**3GPP TSG RAN WG1 #110bis-e R1-2209714**

**e-Meeting, October 10th – 19th, 2022**

**Agenda item:** 9.1.2

**Source:** Moderator (Samsung)

**Title:** Moderator Summary on Rel-18 CSI enhancements

**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 | [110] **Agreement**On the Type-II codebook refinement for CJT mTRP, down-select from the following TRP selection/determination schemes (where N is the number of cooperating TRPs assumed in PMI reporting) by RAN1#110bis-e:* Alt1. N is gNB-configured via higher-layer (RRC) signalling
	+ The N configured TRPs are gNB-configured via higher-layer (RRC) signalling
	+ Note: only one transmission hypothesis is reported
* Alt2. N is UE-selected and reported as a part of CSI report where N$\in ${1,..., NTRP}
	+ N is the number of cooperating TRPs, while NTRP is the maximum number of cooperating TRPs configured by gNB
	+ In this case, the selection of N out of NTRP TRPs is also reported (FFS: exact reporting scheme)
	+ FFS: Configuration of NTRP TRPs and the value of NTRP, whether explicit or implicit
	+ Note: only one transmission hypothesis is reported. UE is not mandated to calculate CSI for multiple transmission hypotheses.

FFS: Whether S-TRP transmission hypothesis is also reported**FL Note**: Companies have correctly pointed out that ***Alt2 (dynamic TRP selection by UE) can already be implemented in Alt1 using NZC selection (bitmap)* – hence there is no W2 overhead reduction from Alt2 compared to Alt1.**  | **Alt1**: Huawei/HiSi, Google, CMCC, MediaTek, Samsung, AT&T, DOCOMO, Nokia/NSB, **Alt2**: IDC, ZTE, Spreadtrum, vivo, Lenovo, OPPO, LG, CATT, Sony, NEC, Xiaomi, Apple, Ericsson, Qualcomm, CEWiT  |
| 1.2 | [110] **Agreement**On the Type-II codebook refinement for CJT mTRP, regarding W2 quantization group and Strongest Coefficient Indicator (SCI) design, for each layer, down-select one from the following alternatives by RAN1#110bis-e:* Alt1. One group comprises one polarization across all TRPs/TRP-groups (*C*group,phase=1, *C*group,amp=2), one (common) SCI across all TRPs/TRP groups
* Alt2. One group comprises one polarization for one TRP/TRP-group (*C*group,phase=N, *C*group,amp=2N), per-TRP/TRP-group SCI
	+ FFS: Quantization of N strongest coefficients
* Alt3. One group comprises one polarization for one TRP/TRP-group with a common phase reference across TRPs/TRP-groups (*C*group,phase=1, *C*group,amp=2N)
	+ FFS: SCI, per-TRP/TRP-group vs. one (common) SCI across all TRPs/TRP groups
	+ FFS: Quantization of N strongest coefficients
* Alt4. For a selected TRP/TRP-group, one group comprises one polarization, and for remaining N-1 TRPs/TRP-groups, one group comprises one polarization across remaining N-1 TRPs/TRP-groups (*C*group,amp=2+2=4), with a common phase reference across all of N TRPs/TRP-groups (*C*group,phase=1)
	+ FFS: The selected TRP/TRP-group

FFS: The need for “strongest” TRP/TRP-group indicator in addition to SCI(s)**Proposal 1.B**: On the Type-II codebook refinement for CJT mTRP, regarding W2 quantization group and Strongest Coefficient Indicator (SCI) design, for each layer, further down-select one from the following alternatives by RAN1#110bis-e:* Alt1. One group comprises one polarization across all TRPs/TRP-groups (*C*group,phase=1, *C*group,amp=2), one (common) SCI across all N CSI-RS resources
* Alt3. One group comprises one polarization for one TRP/TRP-group with a common phase reference across TRPs/TRP-groups (*C*group,phase=1, *C*group,amp=2N), one (common) SCI across all N CSI-RS resources

FFS: The need for “strongest” TRP/TRP-group indicator in addition to the SCI**FL Note**: Out of the 4 candidates, 2 candidates are supported by most companies. It is proposed to better focus our difficult discussion by comparing the 2 most supported candidates. The need for strongest TRP indicator (issue 1.3) will be decided after this is finalized. | **Alt1:** IDC, vivo, MediaTek, Fraunhofer IIS/HHI, Apple, Samsung (2nd pref), DOCOMO (mode-2)**Alt2:** ZTE, LG, CATT, DOCOMO (mode-1)**Alt3:** * **1 SCI**: Huawei/HiSi, Ericsson, Lenovo, Intel, Xiaomi, NEC, CMCC, AT&T, Qualcomm, Nokia/NSB,
* **N SCIs**: ZTE, Spreadtrum, LG

**Alt4:** Samsung, AT&T |
| 1.3 | **Question**: Is “strongest CSI-RS resource indicator” needed given your preference on issue 1.2 (please also state your preference on issue 1.2)?   | **The need for “strongest CSI-RS resource indicator (along with preference on issue 1.2):*** **Yes:** ZTE, LG, CATT, Samsung, NEC, Xiaomi, CMCC
* **No:** Huawei/HiSi, Ericsson, Nokia/NSB, vivo, MediaTek
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| 1.4 | **Proposal 1.D**: On the Type-II codebook refinement for CJT mTRP, following legacy (Rel-16 regular eType-II and Rel-17 PS FeType-II), for a given CSI-RS resource:* SD basis selection is layer-common and polarization-common, with *L*, *N*1, *N*2, *O*1, *O*2 defined per Rel-16 specification for refinement based on Rel-16 regular eType-II, and per Rel-17 specification for refinement based on Rel-17 PS FeType-II
* FD basis selection is
	+ For refinement based on Rel-16 regular eType-II: per-layer with *M*v, *p*v, *N*3, and *R* defined per Rel-16 specification
	+ For refinement based on Rel-17 PS FeType-II: layer-common with *M*, *N*3, and *R* defined per Rel-17 specification
	+ FFS: Details on FD basis selection window

Note: The supported value(s) for each of the defined parameters are to be discussed separately (e.g. possibilities of adding new or removing existing value(s) in addition to those supported by legacy specification).**FL Note**: This issue/proposal has been discussed OFFLINE [1] as offline proposal 1.1 | **Support/fine:** ZTE, Ericsson, MediaTek, vivo, Qualcomm, DOCOMO, Apple, Google, LG, OPPO, Xiaomi, Intel, Spreadtrum, NEC, Fraunhofer IIS/HHI, Lenovo, Sharp, Samsung, IDC, Sony, CMCC, AT&T, Nokia/NSB**Not support:** |
| 1.5 | **Proposal 1.E**: On the SD basis selection for Type-II codebook refinement for CJT mTRP, following legacy (Rel-16 regular eType-II and Rel-17 PS FeType-II), SD basis selection is per CSI-RS-resource. * Down select from the following alternatives (RAN1#110bis-e):
	+ Alt1. Per-CSI-RS-resource *Ln* parameter
		- TBD: Whether {*Ln*, *n*=1, ..., *N*} are higher-layer configured by gNB, or the total $\sum\_{n=1}^{N}L\_{n}$ is higher-layer configured by gNB while {*Ln*, *n*=1, ..., *N*} are reported by the UE
	+ Alt2. Common *L* parameter for all *N* CSI-RS resources

**FL Note**: This issue/proposal has been discussed OFFLINE [1] as offline proposal 1.2 | **Support/fine:** ZTE, Ericsson, Samsung, MediaTek, vivo, DOCOMO, LG, OPPO, Huawei/HiSi, Intel, Spreadtrum, Apple, NEC, Fraunhofer IIS/HHI, Lenovo, Sharp, Xiaomi, IDC, Sony, vivo, Google, Intel, NEC, Apple, CMCC, AT&T, Nokia/NSB, Qualcomm **Not support:** |
| 1.6 | **Proposal 1.F**: On the Type-II codebook refinement for CJT mTRP, following legacy (Rel-16 regular eType-II and Rel-17 PS FeType-II), regarding the location of non-zero coefficients (NZCs) indicated by bitmap (following legacy mechanism), for each layer, support separate bitmaps for all *N* CSI-RS resources * Total size = $\sum\_{n=1}^{N}B\_{n}$ where $B\_{n}$ is the bitmap size for CSI-RS resource *n*
	+ TBD: Whether $B\_{n}=2L\_{n}M\_{v,n}$ ($M\_{v,n}=M\_{v}$ for mode 2) analogous to legacy, or further reduction of bitmap size is supported.
	+ FFS: Depending on the outcome of other issues, whether $M\_{v,n}=M\_{v}$ or $L\_{n}=L$
* FFS: Per-CSI-RS-resource NNZC (number of NZCs) constraint vs. joint NNZC constraint across *N* CSI-RS-resources

