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| **Radiocommunication Study Groups** |  |
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|  | **TECHNOLOGY ASPECTS** |
| Wireless World Research Forum | |
| Evaluation Report on the Candidate Technology Submission For IMT-2020 “EUHT” As Part of the Re-engagement in Step 4 Evaluation | |
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This contribution contains the evaluation report from the Independent Evaluation Group Wireless World Research Forum (WWRF) for EUHT, IMT-2020/17 Submission. Following the finalisation of Step 7 in the IMT-2020 Process, EUHT submission evaluation was granted an extension in the IMT-2020 Process, for re-engagement and re-evaluation.

The evaluation is based on the characteristics defined in Reports ITU-R M.2410 [1], ITU-R M.2411 [2] and ITU-R M.2412 [2] using a methodology described in Report ITU-R M.2412-0 [3].

The report is organized as follows:

– Part I: Administrative aspects of the WWRF

– Part II: Technical aspects of the work of WWRF

– Part III: Conclusions.

# Part I: Administrative aspects of the Independent Evaluation Group

## I-1 Name of the Independent Evaluation Group (IEG)

Wireless World Research Forum (WWRF).

## I-2 Introduction and background of the Independent Evaluation Group

WWRF’s goal is to encourage research that will achieve unbounded communications to address key societal challenges for the future. The term “Wireless World” is used in this broad sense to address the support of innovation and business, the social inclusion, and the infrastructural challenges. This will be achieved by creating a range of new technological capabilities from wide-area networks to short-range communications, machine-to-machine communications, sensor networks, wireless broadband access technologies and optical networking, along with increasing intelligence and virtualization in networks. This will support a dependable future Internet of people, knowledge and things and the development of a service universe. WWRF is the unique forum where the wireless community can tackle the key research challenges. By searching out the issues, flagging them up to opinion leaders, and then working with liaison partners to deal with them, WWRF drives the development of the Wireless World. WWRF organizes two major events each year combining inputs from industry and academic experts, the exchange of ideas and the evolution of the research agenda and technology roadmaps. WWRF’s has a strong publication programme, working with partners such as IEEE and Wiley, makes the key messages and results available to the wireless research sector. To ease standardization, WWRF disseminates and harmonizes views, and together with our major liaison partners, we initiate collaborative research, and develop the global vision.

Over the last ten years, WWRF has championed several activities focused on the wireless evolution to and beyond 5G, including workshops and special sessions, presentations, white papers, and journal special issues. WWRF has been very supportive of the ITU’s evaluation process for IMT-2020 and participates as an independent evaluation group (IEG).

## I-3 Method of work

### I-3-1 Background

The step 4 of IMT-2020 evaluation process was conducted to identify if the candidate RIT met the requirements set by the ITU. However, the step 4 didn’t conclude the decision-making process and an extension was agreed upon, where the steps 4-7 will be carried out to ascertain if the RIT meets the ITU requirements.

### I-3-2 Organizational Issues

The work was organized using the following channels:

1 Regular online meetings of the steering board

2 Weekly meetings of the technical team

3 File sharing through secure shared space

4 Workshops/Seminars organised by the WWRF

5 Monitoring of the ITU Discussion Forum.

## I-4 Administrative contact details

**Name & Affiliation:** Dr Nigel Jefferies, WWRF Chairman.

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## I-5 Technical contact details

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# Part II: Technical aspects of the work of the Independent Evaluation Group

## II-A What candidate technologies or portions of the candidate technologies this IEG is or might anticipate evaluating?

The IEG has evaluated the following scenario for EUHT:

– URLLC for urban macro environment (By Simulation)

## II-B Confirmation of utilization of the ITU-R evaluation guidelines in Report ITU-R M.2412

The IEG has followed the ITU-R evaluation guidelines and the evaluation is conducted under the light of those guidelines.

## II-C Summary of Results

### II-C-1 Requirements from ITU

For any candidate technology, ITU has laid down the minimum requirements for reliability i.e., 1‑10−5 success probability of transmitting a layer 2 PDU (protocol data unit) of 32 bytes within 1 ms in channel quality of coverage edge for the Urban Macro-URLLC test environment, assuming small application data (e.g., 20 bytes application data + protocol overhead).

