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RP-233208

Views on Candidate RF & OTA Topics for Rel-19

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Contents

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BS RF evolution and enhancements

- OTA conformance testing enhancements
- Conformance test for expected EIRP mask
- BS specification improvement

OTA test enhancement

- Motivation
  - > Active Antenna System is widely deployed in NR. The OTA test is a must for type 1-O AAS BS. It has been found that the test time is prohibitive taking up to 3 times the time to perform the conformance testing compared to conducted conformance testing. Excessive OTA testing time has become a constraint for AAS product design, development and certification.
  - > In some cases it may be that the number of test cases could be reduced without impacting the coverage of the testing. OTA TRP testing is particularly time consuming for example; the TX IMD texting comprises of 96 test cases testing output power, ACLR and out of band emissions (all TRP requirements) by contrast the output power, ALCR and out of band emissions tests have only 8 test cases in total, 6 interfere offsets are tested for each (12 for NC operation), these offsets date back to the UTRA requirements and have been carried through for each subsequent RAT however not they are generating such excessive test time so it is appropriate to see if they are all still necessary or can be reduced.

Test requirements	Type	Num of test cases	Num of TCs (TS 37.145-2)
OTA base station output power	TRP	1	ATCR7
OTA ACLR	TRP	3	ANTCR2, ANTCR8,ANTCR7
OTA out-of-band emission	TRP	4	ATCR7, ANTCR7, ATCR2a, ANTCR2
OTA transmitter spurious emission	TRP	1	ANTCR7
OTA transmitter intermodulation	TRP	36	ANTCR2, ANTCR8, ANTCR7
	TRP	48	ATCR7, ANTCR7, ATCR2a, ANTCR2
	TRP	12	ANTCR7

  - > OTA blocking testing is also time consuming where the CW interfering signal is swept with a step size of 1 MHz. there could be potential methods to reduce the testing time for OTA test.

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OTA test enhancement

- Objective
  - > Study and specify the methods to reduce the testing time for TX intermodulation
    - Chose the worst case to reduce the number of test configurations
    - Chose the worst case to reduce the number of test points/offsets
    - The ACLR, OBUE, and spurious emission with the same configuration as TX intermodulation are not tested redundantly.
  - > Study and specify the methods to reduce the testing time for blocking
  - > [Enhancement on co-location test]

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Conformance test for expected EIRP mask

- Motivation
  - > It is expected WRC-23 will introduce the limits of expected EIRP for protection of satellite in 6425 – 7125 MHz. According to [1] and [2], the mask is defined as a vertical spatial mask which is expected equivalent isotropically radiated power (e.i.r.p.) emitted by an IMT base station as below. It requests RAN4 to perform the study on the conformance test and include it in BS RF core specification TS 38.104 and BS conformance specification TS 38.141-2.

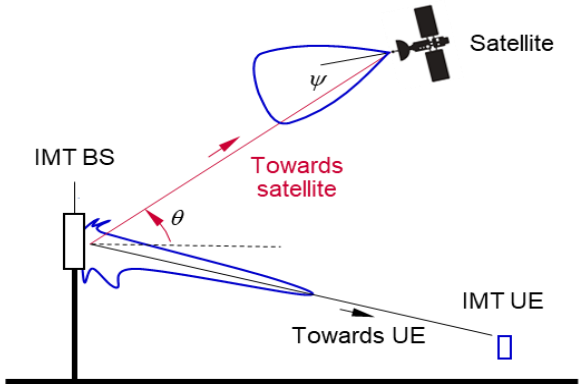
[Example 2]

2.1 the level of expected equivalent isotropically radiated power (e.i.r.p.) emitted by an IMT base station as a function of vertical angle above the horizon in the frequency band 6 425-7 025 MHz or part thereof shall not exceed the following values:

Vertical angle measurement window $\theta_L \le \theta < \theta_H$ (vertical angle θ above horizon)	**Expected e.i.r.p. (dBm/MHz) (NOTE 1)**
$0° \le \theta < 5°$	31.5
$5° \le \theta < 10°$	26.5
$10° \le \theta < 15°$	22.5
$15° \le \theta < 20°$	21.5
$20° \le \theta < 30°$	19.5
$30° \le \theta < 60°$	18.5
$60° \le \theta \le 90°$	18.5

NOTE 1: The expected e.i.r.p. is defined as the average value of the e.i.r.p., with the averaging being performed:

- over horizontal angles between −180° to +180°, and the IMT base station beamforming in a specific direction within its steering range,
- over different beamforming directions within the IMT base station steering range, and
- over the specified vertical angle measurement window $\theta_L \le \theta < \theta_H$.



