**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.

|  |
| --- |
| * 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.*

|  |
| --- |
| ***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

|  |  |
| --- | --- |
| *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 2.5:***

*For codebook-based M-TRP PUSCH repetition by a 3TX UE, for indication of PTRS-DMRS association,*

* When 1 PTRS port is configured by maxNrofPorts in PTRS-UplinkConfig, reuse Rel-17 multi-TRP TDM repetition,
* When 2 PTRS ports are configured by maxNrofPorts in PTRS-UplinkConfig, and maxRank = 2 or 3,
	+ A second PTRS-DMRS association field (1 bit) is used to indicate the association between PTRS ports and DMRS ports for the 2nd SRS resource set (i.e.,2nd TRP).

Table 1 - Companies’ views

|  |  |
| --- | --- |
| **Company** | **Perspective** |
| Samsung | **Proposal 2.1:** Support.**Proposal 2.2:** Support, this is a good catch, and no need to have another fixed muted port other than 4th one.**Proposal 2.3:** Support, to reuse a same principle of Rel-17 UL mTRP.**Proposal 2.4:** Support. In all cases, bitwidth is 2 bits. |
| Google | **Proposal 2.1:** For the second bullet, we think UE can report that it supports maximum 3 ports. For UE capability report, we only needs to tell the NW the number of ports that UE can support. The NW should provide the configuration based on the UE capability.***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 as 3 ~~of up to 3 for a configured 4-port SRS resource.~~

**Proposal 2.2/2.3/2.4:** OK |
| OPPO | Proposal 2.1: Support.Proposal 2.2: It’s fine to support. Deleting ‘e.g.’ also makes it clear.Proposal 2.3: Support.Proposal 2.4: Support. |
| NTT Docomo | Support proposal 2.1, 2.2, 2.3, 2.4. |
| CATT | **Proposal 2.1:** We are ok with the proposal but wondering if this should be a separate new feature.**Proposal 2.2:** Support. It is our view that the updated version is a straightforward solution on which port should be muted.**Proposal 2.3& Proposal 2.4::** Fine to support. |
| Fujitsu | Proposal 2.1: Ok with update from Google.Proposal 2.2: Ok.Proposal 2.3: Ok.Proposal 2.4: Ok. |
| Intel | We support proposal 2.1, 2.2, 2.3 and 2.4. |
| ZTE | **Proposal 2.1:** Support in general. For the second bullet, it seems UE need to report a capability of maximum supported number of SRS ports for 4-port SRS resource? I may be clearer to say ‘A 3TX UE may report a maximum number of supported SRS ports of up to 3 ~~for a configured 4-port SRS resource~~.’**Proposal 2.2:** Support.**Proposal 2.3:** Support.**Proposal 2.4:** Support. |
| vivo | Proposal 2.1: Ok with update from Google.Proposal 2.2/2.3/2.4: Ok. |
| Lenovo | Proposal 2.1: Support.Proposal 2.2: Support.Proposal 2.3: Support. Besides, we think Rel-18 SDM and SFN schemes shall also be supported to utilize the benefits of STxMP.Proposal 2.4: Support. |
| CMCC | Proposal 2.1: Support.Proposal 2.2: Support.Proposal 2.3: Support.Proposal 2.4: Support. |
| Xiaomi | Proposal 2.1: fine with Google’s update.Proposal 2.2: support. Proposal 2.3: Support.Proposal 2.4: fine. |
| MediaTek | Proposal 2.1: Prefer the update from Google.Proposal 2.2: Support.Proposal 2.3: Support.Proposal 2.4: Support. |
| FL  | Added proposal 2.5 based on Samsung suggestion. |
| Nokia | P2.1: agree with Google’s proposal. A UE reports its capability before its configurationP2.2: Original agreement is good enough. No need to update. We already have agreement to support SRS ports with SRS port number 1000, 1001, 1002. This should be clear.P2.3: supportP2.4: okay |
| QC | Proposal 2.1: support the updated version from Google. Proposal 2.2/2.3/2.4: support.  |
| Ericsson | P2.1: Agree with the first bullet. The direction of the second bullet is good in our view, but needs more discussion. The phrase ‘for a configured 4-port SRS resource’ is definitely needed, since we will not define a 3 port SRS resource, nor a new 4 port SRS resource with a zero power port, given the constraints of the WID. Perhaps similar to DOCOMO’s comment, the UE capability is not clear to me yet; I presume the intent is to set the following parameter to 3:- *maxNumberSRS-Ports-PerResource* indicates supported maximum number of SRS antenna port per each SRS resourceHowever, if we set it to 3, this could be confused as requiring a (non-existent) 3 port SRS resource, so we will need some text e.g. in 38.214 (38.306 should not capture behavior in my understanding). Should we instead try to capture behavior first, rather than a UE capability which is normally discussed later? For example, **A UE reporting a maximum number of SRS ports of up to 3 is configured with a 4 port SRS resource for 3 antenna port operation.**P2.2: Support; good clarification.P2.3: OKP2.4: OK |
| Sharp | Proposal 2.1/2.2/2.3/2.4: Ok. |
| LG | Proposal 2.1: Support.Proposal 2.2: Support.Proposal 2.3: Support.Proposal 2.4: Support.Proposal 2.5: Support. |
|  |  |
|  |  |
|  |  |
|  |  |
|  |  |
|  |  |
|  |  |
|  |  |

