**3GPP TSG RAN WG1 #112bis-e R1-230xxxx**

**e-Meeting, April 17th – April 26th, 2023**

**Agenda item:** 9.1.2

**Source:** Moderator (Samsung)

**Title:** Moderator Summary#2 on Rel-18 CSI enhancements: Round 1

**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: CJT

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Issue 2: Doppler

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Issue 3: TDCP

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

Table 1A Summary: issue 1

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| **#** | **Issue** | **Companies’ views** |
| 1.1 | [110bis-e] **Agreement**  On the Type-II codebook refinement for CJT mTRP, regarding W2 quantization group, for each layer:   * Support the following: (Alt1) One group comprises one polarization across all N CSI-RS resources (*C*group,phase=1, *C*group,amp=2)   + FFS: Amplitude quantization table enhancement   + For the amplitude group other than the group associated with the SCI, the reference amplitude is reported * Working assumption: Alt3 is supported in addition to Alt1 (to be confirmed in RAN1#111)   + (Alt3). One group comprises one polarization for one CSI-RS resource with a common phase reference across N CSI-RS resources (Cgroup,phase=1, Cgroup,amp=2N)     - For each of the (2N–1) amplitude groups (other than the group associated with the SCI), the reference amplitude is reported * If the support Alt3 in addition to Alt1 is confirmed, only one of the two schemes will be a basic feature for UEs supporting Rel-18 Type-II CJT codebook   **Proposal 1.A.1**: On the Type-II codebook refinement for CJT mTRP, *revert* the following working assumption:   * Working assumption: Alt3 is supported in addition to Alt1 (to be confirmed in RAN1#111)   + (Alt3). One group comprises one polarization for one CSI-RS resource with a common phase reference across N CSI-RS resources (Cgroup,phase=1, Cgroup,amp=2N)     - For each of the (2N–1) amplitude groups (other than the group associated with the SCI), the reference amplitude is reported   **FL Note**: Just as what we did in RAN1#110bis-e, this has to be decided based on empirical evidence (i.e. SLS results). Per agreement this needs to be concluded in this meeting. Since the WA was made conditioned upon the benefit of Alt3 over Alt1   * If there is no confirmed benefit from Alt3 over Alt1 in the alleged scenarios (inter-site CJT, 500m ISD), the WA should be **reverted** (hence no support of Alt3). * Otherwise, **confirmed** as an agreement.   The available SLS results are summarized as follows for the alleged “missing” scenarios from Alt3 proponents in RAN1#110bis-e (500m ISD or larger, inter-site CJT):   * “Notable” (small in FL perspective) gain: Huawei (2-3% mean UPT), ZTE (0.2-1.2% mean UPT) * No demonstrable gain: Samsung, vivo | **Support/fine (want to revert WA):** vivo, Samsung, OPPO, MediaTek, Fraunhofer IIS/HHI, Apple, DOCOMO, Intel, Nokia/NSB, Ericsson, Sharp, Google, Sony, AT&T  **Not support (want to confirm WA)**: ZTE, Spreadtrum, CATT, LG, Huawei/HiSi, Lenovo, Fujitsu, NEC, Xiaomi, |
| 1.2 | [112bis-e] **Agreement**  On the Type-II codebook refinement for CJT mTRP, *for mode-1*, support the use of per-CSI-RS-resource FD basis selection offset (relative to a reference CSI-RS resource) for independent FD basis selection across *N* CSI-RS resources, i.e. (example formulation) where:   * is commonly selected across *N* CSI-RS resources * is the layer-common FD basis selection offset for CSI-RS resource *n* relative to a layer-common reference CSI-RS resource with   + Therefore, (*N* – 1) FD basis selection offset values are reported   + Basic feature:   + Optional feature: * FFS: UCI design details, details on   **Question 1.B**: The only pending UCI design detailed issue is the reference CSI-RS resource . Three proposals have been mentioned. Please share your preference (with technical justification of the benefits):   * Alt1. Fixed to the first configured CSI-RS resource (lowest CSI-RS resource ID} * Alt2. Selected by the UE and signalled together with the (N-1) FD window offsets * Alt3. Derived from SCI(s) (note: SCI is layer-specific while this reference is layer-common) | **Alt1 (fixed):**  **Alt2 (signalled):**  **Alt3 (derived from SCI):** |