[1] Document 5D/1496-E, "PROPOSAL OF TECHNICAL CONDITIONS UNDER WRC-23 AGENDA ITEM 1.2 (6 425-7 025 MHz) IN RELATION TO THE USE OF IMT BASE STATION E.I.R.P. MASK AS A FUNCTION OF ELEVATION ANGLE FOR THE PROTECTION OF FSS-UL", Telefon AB - LM Ericsson, Huawei Technologies Sweden AB, Nokia Corporation

[2] CPM Report to WRC-23, https://www.itu.int/dms_pub/itu-r/opb/act/R-ACT-CPM-2023-PDF-E.pdf

Conformance test for expected EIRP mask

- Objective
  - > Measurement system set-up
  - > Test method, expected EIRP test can be built based on current TRP test with some additions.
    - define the tested beam directions and the beam probability factors
    - the measured points at upper hemisphere
    - manufacturer declarations
  - > Measurement uncertainty

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BS specification improvement - Co-location and co-existence requirements optimization for network nodes

- Motivation
  - With introduction of a new operating band, both co-location and co-ex requirements need to be updated in multiple specifications (e.g. NR BS, MSR BS, IAB). This is done in order for the new band to be protected from the legacy bands, as well as for the legacy bands to be protected from the newly introduced operating band.
  - The main issue with the existing process is it requires ~ 10 CRs for each new operating band.
  - To improve this, it is proposed to shift all existing and new co-lo and co-ex requirements to a new dedicated TS.
  - With the above, new band co-lo and co-ex would be updated in just one TS (legacy specs would refer to dedicated TS).
- Objectives
  - Introduce new dedicated 37-series TS for RF co-location and co-existence requirements, covering the following:
    1. BS, IAB, and Repeaters requirements
    2. NR, E-UTRA requirements
    3. SRAT, and MSR requirements
    4. Core and Performance parts
    5. Conducted and OTA requirements
  - Optimize handling of core TX spur requirements for the following TS: NR BS, NR Repeaters, NCR, NR IAB, MSR, AAS, E-UTRA BS
  - Optimize handling of core TX spur co-ex for the following TS: NR BS, NR Repeaters, NCR, NR IAB, BS, AAS, E-UTRA BS
  - Optimize handling of core OOB blocking co-location for the following TS: MSR BS, AAS BS, E-UTRA BS

Further UE RF enhancements for FR1

- RF UL enhancements
  - MPR reduction and/or power boosting with relaxed requirements
  - MPR improvement with new PAPR reduction mechanism
  - Applicable ULFPTx modes reporting associated with changed power
- PC1.5 intra-band contiguous/non-contiguous CA and inter-band CA
- 6Rx for handheld UE

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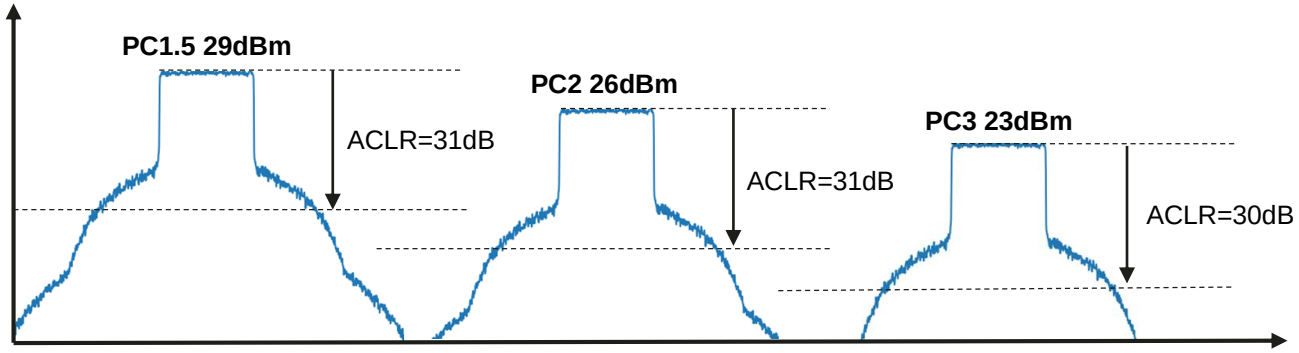
UE RF FR1– RF UL enhancement
MPR reduction and/or power boosting with relaxed requirements

