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Foreword

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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

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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 LTE FDD Band 14. The purpose is to gather the relevant background information and outcome of evaluations to complete the band specific requirements.

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

[2] 3GPP TR 38.861: "Study on high power UE (power class 2) for one NR FDD band".

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

3 Definitions of terms, symbols and abbreviations

3.1 Terms

For the purposes of the present document, the terms given in 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 TR 21.905 [1].

Carrier aggregation: Aggregation of two or more component carriers in order to support wider transmission bandwidths.

Channel bandwidth: The RF bandwidth supporting a single E-UTRA RF carrier with the transmission bandwidth configured in the uplink or downlink of a cell. The channel bandwidth is measured in MHz and is used as a reference for transmitter and receiver RF requirements.

Channel edge: The lowest and highest frequency of the carrier, separated by the channel bandwidth.

3.2 Symbols

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

L_{CRB} Transmission bandwidth which represents the length of a contiguous resource block allocation expressed in units of resources blocks

RB_{start} Indicates the lowest RB index of transmitted resource blocks.

3.3 Abbreviations

For the purposes of the present document, the abbreviations given in 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 TR 21.905 [1].

A-MPR	Additional Maximum Power Reduction
CA	Carrier Aggregation
CBW	Channel BandWidth
DC	Dual Connectivity
FDD	Frequency Division Duplex
EVM	Error Vector Magnitude
HPUE	High Power User Equipment
MPR	Maximum Power Reduction
PA	Power Amplifier
P-MPR	Power Management Maximum Power Reduction
REFSENS	Reference Sensitivity power level
RSD	Reference Sensitivity Degradation
SAR	Specific Absorption Rate
SEM	Spectrum Emissions Mask
TDD	Time Division Duplex
UE	User Equipment
WOLA	Weighted OverLap and Add

4 Background

4.1 Justification

Increasing the transmit power of the UE has significant benefits on extending uplink coverage area and improving the experience of cell edge users. In Rel-16 several study/work items related to HPUE have been proposed and worked on to standardize the requirements for EN-DC (FDD 23dBm+TDD 23/26dBm) scenarios. In Rel-17, PC2 HPUE for NR CA and SUL is also specified. In Rel-18, a new work item was introduced to address single band HPUE (PC2) operation in lower-frequency NR FDD bands.

However, extension of uplink coverage for lower-frequency LTE FDD band is very important for operators and to support public safety scenarios. The increment of UE transmit power would bring performance gain for both cell average and cell edge cases, which were verified under various power control parameters as one of the conclusions in Rel-17 Study on high power UE (power class 2) for one NR FDD band in 3GPP TR 38.861 [2].

In the Rel-17 WI on NR_PC2_UE_FDD, RF requirements including Tx power and tolerance, A-MPR and receiver sensitivity degradation requirements were specified for NR FDD band n1 and n3 under PC2 operation. And there are some further requests proposed by operators on PC2 for more NR FDD bands, including lower-frequency bands in the Rel-18 WI on HPUE_NR_FR1_FDD_R18 to fulfil the commercial deployment demands. It is expected that much of the technical analysis performed for HPUE operation in lower-frequency NR FR1 FDD bands can be leveraged for lower-frequency LTE FDD bands.

This Work Item is proposed to work on specifying RF requirements for HPUE (PC2) operation for LTE FDD band 14.

4.2 Objectives

The objectives of the core part are as follows:

1) Specify the band specific RF requirements for power class 2 LTE Band 14 including
   a) UE maximum output power and Tx power tolerance
   b) A-MPR requirements if needed

c) PC2 sensitivity degradation requirements if needed

NOTE 1: Ensure that the UE RF requirements of power class 2 UEs shall comply with those of power class 3 when the maximum transmit power is limited to 23dBm by eNB configuration.
NOTE 2: To keep within the framework of LTE, only 1Tx UE architecture is considered in this WI.
NOTE 3: A UE-implementation based method within the framework of LTE (P-MPR) will be used to make sure SAR regulation is not violated.

