**3GPP TSG RAN WG1 #110bis-e R1-2210377**

**e-Meeting, October 10th – 19th, 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, enhancements on SRS configuration, impacts resulted from coherency characteristics of such UEs as well as UE operation with full power.

# High Priority Topics

Based on the progress and agreements made in the last meeting [3], and the provided discussion in companies’ contributions [4-26], following topics are recognized as high priority topics to be discussed for decision in this meeting. These are the issues that are essential to be resolved at the earliest possible for progress in future meetings.

* Down-selection from Alt1-b and Alt2-a to identify the UL codebook design for 8TX UE by performing
  + TP analysis according to the agreed evaluation assumptions
  + Estimate of signaling overhead for rank and precoding indication
  + EVM property of the beamformer
* Comparison between the performance of 1 vs. 2 CW transmission, and CW to layer mapping for 8TX UE.

# Codebook Design for UL Transmission for 8TX UE

In the last meeting, two alternatives from the original list candidate schemes were identified for down-selection. The main differences between the two alternatives are,

* Alt2-a offers a **unified solution** based on NR Rel-15 UL 2TX/4TX codebooks in contrast to Alt1-b where NR Rel-15 UL 2TX/4TX codebooks is used for partially/non-coherent UEs, while NR Rel-15 DL Type I is considered for fully-coherent UEs.
* By employing NR Rel-15 DL Type I codebook, Alt1-b can offer a **better throughput** performance for **fully coherent UEs**.

Based on the agreed alternatives, Table 1 captures companies’ preferences for the codebook design for UL 8TX UE. To aid the decision on this topic, 12 companies have provided their results and observations by relying on LLS (2) and SLS (10) simulations.

* Per their evaluation results that indicate a superior performance offered by Alt1-b, **vivo**, **Xiaomi**, **MediaTek**, **Ericsson** and **Samsung** support Alt1-b. Two additional companies **ZTE** and **OPPO**, also support Alt1-b, but at the same time they report that according to their evaluation findings, the performance gap between the two alternative is negligible.
* Based on their conducted simulation results, **Intel**, **Huawei** and **Qualcomm**, have argued in favor of **Alt2-a**. Based on their evaluation outcome, **Huawei** and **Intel** report that the gain observed by use of Alt1-b is not significant and not worth the additional complexity. By considering implementation aspects, **Qualcomm** argues that the expected gain form employing **Alt1-b** diminishes due to random phase errors across the UE TX antenna ports.

Table 1 - Companies standing for Alt1-b and Alt2-a

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| * **Alt1-b:**   + Study NR Rel-15 UL 2TX/4TX codebooks and/or 8x1 antenna selection vector(s) as the starting point for design of the codebook for partially/non-coherent UEs   + Study NR Rel-15 DL Type I codebook as the starting point for design of the codebook for fully-coherent UEs * **Alt2-a:**   + Study NR Rel-15 UL 2TX/4TX codebooks and/or 8x1 antenna selection vector(s) as the starting point for design of codebook for fully/partially/non-coherent UEs | * **Alt1b**: vivo, OPPO, LG, Lenovo, CATT, NEC, Xiaomi, CMCC, Sharp, MediaTek, Apple, Ericsson, Samsung, Nokia, NTT * **Alt2a**: Huawei, Spreadtrum, Qualcomm, Google, Intel, IDC |

Table 2 - Observations and findings reported by companies for codebook structure

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| **Company** | **Observations** |
| CATT (SLS) | * The codebook generated based on NR DL Type I codebook with (𝑂1,2)=(2,1) outperforms the codebook based on Rel-15 UL 4Tx codebook. * For structure (Ng, N1, N2) = (1, 2, 2), comparable performance can be achieved with (O1,O2)=(4,4), (2,2), (2,1) and (1,1); * For structure of (Ng, N1, N2) = (1, 4, 1), comparable performance can be achieved with (O1,O2)=(4,1) and (2,1), but a significant performance loss can be seen by (O1,O2)=(1,1). |
| Intel (SLS) | * For maxRank=1, the performance of full coherent precoders by Alt2-a and Alt1-b are almost the same. For maxRank=4, the Type I codebook (Alt1-b) shows some gain over Alt2-a, but the gain is not big. ((𝑁1,𝑁2)=(4,1) and (𝑂1,𝑂2)=(4,1)) |
| vivo (SLS) | * From the evaluation we observe that nearly 10% performance gain in term of SE for 5 percentile UEs and mean user SE can be achieved with type 1 codebook with O1/O2 equals 2 and 1. 5% performance gain at 95 percentile user SE can be seen. * Type1 codebook with O1/O2 =1 and type 1 codebook with O1/O2 =2 has similar performance, however the overhead is small with O1/O2 =1 for type1 codebook. |
| ZTE (SLS) | * Reusing the DL codebook slightly outperforms enhanced UL codebook (based on legacy 4-Tx UL codebook). * With the increase of oversampling ratio(s) (especially for low-rank cases), significant performance gain can be observed for cell-edge UE, although average UPT gain may be limited. * The trade-off between DCI overhead/UE complexity related to UL codebook size and UL transmission performance should be carefully handled. |
| Huawei (SLS) | * For fully coherent codewords, the average throughput gains of codebook based on UL 4TX than that based on DL type I are -1.29% 🡪 ~8% for antenna layouts 1-a, 2-a and 3-a and 3%~5% for antenna layouts 1-b, 2-b and 3-b. * High-resolution precoder (O1, O2) = (4, 4) such as eigenvector precoder can obtain 20~33% throughput gain compared with that based on DL type I for UL 8TX. |
| Xiaomi (LLS) | * Rel-15 DL Type I based codebook has significant performance gains over the Rel-15 UL 4Tx based codebook. * For (N1, N2) = (4, 1), the codebooks with oversampling (O1, O2) = (2, 1)   + exhibits acceptable performance loss compared with (O1, O2) = (4, 1)   + outperforms (O1, O2) = (1, 1)   + shows a negligible performance loss compared a subset of codebooks with oversampling with (O1, O2) = (2, 1). * For (N1, N2) = (2, 2), the codebooks with different oversampling factors   + have almost the same performance   + outperforms (N1, N2) = (4, 1) |
| OPPO (LLS) | * The performance of Alt.1b and Alt.2a is similar with the same codebook size. * (O1, O2) = (2, 1) or (1, 1) can provide good performance for DL type 1 CB and can be considered for different antenna layouts. |
| MediaTek (SLS) | * Legacy 4Tx CBs of full coherent UE can be deduced from DL Type I CBs of 4Tx by fixing the oversampling and co-phasing factors. Thus, the performance of Legacy CBs is capped by DL Type I. * We see that the DL Type I CBs has better performance compared to Legacy based CBs justifying the principle that DL Type I is superset of Legacy CBs. |
| Ericsson (SLS) | * The performance of Alt2-a is consistently somewhat worse for both the mean and cell edge throughput cases. At mid-to-high loads, there is about 3% mean and 8-10% cell edge user throughput gain for Alt1-b over Alt2-a. |
| Samsung (SLS) | * When compared with Alt1-b, Alt2-a is worse in performance and incurs either the same or more TPMI overhead, hence is always inferior in avg. UPT vs TPM overhead perspective   + Up to ~18% loss on avg. UPT with Alt2-a overhead Alt1-b, for the same TPMI overhead for both. * Increasing oversampling factor improves avg. UPT performance at the cost of additional TPMI overhead of 1-2 bits. |
| NTT (SLS) | * UE SE performance in full buffer traffic, with different oversampling factors for UE antenna layout (1,4,2) with three cases of oversampling factors are evaluated, including (O1, O2)= (4, 1), (O1, O2)= (2, 1), and (O1, O2)= (1, 1). It is observed that the performance gap among different cases is very small, even for the case without oversampling, i.e., (O1, O2)= (1, 1). |
| Qualcomm (SLS) | * In real world, there is random phase error across Tx. The phase error is a i.i.d. random variable uniformly distributed between [-𝜋, 𝜋]. In this scenario, Alt 2a (construct 8Tx codebook based on UL 4 Tx codebook) can yield 7.7%~12% gain over Alt 1b (8Tx DFT codebook). * For structure (M, N, P) = (1, 4, 2), comparing between O1 = 1 and O1 = 4, the performance loss with O1 = 1 is only {1.8%, 3.2%, 1.6%} in terms of the average throughput, while the codebook size with O1 = 1 is only ¼ of the codebook size with O1 = 4. * For structure (M, N, P) = (2, 2, 2), comparing between O1 = O2 = 2 and O1 = O2 = 4, the performance loss with O1 = O1 = 2 is only{1.0%, 1.7%, 2.3%} in terms of the average throughput, while the codebook size with O1 = O2 = 2 is only ¼ of the codebook size with Q1 = O2 = 4. |

***FL Proposal 2.1.A: For 8TX UE codebook-based uplink transmission, Alt1-b is supported.***

***Standing:***

* ***Alt1b: vivo, OPPO, LG, Lenovo, CATT, NEC, Xiaomi, CMCC, Sharp, MediaTek, Apple, Ericsson, Samsung, Nokia, NTT***
* ***Alt2a: Huawei, Spreadtrum, Qualcomm, Google, Intel, IDC***

For a partially coherent UE, antenna ports can be divided into Ng antenna groups, where each group comprises of coherent antenna ports. For PUSCH transmission by a partially coherent 8TX UE, Ng=1, 2 and 4 antenna groups are considered. According to companies’ contributions (**Intel**, **ZTE**, **Lenovo**, **OPPO**, **CATT**, **Sharp**, **IDC**, **Mediatek**, **NEC**, **Apple**, **LG**, **Xiaomi**, **Qualcomm**, **Nokia**, **Samsung**), to properly employ and apply either of codebook candidates, i.e., Alt1-b or Alt2-a, a codebook should be configured according to the Ng. Further, **CATT** has noted that when discussing codebook design for a partially coherent UE, we need to have a consistent and common perspective for identification of coherent ports.

***FL Proposal 2.1.B: Prioritize the following cases for codebook design for an 8TX UE***

* ***Full coherent UE with Ng=1***
* ***Partial coherent UE with Ng=2 and Ng=4***

***FL Proposal 2.1.C: For partial-coherent 8TX UE, whether Ng=2 or Ng=4 should be reported.***

***Support:*** ***Intel, ZTE, Lenovo, OPPO, CATT, Sharp, IDC, MediaTek, NEC, Apple, LG, Xiaomi, Qualcomm, Nokia, Samsung***

***FL Proposal 2.1.D: For codebook design of an 8TX partial-coherent UE, configured with an 8-port SRS resource***

* ***For when Ng=2, the following convention for assumption of port coherency scheme is used*** 
  + ***Two coherent groups of {0, 2, 4, 6} and {1, 3, 5, 7}***
* ***For when Ng=4, the following convention for assumption of port coherency scheme is used***
  + ***Four coherent groups of {0, 2}, {4, 6}, {1, 3} and {5, 7}***

