**3GPP TSG RAN WG1 Meeting #109-e R1-2205221**

**e-Meeting, May 9th – 20th, 2022**

**Agenda Item: 9.1.4.2**

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

**Title:** **FL Summary on SRI/TPMI Enhancements; Second Round**

**Document for:** **Discussion and Decision**

# Background

In RAN plenary #94, the WID for Rel-18 MIMO enhancements was finalized [1]. According to the WID, some enhancements for SRI/TPMI are necessary to enable 8 TX UE transmission.

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| *Objective 5: Study, and if justified, specify UL DMRS, SRS, SRI, and TPMI (including codebook) enhancements to enable 8 Tx UL operation to support 4 and more layers per UE in UL targeting CPE/FWA/vehicle/Industrial devices**- Note: Potential restrictions on the scope of this objective (including coherence assumption, full/non-full power modes) will be identified as part of the study.* |

To accomplish the objective, the scope of this agenda item centers on codebook design for 8TX, CW to layer mapping, SRS enhancements to support 8 ports, impacts resulted from coherency characteristics of such UEs as well as UE operation with full power.

# High Priority Topics:

As it has been discussed by many companies, different variations of antennas placement can be considered where each could differently influence codebook design and coherency characteristics of a UE. Furthermore, to decide on the number of codewords, the number of layers, etc., extensive evaluations are required. And lastly, there are some levels of dependency of other sub-agendas on this work. Having said that it is important to establish a common view on UE antenna layout, evaluation methodologies and related assumptions in meeting WG1 # 109e.

# Antenna Layout for 8TX UE

According to companies’ contributions, different antenna layouts can be considered for 8TX UEs. Since antenna layout has a direct impact on codebook design, it is important to have a decision on this aspect before moving forward (ZTE, vivo, OPPO). Some companies have stated that various antenna layouts should be supported for uplink transmission of an 8TX UE (Huawei, IDC, Samsung, NTT, CATT). However, to save effort and reflect real-life use case, another group of companies have proposed to first identify/prioritize the most-likely device type (Samsung, Ericsson), and/or also identify/prioritize the most-likely antenna layouts (OPPO, Lenovo, NTT, MediaTek, Ericsson, CMCC). Further, some companies have suggested that UE capability reporting should include some information about 8TX UE antenna layout (NTT, IDC). From (NEC) perspective, UE coherency capability reporting is sufficient and can bear related required information.

For Phase I discussion, 4 alternatives were identified based on companies’ views for possible down selection. Table 1 show companies position for each alternative.

**Table 1**

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| **Proposed Alternative** | **Supporting Companies** |
| Alt1: Support linear array (1D/2D) of single-polarized configuration  | Could discuss: Apple, LG, vivo, Intel, CATT, Xiaomi, MediaTek, Ericsson, Nokia |
| Alt2: Support linear array (1D/2D) of cross-polarized configuration | Apple, LG, Samsung, OPPO, NTT, CMCC, Lenovo, NEC, Spreadtrum, ZTE, Huawei, HiSilicon, Intel, CATT, InterDigital, Xiaomi, Qualcomm, Ericsson (outdoor), Nokia, NSB, Sharp, KDDI, vivo |
| Alt3: Support either Alt1 or Alt2 according to a UE indication | - |
| Alt 4: 4-sided directional cross pol array (4 dBi, 110$°$ BW) | Ericsson |

Based on the recent agreement that all three levels of UE coherency are to be considered for 8TX UEs, the following is proposed,

**FL Proposal 2.1: For 8TX UE, study the following UE antenna layout,**

* **Alt1: For non-coherent UEs, study linear array (1D/2D) of single-polarized antenna configuration**
* **Alt2: For fully/partial-coherent UEs, study linear array (1D/2D) of cross-polarized antenna configuration**
	+ **Ng>=1 antenna groups can be considered where each group comprises coherent antennas, and across groups, antennas can be non-coherent/coherent depending on device types**

**Table 2**

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| **Company**  | **Views** |
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# Evaluation Methodologies

Several aspects of 8TX UE operation rely on simulation studies to justify proposed enhancements. For example, determining potential benefits of 2 CW for UL, extending to more than 4 layers transmission, identifying proper codebook design, etc., they all require a baseline evaluation methodology to allow an accurate and fair comparison.

For this meeting, several companies have provided their simulation results. Some system level evaluation results are provided by (vivo, Samsung, ZTE, Ericsson, Intel, NTT, Nokia, Qualcomm, MediaTek), while other companies (vivo, Xiaomi, OPPO, Huawei, Lenovo) have shared their link level findings.

# SLS EVM

There are some differences in EVM assumptions used by companies in their conducted SLS simulation studies. For example, companies have assumed different assumptions for carrier frequency (2GHz, 3.5 GHz, 4GHz, etc.), SCS (15KHz, 30KHz), ISD (200m, 500m, 700m), etc. Therefore, to have a fair and an accurate comparison of provided results, it is important to have a baseline set of EVM parameters. According to the EVM assumptions reported in companies’ contributions, the following is proposed as the reference for SLS evaluation.

