**3GPP TSG-RAN Meeting #103 RP-240709**

**Maastricht, Netherlands, March 18th – 22nd, 2024**

**Title: Moderator's summary for discussion on UE RF enhancements for FR1 and FR2**

**Agenda Item: 9.1.4.1**

**Source: RAN4 chair (Huawei)**

**Document for: Information**

# Introduction

This document provides the summary for potential RAN4 Rel-19 UE RF enhancement work item based on companies’ contributions and the summary provided by RAN Chair and RAN4 Chair.

This document is divided into four parts: High power UE for CA in TN, Power boosting and/or MPR reduction, 6Rx and other proposals.

# HPUE for CA in TN

The summaries in RP-240019 for HPUE for CA in TN are as follow:

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| **UE RF enhancements for FR1 and FR2 (3 topics)**   * **High power UE (HPUE) for CA in TN (including 3Tx)** * Power boosting and/or MPR reduction * 6 Rx * ~~3 Tx 🡪 merged into HPUE for CA in TN~~   Note: High power UE for NTN is merged into a single NTN project | **WI** |

**UE RF: High power UE (HPUE) for CA in TN**

* References: [RP](http://www.3gpp.org/ftp/tsg_ran/TSG_RAN/TSGR_101/Docs/RP-231540.zip)[-](http://www.3gpp.org/ftp/tsg_ran/TSG_RAN/TSGR_101/Docs/RP-232745.zip)[233918](http://www.3gpp.org/ftp/tsg_ran/TSG_RAN/TSGR_102/Docs/RP-233918.zip)
* Potential objectives:
  + High power UE (HPUE) for CA (non-spectrum item for the combinations which need generic requirements)
    - PC1.5 UE for intra-band contiguous CA with or without UL MIMO with 2Tx
    - PC1.5 UE for two band inter-band CA with 2Tx and/or 3Tx for handheld and FWA
      * 3Tx specifics: Also PC2?; EN-DC?
    - Generic framework of support increasing UE power high limit for inter-band CA HPUE (only for TN) for different power classes
      * Do we need a study phase, e.g.. in 2Q’24 (1 quarter)?
  + Further discussion on other type of HPUE CA band combinations.
  + Further discussion on whether to introduction of HPUE for EN-DC
  + Further discussion on whether to introduce PC1.5 for intra-band non-contiguous

Companies’ main proposals for high power UE for CA in TN are summarized in the tables below.

