**3GPP TSG RAN WG1 Meeting #105-e R1-2106070**

**e-Meeting, May 10th – 27th, 2021**

**Agenda Item: 8.1.4**

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

**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, basic codebook structure for Rel-17 Type II port selection codebook enhancement was agreed. For Multi-TRP CSI enhancement in Rel-17, further basic design targets were agreed for CSI measurement setting and also for two options for CSI reporting setting.

In RAN1 104bis-e, some codebook coefficients, based on agreed codebook structure, were agreed for W1 and W2 of Rel-17 port selection codebook. Remaining coefficients or design targets were elaborated for further discussion. For Multi-TRP CSI enhancement in Rel-17, further agreements focus on the size of CMR configuration, QCL-Type D assumption, UCI reporting clarification of RI, CRI etc. Also some remaining issues related to resource/reporting sharing or priorities were elaborated for further discussion.

In RAN1 105e, companies have shared their consideration/preference for further detailed design for both FDD CSI and Multi-TRP CSI, which can be found in Reference and Appendix. General targets in RAN1 105e are:

* For FDD CSI, we may strive to finalize ALL codebook details for Rank 1 as much as possible, by concluding those remaining issues agreed within RAN1 104bis-e. The majority of proposals, therefore, is the leftover of previous meeting and continuous discussion.
  + Prioritize decisions, if they can help reducing RAN1 simulation efforts during summer, e.g. to study higher rank codebook design.
* For MTRP CSI, we may strive to finalize some decisions with alternatives/FFS, which were agreed within RAN1 104e-bis or earlier. The majority of proposals, therefore, is the leftover and continuous discussion.
  + Prioritize decisions, if they may have more RAN2 impact, e.g. to assist Multi-TRP CSI related RAN2 discussion.

# Summary of CSI enhancement for FDD

## Remaining issues of codebook structure for Rel-17 PS for Rank 1

### 2.1.1 Remain issues of codebook structure for

**Issue 1 - Maximal value of P as Pmax**

For the value of , about 11 companies propose the candidate value, which are shown as Table 1.

**Table 1 Summary of Companies’ Views on the maximal value of P as for**

|  |  |
| --- | --- |
| **Views** | **Companies** |
| **=32** | Vivo, Apple, OPPO, Huawei, HiSilicon, Nokia, Nokia Shanghai Bell |
| **=48** | CATT |
| **restrict the number of CSI-RS ports** | Sony, Ericsson(=16) |
| **to be determined** | Samsung(together with the CSI-RS related study) |

Companies preferring **=32** have the following considerations:

* Most companies (e.g. Vivo, Apple, OPPO, Huawei, HiSilicon, Nokia and Nokia Shanghai Bell) propose the maximal value of CSI-RS port number P asis 32, which is the same as R16 PS CB.
* Companies’ simulation results (e.g. Huawei, HiSilicon) show that comparing the best performance of =16 and = 24, the best performance of =32 can provide 6.9% and 2.5% performance gain respectively.

Companies preferring **=48** have the following considerations:

* CATT provides simulation results to show that more than 2% and 6% performance gain can be achieved in terms of average and cell-edge UPT by using 48 SD-FD pairs over 32 SD-FD pairs.

Companies preferring to restrict the number of CSI-RS ports have the following considerations:

* Sony proposes to restrict the set of CSI-RS ports eligible by the UE based on UL CSI can reduce CSI feedback overhead.
* Ericsson prefers **=16** and provides simulation to show that the gain by using 32 CSI-RS ports is either marginal or incurring large overhead for modest benefit.
* Samsung proposes that maximal value of **P** is discussed together with the CSI-RS related study.

Considering companies’ views on this issue, the following proposal is suggested:

***Proposal 1:*** *For Rel-17 port selection codebook, the maximal value of CSI-RS port number P as is 32.*

|  |  |
| --- | --- |
| Company | Comments |
| Mod | Strive to make a decision in RAN1 105 based on the majority |
| vivo | Support. |
| OPPO | Support |
| ZTE | Although we think large than 32 ports is beneficial in terms of network performance, we are okay to accept P\_max = 32 if there is majority view. |
| Ericsson | For the more interesting configuration with Mv=2 (due to robustness), we don’t see any convincing gain to support 32 ports. It is sufficient to support P\_max= 16 ports only for this feature. For Mv=1 the gain is visible with 32 ports but it’s questionable if Mv=1 will be a configuration used in reality due to the issues pointed out with robustness. |
| MediaTek | Support |
| DOCOMO | Support |
| CATT | Moderate performance gain can be obtained by supporting 48 SD-FD pairs compared with 32 SD-FD pairs. We still believe =48should be supported. |
| LG | Support FL’s proposal |
| Nokia/NSB | Support |
| Lenovo/Mot | Support |
| Samsung | OK with the proposal, but suggest to discuss after we conclude CSI-RS study since it (Option 3) may have some impact on P\_max value |
| Intel | Support |
| Fraunhofer IIS,  Fraunhofer HHI | Support |

**Issue 2 – Values of K1**

There are more than 10 companies shared their views on the value of for . The views are listed in the following table.

**Table 2 Summary of Companies’ Views on the value of for**

|  |  |
| --- | --- |
| **Views** | **Companies** |
|  | Sony |
|  | OPPO |
|  | Nokia, Nokia Shanghai Bell |
|  | ZTE, Huawei, HiSilicon |
|  | vivo, Samsung |
| **Any value up to P** | CATT |
| **Values of depends on CSI-RS ports** | Ericsson(), Qualcomm Incorporated(1 value of K1 for CSI-RS ports <=12， up to 2 values of K1 e.g., K1={16,32} for 32-port) |

For values of for :

* Some companies’ simulation results (e.g. Nokia, Nokia Shanghai Bell) show that supporting at least {4, 8, 16, 32} is necessary.
* Companies (e.g. ZTE, Huawei, HiSilicon) propose ={ 4, 8, 12, 16, 24, 32 } to distribute performance gain equally as much as possible.
* Some companies (e.g. Vivo, Samsung) prefer P=2 should also be supported which means {2, 4, 8, 12, 16, 24, 32} for scenarios which has strong UL-DL reciprocity and very few (1 or 2) strong clusters.
* Some companies (e.g. OPPO ({8, 16, 24}), Sony ({2, 4})) prefer smaller values of .
* OPPO provides simulation results to show that increasing K1 value from 24 to 32 does not offer obvious performance gain. Sony thinks that candidate values of can be kept at small values with reducing the number of CSI-RS ports eligible by the UE.
* CATT proposes to support any value of up to P.

The values of depends on CSI-RS ports P:

* Ericsson proposes to use a proportion factor to determine the value of , where . Candidate values can be 0.75 and 1 based the simulation results which shows that small values of relative introduces significant performance loss.
* Qualcomm Incorporated prefers the values of depends on CSI-RS ports considering that the small numbers of , i.e., 2, 4, 8, 12 may not be useful especially for larger number of CSI-RS ports.

Based on above companies view, the following proposal is suggested:

***Proposal 2:*** *At least for rank 1, values of K1 for port selection matrix are {2, 4, 8, 12, 16, 24, 32}.*

* *Note that further reduction for possible parameter combinations among K1 and other codebook parameters of Rel-17 port selection codebook will be discussed jointly once candidate values are determined.*

|  |  |
| --- | --- |
| Company | Comments |
| Mod | Strive to make a decision in RAN1 105 based on the majority. |
| Qualcomm | We still think the number of K1 values per P value should be limited to 2. The small values (K1<=12) do not make sense especially for larger value of #ports. The reason is that CSI-RS is precoded with SD-FD bases, K1 values smaller than 2L in Rel-16 seems useless. Alternatively, we can put a limit on total number of combinations of {K1, beta, M} not exceeding combinations in Rel-16. If neither is agreeable, we think this proposal is not needed because the agreement in last meeting already says further reduction is needed. |
| vivo | Support. |
| ZTE | We are fine with this proposal. |
| Ericsson | Agree with Qualcomm that at most 2 K1 values per P value to reduce the number of possible configurations and implementation work. Also, small K1 values seem useless to support. A guideline on how to select these values is by using the factors alpha = 0,75 and alpha =1 from our proposal. |
| MediaTek | Agree with Qualcomm that small values of K1 should not be considered |
| CATT | Whenis turned off or, assume that is configured to UE and non-zero coefficients are reported to network for a layer. If , there will be no non-zero coefficients reporting for some of the selected ports. Non-zero coefficients indication within selected ports is needed, resulting in additional CSI reporting overhead. If we let, then the overhead for indicating the non-zero coefficients can be saved. Hence, should be reported to network with any value up to *P*. |
| Nokia/NSB | Ok with the proposal.  As pointed out by QC and Ericsson and as indicated in the note, we will have a discussion on the supported parameter combinations of () and eventually only a small number of combinations will be supported as in Rel-16 |
| Lenovo/Mot | Support proposal, OK with reducing the candidates when discussing the codebook parameter combinations |
| Samsung | Support; same view as other companies on reducing #supports para combinations like in R16 |
| Intel | We think that further downselection of supported combinations is necessary |
| Fraunhofer IIS,  Fraunhofer HHI | The values of K1 are upper bounded by the number of CSI-RS ports. Therefore, for clarity, we suggest deriving the number of selected ports using a factor alpha conditioned on the number of CSI-RS ports as , where and the parameter combinations can be discussed for different values of P. In general, we are fine with the proposal. |

**Issue 3 –Polarization-common and combinatorial coefficients**

In RAN1#104b-e, there is FSS on whether there is a need to restrict the number of CSI-RS ports for polarization-common based free-selection. 9 companies (e.g. vivo, ZTE，Sony，Nokia, Nokia Shanghai Bell，Lenovo, Motorola Mobility, Ericsson, Intel Corporation) provide their views on this issues and all of them prefer that polarization-common based free-selection should be supported for all supported number of CSI-RS ports in Rel-17.

There also has on FFS on whether there needs a restriction on combinatorial coefficient used for port selection. 5 companies (e.g. MTK, CATT, Nokia, Nokia Shanghai Bell, Intel Corporation) provide their views on this issue and all of them support that combinatorial coefficient should be supported for all supported configurations of Rel-17 port selection codebook.

Base on above views, following conclusion is suggested:

***Conclusion 1:*** *At least for rank 1, no further restriction or condition is applied for polarization-common based free-selection and combinatorial coefficient based port selection for W1.*

|  |  |
| --- | --- |
| Company | Comments |
| Mod | This can be simple conclusion if there is no further design/enhancement required. |
| vivo | Support. |
| ZTE | Support |
| Ericsson | Support |
| MediaTek | Support |
| CATT | Support |
| LG | Support |
| Nokia/NSB | Support |
| Lenovo/Mot | Support |
| Samsung | Support |
| Intel | Support |
| Fraunhofer IIS,  Fraunhofer HHI | Support |

### 2.1.2 Remain issues of codebook structure for

**Issue 1 - Values of**

For , about 13 companies give proposal on value(s) of >1, which are shown as Table 3.

**Table 3 Summary of Companies’ Views on value of Mv for**

|  |  |
| --- | --- |
| **Views** | **Companies** |
| **=1,2（12）** | HW, HiSilicon, Fraunhofer IIS, Fraunhofer HHI, Nokia, Nokia Shanghai Bell, Lenovo, Motorola Mobility, Ericsson, Samsung(Mv=2 only for P<=12), ZTE(Mv = 1 only for 24/32 ports), Intel |
| **=1,2,3,4（1）** | vivo |

Based on companies’ view, it can be found that =2 is the majority view and companies preferring >2 also supports =2.

For =2, different companies have different views, which are summarized as following.

* Simulation Performance
* Samsung provide simulations result show that for >12, shows small gain or no gain, when compared with turned OFF.
* Vivo provide simulations result show that average gain increases with the increasing at the range of high CSI feedback overhead.
* Many companies (e.g. Fraunhofer IIS and Fraunhofer HHI (1.1%@16 ports; [1.7%@32ports](mailto:1.7%25@32ports)), Huawei, HiSilicon (2.31%@24 ports; [0.87%@32ports](mailto:0.87%25@32ports)) provide simulations result to show that increasing the number of delays significantly increases the performance with a marginal increase in feedback overhead.
* UE complexity:
* ZTE view that it is not needed to support larger Mv values for larger CSI-RS ports, and to support a smaller value of Mv for higher number of CSI-RS ports is beneficial to reduce CSI overhead and UE complexity.
* Intel view that reasonable overhead and robustness trade-off can be achieved for M = 2.

Therefore for the value(s) of >1, the following proposal is suggested:

***Proposal 3:*** *For* ,*Mv =2 is supported for R17 PS codebook*

|  |  |
| --- | --- |
| Company | Comments |
| Mod | Strive to make a decision in RAN1 105 based on the majority. |
| vivo | Expect for Mv=2, we still see the needs to support higher values, at least Mv=4, for the case of smaller number of CSI-RS ports, P. In our simulation results, a larger Mv will increase the upper limit of the performance by about 5% for P=4. |
| OPPO | Support |
| ZTE | We haven’t observed gain for Mv=2 with large number of CSI-RS ports. Hence we support that Mv=2 is applied only when # of CSI-RS ports is smaller than 24. |
| Ericsson | Support |
| MediaTek | Support |
| DOCOMO | Support |
| CATT | Support |
| LG | Support |
| Nokia/NSB | Support  In the results reported in out paper we have observed gain for Mv=2 also for P=32. One important use case is for gNB implementations with lower delay resolution, due for example to limited SRS bandwidth. The gain in this case is very significant across the range of parameter combinations of K1 and when the SRS bandwidth is half that of CSI-RS. We also observed gain for large SRS bandwidth (same as CSI-RS) due to increased robustness against non-ideal reciprocity of delays, for some parameter combinations. |
| Lenovo/Mot | Support. Just a reminder that the reciprocity model used in simulations assumes the angles and delays are perfectly reciprocal, which most likely is not the case in real-world scenarios. We have provided a mathematical analysis in our contribution that emphasizes the impact of angles/delay value mismatch on reciprocity. We therefore believe supporting M=2 is important to ensure some robustness for this feature |
| Samsung | Based on simulation results from two meetings now, we are struggling to justify the need/benefits for supporting Mv=2 for large #CSI-RS ports. There is no performance gain, CSI overhead is high, and UE complexity is increased significantly for large #ports.  Re the robustness and non-ideally arguments, we can use R16 codebook in those scenarios since there is no reciprocity to exploit anyway, so why even bother configuring R17 CB.  So, we can accept this proposal only for up to 12 ports.  ***Proposal 3:*** *For* ,*Mv =2 is supported for R17 PS codebook* ***for #CSI-RS ports <=12*** |
| Intel | Support the proposal. We already agreed to support one value with M > 1. In our view M = 2 provides additional robustness against delay reciprocity errors for any number of CSI-RS ports, thus in our view it should be supported. |
| Fraunhofer IIS  Fraunhofer HHI | Support the proposal. Some companies argue that when the channel is not reciprocal, other codebooks such that the R16 Type II PS can be used. However, we don’t think that R16 Type II PS is a fallback, as this codebook has a stringent constraint on the port selection over the R17 codebook (free selection of ports) and a different beamforming compared to Rel. 16. Relaxation of this stringent constraint on the port selection is one of the reasons why the R17 codebook (even for Mv=1 (or Wf is switched off) performs much better than the R16 Type II PS. Therefore, we cannot consider R16 Type II PS as a fallback. As the UL and DL channels are not completely reciprocal in real-world scenarios, some sort of flexibility shall be provided to the UE to compensate for the wrongly beamformed delays by the gNB. Therefore, regardless of the number of CSI-RS ports, shall be supported for robustness of Rel. 17 PS CB. |

**Issue 2 - Mechanism of configuring/indicating**

There are more than 20 companies have shared their views on the mechanism configuring/indicating , which are listed in the table below.

**Table 4 Summary of Companies’ Views on the mechanism configuring/indicating**

|  |  |
| --- | --- |
| **Views** | **Companies** |
| **Alt 1: FD bases in the window must be consecutive from an orthogonal DFT matrix**  **(18)** | Fraunhofer IIS, Fraunhofer HHI, QC, OPPO, Sony, Spreadtrum, ZTE, CATT, DOCOMO, Lenovo, Motorola Mobility, Ericsson, Samsung(N3 > t, e.g.t=19）, Nokia, Nokia Shanghai Bell, Intel, Huawei, HiSilicon |
| **Alt 2: FD bases in the set can be consecutive/non-consecutive, and are selected freely by gNB from an orthogonal DFT matrix**  **(4)** | vivo, MTK, LG, Samsung（N3 <= t，e.g.t=19） |

Companies support Alt1 with the following consideration:

* Companies (Fraunhofer IIS, Fraunhofer HHI) support Alt 1 since no significant performance difference is observed in the simulation when selecting Mv delays from a window of size 2Mv compared to freely selecting from N3.
* Companies (OPPO, Spreadtrum) thinks that a single window is sufficient to cover channel uncertainty since channel coefficients would be around FD basis 0 in the case of imperfect reciprocity.
* Companies (DOCOMO, Huawei, HiSilicon) support Alt1 because the free selection is equivalent to gNB implementations, e.g. with delay shift.
* Companies (QC, Nokia, Nokia Shanghai Bell, CATT, Spreadtrum) support Alt 1 since the window-based approach can save RRC signaling.
* Samsung proposes that a window-based configuration is beneficial when the value of N3 is larger than a threshold since the FD components in the middle are likely to be weak.

Companies support Alt2 with the following consideration:

* + Some companies (e.g. MTK (~4%), vivo (~1%)) simulation result show that the performance of non-consecutive delay window/set is better than the consecutive one.
  + LG proposes to support Alt 2 since gNB can configure more accurate FD bases for Wf based on DL/UL delay reciprocity, and performance can be improved based on gNB configuration
  + Samsung thinks that for small N3 values, all FD components can be comparable. Hence, limiting to a single window may incur performance loss, and a free selection in that case may be beneficial.

Based on the majority view, we suggest the following proposal:

***Proposal 4:*** *At least for rank 1, FD bases used for Wf quantitation are limited within a single window with size N configured to the UE whereas FD bases in the window must be consecutive from an orthogonal DFT matrix, i.e. Alt 1.*

|  |  |
| --- | --- |
| Company | Comments |
| Mod | Strive to make a decision in RAN1 105 based on the majority. |
| vivo | We do not support the proposal.  We think non-consecutive window can provide much more performance improvement with the same CSI feedback overhead especially for smaller number of CSI-RS ports.  When the number of CSI-RS ports is limited, consecutive window may omit some important delay information because of the window length is short. The configured window will contain the strongest path while another significant path may be out of the window due to short window.  According to our simulation results, when the number of CSI-RS ports is 4, the performance of non-consecutive window and only tap0 precoded in CSI-RS is better than other cases of consecutive windows with size N=2 and 6.   * + Case 1: Consecutive delay window/set and 4 SD-FD pairs with tap 0 precoded on 4 CSI-RS ports.   + Case 2: Consecutive delay window/set and 4 SD-FD pairs with free-selected taps precoded on 4 CSI-RS ports.   + Case 3: Non-consecutive delay window/set and 4 SD-FD pairs with tap 0 precoded on 4 CSI-RS ports.   C:\Users\Administrator\AppData\Roaming\vchat\ChatFiles\2021-05\278a2f0f-c445-473d-b5b1-ff3e3995b119.png  N=2  C:\Users\Administrator\AppData\Roaming\vchat\ChatFiles\2021-05\0821a8b2-22e3-47ff-95b1-769f9ea546b3.png  N=4  C:\Users\Administrator\AppData\Roaming\vchat\ChatFiles\2021-05\9c77187e-6f38-40b6-a9cd-50f89a34960a.png  N=6 |
| OPPO | Support the proposal. |
| ZTE | We are okay with this proposal. |
| Ericsson | Support |
| MediaTek | Do not support. In our opinion, N=Mv > 1 is used when there are insufficient CSI-RS ports to capture all significant SD-FD pairs. In this case, the configured FD basis could be consecutive/non-consecutive to the CSI-RS port precoded by an SD-FD pair. Besides, a free configuration includes the case of consecutive bases as well. So we prefer the additional N-1 FD bases to be configured from a consecutive/ non-consecutive set, with the first FD basis as the all-ones vector. |
| DOCOMO | Support the proposal. |
| CATT | Support |
| LG | We prefer to support Alt2 because Alt2 can provide performance enhancement in some cases as described by vivo. |
| Spreadtrum | Support the proposal. In our views, the one or two FD bases selected by UE should be adjacent. If gNB finds that the candidate FD bases corresponding to the same SD basis are far from each other, gNB can transmit the same SD basis with multiple ports, and shift the FD bases to the same index. |
| Nokia/NSB | Support |
| Lenovo/Mot | Support the proposal |
| Samsung | For large value of N3, the window is OK, but when N3 is small, the free selection makes more sense. We therefore suggest:  *Proposal 4: At least for rank 1, FD bases used for Wf quantitation are*   * *limited within a single window with size N configured to the UE whereas FD bases in the window must be consecutive from an orthogonal DFT matrix, i.e. Alt 1, when N3 > t* * *free selection when N3 <=t* * *FFS: value of t* |
| Intel | We prefer Alt 1 due to simplicity. Alt 2 may provide some benefits depending on the gNB implementation for CSI-RS precoding. |
| Fraunhofer IIS,  Fraunhofer HHI | Support |

Regarding the start point of above window, i.e., , more than 10 companies have shared their view as follows:

**Table 5 Summary of Companies’ Views on start point of the window**

|  |  |
| --- | --- |
| **Views** | **Companies** |
| **starting index of window fixed 0 (7)** | Fraunhofer IIS, Fraunhofer HHI, Spreadtrum, QC, Ericsson, Huawei, HiSilicon |
| **Configurable starting point**  **(5)** | ZTE, CATT, Sony, Lenovo, Motorola Mobility |

Companies preferring fixed have the following considerations.

* Some companies (QC, Spreadtrum, Huawei, HiSilicon) propose to fix because simply provides an offset in delay domain and a phase change does not change the precoder matrix and corresponding value of CQI.
* Ericsson proposes to fix to keep the feature as simple as possible with less RRC parameters
* Fraunhofer IIS, Fraunhofer HHI support fixed since no significant performance difference is observed by fixing Minit to zero compared to UE selection and reporting

Companies preferring configurable have the following considerations:

* ZTE and CATT propose that can be configured by gNB to accommodate the possibility of multiplexing more than 1 delays or UEs in one CSI-RS ports.

Based on the above observation, the following proposal is suggested:

***Proposal 5:*** *At least for rank 1, with regarding to for the single window with size N*

* *Alt 1: can be configured by RRC signalling*
* *Alt 2: is fixed to be 0*

|  |  |
| --- | --- |
| Company | Comments |
| Mod | Strive to make a decision in RAN1 105 based on the majority. |
| Qualcomm | Alt2. The usefulness of configuring Mini is not justified. |
| vivo | Support Alt 1. |
| OPPO | For UE to search FD basis freely, n3(1)-n3(0) < N is sufficient. Minit is not needed. |
| ZTE | We are okay with this proposal and support Alt 1. |
| Ericsson | Support the proposal with Alt.2 preference. Introducing an RRC parameter seems unnecessary, it is better to have a single value in specifications (i.e. Alt.2) |
| MediaTek | Support Alt 2 |
| CATT | Support Alt 1. |
| LG | Support Alt2. |
| Spreadtrum | Support Alt 2. |
| Nokia/NSB | Support Alt2.  The use case for Alt1 does not seem strong enough as network cannot ensure performance for all UE implementations when multiplexing 2 UEs or delays in the same port. |
| Samsung | OK with the proposal; in our view, Alt1 and Alt2 are the same from the perspective of UE implementations; but they are not the same from gNB perspective. |
| Intel | We support Alt 2. |
| Fraunhofer IIS,  Fraunhofer HHI | Support Alt 2. Additional RRC signalling is not required. |

**Issue 3 – The relationship between N and Mv**

For the relationship between N and Mv, about 17 companies give proposal, which are shown as Table 6.

