**3GPP TSG RAN WG1 #117 R1-2405486**

**Fukuoka, Japan, May 20th – 24th, 2024**

**Agenda item:** 9.2.2

**Source:** Moderator (Samsung)

**Title:** Moderator Summary#4 on Rel-19 CSI enhancements: Round 4

**Document for:** Discussion and Decision

## Introduction

The scope given in the Rel-19 NR MIMO Phase 5 WID pertaining to CSI enhancement is as follows:

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| --- |
| 1. Specify CSI support for up to 128 CSI-RS ports, targeting FR1
	1. Type-I codebook refinement supporting up to a total of 128 CSI-RS ports across all resources, assuming legacy CSI-RS resources (with up to 32 CSI-RS ports per resource), based on extension of legacy codebooks
	2. Type-II codebook refinement supporting up to a total of 128 CSI-RS ports across all resources, assuming legacy CSI-RS resources (with up to 32 CSI-RS ports per resource), based on extension of legacy codebooks, **without modifying any codebook parameter other than** introducing additional values for the number of ports codebook parameter(s)
	3. Extension of CRI(s)-based CSI reporting (CQI/PMI/RI calculated per CRI for ≥1 CRIs) for hybrid beamforming supporting up to a total of 128 CSI-RS ports across all resources, with up to 32 CSI-RS ports per resource, without new codebook design
2. Specify UE reporting enhancement for CJT deployments under non-ideal synchronization and backhaul, targeting FR1, both FDD and TDD
3. Inter-TRP time misalignment and frequency/phase offset measurement and reporting, assuming legacy CSI-RS design, with stand-alone aperiodic reporting on PUSCH
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## Summary of companies’ proposals and views

***Ground rules in sharing your inputs:***

* Please do NOT input anything in Tables 1A, 2A, and 3A
	+ Including company names - appreciate your trying to save me some work, but …
	+ For some reason, most likely due to poor MS Word inter-platform/version compatibility support (if any), the formatting of the FL proposals will change (for the worse) if you do so. This has happened several times in Athens and Changsha ☹
* Please input your comments ONLY in Tables 1C, 2C, and 3C, thanks! 😊

### Issue 1 (WID objective 2a and 2b): Type-I and Type-II codebook refinement for up to 128 CSI-RS ports

Table 1A Summary: issue 1

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| **#** | **Issue/proposal** | **Companies’ views** |
| 1.1.1 | **Proposal 1.A.1**: For the Rel-19 Type-I SP codebook refinement for 48, 64, and 128 CSI-RS ports, Scheme-A and Scheme-B are two separate UE features, where Scheme-A is a basic UE feature of Rel-19 Type-I SP CSI**FL assessment**: This seems to be a common understanding and can be agreed now.  | **Support/fine**: Qualcomm, Samsung, OPPO, NTT DOCOMO, Fujitsu, MediaTek, CEWiT, Nokia/NSB, CATT, Fraunhofer IIS/HHI, Ericsson, Tejas, Lenovo/MotM (UE feature), TCL, Spreadtrum, Intel, vivo, Xiaomi, **Not support (too early):** ZTE, Huawei/HiSi,  |
| 1.1.6 | **Proposal 1.A.6**: For the Rel-19 Type-I single-panel (SP) codebook refinement for 48, 64, and 128 CSI-RS ports with RI=5-8, regarding Scheme-B, reuse the legacy Rel-15 Type-I layer pairing scheme, and down-select (by RAN1#118) from the following two alternatives:* Alt1 (fixed mapping between SD basis vectors and layers):
	+ The k-th SD basis vector is associated with the k-th layer-group.
* Alt2 (UE-selected SD basis vector for the orphan layer):
	+ The SD basis vector associated with the orphan layer is selected from the $\left⌈v/2\right⌉$ SD basis vectors and indicated with $\left⌈log⁡(\left⌈v/2\right⌉)\right⌉$ bits
	+ Except for the orphan layer and the associated SD basis vector, the j-th SD basis vector from the remaining SD basis vectors is associated with the j-th layer group from the remaining layer-groups.

Note: The k-th SD basis corresponds to the k-th lowest SD basis index.Note: Each layer-group corresponds to a layer-pair or an orphan layer.**Support/fine:** ZTE (Alt2), TCL, Samsung, OPPO, ZTE, MediaTek, Intel (Alt1), Spreadtrum, Huawei/HiSi (Alt1), NTT DOCOMO (Alt2), vivo (Alt1), Fraunhofer IIS/HHI, Lenovo/MotM, Xiaomi, Qualcomm (Alt2),**Not support:** **Conclusion 1.A.6**: For the Rel-19 Type-I single-panel (SP) codebook refinement for 48, 64, and 128 CSI-RS ports with RI=5-8, regarding Scheme-B, there is no consensus on supporting the following:* additional support for 4 selected SD basis vectors for RI=5-6
* additional support of 'x' selected SD basis vectors for ranks 5-8, x not equal to ceil(v/2)

**Question 1.A.6**: For the Rel-19 Type-I single-panel (SP) codebook refinement for 48, 64, and 128 CSI-RS ports, regarding Scheme-B for RI=5-8, please share your view on the following two FFS points:* FFS1: mapping between the orphan layer and its selected SD basis vector and, if needed, UE reporting of the selection [fixed vs UE indication]
* FFS2: (additional) support of 4 selected SD basis vectors for RI=5-6
* FFS3: (additional) support of 'x' selected SD basis vectors for ranks 5-8, x not equal to ceil(v/2)

FFS2: additional support for 4 selected SD basis vectors for RI=5-6 (note that 3 is already agreed)* **Support/fine**: Huawei/HiSi, Xiaomi, NEC, CEWiT, Tejas,
* **Not support**: ZTE, Intel, Samsung, OPPO, NTT DOCOMO, MediaTek, Fraunhofer IIS/HHI, Ericsson, Nokia/NSB, Lenovo/MotM, Spreadtrum, vivo,

FFS3: additional support of 'x' selected SD basis vectors for ranks 5-8, x not equal to ceil(v/2) (note that 3 is already agreed)* **Support/fine**: CEWiT, Tejas,
* **Not support**: OPPO, NTT DOCOMO, ZTE, MediaTek, Ericsson, Lenovo/MotM, Nokia/NSB, Intel, Spreadtrum, vivo, Fraunhofer IIS/HHI,

