**3GPP TSG RAN WG1 #109-e R1-2205362**

**e-Meeting, May 9th – 20th, 2022**

**Agenda item:** 9.1.2

**Source:** Moderator (Samsung)

**Title:** Moderator Summary#3 on Rel-18 CSI enhancements: ROUND 3

**Document for:** Discussion and Decision

## Introduction

The scope given in the Rel-18 NR Evolved MIMO WID [1] pertaining to CSI enhancement is as follows:

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| 1. Study, and if justified, specify CSI reporting enhancement for high/medium UE velocities by exploiting time-domain correlation/Doppler-domain information to assist DL precoding, targeting FR1, as follows:    * Rel-16/17 Type-II codebook refinement, without modification to the spatial and frequency domain basis    * UE reporting of time-domain channel properties measured via CSI-RS for tracking 2. Study, and if justified, specify enhancements of CSI acquisition for Coherent-JT targeting FR1 and up to 4 TRPs, assuming ideal backhaul and synchronization as well as the same number of antenna ports across TRPs, as follows:    1. Rel-16/17 Type-II codebook refinement for CJT mTRP targeting FDD and its associated CSI reporting, taking into account throughput-overhead trade-off |

## Summary of companies’ views

**General observation**:

* Sufficient number of contributions demonstrating significant benefits of each of the 3 features via simulation and analysis. Furthermore, upon closer look, such benefits are largely within the (already endorsed) EVM scenarios and assumptions
* Operators and vendors have shown sufficient interest in the 3 features for enhancing real-life 5G NR deployments

Based on the above observation and Tdocs, the following moderator proposal is made.

**Proposal 0**:  For Rel-18 CSI enhancements, proceed to support and specify the following features:

* Type-II codebook refinement for CJT mTRP
* Type-II codebook refinement for high/medium UE velocities exploiting time-domain correlation/Doppler-domain information
* UE reporting of time-domain channel properties (TDCP) measured via CSI-RS for tracking

Table 0A Additional inputs: proposal 0

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| --- | --- |
| **Company** | **Input** |
| Mod V0 | **Share your view, if any, on Proposal 0** |
| Ericsson | We support FL’s proposal.  It should be noted that the use cases of item 2 (type II CB refinement for high/medium velocity) is different from the use case of item 3 (TRS based TDCP).  Different companies show analysis of different use cases, where the TRS based TDCP report from UE can be used to:   * adopting CSI-RS periodicity or how often CSI-RS is triggered in case of aperiodic CSI-RS * adopting how frequently CSI feedback is needed * Switching between different CSI codebook types (e.g., when to use Type I feedback vs when to use Type II feedback). * there are many other use cases where the gNB can utilize the TRS TDCP report (as mentioned in our TDoc and other company contributions).   Note that the results presented in [R1-2203955](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_109-e/Docs/R1-2203955.zip) (see Figure 1) show a use case where TRS TDCP report will be beneficial for the gNB. As shown in the results in this figure, type II performance degrades significantly and gets much worse than type I performance beyond a certain velocity (e.g., 15 km/h as shown in the figure). Hence, if the gNB gets a TRS TDCP report from the UE, the gNB can decide whether to trigger Type I CSI or Type II CSI based on the TRS TDCP report.  Note that this is only one use case. Another reason for introducing TRS TDCP is to help UEs that are less capable and do not support Type II feedback. |
| Samsung | Support Proposal 0   * Features 1 and 2: As summarized by FL and Tables 0B/C below, there are more than enough results showing performance gain with the simulation assumptions aligned with the agreed EVM * Feature 3: Based on the agreed 1st and 2nd use case, the need for TDCP seems quite clear because NR spec already includes a number of codebook types/modes (and more). Each codebook may work better in a range of UE speed. Even if such benefit may not be easy to quantify, the need for supporting TDCP is justified. The agreed EVM will be used to sort out the details (which TDCP(s), time-domain behavior, range of values, etc.). In addition, our NW implementation finds that transparent schemes based on UL signals (e.g. SRS) don’t work well especially for FDD scenarios. So a scheme using DL measurement RS such as TRS is preferred.   Therefore, there is no reason not to agree on Proposal 0 and focus on detailed designs for the remaining WI |
| Intel | Feature 3: Generally we expect that TDCP is a long-term property and is adequately captured from uplink RS for use-cases agreed in proposal 3.A. With respect to Type I vs Type II codebook selection use-case, we think this decision depends significantly on whether a simple DFT basis can model the spatial nature of the channel or not, even for a low speed UE, Type I vs Type II decision needs to be made at the gNB. for example for LOS channel or a highly correlated channel a Type I codebook should suffice irrespective of speed. |
| Qualcomm | In our view, it is still too early to say that we will specify all the three items.  Since the EVM has just been agreed in this meeting, we’d like to see more evaluation results with the aligned EVM first, before we decide whether to specify or not.   * Regarding feature 1 (CJT), we’d like to have more evaluations on both co-located-TRP and distributed-TRP scenarios. Currently, not many evaluations on the more practical co-located-TRP scenario have been provided; As for the distributed-TRP scenario, we’d like to see the performance impact regarding practical issues due to XO drift * Regarding feature 3 (TRS-based TDCP report), we agree that some use cases have potentials to be useful. However, till now, we haven’t seen any evaluation results for any of the use cases listed in the work scope agreement (proposal 3.A), and it is also not clear what to report for the use cases (which one or more alternatives in proposal 3.C). Besides, a baseline scheme based on SRS should also be considered for comparison, as mentioned by @Samsung above.   As for the work scope proposals generally agreed in Round 2 discussions, we agree that specification will follow these principles if we decide that we will specify these items |
| Spreadtrum | We can support Proposal 0. Each of these features are beneficial in certain scenarios, we are OK to discuss how to specify them in Rel-18. |
| NEC | Support Proposal 0. We think all of the three features should be supported for different cases. |
| Lenovo | We are OK to support both Feature 1 and Feature 2 given the initial evaluation by companies in addition to the well-defined scope. However, for Feature 3, we agree with QC, no sufficient evidence has been provided to motivate the need for TDCP reporting as a standalone feature, since TDCP can also be implied from the Type-II codebook parameters, without the need of specifying a separate feature. We also have concerns regarding the scope of Feature 3 enhancements, which we have included under comments for issue 3. We believe further study is needed to make sure the scope/spec impact for Feature 3 is manageable and would not dominate the other two features. |
| Ericsson | Regarding Intel/Qualcomm on using UL-RS (or SRS) for estimating TDCP:  the gNB may make decision on which CSI type/parameters etc to be use based on multiple factors. But Doppler spread is a critical factor. SRS cannot be easily used for estimating Doppler spread due to phase incoherency issue. Also, UEs at or near the cell edge will have power limitation, and the SRS from this UE may have quite low SINR. This makes estimating doppler spread based on SRS very challenging. |
| Apple | We are supportive of Proposal 0 |
| ZTE | Support Proposal 0, a good way-forward proposal   * Above three features may have different usages as discussed in the previous rounds. * Technically speaking, we have the following:   + For CJT, the benefit becomes clear, but we may need to considering RX information together for supporting the gNB-side MCS emulation in MU, and saving computation calculation in UE side.   + For Doppler-CSI, we are a little bit worried about the performance gain by introducing Doppler prediction in high mobility (especially for classical UMi case). But, at least, we may have the stable option for moving forward this issue:     - Alt3. Reuse Rel-16/17 (F)eType-II codebook with multiple and a single and report.   + For TDCP reporting, in FDD and cell-edge UE, SRS based estimation may not be feasible besides for phase inconsistency as E/// mentioned above. Some results for relative Doppler shift among different TRRs, and Doppler spread may be beneficial for gNB side decision, e.g., CSI/CSI-RS periodicity.   In short, we think that above proposal 0 can well present what we have now for moving forward Rel-18 MIMO CSI. |
| NTT DOCOMO | Support Proposal 0.  For feature 3, it has clear use cases to be supported. |
| Huawei, HiSilicon | We support FL’s proposal to specify the 3 features. Regarding QC’s comment on CJT, we don’t see much difference between co-located TRP and distributed TRP. For both cases, the BBU can be in the same site with good backhaul connection between each other, and the RRH/AAUs can be calibrated well so that there’s no frequency offset. This is also aligned with the WID with ideal backhaul and sync between TRPs. |

