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**Source:** T-Mobile USA, Inc., Qorvo

**Title:** MPR and NS\_04 A-MPR for 29 dBm

**Agenda item:** 9.1.2

**Document for:** Approval

1 Introduction

As part of the Work Item LTE\_NR\_B41\_Bn41\_PC29dBm for the 29 dBm Power Class, UL MIMO with two separate 26 dBm transmit chains is envisioned. Reverse intermodulation (R-IMD) between the two transmitters may cause an increase in emissions (ACLR, OOBE) or decrease in transmitted signal quality (EVM) compared to a single transmitter at the same power.

This contribution proposed values for a definition of MPR and NS\_04 A-MPR for 29 dBm PC1.5 UL-MIMO.

2 Discussion

2.1 Observations on Baseline UL-MIMO MPR Allowances

In WF [10], it was agreed to use the MPR proposals in [9] as a baseline for further study. The rationale presented in [9] used the existing Rel-15 UL-MIMO MPR definitions as a baseline, but accommodated the clarification that emissions were specified as the “sum of powers from each transmit antenna connector” instead of “at each antenna connector” by tightening the per-antenna specification by 3dB and estimating the additional power backoff required to meet these tighter limits.

The existing Rel-15 NR UL-MIMO MPR allowance is specified by reference to the NR single Tx MPR specification in section 6.2.2 of TS 38.101-1. As explained in [11], this was inherited from LTE UL-MIMO, and the original rationale was an assumption that a 2Tx UE would transmit at 3dB lower power per antenna, and thus could be assumed to produce 3dB lower unwanted emissions per antenna, which results in the same total unwanted emissions levels from the UE.

**Observation1: The original UL-MIMO MPR definition appears to assume that for each Tx chain, 3dB lower output power results in 3dB of lower emissions power, a 1:1 backoff ratio. This implies an assumption that a 2Tx UL-MIMO design would simply use two copies of the same Tx chain hardware (PA, etc.) used for 1Tx, for the same total power. (e.g. PC3 UL-MIMO would use two Tx chains identical to what is used for 1Tx PC3.)**

The reason for the LTE (and Rel-15 NR) language that emissions were specified “at each antenna connector” is unknown. By the reasoning in [11], since the UL-MIMO Power Class is specified as “the sum of the maximum output power at each UE antenna connector”, the emissions limits should also have been specified as the sum of the connectors. Specifying emission at “each” antenna while power is specified as “the sum” of the antennas is effectively a relaxation of emissions specifications relative to power, from the perspective of a single Tx chain. It would result in 3dB higher total emissions from a 2Tx UE compared to a 1Tx UE at the same total power. There is no obvious reason that would be a desirable outcome.

Since the basic reasoning behind the original LTE UL-MIMO MPR allowances would be sound if the output power and emission power had been specified using the same method (either “each”, or “sum of”), one strong possibility is that the language in the LTE spec was a drafting error. If so, the MPR relaxation proposed for NR UL-MIMO MPR in [9] is not justified by the arguments presented. The 3dB tightening of emissions limits per antenna connector was already accounted for in the original LTE UL-MIMO specification, by the fact that each antenna connector would transmit 3dB lower power.

**Observation2: If the “at each antenna connector” language in the original LTE UL-MIMO and Rel-15 NR UL-MIMO MPR specifications was an error, the relaxation of MPR proposed in [9] is not justified by fixing the language to what it should have been, “as the sum of powers from each antenna connector.”**

However, there is another reason why MPR for 2Tx might need to be reassessed: Reverse IMD due to antenna coupling.

The relaxation in MPR allowances proposed in [9] is 1.5 dB for most allocations. One exception is a 3 dB relaxation for Edge allocations, which are presumed to be driven by close-in baseband filter imperfections. The other exception is for 256QAM, which already has large MPR allowances driven by tight EVM requirements.

As shown in the following section, a 1.5dB relaxation of MPR may be a reasonable upper-bound allowance for the increase in emissions caused by 2Tx R-IMD in some cases, given the assumptions of 10dB of antenna isolation and aggressive PA biasing, for outer allocations. The 1.5 dB relaxation may be generous for inner allocations, which have significantly lower OOBE and ACLRs.

