**3GPP TSG-RAN WG4 Meeting #111 R4-240xxxx**

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

**Agenda item:** 10.1.2

**Source:** Moderator (Samsung)

**Title:** Topic summary for [111][125] NR\_ENDC\_RF\_Ph4\_part2

**Document for:** Information

# Introduction

This email thread focuses on two parts,

* Power class related topics (AI 12.2)
* High power UE (HPUE) for CA in terrestrial network (TN) (AI 10.1.1.2)

# Topic #1: Power class related issue

*Main technical topic overview. The structure can be done based on sub-agenda basis.*

## Companies’ contributions summary

|  |  |
| --- | --- |
| **T-doc number and Title** | **Company** |
| R4-2407094 Views on power class fallback issues | Apple |
| R4-2407095 CR to 38.101-1 on mitigating power class fallback issues | Apple |
| R4-2407096 CR to 38.101-3 on mitigating power class fallback issues | Apple |
| R4-2407097 CR to 36.101 on mitigating power class fallback issues | Apple |
| R4-2407528/29 draftCR on power class applicability on single carrier operation | CATT |
| R4-2407530/31 draftCR on power class applicability on NR CA | CATT |
| R4-2407532 Further discussion on power class related issues | CATT |
| R4-2407627 Views on power class related issues | Samsung |
| R4-2407628 LS on further clarification for ue-PowerClassPerBandPerBC-r17 | Samsung |
| R4-2407725 The power-class related issues continued | Ericsson |
| R4-2407726/27 Corrections to configured maximum power for serving cells of UL CA | Ericsson |
| R4-2407728/29 Corrections to HPUE requirements for DL-only CA configurations | Ericsson |
| R4-2407730/31 MPR and A-MPR per serving cell with a derated per-band power class for UL CA | Ericsson |
| R4-2407732/33 Amendment of the maximum output power for single-CC transmission with UL CA | Ericsson |
| R4-2407734/35 Applicability of exceptions to REFSENS for CA and SUL to HPUE | Ericsson |
| R4-2407811 Discussion of applicable power classes for NR CA | Xiaomi |
| R4-2407903 Clarification on ue-PowerClassPerBandPerBC-r17 | China Telecom |
| R4-2407904 Draft CR on gerneral description for ue-PowerClassPerBandPerBC-r17 | China Telecom |
| R4-2407986 UE RF requirement related to power class | LG Electronics |
| R4-2408115 Cleanup of Delta\_powerclass related requirements for HPUE | vivo |
| R4-2408116 CR on 38.101-1 for cleanup of Delta\_powerclass related requirements for HPUE(Alt1) | vivo |
| R4-2408117 CR on 38.101-1 for cleanup of Delta\_powerclass related requirements for HPUE(Alt2) | vivo |
| R4-2408118 CR on 38.101-3 for cleanup of Delta\_powerclass related requirements for HPUE(Alt1) | vivo |
| R4-2408119 CR on 38.101-3 for cleanup of Delta\_powerclass related requirements for HPUE(Alt2) | vivo |
| R4-2408120 Discussion on remaining issues of Power class maintenance | vivo |
| R4-2408234 Discussion on Power class fallback for HPUE in the current specifications | CHTTL |
| R4-2408782 Views on power class indication | ZTE Corporation, Sanechips |
| R4-2408806 Powerclasses and maximum output power | Qualcomm Inc. |
| R4-2408807 /08 [NR\_PC2\_CA\_R17\_2BDL\_2BUL-Core] draft CR to TS 38.101-1: power class corrections | Qualcomm Inc. |
| R4-2409092 Discussion on legacy power class related issues | Google Inc. |
| R4-2409630/31 (NR\_RF\_FR1-Core) CR for TS38101-1 Clarifying transmitted power requirements for NR CA | Huawei, HiSilicon |
| R4-2409632/33 (NR\_RF\_FR1-Core) CR to clarify power class indication for single-carrier configuration | Huawei, HiSilicon |
| R4-2409634 Reply LS on clarification for ue-PowerClassPerBandPerBC-r17 | Huawei, HiSilicon |
| R4-2409635 Discussion on power class fallback for NR CA | Huawei, HiSilicon |
| R4-2409636 Discussion on Tx power requirements for NR CA | Huawei, HiSilicon |