Table 3 - Companies’ views for FL Proposals 2.1.A-D

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| **Company** | **Views** |
| ZTE | * For FL Proposal 2.1.A: Support. * For FL Proposal 2.1.B: Support to prioritize Ng=1 full coherent UE, but whether/how to support Ng>1 full coherent UE should be further discussed in this meeting. * For FL Proposal 2.1.C: Support in principle. A UE can also support Ng=2 and Ng=4, so we suggest following changing.   ***FL Proposal 2.1.C: For partial-coherent 8TX UE, whether Ng=2 and/or Ng=4 should be reported.***  In addition, if a UE can support fully coherent capability with Ng=1, it can naturally support partially coherent with Ng=2/4, and non-coherent from perspective of capability. However, in reality, such full flexibility may not be very useful. Considering overhead reduction, such inclusive compatibility as legacy should be given up. Which number of Ng a UE with fully coherent capability can be supported, especially for DCI dynamic switching, should be configured by gNB, according to reported UE capability.   * For FL Proposal 2.1.D:   Port indexing for UL 8Tx does need discussion. If Alt1-b is adopted, DL codebook based scheme is used for fully coherent case, but UL codebook based scheme is used for partially and non coherent cases. So there may be the following options for port indexing for UL 8Tx:   * Opt1: If following DL port indexing rule, fully coherent **cannot** be aligned with partially coherent with Ng=2, and Ng=4, as shown below.      * Opt2: If following UL port indexing rule, fully coherent **should** be aligned with partially coherent with Ng=2, and Ng=4, as shown below.       We suggest opt 2, and prefer the following changes:  ***FL Proposal 2.1.D: For codebook design of an 8TX partial-coherent UE, configured with an 8-port SRS resource***   * ***For when Ng=2, one of the following conventions for assumption of port coherency scheme is used, to be down-selected***    + ***Alt1: Two coherent groups of {0, 2, 4, 6} and {1, 3, 5, 7}***   + ***Alt2: Two coherent groups of {0, 1~~2~~, 4, 5~~6~~} and {2~~1~~, 3, 6~~5~~, 7}*** * ***For when Ng=4, the following convention for assumption of port coherency scheme is used***   + ***Four coherent groups of {0, 4~~2~~}, {24, 6}, {1, 5~~3~~} and {3~~5~~, 7}***   Among Alt1 and Alt2, we slightly prefer Alt 2. |
| OPPO | We are fine with proposal 2.1.A/B/C.  For proposal 2.1.D, we think the antenna numbering should be consistent between downlink 8Tx and uplink 8Tx, and the same across different coherent assumptions. This would make it easier to reuse the DL 8Tx codebook.  For DL 8Tx codebook, {0,1,2,3} and {4,5,6,7} correspond to different polarizations, and {0,4}{1,5}{2,6}{3,7}correspond to four polarization antenna groups, as shown in left below. With the same antenna layout, we think the two coherent groups should be {0,1,4,5} and {2,3,6,7} for Ng=2, as shown in right below.    For Ng=4, similarly, the four coherent groups should be {0,4}{1,5}{2,6}{3,7}, as shown below. That is, the antennae within a polarization group should be coherent, similar to 4Tx UL codebook. |
| DOCOMO | FL Proposal 2.1.A/B/C: Support.  FL Proposal 2.1.D: We agree with OPPO’s analysis. |
| Lenovo | **Re Proposal 2.1.A:**  Support.  **Re Proposal 2.1.B:**  Support. We believe that some clarity on the definition of Ng is needed. In our understanding, Ng represents the number of coherence groups of the antenna, and not necessarily equivalent to the number of UE panels.  **Re Proposal 2.1.C:**  Support. Re ZTE’s comment, we don’t believe indication of both Ng=2 and Ng=4 is needed. Supporting Ng=2 implies supporting Ng=4 by design.  **Re Proposal 2.1.D:**  We support ZTE’s updated proposal, which ensures that two co-located antennas with different polarization are coherent for cross-polarized UE antenna layout. |
| InterDigital | Proposal 2.1.A: We think Alt2a can still be the baseline option, as just one particular case (for fully-coherent case) has the only difference between the two alternatives and the rest is common for both. We observe the gain is not ground-breaking and the most reported seems 10% which is not observed commonly among companies. Also, specifying two different codebook structures requires additional complexity for codebook design and significant specification efforts.  Proposal 2.1.B/C: Support  Proposal 2.1.D: Open for further discussions |
| QC | We are fine with Proposal 2.1B, and 2.1C.  For proposal 2.1.D, we think it is a less important topic. Any grouping of port indices can actually work. Different grouping would just lead a row permutation on the precoder.  For proposal 2.1.A, we appreciate FL’s effort to make progress. But we object it, because of the following reason.   * Alt 1-a uses DFT codebook for coherent 8 Tx, **which impose more stringent requirement on UE implementation than coherence requirement**. With DFT precoders, UE has to transmit across 4 Tx on one polarization with a linear phase ramp, which requires zero initial phase offset across 4 Tx. This means UE has to calibrate its 4 Tx in one polarization to make sure their initial phases are the same. Please notice that this phase alignment requirement is different than the coherence requirement. Coherence means UE has the keep the same relative phase difference between SRS transmission and PUSCH transmission. While phase alignment means that for PUSCH transmission, the phase across the 4 Tx has to be aligned. **We don’t think coherent UE can meet the additional phase alignment requirement. So, DFT precoder is not implementable by currently existing UE types.** * Performance of Alt 1b is worse than Alt 2a, in case of random phase error in real world. See simulation results in R1-2209970. * Regarding the range of initial phase offset without calibration, the following is current RAN4 spec 38.101. This is about the timing alignment error allowed in UL MIMO. The max error is [-130ns,130ns]. Roughly speaking, if we consider FR1 carrier Freq is 4Ghz, for example, 4GHz freq = 0.25ns waveform duration, which would translate to phase [-pi, pi]. So the current RAN4 spec on Tx timing alignment would definitely allow phase error [-pi,pi]. Even we move it to IF band, say 4Mhz, the waveform duration is 250ns. [-130ns,130ns] timing error will create phase error [-pi,pi].  6.4D.3        Time alignment error for UL MIMO For UE(s) with multiple transmit antenna connectors supporting UL MIMO, this requirement applies to frame timing differences between transmissions on multiple transmit antenna connectors in the closed-loop spatial multiplexing scheme.  The time alignment error (TAE) is defined as the average frame timing difference between any two transmissions on different transmit antenna connectors.  For UE(s) with multiple transmit antenna connectors, the Time Alignment Error (TAE) shall not exceed 130 ns. |
| CMCC | Proposal 2.1.A/B/C: Support  Proposal 2.1.D: Support OPPO’s comment. |
| MediaTek | **Proposal 2.1. B/C:** Support  **Proposal 2.1.D:** We support ZTE/OPPOs updated proposal regarding port grouping. |
| Samsung | Proposal 2.1.A, 2.1.B, 2.1.C: support  Proposal 2.1.D: same view as OPPO |
| LG | Support Proposal 2.1A/B/C  For Proposal 2.1D, is this assumption of consistency intended to be specified? We think it is not needed as in current specification. |
| Sharp | FL Proposal 2.1.A: Support.  FL Proposal 2.1.B: Support.  FL Proposal 2.1.C: Support ZTE’s modification.  FL Proposal 2.1.D: Agree with OPPO’s view. |
| vivo | Proposal 2.1.A looks fine however we are open to discuss performance, technical concerns  Proposal 2.1.B is fine  Proposal 2.1.C and 2.1.D, it is premature to make agreements, since these proposals are closely related to codebook designs. For example, if 2 4-ports SRS constitute 8 ports (partial-coherent) for UL transmission and 2 4Tx TPMIs are used to indicate the 8Tx precoder(s), each TPMI indicates a precoder from 4Tx that means antenna port numbering follows the 4Tx layout. In our view, 4Tx TPMI cover both cases Ng=2 and Ng=4 as the 4Tx full coherent codebook includes partial coherent precoders, which is applicable for Ng=4. Hence, we should discuss the codebook design and based on progress we can discuss what capabilities are reported later. |
| CATT | FL Proposal 2.1.A: Support.  FL Proposal 2.1.B: Support to prioritize the codebook design for full coherent UE with Ng=1, and consider Ng>1 as an option.  FL Proposal 2.1.C: Support both Ng=2 and Ng=4  FL Proposal 2.1.D: Support. Port indexing rule depends on UE capability. The antenna ports can be mapped based on the antenna structure of UE according to the coherent groups given in the proposal. |
| Huawei, HiSilicon | For FL Proposal 2.1.B:   1. For fully coherent UE, we think at least Ng=1 and Ng=2 should be supported to accommodate various UE layouts. Note that for DL type-I multi-panel codebook also considers Ng=1/2 for 8 full coherent antennas. 2. For partial coherent UE, we agree to support Ng=2 and Ng=4.   Hence, we prefer the following changes:  ***FL Proposal 2.1.B: Prioritize the following cases for codebook design for an 8TX UE***   * ***Full coherent UE with Ng=1 and Ng=2*** * ***Partial coherent UE with Ng=2 and Ng=4***   For FL Proposal 2.1.A: we support Alt 2a for the following reasons.   1. Alt 2a has similar performance to Alt 1b with Ng=1. For SU PUSCH with up to 8 layers, the percentage of rank>4 is higher than that of rank<=4 in some scenarios. Compared to Alt 1b, Alt 2a has larger number of codewords for rank>4, which makes it possible to achieve better performance than Alt 1a, as shown in our simulation results. We notice that some companies’ simulation results show Alt 1b is better than Alt 2a, but they only consider rank 1/2 (Samsung, Xiaomi) or max rank 4 (CATT, VIVO). 2. Alt 2a performs better than Alt 1b with Ng=2 and Ng=4, 4%~7% throughput loss compared to Alt 2a can be observed in our simulation results. 3. Alt 2a can achieve a unified codebook for different coherence types, which reduces spec efforts and complexity, for example there’s no need to indicate the switch between full-coherent codebook and partial/non-coherent codebooks. 4. We share similar view with Qualcomm on practical impairment in antenna implementation that there are mismatches between antennas, which introduces random phase error to antenna array. Qualcomm’s simulation results show Alt 2a performs better than Alt 1b in case of phase error across the UE TX antenna ports.   For FL Proposal 2.1.C: we support.  For FL Proposal 2.1.D: we support ZTE’s updated proposal. From our perspective, alt 1 for Ng=2 is more straightforward. |
| Intel | For FL Proposal 2.1A:  Our first preference is Alt 2a which is a unified codebook design for all the coherence. Regarding Alt 1b, our concern is about the overhead for Type I codebook. There should be restriction to reduce the number of precoders based on Type I codebook.  For FL Proposal 2.1B:  We slightly prefer to additionally have Ng=2 and Ng=4 for full coherent case. In the definition of antenna group, it could be full coherent/non-coherent across antenna groups, which means the full coherent UE can also have multiple antenna groups.  For FL proposal 2.1C:  Support.  For FL proposal 2.1D:  Generally fine with the proposal. But the text ***configured with an 8-port SRS resource*** in the main bullet is not needed and can be removed. |
| Nokia, NSB | FL Proposal 2.1.A: Support.  FL Proposal 2.1.B: Ng=1, 2, 4 are already agreed and their related CB design shall follow. Agree.  FL Proposal 2.1.C: Okay. UE should report Ng values.  FL Proposal 2.1.D: In our view, the port numbering is not very critical at this stage. We shall address this issue with detailed partial-coherent codebook. Further study is needed. |
| FL | Many thanks for your valuable comments and suggestions.  **FL Proposal 2.1.A:** We may need a bit more discussion on this.  **FL Proposal 2.1.B:** No update. The content of the proposal is common understanding and should be agreeable to everyone, other proposed cases may be discussed later. This is an important proposal to guide us through codebook design.  **Updated FL Proposal 2.1.C:** Made some minor update based on companies’ input for further clarification.  ***FL Proposal 2.1.C: For partial-coherent 8TX UE, whether Ng=2 or Ng=4 should be reported.***   * ***Note: Indication of Ng=2 means UE can also support Ng=4.***   **Updated FL Proposal 2.1.D:** Made some updates based on ZTE’s and OPPO’s suggestions. This proposal is to help us to have a common language and vocabulary when discussing codebook design for partially-coherent UEs and also later for discussion on full power operation. In practice, a UE vendor can call the indices in whatever manner it wishes. Again, it is just a convention for us to facilitate the discussion when we talk about coherent ports.  ***FL Proposal 2.1.D: For codebook design of an 8TX partial-coherent UE, configured with an 8-port SRS resource***   * ***For when Ng=2, the following convention for assumption of port coherency scheme is used***    + ***Two coherent groups of {0, 1, 4, 5} and {2, 3, 6, 7}*** * ***For when Ng=4, the following convention for assumption of port coherency scheme is used***   + ***Four coherent groups of {0, 4}, {2, 6}, {1, 5} and {3, 7}*** |
| QC2 | @FL, Thanks for updating the proposal. But for proposal 2.1.C, we are not sure adding the note would clarify or confuse the situation. In our understanding, Ng ties with # UE panels, we are not sure why a UE indicate support 2 panels would support 4 panels automatically. We understand the intention of the note is to capture VIVO’s comment about the codebook. If so, we think it is better to discuss the capability report on what codebook(s) UE can support rather than discussing Ng. Because people might have different understand of the meaning of Ng, to us, Ng ties with # panels. While to VIVO, Ng ties with codebooks. |
| Google | For 2.1a, we can accept current proposal. We support 2.1.b/c/d. One minor comment to 2.1.b, shall we remove the word “whether”? |
| Ericsson | **Proposal 2.1.A**: **We are OK with Alt1-b in principle, but think it needs more clarification before agreeing**. Alt 1-b says that Rel-15 2/4 TX is a starting point for partial/non-coherent UEs, while DL Type 1 is a starting point for fully coherent UEs. Discussing in terms of whether UEs are coherent is confusing here, with respect to the codebook subsets that we have in Rel-15, where UEs that support fully coherent precoders support partial and non-coherent precoders, and partially coherent UEs support non-coherent precoders. Such a design can improve performance by using both selection diversity in arrays as well as coherence. This seems a logical starting point for the Rel-18 design, but it can be revisited if needed; however it should at least be clearly not precluded.  ***FL Proposal 2.1.A: For 8TX UE codebook-based uplink transmission, Alt1-b is supported.***  ***Note: How[/whether] fully coherent UEs support partial and non-coherent precoders is to be further discussed.***  **Proposal 2.1B: Do not agree as written.**  If the intention is to discuss how precoders are designed, we should say that directly rather than about fully/partially/non-coherent UEs. For example, fully coherent UEs can support partial or non-coherent precoders, and partially coherent UEs can support non-coherent precoders. Furthermore, non-coherent precoders are to be supported, so they should not be left out of the list. We would be OK with the following:  ***FL Proposal 2.1.B: Prioritize the following cases for codebook design for ~~an~~ 8TX precoders***   * ***Full coherent precoders with Ng=1*** * ***Partial coherent precoders with Ng=2 and Ng=4*** * ***Non-coherent precoders***   **Proposal 2.1C: OK in principle. However, it should be clarified that “For partial-coherent 8TX UE, whether Ng=2 and/or Ng=4 should be reported.”**  **Proposal 2.1D: While an important design aspect, we think further discussion is needed prior to agreeing.** |
| DOCOMO2 | For FL Proposal 2.1.A, we agree with E/// that a common understanding on codebook subset configuration is important and a logical starting point.  For FL Proposal 2.1.C, we share similar comment as QC on the new note. |
| Samsung | **Proposal 2.1C**: in our understanding, the intention of the proposal is that a PC UE will report an Ng value from {2,4}. The UE will have one of the two antenna grouping, not both. If the intention is “Whether a UE reporting Ng=2 can also support precoders for Ng=4”, then it needs to be clarified. Besides, it should be discussed separately. So, the note should be replaced with FFS.  ***FL Proposal 2.1.C: For partial-coherent 8TX UE, whether Ng=2 or Ng=4 should be reported.***   * ***FFS ~~Note:~~ whether Indication of Ng=2 means UE can also support precoders for Ng=4.*** |
| Xiaomi | FL proposal 2.1A: Our first preference is Alt.1b. But we are open to discuss the performance or implementation concerns companies mentioned.  FL proposal 2.1B: Support  FL proposal 2.1C: Support, similar view with QC  FL proposal 2.1D: we also think this is not critical at this stage. Ok for the updated version. |
| ZTE | For FL proposal 2.1.C, in our views, we may simplify this discussion, and how to indicate the candidate Ng list is up to UE capability signaling. We still prefer our previous suggestion as E/// also mentioned. Then the new note can be removed. |
| Intel | For updated FL proposal 2.1C:  We think it’s a valid point whether UE with Ng=2 can also support precoders with Ng=4. Ok with the version from Samsung.  For updated FL proposal 2.1D:  It should be further discussed. We think the co-phasing numbering in the original FL proposal 2.1D should also be included. |
| Apple | P2.1.A: we are fine, but we are also open for discussion on the practical concerns.  P2.1.B: Support  P2.1.C: Support it in principle. Tend to agree with QC that we should understand what this report means exactly. In our view, it should be tied with the corresponding codebook that a UE supports, and the specific antenna configuration is UE’s implementation (even though UE should report the supported codebook(s) based on its own antenna configuration).  P2.1.D: we are fine. No strong view on which option as either one should work. |
| FL | **FL Proposal 2.1.B:** A revised version agreed in the first GTW  **FL Proposals 2.1.C and 2.1.D**: Updated based on the received comments in ROUND1  ***FL Proposal 2.1.C:*** *For partial-coherent 8TX UE, UE reports Ng, the number of antenna groups.*  ***FL Proposal 2.1.D:*** *For codebook design of an 8TX partial-coherent UE, configured with an 8-port SRS resource*   * *For when Ng=2, down-select of the following convention for assumption of port coherency scheme is used*    + *Alt 1: two coherent groups of {0,2,4,6} and {1,3,5,7}*   + *Alt 2: two coherent groups of {0,1,4,5} and {2,3,6,7}*   + *Alt 3: two coherent groups of {0,1,2,3} and {4,5,6,7}* * *For when Ng=4, down-select of the following convention for assumption of port coherency scheme is used*   + *Alt 1: four coherent groups of {0,4}, {1,5}, {2,6}, and {3,7}*   + *Alt 2: four coherent groups of {0,1}, {2,3}, {4,5}, and {6,7}.* |
| FL | For **FL Proposals 2.1.C and 2.1.D:** We continue the discussions by email; the thread is closed.  For **FL Proposal 2.1.A:** Discussion continues in FL summary Section 2.1.1, and then in the next GTW. |
| FL | Thread is closed. |

# Codebook Design; ROUND2

In the first round of the discussion, 15 companies indicated Alt1-b as their preferred codebook structure, while 5 other companies stated their support for Alt2-a. The concerns expressed by the proponent of the companies not supporting Alt1-b can be summarized as follows,

* Alt1-b is not a unified solution; the network is required to support two very different precoding mechanisms.
* The gain of Alt1-b over Alt2-a is not substantial and not always observed by all supporting companies.
* Alt1-b requires excessive additional specification work, i.e., two separate designs for codebook, TPMI, etc.
* Under implementation impairments, Alt2-a performs better than Alt1-b.