**FL Note**: This issue/proposal has been discussed OFFLINE [1] as offline proposal 1.3 | **Support/fine:** ZTE, Ericsson, MediaTek, Samsung, vivo, Qualcomm, DOCOMO, Apple, Google, LG, OPPO, Huawei/HiSi, Xiaomi, Intel, Spreadtrum, NEC, CATT, Fraunhofer IIS/HHI, IDC, Lenovo, Sharp, IDC, Sony, CMCC, AT&T, Nokia/NSB**Not support:** |
| 1.7 | Constraint on the (maximum) number of NZCs (K0) **for each layer**:* Alt1. K0 is defined per-CSI-RS-resource
* Alt2. K0 is defined jointly across all N CSI-RS resources
 | **Alt1 (per resource):** **Alt2 (joint):** vivo, Intel, Samsung, MediaTek, Fraunhofer IIS/HHI, Qualcomm  |
| 1.8 | **Proposal 1.H**: For the Rel-18 Type-II codebook refinement for CJT mTRP, * Only aperiodic CSI reporting is supported (following legacy Rel-16 and Rel-17 spec)
* An associated Resource Setting includes a CMR comprising *K*>1 NZP CSI-RS resources from one CSI-RS resource set
	+ Periodic, semi-persistent, and aperiodic NZP CSI-RS are supported
	+ The supported CSI-RS resource parameter settings follow the legacy specification (without additional enhancement)
	+ FFS: Whether or not the K NZP CSI-RS resources are constrained to be in the same slot

**FL Note**: This basically follows the legacy spec re Type-II codebook (only A-CSI is supported) and reuses the legacy CSI-RS.The use of K>1 NZP CSI-RS resources has been agreed in RAN1#110 | **Support/fine:** Google, LG, MediaTek, Qualcomm**Not support:**  |
| 1.9 | [110] **Agreement**For the Rel-18 Type-II codebook for CJT mTRP, support the following two modes:* Mode 1: Per-TRP/TRP-group SD/FD basis selection which allows independent FD basis selection across N TRPs / TRP groups. Example formulation (*N* = number of TRPs or TRP groups):

$$\left[\begin{matrix}W\_{1,1}\tilde{W}\_{2,1}W\_{f,1}^{H}\\\vdots \\W\_{1,N}\tilde{W}\_{2,N}W\_{f,N}^{H}\end{matrix}\right]$$* Mode 2: Per-TRP/TRP group (port-group or resource) SD basis selection and joint/common (across *N* TRPs) FD basis selection. Example formulation (*N* = number of TRPs or TRP groups):

$$\left[\begin{matrix}W\_{1,1}\tilde{W}\_{2,1}W\_{f}^{H}\\\vdots \\W\_{1,N}\tilde{W}\_{2,N}W\_{f}^{H}\end{matrix}\right]$$* Striving for the two modes to share commonality in detailed designs such as parameter combinations, basis selection, TRP (group) selection, reference amplitude, W2 quantization schemes.
* FFS: Depending on the decision on SCI design, whether additional per-TRP/TRP-group amplitude scaling and/or co-phase is needed or not, and whether they are a part of W2s

[109-e] **Agreement**For the Type-II codebook refinement for CJT mTRP, further study the following issues:* The need for the following additional parameters:
	+ …
	+ Indication of relative offset of reference FD basis per TRP with respect to a reference TRP
	+ …

Some companies suggest to use per-CSI-RS-resource FD basis offset (relative to a reference CSI-RS resource) for “per-TRP/TRP-group” FD basis selection in mode 1. | **Per-CSI-RS-resource FD basis offset (relative to a reference CSI-RS resource) for “per-TRP/TRP-group” FD basis selection in mode-1:*** **Support/fine**: Huawei/HiSi, ZTE, Xiaomi, Ericsson, Samsung, Fraunhofer IIS/HHI, Qualcomm, Nokia/NSB
* **Not support**:

**For mode-1, the number of FD basis vectors (Mv relared to pv for Rel-16, M for Rel-17) is:*** **TRP-common**: Huawei/HiSi, Samsung, Qualcomm
* **TRP-specific**:

**Switching between mode-1 and mode-2 is gNB-configured via higher-layer signalling:*** **Support/fine**: Xiaomi, Samsung, MediaTek, Qualcomm
* **Not support**:
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| 1.10 | The need for new UCI/PMI-related parameters:[109-e] **Agreement**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
	+ …
	+ Information related to the windows for FD basis
	+ Delay/frequency difference(s) across TRPs

… | **RX side info:** Huawei/HiSi, ZTE, Sony**FD basis window info:** ZTE, Xiaomi, LG**Per-TRP delay/frequency offset:** Fraunhofer IIS/HHI (N-1 relative delay offsets), Ericsson (in a phase form) |
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Table 1B Type II CJT: summary of observation from SLS

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| **Company** | **SLS results** |
| **Issue #** | **Metric** | **Observation** |
| Huawei/HiSi | 1.5 | Mean UPT gain vs overhead, 5%-tile UPT gain vs overhead | TRP-specific $L\_{n}$ has a better performance compared to the TRP-common case, with 5~9% gain for mean UPT and 4~10% for 5% UPT. |
| 1.10 (RX side info) | Mean UPT gain vs overhead, 5%-tile UPT gain vs overhead | The full channel feedback for CJT codebook by per-RX reporting can provide 5~10% gain for mean UPT and 18~35% gain for 5% UPT respectively. |
| 1.4 (on R) | Mean UPT gain vs overhead, 5%-tile UPT gain vs overhead | Performance gain can be achieved when the PMI granularity changes from 4RB to 2RB with R=4, with 5% gain for mean UPT and at 8~11% gain for 5% UPT. |
| ZTE | 1.10 (RX side info) | Avg UPT,50% UPT | Through additionally reporting Rxx information, the reporting of receiving side information can bring a significant performance gain. (9~10% avg UPT gain) |
| vivo | 1.1 | Cell mean SE gain (full-buffer)Overhead reduction ratio  | TRP recommendation (by UE) causes marginal performance loss (1~7% cell-mean SE loss), but it can bring maximum reduction in overhead of about 40% because more than 50% of UEs do not need to measure CSI of all TRPs based on simple TRP selection rules and do not need to report CSI for all TRPs in the measurement set. |
| 1.2 | Cell mean SE gain (full-buffer) | Alt2/Alt3/Alt4 bring negligible performance improvement (1~2%) and Alt1 has minimal payload. |
| 1.7 | Cell mean SE gain (full-buffer) | The TRP-specific beta (TRP-specific NNZC constraint) may reduce the feedback of the coefficients corresponding to the strongest TRP, which leads to a decrease in performance (up to 12% cell-mean SE loss).  |
| 1.4(on R) | Cell-mean, 5%-UE, 95%-UE SE gain (full-buffer) | A limited performance gain (up to 2% cell-mean SE gain) is obtained for a larger R for Indoor Hotspot and Intra-site CoMP(Outdoor2). |
| MediaTek | 1.4 (On M) | Avg UPT gain, statistics of dominant FD bases | Mode 1 and Mode 2 codebook structures achieve nearly same performance in intra-cell mTRP scenarios.For Mode 1 codebook structure, the dominant FD bases computed from FD compression of precoder coefficients are the same for all TRPs. |
| 1.2 | Avg UPT gain | Alt 2 quantization has $N$ SCIs, due to which phase coherence cannot be maintained among different TRP precoders and therefore it yields a poor performance.Alt 3 quantization scheme can give a much better performance than Alt 2 by virtue of having a single-phase reference (single SCI whose amplitude and phase is not reported).Alt 1 and Alt 4 quantization schemes achieve nearly same performance. |
| Samsung | 1.1 | Avg UPT gain vs overhead | 1) UE-based dynamic TRP selection degrades the performance of UPT vs overhead (4% avg. UPT loss) especially in the intra-cell scenario due to unpredictable interference fluctuation, and 2) the gNB-based dynamic TRP selection method outperforms (2~4% avg. UPT gain) the other two methods in both of the intra-/inter-cell scenarios. |
| 1.2 | Avg UPT gain vs overhead | Alt4 (#. Ref Groups for amp = 4) yields the best UPT vs overhead trade-off and 2~4% avg. UPT gain over the other methods, Alt1, 2, and 3. |
| 1.5 | Avg UPT gain vs overhead | Multiple (or different) L values (Alt1) can be beneficial as showing ~5% avg. UPT gain over the same L value case (Alt2). TRP-common SD beam selection (Alt3) yields the worst UPT vs overhead trade-off performance. |
| 1.6 | Avg UPT gain vs overhead | TRP-common bitmap incurs large avg. UPT loss that cannot be compensated for the overhead saving (it turns out 2~3% avg. UPT loss).  |
| 1.4(on new ParaComb) | Avg UPT gain vs overhead | A sufficient performance gain (70% - 100%) can be obtained in a low-overhead regime that is comparable to the overhead of sTRP case, when $L=1$ and/or low values of $p\_{v}$ (e.g., 1/8) are allowed. |
| Qualcomm | 1.4  | Throughput gain, Percentage of # TRPs selected  | Throughput gain of UE-determined Ln over configured Ln are show in Table 2. (average throughput gain 5~24% over configured Ln)It is noted that for smaller value of $L\_{tot}$ (e.g. $L\_{tot}=$3 or 4 with 3-TRP), allowing UE to determine $L\_{n}$ basically means allowing $L\_{n}=0$ reported, thus naturally allow TRP selection. |
| **Summary**:  |

