**3GPP TSG-RAN WG4 Meeting #112 R4-2414278**

**Maastricht, Netherlands, 19th -23th Aug, 2024**

**Title:** WF on power domain enhancements

**Agenda Item:** 8.1.3

**Source: Huawei, HiSilicon**

**Document for:** Approval

# Topic #1: Power domain enhancements for single carrier

### Sub-topic 1-1: Approaches to enable MPR reduction for scenario 1

#### **Issue 1-1-1: Approaches for scenario 1**

* Proposals
	+ Proposal 1: For the scenario when there is no adjacent in-band/out-of-band co-existence issue (single operator), introduce network-controlled relaxation on ACLR and SEM mask. (Huawei)
		- For ACLR, the relaxation means e.g. PC3 requirement 30dB can be relaxed to a smaller value.
		- For SEM mask, the relaxation means an upward shift on the whole mask.
		- No change on the reference channel bandwidth or the start of ΔfOOB
		- Check if followings can be adopted for the network-controlled relaxation towards no adjacent in-band/out-of-band co-existence issue (single operator) scenario.
			* Three level of relaxation, e.g. 3dB, 5dB and waived
			* Per band and per region (can be based on operator request)
* Recommended WF
	+ Further evaluate the reduced MPR values with relaxation of ACLR/SEM to certain levels or waived
	+ Strive to a common solution for both single operator case and multiple operator case to address the demand from operators

CMCC: Scenario 1 is helpful in some case like band n41. We support proposal 1.

OPPO: What does it mean no adjacent co-existence issue? If we relax one CC then there is impact on other CC?

Nokia: If it is relaxation means change of ACLR, we are not OK. We want to keep ACLR but discuss the starting point of frequency point.

Qualcomm: 3dB and 5dB are the values suggested.

Huawei: regarding relaxation of ACLR, there is no adjacent operator. In some region, there is no regulation. The whole solution is based on the request of operator. To Qualcomm, 3 and 5dB is just for example.

Skyworks: We are discussing ACLR and SEM mask and how to apply. What is the additional relaxation? Is it the usual ACLR for larger bandwidth.

CATT: For boundary, we would like to keep the existing. The three levels apply to ACLR, SEM at the same time?

Huawei: To CATT, SEM and ACLR are different requirements. We do not need combine them within the same level.

Skyworks: we would like to understand which bandwidth is assumed.

Huawei: for simplicity, we assume that there no adjacent operating band.

China Telecom: In general, the scenario 1 is beneficial for the operator when there is no adjacent operator. ACLR is defined based on the co-existence. IF there is no co-existence issue, ACLR can be relaxed.

AT&T: how can we handle the case for the band for which the signalling cannot be used for other region?

China Unicom: we have deployment for n1 and n78. Support the proposal.

Nokia: We have proposals.

Skyworks: in the single operator case, you need consider IBE issue.

Verizon: We would like to have common solution for both single operator case and multiple operator case.

#### **Issue 1-2-1: Clarification of BS CBW**

* Proposals
	+ Proposal 1: Clarify that the BS channel bandwidth means BS RF bandwidth that covers single carrier, multi-carriers and multi-RATs scenarios. (Huawei)
* Moderator observation
	+ For the first meeting discussion, in the WF (R4-2406584) it said “*No relaxation of ACLR/SEM/SE outside of the BS CBW for one* ***operator holding spectrum*** *for scenario 2, i.e. Narrower UE channel BW within wider BS bandwidth*” and companies had some discussion on operator holding spectrum in the AH. The common understanding is that the operator holding spectrum could be larger than a specific CBW. Some clarification would be helpful for the following discussion.
* Recommended WF
	+ FFS.

Nokia: BS channel bandwidth is the RF bandwidth for BS to transmit. BS still has channel bandwidth. RF implementation is other thing.

Ericsson: same understanding as Nokia.

ZTE: In 38.141-1 there is clear definition of BS channel bandwidth. If BS transmits multiple CC, BS RF channel bandwidth is larger than BS channel bandwidth.

CATT: Why do we need clarify BS channel bandwidth here?

Skyworks: Similar to CATT comment. UE does not need to know what BS bandwidth. UE just needs to know the spectrum range to meet ACLR. It could be something different. UE needs to know when it transmits here what ACLR should be applied.

