**3GPP TSG RAN WG1 #109-e R1-2205423**

**e-Meeting, May 9th – 20th, 2022**

**Agenda item:** 9.1.2

**Source:** Moderator (Samsung)

**Title:** Moderator Summary#4 on Rel-18 CSI enhancements: ROUND 4

**Document for:** Discussion and Decision

## Introduction

The scope given in the Rel-18 NR Evolved MIMO WID [1] pertaining to CSI enhancement is as follows:

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| 1. Study, and if justified, specify CSI reporting enhancement for high/medium UE velocities by exploiting time-domain correlation/Doppler-domain information to assist DL precoding, targeting FR1, as follows:
	* Rel-16/17 Type-II codebook refinement, without modification to the spatial and frequency domain basis
	* UE reporting of time-domain channel properties measured via CSI-RS for tracking
2. Study, and if justified, specify enhancements of CSI acquisition for Coherent-JT targeting FR1 and up to 4 TRPs, assuming ideal backhaul and synchronization as well as the same number of antenna ports across TRPs, as follows:
	1. Rel-16/17 Type-II codebook refinement for CJT mTRP targeting FDD and its associated CSI reporting, taking into account throughput-overhead trade-off
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## Summary of companies’ views

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

Table 1A Summary: issue 1

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| **#** | **Issue** | **Companies’ views** |
| 1.3 | Work scope: Rel-16/17 Type-II codebook/PMI components to be refined or reused for CJT extension1. SD and FD basis vector designs (not precluding adding new values of N1, N2, N3)
2. SD and FD basis selection schemes (not precluding per-TRP or joint-across-TRPs selection, this refers to, e.g. the combinatorial indication and two-step FD basis selection)
3. W2 coefficient quantization scheme
4. Non-zero coefficient selection and indication schemes
5. Strongest coefficient indication scheme
6. Supported parameter combinations (keeping same set of parameters, whether the legacy values are fully reused or possibly refined for, e.g. further overhead reduction) and parameter values (including, e.g. R, K0)
7. Per layer feedback

**FL Note**: Considering work scope and continuity with legacy design (some already being deployed), we should strive for maximum reuse of legacy designs. Although one may claim that evaluation is needed to ensure whether reusing as such results in desirable performance, the above parameters are primarily “format” issue. | **1 (SD/FD basis design):*** **Fully reuse legacy:** Huawei/HiSi (for R17), Lenovo, Samsung, Apple, DOCOMO, NEC, vivo, CMCC, Nokia/NSB, IDC, Fraunhofer IIS/Fraunhofer HHI, Intel, MTK, CATT, ZTE, CEWiT, IITK, Ericsson, Qualcomm, Xiaomi, AT&T, Sony
* **Refinement:** Huawei/HiSi (Joint SD-FD eigen-vector basis for R16)

**2 (SD/FD basis selection scheme):*** **Fully reuse legacy:** Samsung, Nokia/NSB, Apple, NEC, vivo, CMCC, IDC, ZTE, CEWiT, IITK, Ericsson, Xiaomi, AT&T, Sony
* **Refinement:** vivo (per TRP SD basis selection)

**3 (W2 quantization):*** **Fully reuse legacy:** Samsung, Apple, vivo, CMCC, Nokia/NSB (re. co-scaling, both reference amplitudes may need reporting for TRPs other than the strongest), Intel (same as Nokia), CATT, ZTE, CEWiT, IITK, Ericsson, AT&T
* **Refinement:** Xiaomi (TRP specific phase and amplitude)

**4 (NZC):*** **Fully reuse legacy:**
* **Refinement:** Huawei/HiSi (joint across TRPs), Lenovo, vivo (joint across selected TRPs), CMCC, CATT, ZTE (further study the bitmap is for each TRP or N TRPs, the maximal number of non-zero coefficients may be per TRP per layer), Spreadtrum, AT&T