During the discussion in Phase I, companies discussed various aspects of SLS evaluation and narrowed down the extent of the simulations. At a high level, 4 different deployment scenarios were proposed by companies. Based on the discussion in Phase I, the following is proposed as the baseline EVM for LLS

**FL Proposal 2.2.1: Adopt the following Table as the reference EVM for SLS evaluation.**

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

Table 3

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| **Parameter** | **Value** |
| Frequency range | 3.5 GHz |
| Multiple access | OFDMA |
| Numerology | 14 OFDM symbol slotSCS 15 KHz, 30 KHz  |
| Scenario  | 38.901* UMi (ISD = 200 m), 80% Indoor (3Km/h), 20% Outdoor (30km/h)
* UMa (ISD = 500 m), 80% Indoor (3Km/h), 20% Outdoor (30km/h)
* InF, InF type to be selected/reported by company

38.802* Dense urban (ISD=200m), (per Table A.2.1-1)
 |
| Channel model | 38.901 |
| 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 (2,2,2,1,1,2,2) with (dH, dV) = (0.5, 0.5)λ |
| Antenna radiation pattern parameters | 38.901 |
| 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, 30Km/h  |
| UE TX antenna configuration | To be defined according to outcome of Proposal 2.1 |
| Traffic model | FTP model 1, packet size 500KB/s, (RU 20%, 50%, 70%)Full buffer (optional) |
| Suggested benchmarking | R15 UL 4-Tx codebook, Eigen-based, companies report PRG assumption  |
| 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 | 23 dBm (suggested for indoor)32 dBm (suggested for outdoor) |
| Metric | UL mean-user throughput, 5%-ile and 95%-ile UPT |

Table 4

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| **Company**  | **Views** |
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# LLS EVM

There are some differences in EVM assumptions used by companies in their conducted LLS simulation studies. For example, companies have assumed different assumptions for modulation-coding (QPSK and fixed code-rate, AMC, etc.), SCS (15KHz, 30KHz), rank (fixed, adaptive, etc), etc. Therefore, to have a reasonable and an accurate comparison of provided results, it is important to have a baseline set of EVM parameters. According to the EVM assumptions reported in companies’ contributions, the following is proposed for as the reference for LLS evaluation.

During the discussion in Phase I, companies discussed various aspects of LLS evaluation. Based on the discussion in Phase I, the following is proposed as the baseline EVM for LLS evaluation.

**FL Proposal 2.2.2: 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 8Tx UL evaluation**

 Table 5

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| --- | --- |
| **Parameter** | **Value** |
| Carrier Frequency | 3.5 GHz |
| Waveform | CP-OFDM |
| SCS | 15 KHz , 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 (*d*H , *d*V ) = (0.5, 0.5)λ |
| UE TX antenna configuration | To be defined according to outcome of Proposal 2.1 |
| UE speed | 3 Km/h |
| Layer | Adaptive, Fixed (reported by company)  |
| AMC | Adaptive, Fixed (reported by company)  |
| DMRS configuration | Type 1 |
| Channel estimation | Real |
| Channel Model | CDL -A (30ns), CDL -C (300ns) |

 Table 6

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| **Company**  | **Views** |
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# Detailed Topics

In this section, detailed topics related to operation of 8TX UE are discussed. Final decisions on these topics may hinge on evaluation results using an agreed set of EVM.

# Number of Layers

In NR Rel-17, uplink transmission is restricted to single codeword and a maximum of 4 layers for transmission. However, for 8TX UEs, some companies are arguing for increasing the number of codewords and layers.

Companies have discussed benefits of utilizing more than 4 layers for uplink transmission (ZTE, vivo, Xiaomi, CMCC, NTT, MediaTek, Ericsson), and further, some companies have shared their evaluation results indicating a higher achieved throughput when 8 layers are used. However, another group of companies seem to be skeptical about the promised gain, and they also have expressed their concern about the workload related to codebook design for transmission with 8 layers. From their perspectives, support of 4 layers should be prioritized, and then upon further evaluation, if justified by use case and the observed performance gain, transmission with more than 4 layers can be supported (Samsung, Lenovo, MediaTek, Qualcomm, Intel). Given that the main concern expressed by companies for transmission with 8 layers is related to potential complications for codebook design, the following is proposed,

During the discussion in Phase I, companies weighed in on whether uplink transmission with 8 layers should be supported. From the 14 supporting companies for transmission with 8 layers, 6 companies have shared their evaluation results in this meeting. The reported results exhibit a significant gain by using 8 layers for transmission. On the other hand, the minority of companies that are asking for further evaluation, argue that the potential gain achieved by using 8 layers may be marginal and not worth the specification work. Qualcomm is against adoption of 8 layers. According to Qualcomm, by allowing maximum modulation of 256QAM instead of restricting it to 64QAM, there is not much difference between TP achieved between 4- and 8-layer transmission.

Table 7

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| **Proposed Alternative** | **Supporting Companies** |
| Support CB/NCB-based transmission with 8 layers | 14 companies:* **With simulations**: NTT, ZTE, Huawei, HiSilicon, vivo, Ericsson
* **Without simulations**: OPPO, CMCC, CATT, InterDigital, Xiaomi, Nokia, Sharp, CMCC,
 |
| Support CB/NCB-based transmission with more than 4 layers after further study its benefits | 6 companies:* **With simulations**: Intel, MediaTek
* **Without simulations**: Apple, Samsung, Lenovo, OPPO
 |
| Do not support CB/NCB-based transmission with 8 layers | * **With simulations**: Qualcomm
 |

Based on the views expressed by majority of companies, who are in support of transmission with 8 layers, the following is proposed,

**FL Proposal 3.1a: For 8TX UE uplink transmission, study codebook- and non-codebook-based transmission with both 4 and 8 layers.**

Table 8

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# Codebook Design

Most companies believe that both codebook and non-codebook uplink transmissions should be supported for 8TX UEs (ZTE, Xiaomi, Samsung, LG, Lenovo, Apple, Sharp, MediaTek, Qualcomm, Ericsson). However, from the perspective of codebook design there seem to be two main lines of thought. A first group of companies believe that the codebook for 8 TX UE transmission should be based on legacy 2TX/4TX codebooks where by their concatenation and potential co-phasing, an 8TX codebook can be resulted (Huawei, ZTE, Apple, vivo, CATT, Xiaomi, Lenovo, Qualcomm). Alternatively, given the larger number of antennas in an 8 TX UE that may be place in a cross-polarized format, a second group of companies propose to reuse DL Type-I codebook (ZTE, OPPO, Spreadtrum, Apple, vivo, CATT, Xiaomi, Lenovo, NTT, NEC, Samsung, Nokia, MediaTek).