Nokia: Agree with Skyworks. In our proposal, we propose to determine by BS channel bandwidth.

Huawei: UE channel bandwidth does not exceed BS bandwidth. We want consider multiple carrier case.

Nokia: we want to exclude the case UE bandwidth exceeds the BS.

Huawei: Agree with Nokia. UE channel bandwidth may not exceed BS.

#### **Issue 1-2-2: Approaches of converting outer RB allocation to inner RB allocation**

* Proposals
	+ Option 1: The extended UE CBW based method as captured in the WF in last meeting.
	+ Option 2: BS CBW based inner/outer method. (Skyworks)
		- BS NRB instead of UE NRB.
		- Adding the amount of RB by which the UE RBs are shifted within the BS RBs to the UE RBstart.
		- The base station shall signal the extended NRB and RBstart shift for the UE to calculate the new inner, outer, and edge regions and reduce MPR.
		- For margin or stricter emissions, the BS can signal a reduced NRB and RBshift.
	+ Option 3: the feature ‘narrower UE channel BW within wider BS bandwidth’ is specified for a UE configured with a UE-specific CHBW within a wider BS bandwidth, the said UE compliant with selected OOBE requirements applicable for the wider BS bandwidth (the cell bandwidth). (Ericsson)
	+ Option 4: RAN4 could specify at least one guard band configuration larger than the minimum guard band (i.e., additional guard band) or a maximum transmission bandwidth smaller than the legacy maximum transmission bandwidth, and the associated enhanced MPR/power boost. (Nokia)
* Recommended WF
	+ FFS approaches to reduce MPR

Skyworks: the concept to extend UE CBW does not work. UE need to know how many RBs can be extended for each side.

Nokia: We have two proposals, which is similar to Ericsson proposal.

OPPO: Quite similar to Skyworks.

CATT: Proposal from Skyworks is quite smart.

*The following issues are mainly based on extended UE CBW based approach, but in principle the issues relevant to SE/OOBE/IBE are generic to the inner/outer approaches. Common understanding of issues relevant to extended UE CBW does not preclude other approaches to be further evalutated/discussed.*

#### **Issue 1-2-3: whether extended UE CBW edge could exceed the BS CBW edge**

* Proposals
	+ Proposal 1: The extended UE CBW should not exceed the BS CBW. (Samsung, Sony, vivo, MTK, LGE)
	+ Proposal 2: One is that there is no adjacent in-band/out-of-band co-existence issue, in which case, it is feasible that extended UE CBW edge exceeds the BS CBW edge. The other is that there exists adjacent in-band/out-of-band co-existence issue, and extended UE CBW edge cannot exceed the BS CBW edge. (ZTE)
* Recommended WF
	+ Check whether proposal 1 is agreeable

#### **Issue 1-2-4: Whether and where to use IBE in the larger BS CBW**

* Proposals
	+ Proposal 1: IBE should be used between edges of UE CBW and extended UE CBW. (Samsung, Sony, ZTE, CTC, MTK, vivo, Huawei, LGE)
		- And the IBE of this part should be equal to that of the original UE CBW edge. (vivo)
		- it is the “general” part of IBE requirements that applies to the gap between the shifted ΔfOOB and the edge of UE CBW with following adaptation (Huawei)
			* Use the aggregated NRB which corresponds to the frequency span between two shifted ΔfOOB
			* The index of the first adjacent RB outside of the UE CBW should be 1 or -1
	+ Proposal 2: Study the system performance impacts by this extended UE CBW approach, i.e. impacts due to applying IBE instead of ACLR/SEM in the out of band emission regions. (OPPO)
	+ Proposal 3: IBE is unnecessary to use between edges of UE CBW and BS CBW or between edges of UE CBW and extended UE CBW. (Xiaomi)
* Recommended WF
	+ Check whether proposal 1 is agreeable

#### **Issue 1-2-5: Boundary to apply ACLR and SEM**

* Proposals
	+ Proposal 1: ACLR and SEM should be applicable from the edge of extended UE CBW instead of the BS CBW. (Samsung, Sony, ZTE, vivo, LGE)
	+ Proposal 2: ACLR, SEM and spurious emissions would be defined as of today but based on BS channel bandwidth. (Nokia, Ericsson)
* Recommended WF
	+ Check whether proposal 1 is agreeable

