**3GPP TSG RAN WG1 Meeting #106bis-e R1-210xxxx**

**e-Meeting, October 11th – 19th, 2021**

**Agenda Item: 8.1.4**

**Source: Huawei, HiSilicon**

**Title: (Moderator) 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*

Here is general plan for RAN1 106bis:

* According to Mr. Chairman’s guidance, Rel-17 CSI enhancement will be discussed by GTW next Monday, and then likely GWT come back session on Wednesday as well, during next week.
  + To align this schedule, without too much preparation phase before the first GTW, please strive to provide initial round comments by 10th Oct 6pm UTC.
  + I will initiate NWM discussion of Round 1 thereafter, to allow MIMO colleagues to have a quick check. To mitigate burden with such a short preparation phase, Round 1 will mainly focus on proposals with the super majority or proposals paving an immediate path for Round 2 discussion.
  + After Monday GTW, I will kick off Round 2 NWM discussion to follow up or address other proposals in the summary.
* We will use NWM, RAN1-106bis-e-NWM-NR-feMIMO-08 as the document name

# Summary of CSI enhancement for FDD

## Rank 3 ~ 4 for Rel-17 PS Codebook Design

In RAN1#106e, it was agreed that port selection is layer-common for rank 2. For rank 3~4, about 10 companies have shared their views on the issue whether port selection is layer-common or layer-group specific. The views are listed in the following table.

**Table 1 Summary of Companies’ Views on Port selection for rank 3 and rank 4**

|  |  |
| --- | --- |
| **Views** | **Companies** |
| **Layer-common (10)** | CATT，Fraunhofer IIS, Fraunhofer HHI, Intel, Nokia, Nokia Shanghai Bell, Qualcomm, Lenovo, Motorola Mobility, Ericsson |
| **Layer-group specific, 2 groups (3)**  **RI=3: layers {0,1}, {2}**  **RI=4: layers {0,1}, {2,3}** | Huawei, HiSilicon，Samsung |

Companies preferring layer-common port selection have the following considerations:

* Performance/Overhead: Companies’ simulation results (e.g. Fraunhofer IIS and Fraunhofer HHI) show that the performance of layer-common port selection is similar to that of layer-specific PS if assuming the same overhead.
* Complexity: Companies (e.g. Intel, CATT, Nokia, and Nokia Shanghai Bell) consider that port selection is layer-common to reduce the PMI search complexity. Furthermore, Qualcomm prefers that port selection for R17 Type II codebook for rank 3-4 should be similar to rank 1-2.

On the other hand, companies preferring layer-group specific port selection have the following considerations:

* Companies’ (e.g. Huawei and HiSilicon) simulation results show that for port-selection and FD basis subset selection for rank 4, layer-group specific port-selection and FD basis subset selection can achieve average gain up to 4% in medium and high overhead regime, compared with layer-common selection. Layer-group specific selection provides more freedom, but the increase of overhead is only a few bits. Furthermore, Samsung considers that when compared with layer-specific or layer-pair-specific basis vectors, layer-common SD basis vectors are likely to incur performance loss.

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

***Proposal 1:*** *For Rel-17 PS codebook, down-select one from the following Alts for rank 3 and 4:*

* *Alt 1: Support layer-common port selection*
* *Alt 2: Support layer-common port-selection among layers 3 and 4. Moreover, port-selection among layers 1~2 and layers 3~4 can be different.*

|  |  |
| --- | --- |
| Company | Comments |
| Mod | Proposal 1 is suggested based on existing views. It is recommended to take the majority later. |
| Qualcomm | Alt1, unified framework is preferred.  For Alt2, when calculating rank 3 and 4, UE has to redo many procedures of CSI algos which has already been done in Rank 1 and 2. This makes it a lot more complicated than Alt1, but its benefit is yet to justify. |
| Lenovo/Mot | Prefer Alt1. In our understanding, a UE would select ports corresponding to best channel gain. By design, the UE has the freedom to select same/overlapping/disjoint ports for different layers under Alt1 via selecting the non-zero coefficients for each layer |
| ZTE | Support Alt 1. This issue has been discussed a lot in previous release. The outcome is layer –specific port or SD selection is not needed. We don’t see the need in this release either. |
| vivo | Prefer Alt1, considering the complexity of port searching and specification. |
| Ericsson | Alt.1 |
| Samsung | Prefer Alt2  For high rank, multiple layers are likely to come from multiple channel clusters and the chance of having 3-4 layers in one cluster is small (unless the angular spread is too large). So, it is intuitive that for high rank, we allow reporting more layers via multiple clusters. This is akin to multiple orthogonal beam groups for high rank codebooks.  Re the gain, it is not hard to show large gain (as shown in some contributions). |
| Nokia/NSB | Alt 1 is preferred.  With Alt 2 UE complexity increases for all parameter combinations because the SVD size becomes instead of . Similar performance to that of layer-group specific port selection in medium-high overhead regime can be achieved with layer-common port selection and . |

In RAN1#106e, it was agreed that FD basis subset selection is layer-common for rank 2. For rank 3-4, about 8 companies have shared their views on the issue whether FD basis selection is layer-common or layer-group specific. The views are listed in the following tables.

