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| 3GPP TR 37.880 V0.3.0 (2021-02) | |
| Technical Report | |
| 3rd Generation Partnership Project;  Technical Specification Group Radio Access Network;  Evolved Universal Terrestrial Radio Access (E-UTRA) and NR;  High-power UE operation for fixed-wireless/vehicle-mounted use cases in Band 12, Band 5, and Band n71  (Release 17) | |
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# 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:

Version x.y.z

where:

x the first digit:

1 presented to TSG for information;

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3 or greater indicates TSG approved document under change control.

y the second digit is incremented for all changes of substance, i.e. technical enhancements, corrections, updates, etc.

z the third digit is incremented when editorial only changes have been incorporated in the document.

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.

# 1 Scope

The present document captures the findings from the study item "Study on High-power UE operation for fixed-wireless/vehicle-mounted use cases in Band 12, Band 5, and Band n71".

# 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-201261: "New SID on high-power UE operation for fixed-wireless/vehicle-mounted use cases in Band 12, Band 5, and Band n71", U.S. Cellular.

[3] 3GPP TR 36.837: "Public safety broadband high power User Equipment (UE)".

[4] 3GPP TS 38.101-1: "NR; User Equipment (UE) radio transmission and reception; Part 1: Range 1 Standalone".

[5] 3GPP R4-2008924: " LS on Parameters of terrestrial component of IMT for sharing and compatibility studies in preparation for WRC-23 (below 5 GHz)", Ericsson.

[6] 3GPP TR 36.802: "Evolved Universal Terrestrial Radio Access (E-UTRA); NB-IOT; Technical Report for BS and UE radio transmission and reception".

[7] 3GPP TR 36.942: "Evolved Universal Terrestrial Radio Access (E-UTRA); Radio Frequency (RF) system scenarios".

[8] 3GPP TS 36.101: " Evolved Universal Terrestrial Radio Access (E-UTRA); User Equipment (UE) radio transmission and reception".

[9] 3GPP R4-78AH-0150, “Summary of in-band/guard-band interference modeling from various companies”, Intel, Huawei, Ericsson, ZTE, Nokia Networks.

[10] 3GPP R4-163556, “Simulation results of coexistence studies between NB-IoT and LTE, guard-band case”, Intel Corporation.

[11] R4-124522, Architecture of Power Class 1 UE in Band 14, RAN4#64, EADS / Cassidian

[12] R4-1702437, MPR/A-MPR requirement for PC1 HPUE

# 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].

## 3.2 Symbols

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

*CLx-*ile *x*-percentile *CL* value

*P*max UE maximum transmit power

*P*t UE transmit power

*R*min Minimum power reduction ratio

## 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].

3GPP 3rd Generation Partnership Project

BS Base Station

BW Bandwidth

CL Coupling Loss

DL Downlink

HPUE High Power User Equipment

ITU International Telecommunication Union

LTE Long Term Evolution

MTC Machine-Type Communications

NB Narrowband

NR New Radio

OOBE Out Of Band Emissions

PA Power Amplifier

PC Power Class

PRB Physical Resource Block

RF Radio Frequency

Rx Receiver

SW Software

TR Technical Report

Tx Transmitter

UE User Equipment

# 4 Background

## 4.1 Justification

Support for fixed wireless and vehicle mounted user equipment usage scenarios, with broader rural coverage and higher data rates is envisioned as part of deployment configurations in LTE band 12 and band 5, and in NR band n71. Improvements in coverage, availability, and throughput performance to meet the market demands associated with fixed wireless and vehicle mounted usage would be enabled with user equipment specified with a power class 1 (31dBm) up-link transmission capability.

The fixed wireless access scenario provides a variety of benefits consisting of rapid deployment, and a reduction of costs associated with the transport to a customer premise, relative to wireline types of transport. The enablement of fixed wireless user equipment provides backhauling services to an appropriate base station in a serving network, for any other equipment at the customer premise. Similarly, vehicle mounted access scenario provides both direct access to other devices and indirect access to other devices, via the network.

## 4.2 Objective

The objective is to study RF requirements that are applicable for high power UE operation in LTE band 12 and band 5, and in NR band n71 for fixed wireless and vehicle-mounted use cases, in ITU Region 2.

a) Since the OOBE (Out Of Band Emissions) from the Band 12, Band 5, and Band n71 for high power user equipment (Power Class 1) into a neighbouring band is higher than Power class 3, co-existence studies are anticipated to evaluate the throughput OOBE impact on a victim band, from a high power aggressor in Band 12, Band 5, and Band n71.

1) Coexistence studies for B5 to include at a minimum the impact on the B26 DL and the public safety downlink in 851-861 MHz.

2) Coexistence studies for B5 include at a minimum the impact to the B5/n5/B26/n26 uplink including LTE, NR and MTC1 and 2, NB1 and 2 including the A\* and B\* blocks of the US cellular band configuration as well as the public safety uplink in 806-816 MHz.

3) Coexistence studies for B12 to include at a minimum the impact to the B29 DL.

4) Coexistence studies for B12 to include at a minimum the impact to the B12/n12/B71/n71/B85 uplink including LTE, NR and MTC1 and 2, NB1 and 2.

5) Coexistence studies for n71 to include at a minimum the impact to the B12/n12/B71/n71/B85 uplink including LTE, NR and MTC1 and 2, NB1 and 2.

6) Coexistence with B66.

b) Considerations for high power UE operation in Band 12, Band 5, and n71:

1) B12 UE Tx 3rd harmonic falls into B4 UE Rx band – will require more filters on Tx path if Carrier Aggregation is used:

- Harmonic exceptions are usually granted, but harmonics from PC1 could be much higher.

2) B5 UE Tx 3rd harmonic falls into 2.4GHz band – may need more filters on Tx path:

- Harmonic exceptions are usually granted, but harmonics from PC1 could be much higher.

3) n71 UE Tx 3rd harmonic falls into 3GPP victim bands – may need more filters on Tx path:

- Harmonic exceptions are usually granted, but harmonics from PC1 could be much higher.

