**3GPP TSG RAN WG1 #117 R1-2404108**

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

**Agenda item:** 9.2.2

**Source:** Moderator (Samsung)

**Title:** Moderator Summary on Rel-19 CSI enhancements

**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:

|  |
| --- |
| 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
 |

## 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

|  |  |  |
| --- | --- | --- |
| **#** | **Issue/proposal** | **Companies’ views** |
| 1.1.1 | **[116bis] Agreement**For the Rel-19 Type-I SP codebook refinement for 48, 64, and 128 CSI-RS ports with RI=5-8, decide, by RAN1#117, from the following schemes:* Scheme1: adding new (N1, N2) values for the Rel-15 Type-I RI=5-8
* Scheme2:
	+ W1 structure: Independent selection of different ceil(v/2) SD basis vectors for RI = v, where each SD basis vector is applied to two respective layers except that, if v is odd, the last SD basis vector is applied to the orphan layer. Each of the SD basis vectors is freely selected from a group of N1N2 orthogonal SD DFT basis vectors via combinatorial indication
		- FFS: mapping between v layers and ceil(v/2) SD basis vectors
		- FFS: support of 4 selected SD basis vectors for RI=5-6
	+ W2 structure:
		- For inter-polarization co-phasing, M (e.g., M = 4) codepoints for the orphan layer and M/2 codepoints for two layers sharing a same SD basis vector;
		- A fixed  rotation of inter-polarization co-phasing between two layers sharing a same SD basis vector to achieve layer orthogonality.
* Scheme3: the 1st beam is freely selected and subsequent 2 beams (RI=5-6) or 3 beams (RI=7-8) are freely selected such that they are orthogonal in at least one dimension (horizontal or vertical). Layers are mapped to the selected SD basis vectors following legacy Rel-15 for RI=5-8. One co-phasing across all layers ∈{1,j} following legacy Rel-15 Type-I RI=5-8
* Scheme4: concatenate two independently calculated RI=1-4 PMIs for RI=5-8 to reduce UE complexity where each PMI is calculated from the agreed RI=1-4 codebook (Scheme-A or Scheme-B) and the CQI for each of the two CWs is derived assuming it is received by one antenna group of 4 antenna ports (FFS: Whether additional mapping between the two PMIs and the two UE antenna groups is needed)
* Other schemes are not precluded

**Proposal 1.A.1**: For the Rel-19 Type-I SP codebook refinement for 48, 64, and 128 CSI-RS ports with RI=5-8, support the following schemes:* The same O1=O2 value(s) as RI=1-4 are supported
* Scheme-A (based on Scheme3 described in RAN1#116bis):
	+ W1 structure:
		- The 1st SD basis vector is freely selected and subsequent 2 (RI=5-6) or 3 SD basis vectors (RI=7-8) are freely selected such that they are orthogonal in at least one dimension (horizontal or vertical).
		- The v layers are mapped to the selected SD basis vectors following legacy Rel-15 Type-I for RI=5-8.
	+ W2 structure:
		- Following legacy Rel-15 Type-I RI=5-8
* Scheme-B (based on Scheme2 described in RAN1#116bis):
	+ W1 structure:
		- Independent selection of different ceil(*v*/2) SD basis vectors for RI = *v*, where each SD basis vector is applied to two respective layers following legacy Rel-15 Type-I for RI=5-8, except that, if *v* is odd, the last SD basis vector is applied to the orphan layer.
			* FFS: mapping between the orphan layer and its selected SD basis vector and, if needed, UE reporting of the selection
			* FFS: support of 4 selected SD basis vectors for RI=5-6
		- The SD basis vectors are freely selected from a group of N1N2 orthogonal SD DFT basis vectors via combinatorial indication, as well as a layer-common (q1,q2)
	+ W2 structure:
		- For the orphan layer, the inter-polarization co-phasing is selected from {1, j, -1, -j}
		- For two layers sharing a same SD basis vector, the inter-polarization co-phasing between two layers is selected from the following pairs {(1, -1), (j, -j)} to achieve inter-layer orthogonality.
* A UE can be configured by the NW via higher-layer (RRC) signalling with either Scheme-A (RI=1-4+RI=5-8) or Scheme-B (RI=1-4+RI=5-8)

**FL assessment**: This was discussed OFFLINE [2]. Some wording revision (in change marks) to improve clarity without changing the content of the proposalAll companies are fine with Scheme-B, but a number of companies still prefer Scheme1 for Scheme-A (as opposed to the proposed Scheme3). **However, all available SLS results for Scheme-A show that the scheme in the above proposal (Scheme3) is superior to Scheme1 (cf. Table 1B).** A small number of companies prefer other schemes (Scheme 4, 5) but there is no empirical evidence to justify their preferences.  | **Support/fine**: ZTE, Nokia/NSB, Ericsson, NTT DOCOMO, Intel, Samsung, Huawei/HiSi (ok w/ 1.A.2), Qualcomm, MediaTek, vivo (ok), Xiaomi, NEC, HONOR, Kyocera, Sharp, CMCC, KDDI, Google, Apple (ok), OPPO (ok), TCL (ok), Spreadtrum (ok), CATT, Fujitsu (ok), Fraunhofer IIS/HHI (ok), IDC**Not support (SchA=1, SchB ok)**: CEWiT, Tejas, Lenovo/MotM**Not support (other schemes)**: New H3C (Sch4), LG (Sch1 only) |
| 1.1.2 | **Proposal 1.A.2**: For a UE configured with a total of PSRS=6 or 8 ports across ≥1 SRS resources for antenna switching intended for xT6R or xT8R, respectively, support the following fixed SRS port grouping where (with the PSRS ports indexed in an ascending order according to SRS resource ID and port number within each SRS resource): * SRS port group 0, corresponding to CW0, comprises the first PSRS/2 out of PSRS ports; and
* SRS port group 1, corresponding to CW1, comprises the second PSRS/2 out of PSRS ports

FFS: Impact of the above grouping on CQI calculation, if anyNote: different SRS ports are associated with different UE antenna ports.Note: if one single CW is scheduled, both SRS port groups can correspond to the same CWNote: This feature is a separate UE capability and, for UEs supporting this capability, configured via RRC (FFS details on the extend of RRC configuration)**FL assessment**: This was discussed OFFLINE [2]. | **Support/fine**: Huawei/HiSi, Samsung, ZTE, Ericsson, Nokia/NSB, Fujitsu, Tejas, Xiaomi, vivo, NTT DOCOMO, NEC, OPPO, TCL, KDDI, Sharp, MediaTek, Google**Not support**: HONOR, Qualcomm |
| 1.1.3 | **Proposal 1.A.3**: On the NZP CSI-RS resource aggregation of *K*=2, 3 or 4 legacy NZP CSI-RS resources to attain a total of 48, 64, and 128 ports (for Rel-19 Type-I/II codebook refinement), support to configure a CSI-RS resource set with the *K* CSI-RS resources as the associated NZP CSI-RS for each of the SRS resource set(s) with higher layer parameter usage in *SRS-ResourceSet* set to 'nonCodebook',* The previously agreed restrictions on the *K* resources for Rel-19 Type-I/II codebook refinement apply
* Reuse the legacy approach for triggering of the NZP-CSI-RS resources and the legacy timeline for the NZP-CSI-RS resources and SRS

**FL assessment**: This was discussed OFFLINE [2]. | **Support/fine**: vivo, Samsung, Fujitsu, Xiaomi, Spreadtrum, Tejas, Huawei/HiSi, NTT DOCOMO, TCL Google, CMCC, Nokia/NSB, Ericsson, Sharp, Qualcomm, MediaTek, ZTE, OPPO**Not support**: HONOR,  |
| 1.1.4 | **Proposal 1.A.4:** For the Rel-19 Type-I single-panel (SP) codebook refinement for 48, 64, and 128 CSI-RS ports, for Scheme-A RI=3-4, the legacy mapping of i1,3 to (k1,k2) for (N1=3,N2=2) from Table 5.2.2.2.1-4 of TS 38.214 is used for all of the newly supported (N1,N2) values. * FFS: whether the i1,3 table (Table 5.2.2.2.1-4 of TS 38.214) needs to be further extended.

**FL assessment**: This is the only solution that reuses legacy spec to allow 3 orthogonal SD basis vectors. There seems no need for additional extension beyond this but this can be kept FFScid:image001.jpg@01DAA0DC.7225A550 | **Support/fine**: Samsung, ZTE, Google, Qualcomm, IDC, NTT DOCOMO, OPPO, Fraunhofer IIS/HHI, Huawei/HiSi, **Not support**:  |
| 1.2.1 | **[116bis] Agreement**For the Rel-19 Type-I single-panel (SP) codebook refinement for 48, 64, and 128 CSI-RS ports, for RI=1-4, support the following:* …
* Scheme-B (based on Scheme2 in RAN1#116 agreement): Adding new (N1, N2) values where 2N1N2 (>32) is the total number of CSI-RS ports across aggregated NZP CSI-RS resources, and
	+ W1 structure: …
	+ W2 structure: Layer-specific inter-polarization co-phasing with the alphabet {+1, +j, -1, -j}

**[116bis] Agreement**For the Rel-19 Type-I SP codebook refinement for 48, 64, and 128 CSI-RS ports, the UCI parameters are captured in the tables below for Scheme-A and Scheme-B:* Note: The second column includes the location of the parameters when reported with two-part UCI
* FFS (RAN1#117): Select between Alt1 and Alt2 for Scheme-B

…**Scheme-B**

|  |  |  |  |
| --- | --- | --- | --- |
| Parameter | UCI | Details/description | Status |
| … |  |  |  |
| SD basis vector selection indicator for each layer | Alt1: Part 1Alt2: Part 2 Wideband | *v*=1-4: * Alt1: $\left⌈log\_{2}\left(N\_{1}N\_{2}\right)\right⌉$ bit indicator per layer *l=*1*, …, RIMAX*
* Alt2: $\left⌈log\_{2}\left(N\_{1}N\_{2}\right)\right⌉$ bit indicator per layer *l=*1*, …, v*

*v*=5-8: FFS | Pending |
| Inter-pol co-phase selection indicator for each layer | Part 2Wideband or Subband (\*\*) | *v*=1-4: * Alt1: QPSK with orthogonality constraints across *v* layers
* Alt2: QPSK: 2-bit indicator per layer *l=*1*,…,v*

*v*=5-8: FFS | Pending |
| … |  |  |  |

**Proposal 1.B.1**: For the Rel-19 Type-I SP codebook refinement for 48, 64, and 128 CSI-RS ports, regarding UCI parameters for Scheme-B RI=*v*=1-4:* SD basis vector selection indicator for each layer is in Part 2 (wideband) and $\left⌈log\_{2}\left(N\_{1}N\_{2}\right)\right⌉$ bits per layer *l=*1*, …, v*
* Inter-pol co-phase selection indicator for each layer is in Part 2 (wideband or subband) and 2 bits (representing {+1, +j, -1, -j}) per layer *l=*1*,…,v*

