**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

|  |  |  |
| --- | --- | --- |
| **#** | **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 via higher-layer signaling
* The selection of N out of NTRP CSI-RS resources is reported via NTRP-bit bitmap in CSI part 1
	+ Note: The value of N is inferred from the selection
* A restricted configuration (gNB-configured via higher-layer signaling) where N=NTRP is supported
	+ FFS: Whether other RRC-configured TRP selection restriction including configuring the value of N is supported
* Other than the restricted configuration where N=NTRP, this feature is UE optional

Note: per WID, the candidate values for NTRP of are 2, 3, and 4.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, Samsung (ok), DOCOMO (ok), AT&T (ok), CMCC(ok), MediaTek, [Huawei/HiSi] **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: Amplitude quantization table considering transmission power difference between multiple TRPs
		- 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: Amplitude quantization table enhancement
	+ 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 (16):** Huawei/HiSi, Ericsson, Lenovo/MotM, Intel, Xiaomi, NEC, CMCC, AT&T, Qualcomm, Nokia/NSB, ZTE, DOCOMO, CATT  | **Support/fine:** IDC, vivo, MediaTek, Fraunhofer IIS/HHI, Apple, Samsung, DOCOMO, Intel, AT&T, Xiaomi (ok with FFS), CMCC, Spreadtrum, Ericsson (ok)**Concern (still prefer Alt3):** Lenovo, ZTE, LG, Qualcomm, Huawei/HiSi |
| 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)

Moved to Email Endorsement 2. ENDORSED**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, one L configured and {Ln} determined from configured L
	+ 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**: On the SD basis selection for Type-II codebook refinement for CJT mTRP, support the following on the *L* parameter:* 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, one L configured and {*Ln*} determined from configured L
	+ The value of *Ln* is taken from a pre-defined set (possible values FFS)

**FL Notes**: Please input your preference on Alt1 vs Alt2. Moved to Email Endorsement 2. ENDORSED | **Alt1:** Samsung, NEC, ZTE, Ericsson, MediaTek, vivo, Qualcomm, DOCOMO, LG, OPPO, Huawei/HiSi, Intel, Spreadtrum, CATT, Fraunhofer IIS/HHI, Sharp, Xiaomi (Ln RRC), AT&T**Alt2:** Apple**Proposal 1.E.2:** * **Support/fine:** Samsung, NEC, ZTE, Ericsson, MediaTek, vivo, Qualcomm, DOCOMO, LG, OPPO, Huawei/HiSi, Intel, Spreadtrum, CATT, Fraunhofer IIS/HHI, Sharp, Xiaomi (Ln RRC), AT&T
* **Not support:**
 |
| 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 aperiodic and semi-persistent CSI reporting on PUSCH.**FL Note**: The proposal follows legacy (unclear why we need to depart from it). Moved to Email Endorsement 2. ENDORSED  | **Support/fine:** Apple, Lenovo, Samsung (ok), DOCOMO, ZTE, Intel, MediaTek**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.ENDORSED | **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 |

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

|  |  |
| --- | --- |
| **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”[Mod: Done] |
| Lenovo | **Issue 1.1 (Proposal 1.A)**For clarification, gNB configures NTRP value ={1,2,3,4}, and then N={1,..,NTRP} value is UE-selected and inferred from the number of ones in the bitmap?[Mod: Yes, just as any other bitmap] We also prefer to keep the following FFS: “Whether S-TRP transmission hypothesis is also reported”[Mod: Done ☺]**Issue 1.2 (Proposal 1.B.2)**Our preference is Alt3**Issue 1.8 (Proposal 1.G.2)**Small typo, the word “both” is duplicated |
| Samsung | **Proposal 1.A**We still think Alt1 is sufficient for proper semi-static TRP selection performed by NW and TRP selection by the UE (Alt2) has complexity issues (both UE-side and NW-side). So, our preference remains Alt1. However, we can accept this version (w/ bitmap) of Alt2 for progress if the majority prefer Alt2.**Proposal 1.B.2**We support **Proposal 1.B.2** based on the following rationales. 1) From all of SLS results provided by all companies, the same trend of Alt1 > Alt3 is shown for UPT performance, which shows the finer coefficient reporting considering 2 amp ref groups per TRP is over-optimized; 2) Alt3 requires 2N-1 additional reference amplitudes than Alt1, which consumes extra-overhead without any benefits; and 3) Alt1 is better from UE processing perspective since it is legacy and the simplest scheme.**Issue 1.5**We support Alt1 based on our SLS results, showing UPT-overhead trade-off gain. Also, we would prefer to add an example* One L value of configured, and {Ln} is determined based on the configured value.

