**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:** **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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| 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~~ |
|  |  |  |  | ~~8~~ | ~~1,3~~ |
|  |  |  |  | ~~9~~ | ~~2,3~~ |
|  |  |  |  | ~~10~~ | ~~0,1,2~~ |
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|  |  |  |  | ~~12~~ | ~~0,2,3~~ |
|  |  |  |  | ~~13~~ | ~~1,2,3~~ |
|  |  |  |  | ~~14-15~~ | ~~reserved~~ |

Table 1 - Companies’ views

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| **Company** | **Perspective** |
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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** |
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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.*

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

***Proposal 4.3***

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

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

***Proposal 4.4***

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

$$\frac{1}{\sqrt{5}}\left[\begin{matrix}1&1&0\\0&0&1\\1&-1&0\end{matrix}\right]$$

Table 3 - Companies’ views

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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*** $10log\_{10}L\_{x}Q\_{p}$***, 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.***

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***
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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.

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

**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