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| 3GPP TR 37.815 V16.0.0 (2019-12) | |
| Technical Report | |
| 3rd Generation Partnership Project;  Technical Specification Group Radio Access Networks  Study on high power User Equipment (UE) (power class 2) for E-UTRA (Evolved Universal Terrestrial Radio Access) - NR Dual Connectivity (EN-DC) (1 LTE FDD band + 1 NR TDD band)  (Release 16) | |
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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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where:

x the first digit:

1 presented to TSG for information;

2 presented to TSG for approval;

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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 is a technical report for high power UE(power class 2) for EN-DC(1 LTE FDD band + 1 NR TDD FDD). The purpose is to study how to introduce the new power class 2 (1 LTE FDD band + 1 NR TDD band) for EN-DC bands in Rel-16.

# 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] RP-182895: " Study on high power UE (power class 2) for EN-DC (1 LTE FDD band + 1 NR TDD band)", China Unicom.

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

[4] 3GPP TS 38.101-3: "NR; User Equipment (UE) radio transmission and reception; Part 3: Range 1 and Range 2 Interworking operation with other radios".

[5] 3GPP TS 36.101: "E-UTRAN; User Equipment (UE) radio transmission and reception".

[6] 3GPP TS 38.331: "NR; Radio Resource Control (RRC) protocol specification".

# 3 Definitions, symbols and abbreviations

## 3.1 Definitions

For the purposes of the present document, the terms and definitions 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:

<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].

<ACRONYM> <Explanation>

# 4 Background

## 4.1 Justification

In 3GPP, many operators and vendors have realized the significant benefit for increasing the UE transmits power. Now the HPUE for many bands in LTE, e.g., Band 38, Band 40, Band 41 and Band 42 have been completed. This results in significant improvement in UL coverage for these high bands.

Meanwhile, the study of high power UE (HPUE) operation, i.e. power class 2, for NR Band n41, n77, n78 and n79 have been almost completed, motivated by significant benefits in cell coverage and cell edge user throughput that are needed for and can be achieved for NR related networks. Considering E-UTRA and NR need sharing the transmit power in the EN-DC mode, that means the EN-DC UL coverage will be less than NR Standalone and LTE only. This WID will focus on introduce high power UE for EN-DC (1 LTE FDD band + 1 NR TDD band) to the UL coverage of EN-DC networks.

Many issues related to HPUE are common across different combinations. Following the similar approach adopted for LTE TDD HPUE in RAN4, this study item is to study how to introduce power class 2 for EN-DC for 1 LTE FDD band + 1 NR TDD band in Rel-16.

## 4.2 Objective

The objectives of the SI are as follows:

* Study how to introduce the new power class 2 (1 LTE FDD band + 1 NR TDD band) for EN-DC bands in Rel-16
  + Study and define the power class for EN-DC under different power combination such as 23dBm LTE FDD+23dBm NR, 23dBm LTE FDD+26dBm NR in table 4.2-1.
* Table 4.2-1: Example of power class definition

|  |  |  |  |
| --- | --- | --- | --- |
| Case number | EN-DC total power | LTE maximum power | NR maximum power |
| Case 1 | 26dBm | 23dBm | 23dBm |
| Case 2 | 26dBm | 23dBm | 26dBm |
| NOTE1: for case 1 and case 2, the duty cycles of NR TDD can be different.  NOTE2: RAN4 study starts from case 1, but case 2 is not precluded. | | | |

* + Study and define applicable scheme (UE Tx duty cycle) to prevent exceeding local regulatory limits such as SAR
* The example band combination for this study is DC\_3A\_n78n.

# 5 Power class definition for EN-DC

## 5.1 Power class

For EN-DC with 1 LTE FDD band and 1 NR TDD band, UE maximum output power shall be measured over all component carriers from different bands. If each band has separate antenna connectors, maximum output power is measured as the sum of maximum output power at each UE antenna connector. The period of measurement shall be at least one sub frame (1ms). For the example band combination DC\_3A\_n78A, the maximum output power can be specified as in Table 5.1-1.

* Table 5.1-1: Maximum output power for EN-DC

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **DC configuration** | **Power class 2**  **(dBm)** | **Tolerance**  **(dB)** | **Power class 3**  **(dBm)** | **Tolerance**  **(dB)** |
| DC\_3A\_n78A | 26 | +2/-31 | 23 | +2/-31 |
| NOTE 1: 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 2: PPowerClass\_EN-DC is the maximum UE power specified without taking into account the tolerance  NOTE 3: For inter-band EN-DC the maximum power requirement should apply to the total transmitted power over all component carriers (per UE). | | | | |

## 5.2 Power combination of the power class

As stated in clause 4.2, two power combinations are studied i.e.

