**3GPP TSG RAN WG1 #110bis-e R1-2210566**

**e-Meeting, October 10th – 19th, 2022**

**Agenda item:** 9.1.2

**Source:** Moderator (Samsung)

**Title:** Moderator Summary#4 on Rel-18 CSI enhancements: ROUND 3

**Document for:** Discussion and Decision

## Introduction

The scope given in the Rel-18 NR Evolved MIMO WID 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

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

Table 1A Summary: issue 1

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| **#** | **Issue** | **Companies’ views** |
| 1.4 | [110bis-e] **Agreement**  On the Type-II codebook refinement for CJT mTRP, following legacy (Rel-16 regular eType-II and Rel-17 PS FeType-II), for a given CSI-RS resource:   * SD basis selection is layer-common and polarization-common, with *N*1, *N*2, *O*1, *O*2 defined per Rel-16 specification for refinement based on Rel-16 regular eType-II, and per Rel-17 specification for refinement based on Rel-17 PS FeType-II * FD basis selection is   + For refinement based on Rel-16 regular eType-II: per-layer with *M*v, *p*v, *N*3, and *R* defined per Rel-16 specification   + For refinement based on Rel-17 PS FeType-II: layer-common with *M*, *N*3, and *R* defined per Rel-17 specification   + FFS: Details on FD basis selection window   Note: The supported value(s) for each of the defined parameters are to be discussed separately (e.g. possibilities of adding new or removing existing value(s) in addition to those supported by legacy specification).  **Proposal 1.D.2**: On the Type-II codebook refinement for CJT mTRP, regarding the codebook parameters, for a given CSI-RS resource, the supported value(s) of the following parameters follow the legacy (Rel-16 regular eType-II and Rel-17 PS FeType-II) specification:   * *N*1, *N*2, *N*3, *O*1, *O*2 * *M* (only for design based on Rel-17 PS FeType-II)   For the following parameters, decide in RAN1#111 whether the supported value(s) follow the legacy (Rel-16 regular eType-II and Rel-17 PS FeType-II) specification or further refinement is needed:   * *R*: including, e.g. supporting only *R*=1, or supporting larger *R* values * *Mv*/*pv* (Rel-16 regular eType-II): including, e.g. supporting smaller *pv* values such as {1/8, 1/4, 1/2} for v=1,2 and/or removing larger legacy value(s) * **: including, e.g. supporting smaller values such as {1/16, 1/8, 3/8}   Note: The outcome of Parameter Combination discussion will further restrict the supported combinations of parameter value(s)  FFS: For N>1, whether the maximum 2*N*1*N*2 (identical to the number of CSI-RS ports used for CMR) s limited to 32 just as in legacy specification  **FL Note**: Discussion on basic/default parameter values for Rel-19 Type-II CJT will be done in Rel-18 UE feature session.  For M, so far no company proposes to refine the supported values of M.  **Question**: Please share your views on supported value(s) for each of the above parameters, e.g. whether the legacy supported value(s) can be fully reused, or what refinement (removing and/or adding new values) is needed   * This is irrespective of the outcome of supported parameter combinations. For now, each parameter should be considered separately from other | **Support/fine:** Apple, vivo, ZTE, Xiaomi, DOCOMO, NEC, Fraunhofer IIS/HHI, Samsung, Intel, Qualcomm, AT&T, Nokia/NSB, LG, Ericsson, OPPO, CATT, MediaTek, Spreadtrum  **Not support:** |
| 1.6 | [110bis-e] **Agreement**  On the Type-II codebook refinement for CJT mTRP, following legacy (Rel-16 regular eType-II and Rel-17 PS FeType-II), regarding the location of non-zero coefficients (NZCs) indicated by bitmap (following legacy mechanism), for each layer, support separate bitmap per each CSI-RS resource   * Total size = where is the bitmap size for CSI-RS resource *n*   + TBD: Whether ( for mode 2) analogous to legacy, or further reduction of bitmap size is supported.   + …   **Proposal 1.F.2**: On the Type-II codebook refinement for CJT mTRP, regarding the bitmap(s) for indicating the locations of NZCs, down-select from the following alternatives for the size of the bitmap for CSI-RS resource *n* (*Bn*) (by RAN1#111):   * Alt1. Analogous to legacy, ( for mode 2) * Alt2. Non-rectangular bitmap, i.e., NZC bitmap allowing different lengths for different SD/FD basis vectors.   + TBD: How to determine the lengths for different SD/FD basis vectors   **FL Note**: Although Alt1 represents the super-majority (Alt2 is proposed only by vivo), we can study this further to see how much overhead reduction Alt2 can offer over Alt1. This will be decided in RAN1#111.  **Question**: Other than the legacy-based scheme (where ), what other scheme(s) do you intend to propose for down-selection consideration? | **Support/fine:** vivo, ZTE, Xiaomi, DOCOMO, NEC, Fraunhofer IIS/HHI, Samsung, Intel, Qualcomm, AT&T, Nokia/NSB, Lenovo, LG, Ericsson, OPPO, CATT, MediaTek, Spreadtrum  **Not support:** |
| 1.9 | **Proposal 1.I.2**: For the Rel-18 Type-II codebook for CJT mTRP, for mode-1, the number of FD basis vectors (Mv related to pv for Rel-16, M for Rel-17) is common across all N CSI-RS resources  **FL Note**: While FD basis selection can be TRP-specific for mode-1, a number of companies perceive the number of selected FD basis vectors can be common across all the N TRPs. | **Support/fine:** Huawei/HiSi, Qualcomm, Nokia/NSB, Intel, AT&T, Ericsson, Samsung, Apple, vivo, Xiaomi, NEC, Fraunhofer IIS/HHI, MediaTek, ZTE (ok if majority), DOCOMO (ok if majority), Lenovo (flexible), LG (ok), OPPO, Spreadtrum  **Not support:** CATT |