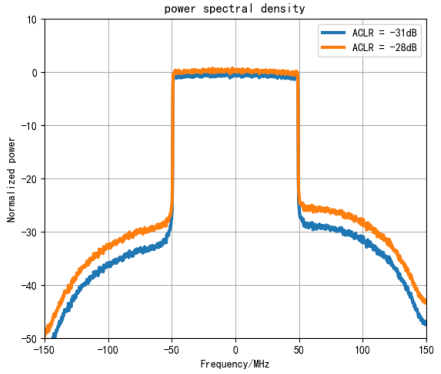
- **Motivation**
  - > UL performance is one of key enablers for 5G-advanced. One of the key evolution directions is to enhance the uplink coverages or performance for different transmission schemes including single carrier or UL CA aggregation, different modulations including QPSK, 16QAM, 64QAM, 256QAM, and different waveforms.
  - > 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 there is no other adjacent operator in the same band.
        - ✓ 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.
      - 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.

UE RF FR1– 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.
  - > To achieve ACLRs for PC2 and PC1.5, the stringent co-existence study is conducted (TR36.886 for PC2 on B41). The evaluation is based on the scenario where two operators have the spectral adjacent to each other in the relative larger ISD. For NR, the major band may be assigned to one operator, the ISD is smaller, and the bandwidth is much larger which lower the spectrum density of OOB interference to adjacent frequency block. Thus ACLR could be relaxed to some extent.
  - > **Condition #1:** To simplify the work in Rel-19, we would like mainly to consider the condition where there is no adjacent operator sharing the band. In such case, network can indicate UE to do power boosting. Whether to discuss the complicated scenario depends on the requests from operators.
  - > **Condition #2:** In the other scenario, the system RF bandwidth would be larger, e.g., 160MHz or 200MHz, and two CCs are configured. For a user, the RPBs which are located on the edge of a single CC but still in the region around the center of the whole spectrum are allocated. The network can schedule uplink transmissions and control the power for all the users, and thus negative impact of higher interference caused by relaxing ACLR and boosting power for part of users could be mitigated.
  - > In our view, ACLR could be relaxed under Condition #1 and #2 to boost uplink transmission power



ACLR requirements for different power classes



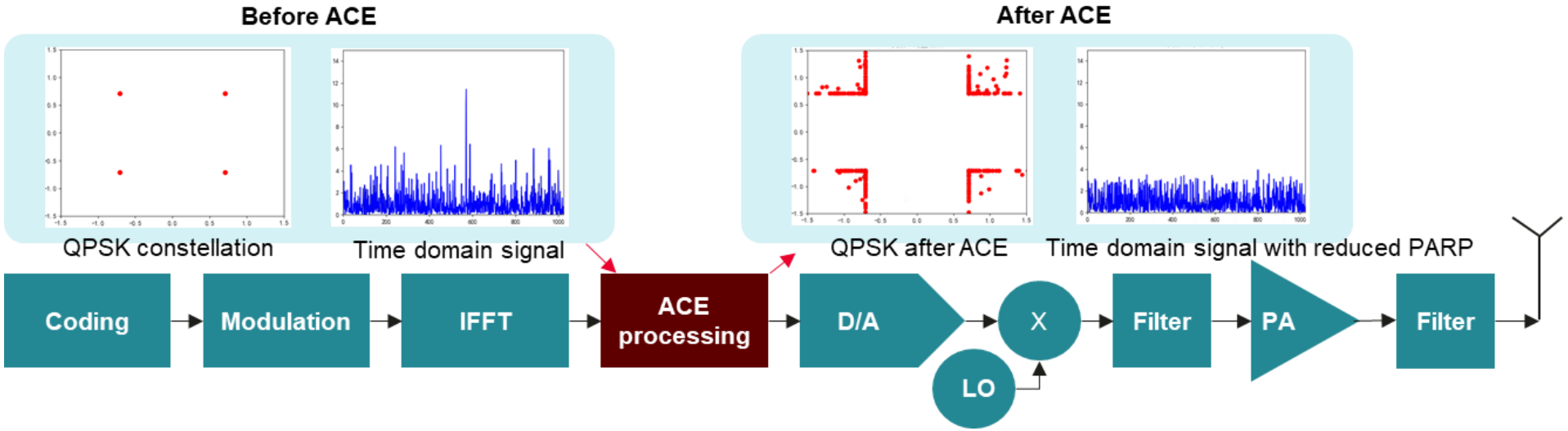
MOP can be increased by 0.8dB, if 2dB ACLR relaxation is allowed