4) B5/n5/B26/n26/B27 eNB Rx blocking from UE Tx power in B5.

5) B85/B12/n12/B17/B66/n66/B71/n71 eNB Rx blocking from UE Tx power in B12.

6) B85/B12/n12/B17/B2/n2/B25/n25/B71/n71 eNB Rx blocking from UE Tx power in n71.

7) Self-desense of B5, B12, and n71 Rx due to PC1 UL Tx power.

c) Considerations in terms of high power user equipment hardware in Band 12, Band 5, and n71:

1) Identify all new RF components needed for B12, B5, and n71, including Power Amplifier, large ceramic duplex filter, switches, possibly antenna tuner.

2) New components will be much larger and produce more heat.

3) Battery power most likely not an option – will need power supply due to high PA current.

4) Modem SW changes needed to support broader power control range, headroom reporting, and higher output power.

d) UE requirements.

The scope of these considered requirements in table 4.2-1 is limited to fixed wireless and vehicle-mounted broadband applications.

Table 4.2-1: Considered UE requirements

|  |  |  |  |
| --- | --- | --- | --- |
| Requirement | LTE Band 12 | LTE Band 5 | NR Band n71 |
| UE Output Power (dBm) | +31dBm +2/-3dB | +31dBm +2/-3dB | +31dBm +2/-3dB |
| 3GPP 36.101 [8] clause 6 Transmitter requirements | Existing Power Class 1 specification | Existing Power Class 1 specification | Existing Power Class 1 specification |
| 3GPP 36.101 clause 7 Receiver requirements | Existing Power Class 1 specification | Existing Power Class 1 specification | Existing Power Class 1 specification |

High power user equipment (power class 1) would require a different RF specification relative to the typical handheld (power class 3) user equipment. The proposal is to study relevant requirements for high power user equipment operation in Band 12, Band 5, and n71, using a framework similar to that specified for high power user equipment operation in Band 14 (700MHz spectrum) in ITU Region 2. These requirements will be captured in the present document.

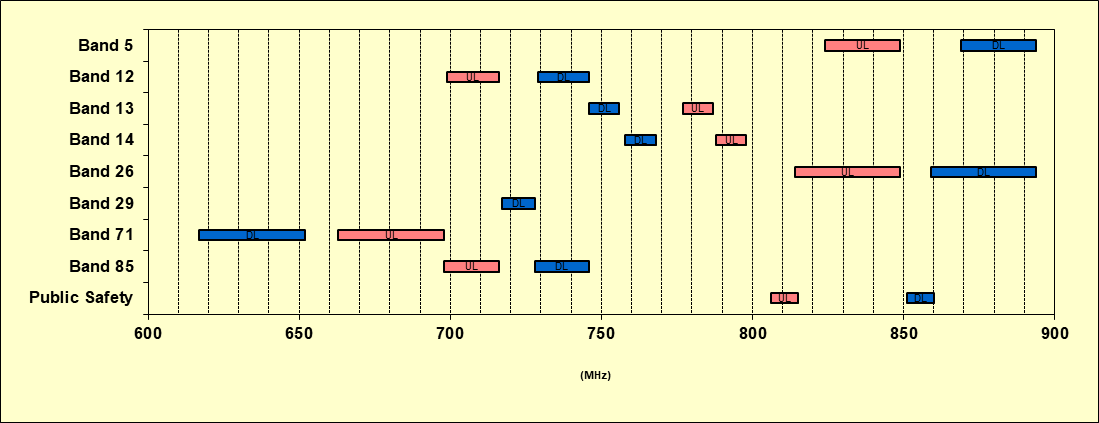
# 5 Co-existence studies

Editor note: This clause the first objective of the study item.

## 5.1 Simulation assumptions

### 5.1.1 General

The band plan within the 600 – 900 MHz frequency range in the USA and the corresponding 3GPP operating bands are shown in figure 5.1.1-1 below.

****

**Figure 5.1.1-1: Band plan within the 600 – 900 MHz frequency range in the USA**

It can be seen from figure 5.1-1 that the coexistence scenarios between a high-power UE aggressor in LTE band 12 and band 5, and in NR band n71 to the adjacent victim bands are much alike to the scenarios between a high-power UE aggressor in band 14 to the adjacent victim bands. Therefore, the simulation assumptions in TR 36.837 [3] for coexistence study of public safety broadband high power UE can be reused in this study.

Moreover, the frequency range of band 14 is approximately in the middle of LTE band 12 and band 5, and in NR band n71, hence the 790 MHz carrier frequency in TR 36.837 can be used for this study and the LTE simulation results in TR 36.837 can be used for reference directly, as the slight change in the carrier frequency should have minor impacts on the simulation results.

For NR operation, it can be seen in TS 38.101-1 [4] that neither band n71 nor its adjacent bands have larger than 20 MHz UE channel bandwidth. Furthermore, it has been agreed in the reply LS to ITU-R WP5D [5] that there is no beamforming assumed for BS and UE below 1.7 GHz. Considering these two factors, the differences between the LTE and NR simulation results will be minor.

For MTC operation, since it is a narrowband LTE operation, the simulation results will be very similar to the LTE results, considering the narrower interference bandwidth (which means less of the adjacent interference will fall into the BS receiver) and noise bandwidth (which means the BS receiver noise floor will be lower). Therefore, the LTE simulation results in TR 36.837 can be used for reference directly for MTC operation.

For NB-IoT operation, the performance metric is SINR degradation instead of throughput loss as recorded in TR 36.802 [6], and the NB-IoT ACIR model in TR 36.802 should be used for simulation of NB-IoT standalone operation. The UE ACLR is the dominant factor here, and it will be scaled down by a factor of 50 (=10/0.2) due to the channel bandwidth difference between the HPUE aggressor and the NB-IoT victim. Here, the standalone NB-IoT operation will be a worse case compared to in-band or guard-band NB-IoT operation considering the internal gap within the 10 MHz LTE channel bandwidth.