Table 2 Additional inputs: issue 1

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| **Company** | **Input** |
| Mod V0 | **PLEASE READ THE FL NOTES**   1. **Check and, if needed, update your view in Table 1A especially on the moderator proposals.** 2. **Share additional inputs here, if needed**   **More moderator proposals may be added in the next revision** |
| Apple | **Issue 1.4**  Legacy value can be start point, except we prefer to have R=1 only  **Issue 1.9**  We are fine with the same number of selected FD basis for each TRP/TRP group |
| vivo | **Issue 1.4**  We support refinement of the legacy parameter values to cover the lower payload range. On the values of the codebook parameters, the minimum value of K\_0 is ⌈0.25M\_1 ⌉, where L=2, and β=0.25. However, for CJT PMI, the number of rows in W\_2 is greater, e.g.,2LT, where T denotes the number of TRPs. Therefore, the value of K\_0 is ⌈2M\_1 ⌉ which has large gap compared to the value of STRP, when T=4, L=2, and β=0.25. Therefore, we think the value of Beta needs to be further reduced to cover the lower payload range, e.g. 0.125, 0.0625.  **Issue 1.6**  We support the following alternative for further evaluation/down-selection. One example can be for all the (Ltot) SD basis and all the FD basis across N CSI-RS resources, the bitmap length is 2Ltot for FD basis vector 0 where SCI locates, and bitmap length is 2Ltot- n \* d for the rest, where n denotes the scaling value and d denotes the modulo difference (e.g., mod Mv/2) between the index of each selected FD basis vector and FD basis vector 0.   * Alt x: Non-rectangular bitmap, i.e., NZC bitmap allowing different lengths for different basis vectors.   + TBD: How to determine the lengths for different basis vectors   **Proposal 1.I.2**  Support |
| ZTE | **Issue 1.4**  In our initial thought, we can use the legacy value of {N1, N2, Q1, Q2} as a starting point. Then, for FD basis, we may still use the legacy, but we wonder whether we need to consider a high-accurate parameter-configurations, especially for L =6 or more.  **Issue 1.6**  We prefer to use the legacy ( for mode 2).  **Proposal 1.I.2**  We prefer to have separate number of FD-basis due to the fact that channel property for different TRP may be different, but if majority support, we can be flexible. |
| Xiaomi | **Issue 1.4**  Legacy values can be considered as starting point  **Issue 1.6**  Prefer legacy-based scheme  **Issue 1.9**  Support common number FD basis vectors across all N CSI-RS resources |
| DOCOMO | **Issue 1.4**  Legacy values can be used as starting point. At least *N*1, *N*2, *O*1, *O*2 can be kept unchanged. For other values, e.g., L, M, beta, R, we’re open to study the candidate values to reduce CSI reporting overhead.  **Issue 1.6**  Prefer legacy-based scheme  **Issue 1.9**  OK with common number of FD basis vectors, if it is supported by majority. |
| NEC | **Issue 1.4**  We prefer to study larger value of R at least for refinement based on Rel-16 codebook, as the frequency selective increased for CJT.  **Issue 1.6**  We prefer legacy analogous scheme.  **Issue 1.9**  Fine with the proposal. |
| Fraunhofer IIS/Fraunhofer HHI | **Issue 1.4:** Prefer legacy values.  Re N3, unlike Rel. 16 and Rel. 17, N3>19 shall be made mandatory as the number of subbands are critical for functioning of this codebook especially for inter-site CJT scenarios. As the delay spread is larger for CJT compared to the single-TRP Rel. 16 CB, a small number of subbands (for example 13) can result in large aliasing of the channels associated with some cooperating TRPs. This will result in a large performance loss. This is what we observed rather frequently in our evaluations and therefore support for larger number of subbands shall be made mandatory.  **Issue 1.6**: We prefer using legacy bitmap  .  **Issue 1.9**: Support |
| Samsung | **Issue 1.4**   * (N1,N2,O1,O2): prefer reusing legacy values * (Mv, pv): We prefer to use parameter instead of using equation to determine Mv based on for simplification and alignment R17-based CJT. Considering large-overhead consumed in the CJT scheme, we think a lower-value range of (than legacy) can be considered, e.g. Mv<=4. This makes a restricted range of for all configurable numbers of SBs, so it can be simpler to determine supported values for than .   + R16-based: Mv=2,3,4   + R17-based: M=1,2, support of M=2 is optional (as in legacy R17) * N3, R: prefer reusing legacy   **Issue 1.6**: we support legacy scheme (), which should be baseline  **Proposal 1.I.2**  We support. |
| Intel | **Issue 1.4.**   * Legacy values for N1, N2, O1, O2 can be reused * pv: {0.25, 0.5} can be further considered for v = 1,2 and two times lower for v = 3,4 (as for legacy codebook) * R = {1,2} can be considered with R = 2 as optional feature   **Issue 1.6.**   * Legacy design can be reused   **Issue 1.9.**  Support the proposal |
| Qualcomm | **Issue 1.4**   * {O1,O2}: Fully reuse; * {N1,N2}: Generally OK to reuse, but total NN1N2 should be limited <=32 at least according to UE capability * N3 and R: Full reuse   + Strongly oppose any increase – also drastic increase of UE complexity   + Larger delay-spread issue can have better way to resolve, e.g. by delay-compensated PDSCH (CDD) as proposed by Ericsson and also by some other companies * Mv:   + Rel-16: OK with smaller-value config by new smaller pv   + Rel-17: Reuse M=1 or 2   **Issue 1.6**  Fully reuse (For any possible methods of Bn reduction, any difference from config a smaller L or M?)  **Issue 1.9**  Support TRP-common value of Mn as a starting point, or even working assumption.  Maybe there can be overhead-UPT performance difference for TRP-specific Mn, if companies are willing to evaluate, and we are also open and interested to see the potential results.  Note that there can be a drawback: If Mn is different for each TRP, the total bitmap size can potentially variate more unstably and made it more difficult for gNB to estimate total PUSCH resources needed for the report in advance (given that Ln is already agreed to be TRP-specific by all the 4 Alts of **Proposal 1.E.3**) |