**Table 2 Summary of Companies’ Views on FD basis subset selection for rank3 and rank 4**

|  |  |
| --- | --- |
| **Views** | **Companies** |
| **Layer-common (8)** | CATT, Intel, Nokia, Nokia Shanghai Bell, Lenovo, Motorola Mobility, Qualcomm, Ericsson |
| **Layer-group specific, 2 groups (2)**  **RI=3: layers {0,1}, {2}**  **RI=4: layers {0,1}, {2,3}** | Huawei, HiSilicon |

Companies preferring layer-common port selection have the following considerations.

* Performance/Overhead: Qualcomm’s simulation results show that Layer-specific FD basis selection is worse than layer-common FD basis selection. FD-basis pair selection is performed after SVD operation so that Layer-specific FD basis selection may not be beneficial for maintaining the orthogonality among layers.
* Complexity: Companies (e.g. Intel, CATT, Nokia, Nokia Shanghai Bell, and Qualcomm) consider that FD basis subset selection is layer-common to reduce the PMI search complexity. Furthermore, Nokia and Nokia Shanghai Bell consider that imperfect UL-DL reciprocity of delays and timing offset between delay estimation at gNB and UE are common across UE receive antennas so that FD basis subset selection should be layer-common.

Companies preferring layer-group specific FD basis subset selection have the following considerations.

* Companies provide simulation results (e.g. Huawei and HiSilicon) show that for port-selection and FD basis subset selection for rank 4, layer-group specific port-selection and FD basis subset selection can achieve average gain up to 4% in medium and high overhead regime, compared with layer-common selection.

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

***Proposal 2:*** *For Rel-17 PS codebook, down-select one from the following Alts for rank 3 and 4:*

* *Alt 1: Support layer-common Wf , when N>Mv and Mv=2*
* *Alt 2: Support layer-common Wf among layers 3 and 4 layer-common when N>Mv and Mv=2. Moreover, reported Wf among layers 1~2 and layers 3~4 can be different.*

|  |  |
| --- | --- |
| Company | Comments |
| Mod | Proposal 2 is suggested based on existing views. It is recommended to take the majority later. |
| Qualcomm | Alt1, same view as for P1.  Besides, we think the text “when N > M and M=2” can be removed, as Wf will be layer-common in all cases of Alt1. |
| Lenovo/Mot | Support Alt1, agree with QC’s comment |
| ZTE | Support Alt 1. Similarly as the comment for the above one. This issue was also discussed a lot in Rel-16. We don’t see the need to further enhance it in Rel-17. |
| vivo | Support Alt1. |
| Samsung | We suggest to add another alternative since for rank 3-4 and Mv>1, the complexity and overhead are much higher than rank 1-2, and there is no significant gain.  Alt3: support only Mv=1 for rank 3-4 |
| Nokia/NSB | Alt 1 is preferred for the reasons captured in the above summary.  Agree with QC that the second part of the sentence in Alt 1 can be removed. |

In RAN1#106-e, it was agreed that non-zero coefficient selection is layer-specific for rank 2. About 8 companies have shared their views on the issue that non-zero coefficient selection is layer-Common or layer-specific for rank 2. Their views are listed as following table.

**Table 3 Summary of Companies’ Views on non-zero coefficient selection for rank 3 and rank4**

|  |  |
| --- | --- |
| **Views** | **Companies** |
| **Layer-specific (9)** | Huawei, HiSilicon, CATT, Samsung, Intel, Lenovo, Motorola Mobility, Qualcomm, Ericsson |
| **Others (0)** | -- |

Companies’ simulation results (e.g. Huawei, HiSilicon (8% /2% low/high overhead regime)) show that the performance of layer-specific non-zero coefficient selection is better assuming with the same overhead. Companies (e.g. CATT, Samsung, Intel, Lenovo & Motorola Mobility, and Qualcomm) also prefer that the locations of NZC selected by UE for different layers can be different.

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

***Proposal 3:*** *For Rel-17 PS codebook Rank 3-4, support layer-specific non-zero coefficient selection of W2.*

|  |  |
| --- | --- |
| Company | Comments |
| Mod | It seems to be common understanding so far. |
| Qualcomm | Support |
| Lenovo/Mot | Support |
| ZTE | Okay with the FL proposal. |
| vivo | Support |
| Ericsson | Support |
| Samsung | Support |

In the RAN1 #106e, it has been agreed that the maximal CSI overhead of rank 3 and 4 is comparable to rank 2, with FFS as following:

* Use a smaller K1 (or alpha) or beta for ranks 3 and 4,
* Limit the maximum number of non-zero coefficients across all layers to 2K0 and per layer to K0 with the same beta.

There are 10 companies have shared their views about the mechanisms of reducing CSI overhead for rank3~4, as shown in the following table.