**5 (SCI):*** **Fully reuse legacy:**
* **Refinement:** Huawei/HiSi (joint across TRPs), Samsung (strongest TRP), Nokia/NSB (FD basis ref), ZTE (FD basis ref), NEC (we also support strongest TRP indication), vivo (joint across TRPs), CMCC, IDC, CEWiT, Spreadtrum, IITK, Ericsson, Xiaomi (reference TRP), AT&T, Sony

**6 (Parameter combination):*** **Fully reuse legacy:**
* **Refinement:** Samsung, ZTE, Huawei/HiSi (R values), Lenovo,NEC (we also support R values), vivo (need evaluation), CMCC, Nokia/NSB, IDC, Fraunhofer IIS/Fraunhofer HHI, MTK, CATT, Ericsson, AT&T

**7 (Per layer feedback):*** **Fully reuse legacy:** Samsung, DOCOMO, vivo, CMCC, Nokia/NSB, Fraunhofer IIS/Fraunhofer HHI, CEWiT, IITK, Ericsson, Xiaomi, AT&T
* **Refinement:** Huawei/HiSi (receiver side information by per-RX feedback), ZTE
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**Proposal 1.E.1**: On the Type-II codebook refinement for CJT mTRP, the resulting codebook(s) are associated with *at least* the following parameters:

* + Parameters for basis reporting, including
		- The number of basis vectors: gNB-configured via higher-layer signaling
			* FFS: Whether it is per layer or layer-specific
		- Basis selection indicator(s): a part of CSI report
		- FFS: whether it is per TRP/TRP-group or common for all TRPs
		- Note: Basis vectors comprise SD+FD (separately, analogous to Rel-16/17) or joint-SD/FD (e.g. DFT or eigenvector) depending on the down-selected codebook structure
	+ Quantized combining coefficients (W2): a part of CSI report
		- FFS: details of quantization scheme
	+ Number of non-zero coefficients and bitmap to indicate non-zero coefficients, including whether it is per TRP/TRP-group (separate) or common for all TRPs/TRP-groups (joint): a part of CSI report
	+ Strongest coefficient indicator(s) (SCI(s)): a part of CSI report
		- FFS: One per TRP/TRP-group or common for all TRPs
		- FFS: Additional need for strongest TRP indicator

**Proposal 1.E.2**: For the Type-II codebook refinement for CJT mTRP, further study the following issues:

* The need for the following additional parameters:
	+ Receiver side information by per RX reporting or per layer, e.g. information related to the left singular matrix U of the channel
	+ For codebooks with per-TRP SD and joint FD basis (structure Alt2), indication of relative offset of reference FD basis across allTRPs
	+ Information related to the windows for FD basis
* Specification entity corresponding to a TRP (e.g. port-group, NZP CSI-RS resource)
* For codebooks with per-TRP SD/FD basis (structure Alt1A/1B), whether to support co-amplitude/phase as a part of CSI report (explicit) or not (implicit)
* Whether polarization-specific reference amplitudes and differential amplitudes are per TRP or across all TRPs, including:
	+ Whether reference amplitudes for both polarizations need reporting
	+ The number of reference amplitudes in relation to the number of cooperating TRPs
* Whether/how supported parameter combinations are refined from Rel-16/17

**Proposal 1.F**: On the Type-II codebook refinement for CJT mTRP, down-select from the following TRP selection/determination schemes (where N is the number of cooperating TRPs assumed in PMI reporting):

* + Alt1. N is gNB-configured via higher-layer (RRC) signaling
		- The N configured TRPs are gNB-configured via higher-layer (RRC) signaling
		- In this case, N = NTRP
	+ Alt2. N is UE-selected and reported as a part of CSI report where N$\in ${1,..., NTRP}
		- NTRP is the maximum number of cooperating TRPs configured by gNB
		- In this case, the selection of N out of NTRP TRPs is also reported (FFS: whether by using the SD basis indicators, CRI, a new indicator, or via an implicit mechanism)
		- FFS: Configuration of NTRP TRPs and the value of NTRP, whether explicit or implicit
		- FFS: In addition to one transmission hypothesis, whether reporting multiple transmission hypotheses (with the same N value or possibly different N values) is supported
	+ Alt3. The UE reports CSI corresponding to K transmission hypotheses, where 1< K ≤ 2N-1
		- The N configured TRPs are gNB-configured via higher-layer (RRC) signaling
		- In this case, N = NTRP
		- FFS: whether the K selected hypotheses are indicated via a combinatorial value or a bitmap

