**3GPP TSG RAN WG1 Meeting #104-e R1-210xxxx**

**E-meeting, January 25th – February 5th, 2021**

**Agenda Item: 8.1.4**

**Source: Moderator (Huawei, HiSilicon)**

**Title: Summary of CSI enhancements for MTRP and FDD (Round 0)**

**Document for: Discussion and Decision**

# Introduction

Enhancement on CSI measurement and reporting:

* Evaluate and, if needed, specify CSI reporting for DL multi-TRP and/or multi-panel transmission to enable more dynamic channel/interference hypotheses for NCJT, targeting both FR1 and FR2
* Evaluate and, if needed, specify Type II port selection codebook enhancement (based on Rel.15/16 Type II port selection) where information related to angle(s) and delay(s) are estimated at the gNB based on SRS by utilizing DL/UL reciprocity of angle and delay, and the remaining DL CSI is reported by the UE, mainly targeting FDD FR1 to achieve better trade-off among UE complexity, performance and reporting overhead

In RAN1 102e, RAN1 have agreed a set of evaluation assumption for above enhancement on CSI measurement and reporting over FDD and NCJT.

In RAN 103e, based on agreed evaluation assumptions, RAN1 have confirmed the interest of enhancements based on evaluation results. Some high level agreement/basic CSI measurement/reporting framework for Multi-TRP CSI enhancement were agreed. Moreover a set of candidate codebook structures for Type II port selection codebook enhancement were agreed as well for further discussion and down-selection.

In RAN1 104e, companies have shared their consideration/preference for some physical layer design of CSI enhancement, which can be found in Reference and Appendix:

* Assuming there are two/three GTW/check points during meeting weeks. The first GTW/check point is to prioritize the decision of Proposals 1 and 2 (i.e. down-selection of codebook structure for FDD CSI) and Proposals 6 and 8 (i.e. further clarification of measurement/reporting framework for Multi-TRP CSI).
* The second check point is to address the rest proposals, which are to provide supplementary decision/information/clarification/FFS over the design agreed by the first check point.
	+ It is also feasible to address some critical design during the second check point. Proponents may think that they are valuable but may not be discussed thoroughly yet by other companies, at least pave a path for better technical discussion next meeting.

# Summary of CSI enhancement for FDD

## Codebook structure for Rel-17 PS

### 2.1.1 Consideration of Rel-17 codebook structure over

Six alternatives were agreed as candidate codebook structures for Rel-17 PS CB enhancement in RAN1#103e. The following table summarizes companies’ views on six alternatives.

**Table 1 Summary of Companies’ Views on codebook structure down selection for R17 PS CB**

|  |  |
| --- | --- |
| **Views** | **Companies** |
| **Alt 0** (1) | Samsung |
| **Alt 1** (4) | QC, MTK, Samsung, CATT |
| **Alt 2** (2) | Spreadtrum, ZTE |
| **Alt 3-0** (11) | Nokia, Nokia Shanghai Bell, LG Electronics, Ericsson, OPPO, Intel, Lenovo, Motorola Mobility, Fraunhofer IIS, Fraunhofer HHI, vivo |
| **Alt 3-1** (4) | Nokia, Nokia Shanghai Bell, OPPO, vivo |
| **Alt 3-2** (4) | NTT DOCOMO, MTK, Spreadtrum, vivo |
| **Alt 4** |  |
| **Alt 5** (5) | Nokia, Nokia Shanghai Bell, Huawei, HiSilicon, China Unicom |

One main difference among above alternatives is whether the codebook structure shall consider matrix. Moreover can be a selection matrix or a DFT matrix, which were discussed by companies (Nokia, Nokia Shanghai Bell, QC, Ericsson, Samsung, Huawei, HiSilicon, China Unicom, OPPO, CATT, vivo).

Companies preferring a DFT matrix have considered following benefits:

* Better performance can be observed when multiple FD vectors are configured to UE
* PMI accuracy can be increased because of imperfect FDD delay reciprocity
* CSI-RS ports/overhead can be reduced by configuring/indicating a UE with limited FD components, and/or applying UE-specific shifts to FD-precoded beamforming vectors at gNB
* Higher flexibility can be provided, e.g. in terms of gNB implementations or the balance between DL/UL overhead and gNB/UE complexity

Companies preferring a selection matrix have considered the following benefits:

* Achieve better trade-off among UE complexity, performance and reporting overhead

Companies preferring a codebook structure without have considered following pros and cons:

* More than one DFT vectors in doesn’t provide performance gain and if there is only one DFT vectors in , is simpler
* DFT matrix increases DL signalling overhead

In FL’s view, there is a clear majority preferring to consider as a DFT matrix(i.e. Alts 3-0, 3-1 and 5) and be supported by 14 companies, e.g. Nokia, Nokia Shanghai Bell, LG Electronics, Ericsson, OPPO, Intel, Lenovo, Motorola Mobility, Fraunhofer IIS, Fraunhofer HHI, vivo, Huawei, HiSilicon, China Unicom. Furthermore, 11 companies (Intel, Nokia, Nokia Shanghai Bell, Lenovo, Motorola Mobility, Huawei, HiSilicon, China Unicom, OPPO, ~~Fraunhofer IIS, Fraunhofer HHI~~) also propose that or should be supported for , i.e. can be limited as one DFT vector for certain simplicity so that (Alt 1/Alt 2) can be considered as a special case of .

In terms of design, 18 companies, Nokia, Nokia Shanghai Bell, OPPO, Lenovo, Motorola Mobility, vivo, Huawei, HiSilicon, China Unicom, NTT DOCOMO, MTK, Spreadtrum, vivo, CATT, Fraunhofer IIS, Fraunhofer HHI, ZTE, Samsung have proposed to consider as a free selection matrix with identity matrix (i.e. Alt0) as a special case of design.

Base on above view, following proposal is suggested as a compromise:

***Proposal 1: For PS codebook enhancements utilization DL/UL reciprocity of angle and/or delay, support codebook structure W=W1W2 WfH whereas***

* ***W1 is a free selection matrix, with identity matrix as special configuration***
* ***Wf is a DFT based compression matrix in which N3 = NCQISubband\*R and Mv>=1***
	+ ***is supported***
	+ ***FFS other candidate values of Mv, R, mechanism of Configured/indicated to the UE and/or mechanism of selected/reported by UE for Wf***

Companies’ further views are collected as follows.

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| --- | --- |
| Company | Comments |
| vivo | Support FL’s proposal.  |
| Nokia/NSB | Support this proposal.Note that, in case of , whether the are reported by a UE, for example, from a configured window of size , or network-configured will be discussed in Proposal 5 |
| Futurewei | Support FL’s proposal. |
| OPPO | If W1 is a free selection matrix, does it imply that it is polarization specific selection? Then why there are still multiple alternatives in proposal 4? |
| Lenovo/MotM | Support |
| Spreadtrum | We can accept FL proposal if there’s a majority support. |
| CATT | We cannot accept the proposal. Including Wf in the codebook structure has the following problem:1. Additional DL signalling overhead as mentioned in the above summary.2. Limitation on selection of FD basis at gNB side. That is, only DFT vector can be used as FD basis.3. Extra CSI feedback overhead to report the bitmap for non-zero coefficients when Mv > 1. With structure of W = W1W2, port selection indication is sufficient for indicating the location of non-zero coefficients and the bitmap reporting is not needed.Regarding the number of supporting companies, we don't think it can be seen as a clear majority to support Wf. |
| Intel | In our view this proposal is reasonable, we support the proposal. As it was pointed out by OPPO, it is not clear if free selection implies per-polarisation selection of ports. |
| LG | Support proposal  |
| ZTE | Not support on M\_v>1. We supports to agree on M\_v =1 first and FFS M\_v>1. In our simulation, we don’t see the gain for M\_v>1. There is no need to spend more UE complexity to search a second DFT vector.  |
| MediaTek | Support the proposal with a note that there needs to be further discussion and a compromise to be found between configuring/indicating FD basis to UE (increase in downlink signaling overhead) and selecting and reporting FD basis by UE (similar UE complexity and feedback overhead as R16 eType II codebook). |
| Qualcomm | We have concern on M > 1 but ok with FFS. As pointed out in our contribution, under same CSI-RS configuration as Alt1, M >1 provides minor gain but more reporting overhead and UE complexity; under same total number of SD-FD pairs (considering beamforming and indicated/reported FD based collectively), Alt3-0 is worse than Alt1 due to limited bases selection (SVD basis is not available). |
| Fraunhofer IIS, Fraunhofer HHI | In the same way as some companies have concerns on Mv>1, we have concerns on Mv=1. It has been quite clear from multiple contributions from companies and also from real-world measurement results that delay reciprocity holds only partially for some scenarios. Therefore, Mv>1 will be required in real-world scenarios. Also, from simulation results using the 3GPP channel model, the performance gain achieved using Mv > 1 UE is significantly higher than with Mv = 1. We therefore think Mv > 1 shall be compulsory and Mv=1 should be FFS.  |
| Apple | We are fine with the proposal |
| Ericsson | Proposal 1 is a good starting point for discussion and seem to capture the main direction. Our concern is the limit to Mv=1 in this proposal is too restrictive. If we look at the measurement results from Fraunhofer, there is uncertainty in the delay profile of a real channel, i.e. the DL and UL delays are not perfectly reciprocal Hence, allowing UE to feed back more than the DC component of the DFT matrix (i.e. Mv larger than 1) improves robustness. We believe that Mv=2 with adjacent DFT columns is sufficient to reach the robustness benefits. In addition, the reason that some companies don’t see gain with M>1 is likely due to the way FD precoders are found. The number of dominant taps within each SD beam may not be the same. If the same number of FD bases (for M=1) or FD windows (for M>1) per SD beam are used for CSI-RS precoding, then gNB needs to precode CSI-RS with some SD-FD pairs that do not correspond to any dominant clusters in the channel, and UE needs to measure these SD-FD pairs, which corresponds to coefficients equal to zero in the feedback. This leads to reduced throughput and additional bits for indicating for a given number of precoded SD-FD pairs. If gNB instead jointly finds SD beam and FD basis or FD window, UE will measure on a more compact beamformed DL channel where fewer coefficients are zero and this makes the feedback more efficient. Hence, we are fine with the Proposal with the following modification* + ***is supported***

. If companies do not select the FD precoder correctly, they may not see the gain of having M>1.  |
| Samsung | We are not supportive of this proposal due to the following reasons.* Performance loss: based on our study and latest simulation results (copied below, and to be included in the update Tdoc soon), we observe performance loss with DFT Wf (Alt3-0) when compared with Alt1 (no Wf) or Alt4 (PS Wf). In particular, the performance loss is large (up to 8% in avg. UPT) in large overhead regime where #SD-FD bases (or beamformed CSI-RS ports) is large. This loss is not small. The reason is simple (eigenvector vs DFT bases for FD compression). It is obvious that eigenvector based FD bases will show better performance. Another reason is the unnecessarily asking UE to report more than what is needed, i.e., there is no need for Wf if gNB provides sufficient number of SD-FD bases via beamformed CSI-RS. Asking more than what is needed starts to show up in performance loss.
* With DFT Wf, the performance is closer (only slight improvement) to R16 codebooks, which is not surprising either since all we are doing is enhancing R16 codebook by (1) allowing free port selection, and (2) supporting additional parameter values such as L>4, R>2 and so on.
* Also, based on the results (from some companies, it will be good if the FL could provide a summary of SLS results similar to what we had in RAN1#103-e), the observations and views of companies are diverging.

W1W2 codebook structure on the other hand has a number of benefits:* It is simple (requires only port selection and coefficient computation) 🡪 least spec-impact
* Due to being simple, it is the simplest in terms of UE implementation.
* More importantly, it can achieve similar or better performance vs overhead tradeoff (depending on the beamforming method used at the gNB) than W1W2Wf^H

Therefore, based on the above, we don’t think Proposal 1 is reasonable. |

### 2.1.2 Consideration of Rel-17 codebook structure over

Conditioned on the discussion of Proposal 1, further down selection/consideration of Rel-17 codebook structure can be discussed among different design over. As summarized in Table 1, companies supporting Alt 3-1 are also supportive for Alt 3-0. Therefore, it is feasible that further discussion mainly focus on Alt 3-0 and Alt 5.

Based on tdoc review, companies’ analysis over between Alt3-0 and Alt 5 are summarized as following:

* Alt3-0 (() ): Alt 3-0 is simpler with one SD-FD precoder per CSI-RS port. On the other hand, in order to reduce CSI-RS overhead and provide flexible CSI-RS resource configuration, certain configuration enhancement may be needed, e.g. discussed in section 2.1.3.
* Alt5 (()): Alt 5 can enable mapping multiple SD-FD bases to a CSI-RS port, which is helpful to reduce CSI-RS overhead and provide flexible CSI-RS Resource configurations. On the other hand, relying on mapping of multiple SD-FD bases to a CSI-RS port would create misalignment with the definition of ‘antenna port’ in the specification and may increase UE complexity of CSI processing.

