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| 3GPP TR 38.830 V0.0.3 (2020-10) |
| Technical Report |
| 3rd Generation Partnership Project;Technical Specification Group Radio Access Network;Study on NR coverage enhancements(Release 17) |
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Contents

Foreword 4

Introduction 5

1 Scope 6

2 References 6

3 Definitions of terms, symbols and abbreviations 6

3.1 Terms 6

3.2 Symbols 6

3.3 Abbreviations 6

4 Evaluation methodology 7

4.1 Antenna gain modelling 7

4.1.1 gNB antenna gain modelling 7

4.1.2 UE antenna gain modelling 8

4.2 Performance metrics 9

4.3 Link budget template 9

5 Baseline coverage performance 10

5.1 Baseline coverage performance for FR1 10

5.2 Baseline coverage performance for FR2 10

6 Potential techniques for coverage enhancements 10

6.1 PUSCH coverage enhancements 10

6.1.1 Time-domain based solutions 10

6.1.2 Frequency-domain based solutions 10

6.1.3 DM-RS enhancements 10

6.1.4 Power-domain based solutions 10

6.1.5 Spatial-domain based solutions 11

6.1.6 Others 11

6.2 PUCCH coverage enhancements 11

6.3 Coverage enhancements for channels other than PUSCH and PUCCH 11

6.3.1 Enhancements for Msg3 PUSCH 11

7 Conclusions 12

Annex <A>: Simulation assumptions 13

A.1 Simulation assumptions for FR1 13

A.2 Simulation assumptions for FR2 17

A.3 Link budget template 22

Annex <B> (informative): Change history 29

# Foreword

This Technical Report has been produced by the 3rd Generation Partnership Project (3GPP).

The contents of the present document are subject to continuing work within the TSG and may change following formal TSG approval. Should the TSG modify the contents of the present document, it will be re-released by the TSG with an identifying change of release date and an increase in version number as follows:

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x the first digit:

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In the present document, modal verbs have the following meanings:

**shall** indicates a mandatory requirement to do something

**shall not** indicates an interdiction (prohibition) to do something

The constructions "shall" and "shall not" are confined to the context of normative provisions, and do not appear in Technical Reports.

The constructions "must" and "must not" are not used as substitutes for "shall" and "shall not". Their use is avoided insofar as possible, and they are not used in a normative context except in a direct citation from an external, referenced, non-3GPP document, or so as to maintain continuity of style when extending or modifying the provisions of such a referenced document.

**should** indicates a recommendation to do something

**should not** indicates a recommendation not to do something

**may** indicates permission to do something

**need not** indicates permission not to do something

The construction "may not" is ambiguous and is not used in normative elements. The unambiguous constructions "might not" or "shall not" are used instead, depending upon the meaning intended.

**can** indicates that something is possible

**cannot** indicates that something is impossible

The constructions "can" and "cannot" are not substitutes for "may" and "need not".

**will** indicates that something is certain or expected to happen as a result of action taken by an agency the behaviour of which is outside the scope of the present document

**will not** indicates that something is certain or expected not to happen as a result of action taken by an agency the behaviour of which is outside the scope of the present document

**might** indicates a likelihood that something will happen as a result of action taken by some agency the behaviour of which is outside the scope of the present document

**might not** indicates a likelihood that something will not happen as a result of action taken by some agency the behaviour of which is outside the scope of the present document

In addition:

**is** (or any other verb in the indicative mood) indicates a statement of fact

**is not** (or any other negative verb in the indicative mood) indicates a statement of fact

The constructions "is" and "is not" do not indicate requirements.

# Introduction

In RAN #86 meeting, a new Rel-17 study item on NR coverage enhancements was approved [2]. The objective of this study item is to study potential coverage enhancement solutions for specific scenarios for both FR1 and FR2. The detailed objectives are as follows.

* The target scenarios and services include
	+ Urban (outdoor gNB serving indoor UEs) scenario, and rural scenario (including extreme long distance rural scenario) for FR1
	+ Indoor scenario (indoor gNB serving indoor UEs), and urban/suburban scenario (including outdoor gNB serving outdoor UEs and outdoor gNB serving indoor UEs) for FR2.
	+ TDD and FDD for FR1.
	+ VoIP and eMBB service for FR1.
	+ eMBB service as first priority and VoIP as second priority for FR2.
	+ LPWA services and scenarios are not included.
* Identify baseline coverage performance for both DL and UL for the above scenarios and services based on link-level simulation
	+ UL channels (including PUSCH and PUCCH) are prioritized for FR1.
	+ Both DL and UL channels for FR2.
* Identify the performance target for coverage enhancement, and study the potential solutions for coverage enhancements for the above scenarios and services
	+ The target channels include at least PUSCH/PUCCH
	+ Study enhanced solutions, e.g., time domain/frequency domain/DM-RS enhancement (including DM-RS-less transmissions)
	+ Study the additional enhanced solutions for FR2 if any
	+ Evaluate the performance of the potential solutions based on link level simulation.

# 1 Scope

The present document captures the results and findings from the study item "New SID on NR coverage enhancement" [2]. The purpose of this TR is to document the baseline coverage performance for both FR1 and FR2 considering the scenarios and services identified in [2], and to document the evaluation and findings of the potential enhancements for the identified scenarios and services.

This activity involves the Radio Access work area of the 3GPP studies and has potential impacts both on the Mobile Equipment and Access Network of the 3GPP systems.

This document is a 'living' document, i.e. it is permanently updated and presented to TSG-RAN meetings.

# 2 References

The following documents contain provisions which, through reference in this text, constitute provisions of the present document.

- References are either specific (identified by date of publication, edition number, version number, etc.) or non‑specific.

- For a specific reference, subsequent revisions do not apply.

- For a non-specific reference, the latest version applies. In the case of a reference to a 3GPP document (including a GSM document), a non-specific reference implicitly refers to the latest version of that document *in the same Release as the present document*.

[1] 3GPP TR 21.905: "Vocabulary for 3GPP Specifications".

[2] 3GPP RP-193240: "New SID on NR coverage enhancement".

