**3GPP TSG RAN WG1 #117 R1-2403851**

**Fukuoka, Japan, May 20th – 24th, 2024**

**Agenda Item: 9.2.3**

**Source: Moderator (InterDigital, Inc.)**

**Title:** **FL Summary Support for 3TX CB-based Uplink; First Round**

**Document for: Discussion and Decision**

# Background

RAN plenary #112 approved the WID for NR MIMO Phase 5 [1]. The WID covers five objectives, where one of the described objectives is to specify 3-antenna-port codebook-based transmissions.

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| * Specify non-coherent UL codebook to facilitate 3-antenna-port codebook-based transmissions, without enhancement on UL full power transmission and without enhancement on SRS resource.

*Note: UL full power transmission mode 1 and 2 are not supported.* |

Following the agreed description of the objective for 3TX UE, the focus of the discussion in Rel-19 NR MIMO is restricted to,

* design of non-coherent UL 3TX codebook,
* reuse of existing SRS resource definition and dimensions,
* exclusion of full power modes 1 and 2.

In [2], the scope of the discussion for this meeting, and a list of all previous agreements related to this objective have been provided.

# Support for 3TX CB-based Operation

In the last two meetings, essential decisions on codebook design, SRS configuration, PTRS-DMRS association and support of M-TRP PUSCH have been made [2]. Towards the completion of the codebook-based operation, following proposals, based on companies’ contributions are prepared for the discussion and decision in RAN1 #117,

***Proposal 2.1:***

*For codebook-based UL transmission by a 3TX UE, subject to its capability,*

* A 3TX UE may report a maximum number of 3 layers,
* A 3TX UE may report a maximum number of SRS ports of up to 3 for a configured 4-port SRS resource.

***Proposal 2.2:***

*Update the agreement made in RAN1 #116bis as the following.*

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| ***Agreement****For a 3TX UE, to support 3-port SRS transmission with reusing a 4-port SRS resource, support the following for muting one of the ports of the configured 4-port SRS resource,**Option 3: Always a same port is muted, ~~e.g.,~~ i.e., the 4th port* |

***Proposal 2.3:***

*For codebook-based M-TRP PUSCH repetition by a 3TX UE, scheduled by DCI format 0\_1/0\_2,*

* Reuse Rel-17 M-TRP PUSCH repetition design, where the second precoding information field only indicates TPMI index, and applies same rank as indicated by the first precoding information field.

***Proposal 2.4:***

*For codebook-based M-TRP PUSCH repetition by a 3TX UE, scheduled by DCI format 0\_1/0\_2,*

* Introduce new tables as Table I, II, III for the second precoding information field, for maxRank=1 or 2 or 3, respectively.
	+ Table I: Second precoding information for 3 antenna ports if maxRank=1

|  |  |
| --- | --- |
| *Bit field* | *codebookSubset=NonCoherent* |
| *0* | *1 layer: TPMI=0* |
| *1* | *1 layer: TPMI=1* |
| *2* | *1 layer: TPMI=2* |
| *3* | *Reserved*  |

* + Table II: Second precoding information for 3 antenna ports if maxRank=2

|  |  |
| --- | --- |
| *Bit field* | *codebookSubset=NonCoherent* |
| *0* | *1 layer: TPMI=0* |
| *1* | *1 layer: TPMI=1* |
| *2* | *1 layer: TPMI=2* |
| *3* | *1 layer: Reserved*  |
| *0* | *2 layer: TPMI=0* |
| *1* | *2 layer: TPMI=1* |
| *2* | *2 layer: TPMI=2* |
| *3* | *2 layer: Reserved* |

* + Table III: Second precoding information for 3 antenna ports if maxRank=3

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| --- | --- |
| *Bit field* | *codebookSubset=NonCoherent* |
| *0* | *1 layer: TPMI=0* |
| *1* | *1 layer: TPMI=1* |
| *2* | *1 layer: TPMI=2* |
| *3* | *1 layer: Reserved*  |
| *0* | *2 layer: TPMI=0* |
| *1* | *2 layer: TPMI=1* |
| *2* | *2 layer: TPMI=2* |
| *3* | *2 layer: Reserved* |
| *0* | *3 layer: TPMI=0* |
| *1~3* | *3 layer: reserved* |

Table 1 - Companies’ views

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| **Company** | **Perspective** |
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# Support for 3TX Non-CB-Based Operation

Non-CB-based operation is an essential for supporting reciprocity-based uplink transmssion. During the offline discussion [3], it has been mentioned by some companies that this mode of operation is already partially supported by the specifications, and it can be fully supported by the following proposals,

***Proposal 3.1:***

*For non-codebook-based UL transmission by a 3TX UE, subject to its capability,*

* A 3TX UE may report a maximum number of 3 layers.

***Proposal 3.2***

*To support non-codebook-based UL transmission by a 3TX UE,*

* A single SRS resource set, with up to NSRS=3 single-port SRS resources, is configured.

***Proposal 3.3***

*To support non-codebook-based UL transmission by a 3TX UE, for SRI indication, re-use the legacy-based solution by only considering the states corresponding to NSRS=2 and NSRS=3.*

Table 2 - Companies’ views

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| **Company** | **Perspective** |
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# Support for 3TX Antenna Switching

During the offline discussion [3], several companies have mentioned that due to the conclusion in RAN1 #115, antenna switching should not be discussed any further. However, given the RAN4 LS [4], the very little required effort, an ample remaining time for this feature and the importance of this functionality for completeness of 3TX operation, several other companies have expressed strong interest in support of basic antenna switching for a 3TX UE. Based on the discussion and companies’ contributions, the following proposals are prepared for discussion and decision in RAN1 #117,

***Proposal 4.1***

*For performing antenna switching for DL CSI acquisition by a 3TX UE,*

* Support 3T3R and 3T6R switching cases.