Therefore considering R17 codebook structure over , following proposal is suggested:

***Proposal 2: For PS codebook enhancements utilization DL/UL reciprocity of angle and/or delay, support codebook structure W=W1W2 WfH with***

* ***Alt 3-0, i.e. W1 ∈ N^{PCSI-RS × K1} (K1 ≤ PCSI-RS ) is a port selection matrix***
* ***Alt 5, i.e. W1∈ N^{PSD-FD × K2} (K2 ≤ PSD-FD=Of PCSI-RS) is a SD-FD basis selection matrix***
* ***Note that PCSI-RS is the number of CSI-RS ports.***

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| Company | Comments |
| vivo | Support Alt 3-0.From the perspective of UE complexity, specification impact and CSI overhead, we think port selection is more acceptable than basis selection.We think this should be discussed after the outcome of proposal 3 and proposal 5 because the method to convey SD-FD bases on CSI-RS ports and signalling may influence the report structure. |
| Nokia/NSB | Support.In our understanding, down-selection, if any, between the two alternatives will happen after discussing Proposal 3.Note that Alt 5 includes Alt 3-0 for . |
| Futurewei | Support FL’s proposal. |
| OPPO | We are fine with the proposal. |
| Lenovo/MotM | Support Alt 3-0. Agree with VIVO regarding the ordering of proposals |
| Spreadtrum | We can support FL proposal. We also think the down selection should be made after deciding whether multiple SD-FD bases can be mapped into one port or not. |
| DOCOMO | Support FL’s proposal |
| Intel | We support Alt 3-0. We are open to discuss CSI-RS optimisation (e.g. reduction of CSI-RS density) instead of Alt. 5 since we believe that it is a cleaner way to achieve the same goals. |
| LG | Support Alt 3-0. |
| ZTE | If we need to do down-selection for Alt 3-0 and Alt 5, we should clarify this in the main bullet. |
| MediaTek | Support Alt 3-0. We think that there needs to be a mechanism of conveying to the UE about which CSI-RS ports (SD-FD pairs) correspond to unique SD bases because it is only possible to linearly combine unique SD bases to form a layer. The UE has to know this information to compute the port selection matrix and linear combination coefficients. |
| Qualcomm | Similar view as Intel. Additionally, even for CSI-RS optimization, RAN1 should justify the gain with clear benefit before specifying any enhancement. We also think proposal 1, 4 and 5 should have high priority than proposal 2. |
| Fraunhofer IIS, Fraunhofer HHI | Support the proposal for down-selection between ALT3-0 and ALT5. |
| Apple | Support Alt 3-0Do not support Alt 5 |
| Ericsson | We only support Alt 3-0. Note that different taps within one beam can be assigned to different ports, therefore W1 in Alt 3-0 can also be viewed as pair selection matrix with one pair per port. We don’t support Alt 5 as an option. Alt 5 has major specification impact and does not provide significant gain over, for example, having multiple FD bases (which has no spec impact). Our evaluations show that the benefit is at most 5%, which doesn’t warrant the specification efforts of extending the 3GPP antenna port definition  |
| Samsung | Not supportive, also same view as QCM and others, we should discuss this after we discuss Proposal 1 and Proposal 3 |

### 2.1.3 Mechanism to convey SD-FD beamforming bases using CSI-RS ports

In RAN1#103e meeting, there are intense discussion on mechanism to convey SD-FD beamforming bases using CSI-RS ports and association mechanism.

* **CSI-RS overhead:** Based on tdoc review, companies (e.g. Nokia, Nokia Shanghai Bell, MTK, Sony, vivo, DCM, CATT, Intel, ZTE) think reduction in CSI-RS overhead is needed for R17 PS CB. Moreover some companies’ (e.g. Intel, ZTE, Huawei, HiSilicon, China Unicom, QC, Nokia, Nokia Shanghai Bell) simulation results show that performance gain can be observed if some solution(s) can be used to reduce the CSI-RS overhead.
* **CSI-RS Configuration:** Some companies (Nokia, Nokia Shanghai Bell, Huawei, HiSilicon, China Unicom) propose some solution(s) to support more flexibility CSI-RS configuration.
* **More than 32 SD-FD pairs:** whether supporting larger than 32 SD-FD pairs for Rel-17 PS codebook, companies’ views are not converging. Based on performance gain from SLS simulation results, some companies (e.g. ZTE (~4%), CATT (2%~6%), vivo(~3%)) support more than 32 SD-FD pairs. On the other hands, some companies (e.g. OPPO (marginal gain), Fraunhofer IIS, Fraunhofer HHI, LG Electronics) think there is no need to support more than 32 SD-FD pairs or depending on further evaluation results.

Based on above motivations, more than 10 companies show their solutions over this issue this meeting as following:

**Table 2 Summary** **on mechanism****to convey SD-FD beamforming bases using CSI-RS ports**

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| **Views** | **Companies** |
| **Option 1** (6) | QC, Nokia, Nokia Shanghai Bell, Intel, Apple, Sony |
| **Option 1 + Option 2** (4) | QC, Huawei, HiSilicon, China Unicom, Nokia, Nokia Shanghai Bell |
| **Option 1 + Option 3** (6) | QC, Huawei, HiSilicon, China Unicom, CATT, ZTE |
| **Option 4** (9) | DCM(FDM), Nokia, Nokia Shanghai Bell, Huawei, HiSilicon, China Unicom, ZTE(FDM),vivo, Spreadtrum |

* **Option 1:** single CSI-RS resource with single CSI-RS pattern per resource and lower CSI-RS density, e.g. 0.25. For this option, it can be used to reduce CSI-RS overhead without sacrificing Rel-17 PS codebook performance.
* **Option 2:** single CSI-RS resource with multiple CSI-RS patterns per resource and normal CSI-RS density. For this option, it can be used to provide higher CSI-RS resource configurations, and potentially support more than 32 SD-FD pairs.
* **Option 3:** multiple CSI-RS resources associated with one CSI report configuration. For this option, it can be used to provide higher CSI-RS resource configurations, and potentially support more than 32 SD-FD pairs.
* **Option 4 (**multiple FD-SD bases per CSI-RS port):This option can be used to provide more flexible CSI-RS resource configurations, and potentially support more than 32 SD-FD pairs. There are two understanding depending on specific codebook structure:
* **Alt 2/5:** (), single CSI-RS resource with single CSI-RS pattern per resource and normal CSI-RS density (e.g. DCM, Nokia, Nokia Shanghai Bell, ZTE)) so that the selection of FD-SD bases per port can be conveyed by reporting.
* **Alt 3-0/3-1:** () and *()*, single CSI-RS resource with single CSI-RS pattern per resource and normal CSI-RS density (e.g. vivo, Spreadtrum) so that the selection of FD-SD bases per CSI-RS port can be conveyed by reporting.

Based on above companies’ views, the following proposal is suggested:

***Proposal 3: For PS codebook enhancements utilization DL/UL reciprocity of angle and/or delay, support one or a combination of following enhancements for CSI-RS configurations associated with Rel-17 PS codebook:***

* + ***Option 1: Support configuring a lower CSI-RS density per CSI-RS resource, e.g. 0.25***
	+ ***Option 2:upport configuring one or multiple CSI-RS patterns per CSI-RS resource associated with Rel-17 PS codebook***
	+ ***Option 3:Support configuring multiple CSI-RS resources per CSI reporting configuration associated with Rel-17 PS codebook***
	+ ***Option 4:***
		- ***W1∈ N^{PSD-FD × K2} (K2 ≤ PSD-FD=Of PCSI-RS), single CSI-RS resource with single CSI-RS pattern per resource and normal CSI-RS density***
		- ***W1 ∈ N^{PCSI-RS × K1} (K1 ≤ PCSI-RS )and Wf ∈ N^{N3 × Mv} (PSD-FD=Of PCSI-RS, Mv ≤ Of ), single CSI-RS resource with single CSI-RS pattern per resource and normal CSI-RS density.***

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| --- | --- |
| Company | Comments |
| vivo | Support Option 4Firstly, we need to clarify the understanding of SD-FD basis. In our view, one CSI-RS port only conveys one SD-FD basis or one SD basis. According to the ***PCSI-RS*** bases conveyed on ***PCSI-RS*** CSI-RS ports and additional indication from gNB, UE can acquire ***PSD-FD*** SD-FD bases, where ***PSD-FD > PCSI-RS***. The indication details can be discussed in section 2.1.5.With gNB indication, there can be only one SD-FD basis on each CSI-RS port and the SD-FD basis may be just a SD basis like in Rel-16. In this method, the number of CSI-RS ports needed is much less and the CSI-RS config including CSI-RS resource, density and pattern remains unchanged. |
| Nokia/NSB | Support.(Preference for Option 2+1 and 4-first bullet, as they offer RS overhead reduction and full flexibility in CSI-RS configuration)Second bullet of Option 4: we propose to remove this bullet, as seems in contradiction with Proposal 1 where is DFT matrix, not selection matrix. From vivo’s comment, they propose selection and reporting of additional FD components for each port, which is applicable to Option 1, 2 and 3, so the second bullet of Option 4 is not needed for their proposal. |
| Futurewei | Support FL’s proposal. |
| LenovoMotM | We have concerns regarding this proposal since the WID was limited to new/modified codebook design, and not CSI-RS configuration enhancements. Option 2 and Option 3 require less spec impact compared with Option 4, however |
| Spreadtrum | Support FL proposal. And further support Option 4. It’s natural that there’re multiple SD-FD bases within one port before UE conducts FD compression. Since multiple SD-FD bases can be differentiated in SD and/or FD basis domain, gNB can map different SD-FD bases into the same REs of one port on purpose. This is not about codebook structure, both R15 and R16 codebook structures can be feasible, and for R16 codebook structure, can be either port selection matrix or DFT matrix. For example, if UE was indicated/pre-defined FD basis location, is a port selection matrix. If a seach window for FD basis location was indicated/pre-defined, is a DFT matrix. |
| DOCOMO | Support FL’s proposal. In particular, Option 4 is preferred |
| CATT | Ok with the FL proposal. Agree with Nokia that the second bullet of Option 4 can be removed.Supporting more than 32 SD-FD pairs shall be listed and iscussed. Among companies providing evaluation results, majority think it is nessary to support more than 32 SD-FD pairs. |
| Intel | From our evaluation results we see that some minor performance improvement can be achieved by using 0.25 CSI-RS density (Option 1), however we are not convinced if Option 2-4 are needed. In our view the following option should be also considered “Option 0: No enhancements” (we understand that it is always considered, however it is better to explicitly point it out). |
| LG | Option 1/2/3 can be discussed regardless of decision of Proposal 1/2. However, it seems that Option 4 is related to specific codebook structure, e.g., Alt 5. So, we prefer to discuss this proposal after the decision on Proposal 1/2, i.e., baseline codebook structure.  |
| ZTE | We support Option 3 and Option 4.Further, we think the WID clearly defines that it is only for CSI reporting, Any change on the existing CSI-RS should not be considered in the scope. The enhancement on this particular item should be focused on how UE does the reporting only. This should be the most important criterion to consider candidate options. |
| Qualcomm | We think RAN1 should first finalize codebook enhancements, e.g., proposal 1, 4, and 5, W2 quantization, high-rank, UCI, CSI omission, etc.Regarding WID scope mentioned by ZTE, in our view, the motivation of this proposal is reducing CSI-RS overhead, all the options have more or less impact to CSI-RS in a way or another (option 4 is an implicit changing of CSI-RS pattern as a port has to be treated as multiple ports; option 3 does not reduce overhead without option 1). So, it seems that this proposal and Alt2/5-0 should be out of scope. But if there is a consensus in studying the CSI-RS overhead and a consensus in the need of doing optimization, we should open the door to all options.Regarding the options, we share similar view as Intel. All options achieve same functionality (option 1 has same overhead as option 4, option 1 + 2/3 achieves same pattern as option 3), but option 1 is cleaner than option 2/3 and much cleaner than option 4. Besides, we are not fully convinced that density 0.25 could provide substantial benefit compared to 0.5. CSI-RS beamforming using > 32 pairs/ports should be considered out of the scope, because it increases network and UE complexity dramatically and it needs justification from realistic deployment.  |
| Apple | We can support option, we do not see a need for Option 2/3/4 |
| Nokia/NSB | @Intel, QC, Apple: Option 1 alone can achieve the same density per SD-FD basis than Option 4, but from network perspective, it does not provide the same RS configuration flexibility in terms of number of UEs that can be scheduled in the same slot (see Fig. 3 in our tdoc, for example). However, combining Option 1+2 adds similar flexibility as Option 4: for example, Option 1+2 with density 0.25 distributes 32 ports in 4 consecutive PRBs, in groups of 8 ports, by using 4 patterns, instead of occupying 32 REs in a single RB. Hence the network can schedule up to 15 such resources (and 15 UEs) in the same slot, like with Option 4.Regarding the performance gain of these schemes, CSI-RS overhead should be included in the UPT calculation to appreciate the benefit. |
| Ericsson | Support option 3 as it allows reduced UE and gNB complexity since CSI-RS ports can be spread out more in time. We don’t see the significant benefits of Option 4 and it can thus be removed from this proposal. Besides “Of” larger than 1 is already discussed under Proposal 2, it is confusing to discuss the same proposal in two different proposals as it creates causality issues. Our suggestion is to focus on the CSI-RS related options 1,2 and 3 in this Proposal |
| Samsung | Not supportive. We observe performance loss with (Assuming FDM), provided in our Tdoc. In addition to the performance loss, we have concern about potential spec-impact, UE implementation, and the unclear need for supporting large #SD-FD bases. In our view, the CSI-RS overhead reduction can also be achieved by gNB implementation. |

### 2.1.4 Polarization common or specific for selection of

For the selection matrix, i.e. being polarization common or specific, a number of companies have provided their views shown in Table 3.

**Table 3 Summary** **on Polarization common or specific for W1**

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| **Views** | **Companies** |
| **Polarization-common** | * **CATT**: polarization-common achieves better tradeoff between performance and overhead
* **Sony**: For minimum specification impact, maintain the polarization-common mechanism of Rel-15/Rel-16. A polarization-specific mechanism should only be introduced if it provides substantial advantage over polarization-common.
* **Lenovo, Motorola Mobility**: Polarization-common port selection and polarization-specific coefficient quantization. In Rel-16, It was shown that the gains achieved due to polarization-specific beam selection is negligible.
 |
| **Polarization specific** | * **MTK:** W1 is a free port selection matrix to choose L ports out of P CSI-RS ports in a polarization specific manner
 |
|  |  |

***Proposal 4: For PMI quantization/reporting over in Rel-17 PS codebook, support one of following options:***

* ***Option 1: Polarization common selection***
* ***Option 2: Polarization specific selection***

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| --- | --- |
| Company | Comments |
| vivo | Support Option 1. |
| Nokia/NSB | Ok with this proposal |
| Futurewei | Support FL’s proposal. |
| OPPO | Maybe our contribution is not correctly interpreted. Our intention is to support polarization specific selection for W1W2 or support polarization common selection for W1W2Wf^H following Rel-16 mechanism. Hence Option 3 can be deleted and option 1 and option 2 is sufficient for further down-selection.  |
| Lenovo/MotM | Support Option 1. A similar study was done for Rel. 16 Type-II codebook and it was found that polarization-common design achieves efficient performance/overhead tradeoff. No justification on why we should deviate from this design for the new codebook |
| Spreadtrum | Support FL proposal and further support Option 1. |
| DOCOMO | Support FL’s proposal |
| CATT | Ok with FL proposal and support Option 1. |
| Intel | OK |
| LG | Ok with proposal  |
| MediaTek | Support the proposal with a preference for Option 2. |
| Fraunhofer IIS, Fraunhofer HHI | Support this proposal for further down-selection.  |
| Apple | Prefer Option 1 |
| Ericsson | Support FL proposal although we need to discuss how to evaluate this. We may need to look at channel measurements as the 3GPP channel model doesn’t capture this. |
| Samsung | OK |

### 2.1.5 Configured/indicated to UE and/or selected/reported by UE of

Companies (e.g. Nokia, Nokia Shanghai Bell, OPPO, vivo, LG Electronics, Lenovo, Motorola Mobility) have considered that based on the delay reciprocity between UL and DL, gNB can configure/indicate few DFT vectors to UE and then UE select/report some DFT vectors for . Therefore, mechanism of configured/indicated to the UE and/or mechanism of selected/reported by UE for should be discussed here, as the FFS point listed in RAN1#103e meeting.