Table 0B Type II CJT: summary of observation from SLS

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| **Company** | **Metric** | **Key observation** |
| Huawei/HiSi | SLS: Mean UPT, 5% UPT | * Observation 4: The CJT codebook design with joint space-frequency domain statistical eigenvectors achieves 10~15% gain for mean UPT and 12~43% gain for 5%-tile UE UPT, compared with DFT basis. * Observation 5: The full channel feedback for CJT codebook can provide about 10~20% gain for mean UPT and 30~90% gain for mean UPT and 5% UPT respectively. * Observation 6: Compared to TRP independent selection of coefficients for W2,   + Joint selection among TRPs can provide about 7~10% and 16~28% performance gains for mean UPT and edge UPT, respectively, when each TRP has 32 CSI-RS ports.   + Joint selection among TRPs can provide up to about 2~6% and 12~22% performance gains for mean UPT and edge UPT, respectively, when each TRP has 8 CSI-RS ports. * Observation 7: There is a significant performance loss at both mean UPT and 5% UPT when the frequency domain granularity changes from 2RB to 4RB, especially at 5% UPT (a loss more than 26%). |
| Ericsson | SLS: Mean UPT, 5%/50%-/95%-UPT | For mean/5%/50%/95% UPT, the gains of mTRP over sTRP are:   * RU20: 1%/5%/0%/0% * RU50: 11%/42%/13%/1% * RU70: 28%/80%/35%/2% * Full buffer: 27%/57%/-/- |
| MTK | SLS: Mean UPT | * Ideal CSI: up to 30% gain, compared to sTRP * mTRP codebook: up to 15% gain, compared to sTRP * Ideal CSI > mTRP codebook > Rel-16 eType-II for mTRP > Rel-16 eType-II for sTRP > Rel-15 Type-I MP for mTRP |
| Samsung | SLS: Mean UPT vs overhead | * Observation 1: CB2 and CB1 yield gain in throughout vs. overhead trade-off over Rel-16 T2 CB, with CB2 outperforming CB1. * Observation 2: The throughputs of CB2 and CB1 do not change significantly as overhead increases. The overhead for both codebooks is high. This implies that the set of parameter combinations can be refined for CB1/CB2 to further reduce the overhead. * Observation 3: for varying number of TRPs (),   + CB2 outperforms CB1 for any value   + The performance of CB2/CB1 remain similar as overhead is increased for the existing Rel-16 paraComb=1,2..,6. * Observation 4: Significant performance gain (e.g.35-45% in avg. UPT with CB2 and 25-35% in avg. UPT with CB1) can be achieved with mTRP C-JT CSI (N=2,3,4) over sTRP CSI (N=1). * Observation 5: the throughput-overhead trade-offs for 4 ports are similar to that for 8 ports. * Observation 6: Further significant performance gain (e.g.70-110% in avg. UPT with CB2 and 50-90% in avg. UPT with CB1) can be achieved with mTRP C-JT CSI (N=2,3,4) over sTRP CSI (N=1). * Observation 7: A similar trend is observed that CB2 (55%) > CB1 (44%) sTRP with Rel-16 eType-II CB (0%) as the case of intra-cell scenarios. |
| Nokia | SLS: Mean UPT, cell-edge (5%) UPT | * In our preliminary simulation results, we observe very significant throughput gains in intra-site (rural macro + RRH) deployment at 700 MHz, in the order of 40% for mean UE throughput and 116% for cell-edge throughput. Gains are also significant, although smaller, for inter-site (urban macro only) deployment, with increase in throughput of about 8% and 34% for mean UE and cell-edge throughput, respectively. |
| ZTE | SLS: Mean UPT, 5%/50%-/95%-UPT | * Observation 4: From evaluation results, it can be observed that, compared with sTRP and NC-JT, C-JT can bring performance gains in terms of both cell-edge and mean UPT. |
| Vivo | SLS: Mean UPT, 5%/50%-/95%- UPT | * Observation 1: Ideally, more significant gain can be obtained by JT in the Indoor Hotspot and intra-site CoMP scenarios. * Observation 2: TRP recommendation causes marginal performance loss, but it reduces feedback overhead and UE complexity significantly because more than 50% of Ues do not need to report CSI for all TRPs in the measurement set. * Observation 3:   + Compared to Scheme 2, Scheme 1 has performance gain. |
| CATT | SLS: Mean UPT, 5% UPT | * Comparing with S-TRP scheme, intra-site C-JT scheme can provide significant gain, both for the cell edge and cell average. Specifically, nearly 200% SE gains for the cell edge Ues, and 21% SE gains for the cell average are achieved. |
| CEWiT | LLS : SE vs SNR | * Observation 1: Dynamic selection of TRPs shows considerable spectral efficiency improvement. * Observation 2: Spectral efficiency gain is considerable across all SNR range. |
| **Summary**:   * Performance gain of Type-II CJT over sTRP   + SLS (UPT, UPT vs overhead): Huawei/HiSi, Ericsson, MTK, Samsung, Nokia, ZTE, vivo, CATT   + Other: CEWiT (SE) * At least eight Tdocs include simulation results demonstrating significant gain of extending Type-II codebook for CJT mTRP | | |