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| **Tdocs** | **Key proposal** |
| Qualcomm 0331 | Introduce a general framework to enable higher output power in inter-band CA for any power class combination (including PC1.5)   * + - No limit on the maximum output power stemming from the constraint that the CA output power should be based on a power class (maximum power would be the sum of the Tx powers in all aggregated bands)     - Per band power class is kept (power class limit in each band is kept) |
| Samsung 0376 | HPUE for CA   * + - PC1.5 UE for intra-band UL contiguous CA with or without UL MIMO with 2Tx       * Candidate example band combos: n41c, n71c     - PC1.5 UE for intra-band UL non-contiguous CA without UL MIMO with 2Tx       * Candidate example band combos: n77(2A)     - PC1.5 UE for two band inter-band CA with 2Tx and/or 3Tx for handheld and FWA       * Candidate example band combos: n41-n77 (TDD-TDD), n25-n77 (FDD-TDD), n25-n66 (FDD-FDD)     - Generic framework of support increasing UE power high limit for inter-band CA HPUE (only for TN) for different power classes       * Study phase with check point at 3Q’24 |
| Mediatek 0453 | 3Tx specifics: Include 3Tx switching (2T+1T <-> 1T+2T) to boost UL MIMO availability with total 3 Tx chains across 2 frequency  Generic Framework for UE power limit: more than 1 quarter study is recommended to ensure any such framework is clear 3.  Prioritize “Inter-band CA |
| Ericsson 0253 | Merely a continuation of basket WIs and business as usual: MSD specified with higher power per band  Q2 2024 study phase on requirements needed for 2Tx/3Tx   * + - Study and evaluate requirements needed for 3Tx architectures, the per-band and per band-combination (BC) power classes to be specified for a BC       * three Tx paths active simultaneously, additional isolation and linearity requirements?     - Study the requirements needed with a supported higherPowerLimit for a BC with 2Tx or 3Tx     - Study whether verification of cross-band isolation and RFFE front-end linearity are necessary for all possible per-band/per-BC power classes     - Study whether support of UL-MIMO in BCs for 3Tx cases require additional changes |
| Vivo 0130 | a study phase of increase power limit at least for PC1.5 3Tx is needed |
| OPPO 0312 | 3Tx with PC2 or PC1.5 for inter-band UL CA/EN-DC   * + - For inter band UL CA or EN-DC, only two bands in uplink are considered     - Introduce handheld UE to Rel-18 power combinations.     - No limitation of UE types in Rel-19     - Study how to accommodate different power combinations with a general approach     - Specify necessary generic requirements for 3Tx inter-band UL CA or EN-DC, e.g. MSD requirements   2Tx with PC1.5 for intra-band contiguous or inter-band UL CA   * + - PC1.5 for TDD intra-band contiguous UL CA       * Take uplink CA\_n41C, CA\_n78C, CA\_n77C as example       * Specify necessary requirements for PC1.5 intra-band contiguous UL CA with or without UL MIMO       * Identify UE architectures, and define requirements including MPR/AMPR       * Specify the mechanism to meet SAR requirements if necessary, and PMPR is used as baseline     - PC1.5 for inter-band UL CA       * Take CA\_n41A-n77A, and CA\_n1A-n78A as example       * Specify necessary requirements for PC1.5 inter-band UL CA without UL MIMO, e.g. MSD requirements       * Specify the mechanism to meet SAR requirements if necessary, and PMPR is used as baseline     - Both handheld UE and FWA are considered   Generic framework of supporting increase UE power high limit for inter-band UL CA/ENDC   * + - Study and specify generic framework of supporting increase power high limit feature for inter-band UL CA/ENDC.       * Note: only TN is considered     - The power combinations of each band in a band combination to be considered including at least:       * PC3 in band A + PC1.5 in band B with 3Tx in total       * PC2 in band A + PC1.5 in band B with 3Tx in total     - Example band combinations: CA\_n41A-n77A, DC\_3A\_n78 |
| Huawei 0429 | Specify UE RF requirement for PC1.5 intra-band CA with 2Tx, including scenarios of   * + - Intra-band contiguous CA w/ or w/o UL MIMO     - Intra-band non-contiguous CA     - Example band combinations: n77/78/79C, n77/78/79(2A)   Specify generic UE RF requirement for PC1.5 inter-band CA with 2Tx and/or 3Tx in two bands for handheld and FWA UE  Study and define generic framework of support increasing UE power high limit for inter-band CA HPUE for different power classes |
| CATT 0394 | Intra-band CA   * + - Both contiguous and non-contiguous     - Both with UL-MIMIO and without UL-MIMO   Inter-band CA   * + - Both 2Tx and 3T   Supportive  However, an efficient way should be developed to specify HPUE with consideration of UL configurations, UL Tx architecture, form-factors, duplex modes, higher power limit, Tx power backoff behavior, etc  For 3Tx, supportive to Moderator’s observation @ RAN#102   * + - For single carrier operation, 3Tx can be captured by Rel-19 UL-MIMO WI.     - For band combination operation, it can be merged with HPUE WI. |
| China Telecom 0349 | 3Tx   * + - Extend the capability for increasing power high limit to more power class use cases including, PC2 + PC3 for 3Tx architecture, PC1.5 + PC2/PC3 for 3Tx architecture     - An general framework e.g. removing the cap of CA power class is a straight forward way to simplify introducing the power class combinations     - PC1.5 supporting for inter-band CA (PC2+PC2) with 2Tx or 3Tx for handheld and FWA     - PC1.5 supporting for intra-band contiguous CA with or without MIMO with 2Tx       * PC1.5 is supported only for single UL in Rel-18, it's suggested to introduce PC1.5(PC2+PC2) inter-band and intra-band combs in Rel-19.       * **If new PC1.5 objectives are captured, it is suggested to refine the existing WI title and objectives or coordinate with other high power UE basket WIs. The intention is to better categorize and trace them.** |
| China Unicom 0404 | To work on the generic requirements for PC2/PC1.5 for UL inter-band/Intra-band CA/DC combos with PC2 capability on FDD band(s) for 2Tx and 3Tx architecture, with following combinations   * + - FDD PC2 + TDD PC2: 1Tx on FDD, 1Tx on TDD; 2Tx on FDD, 1Tx on TDD; 1Tx on FDD, 2Tx on TDD     - FDD PC2 + TDD PC3: 1Tx on FDD, 1Tx on TDD; 2Tx on FDD, 1Tx on TDD     - Intra-band CA FDD PC |
| CHTTL 0486 | Proposal 1: Include the PC2 & PC1.5 **HPUE for FR1 EN-DC** in Rel-19 RAN4-led work items.  Proposal 2: The following three HPUE scenarios of EN-DC for handheld and FWA should be considered in the Rel.19 UE FR1 RF enhancements work item.   * + - PC2 with total 2Tx: LTE FDD + NR FDD with 23+23 & 23+26 (dBm) PA configurations     - PC2 with total 3Tx: LTE FDD + NR FDD with 1Tx PC3 + 2Tx PC2 [23+23 (dBm)] PA configuration     - PC1.5 with total 3Tx: LTE FDD + NR TDD with 1Tx PC3 + 2Tx PC1.5 [26+26 (dBm)] PA configuration   Proposal 3: The generic framework of supporting increasing UE power high limit should be considered for all of the HPUE scenarios in the objectives, and no study phase or study phase within one quarter is enough to move forward to the normative work. |
| CMCC 0152 | Specify HPUE CA RF requirements for handheld and FWA with following:   * + - PC1.5 UE for intra-band contiguous CA with or without UL MIMO with 2Tx     - PC 1.5 UE for two band inter-band CA with 2Tx       * PC2 TDD/FDD band 1Tx+PC2 TDD band 1Tx     - 3Tx for both handheld and FWA       * PC2 3Tx for inter-band CA for handheld (only FWA supported in Rel-18)       * PC1.5 3Tx for inter-band CA:       * TDD + TDD band, including PC2 + PC2, PC1.5 + PC2/PC3       * TDD + FDD band, including PC2+ PC2, PC1.5+PC2     - Enable increase UE high power limit feature for inter-band CA HPUE. |
| Intel 0544 | Requirements for FR1 High power UE (HPUE)for CA   * + - Specify generic framework of support increasing UE power high limit for inter-band and intra-band non-contiguous CA HPUE (only for TN)for different power classes     - Specify requirements for PC1.5 UE for intra-band contiguous CA with or without UL MIMO with 2Tx     - Specify requirements for PC1.5 UE for two band inter-band CA with 2Tx and 3Tx for handheld and FWA |
| NTT DOCOMO 0067 | Specify UE RF requirements to enable 3Tx for NR CA/EN-DC with two bands for handheld UE   * + - In each band only 1CC included. The Tx capability considered is 1Tx in one band, and 2Tx in the other band     - CA power class or EN-DC power class is PC2     - CA power class or EN-DC power class is PC1.5 |
| Spreadtrum 0109 | 3TX can be merged into HPUE for CA |
| Vivo 0130 | a study phase of increase power limit at least for PC1.5 3Tx is needed  3Tx inter-band CA for PC2/PC1.5 handheld UE should be included   * + - EN-DC can be considered as 2nd priority if there is clear interests   PC1.5 for intra-band non-contiguous can be considered based on clear commercial demand |
| CICT 0394 | For single carrier operation, 3Tx can be captured by Rel-19 UL-MIMO WI.  For band combination operation, it can be merged with HPUE WI. |
| Nokia 0257 | Ensuring HPUE support should be a Rel-19 focus topic, including PC1.5 for inter-band EN-DC |

