**3GPP TSG RAN WG1 #117 R1-2403850**

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

**Agenda Item: 9.2.3**

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

**Title:** **Summary of Offline Discussions on 3TX CB-based Uplink ~~FL Summary Support for 3TX CB-based Uplink; Preparatory~~**

**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.

* Closing remaining minor issues and details,
* Discuss other potential functionalities,

# Non-codebook-based Precoding for 3TX UE

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| **Sub-topics** | **Justification** | **Expected progress in RAN1#117** | **Expected progress in RAN1#118** |
| **Non-codebook precoding** | * To further complete 3TX functionality by supporting reciprocity-based precoding * Low effort | 100% | Completion |

***Proposal 2.1***

*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 2.2***

*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.*

***Proposal 2.3***

*To support non-codebook UL transmission by a 3TX UE, for SRI indication,*

* *Up to 3 bits is used*
  + *For Lmax=1*

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| --- | --- | --- | --- | --- | --- |
| Bit field mapped to index | SRI(s), | Bit field mapped to index | SRI(s), | ~~Bit field mapped to index~~ | ~~SRI(s),~~ |
| 0 | 0 | 0 | 0 | ~~0~~ | ~~0~~ |
| 1 | 1 | 1 | 1 | ~~1~~ | ~~1~~ |
|  |  | 2 | 2 | ~~2~~ | ~~2~~ |
|  |  | 3 | reserved | ~~3~~ | ~~3~~ |

* + *For Lmax=2*

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| --- | --- | --- | --- | --- | --- |
| Bit field mapped to index | SRI(s), | Bit field mapped to index | SRI(s), | ~~Bit field mapped to index~~ | ~~SRI(s),~~ |
| 0 | 0 | 0 | 0 | ~~0~~ | ~~0~~ |
| 1 | 1 | 1 | 1 | ~~1~~ | ~~1~~ |
| 2 | 0,1 | 2 | 2 | ~~2~~ | ~~2~~ |
| 3 | reserved | 3 | 0,1 | ~~3~~ | ~~3~~ |
|  |  | 4 | 0,2 | ~~4~~ | ~~0,1~~ |
|  |  | 5 | 1,2 | ~~5~~ | ~~0,2~~ |
|  |  | 6-7 | reserved | ~~6~~ | ~~0,3~~ |
|  |  |  |  | ~~7~~ | ~~1,2~~ |
|  |  |  |  | ~~8~~ | ~~1,3~~ |
|  |  |  |  | ~~9~~ | ~~2,3~~ |
|  |  |  |  | ~~10-15~~ | ~~reserved~~ |

* + *For Lmax=3*

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| Bit field mapped to index | SRI(s), | Bit field mapped to index | SRI(s), | ~~Bit field mapped to index~~ | ~~SRI(s),~~ |
| 0 | 0 | 0 | 0 | ~~0~~ | ~~0~~ |
| 1 | 1 | 1 | 1 | ~~1~~ | ~~1~~ |
| 2 | 0,1 | 2 | 2 | ~~2~~ | ~~2~~ |
| 3 | reserved | 3 | 0,1 | ~~3~~ | ~~3~~ |
|  |  | 4 | 0,2 | ~~4~~ | ~~0,1~~ |
|  |  | 5 | 1,2 | ~~5~~ | ~~0,2~~ |
|  |  | 6 | 0,1,2 | ~~6~~ | ~~0,3~~ |
|  |  | 7 | reserved | ~~7~~ | ~~1,2~~ |
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|  |  |  |  | ~~9~~ | ~~2,3~~ |
|  |  |  |  | ~~10~~ | ~~0,1,2~~ |
|  |  |  |  | ~~11~~ | ~~0,1,3~~ |
|  |  |  |  | ~~12~~ | ~~0,2,3~~ |
|  |  |  |  | ~~13~~ | ~~1,2,3~~ |
|  |  |  |  | ~~14-15~~ | ~~reserved~~ |

