|  |
| --- |
| 3GPP TR 38.837 V0.3.0 (2022-01) |
| Technical Report |
| 3rd Generation Partnership Project;Technical Specification Group TSG RAN;NR;UE RF requirements for Transparent Tx Diversity (TxD); (Release 17) |
|   |
| *5G-logo_175px* | 3GPP-logo_web |
|  |
| The present document has been developed within the 3rd Generation Partnership Project (3GPP TM) and may be further elaborated for the purposes of 3GPP.The present document has not been subject to any approval process by the 3GPPOrganizational Partners and shall not be implemented.This Specification is provided for future development work within 3GPPonly. The Organizational Partners accept no liability for any use of this Specification.Specifications and Reports for implementation of the 3GPP TM system should be obtained via the 3GPP Organizational Partners' Publications Offices. |

|  |
| --- |
|  |
| ***3GPP***Postal address3GPP support office address650 Route des Lucioles - Sophia AntipolisValbonne - FRANCETel.: +33 4 92 94 42 00 Fax: +33 4 93 65 47 16Internethttp://www.3gpp.org |
| ***Copyright Notification***No part may be reproduced except as authorized by written permission.The copyright and the foregoing restriction extend to reproduction in all media.© 2022, 3GPP Organizational Partners (ARIB, ATIS, CCSA, ETSI, TSDSI, TTA, TTC).All rights reserved.UMTS™ is a Trade Mark of ETSI registered for the benefit of its members3GPP™ is a Trade Mark of ETSI registered for the benefit of its Members and of the 3GPP Organizational PartnersLTE™ is a Trade Mark of ETSI registered for the benefit of its Members and of the 3GPP Organizational PartnersGSM® and the GSM logo are registered and owned by the GSM Association |

Contents

Foreword 5

1 Scope 6

2 References 6

3 Definitions of terms, symbols and abbreviations 6

3.1 Terms 6

3.2 Symbols 6

3.3 Abbreviations 7

4 TxD Basic Requirements 7

4.1 Antenna number and declaration 7

4.1.1 Agreements 7

4.1.2 Study process 7

4.2 Summation for Power and Emission 8

4.2.1 Agreements 8

4.2.2 Study process 8

4.3 Transmit modulation quality 8

4.3.1 Error Vector Magnitude 8

4.3.1.1 Agreements 8

4.3.1.2 Study process 9

4.3.2 Spectrum flatness 10

4.3.2.1 Agreements 10

4.3.2.2 Study process 10

4.4 Maximum output power reduction 10

4.4.1 General 10

4.4.1.1 Agreements 10

4.4.1.2 Study process 10

4.5 Additional Maximum output power reduction 12

4.5.1 Agreements 12

4.5.2 Study process 12

4.6 Adjacent channel leakage ratio 13

4.6.1 Agreements 13

4.6.2 Study process 13

5 Other related requirements 13

5.1 Power Class clarification 14

5.1.1 SA 14

5.1.1.1 Agreements 14

5.1.1.2 Study process 14

5.1.2 EN-DC 15

5.1.2.1 Agreements 15

5.1.2.2 Study process 15

5.2 SRS antenna switching 17

5.2.1 Agreements 17

5.2.2 Study process 17

5.3 Uplink Full power transmission (ULFPTx) for UL MIMO 18

5.3.1 Agreements 18

5.3.2 Study process 18

5.3.3 RF Architecture Review for UE with Rel-16 ULFPTx Feature 19

5.3.3.1 ULFPTx Mode 1 (*ul-FullPowerTransmission-r16 = ’fullpowerMode1’*): 19

5.3.3.2 ULFPTx Mode 2 (*ul-FullPowerTransmission-r16 = ’fullpowerMode2’*): 19

5.3.3.3 ULFPTx Mode 0 (*ul-FullPowerTransmission-r16 = ’fullpower’*): 20

6 Applicability and verification 20

6.1 Capability signalling 21

6.1.1 Agreements 21

6.1.2 Study process 21

6.2 Applicable release 23

6.2.1 Agreements 23

6.2.2 Study process 23

6.3 Testing related 25

6.3.1 UE Behaviour under Conformance Testing 25

6.3.1.1 Agreements 25

6.3.1.2 Study process 25

6.3.2 Power Splitting Behaviour 26

6.3.2.1 Agreements 26

6.3.2.2 Study process 26

Annex A: Agreements and Contributions Before RAN#92 27

A.1 Agreements 27

A.1.1 Before RAN4#94-e-bis 27

A.1.2 RAN4#94-e-bis 29

A.1.3 RAN4#95-e 31

A.1.4 RAN#88-e 34

A.1.5 RAN4#96-e 34

A.1.6 RAN4#97-e 36

A.1.7 RAN4#98-e 37

A.1.8 RAN4#98-e-bis 39

A.1.9 RAN4#99e 42

A.2 Key Contributions 45

A.2.1 Before RAN4#94-e-bis 45

A.2.2 RAN4#94-e-Bis 45

A.2.3 RAN4#95-e 45

A.2.4 RAN#88-e 46

A.2.5 RAN4#96-e 46

A.2.6 RAN4#97-e 46

A.2.7 RAN4#98-e 46

A.2.8 RAN4#98-e-bis 46

A.2.9 RAN4#99e 47

Annex <X> (informative): Change history 48

# Foreword

This Technical Report has been produced by the 3rd Generation Partnership Project (3GPP).

The contents of the present document are subject to continuing work within the TSG and may change following formal TSG approval. Should the TSG modify the contents of the present document, it will be re-released by the TSG with an identifying change of release date and an increase in version number as follows:

Version x.y.z

where:

x the first digit:

1 presented to TSG for information;

2 presented to TSG for approval;

3 or greater indicates TSG approved document under change control.

y the second digit is incremented for all changes of substance, i.e. technical enhancements, corrections, updates, etc.

z the third digit is incremented when editorial only changes have been incorporated in the document.

# 1 Scope

This clause shall start on a new page.

The present document …

# 2 References

The following documents contain provisions which, through reference in this text, constitute provisions of the present document.

- References are either specific (identified by date of publication, edition number, version number, etc.) or non‑specific.

- For a specific reference, subsequent revisions do not apply.

- For a non-specific reference, the latest version applies. In the case of a reference to a 3GPP document (including a GSM document), a non-specific reference implicitly refers to the latest version of that document *in the same Release as the present document*.

[1] 3GPP TR 21.905: "Vocabulary for 3GPP Specifications".

…

[x] <doctype> <#>[ ([up to and including]{yyyy[-mm]|V<a[.b[.c]]>}[onwards])]: "<Title>".

It is preferred that the reference to 21.905 be the first in the list.

# 3 Definitions of terms, symbols and abbreviations

This clause and its three subclauses are mandatory. The contents shall be shown as "void" if the TS/TR does not define any terms, symbols, or abbreviations.

## 3.1 Terms

For the purposes of the present document, the terms given in 3GPP TR 21.905 [1] and the following apply. A term defined in the present document takes precedence over the definition of the same term, if any, in 3GPP TR 21.905 [1].

Definition format (Normal)

**<defined term>:** <definition>.

**example:** text used to clarify abstract rules by applying them literally.

## 3.2 Symbols

For the purposes of the present document, the following symbols apply:

Symbol format (EW)

<symbol> <Explanation>

## 3.3 Abbreviations

For the purposes of the present document, the abbreviations given in 3GPP TR 21.905 [1] and the following apply. An abbreviation defined in the present document takes precedence over the definition of the same abbreviation, if any, in 3GPP TR 21.905 [1].

Abbreviation format (EW)

<ABBREVIATION> <Expansion>

# 4 TxD Basic Requirements

Editor’s note: This clause intends to summarize the key part of technical agreements and related background of basic requirements for TxD.

## 4.1 Antenna number and declaration

### 4.1.1 Agreements

Only two antenna connectors were considered for TxD feature.

UE declares which connectors will be active per band under test. TE needs to detect ACK and NACK and any other expected response from UE from all declared TX antenna connectors.

* The word “active” can be replaced by “used for TxD during one test procedure”. (Not necessarily to have transmission all the time.)
* UE declaration needs to describe exact two antenna connectors under test.

### 4.1.2 Study process

Only two antenna connectors were considered for TxD feature and this has been used in multiple cases and appeared in multiple WFs.

The earliest case can reference to agreed WF R4-2005652 for eMIMO in RAN4#94-e-bis, in which the following agreements were made:

* + *If transparent TxD is used in Scenario-1:*
		- *Transmission come out from two antenna connectors;*

In RAN4#97-e meeting, in [R4-2016959] and a WF [R4-2016830] was also agreed. The agreements reached are as following:

* *Declaration for Default TX Connector*
	+ *UE declares which connectors will be active per band under test. TE needs to detect ACK and NACK and any other expected response from UE from all declared TX antenna connectors.*
		- *The word “active” can be replaced by “used for TxD during one test procedure”. (Not necessarily to have transmission all the time.)*
		- *UE declaration needs to describe exact two antenna connectors under test.*

In agreed MPR evaluation assumptions R4-2105331, two antennas are also confirmed in :

* *RF assumptions:*
	+ *4dB post PA losses*
	+ *10dB antenna isolation*
	+ *Equal power and Equal back-off power split for the two antennas*

## 4.2 Summation for Power and Emission

### 4.2.1 Agreements

RAN4 agree to define requirements for MOP and emission so that power is measured correctly for all implementations, including UE with transparent TxD:

* Use “requirements are defined as the sum of powers from both connectors”.
* This shall be interpreted as: Measure the power and emissions per connector and then sum them up afterwards.
* RAN4 will clean-up all requirements related to summing the powers and emissions, including UL MIMO, UL full power transmission requirement.

### 4.2.2 Study process

This issue has been discussed for how to write emission requirements for several meetings, and gradually an agreement has been made in the agreed WF R4-2011768 in RAN4#96-e in which the following agreements were made:

*Summing the Powers and Emissions*

* *RAN4 agree to define requirements for MOP and emission so that power is measured correctly for all implementations, including UE with transparent TxD:*
	+ *Use “requirements are defined as the sum of powers from both connectors”.*
		- *This shall be interpreted as: Measure the power and emissions per connector and then sum them up afterwards.*
		- *RAN4 will clean-up all requirements related to summing the powers and emissions, including UL MIMO, UL full power transmission requirement.*

## 4.3 Transmit modulation quality

### 4.3.1 Error Vector Magnitude

#### 4.3.1.1 Agreements

For TxD, the latest agreements are as following:

* + *Proposals:*
		- *Option 1: As in agreed WF R4-2008465*
			* + $EVM=\sqrt{(P\_{1}\*EVM\_{1}^{2}+ P\_{2}\*EVM\_{2}^{2})/(P1 + P2)}$
		- *Option 2: As in R4-2107369:*
			* $EVM=\frac{P\_{1} ∙EVM\_{1}+P\_{2} ∙EVM\_{2}}{P\_{1}+P\_{2}}$
		- *Option 3: RAN4 considers to update the endorsed draft CR for UL Tx diversity EVM measurement method with the method presented in R4-2107112. (R&S)*
	+ *Agreements(GTW):*
		- *Option 2*
		- *For UL MIMO, Option 3 or options along those lines can be further considered. Once a solution is agreed, RAN4 can discuss from which release onwards it applies*

#### 4.3.1.2 Study process

Originally there was a different agreement from the final one. In agreed WF R4-2008465 in RAN4#95-e as following:

*Issue 3-3-4: EVM for Transparent TxD*

* *Agree EVM defined as*
	+ $EVM=\sqrt{(P\_{1}\*EVM\_{1}^{2}+ P\_{2}\*EVM\_{2}^{2})/(P1 + P2)}$

In RAN4#96-e, new scheme was proposed in R4-2011519, and the EVM discussion was re-started, there is one agreed WF R4-2011768 in which the following agreements were made

*EVM Requirement for Transparent TxD*

* *Background:*
	+ *In RAN4#95e, RAN4 agree to define EVM for transparent TxD as:*
		- $EVM=\sqrt{(P\_{1}\*EVM\_{1}^{2}+ P\_{2}\*EVM\_{2}^{2})/(P1 + P2)}$
* *RAN4 further study new test method and EVM definition proposed in R4-2011519:*
	+ *FFS whether or not to use new EVM definition to replace above definition.*
* *RAN4 agree the location in Specification to capture EVM definition for transparent TxD, as*
	+ *Annex F*

After continuous discussion, in RAN4#98-e-bis, in the WF R4-2105330 is for general TxD and power class issue following agreements were made.