| AT&T | **Issue 1.4**  Support the legacy for N1, N2, O1, O2 and open for refinement for the other parameters: *M*v, *p*v, *N*3, and *R*  **Issue 1.6**  Support the legacy  **Issue 1.6**: **Proposal 1.I.2**  Support |
| Nokia/NSB | **Issue 1.4**  Legacy parameter values can be reused as a starting point. If a gap in performance/OH tradeoff is identified, for example, for low overhead, some parameter combination can be modified  **Issue 1.6**  Legacy-based scheme is enough  **P 1.I.2**  Support |
| MediaTek | **Issue 1.4**  The supported values in legacy Rel-16 and Rel-17 should at least be the baseline. Any enhancement to candidate values should be based on performance-overhead tradeoff study. The usual parameters for candidate value enhancement are and . We believe that lower values of each of these parameters (compared to legacy) should be included. An example of values which can be studied are (considering rank1,2 overhead)  [Mod: Included except for L, which is a separate topic covered in 1.E.3]  **Proposal 1.I.2**  Support |
| Samsung | **Issue 1.4**  After further checking the agreement that we need to follow legacy parameters, we would like to change our previous input on 1.4. For , we support at most (not as in legacy), since CJT has the large-overhead issue as we mentioned (especially when ). |
| Mod V18 | **No revision on 1.I.2**  **Added 1.D.2 and 1.F.2** |
| Lenovo | **Issue 1.6, Proposal 1.F.2:**  We support Alt-1, however we are a little bit confused with Alt-2. For instance, a super bitmap that includes all coefficients per layer (across TRPs) would be non-rectangular under Alt-1, if per TRP Ln, Mn values are supported. We prefer removing Alt-2 unless the proponents provide clear explanation of the underlying design  **Issue 1.9, Proposal 1.I.2:**  We can be flexible on this one, however, in our understanding, different TRPs are characterized by different channels to the same UE, i.e., different PDP. For one TRP, the number of dominant paths may be larger than another TRP. Prefer separate M per CSI-RS resource.  @QC: Regarding UCI overhead, if Mn is network-configured, the gNB can still compute the bitmap overhead precisely, which would be of size |
| LG | Issue 1.4:  Support Proposal 1.D.2.  Issue 1.6:  Alt 1 is sufficient.  Issue 1.9:  We are fine to support proposal 1.I.2 for the sake of progress. |
| Ericsson | **Issue 1.4, Proposal 1.D.2**  Ok with current FL proposal  **Issue 1.6, Proposal 1.F.2**  We prefer legacy approach (Alt 1). But ok to do down-selection in RAN1#111.  **Issue 1.9, Proposal 1.I.2**  ok |
| OPPO | **Proposal 1.D.2**  Fine with the FL proposal  **Proposal 1.F.2**  We are fine with the proposal and prefer Alt1.  **Proposal 1.I.2**  Support. |
| vivo | **Replying to Lenovo on Alt 2 in Proposal 1.F.2**  We are considering to reduce the overhead even if a different Ln is configured for each resource. The final bitmap size for each CSI-RS resource can be smaller than the 2Ln\*Mv,n. If we look at this issue from the angle of each CSI-RS resource, one example can be for each CSI-RS resource, the bitmap length is 2Ln for one reference FD basis vector, and bitmap length is 2Ln- n \* d for the rest, where n denotes the scaling value and d denotes the modulo difference (e.g., mod Mv/2) between the index of each selected FD basis vector and the reference FD basis.  **Proposal 1.D.2**  Support |
| CATT | **Issue 1.4, Proposal 1.D.2**  Support  **Issue 1.6, Proposal 1.F.2**  Support  **Issue 1.9, Proposal 1.I.2**  Similar views with ZTE, Lenovo that we prefer separate numbers of FD basis for each TRP. |
| Qualcomm | Generally OK with all 3 proposals.  A question for the last FFS of **Proposal 1.D.2**:  Does it mean for even for one single TRP, we need to FFS whether 2N1N2 can exceed 32? Seems no company propose this. – Maybe not needed if I didn’t miss any input.  [Mod: Added]  Re @Lenovo:  I agree with you that if both Ln and Mn are configured by gNB, even if they are TRP-specific, bitmap size is pre-known. |
| Mod V27 | **Minor (obvious) clarification on 1.D.2.** |
| vivo | **One minor comment on Proposal 1.F.2**  Since to have different bitmap size for different SD basis basically means different FD basis will also have different bitmap size, we would like to revise the wording for Alt 2 a bit as follows.  **Proposal 1.F.2**: On the Type-II codebook refinement for CJT mTRP, regarding the bitmap(s) for indicating the locations of NZCs, down-select from the following alternatives for the size of the bitmap for CSI-RS resource *n* (*Bn*) (by RAN1#111):   * Alt1. Analogous to legacy, ( for mode 2) * Alt2. Non-rectangular bitmap, i.e., NZC bitmap allowing different lengths for different SD/FD basis vectors.   + TBD: How to determine the lengths for different SD/FD basis vectors   [Mod: Yes sir ☺] |
| Mod V29 | **Added revision from vivo** |
| MediaTek | Support **1.D.2**  Support **1.F.2** |
| Spreadtrum | **Proposal 1.D.2**  Support the proposal.  **Proposal 1.F.2**:  We support Alt1. On the other hand, we are not clear how to generate bitmap based on Alt2. Does it mean # selected FD bases for each SD basis are different?  [Mod: We will discuss more during OFFLINE]  **Proposal 1.I.2**:  Support the proposal. |
| Mod V35 | **No revision** |
| Huawei, HiSilicon | **Issue 1.4**  We are fine with **Proposal 1.D.2**. And we prefer to add a new parameter O3 for FD oversampling. Specifying the frequency domain oversampling can ensure a proper phase rotation for frequency domain compression at the UE for efficient compression and performance gain. For legacy Type-II codebook, O3 is not defined because FD shift is implemented by UE implementation with high accuracy and need not to be reported. However, for CJT, the difference between FD basis of different TRPs may not be accurately represented by current FD basis. To align the FD basis between TRP, different FD basis oversampling for different TRPs will be needed.  **Issue 1.6**  We are fine with **Proposal 1.F.2** and support Alt1 to reuse the legacy scheme.  **Issue 1.9**  We support **Proposal 1.I.2.** |
| CMCC | **Proposal 1.D.2**  Support the proposal.  **Proposal 1.F.2**:  We support this proposal and prefer Alt1. Alt2 seems need additional predefined rules or bitmap patterns.  **Proposal 1.I.2**:  OK with the proposal. |