## Open issues summary

*Before Meeting, moderators shall summarize list of open issues, candidate options and possible WF (if applicable) based on companies’ contributions.*

*Sub-topic description:*

*-In current RAN4 specs, there is ambiguity on the applicable configured maximum output power (PCMAX, f,c), the applicable power class and the applicable requirements for a band in a band combination in terms of 7 different CA cases. In particular, when a band supports higher power class when operating in a single band than that in a band combination.*

*-The concern of the power class fallback issues in current RAN4 specifications has been brought up in RAN4 #110 meeting which could potentially cause misunderstanding on how the UE configured maximum output power can be applied, and that may result in double-counting the PCMAX power reduction as well as excessive allowance of MPR/A-MPR for HPUE. While the issue was generally acknowledged by most RAN4 companies in the past two RAN4 meetings, there was still no concrete way forward on how to mitigate this issue in current RAN4 specifications. (Borrowed from Apple’s paper😊)*

* + 1. Sub-topic 2-1: Legacy NR power class issue

*(This controversial discussion has been conducted over one year and half, companies’ position does not change compared to last meeting. Moderator believe companies already have quite a lot discussion to align understanding, and hope companies can compromise on issues that are not so critical. In this meeting, moderator does not repeat the long summary as it does not help to push/close the discussion. Instead, it is suggested to focus more on CR checking on the following prioritized items)*

### **Issue 1.2.1-1: To reflect the following last meeting’s agreement in spec for ULCA cases**

(WF R4-2406586)



* Recommended WF:
	+ Return to CR R4-2407726 (Ericsson)

### **Issue 1.2.1-2: Clarification on the interaction among power class IEs for single carrier operation**

(This is to reflect the agreement ”For UE that is configured in the single carrier mode (1 DL + 1 UL on this band), the power class is determined by *ue-PowerClass* for this NR band”. RAN4#110 WF R4-2403891)

* Recommended WF
	+ Return to CR R4-2409632 (Huawei)

### **Issue 1.2.1-3: For any DL CA with single carrier UL configured, whether to allow UE transmit higher power than the specified highest power class for this CA? Further, by which approach indicating to NW and from which release?**

* Recommended WF
	+ Return to CR R4-2408807 (Qualcomm)

### **Issue 1.2.1-4: For any ULCA with only one CC activated or scheduled but others deactivated or not scheduled, whether to allow UE transmit higher power than the specified highest power class for this ULCA?**

* Recommended WF
	+ Discuss it after Issue 1-3 has progress

### **Issue 1.2.1-5: Which MPRc and A-MPRc applies per serving cell c of a configured band combination?**

* Proposals：
	+ Option 1: MIN { PPowerClass,c – ΔPPowerClass,c, PPowerClass,CA – ΔPPowerClass,CA }
	+ Option 2: MIN { PPowerClass,c, PPowerClass,CA}
	+ Option 3: The supported UE power class for the NR band specified in Table 6.2.1-1 as indicated by *ue-PowerClassPerBandPerBC-r17*, if present, *ue-PowerClass/ue-PowerClass-v1610* in BandNR otherwise (Refer to CR-2407730)
* Recommended WF
	+ TBD
		1. Sub-topic 2-2: “Power class fallback” issues

**Issue 1.2.2-1: RAN4 specifications revisions to mitigate the power class fallback issue**

Proposal：

* + Option 1: Keep the texts for power class fallback behavior in MOP sections and change “apply all requirements for” a certain power class to a more restricted “apply maximum output power of” this power class (vivo, DCM)
	+ Option 2: Move the text descriptions on UL duty cycle and P-max conditions below the power class tables in “UE maximum output power” sub-clauses to ΔPPowerClass definitions in “Configured output power” sub-clauses (Apple, Samsung, DCM)
	+ Option 3: Keep the current descriptions and the structure for the power class fallback in both the MOP and configured output power section sections in the specifications. Only minor wording improvement or clarification can be considered, and the power class fallback behaviour shall not be changed. (CHTTL, vivo)
	+ Option 4: Keep the texts for power class fallback behavior in MOP sections and change “apply all requirements for” a certain power class to a more restricted “apply maximum output power, MPR, and A-MPR of” this power class. (LGE)
* Recommended WF
	+ TBD

