**3GPP TSG RAN WG1 #110 R1-2207978**

**Toulouse, France, August 22nd – 26th, 2022**

**Agenda item:** 9.1.2

**Source:** Moderator (Samsung)

**Title:** Moderator Summary#3 on Rel-18 CSI enhancements: Round 2

**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

Proposals planned for presentation and potential endorsement on 1st online session for AI 9.1.2:

* Issue 1:

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| **Proposal 1.F**: For the Rel-18 Type-II codebook for CJT mTRP based on the Rel-16 Type-II codebook, SD basis and FD basis are separate, each fully reusing the legacy Rel-16 DFT-based design   * **Support/fine:** Apple, AT&T, DOCOMO, ZTE, NEC, CATT, Samsung, IDC, Spreadtrum, vivo, Lenovo, OPPO, Xiaomi, CMCC, MediaTek, Ericsson, Nokia/NSB, Intel, Google, Qualcomm, LG, Fraunhofer IIS/HHI, Sharp, Sony, CEWiT, * **Not support:** Huawei/HiSi (Alt4) |
| **Agreement**: On the Type-II codebook refinement for CJT mTRP, regarding W2 quantization group and Strongest Coefficient Indicator (SCI) design, for each layer, down-select one from the following alternatives by RAN1#110bis-e:   * ... * Alt4. For a selected TRP/TRP-group, one group comprises one polarization, and for remaining N-1 TRPs/TRP-groups, one group comprises one polarization across remaining N-1 TRPs/TRP-groups (*C*group,amp=2+2=4), with a common phase reference across all of N TRPs/TRP-groups (*C*group,phase=1)   + FFS: The selected TRP/TRP-group |
| **Proposal 1.C**: The Rel-18 Type-II codebook for CJT mTRP 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 * **Support/fine:** Huawei/HiSi, Sharp, Xiaomi, AT&T (1st pref Rel-16), ZTE, Samsung (1st pref Rel-16), Qualcomm, MediaTek (1st pref Rel-16), OPPO, Apple, CMCC, Ericsson (1st pref Rel-16), Intel (no optimization for Rel-17), Fraunhofer IIS/HHI (1st pref Rel-16) * **Not support (Rel-16 only):** CEWiT, Spreadtrum, DOCOMO, NEC, Lenovo, vivo |

* Issue 2:

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| **Proposal 2.F**: On the CSI reporting and measurement for the Rel-18 Type-II codebook refinement for high/medium velocities, when UE-side prediction is assumed, down-select one from the following alternatives by RAN1#110bis-e:   * Alt1.B:  *l* ≥ *n*ref   + *n*ref (a CSI reference resource slot) as boundary * Alt2.B: *l* ≥ *n*   + *n* (report slot) as boundary * **Support/fine:** Sharp, MediaTek, ZTE, vivo, OPPO, NEC, CMCC, CATT, Huawei, HiSi, Ericsson, Intel, Google, Nokia/NSB (2nd pref), Qualcomm, LG, IDC, Lenovo, Samsung, Sharp, Apple, Fraunhofer IIS/HHI * **Not support:** |
| **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 * **Support/fine:** Huawei/HiSi, Xiaomi, AT&T (1st pref Rel-16), ZTE, Qualcomm, Sony, Spreadtrum, Samsung (1st pref Rel-16), LG, CATT, CMCC, OPPO (prefer AP CSI-RS agreed), Sharp, Apple, Fraunhofer IIS/HHI (no DD reciprocity), Lenovo, Intel (no DD reciprocity), * **Not support (Rel-16 only):** CEWiT, DOCOMO, NEC, vivo, MediaTek |
| **Proposal 2.G**: On the CSI reporting and measurement for the Rel-18 Type-II codebook refinement for high/medium velocities, support the following CSI-RS resource types/structures for CMR:   * Time-domain behaviour for NZP CSI-RS resource: periodic, semi-persistent, [aperiodic]   + [FFS: aperiodic] * The use of K≥1 NZP CSI-RS resources:   + FFS: details * **Support:** Google, Samsung, Nokia/NSB, Lenovo, DOCOMO, MediaTek, Qualcomm, LG, Spreadtrum, ZTE, Xiaomi, NEC, OPPO, CATT, CMCC, Sharp, Apple, Huawei/HiSi, Fraunhofer IIS/HHI * **Not support:** vivo (concern on AP) |

* Issue 3:

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| **Proposal 3.B**: For the Rel-18 TRS-based TDCP reporting, down select one of the following alternatives by RAN1#110bis-e:   * AltA. Based on Doppler profile   + E.g., Doppler spread derived from the 2nd moment of Doppler power spectrum, average Doppler shifts, Doppler shift per resource, maximum Doppler shift, relative Doppler shift, etc * AltB. Based on time-domain correlation profile   + E.g. Correlation within one TRS resource, correlation across multiple TRS resources   + Note: The correlation over one or more lags of TRS resource may be considered. The lags may be within one TRS burst or different TRS bursts * AltC: CSI-RS resource and/or CSI reporting setting configuration parameter(s) to assist network   + E.g. gNB configures UE with multiple choices on what to assist (e.g. two or more CSI-RS/report periodicities, or precoding schemes depending mainly on UE velocity), then UE report according to configuration; parameters correspond to CSI reporting periodicity, codebook type, etc.   Note: Different alternatives may or may not apply to different use cases   * **Support/fine:** IDC, Samsung, Spreadtrum, Mavenir, Google, OPPO, CATT, Xiaomi, LG, CEWiT, Apple, Sharp, DOCOMO, ZTE, Huawei/HiSi, vivo, CEWiT, Nokia/NSB, vivo, OPPO, CEWiT, Ericsson, MediaTek, Qualcomm, Fraunhofer IIS/HHI, NEC * **Not support:** |
| **Proposal 3.A**:  For the Rel-18 TRS-based TDCP reporting, the use case of “aiding gNB-side CSI prediction” is refined to “aiding gNB implementation in CSI prediction for TDD”   * **Support/fine**: CATT, DOCOMO, Lenovo, Samsung, Huawei/HiSi, vivo * **No support**: Ericsson, |

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

Table 1A Summary: issue 1

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| **#** | **Issue** | **Companies’ views** |
| 1.3 | [109-e] **Agreement**  The work scope of Type-II codebook refinement for CJT mTRP includes refinement of the following codebooks:   * Rel-16 eType-II regular codebook * Rel-17 FeType-II port selection (PS) codebook   FFS: Whether to prioritize/down-select from the two  **Proposal 1.C**: The Rel-18 Type-II codebook for CJT mTRP 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 | **Support (equal priority for) both Rel-16 eType-II and Rel-17 FeType-II:** Huawei/HiSi, Sharp  **Down-select to only (prioritize) Rel-16 eType-II:** Apple, AT&T, Google, DOCOMO, MediaTek, NEC, CATT, Samsung, IDC, Spreadtrum, vivo, Lenovo, Intel, Xiaomi, Fraunhofer IIS/HHI, Qualcomm, Ericsson, Sony, LG, ZTE (involving R16 port-selection CSI), Sony (at least Rel-16), CEWiT  **Down-select to only (prioritize)Rel-17 FeType-II:**  **Proposal 1.C:**   * **Support/fine:** Huawei/HiSi, Sharp, Xiaomi, AT&T (1st pref Rel-16), ZTE, Samsung (1st pref Rel-16), Qualcomm, MediaTek (1st pref Rel-16), OPPO, Apple, CMCC, Ericsson (1st pref Rel-16), Intel (no optimization for Rel-17), Fraunhofer IIS/HHI (1st pref Rel-16) * **Not support (Rel-16 only):** CEWiT, Spreadtrum, DOCOMO, NEC, Lenovo, vivo |
| 1.6 | [109-e] **Agreement**  On the spatial-domain (SD) and frequency-domain (FD) basis design for the Rel-16 Type-II codebook refinement for CJT mTRP, down-select from the following alternatives:   * Alt1 (separate, legacy DFT): SD basis and FD basis are separate, each fully reusing the legacy Rel-16 DFT-based design * Alt2 (joint, DFT): joint SD-FD DFT-based basis   + FFS: Details on DFT parameters, e.g. length, oversampling (if any), rotation (if any) * Alt3 (joint, eigenvector): joint SD-FD eigenvector-based basis   + FFS: eigenvector codebook design, parametrization * Alt4 (separate, eigenvector): SD basis and FD basis are separate, using eigenvector-based basis   + FFS: eigenvector codebook design, parameterization   **Proposal 1.F**: For the Rel-18 Type-II codebook for CJT mTRP based on the Rel-16 Type-II codebook, SD basis and FD basis are separate, each fully reusing the legacy Rel-16 DFT-based design  **FL note**: This proposal was already discussed at length in round 0 | **Proposal 1.F:**   * **Support/fine:** Apple, AT&T, DOCOMO, ZTE, NEC, CATT, Samsung, IDC, Spreadtrum, vivo, Lenovo, OPPO, Xiaomi, CMCC, MediaTek, Ericsson, Nokia/NSB, Intel, Google, Qualcomm, LG, Fraunhofer IIS/HHI, Sharp, Sony, CEWiT, * **Not support:** Huawei/HiSi (Alt4) |
| 1.9 | **Agreement**: On the Type-II codebook refinement for CJT mTRP, regarding W2 quantization group and Strongest Coefficient Indicator (SCI) design, for each layer, down-select one from the following alternatives by RAN1#110bis-e:   * ... * Alt4. For a selected TRP/TRP-group, one group comprises one polarization, and for remaining N-1 TRPs/TRP-groups, one group comprises one polarization across remaining N-1 TRPs/TRP-groups (*C*group,amp=2+2=4), with a common phase reference across all of N TRPs/TRP-groups (*C*group,phase=1)   FFS: The selected TRP/TRP-group  **FL Note:** Companies to check and give inputs on wording | |
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Table 2 Additional inputs: issue 1