During the discussion in Phase I, companies further discussed different directions for design of the codebook for 8TX UE. The summary of the discussion and position of each company is summarized here,

Table 9

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| **Proposed Alternative** | **Supporting Companies** |
| Based on NR Rel-15 UL 2TX/4TX codebooks | Spreadtrum, Huawei, Hiilicon, Intel,  |
| Based on NR Rel-15 DL Type I codebook | OPPO, NEC, MediaTek, Nokia |
| Select codebook according to UE coherency assumption | Apple, LG, NTT, Lenovo, vivo, Huawei, Hiilicon, CATT, InterDigital, Xiaomi, Qualcomm |

Based on the recent agreement that all three levels of UE coherency are to be considered for 8TX UEs, and also according to companies’ views that the codebook design should be based on coherency characteristics of a UE, the following is proposed.

**FL Proposal 3.2: For 8TX UE codebook-based uplink transmission, down-select one of**

* **Alt1:**
	+ **Study NR Rel-15 UL 2TX/4TX codebooks as the starting point for design of codebook for non-coherent UEs**
	+ **Study NR Rel-15 DL Type I codebook as the starting point for design of codebook for fully/partially-coherent UEs**
* **Alt2:**
	+ **Study NR Rel-15 UL 2TX/4TX codebooks as the starting point for design of codebook for fully/partially/non-coherent UEs**
* **Alt3:**
	+ **Study NR Rel-15 DL Type I codebook as the starting point for design of codebook for fully/partially/non-coherent UEs**

Table 10

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# Feature-lead Proposals for Approval

# Agreements

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| **Agreement** **Study fully-coherent, partially-coherent and non-coherent UEs for uplink transmission with 8TX UEs.** **Agreement****Study full power transmission for 8TX UEs.*** **Details are FFS upon completion of codebook design**
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# List of Companies’ Proposals