**Table 6 Summary of Companies’ Views on relationship between N and Mv for**

|  |  |
| --- | --- |
| **Views** | **Companies** |
| **N = Mv**  **(7)** | Fraunhofer IIS, Fraunhofer HHI, QC, OPPO, Samsung, MTK, LG |
| **N>=Mv**  **(11)** | Sony, ZTE, vivo, CATT, NTT DOCOMO, Ericsson, Nokia, Nokia Shanghai Bell, Intel, HW, HiSilicon |

Forthe relationship between N and Mv, different companies have different views, which are summarized as following.

* Simulation result:
  + Many companies (e.g. Fraunhofer IIS, Fraunhofer HHI, HW, and HiSilicon, Samsung) provide simulation show that, **N>=Mv** shows no significant performance difference, when compared with **N = Mv.**
  + vivo provide simulation result show that with the increasing N, better performance can be obtained with the same CSI feedback overhead. With fixed Mv=2, there is almost 3% gain between N = 2 and N = 4, and there is almost 2% gain between N = 4 and N = 6.
* UE complexity:
  + Many companies (e.g. QC, Samsung, MTK, LG) view **N>Mv** requires additional reporting overhead of Wf, and increase UE complexity and incurs more CSI overhead.
* Robustness & Flexibility:
  + Many companies (e.g. Nokia, Nokia Shanghai Bell, HW, HiSilicon, Ericsson, Intel) view N>Mv help to increase robustness against non-ideal reciprocity and timing offsets. NTT DOCOMO view that N>=Mv should be supported so that UE can select the FD vectors with some flexibility, which helps to improve that performance.
  + ZTE view that to support N>Mv is better for higher ranks as different layers can report different Wf vectors in a common configured length-N window.

Based on companies’ views on the relationship between N and Mv, the following proposal is suggested:

***Proposal 6:***  *At least for rank 1, for relationship between N and Mv, down-select one Alternative from following*

*• Alt 1: N= Mv always*

*• Alt 2: N >= Mv*

|  |  |
| --- | --- |
| Company | Comments |
| Mod | Strive to make a decision in RAN1 105 based on the majority, i.e. do we need N>M? |
| Qualcomm | Alt1.  Window is used to indicate the max offset of the additional FD basis relative to the first FD basis. It is not related to the absolute location of the FD bases for PMI calculation. Timing offset issue can be solved by UE implementation.  Regarding robustness of non-ideal reciprocity, more simulations are needed to justify the benefit of N>=M. To obtain a full picture for evaluation, we suggest to expand the alternatives as  Alt1: N=Mv always, no UE reporting of Wf  Alt2-1: N>=Mv, Wf is reported by UE and Wf is layer-common  Alt2-2: N>=Mv, Wf is reported by UE and Wf is layer-specific |
| vivo | Support Alt 2. |
| ZTE | We support Alt 2. We think to make N=Mv is too restrictive esp. considering higher ranks where Wf is better to be layer specific. |
| Ericsson | Support the proposal |
| MediaTek | Support Alt 1. Agree with Qualcomm's wording for further study. |
| DOCOMO | Support Alt 2. |
| CATT | Support Alt 2. When non-zero coefficients corresponding to a FD basis are all zero, it is not necessary to report UCI (e.g., bitmap) for the FD basis. Allowing UE to choose Mv value could save overhead in this case. |
| LG | Support Alt.1 |
| Spreadtrum | Support Alt 1 based on UE complexity perspective. |
| Nokia/NSB | Support Alt 2.  A larger window size can increase robustness in some scenarios with non-ideal delay reciprocity |
| Lenovo/Mot | Support Alt 2 for M>1 only. No need for window when M=1 |
| Samsung | For rank 1, we don’t see any benefits with N>Mv. For high rank, assuming window is layer-common, it makes sense to either increase N or reduce Mv, e.g., (N,Mv)=(4,2) or (2,1). But, this needs to be evaluated.  So, for rank 1, we prefer Alt1. |
| Intel | We prefer Alt 2 with layer-common Wf |
| Fraunhofer IIS,  Fraunhofer HHI | Support |

Moreover, for the windows size of N, when , companies give proposal on the value(s) of N, which are shown as Table 7.

**Table 7 Summary of Companies’ Views on values of N and Mv for**

|  |  |
| --- | --- |
| **Views** | **Companies** |
| **N = 2 or 4** | ZTE, HW, HiSilicon |
| **N=2,4,[6]** | vivo |
| **N=4** | Intel |

Based on companies’ view, it can be found that most companies (6 out of 7) who support >2 also support =2. Intel view is that N>Mv may help to provide additional flexibility and additional robustness against delay reciprocity in FDD channels. Vivo provide simulation result show that with the increasing N, better performance can be obtained with the same CSI feedback overhead. With fixed Mv=2, there is almost 3% gain between N = 2 and N = 4, and there is almost 2% gain between N = 4 and N = 6.

Therefore if Alt 2 in Proposal 6 is agreeable, the following proposal is suggested for value(s) of N

***Proposal 7:*** *Support N = 2 or 4 for .*

|  |  |
| --- | --- |
| Company | Comments |
| Mod | It seems that Proposal 7 may depend on the outcome of Proposal 6. |
| vivo | We are fine with the proposal. |
| ZTE | We are okay with this proposal assuming Alt 2 in Proposal 6. |
| Ericsson | Support |
| DOCOMO | Support |
| CATT | In our view, N =2 is sufficient. In addition, the N value shall be applicable to both Mv = 1 and Mv = 2. |
| Nokia/NSB | Support |
| Lenovo/Mot | Support, assuming Alt2 in Proposal 6 is agreed |
| Samsung | For rank 1, we don’t need N>Mv. So, we support the following for rank 1:  ***Proposal 7:*** *Support N = 2 for and rank 1*   * *Study N >= Mv for rank > 1* |
| Intel | Support the proposal |
| Fraunhofer IIS,  Fraunhofer HHI | Support |

**Issue 4 - Values of R**

For , about 10 companies give proposal on value(s) of R. The main views can be summarized as follows：

**Table 8 Summary of Companies’ Views on R for**

|  |  |
| --- | --- |
| **Views** | **Companies** |
| **R < 1** | Samsung(R=1/4) |
| **Only R=1** | Apple, QC |
| **R =1 and 2** | Fraunhofer IIS, Fraunhofer HHI, OPPO，ZTE |
| **R= D\* should be supported whereas D is the density of CSI-RS in frequency domain** | CATT, Nokia, Nokia Shanghai Bell, HW, HiSilicon, Ericsson, Intel |

For R<1, companies have the following reviews.

* Samsung thinks when CSI-RS beamforming is the same for different R values, R=1/4 achieves the best performance among R=1/4, ½, 1, and 4
* Fraunhofer IIS and Fraunhofer HHI don’t support R<1. They observed that compared to R=1, there has a loss for R<1, e.g. 0.4% performance loss for R=1/4.

Companies preferring only R =1 have the following considerations.

* QC and Apple don’t support R>1. QC considers that the benefit of R > 1 in Rel-17 FDD CSI is unclear considering increased UE complexity, and the FD basis used in CSI-RS beamforming can be in RB granularity, the network is able to obtain an RB-level precoder even with M=1 or {M > 1, R=1}. Therefore, supporting R > 1 is unnecessary for PMI resolution.

Companies preferring R =1 and 2 have the following considerations.

* ZTE, OPPO, Fraunhofer IIS and Fraunhofer HHI prefer R = 1and 2. And Fraunhofer IIS and Fraunhofer HHI’s simulation results show that when using R=2, the performance of Rel. 17 PS CB improves for all parameter combinations. Further increasing the value of R to 4 results only in a slight improvement in performance.

Companies preferring to supported R= have the following considerations.

* CATT, Nokia, Nokia Shanghai Bell, Ericsson, HW and HiSilicon observed best performance can be observed when R is configured at the maximum value, e.g. R= . For example,
  + Some companies’ simulation results (Nokia, Nokia Shanghai Bell, Ericsson, Huawei and HiSilicon) show that compared with R=2, larger R (e.g. R= ) can provide a better performance.
  + Intel consider that for the codebook introduced for system with FDD reciprocity subband size can be further reduced since the complexity of PMI search is similar for different values of R for the new codebook. In fact, the PMI subband size can be reduced to the minimum possible value such that PMI subband contains one sample of CSI-RS, i.e. PMI subband size is equal to 1/D PRB, where D is CSI-RS density.

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

***Proposal 8:*** *For Rel-17 PS codebook enhancement, following values of R are supported:*

* *R=1*
* *R= is whereas D is the density of CSI-RS in frequency domain and is the CQI subband size in PRBs.*

|  |  |
| --- | --- |
| Company | Comments |
| Mod | For simplicity of configuration and also potential compromise, it is suggested to choose only two values as 1 (the smallest), and another one from another camp (the largest). |
| Qualcomm | We cannot support R=.  The smallest PRG size for DMRS is 2RB, we don’t see the rationale to support RB-level PMI. Regarding complexity, RB-level PMI (or 2RB-level PMI) requires constructing 275 (or 138) different PMIs, which is a significant increase in implementation complexity compared to R=1 (upto 19 PMIs).  Regarding performance, some companies show that there are around 3~5% gain offered by R= vs. R=1. In our view, the gain is resulted by different UE/gNB implementation for R=1 and R=. If UE perform same PMI processing regardless of R value, and the gNB performs PMI interpolation (e.g., replacing Wf with R=1 by a Wf with R > 1), R=1 and R > 1 will yield exact same precoder. On the other hand, even if R value implies different level PMI processing implementation complexity, 3~5% gain is not significant considering the increased complexity of PMI construction. |
| vivo | Support. |
| ZTE | We are okay to keep “R= D\*” and “R= 1”. Further study is needed to down select one alternative, esp. considering gNB has the flexibility of using small granularity for CSI-RS precoding by implementation. The performance difference is from whether UE uses a same or different precoding granularity to derive PMI. |
| Ericsson | We don’t see the need for R=1. Let’s keep the feature simple and only support the larger value is it have more gain, and we avoid unnecessary configurations and RRC parameters |
| MediaTek | We think is very high assuming D=1, which causes higher UE complexity. Support R=1 for a clean solution |
| CATT | Support |
| LG | We support Alt2. (i.e., R=1 and 2) Alt2 is the same as the Rel-16, so performance gain from large R (i.e., R=2) can be obtained without having impact to UE complexity compared to Rel-16. |
| Spreadtrum | Support R = 1. Other R values should be UE optional, if supported. |
| Nokia/NSB | Support *R=* . We are also ok with adding an absolute limit on R, e.g. .  Regarding UE implementation complexity, a UE is not required to evaluate all N3 candidate PMIs corresponding to different FD components for Mv=1. But if a UE chooses to do so in its implementation, for example by calculating an N3 point DFT, it can also limit such search to, e.g., 19 PMIs, for example by sampling the DFT appropriately.  The performance difference by setting R>1 is due to the different precoding applied by the gNB rather than different UE processing.  Regarding the PRG size, although the smallest PRG size is 2PRBs, the edge PRGs can have only 1 PRB. Besides, the higher PMI granularity on CSI-RS can be used by the gNB scheduler/precoder implementation to optimise a lower granularity PDSCH/DMRS precoder. |
| Lenovo/Mot | Agree with QC, at least 2 RBs per PMI sub-band should be supported. A similar argument was discussed for Rel. 16 Type-II codebook. Both R=1,2 should be supported, similar to Rel. 16 |
| Samsung | Based on Tdocs submitted this meeting, it looks like most companies simulated the case wherein the CSI-RS beamforming is according to R values, i.e., FD resolution of CSI-RS beamforming increasing with increasing R. In this case, the gain is expected. We also see some gain (though small). This case, however, is artificial and not interesting.  Not many companies simulated the (2nd) case which is more interesting in practice, wherein the R value for CSI-RS beamforming is fixed to the highest (per PRB level), and then compared the performance of R values for Wf. This in our view is more important, since the gNB can obtain the high resolution beamforming information (in fact, the gNB can obtain eigen basis). As shown in our contribution, we are not seeing any gain with increasing R in this case.  We therefore prefer R <1 or R<=1, at the most. |
| Intel | In our view PRB-level PMI does not add a lot of UE complexity, for Mv = 1 the complexity is actually the same as for R = 1. In our understanding UE may need to reconstruct actual precoding matrix per PRB only for CQI calculation; since CQI calculation can be optimised at the UE (e.g. by using downsampling for frequency granularity) the overall complexity for PMI and CQI can be similar for R = 1 and R = D \* NSB\_PRB |
| Fraunhofer IIS,  Fraunhofer HHI | Our simulation results show that when we have a high resolution at gNB side for CSI-RS beamforming (PRB level) and R<1 at the UE side, a performance degradation is observed compared to R=1. So, we prefer R=1 at least. We are also fine with other values of R>1. |

**Issue 5 - Clarifying on turn off**

There has some discussion on the relationship between turn off and . There are some companies provide views on this issue, which is shown as following.

* QC
* For Rel-17 FDD CSI, clarify that OFF and ON with are same
* Ericsson
* An RRC parameter controls the number of FD bases (e.g. =2), and the default value is a single basis (=1). In this default case, is an all-one vector of length N3.
* Samsung
* Regarding turning ON/OFF,
  + Support an explicit RRC parameter for turning ON/OFF
  + The length of the all-one vector is 1, when is turned OFF
* DoCoMo
* Consider dynamic configuration of turning on/off using DCI

Based on companies’ views, the following conclusion is proposed.

***Proposal 9:*** *For Rel-17 port selection codebook,*

* *Alt 1 - can be turned OFF/ON implicitly by the value of* 
  + *OFF or ON are the same when Mv=1, whereas*  *is an all-one vector of length N3, from the UE perspective.*
* *Alt 2 - can be turn* *OFF/ON by explicit signaling*
  + *When is turned OFF, Wf is an all-one vector of length 1.*

|  |  |
| --- | --- |
| Company | Comments |
| Mod | The proposal intends to align RAN1 understanding further for the agreement, as much as possible. |
| Qualcomm | Alt2 is unclear to us. Are OFF or ON are the same when Mv=1*?* If yes, the difference compared to Alt1 is that the length of all-one vector is 1? |
| ZTE | We think further study is needed and it is too early to discuss signalling details. We agree with QC that it’s better to clarify whether “Wf off” and “Mv=1” are same. Our understanding is they are same, and when Wf is turned off, we shouldn’t restrict the UE implementation to measure PMI, i.e., no need to restrict that Wf is all one vector. Signalling details can be further studied. Hence we think a better formulation is as follows.  *For Rel-17 port selection codebook, “Wf off” and “Mv=1” are same. When Wf is turned off,*   * + *Alt 1 -*  *is an all-one vector of length N3, from the UE perspective.*   + *Alt 2 - Wf is an all-one vector of length 1.* |
| Ericsson | Mv=1 means Wf is the all one vector of length N3. Hence, according to the agreement Mv=1 means Wf is off. |
| MediaTek | Support Alt 1, Wf can be turned ON or OFF implicitly depending on Mv >1 or Mv =1 respectively |
| DOCOMO | Agree with QC to first clarify the Wf OFF and Mv=1. |
| CATT | Support Alt 2. When W*f* is turned off, the parameters N and R do not need to be configured. From this perspective, W*f* turned off is different from W*f* turned on and Mv=1. |
| LG | It seems that this proposal is related to Proposal 5 and 6. If Alt2 in P5 and Alt1 in P6 are assumed, Alt1 in P9 can naturally be supported. So, P9 can be concluded after decision on P5 and P6. |
| Spreadtrum | Our understanding is aligned with Alt 1. |
| Nokia/NSB | From the agreement in Min’s comment (second bullet) it seems we already agreed to support a configuration with Mv=1 and . So, the question is whether “Wf off” is equivalent to this configuration or we need a second configuration, with PMI format indicator set to wideband.  A UE configured with (Mv=1, ) or with (“Wf off”, WB PMI) would report a single PMI in both cases and, in our view, the same PMI can be correctly reported in both cases, which suggests that the two configurations achieve the same result. |
| Lenovo/Mot | Our understanding is also aligned with Alt 1.  @CATT: We can still impose restrictions on reporting R, N when M=1. Value of M is already RRC configured, no need to introduce a duplicate RRC parameter to do the same function |
| Samsung | This issue is related to the CSI reporting format, WB and SB CSI. In our view, both WB and SB CSI should be supported due to the following reason:   * WB CSI can be beneficial for R17 codebook since SB component of the precoder can be obtained via gNB beamforming and WB component can be reported by the UE. * R17 CB is for a BF channel, which tend to have reduced frequency selectively, hence closer to WB CSI. In an ideal case, e.g. TDD, the BF channel can be almost flat, hence WB CSI can be beneficial for both BWP < 24 and >= 24. * For BWP size < 24 PRBs, we have limitation in the current spec, i.e., only WB CSI can be configured (since we don’t have a SB size in this case). As shown in our contribution, we see large gain (~15% in avg. UPT) with supporting R17 codebook for BWP<24 PRBs, and the overhead is not too large (compared with the baseline, i.e. R15 T1 CB). We are not seeing such large gains in any of the other features (such as R>1 and Mv >1 etc.) that we are discussing in R17 CB. |
| Intel | We don’t see any need for additional indication for Wf with M = 1 (Support Alt 1) |
| Fraunhofer IIS,  Fraunhofer HHI | In our view Wf being OFF and are completely equivalent. In either case, a single WB PMI is reported. Additional RRC configuration seems not necessary as the presence of Wf can be indicated via . |

### 2.1.3 Remain issues of codebook structure for

**Issue 1 – Value(s) of**

More than 10 companies study the values of , which their views are shown in Table 9.

**Table 9 Summary of Companies’ Views on values of bitmap for**

|  |  |  |
| --- | --- | --- |
| **Views** | | **Companies** |
| values of beta | 1/8  (4) | CATT, Nokia, Nokia Shanghai Bell(), vivo |
| 1/4  (4) | CATT, Nokia, Nokia Shanghai Bell(), vivo |
| 3/8  (2) | Nokia, Nokia Shanghai Bell() |
| 1/2  (5) | Samsung, CATT, Nokia, Nokia Shanghai Bell(), vivo |
| 3/4  (7) | Ericsson,Samsung, OPPO, CATT, Nokia, Nokia Shanghai Bell(), vivo |
| 1  (10) | Ericsson,Samsung, OPPO, CATT*,* Nokia, Nokia Shanghai Bell(), DOCOMO, vivo(Wf is turned off), Huawei, HiSilicon |

Many companies provide simulation results on different value of , and considering both the performance and overhead trade-off, some candidate values of are proposed. But the candidate values of are inconsistent among companies, which need further study and down-selection in the discussion for supported parameter combinations.

Based on above views, the following proposal is suggested:

***Proposal 10:*** *For the compression coefficient for non-zero coefficients of W2, values of are {[1/8], [1/4], [1/2], 3/4, 1}*

* *Note that further reduction for possible parameter combinations among and other codebook parameters of Rel-17 port selection codebook will be discussed jointly once candidate values are determined.*

|  |  |
| --- | --- |
| Company | Comments |
| Mod | Some values are still in bracket in order to keep candidate values as less as possible. We may strive to make a decision in RAN1 105 based on the majority. |
| vivo | Support. |
| ZTE | We are okay with proposal 10. |
| Ericsson | Ok with the proposal. We don’t foresee any need to support small beta values as in the brackets, due to the reasons stated in our contribution.  Instead of the possibility to configure a small beta, we think it is more reasonable to configure the UE with fewer CSI-RS ports but larger beta value. |
| MediaTek | Do not prefer =1/8, but support the proposal in general |
| DOCOMO | Ok. Even though we think some small values are not needed. |
| CATT | Support |
| Spreadtrum | We prefer to support larger values first. The smaller values can be FFS. |
| Nokia/NSB | As commented in P2 regarding the candidate values for K1, in the end, we will select a limited number (e.g. 6 or 8) of parameter combinations (K1,Mv,beta) as said in the note so it’s probably safer not to restrict the candidate values too much at this stage. In our results so far we observed that the points offer good tradeoff points for and is also a good candidate for . So, our preference is to keep all 6 candidate values for now. |
| Lenovo/Mot | OK to study the proposal. Our understanding is that a subset of the values would be supported as part of the parameter combinations of the codebook |
| Samsung | We also have the view that very small beta value, e.g. 1/8, can be excluded. |
| Intel | OK |
| Fraunhofer IIS,  Fraunhofer HHI | Support |

**Issue 2 – Bitmap for indication non-zero coefficients**

About than 10 companies provide their views on bitmap for indication non-zero coefficients, including whether/how such a bitmap can be absent and whether the bitmap is polarization-common or polarization-specific, which their views are shown in Table 10 and Table 11.

**Table 10 Summary of Companies’ Views on the absent of bitmap for**

|  |  |  |
| --- | --- | --- |
| **Views** | | **Companies** |
| whether/how such a bitmap can be absent | (7) | Ericsson, Nokia, Nokia Shanghai Bell, Lenovo, Motorola Mobility ,Spreadtrum Communications, vivo |
| (5) | CATT, Lenovo, Motorola Mobility, vivo, DOCOMO() |

Regarding the issue of whether a bitmap can be absent, several companies have the following considerations:

* Companies(Ericsson, Nokia, Nokia Shanghai Bell, Lenovo, Motorola Mobility, Spreadtrum Communications, vivo) propose that when , the bitmap does not need reporting since the advantages of using a bitmap would diminish, and the overhead incurred by including the bitmap can dominate the CSI feedback overhead saving resulting from it. Ericsson propose that for rank 1, when is configured, then UE reports all coefficients and the resulting NZC bitmap is all ones and is therefore not reported, but for rank > 1, a bitmap is needed even when .
* Companies (CATT, Lenovo, Motorola Mobility, vivo, DOCOMO) propose that when, the bitmap does not need reporting. CATT propose to adopt polarization-common port selection and polarization-common bitmap of ***W2.*** Under this condition, the indication of port selection can be used to indicate the location of non-zero coefficients for each layer at least when or is turned off if the number of selected port is same to that of reported non-zero coefficients, which implies that bitmap for indicating non-zero coefficients can be absent. DOCOMO’s view is that the bitmap for indication non-zero coefficient is not needed if is small and all the non-zero coefficients within can be reported.