**Observation3: Despite possibly double-counting the relaxation needed for summing the antenna connector powers, the MPR relaxations proposed in [9] may still be reasonable projections for outer allocations, because 2Tx R-IMD is not accounted for in either the original UL-MIMO MPR definition or in [9].**

In addition, it is observed that the Tx chains for UEs supporting Power Class 1.5, with a nominal maximum power of 29 dBm, are likely to use the same commercially available hardware currently used for UEs supporting Power Class 2. The same hardware with the same biasing configuration would be expected to have the same emission and R-IMD behaviors, regardless of nominal power class. In this case, because only the nominal maximum power has increased by 3dB, the MPR and A-MPR allowances for PC1.5 2Tx could be estimated to be 3dB higher than the allowances for PC2 2Tx, reflecting the higher nominal maximum power, and allowing the same actual Tx power as PC2. This would represent an upper bound, representing no optimization for PC1.5.

But it is clearly possible to make changes in PA biasing schemes to allow higher output power at a given level of emissions per Tx chain, albeit at the potential cost of increased current consumption. Indeed, if the PC2 2Tx MPR allowances are taken as optimal, with no potential for tightening, then PC1.5 will not have higher transmit power than PC2 and there will be no benefit to the higher power class. Presumably, UE OEMs supporting PC1.5 will be doing so because there is a realizable performance benefit above PC2.

The assumption that the hardware and biasing are the same for PC1.5 UEs as for PC2 UEs would be extremely conservative, allowing no transmit power benefit for PC1.5.

**Observation4: An extremely conservative upper bound estimate for PC1.5 MPR and A-MPR allowances would be to add 3dB to the corresponding MPR and A-MPR values for PC2, which would allow no transmit power benefit for PC1.5.**

Finally, it is noted that [9] proposes UL-MIMO MPR values only for CP-OFDM waveforms, because precoded UL-MIMO is only applicable to CP-OFDM. But Transmit Diversity (TxD) has also been discussed, and is applicable to 2Tx architectures. The same rationale and methodology used in [9] could be applied to DFT-s-OFDM for TxD.

**Observations 5: The rationale and methodology used in [9] could also be applied to DFT-S-OFDM MPR allowances to estimate values for Transmit Diversity.**

2.1 Measurements for PC1.5 2Tx

**Approach**

New measurements were performed and analysed with an intention to supplement the data provide in [8] by adding several new aspects:

* Refined, conservative, PA biasing schemes
* Use of two separate data streams, to simulate precoded 2-port MIMO transmissions
* Measurements of presumed worst-case NS\_04 A-MPR and general NS\_01 MPR scenarios
* ½ CBW allocations

Using a lab bench setup similar to that used in [8], with two cross-coupled modules, measurements of OOBE, ACLR, and EVM were taken for various power levels. Two different PA biasing schemes were selected to be realistic for use in smartphones, incorporating the design goals of both reasonable performance and minimal current consumption.

Data was taken using 1Tx, using 2Tx with the same data stream on each transmitter (to simulate TxD), and using 2Tx with two different data streams on the two transmitters (to simulate precoded MIMO). Channel bandwidths of both 100MHz and 20MHz were used, and test points targeted at both general MPR and NS\_04 A-MPR emissions restrictions were measured.

Test Setup Details:

* Maximum power of 26dBm MPR0 at each phone antenna to test Power Class 1.5, so 29dBm MPR0 of composite ANT power: 1dB PCB loss between module output and phone antenna (so MPR0 27dBm at each module output).
* Equal back-off, on each Tx chain, in steps of 0.5 or 1.0 dB.
* ANT-ANT isolation: 10dB
* 20 MHz and 100 MHz channels, both using 30 kHz SCS.