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| **Huawei** | ***Proposal 1****: SRI enhancement with overhead reduction to enable 8TX NCB based UL transmission should be supported.* ***Proposal 2****: UL 8TX codebook design should consider various antenna layouts so as to accommodate different UE implementations.* ***Proposal 3****：Frequency selective precoding should be supported for 8TX UL transmission.* ***Proposal 4***：*Block-wise codebook based on legacy 2TX or 4TX UL codebook should be supported to enable 8TX in CB based UL transmission.* ***Proposal 5****: The beamformed CSI-RS should be considered to indicate UL precoders to UE.* |
| **ZTE** | ***Proposal 1:*** *Regarding 8 Tx-UL operation in Rel-18, support 8-TX and more than 4 layers UL transmission.* ***Proposal 2:*** *Both codebook based and non-codebook based UL transmission should be supported in Rel-18 for UL MIMO.* ***Proposal 3:*** *Full coherent and partial coherent capabilities should be supported, and non coherent capability can be precluded or deprioritized in Rel-18 for UL MIMO.* ***Proposal 4****: On 8-Tx UL transmission enhancement, 2 CWs for UL transmission should be supported.* *- Condition of enabling >1 CWs for UL transmission can be further studied in RAN1, e.g., if the number of TX(s) and the number of UL layers exceed threshold(s).* ***Proposal 5:*** *The legacy full power mode 1 and 2 should be supported in Rel-18 for UL MIMO, but details can be discussed after codebook design is clear.* ***Proposal 6****: Antenna layout assumption for partial coherent codebook should be determined before codebook design.* ***Proposal 7:*** *Regarding 8-Tx full coherent codebook design, the following schemes can be considered* *- Scheme 1: reusing DL type I 8Tx codebook scheme* *- Scheme 2: UL 4Tx codebook + additional phase* ***Proposal 8:*** *Regarding 8-Tx partial coherent codebook design, the following schemes can be considered* *- Scheme 1: 8-port full coherent codebook indication + puncture pattern indication (indicating zero-power elements in a matrix)* *- Scheme 2: Multiple port groups, with common or separate precoding information indication* ***Proposal 9:*** *Regarding non codebook based transmission design for 8-Tx,* *- The number of SRS resources in an SRS set can be up to 8* *- Potential optimization for SRI re-design considering DCI overhead, e.g., 8 bits or less* ***Proposal 10:*** *Regarding CW-to-layer mapping, support up to 2 CWs for UL 8-Tx transmission, and then further study the following aspects:* *- Scrambling, layer mapping, and DCI format to support second TB* *- Code rate and TB size when UCI is transmitted on PUSCH*  |
| **Spreadtrum** | ***Proposal 1：****Study the potential methods to reduce DCI overhead, e.g. limit the selection of SRS resource for part of layers.* ***Proposal 2:*** *The following codebook design principle for 8 antenna ports can be considered:* *- Option 1: based on LTE householder matrix* *- Option 2: based on NR DL codebook for 8-layer transmission* *- Option 3: other possible combination of existing precoding matrices*  |
| **InterDigital** | ***Proposal 1:*** *For enabling 8 Tx UL for UEs with many antennas, it should be discussed to use single or dual codeword based on considered scenarios, UE types, coherency types, and so forth.* ***Proposal 2:*** *Consider UE to report its capabilities on a supported type of antenna/panel structure or virtualization capability across UE antenna ports such as SRS antenna ports, enabling up to 8 Tx UL.* ***Proposal 3:*** *Support to retain the full power transmission mode of operation with necessary enhancements to be also applicable for the new enhanced UL-MIMO transmission case supporting up to 8-Tx UL.* |
| **CATT** | ***Proposal 1:*** *Support UL 8Tx with up to 8 layers in Rel-18.* ***Proposal 2:***Codebook designs for non*-coherent, partial-coherent and full-coherent devices are considered for UL 8Tx.* ***Proposal 3:*** *For UL 8Tx with DFT-s-OFDM, precoding matrix in Table 1 is included in non-coherent codebook.* ***Proposal 4:***For PUSCH transmission with CP*-OFDM, down selection of port-selection precoding matrix shall be considered for non-coherent codebook for 8Tx .* ***Proposal 5:***On the design of partial*-coherent codebook(s) for UL 8Tx, one or more typical partial-coherent relationships of antennas are considered* *-Two coherent groups with four coherent antennas per group, and four coherent groups with two coherent antennas per group can be considered with high priority.* ***Proposal 6:***On the design of precoding matrices for partial*-coherent transmission for UL 8Tx, the precoding matrices for 2Tx/4Tx in Rel-15 can be considered for each coherent antenna group as a baseline.* ***Proposal 7:*** Full*-coherent precoding matrix for UL 8Tx for DFT-s-OFDM can be designed by computer search with good distance properties.* ***Proposal 8:*** *For the design of full-coherent precoding matrices for UL 8Tx for CP-OFDM, down selecting precoding matrices from DL Type I codebook can be considered as a start.* ***Proposal 9:*** On full*-coherent codebook design for UL 8Tx for CP-OFDM, supporting multiple codebooks for various types of antenna structures can be considered.* ***Proposal 10:*** *For UL 8Tx, the size of codebook should be carefully determined.* ***Proposal 11:*** *UL full power transmission is supported for UL 8Tx,* *-Whether all of UL full power transmission schemes in Rel-16 are supported can be considered.* ***Proposal 12:*** *For UL 8Tx for codebook based PUSCH, TPMI/SRI indication is designed after the codebook and SRS design are available.* ***Proposal 13:***  *For UL 8Tx for non-codebook based PUSCH, extending the bit width of current SRI field to enable indicating up to 8 SRS resources.*  |
| **vivo** | ***Proposal 1:*** *The supported scenarios and antenna assumptions should be settled in the very first meeting for the group to work in focused manner.* ***Proposal 2:*** *Two SRI fields corresponding to two SRS resource sets for non-codebook transmission can be considered to simplify the SRI indication.* ***Proposal 3:*** *Codebook constructed by two 4Tx precoders indicated by two TPMI fields can be considered for partial and none coherent antenna assumption.* ***Proposal 4:*** *DL type1 codebook can be considered for fully coherent antenna assumption.* ***Proposal 5:*** *Two CWs can be considered for rank>4.* ***Proposal 6:*** *Following issues should be further discussed:* *-PTRS-DMRS association indication when rank>4* *- Impact on full power modes*  |
| **NEC** | ***Proposal 1:*** *Clarifying whether 1-3 layer transmission is based on enhancements with 8Tx or not.* 2 ***Proposal 2:*** *From UE perspective, reporting capability of full, partial and non coherent is sufficient.* ***Proposal 3:*** *Type I single-panel codebook is reused for uplink full coherent codebook enhancement.* ***Proposal 4:*** *Overhead reduction for partial and non coherent codebook should be studied.* |
| **Sony** | ***Proposal 1:*** *Enhanced TPMI indication with finer precoding information can be considered for UE UL transmission enhancements.* ***Proposal 2:*** *Enhanced TPMI indication with finer precoding information can also be considered for UE UL transmission enhancements in multi TRP scenario.*  |
| **Xiaomi** | ***Proposal 1:*** *Support 8Tx with more than 4 transmission layers for the UL.* ***Proposal 2:*** *For the PUSCH, the number of antenna ports should be extended to 8 accordingly.* ***Proposal 3:*** *Support both codebook based UL transmission and non-codebook based UL transmission.* ***Proposal 4:*** *2 codewords should be supported for up to 8 layers of uplink transmission.* ***Proposal 5:*** *The supported 2 codeword transmission scheme can be enabled when more than X transmission layers is configured, X is up to UE capability.* ***Proposal 6:*** *For non-codebook based PUSCH transmission with 8Tx, SRI indicated by the bitmap of the SRS resources or the ports of the SRS resource configured for the SRS resource set is preferred for the simplicity without the effort on the design of new SRI tables.* ***Proposal 7:*** *Three coherence types of codewords should be considered in Rel-18 UL 8Tx codebook design, i.e., full-coherent, partial-coherent, and non-coherent codewords.* ***Proposal 8:*** *8Tx full-coherent codewords can be designed on the basis of Rel-15 DL Type I single-panel 8Tx codebook with selected parameters.* ***Proposal 9:*** *For partial-coherent codewords, the antenna ports can be divided into two or more antenna port groups.* ***Proposal 10:*** *8Tx partial-coherent codewords can be designed on the basis of 8Tx full-coherent codewords.* ***Proposal 11:*** *8Tx partial-coherent codewords can be designed on the basis of Rel-15 UL 4Tx full-coherent codewords.* ***Proposal 12:*** *The scaling factor can be computed as sqrt(1⁄K) where K denotes the number of non-zero elements in 8Tx codewords.* 5/8 ***Proposal 13:*** *The research on DFT-based multi-panel codebook can be left for FFS. Some other pre-designed orthogonal codebooks other than DFT-based codebook can also be left for FFS.* |
| **Samsung** | ***Proposal 1****: for the study of 8 Tx UL operations,* -Prioritize one device type for efficient study and discussions * 1. *-The one device should be the one which is ‘most-likely’ to have 8 Tx antennae for UL operations*
	2. *-1st priority: CPE*
	3. -2nd priority: FWA