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| **Company** | **Input** |
| Huawei, HiSilicon | For proposals 1.E and 1.F, we think the decision should be made based on comparison of feedback overhead and performance. To align the understanding of companies and to have a fair comparison between alternatives, it will be much appreciated if the information of following aspects can be provided, so that we can based on the same understanding to compare the feedback and performance gain. Our understanding of the alternatives is provided as below.   |  |  |  |  |  | | --- | --- | --- | --- | --- | | Per TRP or TRP common basis for W1 and Wf | PMI obtained by SVD over separate TRP channel or over concatenated channel | W2 coefficients separately selected per-TRP or jointly selected across TRPs | Feedback overhead | Performance | | Alt 1A/1B: per-TRP basis for W1, Wf, or Ws-f  Alt 2: per-TRP basis for W1, and TRP common Wf | Alt 1A/1B/2: SVD over concatenated channel | Alt 1A/1B/2: can be jointly selected across TRPs | Alt 1A: per-TRP W1, W2, Wf feedback;  Alt 1B: per-TRP W1, Ws-f feedback; long-term eigenvector basis feedback;  Alt 2: per-TRP W1, W2, and TRP-common Wf feedback.  The same feedback overhead for W1, W2 between alternatives. | Eigenvector basis > DFT basis;  Alt 1B>Alt 1A>W2. | |
| Samsung | Re HW’s questions, in our view, the two modes are different (especially the FD bases part). So, the UE implementation for PMI calculation can also be different. In particular, in mode 1, the FD basis can be selected based on per TRP channel, whereas in mode 2, it can be selected based on aggregated (across TRPs) channel.   |  |  |  |  |  | | --- | --- | --- | --- | --- | | Per TRP or TRP common basis for W1 and Wf | PMI obtained by SVD over separate TRP channel or over concatenated channel | W2 coefficients separately selected per-TRP or jointly selected across TRPs | Feedback overhead | Performance | | Same as HW | Alt 1A/1B: SVD over per TRP channel  Alt2: SVD over concatenated channel | W2 design can be the same or different for all alts | The same feedback overhead for W1. If W2 design is the same for mode 1 and mode2, then the feedback overhead for W2 will also be the same. | (Assuming DFT based Alt2B)  Alt2 >Alt1A~Alt2B  The perf. Of Alt2B can be improved (E.g. per element quantization of eigenvector), but @ cost of increased overhead | |
| Nokia/NSB | Regarding Huawei’s comments on P1.E/1.F: eigenvector-based - assumes UE-specific basis vectors, which requires a redesign of and codebooks, for which companies may have very different proposals. We observe significant performance gains of CJT with the legacy DFT codebooks, so we don’t see the need for this laboursome redesign. Regarding feedback overhead, the difference between Mode 1 and Mode 2 depends on the design of W2 and how Wf is reported in Mode 1. But, in general, we think Mode 2 needs less overhead than Mode 1. Regarding performance, we have same assessment as Samsung in that Alt 2 shows better performance than Alt 1. |
| Vivo | **On Proposal 1.E and 1.F**  We think from standard perspective, the difference between Mode 1 and Mode 2 is a same set of FD basis is selected for multiple TRPs in Mode2, while Mode 1 can allow same or different sets of FD basis for multiple TRPs. Considering this, we don’t agree with the statement that a common size of W2 is always used for both Mode 1 and Mode 2. To maintain a same number of NZ coefficients, the size of W2 can be different for the two modes considering different location distribution of the coordinated TRPs, i.e., the delay range and relative delay difference of different TRPs. Also, different total numbers of FD basis may be observed for the two TRPs. Therefore these two are actually different modes. However, we should strive to have a common design on the mechanism for the UCI reporting details.  Regarding Alt 1B and joint FD/SD basis, we feel like the difference between Alt 1B and Alt 1A includes only UCI design details, which Alt 1B just uses a joint coding for FD basis and SD basis. We don’t see the need of discussing such micro-optimization of UCI signaling at this stage. |
| Intel (2) | We share similar understanding with Samsung on the different modes (proposal 1E). In our understanding different UE implementation may be assumed for different alternatives. Also, W2 design might be different for different alternatives. So, we support this proposals, other details can be considered further. |
| MediaTek | Re Proposal 1.F   1. Per WID, Rel-16/17 codebook would be enhanced for CJT. Although it is up to interpretation, we believe that redesigning SD and FD bases would be much more than enhancement/refinement of these codebooks. 2. Although we agree with HW that long term feedback of eigen bases may reduce overhead, such form of long term feedback is not specified for current Rel-16/17 codebooks. For the ongoing work item on CSI enhancement for high velocities, it is mandated that SD and FD bases would not be modified, even if long term feedback is eventually agreed.   Considering these aspects, the case for joint SD-FD bases (DFT/eigen) and joint or separate eigen bases stands weak. |
| Mod (round 0) | **Thanks for the comments from companies that respond to Huawei’s inquiries re proposals 1.E and 1.F. Overall the concern on joint eigenvector basis for Rel-16-based (hence Alt1B codebook) includes unclear throughput-overhead trade-off benefit (optimization), spec impact, the amount of works involved (vs. scope/TU, time/efforts).**   * **Other companies are encouraged to comment as well**   **Minor revision on proposals 1.B (including the bullet from 1.A) and 1.E (different 🡪 independent)** |
| Huawei, HiSilicon | Not support Proposal 1.F. Since SD-FD joint codebook structure is not agreed, we support Alt4 (separate eigenvector basis). Evaluation results show that Alt4 still has up to 8% performance gain over Alt1.  C:\Users\w00383792\AppData\Roaming\eSpace_Desktop\UserData\w00383792\imagefiles\ADDD351A-7A81-4F91-AAAB-FBF5A3A2B35C.png C:\Users\w00383792\AppData\Roaming\eSpace_Desktop\UserData\w00383792\imagefiles\CC3C5641-4FBF-4C55-BF5D-9E59905CF9F8.png |
| ZTE | **Proposal 1.C:** We can be flexible for progress. One question for double check: If proposal 1.C is approved, does it means that Rel-17 Fe-TypeII PS codebook and Rel-16 eTypeII codebook are treated equally?  [Mod: In some way. The proposal suggests that the work will be done around Rel-16 Type-II and then directly applied to Rel-17 Type-II except for parameter combination. Meaning that the proposal doesn’t increase workload (at least significantly) compared to that for only Rel-16 Type-II] |
| Mod V0 | 1. **Check and, if needed, update your view in Table 1A, especially on the moderator proposals**    1. **Please check the wording of Alt4** 2. **Share additional inputs here, if needed** 3. **Technical discussion re proposal 1.F from ROUND 0 and 1 is copied above.** |
| Samsung | Proposal 1.C   * Although we prefer to prioritize the Rel-16 based refinement, this compromise is acceptable since the additional workload seems small (even parameter combination can perhaps be more unified between the two). * To address some concern that sharing a same design for both may not be possible, perhaps we can make the second bullet on Rel-17 a working assumption.   Issue 1.9 on Alt4: FFS bullet can be deleted.   * Alt4. For 1 TRP/TRP-group, one group comprises one polarization, and for remaining N-1 TRPs, one group comprises one polarization across remaining N-1 TRPs/TRP-groups (*C*group,amp=2+2=4), with a common phase reference across TRPs/TRP-groups (*C*group,phase=1)   + ~~FFS: Quantization of N strongest coefficients~~ |
| Spreadtrum | **Proposal 1.C**  Our first preference is to focus on Rel-16 eType-II regular codebook. But if there’s majority support, we can leave with this proposal. Making Rel-17 FeType-II port selection (PS) codebook as WA is also fine for us. |