**FL assessment**: This was discussed OFFLINE [2]. It was observed that Alt1 for co-phase selection is not aligned with the previous agreement.It was also argued that the overhead reduction from Alt1 (for both) is marginal and highly dependent on UE implementation, while complicating the UE PMI selection algorithm. Therefore Alt2 (as proposed in 1.B.1) is the outcome. | **Support/fine**: Samsung, OPPO, ZTE, NTT DOCOMO, Qualcomm, Fraunhofer IIS/HHI, Apple, CATT, MediaTek, TCL, CEWiT, Intel, New H3C, Nokia/NSB, Huawei/HiSi, Fujitsu, Xiaomi, Spreadtrum, Tejas, Google, NEC, HONOR, Kyocera, Sharp, OPPO, CMCC, KDDI, Lenovo/MotM, IDC, Ericsson **Not support**: vivo (new SDBVI, joint co-phase when >1 layers same SDBV) |
| 1.3 | **Proposal 1.C**: For the Rel-19 Type-I SP codebook refinement for 48, 64, and 128 CSI-RS ports, regarding UCI omission, fully reuse the legacy rules for Rel-15 Type-I SP codebook **FL assessment**: There is no reason to design a different UCI omission rule | **Support/fine**: MediaTek, Intel, Samsung, ZTE, Google, Qualcomm, IDC, Ericsson, NTT DOCOMO, OPPO, Fraunhofer IIS/HHI, Huawei/HiSi, [Lenovo/MotM?]**Not support:** TCL (NES rule) |
| 1.4.1/2 | **[116bis] Agreement**For the Rel-19 Type-I SP and Type-II codebook refinements for 48, 64, and 128 CSI-RS ports via aggregating K>1 CSI-RS resources, regarding timeline, introduce two UE capabilities:* Capability 1: Reuse legacy Z/Z’ values
* Capability 2: Scale the legacy timeline Z/Z’ by ceil(P/32) where P is the total number of ports across all the K aggregated CSI-RS resources

FFS: CPU occupation and active resource counting…**Proposal 1.D.1**: For the Rel-19 Type-I SP and Type-II codebook refinements (except based on Rel-18 Type-II Doppler) for 48, 64, and 128 CSI-RS ports, regarding CPU occupation* For Capability 1 timeline: OCPU = ceil(P/32)
* For Capability 2 timeline: OCPU = 1

**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] [cK] (following legacy)
* For Capability 2 timeline: [1] [cK] (following legacy)

**FL assessment**: Since Capability 2 is quite (too) relaxed, there is no reason to further relax both OCPU and ACR for Capability 2 | **1.D.1:****Support/fine:** Huawei/HiSi, Ericsson, Nokia/NSB, Intel, TCL, Samsung, vivo, Google, OPPO, Fraunhofer IIS/HHI, [Lenovo/MotM], CATT, Qualcomm, MediaTek, [Xiaomi], [NTT DOCOMO]**Not support:****1.D.2:****Support/fine:** Ericsson (1), OPPO (K), Fraunhofer IIS/HHI, Intel, TCL, Samsung (1), vivo, Google, [Lenovo/MotM], CATT, Qualcomm, [Xiaomi], NTT DOCOMO (1), Huawei/HiSi (cK)**Not support:** |
| 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: Common 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, [3], 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 sub-band inter-resource QPSK co-phasing

**FL assessment**: This was discussed OFFLINE [2]. The proposal is a compromise between Scheme1 and Scheme2 (resource-common SD basis instead of resource-specific, just as Scheme1). The majority of companies supporting/ok with 1.E.1 are also supportive of/ok (neutral)with Scheme2, e.g. MediaTek, Ericsson, Samsung, NTT DOCOMO, Nokia/NSB, Huawei/HiSi, vivo, ZTE, Qualcomm, OPPONote that **all the available SLS results show that Scheme2 outperforms Scheme1 (cf. Table 1B).** | **Support/fine (panel-common SD basis, compromise between Scheme1 and 2)**: MediaTek, Qualcomm, Ericsson, Nokia/NSB, vivo (ok), Samsung, Tejas (ok), NTT DOCOMO, CMCC, ZTE, Huawei/HiSi, OPPO **Prefer resource-specific SD basis, i.e. Scheme2**: Fraunhofer IIS/HHI, CATT, CEWiT, New H3C, Fujitsu, NEC, HONOR, KDDI, IDC**Prefer Scheme1:** Intel, LG, **No T1 MP**: Apple, TCL, Xiaomi, Spreadtrum, Google, Lenovo/MotM, Fraunhofer IIS/HHI (2nd)  |
| 1.6.1 | **[116bis] Agreement**For the Rel-19 Type-II codebook refinement for 48, 64, and 128 CSI-RS ports, on CBSR, refine the legacy CBSR as follows:* …
* Group-based CBSR granularity where each bit in the CBSR is associated with a set of X1X2 SD basis vectors, where the set includes X1 adjacent SD basis vectors along the N1 direction and/or X2 adjacent SD bases along the N2 direction
	+ FFS: Value(s) of X1 and X2 and detailed design/spec impact

**[116bis] Agreement**For the Rel-19 Type-I SP codebook refinement for 48, 64, and 128 CSI-RS ports, regarding CBSR design:* …
* $ \frac{N\_{1}⋅O\_{1}⋅N\_{2}⋅O\_{2}}{X\_{1}⋅X\_{2}}$-bit CBSR where each bit in the CBSR is associated with a set of X1X2 SD basis vectors, where the set includes X1 adjacent SD basis vectors along the N1 direction and/or X2 adjacent SD bases along the N2 direction
	+ FFS: Value(s) of X1 and X2 and detailed design/spec impact

**Proposal 1.F.1**: For the Rel-19 Type-I SP and Type-II codebook refinement for 48, 64, and 128 CSI-RS ports, on CBSR, the value of (X1, X2) is NW-configured via higher-layer (RRC) signalling from {[(1,1)], [(1,2)], [(2,1)], (1,4), (4,1), (2,2), (2,4), (4,2), (4,4)} * FFS: Dependence on each supported (X1, X2) value on (N1, N2)

**FL assessment**: The values of (X1,X2) need to be resolved to complete CBSR design | **Support/fine:** Huawei/HiSi, Spreadtrum, Ericsson, [TCL], ZTE, vivo, HONOR, NEC, Google, Qualcomm, Fraunhofer IIS/HHI, NTT DOCOMO, IDC, OPPO**Not support:** Huawei/HiSi (remove 2,4, 4,2, 4,4) |
| 1.6.2 | **[116bis] Agreement**For the Rel-19 Type-I SP codebook refinement for 48, 64, and 128 CSI-RS ports, regarding CBSR design:* 1-bit hard restriction is supported (analogous to Rel-15 Type-I)
* FFS: 3-bit scaling factor for soft restriction with the scaling factor taken into account in CQI/PMI calculation
* …

**Proposal 1.F.2**: For the Rel-19 Type-I codebook refinement for 48, 64, and 128 CSI-RS ports, for RI=v=1, support the following:* for each group of $X\_{1}X\_{2}$ SD basis vectors, a 3-bit scaling factor can be NW-configured via higher-layer (RRC) signalling, where the scaling factors are defined as scalings on the power control offset configured for the associated CSI-RS resources
	+ The values of $X\_{1}$ and $X\_{2}$ for this feature are separately configured from those for CBSR
	+ Separate configuration (RRC signalling) from CBSR
	+ The candidate values of $X\_{1}$ and $X\_{2}$ are the same as those agreed for CBSR
* The codepoints of each of the group-specific 3-bit scaling factors are mapped to values of $\left\{\sqrt{1}, \sqrt{1/2}, \sqrt{1/3} ,\sqrt{1/4},\sqrt{1/6},\sqrt{1/8},\sqrt{1/12},\sqrt{1/16}\right\}$
* Note: This feature is a separate UE capability

FFS: Whether this can be extended to RI=v>1 as well as Type-II codebook refinement **FL assessment**: The proposal is now formulated in terms of scaling factor (not CBSR), but with the same granularity as CBSR. **Ericsson has demonstrated the performance gain within the context of co-existence with NTN (cf. Table 1B).** | **Support/fine:** Ericsson, Huawei/HiSi, ZTE, Samsung, vivo, IDC, Qualcomm, MediaTek, Google, ZTE, Nokia/NSB, OPPO, Fraunhofer IIS/HHI,**Not support:** Lenovo/MotM, NTT DOCOMO,  |
| 1.7 | **[116bis] Agreement**For the Rel-19 Type-I and Type-II codebook refinement for 48, 64, and 128 CSI-RS ports, regarding the mapping from CSI-RS resource index/port index per resource and port index to CSI/PMI calculation, support NW to configure UE with one of the following mapping methods via higher-layer (RRC) signaling, * *Mapping method 1*: Sequential ordering/indexing within (1st resource, 1st polarization), then (2nd resource, 1st polarization), …, then (Kth resource, 1st polarization), then (1st resource, 2nd polarization), then (2nd resource, 2nd polarization), …, then (Kth resource, 2nd polarization)
* *Mapping method 2*: Sequential ordering/indexing within (where K\*n2 = N2):
	+ for the 1st polarization, (1st n2 ports in 1st resource, 1st polarization), (1st n2 ports in 2nd resource, 1st polarization), …, (1st n2 ports in Kth resource, 1st polarization), then (2nd n2 ports in 1st resource, 1st polarization), (2nd n2 ports in 2nd resource, 1st polarization), …, (2nd n2 ports in Kth resource, 1st polarization), … then (N1th n2 ports in 1st resource, 1st polarization), (N1th n2 ports in 2nd resource, 1st polarization), …, (N1th n2 ports in Kth resource, 1st polarization) ,
	+ and then for the 2nd polarization, (1st n2 ports in 1st resource, 2nd polarization), (1st n2 ports in 2nd resource, 2nd polarization), …, (1st n2 ports in Kth resource, 2nd polarization), then (2nd n2 ports in 1st resource, 2nd polarization), (2nd n2 ports in 2nd resource, 2nd polarization), …, (2nd n2 ports in Kth resource, 2nd polarization), … then (N1th n2 ports in 1st resource, 2nd polarization), (N1th n2 ports in 2nd resource, 2nd polarization), …, (N1th n2 ports in Kth resource, 2nd polarization)

FFS: Exact port indexing within each CSI-RS resource or across K CSI-RS resources**Proposal 1.G**: For the Rel-19 Type-I and Type-II codebook refinement for 48, 64, and 128 CSI-RS ports, regarding port mapping, * Following legacy principle, “sequential ordering/indexing within” a group of Q indices {i0, i1, …, iQ-1} is a linearly increasing sequence such that iq < iq+1 (where q=0, 1, …, Q-2 is the port index within a CSI-RS resource, and iq or iq+1 $\in $ {0, 1,…, KQ-1}).
* After resource aggregation, P (=48, 64, or 128) ports are numbered in accordance to Table 7.4.1.5.3-1 from TS 38.211