**FL assessment**: This FFS needs resolution to finalize codebook and UCI design |
| 1.4 | **Proposal 1.D.2**: For the Rel-19 Type-I SP and Type-II codebook refinements (expect based on Rel-18 Type-II Doppler) for 48, 64, and 128 CSI-RS ports, active resource counting is:* For Capability 1 timeline: 1
* For Capability 2 timeline: 1

**FL assessment**: Offline session1: Concern: Huawei/HiSiK: Concern: Qualcomm, Nokia/NSB, {1, cK} UE reports: Concern (with cK, ok with K): Qualcomm, Ericsson, ZTE, SamsungSince Capability 2 is quite (too) relaxed, there is no reason to further relax both OCPU and ARC for Capability 2. For ARC, since the increase in the total # antenna ports (to up to 128) will be addressed in the ‘triplet’, there doesn’t seem any need to double-book this (mostly relevant to measurement buffering) in ARC (hence 1 should be more fitting, and K is excessive). Hence legacy in FG 2-33 can be interpreted as “Ks=1” (post aggregation) rather than “Ks=K”(pre-aggregation) | **Support/fine:** Ericsson, Nokia/NSB, ZTE (ok), Fraunhofer IIS/HHI, Intel, TCL, Samsung, vivo, Google, CATT, Qualcomm, NTT DOCOMO, Xiaomi, HONOR, Lenovo/MotM, Spreadtrum, CMCC, Sharp, OPPO, MediaTek, **Not support (K):** Huawei/HiSi (cK), Fujitsu, Apple |
| 1.5.1 | **[116bis] Agreement**For the Rel-19 Type-I multi-panel (MP) codebook refinement for 48, 64, and 128 CSI-RS ports, for RI=1-4, decide, by RAN1#117, whether to support Type-I multi-panel (MP) codebook refinement in Rel-19. If supported, decide from the following alternatives:* Scheme1. Based on Rel-15 Type-I MP design directly extended with Ng=K (2, 3, and 4), and new (N1, N2) values
* Scheme2. Based on Scheme4/6 as described in the RAN1#116 agreement
	+ W1 structure: Reuse legacy Rel-15 Type-I SP SD basis selection with L=1 independently for each of the K NZP CSI-RS resources
	+ W2 structure:
		- Legacy Rel-15 Type-I inter-polarization co-phasing rules independently in each resource,
		- Layer-common inter-resource M-PSK co-phasing, where M is further down-selected from {2,4}
			* FFS: Whether inter-resource co-phasing is wideband or per subband.

If so, decide, by RAN1#117, whether port mapping scheme similar to, e.g. Rel-18 Type-II CJT, needs to be specified. …**Proposal 1.E.1**: For the Rel-19 Type-I multi-panel (MP) codebook refinement for 48, 64, and 128 CSI-RS ports, for RI=1-4, support the following (compromise between Scheme1 and Scheme2 described in RAN1#116bis):* W1 structure: Independent SD basis selection across all the Ng=K NZP CSI-RS resources, reusing legacy Rel-15 Type-I SP SD basis selection rules with L=1 for RI=1-4
	+ Ng = *K* = {2, 4} denotes the number of NZP CSI-RS resources associated with the Ng panels
* W2 structure:
	+ Legacy Rel-15 Type-I inter-polarization co-phasing rules independently in each resource,
	+ Layer-common wideband inter-resource QPSK co-phasing independently reported for resource n = 2,…,K with respect to the first resource.

Rel-19 Type-I MP does not support RI=5-8.Reuse Rel-15 Type-I MP legacy designs for UCI omission, and CBSR.For CSI calculation, reuse Rel-18 Type II CJT CSI-RS port ordering for UE assumption on the transmitted PDSCH symbols across antenna ports.**FL assessment**: Based on Tuesday morning offline, changing “common” to “independent”. Additional changes after offline. Note that **all the available SLS results show that Scheme2 outperforms Scheme1 (cf. Table 1B).** | **Support/fine**: MediaTek, Qualcomm, Ericsson, Nokia/NSB, vivo, Samsung, Tejas, NTT DOCOMO, CMCC, ZTE, Huawei/HiSi, OPPO, CATT, Intel, HONOR, Fujitsu, LG, CEWiT, Fraunhofer IIS/HHI, New H3C, NEC, KDDI, IDC, Spreadtrum, Xiaomi, **Not support (No T1 MP)**: Apple (not object), TCL, Google, Lenovo/MotM (not object) |

Table 1B SLS results: issue 1

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| --- | --- |
| **Company** | **SLS results** |
| **Issue #** | **Metric** | **Observation** |
| IDC | 1.5.1 | Normalized average throughput | From the result above, it is observed that 8-PSK and 4-PSK based co-phasing in Scheme-2 MP with 32 ports on each panel can achieve a reasonable performance. As shown in the result above, Scheme-2 MP achieves higher performance than the legacy Rel-15 Type-I MP with 32 ports albeit having smaller throughput performance than Rel-19 Type-I SP Scheme-A with 64 ports.  |
| MediaTek | 1.5.1 | Avg UPT gain vs feedback overhead | It is seen that the compromised proposal 1.E.1 shows 1~2 % UPT degradation compared to Scheme 2. This is because Scheme 2 offers flexibility to compensate the angle difference (however small) between panels due to large array size. In case there is no angle difference between panels, Scheme 2 does not preclude the UE report of common SD bases, thereby offering the best performance in either case. Further, we anticipate that the flexibility of Scheme 2 will be more beneficial in non-co-located/mixed deployments. Based on the above observations, we support Rel-19 Type I MP codebook enhancement up to 128 ports based on Scheme 2. |
| Samsung | 1.1.5 | Avg UPT Gain vs overhead | For Rel-19 Type-I for RI=1-4, it is shown in SLS results that the case of O1=O2=2 incurs 2% UPT loss compared to the case O1=O2=4 for both Scheme A and Scheme B. |