| Qualcomm | OK with Proposal 1.C and 1.F  For Issue 1.9 agreement Alt4, my feeling is, it is a special case of TRP grouping as: { {1} {2,…,N} } (thus total 2\*2=4 amp groups taking into account pol);  A more general case may be, the grouping can be configurable (e.g. nearby TRPs are configured by network as in a same group) – then I realize this is already included in the agreed Alt3  Can we say Alt4 is also a special case of Alt3 with N=2? If so, we’d suggest to move it under Alt3 as a sub-bullet |
| LG | Similar view with Samsung and Spreadtrum for Proposal 1.C |
| DOCOMO | For Issue 1.9, a question on ‘Alt4. For 1 TRP/TRP-group, …’. We think it means the strongest TRP/TRP-group? Or any TRP/TRP-group? |
| CATT | Fine wth FL’s proposals. |
| Samsung | @QCM:   * we don’t think Alt4 is a special case of Alt3. In Alt3, number of groups scales with N (which can be 4 🡪 8 groups). Whereas in Alt4, number of groups is fixed to 4 (2 for one TRP, and 2 for remaining N-1 TRPs) * Re configurable number of grouping, this is not the intension with Alt4. It is a new alternative.   @DCM: our intension was that “1 TRP/TRP group” corresponds to legacy (Rel16) grouping, but we can OK to consider other possibilities. So, the details of the “1 TRP/TRP group” can be FFS.  [Mod: Revised text alomg this line for better clarity] |
| Lenovo | **Proposal 1C:**  Concern on supporting both eType-II and FeType-II as baselines, especially that they both differ in spatial and frequency domain transformations (at least in terms of signaling)  **Proposal 1.F:** Support |
| Mod V12 | **Revision on 1.9 wording** |
| vivo | **Proposal 1.C**  We don’t support. We support enhancement on eType II only.  **Propsoal 1.F**  We support it.   1. **9 Alt 4**   So this Alt means to have   * one reference amplitude per pol for one of the N TRPs * one reference amplitude per pol for the rest N-1 TRPs * common phase for all the N TRPs   Based on this understanding, we suggest the following revision on the phase part.   * Alt4. For a selected TRP/TRP-group, one group comprises one polarization, and for remaining N-1 TRPs, one group comprises one polarization across remaining N-1 TRPs/TRP-groups (*C*group,amp=2+2=4), with a common phase reference across N TRPs/TRP-groups (*C*group,phase=1)   FFS: The selected TRP/TRP-group  [Mod: Make sense, done] |
| AT&T | **Proposal 1.C:** We support Proposal 1.C, however our preference is Rel-16 eType-II  **Proposal 1.F:** We support Proposal 1.F, however our preference is Alt1  **Regarding 1.9**, we suggest the following wording for the 4 alternatives:   * One group comprises one polarization for subset of one or more TRPs/TRP-groups (*C*group,phase=Nphase, *C*group,amp= Namp), SCI is per subset of TRP/TRP-group   + Namp∈{2,4,...,2N}) & Nphase∈{1,2,..,N}   + FFS: Quantization of Namp strongest coefficients with Namp >2   + FFS: The need for “strongest” TRP/TRP-group indicator in addition to SCI(s)   [Mod: Thanks for the rewording. I understand the attempt is to combine the 4 alternatives into a more general formulation. But this is not my intention. Indeed, the purpose of my formulation is the down selection of the 4 speficic alternatives. The above rewording would result in even more alternatives (cf. Samsung input in Round 1 that I rejected.  Given the time left for discussion (today is our last ONLINE and we have no official offline, my suggestion is to stick with the current version)] |
| ZTE2 | **Proposal 1.C:** We support Proposal 1.C, although our first preference is Rel-16 eType-II regular codebook. It sounds good if we may have some common design between Rel-16 and Rel-17 codebook enhancement.  **Proposal 1.F:** Support.  **Regarding 1.9:** It seems that the description for this yellow part are inconsistent. Some editorial suggestions:   * Alt4. For a selected TRP/TRP-group, one group comprises one polarization, and for remaining N-1 TRPs/TRP-groups, one group comprises one polarization across remaining N-1 TRPs/TRP-groups (*C*group,amp=2+2=4), with a common phase reference across all of N TRPs/TRP-groups (*C*group,phase=1)   FFS: The selected TRP/TRP-group[Mod: OK]  Then, regarding the last FFS as in sub-bullet, it seems to be redundant for the last FFS as already agreed. The selected TRP/TRP-group is based on the ‘“strongest” TRP/TRP-group indicator’, right?  [Mod: not necessarily according to the previous comments (please check above where Samsung doesn’t say anyting about strongest TRP)]  FFS: The need for “strongest” TRP/TRP-group indicator in addition to SCI(s) |
| Mod V16 | **Minor revision for clarity for issue 1.9 (vivo and ZTE comment)** |
| MediaTek | **Proposal 1.C:** Support, our preference is to down-select to only (prioritize) Rel-16 eType-II  **Proposal 1.F:** Support, our preference is with Alt1  **Proposal 1.9:** Support |
| Xiaomi | We are fine with FL’s proposals.  For Issue 1.9, we share similar view with Quanlcomm. The grouping based on TRPs group configured by gNB is a more general case. |
| OPPO | We are fine with the proposals. |
| Sharp | Proposal 1.C: We can accept to down-select to Rel-16 eType-II for progress  Proposal 1.F: Support |
| Apple | We are fine with Proposal 1.C and 1.F  For adding Alt 4, we are also fine since we anyhow down-select to only one. |
| CMCC | **Proposal 1.C:** We are fine with the proposal. We could first discuss the codebook design based on R16 codebook and then directly apply it to R17 codebook.  **Proposal 1.F**: Support.  **Issue 1.9**: We are ok to put Alt4 as a candidate to down-selct. It seems like a combination of Alt1 and Alt3 in the number of *C*group,amp. |
| Huawei, HiSilicon | We support proposal 1.C.  For issue 1.9, fine to have this alternative for down-selection. |
| Ericsson | Regarding Proposal 1.C, our first preference is to only refine Rel-16 Type II CB. But we can accept refining Rel-17 Type II CB if the workload is deemed feasible.  We support FL’s current Proposal 1.F. We agree with other company comments that we should refine the Rel-16 Type-II CB based on separate SD bases and FD bases. Concepts such as eigenvector based bases are much more than refinement and requires a redesign which is not preferable for us in this release. |
| Intel | We can accept the current proposal 1.F if it is assumed that no optimization will be made for Rel-17 Type II PMI codebook design reusing as much as possible.  Proposal 1F: support  Issue 1.9: OK |
| Mod V31 | **No revision.**  **Re 1.9: companies are so far fine with the latest version. One company prefers more general formulation but that would water down the details we need to agree in the next meeting.** |
| Fraunhofer IIS/Fraunhofer HHI | **Proposal 1.C**: Support in principle, but we prefer discussing Rel. 17 FeType-II PS enhancements after the design of the Rel. 16 eType-II regular codebook based CJT enhancements is clear.  [Mod: This is one way, but parallel is also possible to minimize additional work, i.e. proponents to do quick check and apply agreements to both Rel-16 and Rel-17 based designs]  **Proposal 1.F: Support** |
| Mod V34 | **No revision** |
| NEC | **Proposal 1.C:** Our first preference is refinement only based on Rel-16 TypeII CB. While if majority companies support Rel-17 FeTypeII CB as well, we are fine for the proposal. Regarding the workload, maybe we can say something like  **Updated Proposal 1.C**: The Rel-18 Type-II codebook for CJT mTRP 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, if ~~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 can be applied   [Mod: This rewording doesn’t guarantee no significant increase in workload, which will cause many companies to be concerned ☹]  **Proposal 1.F and 1.9:** Support. |
| AT&T | **Proposal 1.C:** Support, however our preference is Rel-16 eType-II  **Proposal 1.F:** Support, however our preference is Alt1  **Proposal 1.9:** Support |
| Mod V40 | **No revision** |