**FL assessment**: This was discussed in RAN1#116bis but the FL proposal wasn’t well formulated. We decided to postpone to RAN1#117. | **Support/fine:** NTT DOCOMO, Qualcomm, Nokia/NSB, Ericsson, Samsung, Tejas Network, CATT, Lenovo/MotM, OPPO, Fraunhofer IIS/HHI, IDC, [Huawei/HiSi], [LG], [Google] **Not support:**  |
| 1.8.1 | **[116] Agreement**For the Rel-19 Type-I and Type-II codebook refinement for up to 128 CSI-RS ports, regarding NZP CSI-RS resource aggregation to attain 32 < P (or PCSI-RS)≤ 128, support aggregating at least K=2, 3, or 4 legacy NZP CSI-RS resources with equal number of ports* …
* Note: If the supported number of ports does not require aggregation of 3 resources, K=3 can be removed

**Proposal 1.H.1:** For the Rel-19 Type-I and Type-II codebook refinement for 48, 64, and 128 CSI-RS ports, regarding aggregation of K NZP CSI-RS resources to attain 32 < P (or PCSI-RS)≤ 128, support *only* the following combinations of K and P (or PCSI-RS):* For P (or PCSI-RS) = 48, K = 2 (each resource 24 ports) and 3 (each resource 16 ports)
* For P (or PCSI-RS) = 64, K = 2 (each resource 32 ports) [and 4 (each resource 16 ports)]
* For P (or PCSI-RS) = 128, K = 4 (each resource 32 ports)

Note: This implies that K=3 is removed. **FL assessment**: By excluding K=3, the above proposal excludes the cyan aggregation. While there are other aggregations that may not be too useful, there is no need to exclude them (NW implementation and market will determine).

|  |  |  |
| --- | --- | --- |
| **New P** | **New (N1,N2)** | **Legacy resource aggregation** |
| **K** | **Old (N1’,N2’)** |
| 48 | (8,3) | 2; 3;  | (4,3); (8,1);  |
| (6,4) | 2/4; | (6,2)/(6,1);  |
| 64 | (16,2) | 2/4; 2; | (8,2)/(4,2); (16,1);  |
| (8,4) | 2; 2/4; | (4,4); (8,2)/(8,1);  |
| 128 | (16,4) | 4; 4; | (4,4); (16,1);  |
| (8,8) | 4; | (8,2);  |

Blue: mapping #1 (along horizontal dimension)Red: mapping #2 (along vertical dimension) | **Support/fine:** Qualcomm, Google, Samsung, Ericsson (K=3), NTT DOCOMO, OPPO, Huawei/HiSi**Not support:**  |
| 1.8.2 | **[116bis] Agreement**For the Rel-19 Type-II codebook refinement for 48, 64, and 128 CSI-RS ports based on the Rel-18 Type-II Doppler codebook, support the following aperiodic CMR configuration:* A UE can be configured with *KDOPP* = {4, 8, 12} CSI-RS resource groups for the purpose of aperiodic CMR as needed by Type-II Doppler CSI
	+ The time separation between the first resources from two consecutive groups (=*m*) can be configured from {1, 2}
	+ FFS: The need for additional restriction in time domain
* Each CSI-RS resource group comprises *K* NZP CSI-RS resources (K defined in previous agreements) for aggregation associated with a same CSI-RS resource set assuming the agreed resource set rules for Rel-19 Type-I/II codebooks
* All the *KDOPP* CSI-RS resource groups are associated with a same CSI-RS resource set configuration

FFS: the determination of CSI-RS resource group that a CSI-RS resource is associated with**Proposal 1.H.2**: For the Rel-19 Type-II codebook refinement for 48, 64, and 128 CSI-RS ports based on the Rel-18 Type-II Doppler codebook, * Ordering the *KDOPPK* CSI-RS resources ascendingly by the CSI-RS resource index and *kDOPP* ={0,1,…, *KDOPP*  –1}, CSI-RS resources { *kDOPPK*, *kDOPPK* +1, …, (*kDOPP+*1*)K –*1} are associated with the *kDOPP*-th CSI-RS resource group
* FFS: If the CSI-RS resources in a resource group span two consecutive slots, *m* is 2.
* FFS: If the CSI-RS resources in a resource group are located in one slot, *m* can be configured from {1, 2}]

**FL assessment**: This proposal attempts to resolve the two FFS points. The last bullet point (in brackets) is unclear and needs more discussion. | **Support/fine:** Huawei/HiSi, vivo, CATT, Samsung (1st bullet), Ericsson (1st bullet), Qualcomm, IDC, NTT DOCOMO, OPPO, Fraunhofer IIS/HHI, [Fujitsu], [Xiaomi]**Not support:** |
|  |  |  |

Table 1B SLS results: issue 1

|  |  |
| --- | --- |
| **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. |
| Huawei/HiSi | 1.1.1 | UPT gain | The simulation results in the figures above show that UEs with rank 6 can have 11% performance gain if 3 or 4 SD bases can be used compared to 3 SD bases only, and UEs with rank 5 with about 6% performance gain. |
| Samsung | 1.1.1 |  |  |
| on O1,O2 | 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. |
| ZTE | 1.1.1 | Average throughput gain | It is observed in the result above that, both scheme 2(A) and scheme 2(b) can provide over 10% average throughput gain over scheme 1. Besides, by indicating the SD basis applied to the orphan layer, scheme 2(B) further shows approximately 1% throughput gain over scheme 2(A). Note that, the RI is dynamically selected from 1-8 in SLS. For RI = 5 or 7 when the orphan layer occurs, the performance advantage of scheme 2(B) over scheme 2(A) would be more significant. |
| Nokia/NSB | 1.1.1 | Mean UPT gain vs overhead, cell-edge UPT gain vs overhead | **Throughput vs overhead comparison between Scheme 1,2 and 3 for ranks 5-8, with 64 ports and layout (16x2).**It is observed from SLS results (the above figures are the case of port layout (16x2)) that * Scheme 3 outperforms Scheme 1 in throughput, by about 167% to 423% depending on number of antenna ports (64 or 128), port layout (8x4), (16x2) or (8x8), RU (30%,50%,70%), reported rank (5 to 8) and cell-average or cell-edge UEs.
* Scheme 3 outperforms Scheme 2 in throughput, by up to 243%, for ranks 5,6 and 8, depending on number of antenna ports (64 or 128), port layout (8x4), (16x2) or (8x8), RU (30%,50%,70%), and cell-average or cell-edge UEs.
* Lower throughput of Scheme 3 than Scheme 2 is observed for rank 7, because in the legacy Rel15 layer-to-beam mapping, the orphan beam is mapped to beam 2, instead of, which is typically the second strongest beam, instead of weaker beam 4.
 |
| Ericsson | 1.1.1 | Average user relative throughput vs average overhead | **Average overhead vs throughput gain for (M, N, P) = (8, 8, 2) at 10% resource utilization for the different Type-I codebook schemes in dense urban scenario at 3.5GHz****Average overhead vs throughput gain for (M, N, P) = (4, 16, 2) at 10% resource utilization for the different Type-I codebook schemes in dense urban scenario at 3.5GHz**From the evaluation results above, it is observed that when Scheme 1 is used as the baseline in the simulations (the observations are valid for both 3.5 and 6.5GHz):* Scheme 2 has the best overall performance albeit at a slightly larger overhead
* Scheme 3 is able to achieve slight gains when compared to the baseline (Scheme 1), especially at low resource utilization, and at a slightly higher overhead than the baseline.
 |
| 1.4 | Mean user relative throughput,5th percentile user relative throughput | **Average and 5th percentile throughput gain for (M, N, P) = (8, 16, 2) at 20%, 50% and 70% resource utilization for eType-II in dense urban scenario at 3.5GHz with UE speed of 3km/h**From the evaluation results above, it is observed that when considering 4 slots of CSI feedback delay as the baseline in the simulations, the following performance losses:* With an increased feedback delay of 8 slots, up to 25% average throughput loss is observed for 64 CSI-RS ports for UEs at 8km/h.
* With an increased feedback delay of 12 slots, up to 31% average throughput loss is observed for 128 CSI-RS ports for UEs at 3km/h.
 |
|  |  |  |  |

Table 1C Additional inputs: issue 1

|  |  |
| --- | --- |
| **Company** | **Input** |
| Mod V0 | **Please share your inputs on each of the issues and, if applicable, proposals in TABLE 1A** |
| Google | Proposal 1.A.1/2/3/4: SupportProposal 1.B.1: SupportProposal 1.C: SupportProposal 1.D.1/2: SupportProposal 1.E.1: We failed to see the necessity to enhance MP. It seems similar functionality can be achieved by CJT CSI.Proposal 1.F.1: OK. Probably we can consider to remove (1, 2), (1,4) and (2, 4). Usually, horizontal beams are narrower than vertical beams. The granularity for CBSR for horizontal beams could be larger than vertical beams.[Mod: I put those values in brackets for further discussion and see what companies think.]Proposal 1.F.2: We do not think this is needed for high rank case. For high rank, there is already power scaling for each layer. In addition, the actual power scaling factor for each layer should be defined as max(CBSR, sqrt(v)), where CBSR indicates the value configured by the codepoint and v indicates the number of layers. Further, if additional power scaling is applied for some layers, we should allow UE to perform power boosting for some other layers.[Mod: Noted]Proposal 1.G: We do not know why this proposal is needed. Port indexing within each CSI-RS resource should remain the same as legacy.[Mod: Since there were proposals to interleave within group in RAN1#116bis, this proposal says there is no interleaving, i.e. legacy is followed as you said. I added “following legacy”] Proposal 1.H.1: Support |
| Mod V2 | **Added clarification on 1.G per Google comment** |
| Samsung | We support the following proposals:- 1.A.1, 2, 3, 4; 1.B.1; 1.C; - 1.D.1/2 (we are also fine with ACR=1 especially for Capability2 for 1.D.2)- 1.E.1 (we are also fine with Scheme2, i.e. replacing resource-common with resource-specific in 1.E.1)- 1.F.1, but (1,4) should be kept (please remove the square brackets)- 1.F.2; 1.G; 1.H.1; Regarding 1.H.2: 1) OK only with 1st bullet, 2) 2nd and 3rd bullets are not needed since this can be left to NW implementation. It’s quite obvious that m=1 is not feasible when the aggregated resources are across 2 slots. It’s also obvious that when the aggregated resources span 1 slot, both m=1 and 2 are feasible. 3) 4th bullet is unclear  |
| Qualcomm | **Proposal 1.A.2**: Not support* Firstly, this is a topic that was explicitly excluded in RAN plenary.
* Secondly (although we don’t even need to discuss technical details, according to the reason above), anyway some descriptions of this proposal are not clear to us
	+ For linkage b/w SRS ports and CW, it basically couples the procedure of SRS and PDSCH – in legacy, these two are separate procedures in standard (analogous to CSI feedback and PDSCH: Two decoupled procedures)
		- * + Given that for overall rank (i.e. summation of the two SRS port groups) $v$>4, CW0 and CW1 fixedly correspond to the first $\left⌊v/2\right⌋$ and last $\left⌈v/2\right⌉$ layers respectively, does this mean that the two SRS port groups always need to be derived by network as rank-$\left⌊v/2\right⌋$ and rank-$\left⌈v/2\right⌉$ (i.e. same rank, or first rank smaller than second rank by 1)?
	+ Besides, seems this proposal additionally couple CQI and SRS? But CQI is based on PMI and RI, not based on “UE-assumed network utilization of SRS” (which seems to be hinted by this proposal)