Based on above views, the following proposal is suggested:

***Proposal 11:*** *The bitmap for indicating non-zero coefficients for W2 can be absent for CSI reporting,*

* *Alt 1: if*
* *Alt 2: if*

*FFS: additional impact for codebook design when the bitmap is absent*

|  |  |
| --- | --- |
| Company | Comments |
| Mod | The proposal intends to down select to one Alt in order to save UCI overhead, if the bitmap is absent |
| Qualcomm | In our view, whether the bit map can be absent depends on other issues. If UE further reports an actual number of NZC, bitmap is till needed. If rank 3/4 are to be supported and total number of NZC are compared to rank-2, bit map is also needed. If the majority view is not to support either of above, we are open to discuss Alt1 and Alt2. |
| vivo | In our opinion, the bitmap is absent when 𝛽=1, including both 𝛽 is configured to 1 and implicitly defaulted by 1 if Mv=1. |
| ZTE | We think further study is needed for this proposal including whether bitmap can be omitted.  Bitmap is still needed for Alt 1 as beta indicates the maximum number of NZ coefficients and the real number of NZ coefficients can be fewer than the maximum values as in Rel-16. Hence this condition is not correct in our view.  For Alt 2, bitmap can only be absent when Mv=1 and rank = 1. In this case, port selection is equivalent to NZC indication. |
| Ericsson | At least Alt.1 based on our evaluation results. The bitmap is not needed when beta=1 and rank = 1, the total number of NZCs is not reported either, since it implicitly means = |
| MediaTek | For rank 1, Alt 1 is suitable. For higher ranks, agree the views with Qualcomm |
| DOCOMO | Agree with QC that UE can report an actual number of NZC. Further discussion is needed. |
| CATT | Support Alt 2. We share the same view as ZTE for Alt 1. |
| Spreadtrum | When beta value =1, the functionality of bitmap can be replaced by reporting all of the coefficient amplitudes. |
| Nokia/NSB | We agree with previous observations that whether the bitmap can be absent depends on the reported rank for both alternatives, so maybe we can revisit this proposal after evaluating support for higher rank |
| Lenovo/Mot | We believe a bitmap should be absent **only when both β=1 and M=1**. Clearly, bitmap is important when β<1, also if β=1 but M>1 the number of coefficients can be very large, especially with large K1. |
| Samsung | We see there can be overhead saving when bitmap is absent, but, many of those coefficients can be close to 0, hence may be set to 0 by the UE via the bitmap (similar to R16). Since the UE should make this decision, the bitmap may or may not be absent depending on the measure channel. In our view, this can be handled by UCI design depending on the reported K^NZ value in UCI part 1.  So, we prefer the UE to make this decision (absent/present), not forcing/restricting the UE to do so by configuration. |
| Intel | We prefer Alt 1. It is beneficial to reduce the maximum payload size for the CSI report |
| Fraunhofer IIS,  Fraunhofer HHI | We suggest discussing this issue once we have a complete picture of the higher ranks |

**Table 11 Summary of Companies’ Views on polarization-specific or polarization-common for**

|  |  |
| --- | --- |
| **Views** | **Companies** |
| polarization-specific bitmap  (6) | Ericsson, Nokia, Nokia Shanghai Bell, OPPO, Lenovo, Motorola Mobility, |
| polarization-common bitmap  (5) | Lenovo, Motorola Mobility, CATT, Huawei, HiSilicon |

For whether a bitmap is polarization-common or polarization-specific, 9 companies share their views. Due to the reason that polarization specific bitmap is flexible and simple for quantization, 6 companies (Ericsson, Nokia, Nokia Shanghai Bell, OPPO, Lenovo, Motorola Mobility) prefer polarization-specific bitmap. While considering the gains achieved from polarization-specific bitmap is negligible and polarization-common has lower feedback overhead, 5companies (Lenovo, Motorola Mobility, CATT, Huawei, HiSilicon) propose to adopt polarization-common bitmap. From above observation, preferring the polarization-specific bitmap is the majority view.

Based on above views, the following proposal is suggested:

***Proposal 12: A polarization-specific bitmap for indication non-zero coefficients should be supported for W2.***

|  |  |
| --- | --- |
| Company | Comments |
| Mod | Strive to make a decision in RAN1 105 based on the majority. |
| vivo | Support. |
| OPPO | Support |
| ZTE | Okay with FL’s proposal. |
| Ericsson | Support |
| MediaTek | Support |
| CATT | Do not support the proposal. We support polarization-common due to better trade-off between performance and overhead compared with polarization-specific. |
| LG | Support |
| Spreadtrum | Support |
| Nokia/NSB | Support |
| Lenovo/Mot | Support |
| Samsung | Support |
| Intel | Support |
| Fraunhofer IIS,  Fraunhofer HHI | Support |

**Issue 3 – SCI**

For R16 based quantization, we need a strongest polarization indicator (which fixes one of the reference amplitude to 1). In R16, SCI is used for this purpose. In R17, however, since the strongest coefficient has to be within the configured set, it can be anywhere within the set, i.e., not necessarily at FD component = 0. Also, if the circular shift similar to R16 is applied then in fact the strongest coefficient may fall outside of the configured set. Therefore, some discussion is needed regarding the SCI. Several companies share their view about the SCI, shown as following.

**Table 12 Summary of Companies’ Views on SCI**

|  |  |
| --- | --- |
| **Views** | **Companies** |
| Reporting of the position, [, ], of the strongest coefficient of layer , for , using bits.  (1) | Nokia, Nokia Shanghai Bell |
| ***Strongest coefficient indication (SCI) may need to be studied further for Rel-17 port selection codebook, when Mv>1.***  (3) | Samsung, Huawei, HiSilicon, |
| ***The strongest coefficient is indicated by using for l-th layer.***  (1) | CATT |

* Companies (Nokia, Nokia Shanghai Bell) propose to report of the position, [, ], of the strongest coefficient of layer , for , using bits.
* Company (CATT) propose the strongest coefficient corresponds to the DC component after shifting phase and that the strongest coefficient is indicated by usingfor *l-th* layer.
* Companies (Samsung, Huawei and HiSilicon) mention that the SCI may need to be studied further.

Considering companies’ views on this issue, the following proposal is suggested:

***Proposal 13:*** *Study following alternatives for reporting the strongest coefficient indication (SCI) for Rel-17 port selection codebook in W2*

* *Alt 1: Reporting of the position, [, ], of the strongest coefficient of layer , for , using bits without shifting the strongest coefficient to*
* *Alt 2: Shifting the strongest coefficient to , and using bits to indicate the phase shift quantity. The strongest coefficient is indicated by , using for l-th layer.*

|  |  |
| --- | --- |
| Company | Comments |
| Mod | The proposal intends to study/clarify the issue of SCI, for further decision in August Meeting by RAN1 106 |
| vivo | Fine to FFS. |
| OPPO | Fine for study.  For Alt 2, is the phase shift quantity not the Minit (either fixed or configured) in proposal 5? |
| ZTE | We are okay to further study this issue. |
| Ericsson | OK to study |
| MediaTek | Ok to study |
| CATT | Support Alt 2 |
| Spreadtrum | OK to study. |
| Nokia/NSB | Ok to study.  In our proposal for Alt 1 the strongest coefficient is also shifted to as for Alt 2, so we suggest correcting Alt 1 as follows:  *Alt 1: Shifting the strongest coefficient to , and using bits to report its position, [, ], before the shift, for -th layer*  shifting the strongest coeff. to position 0 makes the position of the strongest coefficient more predictable, e.g. if UCI omission occurs and does not come at any extra cost. |
| Lenovo/Mot | Should be discussed after FD basis parameters are finalized |
| Samsung | We are not sure why we need the shifting operation in Alt1, when we are reporting the FD index of the strongest coefficient. This is unnecessary complicating the codebook in our view.  So, we don’t support any shifting operations in Alt1, and also prefer to add Alt0 (which can reduce SCI payload) as follows.  We also prefer to add Alt3, in case the SCI is not supported in R17.  ***Proposal 13:*** *Study following alternatives for reporting the strongest coefficient indication (SCI) for Rel-17 port selection codebook in W2*   * *Alt 0: Reporting of the position, [, ], of the strongest coefficient of layer using bits, where* * *Alt 1: Reporting of the position, [, ], of the strongest coefficient of layer , for , using bits ~~without shifting the strongest coefficient to~~* * *Alt 2: Shifting the strongest coefficient to , and using bits to indicate the phase shift quantity. The strongest coefficient is indicated by , using for l-th layer.* * *Alt 3: SCI is not supported*   + *Note: if SCI is not supported, then the SCI in R16 based quantization scheme (if supported) is replaced with a strongest polarization indicator.* |
| Intel | Ok to study |
| Fraunhofer IIS,  Fraunhofer HHI | Support revision on ALT1 by Nokia. |

**Issue 4 - Quantization of coefficients**

For the quantization of  coefficient, more than 15 companies prefer to reuse the Rel-16 quantization mechanism which are shown as Table 13.

**Table 13 Summary of Companies’ Views on quantization for coefficients of**

|  |  |
| --- | --- |
| **Views** | **Companies** |
| Regarding the quantization of , support the baseline Alt 1: Reusing Rel-16 quantization mechanism  (17) | Qualcomm, Ericsson, Nokia, Nokia Shanghai Bell, Samsung, Lenovo, Motorola Mobility, ZTE, OPPO, CATT, Fraunhofer IIS, Fraunhofer HHI, Spreadtrum Communications, LG Electronics, Intel Corporation, Huawei, HiSilicon |
| Reserved state for reference amplitude in Rel-16 can be replaced with a new value  (1) | Samsung |
| Reserved state for reference amplitude in Rel-16 can be replaced with a smaller value following 1.5 dB step size, i.e. ,.  (1) | ZTE |

Based on the above companies view, it can be found that reusing the Rel-16 quantization mechanism is the majority view, the following proposal is suggested:

***Proposal 14:*** *For the quantization of W2 coefficient, reusing following Rel-16 quantization mechanism for Rank1 at least:*

* *Two polarization-specific reference amplitudes:*
  + *for the polarization associated with the strongest coefficient, the reference amplitude is not reported*
  + *for the other polarization, reference amplitude is quantized to 4 bits*
    - *The alphabet is (-1.5dB step size)*
* *For coefficients other than the strongest coefficient*
  + *differential amplitude is calculated relative to the associated polarization-specific reference amplitude and quantized to 3 bits*
    - *The alphabet is (-3dB step size)*
  + *phase is quantized to 16PSK*
* *For the reserved state for reference amplitude, down-select one Alt from following:* 
  + *Alt 1: it is kept to be reserved*
  + *Alt 2: it is replaced as (1/2)^(15/4),*
  + *Alt 3: it is replaced as (1/2)^(3/8)*

|  |  |
| --- | --- |
| Company | Comments |
| Mod | For W2, the majority companies prefer to reuse so that above proposal is to clarify which design are to be reused, for the sake of discussion. If possible, down-selection from Alt1~3 is preferred this meeting. |
| vivo | Support the proposal and Alt 1 for the third bullet. |
| OPPO | Support |
| ZTE | Support the proposal. We are okay with either Alt 2 or Alt 3 if benefit can be shown with Alt 3. |
| Ericsson | Support and Alt 1 for third bullet is preferred |
| MediaTek | Support, and prefer Alt 1 for third bullet |
| CATT | Support the proposal and Alt1 for the third bullet. |
| LG | The same view with vivo. |
| Spreadtrum | Support. Prefer Alt 1 in the 3rd bullet. |
| Nokia/NSB | Support and preference for Alt 1 in third bullet |
| Lenovo/Mot | Support. Can we add FFS for differential amplitude values?   * *For coefficients other than the strongest coefficient*   + *differential amplitude is calculated relative to the associated polarization-specific reference amplitude and quantized to 3 bits*     - *FFS: The alphabet is (-3dB step size)* |
| Samsung | Support and prefer Alt3 for the reserved value. Also, suggest to revise the bullet related to SCI as shown below, since we have not agreed to supporting SCI yet.   * + *for the polarization associated with the strongest coefficient (if SCI is support) or the strongest polarization indicator (if SCI is not supported), the reference amplitude is not reported* |
| Intel | Support the proposal |
| Fraunhofer IIS,  Fraunhofer HHI | Support Alt 1 for the third bullet |

### 2.1.4 Others

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

|  |  |
| --- | --- |
| **Company** | **View** |
| **QC** | * Support parameter combinations of {K1, beta, M}, and total number of different combinations should not exceed Rel-16 eType II codebook. * UE reporting of actual number of non-zero coefficients. |
| **Lenovo** | * Configure the UE with two frequency compression parameter values for both strong and weak uplink/downlink channel reciprocity, where the UE can select the appropriate parameter value based on the strength of the channel reciprocity. |
| **Samsung** | * P =2 (CSI-RS port Number) should be supported for R17 port selection codebook |

|  |  |
| --- | --- |
| Company | Comments |
|  |  |

## Analysing mechanisms to improve utilization of CSI-RS

For mechanisms to improve utilization of CSI-RS, based on the agreement from RAN1#104bis-e, about 20 companies provide their views on between Option 0, Option 1 and Option 3, which are shown as Table 14.

**Table 14 Summary of Companies’ Views on CSI-RS overhead reduction**

|  |  |
| --- | --- |
| **Views** | **Companies** |
| **Option 0**  **(9)** | Spreadtrum, Fraunhofer IIS, Fraunhofer HHI, Samsung, Apple, QC, MTK(1st), Lenovo, Motorola Mobility |
| **Option 1**  **(11)** | Apple, LG Electronics, CATT(combination with Option3), Nokia, Nokia Shanghai Bell(1st), MTK(2nd), DCM, Huawei, HiSilicon, Intel, Sony |
| **Option 3**  **(6)** | Samsung, CATT, ZTE, Nokia, Nokia Shanghai Bell(2nd), Ericsson |

Companies preferring Option 0 have the following considerations.

* Some companies (Spreadtrum Communications, Lenovo, Motorola Mobility) think Option 1 and Option 3 are out of the scope
* some companies (Fraunhofer IIS, Fraunhofer HHI, Apple) think Option 0 can already achieve good performance with no specification impact

Companies preferring Option 1 have the following considerations.

* Many companies (e.g. LG Electronics, Nokia, Nokia Shanghai Bell, Huawei, HiSilicon, Intel Corporation, Sony and DOCOMO) think Option 1 can reduce the CSI-RS overhead, which is needed for R17 PS CB. Moreover some companies’ (e.g. Intel (5%), Huawei (1.5%~2%), HiSilicon (1.5%~2%)) simulation results show that performance gain can be observed if 0.25 density CSI-RS(Option 1) can be used to reduce the CSI-RS overhead.
* Compared with Option 3, Some companies (Apple, LG Electronics, Sony, MTK) prefers Option1 due to they think Option 1 is simple and clean solution with low impact on the 3GPP standard.

Companies preferring Option 3 have the following considerations.

* Some companies (Nokia, Nokia Shanghai Bell, ZTE, Ericsson and CATT) propose think Option 3 can provide more flexibility CSI-RS configuration. In addition, Ericsson thinks Option 3 can reduce the implementation complexity and the risk of high PAPR for CSI-RS.
* CATT proposes Option 3 due to it can support more than 32 SD-FD pairs. CATT provides simulations to show that using 48 SD-FD pairs can obtain performance gain (2~6%) compared with using 32 SD-FD pairs.

Based on companies’ views, it can be observed that there still has no consensus on this issue, so the following Conclusion is proposed by FL.

***Conclusion 2:***  *For PS codebook enhancements utilizing DL/UL reciprocity of angle and/or delay, there is no consensus of further enhancement for CSI-RS configurations associated with Rel-17 PS codebook.*

|  |  |
| --- | --- |
| Company | Comments |
| Mod | From FL perspective, companies’ preference are almost the same as the last time. |
| Qualcomm | Support |
| vivo | Support. |
| OPPO | Support. Fine with option 1 for majority. |
| ZTE | We support Option 3. |
| Ericsson | We support option 3 |
| MediaTek | Support |
| DOCOMO | Ok. |
| CATT | Support Option 3. |
| LG | We are ok with FL’s proposal. |
| Spreadtrum | Support. |
| Nokia/NSB | We still support Option 1 and are ok with Option 3 |
| Lenovo/Mot | Support |
| Samsung | We can support Option 3 |
| Intel | Support Option 2. Option 3 can be additionally considered on top of Option 2. |
| Fraunhofer IIS,  Fraunhofer HHI | Support |

## Others

Except remaining issues of codebook structure for Rel-17 Port Selection Codebook Rank 1 and mechanism to improve utilization of CSI-RS, many companies provide considerations/views on Rel-17 Port Selection Codebook with Rank 2~4, which is listed as following for reference.

* Principle of High Rank
  + CATT: For Rel-17 port selection codebook, high rank transmission, e.g., 4 layers, should be supported.
  + Nokia, Nokia Shanghai Bell: Support rank 1, 2 and further evaluate support for rank 3 and 4 under the assumption that CSI overhead for rank>2 should be comparable to that of rank 2.
  + Huawei, HiSilicon: Compared to Rel-16 type II port selection codebook, R17 port selection codebook can provide significantly performance gain for Rank 2~4.
  + Intel: Support polarization-common CSI-RS port selection for all the supported number of ports for rank 1-4
  + Samsung: support rank 2, and study rank 3-4 after rank 1-2 design matures.
  + Ericsson: Prioritize rank 1 and 2 in RAN1 work on FDD CSI feature.
* Design detail of High Rank

|  |  |
| --- | --- |
| **Company** | **View** |
| **CATT** | * Port selection can be layer-independent. * When is turned on and the number of selected FD bases is different for all layers, FD bases selection should be layer-independent. * In order to save indication overhead, the port selection can be indicated by using two parts: the first part is used to indicate the ports common to all layers, the second part is used to indicate the remaining selected ports for each layer. * Phase shift can be adopted at UE side. Then, and bits are used to indicate the selected FD bases by UE for the l-th layer. * The strongest coefficient is indicated by using for l-th layer. |
| **QC** | * Max number of non-zero coefficients per layer * Max number of non-zero coefficients across all layers |

Besides high Rank for Rel-17 Port Selection Codebook, some companies provide some proposals related to Rel-17 Port Selection Codebook, which is summarized as following.

|  |  |
| --- | --- |
| **Company** | **View** |
| **Apple** | * For port selection codebook enhancement, more flexible wideband and subband CSI reporting configuration can be considered |
| **Sony** | * Based on UL CSI, further restrict the set of CSI-RS ports eligible by the UE to those compatible with UL signal angles. By reducing the number of choices, less bits are needed to encode the DL CSI feedback reports by the UE. |
| **Samsung** | * Support R17 codebook for BWP size < 24 PRBs with the current restriction in the specification, i.e. support only WB CSI implying Wf is turned OFF |
| **vivo** | * UE can use partial CSI-RS ports to search target tap 0 to reduce the complexity. * gNB can map SD-FD bases to CSI-RS ports with a predetermined order or indicating the ports for timing calibration. |
| **Lenovo/MotM** | * Support PUCCH reporting of R17 codebook. FFS: codebook configuration(s) associated with PUCCH reporting |

# Summary of CSI enhancement for Multi-TRP

## CSI Measurement Enhancements for Multi-TRP

### 3.1.1 Resource setting for CMR

For the default values of *Nmax* and *Ks, max*, a number of companies have provided their views. These companies have the common view that the default value of *Nmax* should be 1 for the sake of implementation complexity at UE. Companies preferring *Ks, max* = 4 have considered that 2 CMRs forming a CMR pair for NCJT measurement hypothesis and two CMRs are used for Single-TRP measurement hypotheses for two TRPs respectively, when the UE cannot support CMR sharing between the different measurement hypotheses. Lenovo/MotM think the default value of *Ks, max* should depend on the operating frequency range. The above CMR sharing should be allowed without restriction in FR1. To limit the UE complexity, *Ks, max* = 2 is sufficient for FR1.

|  |  |
| --- | --- |
| **Views** | **Companies** |
| **Alt 1** (7): *Ks, max* = 4 | Vivo, Frauhofer IIS/Fraunhofer HHI, OPPO, Nokia/NSB, Docomo |
| **Alt 2** (1): *Ks, max* = 2 | InterDigital |
| **Alt 3** (2): *Ks, max* = 4 for FR2, and *Ks, max* = 2 for FR1 | Lenovo/MotM |

Based on the above view, following proposal is suggested:

***Proposal 15:*** *For a CSI-RS resource set with Ks NZP CSI-RS resources configured for CMR and N NZP CSI-RS resource pairs configured for NCJT measurement hypotheses:*

* *the default value of Nmax is 1*
* *the default value of Ks, max, down select one from following alternatives*
  + *Alt 1: Ks, max = 4*
  + *Alt 2: Ks, max = 2*
  + *Alt 3: Ks, max = 4 for FR2, and Ks, max = 2 for FR1*

|  |  |
| --- | --- |
| Company | Comments |
| Mod | Strive to make a decision in RAN1 105 based on the majority |
| ZTE | We support Alt 1, and also accept Alt 3 |
| vivo | We support Alt 1.  We provide a general CSI resource framework which can indicate CMR sharing. That is, if one CMR is shared for X hypotheses, it will be counted X times. |
| QC | Some clarification may be needed as to the intention of the proposal and the meaning of “default”. Even though this is mentioned as FFS, we do not see the need of the proposal at this stage. |
| OPPO | We prefers Alt 3. For FR1, it is sufficient to support Ks=2 to be shared by S-TRP and NC-JT. For FR2, if CMR reusing is not supported, Ks,max=4 can be the default value. |
| MediaTek | We prefer to defer the discussion since it depends on Proposal 18. We are also unclear the meaning of “default”. For example, if Option 1 with X=0 can be considered as “default”, then *Ks, max = 2* is sufficient. |
| Ericsson | For default value of Ks,max, we prefer to support the same value for FR1 and FR2. So we do not support Alt 3. Among Alt 1 and Alt 2, we have a slight preference for Alt 1. |
| DOCOMO | Prefer Alt.1. |
| LG | Support Alt1. |
| CMCC | We support Alt 1. |
| Nokia/NSB | Prefer Alt 1. |
| InterDigital | We can wait until the discussion on CMR sharing in Proposal 18 is finalized. |
| Lenovo/Mot | Support Alt3. The default number of configured CMRs is related to whether CMRs can be reused for multiple hypotheses. Therefore, *Ks, max = 2* suffices for FR1 |
| NEC | Prefer Alt 1. |
| Intel | Share the same view as QC |
| Fraunhofer IIS,  Fraunhofer HHI | Support Alt 1 and Alt3. |
| Samsung | It should be discussed later than Proposal 18 due to the dependency. We support Alt.1 or Alt.2. to use same default number of configured CMRs. |
| CATT | We prefer Alt 1. |

In RAN1 #104b-e meeting, the intense discussion is made on the CMR pair and CMRs configuration. Some issues are recognized and agreed to further study.

The first issue is whether to support dynamic updating, e.g., by MAC-CE, for CMR pairs for NCJT measurement hypotheses, and/or CMRs for Single-TRP measurement hypotheses.

Companies (Nokia/NSB, Ericsson, and Intel) prefer to dynamic updating by MAC-CE for CMR pairs for NCJT measurement hypotheses, and/or CMRs for Single-TRP measurement hypotheses, and/or the number of single-TRP CSIs because the following benefits can be obtained:

* avoid CPU overbooking by reducing number of CSI calculations
* the gNB may dynamically update NCJT pairs based on some prior information of the channel propagating conditions, UE position, traffic load (availability) of the different TRPs etc.
* being able to dynamically adjust the number of single-TRP CSIs allows the gNB to better control the feedback overhead and avoid partial omission of part 2 of the CSI report

For CMRs configured in the CSI-RS resource set, companies (ZTE, Spreadtrum) think that not all CMRs configured in the CSI-RS resource set can be used for Single-TRP measurement hypotheses and additional RRC signaling is needed to configure CMRs from the CSI-RS resource set for Single-TRP measurement hypotheses. Qualcomm think a CMR within a CSI-RS resource set may be neither used in a pair (for NCJT) nor as part of *M* individual CMRs, if the additional is higher layer signalling used to configure *M* (*M*≤ *Ks*) CMRs for Single-TRP measurement hypotheses. To avoid the CMR without usage, Qualcomm prefer to the additional high layer signalling to enable/disable Single-TRP measurement hypothesis using CMR configured within CMR pairs for NCJT measurement hypothesis.