| 1.3 | [112bis-e] **Agreement**  On the Parameter Combination of Type-II codebook refinement for CJT mTRP, only the following linkages are supported (marked ‘x’), for Rel-16 eType-II based   * For *NTRP* =1,   + fully reuse seven out of the eight Parameter Combinations from Rel-16 eType-II as indicated in the table below     - FFS (by RAN1#112bis-e): whether to add one more Parameter Combination for L=4 based on the legacy Rel-16 eType-II FD combo {½, ½, ¼, ¼; ½} or the agreed FD combo {½, ½, ½, ½; ½}, or not to add from the indicated seven below * ….  |  |  |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | --- | --- | | **NTRP** | **SD combo** | **FD combo {pv},** | | | | | | | {1/8, 1/8, 1/16, 1/16}, ¼ | {1/8, 1/8, 1/16, 1/16}, ½ | {1/4, ¼, 1/8, 1/8}, ¼ | {1/4, ¼, 1/8, 1/8}, ½ | {1/4, ¼, ¼, ¼}, ¾ | {1/2, ½, ½, ½}, ½ | | 1 | 2 |  |  | x | x |  |  | | 4 |  |  | x | x | x |  | | 6 w/ restriction |  |  |  | x | x |  | | … |  |  |  |  |  |  |  |   **Question 1.C.5**: Please share your view on the following alternatives for the FFS point on Parameter Combination for NTRP=1 with technical justification (much preferably backed with SLS):   * Alt0 (default outcome if no consensus between Alt1 and Alt2). Not adding another Parameter Combination in addition to the agreed seven * Alt1. Add a combination based on the legacy Rel-16: L=4 and FD combo {**{pv};** {½, ½, ¼, ¼; ½} * Alt2. Add a combination with L=4 and FD combo {**{pv};** {½, ½, ½, ½; ½}   **FL Note:** Alt0 is the default outcome if there is no consensus on this. | **Alt0:**  **Alt1:**  **Alt2:** |
| [112] **Agreement**  On the Parameter Combination of Type-II codebook refinement for CJT mTRP, support linkage between the list of supported {*Ln*} combinations and list of supported {*pv,*} combinations via pairing each combination for {*pv,*} with at least one combination for {*Ln*}, for each *NTRP* value.   * FFS (by RAN1#112bis-e): The exact list of supported pairs/linkage, or restriction of {*Ln*} when paired to each of {*pv,*} * FFS (by RAN1#112bis-e): Whether/How to support configuration signalling for indicating the linkage * Note: While no additional codebook parameter will be introduced, the total number of SD basis vectors across CSI-RS resources can still be used as a criterion for choosing the supported pairs/linkage   [111] **Agreement**  On the Type-II codebook refinement for CJT mTRP, regarding the SD basis selection, for a configured value of *NTRP*, a set of *NL* combinations of values for {*L*1, ..., *LNTRP*} is gNB-configured via higher-layer (RRC) signaling   * When *NL*>1, the selected combination of values for {*L*1, ..., *LNTRP*} is reported in CSI part 1 using an indicator, selected from the *NL* configured combinations   + *NL* =1 is one of the supported candidate values   …  In regard to whether several FD combos can be configured for a UE, the following agreement clearly precludes this because:   * Wording “the value” implies singular, not plural * If >1 FD combo values can be configured as a part of the configured linkages, it allows dynamic (UE selection and reporting) FD combo selection which violates the agreement (gNB-configured by RRC configuration)     [112] **Agreement**  On the Type-II codebook refinement for CJT mTRP, for Rel-16-based refinement, support at least the following combinations of {pv,} from where *the value* of {*pv,*} is gNB-configured via higher-layer (RRC) signaling:  …  Therefore, to allow configuring multiple FD combos in relation to SD and linkages, the group would have to revert a previous agreement (not advisable in such a late stage).  **Conclusion 1.C.2**: (**for clarification**) On the Parameter Combination of Type-II codebook refinement for CJT mTRP, no additional configuration signalling for indicating the linkage is needed. Per previous agreements (RAN1#111 and 112):   * “The [single] value of {*pv,*} is gNB-configured via higher-layer (RRC) signalling” * “[The] set of *NL* combinations of values for {*L*1, ..., *LNTRP*} is gNB-configured via higher-layer (RRC) signalling”   Such configuration shall be according to the supported/agreed linkages.  **FL Note**: This conclusion is clarification in nature, clearly implied from previous agreements | |