# 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

|  |  |
| --- | --- |
| **Company** | **Perspective** |
| Samsung | Proposal 3.1: Support, and we think that this is the only missing part in current specification for supporting 3TX non-codebook based PUSCH transmission.Proposal 3.2: Support for clarification, and we think that this is already supported.Proposal 3.3: Support for clarification, and we think that this is already supported. |
| Google | Do not support. Current WID explicitly mentioned that we should work based on codebook based operation. |
| OPPO | Proposal 3.1: Support. Agree with Samsung. With limited effort, by adding a maximum of 3 layers as a UE capability, we can support 3Tx non-codebook based transmission.Proposal 3.2: Support.Proposal 2.3: Support. |
| CATT | **Proposal 3.1**: We are ok to support non-codebook based UL 3Tx if the majorities are ok. We prefer to have the consensus that this is supported before diving into details. If we finally get into it, we are ok with proposal 3.1.**Proposal 3.2& Proposal 3.3:** Support if non-codebook based UL 3Tx is supported. |
| Fujitsu | If the WID could be revised, then we are ok to support. |
| Intel | We are open to discuss non-codebook based transmission given the workload is not heavy.  |
| ZTE | **Proposal 3.1/3.2/3.3:** Considering limited spec efforts, we are open to discuss non-codebook-based UL transmission. |
| vivo | Non-codebook-based UL transmission was explicitly removed from WID while scoping. This is cannot be taken individually, should be considered together with other additional topics. |
| Lenovo | Proposal 3.1: Support.Proposal 3.2: Support.Proposal 3.3: Support. |
| CMCC | Proposal 3.1/3.2/3.3: Support. We are open to support 3Tx non-codebook based transmission with not too much effort. |
| Xiaomi | Support FL proposal 3.1/3.2/3.3. |
| MediaTek | We are open to NCB-based 3Tx. However, whether to support it should be decided in RAN plenary by WID revision. |
| Nokia | The support of NCB-based 3Tx shall be pending on RAN plenary guidance. If 3TX NCB is agreed to be included for Rel-19:P1: supportP2: “A single SRS resource set” shall be “A single SRS resource set with usage non-codebook based transmission”P3: support |
| QC | From technical perspective, we are fine with these proposals. From RAN working procedure, we think it is better to wait for RAN-plenary update the WID, before working on non-codebook 3Tx.  |
| Ericsson | Purely because it is straightforward to specify and evolves non-codebook along with codebook as we have done since Rel-15, we are OK with the proposal. We would not say this is a crucial feature for Rel-19, however, which was a reason it was not included in the WID. In our understanding, other features such as partially coherent operation and antenna switching have more benefit in terms of near term device support and UL and DL throughput.Provided there is time for them, we think the technical aspects can be discussed in this meeting, and then whether the feature is supported and/or worked on further after this meeting can be decided in RAN. One way would be to conditionally agree to proposals, e.g. ‘If non-codebook based operation is supported in Rel-19, <proposal>’. **P3.1/3.2/3.3** If the disclaimer above or something similar is added, support. |
| Sharp | **Proposal 3.1:** Ok.**Proposal 3.2/3.3:** Agree with Samsung. They are already supported in the current spec. |
| LG | Proposal 3.1: Support. Agree with Samsung and OPPO, we can support 3Tx non-codebook based PUSCH transmission with very limited effort.Proposal 3.2: Support.Proposal 2.3: Support. |
|  |  |
|  |  |
|  |  |
|  |  |
|  |  |
|  |  |
|  |  |
|  |  |
|  |  |
|  |  |
|  |  |