* *CR related – EVM*
	+ *Proposals:*
		- *Option 1: As in agreed WF R4-2008465*
			* + $EVM=\sqrt{(P\_{1}\*EVM\_{1}^{2}+ P\_{2}\*EVM\_{2}^{2})/(P1 + P2)}$
		- *Option 2: As in R4-2107369:*
			* $EVM=\frac{P\_{1} ∙EVM\_{1}+P\_{2} ∙EVM\_{2}}{P\_{1}+P\_{2}}$
		- *Option 3: RAN4 considers to update the endorsed draft CR for UL Tx diversity EVM measurement method with the method presented in R4-2107112. (R&S)*
	+ *Agreements(GTW):*
		- *Option 2*
		- *For UL MIMO, Option 3 or options along those lines can be further considered. Once a solution is agreed, RAN4 can discuss from which release onwards it applies*

### 4.3.2 Spectrum flatness

#### 4.3.2.1 Agreements

The agreements were as following:

* *Agreements*
	+ *Based on R4-2108793 with the following updated equation for composite equalizer:*

$$EC(f)=\frac{P\_{1} ∙|EC\_{1}\left(f\right)|+P\_{2} ∙|EC\_{2}(f)|}{P\_{1}+P\_{2}}$$

#### 4.3.2.2 Study process

This issue has been raised in RAN4#99-e in R4-2108793, and agreements were documented in the agreed WF R4-210774.

## 4.4 Maximum output power reduction

### 4.4.1 General

#### 4.4.1.1 Agreements

Editor’s note: The final requirements have not been completed yet.

It has been agreed that MPRs for UL-MIMO would need to be re-visited.

For MPR Requirement for Transparent TxD:

* *RAN4 agree MPR defined for TxD is applied to the total output power rather than at each antenna connector*

For TxD and UL-MIMO, it has been agreed:

* + *2 Tx MPR should be the same MPR requirement for TX Diversity and UL MIMO for the same power class.*

For eMIMO and ULFPTx related, The agreement reached is as following:

* *“Chair: It is agreed that one set of MPR requirements should be adopted for both UL MIMO (including ULFPTx) and TxD”*

WF R4-2105331 is agreed MPR evaluation assumptions, and it is agreed that an evaluation is necessary to further progress the MPR work.

#### 4.4.1.2 Study process

Editor’s note: The discussion process has not been completed yet.

In RAN4#94-e-bis, in the WF R4-2005216, it has been agreed

* R15 UL MIMO emission requirements shall apply to UE level.
* Relating MPRs are need to be re-visited.

In RAN4#95-e, a WF R4-2008465 was agreed in which:

*Issue 3-3-2: Unwanted emissions for Transparent TxD: MPR study*

* *Possible WF:*
	+ *Simulation/measurement assumptions for MPR study for 2Tx UE’s*
		- *Follow 29 dBm WI assumptions in R4-2005190*
			* *Two 20dBm Tx chains are not precluded*
			* *Two 23dBm Tx chains are not precluded*
			* *Two 26dBm Tx chains are precluded*
* *MPRs are defined for each power class separately*
	+ *PC3 = 2x20dBm*
	+ *PC2 = 2x23dBm*

In RAN4#96-e, the agreed WF R4-2011768 has the following contents:

*MPR Requirement for Transparent TxD*

* *RAN4 agree MPR defined for TxD is applied to the total output power rather than at each antenna connector*

In the meantime, for eMIMO WI, the MPR was an remaining issue:

*“The Chairmain commented that for PC2 and PC3, MPR issues related to 2TX, including UL-MIMO, uplink full power transmission, and TxD, will be further discussed in TEI16.”*

In RAN4#97-e meeting, the transparent TxD was discussed under TEI16 as documented in [R4-2016959] and a WF [R4-2016830] was also agreed.

* *MPR for Transparent and UL MIMO*
	+ *Whether 2 Tx MPR should be the same MPR requirement for TX Diversity and UL MIMO for the same power class.*
	+ *Agreement*
		- *Option 1: Yes*

For eMIMO and ULFPTx related, there is very few maintenance remains and only MPR was discussed. The agreement reached is as following:

*“Chair: It is agreed that one set of MPR requirements should be adopted for both UL MIMO (including ULFPTx) and TxD”*

In RAN4#98-e-bis, the MPR was extensively discussed, but no agreements can be reached, but an evaluation is agreed to be started:

* *CR related - MPR*
	+ *Proposals:*
		- *Option 1: As in last meeting’s Endorsed CR R4-2107307*
		- *Option 2: Base on the proposals in R4-2104538*
			* *1.5dB offset for Edge and outer, 0.5dB offset for inner compared to 1Tx*
		- *Option 3: Reconsider separating MPR requirements for UL-MIMO and TxD*
			* *Also consider A-MPR impact in next issue and as in R4-2107283*
		- *Option 4: Keep the same MPR with 1Tx*
		- *Option 5: Other solution*
	+ *Agreements (GTW) :*
		- *RAN4 to start a evaluation campaign to derive the MPR values for both UL-MIMO and TxD, with agreed evaluation assumptions and UE implementations. Decisions will be made in the May meeting*

Another WF R4-2105331 is MPR evaluation assumptions, it is agreed that an evaluation is necessary to further progress the MPR work, and a detailed assumptions were agreed. The contents were not listed.

In RAN4#99-e, many results and proposals were presented, however, For the MPR, there is no agreement reached and only very wide ranges were proposed. This need to be further discussed.

## 4.5 Additional Maximum output power reduction

### 4.5.1 Agreements

Editor’s note: The final requirements have not been set yet.

There were concerns that MPR change would mean A-MPR would have to be impacted. After some discussions, it has been agreed postpone the discussion on A-MPR and treat MPR first.

### 4.5.2 Study process

Editor’s note: The discussion process has not been completed yet.

In RAN4#98-e-bis, the A-MPR issue was raised and following agreements were made.

* *CR related - MPR*
	+ *Proposals:*
		- *Option 1: As in last meeting’s Endorsed CR R4-2107307*
		- *Option 2: Base on the proposals in R4-2104538*
			* *1.5dB offset for Edge and outer, 0.5dB offset for inner compared to 1Tx*
		- *Option 3: Reconsider separating MPR requirements for UL-MIMO and TxD*
			* *Also consider A-MPR impact in next issue and as in R4-2107283*
		- *Option 4: Keep the same MPR with 1Tx*
		- *Option 5: Other solution*
	+ *Agreements (GTW) :*
		- *RAN4 to start a evaluation campaign to derive the MPR values for both UL-MIMO and TxD, with agreed evaluation assumptions and UE implementations. Decisions will be made in the May meeting*
* *CR related - A-MPR*
* *Proposals*
	+ *Option 1: A-MPR as band specific requirements could be decoupled from the general TxD requirements*
	+ *Option 2: Keeping the agreement of applying same MPR for UL MIMO and Tx Diversity would mean changed to the UL MIMO AMPR, too.*
* *Agreements:*
	+ *Postpone the discussion and treat MPR first*

## 4.6 Adjacent channel leakage ratio

### 4.6.1 Agreements

For TxD, the following agreements have been made:

* *ACLRUE = (PADJ, TX1 + PADJ, TX2) / (POWN, TX1 + POWN, TX2)*
	+ *Where*
		- *PADJ, TX1 = power of the adjacent channel on TX port 1*
		- *POWN, TX1 = power of own channel on TX port 1*
		- *And TX2 similarly.*

### 4.6.2 Study process

In RAN4#95-e, the ACLR for TxD had been agreed in WF R4-2008465.

# 5 Other related requirements

Editor’s note: This clause intends to summarize the key part of technical agreements and related background of related requirements.

## 5.1 Power Class clarification

### 5.1.1 SA

#### 5.1.1.1 Agreements

Editor’s note: The final requirements have not been completed yet.

#### 5.1.1.2 Study process

Editor’s note: The discussion process has not been completed yet.

There is a debate on 1-port transmission fall back mode for SA in both Rel-15 and Rel-16.

For Rel-16, in the agreed WF R4-2005652 for eMIMO in RAN4#94-e-bis, there are some agreements regarding the TxD applicability and relationship with eMIMO features:

* ***Transparent Tx Diversity (TxD) in Rel-16 (TBD its applicability for UEs supporting or not supporting full power transmission)***
	+ - *…*
	+ *From Rel-16 and beyond, SA UE declaring PC2 HPUE shall have 26dBm MOP for both 1TX port transmission and 2TX UL-MIMO (if supported)*
		- *For UE with 23dBm+23dBm PA architecture, transparent TxD shall be used to have 26dBm MOP for 1TX port transmission.*
		- *TBD how the requirements will be specified*
	+ *Conclusion of Rel-16 discussion will have no impact on Rel-15*

And there are following description in Rel-16 38.101-1:

*“If UE is scheduled for single antenna-port PUSCH transmission by DCI format 0\_0 or by DCI format 0\_1 for single antenna port codebook based transmission, the requirements in clause 6.2.1 apply for the power class as indicated by the ue-PowerClass field in capability signalling.”*

For Rel-15, an agreement was reached in R4-2107740 in RAN4#99-e,

*Power class related- Fallback to 1-port Tx for SA in Rel-15*

* *Proposals*
	+ *Option 1: Confirm ue-PowerClass should always be supported for 1-port transmission fall back mode for SA in Rel-15.*
		- *UE do not support TxD capability would equip a full power chain*
		- *For UE support TxD capability, when falls back to 1-port transmission, it is also reasonable to suppose it would use TxD to achieve ue-PowerClass in standalone mode*
	+ *Option 2: Others*
* *Tentative agreements:*
	+ *Option 1*
	+ *Discuss in next meeting whether Rel-15 CR would be introduced to clarify the understanding*

### 5.1.2 EN-DC

#### 5.1.2.1 Agreements

Depending on UE architecture, NR part of EN-DC may have different power class compared to SA NR for the same UE which can support both SA and EN-DC.

For Rel-16, dedicated signalling was introduced for NR part power class in EN-DC, and the NR in EN-DC was to follow this power class. It was specified in 38.101-3 as following:

*“If UE indicates IE powerClassNRPart-r16 as defined in TS 38.331 [9] in EN-DC, UE shall meet NR requirements according to this power class.”*

For Rel-15, no dedicated signalling was introduced for NR part power class in EN-DC. It was specified in 38.101-3 as following:

*” Unless otherwise stated, if UE indicates IE maxNumberSRS-Ports-PerResource = n2 in NR standalone operation mode, the said UE shall meet the NR requirements for either power class 2 or power class 3 in EN-DC within FR1 if UE indicates IE maxNumberSRS-Ports-PerResource = n1 for EN-DC on this NR band.*”

#### 5.1.2.2 Study process

**For Rel-15:**

The power class ambiguity issue was raised since there could be different understanding in SA and EN-DC case, and some ambiguity was originated from the transparent nature of TxD. An early summary R4-1913067 was agreed in RAN4#92bis, in which it was agreed that no new signalling would be introduced for Rel-15.

In RAN4#93, Rel-15 CR R4-1916137 for clarification of ENDC power class has been agreed, in which clarification was added for the scenario that UE supports PC2 SA NR with 2x23 dBm PAs will report PC2 for NR even though it only support PC3 for NR in EN-DC if UE do not declare support of 2-layer for EN-DC on this NR band:

*” Unless otherwise stated, if UE indicates IE maxNumberSRS-Ports-PerResource = n2 in NR standalone operation mode, the said UE shall meet the NR requirements for either power class 2 or power class 3 in EN-DC within FR1 if UE indicates IE maxNumberSRS-Ports-PerResource = n1 for EN-DC on this NR band.*”

This has become a “famuous sentence” in RAN4 for a long time, and is kept as it is. The discussion can be divided into following phases:

Phase 1:

The “famous sentence”, come from the intention that UE do not equip a full-power PA may declare PC2 for SA NR by means of TxD. Vendors want to keep the possibility of non-full power PA implementation for PC2 in Rel-15 (This point itself may also controversial). However, since there is no separate capability for NR within ENDC for Rel-15, without further clarification, one can only assume same power class between NR SA and NR within EN-DC. Then it comes the “famous sentence”, to provide UE this flexibility. However, the descriptions were very indirect and involves many parameters, since there is no sign/capability of architecture.

Phase 2:

After a while, and the “famous sentence” was stable. Some company raise the proposal to revise Pcmax related parameters to achieve more precise PHR reporting, to better adapt the general part “famous sentence”. Later other company has slightly different ones that always assumes a “relaxation” for lower power class.