# 3 Definitions of terms, symbols and abbreviations

## 3.1 Terms

For the purposes of the present document, the terms given in 3GPP TR 21.905 [1] and the following apply. A term defined in the present document takes precedence over the definition of the same term, if any, in 3GPP TR 21.905 [1].

**example:** text used to clarify abstract rules by applying them literally.

## 3.2 Symbols

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

<symbol> <Explanation>

## 3.3 Abbreviations

For the purposes of the present document, the abbreviations given in 3GPP TR 21.905 [1] and the following apply. An abbreviation defined in the present document takes precedence over the definition of the same abbreviation, if any, in 3GPP TR 21.905 [1].

ACK Acknowledgement

BWP Bandwidth Part

BS Base Station

CSI Channel State Information

CCE Control Channel Element

DL Downlink

DMRS Dedicated Demodulation Reference Signals

eMBB enhanced Mobile BroadBand

FDD Frequency Division Duplex

gNB NR Node B

HARQ Hybrid Automatic Repeat reQuest

iBLER initial BLock Error Rate

LLS Link Level Simulation

MCS Modulation and Coding Scheme

NACK Negative Acknowledgement

OS OFDM symbol

PDCCH Physical Downlink Control Channel

PUCCH Physical Uplink Control Channel

PUSCH Physical Uplink Shared Channel

PDSCH Physical Downlink Shared Channel

PRACH Physical Random Access Channel

PRB Physical Resource Block

rBLER residual BLock Error Rate

SCS Subcarrier Spacing

SLS System Level Simulation

SR Scheduling Request

SSB Synchronization Signal Block

TBS Transport Block Size

TDD Time Division Duplex

UCI Uplink Control Information

UE User Equipment

UL Uplink

# 4 Evaluation methodology

* For this study item, the basic evaluation methodology is based on link-level simulation.
* Step 1: Obtain the required SINR for the physical channels under target scenarios and service/reliability requirements.

The simulation assumptions for step 1 are provided in Annex A.1 for FR1 and A.2 for FR 2 respectively.

* Step 2: Obtain the baseline performance based on required SINR and link budget template.
* The evaluation methodology based on system-level simulation is optional and the simulation assumptions for system-level simulation are up to companies’ reports.

## 4.1 Antenna gain modelling

### 4.1.1 gNB antenna gain modelling

For link level simulation, two options for TDL channel model are considered:

* TDL channel model option 1: 2 or 4 gNB RF chains in LLS
* TDL channel model option 2 (optional): number of gNB RF chains in LLS = number of TXRUs

For TDL channel model option 1, the complexity of link level simulation can be simplified, while the practical gNB architecture can be reflected in TDL channel model option 2.

Figure 4.1-1 and Figure 4.1-2 depict gNB antenna gain modelling for TDL channel model option 1, and TDL channel model option 2 and CDL channel model respectively. M is the number of antenna elements, N is the number of TXRUs, k is the number of RF chains considered in LLS. For TDL channel model option 1, gNB antenna gains include 4 components, i.e., antenna gain component 1/2/3/4. For TDL channel model option 2 and CDL channel model, gNB antenna gains include 3 components, i.e., antenna gain component 1/3/4. The antenna gain component 1 is included in LLS, while the antenna gain component 2/3/4 are included in link budget template.



Figure 4.1-1. gNB antenna gain modelling for TDL channel model option 1



Figure 4.1-2. gNB antenna gain modelling for TDL channel model option 2 and CDL channel model

For TDL channel model option 1, the gain of antenna gain component 2 is expressed by:

Antenna gain component 2 = 10 \* log 10(N/k)-Δ1,

where Δ1 is a correction factor to account for various non-idealities impacting the actual gain of antenna gain component 2, and reported by companies.

For TDL channel model option 2 and CDL channel model, antenna gain component 2 = 0.

For TDL channel model option 1, option 2 and CDL channel model, the gain of antenna gain components 3 and 4 is expressed by:

Antenna gain component 3 + Antenna gain component 4 = Antenna Element Gain + 10 \* log 10(M/N) -Δ2.

where Δ2 is a correction factor to account for various non-idealities impacting the actual gain of antenna gain component 3, and reported by companies.

### 4.1.2 UE antenna gain modelling

UE antenna gain is expressed by:

UE antenna gain = Antenna Element Gain + 10 \* log 10(*M*/*k*) -Δ3.

For FR1, antenna element gain = 0dBi$Δ3=0$; while for FR2, antenna element gain = 5dBi.

where *k* is the number of Tx/Rx chains, e.g., number of SRS/CSI-RS ports to be simulated in LLS and *M* is the number of antenna elements used for both transmission and reception, i.e., *M/*2 xpol antenna elements.

For FR1, *k* = *M* is assumed for the simulations, and *k*=1$k=1$ for Tx (optional *k* = 2), while *k*∈{2,4} for Rx.

For FR2, there are two options for simulations:

* Option 1: *k*∈{1,2}for Tx and *k* = 2 for Rx,
* Option 2: *k* = *M* $k=M$.

Δ3 is a correction factor to account for various non-idealities impacting the actual antenna array gain. For FR1, Δ3=0$Δ3=0$; while for FR2, Δ3 is channel/procedure dependent and reported by companies.

## 4.2 Performance metrics

For LLS based methodology, coverage bottleneck(s) identification is performed using at least MIL or MCL (assuming the set of simulation assumptions). Even when SLS is used to obtain some components of MIL or MCL, it is categorized as LLS based methodology. MCL values can also be used to identify the coverage bottleneck(s) when applicable. “Applicable” above means the following situation: [comparing channels with similar antenna (and antenna array) gain, and/or the simulation results with MIL from companies are diverse, and the comparison with MIL is not easy]. MPL can be used as supplemental information for coverage bottleneck(s) identification.

RAN1 strives for satisfying appropriate targets identified by companies particularly operators. The targets may be in the form of one or more of the following:

1. Scenario dependent targets, e.g., ISD/MPL;

2. Service dependent targets, e.g., [MCL=147] dB for VoIP;

3. Relative difference between channels, e.g., MIL(/[MCL]).

**Definition of MCL:**

MCL = Total transmit power – Receiver sensitivity + gNB antenna gain (component 2).

