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| Technical Report |
| 3rd Generation Partnership Project;Technical Specification Group Radio Access Networks;Study on high power UE (power class 2) for one NR FDD band(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:

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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.

# 1 Scope

The present document is a technical report for Study on high power UE (power class 2) for one NR FDD band. The study includes the SAR scheme(s), interference issues, UE implementation issues, and system performance evaluations.

The example bands used for the study are NR band n1 and n3.

# 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 TS 38.101-1: "NR; User Equipment (UE) radio transmission and reception; Part 1: Range 1 Standalone".

[3] 3GPP R4-2111528: "n3 50MHz REFSENS, A-MPR". 3GPP RAN WG4 Meeting#99-e, Skyworks Solutions, Inc.

[4] 3GPP R4-2114695: "n3 PC2 MSD". 3GPP RAN WG4 Meeting#100-e, Skyworks Solutions, Inc.

[5] 3GPP R4-2112834: "Sensitivity analysis results and UE implementation for PC2 FDD band ". 3GPP RAN WG4 Meeting#100-e, LG Electronics.[6] 3GPP R4-2112911: "Discussion on interference for HPUE FDD band ". 3GPP RAN WG4 Meeting#100-e, ZTE Corporation.

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[x] <doctype> <#>[ ([up to and including]{yyyy[-mm]|V<a[.b[.c]]>}[onwards])]: "<Title>".

# 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].

<ABBREVIATION> <Expansion>

# 4 Background

## 4.1 Justification

Increasing the transmit power of UE has significant benefits on extending cell coverage area and improving the experience of cell edge users. In rel-16 one study item and two work items related to HPUE have been proposed and worked on to standardize the requirements for EN-DC scenarios.

However, extension of cell coverage for lower-frequency NR SA FDD band is also important for some operators considering data throughput for cell edge users is not satisfactory even in FDD bands, and further increasing the UE transmit power would be beneficial for improving the performance of cell edge users. Increasing the transmission power will be beneficial for extending uplink coverage. SAR compliance schemes should be considered (e.g. Existing duty cycle based solution could be taken into consideration for this study, other solutions are not precluded.).

This Study Item is proposed to solve SAR issues, and potentially enable Power Class 2 UE for one FDD band with 26 dBm maximum output power (UE types include smart phone, FWA, etc.). NR band n1 and n3 shall be used as example band for this study.

## 4.2 Objective

The objectives of the SI are as follows:

1 Study the applicable scheme(s) for new power class 2 UE for one NR FDD band to comply with the SAR limits with 26dBm UE Tx power, the example band for this study is NR band n1 and n3.

a. Study candidate SAR solutions, e.g. P-MPR, duty cycle capability, etc.

b. Study regulatory requirements related to 26dBm Tx power in FDD bands including SAR.

Note: Prioritize studies for the existing SAR solutions.

2 Study interference issues (e.g. self-desense, cross device coexistence…).

a. Study RF requirements for PC2 UE in FDD band, including self-desense requirements, Tx requirements such as A-MPR, and so on.

b. Study adjacent channel co-existence for FDD band.

c. Investigate issues related to in-device interference, if identified.

3 Study UE implementation related issues such as RF component feasibility to support 26dBm output power in band n1 and n3 at first. Other example FDD bands are not precluded, if needed.

Evaluate system performance gains on spectrum efficiency, and other metrics if needed could also be taken into account, to support NR FDD HPUE.

# 5 SAR Scheme

To accommodate the SAR limits of the NR PC2 FDD High Power UE, both UE-based and network-based solutions are considered in the study phase. For UE-based solution, the UE implementation based mechanism is used to ensure SAR compliance. In addition to UE-based solution, an optional method of reporting duty-cycle capability was also intensively discussed, but there is no conclusion reached.

# 6 Interference

## 6.1 Receiver sensitivity degradation evaluation

Based on following agreement, RAN4 need to evaluate the receiver sensitivity degradation impact in NR band n1 and n3.

* Agreement: RAN4 can study receiver sensitivity degradation due to high max. out power and Tx/Rx isolation levels according to RF component performance in both n1 and n3 FDD bands.
* Companies are encouraged to bring analyses on receiver sensitivity degradation in next meeting.

### Sensitivity degradation results for normal CBW in n1/n3

To derive sensitivity degradation in n1/n3, RAN4 assumed the current RFIC characteristics and Duplexer & PA characteristics in each NR band.

In Table 6.1.1-1, the current RF component characterics are summaried according to each NR band.

**Table 6.1.1-1. RF parameters according to each NR band**

|  |  |  |
| --- | --- | --- |
| parameters | NR n1 band | NR n3 band |
| Total NF (dB) | 9.00 | 9.00 |
| RFIC Noise for Rx band (dBm/Hz) | -153 | -150 |
| PA Noise for Rx band (dBm/Hz) | -125 | -122 |
| PA Gain for Rx band (dB) | 28 | 28 |
| Duplexer Tx/Rx isolation (dB) | 53 | 49 |
| RF Front-End Loss (dB) | 4 | 4 |
| Diversity gain (dB) | 3 | 3 |
| Antenna isolation (dB) | 10 | 10 |

The receiver sensitivity will be impacted by duplexer isolation levels and increasing noise level by RFIC and PA for Rx band at antenna connector based on PC3 REFSENS requirements in each FDD bands.

Hence, the receiver sensitivity degradation will be derived based on the increasing noise level in Rx band by duplexer isolation and RFIC/PA noise for PC2 transmission in FDD band.

The following REFSENS is for PC3 UE in n3 FDD NR band as reference point.

**Table 6.1.1-2. REFSENS reference for PC3 UE in each NR band**

|  |  |  |
| --- | --- | --- |
|  | NR n1 band | NR n3 band |
|  | Main path | Diversity path | Main path | Diversity path |
| C/N requirement (dB) | -1.00 | -1.00 | -1.00 | -1.00 |
| Noise floor at Antenna connector(dBm/Hz) | -165.0 | -165.0 | -165.0 | -165.0 |
| Total NF(RFFE lL + RF NF) (dB) | 9.00 | 9.00 | 9.00 | 9.00 |
| RFIC RX Band Noise level at Antenna connector (dBm/Hz) | -170.5 | -180.5 | -161.5 | -171.5 |
| PA RX Band Noise level at Antenna connector (dBm/Hz) | -170.5 | -180.5 | -161.5 | -171.5 |
| Total RXBN at Antenna connector (dBm/Hz) | -163.1 | -164.7 | -157.6 | -163.4 |
| **Sensitivity with RXBN (PC3 max Tx power)(dBm) \*10MHz BW** | -94.1 | -95.7 | -88.6 | -94.4 |
| **After MRC** | -98.0 (1.2dB margin) | -95.4 (1.6dB margin) |

#### Dominant factor by Duplexer Tx/Rx isolation in each FDD band

Basically, the existing PA for FDD band need to improve the linearity of maximum output power at least 3dB higher than current PA characteristics based on section 7. Also duplexer aspect, filter vendor need to enhanced the Tx/Rx isolation level to guarantee the existing REFSENS or to relax desense impact. But it is also challenge to filter vendors for small Tx/Rx frequency gap such as Band 3 or NR band n3.

So, just asumed 2dB Tx/Rx isolation levels by 3dB Transmission power increasing would be impacted the sensitivity degradation compare to PC3 duplexer in n3.

In Table 6.1.1.1-1, the expected sensitivity degradation levels by decreasing 2dB duplexer isolation level are shown.

**Table 6.1.1.1-1. Sensitivity degradation by duplexer isolation 2dB relaxation**

|  |  |  |
| --- | --- | --- |
|  | NR n1 band | NR n3 band |
|  | Main path | Diversity path | Main path | Diversity path |
| C/N requirement (dB) | -1.00 | -1.00 | -1.00 | -1.00 |
| Noise floor at Antenna connector(dBm/Hz) | -165.0 | -165.0 | -165.0 | -165.0 |
| Total NF(RFFE lL + RF NF) (dB) | 9.00 | 9.00 | 9.00 | 9.00 |
| RFIC RX Band Noise level at Antenna connector (dBm/Hz) | -168.5 | -178.5 | -159.5 | -169.5 |
| PA RX Band Noise level at Antenna connector (dBm/Hz) | -168.5 | -178.5 | -159.5 | -169.5 |
| Total RXBN at Antenna connector (dBm/Hz) | -162.2 | -164.6 | -155.9 | -162.6 |
| Sensitivity with RXBN (PC3 max Tx power)(dBm) \*10MHz BW | -93.2 | -95.6 | -86.9 | -93.6 |
| After MRC | -97.6 dBm 🡪 0.4dB MSD is needed | -94.5 dBm 🡪 0.9dB MSD is needed |

**Observation: In n3 FDD band, the 0.9 dB MSD is needed when Duplexer isolation charateristic is decreased 2dB compare to current filter characteristics.**

**Observation: In n1 FDD band, the 0.4dB MSD is needed when Duplexer isolation charateristic is decreased 2dB compare to current filter characteristics.**

#### Dominant factor by RFIC/PA noise levles in Rx band

In this section, we consider the increased noise level in Rx band by RFIC/PA operation in FDD band. Eventhough filter vendor try to keep or enhance the the current Tx/Rx isolation level in duplexer for each FDD band, the raised leakage problem in Rx band also shall be considered.

