**3GPP TSG RAN WG1 #110bis-e R1-2210370**

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

**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
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## Summary of companies’ views

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

Table 1A Summary: issue 1

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| **#** | **Issue** | **Companies’ views** |
| 1.1 | [110] **Agreement**On the Type-II codebook refinement for CJT mTRP, down-select from the following TRP selection/determination schemes (where N is the number of cooperating TRPs assumed in PMI reporting) by RAN1#110bis-e:* Alt1. N is gNB-configured via higher-layer (RRC) signalling
	+ The N configured TRPs are gNB-configured via higher-layer (RRC) signalling
	+ Note: only one transmission hypothesis is reported
* Alt2. N is UE-selected and reported as a part of CSI report where N$\in ${1,..., NTRP}
	+ N is the number of cooperating TRPs, while NTRP is the maximum number of cooperating TRPs configured by gNB
	+ In this case, the selection of N out of NTRP TRPs is also reported (FFS: exact reporting scheme)
	+ FFS: Configuration of NTRP TRPs and the value of NTRP, whether explicit or implicit
	+ Note: only one transmission hypothesis is reported. UE is not mandated to calculate CSI for multiple transmission hypotheses.

FFS: Whether S-TRP transmission hypothesis is also reported**Proposal 1.A**: On the Type-II codebook refinement for CJT mTRP, the selection of N CSI-RS resources is performed by UE and reported as a part of CSI report where N$\in ${1,..., NTRP} * N is the number of cooperating CSI-RS resources, while NTRP is the maximum number of cooperating CSI-RS resources configured by gNB
* The selection of N out of NTRP CSI-RS resources is also reported via NTRP-bit bitmap in UCI part 1
* Note: only one transmission hypothesis is reported. UE is not mandated to calculate CSI for multiple transmission hypotheses.

**FL Note**: After ROUND 0 discussion, the above proposal is made with the following consideration (by the FL):* No clear difference between Alt1 and Alt2 on the following aspects: W2 coefficient overhead saving, ability of UE to recommend/prefer a subset of TRPs, induced inter-cell interference fluctuation, NW scheduler complication, UE complexity. Therefore, any difference in UPT is not expected.
* Alt2 offers opportunistic (dynamic) overhead reduction over Alt1 for NZC bitmaps and basis selection indication in exchange of an explicit TRP selection indication. With some overhead reduction from Alt2, Alt2 may (slightly) outperform Alt1 in UPT vs PMI overhead trade-off.
* Alt2 is supported by more companies. 2 SLS results (one from proponent, the other from opponent) seem to show potential benefit with UE selection of TRPs.
* To avoid lengthy discussion on TRP selection indication details, a simple length-NTRP bitmap indication is proposed. I cannot afford a lengthy discussion on optimization on this topic since it is simply not worth the effort. Remember max NTRP is 4 per WID.
* Since N includes {1,…,NTRP} the FFS on sTRP is not needed anymore.

**Alt1 (12)**: Huawei/HiSi, Google, CMCC, MediaTek, Samsung, AT&T, DOCOMO, Nokia/NSB, Fraunhofer IIS/HHI**Alt2 (17)**: IDC, ZTE, Spreadtrum, vivo, Lenovo, OPPO, LG, CATT, Sony, NEC, Xiaomi, Apple, Ericsson, Qualcomm, CEWiT, Intel, Sharp  | **Support/fine**: IDC, ZTE, Spreadtrum, vivo, Lenovo, OPPO, LG, CATT, Sony, NEC, Xiaomi, Apple, Ericsson, Qualcomm, CEWiT, Intel, Sharp **Not support**: |
| 1.2 | [110bis-e] **Agreement**On the Type-II codebook refinement for CJT mTRP, regarding W2 quantization group and Strongest Coefficient Indicator (SCI) design, for each layer: * One (common) SCI applies across all N CSI-RS resources
* Further down-select one from the following alternatives by RAN1#110bis-e:
	+ Alt1. One group comprises one polarization across all N CSI-RS resources (*C*group,phase=1, *C*group,amp=2)
		- FFS: [from LG on quantization, I will add after I can access the Chairman Notes]
		- For the amplitude group other than the group associated with the SCI, the reference amplitude is reported
	+ Alt3. One group comprises one polarization for one CSI-RS resource with a common phase reference across N CSI-RS resources (*C*group,phase=1, *C*group,amp=2N)
		- For each of the (2N–1) amplitude groups (other than the group associated with the SCI), the reference amplitude is reported

FFS: The need for “strongest” TRP/TRP-group indicator in addition to the SCI**Proposal 1.B.2**: On the Type-II codebook refinement for CJT mTRP, regarding W2 quantization group, for each layer, support the following:* One group comprises one polarization across all N CSI-RS resources (*C*group,phase=1, *C*group,amp=2)
	+ FFS: [from LG on quantization, I will add after I can access the Chairman Notes]
	+ For the amplitude group other than the group associated with the SCI, the reference amplitude is reported

 **FL Note**: After ROUND 0 discussion, I made the above proposal with the following reasoning* There are only 3 sets of SLS results presented for this issue (see Table 1B, from MediaTek, Samsung, and vivo, showing that Alt1 (slightly) outperforms Alt3.
* There are no SLS results justifying the performance benefit of Alt3 over Alt1. The proponents argue that Alt3 is better due to potential TX power difference across TRPs – unfortunately without any empirical evidence.
* Although Alt3 is preferred by more companies to Alt1, as the FL, I am unable to justify proposing Alt3 for agreement due to lack of empirical and technical evidence (tangible analysis and SLS results) critical for decision making in this case.