***Proposal 2****: Regarding the transmission scheme for 8Tx UL operations,* *-Support both CB and NCB based UL transmission* * 1. -For RAN1 work, adopt a serialized approach,

*-prioritize CB based discussion until RAN1#110* *-NCB based discussion starts after RAN1#110* ***Proposal 3****: regarding the 8 Tx antenna structure, study the following aspects* *-Polarization: co-pol or dual-pol* -Antenna groups: one group or multiple groups * 1. -Antenna panels and coherence types:

*-Single panel: one antenna group and full-coherence* *-Multi-panel: multiple antenna groups and partial-/non-coherence* ***Proposal 4****: support a single unified 8Tx codebook structure for different coherence types (i.e. FC, PC, and NC) based on antenna groups* -Antennae within a group are coherent *-Antennae across multiple groups are non-coherent* ***Proposal 5****: regarding the 8Tx UL codebook,* -The baseline is Rel. 15 NR 8Tx DL Type I codebook * 1. -Support the following parameters for 8Tx UL codebook

-𝑃= *number of antenna polarization;* 𝑃=1 *for co-pol, and* 𝑃=2 *for dual-pol.* -𝑀𝑔= number of antenna groups. -𝑁1= *Number of antennae in 1st dimension.* -𝑁2= *Number of antennae in 2nd dimension.* ***Proposal 6****: investigate both single-stage and dual-stage codebook structures* ***Proposal 7****: Discussion on full power modes can be start after the 8Tx codebook is designed* ***Proposal 8****: regarding 8Tx NCB based UL transmission,* *-Support number of SRS resources (*𝑁𝑆𝑅𝑆*) up to 8* *-Support both one SRS resource set and two SRS resource sets* *-When* 𝑁𝑆𝑅𝑆≤4*, the SRI indication follows legacy (Rel.15) scheme, and* *-When* 𝑁𝑆𝑅𝑆>4*,* *-Study the need for* 𝐿𝑚𝑎𝑥>4 -*study the following SRI indication schemes* *-Alt1: combinatorial index scheme* *-Alt2: bitmap based scheme* ***Proposal 9****: for STx2P, support both* *-Case 1 (1 PUSCH): one SRI indicating a pair of SRS resources (e.g. STx2P to sTRP)* *-Case 2 (2 PUSCHs): two SRIs, each indicating a SRS resource for a TRP (e.g. STx2P to mTRP)* ***Proposal 10****: regarding max number of layers* *-prioritize the RAN1 work for max 4 layers* - >4 layers can be supported, if its need and use cases can be identified ***Proposal 11****: for the study of 8Tx UL operations, support EVM assumptions provided in Table 1.* |
| **OPPO** | ***Proposal 1:*** *Limited antenna pattern(s) should be confirmed for evaluation of 8Tx uplink transmission.* ***Proposal 2:*** *Support full coherent and partial coherent codebook for 8 Tx uplink.* * 1. - *For full-coherent codebook with uniform linear antenna array, DL 8Tx Type 1 CB (wideband beam and co-phasing) as baseline with possible beam reduction.* o *FFS for other antenna array, e.g. clustered or four-sided antenna array*
	2. - *For partial-coherent codebook, only consider intra-polarization coherence (2Tx) similar to Rel-15.*
	3. - *Non-coherent codebook has low priority considering practical antenna pattern and signaling overhead.*