***Proposal 4.2***

*For performing antenna switching for DL CSI acquisition by a 3TX UE, for the case with 3T3R,*

* Up to two SRS resource sets each with one 3-port SRS resource can be configured,
	+ FFS supported resource types, e.g., 'semi-persistent', 'periodic', 'aperiodic'

***Proposal 4.3***

*For performing antenna switching for DL CSI acquisition by a 3TX UE, for the case with 3T6R,*

* Up to two SRS resource sets each with one 3-port SRS resource can be configured, where each SRS resource is transmitted in different symbols,
	+ FFS supported resource types, e.g., 'semi-persistent', 'periodic', 'aperiodic'

Table 3 - Companies’ views

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| **Company** | **Perspective** |
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# Other Potential Issues

Based on the offline discussion [3], several companies have expressed their interest on further discussion on these topics,

* Support of partial-coherent codebook for 3TX UE operation,
* Support of UL PRG for 3TX UE operation.

Given the required effort and the fact that support of partial-coherent codebook for 3TX UE is clearly out of the scope of the WID, some guidance from RAN is needed to make sure that this aspect of 3TX UE will be done according to the RAN completion plan for Rel-19. As for the support of UL PRG for 3TX UE, there are two issues come to mind. Firstly, this would be a new feature that has not been employed by any of earlier UE categories, i.e., 2TX, 4TX and 8TX, hence companies may require additional time for its evaluation. Also, it has not been captured as part of the current scope for Rel-19 3TX work plan.

Having said that, companies are still encouraged to provide their views as how we should make progress on these topics of interest.

Table 4 - Companies’ views

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| **Company** | **Perspective** |
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# Feature-lead Proposals for Approval

# Round 1

Void

# Round 2

Void

# Round 3

Void

# List of Companies’ Proposals

|  |  |
| --- | --- |
| InterDigital, Inc. | ***Proposal 1:*** *To support non-codebook-based precoding by a 3TX UE, reuse the existing SRI indication tables up to .* ***Proposal 2:*** *To enable non-codebook-based precoding by a 3TX UE, support {3T3R, 3T6R} cases for antenna switching.* ***Proposal 3:*** *Study further codebook enhancements to adapt the precoders for the cross-polarized case.*  |
| MediaTek Inc. | ***Proposal 1****: Not support of reverting the conclusion on SRS antenna switching in Rel-19 MIMO.****Proposal 2****: Whether to support non-codebook transmission enhancements for 3Tx should be decided in RAN plenary****Proposal 3****: Whether to support partial coherent codebooks for 3Tx should be decided in RAN plenary** If partial coherent codebooks are supported, select the codebooks as mentioned below with TPMI size not exceeding the 4Tx partial-coherent codebook size.

*A black background with a black square  Description automatically generated with medium confidence* |
| Huawei, HiSilicon | ***Proposal 1:*** *To facilitate codebook-based 3Tx UL transmission, support to report the maximum number of layers and the maximum number of SRS ports per resource as 3.* |
| Intel Corporation | ***Proposal 1:*** *Consider a 2-bit second precoding information field (Table 1) in the DCI format 0\_1/0\_2 for mTRP PUSCH repetitions with 3 antenna ports.*  ***Proposal 2:*** *For mTRP PUSCH repetitions, same table as defined for PTRS-DMRS association is used for second PTRS-DMRS association field.* ***Proposal 3:*** *It is beneficial to support antenna switching for 3 Tx for DL CSI acquisition (3T6R).* * FFS: 3T4R and 3T8R

***Proposal 4:**** It is beneficial to support partial coherent codebook for 3 Tx.
 |
| Spreadtrum Communications | ***Proposal 1:*** *Clarification is necessary for the maximum port number of 4-port SRS using muting methods.****Proposal 2:*** *No update is needed for support of 3Tx codebook-based uplink transmission under full-power Mode 0.* |
| TCL | *Proposal 1: There is no need to update the existing specification for scale factor to support UL 3Tx transmission.* |
| Samsung | ***Proposal 1:*** *Introduce a UE capability for reporting a value of 3 for the maximum number of layers by codebook based 3TX PUSCH transmission.****Proposal 2:*** *Introduce a UE capability for reporting a value of 3 for the maximum number of layers by non-codebook based 3TX PUSCH transmission.****Proposal 3:*** *Support the bitwidth of SRI field for non-codebook based 3TX PUSCH transmission as up to 3 bits.****Proposal 4:*** *Support to reuse SRS features in Rel-18 for SRS resource set with usage of codebook based 3TX PUSCH transmission, without introducing new UE capabilities (i.e., reusing Rel-18 UE capabilities).****Proposal 5:*** *To support codebook based 3TX PUSCH transmission with multi-TRP TDM repetition, support Second TPMI field with 2 bits for maxRank = 1, 2, or 3.****Proposal 6:*** *Support non-codebook based 3TX PUSCH transmission with multi-TRP TDM repetition.** Two SRS resource sets, each of with up to 3 of 1-port SRS resources are configured

***Proposal 7:*** *To support non-codebook based 3TX PUSCH transmission with multi-TRP TDM repetition, support Second SRI field with 1 or 2 bits considering the combination of Lmax and NSRS.** (Lmax, NSRS) = (1, 2), (2, 2), (2, 3) : 1 bit
* (Lmax, NSRS) = (1, 3), (2, 3), (3, 3) : 2 bits

***Proposal 8:*** *For indication of PTRS-DMRS association to support 3TX PUSCH transmission with multi-TRP TDM repetition, reuse the principle of Rel-17 multi-TRP TDM repetition except the following case.** When 2 PTRS ports are configured, and maxRank = 2, Second PTRS-DMRS association field is used to indicate the association between PTRS port(s) and DMRS port(s) for 2nd SRS resource set (i.e.,2nd TRP).
* Note: The above solution is same as when maxRank = 3 or 4 in the current specification.
 |
| vivo | ***Proposal 1:*** *For codebook based 3Tx, the UE capability of MIMO-LayersUL needs to be extended for three-layers.****Proposal 2:*** *For codebook based 3Tx, the UE capability of maxNumberSRS-Ports-PerResource needs to be extended for 3-port SRS.****Proposal 3:*** *Support to define UL PRG, the DL PRG definition can be taken as baseline.* |
| ZTE | ***Proposal 1:*** *Regarding 3Tx UL transmission, support non-codebook-based transmission.** Supporting up to 3 SRS resources in one SRS resource set, and reusing legacy SRI indication mechanism.