**Observation: Eventhough duplexer isolation level keep or enhance the Tx/Rx isolation level, the raised leakage problem in Rx band by RFIC/PA operation in FDD band will be impacted to the sensitivity degradation in FDD band.**

When we consider 3dB Tx power boosting, the noise level could be increased by RFIC/PA operation in Rx band. So we assumed about 1.5dB noise level increasing in Rx band to derive the expected MSD level according to each FDD band.

**Table 6.1.1.2-1. Sensitivity degradation by increasing noise level (1.5dB) by RFIC/PA in Rx band**

|  |  |  |
| --- | --- | --- |
|  | NR n1 band | NR n3 band |
|  | Main path | Diversity path | Main path | Diversity path |
| C/N requirement (dB) | -1.00 | -1.00 | -1.00 | -1.00 |
| Noise floor at Antenna connector(dBm/Hz) | -165.0 | -165.0 | -165.0 | -165.0 |
| Total NF(RFFE lL + RF NF) (dB) | 9.00 | 9.00 | 9.00 | 9.00 |
| RFIC RX Band Noise level at Antenna connector (dBm/Hz) | -169.0 | -179.0 | -160.0 | -170.0 |
| PA RX Band Noise level at Antenna connector (dBm/Hz) | -169.0 | -179.0 | -160.0 | -170.0 |
| Total RXBN at Antenna connector (dBm/Hz) | -162.4 | -164.7 | -156.4 | -162.9 |
| Sensitivity with RXBN (PC3 max Tx power)(dBm) \*10MHz BW | -93.4 | -95.7 | -87.4 | -93.9 |
| After MRC | -97.7 dBm 🡪 0.3dB MSD is needed | -94.7 dBm 🡪 0.7dB MSD is needed |

The expected MSD degradations are almost same as Duplexer isolation degradation as shown in Table 6.1.1.1.

**Observation: In n3 FDD band, the 0.7 dB MSD is needed when assume noise level might be increased about 1.5dB in Rx band by RFIC/PA operation.**

**Observation: In n1 FDD band, the 0.3dB MSD is needed when assume noise level might be increased about 1.5dB in Rx band by RFIC/PA operation.**

#### Dominant factor by Duplexer and RFIC/PA noise levles in Rx band

In here we consider worst case for MSD analysis that means the duplexer isolation could not keep and enhanced such as in n3 FDD band due to small Tx/Rx frequency gap.

Then, above Duplexer performance decreasing and the noise level in Rx band will be increased in RFIC by 3dB Tx power increasing for PC2 UE in FDD band. So, the above two factor will be impacted in the receiver sensitivity degradation in FDD band.

In Table 6.1.1.3-1, we provided the expected sensitivity degradation by considering the duplexer characteristics and incresed noise level in Rx band by RFIC/PA operation.

**Table 6.1.1.3-1. Sensitivity degradation by duplexer isolation (2dB relaxation) & incresed noise level (1.5dB) in Rx band by RFIC/PA operation**

|  |  |  |
| --- | --- | --- |
|  | NR n1 band | NR n3 band |
|  | Main path | Diversity path | Main path | Diversity path |
| C/N requirement (dB) | -1.00 | -1.00 | -1.00 | -1.00 |
| Noise floor at Antenna connector(dBm/Hz) | -165.0 | -165.0 | -165.0 | -165.0 |
| Total NF(RFFE lL + RF NF) (dB) | 9.00 | 9.00 | 9.00 | 9.00 |
| RFIC RX Band Noise level at Antenna connector (dBm/Hz) | -167.0 | -177.0 | -158.0 | -168.0 |
| PA RX Band Noise level at Antenna connector (dBm/Hz) | -167.0 | -177.0 | -158.0 | -168.0 |
| Total RXBN at Antenna connector (dBm/Hz) | -161.5 | -164.5 | -154.6 | -162.0 |
| Sensitivity with RXBN (PC3 max Tx power)(dBm) \*10MHz BW | -92.5 | -95.5 | -85.6 | -93.0 |
| After MRC | -97.2 dBm 🡪 0.8dB MSD is needed | -93.7 dBm 🡪 1.7dB MSD is needed |

Based on the expected RF component degradation, observations are provided as follow

**Observation: In n3 FDD band, the 1.7 dB MSD is needed when both Duplexer isolation charateristic (2dB relaxation) and increased noise level (1.5dB) in Rx band by RFIC/PA operation for PC2 FDD UE.**

**Observation: In n1 FDD band, the 0.8dB MSD is needed when both duplexer isolation charateristic (2dB relaxation) and increased noise level (1.5dB) in Rx band by RFFIC/PA operation for PC2 FDD UE.**

### Wide channel bandwidth sensitivity analysis in n3

For the wide channel bandwidth (CBW) in n3 NR band, RAN4 need study the sensitivity degradation to consider the counter IMD problem such as CIM5 impact in n3 received frequency band as shown in Figure 6.1.2-1.

**Figure 6.1.2-1 Impact on the CIMD5 problem in n3 NR band**

#### LGE sensitivity analysis results in n3

To derive sensitivity degradation in n3 with wide CBW, we assumed the following as shown in Table 6.1.2.1-1.

**Table 6.1.2.1-1. RF parameters according to each NR band**

|  |  |
| --- | --- |
| parameters | NR n3 band |
| Total NF (dB) | 9.00 |
| counter-intermodulation products CIM5 (dBc) | -60 |
| RFIC Noise for Rx band (dBm/Hz) | -150 |
| PA Noise for Rx band (dBm/Hz) | -122 |
| PA Gain for Rx band (dB) | 28 |
| Duplexer Tx/Rx isolation (dB) | 47 |
| RF Front-End Loss (dB) | 4 |
| Diversity gain (dB) | 3 |
| Antenna isolation (dB) | 10 |

The receiver sensitivity will be impacted by duplexer isolation levels and increasing noise level by RFIC and PA for Rx band at antenna connector based on PC3 REFSENS requirements in each CBW.

Hence, the receiver sensitivity degradation will be derived based on the increasing noise level in Rx band by duplexer isolation and RFIC/PA noise due to CIM5 from PC2 transmission in FDD band.

The following REFSENS analysis is for PC3 UE in n3 FDD NR band with 40Mhz and 50MHz CBW as reference point.

**Table 6.1.2.1-2. REFSENS reference for PC3 FDD UE in each CBW(40MHz, 50MHz)**

|  |  |  |
| --- | --- | --- |
|  | NR n3 band40MHz CBW | NR n3 band50MHz CBW |
|  | Main path | Diversity path | Main path | Diversity path |
| C/N requirement (dB) | -1.0  | -1.0  | -1.0  | -1.0  |
| Noise floor at Antenna connector(dBm/Hz) | -165.0  | -165.0  | -165.0  | -165.0  |
| Total NF(RFFE lL + RF NF) (dB) | 9.0  | 9.0  | 9.0  | 9.0  |
| CIM5 at Antenna connector (dBm/Hz) | -152.5  | -162.5  | -150.5  | -160.5  |
| RFIC RX Band Noise level at Antenna connector (dBm/Hz) | -161.5  | -171.5  | -161.5  | -171.5  |
| PA RX Band Noise level at Antenna connector (dBm/Hz) | -161.5  | -171.5  | -161.5  | -171.5  |
| Total RXBN at Antenna connector (dBm/Hz) | -151.3  | -159.9  | -149.7  | -158.7  |
| Sensitivity with RXBN (PC3 max Tx power)(dBm/CBW)  | -76.3  | -84.9 | -73.7  | -82.7  |
| After MRC | -85.5 (3.2dB margin) | -83.2 (3.5dB margin) |

In Table 6.1.2.1-3, we provided the expected sensitivity degradation to consider the counter IMD problem in wide CBW for PC2 UE for n3 band.