# 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

|  |  |
| --- | --- |
| **Company** | **Perspective** |
| Samsung | Proposal 4.1/4.2/4.3: Given the conclusion we made in RAN1#116, SRS for 3TX antenna switching is precluded. So we don’t think further discussion is needed. |
| Google | We think we can start to discuss proposal 4.1. When we made the conclusion to preclude antenna switching, the argument is that this is out of scope. But now the situation changed and this is clearly included in RAN4’s scope. Usually NW configures the same SRS resource for CB and AS. When we introduce 3 port SRS for CB, 3 port SRS for AS should be natually changed.  |
| OPPO | We are open to discuss 3Tx antenna switching. 3T6R can be prioritized to resolve the LS from RAN4. Proposal 4.2/4.3 can be discussed later if Proposal 4.1 is supported. |
| CATT | **Proposal 4.1**: We prefer to support and discuss 3T4R if antenna switching is re-considered for 3Tx as 4Rx UE is the most common case. **Proposal 4.2& Proposal 4.3:** Open to discuss if antenna switching is re-considered. |
| Fujitsu | Ok to support, especially considering the LS from RAN4, but we need to update the WID. |
| Intel | Although there was no consensus to support SRS antenna switching in Rel-19, considering the RAN4 LS on the support of 3T6R, we think it is good to support it at least for 3T6R or 3T3R.  |
| ZTE | **Proposal 4.1:** SRS antenna switching is an important feature to achieve DL CSI acquisition in TDD. Per RAN4’s LS, we support to introduce 3T6R firstly. Then we can further discuss whether other 3TyR can be further supported.**Proposal 4.2/4.3:** We can further discuss after proposal 4.1 being supported. |
| vivo | There is agreement in RAN1#116 not supporting antenna switching for 3Tx, however we understand there is incoming LS from RAN4. If there is consensus among the group we are open discuss the issue of antennaswitching for 3Tx UL. |
| Lenovo | Proposal 4.1: Support.Proposal 4.2: Support same SRS configuration for 3T3R as 1T1R except the number of SRS port of an SRS resource Proposal 4.3: Support same SRS configuration for 3T6R as 1T2R except the number of SRS port of an SRS resource. |
| CMCC | Proposal 4.1: Support. We also hope to support and discuss SRS antenna switching for 3T4R UE. The commercial UEs in current network includes 1T2R, 1T4R, and 2T4R. UEs with 4 Rx are typical and widely commercialized in the market, and we believe that 3T4R is a potential type of commercial UE in the future. Proposal 4.2/4.3 ：Open to discuss. |
| Xiaomi | Proposal 4.1: we support the discussion. Additionally, 3T4R should also be supported.***Proposal 4.1****For performing antenna switching for DL CSI acquisition by a 3TX UE,* * Support 3T3R and 3T6R switching cases.
* FFS: the support for 3T4R.

