencies	
	Company C	Company A	Company B	Company C	Company C
	Reuse 1	Reuse 1	Reuse 1	Reuse 2	Reuse 3
2x1			810		
4x1			900		
8x1			950		
2x2			860		
4x2			930		
8x2			960		

50 percentile 6 km ISD

Table 63

MIMO Setting	No Mitigation	Interference Mitigation of MMSE-IRC scheme as per 3GPP TR 36.884 [i.9]		Hard Reuse of Frequencies	
	Company C	Company A	Company B	Company C	Company C
	Reuse 1	Reuse 1	Reuse 1	Reuse 2	Reuse 3
2x1			1 530		
4x1			1 660		
8x1			1 720		
2x2			1 600		
4x2			1 700		
8x2			1 750		

5 percentile 8 km ISD

Table 64

MIMO Setting	No Mitigation	Interference Mitigation of MMSE-IRC scheme as per 3GPP TR 36.884 [i.9]		Hard Reuse of Frequencies	
	Company C	Company A	Company B	Company C	Company C
	Reuse 1	Reuse 1	Reuse 1	Reuse 2	Reuse 3
2x1			500		
4x1			580		
8x1			780		
2x2			660		
4x2		1 175	800		
8x2			1 000		

50 percentile 8 km ISD

Table 65

MIMO Setting	No Mitigation	Interference Mitigation of MMSE-IRC scheme as per 3GPP TR 36.884 [i.9]		Hard Reuse of Frequencies	
	Company C	Company A	Company B	Company C	Company C
	Reuse 1	Reuse 1	Reuse 1	Reuse 2	Reuse 3
2x1			980		
4x1			1 030		
8x1			1 500		
2x2			1 090		
4x2		3 277	1 170		
8x2			1 700		

6.3.14 1 900 MHz Rural Scenario - DL 63 dBm EIRP 90:10 in kbps

5 percentile 4 km ISD

Table 66

MIMO Setting	No Mitigation	Interference Mitigation of MMSE-IRC scheme as per 3GPP TR 36.884 [i.9]		Hard Reuse of Frequencies	
	Company C	Company A	Company B	Company C	Company C
	Reuse 1	Reuse 1	Reuse 1	Reuse 2	Reuse 3
2x1			315		
4x1			335		
8x1			345		
2x2	70		340	560	370
4x2			350		
8x2			360		

50 percentile 4 km ISD

Table 67

MIMO Setting	No Mitigation	Interference Mitigation of MMSE-IRC scheme as per 3GPP TR 36.884 [i.9]		Hard Reuse of Frequencies	
	Company C	Company A	Company B	Company C	Company C
	Reuse 1	Reuse 1	Reuse 1	Reuse 2	Reuse 3
2x1			1 130		
4x1			1 165		
8x1			1 220		
2x2			1 200		
4x2			1 205		
8x2			1 230		

5 percentile 6 km ISD

Table 68

MIMO Setting	No Mitigation	Interference Mitigation of MMSE-IRC scheme as per 3GPP TR 36.884 [i.9]		Hard Reuse of Frequencies	
	Company C	Company A	Company B	Company C	Company C
	Reuse 1	Reuse 1	Reuse 1	Reuse 2	Reuse 3
2x1			160		
4x1			180		
8x1			190		
2x2	39		170	272	180
4x2			185		
8x2			190		

50 percentile 6 km ISD

Table 69

MIMO Setting	No Mitigation	Interference Mitigation of MMSE-IRC scheme as per 3GPP TR 36.884 [i.9]		Hard Reuse of Frequencies	
	Company C	Company A	Company B	Company C	Company C
	Reuse 1	Reuse 1	Reuse 1	Reuse 2	Reuse 3
2x1			305		
4x1			330		
8x1			345		
2x2	529		320	272	180
4x2			340		
8x2			350		

5 percentile 8 km ISD

Table 70

MIMO Setting	No Mitigation	Interference Mitigation of MMSE-IRC scheme as per 3GPP TR 36.884 [i.9]		Hard Reuse of Frequencies	
	Company C	Company A	Company B	Company C	Company C
	Reuse 1	Reuse 1	Reuse 1	Reuse 2	Reuse 3
2x1			100		
4x1			115		
8x1			155		
2x2	33		130	204	135
4x2			160		
8x2			200		

50 percentile 8 km ISD

Table 71

MIMO Setting	No Mitigation	Interference Mitigation of MMSE-IRC scheme as per 3GPP TR 36.884 [i.9]		Hard Reuse of Frequencies	
	Company C	Company A	Company B	Company C	Company C
	Reuse 1	Reuse 1	Reuse 1	Reuse 2	Reuse 3
2x1			195		
4x1			205		
8x1			300		
2x2	396		220	204	135
4x2			235		
8x2			340		

6.3.15 1 900 MHz Urban Scenario - DL 40 dBm EIRP 50:50 in kbps

5 percentile 2 km ISD

Table 72

MIMO Setting	No Mitigation	Interference Mitigation of MMSE-IRC scheme as per 3GPP TR 36.884 [i.9]		Hard Reuse of Frequencies	
	Company C	Company A	Company B	Company C	Company C
	Reuse 1	Reuse 1	Reuse 1	Reuse 2	Reuse 3
2x1		196	450		
4x1		142	500		
8x1		140	550		
2x2	0	355	490	1 014	1 183
4x2		263	540		
8x2		264	560		

50 percentile 2 km ISD

Table 73

MIMO Setting	No Mitigation	Interference Mitigation of MMSE-IRC scheme as per 3GPP TR 36.884 [i.9]		Hard Reuse of Frequencies	
	Company C	Company A	Company B	Company C	Company C
	Reuse 1	Reuse 1	Reuse 1	Reuse 2	Reuse 3
2x1		812	1 590		
4x1		633	1 750		
8x1		628	1 800		
2x2	2 113	1737	1 730	3 148	2 641
4x2		1285	1 790		
8x2		1291	1 800		

5 percentile 4 km ISD

Table 74

MIMO Setting	No Mitigation	Interference Mitigation of MMSE-IRC scheme as per 3GPP TR 36.884 [i.9]		Hard Reuse of Frequencies	
	Company C	Company A	Company B	Company C	Company C
	Reuse 1	Reuse 1	Reuse 1	Reuse 2	Reuse 3
2x1		0	0		
4x1		0	0		
8x1	0	0	0	174	204
2x2		0	0		
4x2		0	0		
8x2		0	0		

50 percentile 4 km ISD

Table 75

MIMO Setting	No Mitigation	Interference Mitigation of MMSE-IRC scheme as per 3GPP TR 36.884 [i.9]		Hard Reuse of Frequencies	
	Company C	Company A	Company B	Company C	Company C
	Reuse 1	Reuse 1	Reuse 1	Reuse 2	Reuse 3
2x1		55	10		
4x1		15	40		
8x1		14	90		
2x2	685	130	50	919	730
4x2		83	60		
8x2		82	100		

6.3.16 1 900 MHz Urban Scenario - DL 63 dBm EIRP 90:10 in kbps

5 percentile 2 km ISD

Table 76

MIMO Setting	No Mitigation	Interference Mitigation of MMSE-IRC scheme as per 3GPP TR 36.884 [i.9]		Hard Reuse of Frequencies	
	Company C	Company A	Company B	Company C	Company C
	Reuse 1	Reuse 1	Reuse 1	Reuse 2	Reuse 3
2x1			245		
4x1			255		
8x1			270		
2x2	0		250	211	303
4x2		445	260		
8x2		446	280		

50 percentile 2 km ISD

Table 77

MIMO Setting	No Mitigation	Interference Mitigation of MMSE-IRC scheme as per 3GPP TR 36.884 [i.9]		Hard Reuse of Frequencies	
	Company C	Company A	Company B	Company C	Company C
	Reuse 1	Reuse 1	Reuse 1	Reuse 2	Reuse 3
2x1			405		
4x1			430		
8x1			450		
2x2	451		430	754	648
4x2		1 076	440		
8x2		1 136	460		

5 percentile 4 km ISD

Table 78

MIMO Setting	No Mitigation	Interference Mitigation of MMSE-IRC scheme as per 3GPP TR 36.884 [i.9]		Hard Reuse of Frequencies	
	Company C	Company A	Company B	Company C	Company C
	Reuse 1	Reuse 1	Reuse 1	Reuse 2	Reuse 3
2x1			10		
4x1			20		
8x1			20		
2x2	0		20	107	141
4x2		0	25		
8x2		0	30		

50 percentile 4 km ISD

Table 79

MIMO Setting	No Mitigation	Interference Mitigation of MMSE-IRC scheme as per 3GPP TR 36.884 [i.9]		Hard Reuse of Frequencies	
	Company C	Company A	Company B	Company C	Company C
	Reuse 1	Reuse 1	Reuse 1	Reuse 2	Reuse 3
2x1			25		
4x1			35		
8x1			45		
2x2	222		35	393	333
4x2		130	40		
8x2		83	45		

6.3.17 1 900 MHz Urban Scenario - DL 63 dBm EIRP 50:50 in kbps

5 percentile 2 km ISD

Table 80

MIMO Setting	No Mitigation	Interference Mitigation of MMSE-IRC scheme as per 3GPP TR 36.884 [i.9]		Hard Reuse of Frequencies	
	Company C	Company A	Company B	Company C	Company C
	Reuse 1	Reuse 1	Reuse 1	Reuse 2	Reuse 3
2x1			1 220		
4x1			1 280		
8x1			1 360		
2x2	0	3 524	1 250	1 056	1 507
4x2		3 514	1 310		
8x2		3 988	1 400		

50 percentile 2 km ISD

Table 81

MIMO Setting	No Mitigation	Interference Mitigation of MMSE-IRC scheme as per 3GPP TR 36.884 [i.9]		Hard Reuse of Frequencies	
	Company C	Company A	Company B	Company C	Company C
	Reuse 1	Reuse 1	Reuse 1	Reuse 2	Reuse 3
2x1			2 020		
4x1			2 150		
8x1			2 260		
2x2	2 254	8 296	2 140	3 768	3 225
4x2		8 724	2 200		
8x2		9 482	2 290		

5 percentile 4 km ISD

Table 82

MIMO Setting	No Mitigation	Interference Mitigation of MMSE-IRC scheme as per 3GPP TR 36.884 [i.9]		Hard Reuse of Frequencies	
	Company C	Company A	Company B	Company C	Company C
	Reuse 1	Reuse 1	Reuse 1	Reuse 2	Reuse 3
2x1			60		
4x1			90		
8x1			110		
2x2	0		100	537	704
4x2			120		
8x2			140		

50 percentile 4 km ISD

Table 83

MIMO Setting	No Mitigation	Interference Mitigation of MMSE-IRC scheme as per 3GPP TR 36.884 [i.9]		Hard Reuse of Frequencies	
	Company C	Company A	Company B	Company C	Company C
	Reuse 1	Reuse 1	Reuse 1	Reuse 2	Reuse 3
2x1			120		
4x1			180		
8x1			220		
2x2	1 107		180	1 959	1 674
4x2			200		
8x2			230		

6.3.18 1 900 MHz Urban Scenario - DL 40 dBm EIRP 90:10 in kbps

5 percentile 2 km ISD

Table 84

MIMO Setting	No Mitigation	Interference Mitigation of MMSE-IRC scheme as per 3GPP TR 36.884 [i.9]		Hard Reuse of Frequencies	
	Company C	Company A	Company B	Company C	Company C
	Reuse 1	Reuse 1	Reuse 1	Reuse 2	Reuse 3
2x1		12	90		
4x1		9	100		
8x1		9	110		
2x2	0	23	100	204	239
4x2		17	110		
8x2		17	110		

50 percentile 2 km ISD

Table 85

MIMO Setting	No Mitigation	Interference Mitigation of MMSE-IRC scheme as per 3GPP TR 36.884 [i.9]		Hard Reuse of Frequencies	
	Company C	Company A	Company B	Company C	Company C
	Reuse 1	Reuse 1	Reuse 1	Reuse 2	Reuse 3
2x1		27	320		
4x1		16	350		
8x1		17	360		
2x2	423	52	345	627	528
4x2		39	360		
8x2		39	360		

5 percentile 4 km ISD

Table 86

MIMO Setting	No Mitigation	Interference Mitigation of MMSE-IRC scheme as per 3GPP TR 36.884 [i.9]		Hard Reuse of Frequencies	
	Company C	Company A	Company B	Company C	Company C
	Reuse 1	Reuse 1	Reuse 1	Reuse 2	Reuse 3
2x1		0	0		
4x1		0	0		
8x1		0	0		
2x2	0	0	0	33	41
4x2		0	0		
8x2		0	0		

50 percentile 4 km ISD

Table 87

MIMO Setting	No Mitigation	Interference Mitigation of MMSE-IRC scheme as per 3GPP TR 36.884 [i.9]		Hard Reuse of Frequencies	
	Company C	Company A	Company B	Company C	Company C
	Reuse 1	Reuse 1	Reuse 1	Reuse 2	Reuse 3
2x1		0	0		
4x1		0	10		
8x1		0	20		
2x2	137	18	10	185	144
4x2		0	10		
8x2		0	20		

6.3.19 1 900 MHz High Density Scenario - UL 2 km ISD 50:50 in kbps

5 percentile 23 dBm

Table 88

MIMO Setting	No Mitigation	Interference Mitigation of MMSE-IRC scheme as per 3GPP TR 36.884 [i.9]		Hard Reuse of Frequencies	
	Company C	Company A	Company B	Company C	Company C
	Reuse 1	Reuse 1	Reuse 1	Reuse 2	Reuse 3
1x2		222	100		
1x4		380	130		
1x8		460	160		
2x2	268	250	100	1408	1415
2x4		435	140		
2x8		527	190		

50 percentile 23 dBm

Table 89

MIMO Setting	No Mitigation	Interference Mitigation of MMSE-IRC scheme as per 3GPP TR 36.884 [i.9]		Hard Reuse of Frequencies	
	Company C	Company A	Company B	Company C	Company C
	Reuse 1	Reuse 1	Reuse 1	Reuse 2	Reuse 3
1x2		1 109	400		
1x4		2 147	440		
1x8		2 548	460		
2x2	4 211	1 228	420	3 662	2 796
2x4		2 382	430		
2x8			470		

5 percentile 31 dBm

Table 90

MIMO Setting	No Mitigation	Interference Mitigation of MMSE-IRC scheme as per 3GPP TR 36.884 [i.9]		Hard Reuse of Frequencies	
	Company C	Company A	Company B	Company C	Company C
	Reuse 1	Reuse 1	Reuse 1	Reuse 2	Reuse 3
1x2		801	480		
1x4		1 561	510		
1x8		1 845	570		
2x2	0	933	500	1 394	1655
2x4		1 804	540		
2x8		2 106	580		

50 percentile 31 dBm

Table 91

MIMO Setting	No Mitigation	Interference Mitigation of MMSE-IRC scheme as per 3GPP TR 36.884 [i.9]		Hard Reuse of Frequencies	
	Company C	Company A	Company B	Company C	Company C
	Reuse 1	Reuse 1	Reuse 1	Reuse 2	Reuse 3
1x2		2 939	1 350		
1x4		4 612	1 420		
1x8		5 801	1 500		
2x2	3 514	3 180	1 390	3 725	2 859
2x4		5 958	1 450		
2x8		7 645	1 510		

6.3.20 1 900 MHz High Density Scenario - UL 2 km ISD 90:10 in kbps

5 percentile 23 dBm

Table 92

MIMO Setting	No Mitigation	Interference Mitigation of MMSE-IRC scheme as per 3GPP TR 36.884 [i.9]		Hard Reuse of Frequencies	
	Company C	Company A	Company B	Company C	Company C
	Reuse 1	Reuse 1	Reuse 1	Reuse 2	Reuse 3
1x2		414	180		
1x4		708	230		
1x8		856	280		
2x2	479	466	180	2 535	2 442
2x4		811	250		
2x8		983	330		

50 percentile 23 dBm

Table 93

MIMO Setting	No Mitigation	Interference Mitigation of MMSE-IRC scheme as per 3GPP TR 36.884 [i.9]		Hard Reuse of Frequencies	
	Company C	Company A	Company B	Company C	Company C
	Reuse 1	Reuse 1	Reuse 1	Reuse 2	Reuse 3
1x2		2 065	700		
1x4		4 000	770		
1x8		4 746	810		
2x2	7 585	2 287	740	6 592	5 035
2x4		4 437	750		
2x8		5 409	820		

5 percentile 31 dBm

Table 94

MIMO Setting	No Mitigation	Interference Mitigation of MMSE-IRC scheme as per 3GPP TR 36.884 [i.9]		Hard Reuse of Frequencies	
	Company C	Company A	Company B	Company C	Company C
	Reuse 1	Reuse 1	Reuse 1	Reuse 2	Reuse 3
1x2		1 494	840		
1x4		2 907	890		
1x8		3 837	1 000		
2x2	0	1 739	880	2 514	2 986
2x4		3 360	950		
2x8		3 924	1 020		

50 percentile 31 dBm

Table 95

MIMO Setting	No Mitigation	Interference Mitigation of MMSE-IRC scheme as per 3GPP TR 36.884 [i.9]		Hard Reuse of Frequencies	
	Company C	Company A	Company B	Company C	Company C
	Reuse 1	Reuse 1	Reuse 1	Reuse 2	Reuse 3
1x2		5 474	2 360		
1x4		8 591	2 490		
1x8		10 810	2 630		
2x2	6 331	5 924	2 430	6 704	5 141
2x4		11 100	2 540		
2x8		14 240	2 640		

6.3.21 1 900 MHz High Density Scenario - UL 4 km ISD 50:50 in kbps

5 percentile 23 dBm

Table 96

MIMO Setting	No Mitigation	Interference Mitigation of MMSE-IRC scheme as per 3GPP TR 36.884 [i.9]		Hard Reuse of Frequencies	
	Company C	Company A	Company B	Company C	Company C
	Reuse 1	Reuse 1	Reuse 1	Reuse 2	Reuse 3
1x2			0		
1x4			0		
1x8			0		
2x2	0		0	159	196
2x4			0		
2x8			0		

50 percentile 23 dBm

Table 97

MIMO Setting	No Mitigation	Interference Mitigation of MMSE-IRC scheme as per 3GPP TR 36.884 [i.9]		Hard Reuse of Frequencies	
	Company C	Company A	Company B	Company C	Company C
	Reuse 1	Reuse 1	Reuse 1	Reuse 2	Reuse 3
1x2			110		
1x4			170		
1x8			240		
2x2	1 122		210	930	719
2x4			200		
2x8			220		

5 percentile 31 dBm

Table 98

MIMO Setting	No Mitigation	Interference Mitigation of MMSE-IRC scheme as per 3GPP TR 36.884 [i.9]		Hard Reuse of Frequencies	
	Company C	Company A	Company B	Company C	Company C
	Reuse 1	Reuse 1	Reuse 1	Reuse 2	Reuse 3
1x2			200		
1x4			280		
1x8			290		
2x2	0		240	333	400
2x4			270		
2x8			300		

50 percentile 31 dBm

Table 99

MIMO Setting	No Mitigation	Interference Mitigation of MMSE-IRC scheme as per 3GPP TR 36.884 [i.9]		Hard Reuse of Frequencies	
	Company C	Company A	Company B	Company C	Company C
	Reuse 1	Reuse 1	Reuse 1	Reuse 2	Reuse 3
1x2			380		
1x4			430		
1x8			500		
2x2	1 200		450	1 115	981
2x4			480		
2x8			500		

6.3.22 1 900 MHz High Density Scenario - UL 4 km ISD 90:10 in kbps

5 percentile 23 dBm

Table 100

MIMO Setting	No Mitigation	Interference Mitigation of MMSE-IRC scheme as per 3GPP TR 36.884 [i.9]		Hard Reuse of Frequencies	
	Company C	Company A	Company B	Company C	Company C
	Reuse 1	Reuse 1	Reuse 1	Reuse 2	Reuse 3
1x2			0		
1x4			0		
1x8			0		
2x2	0		0	285	356
2x4			0		
2x8			0		

50 percentile 23 dBm

Table 101

MIMO Setting	No Mitigation	Interference Mitigation of MMSE-IRC scheme as per 3GPP TR 36.884 [i.9]		Hard Reuse of Frequencies	
	Company C	Company A	Company B	Company C	Company C
	Reuse 1	Reuse 1	Reuse 1	Reuse 2	Reuse 3
1x2			190		
1x4			300		
1x8			420		
2x2	2 022		370	1 674	1 296
2x4			350		
2x8			390		

5 percentile 31 dBm

Table 102

MIMO Setting	No Mitigation	Interference Mitigation of MMSE-IRC scheme as per 3GPP TR 36.884 [i.9]		Hard Reuse of Frequencies	
	Company C	Company A	Company B	Company C	Company C
	Reuse 1	Reuse 1	Reuse 1	Reuse 2	Reuse 3
1x2			350		
1x4			490		
1x8			510		
2x2	0		420	600	722
2x4			470		
2x8			530		

50 percentile 31 dBm

Table 103

MIMO Setting	No Mitigation	Interference Mitigation of MMSE-IRC scheme as per 3GPP TR 36.884 [i.9]		Hard Reuse of Frequencies	
	Company C	Company A	Company B	Company C	Company C
	Reuse 1	Reuse 1	Reuse 1	Reuse 2	Reuse 3
1x2			670		
1x4			750		
1x8			880		
2x2	2 156		790	2 007	1 767
2x4			840		
2x8			880		

6.4 Identified System Limitations

6.4.1 Overview of System Limitations

The system simulations use several simplifying assumptions, such as perfect synchronization and channel estimation. Furthermore, mobility issues such as handover between cells and aspects related to reliability and latency have not been considered in the present document. There are also uncertainties in which constraints on BS Tx power that will prevail at the time when FRMCS is operational. Therefore, the results from the present document should only be indicative, especially when it comes to absolute performance numbers. To obtain more firm conclusions, the present document can be complemented with, e.g. detailed link-level simulations, field trials, etc.

6.4.2 Comparison of Simulation Methods

Simulation Parameter	A	B	C	Impact on the Variance of the Results
BLER target	10 -1	5 × 10-2	10-2	High
Link to system level interface	Mutual Information link	Calibration - exponential effective SINR mapping	Direct mapping SINR to SNR. Interference distribution looks like noise distribution	Low
MCS chosen	Highest throughput satisfying BLER target Up to 256QAM available	Highest throughput satisfying BLER target, and then does the random experiment if correctly decoded Up to 64QAM available	Highest throughput satisfying BLER target Up to 64QAM available	High
On failure	HARQ retransmission	HARQ retransmission	No HARQ	Medium
Throughput calculation	aggregated correctly decoded bits during the simulation time	aggregated correctly decoded bits during the simulation time	Not applicable	Low
link adaption and CSI feedback delay	5 ms link adaptation delay simulated	Same as Company A except only outer loop link adaptation	Link adaptation implemented. CSI delay is not modelled	Medium
Drop period	2 s	4 s	Not applicable	None
Effect of other UE on UL interference	Varying	varying	Not applied	None
High speed	Not captured except the impact of fast variations in the small-scale fading	Doppler simulated at link level	Doppler simulated at link level	High
Channel estimation errors	Not modelled	Considered	Considered	High
Control channel overhead	See Table 1	30 %, except for the TDD 90/10 DL, where it is 40 %	30 %	Low
MIMO layer	Calculated separately	Only one layer. Diversity (multiple antennas) considered	Only one layer. Link level simulator takes diversity into account	High
Channel model	Detailed in clause 4.6	Detailed in clause 4.6	Detailed in clause 4.6	High
Site setup	20 sites	Fixed 24 km env, cell sites vary	20 sites/1 cell per site	None
Determination of which cell selected	UE attaches to cell with highest path gain	UE attaches to cell with highest RSRP	UE attaches to cell with highest path gain	Low
Train positioning	Random positioning maintaining minimum distance	Uniform spacing travelling along the track	Random positioning maintaining minimum distance	Low
Treatment of edge of simulator universe	Edge results discarded	Wrap around	Not applicable	Low
Traffic model	Full buffer	Full buffer	Full buffer	None
scheduler	Round robin time sharing	Round robin time sharing	Full allocation no time sharing	None
TDD	Separate UL/DL scaling	50:50 not scaled 90:10 scaled	Separate UL/DL scaling	Low
precoding	DL, SVD-based precoding UL release 15 NR codebook Ideal CSI	DL, SVD-based precoding UL release 15 NR codebook Non-ideal CSI	DL, SVD-based precoding UL release 15 NR codebook Ideal CSI	Low
Beamforming gain	Considered	Not Considered	Considered	Medium

Simulation Parameter	A	B	C	Impact on the Variance of the Results
UL precoding	BS evaluates all precoders for all ranks and selects the rank and precoder that gives the highest estimated throughput	1 rank only, not measured at each rank, only precoder selection	Not measured at each rank	Low
Channel ageing - CSI reporting delay	5 ms assumed	5 ms assumed	Not applicable	Low
Dl simulation	best precoder per resource block for the selected rank is then applied in the data transmission	1 rank only, not measured at each rank, only precoder selection	Not applicable	Medium
Link adaptation	Modulation order up to 256QAM	Modulation order up to 64QAM	Modulation order up to 64QAM	Medium
Distance bin size	200 m	100 m	100 m	Low
Uplink Power Control	Full Path Loss Compensation based on the target SNR, SNR_{target}, is set to 7 dBm per UE Tx and BS Rx antenna port. Many trains per cell	Full Path Loss Compensation based on the target Power received at the Base Station. this value is set to -95 dBm. Many trains per cell	Full path loss compensation Power received at the Base Station SNR_{target}, is set to 20 dBm and chose frequency reuse factor accordingly One user per cell	High

7 Summary

7.1 General

The present document studied radio system performance in railway scenarios for different deployments, radio propagation profiles and mobility conditions as well as different multi-antenna and power configurations for the 900 MHz FDD and 1 900 MHz TDD frequency bands which are foreseen for FRMCS. For this, extensive system simulation campaigns based on 5G NR were performed by three companies.

Companies A, B and C used the same input parameters to the system simulators. However, the system simulator process and analysis differed between the 3 Companies. Distinctively, MIMO, Doppler, Uplink Power control target, channel estimation assumption and target MCL differed in the system simulator methods resulting in a wide variance in some simulation scenarios. The link level to system level transforms are different in company A than B and C.

Different interference mitigation techniques have been used by the participating companies, including no mitigation, interference rejection based on channel knowledge, and frequency reuse. It should be noted that frequency reuse could be implemented using different techniques (e.g. partial re-use, soft re-use, etc.) so that spectrum utilization and efficiency can be optimized.

The present document concludes that radio deployments in railway scenarios are governed by the throughput performance in the uplink, i.e. from train to ground infrastructure. In addition, the results show clearly that under railway conditions the throughput performance is mainly interference limited and, hence, interference mitigation techniques as provided by 5G NR are essential.

Cell edge performance degradation in both downlink and uplink caused by Doppler effects (shift and spread) is more significant at 1 900 MHz carrier frequency compared to 900 MHz carrier frequency, especially impacting the uplink direction. Potential Doppler mitigation techniques recommended in 3GPP TR 36.878 [i.12] (such as Doppler compensation or pre-compensation schemes) can be beneficial.

Due to the high variance of the throughput performance in the simulation campaigns, results outlined in the present document are only indicative and detailed design rules for rail deployments cannot be concluded.

NOTE: Several Doppler mitigation techniques, except 30 kHz sub carrier spacing, have been used by the various companies to lower the impact of high train speed in the throughput performance context.

7.2 Conclusion at 900 MHz

For the 900 MHz frequency band following configurations were considered and analysed:

General parameter:

- 5 MHz channel bandwidth.
- 46 dBm conducted downlink power.
- UE power class 1 (31 dBm maximum) and UE power class 3 (23 dBm maximum).
- No DL Power Control, open loop UL Power Control.

Deployment parameter:

- 8 km ISD, rural conditions, train speed 350 km/h.
- 4 km ISD, urban high train density conditions, train speed 80 km/h.
- 2 km ISD, urban high train density conditions, train speed 80 km/h.

NOTE: The considered set of power and deployment configurations was selected for the present document to study in particular trends. Deviations from the assumptions herein under regulatory constraints for FRMCS railway radio deployments may be expected.

Downlink

- Results show that the downlink in the rural and urban scenarios at cell-edge areas are interference limited applicable to all ISDs, which confirms that interference mitigation technique is essential.

Uplink

- For large ISD (i.e. 8 km), the throughput performance at cell-edge is noise limited for both UE power classes.
- For shortened ISDs (i.e. 4 km and 2 km), the throughput performance is interference limited for UE power class 1.
- It can be observed that interference mitigation techniques proposed in 5G NR improves the (5th percentile) cell edge throughput. Although being interference limited, the use of UE power class 1 can improve 5 percentile cell edge throughput performance as long as interference mitigation technique can handle increased uplink power.
- For some UEs the UL throughput performance is impaired by interference. For these UEs, interference suppression in BS multi-antenna receptions can be beneficial.

7.3 Conclusion at 1 900 MHz

For the 1 900 MHz frequency band following configurations were considered and analysed:

General parameter:

- 10 MHz channel bandwidth.
- DL Configuration 1 EIRP: 63 dBm.
- DL Configuration 2 EIRP: 40 dBm.
- UE power class 1 (31 dBm maximum) and UE power class 3 (23 dBm maximum).
- No DL Power Control, open loop UL Power Control.

- TDD UL/DL configuration proportion 50/50.
- TDD UL/DL configuration proportion 90/10.

Deployment parameter:

- 8 km ISD, rural conditions, train speed 350 km/h.
- 6 km ISD, rural conditions, train speed 350 km/h.
- 4 km ISD, rural conditions, train speed 350 km/h.
- 4 km ISD, urban and urban high train density conditions, train speed 80 km/h.
- 2 km ISD, urban and urban high train density conditions, train speed 80 km/h.

NOTE: The considered set of power, UL/DL proportion and deployment configurations was selected for the present document to study trends. Deviations from the assumptions herein under regulatory constraints for FRMCS railway radio deployments may be expected.

Downlink

- Results show that the downlink in rural scenarios at cell-edge areas are interference limited applicable to all ISDs, which confirms that interference mitigation technique is essential.
- 40 dBm EIRP could be used for 4 km and 6 km ISD while 63 dBm EIRP is preferable for 8 km ISD.
- Downlink Urban scenarios are interference limited, and some interference mitigation is essential.

Uplink

- For the 8 km ISD rural scenario the throughput performance at cell-edge is noise limited for both UE power classes.
- For 4 km rural ISD the simulation results show the edge throughput performance is limited by interference.
- The observation of 6 Km ISD performance results at cell edge shows that this ISD may provide a good trade-off between cell edge performance and antenna site density based on the interference mitigation assumptions described above. In uplink, the use of UE power class 1 brings significant increase in guaranteed (5 percentile) cell edge throughput performance.
- For urban scenario ISDs (i.e. 4 km and 2 km), the throughput performance is interference limited, particularly for UE power class 1.
- It can be observed that interference mitigation techniques used in the simulators improve the (5 percentile) cell edge throughput. Although being interference limited, the use of UE power class 1 can improve 5 percentile cell edge throughput performance as long as interference mitigation technique can handle increased uplink power.

7.4 Conclusions on Effects of MIMO

The simulation results show that railway deployments benefit from MIMO receive diversity (RX diversity) gains in both downlink and uplink direction, while gains from transmit diversity were limited in the results of the study.

NOTE: The MIMO conclusions in this clause refer to studies from company A and B.

In the uplink, i.e. ground to train communication, an increase in the number of antennas at the receiving BS side improves the throughout performance for both UE power class 1 and UE power class 3. For urban scenario at 900 MHz and 1 900 MHz, the 5 -percentile cell-edge throughput results from the present document show a significant MIMO gain when the number of antennas is doubled at BS side (with highest gains observed when using 2x4 at 900 MHz and 2x8 at 1 900 MHz, assuming the notion of N_{TX} x N_{RX}) due to interference suppression, signal power gain and spatial multiplexing gain.

In the downlink at 1 900 MHz, the constrained maximum EIRP undermine the potential MIMO beamforming gain as the power per Tx antenna is reduced. Therefore, the throughput is reduced when increasing the number of Tx antennas, e.g. a 2x2 MIMO configuration may provide better performance than 4x2 MIMO. By increasing the number of MIMO receive antennas, potentially higher ISD can be achieved. Urban scenario with higher spatial variation can be enhanced by MIMO but requires a much shortened ISD due to high path loss.

7.5 Estimated Minimal Edge Throughput Ranges per Scenario

Detailed results can be found in clause 6.3 of the present document.

Annex A: Full Set of Simulation Results

A.1 Full results set for 900 MHz

A.1.1 Company A

A.1.1.1 Description, specific assumptions and parameters

A.1.1.1.1 UL Results

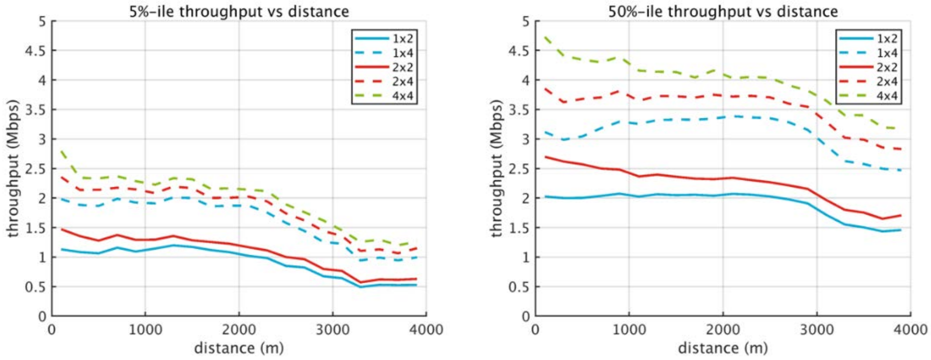


Figure A.1: 5 %- and 50 %-ile throughput as a function of distance for 31 dBm max UE Tx power and different MIMO configurations, 5 MHz bandwidth

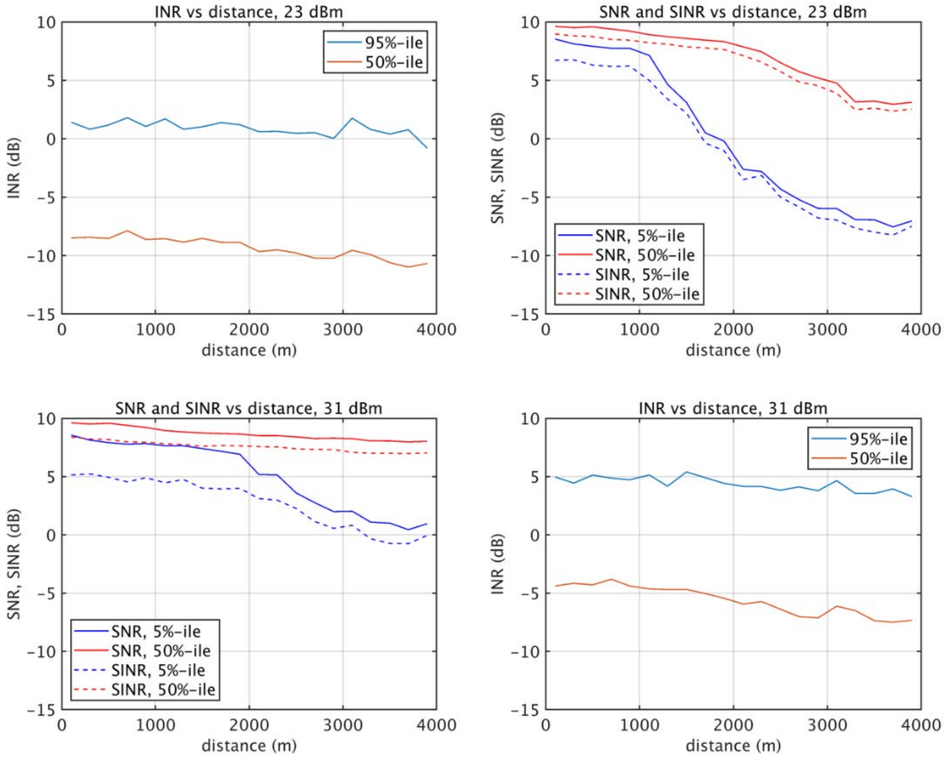


Figure A.2: SNR, SINR and INR for BS antenna port 0 (before the receiver) as a function of distance for 2x2 MIMO configuration and 30 m BS height. Top: 23 dBm max UE Tx power. Bottom: 31 dBm max UE Tx power

A.1.1.2 DL Results

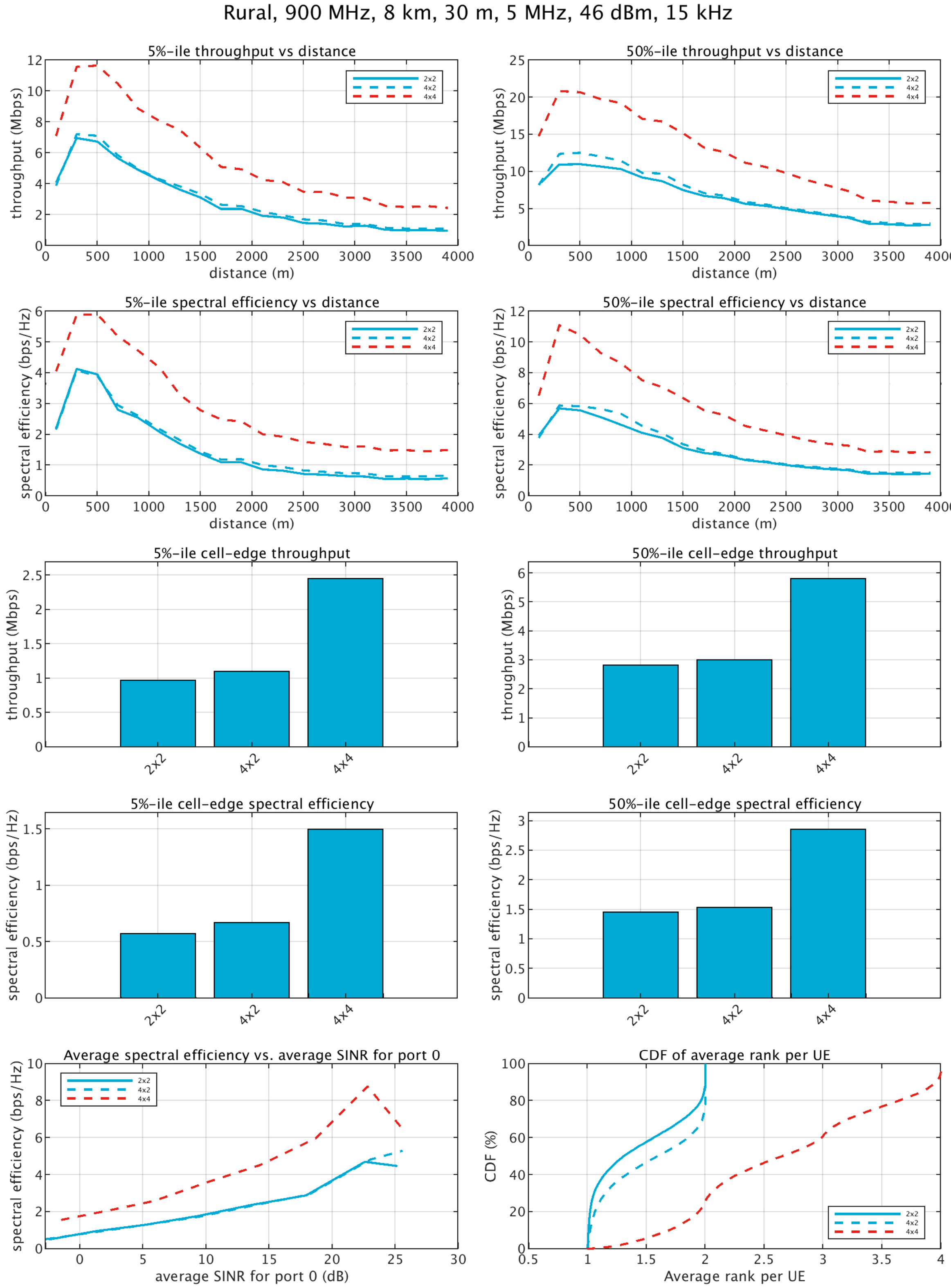


Figure A.3

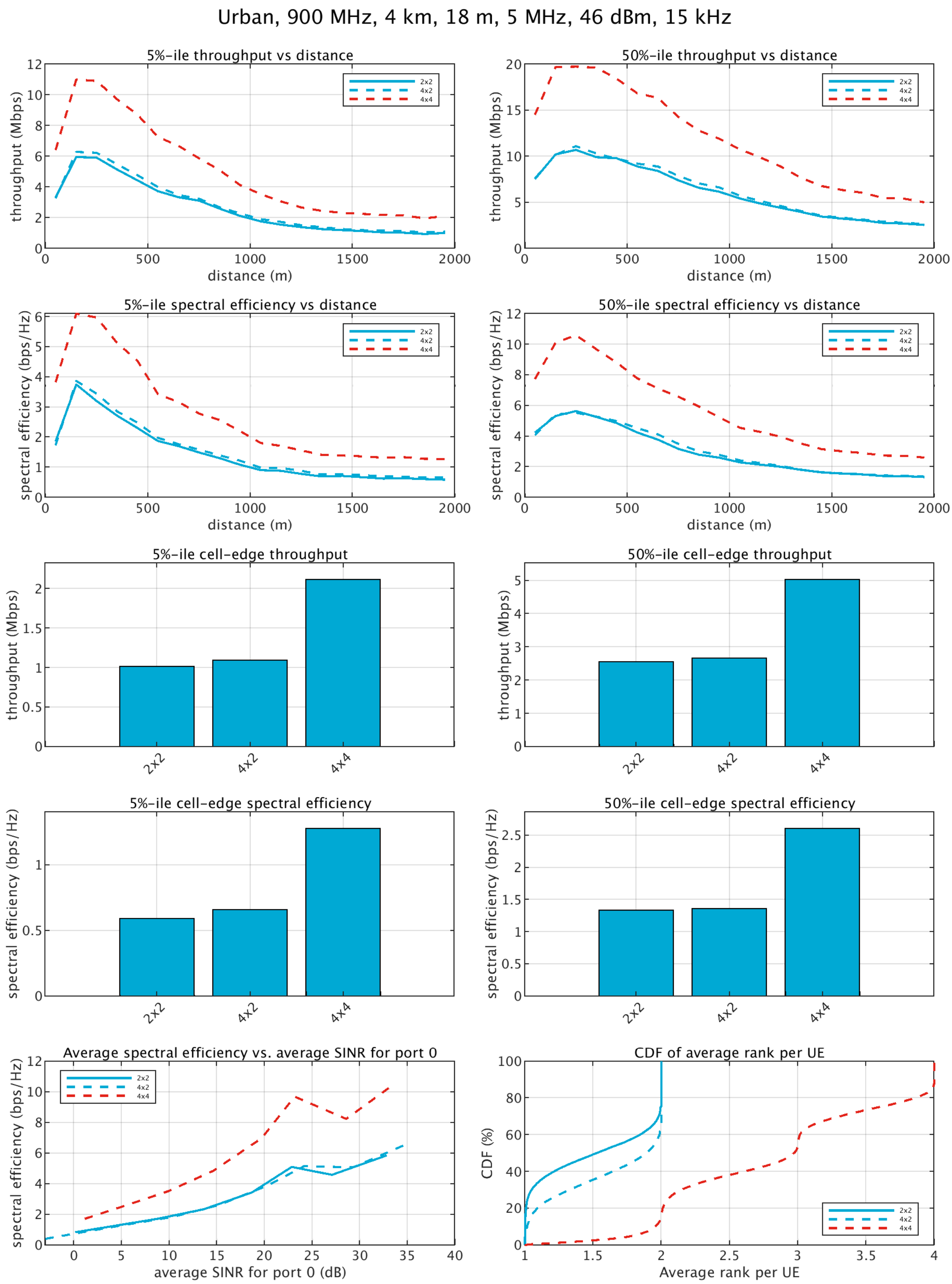

Urban, 900 MHz, 4 km, 18 m, 5 MHz, 46 dBm, 15 kHz
5%-ile throughput vs distance
50%-ile throughput vs distance
throughput (Mbps)
distance (m)
5%-ile spectral efficiency vs distance
50%-ile spectral efficiency vs distance
spectral efficiency (bps/Hz)
5%-ile cell-edge throughput
50%-ile cell-edge throughput
5%-ile cell-edge spectral efficiency
50%-ile cell-edge spectral efficiency
2x2
4x2
4x4
Average spectral efficiency vs. average SINR for port 0
average SINR for port 0 (dB)
CDF of average rank per UE
CDF (%)
Average rank per UE

Figure A.4

A.1.2 Company B

A.1.2.1 Description, specific assumptions and parameters

A.1.2.2 Rural, 8 KM ISD, 2 cells/site

Downlink

DL 2x1

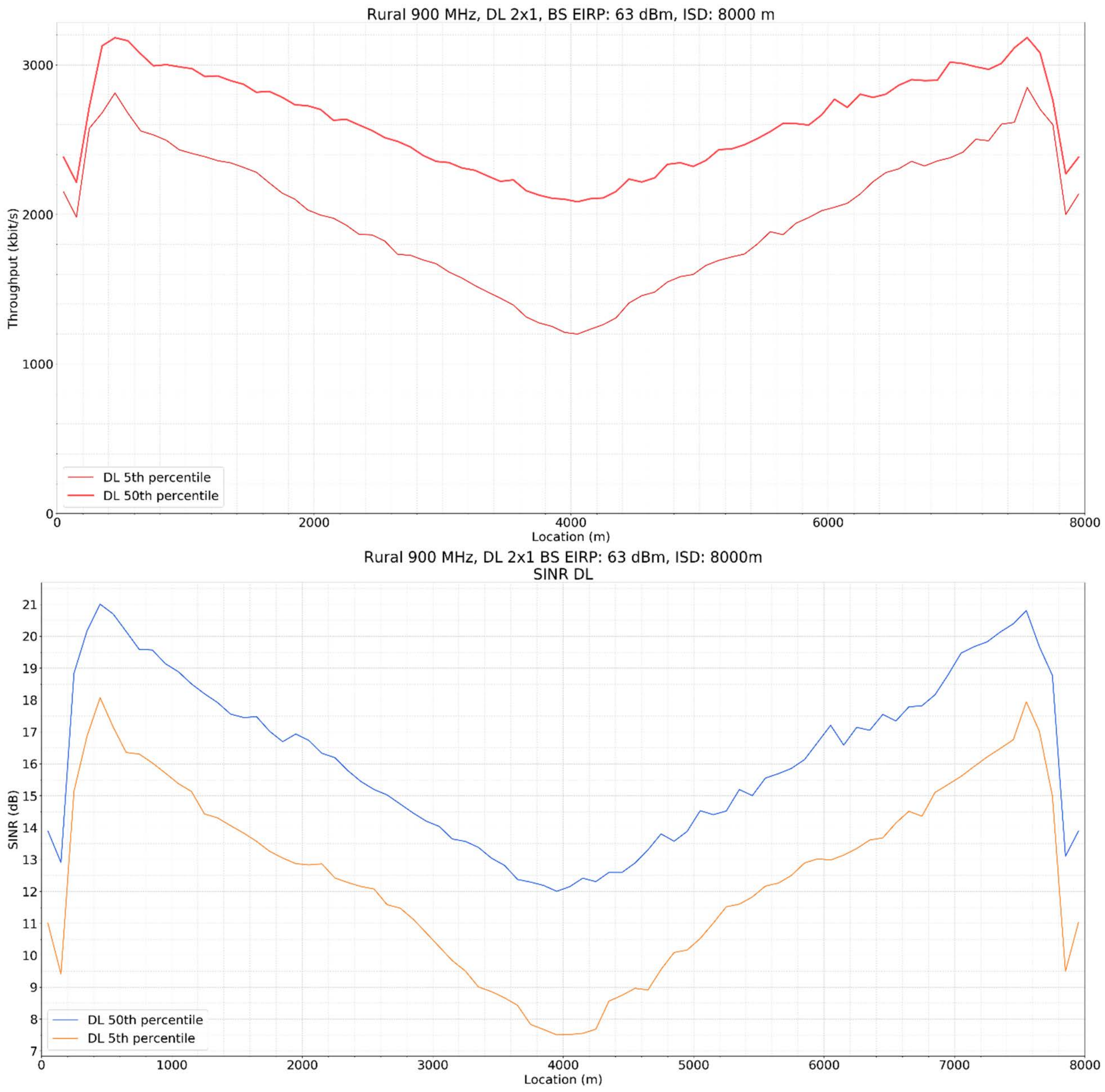


Figure A.5

Interference to noise ratio tables

	5th percentile	50th percentile	95th percentile
Full cell (DL)	-99 dBm	-82 dBm	-66 dBm
Cell centre (DL)	-71 dBm	-67 dBm	-62 dBm
Cell edge (DL)	-91 dBm	-85 dBm	-83 dBm

DL 2x2

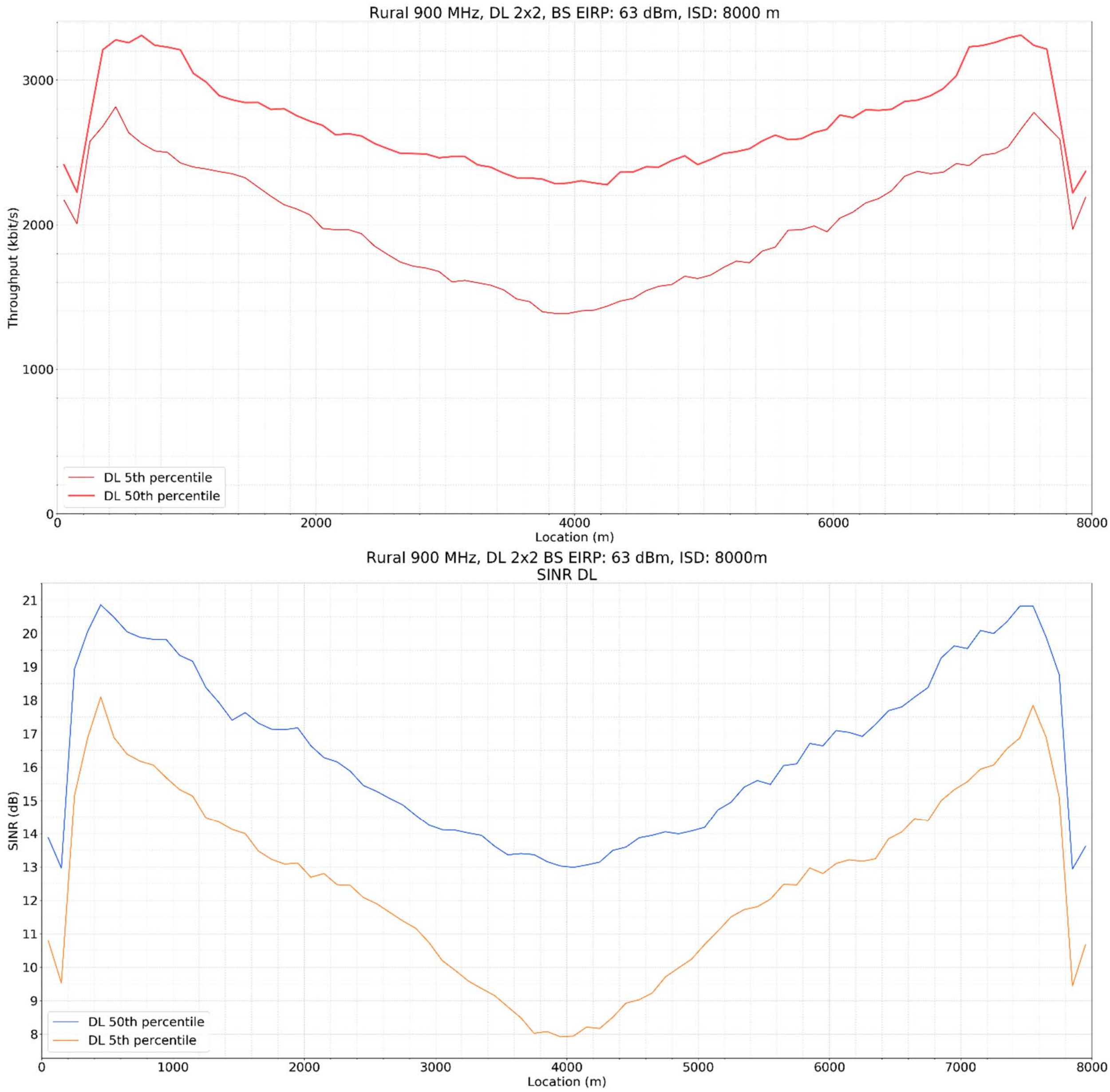


Figure A.6

Interference to noise ratio tables

	5th percentile	50th percentile	95th percentile
Full cell (DL)	-97 dBm	-82 dBm	-67 dBm
Cell centre (DL)	-72 dBm	-70 dBm	-65 dBm
Cell edge (DL)	-88 dBm	-84 dBm	-82 dBm

DL 4x1

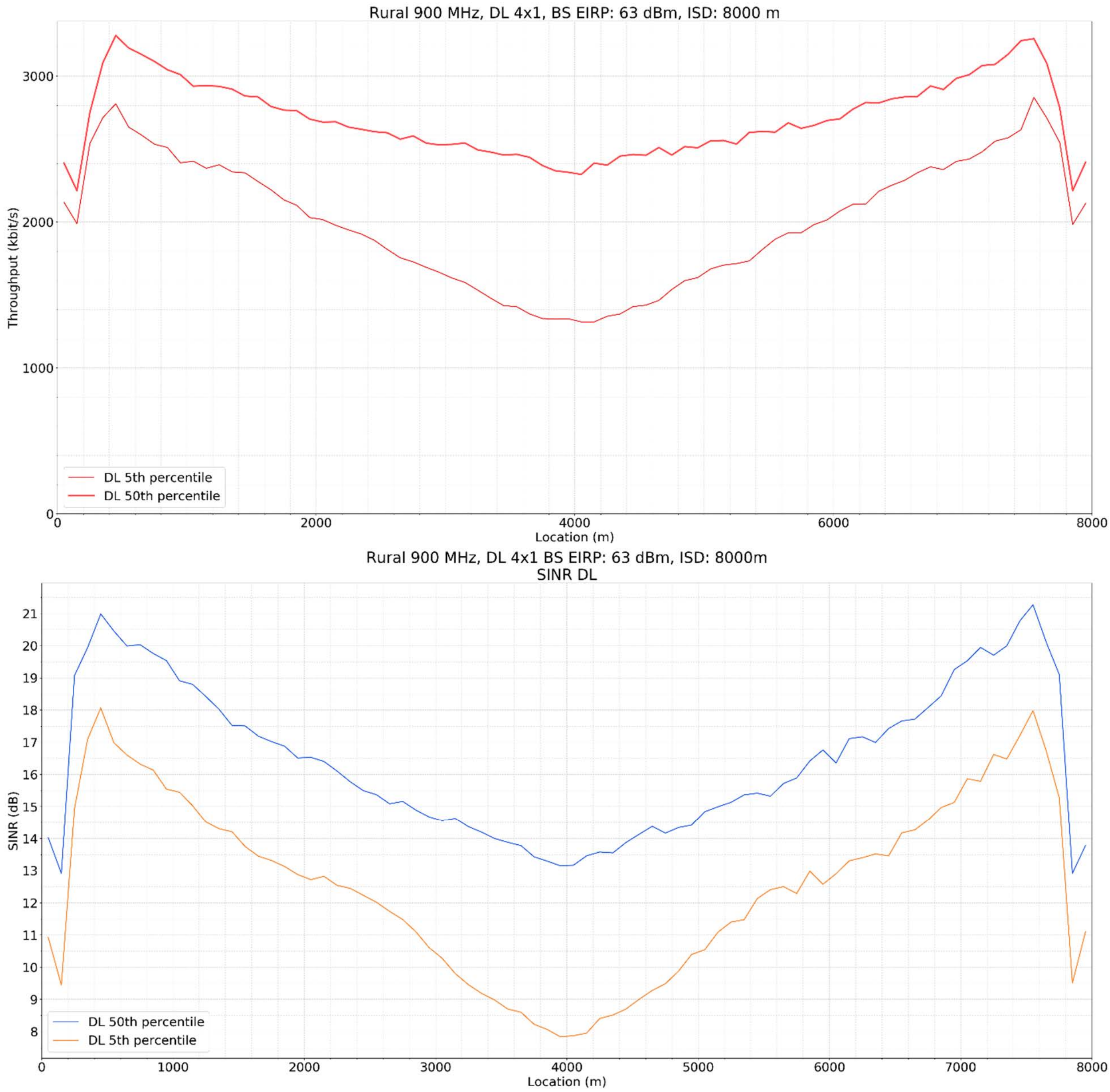


Figure A.7

Interference to noise ratio tables

	5th percentile	50th percentile	95th percentile
Full cell (DL)	-98 dBm	-81 dBm	-66 dBm
Cell centre (DL)	-76 dBm	-68 dBm	-65 dBm
Cell edge (DL)	-89 dBm	-83 dBm	-78 dBm

DL 4x2

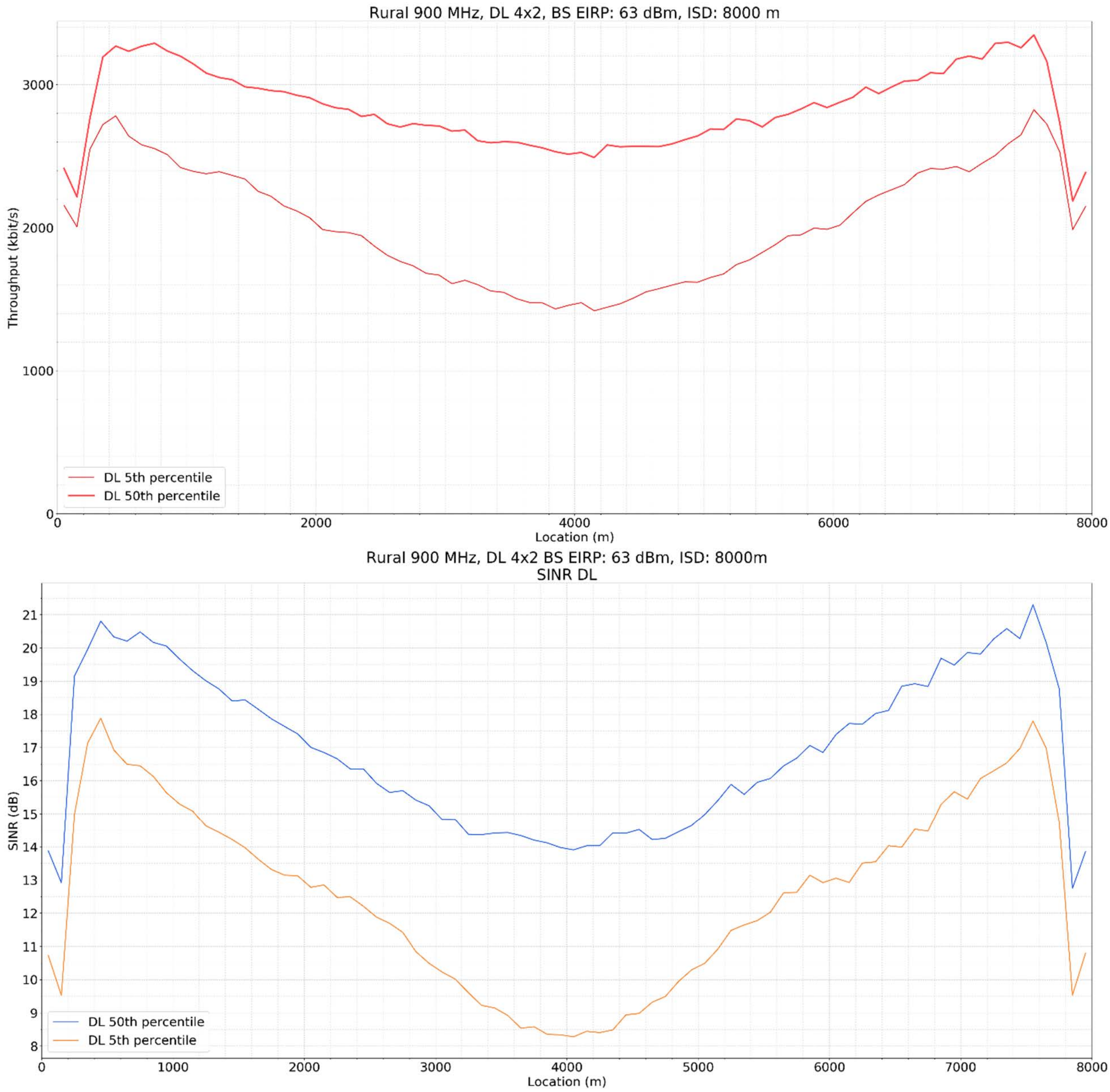


Figure A.8

Interference to noise ratio tables

	5th percentile	50th percentile	95th percentile
Full cell (DL)	-95 dBm	-80 dBm	-66 dBm
Cell centre (DL)	-71 dBm	-69 dBm	-65 dBm
Cell edge (DL)	-86 dBm	-82 dBm	-79 dBm

Uplink, 23 dBm max transmit power

UL 1x2

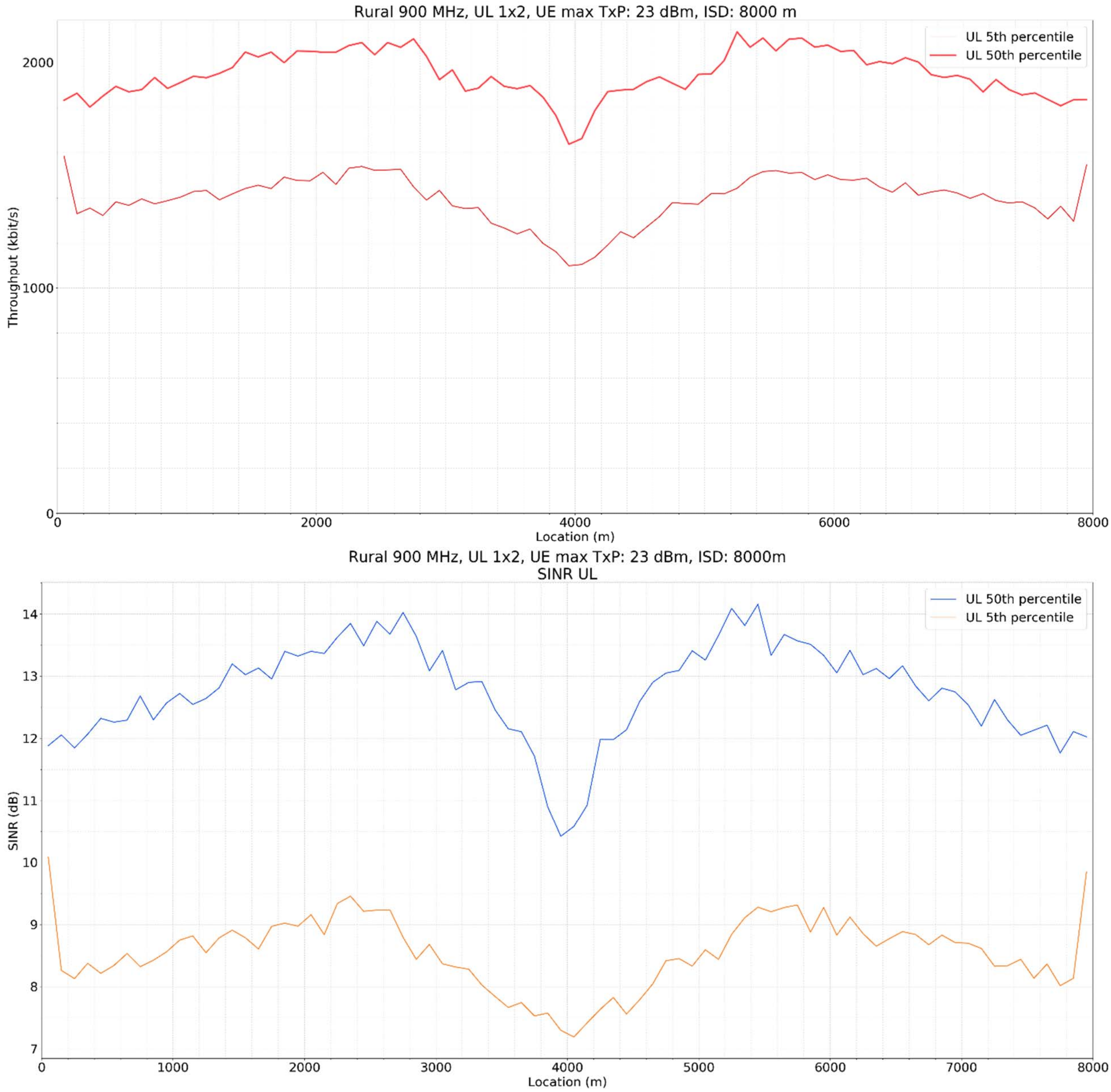
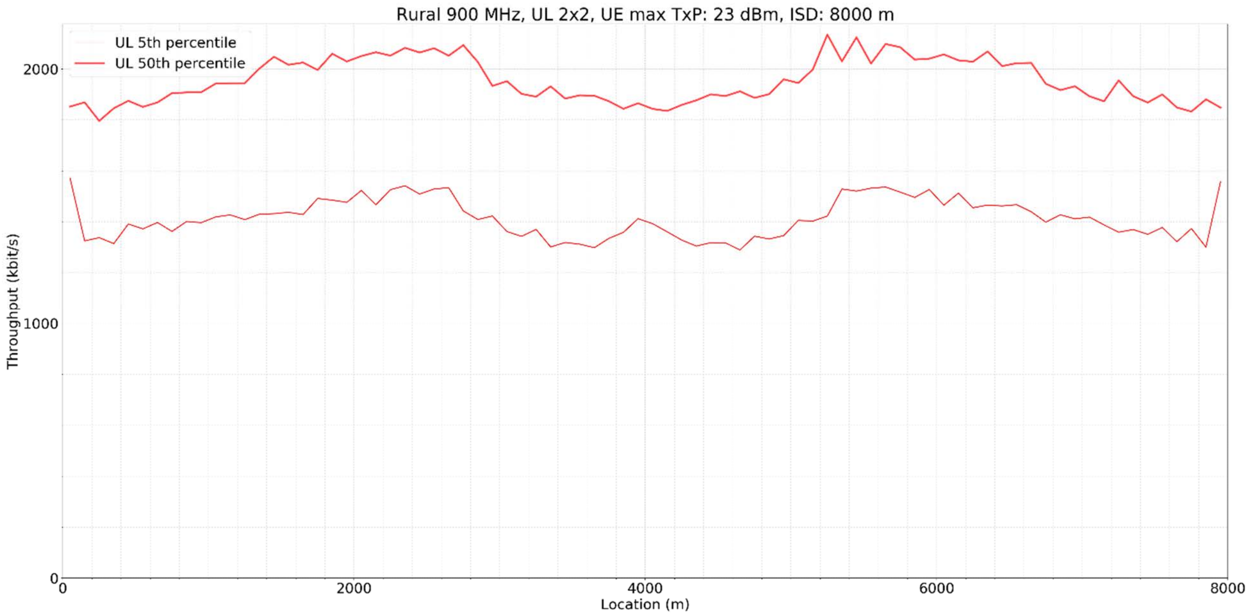


Figure A.9

Interference to noise ratio tables

	5th percentile	50th percentile	95th percentile
Full cell (UL)	-124 dBm	-117 dBm	-104 dBm
Cell centre (UL)	-118 dBm	-115 dBm	-111 dBm
Cell edge (UL)	-118 dBm	-115 dBm	-113 dBm

UL 2x2



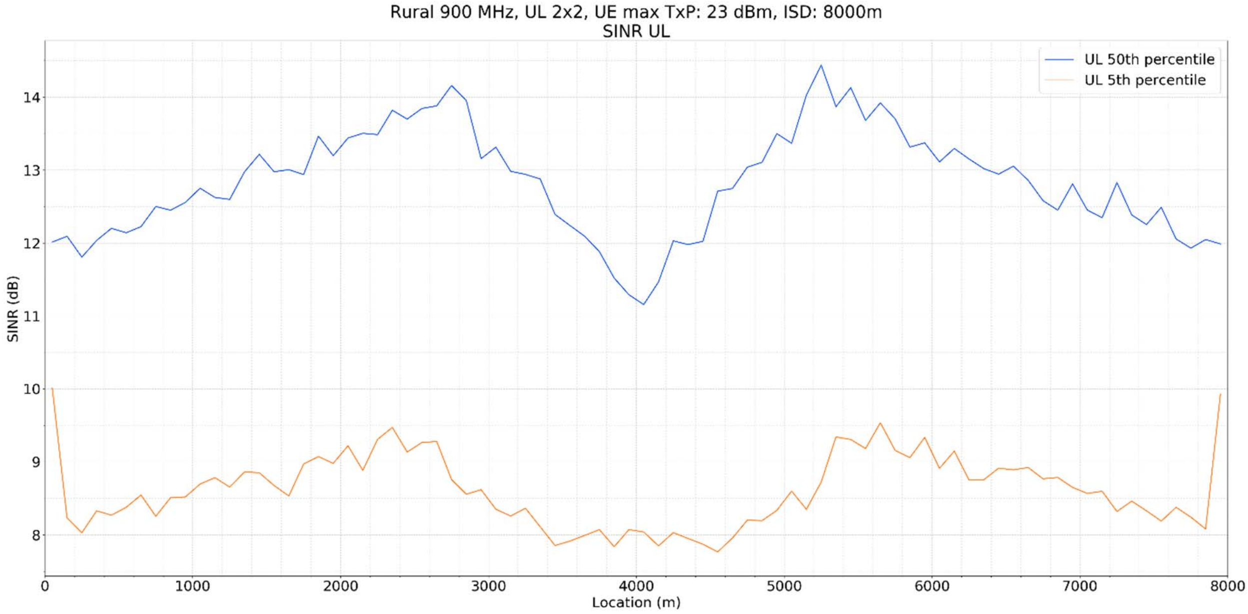
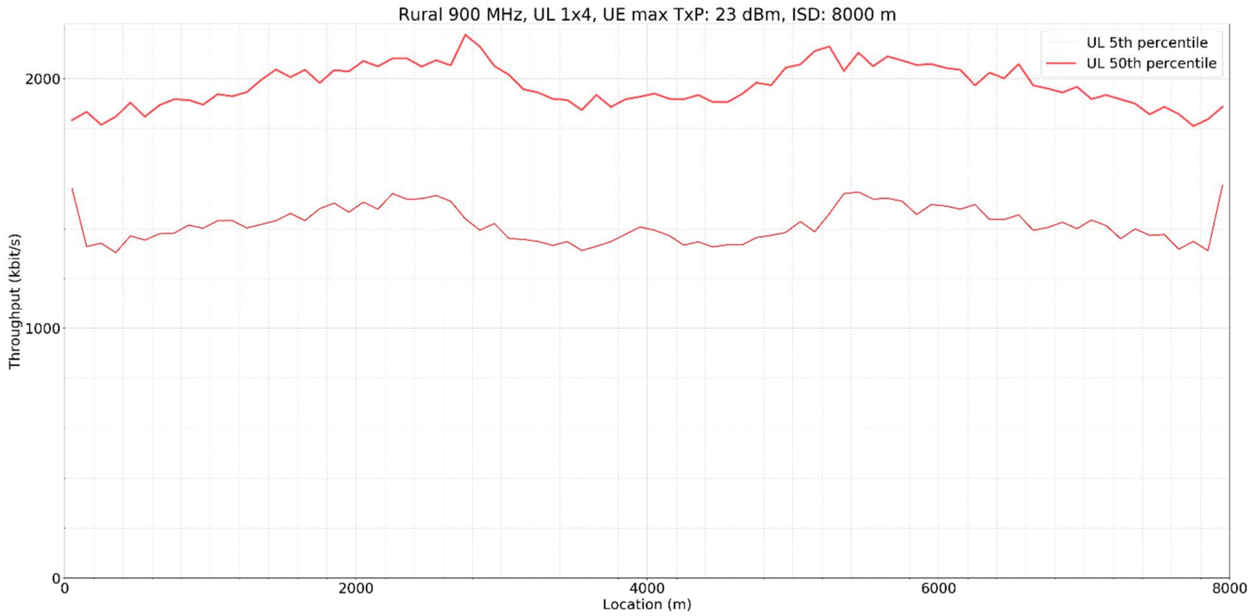


Figure A.10

Interference to noise ratio tables

	5th percentile	50th percentile	95th percentile
Full cell (UL)	-122 dBm	-117 dBm	-105 dBm
Cell centre (UL)	-120 dBm	-116 dBm	-113 dBm
Cell edge (UL)	-116 dBm	-114 dBm	-111 dBm

UL 1x4



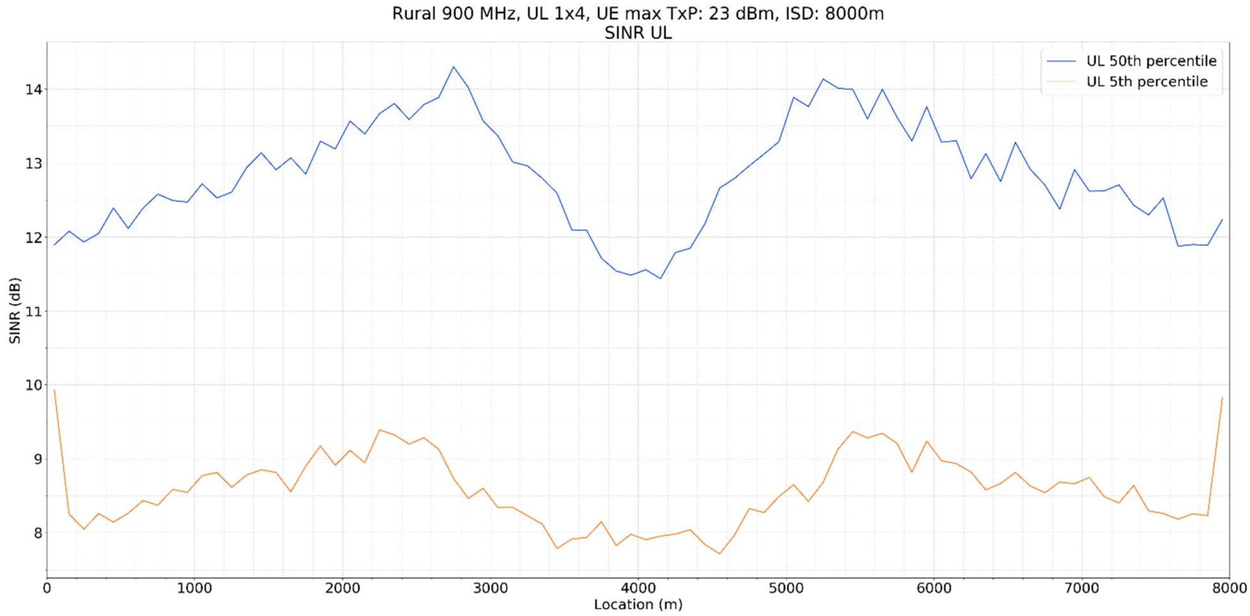
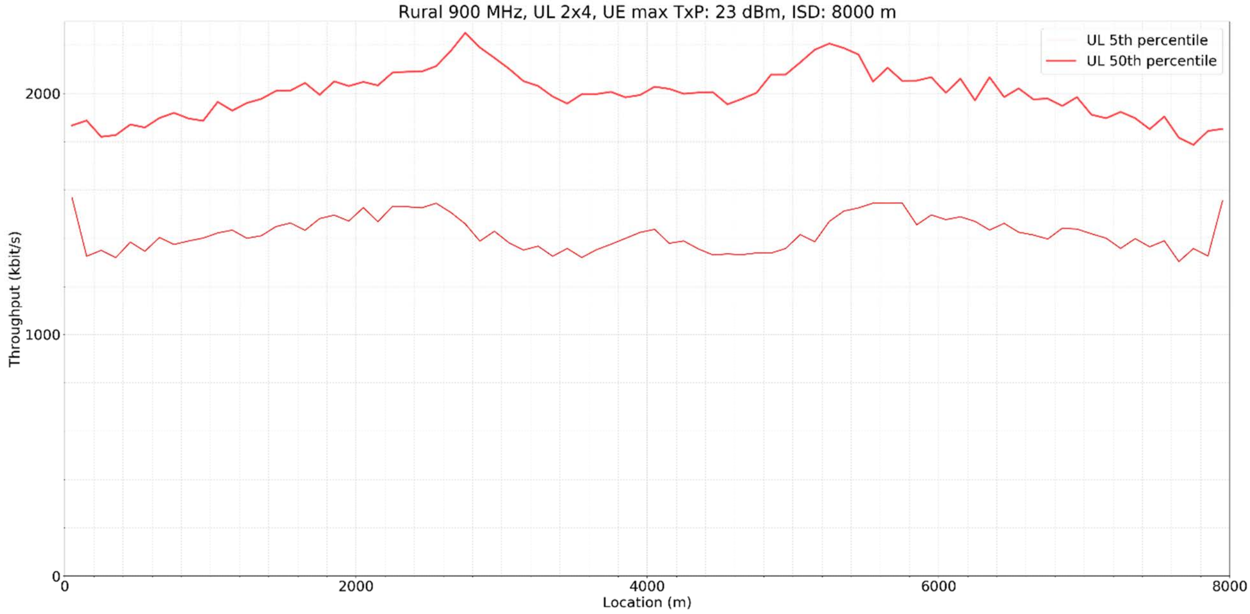


Figure A.11

Interference to noise ratio tables

	5th percentile	50th percentile	95th percentile
Full cell (UL)	-123 dBm	-116 dBm	-102 dBm
Cell centre (UL)	-118 dBm	-115 dBm	-114 dBm
Cell edge (UL)	-113 dBm	-112 dBm	-111 dBm

UL 2x4



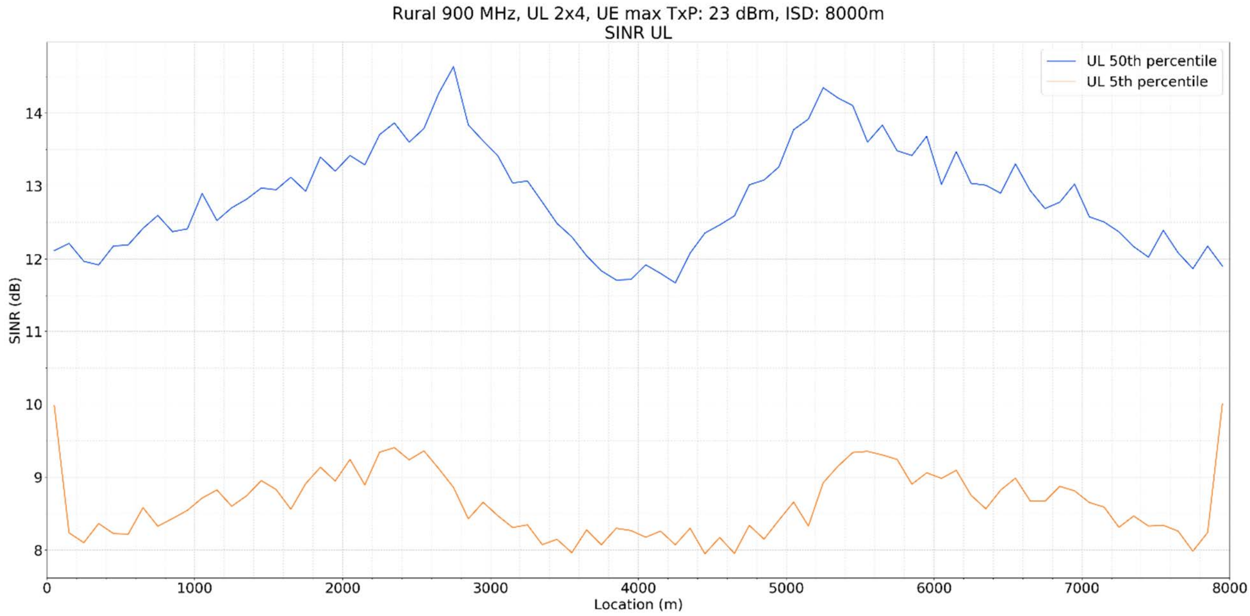


Figure A.12

Interference to noise ratio tables

	5th percentile	50th percentile	95th percentile
Full cell (UL)	-122 dBm	-115 dBm	-103 dBm
Cell centre (UL)	-118 dBm	-115 dBm	-112 dBm
Cell edge (UL)	-113 dBm	-112 dBm	-110 dBm

Uplink, 31 dBm max transmit power

UL 1x2

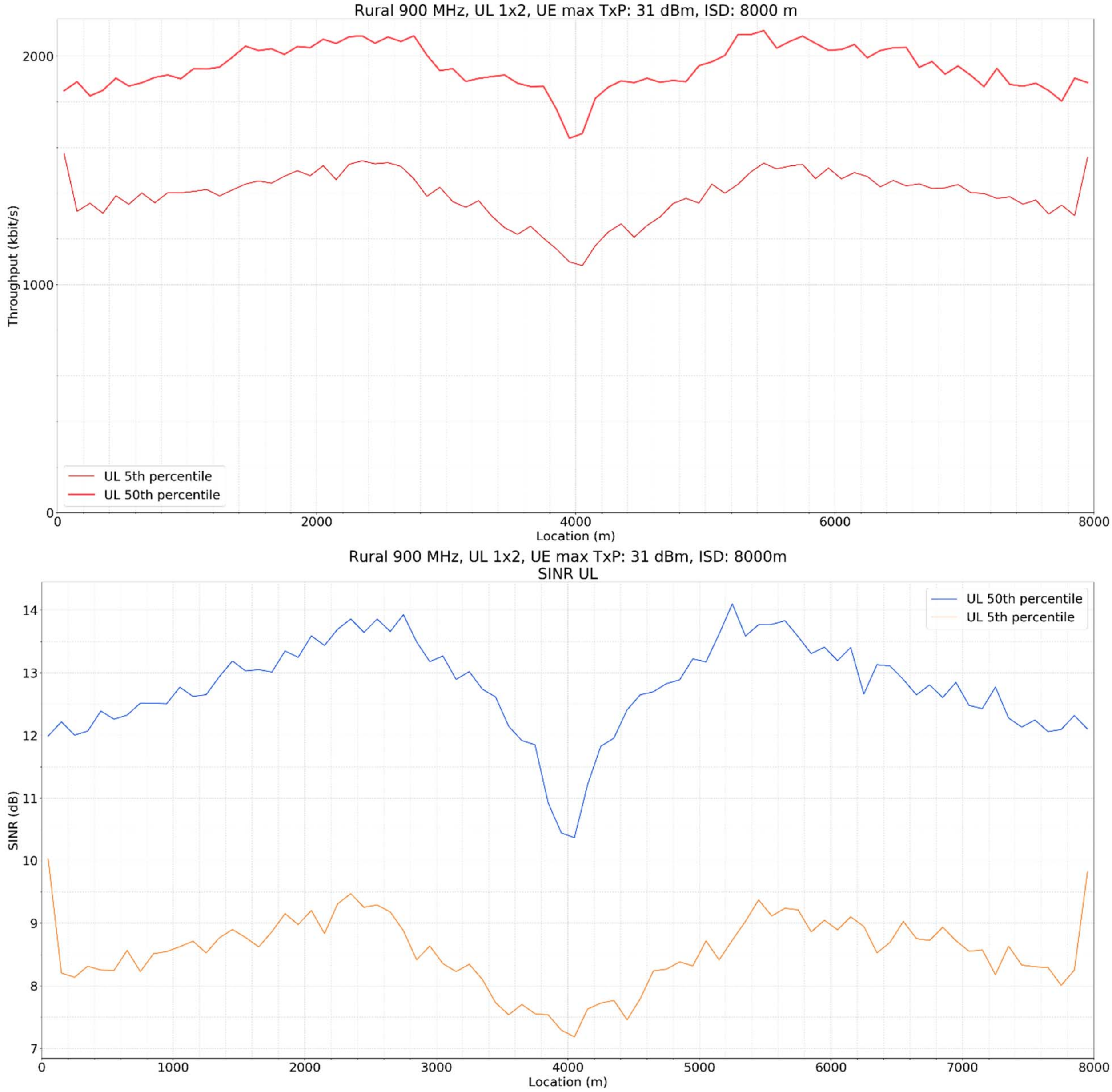


Figure A.13

Interference to noise ratio tables

	5th percentile	50th percentile	95th percentile
Full cell (UL)	-124 dBm	-118 dBm	-104 dBm
Cell centre (UL)	-121 dBm	-116 dBm	-112 dBm
Cell edge (UL)	-118 dBm	-115 dBm	-109 dBm

UL 2x2

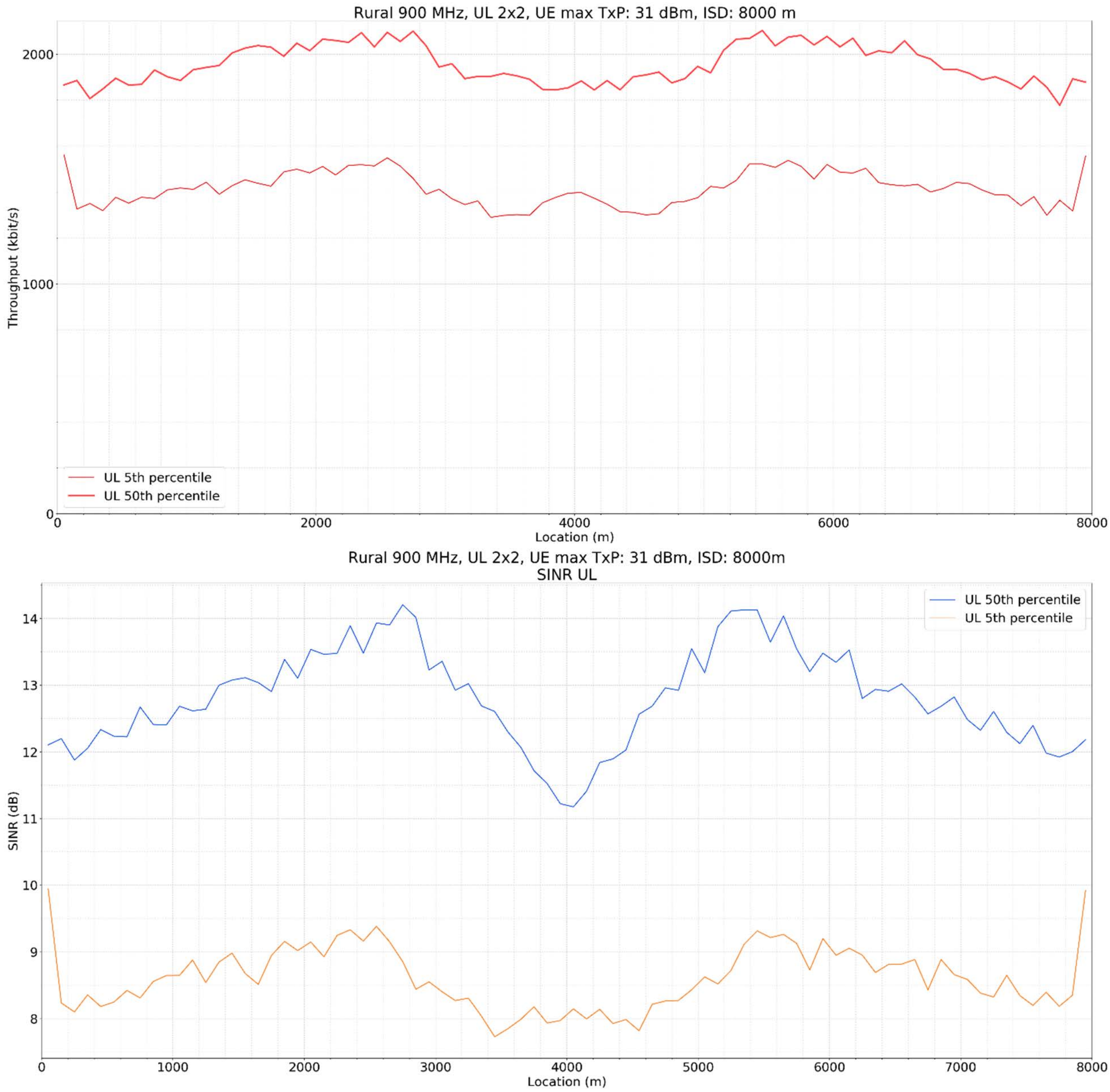


Figure A.14

Interference to noise ratio tables

	5th percentile	50th percentile	95th percentile
Full cell (UL)	-122 dBm	-117 dBm	-105 dBm
Cell centre (UL)	-118 dBm	-116 dBm	-110 dBm
Cell edge (UL)	-119 dBm	-114 dBm	-111 dBm

UL 1x4

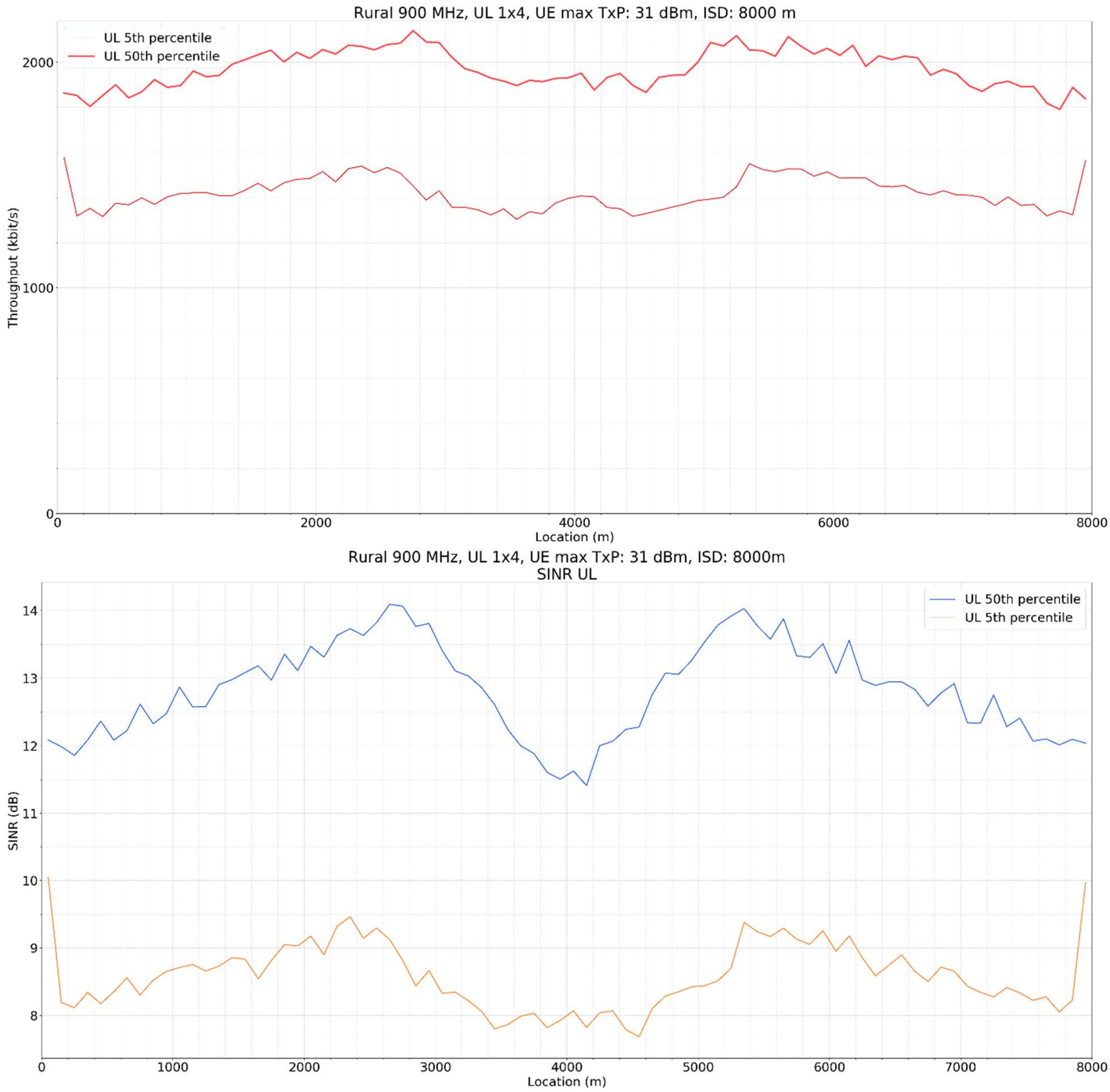


Figure A.15

Interference to noise ratio tables

	5th percentile	50th percentile	95th percentile
Full cell (UL)	-123 dBm	-116 dBm	-102 dBm
Cell centre (UL)	-119 dBm	-115 dBm	-113 dBm
Cell edge (UL)	-112 dBm	-111 dBm	-108 dBm

UL 2x4

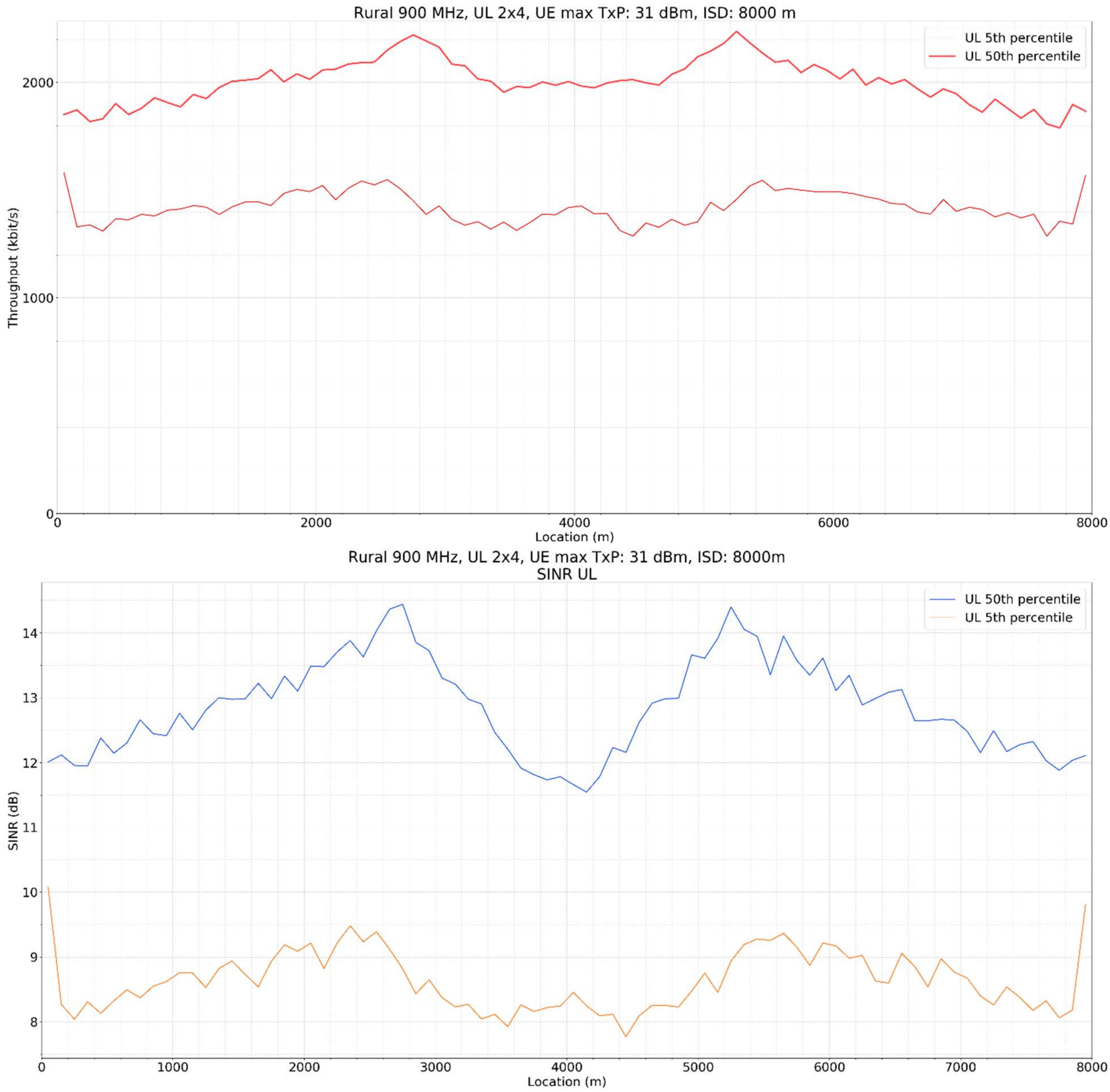


Figure A.16

Interference to noise ratio tables

	5th percentile	50th percentile	95th percentile
Full cell (UL)	-122 dBm	-114 dBm	-103 dBm
Cell centre (UL)	-120 dBm	-114 dBm	-111 dBm
Cell edge (UL)	-112 dBm	-111 dBm	-108 dBm

A.1.2.3 Urban, 2 KM ISD, 2 cells/site

Downlink

DL 2x1

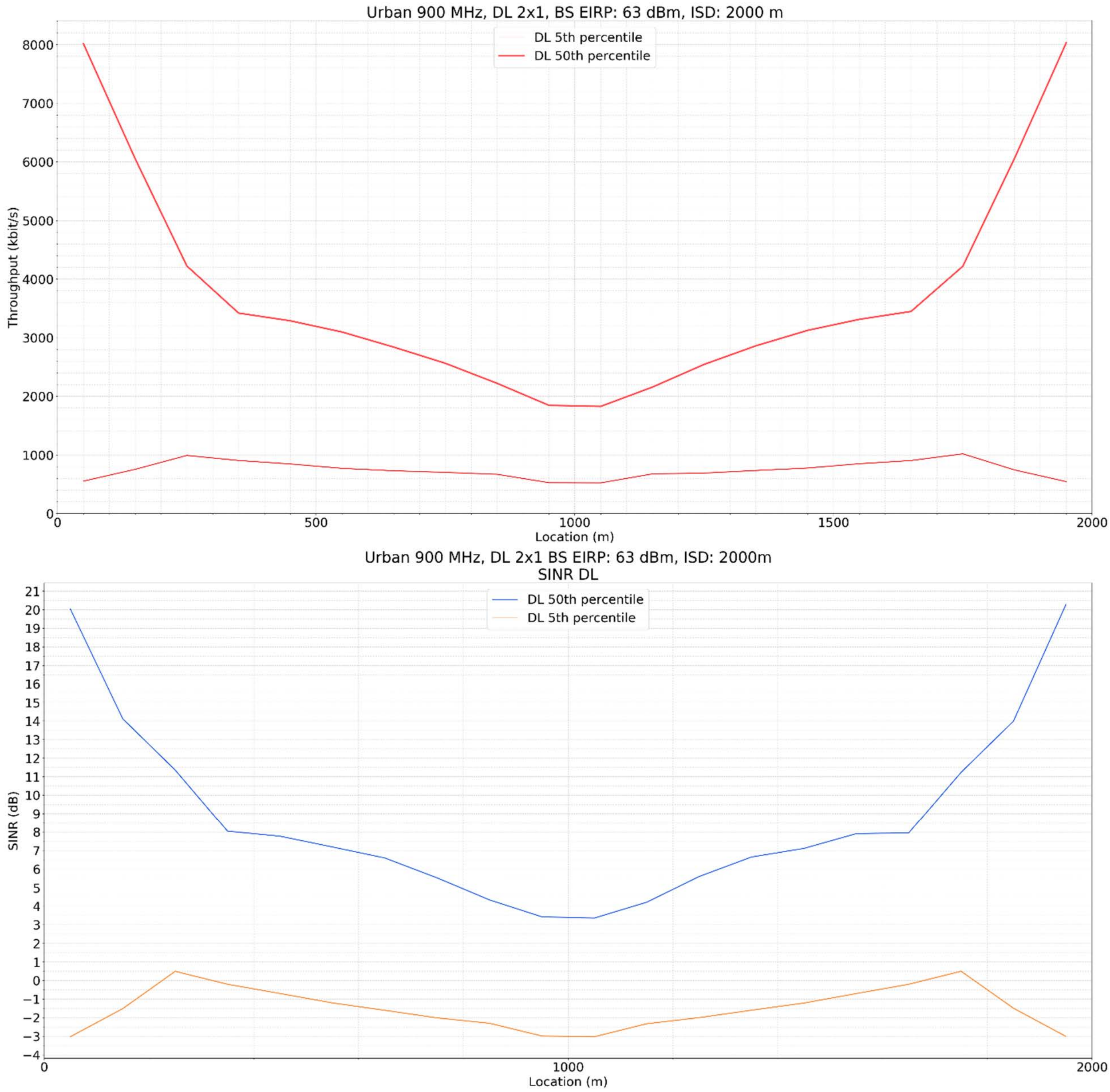


Figure A.17

Interference to noise ratio tables

	5th percentile	50th percentile	95th percentile
Full cell (DL)	-127 dBm	-108 dBm	-79 dBm
Cell centre (DL)	-117 dBm	-94 dBm	-73 dBm
Cell edge (DL)	-118 dBm	-112 dBm	-102 dBm

DL 2x2

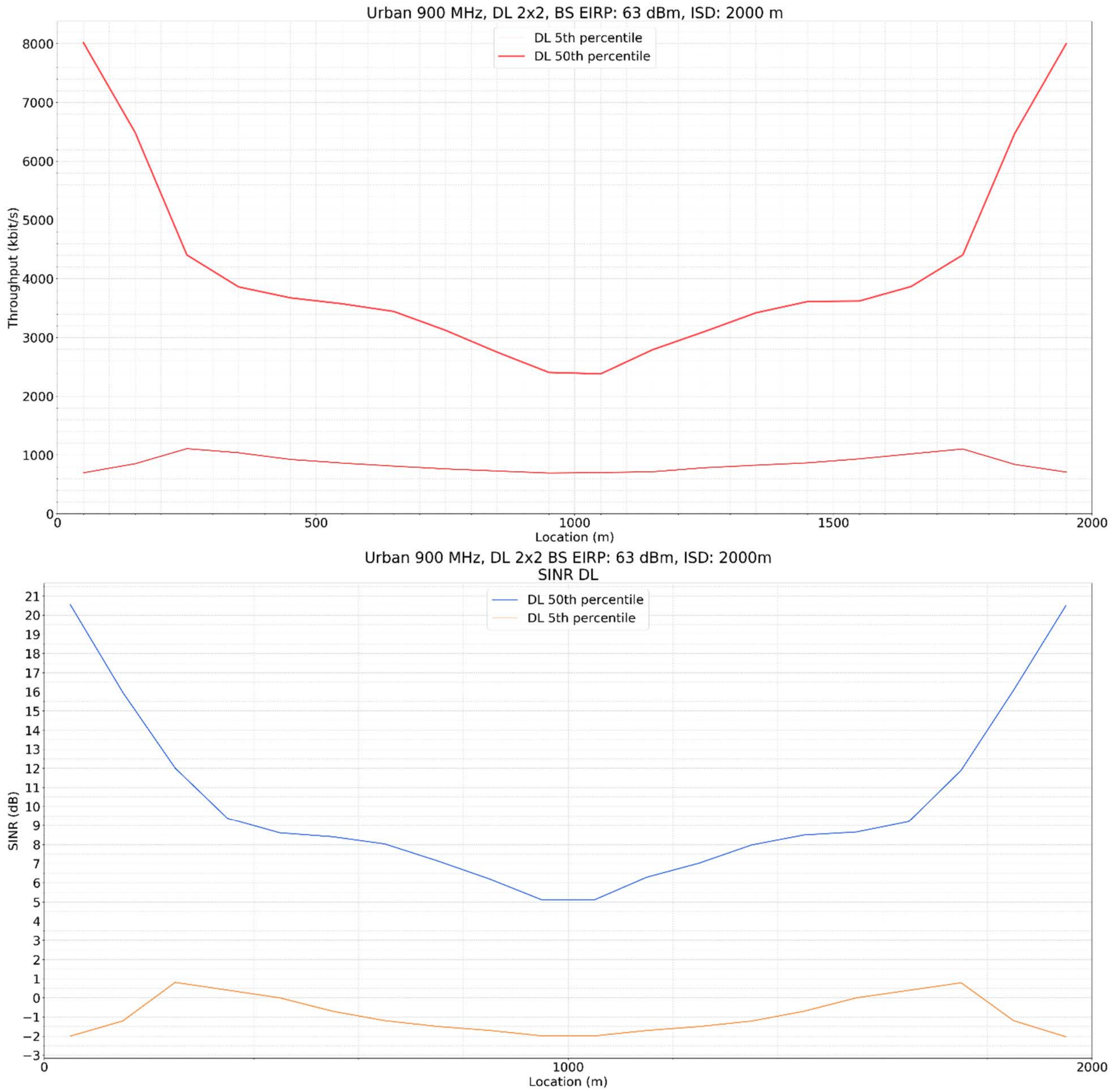


Figure A.18

Interference to noise ratio tables

	5th percentile	50th percentile	95th percentile
Full cell (DL)	-126 dBm	-108 dBm	-82 dBm
Cell centre (DL)	-114 dBm	-97 dBm	-69 dBm
Cell edge (DL)	-119 dBm	-113 dBm	-100 dBm

DL 4x1

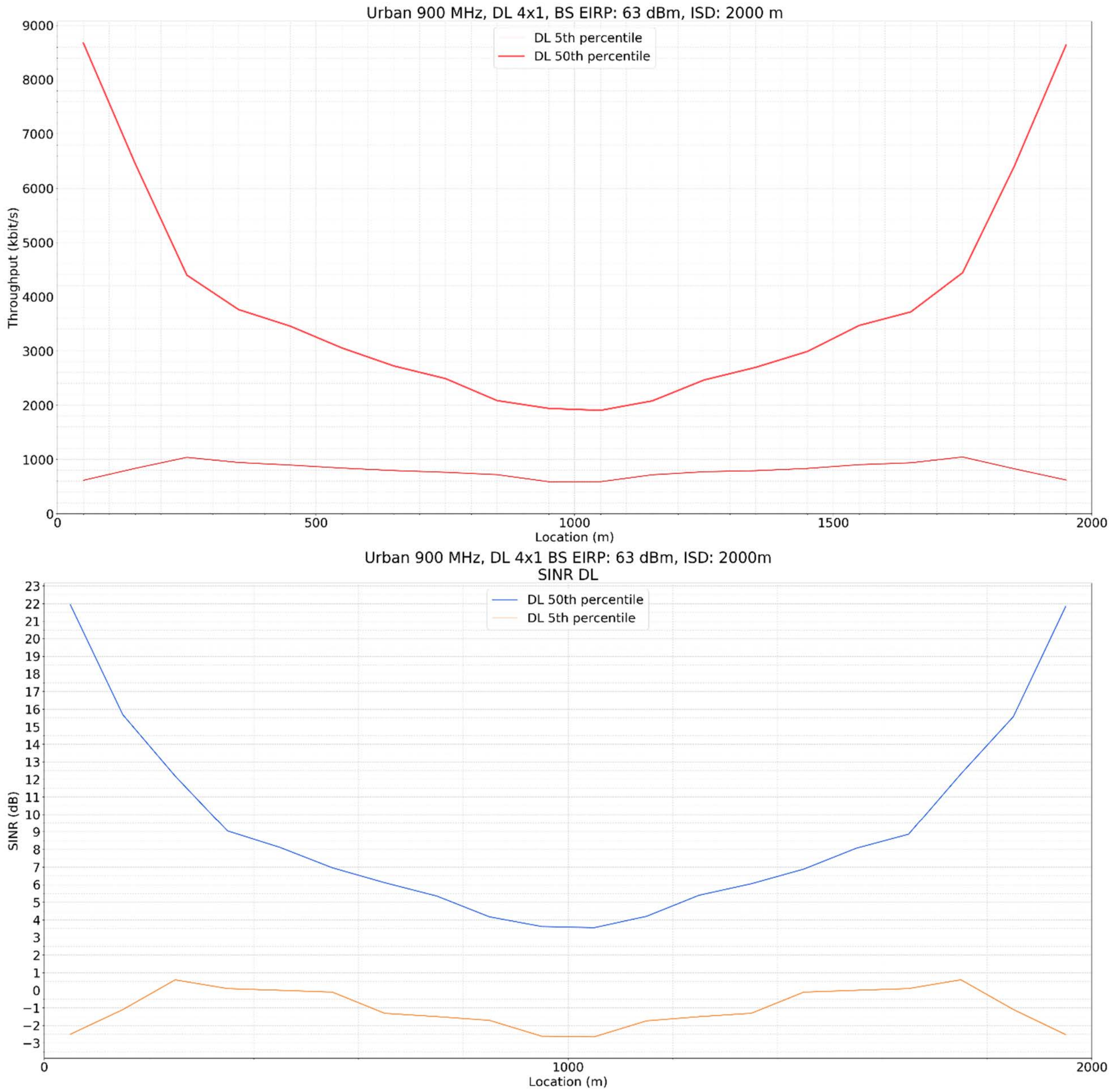


Figure A.19

Interference to noise ratio tables

	5th percentile	**50th percentile**	**95th percentile**
Full cell (DL)	-127 dBm	-106 dBm	-80 dBm
Cell centre (DL)	-118 dBm	-95 dBm	-75 dBm
Cell edge (DL)	-115 dBm	-108 dBm	-98 dBm

DL 4x2

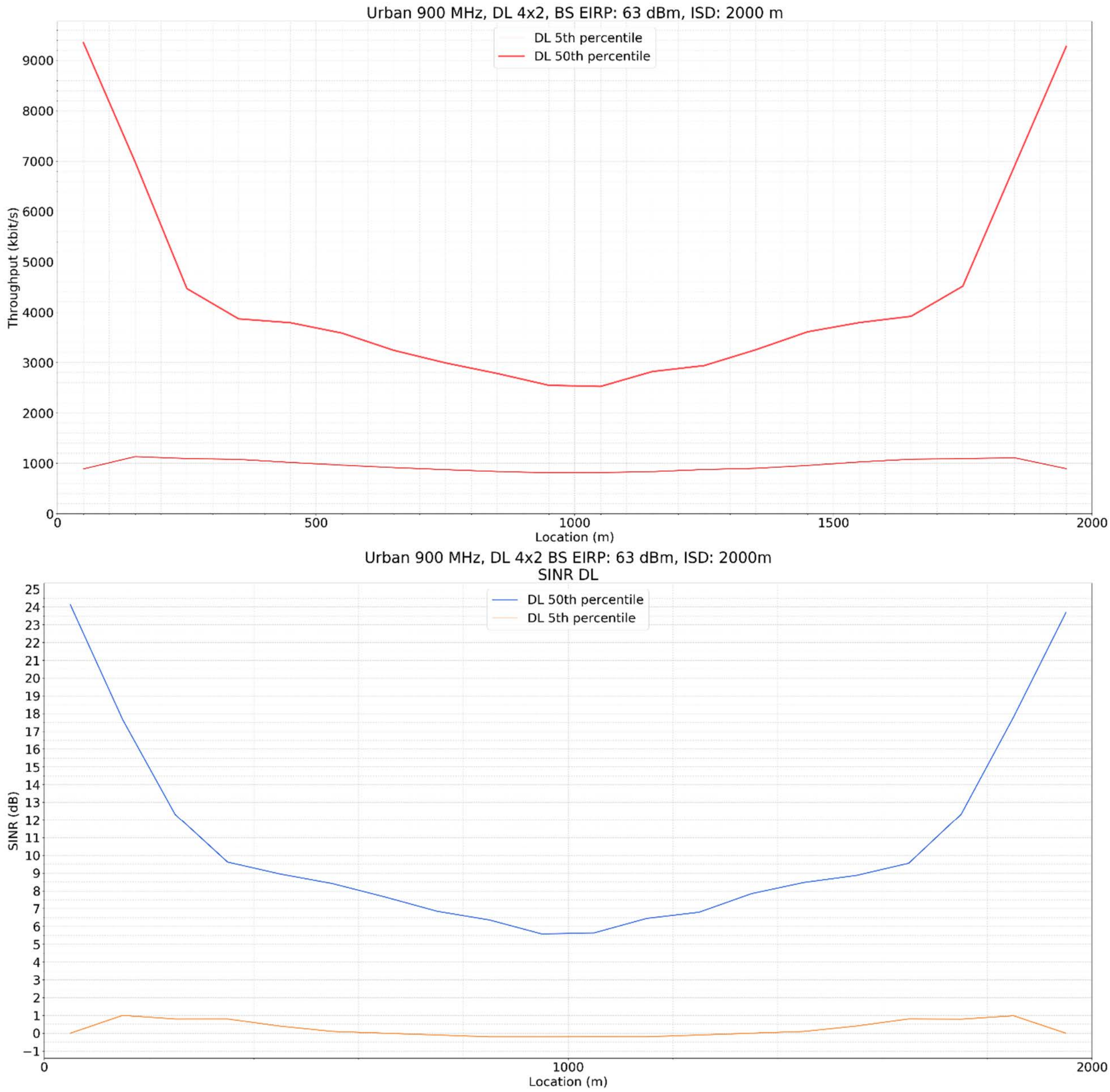


Figure A.20

Interference to noise ratio tables

	5th percentile	50th percentile	95th percentile
Full cell (DL)	-126 dBm	-103 dBm	-74 dBm
Cell centre (DL)	-116 dBm	-82 dBm	-52 dBm
Cell edge (DL)	-119 dBm	-106 dBm	-98 dBm

Uplink, 23 dBm max transmit power

UL 1x2

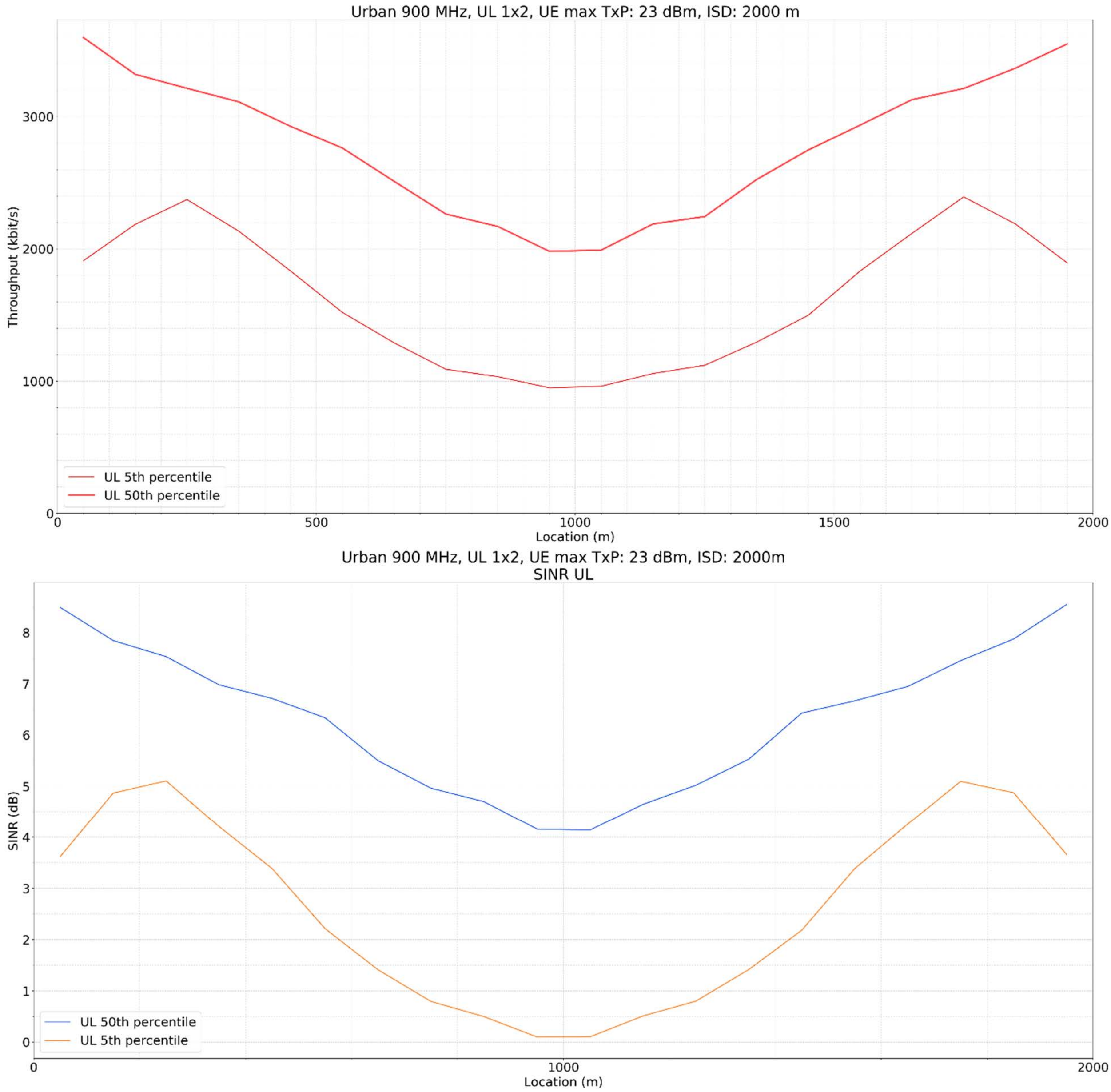


Figure A.21

Interference to noise ratio tables

	5th percentile	50th percentile	95th percentile
Full cell (UL)	-129 dBm	-125 dBm	-112 dBm
Cell centre (UL)	-128 dBm	-127 dBm	-118 dBm
Cell edge (UL)	-126 dBm	-118 dBm	-114 dBm

UL 2x2

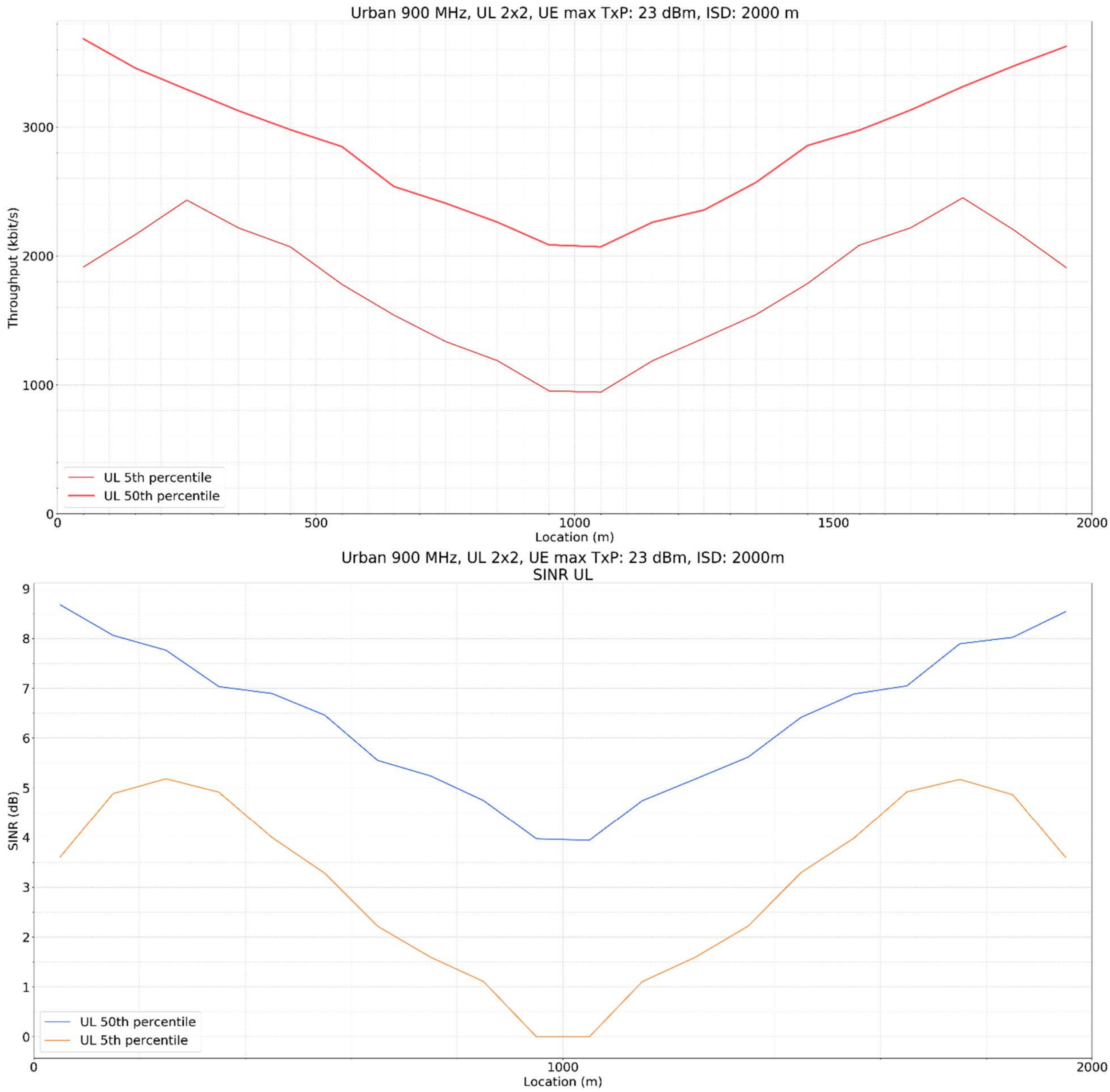


Figure A.22

Interference to noise ratio tables

	5th percentile	50th percentile	95th percentile
Full cell (UL)	-129 dBm	-124 dBm	-111 dBm
Cell centre (UL)	-128 dBm	-125 dBm	-113 dBm
Cell edge (UL)	-126 dBm	-116 dBm	-114 dBm

UL 1x4

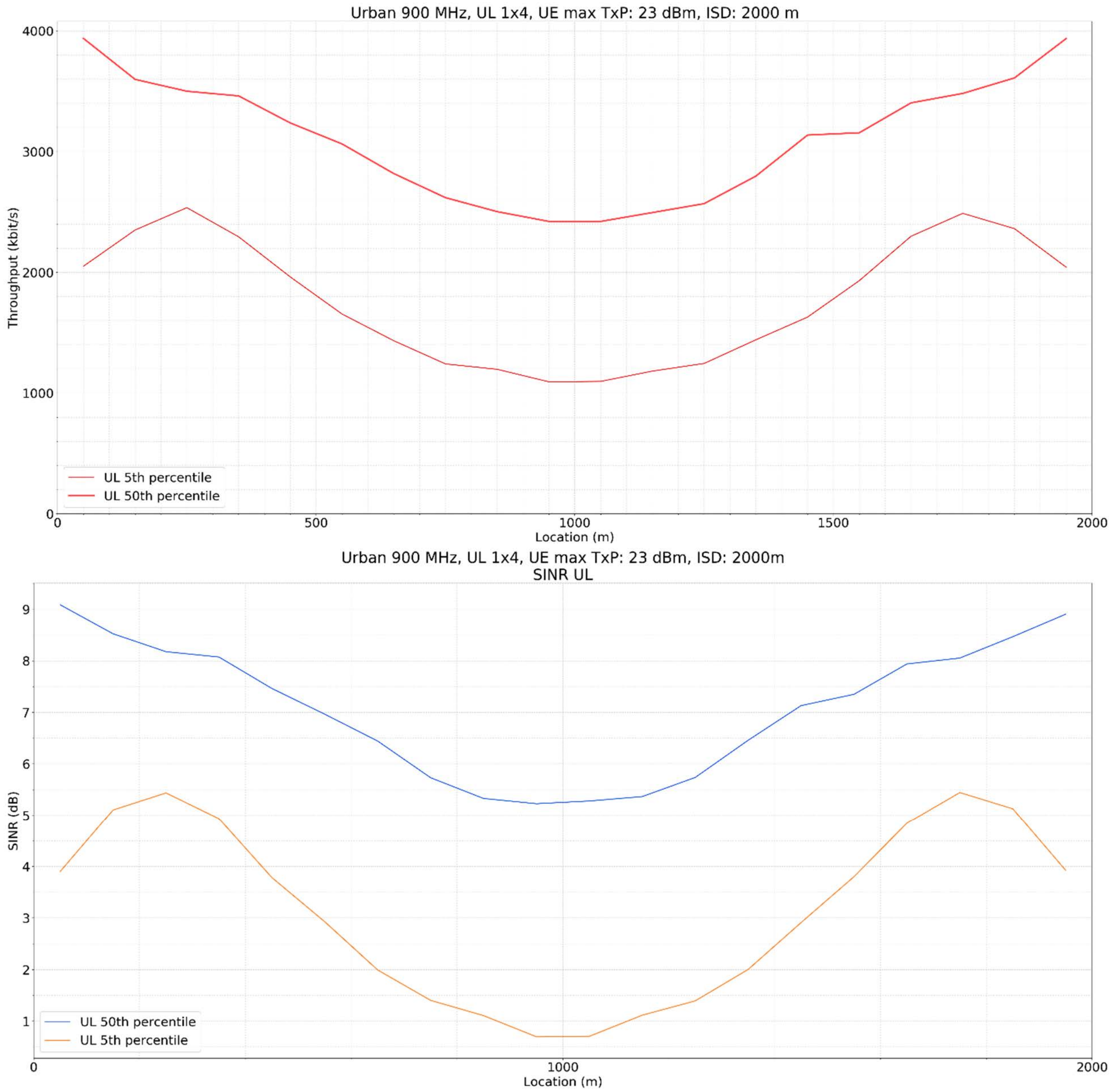


Figure A.23

Interference to noise ratio tables

	5th percentile	50th percentile	95th percentile
Full cell (UL)	-129 dBm	-124 dBm	-109 dBm
Cell centre (UL)	-125 dBm	-123 dBm	-115 dBm
Cell edge (UL)	-120 dBm	-119 dBm	-113 dBm

