**3GPP TSG RAN WG1 #112bis-e R1-2303112**

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

**Agenda item:** 9.1.2

**Source:** Moderator (Samsung)

**Title:** Moderator Summary on Rel-18 CSI enhancements

**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
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## Summary of companies’ views

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

Table 1A Summary: issue 1

|  |  |  |
| --- | --- | --- |
| **#** | **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, AT&T, Nokia/NSB, Ericsson, Sharp, Google, Sony, **Not support (want to confirm WA)**: ZTE, Spreadtrum, CATT, LG, Huawei/HiSi, Lenovo, Fujitsu, NEC, Xiaomi,  |
| 1.2 | **Agreement** On the Type-II codebook refinement for CJT mTRP, *for mode-1*, down select (in RAN1#112) only one from the following schemes* Alt1. 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.
	+ Example formulation: $W\_{f,n}=diag(\left[1 e^{j\frac{2π}{N\_{3}}φ\_{n}}…. e^{j\frac{2π}{N\_{3}}(N\_{3}-1)φ\_{n}}\right]^{})W\_{f}$ where $φ\_{n}$ is the FD basis selection offset for CSI-RS resource *n* relative to a reference CSI-RS resource $\tilde{n}$ with $φ\_{\tilde{n}}=0$, and $W\_{f}$ is commonly selected across N CSI-RS resources
* Alt2. $W\_{f,n}$ independently selected across N CSI-RS resources (without any per-CSI-RS-resource FD basis selection offset)

For all the above alternatives, the legacy FD basis selection indication scheme is applied on each selected FD basis.Note: Per previous agreements, the number of selected FD basis vectors (Mv/pv or M) is gNB-configured via higher-layer signaling and common across the N CSI-RS resources**Proposal 1.B.1**: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) $W\_{f,n}=diag(\left[1 e^{j\frac{2π}{N\_{3}}φ\_{n}}…. e^{j\frac{2π}{N\_{3}}(N\_{3}-1)φ\_{n}}\right]^{})W\_{f}$ where: * $W\_{f}$ is commonly selected across *N* CSI-RS resources
* $φ\_{n}$ is the layer-common FD basis selection offset for CSI-RS resource *n* relative to a layer-common reference CSI-RS resource $\tilde{n}$ with $φ\_{\tilde{n}}=0$
	+ Therefore, (*N* – 1) FD basis selection offset values $\left\{φ\_{n}\right\}\_{n\ne \tilde{n}}$ are reported
	+ Basic feature: $φ\_{n}\in \left\{0,1,2,…,N\_{3}-1\right\}$
	+ Optional feature: $φ\_{n}\in \left\{0,\frac{1}{4},\frac{1}{2}…,N\_{3}-\frac{1}{4}\right\}$
* FFS: UCI design details, details on $\tilde{n}$

**FL Note**: This proposal has been discussed for 5 meetings. To break the stalemate between Alt1 and Alt2 for mode-1 advertised for inter-site CJT where ideal sync/backhaul is nowhere attainable (which is true): * Based on the presented results, it is observed by the FL that the 2 alternatives perform closely to each other in UPT vs overhead even for inter-site CJT.
* Adding the optional feature (fractional offset with o4x oversampling) is an attempt to maximize the commonality with mode-2 while giving more freedom on FD basis selection from Alt2 (a further compromise between Alt1 and Alt2 – **acceptable to the main proponents of Alt2**)
 | **Proposal 1.B.1:*** **Support/fine:** Huawei/HiSi, ZTE, Nokia/NSB, Ericsson, IDC, Samsung, Intel, Sony, Fujitsu, Apple, AT&T, NTT DOCOMO, [vivo], [MediaTek], [Qualcomm],
* **Not support**:

 |
| 1.3 | [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

**Proposal 1.C.1**: On the Parameter Combination of Type-II codebook refinement for CJT mTRP, only the following linkages are supported (marked ‘x’)* For *NTRP* =1,
	+ For Rel-16 eType-II based: 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
	+ For Rel-17 FeType-II based, fully reuse the eight Parameter Combinations from Rel-16 eType-II
* For *NTRP* >1, only the following linkages are supported (marked ‘x’)

|  |  |  |
| --- | --- | --- |
| **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, 1/4, 1/8, 1/8}, ¼  | {1/4, 1/4, 1/8, 1/8}, ½  | {1/4, 1/4, 1/4, 1/4}, ¾  | {1/2, 1/2, 1/2, 1/2}, ½  |
| 1 | 2 |  |  | x | x |  |  |
| 4 |  |  | x  | x | x |  |
| 6 w/ restriction |  |  |  | x | x |  |
| 2 | {2,2} | x |  |  |  |  |   |
| {2,4}{4,2} | x |  |  |  |  |    |
| {4,4} |  | x |   | x |  | x |
| 3 | {2,2,2} | x | x |  |  |  |   |
| {2,2,4} {2,4,2}{4,2,2} | x | x |     |  |  |     |
| {4,4,4} | x | x |  x | x | x | x |
| 4 | {2,2,2,2} | x |  |  |  |  | N/A |
| {2,2,2,4}  | x |  |  |  |  | N/A |
| {2,2,4,4}  |   |  |   | x | x | N/A |
| {4,4,4,4} |   | x |   |  x | x | N/A |

**Proposal 1.C.1**:* **Support/fine:** ZTE, Samsung, vivo, Huawei/HiSi, Ericsson, Nokia/NSB, AT&T, NTT DOCOMO,
* **Not support**:

**FL Note**: This proposal was discussed offline [1]. Below is the summary for companies who provided SLS results

|  |  |  |
| --- | --- | --- |
| **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, 1/4, 1/8, 1/8}, ¼  | {1/4, 1/4, 1/8, 1/8}, ½  | {1/4, 1/4, 1/4, 1/4}, ¾  | {1/2, 1/2, 1/2, 1/2}, ½  |
| 2 | {2,2} | SS, HW |  ZTE |   | ZTE  |   |   |
| {2,4}{4,2} | SS, HW | HW   |    |    |  HW |    |
| {4,4} | SS | SS, ZTE,HW |   | SS, ZTE,HW | SS | SS, ZTE, HW |
| 3 | {2,2,2} | SS, HW, Ericsson, Nokia |  ZTE, Ericsson, Nokia |   |  ZTE | ZTE  |   |
| {2,2,4} {2,4,2}{4,2,2} | SS, HW | SS,HW, Nokia | Nokia    |  HW, Nokia |  HW  |   Nokia  |
| {4,4,4} | SS, Ericsson, Nokia | SS, ZTE, HW |  Ericsson, Nokia | SS, ZTE, HW, Ericsson | SS, HW, Ericsson | SS, ZTE, Ericsson |
| 4 | {2,2,2,2} | SS, ZTE, HW | ZTE  |   | ZTE  |   | N/A |
| {2,2,2,4}  | SS, HW | HW  |   | SS | SS | N/A |
| {2,2,4,4}  |   | SS |  HW | SS, HW | SS, HW | N/A |
| {4,4,4,4} |   | SS, ZTE |   |  ZTE, HW | SS, ZTE | N/A |

 |
| [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**Please share your view on adding another SD combination which includes at least one Ln=6.** * **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]

**FL Note**: This was discussed offline [1].  |
| 1.4 | [112] **Agreement**On the Type-II codebook refinement for CJT mTRP, regarding CBSR, at least for restricting SD basis selection, the legacy CBSR scheme is fully reused for each of the RRC-configured NTRP CSI-RS resources (resulting in CSI-RS-resource-specific SD beam group restriction)* FFS: Whether amplitude restriction is CSI-RS-resource-common or specific, and soft vs hard restriction
* FFS: Whether CBSR can be configured to be off for a CSI-RS resource

The same rank restriction is applied across NTRP CSI-RS resources**Amplitude restriction:*** **Resource-common:** Apple**,** NTT DOCOMO, MediaTek
* **Resource-specific:** Huawei/HiSi, Spreadtrum, Xiaomi,

**Amplitude restriction:*** **Soft (optional per legacy):** Huawei/HiSi, Lenovo/MotM, Samsung, MediaTek (2nd), NEC
* **Hard--only:** vivo, Intel, Xiaomi, Apple, Qualcomm, Ericsson, MediaTek (1st)

**No CBSR config option per resource?*** **Yes:** Huawei/HiSi, NEC,
* **No:**
 |
| 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)=($ \sum\_{k=0}^{n-1}2L\_{k}$) .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 $\sum\_{k=0}^{n-1}2L\_{k}+l\_{n}$, i.e., SD basis index over all resources: Prio(,l,m,n) = 2Ltot.RI.P(m)+ RI.$\sum\_{k=0}^{n-1}2L\_{k}$+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 $\sum\_{k=0}^{n-1}2L\_{k}+l\_{n}$, i.e., SD basis index over all resources: Prio(,l,m,n) = 2Ltot.RI.P(m)+ RI.$\sum\_{k=0}^{n-1}2L\_{k}$+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)

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 (also Alt2),
* **Not support (want Alt2)**: Huawei/HiSi, OPPO, Spreadtrum, CATT, Lenovo/MotM, Fujitsu, CMCC, Qualcomm,
 |
| 1.6 | Next-level (pre-maintenance) details:* Additional restrictions to K>1 CSI-RS resources (CMR), e.g. same slot, same RBs, adjacent slots, same DRX active window
* Interference measurement (IMR) assumption for CSI calculation: one or multiple IMRs
* PDSCH EPRE assumption for CQI calculation (which CSI-RS resource)
* CPU allocation
* Necessary of port indexing across CSI-RS resources
* Configuration of (N1,N2) relative to per-resource CBSR (can be handled by RAN2, alternatively)
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Table 1B Type II CJT: summary of observation from SLS