[Mod: Done]**Proposal 1.G.2**Our view is that there is no need and apparent benefits with SP reporting over PUSCH. It will consume large UL resources. Aperiodic only would suffice. But we acknowledge it is supported in the legacy spec. If the majority wants SP in addition to SP, we are (reluctantly) fine. |
| NEC | **Proposal 1.A:**  Support. One minor update to be more accurate: “via NTRP-bit bitmap in UCI part 1” -> “ via NTRP-bit bitmap in CSI part 1”.[Mod: Done]**Proposal 1.B.2:** Regarding to be added FFS part “FFS: Amplitude quantization table considering transmission power difference between multiple TRPs”, does this mean potential different differential amplitude quantization table per TRP?[Mod: I have no idea. But this issue can be further clarified if/after 1.B.2 is agreed ]**Issue 1.5:** Alt 1 is preferred. |
| DOCOMO | **Proposal 1.A:**  Our first preference is still Alt1. But we can accept this proposal for progress if it is supported by majority. In addition, we’d like to understand and clarify following question for the proposal.* If TRP-selection is reported via NTRP-bit bitmap, there is no SD basis reporting for the TRP indicated as ‘0’ by the bitmap, is that correct understanding?

[Mod: Correct. That’s not needed]* Then for the TRP indicated as ‘1’ by the bitmap, there should be at least one NZC to be reported in W2 for the TRP, is that correct understanding?

[Mod: Correct]**Proposal 1.B.2:**We’re okay with either Alt1 or Alt3. So we can support Proposal 1.B.2.**Conclusion 1.C:**We may not need it right now. We can discuss it a little further after Proposal 1.B.2 is agreed.**Proposal 1.E.2 (Issue 1.5):**We support Alt1.**Proposal 1.G.2 (Issue 1.8):**Okay. |
| ZTE | **Proposal 1.A** It seems that ‘selection restriction’ in the yesterday agreement is not captured herein. From gNB vendor perspective, this restriction is essential for us. We suggest to support the selection restriction (for many inter-site CJT, arbitrary selection from NTRP is not a normal case). Then, regarding TRP selection, ‘CRI’ is our first preference.…* Based on RRC configured selection restriction, the selection of N out of NTRP CSI-RS resources is also reported via NTRP-bit bitmap in UCI part 1

…[Mod: Added FFS on that. It won’t be agreeable for now. This could also be related to CBSR which won’t be discussed until the very end]**Proposal 1.B.2:** Not support. Since having separate amplitude groups for different polarization, TRP-specific gap may be quite larger than that. The minor step/enhancement proposed in Alt3 is deserved, if considering various real-field deployments. **Proposal 1.C:** Not our preference. We tend to agree with the FL that for many other cases, e.g., reference FD-basis in Mode-1, we still need to review the reference TRP indicator again.**Issue 1.5:** We support Alt1 (by higher-layer configured by gNB).**Proposal 1.G.2:** Support**Proposal 1.I:** Support |
| Intel | **Issue 1.1 (Proposal 1.A)**Similar to Lenovo we prefer to keep the FFS on the S-TRP transmission hypothesis. Basically, part of the CJT PMI corresponding to a TRP can be used for S-TRP transmission from that TRP. Hence, it may be useful to report CQI for S-TRP transmission together with CJT PMI, where CQI for the S-TRP transmission is calculated based on the corresponding part of the CJT PMI. **Issue 1.2 (Proposal 1.B.2)**Considering the performance evaluation results submitted by companies, both Alt1 and Alt 3 are acceptable. So, we are fine with the proposal.**Issue 1.3 (Conclusion 1.C**)We don’t see the need for the strongest CSI-RS resource indicator so far. However, in our view conclusion is not needed since the new indicator is not supported until an agreement is made to support it. **Issue 1.5**In our view this issue can be considered further then supported parameter combinations are identified. [Mod: As I mentioned to Samsung during OFFLINE, it’s the other way around ☺ We can’t discuss parameter combination unless this is finalized]**Issue 1.8** We are fine to support aperiodic and SPS CSI report. |
| AT&T | **Issue 1.1: Proposal 1.A**We still prefer Alt1, however, if majority supports Alt2, we are ok with **Proposal 1.A****Issue 1.2: Proposal 1.B.2**We want to add our support to Alt1 and therefore we are ok with **Proposal 1.B.2****Issue 1.5**We prefer Alt1.**Issue 1.9: Proposal 1.I**We support **Proposal 1.I** |
| Mod V09 | **Minor revision on 1.A (added FFS back)** **Added proposal 1.E.2** |
| MediaTek | **Issue 1.1**Not support. As stated earlier our preference is gNB based selection, i.e., Alt1. As sake of progress we can accept the following compromise that be default RRC based TRP selection is supported while UE based TRP selection is a UE capability.[Mod: Added in brackets for companies to check]**Issue 1.2**Support Proposal 1.B.2. Agree with Samsung about the overhead increase in Alt 3 without any obvious improvement in performance. Any difference in TRP amplitudes is already reflected in CJT precoder derived from the SVD of the mTRP channel.**Issue 1.3**Support the conclusion.**Issue 1.5**Prefer Alt 1. Our initial thinking is that gNB configures the *Ln* for each CSI-RS resource, similar to legacy Rel-16. However, from the ongoing discussion and internal study, we observe that gNB vendors do not have confidence in the ability to determine *Ln*, and require UE assistance. In this case, to minimize UE complexity and reporting overhead, we would like to limit the *Ln* values reported by UE. For example, *Ln* could take values among {1,2,4}. From the current wording, it seems that the UE is free to report any value of *Ln*. Therefore, we propose the following for Alt 1* + Alt1. Per-CSI-RS-resource *Ln* parameter
		- TBD: Whether {*Ln*, *n*=1, ..., *N*} are higher-layer configured by gNB, or the total $L\_{tot}\geq \sum\_{n=1}^{N}L\_{n}$ is higher-layer configured by gNB while {*Ln*, *n*=1, ..., *N*} are reported by the UE
		- Note: *Ln* will be restricted to take values from a predefined set, for example, $L\_{n}\in \left\{1,2,4\right\}$ to be discussed as part of parameter combinations