Based on tdoc review, some companies provide detail considerations on mechanisms of configured/indicated to the UE and/or mechanisms of selected/reported by UE for , which is shown as following.

* Nokia, Nokia Shanghai Bell: is a N3×Mν DFT-based compression matrix and the Mν components are network configured or selected and reported within a configured window of size N.
* MTK: When M>1 delay taps are pre-compensated by the gNB using precoded CSI-RS in each of the P beams, gNB can use MP DFT FD bases for CSI-RS precoding and indicate the offset of the remaining M-MP FD bases via dynamic signaling to the UE
* QC: If RAN1 decide to support three-stage codebook ( ), support joint configuration and capability signaling of combination of {number of CSI-RS ports per resource, number of FD bases per port}.
* Sony: Introduce an FD sampling size parameter . Based on UL CSI, further restrictions to can be applied in order to limit the set of FD DFT vectors eligible by the UE

Based on the views provided by companies on this issue, following proposal is suggested:

***Proposal 5: Studying following mechanisms of configured/indicated to the UE and/or mechanism of selected/reported by UE for Wf***

* ***For mechanisms of gNB configured/indicated to the UE for Wf***
	+ ***Option 1: gNB can indicate selected FD bases used for Wf quantization via dynamic signaling***
	+ ***Option 2: The FD bases used for Wf quantitation limited within a window/set of size N can be configured by gNB***
	+ ***Option 3: The number of CSI-RS ports and the value of Mv is jointly configured per codebook parameter combination***
* ***For mechanisms of selected/reported by UE for Wf***
	+ ***Option 1: [if any]***

***Other enhancements are not excluded.***

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| Company | Comments |
| vivo | Support Option 1 and 2.In our understanding, the main purpose of gNB indication is to reduce the CSI overhead and UE complexity, and also support a larger R. In Option 1, the selected FD bases are directly indicated by gNB so there is no need to report any FD basis information and Wf completely follows the gNB indication. This method is for good delay reciprocity cases while the performance may be influenced when delay reciprocity is getting poor. In that case, a window can be configured by gNB for FD basis selection by UE in a limit. Therefore, we think both FD basis indication by signaling and a pre-configured window can be supported for gNB to select according to channel quality. Also, the pre-configured window can be updated by signaling. |
| Nokia/NSB | Support with the following addition to Option 2.* ***Option 2: The FD bases used for Wf quantitation limited within a window/set of size N and initial point can be fixed/configured/indicated by gNB***

(Preference for Option 2)Option 2: In case the components are selected and reported by the UE, is the configured window size and is the initial point of the set of FD components a UE can choose from. This is similar to the window mechanism in Rel16 for where the window has fixed size and is reported by the UE, with the difference that now the window parameter are all determined at the gNB. and can be of fixed value, configured or indicated by the gNB.As noted by vivo, this window mechanism may be useful for relatively large delay uncertainty and/or few available ports available to accommodate FD precoding and/or R=2,4 for which can be large.By applying different values to different UEs, it is also possible to multiplex UEs in the same ports, effectively sharing CSI-RS ports between 2 or more users. For example, with R=2, the network may configure one UE on the first half FD-components and a second UE on the second half. With R=4, up to 4 UEs may share the same ports in this way, by configuring a different for each of them. |
| Futurewei | Support FL’s proposal. |
| OPPO | Fine with the proposalOur preference is option 2. Support with the following addition to Option 2.* ***Option 2: The FD bases used for Wf quantitation limited within one or multiple window/set of size N and initial point can be fixed/configured/indicated by gNB***

Multiple window can be used to support multiple pairs per port if gNB beamforming in CDM-like approach. N = 1 can be a special case. |
| Lenovo/MotM | Support Option 2. Window size can be gNB configured but *M*initial should remain UE indicated to account for phase offset at UE. In general, the overhead of reporting *M*initial is only a few bits, so it is not reasonable to accommodate any performance degradation incurred from not reporting it |
| Spreadtrum | We prefer minimizing UE complexity in this feature. The FD bases candidates should be pre-determined without UE searching, and the number of configured/indicated FD bases candidates should be small. Therefore, Option 3 is supported, and Option 1 can be acceptable.For mechanisms of selected/reported by UE for Wf, we can discuss after mechanisms of gNB configured/indicated to the UE for Wf are decided. |
| CATT | Option3 shall be removed first as it is not a solution for indicating/configuring Wf to UE. The combination of codebook parameter can be discussed later after the codebook structure is decided. |
| Intel | We are fine to study listed options further. Currently our preference is option 2. |
| LG | We are fine to FL’s proposal.  |
| ZTE | The codebook structure should be defined first before discussing this proposal. |
| MediaTek | Support the proposal with a preference for configured/indicated to the UE Option 1. |
| Fraunhofer IIS, Fraunhofer HHI | We prefer to discuss this proposal after proposal 1&2. |
| Ericsson | Support the proposal. |

## Others

Remaining proposals for Rel-17 Port Selection Codebook Enhancements are also listed as follows for reference.

|  |  |  |
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| **Issues** | **Companies** | **Views** |
| **SRSSpreadts****s**Higher Rank | Nokia, Nokia Shanghai Bell | • In case of multiple layers, the bitmap size is multiplied by the reported rank ν |
| Fraunhofer IIS, Fraunhofer HHI | • Study identical port selection for a subset of transmission layers. |
| Others | Ericsson | • Study the order for SVD and port-selection operations, by taking into account the trade-off between UPT, overhead and UE complexity. |
| Lenovo | • Aperiodic SRS triggering is needed in conjunction with the beamformed CSI-RS for the reciprocity-based codebook, with a limited time gap between the transmission of both RSs• Configure the UE with two frequency compression parameter values for both strong and weak channel reciprocity, where the UE can select the appropriate parameter value based on the strength of the channel reciprocity |
| Samsung | • For the study of Rel. 17 codebook alternatives, use Rel. 16 reg. T2 CB as a reference performance, in addition to the Rel. 16 PS T2 CB “baseline” |
| Apple | • Do not introduce SD-FD pairing• For CSI enhancement utilizing partial reciprocity of DL/UL channels, more flexible wideband and subband CSI reporting configuration can be considered |
| CATT | • The bandwidth and density of SRS is configured as same as that of CSI-RS to obtain accurate delay information of uplink channel.• Non-zero coefficients are indicated by using port indication information. |
| Vivo | • Enhance procedure on timing calibration to counteract the timing mismatch between gNB and UE for FDD CSI enhancement |
| sony | • Non-Kronecker SD-FD bases shall be introduced in Rel-17 only if they are shown to offer a better tradeoff among UE complexity, performance and reporting overhead compared to Rel-16.• Based on UL CSI, further restrict the set of CSI-RS ports eligible by the UE to those compatible with UL signal angles.• For FDD systems exploiting DL/UL channel reciprocity, the UE can signal to the gNB the DL covariance matrix of noise and interference. The ways of transferring this information from the Ues to the gNB need to be further studied and specified.• Companies should study the feasibility of signaling to the Ues the set of CSI-RS beams actually used for co-scheduled transmissions. An indication from the UE to the gNB of those beams suppressed by the UE should also be studied. |

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| Company | Comments |
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# Summary of CSI enhancement for Multi-TRP

## CSI Measurement Enhancements for Multi-TRP

### Issue 1: how to configure CMRs in the same resource set for NCJT hypothesis

In last meeting, it is agreed that for CSI measurement associated to a reporting setting, CMRs in a given resource set are associated to different TRPs/TCI states at resource level. When the UE is configured with a group of CMRs associated with different TCI states, one remaining issue is that to determine a CMR pair used for CSI measurement with a NCJT hypothesis. Based on tdoc review, roughly three reference design can be considered as following:

* Option 1 (OPPO[3], Huawei/HiSilicon/China Unicom[4]): For CSI measurement associated to a reporting setting for NCJT, only 2 CMRs are configured in a CMR set and corresponds to a NCJT hypothesis.
* Option 2 (ZTE[5], Nokia/Nokia Shanghai Bell[16], Qualcomm[20]): *N* CMR pairs in the CMR set can be configured to UE. Each CMR pair corresponds to a NCJT hypothesis. The CMRs in the CMR set are divided into 2 or more groups by certain configuration, and a pair of CMRs within different groups construct a NCJT hypothesis.
* Option 3 (FutureWei[1]): The UE can select and determine whether one CSI-RS resource is for CM, IM or muting for CSI measurement under a NCJT hypothesis. The selection and function determination of one CMR pair is to be reported within the CSI reporting.

***Proposal 6: For CSI measurement associated to a reporting setting CSI-ReportConfig for NCJT, the UE can be configured with Ks ≥ 2 NZP CSI-RS resources in a CSI-RS resource set for CMR, whereas***

* ***If Ks = 2, both NZP CSI-RS resources are used for a NCJT measurement hypothesis.***
* ***If Ks > 2 , N ≥ 1 NZP CSI-RS resource pairs are configured to UE by high layer signalling whereas each pair is used for a NCJT measurement hypothesis, with following configuration mechanisms:***
	+ ***Alt.1: Configure UE with N NZP CSI-RS resource pairs within a CMR resource set explicitly, whereas the first th and th CMRs in the set are the nth CMR pair for a NCJT hypothesis () and the rest of CMRs are for single-TRP measurement hypotheses.***
	+ ***Alt.2: The CMR pairing is indicated by a bitmap.***
	+ ***FFS maximal values of N and Ks***

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| --- | --- |
| Company | Comments |
| vivo | In our view, at least in FR1, the CMR used for NCJT hypothesis measurement can reused for STRP hypothesis measurement to simply UE measurement, i.e., UE needn’t perform separate channel estimation for a CMR configured for both NCJT and STRP hypotheses. Secondly, common CMR configuration between CSI enhancement and group-based beam reporting is highly desired, while Alt.1, i.e., CMR pair-wise configuration, cannot be applied to group-based reporting. In our view, CMR one-to-one mapping between two configured groups is a more appropriate way. Therefore, modify the proposal as follows:***Proposal 6: For CSI measurement associated to a reporting setting CSI-ReportConfig for NCJT, the UE can be configured with Ks ≥ 2 NZP CSI-RS resources in a CSI-RS resource set for CMR, whereas*** * ***If Ks = 2, both NZP CSI-RS resources are used for a NCJT measurement hypothesis.***
* ***If Ks > 2 , N ≥ 1 NZP CSI-RS resource pairs are configured to UE by high layer signalling whereas each pair is used for a NCJT measurement hypothesis, with following configuration mechanisms:***
	+ ***Alt.1: Configure UE with N NZP CSI-RS resource pairs within a CMR resource set explicitly, whereas the first th and th CMRs in the set are the nth CMR pair for a NCJT hypothesis () and the rest of CMRs are for single-TRP measurement hypotheses.***
	+ ***Alt.2: The CMR pairing is indicated by a bitmap.***
	+ ***Alt.3: configure UE with two CMR groups within a CSI resource set, applying one-to-one mapping of CMRs between two groups CMRs for STRP can come from the two groups.***
	+ ***FFS maximal values of N and Ks***
 |
| Nokia/NSB | Support with the following clarification for Alt 2* + ***Alt.2: The CMR pairing is RRC configured and/or indicated (MAC-CE) by a bitmap.***

(Preference for Alt 2)Alt 2 provides a mechanism for the network to dynamically restrict the CMR pairs for NCJT measurement in a CSI Reporting Setting. In absence of network indication, a default set of CMR pairs may be included in the Reporting Setting. This mechanism may be useful, for example, if the network can estimate candidate beam pairs from UL channel measurement and use this information to restrict the NC-JT hypotheses configured for UE measurement. |
| QC | We support Alt1 in principle. We prefer a slight modification that the first CMRs (first ) are sTRP and the remaining CMRs construct NCJT hypotheses. This results in CRI codepoints to be firstly mapped to sTRP hypotheses and then to the mTRP hypotheses, which is more natural and consistent with Rel. 15.With Alt2, it should be clarified if number of sTRP hypotheses are always Ks or not (irrespective of bitmap). If yes, then we lose the ability to have CMR pairs that are not individually configured for sTRP hypotheses (this is important in FR2). In Alt1, both are possible: Whether to reuse sTRP CMRs (by configuring the same CSI-RS ID in the resource set) or configuring new CMRs. Note that with Alt1, CPU/resource/port occupations are naturally taken care of. For Alt2, we suggest including the following as a sub-bullet of Alt2. Otherwise it becomes unacceptable to us:**Each pair of CMRs occupies two CPUs, two active resources, and a number of active ports corresponding to both CMRs. These numbers are separate from CPU/resource/port occupation corresponding to each of the two CMRs when considered individually.**  |
| CATT | One question for clarification: with Alt.1, if a resource is included in a group for NC-JT hypothesis, can this resource be used for single-TRP CSI reporting?In addition to the above two alternatives, we would like to include one more alternative.Alt 3: The CMRs can be divided into two groups, each group corresponds to one of TRPs. CMR can be paired and reported with CRI by UE. |
| Futurewei | Not support this proposal in its current form. For the case listed in the second sub-bullet (***Ks > 2),*** it would require larger number of pairs to be configured to the UE to cover all the possible NCJT measurement hypothesises, or some of the hypothesises with good performance might be missed. We would like to modify the second sub-bullet as follows:* ***If Ks > 2 , N ≥ 1 NZP CSI-RS resource pairs are determined by UE, or configured to UE by high layer signalling, whereas each pair is used for a NCJT measurement hypothesis. If the N ≥ 1 NZP CSI-RS resource pairs are configured to UE by high layer signalling, the following configuration mechanisms are supported:***
	+ ***Alt.1: Configure UE with N NZP CSI-RS resource pairs within a CMR resource set explicitly, whereas the first th and th CMRs in the set are the nth CMR pair for a NCJT hypothesis () and the rest of CMRs are for single-TRP measurement hypotheses.***
	+ ***Alt.2: The CMR pairing is indicated by a bitmap.***