|  |  |
| --- | --- |
| **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). |
| 1.2 | Mean UPT gain vs overhead,5% UPT gain vs overhead, | Observation 2: Regarding Alt1 for mode1, layer-specific FD offset with oversampling (over sampling factor 4) outperforms that w/o oversampling with 2~3% edge UPT gain, which has similar performance to Alt2. Observation 3: Layer-specific offset (oversampling factor 4) has ~1% mean UPT gain and 3~5% edge UPT gain compared to layer-common offset (oversampling factor 4).Observation 4: Both Alt2 and Alt 1 with layer-specific and oversampled FD offset outperforms mode2 (TRP-common Wf) with 2~3% mean UPT gain and 8~12% edge UPT gain. |
| 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. |
| Others (Rel-17 ParaComb) | Mean UPT gain vs overhead | As shown in Figure 7 for NTRP=3, it can be observed that {1, 1, 1} can be replaced by {1/2, 1, 1} and {1/2, 3/4, 1} to achieve better performance. For NTRP=4 in Figure 8, {3/4,1,1,1} and {1/2, 1/2,3/4,1} outperforms {1,1,1,1} and {1/2, 1/2, 1/2, 1} respectively at performance-overhead trade-off.  |
| Others (Rx info) | Mean UPT gain vs overhead,5% UPT gain vs overhead, | Observation 11: The full channel feedback for CJT codebook by per-RX reporting can provide 5~10% gain for mean UPT and 18~35% gain for 5% UPT respectively.  |
| 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. |
| 1.2 | Avg UPT gain vs overhead | In the case of TRP-common q3 for both, the average and cell-edge UPT gains of Alt2 over Alt1 can be observed while considering report overhead. While introducing TRP-specific q3 (fractional) for Alt1, there are some performance gains and then performance gap over Alt2 can be reduced.  |
| 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. |
| 1.2 | SE gain vs overhead | Alt 1 has slightly lower performance compared to Alt2, especially in the high-payload region.Performance difference among the alternatives is small.Layer-common Alt 1 has slightly lower performance compared to layer-specific Alt 1.No considerable performance gain can be observed by introducing O3 for Alt 1 Wf selection in Mode 1. |
| Others (on R) | SE gain vs overhead | Some performance gains can be obtained for a larger *R*. However, there is a large increase on PMI payload as well. The performance-overhead curve of R=4 is not superior over R=2. |
| Fraunhofer IIS/HHI | 1.2 | Throughput gain and overhead | For inter-site scenarios, as the FD bases of the cooperating TRPs are not identical, selecting independent FD basis for all TRPs as in Alt 2 results in a best throughput-overhead trade-off compared to Alt 1. |
| Nokia/NSB | 1.2 | Throughput gain | In terms of throughput performance, Alt 1 shows about 1.3% and 3.5% gain in mean and cell edge throughput, respectively, over Alt 2, when using integer offsets, *i.e.*, no oversampling. This gain increases significantly with fractional offsets, *i.e.*, with oversampling, and is about 19% and 47% in mean and cell edge throughput, respectively, with an oversampling factor $O\_{4}=4$.  |
| 1.3 | Average UPT gain vs mean overhead | We observe that for $N\_{TRP}=2,3,4$, the combination(s) with a single $L\_{n}=4$ achieves most of the UPT gain of the combination with $\{L\_{n}=4$,$ n=0,1,…,N\_{TRP}-1\}$, but with smaller overhead and complexity.For $N\_{TRP}=1$, we note that, with 16 ports per TRP, the combinations with $L=6$ achieve similar UPT-overhead trade-off as with $L=4$. Therefore, we propose to keep the same restrictions and supported combinations as for Rel16, with $L=6$ 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. |
| 1.2 | Average UPT gain vs overhead | Mode 1 with Alt 2 per-TRP SVD (the advocated lower complexity benefit for Alt2) incurs ~4% UPT loss (for the same PMI overhead) over Mode 2. Overall, Mode 2 and Mode 1 with Alt 1 and Alt 2 using joint-SVD operation yield similar performance. Mode 1 with Alt 2 needs additional UE processing to find per-TRP FD basis vectors for the case of joint-SVD operation, compared to Mode 2 or Mode 1 with Alt 1 – thereby resulting in higher UE complexity.With TRP-common $q\_{3}$, Mode 1 Alt1 performs slightly better than Alt2, and Mode 1 Alt 1 and Mode 2 perform similarly. With TRP-specific $q\_{3}$ (additional spec impact to be needed), the performance of the both Mode 1 Alt1 and Alt2 can be improved and they yield a small gain (~2% average UPT gain) over Mode 2. Regardless, Mode1 Alt1 and Alt2 perform similarly.  |
| 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. |
| 1.2 | Average UPT gain vs overhead | FD bases selection Alt 1 does not provide any performance benefit over Mode 2 at low to medium ISDs but provides 2~3 % average UPT gain at high ISD scenarios.FD bases selection Alt 2 does not provide any performance benefit over Alt 1 at low to medium ISDs but provides 1~2 % average UPT gain at high ISD scenarios. |
| Ericsson | 1.2 | Average and cell-edge UPT vs overhead | The performance of Alt 1 depends on the oversampling factor $O\_{3}$ for $φ\_{n}$. In general, Alt.1 with $O\_{3}=4$ provides higher throughput comparing to Alt 2. Also, the throughput difference between Alt 1 with $O\_{3}=1$ and Alt 2 is quite small (~0-2%), except for $L\_{n}=2$ where the difference at cell edge can be slightly larger. Given that Alt 1 has a lower overhead and lower specification impact, Alt 1 is preferred. In addition, *Alt.1 with* $O\_{3}=4$ seems to provide better performance gain |
| 1.3 | Average and cell-edge UPT vs overhead | Evaluated the performance of the six combinations with $\left\{L\_{n}\right\}=\left\{2,2,2\right\}$ and $\left\{4,4,4\right\}$ for three TRPs. For $\{L\_{n}\}=\{2,2,2\}$, only $\{p\_{v}, β\}$ combinations #1 and #2 may be supported, while for $L\_{n}=4$, all 6 combinations of $\left\{p\_{v}, β\right\}$ may be supported.  |