**Moderator’s observations:**

* For PC1.5 intra-band UL CA, some companies provided example band combinations and proposed focusing on common requirements in the WI and leave the band combination specific requirements such as MSD to Rel-19 basket WIs, while others proposed to specify those band combination specific requirements in this WI. Quite a number of companies proposed to also include PC1.5 intra-band non-contiguous UL CA in this WI. In the moderators’ view and taking into account the previous experience, it would be better to just focus on common requirements in this WI to control the workload but the example band combinations would be still needed for MPR/A-MPR evaluations.
* For PC1.5 inter-band combinations, no company is against to include 3Tx architecture. Some companies provided a detailed list of the high power band combinations to be considered, while some companies proposed to focus on the common requirements in this WI and leave the band combination specific requirements to the basket WIs. Some companies proposed to enable 3Tx PC2 for handheld UE. Quite a number of companies also proposed to include PC1.5 EN-DC and there is no clear objection observed. In the moderator’s view, 3Tx can be confirmed, and if WI can focus on the common requirements only (i.e., SAR solution and update the specification to enable 3Tx handheld) then it would be possible to capture enabling 3Tx PC2 and PC1.5 EN-DC together with PC1.5 for inter-band UL CA. Otherwise, it is impossible to work on the huge number of high power combinations.
* One company requests the study phase for 3Tx and list the (additional) requirements which need be evaluated and specified and include how to specify the power class, how to combine with UL-MIMO and additional evaluation for cross-band isolation and RF front end linearity. Maybe some clarification on the rationale behind is needed since 3Tx has already been specified in the previous release and the common requirements would be complete. In the moderator’s view, those technique details could be discussed in WG-level and just relative high-level objective is needed to cover them.
* Based on companies’ feedbacks for general framework to enable high power for inter-band CA, it would be acceptable to have objectives with the study phase. There is no significant difference among companies on this topic. But some companies proposed no study while others proposed the longer time for study. Some companies list the detailed high power combinations for consideration. Some companies proposed to extend the scheme to EN-DC also. In the moderator’s view, it is better to keep the current scope and not to extend to EN-DC to control the workload, and keep the study and it would be reasonable to have a longer study phase, i.e., setting the checking point at Q3 2024, considering the potential large number of high power combinations. In this regard, there seems no need to exhaustively list all the high power combinations in the WID to save some effort and leave all the technique details to be discussed in WG level to avoid missing something.