Table 0C Type II Doppler: summary of observation from SLS

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| **Company** | **Metric** | **Key observation** |
| Huawei/HiSi | SLS: Mean UPT | Observation 8: The performances of R16 Type II at 30km/h and 60km/h UE speed have 25.8% and 35.3% loss compared with UE speed of 3km/h. The performances of R17 Type II at 30km/h and 60km/h UE speed have 30.7% and 40.8% loss compared with UE speed of 3km/h.  Observation 9: For UE-based CSI prediction at speed 60km/h with 10ms periodicity of CSI feedback,   * 14% average gain compared with R17 type II * 13% average gain compared with R16 type II. |
| ZTE | SLS: Mean UPT, 50%/5% UPT | Observation 2: Regarding CSI prediction scheme-2 (-based prediction), based on SLS simulation results in UMa, we can observe:   * In LOS, some performance gain and potential CSI overhead reduction can be obtained via exploring Doppler-domain information. * However, for NLOS, it is difficult to identify dominant Doppler components for CSI prediction/extrapolation, and consequently advanced algorithm (like artificial intelligence (AI) for CSI prediction) may be further studied |
| CATT | SLS: Mean UPT, 5% UPT | Observation-1:   * When the CSI feedback periodicity is 5ms, the average throughput of 60km/h has 22% loss and the 5% edge throughput of 60km/h has 45% loss compared with 3km/h. |
| Vivo | SLS: Mean UPT, 95%/50%/5% UPT | Current codebook types only cultivate spatial domain and frequency-delay domain characteristics and feedback the most important components in both domains without considering any Doppler-time domain information. However, performance degrades considerably when the UE is moving in medium/high speed where Doppler effect becomes a crucial factor, as shown by the preliminary simulation results in Figure 1. |
| OPPO | SLS: Mean UPT vs overhead | Multiple types of codebook have been introduced in Rel-15/16/17. However, most codebook design only considers low mobility. In medium/high mobility, the channel response estimated by UE and the channel of practical PDSCH transmission may be mismatched due to UE’s movement. The performance of Rel-16 eTypeII CSI reporting may be worse than that of type I codebook in medium/high mobility as show in figure 1.  Observation 1:   * The enhanced Doppler domain reporting has better performance for speed of 30km/h (Doppler frequency fd<220Hz, about 15% gain over type I) * The CSI overhead would not be increased by Doppler basis reporting. Meanwhile, time domain DFT can be considered as starting point for study. * Burst CSI-RS can further improve the performance for 60-120km/h (220Hz<fd<880Hz, 5%~10% gain) * The performance gain for velocity>=60km/h is small (fd>220Hz, about 5% gain). |
| Nokia/NSB | Autocorrelation | 1. We observe that at medium/high velocity, the coefficients of are significantly less correlated in time than the CSI-RS channel measurements, which suggests that effective compression of PMI in time/Doppler domain is hard to achieve. 2. The low time correlation of seems related to the fact that eigenvectors are calculated with a phase uncertainty, and they are calculated independently for each CSI-RS measurement occasion, hence a random phase factor tend to decorrelate the time sequence of . |
| Fraunhofer/HHI | SLS: Mean UPT vs overhead | Observation 7: Enhanced Type II CB with Doppler domain information outperforms Rel. 16 Type II CB in terms of performance and feedback overhead. |
| MediaTek | CDF of performance | Observation 3: When the channel is LOS, the rank, , and can be the same for 40 ms with acceptable performance, for both the RMa scenario with UE speed 60 km/hr and the UMa scenario with UE speed 30 km/hr.  Observation 4: For the case of RMa 60 km/hr and NLOS, the rank, , and can be the same for 40 ms with acceptable performance.  Observation 5: For the case of UMa 30 km/hr and NLOS, at least the rank and can be the same for 40 ms with acceptable performance. |
| CeWiT | Overhead, MSE | From the above table, it can be seen that with partial CSI feedback, overhead is considerably reduced, while the nMSE are quite low (order of 10-4). |
| Qualcomm | Correlation, CDF of performance | Observation 1: Two issues exist for CSI reporting under fast fading channel environment: (1) Larger overhead with frequent report; (2) CSI outdating due to report latency  Observation 2: Certain performance gain of eType-II-Doppler can be observed over delayed Rel-16 eType-II: 1.7dB @10% CDF, 0.4dB @50% CDF, under ideal environment w/o noise or interference. |
| **Summary**:   * Performance gain of Type-II Doppler (SLS) over Rel-16/17 Type-II: Huawei/HiSi, ZTE (in LoS), OPPO, Fraunhofer/HHI, CeWiT, Qualcomm * Performance loss of Rel-16/17 with medium/high speed: CATT, vivo, OPPO, Nokia/NSB, MTK * At least six Tdocs provided results demonstrating significant gain from using Type-II codebook refinement with Doppler-domain compression | | |