Table 2 Additional inputs: issue 1

|  |  |
| --- | --- |
| **Company** | **Input** |
| Mod V0 | **Please share your inputs on each of the issues and, if applicable, proposals in TABLE 1A** |
| Mod V3 | Small update on 1.C.1 based on offline input from Nokia and Samsung |
| Samsung | **Proposal 1.B.1**We can be OK with the proposal. On more detail aspect for the range of $φ\_{n}$:In our view, a subset of the alphabet (e.g. a window) should be sufficient, since the delay difference across TRPs favorable for CJT operation should not be large. This can be beneficial because the size of alphabet can be reduced (implying overhead can be reduced) especially when $N\_{3}$ is large. Furthermore, for the case of Rel-17 based CJT codebook, the gNB performs beamforming (for delay compensation or channel shortening) on CSI-RS ports, where the beamforming can be designed to compensate for delay difference across TRPs assuming FDD partial reciprocity. In this case, the window size can be very small (e.g. around 4).**Proposal 1.C.1**Support. We have serious concern on including $L\_{n}=6$ for $N\_{TRP}>1$ due to 1) the high UE processing complexity, and 2) worse performance than other combination using $L\_{n}=\{2,4\}$ under a same Ltot constraint that we have observed in our SLS results.**Proposal 1.E.1**Support. No need to over-optimize for UCI omission that rarely happens, with a complicated solution such as Alt 2, which even performs worse than Alt 3 in our SLS evaluations.  |
| Mod V7 | **No change** |
| MediaTek | **Proposal 1.B.1**:We support the basic feature proposed in FL Proposal 1.B.1. We do not believe the optional feature of reporting fractional FD basis selection offset, i.e., $φ\_{n}\in \left\{0,\frac{1}{4},\frac{1}{2}…,N\_{3}-\frac{1}{4}\right\}$. The issues we see with reporting reporting fractional FD basis selection offset are two-fold, 1) the significant UE computational complexity it introduces and 2) the reporting overhead needed, this is while the performance benefits of this feature seem to be limited. However, we are open to discussions if the companies in favor of this optional feature can help clarify how the two main issues raised here can be addressed specifically for larger $N\_{3}$ values can be addressed.**Proposal 1.C.1**:Support.Similar to Samsung we have strong concern on introducing $L\_{n}=6$ for $N\_{TRP}>1$ mainly due to the high UE processing complexity.**Proposal 1.E.1:**Fine, even though our first preference is Alt 1 we are fine with supporting Alt 3. |
| Huawei, HiSilicon | Many thanks for the proposals and discussion on Rel-16 parameter combinations.For rel-17 parameter combinations, the following is proposed for companies’ checking.* For combinations {M, beta}, it is proposed to reuse the legacy as below, with restriction on M=2.

|  |  |  |
| --- | --- | --- |
| **M** | **** |  |
| 1 | 1/2  |  |
| 3/4 |  |
| 1 |  |
| 2 | 1/2  | N\_trp<=3, N\_L=1 |
| 3/4  | N\_trp<=3, N\_L=1 |

* For {alpha\_n} combinations, to simply the discussion, regarding the following FFS, it’s proposed to derive the {alpha\_n} combinations from Rel-16 {Ln} combinations we have agreed.

*FFS (by RAN1#112bis-e): Whether/how the supported combinations of {n} for Rel-17-based refinement are derived from the supported combinations of {Ln} for Rel-16-based refinement* Proposal: Alpha\_n combinations for $N\_{TRP}\in \{2,3,4\}$ are derived from the Ln combinations for Rel-16 based refinement, where each entry in the combination is the nearest value of min{1, 2Ln/Pcsi-rs} to {1/2, ¾, 1}, $P\_{CSI-RS}\in \{4,8,12,16,24,32\}$.* + Note: no other dependency of combinations is introduced, such as dependency on Pcsi-rs.
	+ FFS: pruning on combinations
 |

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

Table 3A Summary: issue 2

|  |  |  |
| --- | --- | --- |
| **#** | **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.1**: 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 is located in UCI part 2**Proposal 2.A.2**: 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.3**: For the Type-II codebook refinement for high/medium velocities, when WCSI>1, if a UE supports X=2 for CQI calculation, the value of X (either 1 or 2) is gNB-configured via higher-layer (RRC) signalling **FL Note**: This topic was discussed OFFLINE [1]* 2.A.1: based on legacy approach for 2nd CQI
* 2.A.2: SLS results show performance loss with fully differential CQI. Differential wideband CQI on the other hand only offers 1-4bit saving which is negligible.
* 2.A.3: implied but need an agreement to ratify
 | **Proposal 2.A.1:*** **Support/fine**: Samsung, NTT DOCOMO, vivo, Spreadtrum, OPPO, Intel, Xiaomi, CATT, Nokia/NSB, Fujitsu, ZTE, Ericsson, CMCC, Sony, Sharp, NEC,
* **Not support**:

**Proposal 2.A.2:*** **Support/fine**: Samsung, NTT DOCOMO, ZTE, MediaTek, Fraunhofer IIS/HHI, LG, vivo, Spreadtrum, OPPO, Qualcomm, Intel, Xiaomi, Nokia/NSB, Fujitsu, Ericsson, IDC, CMCC, Lenovo, Sony, CATT, Sharp, Apple
* **Not support**:

**Proposal 2.A.3:*** **Support/fine**: Samsung
* **Not support**:
 |
| 2.2 | [112] **Agreement**For the Type-II codebook refinement for high/medium velocities, regarding the bitmap(s) for indicating the locations of the NZCs, down-select one from the following alternatives (no later than RAN1#112bis-e): * Alt1. *Q* different 2-dimensional bitmaps where each bitmap reuses the legacy design i.e. the size of the bitmap for each selected DD basis vector is 2*LMv*
* Alt3A: A single 2-dimensional bitmap of size $MQ$ to report the selected $S$ pairs of FD basis vector and DD basis vector and a single 2-dimensional bitmap of size $2LS$ 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 $S$ pairs of FD basis vector and DD basis vector.
* Alt4. A bitmap that includes bits associated with the set of {($f\_{1}$, $s\_{1}$,$ t\_{1}$)} with $d(f\_{1}, s\_{1}, t\_{1})<=d$, where $d$ is the threshold that can be configured by gNB, $d\left(f\_{1}, s\_{1},t\_{1}\right)= min\left(\left|f\_{1}-f\_{0}\right|, M\_{v}-\left|f\_{1}-f\_{0}\right|\right)+ min\left(\left|s\_{1}-s\_{0}\right|, L – \left|s\_{1}-s\_{0}\right|\right)+ min\left(\left|t\_{1}-t\_{0}\right|, Q – \left|t\_{1}-t\_{0}\right|\right).$ $s\_{0}$, $f\_{0}$ and $t\_{0}$ denotes a reference SD basis index and a reference FD basis index and a reference DD basis index associated with SCI, respectively.

Nokia/NSB, Samsung, vivo, and ZTE raised concerns that, in their understanding, Alt3A violates previous agreements for “Q different two-dimensional bitmaps” and/or common DD basis selection across SD/FD basis pairs and hence, to some extent, objective 1 of the WID.[112] **Agreement**For the Type-II codebook refinement for high/medium velocities, regarding the down-selection of bitmap(s) for indicating the locations of the NZCs (in RAN1#112bis-e), the following is used as a guidance for evaluation: * Following the agreed EVM, use “UPT vs. overall overhead (including CQI and PMI)” to compare across alternatives, assuming *at least* FTP1 traffic model and Rel-16 Parameter Combinations (L, beta, pv)
* Use only the supported codebook parameter values (e.g. Q, K, m, d, delta, N4)
* Companies are to state their assumptions on UE-side prediction (e.g. ideal or realistic, CSI-RS type, CSI-RS overhead calculation in relation to UPT, assumptions on *WCSI* and *l*) and the use of rank adaptation

**Proposal 2.B.1:** 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 (for higher CSI overhead, FFS: definition), 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 $MQ$ to report the selected $S$ pairs of FD basis vector and DD basis vector and a single 2-dimensional bitmap of size $2LS$ 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 $S$ 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 $\{(s, f)\}$, satisfying $min(f,M\_{v}-f)+ min(|s-s\_{ref} |, L-|s-s\_{ref} |)\leq D$, where
				+ $s\in \left\{0,…,L-1\right\}$, $f\in \left\{0,…,M-1\right\}$
				+ $s\_{ref}\in \{0,…,L-1\}$ is the SD basis indicated by SCI
				+ Two polarizations have same set of $\{(s, f)\}$ in the bitmap

**FL Note**: This topic was discussed OFFLINE [1]. At least one Alt3A proponent argues that Alt4’ is different from the agreed description of Alt4, hence violating a previous agreement. Likewise, at least 3 companies argue that Alt3A violates previous agreement on “Q 2D bitmaps”. Regardless, the majority view is Alt1.  | **Proposal 2.B.1:*** **Support/fine**: ZTE, vivo, Huawei/HiSi, NTT DOCOMO, Spreadtrum, Fujitsu, Nokia/NSB, Samsung, CMCC, MediaTek, Apple, Qualcomm, Ericsson,
* **Not support**:
 |
| 2.3 | [112] **Conclusion**On the Parameter Combination of Type-II codebook refinement for high/medium velocities, there is no consensus on including another non-UCI Doppler codebook parameter as a variable in the list of supported Parameter Combinations.* Note: This implies that other non-UCI Doppler codebook parameters will be a part of RRC configuration (either explicit or implicit)

**Proposal 2.C.1**: For the Type-II codebook refinement for high/medium velocities based on Rel-16 eType-II regular codebook and Rel-17 FeType-II port selection codebook, the following Parameter Combinations are supported for *L*=4 and 6.

|  |  |  |
| --- | --- | --- |
| $$L$$ | $$p\_{υ}$$ | $$β$$ |
| $$υ \in \left\{1,2\right\}$$ | $$υ \in \left\{3,4\right\}$$ |
| 2 | 1/8 | 1/16 | 1/4 |
| 2 | 1/8 | 1/16 | 1/2 |
| 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  |
| 6 (\*) | 1/4 | -- | 1/2  |
| 6 (\*) | 1/4  | 1--  | 3/4  |

(\*) Note: From legacy. For L=6, the same restriction as legacy applies**FL Note**: Since the legacy framework is used for Parameter Combination and Q=2 is the only supported value, it seems reasonable to fully reuse the legacy Parameter Combinations. However companies show that replacing some legacy combinations with new ones (lower pv and beta) yield better performance. The proposals are based on the SLS from Huawei, ZTE, CATT, Intel, Nokia, and (to some extent) Samsung  | **Support/fine:** Huawei/HiSi, vivo, ZTE, OPPO, CATT, MediaTek, **Not support:** Samsung (legacy only), |
| 2.4 | [110bis-e] **Agreement**For the Rel-18 Type-II codebook refinement for high/medium velocities, support the following codebook structure where N4 is gNB-configured via higher-layer signaling:* For N4=1, Doppler-domain basis is the identity (no Doppler-domain compression) reusing the legacy$W\_{1}$*,* $\tilde{W}\_{2}$*,* and$W\_{f}$*, e.g.* $W\_{1}\tilde{W}\_{2}(W\_{f})^{H}$
* For N4>1, Doppler-domain orthogonal DFT basis commonly selected for all SD/FD bases reusing the legacy$W\_{1}$and$W\_{f}$*,* e.g.$W\_{1}\tilde{W}\_{2}\left(W\_{f}⨂W\_{d}\right)^{H}$
	+ Only Q (denoting the number of selected DD basis vectors) >1 is allowed
	+ TBD (by RAN1#110bis): whether rotation is used or not
	+ FFS: identical or different rotation factors for different SD components
	+ FFS: Whether *Q* is RRC-configured or reported by the UE