**Moderator proposals for objective refinement based on summary RP-240019**

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| **Core part only**   * Specify the generic requirements of high power UE (HPUE) for NR uplink (UL) CA in FR1 and EN-DC with NR FR1 bands   + Power class 1.5 (PC1.5) UE for NR intra-band UL contiguous and non-contiguous CA with or without UL MIMO with 2Tx     - Example band combinations:       * CA\_n41C, CA\_n78C, CA\_n77C for intra-band uplink contiguous CA configurations       * CA\_n41(2A), CA\_n78(2A), CA\_n77(2A) for intra-band uplink non-contiguous CA configurations     - Focus on the maximum output power (MOP), MPR/A-MPR requirements     - NOTE: leave the other band combination specific requirements to the corresponding basket WIs   + PC1.5 UE for two band NR inter-band uplink CA and EN-DC with 2Tx and/or 3Tx for handheld and FWA     - Focus on the SAR solution     - Enable power class 2 (PC2) and PC1.5 of two band inter-band uplink CA and EN-DC with 3Tx for handheld UE       * Identify and update the requirements if necessary     - NOTE: leave the band combination specific requirement including MSD to the corresponding basket WIs   + Generic framework of support increasing UE power high limit for NR inter-band uplink CA HPUE for different power classes     - NOTE: two quarter study phase with check point at RAN#105   + Necessary signaling to support the above objectives   + Release independency if needed |

**Discussions:**

# Power boosting and/or MPR reduction

The summaries in RP-240019 for power boosting and/or MPR reduction are as follow:

|  |  |
| --- | --- |
| **UE RF enhancements for FR1 and FR2 (3 topics)**   * High power UE (HPUE) for CA in TN (including 3Tx) * **Power boosting and/or MPR reduction** * 6 Rx * ~~3 Tx 🡪 merged into HPUE for CA in TN~~   Note: High power UE for NTN is merged into a single NTN project | **WI** |

**UE RF: Power boosting and/or MPR reduction**

* References: [RP](http://www.3gpp.org/ftp/tsg_ran/TSG_RAN/TSGR_101/Docs/RP-231540.zip)[-](http://www.3gpp.org/ftp/tsg_ran/TSG_RAN/TSGR_101/Docs/RP-232745.zip)[233918](http://www.3gpp.org/ftp/tsg_ran/TSG_RAN/TSGR_102/Docs/RP-233918.zip)
* Potential objectives:
  + **(Ensure reasonable load)** Power boosting or MPR reduction for PC2/PC3 with ACLR relaxation with BS indication (Study on whether and how much the requirement can be relaxed first and how often the power boosting can be done, and at least lower modulation order need be studied and FFS on higher modulation order) for FR1 and FR2
    - A study phase is necessary
    - Is there a need to consider RedCap?
  + MPR reduction for UL contiguous CA in FR1/FR2
    - How about a single active UL carrier case when CA is configured?
  + ~~MPR reduction for RedCap via relaxed emission requirements with BS indication (Study on whether and how much the requirement can be relaxed first, and at least lower modulation order need be studied)~~
  + ~~Need further clarification and discussion on including Pi/4 QPSK in the study and check whether there is RAN1 impact~~
  + ~~Need further discussions on whether PAPR reduction is included.~~
  + ~~Need further discussion on whether EVM will be relaxed.~~
  + ~~Need further discussions on whether the power boosting or MPR reduction should be network transparent only~~

Companies’ main proposals for Power boosting and/or MPR reduction are summarized in the tables below.

