**3GPP TSG-RAN WG4 Meeting #111 R4-2410565**

**Fukuoka, Japan, 20-24 May, 2024**

**Title:** WF on higher power UE

**Agenda Item:** 10.1.1.2

**Source:** Samsung

**Document for:** Approval

# 1. General aspect

## 1.1 MSD framework

**Proposals:**

* + Proposal 1: Only one MSD is defined per band combination, no new MSD is defined for higher power classes. (Nokia, Ericsson)
	+ Proposal 2: (Qualcomm)
* If an MSD test case already exists for the band aggregation of the requested band combination, no new MSD test case is defined
* If an MSD test case does not exist for an already enabled band combination, the need for a new MSD test case is evaluated only if there is an increase in the per-band UL power capability in at least one of the constituent bands.
* If the requested band combination is new to the standard, the need for a new MSD test case is evaluated per legacy procedure.



* + Proposal 3: (vivo)
* If MSD of 2TX PC2 is higher than 10dB, MSD of 2TX PC1.5 (26+26 architecture) = MSD of 2TX PC2 + 3n, where n is the order of IMDn, n<=5.
* For the 23+29 3TX architecture of PC1.5, the MSD of IMD2 for 2TX PC1.5 could be reused.
* If the MSD of 2TX PC2 is higher than 10dB, for the intermodulation product of the 23+29 3TX architecture higher than the second order, MSD = 2TX PC2 MSD + 6|y| where y is the coefficient of the 29dBm band.
* If the IIPn of PA increases linearly with the gain and the MSD of PC2 is higher than 10dB, MSD of PC1.5 2TX(26+26) = MSD of PC2 2TX +3. MSD of PC1.5 2TX(23+29) = MSD of PC2 2TX + 6|y| -3(n-1), where y is the coefficient of the 29dBm band and n is the order of IMDn.
* For PC1.5 of inter-band CA, define the duty cycle based SAR scheme based on the scheme for Rel-18 PC1.5 inter-band CA+MIMO (3Tx).
* For Inter-band EN-DC(FDD+FDD) PC2, the duty cycle based SAR scheme of inter-band EN-DC(FDD+TDD) PC2 could be reused with editorial changes.
* For Inter-band EN-DC(TDD+TDD) PC1.5, the duty cycle based SAR scheme is FFS.
	+ Proposal 4: (OPPO)
* The below Rel-18 3Tx MSD conclusions for band combinations with PC2 total power class can be reused in Rel-19 for other cases except FDD 1T +FDD 2T due to no FDD 1T + FDD 1T HPUE in the spec up to now.
	+ - * + No harmonic MSD needs be analyzed for band combination with high band supporting 2Tx
				+ For 3Tx PC2 harmonic mixing and cross-band leakage MSD:

Reuse the MSD of 2Tx band combination for 3Tx band combination as long as the aggressor band has same power class

* + - * + For 3Tx PC2 IMD MSD:

The IMD MSD specified based on 1Tx-1Tx UL configuration are applicable for 1Tx-2Tx UL configuration.

* For FDD 1T +FDD 2T band combinations with PC2 total power class, the MSD will be analyzed case by case with power configurations 20dBm + 20dBm +23dBm.
* Align the MSD requirements between 2Tx and 3Tx PC1.5 band combinations. And if 3Tx is used as baseline for the MSD analysis, the Rel-18 power configuration 23dBm +24.8dBm +24.8dBm can be reused.
* The below Rel-18 3Tx MSD conclusions for band combinations with PC1.5 total power class can be reused in Rel-19.
	+ - * + No harmonic MSD needs be analyzed for band combination with high band supporting 2Tx
				+ For 3Tx PC1.5 harmonic mixing and cross-band leakage MSD:

Reuse the MSD of 2Tx band combination if exist for 3Tx band combination as long as the aggressor band has same power class

* + Proposal 5: (Huawei)

RAN4 to decide whether to specify PC1.5 MSD requirements for both IMD caused by 26+26 with 2Tx and IMD caused by 26+26 with 3Tx

* + Proposal 6: (Samsung)
* For PC1.5 IMD for NR-CA/EN-DC, discuss the following approaches to implement the “agreed PA assumption for IMD evaluation” into spec.