**Definition of MIL:**

MIL = Total transmit power – Receiver sensitivity – Tx loss – Rx loss + gNB antenna gain (component 2 + 3 + 4) + UE antenna gain.

**Definition of MPL:**

MPL = MIL – Shadow fading margin + BS selection/macro-diversity gain – Penetration margin + Other gains.

## 4.3 Link budget template

Single link budget template for both FR1 and FR2 with rows for MIL, MCL, MPL is adopted. The parameter assumptions of the link budget template for step 2 are provided in Annex A.3. RAN1 will not further discuss on specific values for the parameters related to MPL. IMT-2020 values are a starting point, but companies may use other values, and for the parameters that companies think IMT-2020 self-evaluation does not clearly define the values for some scenarios, it is up to companies to report.

# 5 Baseline coverage performance

## 5.1 Baseline coverage performance for FR1

## 5.2 Baseline coverage performance for FR2

# 6 Potential techniques for coverage enhancements

## 6.1 PUSCH coverage enhancements

### 6.1.1 Time-domain based solutions

Time domain based solutions are studied, including increasing the number of repetitions for PUSCH repetition type A, Enhancement on PUSCH repetition Type B, TB processing at least over multi-slot PUSCH, OCC spreading based repetition, symbol-level repetition, TB interleaving, RV repetition, and early termination of PUSCH repetitions. The study on the following solutions is prioritized:

* Increase the number of repetitions for PUSCH repetition type A
	+ PUSCH repetition with non-consecutive slots/on the basis of available slots for TDD
* Enhancement on PUSCH repetition Type B
	+ E.g., actual repetition across the slot boundary, or the length of actual repetition larger than 14 symbols, etc.
* TB processing at least over multi-slot PUSCH
	+ E.g., single TB, sized for a single slot, but transmitted in parts over multiple slots; or single TB, sized for multiple slots, transmitted over multiple slots, and in conjunction with repetition, etc.

### 6.1.2 Frequency-domain based solutions

Frequency domain based solutions are studied, including inter-slot/intra-slot frequency hopping with more frequency offsets/positions, inter-slot frequency hopping with inter-slot bundling to enable cross-slot channel estimation, enhancements on frequency hopping for PUSCH repetition type B, sub-PRB transmission for VoIP.

### 6.1.3 DM-RS enhancements

DM-RS enhancements are studied, including cross-slot channel estimation, lower density (e.g., DM-RS sharing among multiple PUSCH transmissions **or lower DMRS density in the frequency domain**), higher density (e.g., in time or frequency domain, e.g., 1-comb pattern), adaptive configuration, and DM-RS balancing among frequency hops. The study on cross-slot channel estimation is prioritized.

### 6.1.4 Power-domain based solutions

Power domain based solutions are studied, including waveform design to optimize MPR/A-MPR, FDD high power UE, and power boosting for pi/2 BPSK.

### 6.1.5 Spatial-domain based solutions

Spatial domain based solutions are studied with low priority, including multiple layer PUSCH transmission with DFT-s-OFDM and study open-loop/closed loop Tx diversity for PUSCH enhancements.

### 6.1.6 Others

Following solutions are not considered for PUSCH enhancements in this study item in RAN1:

* Enhancements to improve spherical coverage / beam correspondence
* Reflective arrays
* Polarization aspects of the UL and/or DL reference signals

## 6.2 PUCCH coverage enhancements

PUCCH enhancements are studied and the study on the following schemes is prioritized:

* DMRS-less PUCCH
	+ FFS: design detail for DMRS-less PUCCH, e.g., sequence based PUCCH transmission, v.s. reuse Rel-15 scheme to transmit UCI without DMRS
* Rel-16 PUSCH-repetition-Type-B like PUCCH repetition at least for UCI <=11 bits.
* (Explicit or implicit) Dynamic PUCCH repetition factor indication
* DMRS bundling cross PUCCH repetitions
	+ Including study of transmitting a subset of PUCCH repetitions without DMRS, at least for UCI<=11 bits

The following schemes for PUCCH coverage enhancement are studied:

* Sequence based PF 0/1 with Pi/2 BPSK
* Pre-DFT data-RS multiplexing for PF2 with Pi/2 BPSK
* UCI size reduction
* Freq. hopping enhancement for PUCCH
* Short/mini-slot PUCCH repetition
* Power control enhancement for PUCCH (including power boost for pi/2 BPSK)
* Increase maximum # allowed repetitions for PUCCH
* PUCCH transmit diversity scheme
* Symbol-level repetition for long PUCCH
* Split UCI payload on short and long PUCCH on adjacent S and U slots
* Potential higher DMRS density for PUCCH with repetitions

The study of the following schemes for PUCCH coverage enhancement is deprioritized:

* UE Antenna configuration enhancement for FR2
* Relay (including sidelink relay)
* Reflective arrays

## 6.3 Coverage enhancements for channels other than PUSCH and PUCCH

### 6.3.1 Enhancements for Msg3 PUSCH

Msg3 PUSCH enhancement is studied including at least Msg3 PUSCH repetition. Enhancement to PUSCH scheduled by RAR UL grant does not consider the optimization specific for CFRA case.

# 7 Conclusions

Annex <A>:
Simulation assumptions

# A.1 Simulation assumptions for FR1

This subclause describes the link-level simulation assumptions for FR1. Table A.1-1 shows the general parameters for all channels. Table A.1-2~Table A.1-8 shows the channel-specific parameters for each channel respectively.