**Issue 1.2.2-2: Should P-Max be included in the ΔPPowerClass definition?**

Proposal：

* + Option 1: Yes (ZTE, LGE)
	+ Option 2: No (Apple, DCM, vivo)
* Recommended WF
	+ TBD

**Issue 1.2.2-3: How to describe power class fallback UE behavior during SRS transmission occasions for PC2 capable UE with txDiversity-r16 capability or PC1.5 capable UE?**

Proposal：

* + Option 1: No change in current specifications (vivo)
	+ Option 2: Change ΔPPowerClass = 3dB with the wordings that “for PC2 UE with txDiversity-r16 capability, all requirements for the default power class apply, and for PC1.5 UE, all requirements for PC2 apply. (Apple, LGE)
	+ Option 3: (Huawei)
		- Consider to define a new variable (e.g. ΔPMOP) to replace ΔPPowerClass when MOP needs to be reduced but power class fallback is not allowed, such as duty-cycle exceedance. And continue to use ΔPPowerClass for the cases when power class fallback is allowed.
		- NBC changes should be avoided since the current specification allows power class fallback in multiple clauses.
* Recommended WF
	+ TBD

**Issue 1.2.2-4: Is it agreeable to revise the PCMAX\_L formula as below for single carrier and apply the similar change to other UL features?**

Proposal：

* + Option 1: (Apple, DCM, vivo)

PCMAX\_L,f,c = MIN {PEMAX,c– ∆TC,c, (PPowerClass + ΔPPowerBoost) – MAX(MAX(MPRc+∆MPRc, A-MPRc) + ΔTIB,c + ∆TC,c + ∆TRxSRS, P-MPRc, ΔPPowerClass)}

* + Option 2: (Huawei) Consider to define a new variable (e.g. ΔPMOP) to replace ΔPPowerClass when MOP needs to be reduced but power class fallback is not allowed, such as duty-cycle exceedance. And continue to use ΔPPowerClass for the cases when power class fallback is allowed.

PCMAX\_L,f,c = MIN {PEMAX,c– ∆TC,c, (PPowerClass – ΔPPowerClass + ΔPPowerBoost) – MAX(MAX(MPRc+∆MPRc, A-MPRc)+ ΔTIB,c + ∆TC,c +∆TRxSRS, P-MPRc) , PPowerClass – ΔPMOP }

PCMAX\_H,f,c = MIN {PEMAX,c, PPowerClass – ΔPPowerClass + ΔPPowerBoost, PPowerClass – ΔPMOP }

* + Option 3: Keep the existing PCMAX,L formula (LGE)
* Recommended WF
	+ TBD

**Issue 1.2.2-5: Consider to soften the wording in the spec, for example, changing the wording to “… shall allow to apply all the requirements for the default power class…”**

Proposal：

* + Option 1: Yes (Huawei)
	+ Option 2: No
* Recommended WF
	+ TBD

**Issue 1.2.2-6: Consider to replace ΔPPowerClass = -3dB with ΔPPowerBoost = 3dB for the powerBoostPi2BPSK feature**

Proposal：

* + Option 1: Yes (Huawei)
	+ Option 2: No
* Recommended WF
	+ TBD

**Issue 1.2.2-7: If RAN4 agrees to make specifications revisions to mitigate the power class fallback issues, whether to touch LTE spec?**

Proposal：

* + Option 1: Yes
	+ Option 2: No (vivo)
* Recommended WF
	+ TBD

**Issue 1.2.2-8: If RAN4 agrees to make specifications revisions to mitigate the power class fallback issues, which release should be the starting release for the changes?**

Proposal：

* + Option 1: Rel-17 (LGE)
	+ Option 2: Rel-18 (Apple, Samsung)
	+ Option 3: Rel-17 is preferred, or only the following clarification is done from Rel-17 while others from Rel-18 (DCM, more details in R4-2408782)
		- Clarify “when P-max indicated by the network is lower than the UE supported power class or the percentage of UL symbols transmitted in a certain evaluation period is larger than the UE supported UL duty cycle capability, the UE still meets the UE RF requirements(such as MPR/A-MPR/ACLR) associated with UE supported power class indicated by UE capability” from Rel-17 specification.
* Recommended WF
	+ TBD

# Topic #2: High power UE (HPUE) for CA in terrestrial network (TN)

*Main technical topic overview. The structure can be done based on sub-agenda basis.*