The companies’ views can be summarized as:

|  |  |
| --- | --- |
| **Views** | **Companies** |
| Alt 1 (6):support dynamic updating, e.g. by MAC-CE for CMR pairs for NCJT measurement hypotheses, and/or CMRs for Single-TRP measurement hypotheses, and/or TCI states in CMRs, and/or the number of single-TRP CSIs | Interdigital (CMR pairs), Vivo (TCI state), Nokia (CMR, CMR pair, and the number of single-TRP CSIs), Ericsson(CMR pairs), Intel (CMR, CMR pairs) |
| Alt 2 (4): additional high layer signalling is needed to configure M (M≤ Ks) CMRs from the CSI-RS resource set for CMR for Single-TRP measurement hypotheses | ZTE, Spreadtrum, LGE, Intel |
| Alt 3 (1): high layer signalling to enable/disable single-TRP measurement hypothesis using CMR configured within CMR pairs for NCJT measurement hypothesis | Qualcomm |

Based on above views, following proposal is suggested:

***Proposal 16:*** *For CSI measurement associated with a CSI-ReportConfig for NC-JT, down-select zeros, one or more alternatives in RAN1 #105-e:*

* *Alt 1: support dynamic updating, e.g. by MAC-CE,  for CMR pairs for NCJT measurement hypotheses, and/or CMRs for Single-TRP measurement hypotheses, and/or TCI states in CMRs, and/or the number of single-TRP CSIs (i.e. X=0/1/2) in a NCJT CSI report*
* *Alt 2: additional high layer signalling is needed to configure M (M≤ Ks) CMRs from the CSI-RS resource set for CMR for Single-TRP measurement hypotheses*
* *Alt 3: For CMRs configured in the CSI-RS resource set, support high layer signalling to enable/disable single-TRP measurement hypothesis using CMR configured within CMR pairs for NCJT measurement hypothesis*

|  |  |
| --- | --- |
| Company | Comments |
| Mod | From FL perspective, above proposal intends to make agreed “study” a little more concrete in terms of what we shall do next at high level. However it does not mean that companies supporting individual Alt may have same understanding or preference of details. Therefore in order to move forward, some RAN1 discussion/decision may be required to research a certain compromise. |
| ZTE | Support Alt 2  Alt 1 is not preferred. The current CSI framework is flexible enough to use DCI/MACCE for selection from RRC configured CSI reportings, e.g. two CSI reportings can be configured by RRC with the same CMR configuration but with different NCJT/STRP hypotheses, then DCI or MACCE is used to select one. It is equivalent with Alt1 which needs much more spec effort.  Alt 3 is a compromised solution of Alt 2, the benefit is just to save RRC overhead compared with Alt2, but the flexibility is sacrificed. |
| vivo | We support dynamic updating TCI states in CMRs of Alt1 for both P-CSI-RS and AP-CSI-RS by MAC-CE like the way for SP-CSI-RS to provide the flexibility and timeliness of beam pair update of CMR pairs for NCJT and/or CMRs for STRP in FR2.  For Alt2 and Alt3, we’d like to apply a general CSI resource configuration framework to implement without additional RRC parameters. In the CSI resource framework, the main problem to be solved in Alt2 and Alt3 is to indicate whether one or all NZP CSI-RS resources are referred by both a CMR pair configured for NCJT hypothesis and a CMR configured for STRP hypothesis or not. We think a CSI resource configuration framework can solve the issue with no need to introduce other RRC parameters. In the framework, the configured CMRs other than the CMRs in the CMR pair(s) are used for STRP hypothesis measurement, and CMR sharing for NCJT and STRP can be implemented by configuring the same CSI-RS resource ID in the CMR pair and out of the N CMR pairs.  An illustration of CSI resource configuration of CMR pairing and sharing is shown in the following figure for Ks=4, N=1 and K1=K2=2, where CMR0 is configured in the first N=1 CMR in Group0 to form the CMR pair with the first CMR, i.e., CMR1, in Group1, and the second CMR0 in Group0 for STRP hypothesis. |
| QC | Support Alt3.  We think Alt1 is not needed. The existing mechanisms are flexible enough and additional enhancements by introducing new MAC-CEs are not well-justified. Also, Alt1 has many different flavours, and we prefer to spend the time on more basic discussions.  On the other hand, at least one of Alt2 or Alt3 are needed since UE capability as discussed in Proposal 18 require a corresponding RRC signalling as well (to avoid issues related to whether gNB has to implement for both cases always). From this perspective, Alt3 is more aligned with the corresponding UE capability, and also achieves the main goal of controlling the # of sTRP hypotheses and CMR sharing.  @vivo: I think the general CSI resource framework that you mentioned is the same (or similar to) “*Alt.1*” in the RAN1 #104-e (January) discussions. It is true that such framework could have solved the issue (and we supported Alt1 at that time). However, given the discussions and decisions after that, we prefer to not reopen those discussions again. |
| OPPO | Firstly, the agreement in RAN1#104b was to study the three possible enhancements. It doesn’t mean that we should support at least one of them. It is also possible that CSI report for mTRP can work well without any of the enhancements.  For Alt 1, we think current SP/AP CSI report can provide similar flexibility. That is why we don’t need MAC CE for CMR/IMR configuration in Rel-15/16. For periodic CSI report, dynamic updating is unnecessary since the report period is usually long. For semi-persistent CSI or aperiodic CSI, the CSI configuration can be updated dynamically via MAC CE or DCI by different *CSI-reportConfig*. The benefits for dynamic updating is unclear to us.  For Alt 2, if CMR resource(s) is configured to be reused for NC-JT and S-TRP measurement hypothesis (e.g. RRC signaling enables CMR reusing or in FR1, up to another discussion), it is straightforward that the Ks CMRs for channel measurement can be used for S-TRP measurement. Otherwise, the remaining Ks-2N CMRs other than the 2N CMRs for NC-JT can be used for S-TRP measurement. It is not expected to configure a CMR resource not used for any channel measurement. Hence, we don’t think the higher layer signaling is needed.  For Alt 3, the higher layer signaling is needed if whether CMR reusing is feasible in FR2 is up to UE capability (up to the discussion in the following issues). If UE reports the capability of CMR reusing, gNB can further indicate whether the CMRs are reused via RRC. However, if CMR reusing is feasible in FR1 and infeasible for FR2 (e.g. only depended on frequency), the signaling is not needed.  In a word, we don’t think Alt 1 and Alt 2 is necessary. Alt 3 may be supported if there is a UE capability for CMR reusing in FR2. |
| MediaTek | Alt 1 is not needed. Similar view as QC and OPPO. |
| vivo2 | Reply to QC.  We can see the difference between our general CSI resource framework and “Alt.1” in the RAN1 #104-e (January), copied as below:   * *Alt.1: Configure UE with N NZP CSI-RS resource pairs within a CMR resource set explicitly, whereas the first Ks-2N CMRs are for single-TRP measurement hypotheses and the remaining 2N CMRs in consecutive N CMR pairs are for N NCJT hypotheses.*    + *Note: Network can reuse CMRs of single-TRP hypotheses for NCJT hypotheses at least in FR1 (by configuring the same CSI-RS resource ID of any of the first Ks-2N CMRs for any of the remaining 2N CMRs in the resource set)*   In previous Alt.1, there are no CMR groups configured in the resource set so that one cannot tell the Ks-2N CMRs for STRP from the different TRPs. Thus Alt.1 cannot work for Option 1 with X=2 as two STRP hypotheses of same TRP are possibly reported. Our proposed framework, however, is consistent with agreed Alt.3, where   * N CMR pairs are formed by one-to-one mapping of the first N CMRs between two configured CMR groups. * The CMRs other than the CMRs in the CMR pair(s) in each CMR group are used for STRP hypothesis measurement. |
| Ericsson | In Alt 1, we support dynamic updating of NC-JT pairs via MAC CE. We do not see a strong need to update dynamically the sTRP CMRs, the TCI states in CMRs, or the number of single-TRP CSIs. As the current Alt 1 is a collection of multiple enhancements, it would be better to split up the different enhancements and collect company views for each enhancement separately.  Dynamic update of NC-JT CMR pairs (e.g., via MAC CE) is beneficial. Since up to 8 resources were agreed per CMR resource set, there can be 4\*4 =16 different CMR pairs for NC-JT. And, which among the 16 different CMR pairs the UE should consider for NC-JT may differ with time (i.e., the UE moves, the gNB receives updated group-based beam pair reports, etc). Hence, RRC configuring NC-JT CMR pairs is inflexible, and MAC CE based indication of NC-JT pairs seems needed.  What is the higher layer signalling referred to in Alt 2? Is it RRC signalling or MAC CE signalling? We do not think additional signalling of *M* is needed (so we do not support Alt 2). In our view, once the CMR pairs for NC-JT CSI are indicated to the UE, the UE can consider the remaining CMRs in the resource set for single-TRP CSI. Note that the maximum number of CMRs *Ks,max* in the resource set will likely be up to UE capability. So ,we think it is sufficient to have an indication to enable/disable the NC-JT CMR pairs for sTRP as proposed in Alt 3. If whether the CMRs in NC-JT CMR pair(s) can be used for sTRP CSI or not is decided as a UE capability, we see a need to configure a higher layer parameter to enable/disable the sharing of CMRs between NC-JT and sTRP CSI measurement hypothesis. So, the solution in Alt3 seems be inevitable (if the sharing depends on UE capability).  Overall, we support the following:  -> Dynamic update of CMR pairs for NC-JT measurement hypothesis (which is part of Alt 1).  -> enabling/disabling single-TRP measurement hypothesis using CMRs within CMR pairs indicated for NC-JT measurement hypothesis (Alt 3).  Note that the above two solutions are complementary. The remaining enhancements in other alternatives are not well motivated in our view. |
| DOCOMO | Support Alt.2. In FR1, from all the CMRs (configured for NCJT or not), M CMRs can be selected for single-TRP measurement.  Ok to further discuss so many options in Alt.1. |
| Spreadtrum | Alt.1 is not necessary. The flexibility in current specification is enough.  Alt.2 and Alt.3 may depend on proposal 15. For example, if Ksmax =2, Alt.2 and Alt.3 is not necessary. Thus, we suggest to delay it. |
| LG | We do not think Alt1 is necessary because configuration flexibility can be provided based on the current specification. |
| CMCC | We prefer Alt 2.  Alt 1 is not preferred. Considering the existence of SP-CSI and AP-CSI report, the flexibility of CSI report is already enough and we didn’t see the necessity of introducing MAC CE to support dynamic updating.  For Alt 3, with the expense of flexibility, the RRC overhead might be less comparing with Alt 2. |
| vivo3 | We believe Alt.1 is necessary.  In current spec, a UE can be configured with up to 48 CSI reporting settings, including possible STRP configurations for all CCs. It seems OK.  However, this is not the case for MTRP CSI reporting and it may not be feasible to configure all possible CMR pairs in advance and if could, a waste of configuration overhead. Besides the example given by Ericsson, if a UE possibly uses 4 beams from one TRP, and another 4 beams from the other TRP for NCJT, totally 4\*4=16 possible beam pairs may be used for NCJT CSI measurement. Supposing N=2 is configured for the UE, there will be CMR pair combinations. How can a UE be configured with so many reporting settings for MAC CE or DCI selection under existing CSI resource setting framework in advance? |
| Nokia/NSB | We also think it’s useful to split up this proposal in at least two separate proposals to facilitate progress.  - A proposal on the need to limit the number M of single-TRP hypotheses to .  In this respect, we think without any agreement, the default assumption is , which implies a large number of CSI calculations.  So, we think being able to restrict the number of single-TRP measurement hypotheses to is needed. This parameter M is the only RRC parameter needed to achieve maximum flexibility in the configuration of single-TRP hypotheses and minimum RRC overhead.  In fact, without loss of generality, we can assume that the first M CMR resources in the set are those active for single-TRP measurement. This arrangement does not limit the NCJT configuration in any way as any CMR pair can be selected for NCJT measurement.  @Ericsson: on the contrary, assuming for example that only the CMR resources that are not in NCJT pairs are measured for single-TRP hypotheses is restrictive as the network cannot configure the same CMR resource for both NCJT and single-TRP measurement (e.g. in FR1) unless the same CMR resource is repeated twice in the resource set, which creates a lot of RRC redundancy (including for the NCJT pairs configuration)  - A proposal on the need for dynamic indication.  In this respect, we support dynamic updates of:  NCJT pairs  Parameter M  Parameter X  The first two are needed, in our view to control the number of CSI calculations and reduce the chance of CPU overbooking as an MTRP report can be very demanding on CPU occupancy; and also to adapt the measurement hypotheses to prior knowledge the network may have on channel conditions.  The third one is needed to reduce the chance of UCI omissions in case of Option 1 reporting, by adjusting dynamically the number of reported CSIs depending on the available PUCCH/PUSCH resources. |
| InterDigital | We support Alt. 1 for updating the CMR pairs. MAC-CE provides an efficient way to update the pairings. It’s preferred to have the computationally intensive task of calculating NCJT CSI focused on relevant pairs and not waste time/resources calculating CSI on outdated pairs. |
| Lenovo/Mot | Agree with Spreadtrum, dynamic signalling is not needed for default CMR grouping. We can study whether/how dynamic signalling is supported as an optional feature for larger N, Ks |
| NEC | Support Alt 2. |
| Intel | Alt 2 and Alt 3 seems to provide similar functionality – enable STRP CSI for subset of CMR. So, we support Alt 1 and we are OK with Alt 2 and Alt 3. |
| Samsung | We do not support Alt.1 that is not needed. Based on the Proposal 18, if FR2 is agreed with optional UE capability, a corresponding RRC configuration would be needed and that means at least Alt.2 or Alt.3 can be specified. Among them, we support Alt.3. |
| CATT | We support to update CMR pairs via MAC-CE (i.e., Alt 1). |

For CMR sharing between two NCJT measurement hypotheses in FR2, 6 companies (Spreadtrum, CMCC, ZTE, MediaTek, LGE and DoCoMo) think it is infeasible in practical due to the implementation complexity at UE. On the other hand, 9 companies (FutureWei, Vivo, CATT, Qualcomm, Nokia/NSB, Lenovo/MotM, and Ericsson) think that forbidding CMR sharing completely may be too extreme as it results in additional overhead even if the UE is capable of it. The companies’ views can be summarized as:

|  |  |
| --- | --- |
| **Views** | **Companies** |
| Alt 1 (6):It is feasible for FR1 but not for FR2. | Spreadtrum, CMCC, ZTE, MediaTek, DoCoMo, LGE |
| Alt 2 (8): It is feasible for both FR1 and FR2 but subject to further UE capability for FR2. | FutureWei, Vivo, CATT, Qualcomm, Nokia, Lenovo/MotM, Ericsson |

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

***Proposal 17:*** *Whether a NZP CSI-RS resource m can be referred by two CMR pairs (m, a) and (m, b) configured for NCJT measurement hypotheses, down-select one Alternative in RAN1#105e:*

* *Alt 1: It is feasible for FR1 but not for FR2.*
* *Alt 2: It is feasible for both FR1 and FR2 but subject to further UE capability for FR2.*

|  |  |
| --- | --- |
| Company | Comments |
| Mod | Strive to make a decision in RAN1 105 based on the majority |
| ZTE | Support Alt 1  We don’t think the UE capability of three receive beams should be discussed in Rel-17. Even in MTRP beam manage agenda, it is not discussed. This is a Rel-18 or 19 issues. |
| vivo | Support Alt 2. It provides flexibility in configuration to consider performance and CSI-RS overhead. |
| QC | Prefer Alt2. We do not think support of this necessarily implies support of three beams simultaneously. The CMRs m, a, and b are TDMed, and whether UE can support this configuration depends on multi-panel implementation (for a UE that can receive up to 2 beams simultaneously) as well as accuracy of inter-panel interference. |
| OPPO | We prefer Alt 2. |
| MediaTek | Support Alt 1. We share a similar view as ZTE. Three Rx beams are required because one is for channel measurement and two are for interference measurement. @QC: Can you elaborate how a UE supports this configuration? Measurement of inter-layer/inter-link interference cannot be compromised since it is the main point of specifying NCJT CSI. |
| Ericsson | Alt 1 is too limiting. Whether a CMR can be shared among two CMR pairs for NC-JT CSI measurement hypotheses depends on UE implementation/capability. We support Alt. 2. |
| DOCOMO | Prefer Alt.1. Share similar view as ZTE. |
| Spreadtrum | Support Alt.1. Share the same view with ZTE. Three receive beams are needed at least for the use case where the CMRs m, a, and b are not TDMed. |
| LG | Support Alt1. |
| CMCC | Support Alt 1. Same view as ZTE. |
| ZTE2 | @QC Three receiving beams are needed at UE side even CMR m, a and b are TDMed. Assuming CMR m, a and b are aperiodic, when UE receives CMR pair (m, a), UE needs to simultaneously use receiving beam rm and ra to receive both CMR m and a for inter-beam interference measurement. Likewise, when UE receives CMR pair (m, b), UE needs to simultaneously use receiving beam rm and rb to receive both CMR m and b. That is, UE has to simultaneously use three receiving beams rm, ra and rb for reception of CMR m.  During MTRP BM and MTRP PDSCH discussion, we never touched three beams reception case. Support of Alt 2 just make issues strange and complicated. |
| Nokia/NSB | Support Alt 2 as it’s more flexible |
| Lenovo/Mot | Agree with QC, support Alt2 |
| NEC | Prefer Alt 2. |
| Intel | OL with Alt 2. |
| Fraunhofer IIS  Fraunhofer HHI | Support Alt 2. |
| Samsung | Support Alt.2. |
| CATT | Support Alt 2. |

For CMR sharing for Single-TRP and NCJT measurement hypotheses in FR2, 3 companies (Spreadtrum, CMCC, ZTE) think it is infeasible. 12 Companies (FutureWei, Vivo, CATT, Qualcomm, Nokia/NSB, MediaTek, DoCoMo, LGE, Ericsson, Lenovo/MotM) think CMR sharing for Single-TRP and NCJT measurement hypotheses is feasible subject to UE capability. In specific, MediaTek and DoCoMo point out because the best beam for Single-TRP transmission and the best beam pair for NCJT transmission may include the same beam, CMR sharing for Single-TRP and NCJT measurement hypotheses in FR2 is feasible. The companies’ views can be summarized as:

|  |  |
| --- | --- |
| **Views** | **Companies** |
| Alt 2 (3): It is feasible for FR1 but not for FR2. | Spreadtrum, CMCC, ZTE |
| Alt 3 (9): It is feasible for both FR1 and FR2 but subject to further UE capability for FR2. | FutureWei, Vivo, CATT, Qualcomm, Nokia, MediaTek, Docomo, LGE, Ericsson |

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

***Proposal 18:*** *Whether a NZP CSI-RS resource can be referred by both a CMR pair configured for NCJT measurement hypothesis and a CMR configured for Single-TRP measurement hypothesis, down-select one Alternative in RAN1#105e:*

* *Alt 2: It is feasible for FR1 but it is not for FR2. For FR2, the UE is expected to have different NZP CSI-RS resources configured for all CMRs of Single-TRP and NCJT measurement hypotheses respectively.*
* *Alt 3: It is feasible in both FR1 and FR2 but subject to UE capability for FR2. If a UE supports and the sharing is also enabled by gNB, two CMRs from a CMR pair configured for a NCJT measurement hypothesis can be used for Single-TRP measurement hypotheses, otherwise they cannot.*

|  |  |
| --- | --- |
| Company | Comments |
| Mod | Strive to make a decision in RAN1 105 based on the majority |
| ZTE | Support Alt 2. Alt 2 is a clean solution for CSI measurement which can avoid the misalignment between STRP and MTRP CSI measurement. |
| Vivo | Support Alt 3.  It provides flexibility in configuration to consider performance and CSI-RS overhead. Besides, we have shown simulation results that marginal performance difference can be observed when CMRs for NCJT hypothesis are used for STRP hypotheses even in FR2. |
| QC | Support Alt 3. |
| OPPO | Prefer Alt 3.  We cannot see there is any reason to have different conclusions for proposal 17 and 18. |
| MediaTek | Support Alt 3. |
| Ericsson | Alt 2 is too limiting. Whether a CMR can be shared among one CMR pair for NC-JT CSI measurement hypothesis and one single-TRP measurement hypothesis depends on UE implementation/capability. We support Alt. 3. |
| DOCOMO | Okay with Alt 3 considering following case is highly possible: a beam good for single-TRP is also good for a beam pair. |
| LG | Support Alt3. |
| CMCC | If Alt 3 is the majority and UE vendors have solution to implement CMR reusing for NC-JT measurement and S-TRP measurement, we can live with Alt 3. |
| Nokia/NSB | Support Alt 3 as it’s more flexible |
| InterDigital | Support Alt.3. Spatial filters for sTRP and NC-JT hypothesis are not necessarily the same, but if they are then this alternative enables some reduced RS configuration overhead. |
| Lenovo/Mot | Support Alt3 |
| NEC | Prefer Alt 3. |
| Intel | OK with Alt 3 |
| Fraunhofer IIS  Fraunhofer HHI | Support Alt 3. |
| Samsung | Support Alt.3. |
| CATT | Support Alt 3. |

### 3.1.2 Resource setting for IMR

For CSI-IM configuration, four companies (Spreadtrum, CMCC, LGE, Qualcomm) consider that a CSI-IM resource is configured to be associated with either a CMR for Single-TRP measurement hypothesis or a CMR pair for NCJT measurement hypothesis. The main reason is the interference measured on CSI-IM is different between 2 different measurement hypotheses.

Three companies (Vivo, FutureWei, MediaTek) preferring CSI-IM shared by different measurement hypotheses for the saving on overhead of CSI-IM resources. Furthermore, the simulation results provided by Vivo show that configuring only one CSI-IM resource for NC-JT hypothesis measurement and Single-TRP hypotheses measurement cause negligible performance difference for FR2 and FR1 with lower RU, when one NC-JT hypothesis and two Single-TRP hypotheses are measured.