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| **Tdocs** | **Key proposal** |
| Qualcomm 0331 | Specify MPR reduction cases when ACLR can be relaxed  Specify MPR reduction for cases when a UE uses a narrower channel BW within a wider BS bandwidth  Specify MPR reduction based on the UL active CCs (both FR1 and FR2) for intra-band UL CA configuration  Introduce the necessary signaling mechanism to enable these MPR reductions |
| Mediatek 0453 | Focus on improving Tx power to reduce MPR of outer RB allocations (to reduce MPR difference vs inner RB allocation) as a trade-off with ACLR/SEM/Spurious emissions relaxation when operating scenario allows it.  Identify the scenarios where this would be feasible   * + - At least include the case where UE is operating in RBs within 0.5 x UE BW from spectrum block edge – consider RedCap and normal UE (impact inside operator’s spectrum block)     - TBD whether to also include the case where UE is operating in RBs closer to the spectrum block edge (impact outside operator’s spectrum block) |
| Intel 0544 | Study and specify Power boosting or MPR reduction for PC2/PC3 with ACLR relaxation with BS indication for FR1/FR2 for non-RedCap and RedCap devices.  Specify MPR reduction for UL contiguous CA in FR1/FR2 for the case of single activated UL carrier. |
| ZTE 0469 | ACLR relaxation outside of BS channel bandwidth or aggregated channel bandwidth or towards different operator are not allowed in this release.   * + - also used as basis for other regulatory body for sharing and compatibility study (e.g. ITU-R WP5D etc). |
| LGE 0327 | Study FR1 ACLR relaxation to be allowed for power boosting and/or MPR reduction, then specify the power boosting and/or MPR reduction in FR1 with the ACLR relaxation [1]   * + - PC3 and PC2 in a single carrier     - PC3 and PC2 in UL contiguous CA / a single active UL carrier   FR2 requirement can be considered after FR1 requirement is completed |
| Ericsson 0253 | Power boosting and/or MPR reduction: proposed objectives for additional FR1 scenario  Improve coverage and TP for UL intra-band non-contiguous (NC) CA  Introduce additional requirements for   * + - UL intra-band non-contiguous CA (1Tx or 2Tx)       * single UL cell scheduled/active: by reducing MPR to that of non-CA for UL transmissions confined within one of the two cells also for UEs not indicating dualPA-Architecture at least when one of the cells is deactivated       * dual NC UL cells scheduled: by reducing MPR for concurrent transmissions for FDD and TDD regardless of PA architecture with additional side-conditions (LO leakage etc) if needed       * up to 100 MHz carrier separation (intraBandFreqSeparationUL-AggBW-GapBW-r16 class I) as supported by a single TX/PA and RX chain       * enhancements can be subject to UE capability     - combine with UL-MIMO (2Tx) or UL inter-band CA configurations with an UL intra-band NC part (1Tx + 1Tx)   Non-collocated cells can be considered (based on n77 requirements)  Justification: enhance performance of deployments in fragmented intra-band spectrum  Power boosting and/or MPR reduction: MPR reduction for UE-specific BW within carrier   * + - RAN4 requirements specified w r t the channel bandwidth (MHz)       * Unwanted emissions apply outside NR RF carrier, while less stringent in-band emission requirements apply within the carrier     - Consider MPR reduction for UE-specific CHBW smaller than the carrier bandwidth, e.g. for RedCap (see R4-233297)     - Unwanted emissions requirements corresponding to the carrier bandwidth apply at an offset from the UE-specific CHBW (one-sided – see below – or two-sided), MPR can be reduced in parts of the UE-specific CHBW       * The offset known by the UE from SIB1 and ServingCellConfig, the MPR reduction depends on the offset |
| Huawei 0429 | Specify the UE RF requirements of MPR reduction and/or power boosting for the existing power classes by conditionally relaxing ACLR or EVM requirements:   * + - For QPSK and 16QAM, specify the conditions and signaling to relax ACLR and the corresponding relaxed ACLR requirements     - For 64QAM and 256QAM, specify the conditions and signaling to relax EVM and define the relaxed EVM requirements     - NOTE: the enhancement is applicable to OFDM and DFT-s-OFDM waveform   Study and specify improved MPR for FR2 intra-band CA  Specify the improved MPR requirement with new PAPR reduction mechanism   * + - The PAPR reduction mechanism is expected to be transparent to network and with less impact on existing physical layer design     - MPR improvement at least for inner RB allocation region, study and specify the improved MPR for outer RB allocation regions     - Targeted power class is PC3     - Candidate modulation schemes include QPSK, 16QAM |
| CATT 0394 | Supportive to power boosting schemes considering:   * + - ACLR/EVM relaxing approaches     - Limit to single carrier operation     - Making most of existing UE’s hardware capability in a controllable manner with little impacts on system performance. |
| China Telecom 0349 | Power boosting or MPR reduction for PC2/PC3 with conditional requirements relaxation   * + - Under condition of relaxed ACLR or EVM requirements, Specify Power boosting or MPR reduction requirement for specific power class       * Identify the bottleneck requirements within ACLR and EVM for Power boosting or MPR reduction for different modulation orders of QPSK, 16QAM, 64QAM and 256QAM       * Specify the Power boosting or MPR reduction requirements based on identified relaxed ACLR or EVM requirements     - Under condition of PAPR reduction, specify Power boosting or MPR reduction requirement for specific power class       * Study and confirm PAPR reduction methods that shows benefit for smoothing power across frequencies       * Specify the Power boosting or MPR reduction requirements based on identified PAPR reduction requirements       * Optimize the Power boosting or MPR requirements for 2Tx UE architecture according to different implementation of the CBW or PRB allocation for each Tx |
| China Unicom 0404 | To study/specify the MPR-reduction and/or power boosting related mechanisms/requirements for FR1/FR2  To study/specify the MPR reduction for UL CA |
| NTT DOCOMO 0067 | Study and specify improved MPR for FR2 intra-band CA   * + - Study, as one of the improved MPR solution, whether MPR for FR2 intra band CA can be defined based on only UL CBW (i.e., independent from DL CBW). Other solutions are not precluded.     - Target band combination is CA n257I. |
| Spreadtrum 0109 | Low priority |
| Vivo 0130 | The case of “single active UL carrier when CA is configured” can also be considered |
| Nokia 0257 | Review specified MPR values and determine reasonable MPR values for contiguous RB allocations in the light of practical implementation. |
| OPPO 0312 | Power boosting and MPR reduction   * + - Study on whether and how much the requirement can be relaxed and how often the power boosting can be done.     - QPSK/BPSK are prioritized, and modulation order higher than QPSK is 2 nd priority     - After benefits are confirmed, introduce power boosting or MPR reduction for PC2/PC3 with ACLR relaxation with BS indication for FR1 and FR2 |
| Samsung 0376 | Power boosting or MPR reduction for PC2/PC3 with ACLR relaxation with BS indication (Study on whether and how much the requirement can be relaxed first and how often the power boosting can be done, and at least lower modulation order need be studied and FFS on higher modulation order) for FR1 and FR2   * + - Study Tx EVM relaxation for higher modulation orders including 64QAM and 256QAM (study only, w/o normative work in rel-19) |
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**Moderator’s observations:**