Proposal 4.2: fine to discuss. Proposal 4.3: fine to discuss. |
| MediaTek | It is already concluded in R1-116 to not support SRS antenna switching in Rel-19 3Tx. The LS from RAN4 on the support for 3T6R and 4T6R should be discussed together, instead of having an individual discussion for 3T6R in Rel-19 3Tx AI. Considering the above scenarios, we would like to stick to the conclusion not to support SRS antenna switching in Rel-19 MIMO. |
| Nokia | The 3Tx SRS antenna switching shall be pending on RAN plenary guidance, similar to the case of Rel-19 specification for 3Tx NCB. If RAN plenary guidance is favorable:P1: Support. Also support to include 3T4R.P2: supportP3: support |
| QC | We are open to discuss antenna switch for 3Tx. This topic is different than other “out of WID scope” topics. RAN plenary Rel-19 WID RP-240828 asks RAN 4 to “Specify the requirements to support SRS antenna switching including t1r6, t2r6, t3r6, t4r6 depending on UE capability”. Then RAN 4 send LS to RAN1 to ask RAN1 define t3r6, t4r6. Therefore, RAN1 should consider introducing t3r6, t4r6 according to RP-240828. Regarding the detailed proposals, we don’t support 3T3R for antenna switching. In our understanding, there is no 3Rx UE defined in RAN1 spec. We don’t see the motivation to introduce 3T3R then. Maybe I missed something. If that is the case, please correct me.  |
| Ericsson | We observed DL throughput benefits from 3T3R vs. 2T2R, and 3T6R can have overhead savings vs. 2T6R. So from a technical perspective, 3T antenna switching can be beneficial. However, we do have prior agreements, and the WID scope should be addressed in RAN. We are OK with the same conditional agreement approach suggested above for non-codebook i.e. “‘If 3T antenna switching is supported in Rel-19, <proposal>”. Regarding QC’s question on 3R, our thinking was for the case of a 4 Rx UE for power savings with 3 RX active. The UE might be configured with maxMIMOLayers=3. To clarify, we do not propose DL 3 layer UE capability.**P4.1** Conditionally support, as described above.**P4.2:** Conditionally support in principle, but 3 port SRS resources will not be defined. Also, do I understand the intention for resource types to be that all 3 are supported, but how many of each can be configured is FFS? Suggest the following:***Proposal 4.2****If 3T antenna switching is supported in Rel-19, 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: how to identify the SRS resource configuration used for 3T3R
	+ FFS ~~supported~~ if two sets can be configured with the same resource type~~s~~, e.g., 'semi-persistent', 'periodic', 'aperiodic'

P4.3: Same position as above, but is there a typo? Shouldn’t there be two resources per set?***Proposal 4.3****If 3T antenna switching is supported in Rel-19, 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~~ two ~~3-port~~ SRS resources can be configured, where each SRS resource is transmitted in different symbols,
	+ FFS: how to identify the SRS resource configuration used for 3T6R
	+ FFS ~~supported~~ if two sets can be configured with the same resource type~~s~~, e.g., 'semi-persistent', 'periodic', 'aperiodic'
 |
| LG | P1: Support. Also support to include 3T4R.P2: supportP3: support |
|  |  |
|  |  |
|  |  |
|  |  |
|  |  |
|  |  |
|  |  |
|  |  |
|  |  |
|  |  |
|  |  |
|  |  |
|  |  |
|  |  |

