**3GPP TSG RAN WG1 #110bis-e R1-2210566**

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

**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** |
| 1.4 | [110bis-e] **Agreement**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 *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).**Question**: Please share your views on supported value(s) for each of the above parameters, e.g. whether the legacy supported value(s) can be fully reused, or what refinement (removing and/or adding new values) is needed* This is irrespective of the outcome of supported parameter combinations. For now, each parameter should be considered separately from other
 | **{Added later once a proposal is added}** |
| 1.6 | [110bis-e] **Agreement**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 bitmap per each CSI-RS resource * 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.
	+ …

**Question**: Other than the legacy-based scheme (where $B\_{n}=2L\_{n}M\_{v,n}$), what other scheme(s) do you intend to propose for down-selection consideration? | **{Added later once a proposal is added}** |
| 1.9 | **Proposal 1.I.2**: For the Rel-18 Type-II codebook for CJT mTRP, for mode-1, the number of FD basis vectors (Mv related to pv for Rel-16, M for Rel-17) is common across all N CSI-RS resources**FL Note**: While FD basis selection can be TRP-specific for mode-1, a number of companies perceive the number of selected FD basis vectors can be common across all the N TRPs. | **Support/fine:** Huawei/HiSi, Qualcomm, Nokia/NSB, Intel, AT&T, Ericsson, Samsung,**Not support:** [ZTE], [DOCOMO] |

Table 2 Additional inputs: issue 1

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| **Company** | **Input** |
| Mod V0 | **PLEASE READ THE FL NOTES** 1. **Check and, if needed, update your view in Table 1A especially on the moderator proposals.**
2. **Share additional inputs here, if needed**

**More moderator proposals may be added in the next revision** |
| Apple | **Issue 1.4**Legacy value can be start point, except we prefer to have R=1 only **Issue 1.9**We are fine with the same number of selected FD basis for each TRP/TRP group |
| vivo | **Issue 1.4**We support refinement of the legacy parameter values to cover the lower payload range. On the values of the codebook parameters, the minimum value of K\_0 is ⌈0.25M\_1 ⌉, where L=2, and β=0.25. However, for CJT PMI, the number of rows in W\_2 is greater, e.g.,2LT, where T denotes the number of TRPs. Therefore, the value of K\_0 is ⌈2M\_1 ⌉ which has large gap compared to the value of STRP, when T=4, L=2, and β=0.25. Therefore, we think the value of Beta needs to be further reduced to cover the lower payload range, e.g. 0.125, 0.0625. **Issue 1.6**We support the following alternative for further evaluation/down-selection. One example can be for all the (Ltot) SD basis and all the FD basis across N CSI-RS resources, the bitmap length is 2Ltot for FD basis vector 0 where SCI locates, and bitmap length is 2Ltot- n \* d for the rest, where n denotes the scaling value and d denotes the modulo difference (e.g., mod Mv/2) between the index of each selected FD basis vector and FD basis vector 0.* Alt x: Non-rectangular bitmap, i.e., NZC bitmap allowing different lengths for different basis vectors.
	+ TBD: How to determine the lengths for different basis vectors