***FFS maximal values of N and Ks*** |
| OPPO | With the enhancement on beam reporting for M-TRP being discussed in 8.1.2.3, we don’t think *Ks*>2 is needed here. If *Ks*>2 is agreed in RAN1, we agree with vivo that the CMRs for NC-JT measurement can also be used for single-TRP measurement hypotheses. We support to add Alt.3 from vivo and the following Alt.4:***Alt.4: grouping the NZP CSI-RS resources within a CMR resource set into two resource groups, each associated with a TRP, with an implicit mapping between the resources in the two groups for NC-JT measurement. The resources within the two groups are respectively used for single-TRP measurement hypotheses of each TRP.*** |
| Lenovo/MotM | Support FL proposal. Regarding the case with *K*s>2 with 2 CMR groups, we suggest introducing a limit *Ks*≤4, and also allow for non-exclusive CMR pairing, e.g., for *Ks*=4, the case where the first CMR group has 1 CMR and the second CMR group has 3 CMRs (allowing up to 3 NCJT hypotheses with one TRP common in all hypotheses) should not be precluded |
| NEC | We share similar view with vivo and CATT, and we are OK with alt 3 either from vivo or CATT. |
| DOCOMO | Different alts are added by different companies. And we think it is because following discussion points should be clarified first.1. Whether the configured CMR pair(s) used for NC-JT hypothesis can be assumed as CMR(s) for S-TRP hypothesis or not.
	1. If yes, whether additional CMR(s) for S-TRP should be configured or not.
	2. If no, additional CMR(s) for S-TRP should be configured.
2. CMR pairing for NC-JT hypothesis should be configured. Whether the CMR pairing is explicitly configured (e.g., Alt.2) or implicitly linked (e.g., Alt.3/4). How to configure the CMR pairing for NC-JT and CMRs for S-TRP (if supported) in a resource setting.

The detailed signalling format is related to the outcome of Issue (1). |
| Intel | We share the same view with vivo, CATT and NEC: it is important to reuse the CMR for NCJT and STRP to decrease UE complexity, otherwise there is no point to configure CMRs in one ReportConfig other than decreased overhead if downselection is done at the UE. Also, at least for discussion it is important to understand which particular scenarios are covered by the case with Ks > 2. In our view the following scenarios can be considered: 1) >2 TRP with one beam per TRP; 2) 2 TRP with multiple beams per TRP. |
| LG | We also think CMR used for STRP hypothesis measurement can be reused for NCJT hypothesis measurement. For this purpose, it seems that explicit configuration (from vivo) and/or implicit mapping rule (from OPPO) for grouping of CMRs can be a starting point for further discussion.  |
| ZTE | For the new Alt.3 suggested by vivo/CATT and Alt.4 suggested by OPPO, we are unclear how this two new alternatives can work in FR2.As shown in the figure for FR2, if beam 1 and 5 are a pair, UE should simultaneously use two corresponding receive beams (namely as r1 and r5) to measure both resource 1 and resource 5 for inter-beam interference. If beam 1 and another beam can also be allowed for pairing, e.g. beam 1 and beam 7 can also be paired, UE should simultaneously use two corresponding receive beams namely as r1 and r 7 to measure both resource 1 and 7 for inter-beam interference between beam 1 and 7. In such case, how could UE simultaneously uses r1 and r5 , and also simultaneously uses r1 and r7 to measure resource 1?Thus, in FR2, once one resource is configured within one pair, it cannot be present within another pair. Further, once the resource is configured for NCJT, it cannot be for STRP anymore since UE has used the two receive beams. ***Observation :*** *Alternative 3 and 4 do not work in FR2*In FR1, one resource can be configured for both NCJT and STRP. Then the above alternative 3 and 4 can work. However, as QC mentioned, the flexibility will be lost. Since all Ks resources are always mandated for STRP measurement even gNB does not need all resource measurement for STRP in some cases. In the current FL proposal, the first sub-bullet seems one extreme case of the second sub-bullet. Based on the second sub-bullet, if Ks = 2, N=1, it will be the same as the first sub-bullet. Further, it is also possible that N = 0, then all CMRs are not paired, and just for single-TRP transmission as Rel-15/16. Thus, our suggested wording is as follows. ***Proposal 6: For CSI measurement associated to a reporting setting CSI-ReportConfig for NCJT, the UE can be configured with Ks ≥ 2 NZP CSI-RS resources in a CSI-RS resource set for CMR, whereas*** * ***.***
* ***N ≥ 1 NZP CSI-RS resource pairs are configured to UE by high layer signalling whereas each pair is used for a NCJT measurement hypothesis, with following configuration mechanisms:***
	+ ***Alt.1: Configure UE with N NZP CSI-RS resource pairs within a CMR resource set explicitly, whereas the first th and th CMRs in the set are the nth CMR pair for a NCJT hypothesis () and the rest of CMRs are for single-TRP measurement hypotheses.***
	+ ***Alt.2: The CMR pairing is indicated by a bitmap.***
	+ ***FFS maximal values of N and Ks***
	+ ***If N = 0, all Ks CMRs ar for single-TRP measurement hypotheses***
 |
| MediaTek | Even if *Ks* = 2, we should still allow single-TRP hypotheses. We prefer a unified design for both *Ks* = 2 and *Ks* > 2. For hypothesis signalling, we may consider Alt. 3: **Alt. 3: Configure two CRI codepoint-to-resource(s) mappings, one for NCJT measurement hypotheses and one for single-TRP measurement hypotheses.** The signalling overhead for Alt.1, 2, 3 are given by the following table, where *M* is the number of single-TRP hypotheses, *N* is the number of NCJT hypotheses, and *L* is total number of NZP CSI-RS resources:

|  |  |  |  |
| --- | --- | --- | --- |
|  | CMR signalling | single-TRP | NCJT |
| Alt. 1 | 0 | *M* ceil(log2(*L*)) | 2*N* ceil(log2(*L*)) |
| Alt. 2 | *Ks* ceil(log2(*L*)) | *M Ks* | *N Ks* |
| Alt. 3 | *Ks* ceil(log2(*L*)) | *M* ceil(log2(*Ks*)) | *N* ceil(log2(*Ks*(*Ks* -1)/2)) |

It can be checked that Alt. 3 outperforms Alt.2 for all *Ks* ≥ 2. To compare Alt. 1 and Alt. 3, we would like to make the following reasonable assumption since it is unclear to us why a CSI-RS resource is associated with NCJT but cannot be used for DPS/DPB: **If an NZP CSI-RS resource is associated with an NCJT measurement hypothesis, then it must be also associated with a single-TRP measurement hypothesis.** Thus, the number of single-TRP measurement hypotheses *M* should be equal to *Ks* and the table can be updated as

|  |  |  |  |
| --- | --- | --- | --- |
|  | CMR signalling | single-TRP | NCJT |
| Alt. 1 | 0 | *Ks* ceil(log2(*L*)) | 2*N* ceil(log2(*L*)) |
| Alt. 3 | *Ks* ceil(log2(*L*)) | 0 | *N* ceil(log2(*Ks*(*Ks* -1)/2)) |

Note that since *M* = *Ks*, the indices of single-TRP hypotheses can reuse the index order of CMR signalling. Then, we see that Alt. 3 has a smaller signalling overhead than Alt. 1. To summarize, Proposal 6 can be updated as ***Proposal 6: For CSI measurement associated to a reporting setting CSI-ReportConfig for NCJT, the UE can be configured with Ks ≥ 2 NZP CSI-RS resources in a CSI-RS resource set for CMR, whereas**** ***Each of the Ks­ NZP CSI-RS resources is implicitly indexed by its order in the CMR resource set.***
* ***Each of the Ks­ NZP CSI-RS resources is associated with a single-TRP measurement hypothesis.***

***A CRI codepoint-to-resource mapping is introduced for NCJT measurement hypotheses, where each codepoint is mapped to two of the Ks­ NZP CSI-RS resources and the mapping follows a similar design as SLIV.*** |
| Spreadtrum | We don’t understand the use case and necessities for Ks>2. Up to 2 TRPs are supported for NCJT. Ks=2 is enough for CSI for NCJT hypothesis, especially on top of beam pair reporting. In addition, even if there exists multiple NCJT pairs hypothesis, multiple CSI reporting could be configured. |
| Apple | We are fine with the proposal  |
| Nokia/NSB | We share similar view as expressed by vivo, CATT, NEC, Intel on the reuse of CMRs for both NCJT and STRP channel measurements. In Alt 1 the same resource needs to be configured twice if it is used for both measurements. Are these resources/ports counted twice even when the associated CSI-IM is the same? @QC: regarding the ability to configure CMR pairs that are not individually configured for STRP, the network can always configure an NCJT-only report. Besides, the same principle of an RRC bitmap can be used to restrict the STRP measurements.As for the resource/port/CPU count, these capabilities will be considered later in the discussion and adjustments are needed for both Alt 1 and 2. For example, for both Alt 1 and Alt2, the number of simultaneous CSI calculations also depends on the number of CSIs and the type of hypotheses configured in the report. As a general principle, we agree on an NCJT CSI counting twice towards the CPU count. |
| Ericsson | We have a similar view as vivo, CATT, NEC, Intel and others that the CMRs used for NC-JT CSI can also be used for sTRP CSI. As there are many alternatives being proposed for Ks>2, we suggest to further study and downselect the alternatives. Configuring N NZP CSI-RS resource pairs is only one option and there are two alternatives for this option. The alternatives proposed by VIVO and OPPO are not related to N NZP CSI-RS resource pairs in our understanding. In our view, a CMR resource set can contain multiple CMRs corresponding to different TRPs, and the UE may pair any of the two CMRs for NC-JT CSI. This is added as another option below. The revised proposal is as follows: ***Proposal 6: For CSI measurement associated to a reporting setting CSI-ReportConfig for NCJT, the UE can be configured with Ks ≥ 2 NZP CSI-RS resources in a CSI-RS resource set for CMR, whereas*** * ***If Ks = 2, both NZP CSI-RS resources are used for a NCJT measurement hypothesis, and the two NZP CSI-RS resources can also be used for sTRP CSI (if configured).***
* ***If Ks > 2 , further study the following options:***

***Option 1: N ≥ 1 NZP CSI-RS resource pairs are configured to UE by high layer signalling whereas each pair is used for a NCJT measurement hypothesis, with following configuration mechanisms:*** * + - * ***Alt.1-1: Configure UE with N NZP CSI-RS resource pairs within a CMR resource set explicitly, whereas the first th and th CMRs in the set are the nth CMR pair for a NCJT hypothesis () and the rest of CMRs are for single-TRP measurement hypotheses.***
			* ***Alt.1-2: The CMR pairing is indicated by a bitmap.***

***Option 2: When Ks>2 CMRs are configured in a resource set where each CMR corresponds to a different TRP, every pair of the CMRs can be considered for NC-JT measurement, and NC-JT CSI based on one of the pairs is reported. Any of the CMRs in the resource set can also be used for single-TRP CSI.******FFS maximal values of N and Ks*** |

### Issue 2: how to map CSI-IM resource(s) for NCJT hypothesis

Besides the CMR configuration for NCJT, another fundamental issue is the mapping rule of IMR. In Rel-15/16, the number of CMRs equals to the number of CSI-IM resources, and each CMR is resource-wise associated to a CSI-IM resource by the ordering of CMR and CSI-IM resource in the corresponding two resource sets. It means that each CMR and each CSI-IM resource pair corresponds to single CSI measurement hypothesis.

MTK and Qualcomm in [9][20] also propose to reuse the above principle in Rel-17, i.e., a CSI measurement hypothesis can correspond to a CMR (or a CMR pair) and also correspond to a CSI-IM resource. In addition, a CRI codepoint should determine a CSI hypothesis.

***Proposal 7: For CSI measurement associated to a reporting setting CSI-ReportConfig for a NCJT measurement hypothesis, support one-to-one mapping between a NZP CSI-RS resource pair for channel measurement and a CSI-IM resource for interference measurement***

* ***FFS QCL mapping between the NZP CSI-RS resource(s) for channel measurement and the CSI-IM resource(s) for interference measurement***