**Table 4 Summary of Companies’ Views on mechanisms of reducing CSI overhead for rank 3~4**

|  |  |
| --- | --- |
| **Views** | **Companies** |
| **Alt 0: smaller K1 (or alpha) for rank 3/4 (2)** | Lenovo/Motorola Mobility |
| **Alt 1: Limit the maximum number of non-zero coefficients across all layers to 2 *K1\*Mv\*beta12* and per layer to *K1\*Mv\*beta34* with smaller beta for rank 3~4**  **(2)** | ZTE (), MTK (), |
| **Alt2: Limit the maximum number of non-zero coefficients across all layers to *2K1\*Mv\*beta34* and per layer to *K1\*Mv\*beta34* with smaller beta for rank 3~4**  **(4)** | HW, HiSilicon, Lenovo/MotM (2nd preference) |
| **Alt3: Limit the maximum number of non-zero coefficients across all layers to 2 *K1\*Mv\*beta* and per layer to *K1\*Mv\*beta* with the same beta between rank 1~2 and rank 3~4**  **(9)** | OPPO, Samsung, Intel, DOCOMO, QC, Ericsson，CATT, Nokia/NSB |

Companies supporting Al1 or Alt2 have the following considerations:

* MTK considers that reducing in Alt 0 will reduce the number of SD components and makes it difficult to find a precoder for rank 3~4 while decreasing can still maintain a higher SD resolution which is useful for obtaining a good precoder for rank 3~4.
* HW and HiSilicon think that compared to Alt1 or Alt2, the maximal CSI overhead of rank 3~4 in Alt3 may be larger than that of rank 2 due to additional reported bitmap(s) for layers 3 and 4. And it can be observed that Alt2 outperforms Alt 0 if reducing K1 (or alpha).

Companies preferring Alt3 have the following considerations:

* OPPO, Samsung, DOCOMO and Ericsson propose to use the design similar as Rel-16, i.e., to limit 2K0 NZC across all layer and K0 NZC per layer with same.
* QC prefers Alt 3 since using a smaller value of K1 or M increases the complexity of recalculating layer 1 and 2. For rank 3 and 4, Alt3 provides better performance than Alt2, and also allows UE to reuse same implementation in Rel-16 Type II codebook.
* Intel thinks that Alt3 is more flexible than Alt2 and two alternatives have the same overhead.

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

***Proposal 4:*** *To mitigate CSI overhead of Rel-17 PS codebook rank 3~4, down-select one from the following Alts:*

* *Alt 1: the value of beta34 for rank 3 and 4 is smaller than that for rank 1 and 2, i.e. beta34=beta12/2*
  + *Limit the maximum number of non-zero coefficients across all layers to 2K1\*Mv\*beta12 and per layer to K1\*Mv\*beta34*
* *Alt 2: the value of beta34 for rank 3 and 4 is smaller than that for rank 1 and 2*
  + *Limit the maximum number of non-zero coefficients across all layers to 2K1\*Mv\*beta34 and per layer to K~~1~~\*Mv\*beta34*
* *Alt 3: the value of beta for rank 3 and 4 is the same with that for rank 1 and 2*
  + *Limit the maximum number of non-zero coefficients across all layers to 2K1\*Mv\*beta and per layer to K1\*Mv\*beta*

|  |  |
| --- | --- |
| Company | Comments |
| Mod | Proposal 4 is suggested based on existing views. It is recommended to take the majority later. |
| Qualcomm | Alt3, there is no need to have further restriction on per-layer NNZC. |
| Lenovo/Mot | - In our understanding, both Alt1, Alt3 do not guarantee the CSI feedback overhead is similar for ranks 2,4, since this ignores the overhead of reporting the additional bitmaps for layers 3,4 (up to 64 bits of additional overhead for K1=16, M=2) leading to significant increase in CSI overhead. For that reason, in Rel. 16 eType-II CB we have agreed to both fix the total number of coefficients for rank 2,4 to be the same AND also selected a smaller FD basis for rank 3,4, *M*4=0.5*M*2 to maintain similar bitmap reporting overhead. Therefore, we have concerns over Alt1, Alt3.  - Alt 2 can be consistent with the requirement that the CSI feedback overhead is similar for ranks 2,4, if *beta34* is selected such that *2K1\*Mv\*beta12\*7* ≈ *4K1\*Mv\*beta34\*7 + 2K1\*Mv*, where “7” here represents the number of quantization bits per coefficient, e.g., if *β*1,2=1, *β*3,4=3/7. |
| ZTE | Okay with either Alt 1 or Alt 3. |
| vivo | Support Alt3. |
| Ericsson | Alt.3 |
| Samsung | Support Alt3 which should be the baseline (Rel. 16 design) |
| Nokia/NSB | Alt 3 is preferred.  We also tested the possibility of supporting lower values of for rank 3 and 4 but did not observe any benefit in the throughput/overhead trade-off compared to having a single value for all ranks.  In our view, a better solution for controlling the max overhead is to support a smaller value of for large . |

## Parameter Combination for Rel-17 PS Codebook Design

In RAN1#106-e, it was agreed that parameter combinations represented by (alpha, , beta) with K1 = alpha\*P for Rel-17 PS codebook. Moreover, candidate values of alpha are {1/2, 3/4, 1}, ={1, 2}, and values of beta = {[1/4], 1/2, 3/4, 1}. Furthermore, the following principles for reducing parameter combinations can be considered, according to agreements:

* + Principle 1: based on trade-off among UPT performance, feedback overhead, and complexity
  + Principle 2: based on all supported ranks
  + Principle 3: Limit total number of parameter combinations comparable to Rel-16 eType II

According to above principles, about 12 companies have shared their views on preferred parameter combinations. Their views are listed as following table.