UE RF FR1 – 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 other aspect below can be further improved for existing power classes considering the work in Rel-18 HPUE items and 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 each Tx supporting one CC of intra-band contiguous CA, and thus the MPR can be reduced or the power can be boosted because with higher possibility the inner region MPR can be applied.
      - There are some leftover issues from Rel-18 especially for outer region.
- **Objective**
  - > Specify the improved MPR requirement with new PAPR reduction mechanism for single CC case
    - 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.
  - > Specify the lower MPR requirements to allow using two Tx with each Tx supporting one CC for intra-band contiguous CA

UE RF FR1– RF UL enhancement
MPR improvement with new PAPR reduction mechanism (example)

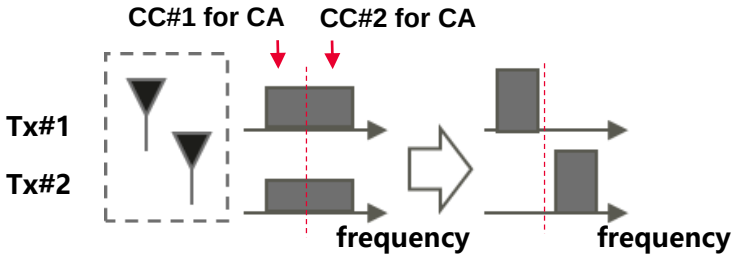
- **Active constellation extension (ACE)**_example PAPR reduction mechanism
  - > ACE is to conduct the power clipping with restriction that the distortion of modulation signal happens in the restricted region of constellation, i.e., allowing modulation symbol distortion only outside the corner regions 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.



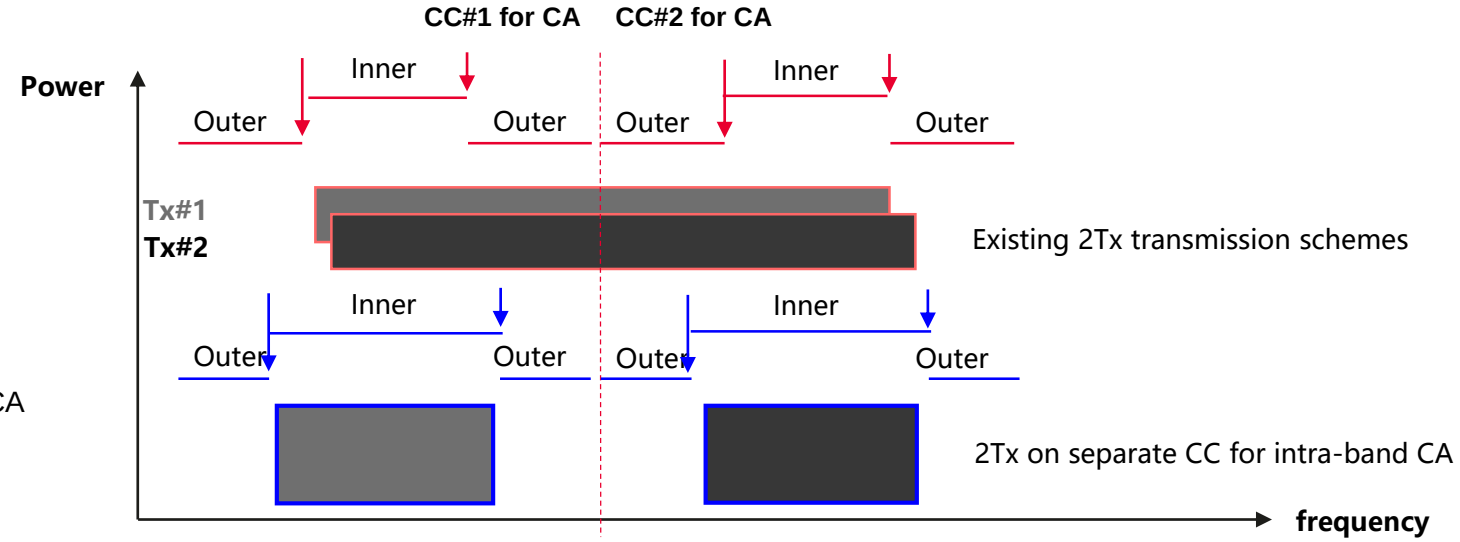
Larger than 1dB SNR gain is expected because of boosting power for PC2 and PC3

