**3GPP TSG RAN WG1 #112bis-e R1-230xxxx**

**e-Meeting, April 17th – April 26th, 2023**

**Agenda item:** 9.1.2

**Source:** Moderator (Samsung)

**Title:** Moderator Summary#4 on Rel-18 CSI enhancements: Round 3

**Document for:** Discussion and Decision

## Introduction

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

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

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

Table 1A Summary: issue 1

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| **#** | **Issue** | **Companies’ views** |
| 1.1 | [110bis-e] **Agreement**On the Type-II codebook refinement for CJT mTRP, regarding W2 quantization group, for each layer:* Support the following: (Alt1) One group comprises one polarization across all N CSI-RS resources (*C*group,phase=1, *C*group,amp=2)
	+ FFS: Amplitude quantization table enhancement
	+ For the amplitude group other than the group associated with the SCI, the reference amplitude is reported
* Working assumption: Alt3 is supported in addition to Alt1 (to be confirmed in RAN1#111)
	+ (Alt3). One group comprises one polarization for one CSI-RS resource with a common phase reference across N CSI-RS resources (Cgroup,phase=1, Cgroup,amp=2N)
		- For each of the (2N–1) amplitude groups (other than the group associated with the SCI), the reference amplitude is reported
* If the support Alt3 in addition to Alt1 is confirmed, only one of the two schemes will be a basic feature for UEs supporting Rel-18 Type-II CJT codebook

**Proposal 1.A.1**: On the Type-II codebook refinement for CJT mTRP, *revert* the following working assumption: * Working assumption: Alt3 is supported in addition to Alt1 (to be confirmed in RAN1#111)
	+ (Alt3). One group comprises one polarization for one CSI-RS resource with a common phase reference across N CSI-RS resources (Cgroup,phase=1, Cgroup,amp=2N)
		- For each of the (2N–1) amplitude groups (other than the group associated with the SCI), the reference amplitude is reported

**FL Note**: Just as what we did in RAN1#110bis-e, this has to be decided based on empirical evidence (i.e. SLS results). Per agreement this needs to be concluded in this meeting. Since the WA was made conditioned upon the benefit of Alt3 over Alt1* If there is no confirmed benefit from Alt3 over Alt1 in the alleged scenarios (inter-site CJT, 500m ISD), the WA should be **reverted** (hence no support of Alt3).
* Otherwise, **confirmed** as an agreement.

The available SLS results are summarized as follows for the alleged “missing” scenarios from Alt3 proponents in RAN1#110bis-e (500m ISD or larger, inter-site CJT):* “Notable” (small in FL perspective) gain: Huawei (2-3% mean UPT), ZTE (0.2-1.2% mean UPT)
* No demonstrable gain: Samsung, vivo
 | **Support/fine (want to revert WA):** vivo, Samsung, OPPO, MediaTek, Fraunhofer IIS/HHI, Apple, DOCOMO, Intel, Nokia/NSB, Ericsson, Sharp, Google, Sony, AT&T**Not support (want to confirm WA)**: ZTE, Spreadtrum, CATT, LG, Huawei/HiSi, Lenovo/MotM, Fujitsu, NEC, Xiaomi,  |
| 1.5 | [112] **Agreement**On the Type-II codebook refinement for CJT mTRP, regarding UCI omission, support reusing the legacy UCI omission mechanism while (Alt3) replacing SD basis index *l* in legacy Prio calculation with $\sum\_{k=0}^{n-1}2L\_{k}+l\_{n}$, i.e., SD basis index over all resources: Prio(,l,m,n) = 2Ltot.RI.P(m)+ RI.$\sum\_{k=0}^{n-1}2L\_{k}$+RI.l(n)+ * FFS: FD permutation P(.) as Rel-16-analogous, or no permutation i.e. P(m)=m

**Question 1.5:** Please share your view on FD permutation P(.)* Alt1. P(m) fully reusing legacy (Rel-16 eType-II)
* Alt2. P(m)=m