[Mod: Added without listing candidate value example (sensitive issue ☺ e.g. L=6 is supported in legacy)]**Issue 1.8**Support |
| Mod V12 | **Revision on 1.A and 1.E.2 per MediaTek’s input****Proposals 1.C, 1.E.2, and 1.G.2 are moved to Email Endorsement 2 thread. Please comment there** |
| LG | Issue 1: Support. We are fine with selection restriction suggested by MTK.Issue 2: Regarding FFS for amplitude quantization, the legacy quantization table may not be adequate to represent inter-TRP power difference and basis power difference at the same time since differential range of legacy table is 10.5dB per polarization. One possible approach is to extend the range by increasing the differential step size. However, we still prefer to support Alt 3 which does not have the above issue. |
| Xiaomi | **Proposal 1.A**As for the second sub-bullet, will the CRI be reported or not? In my understanding, CRI can indicate the selection of NZP CSI-RS resources. In addition, as for the FFS, since N can equal to 1 in the main bullet, we suggest to update the FFS as belowFFS: Whether S-TRP transmission hypothesis is also reported when N>1[Mod: OK]**Proposal 1.B.2**We prefer Alt 3 since the amplitude gap between TRP may be large. But we agree that the problem can be solved by amplitude quantization table enhancement included in the first FFS. We can accept this proposal with the following update since the gap can also be introduced by different TRP location.**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: Amplitude quantization table enhancement ~~considering transmission power difference between multiple TRPs~~
	+ For the amplitude group other than the group associated with the SCI, the reference amplitude is reported

 [Mod: OK] |
| Mod V18 | **Minor revision on 1.A and 1.B.2** |
| CMCC | **Proposal 1.A**Alt2 might have more than NTRP bits overhead reduction in W2 coefficients and basis selection in some cases. Although our first preference is Alt1, we can be OK with this proposal if Alt2 is majority view.**Proposal 1.B.2**If the SLS results do show that the performance difference between Alt 1 and Alt 3, we are fine with this proposal. And Xiaomi’s version is fine for us. The amplitude quantization table design can be discussed latter. |
| Spreadtrum | **Proposal 1.A**:Since reporting format of CSI-RS resources selection has been proposed, we think it’s necessary to decide the maximum value of NTRP together.For Type-II codebook calculation since Rel.15, only 1 CMR can be configured so that UE is not required to find the best channel/beam for the cell. For Type-II codebook for CJT, considering UE complexity, similar rule can be applied so that UE is not required to find the best channel/beam for each TRP. Therefore, we suggest to limit NTRP<=4.**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<=4 is the maximum number of cooperating CSI-RS resources configured by gNB via higher-layer signaling
* The selection of N out of NTRP CSI-RS resources is also reported via NTRP-bit bitmap in CSI part 1
* [A restricted configuration (gNB-configured via higher-layer signaling) where N=NTRP is supported]
	+ FFS: Whether [other] RRC-configured TRP selection restriction is supported
* 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 when N>1**Proposal 1.B.2**:Since one (common) SCI has been agreed and only Alt1 and Alt3 are valid for further down selection, we think Alt1 is simpler. There is an issue for Alt3 + one (common) SCI: since Ln configured per CSI-RS resource is highly possible to be agreed, if UE is configured with L1=4 and L2=2, is UE allowed to report the SCI corresponding to the 3rd SD basis? If yes, how to determine the location of reference amplitude corresponding to the 2nd group? |
| Qualcomm | **Proposal 1.A**: Firstly a couple of different understandings with FL note:* “induced inter-cell interference fluctuation”: As long as W2 (also W1) is freely reported, this interference fluctuation always exist. For TRP selection by a **subset** of N TRPs from a gNB-configured set of NTRP TRPs, seems it mainly reduces some interference from unselected TRPs
* “NW scheduler complication” or MU-MIMO: Seems this restricted selection of TRP **subset** only frees-up some resources of the unselected TRPs – it is not UE-formed/-recommended TRP cluster anyway
* “UE complexity”: Firstly the selection is not based on multi-hypo. It can be SD-selection-based or RSRP-based (to respectively assist small-/large-scale fading properties that are not well-captured at network side by semi-static configuration)

Then for the simple NTRP-bit bitmap proposed by FL, we **support**. We agree it is straight-forward and simple enough to avoid too many diverging and probably trivial alternatives (other alternatives include explicit N, or implicit N with SD basis selection, which can further diverge…, maybe eventually only results in <5 total bits difference)For the TRP-selection restriction, we have concern that it only complicates UE selection, rather than the opposite (as motivated to reduce UE complexity), especially the FFS sub-bullet – seems very like multi-hypo. Thus we propose:

|  |
| --- |
| * [FFS: Whether A restricted configuration (gNB-configured via higher-layer signaling) where N=NTRP is supported]
	+ ~~FFS: Whether [other] RRC-configured TRP selection restriction is supported~~
 |