Table 1 - Companies’ views

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| --- | --- |
| **Company** | **Perspective** |
| Samsung | We are fine with discussion on non-codebook based 3TX PUSCH. Our view is that non-codebook based 3TX PUSCH transmission is already partially supported. The only thing we need to add with specification impact in Rel-19 is to adopt max. 3-layer UE capability which is not covered by above proposal 2.1, 2.2, and 2.3. With this, we are fine with other corresponding editorial updates in TS38.212/214. |
| vivo | We are open to discuss, and believe that introduction of a new UE capability should do, although it is not within WID scope |
| CATT | Open to discuss if the majorities are ok. We are generally fine with the current proposals. |
| Spreadtrum | Fine to discuss, the workload seems not heavy. |
| OPPO | Open to discuss. Similar to Samsung’s view, we suggest adding a maximum of 3 layers as UE capability. |
| Fujitsu | For non-codebook based transmission, the SRI indication for 3-port transmission is already supported by the current spec.  Therefore, Proposal 2.2 and Proposal 2.3 are not necessary.  Proposal 2.1 is sufficient to support non-codebook based transmission for 3Tx UE, considering the following text from TS38.214.  “…*The maximum number of SRS resources per SRS resource set that can be configured for non-codebook based uplink transmission is 1, 2, 4 or 8 depending on UE capability.*…” |
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# Antenna Switching for 3TX UE

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| **Sub-topics** | **Justification** | **Expected progress in RAN1#117** | **Expected progress in RAN1#118** |
| **SRS antenna switching** | * To further complete 3TX UE functionality by supporting DL CSI estimation (NRX>NTX) * Low effort | 75% | Completion |

***Proposal 3.1***

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

* *Support the cases of 3T3R and 3T6R*

***Proposal 3.2***

*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 SRS resource can be configured, where the number of SRS ports for each resource is equal to 3*
  + *Up to 2 SRS resource sets configured with resourceType in SRS-ResourceSet set to 'semi-persistent'*
  + *One SRS resource sets configured with resourceType in SRS-ResourceSet set to 'periodic'*
  + *Up to X3≤2 SRS resource sets configured with resourceType in SRS-ResourceSet set to 'aperiodic'*
  + *FFS values for X1, X2 and X3*

***Proposal 3.3***

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

* *Up to two SRS resource sets can be configured,*
* *Each SRS resource set has two 3-port SRS resources transmitted in different symbols,*
* *The resourceType for a configured SRS resource set can be one of ‘semi-persistent’, ‘periodic’ and ‘aperiodic’*
* *FFS supported number of SRS resource set for each supported resourceType*

Table 2 - Companies’ views

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| --- | --- |
| **Company** | **Perspective** |
| Samsung | Since we already precluded SRS antenna switching in Rel-19, we don’t support, and no need to revert current conclusion. |
| vivo | During WID drafting, it was discussed and later removed considering the limited scope of overall Rel-19 MIMO. There is LS from RAN4 where 3T6R may be discussed however it depends on consensus in RAN1 |
| Xiaomi | We support the discussion. The current configuration 2T4R for 3Tx UE would make the DL CSI sub-optimal and leads directly to a loss in the DL throughput performance. As mentioned by Vivo, RAN4 LS also needs further discussion on the same issue for 3TX. |
| CATT | Although antenna switching is precluded in Rel-19, we are open to discuss it if the majorities are ok. To resolve the LS from RAN4, we are ok to support 3T6R for 3Tx. On the other hand, 3T4R should be supported if we really go back to support antenna switching, as it is a more common case. |
| Spreadtrum | No need to revert the agreed conclusion. |
| OPPO | We are open to discuss 3T6R to address the issue of SRS antenna switching for 6Rx UE, as proposed in RAN4 LS. |
| Fujitsu | Support to discuss antenna switching for 3Tx UE, which is important for DL CSI acquisition in TDD.  Also, there is LS from RAN4 requesting us to considering antenna switching for 3Tx UE in Rel-19 as mentioned by other companies.  We think 3T3R and 3T6R could be firstly considered, which are relatively simple operation. |
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# Partial-Coherent Precoding for 3TX UE

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| **Sub-topics** | **Justification** | **Expected progress in RAN1#117** | **Expected progress in RAN1#118** |
| **Partial-coherent precoding** | * To support UEs with “X /” antenna polarization configuration * Medium effort | 50% | Completion |

***Proposal 4.1***

*For partial-coherent uplink precoding by a 3TX UE, up to 3 bit is used for joint indication of TPMI and TRI.*