### Issue 1: Type-II codebook refinement for CJT

Table 1A Summary: issue 1

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| **#** | **Issue** | **Companies’ views** |
| 1.3 | Work scope: Rel-16/17 Type-II codebook/PMI components to be refined or reused for CJT extension   1. SD and FD basis vector designs (not precluding adding new values of N1, N2, N3) 2. SD and FD basis selection schemes (not precluding per-TRP or joint-across-TRPs selection, this refers to, e.g. the combinatorial indication and two-step FD basis selection) 3. W2 coefficient quantization scheme 4. Non-zero coefficient selection and indication schemes 5. Strongest coefficient indication scheme 6. Supported parameter combinations (keeping same set of parameters, whether the legacy values are fully reused or possibly refined for, e.g. further overhead reduction) and parameter values (including, e.g. R, K0) 7. Per layer feedback   **FL Note**: Considering work scope and continuity with legacy design (some already being deployed), we should strive for maximum reuse of legacy designs. Although one may claim that evaluation is needed to ensure whether reusing as such results in desirable performance, the above parameters are primarily “format” issue. | **1 (SD/FD basis design):**   * **Fully reuse legacy:** Huawei/HiSi (for R17), Lenovo, Samsung, Apple, DOCOMO, NEC, vivo, CMCC, Nokia/NSB, IDC, Fraunhofer IIS/Fraunhofer HHI, Intel, MTK, CATT, ZTE, CEWiT, IITK, Ericsson, Qualcomm, Xiaomi, AT&T, Sony * **Refinement:** Huawei/HiSi (Joint SD-FD eigen-vector basis for R16)   **2 (SD/FD basis selection scheme):**   * **Fully reuse legacy:** Samsung, Nokia/NSB, Apple, NEC, vivo, CMCC, IDC, ZTE, CEWiT, IITK, Ericsson, Xiaomi, AT&T, Sony * **Refinement:** vivo (per TRP SD basis selection)   **3 (W2 quantization):**   * **Fully reuse legacy:** Samsung, Apple, vivo, CMCC, Nokia/NSB (re. co-scaling, both reference amplitudes may need reporting for TRPs other than the strongest), Intel (same as Nokia), CATT, ZTE, CEWiT, IITK, Ericsson, AT&T * **Refinement:** Xiaomi (TRP specific phase and amplitude)   **4 (NZC):**   * **Fully reuse legacy:** * **Refinement:** Huawei/HiSi (joint across TRPs), Lenovo, vivo (joint across selected TRPs), CMCC, CATT, ZTE (further study the bitmap is for each TRP or N TRPs, the maximal number of non-zero coefficients may be per TRP per layer), Spreadtrum, AT&T   **5 (SCI):**   * **Fully reuse legacy:** * **Refinement:** Huawei/HiSi (joint across TRPs), Samsung (strongest TRP), Nokia/NSB (FD basis ref), ZTE (FD basis ref), NEC (we also support strongest TRP indication), vivo (joint across TRPs), CMCC, IDC, CEWiT, Spreadtrum, IITK, Ericsson, Xiaomi (reference TRP), AT&T, Sony   **6 (Parameter combination):**   * **Fully reuse legacy:** * **Refinement:** Samsung, ZTE, Huawei/HiSi (R values), Lenovo,NEC (we also support R values), vivo (need evaluation), CMCC, Nokia/NSB, IDC, Fraunhofer IIS/Fraunhofer HHI, MTK, CATT, Ericsson, AT&T   **7 (Per layer feedback):**   * **Fully reuse legacy:** Samsung, DOCOMO, vivo, CMCC, Nokia/NSB, Fraunhofer IIS/Fraunhofer HHI, CEWiT, IITK, Ericsson, Xiaomi, AT&T * **Refinement:** Huawei/HiSi (receiver side information by per-RX feedback), ZTE |

**Proposal 1.E**: On the work scope of Type-II codebook refinement for CJT mTRP, the resulting codebook(s) include *at least* the following parameters:

* + Parameters for SD+FD or joint SD/FD) basis vector selection, including
    - The number of basis vectors (SD+FD or joint SD/FD)
    - Basis selection indicator(s)
  + Quantized combining coefficients (W2)
  + Number of non-zero coefficients and bitmap to indicate non-zero coefficients
  + Strongest coefficient indicator(s) (SCI(s))
    - FFS: One per TRP or one for all TRPs

FFS: The need for the following additional parameters:

* Receiver side information per RX reporting
* Strongest TRP indicator

FFS: Specification entity corresponding to a TRP (e.g. port-group, NZP CSI-RS resource)

**Proposal 1.F**: On the work scope of Type-II codebook refinement for CJT mTRP, down-select from the following TRP selection/determination schemes (where N is the number of cooperating TRPs assumed in PMI reporting):