Lastly, for the last FFS, we think it can be removed due to two reasons:1. “only one transmission hypothesis is reported” – as in the second last bullet;2. N=1 already included, as commented by Xiaomi

|  |
| --- |
| ~~FFS: Whether S-TRP transmission hypothesis is also reported~~ |

**Proposal 1.B.2**: Can’t agreeFirstly, we want to point out that Alt3 can include Alt1 by reporting all other 2N ampRefs TRP-common (thus equivalent to Alt1, as in an example shown below). Therefore, at least it should not have UPT loss w.r.t. Alt1 (some “slight” UPT loss can be due to some usual simulation variation?)

|  |  |  |  |
| --- | --- | --- | --- |
| ampRef | Alt1 | Alt3 – general | Alt3 – special (**equivalent to Alt1**) |
| Pol-1 | Pol-2 | Pol-1 | Pol-2 | Pol-1 | Pol-2 |
| TRP#1 | **1 (SCI-pol)** | **x** | **1 (SCI-TRP&pol)** | **x** | **1 (SCI-TRP&pol)** | **x** |
| TRP#2 | y2 | x2 | **1** | **x** |
| TRP#3 | y3 | x3 | **1** | **x** |
| TRP#4 | y4 | x4 | **1** | **x** |

Besides, amp difference across-TRP (either co-located or distributed TRPs) is not likely to be smaller than across-pol (the 2 polarizations are definitely co-located with same direction and **same selected beams**), thus it is not reasonable to support 2 different ampRefs across-pol, while common ampRef across-TRP (given that Rel-16 already has 2 ampRefs for the 2-pol of sTRP)Lastly, EVM mainly focus on nearby TRPs – this could be the reason why the benefit of Alt3 is not revealed.**Issue 1.5 (“TBD” of Proposal 1.E.2)**Fine with Proposal 1.E.2 itself, still want to discuss the “TBD” here (we understand “TBD” is not the scope of Email endorsement)Regarding gNB-configured v.s. UE-determined {*Ln*, *n*=1, ..., *N*}, * A couple of sources from both network and UE vendors show UPT gain under a same Ltot and similar overhead;
* From UE complexity perspective, we don’t see much difference b/w (1) selecting Ltot highest-power beams across all TRPs, and (2) selecting Ln highest-power beams respectively for TRP n=1,…,N, given $L\_{tot}=\sum\_{n=1}^{N}L\_{n}$ – similar as Issue 1.1 (proposal 1.A), please note that this is not multi-hypo;
* Besides, we are also interested in the case $L\_{tot}\geq \sum\_{n=1}^{N}L\_{n}$, as commented by MTK (and also by AT&T in round 0). This case may be useful to reduce UE complexity, if “opportunistically” RSRP gap b/w TRPs is large enough (e.g. >20 or 10dB) – maybe this can be discussed in round 2

As for “Ln value taken from a pre-defined set,” we are open to discuss, but it should be FFS at current stage, thus we propose editorial change:

|  |
| --- |
| * + FFS: The value of *Ln* is taken from a pre-defined set ~~(possible values FFS)~~
 |

 |
| Huawei, HiSilicon | For issue 1.1, we still prefer Alt 1 as it can avoid under-estimation of UE on several TRPs to have a better performance. And there’s a concern of Alt 2 on UE complexity, because there’s possibility UE has to try several times to determine N, then it will be problem how to define the UE capability on CPU and #CSI-RS resource if N is reported. In that sense, we think MTK’s proposal is a good direction. To reduce the UE complexity on determination number of TRPs, one way is to configure N by gNB. So, we prefer to rephrase it as following. We also support a UE capability whether UE supports to report the value of N.* ~~[A restricted configuration (gNB-configured via higher-layer signaling) where N=N~~~~TRP~~ ~~is supported]~~ N$\in ${1,..., NTRP} can be higher-layer configured by gNB
	+ If it’s not configured, N is reported by UE
	+ FFS: Whether [other] RRC-configured TRP selection restriction is supported

For the comments from QC below, we are not sure whether multi-hypo is totally prohibited in implementation from any specification/agreement. The implementation for best performance is that UE searches all possible combinations, and reports the best one. * + *“UE complexity”: Firstly the selection is not based on multi-hypo. It can be SD-selection-based or RSRP-based (to respectively assist small-/large-scale fading properties that are not well-captured at network side by semi-static configuration)*