Phase 3:

In RAN4#99, with newly introduced TxD capability used by Rel-15, there is a possible new way to signal architecture by vivo, that is: A UE without TxD capability has to have a full power PA for Rel-15. This was also means TxD capability UE may not have full-power PA. This is the first time that this no-full power PA architecture can be implicitly signaled. To utilize this, a draft CR R4-2113013 was endorsed, and the applicability of this “famous sentence” can be reduced, while keeping the implementation flexibility.

Phase 4:

In RAN4#100e, Different CRs were raised to adapt endorsed CR R4-2113013 was raised. However, no conclusion can be made, and the original endorsed CR in RAN#99e was obsolete since opposed by companies.

In RAN4#101e, this issue was moved to TEI15 agenda, and it was agreed in R4-2119835 that everything to be kept as it is and no more revision is pursued on this issue in Rel-15.

A more detailed history background can reference to a summary document in R4-2118285.

**For Rel-16:**

The power class ambiguity issue for Rel-16 was deviated from Rel-15. The problem for Rel-16 was raised in RAN#88-e in RP-201032. The solution of introducing specific RAN2 signalling was agreed and an LS RP-201392 was approved.

The power class for NR band in MR-DC could be different from that indicated in SA mode. If the power class of NR part is reported for the MR-DC, the UE shall meet the NR requirements for power class indicated by the newly introduced IE. The NR power class in Pcmax should then use the one indicated by the new IE instead.The Rel-16 EN-DC power class ambiguity problem related to TxD was solved.

For power class related issues, a LS was sent back to GCF in R4-2011903 to clarify the Rel-16 status for the power class issues, while the Rel-15 remains to be discussed.

*“”RAN4 thanks GCF CAG for the LS on power class ambiguities in RAN4 specification and would like to inform GCF CAG about the latest progress.*

*1. It is agreed that new power class capability signalling for NR in EN-DC is introduced in Rel-16 to distinguish power class capability of NR in EN-DC from power class capability of NR in SA.*

*2. It is agreed that Rel-16 UE shall meet same power class requirements between single antenna port mode and UL MIMO in SA.*

*3. It is agreed that transparent Tx diversity (TxD) is enabled at least from Rel-16 RAN4 specification.*

*RAN4 will inform GCF about the progress of Rel-15 power class clarification, once consensus is reached.”*

## 5.2 SRS antenna switching

### 5.2.1 Agreements

Editor’s note: The final requirements have not been completed yet.

### 5.2.2 Study process

Editor’s note: The discussion process has not been completed yet.

In RAN4#addition, the SRS antenna switching was discussed. The email summary is as in R4-2105440. The following agreements were captured:

* *Other Issues - Relation with SRS antenna switching*
* *Proposals*
	+ *Option 1: UE that supports transparent TxD can have antenna switching SRS configured in the same band.*
		- *Option 1a. The ∆TRxSRS needs to be increased by 3 dB overall except for the PC2 case which accommodates the use of PA with 3 dB lower power for SRS antenna switching.*
		- *Option 1b. Other solutions or requirements.*
	+ *Option 2: UE that supports transparent TxD can not have antenna switching SRS configured in the same band.*
* *Agreements:*
	+ *Option 1*
	+ *Further confirm SRS*
		- *Requirements based on transmission from physical antenna connector and not by transparent TxD*
	+ *Detailed requirements FFS*

In RAN4#99-e, there is a specific agreed WF for SRS antenna switching requirements for TxD in R4-2107981, since this is a complicated issue that needs further discussion. The following agreements were captured:

* *In GTW, the following are agreed*
	+ *SRS antenna switching which was targeted for DL CSI would not use UL antenna virtualization, i.e. UL TxD*
	+ *SRS antenna switching functionality cannot be excluded for UE supporting TxD.*
* *And Chair guidance:*
	+ *Leave discussion on concrete value for loss and how to combine Option 1 and 2 to further email discussion.*

*Agreed WF*

* *Introduce PC1.5 to spec*
* *Explicit introduce TxD for SRS antenna switching IL, but how to harmonize with the current SRS conditions are FFS, and the exact IL values are FFS*
* *At least following PC2 UE architectures with TxD but without antenna virtualization for all antenna ports are to be analyzed in #100e*
	+ *23PA+23PA*
	+ *26PA+23PA*
	+ *26PA+26PA*
* *At least 1T2R, 1T4R, 2T4R and 1T4R/2T4R srs-TxSwitch are to be analyzed in #100e*
* *A big CR will be used to capture the agreement in #100e together with other TxD issues.*

There are also more detailed background and reference paper in the WF.

## 5.3 Uplink Full power transmission (ULFPTx) for UL MIMO

### 5.3.1 Agreements

Editor’s note: The final requirements have not been set yet.

### 5.3.2 Study process

Editor’s note: The discussion process and analysis have not been completed yet.

In Rel-16, the feature of Uplink full power transmission (ULFPTx) is introduced in the RAN1-led work item of “enhancements on MIMO for NR”. During the Rel-16 RAN4 discussion on ULFPTx, there are some agreement achieved related to transparent TxD.

In RAN4#95-e, there is agreed WF R4-2008462 in which the following agreements in transparent TxD applicability related to ULFPTx was made:

* **Transparent TxD’s applicability for UEs supporting or not supporting ULFPTx in Rel-16**
	+ [Reconfirm previous agreement] “The applicability of Transparent TxD is NOT related to UE supporting or not supporting Rel-16 ULFPTx”
		- [Newly added] In Rel-16, RAN4 **ULFPTx** requirement needs to allow UE to use transparent TxD to achieve the required transmission power in following cases:
			* Mode-1 UE use transparent TxD for single SRS port (either with DCI\_0\_0 or single SRS port with DCI\_0\_1)
			* FFS transparent TxD can be used for UE configured with two SRS ports

In RAN4#100-e, draft CR (R4-2115110), the MOP requirement for fallback DCI in section 6.2D.1 is restricted to UE not indicating Tx diversity (with or without ULFPTx configured). For UE indicating Tx diversity (with or without ULFPTx), the MOP requirement in section 6.2G.1 shall be applied.

In RAN4#101-e, the detailed ULFPTx feature is reviewed, in which different modes of ULFPTx have been analysed and captured in the clause 5.3.3.

### 5.3.3 RF Architecture Review for UE with Rel-16 ULFPTx Feature

In Rel-16, RAN1 has introduced the feature of UL full power transmission (ULFPTx) and RAN4 identified the corresponding impacts on RAN4 requirement. It should be noted the clause 5.3.3 is provided to introduce the ULFPTx feature which is intended to provide information for the relevant Rel-17 TxD discussion, and specifically the three ULFPTx modes are presented in the following sub-clauses.

#### 5.3.3.1 ULFPTx Mode 1 (*ul-FullPowerTransmission-r16 = ’fullpowerMode1’*):

ULFPTx Mode 1 is proposed for the UEs with non-Coherent or partial coherent UL-MIMO codebook, with codbookSubset = nonCoherent. Particularly, new TPMI (originally for fullCoherent codebook in Rel-15) is enabled for partial-/non-coherent codebook as full-power transmission purpose for Rel-16 ULFPTx Mode 1 capable UE, while the same power scaling mechanism as Rel-15 is used. Although it is not explicitly required, ULPFTx Mode 1 is more reasonable to be applied for UE with either (1) UEs with no full-rated PAs on any of TX chains, or (2) UEs with full rated PAs on the subset of TX chains. Because RAN4 discussion is only restricted to 2TX case, so here below is the case which introduce RAN4 specification impact:



Fig. 5.3.3.1-1. Illustration of Rel-16 ULFPTx Mode 1

#### 5.3.3.2 ULFPTx Mode 2 (*ul-FullPowerTransmission-r16 = ’fullpowerMode2’*):

Compared with Mode-1/0, ULFPTx Mode 2 is more complex, since two mechanisms are specified, where one of them is configured by gNB. Similar to Mode 1, although it is not explicitly required, ULPFTx Mode 2 is more reasonable to be applied for UE with either (1) UEs with no full-rated PAs on any of TX chains, or (2) UEs with full rated PAs on the subset of TX chains.

* ULFPTx Mode 2 Mechanism-1 (SRS port virtualization):
	+ In this Mechanism-1, UE is configured multiple SRS resources having different number of ports, while the full power transmission is achieved if SRI is indicated for the SRS with one port. In this mechanism-1, the same power scaling as Rel-15 is applied.



Fig. 5.3.3.2-1. Illustration of Rel-16 ULFPTx Mode 2 (Mechanism-1, SRS port virtualization)

* ULFPTx Mode 2 Mechanism-2 (TPMI indication):
	+ In this Mechanism-2, UE reports existing TPMI(s) available for full power transmission, and the only difference comes from the different behaviour of power scaling:
		- For full power TPMI, Rel-16 power scaling factor s = 1 is applied;
		- For non-full-power TPMI, Rel-15 power scaling factor is applied, as illustrated below.



Fig. 5.3.3.2-2. Illustration of Rel-16 ULFPTx Mode 2 (Mechanism-2, TPMI indication)

#### 5.3.3.3 ULFPTx Mode 0 (*ul-FullPowerTransmission-r16 = ’fullpower’*):

ULFPTx Mode 0 is proposed for the UEs with full-rated PAs on each TX chain. For UE supporting ULFPTx Mode 0, Rel-16 power scaling factor s = 1, which is compared with Rel-15 power scaling factor (i.e., s = ratio of # non-zero PUSCH transmission power to # of SRS ports). For the below case, Rel-16 ULFPTx Mode-0 can enable the full power transmission while Rel-15 mechanism can only achieve half of power, i.e., s = ½ for TPMI = {1 0}.



Fig. 5.3.3.3-1. Illustration of Rel-16 ULFPTx Mode 0

# 6 Applicability and verification

Editor’s note: This clause intends to summarize the key part of technical agreements and related background of applicability and verification. For test related issues, the discussion process and the key options were also prepared to be documented for future reference.

## 6.1 Capability signalling

### 6.1.1 Agreements

Editor’s note: The final requirements have not been completed yet.

For the signalling options for transparent TxD, as in the WF R4-2103390 and outgoing LS R4-2103360, RAN4 has agreed to introduce a new per-band capability signaling in Rel-16 for FR1 UEs supporting transparent TxD. RAN4 would also like to ask RAN2 to enable release-independent support of this new capability from Rel-15 for PC2, if possible.

There is following reply from RAN2.

*RAN2 has discussed whether to enable release-independent support of this new capability from Rel-15, and the following agreements have been achieved:*

* *RAN2 can support release independent capability of transparent TxD for Rel-15, by allowing early implementation of the Rel-16 CRs.*
* *It is possible to only apply the change for this new capability for PC2 UEs for Rel-15, but RAN2 would like to understand whether the Rel-16 capability signalling applies for all PCs, while Rel-15 capability signalling applies for just PC2 (as this difference in Rel-15 and Rel-16 capability might impact the signalling design)?*
* *RAN2 would also like to confirm whether this new capability has any dependencies with other capabilities that should be captured by RAN2 (since the capability is intended as release independent, RAN2 may need to capture such pre-requisites explicitly).”*

After receiving the LS, it is agreed that capability singling for TxD applies for all power classes for both Rel-15 and Rel-16 in the WF R4-2107740.

The dependencies with other capabilities were still under discussion.

In RAN4#100-e, it was formally approved by RAN4 in the LS out to RAN2 in R4-2115111 that:

*RAN4 would like to confirm the capability of transparent TxD applies to all power classes equally in all the applicable releases via a release independent manner.*

This has clarified that the power classes would not be differentiated for release independency.

### 6.1.2 Study process

Editor’s note: The discussion process has not been completed yet.

In RAN4#96-e, the signaling for Transparent TxD was started to be discussed, and continued for several meetings without progress.

in RAN4#98-e, there is major break through in this topic with the TxD capability signlaing and release independency. In the agreed WF R4-2103390, the following agreements were made:

* *Signaling for Transparent TxD*

*Whether and how RAN4 introduce signalling for transparent TxD:*

* + *Option 1: Introduce some sort of signaling by UE*
		- *Option 1a. Use ModifiedMPRbehavior bits to signal additional relaxations;*
		- *Option 1b: Introducing a new ( per band capability) signalling for TxD together with existing power classes*
			* *Capability reporting for supporting TxD*
		- *Option 1c: Introducing a new power class (e.g. PC2.5) for TxD*
	+ *Option 2: Based on UE vendor declaration.*
	+ *Option 3: Using existing signalling to indicate the 2Tx implementation capability.*
* *Recommended WF*
	+ *For R15 UEs, UE vendor declaration can be used in testing*
	+ *For R16 UEs, new signaling, i.e. 1b, is needed to inform the network of the support of TxD. If the signaling can be made to enable release-independent support of TxD from R15 can be consulted with RAN2*

It means that transparent TxD can be at least using UE vendor declaration and used in testing for Rel-15.