***Proposal 2:*** *Regarding antenna switching for 3Tx UE, at least support ‘3T6R’,** In such case, two 4-port SRS resources are configured, and the 4th SRS port is always muted in each SRS resource.
* FFS: whether ‘3T3R’ and ‘3T8R’ can be additionally supported.

***Proposal 3:*** *Regarding 3Tx UL transmission, RAN1 discussion on partially-coherent transmission should be postponed till further enhancements on non-codebook and 3TyR antenna switching are completed.* |
| Apple | ***Proposal 1:*** *If there is consensus in RAN1 to specify partial coherent uplink precoding by a 3TX UE, the precoders given by Tables I/II/III can be supported for 3 antenna ports and codebookSubset = partialAndNonCoherent* * For maxRank equals to 1, TPMI field is 3 bits for DFT-s-OFDM and CP-OFDM
* For maxRank equals to 2 or 3, TPMI field is 4 bits for CP-OFDM

***Proposal 2:*** *If there is consensus in RAN1 to specify partial coherent uplink precoding by a 3TX UE, PTRS-DMRS association follows same procedure as of non-coherent 3Tx.**Table I. Precoding matrix W for single-layer transmission using 3 antenna ports with transform precoding disabled or enabled.**A black background with a black square  Description automatically generated with medium confidence**Table II. Precoding matrix W for two-layer transmission using 3 antenna ports with transform precoding disabled.****A black background with a black square  Description automatically generated with medium confidence****Table III. Precoding matrix W for three-layer transmission using 3 antenna ports with transform precoding disabled.****A black background with a black square  Description automatically generated with medium confidence*** |
| Lenovo | ***Proposal 1:*** *Support Rel-18 STxMP schemes for a 3Tx UE.****Proposal 2:*** *Support table 1 to table 3 to indicate the second TPMI field.****Proposal 3:*** *For a 3Tx UE, the transmission precoder is selected from the uplink codebook that has a number of antenna ports equals to 3 other than nrofSRS-Ports.****Proposal 4:*** *Support to specify partial-coherent codebook for a 3Tx UE.****Proposal 5:*** *Consider the following methods to design partial-coherent codebooks for 3Tx transmission:** Method 1: based on 4Tx partial-coherent codebook;
* Method 2: based on 2Tx full-coherent codebook;

***Proposal 6:*** *Support at least 3T3R and 3T6R configurations for performing antenna switching for a 3TX UE.****Proposal 7:*** *Support same SRS configuration for 3T3R as 1T1R and same SRS configuration for 3T6R as 1T2R except the number of SRS port of a SRS resource.* |
| CATT | ***Proposal 1:*** *To facilitate the TPMI indication scheme for non-coherent precoders for 3Tx, one TPMI table is introduced for DFT-s-OFDM and CP-OFDM with maxRank = 1 and one TPMI table is introduced for CP-OFDM with maxRank = 2 or 3:*

|  |  |
| --- | --- |
| *Bit field mapped to index* | *codebookSubset = nonCoherent, maxRank = 1* |
| *0* | *1 layer: TPMI=0* |
| *1* | *1 layer: TPMI=1* |
| *2* | *1 layer: TPMI=2* |
| *3* | *Reserved* |

|  |  |
| --- | --- |
| *Bit field mapped to index* | *codebookSubset= nonCoherent, maxRank = 2 or 3* |
| *0* | *1 layer: TPMI=0* |
| *1* | *1 layer: TPMI=1* |
| *2* | *1 layer: TPMI=2* |
| *3* | *2 layers: TPMI=0* |
| *4* | *2 layers: TPMI=1* |
| *5* | *2 layers: TPMI=2* |
| *6* | *3 layers: TPMI=0* |
| *7* | *Reserved* |

***Proposal 2:*** *For partial-coherent codebook for UL 3Tx, all the precoders in non-coherent codebook for UL 3Tx are included.**Proposal 3: Adopt the following partial coherent precoders for UL 3Tx:** Rank-1: $\frac{1}{\sqrt{3}}\left[\begin{array}{c}1\\0\\1\end{array}\right]$,$ \frac{1}{\sqrt{3}}\left[\begin{array}{c}1\\0\\-1\end{array}\right]$, $\frac{1}{\sqrt{3}}\left[\begin{array}{c}1\\0\\j\end{array}\right]$, $\frac{1}{\sqrt{3}}\left[\begin{array}{c}1\\0\\-j\end{array}\right]$;
* Rank-2: $\frac{1}{\sqrt{3}}\left[\begin{matrix}1&0\\0&1\\1&0\end{matrix}\right]$, $\frac{1}{\sqrt{3}}\left[\begin{matrix}1&0\\0&1\\-1&0\end{matrix}\right]$, $\frac{1}{\sqrt{3}}$ $\left[\begin{matrix}1&0\\0&1\\j&0\end{matrix}\right]$, $\frac{1}{\sqrt{3}}$ $\left[\begin{matrix}1&0\\0&1\\-j&0\end{matrix}\right]$;
* Rank-3: $\frac{1}{√5}\left[\begin{matrix}1&1&0\\0&0&1\\1&-1&0\end{matrix}\right]$, $\frac{1}{\sqrt{5}}\left[\begin{matrix}1&1&0\\0&0&1\\j&-j&0\end{matrix}\right]$.