* + Alt1. N is gNB-configured via higher-layer (RRC) signaling
  + Alt2. N is UE-selected and reported as a part of CSI report where N{1,..., NTRP} and NTRP is gNB-configured via higher-layer (RRC) signaling
    - In this case, the selection of N out of NTRP TRPs is also reported

FFS: Specification entity corresponding to a TRP (e.g. port-group, NZP CSI-RS resource)

Table 2 Additional inputs: issue 1

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| **Company** | **Input** |
| Mod V0 | **Share your inputs, if any, on moderator proposals** |
| Lenovo | **Proposal 1.E:**  We are fine with the skeleton of the proposal, but prefer to add one bullet corresponding to co-phasing across precoders of different TRPs. Can the moderator (or supporting companies) please clarify the scope of “Receiver side info per RX reporting”? Also, we prefer more clarity on whether the number of non-zero coefficients and bitmap are reported per TRP or across TRP.  **Proposal 1.E**: On the work scope of Type-II codebook refinement for CJT mTRP, the resulting codebook(s) include *at least* the following parameters:   * + Parameters for SD+FD or joint SD/FD) basis vector selection, including     - The number of basis vectors (SD+FD or joint SD/FD)     - Basis selection indicator(s)   + Quantized combining coefficients (W2)   + Amplitude/Phase coefficients corresponding to scaling/co-phasing across precoders of different TRPs   + Number of non-zero coefficients and bitmap to indicate non-zero coefficients, e.g., per TRP or across all TRPs   + Strongest coefficient indicator(s) (SCI(s))     - FFS: One per TRP or one for all TRPs   FFS: The need for the following additional parameters:   * [Receiver side information per RX reporting] * Strongest TRP indicator   FFS: Specification entity corresponding to a TRP (e.g. port-group, NZP CSI-RS resource)  **Proposal 1.F:**  In our opinion, further clarity is needed on the meaning of “N”. For instance, the following interpretations need to be addressed before agreeing on means of signaling of N, as follows:  **Alt.1:** For a given value “N”, the UE reports CSI corresponding to CJT from exactly N TRPs (CSI corresponding to one transmission hypothesis is fed back)  **Alt.2:** For a given value “N”, the UE reports CSI corresponding to CJT from all (or a subset) of the transmission hypotheses corresponding to the N TRPs, e.g., at N=3, Up to 7 transmission hypotheses can be supported: 3 hypotheses corresponding to single-TRP transmission, 3 hypotheses corresponding to CJT from two TRPs, and 1 hypothesis corresponding to TRP from three TRPs  In light of that, we suggest the following update:  **Proposal 1.F**: On the work scope of Type-II codebook refinement for CJT mTRP, down-select from the following TRP selection/determination schemes (where N is the number of cooperating TRPs assumed in PMI reporting):   * + Alt1. N is gNB-configured via higher-layer (RRC) signaling   + Alt2. N is UE-selected and reported as a part of CSI report where N{1,..., NTRP} and NTRP is gNB-configured via higher-layer (RRC) signaling     - In this case, the selection of N out of NTRP TRPs is also reported   FFS: Specification entity corresponding to a TRP (e.g. port-group, NZP CSI-RS resource)  FFS: Whether N corresponds to CSI reporting corresponding to one transmission hypothesis with exactly N TRPs, or multiple transmission hypotheses from a subset of the N TRPs |
| Samsung | Proposal 1.E:   * Question for clarification: SD+FD or joint SD/FD doesn’t mean both will be supported. We will down-select to one of the two. Is that correct? * FFS on additional parameters: Add “for decoupled codebook, the co-amplitude/co-phase” * Add a new FFS: details such as whether parameters (L or alpha, pv or M, beta etc.) are TRP-common/TRP-specific/layer-common/layer-specific, or need reporting   Proposal 1.F:  For Alt2: both number N and indices of N selected TRPs need reporting. The details of reporting (e.g. bitmap, combinatorial) should be FFS. |
| Qualcomm | **Proposal 1.E**  For basis type of SD+FD or joint SD/FD, we’d like to have a note to further down-select b/w the two schemes. Supporting two schemes will increase UE complexity  Suggest to move the FFS sub-bullet “• Strongest TRP indicator” under the SCI bullet, i.e.   * + Strongest coefficient indicator(s) (SCI(s))     - FFS: One per TRP or one for all TRPs     - FFS: The additional need for strongest TRP indicator |
| Spreadtrum | **Proposal 1.E:**   * ‘the number of basis vectors’ under the 1st sub-bullet seems to be a new parameter and it is related with proposal 1.F, it should be FFS. * ‘number of non-zero coefficients’ under the 3rd sub-bullet is required for Type II codebook, but do we consider it as one of codebook parameters? Since it should be in CSI part 1 and it is used to determine the payload size of the PMI in CSI part 2.   **Proposal 1.F:** Support. We suggest to consider Alt1 as default solution if Alt2 is not agreeable. |
| NEC | **Proposal 1.E:**  Based on the views listed in the table, we think another FFS may be needed as “FFS on refinement of parameter combinations”  **Proposal 1.F:**  For Alt 2, we share similar view with Samsung that the details of reporting should be FFS, and it’s also possible that selection of TRPs can be done via co-amplitude or other coefficients. So we propose further update based on Samsung’s version as:  For Alt2: both number N and indices of N selected TRPs need reporting. The details of reporting (e.g. bitmap, combinatorial or via coefficients) should be FFS.  For Alt 1, we think the index(es) of N should also be indicated by network.   * + Alt1. N and the index(es) of TRP are gNB-configured via higher-layer (RRC) signaling |
| Apple | In general, we are fine with both proposals.  One minor comment on Proposal 1.E, one parathesis is missing in the first main sub-bullet |
| ZTE | **Proposal 1.E:**   * Firstly, we share the same views that ‘co-amplitude/co-phase’ is definitely needed for TRP-specific report. * Then, considering that the location of different TRP may not be co-site, the relative offset for the reference FD-basis per TRP may be needed. Note that this relative offset may be used for both SD+FD/joint SD/FD case. So, we have the following suggestion:   + Parameters for SD+FD or joint SD/FD) basis vector selection, including     - The number of basis vectors (SD+FD or joint SD/FD)     - Basis selection indicator(s)     - FFS: relative information about reference FD-basis across TRPs   **Proposal 1.F:** Support in principle. One ambiguities, whether the N is used for CJT hypothesis report, right? The motivation of this proposal is not relevant to support report of sTRP hypothesis besides for mTRP. It may need to be clarified. |
| Intel | Proposal 1E: we think this should be further discussed - “Receiver side information per RX reporting” – we think Rx side information can be discussed with CQI and this can be in brackets |
| NTT DOCOMO | **Proposal 1.E.**  **-** For clarification, does the ‘parameters’ in main bullet mean UE reporting parameters or both NW configuration and UE reporting parameters?  - If ‘FFS: One per TRP or one for all TRPs’ is added under the fourth bullet, it is better to also add the FFS under the 1st bullet (e.g., for the number of basis vectors) and 3rd bullet (e.g., for the number of NZC).  **Proposal 1.F.**  Agree with SS’s comment. |
| Huawei, HiSilicon | Proposal 1.E,   * We prefer to add basis for Rel-16 eType-II codebook. The eigenvector-basis can match the UE-specific statistical subspace of channel matrix better than 2D-DFT/DFT basis, thus it’s sparser than DFT basis. Therefore, the CSI precision can be improved with the same feedback overhead. As from the evaluation results copied as below, the eigenvector-basis can provide significant gain.      * From the summary, it seems many companies support refinement for aspect#6 of issue#1.3. Therefore, we propose to add this to be included also in the work scope. * Clarification on Receiver side information per RX reporting, this is for UE to feedback the receiver side information. This is because in multi-TRP CJT scenario, the UE may have different assumptions of u for different TRPs when reporting the v matrix, by SVD decomposition of channel matrix. As a result, when UE receives the coherently transmitted signal, the signal may be canceled by each other when receiving by the UE because only one receiving beam is used by the UE.   To resolve it, UE can report the receiver side information. For example, UE can report the U matrix. A simpler way may be per RX reporting instead of per layer reporting, that UE feedback full rank feedback, and each rank corresponds to the channel of one receiving antenna port.  Another benefit is that gNB can have a better SINR estimation and thus better scheduling of MCS, especially for MU-MIMO scenarios for CJT.  Therefore, we propose to have it also for a further enhancement.  **Proposal 1.E**: On the work scope of Type-II codebook refinement for CJT mTRP, the resulting codebook(s) include *at least* the following parameters:   * + Parameters for SD+FD or joint SD/FD) basis ~~vector selection~~ reporting, including     - The number of basis vectors (SD+FD or joint SD/FD)     - Basis selection indicator(s)     - The basis for SD+FD or joint SD/FD   + Quantized combining coefficients (W2)   + Number of non-zero coefficients and bitmap to indicate non-zero coefficients   + Strongest coefficient indicator(s) (SCI(s))     - FFS: One per TRP or one for all TRPs   + Supported parameter combinations and parameter values   + Per-layer reporting or receiver side information by per-RX reporting.   FFS: The need for the following additional parameters:   * ~~Receiver side information per RX reporting~~ * Strongest TRP indicator   FFS: Specification entity corresponding to a TRP (e.g. port-group, NZP CSI-RS resource)  Proposal 1.F, we are fine with the proposal. From our understanding, the two alternatives can be combined if UE can indicate the #NZC for each TRP. For example, UE report value 0 of #NZC for a TRP, it means the CSI for this TRP is not reported. |