Table 4 - Companies standing based on ROUND1 discussion for Alt1-b and Alt2-a

|  |  |
| --- | --- |
| * **Alt1-b:**   + Study NR Rel-15 UL 2TX/4TX codebooks and/or 8x1 antenna selection vector(s) as the starting point for design of the codebook for partially/non-coherent UEs   + Study NR Rel-15 DL Type I codebook as the starting point for design of the codebook for fully-coherent UEs * **Alt2-a:**   + Study NR Rel-15 UL 2TX/4TX codebooks and/or 8x1 antenna selection vector(s) as the starting point for design of codebook for fully/partially/non-coherent UEs | * **Alt1b**: ZTE, OPPO, DOCOMO, Lenovo, CMCC, Samsung, LG, Sharp, vivo (open to discuss), CATT, Nokia, google, Ericsson, Xiaomi(open to discuss), Apple(open to discuss), NEC, MediaTek * **Alt2a**: Huawei, Spreadtrum, Qualcomm, Google, Intel, IDC |

Based on the state of the discussion, and comments provided in ROUND1, FL Proposal 2.1.A is updated. The intention of the updated proposal is to address at least some of the concerns raised by the proponents of Alt2-a, while maintaining the core of Alt1-b.

*FL Proposal 2.1.A: For 8TX UE codebook-based uplink transmission,*

* *For partially/non-coherent UEs*
  + *Support NR Rel-15 UL 2TX/4TX codebooks and/or 8x1 antenna selection vector(s) as the starting point for design of codebook*
* *For fully-coherent UEs* 
  + *Support NR Rel-15 single panel DL Type I codebook as the starting point for design of the codebook*
    - *This is a UE optional feature. If not supported, NR Rel-15 UL 2TX/4TX codebooks and/or 8x1 antenna selection vector(s) is used as the starting point for design of codebook*
  + *Study the impact of implementation impairments, e.g., phase misalignment across the antenna ports, and potential mitigation methods.*

Table 5 - Companies’ views for FL Proposals 2.1.A

|  |  |
| --- | --- |
| **Company** | **Views** |
| QC | We agree with FL’s assessment of the pros and cons of Alt 1b vs Alt 2a. And In general, we are supportive to introduce UE capability to indicate UE can support the Rel-15 single panel DL Type I codebook or not. But, before that, we need to know if current coherent UE (following RAN4 coherent UE requirements) can support Alt 1b or not. In our view, the answer is no. But this falls into RAN4 domain, and an LS confirmation from RAN4 is needed.  *QC Modified FL Proposal 2.1.A: For 8TX UE codebook-based uplink transmission,*   * *For partially/non-coherent UEs*   + *Support NR Rel-15 UL 2TX/4TX codebooks and/or 8x1 antenna selection vector(s) as the starting point for design of codebook* * *For fully-coherent UEs*    + *Send an LS to RAN4 to ask the feasibility of coherent 8 Tx UE supporting NR Rel-15 single panel DL Type I codebook*   + *If RAN4 confirms above feasibility, Support NR Rel-15 single panel DL Type I codebook as the starting point for design of the codebook*     - *This is a UE optional feature. If not supported, NR Rel-15 UL 2TX/4TX codebooks and/or 8x1 antenna selection vector(s) is used as the starting point for design of codebook*   + *Study the impact of implementation impairments, e.g., phase misalignment across the antenna ports, and potential mitigation methods.* |
| vivo | The first main bullet for partial/non-coherent is fine.  For full-coherent, we suggest to keep both options for now, agree on details as much as possible for example values of O1, O2 for DL type I codebook, co-phasing alphabets for NR Rel-15 UL 2TX/4TX codebooks and exact combinations etc, whether to restrict to QPSK alphabets etc. This will help compare performance and complexity next meeting. One of the concerns on alt2a is there are too many ways to construct 8Tx precoders with NR Rel-15 UL 2TX/4TX codebooks and too many precoders to evaluate. Companies support alt1-b assumed (I believe) that CPE, FWA type of UEs are higher capable UEs than normal handheld devices. And, for lower capable CPE, FWA devices there are partial and non-coherent codebooks to cover. |
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# Number of Codewords for UL Transmission

In NR Rel-17, uplink transmission is restricted to single codeword. For 8TX UEs, some companies have proposed to enhance uplink transmission by increasing the number of codewords for 8TX UE. In the last meeting, it was agreed that for uplink transmission with rank<=4, only single CW is supported. However, for uplink transmission with rank>4, whether single or dual CW is used requires further discussion [2].

Several companies (18) have indicated that use of dual codeword for uplink transmission results in a higher performance than the case with a single CW. From the group of supporting companies, 7 companies have provided their evaluation results (**CATT**, **vivo**, **ZTE**, **OPPO**, **MediaTek**, **NTT**, **Qualcomm**).

While 5 of the companies report a notable gain resulting from use of 2 CW, **vivo** and **MediaTek** state that the performance gain of dual codeword compared to single codeword is negligible. In their contribution, Qualcomm confirms the gain that can be resulted from use of 2CW, however to keep the spec impact minimal, they propose use of single CW along with allowing use of different modulation per layer.

Table 6 - Companies standing for the number of codewords

|  |  |
| --- | --- |
| Number of codewords with >4 layers for codebook and non-codebook UL transmission for 8TX UE,   * **Alt1**: Single codeword * **Alt2**: Dual codewords | * **Alt2**: Huawei, ZTE, Spreadtrum, Lenovo, OPPO, Google, CATT, Intel, Xiaomi, CMCC, Sharp, Samsung, Nokia, NTT, Sony, Qualcomm(?), LG, IDC * Commented by:   + Not supporting **Alt2**: MediaTek   + Cautious: Apple, vivo |

Table 7 - Observations and findings reported by companies for the number of codewords

|  |  |
| --- | --- |
| **Company** | **Observations** |
| CATT (SLS) | * Results show a higher performance gain than 1CW that grows from %3 to %25 as rank increases from 5 to 8. |
| vivo (SLS) | * Performance gain of 2 CWs against 1 CW with modulation of 64 QAM and 256 QAM is negligible (maxRank=8). |
| ZTE (LLS) | * In LLS (to exactly evaluate Rx demodulation and decoding procedure), compared with 1 CW, 2 CWs bring significant performance gains: ~ 3 dB gain in both SNR and around 20% spectrum efficiency (SE) gains for typical scenarios. |
| OPPO (LLS) | * From the results, it can be found that 2CWs can provide some gain over single CW, at the cost of higher DCI overhead for CW information (e.g. MCS). It is proposed that two CWs and downlink CW-layer-mapping is reused for uplink transmission with rank >4. |
| MediaTek (SLS) | * From the simulations, we observe that the difference between single and dual CW transmission in terms of cell Avg. throughput is not so significant; it is hardly upto 4% in some cases. |
| NTT (SLS) | * For non-codebook-based, 2 CWs provides significant performance gain over 1 CW transmission in terms of 95%-ile and average packet throughput in low, medium, and high RU cases.   + For example, for RU=50%, the performance gain is 24.4% for 95%-ile, 19.3% for average, and 13.2% for 5%-ile packet throughput, respectively. * Compared with non-codebook, the performance gap between 2 CWs and 1 CW transmission with codebook-based becomes much smaller. |
| Qualcomm (LLS) | * Single CW with one modulation order suffers from significant performance loss, compared to the other three schemes, where the other three have almost same performance. Therefore, …, one reasonable compromise is supporting single CW with different modulation orders per layer. |

***FL Proposal 2.2.A - For uplink transmission with rank>4, support dual CW transmission.***

* ***Supported by:*** ***Huawei, ZTE, Spreadtrum, Lenovo, OPPO, Google, CATT, Intel, Xiaomi, CMCC, Sharp, Samsung, Nokia, NTT, Sony, Qualcomm(?), LG, IDC***
* ***Commented by:*** 
  + ***Not support: MediaTek***
  + ***Cautious: Apple, vivo***

If 2 CW is agreed for UL transmission for an 8TX UE, a new CW to layer mapping need to be defined. The codeword to layer mapping for the two cases of non-codebook-based and codebook-based by a fully coherent transmissions seem straightforward. However, since in a partially coherent UE, antenna ports can be divided into Ng antenna groups, codeword to layer mapping for the cases of codebook-based for a partially coherent UE need further discussion.

***FL Proposal 2.2.B – If dual CW is supported for uplink transmission by an 8TX UE, reuse DL Rel-15 codeword to layer mapping for non-codebook-based transmission.***

***FL Proposal 2.2.C – If dual CW is supported for uplink transmission by an 8TX UE, support the followings for codeword to layer mapping for codebook-based transmission,***

* ***For fully coherent UE, reuse DL Rel-15 layer mapping***
* ***For partially and non-coherent UEs, study***
  + ***Alt1: Reuse DL Rel-15 layer mapping for the entire set of antenna ports***
  + ***Alt2: Reuse DL Rel-15 layer mapping per antenna group***

Table 8 - Companies’ views for FL Proposals 2.2.A-C

|  |  |
| --- | --- |
| **Company** | **Views** |
| ZTE | * For FL Proposal 2.2.A: Support. We need further comment that LLS has real decoding procedure which is more closed to real implementation. * For FL Proposal 2.2.B: Support. * For FL Proposal 2.2.C: Support in principle. We prefer Alt2. If Ng=4, and if two CWs are supported for >4 layers, each CW corresponding to 2 port groups. |
| OPPO | We are fine with the proposals 2.2.A and 2.2.B.  For proposal 2.2.C, further clarification is needed for Alt2. If we understand correctly, we don’t think Alt2 can work with only two CWs. For example, for Ng=4, we need 4CWs for Alt2, while we need 8CWs for non-coherent transmission. |
| DOCOMO | FL Proposal 2.2.A/B: support.  FL Proposal 2.2.C: we have similar question as OPPO. How to understand Ng=4/8 for Alt2? |
| Lenovo | Support Proposal 2.2.A and Proposal 2.2.B.  For proposal 2.2.C, for clarity, prefer to add the following modification:  ***FL Proposal 2.2.C – If dual CW is supported for uplink transmission with Rank>4 by an 8TX UE, support the followings for codeword to layer mapping for codebook-based transmission,***   * ***For fully coherent UE, reuse DL Rel-15 layer mapping*** * ***For partially and non-coherent UEs, study***   + ***Alt1: Reuse DL Rel-15 layer mapping for the entire set of antenna ports***   + ***Alt2: Reuse DL Rel-15 layer mapping per antenna group*** |
| InterDigital | Proposal 2.2.A/B/C: Support. Regarding Alt2 of Proposal 2.2.C, we think the raised question can be considered as part of this study, e.g., the possible example mentioned by ZTE. |
| QC | For proposal 2.2.A, although our preference is supporting single CW with two modulation order, we can accept the FL proposal.  For proposal 2.2.B/C, we don’t see why the proposal cannot apply to CB based PUSCH. We understand that there are multiple antenna groups for partial coherent UE. But we don’t see it is a showstopper to apply the proposal. It is true that multiple antenna groups will impact precoding and layer to antenna group mapping, which should be further discussed. But we don’t see how multiple antenna groups will impact CW to layer mapping. |
| CMCC | FL Proposal 2.2.A/B: support.  FL Proposal 2.2.C: Support Alt 1. In Rel-15, for partial coherent UE, one CW can map to two antenna groups. For partial-coherent UE with Ng=4, when transmitting 8 layers, each antenna group would transmit 2 layers. If two CWs are used, one CW is mapped to 1-4 layers transmitted from two antenna groups, the other CW is mapped to 5-8 layers transmitted from the other two antenna groups. From our understanding, this mapping example belongs to Alt 1. |
| MediaTek | Not support proposal 2.2.A. As shown in our contribution is performance gain of 2CWs compared to 1CW is not significant and more importantly is scenario specific. In our view the performance improvement is not significant for the cost of UE hardware complexity in case of dual CW transmission in UL. |
| Samsung | Proposal 2.2.A: support  Proposal 2.2.B/C: same view as QCM, we fail to see the need to discuss NCB-based and CB-based separately, in particular, two different CW-layer mappings. From our side, we can only accept one solution for both, which is DL CW-layer mapping. |
| LG | For Proposal 2.2A, we are generally fine. But, it could be further considered whether to support SW/DW is based on the UE capability.  Proposal 2.2B is ok.  For proposal 2.2C, why do we need different CW-to-layer mapping according to antenna coherency? |
| Sharp | FL Proposal 2.2.A: Support.  FL Proposal 2.2.B: Support.  FL Proposal 2.2.C: The mapping for Alt2 should be clarified. |
| vivo | Proposal 2.2.A is fine  Proposal 2.2.B, in our view we can discuss codeword to layer mapping for codebook-based case first, then similar approach can be considered for non-codebook based case  Proposal 2.2.C, two alternatives for partial/non-coherent UEs for study are not very clear. It would be good to add some text or examples for better understanding |
| CATT | FL Proposal 2.2.A: Support.  FL Proposal 2.2.B: Support.  FL Proposal 2.2.C: We prefer Alt1. In this way, the codeword-to-layer mapping for the uplink and downlink can be consistent. According to Alt2, the mapping is associated with the structure of partial-coherent and non-coherent codebook and may need more than 2 CWs. Through the design of codebook, each antenna group can also be mapped to a different CW. Therefore, Alt 1 is sufficient for partial and non-coherent UEs. |
| Huawei, HiSilicon | We support FL Proposal 2.2.A and 2.2.B. For FL Proposal 2.2.C, we have similar question as other companies. From our understanding, the CW to layer mapping is not related to antenna/antenna groups in legacy. No matter the antenna layout, the layers have been there by precoder matrix. |
| Intel | For FL proposal 2.2A:  Support  For FL proposal 2.2B:  Support  For FL proposal 2.2C:  We don’t understand why the CW to layer mapping has dependency on UE coherence. |
| Nokia, NSB | Support FL proposal 2.2.A and 2.2.B.  FL Proposal 2.2.C: We also share the same concern on Alt 2. Alt 1 is okay. |
| FL | Many thanks for your valuable comments and suggestions.  **FL Proposal 2.2.A:** No update, it seems relatively stable.  **Updated FL Proposal 2.1.B & C:** Based on companies’ inputs, the proposals are merged into one proposal,  ***FL Proposal 2.2.BC – If dual CW is supported for uplink transmission with Rank>4 by an 8TX UE, reuse DL Rel-15 codeword to layer mapping for both codebook-based and non-codebook-based transmission.*** |
| Google | Support 2.2.A/B/C (latest version from FL) |
| Ericsson | **FL Proposal 2.2.A/B/C** We do not support dual codewords at this time. As we show in R1-2209671, we did not find gain from 2 CW transmission at the system level in high or low (outdoor or indoor FWA) SNR scenarios. Gains from two codewords can only be for ranks>4 and where the difference between the MCSs of the two codewords is large enough. By contrast, we find gain from two power control loops (two SRS resource sets), which can be more easily exploited since power control can be used for rank 2 and higher, unlike the rank>4 agreed to consider for two CWs.  We are also wonder how much spec impact there will be with respect to impact on resource allocation, support for retransmission, and what impact there might be on higher layers. Given this potential for large spec impact from 2 codewords, and that companies doing system level simulation have generally found modest or no gain and without considering alternatives like power control, we think the amount of spec impact should be better understood before agreeing to support two codewords. |
| Samsung | Support the latest proposals from the FL |
| Xiaomi | Support FL updated proposal. |
| ZTE | Support 2.2.A/B/C (latest version from FL) for progress, although we slightly prefer to the original version for B/C.  Regarding E///’s comment, it seems to propose a layer-specific power control for PUSCH, and specify the layer (group) to power control setting (e.g., close loop) mapping?   * If so, firstly, we think that the enhancement was discussed but failed (too difficult to maintain two loops since some of them may be cancelled due to dynamically change of RANK) in the very beginning of Rel-15 and LTE. Not doubt, that enhancement is out of scope of this WID. * Then, technically speaking, inter-UE/inter-cell interference can hardly be handled well in real-field case. It is due to that, when raising Tx power of a low-quality link for accommodating MCS/RI of a good link, it may burst the MU-MIMO/inter-cell interference. It is the reason why the link adaptation is mainly to use MCS and RI as usual (without increasing the risk of mutual interference). |
| Intel | Fine with updated FL proposal 2.2 B&C. |
| Apple | P2.2.A: maybe one compromised way is to support UE capability on one CW vs two CWs to address UE complexity issue.  P2.2.B/C: we also do not see why the CW to layer mapping should be different for different antenna coherency. We support the new P2.2.BC. |
| FL | **FL Proposal 2.2.A:** Updated based on Apple’s suggestion in ROUND1,  ***FL Proposal 2.2.A:*** *For uplink transmission with rank>4, support dual CW transmission.*   * *Support of dual CW transmission is based on UE capability.*   We continue the discussion here in FL summary, and then in GTW. |
|  |  |
|  |  |
|  |  |

# Other Topics

In this section, other topics related to the operation of 8TX UE are discussed. These are topics that we could tackle in parallel to the discussion on high priority topics.