**Proposal 1.A.3**: This seems to be an extension of non-codebook-based PUSCH, from <=32port gNB, to {48,64,128}-port gNB – but should this be out of CSI (9.2.2 agenda)?[Mod: Not really 😊 this is a legit use case for the CSI-RS enhancement we do for objectives 2a/b, just as we don’t write “timeline, CPU, ACR, UCI omission, CBSR, …” in objectives 2a/b]**Proposal 1.A.3**: Support**Proposal 1.C**: Support**Proposal 1.D.1**: Support in general.Seems for timeline Capability 1, it is more appropriate to be OCPU = ceil(P/~~16~~32), compared with legacy?[Mod: Good point, thanks]**Proposal 1.D.2**: We propose to define active resource counted as “1” (virtual) CSI-RS resource, not K, at least for timeline Capability 2, and the reason is analysed as following:*For example, a UE may support both Rel-19 Type-I codebook >32port and Rel-15 Type-I codebook <=32port. Then it comes an issue that, UE capability indication mechanism for active CSI-RS resource/port: FG 2-33 (e.g. if Rel-19 has a new version of FG 2-33) – it can’t differentiate b/w the following two cases:** *Case A: 1 non-CRI report with 128-port codebook, being configured with K=4 resources each 32 ports;*
* *Case B: 4 reports each with 1 CSI-RS resource of 32 ports.*

*In our understanding, UE measuring efforts is: Case A << Case B – a UE signing up to do Case A on a certain CC, does not guarantee to do Case B.**To avoid doing Case B, UE may conservatively report a small number of maximum supported active CSI-RS resources/ports, which basically makes 128-port difficult to support.**Therefore, counting active CSI-RS resources as “1,” actually makes this feature more likely to be implemented.*As for timeline Capbility 1, we also prefer to count as “1” due to the same reason above – but we are also open to discuss.**Proposal 1.F.1**: OK**Proposal 1.F.2**: We are not sure how Pc ratio (EPRE offset) works for rank>1.Together with some typo corrections (if we understand the intention correctly), some editorial suggestions:

|  |
| --- |
| **Proposal 1.F.2**: For the Rel-19 Type-I and Type-II codebook refinement for 48, 64, and 128 CSI-RS ports, in addition to the agreed (hard) CBSR, support the following:* for each group of $X\_{1}X\_{2}$ SD basis vectors, a 3-bit scaling factor can be NW-configured via higher-layer (RRC) signalling, where the scaling factors are defined as scalings on the power control offset configured for the associated CSI-RS resources, for the case of rank1
	+ The values of $X\_{1}$ and $X\_{2}$ for this feature are separately configured from those for hard CBSR
	+ Separate configuration (RRC signalling) from hard CBSR
	+ The candidate values of $X\_{1}$ and $X\_{2}$ are the same as those agreed for hard CBSR
* The codepoints of each of the group-specific 3-bit scaling factors are mapped to values of $\left\{\sqrt{1}, \sqrt{1/2}, \sqrt{1/3} ,\sqrt{1/4},\sqrt{1/6},\sqrt{1/8},\sqrt{1/12},\sqrt{1/16}\right\}$
* Note: This feature is a separate UE capability
 |

**Proposal 1.G**: OK with the principle, but seems the wording is not clear.Maybe an example is more clear, we understand this proposal is saying, for 4x32=128 ports, port indices are {0,1,…,127}, rather than #1{0,1,…,31}+#2{0,1,…,31}+#3{0,1,…,31}+#4{0,1,…,31}.If our understanding is correct, some editorial suggestions:

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| --- |
| **Proposal 1.G**: For the Rel-19 Type-I and Type-II codebook refinement for 48, 64, and 128 CSI-RS ports, regarding port mapping, * Following legacy principle, “sequential ordering/indexing within” a group of Q indices {i0, i1, …, iQ-1} is a linearly increasing sequence such that iq < iq+1 (where q=0, 1, …, Q-2 is the port index within a CSI-RS resource, and iq or iq+1 $\in $ {0,1,…,KQ-1}).
* After resource aggregation, P (=48, 64, or 128) ports are numbered in accordance to Table 7.4.1.5.3-1 from TS 38.211
 |

[Mod: Got it]**Proposal 1.H.1**: Support**Proposal 1.H.2**: Fine, but agree that the last bullet in [ ] needs better description. |
| IDC | **Proposal 1.A.1, Proposal 1.A.4, Proposal 1.B.1, Proposal 1.C, proposal 1.F.1, Proposal 1.G, Proposal 1.H.2:** Support |
| Mod V6 | **Revisions to accommodate comments (also offline)** |
| Ericsson | **Proposal 1.A.3**:Support**Proposal 1.B.1**:Although we think some overhead reduction is possible, we can live with the current proposal.**Proposal 1.C**: Support**Proposal 1.D.2**: Support, Our preference for active resource counting is 1 for both Capability 1 and Capability 2.**Proposal 1.F.1**:ok. but do we need all the combinations? (1,1) doesn’t help with reducing the signalling overhead right?[Mod: True]**Proposal 1.F.2**:We think that the scaling can be useful also for high rank since the same elevation beam can be used for multiple layers. This will counterweight the 1/sqrt(v) scaling so that the expected EIRP can become similar for high and low rank. Since the angular spread in elevation is relatively low, it is not likely that many different elevation beams will be used for high rank.Having said that, we are ok with FL’s latest revision to focus the proposal on RI=v=1. We can discuss the case of RI=v>1 and Type II applicability in future.**Proposal 1.H.1:**Not support. If K=3 is removed, then 48 port needs 24 port CSI-RS resources. Since 48 port may be used in bands where there may be legacy UEs, this may limit CSI-RS resource sharing with legacy UEs using 16 port CSI-RS. Hence, we prefer to keep K=3 also.**Proposal 1.H.2:**ok with Only 1st bullet. The remaining bullets need further discussion, so we prefer to make them FFS. Agree with FL that the last bullet is unclear. |
| NTT DOCOMO | **Proposal 1.A.4:**Support. In addition, maybe companies already have common understanding, but we think it is better to also clarify the i\_1,3 for RI=2 case.**Proposal 1.C**: Support**Proposal 1.D.1**: Generally support. But we’d like to add ‘except for Type-II doppler CSI refinement’ in the main bullet, because CPU occupation should be discussed separately for Type-II doppler CSI refinement, similar as legacy.**Proposal 1.D.2**: Generally support. But we’d like to add ‘except for P/SP CSI-RS resource for Type-II doppler CSI refinement’ in the main bullet, because ARC should be discussed separately for P/SP CSI-RS resource for Type-II doppler CSI refinement, similar as legacy.In addition, we prefer ARC to be 1 for two UE capabilities.**Proposal 1.H.1**: Support**Proposal 1.H.2**: OK |
| OPPO | **Proposal 1.A.1**: Fine.**Proposal 1.A.2**: In our original understanding, the association between SRS and PDSCH would only impact PDSCH receiver at UE, That is, UE can select grouping of receive antennae for recovering of two CWs. Now when it is also applied to CQI calculation, there could be two additional issues:1. RI and CQI are calculated together based on indicated CSI-RS ports, so RI should be considered with CQI.
2. Even when RRC configures the association, the UE receiver is still up to UE implementation. UE can still select the legacy receiver without complexity reduction and performance loss. The RI/CQI calculation assumption should be consistent with the actual UE receiver rather than the indicated association.

We propose not to mention CQI here. How to calculate CQI should be consistent with applied UE receiver which is up to UE implementation. One can never prevent UE to use a receiver with better performance (though with higher complexity).[Mod: Please check Huawei’s comments] **Proposal 1.A.3**:Though we still think it is useless, we can live with it if companies have different thinking. {mod: Thanks}**Proposal 1.A.4**/**Proposal 1.B.1**/**Proposal 1.C**/**Proposal 1.D.1**/**Proposal 1.D.1**: Fine.**Proposal 1.D.2**: We prefer K for different timelines. **Proposal 1.F.1**: Fine.**Proposal 1.F.2**: We could be fine with the proposal though we still think it can be up to gNB implementation.[Mod: Thanks]**Proposal 1.H.1**: Fine.**Proposal 1.H.2**: We prefer to define the value of m based on the starting slot of a resource group.**[Mod: now FFS]** |
| Fraunhofer IIS/HHI | **Proposal 1.A.4**: Support**Proposal 1.C**: Support**Proposal 1.D.1**: Support**Proposal 1.D.2**: Support**Proposal 1.E.1**: Our first preference is scheme 2 i.e., resource specific SD basis selection for W1. Our second preference is not supporting MP codebook.**Proposal 1.F.1**: CBSR is an optional feature. Therefore, we think we can limit the number of (X1, X2) combinations to {(1,4) (2,2),(4,1),(4,4)}. To keep it simple, we prefer supporting a single (X1,X2) combination to be associated with a specific (N1,N2) combination.[Mod: Tend to agree, removed some but kept some]**Proposal 1.F.2**: Ok with the proposal. The power difference between two consecutive scaling factors is not uniform across the given scaling factors. We are not sure about the need to agree on non-uniform power difference levels.**Proposal 1.G**: OK**Proposal 1.H.2**: Support |
| Huawei, HiSilicon | **Proposal 1.A.1**We are fine with the proposal if complexity issue is addressed by proposal 1.A.2.For FFS on the supported SD basis vectors for scheme-B, we support 4 SD basis vectors for RI=5-6. As scheme-B is an extension of scheme-B for RI=1-4 targeting better performance, while RI=1-4 has supported up to 4 SD basis vectors, it’s reasonable to support 4 also for RI=5-6.The simulation results can also show that by supporting 3-4 SD basis vectors, UEs with RI=5-6 can have a performance gain of 5~11%. **Proposal 1.A.2,** @QC, for linkage between SRS port grouping and PDSCH CWs, this is needed because gNB and UE need to have the same understanding. The low complexity UEs with two 4R-receivers/port-groups will receive two CWs with two 4R receivers/port-groups separately. Then gNB needs to know which CW is received by which port groups, because gNB needs to determine the percoders derived from a port group should be used for which CW.@QC @OPPO, for CQI, this is also useful for TDD networks to let gNB know the level CQI, to save the time for MCS scheduling adjustment based on HARQ-ACK. Adjusting MCS based on HARQ-ACK can waste time and reduce performance, especially for burst traffic. For TDD network, there may be a large difference between amplitude of UL/DL channels. Therefore, in addition to SRS, network can usually also configure CQI reporting for gNB to have a rough estimation of CQI. And hence gNB needs to know the CQI of each CW corresponds to which port group, for following scheduling of PDSCH CWs.**Proposal 1.A.4**: fine with the proposal.**Proposal 1.C**: fine with the proposal.**Proposal 1.F.1:** Since 128 ports increases the overhead of CBSR 4 times over legacy 32 ports, to keep the same overhead, we suggest to remove (2,4), (4,2) or (4,4).**[Mod: The combos you propose to remove save the most overhead, right?]****Proposal 1.H.1:**For simplicity, one combination is enough to support 48/64/128 ports, therefore, 4 16-port CSI-RS resources for 64 ports is not needed. We suggest to remove it. * For P (or PCSI-RS) = 64, K = 2 (each resource 32 ports) ~~and 4 (each resource 16 ports)~~