### 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 | **Support (equal priority for) both Rel-16 eType-II and Rel-17 FeType-II:** Huawei/HiSi  **Down-select to only (prioritize) Rel-16 eType-II:** Apple, DOCOMO, MediaTek, NEC, Xiaomi, Samsung (1st pref Rel-16), Lenovo, Intel (1st pref Rel-16), Xiaomi. Qualcomm, Apple, DOCOMO, Ericsson, ZTE, Nokia/NSB, LG, Spreadtrum, CMCC  **Down-select to only (prioritize) Rel-17 FeType-II:** Huawei/HiSi  **Proposal 2.A:**   * **Support/fine:** Huawei/HiSi, Xiaomi, AT&T (1st pref Rel-16), ZTE, Qualcomm, Sony, Spreadtrum, Samsung (1st pref Rel-16), LG, CATT, CMCC, OPPO (prefer AP CSI-RS agreed), Sharp, Apple, Fraunhofer IIS/HHI (no DD reciprocity), Lenovo, Intel (no DD reciprocity), * **Not support (Rel-16 only):** CEWiT, DOCOMO, NEC, vivo, MediaTek |
| 2.6 | [109-e] **Agreement**  On the CSI reporting and measurement for the Type-II codebook refinement for high/medium velocities, *at least for discussion purposes*, define the following:   * Assume a CSI report in slot *n*, and let the length of the DD/TD basis vector be *N*4   + Note that basis vector has no span/window in time-domain, only length * CSI-RS measurement window of [*k*,*k*+*W*meas –1], representing the window in which CSI-RS occasion(s) are measured for calculating a CSI report   + *k* is a slot index and *W*meas is the measurement window length (in slots)   + Note: In the legacy Rel-16/17 CSI, the CSI-RS occasion(s) are configured in *CSI-ReportConfig* * CSI reporting window of [*l*,*l*+*W*CSI –1], associated to the CSI report in slot *n*   + *l* is a slot index and *W*CSI is the reporting window length (in slots) * CSI reference resource(s) in time-domain   + The location of a CSI reference resource is denoted as *n*ref (slot index)   [109-e] **Agreement**  On the CSI reporting and measurement for the Type-II codebook refinement for high/medium velocities, consider *at least* the following alternatives for potential down-selection:   * Alt1: *n*ref (CSI reference resource slot) as boundary   + Alt1.A:  *l* + *W*CSI –1 ≤ *n*ref   + Alt1.B:  *l* ≥ *n*ref   + Alt1.C: *l* < *n*ref and *l* + *W*CSI –1 > *n*ref * Alt2: *n* (report slot) as boundary   + Alt2.A: *l* + *W*CSI –1 ≤ *n*   + Alt2.B: *l* ≥ *n*   + Alt2.C: *l* < *n* and *l* + *W*CSI –1 > *n* * Alt3: End slot of *W*meas (*k* + *W*meas –1) as boundary   + Alt3.A: *l* + *W*CSI –1 ≤ *k* + *W*meas –1 with the following as a special case: *l=k,* *W*CSI = *W*meas   + Alt3.B: *l* ≥ *k* + *W*meas –1   + Alt3.C: *l* < *k* + *W*meas –1 and *l* + *W*CSI –1 > *k* + *W*meas –1 with the following as special cases:     - *l=k,* *l* + *W*CSI = *n*     - *l=k,* *l* + *W*CSI > *n*   FFS: whether *n*ref represents the slot index of Rel-15 CSI reference resource or a newly defined CSI reference resource  FFS: whether/how the CSI measurement window and reporting window are configured  **Proposal 2.F**: On the CSI reporting and measurement for the Rel-18 Type-II codebook refinement for high/medium velocities, when UE-side prediction is assumed, down-select one from the following alternatives by RAN1#110bis-e:   * ~~Alt1.A:~~ *~~l~~* ~~+~~ *~~W~~*~~CSI~~ ~~–1 ≤~~ *~~n~~*~~ref~~   + *~~n~~*~~ref~~ ~~(CSI reference resource slot) as boundary~~ * Alt1.B:  *l* ≥ *n*ref   + *n*ref (a CSI reference resource slot) as boundary * Alt2.B: *l* ≥ *n*   + *n* (report slot) as boundary * ~~Alt3.B:~~ *~~l~~* ~~≥~~ *~~k~~* ~~+~~ *~~W~~*~~meas~~ ~~–1~~    + ~~End slot of~~ *~~W~~*~~meas~~ ~~(~~*~~k~~* ~~+~~ *~~W~~*~~meas~~ ~~–1) as boundary, assuming CSI-RS measurement window of [~~*~~k~~*~~,~~*~~k~~*~~+~~*~~W~~*~~meas~~ ~~–1]~~   **FL Note**: Since this proposal is for UE-side prediction, Alt1.A should be excluded. | **Alt1.A:** Spreadtrum, Xiaomi, LG, Fraunhofer IIS/HHI, Qualcomm, DOCOMO  **Alt1.B:** IDC, ZTE, LG, CMCC, DOCOMO  **Alt2.B:** Huawei/HiSi, Spreadtrum, vivo, Google, OPPO, CATT, Intel, CMCC, MediaTek, Ericsson, Nokia/NSB, DOCOMO (optional)  **Alt3.B:** CMCC, Fraunhofer IIS/HHI, Nokia/NSB, Samsung, NEC, [Apple]  **FL Note**: This topic and proposal have been discussed OFFLINE [1].   * Alt1.A: Qualcomm, DOCOMO, LG, Intel, Xiaomi * Alt1.B: Qualcomm, ZTE, LG, OPPO, CMCC, Intel, IDC * Alt1.C: Qualcomm, ZTE, LG, NEC * Alt2.A: * Alt2.B: MediaTek, vivo, OPPO (1st pref), NEC, CMCC, CATT, Huawei, HiSi, Ericsson, Intel, Google, Nokia/NSB (2nd pref) * Alt2.C: * Alt3.A: Samsung, DOCOMO, MediaTek (no need to define Wmeas), Apple (gNB-side prediction ), Fraunhofer IIS/HHI (gNB-side prediction ), Google, * Alt3.B: Samsung, OPPO, NEC, CMCC, Nokia/NSB (1st pref) * Alt3.C: Samsung, NEC   Some discussion points:   * Concern on x.C (UE complexity): MediaTek, Spreadtrum, Xiaomi, vivo * Concern on gNB-side prediction (e.g. Alt3.A): vivo, Ericsson, ZTE, Nokia/NSB * UE-side (only) prediction (x.B) is supported by a number of companies, at least as an optional feature   Based on the offline discussion, I have narrowed down the alternatives by removing the ones with concern and lack of support. *Please fit your preferences on the four remaining alternatives. Else it would be hard for us to focus our discussion.*  **Proposal 2.F:**   * **Support/fine:** Sharp, MediaTek, ZTE, vivo, OPPO, NEC, CMCC, CATT, Huawei, HiSi, Ericsson, Intel, Google, Nokia/NSB (2nd pref), Qualcomm, LG, IDC, Lenovo, Samsung, Sharp, Apple, Fraunhofer IIS/HHI * **Not support:** |
| 2.7 | CSI-RS resource types/structures **supported** for measurement (discussion on whether/how the legacy Resource setting needs enhancement will take place in later rounds)  [109-e] **Agreement**  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: periodicity and offset * Semi-persistent (SP) CSI-RS: activation/deactivation, periodicity, and offset * Aperiodic (AP) CSI-RS: triggering, offset of a group of AP CSI-RS resources   FFS: Support for K>1 NZP CSI-RS resources association with Type-II codebook refinement for high/medium velocities  FFS: Whether specification support for jointly utilizing two types of CSI-RS time-domain behaviors is needed  **Proposal 2.G**: On the CSI reporting and measurement for the Rel-18 Type-II codebook refinement for high/medium velocities, support the following CSI-RS resource types/structures for CMR:   * Time-domain behaviour for NZP CSI-RS resource: periodic, semi-persistent, [aperiodic]   + [FFS: aperiodic] * The use of K≥1 NZP CSI-RS resources:   + FFS: details | **Proposal 2.G:**   * **Support:** Google, Samsung, Nokia/NSB, Lenovo, DOCOMO, MediaTek, Qualcomm, LG, Spreadtrum, ZTE, Xiaomi, NEC, OPPO, CATT, CMCC, Sharp, Apple, Huawei/HiSi, Fraunhofer IIS/HHI * **Not support:** vivo (concern on AP) |
|  |  |  |