### II-C-2 Evaluation methodology

The evaluation methodology followed to evaluate the candidate technology EUHT can be found in section 7.1.5 of Report ITU-R M.2412.

#### II-C-2A System-level simulation parameters and technical assumptions

Network configuration and layout

We have setup the layout for EUHT system-level simulator network as per the guidelines of ITU. A summary of system configuration is provided in Table 1 and a network layout of one test cycle is shown in Figure 1.

Table 1

System configuration

|  |  |
| --- | --- |
| Parameter | Value |
| Number of sites | 19 |
| Number of sectors per site | 3 |
| Frequency reuse factor | 3 |
| Total number of cells | 19 × 3 = 57 |
| Number of UE devices per cell | 10 |
| Total UE devices | 57 × 10 = 570 |
| UE antenna height | 1.5 m |
| BS antenna height | 25 m |
| Inter-site distance | 500 m |

Figure 1

System level simulation network, layout: Urban Macro – URLLC test environment

Chart

Description automatically generated

Table 2

System level technical assumptions & parameters (downlink)

|  |  |
| --- | --- |
| Parameter | Value |
| Base station noise figure | 5 dB |
| UE noise figure | 7 dB |
| BS antenna element gain | 8 dBi |
| UE antenna element gain | 0 dBi |
| Total transmit power per TRxP | 46 dBm for 10 MHz bandwidth |
| UE power class | 23 dBm |
| Thermal noise level | ‒174 dBm/Hz |
| Traffic model | Full buffer |
| Simulation bandwidth | 20 MHz |
| Percentage of high loss and low loss building type | 100% low loss |
| Number of antenna elements per TRxP | 8 |
| Number of UE antenna elements | 2, 4 and 8 |
| Mechanic tilt | 90° in GCS |
| Electronic tilt | 99° in LCS |
| UE mobility model | Fixed and identical speed |v| of all UEs, randomly and uniformly distributed direction |
| UE speeds of interest | 3 km/h |
| Carrier frequency for evaluation | 4 GHz |
| Numerology | 78.125 kHz SCS |
| Duplexing | TDD |

#### II-C-2B Link Simulation parameters and workflow

The link level simulation parameters have been taken from the EUHT specifications provided by **Nufront** and have been cross verified with the *Self Evaluation Report* of EUHT.

Table 3

Link level simulation parameters (Downlink)

|  |  |
| --- | --- |
| Parameter | Value |
| Scenario | Dense Urban |
| Carrier frequency | 4 GHz (Sub 6 GHz Bands) |
| Bandwidth | 20 MHz |
| Signalling waveform | CP-OFDM (SU-MIMO) |
| Subcarrier spacing | 78.125 KHz |
| Delay spread | 363ns |
| Cyclic prefix | FFT Size/4 |
| Guard band | True |
| Propagation channel | Tap Delay Line (TDL) |
| Mobility | True |
| Errors considered | Block Error Rate (BLER) |
| Channel coding | LDPC, code rate 4/7 (as per EUHT Self Evaluation Report) |
| Modulation | QPSK |
| Channel estimation | Imperfect, Non-Ideal |
| Number of transmit antennas | 8 |
| Number of receiver antennas | 2, 4 and 8 |

A stepwise workflow of the simulator is explained as follows:

1 **Update the receiver process:** Checks the FCS in MAC layer for any required transmissions.

2 **Resource grid generation:** Channel Coding and Modulation

3 **Waveform generation:** OFDM Modulation is performed.

4 **Channel modelling:** Pass the waveform through a channel.

5 **Perform synchronization and OFDM demodulation:**Perfect or practical synchronisation is performed.

6 **Perform channel estimation:** Perfect or practical channel estimation is performed by using the demodulation reference signals or common reference signal. Then OFDM demodulation is performed.

7 **Perform equalization and CPE compensation**.

8 **Precoding matrix calculation:** Generate the precoding matrix for the next transmission.

9 **Decode the TCH:** Demodulation and descrambling of the recovered TCH symbols for all transmit and receive antenna pairs, along with a noise estimate is performed.

10 **Decode DL-TCH**.