For the signalling, an LS out R4-2103360 was agreed and sent to RAN2 with the following description and action:

***“1. Overall Description:***

*RAN4 has agreed to introduce a new per-band capability signaling in Rel-16 for FR1 UEs supporting transparent TxD.*

*RAN4 would also like to ask RAN2 to enable release-independent support of this new capability from Rel-15 for PC2, if possible.*

***2. Actions:***

***To RAN2:***

***ACTION:*** *RAN4 respectfully asks RAN2 to define respective signalling in Rel-16 and discuss release independence to Rel-15.”*

In RAN4#99-e, RAN2 Reply LS was received in R4-2107616, in which the feasibility of release independency to Rel-15 by allowing early implementation was confirmed. Further questions were also raised to about applicable power classes and if there are dependencies with other capabilities;

*“RAN2 thanks RAN4 for the LS on signalling scheme of transparent TxD.*

*Regarding the new per-band capability signaling in Rel-16 for FR1 UEs supporting transparent TxD, RAN2 can add the corresponding capability in corresponding specification (TS 38.331 and TS 38.306).*

*RAN2 has discussed whether to enable release-independent support of this new capability from Rel-15, and the following agreements have been achieved:*

* *RAN2 can support release independent capability of transparent TxD for Rel-15, by allowing early implementation of the Rel-16 CRs.*
* *It is possible to only apply the change for this new capability for PC2 UEs for Rel-15, but RAN2 would like to understand whether the Rel-16 capability signalling applies for all PCs, while Rel-15 capability signalling applies for just PC2 (as this difference in Rel-15 and Rel-16 capability might impact the signalling design)?*
* *RAN2 would also like to confirm whether this new capability has any dependencies with other capabilities that should be captured by RAN2 (since the capability is intended as release independent, RAN2 may need to capture such pre-requisites explicitly).”*

The key agreements for TxD and power class related issues were documented in the agreed WF R4-2107740. The TxD related part is as following:

In the WF, the applicable power class for capability signaling was confirmed. However, the dependencies with other capabilities were still under discussion.

*LS related - Applicable power class for capability signaling in different releases*

* *Proposals:*
	+ *Option 1: Applies for all Power Classes for both Rel-15 and Rel-16*
	+ *Option 2: Applies for only PC2 for Rel-15, and for all power classes in Rel-16;*
	+ *Option 3: Others*
* *Agreement (GTW): Option 1*

It means that RAN4 confirm that the capability singling applies for all power classes for both Rel-15 and Rel-16.

In RAN4#100-e, the following contents were agreed in the LS out to RAN2 in R4-2115111 to reflect the previous agreement:

*RAN4 would like to confirm the capability of transparent TxD applies to all power classes equally in all the applicable releases via a release independent manner.*

This has clarified that the power classes would not be differentiated for release independency.

In addition, during the discussion, RAN2 has made agreements that Rel-16 CRs would be approved for this TxD capability signalling, thus conclude the discussion for the release.

## 6.2 Applicable release

### 6.2.1 Agreements

Editor’s note: The final requirements have not been completed yet.

TxD requirements would still in Rel-17 RAN4 specs since it is a Rel-17 WI, and RAN4 would allow release independency from Rel-15 by early implementation of the requirements in Rel-17.

RAN2 would introduce the capability signalling in Rel-16 RAN2 spec, and allow release independency from Rel-15 by early implementation of Rel-16 CRs.

### 6.2.2 Study process

Editor’s note: The discussion process has not been completed yet.

In RAN4#92bis, a WF R4-1913067 was agreed. Though this WF was mainly for power class issue, there is following contents closely related to TxD:

* *Transparent TxD UE behaivor is not specified in Rel-15 RAN4 core requirements*

For the explanation of Rel-15 , the Chair’s explanation is this a “fact” which reflect the situation of that point. From this point, the need for specific requirements for TxD has been officially confirmed by RAN4.

In RAN4#93, a reply LS R4-1916132 from RAN5 was received by RAN4. In the LS, RAN5 reply that it cannot fully evaluate the impact TxD testing since it’s unclear from RAN4 specification, in this LS RAN5 also this question:

1. *Clarify whether the FR1 Tx diversity applies from Rel.-15 or Rel.-16.*

By the time of RAN4#99, this question and LS was not replied and this the main impendence of agreements.

In RAN4#94-e-bis, in the agreed WF R4-2005652 for eMIMO, there are some agreements to confirm TxD should be supported at least from Rel-16:

* ***Transparent Tx Diversity (TxD) in Rel-16 (TBD its applicability for UEs supporting or not supporting full power transmission)***
	+ *Transparent TxD shall be allowed for FR1 in Rel-16:*
		- *Necessary changes to Rel-16 RAN4 specification is needed to allow the UE behavior of transparent TxD in FR1;*
		- *TBD (Accordingly RAN5 will change test cases to allow transparent TxD)*

There is a long debate that whether TxD can be supported from Rel-15, and in RAN4#98-e, there is major break through in this topic with the TxD capability signlaing and release independency. In the agreed WF R4-2103390, the following agreements were made:

* *Signaling for Transparent TxD*

*Whether and how RAN4 introduce signalling for transparent TxD:*

* + *Option 1: Introduce some sort of signaling by UE*
		- *Option 1a. Use ModifiedMPRbehavior bits to signal additional relaxations;*
		- *Option 1b: Introducing a new ( per band capability) signalling for TxD together with existing power classes*
			* *Capability reporting for supporting TxD*
		- *Option 1c: Introducing a new power class (e.g. PC2.5) for TxD*
	+ *Option 2: Based on UE vendor declaration.*
	+ *Option 3: Using existing signalling to indicate the 2Tx implementation capability.*
* *Recommended WF*
	+ *For R15 UEs, UE vendor declaration can be used in testing*
	+ *For R16 UEs, new signaling, i.e. 1b, is needed to inform the network of the support of TxD. If the signaling can be made to enable release-independent support of TxD from R15 can be consulted with RAN2*

After that the applicable release depend on the release dependency which was discussed in the capability signaling part.

The remaining study process for capability signalling can be referenced from clause 6.1.2. RAN2 final agreements are those signalling would be introduced in Rel-16 RAN2 spec, while allow release independency from Rel-15 by early implementation of Rel-16 CRs.

It should be noted that the TxD requirements would still in Rel-17 RAN4 specs since it is a Rel-17 WI, and RAN4 would allow release independency from Rel-15 by early implementation of the requirements in Rel-17.

## 6.3 Testing related

### 6.3.1 UE Behaviour under Conformance Testing

#### 6.3.1.1 Agreements

This issue is agreed to Leave these discussions to RAN5 and not pursue them before agreement of RAN4 CR in RAN4#99, since no agreements could be reached. The following options were listed for reference:

Background: Motivation is to guide how to test requirements that require power changes such as relative power control.

Proposals:

* + Option 1a: UE will keep the tx diversity status unchanged in conformance testing.
	+ Option 1b: Test mode signalling is implemented to instruct UE to keep TX div status unchanged
	+ Option 2a: TE will detect and sum for every power step and change in condition from **declared** connector, with no precondition
	+ Option 2b: TE will detect and sum for every power step and change in condition from **declared** connector, based on pre-condition that a repeatability of TxD activation/deactivation timing in a UE is maintained can be fulfilled.

#### 6.3.1.2 Study process

In RAN4#95-e, there is agreed WF R4-2008465 in RAN4#95e, first introduce this issue.

*Issue 3-3-6: UE behavior under conformance testing*

* *Motivation is to guide how to test requirements that require power changes such as relative power control*
	+ *Option 1a: UE will keep the tx diversity status unchanged in conformance testing.*
	+ *Option 1b: Test mode signalling is implemented to instruct UE to keep TX div status unchanged*
	+ *Option 2: TE will detect and sum for every power step and change in condition from all connector (according to the issue 3-3-5 outcome)*

Unfortunately, basically there is no progress. In RAN4#98e, in the agreed WF R4-2103390, this meeting is the last meeting to list the detailed options in the WF. Though NO AGREEMENTS for any solution could be reached, they could still be considered as future discussion basis which is as following:

* UE Behavior under Conformance Testing

Background: Motivation is to guide how to test requirements that require power changes such as relative power control.

Proposals:

* + Option 1a: UE will keep the tx diversity status unchanged in conformance testing.
	+ Option 1b: Test mode signalling is implemented to instruct UE to keep TX div status unchanged
	+ Option 2a: TE will detect and sum for every power step and change in condition from **declared** connector, with no precondition
	+ Option 2b: TE will detect and sum for every power step and change in condition from **declared** connector, based on pre-condition that a repeatability of TxD activation/deactivation timing in a UE is maintained can be fulfilled.

In RAN4#99-e, it was agreed in WF R4-2107740 that the two controversial testing related issues were moved to RAN5.

***Remaining Issues - Testing related issues***

* *Proposals*
	+ *Option 1: Leave these discussions to RAN5 and not pursue them before agreement of RAN4 CR.*
	+ *Option 2: Continue discussion in RAN4.*

*Agreement:*

* + *Option 1*

### 6.3.2 Power Splitting Behaviour

#### 6.3.2.1 Agreements

This issue is agreed to Leave these discussions to RAN5 and not pursue them before agreement of RAN4 CR in RAN4#99, since no agreements could be reached. The following options were listed for reference:

* + Option 1: Only allow equal power split between connectors
		- Excludes 17+17+20 dBm implementations
		- Excludes power control optimizations
	+ Option 1a: Per instructed as test mode, UE should keep equal power split between connectors in all cases.
	+ Option 2: Allow any power split between connectors

#### 6.3.2.2 Study process

In RAN4#95-e, there is agreed WF R4-2008465 in RAN4#95e, first introduce this issue.

*Issue 3-3-7: Power splitting behaviour*

* *Motivation is to discuss and agree what implementations are excuded*
	+ *Option 1: Only allow equal power split between connectors*
		- *Excludes 17+17+20 dBm implementations*
		- *Excludes power control optimizations*
	+ *Option 2: Allow any power split between connectors*
* *Note for discussion*
	+ *RAN1 language mandates UE to split power equally between logical antenna ports. This allows 17+17 dBm = port 1 and 20 dBm = port 2 case*
	+ *What is the motivation for RAN4 to disallow this? Or power optimization for example for 24 dBm output power realization 23 + 17 dBm for maximized efficiency?*

Unfortunately, basically there is no progress at all, apart from introduce a new option with test mode. In RAN4#98e, in the agreed WF R4-2103390, this meeting is the last meeting to list the detailed options in the WF. Though NO AGREEMENTS for any solution could be reached, they could still be considered as future discussion basis which is as following:

Background: Motivation is to guide how to test requirements that require power changes such as relative power control

**Question 1:** What would be the impact for the requirements and testability with tentative equal power split restriction?

Proposals:

* + Option 1: Only allow equal power split between connectors
		- Excludes 17+17+20 dBm implementations
		- Excludes power control optimizations
	+ Option 1a: Per instructed as test mode, UE should keep equal power split between connectors in all cases.
	+ Option 2: Allow any power split between connectors

In RAN4#99-e, it was agreed in WF R4-2107740 that the two controversial testing related issues were moved to RAN5.

***Remaining Issues - Testing related issues***

* *Proposals*
	+ *Option 1: Leave these discussions to RAN5 and not pursue them before agreement of RAN4 CR.*
	+ *Option 2: Continue discussion in RAN4.*

*Agreement:*

* + *Option 1*

Annex A: Agreements and Contributions Before RAN#92

Editor’s note: This clause intends to summarize and list the agreements and contributions before RAN#92 during which a WI was approved and no SR is available yet and serve as an index for the research history. It is noted that there are cases that certain agreement in certain meeting was repeated, disregarded or even reversed in later stage, and effective one would also be captured in previous clauses.

# A.1 Agreements

Editor’s note: This clause intends to summarize the agreements and basic background for every meeting.