Table 2 Additional inputs: issue 1

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| **Company** | **Input** |
| Mod V0 | 1. **Check and, if needed, update your view in Table 1A especially on the moderator proposals**
2. **Share additional inputs here, if needed**
3. **More moderator proposals may be added in the next revision**
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| vivo | **Issue 1.1**Based on our evaluation in R1-2208628, the overhead saving from Alt 2 can be up to 40% due to the reduction of reporting SD basis, FD basis, coefficients and bitmap associated with the reduced CMR. Further, UE complexity can also be reduced due to UE does not have to further store the temporary CSI values in their buffer. Hence we support Alt 2.We think Alt 1 and Alt 2 can be configured by gNB, which is same as NCJT CSI in Rel-17. gNB can configure a minimum N value to be selected by UE to achieve this.[Mod: It has been pointed out that there is no saving in W2 compared to Alt1 since Alt1 can utilize NZC selection and achieve the same function. To have a more accurate and objective comparison, let’s focus on the correct potential/hypothetical saving, e.g. bitmap size, basis selection indication? If this can be quantified it will help.]**Proposal 1.B**We support Alt 1.* We do not observed clear gain from other Alts in our evaluation in R1-2208628.
* Alt 1 has the smallest overhead.

**Issue 1.3**No need for strongest CSI-RS resource indicator. |
| Mod V2 | **No revision** |
| MediaTek | Regarding Proposal **1.B**, as shown in our contribution R1-2209494 and pointed out by Vivo Alt 1 has better performance compared without increased overhead compared to other down selected Alts. Hence, we support Alt 1.On Proposal **1.E**, we support Alt 1. However, we like to raise our concern regarding UE complexity of selecting and reporting the number of SD beams Ln. Further, from a spatial beam perspective, we think it can create a similar effect of interference fluctuation as TRP selection (i.e., UE selecting a very low value of Ln is equivalent to less spatial interference and vice-versa). We would rather prefer the gNB to configure Ln for each TRP n. Such a gNB configuration extends from the Rel-16 configuration of L.Regarding Proposal **1.H**, we would like to point out based on 38.214 SP CSI is also supported for R16 Type II and R17 FeType II:“Semi-persistent CSI reporting on the PUSCH supports Type I, Type II with wideband, and sub-band frequency granularities, Enhanced Type II and Further Enhanced Type II Port Selection CSI. The PUSCH resources and MCS shall be allocated semi-persistently by an uplink DCI.”However, we are supportive of only supporting AP CSI for CJT enhancements.  |
| Qualcomm | Re 1.1We don’t think Alt2 definitely means smaller overhead than Alt1 – it depends on further design. For example, it is possible that even with less TRPs selected, a same {Ltot, M, K0} can be maintained.But still, we support Alt2 due to evaluation based on nearly same overhead for both Alt1 and Alt2 (same {Ltot, M, K0} ), considerable TPUT gain is observed for Alt2 over Alt1 as in our contribution and FL’s summary listed above (thanks for the concise and accurate capture).Besides, some wording suggestion for Alt2. Since N may be explicit or implicit (depending on further designs on the exact reporting of TRP selection), we suggest to modify the wording of Alt2 as:

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| * Alt2. N is UE-determined ~~selected and reported~~ as a part of CSI report where N$\in ${1,..., NTRP}
 |

Re 1.2Regarding the new proposal 1.B, we want to point out Alt1 may also be a special case of Alt3, i.e. by grouping all TRPs together (thus N=1).Besides, the grouping config can be according to static deployment, which is known by gNBRe 1.5For standard progress, we support current Proposal 1.E (Alt1). Two additional comments: 1. It is noted that under Alt1, the TBD option “{*Ln*, *n*=1, ..., *N*} are reported by the UE” is also relevant to TRP selection (issue 1.1) – depending on whether a certain *Ln*=0 is allowed to report or not.2. Can we leave a note in the agreement like “**tailoring work** specifically for multi-panel deployment can be considered for revisit after PMI reporting mechanisms are stabilized, within Rel-18”?Re 1.8: AgreeFor the FFS (time-constraint of K CSI-RS resources), reuse Rel-17 NCJT can work (i.e. 1 or 2 consecutive slot without DL/UL switch in between the K CSI-RS resources)Besides, also add our preference in some other issues with tracked change. |
| Samsung | Re **Issue** **1.1*** We do not support dynamic TRP selection by UE due to several reasons: 1) the existing feature of NZC selection via bitmap already provides the operation of dynamic TRP selection by UE with a finer granularity, so Alt2 is possible is included in Alt1. 2) In our SLS results, we can’t see any performance gain for dynamic TRP selection by UE even considering the overhead (compared to semi-static gNB-based TRP selection), as we expected due to the unpredictable interference fluctuation. In the worst case, there is no overhead saving with Alt2 over Alt1. 3) The UE complexity with Alt2 is more than Alt1 since the UE has to consier multiple TRP selection hypotheses. 4) Alt2 also adds to gNB complexity due to more involved scheduling across TRPs for different UEs. 5) For MU-MIMO (main use case of Type II), it is desired to group multiple UEs (across TRPs) for MU scheduling. Alt2 makes MU scheduling more challenging.

Re **Proposal 1.B*** Although we still think Alt4 is a superior scheme among Alt1-4, but we can be OK for progress and support Alt 1. In our SLS results, it is shown that Alt3 performs worse than Alt1 from both the overhead and UPT performance perspectives. Also, Alt1 is legacy and the simplest scheme.

Re **Proposal** **1.E*** We support Alt1 with Ln configured by gNB. To simplify parameter combinations on Ln, we prefer that one L is configured, and Ln is determined based on the configured L value.

Issue 1.7: in legacy, we have two constraints: per layer constraint, and constraint on the total number of NZCs across layers. We prefer to clarify this by adding a note.* Note: the constraint on the total number of NZC shall be discussed separately.

**Proposal 1.H**: Support.Issue 1.10: we are supportive of studying the FD basis window for mTRPs, since the FD basis window is there in legacy, and can be beneficial for efficient FD basis/SCI reporting.  |
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### 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** |
| 2.1 | [109-e] **Agreement**The work scope of Type-II codebook refinement for high/medium velocities includes refinement of the following codebooks, based on a common design framework:* Rel-16 eType-II regular codebook
* Rel-17 FeType-II port selection (PS) codebook

FFS: Whether to prioritize/down-select from the two**Proposal 2.A**: The Rel-18 Type-II codebook refinement for high/medium velocities comprises refinement of the following codebooks:* Refinement of the Rel-16 eType-II regular codebook
* Refinement of the Rel-17 FeType-II port selection (PS) codebook, based on the same design details as the Refinement of the Rel-16 eType-II regular codebook, except for the supported set of parameter combinations
	+ Time-/Doppler-domain reciprocity is not assumed