Note: Detailed designs for SD/FD bases including the associated UCI parameters follow the legacy specificationFFS: Whether one CSI reporting instance includes multiple $W\_{2}$ and a single $W\_{1}$ and $W\_{f}$ report.**Proposal 2.D.1**: On the Type-II codebook refinement for high/medium velocity, regarding CBSR, the legacy CBSR scheme is *fully reused* where a single CBSR configuration applies to all the Q DD bases (resulting in common SD beam group restriction for all DD bases), * FFS: Whether amplitude restriction is summed across FD bases for each DD basis, *or* summed across FD and DD bases

Note: This implies that the legacy soft amplitude restriction is reused**FL Note**: There seems to be no reason to use DD-basis-specific CBSR since DD basis is commonly selected for all SD/FD bases | **Support/fine**: Huawei/HiSi, Spreadtrum, Xiaomi, Samsung, **Not support**: |
| 2.5 | [112] **Agreement**On the Type-II codebook refinement for high/medium velocities, regarding UCI omission, down-select between the following three alternatives (by RAN1#112bis-e where q denotes the q-th DD basis vector):* Alt1. Prio(,l,m,q)=2L. Q.RI.P(m)+Q.RI.l+Q.q
	+ Note: This implies that DD basis is designated the highest priority
* Alt2. Prio(,l,m,q)=2L.S(q).RI.N3+2L.RI. P(m)+RI.l+
	+ Note: This implies that DD basis is designated the **lower priority** (after FD basis)
	+ FFS: S(q) maps the index q according to a rule
* Alt3. Prio(,l,m,q)=2L.RI.Mv.q + 2L.RI.P(m)+ RI.l + 
	+ Note: This implies that DD basis is designated the **least priority**
* Alt4. Prio(,l,m,q)=2L.P(m).RI.Q+2L.RI.S(q)+RI.l+
	+ Note: This implies that DD basis is designated with lower priority (after SD basis) and higher priority (before FD basis)
	+ FFS: S(q) maps the index q according to a rule

FFS: FD permutation P(.) as Rel-16-analogous, or no permutation i.e. P(m)=mq=0,…,Q-1**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), Lenovo/MotM, Intel, Xiaomi, LG, Samsung, MediaTek, Qualcomm
* **Not support:**

**Alt1:** IDC, Xiaomi, Nokia/NSB, CMCC, NEC**Alt2:** Huawei/HiSi, OPPO,Fraunhofer IIS/HHI (P=m), CATT (S=q)**Alt3:** ZTE (P(m)=m), Spreadtrum, Fraunhofer IIS/HHI (P=m, S=q), Lenovo/MotM, Intel, Xiaomi, LG, Samsung, MediaTek, Qualcomm, **Alt4:** vivo, Xiaomi,NEC |
| 2.6 | Next-level (pre-maintenance) details:* PDSCH EPRE assumption for CQI calculation (relative to which CSI-RS, UE assuming one Pc)
* Additional restrictions on NZP CSI-RS resources
* CPU allocation (one for each or all CSI-RS resources)
* Whether to support 2-stage PDCCH triggering (CSI-RS then CSI) for Type-II Doppler
 |

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

|  |  |
| --- | --- |
| **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 $S=0.5MQ$ 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* | $$L$$ | $$p\_{υ}$$ | $$β$$ |
| $$υ \in \left\{1,2\right\}$$ | $$υ \in \left\{3,4\right\}$$ |
| 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

|  |  |  |
| --- | --- | --- |
| $$L$$ | $$p\_{υ}$$ | $$β$$ |
| $$υ \in \left\{1,2\right\}$$ | $$υ \in \left\{3,4\right\}$$ |
| 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 $K0=β2LM$ 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 2Table 2 Codebook parameter configurations for *L*, $β$ and $p\_{v}$

|  |  |  |
| --- | --- | --- |
| *L* | $$p\_{v}$$ | $$β$$ |
| $$v\in \{1,2\}$$ | $$v\in \{3,4\}$$ |
| 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 $β$ 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

|  |  |
| --- | --- |
| **Company** | **Input** |
| Mod V0 | **Please share your inputs on each of the issues and, if applicable, proposals in TABLE 3A** |
| ZTE | **Issue 2.3**FYI, our contribution R1-2303893 is uploaded in revision of R1-2302418 for AI 9.1.2 CSI. To be more specific, in Section 2.1.7, we provide further evaluation results and recommended parameter combination for Rel-16 regular eType-II codebook on the Type-II codebook refinement for high/medium velocities.In our updated contribution R1-2303893, we have the following results and proposed combination. In short, we prefer to update the legacy CSI parameter combination(s) accordingly. Then, if having Pv~{1/8,1/16}, {1/2,1/2} and more cases of L=6, directly approving the reuse of legacy table may be too rush. So, as what we did for CJT, we prefer to review the candidate parameter combination (especially for the case that the number of DD-basis = 2). Regarding parameter combination selection for the Type-II codebook refinement for high/medium velocities, the following entries should be supported.