Considering the target completion date of this study item, the simulation results are prioritized according to table 5.1.1-1 according to the discussion above.

Table 5.1.1-1: Priorities of simulation results

|  |  |  |  |
| --- | --- | --- | --- |
| Scenario | Aggressor | Victim | Priority |
| UL HPUE Vs NB-IoT standalone operation | HPUE | NB-IoT | High |
| UL HPUE Vs NR / NB-IoT guard band operation (note) | HPUE | NR | Medium |
| UL HPUE Vs LTE / MTC / NB-IoT in-band operation | HPUE | LTE / MTC | Low |
| Note: NB-IoT guard band impact should be checked with the HPUE ACLR agreed from simulation results. | | | |

### 5.1.2 Macro cell Propagation model - Rural Area

The HPUE will be mainly used for extending the coverage in rural areas. The following Hata rural model [7] is used,

L (R)= 69.55 +26.16log10(f)–13.82log10(Hb)+[44.9-6.55log10(Hb)]log(R) – 4.78(log10 (f))2+18.33 log10 (f) -40.94

where:

R is the base station-UE separation in kilometres

f is the carrier frequency in MHz

Hb is the base station antenna height above ground in metres

For carrier frequency of 790MHz and base station antenna height of 45m above the ground, the propagation model becomes:

(1)

Also, per [7], in rural area, Macro cell MCL is 80dB as show in the table 5.1.2-1.

**Table 5.1.2-1: Minimal Coupling Loss**

|  |  |  |
| --- | --- | --- |
| **Environment** | **Scenario** | **MCL** |
| Macro cell Urban Area | BS ↔ UE | 70 dB |
| Macro cell Rural Area | BS ↔ UE | 80 dB |

### 5.1.3 Power control modelling

In [7], the following power control equation is used for the uplink coexistence simulations:

(2)

where *P*max is the maximum transmit power, *R*min is the minimum power reduction ratio to prevent UEs with good channels to transmit at very low power level, *CL* is the coupling loss defined as max{path loss-G\_Tx-G\_Rx, MCL}, where path loss is propagation loss plus shadow fading, G\_TX is the transmitter antenna gain in the direction of the receiver, G\_RX is the receiver antenna gain in the direction of the transmitter and *CLx-*ile is the *x*-percentile *CL* value. With this power control equation, the *x* percent of UEs that have the highest coupling loss will transmit at *P*max. Finally, 0<γ<=1 is the balancing factor for UEs with bad channel and UEs with good channel.

For HPUEs, it is assumed that *R*min has 10 dB more dynamic range. The parameter sets for power control are also specified in [7] and showed here in table 5.1.3-1.

**Table 5.1.3-1: Power control algorithm parameter for 2GHz band**

|  |  |  |
| --- | --- | --- |
| **Parameter set** | **Gamma** | **CLx-ile (10MHz bandwidth)** |
| **0.5km cell range** |
| Set 1 | 1 | 112 |
| Set 2 | 0.8 | 129 |

However, the power control parameters were specified for carrier frequency of 2 GHz with 500 m cell range. The path loss model was based on Urban Hata model below:

(3)

where:

R is the base station-UE separation in kilometres

Based on equations (1), and (3), the power control parameters can be modified to account for different propagation model, carrier frequency, BS antenna height and cell range. For example, in Table 5.1.3-2, CLx-ile = 112 dB for set 1, which corresponds to R = 0.373 km according to equation (3) assuming total antenna gain of 0 dBi. For 4 km cell range at 700 MHz band, using equation (1) will get CLx-ile = 94.5 + 34×log10(4/0.5×0.373) = 111 dB. Similarly, the modified power control parameters for other cases can be obtained as showed in Table 5.1.3-2.

**Table 5.1.3-2: Power control algorithm parameters for 23 dBm UE at 700 MHz band**

|  |  |  |
| --- | --- | --- |
| **Parameter set** | **Gamma** | **CLx-ile (10 MHz bandwidth, 45 m antenna height)** |
| **4 km cell range** |
| Set 1 | 1 | 111 |
| Set 2 | 0.8 | 126 |

For NB-IoT operation, the power control parameters can be modified to account for different bandwidth with bandwidth scale of 17=10×log10(9000/180), as described in TR 36.802 [6]. The modified power control parameters for NB-IoT operation are shown in Table 5.1.3-3.

**Table 5.1.3-3: Power control algorithm parameters for NB-IoT UE at 700 MHz band**

|  |  |  |
| --- | --- | --- |
| **Parameter set** | **Gamma** | **CLx-ile (10 MHz bandwidth, 45 m antenna height)** |
| **4 km cell range** |
| Set 1 | 1 | 128 |

### 5.1.4 Practical considerations for HPUE deployment

The fractional power control formula (2) can be simplified into the following

for (4)

Note that the unit in the formula above is dB. If a UE is close to its serving eNodeB so that , whether it is a 23 dBm UE or a 31 dBm UE, it should transmit similar power and the transmitted power should be less than 23 dBm. The 31 dBm UE extends the cell range by being able to transmit more than 23 dBm power at areas where the 23 dBm UE can only transmit its maximum power of 23 dBm.

Using equation (4) will get and , where denotes the transmit power of a 23 dBm UE at a location with coupling loss , and denotes the transmit power of a 31 dBm UE at a location with the path loss of . Based on the reasoning above, . Hence

(5)

where:

and

Based on equation (5) and table 5.1.3-2, the new power control parameters for HPUE is obtained in table 5.1.4-1.