## A.1.1 Before RAN4#94-e-bis

**General**

Before RAN4#94-e-Bis can be regarded as early stages for the study of TxD, there is no dedicated agenda for this topic and the papers were spread across different topics such as maintenance, power class issue and the eMIMO.

**Starting point**

The following LS can be regarded as the starting point of introduction of UL transmission diversity concept for RAN4: In RAN4#84-Bis Dubrovnik with LS R4-1710109 from RAN1 saying:

 “*For CP-OFDM waveform based PUSCH, operation with UL transmission diversity is transparent to specification*”.

Later RAN1 also made similar agreements for DFT-s-OFDM. This means UE is allowed to implement diversity schemes and specifications should not limit the implementations.

**Early stage discussion and agreements:**

There were early discussion and agreements of PA architecture for PC2 UE as in R4-1902497 in RAN4#90 documented.:

In Rel-15, for power class 2 UE PA configurations for UL-MIMO, RAN4 had the following two approved WFs [R4-1803259] and [R4-1816615], and the key relating parts are listed below respectively:

*“Only PA configurations of 23+23dBm for UL MIMO and 26dBm for 1Tx are supported by specification for NR TDD bands for PC2 UE in Rel-15”*

 *“Clarify in the Rel-15 specification on ambiguous requirements for UE supporting UL MIMO*

* + *Maximum output power*
		- *Clarity in the spec that if PC2 UE is configured for transmission on single-antenna port, the requirements of the same power class in subclause 6.2.1 apply for the UE.*
		- *How to configure for transmission on single-antenna port is up to UE implementation”*

In RAN4#92, a WF R4-1910343 was agreed in which following agreements was made:

* *No specific requirements for TX diversity is written in RAN4 specification.*
* *RAN4 will follow RAN1 agreements and is discussing possibility for RAN4 requirements to accommodate TX diversity*
* *LS to RAN5 will be sent to ask them to confirm feasibility of TX diversity testing*

The mentioned LS to RAN5 R4-1910344 has been agreed to inform RAN5 about the discussion on introducing Tx diversity requirements in FR1 (see R4-1908472 and R4-1909922) and ask RAN5 about the potential testability issues with Tx diversity. In the LS it was stated that:

 “*During the discussion, concerns have been raised about the testability of this feature, since UEs may utilize multiple antennas during its uplink transmission. Considering the usage of the Tx diversity scheme is up to the UE implementation, it may also be unknown which uplink transmit antennas a UE uses at a certain point in time.*

*RAN4 respectfully asks RAN5 to identify potential issues with the testability of this feature, taking into account uplink transmission from multiple potentially unknown UE antenna connectors.”*.

In RAN4#92bis, a WF R4-1913067 was agreed. Though this WF was mainly for power class issue, there is following contents closely related to TxD:

* *Transparent TxD UE behaivor is not specified in Rel-15 RAN4 core requirements*
	+ *Further work needed in Rel-16 and impact on RAN5 conformance testing investigateg, e.g, replacement of ”antenna connector” with ”antenna port”*

For the explanation of Rel-15 , the Chair’s explanation is this a “fact” which reflect the situation of that point. From this point, the need for specific requirements for TxD has been officially confirmed by RAN4.

In RAN4#93, a reply LS R4-1916132 from RAN5 was received by RAN4. In the LS, RAN5 reply that it cannot fully evaluate the impact TxD testing since it’s unclear from RAN4 specification:

*“RAN5 has discussed the issues presented in the LS and has come to the conclusion that it currently cannot fully evaluate the impact of Tx diversity on UE testing, since in RAN5 understanding Tx diversity requirements are unclear from RAN4 specification. To fully judge the impact of Tx diversity on testing and test system design, RAN5 requires defined requirements which need to be tested and/or an understanding of the expected UE behaviour to be tested, since the Tx diversity behaviour of the UE may impact also TC other than Tx, e.g. RRM, Demod, CSI as outlined in [1].”*

RAN5 also asked some specific questions to RAN4:

1. *Define requirements for FR1 Tx diversity and clarify whether the requirements apply at a UE or at the antenna connector level.*
2. *Confirm that the RAN5 assumption of a maximum of 2 UL antenna connectors for Tx diversity is correct.*
3. *Clarify whether the FR1 Tx diversity applies from Rel.-15 or Rel.-16.*

In the same meeting RAN4#93, a Rel-15 CR R4-1916137 for clarification of ENDC power class in R15 has been agreed in which clarification was added for the scenario that UE supports PC2 SA NR with 2x23 dBm PAs will report PC2 for NR even though it only support PC3 for NR in EN-DC if UE do not declare support of 2-layer for EN-DC on this NR band:

*” Unless otherwise stated, if UE indicates IE maxNumberSRS-Ports-PerResource = n2 in NR standalone operation mode, the said UE shall meet the NR requirements for either power class 2 or power class 3 in EN-DC within FR1 if UE indicates IE maxNumberSRS-Ports-PerResource = n1 for EN-DC on this NR band.*”

This has become a “famuous sentence” in RAN4 for a long time since it creats a lot of controversies in upcoming meetings.

In RAN4#94, no agreements were made.

## A.1.2 RAN4#94-e-bis

In this meeting, the TxD discussion were in two Email threads, UL-MIMO related power class and eMIMO.

In the agreed WF R4-2005652 for eMIMO, there are some agreements regarding the TxD applicability and relationship with eMIMO features:

* ***Transparent Tx Diversity (TxD) in Rel-16 (TBD its applicability for UEs supporting or not supporting full power transmission)***
	+ *Transparent TxD shall be allowed for FR1 in Rel-16:*
		- *Necessary changes to Rel-16 RAN4 specification is needed to allow the UE behavior of transparent TxD in FR1;*
		- *TBD (Accordingly RAN5 will change test cases to allow transparent TxD)*
	+ *From Rel-16 and beyond, SA UE declaring PC2 HPUE shall have 26dBm MOP for both 1TX port transmission and 2TX UL-MIMO (if supported)*
		- *For UE with 23dBm+23dBm PA architecture, transparent TxD shall be used to have 26dBm MOP for 1TX port transmission.*
		- *TBD how the requirements will be specified*
	+ *Conclusion of Rel-16 discussion will have no impact on Rel-15*
	+ *TBD how to capture the requirements for different UEs*
* ***Clarification on Transparent TxD (1/3)***
	+ *Scenario-1:*
		- *NW use DCI format 0\_0 to schedule PUSCH for 1layer 1Tx antenna port transmission, or*

 *NW configured 1 SRS port in one SRS resource and use DCI format 0\_1 to schedule codebook-based PUSCH transmission PUSCH with precoder [1] for 1layer 1Tx antenna port transmission.*

* + *Transparent TxD shall be allowed in Scenario-1;*
	+ *If transparent TxD is used in Scenario-1:*
		- *Transmission come out from two antenna connectors;*
		- *FFS measurement configuration for transparent TxD transmission, e.g.,*
			* *the way to adjustment of relative phase coherence between TX branches;*
			* *the way to derive verdicts under the condition in which the active antennas are unknown;*
			* *the way to derive EVM measurement results after measuring per antenna connector;*
			* *etc.*
* ***Clarification on Transparent TxD (2/3)***
	+ *Scenario-2:*
		- *UE supports 2 SRS ports;*
		- *NW configured 2 SRS ports in one SRS resource;*
		- *NW use DCI format 0\_1 to schedule codebook-based PUSCH transmission with precoder [1 0] or [0 1] in 1layer 2Tx precoder codebook, which corresponding to 2 SRS ports in the SRS resource*
	+ *The scheduled precoder [1 0] or [0 1] in Scenario-2 is not regarded as “transparent TxD” for two antenna connector implementation.*
	+ *In Scenario-2, can “transparent TxD” be applied to non-zero power 1 TX in precoder [1 0] or [0 1]?*
		- *Option-1 (Samsung, Intel): No.*
		- *Option-2: Yes*
* ***Clarification on Transparent TxD (3/3)***
	+ *Scenario-3:*
		- *UE supports 2 SRS ports;*
		- *NW configured 2 SRS ports in one SRS resource;*
		- *NW use DCI format 0\_1 to schedule codebook-based PUSCH transmission with precoder [1 1] in 1layer 2Tx precoder codebook, which corresponding to 2 SRS ports in the SRS resource.*
	+ *The scheduled precoder [1 1] in Scenario-3 is not regarded as “transparent TxD”. (Qualcomm, Intel, Samsung)*

In addition, there is the following agreement documented in the Chairman’s notes under this WF:

“The applicability of Transparent TxD is NOT related to UE supporting or not supporting Rel-16 ULFPTx.”

The detailed discussion can be referenced to the Email discussion summary R4-2005695.

In the power class related discussion, a WF R4-2005216 was agreed and the contents is as following:

* **Requirements for SA UL MIMO PC2 UE are incomplete/ambiguous in current R15 RAN4 specs***.*
	+ *Option1: Continue discussion to complete in R15.*
	+ *Option2: Live with what we have now in r15, continue discussion in R16*
* **Discussion on technical issues needed for transparent Tx diversity**
	+ *This discussion does not differentiate between Rel-15 or Rel-16*
	+ *Main initial analysis reference papers*
		- *R4-2003330(Anritsu), R4-2004211(Keysight), R4-2003028(Qualcomm), R4-2004960(CMCC)…*
* **R15 UL MIMO emission requirements shall apply to UE level.**
* **Relating MPRs are need to be re-visited.**
* **Corresponding work plan & assumptions to be discussed in RAN4#95-e**
* **Further discuss whether it is necessary to evaluate CDD based TxDiv against 1 Tx antenna scheme.**
	+ **R4-2003217 can be used as a reference.**

Basically there is no concrete agreements related to either TxD or power class issue. It should be noted that in R4-2003028, there is more background for power class issue, and could be used as further reference for earlier power class related background.

The Email summary can be reference to R4-2005687.

## A.1.3 RAN4#95-e

The main agreements in this meeting was made under the eMIMO WI, and the discussion of R15 power class didn’t have an WF in this meeting. There is an incoming LS R4-2006116 from GCF was received for clarfication of several power class inalignment issues from the views of GCF.

In agreed WF R4-2008462, there is the following agreements in transparent TxD applicability related to ULFPTx

* ***Transparent TxD’s applicability for UEs supporting or not supporting ULFPTx in Rel-16***
	+ *[Reconfirm previous agreement] “The applicability of Transparent TxD is NOT related to UE supporting or not supporting Rel-16 ULFPTx”*
		- *[Newly added] In Rel-16, RAN4* ***ULFPTx*** *requirement needs to allow UE to use transparent TxD to achieve the required transmission power in following cases:*
			* *Mode-1 UE use transparent TxD for single SRS port (either with DCI\_0\_0 or single SRS port with DCI\_0\_1)*
			* *FFS transparent TxD can be used for UE configured with two SRS ports*

An LS R4-2009171 was agreed and sent to RAN1, in order to make progress of certain discussion of transparent TxD related issues, to get some clarification from RAN1. The contents are as following:

*In RAN4 study of ULFPTx under eMIMO WI, enabling transparent Tx diversity (TxD) was agreed at least from Rel-16, and the applicability of transparent TxD is NOT related to UE supporting or not supporting Rel-16 ULFPTx. Two possible cases were identified in RAN4 to use transparent TxD to achieve the required transmission power, i.e. for a FR1 UE having two TX branches/antennae,*

* *First case: Transparent TxD for UE configured with single SRS port (either with DCI\_0\_0 or single SRS port with DCI\_0\_1);*
* *Second case: Transparent TxD for UE configured with 2 SRS ports (FFS whether TxD is feasible in this case).*

*For the second case, two possible methods to transmit a multi-port SRS resource (i.e. 2Tx ports) with two PAs (PA1 and PA2) were considered, i.e.*

* *Method-1: SRS port-1 maps to PA1, SRS port-2 maps to PA2*
* *Method-2: SRS port-1 maps to PA1+PA2, SRS port-2 maps to PA1+PA2*

*In order to make progress of corresponding discussion of transparent TxD related issues, RAN4 would like to get some clarification from RAN1 for the feasibility of the second case.*

***Question 1****: Whether the two mentioned methods are both feasible to transmit the full output power?*

***Question 2****: If answer is yes, which ULFPTx modes can be supported for these two methods?*

In agreed WF R4-2008465, though not much agreements, many TxD specific issues were raised and options provided. From this point, the discussion for TxD become more speed up and more systematic.