#### **Issue 1-2-6: Boundary to apply SE**

* Proposals
	+ Proposal 1: Do not consider any change to the level and boundary of the spurious emission. (Sony, Xiaomi)
	+ Proposal 2: The application range of SE should be altered with the shifting of the edge of the UE CBW. (Samsung, vivo, MTK, Huawei)
	+ Proposal 3: SE is applied at BS channel bandwidth. (Nokia, Ericsson)
* Recommended WF
	+ Check whether proposal 2 is agreeable

#### **Issue 1-2-7: Which CBW is utilized as the basis for the integral region of OOBE**

* Proposals
	+ Proposal 1: The integral region and the boundary of OOBE should be based on UE CBW. (Samsung, vivo, ZTE, China Telecom)
	+ Proposal 2: The integral region and boundary of OOBE is based on extended UE CBW. (Sony)
* Recommended WF
	+ Check whether proposal 1 is agreeable

#### **Issue 1-2-8: Ratio size of extended CBW between UE CBW and larger BS channel BW**

* Proposals
	+ Proposal 1: (Apple)
		- If the goal is to convert all outer RB allocations into inner RB allocations, then the minimum BS channel needs to be at least twice the size of the UE channel.
		- If the sole goal is to obtain output power improvements, then it is possible to have a more convenient ratio between UE and BS channel such as two-third.
	+ Proposal 2: (Qualcomm)
		- If minimum excess BW equal to half of the original UE BW can be placed on both sides of the original UE BW this extended UE BW can be treated as the new UE BW and all performance metrics can be based on this new BW.
		- If the minimum extended BW on both sides of original UE BW is less than half the original UE BW then the original UE BW should not be extended, and all performance metrics should be based on the original UE BW.
	+ Proposal 3: The required extended bandwidth of the both sides could be set to 2/5 UE CBW as a starting point. (vivo)
	+ Proposal 4: Consider extended UE CBW approach to improve MPR starting from 1.5\*CBW (OPPO)
	+ Proposal 5: (Huawei)
		- For the shifted start point of ΔfOOB, 1/2 UE CBW can be the default value for UE indication.
		- Consider to introduce shorter shifted frequency e.g. 1/3, 1/4 UE CBW in conjunction with the requirement that will be introduced to the shifted frequency.
			* For instance, the modified general part of IBE requirements which is further relaxed by replacing the EVM corresponding to the scheduling modulation order with the one for BPSK
* Recommended WF
	+ FFS with consideration of above proposals in next meeting

#### **Issue 1-2-9: Whether and how to consider the Asymmetrical extended CBW approach**

* Proposals
	+ Proposal 1: For the case where a UE CBW is allocated at the edge of the BS CBW, agree to consider further an “Asymmetrical extended CBW” to allow outer RB allocation MPR reduction applicability for a UE CBW allocated at the edge of the BS CBW. (MTK)
	+ Proposal 2: For the case where minimum excess BW equal to half the allocated UE BW is added only on side of the allocated UE BW use the following equations to describe the inner allocations: (Qualcomm)
		- Case 1: Excess BW added on lower side of allocated UE BW use:

RBStart,Low = max(1, floor(LCRB/2))

RBStart,High = NRB – RBStart,Low – LCRB

RBStart ≤ RBStart,High,and LCRB ≤ ceil(2NRB/3)

* + - Case 2: Excess BW added on higher side of allocated UE BW use:

RBStart,Low = max(1, floor(LCRB/2))

RBStart,High = NRB – RBStart,Low – LCRB

RBStart\_Low ≤ RBStart

* + Proposal 3: For the asymmetrical scenario, the length of BS CBW and the location of UE CBW within BS CBW should be informed to UE. (Huawei)
		- Use the edge of BS CBW band the start point of ΔfOOB
			* The BS channel bandwidth means BS RF bandwidth that covers single carrier, multi-carriers and multi-RATs scenarios
			* To acquire the aggregated maximum number of RBs for inner RB determination, include the indicated shifted frequency together with the given UE CBW
* Recommended WF
	+ FFS with consideration of above proposals in next meeting