UL 2x4

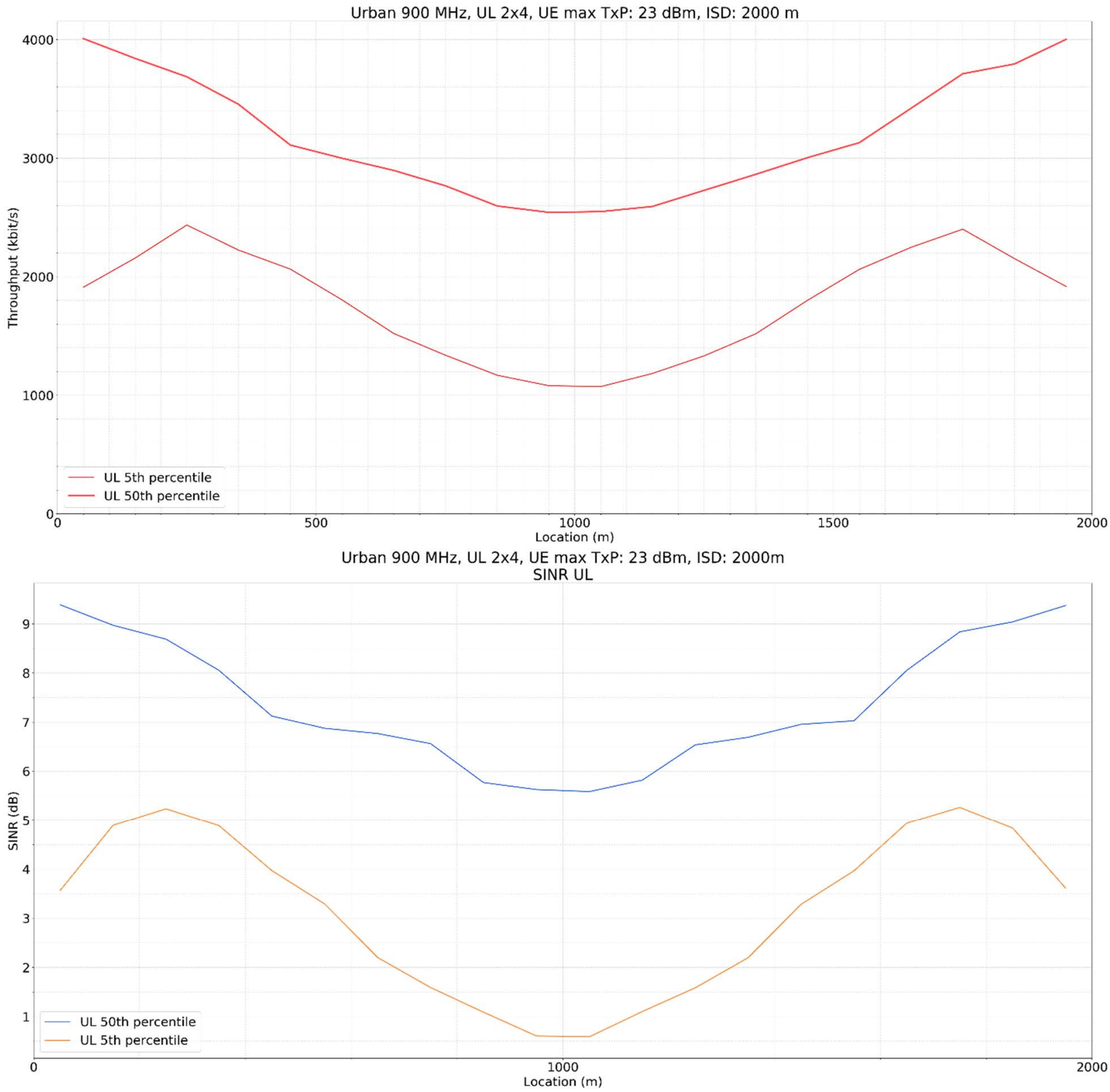


Figure A.24

Interference to noise ratio tables

	5th percentile	50th percentile	95th percentile
Full cell (UL)	-129 dBm	-123 dBm	-110 dBm
Cell centre (UL)	-129 dBm	-125 dBm	-115 dBm
Cell edge (UL)	-123 dBm	-115 dBm	-112 dBm

Uplink, 31 dBm max transmit power

UL 1x2

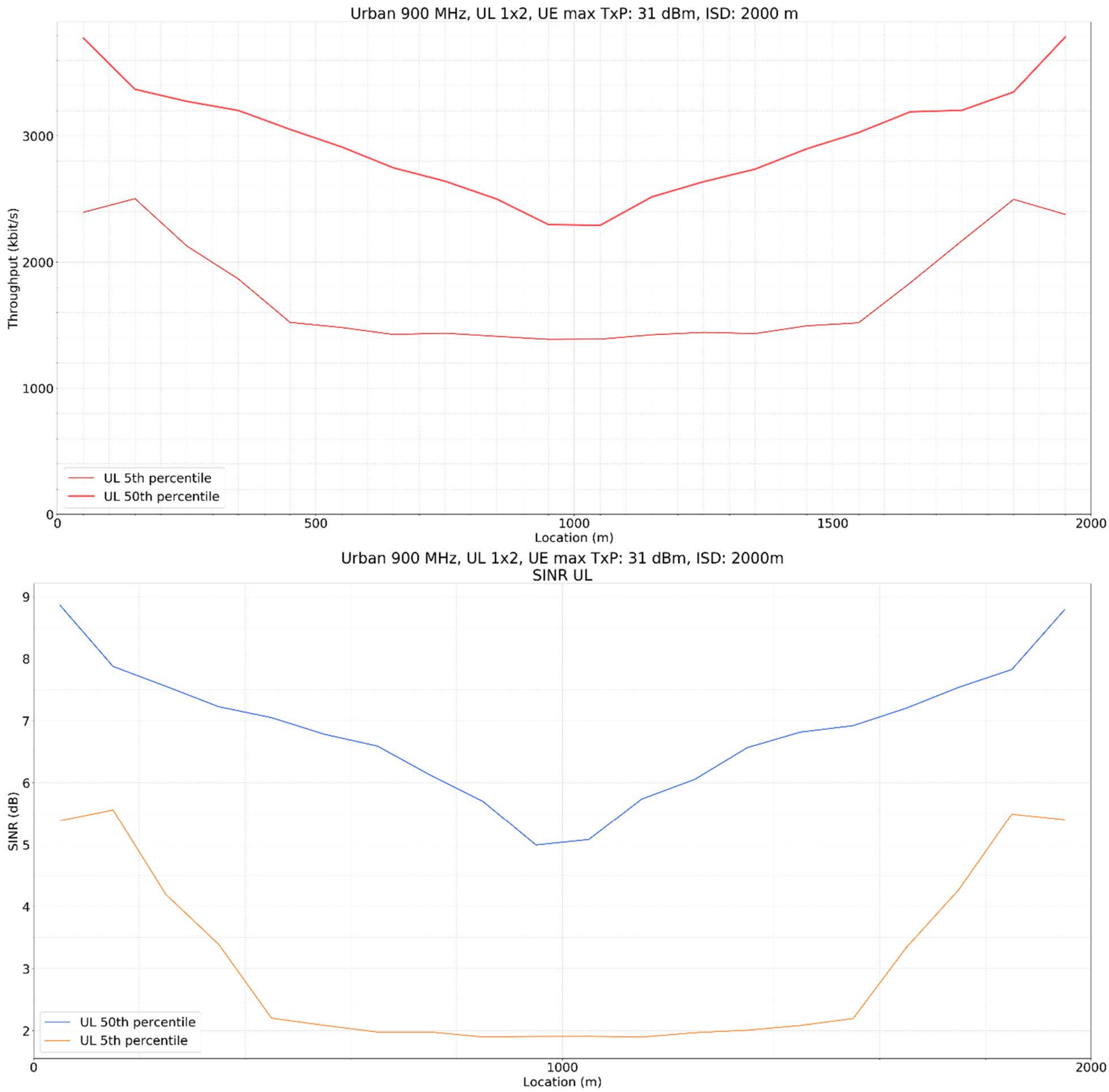


Figure A.25

Interference to noise ratio tables

	5th percentile	50th percentile	95th percentile
Full cell (UL)	-128 dBm	-122 dBm	-109 dBm
Cell centre (UL)	-125 dBm	-122 dBm	-117 dBm
Cell edge (UL)	-123 dBm	-118 dBm	-114 dBm

UL 2x2

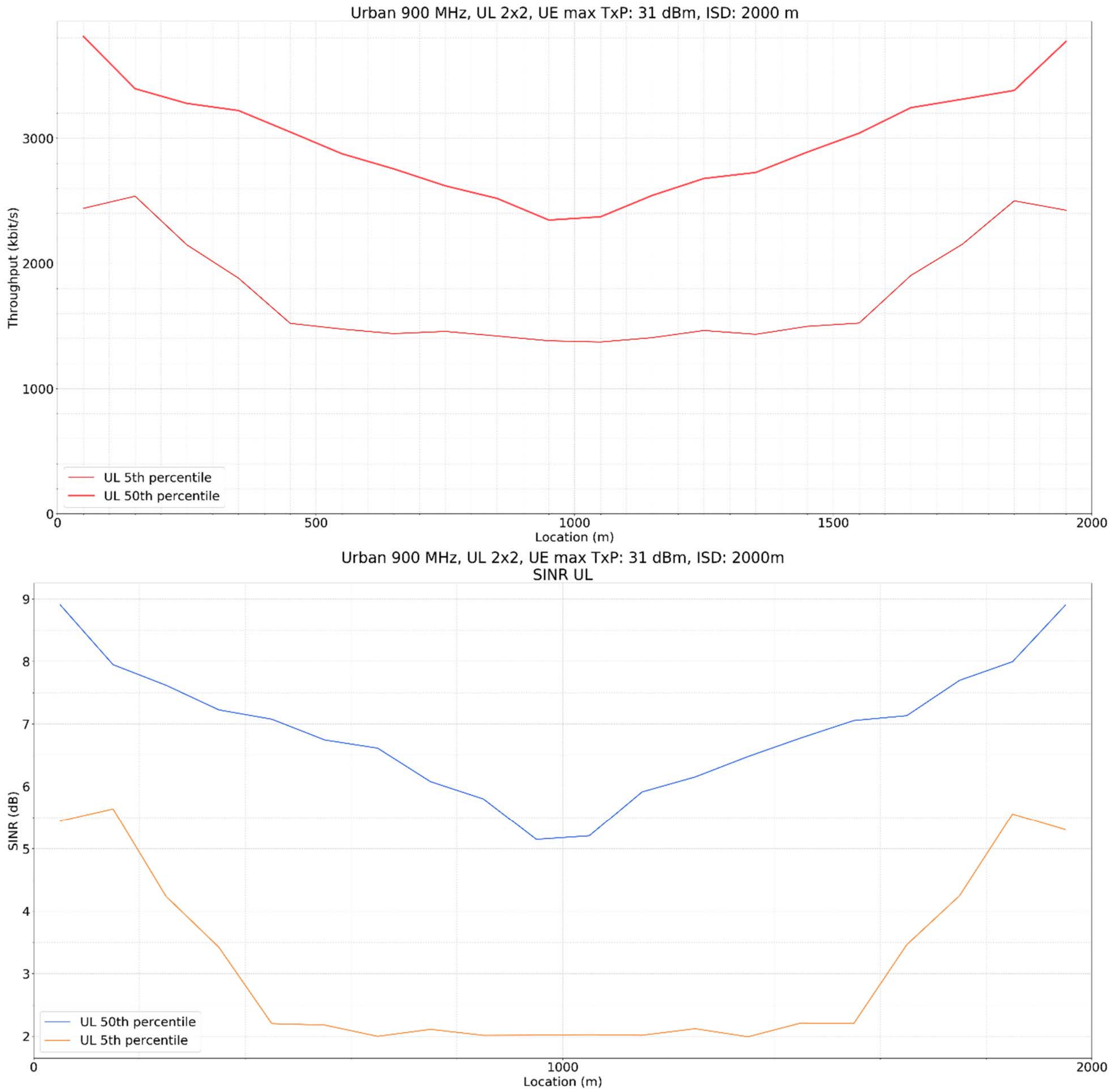
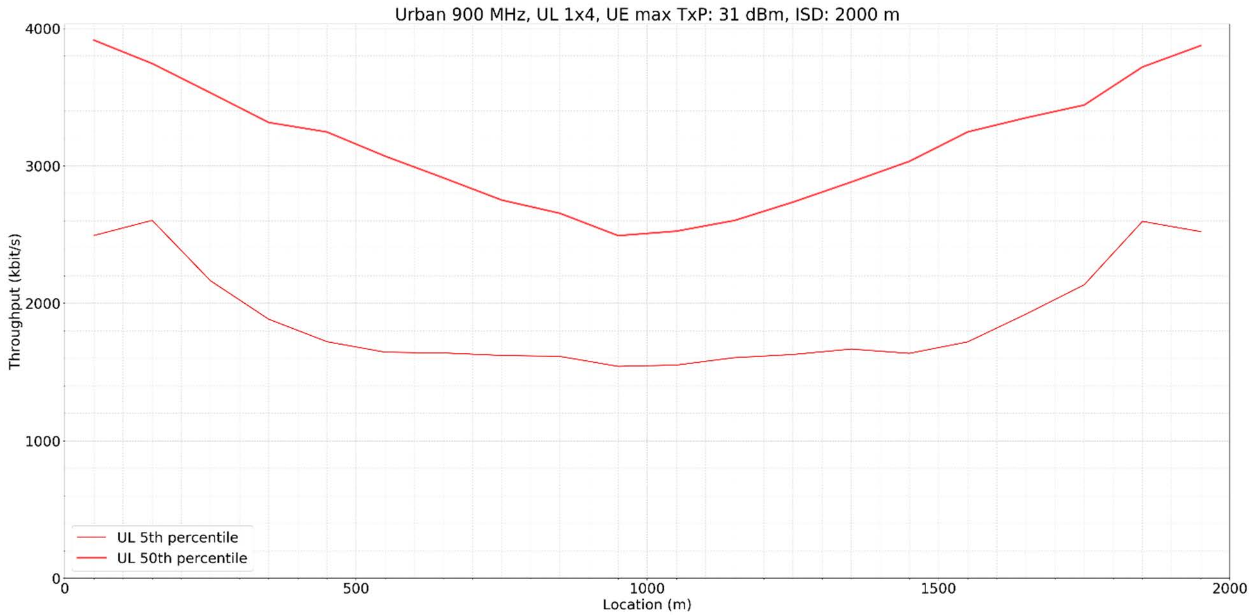


Figure A.26

Interference to noise ratio tables

	5th percentile	50th percentile	95th percentile
Full cell (UL)	-128 dBm	-121 dBm	-108 dBm
Cell centre (UL)	-121 dBm	-121 dBm	-111 dBm
Cell edge (UL)	-125 dBm	-121 dBm	-110 dBm

UL 1x4



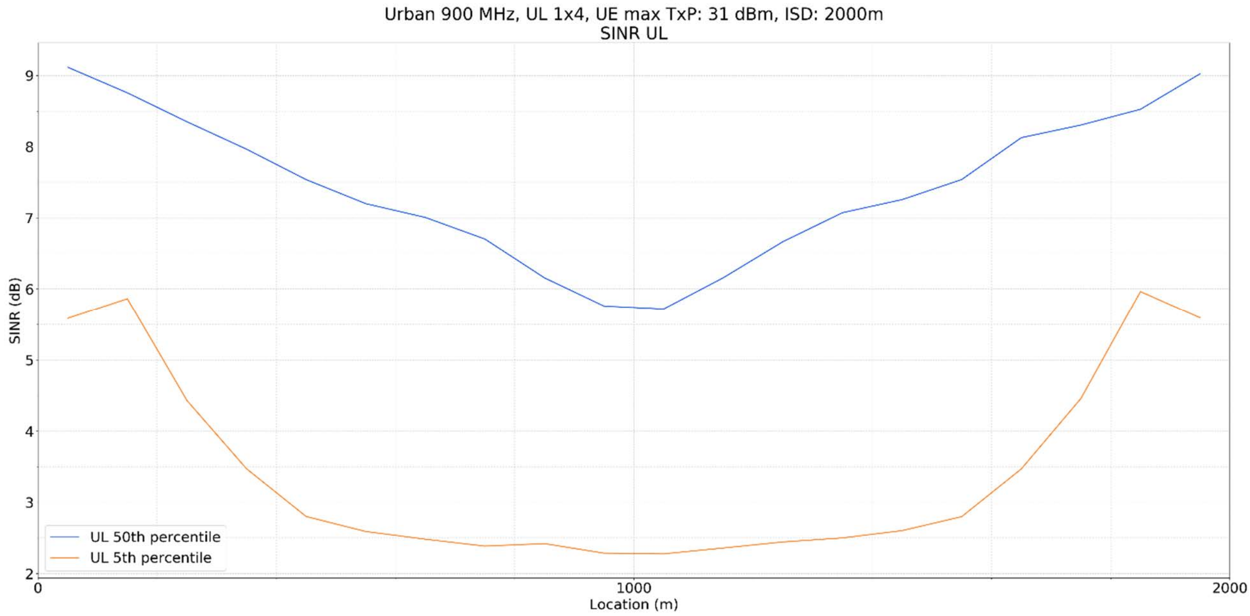


Figure A.27

Interference to noise ratio tables

	5th percentile	**50th percentile**	**95th percentile**
Full cell (UL)	-128 dBm	-120 dBm	-107 dBm
Cell centre (UL)	-130 dBm	-119 dBm	-112 dBm
Cell edge (UL)	-120 dBm	-119 dBm	-109 dBm

UL 2x4

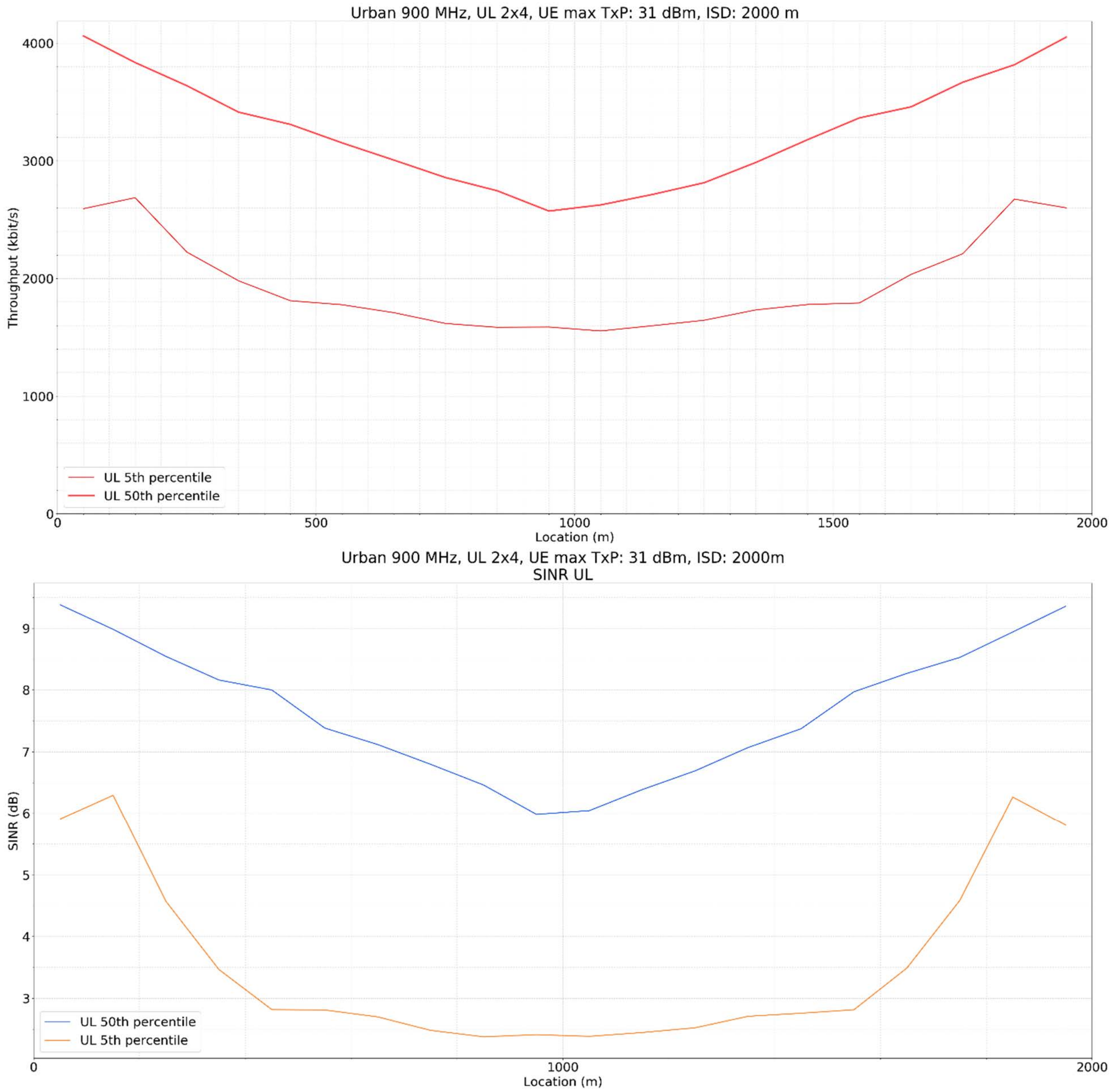


Figure A.28

Interference to noise ratio tables

	5th percentile	50th percentile	95th percentile
Full cell (UL)	-128 dBm	-119 dBm	-107 dBm
Cell centre (UL)	-127 dBm	-120 dBm	-114 dBm
Cell edge (UL)	-122 dBm	-120 dBm	-109 dBm

A.1.2.4 Urban, 4 KM ISD, 2 cells/site

Downlink

DL 2x1

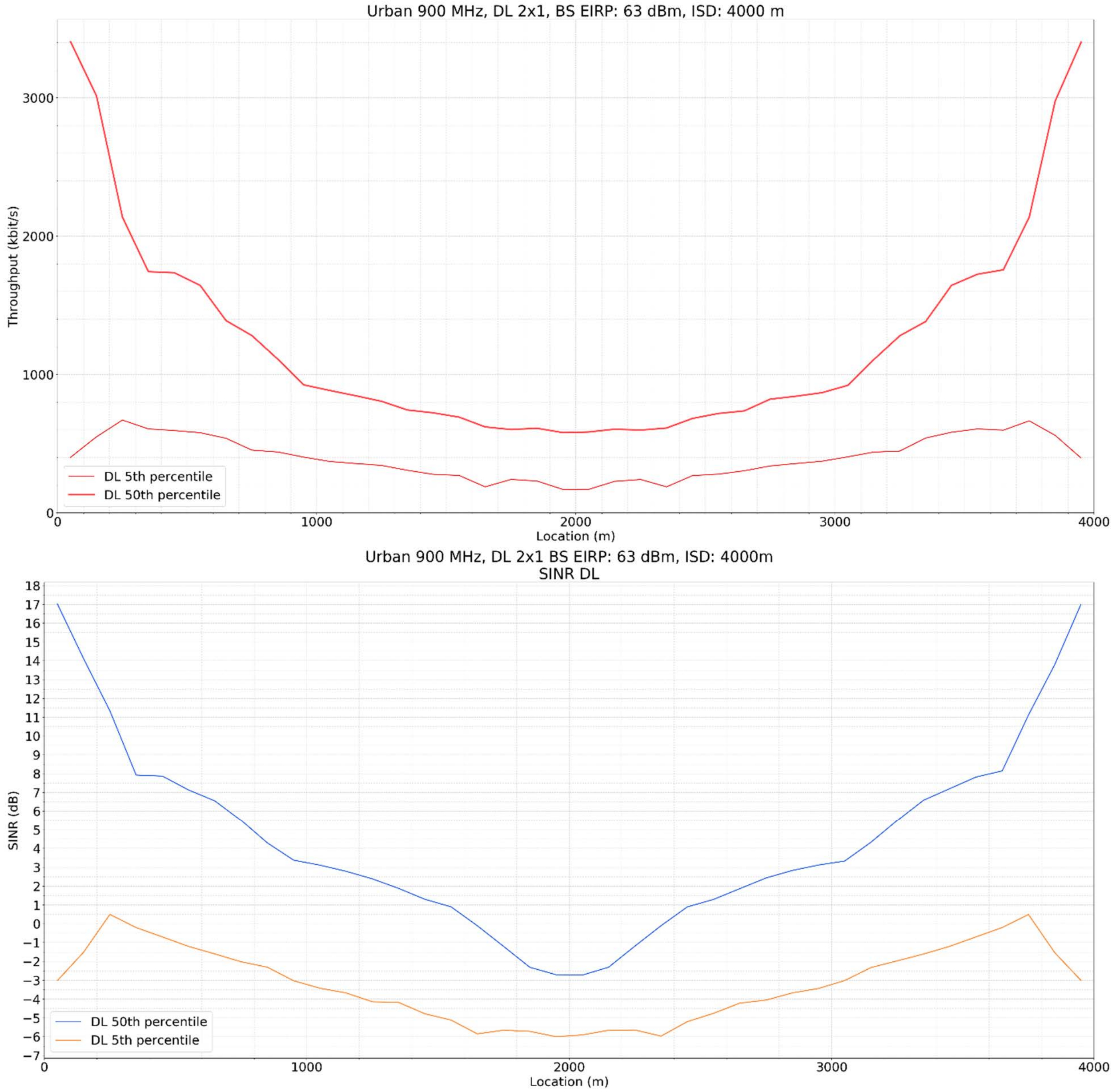


Figure A.29

Interference to noise ratio tables

	5th percentile	50th percentile	95th percentile
Full cell (DL)	-126 dBm	-115 dBm	-88 dBm
Cell centre (DL)	-104 dBm	-87 dBm	-69 dBm
Cell edge (DL)	-120 dBm	-113 dBm	-111 dBm

DL 2x2

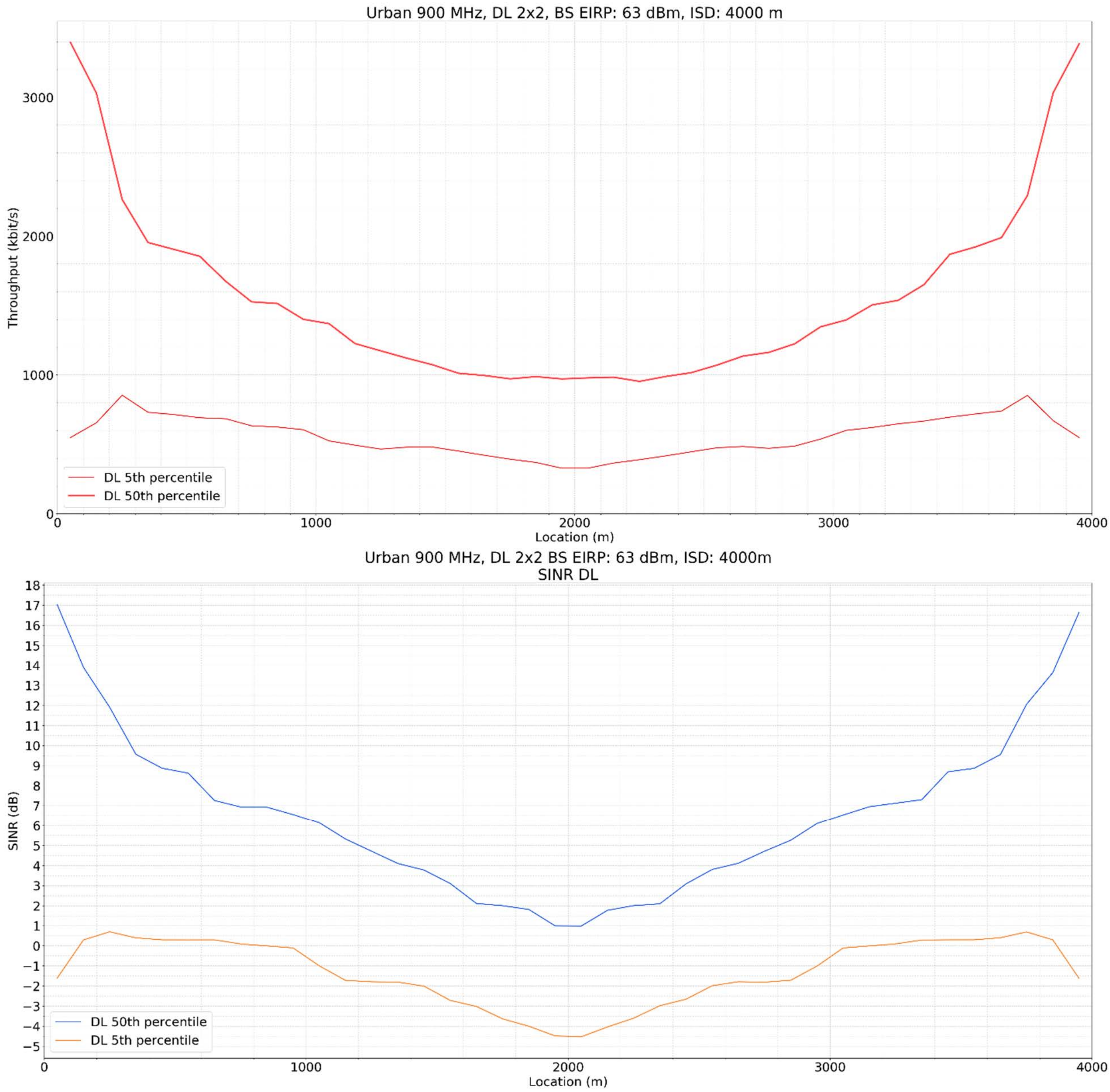


Figure A.30

Interference to noise ratio tables

	5th percentile	50th percentile	95th percentile
Full cell (DL)	-124 dBm	-112 dBm	-84 dBm
Cell centre (DL)	-103 dBm	-87 dBm	-66 dBm
Cell edge (DL)	-120 dBm	-113 dBm	-112 dBm

DL 4x1

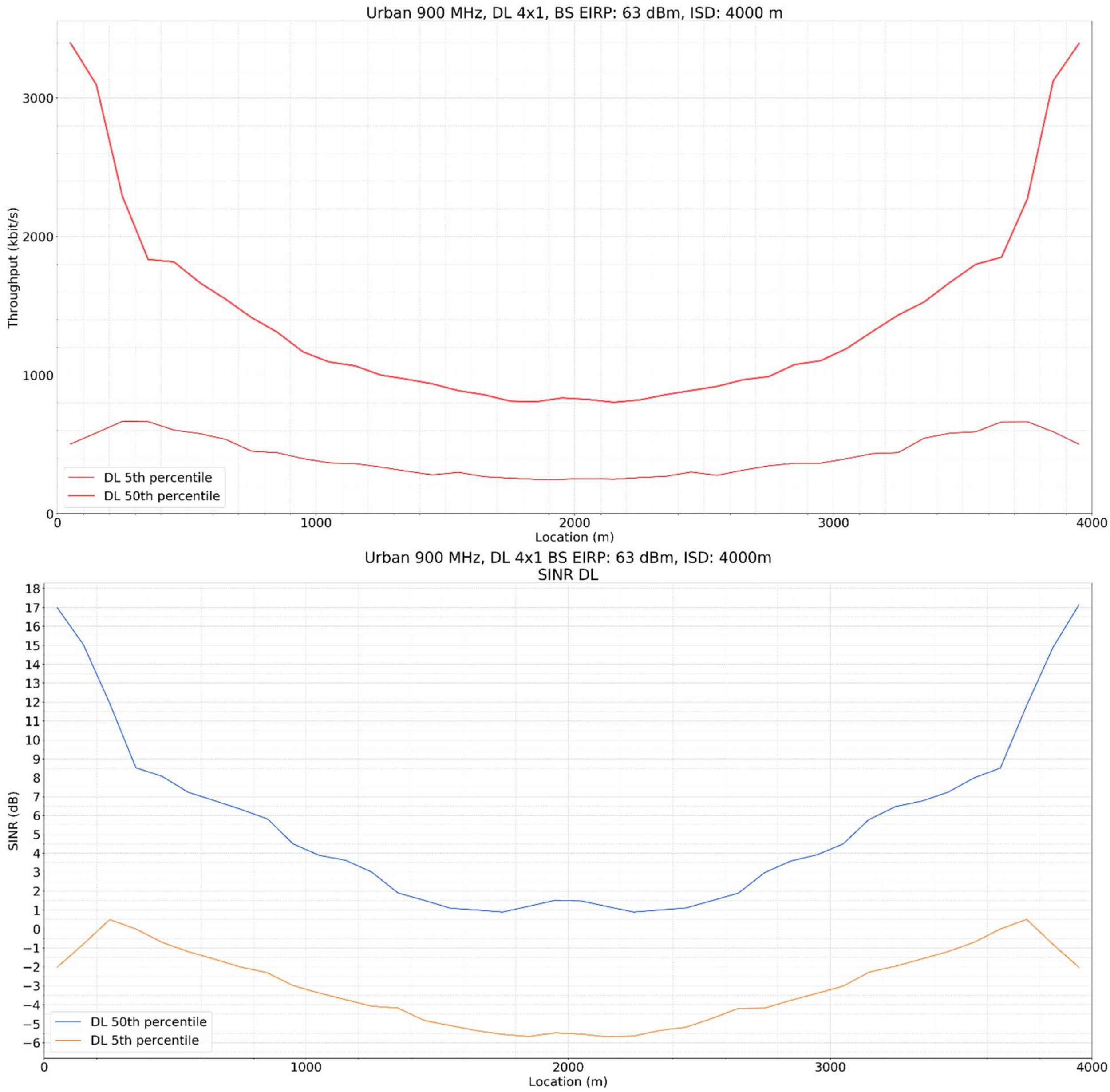


Figure A.31

Interference to noise ratio tables

	5th percentile	50th percentile	95th percentile
Full cell (DL)	-125 dBm	-112 dBm	-85 dBm
Cell centre (DL)	-107 dBm	-89 dBm	-68 dBm
Cell edge (DL)	-119 dBm	-117 dBm	-110 dBm

DL 4x2

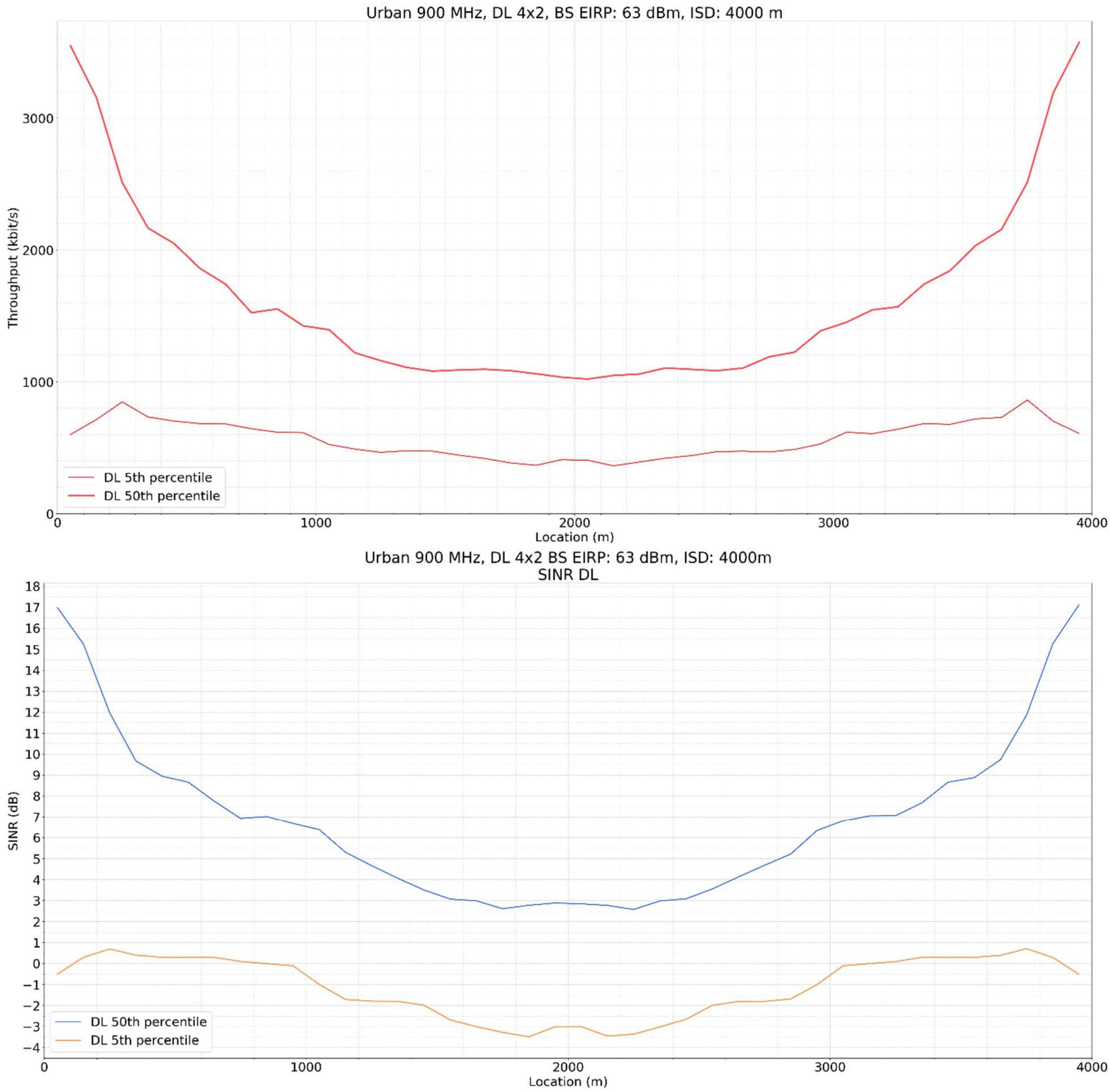


Figure A.32

Interference to noise ratio tables

	5th percentile	50th percentile	95th percentile
Full cell (DL)	-122 dBm	-109 dBm	-80 dBm
Cell centre (DL)	-94 dBm	-75 dBm	-57 dBm
Cell edge (DL)	-119 dBm	-111 dBm	-109 dBm

Uplink, 23 dBm max transmit power

UL 1x2

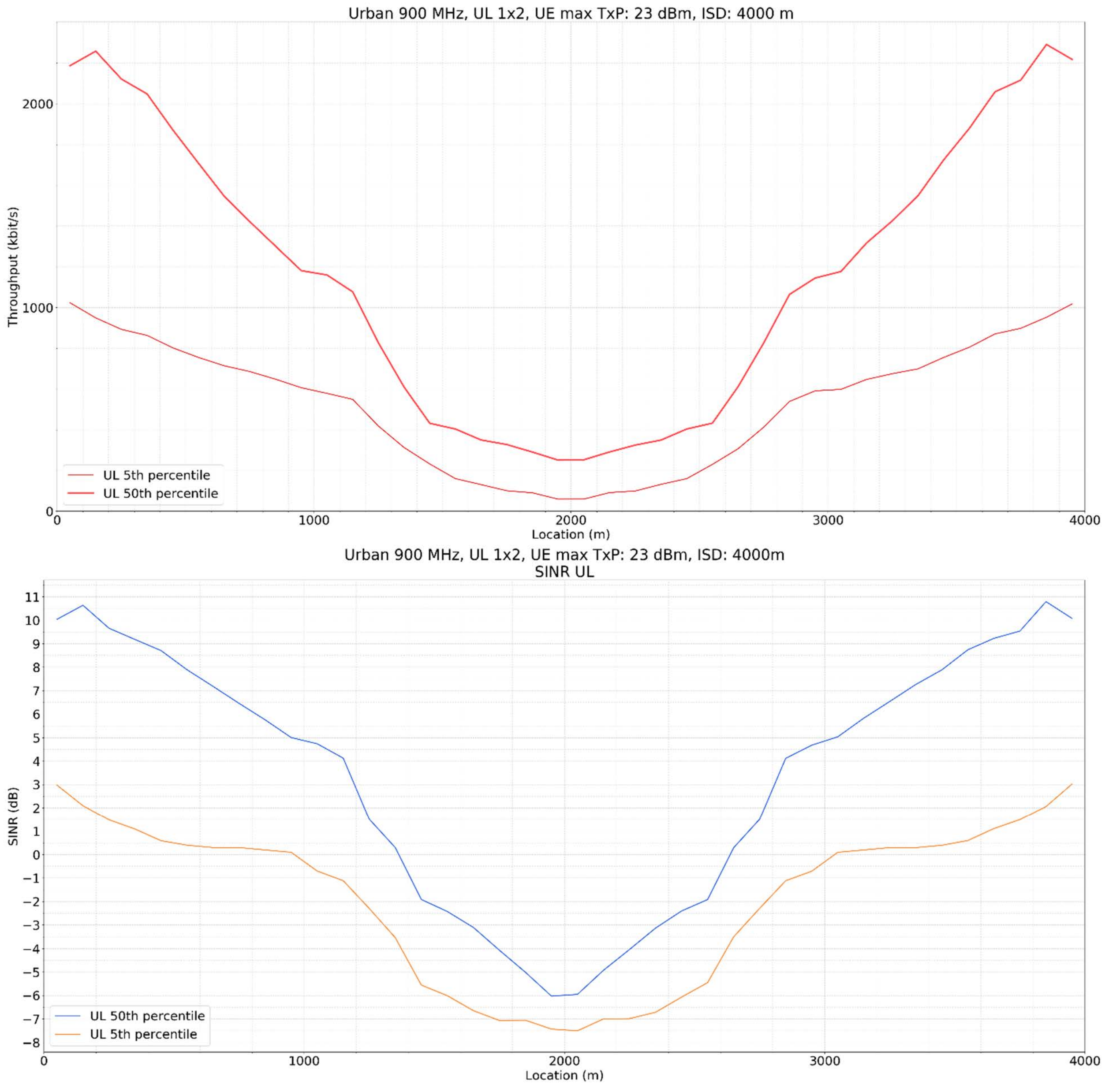


Figure A.33

Interference to noise ratio tables

	5th percentile	50th percentile	95th percentile
Full cell (UL)	-129 dBm	-125 dBm	-114 dBm
Cell centre (UL)	-129 dBm	-126 dBm	-125 dBm
Cell edge (UL)	-121 dBm	-120 dBm	-116 dBm

UL 2x2

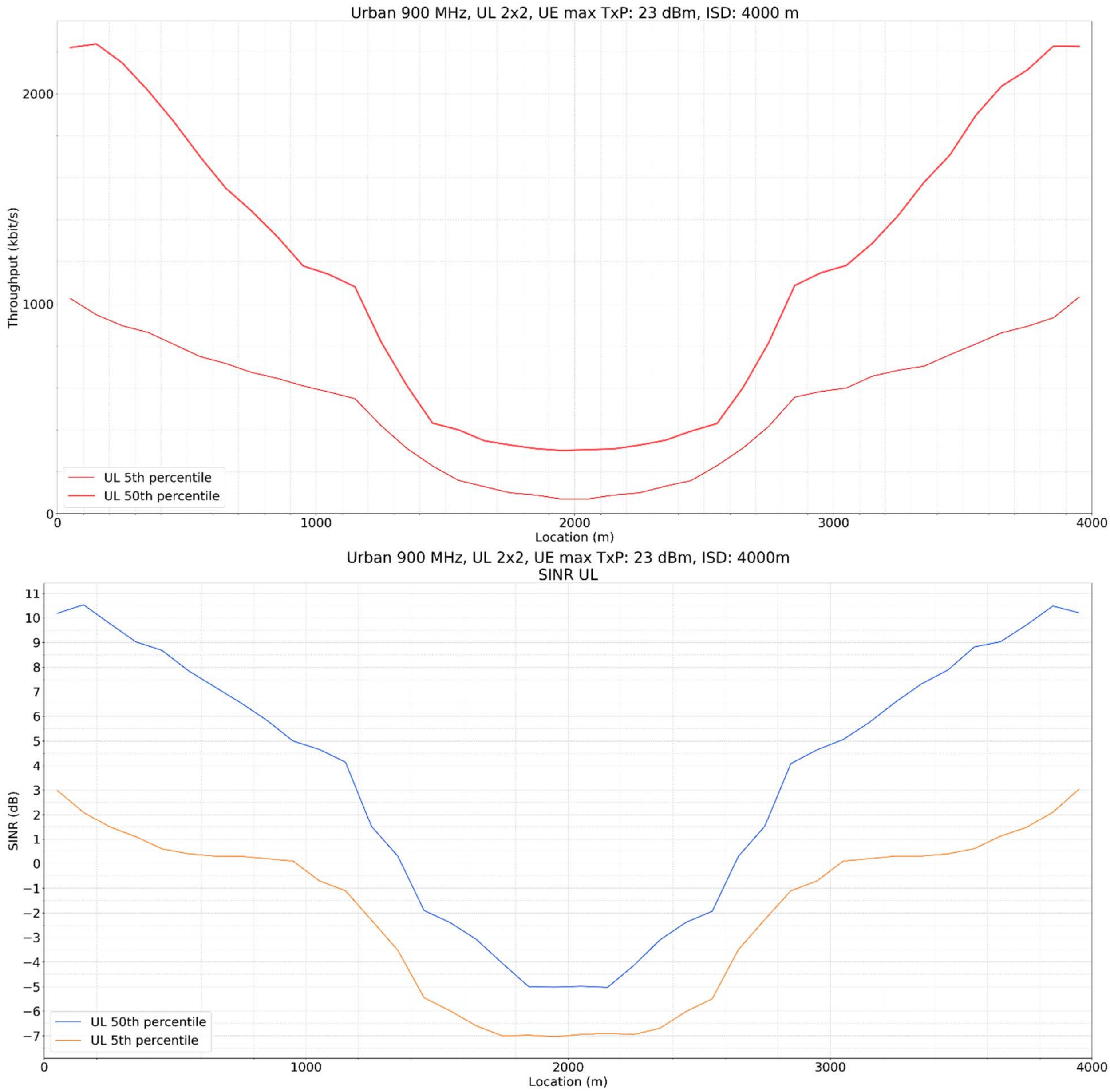


Figure A.34

Interference to noise ratio tables

	5th percentile	50th percentile	95th percentile
Full cell (UL)	-129 dBm	-123 dBm	-114 dBm
Cell centre (UL)	-127 dBm	-125 dBm	-125 dBm
Cell edge (UL)	-119 dBm	-119 dBm	-113 dBm

UL 1x4

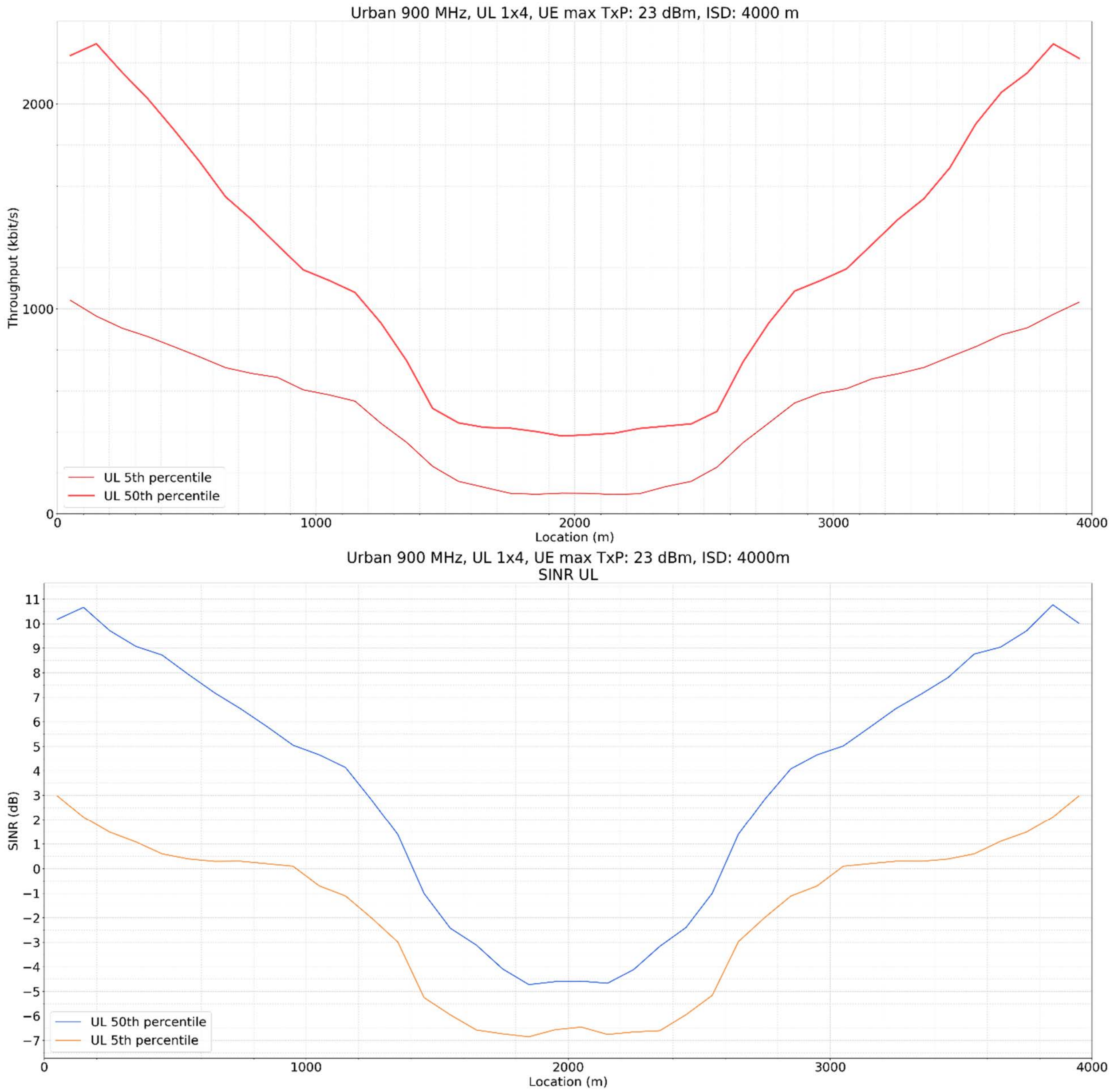


Figure A.35

Interference to noise ratio tables

	5th percentile	50th percentile	95th percentile
Full cell (UL)	-129 dBm	-123 dBm	-112 dBm
Cell centre (UL)	-129 dBm	-126 dBm	-126 dBm
Cell edge (UL)	-120 dBm	-119 dBm	-113 dBm

UL 2x4

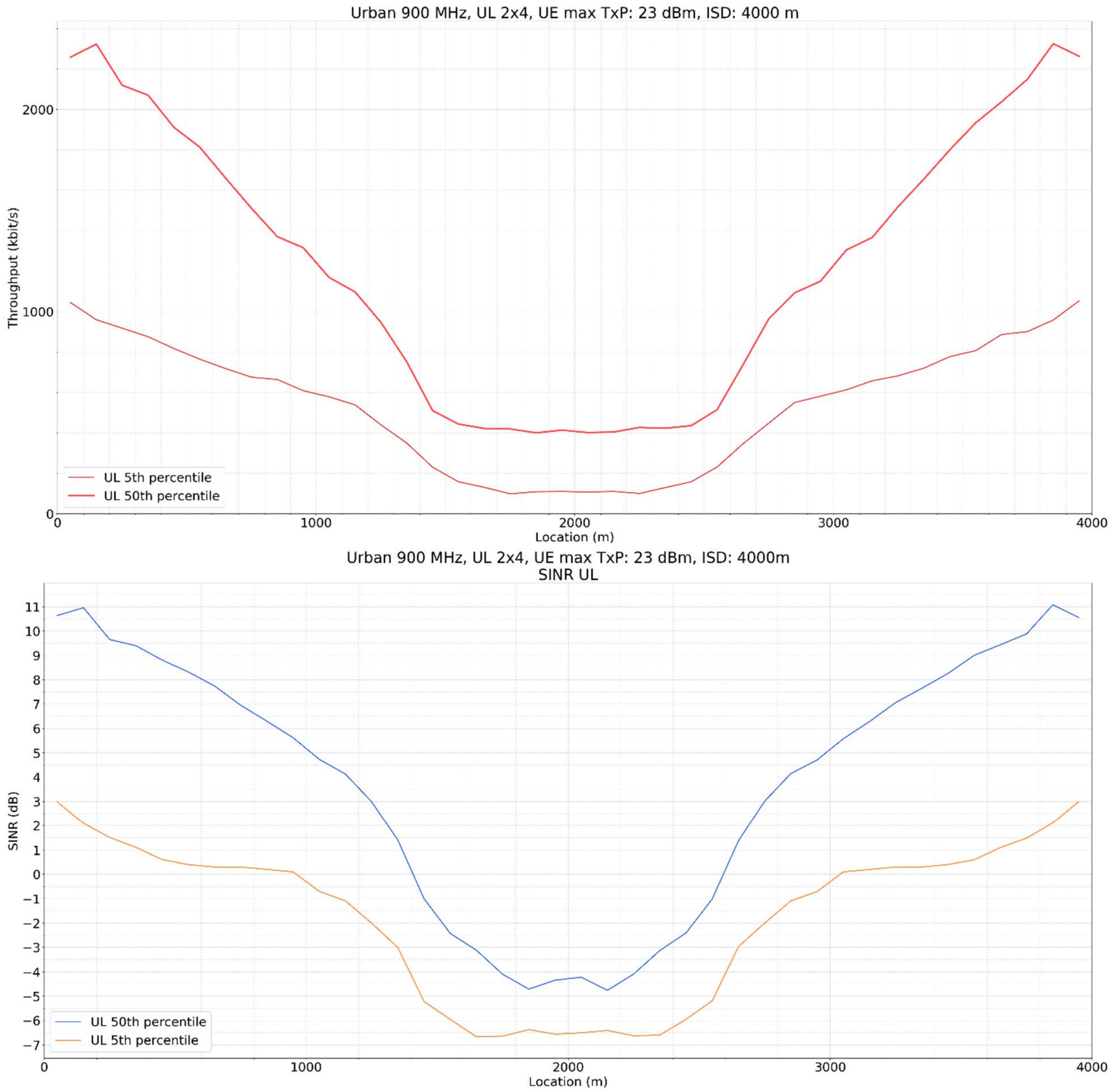


Figure A.36

Interference to noise ratio tables

	5th percentile	50th percentile	95th percentile
Full cell (UL)	-129 dBm	-122 dBm	-112 dBm
Cell centre (UL)	-129 dBm	-126 dBm	-123 dBm
Cell edge (UL)	-118 dBm	-118 dBm	-111 dBm

Uplink, 31 dBm max transmit power

UL 1x2

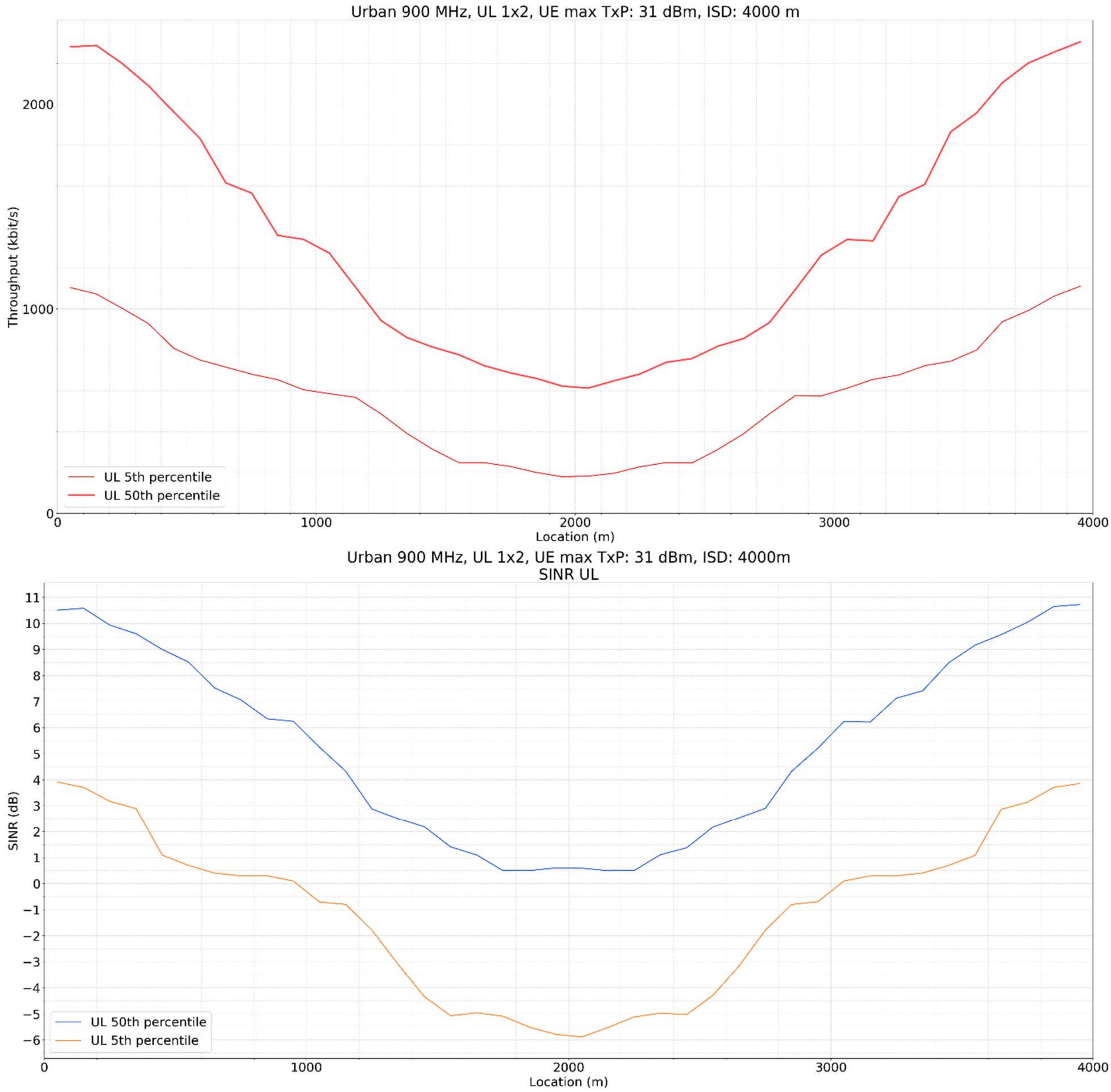
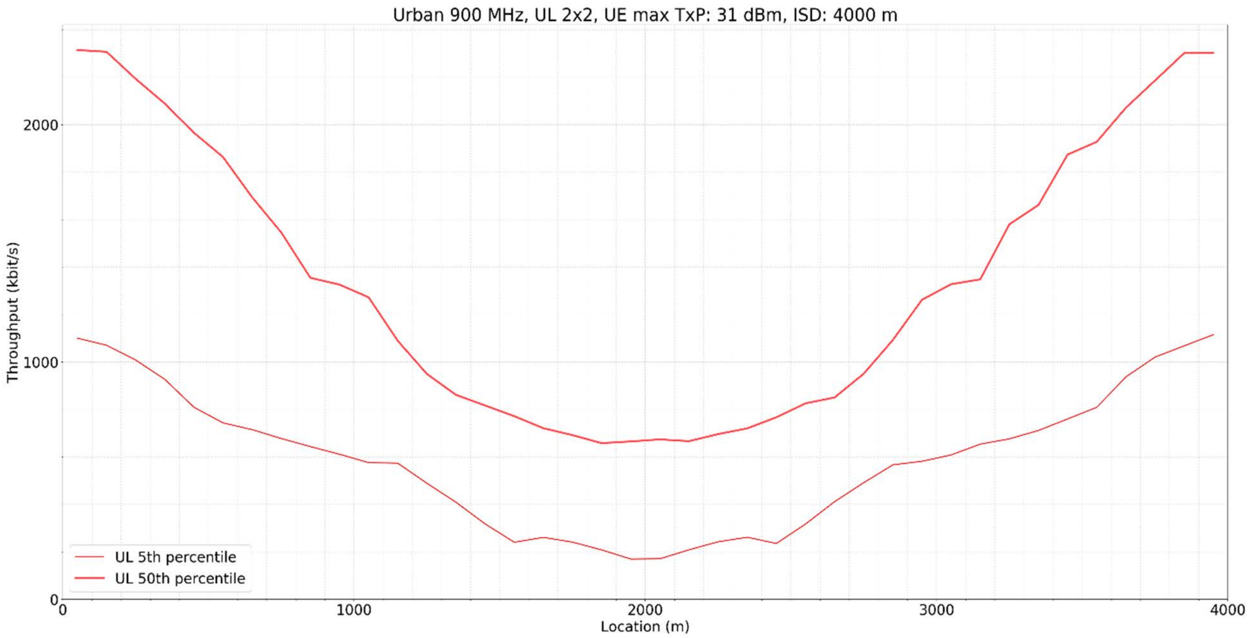


Figure A.37

Interference to noise ratio tables

	5th percentile	50th percentile	95th percentile
Full cell (UL)	-129 dBm	-122 dBm	-111 dBm
Cell centre (UL)	-122 dBm	-122 dBm	-120 dBm
Cell edge (UL)	-123 dBm	-118 dBm	-111 dBm

UL 2x2



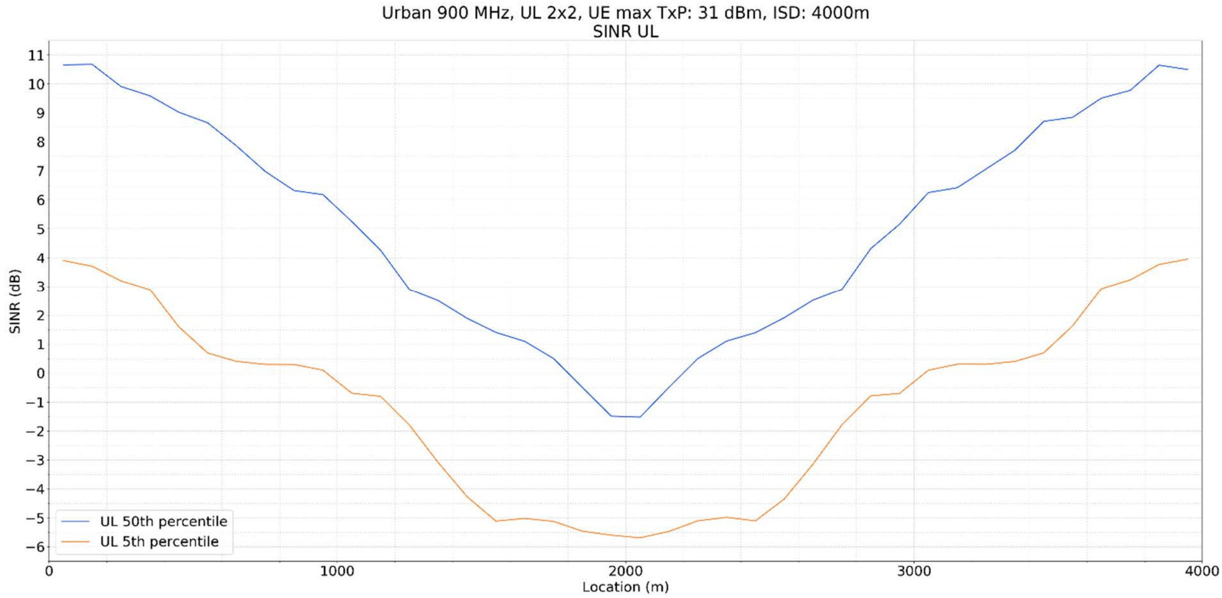


Figure A.38

Interference to noise ratio tables

	5th percentile	50th percentile	95th percentile
Full cell (UL)	-128 dBm	-121 dBm	-111 dBm
Cell centre (UL)	-125 dBm	-125 dBm	-120 dBm
Cell edge (UL)	-121 dBm	-118 dBm	-111 dBm

UL 1x4

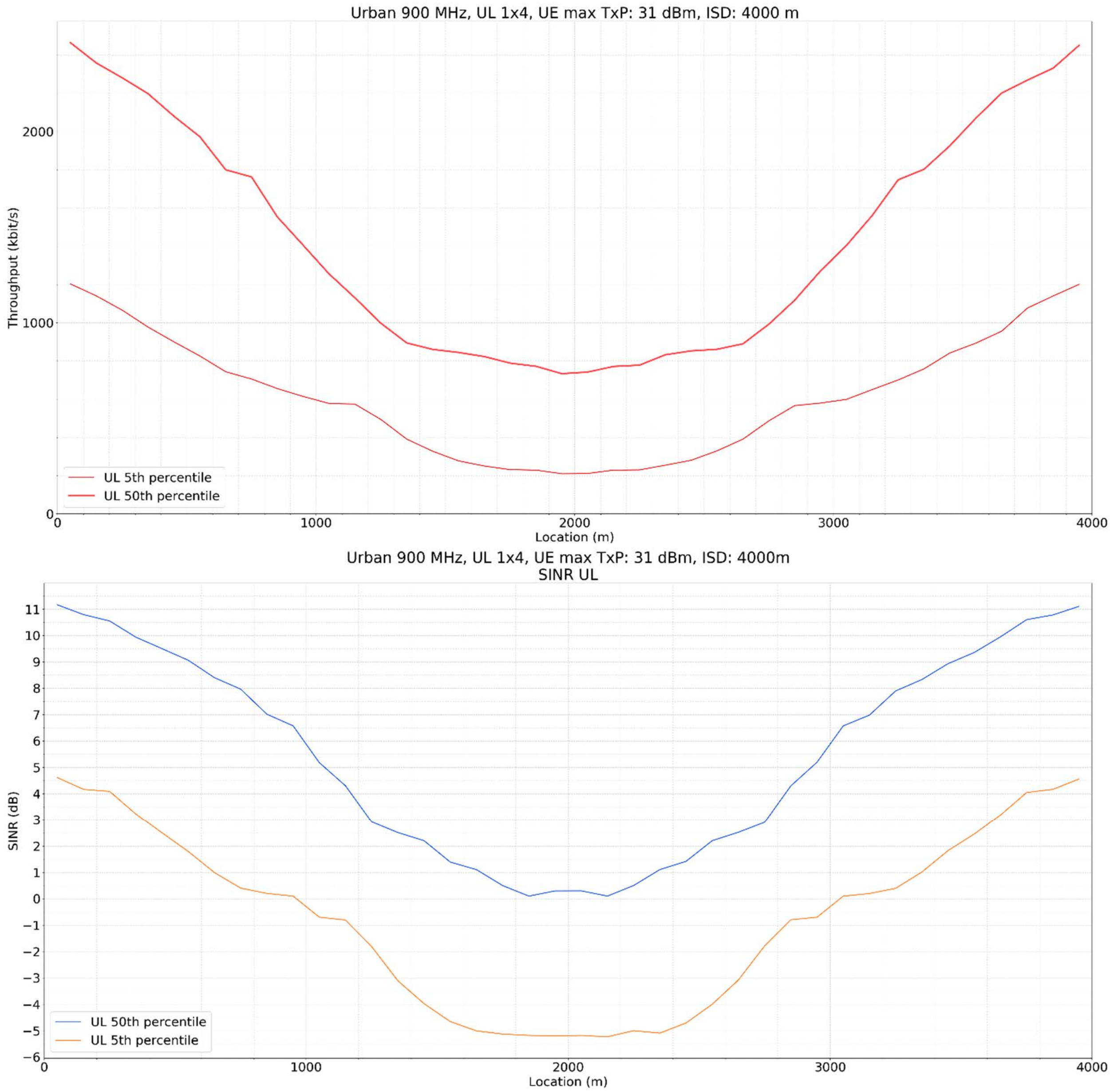


Figure A.39

Interference to noise ratio tables

	5th percentile	**50th percentile**	**95th percentile**
Full cell (UL)	-128 dBm	-120 dBm	-110 dBm
Cell centre (UL)	-127 dBm	-126 dBm	-123 dBm
Cell edge (UL)	-118 dBm	-115 dBm	-113 dBm

UL 2x4

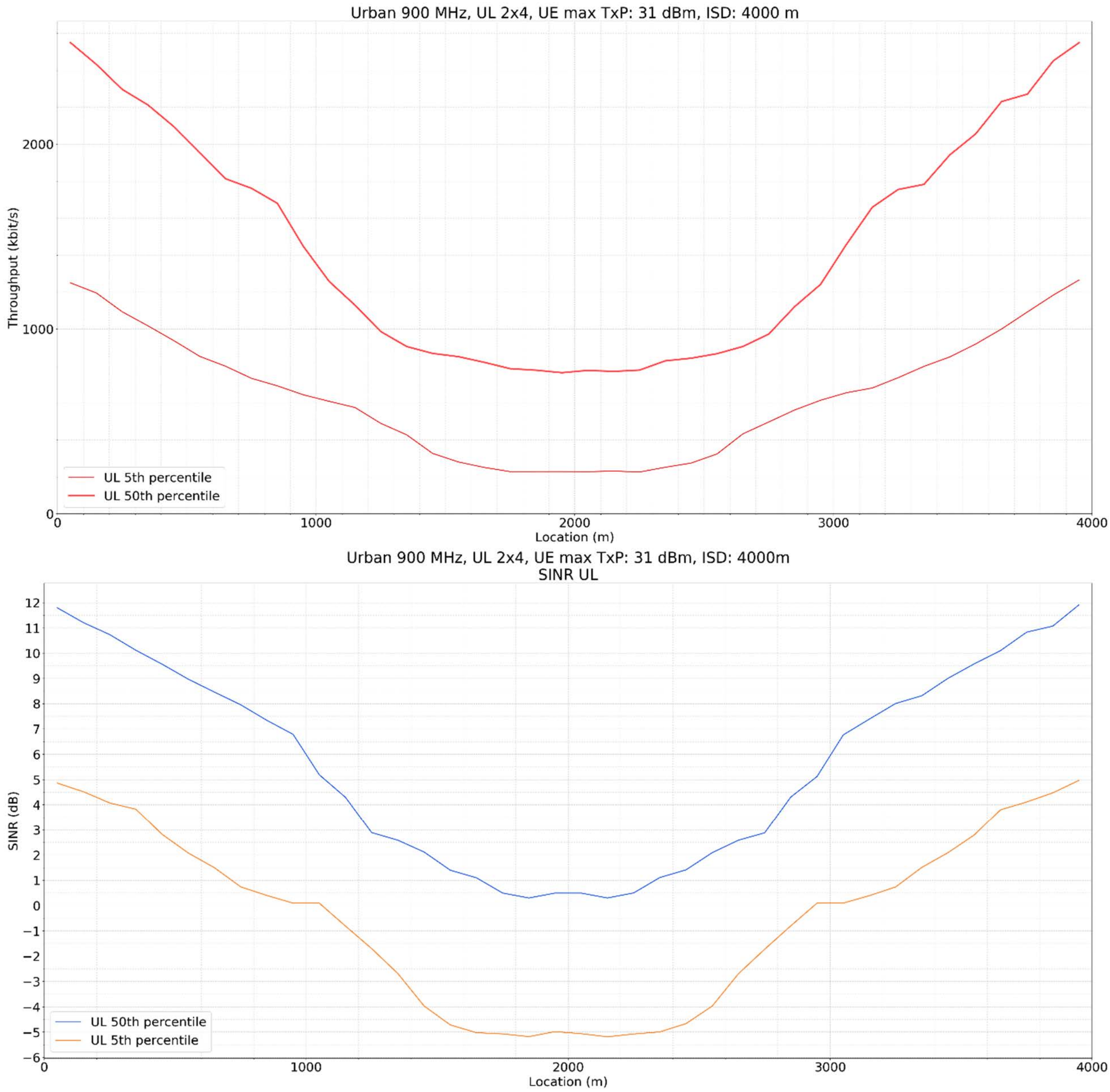


Figure A.40

Interference to noise ratio tables

	5th percentile	50th percentile	95th percentile
Full cell (UL)	-127 dBm	-119 dBm	-109 dBm
Cell centre (UL)	-128 dBm	-122 dBm	-120 dBm
Cell edge (UL)	-114 dBm	-111 dBm	-108 dBm

A.1.3 Company C

A.1.3.1 Description, specific assumptions and parameters

Results Table SINR evaluation

Below are Signal to Interference and Noise Ratio (SINR) statistics for different environments, inter-site distances and different frequency reuse factors. Both 900 MHz and 1 900 MHz carriers are considered.

900 MHz

Rural Area - ISD 8 Km - Uplink 23 dBm

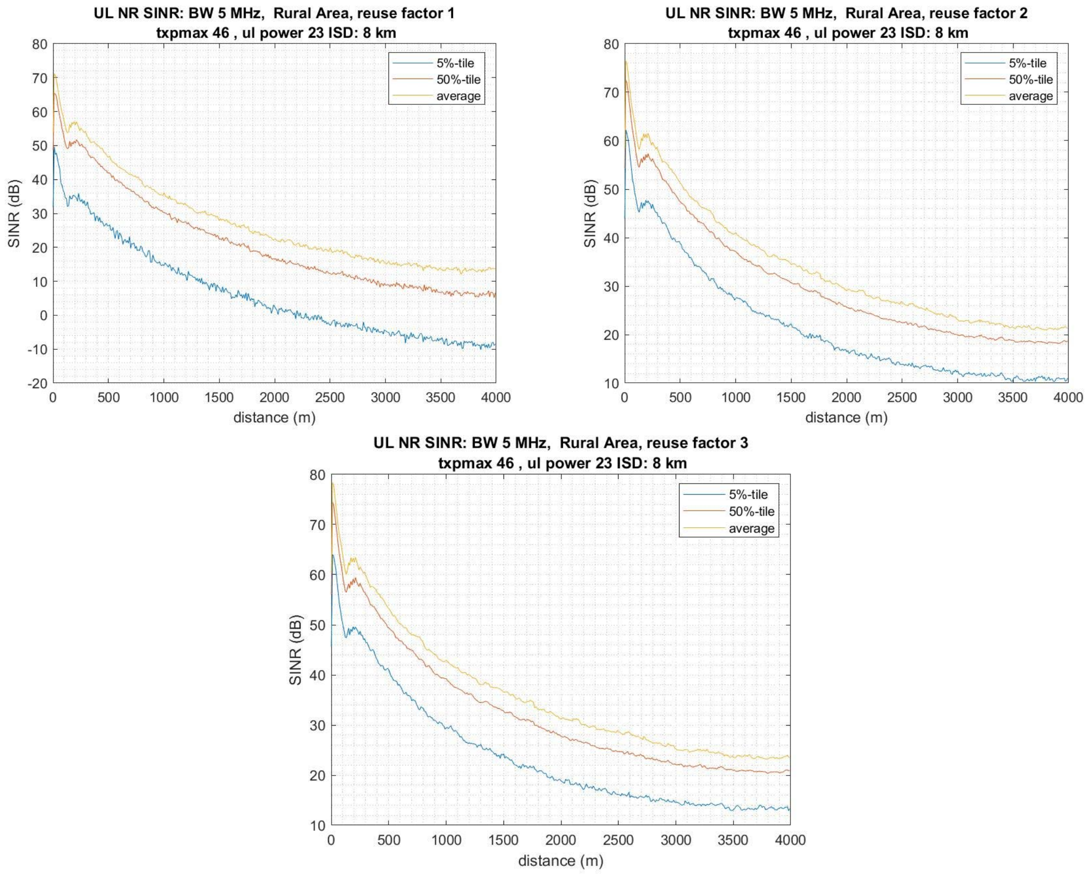


Figure A.41

Rural Area - ISD 8 Km - downlink

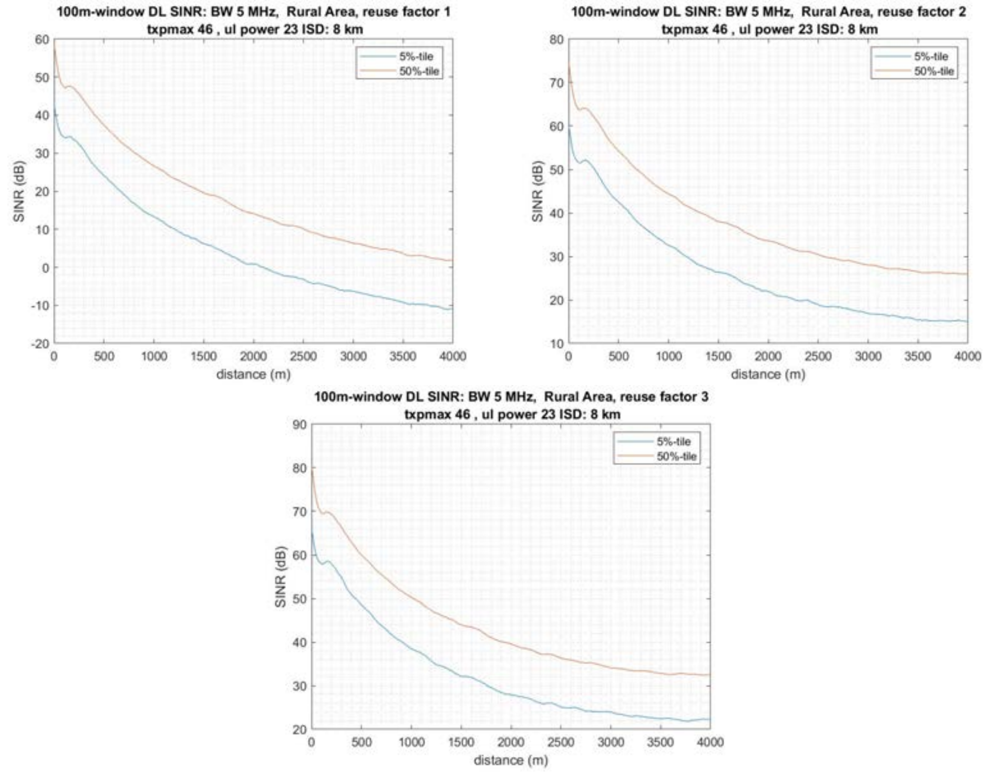


Figure A.42

Hilly Terrain - ISD 8 Km - Uplink 23 dBm

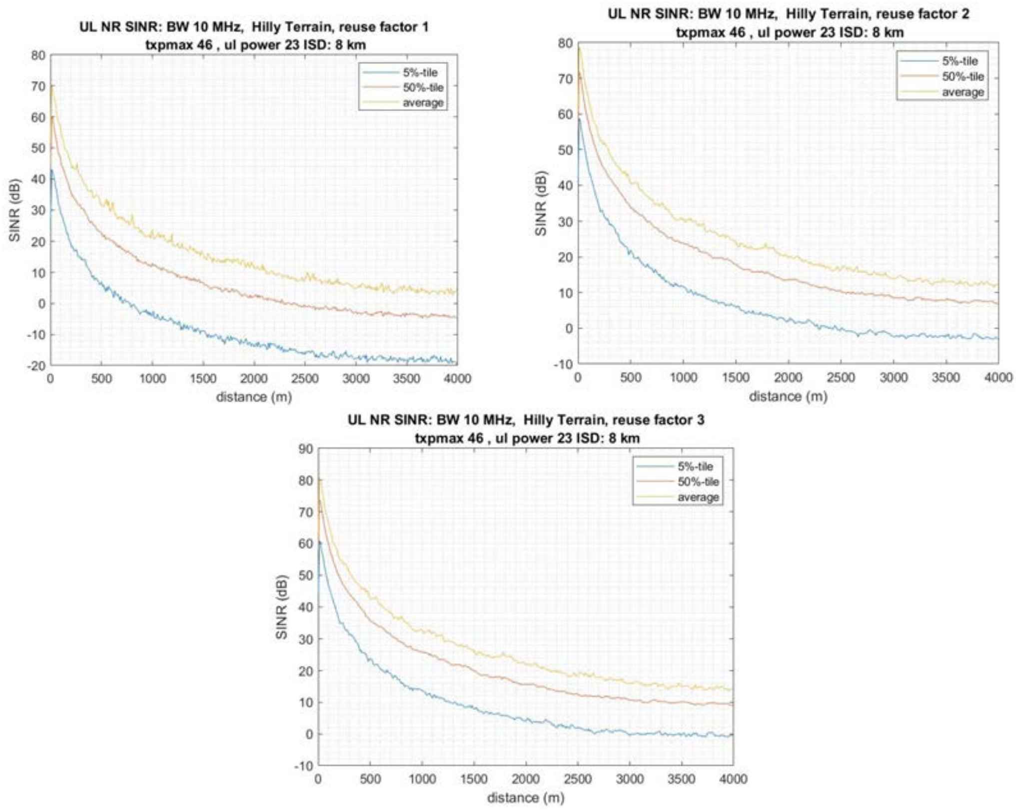


Figure A.43

Hilly Terrain - ISD 8 Km - downlink

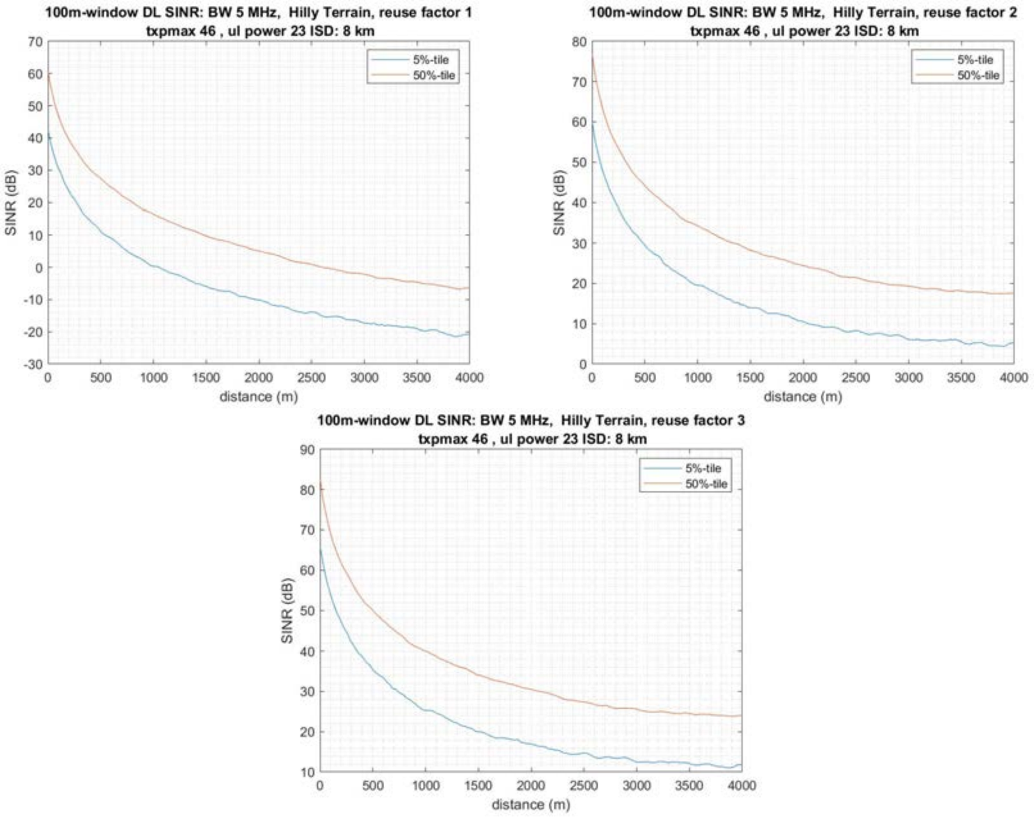


Figure A.44

Urban Area - ISD 2 Km - Uplink 23 dBm

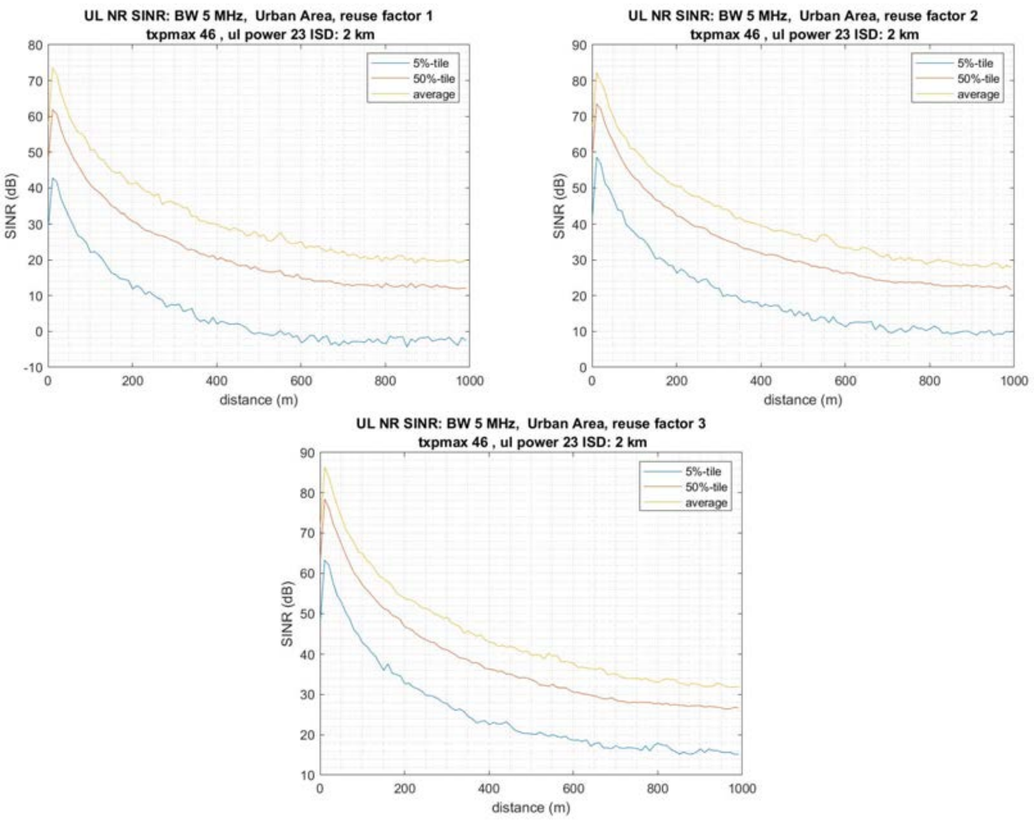


Figure A.45

Urban Area - ISD 2 Km - Downlink

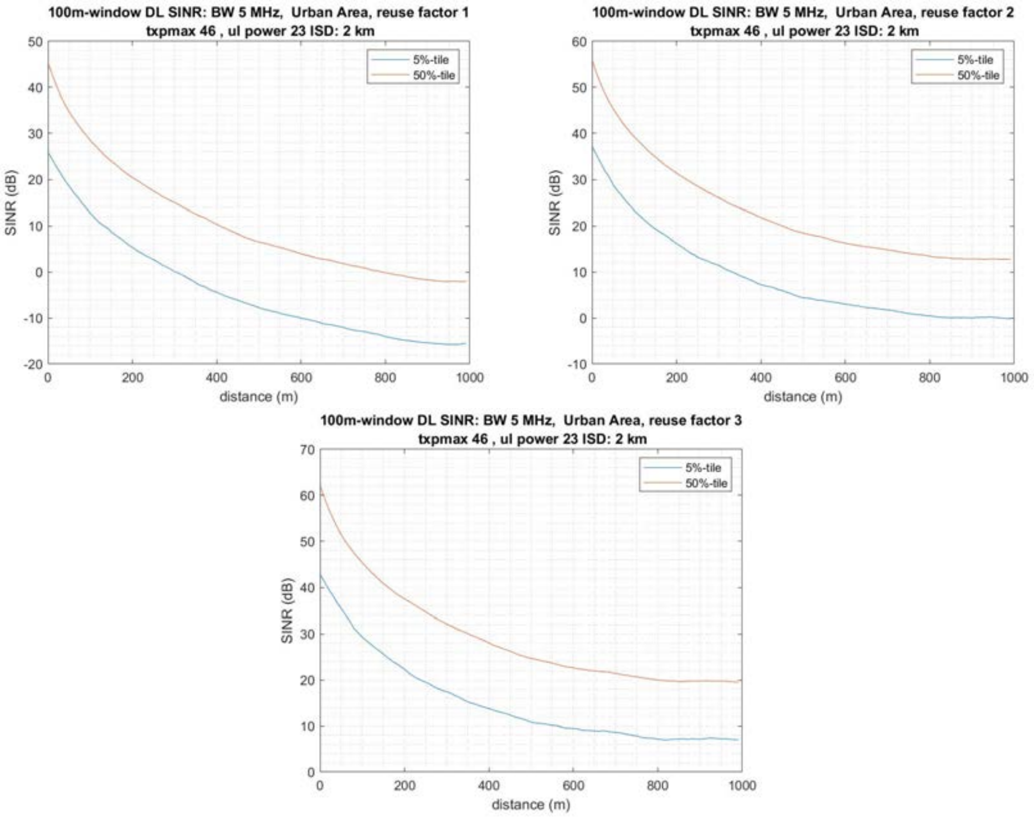


Figure A.46

Urban Area High Density - ISD 4 Km - Uplink 23 dBm

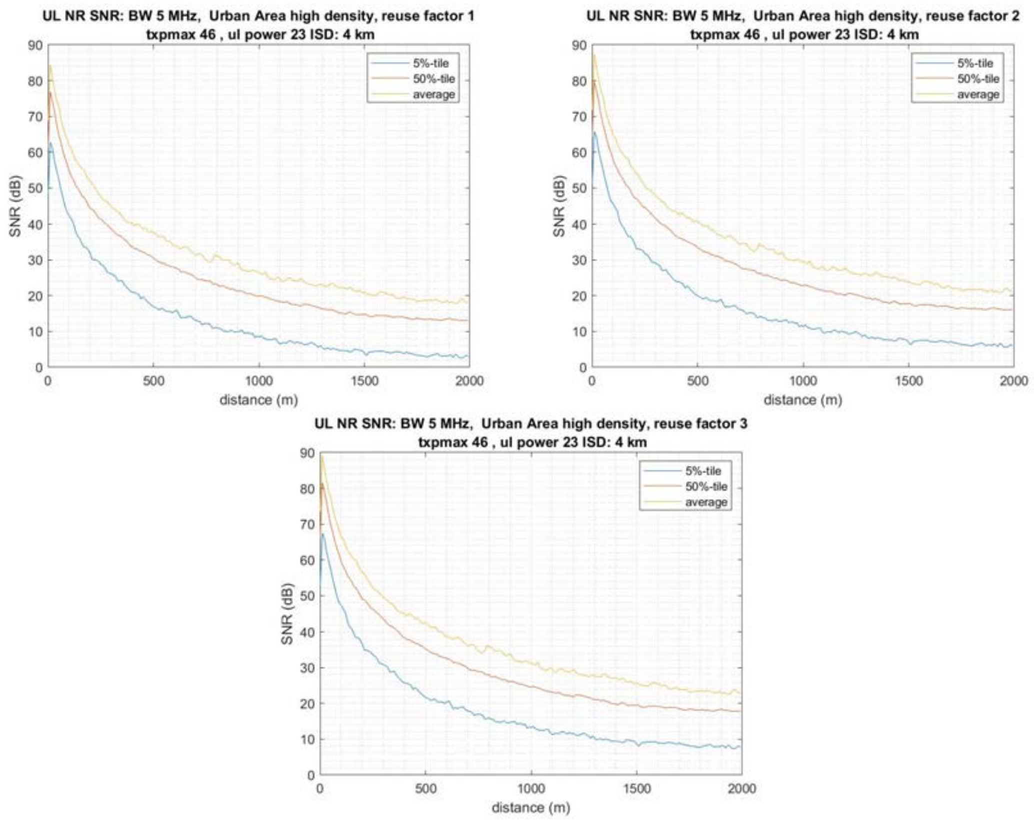


Figure A.47

Urban Area High Density - ISD 4 Km - Downlink

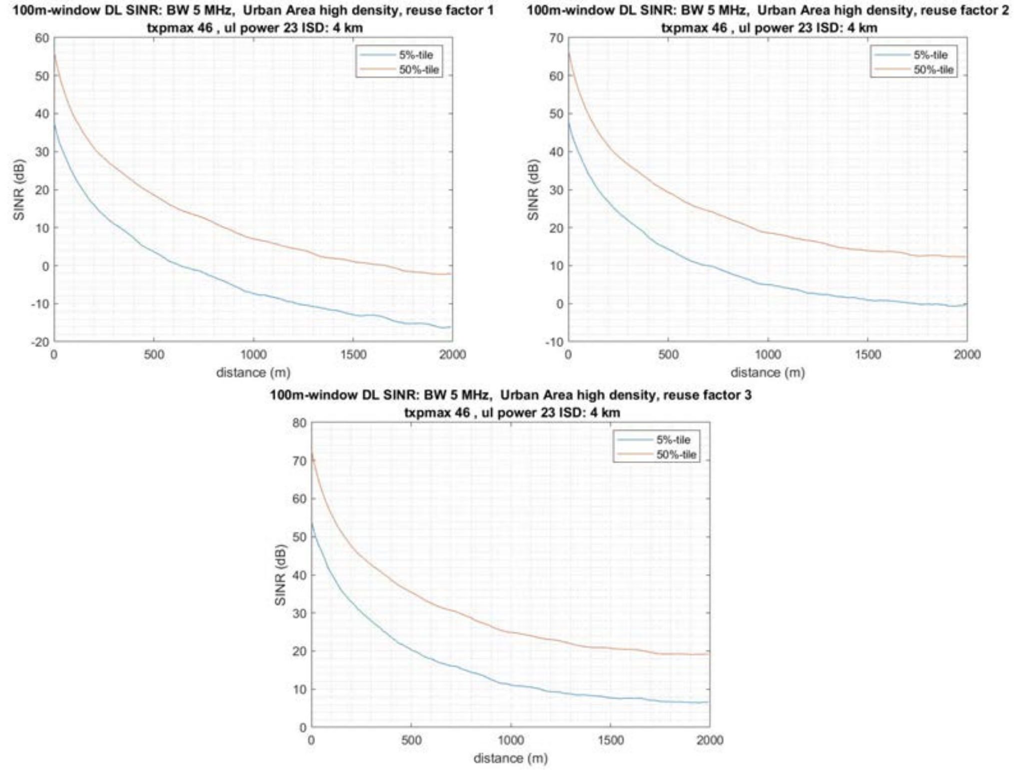


Figure A.48

1 900 MHz

Rural Area - ISD 8 Km - Uplink 23 dBm

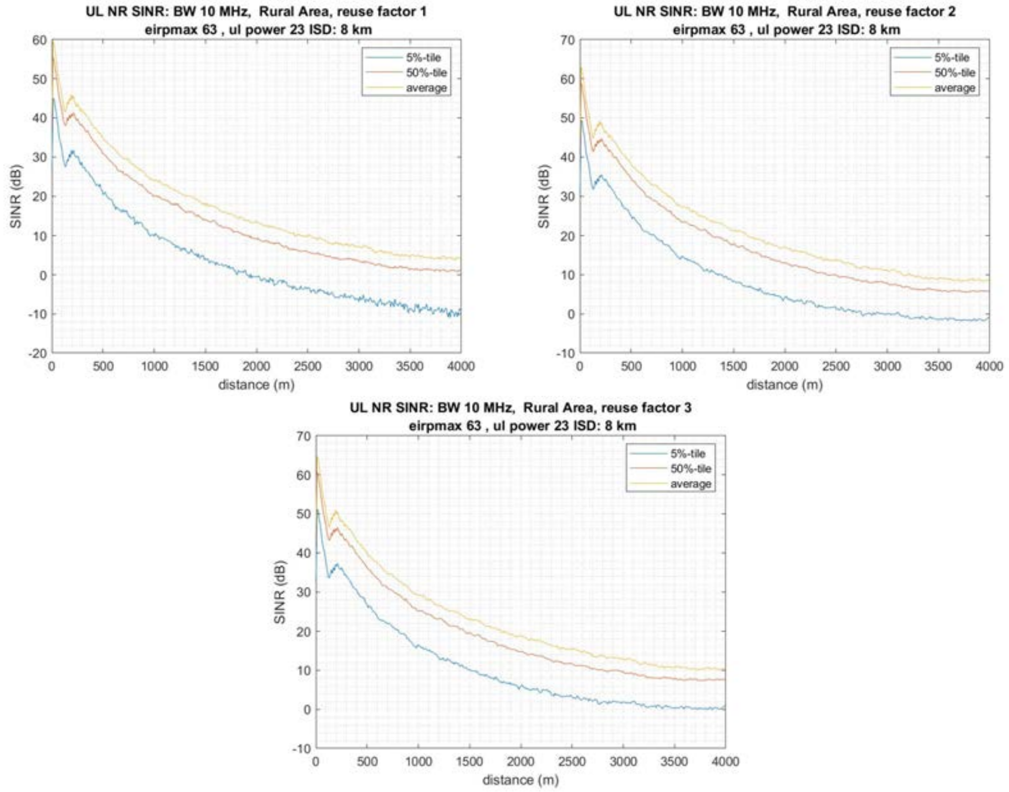


Figure A.49

Rural Area - ISD 8 Km - downlink EIRP 40 dBm

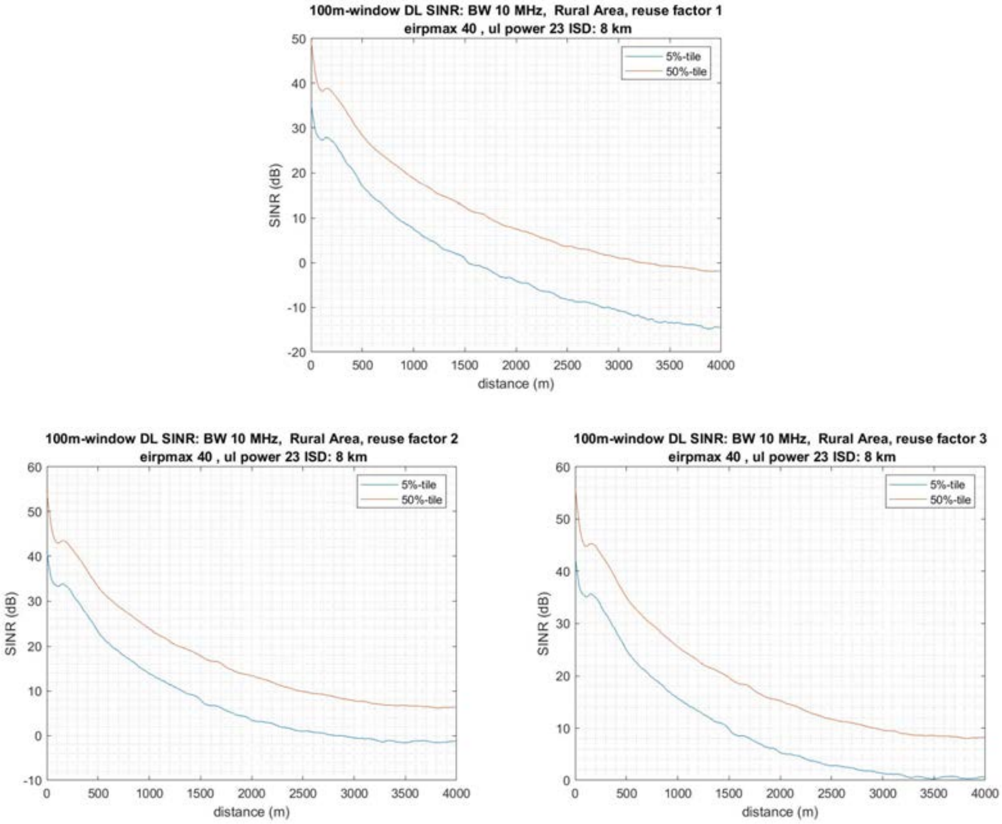


Figure A.50

Rural Area - ISD 8 Km - downlink EIRP 63 dBm

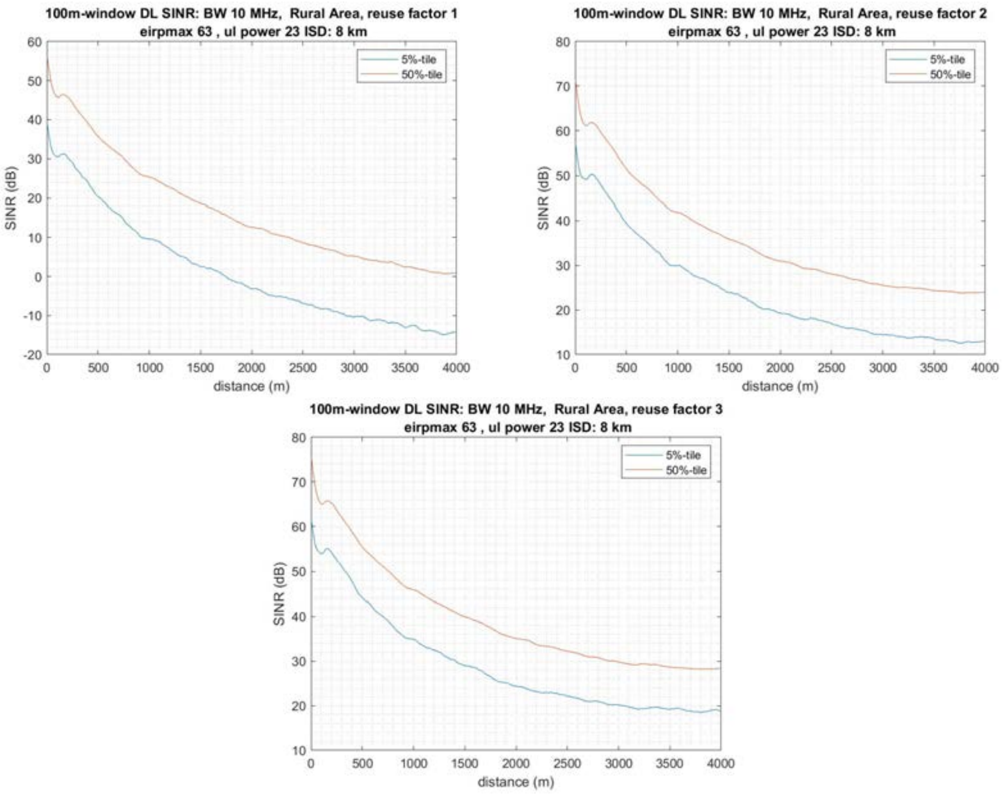


Figure A.51

Rural Area - ISD 6 Km - Uplink 23 dBm

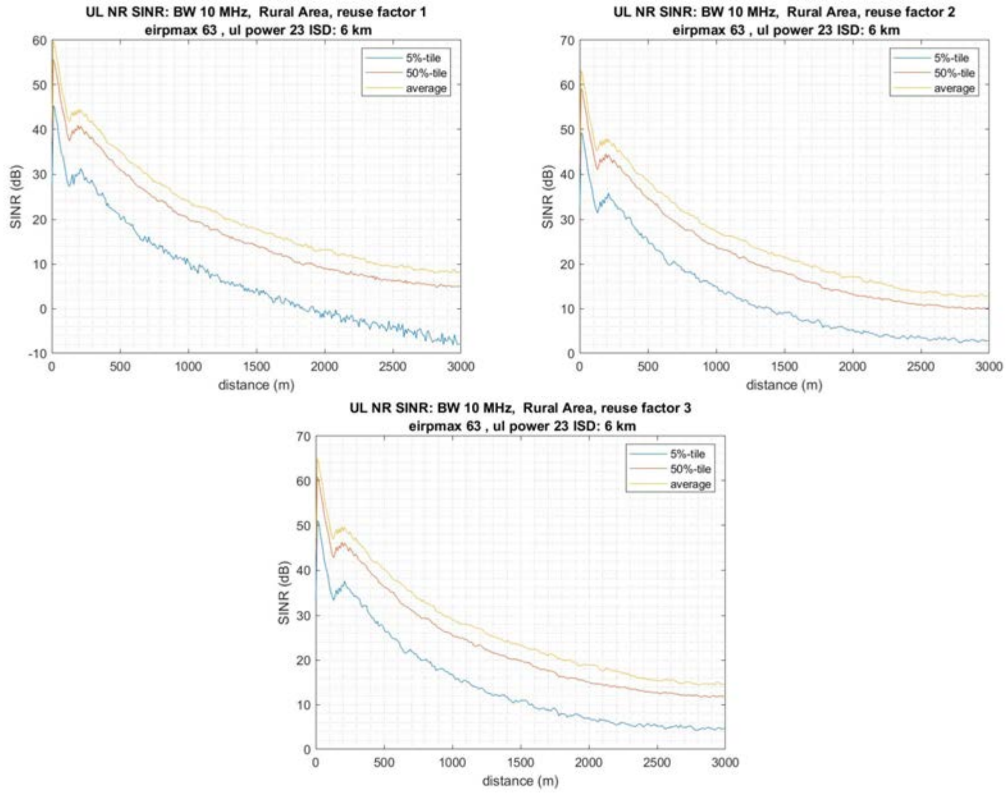


Figure A.52

Rural Area - ISD 6 Km - downlink EIRP 40 dBm

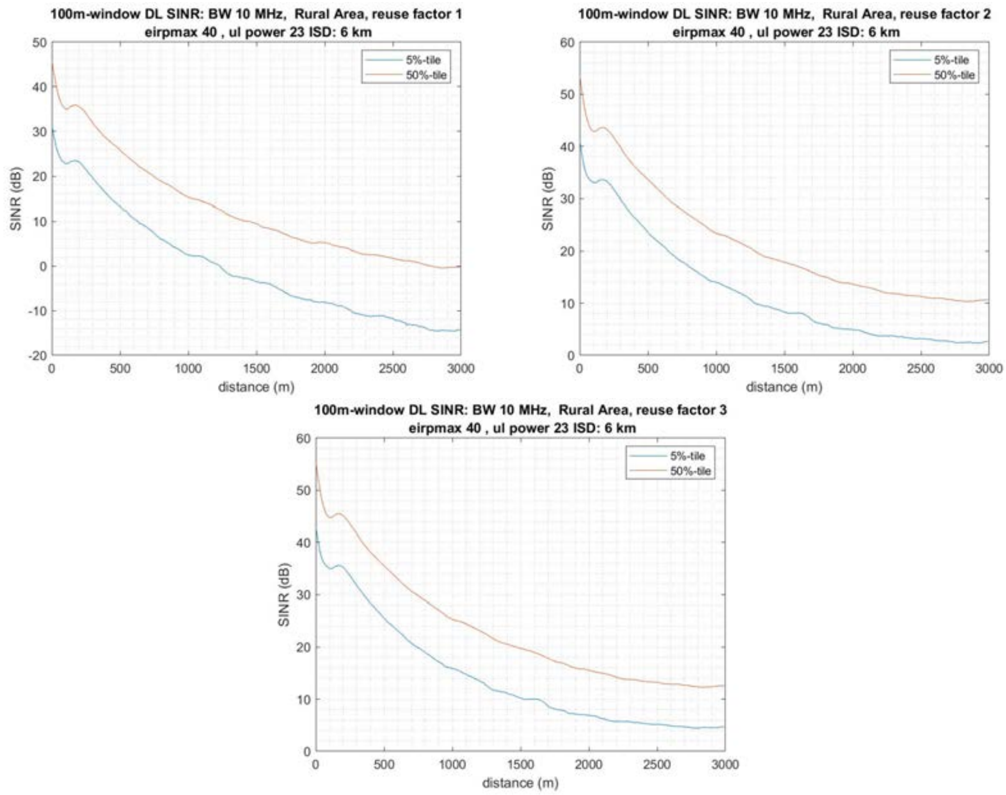


Figure A.53

Rural Area - ISD 6 Km - downlink EIRP 63 dBm

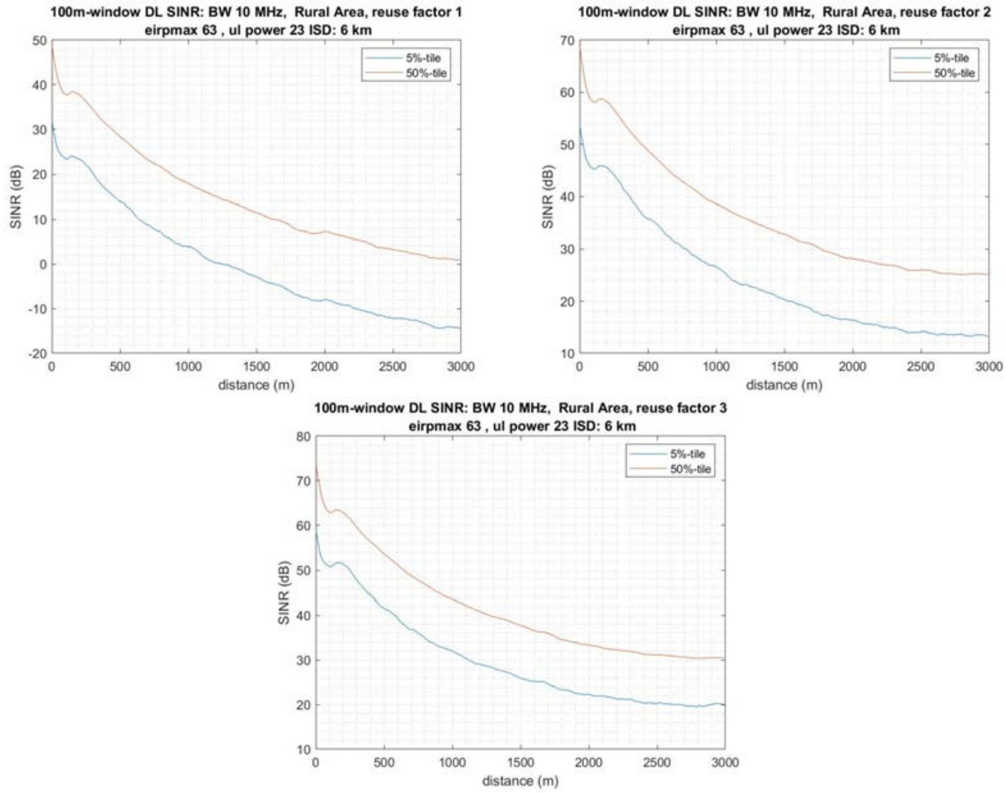


Figure A.54

Rural Area - ISD 4 Km - Uplink 23 dBm

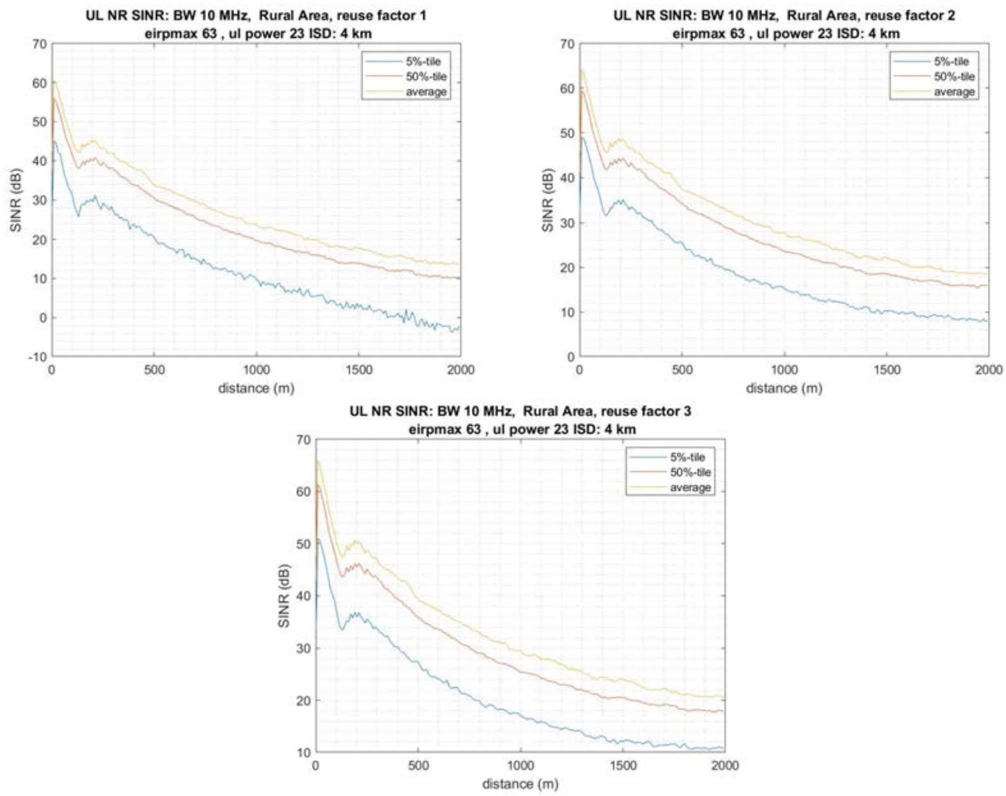


Figure A.55

Rural Area - ISD 4 Km - downlink EIRP 40 dBm

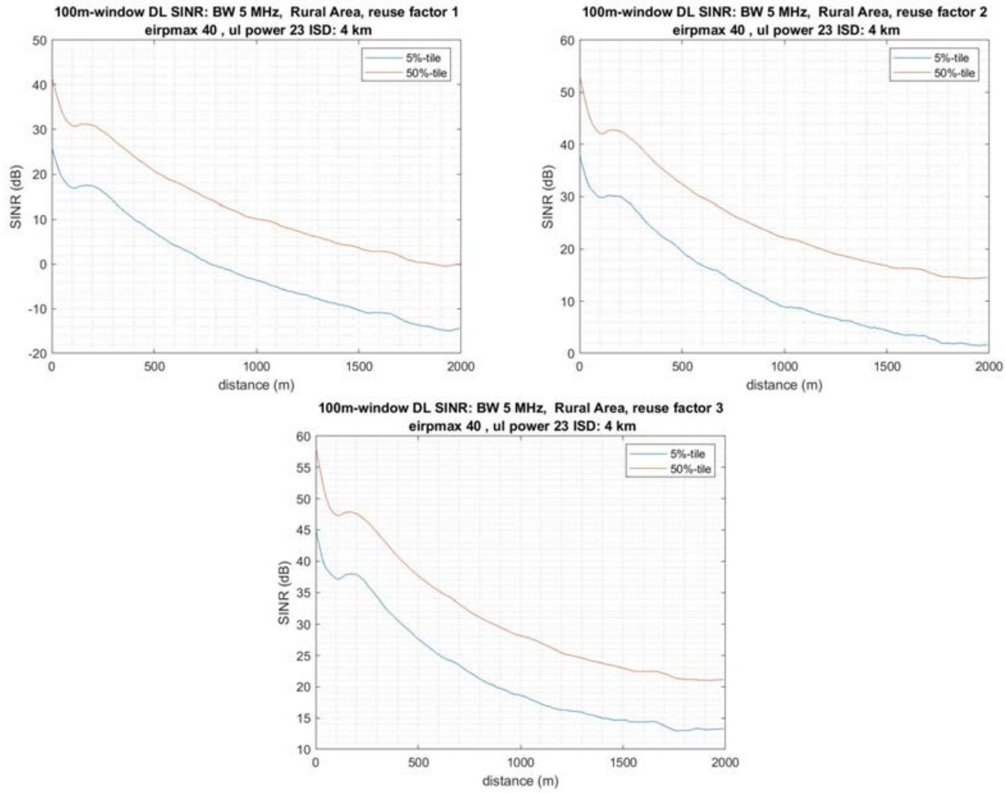


Figure A.56

Rural Area - ISD 4 Km - downlink EIRP 63 dBm

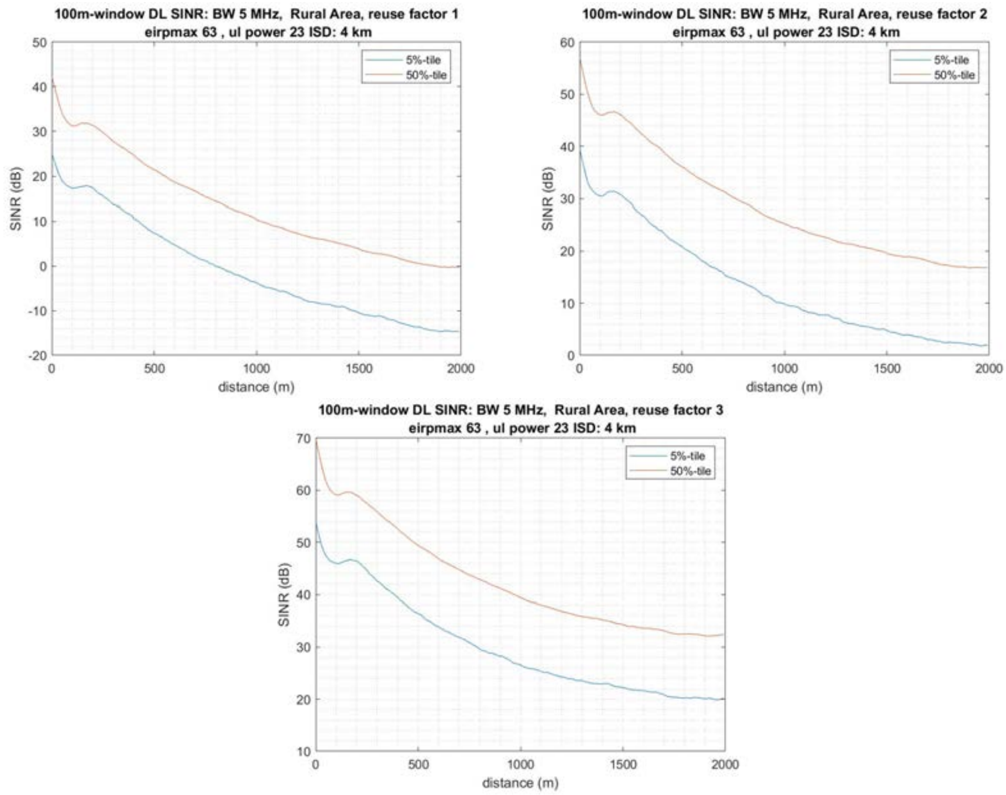


Figure A.57

Urban Area - ISD 2 Km - Uplink 23 dBm

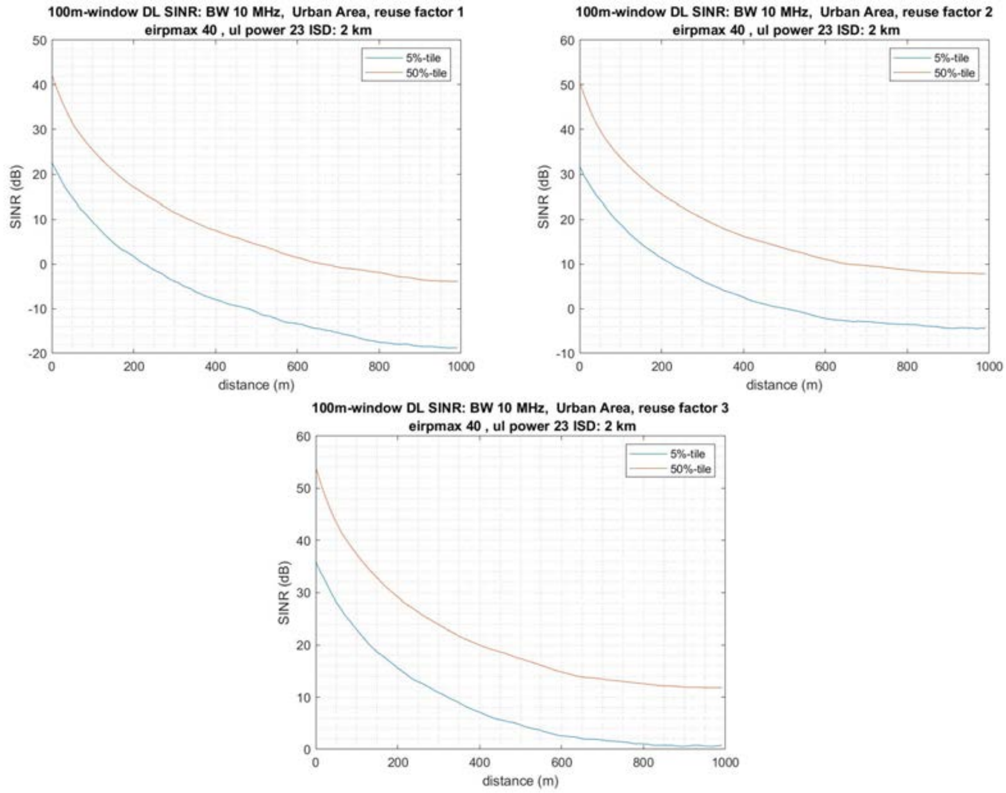


Figure A.58

Urban Area - ISD 2 Km - Downlink EIRP 40 dBm

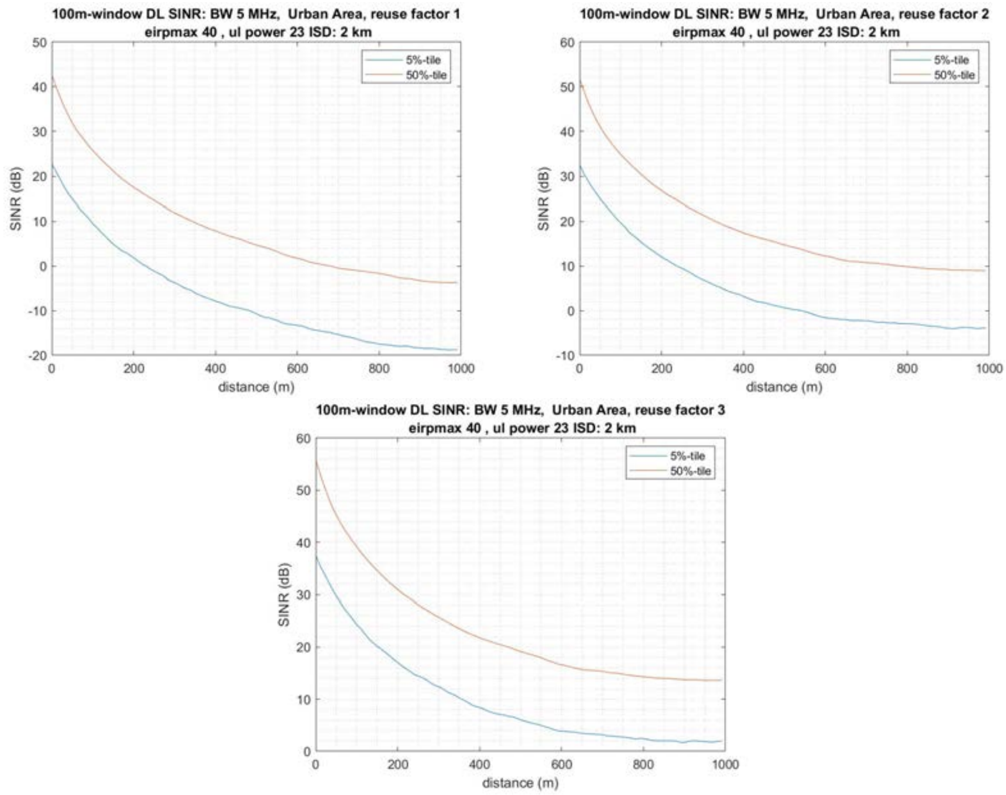


Figure A.59

Urban Area - ISD 2 Km - Downlink EIRP 63 dBm

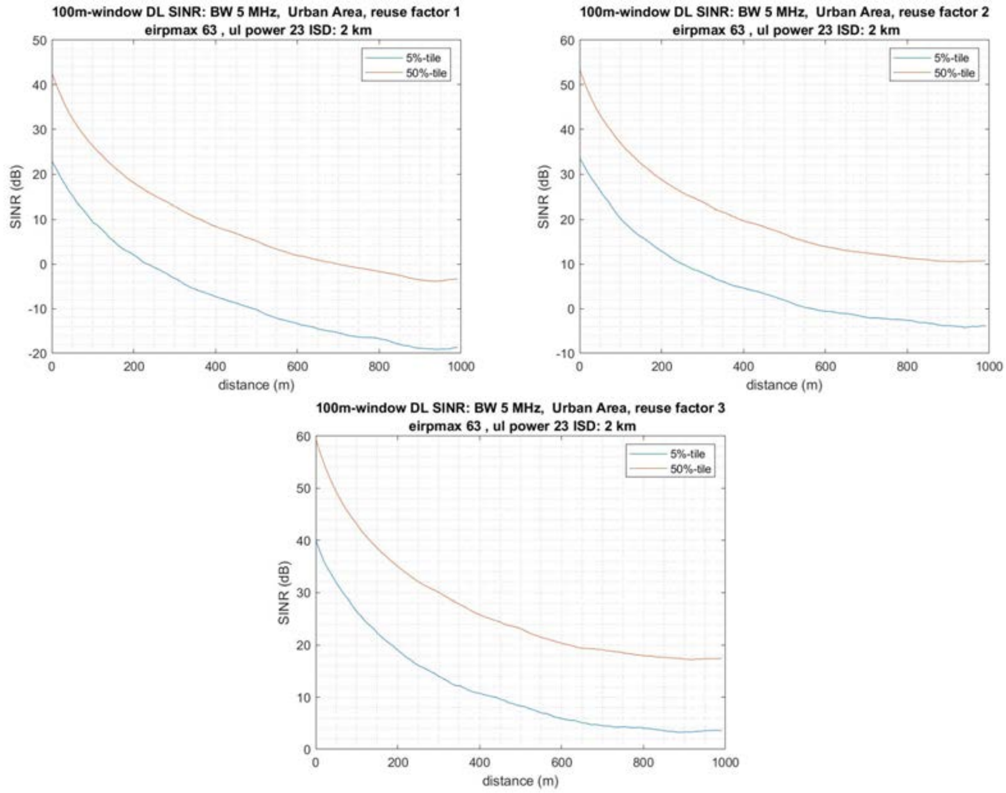


Figure A.60

Urban Area High Density - ISD 4 Km - Uplink 23 dBm

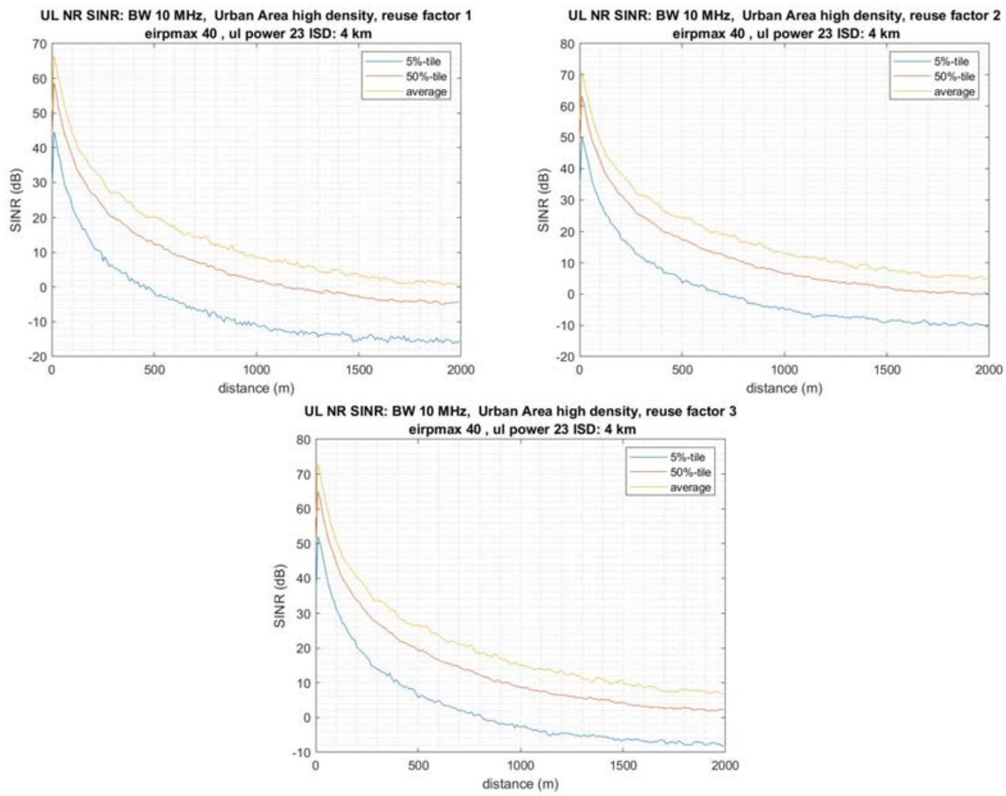


Figure A.61

Urban Area High Density - ISD 4 Km - Downlink EIRP 40 dBm

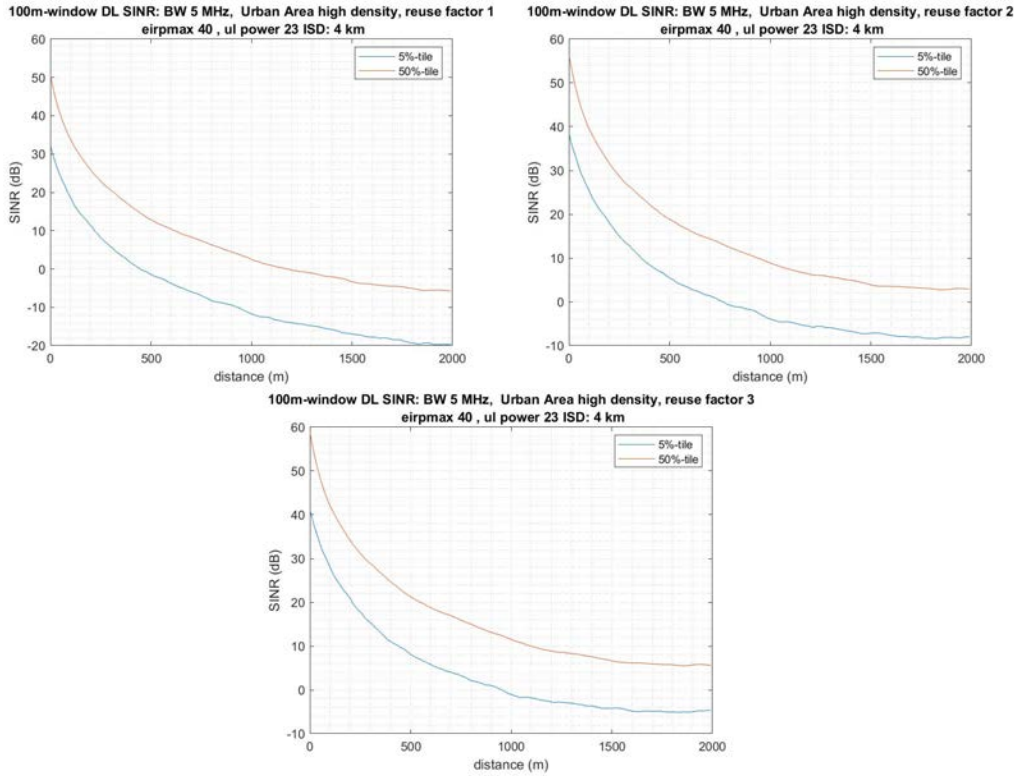


Figure A.62

Urban Area High Density - ISD 4 Km - Downlink EIRP 63 dBm

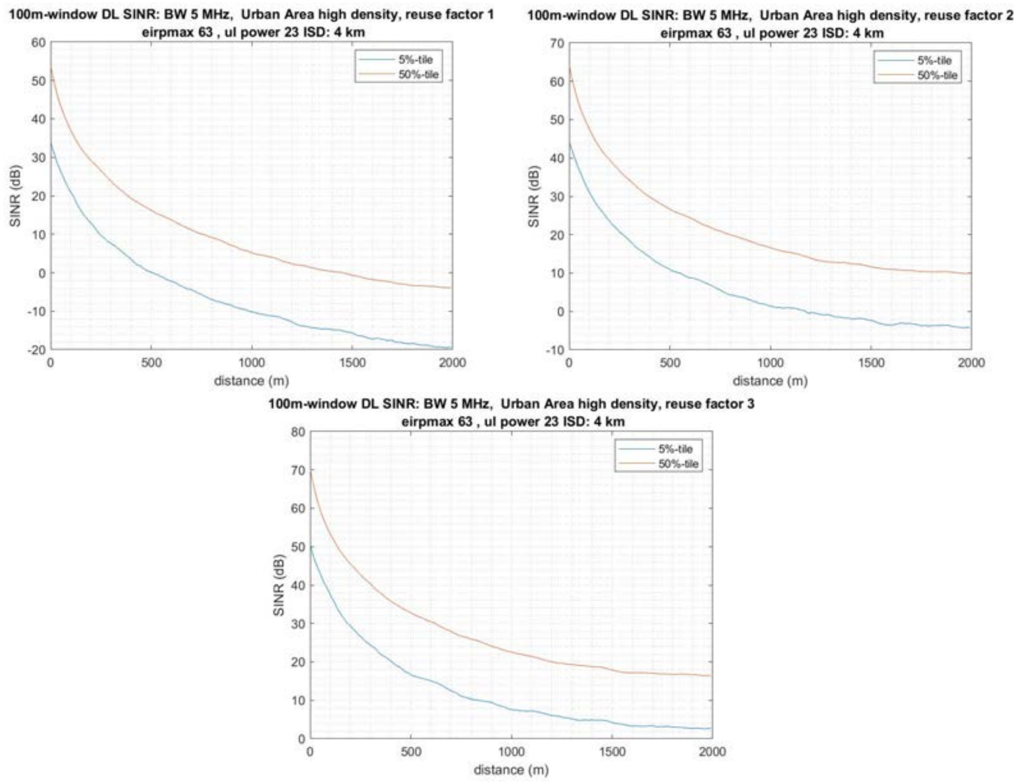


Figure A.63

Interference behaviour

Below are Signal to Interference and Noise Ratio (SINR) statistics for different environments, inter-site distances and different frequency reuse factors. Both 900 MHz and 1 900 MHz carriers are considered.