**FL Note**:  | **Alt1 (legacy P):** ZTE**Alt2 (P=m):** MediaTek, Qualcomm**,**  |

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

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| **Company** | **SLS results** |
| **Issue #** | **Metric** | **Observation** |
| Huawei/HiSi | 1.1 | Mean UPT gain vs overhead | Observation 9: For inter-site CJT with large inter-site distance, Alt 3 (Cgroup,amp=2N) has better performance compared to Alt1 (Cgroup,amp=2). |
| ZTE | 1.1 | Avg UPT gain vs overhead,5% UPT gain vs overhead | We observe that 0.2%~1.2% average UPT gain and 2.2%~12.1% cell-edge UE gain can be achieved using Alt 3 compared with Alt1. |
| Vivo | 1.1 | SE gain vs overhead | Alt3 shows negligible performance improvement over Alt1 for the scenario with 500m ISD and the high payload case of the scenario with 200m ISD.Combining the payload and the SE gain, Alt1 outperforms Alt 3. |
| Samsung | 1.1 | Average UPT gain vs overhead | There is no benefit of Alt3 over Alt1 shown in our SLS results for both mode 1 and mode 2 cases even in the inter-site inter-cell scenarios. |
| MediaTek | 1.1 | Average UPT gain vs different paraComb | We observe that Alt 3 cannot provide consistent performance benefit over Alt 1. Further, the cost of this little performance benefit must be borne by the increased overhead of feeding back multiple reference amplitudes. Therefore, supporting quantization Alt 3 is not necessary. |

Table 2 Additional inputs: issue 1

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| **Company** | **Input** |
| Mod V0 | **Please share your inputs on each of the issues and, if applicable, proposals in TABLE 1A** |
| Qualcomm | Alt2: P(m)=mWe could understand reusing Rel-16 may be more natural in a first thought. But for CJT, different TRPs may have its own “local” strongest FD index (different than e.g. FD index 0 of the reference/first TRP $\tilde{n}$), which diminishes the meaningfulness of permutation $\left[0,N\_{3}-1,1,N\_{3}-2,2,…\right]$Besides, UCI omission is just a small/corner issue and does not deserve such over-optimization |
| vivo | **Question 1.5**Alt 1.We support to reuse legacy P(m) as the whole intention of UCI omission Alt 3 is to reuse legacy Pri as much as possible.Further, based on our evaluation results below, the have FD permutation provides clear performance gain (around 5%) over no permutation. Note in our evaluation, all UEs in a cell omit half of the non-zero coefficients following the current agreement for UCI omission.Therefore, to reuse legacy is clearly more beneficial than no permutation. We don’t see any reason not to reuse legacy. |
| ZTE | We support Alt1 (legacy solution). |

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

Table 3A Summary: issue 2

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| **#** | **Issue** | **Companies’ views** |
| 2.3 | **{Placeholder for PC for Rel-17 based}** |  |
| 2.5 | [112bis-e] **Agreement**On the Type-II codebook refinement for high/medium velocities, regarding UCI omission* When X=2 is configured, the 2nd TD CQI location reuses the legacy rule for the 2nd codeword CQI when RI>4, i.e. wideband CQI in G0, even-indexed sub-band CQIs in G1, odd-indexed sub-band CQIs in G2
* FFS: When the configured value of N4 is >1, whether the DD basis selection indicator is placed in G0 or G1

**Question 2.5:** Please share your view on the location of DDBI when N4>1* Alt1. G0
* Alt2. G1

**FL Note**:  | **Alt1 (DDBI in G0):****Alt2 (DDBI in G1):** |

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

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| **Company** | **SLS results** |
| **Issue #** | **Metric** | **Observation** |
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Table 4 Additional inputs: issue 2

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| **Company** | **Input** |
| Mod V0 | **Please share your inputs on each of the issues and, if applicable, proposals in TABLE 3A** |
| Qualcomm | Alt2: G1 |
| vivo | **Question 2.5**G1. SD basis is in G0, and FD basis is in G1. G0 has higher priority than G1 in UCI mapping and omission. Based on previous discussion on UCI omission, DD basis shouldn’t have higher priority than FD basis. |
| ZTE | We support Alt2. |

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

Table 5A Summary: issue 3

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| **#** | **Issue** | **Companies’ views** |
| 3.1 | [112bis-e] **Agreement** For the Rel-18 TRS-based TDCP reporting, for TDCP measurement and calculation, * KTRS ≥1 TRS resource set(s) can be configured in the CSI reporting setting when ReportQuantity is ‘tdcp’
	+ Note: the TRS resource set(s) configured for TDCP report do not impact or impose any new requirements on the UE behavior when processing TRS used as QCL type A/D source for reception of PDxCH.
* No further spec enhancement on TRS is supported
* All the TRS resources in the configured resource set(s) share the same RE locations
* FFS: Whether to add further restrictions on the TRS resource set(s) on, e.g. QCL relationship, power control, slot offset between TRS resource set(s), relation with resource set used for legacy usage