The companies’ views can be summarized as:

|  |  |
| --- | --- |
| **Views** | **Companies** |
| Alt 1 (3): CSI-IM can be shared by both NCJT and Single-TRP measurement hypotheses | FutureWei, Vivo, MediaTek |
| Alt 2 (4): A CSI-IM resource is configured to be associated with either a CMR for Single-TRP measurement hypothesis or a CMR pair for NCJT measurement hypothesis | Spreadtrum, CMCC, LGE, DoCoMo, ZTE |

Based on the above view, the following proposal is suggested:

***Proposal 19:*** *Companies to study whether a CSI-IM can be referred by both NCJT and Single-TRP measurement hypotheses. Consider following Alternatives and FR1/FR2 differentiation:*

* *Alt 1: CSI-IM can be shared by both NCJT and Single-TRP measurement hypotheses.*
* *Alt 2: A CSI-IM resource is configured to be associated with either a CMR for Single-TRP measurement hypothesis or a CMR pair for NCJT measurement hypothesis*

|  |  |
| --- | --- |
| Company | Comments |
| Mod | Depending on companies’ feedback, we will strive at least to polish Alts to be clearer at least this meeting for future discussion and decision. Otherwise CSI-IM related configuration are missing. |
| ZTE | Support Alt 2.  We don’t know how to use two IMRs for NCJT CSI if Alt 1 is supported. It is noted that Alt 1 just saves RRC signalling rather than IMR resources. |
| Vivo | Support Alt 1.  Firstly, the simulation results provided in our paper show that configuring only one CSI-IM resource for NCJT hypothesis measurement and STRP hypotheses measurement causes negligible performance difference for FR2 and FR1 with lower RU, when one NCJT hypothesis and two STRP hypotheses are measured. Secondly, one shared CSI-IM can be applied when RU is low or UE is scheduled in DPS, where the inter-TRP interference is close to zero. |
| QC | We prefer to directly discuss the number of CSI-IM resources in the resource set (as a function of Ks and N). This proposal may be confusing as it is not clear whether the restriction is wrt reusing same CSI-IM resource two times in the list (which can be up to gNB provided that same CSI-IM is not received with more than 2 beams) or it is about the size of CSI-IM resource set. |
| OPPO | Prefer Alt 2.  If CMR reusing for NC-JT measurement and S-TRP measurement is supported as in proposal 18, Ks CSI-IM resources should be configured with one-to-one mapping to Ks CMRs within a CSI-RS resource set for S-TRP measurement hypothesis. Additional N CSI-IM resources can be configured together with N CMR pairs with one to one mapping for NC-JT measurement hypothesis.  Otherwise, Ks CSI-IM resources can be configured with one-to-one mapping to Ks CMRs within a CSI-RS resource set similar to Rel-15/16. For each CMR pair for NC-JT measurement, the CSI-IM resource associated with the two CMRs should be the same and is used for NC-JT measurement. It is not needed to additionally configure N CSI-IM resource for NC-JT. |
| MediaTek | Support Alt 1. A CSI-IM resource can be shared by an NCJT measurement hypothesis and both the two corresponding single-TRP measurement hypotheses. |
| Ericsson | We support Alt 1. Consider an example where two TRPs belong to a cluster. In this example, it is possible that the gNB configures a CSI-IM to a UE for only measuring the interference from outside the cluster. In this case, the gNB may configure a ZP CSI-RS to overlap with the CSI-IM, and it should be possible to share a CSI-IM between both NCJT and single-TRP measurement hypotheses.  Alt 2 on the other hand introduces an unnecessary restriction, and requires additional overhead for CSI-IM. |
| DOCOMO | Support Alt.2 since the required interference measurement for NCJT and single-TRP can be different.  Okay to discuss the number of CSI-IM resources as suggested by QC. |
| Spreadtrum | Support Alt.2. One-to-one mapping is simple and clean. |
| LG | Support Alt2.  Even if Alt2 is supported, Alt1 can also be supported by configuring the same CSI-IM resource ID for both NCJT and STRP measurement hypotheses. In this case, the difference is only RRC signalling as commented by ZTE. |
| CMCC | Support Alt2.  Considering the interference measured on CSI-IM is different between NCJT and STRP measurement hypotheses, Alt 2 is a better solution. |
| Nokia/NSB | Support Alt2.  Interference should be measured for each configured measurement hypothesis (N+M) rather than for each CMR resource. It’s not clear how interference is measured for an NCJT hypothesis when 2 CSI-IM resources are configured, one for each CMR resource in the pair. |
| InterDigital | Support Alt.2.  Alt.1 can be supported as a special case when the same interference measurement resource is configured to a sTRP CMR and a NCJT CMR pair. |
| Lenovo/Mot | Support Alt1, share similar views as Ericsson. CSI-IM is used to measure interference from sources outside of the candidate TRPs for multi-TRP transmission |
| NEC | Support Alt 2. |
| Intel | Prefer Alt 2 |
| Samsung | Support Alt.2. it is clean solution that CSI-IM is associated with each measurement hypothesis (either single-TRP or NC-JT). Based on Alt.2, Alt.1 can be achieved, too. |
| CATT | Support Alt 1. |

For the NZP-IMR, 10 companies (Spreadtrum, CATT, Qualcomm, OPPO, Apple, MediaTek, Lenovo/MotM, LGE, Intel) consider that in addition to CSI-IM, interference measurement based on NZP CSI-RS outside the CMR pair configured for NCJT measurement hypothesis is not supported in Rel-17. The main reasons are two-fold. Firstly, the MU-MIMO is not supported for NCJT. Secondly, the following restriction is in Rel-16, “Except for L1-SINR, if the interference measurement is performed on NZP CSI-RS, a UE does not expect to be configured with more than one NZP CSI-RS resource in the associated resource set within the resource setting for channel measurement.”

Five companies (Interdigital, CMCC, Fraunhofer IIS, Fraunhofer HHI, DoCoMo) consider that in addition to CSI-IM, the interference can be measured based on NZP CSI-RS outside the CMR pair configured for NCJT measurement hypothesis. CMCC recognize that the UE configured with Multi-TRP scheme still have the possibility to be configured with MU-MIMO mode simultaneously.

The companies’ views can be summarized as:

|  |  |
| --- | --- |
| **Views** | **Companies** |
| Alt 1 (5): support interference measurement based on NZP CSI-RS outside the CMR pair configured for NCJT measurement hypothesis, in addition to CSI-IM | Interdigital, CMCC, Fraunhofer IIS, Fraunhofer HHI, DoCoMo, ZTE |
| Alt 2 (10): Not support interference measurement based on NZP CSI-RS outside the CMR pair configured for NCJT measurement hypothesis, in addition to CSI-IM | Spreadtrum, CATT, Qualcomm, OPPO, Apple, MediaTek, Lenovo/MotM, LGE, Intel |

Based on the above view, the following proposal is suggested:

***Proposal 20:*** *Whether to support interference measurement based on NZP CSI-RS outside the CMR pair configured for NCJT measurement hypothesis, in addition to CSI-IM, down-select one Alternative in RAN1#105e:*

* *Alt 1: Yes, it is supported, subject to limitations, e.g. N=1 CMR pair and Ks=2 CMR resources*
* *Alt 2: No, it is not supported*

|  |  |
| --- | --- |
| Company | Comments |
| Mod | Strive to make a decision in RAN1 105 based on the majority |
| ZTE | Support Alt 1. We are fine with the limitation of the example.  Please noted that NZP CSI-RS can be used for interference measurement other than MU-MIMO |
| vivo | Support Alt 2.  First of all, MU-MIMO is not optimised for Rel-16 MTRP so that NZP CSI-RS for interference measurement is not needed. Secondly, it will surely cause more UE complexity. |
| QC | Support Alt2. The motivation of Alt1 (which is against the existing rule in the spec) is unclear. |
| OPPO | Alt 2.  In Rel-16, it was agreed that NC-JT+MU-MIMO was not supported for DMRS design. Hence, it is not needed to support interference measurement of co-scheduled UE for NC-JT measurement hypothesis, e.g. interference measurement based on NZP CSI-RS outside the CMR pair configured for NC-JT measurement hypothesis. |
| MediaTek | Support Alt 2. |
| Ericsson | We don’t see a strong use case for supporting NC-JT with MU-MIMO. The use case for NC-JT is in low load scenarios where it is possible to improve peak throughput via NC-JT. MU-MIMO is likely to be used in high load scenarios. So, we support Alt 2. |
| DOCOMO | Support Alt.1 with limitations. |
| Spreadtrum | Support Alt.2 |
| LG | Support Alt2. |
| CMCC | Support Alt 1 and OK with the limitations of the example.  In XR traffic scenario, which requires high peak throughout, low latency and high system capacity, supporting NCJT + MU-MIMO might be a possible enhancement direction. Therefore, we think the interference can also be measured based on NZP CSI-RS outside the CMR pair configured for NCJT measurement hypothesis, in addition to CSI-IM. |
| Nokia/NSB | Support Alt 2.  The use case for measuring intra-cell interference other than from the transmitting TRPs involved in the NCJT measurement does not seem so strong. |
| InterDigital | We support Alt.1. The purpose of NZP CSI-RS is not for MU-MIMO but for measuring the interlayer interference in the NCJT case. |
| Lenovo/Mot | Support Alt2. Agree with OPPO |
| NEC | Support Alt 2. |
| Intel | Support Alt 2 |
| Fraunhofer IIS  Fraunhofer HHI | Support Alt 1. |
| CATT | Support Alt 2. |

## CSI Reporting Enhancements for Multi-TRP

Four companies (Lenovo/MotM, Ericsson and Intel) support RI/PMI sharing between the NCJT CSI and single-TRP CSIs for the reduction on CSI overhead and CSI computation complexity. Two companies (DoCoMo and Intel) point out sharing of RI and PMI values may lead to degradation of system performance. Hence DoCoMo does not support the above RI/PMI sharing between NCJT CSI and single-TRP CSIs and Intel propose enabling/disabling of sharing of RI/PMI for NCJT CSI and STRP CSI via RRC.

The companies’ views can be summarized as:

|  |  |
| --- | --- |
| **Views** | **Companies** |
| Alt 1 (4): support RI/PMI sharing between the NCJT CSI and single-TRP CSI | Lenovo/MotM, Ericsson, Intel |
| Alt 2 (1): Not support RI/PMI sharing between the NCJT CSI and single-TRP CSI | DoCoMo |

Based on the above view, the following proposal is suggested:

***Proposal 21:****For a CSI reporting associated with NCJT and single-TRP measurement hypotheses, i.e. Option 1 with X =[1 or ] 2, support PMI sharing between NCJT CSI and single-TRP CSI(s) within CSI part 2:*

* *[Further elaboration of sharing mechanism and to be updated after more companies’ feedback]*

|  |  |
| --- | --- |
| Company | Comments |
| Mod | Strive to make a decision in RAN1 105 based on the majority, at least high level decision for yes or no. If yes, a certain details of elaboration may be required. |
| ZTE | We prefer down-prioritize this discussion.  If we get conclusion for CSI enhancement on MDCI based MTRP, e.g. if we agree option 2, i.e. 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, then the RI/PMI sharing will be unnecessary since only two RI/PMI/CQIs can be sharing for MTRP and STRP in such case. |
| Vivo | Support.  We think PMI/RI sharing between NCJT and STRP is useful for payload reduction of Multi-TRP CSI report. However, the following two aspects need to be considered.  - Ris are the same between the STRP hypothesis and NCJT hypothesis.  - Whether the PMI is shared between the two hypotheses is indicated in part 1. |
| QC | PMI sharing is unclear / not properly defined yet. We consider this as further optimizations at this stage, and think that time should be instead spent on more basic proposals first. |
| OPPO | Needs further discussion.  In our understanding, if the interference from coordination TRP is considered, the best RI/PMI for NC-JT may not be always the same as the best RI/PMI for S-TRP. For example, considering inter-layer (TRP) interference which makes SINR lower, the RI for NC-JT in one TRP is expected to be smaller than RI for S-TRP in the same TRP. The best PMIs for S-TRP may also lead to significant inter-layer interference if directly applied to NC-JT in some cases. |
| MediaTek | Do not support. To save signalling overhead, it suffices to apply Option 2. |
| Ericsson | We support the proposal. Agree with vivo that PMI sharing is beneficial for reducing the payload of MTRP CSI. In addition, our results show that there is very little performance difference between the cases where PMI is shared, and PMI is not shared (see further elaborations below). We provide clarifications to address some companies’ questions and provide technical justifications for the proposal below.  To address Qualcomm’s concern, it would be good to first clarify what is meant by PMI sharing. Our suggestion is to add the following note to the proposal to define PMI sharing:  *Note: For MTRP CSI Option 1, when NC-JT CSI corresponding to TRPs 1 and 2 consists of (RI1, RI2), (PMI1, PMI2), and CQI, PMI sharing is defined as follows:*   * *1st single-TRP CSI consists of (RI1), (PMI1), and CQI1* * *2nd single-TRP CSI consists of (RI2), (PMI2), and CQI2*   @OPPO: The best Ris/PMIs for NC-JT CSI hypothesis may not always the same as the best Ris/PMIs for sTRP CSI hypothesis. The question is how much performance difference is there between the following two cases: (1) when Ris/PMIs are shared between NC-JT CSI hypothesis and sTRP CSI hypothesis, and (2) when Ris/PMIs are different for NC-JT CSI hypothesis and sTRP CSI hypothesis. Based on our simulation results (copied below where RI/PMI sharing is shown in red and different RI/PMI are shown in blue), we do not see much performance loss for the case of PMI/RI sharing. In addition, we showed in our contribution that CSI payload overhead can be reduced by 27% for the 2 Tx port per TRP case. Hence, for scenarios where NC-JT is useful, we see no performance loss but reduce the overhead significantly.  Chart, line chart  Description automatically generatedChart, line chart  Description automatically generated  @MediaTek: With Option 2, the network has no control over which CSI (either NC-JT CSI or sTRP CSI), the UE reports. In fact, a bad UE implementation may always report sTRP CSI and NC-JT CSI may never be reported. MTRP CSI Option 1 was agreed to circumvent this issue with MTRP CSI Option 2. Hence, adopting MTRP CSI Option 2 is not the answer to this problem.  @ZTE: The Multi-DCI MTRP CSI where the UE reports one RI, one PMI, one LI and one CQI per TRP for up to 2 TRPs is different from single-DCI MTRP CSI Option 1 with X=1, 2. Note that the difference is in the CQIs. In the Multi-DCI MTRP CSI, the two CQIs correspond to different codewords transmitted from two different TRPs and they both capture inter-layer interference from the other TRP. In contrast, in the single-DCI MTRP CSI Option 1 with X=1, one of the CQIs correspond to NC-JT CSI hypothesis (where inter-layer interference from other TRP is taken into account), and the other CQI corresponds single-TRP CSI hypothesis. Also, in the case of CSI Option 1 with X=2, three different CQIs will be needed (one corresponding to NC-JT CSI hypothesis, and two other CQIs corresponding to the two single-TRP CSI hypotheses). |
| DOCOMO | Do not support. Share similar concern with QC. |
| LG | We also prefer down-prioritize this issue. As commented by OPPO, the best RI/PMI for each case may be different, and RI/PMI sharing can cause performance degradation. If there is no performance loss from PMI/RI sharing, two different CSI reportings for two STRP CSIs based on the current specification may also be used for NCJT transmission. So, we think it is better to study more before making decision. |
| CMCC | Not support.  Same view with OPPO. PMI sharing might bring some significant performance loss in NCJT or S-TRP transmission. |
| Nokia/NSB | We also prefer not to prioritise this discussion. Sharing PMIs would require further study to ensure performance degradation is limited, for example with respect to the reported CQIs and ranks |
| InterDigital | More evaluation results may be needed to better understand the effect on the system’s performance. |
| Lenovo/Mot | Support the proposal. Ericsson’s simulation results show 27% reduction in CSI feedback overhead with negligible performance impact. Not clear why to down-prioritize, given that reducing the CSI feedback overhead for mTRP CSI framework is one of the top objectives of this WI. |
| NEC | Similar view as most companies, PMI sharing is unclear, which needs further discussion. |
| Intel | Support the proposal 21 with enabling/disabling of PMI sharing by the gNB configuration (RRC).  Also, At the last meeting we had the following agreement  **Agreement**  For the UE configured to report X CSIs (at least when X>0) associated with single-TRP measurement hypotheses and one CSI associated with NCJT measurement hypothesis, study following issues for potential CSI omission/priority/updating rules:   * Issue 1: Prioritize CSI with different measurement hypotheses within the single CSI report, when the UE is configured with CSI Option 1 with X=1 or 2. * Issue 2: Omission of NCJT CSI in CSI part 2 depending on the corresponding CRI or RI or CQI in CSI part 1.   For Issue 2 in our tdoc we proposed to support Omission of NCJT CSI in CSI part 2 depending on the corresponding CRI or RI or CQI in CSI part 1. So, we prefer to include it in this discussion for CSI report enhancements. |
| Samsung | Support the proposal. PMI sharing can reduce CSI overhead. |
| CATT | Not support. |

## 3.3 CSI processing criteria

For the UE configured to report X CSIs associated with Single-TRP measurement hypotheses and one CSI associated with NCJT measurement hypothesis, X+1 CSIs may be omitted together because X+1 CSIs have the same priority. To avoid overkill the NCJT/Single-TRP CSI, three companies (ZTE, Qualcomm, Docomo) consider to change the CSI priority formula.

***Proposal 22****: CSI priority formula for a CSI reporting configuration associated with NCJT measurement hypothesis is updated as*

*Whereas i=0, 1, 2*

* *FFS: i = 0 corresponds to NCJT CSI or i = 0 corresponds to the first single-TRP CSI.*

|  |  |
| --- | --- |
| Company | Comments |
| Mod | Strive to make a decision in RAN1 105 based on the majority |
| ZTE | Support |
| vivo | We need to clarify whether the formula is applied to CSI reports or CSI hypotheses at first.  From the current spec, the priority apples to CSI reports while P22 seems apples to CSI hypotheses.  In TS38.214, “CSI reports are associated with a priority value ”.  This formula is not only used by CSI omission of part 2, but also used by CSI report dropping rule when CSI reports are collided.  Our preference is to determine the formula according to CSI reports rather than CSI hypotheses to minimize spec impact. |
| QC | Support in principle, but perhaps better to clarify that this is for Option 1 with X=2 (for Option 1 with X=1, the denominator should be 2 instead of 3 to avoid confusion; also this is unnecessary for Option 1 with X=0 or for Option 2). |
| OPPO | We have similar view is vivo. The impact to modify the CSI priority formula is too large. For example, for a CSI report with both NC-JT CSI and S-TRP CSI, what is priority of the CSI report for CSI collision? |
| MediaTek | Support in principle. Considering forward compatibility and QC’s concern, we propose the following formula:  *,*  *where .* |
| MediaTek | We revise the proposed formula as  *,*  *where*  and |
| Ericsson | We have similar views as vivo and OPPO. In our view, for MTRP CSI Option 1, the NC-JT CSI and the X (X=1, 2) single TRP CSIs correspond to different CSI measurement hypotheses within a single CSI report. These aren’t different CSI reports. As pointed out by vivo, the priority value formula is used to determine the priority of CSI reports and not different CSI measurement hypotheses within a single CSI report. So, we also prefer not to modify this formula.  Whether and how to prioritize CSI measurement hypotheses within a single CSI report needs a separate discussion. |
| DOCOMO | Support in principle but the specific formula should be further discussed. We think it is okay to determine the priority of different CSI measurement hypotheses within a single CSI report. |
| Spreadtrum | Share the same view with vivo, OPPO and Ericsson. The priority formula in current specification is applied to determine the priority of each CSI report. However, the motivation of the proposal is to determine the priority of the content in a CSI report. Thus, in our opinion, revising the formula is not a good way. Actually in Rel-16 by setting groups in part 2 of one CSI report, the priority of the content in a CSI report could be achieved. The principle should be inherited here. |
| CMCC | Support in principle. |
| Nokia/NSB | Support in principle, but the exact formula needs further study as it’s also used to resolve CPU overbooking, in which case it’s not clear yet how CPUs will be counted and whether the whole report or only some of the CSIs in the report are not updated. |
| InterDigital | We agree that to reduce overhead we may need to prioritize the different hypothesis. However, we share the same view as Ericsson, vivo and OPPO that we should determine a solution to prioritize the hypothesis within the report rather than the priority of different reports. |
| Lenovo/Mot | Support, prefer the revised formula from MediaTek due to its consistency with other parameters, as well as consistency with Rel. 16 priority function which has no fractional values  @VIVO/OPPO/Ericsson/Spreadtrum: It was agreed in RAN1#103-e that a CSI report corresponding to NCJT includes 2 PMI, 2 RI, etc. We understand that each hypothesis is associated with a separate CSI report, otherwise for Option 1, X=2 a CSI report would have up to 4 PMI. Also, regardless of the decomposition, a decision is still needed on whether single-TRP or NCJT CSI quantities have higher priority (for X=1), and which TRP-related CSI quantities for single-TRP hypothesis have higher priority (for X=2). It is more straightforward to discuss these priorities within the CSI priority function |
| Intel | Support original Proposal 22. It is simpler comparing to the proposal from MTK since X may be different across different CSI reports. |

## 3.4 CSI measurement for multi-DCI based NCJT

In RAN1 #104-e, it was agreed that the decision on how to support CSI measurement for multi-DCI based NCJT should be made in RAN1 #105-e.

Six companies (ZTE, Vivo, Spreadtrum, Samsung, Nokia/NSB) support to confirm the working assumption from RAN1 #103e. The main reason is that CSI enhancement for NCJT by multiple CSI reporting settings is more suitable for the scenario where multiple TRPs are connected via a non-ideal backhaul.

Three companies (Qualcomm, MediaTek, DoCoMo(second preference)) support to use a unified solution for both single-DCI and multi-DCI based NCJT.

Three companies (DoCoMo, ZTE, Intel) are fine to not support CSI enhancement for multi-DCI based NCJT due to limited time budget in Rel-17.