#### **Issue 1-2-10: Others**

* Proposals
	+ Proposal 1: Only consider the approach to enable MPR reduction and/or power boosting for a UE channel bandwidth no less than 10MHz. (CATT)
	+ Proposal 2: Consider changing SEM level in the modified OOB domain by extending UE BW and keeping spurious emission domain unchanged. (CATT)
	+ Proposal 3: RAN4 shall examine if the proposed MPR reduction scheme can be enabled for all types of UEs, including TDD and FDD, as well as normal UE, Redcap, and eRedcap UEs. (Sony)
	+ Proposal 4: Where and how to present the mapping relationship between the original UE CBW, the extended UE CBW and the MPR table should be clarified. (vivo)
	+ Proposal 5: Regardless what mechanism will be evaluated and introduced for Rel-19 single carrier MPR reduction, no RF requirements should be applied to the guard band defined in TS 38.101-1 clause 5.3.3. (Huawei)
* Recommended WF
	+ TBA.

#### **Issue 1-2-11: Signaling aspects**

* Proposals
	+ Proposal 1: no changes of signalling are specified for the feature ‘narrower UE channel BW within wider BS bandwidth’ except possibly specification of a capability bit to indicate support of the feature. (Ericsson)
	+ Proposal 2: Need to consider capability for extended UE CBW procedure. (LGE)
	+ Proposal 3: If any reduction of MPR would be specified in the end, it should be an optional feature for UE with per band capability. (Sony)
	+ Proposal 4: The frequency intervals for the UE CBW and the BS CBW should be judged by the NW and the indication of MPR reduction could be directly sent to the UE when the corresponding conditions are met. (vivo)
	+ Proposal 5: Establish a start point and continue to details for BS indication with the deepen in MPR reduction mechanism. (CTC)
* Recommended WF
	+ To discuss the signalling aspects after sufficient evaluation of power boosting and/or MPR reduction in terms of relaxed requirements.

# Topic #2: MPR applicability for FR1 intra-band UL CA

### Sub-topic 2-1: Intra-band contiguous UL CA

#### **Issue 2-1-1: Applicable MPR for intra-band contiguous CA with single activated cell**

* Proposals
	+ Proposal 1: For PC3/PC2 intra-band contiguous carrier aggregation with single CC with activated cell, the single CC MPR requirements can apply. (Samsung)
	+ Proposal 2: For PC3/PC2 intra-band contiguous carrier aggregation with single CC with activated cell, the following MPR requirements are applied (Samsung, CATT,, Nokia, Huawei, LGE)
		- MPR defined in Table 6.2.2-1 applies for UE power class 3 CA bandwidth classes B and C;
		- MPR defined in Table 6.2D.2-1 applies for power class 2 CA bandwidth classes B and C when TxD capability is indicated;
		- MPR defined in Table 6.2.2-2 applies for power class 2 CA bandwidth classes B and C when TxD capability is absent.
* Proposal 3: For PC3 and PC2 contiguous UL CA use the corresponding single CC MPR when only 1 CC is activated and refer to the following MPR tables and corresponding configured Tx power requirements (Qualcomm).
	+ - * + MPR defined in Table 6.2.2-1 applies for UE power class 3 CA bandwidth classes B and C, along with configured Tx power requirements for 6.2.4
				+ MPR defined in Table 6.2D.2-1 applies for power class 2 CA bandwidth classes B and C when TxD capability is indicated, along with configured Tx power requirements for 6.2D.4
				+ MPR defined in Table 6.2.2-2 applies for power class 2 CA bandwidth classes B and C when TxD capability is absent, along with configured Tx power requirements for 6.2.4
* Recommended WF
	+ Agree with proposal2
		- FFS the conditions to apply the single CC MPR based on discussion of the following issues
		- FFS whether power boosting capability for SC MPR is also applicable

#### **Issue 2-1-2: Single CC CBW or aggregated CBW for applying requirements of ACLR/SEM/SE**

* Proposals
	+ Proposal 1: Integral region and boundary of spurious emissions/ACLR/SEM should be based on the activated CC CBW instead of aggregated CBW. (Samsung)
	+ Proposal 2: When only 1 CC is activated the aggregated BW for CA should be used for evaluating metrics such as spurious emissions, SEM and ACLR. (Qualcomm, Huawei)
* Recommended WF
	+ FFS in next meeting

