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On UE RF & OTA Topics for Rel-19

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Further UE RF enhancements for FR1 & FR2

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  - Applicable ULFPTx modes reporting associated with changed power
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- High power UE for CA
- 6Rx for handheld UE

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UE RF UL enhancement
MPR reduction and/or power boosting with relaxed requirements

- **Motivation**
  - > UL performance is one of key enablers for 5G-advanced. One of the key evolution directions is to enhance the uplink coverages or performance for different transmission schemes including single carrier or UL CA aggregation, different modulations including QPSK, 16QAM, 64QAM, 256QAM, and different waveforms. The improvement could be generic for both FR1 and FR2.
  - > It is critical to increase UE uplink transmission power in order to enhance uplink coverage or performance. There are two evolution directions: one is to define the higher power class; the other is to boost transmission power for existing power classes. In our view, the latter one is more cost-efficient and RAN4 should focus on it for Rel-19 non-spectrum item.
  - > One aspect below can be further improved for existing power classes considering the work in Rel-18 HPUE items and Rel-18 coverage enhancement WI:
    - Reduce MPR or boost UL transmission power by conditionally relax the main limiting factors including ACLR or EVM for power boosting
      - Relax ACLR for lower modulation orders: ACLR could be relaxed to allow MPR reduction or power boosting under the following conditions:
        - ✓ When considering and aligning the absolute tolerable OOB emission mean levels across PC3, PC2 and PC1.5.
        - ✓ When narrower UE RB allocation/CBW is located around the center of the wider system bandwidth, e.g., RPB allocation on the edge of 100MHz single CC but still almost in the center of the whole system spectrum i.e., 160MHz ~200MHz spectrum capable for intra-band CA.
        - ✓ When there is no other adjacent operator in the same band.
      - Relax EVM for higher modulation orders: EVM could be relaxed by using lower PAPR schemes without or with less demodulation degradation.
- **Objective**
  - > 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

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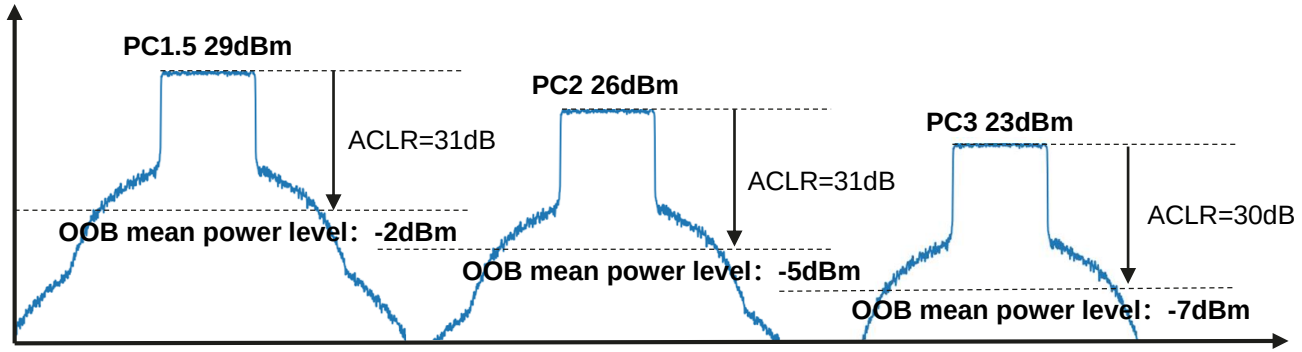
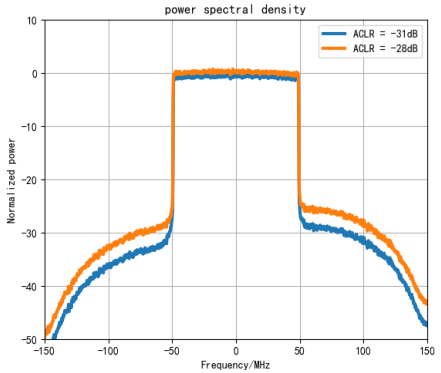
UE RF UL enhancement
MPR reduction and/or power boosting with relaxed requirements (cont.)