**Proposal 1.I.2**Support |
| ZTE | **Issue 1.4**In our initial thought, we can use the legacy value of {N1, N2, Q1, Q2} as a starting point. Then, for FD basis, we may still use the legacy, but we wonder whether we need to consider a high-accurate parameter-configurations, especially for L =6 or more.**Issue 1.6**We prefer to use the legacy $B\_{n}=2L\_{n}M\_{v,n}$ ($M\_{v,n}=M\_{v}$ for mode 2).**Proposal 1.I.2**We prefer to have separate number of FD-basis due to the fact that channel property for different TRP may be different, but if majority support, we can be flexible. |
| Xiaomi | **Issue 1.4**Legacy values can be considered as starting point**Issue 1.6**Prefer legacy-based scheme**Issue 1.9**Support common number FD basis vectors across all N CSI-RS resources  |
| DOCOMO | **Issue 1.4**Legacy values can be used as starting point. At least *N*1, *N*2, *O*1, *O*2 can be kept unchanged. For other values, e.g., L, M, beta, R, we’re open to study the candidate values to reduce CSI reporting overhead.**Issue 1.6**Prefer legacy-based scheme**Issue 1.9**OK with common number of FD basis vectors, if it is supported by majority. |
| NEC | **Issue 1.4**We prefer to study larger value of R at least for refinement based on Rel-16 codebook, as the frequency selective increased for CJT.**Issue 1.6**We prefer legacy analogous scheme.**Issue 1.9**Fine with the proposal. |
| Fraunhofer IIS/Fraunhofer HHI | **Issue 1.4:** Prefer legacy values.Re N3, unlike Rel. 16 and Rel. 17, N3>19 shall be made mandatory as the number of subbands are critical for functioning of this codebook especially for inter-site CJT scenarios. As the delay spread is larger for CJT compared to the single-TRP Rel. 16 CB, a small number of subbands (for example 13) can result in large aliasing of the channels associated with some cooperating TRPs. This will result in a large performance loss. This is what we observed rather frequently in our evaluations and therefore support for larger number of subbands shall be made mandatory.**Issue 1.6**: We prefer using legacy bitmap $B\_{n}=2L\_{n}M\_{v,n}$ .**Issue 1.9**: Support |
| Samsung | **Issue 1.4*** (N1,N2,O1,O2): prefer reusing legacy values
* (Mv, pv): We prefer to use parameter $M\_{v}$ instead of using equation to determine Mv based on $p\_{v}$ for simplification and alignment R17-based CJT. Considering large-overhead consumed in the CJT scheme, we think a lower-value range of $M\_{v}$ (than legacy) can be considered, e.g. Mv<=4. This makes a restricted range of $M\_{v}$ for all configurable numbers of SBs, so it can be simpler to determine supported values for $M\_{v}$ than $p\_{v}$.
	+ R16-based: Mv=2,3,4
	+ R17-based: M=1,2, support of M=2 is optional (as in legacy R17)
* N3, R: prefer reusing legacy

**Issue 1.6**: we support legacy scheme ($B\_{n}=2L\_{n}M\_{v,n}$), which should be baseline**Proposal 1.I.2**We support.  |
| Intel | **Issue 1.4.** * Legacy values for N1, N2, O1, O2 can be reused
* pv: {0.25, 0.5} can be further considered for v = 1,2 and two times lower for v = 3,4 (as for legacy codebook)
* R = {1,2} can be considered with R = 2 as optional feature

**Issue 1.6.*** Legacy design can be reused

**Issue 1.9.**Support the proposal |
| Qualcomm | **Issue 1.4*** {O1,O2}: Fully reuse;
* {N1,N2}: Generally OK to reuse, but total NN1N2 should be limited <=32 at least according to UE capability
* N3 and R: Full reuse
	+ Strongly oppose any increase – also drastic increase of UE complexity
	+ Larger delay-spread issue can have better way to resolve, e.g. by delay-compensated PDSCH (CDD) as proposed by Ericsson and also by some other companies
* Mv:
	+ Rel-16: OK with smaller-value config by new smaller pv
	+ Rel-17: Reuse M=1 or 2

**Issue 1.6**Fully reuse (For any possible methods of Bn reduction, any difference from config a smaller L or M?)**Issue 1.9**Support TRP-common value of Mn as a starting point, or even working assumption.Maybe there can be overhead-UPT performance difference for TRP-specific Mn, if companies are willing to evaluate, and we are also open and interested to see the potential results.Note that there can be a drawback: If Mn is different for each TRP, the total bitmap size $\sum\_{n=1}^{N}2L\_{n}M\_{n}$ can potentially variate more unstably and made it more difficult for gNB to estimate total PUSCH resources needed for the report in advance (given that Ln is already agreed to be TRP-specific by all the 4 Alts of **Proposal 1.E.3**) |
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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* **Concern:** vivo, Lenovo, LG, Apple, DOCOMO, Spreadtrum