* For the single carrier power boosting/MPR reduction topics via ACLR relaxation, companies proposed the detailed conditions for consideration. Companies also proposed to consider both RedCap and non-RedCap. Qualcomm categorized the conditions into a number of scenarios, which could cover all the proposals in general in the moderator’s view. One company proposed to limit the cases. Some companies proposed to clarify that only lower modulation orders should be taken into account for this work. In the moderator’s view, it would be a compromise to first have the study phase for the concrete scenarios before the normative work. Besides, PC3/PC2 have different meaning for FR1 and FR2. It seems that most companies talked about power boosting for FR1. To reduce the workload, the moderator proposed to focus on FR1.
* Quite a number of companies proposed to consider the EVM relaxation for power boosting/MPR reduction for high modulation order transmissions. So the moderator list it for further consideration. Some companies also proposed considering further PAPR reduction. But considering the workload, maybe we have to drop it in this release. One company proposed to also consider SEM relaxation, which can be discussed in the group.
* Regarding MPR reduction for UL intra-band CA, companies proposed quite many details. There would be number of scenarios: intra-band uplink contiguous CA for FR1 where the existing MPR would need be checked and potential enhancement can be conducted, intra-band uplink non-contiguous CA for FR1 where either single uplink CC or dual uplink CCs will be scheduled with the enhanced MPR values, intra-band uplink contiguous CA for FR2. And most of proposals seem to consider the real PRB allocation or actual uplink carrier scheduling to further optimize the transmission power. In the moderator’s view, Qualcomm’s description could be covered most of cases and can be used as the starting point to decide the objective, but the wording “active” may be confusing because the uplink CC in a Cell cannot be (de)-activated in the current specification and only a cell can be activated or deactivated. Thus it is suggested to use wording “scheduled”.

**Moderator proposals for objective refinement based on summary RP-240019**

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| **Core part only**   * Specify power boosting and/or MPR reduction for NR single carrier and NR intra-band UL CA   + Study and specify the power boosting or MPR reduction for PC2 and PC3 with ACLR relaxation with BS indication for NR FR1 on a single UL carrier     - Include the following scenarios:       * Relaxing ACLR requirements when there is no adjacent co-existence issue       * Relaxing ACLR when a UE uses a narrower channel bandwidth within a wider BS bandwidth     - Include both RedCap UE and non-RedCap UE     - Note: two quarter study phase with checking point at RAN#105   + Study MPR reduction with EVM relaxation for 64QAM and 256QAM for NR FR1 and FR2 single carrier scenario     - Note: no normative work in Rel-19   + Specify MPR reduction based on the UL scheduled CCs for NR intra-band UL CA configuration     - Include both intra-band UL contiguous CA and intra-band non-contiguous CA for FR1     - Include intra-band UL contiguous CA for FR2   + Necessary signaling to support the above objectives |

**Discussions:**

# 6Rx

The summaries in RP-240019 for 6Rx are as follow:

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| **UE RF enhancements for FR1 and FR2 (3 topics)**   * High power UE (HPUE) for CA in TN (including 3Tx) * Power boosting and/or MPR reduction * **6 Rx** * ~~3 Tx 🡪 merged into HPUE for CA in TN~~   Note: High power UE for NTN is merged into a single NTN project | **WI** |

**UE RF: 6Rx**

* References: [RP](http://www.3gpp.org/ftp/tsg_ran/TSG_RAN/TSGR_101/Docs/RP-231540.zip)[-](http://www.3gpp.org/ftp/tsg_ran/TSG_RAN/TSGR_101/Docs/RP-232745.zip)[233918](http://www.3gpp.org/ftp/tsg_ran/TSG_RAN/TSGR_102/Docs/RP-233918.zip)
* Potential objectives:
  + Do we need a feasibility study?
  + Investigate and enable 6Rx on higher frequency bands (>2.5GHz ) targeting at support of smartphone and FWA
  + Specify the requirements to support SRS antenna switching
  + FFS on the MIMO layer to be supported.
  + Further discussions on the following potential objective:
    - Improved SRS reporting for antenna switching usage

Companies’ main proposals for Power boosting and/or MPR reduction are summarized in the tables below.