**Alt1 (9):** IDC, vivo, MediaTek, Fraunhofer IIS/HHI, Apple, Samsung (2nd pref), DOCOMO (2nd pref), Intel (2nd pref)**Alt3 (15):** Huawei/HiSi, Ericsson, Lenovo, Intel, Xiaomi, NEC, CMCC, AT&T, Qualcomm, Nokia/NSB, ZTE, DOCOMO, CATT  | **Support/fine:** IDC, vivo, MediaTek, Fraunhofer IIS/HHI, Apple, Samsung, DOCOMO (2nd pref), Intel (2nd pref)**Not support:**  |
| 1.3 | [110bis-e] **Agreement**On the Type-II codebook refinement for CJT mTRP, regarding W2 quantization group and Strongest Coefficient Indicator (SCI) design, for each layer: * One (common) SCI applies across all N CSI-RS resources
* Further down-select one from the following alternatives by RAN1#110bis-e:
	+ Alt1. One group comprises one polarization across all N CSI-RS resources (*C*group,phase=1, *C*group,amp=2)
		- FFS: [from LG on quantization, I will add after I can access the Chairman Notes]
		- For the amplitude group other than the group associated with the SCI, the reference amplitude is reported
	+ Alt3. One group comprises one polarization for one CSI-RS resource with a common phase reference across N CSI-RS resources (*C*group,phase=1, *C*group,amp=2N)
		- For each of the (2N–1) amplitude groups (other than the group associated with the SCI), the reference amplitude is reported

FFS: The need for “strongest” TRP/TRP-group indicator in addition to the SCI**Conclusion 1.C**: On the Type-II codebook refinement for CJT mTRP, regarding W2 quantization group and Strongest Coefficient Indicator (SCI) design, there is no consensus on supporting “strongest” CSI-RS resource indicator in addition to the agreed SCI. * Note: This doesn’t preclude any (future) proposal on reference CSI-RS resource(s) for other purpose(s)

**FL Notes:** No consensus on this issue. Note that the conclusion simply states a fact. The context of this conclusion is strongest TRP indicator for W2 quantization – not for other purposes. **Question**: Is “strongest CSI-RS resource indicator” needed given your preference on issue 1.2 (please also state your preference on issue 1.2)? * **Yes:** ZTE, LG, CATT, Samsung, NEC, DOCOMO, Spreadtrum
* **No:** Huawei/HiSi, Ericsson, Nokia/NSB, vivo, MediaTek, Intel, Apple, IDC, OPPO, Google, CMCC, Xiaomi
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| 1.5 | [110bis-e] **Agreement** On the SD basis selection for Type-II codebook refinement for CJT mTRP, following legacy (Rel-16 regular eType-II and Rel-17 PS FeType-II), SD basis selection is per CSI-RS-resource. * Down select from the following alternatives (RAN1#110bis-e) on the *L* parameter:
	+ Alt1. Per-CSI-RS-resource *Ln* parameter
		- TBD: Whether {*Ln*, *n*=1, ..., *N*} are higher-layer configured by gNB, or the total $\sum\_{n=1}^{N}L\_{n}$ is higher-layer configured by gNB while {*Ln*, *n*=1, ..., *N*} are reported by the UE
	+ Alt2. gNB configures a common *L* parameter for all *N* CSI-RS resources via higher-layer signaling

FFS: Study on additional optimization for collocated multi-panel scenario**Proposal 1.E.2**: […]**FL Notes**: Please input your preference on Alt1 vs Alt2 | **Alt1:** **Alt2:**  |
| 1.8 | [110bis-e] **Agreement** For the Rel-18 Type-II codebook refinement for CJT mTRP, * Only CSI reporting over PUSCH is supported
	+ FFS: Whether AP only, or both AP and SP (following legacy), is supported
* An associated Resource Setting includes a CMR comprising *K*≥1 NZP CSI-RS resources from one CSI-RS resource set
	+ Periodic, semi-persistent, and aperiodic NZP CSI-RS are supported
	+ The supported CSI-RS resource parameter settings follow the legacy specification (without additional enhancement)
	+ FFS: Whether or not the K NZP CSI-RS resources are constrained to be in the same slot

**Proposal 1.G.2**: For the Rel-18 Type-II codebook refinement for CJT mTRP, following legacy, support both both aperiodic and semi-persistent CSI reporting on PUSCH.**FL Note**: The proposal follows legacy (unclear why we need to depart from it)  | **Support/fine:****Not support:** |
| 1.9 | **Proposal 1.I**: For the Rel-18 Type-II codebook for CJT mTRP, the switching between mode-1 and mode-2 is gNB-initiated via RRC signalling**FL Note**: Could CATT please compromise? This proposal is moved to email endorsement 1 | **Support/fine**: Xiaomi, Samsung, MediaTek, Qualcomm, Nokia/NSB (RRC only), Intel (RRC), AT&T, Ericsson, vivo, OPPO, ZTE(RRC), DOCOMO (RRC), CMCC (RRC), Huawei/HiSi, Google, Fraunhofer IIS/HHI, NEC, Spreadtrum, Sharp**Not support**: CATT |
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Table 1B Type II CJT: summary of observation from SLS