**Table 5.1.4-1: Power control algorithm parameters for HPUE at 700 MHz band**

|  |  |  |
| --- | --- | --- |
| **Parameter set** | **Gamma** | **CLx-ile (10 MHz bandwidth, 45 m antenna height)** |
| **8 km cell range** |
| Set 1 | 1 | 119 |
| Set 2 | 0.8 | 136 |

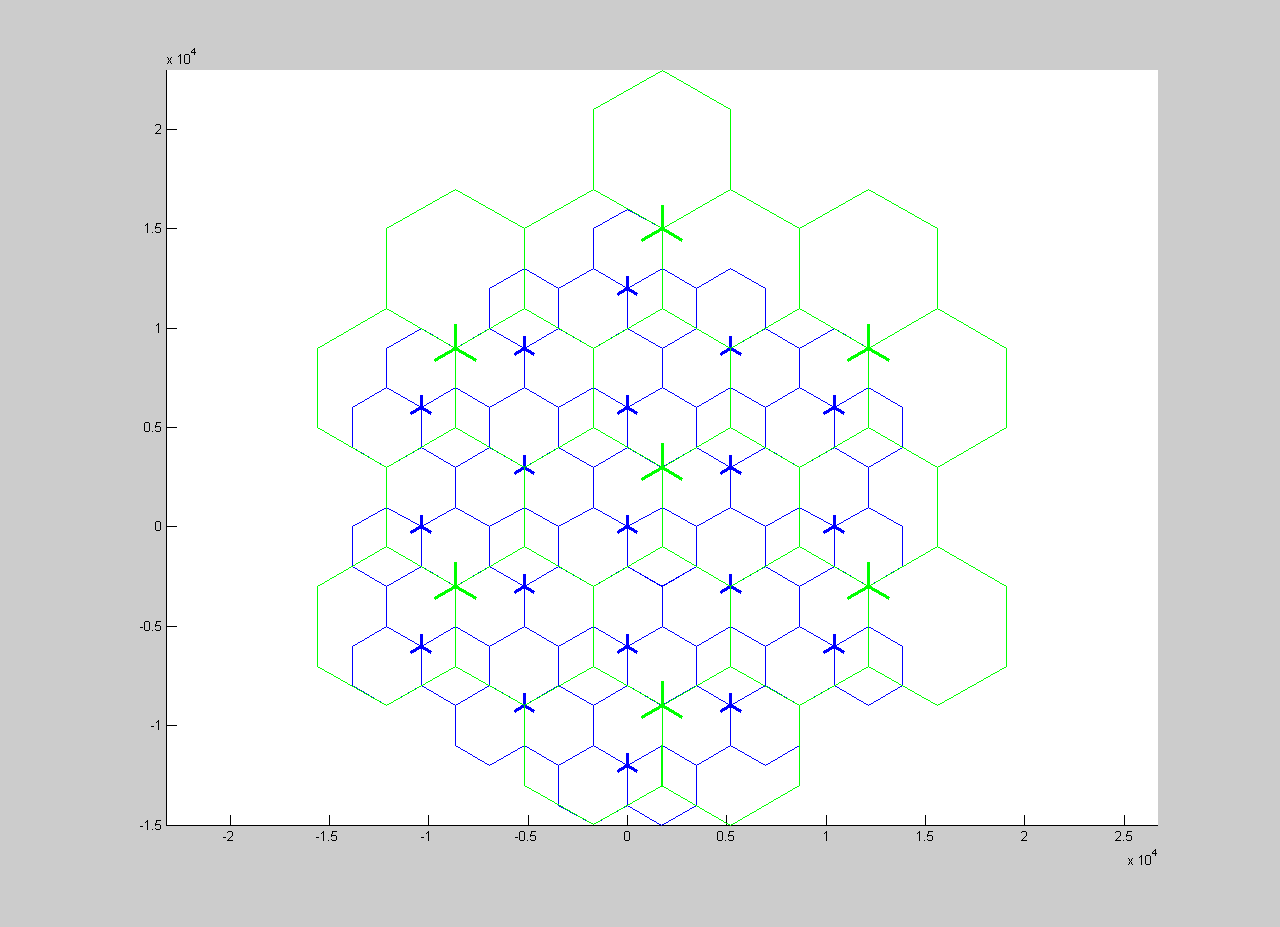
The power control parameters for both aggressor system and victim system are summarized in table 5.1.4-2.

**Table 5.1.4-2: Power control algorithm parameters for UE at 700 MHz band**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Parameter set** | **Gamma** | **CLx-ile (10 MHz bandwidth, 45 m antenna height)** | | |
| **4 km cell range 23 dBm UE** | **4 km cell range NB-IoT UE** | **8km cell range HPUE (31 dBm)** |
| Set 1A | 1 | 111 | 128 | 119 |
| Set 2A | 0.8 | 126 | N/A | 136 |

### 5.1.5 Cell layout

For aggressor system with HPUE, the cell size should be bigger than a victim system with 23 dBm UEs. Figure 5.1.5-1 shows overlay of two systems with different cell ranges. In particular, the cell range of aggressor system (in green) is double the cell range of victim (in blue). Figure 5.1.5-1 shows the worst case in the sense that some of the aggressor sites are located at the cell edge of victim system.

****

**Figure 5.1.5-1 Multi system cell layout with different cell radius**

### 5.1.6 Other simulation assumptions

Other simulation assumptions are summarized in the following tables:

**Table 5.1.6-1: Simulation parameters for aggressor or victim system with 23dBm UE**

|  |  |  |
| --- | --- | --- |
| **Parameter** | **Base Station** | **UE** |
| Carrier frequency | 790 MHz | |
| Channel bandwidth | 10 MHz | |
| Cell range | 4km | |
| Cell layout | Wrap-around 19 tri-sector cells, uncoordinated | |
| Frequency reuse | 1x3x1 | |
| Pathloss model | 94.5+34 log(R), R in km | |
| Lognormal fading | 10 dB | |
| Antenna gain and horizontal antenna pattern | 15 dBi, = 65 degrees,  *Am* = 20 dB | Omni-directional antenna with -6 dBi. |
| Noise figure | 5 dB | 9 dB |
| Transmit power | 46 dBm | 23 dBm |
| Antenna height | 45 m | 1.5 m |
| ACLR | 45 dB | ACLR1: 30+X, ACLR2: 43+X |
| ACS | 45 dB | 33 dB |