|  |  |  |
| --- | --- | --- |
| $$L$$ | $$p\_{υ}$$ | $$β$$ |
| $$υ \in \left\{1,2\right\}$$ | $$υ \in \left\{3,4\right\}$$ |
| 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  |

[Mod: Thanks for providing SLS results. I updated ZTE position (new combos + 2 last legacy combos) and wait for other comments] |
| Mod V3 | **No change** |
| Samsung | Proposal 2.A.3: support; a minor comment: X=2 is possible only when W\_CSI>1**Proposal 2.A.3**: For the Type-II codebook refinement for high/medium velocities, when W\_CSI>1, if a UE supports X=2 for CQI calculation, the value of X (either 1 or 2) is gNB-configured via higher-layer (RRC) signalling[Mod: Thanks]Proposal 2.C.1* Clarification question: is this common understanding that we will have one single table for both N4=1, Q=1 and N4>1, Q=2?

[Mod: Right, there is no technical reason to have N4-dependent Parameter Combos]* If yes, then our preference is to reuse the legacy table for both. So, we can only accept the last three legacy combinations.

[Mod: From the submitted SLS results, the proposed table in 2.C.1 seems to perform better than legacy. Could you explain any other technical reason why we should stick with legacy (other than N4=1)? Besides the proposed table has 3 legacy combos ]* For N4>1, Q=2 case, however, we are open to consider some scaling (c) in order to reduce overhead associated with #NZC or/and bitmap size. For ex: the scaling c=1/2. For ex: we can scale $β$ or $p\_{v}$.

[Mod: This seems to imply N4-dependent Parameter Combination regardless whether the same table is used or not. Let’s see what other say]**Proposal 2.D.1**: typo, On the Type-II codebook refinement for high/medium velocities ~~CJT mTRP~~,[Mod: Thanks]**Proposal 2.E.1**: support |
| Mod V7 | **Revised proposal 2.C.1 based on further look into the submitted SLS results** |
| MediaTek | **Proposal 2.A.1:**Support**Proposal 2.A.2:**Not support. We believe reporting differential CQI for X=2 can be beneficial in terms of overhead reduction. We propose to support differential CQI for at least the WB CQI values which can lead to up to 4-bit overhead reduction without performance degradation. **Proposal 2.A.3:**Support.**Proposal 2.B.1:** We don’t believe two separate bitmap designs for NZC locations is needed and we should strive to have a unified design. However, if companies strongly believe overhead reduction is needed specifically for Q = 2, then based on the simulation results provided in our contribution (R1-2303328), Alt 3A can deliver superior performance compared to Alt 4’ with same or lower overhead. **Proposal 2.C.1:**Support.Regarding questions raised in the comments by Samsung on whether we need different parameter combination for $N\_{4}$ and $Q$ values, we strongly oppose having parameter combination, which is a function of the doppler parameters, due to two main reason 1) we do not see any technical merit why different parameter combination are needed 2) the additional UE complexity and design optimization which needs to be done for having multiple parameter combinations.**Proposal 2.D.1**:Support**Proposal 2.E.1**:Support |

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

Table 5A Summary: issue 3

|  |  |  |
| --- | --- | --- |
| **#** | **Issue** | **Companies’ views** |
| 3.1 | [112] **Agreement**For the Rel-18 TRS-based TDCP reporting, for TDCP measurement and calculation, by RAN1#112bis-e, decide between the following alternatives:* Alt1. Fully reuse legacy TRS
* Alt2. Study enhancements on TRS (e.g. periodicities)

Note. If there is no consensus on Alt2, Alt1 is the default outcome**Proposal 3.A:** 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
* FFS: Whether to add further restrictions on the TRS resource set(s) on, e.g. QCL relationship, power control, RE location, relation with resource set used for legacy usage

**FL Note**: This topic was discussed OFFLINE [1] | **Proposal 3.A:*** **Support/fine:** Nokia/NSB, Samsung, Fujitsu, ZTE, Ericsson, CMCC, Lenovo, Sony, Qualcomm, Mavenir, vivo, MediaTek, NTT DOCOMO, [Google], Intel, Xiaomi, Sharp,
* **Not support:**
 |
| 3.2 | Normalized amplitude quantization:* Alt1: Fully reuse Rel-16 eType-II W2 amplitude quantization
* Alt2: Partial reuse of Rel-16 eType-II W2 amplitude quantization (be specific)
* Alt3: Completely new (be specific)

**Proposal 3.B.1**: 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: $\left\{1-2^{-\left(N-q\right)s}, q=0,1,…,2^{Q}-1\right\}$
	+ TBD: supported value(s) of *N* (e.g. $2^{Q}-1$), *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

**FL Note**: This topic was discussed OFFLINE [1] | **Proposal 3.B.1:*** **Support/fine:** Nokia/NSB, Samsung, Fujitsu, ZTE, Ericsson, CMCC, Sony, Google, Qualcomm, Mavenir, vivo, MediaTek, NTT DOCOMO, OPPO, Intel, [Xiaomi], Sharp,
* **Not support:**
 |
| Phase quantization:* Alt1: Fully reuse Rel-16 eType-II W2 phase quantization
* Alt2: Partial reuse of Rel-16 eType-II W2 amplitude quantization (be specific)
* Alt3: Completely new (be specific)