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| **Company** | **SLS results** |
| **Issue #** | **Metric** | **Observation** |
| Huawei/HiSi | 1.5 | Mean UPT gain vs overhead, 5%-tile UPT gain vs overhead | TRP-specific $L\_{n}$ has a better performance compared to the TRP-common case, with 5~9% gain for mean UPT and 4~10% for 5% UPT. |
| 1.10 (RX side info) | Mean UPT gain vs overhead, 5%-tile UPT gain vs overhead | 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. |
| 1.4 (on R) | Mean UPT gain vs overhead, 5%-tile UPT gain vs overhead | Performance gain can be achieved when the PMI granularity changes from 4RB to 2RB with R=4, with 5% gain for mean UPT and at 8~11% gain for 5% UPT. |
| ZTE | 1.10 (RX side info) | Avg UPT,50% UPT | Through additionally reporting Rxx information, the reporting of receiving side information can bring a significant performance gain. (9~10% avg UPT gain) |
| vivo | 1.1 | Cell mean SE gain (full-buffer)Overhead reduction ratio  | TRP recommendation (by UE) causes marginal performance loss (1~7% cell-mean SE loss), but it can bring maximum reduction in overhead of about 40% because more than 50% of UEs do not need to measure CSI of all TRPs based on simple TRP selection rules and do not need to report CSI for all TRPs in the measurement set. |
| 1.2 | Cell mean SE gain (full-buffer) | Alt2/Alt3/Alt4 bring negligible performance improvement (1~2%) and Alt1 has minimal payload. |
| 1.7 | Cell mean SE gain (full-buffer) | The TRP-specific beta (TRP-specific NNZC constraint) may reduce the feedback of the coefficients corresponding to the strongest TRP, which leads to a decrease in performance (up to 12% cell-mean SE loss).  |
| 1.4(on R) | Cell-mean, 5%-UE, 95%-UE SE gain (full-buffer) | A limited performance gain (up to 2% cell-mean SE gain) is obtained for a larger R for Indoor Hotspot and Intra-site CoMP(Outdoor2). |
| MediaTek | 1.4 (On M) | Avg UPT gain, statistics of dominant FD bases | Mode 1 and Mode 2 codebook structures achieve nearly same performance in intra-cell mTRP scenarios.For Mode 1 codebook structure, the dominant FD bases computed from FD compression of precoder coefficients are the same for all TRPs. |
| 1.2 | Avg UPT gain | Alt 2 quantization has $N$ SCIs, due to which phase coherence cannot be maintained among different TRP precoders and therefore it yields a poor performance.Alt 3 quantization scheme can give a much better performance than Alt 2 by virtue of having a single-phase reference (single SCI whose amplitude and phase is not reported).Alt 1 and Alt 4 quantization schemes achieve nearly same performance. |
| Samsung | 1.1 | Avg UPT gain vs overhead | 1) UE-based dynamic TRP selection degrades the performance of UPT vs overhead (4% avg. UPT loss) especially in the intra-cell scenario due to unpredictable interference fluctuation, and 2) the gNB-based dynamic TRP selection method outperforms (2~4% avg. UPT gain) the other two methods in both of the intra-/inter-cell scenarios. |
| 1.2 | Avg UPT gain vs overhead | Alt4 (#. Ref Groups for amp = 4) yields the best UPT vs overhead trade-off and 2~4% avg. UPT gain over the other methods, Alt1, 2, and 3. |
| 1.5 | Avg UPT gain vs overhead | Multiple (or different) L values (Alt1) can be beneficial as showing ~5% avg. UPT gain over the same L value case (Alt2). TRP-common SD beam selection (Alt3) yields the worst UPT vs overhead trade-off performance. |
| 1.6 | Avg UPT gain vs overhead | TRP-common bitmap incurs large avg. UPT loss that cannot be compensated for the overhead saving (it turns out 2~3% avg. UPT loss).  |
| 1.4(on new ParaComb) | Avg UPT gain vs overhead | A sufficient performance gain (70% - 100%) can be obtained in a low-overhead regime that is comparable to the overhead of sTRP case, when $L=1$ and/or low values of $p\_{v}$ (e.g., 1/8) are allowed. |
| Qualcomm | 1.4  | Throughput gain, Percentage of # TRPs selected  | Throughput gain of UE-determined Ln over configured Ln are show in Table 2. (average throughput gain 5~24% over configured Ln)It is noted that for smaller value of $L\_{tot}$ (e.g. $L\_{tot}=$3 or 4 with 3-TRP), allowing UE to determine $L\_{n}$ basically means allowing $L\_{n}=0$ reported, thus naturally allow TRP selection. |
| **Summary**:  |

Table 2 Additional inputs: issue 1

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| **Company** | **Input** |
| Mod V0 | **PLEASE READ THE FL NOTES** **Except for proposal 1.I (provide comments, if any, on EMAIL ENDORSEMENT 1)**1. **Check and, if needed, update your view in Table 1A especially on the moderator proposals.**
2. **Share additional inputs here, if needed**