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| **Tdocs** | **Key proposal** |
| NTT DOCOMO 0067 | Study and if needed, specify the requirements to support SRS antenna switching for t1r6, t2r6, t4r6  6 DL MIMO layers is considered. |
| Spreadtrum 0109 | MIMO layers should be 4 |
| Vivo 0130 | MIMO layers should be 4  Focus on few example bands at high frequency range (n41 and n78) |
| OPPO 0312 | Example bands: TDD bands with n41, n77/ n78, n79  Consider both single carrier and CA/DC with 6Rx capabilities  Specify requirements to support SRS antenna switching  Introduce necessary capabilities in TS38.306 and TS38.331 to support 6Layer reception and also SRS antenna switching considering the Tx antenans could be up to 3Tx and 4Tx  Release independent will be considered for 6Rx |
| Samsung 0376 | Limit to 4 layers in initial stage, and further study the feasibility of supporting 6 layers  Not consider SRS reporting enhancement |
| Huawei 0429 | Investigate and enable 6Rx on higher frequency bands targeting at support of smartphone  Investigate the feasibility whether 6Rx can be extended to the smartphone, and decide which UE type (smartphone and/or FWA/CPE) will be considered   * + - Feasibility study includes performance gain and form factor   Consider NR TDD bands higher than 1.8GHz and example bands are n41, n77, n78 and n79 (other bands to be introduced in the release independent way later)  Specify the requirements to support 6Rx subject to the conclusion of feasibility study   * + - Specify the UE RF requirements to support 6Rx     - Specify RLM test cases with 6Rx     - Specify UE demodulation performance and CSI requirements to support 6Rx     - Support at least up to 4 MIMO layers, FFS for layer larger than 4   Insertion loss (IL) imbalance reporting for SRS antenna switching   * + - Enable static and/or dynamic IL imbalance reporting with consideration of possibly partial UE compensation of the power imbalance     - No impact to RF requirement i.e. ∆TRxSRS and RAN1 uplink power control and power headroom report mechanism     - The optional SRS IL imbalance reporting could be applicable to 4Rx, 6Rx and 8Rx   Enable semi-static and/or dynamic reporting for ULFPTx applicable modes associated with changed power (RAN1, RAN2, RAN4)   * + - Applicable ULFPTx modes reporting could be companioned with ∆Ppowerclass reporting, but not limited to the case that power reduction is resulting from duty cycle exceedance |
| CATT 0394 | Supportive   * + - Including both FWA and handheld |
| China Telecom 0349 | 6Rx   * + - Investigate and enable 6Rx on higher frequency bands (>2.5GHz ) targeting at support of smartphone and FWA       * **It is proposed to cover the example bands including n41, n77, n78 with smartphone**     - Specify the requirements to support SRS antenna switching |
| CMCC 0152 | 6Rx support for smartphone:   * + - Example bands are n41, n77, n78 and n79 (other bands to be introduced in the release independent way later from Rel-18)     - Applicable frequency upper bound to support 6Rx.     - Requirements to support SRS antenna switching     - Support at least 4 MIMO layers, FFS for 6 MIMO layers |
| Ericsson 0253 | Improvement of SRS reporting and performance for CSI estimation part of study phase  Depending on the outcome of the study:   * + - Specification of a reporting scheme for SRS output power for all configured SRS resources of SRS resource sets (RAN4, RAN2) for 2/4/6/8Rx       * or non-reciprocal UE insertion loss per SRS port(s) if considered feasible     - Limited changes to RAN1 specifications, no change of SRS power control or Type 3 PH     - Improved testing of SRS output power       * essentially no testing of SRS in the UE conformance test specifications |
| CICT 0394 | Study and specify 6Rx support on higher frequency bands for handheld UEs  Specify requirements for SRS antenna switching  Including both FWA and handheld |
| Mediatek 0453 | Need for FWA 6Rx capability unclear (vs. 4/8Rx)  Focus on 4 layers: Most practical  SRS insertion loss reporting: no gain observed   * + - UE can/should self-compensate for power imbalance from insertion loss by using available Tx power     - SRS insertion loss reporting as alternative has been shown to be inferior to UE self-compensation (see e.g. R1-2308034) |
| Qualcomm 0331 | Introduce RF requirements for 6Rx  Introduce SRS switching support and requirements for 3T6R, 4T6R  Introduce demod requirements for 6Rx with up to 6L MIMO  Introduce RRM requirements/tests for 6Rx |
| Intel 0544 | Include the work on mechanisms for “SRS IL compensation and reporting ” in the scope of Objective #3 (6Rx UEs)  Up to 4 layers |

**Moderator’s observations:**

* For 6Rx UE form factor, some companies proposed to include both FWA and smartphone, while others proposed only considering smartphone. Regarding the supported layer number, some companies proposed considering up to 6-layer, while others proposed to focus on 4-layer. In the moderator’s view, if no consensus was reached in RAN level, we have to have the study phase to decide it by doing some evaluation in WG.
* For SRS antenna switching requirements, some companies proposed to consider 2Tx, 3Tx and 4Tx. Maybe more discussions on 3Tx are needed.
* Regarding the improved SRS reporting for antenna switching usage, it is related to the issue of insertion loss imbalance across Tx antennas. Companies had different views on it. In the moderator’s view, maybe some study is needed.
* For the basic scope, one company proposed to specify the requirements of 6Rx for CA and DC and also in release independent manner. In the moderator’s view, we should limit the scope and first focus on the single carrier case, and regarding whether it can be supported in release independent way, it depends on whether there is non-backward compatible issue. The example bands are needed to specify the reference sensitivity requirements and other Rx requirements.

