**3GPP TSG-RAN WG4 Meeting # 100eR4-2114753**

**Electronic Meeting, Aug. 16-27, 2021**

**Source:** Skyworks Solutions, Inc. […..]

**Title:** WF on TxD MPR values

**Agenda Item:** 9.7.2.2 MPR requirements [NR\_RF\_TxD]

**Document for:** Approval

# GTW agreements on 2TX MPR and A-MPR

## MPR table for PC2 2Tx

Agreement: Provide MPR tables in this meeting for further review. Skyworks will provide the draft way forward.

This is the main technical aspect of this way FW which looks at the different power class and their implementations and maps the associated MPR values and discusses the signaling aspect to map the applicable requirements for the different implementation cases.

## A-MPR for 2Tx TxD and UL MIMO

Agreement:

* For PC3, there is no additional work for A-MPR
* For PC2,
	+ UL MIMO AMPR needs to be studied for TxD UE.

Ran4 can study first in this WI and then what is not finished, in UL MIMO bands WI.

Note: the reason why there is no A-MPR work for 2Tx PC3 is because there is consensus that it shares the same MPR than 1Tx PC3 => PC3 UEs declaring TxD or UL MIMO support should support 1TX PC3 MPR.

## MPR for TxD and UL MIMO

Agreement in GTW: **MPR applicability for 2-layer UL MIMO and ULFPTx**

* 1 and 2-layer UL MIMO share the MPR

No agreement was reached on which cases and implementations, TxD and UL MIMO could share the same MPR table. In the way forward, we will highlight which cases should have same MPR values for TxD or UL MIMO and how to discriminate them from signaling point of view and where signaling might be lacking.

# Background

## 2Tx PC2 MPR for two PC3 PA architecture

2Tx one port PC2 MPR requirement has been lacking since R15 for implementations using two PC3 PAs using transparent Tx Diversity (TxD).

Two aspects needed to be evaluated to compare with PC2 1Tx MPR:

* Evaluation of additional MPR due to Reverse IMD contribution due to PA coupling
* Evaluation of additional MPR due to lower linearity of PC3 PAs (30dB ACLR) compared to PC2 PA (31dB ACLR)

Results provided in [1] that form the basis of the MPR table proposal are based on measurements of two coupled PAs with the following assumptions:

* PA calibration: each PC3 PAs are calibrated for 30dB ACLR 1dB MPR for 20MHz QPSK DFT-s-OFDM 100RB0 waveform
* Post PA losses of 4dB
* Antenna Isolation of 10dB

Measurements include:

* QPSK CP-OFDM and DFT-s-OFDM waveforms for 5/20/50MHz with 15kHz SCS
* 600ns delay SD-CDD waveforms for TxD evaluation
* 90deg phase shifted waveform for 1layer UL MIMO
* Uncorrelated waveforms for 2 layer UL MIMO

When compared to 1Tx PC2 PA measurements in the same conditions, the following additional back-off are identified:

* Edge allocations can reuse 1Tx PC2 MPR as they are limited by the spectrum shape in relation to BB filtering (WOLA) and are not dominated by PA non-linearity
* Outer allocations need 1dB additional back-off compared to corresponding 1Tx PC2 MPR
* Inner allocation need 1dB additional back-off compared to corresponding 1Tx PC2 MPR

To meet emissions for higher order modulations, with higher back-off already available, the additional back-off can be reduced until limitation comes from tight EVM budget. For that same reason, CP-OFDM already having higher MPR can have slightly lower additional MPR. Then everything is within the 0.5dB granularity.

Beyond this additional MPR needed to meet emissions, additional back-off is also needed for high order modulations cases to compensate for the additional contribution of RIMD and 1dB lower ACLR linearity. Earlier contributions [4] estimated that 256 QAM DFT-s waveforms need 1 dB more MPR and CP-OFDM 2 dB more MPR for Tx diversity UEs. To be consistent, we also suggest that 0.5dB is added for DFT 64QAM and 1dB for CP.

## 2Tx MPR for other power classes and PA architectures

There are other cases of 2Tx TxD and UL MIMO requirements for different power classes and PA arrangements. Some of these can already point at existing MPR:

* 2Tx PC3 TxD or UL MIMO based on two PC3 PAs can reuse PC3 1Tx MPR table thanks to the 3dB margin on each PA and full power capability for transmissions modes on a single antenna
* 2Tx PC2 UL MIMO based on two PC2 PAs can reuse PC2 1Tx MPR table thanks to the 3dB margin on each PA and full power capability for transmissions modes on a single antenna
	+ As a better alternative since it is based on the same PA architecture this could be derived from PC1.5 MPR table MPR values -3dB with a ceiling at 0dB
	+ The two above statement are confirmed by data taken for PC1.5 in [2] and previous PC1.5 evaluations by multiple companies
* 2Tx PC1.5 MPR table is already available and is intrinsically based on TxD or UL MIMO with 2 PC2 PAs. This MPR values are re-discussed for optimization in release 17

One feasible 2Tx PC2 UL MIMO architecture is based on one PC2 PA used for single antenna transmissions and an additional PC3 PA for two antenna transmissions. In this case one of the two PA has intrinsically 3dB margin. Since Emissions are based on the sum of emissions it is quite possible that 1Tx PC2 MPR is applicable to meet emissions. However for EVM, one side will suffer from lower back-off and reverse IMD. Further investigation might be needed to crosscheck the above.