Case1: LTE FDD power class 3 (23dBm), NR TDD power class 3 (23dBm) and EN-DC power class 2 (26dBm)

Case2: LTE FDD power class 3 (23dBm), NR TDD power class 2 (26dBm) and EN-DC power class 2 (26dBm)

Unless otherwise stated, requirements written in TS 36.101-1 [5] and TS 38.101-1 [3] apply for LTE and NR transmitters respectively.

# 6 Solutions for SAR Compliance

## 6.1 General

To accommodate the SAR limits of the PC2 FDD-TDD High Power UE, a combined UE-based and network-based solution is considered in the study phase. In the network-based solution, there will be a threshold based on the duty cycle and power settings of LTE and NR, the PC2 UE is assumed to be capable of maintaining the PC2 power if the network setting or scheduling does not exceed the threshold. In addition to the network based solution, a UE based solution based on the autonomous UE maximum power back off mechanism, i.e., P-MPR, can further allow the UE to ensure SAR compliance. For the network-based solution following different schemes were discussed in the SI.

## 6.2 Case1 of power class 2

### 6.2.1 Scheme 1

The following equation is applied between the LTE UL duty cycle, NR UL duty cycle and the overall duty threshold.

* **DutyLTE \*( PLTE/ P26) + DutyNR \*(PNR/ P26) ≤ *Duty threshold …*(1)**

PLTE, PNR, P26 represent the maximum linear power (mW) of LTE, NR, and EN-DC power class 2 respectively; DutyLTE, DutyNR represent the maximum uplink percentage of LTE, NR respectively. Duty threshold represents the maximum UL duty cycle that can maintain the PC2 power class for FDD+TDD EN-DC HPUE.

In the case 1 of power class 2 FDD-TDD EN-DC UE, the maximum uplink power of LTE and NR are both 23dBm.By setting the PLTE, PNR to be 23dBm, equation (1) can be simplified to the following equation.

* **0.5\*DutyLTE  + 0.5\*DutyNR ≤ *Duty threshold …*(2)**

DutyNR, the uplink percentage of the NR TDD part is determined by scheduling. DutyLTE, the maximum uplink percentage of the LTE FDD, can be set up by TDM pattern or determined by scheduling. The maximum uplink percentage of LTE FDD might be adjusted in order to keep the PC2 power.

The PC2 case 1 UE is allowed to fallback to PC3 if the LTE uplink scheduling or the TDM pattern setting of the LTE UL, together with the scheduled NR uplink duty cycle exceeds the duty threshold based on the equation (2).

### 6.2.2 Scheme 2

Specific LTE reference configurations are defined for FDD-TDD EN-DC HPUE duty cycle capability reporting. The reported capability is maximal NR UL duty which can fulfil SAR limits when assuming LTE FDD side being configured as the defined reference configurations with the maximum UL power.

For case 1, the LTE reference configuration can be DutyLTE=70%. The default value of NR UL duty capability can be 30% i.e. "DutyLTE=70% and PLTE=23dBm", corresponding to default DutyNR=30%, PNR=23dBm.

Higher DutyNR value can be reported as the UE capability e.g. maxNRDuty. If the scheduled traffic fulfils DutyLTE<70% and DutyNR< maxNRDuty, UE can maintain PC2 power.

For better flexibility, two LTE configurations are supported. Based on the two LTE configurations {DutyLTE1, DutyLTE2}, UE optimizes its SAR compliance capability and reports two DutyNR separately, e.g. {maxNRDuty1, maxNRDuty2}.

### 6.2.3 Scheme 3

To address an issue that the impact of each of the uplink bands on SAR is different, scheme 3 is proposed to consider that aspect in an equation to derive SAR ration effect for each of the RATs as follows:

UplinkDutyCycleLTE\*( pLTE/pPowerClass, EN-DC) \*Ratioeffect + UplinkDutyCycleNR\*(pNR/pPowerClass, EN-DC) ≤ *maxUplinkDutyCycle-EN-DC*;

Where;

* maxUplinkDutyCycle-EN-DC for FDD LTE + TDD NR is to be defined in TS 38.306 and that is the total maxUplinkDutyCycle of LTE FDD and NR TDD uplink. Note in LTE TDD + NR TDD, the value is only for NR TDD uplink.
* UplinkDutyCycleLTE is the percentage of LTE FDD uplink symbols transmitted in a cetain evaluation period;
* UplinkDutyCycleNR is the percentage of NR TDD uplink symbols transmitted in a cetain evaluation period;
* PPowerClass, EN-DC is defined in clause 6.2B.1.3 for inter-band EN-DC. pPowerClass, EN-DC is the linear value of PPowerClass, EN-DC;