## Companies’ contributions summary

|  |  |
| --- | --- |
| **T-doc number and Title** | **Company** |
| R4-2407091 Views on intra-band contiguous and non-contiguous UL | Apple |
| R4-2407371PC1p5 intra-band ULCA MOP for 2Tx and Dual-PA cases | Skyworks Solutions Inc. |
| R4-2407584 RF requirements for HPUE for CA terrestrial networks | Qualcomm Technologies Int |
| R4-2407630 Views on HPUE for Intra-band CA in terrestrial network | Samsung |
| R4-2407713 Proposal for UL CA\_n41C PC2 A-MPR | T-Mobile USA |
| R4-2407721 General framework for intra-band UL CA with PC1.5 | Ericsson |
| R4-2407806 Discussion on PC1.5 TDD intra-band CA | Xiaomi |
| R4-2407980 HPUE for intra-band UL CA | LG Electronics |
| R4-2408028 High power UE RF requirements for intra-band CA UE | Facebook Japan G.K |
| R4-2408123 Further discussion on HPUE for intra-band contiguous and non-contiguous CA | vivo |
| R4-2408351 On R19 PC1.5 Intra-band contiguous and non-contiguous UL CA | ZTE Corporation, Sanechips |
| R4-2409643 Discussion on PC1.5 for intra-band CA | Huawei, HiSilicon |
| R4-2407092 Views on inter-band UL NR-CA/EN-DC with 2 bands and 2Tx and/or 3Tx | Apple |
| R4-2407396 On increased power cases and levels | Skyworks Solutions Inc. |
| R4-2407575 Request for PC2/PC1.5 inter-band FDD-FDD UL CA configuration | Dish Network |
| R4-2407631 Views on HPUE for inter-band NR-CA and EN-DC in terrestrial network | Samsung |
| R4-2407807 Discussion on inter-band UL NR CAEN-DC with 2 bands and 2Tx and or 3Tx | Xiaomi |
| R4-2407892 Discussion on SAR solutions for new Rel-19 inter-band HPUE scenarios | CHTTL |
| R4-2407909 Discussion on Rel-19 UE RF HPUE enhancements for 3Tx configurations | MediaTek (Shenzhen) Inc. |
| R4-2408033 Criteria for specifying new MSD test cases | Qualcomm Incorporated |
| R4-2408131 Discussion on UL inter-band UL CA or DC with 2Tx or 3Tx | vivo |
| R4-2408352 On R19 2Tx/3Tx PC2/1.5 Inter-band NR CA/ENDC | ZTE Corporation, Sanechips |
| R4-2408758 R19 3Tx inter-band enh | OPPO |
| R4-2409644 Discussion on PC1.5 for inter-band UL CA and EN-DC | Huawei, HiSilicon |
| R4-2407093 Views on increasing UE transmission high power limit | Apple |
| R4-2407632 Views on Increasing UE transmission power | Samsung |
| R4-2407808 Discussion on increasing high power limit for inter-band CA DC with 2Tx and or 3Tx | Xiaomi |
| R4-2407982 HPUE for increasing high power limit | LG Electronics |
| R4-2408034 Feasibility of wider application of higherPowerLimit-r17 | Qualcomm Incorporated |
| R4-2408121 Discussion on increasing UE transmission high power limit for CA HPUE | vivo |
| R4-2408353 On R19 Increasing UE transmission power limit | ZTE Corporation, Sanechips |
| R4-2408724 HPUE MSD related issues | Nokia |
| R4-2409029 Discussion on increasing UE high power limit feature | NTT DOCOMO INC. |
| R4-2409645 Discussion on Increasing UE transmission high power limit | Huawei, HiSilicon |
| R4-2407550 Consideration on HPUE for CA and EN-DC | CATT |
| R4-2408076 Views on SAR Solution of R19 HPUE for CA and EN-DC | China Telecom |
| R4-2408136 Further discussion on SAR solution of HPUE | vivo |

## Open issues summary

*Before Meeting, moderators shall summarize list of open issues, candidate options and possible WF (if applicable) based on companies’ contributions.*

* + 1. Sub-topic 2-1: General aspect

#### **Issue 2.2.1-1: MSD rules**

(Moderator heard from Christian: Heard that somebody found this quote in an old house in Stratford upon Avon:

To be or not to be

That’s a question of MSD)