**FL Note**: This proposal has been discussed in RAN1#110  | **Support (equal priority for) both Rel-16 eType-II and Rel-17 FeType-II:** Huawei/HiSi, ZTE (Rel-16 first), Fraunhofer IIS/HHI**Down-select to only Rel-16 eType-II:** Apple, DOCOMO, MediaTek, NEC, Xiaomi, Samsung, Lenovo, Intel (if Rel-17, no DD reciprocity), Xiaomi. Qualcomm, Apple, DOCOMO, Ericsson, Nokia/NSB, LG, Spreadtrum, CMCC, vivo (serious concern on Rel-17)**Proposal 2.A:*** **Support/fine:**
* **Not support (Rel-16 only):**
 |
| 2.2 | Supported RI values**Proposal 2.B**: For the Rel-18 Type-II codebook refinement for high/medium velocities, support RI={1,2,3,4}. | **Support/fine:** Xiaomi, Fraunhofer IIS/HHI, Apple, Samsung, Qualcomm**Not support (1,2 first – 3,4 FFS):** Lenovo, Intel  |
| 2.3 | **Proposal 2.C**: For the Rel-18 Type-II codebook refinement for high/medium velocities, down-select at least one from the following codebooks structures (by RAN1#110bis-e):* Alt1: Doppler-domain orthogonal DFT basis commonly selected for all SD/FD bases reusing the legacy$W\_{1}$and$W\_{f}$*,* e.g.$W\_{1}\tilde{W}\_{2}\left(W\_{f}⨂W\_{d}\right)^{H}$
	+ TBD (by RAN1#110bis): whether rotation is used or not
	+ FFS: identical or different rotation factors for different SD components
* Alt3. Doppler-domain basis is the identity (no Doppler-domain compression) reusing the legacy$W\_{1}$*,* $\tilde{W}\_{2}$*,* and$W\_{f}$*, e.g.* $W\_{1}\tilde{W}\_{2}(W\_{f}⨂I)^{H}$

In addition:* Note: Detailed designs for SD/FD bases including the associated UCI parameters follow the legacy specification
* FFS: Whether one CSI reporting instance includes multiple $W\_{2}$ and a single $W\_{1}$ and $W\_{f}$ report.
* FFS: Whether Doppler-/time-domain (DD/TD) basis vector length (N4) is RRC-configured or reported by the UE
* FFS: Whether the number of selected DD/TD basis vectors (for Alt1) is RRC-configured or reported by the UE

**FL Note**: This issue/proposal has been discussed OFFLINE [1] as offline proposal 2.1 | **Support/fine:** Samsung, ZTE, MediaTek, vivo, Qualcomm, Apple, LG, OPPO, Huawei/HiSi, Xiaomi, Intel, Spreadtrum, DOCOMO, NEC, Fraunhofer IIS/HHI, Lenovo, Sharp, Ericsson, Google, MediaTek, vivo, CATT, IDC, Sony, CMCC, Nokia/NSB, CEWiT **Not support:** |
| 2.4 | **Proposal 2.D**: For the Rel-18 Type-II codebook refinement for high/medium velocities, support the following codebook structure where N4 is gNB-configured via higher-layer signaling:* For N4=[1], Doppler-domain basis is the identity (no Doppler-domain compression) reusing the legacy$W\_{1}$*,* $\tilde{W}\_{2}$*,* and$W\_{f}$*, e.g.* $W\_{1}\tilde{W}\_{2}(W\_{f}⨂I)^{H}$
* For N4>[1], Doppler-domain orthogonal DFT basis commonly selected for all SD/FD bases reusing the legacy$W\_{1}$and$W\_{f}$*,* e.g.$W\_{1}\tilde{W}\_{2}\left(W\_{f}⨂W\_{d}\right)^{H}$
	+ TBD (by RAN1#110bis): whether rotation is used or not
	+ FFS: identical or different rotation factors for different SD components
	+ FFS: Whether the number of selected DD/TD basis vectors (denoted as *Q* at least for discussion purposes)) is RRC-configured or reported by the UE

Note: Detailed designs for SD/FD bases including the associated UCI parameters follow the legacy specificationFFS: Whether one CSI reporting instance includes multiple $W\_{2}$ and a single $W\_{1}$ and $W\_{f}$ report.**FL Note**: This issue/proposal has been discussed OFFLINE [1] as offline proposal 2.2 | **Proposal 1.D:*** **Support/fine:** Samsung, ZTE, Ericsson, Qualcomm, Apple, Google, OPPO, Huawei/HiSi, Intel, Spreadtrum, CATT, DOCOMO, NEC, [Fraunhofer IIS/HHI], Sharp, IDC, vivo, Sony, MediaTek, Nokia/NSB, CEWiT
* **Not support:**

**Rotation factor for DFT basis:*** **No:** Huawei/HiSi, Xiaomi, Ericsson, Qualcomm, MediaTek
* **Yes (details FFS):** Fraunhofer IIS/HHI, ZTE, Samsung
 |
| 2.5 | **Proposal 2.E**: On the CSI reporting and measurement for the Rel-18 Type-II codebook refinement for high/medium velocities, when UE-side prediction is assumed, support UE “predicting” channel/CSI after the slot with a reference resource (*l* ≥ *n*ref) where the location of CSI reference resource is configured (from multiple candidate values) by gNB via higher-layer signalling* Candidates of CSI reference resource location include the legacy slot location (*n* – *nCSI,ref* ) and slot (*n*+*δ*) where *δ* is [gNB-configured via higher-layer signalling from] {0, [2, 4]}
* FFS: Possible value(s) of WCSI

**FL Note**: This issue/proposal has been discussed OFFLINE [1] as offline proposal 2.3 | **Support/fine:** Samsung, vivo, Qualcomm (questionable regarding CQI prediction), DOCOMO, Lenovo, IDC, ZTE, Spreadtrum, vivo, [LG], CATT, Intel, NEC, Xiaomi, CMCC, MediaTek, [Ericsson], [Nokia/NSB] **Not support:** Fraunhofer IIS/HHI (only legacy slot) |
| 2.6 | **Question**: In addition to the already agreed assumption of UE-side prediction, can the Rel-18 Type-II codebook refinement for high/medium velocities be used with the following assumption?1. Legacy UE procedure for CSI measurement/calculation (the only spec impact would be to enable this as an option for CSI measurement/calculation. If proposal 2.E is agreed, the answer to this question is “yes” at least for W\_CSI=1)
2. gNB-side prediction (to be incorporated in the spec, assumed by the UE in CSI measurement/calculation)

**FL Note**: This proposal has been discussed in RAN1#110.  | **Legacy:*** **Yes:** Qualcomm,
* **No:**

**gNB-side prediction (to be specified, assumed by the UE in CSI measurement/calculation):** * **Yes**: Google, CATT, Xiaomi,
* **No**: Samsung, vivo, MediaTek
 |
| 2.7 | CSI-RS resource types/structures **supported** for measurement (discussion on whether/how the legacy Resource setting needs enhancement will take place in later rounds)**Proposal 2.G**: On the CSI reporting and measurement for the Rel-18 Type-II codebook refinement for high/medium velocities, support the following CSI-RS resource types/structures for CMR:* Time-domain behaviour for NZP CSI-RS resource: periodic, semi-persistent, aperiodic
* The use of K≥1 NZP CSI-RS resources:
	+ FFS: details

[109-e] **Agreement**On potential refinement of Resource setting configuration associated with Type-II codebook refinement for high/medium velocities, study the following options to assess whether/how the legacy Resource setting configuration needs to be enhanced for “burst” measurement:* Periodic (P) CSI-RS: periodicity and offset
* Semi-persistent (SP) CSI-RS: activation/deactivation, periodicity, and offset
* Aperiodic (AP) CSI-RS: triggering, offset of a group of AP CSI-RS resources

FFS: Support for K>1 NZP CSI-RS resources association with Type-II codebook refinement for high/medium velocitiesFFS: Whether specification support for jointly utilizing two types of CSI-RS time-domain behaviors is needed**FL Note**: This proposal has been discussed in RAN1#110 | **Proposal 2.G:*** **Support:** Google, Samsung, Nokia/NSB, Lenovo, DOCOMO, MediaTek, Qualcomm, LG, Spreadtrum, ZTE, Xiaomi, NEC, OPPO, CATT, CMCC, Sharp, Apple, Huawei/HiSi, Fraunhofer IIS/HHI
* **Not support:** vivo (concern on AP)
 |
| 2.8 | **Proposal 2.H**: For the Type-II codebook refinement for high/medium velocities, only aperiodic CSI reporting is supported (following legacy Rel-16 and Rel-17 spec)**FL Note**: This basically follows the legacy Rel-16/17 spec re Type-II codebook and reuses the legacy CSI-RS | **Support/fine:** Qualcomm, Samsung**Not support:**  |
| 2.9 | **Proposal 2.I:** For the Type-II codebook refinement for high/medium velocities, the per-layer 2-dimensional bitmap for indicating the location of NZCs used in Rel-16/17 Type-II is extended to a per-layer 3-dimensional bitmap* The third dimension is associated with the number of selected DD basis vectors (denoted as *Q* at least for discussion purposes)
 | **Support/fine:****Not support:** |
| 2.10 | DD basis selection:* Alt1. Per layer,
	+ The number of selected DD basis vector (denoted as *Q*) is layer-common
* Alt2. Layer-common