Test measurement items

* General SEM
* EUTRA-ACLR
* EVM
* NS\_04 SEM

Selected worst case waveforms:

* 273RB/100MHz, RBstart 0, SCS 30KHz, QPSK, CP-OFDM : General SEM, ACLR, EVM
* 270RB/100MHz, RBstart 0, SCS 30KHz, QPSK, DFT-s-OFDM : General SEM, ACLR, EVM
* 273RB/100MHz, RBstart 0, SCS 30KHz, 256QAM, CP-OFDM : General SEM, ACLR, EVM
* 270RB/100MHz, RBstart 0, SCS 30KHz, 256QAM, DFT-s-OFDM : General SEM, SEM with NS\_04, EVM
* 135RB/100MHz, RBstart 0, SCS 30KHz, QPSK, CP-OFDM : General SEM, ACLR, EVM
* 135RB/100MHz, RBstart 0, SCS 30KHz, QPSK, DFT-s-OFDM : General SEM, ACLR, EVM
* 137RB/100MHz, RBstart 0, SCS 30KHz, QPSK, CP-OFDM : General SEM, ACLR, EVM
* 135RB/100MHz, RBstart 0, SCS 30KHz, QPSK, DFT-s-OFDM : General SEM, ACLR, EVM
* 135RB/100MHz, RBstart 138, SCS 30KHz, QPSK, CP-OFDM : General SEM, ACLR, EVM
* 135RB/100MHz, RBstart 135, SCS 30KHz, QPSK, DFT-s-OFDM : General SEM, ACLR, EVM
* 51RB/20MHz, RBstart 0, SCS 30KHz, QPSK, CP-OFDM : General SEM, ACLR, EVM, NS\_04
* 50RB/20MHz, RBstart 0, SCS 30KHz, QPSK, DFT-s-OFDM : General SEM, ACLR, EVM, NS\_04
* 25RB/20MHz, RBstart 0, SCS 30KHz, QPSK, CP-OFDM : General SEM, ACLR, EVM, NS\_04
* 25RB/20MHz, RBstart 0, SCS 30KHz, QPSK, DFT-s-OFDM : General SEM, ACLR, EVM, NS\_04
* 51RB/20MHz, RBstart 0, SCS 30KHz, 256QAM, CP-OFDM : General SEM, ACLR, EVM, NS\_04
* 50RB/20MHz, RBstart 0, SCS 30KHz, 256QAM, DFT-s-OFDM : General SEM, ACLR, EVM, NS\_04
* 25RB/20MHz, RBstart 0, SCS 30KHz, 256QAM, CP-OFDM : General SEM, ACLR, EVM, NS\_04
* 25RB/20MHz, RBstart 0, SCS 30KHz, 256QAM, DFT-s-OFDM : General SEM, ACLR, EVM, NS\_04

Test frequencies:

* 100MHz @ 2546MHz (low channel: ACLR, SEM are invalid on low side)
* 100MHz @ 2593MHz (mid channel: ACLR, SEM are invalid)
* 100MHz @ 2640MHz (high channel: ACLR, SEM are invalid on high side)
* 20MHz @ 2506MHz (low channel: ACLR, SEM are invalid on low side, NS\_04 valid)

**Results**

The measurements show that the difference between the emissions powers from using the same data stream, and the emission power using different data streams is small, <= 0.5 dB in most cases. These correspond to the differences between TxD and UL-MIMO.

**Observation 6: The difference between emission from TxD and UL-MIMO are small, generally <= 0.5 dB.**

For each set of test points and measurements, a set of metrics were derived.

* Backoff ratio: Observed responsiveness of the measurement to power backoff
* 2Tx increase: Observed delta between 2Tx values of the metrics and 1Tx values, for same test points.
* Addition backoff for Same margin: The product of “Backoff Ratio” and “2Tx increase”. This is the additional backoff required to bring the 2Tx measurement back to the observed 1Tx value.
* DFT Margin @MPR0: Approximate margin for 2Tx DFT measurements at 29 dBm composite power
* CP Margin @MPR2: Approximate margin for 2Tx CP measurements at 27 dBm composite power
* DFT Indicated MPR: Total backoff allowance required, allowing for margin, relative to 29 dBm composite power, based on these measurements for DFT 2Tx transmissions.
* CP Indicated MPR: Total backoff allowance required, allowing for margin, relative to 29 dBm composite power, based on these measurements for CP 2Tx transmissions.
* R4-2008046 PC2 CP MPR + 3dB: Backoff allowance for PC1.5, based on PC2 values from R4-2008046. Represents upper bound for PC1.5 MPR.

These derived metrics are shown in the table below:



Derived Summary Metrics for Test Point Sets

It can be observed in the table above that for most test points, the margins are quite large, even with existing PC2 MPR. The exceptions are for full (“outer”) allocations at large offsets from the channel which have only small margins with PC2 MPR, and for NS\_04 specific restrictions, which in some cases have negative margins. In the interest of completion of the Rel-16 specification, it is proposed that MPR for PC1.5 for outer allocations be based on PC2 values from [9] plus 3dB.