The companies’ views can be summarized as:

|  |  |
| --- | --- |
| **Views** | **Companies** |
| Option 1 (4) | ZTE, Vivo, Spreadtrum, Samsung |
| Option 2 (4) | Qualcomm, MediaTek, DoCoMo(second preference), ZTE |

***Proposal 23:*** *For CSI measurement for multi-DCI based NCJT, down select one of following two options in RAN1 #105e:*

* *Option 1: Confirm the Working Assumption from RAN1 103e*
* *Option 2: 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*

|  |  |
| --- | --- |
| Company | Comments |
| Mod | Strive to make a decision in RAN1 105 based on the majority |
| ZTE | We are also fine to support Option 2 after thinking because of less spec impact and unified framework. |
| vivo | We support to confirm the Working Assumption from RAN1 103e.  Some reasons are given as follows:   * Associating two reporting settings CSI-ReportConfigs which are corresponding to two TRPs/TCI states can alleviate the performance loss due to the delay caused by non-ideal backhaul between TRPs. * For M-DCI based Multi-TRP transmission, two CQIs are calculated. CPU occupation for each reporting setting can reuse the rule defined for Cat1 without any further specification effort. * The method of sending the repeated CSI report obtained by Cat1 CSI-ReportConfig twice in non-ideal backhaul will cause useless CSI quantities in CSI reports and increase feedback overhead significantly. Cat2 reporting, however, can divide the CSI quantities into two parts where each part corresponds to a PUCCH resource and a TRP to save the feedback overhead.   For less spec impact, when two CSI reporting settings configured with same fields except the PUCCH resources, almost all of agreements and conclusions made for CSI measurement of Cat1 can be reused in Cat2 design, e.g., Nmax, Ks\_max, CMR configuration, IMR configuration, signaling mechanism, CMR sharing, IMR sharing, etc. |
| QC | Support Option 2 above. Also, the CPU/resource/port occupation should be discussed for multi-DCI (as the previous agreement only applies to single-DCI case).  The meaning of Option 1 should be also clarified as the WA itself has Option 1 and Option 2. |
| OPPO | We think both options should not be supported.  For Option 1, the function can be fully achieved via single CSI report with Rel-17 enhancement. Since gNB cannot be aware of the overlapping situation in non-ideal backhaul, and UE can’t differentiate the CSI for S-TRP and m-DCI with non-overlapped resources, we don’t think there can be performance gain for the enhancement. For Option 2, two CSI report configurations with Rel-15/16 CSI can obtain similar CSI report with higher flexibility. Considering there are so many remaining issues on CSI enhancement for single DCI based M-TRP, we prefer not to introduce additional enhancement for m-DCI. |
| MediaTek | Whether to support multi-DCI based NCJT in R17 should be discussed first. We are fine either way. However, if supported, we prefer Option 2. |
| Ericsson | After some offline discussion, we share the concern from OPPO. For multi-DCI based MTRP, the PDSCHs corresponding to the two TRPs can be fully, partially, or non-overlapping. In the non-ideal backhaul scenario, we are not convinced that the fully overlapping PDSCHs (which corresponds to multi-DCI based NC-JT) is the common case. Hence, our preference is not to specify enhancements specific to multi-DCI based MTRP in Rel-17. |
| DOCOMO | Ok to not support CSI enhancement for multi-DCI based NCJT.  If CSI enhancement for multi-DCI based NCJT is to be supported, prefer Option 2. |
| Spreadtrum | In our opinion, in R17 CSI for multi-DCI based M-TRP should be supported. In Rel-16, in  order to provide much flexibility for network, M-DCI operation and S-DCI operation are  supported, even for ideal backhaul case. The function of CSI measurement and reporting is  to provide assisted information for gNB scheduling. Thus, from the perspective of CSI  report, both M-DCI and S-DCI based transmission could be assumed in Rel-17.  We are also fine with option 2, for the sake of striving unified design with S-DCI based M-TRP. |
| LG | We prefer option 2 for the commonality of CSI reporting between SDCI/MDCI based NCJT. |
| CMCC | Prefer Option 1. |
| vivo3 | We think confirming the WA is necessary for M-DCI-based MTRP for non-ideal backhaul.  First, M-DCI based MTRP has been supported in Rel-16 to achieve higher throughput. As shown in the following tables, the CSI enhancement for M-DCI is beneficial to guarantee the performance of M-DCI based MTRP.  Indoor Hotspot with non-ideal backhaul   |  |  |  |  | | --- | --- | --- | --- | | FR1, RU for STRP (16%) | Mean UPT | 5% UPT | 50% UPT | | MTRP with legacy CSI | -4.49% | -8.37% | -6.67% | | Cat2 | 0.00% | 0.00% | 0.00% |  |  |  |  |  | | --- | --- | --- | --- | | FR1, RU for STRP (38%) | Mean UPT | 5% UPT | 50% UPT | | MTRP with legacy CSI | -12.31% | -13.41% | -15.24% | | Cat2 | 0.00% | 0.00% | 0.00% |   Dense Urban with non-ideal backhaul   |  |  |  |  | | --- | --- | --- | --- | | FR1, RU for STRP (14%) | Mean UPT | 5% UPT | 50% UPT | | MTRP with legacy CSI | -5.36% | -11.18% | -7.84% | | Cat2 | 0.00% | 0.00% | 0.00% |  |  |  |  |  | | --- | --- | --- | --- | | FR1, RU for STRP (25%) | Mean UPT | 5% UPT | 50% UPT | | MTRP with legacy CSI | -4.66% | -11.56% | -4.05% | | Cat2 | 0.00% | 0.00% | 0.00% |   Second, it is a common understanding that the use case for NC-JT is low load/RU scenarios. With enhanced CSI report Option 2, when a UE reports a NCJT hypothesis, overlapping PDSCHs will happen with high possibility in low RU for eMBB, since there would be no other UEs for resource competition when only a few UEs exist in the network. In such cases, each TRP in NJCT transmission would schedule the same UE on all available subbands in every slot before finishing the packets transmission even if it performs independent scheduling. In our simulation, we can observe obvious gain of Cat2 vs. Cat1 for M-DCI at low to median RU although the schedulers of fully, partially, or non-overlapping PDSCH will happen due to independent scheduling.  Indoor Hotspot with non-ideal backhaul   |  |  |  |  | | --- | --- | --- | --- | | FR1, RU for STRP (16%) | Mean UPT | 5% UPT | 50% UPT | | 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 | | Cat2 | 0.00% | 0.00% | 0.00% | | Cat1 (5ms) | -12.43% | -15.91% | -13.79% | | Cat1 (50ms) | -35.44% | -45.29% | -38.42% |   Dense Urban with non-ideal backhaul   |  |  |  |  | | --- | --- | --- | --- | | FR1, RU for STRP (14%) | Mean UPT | 5% UPT | 50% UPT | | 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 | | Cat2 | 0.00% | 0.00% | 0.00% | | Cat1 (5ms) | -3.66% | -8.60% | -4.28% | | Cat1 (50ms) | -16.34% | -36.95% | -21.17% | |
| Nokia/NSB | Similar views as Ericsson and DOCOMO, we prefer not to support CSI enhancement for M-DCI MTRP in Rel-17. |
| Lenovo/Mot | We support Alt2 with a unified solution. We believe a solution for multi-DCI scenario is needed for fully/partially overlapping cases. A solution that is an extension of the single-DCI CSI framework can be supported with reasonable spec impact |
| NEC | We prefer no CSI enhancement for M-DCI. |
| Intel | Prefer Option 2 due to lower spec impact since we can reuse many design features from CSI for single-DCI NCJT. |
| Samsung | Support Alt.1. |

## 3.5 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** |
| How to associate each CRI codepoint with each CMR and each CMR pair | Vivo | * + For CRI reporting in Option1, support separate CRI reporting.   + For CRI reporting in Option2, the first N codepoints are corresponding to N CMR pairs and the remaining codepoints are corresponding to the remaining CMRs. |
| Docomo | * + In Option 1, the X+1 CRIs are reported jointly in one CSI report.   + In Option 2, on mapping between each CRI codepoint and single-TRP/NCJT measurement hypothesis, support mapping to single-TRP measurement hypothesis first, starting from CRI index 0, then mapping to NCJT measurement hypothesis. |
| Whether/how to configure RI restriction/CBSR configuration for NCJT CSI measurement | ZTE | Support a codebook subset restriction (CBSR) to determine some candidates of PMI combinations {PMI1 + PMI2} are allowed or not. |
| Lenovo | Reuse legacy RI restriction/CBSR format for NCJT |
| Huawei/HiSilicon | * + For CSI measurement associated to a reporting setting *CSI-ReportConfig* for NCJT, two RI restrictions can be configured for a given reporting setting whereas:   + One RI restriction corresponds to *M* CMRs for Single-TRP measurement hypothesis   + Another RI restriction corresponds to *N* CMR pairs for NCJT measurement hypothesis   + For CSI measurement associated to a reporting setting *CSI-ReportConfig* for NCJT, two CBSRs can be configured for a given reporting setting whereas each of them corresponds to one CMR group in a CMR set, i.e. per TRP. |
| Whether/how to enhance the CSI updating rule to address CPU overbooking | Huawei/HiSilicon | For a CSI report associated with both Single-TRP and NCJT measurement hypotheses, the UE is required to update the CSI associated with NCJT measurement hypotheses in the CSI report, if , where *N* is the number of CMR pairs associated with NCJT measurement hypotheses, denotes the number of available CPUs on a given OFDM symbol, and is the number of CPUs required to update whole CSI report. |
| Whether/how to introduce new CSI computation delay requirement for NCJT CSI calculation | Spreadtrum | Support to introduce new CSI computation delay requirement for NC-JT CSI. |

***Proposal 24:*** *For Rel-17 CSI enhancement, companies are encouraged to study following potential specification impact:*

* *How to associate each CRI codepoint with each CMR and each CMR pair*
* *Whether/how to configure RI restriction/CBSR configuration for NCJT CSI measurement*
* *Whether/how to enhance the CSI updating rule to address CPU overbooking*
* *Whether/how to introduce new CSI computation delay requirement for NCJT CSI calculation*

|  |  |
| --- | --- |
| Company | Comments |
| Mod | The proposal is a placeholder for remaining issues, which may be needed (or not needed). Given limited input, at least we can strive to formulate questions for the sake of further discussion in August meeting. |
| NEC | Support to further study. |
|  |  |

# Proposals for Online/Offline Discussion

TBD

# Work Plan

TBD

# References

1. 3GPP R1-2104204, CSI enhancement for multi-TRP and FDD, FUTUREWEI, E-meeting, May 10th-27th, 2021.
2. 3GPP R1-2104270, Discussion on CSI Enhancements for Rel-17, Huawei, HiSilicon, E-meeting, May 10th-27th, 2021.
3. 3GPP R1-2104296, Views on CSI Enhancements for NCJT MTRP, InterDigital, Inc., E-meeting, May 10th-27th, 2021.
4. 3GPP R1-2104347, Further discussion and evaluation on Multi-TRP CSI and partial reciprocity, vivo, E-meeting, May 10th-27th, 2021.
5. 3GPP R1-2104415, Discussion on CSI enhancement for multi-TRP and FR1 FDD reciprocity, Spreadtrum Communications, E-meeting, May 10th-27th, 2021.
6. 3GPP R1-2104488, CSI enhancements for Rel-17, CATT, E-meeting, May 10th –27th, 2021.
7. 3GPP R1-2104589, CSI enhancements for Multi-TRP and FR1 FDD reciprocity, ZTE, E-meeting, May 10th –27th, 2021.
8. 3GPP R1-2104603, Enhancements on CSI reporting for Multi-TRP, CMCC, E-meeting, May 10th –27th, 2021.
9. 3GPP R1-2104658, CSI enhancements: MTRP and FR1 FDD reciprocity, Qualcomm Incorporated, E-meeting, May 10th –27th, 2021.
10. 3GPP R1-2104736, CSI enhancement for M-TRP and FDD reciprocity, OPPO, E-meeting, May 10th –27th, 2021.
11. 3GPP R1-2104893, On CSI enhancements for MTRP and FDD, Intel Corporation, E-meeting, May 10th –27th, 2021.
12. 3GPP R1-2105091, Views on Rel-17 CSI enhancement, Apple, RAN1#105e, E-meeting, May 19th – May 27th, 2021.
13. 3GPP, R1-2105155, More considerations on CSI enhancements, Sony, RAN1#105e, E-meeting, May 19th – May 27th, 2021.
14. 3GPP, R1-2105250, Discussion on CSI enhancement for multi-TRP transmission, NEC, RAN1#105e, E-meeting, May 19th – May 27th, 2021.
15. 3GPP R1-2105264, CSI enhancements on Type II PS codebook and multi-TRP, Fraunhofer IIS, Fraunhofer HHI, RAN1#105e, E-meeting, May 19th – May 27th, 2021.
16. 3GPP R1-2105277, Enhancement on CSI measurement and reporting, Nokia, Nokia Shanghai Bell, RAN1#105e, E-meeting, May 19th – May 27th, 2021.
17. 3GPP R1-2105295, Views on Rel. 17 CSI enhancements, Samsung, RAN1#105e, E-meeting, May 19th – May 27th, 2021.
18. 3GPP R1-2105368, CSI enhancement for NCJT and FR1 FDD reciprocity, MediaTek Inc., RAN1#105e, E-meeting, May 10th –May 27th, 2021.
19. 3GPP R1-2105687, Discussion on CSI enhancements, NTT DOCOMO, INC., RAN1#105e, E-meeting, May 10th –May 27th, 2021.
20. 3GPP R1-2105762, CSI enhancements for multi-TRP and FDD reciprocity, Lenovo, Motorola Mobility ,RAN1#105e, E-meeting, May 10th –May 27th, 2021.
21. 3GPP R1-2105783, CSI enhancements for Rel-17, LG Electronics, RAN1#105e, E-meeting, May 10th –May 27th, 2021.
22. 3GPP R1-2105807, CSI enhancements for MTRP and FR1 FDD reciprocity, Ericsson ,RAN1#105e, E-meeting, May 10th –May 27th, 2021.

# Appendix

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

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

|  |  |
| --- | --- |
| **Companies** | **Proposals** |
| **Huawei, HiSilicon** | ***Proposal 1: For R17 port selection codebook, the maximal value of CSI-RS port number P as Pmax is 32.***  ***Proposal 2: 4, 8, 12, 16, 24 and 32 can be supported for candidate values of K1 (K1 <= P) for port selection matrix.***  ***Proposal 3: For R17 port selection codebook, should be supported.***  ***Proposal 4: At least for rank 1, support FD bases used for Wf quantitation limited within a single window with size N configured to the UE whereas FD bases in the window must be consecutive from an orthogonal DFT matrix, i.e. Alt 1.***  ***Proposal 5: For relationship between N and , support Alt 2***   * ***N= if*** * ***N with N=2,4 if***   ***Proposal 6: Support Alt 4, i.e. R= {1, 2, …, } whereas D is the density of CSI-RS in frequency domain), for R17 port selection codebook.***  ***Proposal 7: Polarization-common based bitmap for should be supported for R17 PS CB.***  ***Proposal 8: Considering that gNB can implement compression implicitly, β = 1 should be supported for R17 and other smaller candidate values can be considered as well.***  ***Proposal 9: Option 1, i.e. with a lower CSI-RS density as 0.25, should be supported to improve utilization of CSI-RS for Rel-17 PS codebook.*** |
| **vivo** | **Proposal 19:**  *No restriction of the number of CSI-RS ports for polarization-common report.*  *K1 in {2,4,8,12,16,24,32} with K1 <= P and the maximal value of P is 32.*  **Proposal 20:**  *When Wf is turned off, the non-zero coefficients bitmap can be absent and beta value can be 1;*  *When Wf is turned on, beta values can be 1/4, 1/2 and 3/4 can be supported and additional beta value of 1/8 can be supported for the case of large number of CSI-RS ports.*  **Proposal 21:**  *At least for rank1, the window/set can be consecutive/non-consecutive, and FD bases are selected freely by gNB from an orthogonal DFT matrix.*  *At least for rank1, N ≥ Mv.*  *The candidate values of N can be 2, 4, [6]. The candidate values of Mv can be 1, 2, 3, 4.*  **Proposal 22:**  *UE can use partial CSI-RS ports to search target tap 0 to reduce the complexity.*  *gNB can map SD-FD bases to CSI-RS ports with a predetermined order or indicating the ports for timing calibration.* |
| **Spreadtrum Communications** | ***Proposal 13: Support Alt 1: FD bases in the window must be consecutive from an orthogonal DFT matrix.***  ***Proposal 14: for the window is fixed to be 0.***  ***Proposal 15:*** ***the*** ***bitmap for indication non-zero coefficients can be absent, depending on the value of beta.***  ***Proposal 16: Support Alt1: Reusing Rel-16 quantization mechanism at least for Rank 1.***  ***Proposal 17: Support Option 0: No further CSI-RS enhancement as the baseline.*** |
| **CATT** | **Proposal-1:**   * *When is turned off or, the bitmap for indicating non-zero coefficients should be polarization-common.*   **Proposal-2:**   * *The values of can be configured to 1/8, 1/4, 1/2, 3/4 and 1.*   **Proposal-3:**   * *When is turned off or, the bitmap for indicating non-zero coefficients can be absent.*   **Proposal-4:**   * *The strongest coefficient should be indicated to save feedback overhead.*   **Proposal-5:**   * *Alt1 is supported for coefficient quantization.*   **Proposal-6:**   * *should be reported to network with any value up to P.*   **Proposal-7:**   * *Port selection should be indicated via combinatorial coefficients when is turned off or on.*   **Proposal-8:**   * *The maximal value of P should be equal to 48.*   **Proposal-9:**   * *Consecutive FD bases from an orthogonal DFT matrix should be configured to UE via a window.*   **Proposal-10:**   * *Dynamic indication of should be considered in order to flexibly shift the delay position.*   **Proposal-11:**   * *is supported.*   **Proposa-12:**   * *The number of FD bases and/or the selected FD bases should be allowed to report by UE.*   **Proposa-13:**   * *R= {1, 2,…, D\*NPRBSB} whereas D is the density of CSI-RS in frequency domain should be supported.* * *R is applied when is turned on.* * *R is not applied when is turned off.*   **Proposal-14:**   * *Opiton3 or the combination of both Option1 and Option3 is supported.*   **Proposal-15:**   * *For Rel-17 port selection codebook, high rank transmission, e.g., 4 layers, should be supported.*   **Proposal-16:**   * *Port selection can be layer-independent.*   **Proposal-17:**   * *When is turned on and the number of selected FD bases is different for all layers, FD bases selection should be layer-independent.*   **Proposal-18:**   * *In order to save indication overhead, the port selection can be indicated by using two parts: the first part is used to indicate the ports common to all layers, the second part is used to indicate the remaining selected ports for each layer.*   **Proposal-19:**   * *Phase shift can be adopted at UE side. Then, and bits are used to indicate the selected FD bases by UE for the l-th layer.*   **Proposal-20:**   * *The strongest coefficient is indicated by using for l-th layer.* |
| **ZTE** | **Proposal 7:**   * *Support polarization-common W1 for all the ranks and CSI-RS ports in Rel-17 PS codebook.*   **Proposal 8:**   * *All the values in {4, 8, 12, 16, 24, 32} can be supported for K1 where K1<=P.*   **Proposal 9:**   * *Reuse the Rel-16 non-zero coefficient quantization approach for the amplitudes and phases in W2 of Rel-17 PS codebook.* * *The reserved state for reference amplitude in Rel-16 can be replaced with a smaller value following 1.5 dB step size, i.e., .*   **Proposal 10:**   * *On Wf in Rel-17 PS codebook* * *The set of N candidate vectors of Wf is a consecutive window configured by gNB, where both the window size and the start position M\_initial are configured (e.g., window size N = 2 or 4 for Mv = 1 or 2), and N>Mv.* * *UE selects and reports Mv Wf vectors within the window configured by gNB.* * *Support having smaller Mv values for higher numbers of CSI-RS ports (e.g., Mv = 1 only for 24/32 ports)* * *Support R=1 and 2.*   **Proposal 11:**   * *Support configuring multiple CSI-RS resources per CSI reporting configuration associated with Rel-17 PS codebook.* |
| **Qualcomm Incorporated** | **Proposal 11:**   * *For Rel-17 FDD CSI, clarify that Wf OFF and Wf ON with M=1 are same.*   **Proposal 12:**   * *For Rel-17 FDD CSI, support window-based intermediate set for Wf quantization.*    + *Note: the window does not imply any specific UE implementation in PMI calculation*   **Proposal 13:**   * *For Rel-17 FDD CSI, support window size equal to the number of FD bases in Wf quantization, i.e., N=M. No UE reporting of Wf is needed.*   + *For M=1, the FD basis in Wf is DFT basis 0;*   + *For M=2, the FD bases in Wf are DFT basis 0 and FD basis 1.*   **Proposal 14:**   * *For Rel-17 FDD CSI, no need to define R in the spec or only support R=1 PMI per CQI subband.*   **Proposal 15:**   * *For Rel-17 FDD CSI, support 1 value of K1 for number of CSI-RS ports <=12, and upto 2 values of K1 (number of selected ports) per number of CSI-RS ports, e.g., K1={16,32} for 32-port.*   **Proposal 16:**   * *Support parameter combinations of {K1, beta, M}, and total number of different combinations should not exceed Rel-16 eType II codebook.*   **Proposal 17:**   * *For Rel-17 FDD CSI, support following for linear combination coefficient reporting.*   + *Up to 2 values for*   + *max number of non-zero coefficients per layer is*   + *max number of non-zero coefficients across all layers is .*   + *UE reporting of actual number of non-zero coefficients.*   **Proposal 18:**  *For Rel-17 FDD CSI, no CSI-RS enhancement is needed.* |
| **OPPO** | **Proposal 1:**   * *Support K1 = {8, 16, 24} and Pmax = 32 for Rel-17 codebook.*   **Proposal 2:**   * *Support beta=3/4 for Rel-17 codebook.*   **Proposal 3:**   * *Support polarization-specific bitmap for Rel-17 codebook.*   Proposal 4:   * *Reuse Rel-16 W2 quantization for Rel-17 PS.*   Proposal 5:   * *Support R = 1 and R = 2 as baseline for Mv>1.*   **Proposal 6:**   * *Support Wf:*   + *FD basis in the window are consecutive (Alt.1)*   + *N=Mv always (Alt.1)* |
| **Intel** | ***Proposal 6***:   * *Support polarization-common CSI-RS port selection for all the supported number of ports for rank 1-4*   ***Proposal 7***:   * *Support combinatorial coefficient reporting for CSI-RS port selection for rank 1-4 including the case with one vector in* ***W****f matrix M = 1*   ***Proposal 8***:   * *Support M = 2 for all the supported number of ports as for M = 1*   ***Proposal 9***:   * *Support consecutive window for FD vector selection with the window size N = 4 for M = 2*   + *Selection and reporting of M FD vectors among N FD vectors is layer-common*   ***Proposal 10***:   * *Reuse Rel-16 coefficient quantization design for Rel. 17 (Alt1)*   One more feature which can be reused for Rel. 17 codebook from Rel. 16 codebook is partial CSI omission. Since the PMI has similar structure the same partial CSI omission design can be reused.  ***Proposal 11***:   * *Reuse Rel-16 partial CSI omission design for Rel. 17*   ***Proposal 12***:   * *Support 0.25 CSI-RS density in Rel. 17*   ***Proposal 13***:   * *Support R = D\*NPRBSB whereas D is the density of CSI-RS in frequency domain* |
| **Apple** | ***Proposal 4 For potential CSI-RS enhancement for port selection codebook enhancement,***   * ***Do not introduce SD-FD pairing*** * ***Do not introduce CSI-RS with more than 32 ports*** * ***No CSI-RS enhancement in Rel-17***   ***Proposal 5 For port selection codebook enhancement, more flexible wideband and subband CSI reporting configuration can be considered***  ***Proposal 6 For W1 design for port selection codebook enhancement, W1 is polarization common and combinatorial coefficient is used for port selection for W1 for RI>1***  ***Proposal 7 For Wf design for port selection codebook enhancement,***   * ***UE always selects the DC frequency basis, i.e., frequency basis with all entries equal to 1.***   ***Do not support R>1*** |
| **Sony** | **Proposal 1. If further CSI-RS enhancements are needed for CSI-RS associated with Rel-17 PS codebook, then prefer Option 1.**  **Proposal 2. For minimum specification impact, maintain the polarization-common base selection and reporting mechanism of Rel-15/16. 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 3: Based on UL CSI, further restrict the set of CSI-RS ports eligible by the UE to those compatible with UL signal angles. By reducing the number of choices, less bits are needed to encode the DL CSI feedback reports by the UE.**  **Proposal 4: 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 5: At least for rank 1, the FD bases used for quantization must be consecutive vectors from an orthogonal DFT matrix.**  **Proposal 6: At least for rank 1, support .** |
| **Fraunhofer IIS, Fraunhofer HHI** | ***Proposal: Support for all supported number of CSI-RS ports, i.e., no restriction of the number of CSI-RS ports for .***  ***Proposal: The number of selected ports is less than or equal to 3/4 of the total number of CSI-RS ports (i.e., ).***  ***Proposal: Considering UE complexity, for the Rel. 17 PS CB the size of the window can be fixed to the number of delays .***  ***Proposal: Support fixing or configuring the starting index of window to zero.***  ***Proposal: Do not support R < 1 for Rel. 17 PS CB. Support and .***  ***Proposal: For simplicity, support the Rel. 16 quantization scheme for the R17 codebook.***  ***Proposal: Support option 0 – no further CSI-RS enhancements.*** |
| **Nokia, Nokia Shanghai Bell** | **Proposal 1 Support rank 1,2 and further evaluate support for rank 3 and 4 under the assumption that CSI overhead for rank>2 should be comparable to that of rank 2.**  **Proposal 2 Regarding the gNB configuration of a single measurement window for , support Alt 1, *i.e.*, a window formed by consecutive DFT components.**  **Proposal 3 Regarding the relationship between parameters and , support Alt 2, *i.e.*, .**  **Proposal 4 Support . Consider possible restrictions in relation to other parameters, such as , and , in the discussion on supported parameter combinations and UE capabilities.**  **Proposal 5 Support reporting of nonzero components of using a combinatorial indicator of bits for . For and/or , is not reported.**  **Proposal 6 Regarding the values of , support Alt4. In particular, support the configuration with . Consider limiting configurations for for .**  **Proposal 7 Regarding the quantisation of , support the baseline Alt 1, *i.e.*, reuse Rel-16 quantisation scheme at least up to rank 2.**  **Proposal 8 Regarding the maximum number of NZC per layer, , reuse the definition from Rel-16, such that .**  **Proposal 9 Regarding the bitmap and SCI reporting, support:**   * **Reporting of the position, [, ], of the strongest coefficient of layer , for , using bits.** * **Reporting of the bitmap after remapping the index of the strongest coefficient to .**   **Proposal 10 Regarding the candidate values for , consider for and for . Consider further down-selection in the discussion for supported parameter combinations: . For , the bitmap does not need reporting.**  **Proposal 11 Support polarisation-specific bitmap.**  **Proposal 12 Support polarisation-common based free port selection for at least up to rank 2 and for .**  **Proposal 13 Support the use of combinatorial indication for at least up to rank 2.**  **Proposal 14 Regarding the candidate values for , consider, at least with and for . Consider further down-selection in the discussion for supported parameter combinations: . For , does not need reporting.**  **Proposal 15 Regarding CSI-RS enhancement, support Option 1 (lower density) or Option 3 (multiple resources).** |
| **Samsung** | ***Proposal 7****: Regarding turning Wf ON/OFF,*   * *support an explicit RRC parameter for turning Wf ON/OFF* * *the length of the all-one vector is 1, when Wf is turned OFF*   ***Proposal 8****: support R17 codebook for BWP size < 24 PRBs with the current restriction in the specification, i.e. support only WB CSI implying Wf is turned OFF*  ***Proposal 9****:* **At least for rank 1, r***egarding R value(s),*   * *support Alt0 (R=1/4) and Alt1 (R=1), and* * *value(s) R>1 requires more study considering*   + *the impact of same or different CSI-RS beamforming (depending on R value(s)); and*   + *tradeoff among UE complexity, CSI overhead, potential-specification impact, and the UPT performance*   ***Proposal 10****: Regarding Mv value(s),*   * *support Mv=2 for #CSI-RS ports <= 12* * *do not support Mv>2*   ***Proposal 11****:* **At least for rank 1, r***egarding Wf configuration, support Alt1 (window-based) when N3 > t and Alt1 (free selection) when N3 <= t, where t is threshold (e.g. t=19).*  ***Proposal 12****:* **At least for rank 1,** *for relationship between N and Mv, support Alt1 (N=Mv)*  ***Proposal 13****: For W2 quantization,*   * *support R16 based scheme, and replace the reserved reference amplitude = 0 with a new value* * *Regarding the strongest polarization indicator for one of the two reference amplitudes, down-select from*   + *Alt1-1: based on SCI; details FFS*   + *Alt2-1: based on 1-bit strongest polarization indicator*   ***Proposal 14****: Regarding Rel. 17 codebook parameters,*   * *The maximal value of P is discussed together with the CSI-RS related study* * *Similar to R16, support a joint optimization based on the supported parameter values in order to reduce the #supported combinations, where the supported parameter values are given by:*   + *P from {2,4,8,12,16,24,32}*   + *K1 from {2,4,8,12,16,24,32}*   + *beta from {1,3/4,1/2}*   ***Proposal 15:*** *Regarding CSI-RS related enhancement,*   * *Support option 0 (no enhancement) as baseline* * *Down-select to Option 3 for further study, and the study should consider aspects in Observation 8*   ***Proposal 16****: for R17 codebook,*   * *support polarization-specific bitmap* * *support rank 2, and study rank 3-4 after rank 1-2 design matures* * *study the following regarding the SCI*   + *Alt1: SCI is reported, e.g. SCI is reported via one joint indicator, e.g. using -bits.*   + *Alt2: SCI is not reported, and the role of SCI in R16 quantization scheme is replaced with a 1-bit strongest coefficient indicator* * *reuse UCI omission mechanism and study the following potential simplifications*   + *replacing SCI with the 1-bit strongest polarization indicator*   + *no FD permutation*   + *no bitmap partition*   + *no FD basis indicator* |
| **MTK** | **Proposal 13**: Combinatorial coefficients should be used to convey free port selection using .  **Proposal 14:**  turned off is the same as , in which the UE uses the FD basis 0 (all-ones vector of length ) for PMI reporting.  **Proposal 15:** Configuration of FD basis vectors is not needed when is turned off (equivalently ).  **Proposal 16:** Configuration of FD basis vectors is needed only when is turned on (equivalently ). For the relation between and , prefer .  **Proposal 17**: The FD bases configured to the UE can be consecutive/non-consecutive, and are selected freely by the gNB from an orthogonal DFT matrix of size .  **Proposal 18**: Due to increase in UE complexity with higher values of prefer as mandatory and as optional to the UE.  **Proposal 19**: Prefer Option 0, no further CSI-RS enhancements. As a second preference, support Option 1, lower density CSI-RS, with the minimum density configured jointly with the value of as . |
| **DoCoMo** | **Proposal 11**   * *Support at least beta=1.* * *A bitmap for indication non-zero coefficient is not needed if Mv is small. All the non-zero LC coefficients within W2 can be reported.*   **Proposal 12**   * *At least for rank 1,*    + *on the FD bases, support Alt.1: FD bases in the window must be consecutive from an orthogonal DFT matrix.*   + *on the relationship between N and Mv, support Alt.2: N >= Mv and FFS candidate value(s) of N, e.g. 2, 4.*   + *Above applies when Wf is turned ON*   **Proposal 13**   * *Consider dynamic configuration of turning on/off*  *using DCI.*   **Proposal 14**   * *For CSI-RS configurations associated with Rel-17 PS codebook, support Option 1 (i.e. lower CSI-RS density).* |
| **Lenovo, Motorola Mobility** | 1. No further modification is necessary on the Rel. 17 codebook structure 2. Support *M*=1, 2 for frequency compression parameter values for Rel. 17 Type-II port-selection codebook 3. Do not further restrict the supported number of CSI-RS ports for the Rel. 17 port-selection codebook configured with *M*=2 4. A layer-common, window-based approach is used to configure the FD basis indices for all layers, where the set of FD basis indices is contiguous, and whose location and size are higher-layer configured 5. Support UE-assisted FD basis indices selection for each layer from a layer-common network-configured window 6. Support Option 0: No further CSI-RS enhancement as the baseline 7. Reuse the Rel-16 coefficient quantization approach for the amplitudes and phases of the Rel. 17 port-selection codebook  * FFS: whether modified amplitude quantization values and/or bitwidth are considered  1. A bitmap is not reported for Rel. 17 port selection codebook when most coefficients are quantized, i.e., β=1, or the number of coefficients is small, e.g., *M*=1 2. Polarization-common port selection and polarization-specific coefficient quantization should be supported for Rel. 17 Reciprocity-based Port Selection codebook 3. Study PUCCH reporting of CSI feedback corresponding to Rel. 17 port-selection codebook for some codebook parameter combinations that yield low CSI feedback overhead  * FFS: codebook parameter combination values that support PUCCH reporting |
| **LG Electronics** | **Proposal #6: FD bases are selected freely by gNB from an orthogonal DFT matrix.**  **Proposal #7: N is always equal to Mv.**  **Proposal #8: For the quantization of W2 coefficient, support Alt1, i.e., reusing Rel-16 quantization mechanism.**  **Proposal #9: If enhancement is needed, consider option 1(a lower CSI-RS density per CSI-RS resource) for lower CSI-RS overhead in Rel-17.** |
| **Ericsson** | [**Proposal 1** **Support up to 16.**](#_Toc71667623)  [**Proposal 2** **Use a proportion factor to determine the value , where . Candidate values can be 0.75 and 1.**](#_Toc71667624)  [**Proposal 3** **An RRC parameter controls the number of FD bases (e.g. =2), and the default value is a single basis (=1). In this default case, Wf is an all-one vector of length N3.**](#_Toc71667625)  [**Proposal 4** **Support Alt.1: FD bases in the window must be consecutive from an orthogonal DFT matrix**](#_Toc71667626)  [**Proposal 5** **Support Alt.2: N >= Mv and furthermore, support for and for**](#_Toc71667627)  [**Proposal 6** **Support Alt 2: Minit for the window is fixed to be 0.**](#_Toc71667628)  [**Proposal 7** **Support and , larger value of is not needed.**](#_Toc71667629)  **Support and .**  [**Proposal 9** **For rank 1 transmission, when is configured, then UE reports all coefficients and the resulting NZC bitmap is all ones and is therefore not reported.**](#_Toc71667631)  [**Proposal 10** **Support polarization-specific bitmap, when bitmap is reported.**](#_Toc71667632)  [**Proposal 11** **Support a single and large value, for example , where is the CQI subband size.**](#_Toc71667633)  [**Proposal 12** **Support polarization-common based free selection for all supported number of CSI-RS ports and ranks.**](#_Toc71667634)  [**Proposal 13** **Support combinatorial coefficient for reporting the port selection matrix for all supported codebook configurations.**](#_Toc71667635)  [**Proposal 14** **Support Alt 1, i.e., reuse the Rel-16 quantization mechanism.**](#_Toc71667636)  [**Proposal 15** **Prioritize rank 1 and 2 in RAN1 work on FDD CSI feature**](#_Toc71667637)  [**Proposal 16** **Do not support lower CSI-RS density, e.g., .**](#_Toc71667638) |