### Issue 2: Type-II codebook refinement for high/medium UE velocities (with time/Doppler-domain compression)

Table 3 Summary: issue 2

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| **#** | **Issue** | **Companies’ views** |
| 2.3 | Fundamental time/Doppler-domain compression parameters:   1. TD/DD basis vector length N4 (analogous to 2N1N2 and N3) 2. TD compression unit relative to slot length (analogous to the relation between FD compression unit and CQI sub-band, i.e. for FD compression) 3. The number of selected TD/DD basis vectors (analogous to L and M) 4. …   **FL Note**: While the exact details depend on the waveform (basis design) selection, some fundamental parameters are applicable for any waveform selection | **1 (TD/DD basis length):** Samsung, Nokia/NSB, IDC, Fraunhofer IIS/Fraunhofer HHI, Intel, CEWiT, Ericsson, Qualcomm, Sony  **2 (TD compression unit):** Samsung, MTK, Qualcomm  **3 (# selected basis vectors):** Samsung, Fraunhofer IIS/Fraunhofer HHI, Apple, Nokia/NSB, IDC, Intel, ZTE, Ericsson, Qualcomm, Sony |
| 2.6 | The use of legacy NZP CSI-RS to facilitate necessary measurements   1. P CSI-RS, e.g. periodicity and offset setting 2. SP CSI-RS, e.g. burst setting 3. AP CSI-RS, e.g. group triggering 4. TRS   **FL Note**: **Companies are encouraged to comment on how to use P/SP/AP CSI-RS for the purpose of CSI calculation involving Type-II with TD/DD compression.**  CSI-RS enhancement is out of scope. However, how to use/refine the legacy/current CSI-RS resource setting to facilitate necessary measurements should be discussed as it can affect evaluation and detailed designs. | **P CSI-RS**: LG, MTK, Qualcomm  **SP CSI-RS**: Samsung, LG, Lenovo, IDC, Fraunhofer IIS/Fraunhofer HHI, MTK, Qualcomm, Sony  **AP CSI-RS**: Samsung  **CSI-RS burst for AP and SP (multiple CSI-RS resources/samples):** Huawei/HiSi, Ericsson, CATT, Samsung, Nokia/NSB, DOCOMO (study), CMCC, Futurewei, Fraunhofer IIS/Fraunhofer HHI, Intel, MTK, ZTE, Qualcomm, Xiaomi, Sony  **TRS**: CATT, Nokia/NSB (CSI-RS+TRS), vivo (CSI-RS+TRS), IDC, ZTE(CSI-RS+TRS) , CEWiT, Xiaomi, Sony (study) |