5 SAR Scheme

5.1 UE-Based Solution

To accommodate the SAR limits of the E-UTRA PC2 FDD High Power UE, only the UE-based solution is considered. The UE implementation-based mechanism is used to ensure SAR compliance (i.e., P-MPR).

6 RF Performance

6.1 UE maximum output power

The UE maximum output power and tolerance are listed in Table 6.1-1.

Table 6.1-1: UE Output Power for PC2

EUTRA band	Class 2 (dBm)	Tolerance (dB)
14	26	±2

6.2 A-MPR

6.2.1 NS_06

The introduction of PC2 to band 14 requires A-MPR evaluation for NS_06.

6.2.1.1 A-MPR simulation results from Apple

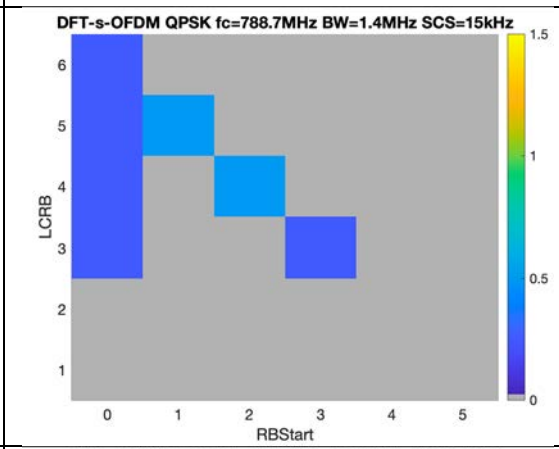
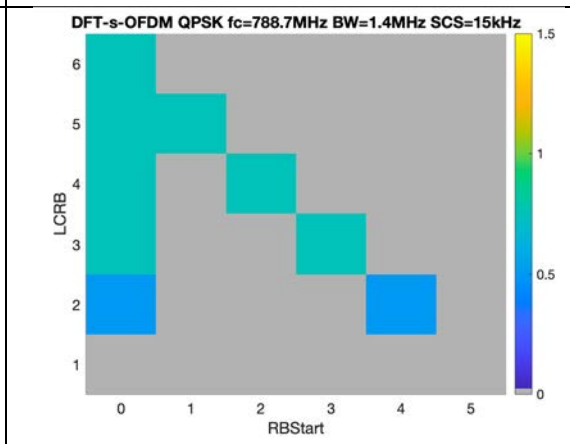
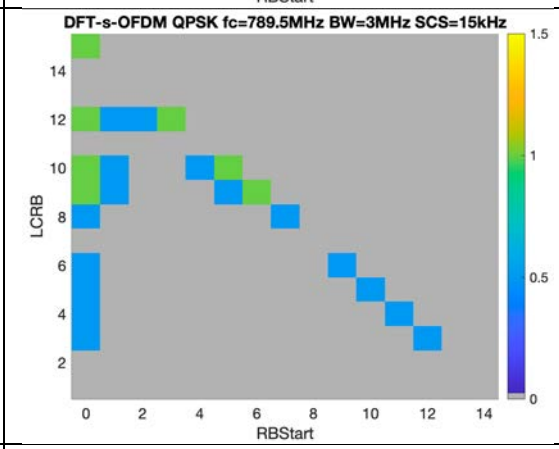
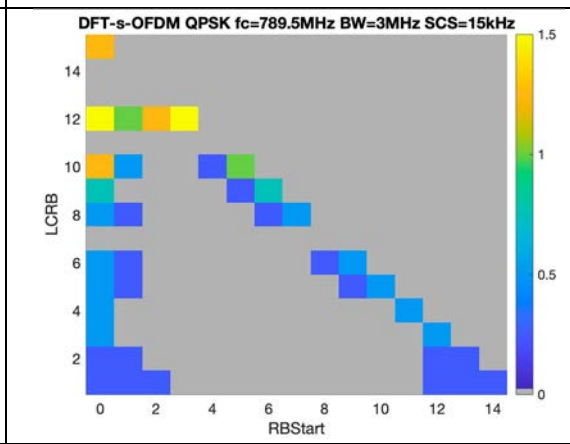
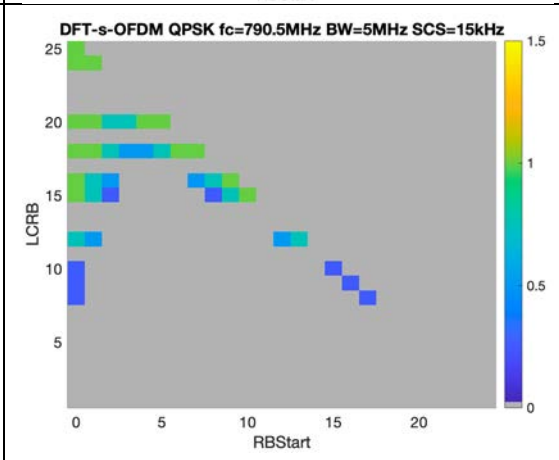
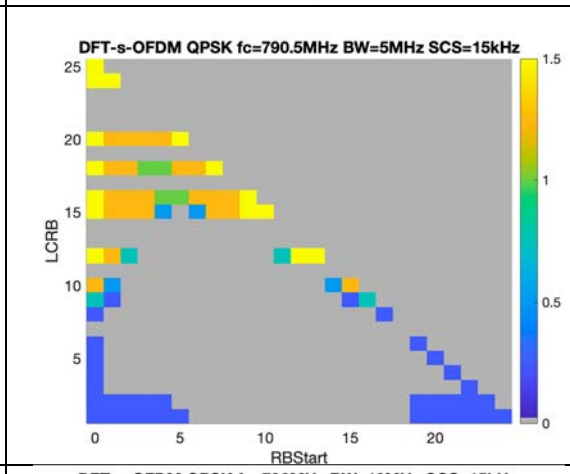
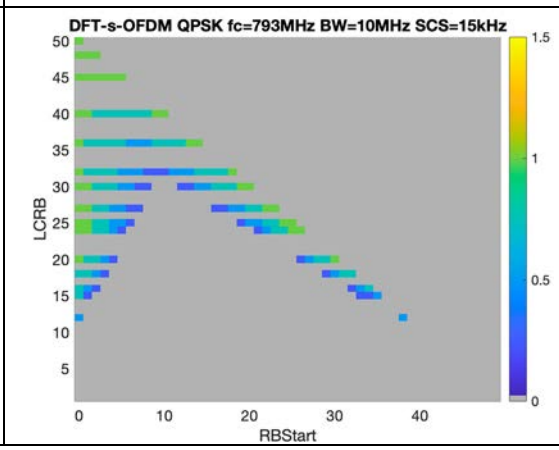
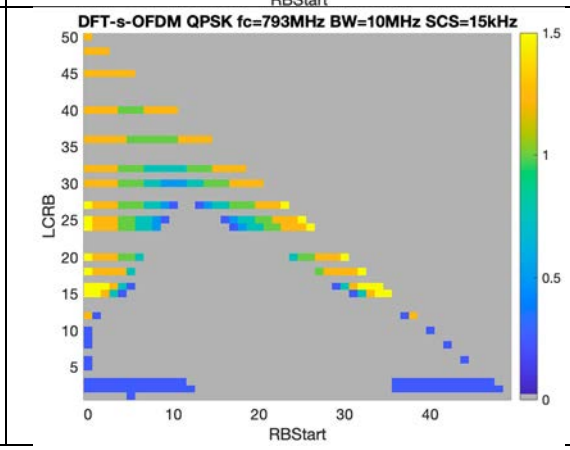
Simulations have been conducted for all channel bandwidth from 1.4MHz to 10MHz. To allow easy comparison the power back-off is provided for PC3 and PC2 and the scaling is the same for all plots.