- Alt 1) 2Tx IMD table and 3Tx IMD table are separate tables

- Alt 2) 2Tx IMD and 3Tx IMD share one table, use different notes to indicate the PA assumption for different MSD values assuming same test configuration/points

* For 2-band inter-band NR-CA/EN-DC with 3Tx (one CC per band), adopt the following assumption for MSD requirements due to IMD

|  |  |
| --- | --- |
| **3Tx configuration** **(one CC per band)** | **MSD Requirements due to IMD** |
| PC3+PC2=PC2PC2+PC2=PC2PC3+PC1.5=PC2PC2+PC1.5=PC2 | Share same requirement with 2Tx PC3+PC3=PC2 |
| PC3+PC1.5=PC1.5 | Requirements (new IMD table) defined in Rel-18 for NR-CA, same approach can be used for EN-DC in Rel-19 |
| PC2+PC1.5=PC1.5PC2+PC2=PC1.5 | Share same requirements with 2Tx PC2+PC2=PC1.5 (To be defined in Rel-19) |

**Way forward:**

* + RAN4 recommend RAN to modify the WID to investigate new MSD framework for HPUE operation

## 1.2 Duty cycle solution for SAR compliance

**Online agreement:** Duty cycle solution is considered for both intra-band CA and inter-band CA/EN-DC

#  2. PC1.5 for intra-band contiguous and non-contiguous UL CA

## 2.1 Assumed UE architecture(s)/parameters/methodology for MPR/A-MPR evaluation

**Online agreement:**

**Agreement:**

* Evaluate MPR/A-MPR numbers for contiguous CA first and then work on non-contiguous CA MPR/A-MPR afterwards.
* The intra-band PC1.5 ULCA R19 work focusses on UE implementing with two 26dBm PAs. Architectures requiring a 29dBm PA are not specified but can be implemented by fulfilling the requirements based on two 26dBm PAs.
* For intra-band contiguous ULCA w/ and w/o UL MIMO, the Architecture#2 is prioritized for MPR/A-MPR evaluation.
	+ If time is allowed, architecture #1 can be evaluated.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Architecture** | **Description** | **Indicated capability** | **Whether can support UL MIMO** | **Applicable cases** |
| #1 | 2x26 dBm PA + 2 LO with 100MHz BW | dualPA-Architecture | No | Contiguous CA |
| #2 | 2x26 dBm PA + 1 LO with 200MHz BW | *TxD* | Yes | Contiguous CA |

* For intra-band NC ULCA w/o UL MIMO, the Architecture#1 is prioritized for MPR/A-MPR evaluation.
	+ FFS on Architecture #2

|  |  |  |  |
| --- | --- | --- | --- |
| **Architecture** | **Description** | **Indicated capability** | **Applicable cases** |
| #1 | 2x26 dBm PA + 2 LO with 100MHz BW | *dualPA-Architecture* | NC CA w/o UL MIMO |
| #2 | 2x26 dBm PA + 1 LO with 200MHz BW | *TxD* | NC CA w/o UL MIMO |

## 2.2 Whether to define separate MRP/A-MPR requirements for handheld UE and FWA respectively?

**Way forward:** Yes, and assuming 20dB minimum antenna isolation for FWA and 10dB for handheld UE

## 2.3 A-MPR for n41/n77/n78

**Way forward:**

* + A-MPR requirements are not needed for PC1.5 n77/n78 intra-band ULCA
	+ Check whether CA\_NS\_04 A-MPR(PC2) has been addressed properly, if no then further discuss how and where to fix it
	+ Evaluate A-MPR requirements for PC1.5 n41 intra-band UL CA