* SRS configuration
  + NCB-based operation; down-selection of identified alternatives
  + CB-based operation; identify alternatives and decision
* Identifying UE power Capability modes
* Solutions for low overhead SRI/PMI indication

# SRS Configuration for 8TX UL Transmission

In the last meeting, three alternatives for SRS configuration for non-codebook UL transmission for an 8TX UE were identified for down-selection,

Table 9 - Companies standing on alternatives for SRS configuration for non-codebook

|  |  |
| --- | --- |
| * **Alt1**:A single SRS resource set configured with up to 8 single-port SRS resources      * **Alt2**: Up to two SRS resource sets, each configured with up to 4 single-port SRS resources * **Alt3**: Support both alternatives | * **Alt1**: Huawei, Spreadtrum, vivo, Lenovo, Google, CATT, CMCC, Apple, Qualcomm, NTT(1) * **Alt2**: vivo, LG      * **Alt3**: ZTE, Xiaomi, Ericsson, Samsung, NTT(2) |

***FL proposal 3.1.A: For SRS configuration for non-codebook UL transmission for an 8TX UE, Alt3 is supported, that is***

* ***A single SRS resource set configured with up to 8 single-port SRS resources***
* ***Up to two SRS resource sets, each configured with up to 4 single-port SRS resources***

***FL proposal 3.1.B: For SRI indication for non-codebook UL transmission by an 8TX UE, down-select from,***

* ***Alt1: Single SRI field with an increased size of bitfield, e.g., up to 8 bits***
* ***Alt2: Two SRI fields, e.g., corresponding to two SRS resource sets***

SRS configuration for codebook-based transmission has been discussed and some proposals are put forward by companies. In their contribution, **vivo** proposes use of 1 SRS resource with 8 ports and 2 SRS resources with 4 ports each to support 8Tx UL transmission. **OPPO**, **CATT** discuss configuration of one or two SRS resources with 8 SRS ports in an SRS resource set. **CMCC**, **Sharp**, **Apple** support configuration of a single 8-port SRS resource in one SRS resource set.

***FL Proposal 3.1.C – For SRS configuration for codebook-based UL transmission for an 8TX UE, down-select from,***

* ***Alt1:*** ***1 SRS resource set containing up to X single 8-port SRS resource, where X is FFS (X = 1, 2)***
* ***Alt2: 1 SRS resource set containing a single 8-port SRS resource or two 4-port SRS resources***

Table 10 - Companies’ views for FL proposals 3.1.A-C

|  |  |
| --- | --- |
| **Company** | **Views** |
| ZTE | * For FL proposal 3.1.A: Support. * For FL proposal 3.1.B: We tend to believe that Alt1 with single SRI field is suitable for single SRS resource set, and Alt2 with two SRI fields is suitable for two SRS resource sets. This is a straightforward solution with less spec impact. So we may not need to do any further down-selection. * For FL proposal 3.1.C: Support Alt1 with following changes:   ***FL Proposal 3.1.C – For SRS configuration for codebook-based UL transmission for an 8TX UE, down-select from,***   * ***Alt1:*** ***1 SRS resource set containing up to X ~~single~~ 8-port SRS resource, where X is FFS (X = 1, 2)*** * ***Alt2: 1 SRS resource set containing a single 8-port SRS resource or two 4-port SRS resources*** |
| OPPO | For proposal 3.1.A, we have strong concern on Alt.3. We cannot understand why both alternatives need to be supported. What is the benefit of Alt2 in case that Alt1 is already supported?  It should be noticed that the standardization effort is different for the two alternatives, e.g. the SRI indication is totally different. Support of both alternatives would double the workload.  For proposal 3.1.C, we think a SRS resource set with up to two SRS resources of 1-8 ports needs to be supported anyway. In this case, Alt.2 is not a complete solution. |
| DOCOMO | FL proposal 3.1.A: We slightly prefer to support one alt. (Alt1) only.  FL proposal 3.1.B: Seems not needed. We can decide proposal 3.1.A first.  FL proposal 3.1.C: we think one SRS resource set with up to two 8-port SRS resources should be supported, similar as legacy. Hence, in Alt1, the value of X is not FFS, but can be configured as 1 or 2. |
| Lenovo | **Re Proposal 3.1.A**  We understand that Alt1 and Alt2 corresponding to different UE capabilities. For the UE can only transmit SRS in the last 6 symbols and can only transmit one SRS resource in a symbol, Alt2 should be supported. However, we agree OPPO’s concern, only one of Alt1 or Alt2 can be configured for a UE with different UE capability. Suggest the following update:  ***FL proposal 3.1.A: For SRS configuration for non-codebook UL transmission for an 8TX UE, Alt3 is supported, that is***   * ***A single SRS resource set configured with up to 8 single-port SRS resources, or*** * ***Up to two SRS resource sets, each configured with up to 4 single-port SRS resources***   **Re Proposal 3.1.B:**  Support Proposal 3.1.B, still prefer Alt1.  **Re Proposal 3.1.C:**  Support, agree with ZTE’s proposed wording correction |
| InterDigital | Proposal 3.1.A: Okay, and aligned with Lenovo’s view. The configuration should be depending on UE’s capability.  Proposal 3.1.B: Support  Proposal 3.1.C: Support with ZTE’s revision |
| QC | For FL proposal 3.1.A, we don’t support it at this stage. We have a question for clarification.  What is the main benefit of configure 2 SRS resource sets? We assume the benefit is applying this to partial coherent UE. When UE has two antenna groups, each antenna group can have an SRS resource set. If so, then why not applying this to a UE with 4 antenna groups? If so, then we need 4 SRS resource sets.  For FL proposal 3.1.B. We prefer Alt 1.  Similarly, for proposal 3.1.C, we think Alt 2 should include the case of four 2-port SRS resources. |
| CMCC | Proposal 3.1.A: Not support. Support Alt1.  Configuring two SRS resource sets may require additional spec restrictions, such as the offset between two SRS resource sets, the consistency of transmission power and phase.  Proposal 3.1.B: Support Alt 1. For Alt 2, how to indicate 1+0, 2+0, 3+0, or 4+0 layer combinations may be need further clarification.  Proposal 3.1.C: Support Alt 1. |
| MediaTek | Proposal 3.1.A: We want to echo other companies that only one Alt should be down selected. Our preference is:  • A single SRS resource set configured with up to 8 single-port SRS resources  Proposal 3.1.B: Support, our preference is Alt 1.  Proposal 3.1.C: Support ZTEs updated wording. |
| Samsung | Proposal 3.1.A, 3.1.B: support  Proposal 3.1.C: support Alt1 |
| LG | For Proposal 3.1A, we also think one configuration is enough. Although our preference is Alt2, we could live with Alt 1 only.  For proposal 3.1.C, we share the view with OPPO. |
| Sharp | FL proposal 3.1.A: Not support. We support Alt 1 because for Alt 2/3, a DCI needs to indicate part of SRS resources in two SRS resource sets even if either of the two SRS resource sets is dropped due to overlapping and waiting delay occurs.  FL proposal 3.1.B: Support and we prefer Alt 1.  FL proposal 3.1.C: Support the ZTE’s proposal and we prefer Alt 1. |
| vivo | Proposal 3.1.A is fine, single resource set with 8 single-port resources for UL 8tx is straightforward, two resource set each with 4 single-port resource where 2 SRI fields are used in DCI, the design principle is similar to STx2P, both scenarios have their own use cases  Proposal 3.1.B, as explained above, both alt1 and alt2 should be supported  Proposal 3.1.C, we would like add alt3, where 2 SRS resource sets each containing X number of 4-ports SRS resource(s), alt3 is analogous to Rel-17 configuration. In our understanding, alt1 is applicable for full-coherent case, and alt3 is applicable for partial/non-coherent cases enables a common design for Rel-17 SDM, Rel-18 STx2P. Hence, alt1 and alt3 should be supported   * ***Alt1:*** ***1 SRS resource set containing up to X single 8-port SRS resource, where X is FFS (X = 1, 2)*** * ***Alt2: 1 SRS resource set containing a single 8-port SRS resource or two 4-port SRS resources*** * ***Alt3: 2 SRS resource sets each containing X 4-ports SRS resources*** |
| CATT | FL Proposal 3.1.A: Not support. We prefer a single SRS resource set configured with up to 8 single-port SRS resources. If 8 single-port SRS resources are configured in two SRS resource sets for UL 8Tx, a mechanism on identifying whether the two SRS resource sets are for UL 8Tx or for M-TRP PUSCH transmission is needed. It would cause unnecessary spec efforts.  FL Proposal 3.1.B: We prefer Alt1. If the maximum number of SRS resources in one SRS resource set is extended from 4 to 8, the same framework of SRI as that in Rel-17 can be used for UL 8Tx.  FL Proposal 3.1.C: Not support. There is no conclusion on whether 8-port SRS resource is supported for CB. If both 8-port SRS resource and 8 SRS ports in multiple SRS resources are supported, both Alts should be supported.  Besides, if 8 SRS ports in multiple SRS resources is supported, supporting more than 2 2/4-port SRS resources configured in one SRS resource set is preferred, since for 2Tx/4Tx, more than one SRS resources in one SRS resource set is supported in Rel-15. |
| Huawei, HiSilicon | For FL Proposal 3.1.A, we support a single SRS resource set, because we fail to see the benefits to use two SRS resource sets. In addition, there will be several issues if two SRS resource sets each with up to 4 SRS resources is supported. For example, if , there can be multiple possibilities in configuration across two SRS resource sets, such as 3+3, 2+4, or 4+2, which needs to be further discussed.  For FL Proposal 3.1.B, we support one SRI field, because we fail to see the benefits to use two SRI fields, such as SRI overhead.  For FL Proposal 3.1.C, if Alt 1 supports X 8-port SRS resource, it seems to be fair to support 2X 4-port SRS resources also for Alt 2, so we suggest the following update:  ***FL Proposal 3.1.C – For SRS configuration for codebook-based UL transmission for an 8TX UE, down-select from,***   * ***Alt1:*** ***1 SRS resource set containing up to X ~~single~~ 8-port SRS resource, where X is FFS (X = 1, 2)*** * ***Alt2: 1 SRS resource set containing up to 2X ~~a single 8-port SRS resource or two~~ 4-port SRS resources, where X is FFS (X = 1, 2)*** * ***Alt3: support both Alt 1 and Alt 2***   We support Alt 3 because Alt 1 and Alt 2 have their pros and cons. Compared to Alt2, Alt1 has lower SRI overhead. Assuming X=2, the SRI overheads of Alt 1 and Alt 2 are respectively 1 bit and 2 bits. However, Alt 2 can save spec effort and obtain higher flexibility. The 8 SRS ports can be divided into two groups and the configurations in current spec can be fully reused for each group, which will avoid designing patterns for an 8-port SRS resource. Furthermore, with Alt2, different resources for different port groups can be configured in FDM/TDM/CDM manner, which provides higher flexibility and suits the channel condition better. |
| Intel | For FL Proposal 3.1A:  What’s the condition to configure single SRS resource set and two SRS resource sets? It should be clarified.  For FL Proposal 3.1B:  This depends on the outcome of Proposal 3.1A and it can be discussed later.  For FL Proposal 3.1C:  Support Alt1 with one more candidate value of X ***(X = 1, 2, 4)***, since up to 4 SRS resources can be configured for full power mode 2 in Rel-16. |
| Nokia, NSB | 3.1.A: In the last meeting, RAN1 has this agreement in the SRS agenda:  **Agreement**  For SRS resource set(s) with usage ‘nonCodebook’ support 8 1-port SRS resources in one or multiple OFDM symbols.   * Note: The maximum number of simultaneous SRS resources is determined via UE-capability signalling.   Therefore, Alt 1 is already supported. With this support, there is no much benefit for Alt 2. We are not supporting 3.1.A.  3.1.B: this is related to 3.1.A. If only single SRS resource set is used, only 3.1.B-Alt1 is needed.  3.1.C: Alt 1, which is the extension of Rel-15 UL design. Alt 2 is not needed. |
| FL | Many thanks for your valuable comments and suggestions.  **Updated FL proposal 3.1.A:** Alt1 seems to be supported by all companies, and there is a majority for supporting only Alt1. Therefore, for now, we can agree to Alt1, and continue the discussion on whether configuration of more than one SRS resource sets, each configured with up to 4 single-port SRS resource is needed.  ***FL proposal 3.1.A: For SRS configuration required for non-codebook-based UL transmission by an 8TX UE, Alt1 is supported, that is***   * ***A single SRS resource set configured with up to 8 single-port SRS resources*** * ***FFS the need for configuration of up to two SRS resource sets, each configured with up to 4 single-port SRS resources***   **FL proposal 3.1.B:** No update at this time, based on companies’ inputs, we could come back to this a bit later.  **Updated FL proposal 3.1.C:** It seems to be the common understanding that Alt1 should be supported, hence based on companies’ inputs, the proposal is updated as,  ***FL Proposal 3.1.C – For SRS configuration for codebook-based UL transmission for an 8TX UE,***   * ***Support*** ***configuration of*** ***1 SRS resource set containing up to X ~~single~~ 8-port SRS resource(s), where ~~X is FFS (~~X = 1, 2~~)~~*** * ***Study the followings as further enhancements***   + ***Configuration of 1 SRS resource set containing a single 8-port SRS resource or two 4-port SRS resources***   + ***Configuration of 2 SRS resource sets each containing X 4-ports SRS resources*** |
| QC2 | Thank FL for updating the proposal. For proposal 3.1.C, if we are studying “Configuration of 2 SRS resource sets each containing X 4-ports SRS resources”, why not studying “Configuration of 4 SRS resource sets each containing Y 2-ports SRS resources”. We don’t have strong view here. But we would like to understand why the latter is excluded? |
| Google | Support latest 3.1.A/B/C. |
| Ericsson | **Original Proposal 3.1A: Support in principle**, but only if up to two sets are supported for both codebook and non-codebook, since the designs should not diverge. Whether a UE has two different panels or just one has nothing to do with whether codebook or non-codebook is supported by the UE. I think we should first agree the following, and then we can address 3.1A and 3.1B.  Furthermore, two sets are being considered for STxMP (as well as already defined for M-TRP), and we think the STxMP and 8 Tx designs should be aligned.  ***Proposal 3.1.A0: For SRS configuration for codebook or non-codebook UL transmission for an 8TX UE, up to two SRS resource sets is supported***  **Proposal 3.1C: Need further discussion.** As we comment above, we found that two SRS resource sets brings more performance than two codewords, is being discussed for STxMP, and is already supported for M-TRP. We would like to have some discussion on the relative performance of two resources in a set vs. two resources in different sets. Two SRS resources in a set is of course possible, although such a UE would have 16 antennas, if not 16 Tx chains. But we wonder how well it fits into Rel-18 scope. We are open to discussing further, however. |
| DOCOMO2 | For FL Proposal 3.1.C, we do not understanding the first half of following bullet to be FFS, because it has been included in the first bullet when X=1.   * + ***Configuration of 1 SRS resource set containing a single 8-port SRS resource or two 4-port SRS resources*** |
| Samsung | Proposal 3.1C: the configurations in the study bullet are not needed. We are not sure we need any enhancement over the 1st bullet. But, we are OK to study the need for any further enhancements.  ***FL Proposal 3.1.C – For SRS configuration for codebook-based UL transmission for an 8TX UE,***   * ***Support*** ***configuration of*** ***1 SRS resource set containing up to X ~~single~~ 8-port SRS resource(s), where ~~X is FFS (~~X = 1, 2~~)~~*** * ***Study the need for ~~followings as~~ further enhancements***   + ***~~Configuration of 1 SRS resource set containing a single 8-port SRS resource or two 4-port SRS resources~~***   + ***~~Configuration of 2 SRS resource sets each containing X 4-ports SRS resources~~*** |
| Xiaomi | We can support the latest FL’s proposals. Fine to make the legacy design related options as FFS. Currently if we have different SRI indication schemes for different SRS resource set configurations in mind, it would lead to the situation that these two options can not live together.  But if the SRI can use the **simple bitmap scheme** (1-1 bitmap mapping with max.8 bits indication) which do not increase the signaling overhead, and also two options of SRS resource configurations can both be supported. The benefits are :  1) No new SRI tables need to be specified which would look redundant from spec point of view.  2) Simple indication rules. For 2 SRS resource sets configuration, only definition of the first and second set is enough;  3) No restrictions on SRS resource configurations, providing more flexibility for both UE and gNB. |
| ZTE | For FL proposal 3.1.C, if we want to further review full Tx power transmission, we may need to open the door for X>2. So, for safe, we have the following suggestions:   * ***Support*** ***configuration of*** ***1 SRS resource set containing up to X ~~single~~ 8-port SRS resource(s), where ~~X is FFS (~~X = 1, 2~~)~~***   + ***FFS: other values for X, e.g., 4 for full Tx power transmission*** |
| Intel | For updated FL proposal 3.1 C:  As we commented, we think X=4 should not be excluded at this stage. The revision from ZTE is fine. |
| Apple | P3.1.A: we support Alt 1 and the updated P3.1.A. We would appreciate if companies can explain the benefit or the targeted use cases for Alt 2.  P3.1.B: we support Alt 1. Even if two SRS resource sets are supported, Alt 1 can still work. There does not seem to be any need to have two separate design.  P3.1.C: I am probably missing something here. Why do we need to support e.g. 2 8-port SRS resources in Alt 1? |
| FL | **FL Proposals 3.1.A and 3.1.C:** Updated based on the received comments in ROUND1,  ***FL proposal 3.1.A:*** *For SRS configuration required for non-codebook-based UL transmission by an 8TX UE, Alt1 is supported, that is*   * *Alt1: A single SRS resource set configured with up to 8 single-port SRS resources* * *FFS the necessity for configuration of up to two SRS resource sets, each configured with up to 4 single-port SRS resources.*   ***FL Proposal 3.1.C:*** *For SRS configuration required for codebook-based UL transmission for an 8TX UE,*   * *Support* *configuration of* *1 SRS resource set containing up to X 8-port SRS resource(s), where X = 2*   + *FFS: other values for X, e.g., 4, for full Tx power transmission.*   For **FL Proposals 3.1.A and 3.1.C,** We continue the discussions by email; the thread is closed. |