**Table 5 Summary of Companies’ Views on Parameter combinations**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
|  |  |  | **β** | **Approx.**  **of Payload**  **(32 ports)** | **Restriction**  **(if any)** | **#** | **Companies** |
| 1 | 1 | 1 | 1 | ~500 | CATT()  MTK(RI 1-2) | **8** | HW, HiSilicon, CATT, *MTK*, Samsung, Nokia, Nokia Shanghai Bell, Ericsson |
| 2 | 1 | 1 | 3/4 | ~400 | Nokia, Nokia Shanghai Bell(P<=12) | **6** | HW, HiSilicon, OPPO, Samsung, Nokia, Nokia Shanghai Bell |
| 3 | 1 | 1 | 1/2 | ~300 | MTK(RI 1-2) | **6** | HW, HiSilicon, *MTK,* Intel, Nokia, Nokia Shanghai Bell, Ericsson |
| 4 | 1 | 1 | 1/4 | ~200 |  | **0** | -- |
| 5 | 1 | 3/4 | 1 | ~400 | CATT(P )  MTK(RI 1-2) and | **5** | CATT , Samsung , *MTK* , Ericsson, ZTE |
| 6 | 1 | 3/4 | 3/4 | ~300 |  | **1** | Samsung |
| 7 | 1 | 3/4 | 1/2 | ~230 | MTK(RI 1-2) and | **4** | *MTK,* Intel, Ericsson, ZTE |
| 8 | 1 | 3/4 | 1/4 | ~150 |  | **0** |  |
| 9 | 1 | 1/2 | 1 | ~250 | CATT (P ), | **1** | CATT |
| 10 | 1 | 1/2 | 3/4 | ~200 | Nokia, Nokia Shanghai Bell(P>12) | **5** | HW, HiSilicon, Nokia, Nokia Shanghai Bell, OPPO |
| 11 | 1 | 1/2 | 1/2 | ~150 | MTK(RI 1-2) | **3** | HW, HiSilicon, *MTK,* Intel |
| 12 | 1 | 1/2 | 1/4 | ~100 |  | **2** | HW, HiSilicon |
| 13 | 2 | 1 | 1 | ~1000 | CATT（P ;）  MTK(only RI 1-2) | **3** | CATT, Samsung, *MTK* |
| 14 | 2 | 1 | 3/4 | ~800 | CATT（P ; *P32*）  Nokia, Nokia Shanghai Bell(P<=12) | **7** | HW, HiSilicon，CATT, Samsung, Nokia, Nokia Shanghai Bell, Ericsson |
| 15 | 2 | 1 | 1/2 | ~600 | CATT（P ;）  Nokia, Nokia Shanghai Bell(P<=12)  MTK(only RI 1-2) | **7** | HW, HiSilicon，CATT, *MTK,* Nokia, Nokia Shanghai Bell, Ericsson |
| 16 | 2 | 1 | 1/4 | ~350 |  | **2** | Intel, Ericsson |
| 17 | 2 | 3/4 | 1 | ~800 | MTK(only RI 1-2) and | **2** | Samsung, *MTK* |
| 18 | 2 | 3/4 | 3/4 | ~600 |  | **3** | Samsung, Ericsson, ZTE |
| 19 | 2 | 3/4 | 1/2 | ~450 |  | **1** | Ericsson |
| 20 | 2 | 3/4 | 1/4 | ~300 |  | **2** | Intel, Ericsson |
| 21 | 2 | 1/2 | 1 | ~500 |  | **1** | OPPO |
| 22 | 2 | 1/2 | 3/4 | ~400 | Nokia, Nokia Shanghai Bell(P>12) | **2** | Nokia, Nokia Shanghai Bell |
| 23 | 2 | 1/2 | 1/2 | ~300 | Nokia, Nokia Shanghai Bell(P>12) | **3** | OPPO, Nokia, Nokia Shanghai Bell |
| 24 | 2 | 1/2 | 1/4 | ~200 |  | **1** | Intel |

Based on performance-overhead trade-off, companies (e.g. Huawei, HiSilicon, vivo, Samsung，and Qualcomm) provide some general observations for parameter combinations. Huawei and HiSilicon consider that parameter combinations of (alpha, ), {alpha = 0.5, =1}, {alpha = 1, =1} and {alpha = 1, =2} are preferred. Vivo considers that the minimum of alpha increases with decreasing number of CSI-RS ports and the maximum of beta decreases with increasing number of CSI-RS ports. Samsung considers that parameter combinations with are better than those with , and parameter combinations with is either worse than or comparable to those with . Qualcomm considers that total number of different combinations should not exceed that of Rel-16 eType II codebook, and the payload of supported parameter combinations should be well separated among each other.

***Observation:*** *Over supported parameter combinations, following parameter combination has relatively stronger support so far:*

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  |  |  | **β** | **Approx.**  **of Payload**  **(32 ports)** | **Restriction**  **(if any)** | **No. companies** |
| 1 | 1 | 1 | 1 | ~500 | CATT()  MTK(RI 1-2) | **8** |
| 2 | 1 | 1 | 3/4 | ~400 | Nokia, Nokia Shanghai Bell(P<=12) | **6** |
| 3 | 1 | 1 | 1/2 | ~300 | MTK(RI 1-2) | **6** |
| 10 | 1 | 1/2 | 3/4 | ~200 | Nokia, Nokia Shanghai Bell(P>12) | **5** |
| 14 | 2 | 1 | 3/4 | ~800 | CATT（P ; *P32*）  Nokia, Nokia Shanghai Bell(P<=12) | **7** |
| 15 | 2 | 1 | 1/2 | ~600 | CATT（P ;）  Nokia, Nokia Shanghai Bell(P<=12)  MTK(only RI 1-2) | **7** |