**Table 6.1.2.1-3. Sensitivity degradation for PC2 FDD UE in each CBW(40MHz, 50MHz)**

|  |  |  |
| --- | --- | --- |
|  | NR n3 band40MHz CBW | NR n3 band50MHz CBW |
|  | Main path | Diversity path | Main path | Diversity path |
| C/N requirement (dB) | -1.0  | -1.0  | -1.0  | -1.0  |
| Noise floor at Antenna connector(dBm/Hz) | -165.0  | -165.0  | -165.0  | -165.0  |
| Total NF(RFFE lL + RF NF) (dB) | 9.0  | 9.0  | 9.0  | 9.0  |
| CIM5 at Antenna connector (dBm/Hz) | -149.5  | -159.5  | -147.5  | -157.5  |
| RFIC RX Band Noise level at Antenna connector (dBm/Hz) | -160.0  | -170.0  | -160.0  | -170.0  |
| PA RX Band Noise level at Antenna connector (dBm/Hz) | -160.0  | -170.0  | -160.0  | -170.0  |
| Total RXBN at Antenna connector (dBm/Hz) | -148.7  | -157.9  | -147.0  | -156.4  |
| Sensitivity with RXBN (PC2 max Tx power)(dBm/CBW) | -73.7  | -82.8  | -71.0  | -80.4  |
| After MRC | -83.3 dBm 🡪 2.1dB MSD is needed | -80.9 dBm 🡪 2.4dB MSD is needed |

**Observation: In 40M CBW, the 2.1 dB MSD by CIMD5 is needed when PC2 transmission in n3 FDD band.**

**Observation: In 50M CBW, the 2.4 dB MSD by CIMD5 is needed when PC2 transmission in n3 FDD band.**

Hence, RAN4 recommand as follow

To reduce the sensitivity degradation in n3/n1 band, filter vendor shall keep or enhance the duplexer Tx/Rx isolation level for FDD bands to support PC2 UE.

Based on RF component improvement, RAN4 can further study for sensitivity degradation requirements when RF component vendor provide these commercial Duplexer, PAs and RFICs for PC2 UE in FDD band in WI phase.

#### SKW sensitivity analysis results in n3

To derive the sensitivity degradation in n3 band, we use the same UL RB allocations than those agreed for PC3 NR UE in n3 band.

The PA noise levels in the receiver band and corresponding MSD levels can be found in Figure 6.1.2.2-1 as below.

 

**Figure 6.1.2.2-1 Measured Tx noise and corresponding MSD levels for all CBW.**

The estimated MSD levels for in 35MHz, 40MHz, 45MHz and 50MHz CBW lead to REFSENS levels that are lower than those agreed for PC3 operation. For these CBW, we tentatively propose to use the same approach as in [3], i.e. we propose PC2 REFSENS levels by evaluating the MSD level difference between PC3 and PC2 and apply this MSD difference to PC3 REFSENS levels. We observe the following MSD difference vs CBW:

* 3.1dB for 50MHz CBW: PC2 MSD of 7.2dB vs PC3 MSD of 4.1dB [3],
* 2.5dB for 45MHz CBW: PC2 MSD of 4.5dB vs PC3 MSD 2dB [3],
* 0.6dB for 40MHz CBW: PC2 MSD of 2.0 dB vs PC3 MSD of 1.5dB [3],
* 0.2dB for 35MHz CBW: PC2 MSD of 0.9 dB vs PC3 MSD of 0.7 dB [3].

For CBW less than or equal to 30MHz, the PC2 MSD can be neglected.

n3 PC2 REFSENS levels and UL configurations are proposed in Table 6.1.2.2-1 and Table 6.1.2.2-2.

**Table 6.1.2.2-1: n3 PC2 REFSENS**

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| UL configuration | SCS(kHz) | 5 MHz(dBm) | 10 MHz(dBm) | 15 MHz(dBm) | 20 MHz(dBm) | 25 MHz(dBm) | 30MHz(dBm) | 35 MHz(dBm) | 40 MHz(dBm) | 45 MHz(dBm) | 50MHz(dBm) | Duplex mode |
| n3 | 15 | -97.0 | -93.8 | -92.0 | -90.8 | -89.7 | -88.9 | -86.0 | -81.7 | -78.8 | -76.6 | FDD |
| 30 |  | -94.1 | -92.1 | -91.0 | -89.8 | -89.0 | -86.1 | -81.8 | -78.9 | -76.7 |
| 60 |  | -94.5 | -92.4 | -91.2 | -90.0 | -89.1 | -86.2 | -82.0 | -79.0 | -76.8 |
| NOTE 1: Four Rx antenna ports shall be the baseline for this operating band except for two Rx vehicular UE. NOTE 2: The transmitter shall be set to PUMAX as defined in clause 6.2.4  |

**Table 6.1.2.2-2: n3 PC2 REFSENS Uplink Configuration**

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| UL configuration | SCS(kHz) | 5 MHz(dBm) | 10 MHz(dBm) | 15 MHz(dBm) | 20 MHz(dBm) | 25 MHz(dBm) | 30MHz(dBm) | 35 MHz(dBm) | 40 MHz(dBm) | 45 MHz(dBm) | 50MHz(dBm) | Duplex mode |
| n3 | 15 | 25 | 501 | 501 | 501 | 501 | 501 | 501 | 501 | 501 | 501 | FDD |
| 30 |  | 241 | 241 | 241 | 241 | 241 | 241 | 241 | 241 | 241 |
| 60 |  | 101 | 101 | 101 | 101 | 101 | 101 | 101 | 101 | 101 |
| NOTE 1: UL resource blocks shall be located as close as possible to the downlink operating band but confined within the transmission bandwidth configuration for the channel bandwidth (Table 5.3.2-1). |

#### ZTE sensitivity analysis results in n3

For band n3, the situation is more complicated since CIM5 may need to be considered for some larger CBWs such as 35MHz, 40MHz 45MHz and 50MHz, shown in Table 6.1.2.3-1. We can see from Table 6.1.2.3-1, there are CIM5 problem for 40MHz, 45MHz and 50MHz with the same UL configurations of 50RB, which will further degrade the REFSEN requirements. Therefore, when the maximum output power increase 3dB, CIM5 value will become large which will cause REFSEN degradation more severe.

**Table 6.1.2.3-1. CIM5 calculation for band n3**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| CBW\_Tx | 20 | 25 | 30 | 35 | 40 | 45 | 50 |
| CBW\_Rx | 20 | 25 | 30 | 35 | 40 | 45 | 50 |
| Ful | 1775 | 1772.5 | 1770 | 1767.5 | 1765 | 1762.5 | 1760 |
| UL RB | 50 | 50 | 50 | 50 | 50 | 50 | 50 |
| Fdl | 1870 | 1867.5 | 1865 | 1862.5 | 1860 | 1857.5 | 1855 |
| Rx\_high | 1880 | 1880 | 1880 | 1880 | 1880 | 1880 | 1880 |
| Rx\_low | 1860 | 1855 | 1850 | 1845 | 1840 | 1835 | 1830 |
| CIM5 low | 1777.7 | 1787.4 | 1797.0 | 1807.1 | 1817.2 | 1826.4 | 1836.5 |
| CIM5 center | 1800.2 | 1809.9 | 1819.5 | 1829.6 | 1839.75 | 1848.9 | 1859.0 |
| CIM5 high | 1822.7 | 1832.4 | 1842.0 | 1852.1 | 1862.2 | 1871.4 | 1881.5 |

Similar with band n1, we cite some measurement results in [3] as follow:

The measured TX noise levels in RX band are:

* 35 MHz: -45 dBm,
* 40 MHz: -40.4 dBm,
* 45 MHz: -38 dBm,
* 50 MHz: -32.3 dBm

In addition, 50 dB Tx to RX and Tx to Antenna duplexer rejection in Rx band, as a worst case assumption. With the above measurement, the MSD levels for CBW>35MHz channel bandwidths are larger than 0.5dB, which means the REFENS requirements cannot be scaled by the channel bandwidth since CIM5 interference needs to be considered.