Table A.1-1: General parameters for FR1

|  |  |
| --- | --- |
| **Parameter** | **Value** |
| Scenario and frequency | Urban: 4GHz (TDD), 2.6GHz (TDD) Rural: 4GHz (TDD), 2.6GHz (TDD), 2GHz (FDD), 700MHz (FDD)Rural with long distance: 700MHz (FDD), 4GHz (TDD) |
| Frame structure for TDD | DDDSU (S: 10D:2G:2U) only for 4GHzDDDSUDDSUU (S: 10D:2G:2U) only for 4GHz DDDDDDDSUU (S: 6D:4G:4U) only for 2.6GHzOther frame structures can be reported by companies. |
| Target data rates for eMBB | Urban: DL 10Mbps, UL 1MbpsRural: DL 1Mbps, UL 100kbpsRural with long distance: DL 1Mbps, UL 100kbps, 30kbps (optional) |
| Packet size for VoIP | A packet size of 320 bits with 20ms data arriving interval is adopted.

|  |  |
| --- | --- |
|   | Size (bits) |
| Payload | 256 |
| CRC | 16 (TBS size lower than 3824 bits) |
| MAC | 16 (with 12 bits SN size) |
| RLC | 8 (with 6 bits SN size) |
| PDCP | 16 |
| RTP/UDP/IP | 24 (w RoHC) |

If applicable, companies report TB size assumed in evaluation.For SIP invite message* Payload of 1500 bytes can be a starting point.
* The assumptions (TB size, time period etc.) are reported by companies.
* Contributions R1-2003464 and [R1-2005259](file:///D%3A%5CA_%E5%B7%A5%E4%BD%9C%5C%5BC%5D%E3%80%902018-09-12%E3%80%91NR%E8%A6%86%E7%9B%96%E7%9B%B8%E5%85%B3%E6%9D%90%E6%96%99%5Cwanshic%5COneDrive%20-%20Qualcomm%5CDocuments%5CStandards%5C3GPP%20Standards%5CMeeting%20Documents%5CTSGR1_102%5CDocs%5CR1-2005259.zip) are taken into account for the evaluation
	+ In addition, 1 second time period can also be considered.
 |
| Latency requirements for VoIP | Latency requirements assumed in VoIP evaluation for TDD and FDD are reported by companies. |
| Pathloss model (select from LoS or NLoS) | Urban: NLoSRural: NLoS and LoS |
| BWP | 100MHz for 4GHz and 2.6GHz.20MHz for 2GHz (FDD)20MHz (optional for 10MHz) for 700MHz. (FDD) |
| Channel model for link-level simulation | TDL-C for NLOS, TDL-D for LOS. |
| Delay spread | Urban: 300nsRural: 300nsRural with long distance: 30ns |
| UE velocity | Urban: 3km/h for indoorRural: 3km/h for indoor, 120km/h (optional 30km/h) for outdoor |
| Number of antenna elements for BS | * Urban: 192 antenna elements for 4GHz and 2.6GHz,

(M,N,P,Mg,Ng) = (12,8,2,1,1)(optional) 128 antenna elements for 4GHz, (M,N,P,Mg,Ng) = (8,8,2,1,1)* Rural: 64 antenna elements for 4GHz and 2.6GHz

(M,N,P,Mg,Ng) = (8,4,2,1,1)32 antenna elements for 2GHz(M,N,P,Mg,Ng) = (8,2,2,1,1)16 antenna elements for 700MHz(M,N,P,Mg,Ng) = (4,2,2,1,1) |
| Number of TxRUs for BS | gNB architectures to study:* 2 or 4 TXRUs for 2GHz, 700 MHz
* 64TxRUs for 2.6 and 4 GHz.
* Optional: 32 TXRUs at 2 GHz

 gNB modeling in LLS for TDL:* Option 1: 2 or 4 gNB RF chains in LLS.
* Option 2 (Optional): Number of gNB RF chains = number of TXRUs in LLS.
* Companies can report if and how correlation is modelled.
 |

Table A.1-2: Channel-specific parameters for PUSCH for FR1

|  |  |
| --- | --- |
| **Parameter** | **Value** |
| Frequency hopping  | w/ or w/o frequency hopping |
| BLER | For eMBB, w/ HARQ, 10% iBLER; w/o HARQ, 10% iBLER.For VoIP, 2% rBLER. |
| Number of UE transmit chains  | 1, 2 (optional)  |
| DMRS configuration  | For 3km/h: Type I, 1 or 2 DMRS symbol, no multiplexing with data.For 120km/h, (Optional: 30km/h): Type I, 2 or 3 DMRS symbol, no multiplexing with data.For frequency hopping: Type I, 1 or 2 DMRS symbol for each hop, no multiplexing with data.PUSCH mapping Type, the number of DMRS symbols and DMRS position(s) are reported by companies. |
| Waveform | DFT-s-OFDM, CP-OFDM (optional) |
| SCS | 30kHz for TDD, 15kHz for FDD. |
| PUSCH duration  | 14 OS |
| Repetitions  | For eMBB, w/o repetition as baseline, w/ repetition (optional). For VoIP, w/ type A repetition, optional for type B repetition.The actual number of repetitions is reported by companies. |
| HARQ configuration  | For eMBB, whether HARQ is adopted is reported by companies. For VoIP, w/ HARQ.The maximum number of HARQ transmission (limited by frame structure and latency requirements) can be reported by companies. |
| PRBs/TBS/MCS for eMBB | Any value of PRBs, and corresponding MCS index, reported by companies will be considered in the discussion. Companies are encouraged to use 30 PRBs for 1Mbps, 4 PRBs for 100kbps, 1 PRB for 30kbps as a starting point.TBS can be calculated based on e.g. the number of PRBs, target data rate, frame structure and overhead. |
| PRBs/MCS for VoIP | [4 PRBs] for VoIP as starting point. Other values of PRBs can be reported by companies.QPSK, pi/2 BPSK (optional) |

Table A.1-3: Channel-specific parameters for PUCCH for FR1

|  |  |
| --- | --- |
| **Parameter** | **Value** |
| PUCCH format  | Format 1, 2bits UCI.Format 3, [4bits (3 bits A/N + 1 bit SR)]/11/22 bits UCI |
| Frequency hopping | w/ frequency hopping |
| BLER | * For PUCCH format 1:

DTX to ACK probability: 1%. NACK to ACK probability: 0.1%.ACK missed detection probability: 1%.* For PUCCH format 3:

BLER for Ack/Nack, SR: 1%BLER for CSI: 1%, optional for 10%. |
| Number of UE transmit chains | 1  |
| DMRS configuration  | FFS: number of DMRS symbols for PUCCH Format 3. |
| SCS | 30kHz for TDD, 15kHz for FDD. |
| Repetitions | w/ repetition (optional), w/o repetition for PUCCH.The maximum number of repetitions is 8. |
| PUCCH duration  | 14 OS |
| Number of PRBs | 1 PRB |