**Proposal 2.E**: On the work scope of Type-II codebook refinement for high/medium velocities, the codebook(s) include *at least* the following *additional* codebook parameters:

* Doppler-/time-domain (DD/TD) basis vector length
* Parameters for DD/TD basis vector selection, including
  + The number of DD/TD basis vectors
  + Basis selection indicator(s)

**Proposal 2.F**: On potential refinement of Resource setting configuration associated with Type-II codebook refinement for high/medium velocities, study the following options to assess whether/how the legacy Resource setting configuration needs to be enhanced for “burst” measurement:

* Periodic (P) CSI-RS (including CSI-RS for tracking): periodicity and offset
* Semi-persistent (SP) CSI-RS: activation/deactivation, periodicity, and offset
* Aperiodic (AP) CSI-RS: triggering

Table 4 Additional inputs: issue 2

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| **Company** | **Input** |
| Mod V0 | **Share your inputs, if any, on moderator proposals**  **On proposal 2.F, feel free to provide some concrete examples** |
| Lenovo | **Proposal 2.E:**  We are fine in general with Proposal 2.E, prefer to add one parameter indicating the basis type, as follows  **Proposal 2.E**: On the work scope of Type-II codebook refinement for high/medium velocities, the codebook(s) include *at least* the following *additional* codebook parameters:   * Doppler-/time-domain (DD/TD) basis vector length * Parameters for DD/TD basis vector selection, including   + The number of DD/TD basis vectors   + Basis selection indicator(s)   + Basis type, e.g., DFT, identity. FFS: whether basis type is indicated or implicit   **Proposal 2.F:**  Support |
| Samsung | Proposal 2.E   * We also need to discuss the definition of TD/DD units (e.g. similar to SB size, we can introduce a TD/DD unit size). Suggest to add an FFS on this   Proposal 2.F:   * For aperiodic, offsets of a group of AP CSI-RS resources also needs to be discussed * Number of CSI-RS resources can be more than 1 (cf. #CSI-RS resources for legacy Type II codebooks is restricted to 1). Suggest to add an FFS on this. |
| Spreadtrum | Proposal 2.E: We agree with the intention of the proposal. But maybe we need to define the TD/DD units firstly, otherwise it seems to be difficulty to understand/define the TD/DD vector length.  Proposal 2.F: Generally we are fine. |
| Qualcomm | **Proposal 2.E**  Parameter 2 of 2.3 is not captured in this proposal, and we suggest to add it as one more bullet:  “TD compression unit relative to slot length ~~(analogous to the relation between FD compression unit and CQI sub-band, i.e. for FD compression)~~”  One more parameter (hasn’t been listed): Size of codebook (basis set) i.e. total number of TD bases to select from (which is a separate parameter from basis length , e.g. equaling to for orthogonal DFT basis, or larger than for non-orthogonal DFT basis)  **Proposal 2.F**  We’d like to have a note for TRS:   * The potential refinement does not include a major enhancement of TRS to multi-port |
| NEC | Proposal 2.E: We are fine with the suggestion from Samsung and Spreadtrum.  Proposal 2.F: Fine with the proposal. |
| Apple | Our understanding is 2.E is analogous to N3/R/FD component selection, so we would have N4/R\_d/TD or DD component selection.  2.F seems a good list to start with. |
| ZTE | **Proposal 2.E:** In our views, whether/how to introduce Doppler-/time-domain (DD/TD) basis vector should be fully justified. Per our simulation, the correlation of W2 may not be good (also mentioned in Nokia’s contribution). Then, considering the following alternatively, we think that besides for confirming DD/TD-basis, we may not need to agree the reporting format right now.  **Agreement**  The work scope of Type-II codebook refinement for high/medium velocities includes down selection from the following codebook structures (for discussion purposes):   * Alt1. Time-domain basis,   + Alt1A: Time-domain basis commonly selected for all SD/FD bases, e.g.   + Alt1B: Time-domain basis independently selected for different SD/FD bases * Alt2. Doppler-domain basis   + Alt2A: Doppler-domain basis commonly selected for all SD/FD bases, e.g.   + Alt2B: Doppler-domain basis independently selected for different SD/FD bases   + Note that may be the identity as a special case * Alt3. Reuse Rel-16/17 (F)eType-II codebook with multiple and a single and report.   **Proposal 2.F:** Support. Then, in our views, for Periodic/Semi-persistent CSI-RS, the above information may be relevant to its transmission mode, like beam. For each of burst, RRC configuration overhead should be large, and so some flexible activation/triggering should be considered, rather than too many pre-configured bursts in RRC level. |
| Intel | Proposal 2F: prefer not to include TRS |
| NTT DOCOMO | Proposal 2.E   * For Lenovo’s suggestion, our understanding is that which basis type(s) is/are supported is separate discussion (which was agreed already). So we do not think the addition is needed. * For suggestions by Samsung and QC, we are fine to capture the definition of TD/DD units.   We are fine with 2F. |
| Huawei, HiSilicon | Proposal 2.E: We are fine with the proposal.  Proposal 2.F: we are fine in general. We share similar view with other companies that perhaps TRS can be discussed in issue 3 instead of here. In addition, for CSI for mobility, it can be measured from multiple CSI-RS resources, therefore we suggest to have a bullet as “Multiple CSI-RS resources for measurement”. |