**Table 5.1.6-2: Simulation parameters for victim system with NB-IoT UE**

|  |  |  |
| --- | --- | --- |
| **Parameter** | **Base Station** | **UE** |
| Carrier frequency | 790 MHz | |
| Channel bandwidth | 10 MHz | |
| Cell range | 4km | |
| Cell layout | Wrap-around 19 tri-sector cells, uncoordinated | |
| Frequency reuse | 1x3x1 | |
| Pathloss model | 94.5+34 log(R), R in km | |
| Lognormal fading | 10 dB | |
| Antenna gain and horizontal antenna pattern | 15 dBi, = 65 degrees,  *Am* = 20 dB | Omni-directional antenna with -6 dBi. |
| Noise figure | 5 dB | 9 dB |
| Transmit power | 46 dBm | 23 dBm |
| Antenna height | 45 m | 1.5 m |
| ACLR | 45 dB | ACLR1: 37+X, ACLR2: 50+X |
| ACS | 45 dB | 35 dB |

**Table 5.1.6-3: Simulation parameters for aggressor system with HPUE**

|  |  |  |
| --- | --- | --- |
| **Parameter** | **Base Station** | **HPUE** |
| Carrier frequency | 790 MHz | |
| Channel bandwidth | 10 MHz | |
| Cell range | 8km | |
| Cell layout | Wrap-around 7 tri-sector cells, uncoordinated (see Figure 5.1.5-1) | |
| Frequency reuse | 1x3x1 | |
| Pathloss model | 94.5+34log(R), R in km | |
| Lognormal fading | 10 dB | |
| Antenna gain and horizontal antenna pattern | 15 dBi, = 65 degrees, *Am* = 20 dB | Omni-directional antenna  -1dBi for vehicle mounted mobile. |
| Noise figure | 5 dB | 9 dB |
| Transmit power | 46 dBm | 33 dBm/31 dBm |
| Antenna height | 45 m | 1.5 m |
| ACLR | 45 dB | ACLR1: 30+X, ACLR2: 43+X |
| ACS | 45 dB | 33 dB |

### 5.1.7 Simulation procedure

For the co-existence study, the following should be performed:

1) Run the aggressor UL to victim UL coexistence study assuming parameters of both systems are according to Table 5.1.6-1 and with victim UL for NB-IoT UE operation using parameters in Table 5.1.6-2. Power control parameters in Table 5.1.4-2 are used. This corresponds to the coexistence of two commercial 23dBm UEs networks operating in adjacent bands and with similar deployment parameters. This is used as the reference. Victim system performance degradation results in this scenario are used as the baseline.

2) Run the aggressor UL to victim UL coexistence study assuming +31dBm power class UE is deployed in the aggressor system using parameters in Table 5.1.6-3, obtain the victim system performance degradation results. The power control parameters in Table 5.1.4-2 are used.

3) Compare the victim system performance degradation in 2) and 1), choose ACLR value for the HPUE so that the victim performance degradation due to HPUE in 2) is comparable to 1).

## 5.2 Simulation results

### 5.2.1 UL HPUE Vs NB-IoT standalone operation

The simulation results of the victim NB-IoT UE (with 2km cell radius) and interfering UE transmit power with 23dBm LTE UE (with 2km cell radius) and 31dBm HPUE (with 4km cell radius) are provided in Figures 5.2.1-1 and 5.2.1-2 below. Here the uplink ACIR is obtained using 30dB LTE UE and 37dB HPUE ACLR and 45dB BS ACS. It can be seen from the figures that around 8% and 5% of the UE are transmitting at maximum power, respectively, with 23dBm LTE UE and 31dBm HPUE.



Figure 5.2.1-1: NB-IoT and 23dBm LTE UE transmit power



Figure 5.2.1-2: NB-IoT and 31dBm HPUE transmit power

The simulation results of the victim NB-IoT UE UL SINR with 23dBm interfering LTE UE (with 2km cell radius) and 31dBm interfering HPUE (with 4km cell radius) are provided in Figures 5.2.1-3 and 5.2.1-4 below. Here again the uplink ACIR is obtained using 30dB LTE UE and 37dB HPUE ACLR and 45dB BS ACS. It can be seen from the figures that the victim NB-IoT UE UL SINR degradation caused by the 23dBm interfering LTE UE and 31dBm interfering HPUE are similar (within 0.5dB difference). It can also be seen from the figures that the victim NB-IoT UE UL SINR degradation caused by the 31dBm interfering HPUE is less than 1dB at 5%, 50%, 95% and 99% CDF points.



Figure 5.2.1-3: NB-IoT UE UL SINR with 23dBm interfering LTE UE



Figure 5.2.1-4: NB-IoT UE UL SINR with 31dBm interfering HPUE

The simulation results of the victim NB-IoT BS received blocking signal power at the antenna connector with 23dBm interfering LTE UE (with 2km cell radius) and 31dBm interfering HPUE (with 4km cell radius) are provided in Figures 5.2.1-5 and 5.2.1-6 below. The 99.99%-tile received blocking signal power levels are around -56dBm and -48dBm, respectively, with 23dBm interfering LTE UE and 31dBm interfering HPUE. Therefore, the currently specified -43dBm BS receiver blocking requirement can provide enough protection for the NB-IoT BS receiver against the HPUE transmission.



Figure 5.2.1-5: NB-IoT BS received blocking signal power with 23dBm interfering LTE UE



Figure 5.2.1-6: NB-IoT BS received blocking signal power with 31dBm interfering HPUE

To summarize, the simulation results have shown that:

1) The victim NB-IoT UE UL SINR degradation caused by the 23dBm interfering LTE UE and 31dBm interfering HPUE are similar (within 0.5dB difference).

2) The victim NB-IoT UE UL SINR degradation caused by the 31dBm interfering HPUE is less than 1dB at 5%, 50%, 95% and 99% CDF points.

3) The currently specified -43dBm BS receiver blocking requirement can provide enough protection for the NB-IoT BS receiver against the HPUE transmission.