***Proposal 4:*** *Non-codebook based UL 3Tx is supported, with up to 3 one-port SRS resources configured in an SRS resource set and the legacy SRI indication scheme reused.****Proposal 5:*** *Support 3T6R and 3T4R for SRS antenna switching for 3Tx.****Proposal 6:*** *On SRS configuration for 3T6R, the legacy SRS configuration schemes for 1T2R are reused by replacing the two 1-port SRS resources with two 4-port SRS resources each with one port muted.****Proposal 7:*** *On SRS configuration for 3T4R, the legacy SRS configuration schemes for 1T2R are reused by replacing one 1-port SRS resource with a 4-port SRS resource with one port muted.* |
| CMCC | ***Proposal 1:*** *Support SRS antenna switching for 3T3R, 3T4R and 3T6R UE.****Proposal 2:*** *For non-codebook-based precoding for 3TX UE, up to 3 bits for SRI indication are needed, and add SRI indication tables as shown in Table 1, Table 2, and Table 3.* |
| LG Electronics | ***Proposal 1:*** *For 3 Tx partial coherent codebook, adopt following codebook structure where the alphabet of x and y can be {1, j, -1, -j}.*

|  |  |
| --- | --- |
|  | *Codebook* |
| *Rank 1* | $\left[\begin{array}{c}1\\x\\0\end{array}\right]$ |
| *Rank 2* | $\left[\begin{array}{c}\begin{matrix}1&1\end{matrix}\\\begin{matrix}x&y\end{matrix}\\\begin{matrix}0&0\end{matrix}\end{array}\right]$ *,* $\left[\begin{array}{c}\begin{matrix}1&0\end{matrix}\\\begin{matrix}x&0\end{matrix}\\\begin{matrix}0&1\end{matrix}\end{array}\right]$ |
| *Rank 3* | $$\left[\begin{array}{c}\begin{matrix}1&1&0\end{matrix}\\\begin{matrix}x&y&0\end{matrix}\\\begin{matrix}0&0&1\end{matrix}\end{array}\right] $$ |

***Proposal 2:*** *For 3-port non-codebook-based PUSCH transmission, introduce value of “3” for the number of supported uplink MIMO layers.****Proposal 3:*** *For 3-port codebook-based PUSCH transmission, scale factor s should be the ratio of the number of antenna ports with a non-zero PUSCH transmission power to 3 when a 3 Tx antenna UE reported the number of supported uplink MIMO layers as 3.****Proposal 4:*** *Support 3-port SRS antenna switching, i.e., specify 3TyR configuration.**FFS: Supported y value of 3TyR* |
| Fujitsu | ***Proposal 1:*** *For codebook-based transmission with 3 ports, RAN1 to discuss the TPMI indication for PUSCH repetition in multi-TRP.****Proposal 2:*** *For 3Tx UE, RAN1 to discuss antenna switching operation at least for 3T3R and 3T6R.* |
| Xiaomi | ***Proposal 1:*** *To support the multi-TRP based TDM repetition scheme, the second TPMI field only indicate the TPMI while the first TPMI field indicate both the TPMI and TRI.* ***Proposal 2:*** *To support the multi-TRP based TDM repetition scheme, the following tables for the second TPMI indication of 3Tx codebook based PUSCH transmission are suggested as below,**Table 1: Second Precoding information and number of layers, for 3 antenna ports, if transform precoder is disabled, maxRank = 2 or 3, and ul-FullPowerTransmission is not configured or configured to fullpower*

|  |  |
| --- | --- |
| *Bit field mapped to index* | *codebookSubset= nonCoherent* |
| *0* | *1 layer: TPMI=0* |
| *1* | *1 layer: TPMI=1* |
| *2* | *1 layer: TPMI=2* |
| *0* | *2 layers: TPMI=0* |
| *1* | *2 layers: TPMI=1* |
| *2* | *2 layers: TPMI=2* |
| *3* | *reserved* |
| *0* | *3 layers: TPMI=0* |
| *1-3* | *reserved* |

*Table 2: Second Precoding information and number of layers, for 3 antenna ports, if transform precoder is disabled, maxRank = 1, and ul-FullPowerTransmission is not configured or configured to fullpower*

|  |  |
| --- | --- |
| *Bit field mapped to index* | *codebookSubset= nonCoherent* |
| *0* | *1 layer: TPMI=0* |
| *1* | *1 layer: TPMI=1* |
| *2* | *1 layer: TPMI=2* |
| *3* | *reserved* |

***Proposal 3:*** *For 3Tx UE, the enhancement of SRS for antenna switching should be supported.****Proposal 4:*** *For 3Tx UE, at least antenna switching configuration of 3T4R should be supported.****Proposal 5:*** *3T6R or 3T8R can be further supported if 6Rx or 8Rx is also be considered for 3Tx UE.****Proposal 6:*** *Corresponding to the antenna switching configuration of 3T4R, the following methods for SRS resource set configuration can be considered:** Alt.1: For P/SP SRS, 1 SRS resource set can be configured containing 4 single-port SRS resources;
	+ For AP SRS, 1 or 2 SRS resource sets can be configured while each resource set containing 4 or 2 single-port SRS resources;
* Alt.2: For P/SP/AP SRS, 1 SRS resource set can be configured containing 2 2-port SRS resources;

***Proposal 7:*** *Suggest to further study the optimization on the guard period configurations for each antenna switching configuration for 3Tx UE.****Proposal 8:*** *Support the non-codebook based PUSCH transmission for 3Tx UE.****Proposal 9:*** *To support the NCB PUSCH, consider the following enhancements:** SRS configuration for sTRP operation: one SRS resource set can be configured which contains at most 3 single port SRS resources;
* SRS configuration for mTRP operation: two SRS resource sets can be configured with equal number of SRS resources, each SRS resource set contains at most 3 single port SRS resources;
* UE reports the capability of supporting a maximum of 3 layers;