#### II-C-2C Channel model

The channel model is based on 3GPP TR 38.901 [1] implementation of a channel model [2][3]. Which is a 3D statistical Spatial Channel Model supporting different propagation environments (e.g., urban, rural, indoor), multi-antenna operations and the modelling of wireless channels between 0.5 and 100 GHz.

The implementation focused on:

– Path loss and shadowing models (3GPP TR 38.901, Sec. 7.4.1)

– Autocorrelation of shadow fading (3GPP TR 38.901, Sec. 7.4.4)

– Channel condition models (3GPP TR 38.901, Sec. 7.4.2).

For authenticating our channel model, we compared the 3GPP TR 38.901 specification with IMT‑2020 channel specification. After careful consideration we observed only a few minor parameter differences which have negligible to zero impact on the simulation results. Hence, we have developed the EUHT channel based on 3GPP channel model.

*The detailed study for this comparison is available upon request.*

### II-C-3 Results

The 5%-tile SINR applied for link level simulation is −2.675 dB as it can be seen in the following figure. It can be seen in Table 4 that the candidate technology does not pass the reliability requirements of ITU.

Figure 2

Downlink SINR distribution obtained from system-level simulations

Chart, line chart

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## II-C-4 Results and observations from Working Party 5D meeting in August 2021

This section contains the updated results for reliability analysis of EUHT. It can be seen in Table 4 that the RIT does not meet the reliability criteria for urban macro URLLC scenario. There are several observations that WWRF has compiled using the Report ITU-R M.2412 and technical specifications for EUHT provided by Nufront.

Observations from Report ITU-R M.2412 and EUHT specification document

– For meeting the reliability criteria (> 99.999%), channel estimation is one of the key processes. In EUHT technology, channel estimation is performed using the common reference signal (CRS).

– As per Report ITU-R M.2412, there are 19×3 cells in Urban Macro-URLLC test environment and all the user terminals will be evaluated in the URLLC evaluation assumptions.

– This means all these terminals have the URLLC traffic with at least 99.999% success probability in 1 millisecond.

– In low error mode, the CRS consists of one unique sequence without any identification.

– During the transmission of one frame, all the cells operate in the same mode i.e., either normal mode or low error mode. Therefore, it can be assumed that all the cells in Urban-Macro URLLC simulations should be in the low error mode.

– This results in all cells sending the same CRS at the same time, which means for any cell, the CRS in the low error mode would be polluted by signals of the neighbouring cells and result in wrong channel estimation. This will lead to CCH performance degradation in URLLC mode. The frame structure is given in Figure 3.

Figure 3

Frame structure of EUHT in physical layer (EUHT Specification)

Timeline

Description automatically generated

– This forms the basis of EUHT Technology not being able to meet the reliability criteria. WWRF further analysed the Downlink TCH (DL-TCH) performance under the same set of conditions.

– As per the self-evaluation report of Nufront for EUHT technology, there are 12 number of repetitions for DL-TCH. WWRF has followed the same test environment in their simulations. As per the Section 8.5.3 in EUHT specification document, a single RU‑OFDMA scheme supports up to 4 repetitions in time domain. WWRF’s simulations are also based on RU-OFDMA.

– As per the EUHT specification document, for RU-OFDMA scheme, CRS is used for channel estimation which means DL-TCH will encounter the same problem as CCH. This will lead to wrong channel estimation and performance degradation for DL-TCH.

– Considering all these assumptions, WWRF concludes that even if antennae elements are increased at the receiver end (2, 4 and 8), wrong channel estimation leads to performance degradation in both CCH and DL-TCH and becomes the basis for EUHT not passing the reliability requirements.

The results are provided in the Table 4 as follows.

Table 4

Results for downlink from August 2021 meeting of WP 5D (antennae config 8×8)

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Minimum technical performance requirements (ITU-R M.2410) | Category | | | Required value | Value | Meets the requirement? | Remarks |
| Usage scenario | Test environment | Downlink or Uplink |
| Reliability | URLLC | Urban macro-URLLC | Downlink | 99.999% | 99.955% | No | *The candidate under evaluation does not meet the reliability criteria due to the provided antenna configuration.* |

– Additionally, in URLLC mode, energy efficiency at the receiver end is one of the key concerns. WWRF has not evaluated EUHT technology for energy efficiency, but it is a well-known and well-researched fact that increasing the number of antennae elements at the receiver leads to degradation in energy efficiency.