## 1Tx PC2 MPR reference

Measurements in [1,2] have been taken together with 1Tx PC2 measurements in the same setup and PA to fully evaluate the delta back-off linked to RIMD and 1dB lower ACLR linearity. Since it is the reference, the 1Tx PC2 MPR is copied here for easy comparison.

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

|  |  |
| --- | --- |
| Modulation | MPR (dB) |
|  | Edge RB allocations | Outer RB allocations | Inner RB allocations |
| DFT-s-OFDM | Pi/2 BPSK | ≤ 3.5 | ≤ 0.5 | 0 |
|  | QPSK | ≤ 3.5 | ≤ 1 | 0 |
|  | 16 QAM | ≤ 3.5 | ≤ 2 | ≤ 1 |
|  | 64 QAM | ≤ 3.5 | ≤ 2.5 |
|  | 256 QAM | ≤ 4.5 |
| CP-OFDM | QPSK | ≤ 3.5 | ≤ 3 | ≤ 1.5 |
|  | 16 QAM | ≤ 3.5 | ≤ 3 | ≤ 2 |
|  | 64 QAM | ≤ 3.5 |
|  | 256 QAM | ≤ 6.5 |

**Note: this table will need to clarify it is valid for 1Tx; and 2Tx UL MIMO with 2 PC2 PA can point at this table**

# Way Forward

## MPR for 2Tx PC3 operation

The GTW agreement that A-MPR studies are not needed for PC3 2Tx modes is based on the assumption that 2Tx operation for TxD or UL MIMO can reuse the 1Tx PC3 MPR.

Way Forward:

* UE declaring PC3 and TxD or UL MIMO with or without ***ULFPTx*** support shall meet 1Tx PC3 MPR table
* 2TX TxD or UL MIMO PC3 single CC operation specification can point to 1Tx MPR **Table 6.2.2-1 in 38.1010-1**

## MPR for 2Tx PC2 based on two PC3 PAs.

Based on the results discussed in the background chapter, the following table is proposed to cover 2Tx transmissions based on two PC3 PAs for both TxD and UL MIMO.

Way forward on 2Tx PC2 MPR for UEs implementing two PC3 PAs and declaring TxD support.

Table xxxxx Maximum power reduction (MPR) for 2Tx power class 2 (2xPC3 PAs)

|  |  |
| --- | --- |
| Modulation | MPR (dB) |
|  | Edge RB allocations | Outer RB allocations | Inner RB allocations |
| DFT-s-OFDM | Pi/2 BPSK | ≤ 3.5 | ≤ [1] | ≤ [0] |
|  | QPSK | ≤ 3.5 | ≤ [2] | ≤ [0.5] |
|  | 16 QAM | ≤ 3.5 | ≤ [2.5] | ≤ [1.5] |
|  | 64 QAM | ≤ 3.5 | ≤ [3] |
|  | 256 QAM | ≤ [5.5] |
| CP-OFDM | QPSK | ≤ 3.5 | ≤ [3.5] | ≤ [2] |
|  | 16 QAM | ≤ 3.5 | ≤ [3.5] | ≤ [2.5] |
|  | 64 QAM | ≤ [4.5] |
|  | 256 QAM | ≤ [8.5] |

## MPR for 2Tx PC2 ULFPTx MIMO based on one PC2 and one PC3 PAs.

This architecture is the baseline assumption behind UL MIMO full Tx power capability where the single port full Tx power is supported by the PC2 PA and thus TxD is not supported.

In this case, one PA has effectively 3dB margin but not the other. For emissions since the ACLR and SEM is based on the sums of each connector, for equal power and equal back-off, one side will have margin to SEM and ACLR versus the other which will compensate. For this reason, it is likely that such architecture can meet the 1Tx PC2 MPR given a 3dB margin one side only has to compensate for the small MPR delta between PC2 1Tx and 2Tx MPR. Given that EVM is also related to the combination of the two sides, such compensation should also exist.