***Proposal 10:*** *The maximum number of non-zero SRS ports reported by 3Tx UE is 3.****Proposal 11:*** *For the maximum number of MIMO layers reported by 3Tx UE, support reporting the maximum number of UL MIMO layers equals 3.* |
| NEC | ***Proposal 1:*** *At least support to design partial coherent codebook for 3Tx.*  |
| Google | ***Proposal 1:*** *Clarify whether the NW can configure a 3-port SRS resource in an SRS resource set for CB for uplink full power mode 2 for a 4-port or 8-port UE.****Proposal 2:*** *Support PT-RS port specific power boosting for 3TX UE, where the power boosting factor for PT-RS port x is* $10log\_{10}L\_{x}Q\_{p}$*, where* $L\_{x}$ *is the number of layers associated with PUSCH ports that associated with the PT-RS port x, and* $Q\_{p}$ *is the number of PT-RS ports.****Proposal 3:*** *Support to define the uplink PRG to improve the reliability for 3-port PUSCH transmission.** As a starting point, support the NW to indicate whether the UE should transmit the PUSCH based on 1 or 2 uplink PRGs
 |
| Transsion Holdings | ***Proposal 1:*** *Support the tables for 3 antenna ports for ‘Second precoding information indication’for M-TRP PUSCH repetition:** For maxRank equals to 1, Table 1 can be shown as:

*Table 1: Second precoding information indication, for 3 antenna ports, maxRank = 1*

|  |  |
| --- | --- |
| *Bit field mapped to index* | *codebookSubset= nonCoherent* |
| *0* | *1 layer: TPMI=0* |
| *1* | *1 layer: TPMI=1* |
| *2* | *1 layer: TPMI=2* |
| *3* | *Reserved* |

* For maxRank equals to 2 or 3, Table 2 can be shown as:

*Table 2: Second precoding information indication, for 3 antenna ports, maxRank = 2 or 3*

|  |  |
| --- | --- |
| *Bit field mapped to index* | *codebookSubset= nonCoherent* |
| *0* | *1 layer: TPMI=0* |
| *1* | *1 layer: TPMI=1* |
| *2* | *1 layers: TPMI=2* |
| *3* | *1 layers: Reserved*  |
| *0* | *2 layers: TPMI=0* |
| *1* | *2 layers: TPMI=1* |
| *2* | *2 layers: TPMI=2* |
| *3* | *2 layers: Reserved*  |
| *0* | *3 layers: TPMI=0* |
| *1~3* | *3 layers: Reserved* |

***Proposal 2:*** *A new rule for determining PUSCH antenna port(s) is necessary for 3 antenna ports codebook based PUSCH transmission.****Proposal 3:*** *Support to enhance the following UE capability to support UL transmission by a 3TX UE:** MIMO-LayersUL can be enhanced to include three-layers.
* maxNumberSRS-Ports-PerResource can be enhanced to include 3-port SRS.
 |
| OPPO | ***Proposal 1:*** *If SRS antenna switching is supported in Rel-19,** At least 3T6R is introduced to resolve the LS from RAN4.
* Further study the specification impact, e.g. the number of SRS resource set, SRS resource set configuration, the number of SRS port(s) per SRS resource.

***Proposal 2:*** *Introduce a UE capability for reporting a value of 3 for the maximum number of layers.** MIMO-LayersUL ENUMERATED {oneLayer, twoLayers, threeLayers, fourLayers}

***Proposal 3:*** *Introduce a UE capability for reporting a value of 3 for the maximum number of SRS ports per resource.** maxNumberSRS-Ports-PerResource ENUMERATED {n1, n2, n3, n4}
 |
| Nokia | ***Proposal 1:*** *Support 3T3R and 3T6R antenna switching in Rel-19, pending RAN plenary clarification on Rel-19 WID scope.****Proposal 2:*** *Support 3T4R and 3T8R antenna switching in Rel-19, pending RAN plenary clarification on Rel-19 WID scope.****Proposal 3:*** *Support 3Tx non-codebook transmission in Rel-19, pending RAN plenary clarification.****Proposal 4:*** *Support a new UE capability with “3Tx non-codebook transmission”.****Proposal 5:*** *One SRS resource set with usage “non-codebook” can be configured to support 3Tx NCB with maximum number of 3 resources.****Proposal 6:*** *Reuse Rel-15 4Tx NCB SRI tables with limitation of maximum rank of 3 for 3Tx NCB.****Proposal 7:*** *Support to use antenna group concept for 3Tx partially coherent codebook design, pending on RAN plenary clarification on Rel-19 3Tx scope.****Proposal 8:*** *Support layer splitting between the two antenna groups, with 2Tx Rel-15 uplink precoders.****Proposal 9:*** *support these rank-1, rank-2, and rank-3 precoders as listed:*Rank 1: (7 precoders)

|  |  |
| --- | --- |
| *TPMI index* | *(ordered from left to right in increasing order of TPMI index)* |
| *0 – 6* | $$\frac{1}{√3}\left[\begin{matrix}1\\0\\0\end{matrix}\right]$$ | $$\frac{1}{√3}\left[\begin{matrix}0\\1\\0\end{matrix}\right]$$ | $$\frac{1}{√3}\left[\begin{matrix}1\\1\\0\end{matrix}\right]$$ | $$\frac{1}{√3}\left[\begin{matrix}1\\-1\\0\end{matrix}\right]$$ | $$\frac{1}{√3}\left[\begin{matrix}1\\j\\0\end{matrix}\right]$$ | $$\frac{1}{√3}\left[\begin{matrix}1\\-j\\0\end{matrix}\right]$$ | $\frac{1}{√3}\left[\begin{matrix}0\\0\\1\end{matrix}\right]$*-* | *-* |