Table 1C Additional inputs: issue 1

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| --- | --- |
| **Company** | **Input** |
| Mod V0 | **Please share your inputs on each of the issues and, if applicable, proposals in TABLE 1A** |
| Samsung | Proposal 1.A.6Support. The decision should be based on SLS evaluations.Proposal 1.D.2We support 1 for both capabilities, and have strong concern on introducing multiple ARC values other than {1,K}.  |
| Ericsson | **Proposal 1.A.6**For scheme B, we’ve agreed that there can be ceil(*v*/2) SD basis vectors, while the number of layers is given by *v*. Then, in Alt 1, we are not sure if it is correct to say k^th SD basis vector is associated with the *k* th layer. Should it be something like *k* th layer (k=1, 2, ..., *v*) is associated with the ceil(*k*/2)th SD basis vector? We may need a similar change for Alt 2 also.[Mod: Actually, it says kth layer-group, not layer. So the current description is fine] |
|  |  |
| Mod V6 | 1.E.1: revision per offline comments (sub-band 🡪 wideband, no support for K=3) |
| OPPO | **Proposal 1.A.6:**Fine to make decision in the next meeting. **Conclusion 1.A.6:**Support.  |
| ZTE | 1.A.6:Support the proposal and prefer Alt 2. To maximize the throughput, the weakest SD basis should be applied to the orphan layer, and it needs to be indicated by UE.Conclusion 1.A.6:Support. |
| MediaTek | **Proposal 1.A.6** Support**Proposal 1.E.1** Support, with the following minor addition for completeness regarding port ordering across resources:For CSI calculation, reuse Rel-18 Type II CJT CSI-RS port ordering for UE assumption on the transmitted PDSCH symbols across antenna ports. |
| Spreadtrum | **Proposal 1.A.1**: Support.**Proposal 1.A.6**: Support. In our views, Alt1 can be considered as baseline, and supporting Alt2 can be supported only if the performance gain over Alt1 is large enough.**Conclusion 1.A.6**: Support.**Proposal 1.E.1**: Considering the majority support on this proposal, we can be OK. |
| Intel | **Proposal 1.A.1**: Support**Proposal 1.A.6**: Support. Our preference is Alt2.  |
| Mod V14 | **Revision per input** |
| Huawei, HiSilicon | Proposal 1.A.6, prefer fixed mapping. From the simulation results, there’s only 1% difference from two options, it seems to be an over-design on UE selection.Conclusion 1.A.6: not support. There’s 5~11% performance gain by supporting up to 4 SD basis vectors. They should be discussed based on evaluation results. |
| NTT DOCOMO | **Proposal 1.A.6:**Support. We prefer Alt2. **Conclusion 1.A.6:**Support.  |
| vivo | **Proposal 1.A.1**:OK.**Proposal 1.A.6**:We are fine with UE reporting of the selection. We think that there is a need for a mapping between the orphan layer and its selected SD basis vector. Besides, for Scheme-B, is it possible to clarify that the layer index of orphan layer follows the Rel-15 CB codebook structure (layer index 5 for orphan layer for RI=5, layer index 3 for orphan layer for RI=7)? If not, in our view, the two layers sharing same SD basis in legacy Rel-15 Type-I codebook can be located in a codeword or can span 2 codewords (e.g., rank 6). Thus, for the orphan layer, fixed indexing is sufficient, e.g., the last layer of the codebook structure is the orphan layer.**Conclusion 1.A.6**:We are fine with this conclusion. When x is greater than ceil(v/2), multiple CB structures may be required. We prefer a fix CB structure, i.e., independent selection of different ceil(v/2) SD basis vectors for RI = v, where each SD basis vector is applied to two respective layers. Therefore, we do not support x greater than ceil(v/2) or x not equal to ceil(v/2).**Proposal 1.E.1**Fine. |
| Fraunhofer IIS/HHI | **Proposal 1.A.6:** Support **Conclusion 1.A.6:** Support  |
| MediaTek | **Proposal 1.E.1**Per some offline discussion, it maybe better to clarify that inter resource co-phasing are independently reported with respect to the first resource (i.e., same as legacy Rel-15 Type I MP), so we suggest modifying the 2nd sub-bullet of W2 structure as follows:* Layer-common wideband inter-resource QPSK co-phasing independently reported for resource n = 2,…,K with respect to the first resource.

Further, after some thinking, we feel that it may not be able to directly reuse the UCI parameters of Rel-15 Type I MP, due to per resource SD basis and co-pol selection. Given that the scope is already reduced much, and to ensure we don’t miss any parameters, we suggest to defer the decision on only the UCI parameters to the next meeting. |
| Lenovo/ MotM | Proposal 1.A.1:SupportProposal 1.A.6:OK to discussConclusion 1.A.6:OK |
| Mod V25 | **Revision per inputs** |
| Xiaomi | **Proposal 1.A.1**:Support**Proposal 1.A.6**:Support.**Conclusion 1.A.6**:Considering obvious gain are obtained while the total overhead is comparable with RI=4, we think 4 selected SD basis vectors for RI=5-6 could be supported. But, in order to make the scheme be more simple, we are fine if major companies can live with it. |
| Qualcomm | **Proposal 1.A.6**: Support the proposal and prefer Alt2 |
| Mod V28 | **No revision** |

### Issue 2 (WID objective 2c): CRI-based CSI for hybrid beamforming (HBF)

Table 2A Summary: issue 2

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| **#** | **Issue** | **Companies’ views** |
| 2.1.2 | **[116bis] Agreement**For the Rel-19 CRI-based CSI refinement for up to 128 CSI-RS ports, for M>1, the M CRIs (each with $\left⌈log\_{2}K\_{S}\right⌉$ bits) are separated indicated * FFS: whether to support NW configuring/requesting the UE to report CRI/RI/PMI/CQI associated with *MR* (<*M*) of *KS* CSI-RS resources, including whether further reduction in the number of hypotheses is supported, i.e. reporting (*M* – *MR*) CRIs (each with $\left⌈log\_{2}\left(K\_{S}-M\_{R}\right)\right⌉$ bits)

**Proposal 2.A.2**: For the Rel-19 CRI-based CSI refinement for up to 128 CSI-RS ports, for A-CSI only, the NW can configure *MR* (<*M*) of *KS* CSI-RS resources to be selected as part of reporting the *M* “quadruplets”: * (*M–MR*) CRIs, each with $\left⌈log\_{2}\left(K\_{S}-M\_{R}\right)\right⌉$ bits are reported, along with the *M* sets of CQI/PMI/RI/(if applicable) LI
* The value of *MR* is NW-configured via higher-layer (RRC) signaling
* The *MR* selected resources are NW-configured via higher-layer (RRC) signaling
* FFS: value of *MR*
* This is an optional UE capability