To roughly simulate the PC2 case, here we increase the additional Tx noise (i.e. delta P from 0~6dB) on top of the above measured Tx noise levels in Rx band , where 0dB means no additional measured Tx noise, i.e. same with PC3 case. The MSD levels are shown in Figure 6.1.2.3-1 as follow:



**Figure 6.1.2.3-1 Expected MSD levels in n3 according to delta P**

In can be seen that the MSD levels are increased by the delta P due to the total Tx noise levels in RX band increased. The slope for larger CBW is steeper than the small CBW. Assuming additional 6dB total Tx noise on top of the existing measured ones, then to guarantee the same REFSEN requirements as PC3 for PC2, ~5dB additional duplexer rejections on top of the existing one would be needed.

**Observation: For band n3, assuming additional 6dB total noise caused by increasing 3dB MOP, then ~5dB additional duplexer rejections on top of the existing one could be needed to guarantee the existing PC3 REFSEN requirements for PC2.**

The duplexers filter can achieve better isolation than what was used as an assumption (i.e. 50dB) for LTE FDD bands and copied to NR considering the today’s duplexer state-of-the-art. Therefore, to reduce the PC2 REFSEN requirements for band n1 or band n3, better duplexer Tx/Rx (more than 50dB such as 55dB) could be needed.

From the above sensitivity degradation simulation results, RAN4 summarize the required sentitivity degradation levels as shown in Table 6.1-1 and Table 6.1-2. The reference points are PC3 REFSENS requirements in TS38.101-1 to decide the required sensitivity level for PC2 UE.

**Table 6.1-1. Required sensitivity degradation levels in n1 NR Band for PC2 UE**

|  |  |  |  |
| --- | --- | --- | --- |
| **n1 band** | **PC2 [5]** | **PC2 [4]** | **PC2 [6]** |
| Reference point  |  |  |  |
| 10 MHz (-96.8dBm) | 0.8 dB | - | - |

**Table 6.1-2. Required sensitivity degradation levels in n3 NR Band for PC2 UE**

|  |  |  |  |
| --- | --- | --- | --- |
| **n3 band** | **PC2 [5]** | **PC2 [4]** | **PC2 [6]** |
| Reference point |   |  0.0 dB |   |
| 10 MHz (-93.8dBm) | 1.7 dB |  0.0 dB |   |
| 20 MHz (-90.8dBm) |   |  0.0 dB |   |
| 30 MHz (-88.9dBm) |   |  0.0 dB |   |
| 35 MHz (-86.2dBm) |   | 0.2 dB | 0.9 dB |
| 40 MHz (-82.3dBm) | 2.1 dB | 0.6 dB | 1.4 dB |
| 45 MHz (-81.3dBm) |   | 2.5 dB | 1.8 dB |
| 50 MHz (-79.7dBm) | 2.4 dB | 3.1 dB | 2.7 dB |

The above two tables will be considered as starting point to determine the exact REFSENS levels for FDD PC2 UE in WI phase.

# 7 UE implementations

In this section, we take a look at the RF component performance in FDD band such as n1/n3.

## 7.1 Current RF component characteristics in FDD band

Generally, RAN4 considered RF front-end loss as 4dB for smart phone form facter for PC3 and PC2 UE. Then, to support PC2 UE in FDD band, both PA and Duplexer shall support the allowed max. output with at least 30 dBm power to support PC2 UE.

### Power Amplifier characteristics

The following characteristics of PA are shown in Table 7.1.1.1 and Table 7.1.1.2

1. **PA characteristic of Linearity Maximum Output power in n3**

**Table 7.1.1.1. PA max. out put power in n3**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Parameter | Symbol | Conditions | Min. | Typ. | Max. | Unit |
| Operating Frequency | f0 |  | 1710 |  | 1785 | MHz |
| Maximum NR Output Power | POUT\_MAX\_NR\_NTC | VCC = 3.8V, NTC | 28 |  |  | dBm |

※Condition : SC-FDMA, MPR 0dB

1. **PA characteristic of Linearity Maximum Output power in n1**

**Table 7.1.1.2. PA max. out put power in n1**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Parameter | Symbol | Conditions | Min. | Typ. | Max. | Unit |
| Operating Frequency | f0 |  | 1920 |  | 1980 | MHz |
| Maximum NR Output Power | POUT\_MAX\_NR\_NTC | VCC = 3.8V, NTC | 27.5 |  |  | dBm |

※Condition : SC-FDMA, MPR 0dB

1. **MMPA characteristic of Linearity Maximum Output power in n1/n2/n3/n4/n25**

**Table 7.1.1.3. MMPA max. out put power in n1/n2/n3/n4/n25**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Parameter | Conditions | Min. | Typ. | Max. | Units |
| Frequency Range | Band 1 | 1920 |  | 1980 | MHz |
| Band 2 | 1850 |  | 1910 |
| Band 3 | 1710 |  | 1785 |
| Band 4 | 1710 |  | 1755 |
| Band 25 | 1850 |  | 1915 |
| Maximum Linear Output Power | HPM, VCC = 3.4V | 28.5(1) |  |  | dBm |
| LPM, VCC = 0.7V | 3.5 |  |  |

※Condition : SC-FDMA, MPR 0dB

Based on above PA performance information in FDD band, we can see that current PA need to improve the linearity of maximum output power at least 3dB higher than current PA characteristics.

### Duplexer characteristics

The following characteristics of Duplexer are shown in Table 7.1.2.1 and Table 7.1.2.2

1. **Duplexer characteristic for the allowed max. input power in n3**

**Table 7.1.2.1. Duplexer max. input power in n3**

|  |  |  |  |
| --- | --- | --- | --- |
| Input power at PIN 1712.50-1782.50MHz | 29 | dBm | source and load impedance 50Ω 5MHz LTE uplink @50℃, 5000h |

※Condition : SC-FDMA, MPR 0dB

1. **Duplexer characteristic for allowed max. input power in n1**

**Table 7.1.2.2. Duplexer max. input power in n1**

|  |  |
| --- | --- |
| Input Power | +29dBm 5000h +55deg.C |

 ※Condition : SC-FDMA, MPR 0dB

Based on above Duplexer performance information in FDD band, we can see that current Duplexer also need to improve the maximum power rating at least 2~3dB higher than the current Duplexer characteristics.

Therefore, RAN4 can study on high power UE (power class 2) for one NR FDD band when RF component vendor are ready to support the RF component performance to support PC2 UE in FDD band.

From the above current RF component characteristics, we share our observation and proposal as follow

**Observation : In FDD band, the PA/Duplexer charateristic is not support PC2 maximum output power since PA linearity and Duplexer allowed maximum power rating shall improve the performance at least 3dB higher than current component charateristics.**

# 8 System Performance Evaluation

## 8.1 Dynamic system level simulation

8.1.1 General

The dynamic system level simulation is usually used to evaluate the system performance gain, which can simulate the behavior of system in more detail. The HPUE feature can improve UL coverage but at the same time increase the interference of the neighboring cells, and the final system performance gain is evaluated by the average cell uplink throughput and 5%-tile cell-edge uplink throughput.

In addition, the SAR issue is also a practical factor that limits HPUE performance. Restricting duty-cycle is a commonly used method to avoid SAR issue, and it is widely used in TDD systems. However, there are some difficulties in compatibility between duty-cycle and FDD systems, but in order to include the potential impact of scheduling constraints on system performance due to the SAR issues, the 50% duty-cycle restriction should also be evaluated.