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

Table 3A Summary: issue 2

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| **#** | **Issue** | **Companies’ views** |
| 2.1 | [109-e] **Agreement**  The work scope of Type-II codebook refinement for high/medium velocities includes refinement of the following codebooks, based on a common design framework:   * Rel-16 eType-II regular codebook * Rel-17 FeType-II port selection (PS) codebook   FFS: Whether to prioritize/down-select from the two  **Proposal 2.A**: The Rel-18 Type-II codebook refinement for high/medium velocities comprises refinement of the following codebooks:   * Refinement of the Rel-16 eType-II regular codebook * Refinement of the Rel-17 FeType-II port selection (PS) codebook, based on the same design details as the Refinement of the Rel-16 eType-II regular codebook, except for the supported set of parameter combinations   + Time-/Doppler-domain reciprocity is not assumed   **FL Note**: This proposal has been discussed in RAN1#110 | **Support (equal priority for) both Rel-16 eType-II and Rel-17 FeType-II:** Huawei/HiSi, ZTE (Rel-16 first), Fraunhofer IIS/HHI   * **Concern:** vivo, Lenovo, LG, Apple, DOCOMO, Spreadtrum   **Down-select to only Rel-16 eType-II:** Apple, DOCOMO, MediaTek, NEC, Xiaomi, Samsung, Lenovo, Intel (if Rel-17, no DD reciprocity), Xiaomi. Qualcomm, Apple, DOCOMO, Ericsson, Nokia/NSB, LG, Spreadtrum, CMCC, vivo, OPPO, Google, Sharp  **Proposal 2.A:**   * **Support/fine:** IDC, ZTE, Huawei/HiSi, Fraunhofer IIS/HHI * **Concern (Rel-16 only):** vivo, LG, Apple, DOCOMO, Spreadtrum, Qualcomm, Lenovo, Nokia/NSB, OPPO |
| 2.4 | [109-e] **Agreement**  For the Rel-18 Type-II codebook refinement for high/medium velocities, support the following codebook structure where N4 is gNB-configured via higher-layer signaling:   * For N4=1, Doppler-domain basis is the identity (no Doppler-domain compression) reusing the legacy *, ,* and *, e.g.* * For N4>1, Doppler-domain orthogonal DFT basis commonly selected for all SD/FD bases reusing the legacyand *,* e.g.   + Only Q (denoting the number of selected DD basis vectors) >1 is allowed   + TBD (by RAN1#110bis): whether rotation is used or not   + FFS: identical or different rotation factors for different SD components   + FFS: Whether *Q* is RRC-configured or reported by the UE   Note: Detailed designs for SD/FD bases including the associated UCI parameters follow the legacy specification  FFS: Whether one CSI reporting instance includes multiple and a single and report.  **Proposal 2.D.3**: For the Rel-18 Type-II codebook refinement for high/medium velocities, when N4>1, down-select from the following alternatives (by RAN1#111) for the orthogonal DFT DD basis:   * Alt1. No rotation factor * Alt2. A rotation factor is selected for each SD basis vector   + FFS: Supported values of rotation factor   Note: At least one company opines that Alt2 is not aligned with the agreement in RAN1#110bis-e and WID objective #1  **FL Note**: This issue should be resolved based on SLS results in RAN1#111. | **Proposal 2.D.3:**   * **Support/fine:** Apple, vivo, ZTE, Xiaomi, NEC, Fraunhofer IIS/HHI, Samsung, Intel, Qualcomm, Nokia/NSB, MediaTek, LG, Ericsson, OPPO, vivo, CATT, Spreadtrum * **Not support:** |
| 2.4 | [110bis-e] **Agreement**  For the Type-II codebook refinement for high/medium velocities, the selection of DD basis vectors is layer-specific   * The number of selected DD basis vector (denoted as *Q*) is layer-common   [110bis-e] **Agreement**  For the Rel-18 Type-II codebook refinement for high/medium velocities, when N4>1, if multiple candidates of Q value are supported, the value of *Q* is gNB-configured via higher-layer (RRC) signalling  **Proposal 2.D.4**: For the Type-II codebook refinement for high/medium velocities, for N4>1, study the supported values for *Q* from (but not limited to) the following candidates, in conjunction with the supported values of N4 and DD units:   * Alt1. Q is determined as a function of N4, e.g., Q=2 for N4=2, and Q=ceil(N4/2) for N4>2 * Alt2. Q is selected from multiple candidate values, e.g., {2, 3, 4, …,} (or a subset thereof, e.g. {2, 3}), the maximum value is FFS * Alt3. Only single value is supported, e.g.,,Q=2 only or Q=4 only   **FL Note**: This issue should be resolved based on SLS results so careful study is needed (may not be finalized in RAN1#111). This also depends on N4 and DD unit.  I am listing some proposals brought up by companies as a starting point.  **Question**: Please share your views on the possible value(s) of *Q* | **Proposal 2.D.4:**   * **Support/fine:** Apple, vivo, ZTE, NEC, Fraunhofer IIS/HHI, Samsung, Intel, Qualcomm, Nokia/NSB, MediaTek, LG, Ericsson, OPPO, vivo, CATT, MediaTek, Spreadtrum * **Not support:** |
| 2.5 | [110bis-e] **Agreement**  On the CSI reporting and measurement for the Rel-18 Type-II codebook refinement for high/medium velocities, when UE-side prediction is assumed, support UE “predicting” channel/CSI after slot *l* where the location of slot *l* is configured (from multiple candidate values) by gNB via higher-layer signalling   * Candidates of slot *l* location include the legacy CSI reference resource location (*n* – *nCSI,ref* ) and slot (*n*+*δ*) where *δ* ≥ 0 * FFS: Possible value(s) of *δ* and possible value(s) of WCSI   Note: Per legacy behavior, the legacy CSI reference resource, i.e., (*n* – *nCSI,ref* ), is reused for locating the last CSI-RS occasion used for a CSI report  For a UE that supports UE-side prediction, the support of *l* = (*n* – *nCSI,ref* ) is UE optional.  **Proposal 2.E.2**: On the CSI reporting and measurement for the Rel-18 Type-II codebook refinement for high/medium velocities, when UE-side prediction is assumed, study the supported value(s) for *δ* and WCSI from (but not limited to) the following candidates, in conjunction with the supported values of N4 and DD units:   * *δ* (slots): {0, 1, 2, 3, 4, 6, 8}, or a subset thereof with at least two values including 0, or a single fixed value (e.g. 0 or 1) * WCSI (slots): 1, N4, following periodicity of P/SP-CSI-RS or SP-CSI (e.g., 4, 5, 8, 10, 16, 20, 40), (*d*=DD unit size in slots, N4 is unit-less)   FFS: Dependence on sub-carrier spacing should also be studied  **FL Note**: This issue should be resolved based on SLS results so careful study is needed (may not be finalized in RAN1#111). This also depends on N4 and DD unit.  I am listing some proposals brought up by companies as a starting point.  **Question**: Please share your views on the possible value(s) of *δ* and possible value(s) of WCSI | **Proposal 2.E.2:**   * **Support/fine:** Apple, vivo, ZTE, NEC, Samsung, Qualcomm, Nokia/NSB. MediaTek, LG, Ericsson, OPPO, vivo, CATT, Spreadtrum * **Not support:** |