**FL assessment**: The additional trigger-state-based update offers flexibility. | **Support/fine:** MediaTek,Huawei/HiSi, Ericsson, Nokia/NSB, Samsung, CATT, HONOR, Fujitsu, NEC, Google, ZTE, Qualcomm, IDC, Apple (ok), Intel, Sharp, KDDI, NTT DOCOMO (ok), OPPO, HONOR, Spreadtrum (ok), Fujitsu (ok), Xiaomi, TCL (ok), CMCC (ok), New H3C, vivo, **Not support:** Lenovo/MotM,  |
| 2.1.6 | **Proposal 2.A.6:** For the Rel-19 CRI-based CSI refinement for up to 128 CSI-RS ports, regarding UCI parameters when two-part UCI/CSI is used:* Part 1: M CRI(s), M RI(s), x sets of CQI values for 1st CW
* Part 2: (M-x) sets of CQI values for 1st CW, M sets of {PMI, LI (if applicable), CQI values for 2nd CW (if applicable)}

FFS (by RAN1#118): For x, decide from the following alternatives: 0, M Note: If proposal 2.A.2 is agreed, the total number of reported CRIs is M-MR**FL assessment**: There is no reason to do otherwise since multi-CRI has been supported since Rel-17. A resource priority rule will be discussed together with UCI omission rule | **Support/fine:** Intel, NTT DOCOMO (x=M),Nokia/NSB, Lenovo/MotM, KDDI, Samsung, Xiaomi, Ericsson, MediaTek, Spreadtrum, OPPO, ZTE (x=M), vivo, Lenovo/MotM, Xiaomi, **Not support:**  |
| 2.2 | **Proposal 2.B:** For the Rel-19 CRI-based CSI refinement for up to 128 CSI-RS ports, regarding CBSR and RI restriction, down-select (by RAN1#118) one from the following alternatives:* Alt1. KS per-resource CBSRs and KS per-resource RI restrictions
* Alt2. (legacy CRI-based) Resource-common CBSR and resource-common RI restriction
* Alt3. KS per-resource CBSRs and resource-common RI restriction

**Question 2.B**: For the Rel-19 CRI-based CSI refinement for up to 128 CSI-RS ports, regarding CBSR and RI restriction, please share your view on the following alternatives:* Alt1. KS per-resource CBSRs and KS per-resource RI restrictions
* Alt2. (legacy CRI-based) Resource-common CBSR and resource-common RI restriction
* Alt3. KS per-resource CBSRs and resource-common RI restriction

Alt1: ZTE, Ericsson, MediaTek, Spreadtrum, NTT DOCOMO, vivo, Qualcomm, Alt2: Nokia/NSB, Samsung, Spreadtrum, Intel, vivo (2nd), Alt3: Xiaomi**FL assessment**: Before deciding which legacy CBSR is reused, whether it is resource-specific or resource-common needs to be finalized |

Table 2B SLS results: issue 2

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Table 2C Additional inputs: issue 2

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| **Company** | **Input** |
| Mod V0 | **Please share your inputs on each of the issues and, if applicable, proposals in TABLE 2A** |
| New H3C | Proposal 2.A.2:support |
| Samsung | Question 2.BWe have misunderstanding on the legacy CBSR for CRI reporting. The legacy is one common CBSR for multiple CSI-RS resources for CRI reporting, and we support the legacy framework (i.e., resource-common CBSR) and resource-common RI restriction (that NW can configure only when needed).  |
| Ericsson | **Proposal 2.A.6**Ok. Fine to discuss x in next meeting. We think x=M is cleaner as all CRIs, RIs, and CQIs corresponding to the first CW will be in CSI Part 1.**Proposal 2.B**Alt 1 seems more natural. |
| Mod V6 | No revision |
| OPPO | **Proposal 2.A.2:**Support the proposal. We just want to make sure that the CPU occupation and timeline is not impacted by this restriction. **Proposal 2.A.6:**Two comments for clarification:1.What is the benefit to place part of CRI and RI in CSI part 2 (x<M)? 2. There may be an issue for x=MR, since x may be larger than the total number of reported CRIs (M-MR) in this case.[Mod: I agree. @Samsung: please address this issue – your proposal is technically flawed]  |
| ZTE | 2.A.6:Support x=M. The CRI, RI, and CQI for the 1st CW were never reported in legacy.2.B:Support Alt 1. |
| MediaTek | **Proposal 2.A.6**Support**Question 2.B**Slightly prefer Alt 1.If resource specific CBSR overhead is a concern, Rel-18 CJT framework could be reused – CBSR is configured for at least one resource and optional for the other resources, and no configuration means no restriction. We believe NW can already handle the interference for some analog beams, so CBSR need not be configured for all resources. |
| Spreadtrum | **Proposal 2.A.6:** Support**Question 2.B**: We are fine with either alternative. The technical reason to choose between Alt1 and Alt2 is whether CBSR can be shared among resources. For example, is it possible to allow different steering angles for different sub-arrays transmitting CSI-RS resources? |
| Intel | **Proposal 2.A.6:** We have similar view as Ericsson. We are not sure if x < M is needed, x = M is simple and straightforward design aligned with legacy UCI reporting. Fine to accept this proposal now and continue to discuss value of x at the next meeting. **Question 2.B**: Support legacy CBSR design for CSI with CRI.  |
| Mod V14 | **No revision** |
| Samsung | Proposal 2.A.6Putting all CRIs, RIs and CQIs for some resources in Part 2 could be beneficial in case of UCI omission happening (since utilizing CRI/RI/CQI only without PMI doesn’t work for HBF MU-MIMO), but we admit this can be overoptimized. Also, CRI/RI bits are small enough so putting CRI/RI for all M resources in Part 1 seems fine, but considering the payload of SB CQIs can be large, we suggest to divide M sets of CQIs only into Part 1 for and Part 2 as follows:Proposal 2.A.6…* Part 1: ~~x~~M CRI(s), ~~x~~M RI(s), x sets of CQI values for 1st CW
* Part 2: ~~(M-x) CRI(s), (M-x) RI(s),~~ (M-x) sets of CQI values for 1st CW, M sets of {PMI, LI (if applicable), CQI values for 2nd CW (if applicable)}