8.1.2 Simulation assumptions

The simulation assumptions for dynamic system level simulation are included in Table 8.1.2-1

Table 8.1.2-1. Simulation Assumptions

|  |  |
| --- | --- |
| Configuration parameters | Values |
| Scenario | Urban macro |
| ISD | 500 m |
| Duplexing | FDD |
| Carrier frequency | 1.8 GHz, 2.1GHz |
| Modulation | Up to 64QAM, 256QAM is optional |
| Numerology | 15 kHz |
| Simulation bandwidth | 40 MHz |
| Transmission scheme | SU-MIMO |
| Codebook | For 2Tx, codebook [1 1]T is used for transmit diversity |
| SU dimension | 1 layer |
| Antenna configuration at TRxP | 4Rx, (M,N,P,Mg, Ng) = (1,2,2,1,1; 1,2); 4Rx, (M, N, P, Mg, Ng) = (1, 4, 2, 1, 2)32Rx, (M,N,P,Mg, Ng) = (8,8,2,1,1; 2,8) |
| Antenna configuration at UE | 1Tx, (M,N,P,Mg, Ng) = (1,1,1,1,1; 1,1),2Tx, (M,N,P,Mg, Ng) = (1,1,2,1,1; 1,1) |
| UE maximal transmit power | For 1Tx, 23 dBm for each TXRUFor 1Tx, 26 dBm for each TXRU (High power UE)For 2Tx, 23 dBm for each TXRU (High power UE) |
| Scheduling | PF |
| Receiver | MMSE-IRC |
| Channel estimation | Ideal |
| Power control parameter | P0=[-60~-76], alpha = [0.6, 0.8] |
| TRxP number per site | 3 |
| TRxP number | 21 |
| Channel model | UMa following TR 38.901 |
| Electronic tilt | 102° |
| Traffic model | FTP3, packet size: 100k / 10k Byte, arrival rate: [1 packet / s, 1 packet/200ms] |
| Uplink duty cycle | 50%, 100% |
| Note: HPUE ratio 100% baseline, 50% and 25% are optional |

Further evaluation based on other traffic models for reference are not precluded.

8.1.3 Simulation results

8.1.3.1 P0 = -76, alpha = 0.6

* **Company 1 (R4-2109699)**

In the simulation, all UEs are assumed to have high power capability and the results are shown in Table 8.1.3.1-1

Table 8.1.3.1-1: Simulation Results for Alpha =0.6

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Antenna** | **Max Tx****Power****/dBm** | **Packet****size** | **Packet****arrival****rate** | **Duty cycle** | **Cell avg.****UPT****/Mbps** | **5% UPT****/Mbps** | **Cell avg.****UPT gain** | **5% UPT****gain** |
| BS: 4R UE: 1T | 23 | 100k Byte | 5 file/s | 100% | 190.1 | 3.04 | 0%, baseline | 0%, baseline |
| BS: 4R UE: 1T | 26 | 100k Byte | 5 file/s | 100% | 192.1 | 4.24 | 1.0% | 39.4% |
| BS: 4R UE: 1T | 26 | 100k Byte | 5 file/s | 50% | 190.3 | 3.12 | 0.1% | 2.7% |

For alpha = 0.6, The proportion of UEs working at high power is relatively small, and the performance gain of PC2 UE is reflected in edge users which is also in line with the expected purpose. However, the 50% duty-cycle will significantly reduce the performance gain because high-power users are mainly distributed at the edge of the cell at this time.

* **Company 3 (R4-2111446)**

Table 8.1.3.1-2: Simulation results for P0 = -76, alpha = 0.6

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Antenna** | **Max Tx power/dBm** | **Packet size** | **Packet arrival rate** | **Cell avg. UPT gain** | **5% UPT gain** |
| BS: 4R UE: 1T | 23 | 10k Byte | 1 file/200ms | 100% | 100% |
| BS: 4R UE: 1T | 26 | 10k Byte | 1 file/200ms | 153.33% | 112.50 % |

8.1.3.2 P0 = -76, alpha = 0.8

* **Company 1 (R4-2109699)**

Table 8.1.3.2-1: Simulation Results for Alpha =0.8

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Antenna** | **Max Tx****Power****/dBm** | **Packet****size** | **Packet****arrival****rate** | **Duty cycle** | **Cell avg.****UPT****/Mbps** | **5% UPT****/Mbps** | **Cell avg.****UPT gain** | **5% UPT****gain** |
| BS: 4R UE: 1T | 23 | 100k Byte | 5 file/s | 100% | 146.2 | 1.36 | 0%, baseline | 0%, baseline |
| BS: 4R UE: 1T | 26 | 100k Byte | 5 file/s | 100% | 179.8 | 1.73 | 23.0% | 27.4% |
| BS: 4R UE: 1T | 26 | 100k Byte | 5 file/s | 50% | 176.9 | 1.53 | 21.0% | 12.2% |

When the alpha rises to 0.8, the proportion of high-power users will increase. PC2 UEs will significantly improve cell average and edge performance. Since high-power users are not only distributed at the 5% edge of the cell at this time, the performance gain reduction caused by the 50% duty-cycle is relatively small. It is worth noting that the alpha change has caused the power of most UEs to rise, which increases the overall interference level, and the absolute value of the cell throughput decreases relative to the case of alpha=0.6.

* **Company 2 (R4-2104922)**

The detailed simulation results for band n3 are shown in Table 8.1.3.2-2

Table 8.1.3.2-2: Dynamic system level simulation results

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Antenna Configuration** | **Maximum Tx Power(dBm)** | **Duty cycle****(%)** | **Packet size****(k Byte)** | **Arrival rate****(file/s)** | **5% UPT****(Mbps)** | **Average UPT****(Mbps)** |
| 1Tx 4Rx | 23 | 100 | 10 | 5 | 7.950% | 45.450% |
| 1Tx 4Rx | 26 | 100 | 10 | 5 | 10.13+27% | 56.84+25% |
| 1Tx 4Rx | 26 | 50 | 10 | 5 | 8.57+8% | 56.62+25% |
| 2Tx 4Rx | 26 | 100 | 10 | 5 | 10.70+35% | 57.14+26% |
| 2Tx 4Rx | 26 | 50 | 10 | 5 | 9.03+14% | 56.98+25% |

* **Company 3 (R4-2107300, R4-2111446)**

In the simulation assumptions, some parameters have more than one set of values. For the different values, more simulation cases are performed. Table 8.1.3.2-3 and 8.1.3.2-4 provides the simulation results.

Table 8.1.3.2-3: Simulation results for P0 = -76, alpha = 0.8

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Antenna** | **Max Tx power/dBm** | **Packet size** | **Packet arrival rate** | **Cell avg. UPT gain** | **5% UPT gain** |
| BS: 4R UE: 1T | 23 | 100k Byte | 1 file/200ms | 100% | 100% |
| BS: 4R UE: 1T | 26 | 100k Byte | 1 file/200ms | 150.11% | 100.03% |
| BS: 4R UE: 2T | 26 | 100k Byte | 1 file/200ms | 147.90% | 101.67% |
| BS: 32R UE: 1T | 23 | 100k Byte | 1 file/200ms | 100% | 100% |
| BS: 32R UE: 1T | 26 | 100k Byte | 1 file/200ms | 150.02% | 107.12% |
| BS: 32R UE: 2T | 26 | 100k Byte | 1 file/200ms | 150.18% | 105.24% |
| **Antenna** | **Max Tx power/dBm** | **Packet size** | **Packet arrival rate** | **Cell avg. UPT gain** | **5% UPT gain** |
| BS: 4R UE: 1T | 23 | 10k Byte | 1 file/200ms | 100% | 100% |
| BS: 4R UE: 1T | 26 | 10k Byte | 1 file/200ms | 159.56% | 105.72% |
| BS: 4R UE: 2T | 26 | 10k Byte | 1 file/200ms | 157.07% | 105.72% |
| BS: 32R UE: 1T | 23 | 10k Byte | 1 file/200ms | 100% | 100% |
| BS: 32R UE: 1T | 26 | 10k Byte | 1 file/200ms | 159.78% | 108.69% |
| BS: 32R UE: 2T | 26 | 10k Byte | 1 file/200ms | 159.77% | 108.69% |
| **Antenna** | **Max Tx power/dBm** | **Packet size** | **Packet arrival rate** | **Cell avg. UPT gain** | **5% UPT gain** |
| BS: 4R UE: 1T | 23 | 100k Byte | 1 file/1s | 100% | 100% |
| BS: 4R UE: 1T | 26 | 100k Byte | 1 file/1s | 151.88% | 100.82% |
| BS: 4R UE: 2T | 26 | 100k Byte | 1 file/1s | 156.11% | 100.53% |
| BS: 32R UE: 1T | 23 | 100k Byte | 1 file/1s | 100% | 100% |
| BS: 32R UE: 1T | 26 | 100k Byte | 1 file/1s | 152.96% | 102.23% |
| BS: 32R UE: 2T | 26 | 100k Byte | 1 file/1s | 155.44% | 100.15% |
| **Antenna** | **Max Tx power/dBm** | **Packet size** | **Packet arrival rate** | **Cell avg. UPT gain** | **5% UPT gain** |
| BS: 4R UE: 1T | 23 | 10k Byte | 1 file/1s | 100% | 100% |
| BS: 4R UE: 1T | 26 | 10k Byte | 1 file/1s | 161.03% | 106.45% |
| BS: 4R UE: 2T | 26 | 10k Byte | 1 file/1s | 160.06% | 106.45% |
| BS: 32R UE: 1T | 23 | 10k Byte | 1 file/1s | 100% | 100% |
| BS: 32R UE: 1T | 26 | 10k Byte | 1 file/1s | 161.34% | 108.69% |
| BS: 32R UE: 2T | 26 | 10k Byte | 1 file/1s | 160.23% | 108.69% |