**Proposal 1.D.1:**Suggest to exclude Rel-19 type-II Doppler codebook, which should be discussed separately.**Proposal 1.D.2:**Suggest to exclude Rel-19 type-II Doppler codebook, which should be discussed separately.Counting as 1 is too restricted, while K is too relaxed. We prefer some value between 1 and K, e.g., K, where  is reported by UE.As the active resources are different for the following two cases, and case 2 is fewer than that of case 1. If 8 8-port CSI-RS resources with CRI are counted as 8 (K=8), then the 2 32-port CSI-RS resources can be counted as a value less than 8.- Case 1: Multiple CRIs with legacy codebooks with ≤ 32 ports, e.g., 8 8-port CSI-RS resources with CRI- Case 2: One CRI report with Rel-19 codebooks with >32 ports, e.g., 2 32-port CSI-RS resources without CRI.**Proposal 1.H.2:**The last bullet seems not clear to us, suggest to remove it for now. |
| Mod V13 | **Revisions per inputs** |

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

Table 2A Summary: issue 2

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| --- | --- | --- |
| **#** | **Issue** | **Companies’ views** |
| 2.1.1 | **RAN1#116bis discussion + OFFLINE****Question 2.F.2:** For the Rel-19 CRI-based CSI refinement for up to 128 CSI-RS ports, for M>1, please share your view on whether the following overhead reduction schemes should be supported:* CRI/resource-common RI value (indication):
	+ *Support/fine*: NTT DOCOMO (1st), Xiaomi, TCL, Huawei/HiSi, CATT
	+ *Not support (CRI/resource-specific RI)*: vivo, Samsung, NEC, Qualcomm, NTT DOCOMO (2nd), Lenovo/MotM, Ericsson, Nokia/NSB, Google, Intel, CMCC, MediaTek, Fujitsu, Sharp, OPPO
* Differential WB CQI (the wideband CQI(s) associated with the 2nd, …, M-th CRI(s) is calculated differentially with respect to the 4-bit largest wideband CQI(s) associated with the 1st CRI into Bd<4 bits):
	+ *Support/fine*: NTT DOCOMO (1st), ZTE, Huawei/HiSi
	+ *Not support (No differential, Bd=4)*: vivo, Samsung, Qualcomm, Lenovo/MotM, Ericsson, Nokia/NSB, Google, Intel, TCL, CMCC, MediaTek, Fujitsu, Sharp, OPPO, NTT DOCOMO (2nd),
* 1-bit differential SB CQIs associated with the 2nd, …, M-th CRI(s), calculated differentially with respect to the 2nd, …, M-th WB CQI(s)
	+ *Support/fine*: Huawei/HiSi
	+ *Not support (No differential, legacy 2-bit)*: vivo, Samsung, Lenovo/MotM, Ericsson, Fujitsu Nokia/NSB, Google, Intel, TCL, CMCC, MediaTek, Sharp, OPPO

**Proposal 2.A.1:** For the Rel-19 CRI-based CSI refinement for up to 128 CSI-RS ports, for M>1, support the following:* Resource-specific RI, i.e. RI is independently calculated and indicated for each of the selected M NZP CSI-RS resources
	+ FFS: If resource-common RI indication is also supported
* 4-bit wideband CQIs are independently calculated and reported across the M selected NZP CSI-RS resources
* 2-bit differential SB CQIs are independently calculated across the M selected NZP CSI-RS resource

**FL assessment**: This was already discussed in RAN1#116bis and also OFFLINE [2]. * Whether RI is CRI-common or CRI-specific should be decided first. In this case, the proponents of CRI-common should demonstrate that CRI-common is better than CRI-specific in UPT vs PMI overhead trade-off
	+ Given the marginal saving in overhead from CRI-common RI, CRI-common RI is justified only if there is practically no loss of UPT relative to CRI-specific RI
* If CRI-common is justified, whether differential CQI is supported or not can be decided with the same methodology (UPT vs PMI overhead). Else, the baseline (non-differential) is the natural outcome
 | **Support/fine**: OPPO, vivo, Samsung, Apple, MediaTek, Intel, CEWiT, Ericsson, NEC, Qualcomm, NTT DOCOMO, Lenovo/MotM, Nokia/NSB, Google, CMCC, Fujitsu, Sharp, Spreadtrum, HONOR, Kyocera, KDDI, Lenovo/MotM, IDC**Not support**: Huawei/HiSi, ZTE, CATT, Xiaomi (CRI-common RI), TCL (CRI-common RI),  |
| 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
	+ In addition, the *MR* selected resources can be updated via DCI (as a part of CSI trigger state)

**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, **Not support:** Spreadtrum, vivo, NTT DOCOMO, OPPO (no DCI) |
| 2.1.3 | **Question 2.A.3:** For the Rel-19 CRI-based CSI refinement for up to 128 CSI-RS ports, for M=2, please share your view on the following proposal:* When Rel-16 eType-II codebook is configured, support resource-common FD basis selection and indication

**Support/fine:** Huawei/HiSi**Not support (resource-specific):** Google, Samsung, Qualcomm, Ericsson, NTT DOCOMO, OPPO**FL assessment**: This is a proposal from Huawei to reduce overhead. Note that the **baseline is resource-specific**, and resource-specific SD basis has been agreed.  |
| 2.1.4 | **Question 2.A.4:** For the Rel-19 CRI-based CSI refinement for up to 128 CSI-RS ports, for M=2, when Rel-16 eType-II codebook is configured, please share your preference on the following alternatives:* Alt1. Resource-specific RRC configuration of Parameter Combination
	+ Support/fine: Google,
	+ Not support: Samsung, Qualcomm
* Alt2. Resource-common RRC configuration of Parameter Combination
	+ Support/fine: Samsung, Qualcomm, Ericsson, NTT DOCOMO, OPPO
	+ Not support:

**FL assessment**: This needs to be resolved for Rel-16 eType-II based HBF. Analogous to Rel-18 Type-II CJT, **the baseline is Alt2.** |
| 2.2 | **Proposal 2.B**: For the Rel-19 CRI-based CSI refinement for up to 128 CSI-RS ports, regarding CBSR, for each of the configured KS NZP CSI-RS resources, reuse per-resource CBSR from the legacy spec as follows: * Rel-17 Type-I NCJT CBSR when Rel-15 Type-I SP is configured
* Rel-18 Type-II CJT CBSR when Rel-16 eType-II is configured

**FL assessment**: No reason not to reuse legacy CBSR  | **Support/fine:** MediaTek, ZTE, Samsung, Lenovo/MotM, HONOR, Xiaomi, Google, Qualcomm, IDC, Ericsson, NTT DOCOMO, OPPO**Not support:** Huawei/HiSi (two-level) |
| 2.4 | **Proposal 2.D**: For the Rel-19 CRI-based CSI refinement for up to 128 CSI-RS ports:* [OCPU = M + KS [-1]]
* Active resource counting = KS (following legacy)

**FL assessment**: This proposal is a synthesis between proposals from vivo and Qualcomm. For further discussion on timeline, Qualcomm proposes* If Ks = 2:
	+ Z= Q/16 \* Z + (M-1) \* Y, Z’= Q/16 \* Z’ + (M-1) \* Y,
* Else if 2 < Ks <= 8:
	+ Z = Q/8 \* Z + (M-1) \* Y, Z’ = Q/8 \* Z’ + (M-1) \* Y

where Y=2 or 1 symbol should be sufficient.Vivo proposes* Multiply legacy Z’ by a factor of M.
* Z is increased by (M–1)\*Z’ to match the increase in Z’
 | **Support/fine:** vivo, Google, OPPO (-1), [ZTE], [Xiaomi], , Samsung, Qualcomm (OCPU and ARC), Huawei/HiSi (ARC), NTT DOCOMO (ARC)**Not support:**  |
| 2.5 | **[116bis] Agreement**For the Rel-19 CRI-based CSI refinement for up to 128 CSI-RS ports, the following report quantities are supported:* *‘cri-RI-PMI-CQI ‘*
* *‘cri-RI-LI-PMI-CQI’ (only for Type-I)*
* *FFS: ‘cri-RI-i1-CQI’ (only for Type-I)*
* *FFS: ‘cri-RI-i1’ (only for Type-I)*

**Proposal 2.E**: For the Rel-19 CRI-based CSI refinement for up to 128 CSI-RS ports, the following report quantities are also supported only when Rel-15 Type-I SP codebook is configured [and only for M=1]:* *‘cri-RI-i1-CQI’*
* *‘cri-RI-i1’*
* [‘*cri-RI-CSI*’]

**FL assessment**: The restriction M=1 only was proposed by Xiaomi (need to check with companies) | **Support/fine:** IDC, MediaTek, Spreadtrum, CMCC, Xiaomi, Huawei/HiSi**Not support:** Google, Samsung, Ericsson |
|  |  |  |

Table 2B SLS results: issue 2

|  |  |
| --- | --- |
| **Company** | **SLS results** |
| **Issue #** | **Metric** | **Observation** |
| Huawei/HiSi | 2.1.2 | Relative Throughput | gNB-assisted reporting beam determination (*M=2, MR*=1*)* provides significant performance gain (~17.5%) over UE-autonomous reporting beam determination(*M=2, MR*=0) |
| 2.1 | Channel Correlation | The normalized power in spatial domain and delay domain of multiple beams are highly correlated  |
|  |  |  |  |