- **ACLR requirement relaxation**
  - > The ACLR is the “the ratio of the filtered mean power centred on the assigned NR channel frequency to the filtered mean power centred on an adjacent NR channel frequency at nominal channel spacing”, which is the relative value of mean OOB emission compared to transmission power.
  - > When UE transmits in the maximum output power defined by certain power classes, the resulted mean powers on the adjacent channels are different across different UE power classes. Actually, when PC1.5 is supported for a certain band, the absolute OOB mean power level could be applied together with SEM and spurious emission to limit maximum output power rather than applying the relative tightened ACLR requirements. In such way, there would be some room to allow further increasing the transmission power for PC2 and PC3.
  - > The ACLR level for PC1.5 was derived based on the co-existence study with the certain assumptions for PC1.5 user population and effect of power control. The same assumptions could also be applicable for PC2 or PC3 UE with the proposed further power boosting.
  - > Besides, as mentioned in the previous slides, in some deployment, there would be no other adjacent operators in the same band, where ACLR could be relaxed with signaling. Or the system bandwidth is larger, e.g., 160MHz or 200MHz, which can support intra-band CA. In such case, the RPBs allocated for a user is located on the edge of a single CC but still in the region around the center of the whole deployed spectrum.





MOP can be increased by 0.8dB, if 2dB ACLR relaxation is allowed

UE RF UL enhancement
MPR improvement with new PAPR reduction mechanism

- **Motivation**
  - > UL performance is one of key enablers for 5G-advanced. One of the key evolution directions is to enhance the uplink coverages or performance for different transmission schemes including single carrier transmission or UL CA, different modulation schemes including QPSK, 16QAM, 64QAM, 256QAM, and different waveforms.
  - > It is critical to increase UE uplink transmission power in order to enhance uplink coverage or performance. There are two evolution directions: one is to define the higher power class; the other is to boost transmission power for existing power classes. In our view, the latter one is more cost-efficient and RAN4 should focus on it for Rel-19 non-spectrum item.
  - > The aspect below can be further improved for existing power classes considering the work in Rel-18 HPUE items and Rel-18 coverage enhancement WI:
    - Further reduce PAPR for DFT-s-OFDM and CP-OFDM especially with QPSK, 16QAM
      - There are some solutions like ACE (active constellation extension) or soft-clipping for single carrier, which are network transparent and may have better performance than existing schemes in Rel-18.
      - For UE supporting 2Tx, PAPR can be further reduced by using two Tx with different narrower RBs allocated on one CC or separate CCs for intra-band contiguous CA, and thus the MPR can be reduced or in other words the power can be boosted.
      - There are some leftover issues from Rel-18 especially for outer region.
- **Objective**
  - > 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

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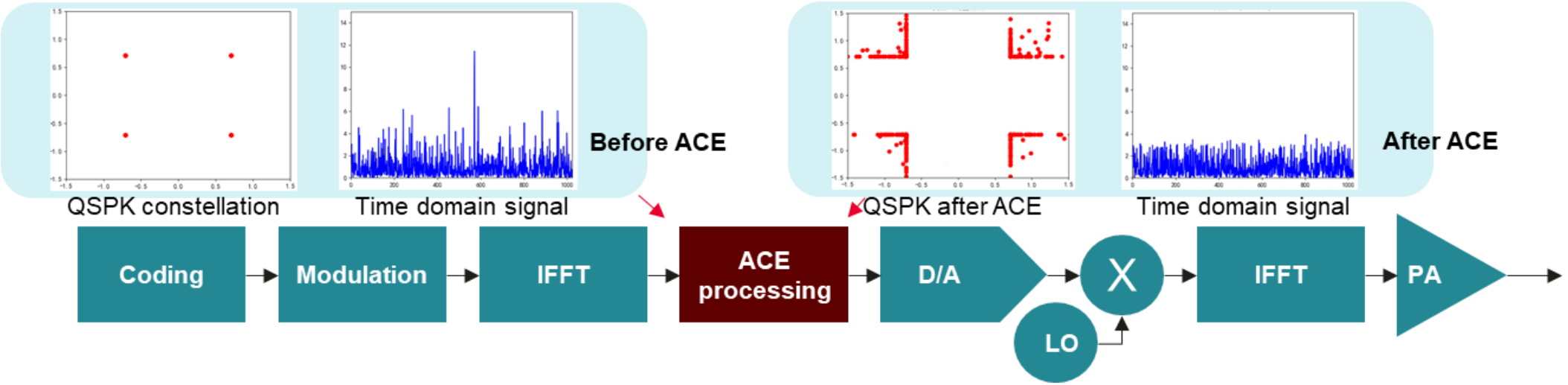
UE RF UL enhancement
MPR improvement with new PAPR reduction mechanism (example)