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

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

|  |  |
| --- | --- |
| **Companies** | **Proposals** |
| **Futurewei** | ***Proposal 1: Regarding whether a NZP CSI-RS resource m can be referred by two CMR pairs (m, a) and (m, b) configured for NCJT measurement hypotheses, FeMIMO supports Alt 2: It is feasible for both FR1 and FR2 but subject to further UE capability for FR2.***  ***Proposal 2: Regarding whether a NZP CSI-RS resource can be referred by both a CMR pair configured for NCJT measurement hypothesis and a CMR configured for Single-TRP measurement hypothesis, FeMIMO supports Alt 3: It is feasible in both FR1 and FR2 but subject to UE capability for FR2. If a UE supports and the sharing is also enabled by gNB, two CMRs from a CMR pair configured for a NCJT measurement hypothesis can be used for Single-TRP measurement hypotheses, otherwise they cannot.***  ***Proposal 3: Regarding whether a CSI-IM can be referred by both NCJT and Single-TRP measurement hypotheses, FeMIMO supports Alt 1: CSI-IM can be shared by both NCJT and Single-TRP measurement hypotheses.*** |
| **Huawei, HiSilicon** | ***Proposal 10: For CSI measurement associated with a CSI-ReportConfig for NC-JT, support M (M ≤ Ks) CMRs from the CSI-RS resource set for CMR to be configured for Single-TRP measurement hypotheses by additional RRC signaling.***  ***Proposal 11: For FR1, a NZP CSI-RS resource m can be referred by:***   * ***Two CMR pairs (m, a) and (m, b) configured for NCJT measurement hypotheses*** * ***Both a CMR pair configured for NCJT measurement hypothesis and a CMR configured for Single-TRP measurement hypothesis.***   ***Proposal 12:* For FR2, a NZP CSI-RS resource *m* cannot be referred simultaneously by:**   * ***Two CMR pairs (m, a) and (m, b) configured for NCJT measurement hypotheses*** * ***Both a CMR pair configured for NCJT measurement hypothesis and a CMR configured for Single-TRP measurement hypothesis.***   ***Proposal 13: A NZP CSI-RS resource set configured with M CMRs for single-TRP measurement hypotheses and N CMR pairs for NCJT measurement hypotheses is associated to a CSI-IM resource set configured with M+N CSI-IM resources,***   * ***Whereas the first M CSI-IM resources are associated with M CMRs one-by-one and remaining N CSI-IM resources are associated with N selected CMR pairs one-by-one.***   ***Proposal 14: For a CMR in a CMR pair, another CMR in the same pair is considered as NZP IMR for that CMR.***  ***Proposal 15: The report quantity is either ‘cri-RI-PMI-CQI’ or ‘cri-RI-LI-PMI-CQI’ if a CSI-ReportConfig is associated with NCJT measurement hypothesis in Rel-17.***  ***Proposal 16:* When one UE is is configured with CSI Option 1,**   * **A CRI with a bitwidth of is used to determine one CMR pair within *N* CMR pairs configured for NCJT measurement hypothesis;** * **A CRI with a bitwidth of is used to determine one CMR within *M* CMRs configured for Single-TRP measurement hypothesis.**   ***Proposal 17:* For CSI measurement associated to a reporting setting *CSI-ReportConfig* for NCJT, two RI restrictions are configured for a given reporting setting, whereas:**   * **One RI restriction corresponds to *M* CMRs for Single-TRP measurement hypothesis.** * **Another RI restriction corresponds to *N* CMR pairs for NCJT measurement hypothesis.**   ***Proposal 18:* For CSI measurement associated to a reporting setting *CSI-ReportConfig* for NCJT, two CBSRs are configured for a given reporting setting whereas each of them corresponds to one CMR group in a CMR set, i.e. per TRP.**  ***Proposal 19:* For a given NCJT report with Option 1, priority reporting levels for Part 2 CSI in the report are defined as following orders, if configured**   * **Part 2 subband CSI of even subbands of NCJT measurement hypothesis** * **Part 2 subband CSI of odd subbands of NCJT measurement hypothesis** * **Part 2 subband CSI of even subbands of the first Single-TRP measurement hypothesis** * **Part 2 subband CSI of odd subbands of the first Single-TRP measurement hypothesis** * **Part 2 subband CSI of even subbands of the second Single-TRP measurement hypothesis** * **Part 2 subband CSI of odd subbands of the second Single-TRP measurement hypothesis**   ***Proposal 20:* For a CSI report associated with both Single-TRP and NCJT measurement hypotheses, the UE is required to update the CSI associated with NCJT measurement hypothesis in the CSI report, if , where *N* is the number of CMR pairs associated with the CSI report, denotes the number of available CPUs on a given OFDM symbol, and is the number of CPUs required to update whole CSI report*.*** |
| **InterDigital, Inc.** | ***Proposal 1:*** *Ks,max=2, Nmax=1 should be considered as the default values.*    ***Proposal 2:*** *There should not be any restriction on pairing of Ks* *and* *N values, and MAC-CE can be used to indicate a preferred pairing.*  ***Proposal 3:*** *CRIs for NCJT can be ordered after the CRIs for single-TRP.*  ***Proposal 4:*** *For option 1 with X reports, prioritize single-TRP CSIs over NCJT measurement hypothesis when X=1, however for 2 ensure that at least one of the CSIs corresponds to the NCJT hypothesis.*  ***Proposal 5****: Support Alt. 1* *to support interference measurement based on NZP CSI-RS.*  ***Proposal 6****: 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 7****: 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* |
| **vivo** | **Proposal 1:**  *The default values of Nmax, Ks\_max are 1 and 4, respectively, and other values of N>1 and Ks>4 can be a UE optional feature.*  **Proposal 2:**  *N CMR pairs are formed by one-to-one mapping of the first N CMRs between two CMR groups.*  *The CMRs other than the CMRs in the CMR pair(s) in each CMR group are used for SINGLE-TRP hypothesis measurement.*  **Proposal 3:**  *It is feasible for both FR1 and FR2 but subject to further UE capability for FR2 that a NZP CSI-RS resource m can be referred by two CMR pairs (m, a) and (m, b) configured for NC-JT measurement hypotheses.*  **Proposal 4:**  *It is feasible in both FR1 and FR2 but subject to UE capability for FR2 that a NZP CSI-RS resource can be referred by both a CMR pair configured for NC-JT measurement hypothesis and a CMR configured for Single-TRP measurement hypothesis.*  **Proposal 5:**  *Support to configure CMRs with same CSI-RS resource ID in one resource set for different measurement hypotheses,*   * + *the CMR with same CSI-RS resource ID is referred by two CMR pairs configured for NC-JT measurement hypotheses, or*   + *the CMR with same CSI-RS resource ID is referred by both a CMR pair configured for NC-JT measurement hypothesis and a CMR configured for Single-TRP measurement hypothesis.*   **Proposal 6:**  *Support dynamic updating TCI states of CMRs by MAC-CE for periodic CSI-RS and aperiodic CSI-RS.*  **Proposal 7:**  *There is no need to introduce high layer signaling to configure M (M≤ Ks) CMRs from the CSI-RS resource set for CMR for Single-TRP measurement hypotheses, or to enable/disable Single-TRP measurement hypothesis using CMR configured within CMR pairs for NC-JT measurement hypothesis.*  **Proposal 8:**  *CSI-IM can be shared by both NC-JT and Single-TRP measurement hypotheses for FR1 and FR2.*  **Proposal 9:**  *Support to configure CSI-IM resources with same CSI-RS resource ID in one CSI-IM resource set for different measurement hypotheses, e.g., NC-JT measurement hypothesis and Single-TRP measurement hypothesis.*  **Proposal 10:**  *For CRI reporting in Option1, support separate CRI reporting.*  **Proposal 11:**  *For CRI reporting in Option2, the first N codepoints are corresponding to N CMR pairs and the remaining codepoints are corresponding to the remaining CMRs.*  **Proposal 12:**  *Support to add the priority between Single-TRP report and Multi-TRP report and to use legacy omission rule.*  **Proposal 13:**  *Support enhancing the CSI reporting mechanism when PMI and CQI granularity are wideband.*  **Proposal 14:**  *Consider different configurations of RI restrictions, codebook subset restriction across TRPs.*  **Proposal 15:**  *Total number of layers of NC-JT reception is no more than 4 for NC-JT CSI reporting.*  **Proposal 16:**  *Support to confirm the work assumption in RAN1#103-e, i.e., Option1.*  **Proposal 17:**  *Support to associate two CSI reporting settings with CMRs configuration same as Cat1 for Cat2 configuration.*  **Proposal 18:**  *Support to specify rules on how to divide and map the generated UCI into two associated reports in Cat2.* |
| **Spreadtrum Communications** | ***Proposal 1: Support to introduce additional high layer signaling to configure M (M<=Ks) CMRs for single TRP measurement hypotheses.***  ***Proposal 2: For whether a NZP CSI-RS resource can be referred by two CMR pairs, support Alt1.***  ***Proposal 3: For whether a NZP CSI-RS resource can be referred by both a CMR pair and a CMR for single-TRP, support Alt2.***  ***Proposal 4: Not support interference measurement based on NZP CSI-RS outside the CMR pair configured for NCJT measurement hypothesis, in addition to CSI-IM.***  ***Proposal 5: For whether a CSI-IM resource can be referred by both NCJT and single-TRP, support Alt2.***  ***Proposal 6: Support to introduce new CSI computation delay requirement for NC-JT CSI.***  ***Proposal 7:******For option 1 with X=0, for UCI composition and structure,***   * ***2RI or joint RI, 1 or 2 CQI(s) should be include into Part1;*** * ***2 PMIs (if required) should be include into Part2;***   ***Proposal 8:******For option 1 with X=1 or X=2, for UCI composition and structure,***   * ***Some CSI information for single TRP, e.g., CRI/RI/CQI for the first CW, should be placed into Part 1;*** * ***Some CSI information for single TRP, e.g.,PMI, CQI for the second CW(if reported), and CSI information for NCJT should be placed into Part 2;***   ***Proposal 9:******For option 2 for UCI composition and structure,***   * ***CRI, RI or joint RI, 1 CQI for the first CW should be include into Part1;*** * ***2 PMIs (if required) for NCJT, or CQI for the second CW (if required) for single TRP and/or 1 PMI (if required) for single TRP transmission should be include into Part2.***   ***Proposal 10: For CSI enhancement on M-TRP operation, M-DCI based M-TRP operation should also be supported.***  ***Proposal 11: For CSI enhancement on M-DCI based M-TRP operation, support option 1, i.e., Confirm the Working Assumption from RAN1 103e.***  ***Proposal 12: For CSI enhancement on M-DCI based M-TRP operation, support to explicitly link two report settings.*** |
| **CATT** | ***Proposal-21: Non-PMI based feedback can be supported for CSI enhancement for M-TRP.***  ***Proposal-22: 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-23: 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-24: CSI feedback enhancements for transmission scheme 2a, 2b, 3 and 4 are supported.***  ***Proposal-25: Further discuss the following alternatives for CSI reporting of M-DCI based NC-JT.***   * ***Alt-1(separate feedback): Two independent reports, for different TRPs respectively*** * ***Alt-2(joint feedback): 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.***   ***Proposal-26: Interference measurement based on NZP CSI-RS outside the CMR pair configured for NCJT measurement hypothesis is not needed.***  ***Proposal-27: If a UE supports and the sharing is also enabled by gNB, two CMRs from a CMR pair configured for a NCJT measurement hypothesis can be used for single-TRP measurement hypotheses, otherwise they cannot.***  ***Proposal-28: CMR resource sharing between CMR pairs is feasible for both FR1 and FR2 but subject to further UE capability for FR2.*** |
| **ZTE** | ***Proposal 1:*** *In FR2, an NZP CSI-RS resource m cannot be referred by two CMR pairs (m, a) and (m, b) for NCJT measurement hypotheses.*  ***Proposal 2:*** *In FR2, an NZP CSI-RS resource cannot be referred by both a CMR pair configured for NCJT measurement hypothesis and a CMR configured for Single-TRP measurement hypothesis.*  ***Proposal 3:*** *For CSI measurement associated with a CSI-ReportConfig for NC-JT, support additional RRC signalling to configure CMRs from the CSI-RS resource set for Single-TRP measurement hypotheses.*  ***Proposal 4:*** *CSI priority formula can be changed as*  *where x = 0, 1 and 2 refer to MTRP CSI, the first STRP CSI and the second STRP CSI (if any) respectively within one single CSI reporting.*  ***Proposal 5:*** *Support a codebook subset restriction (CBSR) to determine some candidates of PMI combinations {PMI1 + PMI2} are allowed or not.*  ***Proposal 6:*** *Confirming the working assumption or having no further CSI enhancement for multi-DCI based NJCT is slightly preferred.* |
| **CMCC** | ***Proposal 1: One NZP CSI-RS resource can’t be referred by two different CMR pairs configured for NCJT measurement hypotheses in FR2 (Alt 1).***  ***Proposal 2: One NZP CSI-RS resource can’t be referred by both a CMR pair configured for NCJT measurement hypothesis and a CMR configured for Single-TRP measurement hypothesis in FR2 (Alt 2).***  ***Proposal 3: Support introducing interference measurement based on NZP CSI-RS outside the CMR pair configured for NCJT measurement hypothesis (Alt 1).***  ***Proposal 4: One CSI-IM resource can’t be shared by both NCJT and Single-TRP measurement hypotheses at least in FR2.***  ***Proposal 5: The CSI associated with NCJT measurement hypotheses could be high prioritized within one single CSI report, when the UE is configured with CSI Option 1 with X=1 or 2.*** |
| **Qualcomm Incorporated** | **Proposal 1: With respect to CMR sharing**   * **Between two pairs of CMRs corresponding to two NCJT hypotheses, support Alt2: It is feasible for both FR1 and FR2 but subject to further UE capability for FR2.** * **Between an individual CMR (corresponding to a single-TRP hypothesis) and a pair of CMRs (corresponding to a NCJT hypothesis), support Alt3: It is feasible in both FR1 and FR2 but subject to UE capability for FR2.**   **Proposal 2: For CSI measurement associated with a CSI-ReportConfig for NC-JT:**   * **The detail of RRC signalling related to configuring one or two CMR pairs for NCJT hypotheses is up to RAN2 to decide.** * **Support RRC signalling to enable/disable single-TRP measurement hypothesis using CMR configured within CMR pairs for NCJT measurement hypothesis.**   + **For FR2, it can be enabled only if UE supports CMR sharing.**   + **If enabled, there are M=Ks single-TRP hypotheses**   + **If disabled, there are M≤ Ks single-TRP hypotheses corresponding to CMRs not used in a CMR pair.** * **Additional dynamic updating by MAC-CE (to update CMR/CMR pairing/TCI state/value of X) is unnecessary.**   **Proposal 3: In a CSI report config in Option 2, CRI codepoint mapping to CSI hypotheses is based on**   * **CRI codepoints are first mapped to M single-TRP hypotheses. The number of such codepoints is determined based on the number of CMRs across both CMR groups and whether the flag enables/disables individual CMRs that are used in a CMR pair.** * **The additional CRI codepoints are mapped to N CMR pairs corresponding to N NCJT hypotheses.**   **Proposal 4: The number of *csi-IM-Resources* in the *CSI-IM-ResourceSet* configured for a *CSI-ReportConfig* is equal to**   * **Ks+N, if all individual CMRs correspond to single-TRP hypotheses and UE is capable of simultaneous reception with different QCL-TypeD properties or in FR1.**    + **The last N CSI-IM resources are used for N NCJT hypotheses.** * **Ks, if individual CMRs that are used in a CMR pair are disabled for single-TRP hypotheses, and UE is capable of simultaneous reception with different QCL-TypeD properties or in FR1**   + **For a NCJT hypothesis associated with a CMR pair, the CSI-IM resource associated with the first CMR or the second CMR is used.** * **FFS: If UE is not capable of simultaneous reception with different QCL-TypeD properties (i.e. for CSI of TDM schemes if agreed)**   **Proposal 5: Do not support interference measurement based on NZP CSI-RS outside the CMR pair configured for NCJT measurement hypothesis.**  **Proposal 6: For RI and LI reporting of a NCJT CSI, the two RI’s and LI’s are based on**   * **Introduce a RRC configuration for NCJT rank restriction with 4-bit bitmap, which determines the number of allowed rank pairs out of {1+1,1+2,2+1,2+2} rank pair hypotheses** * **The size of the RI field is**   + **When Option 1 is configured: bits.**   + **When Option 2 is configured: bits.** * **The two LI’s are reported in CSI part 2, which require 2 / 1 / 0 bits depending on the indicated rank pair.**   **Proposal 7: For Option 1 with X=1 or 2, the order of CSI reports in the UCI as well as CSI priority for CSI omission is based on an order between the two or three CSI’s associated with the *CSI-ReportConfig*. CSI priority can be expressed as , where corresponds to single-TRP CSI(s) and NCJT CSI.**  **Proposal 8: In the NCJT CSI, for subband part of CSI part 2, adopt one of the following alternatives for the order between even/odd subbands versus first/second PMIs:**   * **Alt1: Even and odd subbands of the first PMI are placed first followed by even and odd subbands of the second PMI.** * **Alt2: Even subbands of the first and second PMIs are placed first followed by the odd subbands of the first and second PMIs.**   **Proposal 9: For CSI measurement for multi-DCI based NCJT, support single CSI report setting. For NCJT CSI in this case, UE reports two CQIs assuming two fully overlapping PDSCHs.**  **Proposal 10: Multi-DCI NCJT CSI based on a pair of CMRs assumes to occupy two CPUs, and each CMR and each port of the two CMRs is counted as two times toward active NZP CSI-RS resources and active ports, respectively.** |