**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, OPPO, Google, Sharp **Proposal 2.A:*** **Support/fine:** IDC, ZTE, Huawei/HiSi, Fraunhofer IIS/HHI
* **Concern (Rel-16 only):** vivo, LG, Apple, DOCOMO, Spreadtrum, Qualcomm, Lenovo
 |
| 2.4 | [109-e] **Agreement**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.* $W\_{1}\tilde{W}\_{2}(W\_{f})^{H}$
* 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.$W\_{1}\tilde{W}\_{2}\left(W\_{f}⨂W\_{d}\right)^{H}$
	+ Only Q (denoting the number of selected DD basis vectors) >1 is allowed
	+ TBD (by RAN1#110bis): whether rotation is used or not
	+ FFS: identical or different rotation factors for different SD components
	+ FFS: Whether *Q* 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.**Proposal 2.D.3**: For the Rel-18 Type-II codebook refinement for high/medium velocities, when N4>1, down-select from the following alternatives (by RAN1#111) for the orthogonal DFT DD basis:* Alt1. No rotation factor
* Alt2. A common rotation factor is selected for all SD basis vector
	+ FFS: Supported values of rotation factor
* Alt3. A rotation factor is select for each SD basis vector
	+ FSS: Supported values of rotation factor

**FL Note**: Please share your preference Alt1 vs Alt2 | **Proposal 2.D.3:*** **Support/fine:**
* **Not support:**
 |
| 2.4 | [110bis-e] **Agreement**For the Type-II codebook refinement for high/medium velocities, the selection of DD basis vectors is layer-specific* The number of selected DD basis vector (denoted as *Q*) is layer-common

**Question**: Please share your views on the possible value(s) of *δ* and possible value(s) of *Q* | **{Added later once a proposal is added}** |
| 2.5 | [110bis-e] **Agreement**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 slot *l* where the location of slot *l* is configured (from multiple candidate values) by gNB via higher-layer signalling* Candidates of slot *l* location include the legacy CSI reference resource location (*n* – *nCSI,ref* ) and slot (*n*+*δ*) where *δ* ≥ 0
* FFS: Possible value(s) of *δ* and possible value(s) of WCSI

Note: Per legacy behavior, the legacy CSI reference resource, i.e., (*n* – *nCSI,ref* ), is reused for locating the last CSI-RS occasion used for a CSI reportFor a UE that supports UE-side prediction, the support of *l* = (*n* – *nCSI,ref* ) is UE optional.**Question**: Please share your views on the possible value(s) of *δ* and possible value(s) of WCSI | **{Added later once a proposal is added}** |

Table 4 Additional inputs: issue 2

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| **Company** | **Input** |
| Mod V0 | **PLEASE READ THE FL NOTES** 1. **Check and, if needed, update your view in Table 3A especially on the moderator proposals.**
2. **Share additional inputs here, if needed**