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) |

* Recommended WF
	+ For increasing higher transmission power case, MSD could be discussed/determined in Issue 2.2.4-4 as companies views are aligned on this case
	+ For other cases, first discuss whether to have MSD revolution as proposed by Proposal 1,2
* If not, further discuss the general rules for MSD for inter-band UL NR-CA/EN-DC as proposed by 3-6

#### **Issue 2.2.1-1: Duty cycle solution for SAR compliance**

*(Moderator has no idea how to well summarize this issue, as the key point is not whether the spec can be updated, but whether it is meaningful to spend time to update it. So it is better to discuss this issue online)*

Proposal：(Moderator)

* + For increasing UE transmission power case, SAR can be discussed/determined in Issue 2.2.4-4 as companies views are quite aligned on this case.
	+ For other HPUE cases
* Option 1: Duty-cycle solution is not considered for any HPUE scenarios in this WI, **and the justification?**
* Option 2: Duty-cycle solution is considered for all HPUE scenarios in this WI, **and the justification?**
* Option 3: Duty-cycle solution is considered for limited scenarios, which scenarios to consider? **and the justification?**
* Recommended WF
	+ TBD
		1. Sub-topic 2-2: PC1.5 Intra-band ULCA

#### **Issue 2.2.2-1: Assumed UE architecture(s)/parameters/methodology for MPR/A-MPR evaluation**

* For intra-band contiguous ULCA w/ and w/o UL MIMO which was agreed to be prioritized in last meeting, two architectures for further discussion are:

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **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 |

Proposals：

* + Option 1: Architecture #2 (Apple, Qualcomm, ZTE)
	+ Option 2: Architecture #2 as baseline, FFS whether Architecture#1 is specified, and in any case should be low priority (Skyworks, Samsung, vivo, Huawei, Meta)
	+ Option 3: Both Architecture#1 and #2. (LGE, Xiaomi)
* For intra-band NC ULCA w/o UL MIMO, two architectures for further discussion are:

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Architecture** | **Description** | **Indicated capability** | **Applicable cases** | **Note** |
| #1 | 2x26 dBm PA + 2 LO with 100MHz BW | *dualPA-Architecture* | NC CA w/o UL MIMO | No Frequency Separation limitation;Cannot achieve 29dBm for unequal RB allocations assuming equal PSD |
| #2 | 2x26 dBm PA + 1 LO with 200MHz BW | *TxD* | NC CA w/o UL MIMO | Frequency Separation ≤ 200MHz;BW Gap size＜CC1 +CC2 CBW |

Proposals：

* + Option 1: Architecture #1 (Apple, Qualcomm, ZTE)
	+ Option 2: Architecture #1 as baseline, FFS whether Architecture#2 is specified, and in any case should be low priority (Skyworks, Meta)
	+ Option 3: Both Architecture#1 and #2 given Architecture#1 can only reach 29dBm for equal RB allocation on both CCs. (Samsung, Huawei, LGE, Xiaomi)
* Other proposals relevant to MPR/A-MPR:
	+ Proposal 1: Deprioritize the specifications development for PC1.5 intra-band non-contiguous UL CA due to the limited use cases and performance gain as compared to its PC2 counterpart (Apple)
	+ Proposal 2: The intra-band PC1.5 ULCA R19 work focusses on UE implementing intra-band ULCA PC1.5 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. (Skyworks)
	+ Proposal 3: Establish MPR/A-MPR numbers for contiguous CA first and then work on non-contiguous CA MPR/A-MPR afterwards. (Qualcomm)
	+ Proposal 4: For that dualPA-Architecture how to establish MPR/A-MPR values for RB BW imbalance scenarios should be left for further study. (Qualcomm)
	+ Proposal 5: RAN4 can consider the following Table power combination to derive MPR requirements with same power density level for both CCs in 1st phase. (Meta)



* + Proposal 6: RAN4 to discuss and agree on the following evaluation assumptions for PC1.5 intra-band UL CA. (Huawei)
* Coupled 2xPC2 with isolation=10, 20dB
* 4dB post PA losses
* PC2 PAs calibrated at 31dB ACLR at 1dB MPR for 20MHz QPSK 100RB0 waveform
* Carrier Leakage: 28dBc
* Image: 28dBc
* CIM3: 60dBc
* CIM5: 70dBc
* 3GPP SEM & ACLR
	+ Proposal 7: To adopt above RF assumptions, requirements for back-off evaluation, evaluation scenarios as a starting point for MPR measurement campaign for PC1 intra-band contiguous and non-contiguous CA. (vivo)