### 5.2.2 UL HPUE Vs NR / NB-IoT guard band operation

The interference leaked from LTE UL to NB-IoT UL (on 3.75kHz subcarrier level) are the average leakage values based on the inputs from several interested companies [9] and provided in Table 5.2.2-1 below [10].

**Table 5.2.2-1: LTE leakage to NB-IoT**

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **LTE to NB-IoT, leakage in dB** | | | | | | | | |
| NB-IoT subcarrier | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| Leakage | -5.38 | -14.87 | -14.69 | -10.43 | -11.99 | -19.59 | -16.56 | -13.54 |
| NB-IoT subcarrier | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
| Leakage | -15.59 | -20.50 | -18.97 | -15.84 | -17.58 | -22.04 | -20.38 | -17.60 |
| NB-IoT subcarrier | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 |
| Leakage | -18.75 | -22.70 | -20.76 | -18.67 | -19.62 | -23.43 | -21.75 | -19.67 |
| NB-IoT subcarrier | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 |
| Leakage | -19.98 | -23.72 | -22.52 | -20.82 | -20.65 | -24.57 | -23.82 | -21.37 |
| NB-IoT subcarrier | 32 | 33 | 34 | 35 | 36 | 37 | 38 | 39 |
| Leakage | -21.02 | -25.10 | -24.10 | -22.03 | -21.71 | -25.57 | -25.2.12 | -21.84 |
| NB-IoT subcarrier | 40 | 41 | 42 | 43 | 44 | 45 | 46 | 47 |
| Leakage | -21.76 | -25.83 | -26.69 | -22.05 | -22.07 | -26.49 | -27.00 | -22.33 |

The simulation results of the victim NB-IoT UE (with 2km cell radius) and interfering UE transmit power with 23dBm LTE UE (with 2km cell radius) and 31dBm HPUE (with 4km cell radius) are provided in Figures 5.2.2-1 and 5.2.2-2 below. It can be seen from the figures that around 8% and 5% of the interfering UE are transmitting at maximum power, respectively, with 23dBm LTE UE and 31dBm HPUE.



**Figure 5.2.2-1: NB-IoT and 23dBm LTE UE transmit power**

****

**Figure 5.2.2-2: NB-IoT and 31dBm HPUE transmit power**

The simulation results of the victim NB-IoT UE UL SINR with 23dBm interfering LTE UE (with 2km cell radius) and 31dBm interfering HPUE (with 4km cell radius) are provided in Figures 5.2.2-3 and 5.2.2-4 below. It can be seen from the figures that the victim NB-IoT UE UL SINR degradation caused by the 23dBm interfering LTE UE and 31dBm interfering HPUE are similar (within 1.5dB difference).



**Figure 5.2.2-3: NB-IoT UE UL SINR with 23dBm interfering LTE UE**

****

**Figure 5.2.2-4: NB-IoT UE UL SINR with 31dBm interfering HPUE**

The victim NB-IoT UE UL SINR degradation caused by the 23dBm interfering LTE UE and 31dBm interfering HPUE at 5%, 50%, 95% and 99% CDF points are summarized in Table 5.2.2-2 below. It can be seen from the table that the victim NB-IoT UE UL SINR degradation caused by the 23dBm interfering LTE UE and 31dBm interfering HPUE have 1.5dB, 0.6dB, 0.3dB and 0.3dB differences, respectively, at 5%, 50%, 95% and 99% CDF points.

**Table 5.2.2-2: NB-IoT UE UL SINR loss at different CDF points**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Interfering UE maximum output power (dBm)** | **NB-IoT UE UL SINR loss at 5% (dB)** | **NB-IoT UE UL SINR loss at 50% (dB)** | **NB-IoT UE UL SINR loss at 95% (dB)** | **NB-IoT UE UL SINR loss at 99% (dB)** |
| 23 | 1.5 | 0.9 | 1.1 | 1.1 |
| 31 | 3 | 1.5 | 1.4 | 1.4 |

To summarize, the simulation results have shown that:

1) The victim NB-IoT UE UL SINR degradation caused by the 23dBm interfering LTE UE and 31dBm interfering HPUE are similar (within 1.5dB difference).

2) The 31dBm interfering HPUE generate 1.5dB, 0.6dB, 0.3dB and 0.3dB (respectively, at 5%, 50%, 95% and 99% CDF points) additional UL SINR degradation to NB-IoT UE UL SINR comparing to the 23dBm interfering LTE UE.

It should be noted that this evaluation is done considering a worst case deployment, where the NB-IoT PRB is adjacent to LTE PRBs, which might not always be the case depending on the considered LTE channel BW and if NB-IoT carrier is an anchor carrier or not. Moreover, as the NB-IoT subcarriers are located within the operator’s own spectrum, it is expected that the operator will handle the UL SINR degradation using mitigation techniques like improved filtering or internal gap between the NB-IoT and LTE subcarriers.

5.3 Coexistence with Public Safety

For Public Safety operation, it is uncertain whether coexistence simulation would be carried out within the time frame of this study item, as RAN4 has not carried out coexistence simulation with Public Safety system and thus the simulation assumptions and methodology will need to be investigated from inception. The impact on Public Safety downlink at 851-861 MHz can be accessed using analysis.

# 6 UE operation

Editor note: This clause the second objective of the study item.

## 6.1 UE transmitter third harmonic

Table 1 presents UL harmonic analysis based on UE to UE co-existence tables in 36.101 and 38.101-1. Table is not exhaustive presentation. It can be seen that newly proposed band 2 has 2nd harmonic landing on bands 50 and 51 and 3rd and 5th order harmonics interfering some bands. Band 5 has 3rd and 4th order harmonics interfering some bands and n71 has 3rd, 4th and 5th harmonic relation with some bands. However as can been also seen from Table 1 already existing PC1 bands 3, 14, 20 and 28 have also 2nd, 3rd, 4th and 5th order harmonics interfering other bands and no additional requirement or relaxations is specified due to that. Therefore, it is justified that for bands 5, 12 and n71 the introduction of PC1 does not create any additional requirements or relaxations due to uplink harmonics.