**More moderator proposals may be added in the next revision** |
| Apple | **Issue 2.1**We prefer to prioritize Rel-16 eType-II over Rel-17 FeType-II PS **Issue 2.4**We prefer Alt1, no rotation factor**Issue 2.5**It depends on the channel coherent time. Assume it is around 30ms, corresponding to roughly 30Hz coherent BW. Consider 30kHz SCS of 0.5ms slot.δ can be up to 64?We are open to more discussion as well |
| vivo | **Issue 2.1**We don’t support proposal 2.A. We support to enhance Rel-16 eType II only.**Proposal 2.D.3**Support. Further evaluation is needed. We prefer Alt 1 at the current stage.**Issue 2.4**We suggest to define Q=ceil(N4/2) for N4>2.For N4=2, the only case we can have now is Q=2.**Issue 2.5**For delta, we support {0, 2, 4} as the candidate values for configuration.For W\_CSI, we think one value is sufficient. Either W\_CSI =1 or N4 is fine. We slightly prefer W\_CSI =1 for lower UE complexity.  |
| ZTE | Proposal 2.A: SupportProposal 2.D.3: Although we prefer to have rotation factor that is good for CSI compression, we tend to agree that it can be up to implementation.Issue 2.4: Q can be configured and then we may have candidate value of Q = 2, 3, 4, 5, …. Regarding upper bound, we may have further evaluation. Considering that N4 may be limited (e.g., <20 slot), we think that the candidate value of Q may not be too many, e.g., up to 5 or 9, according to our evaluation. Issue 2.5: We prefer to consider a large value of delta (e.g., from 0 to 8 in slot with a step of 2). The value of W\_CSI (i.e., N4, right?) should consider the periodicity of CSI report/measurement (e.g., 4, 5, 8, 10, 16, 20, …) (e.g., in terms of uniform sample and prediction). The upper bound may further be studied, but it seems that up to 40 seems sufficient.CSI-ReportPeriodicityAndOffset ::= CHOICE { slots4 INTEGER(0..3), slots5 INTEGER(0..4), slots8 INTEGER(0..7), slots10 INTEGER(0..9), slots16 INTEGER(0..15), slots20 INTEGER(0..19), slots40 INTEGER(0..39), slots80 INTEGER(0..79), slots160 INTEGER(0..159), slots320 INTEGER(0..319)} |
| Xiaomi | **Proposal 2.D.3**Support Proposal 2.D.3. For Alt2, as analyzed in our tDoc, if a common rotation factor is applied to all SD basis vector, its effect is similar to that of nonrotation factor applied to all SD basis vector. The reason is that the phase rotation for the precoder of all subbands at one instance does not affect performance. Therefore, Alt2 should be equivalent to Alt1. **Issue 2.4**In our view, the value of Q can be determinate through simulation results considering the tradeoff between performance and overhead, which is similar to determination of number of SD basis and FD basis. The value of Q may be calculated as $\left⌈γN\_{4}\right⌉$, where $γ\leq 1$ is a scaling factor.**Issue 2.5**For *δ*, *δ*=0 can be supported, which is straightforwardly. Considering the processing time of gNB after receiving the CSI reporting, *δ*>0 can also be supported.For WCSI, if $N\_{4}=1$, it is sufficient that WCSI =1. If $N\_{4}>1$, WCSI =1 can calculated as $\left⌈dN\_{4}\right⌉$, where *d* is DD/TD compression unit. |
| NEC | **Issue 2.1**We prefer to down-select to based on Rel-16 (at least prioritized)**Proposal 2.D.3**Support, and Alt 1 is preferred.**Issue 2.4**We think the value of N4 may be needed to be firstly determined (or at least jointly considered, which is also related to WCSI in Issue 2.5), as the value of Q may be related to the value of N4.**Issue 2.5**Considering the processing/scheduling preparation time, we prefer *δ* > 0, maybe starting from 1. The candidate values may be {1,2,3,4}.We share similar view with Xiaomi, WCSI = d\*N4, where d is DD unit. So one parameter needs to be determined is d, and d may be in term of slots, we think either periodicity/interval of CSI or CSI-RS can be applied. At least 4 should be supported for d, i.e. WCSI = 4\*N4 |
| Fraunhofer IIS/Fraunhofer HHI | **Proposal 2.A: Support**We think that refining Rel. 17 PS codebook is straightforward, and workload is small as **Time-/Doppler-domain reciprocity is not assumed**. In our view, only some of the parameter combinations need some refinement as all other codebook aspects are straightforward extensions.**Proposal 2.D.3:**In Alt 2, a single/common rotation factor is used for all SD components which is equivalent to multiplying the precoder with a common phase value. The common phase value has no significance in the precoder calculations. Hence, in our view, Alt 1 and Alt 2 are the same and hence Alt2 can be removed. Alt 3 on the other hand uses a different rotation factor for each SD component. For example, for oversampling factors of four, for each SD component, the DD components are selected from a single orthogonal sub-matrix out of four orthogonal sub-matrices. Our simulations results (oversampling factors **two** and **four**) using a rotation factor per SD component significantly improved the performance of the Rel.18 Codebook compared to the baseline.**Issue 2.4&2.5:** In our observations, up to $Q=4$ seems to be sufficient for CSI prediction up to $W\_{CSI}=20$ slots. |
| Samsung | Proposal 2.D.3: we support Alt3Issue 2.4* We support Q=2, and ok to study Q=3. Note larger value Q will incur more overhead, and small UPT improvements.