**More moderator proposals may be added in the next revision** |
| Apple | **Issue 1.1**We support Proposal 1.A**Issue 1.2**We support Proposal B.2**Issue 1.3**We support Proposal conclusion 1.C**Issue 1.5**We prefer Alt2.**Issue 1.8**We are fine with Proposal 1.G.2. Editorial: remove duplicate “both” |
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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** |
| 2.2 | Supported RI values**Proposal 2.B**: For the Rel-18 Type-II codebook refinement for high/medium velocities, support RI={1,2,3,4}.**FL Note**: Can Lenovo please compromise. This proposal is moved to email endorsement 1 | **Support/fine:** Xiaomi, Fraunhofer IIS/HHI, Apple, Samsung, Qualcomm, Nokia/NSB, IDC, vivo, OPPO, Google, ZTE, Ericsson, Huawei/HiSi, CMCC, MediaTek, Spreadtrum, Sharp, Intel (can discuss 1,2, first)**Not support (3,4 FFS):** Lenovo |
| 2.4 | **Proposal 2.D**: 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.**FL Note**: Can Nokia, Ericsson, and vivo please compromise? This proposal is moved to email endorsement 1. | **Proposal 1.D:*** **Support/fine:** Samsung, ZTE, Qualcomm, Apple, Google, OPPO, Huawei/HiSi, Intel, Spreadtrum, CATT, DOCOMO, NEC, Fraunhofer IIS/HHI, Sharp, IDC, Sony, MediaTek, CEWiT, LG, ZTE, CMCC
* **Support if switching at N4=2:** Nokia/NSB, Ericsson, vivo
* **Not support:**
 |
| 2.5 | **Proposal 2.E**: On the CSI reporting and measurement for the Rel-18 Type-II codebook refinement for high/medium velocities, when UE-side prediction is assumed, support UE “predicting” channel/CSI after slot *l* where the location of slot *l* is configured (from multiple candidate values) by gNB via higher-layer signalling* Candidates of slot *l* location include the legacy CSI reference resource location (*n* – *nCSI,ref* ) and slot (*n*+*δ*) where *δ* ≥ 0
* FFS: Possible value(s) of *δ* and possible value(s) of WCSI

Note: Per legacy behavior, the legacy CSI reference resource, i.e., (*n* – *nCSI,ref* ), is reused for locating the last CSI-RS occasion used for a CSI report**FL Note**: Can Apple please provide some tangible proposal to resolve your concern? Please keep in mind that this proposal keeps the legacy reference resource definition. This proposal is moved to email endorsement 1.  | **Support/fine:** Samsung, vivo, Qualcomm (questionable regarding CQI prediction), DOCOMO, Lenovo, IDC, ZTE, Spreadtrum, vivo, [LG], CATT, Intel, NEC, Xiaomi, CMCC, MediaTek, Ericsson, [Nokia/NSB], OPPO, Huawei, HiSi, Fraunhofer IIS/HHI, Google (ok), Sharp**Not support:** Apple |
| 2.6 | **Conclusion 2.F**: On the usage of CSI reporting and measurement for the Rel-18 Type-II codebook refinement for high/medium velocities, there is no consensus in *supporting any specification enhancement* for the following assumptions:* Legacy UE procedure for CSI measurement/calculation
* gNB-side prediction
	+ Note: This doesn’t preclude any gNB implementation

**FL Note**: This conclusion merely states the fact**Legacy:*** **Yes:** Qualcomm, Lenovo, LG, Apple, Google, ZTE, Xiaomi
* **No:** MediaTek, Nokia/NSB, Ericsson (ok for CSI-RS measurement but not for CSI calculation)

**gNB-side prediction (to be specified, assumed by the UE in CSI measurement/calculation):** * **Yes**: Google, CATT, Xiaomi, Spreadtrum
* **No**: Samsung, vivo, MediaTek, LG, Nokia/NSB, Ericsson, CMCC, Huawei/HiSi,
 |
| 2.7 | [109-e] **Agreement**On potential refinement of Resource setting configuration associated with Type-II codebook refinement for high/medium velocities, study the following options to assess whether/how the legacy Resource setting configuration needs to be enhanced for “burst” measurement:* Periodic (P) CSI-RS: periodicity and offset
* Semi-persistent (SP) CSI-RS: activation/deactivation, periodicity, and offset
* Aperiodic (AP) CSI-RS: triggering, offset of a group of AP CSI-RS resources

FFS: Support for K>1 NZP CSI-RS resources association with Type-II codebook refinement for high/medium velocitiesFFS: Whether specification support for jointly utilizing two types of CSI-RS time-domain behaviors is needed**Proposal 2.G**: On the CSI reporting and measurement for the Rel-18 Type-II codebook refinement for high/medium velocities, support the following CSI-RS resource types/structures for CMR:* Time-domain behaviour for NZP CSI-RS resource: periodic (P), semi-persistent (SP), aperiodic (AP)
	+ FFS: Whether to introduce constraints on allowed configuration
* ~~The use of K≥1 NZP CSI-RS resources:~~
	+ ~~FFS: details~~
* Support K>1 NZP CSI-RS resources for aperiodic (AP)-CSI-RS-based channel measurement in a same CSI-RS resource set where the separation between 2 consecutive AP-CSI-RS resources is 1 slot:
	+ FFS: Details, e.g., supported value(s) of K, other use cases for the AP-CSI-RS resources (e.g., for training filter coefficients, prediction or performance monitoring)
* Support only one NZP CSI-RS resource for P or SP-CSI-RS-based channel measurement

**FL Note**: This proposal has been discussed in RAN1#110. From ROUND 0 discussion, some concern voiced by vivo and Intel on UE complexity (buffering) and prediction inaccuracy associated with AP-CSI-RS applies only when AP-CSI-RS is badly configured without taking into account UE-side prediction. On the other hand, it is acknowledged that minor spec tweak on AP-CSI-RS for burst measurement (with >0 offset between K>1 resources in the same CSI-RS resource set) can be quite beneficial. This is proposed by a number of companies. Therefore, the revised proposal 2.G should address the concern from vivo and Intel. Meanwhile the use of K>1 resources is restricted to AP-CSI-RS**ROUND 0 Proposal 2.G:*** **Support:** Google, Samsung, Nokia/NSB, Lenovo, DOCOMO, MediaTek, Qualcomm, LG, Spreadtrum, ZTE, Xiaomi, NEC, OPPO, CATT, CMCC, Sharp, Apple, Huawei/HiSi, Fraunhofer IIS/HHI, IDC, Ericsson
* **Not support:** vivo (concern on AP), Intel (concern on AP)
 | **Support/fine:** **Not support:**  |
| 2.8 | **Proposal 2.H**: For the Type-II codebook refinement for high/medium velocities, only CSI reporting over PUSCH is supported * Following legacy, support both both aperiodic and semi-persistent CSI reporting on PUSCH.