Table 4 Additional inputs: issue 2

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| **Company** | **Input** |
| Mod V0 | **PLEASE READ THE FL NOTES**   1. **Check and, if needed, update your view in Table 3A especially on the moderator proposals.** 2. **Share additional inputs here, if needed**   **More moderator proposals may be added in the next revision** |
| Apple | **Issue 2.1**  We prefer to prioritize Rel-16 eType-II over Rel-17 FeType-II PS  **Issue 2.4**  We prefer Alt1, no rotation factor  **Issue 2.5**  It depends on the channel coherent time. Assume it is around 30ms, corresponding to roughly 30Hz coherent BW.  Consider 30kHz SCS of 0.5ms slot.  δ can be up to 64?  We are open to more discussion as well |
| vivo | **Issue 2.1**  We don’t support proposal 2.A. We support to enhance Rel-16 eType II only.  **Proposal 2.D.3**  Support. Further evaluation is needed. We prefer Alt 1 at the current stage.  **Issue 2.4**  We suggest to define Q=ceil(N4/2) for N4>2.  For N4=2, the only case we can have now is Q=2.  **Issue 2.5**  For delta, we support {0, 2, 4} as the candidate values for configuration.  For W\_CSI, we think one value is sufficient. Either W\_CSI =1 or N4 is fine. We slightly prefer W\_CSI =1 for lower UE complexity. |
| ZTE | Proposal 2.A: Support  Proposal 2.D.3: Although we prefer to have rotation factor that is good for CSI compression, we tend to agree that it can be up to implementation.  Issue 2.4: Q can be configured and then we may have candidate value of Q = 2, 3, 4, 5, …. Regarding upper bound, we may have further evaluation. Considering that N4 may be limited (e.g., <20 slot), we think that the candidate value of Q may not be too many, e.g., up to 5 or 9, according to our evaluation.  Issue 2.5: We prefer to consider a large value of delta (e.g., from 0 to 8 in slot with a step of 2). The value of W\_CSI (i.e., N4, right?) should consider the periodicity of CSI report/measurement (e.g., 4, 5, 8, 10, 16, 20, …) (e.g., in terms of uniform sample and prediction). The upper bound may further be studied, but it seems that up to 40 seems sufficient.  CSI-ReportPeriodicityAndOffset ::= CHOICE {  slots4 INTEGER(0..3),  slots5 INTEGER(0..4),  slots8 INTEGER(0..7),  slots10 INTEGER(0..9),  slots16 INTEGER(0..15),  slots20 INTEGER(0..19),  slots40 INTEGER(0..39),  slots80 INTEGER(0..79),  slots160 INTEGER(0..159),  slots320 INTEGER(0..319)  } |
| Xiaomi | **Proposal 2.D.3**  Support Proposal 2.D.3. For Alt2, as analyzed in our tDoc, if a common rotation factor is applied to all SD basis vector, its effect is similar to that of nonrotation factor applied to all SD basis vector. The reason is that the phase rotation for the precoder of all subbands at one instance does not affect performance. Therefore, Alt2 should be equivalent to Alt1.  **Issue 2.4**  In our view, the value of Q can be determinate through simulation results considering the tradeoff between performance and overhead, which is similar to determination of number of SD basis and FD basis. The value of Q may be calculated as , where is a scaling factor.  **Issue 2.5**  For *δ*, *δ*=0 can be supported, which is straightforwardly. Considering the processing time of gNB after receiving the CSI reporting, *δ*>0 can also be supported.  For WCSI, if , it is sufficient that WCSI =1. If , WCSI =1 can calculated as , where *d* is DD/TD compression unit. |
| NEC | **Issue 2.1**  We prefer to down-select to based on Rel-16 (at least prioritized)  **Proposal 2.D.3**  Support, and Alt 1 is preferred.  **Issue 2.4**  We think the value of N4 may be needed to be firstly determined (or at least jointly considered, which is also related to WCSI in Issue 2.5), as the value of Q may be related to the value of N4.  **Issue 2.5**  Considering the processing/scheduling preparation time, we prefer *δ* > 0, maybe starting from 1. The candidate values may be {1,2,3,4}.  We share similar view with Xiaomi, WCSI = d\*N4, where d is DD unit. So one parameter needs to be determined is d, and d may be in term of slots, we think either periodicity/interval of CSI or CSI-RS can be applied. At least 4 should be supported for d, i.e. WCSI = 4\*N4 |
| Fraunhofer IIS/Fraunhofer HHI | **Proposal 2.A: Support**  We think that refining Rel. 17 PS codebook is straightforward, and workload is small as **Time-/Doppler-domain reciprocity is not assumed**. In our view, only some of the parameter combinations need some refinement as all other codebook aspects are straightforward extensions.  **Proposal 2.D.3:**  In Alt 2, a single/common rotation factor is used for all SD components which is equivalent to multiplying the precoder with a common phase value. The common phase value has no significance in the precoder calculations. Hence, in our view, Alt 1 and Alt 2 are the same and hence Alt2 can be removed. Alt 3 on the other hand uses a different rotation factor for each SD component. For example, for oversampling factors of four, for each SD component, the DD components are selected from a single orthogonal sub-matrix out of four orthogonal sub-matrices. Our simulations results (oversampling factors **two** and **four**) using a rotation factor per SD component significantly improved the performance of the Rel.18 Codebook compared to the baseline.  **Issue 2.4&2.5:** In our observations, up to seems to be sufficient for CSI prediction up to slots. |
| Samsung | Proposal 2.D.3: we support Alt3  Issue 2.4   * We support Q=2, and ok to study Q=3. Note larger value Q will incur more overhead, and small UPT improvements.   Issue 2.5   * We support only one Delta value (delta=0), and the need for more than delta value is unclear to us. * Following frequency domain, W\_CSI = N4/x, where N4 (total number of slots) and x (DD/TD unit size) are configured.   [Mod: This formulation is incorrect. It seems you assume N4 is in slots. Based on the previously agreed definition N4 has no unit. Check Xiaomi’s formula which I believe is the correct one] |
| Intel | Issue 2.4.   * Alt 2 can be removed as explained by Fraunhofer IIS/Fraunhofer HHI for Proposal 2.D.3 * Q can be related to N4 (e.g. Q = ceil(0.5\*N4))   Issue 2.5.   * Fixed value of delta can be considered (e.g. delta = 1). |
| Qualcomm | Fine with **Proposal 2.D.3**  **Issue 2.4**: At least support Q={2,3}  **Issue 2.5**: WCSI size depends on coherent time (UE speed), and also depends on SCS if configured in # slots |