# 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

|  |  |
| --- | --- |
| **Company** | **Perspective** |
| Samsung | - Partial coherent codebook: Not support, it requires unnecessary lengthy discussion.- UL PRG: We are fine.In addition, we would like to put some other potential issues, which is simple follow-up issues from 3TX agreements we made so far.1) Non-codebook based Rel-17 mTRP PUSCH repetition- Since codebook based 3TX PUSCH has been agreed, and if we agree on proposals in section 3, this aspect is also needed to adopt.- We can easily finalize on discussing SRS resource set configuration and Second SRI field.2) PTRS-DMRS association for Rel-17 mTRP PUSCH repetition- We agreed on PTRS-DMRS association for 3TX. - To support Rel-17 mTRP PUSCH repetition completely, the discussion on PTRS-DMRS association considering mTRP is needed.- We can reuse the principle of PTRS-DMRS association for multi-TRP which was adopted in Rel-17.- Only one case (i.e., maxRank=2 and 2 PTRS ports are configured) we cannot directly reuse R17 principle, but even for this case, we can apply the method for other case (e.g., the method for maxRank=3) to this case. Details are described in our tdoc. |
| Google | In the WID, the partial coherent has been explicitly precluded, but UL PRG has not. We support discussing UL PRG.In addition, two of our proposals below are missing in the FL summary. Please note that they are some follow-up discussions based on previous agreement, which should be within the scope.***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.*** |
| OPPO | If time permits in Rel-19, we are open to discuss partial coherent codebook. Partial coherent codebook transmission with full power mode 0 can achieve considerable cell average spectral efficiency gain compared with 2Tx non-coherent/full coherent transmission based on our evaluation. For UL PRG, some clarification is needed. Is it for non-codebook based transmission, or for codebook-based transmission, or both? Non-codebook based transmission for 3Tx is not agreed yet. For codebook based transmission, how to derive the subband precoder if there is no enhancement to DCI signaling?  |
| NTT Docomo | Support UL PRG. Share similar view as Google that UL PRG is not precluded by WID. |
| CATT | As we have already started to discuss many issues that are clearly out of scope, we are open to discuss partial coherent codebook and UL PRG as long as the time scope is not limited. |
| Fujitsu | We don’t see the strong need for partial coherent codebook. |
| Intel | Considering the practical implementation of 3 Tx UE, e.g., a cross-polarized antenna pair capable of coherent transmission and a single-polarized antenna, we are open to discuss partial coherent codebook so as to utilize the full capability of such a UE hardware. |
| ZTE | Regarding partially-coherent codebook, we are open to discuss after other issues being finalized.Regarding UL PRG, we are open to discuss. |
| vivo | Partial-coherent codebook was explicitly excluded in WID while scoping, and it wouldn’t be simple as some companies proposed.We support defining ULPRG to support open loop precoder cycling in frequency domain which provided robust UL transmission in high speed scenario. In R1-2404172 we have provided system level evaluation which shows gain in high speed scenario against non-coherent codebook. |
| Xiaomi | We are open for the discussion on PC codebook or UL PRG. We think the issue of PTRS-DMRS association for 3TX raised by Samsung also needs discussion. |
| MediaTek | We are open to NCB-based 3Tx. However, whether to support them should be decided in RAN plenary by WID revision. |
| FL | Added Proposal 2.5 related to PTRS-DMRS association for MTRP PUSCH repetition per Samsung’s suggestion. |
| Nokia | Similar to 3TX NCB and 3TX related antenna switching, RAN plenary shall provide guidance on the update of Rel-19 WID. Whether 3TX partially-coherent CB or UL PRG should be included for Rel-19 would be up to RAN plenary decision. |
| QC | Based on our understanding of RAN working procedure, those proposals are out of WID scope and RAN1 don’t need to spend time to discuss them unless the WID is updated by RAN-plenary to include them.  |
| Ericsson | **Partially coherent precoding**We suggest partially coherent precoding be supported, since it is quite easy to do so, and has a small (15 state) codebook. Without full power PAs / Mode 0 operation, 3 Tx often has worse cell edge throughput than 2 Tx, while using partially coherent precoders restores cell edge gain over 2 Tx, despite that each PA is capable of Pcmax/3. It is important to remember that high power class UEs (above 23 dBm) and transparent TxD capable can rely on low power PAs, and so are less likely to support Mode 0, so exploiting partial coherence in such UEs provides a better toolbox for UE vendors to create 3 Tx UEs.We suggest the codebook support the following precoding table when partially coherent operation is configured. Details of the design and the system level performance are in R1-2405119 and prior contributions.

|  |
| --- |
| 3-Tx PC (+ NC ) precoders |
| $$Rank 1: \frac{1}{\sqrt{3}}\left[\begin{matrix}1\\0\\0\end{matrix}\right],\frac{1}{\sqrt{3}}\left[\begin{matrix}0\\1\\0\end{matrix}\right],\frac{1}{\sqrt{3}}\left[\begin{matrix}0\\0\\1\end{matrix}\right],\frac{1}{\sqrt{3}}\left[\begin{matrix}1\\0\\1\end{matrix}\right],\frac{1}{\sqrt{3}}\left[\begin{matrix}1\\0\\-1\end{matrix}\right],\frac{1}{\sqrt{3}}\left[\begin{matrix}1\\0\\j\end{matrix}\right],\frac{1}{\sqrt{3}}\left[\begin{matrix}1\\0\\-j\end{matrix}\right]$$ |
| $$Rank 2: \frac{1}{\sqrt{6}}\left[\begin{matrix}1&0\\0&1\\0&0\end{matrix}\right],\frac{1}{\sqrt{6}}\left[\begin{matrix}1&0\\0&0\\0&1\end{matrix}\right],\frac{1}{\sqrt{6}}\left[\begin{matrix}0&0\\1&0\\0&1\end{matrix}\right],$$$$\frac{1}{\sqrt{6}}\left[\begin{matrix}1&0\\0&1\\1&0\end{matrix}\right], \frac{1}{\sqrt{6}}\left[\begin{matrix}1&0\\0&1\\-j&0\end{matrix}\right], \frac{1}{\sqrt{6}}\left[\begin{matrix}1&0\\0&1\\-1&0\end{matrix}\right], \frac{1}{\sqrt{6}}\left[\begin{matrix}1&0\\0&1\\j&0\end{matrix}\right]$$ |
| $$Rank 3: \frac{1}{3}\left[\begin{matrix}1&0&0\\0&1&0\\0&0&1\end{matrix}\right]$$ |