Table A.1-4: Channel-specific parameters for PRACH for FR1

|  |  |
| --- | --- |
| **Parameter** | **Value** |
| Format | Format 0, Format B4, or Format C2 |
| SCS | Reported by companies. |
| Performance metric | 1% missed detection at 0.1% false alarm probabilityFFS: 10% missed detection. |
| Number of UE transmit chains | 1, 2 (optional) |
| Other parameters | Reported by companies. |

Table A.1-5: Channel-specific parameters for PUSCH of Msg.3 for FR1

|  |  |
| --- | --- |
| **Parameter** | **Value** |
| Frequency hopping | w/ or w/o frequency hopping |
| Number of UE transmit chains | 1, 2 (optional) |
| Number of DMRS symbol | w/o frequency hopping: 3,w/ frequency hopping: 2 for each hop |
| Waveform  | DFT-s-OFDM |
| SCS | 30kHz for TDD, 15kHz for FDD. |
| HARQ configuration | For eMBB, whether HARQ is adopted is reported by companies. For VoIP, w/ HARQ.The maximum number of HARQ transmission (limited by frame structure and latency requirements) can be reported by companies. |
| PUSCH duration  | 14 OS |
| Number of PRBs | 2 |
| TBS | 56 bits |
| Other parameters | Reported by companies. |

Table A.1-6: Channel-specific parameters for PDSCH for FR1

|  |  |
| --- | --- |
| **Parameter** | **Value** |
| BLER | For eMBB, w/ HARQ, 10% iBLER; w/o HARQ, 10% iBLER.For VoIP, 2% rBLER. |
| Waveform | CP-OFDM |
| Number of UE receive chains | 4 for 4GHz/2.6GHz, 2 or 4 for 2GHz, 2 for 700MHz |
| SCS | 30kHz for TDD, 15kHz for FDD. |
| HARQ configuration | For eMBB, whether HARQ is adopted is reported by companies. For VoIP, w/ HARQ.The maximum number of HARQ transmission (limited by frame structure and latency requirements) can be reported by companies. |
| DMRS configuration | 3 DMRS symbols is used for PDSCH of Msg.2.For 3km/h: Type I, 1 or 2 DMRS symbol, no multiplexing with data.For 120km/h, (Optional: 30km/h): Type I, 2 or 3 DMRS symbol, no multiplexing with data.For frequency hopping: Type I, 1 or 2 DMRS symbol for each hop, no multiplexing with data.PDSCH mapping Type, the number of DMRS symbols and DMRS position(s) are reported by companies. |
| PRBs/MCS/TBS | Reported by companies. |
| PDSCH duration | 12 OSFor PDSCH of Msg.4, 12 OS |
| Payload size for PDSCH of Msg.4 | 1040 bits |
| Other parameters | Reported by companies. |

Table A.1-7: Channel-specific parameters for PDCCH for FR1

|  |  |
| --- | --- |
| **Parameter** | **Value** |
| Number of UE receive chains | 4 for 4GHz/2.6GHz, 2 or 4 for 2GHz, 2 for 700MHz |
| SCS | 30kHz for TDD, 15kHz for FDD. |
| Aggregation level | 16 |
| Payload | 40 bits |
| CORESET size | 2 symbols, 48 PRBs |
| Tx Diversity | Reported by companies |
| BLER | 1% BLERoptional for 10% BLER |
| Number of SSB for broadcast PDCCH of Msg.2 | Reported by companies |
| Other parameters | Reported by companies |

Table A.1-8: Channel-specific parameters for SSB for FR1

|  |  |
| --- | --- |
| **Parameter** | **Value** |
| Number of UE receive chains | 4 for 4GHz/2.6GHz, 2 or 4 for 2GHz, 2 for 700MHz |
| SCS | 30kHz for TDD, 15kHz for FDD. |
| Periodicity | 20ms |
| Performance metric | Combination of 4 SSBs in 80ms.Note: UE is not assumed to know the SS/PBCH block index |
| Other parameters | Reported by companies. |

# A.2 Simulation assumptions for FR2

This subclause describes the link-level simulation assumptions for FR2. Table A.2-1 shows the general parameters for all channels. Table A.2-2~Table A.2-8 shows the channel-specific parameters for each channel respectively.

Table A.2-1: General parameters for FR2

|  |  |
| --- | --- |
| **Parameter** | **Value** |
| Scenario and frequency | Indoor: 28GHz (TDD) Urban: 28GHz (TDD)Suburban: 28GHz (TDD) |
| Frame structure for TDD | DDDSU (S: 10D:2G:2U)DDSU (S: 11D:3G:0U)Other frame structures can be reported by companies. |
| Target data rates for eMBB | Indoor: DL: 25Mbps, UL:5Mbps Urban: DL: 25Mbps, UL: 5MbpsSuburban: DL: 1Mbps, UL: 50kbps (low priority) |
| Packet size for VoIP | A packet size of 320 bits with 20ms data arriving interval is adopted.

|  |  |
| --- | --- |
|   | Size (bits) |
| Payload | 256 |
| CRC | 16 (TBS size lower than 3824 bits) |
| MAC | 16 (with 12 bits SN size) |
| RLC | 8 (with 6 bits SN size) |
| PDCP | 16 |
| RTP/UDP/IP | 24 (w RoHC) |