**FL Note**: The above alternatives are analogous to legacy principle for SD/FD compression.  | **Alt1:** Intel, Qualcomm, Samsung**Alt2:** |
| 2.11 | For one CSI reporting instance associated with the Type-II codebook refinement for high/medium velocities, for a given CQI sub-band and a given layer, how many CQIs (sampled across time-/Doppler-domain) are included?  | **Only 1:** Google, Qualcomm, vivo**≥1 (configurable):** ZTE, NEC, Samsung, Ericsson, Nokia/NSB, Huawei/HiSi |
| 2.12 | [110] **Agreement**For the Rel-18 Type-II codebook refinement for high/medium velocities, support DD/TD (compression) unit (analogous to PMI sub-band for Rel-16 codebook) as a codebook parameter.* FFS: whether this parameter is defined as a function of another parameter
* FFS: whether this is used for PMI only, or PMI/CQI
 | **PMI only:** Huawei/HiSi, ZTE, MediaTek, Qualcomm**PMI and CQI (common vs independent FFS):** Samsung |
|  |  |  |

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

|  |  |
| --- | --- |
| **Company** | **SLS results** |
| **Issue #** | **Metric** | **Observation** |
| Huawei/HiSi | 2.3, 2.4 | SLS: UPT | Observation 7: For R17 FeType II and R16 eTypeII codebook enhancement, Alt2B has no obvious performance gain compared with Alt2A.Observation 8: For R17 FeTypeII and R16 eTypeII codebook enhancement, compared with Alt2A, Alt3 which reports double W2 is worse than Alt 2A with double CSI overhead.Observation 9: For R17 FeType II and R16 eTypeII codebook enhancement, there’s no obvious performance gain between orthogonal DFT without rotation factor, orthogonal DFT with rotation factor and oversampled DFT. |
| ZTE | 2.5, 2.12 | SLS: UPT | Based on the SLS results for high/medium UE velocities in UMa in Figure 5, the distinct average UPT and cell-edge UPT gain can be obtained between CSI prediction scheme (Alt1.B or Alt2.B) and legacy CSI scheme. However, it is not observed that there is a big difference between Alt1.B and Alt2.B. Moreover, we also observe that the variation of CQI is quite slow, which means that the parameter for supporting DD/TD compression unit, described in Agreement#5, can be used for PMI only as a starting point |
| 2.7 | Cross-correlation  | * For periodic CSI-RS configuration, it can be observed in Figure 1 that the periodicity of CSI-RS transmission marked in green is 5 slots. Under 5 measurement samples, cross-correlation from slot n+6 to n+10 between predicted channel (Wiener and extrapolation) and real-time channel can be greater than 0.97, as shown in Figure 3.
* In addition, for aperiodic CSI-RS configuration as shown in Figure 2, it is observed that the cross-correlation from slot n+6 to n+10 between predicted channel and real-time channel is still greater than 0.93, shown in Figure 4.
 |
| Vivo | 2.3, 2.4, 2.5 | SLS: UPT | For UE based CSI prediction performance * + UE based prediction assuming Alt 2B and N4=1 achieves significant performance gain
	+ Smaller N4 brings higher performance gain than larger N4 values
	+ Measurement with 16 CSI-RS occasions has higher performance gain than 8 CSI-RS occasions, especially for medium or large N4 values

We evaluate the performance of DD compression ratio 0.2 and 1 (No compression) for N4=6. The results are given in Table 2. It can be observed that clear performance loss exists. This loss will basically eliminate the gain of CSI prediction for N4=6 as the gain for no compression compared with no prediction is only 4.15% as show in Table 1. |
| OPPO | 2.3, 2.13 | UPT vs overhead | DFT basis outperform identity basis at low overhead, the gain is about 10% for N2=2We show the performance of N4 >= 1 in figure 3. The measurement window is set to {16, 24, 32} ms respectively. There are {4, 6, 8} CSI-RS occasions for time unit 4 slots and {8, 12, 16} CSI-RS occasions for time unit 2 slots. We assumed time unit equals CSI-RS spacing. Frequency-time domain LMMSE is used for channel prediction where covariance is measured from Wmeas. Reporting window size is prediction horizon (from the latest CSI-RS occasion). The overhead for each setting of W\_CSI is about 300 bits, R16 PC6 is the reference. Although the prediction is less reliable as W\_CSI increase, the performance gain is still obvious. Moreover, supporting N4 > 1 could reduce the normalized overhead. At medium velocity, precoder may only hold on in duration of 1~2 ms, supporting N4=1 only may be quite wasteful in terms of CSI-RS and CSI overhead |
| Google | 2.3, 2.4 | Square cosine similarity | When the UE velocity is high and the interval between the CMR instances is large, the performance loss due to the DD/TD domain compression could be big. Figure 2 illustrates the square cosine similarity (SCS) distribution for the CSI with DD/TD domain compression with different number of DD/TD basis, where N4 is assumed as 10, the interval between each CMR instance is 1 ms and the UE velocity is 120 km/h. The SCS is calculated based on the ideal channel eigenvector and the decompressed channel eigenvector for each CMR instance. Figure 3 illustrates the SCS distribution when the UE velocity is 60 km/h. Figure 4 illustrates the SCS distribution when the UE velocity is 10 km/h.It can be observed that the best number of DD/TD basis should be different for different UE velocity. When the UE velocity is too high, the identity matrix can be used. When the UE velocity reduces, DD/TD compression can be used. |
| Intel | 2.3, 2.4 | UPT vs overhead | Observation 1: * PMI codebooks with DFT-based DD compression (Alt. 2A, Alt. 2B) has significantly lower overhead comparing to Alt. 3

Alt. 2A outperforms Alt 2B for most of codebook configurations |
| MediaTek | 2.3, 2.4, 2.5, 2.7 | UPT | * Extrapolation performance degrades as the size of CSI reporting window increases.
* Assuming CSI interpolation, joint CSI calculation for the entire TD unit is more robust than individual CSI calculation for each slot.

Next, we compare the case of using the latest CSI-RS transmission occasion as reference and the case of using the predicted CSI as reference. Specifically, the reference is used to calculate single $W\_{1}, W\_{f}$, RI, and CQI for the entire CSI reporting window. Both cases assume Scheme 3 and the results are shown in Table 2. It can be seen that for the UMa scenario with UE speed 30 km/h, using the predicted CSI as reference provides a better performance. To summarize, from the perspectives of performance and UE complexity, it is worth the specification effort to support that the CSI reporting window starts no earlier than the CSI reporting slot $n$* To enhance the throughput for the case of UMa 60 km/h, reducing CSI-RS periodicity to 2, 3 ms is beneficial.
* Linear prediction does not perform well under CSI-RS burst measurement.
 |
| Fraunhofer IIS/HHI | 2.3, 2.4, 2.13 | UPT | * The performance gain increases with increasing oversampling factor.
* Rotation factor reporting per SD component further reduces the feedback overhead in reporting the selected TD/DD components.
* An oversampling factor of four suffices to provide a significant better performance compared to the baseline.
* Enhanced Type II CB with Doppler domain information outperforms Rel. 16 eType-II CB in terms of both performance and feedback overhead by a large margin
 |
| Samsung | 2.3, 2.4, 2.5, 2.7, 2.11, 2.12 | UPT vs overhead | Observation 13: Alt1 and Alt2 achieve similar performance vs overhead trade-offObservation 14:* Alt1B outperforms Alt2B
* There is an ‘optimal’ $W\_{CSI}$ (predicting beyond this window does not help)
	+ Alt1B with CSI window $[n\_{ref},n+X]$ is the best among the considered CSI windows
	+ In general, the value of $X$ depends on UE speed (cf. Appendix C)

Observation 15: * 2 CQIs can achieve better UPT vs overhead trade-off than one CQI (up to 2% gain in avg. UPT gain)
* The order of the overall UPT vs overhead trend is 2 CQIs > 4 CQIs ~ per slot CQI > 1 CQI