The following assumptions and requirements are used for the simulations:

- Power Class 3 & 2
- Fixed Bias
- LTE Waveform
- Calibration: 1dB MPR: DFT-s-OFDM QPSK 20MHz, 100RB
- Carrier Leakage: 25dBc
- Image: 25dBc
- CIM3: 60dBc

The NS_06 Additional SEM is specified in clause 6.6.2.2.3 of 3GPP 36.101 [3]. Simulation results can be found in Table 6.2.1.1-1. Typically, the plots are quantised to 0.5dB steps. As this resolution is too coarse for a range of 0 to 1.5dB the granularity is improved by using 0.25dB steps.

Table 6.2.1.1-1: Power back-off for QPSK and NS_06

CBW MHz	PC3	PC2
1.4		
3		
5		
10		

By comparing the power back-off between PC3 and PC2, it can be observed that there is roughly a 0.5dB difference between PC3 and PC2. Higher order modulations such as 64QAM and 256QAM are EVM limited and the back-off is not dominated by the requirements of NS_06. Therefore, it is proposed to introduce a 0.5dB relaxation for QPSK and 16QAM.

6.2.1.2 A-MPR requirements

Based on the simulation results from previous section, the PC2 A-MPR requirements for NS_06 are proposed below in Table 6.2.1.2-1.

Table 6.2.1.2-1: Additional Maximum Power Reduction (A-MPR) for NS_06 for Power Class 2

Channel bandwidth [MHz]	Parameters	Region A	Region B	Region C
1.4	RB_{start} [RB]	≥ 0	0	≥ 4
	L_{CRB} [RB]	> 2	≤ 2	≤ 2
	A-MPR [dB]	0.5	0.5	0.5
3	RB_{start} [RB]	≥ 0	0	≥ 13
	L_{CRB} [RB]	> 4	≤ 2	≤ 2
	A-MPR [dB]	0.5	0.5	0.5
5	RB_{start} [RB]	≥ 0	0	≥ 23
	L_{CRB} [RB]	> 6	≤ 2	≤ 2
	A-MPR [dB]	0.5	0.5	0.5
10	RB_{start} [RB]	≥ 0	0	≥ 48
	L_{CRB} [RB]	> 10	≤ 2	≤ 2
	A-MPR [dB]	0.5	0.5	0.5

Region A re-uses slightly extended MPR regions and allows for 0.5dB additional back-off. When comparing the limits from NS_06 to standard SEM, it can be found that the requirements are tighter inside the very first MHz outside the channel. Edge allocations are very sensitive to the deployed channel filter and WOLA setup. Therefore, it is proposed to introduce a mild relaxation of 0.5dB for those allocations. The approach is similar to Edge RB allocations in NR. Relaxation for the RBs directly bordering the channel edge is captured with regions B and C.

6.3 Receiver sensitivity degradation evaluation

The receiver sensitivity degradation evaluation for PC2 LTE Band 14 can leverage the evaluation done for PC2 NR Band n14 for the 1Tx case. The RSD from PC2 to PC2 for NR Band n14 for UE not supporting Tx Diversity is based on using the average result of RSD analyses performed by several companies as shown in 6.3-1:

Table 6.3-1: Reference Sensitivity Degradation from PC3 to PC2 for FDD bands for UE not supporting Tx Diversity

Operating Band	Source	5 MHz (dB)	10 MHz (dB)	15 MHz (dB)	20 MHz (dB)	25 MHz (dB)	30 MHz (dB)	35 MHz (dB)	40 MHz (dB)	45 MHz (dB)	50 MHz (dB)
n14	Skyworks (R4-2311152)	0.4	0.8								
	Apple (R4-2311251)	0.3	0.6								
	Huawei, HiSilicon(R4-2316472)	0.9	1.0								
	Murata (R4-2318253)	0.7	0.8								
Average		0.6	0.8								

The 5MHz CBW PC3 REFSENS requirement for NR Band n14 is identical to the 5MHz CBW PC3 REFSENS requirement for LTE Band 14. Therefore, the 5MHz CBW PC2 REFSENS requirement for LTE Band 14 can be easily derived by adding the RSD determined for NR Band n14.