| [112] **Agreement**  On the Type-II codebook refinement for CJT mTRP, for Rel-16-based refinement, support *at least* the following combinations of {*Ln*} for the higher-layer-configured value of NTRP:   |  |  | | --- | --- | | **NTRP** | **{Ln} combination** | | 1 | {2} | | {4} | | {6} (analogous to legacy, only for total # ports =32, rank 1-2, R=1) | | 2 | {2,2} | | {2,4}, {4,2} | | {4,4} | | 3 | {2,2,2} | | {2,2,4}, {2,4,2}, {4,2,2} | | {4,4,4} | | 4 | {2,2,2,2} | | {2,2,2,4} | | {2,2,4,4} | | {4,4,4,4} |   FFS: For *NTRP*>1, in addition to the supported combinations/permutations, whether to support at least one additional combination where at least one of the *Ln* values (*n*=1, …, *NTRP*) is 6  **Conclusion 1.C.2:** On the Type-II codebook refinement for CJT mTRP, for Rel-16-based refinement, for *NTRP*>1, in addition to the supported SD combinations/permutations, there is no consensus on supporting at least one additional combination where at least one of the *Ln* values (*n*=1, …, *NTRP*) is 6  **FL Note**: This was discussed offline [1] and the current situation   * **Support/fine:** Huawei/HiSi, NTT DOCOMO (when N=1), ZTE, NEC (when N=1), CATT, CMCC (when N=1) , vivo (as long as Ltot≤16) * **Not support/concern:** Samsung, Apple, MediaTek, LG, Spreadtrum, OPPO, Qualcomm, Intel, Xiaomi, AT&T, Nokia/NSB, Ericsson, Lenovo/MotM, Sony, Sharp, Google   Note that the conclusion (1.C.2) is based on the fact/reality that there is no consensus hence the implication follows whether one can accept (cope with) reality (that no consensus means no support) or not. | |
| 1.4 | [112bis-e] **Agreement**  On the Type-II codebook refinement for CJT mTRP, regarding CBSR, amplitude restriction is CSI-RS-resource-specific.   * FFS: Whether CBSR is always configured for each CSI-RS resource or not   **Proposal 1.D.3:** On the Type-II codebook refinement for CJT mTRP, regarding CBSR, each of the NTRP configured CSI-RS resources can be ‘configured’ or ‘not configured’ with CBSR  **FL Note: No CBSR config option per resource? (No company seems to have concern on this)**   * **Yes:** Huawei/HiSi, NEC, Nokia/NSB * **No:** | **Proposal 1.D.3:**   * **Support/fine:** Huawei/HiSi, NEC, Nokia/NSB, * **Not support:** |
| 1.5 | [112] **Agreement**  On the Type-II codebook refinement for CJT mTRP, regarding UCI omission, down-select between the following three alternatives (by RAN1#112-bis where n denotes the n-th CSI-RS resource):   * Alt1. Prio(,l,m,n)=() .N.RI.P(m)+N.RI.l(n)+N.n   + Note: This implies that CSI-RS resource is designated the highest priority * Alt2. Prio(,l,m,n)=2L’.Q(n).RI.N3+2L’.RI. P(m)+RI.l(n)+   + Note: This implies that CSI-RS resource is designated the lowest priority (after FD basis)   + Note: L’ denotes the max value of Ln from all selected N CSI-RS resources   + FFS: Q(n) maps the index n according to a rule, e.g., Q(n)=n, or Q(n)=0 if n corresponds to strongest TRP/SCI. * Alt3. Replace SD basis index *l* in legacy Prio calculation with , i.e., SD basis index over all resources: Prio(,l,m,n) = 2Ltot.RI.P(m)+ RI.+RI.l(n)+   FFS: FD permutation P(.) as Rel-16-analogous, or no permutation i.e. P(m)=m  **Proposal 1.E.1**: On the Type-II codebook refinement for CJT mTRP, regarding UCI omission, support reusing the legacy UCI omission mechanism while (Alt3) replacing SD basis index *l* in legacy Prio calculation with , i.e., SD basis index over all resources: Prio(,l,m,n) = 2Ltot.RI.P(m)+ RI.+RI.l(n)+   * FFS: FD permutation P(.) as Rel-16-analogous, or no permutation i.e. P(m)=m   **FL Note**: This was discussed offline [1].   * Alt2 and Alt3 are almost equally supported * Based on the available SLS results, Alt2 results in larger performance loss over Alt3 upon UCI overflow * Alt2 opponents argue that since UE reporting of dynamic TRP selection is already supported, truncating CJT reporting to sTRP in case of UCI overflow is overkill and leaves NW with the least CSI for CJT operation (which is technically valid)   **FL Note**: The only available SLS results (Samsung) show that Alt3 performs slightly better than Alt2 upon UCI omission  Alt1: Samsung, NTT DOCOMO (2nd), *Apple*, MediaTek, Nokia/NSB (2nd), *IDC*  Alt2: *ZTE, Fraunhofer IIS/HHI*, NEC, vivo (2nd), *Spreadtrum, OPPO, Qualcomm, CATT*, *Huawei/HiSi, Fujitsu*, Ericsson (2nd), *CMCC, Lenovo, Sony*  [1.E.1] Alt3: Samsung (2nd), NTT DOCOMO, MediaTek (2nd), LG, NEC (2nd), vivo, Intel, Xiaomi, Nokia/NSB, Ericsson, Google | **Proposal 1.E.1:**   * **Support/fine:** Samsung, NTT DOCOMO, MediaTek (P=m), LG, NEC, vivo, Intel, Xiaomi, Nokia/NSB, Ericsson, Google, AT&T, ZTE (ok, 2nd pref though 1st pref is Alt2), OPPO, Qualcomm (P=m), CMCC, IDC, Sony, Apple, * **Not support (want Alt2)**: Huawei/HiSi, Spreadtrum, CATT, Lenovo/MotM, Fujitsu, Fraunhofer IIS/HHI, |