- PLTE is the value given by the field *p-maxEUTRA-r15* of the *RRCConnectionReconfiguration-v1510* IE as defined in TS 38.331. pLTE is the linear value of PLTE;

- PNR is the value given by the field *p-NR-FR1* of the *PhysicalCellGroupConfig* IE as defined in TS 38.331. pNR is the linear value of PNR;

- Ratioeffect is to be defined in TS 38.306 as coefficient taking into account electromagnetic energy absorption effect ratio of the LTE FDD band and the NR TDD band;

The above equations of would be able to consider the important aspects which should be considered while both are mutually exclusive relationships.

The above equations of would be able to consider the important aspects which should be considered while both are mutually exclusive relationships.

From the performance aspect, it is better to introduce Ratioeffect in the equation to utilize the UE's ability. For example, it is assumed that a UE has imbalance of SAR effect such as Ratioeffect =2, that is SAR effect of NR band is 2 times as large as that of LTE band. In this case, if we do not capture Ratioeffect factor in the equation, UE is forced to report lower EN-DC total duty cycle than what it really has. That is, assuming one of boundary condition is such that DutyLTE=100% for LTE alone transmission and DutyNR=50% for NR alone transmission, and if we does not introduce Ratioeffect, UE are forced to report EN-DC total duty cycle as 50% to consider the worst case scenario although the UE has ability to transmit higher than 50% UL EN-DC duty cycle.

On the other hands, the scheme 3 becomes meaningful only when Ratioeffect is within reasonable range. If the value in the equationis set to 20, which was mentioned by a certain company, LTE FDD uplink is almost not allowed. Given that maxUplinkDutyCycle-EN-DC = 100% while LTE FDD (23dBm) + NR TDD (23dBm) are assumed. If NR TDD uplink duty cycle is 50% for instance, the LTE FDD uplink duty cycle is 2.5%. Even if NR TDD uplink duty cycle is 30%, still LTE FDD duty cycle is 3.5%. The impact on LTE TDD uplink duty cycle depends on the total maxuplink duty cycle. Hence, the range of Ratioeffect together with the total maxuplinkdutycycle for EN-DC if that is introduced should be discussed.

## 6.3 Case2 of power class 2

### 6.3.1 Scheme 1

The following equation is applied between the LTE UL duty cycle, NR UL duty cycle and the overall duty threshold.

* **DutyLTE \*( PLTE/ P26) + DutyNR \*(PNR/ P26) ≤ *Duty threshold …*(1)**

PLTE, PNR, P26 represent the maximum linear power (mW) of LTE, NR, and EN-DC power class 2 respectively; DutyLTE, DutyNR represent the maximum uplink percentage of LTE, NR respectively. Duty threshold represents the maximum UL duty cycle that can maintain the PC2 power class for FDD+TDD EN-DC HPUE.

In the case 2 of power class 2 FDD-TDD EN-DC UE, the maximum uplink power of LTE and NR are 23dBm and 26dBm respectively. By setting the PLTE, PNR to be 23dBm and 26dBm, equation (1) can be simplified to the following equation. But note that in case 2 PC2 UE, the total maximum power of LTE and NR cannot exceed 26dBm when transmitting both LTE UL and NR UL at the same time.

* **0.5\*DutyLTE  + DutyNR ≤ *Duty threshold…*(2)**

As same as the scheme in clause 6.2.1, DutyNR is determined by scheduling. DutyLTE can be set up by TDM pattern or determined by scheduling.

The PC2 case 2 UE is allowed to fallback to PC3 if the LTE uplink scheduling or the TDM pattern setting of the LTE UL, together with the scheduled NR uplink duty cycle exceeds the duty threshold based on the equation (2).

### 6.3.2 Scheme 2

Specific LTE reference configurations are defined for FDD-TDD EN-DC HPUE duty cycle capability reporting. The reported capability is maximal NR UL duty which can fulfil SAR limits when assuming LTE FDD side being configured as the defined reference configuration with the maximum UL power.

For case 2, the LTE reference configuration can be DutyLTE=40%. The default value of NR UL duty capability can be 30% i.e. "DutyLTE=40% and PLTE=23dBm", corresponding to default DutyNR=30%, PNR=26dBm.

Higher DutyNR value can be reported as the UE capability e.g. maxNRDuty. If the scheduled traffic fulfils DutyLTE<40% and DutyNR< maxNRDuty, UE can maintain PC2 power.