For issue 1.2, we don’t support it, as the signal strength from different TRPs may vary significantly, with per-TRP reference amplitude and per-TRP per-polarization amplitude group, the range of amplitude within each group is smaller and can be quantified more accurately with a limited quantization alphabet. |
| Qualcomm | Re Huawei:Here what we mainly want to point is, complexity may not be a concern of UE-determined N.What you mentioned about extensively scanning all hypos, it is not forbidden, but not **mandated** – maybe UE is free to implement in that way (regardless of reasonable or not) – but this does not make it an argument for UE complexity issue on determining N.Actually, from some evaluations, it is observed SD basis selection is already pretty good on determining N. We did not try to go deeper (e.g. after FD compression) to scan all hypos, since this is not mandated due to high complexity. |
| vivo | **Proposal 1.A**We generally support this proposal. Some further comments are given belowFirst, maybe it’s clear enough, but it is better to clarify that the value N is also determined by UE. Hence we suggest the following minor wording change.**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 via higher-layer signaling
* The value N and the selection of N out of NTRP CSI-RS resources are reported via NTRP-bit bitmap in CSI part 1
* [A restricted configuration (gNB-configured via higher-layer signaling) where N=NTRP is supported]
	+ FFS: Whether [other] RRC-configured TRP selection restriction is supported
* 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 reportedSecondly, based on the discussion so far, it seems the only contentious point is the third bullet in brackets. We tend to agree with QC that if the concern comes from UE side, it should be fine as how to select the TRPs is totally up to UE. As long as the RAN4 requirement is satisfied, no one can mandate UE to calculate multiple hypothesis. Further, we already have a note to clarify this. Hence it is better to put this bullet in FFS if it cannot be resolved in this meeting. * Further, regarding the comments from HW, my understanding on HW’s request is to further restrict that the value N is configured by gNB. It can be covered by the FFS: Whether [other] RRC-configured TRP selection restriction is supported. Maybe we can make it more explicit by adding the following:
	+ FFS: Whether [other] RRC-configured TRP selection restriction including the value N is supported.

**Proposal 1.B.2**Support. All the submitted simulation results shows Alt 1 is superior of Alt 3. Hence there is no reason to take Alt 3 which is a more complex design than Alt 1.**Conclusion 1.C**OK**Proposal 1.E.2**OK**Proposal 1.G.2**Support**Proposal 1.I** Support |
| Mod V27 | **Revision on proposal 1.A** |
| Lenovo | The note regarding adding *“UE-based CSI-RS resource selection”* is not clear to us. Since each TRP is associated with a distinct CSI-RS resource Why is this needed if an NTRP sized bitmap is fed back by the UE for TRP selection? We just need to have better understanding of the motivation to include this feature[Mod: No, this is not a separate feature. Please check revised version which should be clearer] |
| Ericsson | **On Proposal 1.A** We are generally fine with the direction of Proposal 1.A. We have a couple of comments:1. In the already agreed Proposal 1.E.2, there are two different options which are still TBD:

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, one L configured and {*Ln*} determined from configured Lif we select the option of {*Ln*, *n*=1, ..., *N*} are reported by the UE, then *Ln* may need to be indicated in CSI part 1 as well. This may impact the detailed signaling design. It is too early to discuss the exact signaling design now. So, we prefer the defer the exact signaling design to a later discussion once we have agreement on the complete design. Our suggested revision is as follows:* + 1. The selection of N out of NTRP CSI-RS resources is reported ~~via N~~~~TRP~~~~-bit bitmap~~ in CSI part 1
			- FFS: the exact details on how to signal N out of NTRP
			- Note: The value of N is inferred from the selection

[Mod: Since the use of simple TRP bitmap is an important part of a compromise for some stout Alt1 proponents, I cannot make this FFS at the risk of failing this agreement. But regardless, coupling the Ln issue with TRP selection is totally unnecessary. Once the TRP bitmap is agreed, any of the Ln schemes (from simple RRC for each Ln to the fancy UE-selected Ln) is unaffected. If Ln is reported by the UE and, say, the bitmap indicates 1001 in UCI part 1, the UE only needs to report L1 and L4.Lastly, coupling the two issues would end up generating many alternatives to down select in the next meetings. This is not helpful from work flow perspective considering the scope of this AI.]1. We think it is good to clarify the candidate values of NTRP. We suggest to add this as a sub-bullet:
	* 1. Note: the candidate values of NTRP are 2, 3, and 4.

[Mod: OK, thanks for the good catch]**On Proposal 1.B.2** Our first preference is Alt 3, but we can accept Alt 1 for progress.[Mod: Appreciated] |
| Mod V32 | **Revision on proposal 1.A to improve clarity** |

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

Table 3A Summary: issue 2

|  |  |  |
| --- | --- | --- |
| **#** | **Issue** | **Companies’ views** |
| 2.2 | 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. ENDORSED | **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. ENDORSED | **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, Lenovo/MotM
* **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. ENDORSED | **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 |
| 2.4 | [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.2:** For the Rel-18 Type-II codebook refinement for high/medium velocities, when N4>1, the value of *Q* is gNB-configured via higher-layer (RRC) signallingMoved to Email Endorsement 3**FL Note**: With DFT basis, there doesn’t seem to be any motivation for doing otherwise | **Support/fine:** LG, CMCC, Spreadtrum, Qualcomm, **Not support:** |
| 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. Moved to Email Endorsement 2. ENDORSED**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
* Down select from the following:
	+ Alt1. Support K>1 NZP CSI-RS resources, received via a single triggering instance, 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 m slot(s):
	+ Alt2. Support one NZP CSI-RS resource in a CSI-RS resource set, where K>1 occasions are received via a single triggering instance, for aperiodic (AP)-CSI-RS-based channel measurement where the separation between 2 consecutive AP-CSI-RS resources is m slot(s).
	+ For any of the alternatives:
		- No CRI is reported
		- [FFS: Details, e.g., supported value(s) of K, m, 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: [**Lenovo], Samsung, ZTE (no SP with K), Intel, MediaTek (A2), LG (A1), Xiaomi (A1, no SP with K), CMCC (A1), Spreadtrum, Qualcomm (A1), Huawei/HiSi (A1), vivo, Ericsson**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 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-RSMoved to Email Endorsement 2. ENDORSED | **Support/fine:** Ericsson, Nokia/NSB, Lenovo, Intel, Xiaomi, vivo**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. ENDORSED | **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