FFS: Specification entity corresponding to a TRP (e.g. port-group, NZP CSI-RS resource)

Table 2 Additional inputs: issue 1

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| **Company** | **Input** |
| Mod V0 | **Share your inputs, if any, on moderator proposals (minor changes from the latest version from Round 3 since we have agreed to support)**  |
| Qualcomm | Proposal 1.EMinor comment on “number of non-zero coefficients and bitmap…” where the bitmap cannot be “common” across TRPs – probably what want to say is separately or jointly indicated[Mod: OK]We’d like to add one note for the FFS co-amplitude/phase* Implicit co-amplitude/phase is not precluded

[Mod: OK]Proposal 1.FWe’d like to add one more option for UE-reported TRP selection in Alt2: “In this case, the selection of N out of NTRP TRPs is also reported (FFS: whether by using the SD basis indicators, or CRI, or with a new indicator, using bitmap or combinatorial)”[Mod: OK] |
| Mod V2 | **Group the FFSs into proposal 1.E.2**  |
| Samsung | Proposal I.E.2* 1st bullet, 2nd subbullet: reference FD basis can be only one (e.g. when Wf is joint). So suggest to delete ‘per TRP’

[Mod: OK]* 4th bullet: We prefer to study number of reference amplitudes (x=2+y), where 0<=y<=2N-2, where N = #cooperating TRPs. For the weaker TRPs, we don’t see the need for reporting 2 reference amplitudes per TRP

[Mod: OK]Proposal 1.F* Alt2, 2nd subbullet: TRP selection can also be indicated implicitly via existing parameters, e.g. amplitude or co-amplitude, K^NZ, bitmap etc. We suggest to add the following: “including implicit reporting using existing Rel16 UCI parameters”

[Mod: OK, added implicit. I don’t see how “existing Rel-16 UCI parameters” can be used since it is unlikely that Rel-18 CSI reporting includes any “existing” Rel-16 UCI parameter. So I didn’t add this.] |
| Lenovo | **Proposal 1.E.1:**We are fine with the proposal structure. Propose adding a sub-bullet under “Quantized combining coefficients”, as follows: **“FFS: quantization scheme details”**[Mod: OK]**Proposal 1.E.2**Support**Proposal 1.F**We prefer adding Alt3 corresponding to multi-hypothesis CSI reporting to maintain consistency with Rel-17 NCJT CSI reporting, as follows:Alt3. The UE reports CSI corresponding to K transmission hypotheses , where 1< K ≤ 2N-1* FFS: whether the K selected hypotheses are indicated via a combinatorial value or a bitmap

[Mod: OK, but check my added 2 bullets since I am sure someone (not FL ☺) will ask how N and N\_TRP are related] |
| Mod V8 | **Proposal 1.E.1 are 1.E.2 are quite stable.** **Some revisions based on inputs** |
| Spreadtrum | **Proposal 1.E.2:** For reference amplitudes, we would like to add one more alternative to consider a single reference amplitude for both polarizations per TRP. The reason is that, if reference amplitudes are per polarization as well as per TRP, there will be up to 8 reference amplitudes (including the strongest one(s)). Considering the tradeoff between performance and overhead, we may consider to adopt either per polarization or per TRP, but not both per polarization and per TRP.* Whether reference amplitudes and differential amplitudes are per TRP or across all TRPs, including:
	+ Whether reference amplitudes are polarization common or polarization specific
	+ Whether all of the reference amplitudes need reporting