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| Company | Comments |
| vivo | In Rel-15/16, the number of CMRs equals to the number of CSI-IM resources so that there will be no spec change in QCL assumption on the IMR associated to a CMR. Of course, IMRs with same ID can be mapped to a CMR pair. We propose to reuse the above principle in Rel-17. Therefore, modify the proposal as follow:***Proposal 7: For CSI measurement associated to a reporting setting CSI-ReportConfig for a NCJT measurement hypothesis,*** ***Alt1: support one-to-one mapping between a NZP CSI-RS resource pair for channel measurement and a CSI-IM resource for interference measurement******Alt2: support one-to-one mapping between a NZP CSI-RS resource for channel measurement and a CSI-IM resource for interference measurement.**** ***FFS QCL mapping between the NZP CSI-RS resource(s) for channel measurement and the CSI-IM resource(s) for interference measurement***
 |
| Nokia/NSB | Agree with vivo.In case of Alt 2 in Proposal 6, no spec change is needed for CSI-IM: there is no need for additional CSI-IM resource mapping to CMR pairs because there are no separate resources configured for NCJT.***Proposal 7: For CSI measurement associated to a reporting setting CSI-ReportConfig for a NCJT measurement hypothesis,**** ***Alt 1:support one-to-one mapping between a NZP CSI-RS resource pair for channel measurement and a CSI-IM resource for interference measurement***
* ***Alt 2: use Rel-15/16 resource-wise association between CMR and CSI-IM resources***
* ***FFS QCL mapping between the NZP CSI-RS resource(s) for channel measurement and the CSI-IM resource(s) for interference measurement***
 |
| QC | Support the proposal. With Alt2 added by vivo/Nokia, how CSI-IM is configured for three hypotheses: CMR0 (sTRP), CMR1 (sTRP), {CMR0,CMR1} (NCJT)? This is illustrated below:In other words, how CSI-IM 0 and 1 can be used for the NCJT hypothesis? Note that NZP-IMR (NZP-CSI-RS for interference measurements) cannot be configured when number of CMRs is larger than 1. |
| CATT | For FR1, it’s reasonable to support one-to-one mapping between a NZP CSI-RS resource pair for channel measurement and a CSI-IM resource for interference measurement. However, for FR2, the same pair of beams as used for channel measurement are needed to measure interference. Therefore, to support Proposal 7, the CSI-IM resource for interference measurement needs to be configured with two beams. |
| Futurewei | Not support this proposal. This proposals would require larger number of pairs of NZP CSI-RS resource for channel measurement and CSI-IM resource for interference measurement to be configured to the UE to cover all the possible NCJT measurement hypothesises, resulting in larger CSI-RS/CSI-IM resource overhead and configuration signalling overhead, or some of the hypothesises with good performance might be missed, |
| OPPO | It should be clarified whether the CSI-IM resource(s) is also used for interference measurement of single TRP measurement hypothesis based on the NZP CSI-RS resource in the pair. |
| Lenovo/MotM | Support the updated proposal by vivo |
| DOCOMO | Generally, support the proposal.But better to clarify some issues on CMR configuration in Proposal 6 first, e.g., whether the configured CMR pair(s) used for NC-JT hypothesis can be used as CMR(s) for S-TRP hypothesis or not, whether additional CMR(s) for S-TRP should be configured or not. Then companies can understand the number of CSI-IM and the configuration signalling structure based on Proposal7. |
| Intel | In principle we support the proposal. |
| LG | Support the proposal. As commented by QC, if the same CMR can be used for both STRP and NCJT hypotheses, it is not clear how to use the same CSI-IM for both STRP and NCJT hypotheses. |
| ZTE | We basically support this proposal. However, the details of this proposal may depend on how the agreement of issue 1 is.  |
| MediaTek | Support the proposal. To save signalling overhead, we may introduce a new configuration where the same CSI-IM is assumed by all measurement hypotheses. UE may use the same panel or different panels for NCJT and how to apply the ‘typeD’ QCL assumption is up to UE implementation. For QCL mapping, we suggest to simply state in the specification that For one CSI reporting, when receiving CSI-IM resource(s) for interference measurement, the UE applies the QCL assumption(s) with respect to ‘typeD’ of the NZP CSI-RS resource(s) for channel measurement. |
| Spreadtrum | Support |
| Apple | What if we need to perform sTRP measurement, for example(CMR0, CMR1) -> CSI-IM0(CMR0, CMR2) -> CSI-IM1If we perform sTRP measurement on CMR0, what is the interference measurement?  |
| Nokia/NSB | @QC: there is no need to change the current resource-wise association between CMR and CSI-IM with Alt 2, because the inter-cell interference for the two TRPs is measured with two different QCL-Type D assumptions on either the same of two different CSI-IM resources. In fact, in your illustration CSI-IM resource 2 is also measured twice with two different spatial filters. |
| Ericsson | The modifications made by VIVO and Nokia can be used as starting point for further discussion/downselection. |

## CSI Reporting Enhancements for Multi-TRP

### Issue 3: Reporting mechanism

In last meeting, the following three alternatives on UE reporting mechanism are agreed for a CSI reporting setting for further discussion this meeting:

* Alt 1: the UE can be expected to report one CSI associated with the best single-TRP measurement hypothesis and one CSI associated with the best NCJT measurement hypothesis, if configured
* Alt 2: the UE can be expected to report one CSI associated with the best one among NCJT and/or single-TRP measurement hypotheses, if configured
* Alt 3: the UE can be expected to report two CSIs associated with the two best single-TRP measurement hypotheses associated with CMRs from two TRPs and one CSI associated with the best NCJT measurement hypothesis, if configured

**Table 4 Summary of Companies’ Views on CSI Reporting Mechanism**

|  |  |
| --- | --- |
| **Views** | **Companies** |
| **Alt 1** (12) | Huawei, HiSilicon, China Unicom, NEC (1st preference), MTK, CMCC, Qualcomm, Intel, Nokia, Nokia Shanghai Bell, Apple, DOCOMO |
| **Alt 2** (11) | OPPO, ZTE, Fraunhofer IIS, Fraunhofer HHI, LGE, Spreadtrum, MTK, CMCC, Qualcomm, Apple, vivo |
| **Alt 3** (9) | FutureWei, NEC(2nd preference), Lenovo, Motorola Mobility, Intel, Nokia, Nokia Shanghai Bell, Apple, Ericsson |

With regarding to Alt 1, UE can be expected to report one CSI associated with the best single-TRP measurement hypothesis and one CSI associated with the best NCJT measurement hypothesis. Even though this may increase the reporting overhead, two CSI reports can be helpful for gNB to make proper scheduling decisions (Qualcomm[20]). Alt. 1 can achieve a trade-off between the CSI reporting overhead and the flexible scheduling at gNB (Huawei/HiSilicon/China Unicom[4]) and therefore is preferred by 9 companies. However ZTE [5] points out that Alt.1 can be implemented by two CSI reporting where one is for sTRP hypotheses and the other is for NCJT hypotheses.

With regarding to Alt.2, one CSI report is from either one best TRP or NCJT, with the least overhead compared to other Alternatives. Nine companies support Alt.2. However the measurement hypothesis associated to the reported CSI is determined by the UE. It means that Alt.2 is pretty much up to the UE so that the gNB scheduling will follow the UE preference likely (Huawei/HiSilicon/China Unicom[4]).

With regarding to Alt 3, UE can be expected to report two CSIs associated with the two best single-TRP measurement hypotheses associated with CMRs from two TRPs and one CSI associated with the best NCJT measurement hypothesis. Alt 3 is actually a super set that can cover both Alt 1 and Alt 2 when “report a subset of the CSI report quantities” is supported (FutureWei [1]). In addition, Alt.3 can provide the best flexibility on the network side. So seven companies support Alt.3. However many companies have raised a concern for the feedback payload required by Alt.3.

Considering diverse views, here is proposed compromise, from FL perspective:

***Proposal 8: For a CSI report associated with a Multi-TRP/panel NCJT measurement hypothesis configured by single CSI reporting setting, the UE can be configured to report:***

* ***Up to two (can be 0) CSI associated with the best single-TRP measurement hypothesis and one CSI associated with the best NCJT measurement hypothesis***
	+ ***FFS omission of CSI associated with NCJT measurement hypothesis***
* ***One CSI associated with the best one among NCJT and single-TRP measurement hypotheses***
	+ ***FFS how to report recommended measurement hypothesis associated with that CSI report***

|  |  |
| --- | --- |
| Company | Comments |
| vivo | Support FL’s proposal.We prefer the second configuration, i.e., one CSI associated with the best one among NCJT and single-TRP measurement hypotheses |
| Nokia/NSB | Support |
| QC | We suggest to change “up to two” to “up to one”. We have a question for clarification: In the case that 2 CSIs associated with the best sTRP hypotheses are reported, is it up to the UE which two? For example if there are two TCI states from TRP1 (CMR0 and 1) and two TCI states from TRP2 (CMR2 and 3), can the UE report CSIs corresponding to CMR0 and CMR1 (same TRP) if they are the best? If yes, then what is the benefit? Furthermore, reporting more than one CSI for sTRP hypotheses seem to be a DPS enhancement (not necessarily related to NCJT; one could propose the same even for Rel. 15 CSI). Hence, we are not sure if this is in scope here. |
| CATT | We support Alt 3. |
| Futurewei | Support FL’s proposal. |
| OPPO | The proposal is unclear. For the first sub-bullet, is the case of one CSI associated with the best single-TRP measurement hypothesis refers to Alt.1, while two CSIs associated with the best single-TRP measurement hypothesis refer to Alt.3? |
| Lenovo/MotM | Support the FL proposal |
| NEC | Support the proposal. |
| DOCOMO | Support the FL proposal |
| Intel | Support the proposal |
| LG | Regarding the second bullet, we prefer the original wording captured in the previous agreement as follows.***One CSI associated with the best one among NCJT and/or single-TRP measurement hypotheses*** |
| ZTE | We have the same question as OPPO. We prefer only supporting Alt.2, but we can accept supporting both Alt.1 and 2. The wording suggestion is following***Proposal 8: For a CSI report associated with a Multi-TRP/panel NCJT measurement hypothesis configured by single CSI reporting setting, the UE can be configured to report:**** ***Two CSIs where one CSI associated with the best single-TRP measurement hypothesis and the other CSI associated with the best NCJT measurement hypothesis***
	+ ***FFS omission of CSI associated with NCJT measurement hypothesis***
* ***One CSI associated with the best one among NCJT and single-TRP measurement hypotheses***
	+ ***FFS how to report recommended measurement hypothesis associated with that CSI report***
 |
| MediaTek | We support QC’s suggestion and are fine with ZTE’s version. |
| Spreadtrum | Generally fine with the proposal  |
| Apple | “Up to two” needs to be for further discussion. We need to first decide how many TRPs cannot configured in CMR |
| Ericsson | We have a concern with Alt 2. With Alt 2, scheduling flexibility is reduced as the gNB can only schedule based on what the UE reports for CSI. For instance, if the UE feeds back an NC-JT CSI, then the gNB can only schedule NC-JT based on the reported CSI. In this case, if one of the TRPs is not available to be scheduled to the UE, then the NC-JT CSI cannot be utilized for PDSCH scheduling. In our understanding the first sub-bullet includes both Alt 1 and Alt 3.From our perspective, Alt 3 provides the full flexibility, but we can accept Alt 3 and Alt 1 as a compromise. Our revised proposal is as follows:***Proposal 8: For a CSI report associated with a Multi-TRP/panel NCJT measurement hypothesis configured by single CSI reporting setting, the UE can be configured to report:**** ***Up to two (can be 0) CSIs associated with single-TRP measurement hypotheses and one CSI associated with the best NCJT measurement hypothesis***

***FFS omission of CSI associated with NCJT measurement hypothesis*** |

### Issue 4: whether to support 2 CQIs when RI 4

Four companies (Spreadtrum, CMCC, Samsung, Apple) propose that both Multi-DCI and single-DCI based transmission could be assumed and considered using single CSI reporting setting (Category 1). In Multi-DCI based NCJT, gNB can schedule two TB by TRPs independently, even when the total transmission layers is less than or equal to 4. Hence Spreadtrum, CMCC and Apple propose that for a CSI report associated with NCJT measurement hypothesis, the UE can be expected to report 2 CQIs.

***Proposal 9: For a CSI report associated with a Multi-TRP/panel NCJT measurement hypothesis configured by single CSI reporting setting, the UE can be expected to report:***

* ***one RI, one PMI, one LI and one CQI per TRP, up to 2 TRPs, for Multi-DCI based NCJT when the maximal transmission layers is less than or equal to 4.***

|  |  |
| --- | --- |
| Company | Comments |
| Nokia/NSB | The need to report 2 CQIs in the same CSI report in case of M-DCI based NCJT is not clear. For M-DCI based, the two CQIs would be transmitted in two separate CSI reports (different PUCCH/PUSCH resources).  |
| QC | Agree with Nokia. For multi-DCI, Cat2 can be later discussed (after finishing details of one report setting). We do not see the need for multiple solutions for multi-DCI. We think the focus of single report setting should be on single-DCI. |
| CATT | As mentioned by FL, two TBs are scheduled by TRPs independently. So, for M-DCI case, if the total number of transmission layer is larger than 1, one CQI per TRP is equivalent to one CQI per codeword. |
| Futurewei | Support FL’s proposal. |
| OPPO | We are not sure why this functionality can’t be achieved by current CSI framework. If gNB wants UE to report the CSIs of two TRPs separately, one CSI report configuration can be configured for each TRP. We can’t see any benefit to report two CSIs without any association within one CSI report, other than the risk of CSI omission. |
| Lenovo/MotM | Do not support the proposal. Not clear what is the advantage of having a single CSI report if it includes a pair of each of the PMI, RI, LI, CQI, rather than having 2 CSI reports. The proposed CSI report structure would have similar CSI feedback overhead to two CSI Reports configured with a single CMR each and a report quantity set to “cri-RI-LI-PMI-CQI”, with the penalty of additional spec impact |
| NEC | We share similar view with Nokia, QC, OPPO and Lenovo, there is no need to report CQI per TRP in one CSI report. |
| DOCOMO | Support the proposal.The difference from two separate CSI reporting in R16 is that, inter-TRP interference can be considered in the two CSIs in the single CSI reporting. |
| Intel | Support the proposal. In our view it is better to support single-DCI and multi-DCI based NCJT with the same framework, moreover it gives additional efficiency for UE implementation and UE complexity to calculate STRP CSI and NCJT CSI. |
| LG | Support the proposal. Based on the proposal, gNB can acquire two CQIs applied inter-TRP interference. So, this can provide more accurate scheduling information to gNB for multi-DCI based NCJT.  |
| ZTE | We support this proposal for inter-beam interference measurement between two TRPs for MDCI based MTRP. |
| MediaTek | Support the proposal. The current CSI framework cannot support joint PMI optimization because each port of NZP-IMR is considered as an interference layer. There is no PMI selection for NZP-IMR. Thus, either the scheme in Proposal 9 or Cat 2 is required. Cat 2 also requires to specify the association between two CSI reports, so increasing the number of CQI to two in Cat 1 would be more straightforward. |
| Spreadtrum | Support the proposal. Share the same view with DOCOMO and Intel.  |
| Apple | For single CSI report, mDCI mTRPUE needs to report 1 RI/PMI/LI/CQI per TRP since mDCI mTRP allows independent PDSCH scheduling. So we need total 2 RI/PMI/LI/CQI total as reportQuantity |
| Ericsson | Do not support the proposal. For multi-DCI based NC-JT we already have a working assumption. We do not support optimizing single report based NC-JT CSI for multi-TRP. |

## Others

Companies are also proposing other enhancements/issues related to Multi-TRP CSI, which can be discussed further once basic CSI measurement enhancement is more or less clarified and agreed by RAN1. So far following views are not converged too much, based on tdoc review.