**FL Note**: This basically follows the legacy Rel-16/17 spec re Type-II codebook and reuses the legacy CSI-RS | **Support/fine:** Ericsson, Nokia/NSB, Lenovo, **Not support:**  |
| 2.9 | **Proposal 2.I:** For the Type-II codebook refinement for high/medium velocities, down-select from the following alternatives: * Alt1. *Q* different 2-dimentional bitmaps are introduced for indicating the location of the NZCs, where the qth (q=1,…., *Q*) 2-dimentional bitmap corresponds to qth selected DD basis vector
	+ The number of selected DD basis vectors is denoted as *Q*
	+ This implies that for each layer, the location of NZCs in SD-FD can be different for different selected DD basis vectors.
* Alt2. A DD-basis-common per-layer 2-dimensional bitmap for indicating the location of NZCs used in Rel-16/17 Type-II is used
	+ This implies that for each layer, the location of NZCs in SD-FD is common across all the Q selected DD basis vectors

FFS: Further overhead reduction on bitmap(s)FFS: Whether the number of NZCs is upper bounded across all DD basis vectors or per DD basis vector**FL Notes:** This proposal is moved to email endorsement 1. | **Support/fine:** Qualcomm, Samsung (Alt2), Intel (Alt1), IDC (Alt2), vivo, OPPO, ZTE(Alt1)**,** Xiaomi(Alt1), DOCOMO, CATT, Ericsson (Alt1), CMCC (Alt1), Huawei/HiSi, Sharp**Not support:** |
| 2.10 | **Proposal 2.J:** For the Type-II codebook refinement for high/medium velocities, the selection of DD basis vectors is layer-specific* The number of selected DD basis vector (denoted as *Q*) is layer-common
 | **Support/fine:** Intel, Qualcomm, Samsung, Apple, Google, ZTE, CMCC, Huawei/HiSi**Not support:**  |
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Table 3B Type II Doppler: summary of observation from SLS

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| **Company** | **SLS results** |
| **Issue #** | **Metric** | **Observation** |
| Huawei/HiSi | 2.3, 2.4 | SLS: UPT | Observation 7: For R17 FeType II and R16 eTypeII codebook enhancement, Alt2B has no obvious performance gain compared with Alt2A.Observation 8: For R17 FeTypeII and R16 eTypeII codebook enhancement, compared with Alt2A, Alt3 which reports double W2 is worse than Alt 2A with double CSI overhead.Observation 9: For R17 FeType II and R16 eTypeII codebook enhancement, there’s no obvious performance gain between orthogonal DFT without rotation factor, orthogonal DFT with rotation factor and oversampled DFT. |
| ZTE | 2.5, 2.12 | SLS: UPT | Based on the SLS results for high/medium UE velocities in UMa in Figure 5, the distinct average UPT and cell-edge UPT gain can be obtained between CSI prediction scheme (Alt1.B or Alt2.B) and legacy CSI scheme. However, it is not observed that there is a big difference between Alt1.B and Alt2.B. Moreover, we also observe that the variation of CQI is quite slow, which means that the parameter for supporting DD/TD compression unit, described in Agreement#5, can be used for PMI only as a starting point |
| 2.7 | Cross-correlation  | * For periodic CSI-RS configuration, it can be observed in Figure 1 that the periodicity of CSI-RS transmission marked in green is 5 slots. Under 5 measurement samples, cross-correlation from slot n+6 to n+10 between predicted channel (Wiener and extrapolation) and real-time channel can be greater than 0.97, as shown in Figure 3.
* In addition, for aperiodic CSI-RS configuration as shown in Figure 2, it is observed that the cross-correlation from slot n+6 to n+10 between predicted channel and real-time channel is still greater than 0.93, shown in Figure 4.
 |
| Vivo | 2.3, 2.4, 2.5 | SLS: UPT | For UE based CSI prediction performance * + UE based prediction assuming Alt 2B and N4=1 achieves significant performance gain
	+ Smaller N4 brings higher performance gain than larger N4 values
	+ Measurement with 16 CSI-RS occasions has higher performance gain than 8 CSI-RS occasions, especially for medium or large N4 values