If applicable, companies report TB size assumed in evaluation.For SIP invite message* Payload of 1500 bytes can be a starting point.
* The assumptions (TB size, time period etc.) are reported by companies.
* Contributions R1-2003464 and [R1-2005259](file:///D%3A%5CA_%E5%B7%A5%E4%BD%9C%5C%5BC%5D%E3%80%902018-09-12%E3%80%91NR%E8%A6%86%E7%9B%96%E7%9B%B8%E5%85%B3%E6%9D%90%E6%96%99%5Cwanshic%5COneDrive%20-%20Qualcomm%5CDocuments%5CStandards%5C3GPP%20Standards%5CMeeting%20Documents%5CTSGR1_102%5CDocs%5CR1-2005259.zip) are taken into account for the evaluation
* In addition, 1 second time period can also be considered.
 |
| Latency requirements for VoIP |  Latency requirements assumed in VoIP evaluation for TDD and FDD are reported by companies. |
| BWP | 100MHz, [400MHz] |
| Channel model for link-level simulation | CDL- A, TDL-A, [urban/suburban: TDL-C]Note: company can provide simulation results based on either TDL channel or CDL model |
| Delay spread | Indoor scenario: 30nsUrban scenario: 100nsSuburban scenario: 100ns |
| UE velocity | Indoor scenario:3km/hUrban scenario: 3km/h for indoor, 30km/h for outdoor. Suburban scenario: 3km/h for indoor, 30km/h, (optional: 120km/h) for outdoor. |
| Number of antenna elements for BS | Indoor scenario: 128(M, N, P, Mg, Ng) = (8, 8, 2, 1, 1)Urban/suburban scenario: 256, (M,N,P,Mg,Ng) = (4, 8, 2, 2, 2)Optional: 512, (M,N,P,Mg,Ng) = (8,8,2,2,2) |
| Number of TxRUs for BS | 2Note: Analog beamforming is assumed. |
| Number of UE antenna elements | 8, one panel:(M, N, P) = (2,2,2),  |

Table A.2-2: Channel-specific parameters for PUSCH for FR2

|  |  |
| --- | --- |
| **Parameter** | **Value** |
| Frequency hopping | w/ or w/o frequency hopping |
| BLER | For eMBB, w/ HARQ, 10% iBLER, Optional: companies report rBLER.w/o HARQ, 10% iBLER.For VoIP, 2% rBLER. |
| Number of UE Tx/Rx chains | 1T2R, 2T2R |
| DMRS configuration | For 3km/h: Type I, 1 or 2 DMRS symbol, no multiplexing with data.For 30km/h (optional: 120km/h): Type I, 2 or 3 DMRS symbol, no multiplexing with data.For frequency hopping for PUSCH: Type I, 1 or 2 DMRS symbol for each hop, no multiplexing with data.PUSCH/PDSCH mapping Type, the number of DMRS symbols and DMRS position(s) are reported by companies. |
| Waveform | DFT-s-OFDM  |
| SCS | 120kHz. |
| PUSCH duration  | 14 OS |
| Repetitions  | For eMBB, w/o repetition as baseline, w/ repetition (optional). For VoIP, w/ repetition. The actual number of repetitions is reported by companies.Only PUSCH repetition type A is considered for baseline performance evaluation. o Note: companies are not precluded to report results for repetition type B. |
| HARQ configuration | For eMBB, whether HARQ is adopted is reported by companies. For VoIP, w/ HARQ.The maximum number of HARQ transmission (limited by frame structure and latency requirements) can be reported by companies. |
| PRBs/TBS/MCS for eMBB | Any value of PRBs, and corresponding MCS index, reported by companies will be considered in the discussion. Companies are encouraged to use [30] PRBs for 5Mbps for PUSCH as a starting point.TBS can be calculated based on e.g. the number of PRBs, target data rate, frame structure and overhead. |
| PRBs/MCS for VoIP  | [4 PRBs] for VoIP as starting point. Other values of PRBs can be reported by companies.QPSK for PUSCHOptional: pi/2 BPSK for PUSCH |

Table A.2-3: Channel-specific parameters for PUCCH for FR2

|  |  |
| --- | --- |
| **Parameter** | **Value** |
| PUCCH format  | Format 1, 2bits UCI.Format 3, [4bits (3 bits A/N + 1 bit SR)]/11/22 bits UCI |
| Frequency hopping | w/ frequency hopping |
| BLER | * For PUCCH format 1:

DTX to ACK probability: 1%. NACK to ACK probability: 0.1%.ACK missed detection probability: 1%.* For PUCCH format 3:

BLER: 1% |
| Number of UE transmit chains | 1 |
| DMRS configuration for | 4 DMRS symbols for PUCCH Format 3. |
| SCS | 120kHz |
| Repetitions | w/ repetition (optional), w/o repetition for PUCCH.The maximum number of repetitions is 8. |
| PUCCH duration  | 14 OFDM symbols |
| Number of PRBs  | 1 PRB |

Table A.2-4: Channel-specific parameters for PRACH for FR2

|  |  |
| --- | --- |
| **Parameter** | **Value** |
| Format | Format B4, (Optional: Format C2) |
| SCS | Reported by companies. |
| Performance metric | 0.1% false alarm, 1% miss-detection |
| Number of UE Tx chains | 1T, 2T |
| Number of SSB beams | Reported by companies |
| Other parameters | Reported by companies. |

Table A.2-5: Channel-specific parameters for PUSCH of Msg.3 for FR2

|  |  |
| --- | --- |
| **Parameter** | **Value** |
| Frequency hopping | w/ or w/o frequency hopping |
| Number of UE Tx chains | 1T, 2T |
| Number of DMRS symbol | w/o frequency hopping: 3,w/ frequency hopping: 2 for each hop |
| Waveform  | DFT-s-OFDM |
| SCS | 120kHz |
| HARQ configuration | For eMBB, whether HARQ is adopted is reported by companies. For VoIP, w/ HARQ.The maximum number of HARQ transmission (limited by frame structure and latency requirements) can be reported by companies. |
| TBS | 56 bits |
| PUSCH duration  | 14 OS |
| Number of PRBs | 2 |
| Other parameters | Reported by companies. |