The number of reference amplitudes in relation to the number of cooperating TRPs |
| CATT | **Proposal I.F:**We are open to discuss Alt 1,2,3. And we have the similar views as Lenovo that for CSI enhancement for CJT, it is reasonable to maintain consistency with Rel-17 NCJT CSI. Thus, extensions based on the R17 CSI NCJT framework can be at least discussed, e.g. multi-hypothesis CSI reporting, TRP-groups ports/resources and the pair indication for MTRP measurement hypothesis.We have two comments for the last proposal 1.F.1. Based the current proposal, since NTRP is a condition for both alternatives, we suggest to list ‘the FFS: Configuration of NTRP TRPs and the value of NTRP’ separately, not only for Alt 2.
2. Re the new Alt 3, we support to study reporting multiple hypothesis in principle. In our understanding, K should be small than N+1 because UE can report N CSIs for S-TRP and one CSI for CJT when N = NTRP for multiple hypothesis, similar like Rel-17 NCJT. In this case, the enhancement of reporting multiple hypothesis could be included in Alt 1. But when K is small and equal than 2N-1 for Alt 3, UE might report multiple CJT hypothesis, e.g. UE can report N CSIs for S-TRP and multiple CSIs for 2-TRP CJT, 3-TRP CJT and 4-TRP CJT for example NTRP=4, currently the case of N = NTRP is inaccurate and multiple N should be defined which is also regraded as UE-selected.

Based our understanding, the following updated proposal is suggested:**Proposal 1.F**: On the Type-II codebook refinement for CJT mTRP, down-select from the following TRP selection/determination schemes (where N is the number of cooperating TRPs assumed in PMI reporting):* + Alt1. N is gNB-configured via higher-layer (RRC) signaling
		- The N configured TRPs are gNB-configured via higher-layer (RRC) signaling
		- In this case, N = NTRP
		- FFS: In addition to one transmission hypothesis, whether reporting multiple transmission hypotheses (with the same N value or possibly different N values) is supported
	+ Alt2. N is UE-selected and reported as a part of CSI report where N$\in ${1,..., NTRP}
		- NTRP is the maximum number of cooperating TRPs configured by gNB
		- In this case, the selection of N out of NTRP TRPs is also reported (FFS: whether by using the SD basis indicators, CRI, a new indicator, or via an implicit mechanism)
		- ~~FFS: Configuration of N~~~~TRP~~ ~~TRPs and the value of N~~~~TRP~~~~, whether explicit or implicit~~
		- FFS: In addition to one transmission hypothesis, whether reporting multiple transmission hypotheses (with the same N value or possibly different N values) is supported
	+ ~~Alt3. The UE reports CSI corresponding to K transmission hypotheses, where 1< K ≤ 2N-1~~
		- ~~The N configured TRPs are gNB-configured via higher-layer (RRC) signaling~~
		- ~~In this case, N = N~~~~TRP~~
		- ~~FFS: whether the K selected hypotheses are indicated via a combinatorial value or a bitmap~~

FFS: Configuration of NTRP TRPs and the value of NTRP, whether explicit or implicitFFS: Specification entity corresponding to a TRP (e.g. port-group, NZP CSI-RS resource) |
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### Issue 2: Type-II codebook refinement for high/medium UE velocities (with time/Doppler-domain compression)

Table 3 Summary: issue 2

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| **#** | **Issue** | **Companies’ views** |
| 2.3 | Fundamental time/Doppler-domain compression parameters:1. TD/DD basis vector length N4 (analogous to 2N1N2 and N3)
2. TD compression unit relative to slot length (analogous to the relation between FD compression unit and CQI sub-band, i.e. $p\_{υ}$ for FD compression)
3. The number of selected TD/DD basis vectors (analogous to L and M)
4. …

