**3GPP TSG RAN WG1 #118 R1-2407280**

**Maastricht, The Netherlands, August 19th – 23rd, 2024**

**Agenda item:** 9.2.2

**Source:** Moderator (Samsung)

**Title:** Moderator Summary#3 on Rel-19 CSI enhancements: Round 3

**Document for:** Discussion and Decision

## Introduction

The scope given in the Rel-19 NR MIMO Phase 5 WID pertaining to CSI enhancement is as follows:

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| 1. Specify CSI support for up to 128 CSI-RS ports, targeting FR1    1. Type-I codebook refinement supporting up to a total of 128 CSI-RS ports across all resources, assuming legacy CSI-RS resources (with up to 32 CSI-RS ports per resource), based on extension of legacy codebooks    2. Type-II codebook refinement supporting up to a total of 128 CSI-RS ports across all resources, assuming legacy CSI-RS resources (with up to 32 CSI-RS ports per resource), based on extension of legacy codebooks, **without modifying any codebook parameter other than** introducing additional values for the number of ports codebook parameter(s)    3. Extension of CRI(s)-based CSI reporting (CQI/PMI/RI calculated per CRI for ≥1 CRIs) for hybrid beamforming supporting up to a total of 128 CSI-RS ports across all resources, with up to 32 CSI-RS ports per resource, without new codebook design 2. Specify UE reporting enhancement for CJT deployments under non-ideal synchronization and backhaul, targeting FR1, both FDD and TDD 3. Inter-TRP time misalignment and frequency/phase offset measurement and reporting, assuming legacy CSI-RS design, with stand-alone aperiodic reporting on PUSCH |

## Summary of companies’ proposals and views

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***Ground rules in sharing your inputs:***

* **Please do NOT input anything in Tables 1A, 2A, and 3A**
  + **Including company names - appreciate your trying to save me some work, but …**
  + **For some reason, most likely due to poor MS Word inter-platform/version compatibility support (if any), the formatting of the FL proposals will change (for the worse) if you do so. This has happened several times in Athens and Changsha ☹**
* **Please input your comments ONLY in Tables 1C, 2C, and 3C, thanks! 😊**