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

***Proposal 5:*** *On the supported parameter combinations, up to 8 parameter combinations are supported in Rel-17 PS codebook, with following ones:*

|  |  |  |
| --- | --- | --- |
|  |  | β |
| 1 | 1 | 1 |
| 1 | 1 | 3/4 |
| 1 | 1 | 1/2 |
| 1 | 1/2 | 3/4 |
| 2 | 1 | 3/4 |
| 2 | 1 | 1/2 |

* *FFS: further restrictions for given parameter combination(s)*
* *FFS: the rest parameter combinations in RAN1 106bis*

|  |  |
| --- | --- |
| Company | Comments |
| Mod | Above proposal is just a starting point and likely to be updated after more company input.  A general plan is to agree with the most favourable ones during Round 1. Then the rest one can be decided in Round 2 in RAN1 106bis.  Please also note that a certain restrictions can be discussed and applied for given parameter combination(s), if RAN1 is OK. But I prefer separating this discussion, with clear text later, after more comments available. |
| Lenovo/Mot | OK with the proposed combinations, but can we remove the subscript *v* in “*Mv*”, and instead add an FFS discussing updating the values for Rank 3,4, based on outcome of Proposal 4? For example,   * FFS: whether values of *M*, *α*, *β*, are dependent on Rank *v*, e.g., *βv* where *β*2≠*β*4 |
| Qualcomm | We support upto 8 parameter combinations, but have concern with (M,alpha,beta)=(2,1,3/4) as the WI is to reduce payload but it yields larger payload than Rel-16 codebook. For instance, considering 20MHz with 13 subbands, Rel-16 codebook has maximally 32 non-zero coefficients per layer (para-combo 8) but (M,alpha,beta)=(2,1,3/4) in Rel-17 gives 48. For Rel-16, the number of NZCs per layer is upto 45 even with 19 subbands. |
| ZTE | We think more discussion is needed. We also think parameter combinations with are better than those with . Based on companies’ simulation results provided so far, we also support candidates 5, 7 and 18.  Further, based on the discussion so far, it seems not needed to make the number of selected FD basis rank specific. So “Mv” should be revised to “M” in the final list. |
| vivo | We support to include the combinations with alpha =3/4.  Firstly, our simulations show that alpha = 3/4 in most cases have better performance vs. overhead than those of alpha = 1. That is, alpha = 3/4 can achieve similar performance as alpha = 1 but with less overhead than alpha =1. Even for 32 CSI-RS ports, alpha = 3/4 only needs 11bits to report the selection results, which is less than the bits of two additional coefficients to be reported.  Secondly, our simulation results also show that alpha = 3/4 rather than 1 is almost always selected for 32 CSI-RS ports. While the chances of selecting alpha = 3/4 and alpha = 1 are almost equal for 8 CSI-RS ports. |
| Ericsson | For Mv=2, the value of beta should be smaller than then the beta value for Mv=1. In principle, Mv\*alpha\*beta reflects the number of dominant clusters for a given channel. Therefore, if Mv is increased, beta shall be reduced. In our simulations, we don’t see much different in performance between (Mv, alpha, beta) = (1, 1, 3/4) and (2, 1 3/4), and (1,1,1/2) and (2,1,1/2), although a huge difference in overhead. |
| Samsung | We prefer simple solution, e.g. parameter combinations which do not require any restrictions in specification, and apply to all rank values (i.e. no rank-specific parameters) |
| Nokia/NSB | The proposed combinations are a very good starting point in our view. There are a couple of issues that can be addressed:  - as noted by QC, we can limit the max NZC to 32, when , by supporting a smaller value of for large  - the combination gives for , which is not in the agreed candidate list for . This issue can also be addressed by supporting this combination only for  With the proposed modifications the proposed table would look like below   |  |  |  |  | | --- | --- | --- | --- | |  |  | |  | |  |  | | 1 | 1 | 1 | ½ | | 1 | 1 | ½ | ¾ | | 1 | 1 | 1 | 1 | | 2 | 1 | 1 | ½ | | 2 | 1 | ½ | ½ | | 2 | 1 | ½ | ¾ | |

## Discussion related to RRC Parameters

Regarding of the design of high layer parameters, 4 companies have shared their views on whether to support RI restriction. The views are listed in the following table.

**Table 6 Summary of Companies’ Views on RI restriction**

|  |  |
| --- | --- |
| **Views** | **Companies** |
| **Support RI restriction** | Huawei, HiSilicon, CATT, Samsung, |
| **Don‘t support RI restriction** |  |

Companies supporting RI restriction have the following considerations:

* Huawei, HiSilicon and Samsung think that RI restriction is beneficial and corresponding R16 PS codebook design for RI restriction can be reused in Rel-17 to support MU-MIMO operation more efficiently with adaptive SU/MU switching.
* CATT proposes that it’s straightforward to support RI restriction for Rel-17 port selection codebook to efficiently manage the interference or implement MU-MIMO scheduling by gNB and a new value “*typeII-PortSelectionRI-Restriction-r17”* can be introduced to indicate which layer is restricted.