900 MHz

Rural Area - ISD 8 Km - Uplink 23 dBm

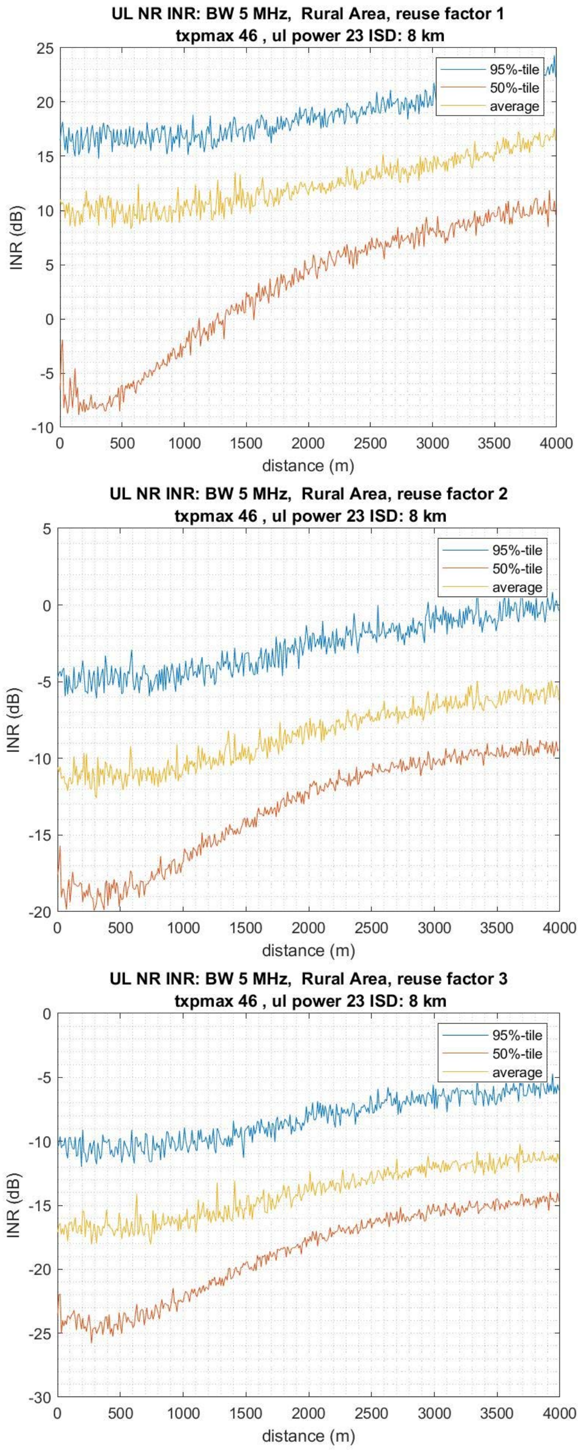


Figure A.64

Rural Area - ISD 8 Km - downlink

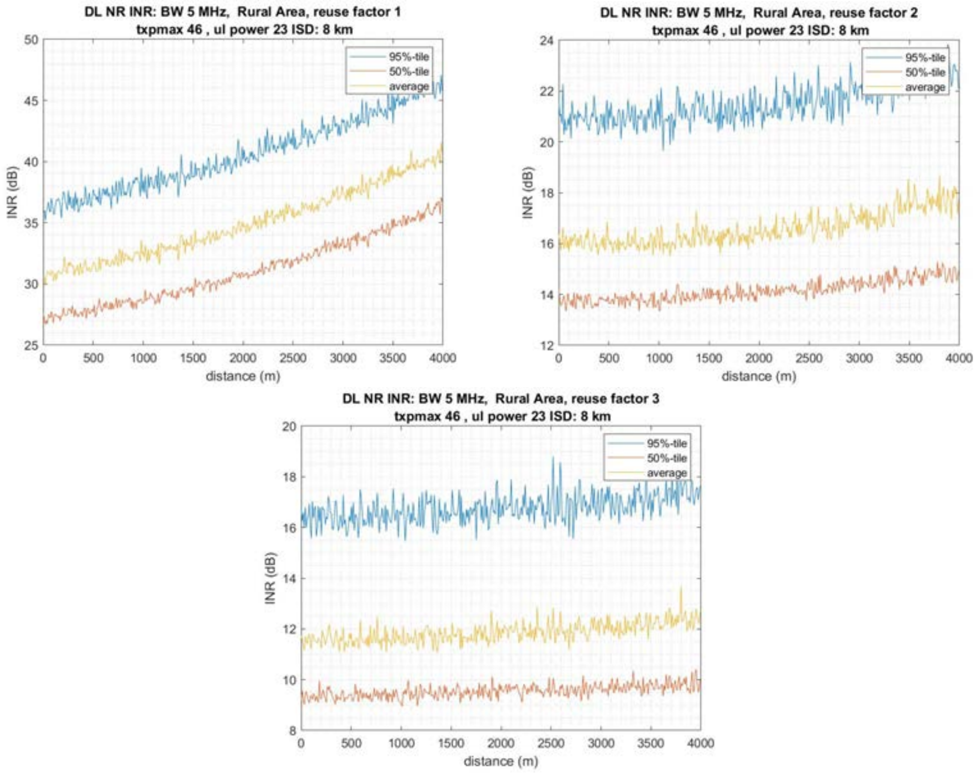


Figure A.65

Urban Area - ISD 2 Km - Uplink 23 dBm

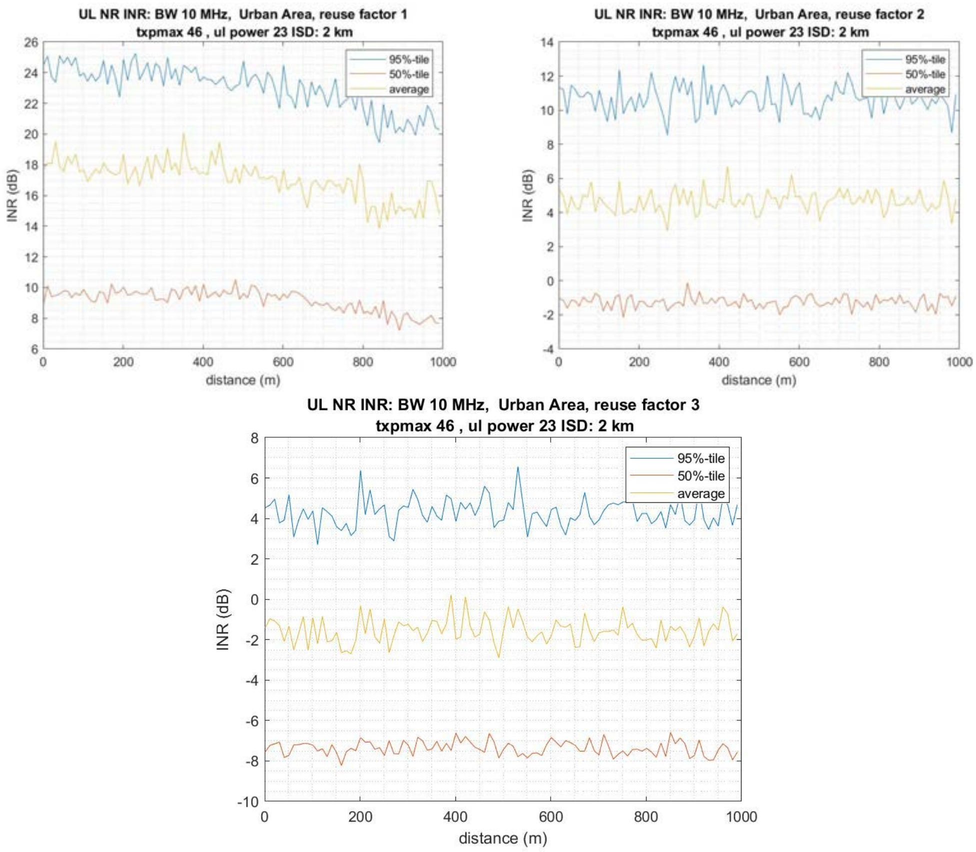


Figure A.66

Urban Area - ISD 2 Km - Downlink

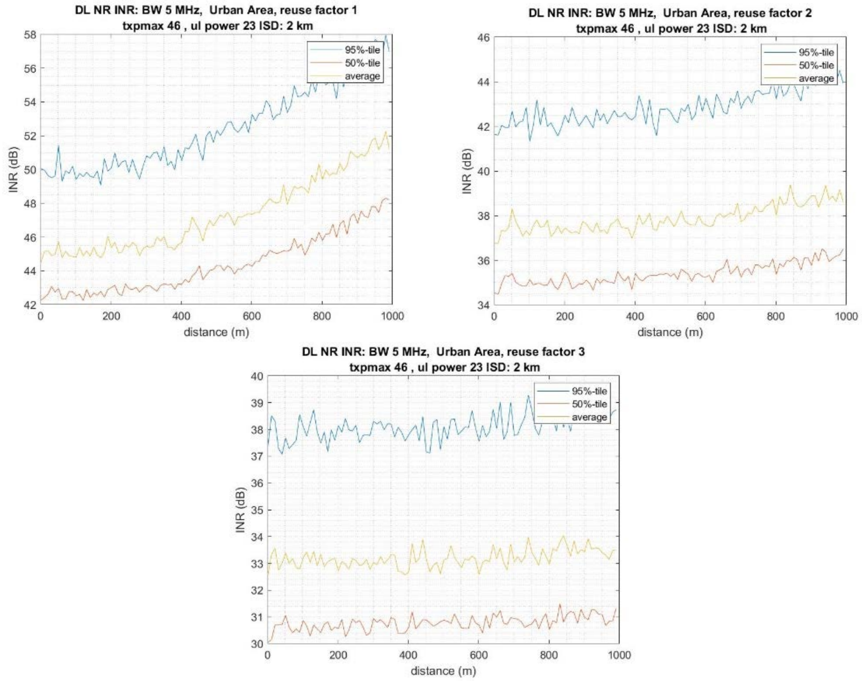


Figure A.67

Urban Area High Density - ISD 4 Km - Uplink 23 dBm

Urban Area High Density - ISD 4 Km - Downlink

1 900 MHz

Rural Area - ISD 8 Km - Uplink 23 dBm

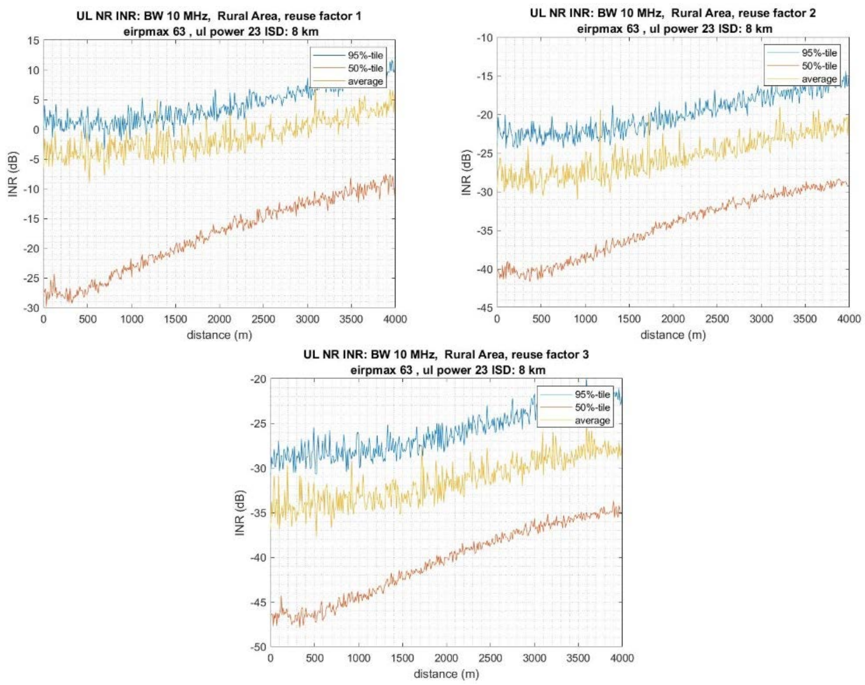


Figure A.68

Rural Area - ISD 8 Km - downlink EIRP 40 dBm

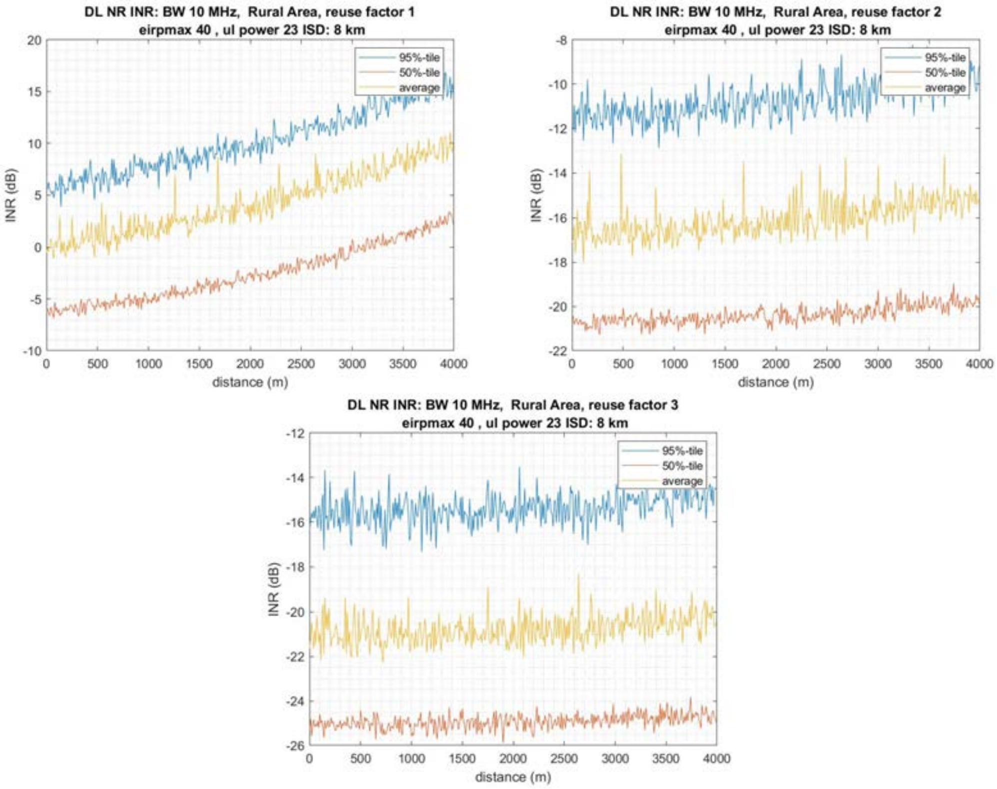


Figure A.69

Rural Area - ISD 8 Km - downlink EIRP 63 dBm

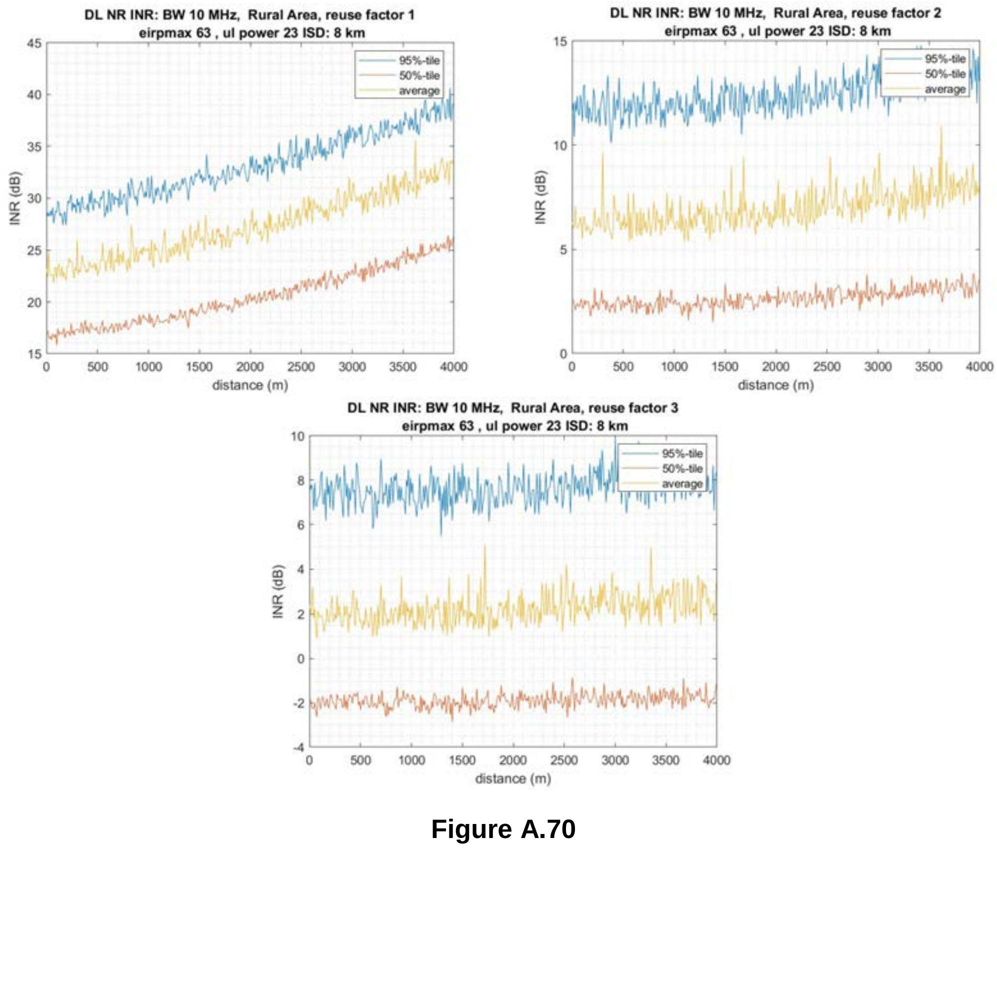


Figure A.70

Rural Area - ISD 6 Km - Uplink 23 dBm

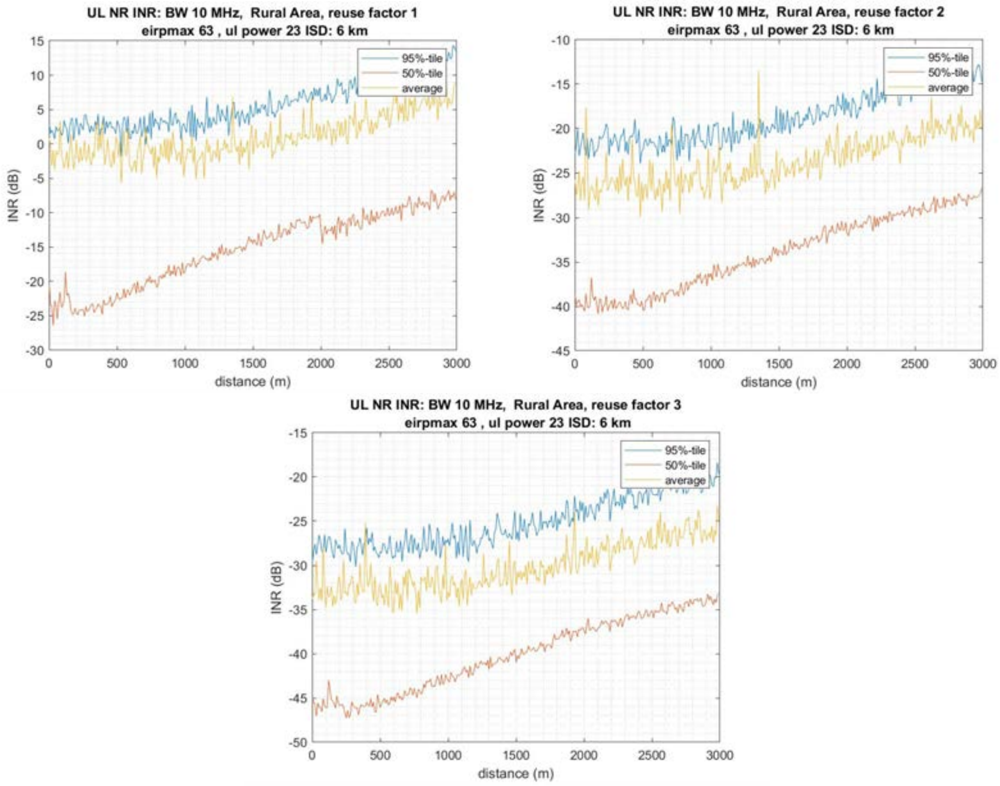


Figure A.71

Rural Area - ISD 6 Km - downlink EIRP 40 dBm

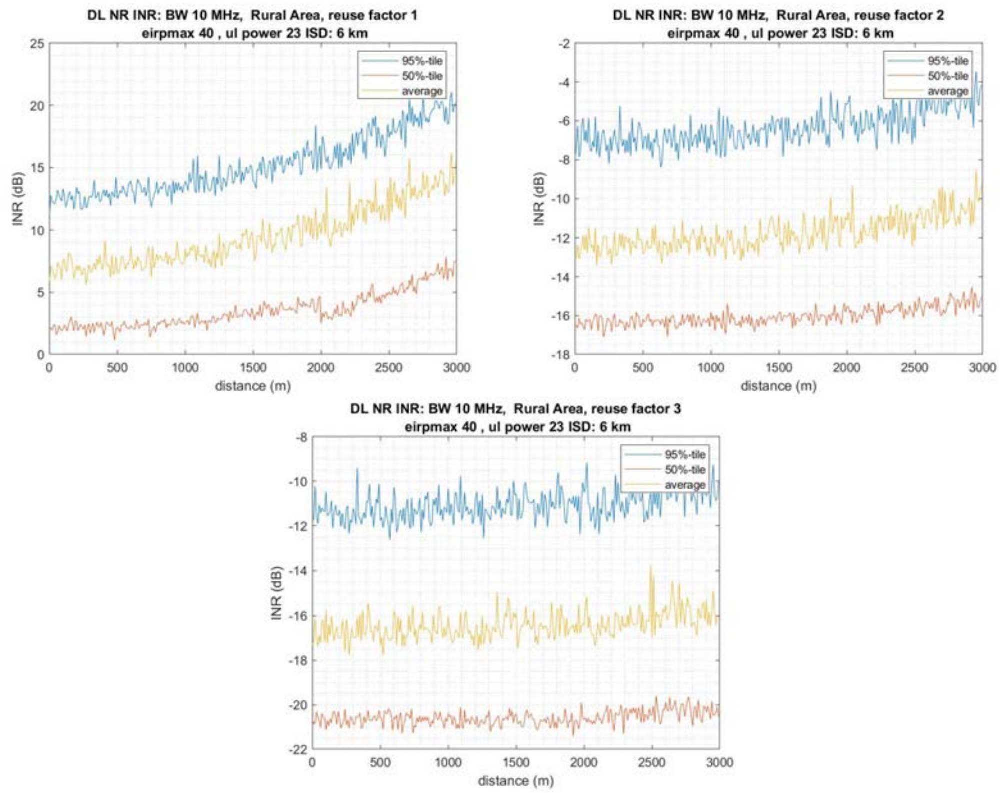


Figure A.72

Rural Area - ISD 6 Km - downlink EIRP 63 dBm

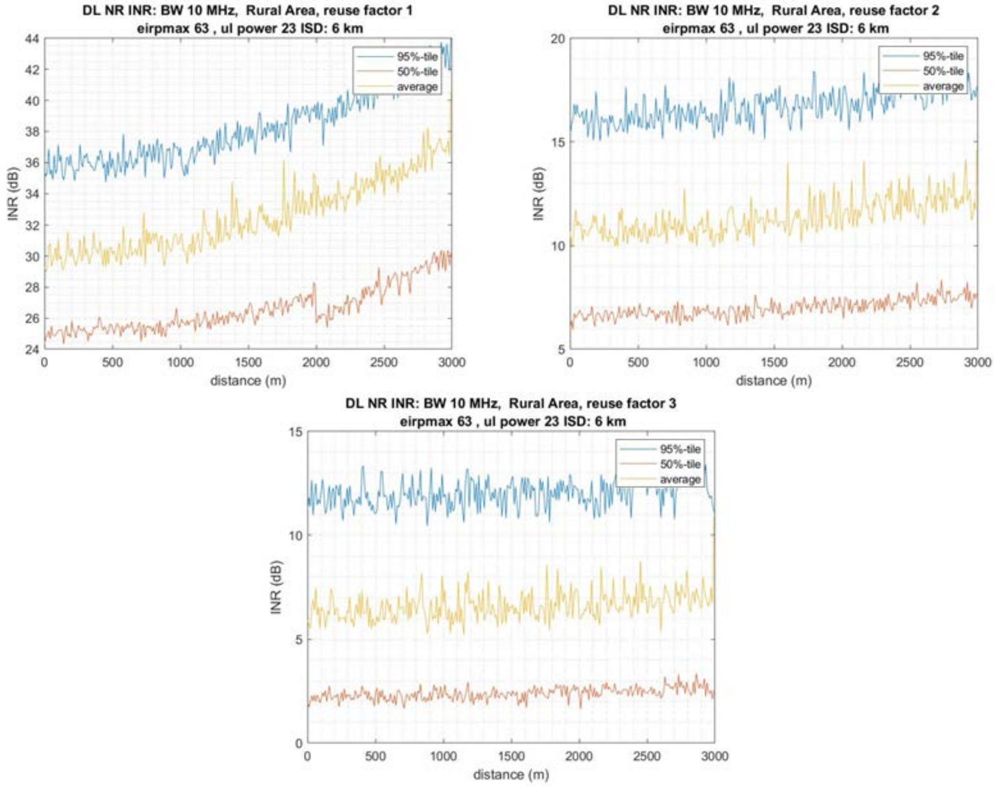


Figure A.73

Rural Area - ISD 4 Km - Uplink 23 dBm

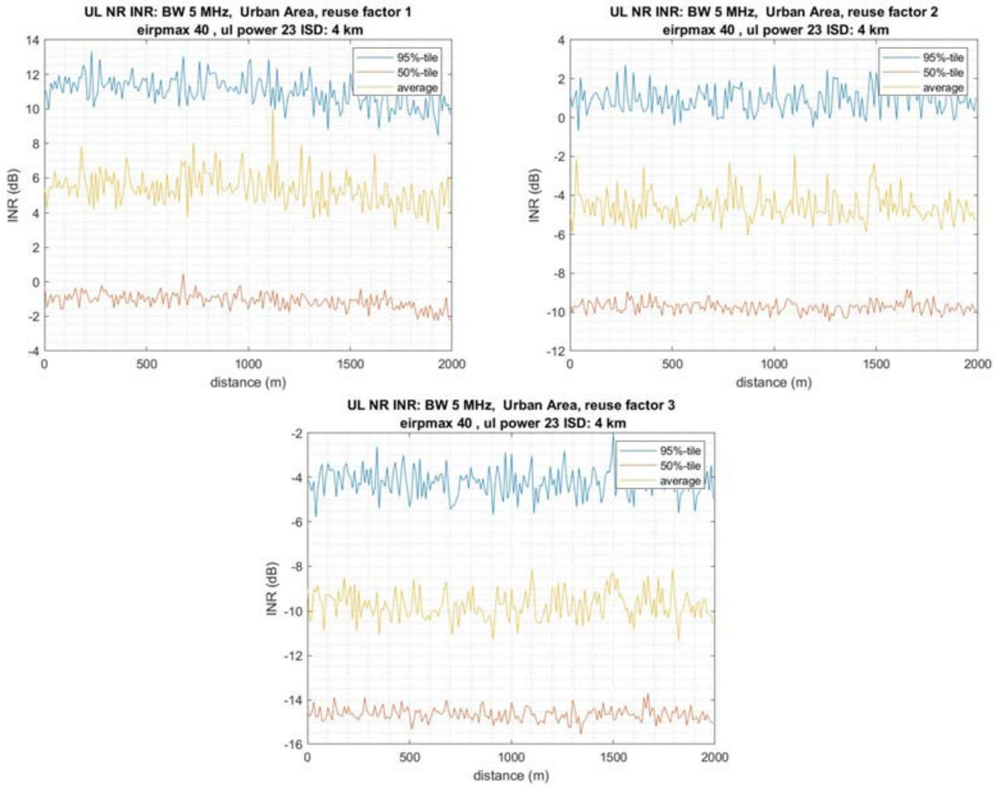


Figure A.74

Rural Area - ISD 4 Km - downlink EIRP 40 dBm

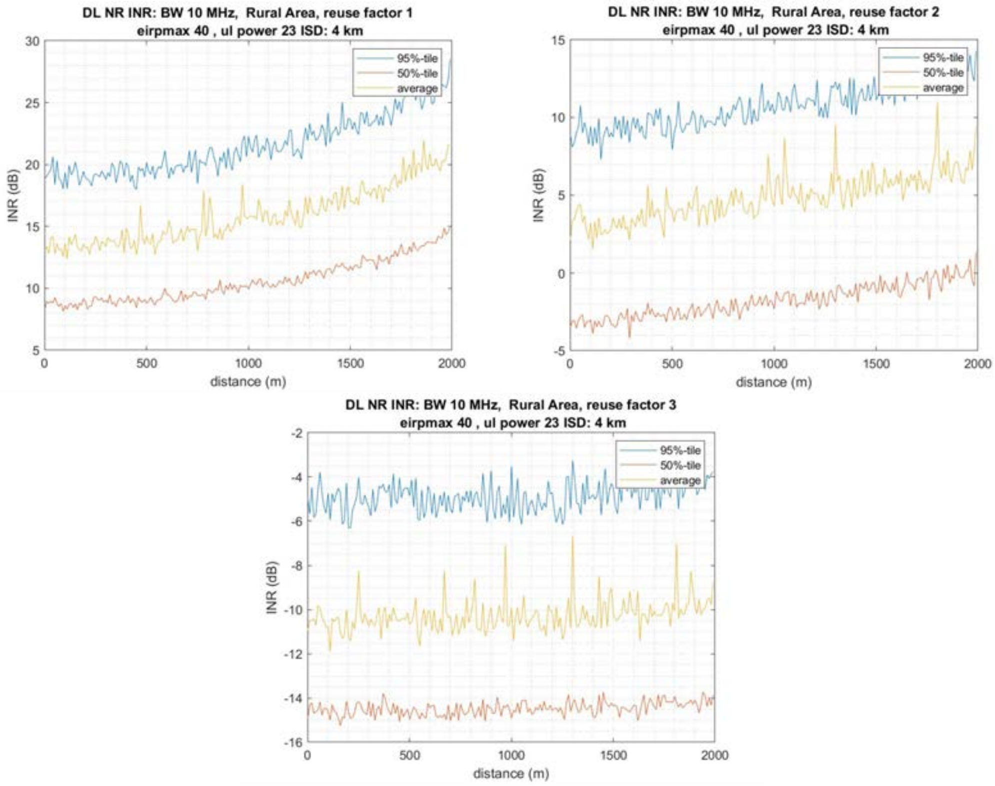


Figure A.75

Rural Area - ISD 4 Km - downlink EIRP 63 dBm

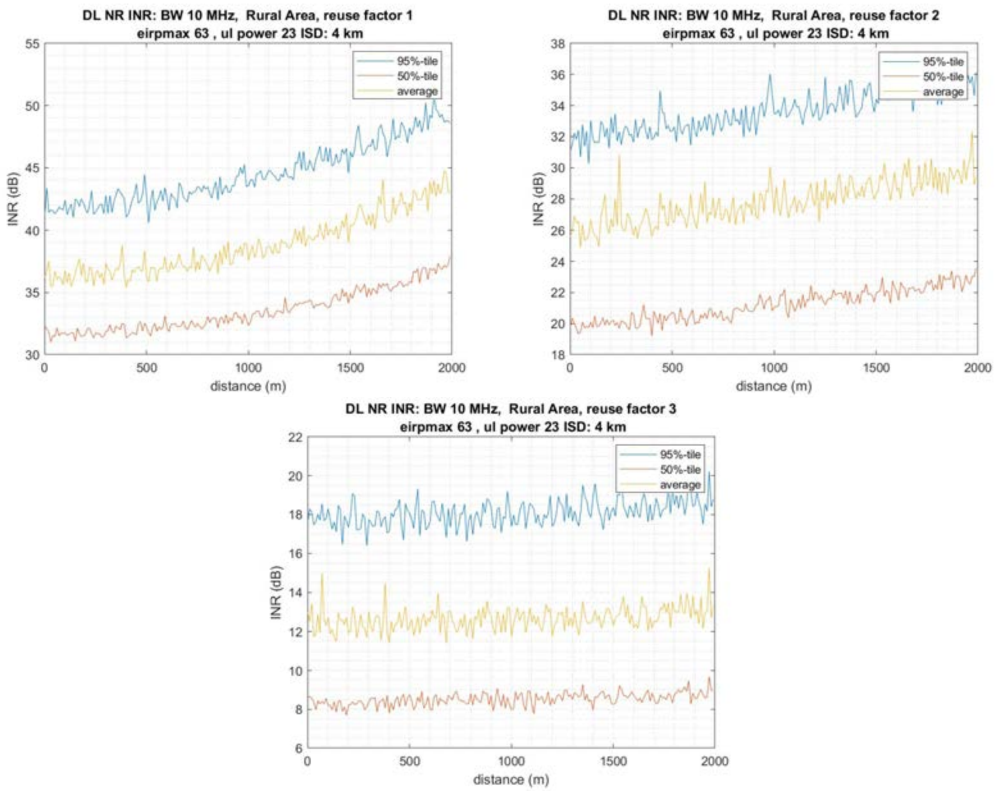


Figure A.76

Urban Area - ISD 2 Km - Uplink 23 dBm

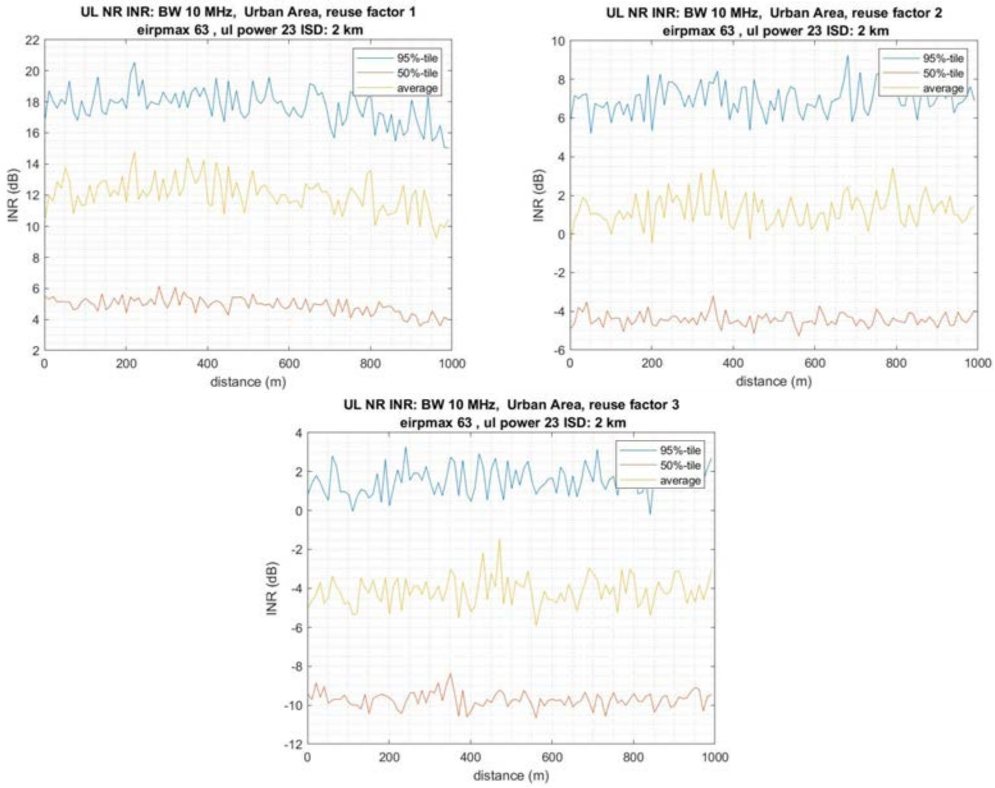


Figure A.77

Urban Area - ISD 2 Km - Downlink EIRP 40 dBm

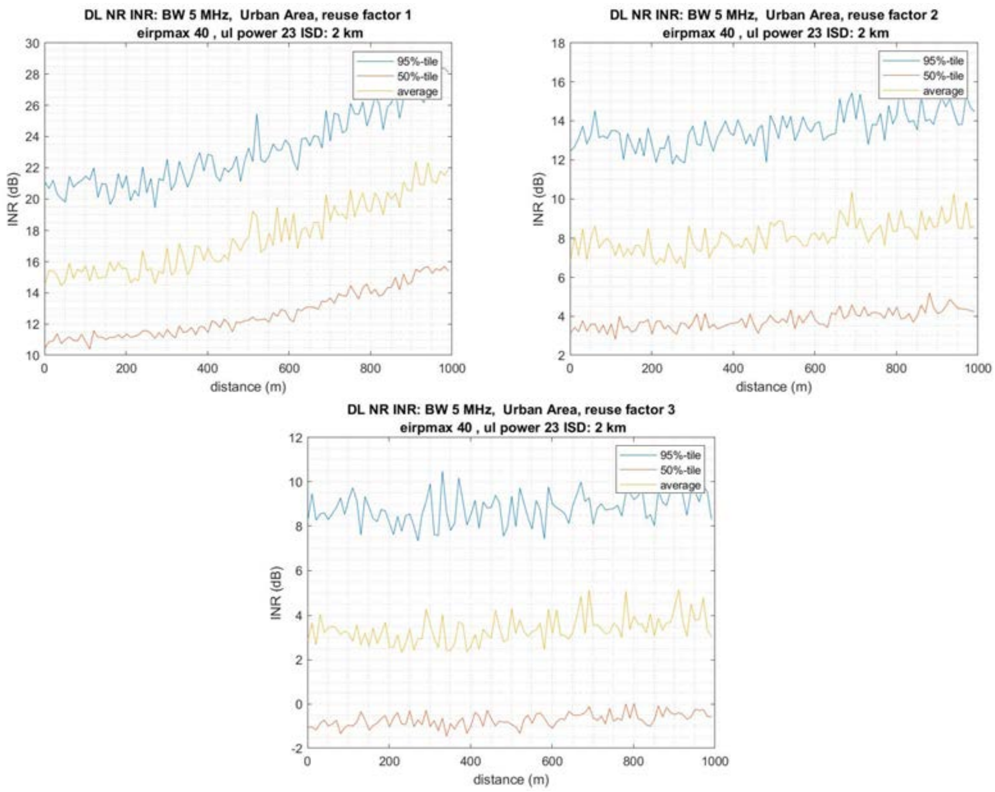


Figure A.78

Urban Area - ISD 2 Km - Downlink EIRP 63 dBm

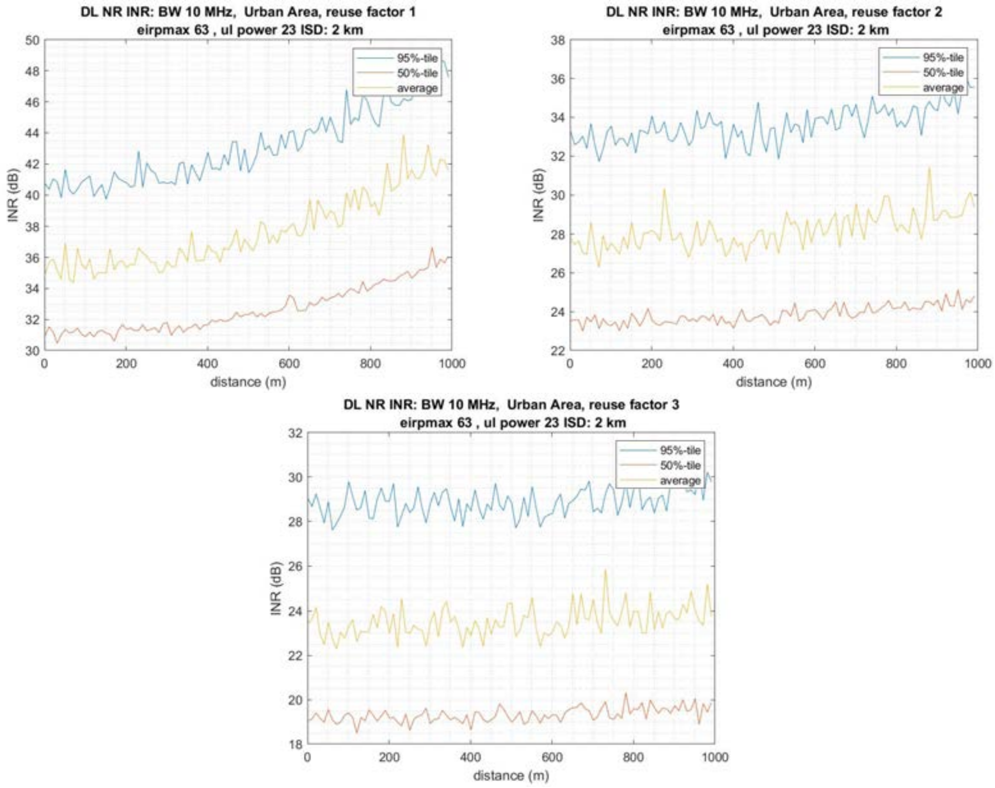


Figure A.79

Urban Area High Density - ISD 4 Km - Uplink 23 dBm

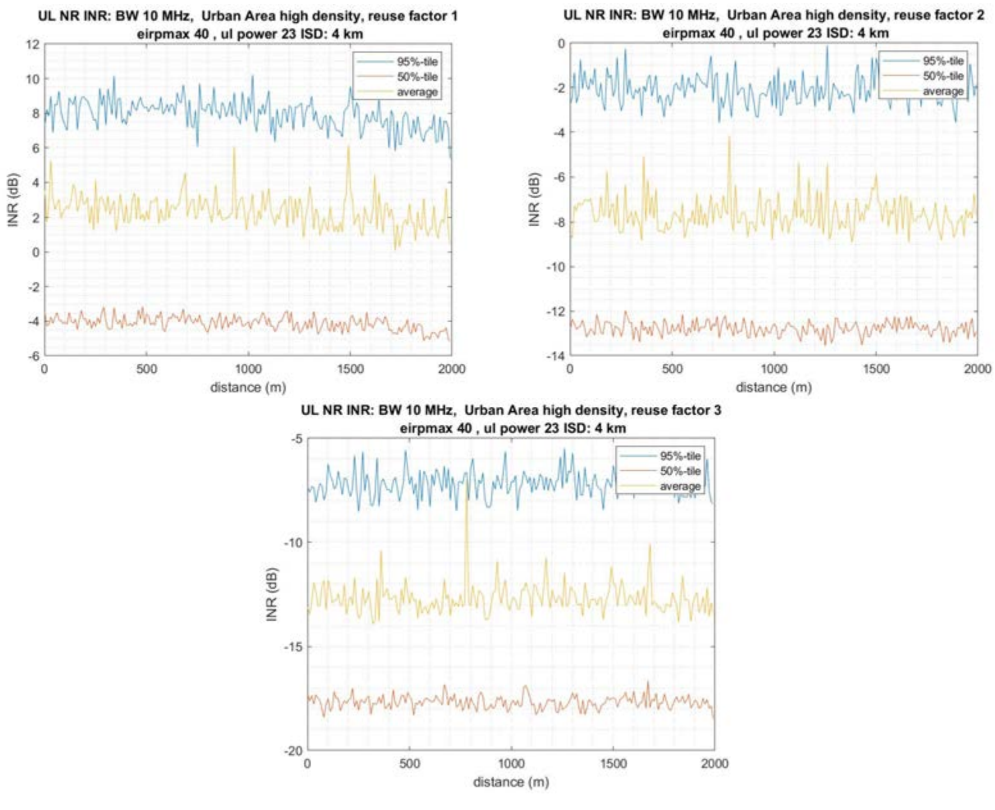


Figure A.80

Urban Area High Density - ISD 4 Km - Downlink EIRP 40 dBm

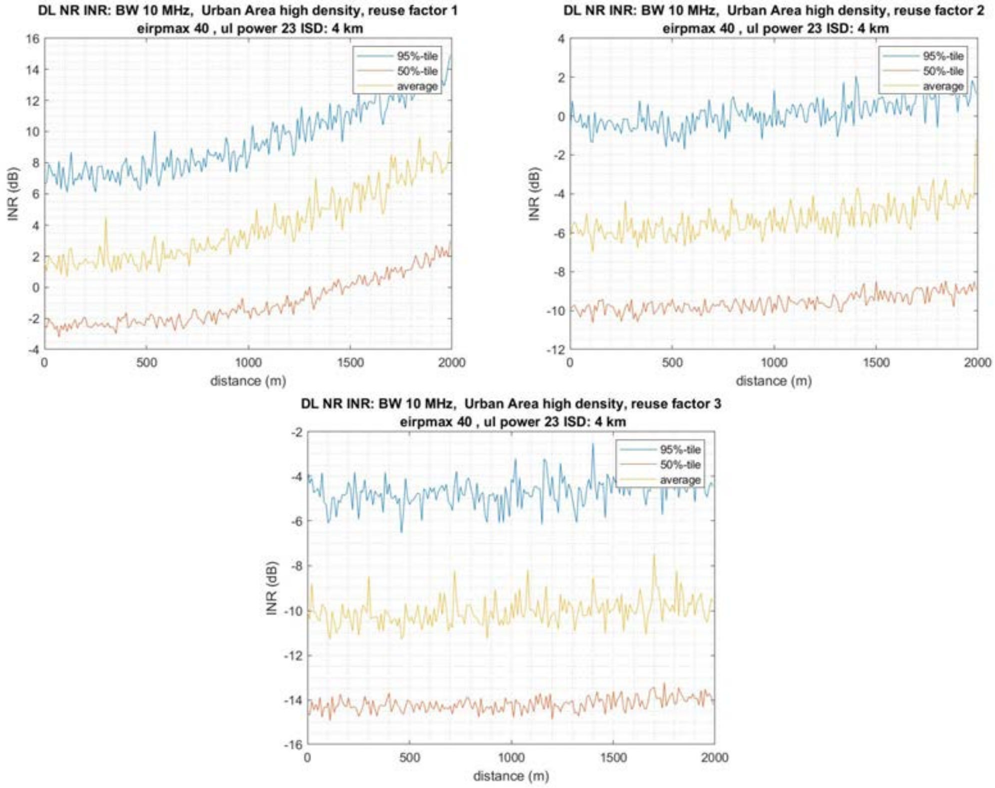


Figure A.81

Urban Area High Density - ISD 4 Km - Downlink EIRP 63 dBm

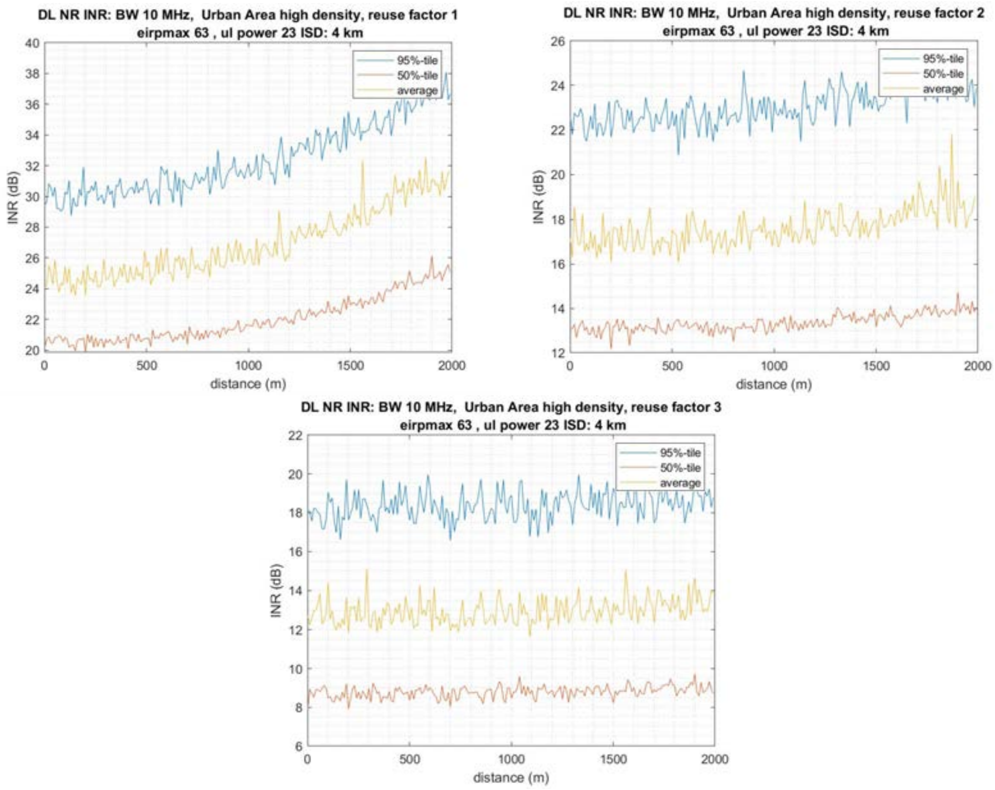


Figure A.82

A.2 Full results sets for 1 900 MHz

A.2.1 Company A

A.2.1.1 Description, specific assumptions and parameters

A.2.1.1.1 UL Results

Uplink Rural 23 dBm EIRP 50:50 (UL:DL) 4 km ISD

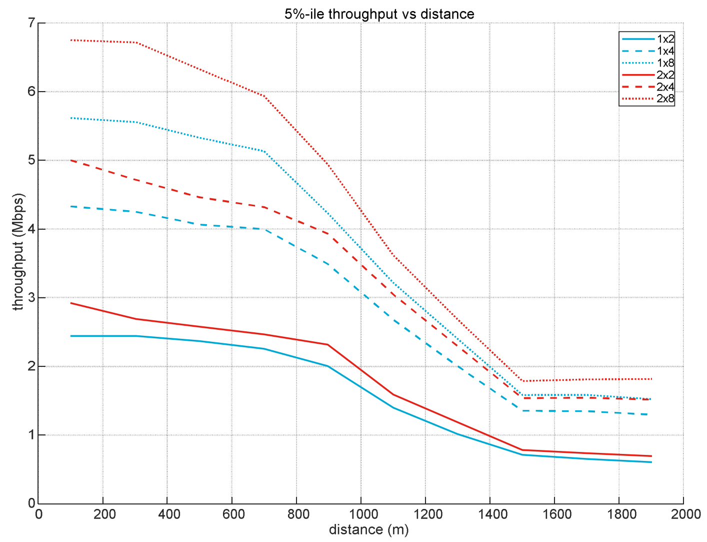


Figure A.83

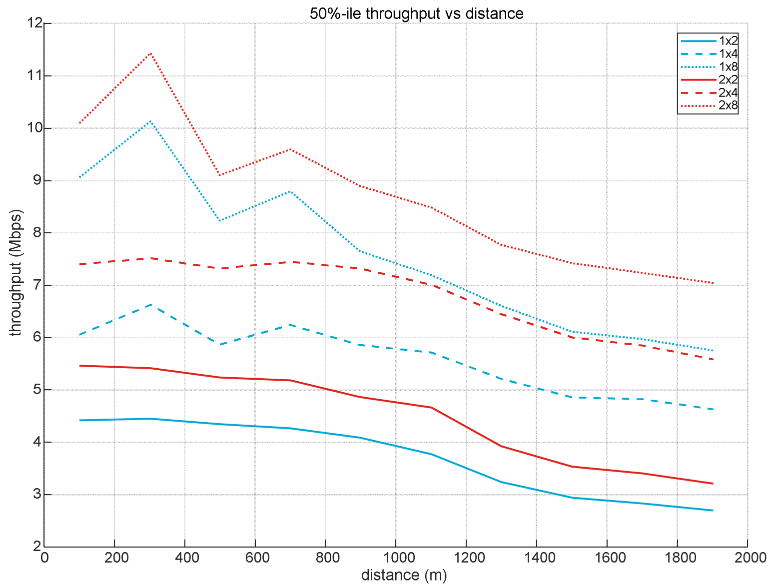


Figure A.84

Uplink Rural 23 dBm EIRP 90:10 (UL:DL) 4 km ISD

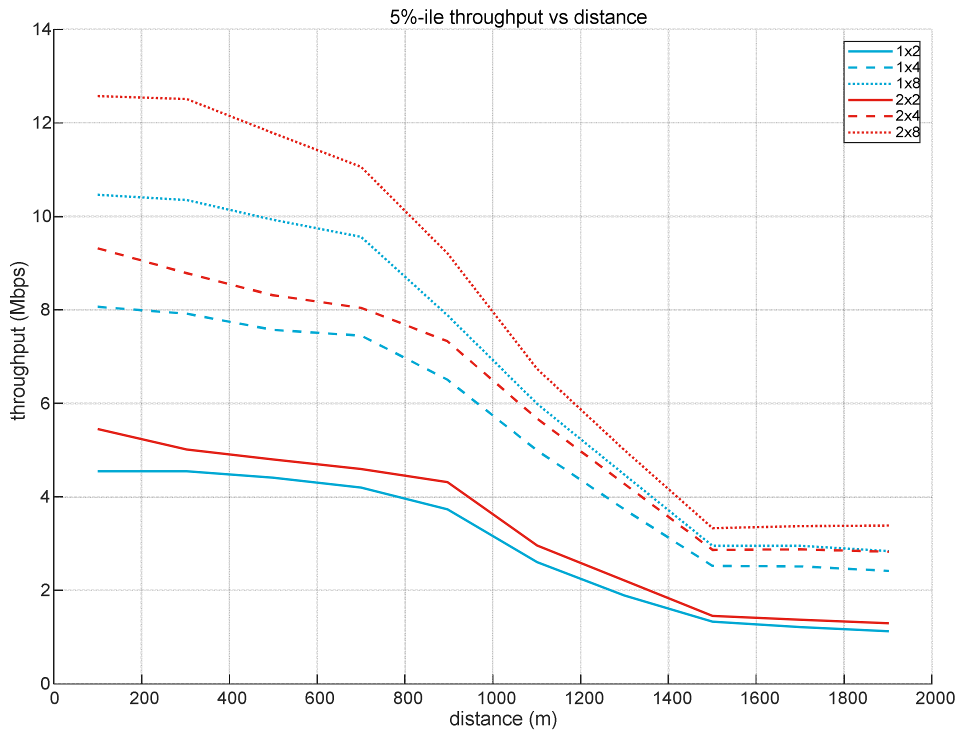


Figure A.85

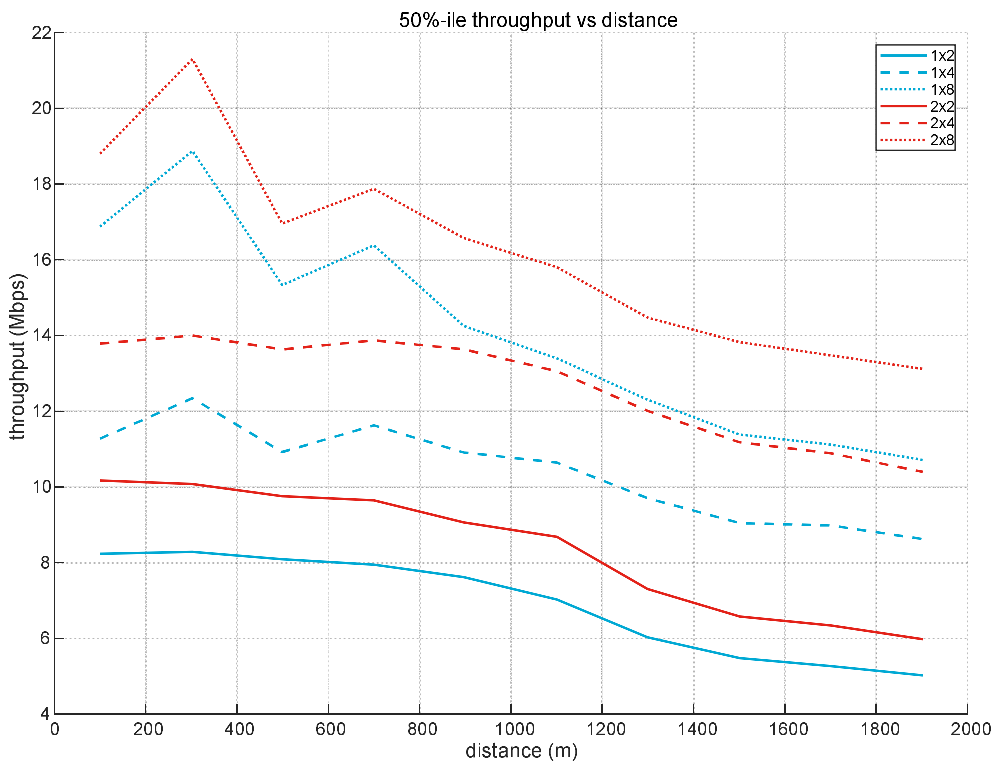


Figure A.86

Uplink Rural 31 dBm EIRP 50:50 (UL:DL) 4 km ISD

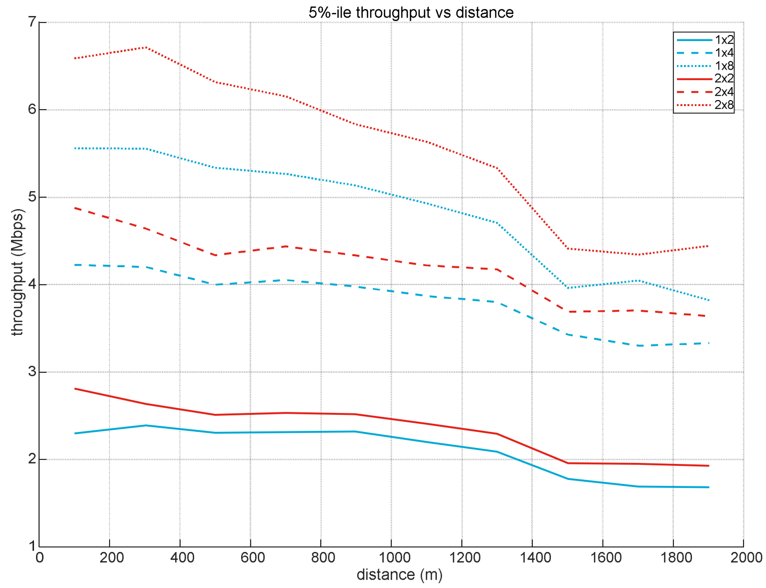


Figure A.87

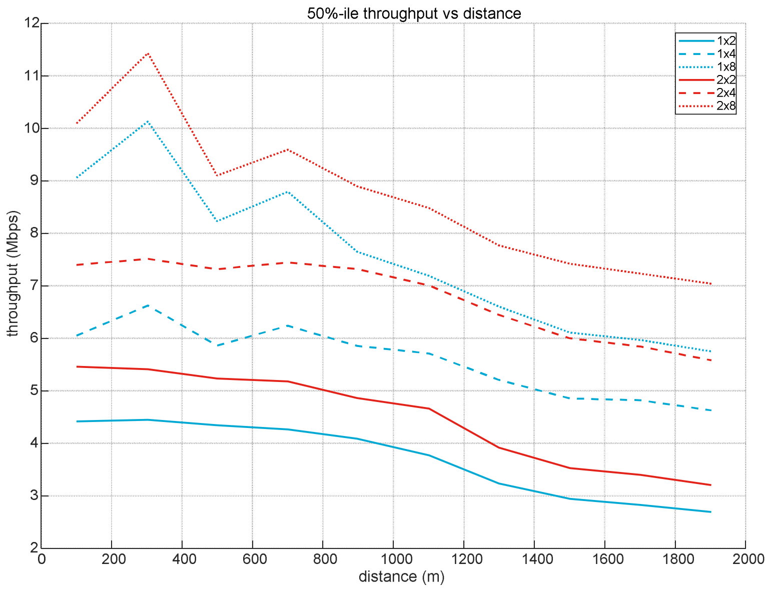


Figure A.88

Uplink Rural 31 dBm EIRP 90:10 (UL:DL) 4 km ISD

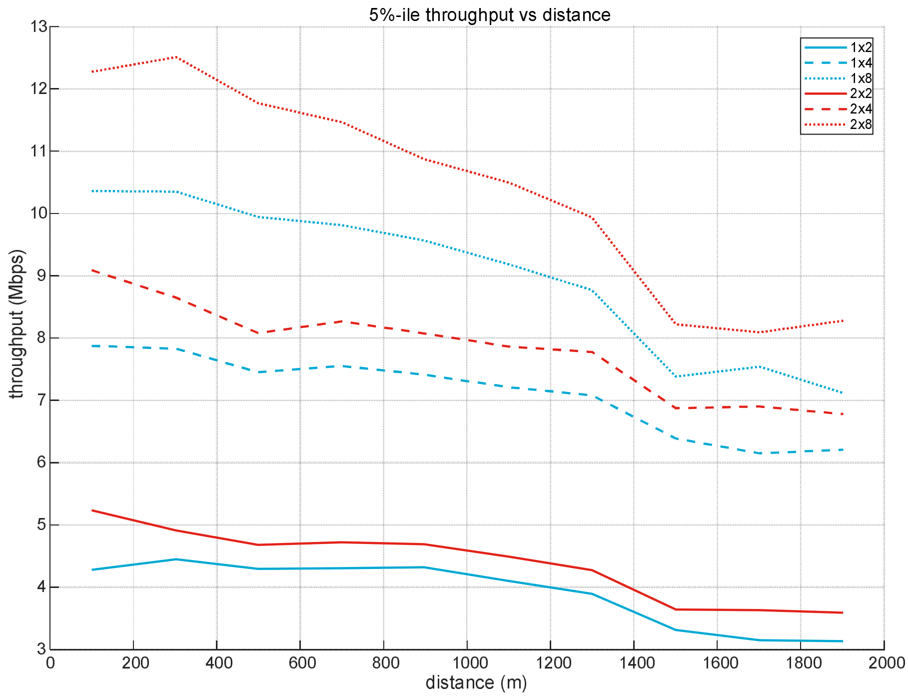


Figure A.89

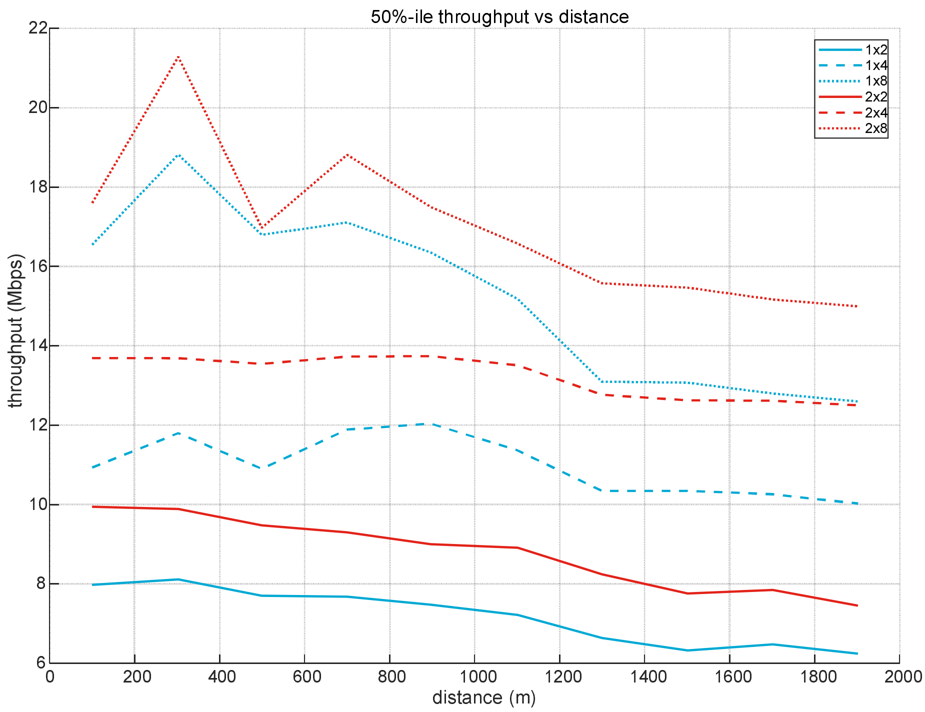


Figure A.90

Uplink Urban 23 dBm EIRP 50:50 (UL:DL) 4 km ISD

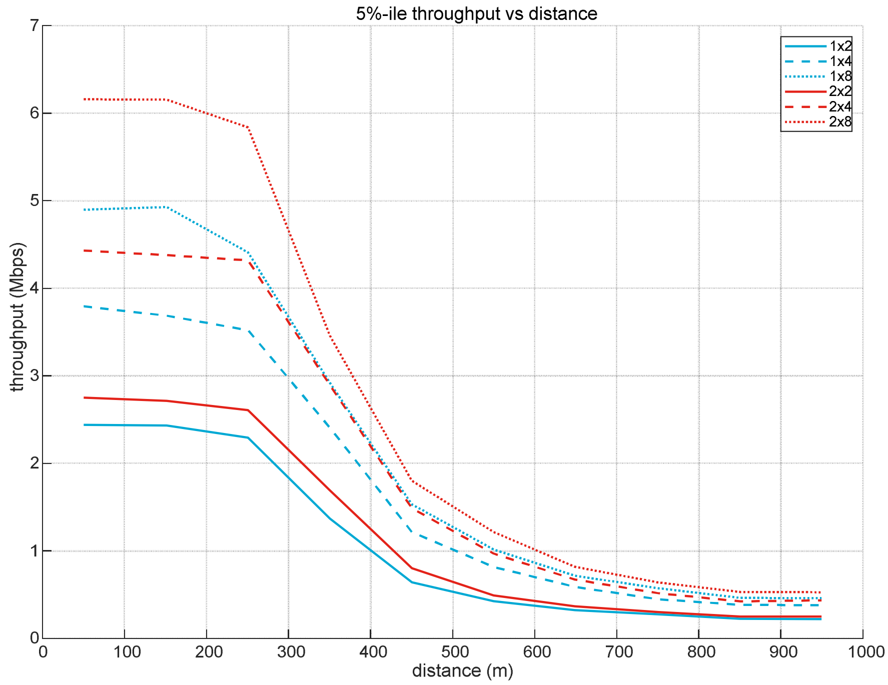


Figure A.91

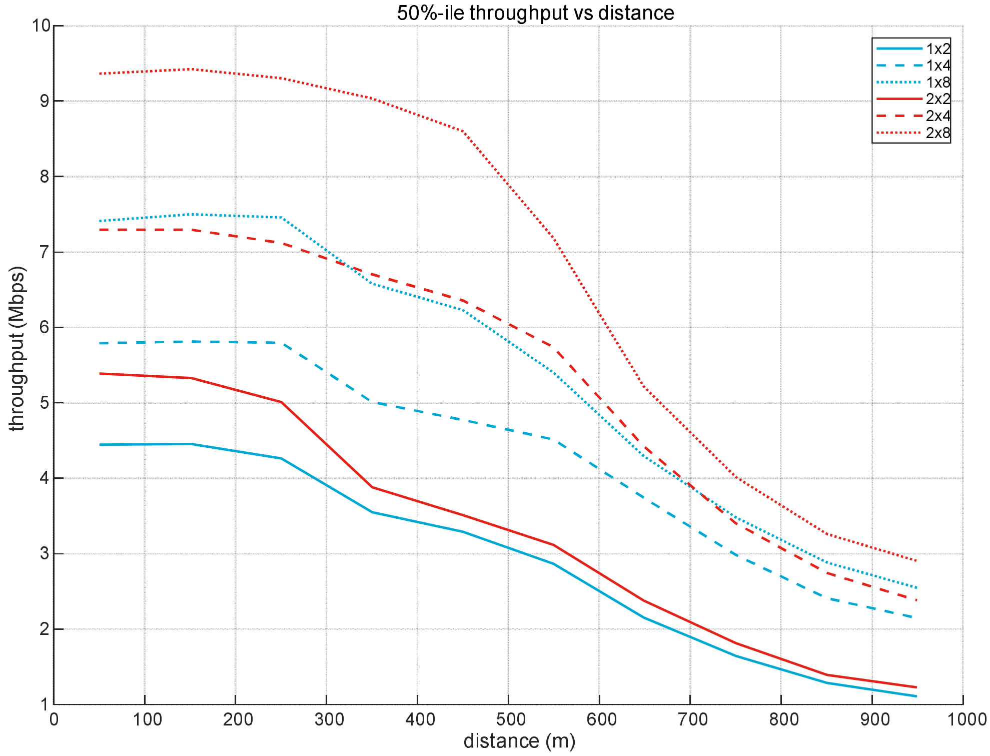


Figure A.92

Uplink Urban 23 dBm EIRP 90:10 (UL:DL) 4 km ISD

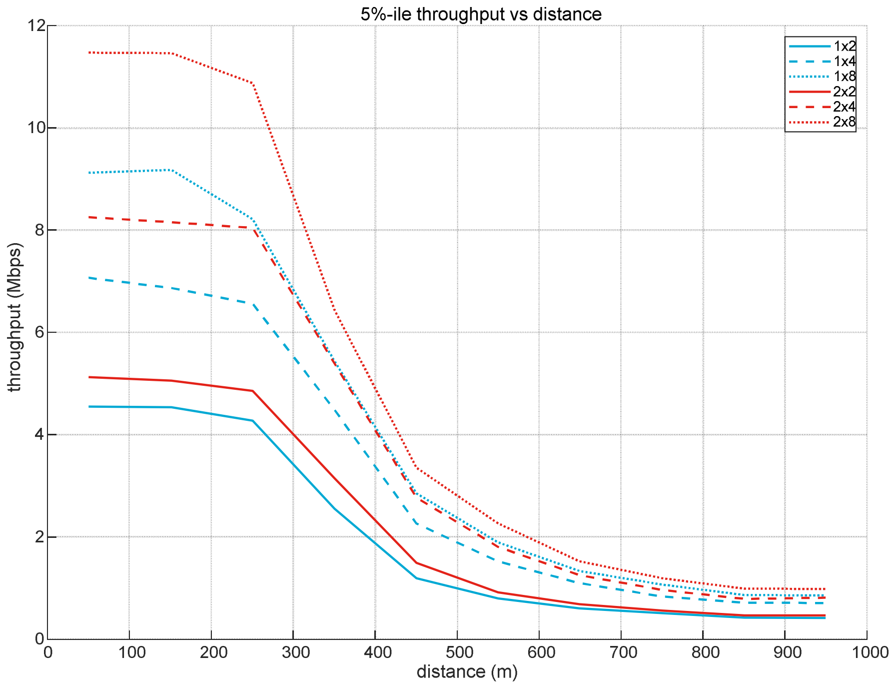


Figure A.93

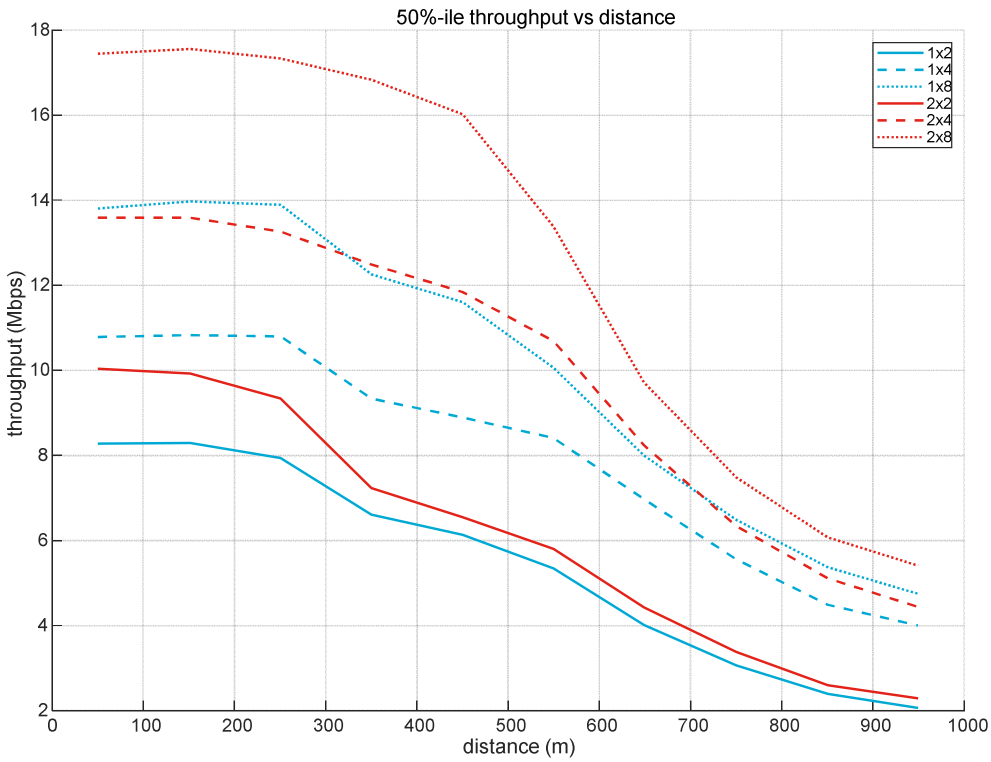


Figure A.94

Uplink Urban 31 dBm EIRP 50:50 (UL:DL) 4 km ISD

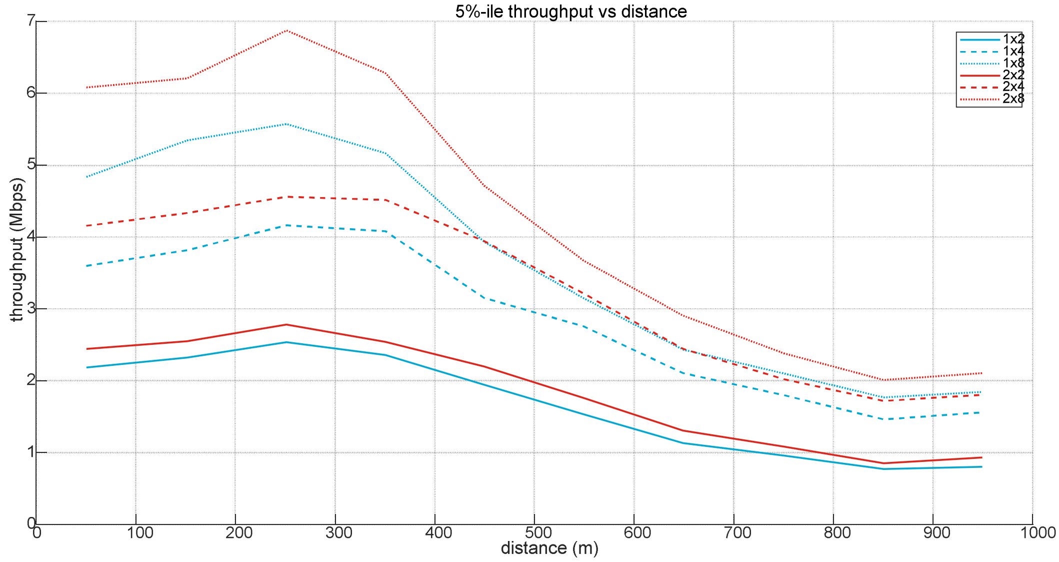


Figure A.95

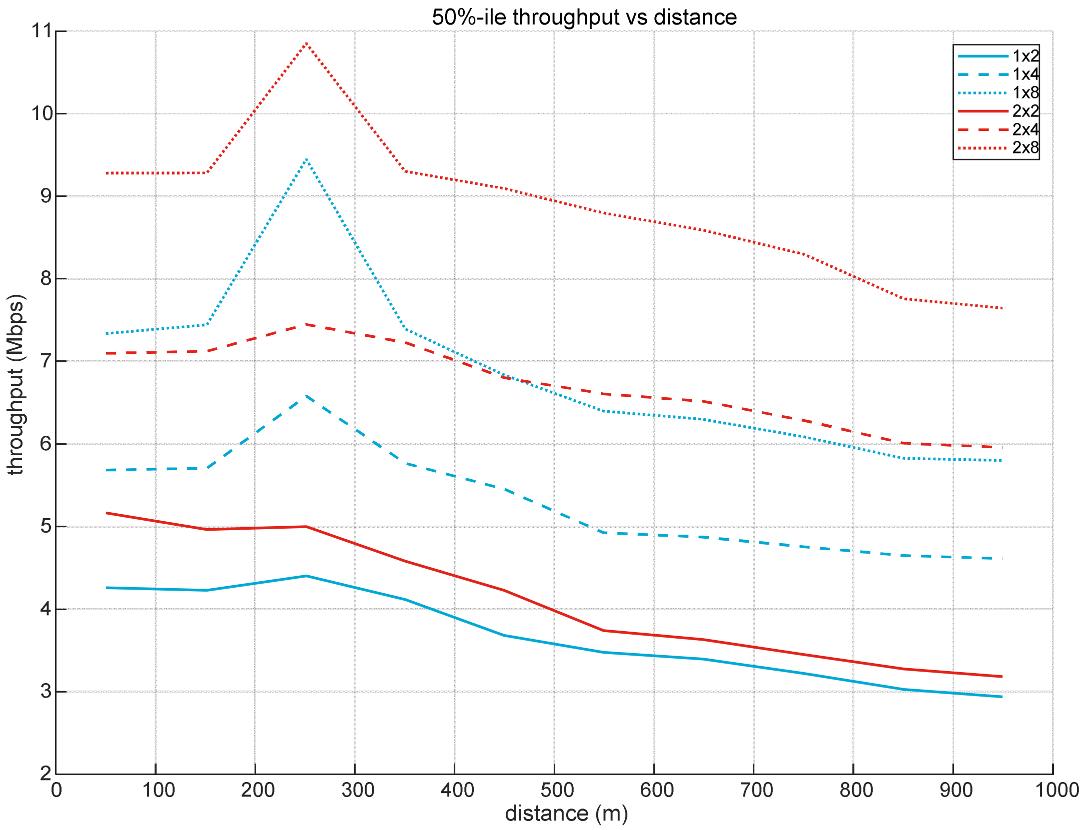


Figure A.96

Uplink Urban 31 dBm EIRP 90:10 (UL:DL) 4 km ISD

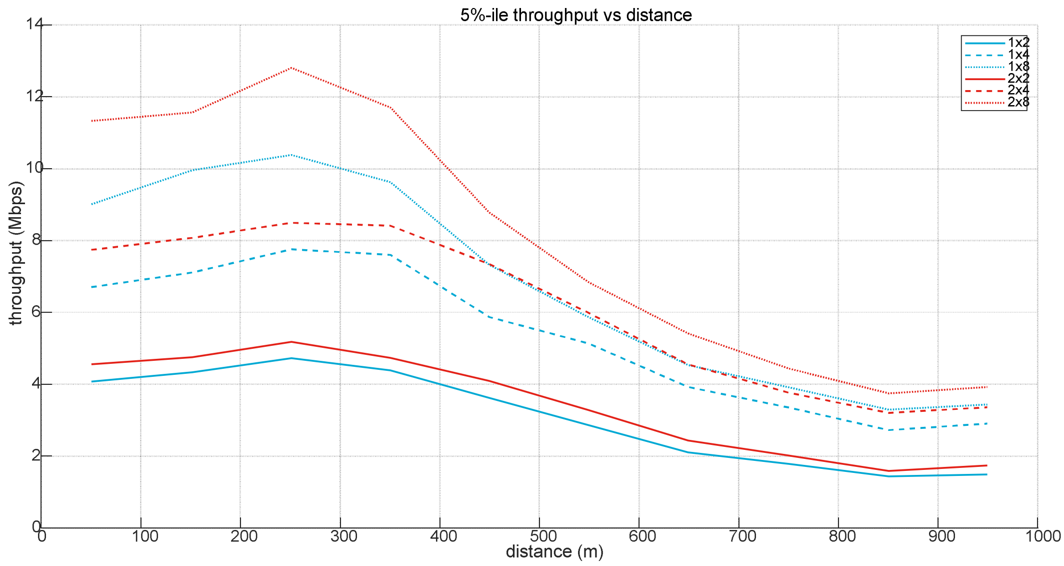


Figure A.97

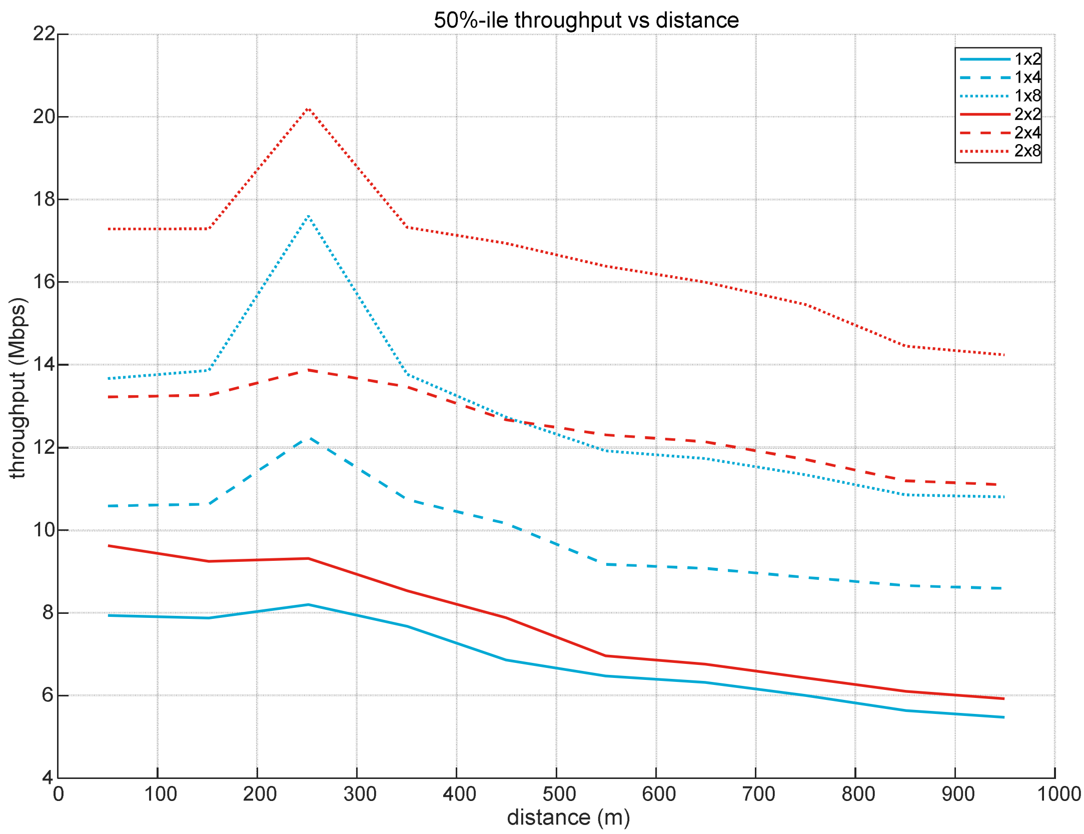


Figure A.98

Rural Downlink 4 km ISD 50:50 UL:DL 40 dBm EIRP

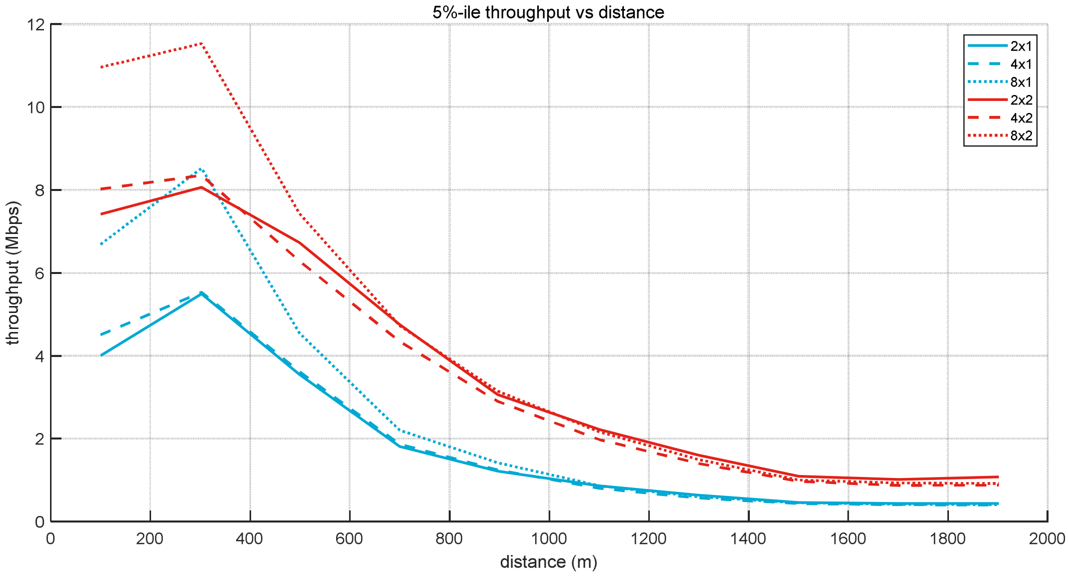


Figure A.99

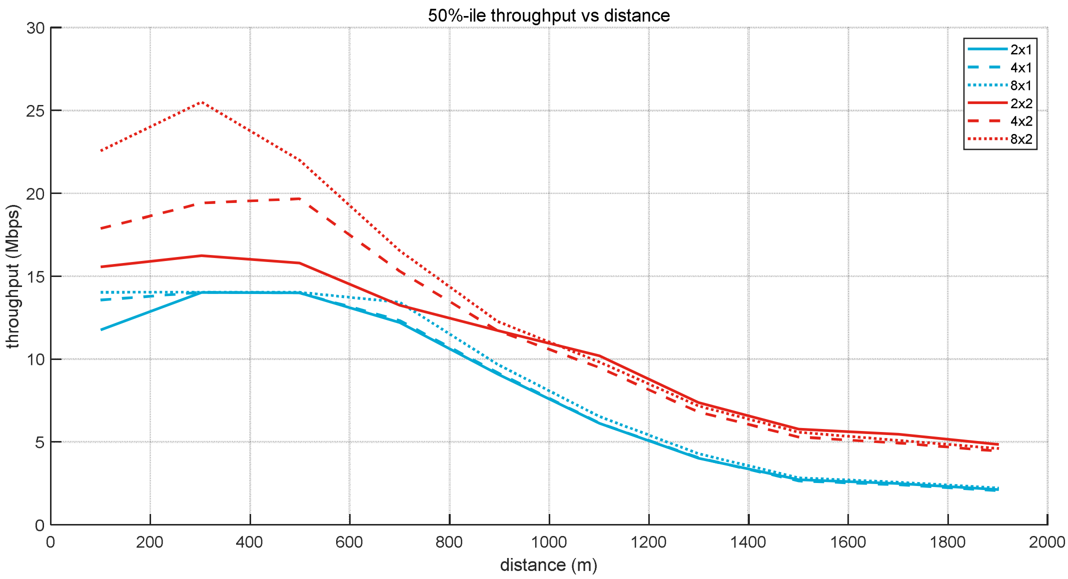


Figure A.100

Rural Downlink 6 km ISD 50:50 UL:DL 40 dBm EIRP

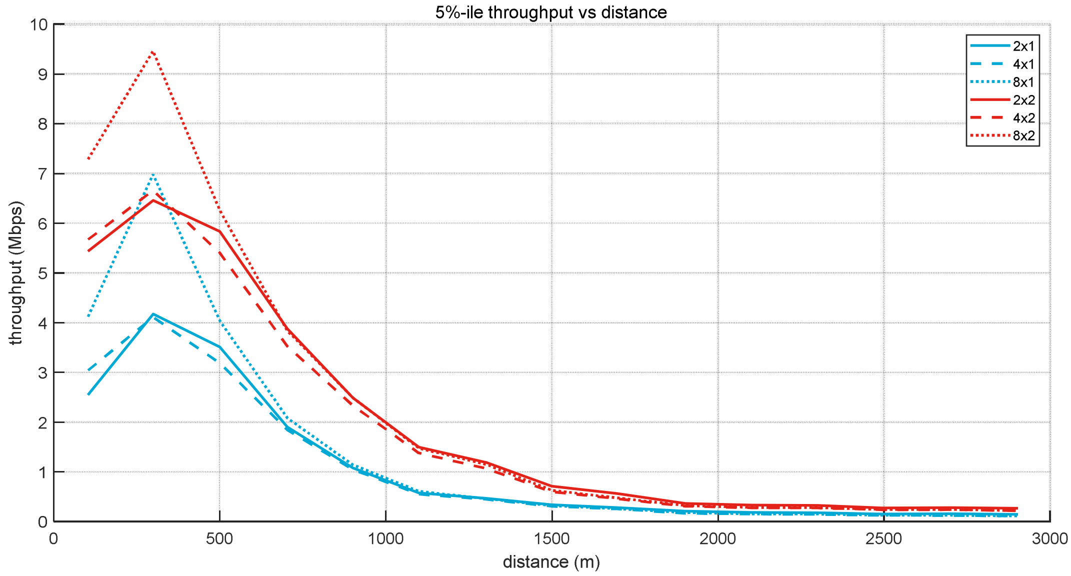


Figure A.101

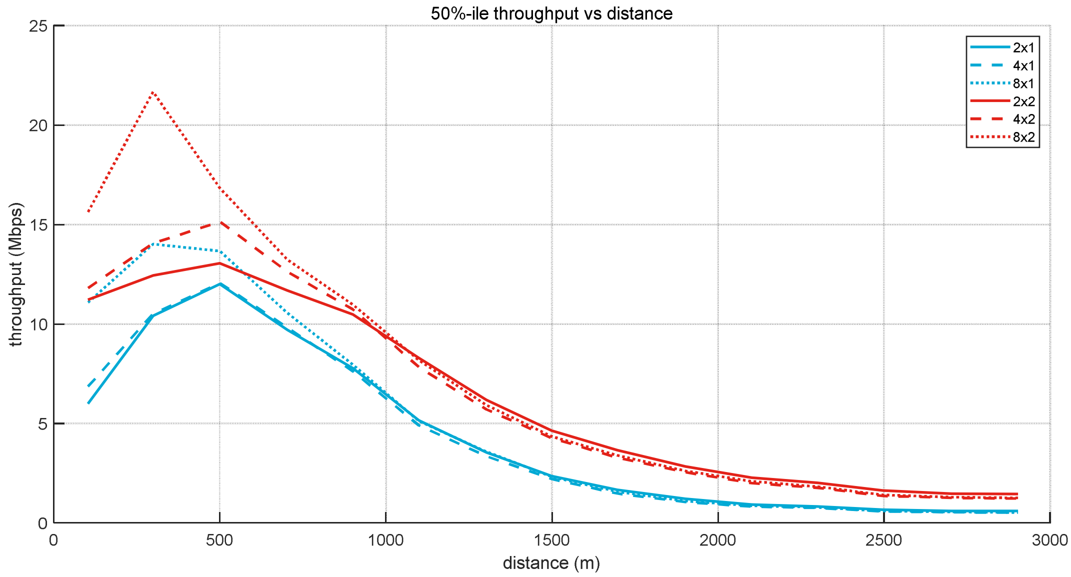


Figure A.102

Rural Downlink 8 km ISD 50:50 UL:DL 40 dBm EIRP

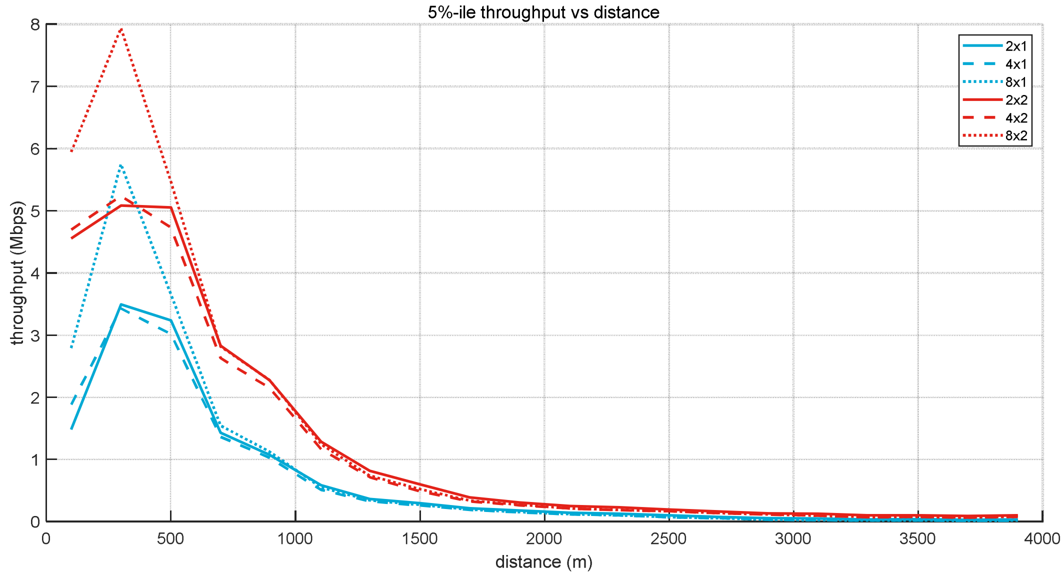


Figure A.103

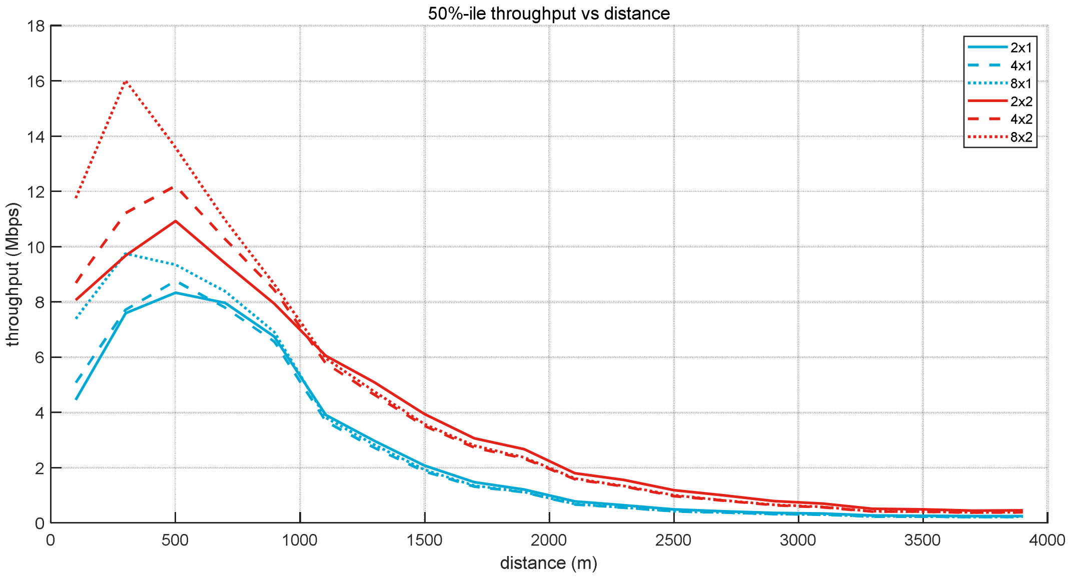


Figure A.104

Rural Downlink 4 km ISD 90:10 UL:DL 40 dBm EIRP

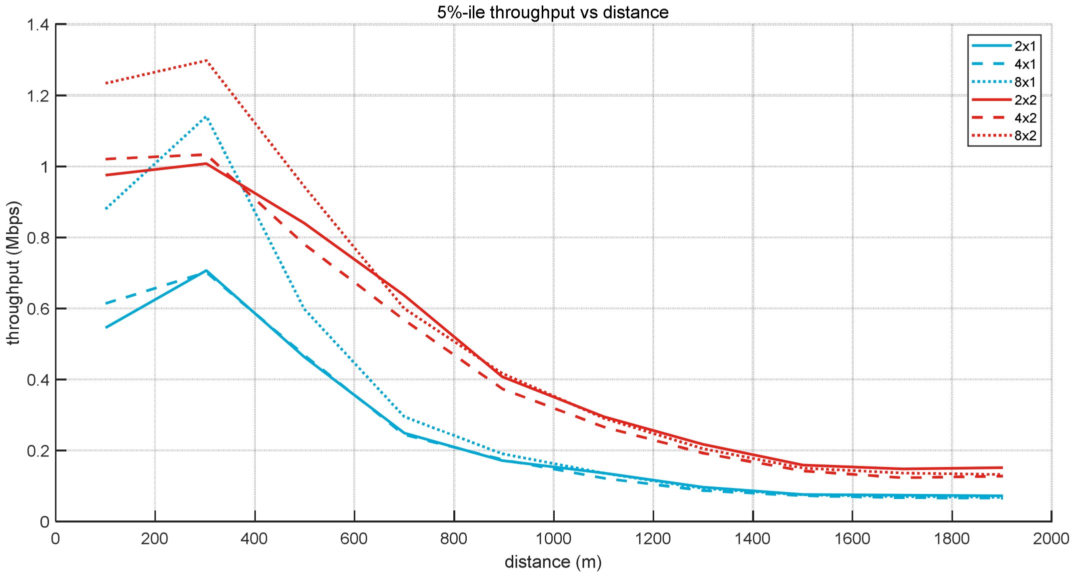


Figure A.105

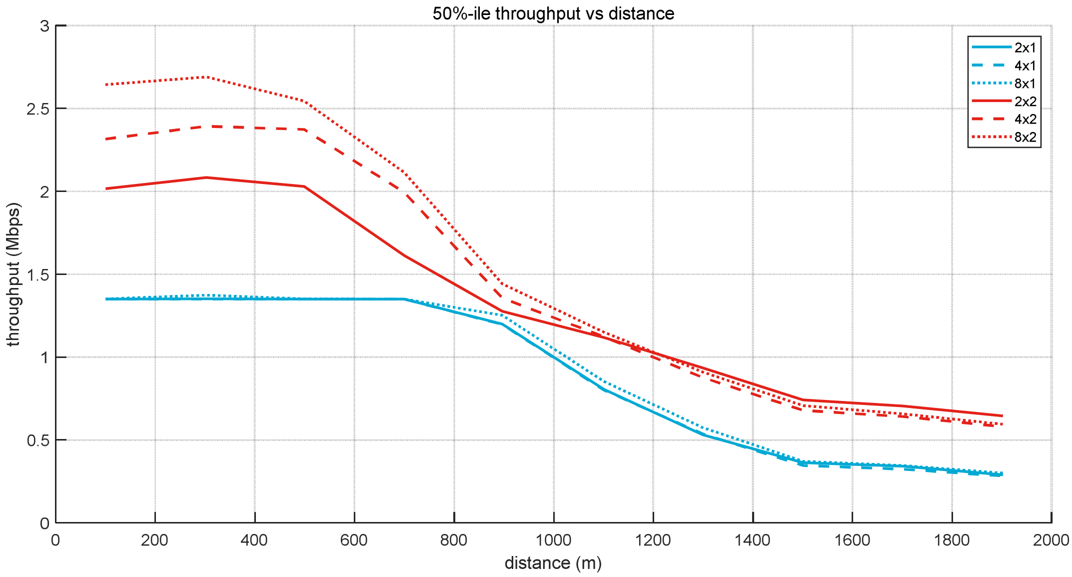
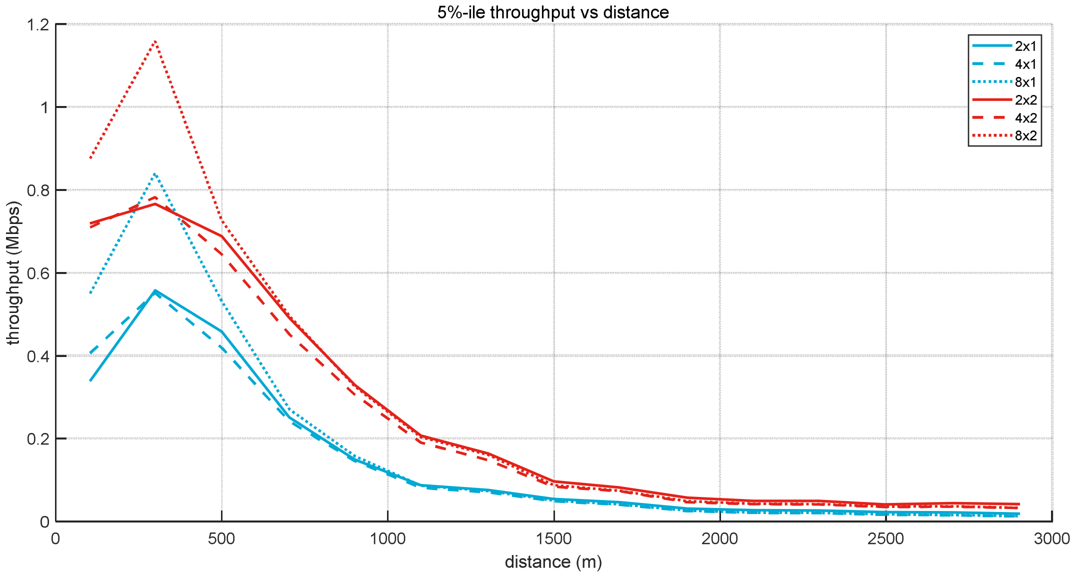