…**[Mod: OK, but having x=MR candidate isn’t clearly motivated. Fixed the proposal and added FFS for MR]** |
| NTT DOCOMO | **2.A.6:**Support x=M. **Question 2.B**:We prefer Alt.1 except for the case of resource-common RI indication (if supported). |
| vivo | **Proposal 2.A.2**: We have following updates:**Proposal 2.A.2**: For the Rel-19 CRI-based CSI refinement for up to 128 CSI-RS ports, for A-CSI only, the NW can configure *MR* (<*M*) of *KS* CSI-RS resources to be selected as part of reporting the *M* “quadruplets”: * (*M–MR*) CRIs, each with $\left⌈log\_{2}\left(K\_{S}-M\_{R}\right)\right⌉$ bits are reported, along with the *M* sets of CQI/PMI/RI/(if applicable) LI
* The value of *MR* is NW-configured via higher-layer (RRC) signaling
* The *MR* selected resources are NW-configured via higher-layer (RRC) signaling
* FFS: value of *MR*
* This is an optional UE capability

**Proposal 2.A.6:**We agree the FL assessment that the UCI rule of Rel-17 shall be reused. Therefore, we support the following updated proposal.**Proposal 2.A.6:** For the Rel-19 CRI-based CSI refinement for up to 128 CSI-RS ports, regarding UCI parameters when two-part UCI/CSI is used:* Part 1: (M-x) ~~x~~ CRI(s), M  ~~x~~ RI(s), M  ~~x~~ sets of CQI values for 1st CW
* Part 2: ~~(M-x) CRI(s), (M-x) RI(s), (M-x) sets of CQI values for 1~~~~st~~ ~~CW~~, M sets of {PMI, LI (if applicable), CQI values for 2nd CW (if applicable)}

FFS (by RAN1#118): For x, decide from the following alternatives: ~~1, M,~~ 0 and (if supported) MR Note: If proposal 2.A.2 is agreed, the total number of reported CRIs is M-MR**Question 2.B**:We slightly prefer Alt1 due to its flexibility, but we are also OK with the legacy framework (Alt2). |
| Lenovo/ MotM | **Proposal 1.A.1:**Prefer to revisit this issue in RAN1#118 for further evaluation**Proposal 2.A.6:**All RI should be reported in CSI Part 1 to enable determination of CSI Part 2 by the UE |
| Mod V25 | **Revision per inputs** |
| Xiaomi | **Proposal 2.A.6:**Support. For Rel-16 Type II codebook, Part 1 also includes the indication information of non-zero coefficients across all layers. Will the priority for UCI omission be discussed in next meeting？**Question 2.B**:We prefer to add Alt3, i.e., KS per-resource CBSRs and resource-common RI restriction. |
| Qualcomm | **Question 2.B**: Alt1 |
| Mod V28 | **Added proposal 2.B** |

### Issue 3 (WID objective 3): CJT calibration reporting for non-ideal synchronization and backhaul

Table 3A Summary: issue 3

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| **#** | **Issue** | **Companies’ views** |
| 3.2 | **Proposal 3.B.2**: For the Rel-19 aperiodic standalone CJT calibration reporting, when ReportQuantity is ‘cjtc-P’ (DL/UL phase offset), ***support*** >1 (sub-band reporting) as follows:* A sub-band size is selected from {8,16} PRBs
	+ The sub-band size is NW-configured via higher-layer (RRC) signalling
* Denoting the number of sub-bands within the configured CSI reporting band as NSB-P, and the sub-bands are indexed as {0, 1, …, NSB-P –1}, decide, by RAN1#117, from the following reporting options:
	+ Opt1: {(n,, n), n=0, 1, …, NTRP – 1, n≠nref}, where n,is the phase offset corresponding to sub-band 0 and the phase offset for sub-band  can be calculated as n, + n
		- $Γ\_{n}\in \left\{0,\frac{2π}{M\_{Γ}}, ….,\frac{2π(M\_{Γ}-1)}{M\_{Γ}}\right\}$, where $M\_{Γ}$={64, 128}
	+ Opt2: = NSB-P, i.e. {(n,, n,, n,NSB-P), n=0, 1, …, NTRP – 1, n≠nref}
		- The alphabet for n, follows the previously agreed alphabet for =1, including the ‘invalid’ state
		- The maximum NSB-P is 4
	+ Note: For all the above reporting options, the UE performs measurement over the entire configured CSI reporting band
	+ FFS: Further restriction on CSI-RS (e.g. RE density)
	+ Opt1 and Opt2 are separate UE capabilities

**Support/fine (Opt1+2)**: ZTE, Qualcomm, CATT, Ericsson, Samsung, Fujitsu, NEC, TCL, Sony, KDDI, CMCC, NICT, Sharp, MediaTek, Huawei/HiSi, NTT DOCOMO, Sony, NewH3C, * **Strong Concern**: vivo, Nokia/NSB, OPPO, [Google], [Lenovo/MotM]

**Support only Opt1**: * **Strong Concern**: vivo, Samsung, Lenovo/MotM, CATT, Panasonic, Nokia/NSB,

**Support only Opt2**: Lenovo/MotM, Intel, Panasonic, Nokia/NSB, OPPO, Apple, Google* **Strong Concern**: vivo, Qualcomm, ZTE, Ericsson

**FL assessment**: Offline session outcomesBased on the arguments from proponents, Opt1 is suitable when BF CSI-RS is used and the frequency selectivity is caused by TAE (hence linear); Opt2 is suitable when non-precoded CSI-RS is used and frequency selectivity is mixed with the channel, and possibly additional RF impairments |
| 3.3.2 | **Proposal 3.C.2**: For the Rel-19 aperiodic standalone CJT calibration reporting, when ReportQuantity is ‘cjtc-P’ (DL/UL phase offset), regarding how to determine the SRS port corresponding to the ‘reference UE antenna port’, support the following* Scheme1. The UE is configured by NW (via higher-layer/RRC signaling) PSRS SRS port(s) selected from all the port(s) from the configured Q associated SRS resource(s) for phase offset reporting
	+ FFS: Exact details of configuration mechanism
	+ FFS: Supported value(s) of PSRS
* Scheme2. The UE selects PSRS SRS port(s) out of all the ports across Q resources and includes the selection in the phase offset report
	+ FFS: Supported value(s) of PSRS