• Emission requirements (ACLR/SEM/spurious emissions of the targeted power class) are checked by summing the power of the two transmit paths

• EVM is checked for the agreed composite EVM equation

• MPR is provided in the form of back off of total power versus power class nominal power level

• EVM budget for PA:

• QPSK 10%

• 16QAM 8%

• 64QAM 4%

• 256QAM 1.8%

• Evaluation scenarios:

• Both CP-OFDM and DFT-s-OFDM waveforms are evaluated

• Since simulation may not be available, at least some worst case corners are evaluated for inner/outer and edge allocations

• Since it has the tighter requirements and highest PSD the lowest valid SCS should be used.

• All modulation orders should be checked:

• Pi/2 BPSK (no shaping), QPSK, 16QAM, 64QAM, 256QAM (for 256QAM mostly EVM with proper image level)

• Channel BW configurations should cover the entire channel bandwidth range:

• At least 5, 20, 50, 100MHz channel bandwidths (depends on the supported CBW of the operating band)

* Recommended WF

(*Moderator: Check online whether the following can be a compromise*)

* + 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 following Architecture#2 is selected as baseline for MPR/A-MPR evaluation.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **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 following Architecture#1 is studied first for MPR/A-MPR evaluation.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Architecture** | **Description** | **Indicated capability** | **Applicable cases** | **Note** |
| #1 | 2x26 dBm PA + 2 LO with 100MHz BW | *dualPA-Architecture* | NC CA w/o UL MIMO | No Frequency Separation limitation;Cannot achieve 29dBm in some extreme RB allocations assuming equal PSD |
| #2 | 2x26 dBm PA + 1 LO with 200MHz BW | *TxD* | NC CA w/o UL MIMO | Frequency Separation ≤ 200MHz;BW Gap size＜CC1 +CC2 CBW |

* + Check Proposal 5-7 online

#### **Issue 2.2.2-2: Whether to define separate MRP/A-MPR requirements for handheld UE and FWA respectively?**

Proposals：

* + Option 1: Yes, and assuming 20dB minimum antenna isolation for FWA and 10dB for handheld UE (Apple, Samsung, Qualcomm, LGE, Huawei)
	+ Option 2: No
* Recommended WF
	+ Option 1

#### **Issue** **2.2.2-3:** **A-MPR for n41/n77/n78**

Proposals：

* + Proposal 1: No A-MPR requirements are defined for PC1.5 n77/n78 intra-band CA and A-MPR requirements are needed to be revisited for PC1.5 n41 intra-band CA.(ZTE)
	+ Proposal 2: (T-Mobile USA)
		- PC2 for CA\_n41C has been defined, but it is not clear if CA\_NS\_04 A-MPR has been addressed.
		- A-MPR for CA\_n41C with CA\_NS\_04 should be addressed if necessary in the NR\_ENDC\_RF\_Ph4 WID.
* Recommended WF
	+ 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
	+ FFS on A-MPR requirements for PC1.5 n41 intra-band UL CA

#### **Issue 2.2.2-4: 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: For intra-band non-contiguous CA supported for PC1.5 by a dual PA architecture (Architecture #1), the MPRc for the serving cells c shall not be equal, MPRc ≠ MPR with MPR the reduction of the total UE power. The transmit power can be increased (almost) independently on the CCs, although there may be dependence between the required power reduction on serving cells depending on power levels. (Ericsson)
	+ Proposal 3: Changes to TS 38.101-1 for dual-PA architecture, inset new equation for PCMAX,*c* (Ericsson, more details refer to R4-2407721)
	+ ~~Proposal 4: Given that the changes would be overlapped, discuss CRs to the Pcmax clause for PC1.5 inter-band CA with 2Tx after the discussions on the legacy power class issues are concluded. (Huawei, Moderator)~~
* Recommended WF
	+ TBD

#### **Issue 2.2.2-5: PCMAX**

* + 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))

* Recommended WF
	+ TBD

#### **Issue 2.2.2-6: PCMAX tolerance**

Proposal：The PCMAX tolerance for uplink intra-band contiguous/non-contiguous CA are: (ZTE)

|  |  |  |
| --- | --- | --- |
| **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 |

* + Option 1: Agree
	+ Option 2: Not agree
* Recommended WF
	+ Option 1
		1. Sub-topic 2-3: 2-band PC2/PC1.5 inter-band NR-CA/EN-DC with 2Tx or 3Tx

#### **Issue 2.2.3-1: Requirements between handheld UE and FWA**

Proposal：(Apple, MTK)

* + For 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.
* Recommended WF
	+ 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.