Table A.2-6: Channel-specific parameters for PDSCH for FR2

|  |  |
| --- | --- |
| **Parameter** | **Value** |
| BLER | For eMBB, w/ HARQ, 10% iBLER, Optional: companies report rBLER.w/o HARQ, 10% iBLER.For VoIP, 2% rBLER. |
| Waveform | CP-OFDM |
| Number of UE receive chains | 2 |
| SCS | 120kHz |
| HARQ configuration | For eMBB, whether HARQ is adopted is reported by companies. For VoIP, w/ HARQ.The maximum number of HARQ transmission (limited by frame structure and latency requirements) can be reported by companies. |
| DMRS configuration | For 3km/h: Type I, 1 or 2 DMRS symbol, no multiplexing with data.For 30km/h (optional: 120km/h): Type I, 2 or 3 DMRS symbol, no multiplexing with data.For frequency hopping for PUSCH: Type I, 1 or 2 DMRS symbol for each hop, no multiplexing with data.PUSCH/PDSCH mapping Type, the number of DMRS symbols and DMRS position(s) are reported by companies. |
| PRBs/TBS/MCS for eMBB | Any value of PRBs, and corresponding MCS index, reported by companies will be considered in the discussion. Companies are encouraged to use full bandwidth for 25Mbps for PDSCH as a starting point.TBS can be calculated based on e.g. the number of PRBs, target data rate, frame structure and overhead. |
| PRBs/MCS for VoIP | [4 PRBs] for VoIP as starting point. Other values of PRBs can be reported by companies.QPSK for PDSCH |
| PDSCH duration | 12 OSFor PDSCH of Msg.4, 12 OS |
| Payload size for PDSCH of Msg.4 | 1040 bits |

Table A.2-7: Channel-specific parameters for PDCCH for FR2

|  |  |
| --- | --- |
| **Parameter** | **Value** |
| Number of UE receive chains | 2 |
| SCS | 120kHz |
| Aggregation level | 16 |
| Payload | 40 bits |
| CORESET size | 2 symbols, 48 PRBs |
| Tx Diversity | Reported by companies |
| BLER | 1% BLER |
| Number of SSB for broadcast PDCCH of Msg.2 | Reported by companies |
| Other parameters | Reported by companies |

Table A.2-8: Channel-specific parameters for SSB for FR2

|  |  |
| --- | --- |
| **Parameter** | **Value** |
| Number of UE Tx/Rx chains | 1T2R, 2T2R |
| SCS | 120kHz |
| Periodicity | 20ms |
| Performance metric | Combination of 4 SSBs in 80ms.Note: UE is not assumed to know the SS/PBCH block index |
| Other parameters | Reported by companies. |