Table 1: UL harmonic analysis

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | 2nd harmonic | 3rd harmonic | 4th harmonic | 5th harmonic |
| Band 3 | 22, 42, 52, n77, n78 |  |  |  |
| Band 5 |  | 41, 52 | n77, n78 |  |
| Band 12 | 50, 51 | 4, 66 |  | n77 |
| Band 14 |  |  |  | n77 |
| Band 20 |  | 38, 69 | 42, 52, n77, n78 |  |
| Band 28 | 32, 50, 51,74 | 1, 4, 66 |  | 42, n77,n78 |
| Band n71 |  | 2, 25, 70 | 41 | n77 |

## 6.2 BS receiver blocking

## 6.3 UE self-dense

Only receiver requirement that has been defined for PC1 UE is the exception due to the high-power leakage or blocking issue for band 20, see Table 7.3.1-1b below. From [12] we can learn that REFSENS exception due to PC1 operation relates IQ-image and carrier leakage components distorting on the PA and 5th order IM products hit on own Rx band. In PC3 operation this is handled with NS-10 and with special UL allocation during REFSENS test which avoids MSD.

**Table 7.3.1-1b: Reference sensitivity for power class 1 QPSK PREFSENS (Exception due to high power issue)**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Channel bandwidth** | | | | | | | |
| **E-UTRA Band** | **1.4 MHz (dBm)** | **3 MHz (dBm)** | **5 MHz (dBm)** | **10 MHz (dBm)** | **15 MHz (dBm)** | **20 MHz (dBm)** | **Duplex Mode** |
| 20 |  |  | -92.8 | -90.9 | -89.5 | -88.5 | FDD |
| NOTE 1: The transmitter shall be set to PUMAX as defined in subclause 6.2.5  NOTE 2: Reference measurement channel is A.3.2 with one sided dynamic OCNG Pattern OP.1 FDD/TDD as described in Annex A.5.1.1/A.5.2.1  NOTE 3: The signal power is specified per port. | | | | | | | |

This relaxation has not been defined for other PC1 bands such as 3, 14, 28, 31, 72, 87 and 88.

In Figure1 existing PC1 bands 14, 20 and 28 are compared to new PC1 bands 5, 12 and n71. Uplink channel edge separation to downlink channel edge is presented pictorially and a figure of merit (FOM) is calculated as CH BW / (ULedge to DLedge separation) then bands are ranked based on this FOM to determine if current PC3 REFSENS can be met in PC1 operation.

As can be seen from Fig 6.3-1 band 20 ranks the most difficult and as mentioned earlier there is REFSENS exception specified due to this. Easiest is the band 5 in this context and given that band 14 does not have specified exception it is clear that band 5 does not need it either.

From Fig 6.3-1 ranking and FOM perspective there is a need to study if band n71 needs REFSENS exception due to PC1 operation. Bands 28 and n71 are both based on dual duplexer architecture and band 28 does not have exception but FOM is on the other hand lower 0.6 compared to 0.8 for n71.

Then when studying the band 12 it can be seen that the FOM is 0.5 which is same as band 14 which does not have REFSENS exception specified however band 14 has seven MHz wider duplex-gap which helps filters to reach adequate attenuation. Current PC1 band 28 does not have exception and it has higher FOM of 0.6 compared to band 12. One thing that helps band 28 is that specification assumes 2x30 MHz filtering which gives extra 15 MHz compared to duplex gap to settle. Given the difficulty ranking and keeping in mind the band 28 dual-duplexer arrangement it may be considered that no REFSENS exception is needed for band 12 in PC 1 operation.



## Figure 6.3-1: PC16.4 Modem SW changes

# 7 UE hardware

Editor note: This clause the third objective of the study item.

## 7.1 New RF components

During Rel-11 when band 14 PC1 requirements were developed Technical report Public safety broadband high power User Equipment (UE) for band 14 [3] and a contribution [11] discussed necessary hardware changes to realize PC1 vehicular mobile form factor compared to PC3 normal handheld formfactor. These studies in [3][11] are considered to be relevant also to this WI targeting high-power UE operation for fixed-wireless/vehicle-mounted use cases in LTE bands 5 and 12 and NR band n71.

Main take away from [3][11] is that in order to minimize implementation complexity and utilize the Power Class 3 eco-system it was considered that changes to the baseband IC and RF IC should be avoided and only changes to the discrete RF combining front end elements are considered. This manifests mainly to need of frontend filters with better power handling capabilities. Suitable technologies mentioned were ceramic-filters and cavity-filters. Furthermore power amplifiers that are capable for PC1 operation are obviously necessity. Few filter examples are presented below with input power capabilities of 43 dBm which obviously in more than needed for PC1 operation even considering the post PA-losses but this demonstrates that capable technology is available.

Band 5 duplex-filter [UMD005A (ctscorp.com)](https://www.ctscorp.com/wp-content/uploads/UMD005A.pdf)

## Band 12 duplex-filter [UMD012A (ctscorp.com)](https://www.ctscorp.com/wp-content/uploads/UMD012A.pdf)7.2 Components size and heat

Components for PC1 are larger especially the ceramic filters and produce more heat especially the power amplifier. But as the formfactors in question are not handheld devices, instead target is FWA (for example customer premise equipment) or a vehicular use then these issues are manageable.

## 7.3 Power supply

Given the target form factors the end products are not intended to run on battery power.

# 8 UE requirements

Editor note: This clause the fourth objective of the study item.