Figure A.106

Rural Downlink 6 km ISD 90:10 UL:DL 40 dBm EIRP



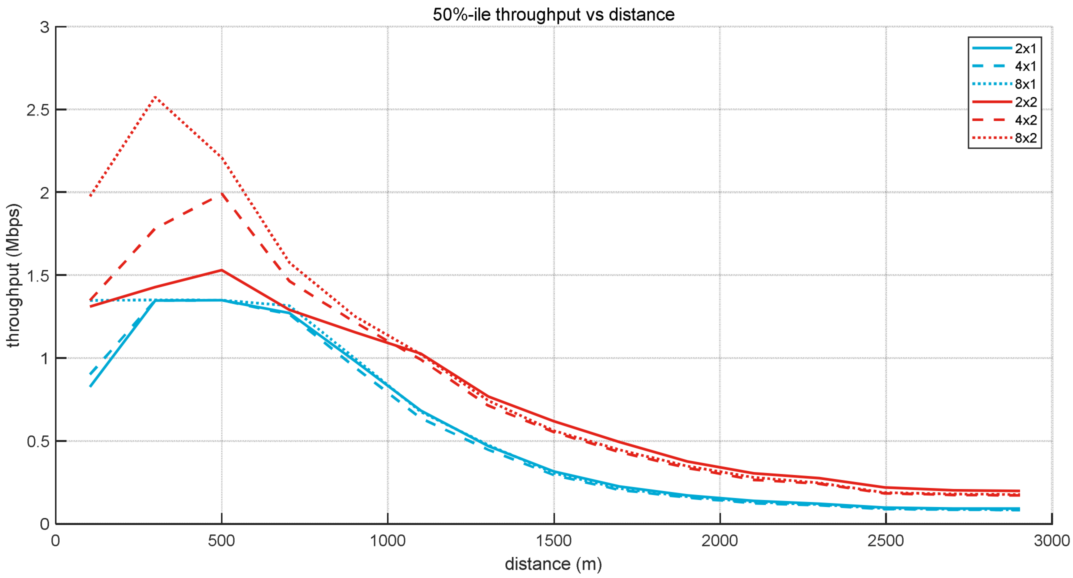


Figure A.107

Rural Downlink 8 km ISD 90:10 UL:DL 40 dBm EIRP

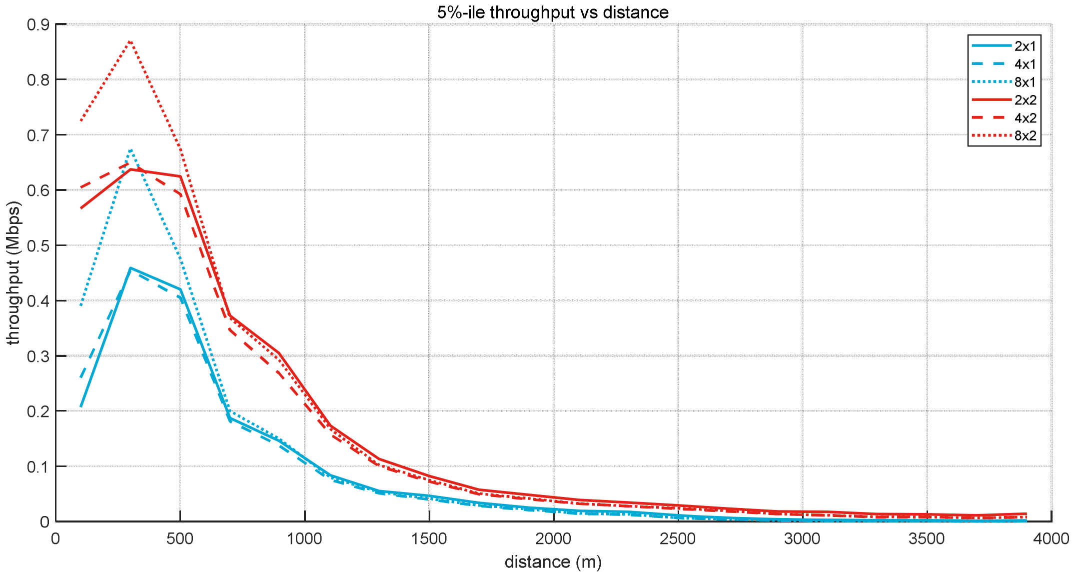


Figure A.108

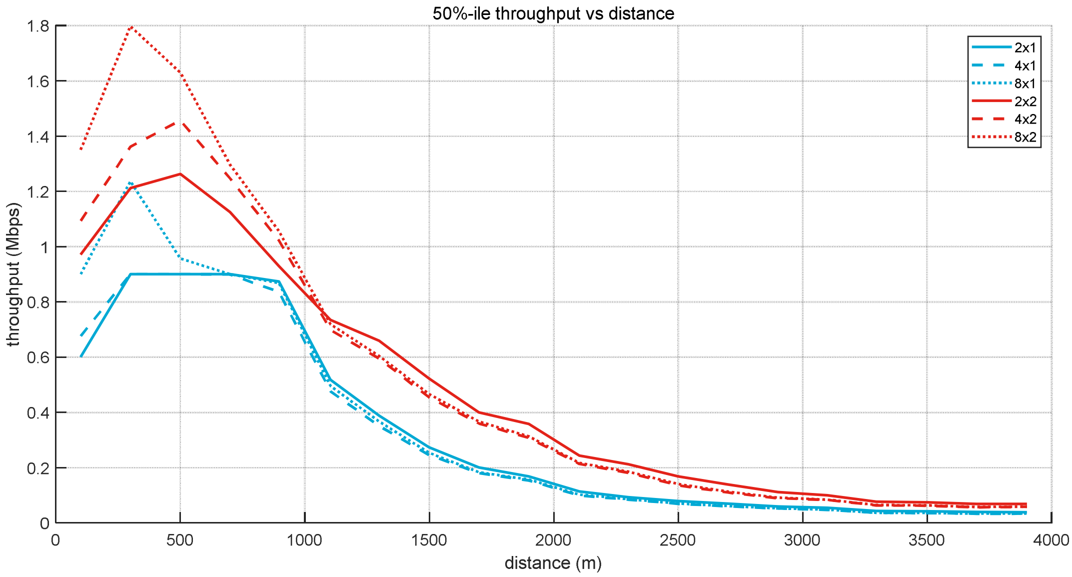


Figure A.109

Urban Downlink 2 km ISD 50:50 UL:DL 40 dBm EIRP

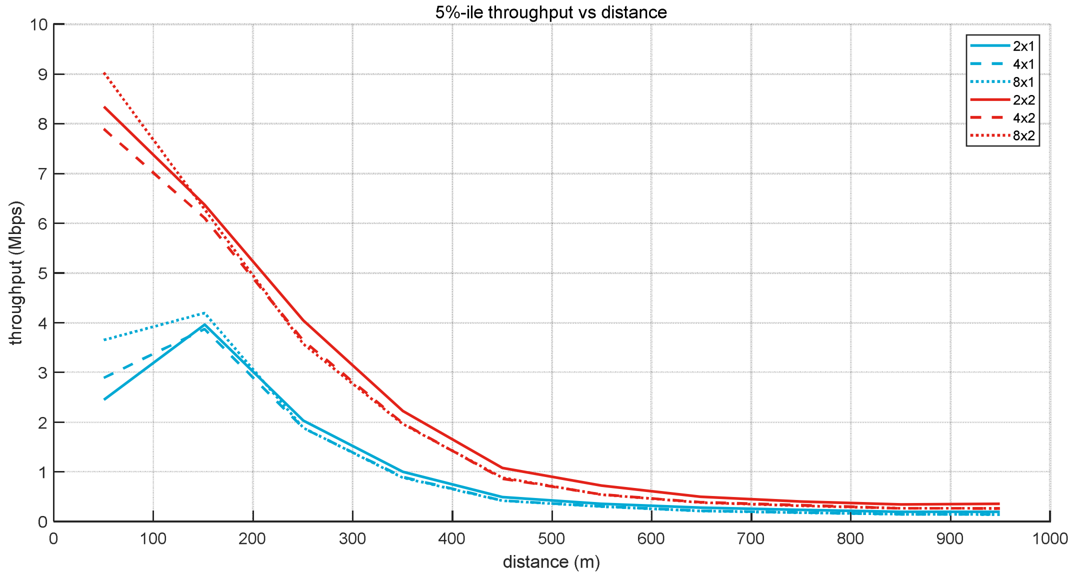


Figure A.110

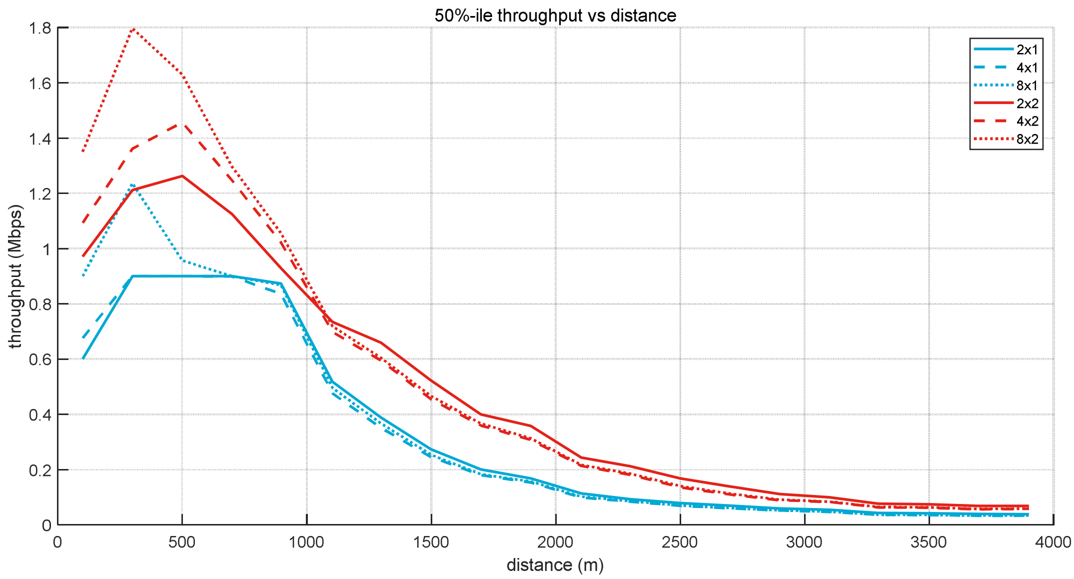


Figure A.111

Urban Downlink 4 km ISD 50:50 UL:DL 40 dBm EIRP

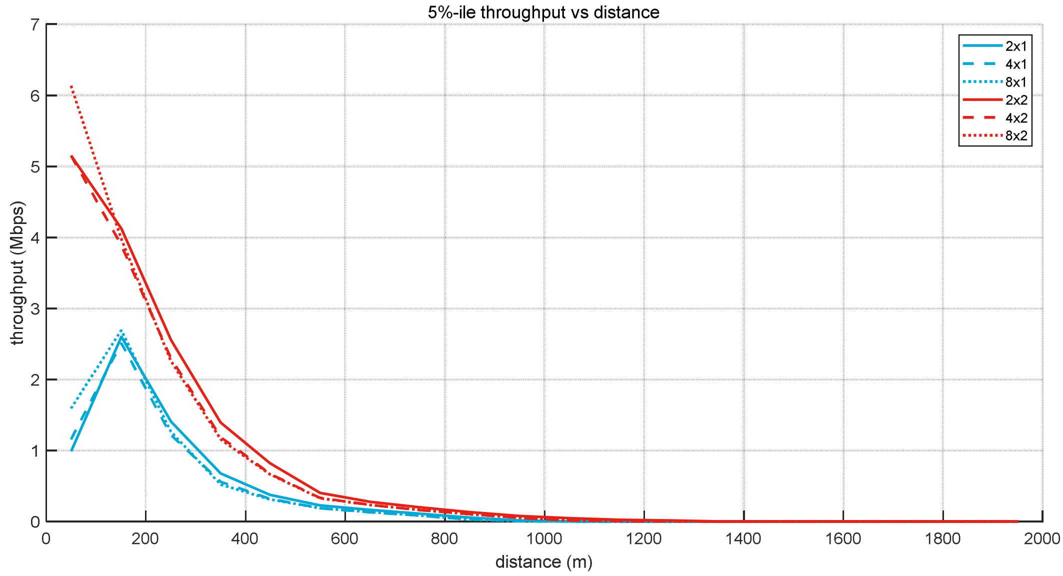


Figure A.112

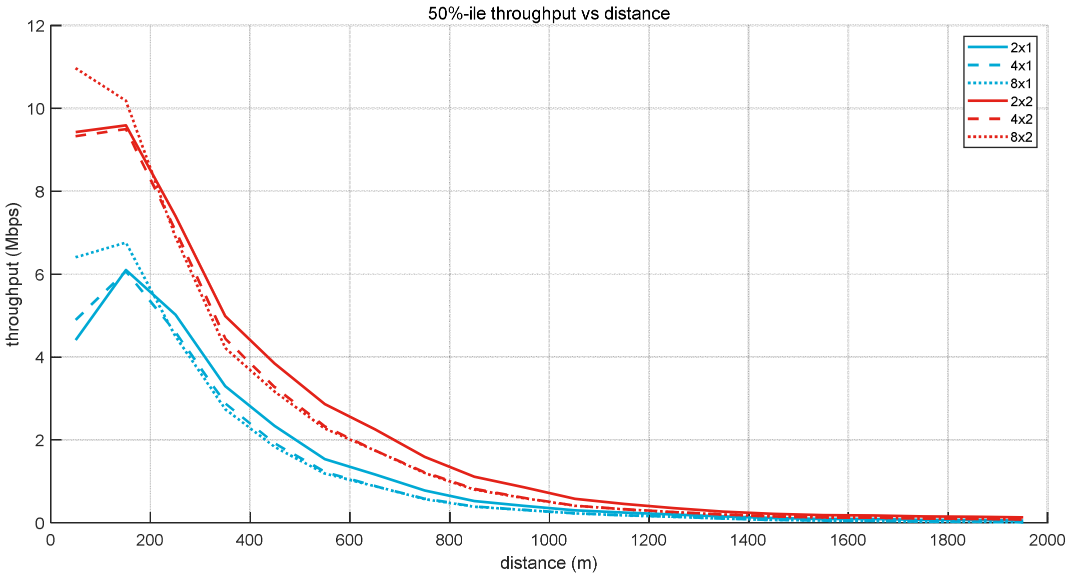


Figure A.113

Urban Downlink 2 km ISD 90:10 UL:DL 40 dBm EIRP

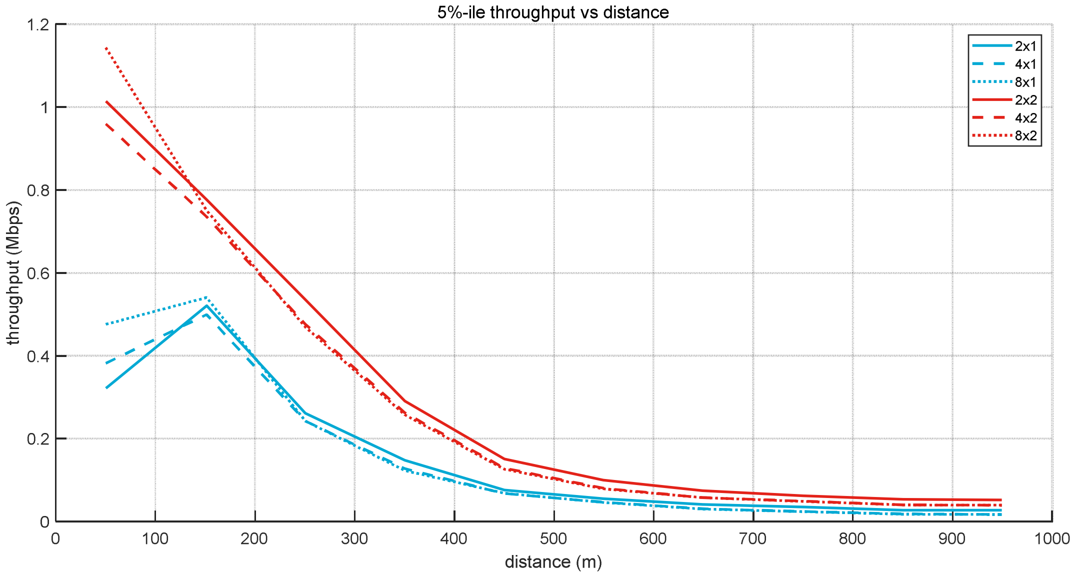


Figure A.114

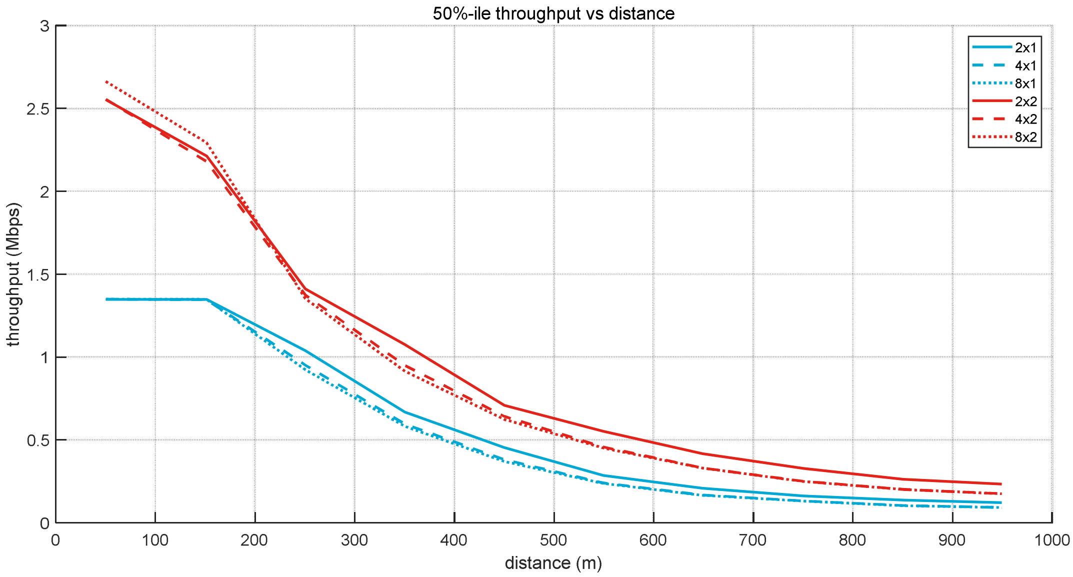


Figure A.115

Urban Downlink 4 km ISD 90:10 UL:DL 40 dBm EIRP

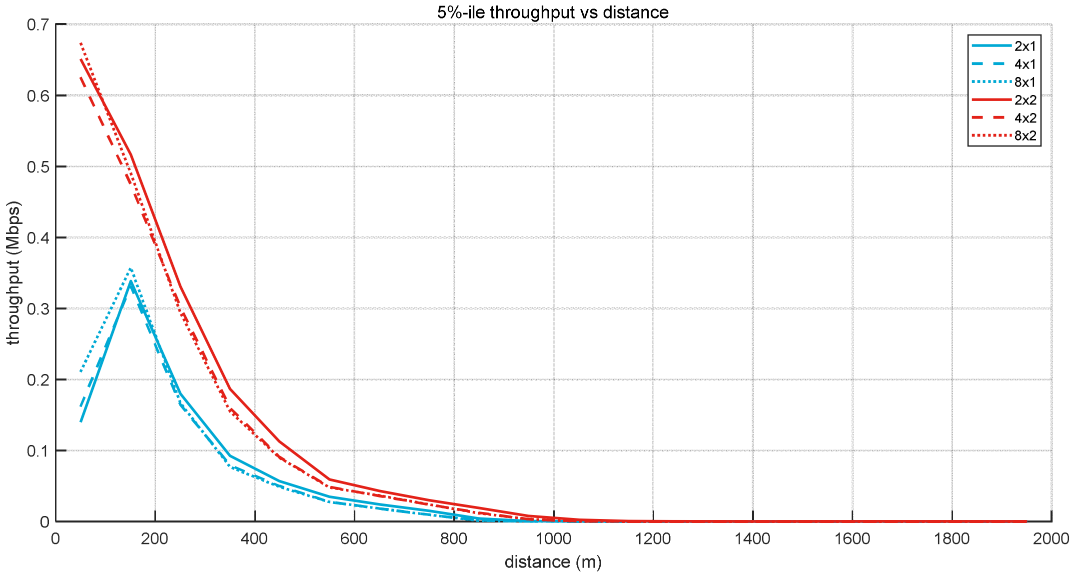


Figure A.116

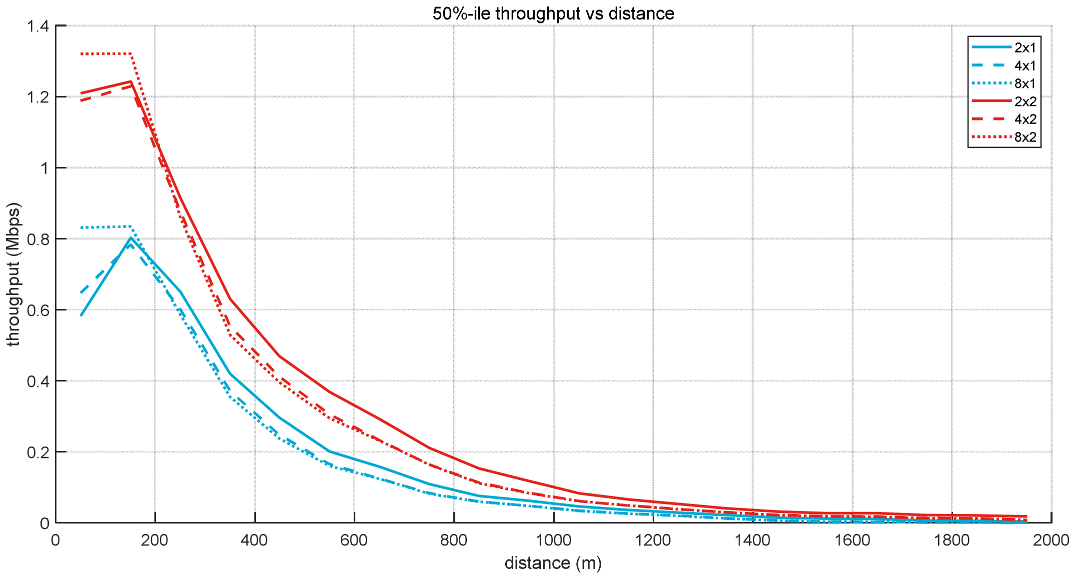


Figure A.117

Rural Downlink 8 km ISD 50:50 UL:DL 46 dBm EIRP

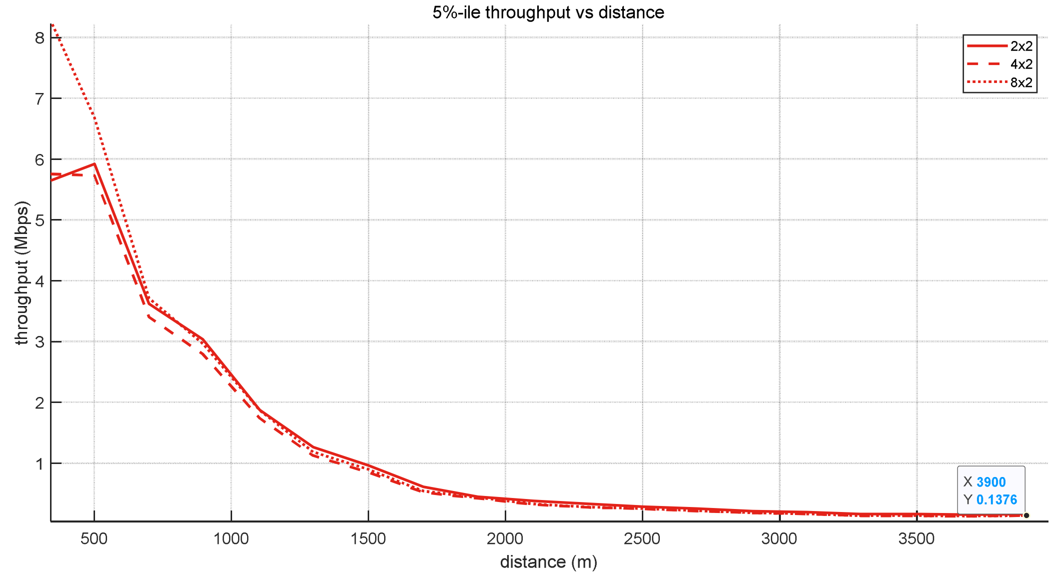


Figure A.118

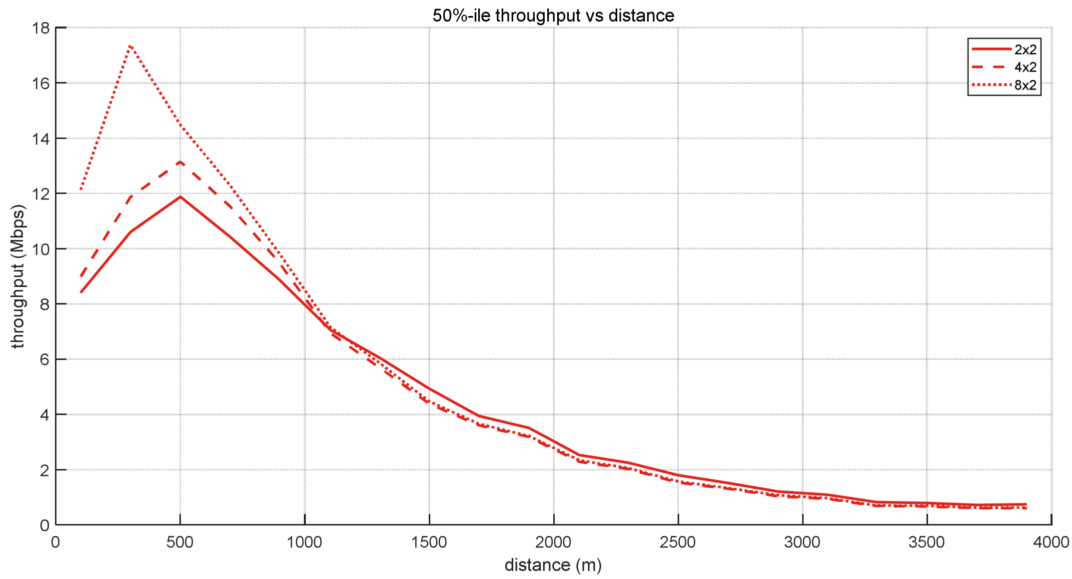


Figure A.119

Rural Downlink 8 km ISD 50:50 UL:DL 46 dBm Total Power at radio output (4x2 MIMO transmits 63 dBm EIRP)

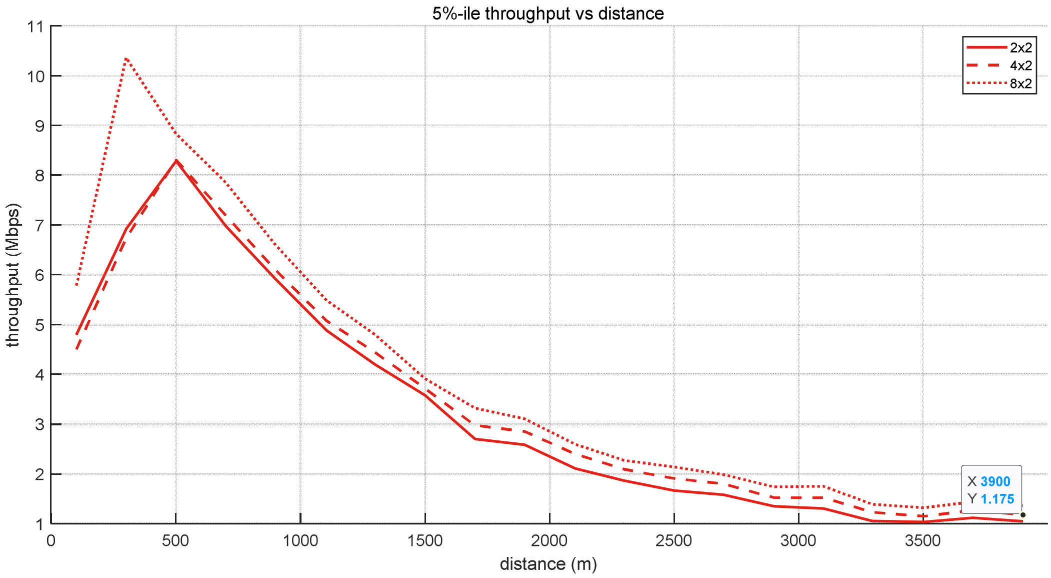


Figure A.120

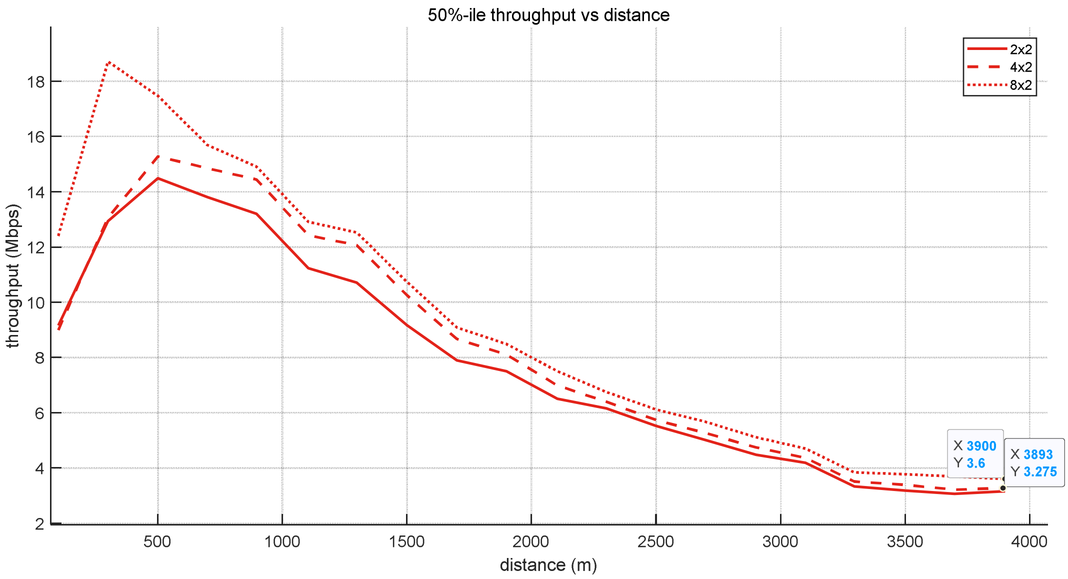


Figure A.121

Rural Uplink 8 km ISD 50:50 31 dBm EIRP

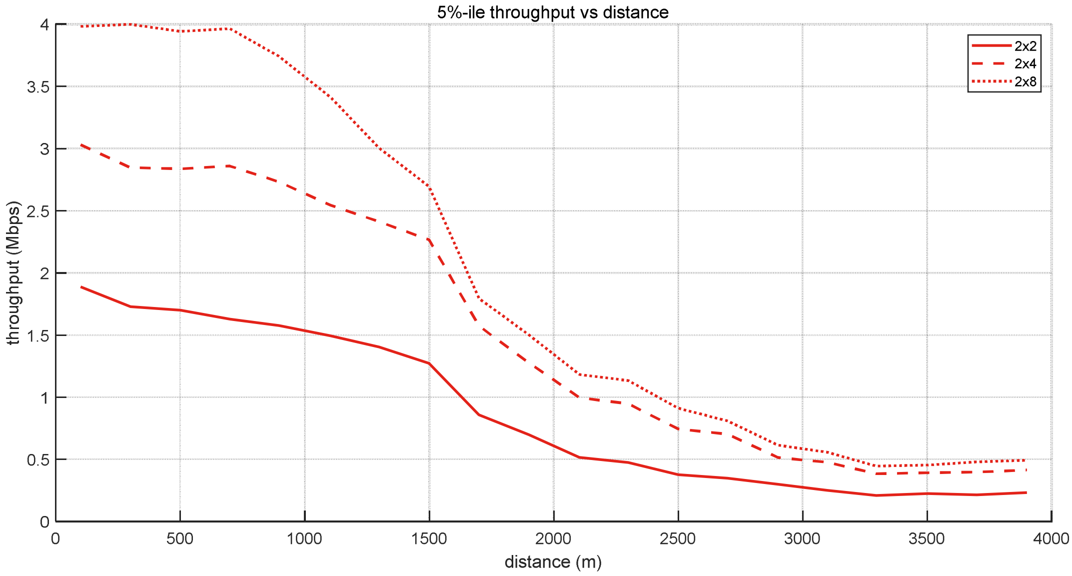


Figure A.122

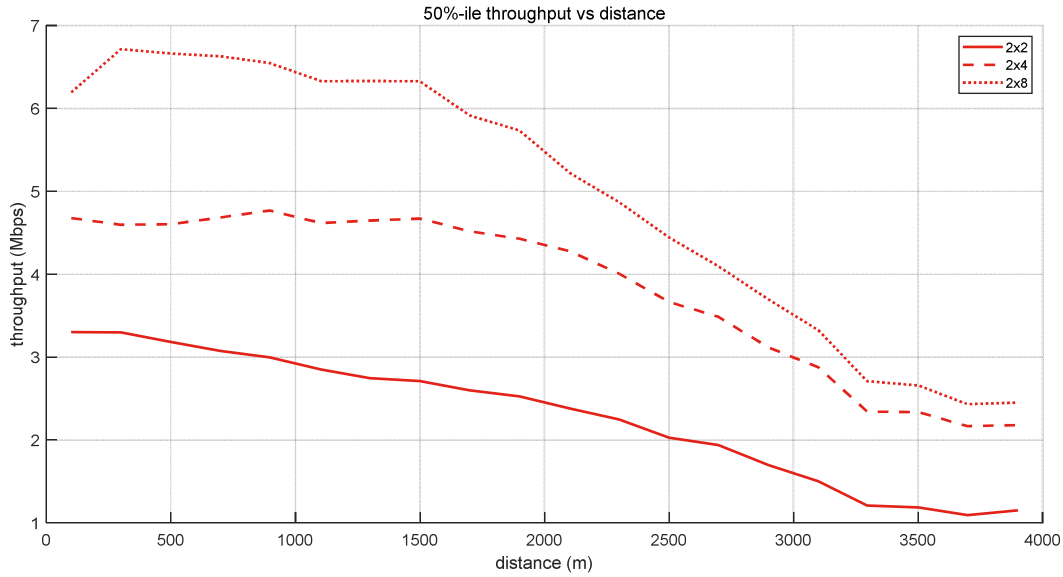


Figure A.123

Rural, 1 900 MHz, 10 MHz bandwidth, 31 dBm UE Tx power, 15 kHz SC spacing

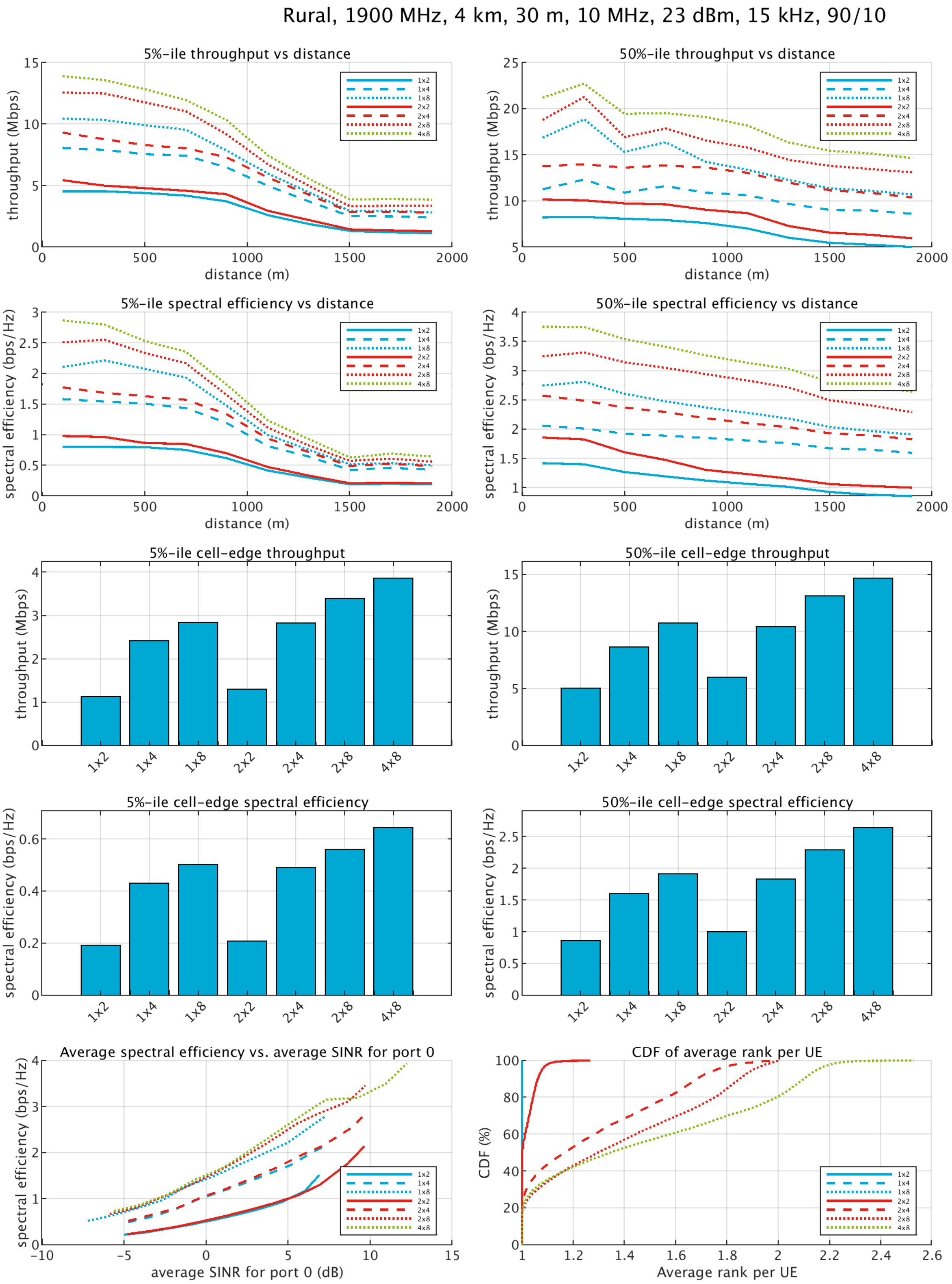


Figure A.124

Rural, 1 900 MHz, 10 MHz bandwidth, 23 dBm UE Tx power, 15 kHz SC spacing

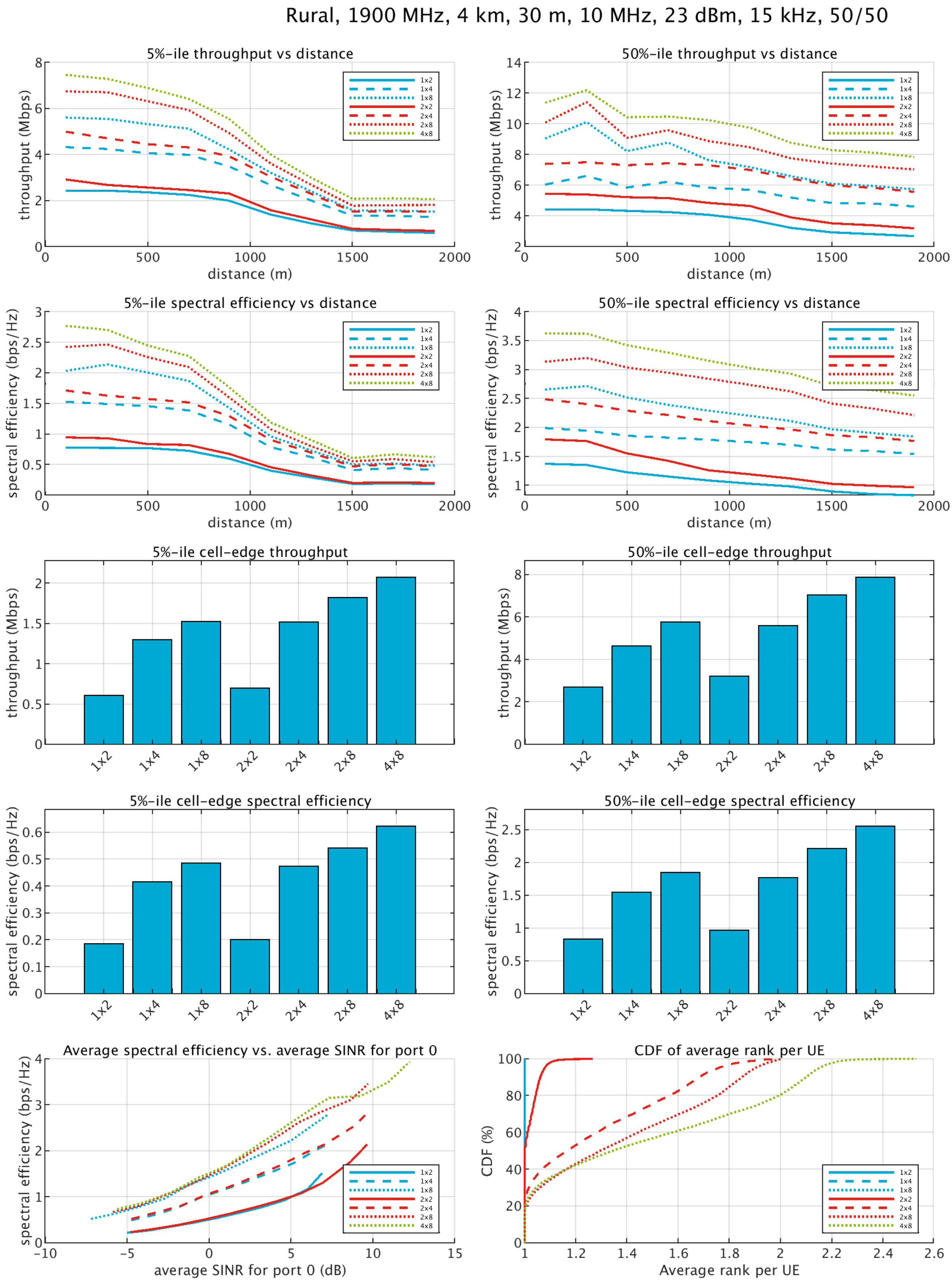


Figure A.125

Rural, 1 900 MHz, 10 MHz bandwidth, 31 dBm UE Tx power, 15 kHz SC spacing

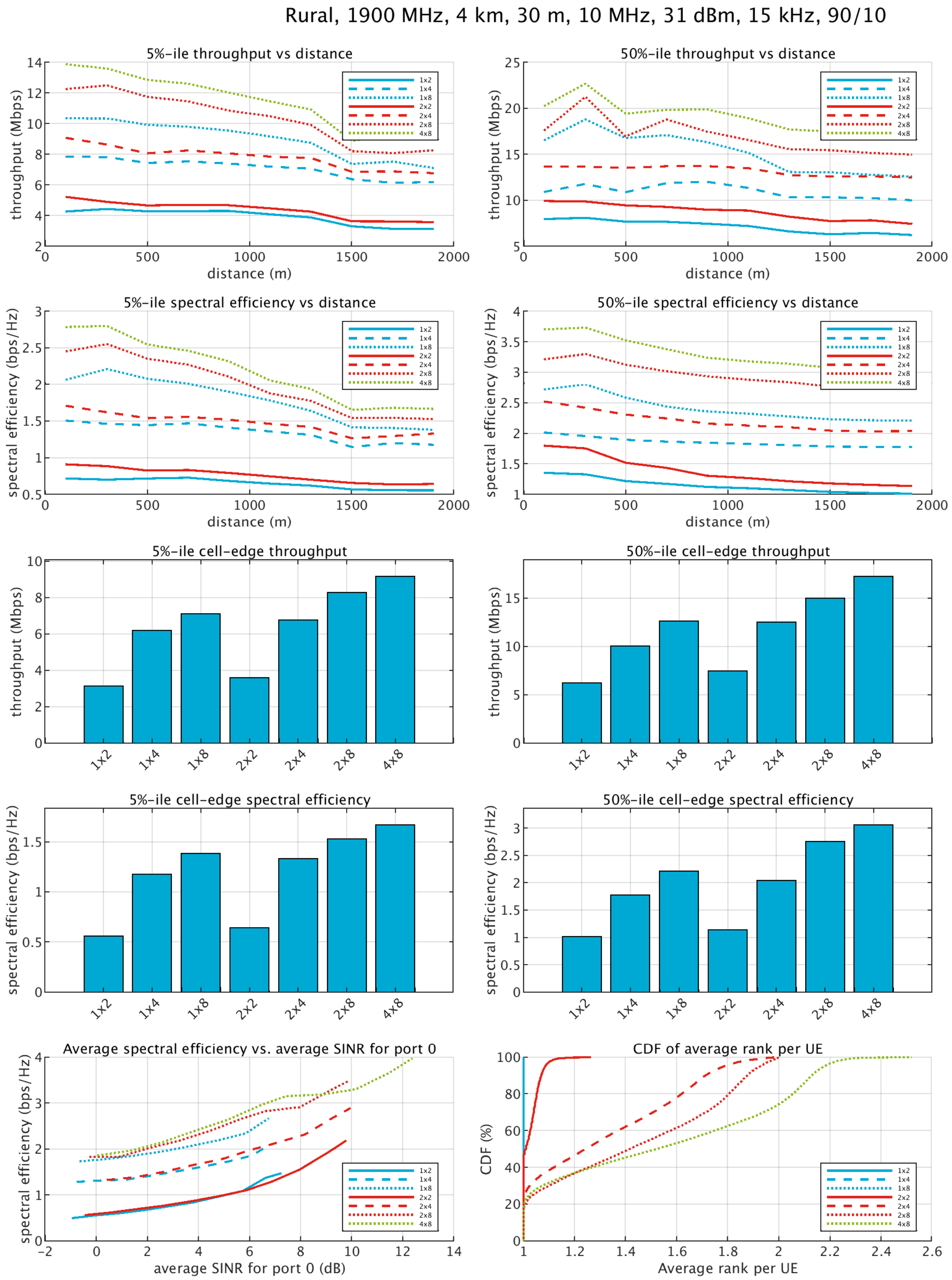


Figure A.126

Rural, 1 900 MHz, 10 MHz bandwidth, 31 dBm UE Tx power, 15 kHz SC spacing

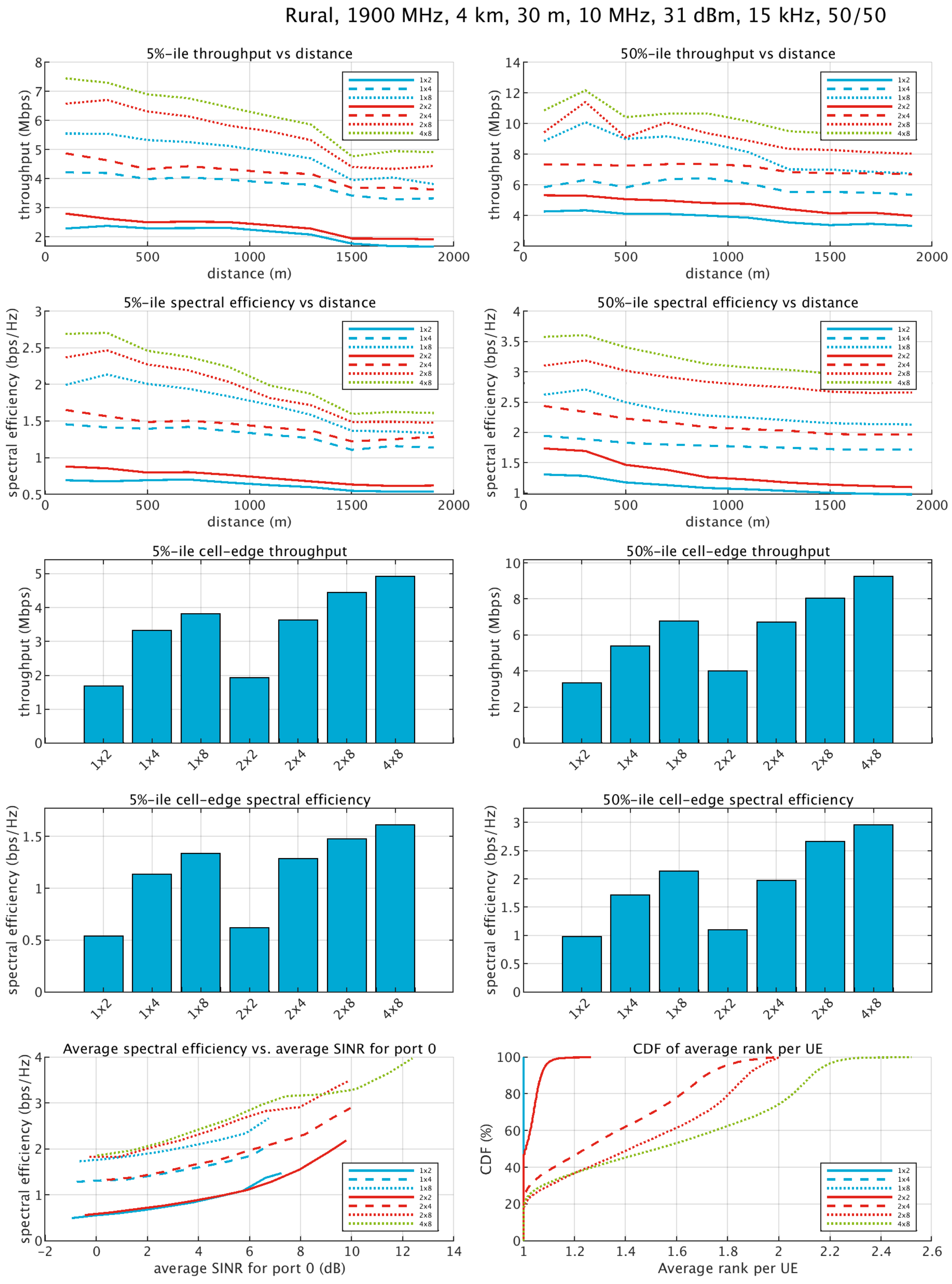


Figure A.127

Urban, 1 900 MHz, 10 MHz bandwidth, 23 dBm UE Tx power, 15 kHz SC spacing

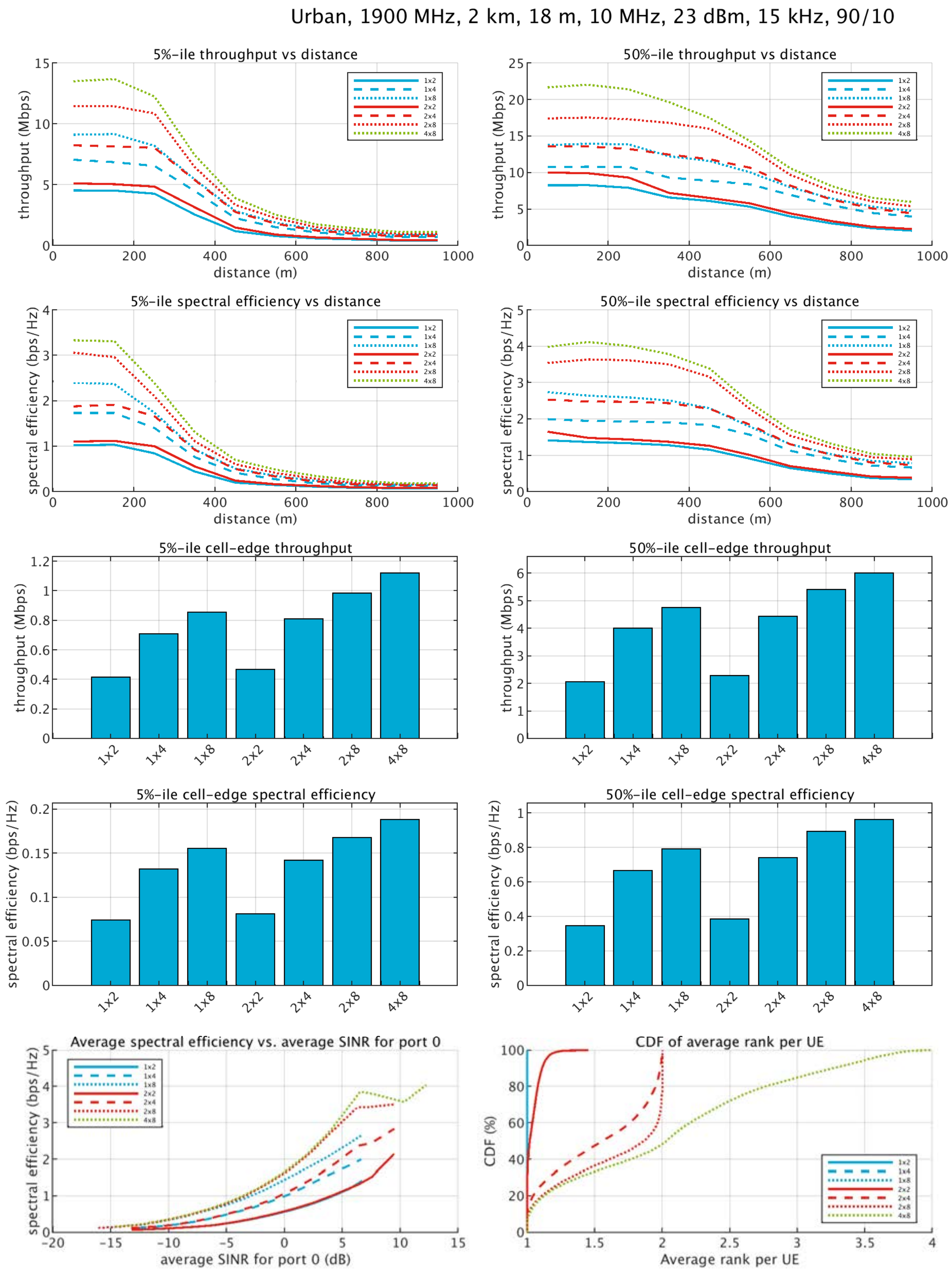


Figure A.128

Urban 1 900 MHz, 10 MHz bandwidth, 23 dBm UE Tx power, 15 kHz SC spacing

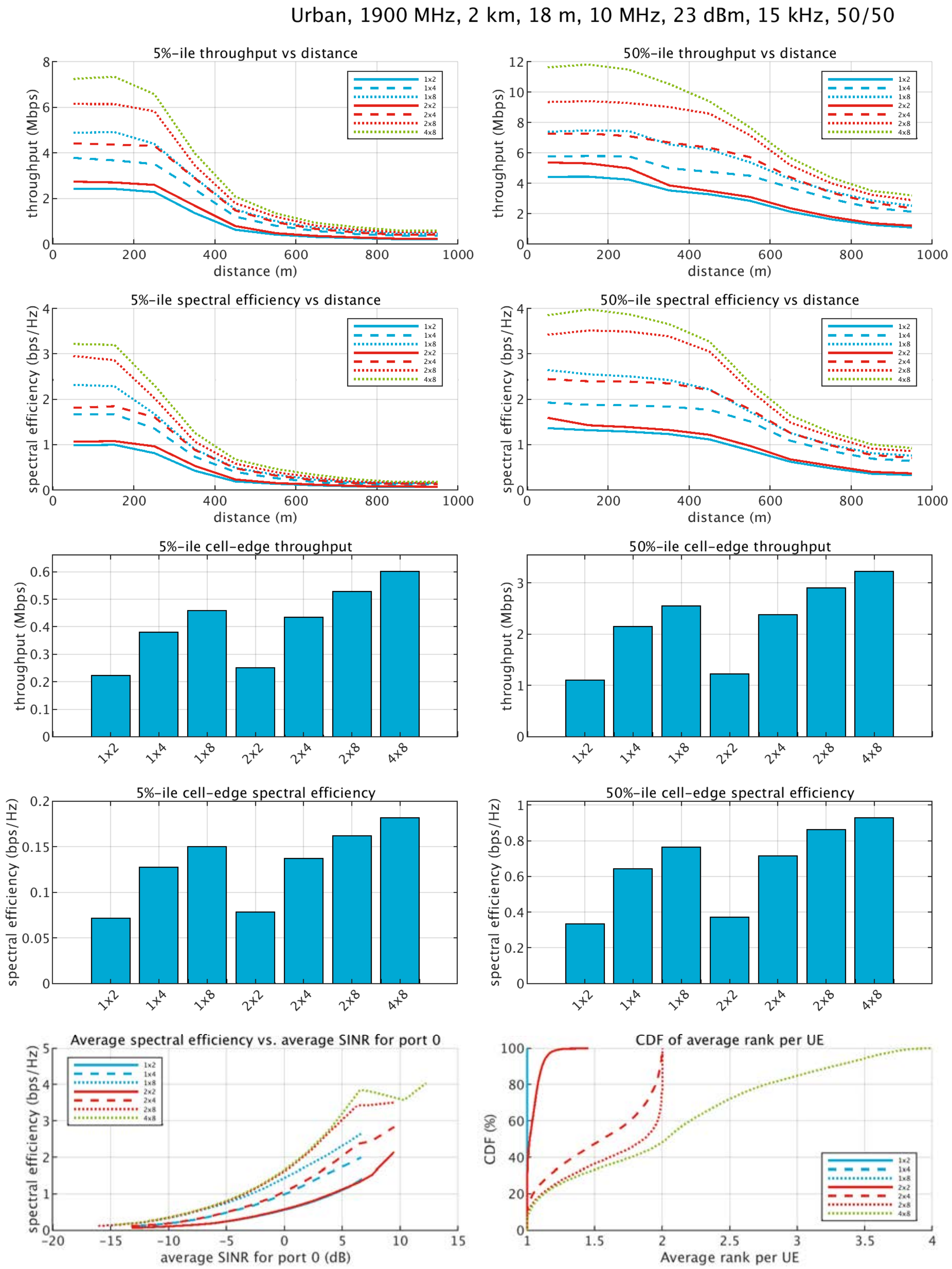


Figure A.129

Urban, 1 900 MHz, 10 MHz bandwidth, 31 dBm UE Tx power, 15 kHz SC spacing

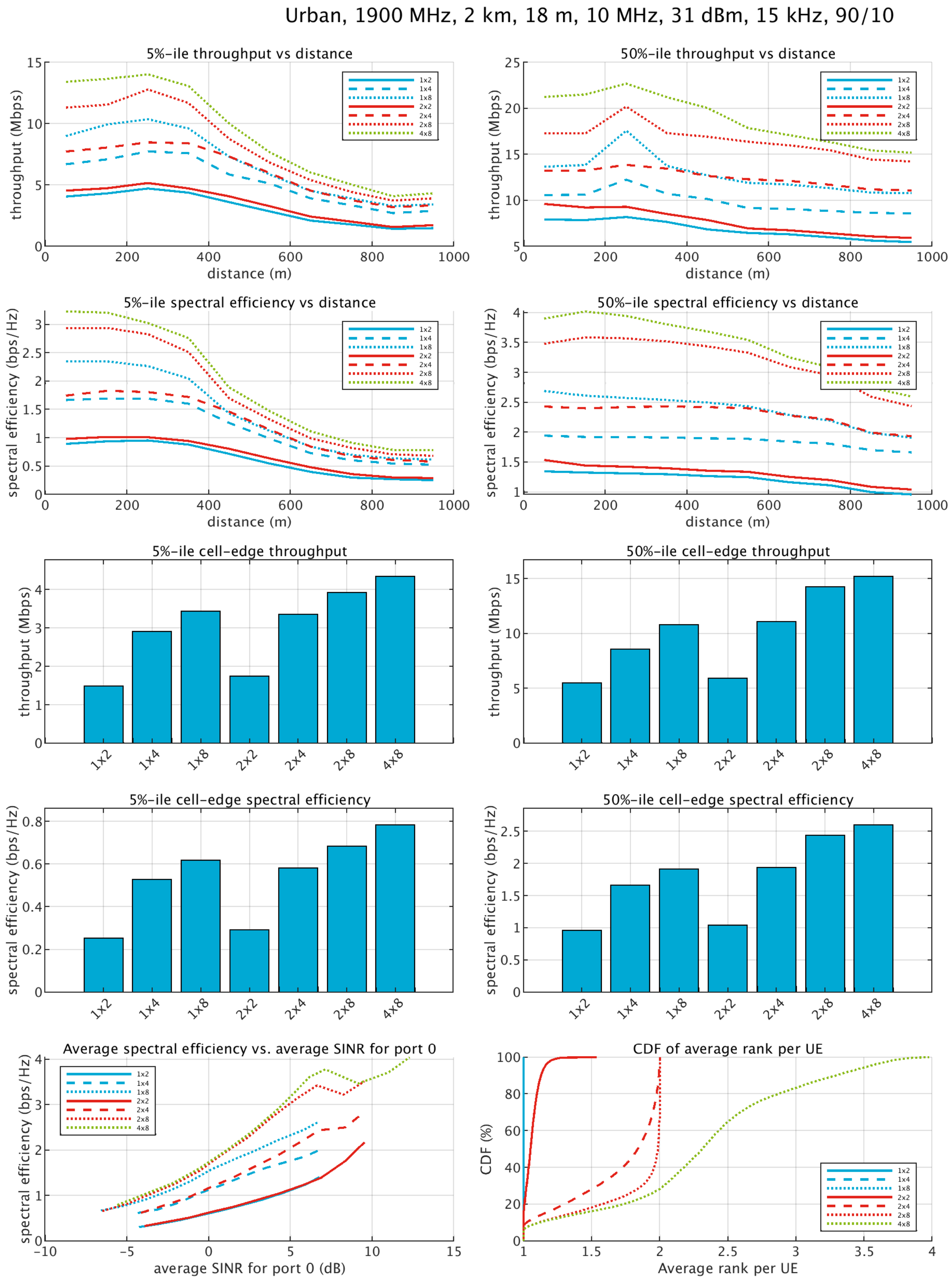


Figure A.130

Urban, 1 900 MHz, 10 MHz bandwidth, 31 dBm UE Tx power, 15 kHz SC spacing

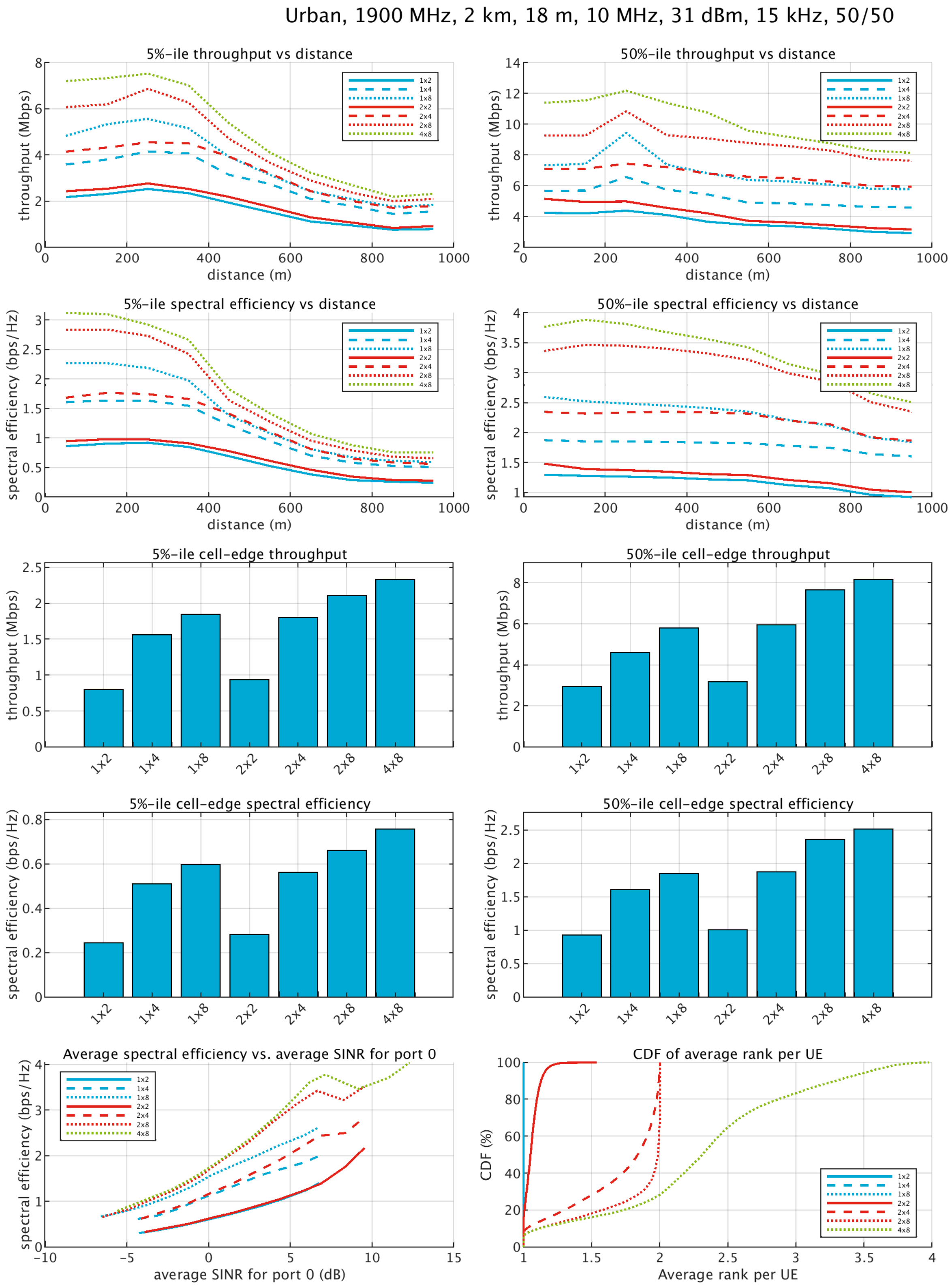


Figure A.131

A.2.1.1.2 DL Results

Rural, 1 900 MHz, 10 MHz bandwidth, power case 1, 15 kHz SC spacing

NOTE 1: 43 dBm EIRP is for reference purposes only and not used for comparison to other simulation results.

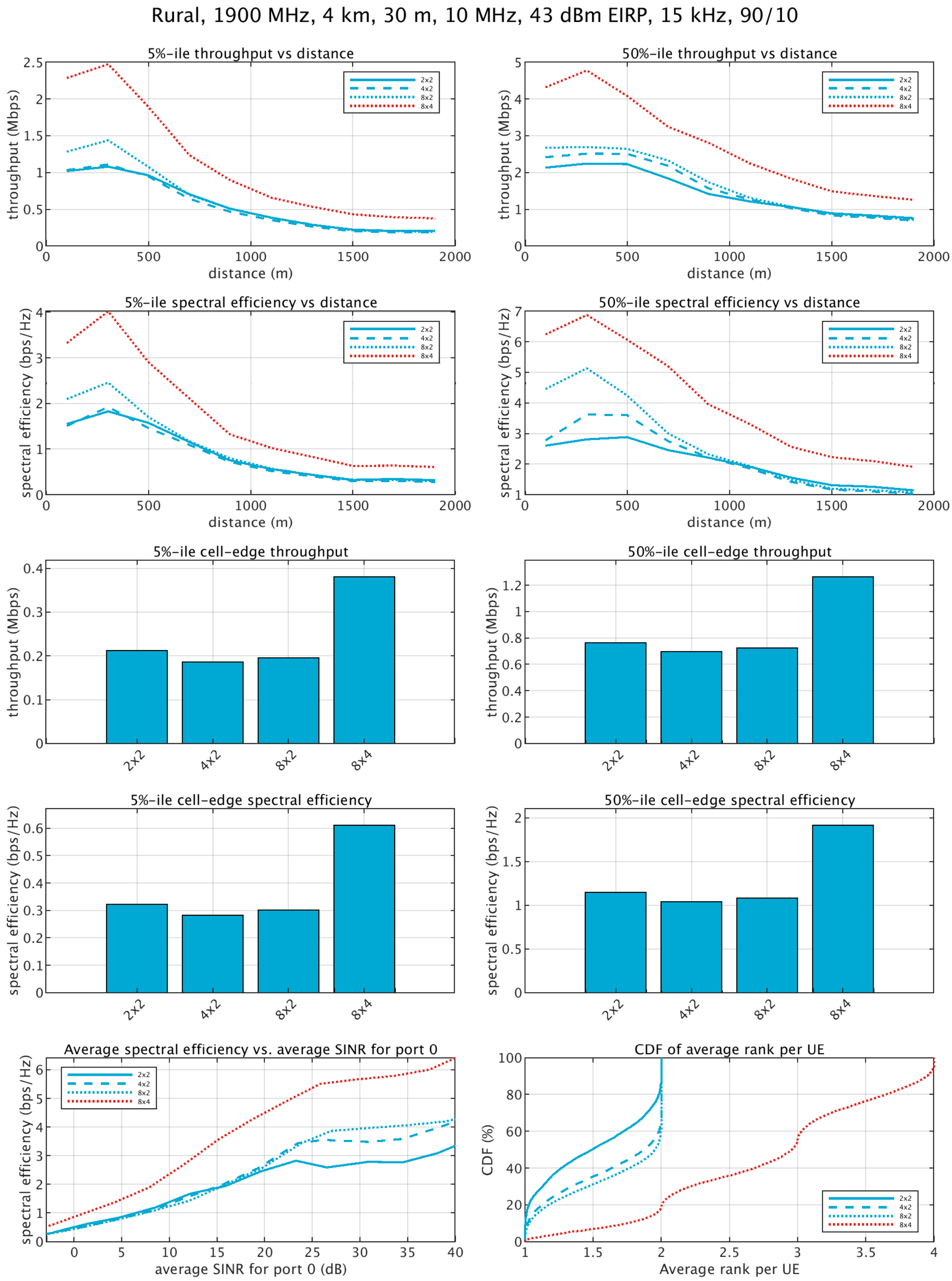


Figure A.132

Rural, 1 900 MHz, 10 MHz bandwidth, power case 1, 15 kHz SC spacing

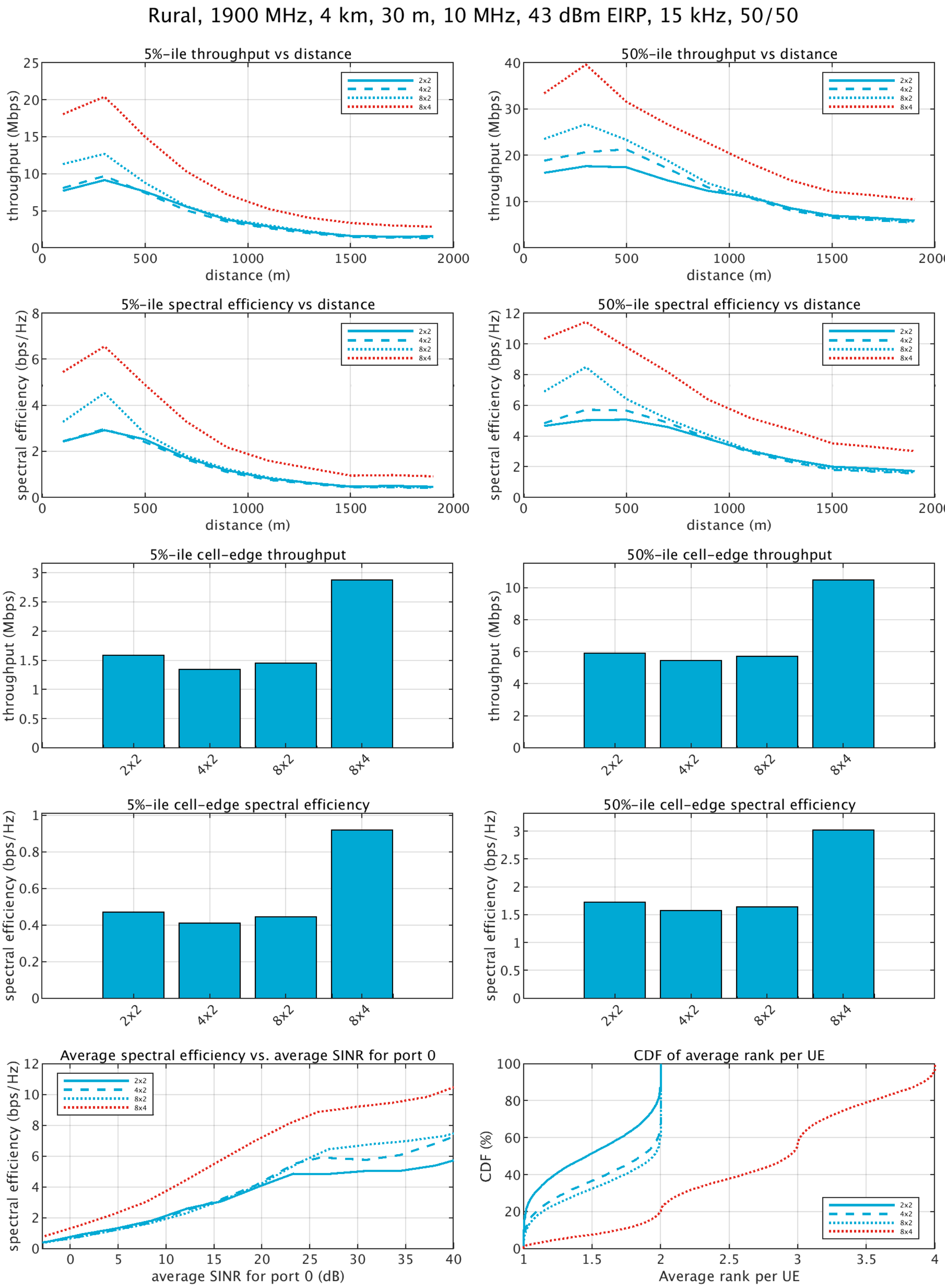


Figure A.133

Rural, 1 900 MHz, 10 MHz bandwidth, power case 2, 15 kHz SC spacing

NOTE 2: In the case of 4x2 MIMO, the resulting EIRP is 63 dBm.

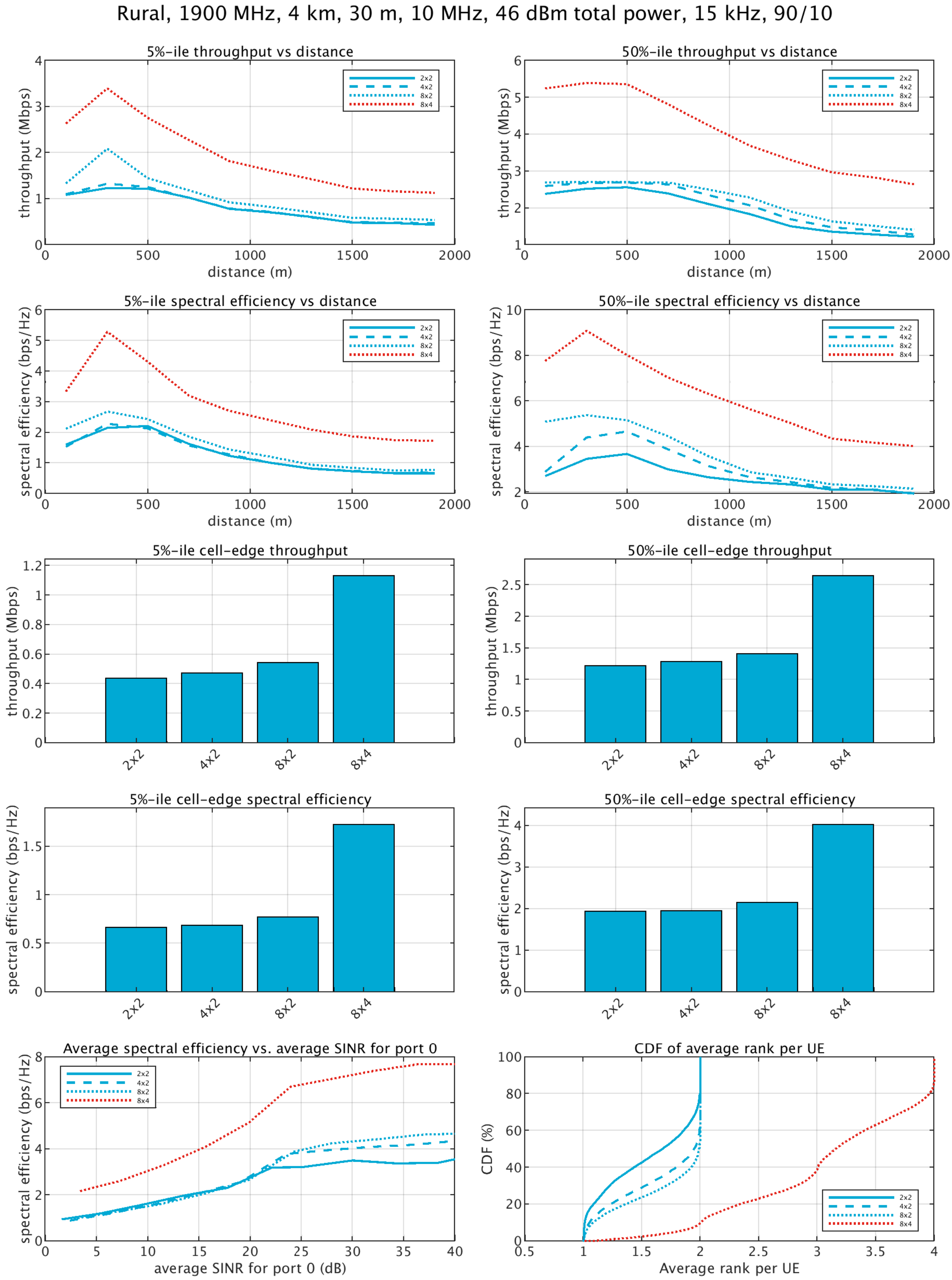


Figure A.134

Rural, 1 900 MHz, 10 MHz bandwidth, power case 1, 15 kHz SC spacing

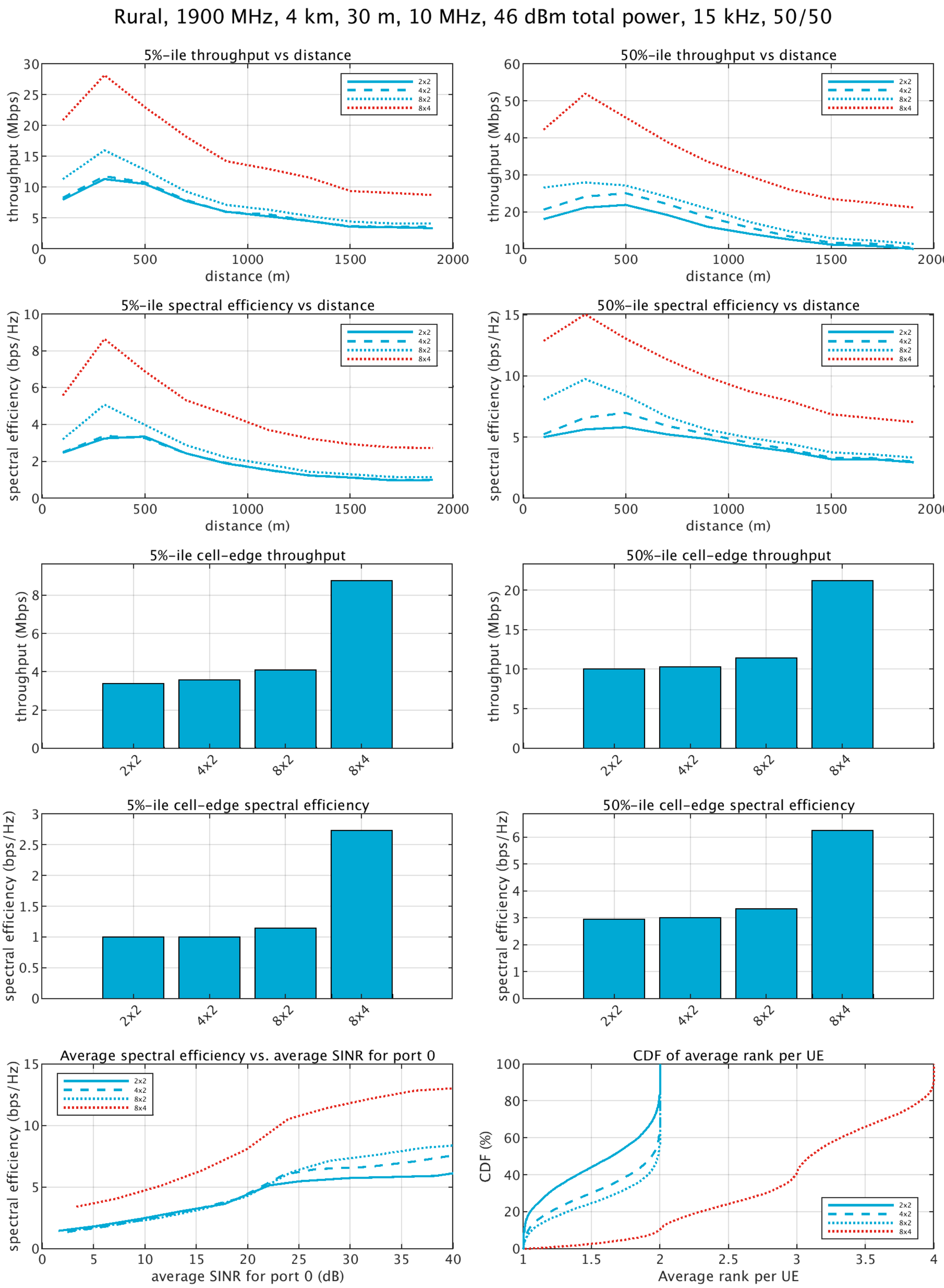


Figure A.135

Urban, 1 900 MHz, 10 MHz bandwidth, power case 1, 15 kHz SC spacing

NOTE 3: 43 dBm EIRP is for reference purposes only and not used for comparison to other simulation results.

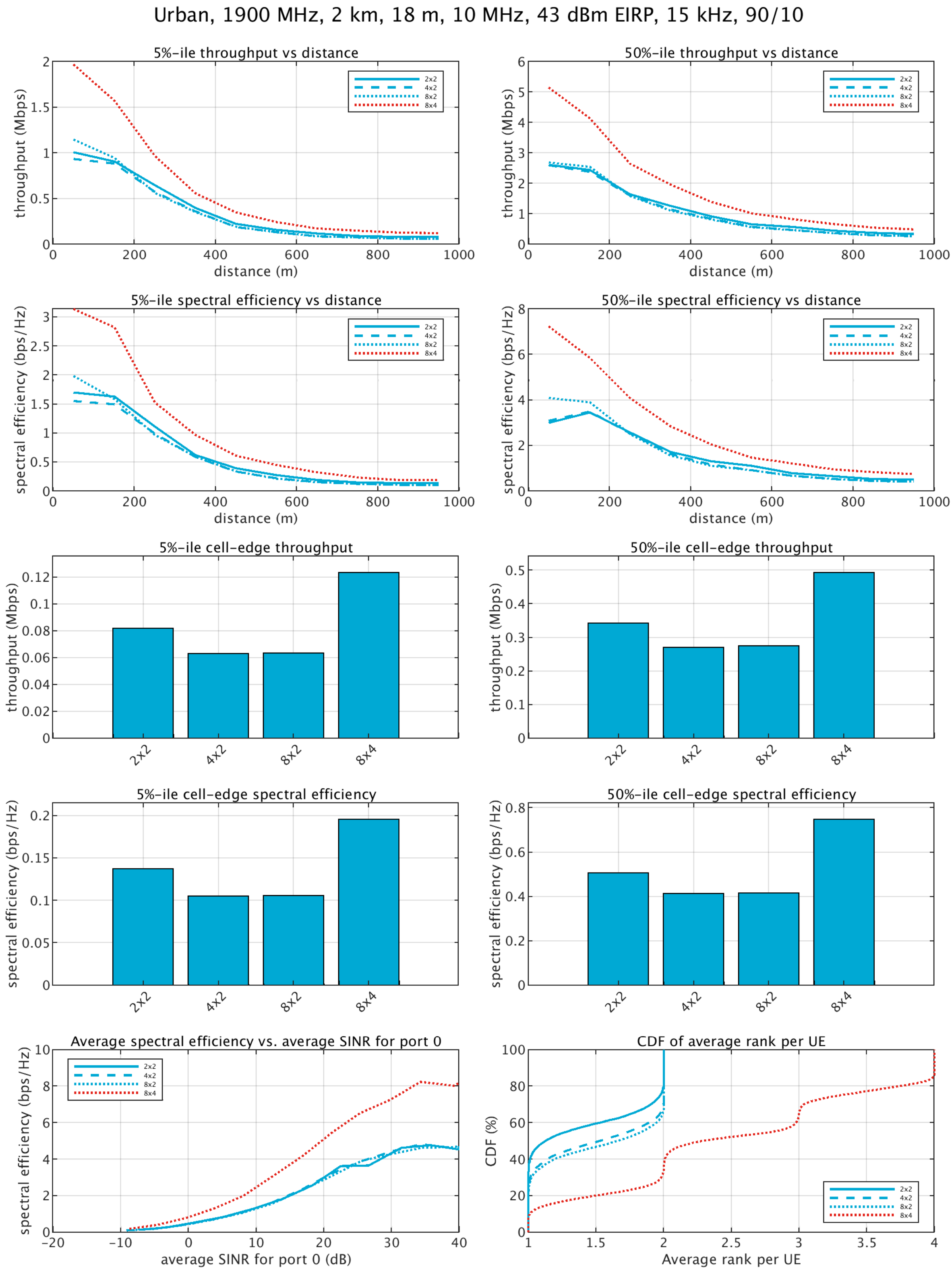


Figure A.136

Urban, 1 900 MHz, 10 MHz bandwidth, power case 1, 15 kHz SC spacing

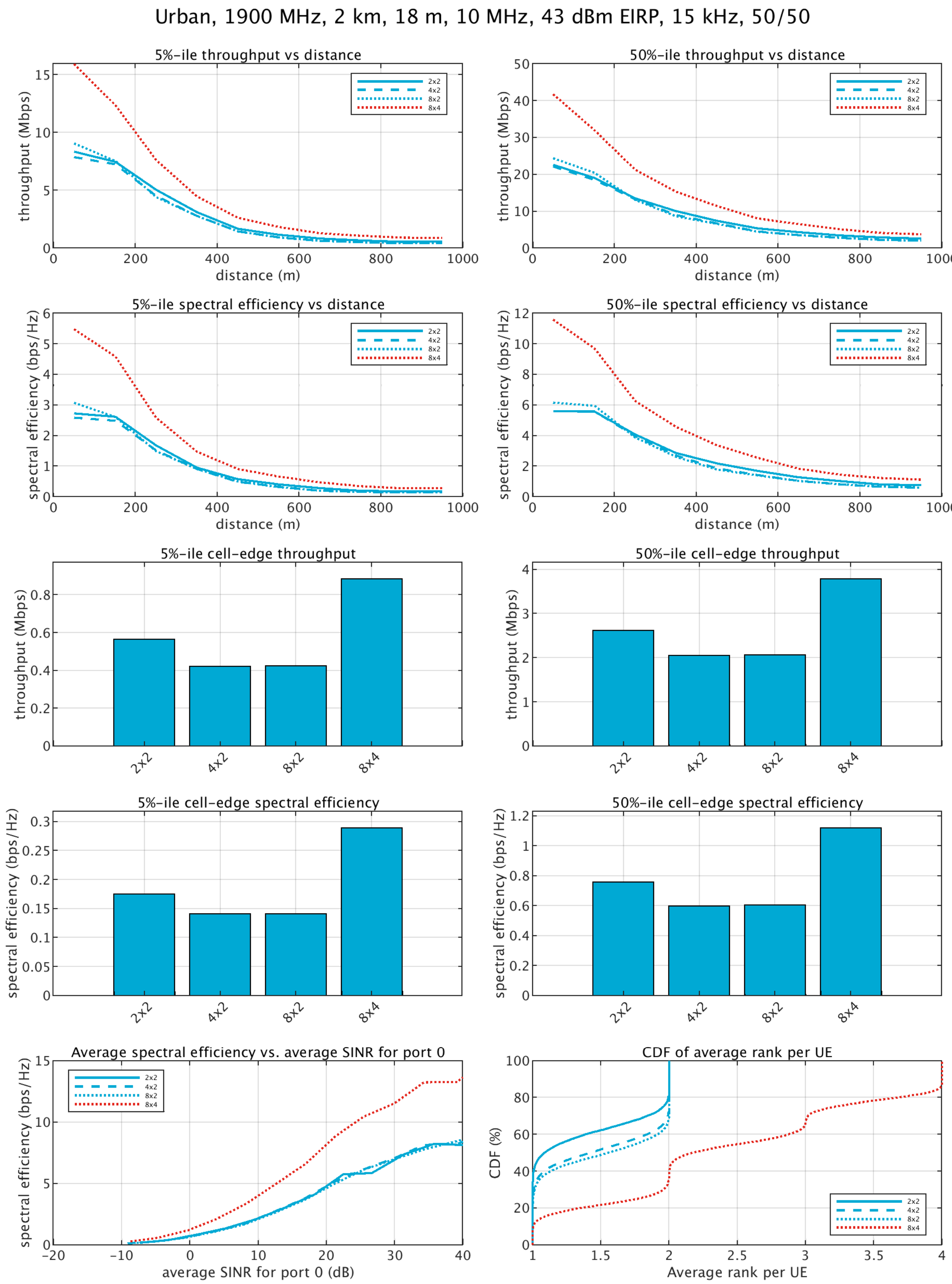


Figure A.137

Urban, 1 900 MHz, 10 MHz bandwidth, power case 2, 15 kHz SC spacing

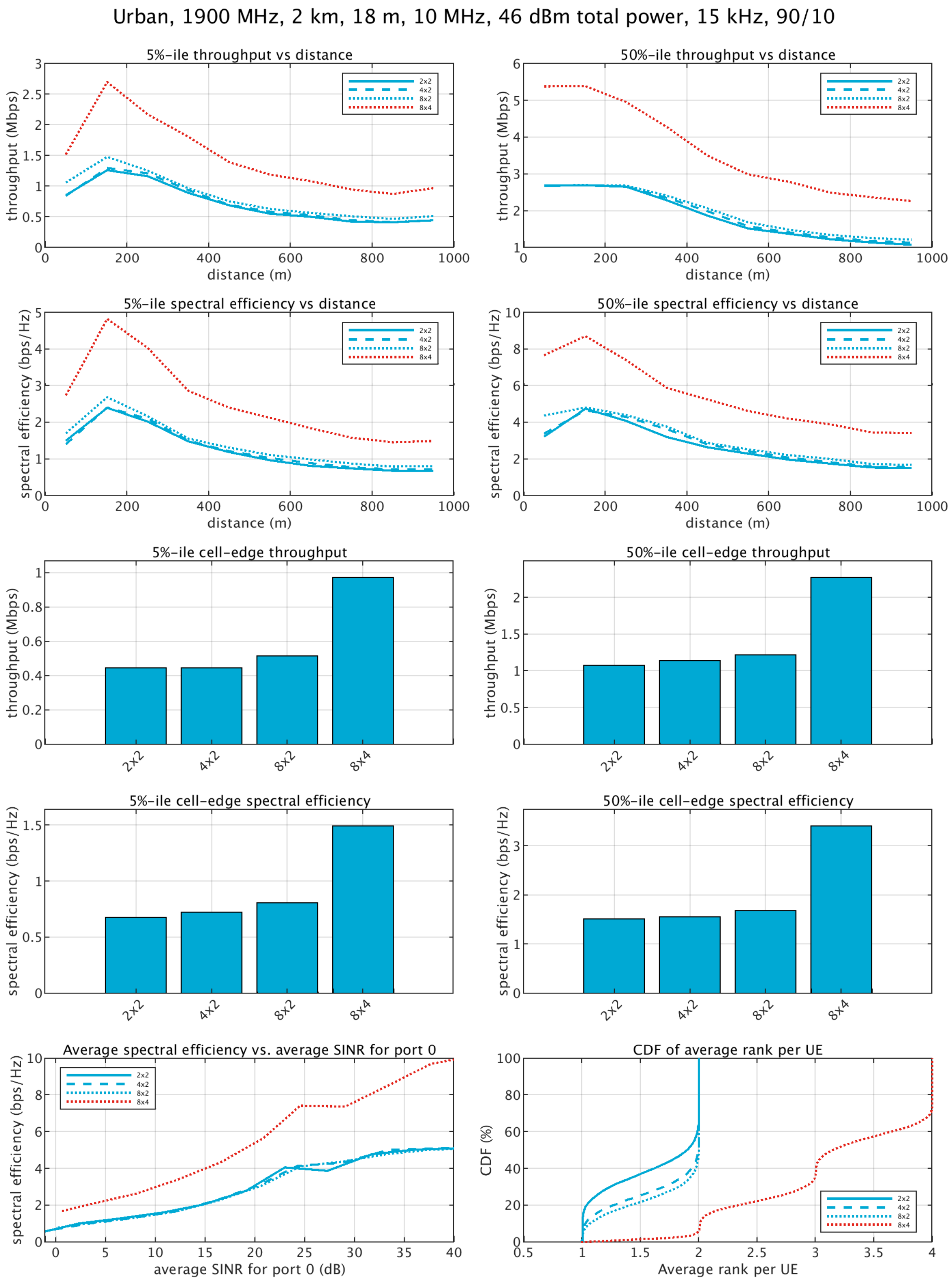


Figure A.138

A.2.2 Company B

A.2.2.1 Description, specific assumptions and parameters

In cases where the scale is not visible for the 90/10 ratios, the grid lines are placed every 200 kbit/s.

A.2.2.2 Rural, 8 KM ISD, 2 cells/site

A.2.2.2.1 Downlink, 63 dBm EIRP

DL 2x1

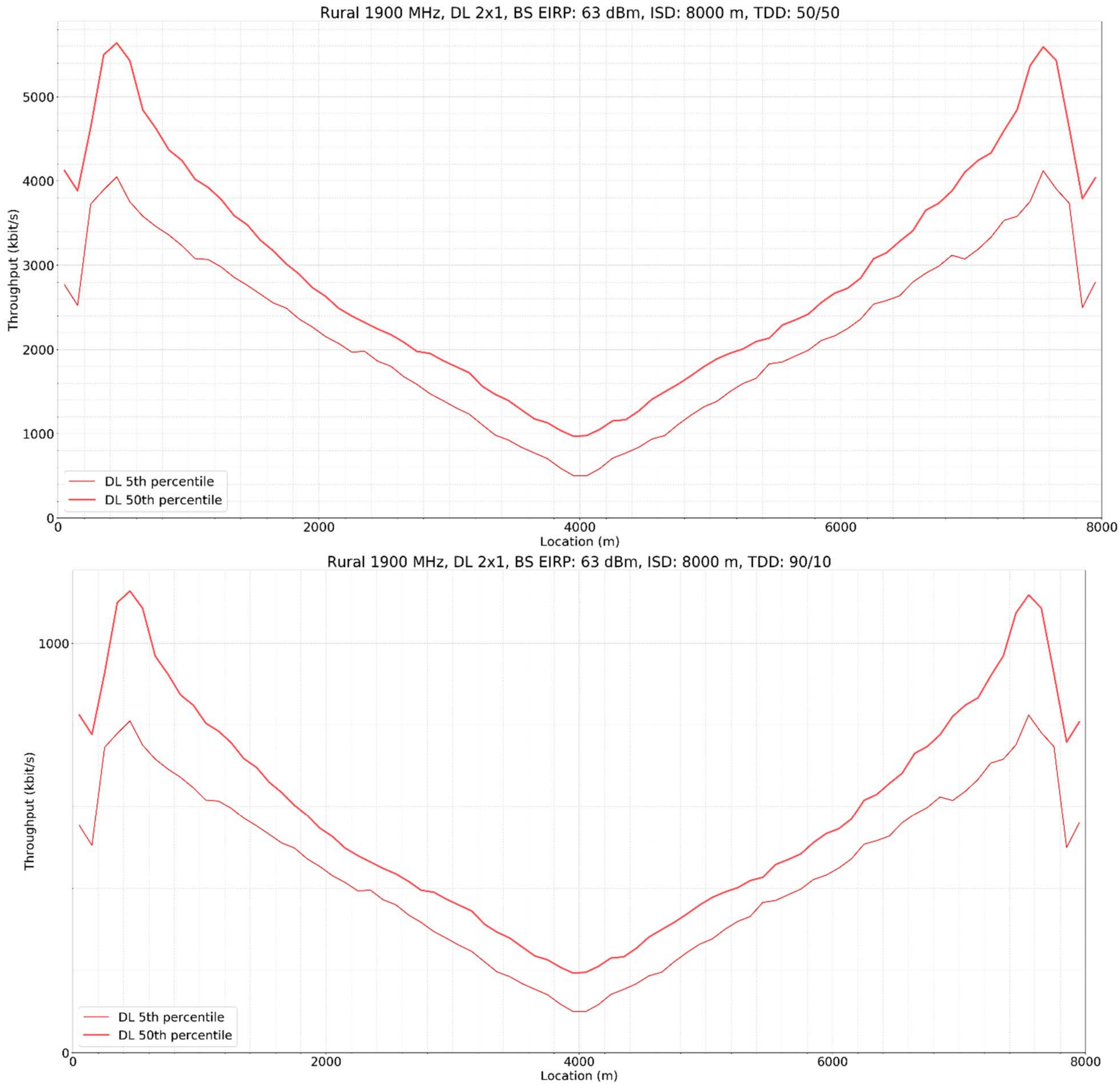


Figure A.139

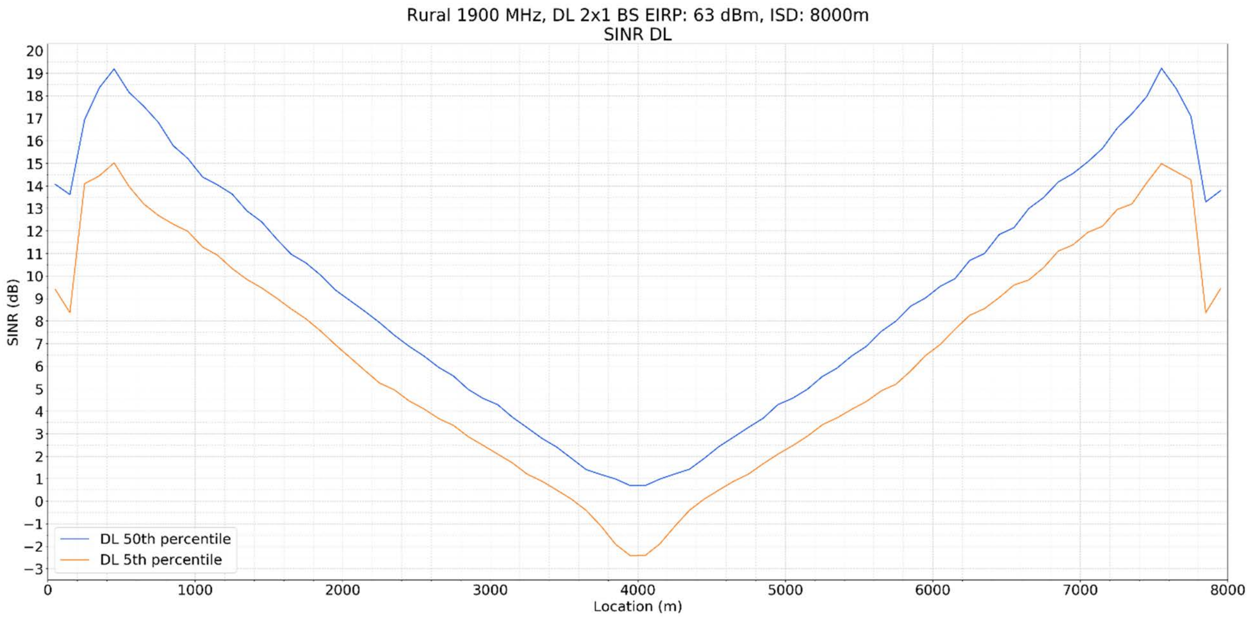


Figure A.140

Interference to noise ratio tables

	5th percentile	50th percentile	95th percentile
Full cell (DL)	-102 dBm	-86 dBm	-70 dBm
Cell centre (DL)	-82 dBm	-71 dBm	-65 dBm
Cell edge (DL)	-91 dBm	-87 dBm	-82 dBm

DL 2x2

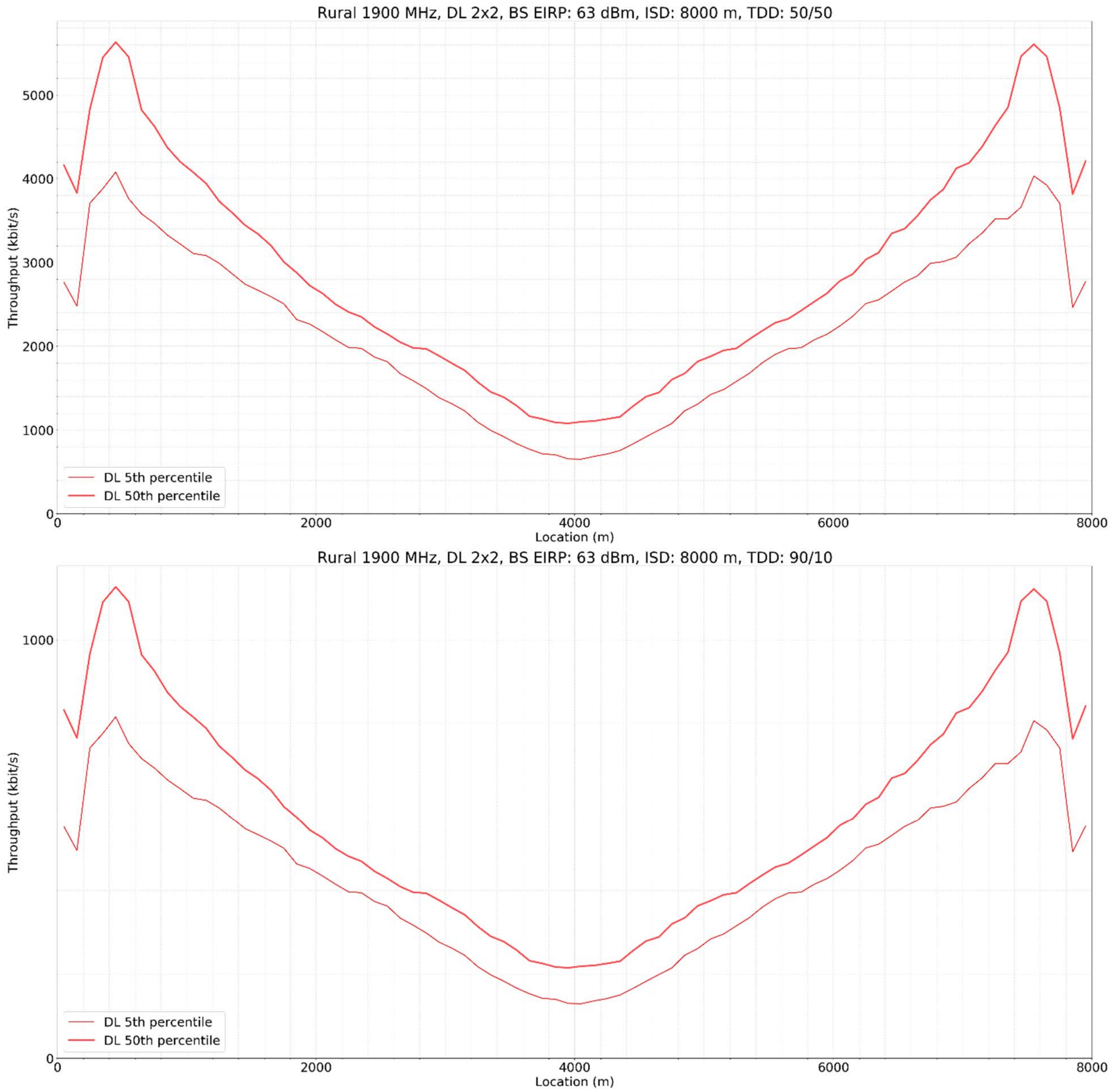


Figure A.141

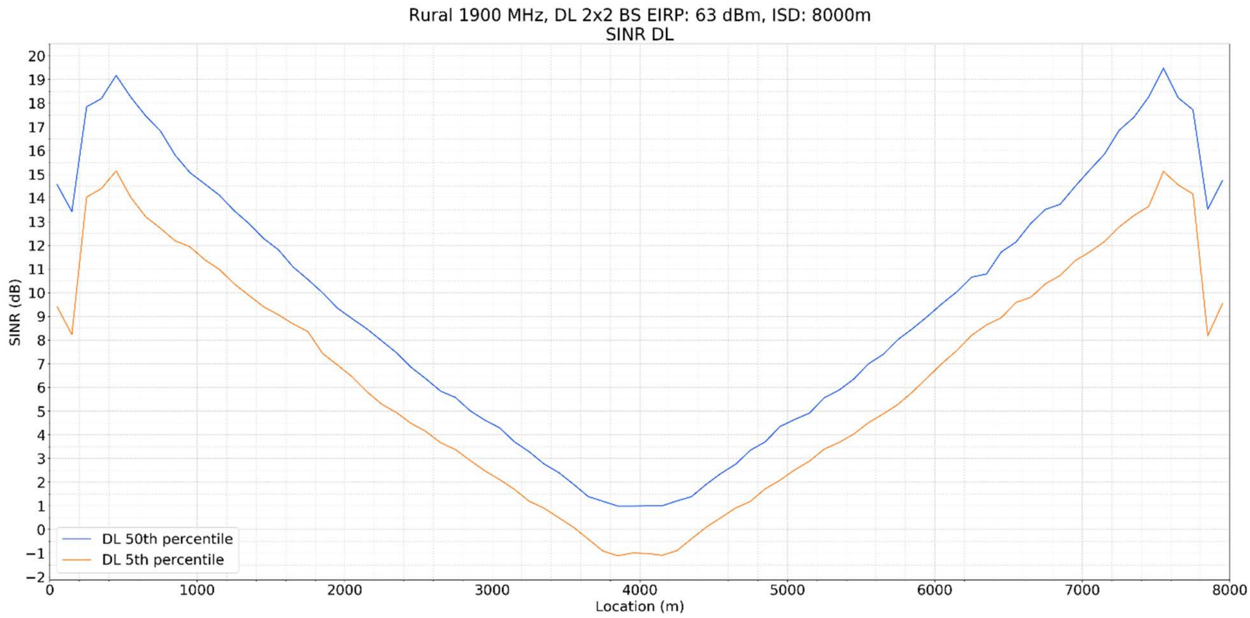


Figure A.142

Interference to noise ratio tables

	5th percentile	**50th percentile**	**95th percentile**
Full cell (DL)	-105 dBm	-87 dBm	-71 dBm
Cell centre (DL)	-81 dBm	-72 dBm	-66 dBm
Cell edge (DL)	-92 dBm	-88 dBm	-82 dBm

DL 4x1

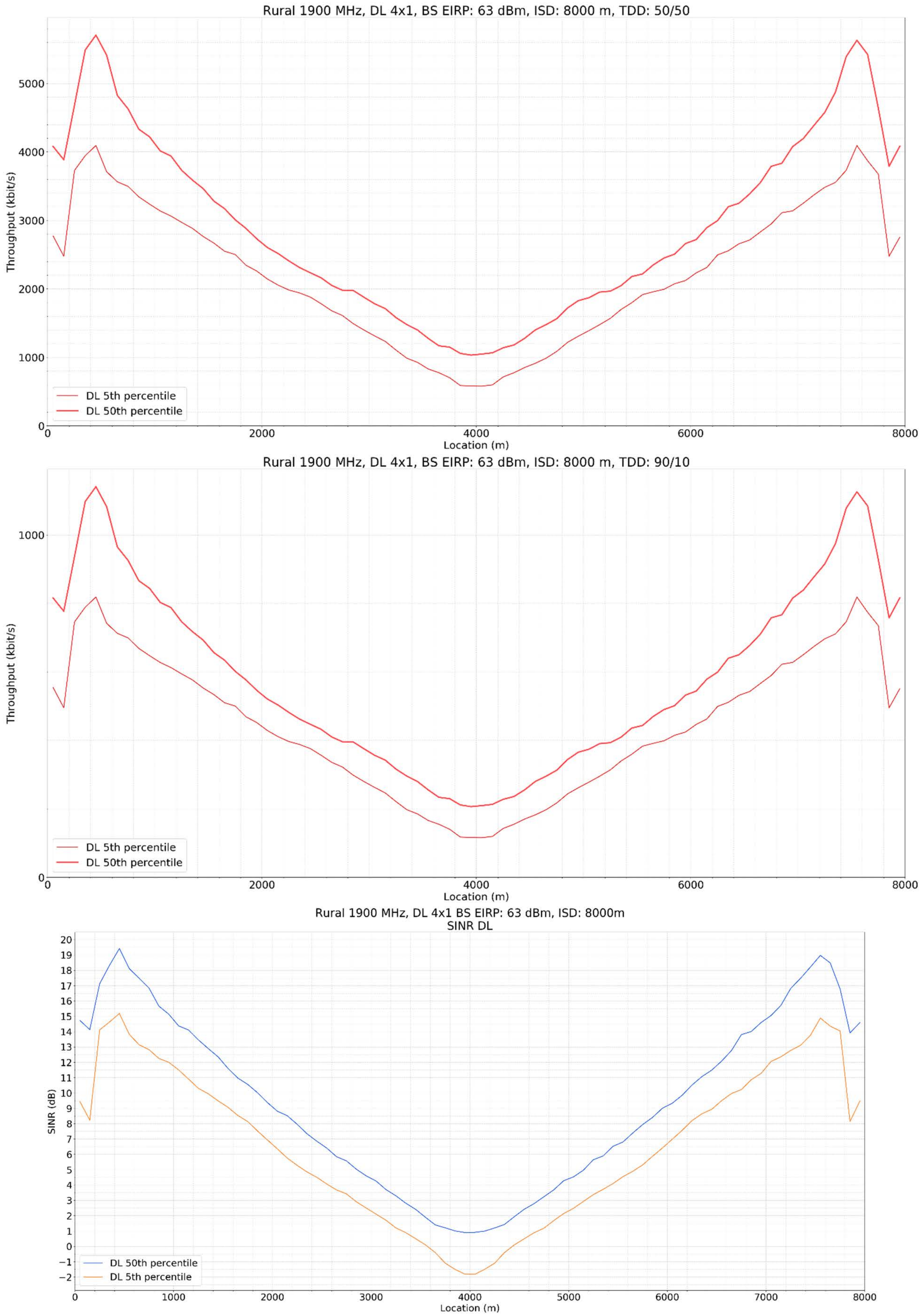


Figure A.143

Interference to noise ratio tables

	5th percentile	50th percentile	95th percentile
Full cell (DL)	-100 dBm	-84 dBm	-69 dBm
Cell centre (DL)	-79 dBm	-72 dBm	-67 dBm
Cell edge (DL)	-90 dBm	-85 dBm	-80 dBm

DL 4x2

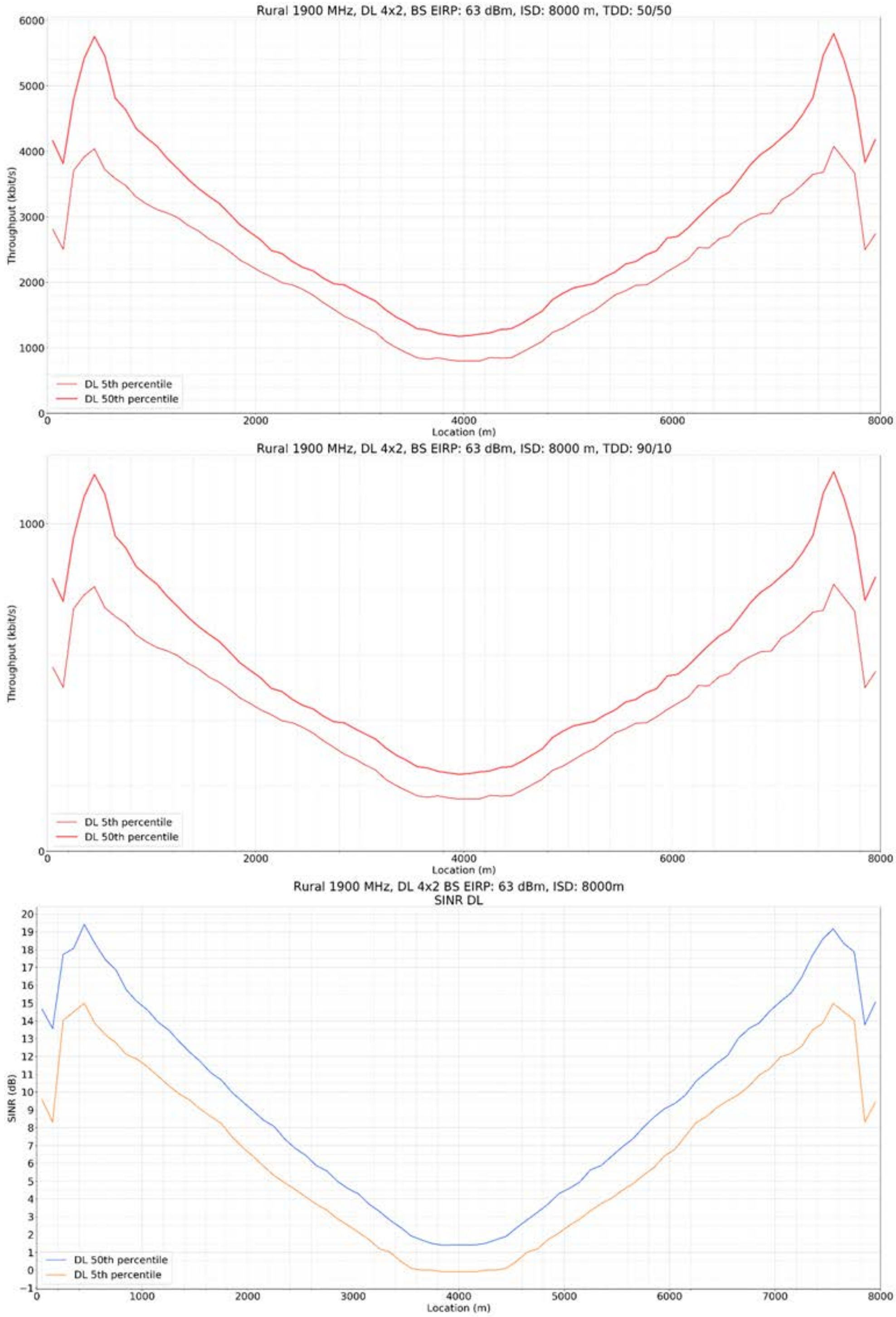


Figure A.144

Interference to noise ratio tables

	5th percentile	50th percentile	95th percentile
Full cell (DL)	-103 dBm	-85 dBm	-70 dBm
Cell centre (DL)	-80 dBm	-73 dBm	-66 dBm
Cell edge (DL)	-91 dBm	-86 dBm	-81 dBm

DL 8x1

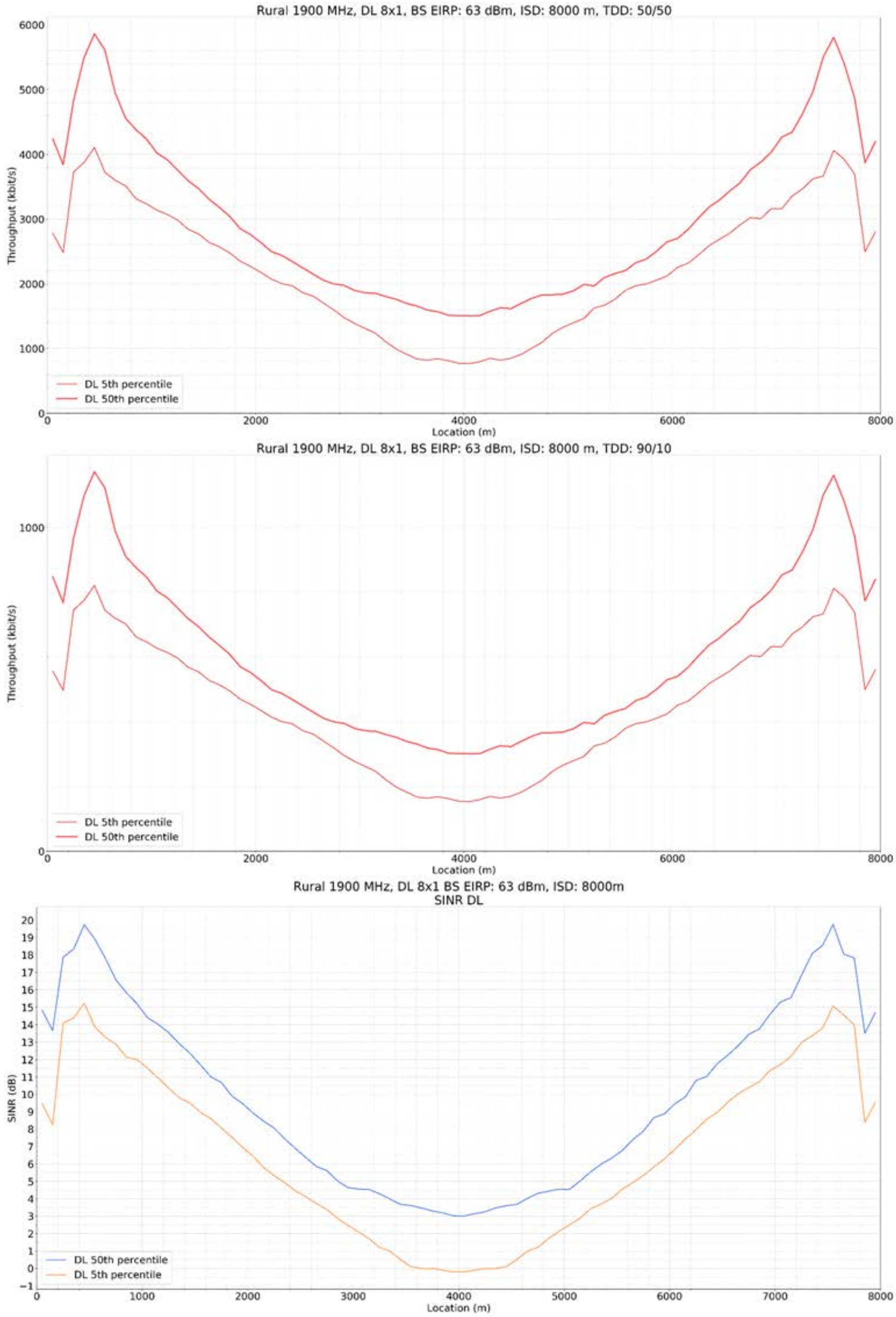


Figure A.145

Interference to noise ratio tables

	5th percentile	50th percentile	95th percentile
Full cell (DL)	-99 dBm	-83 dBm	-69 dBm
Cell centre (DL)	-77 dBm	-71 dBm	-65 dBm
Cell edge (DL)	-88 dBm	-83 dBm	-78 dBm

DL 8x2

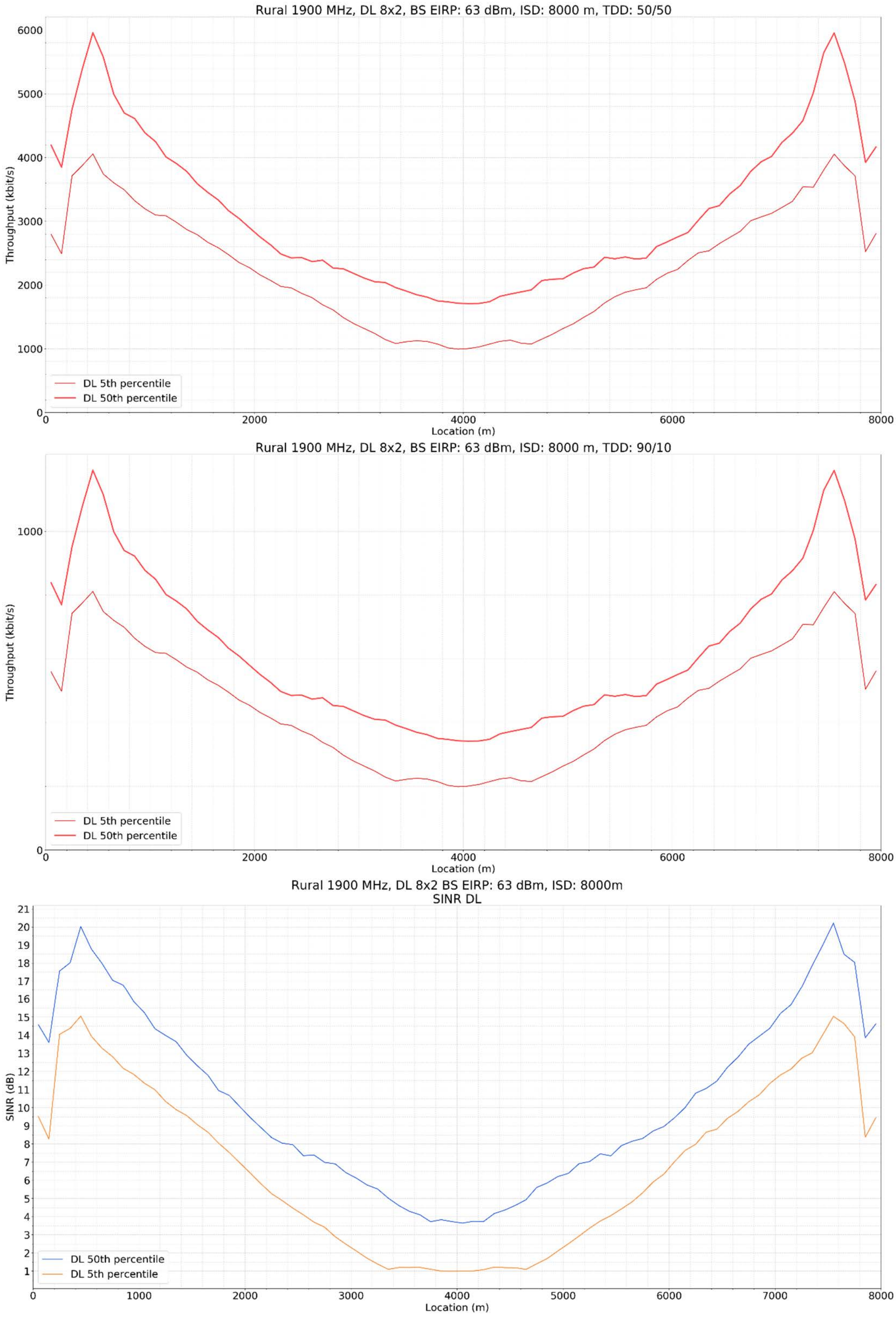


Figure A.146

Interference to noise ratio tables

	5th percentile	50th percentile	95th percentile
Full cell (DL)	-102 dBm	-84 dBm	-70 dBm
Cell centre (DL)	-81 dBm	-74 dBm	-67 dBm
Cell edge (DL)	-90 dBm	-85 dBm	-80 dBm

A.2.2.2.1 Downlink, 40 dBm EIRP

DL 2x1

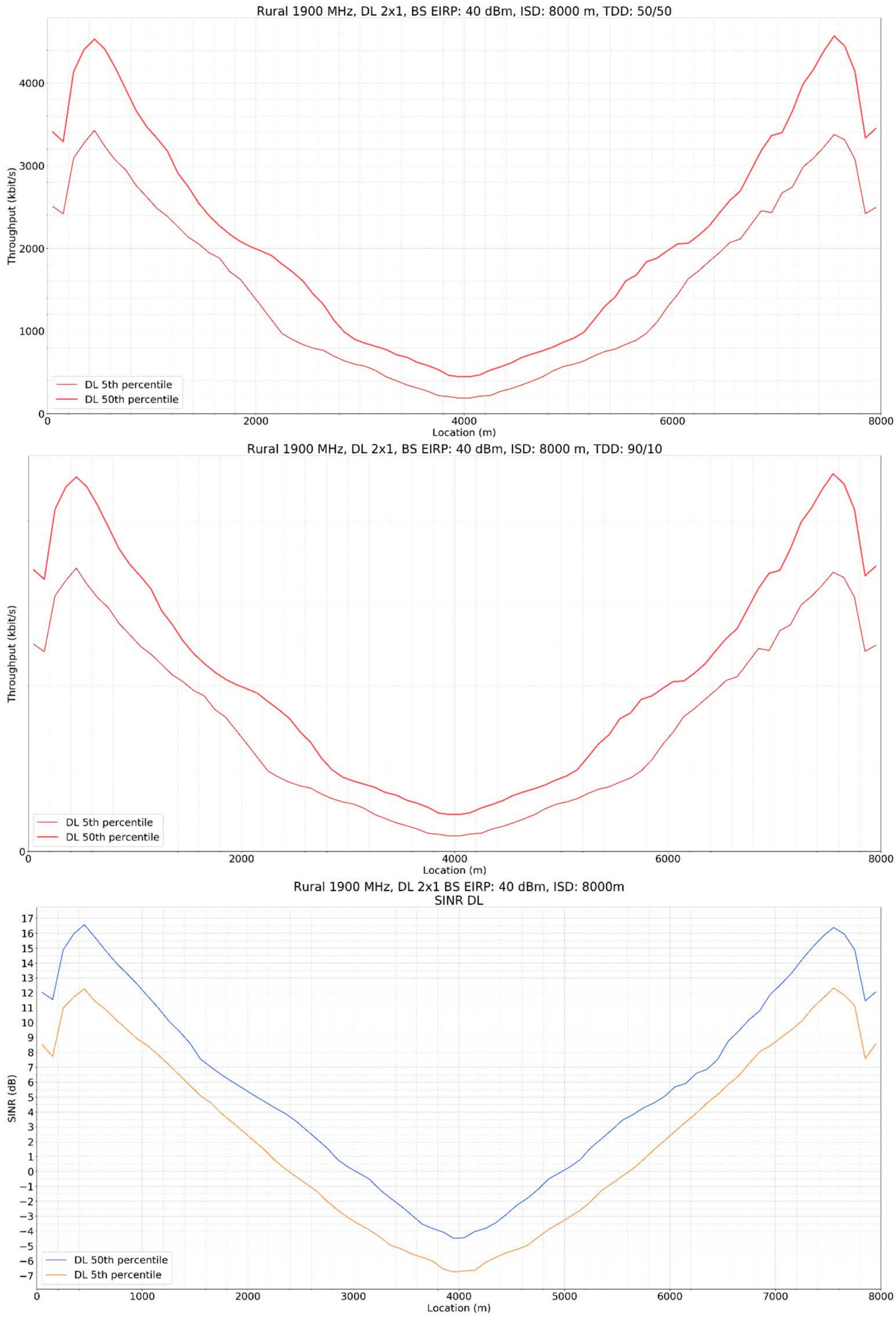


Figure A.147

Interference to noise ratio tables

	5th percentile	50th percentile	95th percentile
Full cell (DL)	-123 dBm	-109 dBm	-93 dBm
Cell centre (DL)	-102 dBm	-95 dBm	-88 dBm
Cell edge (DL)	-114 dBm	-110 dBm	-106 dBm

DL 2x2

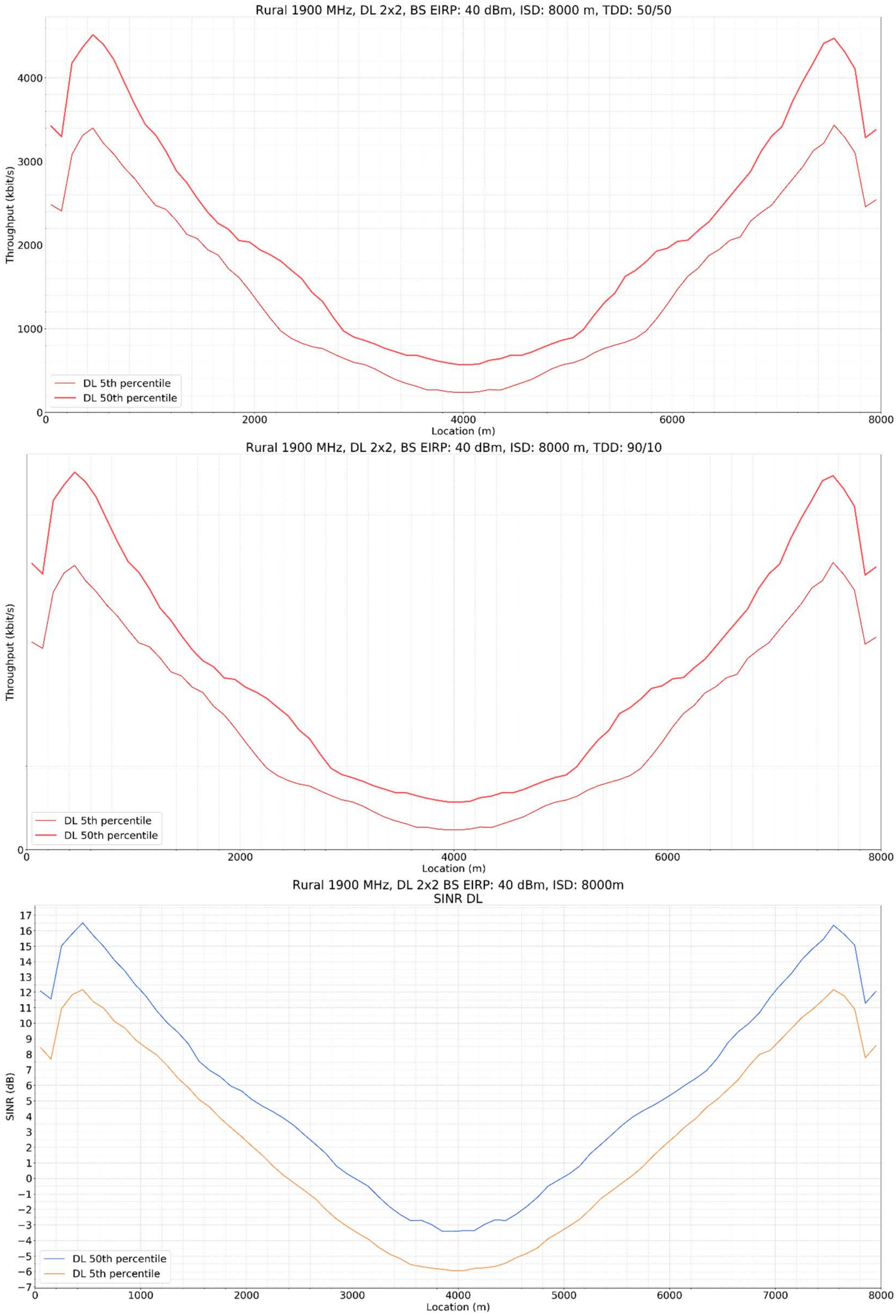


Figure A.148

Interference to noise ratio tables

	5th percentile	50th percentile	95th percentile
Full cell (DL)	-124 dBm	-110 dBm	-94 dBm
Cell centre (DL)	-102 dBm	-96 dBm	-89 dBm
Cell edge (DL)	-114 dBm	-110 dBm	-105 dBm

DL 4x1

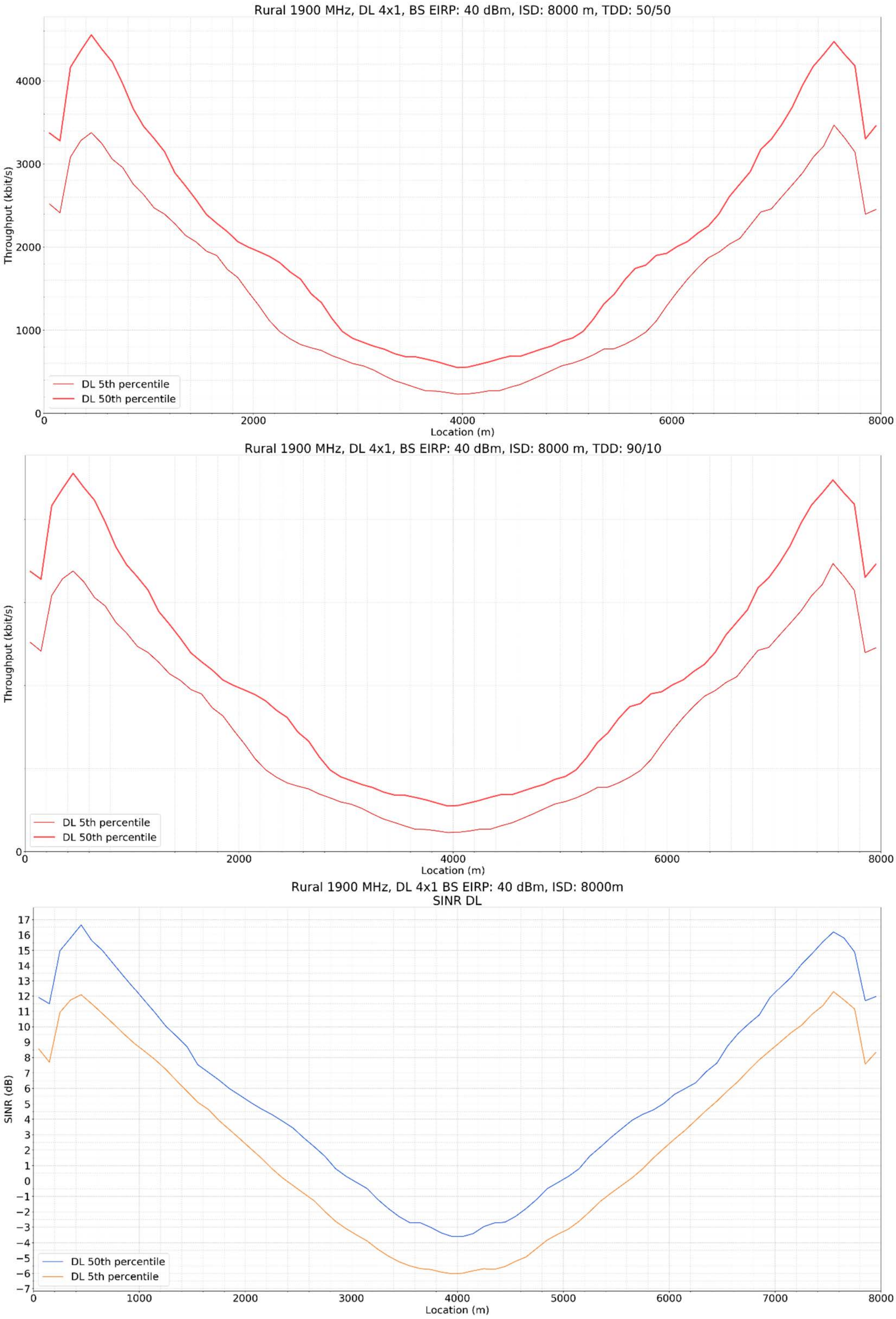


Figure A.149

Interference to noise ratio tables

	5th percentile	50th percentile	95th percentile
Full cell (DL)	-122 dBm	-107 dBm	-93 dBm
Cell centre (DL)	-102 dBm	-95 dBm	-90 dBm
Cell edge (DL)	-111 dBm	-107 dBm	-102 dBm

