**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.

|  |
| --- |
| * *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~~ |
|  |  |  |  | ~~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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| **Company** | **Perspective** |
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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** |
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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