|  |  |  |
| --- | --- | --- |
| **Issues** | **Companies** | **Views** |
| Whether to support other codebook type in addition to ‘typeI-SinglePanel’ | CATT[6], MTK[9],Samsung[18],  | Support to enhance non-PMI based CSI feedback for NCJT |
| Lenovo/Motorola Mobility [15] | Support Type-II codebook for NCJT |
| Whether to support interference measurement based on NZP CSI-RS | InterDigital[2], Samsung[18] | For CSI measurement for NCJT, support NZP-IMR. |
| MTK[9], Spreadtrum[12] | MU-MIMO is not supported for NCJT scheduling, and therefore NZP-IMR is not supportive for a CSI report associated with NCJT measurement hypothesis. |
| Confirm working assumption on category 2 | ZTE[5] | Suggest completing Category 1 first and further discuss Category 2 if time is allowed. |
| vivo[7] | Confirm the working assumption on multiple CSI reporting settings for NC-JT. |
| Ericsson[21] | Prioritize finalizing NC-JT CSI enhancement with single reporting setting in Rel-17 before further discussion of NC-JT CSI enhancement with multiple reporting settings. |
| Enhancement of CSI measurement for URLLC | Intel[11] | Support CSI enhancement for TDM/FDM URLLC |
| Ericsson[21] | In NR Rel-17, unify the Rel-17 MTRP CSI framework enhancements to consider MTRP CSI for both NC-JT and multi-TRP URLLC schemes. |
| Enhancement of CSI measurement for HST-SFN | Lenovo/Motorola Mobility [15] | Support CSI enhancement for HST-SFN |
| DOCOMO | For single CSI reporting setting, UE can be configured to report one RI, two PMIs, one LI and one CQI, for HST-SFN |

|  |  |
| --- | --- |
| Company | Comments |
| vivo | We prefer to confirm the working assumption on Cat2: with our evaluation results for non-ideal backhaul scenarios, Cat2 is well justified. Some evaluation results in non-ideal backhaul scenarios (with 5ms and 50ms backhaul delay) are as following for your reference. From the results, UE recommendation of transmission scheme to different TRPs would help the different TRPs to schedule independently and make the feature more usable in real deployment.Table 1: Indoor Hotspot with non-ideal backhaul

|  |  |  |  |
| --- | --- | --- | --- |
| FR1, RU for STRP (16%) | Mean UPT | 5% UPT | 50% UPT |
| STRP | -32.52% | -28.20% | -25.33% |
| DPS | -24.41% | -6.58% | -13.85% |
| Legacy CSI | -4.49% | -8.37% | -6.67% |
| Cat2 | 0.00% | 0.00% | 0.00% |
| Cat1 (5ms) | -4.69% | -6.96% | -7.57% |
| Cat1 (50ms) | -21.51% | -37.50% | -29.88% |

|  |  |  |  |
| --- | --- | --- | --- |
| FR1, RU for STRP (38%) | Mean UPT | 5% UPT | 50% UPT |
| STRP | -31.63% | -35.61% | -30.45% |
| DPS | -14.43% | -13.14% | -7.06% |
| Legacy CSI | -12.31% | -13.41% | -15.24% |
| Cat2 | 0.00% | 0.00% | 0.00% |
| Cat1 (5ms) | -12.43% | -15.91% | -13.79% |
| Cat1 (50ms) | -35.44% | -45.29% | -38.42% |

Table 2: Dense Urban with non-ideal backhaul

|  |  |  |  |
| --- | --- | --- | --- |
| FR1, RU for STRP (14%) | Mean UPT | 5% UPT | 50% UPT |
| STRP | -13.33% | -13.85% | -9.61% |
| DPS | -12.11% | -6.53% | -9.61% |
| Legacy CSI | -5.36% | -11.18% | -7.84% |
| Cat2 | 0.00% | 0.00% | 0.00% |
| Cat1 (5ms) | -2.52% | -5.85% | -4.08% |
| Cat1 (50ms) | -10.38% | -33.48% | -14.92% |

|  |  |  |  |
| --- | --- | --- | --- |
| FR1, RU for STRP (25%) | Mean UPT | 5% UPT | 50% UPT |
| STRP | -8.53% | -13.78% | -4.05% |
| DPS | -6.51% | -7.41% | -1.22% |
| Legacy CSI | -4.66% | -11.56% | -4.05% |
| Cat2 | 0.00% | 0.00% | 0.00% |
| Cat1 (5ms) | -3.66% | -8.60% | -4.28% |
| Cat1 (50ms) | -16.34% | -36.95% | -21.17% |

Some illustration of evaluated schemes:

|  |  |  |  |
| --- | --- | --- | --- |
| Scheme | CSI report | Scheduling | UE’s working mode |
| STRP | STRP CSI report to the serving TRP | UE scheduled by serving TRP | STRP |
| DPS | Cat2 framework: DPS CSI report to both TRPs | Independent scheduling | DPS |
| Legacy CSI\* | Two CSI report settings in legacy CSI framework: each with a STRP CSI report to its corresponding TRP | Independent scheduling | DPS or NCJT |
| Cat2 | Cat2 framework: UE selected NCJT CSI or DPS CSI report to both TRPs | Independent scheduling | DPS or NCJT |
| Cat1 (5ms) | Cat1 framework: UE selected NCJT CSI or DPS CSI report to a single TRP, CSI exchange with 5ms latency | Independent scheduling | DPS or NCJT |
| Cat1 (50ms) | Cat1 framework: UE selected NCJT CSI or DPS CSI report to a single TRP, CSI exchange with 50ms latency | Independent scheduling | DPS or NCJT |

 |
| LG | **The number of reported LIs in a CSI report associated with a NCJT measurement hypothesis should be determined based on the maximum number of PTRS ports.** The maximum number of PTRS ports can be configured to 1 even in the case of NCJT transmission. If the maximum number of PTRS ports is configured to 1 and UE reports two LI values, gNB cannot know the best layer preferred by the UE. As a result, reporting two LI values irrespective of the maximum number of PTRS ports can cause unnecessary CSI payload and performance degradation. |

# Proposals for Online/Offline Discussion

TBD

# Work Plan

TBD

# References

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# Appendix

* **Companies’ proposals on CSI enhancements for FDD**

**Table A-1 Companies’ proposals on CSI enhancements for FDD**

|  |  |
| --- | --- |
| **Companies** | **Proposals** |
| **Huawei, HiSilicon, China Unicom** | ***Proposal 1:*** *Taking Alt 5 as basic codebook structure for R17 port selection codebook structure.* * *should be supported for , and further study other candidate values of and N.*
 |
| **vivo** | * *The SD information and partial FD information can be precoded on CSI-RS ports and other FD information can be indicated by signaling.*
* *With gNB indication, UE can obtain more than 32 SD-FD pair candidates with up to 32 CSI-RS ports.*
* *We prefer codebook structure Alt 3. W1 is for CSI-RS port selection. Wf is for index selection from the range indicated or configured by gNB. For all the selected CSI-RS ports, Wf is the same.*
	+ *W1 can be an identity matrix to represent all CSI-RS ports reported.*
	+ *Wf can be a complete DFT matrix indicated by gNB to represent all FD information reported.*

*Enhance procedure on timing calibration to counteract the timing mismatch between gNB and UE for FDD CSI enhancement.* |
| **ZTE** | **Proposal 4:** *For codebook structure in Rel-17 FDD reciprocity based CSI, support Alt 2.** *On the mapping between SD-FD pairs and CSI-RS ports, support one of the following.*
* *Opt 1: 2 or 4 SD-FD pairs are FDMed mapped to 1 port*
* *Opt 2: Aggregating multiple CSI-RS resources to generate one PMI*

  |
| **CATT** | **Proposal-1:** *is used as Rel-17 PS codebook structure.***Proposal-2:** *For , should be a selection matrix.***Proposal-3:** *At least 48 SD-FD pairs shall be supported in specification.***Proposal-4:***More than one CSI-RS resource can be configured for mapping SD-FD pair to CSI-RS port.***Proposal-5:** *Port selection should be polarization-common.***Proposal-6:** *The bandwidth and density of SRS is configured as same as that of CSI-RS to obtain accurate delay information of uplink channel.***Proposal-7:***Non-zero coefficients are indicated by using port indication information.*  |
| **Intel Corporation** | ***Proposal 6*:*** *Consider optimization of CSI-RS design instead of codebook design with multiple SD-FD precoders multiplexed in one CSI-RS port*

***Observation 4*:*** *Rel. 17 codebook with CSI-RS density D = 0.25 has around 5% performance gain in cell-edge UE throughput comparing to Rel. 17 codebook with CSI-RS density D = 0.5*

***Proposal 7***: * *Support of lower CSI-RS density can be considered in Rel. 17 by RAN1*

***Proposal 8***: * *Support Rel. 17 codebook structure according to Alt. 3-0 with M = 1*
	+ *FFS: M > 1*
 |
| **Samsung** | ***Proposal 4:*** *for the study of Rel. 17 codebook alternatives, use Rel. 16 reg. T2 CB as a reference performance, in addition to the Rel. 16 PS T2 CB “baseline****Proposal 5:*** *codebook alternatives (Alt2, 3-1, 3-2, and 5) that are based on conveying multiple SD-FD bases per CSI-RS port () require further study and justification, hence should be deprioritized.****Proposal 6:*** *for Rel. 17 codebook design, support Alt1 (W=W1W2)* * *Alt0 (W=W2) can be supported when number of CSI-RS ports is small*
 |
| **OPPO** | ***Proposal 1:*** * *No need to support more than 32 CSI-RS ports/SD-FD pairs in Rel-17.*

***Proposal 2:*** * *Support codebook structure Alt 3-0 or Alt 3-1 for Rel-17 PS.*
 |
| **Sony** | **Proposal 1.** *Non-Kronecker* *SD-FD bases shall be introduced in Rel-17* only *if they are shown to offer a better tradeoff among UE complexity, performance and reporting overhead compared to Rel-16.***Proposal 2.** *Study the feasibility of reducing the density of CSI-RS pilot in the frequency domain.***Proposal 3.** *For minimum specification impact, maintain the polarization-common base selection and reporting mechanism of Rel-15/Rel-16. A polarization-specific mechanism should only be introduced if it can be shown that, at least for some scenarios of interest, it provides substantial advantage over polarization-common.* **Proposal 4:** *Based on UL CSI, further restrict the set of CSI-RS ports eligible by the UE to those compatible with UL signal angles.***Proposal 5:** *Introduce an FD sampling size parameter . Based on UL CSI, further restrictions to can be applied in order to limit the set of FD DFT vectors eligible by the UE.***Proposal 6***: For FDD systems exploiting DL/UL channel reciprocity, the UE can signal to the gNB the DL covariance matrix of noise and interference. The ways of transferring this information from the UEs to the gNB need to be further studied and specified.***Proposal 7:** *Companies should study the feasibility of signaling to the UEs the set of CSI-RS beams actually used for co-scheduled transmissions. An indication from the UE to the gNB of those beams suppressed by the UE should also be studied.* |
| **Apple** | ***Proposal 4 For port selection codebook enhancement,**** ***Do not introduce SD-FD pairing***
* ***Do not introduce CSI-RS with more than 32 ports***
* ***We can consider CSI-RS enhancement to allow more users to be multiplexed in the same amount of REs, solution can be allowing lower density CSI-RS, e.g., 0.5, 0.25***

***Proposal 5 For CSI enhancement utilizing partial reciprocity of DL/UL channels, more flexible wideband and subband CSI reporting configuration can be considered*** |
| **LG Electronics** | **Proposal #5:** Alternatives based on multiple SD-FD bases to single CSI-RS port for baseline codebook structure, i.e., Alt2, Alt3-1, Alt3-2, and Alt5, should be avoided.**Proposal #6:** Support Alt3-0 as a baseline codebook structure in Rel-17 Type 2 PS CB. **Proposal #7:** Support of more than 32 CSI-RS port should be deprioritized unless clear benefic is observed.  |
| **FraunhoferIIS, Fraunhofer HHI** | ***Proposal:*** *The constraint on the neighboring port selection as in the Rel.-15/16 codebooks shall be relaxed for the Rel. 17 PS codebook.****Proposal:*** *Support ALT 3-0 for the Rel. 17 PS codebook.* ***Proposal:*** *The number of SD-FD basis pairs used for CSI-RS precoding should not be larger than 32.****Proposal:*** *Support fixing/pre-configuring the delays.* ***Proposal:*** *Study identical port selection for a subset of transmission layers.* |
| **Nokia,Nokia Shanghai Bell** | **Proposal 1. Support the codebook structure , where is a DFT-based compression matrix (Alt 5, 3.0, 3.1) and the components are network configured or selected and reported within a configured window of size** * **FFS: configured or selected and reported by a UE**
* **FFS: values of and**
	+ **, *i.e.*, WB reporting**

**Proposal 2. is a free selection matrix, if reported.*** **FFS: whether has Kronecker structure (Alt 3.2 and 4),**
* **FFS: feedback overhead increase if is not reported (Alt 0)**

**Proposal 3. Support further study of at least the following two additional mechanisms to reduce the CSI-RS overhead*** **Mapping SD-FD bases in a CSI-RS resource port, with**
* **Reduced CSI-RS resource density of 0.25 with RB comb offset:**

**Proposal 4. Study multiplexing of SD-FD pairs of different UEs in delay domain by applying UE-specific shifts to FD-precoded beamforming vectors at gNB, in order to further reduce CSI-RS overhead on top of previously mentioned schemes.** |
| **Lenovo, Motorola Mobility** | 1. Alt1 and Alt2 should not be considered for Rel. 17 Reciprocity codebook
2. Introduce additional parameter values for Rel. 16 Type-II port selection codebook, e.g., include WB reporting with *M*=1
3. Alt0 should not be considered for Rel. 17 Reciprocity codebook
4. Support Alt3-0 or Alt3-2 for reciprocity-based Rel. 17 Type-II Port Selection Codebook
5. Polarization-common port selection and polarization-specific coefficient quantization are supported for Rel. 17 Reciprocity-based Port Selection codebook
6. Aperiodic SRS triggering is needed in conjunction with the beamformed CSI-RS for the reciprocity-based codebook, with a limited time gap between the transmission of both RSs
7. Configure the UE with two frequency compression parameter values for both strong and weak channel reciprocity, where the UE can select the appropriate parameter value based on the strength of the channel reciprocity
 |
| **Spreadtrum Communications** | ***Proposal 7:*** *Regarding codebook structure, support Alt2 or Alt3-2.****Proposal 8:*** *Whether supporting more than 32 SD-FD bases should be decided based on evaluation results** *If supported, multiple SD-FD bases can be mapped into a single port with different pre-determined delay position.*
 |
| **NTT DOCOMO, INC** | **Proposal 8:*** *Consider following Type II PS codebook structure for NR Rel-17:*