Table 1B Type II CJT: summary of observation from SLS

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| **Company** | **SLS results** | | |
| **Issue #** | **Metric** | **Observation** |
| Huawei/HiSi | 1.1 | Mean UPT gain vs overhead | Observation 9: For inter-site CJT with large inter-site distance, Alt 3 (Cgroup,amp=2N) has better performance compared to Alt1 (Cgroup,amp=2). |
| 1.3 | Mean UPT gain vs overhead | For {Ln} combinations where each Ln equals 2, adding overhead by increasing pv and/or beta (such as {pv, beta} combo #3~#6) has no significant performance improvement compared with other {Ln} combinations.  For a given NTRP, the {Ln} combinations with at least one Ln=4 have similar performance-overhead tradeoff. It may be hard to select some of the pairs. Therefore, it is more reasonable to configure {Ln} and {pv, beta} pairs based on gNB implementation other than predefined pairs/linkage.  Observation 6: For {Ln} combinations where each Ln equals 2, adding overhead by increasing pv and/or beta has no significant performance improvement.  Observation 7: The uneven {Ln} combination and its permutations with the same Ltot (such as {2,2,4},{2,4,2}, {4,2,2}) should be treated as one combination, due to the same overhead and performance with proper gNB configuration.  Observation 8: Adding {Ln} combinations including Ln=6 does not increase the overhead and UE complexity as long as Ltot does not exceed the current maximum Ltot value, and can increase performance. |
| ZTE | 1.1 | Avg UPT gain vs overhead,  5% UPT gain vs overhead | We observe that 0.2%~1.2% average UPT gain and 2.2%~12.1% cell-edge UE gain can be achieved using Alt 3 compared with Alt1. |
| 1.3 | Avg UPT gain vs overhead | Ln=6 combination pairs for NTRP=2/3 can also show good performance under medium & high overhead; then considering the CSI report overhead is still acceptable, we prefer to have them as in the candidate list for SD-basis.  Then, clearly, pv = {1/2,1/2} combined with Ln={4,6} can provide good performance under medium & high overhead. |
| 1.5 | Avg UPT gain | That can be observed that, if going with Alt-2, n (n-th CSI-RS resource) should be taken as the most significant parameter (after FD basis), that is, fall-back to less co-ordinated TRP(s). That is beneficial for releasing some TRPs for serving other Ues, which is the reason why we observe some performance benefits for that. |
| Vivo | 1.1 | SE gain vs overhead | Alt3 shows negligible performance improvement over Alt1 for the scenario with 500m ISD and the high payload case of the scenario with 200m ISD.    Combining the payload and the SE gain, Alt1 outperforms Alt 3. |
| Nokia/NSB | 1.3 | Average UPT gain vs mean overhead | We observe that for , the combination(s) with a single achieves most of the UPT gain of the combination with ,, but with smaller overhead and complexity.  For , we note that, with 16 ports per TRP, the combinations with achieve similar UPT-overhead trade-off as with . Therefore, we propose to keep the same restrictions and supported combinations as for Rel16, with applicable only for 32 ports. |
| Samsung | 1.1 | Average UPT gain vs overhead | There is no benefit of Alt3 over Alt1 shown in our SLS results for both mode 1 and mode 2 cases even in the inter-site inter-cell scenarios. |
| 1.3 | Average UPT gain vs overhead | We support the offline proposal 1.C.1 as we have verified that the selected linkages yield good performance overall compared to other linkages and the overhead of them are well uniformly-spaced. |
| 1.5 | Average UPT loss w.r.t. paraComb | UCI omission with Alt3 is more beneficial than Alt2 in CJT operation. |
| MediaTek | 1.1 | Average UPT gain vs different paraComb | We observe that Alt 3 cannot provide consistent performance benefit over Alt 1. Further, the cost of this little performance benefit must be borne by the increased overhead of feeding back multiple reference amplitudes. Therefore, supporting quantization Alt 3 is not necessary. |
| Ericsson | 1.3 | Average and cell-edge UPT vs overhead | Evaluated the performance of the six combinations with and for three TRPs. For , only combinations #1 and #2 may be supported, while for , all 6 combinations of may be supported. |