DL 4x2

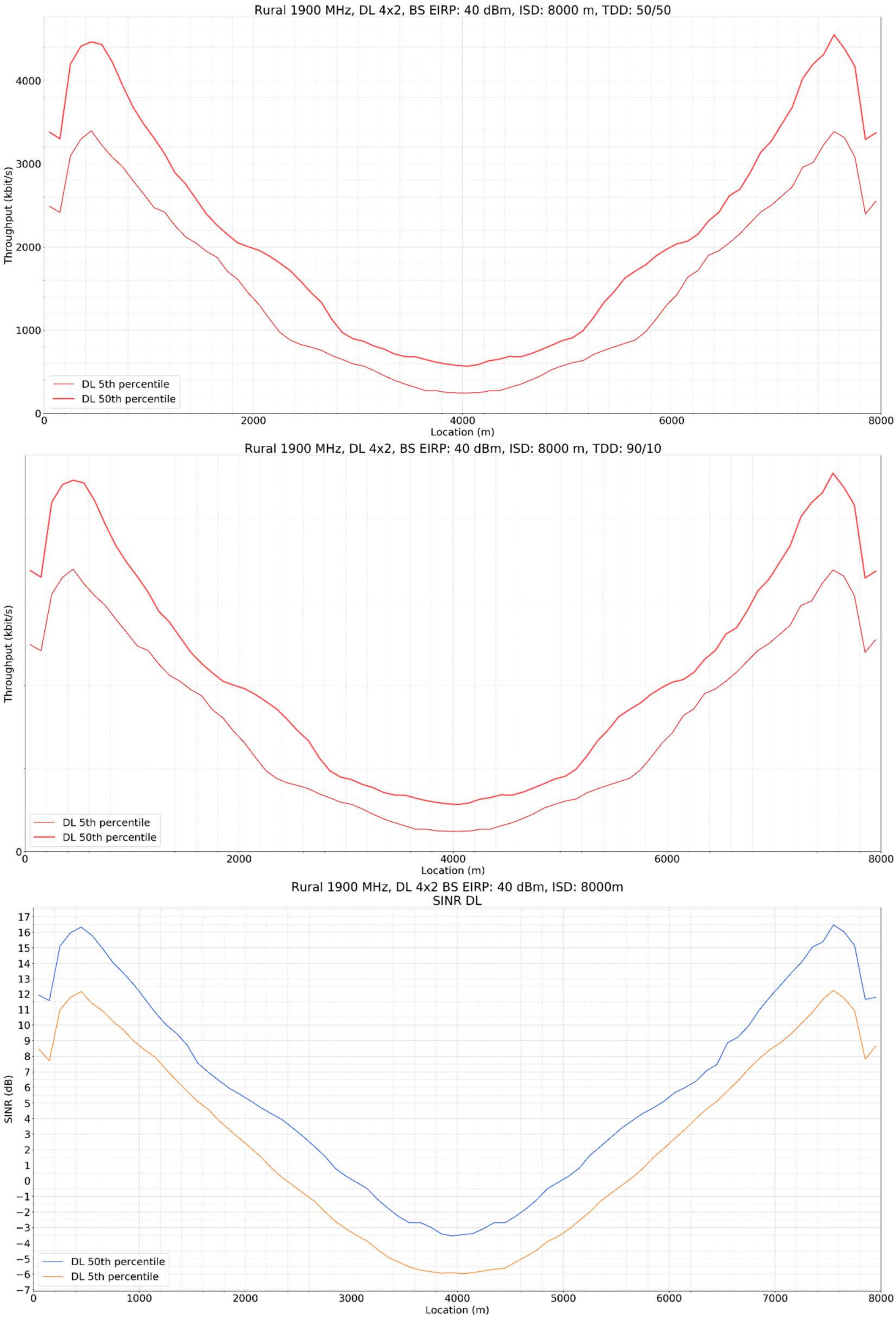


Figure A.150

Interference to noise ratio tables

	5th percentile	50th percentile	95th percentile
Full cell (DL)	-123 dBm	-108 dBm	-93 dBm
Cell centre (DL)	-103 dBm	-97 dBm	-91 dBm
Cell edge (DL)	-112 dBm	-108 dBm	-103 dBm

DL 8x1

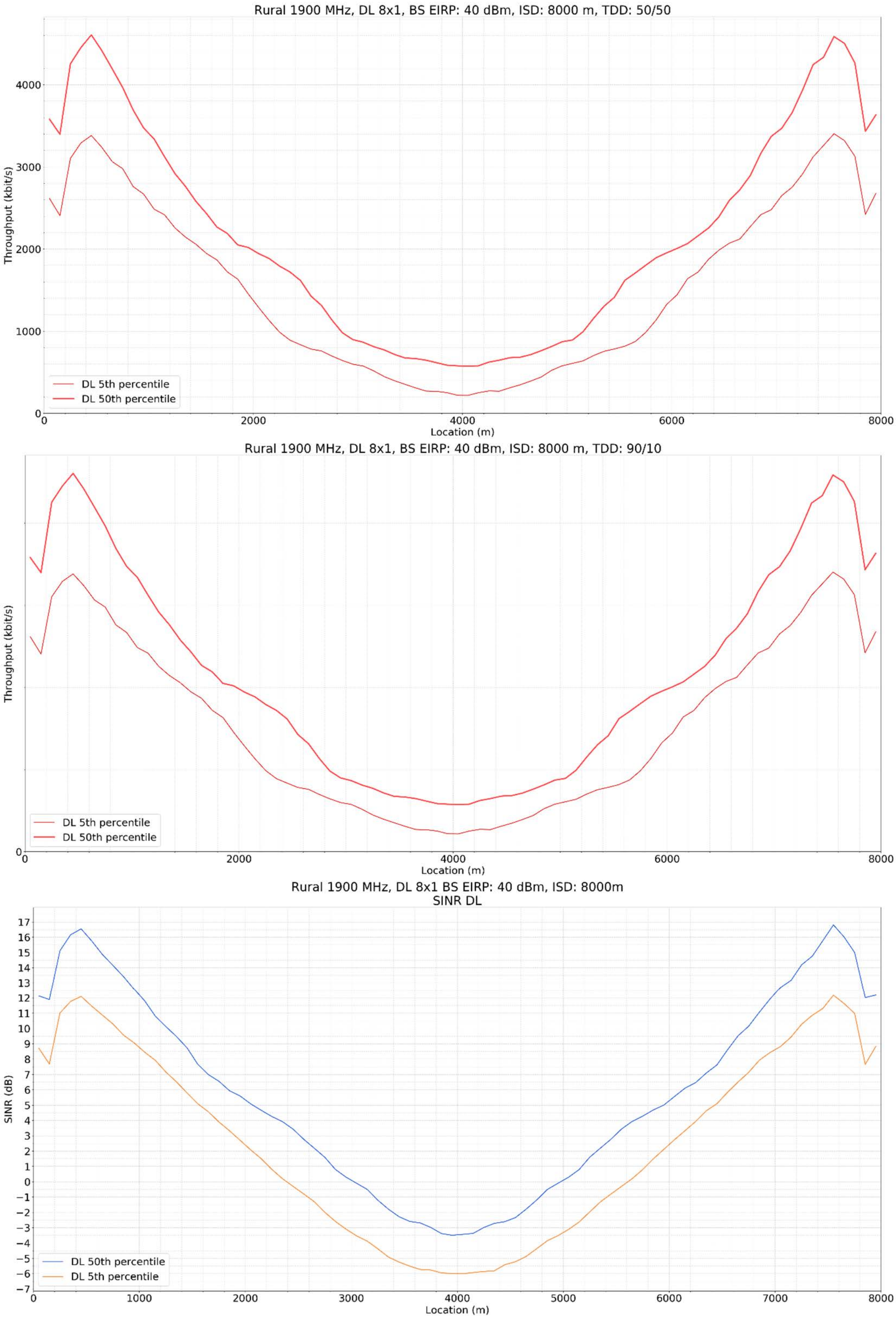


Figure A.151

Interference to noise ratio tables

	5th percentile	50th percentile	95th percentile
Full cell (DL)	-121 dBm	-106 dBm	-92 dBm
Cell centre (DL)	-101 dBm	-95 dBm	-89 dBm
Cell edge (DL)	-110 dBm	-106 dBm	-102 dBm

DL 8x2

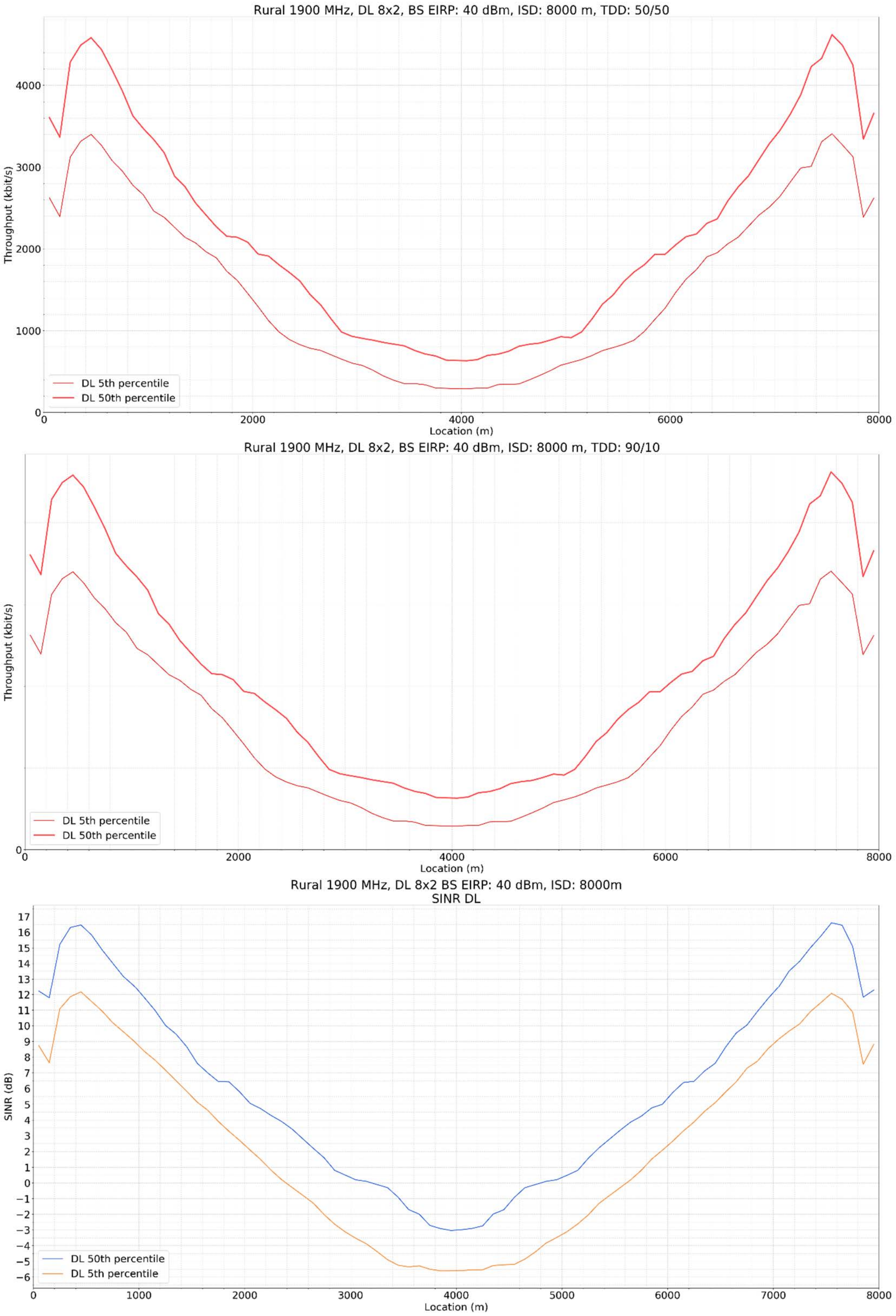


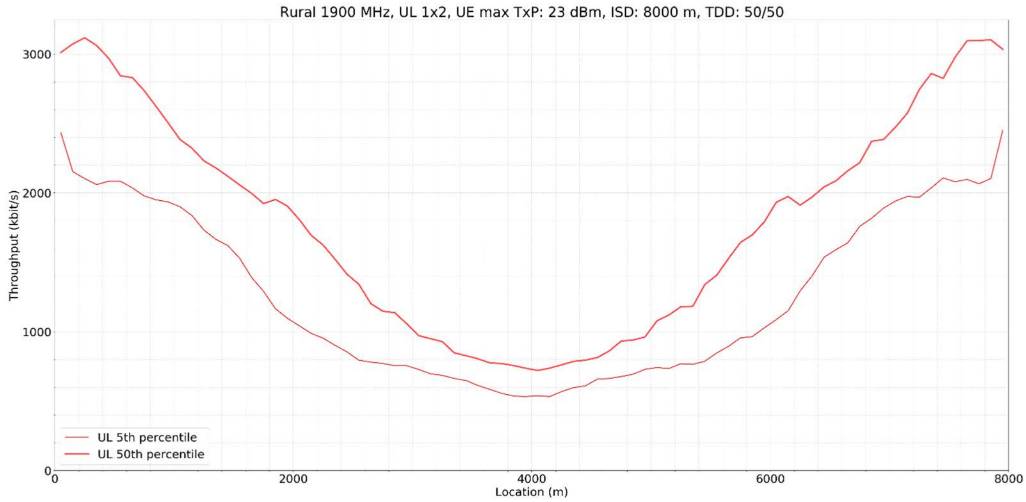
Figure A.152

Interference to noise ratio tables

	5th percentile	50th percentile	95th percentile
Full cell (DL)	-123 dBm	-107 dBm	-93 dBm
Cell centre (DL)	-105 dBm	-97 dBm	-90 dBm
Cell edge (DL)	-112 dBm	-108 dBm	-102 dBm

A.2.2.2.3 Uplink, 23 dBm max transmit power

UL 1x2



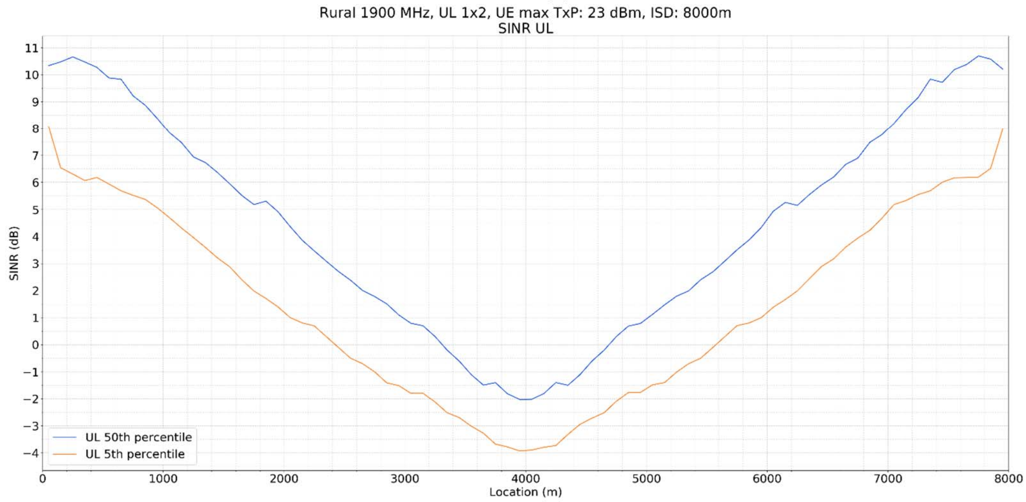


Figure A.153

Interference to noise ratio tables

	5th percentile	50th percentile	95th percentile
Full cell (UL)	-118 dBm	-103 dBm	-85 dBm
Cell centre (UL)	-109 dBm	-104 dBm	-101 dBm
Cell edge (UL)	-103 dBm	-99 dBm	-96 dBm

UL 2x2

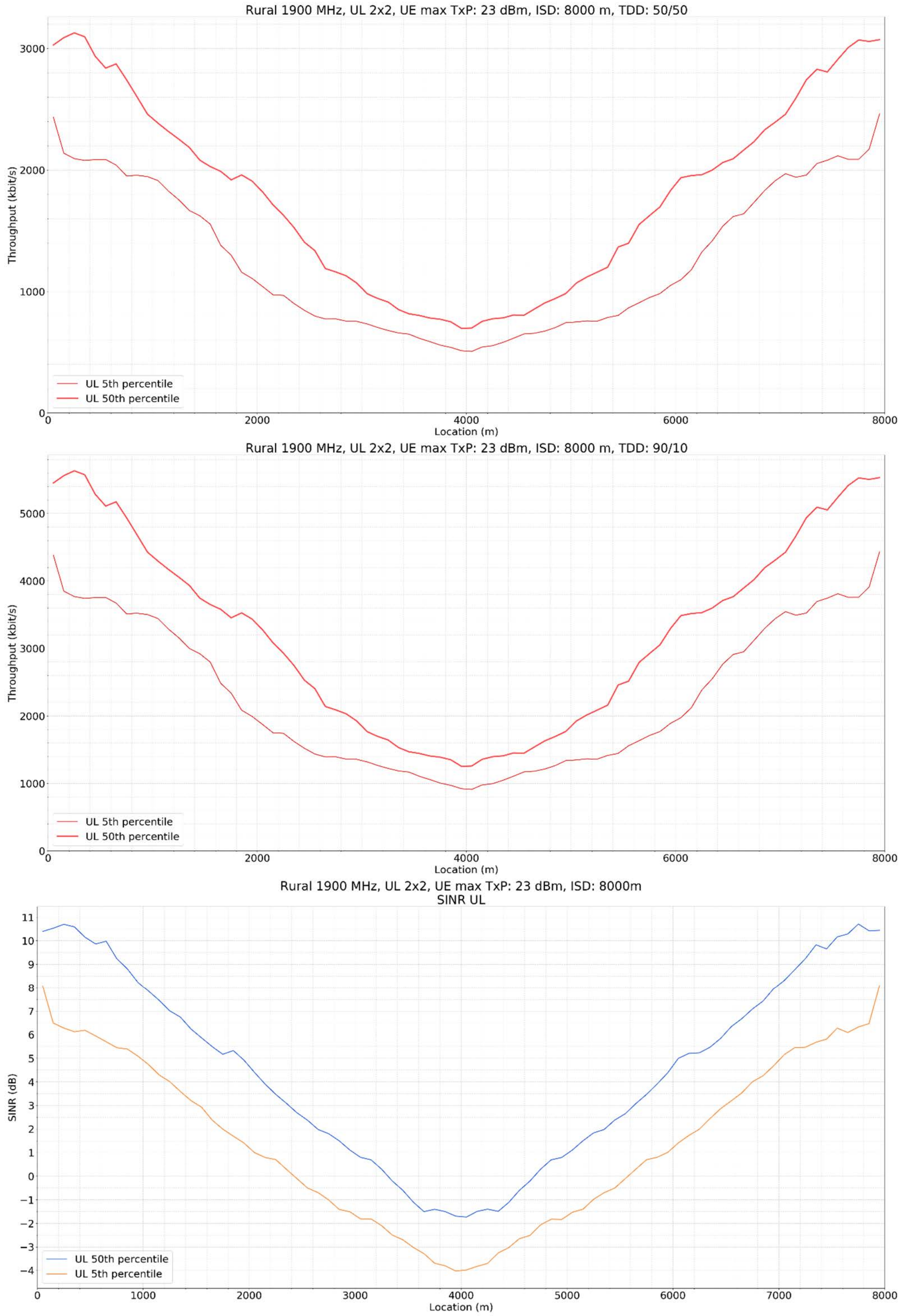


Figure A.154

Interference to noise ratio tables

	5th percentile	50th percentile	95th percentile
Full cell (UL)	-118 dBm	-103 dBm	-86 dBm
Cell centre (UL)	-108 dBm	-104 dBm	-101 dBm
Cell edge (UL)	-102 dBm	-100 dBm	-97 dBm

UL 1x4

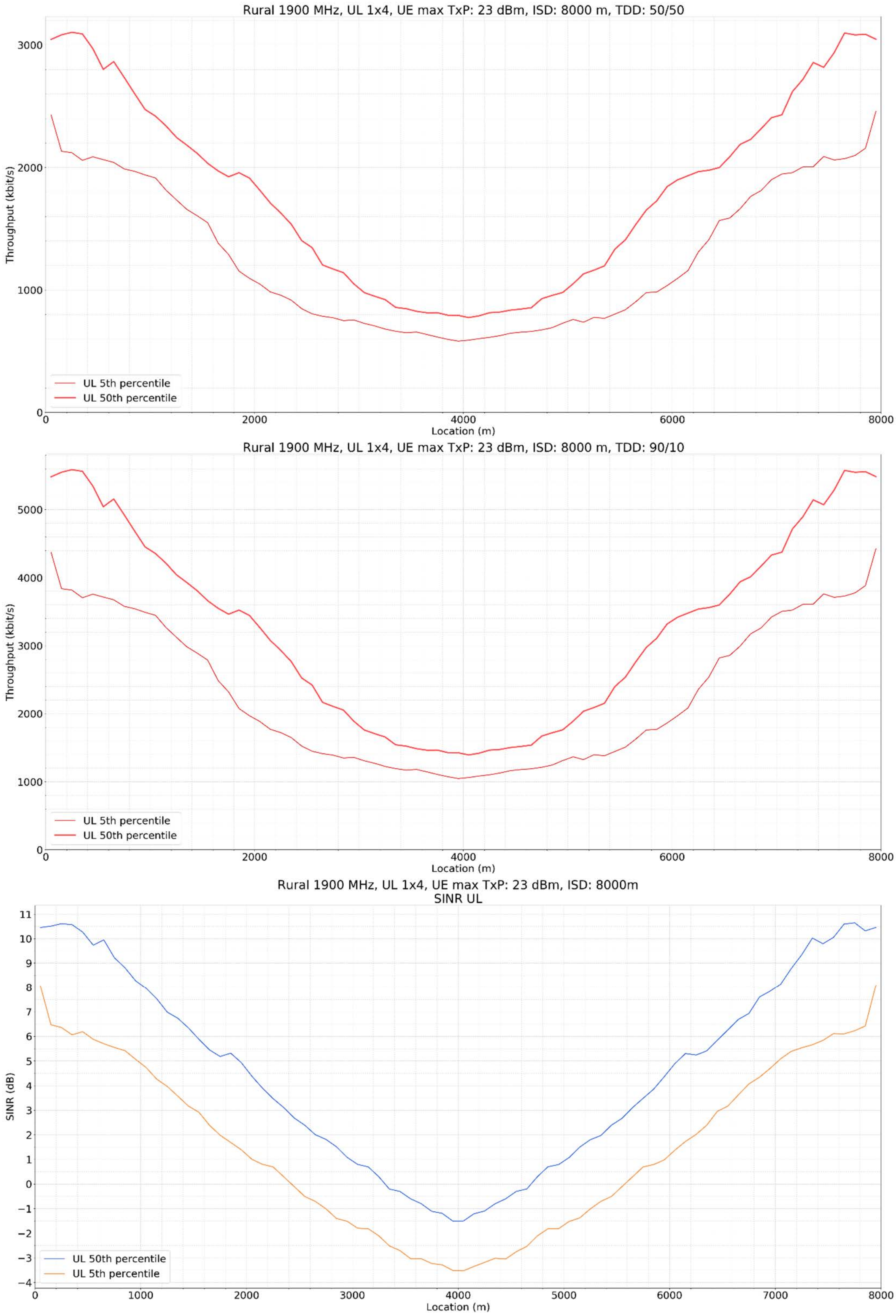


Figure A.155

Interference to noise ratio tables

	5th percentile	50th percentile	95th percentile
Full cell (UL)	-116 dBm	-101 dBm	-84 dBm
Cell centre (UL)	-112 dBm	-105 dBm	-99 dBm
Cell edge (UL)	-100 dBm	-96 dBm	-94 dBm

UL 2x4

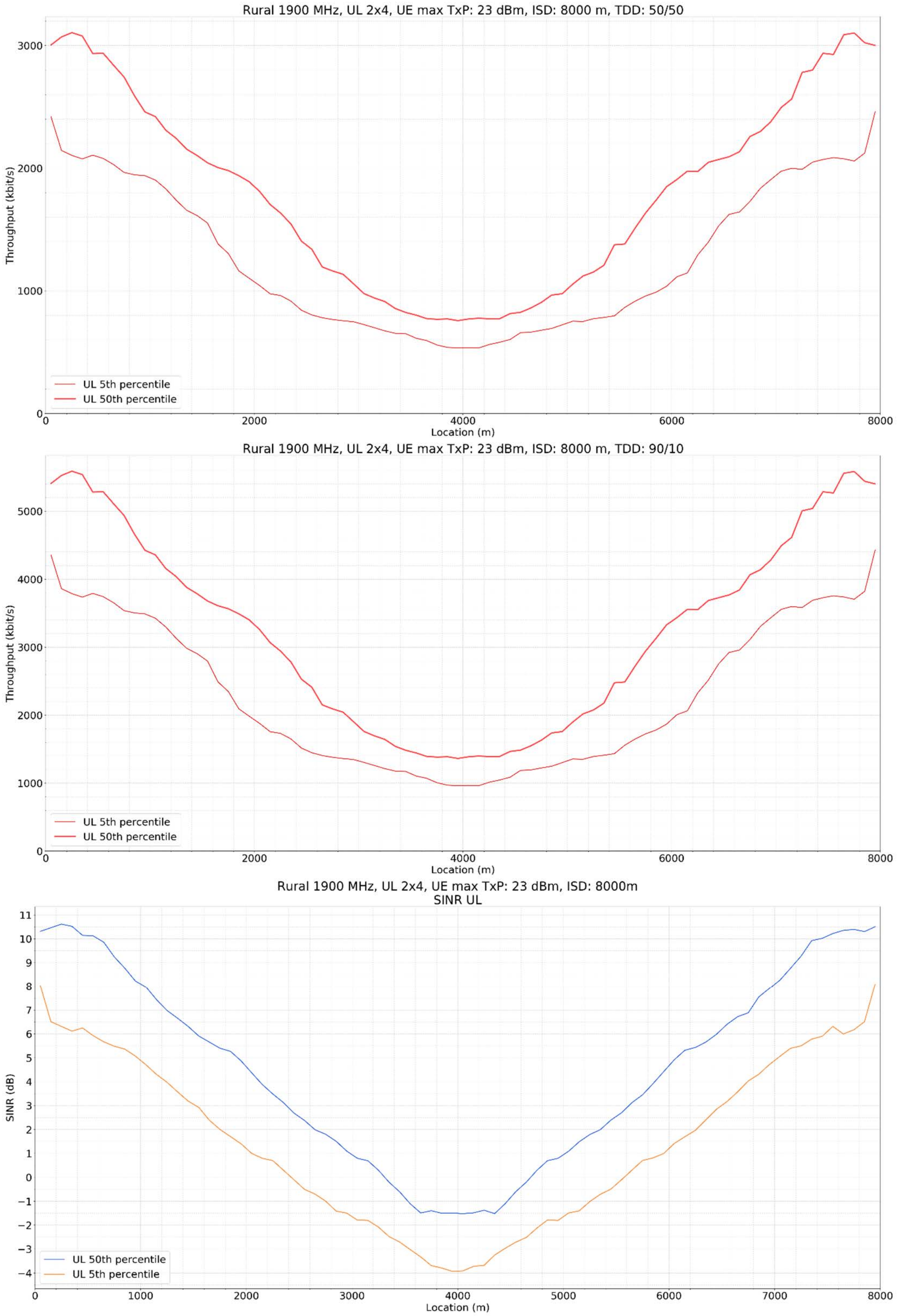


Figure A.156

Interference to noise ratio tables

	5th percentile	50th percentile	95th percentile
Full cell (UL)	-116 dBm	-101 dBm	-84 dBm
Cell centre (UL)	-112 dBm	-104 dBm	-99 dBm
Cell edge (UL)	-100 dBm	-97 dBm	-94 dBm

UL 1x8

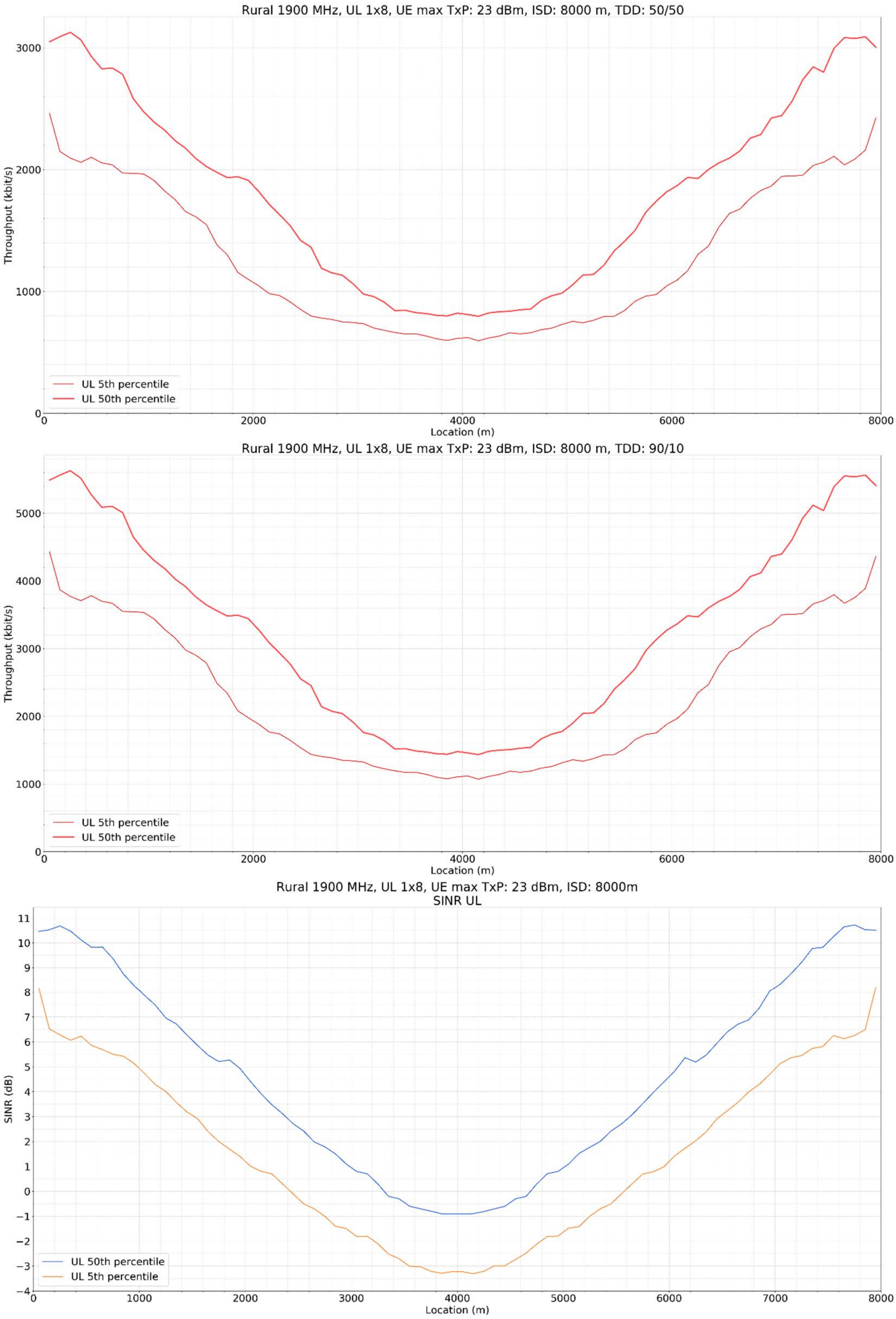


Figure A.157

Interference to noise ratio tables

	5th percentile	50th percentile	95th percentile
Full cell (UL)	-117 dBm	-100 dBm	-82 dBm
Cell centre (UL)	-112 dBm	-106 dBm	-97 dBm
Cell edge (UL)	-98 dBm	-95 dBm	-91 dBm

UL 2x8

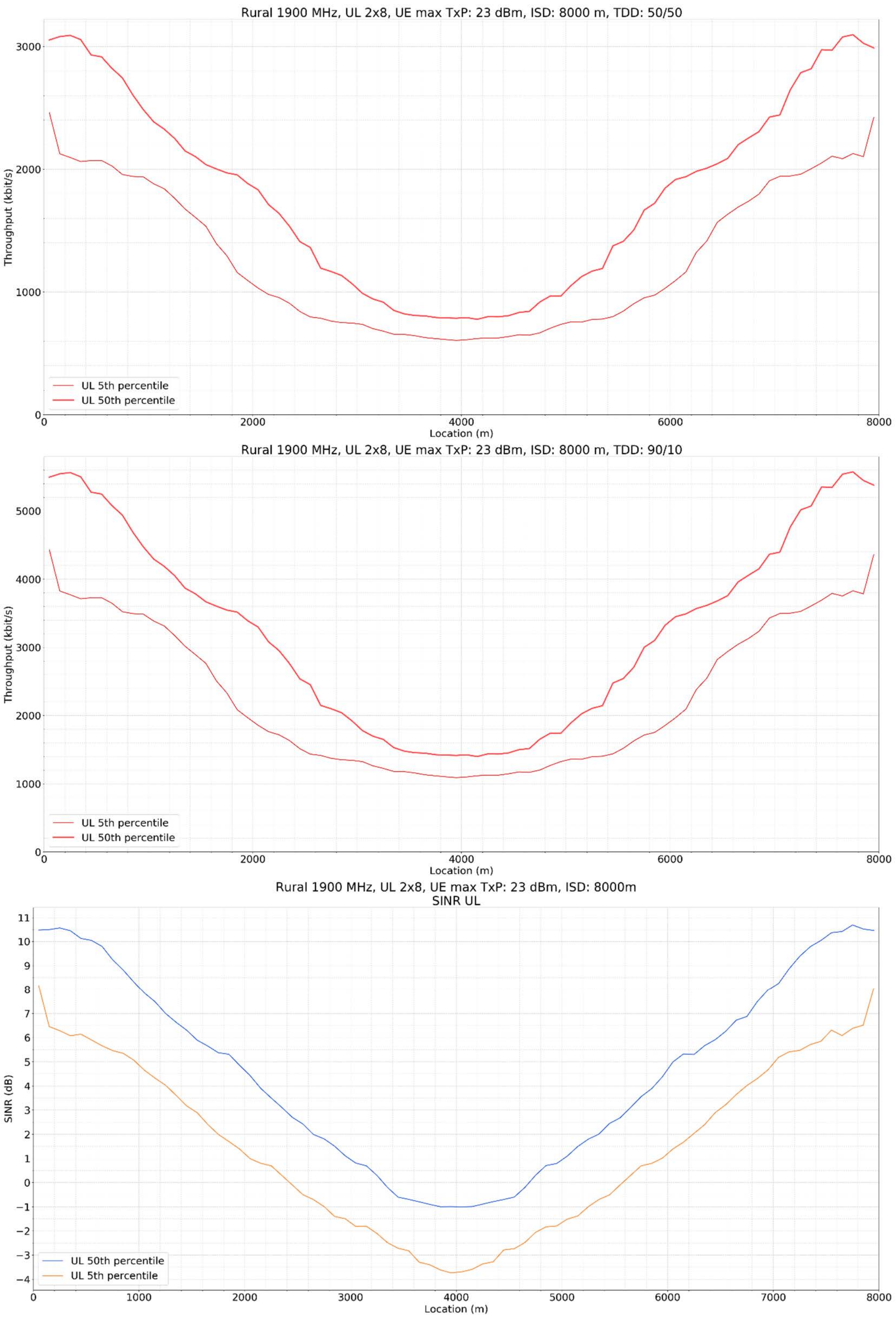


Figure A.158

Interference to noise ratio tables

	5th percentile	50th percentile	95th percentile
Full cell (UL)	-117 dBm	-100 dBm	-83 dBm
Cell centre (UL)	-113 dBm	-106 dBm	-96 dBm
Cell edge (UL)	-98 dBm	-95 dBm	-92 dBm

A.2.2.2.4 Uplink, 31 dBm max transmit power

UL 1x2

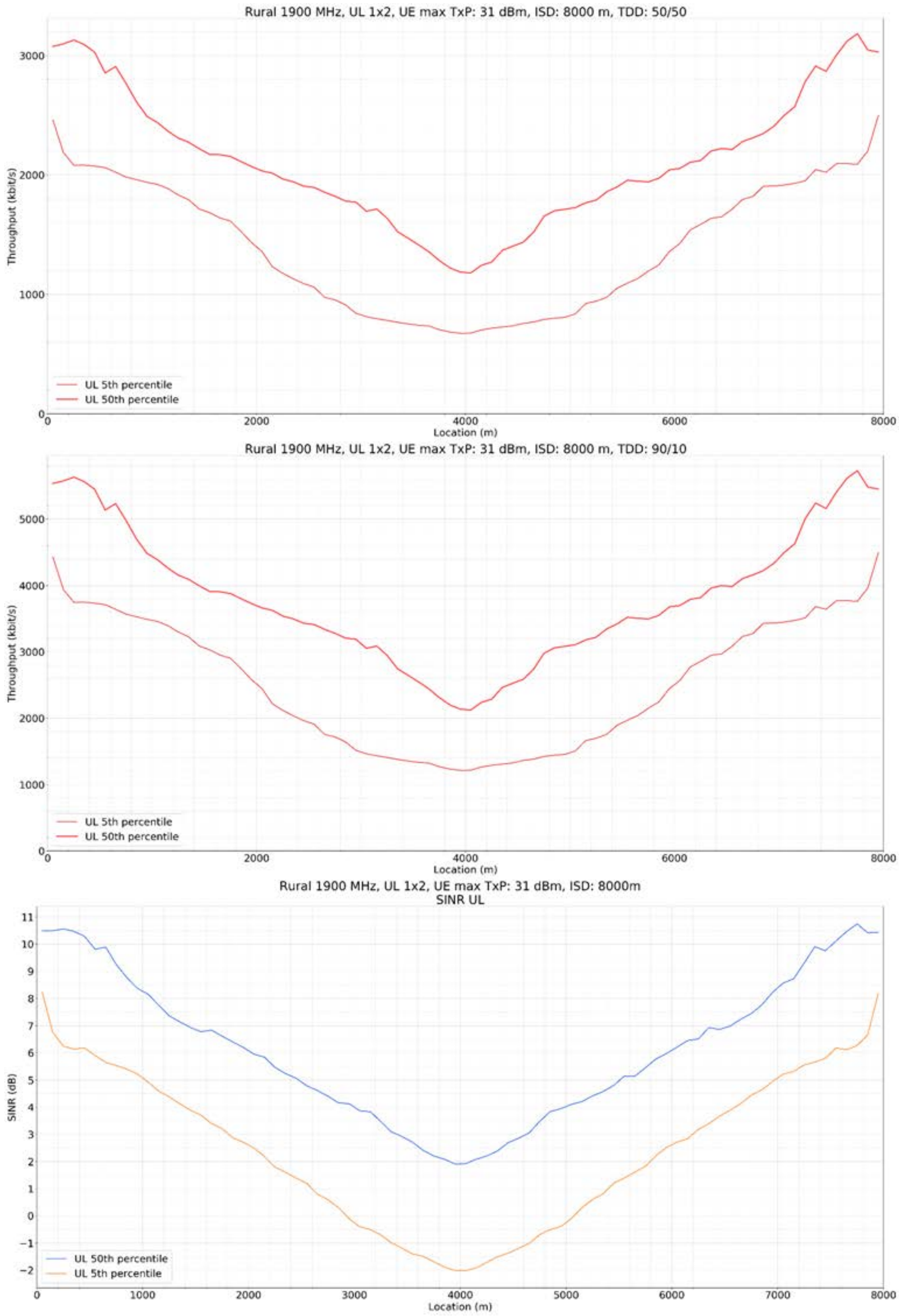


Figure A.159

Interference to noise ratio tables

	5th percentile	50th percentile	95th percentile
Full cell (UL)	-110 dBm	-95 dBm	-77 dBm
Cell centre (UL)	-99 dBm	-95 dBm	-92 dBm
Cell edge (UL)	-94 dBm	-91 dBm	-89 dBm

UL 2x2

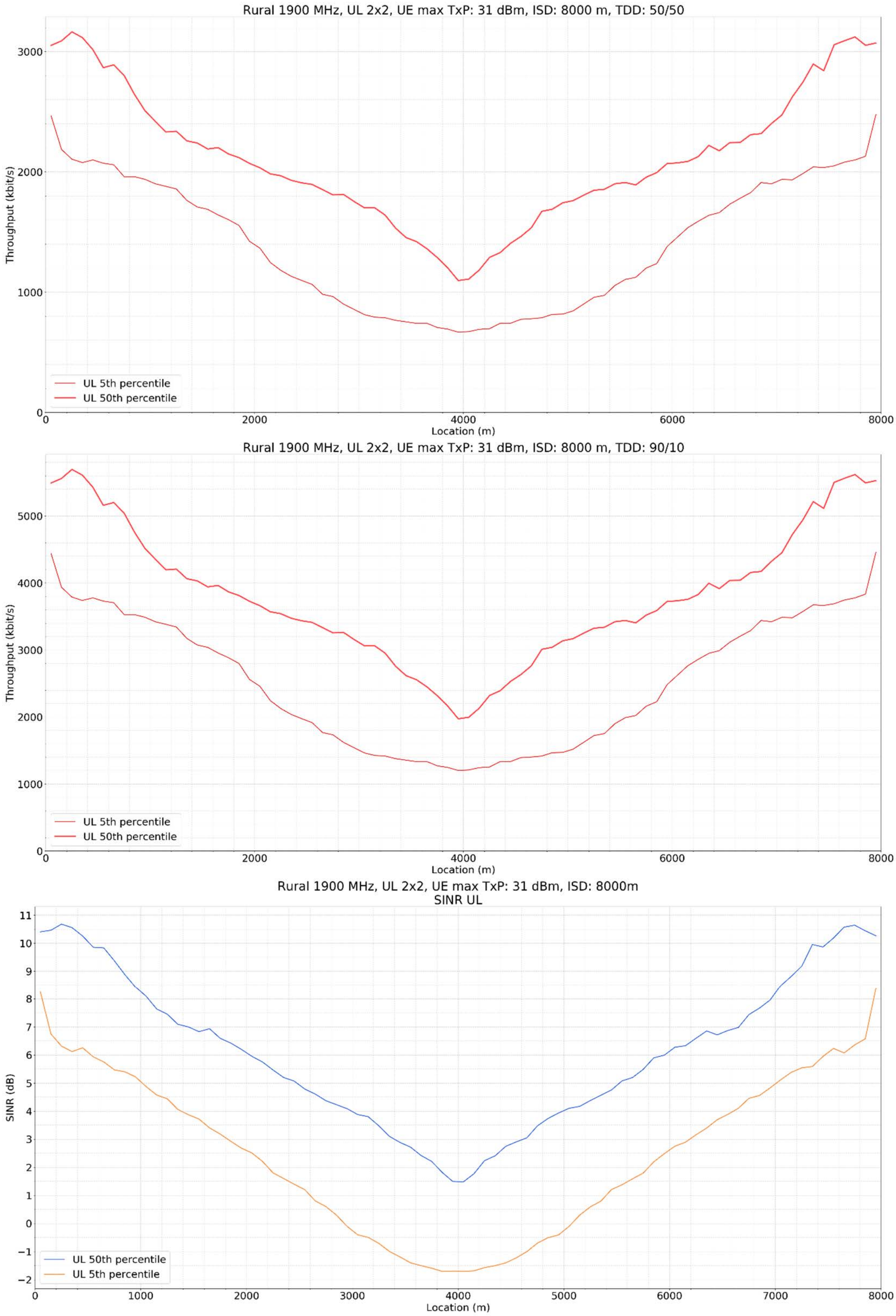


Figure A.160

Interference to noise ratio tables

	5th percentile	50th percentile	95th percentile
Full cell (UL)	-110 dBm	-95 dBm	-78 dBm
Cell centre (UL)	-101 dBm	-96 dBm	-93 dBm
Cell edge (UL)	-95 dBm	-91 dBm	-88 dBm

UL 1x4

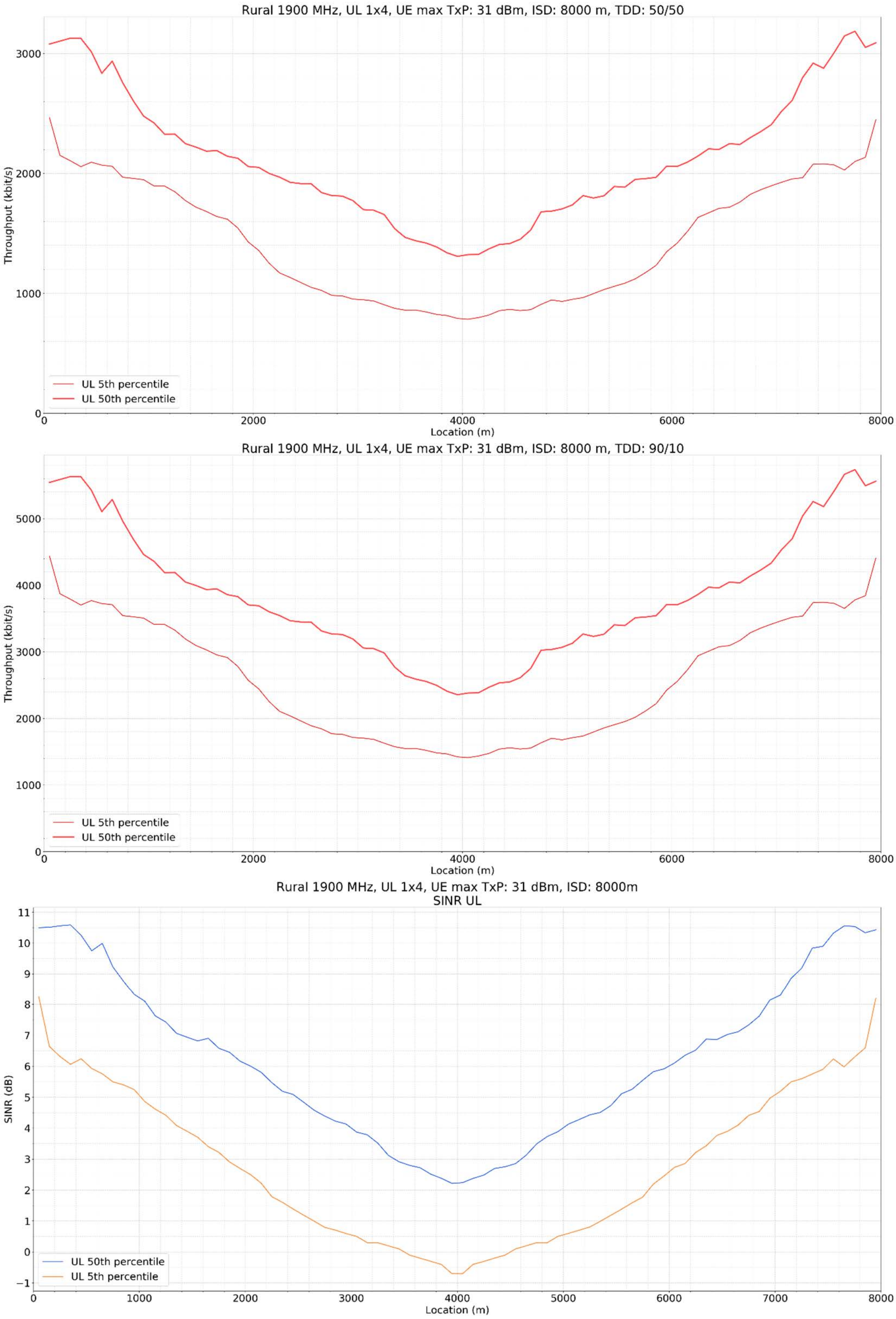


Figure A.161

Interference to noise ratio tables

	5th percentile	50th percentile	95th percentile
Full cell (UL)	-109 dBm	-93 dBm	-76 dBm
Cell centre (UL)	-104 dBm	-96 dBm	-91 dBm
Cell edge (UL)	-92 dBm	-88 dBm	-86 dBm

UL 2x4

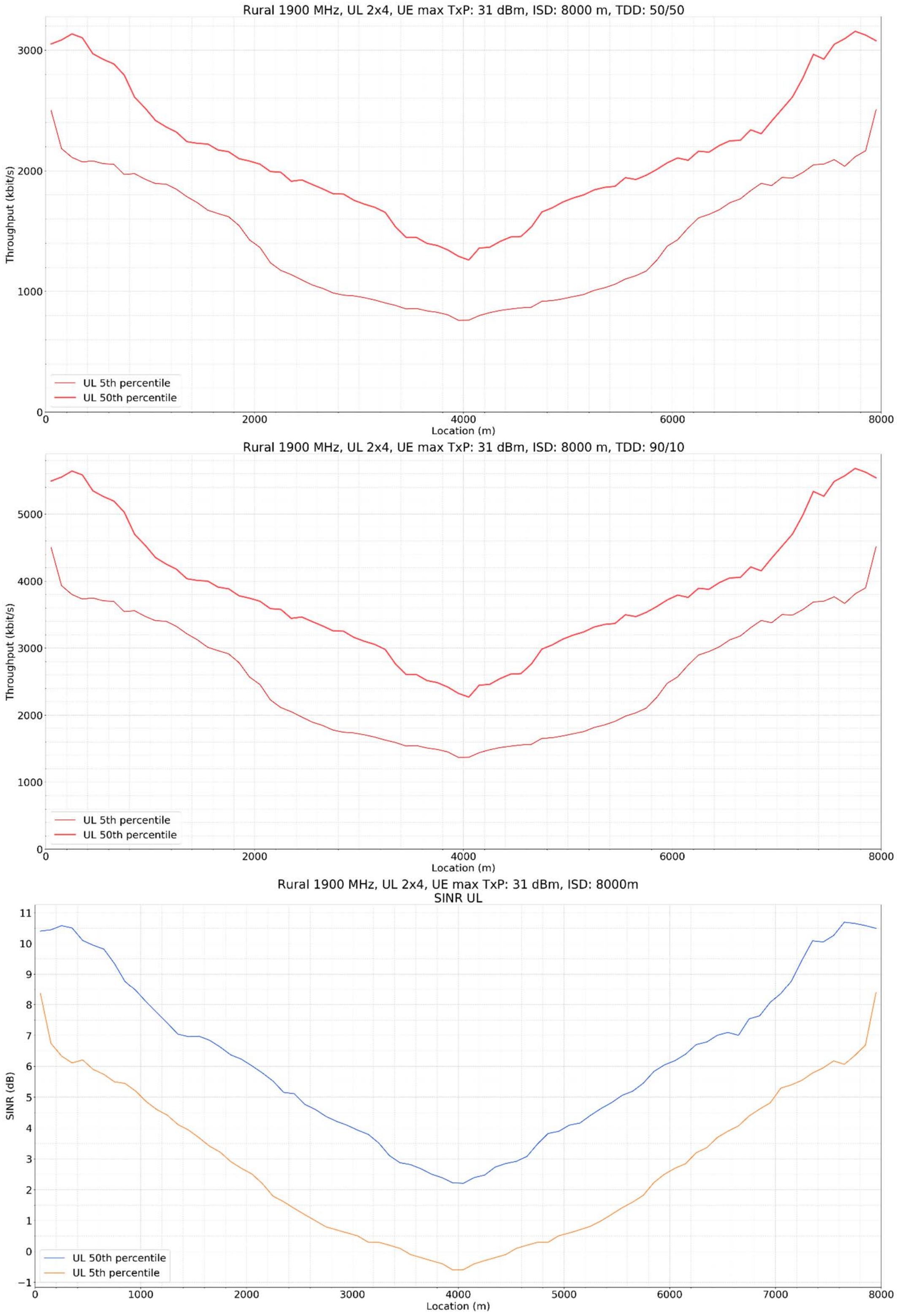


Figure A.162

Interference to noise ratio tables

	5th percentile	50th percentile	95th percentile
Full cell (UL)	-108 dBm	-93 dBm	-76 dBm
Cell centre (UL)	-104 dBm	-96 dBm	-91 dBm
Cell edge (UL)	-92 dBm	-89 dBm	-86 dBm

UL 1x8

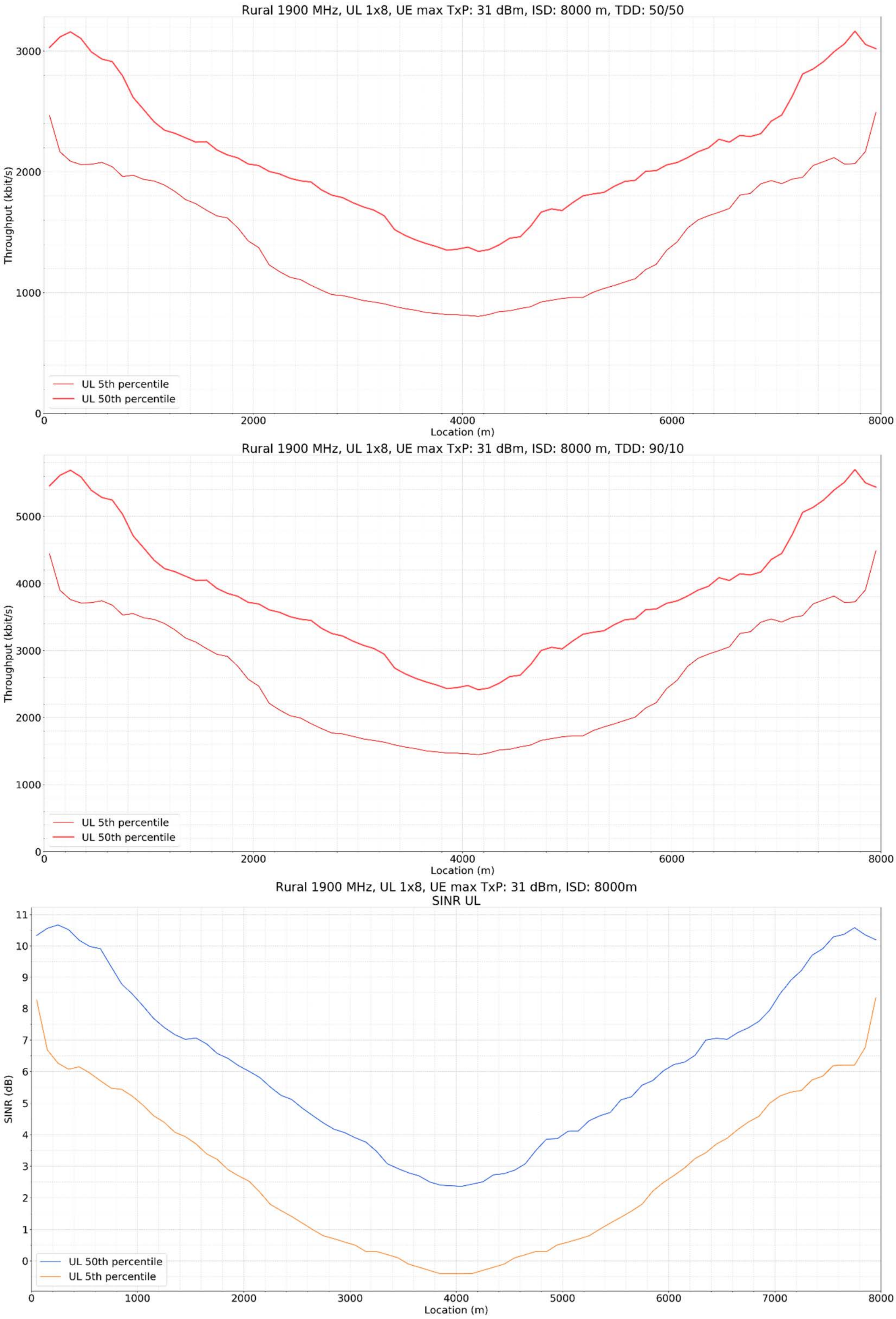


Figure A.163

Interference to noise ratio tables

	5th percentile	50th percentile	95th percentile
Full cell (UL)	-109 dBm	-92 dBm	-74 dBm
Cell centre (UL)	-105 dBm	-98 dBm	-90 dBm
Cell edge (UL)	-90 dBm	-87 dBm	-83 dBm

UL 2x8

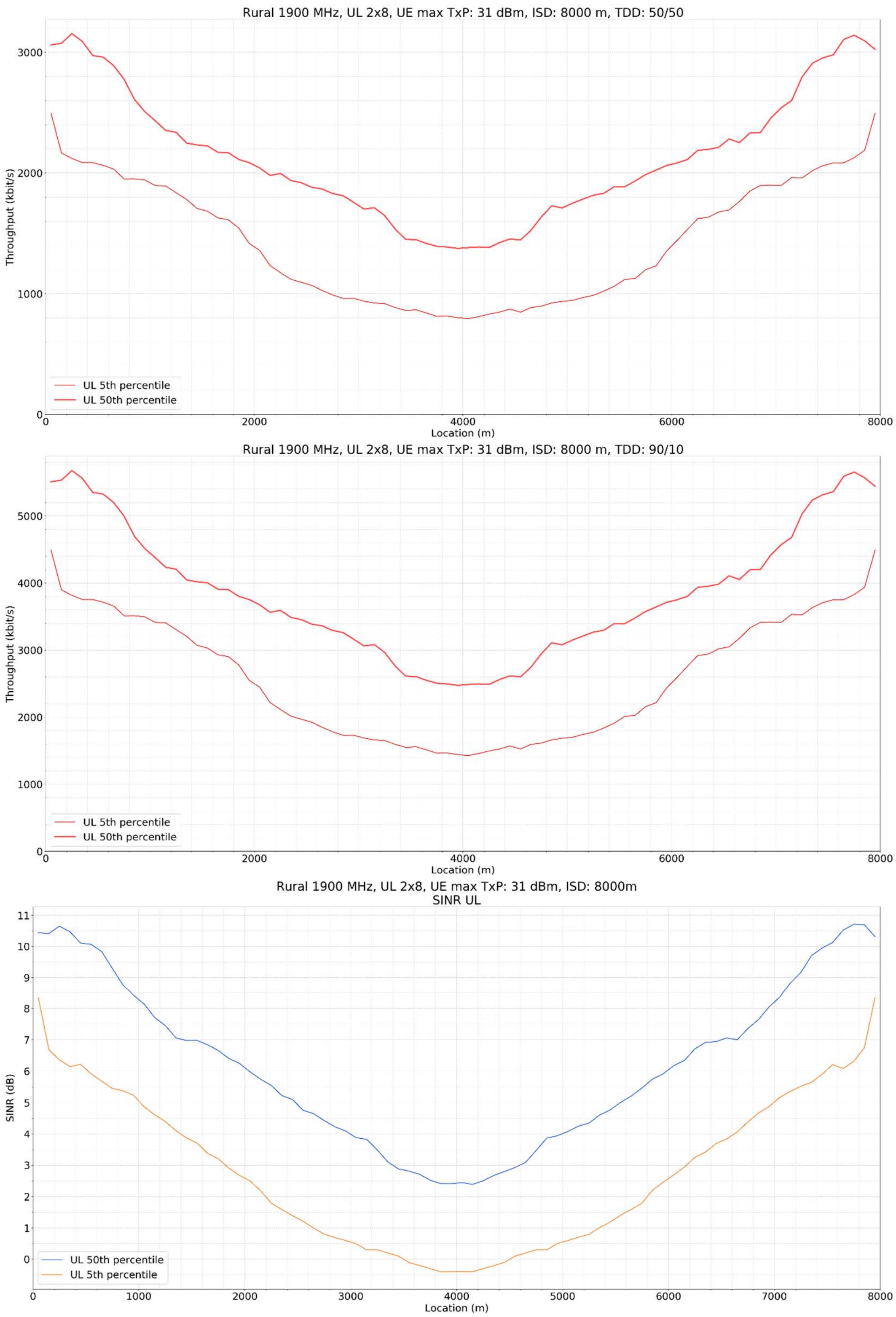


Figure A.164

Interference to noise ratio tables

	5th percentile	50th percentile	95th percentile
Full cell (UL)	-109 dBm	-91 dBm	-74 dBm
Cell centre (UL)	-104 dBm	-98 dBm	-89 dBm
Cell edge (UL)	-91 dBm	-87 dBm	-84 dBm

A.2.2.3 Rural, 6 KM ISD, 2 cells/site

A.2.2.3.1 Downlink, 63 dBm EIRP

DL 2x1

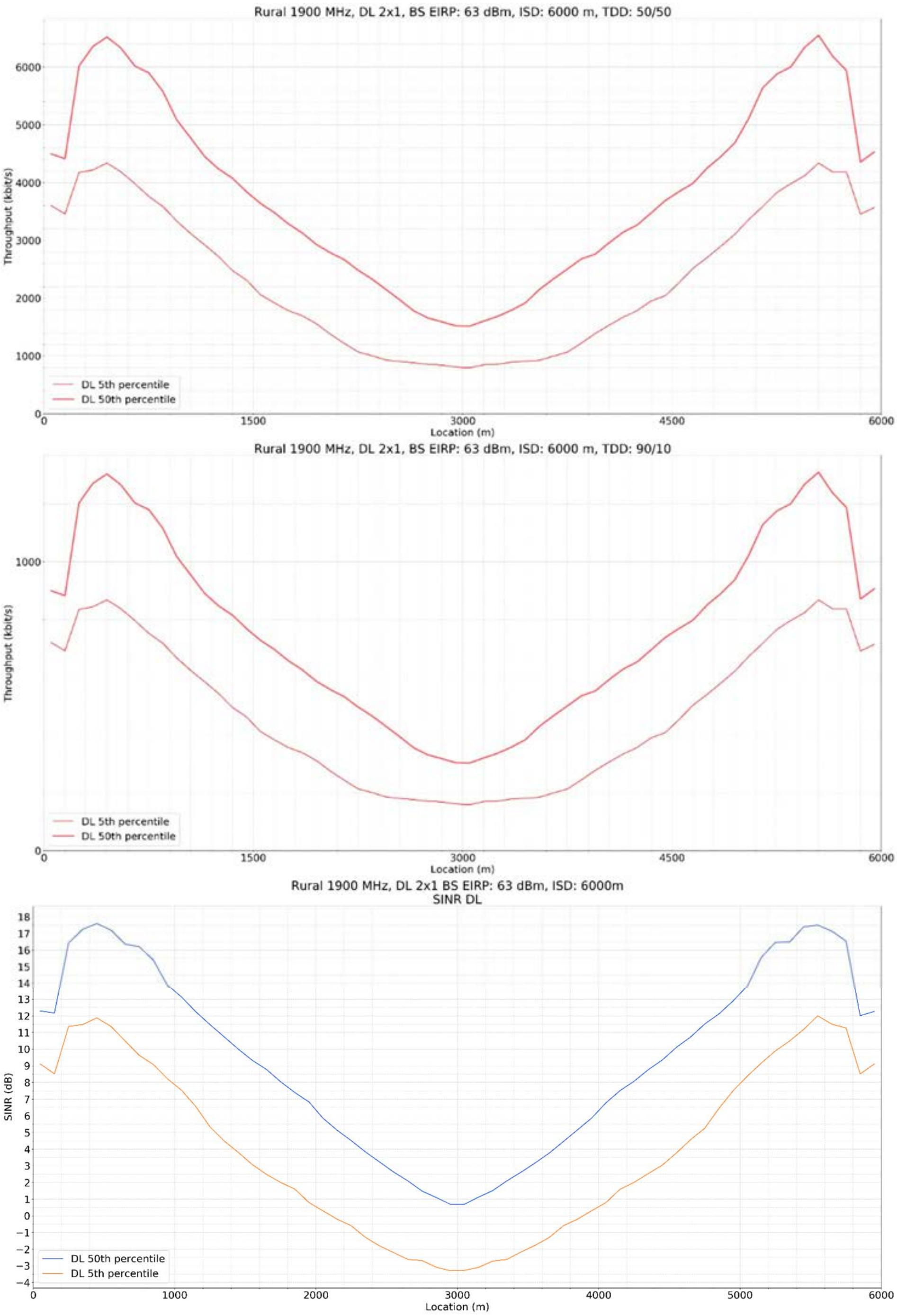


Figure A.165

Interference to noise ratio tables

	5th percentile	50th percentile	95th percentile
Full cell (DL)	-107 dBm	-85 dBm	-67 dBm
Cell centre (DL)	-86 dBm	-77 dBm	-66 dBm
Cell edge (DL)	-94 dBm	-88 dBm	-82 dBm

DL 2x2

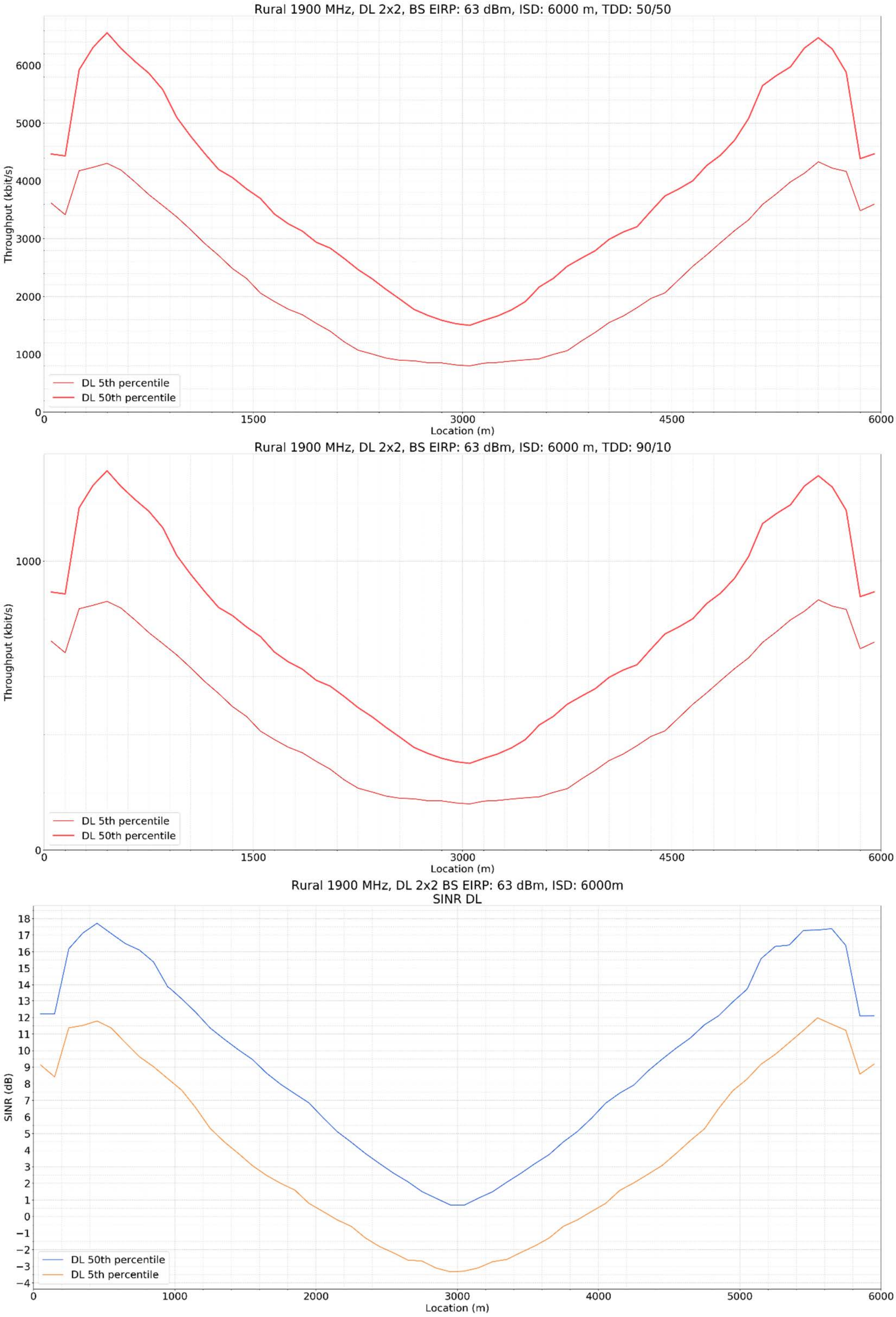


Figure A.166

Interference to noise ratio tables

	5th percentile	50th percentile	95th percentile
Full cell (DL)	-109 dBm	-87 dBm	-69 dBm
Cell centre (DL)	-88 dBm	-80 dBm	-71 dBm
Cell edge (DL)	-95 dBm	-89 dBm	-84 dBm

DL 4x1

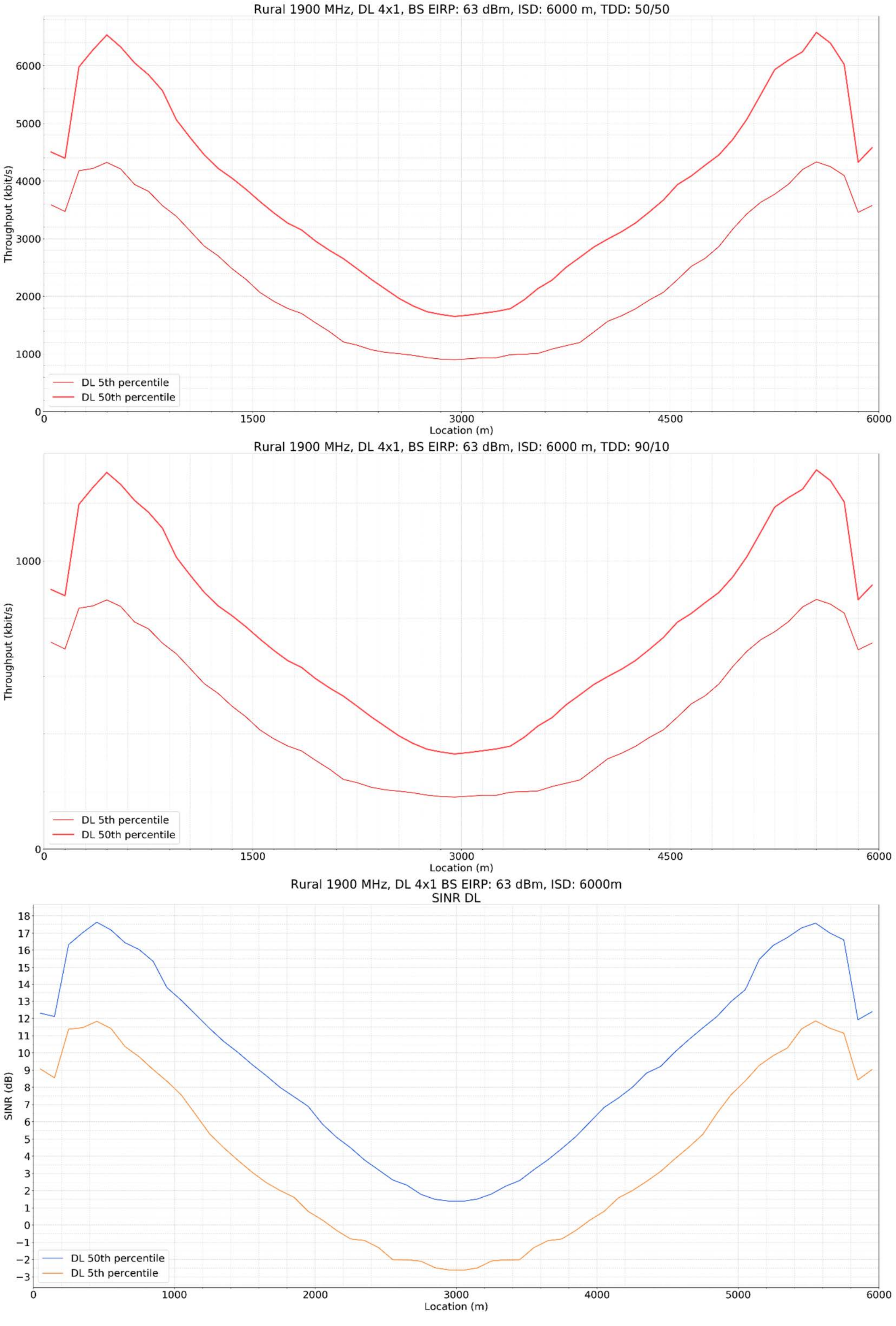


Figure A.167

Interference to noise ratio tables

	5th percentile	50th percentile	95th percentile
Full cell (DL)	-105 dBm	-83 dBm	-67 dBm
Cell centre (DL)	-86 dBm	-76 dBm	-68 dBm
Cell edge (DL)	-92 dBm	-86 dBm	-80 dBm

DL 4x2

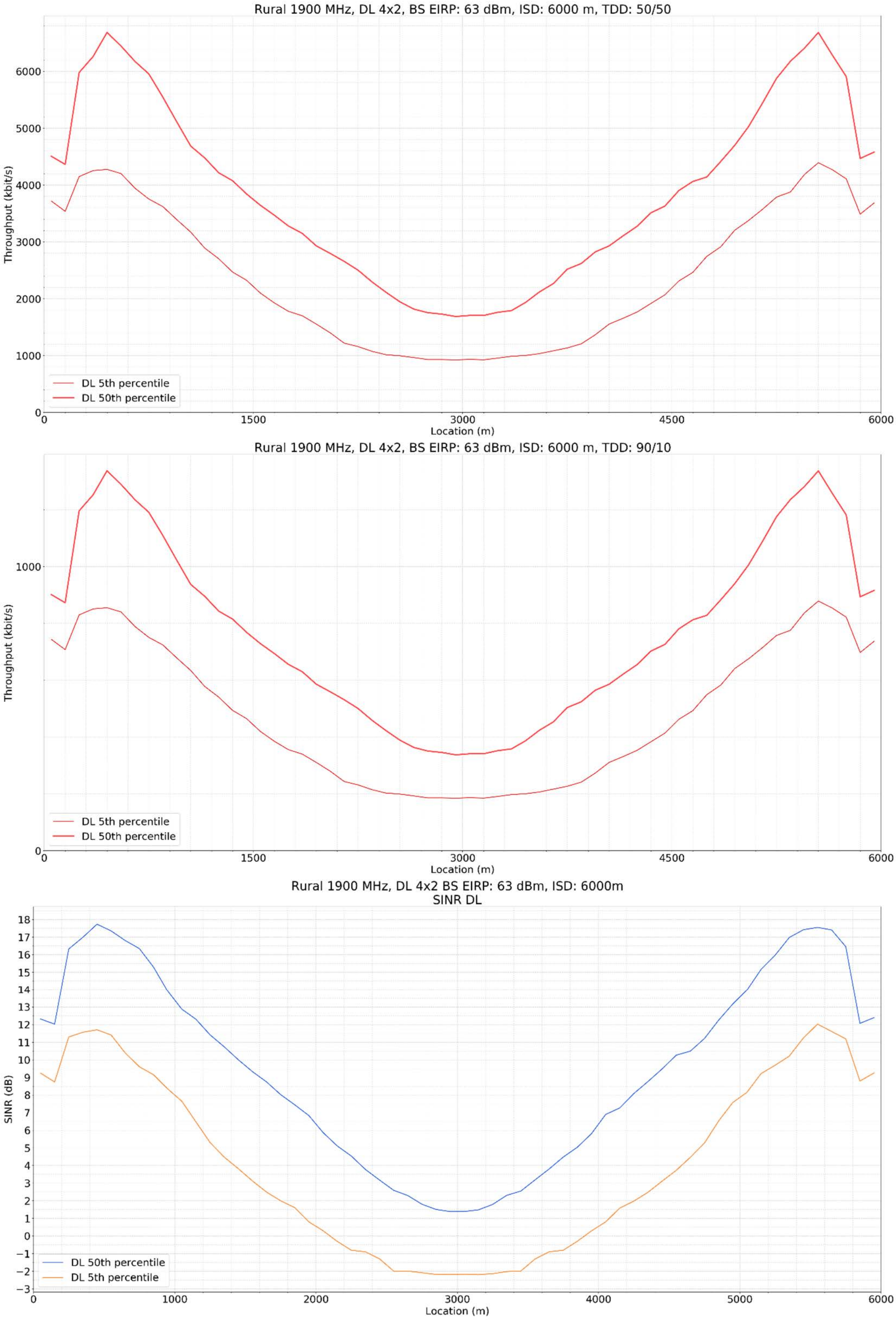


Figure A.168

Interference to noise ratio tables

	5th percentile	50th percentile	95th percentile
Full cell (DL)	-108 dBm	-85 dBm	-68 dBm
Cell centre (DL)	-86 dBm	-79 dBm	-69 dBm
Cell edge (DL)	-93 dBm	-87 dBm	-82 dBm

DL 8x1

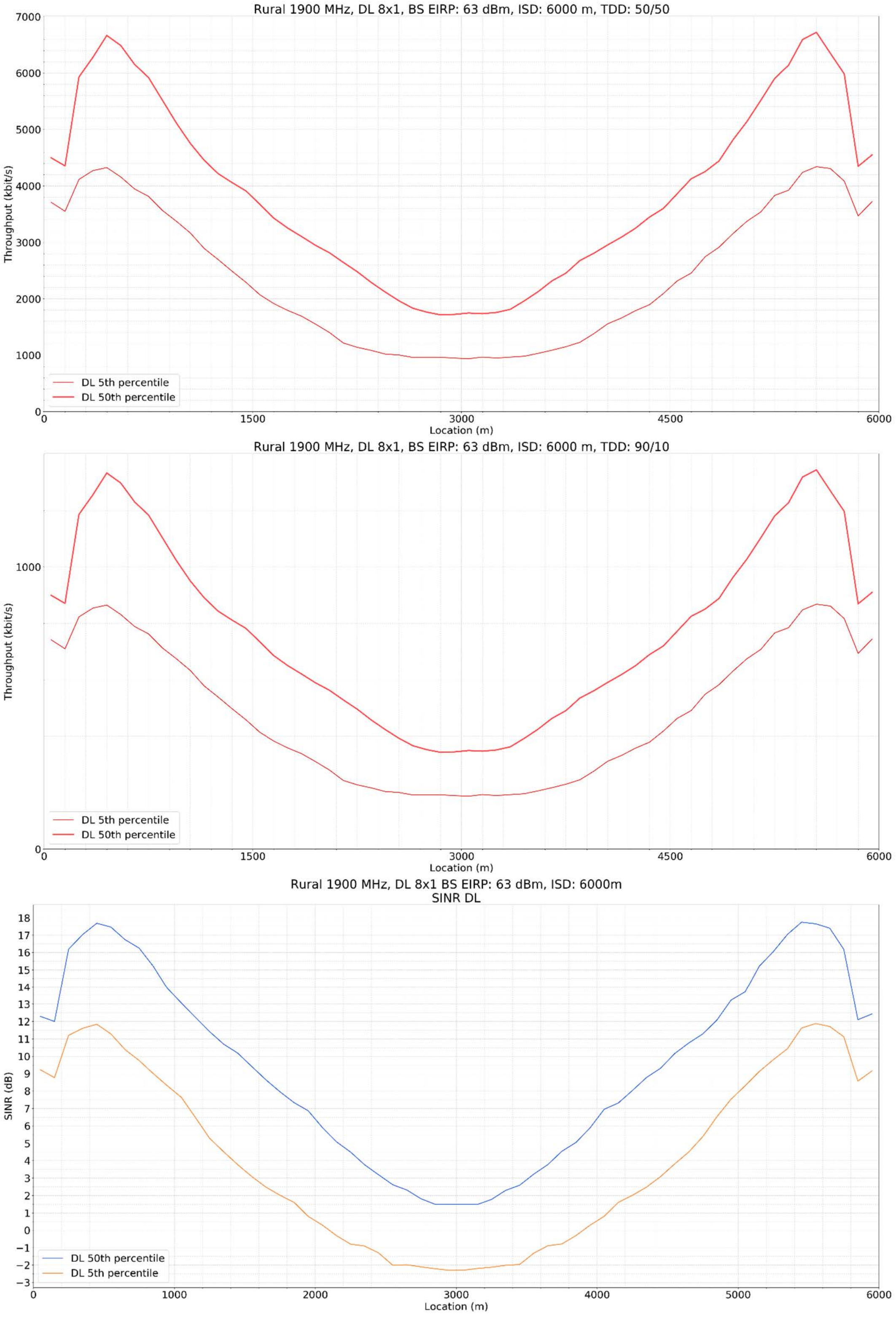


Figure A.169

Interference to noise ratio tables

	5th percentile	50th percentile	95th percentile
Full cell (DL)	-105 dBm	-83 dBm	-67 dBm
Cell centre (DL)	-85 dBm	-78 dBm	-71 dBm
Cell edge (DL)	-91 dBm	-84 dBm	-79 dBm

DL 8x2

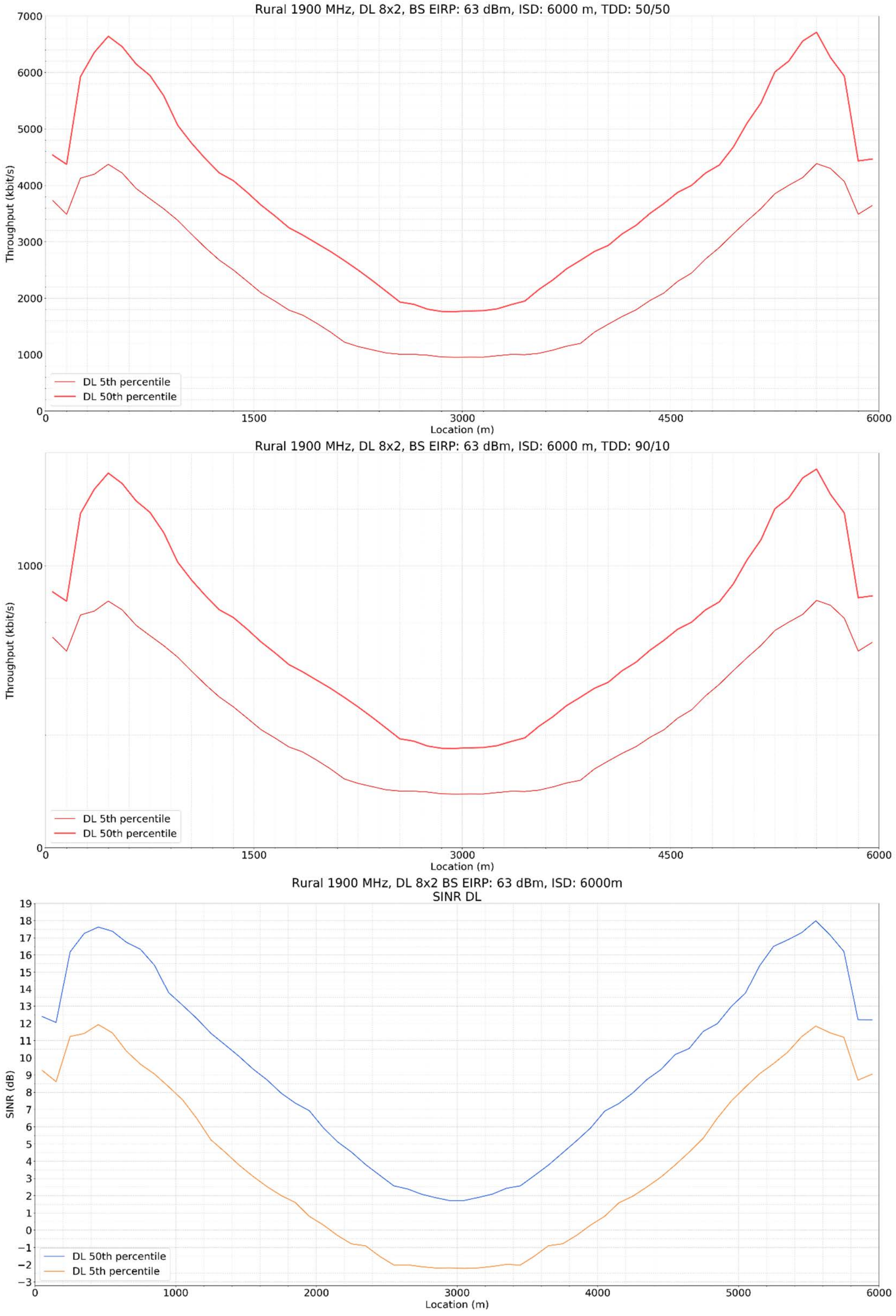


Figure A.170

Interference to noise ratio tables

	5th percentile	50th percentile	95th percentile
Full cell (DL)	-107 dBm	-84 dBm	-68 dBm
Cell centre (DL)	-85 dBm	-79 dBm	-70 dBm
Cell edge (DL)	-92 dBm	-86 dBm	-80 dBm

A.2.2.3.2 Downlink, 40 dBm EIRP

DL 2x1

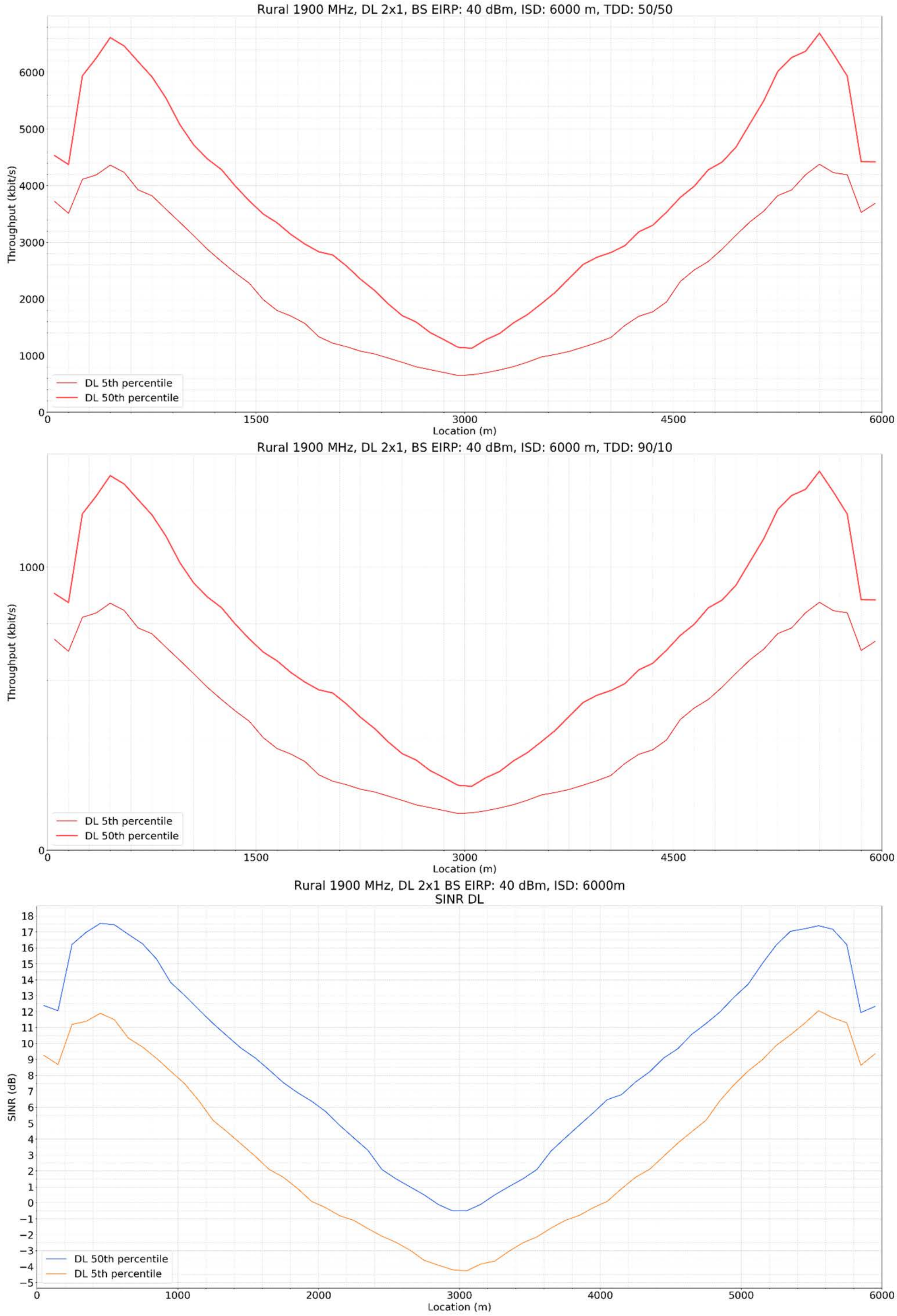


Figure A.171

Interference to noise ratio tables

	5th percentile	50th percentile	95th percentile
Full cell (DL)	-123 dBm	-106 dBm	-81 dBm
Cell centre (DL)	-104 dBm	-97 dBm	-89 dBm
Cell edge (DL)	-111 dBm	-107 dBm	-99 dBm

DL 2x2

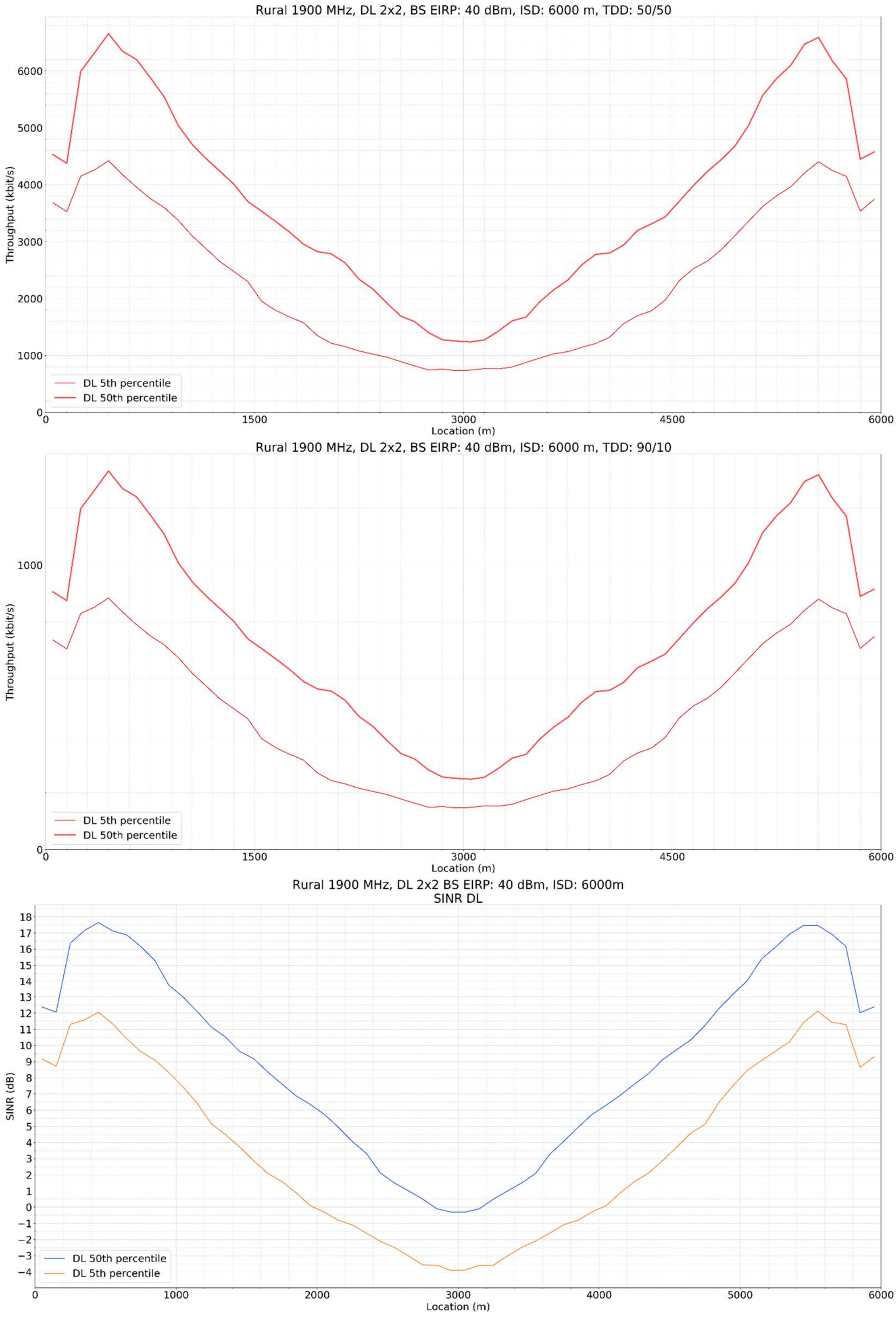


Figure A.172

Interference to noise ratio tables

	5th percentile	50th percentile	95th percentile
Full cell (DL)	-124 dBm	-107 dBm	-83 dBm
Cell centre (DL)	-107 dBm	-100 dBm	-94 dBm
Cell edge (DL)	-112 dBm	-108 dBm	-99 dBm

DL 4x1

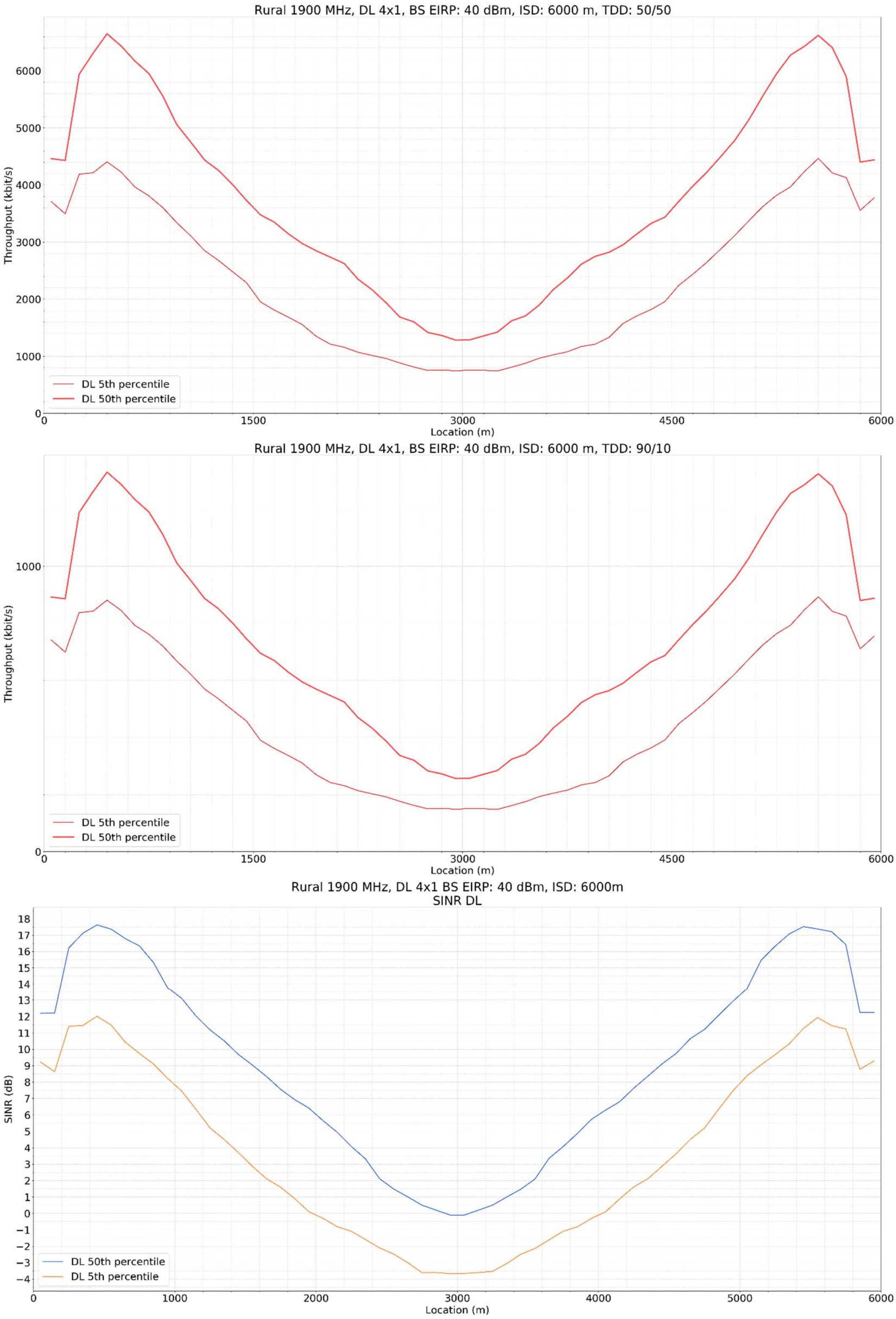


Figure A.173

Interference to noise ratio tables

	5th percentile	50th percentile	95th percentile
Full cell (DL)	-122 dBm	-104 dBm	-80 dBm
Cell centre (DL)	-102 dBm	-95 dBm	-90 dBm
Cell edge (DL)	-110 dBm	-104 dBm	-98 dBm

DL 4x2

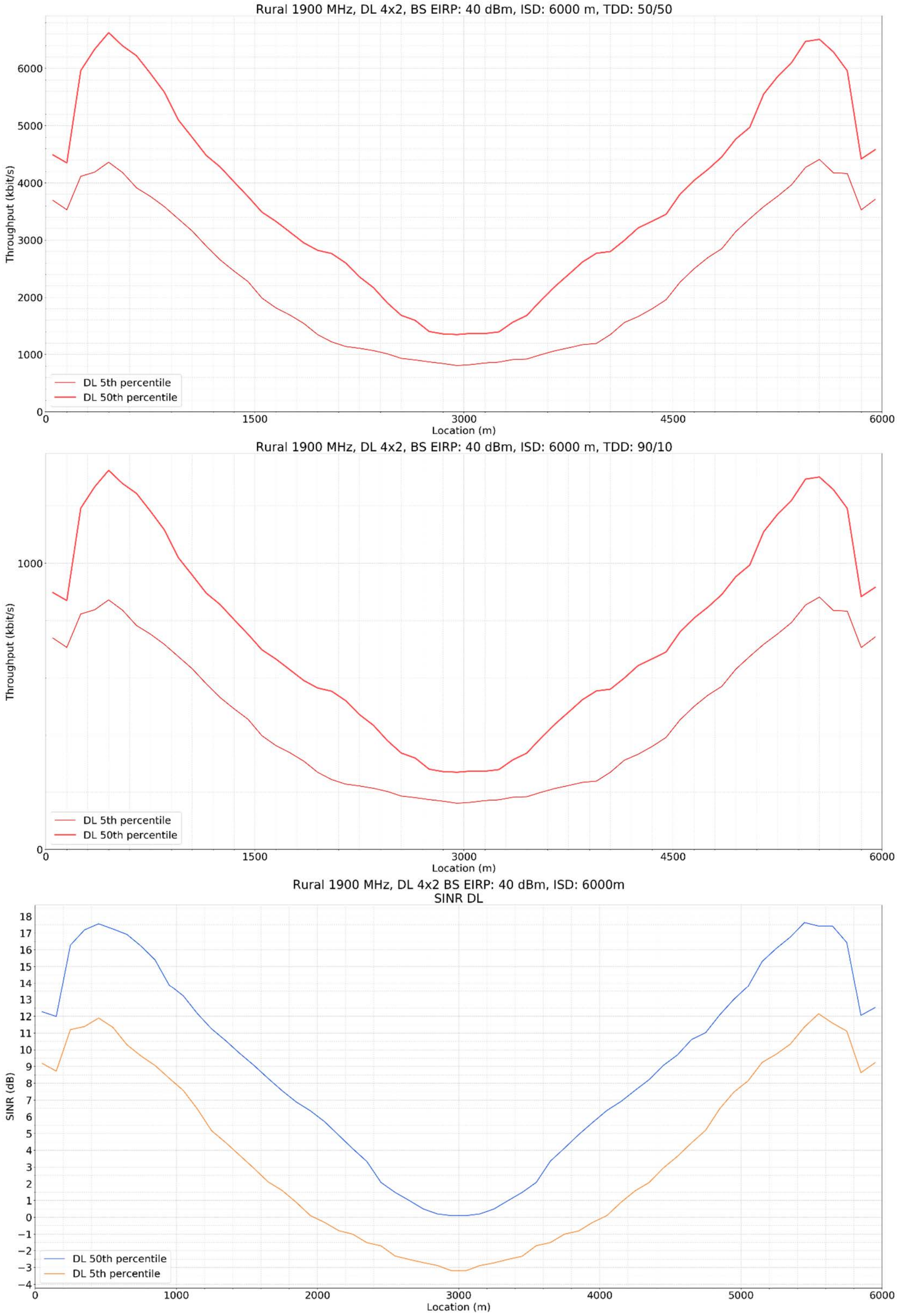


Figure A.174

Interference to noise ratio tables

	5th percentile	50th percentile	95th percentile
Full cell (DL)	-123 dBm	-105 dBm	-83 dBm
Cell centre (DL)	-105 dBm	-98 dBm	-92 dBm
Cell edge (DL)	-111 dBm	-106 dBm	-99 dBm

DL 8x1

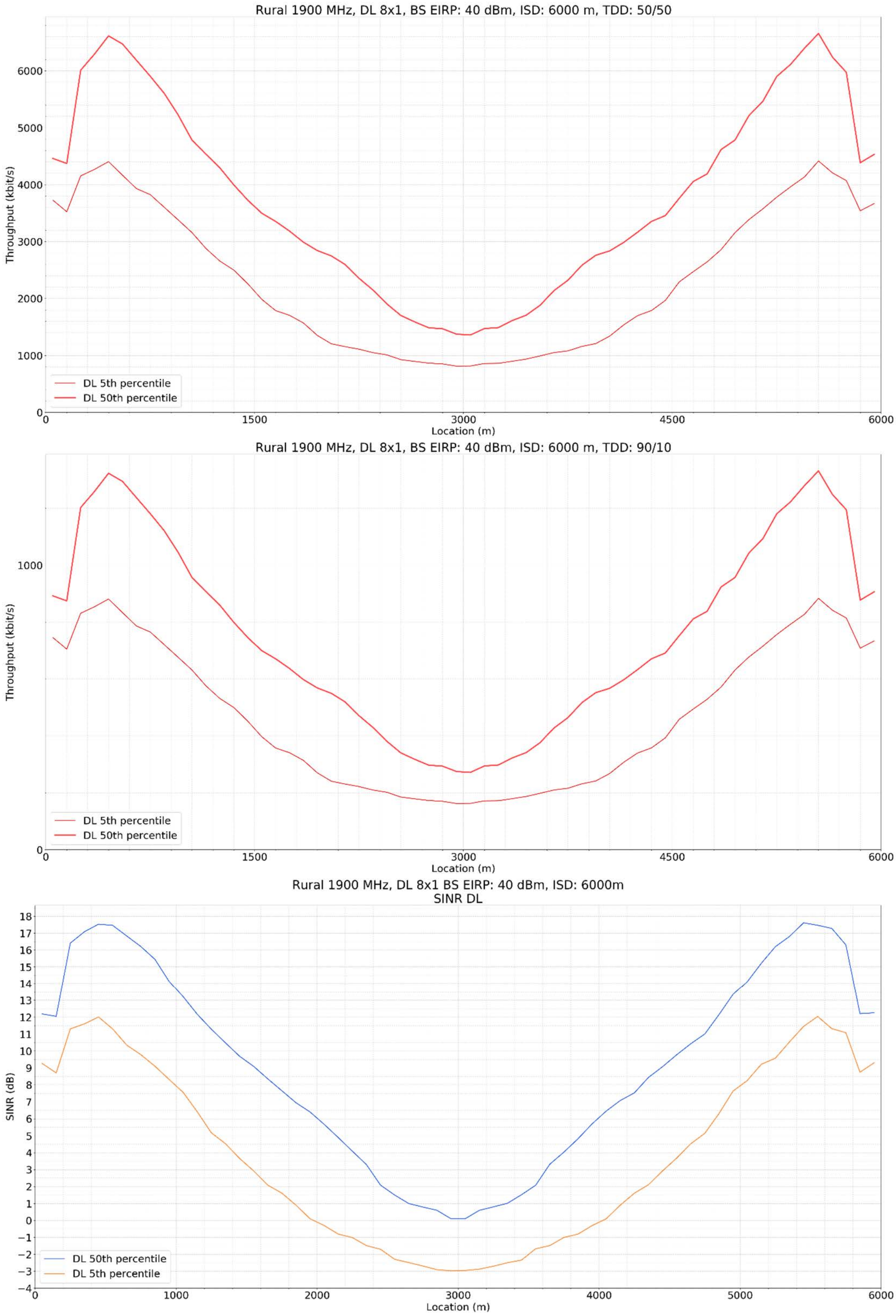


Figure A.175

Interference to noise ratio tables

	5th percentile	50th percentile	95th percentile
Full cell (DL)	-121 dBm	-103 dBm	-82 dBm
Cell centre (DL)	-102 dBm	-96 dBm	-89 dBm
Cell edge (DL)	-109 dBm	-103 dBm	-97 dBm

DL 8x2

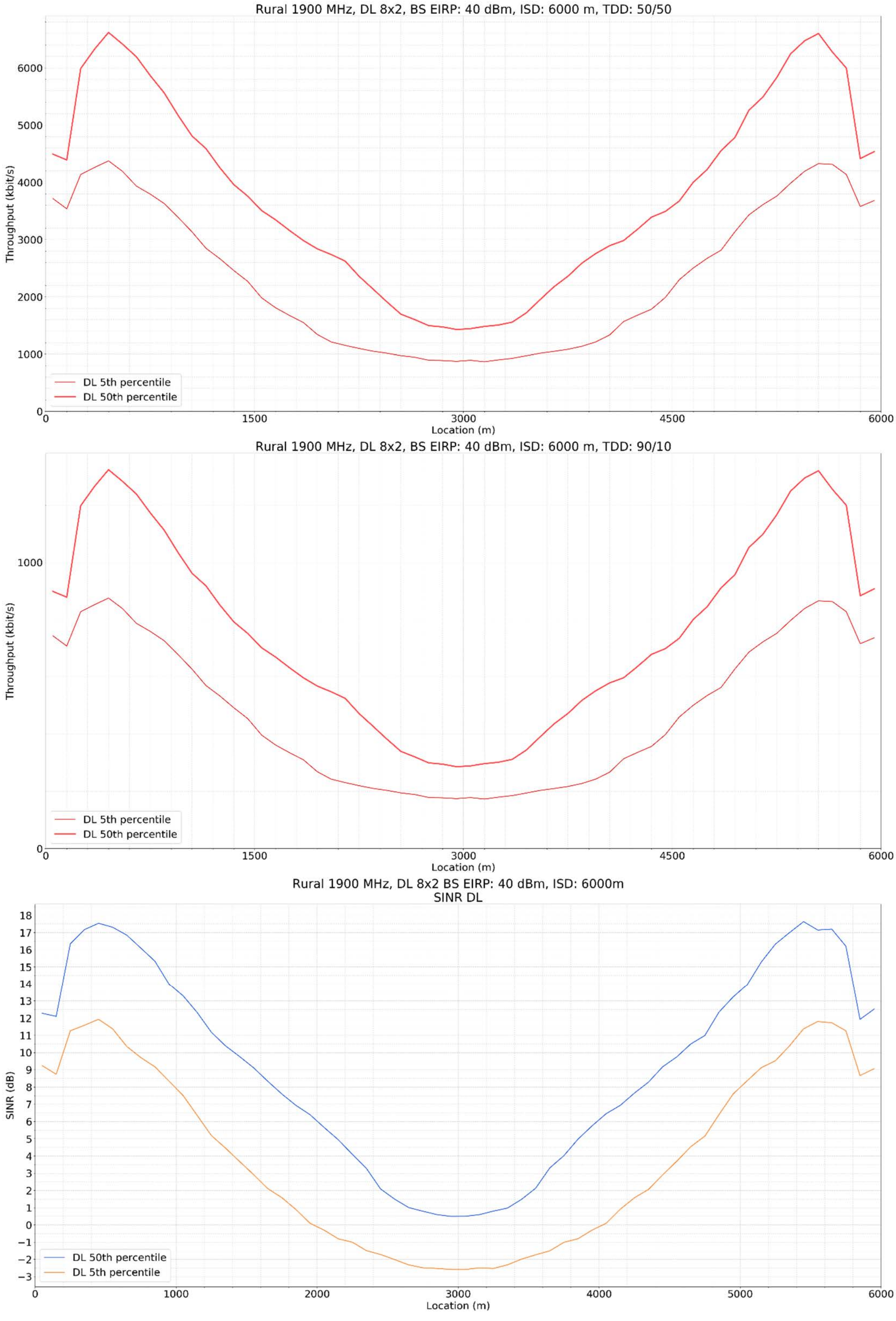


Figure A.176

Interference to noise ratio tables

	5th percentile	50th percentile	95th percentile
Full cell (DL)	-123 dBm	-105 dBm	-84 dBm
Cell centre (DL)	-104 dBm	-99 dBm	-93 dBm
Cell edge (DL)	-110 dBm	-105 dBm	-97 dBm

A.2.2.3.3 Uplink, 23 dBm max transmit power

UL 1x2

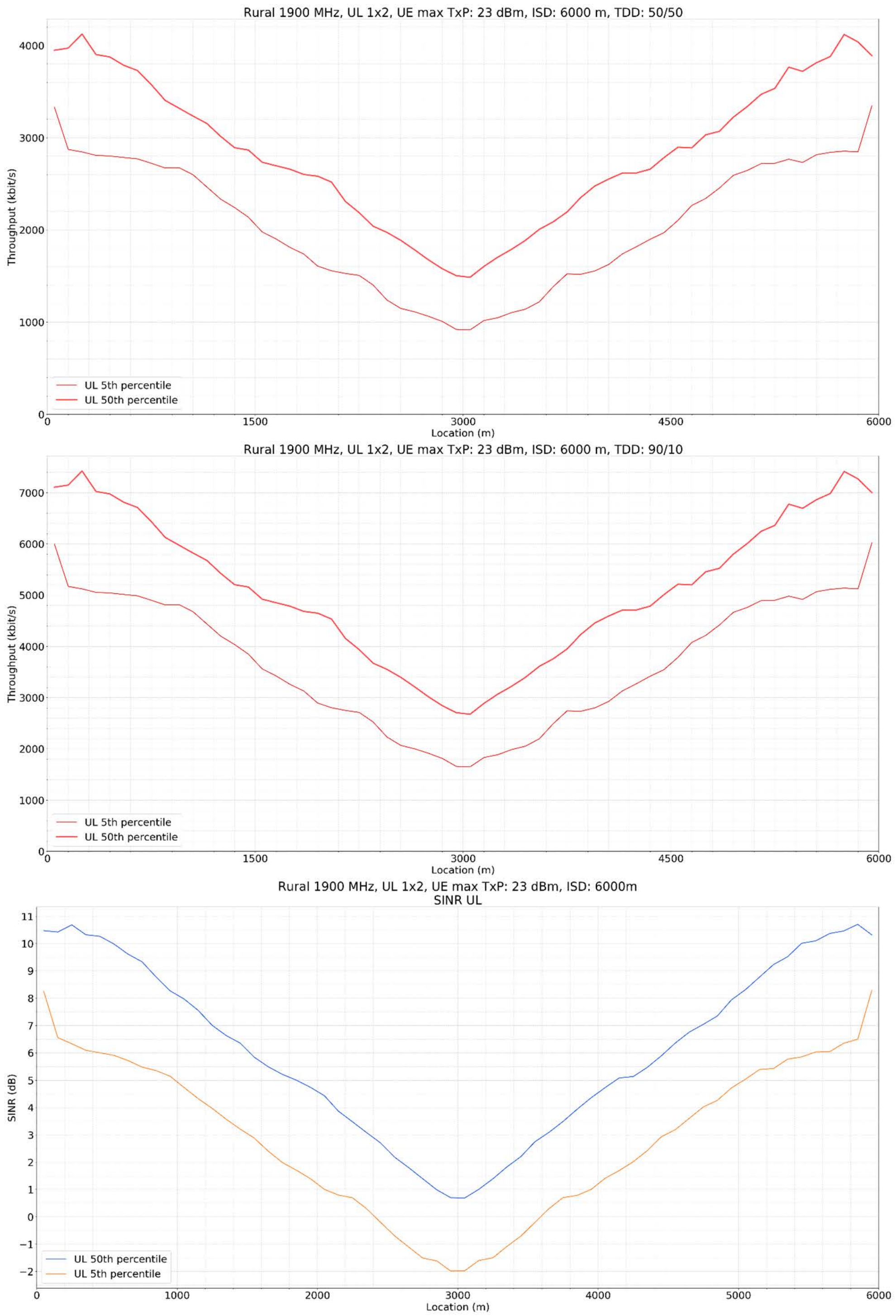


Figure A.177

Interference to noise ratio tables

	5th percentile	50th percentile	95th percentile
Full cell (UL)	-116 dBm	-100 dBm	-80 dBm
Cell centre (UL)	-105 dBm	-100 dBm	-96 dBm
Cell edge (UL)	-101 dBm	-97 dBm	-93 dBm

UL 2x2

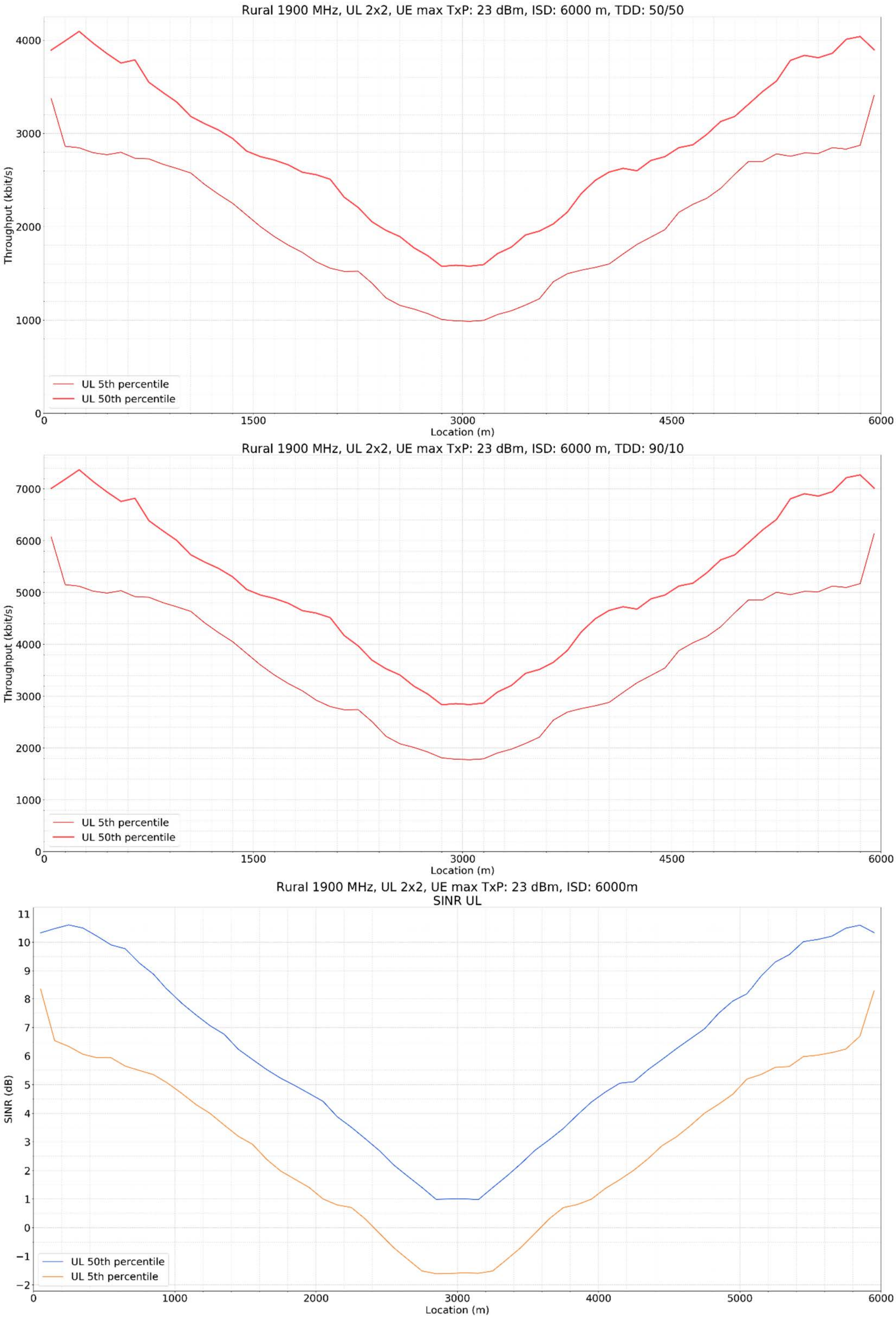


Figure A.178

Interference to noise ratio tables

	5th percentile	50th percentile	95th percentile
Full cell (UL)	-117 dBm	-101 dBm	-80 dBm
Cell centre (UL)	-105 dBm	-100 dBm	-96 dBm
Cell edge (UL)	-105 dBm	-98 dBm	-94 dBm

UL 1x4

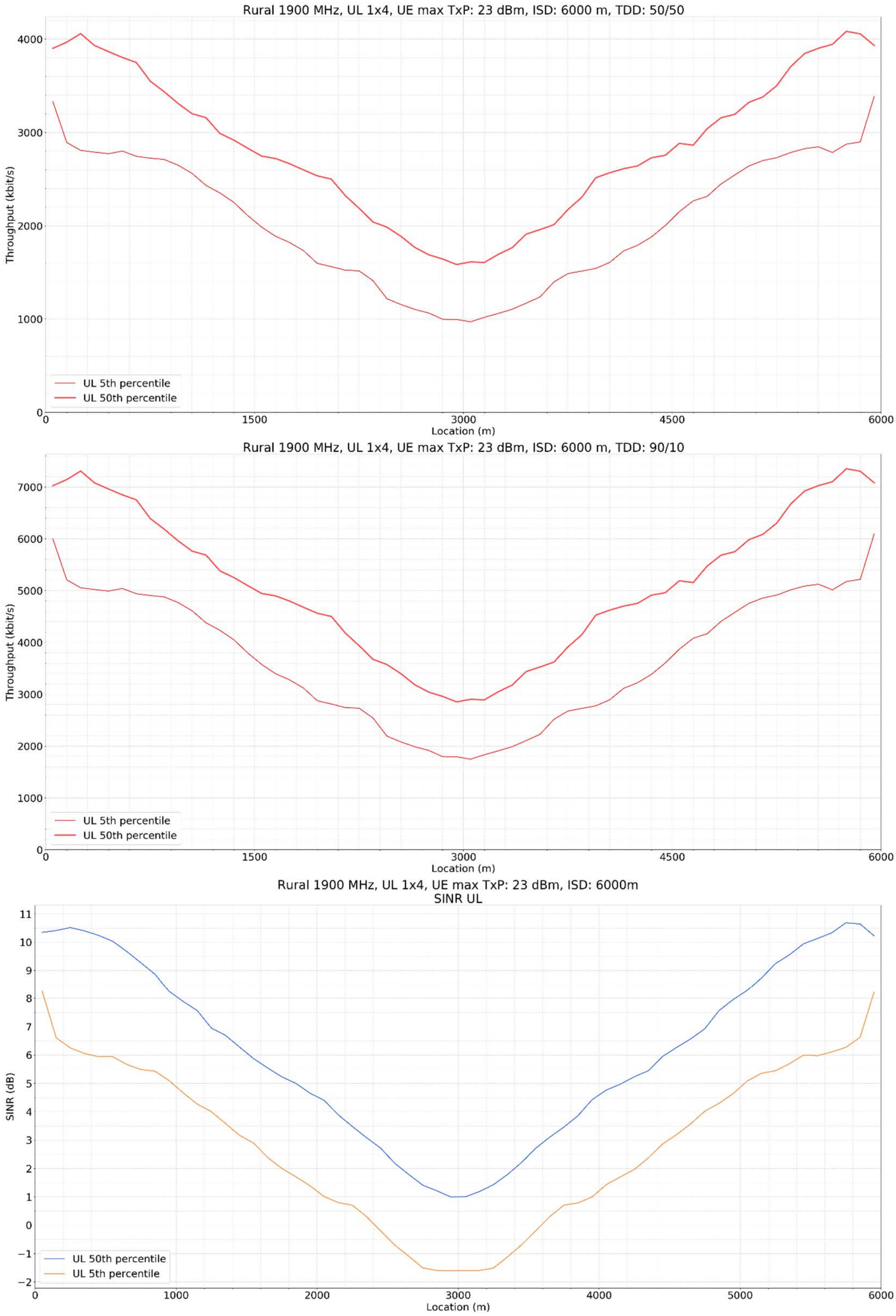


Figure A.179

Interference to noise ratio tables

	5th percentile	50th percentile	95th percentile
Full cell (UL)	-116 dBm	-99 dBm	-78 dBm
Cell centre (UL)	-108 dBm	-100 dBm	-95 dBm
Cell edge (UL)	-99 dBm	-94 dBm	-91 dBm

UL 2x4

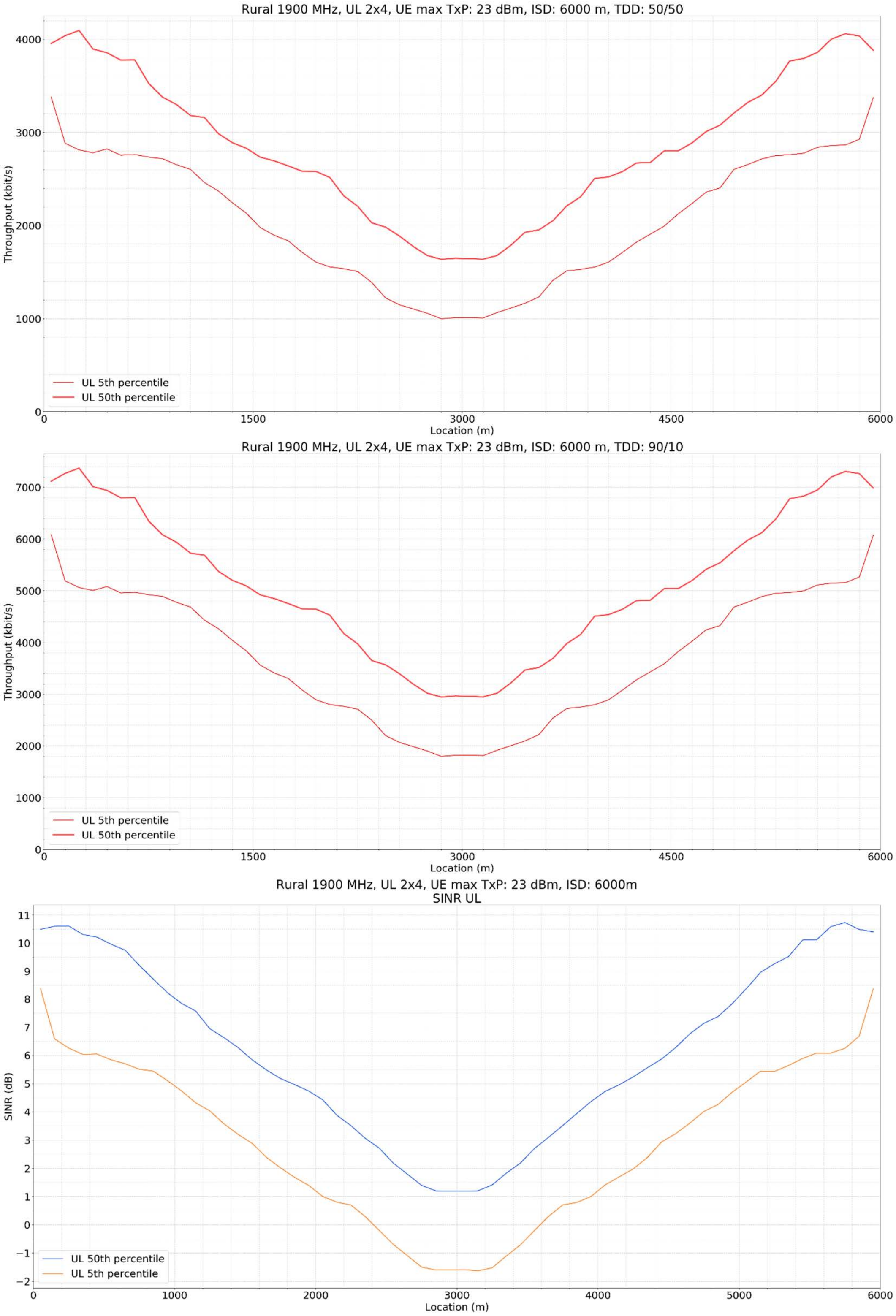


Figure A.180

Interference to noise ratio tables

	5th percentile	50th percentile	95th percentile
Full cell (UL)	-115 dBm	-99 dBm	-78 dBm
Cell centre (UL)	-108 dBm	-100 dBm	-94 dBm
Cell edge (UL)	-101 dBm	-95 dBm	-91 dBm