For better flexibility, two LTE configurations are supported. Based on the two LTE configurations {DutyLTE1, DutyLTE2}, UE optimizes its SAR compliance capability and reports two *DutyNR* separately, e.g. {*maxNRDuty1, maxNRDuty2*}.

### 6.3.3 Scheme 3

The equation is same as that described in clause 6.2.3 while PLTE and PNR is set according to Case2 in Table 4.2-1.

# 7 Rx sensitivity degradation (if applicable)

# 8 specification impacts

## 8.1 Impacts on RAN4 specifications

Required changes in UE RF specification TS 38.101-3 are shown in Table 8.1-1.

Table 8.1-1: Required changes in TS 38.101-3

|  |  |  |
| --- | --- | --- |
| Clause | Requirement | Required changes in TS 38.101-3 compared to the same band combination for power class 3 |
| 6.2B.1 | UE maximum output power for EN-DC | Add power class 2 for inter-band EN-DC. The additional details of power class for LTE and NR may be also needed |
| 6.2B.4.1.3 | Configured output power for inter-band EN-DC within FR1 | It shall be verified whether the existing Pcmax for inter-band EN-DC can be applied to HP UE. Some changes shall be needed to address SAR issue. |
| 7.3B.2.3.1 | Reference sensitivity exceptions due to UL harmonic interference for EN-DC in NR FR1 | No changes for case 1  No changes for case 2 considering the harmonic product of TDD band (high band) would not be possible to affect the lower FDD band. |
| 7.3B.2.3.2 | MSD due to receiver harmonic mixing for EN-DC in NR FR1 | No changes for case 1  MSD value may need to be re-evaluated for case 2 |
| 7.3B.2.3.3 | Reference sensitivity exceptions due to close proximity of bands for EN-DC in NR FR1 | No changes for case 1  MSD value may need to be re-evaluated for case 2 |
| 7.3B.2.3.4 | Reference sensitivity exceptions due to cross band isolation for EN-DC in NR FR1 | No changes for case 1  MSD value may need to be re-evaluated for case 2 |
| 7.3B.2.3.5 | Reference sensitivity exceptions for intermodulation interference due to dual uplink operation for EN-DC in NR FR1 | MSD value may need to be re-evaluated for case 1 and case 2 |

## 8.2 Impacts on specifications for the other WGs (if applicable)

# 9 Summary

In this study item, different solutions which could facilitate Power Class 2 FDD-TDD EN-DC High Power UE to comply with applicable SAR requirement has been throughout studied, with considering the fact that two kinds of UE implementations could exist, i.e., UE implementation case 1 with power class 3 capability for both LTE and NR, and case 2 with power class 3 capability for LTE and power class 2 capability for NR.

The scheme 1, 2, 3 provided in Clause 6 are UE capability reporting based solutions for SAR limitation compliance designed for PC2 FDD-TDD EN-DC HPUE. Particularly, the scheme 2 introduces the UE capability reporting containing the upper limit(s) for the configurable UL duty cycle for NR TDD carrier under the certain pre-defined LTE configuration(s) with upper limit(s) on the ratio of accumulated time allowed for UE maximum power transmission scheduling over the entire evaluation period. By comparing proposed schemes, RAN4 conclude that with introducing the mechanism in scheme 2, network can be indicated with the proper information to facilitate corresponding network configuration for PC2 FDD-TDD EN-DC HPUE with the applicable SAR limit compliance.

During the study item, RAN4 identified that the scheme 2 shall be introduced for specific FDD+TDD EN-DC band combination(s), and RAN4 observed that detailed signalling design to enable scheme 2 shall have RAN2 specification impact.

Meanwhile, RAN4 identified that network-configuration-based scheme in which the HPUE set its total EN-DC power based on higher-layer signalling could also provide the alternative methodology for PC2 FDD-TDD EN-DC HPUE SAR requirement compliance without explicit 3GPP specification impact and without need for signalling and cell-group coordination, while some concern raised for the resultant LTE coverage reduction, and for the applicable SAR limit compliance..

Annex A:  
Change history

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Change history** | | | | | | | |
| **Date** | **Meeting** | **TDoc** | **CR** | **Rev** | **Cat** | **Subject/Comment** | **New version** |
| 2019-2 | RAN4#90 | R4-1900694 |  |  |  | Skeleton TR | v0.0.1 |
| 2019-12 | RAN#86 | RP-192798 |  |  |  | Version for approval to RAN | v1.0.0 |
| 2019-12 | RAN#86 |  |  |  |  | Approved by plenary – Rel-16 spec under change control | 16.0.0 |