Table 2 Additional inputs: issue 1

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| **Company** | **Input** |
| Mod V0 | **Please share your inputs on each of the issues and, if applicable, proposals in TABLE 1A** |
| Samsung | **Question 1.B**  In our Tdoc, we proposed to limit the range for the FD offset. In this case, Alt2 would be the best solution in terms of overhead. However, since the agreed version of Alt1 includes the full range for FD offset, the benefit of Alt2 is reduced. In addition, Alt3 doesn’t work since SCI (as mentioned) is layer-specific. Given the situation we are ok with Alt1 in principle. However, there is no need for using the resource ID as the criterion for fixed reference. Using   should suffice. No need to determine reference CSI-RS resource by the UE, since the precoder is the same regardless of reference CSI-RS resource index  . If Alt1 is revised as such, we are fine with Alt1.  **On Conclusion 1.C.2**: (**for clarification**) “On the Parameter Combination of Type-II codebook refinement for CJT mTRP, no additional configuration signalling for indicating the linkage is needed. …”  We agree that the conclusion is simply according to the existing agreements. BTW, the proposal numbering should be fixed. There are two conclusions in Issue 1.2 with duplicated numbering 1.C.2.  **Question 1.C.5**  Support Alt0.  **Proposal 1.D.3**  We prefer to follow the legacy framework, i.e., CBSR is always configured for each of the CSI-RS resources. We think configuring CBSR can be beneficial to handle interference in the CJT network, since mTRP capable of CJT operation can be aware of interfering links for its serving UEs. |
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### 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 | [112] **Agreement**  …   * X=2 and   + The 1st CQI is associated with the first/earliest slot of the CSI reporting window (slot *l*) and the first/earliest of the *N*4 **W**2 matrices, and   + The 2nd CQI is associated with the middle slot of the CSI reporting window (slot *l*+*WCSI*/2) and the (*N*4 /2)-th**W**2 matrix   + FFS: Whether/how to include CQI overhead reduction for X=2   **Proposal 2.A.2 (V1)**: For the Type-II codebook refinement for high/medium velocities, when a UE is configured with X=2 for CQI calculation and reporting, the 2nd CQI includes 4-bit wideband CQI and 2-bit sub-bands CQIs calculated independently from the 1st CQI  **Proposal 2.A.2 (V2)**: For the Type-II codebook refinement for high/medium velocities, when a UE is configured with X=2 for CQI calculation and reporting, the 2nd CQI includes [2]-bit wideband CQI and 2-bit sub-bands CQIs   * The 2nd (differential) wideband CQI is defined relative to the 1st wideband CQI, reusing the alphabet from the legacy 2-bit differential CQI table * The 2nd (differential) sub-band CQIs are calculated relative to the 2nd (differential) wideband CQI, reusing the alphabet from the legacy 2-bit differential CQI table   **FL Note**: This topic was discussed OFFLINE [1]   * From SLS results, it seems UPT vs overhead performance between v1 and v2 is almost none. At the same time v2 offers 2 bits 😊 of “overhead saving” | **Proposal 2.A.2**  **V1:**   * **Support/fine**: Samsung, NTT DOCOMO, ZTE, vivo, Spreadtrum, OPPO, Qualcomm, Intel, Xiaomi, Nokia/NSB, Fujitsu, Ericsson, IDC, CMCC, Sony, CATT, Sharp, Apple * **Serious concern**:   **V2:**   * **Support/fine**: MediaTek, Huawei/HiSi, Lenovo/MotM, Google, NEC, Fraunhofer IIS/HHI, LG * **Serious concern**: |
| 2.2 | [112bis-e] **Agreement**  For the Type-II codebook refinement for high/medium velocities, regarding the bitmap(s) for indicating the locations of the NZCs,   * When the UE is configured with Q=1: for each layer, one 2-dimensional bitmap of size-2LM reusing the legacy design is used * When the UE is configured with Q=2: for each layer,   + Basic feature: two 2-dimensional bitmaps, each of size-2LM reusing the legacy design for each of the two selected DD basis vectors, are used   + Optional feature, if the following down-selection succeeds: down-select from the following two alternatives in RAN#112bis-e:     - Alt3A: A single 2-dimensional bitmap of size to report the selected pairs of FD basis vector and DD basis vector and a single 2-dimensional bitmap of size for indicating the location of the NZCs, where each row corresponds to a selected SD basis vector and each column corresponds to one of the selected pairs of FD basis vector and DD basis vector.     - Alt4’: Q different bitmaps are supported for each layer, each of the Q bitmaps corresponds to DD basis q = 0 or 1.       * For each polarization, each of the Q bitmaps contains bits included in a set of SD basis and FD basis pairs , satisfying , where         + ,         + is the SD basis indicated by SCI         + Two polarizations have same set of in the bitmap   **FL Note**: | **Optional Q=2**   * **Alt3A**: Fraunhofer IIS/HHI * **Alt4’**: vivo |
| 2.3 | [112bis-e] **Agreement**  ….   * Select at most 3 additional Parameter Combinations from the list below  |  |  |  |  |  | | --- | --- | --- | --- | --- | |  |  | |  | **Companies’**  **views** | |  |  | | 2 | 1/8 | 1/16 | 1/4 | **Support/fine**:  **Not support**: | | 2 | 1/8 | 1/16 | 1/2 | **Support/fine**:  **Not support**: | | 2(\*) | ¼ | 1/8 | ¼ | **Support/fine**:  **Not support**: | | 2 (\*) | ¼ | 1/8 | ½ | **Support/fine**:  **Not support**: | | 4 | 1/8 | 1/16 | 1/4 | **Support/fine**:  **Not support**: | | 4 (\*) | ¼ | 1/8 | 1/4 | **Support/fine**:  **Not support**: |   (\*) Note: From legacy.  **Question 2.C**: Please share your view in the above table  **FL Note**: As suggested by vivo in ROUND 0, the most natural grouping would be Alt1 (legacy) with combos 3, 4, 6 vs Alt2 (new) with combos 1, 2, 5. | |
| 2.4 | [112bis-e] **Agreement**  On the Type-II codebook refinement for high/medium velocity, regarding CBSR, a single SD beam group restriction per legacy design is used from signalling perspective,   * FFS: Whether amplitude restriction is summed across FD bases for each DD basis, *or* summed across FD and DD bases, or applied per DD unit * FFS: Whether the legacy (optional) soft amplitude restriction is also supported or only hard amplitude restriction is supported   **Question 2.D**: Please share your view on the two FFS points | **Def of amplitude restriction:**   * **Per DD basis:** * **Summed across DD bases:**   **Hard-only vs soft amplitude restriction:**   * **Hard-only:** * **Hard + soft:** |
| 2.5 | **Proposal 2.E.1**: On the Type-II codebook refinement for high/medium velocities, regarding UCI omission, support reusing the legacy UCI omission mechanism with (Alt3) the following priority function: Prio(,l,m,q)=2L.RI.Mv.q + 2L.RI.P(m)+ RI.l +  where P(m) = m   * Note: This implies that DD basis is designated the least priority * FFS: Details on the location of the new UCI parameters in G0/1/2   **FL Note**: | **Proposal 2.E.1:**   * **Support/fine:** ZTE (P(m)=m), Spreadtrum, Fraunhofer IIS/HHI (P=m, S=q), Intel, Xiaomi, LG, Samsung, MediaTek, Qualcomm, Fujitsu, OPPO, Google, CATT, Ericsson, NTT DOCOMO, Nokia/NSB, CMCC, Huawei/HiSi, Apple * **Not support:** vivo, Lenovo/MotM, |