FFS: Whether further restriction(s) to limit the time gap between the received CSI-RS and the transmitted associated SRS are needed**FL assessment**: This proposal is needed so that the UE and gNB know the exact SRS port(s) used for the linkage in 3.C.1. Scheme2 offers an additional freedom for the UE to select the port(s) according to its implementation, while Scheme1 relies on NW configuration. In some Tdocs it was argued that Scheme2 facilitates NW implementation using non-precoded CSI-RS linked with SRS.Supporting both schemes facilitates more use cases and deployment scenarios for PO report. | **Support/fine:** Qualcomm, Ericsson, Nokia/NSB, Samsung, vivo, MediaTek, IDC, CATT, NTT DOCOMO (also ok w Sch1 only), Sony, [Google]**Not support (only Scheme1):** OPPO, Apple, Intel, Panasonic, Xiaomi, Lenovo/MotM, ZTE, Huawei/HiSi,  |
| 3.4 | **Conclusion 3.D**: For the Rel-19 aperiodic standalone CJT calibration reporting, there is no consensus on supporting the following joint report formats:* Joint Dd + wideband PO
* Joint FO + wideband PO
* Joint Dd + FO + wideband PO

**Question 3.D**: For the Rel-19 aperiodic standalone CJT calibration reporting, please share and justify your view whether the following joint report formats should be supported:* Joint Dd + wideband PO:
	+ Support/fine: NTT DOCOMO,
	+ Not support: Samsung, OPPO, Huawei/HiSi, vivo, Lenovo/MotM
* Joint FO + wideband PO:
	+ Support/fine: NTT DOCOMO,
	+ Not support: Samsung, OPPO, Huawei/HiSi, vivo, Lenovo/MotM
* Joint Dd + FO + wideband PO:
	+ Support/fine: NTT DOCOMO,
	+ Not support: Samsung, OPPO, Huawei/HiSi, vivo, Lenovo/MotM

**FL assessment**: If any of the above combinations is agreed, detailed UCI parameter design aspects can be discussed later. The questions  |
| 3.5 | **Proposal 3.E.2**: For the Rel-19 aperiodic standalone CJT calibration reporting, when ReportQuantity is ‘cjtc-Dd-F’ (joint Doffset+d and FO)* Fully reuse timeline and active resource counting from Rel-18 TDCP reporting
* OCPU = 2X.NTRP where X≥1 is defined based on UE capabilities and determined by the UE for each CJT calibration report type

**FL assessment**: This is for the joint Dd+FO report | **Support/fine:** ZTE, Samsung, OPPO, CATT, NTT DOCOMO, vivo, **Not support:** Huawei/HiSi |
| 3.8.3 | **[116bis] Agreement**For the Rel-19 aperiodic standalone CJT calibration reporting, regarding the applicable type(s) of the configured NTRP NZP CSI-RS resources/resource sets when ReportQuantity is ‘cjtc-Dd’ (Doffset+d) or ‘cjtc-F’ (frequency offset), periodic TRS (‘CSI-RS for tracking’) resource set is used for each of the NTRP NZP CSI-RS resource sets* …
* FFS: additional time separation between RSs
* FFS: The exact number of CSI-RS resource(s) within each TRS resource set
* FFS: applicable type(s) if joint reporting of both Doffset/d and FO is supported

**Conclusion 3.H.3**: For the Rel-19 aperiodic standalone CJT calibration reporting, regarding the applicable type(s) of the configured NTRP NZP CSI-RS resources/resource sets when ReportQuantity is ‘cjtc-Dd’ (Doffset+d) or ‘cjtc-F’ (frequency offset), there is no consensus on supporting the following:* Any additional time separation between RSs beyond what’s already permissible by the use of TRS resource sets
* Any restriction on the number of resources within each resource set
* CSI-RS type(s) other than TRS can be used for joint reporting of Doffset+d and FO

**Question 3.H.3**: For the Rel-19 aperiodic standalone CJT calibration reporting, regarding the applicable type(s) of the configured NTRP NZP CSI-RS resources/resource sets when ReportQuantity is ‘cjtc-Dd’ (Doffset+d) or ‘cjtc-F’ (frequency offset), please share your view on the following:* Any additional time separation between RSs beyond what’s already permissible by the use of TRS resource sets?
	+ No need (baseline): Samsung, Ericsson, CATT, Huawei/HiSi, NTT DOCOMO,
	+ Yes (be specific): ZTE
* Any restriction on the number of resources within each resource set?
	+ No need (baseline): Samsung, Ericsson, CATT, Huawei/HiSi, NTT DOCOMO,
	+ Yes (be specific):
* Whether CSI-RS type(s) other than TRS can be used for joint reporting of Doffset+d and FO
	+ No need (baseline): Samsung, Ericsson, OPPO, CATT, Huawei/HiSi, NTT DOCOMO, vivo,
	+ Yes (be specific):

**FL assessment**: The FFS points need to be resolved |
| 3.8.4 | **[116bis] Agreement**For the Rel-19 aperiodic standalone CJT calibration reporting, regarding the applicable type(s) of the configured NTRP NZP CSI-RS resources/resource sets when ReportQuantity is ‘cjtc-P’ (DL/UL phase offset), single-port CSI-RS(s) for CSI is used * …
* FFS: The exact number of CSI-RS resource(s) within each resource set
* …
* FFS: additional restrictions e.g. time separation between RSs, bandwidth

**Proposal 3.H.4**: For the Rel-19 aperiodic standalone CJT calibration reporting, regarding the applicable type(s) of the configured NTRP NZP CSI-RS resources/resource sets when ReportQuantity is ‘cjtc-P’ (DL/UL phase offset), 1 CSI-RS resource set with NTRP resources is supported * FFS: 1 CSI resource set with P$⋅$NTRP resources where P>1 is the number of CSI-RS resources per TRP