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

***Proposal 6:*** *For Rel-17 PS codebook, down-select one from following alternatives:*

* *Alt 1: Support RI restriction which is the same with Rel-16 PS codebook, i.e., 4 bits are used to indicate the number of ranks respectively.*
* *Alt 2: RI restriction is not needed for Rel-17 PS codebook*

|  |  |
| --- | --- |
| Company | Comments |
| Mod | Proposal 6 is suggested due to potential RAN2 impact. We need a RAN1 decision. |
| Lenovo/Mot | Support Alt1 |
| Qualcomm | Ok with Alt1 with understanding of reusing Rel-16 RI restriction design. |
| ZTE | Support Alt 1. |
| vivo | Alt1 |
| Ericsson | Support Alt 1 reusing the Rel-16 RI restriction design. |
| Samsung | Support Alt1 |
| Nokia/NSB | Alt 1 is preferred |

In addition, Ericsson suggests to check views over CBSR about whether/how to support CBSR. A potential issue with reusing Rel-16 Type II CBSR is that, in Rel-17 Type II PS, multiple ports may correspond to the same direction, therefore limiting the power per port may not be sufficient.

**Table 8 Summary of Companies’ Views on CBSR Configuration**

|  |  |
| --- | --- |
| **Views** | **Companies** |
| **Discuss whether/how to support CBSR** | Ericsson |

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

***Proposal 7:*** *For Rel-17 PS codebook, down-select one from following alternatives:*

* *Alt 1: Support CBSR*
* *Alt 2: CBSR is not needed*

|  |  |
| --- | --- |
| Company | Comments |
| Mod | Proposal 7 is suggested due to potential RAN2 impact. We need a RAN1 decision. |
| Qualcomm | Alt2, not support CBSR. |
| Lenovo/Mot | No need to support CBSR since the assumption is that the CSI-RS is beamformed. Network can avoid undesired beams by CSI-RS beamforming design |
| ZTE | We don’t think CBSR is needed for port selection codebook, same as Rel-15 and Rel-16. |
| vivo | Alt2, same view as Lenovo/Mot |
| Ericsson | Alt.2 is fine with us. It’s good to conclude. |
| Samsung | It is unclear what CBSR mean here. Is beam and amplitude restriction as in R16 or something else? |
| Nokia/NSB | Alt 2 is preferred, same view as Lenovo/Mot |

About 11 companies provide view on whether to configure parameter *pmiReportingFormat,*  as following table:

**Table 7 Summary of Companies’ Views on pmiReportingFormat Configuration**

|  |  |
| --- | --- |
| **Views** | **Companies** |
| **No need to configure pmiReportingFormat (10)** | Spreadtrum, Fraunhofer IIS, Fraunhofer HHI, Intel, Sony, Nokia, Nokia Shanghai Bell, LG, Lenovo, Motorola Mobility |
| **Need to configure pmiReportingFormat(3)** | CATT, Samsung, ZTE |

The companies prefer ignoring *pmiReportingFormat* have the following considerations:

* Companies (e.g. Spreadtrum, Fraunhofer IIS, Fraunhofer HHI, Nokia, Nokia Shanghai Bell and Sony) thinks that the spec inconsistency issue is purely editorial
* LG considers that a UE is not expected to be configured with *pmiReportingFormat* if Rel-16 codebook structure is configured.
* Intel considers that for *M* = 1 and *M* = 2 this parameter can be ignored since for *M* = 1 wideband PMI and subband PMI corresponds to the same precoding vectors and for *M* = 2 wideband PMI has no meaning

Other companies proposing to configure *pmiReportingFormat* have the following considerations:

* CATT and Samsung support to configure *pmiReportingFormat* since the CSI reporting setting is subband frequency-granularity according to current specification, which is not consistent with the wideband PMI reporting when Wf is turned OFF.
* ZTE proposes to use PMI format in the CSI reporting configuration to configure whether it is Wf off or Wf on (for Mv=2) so that there is no need to introduce a new RRC parameter of Mv.

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

***Proposal 8:*** *For Rel-17 PS codebook, down-select one from following alternatives:*

* *Alt 1: pmiReportingFormat can be configured optionally when Mv=2. If it is configured, corresponding value can be configured as Wideband.*
* *Alt 2: pmiReportingFormat is not needed for Rel-17 PS codebook*