UL 1x8

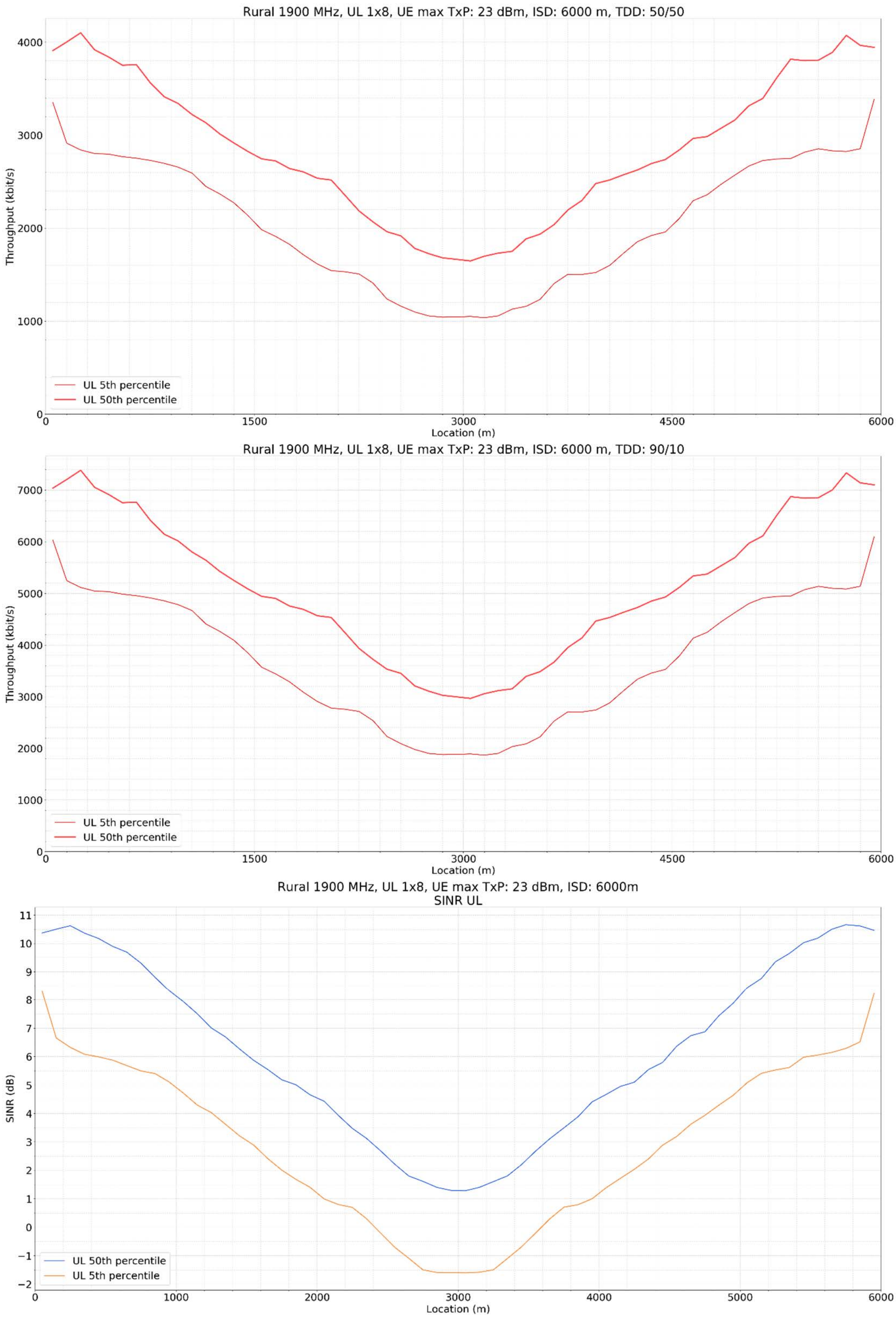


Figure A.181

Interference to noise ratio tables

	5th percentile	50th percentile	95th percentile
Full cell (UL)	-117 dBm	-98 dBm	-76 dBm
Cell centre (UL)	-109 dBm	-102 dBm	-94 dBm
Cell edge (UL)	-97 dBm	-92 dBm	-89 dBm

UL 2x8

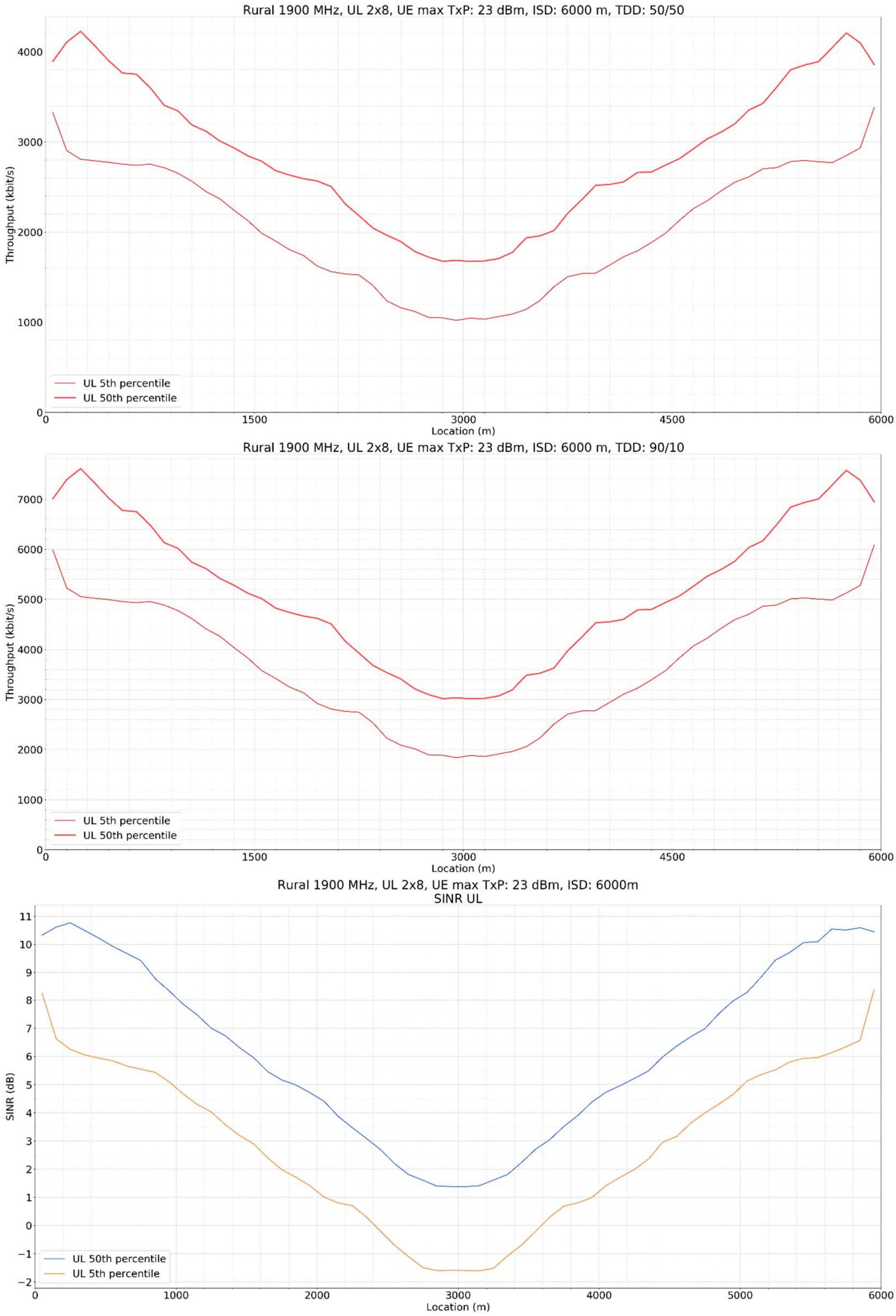


Figure A.182

Interference to noise ratio tables

	5th percentile	50th percentile	95th percentile
Full cell (UL)	-117 dBm	-98 dBm	-76 dBm
Cell centre (UL)	-110 dBm	-103 dBm	-93 dBm
Cell edge (UL)	-98 dBm	-93 dBm	-89 dBm

A.2.2.3.4 Uplink, 31 dBm max transmit power

UL 1x2

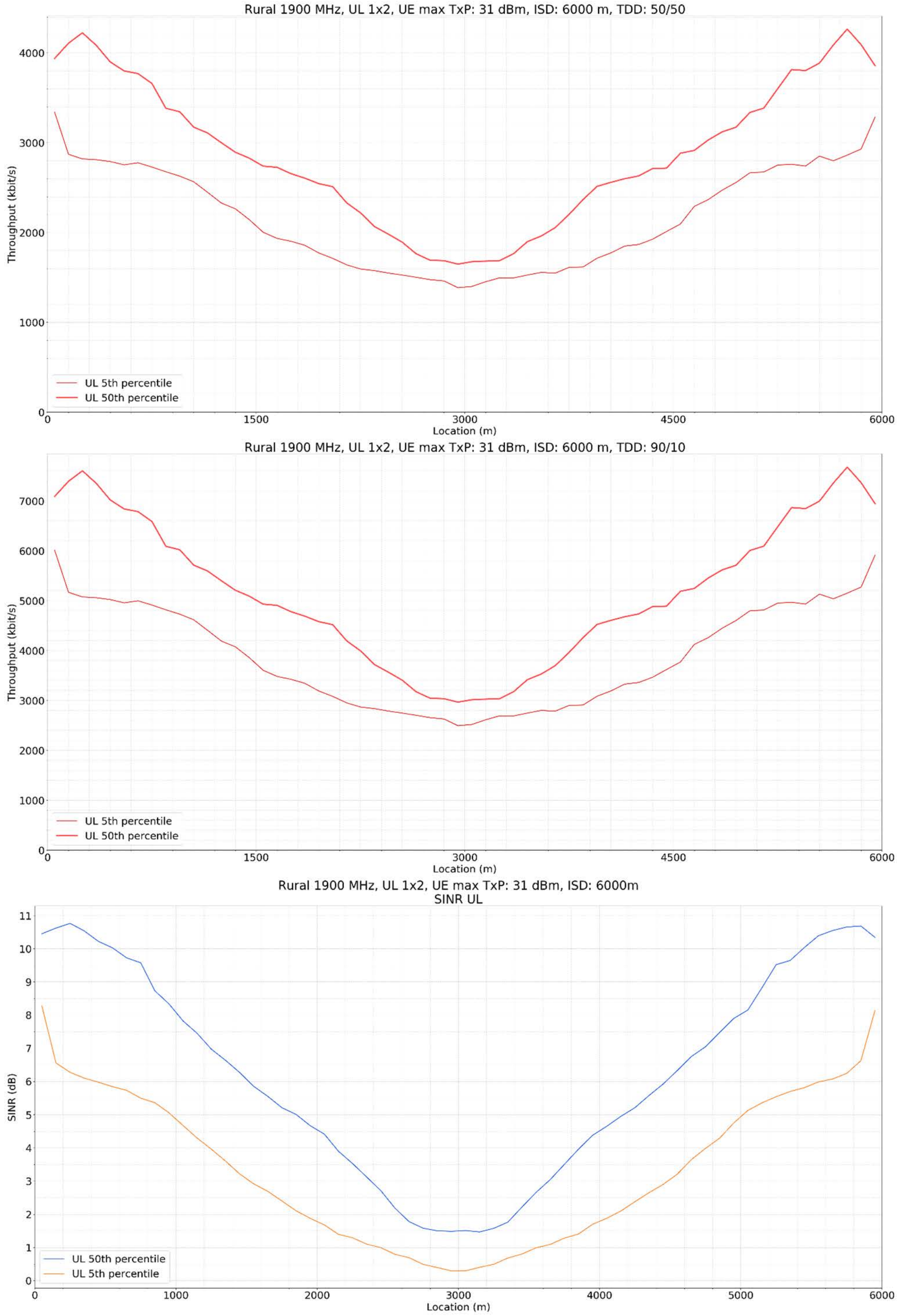


Figure A.183

Interference to noise ratio tables

	5th percentile	50th percentile	95th percentile
Full cell (UL)	-109 dBm	-93 dBm	-73 dBm
Cell centre (UL)	-98 dBm	-93 dBm	-88 dBm
Cell edge (UL)	-95 dBm	-90 dBm	-85 dBm

UL 2x2

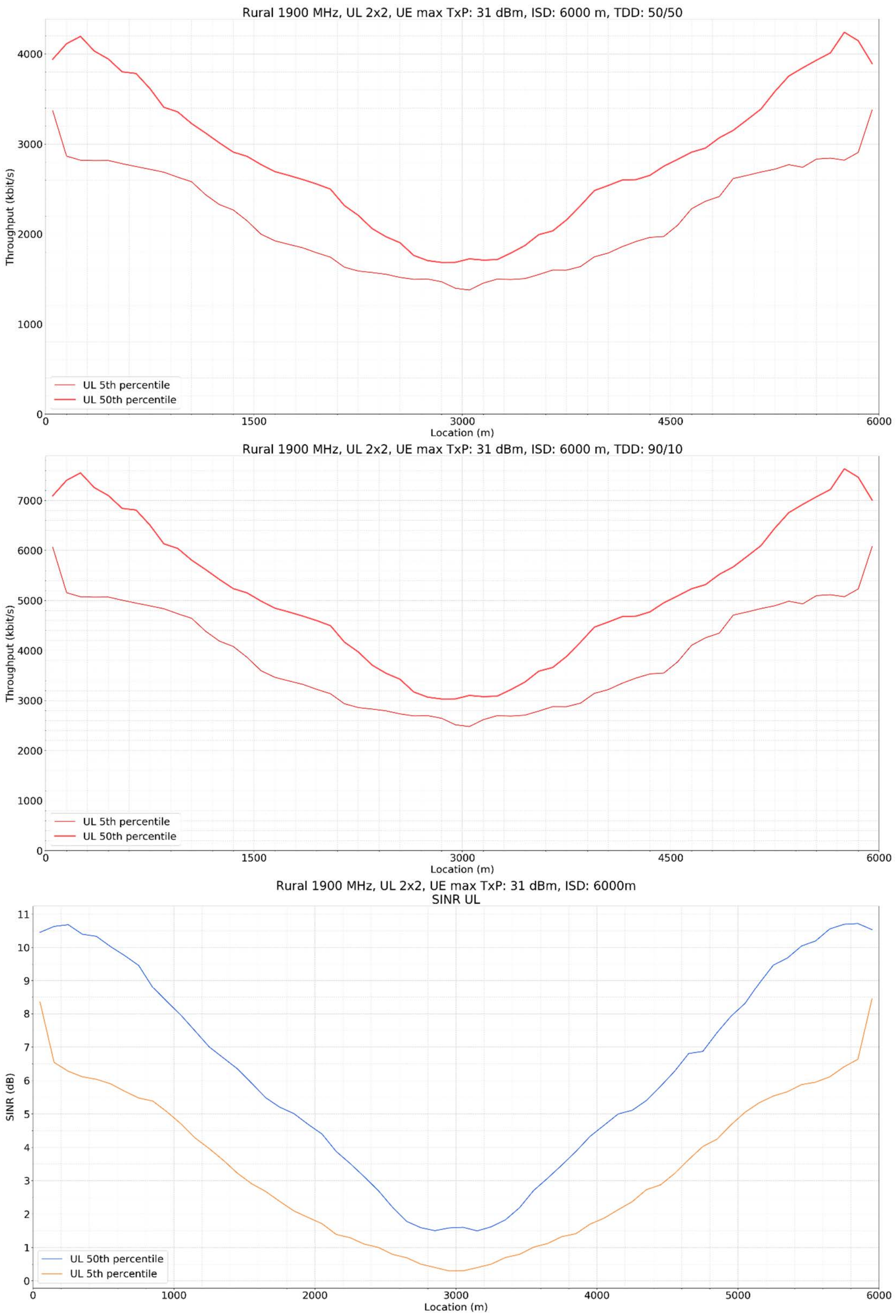


Figure A.184

Interference to noise ratio tables

	5th percentile	50th percentile	95th percentile
Full cell (UL)	-110 dBm	-94 dBm	-75 dBm
Cell centre (UL)	-101 dBm	-94 dBm	-88 dBm
Cell edge (UL)	-96 dBm	-90 dBm	-86 dBm

UL 1x4

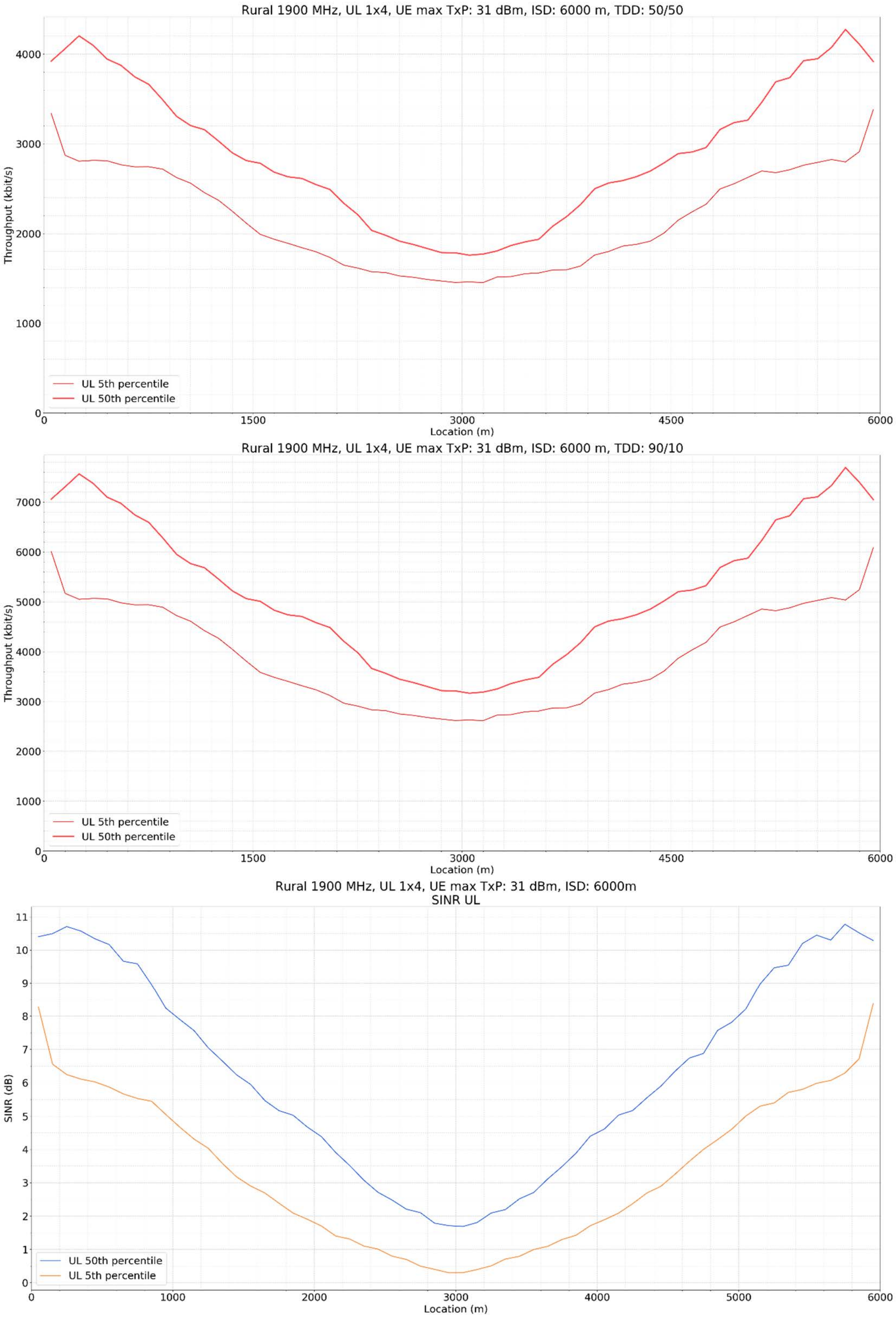


Figure A.185

Interference to noise ratio tables

	5th percentile	50th percentile	95th percentile
Full cell (UL)	-108 dBm	-91 dBm	-72 dBm
Cell centre (UL)	-102 dBm	-94 dBm	-88 dBm
Cell edge (UL)	-93 dBm	-87 dBm	-82 dBm

UL 2x4

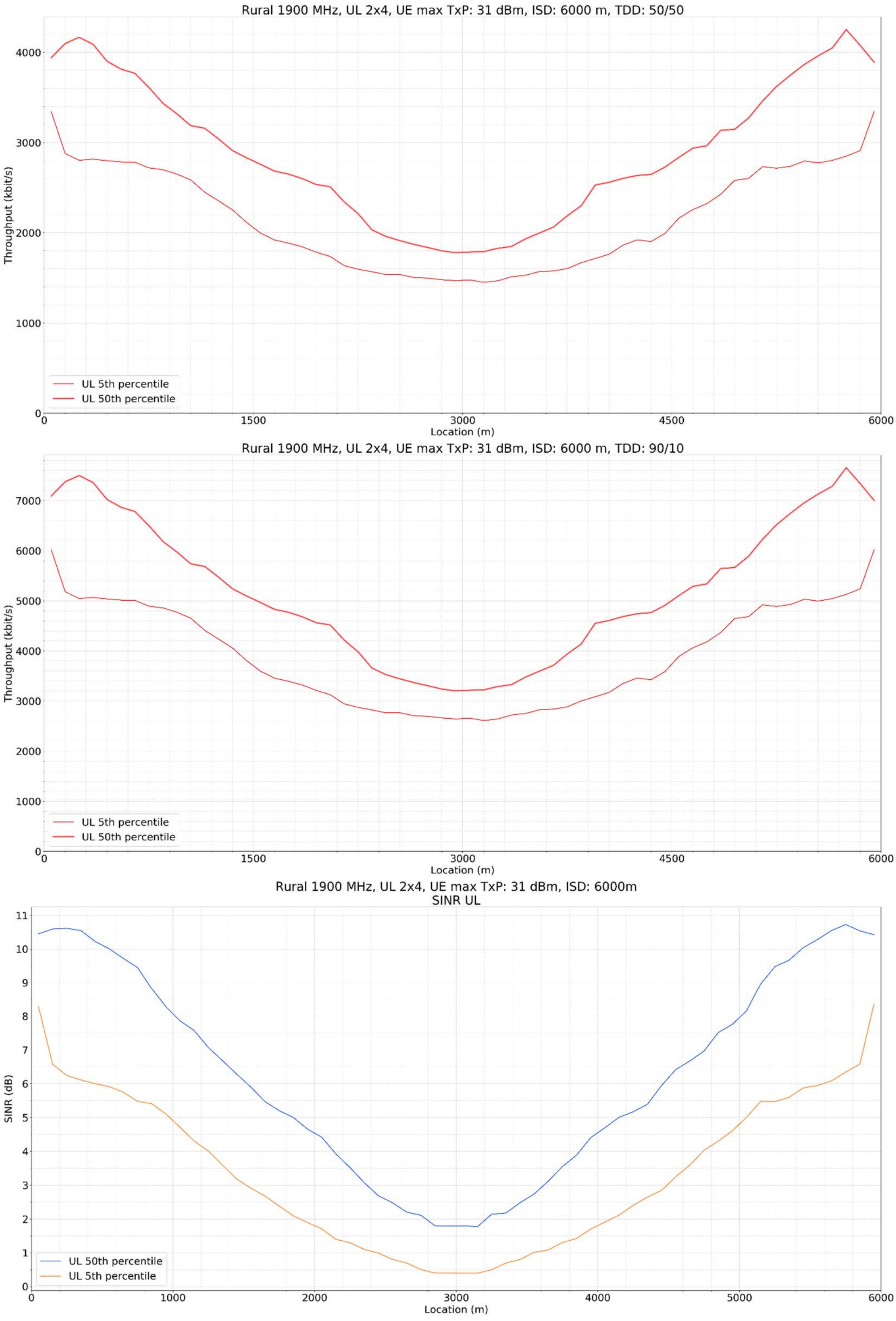


Figure A.186

Interference to noise ratio tables

	5th percentile	50th percentile	95th percentile
Full cell (UL)	-108 dBm	-92 dBm	-73 dBm
Cell centre (UL)	-104 dBm	-94 dBm	-87 dBm
Cell edge (UL)	-93 dBm	-88 dBm	-82 dBm

UL 1x8

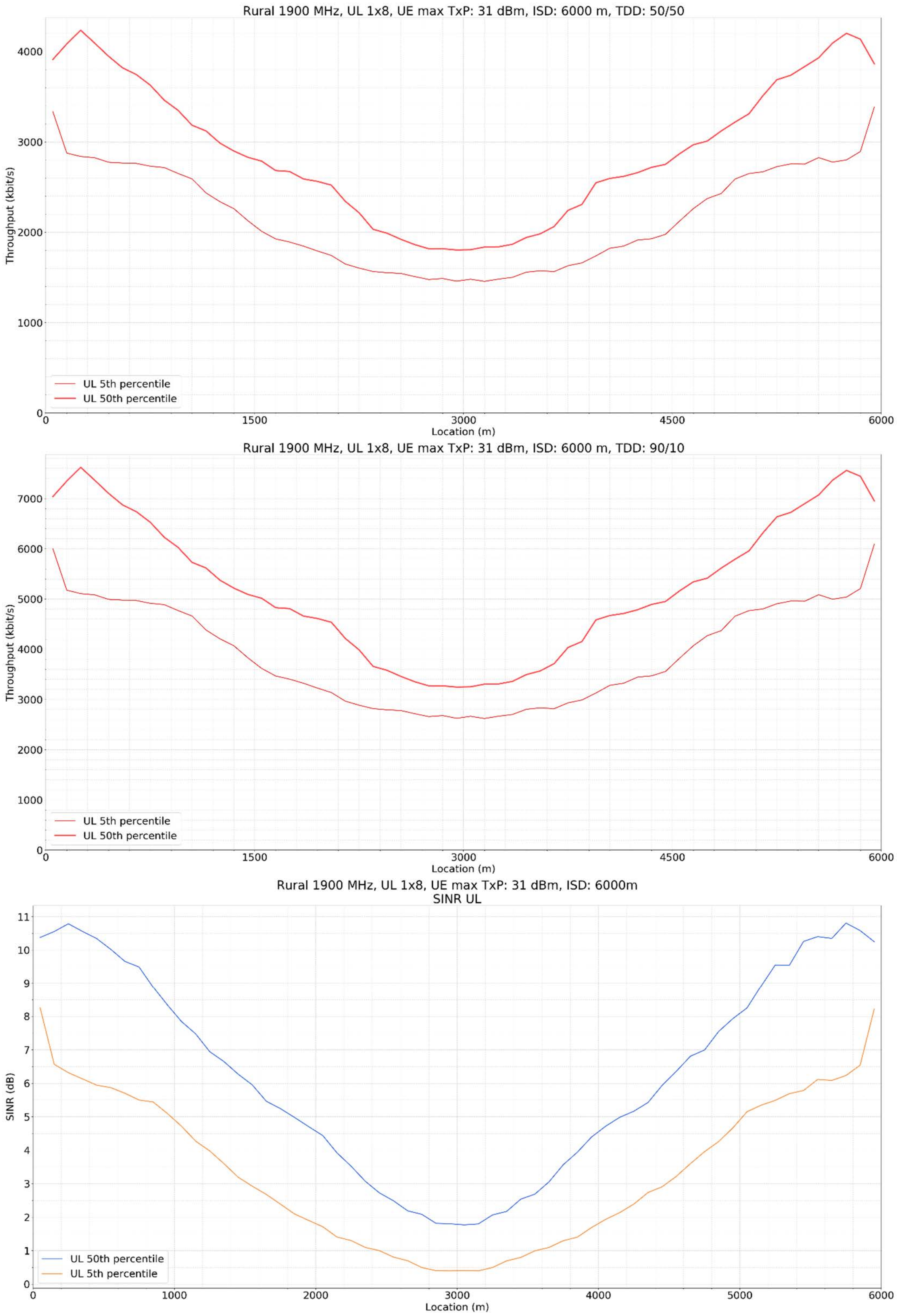


Figure A.187

Interference to noise ratio tables

	5th percentile	50th percentile	95th percentile
Full cell (UL)	-110 dBm	-91 dBm	-70 dBm
Cell centre (UL)	-105 dBm	-96 dBm	-86 dBm
Cell edge (UL)	-91 dBm	-85 dBm	-81 dBm

UL 2x8

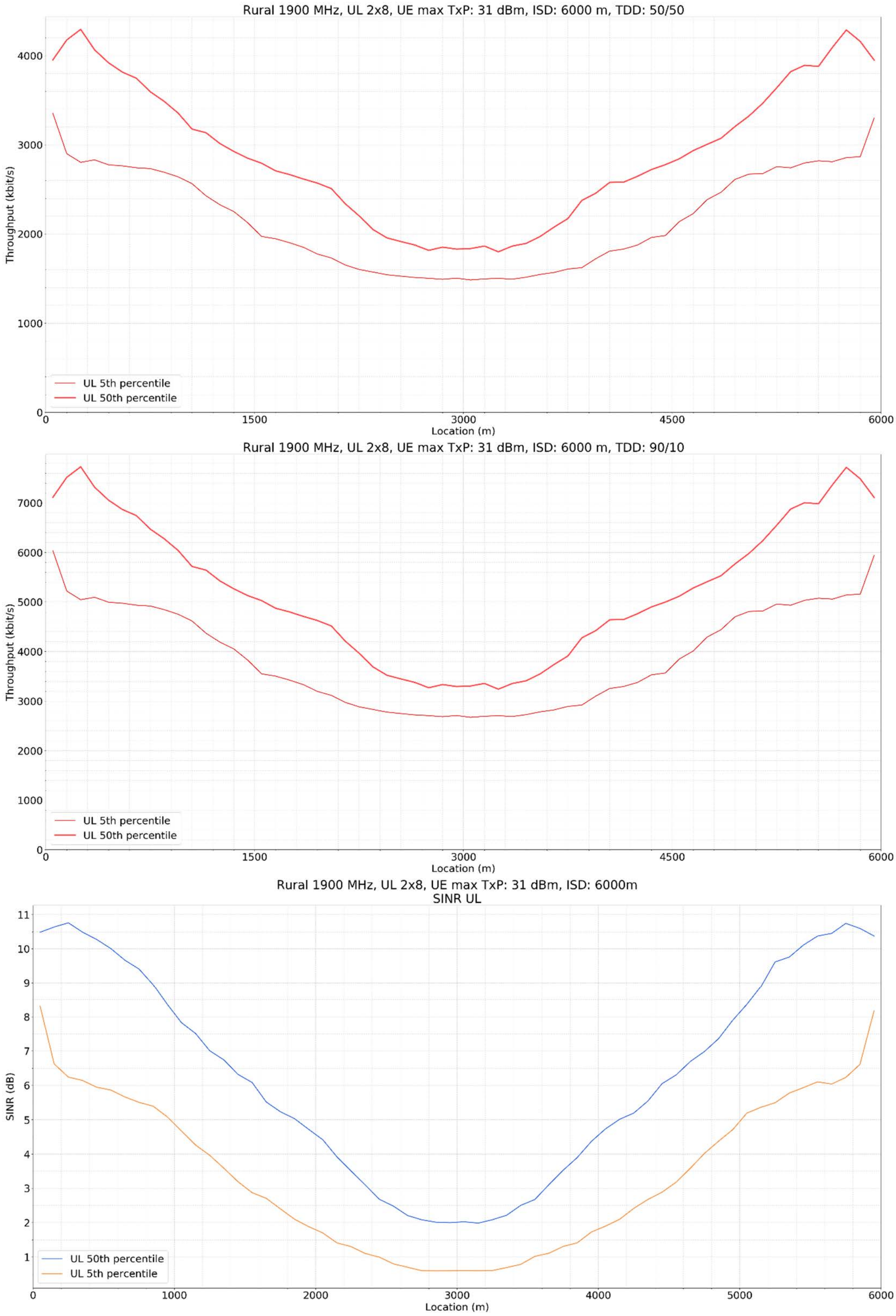


Figure A.188

Interference to noise ratio tables

	5th percentile	50th percentile	95th percentile
Full cell (UL)	-110 dBm	-91 dBm	-71 dBm
Cell centre (UL)	-106 dBm	-97 dBm	-87 dBm
Cell edge (UL)	-91 dBm	-85 dBm	-80 dBm

A.2.2.4 Rural, 4 KM ISD, 2 cells/site

A.2.2.4.1 Downlink, 63 dBm EIRP

DL 2x1

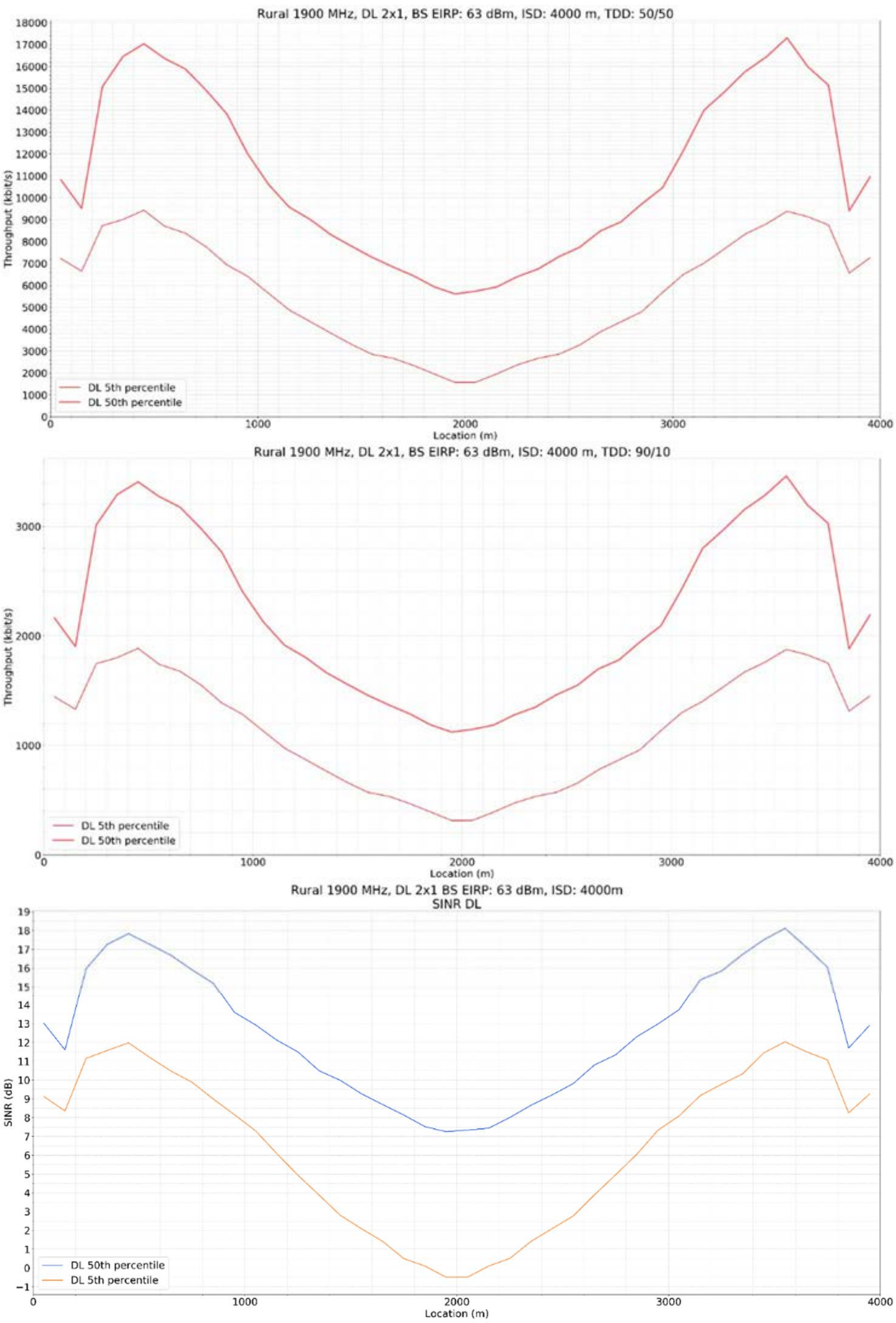


Figure A.189

Interference to noise ratio tables

	5th percentile	50th percentile	95th percentile
Full cell (DL)	-98 dBm	-80 dBm	-64 dBm
Cell centre (DL)	-83 dBm	-75 dBm	-69 dBm
Cell edge (DL)	-88 dBm	-82 dBm	-76 dBm

DL 2x2

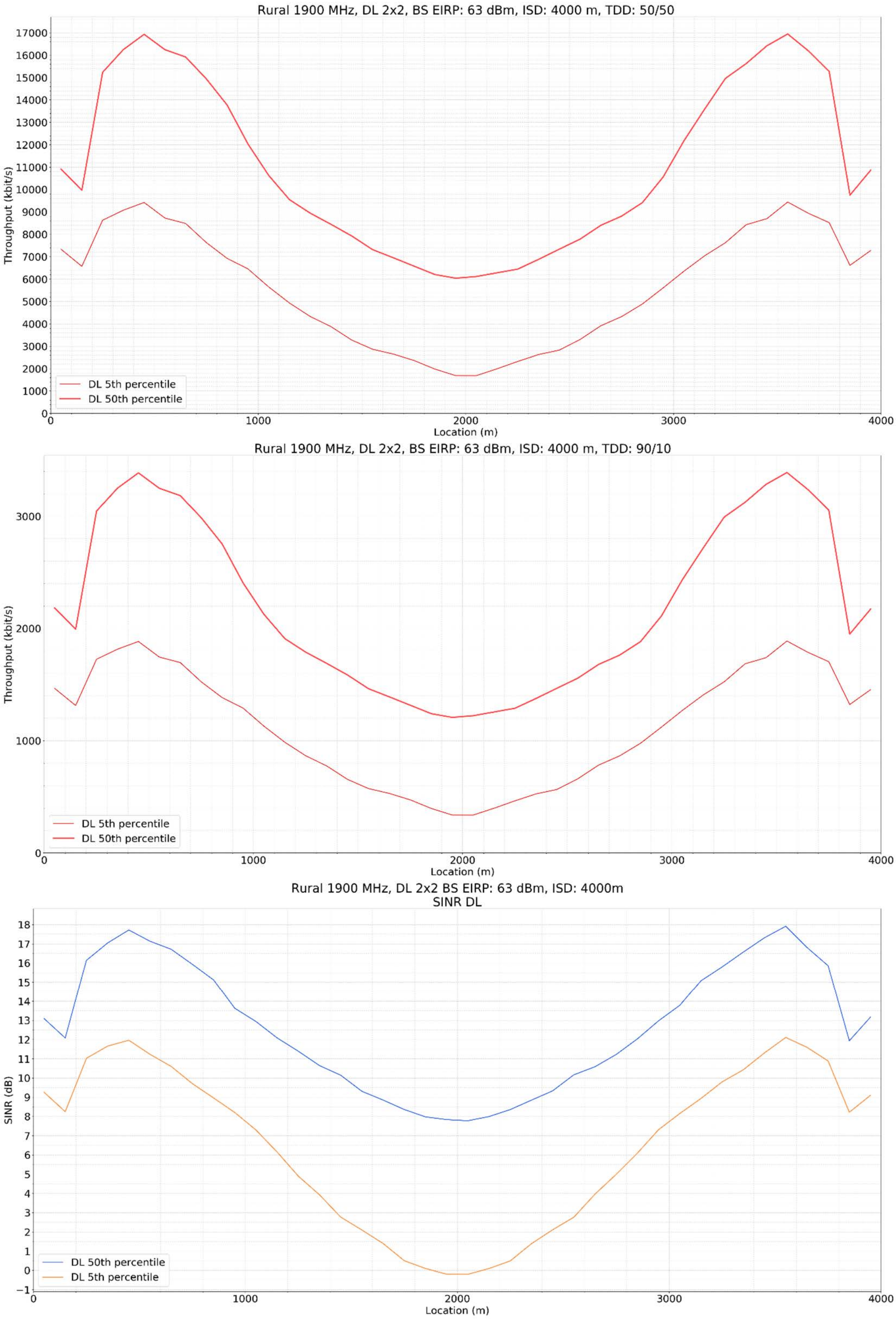


Figure A.190

Interference to noise ratio tables

	5th percentile	50th percentile	95th percentile
Full cell (DL)	-100 dBm	-82 dBm	-65 dBm
Cell centre (DL)	-84 dBm	-77 dBm	-71 dBm
Cell edge (DL)	-89 dBm	-83 dBm	-78 dBm

DL 4x1

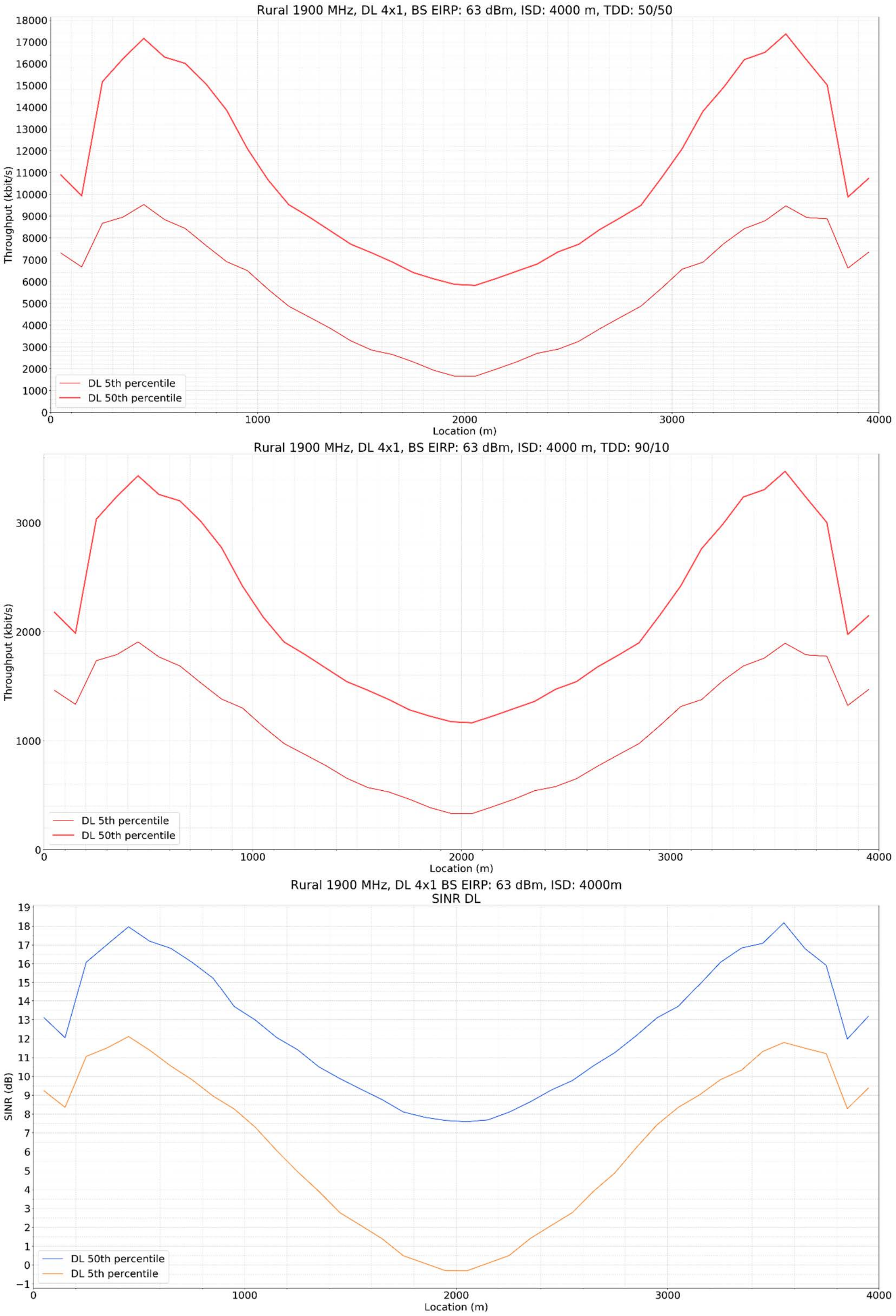


Figure A.191

Interference to noise ratio tables

	5th percentile	50th percentile	95th percentile
Full cell (DL)	-97 dBm	-79 dBm	-63 dBm
Cell centre (DL)	-83 dBm	-75 dBm	-69 dBm
Cell edge (DL)	-86 dBm	-80 dBm	-74 dBm

DL 4x2

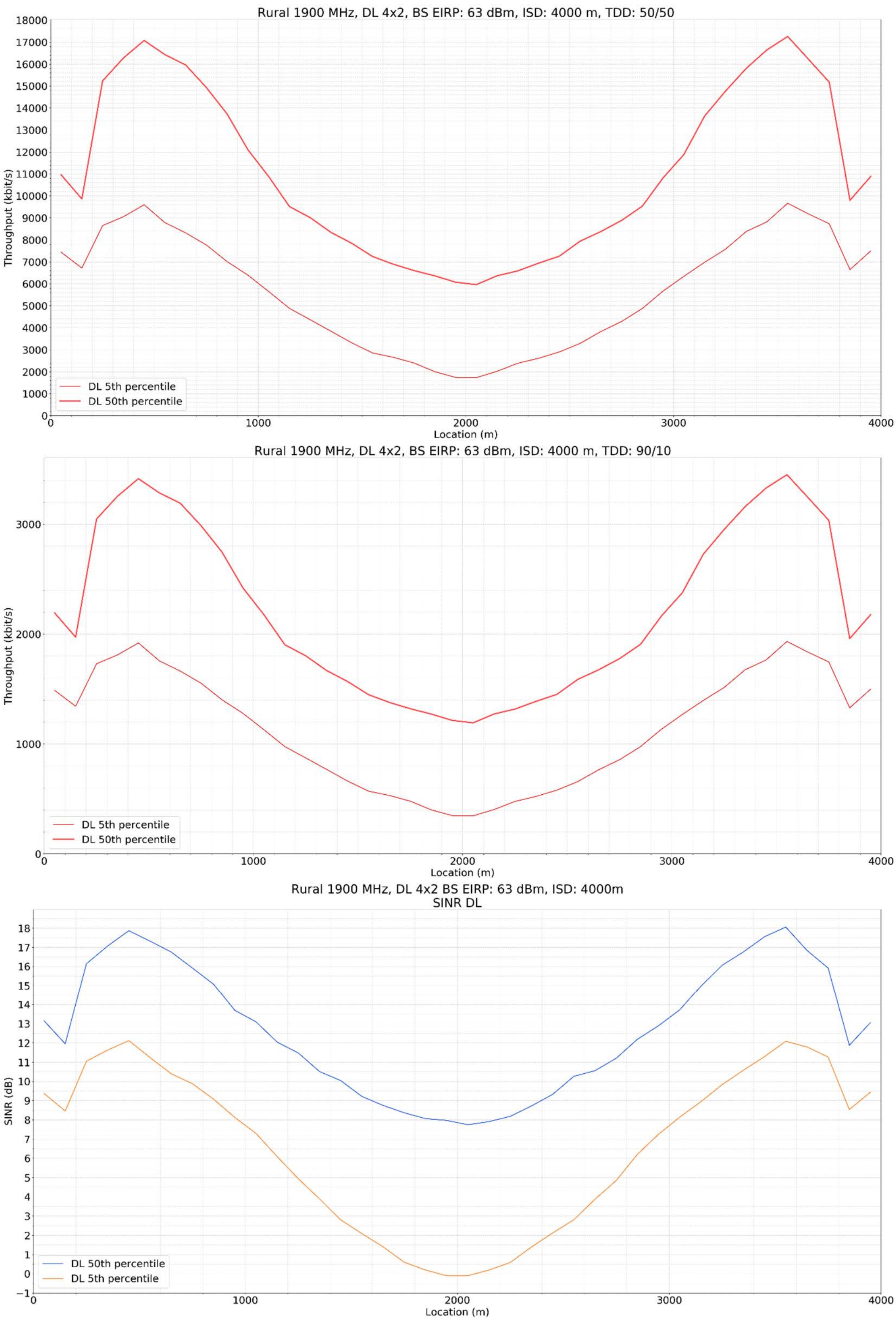


Figure A.192

Interference to noise ratio tables

	5th percentile	50th percentile	95th percentile
Full cell (DL)	-99 dBm	-80 dBm	-64 dBm
Cell centre (DL)	-83 dBm	-77 dBm	-70 dBm
Cell edge (DL)	-87 dBm	-81 dBm	-75 dBm

DL 8x1

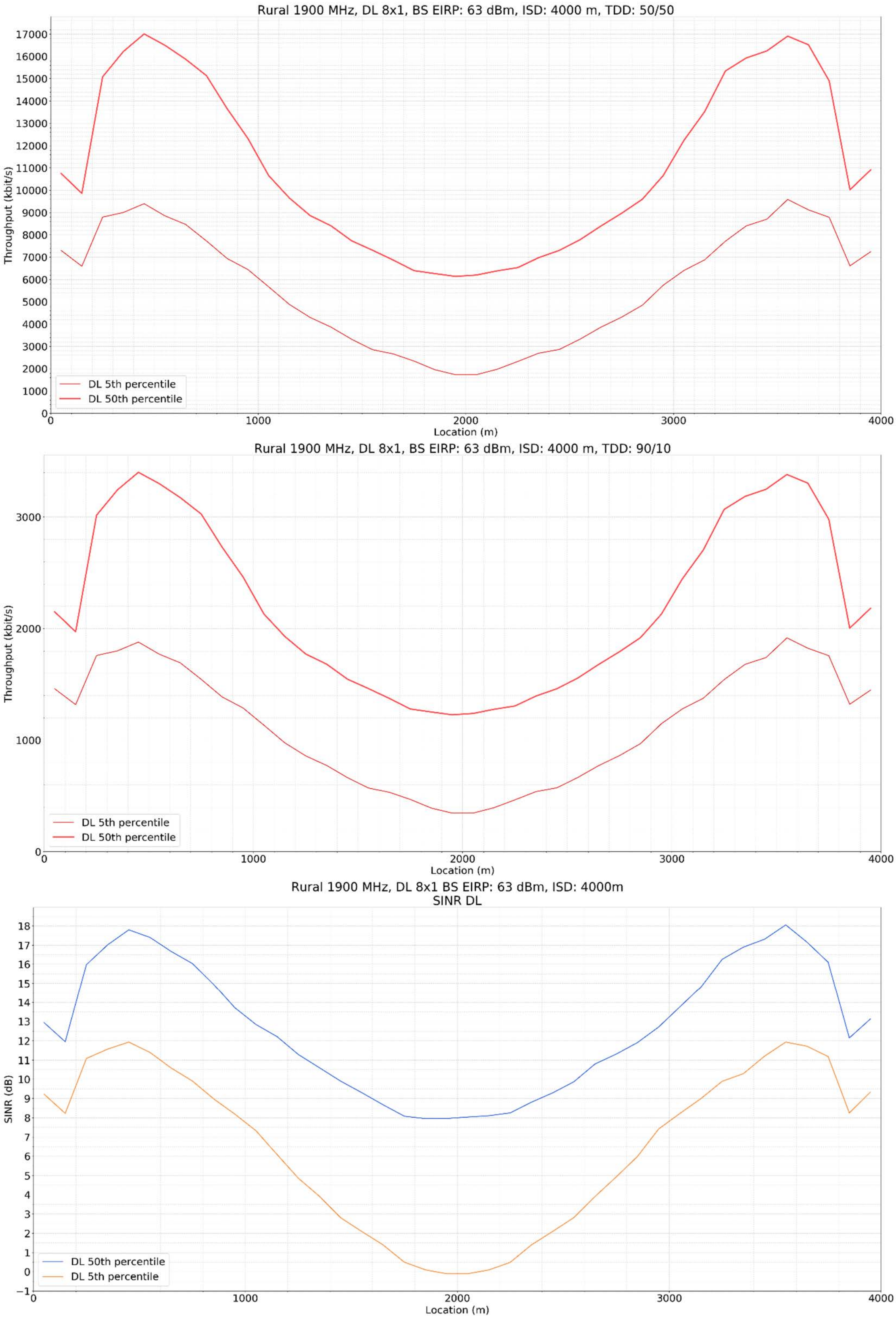


Figure A.193

Interference to noise ratio tables

	5th percentile	50th percentile	95th percentile
Full cell (DL)	-98 dBm	-79 dBm	-62 dBm
Cell centre (DL)	-81 dBm	-75 dBm	-69 dBm
Cell edge (DL)	-85 dBm	-76 dBm	-73 dBm

DL 8x2

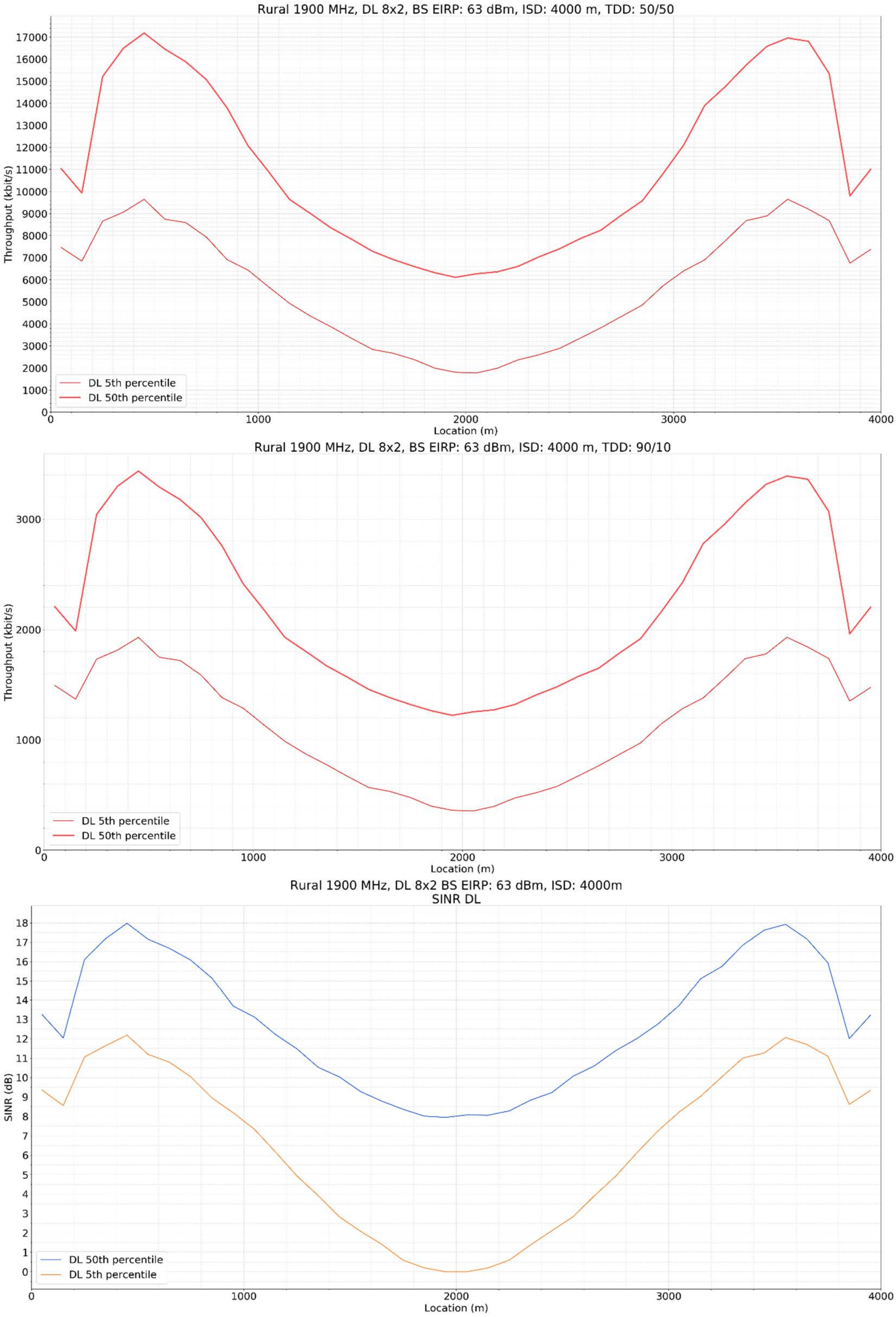


Figure A.194

Interference to noise ratio tables

	5th percentile	50th percentile	95th percentile
Full cell (DL)	-100 dBm	-80 dBm	-62 dBm
Cell centre (DL)	-84 dBm	-76 dBm	-70 dBm
Cell edge (DL)	-86 dBm	-80 dBm	-74 dBm

A.2.2.4.2 Downlink, 40 dBm EIRP

DL 2x1

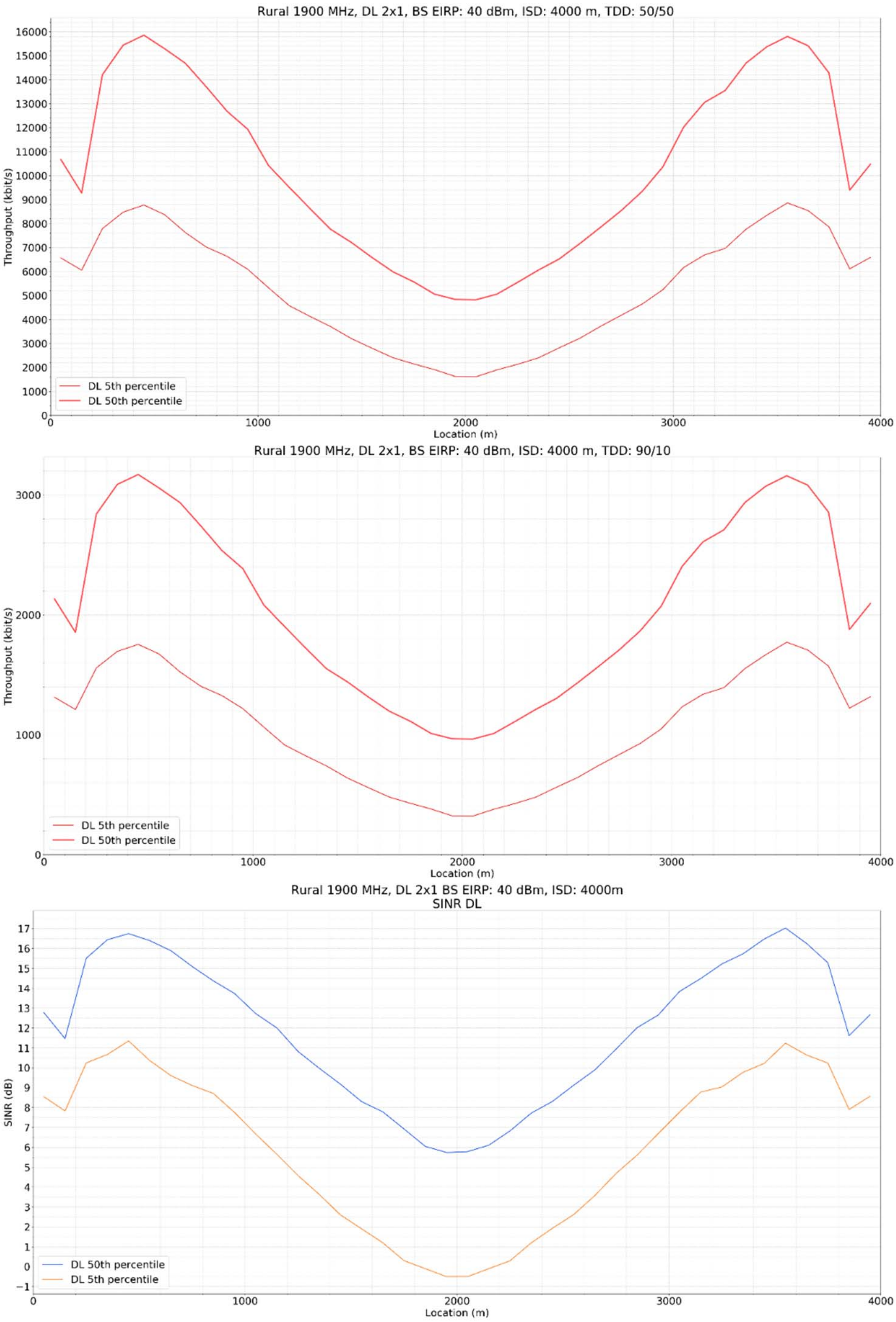


Figure A.195

Interference to noise ratio tables

	5th percentile	50th percentile	95th percentile
Full cell (DL)	-120 dBm	-103 dBm	-87 dBm
Cell centre (DL)	-106 dBm	-98 dBm	-92 dBm
Cell edge (DL)	-110 dBm	-104 dBm	-99 dBm

DL 2x2

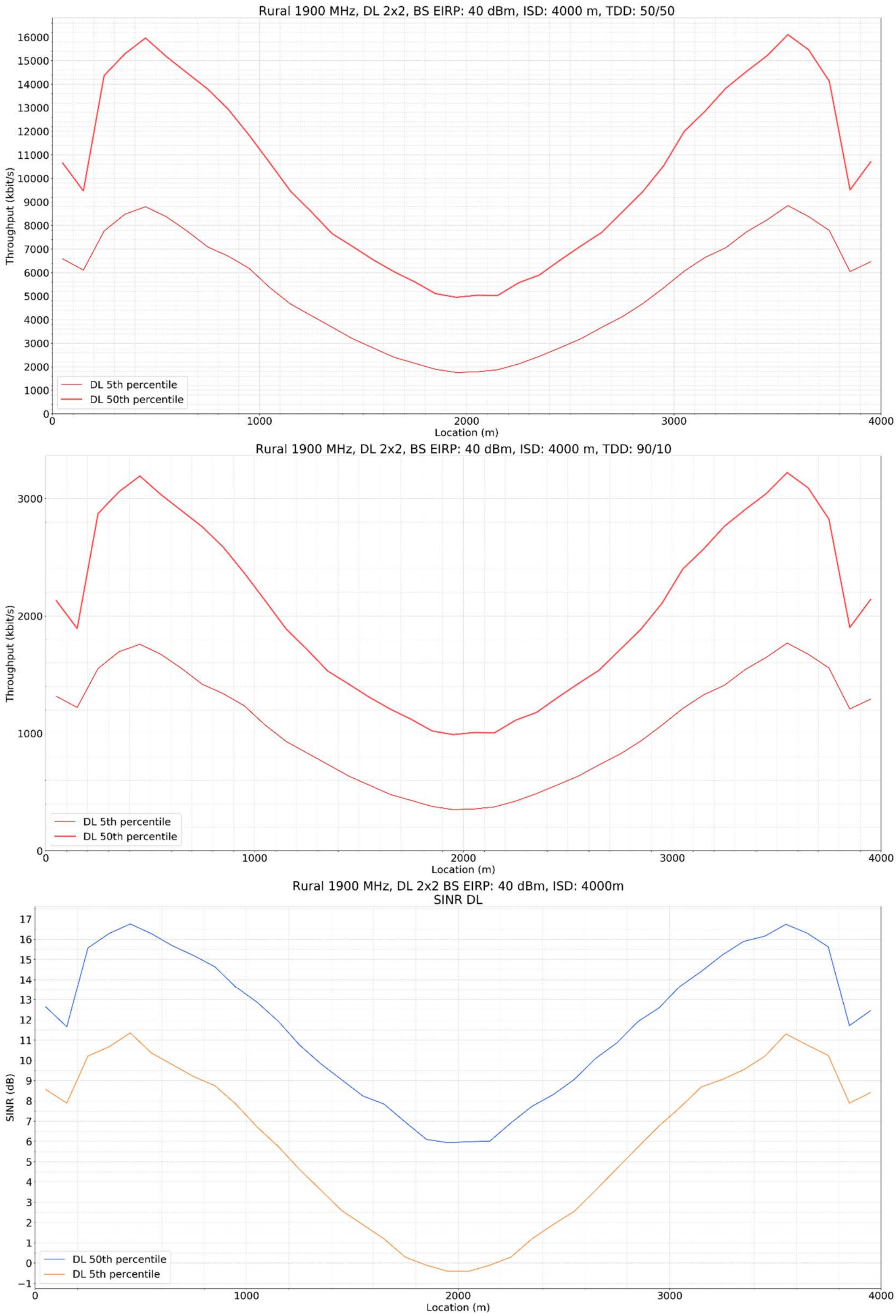


Figure A.196

Interference to noise ratio tables

	5th percentile	50th percentile	95th percentile
Full cell (DL)	-122 dBm	-105 dBm	-88 dBm
Cell centre (DL)	-106 dBm	-100 dBm	-94 dBm
Cell edge (DL)	-111 dBm	-105 dBm	-100 dBm

DL 4x1

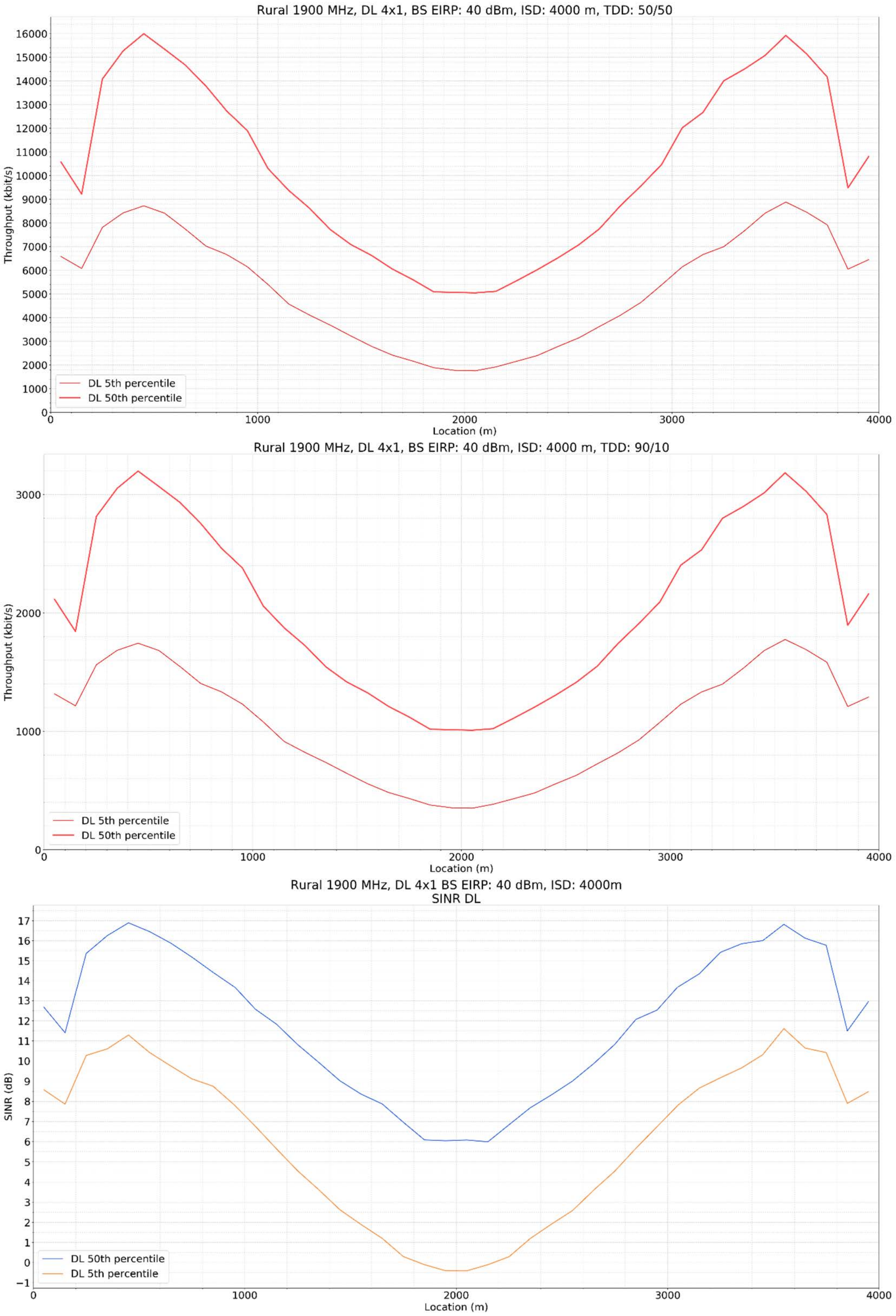


Figure A.197

Interference to noise ratio tables

	5th percentile	50th percentile	95th percentile
Full cell (DL)	-119 dBm	-102 dBm	-86 dBm
Cell centre (DL)	-105 dBm	-97 dBm	-91 dBm
Cell edge (DL)	-108 dBm	-102 dBm	-97 dBm

DL 4x2

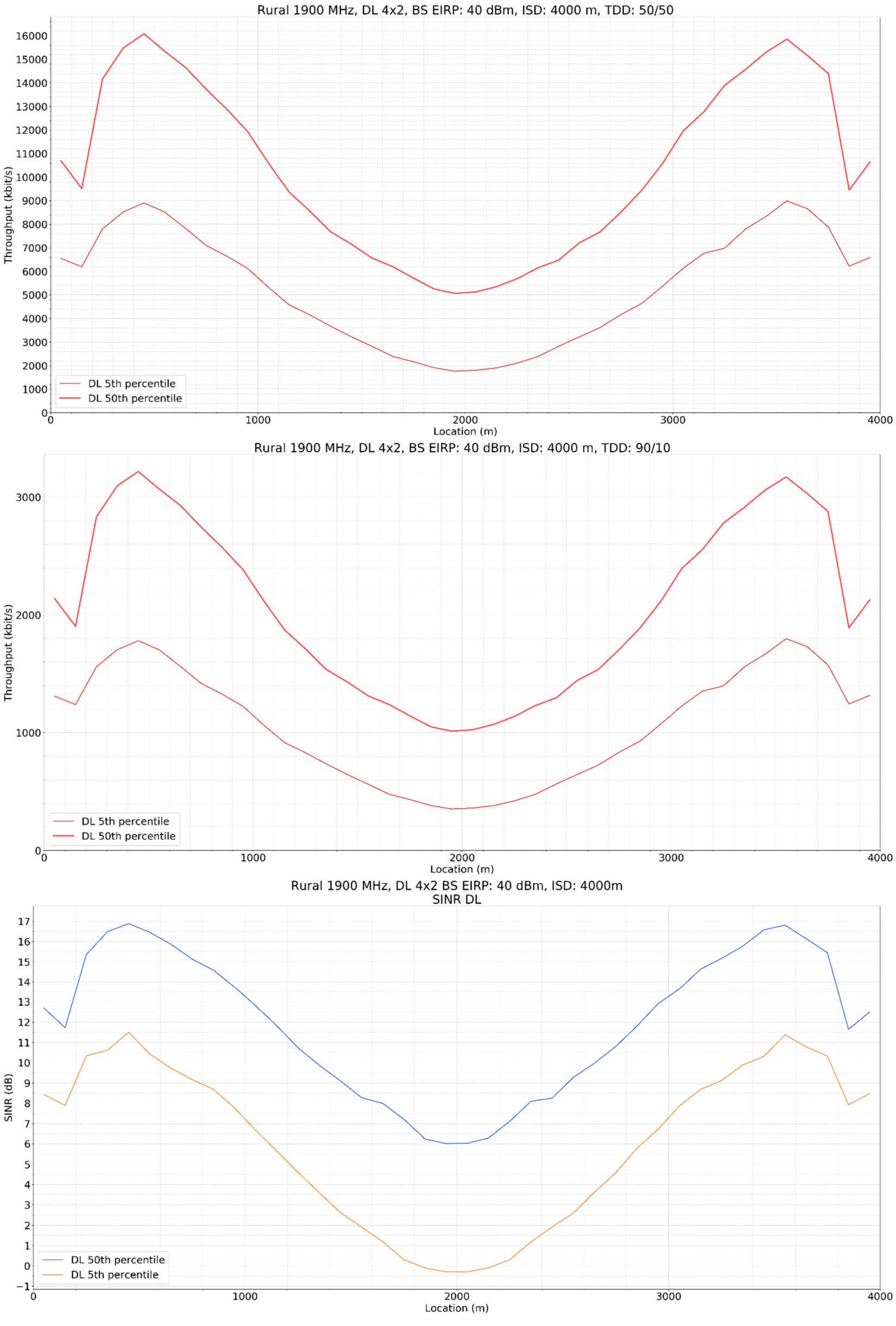


Figure A.198

Interference to noise ratio tables

	5th percentile	50th percentile	95th percentile
Full cell (DL)	-121 dBm	-103 dBm	-87 dBm
Cell centre (DL)	-107 dBm	-100 dBm	-92 dBm
Cell edge (DL)	-109 dBm	-103 dBm	-98 dBm

DL 8x1

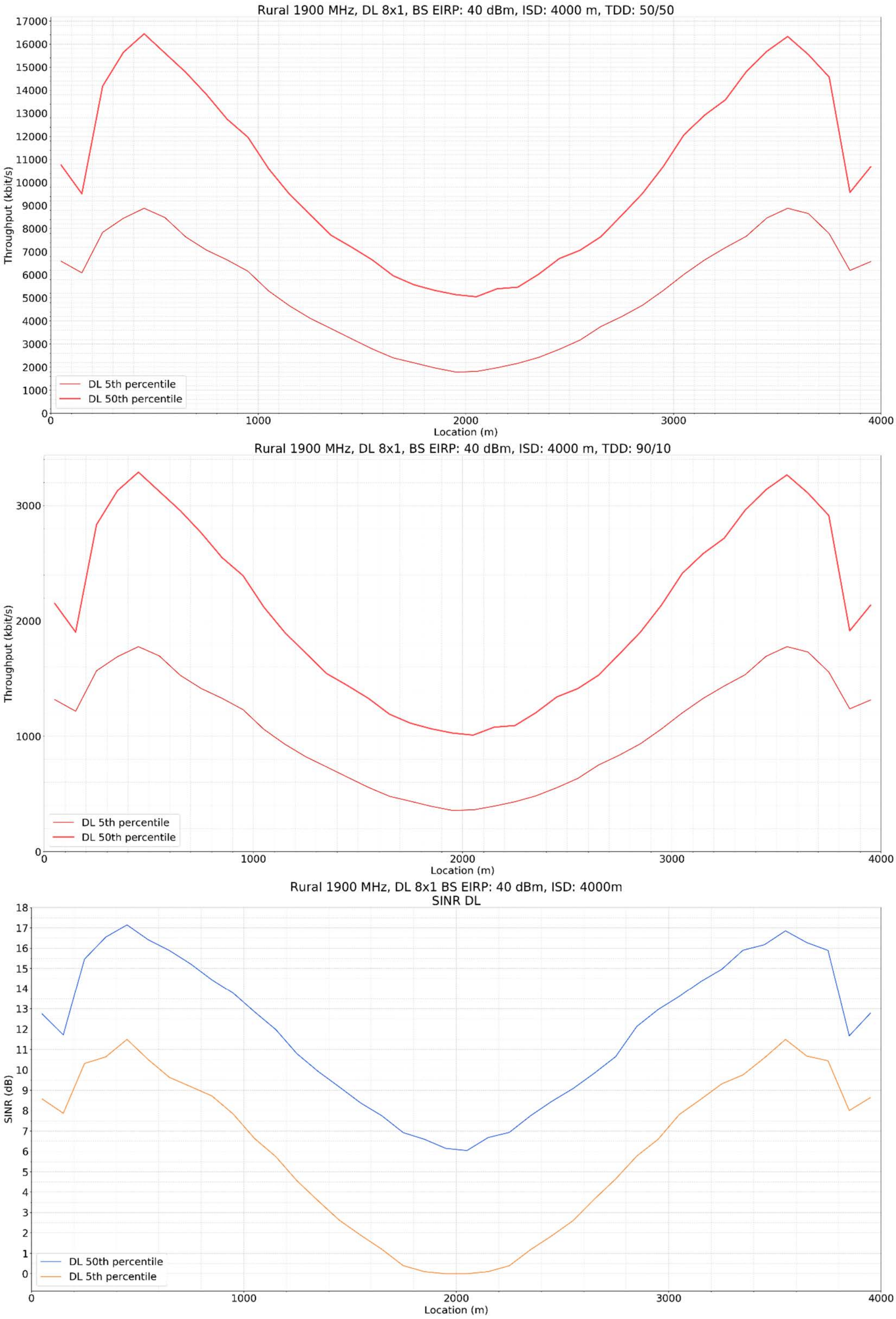


Figure A.199

Interference to noise ratio tables

	5th percentile	50th percentile	95th percentile
Full cell (DL)	-120 dBm	-102 dBm	-85 dBm
Cell centre (DL)	-107 dBm	-98 dBm	-92 dBm
Cell edge (DL)	-107 dBm	-101 dBm	-96 dBm

DL 8x2

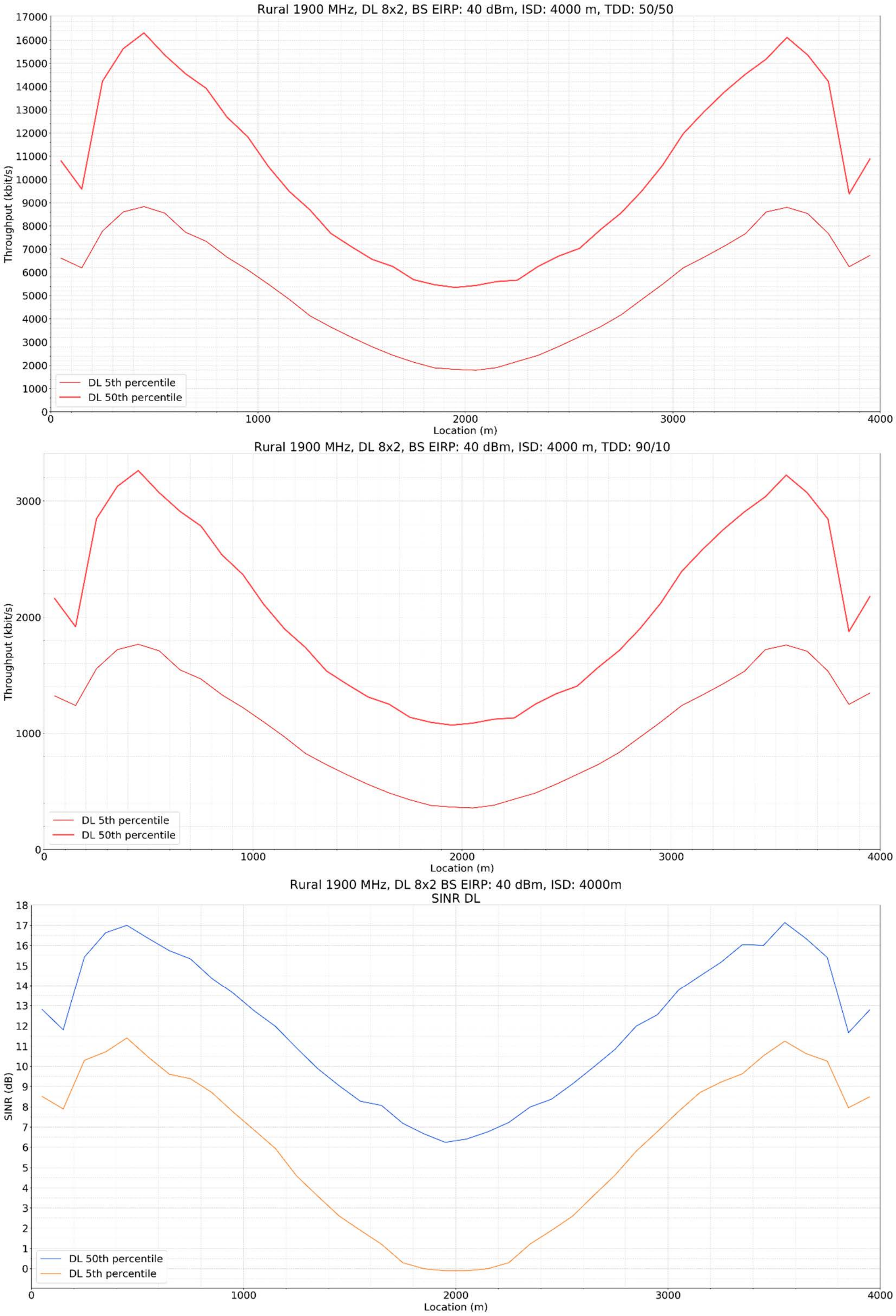


Figure A.200

Interference to noise ratio tables

	5th percentile	50th percentile	95th percentile
Full cell (DL)	-122 dBm	-103 dBm	-86 dBm
Cell centre (DL)	-106 dBm	-100 dBm	-94 dBm
Cell edge (DL)	-108 dBm	-102 dBm	-97 dBm

A.2.2.4.3 Uplink, 23 dBm max transmit power

UL 1x2

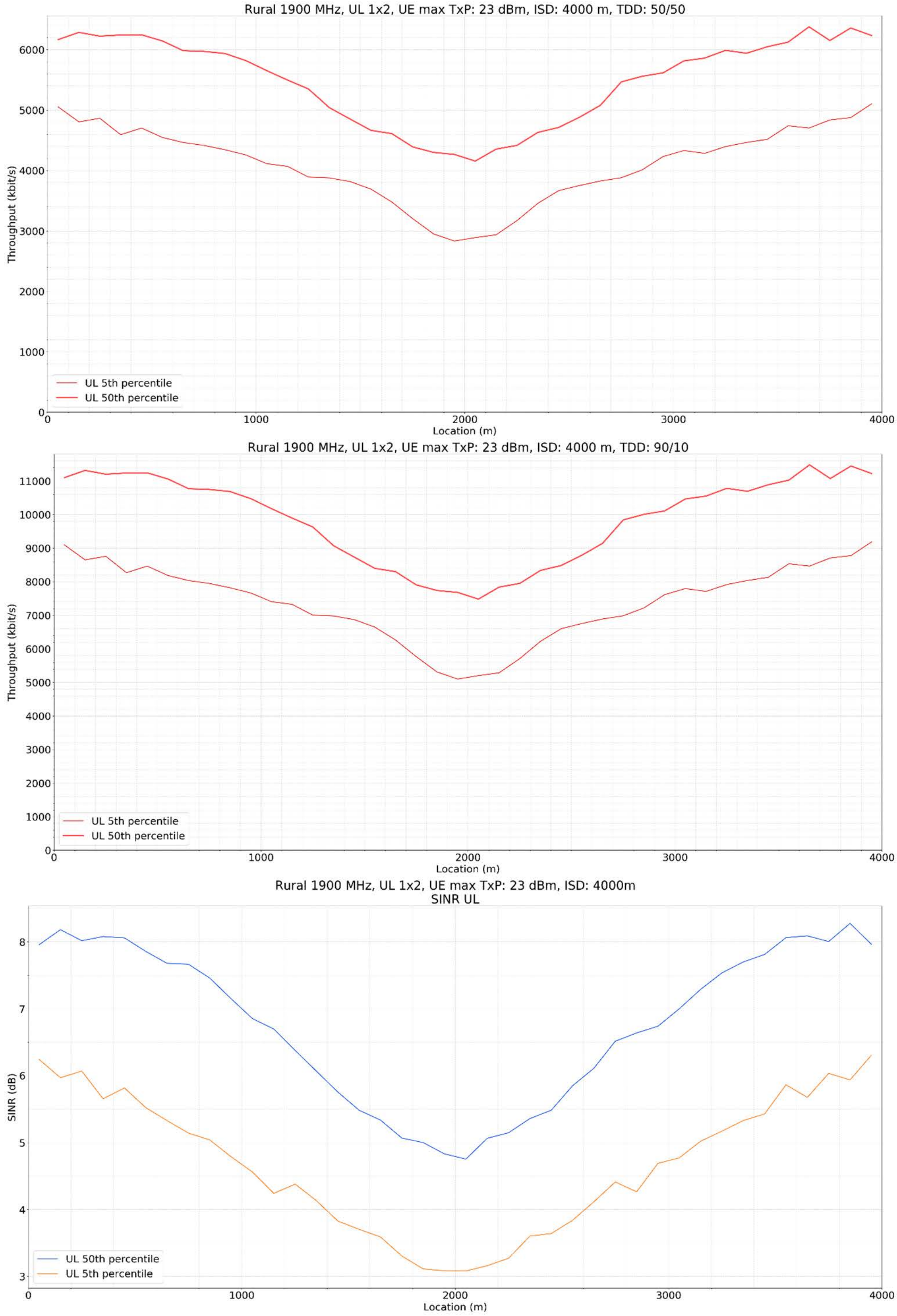


Figure A.201

Interference to noise ratio tables

	5th percentile	50th percentile	95th percentile
Full cell (UL)	-112 dBm	-97 dBm	-83 dBm
Cell centre (UL)	-106 dBm	-96 dBm	-92 dBm
Cell edge (UL)	-100 dBm	-96 dBm	-92 dBm

UL 2x2

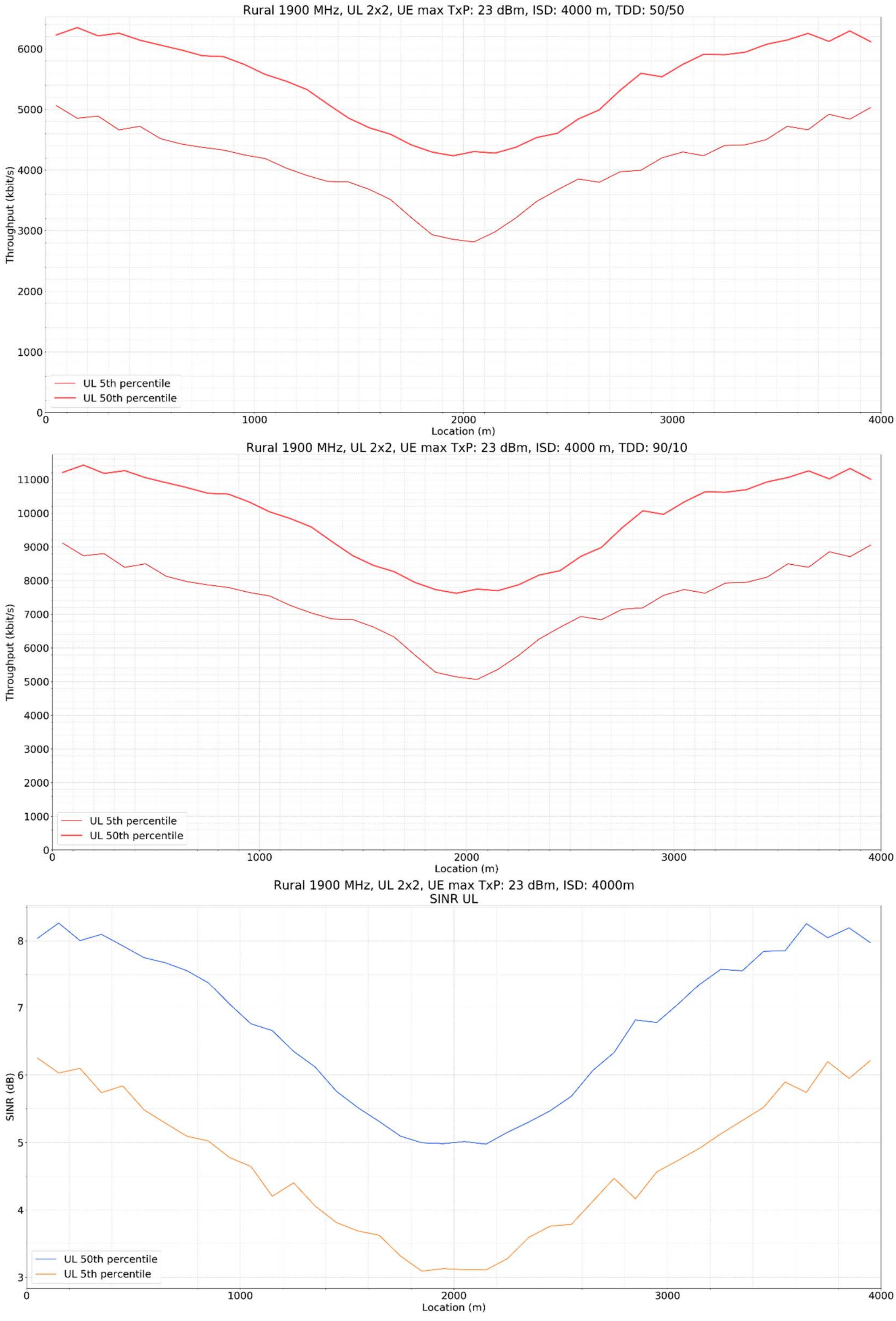


Figure A.202

Interference to noise ratio tables

	5th percentile	50th percentile	95th percentile
Full cell (UL)	-113 dBm	-98 dBm	-84 dBm
Cell centre (UL)	-107 dBm	-97 dBm	-94 dBm
Cell edge (UL)	-102 dBm	-96 dBm	-94 dBm

UL 1x4

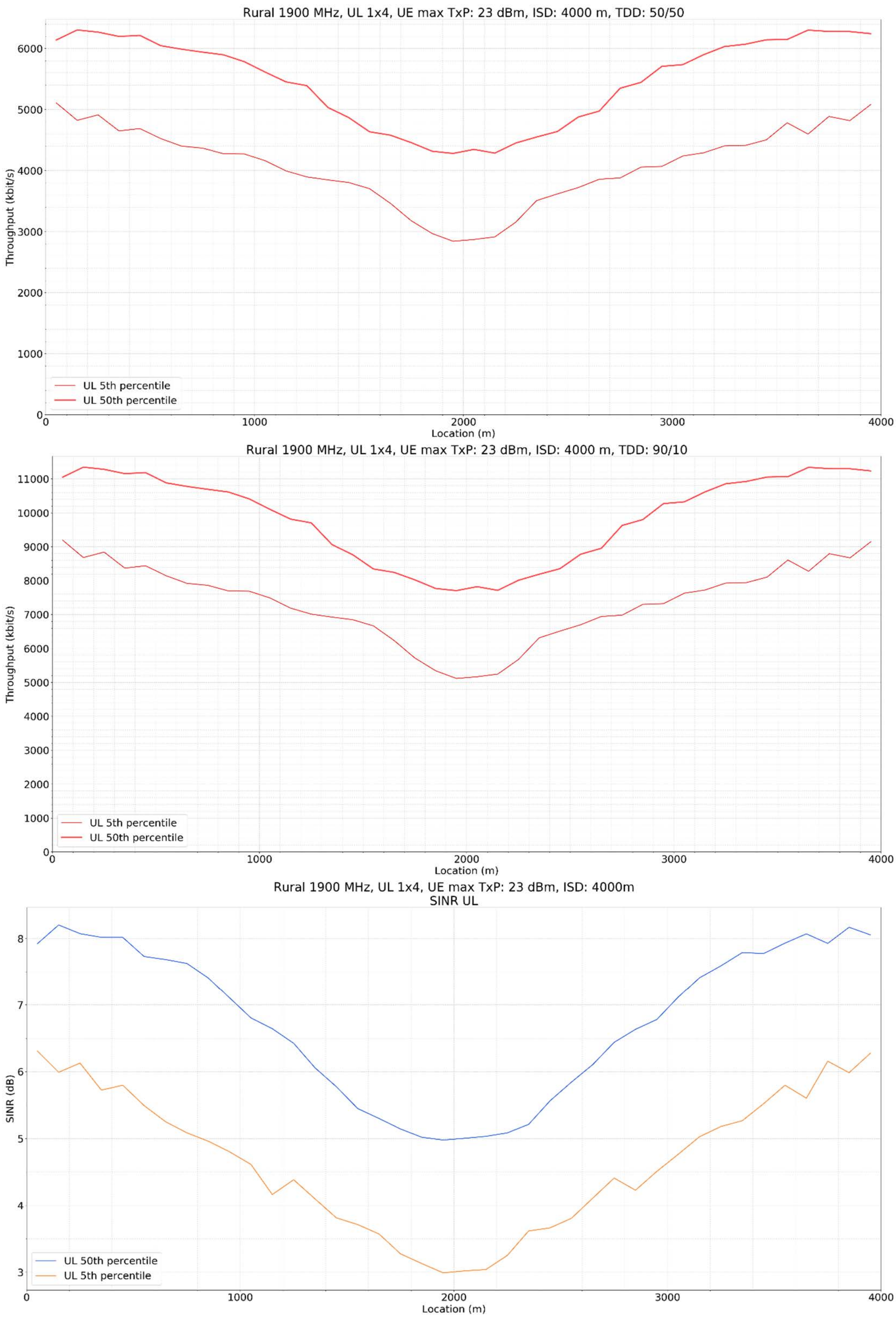
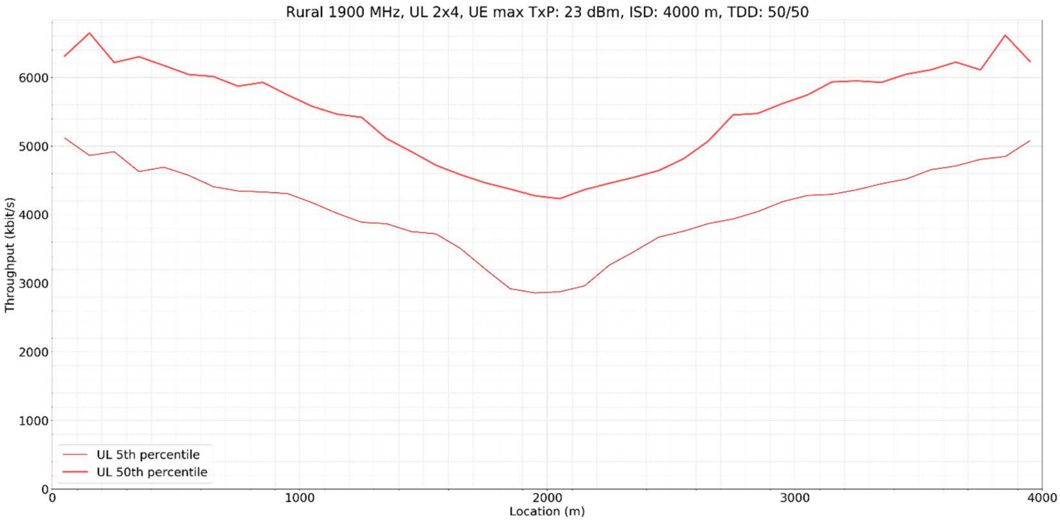


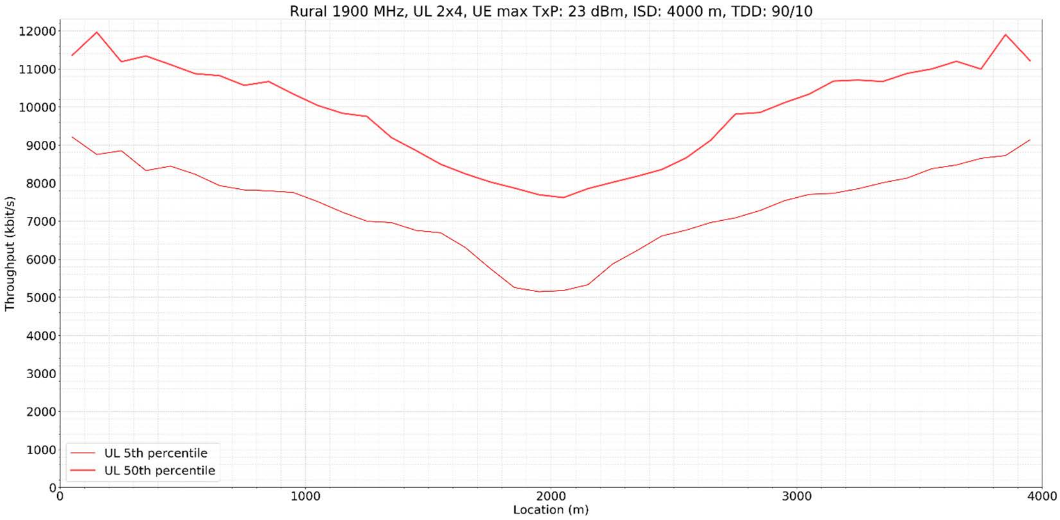
Figure A.203

Interference to noise ratio tables

	5th percentile	50th percentile	95th percentile
Full cell (UL)	-112 dBm	-96 dBm	-81 dBm
Cell centre (UL)	-106 dBm	-97 dBm	-92 dBm
Cell edge (UL)	-98 dBm	-93 dBm	-90 dBm

UL 2x4





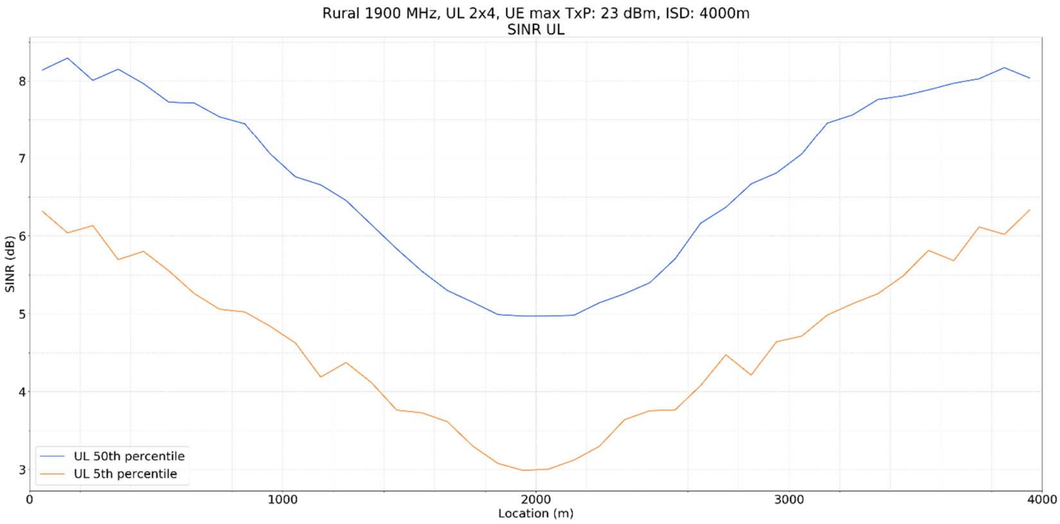


Figure A.204

Interference to noise ratio tables

	5th percentile	50th percentile	95th percentile
Full cell (UL)	-112 dBm	-96 dBm	-82 dBm
Cell centre (UL)	-107 dBm	-98 dBm	-92 dBm
Cell edge (UL)	-99 dBm	-94 dBm	-90 dBm

UL 1x8

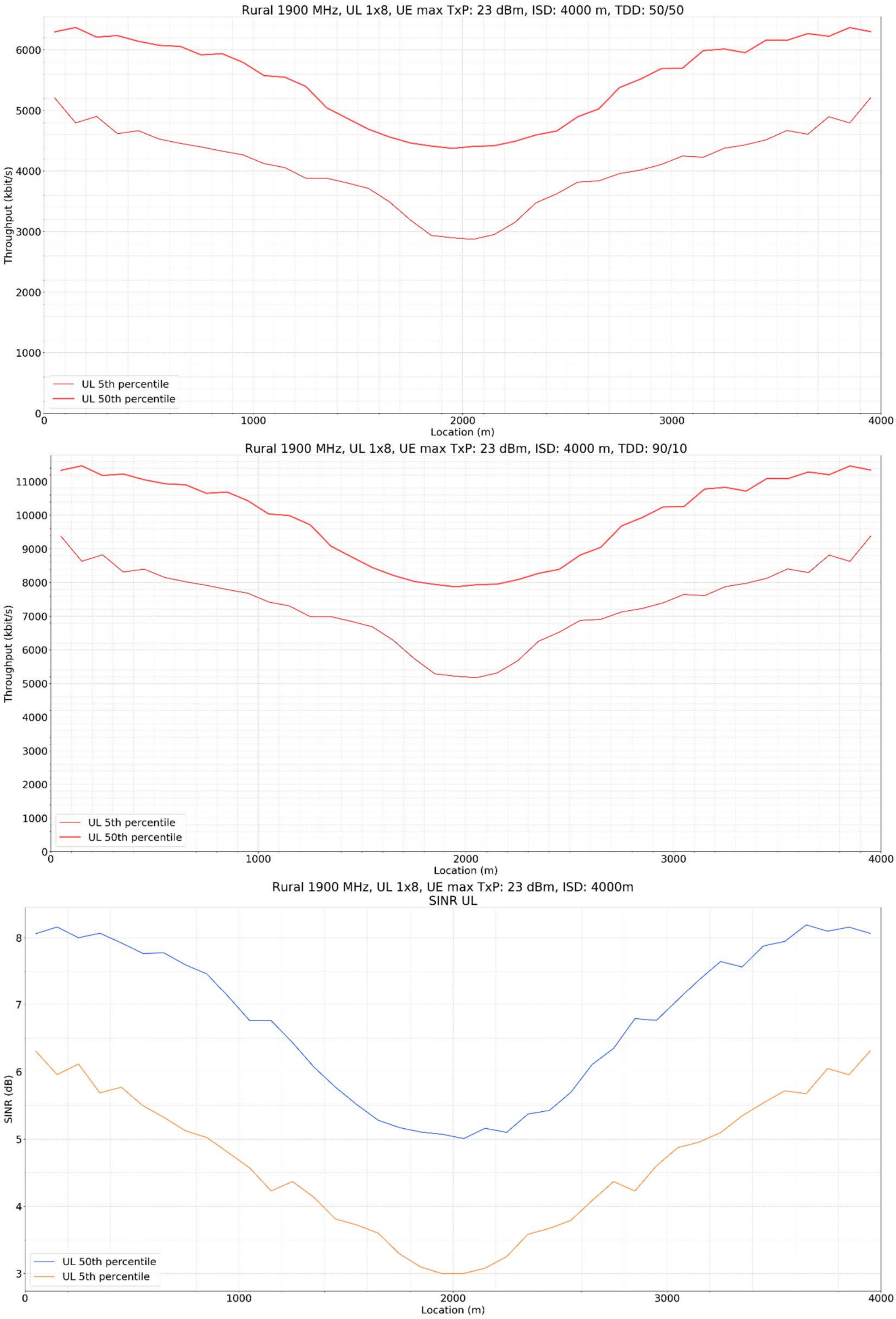


Figure A.205

Interference to noise ratio tables

	5th percentile	50th percentile	95th percentile
Full cell (UL)	-114 dBm	-95 dBm	-80 dBm
Cell centre (UL)	-108 dBm	-99 dBm	-90 dBm
Cell edge (UL)	-96 dBm	-91 dBm	-87 dBm

UL 2x8

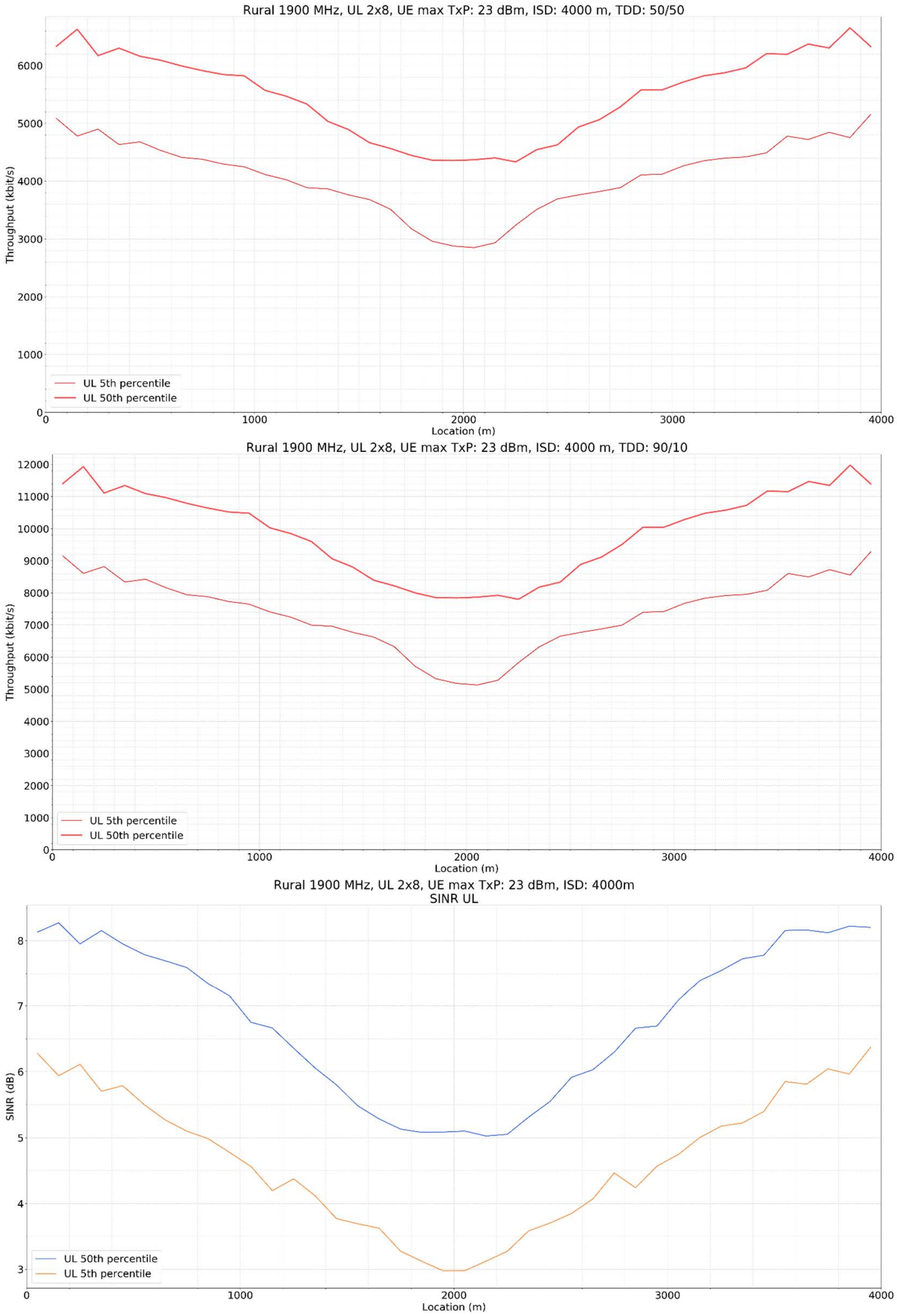


Figure A.206

Interference to noise ratio tables

	5th percentile	50th percentile	95th percentile
Full cell (UL)	-114 dBm	-95 dBm	-80 dBm
Cell centre (UL)	-110 dBm	-100 dBm	-91 dBm
Cell edge (UL)	-96 dBm	-91 dBm	-88 dBm

A.2.2.4.4 Uplink, 31 dBm max transmit power

UL 1x2

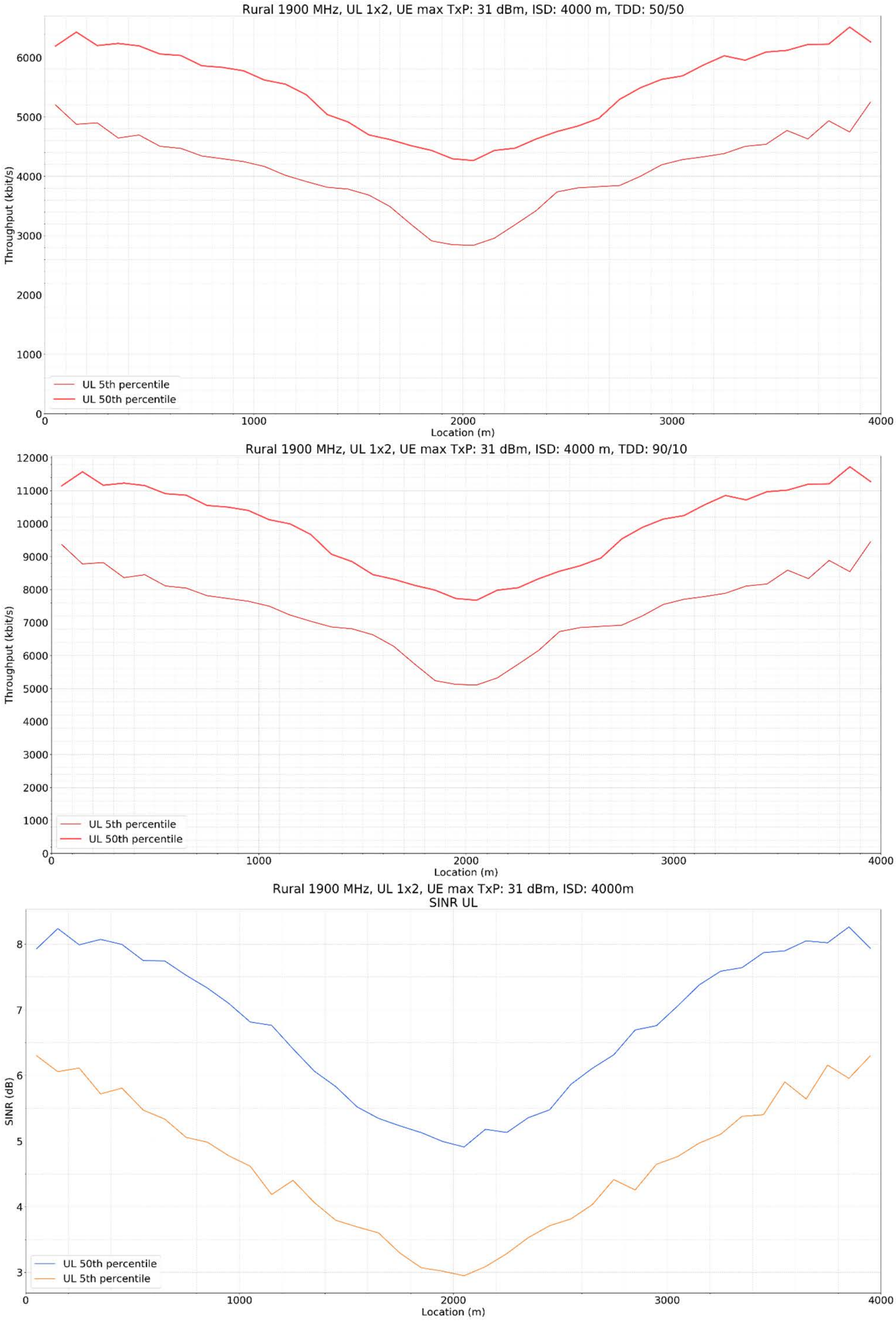


Figure A.207

Interference to noise ratio tables

	5th percentile	50th percentile	95th percentile
Full cell (UL)	-105 dBm	-89 dBm	-75 dBm
Cell centre (UL)	-99 dBm	-89 dBm	-85 dBm
Cell edge (UL)	-92 dBm	-87 dBm	-85 dBm

UL 2x2

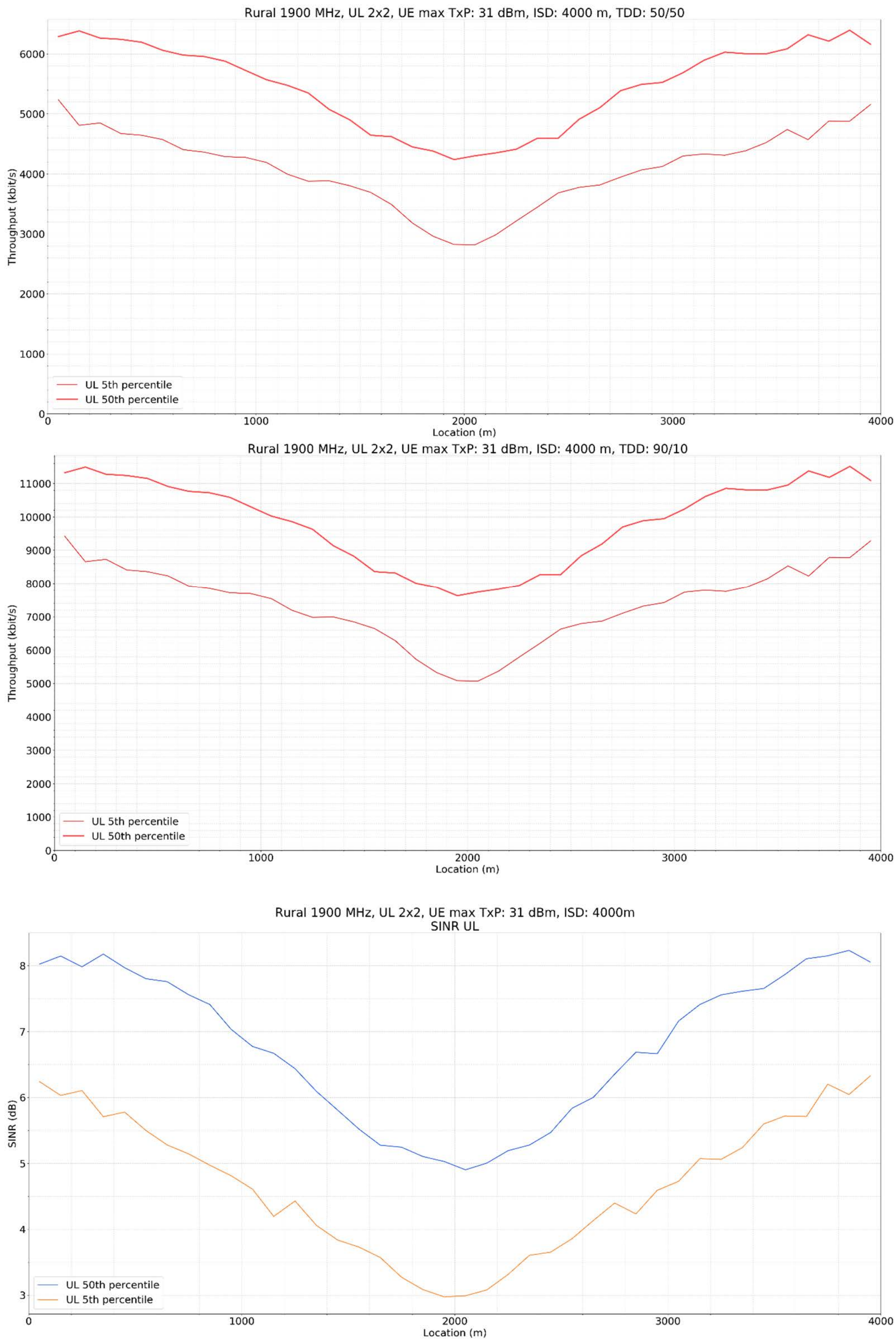


Figure A.208

Interference to noise ratio tables

	5th percentile	50th percentile	95th percentile
Full cell (UL)	-105 dBm	-90 dBm	-76 dBm
Cell centre (UL)	-99 dBm	-89 dBm	-86 dBm
Cell edge (UL)	-93 dBm	-88 dBm	-85 dBm

UL 1x4

Figure A.209

Interference to noise ratio tables

	5th percentile	50th percentile	95th percentile
Full cell (UL)	-104 dBm	-88 dBm	-73 dBm
Cell centre (UL)	-98 dBm	-89 dBm	-84 dBm
Cell edge (UL)	-90 dBm	-85 dBm	-82 dBm

UL 2x4

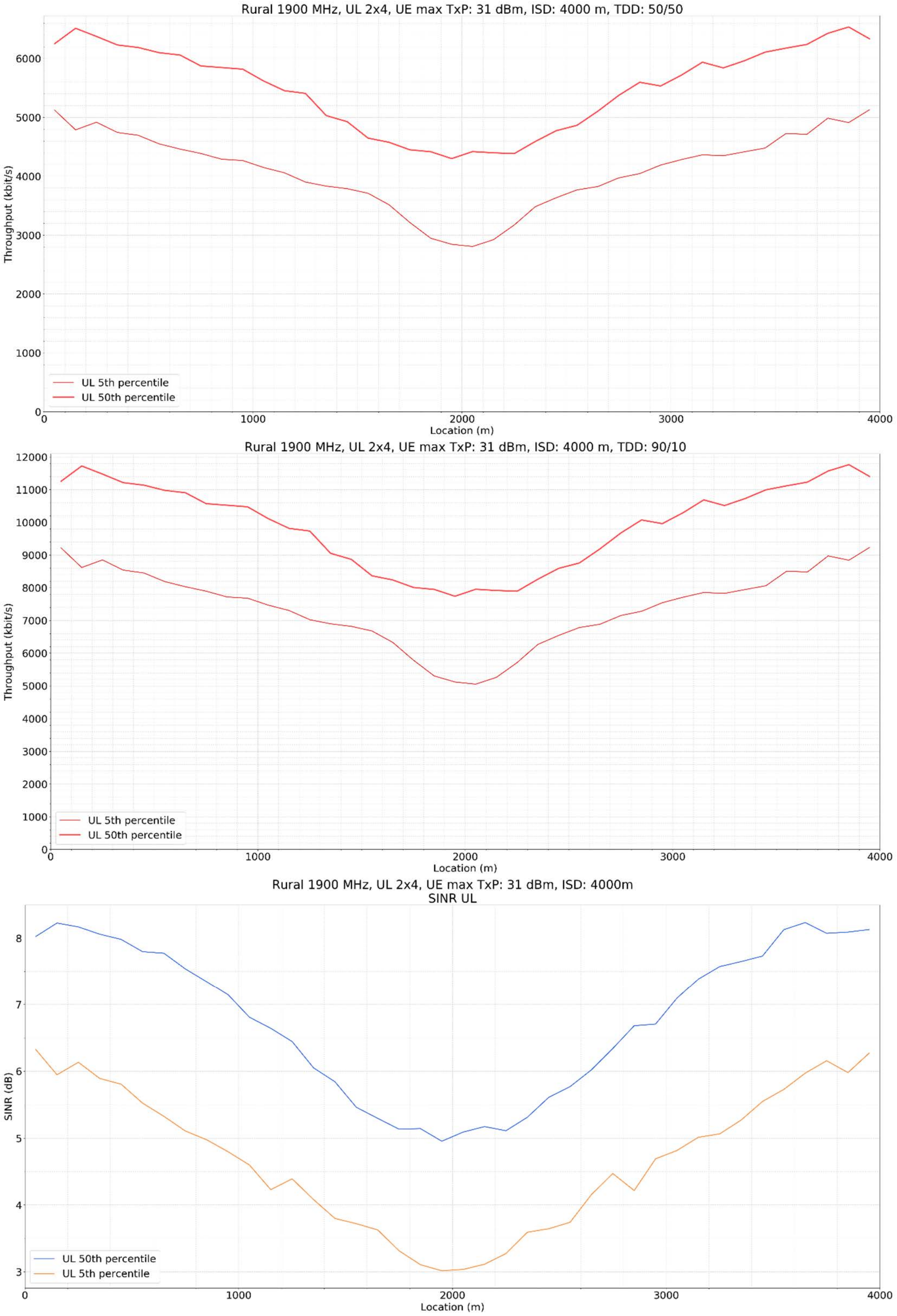


Figure A.210

Interference to noise ratio tables

	5th percentile	50th percentile	95th percentile
Full cell (UL)	-104 dBm	-88 dBm	-74 dBm
Cell centre (UL)	-100 dBm	-90 dBm	-84 dBm
Cell edge (UL)	-90 dBm	-86 dBm	-82 dBm

UL 1x8

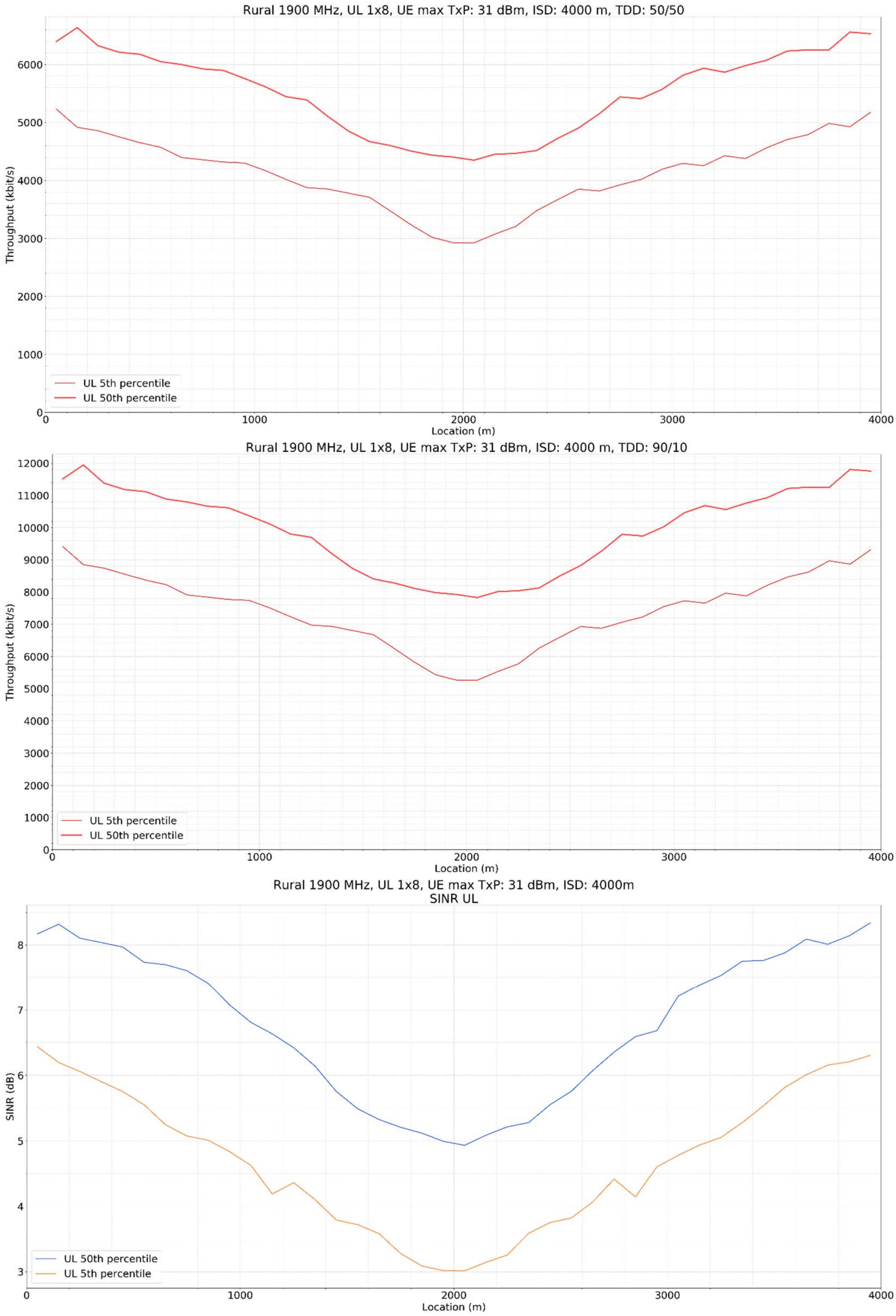


Figure A.211

Interference to noise ratio tables

	5th percentile	50th percentile	95th percentile
Full cell (UL)	-106 dBm	-87 dBm	-72 dBm
Cell centre (UL)	-101 dBm	-92 dBm	-83 dBm
Cell edge (UL)	-89 dBm	-83 dBm	-80 dBm