Table 4 Additional inputs: issue 2

|  |  |
| --- | --- |
| **Company** | **Input** |
| Vivo (from ROUND 0) | **Proposal 2.G**  We have concern on supporting aperiodic CSI-RS for this high/medium CSI enhancement. Based on our study, to have a satisfied prediction performance, it is needed to use sufficient number of CSI-RS occasion (e.g., 16 for 2-ms CSI-RS periodicity) to perform measurement. 16 CSI-RS occasions mean at least 32 ms to measure CSI-RS. In 30kHz SCS, it is 64 slots. Such huge delay makes to trigger aperiodic CSI-RS nearly impossible as it introduces large CSI latency. It does not make sense that gNB triggers CSI-RS and wait more than 64 slots to get the CSI. Further, if the CSI-RS periodicity is larger, saying 4-ms, more CSI-RS occasions will be needed to ensure the performance, e.g., 32 occasions in our evaluation. Such latency will increase to 256 slots, which is not practical at all for aperiodic CSI-RS.  Further, the need to have multiple CSI-RS resources for measurement is not justified. In our understanding, at least periodic or semi-persistent CSI-RS does not require multiple resources to measure. UE can just uses the multiple periodic CSI-RS occasions. |
| Samsung | @**vivo: re Proposal 2.G** in our view, Ap-CSI-RS should be supported, since some scenarios P or SP CSI-RS resources can’t be used, e.g., due to limitations such as a min periodicity of 4 slots. If the NW wants to configure measurement faster than 4 slots (i.e. periodicity < 4 slots), then the current P/SP CSI-RS resource can’t be used. We need some enhancements in measurement to support this important use case. |
| Huawei, HiSilicon | **Support proposal 2.A**, Rel-17 Type II codebooks can reuse the Rel-16 Type II codebooks enhancement for mobility including codebook structure, oppler basis waveform, CSI measurement and reporting configuration etc, which needs little spec effort to support. Moreover, Rel-17 Type II has better performance than Rel-16 Type II. |
| Mod V0 | 1. **Check and, if needed, update your view in Table 3A, especially on the moderator proposals** 2. **Share additional inputs here, if needed** |
| Samsung | Proposal 2.A: same comment as Proposal 1.C   * Although we prefer to prioritize the Rel-16 based refinement, this compromise is acceptable since the additional workload seems small (even parameter combination can perhaps be more unified between the two). * To address some concern that sharing a same design for both may not be possible, perhaps we can make the second bullet on Rel-17 a working assumption. |
| Spreadtrum | **Proposal 2.A**  Our first preference is to focus on Rel-16 eType-II regular codebook. But if there’s majority support, we can leave with this proposal. Making Rel-17 FeType-II port selection (PS) codebook as WA is also fine for us. |
| Qualcomm | OK with Proposal 2.A and 2.G  For proposal 2.F, although we still think it is a typical performance-complexity trade-off depending on how long N4 is, we are OK with the proposal itself for standard progress.  However, we suggest some modification to the FL note below it:  “**FL Note**: Since this proposal is on UE-side prediction, Alt1.A should be excluded.”  [Mod: Done]  My understanding is, we have agreed UE-side prediction, while gNB-side prediction is still FFS (main concern is, gNB-side has to rely on W-based extrapolation, and many company questioned whether it is doable)  However, due to the obvious two benefits of W-based extrapolation (1. UE complexity; 2. Robust to random phase at each CSI-RS occasion in the burst), we suggest to have more time to study before shutting down the door, at least not in RAN1#110.  [Mod: Correct]  We are OK to have a note “decide whether to support gNB-side prediction in RAN1#110bis”  [Mod: This is not needed since gNB-side prediction is not excluded per Chairman’s remark. If you want an agreement on what to study for gNB-side prediction, please propose something. But adding a note like this doesn’t provide any direction.] |
| LG | Similar view with Samsung and Spreadtrum for Proposal 2.A |
| CATT | Fine with Proposal 2.A and 2.G.  Regarding Proposal 2.F, we support in principle. But we think the differene of Proposal 2.D agreed in today’s online session and Proposal 2.F is unclear by the current description.  [Mod: 2.D is on reference point ONLY, 2.F is on the property of CSI reporting window involcing l and W\_CSI] |
| Lenovo | **Proposal 2A:**  Concern on supporting both eType-II and FeType-II as baselines, especially that they both differ in spatial and frequency domain transformations (at least in terms of signaling)  **Proposals 2.F and 2.G:** Support |
| Mod V12 | **No revision** |
| Vivo | **Proposal 2A**  We don’t support. We support to enhance eType II CSI only.  **Proposal 2.F**  Support.  **Proposal 2.G**  We think our concern on aperiodic CSI-RS hasn’t been addressed. To use aperiodic CSI-RS may cause larger delay than just 4 slots as gNB can only trigger the RS and wait for a large number of occasions to get the prediction CSI. We haven’t seen results shown the feasibility of using a small number of CSI-RS occasions to achieve good UE prediction performance. Apparently, more study is needed.  Further, we also agree with the statement that K>1 resources are useful only for aperiodic CSI-RS.  We could be okay with the following.  **Proposal 2.G**: On the CSI reporting and measurement for the Rel-18 Type-II codebook refinement for high/medium velocities, support the following CSI-RS resource types/structures for CMR:   * Time-domain behaviour for ~~each~~ NZP CSI-RS resource: periodic, semi-persistent~~, aperiodic~~   + FFS aperiodic * The use of ~~K≥~~1 NZP CSI-RS resource~~s~~:   + FFS: the use of K>1 resources, and if supported, whether the resources are in the same CSI-RS resource set, other details including whether different resources are associated with different time-domain behaviors   [Mod: OK, the last FFS is better reworded as “details”] |
| ZTE | **Proposal 2A:** Support  **Proposal 2F:** Support  **Proposal 2G:** Support It seems that our previous comments are not considered/missing. So I copy here again for cross reviews.  [Mod: No. I have responded in Round 1 – please check round 1 summary. But for your convenience I’ll repeat again here. Next time please check if this has been addressed in the previous rounds ☺  Note that your comment is based on an old Round 1 version of proposal 2.G, please check the latest version in Table 3.A]  One minor comments. For K≥1 NZP CSI-RS resources, it is just relevant to aperiodic CSI-RS resource, right? Does it means that even for periodic or semi-persistent we also need to specify the CSI measurement window in such case. Then, I guess that only CMR is discussed herein right?  [Mod: From my reading of other companies Tdocs, at least a few companies want to use K>1 for P and SP. So yourbullet below would make this proposal pointless]  NZP-IMR and ZP-IMR may be discussed separately?  [Mod: Yes, in that case there is no need to mention this]  **Proposal 2.G**: On the CSI reporting and measurement for the Rel-18 Type-II codebook refinement for high/medium velocities, support the following CSI-RS resource types/structures:   * Time-domain behaviour for each NZP CSI-RS resource for channel measuement: periodic, semi-persistent, aperiodic * The use of K≥1 NZP CSI-RS resources:   + For periodic/semi-persistent, K=1 is considered as a starting point.   + FFS: whether the resources are in the same CSI-RS resource set, other details   + FFS: whether different resources are associated with different time-domain behaviors * FFS: resource configuration for NZP-IMR and ZP-IMR, and association between CMR and NZP/ZP-IMR   [Mod: I have added CMR already in Round 1] |
| Mod V16 | **Revise 2.G per vivo’s comment** |
| MediaTek | **Proposal 2.A**: We propose to prioritize R16 eType II only  **Proposal 2.F:** Support  **Proposal 2.G:** We support in principle, however we propose to remove the following  o ~~FFS: whether different resources are associated with different time-domain behaviors~~  We believe this will have a huge spec impact to have different time domain behaviour CSI-RS associated with the same report, unless the intention of the proposal is to have multiple CSI report config, in which case we need more clarification on why this would be needed.  **@Vivo,** regarding Aperiodic time we are not sure what is meant by you rcomment regarding the dealy of larger than 4 slots? Is the CSI processing time of Z, Z’ you are concerned about? If that processing time is definitely smaller than 4 slots in periodic. |
| Samsung | Proposal 2.G   * We don’t agree with vivo’s comment regarding aperiodic resource. In our view, P and SP resources can be used for low speed (e.g. 10kmph), the UE can measure over a longer measurement window and a periodicity >=4 slots. For a higher speed (e.g. 20kmph), the UE needs to measure faster than 4 slots (i.e., <4 periodicity) within a shorter window (than P and SP based measurement window). In our view, the UE may need to measure every slot or every 2 slots within a measurement window, say 8 slots. Such a measurement window can be provided to the UE based on a group of K>1 AP resources.   So, we prefer the original wording from the FL. |