The 10MHz CBW PC3 REFSENS requirement for NR Band n14 is slightly different than the 10MHz CBW PC3 REFSENS requirement for LTE Band 14. Therefore, the RSD determined for NR Band n14 cannot be directly added to the 10MHz CBW PC3 REFSENS requirement for LTE Band 14. In order to derive the 10MHz CBW PC2 REFSENS

requirement for LTE, the noise power impact in mW due to the PC2 transmitter needs to be determined and added linearly to the 10MHz CBW PC3 REFSENS requirement in mW for LTE Band 14.

The noise power impact in mW due to the PC2 transmitter can be determined by taking the 10MHz PC3 REFSENS requirement in mW for NR Band n14 and calculating the noise power in mW necessary to result in the 10MHz PC2 REFSENS requirement in mW for NR Band n14. Assuming similar noise power impact due to the PC2 transmitter in LTE, the noise power impact in mW can be added to the 10MHz PC3 REFSENS requirement in mW for LTE Band 14 to determine the 10MHz PC2 REFSENS requirement in mW for LTE Band 14.

The derivation of the 10MHz PC2 REFSENS requirement in dBm for LTE Band 14 is shown in Table 6.3-2.

Table 6.3-2: 10MHz reference sensitivity for PC2 for LTE Band 14

Evaluation Quantity	Value
PC3 NR REFSENS (dBm)	-93.8
PC3 NR REFSENS (mW)	4.16869E-10
PC2 NR REFSENS (dBm)	-93.0
PC2 NR REFSENS (mW)	5.01187E-10
Impact of noise (mW)	8.43179E-11
-	-
PC3 LTE REFSENS (dBm)	-94.0
PC3 LTE REFSENS (mW)	3.98107E-10
Impact of noise (mW)	8.43179E-11
PC2 LTE REFSENS (mW)	4.82425E-10
PC2 LTE REFSENS (dBm)	-93.1657018

The B14 PC2 REFSENS requirement will be specified in 3GPP TS 36.101 [3] as an absolute power level as shown in Table 6.3-3.

Table 6.3-3: Reference sensitivity QPSK $P_{REFSENS}$

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**
…							
14			-97	-94			FDD
			-96.4[X]	-93.2[X]			
…							
NOTE X: The requirement is applicable for power class 2 UE.							

7 UE implementations

7.1 Current RF component characteristics in FDD band

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

From the current RF component characteristics described below, the following observation follows:

Observation : In FDD band, the PA charateristics should be able to support PC2 maximum output power since PA linearity and output power of existing TDD band PAs are sufficient and an FDD band PA for band 14 and other low FDD bands should be feasible. In FDD band, the Duplexer charateristic is not supporting PC2 maximum output power since Duplexer allowed maximum power rating shall improve the performance at least 3dB higher than current component charateristics.

7.1.1 Power Amplifier characteristics

The following characteristics of PA are shown in Table 7.1.1-1.

Table 7.1.1-1: 1Tx PC2 TDD PA max. output power in n41 and n77 for QPSK SC-FDMA, MPR 0dB

Parameter	Symbol	Conditions	Min.	Typ.	Max.	Unit
n41 Operating Frequency	f_0		2496		2690	MHz
n77 Operating Frequency	f_0		3300		4200	MHz
Maximum NR Output Power	POUT_MAX_NR_NTC	Boosted battery VCC = 5V, NTC	30		32.5	dBm

The TDD PC2 PAs are designed to account for approximately 4.5dB maximum post-PA loss for n41 and n77 TDD bands. The post PA losses for these operating bands should be equivalent as the steeper band 41 filter has higher losses compared to the band n77 wideband filter losses, but these losses are compensated by higher trace and switch losses at 3.5GHz versus 2.5GHz.