UL 2x8

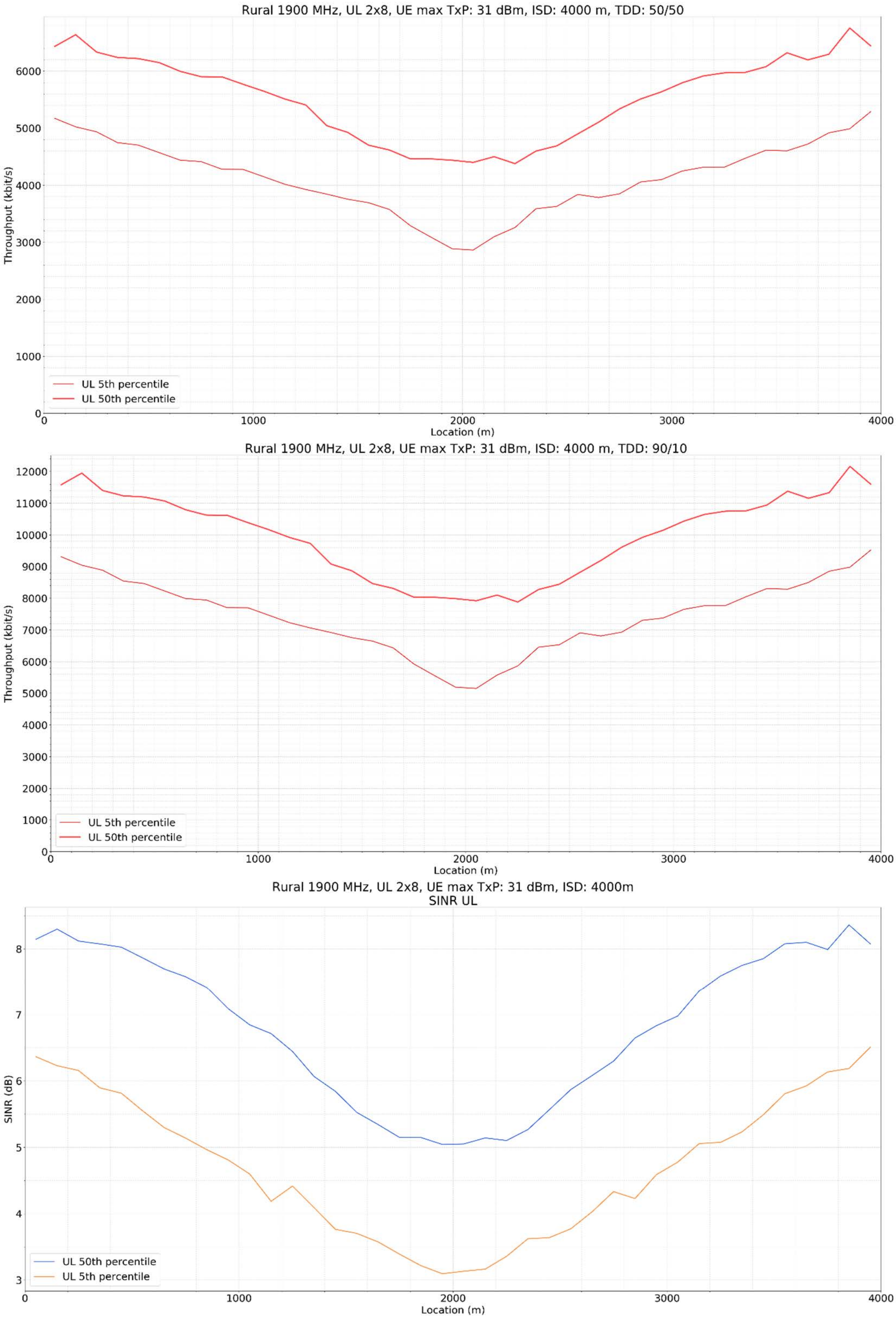


Figure A.212

Interference to noise ratio tables

	5th percentile	50th percentile	95th percentile
Full cell (UL)	-106 dBm	-87 dBm	-72 dBm
Cell centre (UL)	-100 dBm	-91 dBm	-83 dBm
Cell edge (UL)	-89 dBm	-83 dBm	-80 dBm

A.2.2.5 Urban, 2 KM ISD, 2 cells/site

A.2.2.5.1 Downlink, 63 dBm EIRP

DL 2x1

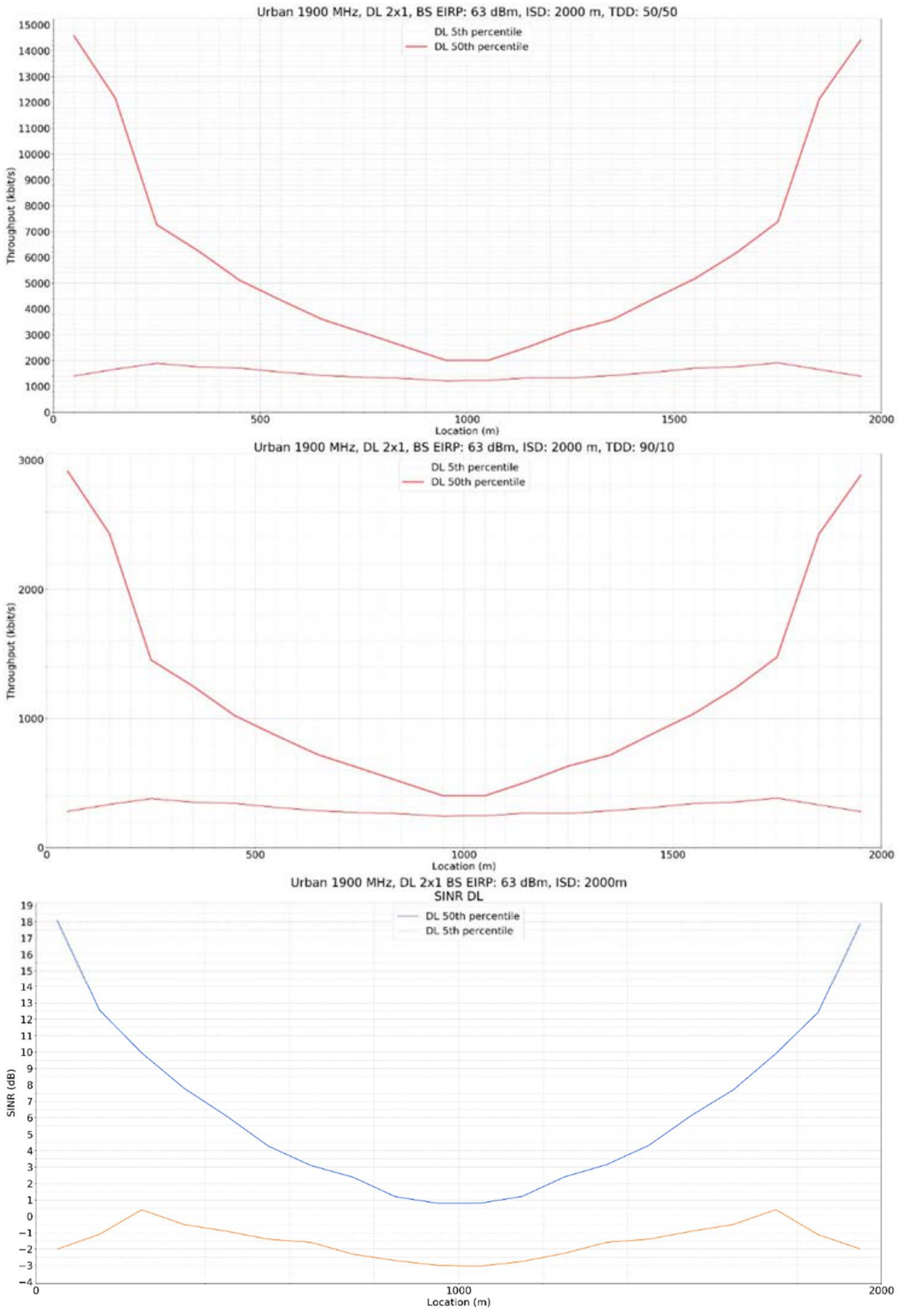


Figure A.213

Interference to noise ratio tables

	5th percentile	50th percentile	95th percentile
Full cell (DL)	-127 dBm	-116 dBm	-88 dBm
Cell centre (DL)	-120 dBm	-104 dBm	-87 dBm
Cell edge (DL)	-121 dBm	-116 dBm	-109 dBm

DL 2x2

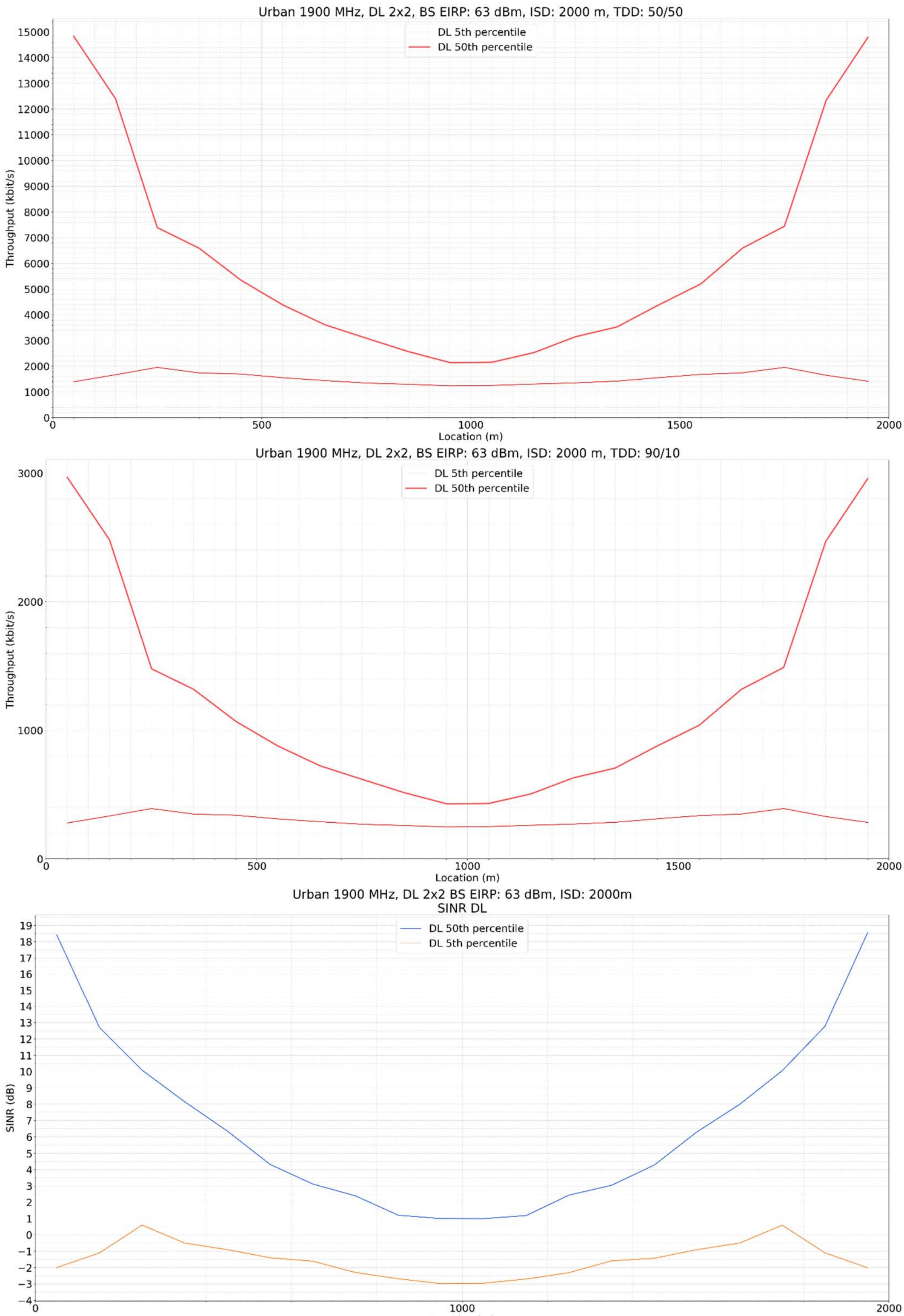


Figure A.214

Interference to noise ratio tables

	5th percentile	50th percentile	95th percentile
Full cell (DL)	-127 dBm	-117 dBm	-91 dBm
Cell centre (DL)	-121 dBm	-107 dBm	-88 dBm
Cell edge (DL)	-122 dBm	-117 dBm	-110 dBm

DL 4x1

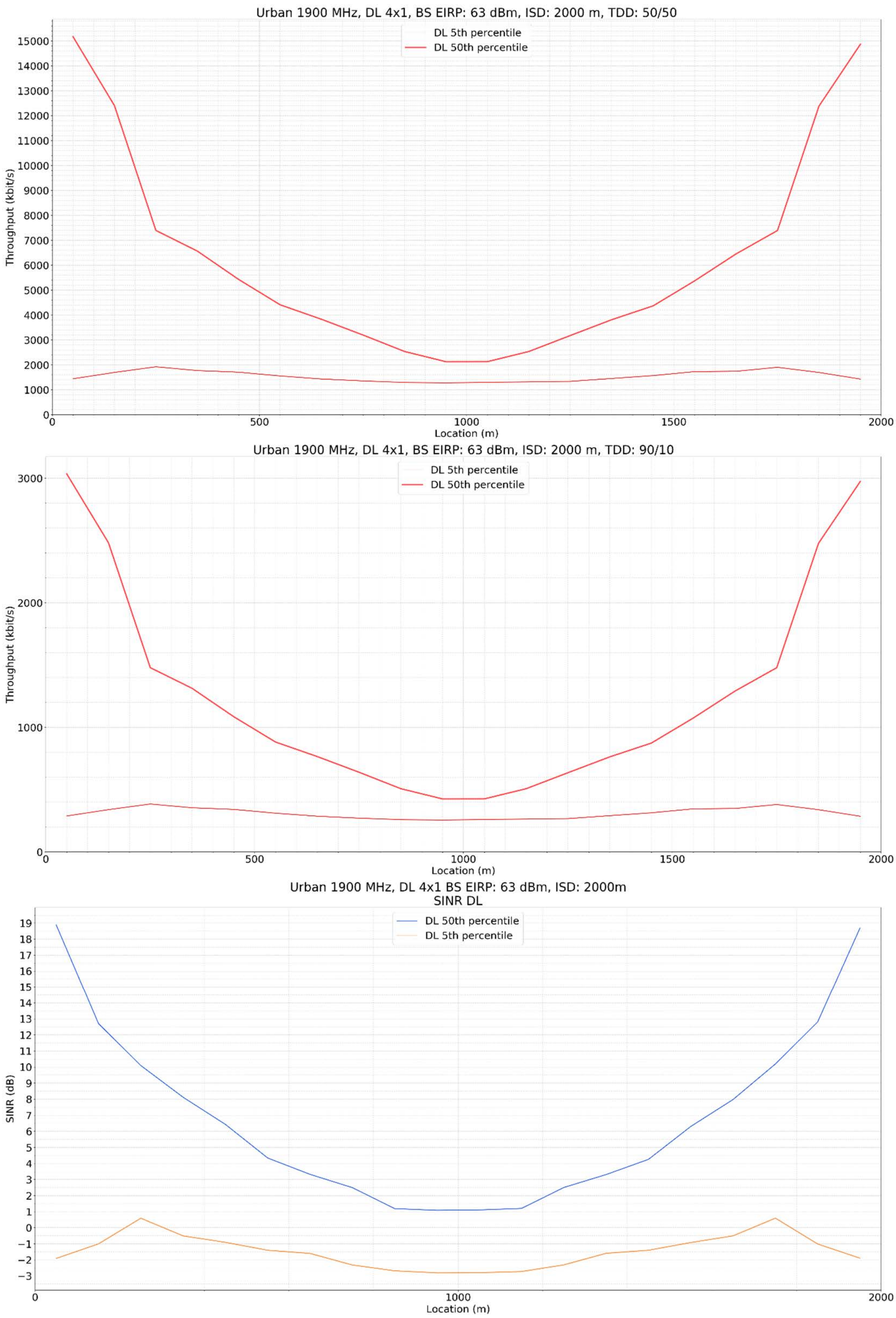


Figure A.215

Interference to noise ratio tables

	5th percentile	50th percentile	95th percentile
Full cell (DL)	-127 dBm	-113 dBm	-87 dBm
Cell centre (DL)	-118 dBm	-104 dBm	-85 dBm
Cell edge (DL)	-119 dBm	-113 dBm	-106 dBm

DL 4x2

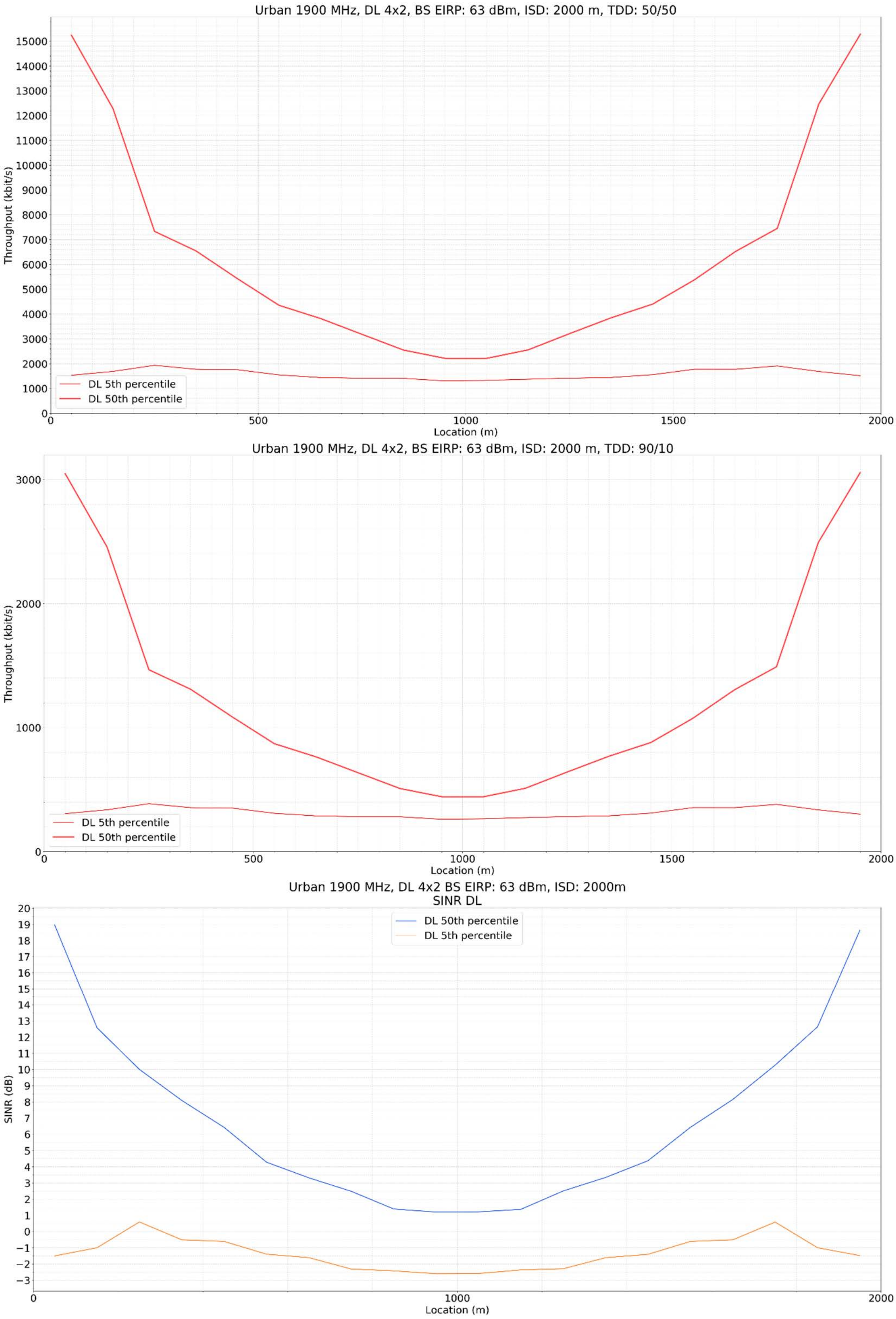


Figure A.216

Interference to noise ratio tables

	5th percentile	50th percentile	95th percentile
Full cell (DL)	-127 dBm	-116 dBm	-90 dBm
Cell centre (DL)	-120 dBm	-107 dBm	-91 dBm
Cell edge (DL)	-121 dBm	-116 dBm	-110 dBm

DL 8x1

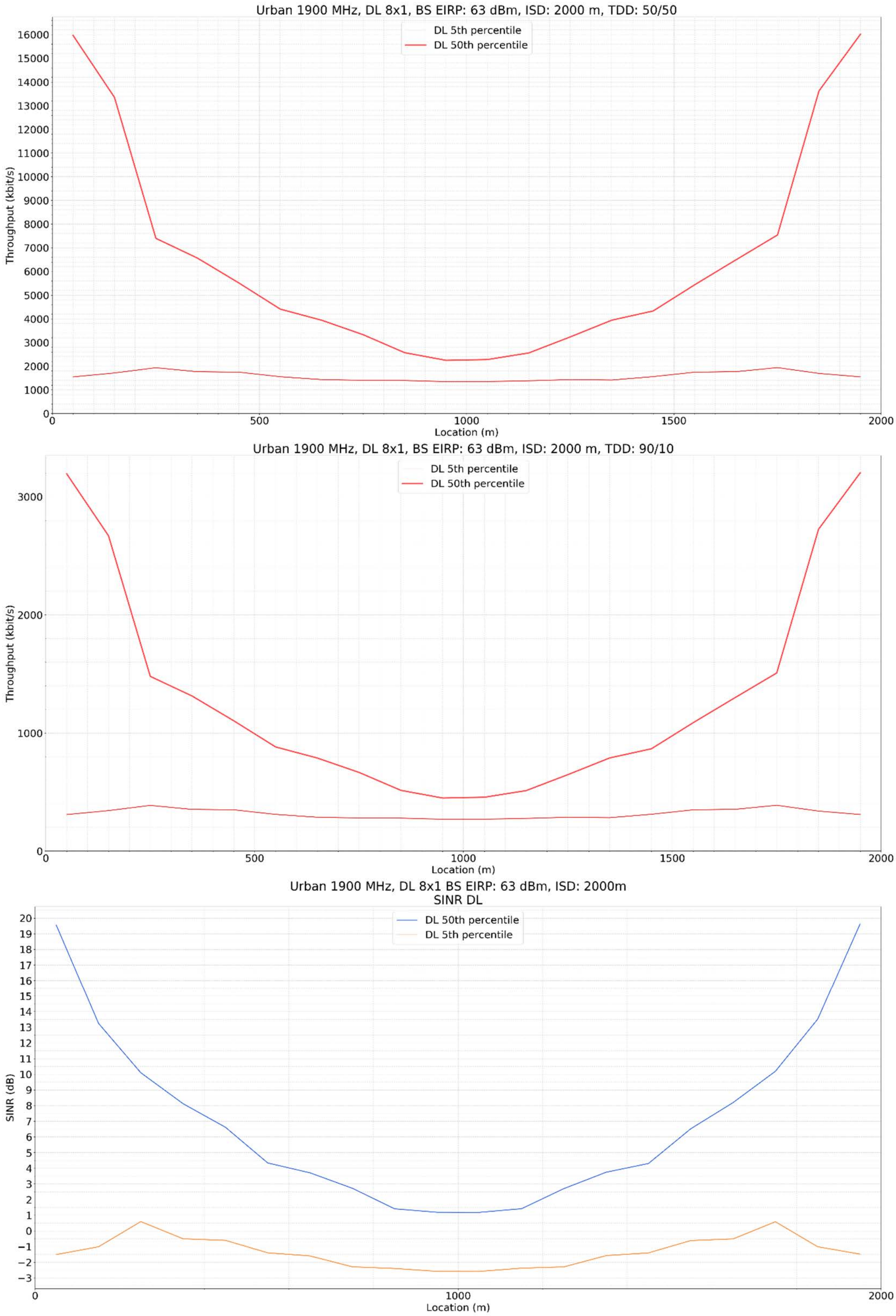


Figure A.217

Interference to noise ratio tables

	5th percentile	50th percentile	95th percentile
Full cell (DL)	-127 dBm	-112 dBm	-88 dBm
Cell centre (DL)	-118 dBm	-104 dBm	-87 dBm
Cell edge (DL)	-118 dBm	-112 dBm	-105 dBm

DL 8x2

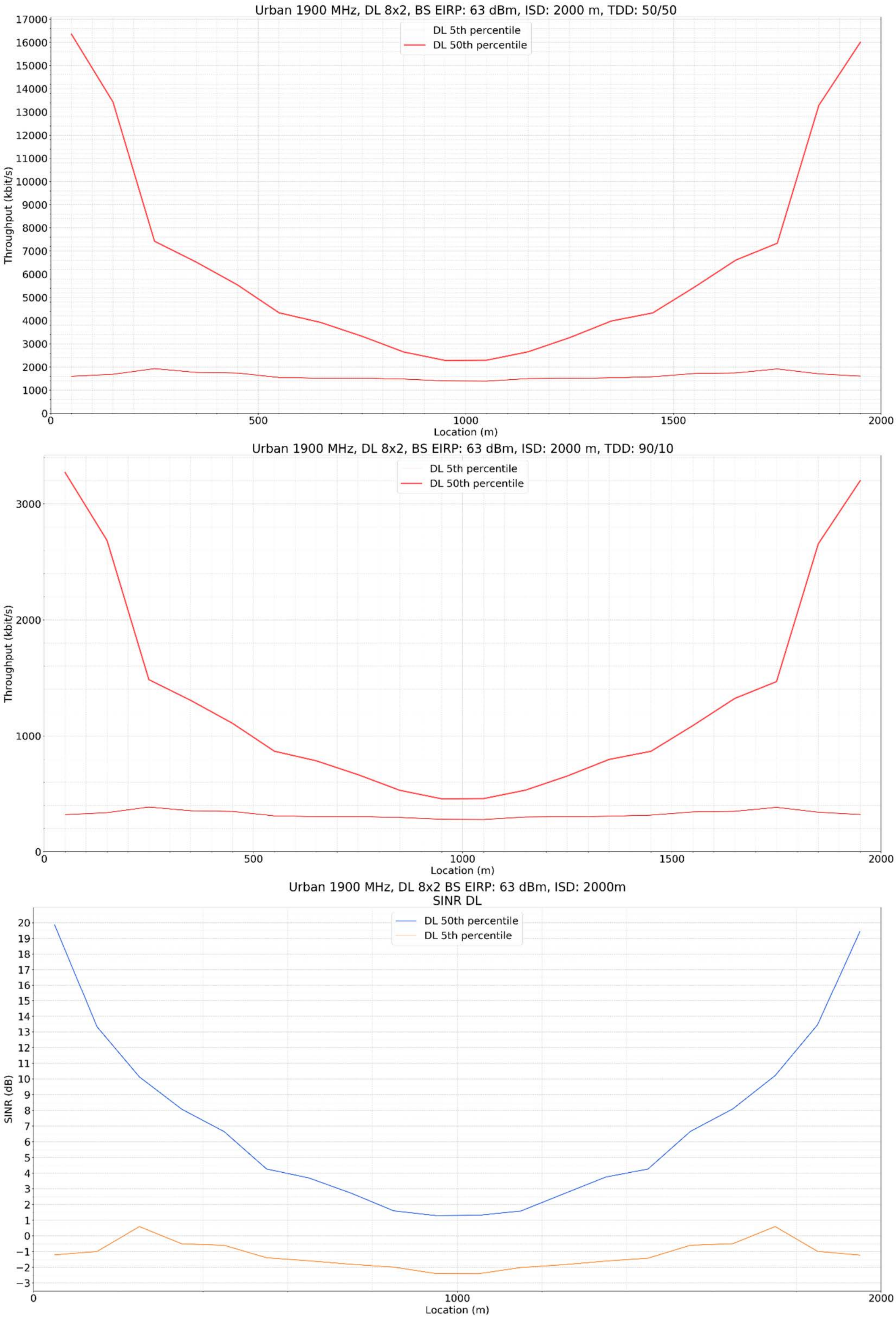


Figure A.218

Interference to noise ratio tables

	5th percentile	50th percentile	95th percentile
Full cell (DL)	-127 dBm	-111 dBm	-87 dBm
Cell centre (DL)	-119 dBm	-104 dBm	-83 dBm
Cell edge (DL)	-119 dBm	-113 dBm	-104 dBm

A.2.2.5.2 Downlink, 40 dBm EIRP

DL 2x1

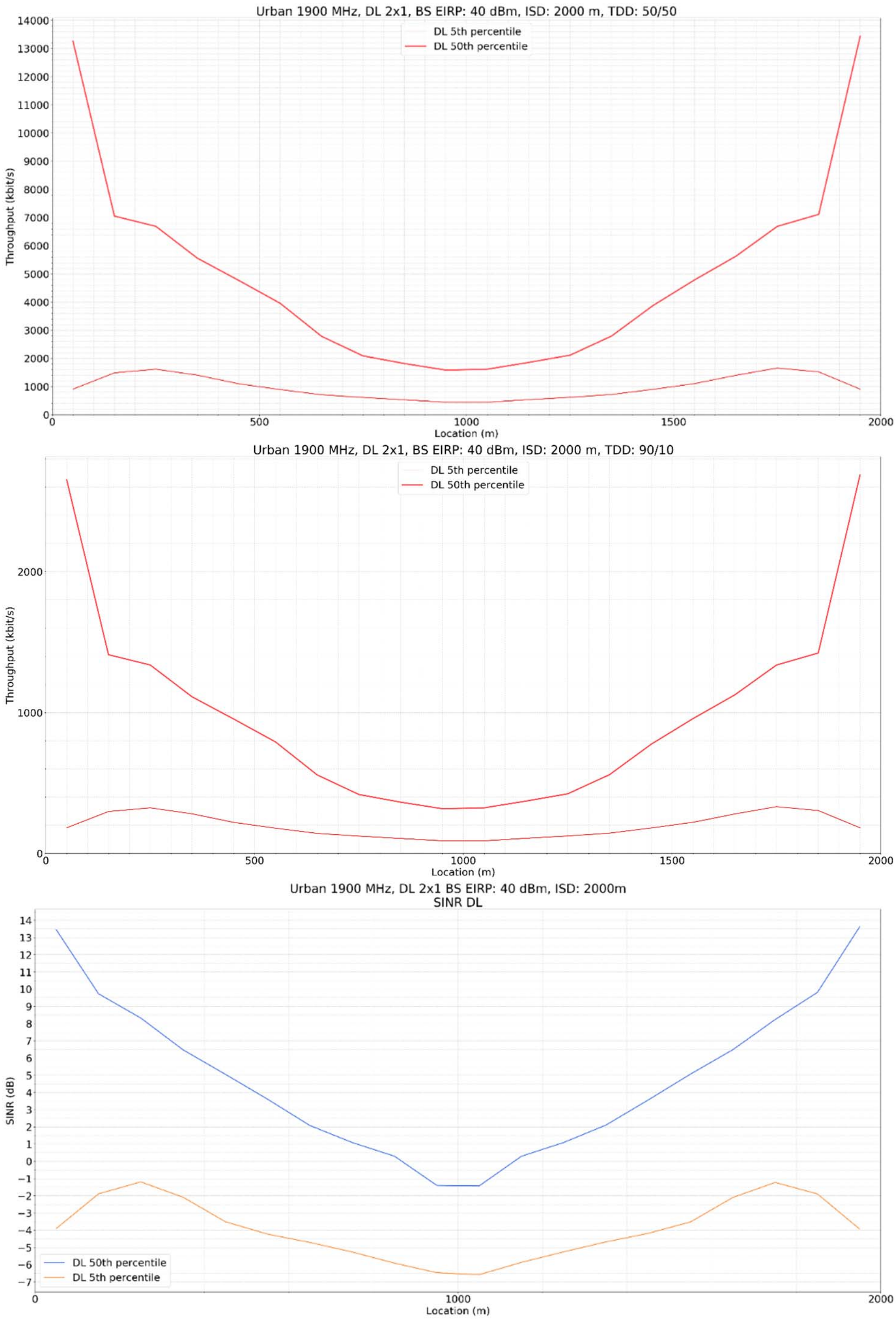


Figure A.219

Interference to noise ratio tables

	5th percentile	50th percentile	95th percentile
Full cell (DL)	-127 dBm	-127 dBm	-110 dBm
Cell centre (DL)	-127 dBm	-117 dBm	-102 dBm
Cell edge (DL)	-127 dBm	-127 dBm	-124 dBm

DL 2x2

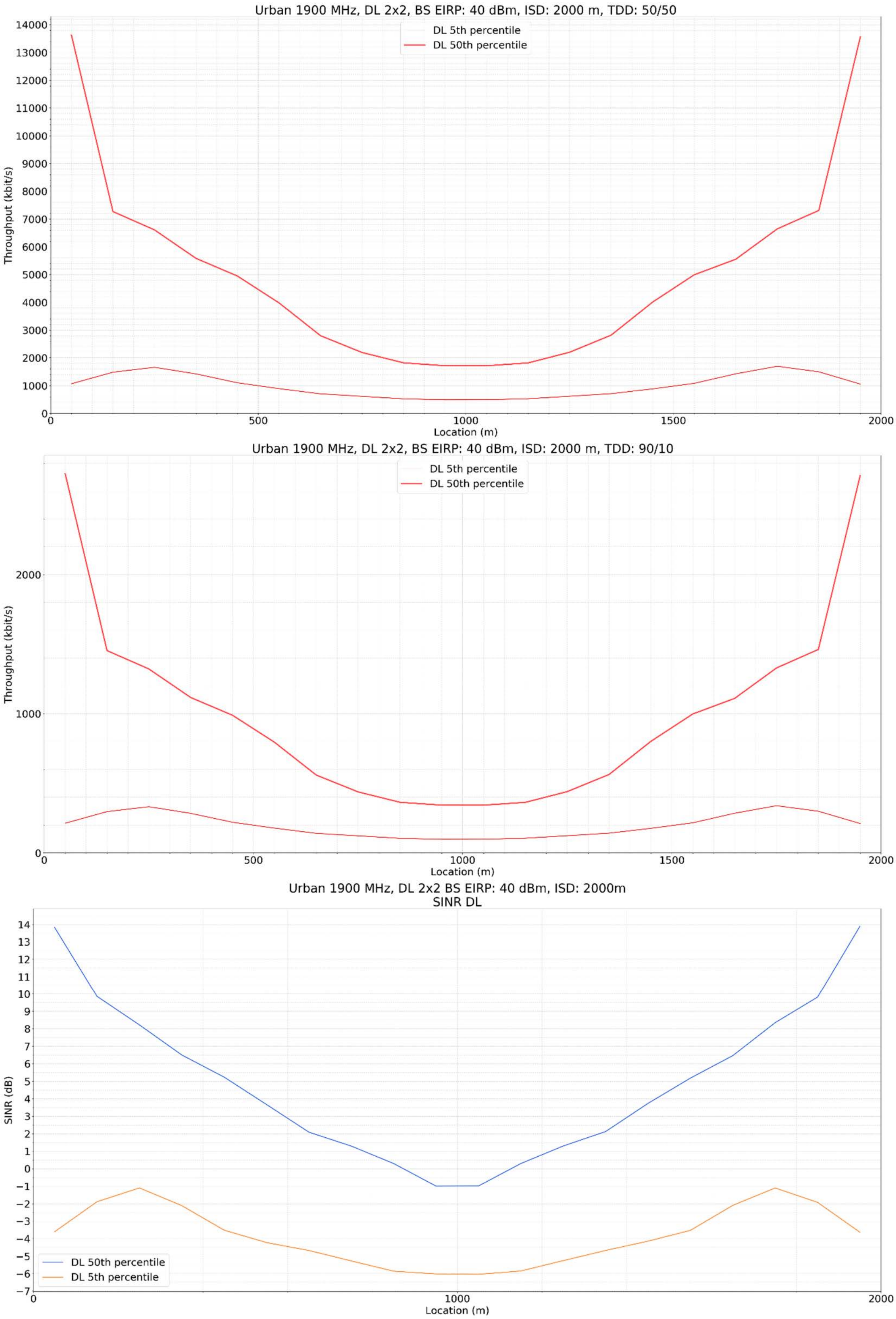


Figure A.220

Interference to noise ratio tables

	5th percentile	50th percentile	95th percentile
Full cell (DL)	-127 dBm	-127 dBm	-114 dBm
Cell centre (DL)	-127 dBm	-119 dBm	-106 dBm
Cell edge (DL)	-127 dBm	-126 dBm	-125 dBm

DL 4x1

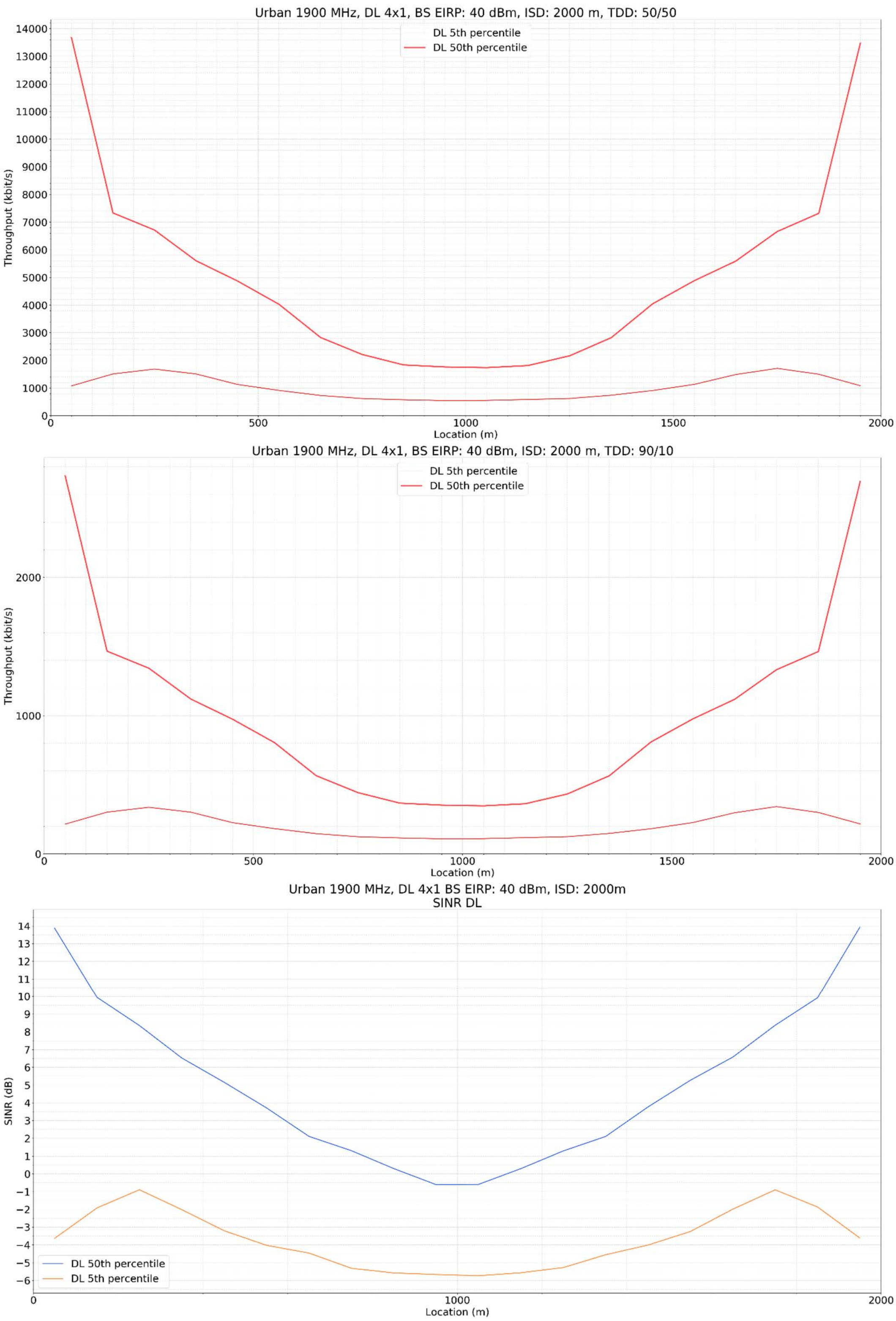


Figure A.221

Interference to noise ratio tables

	5th percentile	50th percentile	95th percentile
Full cell (DL)	-127 dBm	-126 dBm	-109 dBm
Cell centre (DL)	-127 dBm	-118 dBm	-101 dBm
Cell edge (DL)	-127 dBm	-126 dBm	-122 dBm

DL 4x2

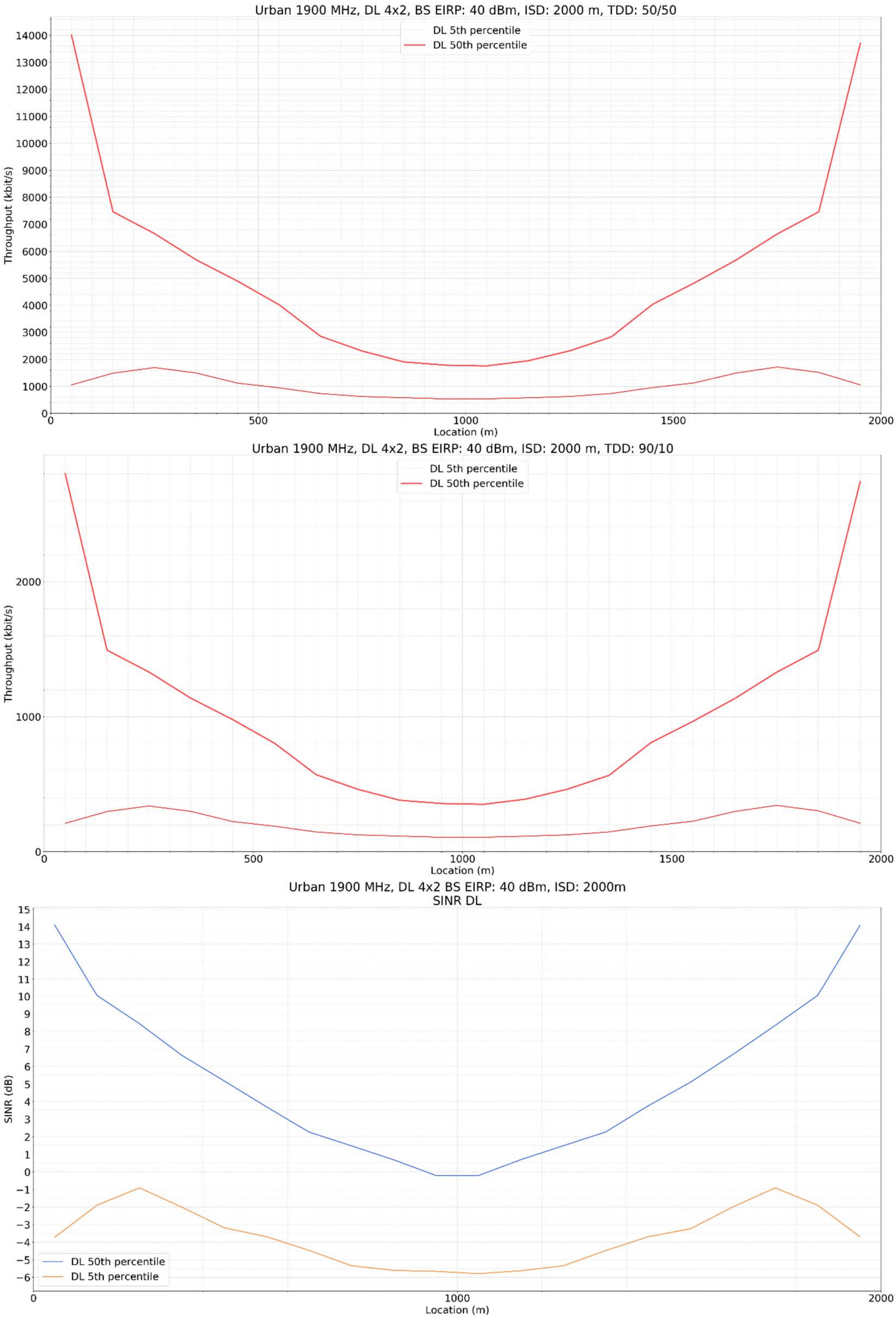


Figure A.222

Interference to noise ratio tables

	5th percentile	50th percentile	95th percentile
Full cell (DL)	-127 dBm	-127 dBm	-112 dBm
Cell centre (DL)	-127 dBm	-119 dBm	-105 dBm
Cell edge (DL)	-127 dBm	-126 dBm	-124 dBm

DL 8x1

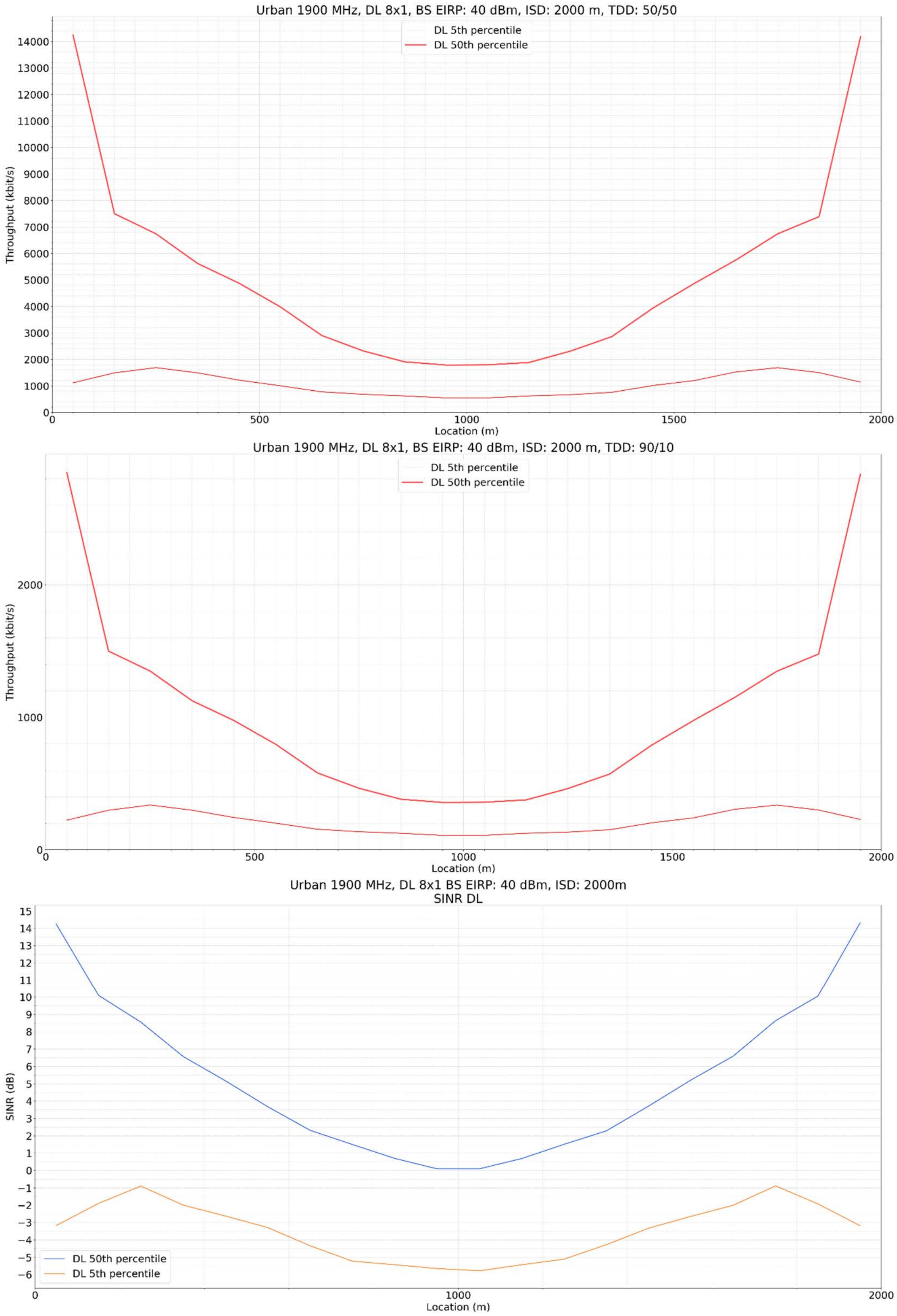


Figure A.223

Interference to noise ratio tables

	5th percentile	50th percentile	95th percentile
Full cell (DL)	-127 dBm	-126 dBm	-108 dBm
Cell centre (DL)	-127 dBm	-116 dBm	-100 dBm
Cell edge (DL)	-127 dBm	-125 dBm	-122 dBm

DL 8x2

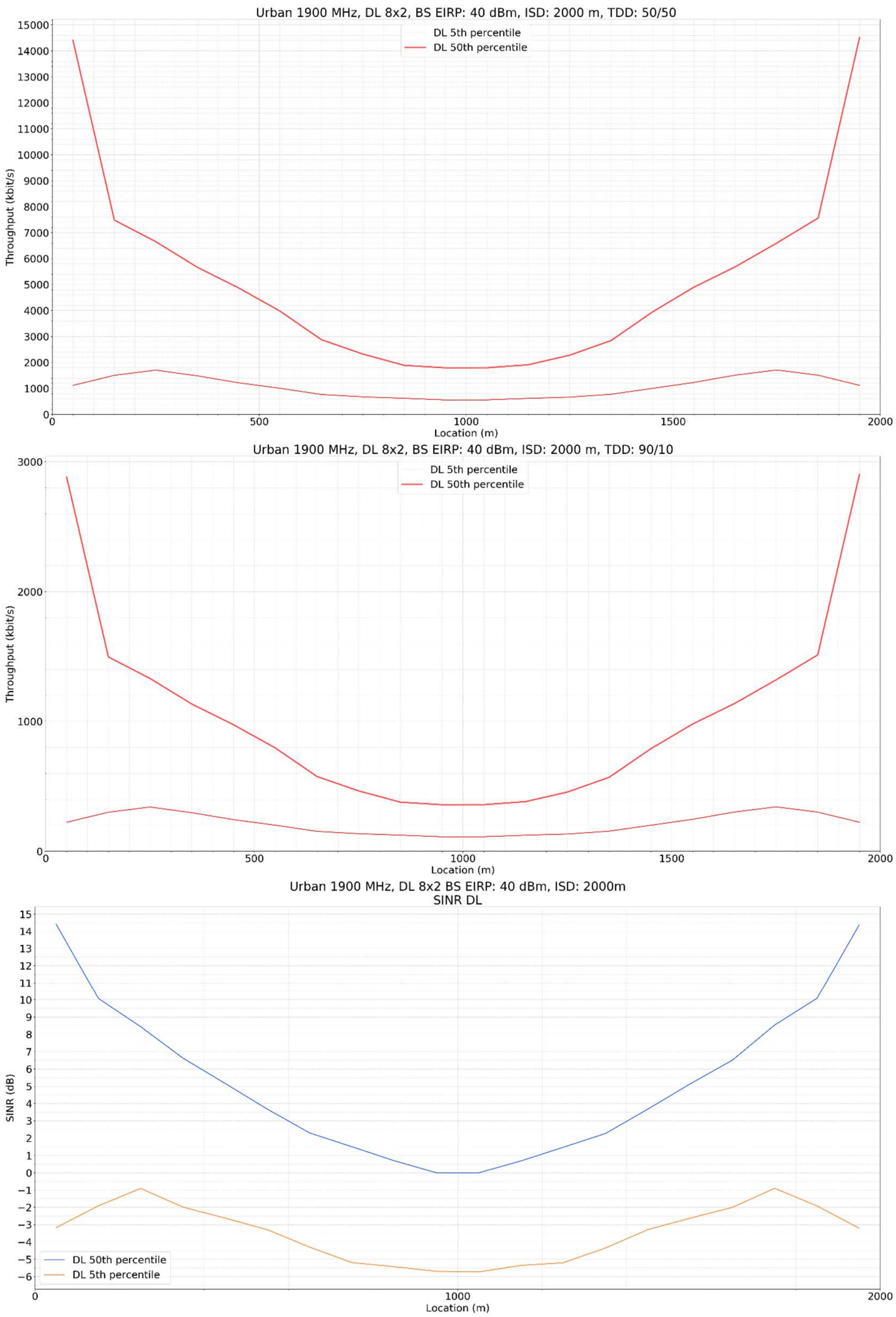


Figure A.224

Interference to noise ratio tables

	5th percentile	50th percentile	95th percentile
Full cell (DL)	-127 dBm	-126 dBm	-112 dBm
Cell centre (DL)	-127 dBm	-119 dBm	-105 dBm
Cell edge (DL)	-127 dBm	-125 dBm	-122 dBm

A.2.2.5.3 Uplink, 23 dBm max transmit power

UL 1x2

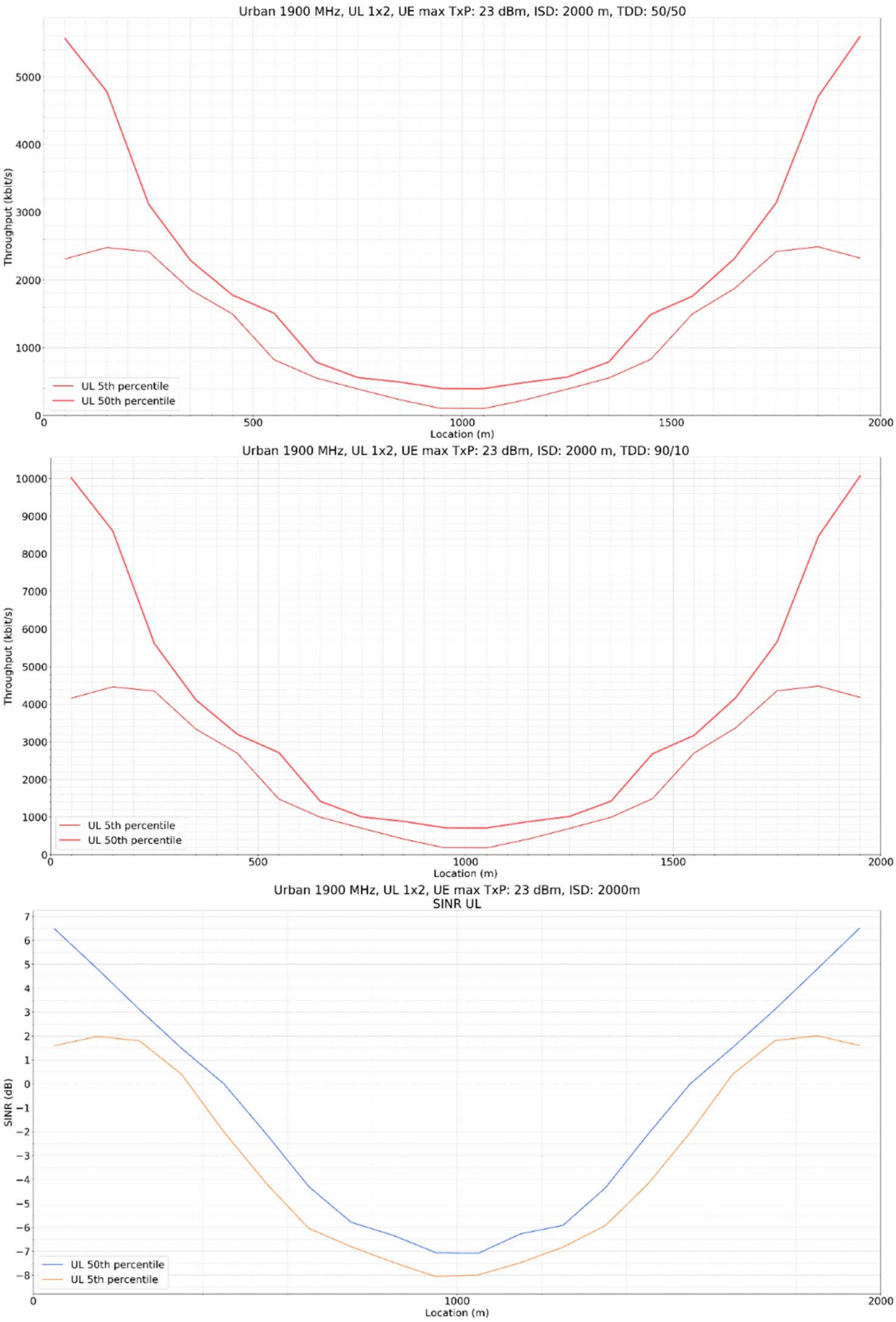


Figure A.225

Interference to noise ratio tables

	5th percentile	50th percentile	95th percentile
Full cell (UL)	-129 dBm	-128 dBm	-112 dBm
Cell centre (UL)	-129 dBm	-126 dBm	-120 dBm
Cell edge (UL)	-126 dBm	-122 dBm	-117 dBm

UL 2x2

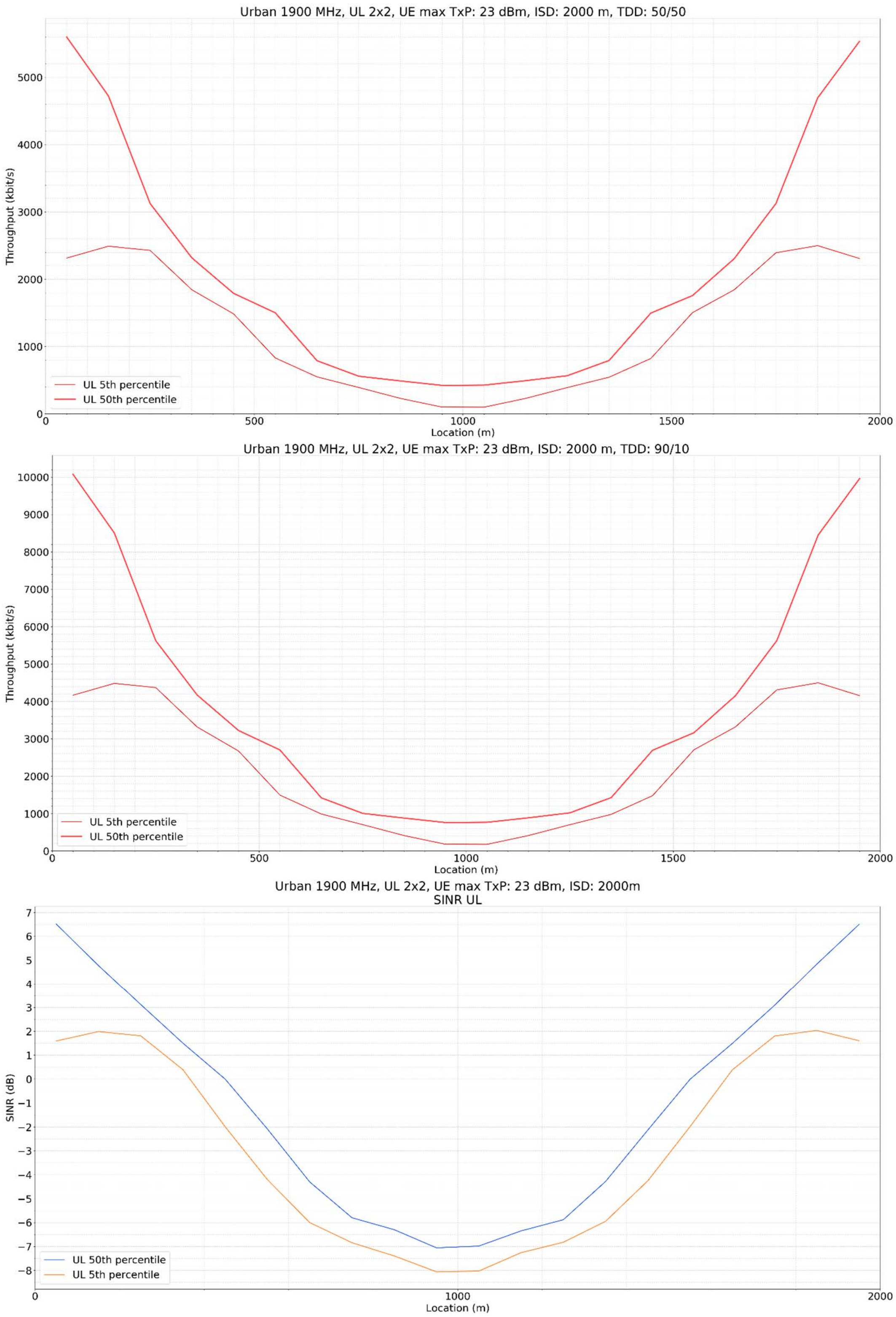


Figure A.226

Interference to noise ratio tables

	5th percentile	50th percentile	95th percentile
Full cell (UL)	-129 dBm	-128 dBm	-112 dBm
Cell centre (UL)	-129 dBm	-126 dBm	-120 dBm
Cell edge (UL)	-126 dBm	-122 dBm	-117 dBm

UL 1x4

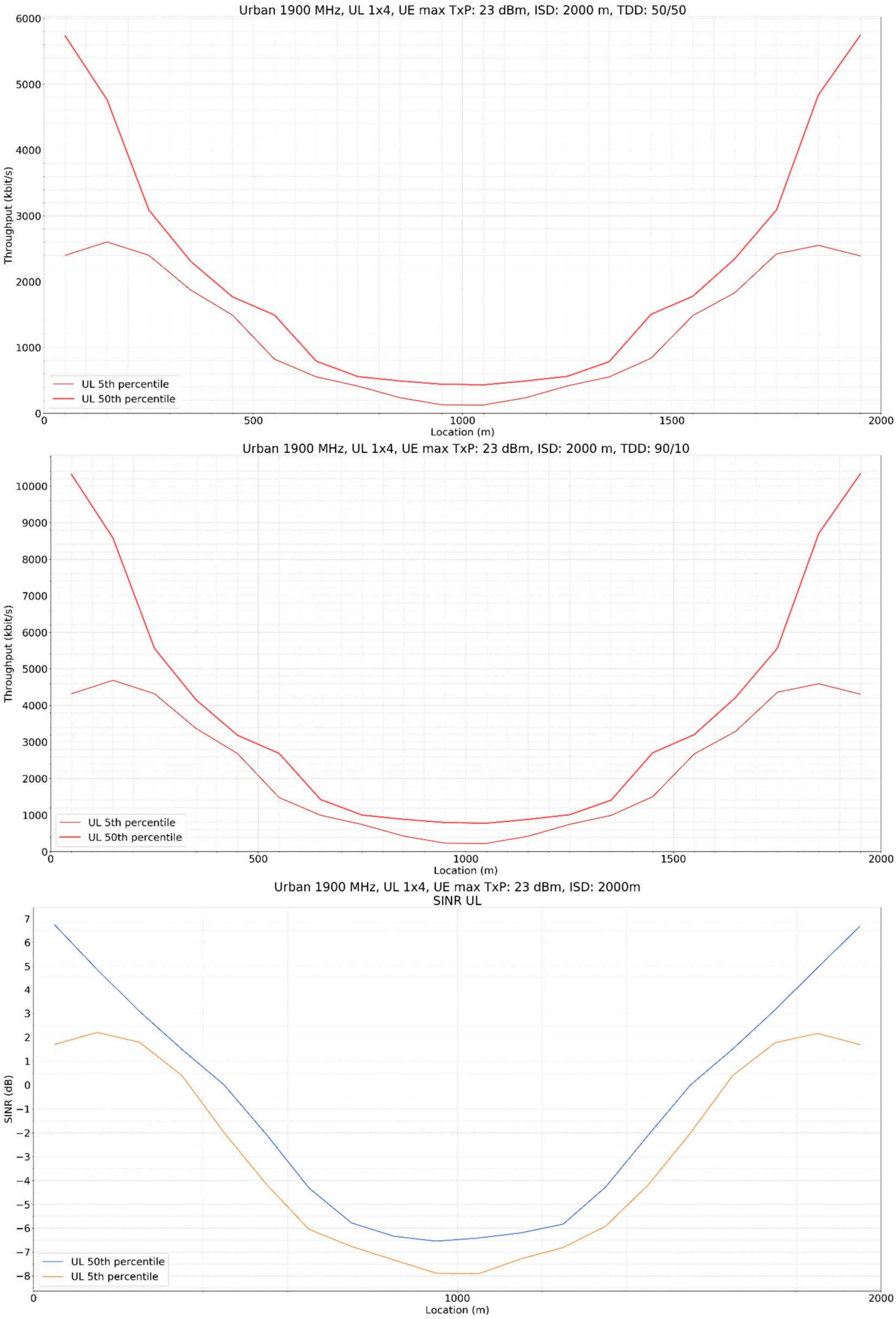


Figure A.227

Interference to noise ratio tables

	5th percentile	50th percentile	95th percentile
Full cell (UL)	-129 dBm	-128 dBm	-112 dBm
Cell centre (UL)	-129 dBm	-127 dBm	-120 dBm
Cell edge (UL)	-125 dBm	-121 dBm	-114 dBm

UL 2x4

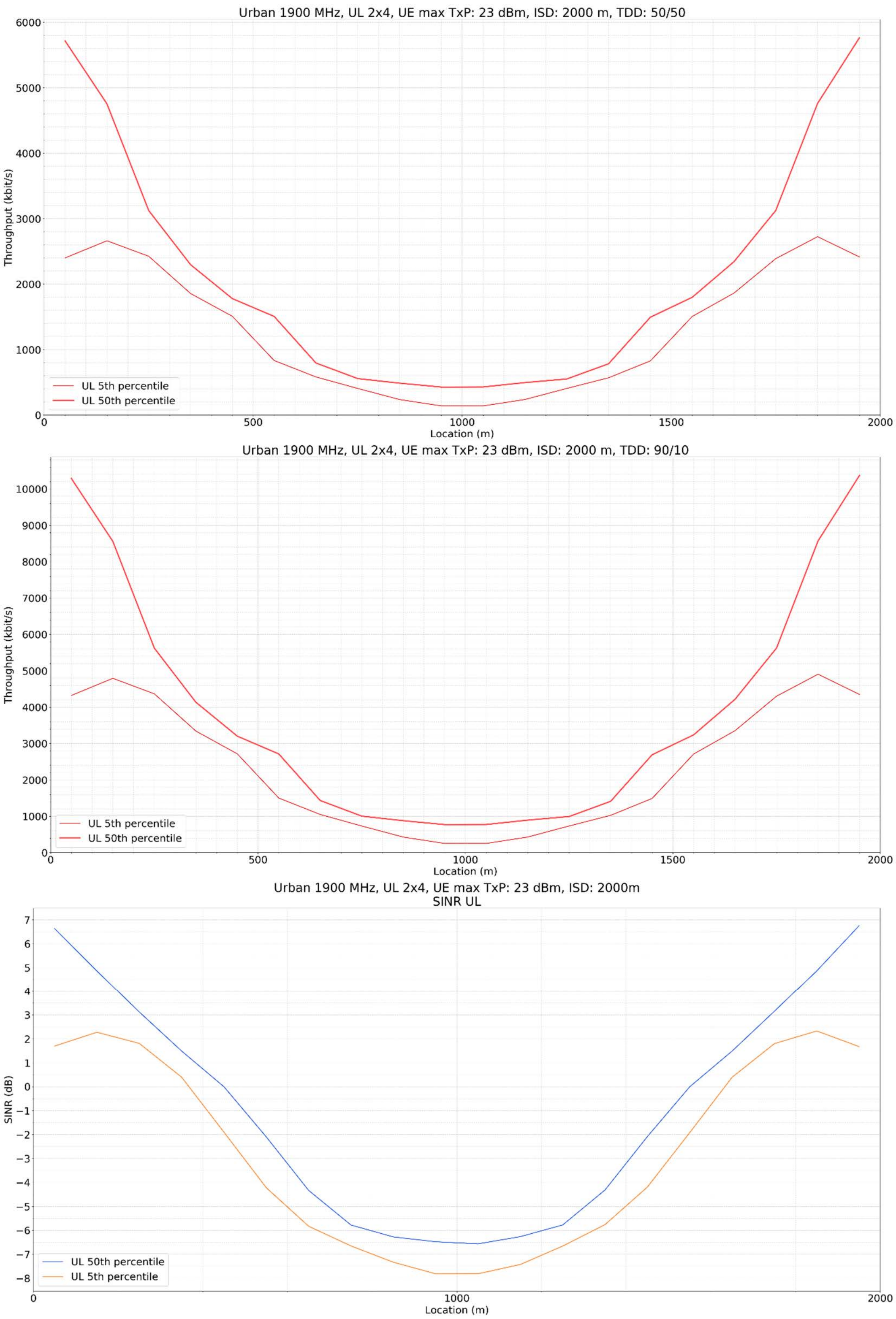


Figure A.228

Interference to noise ratio tables

	5th percentile	50th percentile	95th percentile
Full cell (UL)	-129 dBm	-128 dBm	-111 dBm
Cell centre (UL)	-129 dBm	-127 dBm	-120 dBm
Cell edge (UL)	-126 dBm	-121 dBm	-115 dBm

UL 1x8

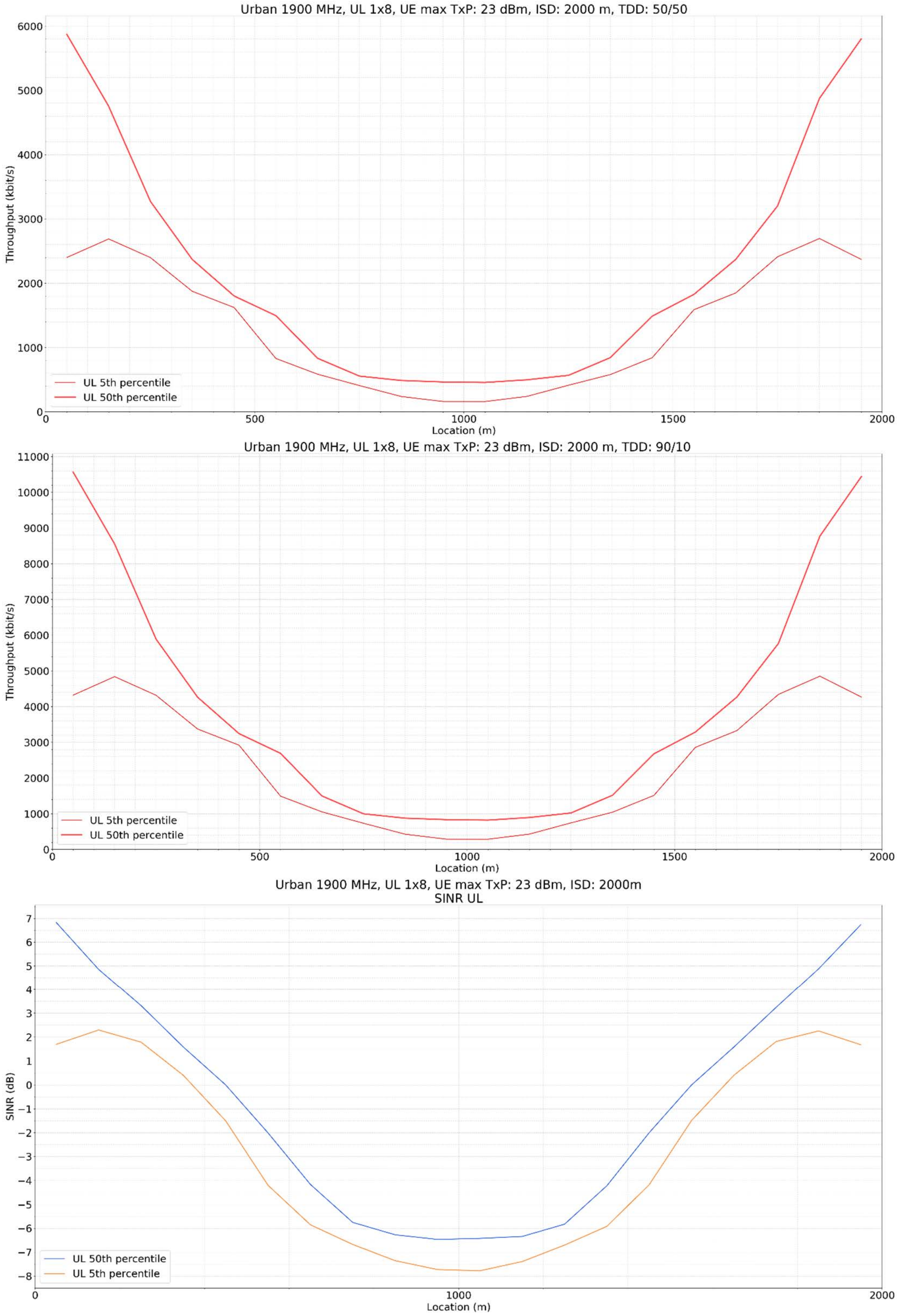


Figure A.229

Interference to noise ratio tables

	5th percentile	50th percentile	95th percentile
Full cell (UL)	-129 dBm	-128 dBm	-110 dBm
Cell centre (UL)	-129 dBm	-127 dBm	-120 dBm
Cell edge (UL)	-125 dBm	-119 dBm	-112 dBm

UL 2x8

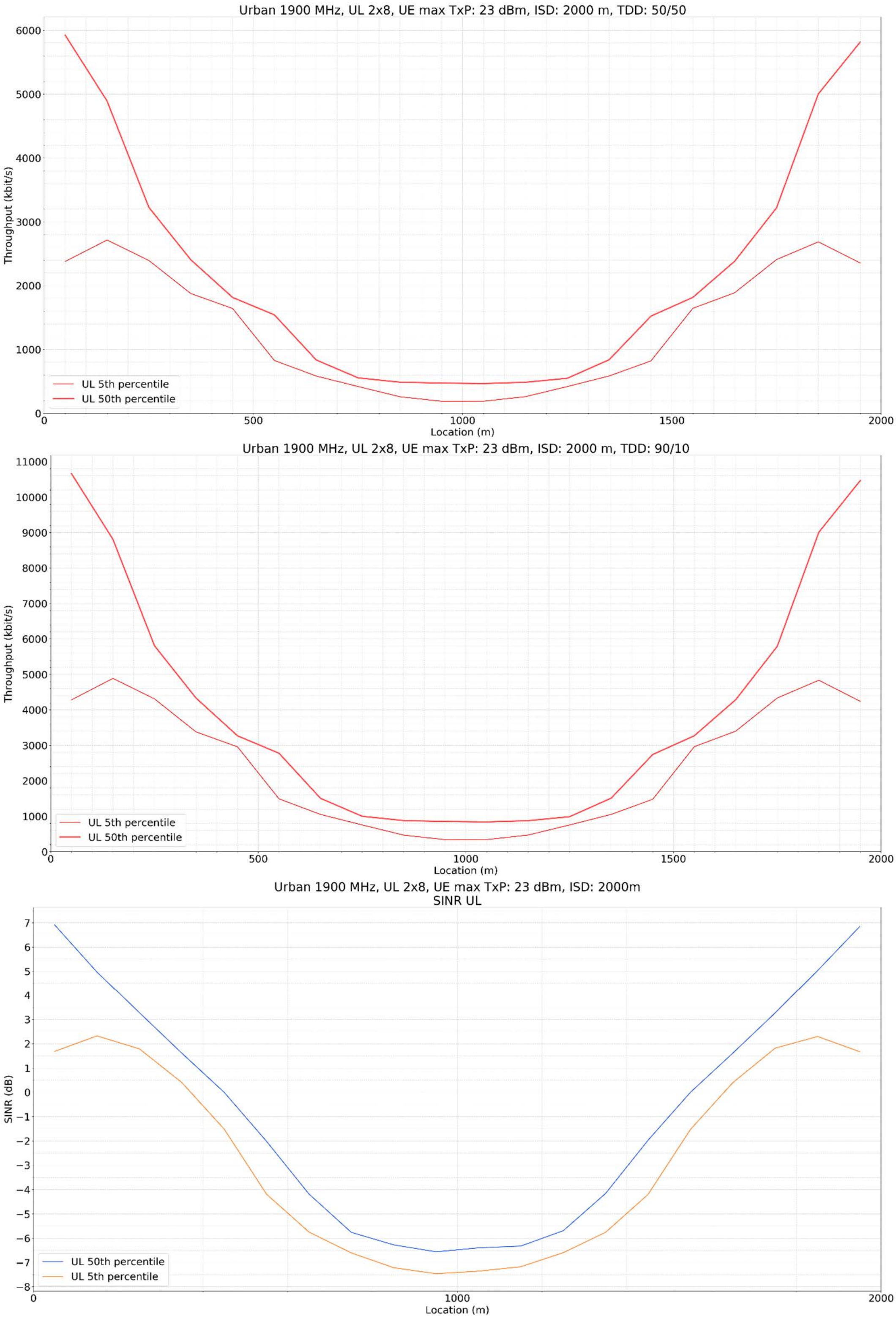


Figure A.230

Interference to noise ratio tables

	5th percentile	50th percentile	95th percentile
Full cell (UL)	-129 dBm	-128 dBm	-111 dBm
Cell centre (UL)	-129 dBm	-127 dBm	-119 dBm
Cell edge (UL)	-125 dBm	-119 dBm	-112 dBm

A.2.2.5.4 Uplink, 31 dBm max transmit power

UL 1x2

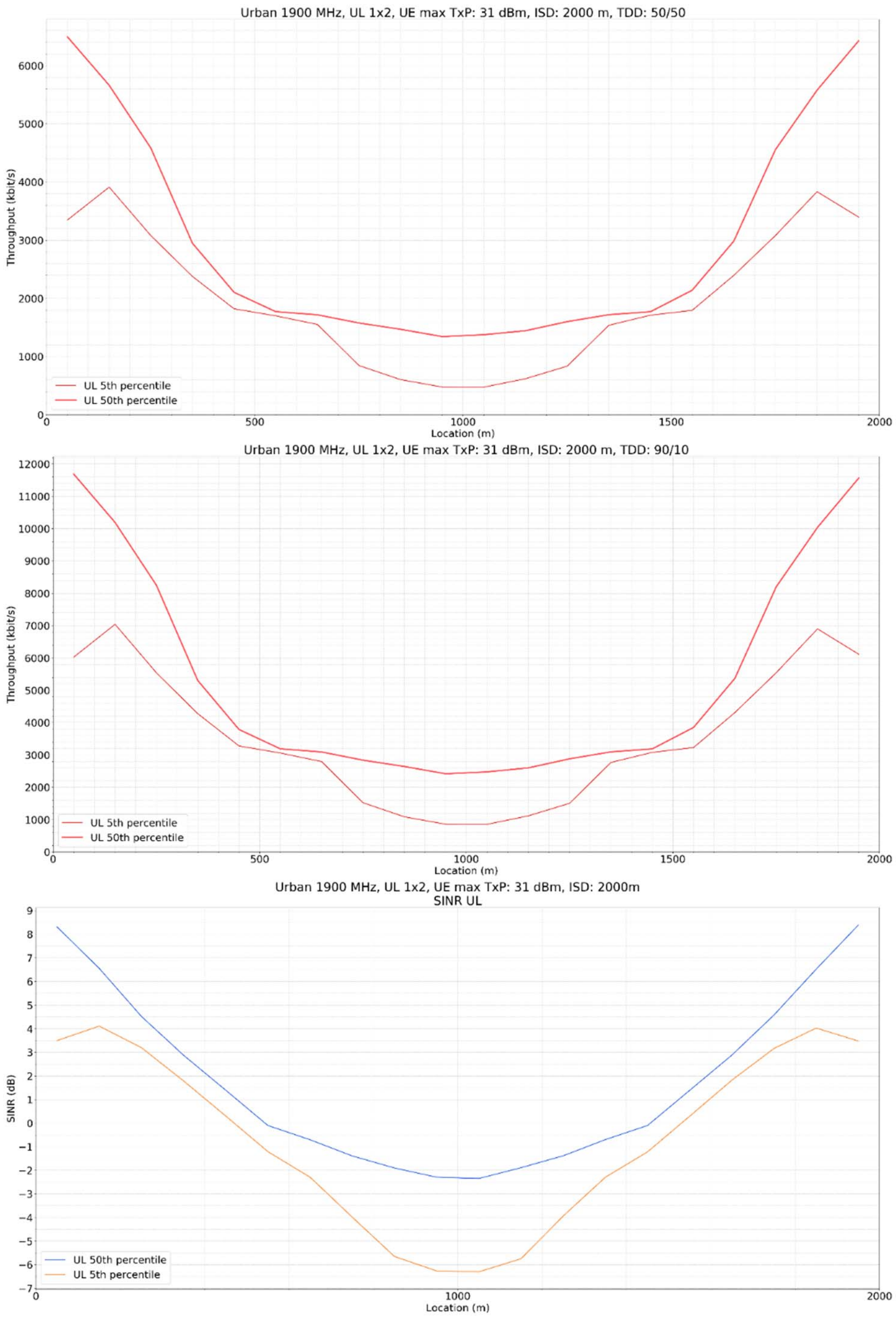


Figure A.231

Interference to noise ratio tables

	5th percentile	50th percentile	95th percentile
Full cell (UL)	-129 dBm	-125 dBm	-110 dBm
Cell centre (UL)	-127 dBm	-124 dBm	-119 dBm
Cell edge (UL)	-126 dBm	-122 dBm	-116 dBm

UL 2x2

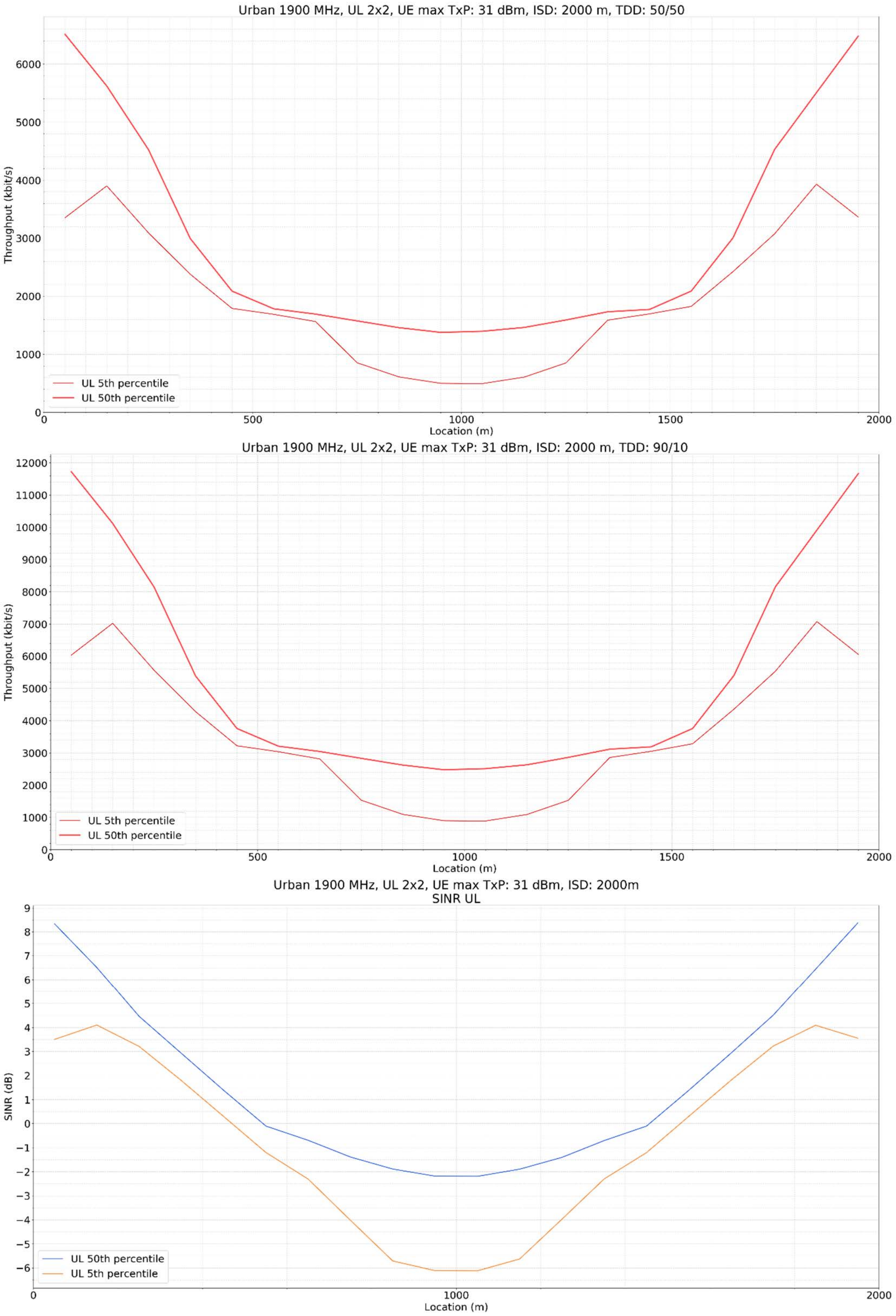


Figure A.232

Interference to noise ratio tables

	5th percentile	50th percentile	95th percentile
Full cell (UL)	-129 dBm	-125 dBm	-109 dBm
Cell centre (UL)	-127 dBm	-123 dBm	-119 dBm
Cell edge (UL)	-126 dBm	-122 dBm	-118 dBm

UL 1x4

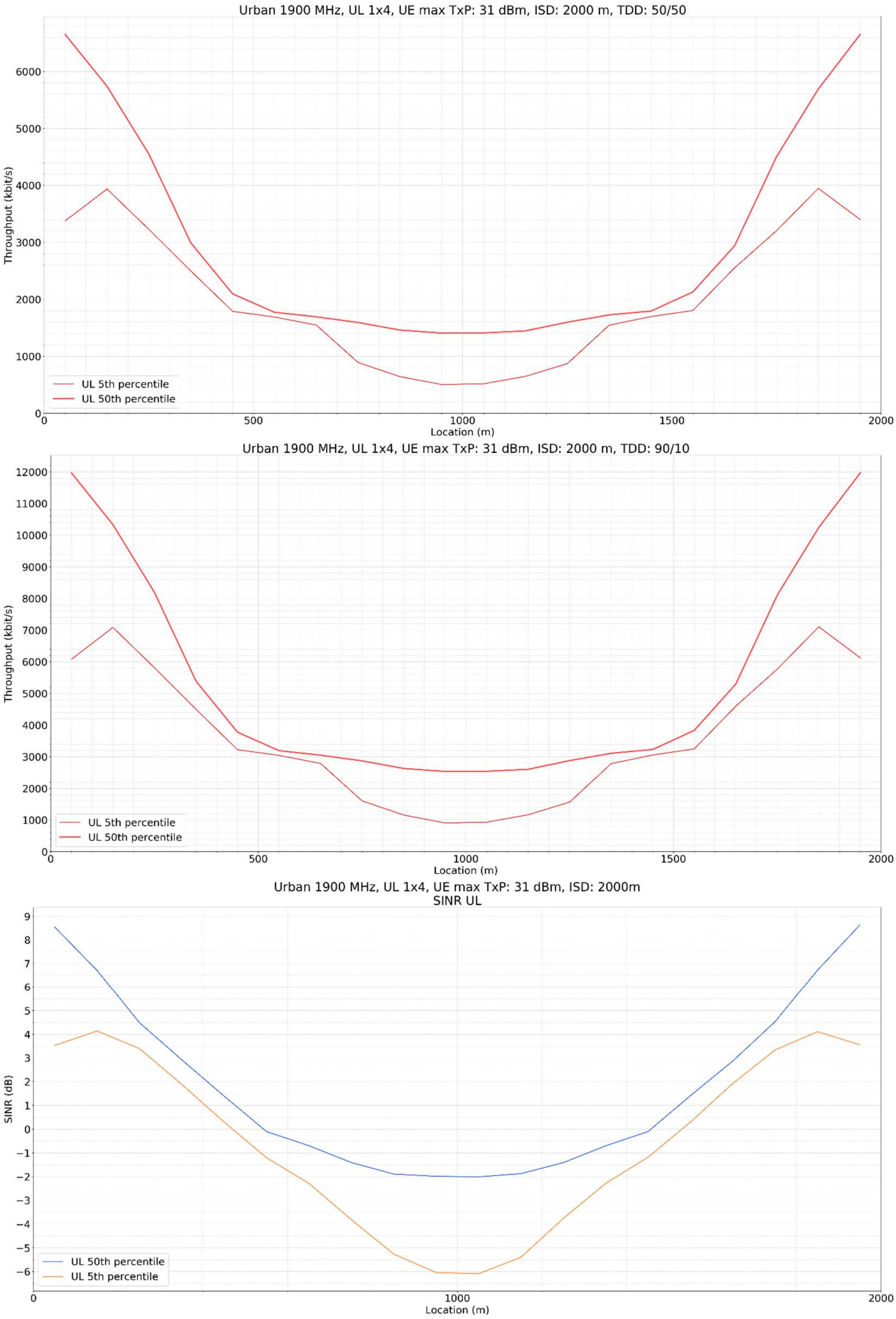


Figure A.233

Interference to noise ratio tables

	5th percentile	50th percentile	95th percentile
Full cell (UL)	-129 dBm	-124 dBm	-108 dBm
Cell centre (UL)	-128 dBm	-125 dBm	-119 dBm
Cell edge (UL)	-125 dBm	-121 dBm	-116 dBm

UL 2x4

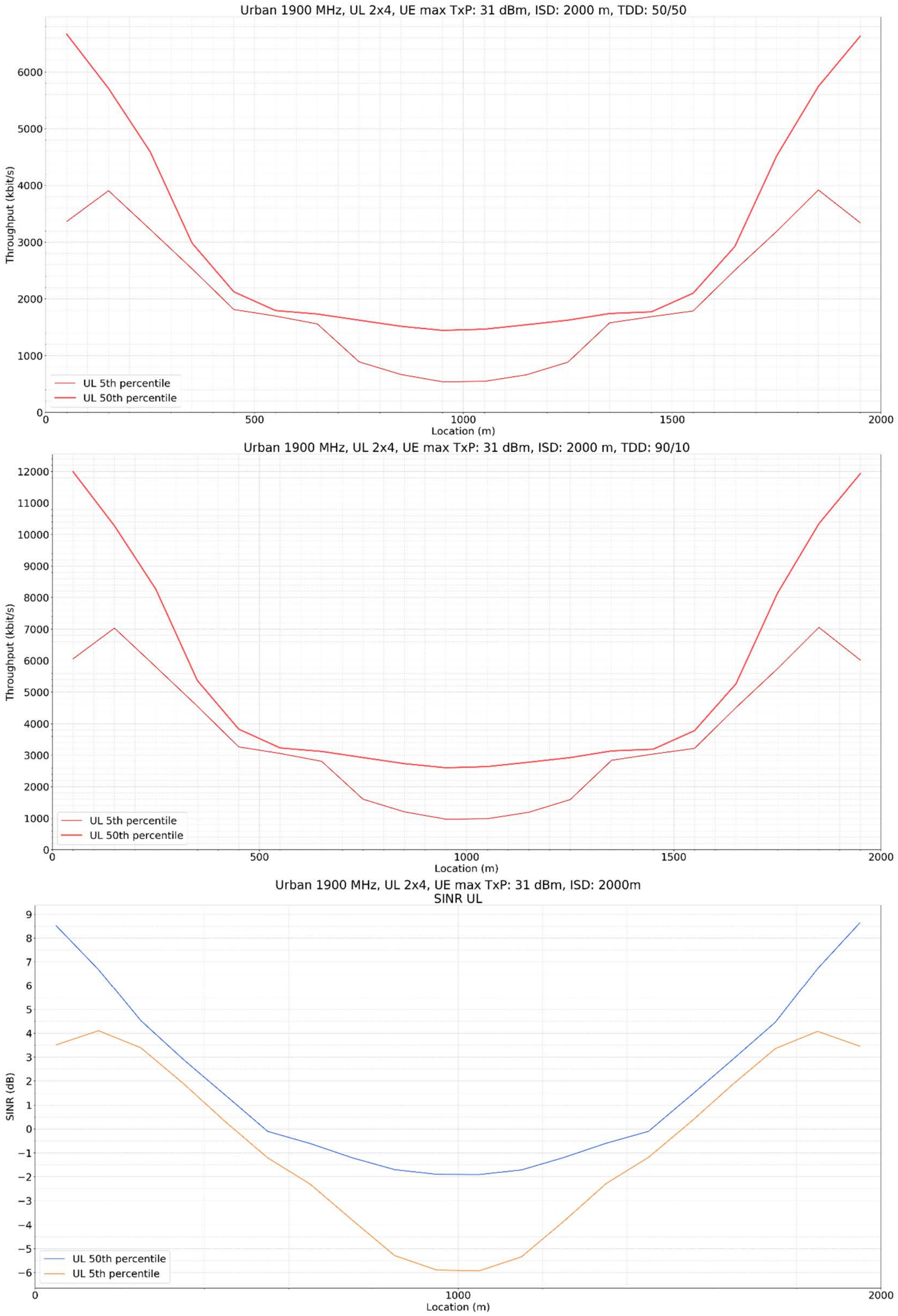


Figure A.234

Interference to noise ratio tables

	5th percentile	50th percentile	95th percentile
Full cell (UL)	-129 dBm	-123 dBm	-108 dBm
Cell centre (UL)	-128 dBm	-125 dBm	-119 dBm
Cell edge (UL)	-125 dBm	-120 dBm	-115 dBm

UL 1x8

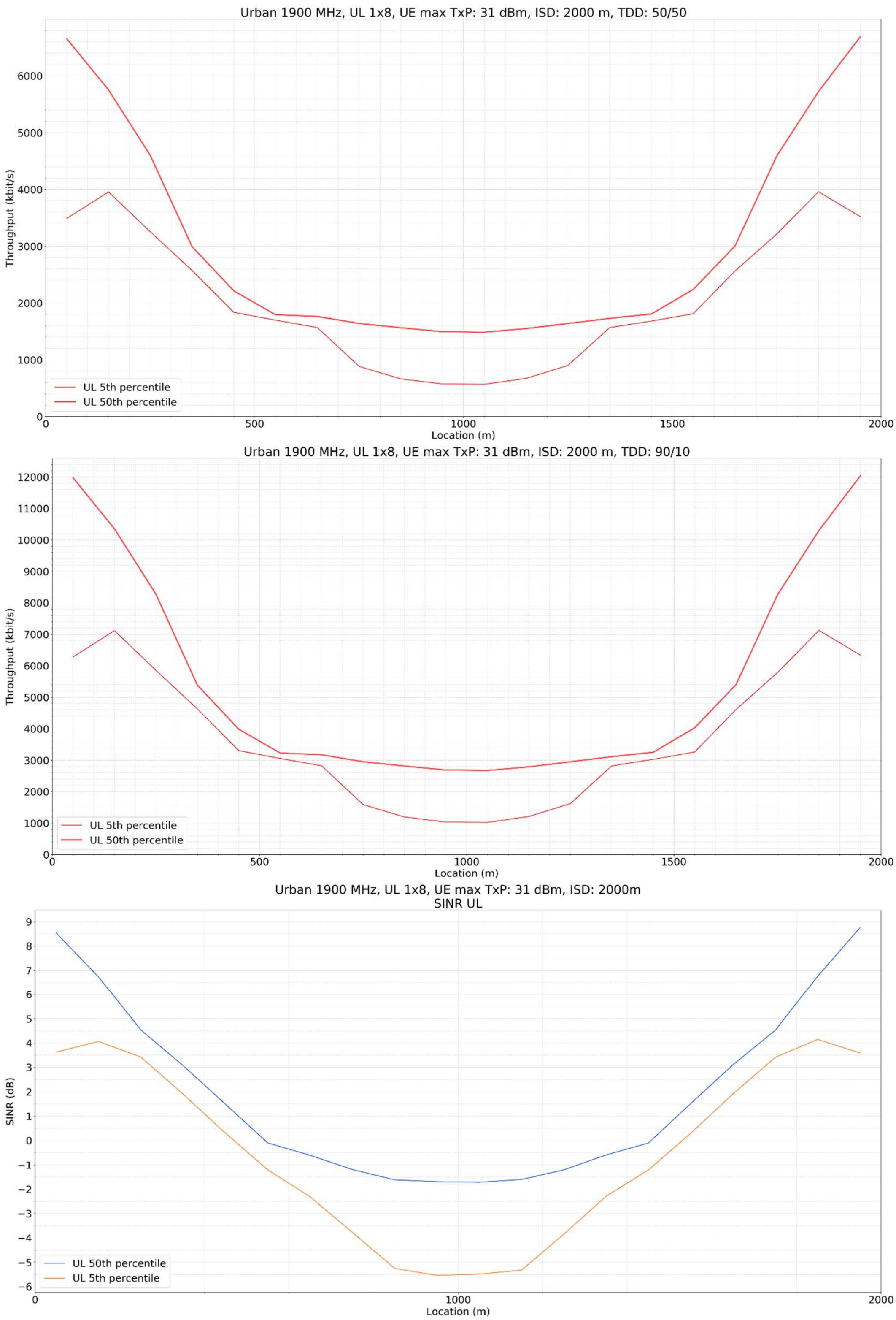


Figure A.235

Interference to noise ratio tables

	5th percentile	50th percentile	95th percentile
Full cell (UL)	-129 dBm	-124 dBm	-106 dBm
Cell centre (UL)	-128 dBm	-125 dBm	-119 dBm
Cell edge (UL)	-124 dBm	-119 dBm	-113 dBm

UL 2x8

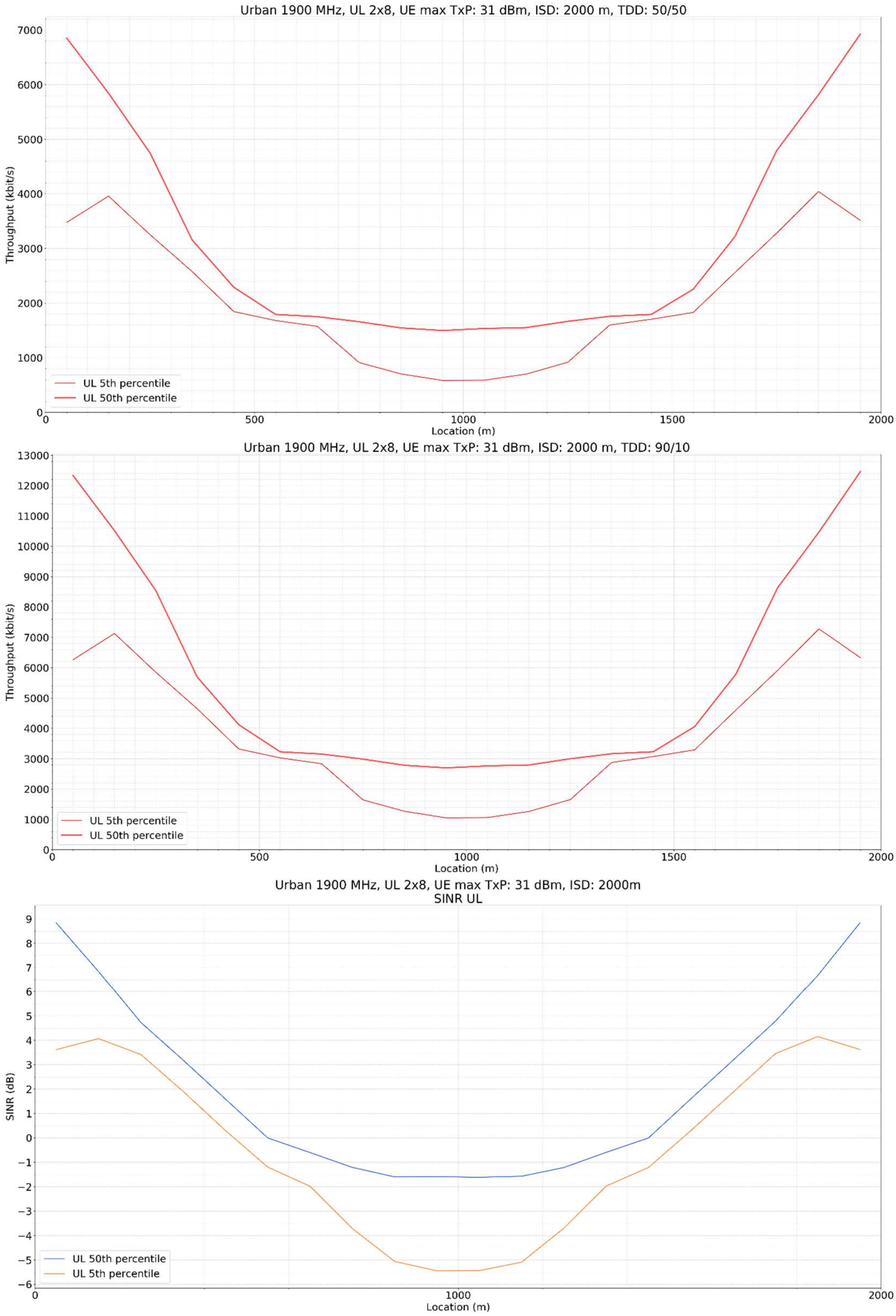


Figure A.236

Interference to noise ratio tables

	5th percentile	50th percentile	95th percentile
Full cell (UL)	-129 dBm	-124 dBm	-106 dBm
Cell centre (UL)	-128 dBm	-125 dBm	-118 dBm
Cell edge (UL)	-125 dBm	-119 dBm	-112 dBm

A.2.2.6 Urban, 4 KM ISD, 2 cells/site

A.2.2.6.1 Downlink, 63 dBm EIRP

DL 2x1

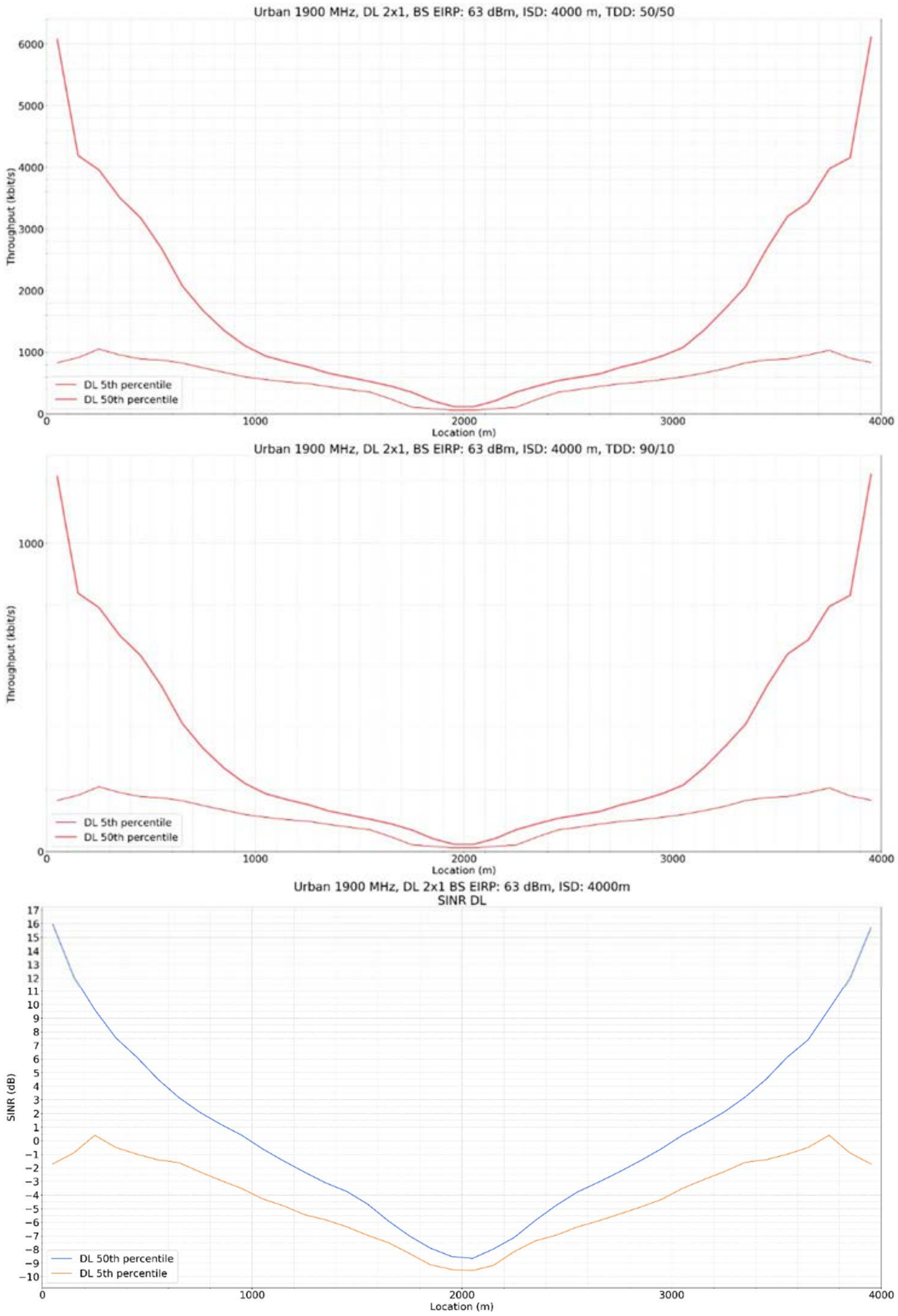


Figure A.237

Interference to noise ratio tables

	5th percentile	50th percentile	95th percentile
Full cell (DL)	-127 dBm	-118 dBm	-92 dBm
Cell centre (DL)	-109 dBm	-93 dBm	-71 dBm
Cell edge (DL)	-123 dBm	-119 dBm	-113 dBm

DL 2x2

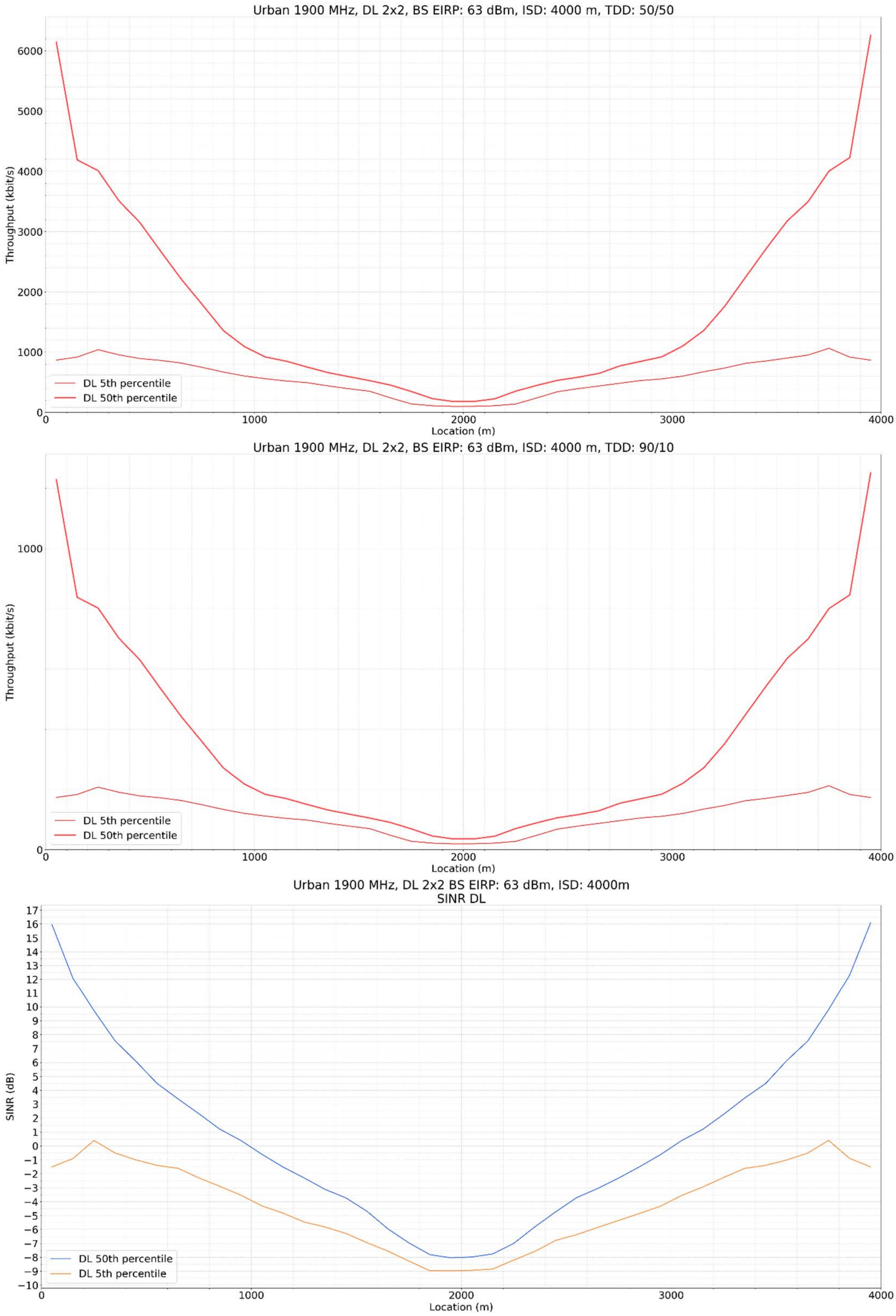


Figure A.238

Interference to noise ratio tables

	5th percentile	50th percentile	95th percentile
Full cell (DL)	-127 dBm	-120 dBm	-94 dBm
Cell centre (DL)	-112 dBm	-94 dBm	-74 dBm
Cell edge (DL)	-124 dBm	-120 dBm	-115 dBm

DL 4x1

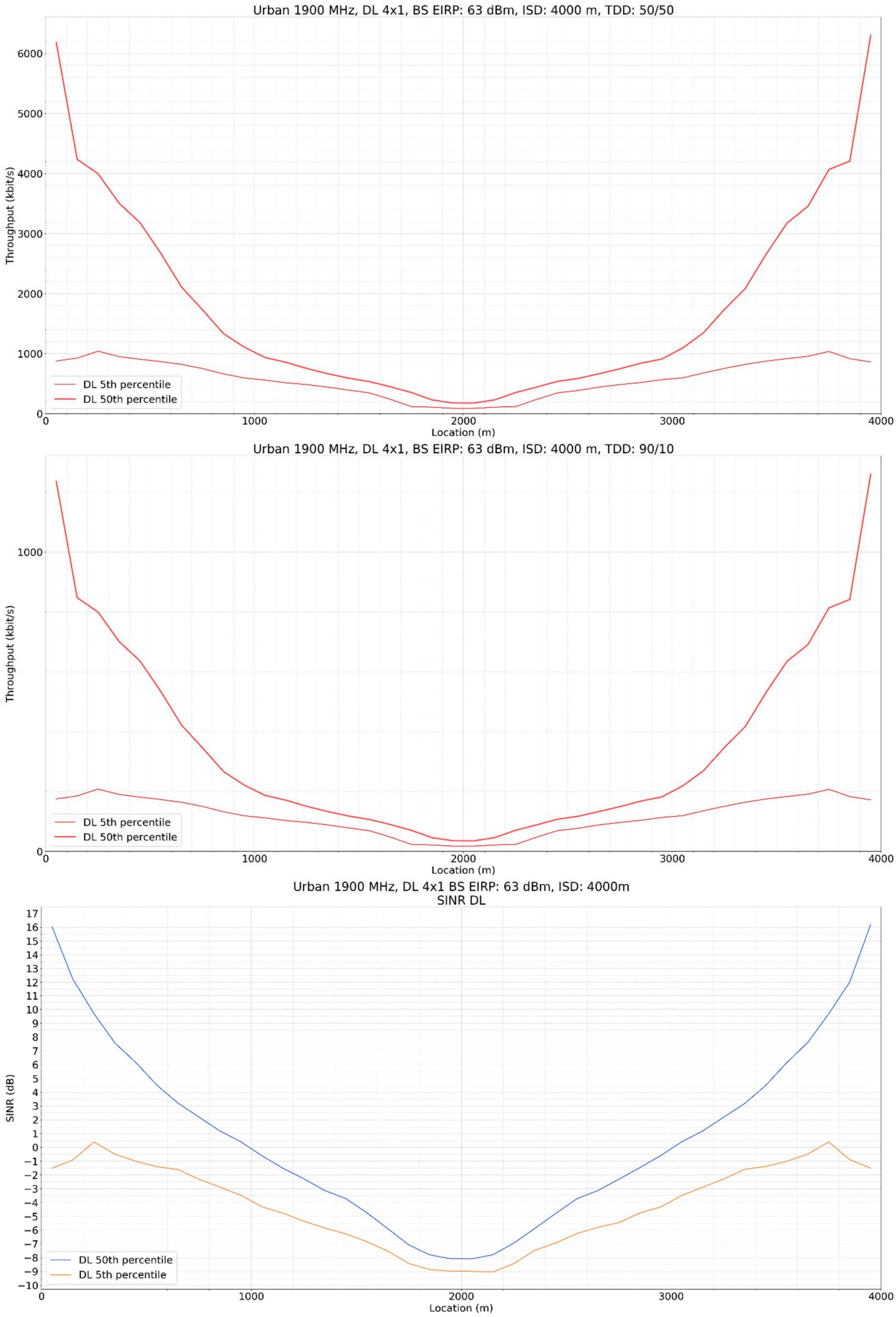


Figure A.239

Interference to noise ratio tables

	5th percentile	50th percentile	95th percentile
Full cell (DL)	-126 dBm	-116 dBm	-91 dBm
Cell centre (DL)	-109 dBm	-94 dBm	-77 dBm
Cell edge (DL)	-122 dBm	-117 dBm	-112 dBm

DL 4x2

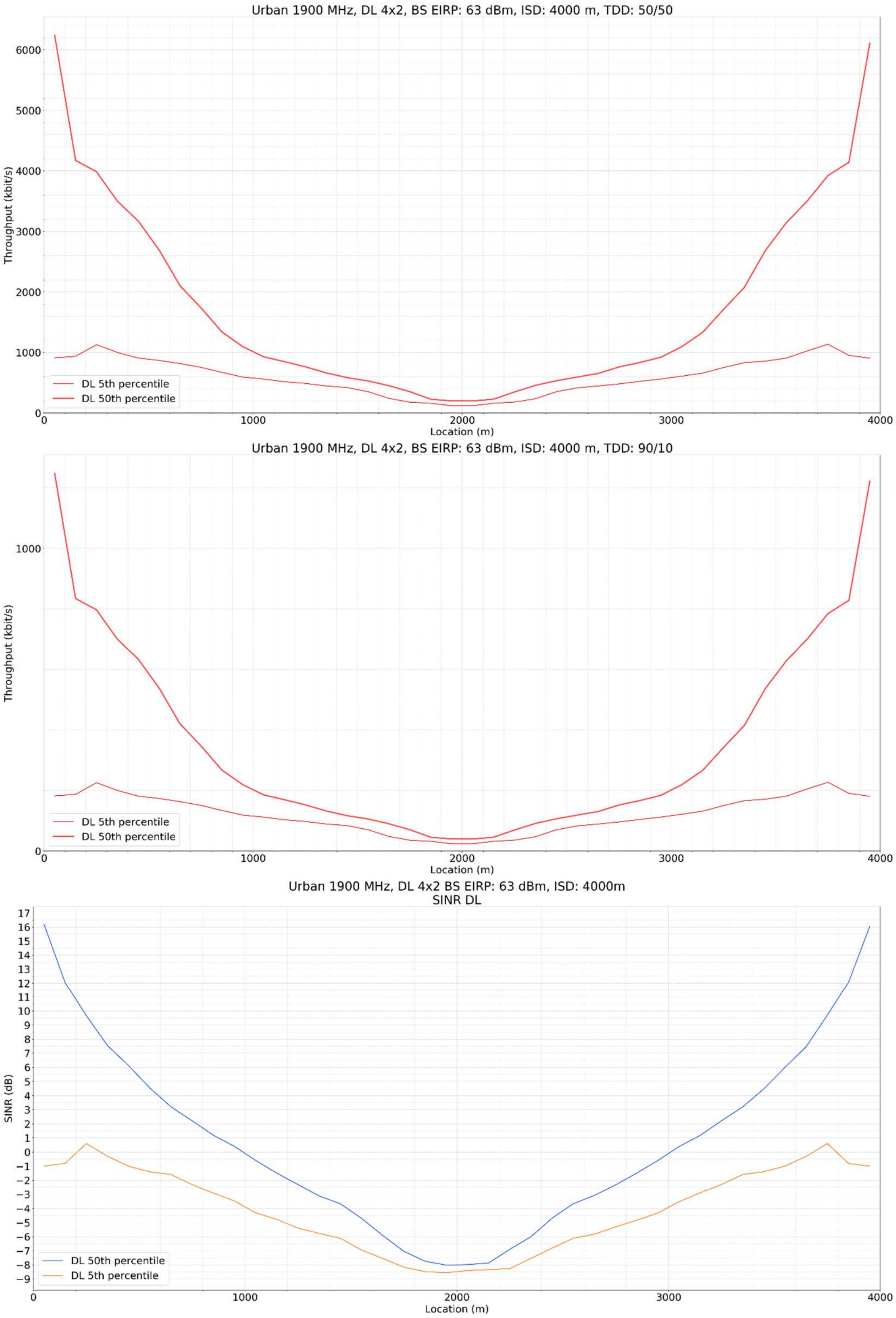


Figure A.240

Interference to noise ratio tables

	5th percentile	50th percentile	95th percentile
Full cell (DL)	-127 dBm	-118 dBm	-93 dBm
Cell centre (DL)	-111 dBm	-96 dBm	-76 dBm
Cell edge (DL)	-123 dBm	-119 dBm	-113 dBm

DL 8x1

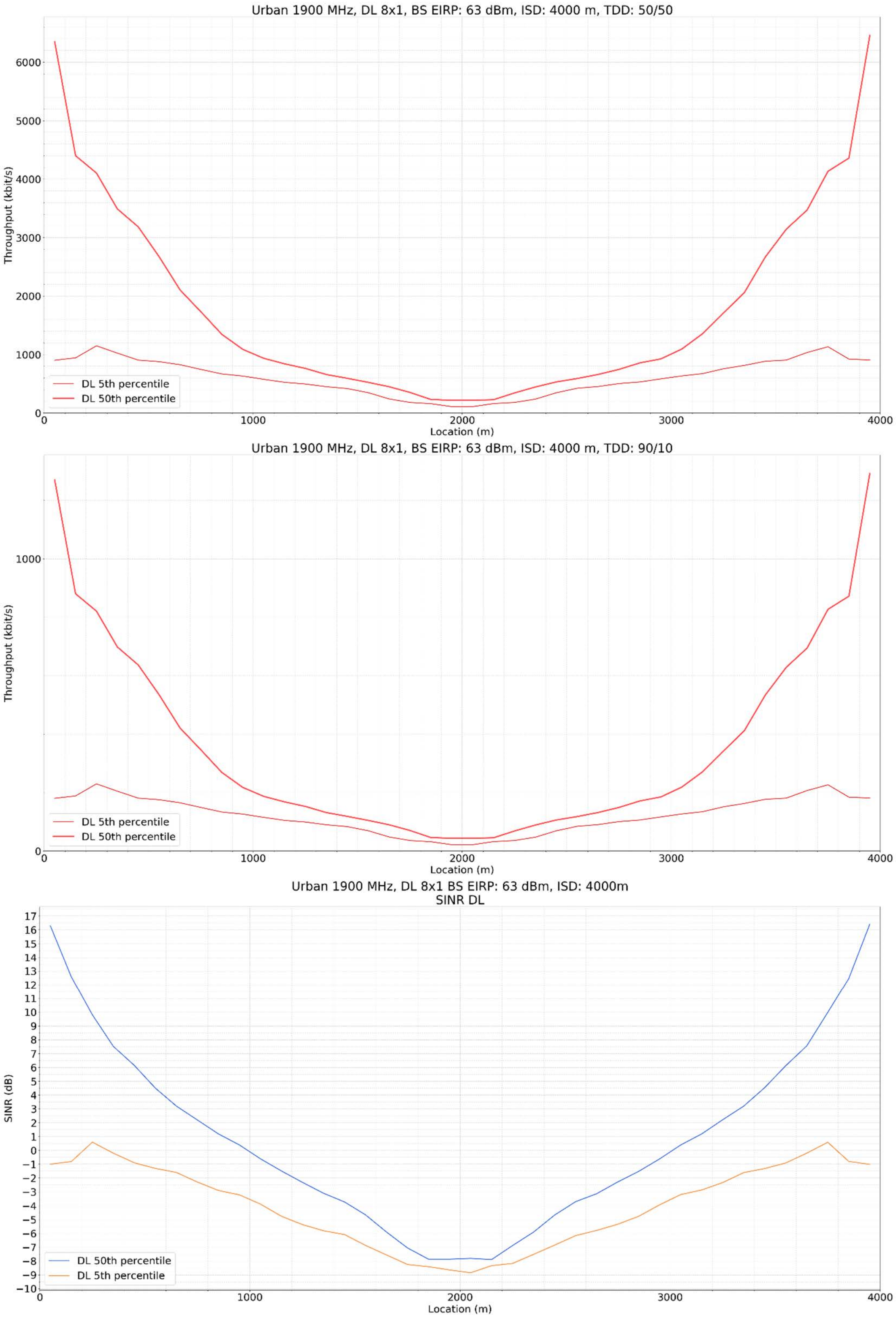


Figure A.241

Interference to noise ratio tables

	5th percentile	50th percentile	95th percentile
Full cell (DL)	-126 dBm	-114 dBm	-91 dBm
Cell centre (DL)	-110 dBm	-95 dBm	-75 dBm
Cell edge (DL)	-120 dBm	-115 dBm	-109 dBm

DL 8x2

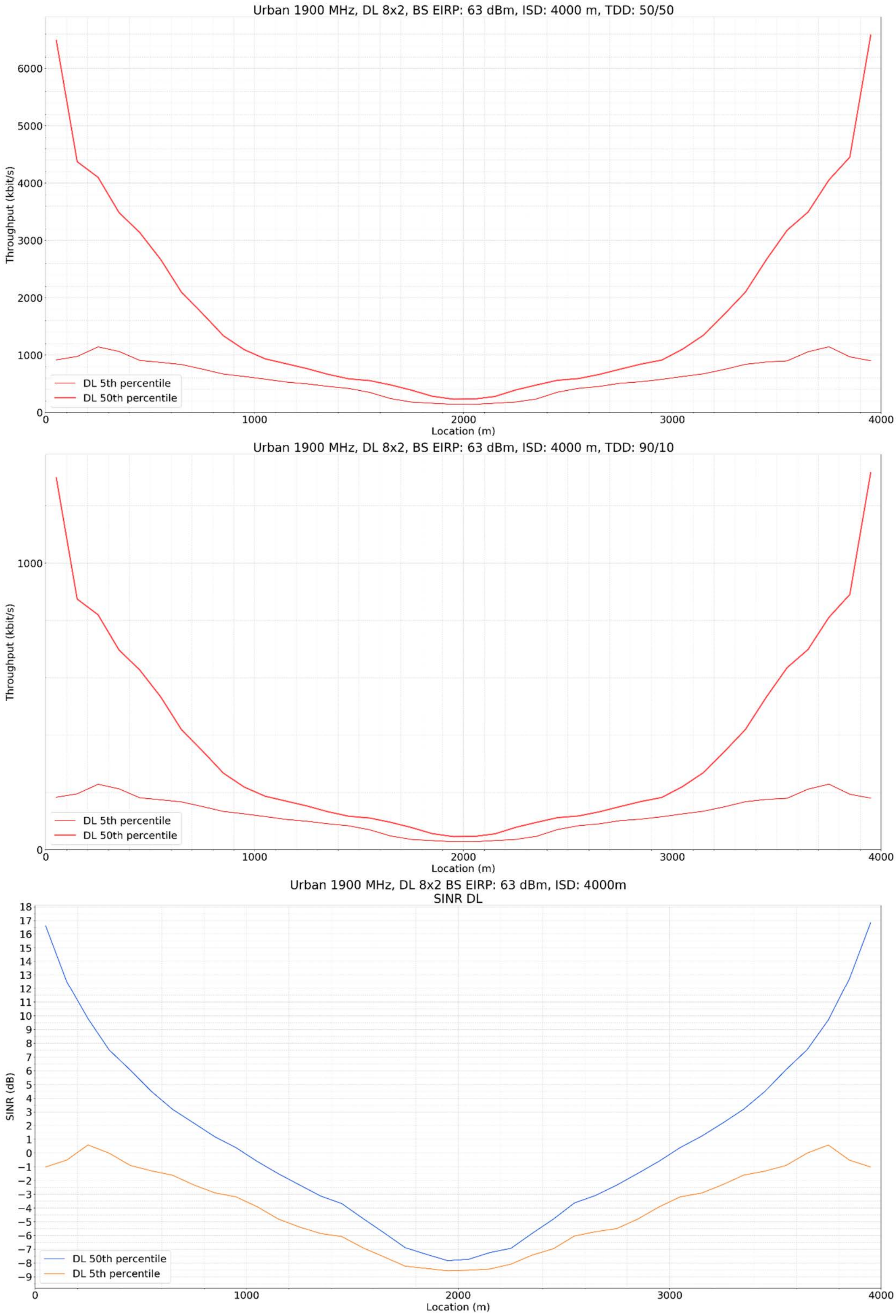


Figure A.242

Interference to noise ratio tables

	5th percentile	50th percentile	95th percentile
Full cell (DL)	-126 dBm	-115 dBm	-92 dBm
Cell centre (DL)	-109 dBm	-95 dBm	-73 dBm
Cell edge (DL)	-122 dBm	-116 dBm	-109 dBm