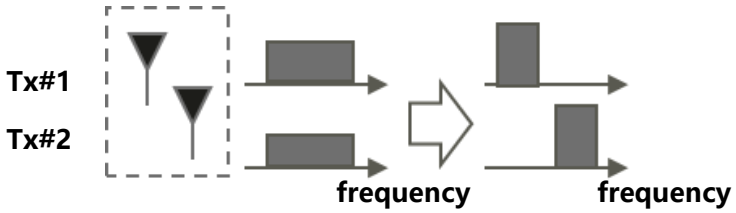
- **Active constellation extension (ACE)**_example PAPR reduction mechanism
  - > ACE is to conduct the power clipping with restriction that the distortion of modulation signal happens in the restricted region of constellation, i.e., allowing modulation symbol distortion only outside the corner regions of constellations as show below for QSPK after ACE, which would not decrease the minimum Euclidean distance between constellation points and thus the performance degradation is negligible.
    - ACE does not impact the physical layer (including modulation process) and it can be viewed as a special clipping (CFR) process after IFFT.
    - ACE is transparent to network and please refer to IEEE papers about ACE for more details
  - > ACE is just an example scheme to conduct further PAPR reduction. There would be also other network transparent schemes for it. The intention here is to enable further PAPR reduction with less performance impact. At the end of the day, only the allowed power boosting level with necessary UE capability needs be specified.



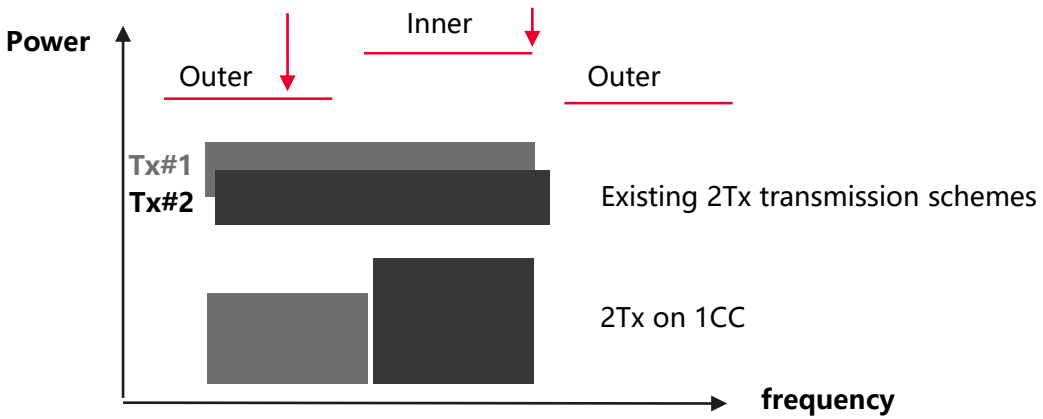
Larger than 1dB SNR gain is expected because of boosting power for PC2 and PC3

UE RF UL enhancement
MPR improvement with new PAPR reduction mechanism

- **MPR reduction by using two Tx on one CC or for intra-band UL CA case**
  - > The smaller MPR corresponding inner region can be applied to UE, if UE utilizes the 2Tx to transmit signals with the reduced transmission frequency block per Tx, since outer region will be reduced for the smaller transmission bandwidth.
  - > Reduce MPR by using two Tx simultaneous transmissions with separate PRB allocations for each Tx on one CC or for intra-band CA to make each RPB allocation within the inner region of one CC.
    - Since each Tx transmit relatively smaller frequency block, those allocated PRBs could be in the inner region with more possibility.



2Tx transmission on one CC



Benefit: Less power back-off (potential reduced MPR)

NOTE: ACE and using Tx on one CC/band are two independent techniques and can be used separately

UE RF UL enhancement
Applicable ULFPTx modes reporting associated with changed power

- **Motivation**
  - > $\Delta P_{PowerClass}$ reporting and ULFPTx modes reporting associated with changed power have been discussed extensively in Rel-18. Due to limited time and possible RAN1 impact, ULFPTx modes reporting was dropped from Rel-18
    - $\Delta P_{PowerClass}$ reporting agreed in Rel-18 is only for the case where $\Delta P_{PowerClass}$ change resulting from duty cycle exceedance (power reduced) or return from duty cycle exceedance (power return)
    - The power reduction could also occur for other cases, e.g. Pmax configured to the UE
    - RAN1 confirmed in the reply LS (R1-2310518) that inclusion of $\Delta P_{PowerClass}$ in a report to network has no RAN1 impact, but no conclusion on the RAN1 impact for supporting uplink full power MIMO transmission dependency on $\Delta P_{PowerClass}$ report
  - > During RAN4 discussion, some companies have identified that UE may be capable of different ULFPTx mode in order to satisfy RF exposure conditions or handle human tissue blockage.