## 8.1 UE Output Power

In order a band to have PC1 operation possible power class needs to be captured into Table 6.2.2-1 or Table 6.2.1-1 in specifications 36.101 and 38.101-1 respectively. LTE specification has also *NOTE 8: Generally, PC1 UE is not targeted for smartphone form factor* associated for PC1 operation but NR specification does not have this note. Tolerance is band agnostic +2/-3 therefore necessary changes are highlighted in yellow. (Note to keep table shorter many bands are not listed)

Table 6.2.2-1: UE Power Class

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| EUTRA band | Class 1 (dBm) | Tolerance (dB) | Class 2 (dBm) | Tolerance (dB) | Class 3 (dBm) | Tolerance (dB) | Class 4 (dBm) | Tolerance (dB) |
| 1 |  |  |  |  | 23 | ±2 |  |  |
| 2 |  |  |  |  | 23 | ±22 |  |  |
| 3 | 31 | +2/-3 |  |  | 23 | ±22 |  |  |
| 4 |  |  |  |  | 23 | ±2 |  |  |
| 5 | 31 | +2/-3 |  |  | 23 | ±2 |  |  |
| 6 |  |  |  |  | 23 | ±2 |  |  |
| 11 |  |  |  |  | 23 | ±2 |  |  |
| 12 | 31 | +2/-3 |  |  | 23 | ±22 |  |  |
| 13 |  |  |  |  | 23 | ±2 |  |  |
| 14 | 31 | +2/-3 |  |  | 23 | ±2 |  |  |
|  |  |  |  |  |  |  |  |  |
| 19 |  |  |  |  | 23 | ±2 |  |  |
| 20 | 31 | +2/-3 |  |  | 23 | ±22 |  |  |
| 21 |  |  |  |  | 23 | ±2 |  |  |
| 27 |  |  |  |  | 23 | ±2 |  |  |
| 28 | 31 | +2/-3 |  |  | 23 | +2/-2.5 |  |  |
| 30 |  |  |  |  | 23 | ±2 |  |  |
| 31 | 31 | +2/-3 |  |  | 23 | ±2 |  |  |
| … |  |  |  |  |  |  |  |  |
| 72 | 31 | +2/-3 |  |  | 23 | ±2 |  |  |
| 73 |  |  |  |  | 23 | ±2 |  |  |
| 85 |  |  |  |  | 23 | ±22 |  |  |
| 87 | 31 | +2/-3 |  |  | 23 | ±2 |  |  |
| 88 | 31 | +2/-3 |  |  | 23 | ±2 |  |  |
| NOTE 8: Generally, PC1 UE is not targeted for smartphone form factor. | | | | | | | | |

Table 6.2.1-1: UE Power Class

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| NR  band | Class 1 (dBm) | Tolerance (dB) | Class 1.5 (dBm) | Tolerance (dB) | Class 2 (dBm) | Tolerance (dB) | Class 3 (dBm) | Tolerance (dB) |
| n8 |  |  |  |  |  |  | 23 | ±23 |
| n12 |  |  |  |  |  |  | 23 | ±23 |
| n14 | 31 | +2/-3 |  |  |  |  | 23 | ±23 |
| n18 |  |  |  |  |  |  | 23 | ±2 |
| n71 | 31 | +2/-3 |  |  |  |  | 23 | +2/-2.5 |
| NOTE 1: PPowerClass is the maximum UE power specified without taking into account the tolerance  NOTE 2: Powerclass 3 is default power class unless otherwise stated  NOTE 3: Refers to the transmission bandwidths confined within FUL\_low and FUL\_low + 4 MHz or FUL\_high – 4 MHz and FUL\_high, the maximum output power requirement is relaxed by reducing the lower tolerance limit by 1.5 dB.  NOTE 4: The maximum output power requirement is relaxed by reducing the lower tolerance limit by 0.3 dB  NOTE 5: Achieved via dual Tx | | | | | | | | |

## 8.2 Transmitter requirements

### 8.2.1 UE maximum output power for CA

In 6.2.2A of 36.101 there is a sentence

For inter-band carrier aggregation with one uplink component carrier assigned to one E-UTRA band in Band 3, 20, 28, or 31, the requirements for power class 1 are not applicable and the corresponding requirements for a power class 3 UE shall apply.

Therefore, there may be a need to add bands 5 and 12 into the list, as an observation not all PC 1 bands are listed currently. NR specification does not have such a list but currently only n14 is valid for NR PC1 and it is not mentioned in E-UTRA list either.

### 8.2.2 UE maximum output power for modulation / channel bandwidth

LTE MPR is defined to be power class agnostic hence no changes are required.

NR MPR clause does not mention PC1 applicability even though n14 PC 1 is already specified. Following E-UTRA approach NR MPR could be also valid for PC1.

### 8.2.3 UE maximum output power with additional requirements

LTE A-MPR is defined to be valid also for PC1

NR A-MPR clause does not mention if A-MPR is valid for PC1 but currently only valid NR PC1 band is n14 and it does not have A-MPR defined. Neither has n71 but it would be necessary to discuss if PC1 needs A-MPR for band n71.

### 8.2.4 ACLR

E-UTRAACLR is already defined for PC1 in Table 6.6.2.3.1-2 hence no changes are required.

In 36.101 it is stated that UTRAACLR is not applicable to the power class 1 UE operating in Band 3, 20, 28, 31 or 72.

NR ACLR requirement does not mention PC1. E-UTRA PC1 ALCR of 37 dB could be re-used in NR specification.

## N71 does not have UTRA operation hence no UTRAACLR requirement is needed.8.3 Receiver requirements

Apart from possible REFSENS exception which is discussed in clause 6.3 no receiver requirements are needed for PC1.

Annex A (informative):  
Change history

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Change history** | | | | | | | |
| **Date** | **Meeting** | **TDoc** | **CR** | **Rev** | **Cat** | **Subject/Comment** | **New version** |
| 2020-08 | RAN4#96-e | R4-2011219 |  |  |  | Skeleton TR | 0.0.1 |
| 2020-10 | RAN4#97-e | R4-2014479 |  |  |  | Implement approved TP in RAN4#96-e: R4-2011833, and editorial suggestions from ETSI editHelp. | 0.1.0 |
| 2021-01 | RAN4#98-e | R4-2101799 |  |  |  | Implement approved TP in RAN4#97-e: R4-2016934. | 0.2.0 |
| 2021-02 | RAN4#98-e | R4-2103283 |  |  |  | Implement approved TP in RAN4#98-e: R4-2100131, R4-2103284. | 0.3.0 |