**Proposal 2.A.3**: For the Rel-18 TRS-based TDCP reporting, for TDCP measurement and calculation, at least the following restrictions are supported:* When all the configured KTRS resource sets are periodic, all the resource sets share a same QCL-Type-A/C and, if applicable, Type-D source
* When (KTRS – 1) of the KTRS configured resource sets are aperiodic, all the resource sets share a same QCL-Type-A and, if applicable, Type-D source as the first periodic TRS resource set

**FL Note**: From Round 2:* Same QCL Type-A and, if applicable, Type-D for K\_TRS resource sets: ZTE
* Either the QCL-TypeA/D source of resources in KTRS-1 resource set(s) is the first set (if the first set is P-TRS), or, the QCL-TypeA/D source of resources in all KTRS resource set(s) is the same (if the first set is AP-TRS): Qualcomm, [ZTE, NEC, Ericsson]
* Same (type-C/D) QCL source for all periodic $K\_{TRS}$ and same (type-A/D) P-TRS QCL source for all $K\_{TRS}-1$ AP-TRS”: Nokia/NSB
 | **Proposal 2.A.3:*** **Support/fine:**
* **Not support:**
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| 3.2 | **Proposal 3.B.3**: For the Rel-18 TRS-based TDCP reporting, regarding phase quantization, down-select (by RAN1#113) from the following candidates:* Alt1. 1-bit (early vs. late) phase indicator
* Alt2. 3-bit (8-PSK) uniform quantization
* Alt3. 4-bit (16-PSK) uniform quantization (full reuse of Rel-16 eType-II W2 phase quantization)
* Alt4. Adaptive/gNB-configurable phase quantizer e.g. based on some combination of Alt1/2/3, based on amplitude or additional sign indicator in TDCP report, $e^{\frac{j2πn}{k×2^{N}}}$ where parameter $k$ controls the adaptation
* Alt5. A given correlation phase value $θ(D)$ is quantized to $\hat{θ}(D)$ based on the following alphabet (where $D$ denotes delay):
	+ $\hat{θ}(D)\in \left\{2^{-(N-q)∙s} ∙π, q=0,1,2,…, 2^{Q}-1\right\}$,
	+ When $θ\left(D+ε\right)<θ\left(D\right)$: $\hat{θ}(D)\in \left\{-2^{-(N-q)∙s} ∙π, q=0,1,2,…, 2^{Q}-2\right\}$,
	+ When $θ\left(D+ε\right)=θ\left(D\right)$: $\hat{θ}\left(D\right)=0$
* Alt6. A given correlation phase value $θ(D)$ is quantized to $\hat{θ}(D)$ based on the following alphabet (where $D$ denotes delay and p(.) denotes amplitude quantization values used for Rel-16 e-TypeII codebook):
	+ When $θ\left(D+ε\right)\geq θ\left(D\right)$: $\hat{θ}(D)\in \left\{p(q)^{2}∙2π, q=0,1,2,…, 2^{Q}-1\right\}$,
	+ When $θ\left(D+ε\right)<θ\left(D\right)$: $\hat{θ}(D)\in \left\{\left(1-p(q)^{2}\right)∙2π, q=0,1,2,…, 2^{Q}-1\right\}$

The evaluation should consider the impact of delay tracking operation at the UE where the phase difference between two slots can be close to zero.**Question 3.2: The text for Alts 1 to 4 is stable. Please check the text for Alt5 and Alt6****FL Note**:  | **Proposal 3.B.3:*** **Support/fine:** Samsung, Xiaomi, OPPO, Qualcomm, vivo, Fujitsu, NTT DOCOMO, ZTE, Lenovo/MotM, Ericsson
* **Not support:**
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Table 5B TDCP: summary of observation from simulation

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| **Company** | **SLS results** |
| **Issue #** | **Metric** | **Observation** |
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Table 6 Additional inputs: issue 3

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| **Company** | **Input** |
| Mod V0 | **Please share your inputs on each of the issues and, if applicable, proposals in TABLE 5A** |
| Qualcomm | **Proposal 2.A.3**: We suggest to:1. KTRS-1 resource sets, whether P or AP, not defined as TRS (why bother to name them TRS since agreement says they are not intended for loop tracking, they can be treated similar as CSI-RS, but only single-port and freq-density 3) – thus their QCL-TypeA source can’t be SSB, and can be the (1st) resource set: TRS
2. Leave the case of P+AP resources FFS to RAN1#113