#### **Issue 2.2.3-2: Whether to collect configurations to derive general requirements?**

*(The WF of last meeting are*

*-For 2Tx inter-band NR-CA, strive to define general requirements in a band-combination configuration agnostic way -For 2Tx inter-band EN-DC, strive to define general requirements in a band-combination configuration agnostic way further check whether there is demand on FDD-FDD*

*-For 3Tx inter-band NR-CA and EN-DC, no restriction on the power/MIMO configurations of each band in the band combination*

*The background of above WF are: the intention is to avoid configuration collection which is low efficiency, while strive to define general requirements in a BC configuration agnostic way for future proof. Meanwhile, several companies hoped to understand whether PC2/PC1.5 FDD-FDD EN-DC should also be considered given there is no corresponding RAN2 duty-cycle IE by now and duty-cycle solution was not specified as well for PC2 FDD single band operation. Companies also want to check whether there is real operators’ demand on PC2/PC1.5 FDD-FDD configuration for NR-CA/ENDC.*

*In this meeting, two operators deliver clear demand on HPUE FDD-FDD configuration, DISH for NR-CA(R4-2407575), CHTTL for EN-DC(R4-2407892). Two vendors LGE(R4-2407981) and MTK(R4-2407909) also show their interested configurations.*

*Meanwhile, as Apple(R4-2407092) pointed out, new MSD framework maybe required only for UL configurations consisting of PC2 FDD band(s) hence RAN4 can discuss whether PC2 FDD bands would be considered at early phase of WI.*

*In addition, Nokia(R4-2408724), Qualcomm(R4-2408033), Ericsson (R4-2407734) propose to have some MSD evolution for HPUE which would be discussed on Issue 2.2.1-2,*

*With above, moderator still suggest to follow last meeting’s agreement which is “strive to define general requirements in a configuration agnostic way”, and donot collect and discuss configurations at least in this meeting.*

Proposal：(Moderator)

* + Follow 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
* Recommended WF
	+ Follow 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

#### **Issue 2.2.3-3: 3UL CC with 3Tx**

Proposal：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. (Samsung)

* Recommended WF
	+ TBD

#### **Issue 2.2.3-4: Release independent**

Proposal：To discuss the release independence for 3Tx band combination for handheld UE: from Rel-17 or Rel-18 or Rel-19: (ZTE)

* Recommended WF
	+ TBD

#### **Issue 2.2.3-5: Proposals for Rel-19 basket WI**

Proposal：

* + Proposal 1：To extend the scope of HPUE\_FR1\_TDD\_NR\_CADC\_SUL\_R18 basket WID in Rel-19 to include 2Tx PC1.5 NR inter-band UL CA. (ZTE)
	+ Proposal 2: The specific types of 3Tx PC2/1.5 NR inter-band UL CA/ENDC should be discussed in R19 basket WID. (ZTE)
	+ Proposal 3: It is proposed that configurations in the following Table are considered in RAN4 future work when creating basket WI for specific band combinations. (DISH)

|  |  |  |
| --- | --- | --- |
| **Band combination** | **UL configuration** | **Power class**  |
| CA\_n66A-n71A | CA\_n66A-n71A | 2Tx: PC3@n66 1Tx, PC3@n71 1Tx; CA power class PC22Tx: PC2@n66 1Tx, PC2@n71 1Tx; CA power class PC1.5 3Tx: PC3@n66 (UL MIMO 2Tx 20+20 dBm), PC3 n71 1Tx ; CA power class PC23Tx: PC2@n66 (UL MIMO 2Tx 23+23 dBm), PC2 n71 1Tx ; CA power class PC1.5 |
| CA\_n70A-n71A | CA\_n70A-n71A | 2Tx: PC3@n70 1Tx, PC3@n71 1Tx; CA power class PC22Tx: PC2@n70 1Tx, PC2@n71 1Tx; CA power class PC1.53Tx: PC3@n70 (UL MIMO 2Tx 20+20 dBm, PC3 n71 1Tx ; CA power class PC23Tx: PC2@n70 (UL MIMO 2Tx 23+23 dBm, PC2 n71 1Tx ; CA power class PC1.5 |