*Issue 3-3-1: Summing the power and emissions*

* *Motivation is to define requirements so that power is measured correctly for all implementations*
	+ *Option 1: Use “requirements apply to a sum of both connectors”.*
	+ *Option 2: Use “measured as sum of each antenna connector”.*

*Issue 3-3-2: Unwanted emissions for Transparent TxD: MPR study*

* *Possible WF:*
	+ *Simulation/measurement assumptions for MPR study for 2Tx UE’s*
		- *Follow 29 dBm WI assumptions in R4-2005190*
			* *Two 20dBm Tx chains are not precluded*
			* *Two 23dBm Tx chains are not precluded*
			* *Two 26dBm Tx chains are precluded*
* *MPRs are defined for each power class separately*
	+ *PC3 = 2x20dBm*
	+ *PC2 = 2x23dBm*

*Issue 3-3-2: Unwanted emissions for Transparent TxD: how to write emission requirements*

* *Motivation is to ensure correct requirement setting for unwanted emissions*
	+ *Option 1: Define “requirements apply to a sum of both connectors”. Issue 3-3-1 option 1*
	+ *Option 2: Define “measured as the sum of the emissions from all antenna connectors”. Same as issue 3-3-1 Option 2*
	+ *Option 3: Measured per antenna connector against a 3 dB tighter emissions requirement per connector (for two antenna connectors).*

*Issue 3-3-3: ACLR for Transparent TxD*

* *ACLR is defined as follows*
* *ACLRUE = (PADJ, TX1 + PADJ, TX2) / (POWN, TX1 + POWN, TX2)*
	+ *Where*
		- *PADJ, TX1 = power of the adjacent channel on TX port 1*
		- *POWN, TX1 = power of own channel on TX port 1*
		- *And TX2 similarly.*

*Issue 3-3-4: EVM for Transparent TxD*

* *Agree EVM defined as*
	+ $EVM=\sqrt{(P\_{1}\*EVM\_{1}^{2}+ P\_{2}\*EVM\_{2}^{2})/(P1 + P2)}$
* *Needed changes into the TS are TBD*
	+ *Annex F*
	+ *6.4D*

*Issue 3-3-5: Declaration for default TX connector*

* *Motivation is to clarify what is UE behavior and TE assumptions in RX and BB tests*
* *Narrow down to one of the following in next meeting*
	+ *Option 1a: TE needs to detect all antenna connectors for ACK and NACK and any other expected response from UE*
	+ *Option 1b: TE needs to detect all declared TX antenna connectors for ACK and NACK and any other expected response from UE*
	+ *Option 2: UE declares which connector is primary TX connector from which ACK and NACK and any other expected response from UE is transmitted in all cases*
* *And send LS to RAN5 about RAN4 conclusion*

*Issue 3-3-6: UE behavior under conformance testing*

* *Motivation is to guide how to test requirements that require power changes such as relative power control*
	+ *Option 1a: UE will keep the tx diversity status unchanged in conformance testing.*
	+ *Option 1b: Test mode signalling is implemented to instruct UE to keep TX div status unchanged*
	+ *Option 2: TE will detect and sum for every power step and change in condition from all connector (according to the issue 3-3-5 outcome)*

*Issue 3-3-7: Power splitting behaviour*

* *Motivation is to discuss and agree what implementations are excuded*
	+ *Option 1: Only allow equal power split between connectors*
		- *Excludes 17+17+20 dBm implementations*
		- *Excludes power control optimizations*
	+ *Option 2: Allow any power split between connectors*
* *Note for discussion*
	+ *RAN1 language mandates UE to split power equally between logical antenna ports. This allows 17+17 dBm = port 1 and 20 dBm = port 2 case*
	+ *What is the motivation for RAN4 to disallow this? Or power optimization for example for 24 dBm output power realization 23 + 17 dBm for maximized efficiency?*

Among them actually only *Issue 3-3-3 and Issue 3-3-4* are agreements without different options, and issue 3-3-4 was gradually reversed in later stage.

The Email summary for eMIMO and R15 power class can be found in R4-2008946 and R4-2008935.

## A.1.4 RAN#88-e

The power class ambiguity issue for Rel-16 was raised in RAN#88-e in RP-201032. The solution of introducing specific RAN2 signalling was agreed and an LS RP-201392 was approved.

The power class for NR band in MR-DC could be different from that indicated in SA mode. If the power class of NR part is reported for the MR-DC, the UE shall meet the NR requirements for power class indicated by the newly introduced IE. The NR power class in Pcmax should then use the one indicated by the new IE instead.The Rel-16 EN-DC power class ambiguity problem related to TxD was solved.

## A.1.5 RAN4#96-e

In this meeting, TxD related requirements were mainly discussed with power class related issue in one thread.

There is one agreed WF R4-2011768 in which the following agreements were made:

*Summing the Powers and Emissions*

* *RAN4 agree to define requirements for MOP and emission so that power is measured correctly for all implementations, including UE with transparent TxD:*
	+ *Use “requirements are defined as the sum of powers from both connectors”.*
		- *This shall be interpreted as: Measure the power and emissions per connector and then sum them up afterwards.*
		- *RAN4 will clean-up all requirements related to summing the powers and emissions, including UL MIMO, UL full power transmission requirement.*

*MPR Requirement for Transparent TxD*

* *RAN4 agree MPR defined for TxD is applied to the total output power rather than at each antenna connector*

For EVM, in response to newly raised proposals, the WF has the following update:

 *EVM Requirement for Transparent TxD*

* *Background:*
	+ *In RAN4#95e, RAN4 agree to define EVM for transparent TxD as:*
		- $EVM=\sqrt{(P\_{1}\*EVM\_{1}^{2}+ P\_{2}\*EVM\_{2}^{2})/(P1 + P2)}$
* *RAN4 further study new test method and EVM definition proposed in R4-2011519:*
	+ *FFS whether or not to use new EVM definition to replace above definition.*
* *RAN4 agree the location in Specification to capture EVM definition for transparent TxD, as*
	+ *Annex F*

For other issues, different options were raised and basically no agreements and progress were made, the titles were included below while the details were omitted.

*Declaration for Default TX Connector*

*UE Behavior under Conformance Testing*

*Power Splitting Behavior*

*Signaling for Transparent TxD*

*Applicability of Transparent TxD Requirement*

*CDD-related Requirement*

For power class related issues, a LS was sent back to GCF in R4-2011903 to clarify the Rel-16 status for the power class issues, while the Rel-15 remains to be discussed.

*“”RAN4 thanks GCF CAG for the LS on power class ambiguities in RAN4 specification and would like to inform GCF CAG about the latest progress.*

*1. It is agreed that new power class capability signalling for NR in EN-DC is introduced in Rel-16 to distinguish power class capability of NR in EN-DC from power class capability of NR in SA.*

*2. It is agreed that Rel-16 UE shall meet same power class requirements between single antenna port mode and UL MIMO in SA.*

*3. It is agreed that transparent Tx diversity (TxD) is enabled at least from Rel-16 RAN4 specification.*

*RAN4 will inform GCF about the progress of Rel-15 power class clarification, once consensus is reached.”*

The detailed Email summary is in R4-2011860.

In addition, a draft CR to reflect the agreements of new UE capability signalling to reflect the power class for NR band in MR-DC could be different from that indicated in SA mode was technically endorsed in R4-2011770. The contribution was discussed during email thread [96e][121] NR\_R16\_Maintenance. The discussion was recorded in R4-2011861.

For eMIMO, reply LS R4-2013040 was received from RAN1 in that the following answers were provided:

***Question 1:*** *Whether the two mentioned methods are both feasible to transmit the full output power?*

***Answer 1:*** *From RAN1’s perspective, both Method-1 and Method-2 can be supported for UL full power transmission.*

*For two SRS port transmission in method-2, the UE will need to transmit two SRS ports on each PA in a symbol, while for method-1 each PA carries one SRS port.*

***Question 2:*** *If answer is yes, which ULFPTx modes can be supported for these two methods?*

***Answer 2:*** *From RAN1’s perspective, Method-1 can be supported for any UL full power transmission modes, and Method-2 can be supported at least for Mode-2 and Mode-full power (i.e., the other mode).*

***Question 3:*** *Whether the ULFPTx mode-2 and the other ULPFTx mode are feasible for FR2 UE?*

***Answer 3:*** *From RAN1’s perspective, UL full power modes {Mode-1, Mode-2 and Mode-full power (i.e., the other mode)} can be supported for FR2.*

It can be seen that RAN1 do not mandate any implementation for those modes.

The previously endorsed feature CRs was officially agreed for 38.101-1 and 38.101-2 in R4-2011762 and R4-2011920 respectively. Some remaining issues were put into maintenance stage from next meeting as documented in the chairman’s notes:

*“The Chairmain commented that for PC2 and PC3, MPR issues related to 2TX, including UL-MIMO, uplink full power transmission, and TxD, will be further discussed in TEI16.”*

The Email summary for eMIMO can be referenced in R4-2011852.

## A.1.6 RAN4#97-e

In RAN4#97-e meeting, the transparent TxD was discussed under TEI16 as documented in [R4-2016959] and a WF [R4-2016830] was also agreed. The agreements reached are as following:

* *Declaration for Default TX Connector*
	+ *UE declares which connectors will be active per band under test. TE needs to detect ACK and NACK and any other expected response from UE from all declared TX antenna connectors.*
		- *The word “active” can be replaced by “used for TxD during one test procedure”. (Not necessarily to have transmission all the time.)*
		- *UE declaration needs to describe exact two antenna connectors under test.*
* *MPR for Transparent and UL MIMO*
	+ *Whether 2 Tx MPR should be the same MPR requirement for TX Diversity and UL MIMO for the same power class.*
	+ *Agreement*
		- *Option 1: Yes*

 There are still divided views and some new options were also discussed. The main points including:

* New EVM definition for transparent TxD
* UE behavior on keeping the tx diversity under conformance testing
* UE behaviour for power splitting
* Signaling for Transparent TxD
* Applicability of TxD procedure & requirements
* Necessity of CDD related requirement

In addition, there is a long standing RAN5 LS in [R4-1916132] that have not been replied. One draft reply was prepared in [R4-2015321] but was not discussed.

For power class related issue, still no concrete agreements can be reached, the following topic was discussed and only limited progress was made:

* RAN4 clarification of NSA NR power class (Rel-15)

The Email summary is referenced to R4-2016959 .

For eMIMO and ULFPTx related, there is only very few maintenance remains and only MPR was discussed. The agreement reached is as following:

*“Chair: It is agreed that one set of MPR requirements should be adopted for both UL MIMO (including ULFPTx) and TxD”*

The email summary is R4-2016955.

## A.1.7 RAN4#98-e

In RAN4#98-e, there are major break through in this topic, and there are clear agreements and WF for TxD signaling and release independency. In the agreed WF R4-2103390, the following agreements were made:

* *Signaling for Transparent TxD*

*Whether and how RAN4 introduce signalling for transparent TxD:*

* + *Option 1: Introduce some sort of signaling by UE*
		- *Option 1a. Use ModifiedMPRbehavior bits to signal additional relaxations;*
		- *Option 1b: Introducing a new ( per band capability) signalling for TxD together with existing power classes*
			* *Capability reporting for supporting TxD*
		- *Option 1c: Introducing a new power class (e.g. PC2.5) for TxD*
	+ *Option 2: Based on UE vendor declaration.*
	+ *Option 3: Using existing signalling to indicate the 2Tx implementation capability.*
* *Recommended WF*
	+ *For R15 UEs, UE vendor declaration can be used in testing*
	+ *For R16 UEs, new signaling, i.e. 1b, is needed to inform the network of the support of TxD. If the signaling can be made to enable release-independent support of TxD from R15 can be consulted with RAN2*
* *CDD-related Requirement*

*For transparent TxD UE, necessity of CDD related requirements, e.g. requirement on TAE+CDD, is need to be further studied:*

* *Proposals*
	+ *Option 1: Yes*
	+ *Option 2: No.*
	+ *Option 2b. No at least for Rel-16*
* *Recommended WF*
	+ *Option 2b*

For the signalling, an LS out R4-2103360 was agreed and sent to RAN2 with the following description and action:

***“1. Overall Description:***

*RAN4 has agreed to introduce a new per-band capability signaling in Rel-16 for FR1 UEs supporting transparent TxD.*

*RAN4 would also like to ask RAN2 to enable release-independent support of this new capability from Rel-15 for PC2, if possible.*

***2. Actions:***

***To RAN2:***

***ACTION:*** *RAN4 respectfully asks RAN2 to define respective signalling in Rel-16 and discuss release independence to Rel-15.”*

For testing related UE behaviour and power splitting behaviour, this meeting is the last meeting to list the detailed options in the WF, and though NO AGREEMENTS for any solution could be reached, they could still be considered as future discussion basis which is as following:

* UE Behavior under Conformance Testing

Background: Motivation is to guide how to test requirements that require power changes such as relative power control.