| Xiaomi | We are fine with FL’proposal. But for proposal 2.F, we have same understanding with CATT. We can not see there are difference between Proposal 2.D and Prposal 2.F. Indeed, Proposal 2.D is on referece point. Compared with Proposal 2.D and 2.F, the reference point is just the left bound of CSI reporting window, i.e., *l*. right? This is why I concerned Proposal 2.D online meeting yesterday. We think the CSI reporting window is sufficient to define the UE behavor. Now that we have agreed Proposal 2.D. The Proposal 2.F seems to be not necessary. If we missed something, please futher clarification is provided for us.  [Mod: With proposal 2.D, we haven’t agreed on CSI reporting window (check the wording and no mention on this whatsoever). The terms were only defined in the last meeting for discussion only (please check yourself). Then we had another agreement of 9 candidates for down-selection. With proposal 2.F, we indeed define CSI reporting window as I said to CATT and down select from 9 to 2 (see highlighted Alt1.B and Alt2.B from previous agreement, identical with proposal 2.F). Just observe the wording and compare with the previous agreement that includes 9 alternatives.  I hope this finally clears up your confusion and misunderstanding.  [109-e] **Agreement**  On the CSI reporting and measurement for the Type-II codebook refinement for high/medium velocities, *at least for discussion purposes*, define the following:   * Assume a CSI report in slot *n*, and let the length of the DD/TD basis vector be *N*4   + Note that basis vector has no span/window in time-domain, only length * CSI-RS measurement window of [*k*,*k*+*W*meas –1], representing the window in which CSI-RS occasion(s) are measured for calculating a CSI report   + *k* is a slot index and *W*meas is the measurement window length (in slots)   + Note: In the legacy Rel-16/17 CSI, the CSI-RS occasion(s) are configured in *CSI-ReportConfig* * CSI reporting window of [*l*,*l*+*W*CSI –1], associated to the CSI report in slot *n*   + *l* is a slot index and *W*CSI is the reporting window length (in slots) * CSI reference resource(s) in time-domain   + The location of a CSI reference resource is denoted as *n*ref (slot index)   **Agreement**  On the CSI reporting and measurement for the Type-II codebook refinement for high/medium velocities, consider *at least* the following alternatives for potential down-selection:   * Alt1: *n*ref (CSI reference resource slot) as boundary   + Alt1.A:  *l* + *W*CSI –1 ≤ *n*ref   + Alt1.B:  *l* ≥ *n*ref   + Alt1.C: *l* < *n*ref and *l* + *W*CSI –1 > *n*ref * Alt2: *n* (report slot) as boundary   + Alt2.A: *l* + *W*CSI –1 ≤ *n*   + Alt2.B: *l* ≥ *n*   + Alt2.C: *l* < *n* and *l* + *W*CSI –1 > *n* * Alt3: End slot of *W*meas (*k* + *W*meas –1) as boundary   + Alt3.A: *l* + *W*CSI –1 ≤ *k* + *W*meas –1 with the following as a special case: *l=k,* *W*CSI = *W*meas   + Alt3.B: *l* ≥ *k* + *W*meas –1   + Alt3.C: *l* < *k* + *W*meas –1 and *l* + *W*CSI –1 > *k* + *W*meas –1 with the following as special cases:     - *l=k,* *l* + *W*CSI = *n*     - *l=k,* *l* + *W*CSI > *n*   FFS: whether *n*ref represents the slot index of Rel-15 CSI reference resource or a newly defined CSI reference resource  FFS: whether/how the CSI measurement window and reporting window are configured  **Agreement**  On the CSI reporting and measurement for the Rel-18 Type-II codebook refinement for high/medium velocities assuming the UE-side prediction, on the definition of UE-side prediction, down-select one from the following alternatives by RAN1#110bis-e:   * Alt1. UE “predicting” channel/CSI after the slot with a reference resource * Alt2. UE “predicting” channel/CSI after slot n (where the CSI is reported)   ] |
| ZTE3 | Thank you, Moderator, for your reply. Sorry for missing your reply, and it seems that the final version is submitted for online quickly. We are fine for leaving IMR issue open herein, and just focus on CMR.  Then, we believe that aperiodic CMR should be supported together, which is only the meaningful usage for K>1 case in our views, since the moderator think that K>1 is essential for the proposal.   * From MediaTek and ZTE’s contribution, the simulation results proves that UE side prediction for periodic/semi-persistent does not perform well under CSI-RS burst measurement. So, we think that the benefits for K>1 is much relevant to aperiodic CMR.   Therefore, we prefer to support ‘aperiodic’ (clearly super majority support), otherwise we are not sure the usage of K>1 herein. The original part implies the potential usage/schemes.  [Mod: Understood] |
| OPPO | **Proposal 2.A**: We are fine to study R17 PS codebook. However, R17 PS is based on UE-specific RS, we prefer to finalize AP CSI-RS (if support) firstly.  **Proposal 2.F, 2.G:** support |
| Sharp | Proposal 2A: We are OK to down-select to Rel-16 eTypeII codebook  Proposal 2F: Support  Proposal 2G: Support |
| Apple | We aer fine with proposal 2.A, 2.F and 2.G |
| CMCC | **Proposal 2.A:** We are fine with the proposal. We could first discuss the codebook design based on R16 codebook and then directly apply it to R17 codebook.  **Proposal 2.F:** Support.  **Proposal 2.G:** Support. |
| Huawei, HiSilicon | Support proposals 2.A, 2.F and 2.G. |
| vivo | **Some reply to the previous comments on 2.G**  To MTK:  The reporting is aperiodic for sure. What we are talking about is whether the CSI-RS is periodic, semi-persistent or aperiodic. For aperiodic CSI based on periodic or semi-persistent CSI-RS, gNB does not need to wait for the transmission of multiple CSI-RS occasions as the CSI-RS is already transmitted. But for aperiodic CSI-RS, as the UE needs sufficient number of CSI-RS occasions to have a good prediction, gNB has to wait for these occasions to be transmitted after these CSI-RS occasions are triggered together with the CSI request. Hence the delay for gNB to acquire the CSI is much larger.  To Samsung:  For P and SP, if the UE speed is too high to use 4-slot periodicity, whether to enhance the CSI-RS periodicity subjects to further discussion, which is an indepent issue. Based on our evaluation, 4-slot periodicity (which is 2ms for 30kHz) is sufficient to provide good prediction performance in 30km/h UE speed. For UE prediction that we have suppored, to overcome about 4ms CSI latency, prediction window should be located with sufficient gap after the last CSI-RS occasion. To achieve this, whether a small number of CSI-RS occasions are sufficient is doubtful for high UE speed. That is why we think more study is needed.  **On the updated 2.G**  The current 2.G seems to support more than one CSI-RS resource for P and SP CSI-RS. Could the proponents elaborate the reason to support more than one CSI-RS resource for P and SP CSI-RS? Without justification, we suggest to start with one CSI-RS resource for P and SP.  **Proposal 2.G**: On the CSI reporting and measurement for the Rel-18 Type-II codebook refinement for high/medium velocities, support the following CSI-RS resource types/structures for CMR:   * Time-domain behaviour for NZP CSI-RS resource: periodic, semi-persistent   + FFS: aperiodic * The use of ~~K≥~~1 NZP CSI-RS resource~~s~~:   + FFS: The use of K>1 CSI-RS resources and if supported, details   [Mod: We can try to discuss offline]  **Proposal 2.F**  We support it, but just one minor suggestion to align with the wording we have for the agreed 2.D.  **Proposal 2.F**: On the CSI reporting and measurement for the Rel-18 Type-II codebook refinement for high/medium velocities, when UE-side prediction is assumed, down-select ~~at least~~ one from the following alternatives by RAN1#110bis-e:   * ~~Alt1.A:~~ *~~l~~* ~~+~~ *~~W~~*~~CSI~~ ~~–1 ≤~~ *~~n~~*~~ref~~   + *~~n~~*~~ref~~ ~~(CSI reference resource slot) as boundary~~ * Alt1.B:  *l* ≥ *n*ref   + *n*ref (aCSI reference resource slot) as boundary * Alt2.B: *l* ≥ *n*   + *n* (report slot) as boundary * ~~Alt3.B:~~ *~~l~~* ~~≥~~ *~~k~~* ~~+~~ *~~W~~*~~meas~~ ~~–1~~    + ~~End slot of~~ *~~W~~*~~meas~~ ~~(~~*~~k~~* ~~+~~ *~~W~~*~~meas~~ ~~–1) as boundary, assuming CSI-RS measurement window of [~~*~~k~~*~~,~~*~~k~~*~~+~~*~~W~~*~~meas~~ ~~–1]~~   [Mod: done] |
| Intel | Assumption on Doppler-Domain reciprocity should be clarified for Proposal 2A (e.g. no DD reciprocity is assumed).  [Mod: Noted and good point] |
| Lenovo | For Proposal 2.G, we prefer to keep the detailed FFS to ensure the same discussion points are addressed by companies, maybe add “e.g.,” for flexibility?  **Proposal 2.G**: On the CSI reporting and measurement for the Rel-18 Type-II codebook refinement for high/medium velocities, support the following CSI-RS resource types/structures for CMR:   * Time-domain behaviour for NZP CSI-RS resource: periodic, semi-persistent   + FFS: aperiodic * The use of K≥1 NZP CSI-RS resources:   + FFS: details, e.g., whether the resources are in the same CSI-RS resource set, whether different resources are associated with different time-domain behaviors   [Mod: Let’s see if the fundamental issue can be agreed first] |
| Mod V31 | **Minor revision on 2.F (adding “a” per vivo comment)** |
| CATT | For Proposal 2.G, we prefer the original proposal to support ‘aperiodic’. |
| Fraunhofer IIS/Fraunhofer HHI | Proposal 2.A: Support in principle with the following note  “No TD reciprocity is assumed for the refinements on Rel. 17 FeType-II PS codebook for high/medium velocities”  Proposal 2.F: Support  Proposal 2.G: Support |
| Mod V34 | **Added “no DD reciprocity assumed” for proposal 2.A** |
| Qualcomm | Re discussion b/w **vivo** and **MTK**  For AP-report, regarding PUSCH report latency, we don’t see a difference b/w AP-CSI-RS burst and P-/SP-CSI-RS, under a practical UE implementation.  If we assume for P-/SP-CSI-RS, UE can be prepared anytime to report an TD-CSI triggered by a potential PDCCH anytime, it means UE has to always buffer a long series of recently received CSI-RS occasions – dramatical increase of UE memory requirement, and wasted power consumption.  Therefore, in our view, regardless of AP- or P-CSI-RS, the report latency is unavoidable, for a practical implementation.  On the other side, a good information is, this latency is totally acceptable. Since during the report latency, some previously reported TD-CSI can be used – an example provided below for more intuitive explanation    Hope this clarifies something. |
| vivo | Thanks Qualcomm for the reply.  Our understanding is UE has a limited buffer size, this is quantized by active resource/port triplets. UE can use the occasions in storage to perform CSI prediction upon triggering. For CSI precition, this type of storage may cost more than other CSI types. But it’s okay as long as the total memory size is limited by active CSI-RS port/resource triplets. So the delay is just CSI prediction processing time.  However, for aperiodic CSI-RS, UE has to wait much longer to have (e.g.,) more than 10 CSI-RS occasions before start the prediction. Hence the delay is the time span of a large number of CSI-RS occasions and CSI processing time, which is much larger than P/SP CSI-RS. |
| NEC | **Proposal 2.A:** Our first preference is refinement only based on Rel-16 TypeII CB. While if majority companies support Rel-17 FeTypeII CB as well, we are fine for the proposal. Regarding the workload, maybe we can say something like  **Updated 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, if ~~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 can be applied   + Time-/Doppler-domain reciprocity is not assumed   [Mod: This rewording doesn’t guarantee no significant increase in workload, which will cause many companies to be concerned ☹] |
| Mod V40 | **No revision** |