### Issue 1 (WID objective 2a and 2b): Type-I and Type-II codebook refinement for up to 128 CSI-RS ports

Table 1A Summary: issue 1

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| **#** | **Issue/proposal** | **Companies’ views** |
| 1.2.1 | **Proposal 1.B.1**: For the Rel-19 Type-I SP and Type-II codebook refinements (except based on Rel-18 Type-II Doppler) for 48, 64, and 128 CSI-RS ports, active resource counting is:   * FFS: For Capability 1 timeline: 1 vs K * For Capability 2 timeline: 1   **FL assessment**: This was discussed OFFLINE [2].  Since Capability 2 is quite (too) relaxed, there is no reason to further relax both OCPU and ARC for Capability 2.  For ARC, since the increase in the total # antenna ports (to up to 128) will be addressed in the ‘triplet’, there doesn’t seem any need to double-book this (mostly relevant to measurement buffering) in ARC (hence 1 should be more fitting, and K is excessive). Hence legacy in FG 2-33 can be interpreted as “Ks=1” (post aggregation) rather than “Ks=K”(pre-aggregation) | **1:**  **Support/fine:** Ericsson, Nokia/NSB, ZTE, Fraunhofer IIS/HHI, Intel, TCL, Samsung, vivo, Google, CATT, Qualcomm, NTT DOCOMO, Xiaomi, HONOR, Lenovo/MotM (Cap2), Spreadtrum, CMCC, Sharp, OPPO, MediaTek, NEC, New H3C, KDDI, Kyocera,  **Concern:** Huawei/HiSi, Fujitsu (Cap1), Apple (Cap1)  **K:**  **Support/fine:** Huawei/HiSi, Fujitsu (Cap1), Apple (Cap1), Samsung (2nd), vivo, OPPO, Google (Cap 1), Lenovo/MotM (Cap1),  **Concern:** Qualcomm  **1 and K (UE indicates):**  **Support/fine:** Apple, Fujitsu, Qualcomm,  **Concern:** Huawei/HiSi, Samsung, Ericsson, CMCC, vivo, |
| 1.3.1 | **[117] Agreement**  For the Rel-19 Type-I codebook refinement for 48, 64, and 128 CSI-RS ports, for RI=v=1, support the following:   * for each group of SD basis vectors, a 3-bit scaling factor can be NW-configured via higher-layer (RRC) signalling, where the scaling factors are defined as scalings on the power control offset configured for the associated CSI-RS resources   + The values of and for this feature are separately configured from those for CBSR   + Separate configuration (RRC signalling) from CBSR   + The candidate values of and are the same as those agreed for CBSR * The codepoints of each of the group-specific 3-bit scaling factors are mapped to values of * Note: This feature is a separate UE capability   FFS: Whether this can be extended to RI=v>1 …  **Proposal 1.C.1**: For the Rel-19 Type-I codebook refinement for 48, 64, and 128 CSI-RS ports, for RI= >1, apply the 3-bit scaling factor(s) as agreed in RAN1#117, where the scaling factor applied to the selected SD basis vector is given by , where is the scaling factor associated with the beam, and is the number of layers transmitted using the SD basis vector.   * Note: This feature is a separate UE capability   **Question 1.C.1**: For the Rel-19 Type-I SP codebook refinement for 48, 64, and 128 CSI-RS ports, regarding the 3-bit scaling factor, please share your view whether this can be extended to RI=v>1 (and provide justification)  **Yes**: Ericsson, Nokia/NSB,  **No**: IDC, TCL, OPPO, Xiaomi, Huawei/HiSi, ZTE, Fujitsu,  **Need more discussion/study**: Qualcomm, CMCC, Samsung, Apple, NTT DOCOMO, Xiaomi (ok), HONOR, Google, Lenovo/MotM, Fraunhofer IIS/HHI, | **Support/fine:** Ericsson, Nokia/NSB, MediaTek, Lenovo/MotM, NTT DOCOMO, [Qualcomm], Spreadtrum,  **Not support:** ZTE,Apple (more discussion) |
| 1.5.3 | **[117] Agreement**  For the Rel-19 Type-I SP codebook refinement for 48, 64, and 128 CSI-RS ports with RI=5-8, support the following schemes:   * The same O1=O2 value(s) as RI=1-4 are supported * Scheme-A (based on Scheme3 described in RAN1#116bis):   + W1 structure:     - The 1st SD basis vector is freely selected and subsequent 2 (RI=5-6) or 3 SD basis vectors (RI=7-8) are freely selected such that they are orthogonal in at least one dimension (horizontal or vertical).     - …   **Proposal 1.E.3**: For the Rel-19 Type-I SP codebook refinement for 48, 64, and 128 CSI-RS ports, for Scheme-A RI=5-8, by RAN1#118, decide, from the following alternatives, the selection scheme for the other SD basis vectors (in Part 2 UCI, wideband):   * Alt1: Comprising a 1-bit flag i3∈{0,1} and for each of the *nSDBV* other selected SD basis vectors,   + If i3=0:     - -bit and -bit indicators, and     - q2 ( bits)       * In this case, q1 = mod(i1,O1) of the first SD basis vector   + If i3=1:     - -bit and -bit indicators, and     - q1 ( bits)       * In this case, q2 = mod(i2,O2) of the first SD basis vector   Note: It is up to the editor this is captured in the specification  Note: (q1,q2) is analogous to (i1,i2) for Type-II CSI   * Alt2: -bit indicator for each of the *nSDBV* other selected SD basis vectors * Alt3: -bit indicator, selecting *nSDBV* SD basis vectors from the beams orthogonal to first beam * Alt4: One-bit orthogonal beam group indicator, and separate indicator per SD basis vector, with   + , , if , or   + , , if * Alt5: A -bit indicator to indicate the clusters of size , where the selected SD basis vectors are located, a 1-bit flag to indicate the orthogonal beam group and a -bit indicator of the position within the cluster for each of the selected SD basis vectors, where if and if .   Note (from previous agreement): *nSDBV*=2 (*v*=5-6) or 3 (*v*=7-8)  **FL assessment**: This needs to be resolved. The previous agreement leaves the details on indication open. While there are other slightly different alternatives, the above represent the ones that are aligned with the previous agreement and specific enough not to leave any open issue.  Alt1: ZTE, Qualcomm, Ericsson, Fujitsu, Google, Lenovo/MotM, Tejas, Intel,  Alt2: Xiaomi, vivo, NTT DOCOMO, Apple, Spreadtrum,   * Concern (overhead): OPPO   Alt3: Huawei/HiSi, Samsung, vivo, NEC, Apple, CMCC   * Concern (combinatorial memory): Qualcomm, MediaTek, Fraunhofer IIS/HHI, CATT, Spreadtrum,   Alt4: Nokia/NSB, MediaTek, Qualcomm, Ericsson,  Alt5: Fraunhofer IIS/HHI, MediaTek, | **Support/fine**: Huawei/HiSi, vivo, Xiaomi, ZTE, Nokia/NSB, Qualcomm, Samsung, Ericsson, MediaTek, Fujitsu, Google, Lenovo/MotM, Fraunhofer IIS/HHI, Tejas,  **Not support**: |
| 1.9 | **Proposal 1.I**: For the Rel-19 Type-I SP and MP codebook refinement for 48, 64, and 128 CSI-RS ports, for RI=*v*>1, for each PMI sub-band, UE shall select a recommended *P*-by-*v* precoder matrix (associated with the reported PMI) with *v* orthogonal columns.  **FL assessment**: This is to ensure orthogonality constraint for Type-I is maintained. It is argued that this is especially crucial for SU-MIMO where the gNB typically follows the recommended PMI. | **Support/fine:** Qualcomm,ZTE (open), MediaTek (SP), Nokia/NSB, Apple,  **Not support:** vivo, Samsung, Fujitsu, Lenovo/MotM, NTT DOCOMO, Huawei/HiSi, CMCC, |
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Table 1B SLS results: issue 1