In band 14 and other low FDD bands, similar post-PA losses are anticipated (lower trace loss but higher filter losses in duplexers due to higher power handling) with PA performance with better gain and efficiency since the PA is operating at lower frequencies and smaller channel bandwidths.

The PC2 FDD band 14 PA should be feasible.

7.1.2 Duplexer characteristics

The following characteristics of the Duplexer is shown in Table 7.1.2-1.

- Duplexer characteristic for the allowed max. input power in Band 14

Table 7.1.2-1: Duplexer max. input power in Band 14

Operating Frequency	Maximum Input Power	Units	Conditions
Input power at PIN 788-798 MHz	30.0	dBm	source and load impedance 50Ω 5MHz LTE, NR uplink @50℃, 5000h Condition: SC-FDMA, MPR 0dB
Input power at PIN 788-798 MHz	31.0	dBm	Condition: Continuous wave

Based on the above Duplexer performance information in FDD band, the current Duplexer needs to improve the maximum power rating by at least 2~3dB higher than the current Duplexer characteristics.

8 Conclusions

In this work item, different aspects of enabling PC2 in NR FDD band 14 were addressed. The contents of the work included the applicable schemes to comply with SAR limits with 26dBm UE Tx power, the maximum output power limits, A-MPR requirements, the REFSENS degradation raised by FDD PC2, and UE implementations.

To accommodate the SAR limits of the E-UTRA PC2 FDD High Power UE, only the UE-based solution was considered. The UE-implementation based methods (i.e., P-MPR) are considered feasible to make sure SAR regulation is not violated.

In order to support 26dBm UE Tx power, only one RF architecture (i.e. 1Tx×26dBm) was considered. It was found that FDD HPUE with 1Tx architecture may need to use newly designed components. However, the design and performance of the components were determined to be feasible.

In conclusion, it has been shown in this work item that high power UE (power class 2) for NR FDD band 14 is feasible. The corresponding core requirements for maximum output power, A-MPR for NS_06 for PC2, and the reference sensitivity degradation were determined.

Annex A:
Change history

Change history							
Date	**Meeting**	**TDoc**	**CR**	**Rev**	**Cat**	**Subject/Comment**	**New version**
2023-11	RAN4-108-bis	R4-2315273				TR Skeleton for Work Item on High Power UE (Power Class 2) for LTE FDD Single Band	0.1.0
2023-11	RAN4-109	R4-2318088				TP for TR 36.770 Scope and Background	0.1.0
2023-11	RAN4-109	R4-2318089				TP for TR 36.770 SAR Scheme	0.1.0
2024-02	RAN4-110	R4-2400693				TP for TR 36.770 UE maximum output power	0.2.0
2024-02	RAN4-110	R4-2400695				TP for TR 36.770 Receiver sensitivity degradation evaluation	0.2.0
2024-02	RAN4-110	R4-2400696				TP for TR 36.770 UE implementations	0.2.0
2024-02	RAN4-110	R4-2400697				TP for TR 36.770 Removal of System Performance Evaluation Clause	0.2.0
2024-02	RAN4-110	R4-2400698				TP for TR 36.770 Conclusions	0.2.0
2024-02	RAN4-110	R4-2403607				TP for TR 36.770 A-MPR requirements	0.2.0
2024-03	RAN-103	RP-240076				TR 36.770 v1.0.0 HPUE_LTE_FDD_B14	1.0.0

Change history							
Date	**Meeting**	**TDoc**	**CR**	**Rev**	**Cat**	**Subject/Comment**	**New version**
2024-03	RAN#103					Approved by plenary – Rel-18 spec under change control	18.0.0

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