***Proposal 4.2***

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

***Proposal 4.3***

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

*, ,*

***Proposal 4.4***

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

Table 3 - Companies’ views

|  |  |
| --- | --- |
| **Company** | **Perspective** |
| Samsung | Not support. The reason why we added non-coherent codebook for 3TX is to avoid length discussion and to adopt simple codebook with straightforward way. |
| vivo | The during WID drafting, this was discussed but excluded considering over all Rel-19 MIMO scope, and technically it will take lots of work to specify partial-coherent codebook. |
| CATT | Open to discuss if the majorities are ok. However, we agree with vivo that discussing partial-coherent codebook may take much more efforts. Prefer to have consensus to support (or not) before discussing details. |
| Spreadtrum | We are open to discuss. Limited effort is expected on this topic. |
| OPPO | We are open to discuss. If we reach a consensus to support partial coherent precoding, I have one comment on proposal 4.1. Since non-coherent and partial coherent codebooks are indicated together, up to 4 bits may be needed. |
| Fujitsu | We don’t see the strong necessity. |
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# Other Potential Issues

Please list any other relevant 3TX-specific issue that may need to be discussed.

Table 4 - Companies’ views

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| **Company** | **Perspective** |
| Google | We think the following two issues should be discussed. For other issues in the sections above, it seems they are either precluded explicitly and clearly by WID or precluded in previous conclusion, although we supported some of them.  Issue 1: PT-RS power boosting. The 2-port PT-RS for 3TX are asymmetric: one associated with 2 PUSCH ports and the other one associated with 1 PUSCH port. Therefore, port-specific PT-RS power boosting should be considered. We suggest we discuss the following proposal:  ***Proposal 1: Support PT-RS port specific power boosting for 3TX UE***   * ***The power boosting factor for PT-RS port x is , where is the number of layers associated with PUSCH ports that associated with the PT-RS port x, and is the number of PT-RS ports.***   Issue 2: UL PRG size. For 3TX, although we always mute the last antenna port, the actually muted antenna is still up to UE implementation. With regard to the UL reliability, one possible way is to transmit different UL PRG from different UE antenna(s). Then the UL PRG could be important. We suggest we discuss the following proposal:  ***Proposal 2: 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*** |
| Samsung | We are fine with discussion on Issue 2 as Google mentioned, i.e., UL PRG. |
| Docomo | Second precoding information field of M-TRP repetition of 3Tx needs to be discussed. In Rel-17 M-TRP PUSCH repetition, first TPMI field (Precoding information and number of layers field) indicates rank and TPMI index of first TRP. Second TPMI field (Second precoding information field) only indicates TPMI index of second TRP and applies same rank as indicated by first TPMI field. Same design can be reused by M-TRP PUSCH repetition of 3Tx. In this case, Second precoding information field for Rel-17 M-TRP PUSCH repetition for 3Tx is 2 bits for maxRank=1 or 2 or 3.  We suggest discussing following proposals.   * **Proposal: 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: Second precoding information field for M-TRP PUSCH repetition for 3Tx is 2 bits for maxRank=1 or 2 or 3.** |
| vivo | If additional topic is considered in Rel-19 MIMO, then UL PRG should be one of the candidates which requires very minimal spec change in RAN1. DL PRG definition in current spec can be the starting point. Hence, we propose to support defining UL PRG. |
| Docomo 2 | In addition to the Second precoding information field of M-TRP repetition of 3Tx as in our previous comment, we are also fine to support UL PRG. |
| Xiaomi | Agree with DCM that the TPMI for codebook based MTRP operation also needs further discussion.  We are open to support the UL PRG. |
| CATT | Support to discuss UL PRG or second TPMI for mTRP scenarios proposed by Google and Docomo, respectively. |
| Spreadtrum | We are fine to include UL Frequency selective precoding. |
| Fujitsu | Just one question for clarification.  Regarding the power boosting issue for 3Tx UE, in legacy 4-port precoder with Rank-3, the asymmetric mapping already exists for the non-coherent precoder? |
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# Feature-lead Proposals for Approval

# Round 1

Void

# Round 2

Void

# Round 3

Void

# List of Companies’ Proposals

# 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.

**Agreement**

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

, ,

**Agreement**

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

**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 slot  SCS , 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)𝜆  Optional:  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: **|**
* A configuration of a cross-polarized and a single-polarized antennas,
  + For example:

**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 port  Reserved |

**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