**UL PRG**UL PRG, and frequency selective precoding in general, has broad implications and should be considered carefully. Moreover, it is a much bigger step than supporting existing MIMO features such as partial coherence, antenna switching, and non-codebook. In our understanding, because only wideband UL precoding has been supported since Rel-15, it would have to be explicitly called out in the WID to be part of the work.  |
| Sharp | Partial coherent codebook/UL PRG: Not support. These topics require evaluation so it is not enough time to discuss. |
| Sony | We are open for the discussion on PC codebook and UL PRG. However, it should be discussed by RAN-plenary whether it includes in the scope. |
|  |  |
|  |  |
|  |  |
|  |  |
|  |  |
|  |  |
|  |  |

# 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

# References

1. RP-234007, “New WID: NR MIMO Phase 5”, Samsung, 3GPP RAN Meeting #112, December 11-15, 2023
2. R1-2402086, Recommended Direction on 3TX CB-based Uplink in RAN1#117, RAN1 #116-bis, Moderator (InterDigital Inc.), April, 2024
3. R1-2403850, Summary of Offline Discussions on 3TX CB-based Uplink, RAN1 #117, May, 2024
4. R1-2403834, LS on 3T6R and 4T6R antenna switching SRS RAN4, Huawei
5. R1-2403848, Discussion on Rel-19 CB-based UL for 3TX UE, InterDigital, Inc.
6. R1-2403902, Support for 3-antenna-port codebook-based transmissions, MediaTek Inc.
7. R1-2403946, On codebook for 3-antenna-port UL transmission Huawei, HiSilicon
8. R1-2403983, Support for 3Tx UL MIMO, Intel Corporation
9. R1-2404021, Discussion on 3-antenna-port codebook-based transmissions, Spreadtrum Communications
10. R1-2404046, Discussion on Rel-19 CB-based UL transmission for 3TX UE, TCL
11. R1-2404110, Views on Rel-19 3-antenna-port codebook-based transmissions, Samsung
12. R1-2404172, Discussion on 3-antenna-port codebook-based uplink transmissions, vivo
13. R1-2404241, Discussion on 3-antenna-port codebook-based transmissions, ZTE
14. R1-2404279, Views on R19 3Tx codebook based transmission, Apple
15. R1-2404338, Support for 3-antenna-port codebook-based transmissions, Lenovo
16. R1-2404396, Views on support for 3-antenna-port codebook-based transmissions, CATT
17. R1-2404451, Discussion on support for 3-antenna-port codebook-based transmissions, CMCC
18. R1-2404552, Discussions on 3-antenna-port codebook-based transmissions, LG Electronics
19. R1-2404589, Discussion on uplink enhancement for UE with 3Tx, Fujitsu
20. R1-2404613, Discussion on the support of 3-antenna-port CB based transmissions, Xiaomi
21. R1-2404669, Discussion on 3-antenna-port codebook-based transmissions, NEC
22. R1-2404688, Uplink 3 Port Codebook based Transmission, Google
23. R1-2404814, Discussion on 3-antenna-port codebook-based transmissions, Transsion Holdings
24. R1-2404884, Discussion on 3-antenna-port codebook-based transmissions, OPPO
25. R1-2404920, On the support for 3-antenna-port codebook-based transmissions, Nokia
26. R1-2404972, Support for 3-antenna-port codebook-based transmission, Sharp
27. R1-2405037, Discussion on support for 3-antenna-port codebook-based transmissions, NTT DOCOMO, INC.
28. R1-2405119, Support for 3 Tx UL transmissions, Ericsson
29. R1-2405150, 3 Tx UL MIMO transmissions, Qualcomm Incorporated INC.