# SRI/TPMI Indication for Codebook UL Transmission

In the last meeting, to avoid excessive overhead associated to rank, precoding, and SRS resource indication, it was agreed to study low overhead solutions for SRI and/or transmitter precoder matrix indication for codebook-based for UL transmission by an 8TX UE.

In this meeting, companies have provided their initial solutions and thoughts on the topic. Based on the provided inputs by companies, there does not seem to be a converged view in offered solutions yet, and further discussion may be needed. Here is a summary of the comments and proposals that are made by more than one company. **ZTE**, **Ericsson** and **Sharp** have proposed that indication of one or multiple TPMI/SRI can be according to the UE coherency, i.e., number of antenna groups. For SRI indication, **CATT** and **CMCC** have proposed use of a single SRI field as the existing SRI indication in Rel-17. To reduce the DCI overhead, **Xiaomi**, **LG** are proposing a multi-level indication mechanism where in **LG** proposal a combination of MAC-CE + DCI is used, while **Xiaomi** proposes separate indication of rank and precoding information. **Samsung** and **CATT** suggest consideration of both Rel-17 framework, i.e., one TPMI field indicating one TPMI and TRI, or, a new TPMI indication framework.

***FL Proposal 3.2.A – For SRI and/or transmitter precoder matrix indication for codebook-based uplink transmission by an 8TX UE, study***

* ***Indication of one or multiple TPMI/SRI, according to the number of antenna groups***
* ***Whether/how Rel-17 framework can be reused with no specification impact***
* ***Separate indication of rank and precoding information***

Table 11 - Companies’ views for FL proposals 3.2.A

|  |  |
| --- | --- |
| **Company** | **Views** |
| ZTE | For FL Proposal 3.2.A:   * TPMI and rank indication should be based on port group. E.g., for each port group, there is a joint indication for TPMI and rank, as legacy. * SRI scheme depends on design of SRS resource (with # of ports) and SRS resource set. If supporting 8-port SRS resource, SRI is not needed to indicate port groups. * Rel-17 framework on SRI and TPMI cannot be reused directly without spec impact. Anyway, it is not proper for UL 8Tx fully coherent codebooks, and Rel-17 does not provide the mechanism of handling partial coherent case with Ng=2 and Ng=4. * According to our evaluation, separate indication of rank and TPMI cannot bring benefit for overhead reduction. So we generally do not prefer to split rank and precoding indication. |
| OPPO | We are fine to study. |
| DOCOMO | Before discussing TPMI/RI indication, we need to discuss and decide codebooksubset configuration first, which has impact on DCI indication design, in our understanding.  If legacy mechanism is used, it means that a fully-coherent UE can be configured with fully-coherent, partially-coherent and non-coherent precoders. In this case, a DCI field should be able to dynamically indicate from fully-/partially-/non-coherent precoders, thus, a unified design is needed, e.g., one joint field of TPMI/RI is needed for all coherent type precoders.  If legacy mechanism is not used, and if a certain type of UE can be configured with a certain type of precoders only, e.g., if a fully-coherent UE can be configured with fully-coherent precoders only, it is possible to consider different DCI indication methods for different coherent type precoders, e.g., one joint field of TPMI/RI for fully-coherent precoders, and multiple fields of TPMI/RI for partially-coherent precoders for multiple antenna groups.  Hence, it is important to discuss codebooksubset configuration for fully-coherent UE and partially-coherent UE first. |
| Lenovo | OK to study, prefer the following minor rewording:  ***FL Proposal 3.2.A – For SRI and/or transmitter precoder matrix indication for codebook-based uplink transmission by an 8TX UE, study***   * ***Indication of one or multiple TPMI/SRI, according to the number of antenna groups*** * ***Whether/how Rel-17 framework can be reused with no specification impact***   ***Whether/how separate indication of rank and precoding information is needed*** |
| InterDigital | Support for study. Re the comment from DOCOMO, we think the codebooksubset part needs also to be a part of this study. Whether to retain the legacy mechanism having the big joint TPMI/RI field in a DCI itself needs study. For example, rank indication part and associated TPMI indexes can be at least partially separately from the field to be indicated less frequently, or the coherency type by the UE capability can directly restrict the other TPMI indexes, where if fully-coherent then only includes fully-coherent precoders and not others, etc. |
| QC | We think the discussion of this signaling scheme can be deferred and resumed after the codebook design is settled. |
| CMCC | OK to study. The design of SRI field may depend on the outcome of SRS resource/sets discussion in Section 3.1. If 1 SRS resource set containing up to X 8-port SRS resource (X=1/2), existing SRI field can be reused. |
| MediaTek | Support to study |
| Samsung | Ok to study, and prefer to add the following   * Separate indication of number of antenna groups (n<=Ng) |
| LG | Fine to study. One clarification is what is Rel-17 framework? Isn’t it Rel-15? |
| Sharp | Support. We are open to discuss the codebooksubset configuraiton. |
| vivo | Generally fine with the proposal, on the first sub-bullet, it should be “Indication of one or multiple TPMI/SRI, according to coherence capability” |
| CATT | FL Proposal 3.2.A:   * We prefer one SRI indication. * If all of the SRS resources configured in the same SRS resource set, the SRI indication can be the same as that for Rel-17. * For TPMI indication for a UL 8Tx UE, * Alt 1: The same TPMI indication framework as that in Rel-17 is supported, i.e., one TPMI field indicating one TPMI and TRI; * Alt 2: A new TPMI indication framework is supported.   Considering different codebooks requires different TPMI indication frameworks ,the design of codebook structure should be prior, including the following issues:   * whether the higher coherency level codebook includes precoding matrices of lower coherency level coherent codebooks; * the TPMI indication scheme for full-coherent codebook and partial-coherent codebook   Thus, we prefer to update the proposal as follows:  ***FL Proposal 3.2.A – For SRI and/or transmitter precoder matrix indication for codebook-based uplink transmission by an 8TX UE, study***   * ***Indication of one ~~or multiple~~ TPMI/SRI~~, according to the number of antenna groups~~*** * ***Whether/how Rel-17 framework can be reused with no specification impact*** * ***Separate indication of rank and precoding information*** |
| Huawei, HiSilicon | We have the following comments:   1. We think the indication of one or multiple TPMI should be studied after the 8Tx codebook is decided. It is agreed to design partially coherent codebook based on Rel-15 UL 2TX/4TX codebooks. One possible codebook structure based on Rel-15 UL 4TX codebook:   Rank<=4 Rank>4    where and are selected from partially/non-coherent codewords of Rel-15 UL 4TX codebook. Here the number of TPMI is according to the number of transmission layers, rather than the number of antenna groups.   1. We think the indication of one or multiple SRI should be studied after the SRS resource is decided. If the number of antenna ports in one SRS resource is increased to 8, legacy SRI is fine. If two 4-port SRS resources are used for channel sounding of 8TX, TRP can indicate one SRI or two SRI. 2. We prefer to study both separate and joint indication of TRI and TPMI. For separate indication, there may be DCI blind detection issues because the number of codewords for each rank is typically different.   ***Separate/joint indication of rank and precoding information***   1. We prefer to consider beamformed CSI based precoder indication as another option to save overhead. Any way to reduce overhead will have negative impact on the accuracy of codebooks. One way to resolve this issue is that we can use beamformed CSI to indicate precoder with low overhead and high resolution. Specifically, TRP transmits a beamformed CSI-RS with precoder *WDL,* then UE can receive the CSI-RS as a vector of *PUL* as   By choosing the precoder WDL of CSI-RS, the selected codeword PUL can be indicated to UE with high precision. Because the CSI-RS overhead is not related to the number of codewords, we can design a high-resolution codebook with large codebook size. Even we can use beamformed CSI-RS to indicate optimal precoder without quantification.  As for the indication overhead, 8 CSI-RS ports are required for 8TX UL transmission with up to 8 layers, which occupies 8 resource elements. If we use the 8 resource elements to transmit DCI in PDCCH with QPSK modulation, the number of bits to be transmitted is typically 8\*2\*0.2=3.2, where 0.2 is a typical value of coderate in PDCCH. Compared to the DCI indication overhead in the candidate UL 8TX codebook, the overhead of beamformed CSI-RS based UL precoder indication is greatly reduced. |
| Intel | Generally fine with the proposal.  Just one question regarding the second bullet, what does it mean by “***with no specification impact***”. How can it work without any spec impact at all? Suggest to remove it. |
| Nokia, NSB | Okay for these feasibility study.. |
| FL | Many thanks for your valuable comments and suggestions.  **Updated FL proposal 3.2.A:** Updated the proposal to cover all study aspects proposed by companies.  ***FL Proposal 3.2.A – For SRI and/or transmitter precoder matrix indication for codebook-based uplink transmission by an 8TX UE, study***   * ***Whether/how to indicate ~~Indication of~~ one or multiple TPMI/SRI, according to the number of antenna groups, coherence capability, etc.*** * ***Whether/how to extend Rel-17 framework ~~can be reused with no specification impact~~*** * ***Whether/how to separate/joint indication of rank and precoding information*** |
| Google | We are a bit confused, why do we need to indicate >1 SRI for CB based operation? |
| Ericsson | OK to study according to latest FL proposal. |
| DOCOMO2 | We suggest following revisions.  ***FL Proposal 3.2.A – For SRI and/or transmitter precoder matrix indication for codebook-based uplink transmission by an 8TX UE, study***   * ***Whether/how to indicate ~~Indication of~~ one or multiple TPMI/SRI, according to the number of antenna groups, coherence capability, codebooksubset configuration, etc.*** * ***Whether/how to extend Rel-17 framework ~~can be reused with no specification impact~~*** * ***Whether/how to indicate separate/joint indication of rank and precoding information*** |
| Samsung | Our suggestion on separate indication of number of antenna groups is missed, suggest to include it in the stuty.  ***FL Proposal 3.2.A – For SRI and/or transmitter precoder matrix indication for codebook-based uplink transmission by an 8TX UE, study***   * ***Whether/how to indicate ~~Indication of~~ one or multiple TPMI/SRI, according to the number of antenna groups, coherence capability, etc.*** * ***Whether/how to extend Rel-17 framework ~~can be reused with no specification impact~~*** * ***Whether/how to separate/joint indication of rank and precoding information*** * ***Separate indication of number of antenna groups (n<=Ng)*** |
| Xiaomi | Fine with the latest FL proposal |
| ZTE | Support the FL proposal. |
| Intel | Generally fine with the latest FL proposal. |
| Apple | We are fine to study further, but it may be better to discuss the signaling detail after the codebook design becomes clearer. |
| FL | **FL Proposal 3.2.A:** Updated based on received comments in ROUND1,  ***FL Proposal 3.2.A:****For SRI and/or transmitter precoder matrix indication for codebook-based uplink transmission by an 8TX UE, study*   * *Whether/how to indicate one or multiple TPMI/SRI, according to the number of antenna groups, coherence capability, etc.* * *Whether/how to extend Rel-17 framework* * *Whether/how to separate/joint indication of rank and precoding information.* * *Whether/how to indicate n (<=Ng) selected antenna group(s) separately from TPMI/TRI indication* |
| FL | We continue the discussion by email; the thread is closed. |

# Full Power Operation

Many companies have expressed the importance of full power transmission for 8TX UE. In Rel-16, full power transmission for codebook transmission is supported by Mode 0, Mode 1 and Mode 2. Nokia, Qualcomm and IDC have stated that to support full power transmission for an 8 TX UE, Rel-16 full power transmission schemes can be re-used with necessary enhancements. Apple and CMCC have proposed to consider only advanced UEs (UEs with full-rated power capability for full power operation. Intel has brought up the issue that RAN1 needs to first discuss potential PA architecture for 8TX UEs prior to discussing full power operation.