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

Table 5A Summary: issue 3

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| --- | --- | --- |
| **#** | **Issue** | **Companies’ views** |
| 3.1 | [109-e] **Agreement**  The work scope of TRS-based TDCP reporting focuses on the following use cases for evaluation purposes:   * Targeting medium and high UE speed, e.g. 10-120km/h as well as HST speed * Aiding gNB to determine   + CSI reporting configuration and CSI-RS resource configuration parameters,   + Precoding scheme, using one of the CSI feedback based precoding schemes or an UL-SRS reciprocity based precoding scheme * Aiding gNB-side CSI prediction   [109-e] **Agreement**  For Rel-18 CSI enhancements, proceed to support and specify the following features (the previously agreed work scopes apply):   * 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   + The use case of aiding gNB-side CSI prediction is to be confirmed in RAN1#110   **Proposal 3.A**:  For the Rel-18 TRS-based TDCP reporting, the use case of “aiding gNB-side CSI prediction” is refined to “aiding gNB implementation in CSI prediction for TDD”  **FL Note**: Need to decide whether this use case is kept or not. This topic has been discussed OFFLINE [1] | **TDCP use case of “aiding gNB-side CSI prediction”**   * **Confirm**: CATT, DOCOMO, Lenovo, Samsung (if implementation), Huawei/HiSi, * **Remove**: Ericsson, vivo, Samsung (if spec), LG,     **Proposal 3.A**:   * **Support/fine**: CATT, DOCOMO, Lenovo, Samsung, Huawei/HiSi, vivo * **No support**: Ericsson,   [Mavenir] Propose to add additional use cases:   * Aiding gNB to determine   + whether to enable joint channel estimation for PUSCH/PUCCH or not and the time domain window size if applicable.   [Mod: Similar proposal was brought up in the last meeting but it was opposed by many. It is not within the scope of CSI agenda item 9.1.2]   * + TDCP-aware (Doppler shift aware) LA   [Mod: It is not within the scope of CSI agenda item 9.1.2]  [Mod: Re use cases, we appreciate the proposals for new use cases. But the use cases have been finalized in the last meeting. Unless the group can agree on adding new use cases, we cannot go back and add new ones.] |
| 3.2 | [109-e] **Agreement**  The work scope of TRS-based TDCP reporting includes down selection from the following TDCP parameters:   * Alt1. Doppler shift * Alt2. Doppler spread **(=max Doppler shift)** * Alt3. Cross-correlation in time * Alt4A. Relative Doppler shift of a number of peaks in CIR * Alt4B. Relative Doppler shifts of different TRSs * Alt5: CSI-RS resource and/or CSI reporting setting configuration assistance   **Proposal 3.B**: For the Rel-18 TRS-based TDCP reporting, down select one of the following alternatives by RAN1#110bis-e:   * AltA. Based on Doppler profile   + E.g., Doppler spread derived from the 2nd moment of Doppler power spectrum, average Doppler shifts, Doppler shift per resource, maximum Doppler shift, relative Doppler shift, etc * AltB. Based on time-domain correlation profile   + E.g. Correlation within one TRS resource, correlation across multiple TRS resources   + Note: The correlation over one or more lags of TRS resource may be considered. The lags may be within one TRS burst or different TRS bursts * AltC: CSI-RS resource and/or CSI reporting setting configuration parameter(s) to assist network   + E.g. gNB configures UE with multiple choices on what to assist (e.g. two or more CSI-RS/report periodicities, or precoding schemes depending mainly on UE velocity), then UE report according to configuration; parameters correspond to CSI reporting periodicity, codebook type, etc. * Note:Different alternatives may or may not apply to different use cases | **AltA:** IDC, Samsung, Spreadtrum, Mavenir, Google, OPPO, CATT, Xiaomi, LG, CEWiT, Apple, Sharp, DOCOMO, ZTE, Huawei/HiSi, vivo, CEWiT, Nokia/NSB  **AltB:** vivo, OPPO, CEWiT, Ericsson  **AltC:** MediaTek, Qualcomm  **Proposal 3.B:**   * **Support/fine:** IDC, Samsung, Spreadtrum, Mavenir, Google, OPPO, CATT, Xiaomi, LG, CEWiT, Apple, Sharp, DOCOMO, ZTE, Huawei/HiSi, vivo, CEWiT, Nokia/NSB, vivo, OPPO, CEWiT, Ericsson, MediaTek, Qualcomm, Fraunhofer IIS/HHI, NEC * **Not support:** |
|  |  |  |