**Conclusion 3.H.4**: For the Rel-19 aperiodic standalone CJT calibration reporting, regarding the applicable type(s) of the configured NTRP NZP CSI-RS resources/resource sets when ReportQuantity is ‘cjtc-P’ (DL/UL phase offset), there is no consensus on supporting any additional time separation between RSs beyond what’s already permissible by the use of TRS resource sets **Question 3.H.4**: For the Rel-19 aperiodic standalone CJT calibration reporting, regarding the applicable type(s) of the configured NTRP NZP CSI-RS resources/resource sets when ReportQuantity is ‘cjtc-P’ (DL/UL phase offset), please share your view on the following:* Depending on the number resource sets, how many CSI-RS resources can be configured?
	+ 1 set, NTRP resources: Samsung, OPPO, CATT, Huawei/HiSi, NTT DOCOMO, vivo, Qualcomm,
* Any additional time separation between RSs beyond what’s already permissible by the use of TRS resource sets?
	+ No (baseline): Samsung, CATT, Huawei/HiSi, NTT DOCOMO,
	+ Yes (be specific): ZTE,

**FL assessment**: The FFS points need to be resolved |

Table 3B LLS/SLS results: issue 3

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| --- | --- |
| **Company** | **LLS/SLS results** |
| **Issue #** | **Metric** | **Observation** |
| Samsung | 3.2.2 | Avg UPT Gain | For CJTC phase-offset reporting, it is identified that Option 1 can perform sufficiently well and nearly achieve the performance of Option 2 and ideal calibration in the scenario with maxTAE=65ns, when only small measurement errors exist (without additional hardware impairments). However, when large measurement errors exist, Option 1 incurs some performance degradation (2% UPT loss) than Option 2, because the large measurement errors affect the underlying assumption of linear phase drift not working well. |
| ZTE | 3.1 | Average throughput gain  | The figure above shows the SLS results of average throughput gain for MD = 32, AD = CP (baseline) or $\frac{1}{12∆f\_{SCS}}$. It is shown that, the performance of AD = CP and AD = $\frac{1}{12∆f\_{SCS}}$ is very close.The figure above shows the SLS results of average throughput gain for MFO = 16, AFO = 0.2ppm (baseline) or $\frac{1}{32∆t\_{symbol}}$. It is shown that the performances of AFO = 0.2ppm and AFO = $\frac{1}{32∆t\_{symbol}}$ are very close. |
| CATT | 3.2.2 | Mean UPT gain | The SLS results above show that the proposed low feedback overhead based calibration scheme with$ Σ=4$ (UE selects some SBs and reports Pos corresponding to the selected SBs 🡺 NW inter/extrapolates missing SBs) can also achieve quite good performance while maintaining a moderate overhead cost.The SLS results above show that 1) aligned 4 subbands based calibration achieves similar performance to all subbands based calibration, and 2) calibration performance is degraded if misaligned frequency resources in DL and UL are used for phase offset calculation.  |
| Sony | 3.2.2 | Average throughput | The LLS simulations show that reporting information about the evolution of the phase offsets $Φ\_{n,σ}$ in the frequency domain improves the system’s throughput, at least for TAEs of 65 ns or larger. (2% gain over wideband PO reporting) |
| Nokia/NSB | 3.3.1 | Mean spectral efficiency gain  | A graph with different colored bars  Description automatically generatedA graph with different colored squares  Description automatically generatedIn the left figure, 2 out of 4 antennas at UE side are sounded and the same antennas are used to estimate the phase difference between the CSI-RS signals transmitted by TRP $n$ and the reference TRP, and received by antenna $i$, $Φ\_{i,n}^{UE}$. In the right figure, only 1 SRS antenna port is sounded in UL and all receive antennas are used to compute $Φ\_{i,n}^{UE}$. We can see how the mismatch between the SRS ports used to compute $Φ\_{n,i}^{TRP} $ and the receive antennas used to compute $Φ\_{i,n}^{UE}$, has impacted the performance greatly as shown in the right figure, where we can see about 60% loss. |
| Qualcomm | 3.2.2 |  | A couple of graphs with lines and numbers  Description automatically generated with medium confidenceAs seen in the results above, it is observed that tens of nano seconds can cause nearly 10% UPT loss. Furthermore, it is observed that the UPT loss is still significant, when a small bit, (e.g., 3-to-5 bits, i.e., 8 to 32 quantization levels) is used for TAE quantization. The UPT loss is around 2% to 10%, depending on the exact TAE value – this is due to some TAE value close to certain quantization point by chance. |
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Table 3C Additional inputs: issue 3

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| --- | --- |
| **Company** | **Input** |
| Nokia/NSB | **Proposal 3.C.2**@OPPO, @Apple, @Intel. As you know, there are two different NW implementation for PO calibration.One implementation requires MRT-precoded CSI-RS, and the UE can only be configured with one receive antenna for measurement, the antenna corresponding to the SRS port used to obtain the CSI-RS precoder. Another implementation can use TRS or CSI-RS without need to be precoded, and the UE can measure from multiple receive antennas for better robustness against measurement error.The second implementation in our view is clearly more robust against UL/DL channel reciprocity errors (because it does not rely on a precoder matched to the exact channel), against measurement error (because a UE can average measurements across receive antennas), and can reuse the same TRS used for the other calibration measurements, without need of a dedicated precoded CSI-RS.This is an example of the measurement procedure with nonprecoded CSI-RS:* A UE supporting xTyR transmits SRS with antenna switching, sounding y antennas, as per usual TDD operation
* gNB measures phase difference from all SRS ports and triggers a UE to report a PO measurement averaged from $P\_{SRS}$≤y receive antennas, where the value of $P\_{SRS}$ is network configured. Which $P\_{SRS}$ antennas to measure may be network configured, e.g. $P\_{SRS}=R$, or UE selected
* UE reports the PO measurement from the configured/selected $P\_{SRS}$ receive antennas and reports the selection if applicable.