Moved to Email Endorsement 2. ENDORSED | **Support/fine:** Intel, Qualcomm, Samsung, Apple, Google, ZTE, CMCC, Huawei/HiSi, vivo**Not support:**  |
|  |  |  |

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

|  |  |
| --- | --- |
| **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

|  |  |
| --- | --- |
| **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. |
| Lenovo | **Issue 2.2 (Proposal 2.B)**We are OK to compromise for the sake of progress**Issue 2.4 (Proposal 2.D)**We would also support if switching is at N4=2. At N4=1, Wd is a scalar value, which would just be a fallback approach to legacy codebook design, and both Alt1 and Alt3 would coincide**Issue 2.5 (Proposal 2.E)**Support**Issue 2.6 (Conclusion 2.F)**Support**Issue 2.7 (Proposal 2.G)**We prefer the first version of Proposal 2.G, which was more high level and a good starting point for further discussion. We prefer to include both SP and AP CSI-RS resources, and also consider *m* slots separation, with *m*=1,2 would not need any deactivation. Can we consider the following?**Proposal 2.G**: On the CSI reporting and measurement for the Rel-18 Type-II codebook refinement for high/medium velocities, support the following CSI-RS resource types/structures for CMR:* Time-domain behaviour for 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 either aperiodic (AP) or semi-persistent (SP)-CSI-RS-based channel measurement in a same CSI-RS resource set where the separation between 2 consecutive AP-CSI-RS resources is *m* slot(s):
	+ FFS: Details, e.g., supported value(s) of K, *m*, 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
 |
| Samsung | Conclusion 2.F: OKProposal 2.G: support * @Apple: the value of K is FFS. Based on our study, K=4,8 can work and show UPT gain (off course large K can help, but then there is a CSI reporting delay, so there seems to be a tradeoff value, which is aroung K=4,8 in our view). So, we don’t think very large K is needed. Re the 1st point, yes, the current spec does not allow measuring K>1 AP CSI-RS resources via one CSI-RS resource set. This proposal means we need a small enhancement to relax this constraint for Doppler burst measurement, and allow K>1 AP CSI-RS resources configured via 1 CSI-RS resource set and measurement in consecutive slots.
* @Lenovo: Although in principle this proposal may work, we are not sure we need to enhance both AP and SP, we think AP is sufficient. Are there any additional benefits with SP CSI-RS resource that AP can’t provide especially after the offset enhancement?

Proposal 2.H: same view as CJT case, we think AP only should suffice and SP is cumbersome (without sufficient and tangible benefit). But if the majority prefers to support both SP and AP just as legacy, we are (reluctantly) fine. |
| ZTE | Conclusion 2.F: To be honest, we fail to understand the first subbullet of ‘Legacy UE procedure for CSI measurement/calculation’, which is supported if having N4=1 in proposal 2.D, right? It seems also to be aligned with the FL’s previous clarification. If so, we suggest to remove the bullet.Proposal 2.G: We are fine with this direction. But we can not agree that ‘the separation between 2 consecutive AP-CSI-RS resources is 1 slot’ is sufficient, due to the same reason mentioned by Haitong. Instead, we think that that can be configured. After that, we think that in such case, we do not need to additionally report CRI, right?BTW, we do not identify why we need to further enhance SP-CSI-RS. Based on our and other companies’ simulation results, uniformed space for SP/P CSI-RS is much better. * 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 X slots, where X is RRC configured:
	+ FFS: Details, e.g., supported value(s) of K and X, 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
* Note: In such case, no CRI is reported in the CSI.

Proposal 2.I: Support and we prefer Alt1. |
| Intel | **Issue 2.7**It is not clear for us how training of the filter coefficients for prediction can be done for aperiodic CSI-RS. In particular, it is not clear whether the filter can be averaged over multiple aperiodic CSI bursts. Considering that the details are FFS we are fine with the proposal. **Issue 2.8** We are fine to support aperiodic and SPS CSI report.**Issue 2.10**Support the proposal |
| Mod V09 | **Revision on proposal 2.G** |
| MediaTek | For Proposal 2.G, we would like to also emphasis that for AP CSI-RS a single DCI will be triggering all the K instances of CSI-RS occasions. Hence, propose to add the following sub-bullet : * Support K>1 NZP CSI-RS resources for aperiodic (AP) [as well as semi-persistent (SP)]-CSI-RS-based channel measurement in a same CSI-RS resource set where the separation between 2 consecutive AP-CSI-RS resources is m slot(s):
	+ No CRI is reported
	+ The K instance of the Aperiodic (AP)-CSI-RS-based channel measurement in different slots will be triggered by single DCI
	+ FFS: Details, e.g., supported value(s) of K, m, other use cases for the AP-CSI-RS resources (e.g., for training filter coefficients, prediction or performance monitoring)