##  PCMAX,C

**Proposals:**

* + Proposal 1: Define PCMAX,c limitation for each component carrier considering PC1.5 UE architecture of intra-band UL CA. (LGE)
* For dualPA-architecture
	+ PCMAX,C limitation for each component carrier is 26dBm
* For TxD (dualTx)
	+ PCMAX,CC1 = $26+10\*log\_{10}( \frac{LCRB1\*SCS1}{LCRB1\*SCS1+LCRB2\*SCS2})+3$
	+ PCMAX,CC2 = $26+10\*log\_{10}( \frac{LCRB2\*SCS2}{LCRB1\*SCS1+LCRB2\*SCS2})+3$
	+ Proposal 2: Changes to TS 38.101-1 for dual-PA architecture, inset new equation for PCMAX,*c* (Ericsson, more details refer to R4-2407721)

**Way forward**: FFS in future meetings

## 2.5 PCMAX

**Proposals:**

* + Option 1: (Skyworks)
	+ MOP for 2Tx architectures (TxD w/wo UL MIMO) is: *29* dBm
	+ MOP for Dual-PA architectures (one PA/CC, 2LO) is:

*PCmax= 29 + 10\*log(1/2\*(1+Min(LCRB1\*SCS1,LCRB2\*SCS2)/Max(LCRB1\*SCS1,LCRB2\*SCS2)))* dBm

* + Option 2: (Skyworks)

MPR for Dual-PA architectures (one PA/CC, 2LO) is modified by: *10\*log(1/2\*(1+Min(LCRB1\*SCS1,LCRB2\*SCS2)/Max(LCRB1\*SCS1,LCRB2\*SCS2)))* dB

* + Option 3: (Captured in last meeting’s WF)

For R19 PC1.5 intra-band non-contiguous /contiguous ULCA with two 26dBm PAs and one PA per CC, the PCMAX is modified as follows to account for RB BW imbalances

PCmax=10\*log(10^(26/10) + 10^((26-10\*log(LCRB1\*SCS1/(LCRB2\*SCS2)))/10))

* + Option 4: For UEs indicating dualPA-Architecture (Architecture #1) the total configured output power PCMAX for the band combination is given by clause 6.2A.4.1.3 for inter-band CA in the current version of 38.101-1, the same applies for TxD (Ericsson)

**Way forward**: FFS in future meetings

## 2.5 PCMAX tolerance

**Agreement**: The PCMAX tolerance for uplink intra-band contiguous/non-contiguous CA are:

|  |  |  |
| --- | --- | --- |
| **PCMAX(dBm)** | **ToleranceTLOW(PCMAX)(dB)** | **ToleranceTHIGH(PCMAX)(dB)** |
| 23 < PCMAX ≤ 29 | 3 | 2 |
| 21 ≤ PCMAX ≤ 23 | 2.0 |
| 20 ≤ PCMAX < 21 | 2.5 |
| 19 ≤ PCMAX < 20 | 3.5 |
| 18 ≤ PCMAX < 19 | 4.0 |
| 13 ≤ PCMAX < 18 | 5.0 |
| 8 ≤ PCMAX < 13 | 6.0 |
| -40 ≤ PCMAX < 8 | 7.0 |

# 3. 2-band Inter-band UL NR-CA/EN-DC with 2Tx and/or 3Tx

## Requirements between handheld UE and FWA

**Way forward**:

* + For PC2 and PC1.5 2-band inter-band UL CA with 2Tx or 3Tx, only define one set of UE RF requirements for both handheld UE and FWA
	+ For PC2 and PC1.5 2-band inter-band EN-DC with 2Tx or 3Tx, only define one set of UE RF requirements for both handheld UE and FWA.

## 3.2 Whether to collect configurations to derive general requirements?

**Way forward:**

* + Maintain last meeting’s agreement, i.e., strive to define general requirements in a band-combination configuration agnostic way
	+ Do not collect and discuss configurations in this meeting

## 3.3 3UL CC with 3Tx

**Way forward:** RAN4 to discuss whether there is demand for 3CC with 3Tx scenario (such as CA\_nXA-nY(2A) and CA\_ nXA-nYB), and whether it is desirable to be introduced in Rel-19.