#### **Issue 2-1-3: Single CC or CA requirements of ACLR/SEM/SE applied for single activated cell**

* Proposals
	+ Proposal 1: Even when transmitted RBs are allocated in only one of the CC, the emissions requirement based on the configured intra-band contiguous ULCA are used (SEM, ACLR, spurious emissions) and all allocations can use the single CC MPR for inner. FFS if a similar approach is applicable to some additional emission requirements. (Skyworks)
	+ Proposal 2: Apply single carrier spurious emission/ACLR/SEM requirements for contiguous UL CA with only 1 CC transmitted. (CATT, Samsung, ZTE, vivo)
	+ Proposal 3: For Rel-19 MPR applicability for FR1 intra-band contiguous UL CA, the spurious emissions/ACLR/SEM are kept for aggregated CBW. (Huawei)
* Recommended WF
	+ FFS in next meeting

#### **Issue 2-1-4: Draft Rel-19 CR on MPR applicability for intra-band contiguous CA with single CC with activated cell**

* Proposals
	+ Proposal 1: Add the following description into clause 6.2A.2.1:
		- “For intra-band contiguous carrier aggregation with single CC with activated cell, MPR defined in Table 6.2.2-1 applies for UE power class 3 CA bandwidth classes B and C. MPR defined in Table 6.2D.2-1 applies for power class 2 CA bandwidth classes B and C when TxD capability is indicated. MPR defined in Table 6.2.2-2 applies for power class 2 CA bandwidth classes B and C when TxD capability is absent.”
* Recommended WF
	+ Endorse the draft CR

### Sub-topic 2-2: Intra-band non-contiguous CA

*Sub-topic description*

*Open issues and candidate options before meeting:*

#### **Issue 2-2-1: General considerations**

* Proposals
	+ Proposal 1: The work scope for FR1 NC CA should be limited to only study MPR applicability. (Samsung)
* Recommended WF
	+ Agree with the proposal as it is aligned with the WID

#### **Issue 2-2-2: Applicable MPR for FR1 intra-band non-contiguous UL CA**

* Proposals
	+ Proposal 1: for PC3 and PC2 intra-band non-contiguous CA as the standard already accounts for the use of the single CC MPR tables when only 1 CC is scheduled no further changes to the standard are required. (Qualcomm, ZTE, Huawei)
	+ Proposal 2: When DualPA is not signalled or TxD or UL MIMO is signalled, transmit interruption may be needed to allow LO switching and the single carrier MPR can be sued when transmitted RBs are allocated in only one of the CC. (Skyworks)
	+ Proposal 3: for non-contiguous UL CA configurations with sub-blocks consisting of one cell and supported by dual PA architecture, the non-CA (single CC) MPR applies for one cell active among the configured uplink serving cells, the other cell deactivated. (Ericsson)
	+ Proposal 4: for non-contiguous UL CA configurations with sub-blocks consisting of one cell not supported by a dual PA architecture, applicability of the non-CA (single CC) MPR for one active cell among the configured uplink serving cells, the other cell deactivated, is subject to UE capability, e.g. indication of [mpr-singleCC-activated-FR1] for the band combination. (Ericsson)
* Recommended WF
	+ Proposal 1 is only valid for UE indicating DualPA capability.
	+ FFS the case UE not indicating DualPA capability with consideration of observations in Skyworks paper.

# Topic #3: MPR applicability for FR2

### Sub-topic 3-1: Scope and cases considered for FR2 MPR enhancements

#### **Issue 3-1-1: Whether new CA MPR for CABW < 400MHz should be considered in the WI**

**Agreement in main session:**

* + Hold on discussions on whether new MPR requirement is defined for CABW < 400MHz unless the WID can be updated accordingly.
	+ Only MPR applicability needs to be discussed in this WID, and defining new MPR requirement is out of scope.

#### **Issue 3-1-2: whether FR2 MPR enhancement for the single UL case is also applicable for intra-band DL non-contiguous CA with single UL**

**Way forward:**

* + FR2 MPR enhancement for the single UL case is not applicable for intra-band DL non-contiguous CA with single UL unless the WID is revised

#### **Issue 3-1-3: Power classes considered for FR2 MPR enhancement**

**Agreement in main session:**

All FR2 power classes could be considered for the MPR enhancement

#### **Issue 3-1-4: sub-FR2 frequency ranges**

**Agreement in main session:**

Agreement: MPR reduction applies to both FR2-1 and FR2-2.