***FL Proposal 3.3.A – In Rel-18, for full power operation by a partial/non-coherent 8TX UE configured with codebook-based transmission, support only advanced UEs (full rated PAs in all TX chains).***

Table 12 - Companies’ views for FL proposals 3.3.A

|  |  |
| --- | --- |
| **Company** | **Views** |
| ZTE | Regarding full power transmission for 8Tx, we tend to agree with Intel that potential PA architecture should be discussed firstly. |
| OPPO | We are fine with the proposal, which makes the standardization effort easier. |
| DOCOMO | Not support.  We agree with Intel/ZTE that potential PA architectures should be discussed firstly. |
| Lenovo | Support |
| InterDigital | Support |
| QC | We cannot accept this proposal, as it is very unlikely a UE will equip full rated PA in all 8 Tx chains. To make full power feasible for 8 Tx UE, RAN1 should allow other modes.  We actually have a proposal to enhance mode 0, to allow UE boost Tx power in a similar way as in mode 0, when the UE is not equipped with full rated PA on all Tx chains. For convenience of the discussion, we copied the proposal below. The details can be found in R1-2209973.  **Proposal: In addition to reusing Rel-16 full power mode 0/1/2, support a new mode 0A for full power transmission for PUSCH with 8 Tx.**   * **Mode 0A set the power scaling factor = for a PUSCH transmission, where is the power scaling factor the i-th Tx port. if i-th Tx port is used in the PUSCH transmission, otherwise.** |
| CMCC | Full power transmission for advanced UEs (full rated PAs in all TX chains) can be discussed firstly, which is independent of codebook design. Other PA architectures can be discussed when the codebook design is finished.  ***FL Proposal 3.3.A – In Rel-18, for full power operation by a partial/non-coherent 8TX UE configured with codebook-based transmission, ~~support only~~ advanced UEs (full rated PAs in all TX chains) can be discussed firstly.***  ***FFS full power operation for other PA architectures.*** |
| MediaTek | We support the proposal by QC. We don’t think its realistic to assume full rated PAs on all 8 TX chains. |
| Samsung | Prefer to defer this discussion later after codebook design |
| LG | Not support, agree with Intel/ZTE and Docomo. Besides, we still don’t have full picture of Rel-18 UL codebook, so it seems premature to agree this proposal. |
| Sharp | We have similar view with LG. |
| vivo | Full rated Pas in all Tx chains, i.e. mode 0 (according to Rel-16 discussion), should be supported. Other PA architectures can be further discussed, we understand that the discussion could be very diverse (there could be hundreds of possible architectures), if the group can agree on minimal set of PA architectures mode 2 can be discussed later. Mode 1 should be straightforward, additional non-antenna selection precoders for partial/non-coherent UEs. |
| CATT | Fine to discuss. We prefer to update the proposal as follows:  ***FL Proposal 3.3.A – In Rel-18, for full power operation by a partial/non-coherent 8TX UE configured with codebook-based transmission, support ~~only~~at least advanced UEs (full rated PAs in all TX chains).*** |
| Huawei, HiSilicon | We don’t support it and agree with Intel/ZTE/DOCOMO that potential PA architecture should be discussed firstly. From our point of view, full power mode 0/2 should be supported for better performance. |
| Intel | We are open to discuss the UE PA architecture for 8Tx operation. But it’s too early that only full rated PA in all Tx chains is supported. |
| Nokia, NSB | Concern about the wording “support only”. Does this mean that UE without full rated PAs cannot support full power Tx with 8Tx? This would make the 8Tx UE even worse than 4Tx UE with full Tx power capability (Rel-16 feature). Don’t agree with the proposal. |
| FL | Many thanks for your valuable comments and suggestions.  **Updated FL proposal 3.3.A:** Made some updates based on companies’ inputs. I appreciate that there are some interdependencies between codebook design, SRS configuration, … and full power operation, however we cannot wait until all details are settled down for other topics before we even start discussing full power. This proposal is to set the direction and take one step at the time towards the final objective.  ***FL Proposal 3.3.A – In Rel-18, for full power operation by a partial/non-coherent 8TX UE configured with codebook-based transmission, support ~~only~~at least Mode-0 that is by advanced UEs (full rated PAs in all TX chains).***   * ***FFS full power operation for other PA architectures.*** * ***FFS support of Mode-1 and Mode-2.*** |
| QC2 | We thank FL for updating the proposal. But we cannot support it. To us, mode 0 is the least useful full power mode for 8 Tx UE. Like we already commented, it is unlikely a UE will have 8 fully rated PAs. If RAN1 want to pick only a mode to support full power first, mode 1 should be the one. It has the smallest spec impact, can work with any PA structure, and does not require complicated capability signaling. |
| Google | Support the latest proposal from FL. |
| Ericsson | We agree with earlier comments that it is too early to downselect or prioritize full power modes. To my knowledge, there are no performance results on this, and without decisions on codebooks, SRS resources, and codewords, it seems difficult to have even a qualitative discussion of full power operation at this stage. We also think it is dangerous to assume that the highest amount of complexity or power can always be supported in FWA UEs; we prefer to have some flexibility in the design to allow as many UEs as possible bring the benefit of 8 Tx to networks. |
| Samsung | Do not support and prefer to discuss later. There is no reason to support one mode and not other two without any discussions. |
| Xiaomi | Support the latest FL proposal. |
| Apple | We are fine with the updated P3.3. |
| FL | **FL Proposal 3.3.A:** Updated based on received comments in ROUND1,  ***FL Proposal 3.3.A:*** *In Rel-18, on support of full power operation by a partial/non-coherent 8TX UE configured with codebook-based transmission,*   * *Identify and agree on at least one potential PA architecture by RAN1 meeting #111* * *Identify and agree on at least one mode of full power operation by RAN1 meeting #112* * *Note: If any of the above objectives was not met by the proposed timeline, full power operation is not supported in Rel-18.*   **FL Proposal 3.3.A:** Discussion will continue by email; the thread is closed. |

# Feature-lead Proposals for Approval

# Round1

**Agreement**

**Support the following cases for codebook design for 8TX precoders**

* **Full coherent precoders with Ng=1**
  + **FFS: Full coherent precoders with Ng=2, Ng=4**
* **Partial coherent precoders with Ng=2 and Ng=4**
  + **This does not imply any relation with the number of TPMI indications for 8TX precoder**
* **Non-coherent precoders**

***FL Proposal 2.1.C: For partial-coherent 8TX UE, whether Ng=2 and/or Ng=4 should be reported.***

* ***Note: FFS whether indication of Ng=2 means UE can also support precoders for Ng=4.***

***FL Proposal 2.1.A: For 8TX UE codebook-based uplink transmission, Alt1-b is supported.***

***FL Proposal 2.2.A - For uplink transmission with rank>4, support dual CW transmission.***

***FL Proposal 2.2.BC – If dual CW is supported for uplink transmission with Rank>4 by an 8TX UE, reuse DL Rel-15 codeword to layer mapping for both codebook-based and non-codebook-based transmission.***

***FL proposal 3.1.A: For SRS configuration required for non-codebook-based UL transmission by an 8TX UE, Alt1 is supported, that is***

* ***A single SRS resource set configured with up to 8 single-port SRS resources***
* ***FFS the need for configuration of up to two SRS resource sets, each configured with up to 4 single-port SRS resources***

***FL Proposal 3.1.C – For SRS configuration for codebook-based UL transmission for an 8TX UE,***

* ***Support*** ***configuration of*** ***1 SRS resource set containing up to X 8-port SRS resource(s), where X = 1, 2***
* ***Study the need further enhancements***
* ***FFS: other values for X, e.g., 4 for full Tx power transmission***

***FL Proposal 2.1.D: For codebook design of an 8TX partial-coherent UE, configured with an 8-port SRS resource***

* ***For when Ng=2, the following convention for assumption of port coherency scheme is used*** 
  + ***Two coherent groups of {0, 1, 4, 5} and {2, 3, 6, 7}***
* ***For when Ng=4, the following convention for assumption of port coherency scheme is used***
  + ***Four coherent groups of {0, 4}, {2, 6}, {1, 5} and {3, 7}***

***FL Proposal 3.2.A – For SRI and/or transmitter precoder matrix indication for codebook-based uplink transmission by an 8TX UE, study***

* ***Whether/how to indicate one or multiple TPMI/SRI, according to the number of antenna groups, coherence capability, etc.***
* ***Whether/how to extend Rel-17 framework***
* ***Whether/how to separate/joint indication of rank and precoding information***
* ***Whether/how to consider indication of number of antenna groups (n<=Ng)***