***Proposal 3:*** *Consider separate indication of TRI and TPMI for 8 Tx uplink.* ***Proposal 4:*** *Introduce SRI enhancement to indicate up to 8 SRS resources for non-codebook uplink transmission, considering signaling overhead and standardization complexity.* |
| **LG** | ***Proposal 1:*** *Support both codebook and non-codebook based 8Tx UL transmission in Rel-18 MIMO.* ***Proposal 2:*** *Support up to 8 layers for 8Tx UL transmission in Rel-18 MIMO, and reuse the same codeword-to-layer mapping used in DL transmission.* ***Proposal 3:*** *Support full power 8Tx UL Transmission, and the details can be further discussed after finishing 8 Tx UL codebook design.* ***Proposal 4:*** *Support two-level partial coherency for codebook based 8Tx UL transmission.* *-Level-1: 4-pair 2-Tx coherency* *- Level-2: 2-pair 4-Tx coherency* ***Proposal 5:*** *Adopt Table 4 for rank 1 8 Tx codebook for CP-OFDM.* ***Proposal 6:*** *Adopt Table 5 for rank 1 8 Tx codebook for DFT-s-OFDM.* ***Proposal 7:*** *Consider following alternatives for enabling 8Tx non-codebook based UL Transmission.* *-Alt1. Increase # of SRS resource from 4 to 8.* *- Alt2. Allow max 2 SRS ports per SRS resource* *- Alt3. Reuse Rel-17 S-DCI based M-TRP PUSCH mechanism*  |
| **Lenovo** | ***Proposal 1:*** *Both codebook and non-codebook based PUSCH should be supported for 8Tx UL operation* ***Proposal 2:*** *Evaluate 8Tx UL operation for both Rank = 4 and Rank > 4. Rank > 4 is supported only if the potential gains exceed the complexity corresponding to rank upgrade.* ***Proposal 3:*** *Support of less than rank 4 is not precluded for 8Tx UL operation.* ***Proposal 4:*** *Study codeword-to-layer mapping for 8Tx UL operation if Rank>4 is supported* ***Proposal 5:*** *To support 8Tx UL transmission, on the SRS configuration,* *-One or two SRS resources with 8 SRS ports can be configured in the SRS resource set for CB when codebook based UL transmission is configured, and* *-Up to 8 SRS resources with single port can be configured in the SRS resource set for nCB when non-codebook based UL transmission is configured.* ***Proposal 6:*** *Prioritize full coherence and partial coherent UE capability for 8Tx UL operation.* ***Proposal 7:*** *For full coherent single panel UE, the antenna configurations illustrated in Figure 1 are considered for evaluation of 8Tx UL operation.****Proposal 8:*** *For multi-panel UE, the antenna configurations illustrated in Figure 2 are considered for evaluation of 8Tx UL operation.* ***Proposal 9:*** *Study different codebook design alternatives for 8Tx UL operation.* ***Proposal 10:*** *Dual-stage codebook should be adopted for 8Tx UE and Rel-15 DL Type-I CSI codebook for 8 ports can be adopted as a starting point.* ***Proposal 11:*** *TPMI signaling overhead is considered as a performance metric when studying different alternatives for 8Tx UL codebook design.* ***Proposal 12:*** *Study the performance benefits, signaling overhead and specification impact of supporting frequency-selective precoding for 8Tx UE.* |
| **Apple** | ***Proposal 1:*** *Consider at least full coherent and partial coherent antenna configurations, and use the antenna configurations in Figure 1 as the baseline.* *-FFS non-coherent antenna configurations* ***Proposal 2:*** *Consider both codebook based and non-codebook based UL transmission schemes for 8 Tx UL operation.* ***Proposal 3:*** *For codebook based transmission scheme with full coherent antenna configuration, use the DL Type I codebook design for 8 Tx as the starting point for 8 Tx UL.* ***Proposal 4:*** *If separate beam indication is to be considered for the partial coherent antenna configurations, clarify whether this should be further discussed in this AI or merged into the AI on simultaneous multi-panel UL transmission.* ***Proposal 5:*** *For codebook based transmission with partial coherent antenna configuration, use the legacy codebook for 4 Tx UL as the starting point for the per-panel precoding.* ***Proposal 6:*** *If full power mode is to be considered, advanced UEs similar to a UE that supports ul-FullPwrMode-r16 in Rel-16 (with all full-rated PAs) should be assumed to simplify the design.* ***Proposal 7:*** *For non-codebook based transmission, consider SRI enhancements to support up to 8 layers. Potential overhead reduction for SRI field can be considered.* |
| **CMCC** | ***Proposal 1:*** *All the 1-8 layers UL transmission should be considered for 8 TX UL transmission.* ***Proposal 2:*** *SRI field in Rel-15 can be reused for codebook based 8 TX UL transmission.* ***Proposal 3:*** *How to indicate up to 8 transmission rank and corresponding PUSCH precoder without increasing the SRI overhead for non-codebook UL transmission can be further studied.* ***Proposal 4:*** *The supported configurations of (N1, N2) for 8 TX UE can be N1=N2=2 or N1=4, N2=1 with the consideration of dual polarization, and the supported configurations of over sampling factor (O1, O2) can be further discussed.* ***Proposal 5:*** *Enable 2 CWs with individual MCS, RV and NDI for 8 TX UL transmission can be further studied.* ***Proposal 6:*** *Full TX power enhancement for enabling 8 TX UL transmission should be discussed for fullpower, fullpowerMode1, and fullpowerMode2.* |
| **NTT DOCOMO** | ***Proposal 1:*** *Support 8TX UL transmission with up to 8 layers per UE.* ***Proposal 2:*** *-Discuss 8TX UE antenna layout and identify the important UE antenna layout in commercial NW.* *-Support UE capability reporting of 8TX UE antenna layout.* *-Rel-18 design should be able to applicable to any 8TX UE antenna layout.* ***Proposal 3:*** ***-****Support two codewords for PUSCH transmission for more than 4 layers. Following enhancements can be further discussed.* *- codeword-to-layer mapping for more than 4 layers for spatial multiplexing* *- DCI enhancement with codeword-specific indications of MCS, NDI, and RV* *- UCI multiplexing on two codewords PUSCH* *-Support two codewords for simultaneous multi-panel UL transmission for less than 4 layers. The design on support of two codewords PUSCH is common and discussed jointly for 8TX UL transmission and multi-panel UE transmission.* ***Proposal 4:*** *-Support antenna port indication enhancement for UL rank from 5 to 8.* *-Support enhanced PTRS-DMRS association for more than 4 scheduled DMRS ports.* ***Proposal 5:*** *-Support codebook-based PUSCH transmission for more than 4 layers.* *-Support to define new UL 8TX codebook, which should consider non-coherent, partial-coherent, and full-coherent UEs, and applicable to any 8TX UE antenna layout.* *-Support UE capability reporting of coherent ports for partial-coherent UE.* *-Support NR DL Type 1 single-panel codebook as starting point for UL full-coherent precoders.* *-The number of supported non-coherent, partial-coherent, and full-coherent precoders should be carefully considered to reduce the DCI indication overhead.* *-Support full power transmission enhancements for non-coherent and partial-coherent precoders.* ***Proposal 6****: Support 8-port SRS resource with usage of ‘codebook’.* ***Proposal 7:****-Support non-codebook-based PUSCH transmission for more than 4 layers.* *-Support configuration of eight 1-port SRS resources in an SRS resource set with usage of ‘noncodebook’.* *-Support SRI indication enhancement for non-codebook-based PUSCH for 8 SRS resources configured with usage of ‘noncodebook’ for maximum UL rank from 1 to 8.* ***Proposal 8:*** *Support to discuss SRS enhancement for antenna switching for 8T8R.*  |