Table 8.1.3.2-4: Simulation results for P0 = -76, alpha = 0.8

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Antenna** | **Max Tx power/dBm** | **Packet size** | **Packet arrival rate** | **Cell avg. UPT gain** | **5% UPT gain** |
| BS: 4R UE: 1T | 23 | 10k Byte | 1 file/200ms | 100% | 100% |
| BS: 4R UE: 1T | 26 | 10k Byte | 1 file/200ms | 167.50% | 109.1% |

8.1.3.3 P0 = -60, alpha = 0.6

* **Company 2 (R4-2109763)**

Table 8.1.3.3-1: Dynamic system level simulation results for 10kB packet size

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Antenna Configuration** | **Maximum Tx Power(dBm)** | **Duty cycle****(%)** | **Packet size****(k Byte)** | **Arrival rate****(file/s)** | **5% UPT****(Mbps)** | **Average UPT****(Mbps)** |
| 1Tx 4Rx | 23 | 100 | 10 | 5 | 20.650% | 63.810% |
| 1Tx 4Rx | 26 | 100 | 10 | 5 | 31.66+53% | 72.38+13% |
| 1Tx 4Rx | 26 | 50 | 10 | 5 | 32.69+58% | 72.43+14% |
| 2Tx 4Rx | 26 | 100 | 10 | 5 | 31.87+54% | 73.22+15% |
| 2Tx 4Rx | 26 | 50 | 10 | 5 | 32.31+56% | 73.22+15% |

* **Company 3 (R4-2107300)**

Table 8.1.3.3-2: Simulation results for P0 = -60, alpha = 0.6

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Antenna** | **Max Tx power/dBm** | **Packet size** | **Packet arrival rate** | **Cell avg. UPT gain** | **5% UPT gain** |
| BS: 4R UE: 1T | 23 | 100k Byte | 1 file/200ms | 100% | 100% |
| BS: 4R UE: 1T | 26 | 100k Byte | 1 file/200ms | 148.14% | 100.03% |
| BS: 4R UE: 2T | 26 | 100k Byte | 1 file/200ms | 143.43% | 108.01% |
| BS: 32R UE: 1T | 23 | 100k Byte | 1 file/200ms | 100% | 100% |
| BS: 32R UE: 1T | 26 | 100k Byte | 1 file/200ms | 151.49% | 100.97% |
| BS: 32R UE: 2T | 26 | 100k Byte | 1 file/200ms | 151.38% | 104.57% |
| **Antenna** | **Max Tx power/dBm** | **Packet size** | **Packet arrival rate** | **Cell avg. UPT gain** | **5% UPT gain** |
| BS: 4R UE: 1T | 23 | 10k Byte | 1 file/200ms | 100% | 100% |
| BS: 4R UE: 1T | 26 | 10k Byte | 1 file/200ms | 160.12% | 105.72% |
| BS: 4R UE: 2T | 26 | 10k Byte | 1 file/200ms | 157.12% | 105.72% |
| BS: 32R UE: 1T | 23 | 10k Byte | 1 file/200ms | 100% | 100% |
| BS: 32R UE: 1T | 26 | 10k Byte | 1 file/200ms | 163.25% | 108.69% |
| BS: 32R UE: 2T | 26 | 10k Byte | 1 file/200ms | 163.12% | 108.69% |
| **Antenna** | **Max Tx power/dBm** | **Packet size** | **Packet arrival rate** | **Cell avg. UPT gain** | **5% UPT gain** |
| BS: 4R UE: 1T | 23 | 100k Byte | 1 file/1 s | 100% | 100% |
| BS: 4R UE: 1T | 26 | 100k Byte | 1 file/1 s | 153.16% | 100.78% |
| BS: 4R UE: 2T | 26 | 100k Byte | 1 file/1 s | 151.74% | 104.03% |
| BS: 32R UE: 1T | 23 | 100k Byte | 1 file/1 s | 100% | 100% |
| BS: 32R UE: 1T | 26 | 100k Byte | 1 file/1 s | 155.10% | 102.41% |
| BS: 32R UE: 2T | 26 | 100k Byte | 1 file/1 s | 154.49% | 102.41% |
| **Antenna** | **Max Tx power/dBm** | **Packet size** | **Packet arrival rate** | **Cell avg. UPT gain** | **5% UPT gain** |
| BS: 4R UE: 1T | 23 | 10k Byte | 1 file/1 s | 100% | 100% |
| BS: 4R UE: 1T | 26 | 10k Byte | 1 file/1 s | 162.77% | 106.45% |
| BS: 4R UE: 2T | 26 | 10k Byte | 1 file/1 s | 161.15% | 106.45% |
| BS: 32R UE: 1T | 23 | 10k Byte | 1 file/1 s | 100% | 100% |
| BS: 32R UE: 1T | 26 | 10k Byte | 1 file/1 s | 164.53% | 108.69% |
| BS: 32R UE: 2T | 26 | 10k Byte | 1 file/1 s | 164.49% | 108.69% |

8.1.3.4 P0 = -60, alpha = 0.8

* **Company 3 (R4-2107300)**

Table 8.1.3.4-1: Simulation results for P0 = -60, alpha = 0.8

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Antenna** | **Max Tx power/dBm** | **Packet size** | **Packet arrival rate** | **Cell avg. UPT gain** | **5% UPT gain** |
| BS: 4R UE: 1T | 23 | 100k Byte | 1 file/200ms | 100% | 100% |
| BS: 4R UE: 1T | 26 | 100k Byte | 1 file/200ms | 132.77% | 100.02% |
| BS: 4R UE: 2T | 26 | 100k Byte | 1 file/200ms | 134.44% | 100.81% |
| BS: 32R UE: 1T | 23 | 100k Byte | 1 file/200ms | 100% | 100% |
| BS: 32R UE: 1T | 26 | 100k Byte | 1 file/200ms | 127.14% | 100.52% |
| BS: 32R UE: 2T | 26 | 100k Byte | 1 file/200ms | 126.51% | 102.70% |
| **Antenna** | **Max Tx power/dBm** | **Packet size** | **Packet arrival rate** | **Cell avg. UPT gain** | **5% UPT gain** |
| BS: 4R UE: 1T | 23 | 10k Byte | 1 file/200ms | 100% | 100% |
| BS: 4R UE: 1T | 26 | 10k Byte | 1 file/200ms | 133.91% | 105.12% |
| BS: 4R UE: 2T | 26 | 10k Byte | 1 file/200ms | 132.87% | 105.12% |
| BS: 32R UE: 1T | 23 | 10k Byte | 1 file/200ms | 100% | 100% |
| BS: 32R UE: 1T | 26 | 10k Byte | 1 file/200ms | 137.62% | 107.41% |
| BS: 32R UE: 2T | 26 | 10k Byte | 1 file/200ms | 136.81% | 107.41% |
| **Antenna** | **Max Tx power/dBm** | **Packet size** | **Packet arrival rate** | **Cell avg. UPT gain** | **5% UPT gain** |
| BS: 4R UE: 1T | 23 | 100k Byte | 1 file/1 s | 100% | 100% |
| BS: 4R UE: 1T | 26 | 100k Byte | 1 file/1 s | 127.75% | 100.63% |
| BS: 4R UE: 2T | 26 | 100k Byte | 1 file/1 s | 128.25% | 101.69% |
| BS: 32R UE: 1T | 23 | 100k Byte | 1 file/1 s | 100% | 100% |
| BS: 32R UE: 1T | 26 | 100k Byte | 1 file/1 s | 125.74% | 101.48% |
| BS: 32R UE: 2T | 26 | 100k Byte | 1 file/1 s | 124.84% | 105.37% |
| **Antenna** | **Max Tx power/dBm** | **Packet size** | **Packet arrival rate** | **Cell avg. UPT gain** | **5% UPT gain** |
| BS: 4R UE: 1T | 23 | 10k Byte | 1 file/1 s | 100% | 100% |
| BS: 4R UE: 1T | 26 | 10k Byte | 1 file/1 s | 133.45% | 106.45% |
| BS: 4R UE: 2T | 26 | 10k Byte | 1 file/1 s | 133.46% | 106.45% |
| BS: 32R UE: 1T | 23 | 10k Byte | 1 file/1 s | 100% | 100% |
| BS: 32R UE: 1T | 26 | 10k Byte | 1 file/1 s | 137.95% | 107.41% |
| BS: 32R UE: 2T | 26 | 10k Byte | 1 file/1 s | 137.70% | 107.41% |