# Round2

**TBD**

# Round3

**TBD**

# List of Companies’ Proposals

|  |  |
| --- | --- |
| **Huawei, HiSilicon** | ***Proposal 1:*** *A single SRS resource set configured with up to 8 single-port SRS resources is supported.*  ***Proposal 2:*** *To reduce overhead of SRI for NCB PUSCH, reduce the flexibility of SRS resource selection.*  ***Proposal 3*：***Alt2-a should be supported for UL 8TX codebook.*  ***Proposal 4***：*For UL 8TX partially/non-coherent antennas, support*   * *for rank <= 4, and* * *for rank >4.*   ***Proposal 5:*** *The beamformed CSI-RS should be considered to indicate UL precoders to UE.*  ***Proposal 6:*** *Dual CW is used for uplink transmission with rank>4.*  ***Proposal 7:*** *Re-use the CW-layer mapping of Rel-15 PDSCH for uplink transmission with rank>4.* |
| **InterDigital, Inc.** | ***Proposal 1:*** *For the case of more than 4 layers for 8 Tx UL, RAN1 should discuss how/when to use single or dual codeword transmission, e.g., based on considered scenarios, UE types, coherency types, etc.*  ***Proposal 2:*** *Consider UE to report its capabilities on the number of antenna groups, supported type of antenna/panel structure or virtualization capability across UE antenna ports, etc.*  ***Proposal 3:*** *Support Alt2-a (based on Rel-15 UL 2TX/4TX codebooks) as baseline, and consider Alt1-b only if use of Rel-15 DL Type 1 codebook for fully-coherent UEs leads to a significant gain in throughput.*  ***Proposal 4:*** *RAN1 studies determination of preferred basis vectors based on UE’s precoded SRS transmissions, where the gNB can signal preferred basis vectors, through SRI indication.*  ***Proposal 5:*** *To reduce signaling overhead associated to SRI/TPMI indication for a 8TX UE, RAN1 studies partial update of TPMI/SRI information for 8TX UE.*  ***Proposal 6:*** *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.* |
| **ZTE** | ***Proposal 1:*** *Regarding full-coherent codebook design for 8-Tx,*   * *For full-coherent codebook with single port group, specify that: - Alt 1-b (Rel-15 DL type I for single panel) is reused;* * *For full-coherent codebook with multiple port groups: - Alt 2-a (Rel-15 UL 4-Tx/2-Tx UL codebooks) is reused.*   ***Proposal 2:*** *Regarding full-coherent codebook design for 8-Tx based on NR Rel-15 DL type I,*   * *Oversampling value (O1/O2) can be higher for lower rank(s), e.g., 4 for rank=2 or 3, but 1 for other rank values.*   ***Proposal 3:*** *Regarding partial-coherent codebook based on NR Rel-15 UL 4-Tx/2-Tx UL codebooks,*   * *Only full-coherent UL 4-Tx/2-Tx UL codebooks is preferred instead of full+partial+non coherent UL 4-Tx/2-Tx UL codebooks*   ***Proposal 4:*** *Regarding partial-coherent codebook design, the following category (CAT-C2 in Table 1) should be considered:*   * *For 4 port groups case, each port groups has 2 ports, and 4 ports among each 2 port groups (i.e., port group pair) are coherent, but ports across two group pairs are not coherent.*   ***Proposal 5:*** *Regarding non-coherent codebook design, the following aspects can be considered to reduce candidate non-coherent codebooks:*   * *Number of port groups* * *Limited starting port index, e.g., depending on number of port groups* * *A predefined port index order, e.g., (0,4,1,5,2,6,3,7)*   ***Proposal 6:*** *Regarding codebook indication for 8-Tx, Option B should be adopted:*   * *Option B: Indication for # of port groups, and separate fields each indicating rank+TPMI for a port group*   ***Proposal 7:*** *Regarding overhead reduction for codebook indication for 8-Tx:*   * *Candidate set of Ng which can be dynamically indicated in DCI can be configured by RRC signaling.*    + *E.g., for a UE supporting full-coherent 8-Tx ports, Ng=1, and Ng=2 can be configured by RRC, and DCI only needs to indicate the value of Ng for corresponding codebook selection.*   ***Proposal 8:*** *Regarding non codebook based transmission design for 8-Tx, with single SRS resource set configured with up to 8 single-port SRS ports*   * *Potential optimization for SRI re-design considering DCI overhead, e.g., 8 bits or less*    + *E.g., reduce the number of candidate SRS resource combination with “consecutive” number of SRS resources combination*   ***Proposal 9:*** *Regarding non codebook based transmission design for 8-Tx, support Alt3 of the following.*   * *Alt1: A single SRS resource set configured with up to 8 single-port SRS resources* * *Alt2: Up to two SRS resource sets, each configured with up to 4 single-port SRS resources* * *Alt3: Support both alternatives.*   ***Proposal 10****: On 8-Tx UL transmission enhancement, 2 CWs should be supported for more than 4 layers UL 8-Tx transmission.* |
| **Spreadtrum Communications** | ***Proposal 1:*** *For 8TX UE codebook-based uplink transmission, Alt2-a is preferred.*  ***Proposal 2:*** *Dual CW should be supported for uplink transmission with rank > 4.*  ***Proposal 3:*** *Alt1 for SRS configuration should be supported.*  ***Proposal 4:*** *Single filed for SRI for non-codebook-based transmission should be supported.*  ***Proposal 5:*** *Single filed or separate fields for TPMI for codebook-based transmission should be decided after codebook design is stable.* |
| **vivo** | ***Proposal 1****: Two SRI fields corresponding to two SRS resource sets for non-codebook transmission can be considered to simplify the SRI indication.*  ***Proposal 2:*** *DL type1 codebook is supported/configured to UE supporting full coherent capability for 8Tx UL transmission. And, one field in DCI to indicate TPMI for PUSCH transmission.*  ***Proposal 3:*** *Codebook constructed by two 4Tx precoders indicated by two TPMI fields is supported for partial and none-coherent UEs.*  ***Proposal 4:*** *SRS configuration for non-codebook based scheme, down select between alternative 1 and 2 from RAN1#110, the use case of simultaneous multi-panel transmission should also be considered while making decision.*  ***Proposal 5:*** *SRS configuration for codebook based scheme, to support both full-coherent (type 1) codebook and partial/non-coherent codebook, support 1 SRS resource with 8 ports and 2 SRS resources with 4 ports each to support 8Tx UL transmission.*  ***Proposal 6****: Carefully consider whether to support 1 CW or 2 CWs for transmission rank>4. If 2 CWs are supported, how to multiplex UCI and other potential spec impacts shall be further discussed.*  ***Proposal 7:*** *Following issues should be further discussed:*   * *PTRS-DMRS association indication when rank>4, if supported* * *Impact on full power modes*   ***Proposal 8:*** *Support type 1 codebook for full-coherent 8Tx antenna configuration.* |
| **Lenovo** | ***Proposal 1:*** *Prioritize full coherence and partial coherent UE capability for 8Tx UL operation*  ***Proposal 2:*** *Use antenna grouping to represent different UL Tx coherence assumptions, with the following conditions*   * *Antenna configurations of different antenna groups are identical* * *Antennas within an antenna group are coherent.* * *Coherence assumptions of two antennas across two antenna groups are the same*   ***Proposal 3:*** *A number of antenna coherence groups Nc is used to characterize the coherence assumption across antenna groups, where Nc≤Ng*  ***Proposal 4:*** *Introduce bitmap based TPMI indication for non-coherent 8Tx UE.*  ***Proposal 5:*** *Adopt Alt1-b for 8Tx codebook design.*  ***Proposal 6:*** *8Tx partial-coherent codebook can be contructed by the following methods:*   * *For rank 1, the 8Tx codebook can be obtained by indicating a rank 1 2Tx or 4Tx precoding matrix and antenna group, and apply the 2Tx/4Tx precoding matrix to the antennas from the selected antenna group.* * *For rank 2, 3, 4 with Ng=2, 8Tx codebook can be obtained by indicating a rank 2, 3, 4 4Tx precoding matrix and assigning the precoding vectors to two antenna groups.* * *For rank 2, 3, 4 with Ng=4, 8Tx codebook can be obtained by indicating 2 or 3 or 4 antenna groups and indicating a 2Tx rank 1 precoding matrix for each antenna group.* * *For rank>4 with Ng=2, two CWs shall be scheduled and each CW is transmitted by an antenna group by indicating a 4Tx precoding matrix.* * *For rank>4 with Ng=4, two CW shall be scheduled and each CW is transmitted by two antenna groups by indicating a 4Tx partial/non-coherent 4Tx precoding matrix*   ***Proposal 7:*** *Study mechanism to indicate paramters for a UE to obtain a full coherent precoding matrix. Use mode 1 of Rel-15 DL Type 1 codebook as a baseline.*  ***Proposal 8:*** *TPMI signaling overhead is considered as a performance metric when studying different alternatives for 8Tx UL codebook design*  ***Proposal 9:*** *More than 4 layers PUSCH transmission should be supported for 8TX PUSCH transmission with 2 codewords.*  ***Proposal 10:*** *Study codeword-to-layer mapping for 8TX UL PUSCH transmission with more than 4 layers scheduling.*  ***Proposal 11:*** *Study UCI multiplexing in PUSCH scheduled with 2 codewords.*  ***Proposal 12:*** *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 13:*** *Introduce bitmap based SRI indication for non-codebook based 8Tx PUSCH transmission.*  ***Proposal 14:*** *Study the performance benefits, signaling overhead and specification impact of supporting frequency-selective precoding for 8Tx UE* |
| **OPPO** | ***Proposal 1:*** *Strive for a unified codebook design applicable to all considered antenna layouts.*  ***Proposal 2:*** *Support Alt 1b for UL 8Tx codebook*   * *For full-coherent codebook, NR DL 8Tx Type 1 CB (wideband beam and co-phasing) with smaller (O1,O2) is used as baseline.* * *For partial-coherent codebook, support codebook design based on Rel-15 UL 2TX/4TX codebooks, and both Ng=2 and 4 should be considered.* * *For non-coherent codebook, support 8x1 antenna selection vector for each layer with restricted codebook size.* * *For cross-polarized antennae array, the antennae within a polarization group should be coherent.*   ***Proposal 3:*** *Consider separate indication of TRI and TPMI if two-stage codebook is agreed for 8 Tx uplink.*  ***Proposal 4:*** *For uplink transmission with rank>4, two CWs with the same CW-layer-mapping as downlink is applied.*  ***Proposal 5:*** *A single SRS resource set is configured with up to 8 single-port SRS resources for 8 TX non-codebook transmission.*  ***Proposal 6:*** *Introduce SRI enhancement to indicate up to 8 SRS resources for non-codebook uplink transmission. Two solutions can be considered for SRI overhead reduction:*   * *Opt.1: Introduce SRI indication to select 5-8 SRS resources from a SRS resource set for Lmax=5-8, where the legacy indication is reused for 1-4 layers.*    + *For overhead reduction, it may not be necessary to support all the SRS resource combinations for rank>4.*   + *Separate tables are introduced for Lmax=5-8 similar to Rel-15.* * *Opt.2: New tables are introduced to support 8Tx non-codebook transmission with 1-8 layers*   + *The legacy indication for 1-4 layers can be re-designed for lower overhead.*   + *For rank M, consider to only indicate the first M SRS resources from SRS resource set.*   + *Separate tables are introduced for Lmax=1-8 similar to Rel-15.* |
| **Google** | ***Proposal 1:*** *The enhancement of 8Tx transmission supports both coherent and partial coherent transmission, where the partial coherent transmission assumes coherent transmission within a panel.*  ***Proposal 2:*** *Support to define the 8Tx UL codebook based on NR Rel-15 UL 2TX/4TX codebooks and/or 8x1 antenna selection vector(s) as the starting point for design of codebook for fully/partially/non-coherent UEs (Alt2-a).*  ***Proposal 3:*** *For uplink transmission with rank>4, two CWs are supported based on the downlink codeword-to-layer mapping scheme.*  ***Proposal 4:*** *Support up to 1 PT-RS port for 8Tx transmission.*  ***Proposal 5:*** *Support a single SRS resource set for NCB configured with up to 8 single-port SRS resources (Alt1).* |
| **LG Electronics** | ***Proposal 1:*** *Whether to support single codeword or dual codeword can be determined by X where X can be 4, 6, 8.*  ***Proposal 2:*** *Support Alt1-b for 8Tx codebook design.*  ***Proposal 3:*** *Support fully-coherent, partial-coherent and non-coherent UEs for 8Tx uplink transmission.*  ***Proposal 4:*** *Support two-level partial coherency for codebook based 8Tx UL transmission.*   * *Level-1: 4-group 2Tx coherency* * *Level-2: 2-group 4Tx coherency*   ***Proposal 5:*** *For 8Tx UL codebook construction, consider the following two options*   * *Option 1. Common UL codebook for all potential antenna layouts* * *Option 2. Multiple UL codebooks*   ***Proposal 6:*** *Consider Table 4 for rank 1 8Tx codebook for CP-OFDM.*  ***Proposal 7****: Consider Table 5 for rank 1 8Tx codebook for DFT-s-OFDM.*  ***Proposal 8:*** *Consider Alt2 for SRS configuration of 8Tx non-codebook based UL transmission.*  ***Proposal 9****: Consider following alternatives for overhead reduction for 8Tx codebook based UL transmission.*   * *Alt1. Legacy TRI and TPMI indication, i.e. joint encoding in one field.* * *Alt2. Codebook sub sampling* * *Alt3. Hierarchical indication (e.g., MAC-CE + DCI)* |
| **CATT** | ***Proposal 1:*** *For UL 8Tx with DFT-s-OFDM, precoding matrices in Table 1 are adopted for non-coherent codebook.*  ***Proposal 2:*** *For UL 8Tx operation, whether all or a subset of port selection precoding matrices are supported for non-coherent codebook is considered.*  ***Proposal 3:*** *For UL 8Tx operation, if only a subset of port selection precoding matrices are supported for non-coherent codebook, all port selection precoding matrices for low ranks(i.e. for rank=1,2) are kept, and down selection of precoding matrices for high ranks(i.e. for rank>2) are considered.*  ***Proposal 4:*** *For UL 8Tx operation, a subset of precoding matrices in non-coherent codebook included in partial-coherent codebook and full-coherent codebook is considered.*  ***Proposal 5:*** *On the codebook design for partial-coherent UEs with UL 8Tx, two coherent groups with four coherent antennas per group, and four coherent groups with two coherent antennas per group are considered.*  ***Proposal 6:*** *On codebook design for partial-coherent UEs with UL 8Tx,*   * *For two coherent groups, one of the following port coherency schemes is selected:*    + *Alt 1: two coherent groups of {0,2,4,6} and {1,3,5,7}*   + *Alt 2: two coherent groups of {0,1,4,5} and {2,3,6,7}*   + *Alt 3: two coherent groups of {0,1,2,3} and {4,5,6,7}* * *For four coherent groups, one of the following port combination schemes is selected:*   + *Alt 1: four coherent groups of {0,4}, {1,5}, {2,6}, and {3,7}*   + *Alt 2: four coherent groups of {0,1}, {2,3}, {4,5}, and {6,7}*   ***Proposal 7：****UL 8Tx partial coherent UEs with 2 coherent groups, the codebook with the structure of* *or matrices generated by row transformation of**is considered, where , are 4Tx partial-coherent precoders selected from Rel-15 UL 4Tx partial-coherent codebook,* ***,*** *, and* ***.***  ***Proposal 8:*** *For 8Tx full-coherent UEs with one antenna group, the full-coherent codebook can be generated based on NR Rel-15 DL Type I SP 8Tx codebook.*  ***Proposal 9:*** *For UL 8Tx full-coherent UEs, the codebook can be generated based on NR Rel-15 DL Type 1 codebook, with the following oversampling ratios considered:*   * *For UPA structure with (Ng, N1, N2) = (1, 2, 2), (O1, O2)=(1,1)* * *For UPA structure with (Ng, N1, N2) = (1, 4, 1), (O1, O2)=(2,1)*   ***Proposal 12:*** *For UL 8Tx full-coherent UEs with 2 antenna groups, design the UL 8Tx full-coherent codebook based on NR Rel-15 DL Type I MP codebook is considered.*  ***Proposal 13:*** *For the design of codebook for UL 8Tx UEs, Alt 1-b is supported (i.e. NR Rel-15 UL 2TX/4TX codebooks and/or 8x1 antenna selection vector(s) as the starting point for design of the codebook for partially/non-coherent UEs; and NR Rel-15 DL Type I codebook as the starting point for design of the codebook for fully-coherent UEs).*  ***Proposal 14:*** *For UL 8Tx for codebook based PUSCH, only one SRI field is used for SRS resource indication.*  ***Proposal 15:*** *For UL 8Tx for codebook based PUSCH with 8-port SRS resource(s) configured, keeping the existing SRI indication as that in Rel-17.*  ***Proposal 16:*** *For TPMI indication for a UL 8Tx UE, down selection one of the following:*   * *Alt 1: The same TPMI indication framework as that in Rel-17 is supported, i.e., one TPMI field indicating one TPMI and TRI* * *Alt 2: A new TPMI indication framework is supported*   ***Proposal 17:*** *For SRS configuration for non-codebook UL transmission for an 8Tx UE, a single SRS resource set configured with up to 8 single-port SRS resources is supported.*  ***Proposal 18:*** *For SRI for UL 8Tx for non-codebook based PUSCH, same framework as that in Rel-17 is used, i.e., one SRI field is used to indicate SRS resource(s) from the SRS resource set.*  ***Proposal 19:*** *For 8Tx PUSCH, 2 CWs for rank>4 is supported.*  ***Proposal 20:*** *For an 8Tx PUSCH transmission with rank v>4, the first ⌊𝒗𝟐⌋ layers are mapped to the first codeword, and the other layers are mapped to the other codeword, where v is the number of layers for the PUSCH transmission.* |