| **Sharp** | ***Proposal 1:*** *8 Tx UL operation should be introduced in Rel-18.* ***Proposal 2:*** *More than 4 layers should be supported in Rel-18.* ***Proposal 3:*** *The number of layers should be 5, 6, 7 and 8 for study purpose in Rel-18.* |
| **Nokia** | ***Proposal 1:*** *Study NR DL 8Tx codebooks for uplink transmission, with consideration of uplink antenna implementations for CPE/FWA/vehicle/Industrial devices.* ***Proposal 2:*** *Consider 8Tx codebook design with azimuth/elevation antenna port configuration (𝑵𝟏,𝑵𝟐)=(𝟒,𝟏) of Type-I 8Tx codebook.* ***Proposal 3:*** *RAN1 shall discuss on whether 8Tx multi-panel codebook should be studied in Rel-18 under Objective 5.* ***Proposal 4:*** *RAN1 shall study system level performance for 8Tx codebook design with frequency selective precoding.* ***Proposal 5:*** *RAN1 shall agree on simulation assumptions for system-level evaluation for 8Tx performance.* ***Proposal 6:*** *Consider a common DCI format for sub-band precoder indication for various UL resource allocation sizes.* ***Proposal 7:*** *Consider to group coherence antenna ports to support the indication of 8Tx coherence levels.* |
| **Mediatek** | ***Proposal 1:***Support both Codebook and Non-Codebook-based UL Transmission precoding for 8 TX UL. ***Proposal 2:***Study and if justified, support more than 4 transmission layers. ***Proposal 3:***Study, and if justified, support two codewords for more than 4-layer transmission, where codeword-to-layer mapping follows its DL equivalent defined in 3GPP TS 38.211 Section 7.3.1.3. ***Proposal 4:*** For the evaluations of 8 TX UL, 8 Rx antennas should be considered for the baseline evaluation. ***Proposal 5:*** *Support uniform antenna arrays for UL 8 TX codebook, with 4x1 and 2 antenna configurations.* ***Proposal 6:***Study the effect of precoding accuracy as a function of the transmission rank, and if justified, design the precoder CB with variable accuracy at different ranks. ***Proposal 7:***Specify the 8 TX UL precoder codebook as a subset of (or identical to) the 8-TX DL Type 1-SP precoder codebook. ***Proposal 8:***With Release 15 Type I SP CB as a baseline design for 8 TX UL CB, subsets of Type I CB can be chosen to help reduce PMI overhead through the following techniques: -Lower DFT oversampling factors (which can be rank-dependent). -Smaller number of beam co-phasing choices. -FFS: Other schemes ***Proposal 9:***For Type I SP based UL precoder, study and if justified specify a two-stage PMI feedback to limit feedback overhead, where -Slow-changing PMI elements are grouped in one stage with low feedback frequency -Fast-changing PMI elements are grouped in the other stage with higher feedback frequency -Information from both PMI feedback stages construct a complete PMI. ***Proposal 10:***Study and if justified specify an 8 TX UL precoder codebook using linear combination coefficients of DFT beams. -Example: A subset of the Type II DL CB. ***Proposal 11:***For 8 TX UEs, partially coherent antenna groups should be uniformly divided into one or more of the following: -Two groups of 4 coherent ports each -Four groups of 2 coherent groups each ***Proposal 12:***For Partially coherent 8TX antenna ports, each antenna group of size M should be designed such that: -The port group exclusively transmits up to M layers, which are not transmitted by the other port groups. -The precoding weights for those port in the focus group constitute a sub-matrix of the full precoder matrix with size M (where L is the number of layers and ) -The submatrix is populated using wither (i) the legacy coherent precoders for M TX ports with L layers, or (ii) alternative precoder design. ***Proposal 13:***Support non-coherent antenna ports for 8 TX UEs. ***Proposal 14:***For SRS Resource Sets configured for non-codebook usage, support up to 8 SRS Resources. ***Proposal 15:***UL 8 TX to be evaluated under low to moderate UE velocity scenarios as 8 TX is aimed for relatively static CPE devices. Study Dense Urban with ISD=200m and UMa with ISD=500m to evaluate scenarios under larger ISD. |
| **Intel** | ***Proposal 1:*** *RAN1 to consider full coherence UE as starting point for UL transmission with 8Tx* ***Proposal 2:*** *RAN1 to consider full power Mode 0 as starting point for codebook-based UL transmission with 8Tx* ***Proposal 3:*** *RAN1 to discuss the codebook construction for codebook-based UL transmission with 8Tx* ***Proposal 4:*** *RAN1 to consider 4 layers as starting point for codebook-based UL transmission with 8Tx* ***Proposal 5:*** *RAN1 to discuss the SRS configuration for codebook-based UL transmission with 8Tx* ***Proposal 6:*** *RAN1 to discuss the TPMI indication enhancement for codebook-based UL transmission with 8Tx* ***Proposal 7:*** *For non-codebook based transmission in Rel-18, RAN1 to discuss the SRS configuration, i.e., one SRS resource set vs. two SRS resource sets* ***Proposal 8:*** *For non-codebook based transmission in Rel-18, RAN1 to discuss the SRI field enhancement, i.e., one SRI field vs. two SRI fields*  |
| **Ericsson** | ***Proposal 1:*** Define a limited set of deployment scenarios for Rel-18 UL MIMO relevant to market needs. -Use the scenarios given in [2] as a starting point. -Down select among FWA/CPE, vehicular, and industrial scenarios if possible. -Use realistic UE transmit chains and antenna implementations. ***Proposal 2:*** Techniques are compared primarily using system-level simulation studies. -Net benefits of Rel-18 UL MIMO designs are evaluated considering UE and gNB antenna directionality and SINR conditions over the cells. -Link level simulations can additionally be used e.g. for impairments such as channel estimation -Evaluations are used to determine which Rel-15/16/17 UL MIMO modes should be enhanced. ***Proposal 3:*** Study the following alternatives to support 8 Tx -8 port UL MIMO codebooks, including fully/partially/non-coherent operation and all full power modes. -Extending Rel-15 NCB-based operation to 8 layers -Indicating multiple Rel-15/16 TPMIs, each corresponding to an SRS resource  |
| **Qualcomm** | **Proposal 1:** Study the performance of 8 Tx PUSCH via SLS. Prioritize 8Tx CPE/FWA devices in this study. **Proposal 2:** Adopt the following SLS assumptions as a starting point to study the performance of 8 Tx PUSCH.