| Nokia/NSB | **Issue 2.1**  Rel-16-Type-II enhancement only is enough.  **P 2.D.3**  Ok with the proposal, but we think Alt 1 and Alt 2 are equivalent because a common phase rotation across SD beams does not change the precoder.  Our preference, for now, is Alt 1, but further evaluation is needed for Alt 3. In Alt 3, for clarification, are the Q DD basis indices the same for all SD beams, but drawn from different orthogonal groups (i.e. L rotation factors, Q DD bases), or are they different for each SD beam (i.e., L rotation factors, Q\*L DD bases)? In our understanding, the previous agreement seems to exclude the latter interpretation: “orthogonal DFT basis commonly selected for all SD/FD bases”  **Issue 2.4**  For N4=2, Q=2 is the only allowed value.  **Issue 2.5**  For delta, only value 0 may be enough.  For W\_CSI, we think this parameter can be defined as a function of N4 and the time-domain unit, which determines the validity period for each reported CSI. For example: W\_CSI=N4\*time\_unit |
| MediaTek | **Issue 2.1**  We believe only Rel-16-Type-II enhancement should be considered.  **Proposal 2.D.3**  Support this Proposal. We think Alt2 can be removed. As proved by Qualcomm, the performance of Alt2 would be the same as Alt1.  **Issue 2.4**  At least should be supported.  **Issue 2.5**  can be supported.  (slots) can be supported, a subset of CSI report periodicity supported in NR.  New values are not desirable, as it may complicate gNB’s scheduling.  is mainly for medium speeds 10, 20 km/h.  Supporting larger values is undesirable because   1. CSI prediction for a long range is difficult at high/medium speeds; 2. CSI prediction at low speeds requires buffering (high UE complexity) for a long time to detect channel variation; “sample and hold” is sufficient   We would like to also share our design principle for TD units: 1) unit size is a divisor (factor) of ; 2) we prefer ; 3) can be supported for each value of . The following are our preferred sizes of TD units for each value of :   * : 1, 2, 4 * : 1, 5 * : 1, 2, 4, 8 * : 1, 2, 5, 10 * : 2, 4, 8, [16] * : 2, 5, 10, [20] * : 4, 5, 8, 10, 20   [Mod: Thanks. We will discuss DD unit issue starting this week ☺ in OFFLINE thread] |
| Fraunhofer IIS/Fraunhofer HHI\_2 | @Nokia, per agreement, UE selects Q DD basis vectors commonly for all SD/FD basis from an orthogonal DFT basis. But it does not preclude associating each SD component with a rotation factor. Even when a rotation factor is associated per SD component, only Q DD components are reported and not QL components. |
| Mod V18 | **Revised proposal 2.D.3 by removing Alt2 (many companies commented Alt2 doesn’t differ from Alt1 in performance, which is mathematically obvious)**  **Added 2.D.4 and 2.E.2** |
| Samsung | **Proposal 2.D.4**: we prefer to add another example Q=2 as a single value in Alt3. Based on our study, there is no/small gain with larger Q values, but the overhead can be large.   * Alt3. Single value Q=2 or 4 ~~only~~ |
| Lenovo | **Issue 2.1, Proposal 2.A**  Do not support. Only Rel-16 eType-II codebook is used as the basis  **Issue 2.4, Proposal 2.D.4**  Do we really need Alt-3? Alt-2 already implies selecting a single value, which can be Q=4  [Mod: Please check the revised version. Some companies want to keep Alt3 separate]  **Issue 2.5, Proposal 2.E.2**  Fine with the proposal, just a small typo: “*d*=DD unit size ***in*** slots”  [Mod: Thanks] |
| LG | Issue 2.1  We support Rel-16 codebook enhancement only.  Proposal 2.D.3  Support, and Alt 1 is preferred unless meaningful gain of Alt 2 is observed.  **Proposal 2.D.4**:  We suggest to make it general not to preclude other options.  For the Type-II codebook refinement for high/medium velocities, for N4>1, study the supported values for *Q* from (but not limited to) the following candidates, in conjunction with the supported values of N4 and DD units:   * Alt1. Q is determined as a function of N4, e.g.,Q=2 for N4=2, and Q=ceil(N4/2) for N4>2 * Alt2. Q is selected from multiple candidate values, e.g., {2, 3, 4, …,} (or a subset thereof, e.g. {2, 3}), the maximum value is FFS * Alt3. Only single value is supported, e.g., Q=4 only or Q=2 only   [Mod: Thanks, this is better, done]  **Proposal 2.E.2**:  Support. |
| Ericsson | **Issue 2.4, Proposal 2.D.3**  Ok with proposal and we can down-select at next meeting.  **Issue 2.4, Proposal 2.D.4**  Ok to study further.  **Issue 2.5, Proposal 2.E.2**  For delta, we support to include a few values > 0. So the current range listed in the proposal is a good starting point.  For W\_CSI, we think defining it in terms of DD compression unit d is good. |
| OPPO | **Issue 2.1**  We support to enhance Rel-16 eType II only.  **Proposal 2.D.3**  Support, our preference is Alt1, fine for further study.  **Proposal 2.D.4**  Prefer Q=2 only, we don’t observe more gain for Q>2  **Proposal 2.E.2**:  Support. On Wcsi, we are fine with Wcsi=dN4. We prefer small N4 value (e.g. N4 <= 4) since there are N4 times SVD operations compared with Rel-16. |
| vivo | **Proposal 2.D.3**  Our understanding is that this Alt 2 “A rotation factor is selected for each SD basis vector” has been excluded by the following agreement. Specifically, we have agreed the selected DD basis vector is common for all SD bases. Then how can we apply different rotation factors for different SD bases, which will lead to different DD basis vector for different SD bases?   |  | | --- | | **Agreement**  For the Rel-18 Type-II codebook refinement for high/medium velocities, support the following codebook structure where N4 is gNB-configured via higher-layer signaling:   * For N4=1, Doppler-domain basis is the identity (no Doppler-domain compression) reusing the legacy , , and , e.g. * For N4>1, Doppler-domain orthogonal DFT basis commonly selected for all SD/FD bases reusing the legacy and , e.g.   + Only Q (denoting the number of selected DD basis vectors) >1 is allowed   + TBD (by RAN1#110bis): whether rotation is used or not   + FFS: identical or different rotation factors for different SD components   + FFS: Whether *Q* is RRC-configured or reported by the UE   Note: Detailed designs for SD/FD bases including the associated UCI parameters follow the legacy specification  FFS: Whether one CSI reporting instance includes multiple and a single and report. |   [Mod: Added a note re your understanding. This can be discussed further in the next meeting]  **Proposal 2.D.4**  Support  **Proposal 2.E.2**  We don’t think to have a fixed *δ* as 0 works for N4=1. In this case, the CSI report does not contain any future CSI when gNB receiving such report. Hence to support N4=1, we need to have a non-zero delta value. Hence we suggest the following change.  **Proposal 2.E.2**: On the CSI reporting and measurement for the Rel-18 Type-II codebook refinement for high/medium velocities, when UE-side prediction is assumed, study the supported value(s) for *δ* and WCSI from (but not limited to) the following candidates, in conjunction with the supported values of N4 and DD units:   * *δ* (slots): {0, 1, 2, 3, 4, 6, 8} (smaller values) or a subset thereof, or a single fixed non-zero value (e.g. ~~0 or~~ 1)   + At least one *δ* value larger than 0 is supported * WCSI (slots): 1, N4, following periodicity of P/SP-CSI-RS or SP-CSI (e.g., 4, 5, 8, 10, 16, 20, 40), (*d*=DD unit size is slots, N4 is unit-less)   FFS: Dependence on sub-carrier spacing should also be studied  [Mod: At least one company proposes a single value which doesn’t include delta>0. Since we simply list different alternatives for further study, including your suggestion will prematurely preclude that proposal. I revised the wording to capture our preference as well, which should be enough for you] |
| CATT | **Issue 2.4, Proposal 2.D.3**  Support and Alt1 is preferred.  **Issue 2.4, Proposal 2.D.4**  We share the same view with LG, and the decision can be made based on SLS result.  **Issue 2.5, Proposal 2.E.2**  We prefer fixed value of delta, e.g. delta = the minimum processing time of gNB after receiving the CSI reporting. |
| Mod V27 | **Some minor revisions to capture inputs** |
| Samsung | Proposal 2.D.3,   * We agreed to a common DD basis, and we had an FFS also in the same agreement that the rotation factor can be identical or different across SD components. In proposal 2.D.3, Alt1 corresponds to identical rotation factor, and Alt2 corresponds to different rotation factors. With the agreement, what we excluded is the case when the DD basis vectors are not common, (i.e., they are different) across SD components. * Re WID objective #1, we are not sure why Alt2 is not aligned. This proposal is about DD basis vectors (not SD/FD basis vectors), the WID wording is about SD/FD basis, isn’t it?   [Mod: My understanding of vivo’s argument (in my own language ☺) is that adding rotation factor per Alt2 is a way to introduce different DD basis selections for different SD components which is not aligned with the agreement we made.  But if the proponents of Alt2 deny this assertion and maintain that the DD basis selection is common across all SD components, the rotation factor is effectively modifying the “legacy” SD basis which is not aligned with WID objective #1.  Basically vivo argues that either one of the above must be true, i.e. if one is denied, the other is automatically true/  Anyway I added the Note which should resolve vivo’s concern since it reflects the fact (which the proponents of Alt2 cannot disagree either.] |
| MediaTek | Support **2.D.4**  Support **2.E.2** |
| Spreadtrum | **Proposal 2.A**:  We still prefer Refinement of the Rel-16 eType-II only.  **Proposal 2.D.3**:  Support the proposal. Our preference is Alt1.  **Proposal 2.D.4**:  Support. We think the value of Q should be fixed or gNB configured rather than UE determined. Otherwise, a threshold will be needed for UE to select the DD basis.  **Proposal 2.E.2**:  Support. |
| Fraunhofer IIS/Fraunhofer HHI | We would like to clarify that “Doppler-domain orthogonal DFT basis commonly selected for all SD/FD bases” does not preclude that different rotation factors can be used for the SD components. In the first step, UE selects Q DD components commonly across all SD/FD from an orthogonal DFT basis. In the second step, the Q DD components of each beam are rotated with respect to a rotation factor selected by the UE. This can be seen as an addition to the first step. So, we disagree with Vivo’s observation.  By performing the above steps, the SD/FD components are not rotated either and we also believe SD/FD component rotation is out of the WID scope. Therefore, we also disagree with the FL.  [Mod: You need to read the FL “comment” more clearly. The FL simply paraphrases what vivo says since Samsung’s comment doesn’t seem to address vivo’s question (and I suspect neither is yours). Read again: the FL neither agrees nor disagrees with vivo. Therefore, your statement that “we also disagree with the FL” is misplaced (at best) in this case.  Regardless the Note I added should settle this issue for this meeting. You/Samsung/vivo can continue your arguments in the next meeting.] |
| Mod V35 | **No revision** |
| Huawei, HiSilicon | **Proposal 2.A**  Support the proposal. For concerns on work load, there’s no real difference between refinements for Rel-16 and Rel-17, we don’t see further efforts for Rel-17 really. For time/Doppler-domain reciprocity, there’s nothing preventing gNB to do it in implementation, but no optimization is needed as in proposal 2.A. On the change of delay property, assuming a UE with 60km/h and CSI-RS periodicity of 5ms, then the delay change of adjacent CSI-RS is less than 0.3ns, which can still be compensated by gNB. Even refinement on Rel-16 only considers Doppler domain compression, without feedback of change of delay. So, we don’t see the real concern on proposal 2.A.  **Proposal 2.D.3**  We are fine with the proposal.  **Proposal 2.D.4**  Fine with the proposal. Support at least Q={2,3}, we don’t support larger value for Q considering CSI overhead.  **Proposal 2.E.2**  Fine with the proposal. |
| Nokia/NSB | **Proposal 2.D.3**  @Fraunhofer. Following your explanation, with different rotation factors for different SD beams, the end result is that the DD bases are SD-beam specific and the DD bases of different SD beams are nonorthogonal. This does not seem consistent with the previous agreement and the codebook structure, because the DD bases are supposed to be SD-FD common and orthogonal, as we and vivo pointed out in our previous comments and captured in the note.  A similar understanding, in our view, applies to Mode 1 in CJT, where, a UE may report the same M FD bases for all TRPs and N FD basis offsets. The end result is that the FD bases are TRP-specific, not TRP-common  **Proposal 2.E.2**  Small correction: the ceiling operation in is not needed as both and should be integers |
| CMCC | **Proposal 2.D.3**:  Support the proposal. We prefer Alt1 if no clear gain is observed in Alt2.  **Proposal 2.D.4**:  Support.  **Proposal 2.E.2**:  Support. On WCSI, we think determining it as a function of N4 and DD unit size is a good starting point. |