Table 6 Additional inputs: issue 3

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| --- | --- |
| **Company** | **Input** |
| Ericsson | Regarding AltC, we share similar understanding as vivo that gNB and UE may have implementation details. So what is recommended by UE may not be suitable for gNB. For example, consider the case the UE recommends a CSI report setting with type II CSI to the gNB. But if the gNB does not see an opportunity to do MU-MIMO scheduling, it may simply schedule with type I CSI.  Also, one question for the proponents of AltC. Could you provide some high level description of this alternative? We assume this is still based on TRS measurements of some sort that trying to quantify how much the channel is changing? |
| MediaTek | **@Ericsson,** Thank you for the comments on poroposal 3.B, regarding AltC, as you pointed out there are implementation specific factors for each Ue which can impact the optimal choice of CSI/CSI-RS parameters for a given scenario, for example some Ues may be handle to higher ractic more gracefully than others or Ues can report CSI/CSI-Rs periodicity which can deliver the best power vs performance tradeoff, these UE implementation specific details are missing at the gNB side and hence can lead to same issue we are trying to fix by introducing the TDCP feature.  As you pointed out, the CSI/CSI-RS parameters which UE reports back part of this TDCP has to carefully chosen to d  eliver meanginful configurations details. We don’t believe in this report UE needs to report back its perfernce for Type I/Type II codebook but rather information such as: CSI-RS/CSI periodicity preferences, reporting granularity, i.e., whether WB or SB PMI/CQI is needed, SB size when in SB reporting mode, rank restriction (based on the antenna correlation computed through TRS). |
| Mod V0 | 1. **Check and update your view in Table 5, especially on the moderator proposals**     1. **Conclusion 3.A: @Huawei, Ericsson, vivo, OK confirming this use case or still proposing to remove?**    2. **Proposal 3.B: @Proponents of AltC, please provide wording proposal for more description** 2. **Share additional inputs here if needed** |
| Samsung | We are fine to confirm the use case “to aid gNB-side prediction” as long as it is understood that it is a matter of NW implementation, i.e. no spec impact on how TDCP is designed. But if this is intended to lead to some spec impact, we prefer to remove it |
| Ericsson | On 3.A, we don’t see how TRS can be used for CSI prediction since TRS is single port. |
| Qualcomm | Some Input to proposal 3.B – AltC:  E.g. gNB configures UE with multiple choices on what to assist (e.g. two or more CSI-RS/report periodicities, or precoding schemes depending mainly on UE velocity), then UE report according to configuration  [Mod: OK] |
| LG | On 3.1, we support FL’s conclusion. |
| CATT | @ Samsung: We are fine to discuss the spec impact for gNB-side prediction. But in our understanding, the whole feature for TDCP reporting is needed the spec impact.  [Mod: In my understanding, Samsung refers to the spec impact of this use case “gNB-side prediction” on TDCP design, not the spec impact of TDCP itself – which obviously needs spec impact.].  Because UE cannot report Doppler information when CSI resource is configured as ‘*trsInfo*’ based the current specs. Besides, the current Proposal 3.B of reporting quantities are supported to both single Doppler shift or multiple Doppler shifts, which can also cover the use case of gNB-side prediction.  @Ericsson: In our observations, the relative distribution of delay paths is similar across different antenna ports. For example, the strongest path might have big difference between the channels of different antenna ports, but the relative delay is similar, and the Doppler shift is highly related with delay path. If gNB can obtain the Doppler shift of each delay path, gNB can match the delay path between SRS and TRS, which is path-level, not port-level. Maybe that’s the reason why separate or common TD basis have the similar performance gains for different SD/FD basis in the feature of Type II CB refinement. But we are fine to discuss the further enhancement to distinguish multi-paths clearly, e.g. multiple TRSs in current Proposal 3.B and reporting relative Doppler shifts by multi-TRSs.  Besides, for TDD system, considering the UL RS problems of pattern restriction and random phase noise, it seems no perfect solutions for CSI-aging via UL RS. And we can see the obvious performance gains for CSI-aging via TRS based our initial simulations. So the confirmation and further study is needed at least for TDD system. |
| Lenovo | Fine to confirm “to aid gNB-side prediction”. No need to single out the sub-use case for omission.  Regarding Proposal 3.B Alt C, upon the moderator’s request for more descriptive wording, we suggest the following:  ***e.g., Parameters correspond to CSI reporting periodicity, codebook type, spatial/frequency domain compression, etc.***  [Mod: OK] |
| Mod V12 | **Revision of wording of AltC per Qualcomm and Lenovo** |
| vivo | We are okay to study the use case of gNB prediction with the understanding that this is for TDD high speed use case, where prediction itself is implementation. |
| Mod V16 | **Alternative wording for conclusion 3.A** |
| MediaTek | Support the modification for proposal 3.B. |
| Xiaomi | We are fine to confirm “to aid gNB-side predication”. The rewording “to aid gNB-side implmetation” is ok for us. |
| OPPO | Support proposal 3.B |
| Sharp | We support proposal 3.B. |
| Apple | For conclusion 1.A, we fail to see the necessity, since once UE reports TDCP, it is up to gNB on how to use it. It is hard to argue that gNB cannot use TDCP report to aid CSI prediction. But if we need a conclusion, we are also okay.  We are okay with Proposal 3.B |
| CMCC | **Conclusion 1.A**: We are ok to further study the use case of “aiding gNB implementation in CSI prediction for TDD”, FL’s rewording seems clear.  **Proposal 3.B:** Supprot and we prefer AltA. |
| Huawei, HiSilicon | We are fine to not remove “aiding gNB-side prediction”. |
| Ericsson | Regarding the description added for Alt C in Proposal 3B, we have some questions:  -> what is meant by ‘depending mainly on UE velocity’? Does this mean UE will feedback a choice mainly based on UE velocity and not based on TRS measurements? We do not think UE speed alone determines channel variation in time domain, as channel variations also depend on other factors such as the relative angles between the UE velocity vector and the different channel rays, etc.  -> Also, how is spatial/frequency domain compression determined from measurements on TRS? These two do not seem related to time-domain channel properties.  -> Seems comments from Lenovo and MediaTek are contradictory. MediaTek says ‘We don’t believe in this report UE needs to report back its perfernce for Type I/Type II codebook’. But Lenovo proposes to capture ‘codebook type’ as part of feedback. Some clarification may be needed from the proponents of Alt C in Proposal 3B if ‘codebook type’ should be included in the description or not. |
| Mavenir | **Issue 3.1:** We are fine to add “aiding gNB-side prediction” only if it is transparent to spec.  **Issue 3.2:** Regarding AltC, we have similar opinion as Erission and Vivo. The UE-side CSI report may not be optimized for gNB/network for many reasons mentioned above. Taking CSI periodicity as an example, gNB need to consider many other factors in addition to Doppler shift such as CSI-RS overhead to optimize overall network performance. For the same reason, MediaTek’s concern, the UE-specific capapbity to handle Doppler shift which is missed on gNB side, should be deprioztied in comparison with overall network performance.  **@CATT**: Regarding the CSI predication, please explain why it cannot be replaced/simplified by proper spec design on reporting mechanism/periodicity. In addition, TRS is single port and could be wide-beamformed, while CSI-RS/PDSCH could be multiple-port and narrow-beamformed in ractice. As a result, TRS may experice very different Doppler shift/CS than CSI-RS/PDSCH and then the meaning of CSI predication here is questionable. Furthermore, some details need to be clarified in the LLS result to show CSI predication gain. For example, is TDCP report practical or ideal in your simulation? Because according to our evaluations, Doppler shift estimation error is so large that CSI predication is not practical in your SNR region. In addition, is LLS result enough or SLS result need to be provided as well? Because some performance degradation observed in LLS could be easiy overcomed in SLS by L2 algorithms such as LA.  **@ MediaTek**: For the same reason above, antenna correlation cannot be obtained by TRS. |
| Mod V31 | **No revision** |
| CATT2 | For the rewording “aiding gNB implementation in CSI prediction for TDD”, we are fine with vivo’s suggestion that the behavior of prediction itself is implemented by gNB, which is related with gNB’s algorithm. But we are confused that could we down-select reporting quantities based on this separate use case? In our understanding, each use case should be treated equally, and the reporting quantities needed for all the use case can be covered by current high-level Proposal 3.B. So if we can select by different use cases independently, which is also not needed additional specs impact, we agree the rewording “aiding gNB implementation in CSI prediction for TDD”. So if gNB implementation in CSI prediction for TDD is confirmed, the note for Proposal 3B can be updated.  **Proposal 3.B**: For the Rel-18 TRS-based TDCP reporting, down select one of the following alternatives by RAN1#110bis-e:   * AltA. Based on Doppler profile   + E.g., Doppler spread derived from the 2nd moment of Doppler power spectrum, average Doppler shifts, Doppler shift per resource, maximum Doppler shift, relative Doppler shift, etc * AltB. Based on time-domain correlation profile   + E.g. Correlation within one TRS resource, correlation across multiple TRS resources   + Note: The correlation over one or more lags of TRS resource may be considered. The lags may be within one TRS burst or different TRS bursts * AltC: CSI-RS resource and/or CSI reporting setting configuration parameter(s) to assist network   + E.g. gNB configures UE with multiple choices on what to assist (e.g. two or more CSI-RS/report periodicities, or precoding schemes depending mainly on UE velocity), then UE report according to configuration; parameters correspond to CSI reporting periodicity, codebook type, spatial/frequency domain compression, etc. * Note: the alternatives above can be selected by different use cases independently.   @ Mavenir: If the high/medium scenarios for TDD can be implement by the current specs, e.g. UL RS or reporting mechanism/periodicity as you said, I think the whole feature is unnecessary. Because of some limitations of the pattern /random noise for UL RS and TDCP reporting by TRS, we enhance codebook refinement for FDD in issue 2, so we need enhance for TDD respectively. And for the rewording of gNB-implement, please check our views for the rewording above.  Besides, in our initial simulation, the precoder of PDSCH is SVD-based by SRS and the precoder of TRS is based port-selection. Based our obversation, the PDP of TRS and SRS for nultiple antennas ports is similar,e.g. the strongest path might have big difference between the channels of different antenna ports, but the relative delay is similar, and the Doppler shift is highly related with delay path. For TDL-A channel and 300ns, the TDCP report is practical by Real channel estimation via TRS.  If you think the single port TRS can not reflect the multi-paths of multi-ports channel, we agree with the antenna correlation or autocorrelation by multi-paths/lags can not be obtained by single port TRS neither. |
| Fraunhofer IIS/Frauhofer HHI | **Proposal 3.B**: Support |
| Mod V34 | **No revision** |
| Qualcomm | Re **Ericsson**  Firstly, I want to say Ericsson has my personal full respect regardless of view on this item.  Extract your first question (the only question related to our input) here to response:  -> what is meant by ‘depending mainly on UE velocity’?  Since this feature is motivated by Doppler, UE will understand the report of precoding scheme choice as being based on Doppler, which is mainly determined by UE mobility/velocity (we are not assuming cluster mobility, right?) UE can report its choice by TRS measurement, and it can be according to UE implementation regarding the understanding of which precoding scheme (e.g. Type-I CSI feedback) is more robust under a certain Doppler or UE velocity.  I also have a few questions regarding Ericsson’s autocorrelation scheme:  1. For your exampled cross-burst autocorrelation (forgive me to use ways I am more familiar with), where can be tens of slots, is phase coherence required b/w and ?  2. For the theoretical achievement of autcorrelation according to your formulas, how many samples of (and ) are needed?  3. Are you assuming UE has to receive every TRS burst and symbol to prepare an aperiodic report (already agreed) of cross-burst autocorrelation potentially triggered anytime? |
| Lenovo | **Proposal 3.B**:  @Ericsson: OK to remove spatial/frequency domain compression. Regarding other comments, I do not see a problem that different proponents of AltC have different views on the related parameters, we only need to include this for down selection in RAN1#110bis-e, we just added examples upon the moderator’s request and can work on refinement until next meeting. Other alternatives (AltA, AltB) have different sub-options/sub-alternatives too and are not yet refined |
| NEC | **Proposal 3.B:** Support the proposal. |
| Mod V40 | **Revision based on Ericsson and Lenovo** |

# References

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| --- | --- | --- | --- |
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| 11 | [R1-2206377](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_110/Docs/R1-2206377.zip) | On Rel-18 CSI enhancements for high/medium UE velocities and coherent JT | CATT |
| 12 | [R1-2206459](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_110/Docs/R1-2206459.zip) | Discussion on CSI enhancement | NEC |
| 13 | [R1-2206572](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_110/Docs/R1-2206572.zip) | On CSI enhancements | Intel Corporation |
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| 15 | R1-2206812 | Moderator summary on Rel-18 CSI enhancements | Moderator (Samsung) |
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