Observation 16: CSI-RS burst separation = 1 slot achieves better UPT vs overhead trade-off than CSI-RS burst separation = 5 slots. |
| Ericsson | 2.3, 2.4, 2.12 | UPT vg overhead | 1. For type II Doppler codebook with a 16Tx2Rx and 60 km/hr scenario, Alt 2 results in a larger overhead compared to Alt1, and Alt 2 only provides some small gains over Alt 1.
2. Alt3 is beneficial for the case where reporting a single predicted PMI results in significant performance improvement
3. For type II Doppler codebook with a 16Tx2Rx and 60 km/hr scenario, when AR prediction is considered, Alt3 with a single predicted PMI provides similar gains as Alt1 and Alt2 but at a much reduced overhead.
4. Performance of Alt1 compared to Alt3 depends on the accuracy of the UE side channel predictor.
5. We find no performance gain in considering DFT TD-bases with a rotation factor

As shown in Figure 14, there are some reductions of the gains compared to Rel-16 when only a single CQI is used instead of $N\_{CQI}$=$N\_{4}$, especially for the cell-edge users and for longer CSI feedback periodicity $T\_{F}$. However, we have also found simulation cases, e.g., 4 RX, with limited gain of using $N\_{CQI}$=$N\_{4}$ compared to $N\_{CQI}$ =1, and thus selecting a good $N\_{CQI}$ value may be scenario dependent |
| Qualcomm | 2.3, 2.4, 2.5 | UPT, overhead | Observation 1: Beam-specific TD basis selection has about 1% TPUT gain over beam-common, at a cost of 7.7% increased overhead.Observation 3: For different CSI window location (starting slot *l*), similar performance is obtained based on a same CSI window length N4. |
| Nokia/NSB | 2.5 | UPT, cosine similarity | In Figure 4, Figure 5, Figure 6, the cosine similarity is compared for each of the two layers, for UE speed of 10, 30 and 60km/h, whilst in Figure 7 and Figure 8, mean and cell-edge throughput are compared, respectively. We observe that the prediction gain of Type-II-Doppler is generally consistent with speed. However, the relatively significant gain observed in cosine similarity does not appear as large in throughput. Also note that the feedback overhead is larger for Type-II-Doppler than for the baseline because two CSIs are sent per report rather than one, although they share the same $W\_{1}$ and $W\_{f}$. |
| **Summary**:  |

Table 4 Additional inputs: issue 2

|  |  |
| --- | --- |
| **Company** | **Input** |
| Mod V0 | 1. **Check and, if needed, update your view in Table 3A, especially on the moderator proposals**
2. **Share additional inputs here, if needed**
3. **More moderator proposals may be added in the next revision**
 |
| vivo | **Proposal 2.A**We don’t agree to further span the scope of 9.1.2 after we have already done so in last meeting. We support to only enhance Rel-16 eType II CSI. We have serious concern to include the work on Rel-17 FeType II CSI due to the workload.**Proposal 2.D**We think the intention of this proposal is to support Alt 3 and Alt 1 based on the configured N4 value. For N4 < the switching point, at least N4 =1 is supported. The detailed value of the switch point can be further studied, for which we propose N4=4. Hence we think a more accurate formulation of the current status is the following.**Proposal 2.D**: For the Rel-18 Type-II codebook refinement for high/medium velocities, support the following codebook structure where N4 is gNB-configured via higher-layer signaling:* For N4<= N0, Doppler-domain basis is the identity (no Doppler-domain compression) reusing the legacy$W\_{1}$*,* $\tilde{W}\_{2}$*,* and$W\_{f}$*, e.g.* $W\_{1}\tilde{W}\_{2}(W\_{f}⨂I)^{H}$
	+ At least N4=1 is supported
* For N4> N0, Doppler-domain orthogonal DFT basis commonly selected for all SD/FD bases reusing the legacy$W\_{1}$and$W\_{f}$*,* e.g.$W\_{1}\tilde{W}\_{2}\left(W\_{f}⨂W\_{d}\right)^{H}$
	+ TBD (by RAN1#110bis): whether rotation is used or not
	+ FFS: identical or different rotation factors for different SD components
	+ FFS: Whether the number of selected DD/TD basis vectors (denoted as *Q* at least for discussion purposes)) is RRC-configured or reported by the UE
* For the switch point N0, support one of the following
	+ Opt 1: N0 = 4
	+ …

Note: Detailed designs for SD/FD bases including the associated UCI parameters follow the legacy specificationFFS: Whether one CSI reporting instance includes multiple $W\_{2}$ and a single $W\_{1}$ and $W\_{f}$ report.[Mod: There are at least 2 companies, e.g. Fraunhofer IIS/HHI, who have serious concern on Alt3 and can only compromise with N4=1 as the switching point. Else, I’d have no choice but to propose the original offline proposal 2.2 which seems to have represented super-majority. Regardless I put “1” in brackets. SO there is no need to revise the formulation per your suggestion since this needs to be discussed anyway,]**Proposal 2.E**Regarding the reference of CSI reporting window in case UE-side prediction is assumed, **it has been agreed in RAN1#109e that it is a length-WCSI window starting from slot l, i.e., it is a window of [*l*, *l*+*W*CSI –1]**. Two alternatives are suggested down selecting in RAN1#110, i.e.,* Alt 1B: **l ≥ n\_ref**, where n\_ref is a CSI reference resource slot as boundary
* Alt 2B: **l ≥ n**, where n is the CSI reporting slot as boundary

It is clear that from the previous agreements, the start of the CSI reporting window is l, and l >= n is defined for Alt 2B. Hence it is clear that Alt 2B includes the case that the start of the CSI reporting window is after slot n. Further, to support the case with N4=1, it only makes sense for UE prediction to have l>n, as gNB needs to know the CSI after the CSI report reception. Hence we suggest the following change.**Proposal 2.E**: On the CSI reporting and measurement for the Rel-18 Type-II codebook refinement for high/medium velocities, when UE-side prediction is assumed, support UE “predicting” channel/CSI after the slot with a reference resource (*l* ≥ *n*ref) where the location of CSI reference resource is configured (from multiple candidate values) by gNB via higher-layer signalling* Candidates of CSI reference resource location include the legacy slot location (*n* – *nCSI,ref* ) and slot *n+ndelta,* where *ndelta* is configured from thenumbers {0, 2, 4}
* FFS: Possible value(s) of WCSI

[Mod: OK, putting the values 2, 4 in brackets for now]**Issue 2.6**We don’t support gNB side prediction. **Proposal 2.G**We still have concern on the supporting AP CSI-RS, due to the following reasons* It introduces large latency for CSI reporting due to triggering a number of CSI-RS occasions after sending the CSI triggering DCI.
* The large CSI latency requires gNB to schedule PUSCH with long duration between DCI and PUSCH. It will forbid gNB to schedule any other PUSCH for this UE due to out of order (OOO) issue during this long duration, which will reduce UL throughput.
* Last but not least, to support AP CSI-RS, RS enhancement is needed as the current specification does not support to use one DCI to trigger AP CSI-RS spanning more than 1 slot. However, RS enhancement is not included in the WID.