- **Objective**
  - > 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 $\Delta P_{powerclass}$ reporting, but not limited to the case that power reduction is resulting from duty cycle exceedance

UE RF UL enhancement
MPR improvement for FR2 intra-band CA

- Motivation
  - MPR for intra-band CA is quite large, which could be improved with further evaluation

- Objective
  - Study and specify improved MPR for intra-band CA

High power UE for CA

- Motivation
  - The band combination for PC1.5 intra-band contiguous/non-contiguous CA was already proposed in Rel-18, and it has impact on general requirement
  - Operators show interest for UE supporting this feature to accommodate the deployment demand
    - Example band combination could be n77C, n78C, n79C, n77(2A), n78(2A), n79(2A)
  - Strong demand for companies to consider a HPUE framework for NR CA

- Objective
  - 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 UE RF requirement for PC1.5 inter-band CA with 2Tx and 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

6Rx for handheld UE

- Motivation
  - > 6Rx for handheld UE was discussed extensively at the beginning of Rel-18 for RAN4 scope
  - > Operators show strong interest to enable the feature for handheld UE
- Objective
  - > 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 and n78 (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. ΔT_{RxSRS} and RAN1 uplink power control and power headroom report mechanism
    - The optional SRS IL imbalance reporting could be applicable to 4Rx, 6Rx and 8Rx

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MIMO OTA evolution and enhancements

- MIMO OTA
  - Additional bands in FR1 and FR2
  - Develop test procedures and performance requirements for Multiple TRP scenarios for FR1

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Multiple TRP test scenarios for FR1 MIMO OTA

- Motivation
  - > Multiple TRP for FR1 is a Release 16 feature and a number of commercial device models already support Release 16 functionalities.
  - > By the time this work item enters the measurement campaign phase to define performance requirement around Q1 2025, more commercial device models supporting Release 16 features would become available.
  - > Multiple TRP is a key feature to improve cell edge performance, which is a problem faced by many operators.
  - > Current MIMO OTA test is only for a single TRP. Therefore, tests should evolve with functionality enhancement.

- Objective
  - > Develop scenarios and associated channel conditions for multiple TRP tests for FR1 MIMO OTA.
  - > Ensure that test equipment can support multiple TRP tests
  - > Develop test procedures and performance requirement through measurement campaign

Reference:

Enhanced Reliability and Capacity with Multi-TRP Transmission, M. Khoshnevisan, et al, IEEE Communications Standards Magazine, March 2022, pp.13-19

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Additional bands in FR1 and FR2 for MIMO OTA test

- Motivation
  - Currently only a limited number of bands are covered under R18 work item.
  - However, more frequency bands have been deployed across the world.
  - The aim is to cover representative bands in both FR1 and FR2

- Objective
  - Based on operators' requests, agree on the bands to be covered in FR1 and FR2
  - Use existing test procedures to define performance for additional bands in FR1 and FR2 through measurement campaign.

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TRP TRS evolution and enhancements

- TRP TRS
  - Additional bands for FR1
  - Fully develop test procedures and performance requirements for CA TRP and TRS beyond 2CC for single Tx
  - Complete the test procedures and performance requirements for 2Tx scenarios

Additional bands for FR1

- Motivation
  - Only limited bands would be completed in R18 work item.
  - Performance requirements for more bands are required by operators.

- Objective
  - Consider bands outside those defined in R18 WID (RP-223112).
  - Also complete the performance requirements for bands not finished, if any, in Release 18 work item

CA TRP and TRS beyond 2CC for single Tx

- Motivation
  - Release 18 work item only completed OTA test procedures for DL 2CC CA.
  - The remaining work is UL 2CC CA test procedure and performance requirements for both UL and DL 2CC CA.
  - R19 should extend the test procedure and performance requirements beyond 2CC in both UL and DL

- Objective
  - Develop test procedures for 2CC UL CA.
  - Define performance requirements for 2CC UL and DL CA
  - Develop test procedures and associated performance requirements for UL and DL CA beyond 2CC

Complete test procedures and performance metrics for 2Tx

- Motivation
  - R18 work item did not complete the work for 2Tx scenarios, e.g. TxD and non-coherent UL MIMO.
  - R19 should address the left-over issues in 2Tx, e.g. phase drift between the two transmit antenna during TRP measurement.

- Objective
  - Develop test procedures and associated performance requirements for 2Tx scenarios.

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