### Sub-topic 3-2: Applicable MPR

*Sub-topic description*

*Open issues and candidate options before meeting:*

#### **Issue 3-2-1: Applicable MPR for FR2 single carrier UL with DL intra band CA**

* Proposals
	+ Proposal 1: For the case of DL intra band CA with single UL CC (activated or configured), the reference MPR (originally being Table 6.2A.2.4-1) is changed as the MPR requirement for single carrier. (Huawei)
* Recommended WF
	+ For the case of single carrier UL with DL intra band CA, the MPR requirements of single carrier case in clause 6.2.2 of TS 38.101-2 should apply.

OPPO: this is FR2. Tx and Rx shares the same LO. For single uplink with DL CA, the LO is in the middle. There is image. Can we reuse the same MPR?

NTT DOCOMO: UE architecture is one implementation. We are discussing the new architecture.

Huawei: Similar understanding as NTT DOCOMO.

OPPO: Does it mean requirements apply to both 1 LO and 2 LO cases?

#### **Issue 3-2-2: Applicable MPR for FR2 UL CA with DL intra band CA**

* Proposals
	+ Proposal 1: For the case of DL intra band CA with UL CA, the reference MPR (originally being Table 6.2A.2.4-1) is changed as. (Huawei)



The existing relaxation targeting CABW < 400 MHz and also subject to specific modulation order and waveform should be ignored

* + Proposal 2: For FR2-2, it is necessary to take the minimum values of MPR between the intra-band CA case and the single carrier case. (NTT DOCOMO)
	+ Proposal 3: RAN4 not to specify new column for <400MHz CABW in the MPR table, but to change the MPR calculation for DFT-s-BPSK or DFT-s-QPSK from “MPRC\_CA = MAX(MPR1, MPR2)” to “MPRC\_CA = MPR2”, for UE with UE indication of new capability for MPR improvement. (Samsung)
	+ Proposal 4: RAN4 to focus on activation based MPR applicability. If configuration based MPR applicability is also considered, more clarification is needed. (Samsung)
* Recommended WF
	+ In general, MPR based on UL BWchannel\_CA applies instead that based on cumulative aggregated channel BW (CABW)
		- If only 1 UL CC is activated, the MPR requirements of single carrier could be reused
		- No need to specify new column for <400MHz CABW in the MPR table. FFS specific spec change to accommodate 200MHz BW granularity
		- FFS whether to take the minimum values of MPR between the intra-band CA case and the single carrier for FR2-2

OPPO: the first sub-bullet is the same as the previous issue.

### Sub-topic 3-3: UE capability

*Sub-topic description*

*Open issues and candidate options before meeting:*

#### **Issue 3-3-1: Whether an optional UE capability is considered**

* Proposals
	+ Proposal 1: no need to introduce a new UE capability for such MPR improvement as Network does not need to enable the MPR improvement originating from the application of MPR requirements. (CATT)
	+ Proposal 2: The new capability shall be defined as optional and per UE, and only applicable to FR2. In addition, it could be release independent. (ZTE)
	+ Proposal 3: RAN4 to consider as an optional capability. (Qualcomm)
	+ Proposal 4: Subject to UE capability indication on the support of Rel-19 MPR applicability for FR2 CA. (Huawei)
* Recommended WF
	+ An optional UE capability is considered, FFS on the granularity of the capability and release independent issue.

#### **Issue 3-3-2: Whether UE capability, if needed, is agnostic to specific LO implementations**

* Proposals
	+ Proposal 1: Consider all possible UE implementations, including UE with fast LO switching, or with dedicated LOs for Tx and Rx paths for the new UE capability. (ZTE)
	+ Proposal 2: Capability should not be dependent on a specific implementation. (NTT DOCOMO)
* Recommended WF
	+ TBA

#### **Issue 3-3-3: Proposal for CC activation-based MPR improvement**

* Proposals
	+ Proposal 1: FR2 UE CA MPR is based on the activated subset of the CCs in the CA configuration that are also enabled for UL, provided the activated CCs with UL comprise a contiguous block. (Qualcomm)
* Recommended WF
	+ TBA