Table 3B Type II Doppler: summary of observation from SLS

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| **Company** | **SLS results** | | |
| **Issue #** | **Metric** | **Observation** |
| Issue # 2.1 | | | |
| Samsung | 2.1 | UPT vs overhead | There is no benefit with Alt1.2/1.3 (differential w.r.t. the 1st CQI) over Alt1.1 (independent of the 1st CQI) |
| Issue # 2.2 | | | |
| Huawei | 2.2 | UPT vs overhead | Alt.3A has better UPT vs. overhead tradeoff than Alt.1. |
| ZTE | UPT vs overhead | ***On Alt1 vs 4’***  In addition, we evaluate the performance on average UPT vs overhead between Alt1, Alt4\_1 based on d=3 and Alt4\_2 based on d=5 in Figure 2. Parameter combination is shown in Table2. There are some performance benefits in the case of low-overhead region in Figure 2. However, serious performance loss is observed in SLS on Alt4 both d=3 and d=5 in Figure 2 in high-overhead region.  ***On Alt3A***  For Alt3A, we have the concerns that Alt3A may violate previous agreements for “Q different two-dimensional bitmaps”, to some extent. Then, we provide SLS simulation in Figure 2 with Alt3A\_1 based on S = 0.5\*MQ and Alt3A\_2 based on S = 0.75\*MQ. It is observed that, with sufficient small parameter (e.g., S =0.5\*MQ) for reducing value of S, there are some performance benefits in the case of low CSI report overhead. |
| Vivo | UPT vs overhead | * Under Q=2 and legacy CB parameter combinations (pv, beta, L), Alt 4’ UPT-overhead curve outperforms Alt 1 and Alt 3A. * For lower overhead or ideal prediction, for each (pv, beta, L) configuration, Alt 4’ can save about 50 bits for each layer with nearly no performance loss. * The benefit from Alt 4’ in terms of performance is even clearer in high overhead and real prediction. Alt 4’ can address the issue of coefficient unreliability caused by prediction error. * Alt 3A does not provide better performance-overhead trade-off than Alt 1. |
| OPPO | UPT vs overhead | Alt3A can reduce 10% overall overhead without UPT loss. |
| Fraunhofer | UPT vs overhead | Alt 3A with results in feedback overhead saving of 48 bits, 160 bits and 84 bits for parameter combinations 1-4, 5 and 6, respectively, compared to Alt 1 with negligible loss in performance.  For Alt 3A, using S = 0.5MQ results in a similar average UPT to that of Alt 1 with large feedback overhead saving. |
| CATT | UPT vs overhead | The average throughput versus bitmap overhead is shown in Figure 1. Based on the simulation results, it is observed that Alt3A has negligible performance loss compared with Alt1 with less bitmap overhead. |
| Intel | UPT vs overhead | * Performance degradation of up to 0.8% in average UE throughput and up to 2% for cell-edge UE throughput is observed for Alt3A comparing to Alt1. * 48 bits can be saved for configurations with M = 4 and 84 bits for configuration with M = 7 for Alt3A comparing to Alt1 |
| Samsung | UPT vs overhead | * Alt3A and Alt1 are similar in UPT vs overhead trade-off for all of avg. UPT, 50% UPT, and 5% UPT. * For any (UPT, overhead) achieved by Alt3A, there is a similar (UPT, overhead) achieved by Alt1 * Alt4’ can improve UPT vs overhead trade-off |
| MediaTek | UPT vs overhead | NZC indication by Alt 3A can provide 50~60 bits overhead saving compared with Alt 1 with <1 % performance loss.  NZC indication by Alt 4 and D = 3 can achieve similar performance as Alt 1 without significant overhead saving.  NZC indication by Alt 4 and D = 2 degrades in performance especially at higher parameter combinations, due to forcing zero coefficients in certain SD, FD positions. |
| Qualcomm | Separate UPT, and overhead | For Type-II-Doppler, Alt1 2-stage (MQ+2LS)-bit bitmap (Alt3A) achieves similar average throughput as 2LMQ-bit 3D bitmap, while overall feedback overhead can be reduced by more than 10% (659 to 575 bits). |
| Ericsson | Separate UPT, and overhead | Bitmap alternative Alt1 with reporting of only non-empty DD bitmaps is close to Rel-16 Type-II implementation in complexity and is a simpler reporting format |
| Issue # 2.3 | | | |
| Huawei | 2.3 | UPT vs overhead | The following values paraComb achieves the best UPT vs overhead trade-off:   |  |  |  |  |  | | --- | --- | --- | --- | --- | | *paramCombination-Type II doppler* |  |  | |  | |  |  | | 1 | 2 | 1/8 | 1/16 | 1/2 | | 2 | 4 | 1/8 | 1/16 | 1/4 | | 3 | 4 | 1/8 | 1/16 | 1/2 | | 4 | 4 | 1/4 | 1/8 | 1/4 | | 5 | 4 | 1/4 | 1/8 | 1/2 | | 6 | 4 | 1/4 | 1/4 | 1/2 | | 7 | 6 | 1/4 | 1/8 | 1/2 | | 8 | 6 | 1/4 | 1/4 | 1/2 | |
| ZTE | UPT vs overhead | Based on SLS results, the following is proposed   |  |  |  |  | | --- | --- | --- | --- | |  |  | |  | |  |  | | 2 | 1/8 | 1/16 | 1/8 | | 2 | 1/8 | 1/16 | 1/4 | | 4 | 1/8 | 1/16 | 1/8 | | 4 | 1/8 | 1/16 | 1/4 | | 4 | 1/4 | 1/4 | 1/4 | | 4 | 1/4 | 1/4 | 1/2 | | 4 | 1/4 | 1/4 | 3/4 | | 4 | 1/2 | 1/2 | 1/2 | | 6 | 1/4 | 1/4 | 1/2 | | 6 | 1/4 | 1/4 | 3/4 | |
| OPPO | UPT vs overhead | We evaluated R16 and R17 parameter combination, where AP CSI-RS overhead is not considered. For R17 parameter combination, legacy parameter is good. For R16, we used and there is no any significant gain for large K0, which imply legacy parameter combination can be reused for N4 > 1 |
| CATT | UPT vs overhead | Based on our simulation results, we identified several Parameter Combinations that offer a good tradeoff between performance and overhead. As a result, we recommend using the Parameter Combinations outlined in Table 2    Table 2 Codebook parameter configurations for *L*, and   |  |  |  |  | | --- | --- | --- | --- | | *L* |  | |  | |  |  | | 2 | 1/8 | 1/16 | 1/4 | | 2 | 1/8 | 1/16 | 1/2 | | 4 | 1/8 | 1/16 | 1/4 | | 4 | 1/8 | 1/16 | 1/2 | | 4 | 1/4 | 1/8 | 1/2 | | 4 | 1/2 | 1/4 | 1/2 | | 6 | 1/8 | - | 1/2 | | 6 | 1/4 | - | 1/2 | |
| Intel | UPT vs overhead | * Parameter combinations {p1,2, beta} = {1/8, 1/4}, {1/8, 1/2}, {1/4, 1/2}, {1/4, 3/4} provide good performance/overhead tradeoff considering both average and cell-edge UE throughput |
| Nokia | UPT vs overhead | * For Type-II-Doppler, for average and cell-edge UPT gain over Rel-16 Type-II increase with overhead, for the same parameter combinations. * For Type-II-Doppler, cell-edge UPT gain over Rel-16 Type-II tend to be noticeably higher than average UPT gain. |
| Samsung | UPT vs overhead | Different (smaller) beta than legacy (beta=1/8)   * Smaller than legacy can be beneficial * Weak coefficients increase overhead, but don’t provide UPT gain (🡪 beta can be small) |