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

{No issue to be discussed in this round}

Table 5A Summary: issue 3

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| **#** | **Issue** | **Companies’ views** |
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Table 6 Additional inputs: issue 3

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| **Company** | **Input** |
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# References

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| --- | --- | --- | --- |
| 1 | R1-2209715 | Summary of OFFLINE discussion on Rel-18 MIMO CSI | Moderator (Samsung) |
| 2 | R1-2208441 | CSI enhancement for coherent JT and mobility | Huawei, HiSilicon |
| 3 | R1-2208495 | Enhanced CSI for CJT and High Doppler Operations | InterDigital, Inc. |
| 4 | R1-2208504 | CSI enhancement for high/medium UE velocities and CJT | ZTE |
| 5 | R1-2208541 | Discussion on CSI enhancement for high/medium UE velocities and coherent JT | Spreadtrum Communications |
| 6 | R1-2208628 | Discussion on CSI enhancement for high-medium UE velocities and coherent JT | vivo |
| 7 | R1-2208742 | Discussion of CSI enhancement for high speed UE and coherent JT | Lenovo |
| 8 | R1-2208794 | CSI enhancement for high/medium UE velocities and coherent JT | OPPO |
| 9 | R1-2208872 | On CSI Enhancement | Google |
| 10 | R1-2208893 | Potential CSI enhancement for high/medium UE velocities and coherent JT | LG Electronics |
| 11 | R1-2208947 | Discussion on CSI enhancements | CATT |
| 12 | R1-2209041 | On CSI enhancements | Intel Corporation |
| 13 | R1-2209090 | Further considerations on CSI enhancement for high/medium UE velocities and CJT | Sony |
| 14 | R1-2209140 | Discussion on CSI enhancement | NEC |
| 15 | R1-2209247 | Discussion on CSI enhancement | Mavenir |
| 16 | R1-2209258 | Discussion on CSI enhancement for high/medium UE velocities and CJT | xiaomi |
| 17 | R1-2209322 | Discussion on CSI enhancement for high/medium UE velocities and CJT | CMCC |
| 18 | R1-2209381 | CSI enhancement | Sharp |
| 19 | R1-2209494 | CSI enhancement | MediaTek Inc. |
| 20 | R1-2209545 | CSI enhancements for medium UE velocities and coherent JT | Fraunhofer IIS, Fraunhofer HHI |
| 21 | R1-2209570 | Views on Rel-18 MIMO CSI enhancement | Apple |
| 22 | R1-22010241 | Views on CSI enhancements | Samsung |
| 23 | R1-2209793 | Views on CSI Enhancements for CJT | AT&T |
| 24 | R1-2209852 | On CSI enhancements for Rel-18 NR MIMO evolution | Ericsson |
| 25 | R1-2209890 | Discussion on CSI enhancement | NTT DOCOMO, INC. |
| 26 | R1-2209969 | CSI enhancements for high/medium UE velocities and Coherent-JT | Qualcomm Incorporated |
| 27 | R1-2210063 | CSI enhancement for high/medium UE velocities and CJT | Nokia, Nokia Shanghai Bell |
| 28 | R1-2210105 | Discussion on CSI Enhancements for high/medium UE velocities and coherent JT | CEWiT |
|  |  |  |  |