### Issue 3: TRS-based reporting of time-domain channel properties (TDCP)

Table 5 Summary: issue 3

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| **#** | **Issue** | **Companies’ views** |
| 3.5 |  |  |
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**Proposal 3.A**: (added later after companies share views on Q1 and Q2)

Table 6 Additional inputs: issue 3

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| **Company** | **Input** |
| Mod V0 | **Please share your views on the following questions on TDCP reporting formats:**   * **Q1: “Alt1. Stand-alone reporting (no inter-dependence with other CSI/UCI parameters)” which time-domain behaviors should be supported?** * **Q2: “Alt2. Inter-dependent and reported with other CSI parameter(s)” could the proponents give some concrete proposals so that they can be studied for comparison?** |
| Lenovo | We believe further clarity of the scope/use cases of TDCP reporting is needed before tackling the moderator questions, since it is clear from prior discussion rounds that companies have different views on use cases, which would lead to different answers to the moderator questions corresponding to different functionalities. Therefore, we respectfully suggest discussing a proposal to down-select/discuss the use cases of TDCP, one example of which is as follows:  **Proposal 3.D**: Identify the scope of TDCP reporting from the following alternatives:  Alt.1: TDCP reporting corresponds to Rel-17 HST-SFN Doppler shift pre-compensation reporting  Alt.2: TDCP reporting comprises auxiliary feedback information to enable refinement of CSI reporting configuration and/or codebook configuration parameters  Alt.3: TDCP reporting corresponds to a subset of the Type-II codebook parameters fed back by the UE that are measured via TRS  We would also be OK with other proposals from the moderator/companies that clarify the scope of TDCP reporting |
| Samsung | Since we prefer stand-alone, we will answer Q1 only.  Q1: Aperiodic reporting alone should be enough. If another mode is needed, periodic reporting (with very large periodicity). We expect TDCP to change slowly. |
| Spreadtrum | We prefer stand-alone reporting since TRS is utilized for the reporting. We also think AP reporting is enough, but we are fine with p/sp reporting with relatively large periodicity. |
| Apple | Alt. 1 seems more practical. Given different paths can have different Doppler shifts, identify Doppler components from a single port transmission may not be easy. |
| ZTE | Firstly, we prefer stand-alone reporting, but we are open to the second alternatively, if we can have the clear usage,  For time domain behavior, we think that P/SP/AP should be supported all as a starting point. At this moment, it is too early to preclude some candidates now. For instance, periodic TDCP reporting may be used for a general measurement/report (as what we do for normal CSI), but for some specific case or estimating sudden channel update in terms of Doppler domain, the gNB may trigger AP report as well. |
| NTT DOCOMO | For Q1, we are open for time-domain behavior to be reported.  For Q2, what we hope is to support TDCP reporting regardless of whether to turn on a specific CSI codebook type. As far as it is possible, we would be open to discuss to combine TDCP with other CSI parameter(s).    If we go with down-selection suggested by Lenovo, Alt-2 is what we are thinking now. We are fine with considering more than one use case as fa as Alt 2 is considered. |
| Huawei, HiSilicon | We prefer Alt.1, which is enough to report what can be derived from TRS. |

# References

|  |  |  |  |
| --- | --- | --- | --- |
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| 2 | R1-2203229 | On CSI enhancements for Rel-18 NR MIMO evolution | Ericsson |
| 3 | R1-2203265 | CSI enhancement for high/medium UE velocities and CJT | ZTE |
| 4 | R1-2203322 | Discussion on CSI enhancement for coherent JT | Spreadtrum Communications |
| 5 | R1-2203380 | Aspects of CSI Enhancements | InterDigital, Inc. |
| 6 | R1-2203443 | On Rel-18 CSI enhancements | CATT |
| 7 | R1-2203543 | Views on CSI enhancement for high-medium UE velocities and coherent JT | vivo |
| 8 | R1-2203683 | Discussion on CSI enhancement | NEC |
| 9 | R1-2203725 | Considerations on CSI enhancement for high/medium UE velocities and coherent JT (CJT) | Sony |
| 10 | R1-2203795 | Discussion on CSI enhancement | xiaomi |
| 11 | R1-2203890 | Views on CSI enhancements | Samsung |
| 12 | R1-2203955 | CSI enhancement for high/medium UE velocities and coherent JT | OPPO |
| 13 | R1-2204099 | CSI enhancement for high/medium UE velocities and CJT | FUTUREWEI |
| 14 | R1-2204143 | Potential CSI enhancement for high/medium UE velocities and coherent JT | LG Electronics |
| 15 | R1-2204164 | Discussion of CSI enhancement for high speed UE and coherent JT | Lenovo |
| 16 | R1-2204231 | Views on Rel-18 MIMO CSI enhancement | Apple |
| 17 | R1-2204289 | Discussion on CSI enhancement for high/medium UE velocities and CJT | CMCC |
| 18 | R1-2204369 | Discussion on CSI enhancement | NTT DOCOMO, INC. |
| 19 | R1-2204468 | Discussion on CSI enhancement for coherent JT | Spreadtrum Communications |
| 20 | R1-2204508 | CSI enhancement | Sharp |
| 21 | R1-2204540 | CSI enhancement for high/medium UE velocities and CJT | Nokia, Nokia Shanghai Bell |
| 22 | R1-2204679 | CSI enhancements for medium UE velocities and coherent JT | Fraunhofer IIS, Fraunhofer HHI |
| 23 | R1-2204691 | CSI enhancment for high/medium UE velocities and coherent JT | MediaTek Inc. |
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| 29 | R1-2203548 | Discussion on CSI prediction at UE | vivo |
| 30 | R1-2203895 | Initial SLS results on Type-II CSI enhancements for CJT | Samsung |
| 31 | R1-2204913 | Discussion on field test results of CSI enhancement for coherent JT | Huawei, HiSilicon |