|  |  |
| --- | --- |
| Company | Comments |
| Mod | Proposal 8 is suggested based on existing views. It is recommended to take the majority later. |
| Qualcomm | Alt2. Alt1 is unclear, why the value is wideband when M=2? |
| Lenovo/Mot | Support Alt2 |
| ZTE | We support Alt 1. Just to clarify that our intention is not to apply WB PMI for M=2. The intention is whether WB or SB PMI format can be used to configure the value of M. WB PMI format means M=1 and/or Wf off. |
| vivo | Support Alt2 |
| Ericsson | Alt.2 |
| Samsung | We support Alt 1 revised as follows.   * Alt 1: pmiReportingFormat is configured as wideband   Some comments:   * For Rel16/17 codebooks, pmiformat is actually WB since a single PMI (i1,i2) is reported for the entire CSI reporting band. Whether it indicates a single precoding matrix and multiple precoding matrices depends on Mv values (1 vs >1). * If pmiFormat is not provided, then the 214 spec is contradictory as explained in our contribution. * A simple way to fix this is to set pmiFormat = WB (which can be supported easily based on the current spec, there is no spec change needed) |
| Nokia/NSB | Alt 2  We suggest replacing ‘pmiReportingFormat’ with ‘pmi-FormatIndicator’ in the proposal, or else clarify that Alt 1 proposes to introduce a new RRC parameter.  Some comments taken from our contributions:   * There is no reporting format issue related to the classification of Rel-17 PS as WB for and SB for . The reporting format is not dependent on the WB vs SB classification and can be different for different codebook types with the same frequency granularity. For example, SB reporting format for Type I and Type II is different from that of eType II. * Rel-17 PS codebook can retain its own reporting format, similar to eType II, for both and , without causing any inconsistency. This is just an editorial issue, in fact, the editor may consider adding another case to the list of Reporting Settings with WB frequency granularity, for example, as follows   A CSI Reporting Setting is said to have a wideband frequency-granularity if  - *reportQuantity* is set to 'cri-RI-PMI-CQI', or 'cri-RI-LI-PMI-CQI', *cqi-FormatIndicator* is set to 'widebandCQI'  and *pmi-FormatIndicator* is set to 'widebandPMI', or  - *reportQuantity* is set to 'cri-RI-PMI-CQI', or 'cri-RI-LI-PMI-CQI', *codebookType* is set to 'typeII-r16', 'typeII-PortSelection-r16', or 'typeII-PortSelection-r17' and , or  - *reportQuantity* is set to 'cri-RI-i1' or  - *reportQuantity* is set to 'cri-RI-CQI' or 'cri-RI-i1-CQI' and *cqi-FormatIndicator* is set to 'widebandCQI', or  - *reportQuantity* is set to 'cri-RSRP' or 'ssb-Index-RSRP' or 'cri-SINR', or 'ssb-Index-SINR'  otherwise, the CSI Reporting Setting is said to have a subband frequency-granularity. |

## Other Remaining Issues

In RAN1#106e, it was agreed that whether/how the NZC bitmap can be absent from the CSI reporting would be discussed in RAN1#106bis-e as following

* **Alt 1**: At least for rank 1 PMI, the bitmap of indicating non-zero coefficients is not needed if Mv=1 and Beta=1.
* **Alt 2**: For rank 1~2 PMI, the bitmap(s) of indicating non-zero coefficients for corresponding layer(s) is absent if reported KNZ=K1\*Mv\*rank
* **Alt 3**: In addition to Alt 2, additional field is reported by UE to inform whether the bitmap of indicating non-zero coefficients for specific layer is absent if rank>1.
* **Alt 4**: The bitmap of indicating non-zero coefficients is not needed if the number of coefficients is sufficiently small, i.e. K1Mv ≤ δ
* Note: If none of above Alternative is agreed in RAN1#106bis-e, the bitmap for indicating non-zero coefficient is always present by default.

About 19 companies have shared their views on the bitmap absent issue, which are listed in the table below.

**Table 9 Summary of Companies’ Views on whether/how the bitmap can be absent**

|  |  |  |
| --- | --- | --- |
| **Views** | | **Companies** |
| **Can’t Absent/No need (6)** | | vivo, Fraunhofer IIS, Fraunhofer HHI, LG, QC, Ericsson |
| **Absent(13)** | **Alt 1 (5)** | Lenovo, Motorola Mobility, DoCoMo, Spreadtrum(1st preference), Intel(1st preference) |
| **Alt 2 (8)** | ZTE, Samsung, Nokia, Nokia Shanghai Bell, DoCoMo, Spreadtrum(2nd preference), Intel (2nd preference), Sony |
| **Alt 3 (3)** | CATT, Huawei, HiSilicon |
| **Alt 4 (2)** | Lenovo, Motorola Mobility |

13 companies (Lenovo, Motorola Mobility, DoCoMo, Spreadtrum, Intel, ZTE, Samsung, Nokia, Nokia Shanghai Bell, Sony, CATT, Huawei, and HiSilicon) think the bitmap for indicating non-zero coefficients for can be absent in Rel-17 to reduce the CSI feedback overhead considering UL/DL channel reciprocity.

* Five companies (Lenovo, Motorola Mobility, DoCoMo, Spreadtrum (1st preference) and Intel (1st preference)) prefer Alt 1. For this Alt, the bitmap for indication non-zero coefficient can be absent when and for rank 1. Intel provides the cumulative probability distribution for the number of non-zero coefficients per layer with *K*1 = 32, *M* = 1 and Beta = 1 and it can be found that the bitmap absent probability is about 30%. Also it is observed that performance/overhead is slightly better if bitmap is not reported by the UE for M = 1 for rank 1 and 2.
* Eight companies (ZTE, Samsung, Nokia, Nokia Shanghai Bell, DoCoMo, Spreadtrum (2nd preference), Intel (2nd preference) and Sony prefer Alt 2. These companies think that UE still can select and report a subset of NZ coefficients even when and. Hence it is insufficient to omit the bitmap always if beta = 1, otherwise it may restrict the flexibility of UE implementation. For Alt 2, if β=1 and UE reports () nonzero coefficients, the bitmap for indicating non-zero coefficient can be absent. Alt 2 doesn’t require any new UCI parameter.
* Three companies (CATT, Huawei, and HiSilicon) prefer Alt 3 because Alt 2 shall be applied to both layers’ bitmaps being absent or not simultaneously. It introduces a significant limitation over scenarios that the bitmap can be absent. Huawei and HiSilicon show that the bitmap absent is not a corner case based on simulation results. When β = 1 and rank 2 PMI, the probability of bitmap being absent for at least one PMI layer is about 65% and 30% for P=16 ports and P=32 ports respectively. Alt 3 can save more 3~4 bits than Alt 2 on average.
* Lenovo, Motorola Mobility prefer Alt 4, in which the bitmap for indication non-zero coefficient can be absent when the number of coefficients is small, e.g., K1Mv ≤ δ, e.g. δ=4.