# A.3 Link budget template

Table A.3: Link budget template

|  |
| --- |
| **System configuration** |
| Channel for evaluation | PUSCH/ PUCCH/ Msg.3 PUSCH/ PRACH/ Msg.2 PDCCH/ Msg.2 PDSCH/ Msg.4 PDSCH/ PDSCH/ PDCCH/ SSB/ [PUSCH for CSI]/ [PUCCH with HARQ-ACK for Msg.4] |
| Scenarios and Carrier frequency (GHz) | For FR1:- Urban 4 GHz TDD/ 2.6 GHz TDD- Rural 4 GHz TDD/ 2.6 GHz TDD/ 2 GHz FDD/ 700 MHz FDD- Rural with long distance 700 MHz FDD/ 4 GHz TDDFor FR2:- Indoor 28 GHz TDD- Urban 28 GHz TDD- Suburban 28 GHz TDD |
| BS antenna heights (m) | Reported by companies, 25m for urban, 35m for rural can be used as a starting point. |
| UT antenna heights (m) | Reported by companies, 1.5m can be used as a starting point. |
| Cell area reliability (%) | Reported by companies, 95% for control channel, 90% for data channel can be used as a starting point. |
| Lognormal shadow fading std deviation (dB) | Reported by companies |
| Tx Diversity | Reported by companies |
| Number of SSB | Reported by companies |
| **Transmitter** |
| (1) Number of transmit antenna elements | For FR1 BS:- Urban: - 192 antenna elements for 4GHz and 2.6GHz- (optional) 128 antenna elements for 4GHz- Rural:- 64 for 4GHz and 2.6GHz- 32 antenna elements for 2GHzFor FR2 BS:- Indoor scenario: 128- Urban/suburban scenario: 256, Optional: 512For FR1 UE:- 1- 2 (optional)For FR2 UE:- 8 |
| (2) Number of [transmit TxRUs]Note: this row is void (left empty) for uplink | FR1 BS:- 2 or 4 TXRUs for 2GHz, 700 MHz- 64TxRUs for 2.6 and 4 GHz- Optional: 32 TXRUs at 2 GHzFR2 BS:- 2 |
| (2a) Number of transmit chains modelled in LLS | For FR1 BS:- Option 1: 2 or 4 gNB transmit chains in LLS.- Option 2 (optional): Number of gNB transmit chains = number of TXRUsFR2 BS:- 2For FR1 UE:- PUSCH/ Msg.3 PUSCH/ PRACH: 1, 2 (optional)- PUCCH: 1For FR2 UE:- Option 1: PUSCH/ Msg.3 PUSCH/ PRACH: 1, 2; PUCCH: 1- Option 2: 8 |
| (3) Total transmit power (dBm) Note: total transmit power for system bandwidth  | For FR1 UE:- 23 dBm for UE For FR2 UE:- 23 dBm and/or 12 dBm for UE (other values can be reported by companies) |
| (3a) System bandwidth for downlink, or occupied bandwidth for uplink (Hz) | For downlink:System bandwidth for FR1:- 100MHz for 4GHz and 2.6GHz- 20MHz for 2GHz (FDD)- 20MHz (optional for 10MHz) for 700MHz. (FDD)System bandwidth for FR2:- 100MHz, [400MHz]For uplink:- Occupied bandwidth is reported by companies |
| (3b) Power Spectrum Density = (3) - 10 log( (3a) / 1000000 ) (dBm/MHz) Note: For FR1 downlink, (3b) should satisfy the following:  For 4GHz frequency, 24 and 33 For 2.6 GHz frequency, 33 For 700MH and 2GHz frequency, 36Note: For FR2 downlink, the following should be satisfied: 40 dBm for 100 MHz Urban scenario, 23 dBm for 100 MHz Indoor scenario.Note: no PSD constraint for uplink |  |
| (3c) Bandwidth used for the evaluated channel (Hz)Note: (3c) is identical to the number of PRBs assigned to the channel evaluated.For uplink, (3a) = (3c) |  |
| (3bis) Total transmit power for occupied bandwidth = (3b) + 10 log ( (3c) / 1000000 ) (dBm) |  |
| (4) Total antenna gain at antenna gain component 3 & antenna gain component 4 of transmitter = (4a) – (4b) (dB) |  |
| (4a) Antenna gain at antenna gain component 3 & antenna gain component 4 of transmitter= (4c) + 10 log ( (1) / (2) ) (dB) for downlink, and= (4c) + 10 log ( (1) / (2a) ) (dB) for uplink |  |
| (4b) Antenna gain correction factor at antenna gain component 3 & antenna gain component 4 of transmitter (dB) | Reported by companies |
| (4c) Gain of antenna element (dBi)  | For BS:- 8 dBi or reported by companiesFor UE: - 0 dBi for FR1- 5 dBi for FR2 |
| (5) Total antenna gain at antenna gain component 2 of transmitter = (5a) - (5b) (dB)Note: zero for uplink |  |
| (5a) Antenna gain at antenna gain component 2 of transmitter = 10 log( (2)/(2a)) (dB)Note: zero for uplink |  |
| (5b) Antenna gain correction factor at antenna gain component 2 of transmitter (dB)Note: zero for uplink | Reported by companies |
| (8) Cable, connector, combiner, body losses, etc. (enumerate sources) (dB) (feeder loss must be included for and only for downlink) | Reported by companies |
| (9) EIRP = (3bis) + (4) + (5) – (8) dBm |  |
| **Receiver** |
| (10) Number of receive antenna elements | For FR1 BS:Urban: - 192 antenna elements for 4GHz and 2.6GHz- (optional) 128 antenna elements for 4GHzRural:- 64 for 4GHz and 2.6GHz- 32 antenna elements for 2GHzFor FR2 BS:- Indoor scenario: 128- Urban/suburban scenario: 256, Optional: 512For FR1 UE:- 1- (optional) 2For FR2 UE:-8 |
| (10a) Number of [receive TxRUs]Note: this row is void (empty) for downlink | FR1 BS:- 2 or 4 TXRUs for 2GHz, 700 MHz- 64TxRUs for 2.6 and 4 GHz- Optional: 32 TXRUs at 2 GHzFR2 BS:- 2 |
| (10b) Number of receive chains modelled in LLS | For FR1 BS:- Option 1: 2 or 4 gNB receive chains in LLS.- Option 2 (optional): Number of gNB receive chains = number of TXRUsFR2 BS:- 2For FR1 UE:- 4 for 4GHz/2.6GHz- 2 or 4 for 2GHz- 2 for 700MHzFor FR2 UE:- Option 1: 2- Option 2: 8 |
| (11) Total antenna gain at antenna gain component 3 & antenna gain component 4 of receiver = (11a) - (11b) (dB)  |  |
| (11a) Antenna gain at antenna gain component 3 & antenna gain component 4 of receiver = (11c) + 10 log ( (10)/(10a) ) (dB) for uplink = (11c) + 10 log ( (10)/(10b) ) (dB) for downlink |  |
| (11b) Antenna gain correction factor at antenna gain component 3 & antenna gain component 4 of receiver (dB) | Reported by companies |
| (11c) Gain of antenna element (dBi) | For BS:- 8 dBi or reported by companiesFor UE: - 0 dBi for FR1,- 5 dBi for FR2 |
| (11bis) Total antenna gain at antenna gain component 2 of receiver = (11bis-a) - (11bis-b) (dB)Note: zero for downlink |  |
| (11bis-a) Antenna gain at antenna gain component 2 of receiver = 10 log( (10a)/(10b)) (dB)Note: zero for downlink |  |
| (11bis-b) Antenna gain correction factor at antenna gain component 2 of receiver (dB)Note: zero for downlink | Reported by companies |
| (12) Cable, connector, combiner, body losses, etc. (enumerate sources) (dB) (feeder loss must be included for and only for uplink) | Reported by companies |
| (13) Receiver noise figure (dB) | Reported by companies |
| (14) Thermal noise density (dBm/Hz) | Reported by companies |
| (15) Receiver interference density (dBm/Hz)  | Reported by companies |
| (16) Total noise plus interference density = 10 log (10^(( (13) + (14))/10) + 10^((15)/10)) (dBm/Hz) |  |
| (18) Effective noise power = (16) + 10 log ((3c)) (dBm) |  |
| (19) Required SNR (dB) |  |
| (20) Receiver implementation margin (dB) | Reported by companies |
| (21) H-ARQ gain (dB)Note: Only applicable if HARQ is not considered in LLS | Reported by companies |
| (22) Receiver sensitivity = (18) + (19) + (20) – (21) (dBm) |  |
| (22bis) MCL = (3bis) – (22) + (5) + (11bis) (dB) | (22bis) MCL = (3bis) – (22) + (5) + (11bis) (dB) |
| (23) Hardware link budget, a.k.a. MIL = (9) + (11) + (11bis) − (12) − (22) (dB)Note: MIL can also be derived by (22bis) + (4) – (8) + (11) − (12) | (23) Hardware link budget, a.k.a. MIL = (9) + (11) + (11bis) − (12) − (22) (dB)Note: MIL can also be derived by (22bis) + (4) – (8) + (11) − (12) |
| **Calculation of available pathloss** |
| (25) Shadow fading margin (function of the cell area reliability and lognormal shadow fading std deviation) (dB) | Reported by companies |
| (26) BS selection/macro-diversity gain (dB) | Reported by companies |
| (27) Penetration margin (dB) | Reported by companies |
| (28) Other gains (dB) (if any please specify) | Reported by companies |
| (29) Available path loss = (23) – (25) + (26) – (27) + (28) (dB) |  |
| **Range/coverage efficiency calculation** |
| (30) Maximum range (based on (29) and according to the system configuration section of the link budget) (m) |  |

Annex <B> (informative):
Change history

|  |
| --- |
| **Change history** |
| **Date** | **Meeting** | **TDoc** | **CR** | **Rev** | **Cat** | **Subject/Comment** | **New version** |
| 2020-05 | RAN1#101e | R1-2004753 |  |  |  | Skeleton TR | 0.0.1 |
| 2020-08 | RAN1#102e | R1-2005730 |  |  |  | Inclusion of agreements made at RAN1#101e on evaluation methodology and simulation assumptions | 0.0.2 |
| 2020-10 | RAN1#103e | R1-2007992 |  |  |  | Inclusion of agreements made at RAN1#102e and post email discussion | 0.0.3 |