Table 4 Additional inputs: issue 2

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| --- | --- |
| **Company** | **Input** |
| Mod V0 | **Please share your inputs on each of the issues and, if applicable, proposals in TABLE 3A** |
| Samsung | P 2.A.2: support V1. V2 is worse than V1 in terms UPT vs overhead tradeoff, as shown in our contribution (copied below). Besides, the overhead saving tiny. We therefore can’t accept V2.  ***Observation 11****: there is no benefit with Alt1.2/1.3 (differential w.r.t. the 1st CQI) over Alt1.1 (independent of the 1st CQI)*  Figure 11  Issue 2.2   * We are open to discuss this scheme only in high overhead regime, with the condition that they don’t break precious agreement (which 3A does). * Besides, if this down-selection succeeds, we prefer to use existing optional feature such as paraComb with L=6, and not to introduce another optional UE capability.   Issue 2.3: support legacy combinations  Issue 2.4:   * the legacy restriction is on each SD beam, and is kind of avg. restriction since we sum over FD. The same principle can simply be extended, i.e., by summing over FD and DD. * Support legacy Hard+soft (optinal) restriction   P 2.E.1: support |
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### 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 | [112bis-e] **Working assumption:**  For the Rel-18 TRS-based TDCP reporting, for TDCP measurement and calculation,   * KTRS ≥1 TRS resource set(s) can be configured in the CSI reporting setting when ReportQuantity is ‘tdcp’   + Note: the TRS resource set(s) configured for TDCP report do not impact or impose any new requirements on the UE behavior when processing TRS used as QCL type A/D source for reception of PDxCH. * No further spec enhancement on TRS is supported * [All the TRS resources in the configured resource set(s) share the same RE locations] * FFS: Whether to add further restrictions on the TRS resource set(s) on, e.g. QCL relationship, power control, [RE location], slot offset between TRS resource set(s), relation with resource set used for legacy usage   **Question 3.A**: Please share your view on the bracketed text from Google | |
| 3.2 | [112bis-e] **Agreement**  For the Rel-18 TRS-based TDCP reporting, regarding the quantization of wideband normalized amplitude value,   * At least the following size-*Q* quantization alphabet is supported: where   + TBD: supported value(s) of *N* (e.g. or a larger value), *Q*, s (e.g. ½, ¼, 1/8, …), whether a center threshold is also supported (and if so, higher-layer configured) * FFS: Whether different schemes can be supported for different use cases   **Question 3.B**: Please share your views on the TBD points (N, Q, s, and whether a configurable center threshold should be supported)  **FL Note**: | |
| 3.3 | [112] **Agreement**  For aiding gNB determination of codebook switching and SRS periodicity with the Rel-18 TRS -based TDCP reporting, support reporting quantized wideband normalized amplitude/phase of the time-domain correlation profile with Y≥1 delay(s) as follows:   * Basic feature: Y=1 with delay≤ Dbasic symbols, only wideband quantized normalized amplitude is reported   + FFS: Candidate values for delay * Optional feature: Y=1 with delay>Dbasic symbols and Y≥1, wideband quantized normalized amplitude and phase for each delay are reported   + For Y>1, the phase can be configud to be absent for all the Y delays   + TBD: Whether the value of Y is configurable or following the delays from the configured TRS resource   + TBD: Candidate value(s) for Y>1 * FFS: Value of Dbasic   **Proposal 3.C.1:** For the Rel-18 TRS-based TDCP reporting, regarding the value of parameter Y, in addition to Y=1, support Y=2, 3, 4, [7]  **Proposal 3.C.2:** For the Rel-18 TRS-based TDCP reporting, support the following D (delay) values where Dbasic is equal to 2 slots   * 4 symbols, 1 slot, 2 slots, 3 slots, 4 slots, 5 slots, 6 slots, [10 slots] | **Proposal 3.C.1:**   * **Support/fine:** * **Not support:**   **Proposal 3.C.2:**   * **Support/fine:** * **Not support:** |
| 3.4 | **Proposal 3.D**: For the Rel-18 TRS-based TDCP reporting, regarding the value of parameter Y for Y>1, the value of Y is gNB-configured via higher-layer (RRC) signalling   * Note: whether value 0 can be reported for a given delay will be decided separately   **FL Note**: The note (albeit obvious and not precluded by any means – since this is related to the alphabet design in issue 3.2) was added per Samsung request | **Proposal 3.D:**   * **Support/fine:** Huawei/HiSi, ZTE, Google, vivo, Ericsson, NTT DOCOMO, Qualcomm, Spreadtrum, Nokia/NSB, CMCC, Ericsson, LG, Apple, Samsung * **Not support:** Lenovo/MotM, Xiaomi, |
| 3.5 | [112] **Agreement**  For the Rel-18 TRS-based TDCP reporting, the priority of the CSI report(s) associated with TDCP reporting is down-selected from the following alternatives:   * Alt1. Lower than other CSI reports * Alt2. Same as CSI report(s) not carrying L1-RSRP or L1-SINR * Alt3. Higher than other CSI reports * Other alternatives are not precluded   **Proposal 3.E**: For the Rel-18 TRS-based TDCP reporting, the priority of the CSI report(s) associated with TDCP reporting is lower than other CSI reports  **FL Note**: While Alt2 seems to result in the least spec effort, this may not work since TDCP is a stand-alone report and can collide with regular CSI reports and co-multiplexing isn’t always an available option. | **Proposal 3.E:**   * **Support/fine:** Samsung, Intel, ZTE, Ericsson, OPPO, Fujitsu, Google, Spreadtrum, Sony, Apple, NTT DOCOMO, Qualcomm, Nokia/NSB, CMCC, * **Not support (want Alt2, no spec impact: ”***Same as CSI report(s) not carrying L1-RSRP or L1-SINR***”):** vivo, Huawei/HiSi, Lenovo/MotM, Xiaomi, LG |