[Mod: Done. I use the term “received via a single triggering instance”] |
| Mod V12 | **Slight revision on proposal 2.G per MediaTek’s input****Added proposal 2.D.2****Proposals 2.F, 2.H, 2.J are moved to Email Endorsement 2. Please comment there.** |
| LG | **Issue 2.4**Support Proposal 2.D.2.**Issue 2.7**Support Proposal 2.G |
| MediaTek | Thank you, FL, for the latest updates to proposal 2G.We wanted to also discuss an alternative solution for AP CSI-RS case where a single resource in a set in repeated multiple times across consecutive slots, similar for repletion flag operation we currently have for BM operations only. The benefits of this approach for us are two-fold, 1) more compact RRC signaling as we don’t need to configure so many CSI-RS resources to cover each repetition, 2) reduce the logical operations at the UE to logically connect multiple resource with different IDs to the same prediction model. SO we propose the following update:**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~~
* Alt1: Support K>1 NZP CSI-RS resources, received via a single triggering instance, for aperiodic (AP) [as well as semi-persistent (SP)]-CSI-RS-based channel measurement in a same CSI-RS resource set where the separation between 2 consecutive AP-CSI-RS resources is m slot(s).
* Alt2: Support one NZP CSI-RS resource in a CSI-RS resource set, where K>1 occasions are received via a single triggering instance, for aperiodic (AP) [as well as semi-persistent (SP)]-CSI-RS-based channel measurement where the separation between 2 consecutive AP-CSI-RS resources is m slot(s).
	+ No CRI is reported
	+ FFS: Details, e.g., supported value(s) of K, m, 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

[Mod: OK] |
| Xiaomi | **Proposal 2.D.2:**Support the proposal.**Proposal 2.G**:We are fine with the proposal. But we fail to see the motivation of K>1 SP CSI-RS based channel measurement. In our view, K>1 AP CSI-RS resources is sufficient. [Mod: OK, removed SP]**Proposal 2.H**:Support the proposal.**Proposal 2.J:**The indication overhead of non-zero coefficients (NZC) is linearly increased as rank increases. For large value of rank, e.g, rank=3 or 4, the indication overhead is significant, which may deteriorate the tradeoff between performance and overhead. In order to reduce the indication overhead of NZC, small Q values is preferred for lager value of rank. Hence, at this stage, it is fine that the number of selected DD basis vector is layer-common for small value of rank, i.e., rank=2. We prefer the bullet of proposal can be rewording as follows.**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 for rank=2.
 |
| Mod V18 | **Revised proposals per input** |
| LG | @MTK: regarding Alt 2 in Proposal 2.G, in my understanding, Alt 1 and 2 achieve the same functionality but, for Alt 2, new signaling is needed to indicate K occasions. Is this correct? Also, could you elaborate how to indicate K occasion in Alt 2? |
| CMCC | **Proposal 2.D.2:**Support the proposal.**Proposal 2.G**:We are OK with current proposal. In Alt 2, the AP-CSI-RS transmission seems more like P/SP CSI-RS, also with multiple transmission occasions.  |
| Spreadtrum | **Proposal 2.D.2:**Support the proposal. **Proposal 2.G**:Support. |
| Qualcomm | **Proposal 2.D.2**: Support**Proposal 2.G**: Support Alt1 for less change to current RRC signaling (similar as TRS, but different time spacing, and multi-port) |
| Huawei, HiSilicon | For issue 2.7, we are fine with proposal 2.G, our preference is alt 1. In addition, it would be much appreciated if the following use cases can be clarified. Our understanding is the consideration here are all objected at uses cases for channel prediction.* other use cases for the AP-CSI-RS resources (e.g., for training filter coefficients, prediction or performance monitoring)
 |
| vivo | **Proposal 2.B**Support**Conclusion 2.F**OK**Proposal 2.G**Although we are not convinced on the benefit of AP CSI-RS due to the large delay it causes, we can be fine with the proposal for the sake of progress.We don’t support to have multiple resources for SP or P CSI-RS. There is no clear use case for such enhancement as SP or P CSI-RS can already form a burst-like pattern in time domain. Hence we don’t support to have SP CSI-RS in the second sub-bullet. Replying to HW’s question:Based on typical UE prediction algorithms, CSI-RS measurement can be used on three use cases. * Calculate the filter matrix used to predict CSI
* Measure CSI-RS occasions and use the calculated filter to predict channel matrix
* Monitor the prediction performance