Table 2C Additional inputs: issue 2

|  |  |
| --- | --- |
| **Company** | **Input** |
| Mod V0 | **Please share your inputs on each of the issues and, if applicable, proposals in TABLE 2A** |
| Google | Proposal 2.A.1: SupportProposal 2.A.2: SupportProposal 2.A.3: We think all the CSI components should be resource-specific. Q 2.A.3: Support Alt1. Proposal 2.B: We think CBSR should be configured in resource-specific manner. The digital precoder status can be different on top of different beams.Proposal 2.D: SupportProposal 2.E: We failed to see the necessity to support these report quantities. |
| Mod V2 | **No revision** |
| Samsung | We support the following proposals: * 2.A.1, 2; 2.B; 2.D;

We don’t support proposal 2.E. Although it was supported in legacy Rel-15 CRI-based, we see no use case for the so-called semi-open-loop precoder cycling for HBF. We agree with Google.Question 2.A.3: Not support. This would complicate UE implementation further when Type-II is configured since now the UE needs to perform joint optimization for FD basis selection across CRIs/resources. The UE can’t assume that the KS panels are heavily correlated and calculate Wf selection only for 1 panel.Question 2.A.3: Support Alt2. We see no motivation for Alt1. It complicates both UE and NW implementation. |
| Qualcomm | **Proposal 2.A.2**: Not support.We think this proposal is unnecessary, and the intention is already supported with existing RRC.To support this functionality, simply configuring separate reports can also work, e.g.For M=2, and network think 1 certain CRI#x should always be reported;Then we can just configure 1 non-CRI report associated with the resource#x, and 1 single-CRI report associated with the KS-1 resources.**Question 2.A.3**: Not support.We want to remind that PMI FD bases correspond to “delay” components of the precoder, not the measured channel **H****Question 2.A.3**: Support the simpler Alt2**Proposal 2.B**: OK**Proposal 2.D**: OK with CPU and active resource counting.Regarding timeline, we have a slightly different view. While we agree “M” would increase timeline, we think # ports per resource should be more significant; Besides, the increased Ks over legacy may also need to consider.Although a little complicated, we still suggest to consider our proposal by starting from legacy:*Legacy*:

|  |  |  |
| --- | --- | --- |
| **KS** | **Maximum # ports per resource** | M |
| 2 | 16 | 1 |
| Up to 8 | 8 |

*Proposed*: Linear scaling with # ports per resource (Q) over legacy, and consider the increased M-1 (multi-CRI over legacy single-CRI):* If Ks = 2:
	+ Z= Q/16 \* Z + (M-1) \* Y, Z’= Q/16 \* Z’ + (M-1) \* Y,
* Else if 2 < Ks <= 8:
	+ Z = Q/8 \* Z + (M-1) \* Y, Z’ = Q/8 \* Z’ + (M-1) \* Y

where Y=2 or 1 symbol should be sufficient. |
| IDC | **Proposal 2.A.2, Proposal 2.B:** Support. |
| Mod V6 | **Revisions to address inputs (including offline)** |
| Ericsson | **Question 2.A.3:**Since this is for hybrid beamforming M=2, the FS basis selection and indication should be independent for each resource. So, we prefer resource-specific FD basis selection and indication.**Question 2.A.4**Fine with Alt 2.**Proposal 2.B**:Ok.**Proposal 2.E**:Not support. |
| NTT DOCOMO | **Question 2.A.3:**Not support.**Question 2.A.4:**We think it is sufficient to support Alt.2.**Proposal 2.B**:OK.**Proposal 2.D**:We think *OCPU = Ks* can be considered at least for Type-I based refinement. |
| OPPO | **Proposal 2.A.1:**Fine.**Proposal 2.A.2:**Regarding the MR selected resources, we don’t think update via DCI is necessary. It would impact the scheduling flexibility considering the trigger state is limited. **Proposal 2.A.3:**Not need for resource-common FD basis. **Proposal 2.A.4:**Prefer Alt.2. **Proposal 2.B:**Fine.**Proposal 2.D:**For Rel-15 single CRI based CSI report, O\_CPU is equal to Ks. For M-CRI based CSI report in Rel-15, The number of CPU is expected to be increase by M-1. Hence, we think Ks + M -1 may be more accurate.  |
| Huawei, HiSilicon | **Proposal 2.A.1/Question 2.A.3:** Given the comparatively high correlation among analog beams as pasted above, we prefer CRI-common RI, differential wideband CQI and common FD basis vectors.**Proposal 2.A.2:** Support.This proposal provides gNB with the ability to serve the UE with its preferred analog beam decided based on traffic requirement and UE distribution, which contributes to create more MU MIMO scheduling opportunities and brings apparent performance gain as pasted above.Regarding the comment raised by QC, ‘simply configuring separate reports can also work’, considering that the UE only support limited number of CSI reports, wasting multiple reports to achieve similar functionality should definitely be avoided, which encumbers the gNB from acquiring sufficient CSI.**Proposal 2.A.3:** Prefer Alt2.**Proposal 2.B:** Not support.As discussed in our contribution, multiple analog beams may partially share similar restricted SD basis vectors regarding inter-cell interference handling under HBF architecture; while they may also have different restricted SD basis vectors regarding intra-cell interference handling given the distinct pairing situation. Taking above analysis into consideration, a two-level CBSR that satisfies the requirement of both inter- and intra-cell interference handling with significant RRC overhead reduction should be considered as below:* First level: CRI-common group-based restriction via $\frac{N\_{1}⋅O\_{1}⋅N\_{2}⋅O\_{2}}{X\_{1}⋅X\_{2}}$-bit bitmap similar to the already agreed CBSR for 128 CSI-RS ports
* Second level: CRI-specific restriction via *X*1·*X*2-bit bitmap for each unrestricted group

**Proposal 2.D**: Not support.At least one possible approach to conduct CRI-based CSI calculation is based on so-called short-cut principle, i.e., the CSI is only completely calculated for the M selected CRIs, and an additional CRI selection procedure is needed. Based on this assumption, we suggest to consider the following timeline/OCPU/active resource counting:For the Rel-19 CRI-based CSI refinement for up to 128 CSI-RS ports:* OCPU = M + 1
* Timeline: Multiply legacy Z/Z’ by a factor of M.
* Active resource counting = KS

**Proposal 2.E:** Generally fine.Since TDD is also an important scenario under HBF architecture, we would like to check with companies whether report quantity *‘cri-RI-CQI’* can be supported as well. |
| Mod V13 | **Revisions per inputs** |

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

Table 3A Summary: issue 3

|  |  |  |
| --- | --- | --- |
| **#** | **Issue** | **Companies’ views** |
| 3.1.1/2 | **[116bis] Agreement**For the Rel-19 aperiodic standalone CJT calibration reporting, the dynamic range and resolution parameters for delay offset reporting Dn,offset, i.e. (AD, MD), are NW-configured via higher-layer (RRC) signalling from the following candidate values:* AD ={0.5CP, 0.75CP, CP, 1.5CP, 2CP, $\frac{1}{4∆f}$, $ \frac{1}{12∆f}$, $\frac{1}{24∆f}$} where CP and $∆f$ denote the length of the cyclic prefix according to the current specifications (for normal CP) within a slot and the SCS, respectively
	+ FFS: Further down-selection of the above candidate values for AD, including the use of a same unit for all supported values
* MD ={32, 64}
	+ FFS: If TDD TX/RX timing misalignment report is supported, whether different set of candidate MD values is needed

…**[116bis] Agreement**For the Rel-19 aperiodic standalone CJT calibration reporting, the dynamic range and resolution parameters for frequency offset reporting FOn, i.e. (AFO, MFO), are NW-configured via higher-layer (RRC) signalling from the following candidate values:* AFO = {0.01ppm, 0.1ppm, 0.2ppm, f, f/2, f/4,f/8, 1/(4t), 1/(8t), 1/(16t), 1/(32t), 1/(512t)} where f and t denote the SCS and duration of one OFDM symbol, respectively
	+ FFS: Further down-selection of the above candidate values for AFO, including the use of a same unit for all supported values
* MFO = {16,32}

…**Proposal 3.A.1**: For the Rel-19 aperiodic standalone CJT calibration reporting, regarding the dynamic range for delay offset reporting Dn,offset, i.e. AD, at least support the following values: {0.5CP, CP}* Decide, by RAN1#117, whether any of the following candidate values are supported: {0.75CP, 1.5CP, $\frac{1}{24∆f}$}

**Proposal 3.A.2**: For the Rel-19 aperiodic standalone CJT calibration reporting, regarding the dynamic range for frequency offset reporting FOn, i.e. AFO, at least support the following values: {0.1ppm, 0.2ppm}* Decide, by RAN1#117, whether any of the following candidate values are supported: {0.025ppm, 0.05ppm, 1/(8t), 1/(16t), 1/(32t)}