|  |  |
| --- | --- |
| Parameter  | Value  |
| Metric  | UL throughput  |
| Baseline  | Rel-16 UL NCB and CB based PUSCH with 4Tx  |
| Carrier frequency  | 3.5GHz  |
| SCS  | 30KHz  |
| System bandwidth  | 20MHz/40MHz/100MHz  |
| UE antennas layout  | (M, N, P) = (1,4,2) for ULA; (M, N, P) = (2,2,2) for UPA, (dH,dV) = (0.5, 0.5)λ  |
| UE speed  | 3km/h  |
| Scenario  | Umi/Uma  |

**Proposal 3:** Rel-18 prioritize the specification for 8 Tx PUSCH with up to 4 layers. **Proposal 4:** For codebook based 8 Tx PUSCH in Rel-18, prioritize the specification for non-coherent and partial coherent 8 Tx precoders. **Proposal 5:** Rel-18 support both codebook and non-codebook based 8 Tx PUSCH. **Proposal 6:** NR Rel-18 reuse and concatenate existing Rel-15 2 Tx and/or 4 Tx PUSCH precoders to support 8 Tx PUSCH precoders with partial coherent or noncoherent 8 Tx. * 1. -Prioritize the specification of the following two cases.
		1. -Concatenate two 4 Tx precoders to build an 8 Tx precoder.
		2. -Concatenate four 2 Tx precoders to build an 8 Tx precoder.
	2. -FFS details on signalling to reuse and concatenate existing Rel-15 precoders.

**Proposal 7:** As a starting point, Rel-18 study the new precoder codebook for PUSCH with fully coherent 8 Tx based on DFT matrix or Householder matrix. **Proposal 8:** Rel-18 specify SRS and SRI enhancement to support non-codebook based PUSCH with 8 Tx. -FFS details on SRI enhancement for 8 SRS ports sounding via a single SRS resource set. -FFS details on SRI enhancement for 8 SRS ports sounding via multiple SRS resource set, each sounding less than 8 ports. **Proposal 9:** For 2 CWs PUSCH with 8 layers in Rel-18, reuse Rel-15 2 CWs PDSCH CW to layer mapping procedure. **Proposal 10:** Study, and if necessary, specify HARQ enhancement to support two codewords PUSCH with 8 Tx including at least the following aspects -NDI, RV, MCS signaling for the second CW -CBG based PUSCH with 2 CWs -Dynamic switch between 2 CW and single CW PUSCH **Proposal 11:** Study, if necessary, specify the UCI-multiplexing enhancement to support UCI multiplexing on two codewords PUSCH with 8 Tx including at least the following aspects -Multiplex UCI only on one of the CWs or both CWs -Whether allowing different beta offset values for the two CWs **Proposal 12:** Study, if necessary, specify the signaling on DMRS port indication in DCI to support PUSCH with more than 4 layers.**Proposal 13:** Support reusing Rel-16 full power transmission schemes for PUSCH with 8 Tx, with necessary enhancement if identified. -Strive to minimize spec impact.  |

# References

1. RP-213598, “New WI: MIMO evolution for Downlink and Uplink”, Samsung, 3GPP RAN Meeting #94e, Dec.6-17, 2021
2. R1-2203155, Discussion on SRI/TPMI enhancement for enabling 8 TX UL transmission, Huawei, HiSilicon
3. R1-2203269, SRI/TPMI enhancement for enabling 8 TX UL transmission, ZTE
4. R1-2203326, Discussion on SRI/TPMI enhancement for enabling 8 TX UL transmission, Spreadtrum Communications
5. R1-2203384, On SRI/TPMI Enhancement, InterDigital, Inc.
6. R1-2203447, On SRI/TPMI enhancement for UL 8 TX, CATT
7. R1-2203547, Views on enabling 8 TX UL transmission, vivo
8. R1-2203687, Discussion on SRI/TPMI enhancement, NEC
9. R1-2203727, Considerations on TPMI enhancement for UL transmission, Sony
10. R1-2203799, Enhancements on 8Tx uplink transmission, xiaomi
11. R1-2203894, Views on TPMI/SRI enhancements for 8Tx UL transmission, Samsung
12. R1-2203959, SRI TPMI enhancement for 8 TX UL transmission, OPPO
13. R1-2204147, SRI/TPMI enhancement for enabling 8 TX UL transmission, LG Electronics
14. R1-2204168, SRI/TPMI enhancement for enabling 8TX UL transmission, Lenovo
15. R1-2204235 Views on SRI/TPMI enhancement for enabling 8 TX UL transmission, Apple
16. R1-2204293, Discussion on SRI/TPMI enhancement for enabling 8 TX UL transmission, CMCC
17. R1-220437, Discussion on 8 TX UL transmission, NTT DOCOMO, INC.
18. R1-2204512, Views on 8 TX UL transmission, Sharp
19. R1-2204544, UL enhancements for enabling 8Tx UL transmission, Nokia, Nokia Shanghai Bell
20. R1-2204692, SRI/TPMI enhancment for enabling 8 TX UL Tranmission, MediaTek Inc.
21. R1-2204791, Discussion on enhancement for 8Tx UL transmission, Intel Corporation
22. R1-2204876, SRI/TPMI enhancement for enabling 8 TX UL transmission, Ericsson
23. R1-2205020, Enhancements for 8 Tx UL transmissions, Qualcomm Incorporated