| **OPPO** | Proposal 7:Support Ks,max=4 up to UE capability. FFS: Ks,max=8.  Proposal 8: The signaling design for indication of two CMR groups and N CMR pairs is up to RAN2.  Proposal 9: A unified design for CMR reusing between different NC-JT measurement hypotheses and between NC-JT measurement hypothesis and S-TRP measurement hypothesis.  Proposal 10: CMR pairs for NCJT measurement hypotheses, CMRs for Single-TRP measurement hypotheses, TCI states for CMRs and the number of single-TRP CSIs (i.e. X=0/1/2) for a CSI report are configured by RRC.  Proposal 11: Additional high layer signaling to configure M (M≤ Ks) CMRs from the CSI-RS resource set for single-TRP measurement hypotheses is not needed.  Proposal 12: The configuration of CSI-IM depends on whether CMR can be reused between S-TRP and NC-JT measurement hypotheses.   * ***If CMR reusing for NC-JT measurement and S-TRP measurement is supported, e.g. for FR1, Ks CSI-IM resources are configured with one-to-one mapping to Ks CMRs within a CSI-RS resource set for S-TRP measurement hypothesis. Additional N CSI-IM resources are configured together with N CMR pairs with one to one mapping for NC-JT measurement hypothesis.*** * ***If CMR reusing for NC-JT measurement and S-TRP measurement is not supported, e.g. for FR2, Ks CSI-IM resources are configured with one-to-one mapping to Ks CMRs within a CSI-RS resource set similar to Rel-15/16. For each CMR pair for NC-JT measurement, the CSI-IM resource associated with the two CMRs should be the same and is used for NC-JT measurement.***   Proposal 13: Don’t support interference measurement based on NZP CSI-RS outside the CMR pair configured for NCJT measurement hypothesis.  ***Proposal 14: For Option 2,***   * ***If CMR reusing for NC-JT measurement and S-TRP measurement is supported, e.g. for FR1, the bit number of CRI is log2(Ks+N), which indicates Ks S-TRP measurement hypotheses and N NC-JT measurement hypothesis.*** * ***If CMR reusing for NC-JT measurement and S-TRP measurement is not supported, e.g. for FR2, the bit number of CRI is log2(Ks-N), which indicates (Ks-2N)S-TRP measurement hypotheses and N NC-JT measurement hypothesis.*** * ***CRI, two RIs and CQI for first CW are reported via CSI part 1.*** * ***One or two PMI(s) corresponding to the reported hypothesis, possible CQI for second CW are reported in CSI part 2.***   Proposal 15: For CSI for NC-JT hypothesis in the CSI report of Option 1 and type 1 codebook,   * ***CRI, two RIs and CQI for first CW are reported via CSI part 1 similar to Option 2.*** * ***Two PMIs, possible CQI for second CW are reported in CSI part 2.***   Proposal 16: The benefit of CSI enhancement for multi-DCI based M-TRP transmission should be justified for different overlapping cases. |
| **Intel** | ***Proposal 1***:   * *Support MAC-CE based update of CMRs for NCJT and STRP* * *Support configuration of M < Ks CMRs for STRP*   ***Proposal 2***:   * *NZP CSI-RS based interference measurements is not supported for MTRP CSI in Rel. 17*   ***Proposal 3***:   * *Strive to minimize standardization efforts to support CSI for multi-DCI based NCJT*   ***Proposal 4***:   * *Enabling/disabling of sharing of RI/PMI for NCJT CSI and STRP CSI via RRC shall be considered if sharing of RI/PMI for NCJT CSI and STRP CSI is supported*   ***Proposal 5***:   * *Support omission of CSI for NCJT measurement hypothesis in CSI part 2*   + *Omission of NCJT measurement hypothesis is indicated in CSI part 1 by using CRI/RI or CQI fields* |
| **Apple** | ***Proposal 1 For interference measurement under NCJT, CMR, including RI/PMI decision, CMR from one TRP should be considered as the interference, i.e. IMR, to the other TRP.***  ***Proposal 2 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 as capability*** * ***The CPU and active RS counting rule needs to be further discussed and clarified***   ***Proposal 3 Regarding IMR configuration for multi-TRP CSI reporting enhancement***   * ***For CSI-IM, a CSI-IM resource is configured to be associated with either a CMR for Single-TRP measurement hypothesis or a CMR pair for NCJT measurement hypothesis with one to one mapping*** * ***For NZP-IMR, NZP-IMR cannot be configured together with multi-TRP CSI reporting enhancement*** |
| **NEC** | ***Proposal 1: TRP specific CBSR and RI restriction can reduce the UE complexity considerably, which should be introduced at least for NCJT measurement hypothesis.***  ***Proposal 2: The joint RI field with restricted combination of two RI values should be supported when the maximal transmission layers is larger than 4.*** |
| **Fraunhofer IIS, Fraunhofer HHI** | ***Proposal: The default value of Nmax should be 1 and the default Ks,max should be given by a value that is not larger than 4.***  ***Proposal: For the CRI mapping, a set of N CMR pairs (representing the N NCJT measurement hypotheses) from the two groups is mapped to N CRI codepoints and the remaining CMRs (representing single-TRP measurement hypotheses) in a group are mapped to additional CRI codepoints.***  ***Proposal: Support interference measurement based on NZP CSI-RS outside the CMR pair configured for NCJT measurement hypothesis.*** |
| **Nokia, Nokia Shanghai Bell** | **Proposal 16 Support higher-layer signalling of the number of single-TRP hypotheses, with . The first resources in the CSI-RS resource set for channel measurement are associated to the single-TRP measurement hypotheses.**  **Proposal 17 Support RRC and MAC-CE indication of the number of single-TRP hypotheses, , with .**  **Proposal 18 Support RRC and MAC-CE indication of the NCJT pairs by means of a bitmap of size .**  **Proposal 19 Support RRC and MAC-CE indication of the number of reported single-TRP CSIs, .**  **Proposal 20 Support the use of parameters and to configure Option 1/Option 2 reporting: configures Option 2 with 1 CSI (best of hypotheses); otherwise Option 1 is configured with CSI(s).**  **Proposal 21 For the same CMR resource to be configurable in two different NCJT measurement hypotheses, support Alt 2.**  **Proposal 22 For the same CMR resource to be configurable in both a single-TRP and an NCJT measurement hypothesis, support Alt 3.**  **Proposal 23 Support default values of and , with a maximum value for given by .**  **Proposal 24 For the possible combinations of and , support any value of and any value of , with .**  **Proposal 25 Regarding CBSR and RI restriction, support a single *CodebookConfig*** **configuration for a CSI Reporting Setting with two CMBS and RI restrictions, one for each CMR group.**  **Proposal 26 For Option 1, support separate CRI(s), with bit width for , and , for , and , and for , where and are the number of active single-TRP hypotheses from CMR group 1 and 2, respectively, with .**  **Proposal 27 For Option 2, support a CRI mapping with bits, where the first codepoints are associated to the configured NCJT hypotheses and the last codepoints are associated to the first CMR resources in the CSI-RS resource set.**  **Proposal 28 Regarding the split of CSI quantities between part 1 and part 2, support adding complementary information and an explicit indication in part 1 if sharing occurs.**  **Proposal 29 Support extending the definition of the priority function to include the CSIs reported in a single M-TRP CSI report.**  **Proposal 30 Regarding CSI-IM configuration for a single Reporting Setting, support Alt 2: each CSI-IM resource is configured to be associated with either a CMR for Single-TRP measurement hypothesis or a CMR pair for NCJT measurement hypothesis.** |
| **Samsung** | ***Proposal 1:*** *On CSI enhancements for multi-DCI based NC-JT, support both Category 1 and 2, and allow UE to be configured one of two Categories.*  ***Proposal 2:*** *On CSI enhancement for multi-DCI based NC-JT, support confirming the working assumption with from RAN1#103-e.*  ***Proposal 3:*** *On CSI enhancements for multi-TRP, support CMR to be re-used as IMR for both non pre-coded and pre-coded CSI-RS*  ***Proposal 4:*** *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 5:*** *Design new CPU occupation rule for dynamic NC-JT CSI report*  ***Proposal 6****: Upon reporting of PMI for both NCJT and single-TRP hypotheses*   * *Support full and/or partial compression/omission/Sharing of PMI among single-TRP and NCJT hypotheses.* * *Support the dynamic variation on the level of compression/omission/Sharing of PMI and the associated payload of PMI for single-TRP and NCJT hypotheses.* |
| **MTK** | **Proposal 1**: Interference measurement based on NZP CSI-RS outside the CMR pair configured for NCJT measurement hypothesis is not supported.  **Proposal 2**: NZP IMR can be configured for each single-TRP measurement hypothesis in a CSI reporting setting with NCJT CSI measurement.  **Proposal 3**: How to interpret the two CMRs configured for an NCJT measurement hypothesis can be up to UE implementation.  **Proposal 4**: CSI-IM can be shared by both NCJT and single-TRP measurement hypotheses in both FR1 and FR2 but subject to UE capability for FR2.  **Proposal 5**: If UE reports incapable of CSI-IM and/or NZP CSI-RS reference by both NCJT and single-TRP in FR2, then gNB only configures Option 1 with X = 0 for NCJT CSI.  **Proposal 6**: An NZP CSI-RS resource *m* can be referred by two CMR pairs (*m, a*) and (*m, b*) configured for NCJT measurement hypotheses in FR1 but not in FR2.  **Proposal 7**: An NZP CSI-RS resource can be referred by both a CMR pair configured for NCJT measurement hypothesis and a CMR configured for single-TRP measurement hypothesis in both FR1 and FR2 but subject to UE capability for FR2.  **Proposal 8**: For Option 1, the X+1 CRIs are reported as separate CSI reports.  **Proposal 9**: For Option 1 with X = 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 10**: For Option 1 with X = 2, the following priority order should be adopted: best single-TRP → best NCJT → 2nd best single-TRP.  **Proposal** **11**: Support CSI measurement for multi-DCI based NCJT in R17, assuming the case of full overlap.  **Proposal 12**: CSI measurement for multi-DCI based NCJT is configured in a 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. |
| **DOCOMO** | **Proposal 1**   * *Default value of Nmax is 1. Default value of Ks,max is 4.* * *For any value of Ks, N=1 or N=2 can be supported as long as N<=Ks/2 for FR1, and N <= min (K1, K2) for FR2.*   **Proposal 2**   * *Support interference measurement based on NZP CSI-RS for NCJT measurement hypothesis with certain limitations, e.g., N=1 CMR pair and Ks=2 CMR resources.*   + *For Option 1 with X=1/2 and Option 2, further study whether to allow interference measurement based on NZP CSI-RS for single-TRP measurement hypothesis in the same CSI reporting setting.*   **Proposal 3**   * *On whether a NZP CSI-RS resource m can be referred by two CMR pairs (m, a) and (m, b) configured for NCJT measurement hypotheses, support* *Alt.1.*   + *Alt.1: It is feasible for FR1 but not for FR2.* * *On whether a NZP CSI-RS resource can be referred by both a CMR pair configured for NCJT measurement hypothesis and a CMR configured for single-TRP measurement hypothesis, prefer Alt.2 but also okay with Alt.3 considering the potential use case.* * *On whether a CSI-IM can be referred by both NCJT and single-TRP measurement hypotheses, support Alt.2 for both FR1 and FR2.*   + *Alt.2: A CSI-IM resource is configured to be associated with either a CMR for single-TRP measurement hypothesis or a CMR pair for NCJT measurement hypothesis.*   **Proposal 4**   * *If configured by a new RRC parameter, each CMR resource within a CMR pair should be assumed as NZP interference when deriving CSI based on the other CMR resource within the CMR pair.*   **Proposal 5**   * *To indicate the valid CMR pair(s) for NCJT measurement hypothesis, higher layer signaling can explicitly indicate the ordering index(es) of one or two CMR pairs from all the possible K1\*K2 CMR pairs. The bit size of*  *is needed to indicate a CMR pair.*   **Proposal 6**   * *Support additional higher-layer indication of M (M<=Ks) CMRs for single-TRP measurement hypothesis..*   **Proposal 7**   * *In Option 2, on mapping between each CRI codepoint and single-TRP/NCJT measurement hypothesis, support mapping to single-TRP* *measurement hypothesis first, starting from CRI index 0, then mapping to NCJT measurement hypothesis.* * *In Option 1, the X+1 CRIs are reported jointly in one CSI report.* * *Do not support shared RI/PMI for single-TRP and NCJT hypotheses.*   **Proposal 8**   * *On CSI priority calculation, introduce a new parameter j, where j=0 for single-TRP CSI of the first TRP, j=1 for single-TRP CSI of the other TRP, and j=2 for NCJT CSI.*   **Proposal 9**   * *For a CSI report associated with a Multi-TRP/panel NCJT measurement hypothesis configured by single CSI reporting setting for single-DCI based NCJT, the UE is expected to report,*   + *two RIs, two PMIs, two LIs and one CQI per codeword, when the maximal transmission layer is larger than 4;*   + *one RI, two PMIs, one LI and one CQI, for HST-SFN.*   **Proposal 10**   * *For multi-DCI based NCJT,*   + *first preference is to not support CSI enhancement for it,*   + *second preference is to support Option 2 with single CSI reporting setting for it.* |
| **Lenovo, Motorola Mobility** | 1. For FR2, a CMR associated with an NCJT hypothesis can be reused for a single-TRP hypothesis conditioned on an optional UE capability 2. For FR2, a CMR associated with an NCJT hypothesis can be reused for another NCJT hypothesis conditioned on an optional UE capability 3. Support the pair (*K*s, *N*) = (2,1) as mandatory parameter values for multi-TRP transmission. For UEs that do not support reusing an NCJT CMR for a single-TRP hypothesis, support the pair (*K*s, *N*) = (4,1) as mandatory parameter values for FR2 4. Study the following candidates for the parameter pair values (*K*s, *N*) = {(3,1), (4,2), (6,2), (8,2)}, where the two pair values (*K*s, *N*) = {(6,2), (8,2)} can be restricted to FR2 5. Modify the notation (*Ks*, *N*) to fit the scenario where a CMR is shared across more than one NCJT hypothesis 6. At least as a mandatory feature of multi-TRP CSI Reporting, the number of configured CMRs in the CSI Report Configuration should match that of CMRs needed for CSI reporting 7. Study dynamic signaling of *M* selected CMRs for CSI Reporting out of the *Ks* configured CMRs as an optional UE feature. Further details are FFS 8. Reuse PMI, RI across NCJT and single-TRP hypotheses for CSI reporting under Option 1 with X=1,2 9. A CSI report corresponding to single-TRP hypothesis has higher priority compared with a CSI report corresponding to NCJT hypothesis 10. For a CSI reporting configuration with X=2 single-TRP CSI reports, ties must be broken between the two single-TRP CSI reports to prioritize one CSI report over the other, e.g., based on associated CSI-RS Resource ID 11. For CSI omission based on reported CQI value, study the following aspects  * Whether Part 2 CSI is fully or partially omitted * The rule which identifies the CSI report(s) whose Part 2 CSI is omitted  1. Reuse legacy RI restriction format for NCJT, such that an RI restriction applies to the total number of layers transmitted from the TRP(s) for a given transmission hypothesis 2. Reuse legacy CBSR format for NCJT, such that a CBSR applies to all codebooks corresponding to a given CSI reporting configuration 3. At least for single-DCI case, do not support inter-TRP interference measurement for NCJT based on NZP CSI-RS outside the CMR pair configured for NCJT measurement hypothesis 4. Configuring the UE with an NZP CSI-RS for interference measurement transmitted from a TRP outside the set of candidate TRPs for NCJT is not precluded 5. Under implicit CSI reporting for multi-DCI based NCJT, select one or more of the following alternatives  * Alt1: the CSI reporting configuration triggers the UE with either a single-DCI or a multi-DCI based NCJT CSI reporting * Alt2: A CSI reporting configuration triggers the UE with an NCJT CSI report that includes up to three CQI values (one for single-DCI based NCJT and two for multi-DCI based NCJT) * Alt3: A CSI reporting configuration corresponding to multi-DCI based NCJT reporting is triggered with aperiodic reporting only, where the multi-DCI based NCJT CSI report includes two CQI values, corresponding to two codeword transmissions * Alt4: A CSI reporting configuration corresponding to multi-DCI based NCJT reporting is inferred from RI restriction, i.e., whether RI>4 is restricted   Note: RAN1 should strive to support a unified CSI reporting framework for both single-DCI and multi-DCI based multi-TRP transmission |
| **LG Electronics** | **Proposal #1: Support additional high layer signaling for configuring M CMRs for single TRP CSI from CSI-RS resource set considering the case that only one or none CMR in a CMR pair is used for single TRP CSI calculation.**  **Proposal #2: For the purpose of NCJT CSI calculation, support an independent ZP IMR corresponding to a CMR pair, in addition to two ZP IMRs for STRP CSI corresponding to two CMRs of the CMR pair, respectively.**  **Proposal #3: Interference measurement based on NZP IMR is not supported for NCJT CSI.**  **Proposal #4:** **A NZP CSI-RS resource can be referred by both a CMR pair configured for NCJT measurement hypothesis and a CMR configured for Single-TRP measurement hypothesis based on UE capability for FR2.**  **Proposal #5: A NZP CSI-RS resource can be referred by two different CMR pairs, e.g., (m, a) and (m, b) only for FR1.** |
| **Ericsson** | [**Proposal 17 Support Option 3: Support configuring multiple CSI-RS resources per CSI reporting configuration associated with Rel-17 PS codebook**](#_Toc71667639)  [**Proposal 18 Support dynamic update of CMR pairs for NC-JT CSI measurement hypothesis using MAC-CE and/or RRC signalling**](#_Toc71667640)  [**Proposal 19 Do not support higher layer signalling to dynamically update CMRs for sTRP measurement hypotheses.**](#_Toc71667641)  [**Proposal 20 Support sharing a NZP CSI-RS resource m by two CMR pairs (m, a) and (m, b) configured for NCJT measurement hypotheses for FR1 and FR2 (where the support is conditioned on UE capability signalling for FR2).**](#_Toc71667642)  [**Proposal 21 Support sharing a NZP CSI-RS resource configured in a CMR pair used for NCJT measurement hypothesis and a CMR configured for Single-TRP measurement hypothesis for FR1 and FR2 (where the support is conditioned on UE capability signalling for FR2).**](#_Toc71667643)  [**Proposal 22 For a CSI report containing both NC-JT CSI and single-TRP CSIs (e.g., Option 1 with X =1, 2) associated with the same CMRs, support RI/PMI sharing between the NC-JT CSI and single-TRP CSIs**](#_Toc71667644)  [**Proposal 23 Support NC-JT CSI omission under certain conditions when X=1 or 2 is configured with omission indicated in a CSI report.**](#_Toc71667645)  [**Proposal 24 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.**](#_Toc71667646)  [**Proposal 25 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 correspond to different interference sources.**](#_Toc71667647)  [**Proposal 26 A CSI-IM resource can be configured for one of NC-JT and sTRP or for both NC-JT and sTRP, this should be left for gNB implementation.**](#_Toc71667648) |