| **Intel Corporation** | ***Proposal 1:*** *For 8Tx UL codebook design, if RAN1 strives for unified solution for different coherence, then Alt2-a is preferred; otherwise, the codebook design could be based on Alt1-b.*  ***Proposal 2:*** *For partial coherent UE with 8Tx, the number of antenna groups should be reported.*  ***Proposal 3:*** *RAN1 to further discuss how to reduce the amount of precoders for Alt2-a and Alt1-b.*  ***Proposal 4:*** *RAN1 to further discuss the TPMI indication for PUSCH transmission with 8Tx.*  ***Proposal 5:*** *For 8Tx UL, RAN1 to discuss the codebook subset configuration, i.e., whether to follow the principle in Rel-15.*  ***Proposal 6:*** *For 8Tx UL, two codewords can be used if the rank is larger than 4. The downlink codeword-to-layer mapping could be reused.*  ***Proposal 7:*** *For 8Tx UL transmission, RAN1 to discuss the switching between single codeword and dual codewords operation.*  ***Proposal 8:*** *For two codewords, RAN1 to consider different MCS/RV/NDI for different codewords.*  ***Proposal 9:*** *RAN1 to discuss the UCI multiplexing when two codewords are used, i.e., whether the UCI is multiplexed with only one codeword or the UCI can be multiplexed with both codewords.*  ***Proposal 10:*** *For codebook based transmission with 8Tx, one SRS resource set could be configured. The number of SRS resources and number of ports for SRS resources could be discussed together with full power operation.*  ***Proposal 11:*** *RAN1 to discuss the UE PA architectures to be considered for full power operation with 8Tx in Rel-18.*  ***Proposal 12:*** *For non-codebook based transmission, one SRS resource set could be configured, and joint encoding of SRI and RI is preferred.* |
| **Sony** | ***Proposal 1:*** *Support two CWs for UL transmission with rank>4.*  ***Proposal 2:*** *Panel-specific CW to layer mapping can be considered for multi-panel UE UL transmission.*  ***Proposal 3:*** *Channel state-based CW to layer mapping can be considered for 8 Tx UE UL transmission.*  ***Proposal 4:*** *Dynamic CW to layer mapping indication scheme can be considered 8 Tx UE UL transmission.* |
| **NEC** | ***Proposal 1:*** *From UE perspective, reporting capability of full, partial and non coherent is sufficient. And considering the partial coherent layouts, more than one type of partial coherent for different number of antennas within a group can be introduced.*  ***Proposal 2:*** *For codebook based uplink transmission, support Alt 1-b (DL Type I codebook for full-coherent UE, and UL 2Tx/4Tx for partial/non-coherent UE) for codebook design.*  ***Proposal 3:*** *Overhead reduction for partial and non coherent codebook should be studied, for example, based on antenna groups.* |
| **xiaomi** | ***Proposal 1****: Dual codewords can be supported for up to 8 layers of uplink transmission.*  ***Proposal 2:*** *For SRS configuration for NCB, support Alt.3.*  ***Proposal 3:*** *For non-codebook based PUSCH transmission with 8Tx, SRI indicated in bitmap for both approaches of SRS configurations can be unified, and is preferred for the simplicity without any effort on the design of new SRI tables.*  ***Proposal 4****: To make a trade-off between performance and signalling overhead, the subset of the Rel-15 DL Type I 8Tx codebook with reduced oversampling factors (N1,N2,O1,O2)=(4,1,2,1) and (2,2,2,2) can be used for Rel-18 UL 8Tx fully-coherent codebook.*  ***Proposal 5:*** *The subset selection can be based on CSI estimation, SVD algorithm, and etc. A group of* *high-probability codewords with the same beam (i1) and co-phasing (i2) can be selected.*  ***Proposal 6:*** *Concatenating two or four Rel-15 UL 4Tx fully-coherent codewords with a co-phasing factor (e.g., +1, -1, +j, -j) can be adopted for Rel-18 UL 8Tx fully-coherent codebook. For different number of ranks L, for, the codewords is designed as . For, the codewords can be designed as, e.g., , , , or arbitrary L layers of .*  ***Proposal 7:*** *Support Alt1b for Rel-18 UL 8Tx codebook.*   * *Study NR Rel-15 UL 2TX/4TX codebooks and/or 8x1 antenna selection vector(s) as the starting point for design of the codebook for partially/non-coherent UEs.* * *Study NR Rel-15 DL Type I codebook as the starting point for design of the codebook for fully-coherent UEs.*   ***Proposal 8:*** *The codewords with QPSK constellation entries can be selected from Rel-15 DL Type I (N1,N2,O1,O2)=(4,1,2,1) codebook with high priority to reduce the computational complexity of the hardware implementation by replacing the complex-number multiplication operations with the addition operations.*  ***Proposal 9:*** *The antenna ports can be divided into two or four antenna port groups for 8Tx partially-coherent UE. For two antenna port groups, the antenna ports can be divided into {0,1,4,5} and {2,3,6,7}. For four antenna port groups, the antenna ports can be divided into {0,4}, {1,5}, {2,6}, and {3,7}.*  ***Proposal 10****: For partially-coherent codewords, four or two same/different Rel-15 UL 4Tx fully-coherent codewords are concatenated for two or four antenna port groups, respectively, i.e., or for two antenna port groups, and for four antenna port groups.*  ***Proposal 11:*** *Each row of Rel-15 UL 4Tx/2Tx codewords should be set as the corresponding antenna ports when different antenna port partition schemes are used.*  ***Proposal 12:*** *Antenna selection* *vectors/matrixes can be used for the Rel-18 UL 8Tx non-coherent codebook. Considering the signalling overhead, all antenna selection vectors/matrixes can be used for rank≤X while the subset can be selected for rank>X. The value of X can be left for further study, e.g., L=2.*  ***Proposal 13****: Considering the signaling overhead, the bit width of TPMI for Rel-18 UL 8Tx codebook can be set as 6, 7, or at most 8 bits.*  ***Proposal 14****: The precoding matrix can be indicated jointly or* *separately by TPMI and RI.* |
| **CMCC** | ***Proposal 1:*** *Support Alt1-b: NR Rel-15 DL Type I codebook as the starting point for design of the codebook for 8TX fully-coherent UE.*  ***Proposal 2:*** *The supported configurations of (N1, N2) for 8 TX UE can be (Ng=1, N1=2, N2=2), (Ng=1, N1=4, N2=1), (Ng=2, N1=2, N2=1), (Ng=4, N1=1, N2=1) with the consideration of dual polarization, and the supported configurations of over sampling factor (O1, O2) can be further discussed for the codebook design of 8 TX fully-coherent UE.*  ***Proposal 3:*** *Support Alt1-b: NR Rel-15 UL 2TX/4TX codebooks as the starting point for design of the codebook for partially-coherent UE.*  ***Proposal 4:*** *If same spatial vector can be assumed among different antenna groups, the common spatial vector and phase offset design should support to indicate both partial-coherent and non-coherent codebooks for partially-coherent UE.*  ***Proposal 5:*** *If different spatial vectors are assumed for different antenna groups, multiple TPMIs should be indicated to UE for each antenna groups for partially-coherent UE.*  ***Proposal 6:*** *Support Alt1-b: 8x1 antenna selection vector(s) as the starting point for design of the codebook for non-coherent UE.*  ***Proposal 7:*** *Support 8-port SRS resource in one SRS resource set with usage ‘codebook’.*  ***Proposal 8:*** *SRI field in Rel-15 can be reused for codebook based 8 TX UL transmission, when only one SRS resource is configured, the SRI field in DCI is absent, when two SRS resources are configured, 1 bit of SRI field in DCI is reused to indicate the selected SRS resource.*  ***Proposal 9:*** *Support Alt1: A single SRS resource set configured with up to 8 single-port SRS resources for ‘non-codebook’.*  ***Proposal 10:*** *Support single SRI field with up to 8 bits for ‘non-codebook’.*  ***Proposal 11:*** *For uplink transmission with rank>4, enable 2 CWs with individual MCS, RV and NDI for 8 TX UL transmission.*  ***Proposal 12:*** *Full power transmission for 8 TX UE with full rated PAs on each Tx chain can be discussed firstly, which is independent of codebook design.* |
| **Sharp** | ***Proposal 1:*** *We should reconfirm definition of antenna group*  ***Proposal 2:*** *Support the correspondence between Ng and each coherent type for codebooksubset as follows.*   * *Full coherent: Ng=1* * *Partial coherent: Ng=2,4.* * *(Non coherent: Ng=8)*   ***Proposal 3:*** *Support oversampling ratio (O1, O2) = (1,1), (2,1) and (2,2) for DL Type I codebook.*  ***Proposal 4:*** *Support Alt1-b for codebook design of 8TX UL codebook-based transmission.*  ***Proposal 5:*** *Support 1CW with rank<=4 and 2CW with rank>4.*  ***Proposal 6:*** *Support a single SRS resource set configured with up to 8 single-port SRS resources and low overhead solutions should be discussed.*  ***Proposal 7:*** *TPMI indication table should be separated according to the number of antenna group for 8Tx transmission.* |
| **MediaTek Inc.** | ***Proposal 1:*** *Support single CW over dual CWs for >4-layer transmission as the performance gain of dual CW is limited in UL.*  ***Proposal 2:*** *Due to superior performance, down select Alt-1b for 8TX codebook design:*   * *Study NR Rel-15 UL 2TX/4TX codebooks and/or 8x1 antenna selection vector(s) as the starting point for design of the codebook for partially/non-coherent UEs* * *Study NR Rel-15 DL Type I codebook as the starting point for design of the codebook for fully-coherent UEs*   ***Proposal 3:*** *Prioritize Partial and No coherent codebook designs for Multi-panel transmission. Coherency not to be assumed across the panels at least for codebook design.*  ***Proposal 4:*** *DL (SP) Type I CBs to be considered as starting point for all UE antenna layouts for full coherent transmission.*  ***Proposal 5:*** *Prioritize the CB design for partially coherent UE with two and four coherent antenna groups.*  ***Proposal 6:*** *Study feedback overhead reduction methods for Partial coherent UEs where the CB design is based on concatenation of the Legacy 4Tx/2Tx CBs.* |
| **Apple** | ***Proposal 1:*** *For the support of 8 Tx UL with codebook based transmission scheme, UE reports:*   * *Whether it supports full coherency, partial coherency, or non-coherency in antenna configuration.* * *For a full-coherent or partial coherent UE, it further reports the antenna layout.*    + *For a full-coherent UE, it reports whether it supports (2, 2, 2) or (4, 1, 2) layout.*     - *Note that whether the layout is considered as (4, 1, 2) or (1, 4, 2) is not critical for the UE, because the UE may rotate the direction.* * *For a partial-coherent UE, it reports whether it supports 2 or 4 antenna groups.*   ***Proposal 2:*** *For codebook based transmission scheme with 8Tx UL, support 1 SRS resource with up to 8 ports.*  ***Proposal 3:*** *For codebook based transmission scheme with 8Tx, support Alt 1b.*   * *For full coherent antenna configuration, reuse the Rel-15 DL Type I codebook design for 8 Tx with small oversampling factor (O=2).* * *For partial coherent antenna configuration, use the Rel-15 UL 2Tx/4Tx codebooks for the per-antenna-group precoding.*   + *FFS how the layers are split among the groups* * *For non-coherent antenna configuration, a mechanism that provides full flexibility for the antenna port selection is considered as the starting point for the design.*   + *FFS overhead reduction*   ***Proposal 4:*** *For full power transmission, 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 5:*** *For non-codebook based transmission scheme with 8Tx UL, support Alt 1: a single SRS resource set configured with up to 8 single-port SRS resources.*  ***Proposal 6:*** *For non-codebook based transmission scheme with 8Tx UL, a mechanism that provides full flexibility for the SRI indication is considered as the starting point for the design.*   * + *FFS overhead reduction*   ***Proposal 7:*** *For uplink transmission with rank > 4, single CW is considered as the baseline. Two CWs can be considered only if significant gain is identified.* |
| **Ericsson** | ***Proposal 1:*** *Restrict codebooks for 8 TX UEs such that elements of the precoding matrices are limited to the set {+1, +j, -1, -j}. This implies that (𝑶𝟏, 𝑶𝟐) = (1,1) for 𝑵𝐠 = 1 and (𝑵𝟏, 𝑵𝟐) = (4, 1), and that (𝑶𝟏, 𝑶𝟐) = (2, 2) for 𝑵𝐠 = 1 and (𝑵𝟏, 𝑵𝟐) = (2, 2).*  ***Proposal 2:*** *8 Tx codebooks support coherent combining of 8 ports in an SRS resource using precoders based on the Rel-15 DL Type I codebook.*  ***Proposal 3****: If multi-SRS resource set operation is defined, it is defined for both CB-based and NCB-based operation.*  ***Proposal 4:*** *Both single and dual SRS resource set configurations are supported for Rel-18 NCB-based operation.*  ***Proposal 5:*** *Focus the study of Rel-18 NCB-based operation with up to 8 layers on using Rel-15 principles, allowing any combination of SRS resources for a given maximum number of layers and SRS resources.*  ***Proposal 6:*** *Support indication of one or multiple precoders and SRS resources, where UEs transmit a portion of layers according to a Rel-15 precoder that corresponds to an indicated SRS resource with 4 ports or less, and support indication of an 8-port coherent precoder corresponding to one 8-port SRS resource* |
| **Samsung** | ***Proposal 1****: 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, and antennae across multiple groups are non-coherent* * *FC/PC precoders: comprises two components*    + *selection of antenna group(s), where a group comprises 2, 4, or 8 antennae (number of groups )*   + *precoder across the selected antenna group(s)* * *NC precoders: selection of antenna group(s), where group comprises single antenna (number of groups )*   ***Proposal 2****: regarding the 8Tx UL codebook,*   * *support Alt1-b* * *reuse DL Type I codebook parameters () to describe/configure 8Tx UL codebook*   + *FC:*   + *PC:*   + *NC:*   ***Proposal 3:*** *study the following approaches to reduce TPMI payload*   * *Approach 1: based on codebook parameter, e.g. , lower oversampling factors* * *Approach 2: based on efficient signalling for the indication of (A) antenna group(s), and (B) UL precoding matrix, e.g. two separate indicators, e.g. SRI for (A) and TPMI for (B)*   ***Proposal 4****: Discussion on full power modes can start after the 8Tx codebook design is sufficiently mature*  ***Proposal 5****: regarding 8Tx NCB based UL transmission,*   * *Number of SRS resources (): support up to 8* * *Number of SRS resource sets: support Alt3 (both one SRS resource set and two SRS resource sets)* * *When , the SRI indication follows legacy (Rel.15) scheme (i.e. based on combinatorial tables), and* * *When , the SRI indication is based on a length- bitmap*   ***Proposal 6****: 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 7**: for uplink transmission with rank > 4, support 2 CWs (reusing legacy DL CW-layer mapping) |
| **NTT DOCOMO, INC.** | ***Proposal 1:*** *Support 2 CWs for more than 4-layer PUSCH transmission.*  ***Proposal 2:*** *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 (reuse DL codeword-to-layer mapping)* * *DCI enhancement with codeword-specific indications of MCS, NDI, and RV* * *UCI multiplexing on two codewords PUSCH*   ***Proposal 3:****For 8TX UL codebook design, support Alt1-b.*   * *For fully-coherent precoders, new 8TX precoder (each with a new TPMI index) is designed based on existing Rel-15 DL Type I codebook.*   + *Support one candidate value of (N1, N2) and (O1, O2), e.g., (N1, N2)=(4, 1), (O1, O2)=(1, 1).*   ***Proposal 4:*** *Similar as legacy, fully-coherent UEs can be configured with 'fullyAndPartialAndNonCoherent' codebook subset; partially-coherent UEs can be configured with 'partialAndNonCoherent' codebook subset.*  ***Proposal 5:*** *Support a unified TPMI/RI indication method for fully-/partially/non-coherent UEs/precoders.*   * *Support joint indication of layer and TPMI.* * *For TPMI, support single precoder indication (with one TPMI index) for fully/partially/non-coherent precoders.*   ***Proposal 6:*** *For SRS configuration for non-codebook UL transmission for an 8TX UE, prefer to support Alt1. Can also accept Alt3.*   * *If Alt3 is supported, different configuration methods are applicable to UEs with different antenna coherent capabilities.* |
| **Qualcomm Incorporated** | ***Proposal 1:*** *For 8 Tx PUSCH in Rel-18, Ng=2, 4 are not applicable to fully coherent 8 Tx.*  ***Proposal 2:*** *adopt Alt 2a for 8 Tx PUSCH fully coherent precoder codebook.*   * *Construct the codebook for fully coherent 8 TX PUSCH based on NR Rel-15 UL 2TX/4TX codebooks.*   ***Proposal 3:*** *8 Tx UL codebooks reuse entries from QPSK constellation, without introducing constellation higher than QPSK.*  ***Proposal 4:*** *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 (i.e., Alt 1-b).*   * *Prioritize the specification of the following two cases. o Concatenate two 4 Tx precoders to build an 8 Tx precoder.*    + *Concatenate four 2 Tx precoders to build an 8 Tx precoder.* * *FFS details on signalling to reuse and concatenate existing Rel-15 precoders.* * *FFS how to reduce the size of the codebook.*   ***Proposal 5:*** *For SRS configuration for non-codebook UL transmission for an 8TX UE, support Alt 1.*   * *Alt1: A single SRS resource set configured with up to 8 single-port SRS resources.*   ***Proposal 6:*** *Support using single CW with two modulation orders to transmit PUSCH with more than 4 layers.*  ***Proposal 7:*** *For 2 CWs PUSCH with 8 layers in Rel-18, reuse Rel-15 2 CWs PDSCH CW to layer mapping procedure.*  ***Proposal 8:*** *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 9:*** *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 10:*** *In addition to reusing Rel-16 full power mode 0/1/2, support a new mode 0A for full power transmission for PUSCH with 8 Tx.*   * *Mode 0A set the power scaling factor = for a PUSCH transmission, where is the power scaling factor the i-th Tx port. if i-th Tx port is used in the PUSCH transmission, otherwise.* |
| **Nokia, Nokia Shanghai Bell** | ***Proposal 1:*** *Support Alt1-b: study Rel-15 DL Type I CB design for full-coherent 8Tx, and study Rel-15 UL CB design for partial-coherent 8Tx.*  ***Proposal 2:*** *For 8Tx PUSCH, for full coherent case, the antenna group number Ng=1.*  ***Proposal 3:*** *Consider reusing Rel-15 uplink codebook design principle for 8Tx partial coherent codebooks with* 𝑵𝒈=𝟐 *and* 𝑵𝒈=𝟒*.*  ***Proposal 4:*** *Extend Rel-16 full power mode 1 and mode 2 support to 8Tx.*  ***Proposal5:*** *For uplink transmission with rank>4, dual CW shall be used.*  ***Proposal 6:*** *If two codewords are supported for uplink Tx, consider supporting rank combinations of 2+3, 3+3, 3+4, and 4+4.* |

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