– Furthermore, it should be noted that as per ITU-R M. 2410-0 (Section 4.9), following are the requirements for energy efficiency. It can be observed that the ITU report does not define a numerical value for energy efficiency requirements, instead it is mainly relying on measurement of Spectral Efficiency. Furthermore, the requirement is defined mainly for **eMBB usage scenario only** highlighted as follows.

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### II-C-5 Previous correspondence with Nufront

After the WP 5D meeting in June 2021, WWRF approached Nufront to clarify the antennae configurations used in URLLC Urban Macro Scenario for Configuration A. Nufront responded with reference to EUHT specification document and Report ITU-R M.2412.

Based on this clarification, WWRF has provided the updated results and several observations in the previous section and the preliminary results from previous report are available in Appendix A-I.

### II-C-6 Recent correspondence with Nufront (post August 2021 meeting of WP 5D)

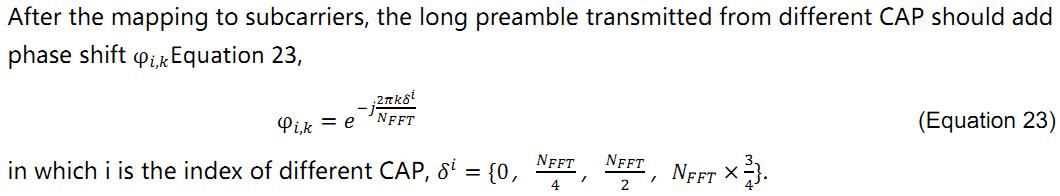
Based on agreed actions in the August 2021 meeting of WP5D that are available at the share-point [4], WWRF IEG liaised with Nufront to address the queries of Nufront regarding the evaluation of EUHT for reliability requirements as per Report ITU-R M.2412. WWRF IEG raised concerns regarding RS Pollution in the Common Reference Signal (CRS) of EUHT technology (detailed observations provided in Section II-C-4).

Nufront provided WWRF IEG with responses and suggestions to overcome the problem of RS pollution, followed by an online meeting on 10 September 2021 between Nufront and WWRF IEG. A summary of suggestions from Nufront are provided as follows:

Nufront’s suggestion for RS pollution (copied directly from their PPT) problem

– The frame mode (normal or low error) of one cell is dependent on the SINR of current scheduled user in this cell. Low error mode: if the user has extremely low SINR. The SINR values of the current scheduled users in different cells are different. Therefore, different cells can use different frame mode. The number of cells which are simultaneously transmitting low error mode frames is low since it has low possibility that many cells are serving users with extremely low SINR.

– Secondly, even with the interference from adjacent low error cells, the correct channel estimation can still be obtained with the phase shift on long preamble. In EUHT specification, phase shift is used for the long preamble without the limitation of mode. Phase shift can be easily added to long preamble in low error mode.



*Snapshot From EUHT Specification document, Section 8.3, Page 99*

Nufront’s suggestions for increasing number of receiver antennae (copied directly from their PPT)

– Current results with 2 Rx antenna: 99.875% from WWRF, which is close to the requirement. As clarified before, channel estimation will not lead to serious performance degradation. As WWRF stated, more Rx antenna will bring significant performance improvement over 2Rx.

– 4Rx: 3 dB array gain, 2x diversity gain

– 8Rx: 6 dB array gain, 4x diversity gain

– We believe that WWRF will find the EUHT-5G can meet the requirement with 4Rx or 8Rx after the channel estimation (RS pollution) is clarified.

Based on these suggestions provided by Nufront, WWRF decided to re-simulate for estimating the reliability for URLLC Urban-Macro Scenario. The updated result and responses to Nufront’s suggestions are summarised in the next section.

### II-C-7 Updated results after re-simulation and WWRF IEG’s response

It can be observed as follows that the RIT EUHT does not meet the requirements for reliability in Urban-macro-URLLC scenario. These results are provided after performing re-simulations as per Nufront’s suggestion.