Issue 2.5* We support only one Delta value (delta=0), and the need for more than delta value is unclear to us.
* Following frequency domain, W\_CSI = N4/x, where N4 (total number of slots) and x (DD/TD unit size) are configured.
 |
| Intel | Issue 2.4.* Alt 2 can be removed as explained by Fraunhofer IIS/Fraunhofer HHI for Proposal 2.D.3
* Q can be related to N4 (e.g. Q = ceil(0.5\*N4))

Issue 2.5.* Fixed value of delta can be considered (e.g. delta = 1).
 |
| Qualcomm | Fine with **Proposal 2.D.3****Issue 2.4**: At least support Q={2,3}**Issue 2.5**: WCSI size depends on coherent time (UE speed), and also depends on SCS if configured in # slots |

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

{No issue to be discussed in this round}

Table 5A Summary: issue 3

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| **#** | **Issue** | **Companies’ views** |
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Table 6 Additional inputs: issue 3

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| **Company** | **Input** |
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# References

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| --- | --- | --- | --- |
| 1 | R1-2209715 | Summary of OFFLINE discussion on Rel-18 MIMO CSI | Moderator (Samsung) |
| 2 | R1-2208441 | CSI enhancement for coherent JT and mobility | Huawei, HiSilicon |
| 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 |
| 10 | R1-2208893 | Potential CSI enhancement for high/medium UE velocities and coherent JT | LG Electronics |
| 11 | R1-2208947 | Discussion on CSI enhancements | CATT |
| 12 | R1-2209041 | On CSI enhancements | Intel Corporation |
| 13 | R1-2209090 | Further considerations on CSI enhancement for high/medium UE velocities and CJT | Sony |
| 14 | R1-2209140 | Discussion on CSI enhancement | NEC |
| 15 | R1-2209247 | Discussion on CSI enhancement | Mavenir |
| 16 | R1-2209258 | Discussion on CSI enhancement for high/medium UE velocities and CJT | xiaomi |
| 17 | R1-2209322 | Discussion on CSI enhancement for high/medium UE velocities and CJT | CMCC |
| 18 | R1-2209381 | CSI enhancement | Sharp |
| 19 | R1-2209494 | CSI enhancement | MediaTek Inc. |
| 20 | R1-2209545 | CSI enhancements for medium UE velocities and coherent JT | Fraunhofer IIS, Fraunhofer HHI |
| 21 | R1-2209570 | Views on Rel-18 MIMO CSI enhancement | Apple |
| 22 | R1-22010241 | Views on CSI enhancements | Samsung |
| 23 | R1-2209793 | Views on CSI Enhancements for CJT | AT&T |
| 24 | R1-2209852 | On CSI enhancements for Rel-18 NR MIMO evolution | Ericsson |
| 25 | R1-2209890 | Discussion on CSI enhancement | NTT DOCOMO, INC. |
| 26 | R1-2209969 | CSI enhancements for high/medium UE velocities and Coherent-JT | Qualcomm Incorporated |
| 27 | R1-2210063 | CSI enhancement for high/medium UE velocities and CJT | Nokia, Nokia Shanghai Bell |
| 28 | R1-2210105 | Discussion on CSI Enhancements for high/medium UE velocities and coherent JT | CEWiT |
|  |  |  |  |