Rank 2: (9 precoders)Layer split = (2,0):

|  |  |
| --- | --- |
| *TPMI index* | *(ordered from left to right in increasing order of TPMI index)* |
| *0 – 2* | $$\frac{1}{√2√3}\left[\begin{matrix}1&0\\0&1\\0&0\end{matrix}\right]$$ | $$\frac{1}{√2√3}\left[\begin{matrix}1&1\\1&-1\\0&0\end{matrix}\right]$$ | $$\frac{1}{√2√3}\left[\begin{matrix}1&1\\j&-j\\0&0\end{matrix}\right]$$ |  |  |  | *-* | *-* |

Layer split = (1,1):

|  |  |
| --- | --- |
| *TPMI index* | *(ordered from left to right in increasing order of TPMI index)* |
| *3 – 8* | $$\frac{1}{√2√3}\left[\begin{matrix}1&0\\0&0\\0&1\end{matrix}\right]$$ | $$\frac{1}{√2√3}\left[\begin{matrix}0&0\\1&0\\0&1\end{matrix}\right]$$ | $$\frac{1}{√2√3}\left[\begin{matrix}1&0\\1&0\\0&1\end{matrix}\right]$$ | $$\frac{1}{√2√3}\left[\begin{matrix}1&0\\-1&0\\0&1\end{matrix}\right]$$ | $$\frac{1}{√2√3}\left[\begin{matrix}1&0\\j&0\\0&1\end{matrix}\right]$$ | $$\frac{1}{√2√3}\left[\begin{matrix}1&0\\-j&0\\0&1\end{matrix}\right]$$ | *-* | *-* |

Rank 3: (3 precoders)Layer split = (2,1):

|  |  |
| --- | --- |
| *TPMI index* | *(ordered from left to right in increasing order of TPMI index)* |
| *0 – 2* | $$\frac{1}{√3√3}\left[\begin{matrix}1&0&0\\0&1&0\\0&0&1\end{matrix}\right]$$ | $$\frac{1}{√3√3}\left[\begin{matrix}1&1&0\\1&-1&0\\0&0&1\end{matrix}\right]$$ | $$\frac{1}{√3√3}\left[\begin{matrix}1&1&0\\j&-j&0\\0&0&1\end{matrix}\right]$$ |  |  |  | *-* | *-* |

 |
| Sharp | ***Proposal 1:*** *RAN1 should study how to determine the cyclic shift for 3Tx UE.****Proposal 2:*** *When* $N\_{ap}^{SRS}=4$ *for 3Tx UE,* $\overbar{N}\_{ap}^{SRS}$ *should be set to 3.****Proposal 3:*** *Introduce a new* $n\_{SRS}^{cs,max}$ *set to 24 when* $K\_{TC}=2$ *for 3Tx UE.* |
| NTT DOCOMO, INC. | ***Proposal 1:*** *Second precoding information field of M-TRP PUSCH repetition of 3Tx reuse Rel-17 M-TRP PUSCH repetition design, i.e., Second precoding information field only indicates TPMI index and applies same rank as indicated by Precoding information and number of layers field.****Proposal 2:*** *Introduce new tables as Table I, II, III for Second precoding information field for M-TRP PUSCH repetition for 3Tx, for maxRank=1 or 2 or 3, respectively.** Table I: Second precoding information for 3 antenna ports if maxRank=1

|  |  |
| --- | --- |
| *Bit field* | *codebookSubset=NonCoherent* |
| *0* | *1 layer: TPMI=0* |
| *1* | *1 layer: TPMI=1* |
| *2* | *1 layer: TPMI=2* |
| *3* | *Reserved*  |

* Table II: Second precoding information for 3 antenna ports if maxRank=2

|  |  |
| --- | --- |
| *Bit field* | *codebookSubset=NonCoherent* |
| *0* | *1 layer: TPMI=0* |
| *1* | *1 layer: TPMI=1* |
| *2* | *1 layer: TPMI=2* |
| *3* | *1 layer: Reserved*  |
| *0* | *2 layer: TPMI=0* |
| *1* | *2 layer: TPMI=1* |
| *2* | *2 layer: TPMI=2* |
| *3* | *2 layer: Reserved* |

* Table III: Second precoding information for 3 antenna ports if maxRank=3

|  |  |
| --- | --- |
| *Bit field* | *codebookSubset=NonCoherent* |
| *0* | *1 layer: TPMI=0* |
| *1* | *1 layer: TPMI=1* |
| *2* | *1 layer: TPMI=2* |
| *3* | *1 layer: Reserved*  |
| *0* | *2 layer: TPMI=0* |
| *1* | *2 layer: TPMI=1* |
| *2* | *2 layer: TPMI=2* |
| *3* | *2 layer: Reserved* |
| *0* | *3 layer: TPMI=0* |
| *1~3* | *3 layer: reserved* |

***Proposal 3:*** *Second precoding information field for M-TRP PUSCH repetition for 3Tx is 2 bits for maxRank=1 or 2 or 3.* |
| Ericsson | ***Proposal 1:*** *If time is available in the Rel-19 work for it, 8 partially coherent precoders are added to the 3 Tx codebook that are generated by setting a same row of all 4 Tx precoders to zero (‘port blanking’).****Proposal 2:*** *If time is available in the Rel-19 work for it, consider defining a maximum 3-layer capability for non-codebook based operation.****Proposal 3:*** *Adapt non-full power PUSCH power scaling in 3 Tx transmission to divide the non-zero PUSCH ports by factor of 3.****Proposal 4:*** *If time is available in the Rel-19 work for it, support 3T3R antenna switching using one muted 4-port SRS resource.****Proposal 5:*** *If time is available in the Rel-19 work for it, support 3T6R antenna switching using two muted 4-port SRS resources.****Proposal 6:*** *Do not support 3T4R antenna switching in Rel-19.* |
| Qualcomm Incorporated | ***Proposal 1:*** *update the agreement made in RAN1 #116bis as the following.****Agreement****For a 3TX UE, to support 3-port SRS transmission with reusing a 4-port SRS resource, support the following for muting one of the ports of the configured 4-port SRS resource,** Option 3: Always a same port is muted, ~~e.g.~~ i.e., the 4th port