* Recommended WF
	+ No conclusion needed, companies can take above into account in future work
		1. Sub-topic 2-4: Increasing UE transmission power

#### **Issue 2.2.4-1: The methodology**

Proposal：

* + Option 1: Reusing the Rel-17/Rel-18 higher power limit capability and keep the way of modifying CA/EN-DC power class as sum of individual RF chain power classes. (vivo)
	+ Option 2: (Moderator try to rewording based on Option 1)

Reusing the Rel-17/Rel-18 higher power limit capability. If the capability is indicated,

* + - PPowerClass,CA is replaced by 10 log10 ∑ pPowerClass,c , if only one CC is supported for each band;
		- PPowerClass,CA is replaced by 10 log10 (pPowerClass,A + pPowerClass,CA,B), if one CC is supported for band A and intra-band carrier aggregation is supported for band B.
* Recommended WF
	+ Option 2? and further refine if needed

#### **Issue 2.2.4-2: Whether increasing power limit applicability requires** **ΔPPowerClass,CA /ΔPPowerClass,EN-DC =0.**

Proposal：

* + Option 1: Yes (vivo)
	+ Option 2: No
* Recommended WF

*(There is similar discussion during Rel-18 cov\_ehn WI, the agreement was agreed and captured in WF R4-2317769. Therefore moderator use it as recommended WF and further correct* ***ΔPPowerClass*** *to* ***ΔPPowerClass,CA*** ***/******ΔPPowerClass,EN-DC )***

* + The high-power limit feature only applies with ΔPPowerClass,CA /ΔPPowerClass,EN-DC = 0 dB, which is aligned with the Rel-17 agreement i.e. P-MPR is used for SAR mitigation for high power limit feature.

#### **Issue 2.2.4-3: The scenarios to be considered in Rel-19**

*(For information, the following scenarios are defined in Rel-17/18)*

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **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(TDD) | Support from Rel-17  | One CC per band |
| PC3 | PC5(NRU band) | PC3(FDD or TDD) | Support from Rel-18 | One CC per band; One CC on band B, 2CC on band A(NRU band) |

Proposal：

* + 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*

* Recommended WF

*（Check online whether the following can be a compromise）*

* For 2Tx, higher power limit feature is enabled for any standardized inter-band band combination.
* For 3Tx, 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** |
| PC2 | PC3 | PC2 | 27.8 | -One CC per band -One CC on 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 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  |

#### **Issue 2.2.4-4: MSD and SAR complicance**

Proposal：

* + Proposal 1：For the possible new UL configurations to support “increasing UE power high limit” feature, the MSD framework is to follow the same principle of PC2 inter-band UL combinations with “increasing UE power high limit” feature. (Apple)
	+ Proposal 2：Try to avoid new verification points, and not to define new MSD requirements for increasing power limit. (vivo)
	+ Proposal 3: For Rel-19 new scenarios of increasing high power limit feature, no need to define MSD. (Samsung)
	+ Proposal 4: For Rel-19 new scenarios of increasing high power limit feature, P-MPR is adopted for SAR compliance. (Samsung)
	+ Proposal 5: Follow the similar approach in R17 and R18, not to reconsider additional MSD requirements on top of the MSD requirement specified for normal band combination Power class. (Xiaomi)
	+ Proposal 6: Consider impact on UL duty-cycle solution for the scenarios of inceasing high power limit when higherPowerLimit is configured. (LGE)
	+ Proposal 7: Only one MSD is defined per band combination, no new MSD is defined for higher power classes. (Nokia)
	+ Proposal 8: For increasing UE transmission power limit, no additional MSD requirements for a given band combination are needed as long as the MSD requirements for the CA/DC power class (such as PC2 or PC1.5) have been specified. (Huawei)
	+ Proposal 9: There is no need to study the MSD for increasing higher power limit. The MSD requirements for the new configurations should be studied in the corresponding R19 basket WID. (ZTE)
* Recommended WF
	+ For SAR compliance and MSD, adopt same methodology with Rel-17/18 increasing higher power limit capability
* 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