**FL assessment**: This was discussed OFFLINE [2] and this is the current situation justifying the above proposals

|  |  |  |
| --- | --- | --- |
| **Parameter** | **Value** | **Company view** |
| AD | 0.5CP | Support/fine: Samsung, OPPO, Qualcomm, Apple, Intel, Ericsson, NTT DOCOMO, Fujitsu, NEC, Google, Xiaomi, Sharp, KDDI, Lenovo/MotM, IDC, vivoNot support: ZTE, Nokia/NSB, |
| 0.75CP | Support/fine: Intel, Ericsson, NTT DOCOMO, Xiaomi, Google, NEC, Sharp, KDDI, IDCNot support: ZTE, Nokia/NSB, |
| CP | Support/fine: Samsung, OPPO, Qualcomm, Apple, Intel, Ericsson, NTT DOCOMO, Fujitsu, Google, Xiaomi, NEC, Kyocera, Sharp, KDDI, , Lenovo/MotM, IDCNot support: ZTE, Nokia/NSB, |
| 1.5CP | Support/fine: Samsung, Ericsson, NTT DOCOMO, Fujitsu, NEC, KDDINot support: ZTE, Nokia/NSB, Xiaomi, Google, Sharp, IDC,  |
| 2CP | Support/fine: NEC,Not support: ZTE, Nokia/NSB, Xiaomi, Google, Sharp, KDDI, IDC, vivo,  |
| $$\frac{1}{4∆f}$$ | Support/fine: ZTE, Huawei/HiSi, Nokia/NSB, CATTNot support: Samsung, OPPO, Apple, Intel, Xiaomi, Google, Fujitsu, NEC, Sharp, KDDI, IDC, |
| $$\frac{1}{12∆f}$$ | Support/fine: ZTE, Huawei/HiSi, Nokia/NSB, CATTNot support: Samsung, OPPO, Apple, Intel, Xiaomi, Google, Fujitsu, NEC, Sharp, KDDI, IDC, |
| $$\frac{1}{24∆f}$$ | Support/fine: ZTE, Huawei/HiSi, Qualcomm, Nokia/NSB, vivo, CATTNot support: Samsung, OPPO, Apple, Intel, Xiaomi, Google, Fujitsu, NEC, Sharp, KDDI, IDC, |
| AFO | 0.01ppm | Support/fine: Samsung, Qualcomm, Intel, Ericsson, NTT DOCOMO, Xiaomi, Sharp, IDC, vivo, Not support: ZTE, Huawei/HiSi, Apple, Nokia/NSB, NEC, Kyocera, |
| 0.1ppm (RAN4) | Support/fine: Samsung, OPPO, Qualcomm, Intel, Ericsson, NTT DOCOMO, Fujitsu, Xiaomi, NEC, Kyocera, Sharp, Lenovo/MotM, IDC, vivoNot support: ZTE, Huawei/HiSi, Apple, Nokia/NSB |
| 0.2ppm (RAN4) | Support/fine: Samsung, OPPO, Qualcomm, Intel, Ericsson, NTT DOCOMO, Fujitsu, Xiaomi, NEC, Kyocera, Sharp, Lenovo/MotM, IDC, vivoNot support: ZTE, Huawei/HiSi, Nokia/NSB |
| f | Support/fine:Not support: ZTE, Huawei/HiSi, Intel, Ericsson, Nokia/NSB, Samsung, Xiaomi, Fujitsu, NEC, IDC, vivo,  |
| f/2 | Support/fine: Google,Not support: ZTE. Huawei/HiSi, Intel, Ericsson, Nokia/NSB, Samsung, Xiaomi, Fujitsu, NEC, IDC, vivo,  |
| f/4 | Support/fine: Google,Not support: ZTE, Huawei/HiSi, Intel, Ericsson, Nokia/NSB, Samsung, Xiaomi, Fujitsu, NEC, IDC, vivo,  |
| f/8 | Support/fine: Apple, Google, Not support: ZTE, Huawei/HiSi, Intel, Ericsson, Nokia/NSB, Samsung, Xiaomi, Fujitsu, NEC, IDC, |
| 1/(4t) | Support/fine: Nokia/NSBNot support: Samsung, Apple, Intel, Ericsson, Xiaomi, Fujitsu, NEC, IDC, vivo,  |
| 1/(8t) | Support/fine: ZTE, Huawei/HiSi, CATTNot support: Samsung, Apple, Intel, Ericsson, Xiaomi, Fujitsu, NEC, IDC, |
| 1/(16t) | Support/fine: ZTE, Huawei/HiSi, Nokia/NSB, CATTNot support: Samsung, Apple, Intel, Ericsson, Xiaomi, Fujitsu, IDC, NEC |
| 1/(32t) | Support/fine: ZTE, Huawei/HiSi, Nokia/NSB, CATTNot support: Samsung, Apple, Intel, Ericsson, Xiaomi, Fujitsu, IDC,  |
| 1/(512t) | Support/fine: Qualcomm, Nokia/NSB, NECNot support: Samsung, Apple, Intel, Ericsson, Xiaomi, Fujitsu, IDC, |

 | **3.A.1:****Support/fine**: NTT DOCOMO, Sharp, OPPO, TCL, Sony, KDDI, Lenovo/MotM, IDC, Intel, Samsung, vivo, Xiaomi, NEC, Ericsson, Qualcomm, Google**Not support**: **3.A.2:****Support/fine**: NTT DOCOMO, Sharp, OPPO, TCL, Sony, KDDI, Lenovo/MotM, IDC, Intel, Samsung, vivo, Xiaomi, NEC, Ericsson, Qualcomm, Google**Not support**: Huawei/HiSi |
| 3.2.1 | **[116bis] Agreement**For the Rel-19 aperiodic standalone CJT calibration reporting, given the NTRP configured NZP CSI-RS resources/resource sets and the selected N resources/resource sets, support reporting, in one CSI reporting instance, {n, , n=0, 1, …, N – 1, n≠nref, =0,1,…,-1}, where n, denotes the measured phase offset between the n-th CSI-RS resource/resource set and the reference CSI-RS resource/resource set nref for the -th frequency unit *  =1 is supported
	+ FFS: whether >1 (sub-band reporting) is also supported. For this decision, companies are encouraged to evaluate performance loss without the support of >1 due to phase offset induced by TX-RX timing misalignment.

…**Proposal 3.B.1**: For the Rel-19 aperiodic standalone CJT calibration reporting, when ReportQuantity is ‘cjtc-P’ (DL/UL phase offset), =1 only (agreed in RAN1#116bis) implies that the measured/reported phase offsets {n,, n=0, 1, …, NTRP – 1, n≠nref} are associated with the entire configured CSI reporting band (i.e. ‘wideband’)**FL assessment**: Needed to clarify what =1 means, and set it apart from >1 (including the slope scheme) | **Support/fine:** Huawei/HiSi, Samsung, Ericsson, Google, Nokia/NSB, ZTE, Qualcomm, vivo, MediaTek, OPPO**Not support:**  |
| 3.2.2 | **[116bis] Agreement**For the Rel-19 aperiodic standalone CJT calibration reporting, given the NTRP configured NZP CSI-RS resources/resource sets and the selected N resources/resource sets, support reporting, in one CSI reporting instance, {n, , n=0, 1, …, N – 1, n≠nref, =0,1,…,-1}, where n, denotes the measured phase offset between the n-th CSI-RS resource/resource set and the reference CSI-RS resource/resource set nref for the -th frequency unit *  =1 is supported
	+ FFS: whether >1 (sub-band reporting) is also supported. For this decision, companies are encouraged to evaluate performance loss without the support of >1 due to phase offset induced by TX-RX timing misalignment.

…**Proposal 3.B.2**: For the Rel-19 aperiodic standalone CJT calibration reporting, when ReportQuantity is ‘cjtc-P’ (DL/UL phase offset), decide, by RAN1#117, whether to also support >1 (sub-band reporting) as follows:* A sub-band size is selected from {8,16} PRBs
	+ FFS: Whether the sub-band size is NW-configured via higher-layer (RRC) signalling or selected (hence reported) by the UE
* 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
		- $Γ\_{n}\in \left\{0,\frac{2π}{M\_{Γ}}, ….,\frac{2π(M\_{Φ}-1)}{M\_{Γ}}\right\}$, where $M\_{Γ}\in $ {[32], [64], [128], [256]}
	+ Opt2: = NSB-P, i.e. {(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
		- FFS: Whether restriction on the maximum payload size is needed
	+ Note: For all the above reporting options, the UE performs measurement over the entire configured CSI reporting band

**FL assessment**: This was discussed OFFLINE [2]. This is the current situation:**Support/fine >1**: ZTE (both), Qualcomm (both), CATT, Ericsson (both), NTT DOCOMO (Opt1), Samsung (both), Fujitsu, NEC (Opt1), TCL, Sony (Opt1), KDDI, Lenovo/MotM (Opt2), CMCC (Opt2), NICT (Opt1), Sharp (Opt2), MediaTek (both), Nokia/NSB (both), Huawei/HiSi (both) **Not support >1 (separate D/d+WB PO enough)**: OPPO, Apple, Intel, vivo, Google,  | **Support/fine:** ZTE, Qualcomm, CATT, Ericsson, NTT DOCOMO, Samsung, Fujitsu, NEC, TCL, Sony, KDDI, Lenovo/MotM, OPPO, Apple, Intel, vivo, Google, Nokia/NSB, Huawei/HiSi, CMCC, NICT, Sharp **Not support:**  |
| 3.3.1 | **Proposal 3.C.1**: For the Rel-19 aperiodic standalone CJT calibration reporting, when ReportQuantity is ‘cjtc-P’ (DL/UL phase offset),* For a given phase offset reporting configuration, the UE can be configured (via higher-layer/RRC signaling) with Q associated SRS resource(s) for antenna switching
	+ FFS: The supported value(s) of Q
* The UE antenna port(s) for transmitting the selected/configured port(s) from the associated SRS resource(s) are same as the UE antenna port(s) for receiving the CSI-RS configured for phase offset measurement
	+ For discussion purposes only (not necessarily for specification), the UE antenna port is referred to as the ‘reference UE antenna port’

**FL assessment**: To ensure no additional impairments and phase misalignment occur, the SRS and CSI-RS used for PO measurement should be linked via UE antenna port (since the SRS used here is SRS for AS) | **Support/fine:** Qualcomm, ZTE, CATT, Ericsson, Nokia/NSB, Huawei/HiSi, Samsung, vivo, MediaTek, CATT, Google, IDC, **Not support:** OPPO |
| 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) 1 or more 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: Whether >1 SRS ports can also be selected
* Scheme2. The UE selects 1 or more SRS port(s) out of all the ports across Q resources and includes the selection in the phase offset report
	+ FFS: Whether >1 SRS ports can also be selected

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, [Google]**Not support:** OPPO,  |
| 3.5 | **Proposal 3.E**: For the Rel-19 aperiodic standalone CJT calibration reporting, regarding [timeline,] [OCPU, and] active resource counting, when ReportQuantity is ‘cjtc-P’ (DL/UL phase offset) or cjtc-F’ (frequency offset), fully reuse those from Rel-18 TDCP reporting* [For OCPU, Y denotes the number of reported offset values, i.e. NTRP for each CJT calibration report type]

**FL assessment**: No strong reason to do otherwise | **Support/fine:** Samsung, vivo, ZTE, Xiaomi, NTT DOCOMO, Google (timeline needs more discussion), Qualcomm (OPCU needs discussion), IDC, Ericsson**Not support:**  |
| 3.6 | **[116bis] Agreement**For the Rel-19 aperiodic standalone CJT calibration reporting, an ‘invalid’ quantization state/hypothesis is supported for frequency offset and phase offset CJT calibration reporting* Note: already supported as ‘out-of-range’ for the (Dn,offset, dn) reporting
* FFS (RAN1#117): The need for a condition/event for ‘invalid’ to be specified as a UE procedure e.g. RSRP-based

**Question 3.F**: For the Rel-19 aperiodic standalone CJT calibration reporting, regarding the ‘out of range’ or ‘invalid’ quantization state/hypothesis, please share our view whether a condition/event for such state needs to be specified and, if so, please be specific**Yes (RSRP-based with RRC-configured threshold, e.g. RAN3)**: IDC, CATT, NEC, Google, Nokia/NSB, **No (UE implementation)**: CMCC, KDDI, Qualcomm, Ericsson, OPPO, Huawei/HiSi**Need discussion (need for other metrics? Testing?)**: Samsung**FL assessment**: Please share your views |
| 3.7 | **Proposal 3.G.1**: For the Rel-19 aperiodic standalone CJT calibration reporting, when ReportQuantity is ‘cjtc-Dd’ (Doffset+d), support the following* UE to compensate the delay offset for CSI-RS resources for CJT CSI reporting (e.g. with Rel-18 Type-II CJT codebook)
* Link the report to the CJT CSI reporting (e.g. with Rel-18 Type-II CJT codebook) so that the delay offset values for the transceiver compensation are aligned