***Proposal 2:*** *if noncodebook based 3-Tx PUSCH is supported in Rel-19, introduce configuration of an SRS resource set with 3 single port SRS resources for usage of noncodebook.*  |

# RAN1 Agreements for Sub-agenda 9.2.3

**RAN1 #116**

**Agreement**

For non-coherent uplink precoding by a 3TX UE, at least following precoders are supported for single-layer transmission.

$$\frac{1}{\sqrt{3}}\left[\begin{array}{c}1\\0\\0\end{array}\right],\frac{1}{\sqrt{3}}\left[\begin{array}{c}0\\1\\0\end{array}\right],\frac{1}{\sqrt{3}}\left[\begin{array}{c}0\\0\\1\end{array}\right]$$

**Agreement**

For non-coherent uplink precoding by a 3TX UE, at least following precoders are supported for two-layer transmission.

$\frac{1}{\sqrt{3}}\left[\begin{matrix}1&0\\0&1\\0&0\end{matrix}\right]$, $\frac{1}{\sqrt{3}}\left[\begin{matrix}1&0\\0&0\\0&1\end{matrix}\right]$, $\frac{1}{\sqrt{3}}$ $\left[\begin{matrix}0&0\\1&0\\0&1\end{matrix}\right]$

**Agreement**

For non-coherent uplink precoding by a 3TX UE, at least following precoders are supported for three-layer transmission.

$$\frac{1}{\sqrt{3}}\left[\begin{matrix}1&0&0\\0&1&0\\0&0&1\end{matrix}\right]$$

**Agreement**

For SRS configuration supporting codebook-based UL transmission by a 3TX UE, down-select one of

* Alt1 – Support configuration of X 4-port SRS resources in a resource set where one the ports is muted
* Alt2 – Support configuration of X SRS resources with equal/unequal number of ports (e.g. 2 + 1 or 1 + 1 + 1) in a resource set,

The value for X is FFS, and it will be determined according to the selected alternative.

**Agreement**

For a 3TX UE, down-select one of the following options for the number of PTRS ports,

* Option-1: A single PTRS port is supported.
* Option- 2: Up to 2 PTRS port may be configured.

**Agreement**

For a 3-antenna-port codebook-based UL transmission, study PTRS-DMRS association.

**Agreement**

For a 3-antenna-port codebook-based UL transmission, study power split for each port of SRS and PUSCH.

**Agreement**

For codebook-based uplink transmission by a 3TX UE, support full-power Mode 0, subject to UE capability.

**Conclusion**

There is no consensus in RAN1 to support antenna switching for 3TX UE in Rel-19

**Agreement**

For performance evaluation of 3TX UE, adopt the following Table as the reference EVM for LLS evaluation

* Companies may provide additional evaluation results per their case of interest
* LLS is optionally used for 3Tx UL evaluation, if needed

|  |  |
| --- | --- |
| **Parameter** | **Value** |
| Carrier Frequency | 3.5 GHz |
| Waveform | CP-OFDM |
| SCS | 30 KHz |
| System bandwidth | 20 MHz, 100 MHz |
| Scheduled PRBs | 5, 25, 50, 260 PRBs |
| gNB RX antenna setup and port layouts(𝑀,𝑁,𝑃,𝑀𝑔,𝑁𝑔,𝑀𝑝,𝑁𝑝) | (8,8,2,1,1,4,8) with (𝑑H, 𝑑V) = (0.5, 0.8)𝜆(4,4,2,1,1,4,4) with (𝑑H, 𝑑V) = (0.5, 0.8)𝜆(2,2,2,1,1,2,2) with (dH , dV ) = (0.5, 0.5)λ |
| UE speed | 3 Km/h |
| Number of Layers | Adaptive, Fixed (reported by company)  |
| AMC | Adaptive, Fixed (reported by company)  |
| DMRS configuration | Type 1; 1 front loaded + 1 additional symbol |
| Channel estimation | Real |
| Channel Model | CDL-A (30ns), CDL-B (100ns), CDL-C (300ns) |

**Agreement**

For performance evaluation of 3TX UE, adopt the following Table as the reference EVM for SLS evaluation.

* Companies may provide additional evaluation results per their case of interest.

Note: The considered EVM is to be used as a baseline set of assumption for future potential studies related to 3TX.

|  |  |
| --- | --- |
| **Parameter** | **Value** |
| Frequency range | 3.5 GHz |
| Multiple access | OFDMA  |
| Numerology | 14 CP-OFDM symbol slotSCS , 30 KHz   |
| Scenario | eMBB:Dense Urban (200m), 3.5GHz Outdoor FWA:UMa (500m), 3.5GHz |
| UE Outdoor/Indoor (%) | eMBB:80%, 20%Outdoor FWA:100%, 0% |
| System bandwidth | 20 MHz, 100 MHz  |
| gNB RX antenna setup and port layouts(𝑀,𝑁,𝑃,𝑀𝑔,𝑁𝑔,𝑀𝑝,𝑁𝑝)  | (8,8,2,1,1,4,8) with (𝑑H, 𝑑V) = (0.5, 0.8)𝜆(4,4,2,1,1,4,4) with (𝑑H, 𝑑V) = (0.5, 0.8)𝜆Optional: Classical: two 8x1 xpols, 4λ apart; 4 TXRUs tilt=[104°]  |
| gNB antenna radiation pattern parameters | * Outdoor/Indoor