8.1.3.5 Other

* **Company 1 (R4-2109699, R4-2113025)**

In addition, the statistics of resource utilization (RU) are shown in Table 8.1.3.5.1-1

Table 8.1.3.5-1: The resource utilization in simulation

|  |  |
| --- | --- |
| **Alpha = 0.6** | **Alpha = 0.8** |
| 14.4% | 2.3% |

Resource utilization is at a relatively low level which may cause some potential simulation vulnerabilities. Low resource utilization may mean that high-power users at the edge complete data transmission quickly, and there will be no scheduling conflicts between different UEs. This will cause the interference increase caused by high power to be hidden. To remedy this problem, some simulation results of higher resource utilization are provided as Table 8.1.3.5.1-2 and Table 8.1.3.5.1-3

Table 8.1.3.5-2: High data density transmission simulation result

（alpha =0.6, 100% duty-cycle）

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  |  | **PC3（baseline）** | **PC2** |  |  |
| **packet size****(k Byte)**  | **arrival rate****(file/s)** | **RU（%）** | **Cell avg. UPT****/Mbps** | **5% UPT****/Mbps** | **RU（%）** | **Cell avg. UPT****/Mbps** | **5% UPT****/Mbps** | **Cell avg. UPT gain** | **5% UPT gain** |
| 100K | 10 | 32.81 | 184.85 | 2.76 | 34.36 | 186.17 | 3.78 | 0.72% | 37.1% |
| 100K | 20 | 54.83 | 166.9 | 1.75 | 57.18 | 167.31 | 2.39 | 0.24% | 36.1% |
| 100K | 40 | 80.3 | 136.6 | 0.15 | 82.5 | 135.9 | 0.16 | -0.48% | 7.5% |

Table 8.1.3.5-3: High data density transmission simulation result

（alpha =0.8, 100% duty-cycle）

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  |  | **PC3（baseline）** | **PC2** |  |  |
| **packet size****(k Byte)** | **arrival rate****(file/s)** | **RU（%）** | **Cell avg. UPT****/Mbps** | **5% UPT****/Mbps** | **RU（%）** | **Cell avg. UPT****/Mbps** | **5% UPT****/Mbps** | **Cell avg. UPT gain** | **5% UPT gain** |
| 500K | 10 | 23.46 | 268.42 | 0.06 | 24.32 | 340.37 | 0.066 | 26.8% | 10% |
| 500K | 20 | 35.80 | 235.8 | 0.052 | 38.76 | 296.97 | 0.056 | 25.9% | 7.7% |
| 500K | 40 | 47.43 | 215.1 | 0.045 | 53.7 | 262.86 | 0.0453 | 22.2% | 0.5% |

The result shows that when the resource utilization increase, the system performance gain of cell average still considerable. However, the performance of cell edge will be tiny when the RU rise to about 50%. Note that under the same traffic model, the RU of PC2 UE will be slightly larger than that of PC3. This is caused by the decrease in SINR due to increased interference at high power.

* **Company 3 (R4-2111446)**

Figure 8.1.3.5-1 shows the CDF curve of the UE. From Figure 1, although the interference increases with the increase of transmit power of PC2 UE, there is still 1dB gain compared with the PC3 UE. And Figure 8.1.3.5-2 shows the actual number of scheduled RB for the PC2 UE and PC3 UE sorted by UE throughput. For the cell edge UE (5% UPT UE), the number of the scheduled RB for PC2 UE is more than twice of the PC3 UE. Therefore, even though the PC2 UE has 50% restriction, due to the gain of the SINR and the more scheduled RB for PC2 UE, the average and cell edge cases could have an obvious performance gain.



Figure 8.1.3.5-1 SINR CDF of PC2 UE (50% duty cycle) and PC3 UE (100% duty cycle)



Figure 8.1.3.5-2 Number of scheduled RB per UE sorted by the UE throughput

## 8.2 Monte Carlo simulation

8.2.1 Simulation methodology

The Monte Carlo based static system level simulation is typical simulation method used in the coexistence study and can also be used for the simplified system performance evaluation. The sub-snapshot method is agreed as one of possible methods to simulate the HPUE feature.

The difference for UL duty cycle is emulated by assuming there are N sub-snapshots within one snapshot. For example, we can set N=2 for the case of 50% duty cycle for FDD HPUE. Similarly, we can set N=4 for the case of 25% duty cycle. In each snapshot, UEs are randomly placed in a predefined deployment scenario. But within one snapshot, the UEs’ locations for N sub-snapshots are fixed. Table 8.2.1-1 illustrates the sub-snapshot concept and the simulation method. When the simulation performance is assumed to be measured within one frame (e.g., 10ms) and only 50% time can be used for UL transmission within one frame assuming 50% duty cycle. Then each sub-snapshot can be considered as 5ms in the Monte-Carlo simulation.

**Table 8.2.1-1. An example to compare FDD PC2 UE (50% DC) and FDD PC3 UE (100% DC)**

|  |  |  |  |
| --- | --- | --- | --- |
| UE type  | The first sub-snapshot | The second sub-snapshot | UL duty cycle |
| FDD PC3 UEs | Max. Tx power is 23dBm | Max. Tx power is 23dBm | 100% |
| FDD PC2 UEs with transmission power >23dBm | Max. Tx power is 26dBm | No transmission | 50% |
| Note 1: For PC2 UEs with transmission power ≤ 23dBm, there is no need to reduce the UL duty cycle since there is no SAR issue.Note 2: For simplicity, 50% UL duty cycle will be applied once PC2 UEs transmit power is larger than 23dBm.Note 3: PC2 UEs with 50% UL duty can randomly transmit power at the first or the second sub-snapshot. |

Non-full buffer and full buffer scenarios are both considered in the simulation. For the non-full buffer scenario, the resource will not be used in the sub-snapshot which there is no transmission for the UE with >23dBm Tx power. For the full buffer scenario, a new user will be scheduled in one of the two sub-snapshots when the UE with >23dBm Tx power will not transmit in that correspondent sub-snapshot due to 50% duty cycle.

There are also other evaluation methods can be implemented to stimulate the duty cycle in the Monte Carlo simulation, such as drawing a random number in each snapshot. If the random number is larger than the duty cycle, then the HPUE will be replaced with another UE; If the random number is less than the duty cycle, then the HPUE will transmit normally with Tx power up to 26 dBm.

8.2.2 Simulation assumptions

The simulation assumptions using Monte-Carlo simulation are as Table 8.2.2-1.

**Table 8.2.2-1. System Assumptions**

|  |  |  |
| --- | --- | --- |
| Parameter | Base Station | UE |
| Carrier frequency | 2GHz |
| Channel bandwidth | 40MHz |
| Active UE number in UL | 3 |
| PC2 UE ratio | 25%, 50%, 100% |
| Inter-site distance | 750m |
| Cell layout | Wrap-around 19 tri-sector cells |
| Lognormal fading | 10 dB |
| Shadowing correlation | Between cells: 0.5, between sites: 1.0 |
| MCL (including antenna gain) | 70 dB (urban) |
| Antenna gain and horizontal antenna pattern | $A\left(θ\right)=-min⁡[ 12 \left( \frac{θ}{θ\_{3dB}} \right)^{2},A\_{m}]$,17 dBi, $θ\_{3dB}$ = 65 degrees,Am = 20 dB | Omni-directional antenna with -3.5 dBi. |
| Noise figure | 5 dB | 9 dB |
| Transmit power | 46 dBm | 23 dBm for UE, 26dBm for HPUE |
| Antenna height | 45 m | 1.5 m |

The power control (PC) set 4A and 4B are selected for performance evaluation which refers to TR36.886 chapter 5.10.1.2. The parameters are presented in Table 8.2.2-2.