**Moderator proposals:**

|  |
| --- |
| **Core part**   * Specify the core requirements to enable 6Rx for higher frequency bands (>2.5GHz) targeting at support of smartphone and FWA for NR FR1 single carrier scenario   + Example bands: n41, n77/n78, n79   + Support 4 MIMO layers at least, and study the gain and feasibility and if feasible, support 6 MIMO layers   + Specify the Rx requirements including reference sensitivity requirements for support 6Rx   + Specify the requirements to support SRS antenna switching including t1r6, t2r6, t3r6, t4r6     - Study and specify the improved SRS reporting for antenna switching usage   **Perf. part**   * Specify the performance requirements to enable 6Rx on higher frequency bands (>2.5GHz) targeting at support of smartphone and FWA for NR FR1 single carrier scenario   + Investigate and if necessary, specify RLM test cases to support 6Rx   + Specify UE PDSCH demodulation performance and CSI requirements to support 6 Rx     - Study whether up to 6 MIMO layers need be supported   + Specify the SDR requirements to support 6Rx * Specify release independence requirements in TS 38.307, if needed and feasible. |

**Discussions:**

# Other proposals

**Fragmented carriers in the DL**

Companies’ main proposals are summarized in the tables below.

|  |  |
| --- | --- |
| **Tdocs** | **Key proposal** |
| Telus et al 0503/0498 | Study Item to identify a solution for minimizing the number of UE Rx chains needed for intra-band non-contiguous CA  Objective:   * + - Study methods by which a UE can dynamically switch the number of Rx chains (one or two) needed for a single DL band of ≤ 100 MHz within a CA combination, considering       * ACLR implications       * The near-far problem   RAN4 led item with minimal RAN2 impact and no RAN1 impact is foreseen  Timescale:   * + - Start Q3 2024     - Target completion Q2 2025 |

**Applicable ULFPTx modes reporting associated with changed power**

Companies’ main proposals are summarized in the tables below.

|  |  |
| --- | --- |
| **Tdocs** | **Key proposal** |
| Huawei 0429 | Enable semi-static and/or dynamic reporting for ULFPTx applicable modes associated with changed power (RAN1, RAN2, RAN4)   * + - Applicable ULFPTx modes reporting could be companioned with ∆Ppowerclass reporting, but not limited to the case that power reduction is resulting from duty cycle exceedance |

**FR2 Intra+Inter UL CA with different frequency bands for PC1/2/3/5**

Companies’ main proposals are summarized in the tables below.

|  |  |
| --- | --- |
| **Tdocs** | **Key proposal** |
| NTT DOCOMO 0067 | Specify UE RF requirements to enable FR2 intra+inter band UL CA with different frequency bands with IBM   * + - Target power class: PC1/2/3/5     - Example band combination: n257I+n259M |

**Further complexity reduction for eRedCap devices enabling single SKU design (SAW-lesss)**

Companies’ main proposals are summarized in the tables below.

|  |  |
| --- | --- |
| **Tdocs** | **Key proposal** |
| Sony 0165 | Include the following objectives for Rel-19 Further complexity reduction for eRedcap devices as part of RAN4 work:   * + - RAN4 to investigate the limiting factors in UE RF requirements in TS 38.101-1 to enable SAW-less designs in Rel-19.     - Focus on PC3 HD-FDD eRedcap with baseband bandwidth reduction BW3/PR3 deRAN4 to investigate the limiting factors in UE RF requirements in TS 38.101-1 to enable SAW-less designs in Rel-19.     - vice (IE supportOfERedCap-r18 is present and IE eRedCapNotReducedBB-BW-r18 is NOT present).       * Note: examples of limiting factors are such as band specific transmitter out of band emissions and receiver out of band blocking.     - Based on the identified limiting factor, RAN4 to specify the corresponding mechanism(s) to enable SAW-less eRedcap designs in Rel-19.       * The mechanism to enable SAWless eRedcap designs should guarantee the public safety band protection, and that the corresponding spurious emission for UE co-existence level is not relaxed. |

**3Tx switching (2T+1T <-> 1T+2T) to boost UL-MIMO availability with total 3Tx chains across 2 frequency**

Companies’ main proposal are summarized in the tables below.

|  |  |
| --- | --- |
| **Tdocs** | **Key proposal** |
| Mediatek 0453 | 3Tx specifics: Include 3Tx switching (2T+1T <-> 1T+2T) to boost UL MIMO availability with total 3 Tx chains across 2 frequency  Generic Framework for UE power limit: more than 1 quarter study is recommended to ensure any such framework is clear 3.  Prioritize “Inter-band CA |

**Enhancement for power class reporting solution and SAR solution**

Companies’ main proposal are summarized in the tables below.

|  |  |
| --- | --- |
| **Tdocs** | **Key proposal** |
| China Telecom 0349 | Continue optimize the power class related reporting solution   * + - Introduce ‘duration’ information (e.g., a UE can sustain UL at a previously or concurrently reported PCmax) report for FR1     - Consider UE full-power transmission capability report method, and specify the corresponding configuration/indication method for full-power transmission mode   Discuss to distinguish UE capabilities about SAR solution for single carrier /CA/DC and whether to introduce P-MPR report in FR1 |

# Conclusions

The proposed objectives are summarized below.

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