**Proposal 1: That CP-OFDM MPR for PC1.5 for outer and edge allocations be based on PC2 values from [9] plus 1.5dB, and that DFT-S-OFDM MPR for PC1.5 for outer and edge allocations be projected using the same methodology.**

On the other hand, margins on measurements of OOBE and ACLR from test points for “inner” allocation remain large. The explanation for this is that the “inner” designation was designed so that regrowth and IM3s from these allocations are contained within the channel.

EVM could conceivably drive a need for increased MPR for inner allocations, but there are several arguments against that. First, EVM from the two Tx chains does not sum linearly like power values do, so 2 Tx chains do not make EVM twice as bad. As discussed in the previous section, the MPR proposals from [9] can be considered to already have relaxations for R-IMD, which may cover any need due to EVM. There are also serious questions about how EVM may be measured in a way that accounts for real antenna coupling (radiated EVM tests?), and EVM does not have regulatory impacts. Finally, measurements show that EVM is not sensitive to power backoff in any case, so increased MPR allowances appear to be a poor tool for addressing any EVM issues there may be. For all these reasons, it is proposed that MPR allowances for PC1.5 inner allocations for PC1.5 be taken directly from [9] without further additions.

**Observation 7: Inner allocations appear to have large margins against OOBE and ACLR specification with low MPR, and MPR increases do not appear to be an effective tool for potential EVM issues.**

**Proposal 2: That CP-OFDM MPR for PC1.5 for inner allocations be based on PC2 values from [9] without further additions, and that DFT-S-OFDM MPR for PC1.5 for inner allocations be based on the methodology from [9] with no further additions.**

**Proposal 3: That NS\_04 A-MPR values for PC1.5 be based on corresponding PC2 A-MPR values, plus 1.5 dB.**

**Proposed MPR and A-MPR values**

Table 6.2.2-2a Maximum power reduction (MPR) for power class 1.5

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Modulation | | MPR (dB) | | |
| Edge RB allocations | Outer RB allocations | Inner RB allocations |
| DFT-s-OFDM | Pi/2 BPSK | ≤ 6.5 | ≤ 3.5 | ≤ 1.5 |
| QPSK | ≤ 6.5 | ≤ 4 | ≤ 1.5 |
| 16 QAM | ≤ 6.5 | ≤ 5 | ≤ 2.5 |
| 64 QAM | ≤ 6.5 | ≤ 5.5 | ≤ 4 |
| 256 QAM | ≤ 7.5 | ≤ 7.5 | ≤ 7.5 |
| CP-OFDM | QPSK | ≤ 6.5 | ≤ 6 | ≤ 3 |
| 16 QAM | ≤ 6.5 | ≤ 6 | ≤ 3.5 |
| 64 QAM | ≤ 6.5 | ≤ 6.5 | ≤ 5 |
| 256 QAM | ≤ 9.5 | ≤ 9.5 | ≤ 9.5 |

Table 6.2D.2-x Maximum power reduction (MPR) for power class 1.5 for UL MIMO

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Modulation | | MPR (dB) | | | |
| Edge RB allocations | Outer RB allocations | | Inner RB allocations |
| CP-OFDM | QPSK | ≤ 6.5 | ≤ 6 | | ≤ 3 |
| 16 QAM | ≤ 6.5 | ≤ 6 | | ≤ 3.5 |
| 64 QAM | ≤ 6.5 | ≤ 6.5 | ≤ 5 | |
| 256 QAM | ≤ 9.5 | ≤ 9.5 | ≤ 9.5 | |