## 3.4 Release independence

**Way forward:**

Discuss the release independence for 3Tx band combination for handheld UE and FWA at later stage of this WI

* + For FWA, only discuss the configurations that were not introduced in Rel-18

# 4. Increasing UE transmission power

## 4.1 The methodology

**Online agreement:** Use the higherPowerLimit-R17 and higherPowerLimtMRDC-R17 capability as the starting point.

## 4.2 Whether increasing power limit applicability requires ΔPPowerClass,CA /ΔPPowerClass,EN-DC =0

**Way forward:** The high-power limit feature (higherPowerLimit-R17/higherPowerLimtMRDC-R17) only applies with ΔPPowerClass,CA /ΔPPowerClass,EN-DC = 0 dB, which is aligned with the Rel-17 agreement.

## 4.3 The scenarios to be considered in Rel-19

**Proposals:**

* + Proposal 1: (Samsung)
* For 2Tx, the following scenario can be considered for NR-CA/EN-DC.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Indicated PC for A-B****(2Tx in total)** | **PC for band A of A-B** | **PC for band B of A-B** | **From which release increasing high power limit feature supported** | **Note** |
| PC2 | PC3(FDD or TDD) | PC2 (FDD or TDD) | Support from Rel-19 | One CC on band A, 2CC on band B |
| PC2 | PC3(FDD or TDD) | PC2(FDD) | Support from Rel-19 | One CC per band |

* For 3Tx, the following scenarios may could be considered for NR-CA/EN-DC.

*(Note the analysis is based on the implementation feasibility)*

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Indicated PC for A-B****(3Tx in total)** | **PC for band A of A-B****(1Tx)** | **PC for band B of A-B****(2Tx)** | **The total power****(dBm)** | **Note** |
| PC2 | PC3 | PC2 | 27.8 | One CC per band One CC in band A, 2CC on band B (if this scenario would be introduced for 3Tx) |
| PC1.5 | PC3 | PC1.5 | 30.0 | One CC per band; For FWA onlyOne CC in band A, 2CC on band B (if this scenario would be introduced for 3Tx); For FWA only |

* + Proposal 2: Consider PC3+PC2 and PC3+PC1.5 for 3Tx as scenarios for increasing power limit Rel-19. (vivo)
	+ Proposal 3: (Qualcomm)
* higherPowerLimit-r17 is enabled for any standardized inter-band band combination. Cases where there is concern about exceeding local regulation are treated separately as exceptions.
* RAN4 to rely on network operators (carriers) to identify if local regulatory limits are exceeded when higherPowerLimit-r17 is enabled for their band combination.
* RAN4 to evaluate best method to identify corner case UL CA configuration (band combination + power class aggregation) where higherPowerLimit-r17 may NOT be used due to local regulation. Options:
	+ - Set up an NS case
		- Rely on PEMAX,CA, the value indicated by p-NR-FR1 or by p-UE-FR1
		- Maintain an exception list in 38.101-x for UL CA configurations where higherPowerLimit-r17 may NOT be used
* Remove references to power class or TR duplexing type from sections of the standard that enable use of higherPowerLimit-r17
	+ Proposal 4: (Skyworks)
* Regardless of the down selected increased power cases for Release 19, to be future proof, the work should address PCmax equations in order to support:
* Power increase for 3 levels (0.5/1/1.8dB).
* Power boosting on one or two bands.
* Increased power with power boosting additionally.
* Increased power of 3dB should not be allowed and a higher band combination power class signalled instead.
	+ FFS on how to deal with cases with 3dB increases above PC1.5
	+ FFS if this rule applies to cases where the 3dB increase is the result of power boosting.
	+ Proposal 5: The following power class configuration could be considered in Rel 19 for UE increasing high power limit. (Xiaomi)
* PC3 (TDD/FDD) +PC1.5 indicating PC1.5 with 3Tx
* PC2 (TDD with TxD) +PC3 (TDD/FDD) indicating PC2 with 3Tx
	+ Proposal 6: Consider Option 3 as the scenarios of increasing higher power limit in Rel-19. (LGE)
* For PC2 2Tx inter-band NR CA and ENDC:
* Inter-band with intra-band UL CA in one of the bands
* For HPUE 3Tx inter-band NR CA and ENDC:
* PC2 band combination of PC3+PC2 with single carrier in each band.
* PC1.5 band combination of PC3+PC1.5 with single carrier in each band.
* PC1.5 band combination of PC2+PC1.5 with single carrier in each band.
* Note: Only PC3 is considered for LTE FDD in EN-DC
	+ Proposal 7: Both FWA and handheld UE can support PC3+PC1.5 with increasing UE high power limit feature in Rel-19 if technical issues are not provided. (DCM)
	+ Proposal 8: (Huawei)
* Consider the following list of scenarios for increasing UE transmission power limit as shown in Table 1 below. And Increasing the total Tx power limit beyond PC1.5 is only for FWA UEs, not for handheld UEs.