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| **Company** | **SLS results** | | |
| **Issue #** | **Metric** | **Observation** |
| Huawei/HiSi | Other (SRS port grouping) | Normalized throughput (LLS) | *It is observed in Figure 4 that 43% performance gain can be achieved by PDSCH reception with SRS port grouping compared to max Rank-4. The performance of 8R rank-8 is also shown in the figure as an upper bound, which is difficult to be implemented due to the high complexity currently.* *Moreover, it can be observed from figure 9 that the performance of low complexity receiver (two antenna groups) without SRS port grouping enhancement is very poor even at high SNR.*    Figure 4 Performance of 8Rx UE with different receiver schemes under practical interference |
| Samsung | Other (SRS port grouping) | Avg UPT gain | *The case of low complexity 8 RX receiver w/o SRS port grouping incurs 65% UPT loss com-pared to 4RX scenario. This basically implies that it is not possible to work for RI>4 without SRS port grouping assumption for low-complexity 8RX receiver* |
| Ericsson | 1.3.3 | Mean user throughput gain, 5%-tile throughput gain | *In the table below, it is shown that the impact of using a group size larger than 1 along the dimension, i.e., . As seen in the results, the mean and 5th-percentile throughput decrease with increasing group sizes along the dimension.* |

Table 1C Additional inputs: issue 1

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| **Company** | **Input** |
| Mod V0 | **Please share your inputs on each of the issues and, if applicable, proposals in TABLE 1A** |
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### Issue 2 (WID objective 2c): CRI-based CSI for hybrid beamforming (HBF)