**Proposal 3.G.2**: For the Rel-19 aperiodic standalone CJT calibration reporting, when ReportQuantity is ‘cjtc-F’ (frequency offset), support the following:* link the FO report to the CJT CSI reporting (e.g, with Rel-18 Type-II CJT codebook) so that the FO values for both UE and gNB compensation are aligned

**FL assessment**: Please share your views | **3.G.1****Support/fine:** vivo, ZTE, [Apple], Samsung (discuss), Qualcomm (discuss), Ericsson**Not support:** Google, OPPO**3.G.2****Support/fine:** vivo, [Apple], Samsung (discuss), Qualcomm (discuss), Ericsson**Not support:** Google, OPPO |
|  |  |  |

Table 3B LLS/SLS results: issue 3

|  |  |
| --- | --- |
| **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. |
| vivo | 3.1 | SE gain vs maximum payload | It is observed in the result above that when the carrier is 2.2GHz, a frequency error of 0.01 ppm (~ 22Hz) results in a performance loss in the range of 3%, but a frequency error of 0.05 ppm results in a loss of 20% in DU scenarios, which is significant. |
| 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 | 3.6 | Mean cell UPT vs total overhead | A graph with numbers and linesA graph with a line and a chart with numbers1. (b)

Normalized mean cell UPT (a) without RSRP condition on the invalid state and (b) when an RSRP threshold of 9dB is configured as a condition for invalid stateConfiguring an RSRP threshold of 8dB as condition for the invalid state for FO reporting shows average UPT gain of around 5% over not configuring an RSRP threshold. |
| 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. |
|  |  |  |  |

Table 3C Additional inputs: issue 3

|  |  |
| --- | --- |
| **Company** | **Input** |
| Mod V0 | **Please share your inputs on each of the issues and, if applicable, proposals in TABLE 3A** |
| Google | Proposal 3.A.1: SupportProposal 3.A.2: OKProposal 3.B.1: OKProposal 3.B.2: What is the use case for the proposed subband PO report? For both proposals, is it possible for UE to report “invalid” for some subbands?[Mod: Added clarification. The answer is yes]Proposal 3.C.1: OK. One minor editorial comment, in the second bullet, “UE antenna port” should be “UE antenna port(s)”, since whether to use one or multiple ports are still open. [Mod: OK]Proposal 3.C.2 (Issue 3.3.2): One question, if only one or a subset of UE ports are selected/configured, how about the phase offset for other UE ports? [Mod: The proposal doesn’t address the other UE antenna ports. This will be left to UE implementation. We just focus on the UE antenna port(s) used for transmitting SRS and receiving CSI-RS for PO measurement/reporting]Proposal 3.C.2 (Issue 3.5): Support for Ocpu and active resource counting, but the timeline may depend on how we define the condition to report “invalid”. If the “invalid” requires UE to measure SINR/RSRP or something else, more time needs to be considered. In addition, the timeline for PO report also depends on whether UE needs to calculate/compensate the TO/FO.[Mod: OK, we can discuss timeline in later rounds, I put timeline in brackets for now, waiting for the conclusion if event is needed for ‘invalid’]Proposal 3.F: We think the condition could follow what has been defined in RAN4 for the condition to determine one resource is measurable, which are as follows:* RSRP > threshold1
* SINR > threshold2
* Delay offset is between the CSI-RS and the reference CSI-RS the UE has reported is smaller than CP

Proposal 3.G.1/2: Do not support. We think the NW should perform the pre-compensation to transmit the CSI-RS resources. Therefore, the NW can provide the corresponding QCL indication for the CSI-RS resources to tell UE whether pre-compensation has been done or not. Therefore, we propose the followings:**Support the network to indicate the QCL for the CSI-RS resources configured as CMR for CJT CSI based on one of the following schemes:*** **Scheme 1: Independent TCI configuration for each CSI-RS resources (Already supported)**
* **Scheme 2 (DO pre-compensation): Independent TCI configuration for each CSI-RS resources for QCL indication other than delay offset, and configure a common TCI for all the CSI-RS resources for QCL indication for delay offset**
* **Scheme 3 (FO pre-compensation): Independent TCI configuration for each CSI-RS resources for QCL indication other than Doppler shift, and configure a common TCI for all the CSI-RS resources for QCL indication for Doppler shift**

**[Mod: I saw the proposal and already planned to discuss this for later rounds]** |
| Mod V2 | **Minor revision on 3.B.2 and 3.C.2 to address Google’s comments** |
| Samsung | We support the following proposals:* 3.A.1,2; 3.B.1,2; 3.C.1,2; 3.E (it seems FL mislabeled this as 3.C.2 for issue 3.5)

Question 3.F: RSRP is not the only reason a report should be declared invalid. Another reason is interference (then should we also include L1-SINR which would require IMR support?). This is especially complicated for PO reporting since both SRS and CSI-RS are used. L1-RSRP doesn’t reflect the quality of SRS (there is SRS-RSRP as well, should this be included as well?).* Without saying whether this should be supported or not, we think this needs to be discussed further. The main question would be, if there is no event/condition specified, does this affect the system performance? This also needs tob e understood together with RAN4 aspect (e.g. how CJT reporting will be tested in RAN4)

Proposal 3.G.1/2: In general, we are supportive of the direction, but further discussion is needed before we can support the proposals at least on the following issues:* When both CSI-RS (requiring UE-specific CSI-RS) and PDSCH for a UE are compensated, there is no need for an additional spec support since this is NW implementation
* When only PDSCH is delay-compensated (but not CSI-RS), the nature of compensation for PDSCH needs to be clarified. Is it digital or analog?
* For FO (3.G.2), it is clear this can be done. But what type of linkage is needed?
 |
| Qualcomm | **Proposal 3.A.2**: We propose to change the FFS value “~~0.01ppm~~” (our own proposed) to 0.025ppm and 0.05ppmThe reason is, FO does not only comprise XO (clock) frequency drift, but also Doppler due to UE velocity.0.01ppm=2v/c only corresponds to 1.5m/s UE velocity (in a worst case where UE moves from TRP1 towards TRP2) – can work only with walking speed, which may not be very practical.**Proposal 3.B.1**: Support to clarify, and we think this should be the common understanding.**Proposal 3.B.2**: Support both options configurable (sorry to repeat)* Opt1 is beneficial for TDD reciprocity calibration with the method of “CSI-RS precoded by (hUL)\* ” (where phase over frequency is linear due to single delay component: TAE), which should not be precluded (since at least 4 companies propose this method);
* Opt2 can be beneficial for

(1) Another TDD reciprocity calibration method with normal non-precoded CSI-RS (where phase over frequency is not linear, due to multi-path channel propagation), as also suggested by @CATT(2) Hardware calibration (where phase over frequency is not linear due to RF characteristics – also suggested by @CATT)**Proposal 3.C.2**: Support in-principle to reuse legacy TDCPSeems timeline and active resource counting is straight-forward; but seems TDCP CPU is a little complicated – will input more in later Round2/3.**Question 3.F**: No need for RSRP-based.We think this RSRP-based “reliability” design can be standard-transparent, e.g. network just configure UE to report RSRP in another report – which is already supported with existing RRC.Actually, this “invalid” codepoint indeed has a use case: When CMR is not available, instead of dropping the report (as in 5.2.2.5 of 38.214), reporting this “invalid” codepoint would not change the UCI payload size and would prevent from UCI error propagation.**Proposal 3.G.1/2**: Open to discuss the technical perspective, but the design of report linkage looks bad – for example, if we need to also consider Type-II-CJT CQI depending on a recently reported delay/FO, how to define “recent” (or “most recent”, and/or the related timeline)? We think a cleaner design is to report the delay/FO compensation and Rel-18 Type-II-CJT in a single report – which we are in favor, but we also understand it is out of Rel-19 scope |
| IDC | **Proposal 3.A.1, Proposal 3.A.2, Proposal 3.C.1, Proposal 3.C.2** (issues 3.3.2 and 3.5)**:** Support. **Question 3.F:** RSRP is the most straightforward threshold that could be specified, but we are open to further discussing other conditions/event that could be specified (e.g., SINR).  |
| Mod V6 | **Revisions to address inputs** |
| Ericsson | **Proposal 3.E:** Does this proposal apply to only FO and TO reporting? For PO reporting, we don’t use TRS, so not sure if we have to reuse the rules from TDCP for PO reporting.[Mod: Thanks for the good catch]**Question 3.F**Ok to leave this to UE implementation**Proposal 3.G.1:** Support **Proposal 3.G.2:**Support |
| OPPO | **Proposal 3.A.1/3.A.2:** Fine.**Proposal 3.B.1:** Fine.**Proposal 3.C.1/2:** In our understanding, it is not needed to restrict the UE receive antenna to receive the CSI-RS. For example, when only part of antennae are used for SRS antenna switching, UE can still use all receive antennae to improve the accuracy of phase offset estimation. There is no such restriction to PDSCH though reciprocity based PDSCH is also associate with SRS. The association between UL/DL antennae should be ensured at gNB side rather than UE side (since it is UL/DL phase imbalance at gNB side).[Mod: Without this proposal, phase offset measurement will be contaminated by other antenna impairments such as RF mutual coupling due to S12/S21\*, inter-element phase offset, etc. So pPO report will be inaccurate and won’t be useful since UE cannot compensate for them]**Proposal 3.F:** Condition/event is not needed. Out of range can naturally indicate that the value is out of the quantization range or the value is not measured by UE. **Proposal 3.G.1:** Further study is needed. We think gNB compensation could be sufficient. **Proposal 3.G.2:** Further study is needed. We think gNB compensation could be sufficient.  |
| Huawei, HiSilicon | **Proposal 3.A.2:**The range for 0.1ppm, 0.2ppm, 0.01ppm is too small (40~400 Hz for 4GHz carrier), while the range that UE can measure is 1/4∆t (about 3kHz for 15kHz SCS). We support 1/(4∆t), 1/(8t), 1/(16t), 1/(32t) as the range.**Question 3.F:**It can be considered as UE implementation. If a condition is to be considered, then the RSRP gap between two TRPs exceeds a threshold, then the TRP with lower RSRP can be considered as invalid, as in this case the TRP with lower RSRP does not bring much performance gain using CJT. |
| Mod V13 | **Minor revision.** **@OPPO/Wenhong, please check my reply re 3.C.1/2** |

# References

|  |  |  |  |
| --- | --- | --- | --- |
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| 2 | R1-2404107 | Moderator Summary for OFFLINE discussion on Rel-19 CSI enhancements | Moderator (Samsung) |
| 3 | [R1-2403847](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_117/Docs/R1-2403847.zip) | Discussion on Rel-19 Enhancements of CSI | InterDigital, Inc. |
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| 29 | [R1-2405005](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_117/Docs/R1-2405005.zip) | CSI enhancements for large antenna arrays and CJT | Ericsson |
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