We suggest to perform more study on this. These use cases may impact the decision on some of the design of the burst, e.g., the values K and m.**Proposal 2.H**OK**Proposal 2.J**OK |
| MediaTek | **@LG:** Thanks for your questions. Yes, both alternatives achieve the same functionality. Indeed, for indicating K, new signaling is needed for Alt2. However, we believe it is simpler to signal a number K than to signal a sequence of K CSI-RS resource IDs and populating relevant information for K different CSI-RS at RRC. With Alt2, the current CPU occupancy rule can be reused:“$O\_{CPU}=K\_{s}$, where $K\_{s} $is the number of CSI-RS resources in the CSI-RS resource set for channel measurement.”“An aperiodic CSI report occupies CPU(s) from the first symbol after the PDCCH triggering the CSI report until the last symbol of the scheduled PUSCH carrying the report.”For Alt1, we need to add a restriction that $O\_{CPU}=1$.Both the number K and the separation m can be indicated through RRC IE *NZP-CSI-RS-ResourceSet*, like *aperiodicTriggeringOffset(-r16)*. With the triggering offset, the separation m, and the total number K, UE can infer all the locations of CSI-RS occasions. |
| Mod V27 | **No revision****Proposal 2.D.2 is moved to Email Endorsement 3 sub-thread. Please comment there** |
| Ericsson | On **proposal 2.G**, we are fine to support the proposal. |

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

Table 5A Summary: issue 3

|  |  |  |
| --- | --- | --- |
| **#** | **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 profile, difference between lowest- and highest-value Doppler shifts in Doppler profile
* AltA3. Relative Doppler shift(s)
	+ A relative Doppler shift corresponds to a Doppler frequency with non-zero energy in Doppler profile
	+ E.g., average Doppler shifts, (Relative) Doppler shift per TRS resource (if >1 TRS resources are supported), Doppler shift corresponding to the peak energy 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**MOVED TO Proposal 3.A THREAD****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.Moved to Email Endorsement 2**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, Lenovo
* **No:** LG, Nokia/NSB, OPPO

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

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

|  |  |
| --- | --- |
| **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

|  |  |
| --- | --- |
| **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 |
| Lenovo | **Issue 3.2**OK to consider SP and/or event-triggered TDCP reporting |
| Samsung | Conclusion 3.B:* We think it is too early to conclude since we have not made any meaningful agreement on TDCP yet. So, we prefer to keep the door open, at least for event-triggered reporting.

[Mod: Actually some companies use this as an “what if” argument for issue 3.1. In addition this has been a separate/parallel issue to CSI content since Rel-8 LTE ☺ where we agreed on the TD modes first before the definition of CQI, RI, PMI was finalized. So it is not too early to state the fact that there is no consensus. ] |
| ZTE | **Issue 3.1**We prefer AltA3 and can live with AltA2.**Issue 3.2**We can live with conclusion 3.B, although it is not our preference.  |
| Mod V09 | **No revision** |
| MediaTek | Agree with Samsung’s comments. We would also like to discuss UE initiated TDCP reporting further.  |
| Ericsson | Issue 3.1Since the UE has no absolute frequency reference, but only a frequency reference based on the RX signal, the UE can only measure relative Doppler shifts. The term Doppler shift should therefore be replaced with relative Doppler shift in the proposal. For the same reason we don’t understand what is meant with average Dopplershift. What is it related to? Maybe the proponents can explain?[Mod: Added “relative”]The Doppler shift measure should also be broken down further into two alternatives. Except for the ‘average Dopplershift’ which we don’t understand there are also:**i. Relative Dopplershift per TRS resources****ii. Relative Dopplershift per peak in the Doppler profile**[Mod: Since we haven’t agreed to support >1 TRS resources this is not necessary. The same applies to correlation. We will discuss the # TRS resources after 3.1 is finalized]These two alternatives address different use cases and have nothing to do with each other.We note also that the second alternative above only makes sense if the relative Dopplershift is reported for multiple peaks in the Doppler profile since the frequency of one peak is needed as a reference in forming relative Doppler shifts for the other peaks.We also want to stress again that the difference between lowest- and highest-value Doppler shifts in Doppler profile, i.e. the maximum Dopplershift is a very bad measure. It depends in a volatile way on which channel rays are visible over noise and interference. In addition, it doesn’t reflect channel variability in a good way. Note that it’s the channel variability in time we want to estimate, not the UE velocity. The same UE velocity can give widely different channel variability in time dependent on both the direction of the UE and the spatial distribution and power of channel rays.The second moment of the Doppler power spectrum, on the other hand is a decent measure that at least reflects channel variability over small time intervals. It can be defined in terms of the Autocorrelation function since  |
| Mod V12 | **Revised 3.A per Ericsson’s comment** |
| Ericsson | On Proposal 3A, we can live with FL’s version in V12. Further details related to Proposal 3A can be discussed in the future. |
| LG | **Issue 3.2**We support conclusion 3.B |
| Xiaomi | **Proposal 3.A**We are fine with Proposal 3.A. Our preference is AltA2/AltA3. But we can open to study AltB.**Conclusion 3.B** Support. |
| Mod V18 | **Moved proposal 3.A to Proposal 3.A email thread. Please comment there** |
| vivo | **Conclusion 3.B**OK |
| Mod V29 | **Moved conclusion 3.B to Email Endorsement 3 sub-thread. Please comment there**  |

# References

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