Table 2A Summary: issue 2

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| **#** | **Issue** | **Companies’ views** |
| 2.3.1 | **Proposal 2.C.1**: For the Rel-19 CRI-based CSI refinement for up to 128 CSI-RS ports based on Rel-16 eType-II, regarding UCI omission for the UCI reported *in CSI part-2*, other than priority 0 (G0), the UCI packing order and the 2M consecutive priority levels are defined w.r.t the M CRIs (including the non-reported MR CRIs) as follows:   * Consecutive priority levels (higher to lower):   + **G1 PMI components** associated with the first configured CMR among the non-reported MR CRIs,   + **G2 PMI components** associated with the first configured CMR among the non-reported MR CRIs,   + …,   + **G1 PMI components** associated with thelast configured CMRamong the non-reported MR CRIs,   + **G2 PMI components** associated with the last configured CMRamong the non-reported MR CRIs,   + **G1 PMI components** of the **1st reported CRI**,   + **G2 PMI components**of the **1st reported CRI**,   + …,   + **G1 PMI components** of the **(M-MR)th reported CRI**,   + **G2 PMI components** of the **(M-MR)th reported CRI**.   Note: For UCI fields in wideband (G0), **G1 PMI components**, and **G2 PMI components**, legacy design is fully reused.  **FL assessment**: Based on Round-2 agreement for Type-I, replace “even/odd sub-bands” with “G1/G2 PMI components” (no sub-band notion for Rel-16 eType-II) for clarity | **Support/fine:**  **Not support:** |
| 2.3.2 | **Question 2.C.2**: For the Rel-19 CRI-based CSI refinement for up to 128 CSI-RS ports, regarding UCI omission for the UCI reported *in CSI part-1 (only applicable to PUCCH-based reporting and Rel-15 Type-I codebook)*, **please share your preference between Alt1 and Alt2**:  Alt1 (extension of legacy): M consecutive priority levels are defined w.r.t the M CRIs (including the non-reported MR CRIs) as follows:   * (M-MR) consecutive priority levels (higher to lower): CSI part-1 of the 1st reported CRI, CSI part-1 of the 2nd reported CRI, …   + The UCI associated with the non-reported MR CRIs is assigned the highest MR priority levels, ordered based on their MR CSI-RS resource IDs (the smaller ID is reserved the higher priority level)   Alt2 (following PUSCH-based): CSI part-1 is either reported entirely or dropped entirely  Summary   * Alt1: vivo, Qualcomm, Huawei/HiSi, Samsung, Lenovo/MotM, NTT DOCOMO, ZTE, Ericsson, MediaTek, Xiaomi, CATT, Fujitsu, Apple, Spreadtrum, Tejas, * Alt2: Nokia/NSB, Lenovo/MotM, NTT DOCOMO   **FL assessment**: Although it can be argued that Alt1 is closer to legacy, Alt2 should be the baseline since it is analogous to PUSCH | |
| 2.4.1 | **Proposal 2.D.1**: For the Rel-19 CRI-based CSI refinement for up to 128 CSI-RS ports, regarding timeline:   * Multiply legacy Z’ by a factor of max(M,2). * Z is increased by max((M–1),1)\*Z’ to match the increase in Z’   **FL assessment**: This proposal is a synthesis between proposals from vivo and Qualcomm | **Support/fine**: vivo, Qualcomm, Huawei/HiSi, Apple, NTT DOCOMO, LG, IDC, Spreadtrum, Qualcomm, Nokia/NSB, CMCC, Samsung, Ericsson (as long as Alt3 OCPU), Sharp, MediaTek, Lenovo/MotM (ok),  **Not support**: MediaTek (legacy), Intel (legacy), Xiaomi (legacy), HONOR (legacy), ZTE (Ks.Z’), Google (legacy), |
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Table 2B SLS results: issue 2

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Table 2C Additional inputs: issue 2

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| **Company** | **Input** |
| Mod V0 | **Please share your inputs on each of the issues and, if applicable, proposals in TABLE 2A** |
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### Issue 3 (WID objective 3): CJT calibration reporting for non-ideal synchronization and backhaul