Hence we support to have only P/SP CSI-RS with one resource in this proposal.[Mod: Thanks, we can check if other UE vendors share your concern as well]**Issue 2.11**We support only one CQI, which means W\_CSI is 1 or N4 TD units in this case. |
| Mod V2 | **Revised proposals 2.E per vivo input, please check** |
| MediaTek | **Issue 2.4**: We can be fine with Proposal 2.D with brackets. We prefer the identity basis is supported for $N\_{4}=1$, 2.With the same feedback overhead as the agreed baseline in EVM, $N\_{4}=1$ can provide a competitive throughput gain compared with larger $N\_{4}$ values. In addition, NR is designed to be flexible, so the case of $N\_{4}=1$ should be supported. Identity basis should also be supported for $N\_{4}=2$. If Doppler-domain orthogonal DFT basis is commonly selected for all SD/FD bases, then time-domain compression implies gNB only acquires one Doppler component. Recovery from a single Doppler component involves merely phase rotation. As common phase rotation does not change the performance of precoders, gNB might as well double the size of TD unit and set $N\_{4}=1$.As proved by Qualcomm, rotation is not needed to be specified when Doppler-domain orthogonal DFT basis is commonly selected for all SD/FD bases. We remark that rotation can be useful for compression, but it can be absorbed into $W\_{2}$ and thus transparent to gNB.**Issue 2.5**: We support Proposal 2.E in general. We share the same view as vivo that the starting position of CSI reporting window can be configurable, depending on gNB’s processing capability and scheduling. The supported set of values for $δ$ can be FFS.Although we do not prefer to include the legacy slot location ($n-n\_{CSI\\_ref}$), we can make a compromise for making progress. In our understanding, the legacy CSI reference resource, i.e., slot $n-n\_{CSI\\_ref}$, should be reused for locating the last CSI-RS occasion used for a CSI report. In other words, the legacy CSI reference resource is reused for CSI measurement. We prefer to add a note to Proposal 2.E:**Note: The legacy CSI reference resource, i.e., slot** $n-n\_{CSI\\_ref}$**, is reused for locating the last CSI-RS occasion used for a CSI report.****Issue 2.6**: Legacy UE procedure for CSI measurement/calculation can be assumed up to UE implementation, so the answer to the question should have no specification impact. We think the configuration of $l=n-n\_{CSI\\_ref}$ and $W\_{CSI}=1$ is redundant and should be avoided.As for gNB-side prediction, no promising gains are reported by companies, so we prefer not to incorporate gNB-side prediction into specification. If any company would require more time, we are fine to defer the final decision until the next RAN1 meeting.Regarding Proposal **2.H**, we would like to point out based on 38.214 SP CSI is also supported for R16 Type II and R17 FeType II:“Semi-persistent CSI reporting on the PUSCH supports Type I, Type II with wideband, and sub-band frequency granularities, Enhanced Type II and Further Enhanced Type II Port Selection CSI. The PUSCH resources and MCS shall be allocated semi-persistently by an uplink DCI.”However, we are supportive of only supporting AP CSI for Type-II codebook refinement for high/medium velocities |
| Fraunhofer IIS/HHI | We have serious concerns with Vivo’s proposal. We have extensively discussed this issue offline and as a compromise we have accepted N4 = 1 with out compression. Any other value other than 1 will not be acceptable to us. We do not agree with the point that compression cannot be achieved with N4 =2. Compression can still be achieved with N4 = 2 as pointed out by many companies (please look to our response in the previous offline discussion).   |
| Qualcomm | Re 2.5We are OK with the proposal for standard progress.We have question/concern on the feasibility of CQI prediction – regarding “the location of CSI reference resource is configured (from multiple candidate values) by gNB” in proposal 2.E, although we are open to study.Anyhow, in our view, CQI prediction should be conditional on UE capability.Re 2.7We are OK with the proposal for standard progress. Still, we want to point out:AP CSI-RS burst would be more friendly to UE implementation due to it being “causal” (i.e. all CSI-RS occasions occur after PDCCH): (1) No need to pre-buffer CSI-RS occasion(s); (2) More importantly, it can be notified to UE to receive with phase continuity, before receiving a burst of CSI-RS occasions. (Since most companies’ assumption is H-based extrapolation, receiving phase continuity is essential.)For AP/SP CSI-RS, some restriction should be satisfied for “causal”-like usage.Therefore, for vivo’s concern on long latency b/w PDCCH and PUSCH, still, we haven’t changed our view as provided in the last meeting: We don’t see a difference b/w AP CSI-RS and P/SP.Re 2.9We’d like to add a sub-bullet for some clarification regarding the size of the 3-D bitmap:

|  |
| --- |
| * FFS: The size of this 3-dimensional bitmap (2LMQ or smaller)
 |

Besides, also add our preference in some other issues with tracked change. |
| Samsung | **Proposal 2.D:** support the FL proposal. We have similar concerns (large overhead) with identity DD basis (Alt3) for N4>1. Re N4=2 commented by e.g. MediaTek.* With identity basis, the overhead is large (2x) due to 2 W2
* With DFT basis, Q can be either 1 or 2. The issue brought up on Q=1 (that it only performs phase rotation and has no impact on PMI selection along DD) applies to any N4 value, not only to N4=2. With Q=2, for a given (SD,FD) basis pair, the UE can select 0, 1, or 2 DD basis vectors (using NZC selection), so there is still some compression gain (which isn’t possible for identity basis).

Therefore, we tend to agree with, e.g. Fraunhofer, that DFT basis is still prevalent for N4=2.**Proposal 2.G:** * we support AP and SP, and can be OK with P for progress, although we don’t see any need for P CSI-RS if SP CSI-RS is supported.
* Based on our SLS results, we do see a need for supporting faster CSI-RS measurement (E.g. per slot), which can’t be supported with current spec on P/SP CSI-RS (the min period can be 4).
* Besides, Type II CSI report is AP, and AP CSI-RS resource is a natural choice for AP CSI report. P/SP CSI-RS measurement for Type II CSI can be an over-burden for a UE.

**Proposal 2.I*** The overhead of a 3D bitmap can be $2LMQ$ per layer, which can be large if legacy $(L,M$) are supported, and even if $Q$ is small (e.g. 2,3). There are two options to control the overhead:
	+ Option 1: 3D bitmap size ($2LMQ$) is at most or similar to legacy (Rel16), i.e., Rel. 16 bitmap overhead is an upper bound
	+ Option 2: 2D bitmap (e.g. legacy bitmap applied to all DD/TD units).

We prefer to study these options.**Proposal 2.I:** For the Type-II codebook refinement for high/medium velocities, study* Option 1: the per-layer 2-dimensional bitmap for indicating the location of NZCs used in Rel-16/17 Type-II is extended to a per-layer 3-dimensional bitmap
	+ The third dimension is associated with the number of selected DD basis vectors (denoted as *Q* at least for discussion purposes)
* Option 2: the per-layer 2-dimensional bitmap for indicating the location of NZCs used in Rel-16/17 Type-II is reused for all DD/TD units

Issue 2.12* Based on our SLS results, we do see up to 2% avg. UPT gain with 2 CQIs (over 1 CQI). So, at least 2 DD/TD units for CQI reporting should be supported. More than 2 can be studied further.
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### 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 | [110] **Agreement**For the Rel-18 TRS-based TDCP reporting, down select one of the following alternatives by RAN1#110bis-e:* AltA. Based on Doppler profile
	+ E.g., Doppler spread derived from the 2nd moment of Doppler power spectrum, average Doppler shifts, Doppler shift per resource, maximum Doppler shift, relative Doppler shift, etc
* AltB. Based on time-domain correlation profile
	+ E.g. Correlation within one TRS resource, correlation across multiple TRS resources
	+ Note: The correlation over one or more lags of TRS resource may be considered. The lags may be within one TRS burst or different TRS bursts
* AltC: CSI-RS resource and/or CSI reporting setting configuration parameter(s) to assist network
	+ E.g. gNB configures UE with multiple choices on what to assist (e.g. two or more CSI-RS/report periodicities, or precoding schemes depending mainly on UE velocity), then UE report according to configuration; parameters correspond to CSI reporting periodicity, codebook type, etc.

Note: Different alternatives may or may not apply to different use cases**Proposal 3.A**: For the Rel-18 TRS-based TDCP reporting, down select one of the following alternatives by RAN1#110bis-e:* AltA. Based on Doppler profile
	+ E.g., Doppler spread derived from the 2nd moment of Doppler power spectrum, average Doppler shifts, Doppler shift per resource, maximum Doppler shift, relative Doppler shift, etc
* AltB. Based on *quantized amplitude of* time-domain correlation profile
	+ E.g. Correlation within one TRS resource, correlation across multiple TRS resources
	+ Note: The correlation over one or more lags of TRS resource may be considered. The lags may be within one TRS burst or different TRS bursts

Note: Different alternatives may or may not apply to different use cases**FL Note**: This issue/proposal has been discussed OFFLINE [1] as offline proposal 3.1This is the current situation. * AltA: Samsung (2nd pref), ZTE, vivo, Google, LG, OPPO, Huawei/HiSi, Xiaomi, Fraunhofer IIS/HHI, Mavenir, Apple (1st pref), CATT, IDC, Spreadtrum, NEC (2nd pref), Nokia/NSB
* AltB: Samsung (1st pref), Ericsson, MediaTek, vivo, Qualcomm, DOCOMO, LG, OPPO, Sharp, Lenovo, Apple (2nd pref), IDC, NEC (1st pref), CEWiT
 | **Proposal 3.A:*** **Support/fine**: Samsung, ZTE, vivo, Google, LG, OPPO, Huawei/HiSi, Xiaomi, Fraunhofer IIS/HHI, Mavenir, Apple, CATT, Ericsson, MediaTek, vivo, Qualcomm, DOCOMO, OPPO, Sharp, Lenovo, Sony, Nokia/NSB
* **Not support**:
 |
| 3.2 | Whether the following time-domain behaviour of TDCP reporting is supported:* Periodic
* Semi-persistent
* Event-triggered (UE-initiated)