We evaluate the performance of DD compression ratio 0.2 and 1 (No compression) for N4=6. The results are given in Table 2. It can be observed that clear performance loss exists. This loss will basically eliminate the gain of CSI prediction for N4=6 as the gain for no compression compared with no prediction is only 4.15% as show in Table 1. |
| OPPO | 2.3, 2.13 | UPT vs overhead | DFT basis outperform identity basis at low overhead, the gain is about 10% for N2=2We show the performance of N4 >= 1 in figure 3. The measurement window is set to {16, 24, 32} ms respectively. There are {4, 6, 8} CSI-RS occasions for time unit 4 slots and {8, 12, 16} CSI-RS occasions for time unit 2 slots. We assumed time unit equals CSI-RS spacing. Frequency-time domain LMMSE is used for channel prediction where covariance is measured from Wmeas. Reporting window size is prediction horizon (from the latest CSI-RS occasion). The overhead for each setting of W\_CSI is about 300 bits, R16 PC6 is the reference. Although the prediction is less reliable as W\_CSI increase, the performance gain is still obvious. Moreover, supporting N4 > 1 could reduce the normalized overhead. At medium velocity, precoder may only hold on in duration of 1~2 ms, supporting N4=1 only may be quite wasteful in terms of CSI-RS and CSI overhead |
| Google | 2.3, 2.4 | Square cosine similarity | When the UE velocity is high and the interval between the CMR instances is large, the performance loss due to the DD/TD domain compression could be big. Figure 2 illustrates the square cosine similarity (SCS) distribution for the CSI with DD/TD domain compression with different number of DD/TD basis, where N4 is assumed as 10, the interval between each CMR instance is 1 ms and the UE velocity is 120 km/h. The SCS is calculated based on the ideal channel eigenvector and the decompressed channel eigenvector for each CMR instance. Figure 3 illustrates the SCS distribution when the UE velocity is 60 km/h. Figure 4 illustrates the SCS distribution when the UE velocity is 10 km/h.It can be observed that the best number of DD/TD basis should be different for different UE velocity. When the UE velocity is too high, the identity matrix can be used. When the UE velocity reduces, DD/TD compression can be used. |
| Intel | 2.3, 2.4 | UPT vs overhead | Observation 1: * PMI codebooks with DFT-based DD compression (Alt. 2A, Alt. 2B) has significantly lower overhead comparing to Alt. 3

Alt. 2A outperforms Alt 2B for most of codebook configurations |
| MediaTek | 2.3, 2.4, 2.5, 2.7 | UPT | * Extrapolation performance degrades as the size of CSI reporting window increases.
* Assuming CSI interpolation, joint CSI calculation for the entire TD unit is more robust than individual CSI calculation for each slot.

Next, we compare the case of using the latest CSI-RS transmission occasion as reference and the case of using the predicted CSI as reference. Specifically, the reference is used to calculate single $W\_{1}, W\_{f}$, RI, and CQI for the entire CSI reporting window. Both cases assume Scheme 3 and the results are shown in Table 2. It can be seen that for the UMa scenario with UE speed 30 km/h, using the predicted CSI as reference provides a better performance. To summarize, from the perspectives of performance and UE complexity, it is worth the specification effort to support that the CSI reporting window starts no earlier than the CSI reporting slot $n$* To enhance the throughput for the case of UMa 60 km/h, reducing CSI-RS periodicity to 2, 3 ms is beneficial.
* Linear prediction does not perform well under CSI-RS burst measurement.
 |
| Fraunhofer IIS/HHI | 2.3, 2.4, 2.13 | UPT | * The performance gain increases with increasing oversampling factor.
* Rotation factor reporting per SD component further reduces the feedback overhead in reporting the selected TD/DD components.
* An oversampling factor of four suffices to provide a significant better performance compared to the baseline.
* Enhanced Type II CB with Doppler domain information outperforms Rel. 16 eType-II CB in terms of both performance and feedback overhead by a large margin
 |
| Samsung | 2.3, 2.4, 2.5, 2.7, 2.11, 2.12 | UPT vs overhead | Observation 13: Alt1 and Alt2 achieve similar performance vs overhead trade-offObservation 14:* Alt1B outperforms Alt2B
* There is an ‘optimal’ $W\_{CSI}$ (predicting beyond this window does not help)
	+ Alt1B with CSI window $[n\_{ref},n+X]$ is the best among the considered CSI windows
	+ In general, the value of $X$ depends on UE speed (cf. Appendix C)

Observation 15: * 2 CQIs can achieve better UPT vs overhead trade-off than one CQI (up to 2% gain in avg. UPT gain)
* The order of the overall UPT vs overhead trend is 2 CQIs > 4 CQIs ~ per slot CQI > 1 CQI

Observation 16: CSI-RS burst separation = 1 slot achieves better UPT vs overhead trade-off than CSI-RS burst separation = 5 slots. |
| Ericsson | 2.3, 2.4, 2.12 | UPT vg overhead | 1. For type II Doppler codebook with a 16Tx2Rx and 60 km/hr scenario, Alt 2 results in a larger overhead compared to Alt1, and Alt 2 only provides some small gains over Alt 1.
2. Alt3 is beneficial for the case where reporting a single predicted PMI results in significant performance improvement
3. For type II Doppler codebook with a 16Tx2Rx and 60 km/hr scenario, when AR prediction is considered, Alt3 with a single predicted PMI provides similar gains as Alt1 and Alt2 but at a much reduced overhead.
4. Performance of Alt1 compared to Alt3 depends on the accuracy of the UE side channel predictor.
5. We find no performance gain in considering DFT TD-bases with a rotation factor

As shown in Figure 14, there are some reductions of the gains compared to Rel-16 when only a single CQI is used instead of $N\_{CQI}$=$N\_{4}$, especially for the cell-edge users and for longer CSI feedback periodicity $T\_{F}$. However, we have also found simulation cases, e.g., 4 RX, with limited gain of using $N\_{CQI}$=$N\_{4}$ compared to $N\_{CQI}$ =1, and thus selecting a good $N\_{CQI}$ value may be scenario dependent |
| Qualcomm | 2.3, 2.4, 2.5 | UPT, overhead | Observation 1: Beam-specific TD basis selection has about 1% TPUT gain over beam-common, at a cost of 7.7% increased overhead.Observation 3: For different CSI window location (starting slot *l*), similar performance is obtained based on a same CSI window length N4. |
| Nokia/NSB | 2.5 | UPT, cosine similarity | In Figure 4, Figure 5, Figure 6, the cosine similarity is compared for each of the two layers, for UE speed of 10, 30 and 60km/h, whilst in Figure 7 and Figure 8, mean and cell-edge throughput are compared, respectively. We observe that the prediction gain of Type-II-Doppler is generally consistent with speed. However, the relatively significant gain observed in cosine similarity does not appear as large in throughput. Also note that the feedback overhead is larger for Type-II-Doppler than for the baseline because two CSIs are sent per report rather than one, although they share the same $W\_{1}$ and $W\_{f}$. |
| **Summary**:  |