Proposals:

* + Option 1a: UE will keep the tx diversity status unchanged in conformance testing.
	+ Option 1b: Test mode signalling is implemented to instruct UE to keep TX div status unchanged
	+ Option 2a: TE will detect and sum for every power step and change in condition from **declared** connector, with no precondition
	+ Option 2b: TE will detect and sum for every power step and change in condition from **declared** connector, based on pre-condition that a repeatability of TxD activation/deactivation timing in a UE is maintained can be fulfilled.
* Power Splitting Behavior

Background: Motivation is to guide how to test requirements that require power changes such as relative power control

**Question 1:** What would be the impact for the requirements and testability with tentative equal power split restriction?

Proposals:

* + Option 1: Only allow equal power split between connectors
		- Excludes 17+17+20 dBm implementations
		- Excludes power control optimizations
	+ Option 1a: Per instructed as test mode, UE should keep equal power split between connectors in all cases.
	+ Option 2: Allow any power split between connectors

A draft CR for 38.101-1 was also technically endorsed. Howver, there are still unsolved issues such as MPR and the draft CR would be continuiously discussed an updated in next meeting.

For power class issue, some more issues were raised without proguress.

The Email discussion summary is in R4-2103302.

There is no more discussion in eMIMO agenda.

## A.1.8 RAN4#98-e-bis

In this meeting, there are two way forwards were agreed.

One WF R4-2105330 is for general TxD and power class issue. There are agreements in EVM and the need for futher MPR evaluation, There are also discussion on SRS antenna switching and some preliminary agreements were made.

* *CR related – EVM*
	+ *Proposals:*
		- *Option 1: As in agreed WF R4-2008465*
			* + $EVM=\sqrt{(P\_{1}\*EVM\_{1}^{2}+ P\_{2}\*EVM\_{2}^{2})/(P1 + P2)}$
		- *Option 2: As in R4-2107369:*
			* $EVM=\frac{P\_{1} ∙EVM\_{1}+P\_{2} ∙EVM\_{2}}{P\_{1}+P\_{2}}$
		- *Option 3: RAN4 considers to update the endorsed draft CR for UL Tx diversity EVM measurement method with the method presented in R4-2107112. (R&S)*
	+ *Agreements(GTW):*
		- *Option 2*
		- *For UL MIMO, Option 3 or options along those lines can be further considered. Once a solution is agreed, RAN4 can discuss from which release onwards it applies*
* *CR related - MPR*
	+ *Proposals:*
		- *Option 1: As in last meeting’s Endorsed CR R4-2107307*
		- *Option 2: Base on the proposals in R4-2104538*
			* *1.5dB offset for Edge and outer, 0.5dB offset for inner compared to 1Tx*
		- *Option 3: Reconsider separating MPR requirements for UL-MIMO and TxD*
			* *Also consider A-MPR impact in next issue and as in R4-2107283*
		- *Option 4: Keep the same MPR with 1Tx*
		- *Option 5: Other solution*
	+ *Agreements (GTW) :*
		- *RAN4 to start a evaluation campaign to derive the MPR values for both UL-MIMO and TxD, with agreed evaluation assumptions and UE implementations. Decisions will be made in the May meeting*
* *CR related - A-MPR*
* *Proposals*
	+ *Option 1: A-MPR as band specific requirements could be decoupled from the general TxD requirements*
	+ *Option 2: Keeping the agreement of applying same MPR for UL MIMO and Tx Diversity would mean changed to the UL MIMO AMPR, too.*
* *Agreements:*
	+ *Postpone the discussion and treat MPR first*
* *Other Issues - Relation with SRS antenna switching*
* *Proposals*
	+ *Option 1: UE that supports transparent TxD can have antenna switching SRS configured in the same band.*
		- *Option 1a. The ∆TRxSRS needs to be increased by 3 dB overall except for the PC2 case which accommodates the use of PA with 3 dB lower power for SRS antenna switching.*
		- *Option 1b. Other solutions or requirements.*
	+ *Option 2: UE that supports transparent TxD can not have antenna switching SRS configured in the same band.*
* *Agreements:*
	+ *Option 1*
	+ *Further confirm SRS*
		- *Requirements based on transmission from physical antenna connector and not by transparent TxD*
	+ *Detailed requirements FFS*

For the Rel-15 NSA power class issue, there is no progress and companies are waiting for RAN2’s feed back about the release independency to Rel-15:

*”Wait for feedback from Ran2 or wait for ran2 to conclude the work to add TX diversity capability and conclusion on applicable release.”*

Another WF R4-2105331 is MPR evaluation assumptions, it is agreed that an evaluation is necessary to further progress the MPR work, and a detailed assumptions were agreed:

*WF on architecture*

* *PC2 with 2x23dBm PAs => 2Tx NR MPR (High priority)*
* *[PC2 with 2x26dBm PAs => 2Tx NR MPR]*
* *[PC2 with 23+26dBm PAs => 2Tx NR MPR]*

*WF: MPR/AMPR evaluation assumptions (1)*

* *RF assumptions:*
	+ *4dB post PA losses*
	+ *10dB antenna isolation*
	+ *Equal power and Equal back-off power split for the two antennas*
* *Usual 3GPP PA calibration for 20MHz QPSK DFT-s-OFDM 100RB0 waveform based on 4dB post PA losses and 1dB MPR.*
	+ *For 26dBm PA: 29dBm at 31dB ACLR*
	+ *For 23dBm PA: 26dBm at 30dB ACLR*
* *RF impairments:*
	+ *Image and carrier leakage is 28dB for up to 64QAM, image is 35dB for 256QAM*
	+ *CIM3 is 60dB and CIM5 is 70dB*
	+ *Measurements/simulation is used where two PA are coupled at their outputs recreating the 10dB antenna isolation assumption with the Reverse IMD*
	+ *To recreate the effect of CDD the two signal on each antennas can simply have a small delay between each other (a fraction of CP)*
* *Requirements for back-off evaluation:*
	+ *Emission requirements (ACLR/SEM/spurious emissions of the targeted power class) are checked by summing the power of the two transmit paths*
	+ *EVM is checked for the agreed composite EVM equation but with P1 and P2 assumed equal. EVM should be checked especially for inner at high order modulations where RIMD will further degrade the in channel noise floor.*
	+ *Whether IBE is checked per antenna or as the sum should be clearly stated*
	+ *MPR is provided in the form of back off of total power versus power class nominal power level*
* *EVM budget for PA:*
	+ *QPSK             10%*
	+ *16QAM          8%*
	+ *64QAM          4%*
	+ *256QAM        1.8%*
* *Evaluation scenarios:*
	+ *Both CP-OFDM and DFT-s-OFDM waveforms are evaluated*
	+ *Since simulation may not be available, at least some worst case corners are evaluated for inner/outer and edge allocations*
	+ *Since it has the tighter requirements and highest PSD the lowest valid SCS should be used.*
	+ *All modulation orders should be checked:*
		- *Pi/2 BPSK (no shaping), QPSK, 16QAM, 64QAM, 256QAM (for 256QAM mostly EVM with proper image level)*
	+ *Channel BW configurations should cover the entire channel bandwidth range:*
		- *At least 5, 20, 50, 100MHz channel bandwidths (depends on the supported CBW of the operating band)*

In addition, there is following chairman’s notesChair: Charter requested “[PC3 with 2x20dBm PAs => 2Tx NRU MPR (Low priority)]” be added to page 2.

The email summary is as in R4-2105440.

## A.1.9 RAN4#99e

In this meeting, RAN2 Reply LS was received in R4-2107616, in which the feasibility of release independency to Rel-15 by allowing early implementation was confirmed. Further questions were also raised to about applicable power classes and if there are dependencies with other capabilities;

*“RAN2 thanks RAN4 for the LS on signalling scheme of transparent TxD.*

*Regarding the new per-band capability signaling in Rel-16 for FR1 UEs supporting transparent TxD, RAN2 can add the corresponding capability in corresponding specification (TS 38.331 and TS 38.306).*

*RAN2 has discussed whether to enable release-independent support of this new capability from Rel-15, and the following agreements have been achieved:*

* *RAN2 can support release independent capability of transparent TxD for Rel-15, by allowing early implementation of the Rel-16 CRs.*
* *It is possible to only apply the change for this new capability for PC2 UEs for Rel-15, but RAN2 would like to understand whether the Rel-16 capability signalling applies for all PCs, while Rel-15 capability signalling applies for just PC2 (as this difference in Rel-15 and Rel-16 capability might impact the signalling design)?*
* *RAN2 would also like to confirm whether this new capability has any dependencies with other capabilities that should be captured by RAN2 (since the capability is intended as release independent, RAN2 may need to capture such pre-requisites explicitly).”*

The key agreements for TxD and power class related issues were documented in the agreed WF R4-2107740. The TxD related part is as following:

In the WF, the applicable power class for capability signaling was confirmed. However, the dependencies with other capabilities were still under discussion.

*LS related - Applicable power class for capability signaling in different releases*

* *Proposals:*
	+ *Option 1: Applies for all Power Classes for both Rel-15 and Rel-16*
	+ *Option 2: Applies for only PC2 for Rel-15, and for all power classes in Rel-16;*
	+ *Option 3: Others*
* *Agreement (GTW): Option 1*

For the MPR, there is no agreement reached and only very wide ranges were proposed. This need to be further discussed.

* In this meeting, RAN4 will try to agree on the ranges for MPR values if possible, and in the next meeting, RAN4 can down-select to concrete value within the agreed range.

New agreements were reached on TxD EVM spectrum flatness;

***Remaining Issues - TxD EVM spectrum flatness***

* *Agreements*
	+ *Based on R4-2108793 with the following updated equation for composite equalizer:*

$$EC(f)=\frac{P\_{1} ∙|EC\_{1}\left(f\right)|+P\_{2} ∙|EC\_{2}(f)|}{P\_{1}+P\_{2}}$$

The two controversial testing related issues were moved to RAN5.

***Remaining Issues - Testing related issues***

* *Proposals*
	+ *Option 1: Leave these discussions to RAN5 and not pursue them before agreement of RAN4 CR.*
	+ *Option 2: Continue discussion in RAN4.*

*Agreement:*

* + *Option 1*

***Remaining Issues - TxD antenna and channel models***

* *Proposals*
	+ *Option 1: No more discussion on these issues.*
	+ *Option 2: Further discuss the relevant antenna and channel models and their impact as part of, and prior to, concluding on conformance testing methodologies and reference receivers for TxD with conducted measurements.*

*Agreements:*

* + *Option 1*

Significant progress for power class issues were reached in this meeting, since there is a confirmation of feasibility of release independency of TxD from Rel-15.

For Rel-15 EN-DC power class issue, i.e. the “famous sentence”, a draft CR R4-2107781 was endorsed, in which the description of multiple power class possibilities for NR part of NSA in Rel-15 was confined only be allowed in case TxD is supported and signaled. In case TxD was not indicated by signaling, the current behaviour of multiple power class possibilities for NR part of NSA can be removed.