Note: Aperiodic TDCP reporting has been agreed in RAN1#110**FL Note**: This can be decided after 3.1 is finalized. | **Periodic:*** **Yes:** Qualcomm,
* **No:** Spreadtrum, Samsung, MediaTek, vivo

**Semi-persistent:*** **Yes:** Lenovo,
* **No:** Spreadtrum, Samsung, MediaTek, vivo

**Event-triggered/UE-initiated via UL MAC CE:*** **Yes:** Samsung, MediaTek
* **No:**
 |
| 3.3 | Whether using >1 TRS resources for TDCP measurement is supported in addition to only 1 TRS resource**FL Note**: This can be decided after 3.1 is finalized. | **Yes:** Samsung**No:**  |
|  |  |  |

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

|  |  |
| --- | --- |
| **Company** | **LLS/SLS results** |
| **Issue #** | **Metric** | **Observation** |
| Huawei/HiSi | 3.1 | Doppler profile | Observation 10: SRS could not provide accurate Doppler shift information.Observation 11: Due to the common feature of Doppler profile among gNB antennas, TRS could provide sufficient Doppler shift information even if it is single port.Observation 12:A “common Doppler profile” of multiple delay paths is a satisfying depict of the Doppler profile. |
| vivo | 3.1 | Auto-correlation vs lags | The Figure 4 shows the relationship between temporal correlation at different lags and maximum doppler shift in term of Bessel function.…Since maximum lags between four TRS resources in two consecutive slots is 14 symbols (or say 1 slot) and the values of correlation are [1, 0.97, 0.90] respectively corresponding to [3km, 30km, 60km], UE would not identify the minor difference taking noise and interference into account in practical algorithm unless AP TRS is triggered to compensate lacked occasions of P TRS. Hence it means to make the TDCP use case work, gNB has to trigger AP TRS to assist P TRS for this TDCP reporting. How this works for periodic or semi-persistent CSI reporting requires further study as P or SP CSI report cannot be associated with aperiodic RS |
| Google | 3.1 | Square cosine similarityAuto-correlation | Figure 5 illustrates SCS for the first layer at each Doppler spread. Figure 6 illustrates the Doppler spread at different UE velocity. It can be observed that with the help of Doppler spread, it is possible to predict the UE velocity. However, the SCS span can still be large. At some UE velocities, it is hard to determine whether the CSI could change quickly or not based on the Doppler spread.Figure 7 illustrates the SCS distribution at different channel auto-correlation, where different color indicates different SCS. Figure 8 illustrates the UE velocity distribution at different channel auto-correlation, where different color indicates different UE velocity. It can be observed that with channel auto-correlation only cannot help to distinguish the UE velocity and it is hard to identify the proper CSI report periodicity. |
| CATT | 3.1 | LLS: normalized TP | * + Observation-3:

Compared with no gNB-side CSI prediction, the single Doppler reporting has slight performance gain, and obvious performance gain can be achieved by the solutions with multiple Doppler reporting with the enhanced matching algorithm |
| Mavenir | 3.1 | Correlation vs lag | Observation 3. For given Doppler shift, different lags result in different time correlations |
| Samsung | 3.1 | Correlation vs lag | Observation 15:* The perceived Doppler spread increases as the number of reported correlation lags decreases due to windowing before FFT operation.
* For a given UE speed, there is a minimum number of reported correlation lags that can represent the Doppler spread accurately.
 |
| Ericsson | 3.1 | Correlation vs lag | However, we don’t think it’s crucial to capture the sign changes of the autocorrelation. It’s the behaviour of the autocorrelation for low lags corresponding to an autocorrelation above zero that is of most interest (see Figure 3). Also, the measure $A\_{alt}\left(t,τ\right)$ would not be robust towards phase jumps. Thus, if UE manufacturers prefer the measure $A\left(t,τ\right)$ to avoid problems with phase jumps, that is perfectly fine with us.1. Maximum doppler shift would be the same for channels with vastly different channel variabilities, and it does not reflect how fast channel varies with time.

Thus, the second moment of the Doppler power spectrum is a much better measure of channel variability than the maximum Doppler shift. However, it can’t predict the rather abrupt break-off point where the autocorrelation of the CDL channels takes off steeply downwards as can be seen in Figure 5. Compared to the autocorrelation it gives less information about the channel variations. The second moment of the Doppler power spectrum is therefore not our preferred TDCP measure.To measure the relative Doppler shift of a number of channel peaks is also a very complex measurement which in the end gives worse performance than the autocorrelation as shown in Figure 6. In Figure 6, we show the result, showing that the Autocorrelation based estimate totally outperforms the channel peak based estimate. It has both lower bias and lower standard deviation than the peak based estimate. This should be viewed as an illustration of the general fact that the measurement of relative Doppler shifts per peak is a complex and inaccurate measurement while the Autocorrelation is a simple and comparably accurate one.1. Estimates based on intra-TRS autocorrelation lags doesn’t give decent accuracy below 50km/h.
2. Estimates based on inter-TRS : autocorrelation lags of 20 or 40 slots perform best at 3km/h; autocorrelation lags of 10 and 5 slots performs best at 6km/h and 10km/h respectively.
3. Different autocorrelation lags are suitable for different UE velocities.
4. Based on the evaluated use cases, reporting of the Autocorrelation for the four lags, 4 symbols, 1 slot, ~5 slots and ~10 slots look reasonable.
 |
| **Summary**:  |

Table 6 Additional inputs: issue 3

|  |  |
| --- | --- |
| **Company** | **Input** |
| Mod V0 | 1. **Check and update your view in Table 5A, especially on the moderator proposals**
2. **Share additional inputs here if needed**
3. **More moderator proposals may be added in the next revision**
 |
| vivo | **Issue 3.2**We would like to check companies’ view on the following issue for P/SP reporting.Since maximum lags between four TRS resources in two consecutive slots is 14 symbols (or say 1 slot) and the values of correlation are [1, 0.97, 0.90] respectively corresponding to [3km, 30km, 60km], UE would not identify the minor difference taking noise and interference into account in practical algorithm unless AP TRS is triggered to compensate lacked occasions of P TRS. Hence it means to make the TDCP use case work, gNB has to trigger AP TRS to assist P TRS for this TDCP reporting. We are wondering how this works for periodic or semi-persistent CSI reporting as P or SP CSI report cannot be associated with aperiodic RS.Correlation vs maximum doppler shift |
| Mod V2 | **No revision** |
| Qualcomm | Re 3.2We are fine with periodic report.Periodic report would have smaller issue even than the agreed aperiodic, since everything is pre-determined and no need to buffer TRS, especially for cross-burst measurementRe 3.3We have questions regarding multi-TRS (or cross-burst) measurement.We can understand its motivation for longer lag measurement (e.g. 5msec, 10msec), but it may not need to be tied with multi-TRS based on existing TRS definition, i.e. each with 4 symbols within 2 consecutive slots – large overhead.To save the overhead, a simpler way is to define a set of single-port CSI-RSs with different time spacing (e.g. 5msec, 10msec for longer lag) than existing TRS – this can also be seen as enhancements of TRS(I guess this is also relevant to vivo’s question regarding longer lag) |
| Samsung | Proposal 3.A: since Doppler profile can be obtained if sufficient number of auto-correlation values for multiple lags are reported, Doppler profile is also possible via AltB. So, we prefer AltB over AltA.Issue 3.3* We support > 1 TRS resources for TDCP reporting
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| 3 | R1-2208495 | Enhanced CSI for CJT and High Doppler Operations | InterDigital, Inc. |
| 4 | R1-2208504 | CSI enhancement for high/medium UE velocities and CJT | ZTE |
| 5 | R1-2208541 | Discussion on CSI enhancement for high/medium UE velocities and coherent JT | Spreadtrum Communications |
| 6 | R1-2208628 | Discussion on CSI enhancement for high-medium UE velocities and coherent JT | vivo |
| 7 | R1-2208742 | Discussion of CSI enhancement for high speed UE and coherent JT | Lenovo |
| 8 | R1-2208794 | CSI enhancement for high/medium UE velocities and coherent JT | OPPO |
| 9 | R1-2208872 | On CSI Enhancement | Google |
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| 11 | R1-2208947 | Discussion on CSI enhancements | CATT |
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