A.2.2.6.2 Downlink, 40 dBm EIRP

DL 2x1

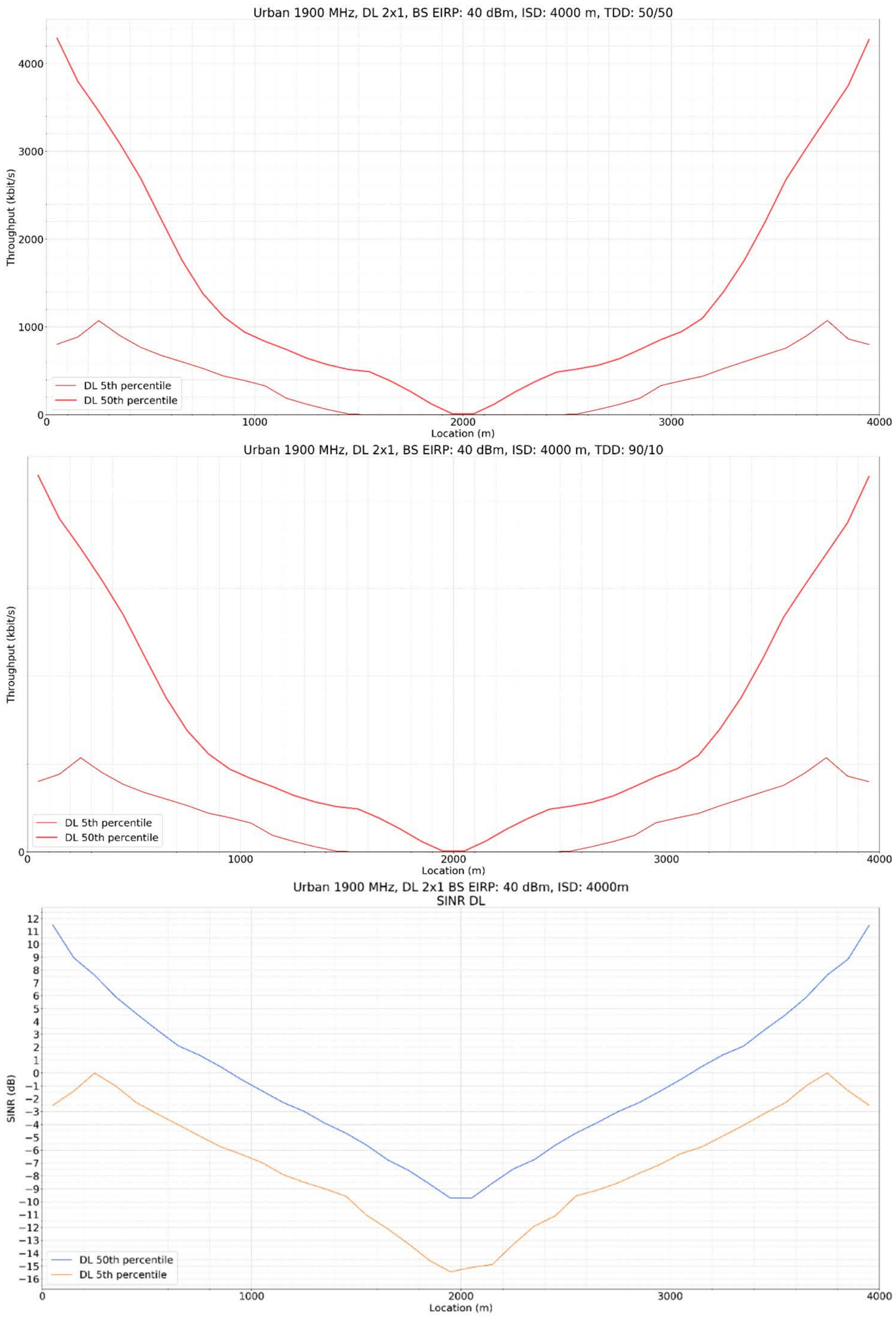


Figure A.243

Interference to noise ratio tables

	5th percentile	50th percentile	95th percentile
Full cell (DL)	-127 dBm	-127 dBm	-109 dBm
Cell centre (DL)	-122 dBm	-111 dBm	-93 dBm
Cell edge (DL)	-127 dBm	-127 dBm	-125 dBm

DL 2x2

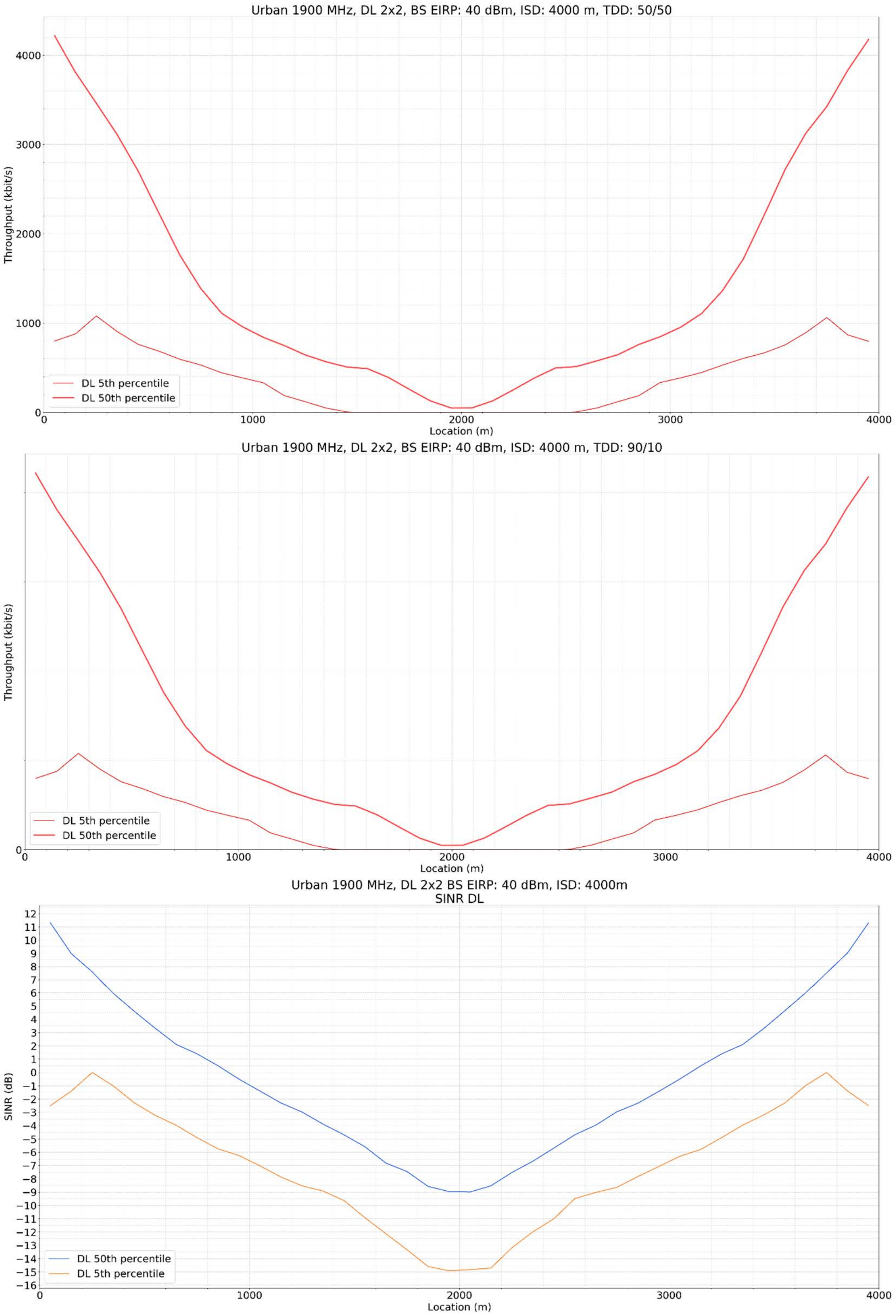


Figure A.244

Interference to noise ratio tables

	5th percentile	50th percentile	95th percentile
Full cell (DL)	-127 dBm	-127 dBm	-115 dBm
Cell centre (DL)	-124 dBm	-122 dBm	-98 dBm
Cell edge (DL)	-127 dBm	-127 dBm	-126 dBm

DL 4x1

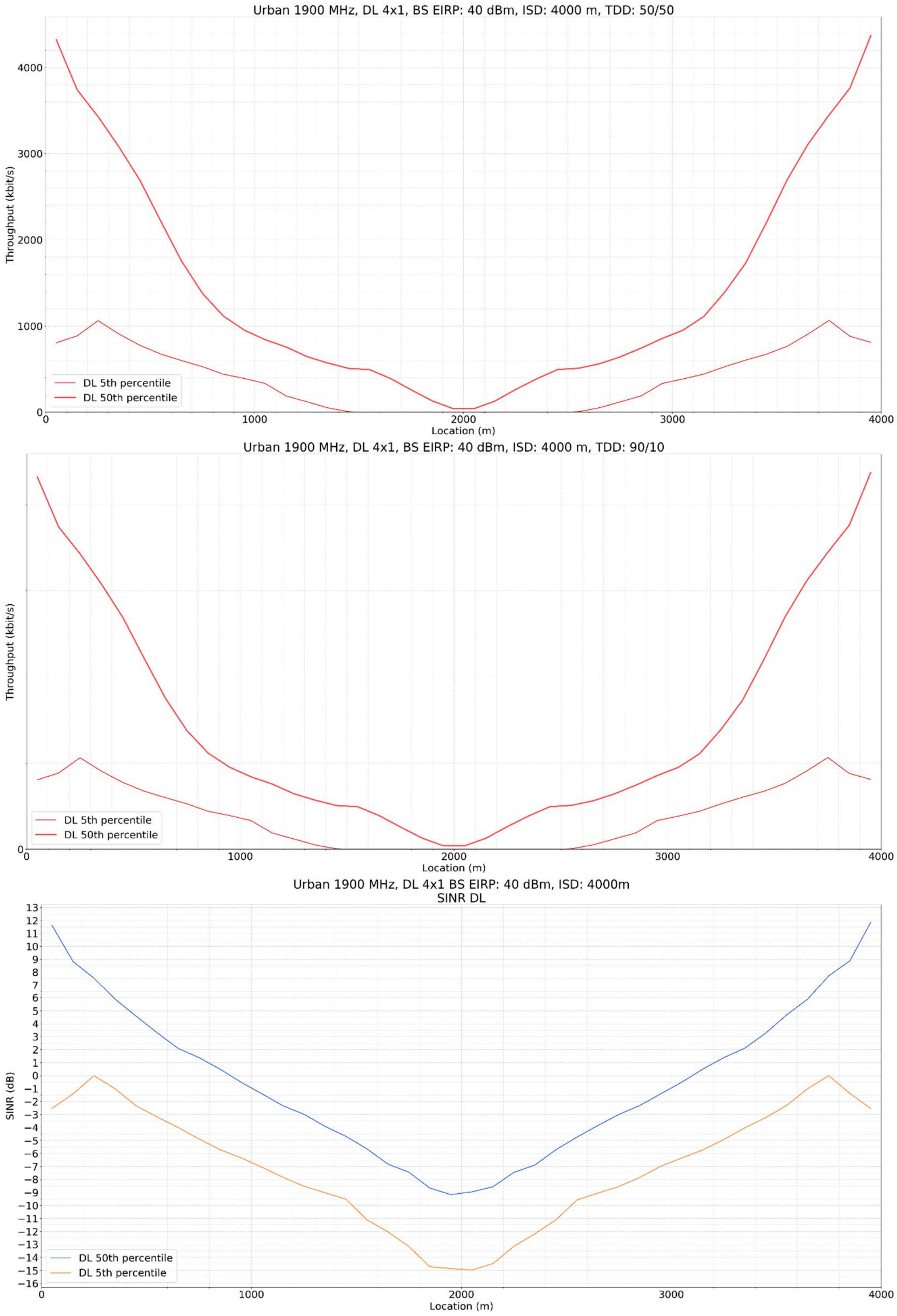


Figure A.245

Interference to noise ratio tables

	5th percentile	50th percentile	95th percentile
Full cell (DL)	-127 dBm	-127 dBm	-110 dBm
Cell centre (DL)	-123 dBm	-113 dBm	-96 dBm
Cell edge (DL)	-127 dBm	-127 dBm	-123 dBm

DL 4x2

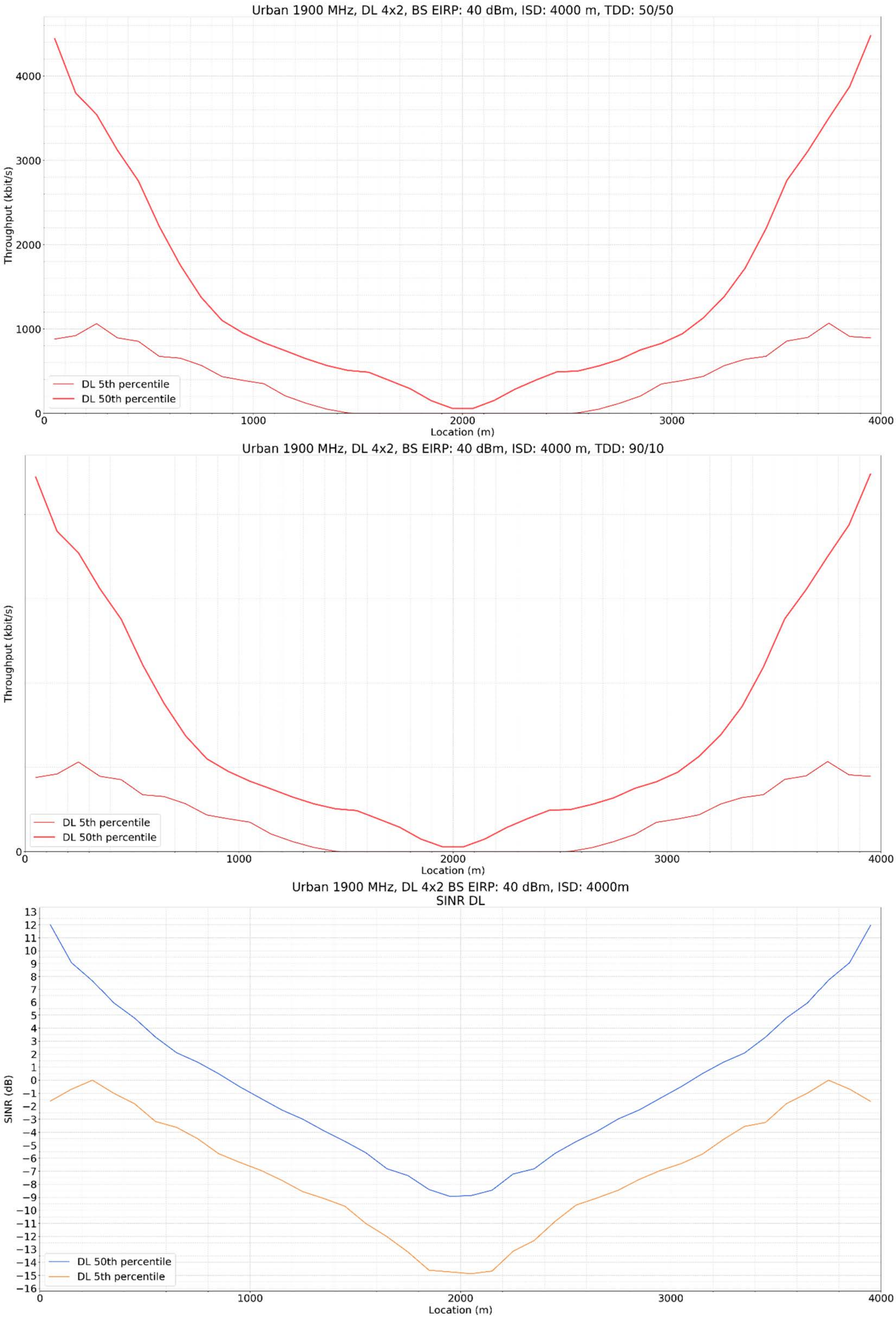


Figure A.246

Interference to noise ratio tables

	5th percentile	50th percentile	95th percentile
Full cell (DL)	-127 dBm	-127 dBm	-114 dBm
Cell centre (DL)	-124 dBm	-114 dBm	-98 dBm
Cell edge (DL)	-127 dBm	-127 dBm	-125 dBm

DL 8x1

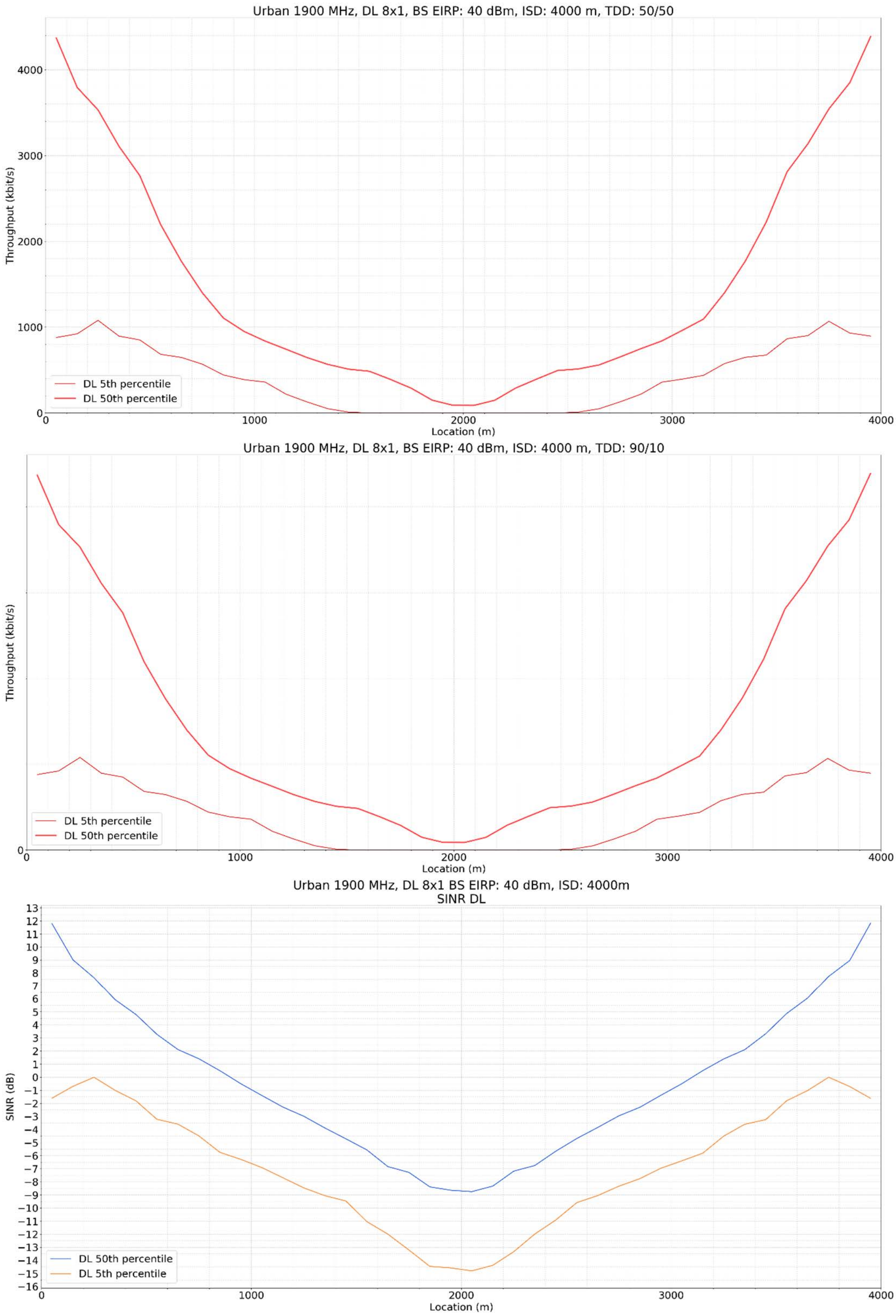


Figure A.247

Interference to noise ratio tables

	5th percentile	50th percentile	95th percentile
Full cell (DL)	-127 dBm	-127 dBm	-112 dBm
Cell centre (DL)	-123 dBm	-114 dBm	-93 dBm
Cell edge (DL)	-127 dBm	-126 dBm	-125 dBm

DL 8x2

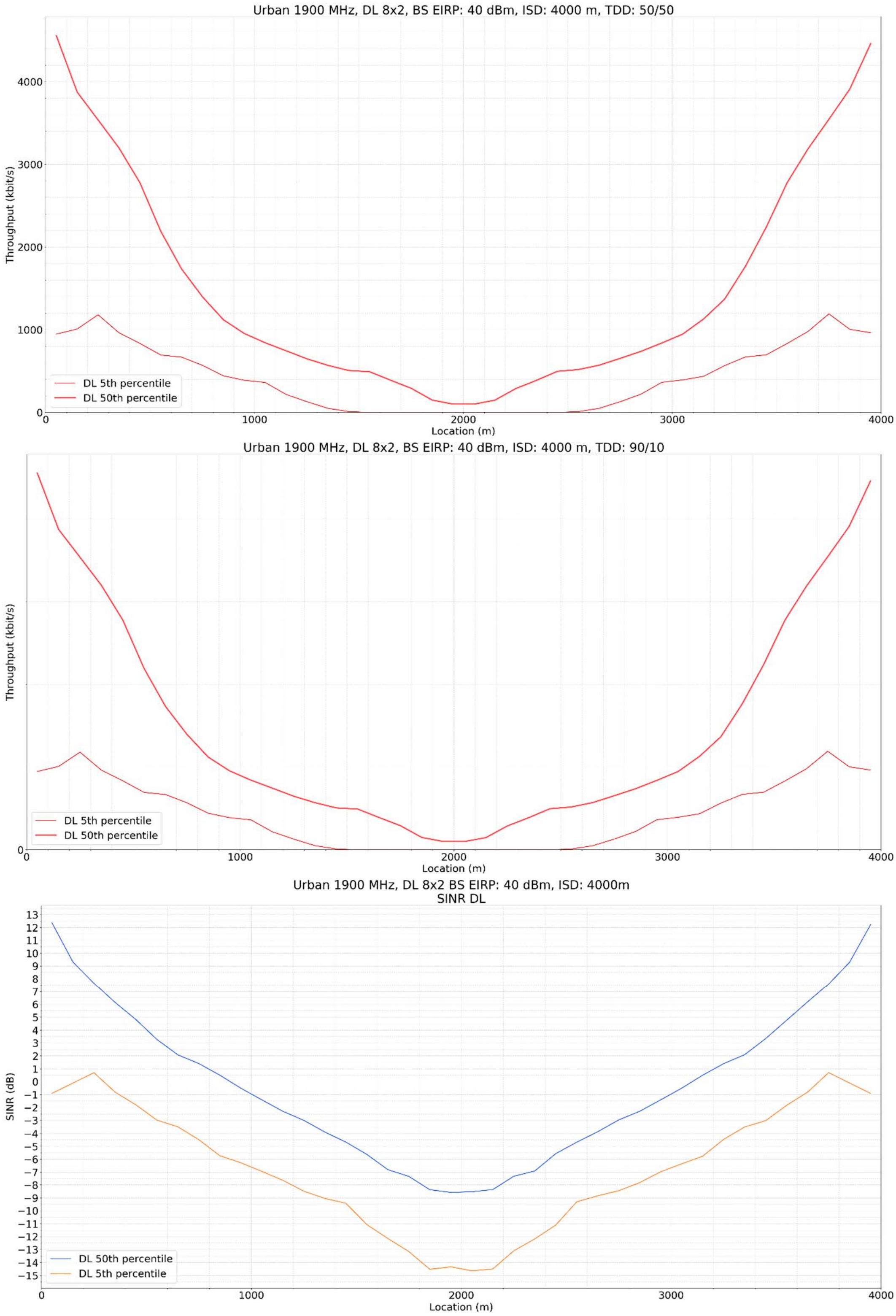


Figure A.248

Interference to noise ratio tables

	5th percentile	50th percentile	95th percentile
Full cell (DL)	-127 dBm	-127 dBm	-115 dBm
Cell centre (DL)	-124 dBm	-114 dBm	-97 dBm
Cell edge (DL)	-127 dBm	-127 dBm	-125 dBm

A.2.2.6.3 Uplink, 23 dBm max transmit power

UL 1x2

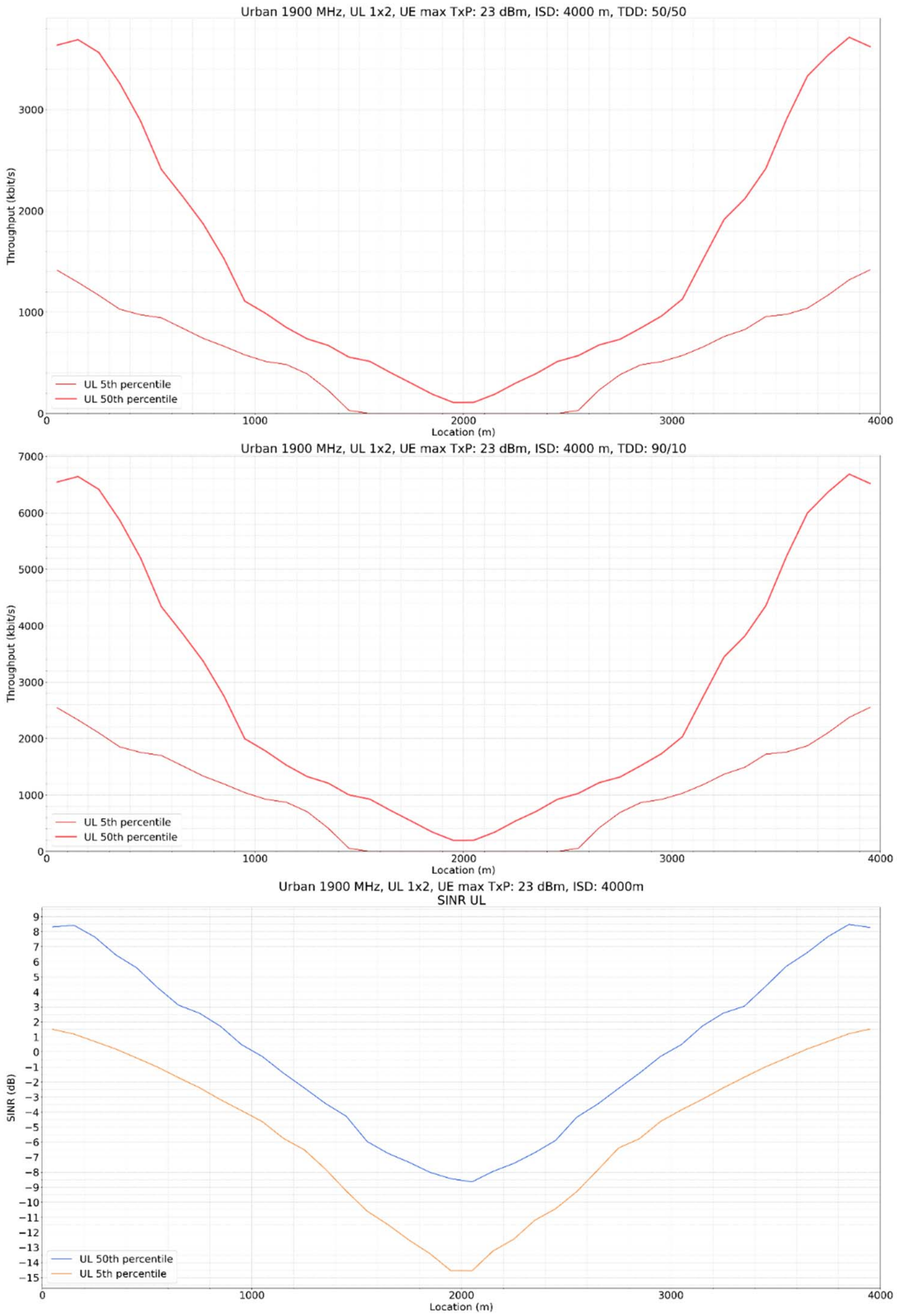


Figure A.249

Interference to noise ratio tables

	5th percentile	50th percentile	95th percentile
Full cell (UL)	-129 dBm	-129 dBm	-115 dBm
Cell centre (UL)	-129 dBm	-127 dBm	-123 dBm
Cell edge (UL)	-129 dBm	-122 dBm	-116 dBm

UL 2x2

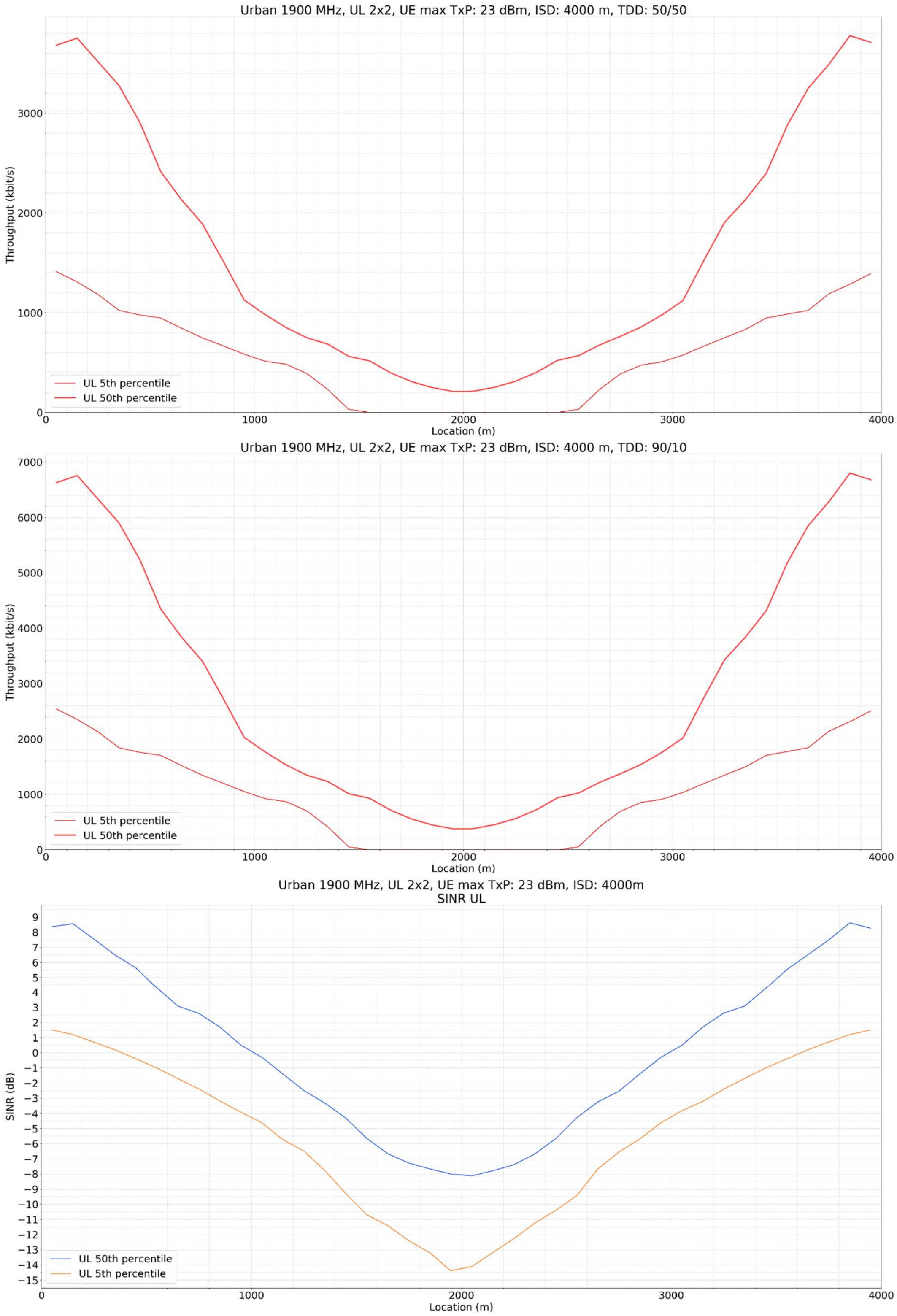


Figure A.250

Interference to noise ratio tables

	5th percentile	50th percentile	95th percentile
Full cell (UL)	-129 dBm	-129 dBm	-116 dBm
Cell centre (UL)	-129 dBm	-127 dBm	-125 dBm
Cell edge (UL)	-127 dBm	-123 dBm	-118 dBm

UL 1x4

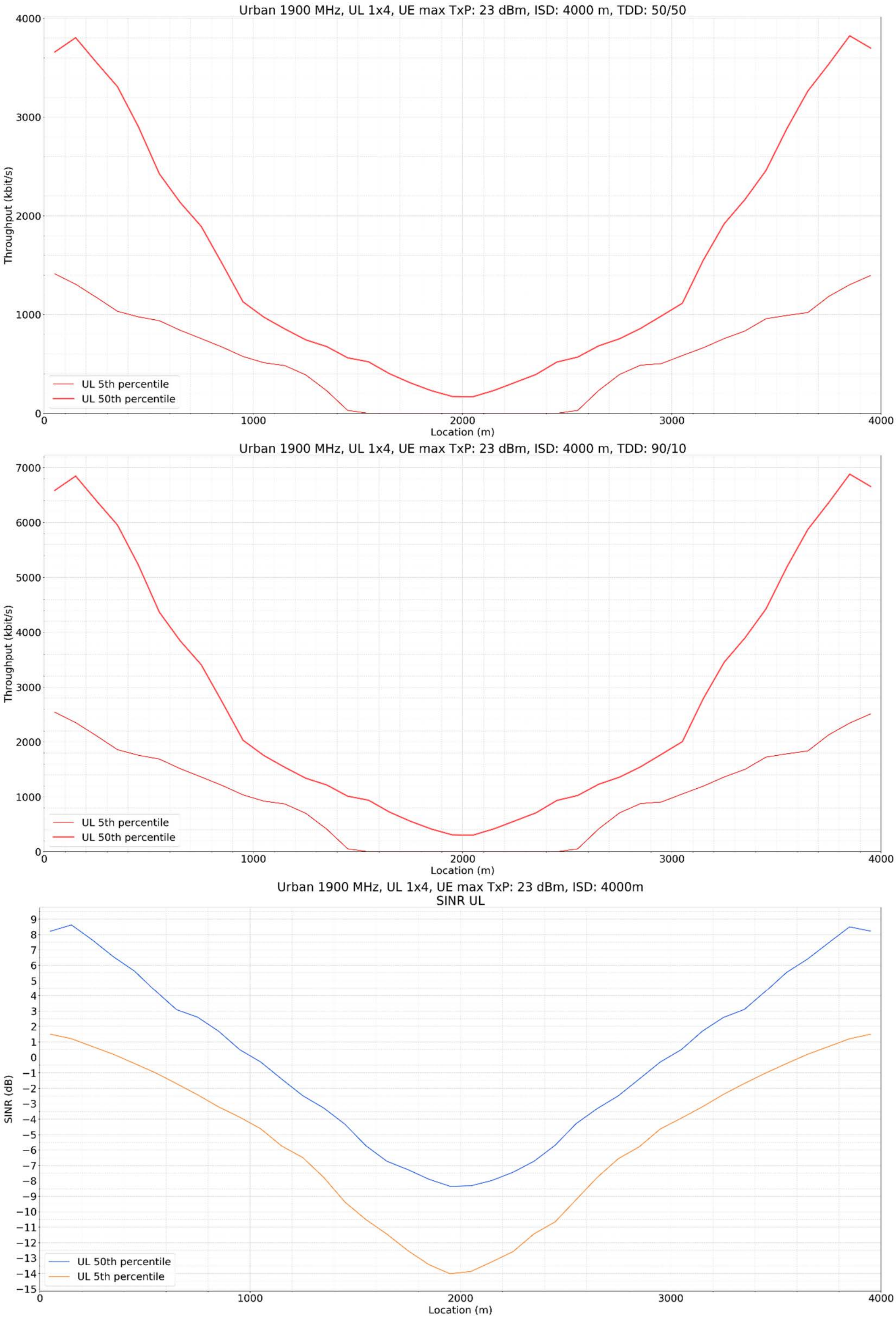


Figure A.251

Interference to noise ratio tables

	5th percentile	50th percentile	95th percentile
Full cell (UL)	-129 dBm	-129 dBm	-114 dBm
Cell centre (UL)	-129 dBm	-128 dBm	-122 dBm
Cell edge (UL)	-125 dBm	-120 dBm	-114 dBm

UL 2x4

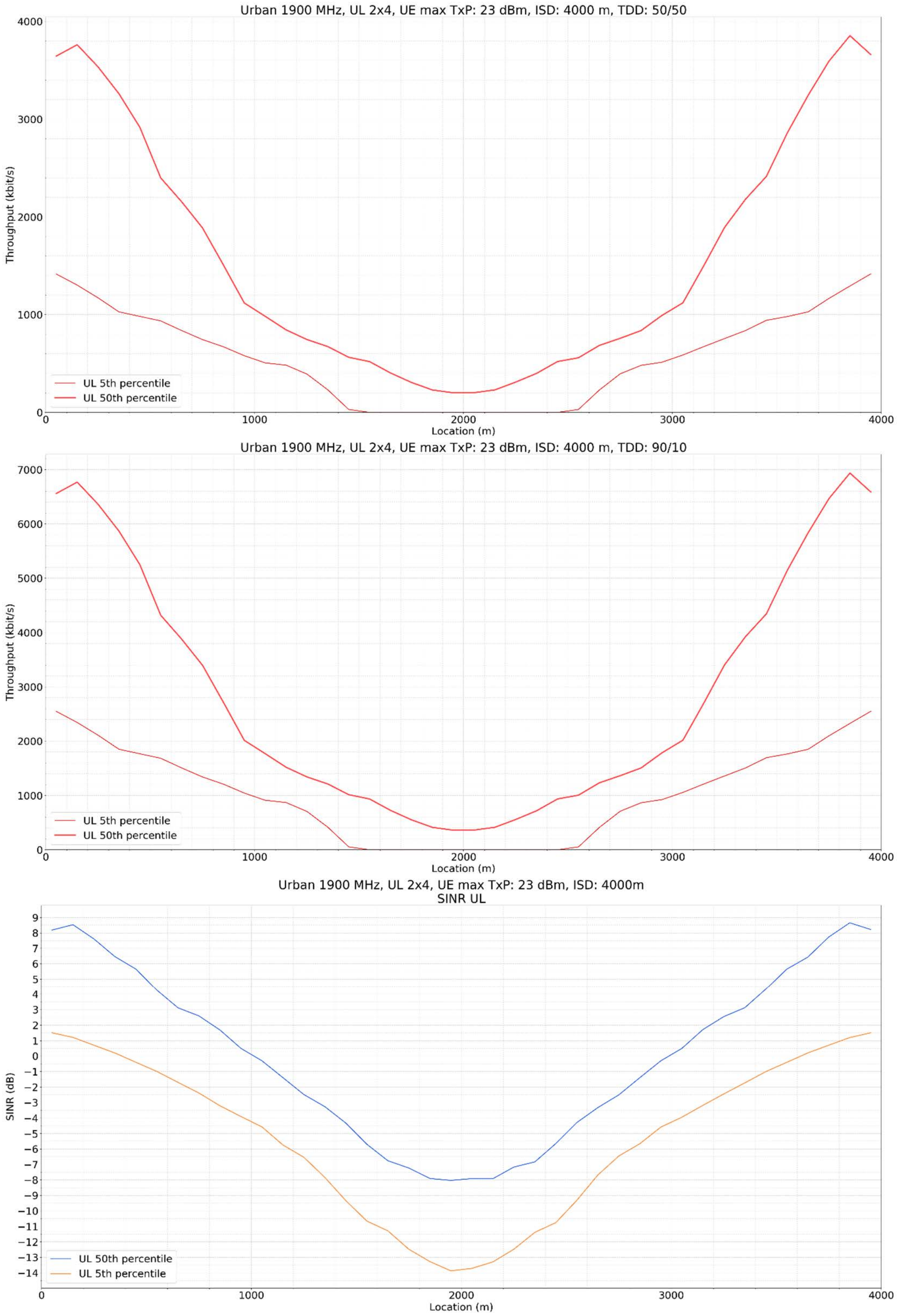


Figure A.252

Interference to noise ratio tables

	5th percentile	50th percentile	95th percentile
Full cell (UL)	-129 dBm	-129 dBm	-114 dBm
Cell centre (UL)	-129 dBm	-128 dBm	-124 dBm
Cell edge (UL)	-127 dBm	-121 dBm	-117 dBm

UL 1x8

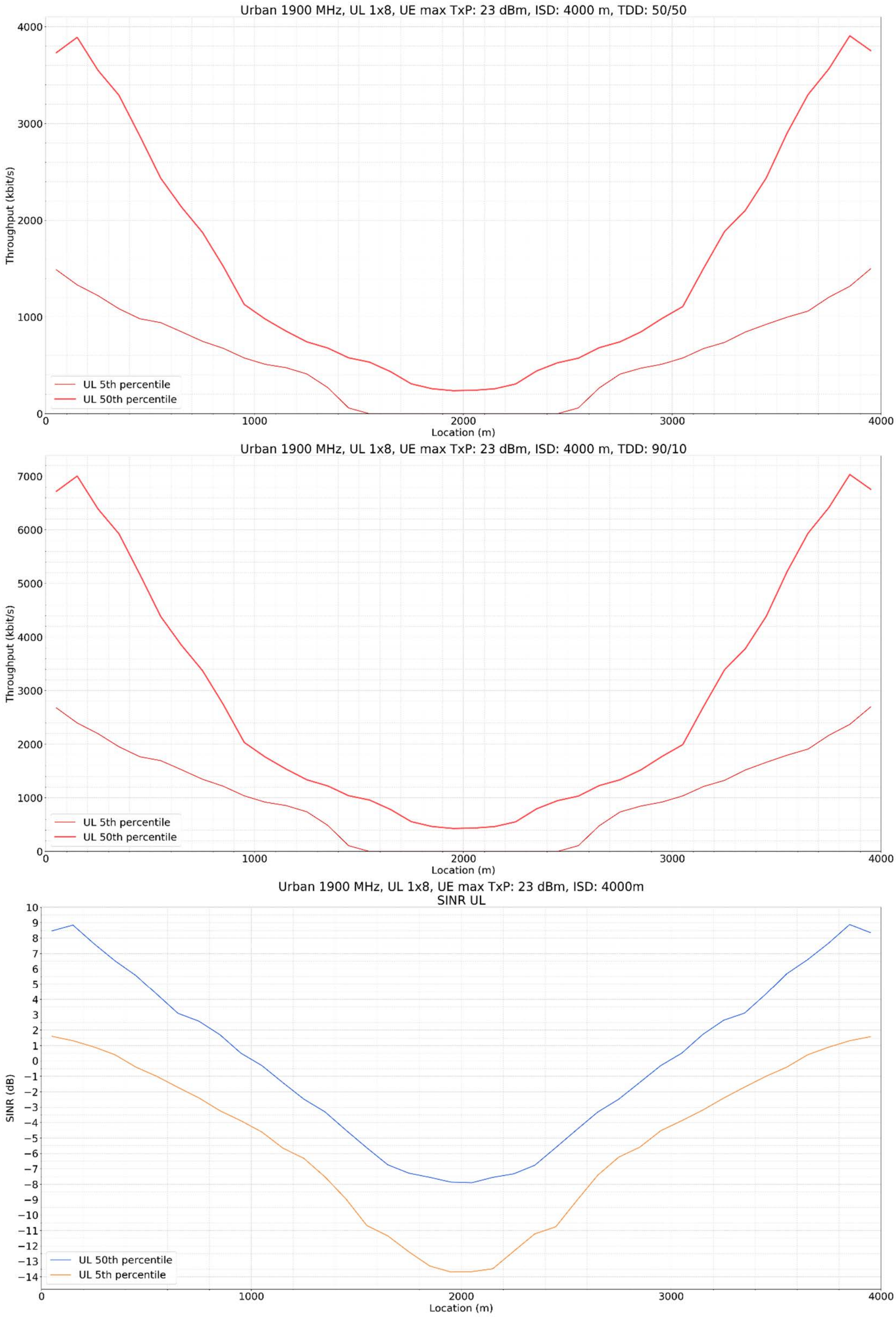


Figure A.253

Interference to noise ratio tables

	5th percentile	50th percentile	95th percentile
Full cell (UL)	-129 dBm	-129 dBm	-113 dBm
Cell centre (UL)	-129 dBm	-128 dBm	-124 dBm
Cell edge (UL)	-124 dBm	-119 dBm	-114 dBm

UL 2x8

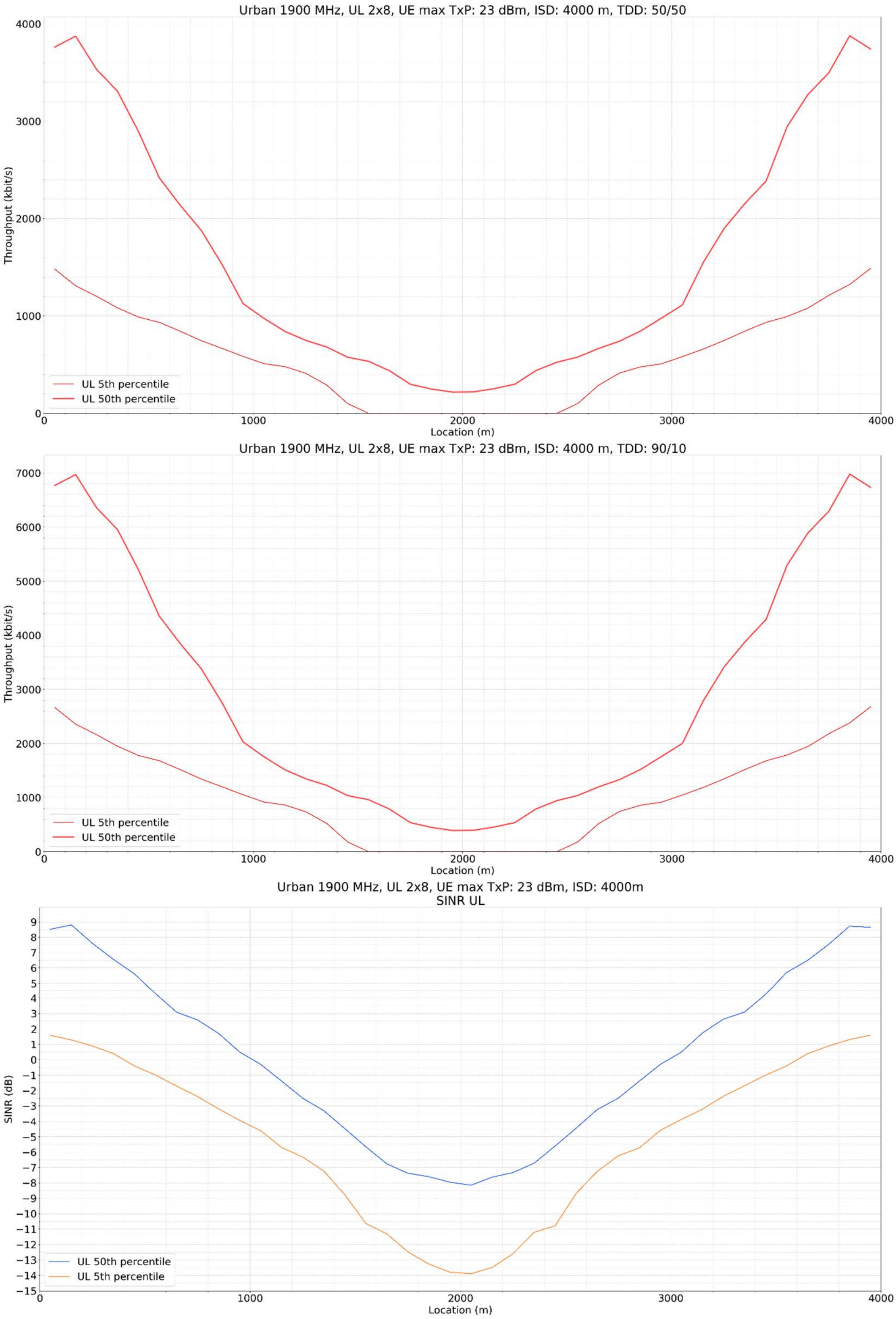


Figure A.254

Interference to noise ratio tables

	5th percentile	50th percentile	95th percentile
Full cell (UL)	-129 dBm	-129 dBm	-113 dBm
Cell centre (UL)	-129 dBm	-128 dBm	-124 dBm
Cell edge (UL)	-123 dBm	-119 dBm	-113 dBm

A.2.2.6.4 Uplink, 31 dBm max transmit power

UL 1x2

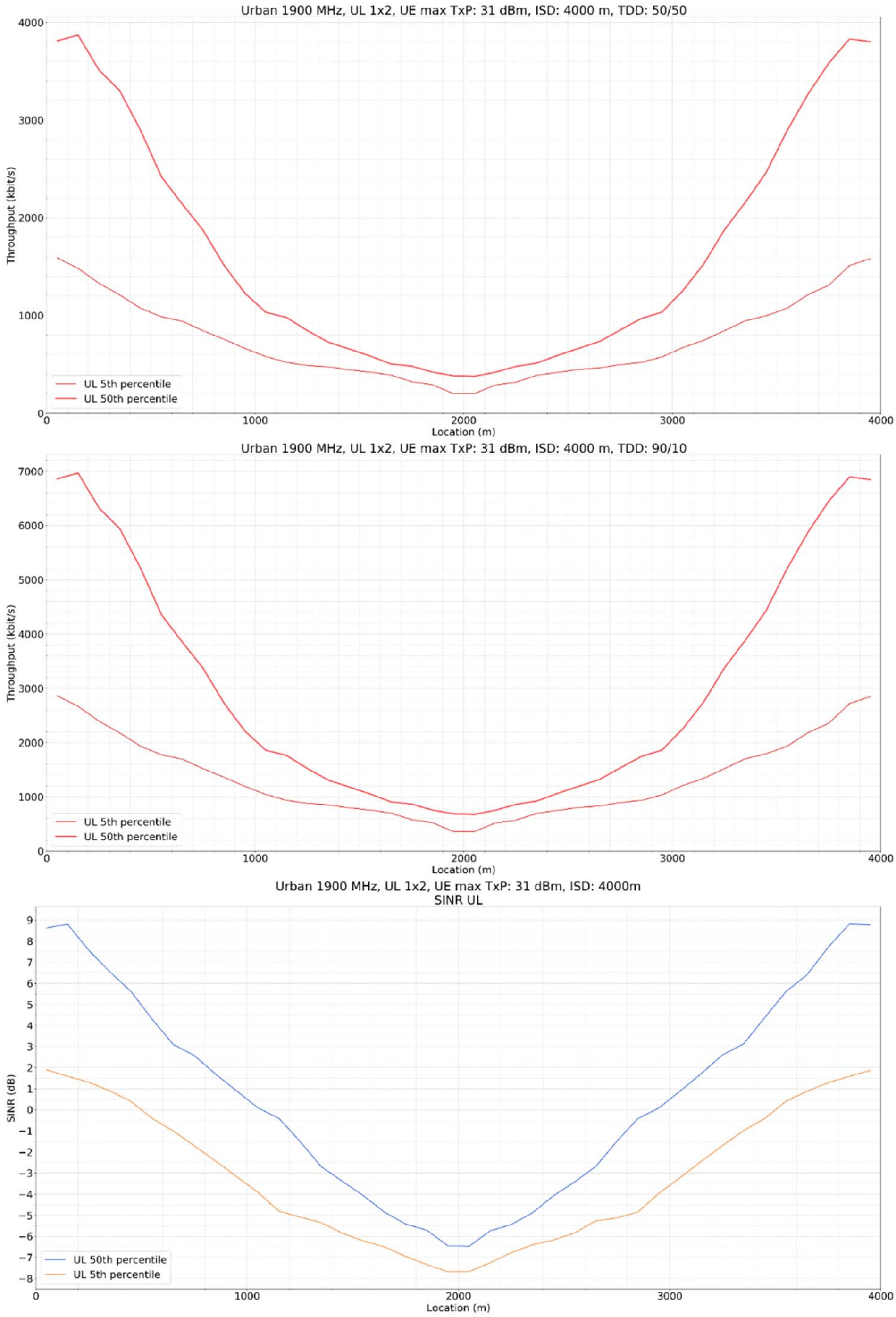


Figure A.255

Interference to noise ratio tables

	5th percentile	50th percentile	95th percentile
Full cell (UL)	-129 dBm	-127 dBm	-113 dBm
Cell centre (UL)	-128 dBm	-126 dBm	-123 dBm
Cell edge (UL)	-125 dBm	-122 dBm	-117 dBm

UL 2x2

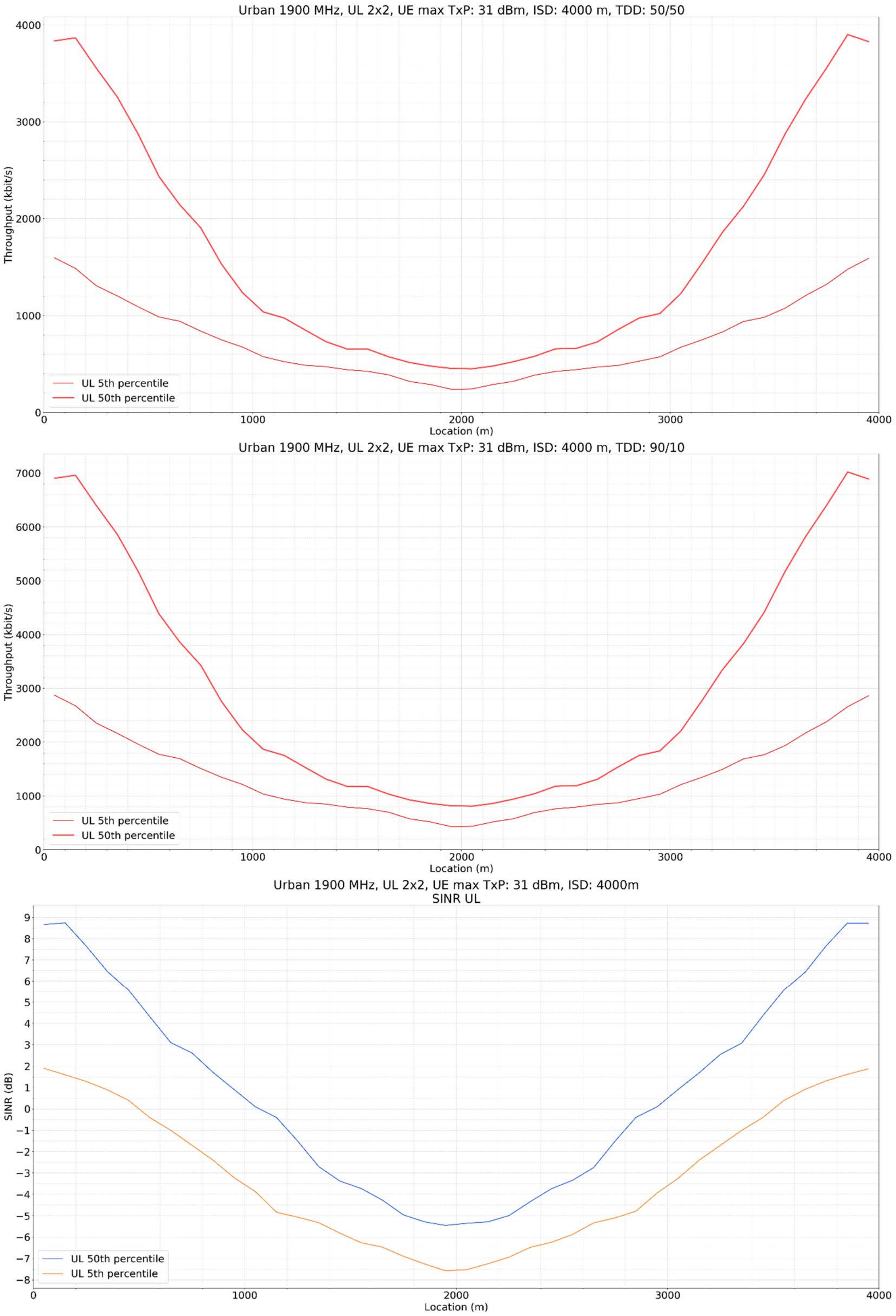


Figure A.256

Interference to noise ratio tables

	5th percentile	50th percentile	95th percentile
Full cell (UL)	-129 dBm	-127 dBm	-113 dBm
Cell centre (UL)	-127 dBm	-126 dBm	-122 dBm
Cell edge (UL)	-125 dBm	-122 dBm	-117 dBm

UL 1x4

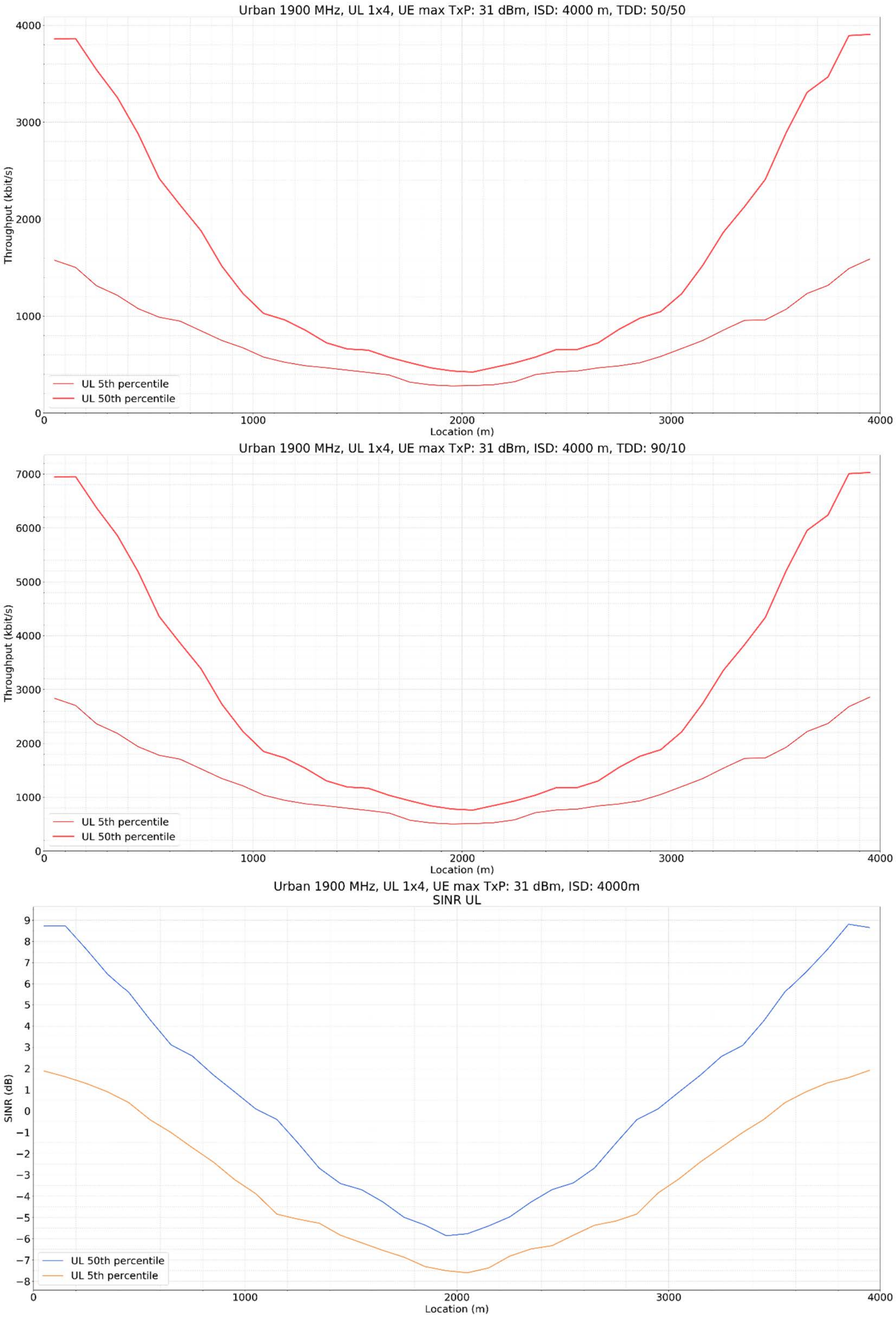


Figure A.257

Interference to noise ratio tables

	5th percentile	50th percentile	95th percentile
Full cell (UL)	-129 dBm	-127 dBm	-112 dBm
Cell centre (UL)	-128 dBm	-127 dBm	-123 dBm
Cell edge (UL)	-125 dBm	-120 dBm	-115 dBm

UL 2x4

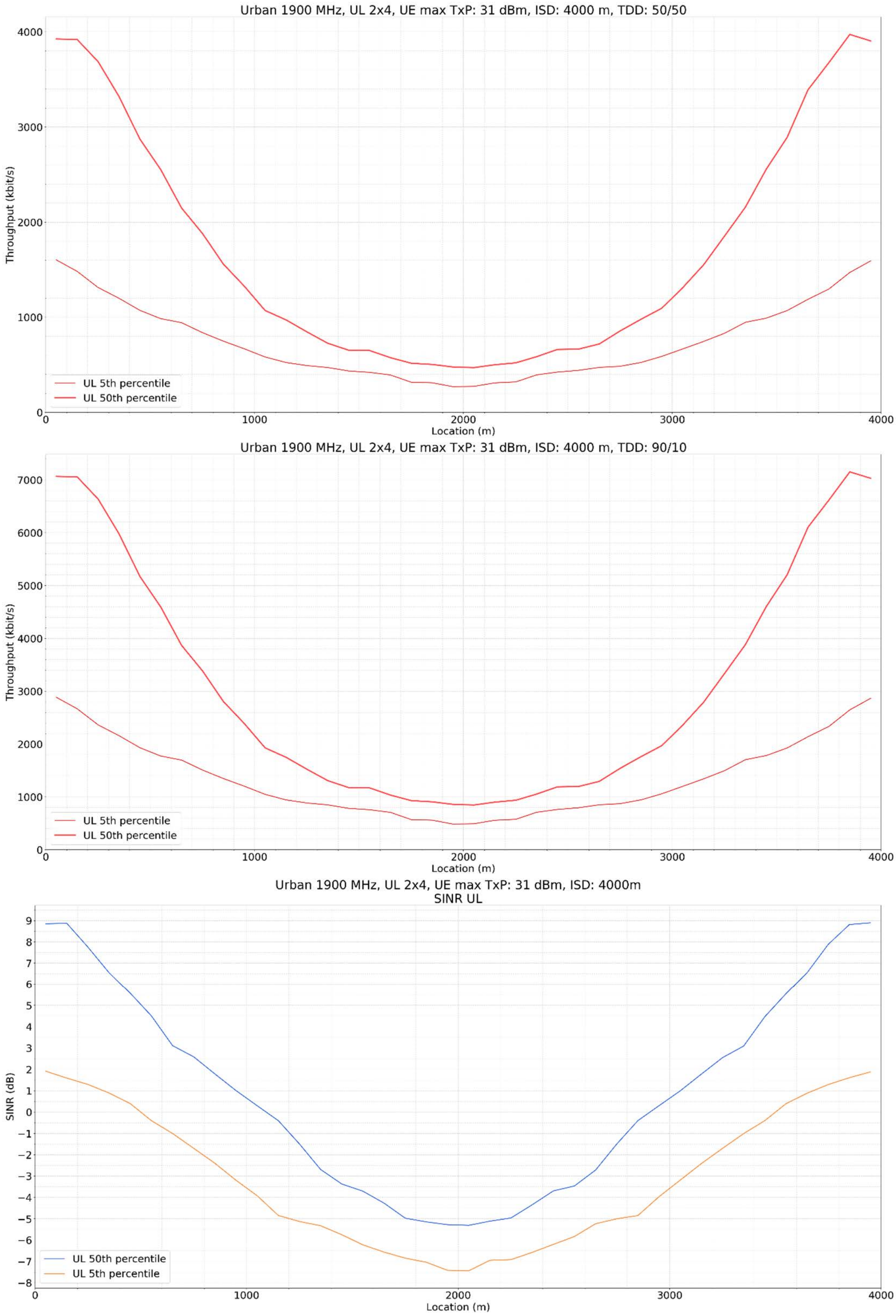


Figure A.258

Interference to noise ratio tables

	5th percentile	50th percentile	95th percentile
Full cell (UL)	-129 dBm	-127 dBm	-112 dBm
Cell centre (UL)	-128 dBm	-126 dBm	-123 dBm
Cell edge (UL)	-125 dBm	-120 dBm	-115 dBm

UL 1x8

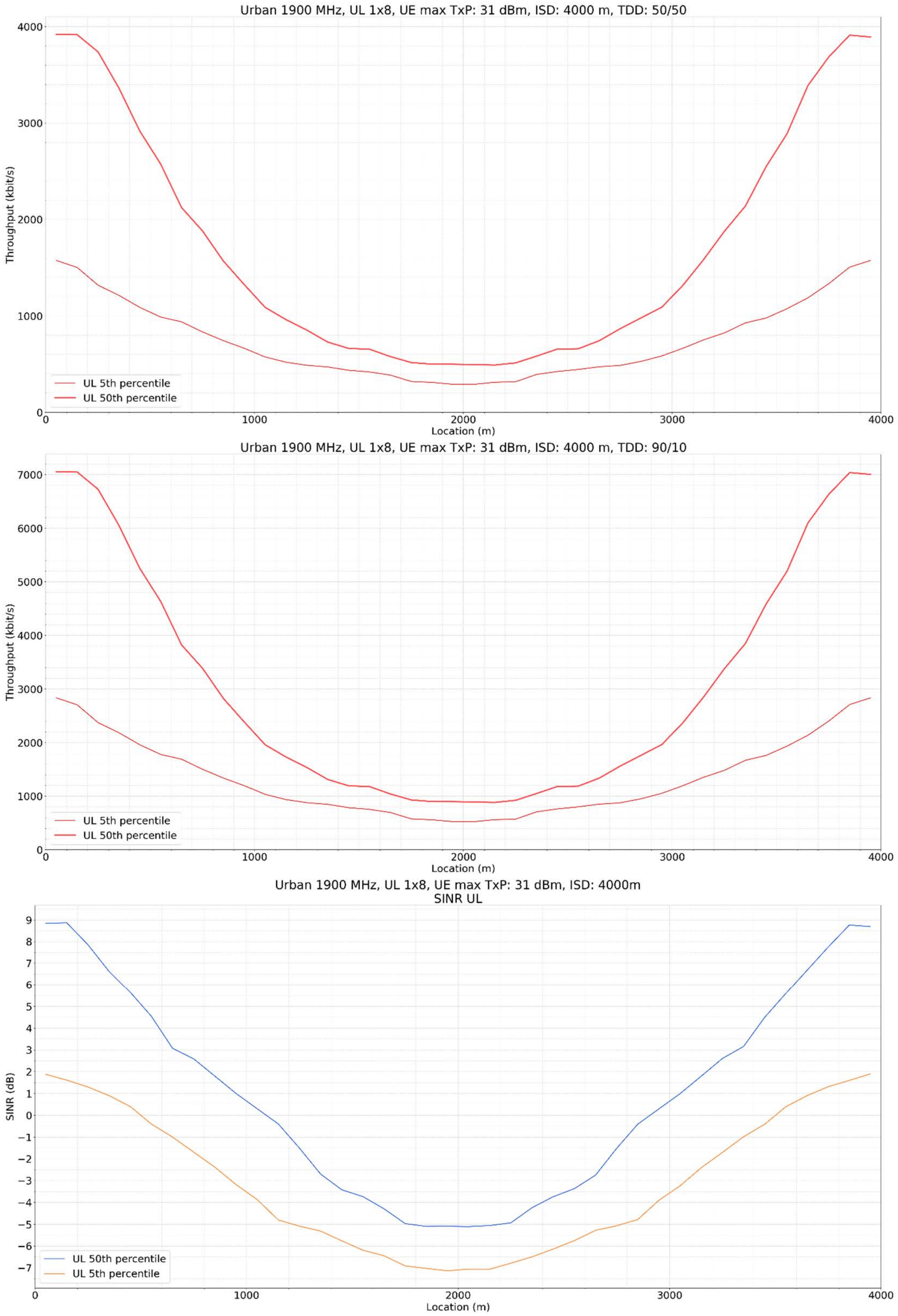
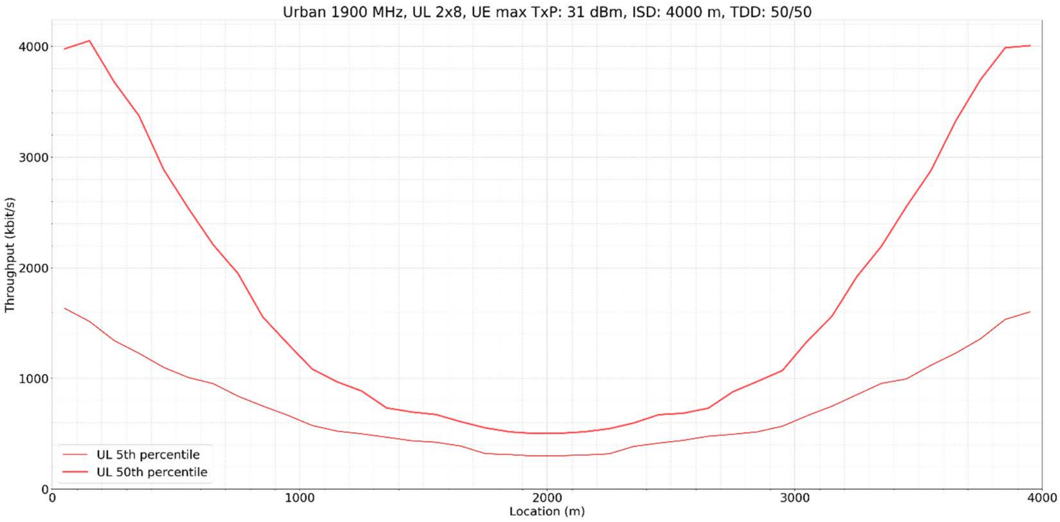


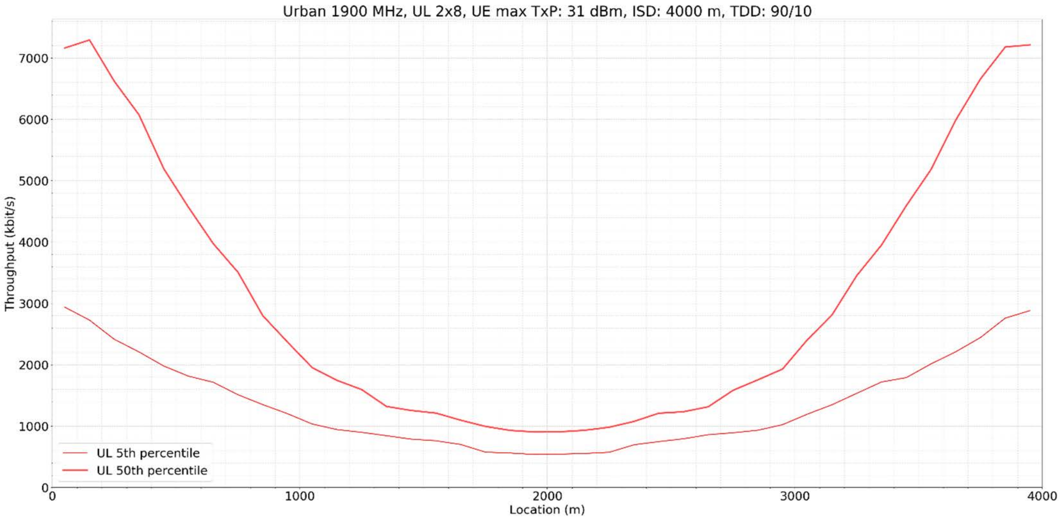
Figure A.259

Interference to noise ratio tables

	5th percentile	50th percentile	95th percentile
Full cell (UL)	-129 dBm	-126 dBm	-110 dBm
Cell centre (UL)	-128 dBm	-127 dBm	-123 dBm
Cell edge (UL)	-124 dBm	-118 dBm	-113 dBm

UL 2x8





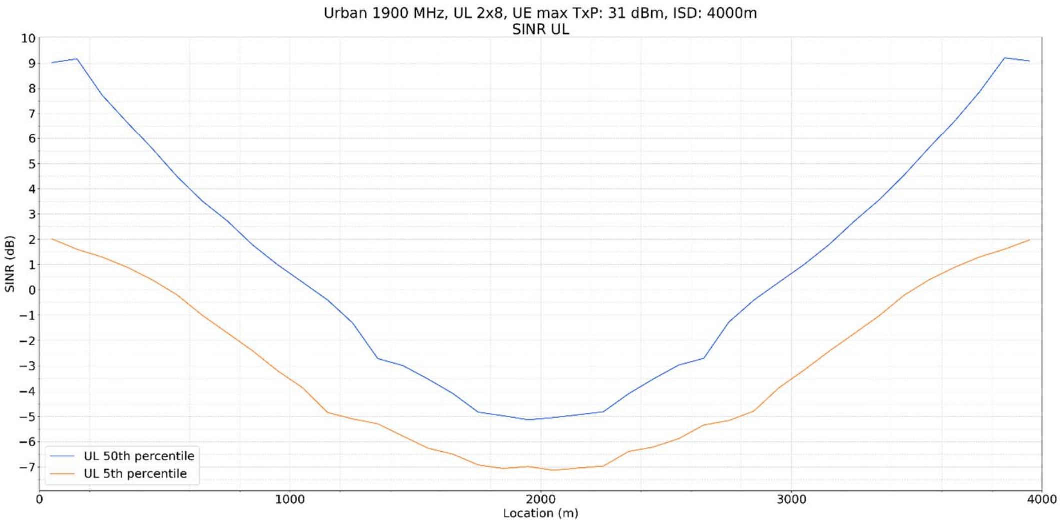


Figure A.260

Interference to noise ratio tables

	5th percentile	50th percentile	95th percentile
Full cell (UL)	-129 dBm	-126 dBm	-111 dBm
Cell centre (UL)	-129 dBm	-127 dBm	-123 dBm
Cell edge (UL)	-124 dBm	-119 dBm	-114 dBm

A.3 Further Notes and remarks

A.3.1 Company A

A.3.1.1 Interference or noise limitation

In this clause, a comparison of the relative signal, interference, and noise levels are compared between the different scenarios for the UL to get an indication on if the UL performance is mostly limited by noise or by interference. Figure A.261 summarizes the cell-edge SNR, INR, and SINR distributions for the different scenarios. For each scenario, the plot shows the 5, 50 and 95 -percentile in the CDF of the UEs located in the last distance bin, i.e. the bin closest to the geometrical cell-edge. SNR, INR, and SINR have been calculated before the receiver at BS antenna port 0. The 'o' marker indicates the 50 -percentile and the vertical line through the median marker starts at the 5 -percentile and ends at the 95 -percentile. The SNR distributions are shown in green, the INR distributions in red, and the SINR distributions in blue. The left plot shows the distributions for 23 dBm max UE Tx power and the right plot for 31 dBm max UE Tx power. The antenna height was 30 m in the rural scenario and 18 m in the urban scenario. The bandwidth was 5 MHz at 900 MHz carrier frequency and 10 MHz at 1 900 MHz. For all cases, the 2x2 MIMO configuration was used.

With 23 dBm UE Tx power the interference is below the noise floor in almost all cases. Only the 95 -percentile INR in the rural scenario at 1 900 MHz is above zero by a few dBm. The median INR is less than -10 dB in all cases. The three SINR percentiles are approximately the same as the corresponding SNR percentiles, which means that interference has no significant impact on the SINR. The 50 -percentile SINR is between 0,3 dB to 0,9 dB lower than the 50 -percentile SNR for the different cases, and the 5 -percentile SINR is between 0,4 dB to 0,6 dB lower than the 5 -percentile SNR.

With 31 dBm UE Tx power, the interference level is higher. The 95 -percentile INR is above zero for all cases but the median is below -5 dB. The impact of interference on SINR is stronger with 31 dBm UE Tx power, but still rather weak. The 50 -percentile SINR is between 0,6 dB to 1,3 dB lower than the 50 -percentile SNR, and the 5 -percentile SINR is between 0,8 dB to 1,9 dB lower than the 5 -percentile SNR.

With 23 dBm max UE Tx power, the 5 -percentile SNR is lower than the target SNR at 7 dB in all scenarios. The 50 -percentile SNR is above the target SNR in the rural 1 900 MHz case. Also, with 31 dBm max UE Tx power, the 5 -percentile SNR is lower than the target SNR at 7 dB in all scenarios. In this case, 50 -percentile SNR is above the target SNR in the rural scenario at both 900 MHz and 1 900 MHz.

From these observations it can be concluded that cell-edge UEs are mainly noise-limited in the uplink for all scenarios and it is the UE Tx power that is the limiting factor on cell-edge performance. However, for some UEs the interference can be significant. This can be mitigated by an IRC receiver in the BS.

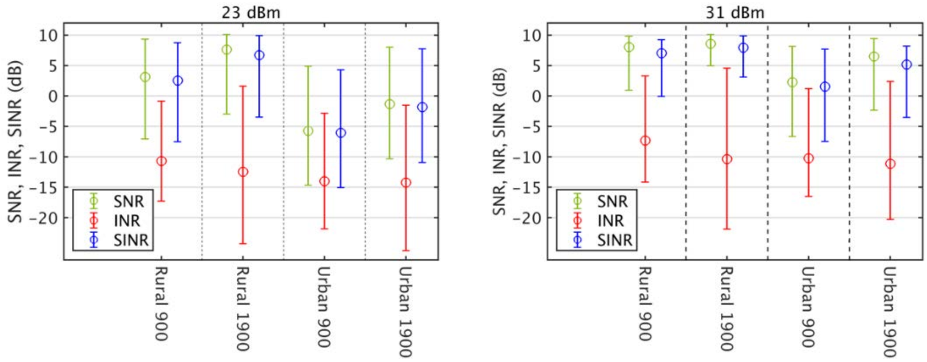


Figure A.261: Cell-edge SNR, INR and SINR distributions before the BS receiver for the different scenarios with 23 dBm (left) and 31 dBm (right) max UE Tx power

A.3.1.2 Impact of the number of antennas

In this clause, the impact of the number of UE Tx antennas and the number of BS Rx antenna ports on the received signal and interference is investigated.

Number of UE Tx antennas

Multiple UE Tx antennas can improve performance by precoding (or beamforming) gain and/or spatial multiplexing gain. To illustrate the precoding gain obtained in the system simulations, FigureA.262 shows the signal power gain with 2 and 4 UE Tx antennas as a function of distance for the four different scenarios. Signal power gain is here calculated as the average received signal power on BS antenna port 0 for all rank-1 transmissions with 2 or 4 UE Tx antennas divided by the received power using a single UE Tx antenna. 22 UE Tx antennas can give up to 2 dB gain and 4 UE Tx antennas up to 4,5 dB gain. The gain is higher for short distances. A possible explanation for this is that the LoS probability is higher at short distances. At the cell-edge, the gain is in the order of 1 dB for 2 UE Tx antennas and 2 dB to 3 dB for 4 UE Tx antennas. The gain is less than the ideal gains of 3 dB and 6 dB for 2 and 4 antennas, respectively. This is expected since the UE can only select a wideband precoder from a codebook and the channel is frequency selective and has angular spread.

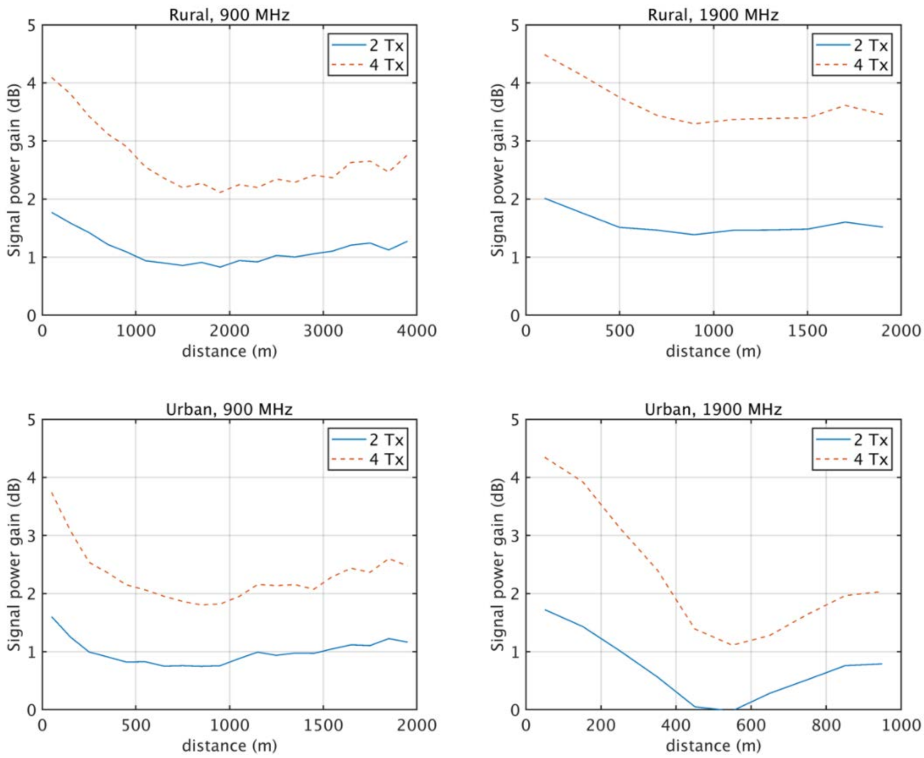


Figure A.262: Received signal power gain with 2 and 4 UE Tx antennas as a function of distance for the different scenarios

Number of BS Rx antennas

Figure A.263 shows the signal power gain of the BS receiver as a function of distance for different number of BS Rx antenna ports and a single UE Tx antenna. Hence, only rank-1 transmissions are possible. The signal power gain was calculated as the average signal power at the output of the receiver divided by the averaged received signal power at the input to the receiver on BS antenna port 0. It can be seen that the signal power gain is close to the ideal gain values $10\log_{10}(2) = 3$ dB, $10\log_{10}(4) = 6$ dB, and $10\log_{10}(8) = 9$ dB, respectively, for all scenarios and distances. This can be expected since it has been assumed that the receiver has perfect channel knowledge.

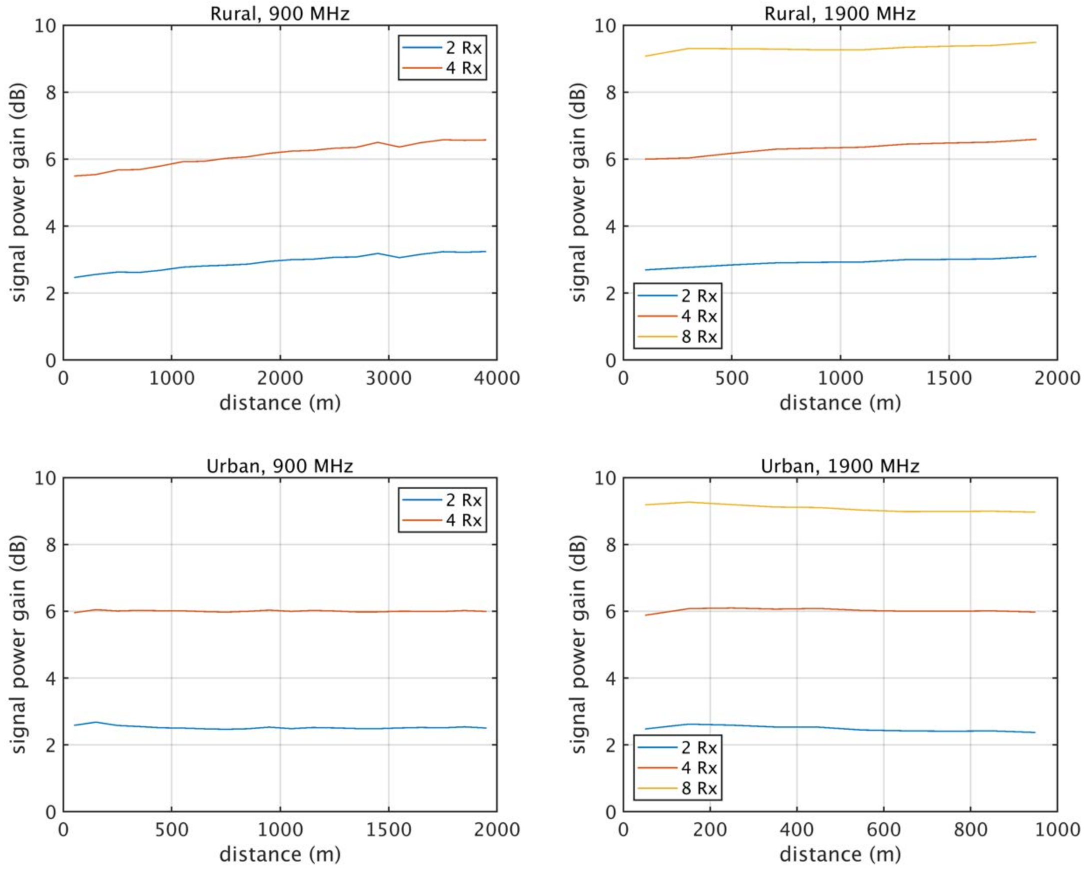


Figure A.263: Average signal power gain in the BS receiver as a function of distance for different number of BS Rx antenna ports and a single UE Tx antenna

Figure A.264 shows the corresponding SINR gain of the BS receiver. Two different SINR gain values have been calculated: gain in mean and 5 -percentile SINR. The gain in mean SINR was calculated as the average SINR at the output of the receiver divided by the average SINR before the receiver at BS antenna port 0. The gain in 5 -percentile SINR was calculated as the 5 -percentile SINR at the output of the receiver divided by the 5 -percentile SINR before the receiver at BS antenna port 0. The SINR gain is higher than the corresponding signal power gain. Hence, there is also some gain in interference suppression. The interference suppression gain is small on average but the gain in the 5 -percentile can be significant, up to 3 dB for 8 BS Rx antenna ports. This indicates that, although system performance is mainly limited by noise, the UEs with lowest performance are impaired by intercell interference and their performance can be improved by having many antenna ports and an interference suppression receiver in the BS.

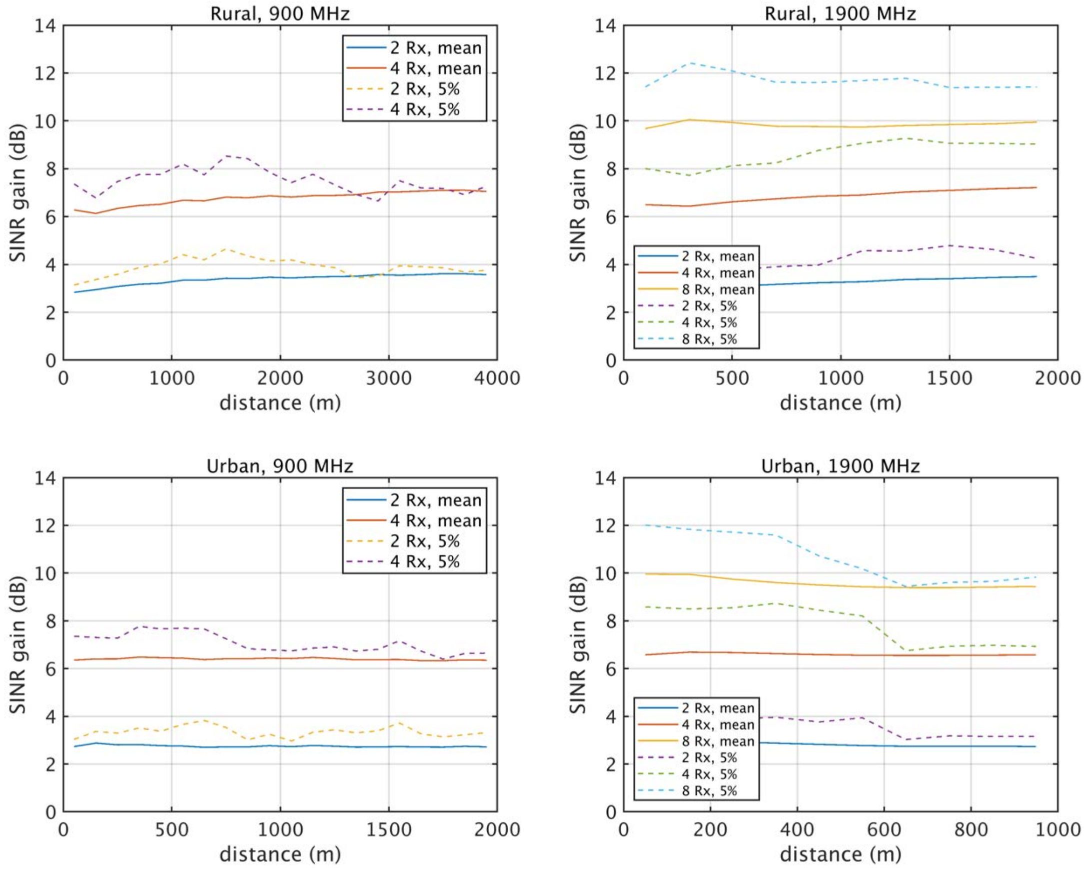


Figure A.264: SINR gain in the BS receiver as a function of distance for different number of BS Rx antenna ports and a single UE Tx antenna

A.3.1.3 Antenna port 0 measurements

In the present document, antenna port 0 related measurements are often used, such as port 0 signal power, port 0 interference power, and port 0 SINR. Port 0 refers to the first antenna port at the receiver, therefore, these measurements are before receive combining and is wideband. The port 0 measurements are useful, for example, when checking if a scenario is interference-limited or noise-limited.

A.3.1.4 Impact of UL power control parameters

This clause gives some motivation for the values that have been used for the UL power control parameters in the system simulations. To this end, the present document shows results on optimization of the path loss compensation factor and target SNR.

Two parameters, namely α and SNR_{target}, are optimized for UL power control. In general, the optimal power control parameters depend on various aspects, such as scenario and performance metric. Therefore, it is unlikely to find a single configuration that fits all cases. In the present document, the power control parameters are optimized for a rural scenario with 4 km ISD at 1900 MHz, where each BS has two antennas with orthogonal polarizations while each train has two antennas with vertical polarization. Nevertheless, the optimized parameters for this case will also be applied on other scenarios. Moreover, as cell-edge performance is of the most interest, the simulation uses cell-edge throughput as the performance metric. In summary, $\alpha = 1$ and $SNR_{target} = 7$ dB is chosen.

The fractional path loss compensation parameter $0 \leq \alpha \leq 1$ is configured by the network and determines an extent to which the path loss is compensated for.

- For $\alpha = 0$, known as no path loss compensation, $P_{PUSCH} = P_{CMAX}$, all UEs will always transmit with full power, thus the received SNR increases with lower path loss. In this case, the total system throughput is the highest as all UEs are transmitting with full power. However, cell-edge UEs, which is a limiting factor in the present document, will suffer from high inter-cell interference.

- For $\alpha = 1$, i.e. full path loss compensation, $P_{PUSCH} = \min(P_{CMAX}, SNR_{target} + P_n + PL)$, UE will restrict the transmit power only so that SNR_{target} is reached, thus UE with lower path loss will decrease the transmit power, while cell-edge UE, which is power-limited, can still transmit with full power P_{CMAX}.
- For $0 < \alpha < 1$, path loss will be partially compensated. In this case, a properly selected α value gives a good trade-off between cell-edge performance and total network throughput.

Given $SNR_{target} = 7$ dB, the CDF of Tx power with different α values is plotted in Figure A.265. When $\alpha = 0$, all UEs transmit with full power of 23 dBm. As α decreases, UEs that have lower path loss, will transmit with less power. When $\alpha = 1$, only less than 10 of UEs, which correspond to UEs at cell-edge with high path loss, will transmit with full power.

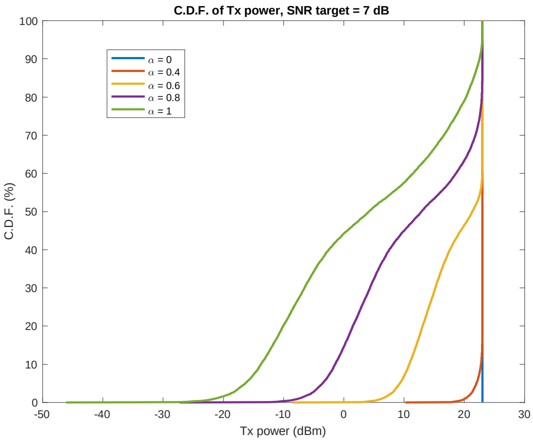


Figure A.265: Tx power C.D.F for SNR target 7 dB for different α values, max power 23 dBm

The 5 -percentile and 50 -percentile cell-edge user throughput are plotted in Figure A.266 for the same set of α values and SNR target. As one can see, the 5 cell-edge throughputs monotonically improves as α increases. When $\alpha = 1$, only the worst cell-edge UEs, i.e. 5 -percentile cell-edge UEs, transmit with full power, whereas all other UEs can still fulfil the SNR target with lower transmit power. This makes the worst UEs experience less interference, thus achieving higher throughput. However, the highest 5 -percentile cell-edge throughput comes at a cost of the overall system throughput, as seen in the RHS plot in Figure A.266, where $\alpha = 1$ gives the lowest 50 -percentile cell-edge throughput. Nevertheless, $\alpha = 1$ is selected, since 5 -percentile cell-edge throughput is the performance metric used in the present document.

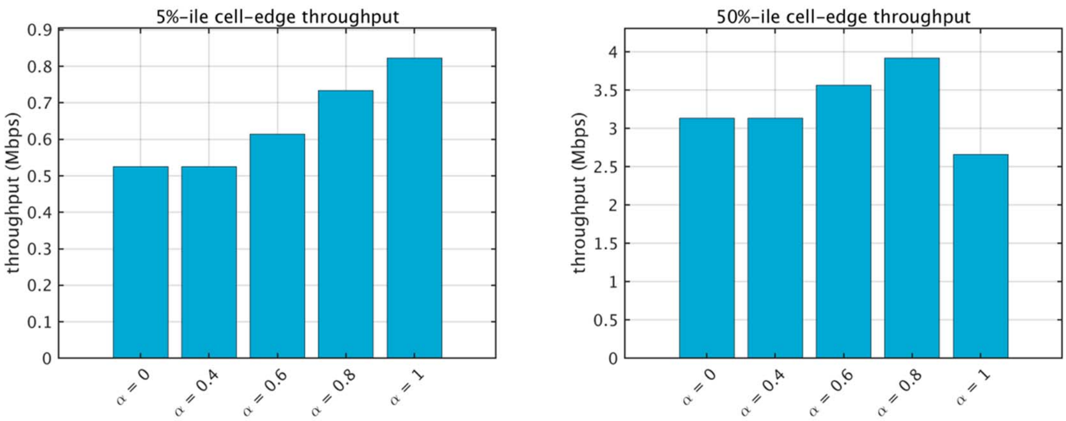


Figure A.266: Cell-edge user throughput for SNR target 7 dB and different α values

Fixing the fractional path loss compensation parameter $\alpha = 1$, the SNR target is swept from 4 to 16 dB at a 3 dB interval, to see its impact on user throughput. Low SNR target will cause low signal power as well as low interference power; vice versa for high SNR target. The left subplot in Figure A.267 indicates that the 5 -percentile cell-edge user throughput is not quite sensitive to the SNR target, even though there is a decreasing trend as SNR target increases. For the 50 -percentile cell-edge throughput, however, increasing the SNR target clearly shows an improvement. As 5 -percentile cell-edge throughput is the performance metric, 7 dB is selected as the SNR target.

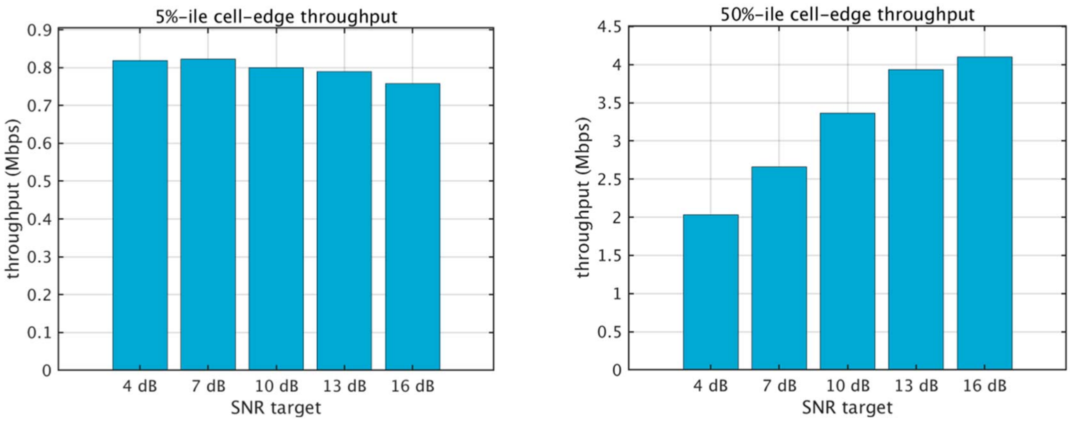


Figure A.267: Cell-edge user throughput for $\alpha = 1$ and different SNR targets

A.3.1.5 Impact of overhead

This clause shows how overhead impact the throughput obtained from system simulations. The purpose is to investigate in which cases the net throughput can be obtained by a simple scaling of the throughput from a simulation without overhead.

Figure A.268 shows the result from an experiment with the overhead varying from 0 to 99 in the UL (DL is similar). The blue bars represent the throughput that is obtained by simulating with the actual overhead, while the red bars represent the throughput that is obtained by linearly scaling the throughput according to overhead percentage. It is observed that for relatively low overhead, e.g. 10, 25, it is accurate to simply scale the throughput, while for high overhead value, for example 50 and onwards, scaling the throughput may introduce notable mismatches. In the present document, the UL overhead is relatively low, whereas the DL overhead can be as high as 54. Therefore, for UL, the throughput is scaled proportionally to the overhead, in order to save simulation time; while for DL, separate simulations with exact overheads are performed due to the non-linear scaling behaviour for high overhead.

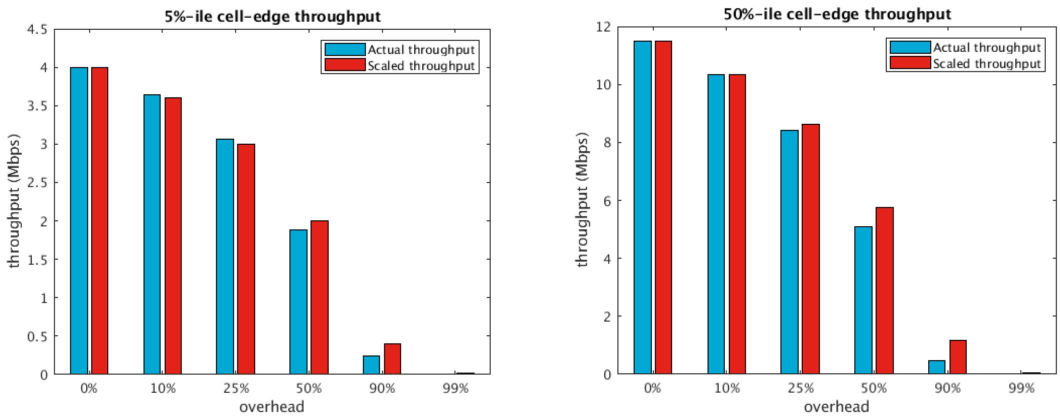


Figure A.268: 5 - and 50 -percentile cell-edge throughput by simulating with the actual overhead and by simulating with no overhead but scale the throughput afterwards

A.3.1.6 Antenna model

A.3.1.6.1 BS antenna (Trackside)

The Kathrein 80010991 antenna is used as a reference antenna. This is a 12-port dual-band antenna covering both the 900 MHz and 1 900 MHz bands. It has 4 antenna ports in the 900 MHz band and 8 antenna ports in the 1 900 MHz band with 45° polarization, allowing advanced multi-antenna configurations. A schematic layout of the antenna is shown below. R1 and R2 are two subarrays for the low frequency band, and Y1-Y4 are four subarrays for the high frequency band. Each subarray has two ports, one for each polarization.

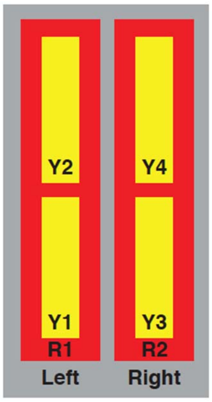


Figure A.269: Schematic layout of the Kathrein 80010991 antenna [i.6]

Instead of using measured antenna radiation patterns of the Kathrein 80010991 antenna in the simulations, an antenna pattern model fitted to this antenna is used. Figure A.270 shows measured antenna radiation patterns in the azimuth and elevation cardinal cuts for the 4 ports of the Kathrein antenna at 880 MHz. It is shown that the used model is an accurate representation of the Kathrein antenna. For angles outside the shown cardinal cuts, the antenna gain values have been interpolated from the azimuth and elevation patterns. For all track positions, except very close to the BS, the LoS angle to a train will be in the cardinal cuts, so this interpolation is not expected to have any significant impact on the results.

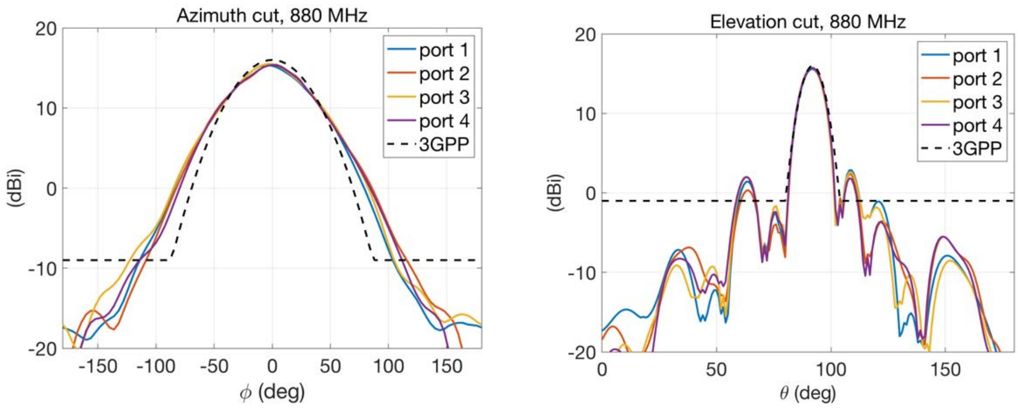


Figure A.270: Measured azimuth and elevation patterns of the Kathrein 80010991 antenna compared with the used 3GPP antenna model parametrized to the Kathrein antenna attributes

An advantage with using a model instead of measured patterns is more flexibility in studying different antenna options. For example, it gives the possibility to study antenna configurations and parameters that do not correspond exactly to that specific product.

The radiation pattern of a single antenna port is modelled with the same model that has been used in ITU and 3GPP, but with different settings of the model parameters in order to match the Kathrein 80010991 antenna. A 2-D antenna pattern for $\theta_{3dB} = 10°$, $\phi_{3dB} = 61°$, and $\theta_{tilt} = 0°$ is shown in Figure A.271 which is used as a model for an antenna port at 900 MHz. Similarly, the antenna patterns for ports at 1 900 MHz match with the numbers in the data sheet in [i.6].

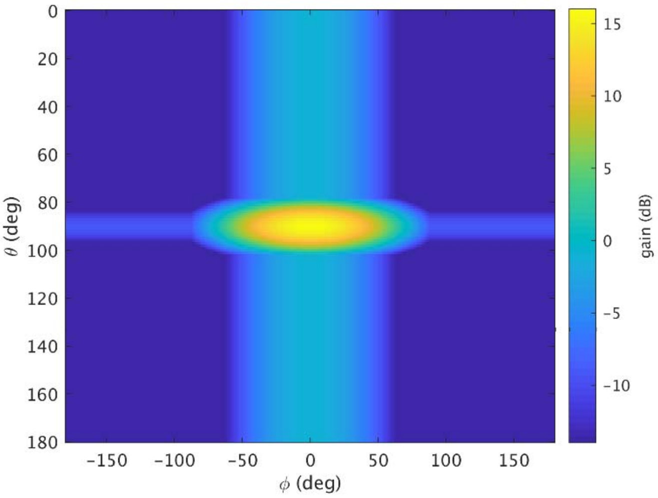
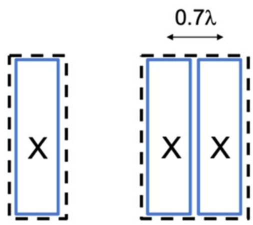


Figure A.271: Antenna radiation pattern model for an antenna port at 900 MHz

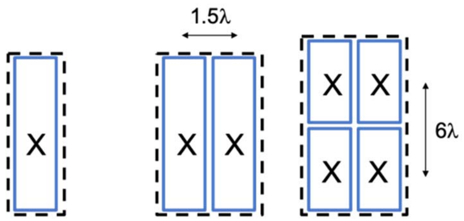
For the 900 MHz band, BS antenna configurations with two and four ports are evaluated in the system simulations. The 2-port configuration uses a single column with two ports, one for each polarization. The 4-port configuration uses two such columns separated by 0,7 λ, where λ is the carrier wavelength. These configurations are illustrated in Figure A.272 where also the antenna model parameters per antenna port are given in a table. Unless otherwise stated, the tilt is 0° in the simulations. Since the minimum electrical downtilt of the Kathrein 80010991 antenna is 2º, a 2º mechanical uptilt was applied to the Kathrein antenna in the simulations in order to achieve a total tilt of 0º.

For the 1 900 MHz band, 2-, 4-and 8-port antenna configurations are evaluated. The Kathrein 80010991 antenna has eight ports at this frequency band. In order to evaluate configurations with two and four ports, subarrays with similar height as a column at 900 MHz are modelled. The antenna gain for a column should be 3 dB higher for 1 900 MHz compared to 900 MHz if the physical height should be the same. However, in order to comply with assumptions made in ETSI on 18 dBi maximum antenna gain, the antenna gain per port has been limited to 18 dBi in the present document. Therefore, the modelled 2- and 4-port antennas at 1 900 MHz correspond to somewhat physically smaller antennas than at 900 MHz. The elevation beam width has been scaled to correspond to the assumed gain value. The 8-port antenna consists of 2x2 subarrays with two ports each. The horizontal and vertical separation is assumed to be 1,5 λ, and 6 λ, respectively. The antenna configurations and model parameters for the 1 900 MHz evaluations are shown in Figure A.273.



nr of antennna ports	2	4
gain per port (dBi)	16	16
azimuth HPBW per port (deg)	61	61
elevation HPBW per port (deg)	10	10

Figure A.272: Antenna configurations and model parameters used in the 900 MHz evaluations



nr of antennna ports	2	4	8
gain per port (dBi)	18	18	16
azimuth HPBW per port (deg)	64	64	64
elevation HPBW per port (deg)	6	6	10

Figure A.273: Antenna configurations and model parameters used in the 1 900 MHz evaluations

A.3.1.6.2 UE antenna (Train side)

For the train it assumed that isotropic antennas with vertical polarization are mounted on the roof of the train. Configurations with one and two are evaluated for both 900 MHz and 1 900 MHz. The relative placement of the train antennas is illustrated in Figure A.274. An additional simulation was performed for reference purposes with four UE antennas and not intended for comparison purposes to other simulation exercises. It is understood that most rolling stock have room for only two UE antennas there are a significant rolling stock which could utilize four UE antennas

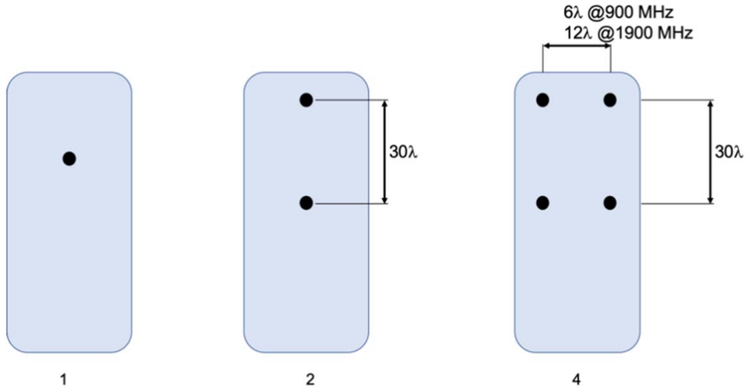


Figure A.274: Topside view of train with relative antenna positions

A.3.2 Company B

Link level parameters

For the generation of the link level results, the following parameters were used.

Table A.1

Parameter		Value
General	Channel	PUSCH with transform precoding disabled
	Subcarrier Spacing	15 kHz
	Carrier Frequency	900 MHz 1 900 MHz
	Channel bandwidth	5 MHz
	Antenna Configuration	1T2R
	Speed	80 kph, 350 kph
	KPI	absolute TPUT -10 % vs. SNR.
	Target BLER	$<10^{-2}$
	MCS	QPSK, 16QAM, 64QAM R = 1/6, 1/4, 1/3, 1/2, 2/3, 3/4, 5/6
	Channel estimation	MMSE
MIMO (only for 2Tx)	Number of Layers	1
	Precoder	Single layer D Index = 2, i.e. $\frac{1}{\sqrt{2}}\begin{pmatrix}1\\1\end{pmatrix}$
Propagation conditions	Channel Model	Case 1: CDL-C, RMS delay spread DS = 500 ns Case 2: AWGN
	Doppler Profile	None. Frequency offset dependent on speed and heading of UE drop.
HARQ	Maximum number of HARQ transmissions	1
	Redundancy version	0
DM-RS	DM-RS configuration type	1
	DM-RS duration	single-symbol DM-RS
	Additional DM-RS position	Pos2
	Number of DM-RS CDM group(s) without data	2
	Ratio of PUSCH EPRE to DM-RS EPRE	-3 dB
	DM-RS port	{0}
	DM-RS sequence generation	N_{ID}^{0}=0, n_{SCID} =0
Time domain resource assignment	PUSCH mapping type	A
	Start symbol	0
	Allocation length	14
Frequency domain resource assignment	RB assignment	25 PRB
	Frequency hopping	Disabled

While the speed is set to 80 kmph and 350 kmph, the results have been calculated at 160 kmph and 700 kmph, respectively. This is done to simulate the double Doppler effect. This is done because the UE synchronizes its own clock to the reference signal coming from the base station, which is already affected by the Doppler shift. When the UE transmits data, based on this wrong frequency, the transmitted signal will again be affected by the Doppler shift, doubling the effect. Therefore, the speed is doubled, and this case represents the worst-case scenario.

Link level results

Link level results can be found in RT(20)076043.

A.3.3 Summary of scenario for NR performance evaluation for all Companies

A.3.3.1 Introduction

In ETSI TR 103 554-1 [i.1], performance evaluation has done for LTE 900 MHz (carrier 1,4 and 5 MHz). The purpose of the present document is to define the technical parameters to be considered in the the present document for performance evaluation for LTE 1 900 MHz and for NR 900/1 900 MHz.

A.3.3.2 Technical assumptions for NR 900 MHz simulations

The same technical assumptions as used for LTE 900 MHz simulations have to be used for NR 900 MHz performance evaluation (see ETSI TR 103 554-1 [i.1]). as follows:

- Carrier/bandwidth: 5 MHz FDD (875 MHz to 880 MHz /920 MHz to 925 MHz) - LTE 1,4 MHz carrier is not applicable for NR/5G
- Inter-site distance (ISD) (same as used ETSI TR 103 554-1 [i.1]):
    - Rural: 8 km
    - Urban: 2 km and 4 km
- Antenna height (according to technical assumptions used by PT1 and SE 07 - see Recommendation ITU-R M.2135-1 [i.2]):
    - Rural: 35 m (30 m to 40 m considered ETSI TR 103 554-1 [i.1])
    - Urban: 20 m (18 m considered ETSI TR 103 554-1 [i.1])
- Train antenna height: 4 m (same as used in Recommendation ITU-R M.2135-1 [i.2])
- Tower to track distance: 15 m (same as used in ETSI TR 103 554-1 [i.1] and Recommendation ITU- M.2135-1 [i.2])
- Scenarios to be considered (Inter-site distance (ISD), neighbour cells load and speed) (same as used in ETSI TR 103 554 [i.1]):

Table A.2

Scenario name	Model and speed	ISD (km)	Neighbour cell load (trains)
Urban	Urban (80 km/h)	2	6
High Density	Urban (80 km/h)	4	4
Hilly (see note)	Hilly (160 km/h)	8	2
High speed	Rural (350 km/h)	8	2

- BTS EIRP (DL): 63 dBm (including feeder losses and antenna gain) - same as used in ETSI TR 103 554-1 [i.1]
- UE power (UL): 23, 26 and 31 dBm
- Antenna: see Recommendation ITU-R M.2135-1 [i.2]

A.3.3.3 Technical assumptions for NR/LTE 1 900 MHz simulations

- Carrier/bandwidth: 10 MHz TDD (1 900 MHz to 1 910 MHz)
- Inter-site distance (ISD):
    - Rural: 4, 6 and 8 km

- Urban: 2 and 4 km

- Antenna height (same as used in Recommendation ITU-R M.2135-1 [i.2]):
  - Rural: 35 m
  - Urban: 20 m
- Train antenna height: 4 m (same as used in Recommendation ITU-R M.2135-1 [i.2])
- Tower to track distance: 15 m (same as used in Recommendation ITU-R M.2135-1 [i.2])
- Scenarios to be considered:

Table A.3

Scenario name	Model and speed	ISD (km)	Neighbour cell load (trains)
Urban	Urban (80 km/h)	2	6
High Density	Urban (80 km/h)	4	4
High speed 1	Rural (350 km/h)	4	2
High speed 2	Rural (350 km/h)	6	2
High speed 3	Rural (350 km/h)	8	2

- BTS EIRP (DL): 40 dBm/10 MHz and 63 dBm/10 MHz (including feeder losses and antenna gain)
- UE power (UL): 23 dBm, 26 dBm and 31 dBm
- Antenna: see Recommendation ITU-R M.2135-1 [i.2]

In red colour: additional scenario in comparison with 900 MHz simulation

A.3.4 Company C

A.3.4.1 Scheduler impact estimation for NR performance comparison

A.3.4.1.1 Introduction

In the present document, Company A and Company B simulators include a round-robin scheduler and assume several trains on the serving cell depending on the scenario. The throughput results correspond to what a UE could expect in the given scenario. Mitsubishi simulator does not include a scheduler. Results corresponds then to the available throughput in the serving cell at a given position. This throughput is reduced when the resources (RBs) are shared in a cell with more than one train.

In order to be able to compare the results between the two approaches, it is necessary to evaluate the impact of the scheduler.

A.3.4.1.2 Scheduler impact evaluation

The evaluation is based on spectral efficiency (*Se*) results provided by Company A. Indeed, in their results, the spectral efficiency is computed on the bandwidth allocated to a UE, and thus does not depend on the number of UEs that are to be served in the cell by the scheduler. Company C has then computed an apparent spectral efficiency (*Sa*), corresponding to the throughput per UE after the scheduling divided by the total bandwidth. The ratio between the two spectral efficiency values (*Se/Sa*) provides an evaluation of the impact of the scheduler for a given scenario.

Detailed computation of *Se/Sa* is provided in Table A.4 for 900 MHz FDD. *Sa* is computed considering a 5 MHz bandwidth. The *average Se/Sa* values corresponds the average per scenario.

Table A.4: Spectral efficiency ratio computation per scenario

Scenario	Se = Spectral efficiency without scheduler	Throughput per UE (with scheduler), Mbit/s	Sa = Apparent spectral Efficiency (with scheduler)	Se/Sa	Average (Se/Sa)
900 MHz Urban ISD = 4 km					**2,70**
UL 2x2 23 dBm 5 %-ile	0,032	0,057	0,01	2,81	
UL 2x2 23 dBm 50 %-ile	0,15	0,307	0,06	2,44	
UL 2x2 31 dBm 5 %-ile	0,125	0,229	0,05	2,73	
UL 2x2 31 dBm 50 %-ile	0,55	1,1	0,22	2,50	
DL 2x2 5 %-ile	0,6	1,015	0,20	2,96	
DL 2x2 50 %-ile	1,4	2,555	0,51	2,74	
900 MHz Urban ISD = 2 km					**1,42**
UL 2x2 23 dBm 5 %-ile	0,25	0,822	0,16	1,52	
UL 2x2 23 dBm 50 %-ile	0,9	2,845	0,57	1,58	
UL 2x2 31 dBm 5 %-ile	0,6	1,982	0,40	1,51	
UL 2x2 31 dBm 50 %-ile	1,1	3,431	0,69	1,60	
DL 2x2 5 %-ile	1,8	7,274	1,45	1,24	
DL 2x2 50 %-ile	4	19,07	3,81	1,05	
900 MHz Rural ISD = 8 km					**2,75**
UL 2x2 23 dBm 5 %-ile	0,11	0,191	0,04	2,88	
UL 2x2 23 dBm 50 %-ile	0,57	1,043	0,21	2,73	
UL 2x2 31 dBm 5 %-ile	0,34	0,63	0,13	2,70	
UL 2x2 31 dBm 50 %-ile	0,9	1,706	0,34	2,64	
DL 2x2 5 %-ile	0,57	0,964	0,19	2,96	
DL 2x2 50 %-ile	1,45	2,82	0,56	2,57	

For a given scenario, the *Se/Sa* ratio is quite stable whatever the statistics (5 %-ile or 50 %-ile), the transmit power in UL (23 dBm or 31 dBm) and the direction (UL or DL), except in one scenario (900 MHz Urban ISD = 2 km).

The average *Se/Sa* ratio can be compared to the average number of UEs in the serving cell provided by Company A, as shown in Table A.5.

Table A.5: Average spectral efficiency ratio and average number of UE per cell

Scenario	Average (Se/Sa)	Av. number of UEs as provided in TR
900 MHz Urban ISD = 4km	2,70	2
900 MHz Urban ISD = 2km	1,42	1
900 MHz Rural ISD = 8km	2,75	2

It can be seen that *Se/Sa* fits the average number of UEs. Hence, it can be considered that *Se/Sa* as a good evaluation of the effect of the scheduler.

A.3.4.1.3 Throughputs comparison

The calculated Se/Sa ratio is applied to Company C values in the results comparison in clause 6.3.1 to compensate for the scheduler differences in Company C simulator to those of Companies A and B.

A.3.4.1.4 900 MHz FDD

Se/Sa ratio from Table A.5.

A.3.4.1.5 900 MHz Rural scenario 8 km ISD

Downlink

MIMO setup	5th percentile (kbps)					50th percentile (kbps)				
	A	B	C (Reuse 1/2/3) - Aligned			A	B	C (Reuse 1/2/3) - Aligned		
2x2	964	500	200	1 956	1 313	2 820	1 800	1 982	1 971	1 313

Uplink, 23 dBm transmit power

MIMO setup	5th percentile (kbps)					50th percentile (kbps)				
	A	B	C (Reuse 1/2/3) - Aligned			A	B	C (Reuse 1/2/3) - Aligned		
2x2	191	510	429	1 069	713	1 043	1 000	2 142	1 069	713

Uplink, 31 dBm transmit power

MIMO setup	5th percentile (kbps)					50th percentile (kbps)				
	A	B	C (Reuse 1/2/3) - Aligned			A	B	C (Reuse 1/2/3)- Aligned		
2x2	630	690	1 120	1 069	713	1 706	1 300	2 142	1 069	713

A.3.4.1.6 900 MHz High Density Urban scenario 2 km ISD

Downlink

MIMO setup	5th percentile (kbps)					50th percentile (kbps)				
	A	B	C (Reuse 1/2/3) - Aligned			A	B	C (Reuse 1/2/3) - Aligned		
2x2	7 274	1 180	0	1 176	1 542	19 070	3 300	2 486	3 662	3 169

Uplink, 23 dBm transmit power

MIMO setup	5th percentile (kbps)					50th percentile (kbps)				
	A	B	C (Reuse 1/2/3) - Aligned			A	B	C (Reuse 1/2/3) - Aligned		
2x2	822	240	1 761	3 077	2 958	2 845	610	7 852	5 183	3 458

Uplink, 31 dBm transmit power

MIMO setup	5th percentile (kbps)					50th percentile (kbps)				
	A	B	C (Reuse 1/2/3) - Aligned			A	B	C (Reuse 1/2/3) - Aligned		
2x2	1 982	530	3232	4 261	3 458	3 431	1 300	9 641	5 183	3 458

A.3.4.1.7 900 MHz High Density Urban scenario 4 km ISD

Downlink

MIMO setup	5th percentile (kbps)					50th percentile (kbps)				
Company	A	B	C (Reuse 1/2/3) - Aligned			A	B	C (Reuse 1/2/3) - Aligned		
2x2	1 015	400	0	607	778	2 555	1 130	922	1 896	167

Uplink, 23 dBm transmit power

MIMO setup	5th percentile (kbps)					50th percentile (kbps)				
Company	A	B	C (Reuse 1/2/3) - Aligned			A	B	C (Reuse 1/2/3) - Aligned		
2x2	57	0	296	819	822	307	120	2 400	2 148	1 696

Uplink, 31 dBm transmit power

MIMO setup	5th percentile (kbps)					50th percentile (kbps)				
Company	A	B	C (Reuse 1/2/3) - Aligned			A	B	C (Reuse 1/2/3) - Aligned		
2x2	229	40	104	726	900	1 100	200	1 963	2 133	1 774

A.3.4.1.8 1 900 MHz FDD

It is possible to assume that the scheduler effect does not depend on the bandwidth, thus *Se/Sa* values from Table A.5 are still valid. For rural scenarios with ISD of 4 and 6 km, the assumption is that the UE density remains the same, thus *Se/Sa* can be computed by linear interpolation from the ISD=8 km. this lead to ratios of Table A.6.

Table A.6: Average spectral efficiency computed and interpolated

Scenario	Average (Se/Sa)
1 900 MHz Urban ISD = 2 km	1,42
1 900 MHz Urban ISD = 4 km	2,70
1 900 MHz Rural ISD = 6 km	2,06
1 900 MHz Rural ISD = 8 km	2,75
1 900 MHz Rural ISD = 4 km	1,38

A.3.4.1.9 1 900 Rural Scenario - 4 km ISD UL 50:50

MIMO	5 -percentile 23 dBm					50 -percentile 23 dBm				
	A	B	C (Reuse 1/2/3) - Aligned			A	B	C (Reuse 1/2/3) - Aligned		
2x2	690	560	1 455	735	495	3 209	1 700	1 476	735	495

MIMO	5 -percentile 31 dBm					50 -percentile 31 dBm				
	A	B	C (Reuse 1/2/3) - Aligned			A	B	C (Reuse 1/2/3) - Aligned		
2x2	1 296	770	1 455	735	495	4 002	2 030	1 476	735	495

A.3.4.1.10 1 900 Rural Scenario - 4 km ISD DL 40 dBm EIRP 90:10

MIMO	5 -percentile 4 km					50 -percentile 4 km				
	A	B	C (Reuse 1/2/3) - Aligned			A	B	C (Reuse 1/2/3) - Aligned		
2x2	1 073	220	58	400	269	4 860	330	764	407	269

Annex B:
Bibliography

- 3GPP TR 38.802: "Study on New Radio Access Technology. Physical Layer Aspects".

History

Document history		
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