Table 4 Additional inputs: issue 2

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| --- | --- |
| **Company** | **Input** |
| Mod V0 | **PLEASE READ THE FL NOTES** **Except for proposal 2.B, 2.D, 2.E, and 2.I (provide comments, if any, on EMAIL ENDORSEMENT 1)**1. **Check and, if needed, update your view in Table 3A especially on the moderator proposals.**
2. **Share additional inputs here, if needed**

**More moderator proposals may be added in the next revision** |
| Apple | **Issue 2.4**We are fine with Proposal 2.D**Issue 2.6**We are fine with conclusion 2.F**Issue 2.7**We think the last two sub-bullets may need further discussion. In the current specification, AP-CSI-RS resource set cannot be configured in more than 1 slot. More technical question is that CSI prediction may only be meaningful for low to medium doppler, for example, 10km/hr, with the doppler around 20-100Hz. If we have two CSI-RS on slot away, that is 0.5ms for 30kHz, which is around 2kHz. Is that necessary which means we may need a very large K? **Issue 2.8**We are fine with proposal 2.H. Editorial: Remove duplicate “both”**Issue 2.10**We are fine with proposal 2.J. |
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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 | [110] **Agreement**For the Rel-18 TRS-based TDCP reporting, down select one of the following alternatives by RAN1#110bis-e:* AltA. Based on Doppler profile
	+ E.g., Doppler spread derived from the 2nd moment of Doppler power spectrum, average Doppler shifts, Doppler shift per resource, maximum Doppler shift, relative Doppler shift, etc
* AltB. Based on time-domain correlation profile
	+ E.g. Correlation within one TRS resource, correlation across multiple TRS resources
	+ Note: The correlation over one or more lags of TRS resource may be considered. The lags may be within one TRS burst or different TRS bursts
* AltC: CSI-RS resource and/or CSI reporting setting configuration parameter(s) to assist network
	+ E.g. gNB configures UE with multiple choices on what to assist (e.g. two or more CSI-RS/report periodicities, or precoding schemes depending mainly on UE velocity), then UE report according to configuration; parameters correspond to CSI reporting periodicity, codebook type, etc.

Note: Different alternatives may or may not apply to different use cases**Proposal 3.A**: For the Rel-18 TRS-based TDCP reporting, down select one of the following alternatives by RAN1#110bis-e:* AltA2. Doppler spread
	+ E.g. Doppler spread derived from the 2nd moment of Doppler power spectrum, difference between lowest- and highest-value Doppler shifts in Doppler profile
* AltA3. Doppler shift(s)
	+ E.g., average Doppler shifts, (Relative) Doppler shift per TRS resource, Doppler shift corresponding to the peak in Doppler profile,
* AltB. *Quantized amplitude of* time-domain correlation profile (amplitude vs. delay)
	+ FFS: Correlation within one TRS resource, correlation across multiple TRS resources
	+ Note: The correlation over one or more lags of TRS resource may be considered. The lags may be within one TRS burst or different TRS bursts

Note: Different alternatives may or may not apply to different use casesFFS: The need for a measure of confidence level in the TDCP report, and/or UE behaviour when the quality of TDCP measurement is not sufficiently high**FL Note**: Please check the revised proposal 3.A taking into account Ericsson’s input in breaking AltA into multiple proposalsThis is the current situation. * AltA: ZTE, vivo, Google, LG, OPPO, Huawei/HiSi, Xiaomi, Fraunhofer IIS/HHI, Mavenir, Apple (1st pref), CATT, IDC, Spreadtrum, NEC (2nd pref), Nokia/NSB
* AltB: Samsung, Ericsson, MediaTek, vivo, Qualcomm, DOCOMO, OPPO, Sharp, Lenovo, Apple (2nd pref), IDC, NEC (1st pref), CEWiT
 | **Proposal 3.A:*** **Support/fine**: Samsung, ZTE, vivo, Google, LG, OPPO, Huawei/HiSi, Xiaomi, Fraunhofer IIS/HHI, Mavenir, Apple, CATT, Ericsson, MediaTek, vivo, Qualcomm, DOCOMO, OPPO, Sharp, Lenovo, Sony, Nokia/NSB, CMCC, Spreadtrum
* **Not support**:
 |
| 3.2 | **Conclusion 3.B**: For the Rel-18 TRS-based TDCP reporting, there is no consensus in supporting periodic, semi-persistent, and event-triggered/UE-initiated TDCP reporting.**FL Notes**: This conclusion merely states the fact. **Periodic:*** **Yes:** Qualcomm, Nokia/NSB, ZTE, Sharp
* **No:** Spreadtrum, Samsung, MediaTek, vivo, LG, OPPO