**FL Note**: While the exact details depend on the waveform (basis design) selection, some fundamental parameters are applicable for any waveform selection | **1 (TD/DD basis length):** Samsung, Nokia/NSB, IDC, Fraunhofer IIS/Fraunhofer HHI, Intel, CEWiT, Ericsson, Qualcomm, Sony**2 (TD compression unit):** Samsung, MTK, Qualcomm**3 (# selected basis vectors):** Samsung, Fraunhofer IIS/Fraunhofer HHI, Apple, Nokia/NSB, IDC, Intel, ZTE, Ericsson, Qualcomm, Sony |
| 2.6 | The use of legacy NZP CSI-RS to facilitate necessary measurements 1. P CSI-RS, e.g. periodicity and offset setting
2. SP CSI-RS, e.g. burst setting
3. AP CSI-RS, e.g. group triggering
4. TRS

**FL Note**: **Companies are encouraged to comment on how to use P/SP/AP CSI-RS for the purpose of CSI calculation involving Type-II with TD/DD compression.** CSI-RS enhancement is out of scope. However, how to use/refine the legacy/current CSI-RS resource setting to facilitate necessary measurements should be discussed as it can affect evaluation and detailed designs. | **P CSI-RS**: LG, MTK, Qualcomm**SP CSI-RS**: Samsung, LG, Lenovo, IDC, Fraunhofer IIS/Fraunhofer HHI, MTK, Qualcomm, Sony**AP CSI-RS**: Samsung**CSI-RS burst for AP and SP (multiple CSI-RS resources/samples):** Huawei/HiSi, Ericsson, CATT, Samsung, Nokia/NSB, DOCOMO (study), CMCC, Futurewei, Fraunhofer IIS/Fraunhofer HHI, Intel, MTK, ZTE, Qualcomm, Xiaomi, Sony**TRS**: CATT, Nokia/NSB (CSI-RS+TRS), vivo (CSI-RS+TRS), IDC, ZTE(CSI-RS+TRS) , CEWiT, Xiaomi, Sony (study) |

**Proposal 2.E.1**: On the Type-II codebook refinement for high/medium velocities, for codebook structures with TD or DD basis (Alt1 or Alt2 from codebook structure agreement), the codebook(s) include *at least* the following *additional* codebook parameters:

* Doppler-/time-domain (DD/TD) basis vector length
* Parameters for DD/TD basis vector selection, including
	+ The number of DD/TD basis vectors (FFS: restrictions on the basis vector selection)
	+ If applicable, Basis selection indicator(s)
	+ If applicable, the total number of available DD/TD basis vectors (not needed orthogonal DFT basis set), whether explicitly or implied from another parameter (e.g. oversampling factor)
* DD/TD (compression) unit relative to slot length (analogous to PMI sub-band for Rel-16 codebook)

**Proposal 2.E.2**: For the Type-II codebook refinement for high/medium velocities, further study the following issues:

* The need for basis type indicator, if both a trivial basis (e.g. identity) and a non-trivial (e.g. DFT) basis are supported, and if so, whether implicit or explicit
* The relation between DD/TD basis vector length (e.g. N4) and the CSI-RS measurement window (W), including whether N4 is within W or can be outside W

**Proposal 2.F**: On potential refinement of Resource setting configuration associated with Type-II codebook refinement for high/medium velocities, study the following options to assess whether/how the legacy Resource setting configuration needs to be enhanced for “burst” measurement:

* Periodic (P) CSI-RS: periodicity and offset
* Semi-persistent (SP) CSI-RS: activation/deactivation, periodicity, and offset
* Aperiodic (AP) CSI-RS: triggering, offset of a group of AP CSI-RS resources

FFS: Support for K>1 NZP CSI-RS resources association with Type-II codebook refinement for high/medium velocities

FFS: Whether specification support for jointly utilizing two types of CSI-RS time-domain behaviors is needed