Table 5

Results for Downlink after re-simulations (antennae config 8×8)

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Minimum technical performance requirements (ITU-R M.2410) | Category | | | Required value | Value | Meets the Requirement? | Remarks |
| Usage scenario | Test environment | Downlink or Uplink |
| Reliability | URLLC | Urban macro-URLLC | Downlink | 99.999% | 99.985% | No | *EUHT does not meet the reliability criteria due to the observations summarised in this section.*  *Note: The results in this table are based on multiple iterations per simulation. The reported % reliability is the maximum achieved after 10 000 iterations.* |

WWRF’s response for the solution provided for RS pollution

– In a loaded Urban-Macro environment, the probability of cell-edge users with low SINR is much higher, hence assuming that low SINR users are not present in adjacent cells is not realistic.

– Furthermore, as per ITU-R M.2412 [3], there are 19×3 cells in Urban Macro-URLLC test environment and all the user terminals will be evaluated in the URLLC evaluation assumptions. This means all these terminals have the URLLC traffic with at least 99.999% success probability in 1 millisecond. **To allow repetitions, the user terminals need to operate in the Low error mode as there are no repetitions in Normal mode. This means that all the user terminals should operate in the low error mode to fulfil the reliability requirements.**

– WWRF IEG has considered the suggested solution by Nufront which involves using ‘phase shift on the long preamble’ in the adjacent cells to overcome the problem of RS pollution. We have observed that the phase shift in long preamble makes negligible to no difference to the correct channel estimation. It should be observed that, even after phase shift is applied, there are high interference neighbouring cells, in a loaded **19×3 cells scenario,** which have the same phase as the serving cell. These high interference neighbouring cells result in degraded channel estimation, hence leading to wrong channel estimation and performance degradation for CCH and DL-TCH.

WWRF IEG’s response for Nufront’s suggestion for increasing Antennae Elements:

– WWRF IEG previously considered the suggested increase in number of antennae elements for the receiver i.e., 2, 4 and 8 receiver antennae elements. The results provided in the previous submission in August 2021 (Table 4) were based on 8 receiver antennae elements.

– Also, in the re-simulations, WWRF IEG has considered 2, 4 and 8 receiver antennae elements. The results for the re-simulations provided in Table 5 are based on 8 receiver antennae elements.

### II-C-8 Overall summary of results for EUHT technology

In this section, the IEG has provided a summary of all the results to date, including submitted reports from last year’s round of evaluations. It can be observed that the RIT does not meet the requirements for reliability in Urban-macro-URLLC scenario, based on WWRF’s last year’s conclusion. The IEG continued to develop its link and system level simulators by further refining the results based on EUHT self-evaluation report and technical specifications. Based on two rounds of simulation-based analysis, the EUHT technology does not meet the reliability requirements from [1].

Whereas, in case of mobility in rural-eMBB scenario, the RIT passes the ITU requirements (as seen in the table below) which was presented in last year’s submission. The IEG was satisfied with the information provided for Mobility evaluation in Rural-eMBB scenario, to have correct and meaningful simulations. Therefore, the IEG would like to keep the evaluation results for Mobility (rural-eMBB scenario) as they are, by concluding that EUHT technology meets the requirements.

Table 6

Overall Results to date for EUHT technology (Reliability & Mobility)

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Date (Report submitted) | Minimum technical performance requirements (ITU-R M.2410) | Category | | | Required value | Value | Meets the Requirement? | Remarks |
| Usage scenario | Test environment | Downlink or Uplink |  |
| September 2021 (after re-simulation) | Reliability | URLLC | Urban macro-URLLC | Downlink | 99.999% | 99.985% | No | *EUHT does not meet the reliability criteria due to the observations summarised in this section.* |
| August 2021 | Reliability | URLLC | Urban macro-URLLC | Downlink | 99.999% | 99.955% | No | *The IEG concludes that candidate under evaluation does not meet the reliability criteria.* |
| June 2021 | 99.875% | *The IEG requested further information from Nufront for EUHT’s receiver design.* |
| Feb 2020 | 99.9942% | *The IEG concluded that candidate under evaluation does not meet the reliability criteria.*  *\*System level simulations needed further investigation.* |
| Mobility  (Pedestrian, Vehicular, High speed vehicular) | eMBB | Rural | Uplink | 0.45 bits/s/Hz @ 500 km/h | 0.16 bit/s/Hz | No | *This simulation result is based on a single stream.*  *ITU Requirements achieved only 1% of simulation time.* |
| 0.29 bit/s/Hz | *This simulation result is based on two streams.*  *ITU Requirements achieved only 10% of simulation time.* |
| 0.42 bit/s/Hz | *This simulation result is based on three streams.*  *ITU Requirements achieved only 45% of simulation time.* |
| eMBB | Rural | Uplink | 0.45 bits/s/Hz @ 500 Km/h | 0.56 bit/s/Hz | Yes | *Only the iteration with 4 streams (0.58 bit/s/Hz) can achieve ITU requirements (0.45 bit/s/Hz as defined in Report ITU-R M.2410 TABLE 4).*  *ITU Requirements achieved 77% of simulation time.* |