Tentative way forward:

* Further study if such architecture can reuse 1Tx PC2 MPR
* FFS signalling to differentiate from two PC2 PAs implementation

## MPR for 2Tx PC2 ULFPTx MIMO based on two PC2 PAs.

Similarly to the PC3 case with two PC3 PAs, the PC2 case with two PC2 PAs could re-use the 1Tx PC2 MPR table. However, there is another alternative that is more fit to the purpose since it is based on the same PA architecture: Derive from PC1.5 MPR table since the only difference is the 3dB higher power class reference. Which means that 2Tx PC2 MPR with 2 PC2 PAs equal Max[0dB, R17 PC1.5 1Tx MPR -3dB]. Using this equation, the agreement can be independent of the on-going optimization effort for PC1.5. Still to provide some numbers to look at we show the Table below where when current R16 PC1.5 MPR-3dB is still worse than PC2 1Tx MPR, the latter is used (i.e. we use Max[0dB, Min[R16 PC1.5 2Tx MPR -3dB, R16 PC2 1Tx MPR]]).

Table xxxxx Maximum power reduction (MPR) for 2Tx power class 2 (2xPC2 PAs)

|  |  |
| --- | --- |
| Modulation | MPR (dB) |
|  | Edge RB allocations | Outer RB allocations | Inner RB allocations |
| DFT-s-OFDM | Pi/2 BPSK | ≤ 3.5 | ≤ 0.5 | 0 |
|  | QPSK | ≤ 3.5 | ≤ 1 | 0 |
|  | 16 QAM | ≤ 3.5 | ≤ 2 | 0 |
|  | 64 QAM | ≤ 3.5 | ≤ 2.5 | ≤1 |
|  | 256 QAM | ≤ 4.5 |
| CP-OFDM | QPSK | ≤ 3.5 | ≤ 3 | 0 |
|  | 16 QAM | ≤ 3.5 | ≤ 3 | ≤ 0.5 |
|  | 64 QAM | ≤ 3.5 | ≤2 |
|  | 256 QAM | ≤ 6.5 |

However, based on current signaling there is no possibility to differentiate this case from the one PC2 PA + one PC3 PA case

Tentative way forward:

* PC2 MPR = Max[0dB, Min[PC1.5 2Tx MPR-3dB, PC2 1Tx MPR]]
* FFS signalling to differentiate from one PC2 + one PC3 PA implementation

## PC2 Signalling aspects

The PC2 architecture based on two PC2 PAs would signal PC2 UL MIMO with *ULFPTx* but not TxD. But cannot be differentiated from the case with one PC2 PA + one PC3 PA with the same signaling, additional signalling main be needed to differentiate these two cases. For example declaring *ULFPTx* with two bits instead of one which may also allow covering PC2 with two PC3 PAs and TxD.This may possibly also enable to differentiate SRS antenna switching output power capability.

Based on current signaling here are the possibilities that does not allow optimum MPR for PC2 with two PC2 PAs

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| *PC* | *TxD* | *UL MIMO* | *ULFPTx possible?* | implementation | MPR table |
| 2 | yes | yes | Yes with TxD | Two PC3 PAs | 2Tx PC2 MPR |
| 2 | No | yes | Yes with PC2 PA | One PC3 PA + one PC2 PA or two PC2 PAs | 1Tx PC2 MPR TBC1Tx PC2 MPR |

With 2 bits for ULFPTx

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| *PC* | *TxD* | *UL MIMO* | *Code /ULFPTx possible?* | implementation | MPR table |
| 2 | yes | yes | 00 / yes with TxD | Two PC3 PAs | 2Tx PC2 MPR |
| 2 | No | yes | 10 / yes | One PC3 PA + one PC2 PA  | 1Tx PC2 MPR TBC |
| 2 | No | yes | 11 / yes | or two PC2 PAs | Max[0dB,PC1.5 MPR-3dB] |

Note:

* PA capabilities are examples based on agreed 3GPP PA calibration point but other architecture are not precluded as long as the behaviour and requirements are met.
* Compared to current specification, only 2Tx PC2 MPR table is added
* For PC3 there is no ambiguity for ULFPTx then 1 PC3 PA is used or if TxD is used it can only support ULFPTx for two layers
* For PC1.5, support of TxD is de facto because it is the only way to reach the power class level for single port transmission. ULFPTx MIMO can only work for two layer MIMO

Tentative way forward:

* Study two bit ULFPTx signaling or other means to differentiate PC2 ULFPTx MIMO MPR requirement between two PC2 PA and one PC2 + one PC3 implementations

# References

[1] RP-211597 New WID on UE RF requirements for Transparent Tx Diversity (TxD) for NR, Nokia, Qualcomm, RAN#92e

[2] R4-2114545 PC2 TxD MPR evaluation and SD-CDD waveform choice, Skyworks Solutions Inc., RAN4#100e

[3] R4-2114556 PC1.5 MPR evaluation for FWA, Skyworks Solutions Inc., RAN4#100e

[4] R4-2108794, MPR for 2tx devices, Qualcomm Incorporated, RAN4#99e