Table 4 Additional inputs: issue 2

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| --- | --- |
| **Company** | **Input** |
| Mod V0 | **Share your inputs, if any, on moderator proposals (minor changes from the latest version from Round 3 since we have agreed to support)** |
| Qualcomm | Proposal 2.E:It might be misleading to say the TD compression unit analogous to R for Rel-16 eType-II. R is named “*numberOfPMI-SubbandsPerCQI-Subband*” in spec, and there has been no agreement on the definition of CQI unit in time-domain. Maybe a simpler saying is “analogous to PMI subband in frequency domain”[Mod: OK]One more parameter to be considered: Time-location of the TD codebook, probably including the following two optionsOpt1: Relative to CSI-RS observations (burst);Opt2: Relative to CSI reference resource (Rel-15 reference resource as a starting point)[Mod: Before I include this, is it only for TD basis (Alt1 structure)?] |
| Mod V2 | **Minor revision** |
| Samsung | Proposal 2.E* We suggest to add an FFS.
	+ FFS: the relation b/w TD/DD basis vector length (say N4) and the CSI-RS measurement window (W), e.g. whether N4 is within W or can be outside W

[Mod: OK] |
| Lenovo | **Proposal 2.E:**The current wording of the FFS implies the possibility of toggling between two non-trivial basis types, which is not the intention. Is it possible to clarify this in the FFS, e.g., FFS: The need for basis type indicator ~~(if two types of basis are supported)~~ (to enable switching between a trivial and non-trivial bases), if so, whether implicit or explicit[Mod: OK]**Proposal 2.F:**Support |
| Qualcomm 2 | Re FL’s questionAccording to my understanding, this can apply to both Alt1 and Alt2 codebook structure. Besides, I don’t see the difference b/w $W\_{t}$ in Alt1 and $W\_{d}$ in Alt2 (some companies also pointed out this during Round2/3 discussions), could you please elaborate more on your thought to differentiate them?[Mod: Please check if this is captured in the second bullet of 2.E.2 from Samsung. I am not sure what time location of codebook is.] |
| Mod V8 | **Since the # FFS proposals is growing, I grouped the FFSs into proposal 2.E.2****Overall 2.E.1 and 2.F are stable.** |
| Qualcomm 3 | Thanks for FL’s updates.The FFS bullet 2 in the updated proposal 2.E.2 is aligned with our proposed opt1, which assumes the time-location (let's say starting slot for instance) relative to (e.g. aligned with) the starting CSI-RS slot in W;Our proposed opt2, however, has different definition of time-location based on CSI reference resource, which can be more aligned with the mechanism of legacy releases (since time-location is part of the purpose of defining a reference resource) |
| CATT | **Proposal 2.E.2**:We support the proposal in principle. We think the meaning of the CSI-RS measurement window (W) should be confirmed firstly. |

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

Table 5 Summary: issue 3

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| **#** | **Issue** | **Companies’ views** |
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**Proposal 3.D**: The TRS-based TDCP reporting is down selected from the following alternatives:

* Alt1 (stand-alone): TDCP reporting comprises auxiliary feedback information to enable refinement of CSI reporting configuration, and/or codebook configuration parameters, and/or (to be confirmed in RAN1#110) gNB-side CSI prediction
	+ Aperiodic and periodic reporting are supported
	+ FFS: Whether semi-persistent and/or event-triggered (UE-initiated) reporting are supported
* Alt2 (non-stand-alone): TDCP reporting corresponds to a subset of the UCI parameters associated with Type-II codebook reported by the UE and measured via TRS

Table 6 Additional inputs: issue 3

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| **Company** | **Input** |
| Mod V0 | **Added proposal 3.D using the framework proposed by Lenovo** **Share your inputs, if any, on moderator proposals (minor changes from the latest version from Round 3 since we have agreed to support)** |
| Ericsson | Support proposal 3.D. Our preference is Alt1, but we are ok to down select later. |
| Samsung | We support Alt1. TDCP reporting is beneficial for various use cases. We prefer not to limit it to Type II codebooks only. So, we don’t support Alt2. |
| DOCOMO | We share Samsung’s view. Support Alt 1.  |
| Lenovo | Agree with the proposal wording, down-selection/refinement of alternatives can be discussed later |
| Mod V8 | **Proposal 3.D is stable** |
| CATT | Support the FL’s proposal. In this stage, we are open to discuss both alternatives.  |