*where both* *and**are selection matrices. As discussed above, proposed Alt0 and Alt1/2 codebook structures are special cases of this codebook structure.***Proposal 9:*** *Since the UL dominant sub-space is different than that of DL when considering phased arrays (with fixed inter-element spacing) for transmission, allow UE to pick SD beams out of the beamformed CSI-RS ports.*

**Proposal 10:*** *Allow UE to select FD bases as well in order to provide higher flexibility and performance. FD bases selection can be either SD beam common or SD beam specific.*

**Proposal 11:*** *Support FDM based many-to-one mapping between SD-FD pairs and CSI-RS ports.*

**Proposal 12:***Consider how to determine, the number of frequency partitions, and PRBs associated with each frequency partition, for FDM based many-to-one mapping between SD-FD pairs and CSI-RS ports.*  |
| **Ericsson** | [Proposal 1**:** Study the order for SVD and port-selection operations, by taking into account the trade-off between UPT, overhead and UE complexity.](#_Toc61906726)[Proposal 2**:** Rel-17 PS codebook should include a DFT-based as the FD compression matrix.](#_Toc61906727)[Proposal 3**:** Support Alt. 3-0 as it is a robust alternative that allows flexible implementation of Rel-17 enhancements of Type II CSI](#_Toc61906728)[Proposal 4**:** Multiplexing multiple pairs per CSI-RS port () should not be supported as the benefit is not significant (~5%) and given the increased complexity at UE and gNB and specification impact.](#_Toc61906729) |
| **Qualcomm Incorporated** | **Proposal 9: For Rel-17 FDD CSI, support two-stage codebook structure () where W1 as port-selection and W2 as linear combination coefficients. W1 and W2 are reported in wideband sense. (Alt1)****Proposal 10: RAN1 should study and justify the gain of three-stage codebook if decide to specify it.****Proposal 11: if RAN1 decide to support three-stage codebook (), support joint configuration and capability signalling of combination of {number of CSI-RS ports per resource, number of FD bases per port}.****Proposal 12: RAN1 should not consider many-to-one mapping between SD-FD bases and CSI-RS port.** |
| **MediaTek Inc** | **Proposal 10**:Port selection codebook enhancements utilizing DL/UL reciprocity of angle and delay should be supported in Rel-17.**Proposal 11**: For the case of a single dominant tap in each beam pre-compensated by the gNB by means of precoded CSI-RS, the codebook structure is , where is a free port selection matrix to choose ports out of CSI-RS ports in a polarization specific manner and each column of has a single non-zero entry of 1.**Proposal 12**: In order to capture more channel information on the main beam, delay pre-compensation of dominat delay taps per beam should be further investigated in RAN1.**Proposal 13**: For the case of more than one dominant tap in each beam pre-compensated by the gNB by means of precoded CSI-RS, the codebook structure is , where and are free SD and FD port selection matrices to choose out of beams in a polarization specific manner, and out of delays, such that each column of and have a single non-zero entry of 1.**Proposal 14**: RAN1 should further discuss the PMI component and CQI reporting mechanism considering delay pre-compensation using FDD reciprocity.**Proposal 15**: When delay taps are pre-compensated by the gNB using precoded CSI-RS in each of the beams, gNB can use DFT FD bases for CSI-RS precoding and indicate the offset of the remaining FD bases via dynamic signaling to the UE. |

* **Companies’ proposals on CSI enhancements for Multi-TRP**

**Table A-2 Companies’ proposals on** **CSI enhancements for Multi-TRP**

|  |  |
| --- | --- |
| **Companies** | **Proposals** |
| **Futurewei** | **Proposal 1:** * *FeMIMO supports associating a group of measurement resources to one CSI report configuration of a UE and let the UE determine or select whether a measurement resource is for CM, IM, or muting.*

**Proposal 2:** * *Regarding UE reporting mechanism, FeMIMO supports Alt 3: the UE can be expected to report two CSIs associated with the two best single-TRP measurement hypotheses associated with CMRs from two TRPs and one CSI associated with the best NCJT measurement hypothesis, if configured. FeMIMO also support reporting a subset of the CSI report quantities.*

**Proposal 3:** * *For a CSI report associated with a Multi-TRP/panel NCJT measurement hypothesis configured by single CSI reporting setting, the UE is expected to report*

*Two CRIs, two RIs, two PMIs, two LIs and one CQI per codeword, for single-DCI based NCJT when the maximal transmission layers is less than or equal to 4* |
| **InterDigital, Inc.** | ***Proposal 2****:* *Study two-step CSI-RS measurement reporting for NCJT where** *NZP CSI-RS is configured per TRP,*
* *in the first step, a PMI corresponding to the first TRP, and in the second step a PMI corresponding to the second TRP is determined and reported.*

***Proposal 3****:* *Study a two-step SRS plus CSI-RS measurement/reporting for NCJT where** *NZP CSI-RS is configured per TRP,*
* *in the first step UE transmits an SRS, and in the second step based on the received precoded CSI-RS from each TRP, UE estimates and report the CSI*
 |
| **Huawei, HiSilicon, China Unicom** | ***Proposal 2:*** *For CSI reporting for NCJT in Rel-17, the number of CMRs associated to a CSI-ReportingConfig is restricted to 2.****Proposal 3:*** *The UE can report one CSI associated with the best single-TRP measurement hypothesis and one CSI associated with the best NC-JT measurement hypothesis, if configured* |
| **vivo** | * *Confirm the working assumption on multiple CSI reporting settings for NC-JT.*
* *RAN1 shall strive for commonality for NC-JT CSI measurement configured by single or multiple CSI reporting setting(s) as well as the MTRP beam enhancement.*
* *For CSI measurement associated with a CSI reporting setting, grouping the CMR can realize the CMR association with two TRPs.*
* *For CSI measurement associated with multiple CSI reporting settings, explicitly configuring the associated reporting setting in a reporting setting can realize the CMR association of two TRPs.*
* *For the CSI measurement for NC-JT, support one-to-one mapping between the CMRs of the two TRPs when multiple CMRs are configured for each TRP.*
* *To save signaling overhead and achieve more flexible CSI measurement, support CMR pair modification/activation/deactivation and CMR association by MAC CE.*
* *Support a one-to-one mapping between CMR and IMR.*
* *Support to report one CSI associated with the best one among NC-JT and/or single-TRP measurement hypotheses selected by the UE.*
* *Support CSI enhancement for different single-DCI-based MTRP transmission schemes, including HST-SFN schemes specified in Rel-17.*
* *For the NC-JT assumption, the number of CPUs should correspond to the number of associated CMRs, and the CPU occupation timeline needs further study.*
 |
| **ZTE** | **Proposal 1:** *Support Category 1, i.e.** *For a reporting setting CSI-ReportConfig, more than one CSI-RS port groups in a resource or resources or resource sets are associated to different TRPs/TCI states,*
	+ *the UE will determine CSI reporting quantities based on pre-defined/indicated/configured/UE-selected channel and interference hypotheses across TRPs /TCI states*
	+ *and then report one or more CSIs within a single CSI report.*

**Proposal 2*:*** *In one CSI-RS resource set for channel estimation, two CSI-RS resources configured with the same two TCI states are associated to different TRPs,* * *If UE selects a CRI corresponding to a CSI-RS resource with two TCI states, UE will determine CSI based on the interference between the CSI-RS resource and its associated CSI-RS resource.*
	+ *The CSI includes two RI, PMI, LI and one combined CQI.*

**Proposal 3:** *UE shall calculate interference from the coordinated TRP considering the selected precoder and beam used by the coordinated TRP.* |
| **CATT** | **Proposal-8:***Non-PMI based feedback can be supported for CSI enhancement for M-TRP.***Proposal-9:** *For CSI reporting based on single report setting, two associated CMR resources in the same resource set are used for channel measurement of two TRPs. In CSI calculation, the UE assumes that in PDSCH transmission, PMI-1/RI-1 and PMI-2/RI-2 are applied to the channel of TRP 1 and 2 respectively. By doing so, inter-TRP interference measurement can be achieved without introducing non-precoded IMR.***Proposal-10:** *Considering the impacts of the two options on spec, option 1 is slightly preferred.** *Option 1 (Explicit): CMRs corresponding to different TRPs can be associated with different reporting settings respectively, with the same configurations between two settings except for PUCCH/PUSCH resources and CMR/IMR resources setting(s)*

**Proposal-11:***One CQI per codeword is reported even if the reported rank is more than 5 in CSI for NC-JT.* **Proposal-12:***In CSI reporting for NC-JT, the possible combinations of rank reported to each of the TRPs should follow the rule of DMRS allocation.***Proposal-13:** *Indication/configuration/report on the transmission scheme assumed for CSI calculation can be considered.***Proposal-14:** *Further discuss the following alternatives for CSI reporting of M-DCI based NC-JT.** *Alt-1: Two independent reports, for different TRPs respectively*
* *Alt-2: One set of report quantities can be reported to any of the two TRPs*

*Alt-3: Separate reports (i.e., Alt-1) can be used if the resources for CSI reporting towards different TRPs are different. If resources for CSI reporting towards different TRPs are overlapped, joint CSI reporting (i.e., Alt-2) can be used****.*** |
| **CMCC** | ***Proposal 1: The UE shall be expected to report two CRIs for single-DCI based NCJT.******Proposal 2: Two CRIs, and corresponding two CQIs, two RIs and/or two PMIs could be reported in single CSI reporting for multi-DCI based NCJT.******Proposal 3: Support Alt 1(the UE can be expected to report one CSI associated with the best single-TRP measurement hypothesis and one CSI associated with the best NCJT measurement hypothesis) and Alt 2(the UE can be expected to report one CSI associated with the best one among NCJT and/or single-TRP measurement hypotheses) for single CSI reporting setting.******Proposal 4: One exact CSI reporting mechanism among Alt 1 and Alt 2 could be configured by RRC.*** |
| **Samsung** | ***Proposal 1:*** *On CSI enhancements for multi-TRP,** *Support Category 1 for single-DCI based multi-TRP*
* *Allow UE to be configured between Category 1 and 2 for multi-DCI based multi-TRP*
* *Support CMR to be re-used as IMR for both non pre-coded and pre-coded CSI-RS*

***Proposal 2:*** *For NC-JT CSI reporting enhancement, support and study followings:** *Support CRI-based dynamic reporting between NC-JT and non-NC-JT CSI*
* *Support non-PMI based port-selection*
* *Support restrictions among reported RIs or PMIs*
* *Study UCI structure optimized for dynamic NC-JT CSI report*

***Proposal 3:*** *Design new CPU occupation rule for dynamic NC-JT CSI report* |
| **OPPO** | Proposal 3: For CSI report(s) associated to single CSI reporting setting for NCJT,* *It is preferred to support at most Ks=2 CMRs in a CSI-RS resource set. Whether CRI is needed depends on the supported UE reporting mechanism.*
* *If Ks>2 CMRs is supported in a CSI-RS resource set, an implicit association between CSI-RS resources is supported for NC-JT measurement.*
* *If Ks CMRs are configured in a CSI-RS resource set, 2Ks CPUs are counted for the CSI report (Ks CPUs respectively for single-TRP and NCJT measurement hypothesis).*

Proposal 4: For CSI report(s) associated to single CSI reporting setting for NCJT, support at least Alt 2 considering performance and CSI overhead.Proposal 5: CSI enhancement for multi-DCI based M-TRP transmission (including Category 2) should have low priority. If enhancement is needed, consider joint CSI report to support overlapped PDSCHs, non-overlapped PDSCHs and S-TRP. |
| **Apple** | ***Proposal 1 For a CSI report associated with multi-DCI based Multi-TRP/panel NCJT measurement hypothesis configured by single CSI reporting setting, the UE is expected to report**** ***Two RIs, two PMIs, two LIs and two CQIs***

***Proposal 2 For interference measurement under NCJT, CMR, including RI/PMI decision, from one TRP should be considered as the interference, i.e. IMR, to the other TRP.******Proposal 3 For reporting mechanism, regarding the following three cases**** ***Single TRP operation: Report the best TRP under the assumption that the other TRP is blanked***
* ***Single TRP operation: Report each TRP under the assumption that the other TRP is blanked***
* ***Multiple TRP operation: Report both TRP under NCJT operation***

***gNB can configure one or multiple of them*** * ***UE can independently indicate whether UE supports each reporting or not***
* ***The CPU and active RS counting rule needs to be further discussed and clarified***
 |
| **LG Electronics** | **Proposal #1:** Support Alt 2. * Alt 2: The UE can be expected to report one CSI associated with the best one among NCJT and/or single-TRP measurement hypotheses, if configured.