Table 5B TDCP: summary of observation from simulation

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| --- | --- | --- | --- |
| **Company** | **SLS results** | | |
| **Issue #** | **Metric** | **Observation** |
| ZTE | 3.2 | UPT vs speed,  use case = SRS periodicity | *Amplitude quantization scheme*  outperforms and with higher DL throughput in the use case of SRS periodicity determination.   1. 1   *Phase quantization scheme q1 outperforms q0 and q2 with higher throughput in the use case of SRS periodicity determination* |
| OPPO | 3.2 | SE vs UE speed, use case: T1/T2 CB switch | *Observation 2: The threshold of codebook switching is close to 1, and R16 amplitude is coarse for TDCP reporting.* |
| Xiaomi | 3.1 | Switching accuracy vs delay | *Observation 1: Two TRS resource sets with delay 5 slots can obtain better TDCP measurement.* |
| Nokia | 3.2 | UPT vs UE speed, use case: T1/T2 CB switch | By comparing the performance gains in 1ms delay scenario and 10ms delay scenario one can notice that codebook with N=41 shows best performance, while all other codebooks lead to preferring Type-II too often, what is explained by the fact that highest quantisation level is still is not high enough for 1ms delay correlation profile calculation. But in case of 10ms delay (see Figure 15) codebook with N=20 shows best performance, and N=41 shows very poor performance.    Performance degradation of Type-I/Type-II switching with noisy TDCP measurements does not increase for shorter delays. |
| Mavenir | 3.3 | Doppler spread vs UE speed | Observation 2. 20-slot delay has shown worse accuracy. Delay <= 5 slots can ensure the estimation for time variation of channel. 5-slot delay is better for smaller UE velocity (<=30km/h), whereas 1-slot delay is suitable in scenario of higher velocity. |
| Samsung | 3.2 | UPT vs UE speed, use case: T1/T2 CB switch | *For T1/T2 CB switch based on threshold = 0.86, and Y=1*   * *3-bit R16-based quantization is sufficient*   + *1-v^2 is the best at low speed (<=10kmph)*   + *1-v is good overall* * *4-bit/5-bit doesn’t offset any gain over 3-bit*   *Based on LLS evaluations,*   * *The BLER performance of un-quantized and 1st 8 levels from Rel-16 legacy 4-bit reference codebook is almost same*   *Based on LLS evaluations,*   * *The BLER performance with 16-PSK for phase quantization is least, provides close match with un-quantized performance* * *QPSK has highest BLER among 3 phase quantization methods.* |
| MediaTek |  | UPT vs speed, use case: T1/T2 CB switch | If are the quantization levels from E-Type amplitude quantization, then using for TDCP quantization offers better quantization performance compared to for TDCP values well below 1. |
| Ericsson | 3.1 | UPT vs UE speed, use case: T1/T2 CB switch | In Figure 15 ,we show the performance of time correlation-based switching between CSI Type I and CSI type II for 100MHz bandwidth for small correlation delays, without averaging over time and with averaging over ten consecutive measurement occasions. In both cases we see that there is a significant improvement in performance when averaging over time is done. |
| 3.2 | UPT vs UE speed, use case: T1/T2 CB switch | In the simulations in Figure 8 and Figure 9 we see the performance for the quantization schemes for s equal to ½, 1/3, ¼ and 1/8 for a correlation delay of 5 slots and 3 slots. We see that higher granularity (i.e. smaller s) gives better performance but the difference is small, less than one percent in throughput  …  Thus, we confirm that at least for the use case of CSI Type I - Type II switching, already the granularity is sufficient.  For TDCP amplitude, an upper limit of 0.995 for the quantization range needs to be considered. |
| 3.3 | UPT vs speed, use case: T1/T2 CB switch | For case with TRS colliding with PDSCH, a delay of 84 symbols gives the best performance at low SNRs.  For case with TRS colliding with PDSCH, a delay of 36 symbols gives good performance at medium to high SNRs.  For case with TRS colliding with TRS, a delay of 140 symbols is needed for good switching performance. |

Table 6 Additional inputs: issue 3

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| **Company** | **Input** |
| Mod V0 | **Please share your inputs on each of the issues and, if applicable, proposals in TABLE 5A** |
| Samsung | Q 3.A: it is still unclear; do we have such restrictions in legacy TRP resource set configurations?Also, are we talking about TRS resources in one or across multiple sets  Q3.B: we support   * N > 2^Q-1, which is needed for low speed or low delay values, as shown in our revised contributions. For example, N can be from {6, 8,12,16,20,24,28} depending on delay values. * Q=3 is sufficient for a target MSE = 0.1%, if N is chosen properly, as shown in our revised Tdoc (2303901). * s can be from this set [1/4, 1/3,1/2, 2/3, 3/4]. * We are open to discuss configurable center, and perhaps it can be merged with a configurable N value   3.C.1: support  P 3.D: support with Note the below   * Note: whether value 0 can be reported for a given delay will be decided separately (i.e., this proposal does not preclude 0 value for the amp) |
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# References

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| --- | --- | --- | --- |
| 1 | R1-2303113 | Summary of OFFLINE discussion on Rel-18 MIMO CSI | Moderator (Samsung) |
| 2 | R1-2302301 | Further Details on CSI for CJT and Medium/High UE Velocities | InterDigital, Inc. |
| 3 | R1-2302372 | CSI enhancement for coherent JT and mobility | Huawei, HiSilicon |
| 4 | R1-2302418 | CSI enhancement for high/medium UE velocities and CJT | ZTE |
| 5 | R1-2302471 | Further discussion on CSI enhancement for high-medium UE velocities and coherent JT | vivo |
| 6 | R1-2302534 | CSI enhancement for high/medium UE velocities and coherent JT | OPPO |
| 7 | R1-2302587 | Discussion on CSI enhancement for high/medium UE velocities and coherent JT | Spreadtrum Communications |
| 8 | R1-2302636 | CSI enhancements for medium UE velocities and coherent JT | Fraunhofer IIS |
| 9 | R1-2302682 | Discussion on CSI enhancement for high/medium UE velocities and coherent JT | CATT |
| 10 | R1-2302725 | Discussion of CSI enhancement for high speed UE and coherent JT | Lenovo |
| 11 | R1-2302782 | On CSI enhancements | Intel Corporation |
| 12 | R1-2302839 | Views on CSI enhancement for high/medium UE velocities and CJT | Sony |
| 13 | R1-2302901 | Discussion on Rel-18 MIMO CSI enhancement | Fujitsu |
| 14 | R1-2302961 | CSI enhancement for high/medium UE velocities and CJT | Xiaomi |
| 15 | R1-2303007 | CSI enhancement for high/medium UE velocities and CJT | Nokia, Nokia Shanghai Bell |
| 16 | R1-2303044 | On CSI Enhancement | Google |
| 17 | R1-2303070 | Potential CSI enhancement for high/medium UE velocities and coherent JT | LG Electronics |
| 18 | R1-2303084 | Discussion on CSI enhancement | Mavenir |
| 19 | R1-2303114 | Views on CSI enhancements | Samsung |
| 20 | R1-2303191 | CSI enhancement | Sharp |
| 21 | R1-2303218 | Discussion on CSI enhancement for high/medium UE velocities and CJT | CMCC |
| 22 | R1-2303328 | CSI Enhancements | MediaTek Inc. |
| 23 | R1-2303469 | Views on Rel-18 MIMO CSI enhancement | Apple |
| 24 | R1-2303575 | CSI enhancements for medium UE velocities and Coherent-JT | Qualcomm Incorporated |
| 25 | R1-2303650 | Views on CSI Enhancements for CJT | AT&T |
| 26 | R1-2303677 | Discussion on CSI enhancement | NEC |
| 27 | R1-2303699 | Discussion on CSI enhancement | NTT DOCOMO, INC. |
| 28 | R1-2303783 | On CSI enhancements for Rel-18 NR MIMO evolution | Ericsson |
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