UE RF FR1– RF UL enhancement
MPR improvement with new PAPR reduction mechanism

- **MPR reduction by using two Tx for intra-band contiguous UL CA**
  - > 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 decreased for the smaller transmission bandwidth.
  - > Reduce MPR by using two Tx simultaneous transmissions with each Tx supporting one CC for intra-band contiguous CA.
    - Since each Tx transmit relatively smaller frequency block, those allocated PRBs could be in the inner region with more possibility.
    - Such scheme could also be used for the single CC case where the separate narrower PRBs are allocated for each Tx.



2Tx transmission on one CC or uplink intra-band contiguous CA



Benefit: Less power back-off (potential reduced MPR shown for one CC)

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

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UE RF FR1– 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

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UE RF FR1
PC1.5 intra-band contiguous/non-contiguous CA/inter-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 <u>general requirement</u>
  - > 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)

- 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 (PC2 TDD/FDD + PC2 TDD)

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UE RF FR1
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 (RAN4)
  - > 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

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Further UE RF enhancements for FR2

- RF UL enhancements
  - MPR reduction with relaxed EVM requirement
  - MPR reduction for intra-band UL CA

UE RF FR2
RF UL enhancement

- Motivation
  - Enabling UE side to transmit more power (with less power back-off) is also a way to enhance the UL coverage in mmWave, i.e., reduce MPR with relaxed EVM requirements for mmWave terminals. gNB side can optionally support non-linear receiver to match the nonlinearity of signals. Whether to allow UE to use relaxed EVM in exchanging larger output power is controlled by NW signaling. Specific NW perf requirements and test cases may not be necessary.
  - MPR for intra-band CA is quite large, which could be improved with further evaluation

- Objective
  - Specify the UE RF requirements of MPR reduction with conditionally relaxed EVM requirement
  - Study and specify improved MPR for intra-band CA

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UE RF FR2
RF UL enhancement (cont.)

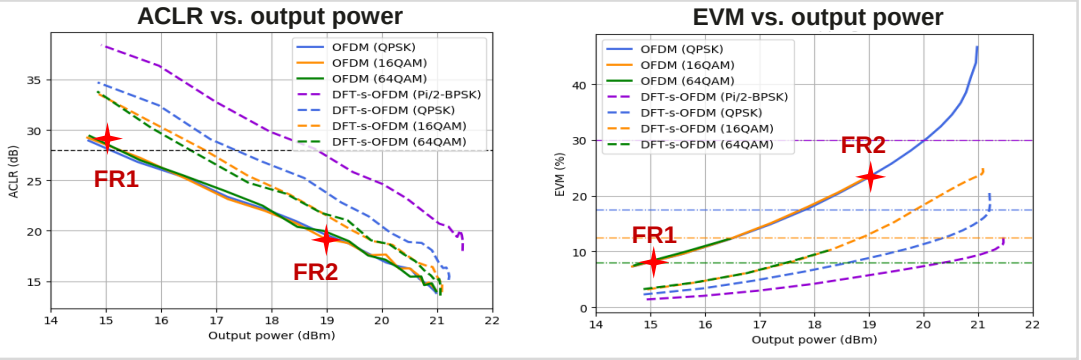
MPR of mmWave terminal reduces UL coverage