Table 3A Summary: issue 3

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| **#** | **Issue** | **Companies’ views** |
| 3.1 | **Question 3.A.1**: For the Rel-19 aperiodic standalone CJT calibration reporting, when ReportQuantity is ‘cjtc-P’ (DL/UL phase offset), regarding the support of sub-band reporting (>1), please share your view on the following FFS points:   * Supported sub-band size(s), e.g. following the legacy CSI sub-band definition, vs {1, 2, 4, 8, 16 PRBs} * Whether the UE performs measurement over the entire configured CSI reporting band WCSI * If needed, mechanism to limit CSI reporting overhead (e.g. maximum NSB-P) * If needed, configuration of whether the CSI-RSs are MRT-beamformed in frequency-domain or not   **FL assessment:** This needs resolution | |
| 3.3 | **Proposal 3.C.3**: For the Rel-19 aperiodic standalone CJT calibration (CJTC) reporting, to facilitate UE-specific delay offset pre-compensation on PDSCH by the NW, support configuring a UE (via RRC signaling) to perform PMI calculation for the Rel-18 eType-II CJT CSI report assuming pre-compensation using the UE-reported delay offset (when ReportQuantity is ‘cjtc-Dd’).   * The two separately configured reports (i.e. Rel-18 eType-II CJT CSI report and the CJTC delay offset report) can be separately or jointly triggered [and carried on a same PUSCH (hence on a same slot)] following legacy joint triggering mechanism   + When separately triggered, the delay offset value to be compensated is the latest reported delay offset (DO) whose reporting instance is before the DCI triggering of the CJT CSI reporting     - FFS: whether some expiration time interval is needed   + When jointly triggered, the delay offset value to be compensated is the reported delay offset (DO) in the same reporting instance   FFS: NW indicates the delay offset value to be compensated for the Rel-18 eType-II CJT CSI report  FFS: Whether only AP-CSI-RS, or any type of CSI-RS (P, SP, or AP) can be configured as the CMR for the Rel-18 eType-II CJT reporting  FFS: Support for SP-CSI for CJTC report  The above only applies when the CMRs do not share common QCL source for average delay indication  **FL assessment**: The yellow part indicates some revision from the Tuesday OFFLINE | **Support/fine:** vivo, ZTE, Qualcomm, Ericsson, CATT, Nokia/NSB, IDC, Samsung (ok), Huawei/HiSi (ok), Xiaomi, NEC, NTT DOCOMO, Fujitsu, Lenovo/MotM,  **Not support:** Apple (too early), Google, Intel |
| 3.4.2 | **Proposal 3.D.2:** For the Rel-19 aperiodic standalone CJT calibration reporting, support joint Dd + phase offset (PO) reporting as follows:   * Only wideband (=1) PO is supported * No further optimization of CSI reporting format, e.g. configurability of not reporting {dn} * The UCI parameters are captured in the table below   *When ReportQuantity is ‘cjtc-Dd-P’ (joint Doffset+d and PO)*   |  |  | | --- | --- | | Parameter | Details/description | | nref1 | Reference TRS resource set index for Doffset+d, based on the ordering from RRC configuration:  bits | | nref2 | Reference TRS resource set index for PO, based on the ordering from RRC configuration: bits | | {Dn,offset,  n=0, 1, …, NTRP – 1 n≠nref1} | Delay offset for CSI-RS resource n:  bits | | {dn,  n=0, 1, …, NTRP – 1, n≠nref1 } | 1-bit inside/outside indicator for CSI-RS resource set n: bits | | {POn ,  n=0, 1, …, NTRP –1, n≠nref2} | Wideband phase offset for CSI-RS resource n:  bits |  * The UCI mapping order is as follows:   + nref1,   + nref2,   + {Dn,offset, n=0, 1, …, NTRP – 1, n≠nref} ordered from the lowest to highest CSI-RS resource set ID,   + {dn, n=0, 1, …, N TRP – 1, n≠nref} ordered from the lowest to highest CSI-RS resource set ID   + {POn, n=0, 1, …, NTRP – 1, n≠nref} ordered from the lowest to highest CSI-RS resource ID, | **Support/fine:** Qualcomm, vivo, Sony, Samsung (ok), Google, ZTE, Fujitsu, Sony,  **Not support**: Huawei/HiSi, MediaTek, NTT DOCOMO, Ericsson, NEC, Intel, Apple, TCL, Huawei/HiSi, Xiaomi, IDC, Sharp, KDDI, CMCC, ETRI, OPPO, Lenovo/MotM (open, only if TRS can be used for PO), Apple (same as Lenovo) |
| 3.4.3 | **Proposal 3.D.3:** For the Rel-19 aperiodic standalone CJT calibration reporting, support reporting, in one CSI reporting instance, L1-RSRPs associated with the configured NTRP CSI-RS resources and the following CJT calibration report type:   * ReportQuantity is ‘cjtc-Dd’ (delay offset), or * ReportQuantity is ‘cjtc-F’ (frequency offset), or * ReportQuantity is ‘cjtc-Dd-F’ (delay+frequency offset), or * ReportQuantity is ‘cjtc-P’ (DL/UL phase offset)   Regarding the L1-RSRP:   * The legacy L1-RSRP is fully reused, where the L1-RSRP associated with nref is the reference for the other (NTRP-1) differential L1-RSRP(s)   + The NTRP CRI(s) are not reported * FFS: Whether this is supported via a new ReportQuantity or a joint CSI request/triggering   **FL assessment**: This proposal is an optimization primarily for TRP selection (which utilizes both RSRP and CJTC report) | **Support/fine:** NEC, NTT DOCOMO,  **Not support**: ZTE, Xiaomi, Fujitsu, Ericsson, Apple, Huawei/HiSi, |
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Table 3B LLS/SLS results: issue 3