## II-E Verification as per Report ITU-R M.2411 of the compliance templates and the self-evaluation for each candidate technology as indicated in A)

The verification of compliance templates and the self-evaluation is considered as per Report ITU-R M.2411.

## II-F Assessment as per Reports ITU-R M.2410, ITU-R M.2411 and ITU-R M.2412 for each candidate technology as indicated in A)

The assessment has been carried out as per Reports ITU-R M.2410, ITU-R M.2411, and ITU-R M.2412.

## II-G Questions and feedback to WP 5D and/or the proponents or other IEGs

This IEG has referred to the self-evaluation report provided by the EUHT and utilized the parameters used by the EUHT self-evaluation to cross verify the findings. Also, the IEG formally contacted Nufront for clarification on some parameters in the receiver design.

## II-H Proposed next steps

The IEG aims to assess the EUHT technology for Mobility Interruption Time (by inspection).

# Part III: Conclusions

In this report, we present the methodology that we have used for evaluating the RIT for urban macro URLLC scenario. We have detailed the system and link-level simulation parameters, technical assumptions, and the network layout.

Further to the discussion, communication and input from Nufront in September 2021, we have re-simulated the Urban-macro URLLC scenario for the reliability evaluation. Therefore, the WWRF IEG would like to confirm that the EUHT technology does not pass the reliability criteria for Urban-Macro URLLC, which was also the case in our previous report (Table 4) as it was submitted in the ITU-R WP 5D August 2021 meeting.

Furthermore, based on the re-simulation, several observations were made, and they are detailed and discussed in the previous sections.

References and additional material

[1] ITU-R: *Minimum requirements related to technical performance for IMT-2020 radio interface(s)*. Report [ITU-R M.2410-0](https://www.itu.int/pub/R-REP-M.2410) (11/2017).

[2] ITU-R: *Requirements, evaluation criteria and submission templates for the development of IMT-2020*. Report [ITU-R M.2411-0](https://www.itu.int/pub/R-REP-M.2411) (11/2017).

[3] ITU-R: *Guidelines for evaluation of radio interface technologies for IMT-2020*. Report [ITU-R M.2412-0](https://www.itu.int/pub/R-REP-M.2412) (10/2017).

[4] ITU-R Document [5B/746](https://www.itu.int/md/R19-WP5D-C-0746/en) – *Report on the meeting of Working Group Technology Aspects (Option 2)*, e-Meeting, 23-27 August 2021.

Appendix A

## A-I Previous results

These results follow an antennae configuration of 8 × 2 i.e., 8 Tx and 2 Rx antennae elements. For this antennae configuration the RIT does not meet the reliability criteria, however, even after increasing the number of Rx antenna elements, the RIT does not meet the reliability criteria as shown in Section II-C-4 of this report.

Previous results (antennae config 8 × 2), June 2021

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Minimum technical performance requirements (ITU-R M.2410) | Category | | | Required value | Value | Meets the requirement? | Remarks |
| Usage scenario | Test environment | Downlink or Uplink |
| Reliability | URLLC | Urban macro-URLLC | Downlink | 99.999% | 99.875% | No | *The candidate under evaluation does not meet the reliability criteria due to the provided antenna configuration.*  *\* Increasing the number of receiver antenna elements may result in better reliability as Diversity increases.* |

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