- **Motivation: UL coverage of mmWave is limited by large MPR of terminals**
  - UE SINR can be improved significantly by the high BS large antenna array
  - However, UL coverage is limited by PA/RF imperfect effects
  - Due to the PA nonlinearity, the large power back-off is expected for mmWave terminal

Max power reduction of mmWave terminals (38.101)

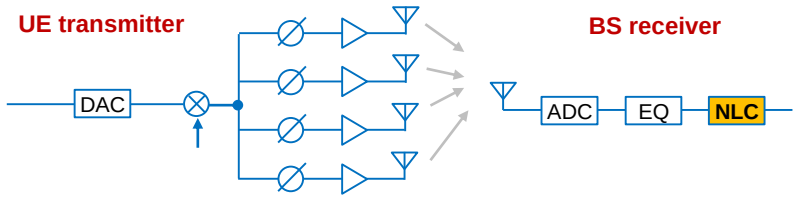
	pi/2-BPSK	QPSK	16QAM	64QAM	256QAM
DFTs	0dB	2dB	3.5dB	5.5dB	[8.5]dB
OFDM	-	4dB	5dB	7.5dB	[10.5]dB

- **For coexistence reason, the transmitted signal should meet ACLR requirements**
  - **For FR2**: Even ACLR requirement is met, the EVM is worse than requirement of QPSK



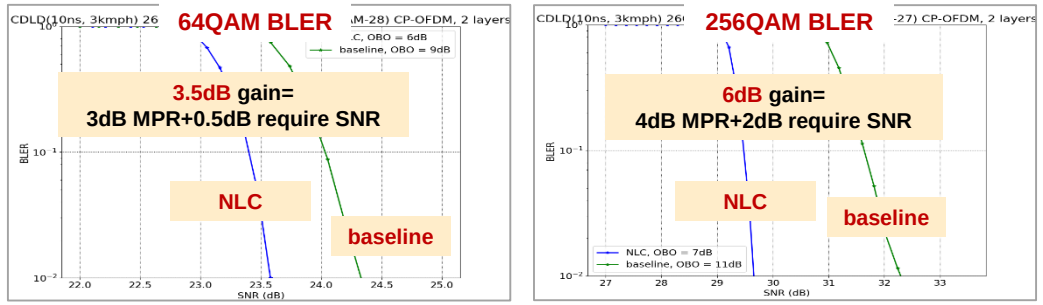
Uplink nonlinearity compensation to improve UL coverage

- **Uplink receiver nonlinearity compensation: Improve uplink coverage by reducing the MPR of terminals**



- **UE transmitter:** Relax the EVM requirement for large transmission power (small MPR)
- **BS receiver**: Perform receiver nonlinearity compensation to improve the EVM

- **Simulation: Performance gain=power gain (MPR reduction)+demodulation gain**



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
  - Use reverberation chamber method for FR2 tests

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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
  - Use reverberation chamber method for FR2 tests

- 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.
  - RC (Reverberation Chamber) method as a candidate for FR2 tests

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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

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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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Huawei proposals for Rel-19 RAN4 RF & OTA topics

BS RF

OTA test enhancement
- Improve the OTA test efficiency

Conformance test for expected EIRP mask
- Study the test methods for the new regulatory requirement

BS specification improvement
- Co-location and co-existence requirements optimization for network nodes

UE RF FR1

RF UL enhancements
- MPR reduction and/or power boosting with relaxed requirements
- MPR improvement with new PAPR reduction mechanism
- Applicable ULFPTx modes reporting associated with changed power

PC1.5 intra-band C/NC CA

6Rx for handheld UE

UE RF FR2

RF UL enhancements
- MPR reduction with relaxed requirements
- MPR improvement for intra-band CA

OTA enhancements

MIMO OTA enhancements
- Additional bands in FR1 and FR2
- Multiple TRP for FR1
- RC method as a candidate for FR2 tests

TRP/TRS enhancements
- Additional bands for FR1
- CA test for single Tx with >2CC
- Test procedures and performance metrics for 2Tx

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