For Rel-15 SA power class issue, an agreement was reached in R4-2107740,

*Power class related- Fallback to 1-port Tx for SA in Rel-15*

* *Proposals*
	+ *Option 1: Confirm ue-PowerClass should always be supported for 1-port transmission fall back mode for SA in Rel-15.*
		- *UE do not support TxD capability would equip a full power chain*
		- *For UE support TxD capability, when falls back to 1-port transmission, it is also reasonable to suppose it would use TxD to achieve ue-PowerClass in standalone mode*
	+ *Option 2: Others*
* *Tentative agreements:*
	+ *Option 1*
	+ *Discuss in next meeting whether Rel-15 CR would be introduced to clarify the understanding*

However, there is still no conclusion for Pcmax for NR for Rel-15 EN-DC, which is also documented in R4-2107740,

*Power class related- The Pcmax for NR for Rel-15 EN-DC*

* *Proposals*
	+ *Option 1: The Pcmax for NR is modified to use the lower possible power class to decide the lower bound of the configured power. (Huawei)*
	+ *Option 2: The Pcmax for NR is modified according to the declared NR power capability for NSA so that the PHR becomes correct. (Ericsson)*
	+ *Option 3:Do not consider further refinements of Pcmax for NR.*
	+ *Option 4: Others*
* *Agreements :*
	+ *FFS*

In addition, there is another specific agreed WF for SRS antenna switching requirements for TxD in R4-2107981, since this is a complicated issue that needs further discussion. The following agreements were captured:

* *In GTW, the following are agreed*
	+ *SRS antenna switching which was targeted for DL CSI would not use UL antenna virtualization, i.e. UL TxD*
	+ *SRS antenna switching functionality cannot be excluded for UE supporting TxD.*
* *And Chair guidance:*
	+ *Leave discussion on concrete value for loss and how to combine Option 1 and 2 to further email discussion.*

*Agreed WF*

* *Introduce PC1.5 to spec*
* *Explicit introduce TxD for SRS antenna switching IL, but how to harmonize with the current SRS conditions are FFS, and the exact IL values are FFS*
* *At least following PC2 UE architectures with TxD but without antenna virtualization for all antenna ports are to be analyzed in #100e*
	+ *23PA+23PA*
	+ *26PA+23PA*
	+ *26PA+26PA*
* *At least 1T2R, 1T4R, 2T4R and 1T4R/2T4R srs-TxSwitch are to be analyzed in #100e*
* *A big CR will be used to capture the agreement in #100e together with other TxD issues.*

There are also more detailed background and reference paper in the WF.

The previous endorsed general TxD draft CR were also updated in this meeting as R4-2107782, however it was postponed in this meeting, since there are some items were deemed not included yet.

The Email discussion summary can be referenced to R4-2107919.

# A.2 Key Contributions

Editor’s note: This clause intends to list key related documents for every meeting and all the CRs/WF/LS were approved/agreed unless otherwise stated.

## A.2.1 Before RAN4#94-e-bis

* R4-1710109, “LS on UL diversity transmission for PUSCH with CP-OFDM”, RAN1, Mitsubitshi, 3GPP TSG RAN WG4 Meeting #84Bis, Dubrovnik, Croatia, 09 - 13 October, 2017
* R4-1803259, Proposal on NR HPUE definition for PC2, CMCC, Huawei, HiSilicon, OPPO, vivo, Xiaomi, ZTE, CATT, Intel, Qorvo, Skyworks, broadcom
* R4-1816615, WF on PC2 UL MIMO, Huawei, HiSilicon, Qualcomm
* R4-1902497, Reply LS on new UE capability for Full TX power UL transmission, vivo
* R4-1910343, WF on how to enable TX diversity type UEs, Qualcomm, RAN4#92
* R4-1910344, LS on the testability of FR1 Tx diversity, RAN4#92
* R4-1908472, “How to enable TX diversity type UEs“, Qualcomm Incorporated
* R4-1909922, “On UL MIMO and Tx diversity requirements”, Huawei
* R4-1913067, Summary of Tx diversity and eMIMO full power transmission, Ericsson, RAN4#92bis
* R4-1916132, Response LS on the testability of FR1 Tx diversity, RAN4#93
* R4-1916137, CR to 38.101-3: clarification of ENDC power class in R15, vivo, RAN4#93

## A.2.2 RAN4#94-e-Bis

* R4-2005652, WF on Uplink Full Power Transmission, Samsung
* R4-2005695, Email discussion summary for [94e Bis][12] NR\_eMIMO\_UE\_RF
* R4-2005687, Email discussion summary for [94e Bis][3] NR\_NewRAT\_UE\_RF\_Part\_2
* R4-2005216, WF on Power Class related UL MIMO and other requirements

## A.2.3 RAN4#95-e

* R4-2008462           WF on Uplink Full Power Transmission
* R4-2008465           WF on Enabling Transparent TxD in Rel-16
* R4-2009171           LS on clarification of transparent diversity feasibility
* R4-2008946           Email discussion summary for [95e][116] NR\_eMIMO\_UE\_RF
* R4-2008935 Email discussion summary for [95e][104] NR\_NewRAT\_UE\_RF\_Part\_3
* R4-2006116, LS on requirement in Power Class 2 for UL MIMO Test cases, GCF-CAG, RAN4#95-e

## A.2.4 RAN#88-e

* RP-201032 On Rel-16 EN-DC power class Huawei, HiSilicon
* RP-201392 LS on introducing UE capability for power class for NR band in MR-DC combination (From: RAN; to: RAN2; cc: RAN4; contact: Huawei)

## A.2.5 RAN4#96-e

* R4-2011860 Email discussion summary for [96e][120] NR\_TxD Moderator (vivo)
* R4-2011768 WF on Rel-16 TxD Samsung
* R4-2011903 LS on NR power class clarification to GCF CAG, cc RAN5 Source: RAN4
* R4-2011852 Email discussion summary for [96e][112] NR\_eMIMO\_UE\_RF Source: Moderator (Samsung)
* R4-2011770 draft CR for TS 38.101-3 introduce new power class for EN-DC Huawei
* R4-2011762 CR to TS38.101-1 on introduction of Uplink Full Power Transmission Source: Samsung, Qualcomm
* R4-2011920 CR to TS38.101-2 on ULFPTx and UE SRS port configuration clarification Source: Qualcomm Incorporated
* R4-2013040 Reply LS on feasibility of UL FPT modes and transparent TxD for certain UE implementations RAN1

## A.2.6 RAN4#97-e

* R4-2016959 Email discussion summary for [97e][115] NR\_TxD Source: Moderator (vivo)
* R4-2016830 WF on NR TxD & Power Class Source: vivo
* R4-2016955 Email discussion summary for [97e][111] NR\_eMIMO\_UE\_RF Source: Moderator (Samsung)

## A.2.7 RAN4#98-e

* R4-2103302 Email discussion summary for [98e][112] NR\_TxD Source: Moderator (vivo)
* R4-2103390 Way forward on NR TxD Source: vivo
* R4-2103360 LS on Signaling scheme of Transparent TxD to RAN2, cc RAN1, RAN5 Source: RAN4
* R4-2103156 CR for TS 38.101-1: TxD requirements Source: Huawei, HiSilicon

## A.2.8 RAN4#98-e-bis

* R4-2105440 Email discussion summary for [98-bis-e][101] NR\_TxD Source: Moderator (vivo)
* R4-2105330 Way forward on NR TxD & Power Class Source:vivo
* R4-2105331 Way forward on MPR evaluation for NR TxD & UL-MIMO Source:vivo, Skyworks

## A.2.9 RAN4#99e

* R4-2107616 Reply LS to RAN4 on the capability of transparent TxD (RAN2) Type: LS in For: Information Original outgoing LS: -, to RAN4, cc RAN1, RAN5
* R4-2107919 Email discussion summary for [99-e][109] NR\_TxD Source: Moderator (Vivo)
* R4-2107740 Way Forward on NR TxD & Power Class Source: Vivo
* R4-2107981 Way Forward on SRS antenna switching requirements for TxD Source: OPPO
* R4-2107782 CR for TS 38.101-1 Tx diversity requirements (Postponed) Source: Huawei,HiSilicon, vivo, OPPO
* R4-2107781 Correction of general description of EN-DC related power class based on the TxD capability Source: vivo

Annex <X> (informative):
Change history

Use style "Heading 8" in TSs and "Heading 9" in TRs. Do not use "informative" in the title in TRs.

This is the last annex for TS/TSs which details the change history using the following table.
This table is to be used for recording progress during the WG drafting process till TSG approval of this TS/TR.
For TRs under change control, use one line per approved Change Request
Date: use format YYYY-MM
CR: four digits, leading zeros as necessary
Rev: blank, or number (max two digits)
Cat: use one of the letters A, B, C, D, F
Subject/Comment: for TSs under change control, include full text of the subject field of the Change Request cover
New vers: use format [n]n.[n]n.[n]n

|  |
| --- |
| **Change history** |
| **Date** | **Meeting** | **TDoc** | **CR** | **Rev** | **Cat** | **Subject/Comment** | **New version** |
| 2021-08 | RAN4#100-e | R4-2114358 |  |  |  | TR skeleton  | 0.0.1 |
| 2021-11 | RAN4#101-e | R4-2117790 |  |  |  | R4-2113009, TP for TR 38.837 on Annex part for Transparent Tx DiversityR4-2114970, TP for TR 38.837 on Requirements part for Transparent Tx Diversity | 0.1.0 |
| 2021-11 | RAN4#101-e | R4-2119975 |  |  |  | R4-2118282, TP for TR 38.837 on capability signaling and applicable releaseR4-2119979, TP to TR 38.837 for TxD’s impact on ULFPTx-related requirement | 0.2.0 |

Change history of this template:

|  |  |  |
| --- | --- | --- |
| 2001-07 | Copyright date changed to 2001; space character added before TTC in copyright notification; space character before first reference deleted. | 1.3.3 |
| 2002-01 | Copyright date changed to 2002. | 1.3.4 |
| 2002-07 | Extra Releases added to title area. | 1.3.5 |
| *2002-12* | *"TM" added to 3GPP logo.* | *1.3.6* |
| *2003-02* | *Copyright date changed to 2003.* | *1.3.7* |
| *2003-12* | *Copyright date changed to 2004. Chinese OP changed from CWTS to CCSA* | *14.0* |
| *2004-04* | *North American OP changed from T1 to ATIS* | *1.5.0* |
| *2005-11* | *Stock text of clause 3 includes reference to 21.905.*  | *1.6.0* |
| *2005-11* | *Caters for new TSG structure. Minor corrections.* | *1.6.1* |
| *2006-01* | *Revision marks removed.* | *1.6.2* |
| *2008-11* | *LTE logo line added, © date changed to 2008, guidance on keywords modified; acknowledgement of trade marks; sundry editorial corrections and cosmetic improvements* | *1.7.0* |
| *2010-02* | *3GPP logo changed for cleaner version, with tag line;LTE-Advanced logo line added; © date changed to 2010;editorial change to cover page footnote text;trade marks acknowledgement text modified;additional Releases added on cover page;proforma copyright release text block modified* | *1.8.0* |
| *2010-02* | *Smaller 3GPP logo file used.* | *1.8.1* |
| *2010-07* | *Guidance note concerning use of LTE-Advanced logo added.* | *1.8.2* |
| *2011-04-01* | *Guidance of use of logos on cover page modified; copyright year modified.* | *1.8.3* |
| *2013-05-15* | *Changed File Properties to MCC macro default.* *Removed R99, added Rel-12/13.**Modified Copyright year.**Guidance on annex X Change history.* | *1.8.4* |
| *2014-10-27* | *Updated Release selection on cover. In clause 3, added "3GPP" to TR 21.905.* | *1.8.5* |
| *2015-01-06* | *New Organizational Partner TSDSI added to copyright block.Old Releases removed.* | *1.9.0* |
| *2015-12-03* | *Provision for LTE Advanced Pro logo Update copyright year to 2016* | *1.10.0* |
| *2016-03-08* | *Standarization of the layout of the Change History table in the last annex.(Unreleased)* | *1.11.0* |
| *2016-06-15* | *Minor adjustment to Change History table heading* | *1.11.1* |
| *2017-03-13* | *Adds option for 5G logo on cover* | *1.12.0* |
| *2017-05-03* | *Smaller 5G logo to reduce file size* | *1.12.1* |
| *2019-02-25* | *Replacement of frames on cover pages by in-line text.**Clarification of help text on when to use 5G logo.Removal of defunct keywords frame on page 2.Add Rel-16, Rel-17 options, eliminated earlier, frozen, Releases (cover page, below title)Corrections to some guidance text, addition of guidance text concerning automatic page headers under Word 2016 ff.Use of modal auxiliary verbs added to Foreword.More explicit guidance on Bibliography and Index annexes.Converted to .docx format.* | *1.13.0* |
| *2019-09-12* | *Cover page table outline shown dotted for ease of logo selection. (Author to hide outline after logo selection.) User now needs to delete whole table rows instead of individual cells, which proved to be tricky.**Change of style for "notes" in the Foreword to normal paragraphs.**Insertion of new bookmarks, correction of location of existing bookmarks. (To improve navigation.)**Improvements to guidance text.* | *1.13.1* |
| *2021-06-18* | *Provision for 5G Advanced logo Update copyright year to 2021Additional guidance on the use of Heading 8/9 in annexes C, D and X.* | *1.14.0* |