Therefore, two editorial suggestions:

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| **Proposal 2.A.3**: For the Rel-18 TRS-based TDCP reporting, for TDCP measurement and calculation, at least the following restrictions are supported:* When all the configured KTRS resource sets are periodic, all the resource sets share a same QCL-Type-A/C and, if applicable, Type-D source
	+ It does not preclude the QCL source of KTRS-1 resource sets is the first periodic TRS resource set (QCL-source inheritance)
* When (KTRS – 1) of the KTRS configured resource sets are aperiodic, all the resource sets share a same QCL-Type-A and, if applicable, Type-D source as the first periodic TRS resource set
	+ It does not impact whether P-TRS + (KTRS – 1) aperiodic resource set(s) should be supported
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**Proposal 3.B.3**: We’d like to add one note:

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| For this optional UE capability of phase report, it does not preclude UE only supports a limited delay e.g. 4-symbol only |

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| vivo | **Proposal 2.A.3**: It seems the second sub-bullet implies there may be multiple AP TRS sets triggered by a DCI. This is not a TRS mechanism supported in the current specification, and we have agreed no further spec enhancement on TRS is supported. Hence we think it is needed to clarify in the proposal that no more than one AP TRS resource can be triggered in one DCI.We suggest the following revision.For the Rel-18 TRS-based TDCP reporting, for TDCP measurement and calculation, at least the following restrictions are supported:* When all the configured KTRS resource sets are periodic, all the resource sets share a same QCL-Type-A/C and, if applicable, Type-D source
* When *~~(K~~~~TRS~~ ~~– 1)~~ one* of the KTRS configured resource sets *~~are~~ is* aperiodic, all the resource sets share a same QCL-Type-A and, if applicable, Type-D source as the first periodic TRS resource set
* *No more than 1 of the KTRS resource sets is aperiodic*
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| ZTE | **Proposal 2.A.3**: @QC: We have already agreed to use legacy TRS to measure TDCP. Therefore, all KTRS resource sets should be TRS, even with some trimming mechanisms. Besides, for avoiding ambiguities of cross TRS QCL relationship (e.g., between two P-TRS or two AP-TRS) or QCL source RS (i.e., SSB or first TRS), as QC mentioned, we may add a separate bullet as a general assumption in red.**Proposal 2.A.3**: For the Rel-18 TRS-based TDCP reporting, for TDCP measurement and calculation, at least the following restrictions are supported:* When all the configured KTRS resource sets are periodic, all the resource sets share a same QCL-Type-A/C and, if applicable, Type-D source
* When (KTRS – 1) of the KTRS configured resource sets are aperiodic, all the resource sets share a same QCL-Type-A and, if applicable, Type-D source as the first periodic TRS resource set

UE can assume that all TRS resources in KTRS resource sets are QCLed with respect to QCL-Type-A, and if applicable, QCL-Type-D. **Proposal 3.B.3**: To make Alt6 clearer, we prefer the following modification. That is, from spec perspective, we do not need to mentioned condition of “when $θ\left(D+ε\right)\geq θ\left(D\right)$ or not”, besides that indicating which phase quantization mode (i.e., mode-1 corresponds to the first bullet, mode-2 corresponds to the second subbullet) is used by 1-bit indicator.* Alt6. A given correlation phase value $θ(D)$ is quantized to $\hat{θ}(D)$ based on the following alphabet (where $D$ denotes delay and p(.) denotes amplitude quantization values used for Rel-16 e-TypeII codebook):
	+ When $θ\left(D+ε\right)\geq θ\left(D\right)$: $\hat{θ}(D)\in \left\{p(q)^{2}∙2π, q=0,1,2,…, 2^{Q}-1\right\}$,
	+ When $θ\left(D+ε\right)<θ\left(D\right)$: $\hat{θ}(D)\in \left\{\left(1-p(q)^{2}\right)∙2π, q=0,1,2,…, 2^{Q}-1\right\}$
	+ Whether $θ\left(D+ε\right)\geq θ\left(D\right)$ or $θ\left(D+ε\right)<θ\left(D\right)$ is indicated by a 1-bit indicator, the indicator is determined by UE and reported to gNB
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# References