Per 38.901, Table 7.3-1  |
| gNB receiver noise figure | 5dB  |
| gNB receiver | MMSE-IRC |
| gNB scheduler | Single user with proportional fair |
| Modulation | -    Up to 64 QAM  -    Up to 256QAM   |
| MIMO scheme | SU-MIMO with rank adaptation |
| UE speed | 3 Km/h |
| UE antenna config  | eMBB:* Xpol+1pol; isotropic ULA
* Xpol+1pol; 110°, 4 dBi

Outdoor FWA:* Xpol+1pol; isotropic ULA
* 3 directional 1pol: 110°, 4 dBi
 |
| Traffic model | -    FTP model 1: Packet size 500KB, RU= 50% and suggested low/high RU of values of 20% and 70%-   Full buffer (optional)  |
| Suggested benchmarking | Rel-15 2Tx non-coherent |
| Precoder granularity | Wideband  |
| Power control | Open loop, -    alpha = 0.8-    P0= -50, -80 dBm  to be selected according to the deployment scenario  |
| UE power rating | eMBB:23 dBm, UL FPTx mode 0 or Rel-15 power scaling Outdooe FWA:31 dBm, UL FPTx mode 0 |
| Metric | UL mean-user throughput, 5%-ile and 95%-ile UPT |

**Agreement**

For performance evaluation of 3TX UE, consider following reference configurations,

* A linear array (1D) of single-polarized antenna configuration with a spacing of 0.5λ,
	+ For example: $|\leftarrow 0.5λ\rightarrow |\leftarrow 0.5λ\rightarrow $**|**
* A configuration of a cross-polarized and a single-polarized antennas,
	+ For example: $×\leftarrow 0.5λ \rightarrow ⁄$

**Agreement**

For SRS configuration supporting codebook-based UL transmission by a 3TX UE, one SRS resource set is configured for single TRP operation.

**Agreement**

For codebook-based transmission by a 3TX UE,

* Only PUSCH antenna ports 1000, 1001, 1002 are used
* Option- 2: Subject to UE capability, up to 2 PTRS ports may be configured in PTRS-UplinkConfig,
* FFS whether a single bit or 2 bits are used for PTRS-DMRS association indication.

Above is only for single panel transmission.

**RAN1 #116-bis**

**Agreement**

To support codebook-based UL transmission by a 3TX UE, the agreed rank1 precoders in RAN1#116 can also be used when transform precoding is enabled (DFT-s-OFDM ).

**Agreement**

To indicate precoding information for codebook-based UL transmission by a 3TX UE,

* Reuse legacy TPMI indication framework where TPMI and TRI are jointly indicated
* TPMI field is 2 or 3bits for 3-antenna-port transmission
* For maxRank equals to 1, TPMI field is 2 bits for DFT-s-OFDM and CP-OFDM
* For maxRank equals to 2 or 3, TPMI field is 3 bits for CP-OFDM

**Agreement**

For SRS configuration supporting codebook-based UL transmission by a 3TX UE, support Alt1,

* Alt1: Support configuration of X 4-port SRS resources in a resource set where one the ports is muted
* FFS muting mechanism

where X can be up to 2, subject to UE capability.

**Agreement**

For codebook-based UL transmission by a 3TX UE, when 2 PTRS ports are configured by maxNrofPorts in PTRS-UplinkConfig, PTRS-DMRS association indication is as follows:

|  |  |  |  |
| --- | --- | --- | --- |
| Value of MSB  | DMRS port  | ~~Value of LSB~~  | ~~DMRS port~~  |
| 0  | 1st DMRS port which shares PTRS port 0  | ~~0~~  | ~~1st DMRS port which shares PTRS port 1~~  |
| 1  | 2nd DMRS port which shares PTRS port 0  | ~~1~~  | ~~2nd DMRS port which shares PTRS port 1~~ |

* Note: PUSCH antenna port 1000 and 1002 in indicated TPMI(s) share PT\_RS port 0, and PUSCH antenna port 1001 is associated with PT\_RS port 1
* Number of bits used for the indication
* 1 bit

**Agreement**

For a 3TX UE, to support 3-port SRS transmission with reusing a 4-port SRS resource, support the following for muting one of the ports of the configured 4-port SRS resource,

* Option 3: Always a same port is muted, e.g., the 4th port

**Agreement**

For a 3TX UE, to support 3-port SRS transmission with reusing a 4-port SRS resource, UE splits a linear SRS power equally across the 3 unmuted antenna ports of the 4-port SRS resource.

**Agreement**

For 3-port codebook-based PUSCH transmission for a 3TX UE, scale factor s should be the ratio of the number of antenna ports with a non-zero PUSCH transmission power to 3 (except for full-power Mode 0).

* FFS: Whether specification needs to be updated to reflect the above

**Agreement**

For codebook-based UL transmission by a 3TX UE, when 1 PTRS port is configured by maxNrofPorts in PTRS-UplinkConfig, PTRS-DMRS association indication is as follows:

* **Alt2:** 2-bit indication

PTRS-DMRS association when 1 PT-RS port is configured

|  |  |
| --- | --- |
| Value | DMRS port |
| 0 | 1st scheduled DMRS port |
| 1 | 2nd scheduled DMRS port |
| 2 | 3rd scheduled DMRS port |
| 3 | 4th scheduled DMRS portReserved  |

**Agreement**

For a 3TX UE, support Rel-17 M-TRP PUSCH repetition where,

* Two SRS resource sets, each with up to 2 of 4-port SRS resources are configured,

Note: The configured 4 port SRS resources are used to enable 3-port SRS transmission

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