**Proposal #2:** UE selects 1 or 2 CMRs from up to 8 CMRs for S-TRP or NCJT transmission.**Proposal #3:** The number of reported LI values in a CSI report associated with a NCJT measurement hypothesis should be determined by the maximum number of PTRS ports, i.e., maxNrofPorts-r16 in PTRS-DownlinkConfig.**Proposal #4:** Support Option 1(Explicit association between CSI reporting settings). |
| **FraunhoferIIS, Fraunhofer HHI** | ***Proposal:*** *The UE is pre-configured with CMR/IMR sets, and it selects one or more CMR/IMR sets to report a non-NC-JT or NC-JT CSI, or the UE decides which resource is for channel or interference measurement and selects and reports a subset of the CMRs which are associated with a NC-JT or non-NC-JT CSI.****Proposal:*** *For a single CSI report setting, support ALT2 such that a CSI report comprises one CSI associated with the best NC-JT or non-NC-JT measurement hypothesis.* |
| **Nokia,Nokia Shanghai Bell** |  **Proposal 5. Introduce higher-layer configuration for grouping resources such that a TRP association is known for each CMR resource. The grouping of CMR resources can be understood by the UE based on either of the following methods:*** **Alt-1: grouping (or TRP association) of CMR resources.**
* **Alt-2: grouping (or TRP association) of SSB resources and QCL-TypeD chain is used to determine the TRP association of a CMR.**

**Proposal 6. Support network indication of the CMR pairing to restrict the NC-JT measurement hypotheses when more than 2 CMR resources are configured in a resource set.****Proposal 7. For the number of reported CSIs in a single Reporting Setting, support a combination of Alt 3 and Alt 1 with three possible configurations:**1. **3 CSIs: two best single TRP measurements, one for TRP 0 and one for TRP 1, and 1 best NC-JT measurement**
2. **2 CSIs: two best single TRP measurements, one for TRP 0 and one for TRP 1**
3. **2 CSIs: one best single TRP measurement, one best NC-JT measurement**

**Proposal 8. For M-TRP CSI measurement, support extension of the maximum number of ports per CSI-RS resource to 32.****Proposal 9. When an NC-JT CSI is included in a multi-TRP report, support extension of the CRI definition to include the CMR pairs configured/indicated by the network for NC-JT measurements.****Proposal 10. For NC-JT CSI, support restriction of the combination of reported RIs to the following sets: {1,1}, {1,2}, {2,1}, {2,2}.****Proposal 11. Postpone any decision on multi-DCI based NCJT measurement after a decision is made on the TRP association to CMRs for single Reporting Setting.****Proposal 12. If TRP association to CMRs is agreed for single Reporting Setting, modify the working assumption on multi-DCI based NCJT measurement with implicit or explicit association between two Reporting Settings having the same configurations except for PUCCH/PUSCH resources.****Proposal 13. Regarding the FFS on CQI calculation in multi-DCI NC-JT measurement, further clarify that a UE assumes two codewords are received fully overlapping in time and frequency and that each codeword is mapped to the spatial layers associated to one TRP.** |
| **NEC** | ***Proposal 1: Two subsets of CSI-RS resources should be designed in a CSI-RS resource set, and each subset can be associated with one TRP.*** ***Proposal 2: For a CSI reporting setting, we support Alt 1 (one CSI associated with the best single-TRP measurement hypothesis and one CSI associated with the best NCJT measurement hypothesis) as 1st preference, and Alt 3 (two CSIs associated with the two best single-TRP measurement hypotheses associated with CMRs from two TRPs and one CSI associated with the best NCJT measurement hypothesis) as 2nd preference.******Proposal 3: Payload for CRI reporting can be reduced based on the structure of two CSI-RS resource subsets. And for NCJT hypothesis, either one CRI or two CRIs reporting in the CSI is OK, which depends on whether there is association between CSI-RS resources in two subsets.******Proposal 4: TRP specific CBSR and RI restriction can reduce the UE complexity considerably, which should be introduced at least for NCJT measurement hypothesis.******Proposal 5: Restriction on possible values of the two reported RIs should be considered to reduce the overhead.*** |
| **MediaTek Inc** | **Proposal 1**:For NCJT CSI measurement configured with single reporting setting, only support interference measurement based on CSI-IM.**Proposal 2**: How to interpret the two CMRs configured for an NCJT measurement hypothesis can be up to UE implementation.**Proposal 3**: For a CSI reporting setting, support Alt. 1 and Alt. 2 as UE reporting mechanism.**Proposal 4**: For Alt. 1, the CSI associated with the best NCJT measurement hypothesis has a lower reporting priority than the CSI associated with the best single-TRP measurement hypothesis.**Proposal 5**: For Alt. 2, the second RI can be reported as 0 to signal the best single-TRP measurement hypothesis.**Proposal 6**: For an NCJT interference hypothesis, the corresponding CRI is associated with two CMRs, whereas the mapping from CRI to IMR remains one-to-one.**Proposal 7**: The allowed RI pairs for an NCJT measurement hypothesis assuming the maximal transmission layers less than or equal to 4 should be (1, 1), (1, 2), (2, 1), (2, 2).**Proposal 8**: Non-PMI based port-selection is supported for a CSI report associated with an NCJT measurement hypothesis configured by single CSI reporting setting.**Proposal 9**: The higher layer parameter *reportQuantity* can be 'cri-RI-PMI-CQI ', 'cri-RI-i1', 'cri-RI-i1-CQI', 'cri-RI-CQI', and 'cri-RI-LI-PMI-CQI' for a CSI report associated with an NCJT measurement hypothesis configured by single CSI reporting setting. |
| **Intel Corporation** | ***Proposal 1***: * *Support configuration of a reporting setting CSI-ReportConfig for NCJT with different number of CSI-RS ports in CMRs corresponding to different TRPs*
	+ *Different number of CSI-RS ports in CMRs is optional feature with separate UE capability signaling parameter*
	+ *Additional constraint on the number of CSI-RS ports in one of the CSI-RS resources can be considered*

***Proposal 2*:** * *Support CSI configuration where CSI for NCJT and CSI for STRP are both reported*
	+ *Alt 1: the UE can be expected to report one CSI associated with the best single-TRP measurement hypothesis and one CSI associated with the best NCJT measurement hypothesis, if configured*
	+ *Alt 3: the UE can be expected to report two CSIs associated with the two best single-TRP measurement hypotheses associated with CMRs from two TRPs and one CSI associated with the best NCJT measurement hypothesis, if configured*

***Proposal 3*:** * *Support omission of CSI associated with NCJT measurement hypothesis*
	+ *CSI for NCJT is contained in CSI part 2, information about omission of CSI for NCJT is reported in CSI part 1*

***Proposal 4*:** * *CSI measurement for multi-DCI based NCJT with non-ideal backhaul is supported by configuring two CSI reports with proper interference measurements (Implicit approach)*

***Proposal 5***: * *Support enhanced CSI feedback for MTRP transmission with PDSCH repetition (for URLLC)*
	+ *Alt 1: One CSI report with CQI calculated for MTRP transmission with PDSCH repetition (Category 1 MTRP CSI)*
	+ *Alt. 2: Two CSI reports corresponding to two TRP with aligned RI value (Category 2 MTRP CSI)*
 |
| **Lenovo, Motorola Mobility** | 1. At least for the single-DCI multi-TRP scenario, discuss the number of CSI Reports configured per CSI Reporting Setting
2. Clarify the relationship between CSI Reports and channel hypotheses
3. Support multi-DCI mTRP CSI enhancements along with single-DCI mTRP
4. The UE should be configured by the network to report NCJT-based CSI feedback under multi-DCI setup
5. Support explicit CSI-ReportConfig from each TRP for multi-DCI based NCJT
6. RAN1 should strive to develop a codebook-transparent framework for CSI Reporting under NCJT
7. Support Type-II codebook for NCJT along with Type-I single-panel codebook type
8. For a UE configured with Type-II codebook, it can be configured with more than one CSI-RS resource for CMR under aperiodic CSI Reporting
9. Further study the motivation to support non-PMI based port-selection for NCJT
10. Support Alt3 for CSI Reporting mechanism under NCJT
11. Discuss whether CSI enhancements for NCJT should support transmission with rank exceeding four
12. For multi-DCI based NCJT, the first and second PMIs in the CSI report correspond to the same TRP under single-TRP transmission and NCJT transmission, respectively
13. CSI Report for HST-SFN should include 2 PMI/CRI and 1 RI/LI/CQI
14. TRP-specific CSI-RS Resources should be used in HST-SFN deployment
15. Support dynamic omission of CSI from one of the two TRPs in HST-SFN based on the difference in RSRP value with respect to the other TRP
 |
| **Spreadtrum Communications** | ***Proposal 1:*** *For a CSI report associated with a Multi-TRP/panel NCJT measurement hypothesis configured by single CSI reporting setting, the UE is expected to report two RIs, two PMIs, two LIs and two CQIs.****Proposal 2:*** *Not support interference measurement based on NZP CSI-RS given by nzp-CSI-RS-ResourcesForInterference for a CSI report associated with NCJT measurement hypothesis.****Proposal 3:*** *Support interference measurement based on CSI-IM given by csi-IM-ResourcesForInterference for a CSI report associated with NCJT measurement hypothesis.****Proposal 4:*** *For a CSI reporting setting, UE reporting mechanism Alt.2 at least should be supported, i.e., the UE can be expected to report one CSI associated with the best one among NCJT and/or single-TRP measurement hypotheses.****Proposal 5:*** *Study how to demonstrate the validity of CSI parameters for joint reporting in NC-JT.****Proposal 6:*** *A new design of CSI composition and CSI Part 2 omission priority should be considered for CSI reporting with NCJT assumption.* |
| **NTT DOCOMO, INC** | **Proposal 1:*** *The premise to confirm the working assumption is making sure that the discussion on Category 2 will not impact the function and progress of Category 1.*

**Proposal 2:*** *Support Category 1 for both single-DCI and multi-DCI based MTRP transmission schemes, including DL MTRP transmission scheme in HST-SFN.*
	+ *For CSI measurement associated to a reporting setting CSI-ReportConfig for NCJT, ~~[~~at least for multi-DCI based and single-DCI based schemes (scheme 1a)~~]~~, NZP CSI-RS resources for channel measurement are associated to different TRPs/TCI states at resource level.*

**Proposal 3:*** *For a CSI report associated with a Multi-TRP/panel NCJT measurement hypothesis configured by single CSI reporting setting, the UE is expected to report following reporting quantities for different transmission schemes based on indication signaling,*
	+ *two RIs, two PMIs, two LIs and one CQI per codeword, for single-DCI based NCJT*
	+ *two RIs, two PMIs, two LIs and two CQIs, for multi-DCI based NCJT*
	+ *one RI, two PMIs, one LI and one CQI, for HST-SFN*

**Proposal 4:*** *For NCJT CSI measurement configured with single reporting setting,*
	+ *Existing interference measurement based on CSI-IM given by csi-IM-ResourcesForInterference and based on NZP CSI-RS given by nzp-CSI-RS-ResourcesForInterference is baseline.*
	+ *The CSI-IM and NZP-CSI-RS for interference measurement are shared by two TRPs, with one-to-one mapping between CMR associated with each TRP and CSI-IM/NZP-CSI-RS for interference measurement.*

**Proposal 5:*** *For a CSI report associated with a Multi-TRP/panel NCJT measurement hypothesis configured by single CSI reporting setting, the UE is expected to report one CRI, which corresponds to two NZP CSI-RS resources.*

**Proposal 6:*** *For NCJT CSI measurement configured with single reporting setting,*
	+ *If configured, CMR associated with the 2nd TRP is assumed for interference measurement for CMR associated with the 1st TRP, and vice versa.*

**Proposal 7:*** *At least support Alt.1: the UE can be expected to report one CSI associated with the best single-TRP measurement hypothesis and one CSI associated with the best NCJT measurement hypothesis, if configured.*
* *Do not support Alt.2.*
* *Alt.3 can be further studied.*
 |
| **Ericsson** | [Proposal 5**:** Prioritize finalizing NC-JT CSI enhancement with single reporting setting in Rel-17 before further discussion of NC-JT CSI enhancement with multiple reporting settings.](#_Toc61906730)[Proposal 6**:** Reducing CSI feedback overhead with 3 or 4 TRPs in a serving cell should be the main goal for NC-JT CSI feedback design.](#_Toc61906731)[Proposal 7**:** For NC-JT CSI enhancement with single reporting setting, support the configuration of up to 3 or 4 NZP CSI-RS resources per channel measurement resource set.](#_Toc61906732)[Proposal 8**:** For NC-JT CSI enhancement with single reporting setting, support reporting of 2 CRIs as part of the NC-JT CSI to select two TRPs.](#_Toc61906733)[Proposal 9**:** For NC-JT CSI enhancement with single reporting setting, support Alt.3.](#_Toc61906734)[Proposal 10**:** To reduce CSI overhead with Alt 3, support UE CSI reporting where the same PMIs and RIs are shared between NC-JT CSI and single TRP CSIs.](#_Toc61906735)[Proposal 11**:** If the rank of one of the single TRP CSIs to be reported is above a configured threshold, then the UE may omit CSI associated with NCJT measurement hypothesis.](#_Toc61906736)[Proposal 12**:** For NC-JT CSI with a single CSI reporting setting , if the NZP CSI-RS resources for channel measurement are configured without QCL-type D or with the same QCL-type D, a UE assumes that the interference on the CSI-IM resources represents two observations of a same interference.](#_Toc61906737)[Proposal 13**:** For NC-JT CSI with a single CSI reporting setting, if the NZP CSI-RS resources for channel measurement are configured with different QCL-type D source RS, a UE assumes that the interferences on different CSI-IM resources may correspond to different interference sources.](#_Toc61906738)[Proposal 14**:** For NC-JT CSI with a single CSI reporting setting, a UE assumes that an NZP CSI-RS or CSI-IM resource for interference measurement is QCLed with respect to “QCL-type D” with the associated NZP CSI-RS resource for channel measurement.](#_Toc61906739)[Proposal 15**:** In NR Rel-17, unify the Rel-17 MTRP CSI framework enhancements to consider MTRP CSI for both NC-JT and multi-TRP URLLC schemes.](#_Toc61906740) |
| **Qualcomm Incorporated** | **Proposal 1: Support one of the following options for CMR paring / NCJT hypotheses configuration:*** **Option 3: CMRs are divided in to two or more groups, and a pair of CMRs belonging to different groups construct a NCJT hypothesis.**
* **Option 4: One or more pairs of CMRs are explicitly configured within a resource set.**

**Proposal 2: In a CSI report config with 𝐾 CMRs, CRI codepoint mapping to CSI hypotheses is be based on** * **First 𝐾 CRI codepoints are mapped to single-TRP hypotheses (same as Rel. 15).**
* **The additional CRI codepoints are mapped to CMR pairs corresponding to NCJT hypotheses.**

**Proposal 3: Support one-to-one mapping between CSI-IM and CRI codepoint for a given *CSI-ReportConfig*.** **Proposal 4: QCL-Type D of the CMRs associated with a NCJT hypothesis are applied to the corresponding CSI-IM resource.****Proposal 5: An NCJT CSI hypothesis occupies two CPUs, two active resources, and a number of active ports corresponding to both CMRs. These numbers are separate from single-TRP hypotheses.****Proposal 6: Codebooks other than ‘typeI-SinglePanel’ are not supported for NCJT CSI.****Proposal 7: For NCJT CSI reporting, support both Alt1 and Alt2.*** **FFS: How to configure / select between Alt1 and Alt2.**

**Proposal 8: For Alt1, the order of CSI reports in the UCI as well as CSI priority for CSI omission is based on an order between the two CSI reports associated with the *CSI-ReportConfig*. CSI priority can be expressed as , where corresponds to single-TRP CSI and NCJT CSI, respectively.** |