**Table 8.2.2-2. PC set parameters for 23dBm UE and 26 dBm UE with 0.75 km ISD**

|  |  |  |
| --- | --- | --- |
| Power control set parameter  | Gamma | CLx-ile for BW 40MHz |
| 23dBm | 26dBm |
| Set 4A | 1 | 104 | 107 |
| Set 4B | 1 | 100 | 103 |
| Note: the original table in 36.886 is for 20MHz bandwidth, thus the value needed to be adjusted for 40MHz bandwidth correspondently.  |

Figure 8.2.2-1 and 8.2.2-2 are the CDF curve of Tx power for power control set 4A and 4B, respectively, to show the difference between FDD PC2 and PC3.



**Figure 8.2.2-1. UL Tx power CDF for power control set 4A**

****

**Figure 8.8.2-2. UL Tx power CDF for power control set 4B**

8.2.3 Simulation results

8.2.3.1 Simulation results for power control set 4A

The ratio of UL Tx power > 23dBm is about 4.9% for power control set 4A.

In a more realistic situation, for example, considering a relatively long-time duration, the time restriction for UE duty cycle can be relaxed assuming that UE can keep transmit with >23dBm power in its scheduled duration. After the UE finishes its transmission, another UE will be scheduled. In this scenario, the UE can naturally realize the 50% duty cycle by the scheduling time since the UE will not be always scheduled. The duty cycle then does not need to be considered in the result processing. Therefore, the system performances are shown in Table 8.2.3.1-1 and Table 8.2.3.1-2.

 **Table 8.2.3.1-1. PC2 system performance for non-full buffer case with PC set 4A**

**when 50% duty cycle is considered in a longer duration**

|  |  |  |  |
| --- | --- | --- | --- |
| Power control set | 4A  | 4A | 4A |
| PC2 UE ratio | 25% | 50% | 100% |
| 5% throughput gain | 1.22% | 2.44% | 4.27% |
| Cell throughput gain | 0.40% | 1.04% | 2.39% |

**Table 8.2.3.1-2. PC2 system performance for full buffer with PC set 4A**

**when 50% duty cycle is considered in a longer duration**

|  |  |  |  |
| --- | --- | --- | --- |
| Power control set | 4A  | 4A | 4A |
| PC2 UE ratio | 25% | 50% | 100% |
| 5% throughput gain | 0.61% | 1.83% | 3.05% |
| Cell throughput gain | 0.48% | 1.12% | 2.55% |

As shown in Table 8.2.3.1-1 and Table 8.2.3.1-2:

* When 50% duty cycle can be realized in a longer duration, performance gain can be observed for the 5% throughput. The gain’s value depends on the PC2 UE ratio and the traffic loading.
* When 50% duty cycle can be realized in a longer duration, performance gain can be observed for the average cell throughput. The gain’s value depends on the PC2 UE ratio and the traffic loading.
* When 50% duty cycle can be realized in a longer duration, higher PC2 UE ratio will bring higher 5%-throughput gain as well as the average cell throughput gain. The system performance gain is highly related with PC2 UE ratio.

8.2.3.2 Simulation results for power control set 4B

The Tx power ratio UL Tx power > 23dBm is about 17.8% for power control set 4B.

Similar consideration is applied, when 50% duty cycle can be realized in a longer duration, the 50% duty cycle need not be considered in the performance processing. Therefore, the system performance is shown in Table 8.2.3.2-1 and Table 8.2.3.2-2.

**Table 8.2.3.2-1. PC2 system performance for non-full buffer with PC set 4B**

**when 50% duty cycle is considered in a longer duration**

|  |  |  |  |
| --- | --- | --- | --- |
| Power control set | 4B | 4B | 4B |
| PC2 UE ratio | 25% | 50% | 100% |
| 5% throughput gain | 5.13% | 10.26% | 17.31% |
| Cell throughput gain | 0.81% | 1.98% | 5.50% |

**Table 8.2.3.2-2. PC2 system performance for full buffer with PC set 4B**

**when 50% duty cycle is considered in a longer duration**

|  |  |  |  |
| --- | --- | --- | --- |
| Power control set | 4B | 4B | 4B |
| PC2 UE ratio | 25% | 50% | 100% |
| 5% throughput gain | 3.85% | 8.33% | 15.38% |
| Cell throughput gain | 1.03% | 2.20% | 4.84% |

From the simulation results shown in chapter 8.2.3.2, the similar performance variance trend can be observed for the power control set 4B, compared with power control set 4A.

8.2.3.3 Simulation observations

The system performance is sensitive to the power control set parameters. In realistic situation, where several UEs are multiplexed in the same cell, non-negligible gain in UL performance can be observed in both mean and 5%-tile throughput.

# 9 SI Conclusion

In this study item, different aspects of enabling PC2 in NR FDD band n1 and n3 are thoroughly studied. The contents of the study include the applicable schemes to comply with SAR limits with 26dBm UE Tx power, the interference issues raised by FDD PC2, UE implementation and RF architectures, as well as system performance evaluation to support NR FDD HPUE.

Several SAR compliance solutions are studied and discussed in RAN4, including UE-implementation based methods, reusing of existing duty-cycle reporting method, and half-duplex operation method. After careful studies and thorough discussions, the UE-implementation based methods are considered feasible to make sure SAR regulation is not violated. In addition, optional feature of applying duty cycle is also considered, as a standardized solution, to solve SAR compliance issue.

Regarding the interference issues, it was identified by the group that both MSD and UL configuration are possible alternatives to handle REFSENS degradation in FDD PC2, and the MSD method will be adopted for the cases of n1 and n3 PC2. MSD values can first be calculated based on available RF components and existing assumptions. If there are new components available in the future with better performance, new assumptions can also be considered for MSD calculations.

In order to support 26dBm UE Tx power, two RF architectures (i.e. 2Tx×23dBm and 1Tx×26dBm) are considered and agreed during the study. It is found out that FDD HPUE with 2Tx architecture is feasible and can reuse existing RF components targeted for PC3, while 1Tx may need to use newly designed components. So further analyses of 1Tx architecture could be carried out when the new components become available.

To fully evaluate the impacts of FDD HPUE to the system performance, Dynamic system level simulations and Monte Carlo simulations are carried out. In dynamic system level simulation, performance gain for both cell average and cell edge cases are verified under various power control parameters. On the other hand, performance gain can be observed for the 5%-tile throughput and average cell throughput under Monte Carlo simulation. The potential DL degradation due to Tx/Rx de-sense does not lead to substantial performance degradation in typical interference limited scenarios.

In conclusion, it is shown in this SI that high power UE (power class 2) for NR FDD band brings positive system performance gain to the network, and it is feasible to reuse existing RF components to support 26dBm UE Tx power, while new components with performance improvement are also expected to be available in the future. UE implementation based solution (P-MPR) is used for SAR compliance. There is no consensus on the optional report of duty cycle capability, but duty cycle used as an UE implementation method is not precluded. Specific MSD values and other specification impact(s) will be determined in the Work Item phase.

# Annex <X> (informative):Change history

|  |
| --- |
| **Change history** |
| **Date** | **Meeting** | **TDoc** | **CR** | **Rev** | **Cat** | **Subject/Comment** | **New version** |
| 2021-04 | RAN4-98-bis-e | R4-2106912 |  |  |  | Initial TR skeleton | 0.0.1 |
| 2021-05 | RAN4-99-e | R4-2110798 |  |  |  | TP to TR38.861: Simulation results for FDD HPUE | 0.1.0 |
| 2021-05 | RAN4-99-e | R4-2108866 |  |  |  | TR 38.861 v0.1.0 FS\_NR\_PC2\_UE\_FDD | 0.1.0 |
| 2021-06 | RAN-92-e | RP-211346 |  |  |  | TR 38.861 v1.0.0 FS\_NR\_PC2\_UE\_FDD | 1.0.0 |
| 2021-08 | RAN4-100-e | R4-2115062 |  |  |  | TP for TR 38.861: Conclusion of SI for FDD HPUE | 1.1.0 |
| 2021-08 | RAN4-100-e | R4-2115063 |  |  |  | TP on Sensitivity analysis results and UE implementation for PC2 FDD band | 1.1.0 |
| 2021-08 | RAN4-100-e | R4-2113001 |  |  |  | TP to TR38.861 Dynamic system level simulation results for FDD HPUE | 1.1.0 |
| 2021-08 | RAN4-100-e | R4-2112470 |  |  |  | TR 38.861 v1.1.0 FS\_NR\_PC2\_UE\_FDD | 1.1.0 |