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| **Company** | **LLS/SLS results** | | |
| **Issue #** | **Metric** | **Observation** |
| ZTE | 3.3 | Average UPT and cell-edge UPT | *The figure below shows the SLS performance evaluation results for non-compensated CJT and UE-specific DO/FO pre-compensated CJT. It is observed that, the UE-specific DO/FO pre-compensation provides 56.41% throughput gain for cell-edge UE and 17.81 throughput gain in average.* |
| Nokia/NSB | 3.3 | Mean UE throughput vs overhead | *It is shown in the SLS results below that ~4% performance loss is encountered in the one-sided case compared to no delay compensation, due to the mismatch between the channel seen by the PDSCH (after precoder compensation at gNB side) and the PMI actually calculated at UE side.*    ***Performance comparison with and without delay compensation of CSI-RS resources at the UE side for CSI calculation. Delay compensation is also applied at the gNB to calculate PDSCH precoder.*** |
| Ericsson | 3.3 | Throughput vs SNR | *Comparing the CJT performance with and without UE side DO/FO pre-compensation, the simulation results below demonstrate a 15% performance gain at SNR 10 dB with DO/FO pre-compensation.*    *The figure below provides simulation results which illustrate that synchronizing CJT PMI reporting periodicity and DO/FO reporting periodicity does not provide any meaningful performance gain over the case when CJT PMI reporting periodicity and DO/FO reporting periodicity are different.* |

Table 3C Additional inputs: issue 3

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| **Company** | **Input** |
| Mod V0 | **Please share your inputs on each of the issues and, if applicable, proposals in TABLE 3A** |
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# References

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| --- | --- | --- | --- |
| 1 | RP-240087 | Revised WID: NR MIMO Phase 5 | Samsung (Moderator) |
| 2 | R1-2406643 | Moderator Summary for OFFLINE discussion on Rel-19 CSI enhancements | Moderator (Samsung) |
| 3 |  |  |  |
| 4 |  |  |  |