Table 6.2.3.2-2: A-MPR' values

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Modulation/Waveform | | A-MPR' (dB) | | | | | |
| PC3\_A1 | PC3\_A2 | PC2\_A3 | PC2\_A4 | PC1.5\_A51 | PC1.5\_A61 |
| DFT-s-OFDM | Pi/2-BPSK | ≤ 3.5 | ≤ 3.5 | ≤ 3.5 | ≤ 5.5 | ≤ 5 | ≤ 7 |
| QPSK | ≤ 4 | ≤ 4 | ≤ 4.5 | ≤ 6 | ≤ 6 | ≤ 7.5 |
| 16 QAM | ≤ 4 | ≤ 4 | ≤ 5 | ≤ 6 | ≤ 6.5 | ≤ 7.5 |
| 64 QAM | ≤ 4 | ≤ 4.5 | ≤ 5 | ≤ 6.5 | ≤ 6.5 | ≤ 8 |
| 256 QAM | ≤ 4.5 | ≤ 6 | ≤ 6.5 | ≤ 8 | ≤ 8 | ≤ 9.5 |
| CP-OFDM | QPSK | ≤ 5.5 | ≤ 5.5 | ≤ 6.5 | ≤ 7.5 | ≤ 8 | ≤ 9 |
| 16 QAM | ≤ 5.5 | ≤ 5.5 | ≤ 6.5 | ≤ 7.5 | ≤ 8 | ≤ 9 |
| 64 QAM | ≤ 5.5 | ≤ 5.5 | ≤ 6.5 | ≤ 7.5 | ≤ 8 | ≤ 9 |
| 256 QAM | ≤ 6.5 | ≤ 8 | ≤ 7.5 | ≤ 10 | ≤ 9 | ≤ 11.5 |
| NOTE 1: PC1.5 assumes dual Tx. | | | | | | | |

3 Conclusions

**Observation1: The original UL-MIMO MPR definition appears to assume that for each Tx chain, 3dB lower output power results in 3dB of lower emissions power, a 1:1 backoff ratio. This implies an assumption that a 2Tx UL-MIMO design would simply use two copies of the same Tx chain hardware (PA, etc.) used for 1Tx, for the same total power. (e.g. PC3 UL-MIMO would use two Tx chains identical to what is used for 1Tx PC3.)**

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**Observation3: Despite possibly double-counting the relaxation needed for summing the antenna connector powers, the MPR relaxations proposed in [9] may still be reasonable projections for outer allocations, because 2Tx R-IMD is not accounted for in either the original UL-MIMO MPR definition or in [9].**

**Observation4: An extremely conservative upper bound estimate for PC1.5 MPR and A-MPR allowances would be to add 3dB to the corresponding MPR and A-MPR values for PC2, which would allow no transmit power benefit for PC1.5.**

**Observations 5: The rationale and methodology used in [9] could also be applied to DFT-S-OFDM MPR allowances to estimate values for Transmit Diversity.**

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**Proposal 3: That NS\_04 A-MPR values for PC1.5 be based on corresponding PC2 A-MPR values, plus 1.5 dB.**

4 References

1. R4-2002913, “Way Forward on A-MPR for PC1.5 intra-band EN-DC,” Sprint, Qorvo, Intel, [Skyworks], [Qualcomm], [Apple], RAN4#94-e
2. R4-1804270, “DC\_(n)41X PC2&3 and 1&2TX Measurements,” Skyworks Solutions Inc.
3. R4-1807833, “Measurements for Band 41/n41 EN-DC A-MPR,” Sprint Corporation
4. R4-2001547, “[29 dBm] EVM Impact of Reverse IMD3 on UL MIMO Modulation Order Capability”, Skyworks Solutions, Inc., RAN4#94-e
5. R4-2005190 “Way Forward on MPR for PC1.5 UL MIMO and Tx div”, T-Mobile USA
6. R4-2008902 “WF on UL MIMO MPR/A-MPR for 29 dBm”, T-Mobile USA, RAN4#95-e
7. R4-2008204 “MPR and NS\_04 A-MPR for 29 dBm”, T-Mobile USA, RAN4#95-e
8. R4-2004466 “Measurements for 29 dBm UL-MIMO MPR”, T-Mobile USA, RAN4#94bis-e
9. R4-2008046 “UL MIMO open items from WF and LS”, Qualcomm Incorporated, RAN4#95-e
10. R4-2008408 “WF on Power Class related UL MIMO and other requirements”, Vivo, RAN4#95-e
11. R4-2000795 “On the condition of antenna configuration for UL-MIMO in FR1”, SoftBank Corp., RAN4#94-e
12. R4-2009943 “PC1.5 UL MIMO MPR”, Apple Inc., RAN4#96-e