**Semi-persistent:*** **Yes:** Lenovo, Nokia/NSB, ZTE, Sharp
* **No:** Spreadtrum, Samsung, MediaTek, vivo, LG, OPPO

**Event-triggered/UE-initiated via UL MAC CE:*** **Yes:** Samsung, MediaTek, Google
* **No:** LG, Nokia/NSB, OPPO

**Conclusion 3.B:** Xiaomi, Huawei, HiSi, Spreadtrum |
|  |  |  |

Table 5B TDCP: summary of observation from LLS/SLS

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| **Company** | **LLS/SLS results** |
| **Issue #** | **Metric** | **Observation** |
| Huawei/HiSi | 3.1 | Doppler profile | Observation 10: SRS could not provide accurate Doppler shift information.Observation 11: Due to the common feature of Doppler profile among gNB antennas, TRS could provide sufficient Doppler shift information even if it is single port.Observation 12:A “common Doppler profile” of multiple delay paths is a satisfying depict of the Doppler profile. |
| vivo | 3.1 | Auto-correlation vs lags | The Figure 4 shows the relationship between temporal correlation at different lags and maximum doppler shift in term of Bessel function.…Since maximum lags between four TRS resources in two consecutive slots is 14 symbols (or say 1 slot) and the values of correlation are [1, 0.97, 0.90] respectively corresponding to [3km, 30km, 60km], UE would not identify the minor difference taking noise and interference into account in practical algorithm unless AP TRS is triggered to compensate lacked occasions of P TRS. Hence it means to make the TDCP use case work, gNB has to trigger AP TRS to assist P TRS for this TDCP reporting. How this works for periodic or semi-persistent CSI reporting requires further study as P or SP CSI report cannot be associated with aperiodic RS |
| Google | 3.1 | Square cosine similarityAuto-correlation | Figure 5 illustrates SCS for the first layer at each Doppler spread. Figure 6 illustrates the Doppler spread at different UE velocity. It can be observed that with the help of Doppler spread, it is possible to predict the UE velocity. However, the SCS span can still be large. At some UE velocities, it is hard to determine whether the CSI could change quickly or not based on the Doppler spread.Figure 7 illustrates the SCS distribution at different channel auto-correlation, where different color indicates different SCS. Figure 8 illustrates the UE velocity distribution at different channel auto-correlation, where different color indicates different UE velocity. It can be observed that with channel auto-correlation only cannot help to distinguish the UE velocity and it is hard to identify the proper CSI report periodicity. |
| CATT | 3.1 | LLS: normalized TP | * + Observation-3:

Compared with no gNB-side CSI prediction, the single Doppler reporting has slight performance gain, and obvious performance gain can be achieved by the solutions with multiple Doppler reporting with the enhanced matching algorithm |
| Mavenir | 3.1 | Correlation vs lag | Observation 3. For given Doppler shift, different lags result in different time correlations |
| Samsung | 3.1 | Correlation vs lag | Observation 15:* The perceived Doppler spread increases as the number of reported correlation lags decreases due to windowing before FFT operation.
* For a given UE speed, there is a minimum number of reported correlation lags that can represent the Doppler spread accurately.
 |
| Ericsson | 3.1 | Correlation vs lag | However, we don’t think it’s crucial to capture the sign changes of the autocorrelation. It’s the behaviour of the autocorrelation for low lags corresponding to an autocorrelation above zero that is of most interest (see Figure 3). Also, the measure $A\_{alt}\left(t,τ\right)$ would not be robust towards phase jumps. Thus, if UE manufacturers prefer the measure $A\left(t,τ\right)$ to avoid problems with phase jumps, that is perfectly fine with us.1. Maximum doppler shift would be the same for channels with vastly different channel variabilities, and it does not reflect how fast channel varies with time.

Thus, the second moment of the Doppler power spectrum is a much better measure of channel variability than the maximum Doppler shift. However, it can’t predict the rather abrupt break-off point where the autocorrelation of the CDL channels takes off steeply downwards as can be seen in Figure 5. Compared to the autocorrelation it gives less information about the channel variations. The second moment of the Doppler power spectrum is therefore not our preferred TDCP measure.To measure the relative Doppler shift of a number of channel peaks is also a very complex measurement which in the end gives worse performance than the autocorrelation as shown in Figure 6. In Figure 6, we show the result, showing that the Autocorrelation based estimate totally outperforms the channel peak based estimate. It has both lower bias and lower standard deviation than the peak based estimate. This should be viewed as an illustration of the general fact that the measurement of relative Doppler shifts per peak is a complex and inaccurate measurement while the Autocorrelation is a simple and comparably accurate one.1. Estimates based on intra-TRS autocorrelation lags doesn’t give decent accuracy below 50km/h.
2. Estimates based on inter-TRS : autocorrelation lags of 20 or 40 slots perform best at 3km/h; autocorrelation lags of 10 and 5 slots performs best at 6km/h and 10km/h respectively.
3. Different autocorrelation lags are suitable for different UE velocities.
4. Based on the evaluated use cases, reporting of the Autocorrelation for the four lags, 4 symbols, 1 slot, ~5 slots and ~10 slots look reasonable.
 |
| **Summary**:  |

Table 6 Additional inputs: issue 3

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| --- | --- |
| **Company** | **Input** |
| Mod V0 | **PLEASE READ THE FL NOTES** 1. **Check and, if needed, update your view in Table 5A especially on the moderator proposals.**
2. **Share additional inputs here, if needed**

**More moderator proposals may be added in the next revision** |
| Apple | **Issue 3.2**We are fine with conclusion 3.B |
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| 4 | R1-2208504 | CSI enhancement for high/medium UE velocities and CJT | ZTE |
| 5 | R1-2208541 | Discussion on CSI enhancement for high/medium UE velocities and coherent JT | Spreadtrum Communications |
| 6 | R1-2208628 | Discussion on CSI enhancement for high-medium UE velocities and coherent JT | vivo |
| 7 | R1-2208742 | Discussion of CSI enhancement for high speed UE and coherent JT | Lenovo |
| 8 | R1-2208794 | CSI enhancement for high/medium UE velocities and coherent JT | OPPO |
| 9 | R1-2208872 | On CSI Enhancement | Google |
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