If we don’t have UE dynamic indication, as per scheme 2, we would need a very large number of trigger states, under scheme 1, to trigger all different combinations of just 1 and 2 ports, for xT2R, xT4R, xT6R, xT8R. |
| Mod V0 | **Please share your inputs on each of the issues and, if applicable, proposals in TABLE 3A****Please check Nokia’s explanation for 3.C.2** |
| New H3C | **Proposal 3.B.2: support (Opt1+2)** |
| Samsung  | Question 3.DDon’t support all the joint report-types in the list.Proposal 3.E.2OkQuestion 3.H.3First two bullets: No, they are up to NW implementation (leave it to NW config/implementation)Last bullet: No.Question 3.H.4First bullet: We support 1 CSI-RS resource set comprising NTRP CSI-RS resources. For >1 resource set or >NTRP CSI-RS resources, we think the benefit of introducing those cases requires further evaluation/validation.Second bullet: No, it is up to NW implementation |
| Ericsson | **Question 3.H.3**Do not see need for any additional time separation between RSs, but open to discuss this further until next meeting.Do not see the need for any restrictions no the number of resources within each resource setNo need for other CSI-RS type(s) other than TRS. |
| Mod V6 | No revision |
| OPPO | **Proposal 3.B.2:**If subband precoding is supported by majority companies, we can live with it. Our preference is supporting only one of the two options, either Opt.1 or Opt.2 could be fine to us. Supporting both options is a bit redundant. If that is the conclusion, separate UE capabilities are needed for two options and UE doesn’t need to support both. **Proposal 3.C.2:**We still think scheme 1 could be sufficient. gNB can measure all the SRS ports and configure the best P\_SRS port(s) to UE for phase offset measurement. This can work regardless of P\_SRS>1 or not and non-precoded/precoded CSI-RS. In our understanding blockage is not a dynamic event and RRC configuration of measurement port is enough (no dynamical signalling is needed). Scheme 2 would introduce additional and unnecessary UE complexity. **Question 3.D:**Joint Dd + wideband PO: If subband phase reporting is supported, this seems not needed since the function is similar. Joint FO + wideband PO: Not needed. Joint Dd + FO + wideband PO: Not needed. **Proposal 3.E.2:**If Y denotes the number of reported offset values, it should be N\_TRP-1 for each CJT calibration report type.**Question 3.H.3:**No CSI-RS type(s) other than TRS is needed. **Question 3.H.4:**We think NTRP NZP CSI-RS resources could be sufficient. |
| ZTE | 3.E.2:It is NOT needed to change the timeline. But the OCPU can be multiplied by 2.3.H.3:The restriction of time separation is needed. If the time separation is too large, the channel variation may lead to significant measurement error.3.H.4:For PO measurement, the time separation restriction is more important. The channel phase may suffer from more serious fluctuation over time. To avoid the measurement error caused by the channel variation, the time separation restriction is needed. |
| Spreadtrum |  |
| Intel | **Proposal 2.A.6:** We have similar view as Ericsson. We are not sure if x < M is needed, x = M is simple and straightforward design aligned with legacy UCI reporting. Fine to accept this proposal now and continue to discuss value of x at the next meeting. **Question 2.B**: Support legacy CBSR design for CSI with CRI.  |
| CATT | **Proposal 3.E.2**: OK**Question 3.H.3**:No need for all three bullets**Question 3.H.4**:1st bullet: 1 resource set with NTRP resources2nd bullet: no need |
| Mod V15 | **Revision on 3.B.2 to simplify****Corrected 3.E.2** |
| Samsung | Question 3.DWe think each of the joint report is an over-optimization. Also, we don’t see any need or use case, given that D/d and FO reporting are UE-specific but PO reporting is TRP-specific.  |
| NICT | **Proposal 3.B.2:** Support both the options (Opt1+2). Please remove NICT from the companies supporting only Opt1. |
| Huawei, HiSilicon | Proposal 3.C.2, scheme 1 is enough.Question 3.D, the joint report formats are not needed.Proposal 3.E.2, prefer to discuss it next meeting.Question 3.H.3, no need for the three questions.Question 3.H.4, 1 resource set (e.g., 1 TRS resource set) and NTRP resources are configured. No additional time separation between RSs beyond what’s already permissible by the use of TRS resource sets. |
| NTT DOCOMO | Proposal 3.B.2: We are also okay with FL’s proposed way-forward over email Proposal 3.C.3:We are supportive for the proposal while we are also flexible to go with Scheme 1 only. Question 3.H.4:We are fine with all the combinations listed. Proposal 3.E.2:Support. Question 3.H.3:We prefer no additional restriction for the three points. Question 3.H.4:1st bullet: 1 resource set with NTRP resources2nd bullet: no need |
| vivo | Proposal 3.B.2:Not support.We don’t see the need to support subband phase. This same functionality can be achieved by the agreed DO reporting, and we are open to discuss the granularity of DO reporting if needed.Proposal 3.C.2:Support. We think Scheme 2 is more flexible and friendlier to UE implementation as UE can determine the mapping between the SRS ports and physical antennas based on its own need for implementation. This is also the principle we have in the current spec and NR UE implementation.Question 3.D:Given DO reporting and FO reporting are UE-specific yet PO reporting is TRP-specific, we do not support Dd+PO, FO+PO, D/d+FO+PO.Proposal 3.E.2:OK.Question 3.H.3:Support only periodic TRS (‘CSI-RS for tracking’) resource set is used for each of TRPs.Question 3.H.4:Support one resource set for PO reporting with up to 4 single-port CSI-RS configured in the resource set. |
| Lenovo/ MotM | **Proposal 3.B.2:**No need to support both solutions since Option 2 can achieve whatever Option 1 can achieve. Our first preference is Option 2 only, and our second preference is no support**Question 3.D:**Do not support any of the proposed mixtures |
| Mod V25 | **Added proposals/conclusions 3.D, 3.H.3/4** |
| Qualcomm | **Proposal 3.H.4**: We recommend to have FFS with >1 CSI-RSs per TRP (we have shown some theoretically-analyzed benefit of PSRS>1, but haven’t got time to simulate)Besides, seems there are some typos

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| **Proposal 3.H.4**: For the Rel-19 aperiodic standalone CJT calibration reporting, regarding the applicable type(s) of the configured NTRP NZP CSI-RS resources/resource sets when ReportQuantity is ‘cjtc-P’ (DL/UL phase offset), 1 ~~CSI-RS for~~ CSI resource set with NTRP resources is ~~configured~~ supported* FFS 1 CSI resource set with P$⋅$NTRP resources where P>1 is the number of CSI-RS resources per TRP
 |

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| Mod V28 | **Revision per input** |
|  |  |

# References