**Question 3.B.2**: Please share your view re wideband phase quantization for Y>1 | **1 bit (early late – due to DLL):** Ericsson**3 bits:** ZTE**4 bits:** Lenovo/MotM, Intel,  |
| 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 configured 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

**Question 3.C**: Please share your view re supported Y values (for Y>1), Dbasic, and delay values | **Dbasic:*** **4 symbols:** Fujitsu
* **2 slots:** MediaTek, Samsung
* **5 slots:** ZTE, Samsung (2nd)
* **10 slots:** Ericsson

**Y>1:*** **2,4:** Samsung
* **3,7:** ZTE
* **>5:** Fujitsu

**Delays:*** **Inferred from CSI-RS slot offset:** Intel, Samsung
* **1,2,3,4,14,18 slots:** Google
* **5 slots:** Qualcomm
 |
| 3.4 | [112] **Agreement**For the Rel-18 TRS-based TDCP reporting, regarding the value of parameter Y for Y>1, down-select from the following alternatives:* Alt1. The value of Y is gNB-configured via higher-layer (RRC) signalling
* Alt2. The value of Y follows the delays from the configured TRS resource
* Alt3. The value of Y is UE-selected and reported

The value of Y is a UE capability**Question 3.D**: Please share your view re the signalling/configuration of Y  | **Alt1:** Huawei/HiSi, ZTE, Lenovo/MotM, Google, **Alt2:** IDC, Huawei/HiSi, vivo, NEC**Alt3:** Lenovo/MotM, Xiaomi, Samsung |
| 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**: | **Proposal 3.E:*** **Support/fine:** Samsung
* **Not support:**

**Alt1:** ZTE, Spreadtrum, Sony, Google, Samsung, Apple **Alt2:** vivo,Sony, **Alt3:** IDC,Lenovo/MotM, LG, |
| 3.6 | Next-level (pre-maintenance) details:* How to determine SCS for Z’
* CPU allocation
 |

Table 5B TDCP: summary of observation from simulation

|  |  |
| --- | --- |
| **Company** | **SLS results** |
| **Issue #** | **Metric** | **Observation** |
| ZTE | 3.2 | UPT vs speed, use case = SRS periodicity | *Amplitude quantization scheme* $q\_{3}$ outperforms $q\_{1}$ and $q\_{2}$ with higher DL throughput in the use case of SRS periodicity determination.1. $q\_{1}(k)=1-q(k)^{2}, k=0, 1, …, 2^{n}-1$
2. $q\_{2}(k)=1-q(k), k=0, 1, …, 2^{n}-1$
3. $q\_{3}(k)=2\frac{k+1}{ 2^{n}}-\left(\frac{k+1}{2^{n}}\right)^{2}, k=0, 1, …, 2^{n}-$1

*Phase quantization scheme q1 outperforms q0 and q2 with higher throughput in the use case of SRS periodicity determination*1. $q\_{0}(l)=\frac{l}{2^{n}}∙2π, l=0, 1, …, 2^{n}-1$

1. $q\_{1}\left(l\right)=\left\{\begin{matrix}q(l)^{2}∙2π, mode=0\\\left(1-q(l)^{2}\right)∙2π, mode=1\end{matrix}\right. , l=0, 1, …, 2^{n}-1$
2. $q\_{2}\left(l\right)=\left\{\begin{matrix}q\left(l\right)∙2π, mode=0\\\left(1-q(l)\right)∙2π, mode=1\end{matrix}\right. , l=0, 1, …, 2^{n}-1$
 |
| 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 $p\_{i}$ are the quantization levels from E-Type amplitude quantization, then using $1-p\_{i}$ for TDCP quantization offers better quantization performance compared to $1-p\_{i}^{2}$ 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 $s=\frac{1}{2}$ 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

|  |  |
| --- | --- |
| **Company** | **Input** |
| Mod V0 | **Please share your inputs on each of the issues and, if applicable, proposals in TABLE 5A** |
| Samsung | **Question 3.B.2**:* We prefer to reuse legacy as much as possible. However, depending on the delay values, the phase can be concentrated around +1 or -1. So, the range of values need to be adaptive according to delay values. For ex: $φ\_{n}= e^{j\frac{2πn}{k×2^{N}}}$ where $N$ is #bits for phase quantization, and $k$ is scaling to adapt the range of phase values. The value of $k$ depends on the delay values.

**Question 3.C**:* Dbasis: support 2 slots, or 5 slots (2nd preference)
* Delays: support Y smallest delays based on the periodicity/offset of TRS resource set configurations

**Question 3.D**:* Support Alt3. For given Y, all Y correlation values may not need reporting due to small amplitude (e.g. below the quantization noise). The UE should be allowed to report the value of y<=Y.

**Proposal 3.E**: support |
| Mod V7 | **No change** |
| MediaTek | **Proposal 3.A:** Support. Regarding the FFS bullet on restrictions, we believe the TRS resource set(s) used for a TDCP report should be configured with the same TCI state ID, subcarriers bandwidth, RE locations, powerControlOffset and powerControlOffsetSS values across all resources. If the mentioned restrictions are not enforced the can directly impact the performance and usefulness of the agreed TDCP metric.**Proposal 3.B.1:**Support.**Question 3.C:**Regarding Y values, we believe the max Y value should be capped to four, i.e., $Y\leq 4$Regarding delay value, our preference is to limit the value to 4 slots, any value above 4 slots is highly susceptible to aliasing problem, as we discussed in our contribution (R1-2303328). |

# References

|  |  |  |  |
| --- | --- | --- | --- |
| 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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|  |  |  |  |