 **Table 1: A list of applicable scenarios for increasing UE transmission power limit**

|  |  |  |  |
| --- | --- | --- | --- |
| **CA power class** | **Power class configuration****Band A + Band B** | **2Tx** | **3Tx** |
| PC3 | PC3 | PC5 | Completed in R18 | N/A |
| PC2 | PC2 | PC3 | Completed in R17 | R19 |
| PC5 | R19 | R19 |
| PC1.5 | PC1.5 | PC2 | N/A | R19 |
| PC3 | N/A | R19 |
| PC5 | N/A | R19 |

* + Proposal 9: (ZTE)
* To consider the following additional eligible PC2 2Tx inter-band NR CA and ENDC to enable increasing higher power limit in Rel-19:
* Inter-band with intra-band UL CA in one of the NR band
* To consider the following additional eligible HPUE 3Tx inter-band NR CA and ENDC with up to 3CC in UL bands to enable increasing higher power limit in Rel-19:
* PC2 band combination of PC3+PC2
* PC1.5 band combination of PC3+PC1.5
* PC1.5 band combination of PC2+PC1.5

*Note: Only PC3 is considered for LTE FDD in EN-DC*

* + Proposal 10: (CATT)
		- For 2Tx transmission, there is no new scenarios for increasing UE transmission power
		- For 3Tx transmission, there are three new scenarios for increasing UE transmission power as shown in the table below:

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| ***Indicated PC for A-B******(3Tx in total)*** | ***PC for band A of A-B******(1Tx)*** | ***PC for band B of A-B******(2Tx)*** | ***The total power******(dBm)*** | ***Note*** |
| *PC2* | *PC3* | *PC2* | *27.8* | *One CC per band*  |
| *PC1.5* | *PC3* | *PC1.5* | *30.0* | *One CC per band; For FWA only* |
| *PC1.5* | *PC2* | *PC1.5* | *30.8* | *One CC per band; For FWA only* |

**Way forward:** If higherPowerLimit-R17/higherPowerLimtMRDC-R17 capability is adopted for increasing UE transmission power. FFS the following:

* For 2Tx and 3Tx FWA, higherPowerLimit-R17/higherPowerLimtMRDC-R17 is enabled for any standardized inter-band band combination with different power classes.
* For 3Tx handheld UE, the following scenarios could be considered for NR-CA/EN-DC.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Indicated PC for A-B****(3Tx in total)** | **PC for band A of A-B****(1Tx)** | **PC for band B of A-B****(2Tx)** | **The total power****(dBm)** | **Note** |
|  |  |  |  |  |
| PC1.5 | PC3 | PC1.5 | 30.0 | -One CC per band; [For FWA only[-One CC in band A, 2CC on band B (if this scenario would be introduced for 3Tx); [For FWA only] |
| PC1.5  | PC2 | PC1.5 | 30.8 | -One CC per band; [For FWA only]-One CC in band A, 2CC on band B (if this scenario would be introduced for 3Tx); [For FWA only]  |

## 4.4 MSD and SAR compliance

**Way forward:**

* + For SAR compliance and MSD, adopt same methodology as for higherPowerLimit-R17/ higherPowerLimtMRDC-R17, [if higherPowerLimit-R17/higherPowerLimtMRDC-R17 capability is adopted for increasing UE transmission power]. More specific,
* For a given band combination, no additional MSD requirements are needed in addition to the MSD requirements of its legacy power class(es)
* No new duty-cycle solution/mechanism for SAR compliance is considered
* P-MPR is used for SAR mitigation