On the other hand, 6 companies (vivo, Fraunhofer IIS, Fraunhofer HHI, QC, LG and Ericsson) prefer that the bitmap for indicating non-zero coefficients always exists because benefits of being absent are insufficient and unjustified yet.

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

***Proposal 9-1:*** *For Rel-17 PS codebook, whether the bitmap for indicating non-zero coefficients can be absent*

* *Alt 1: the bitmap for indicating non-zero coefficient can be absent*
* *Alt 2: the bitmap for indicating non-zero coefficient is always present*

***Proposal 9-2****: Down-selecting an alternative from previous agreement in RAN1 106bis, after Proposal 9-1*

|  |  |
| --- | --- |
| Company | Comments |
| Mod | Proposal 9-1 is suggested based on existing views. Instead of further debating specific solutions in Proposal 9-2, it can be more efficient to determine firstly whether such use case/optimization is useful enough for RAN1.  If RAN1 conclusion is that such use case is not needed, we can save effort to debate which specific Alt is preferred, given that there are quite some companies being conservative already. The note from previous agreement is applied.  If RAN1 conclusion is that we can do something, companies may change views later. |
| Qualcomm | Alt2, no need of further discussion. |
| Lenovo/Mot | Support Alt1 |
| ZTE | We support Alt 2 in the solution list if the bitmap can be absent. |
| vivo | Support Alt2 |
| Ericsson | Alt.2, we can close the discussion. |
| Samsung | Support Alt1 since the overhead saving (which can be large) is for free. |
| Nokia/NSB | Alt 2  Given the difficulty to converge to Alt 2, which in our view is the only simple optimisation that is worth pursuing, and the limited benefit of such an optimisation, we prefer to abandon this discussion |

About 6 companies have shared their views over Part II for UCI groups, which are listed in the table below.

**Table 11 Summary of Companies’ Views on** **the design of three groups of Part II**

|  |  |
| --- | --- |
| **Views** | **Companies** |
| **Port selection indicator, SCI, and FD indicator in Group 0** | MediaTek, Huawei, HiSilicon, Ericsson |
| **Bitmap in Group 0 or Group 1** | Samsung |
| **Reuse R16 design** | CATT |

* Companies (MediaTek, Huawei, HiSilicon, Ericsson) propose to report FD indicator in Group 0 because gNB may not be able to construct a meaningful DL precoder merely based on existing Group 0 UCI, if Group 1 and Group 2 CSI are dropped due to CSI omission.
* Samsung prefer no bitmap partition and report bitmap in G0 or G1 of UCI part 2 since the bitmap size is likely to be much smaller than Rel.16 Type II PS.
* CATT thinks that since the reporting parameters of Rel-17 port selection codebook is similar to that of Rel-16 Type II port selection codebook, the contents in CSI Part 2 for Rel-17 port selection codebook should be similar to that of Rel-16 Type II port selection codebook except for the starting position of the FD basis window for N\_3>19 in Group 1.

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

***Proposal 10****:* Support *one or more from the following alternatives for UCI Part II of Rel-17 PS codebook:*

* *Alt 1: Report Port indicator, SCI, and FD indicator in Group 0*
* *Alt 2: Report bitmap in Group 0 or Group 1 without bitmap partition*
* *Alt 3: Three groups of UCI Part 2 for Rel-16 PS codebook is reused for Rel17 PS codebook enhancement except that the starting position of the FD basis window is not needed*

|  |  |
| --- | --- |
| Company | Comments |
| Mod | Proposal 10 is suggested based on existing views. It is recommended to take the majority later. |
| Qualcomm | Agreeing on alternatives is premature, we think further study is needed. |
| Lenovo/Mot | We believe this is an important issue that needs to be discussed this meeting, however we prefer if it is discussed in a later round after a few Rank 3,4 details are finalized |
| ZTE | We support Alt 3. We think Alt 3 should be the baseline as the reported parameters in Rel-17 is almost same as Rel-16. We are also open to consider Alt 1. We don’t support Alt 2 as this issue has been discussed a lot in Rel-16. We don’t think to repeat the discussion is a good idea. |
| Ericsson | Prefer to discuss this after the codebook parameter discussion is final. |
| Samsung | Support Alt 1 and 2  Re Alt 2, in our view, unlike Rel.16, since the bitmap size is small (K1\*v or 2K1\*v), there is no need to partition. This can save some UE operations |
| Nokia/NSB | Considering that the bitwidth for some indicators whether they are layer-common or layer-group specific for rank 3,4 has not been agreed yet, we also prefer to finalise those remaining issues first. |

3 companies have shared their views over the priority ofmapping coefficients, which are listed in the table below.

**Table 12 Summary of Companies’ Views on** **the priority of mapping coefficients**

|  |  |
| --- | --- |
| **Views** | **Companies** |
| **1stport indices, 2nd FD basis indices, 3rd layers** | Qualcomm |
| **1stlayers, 2nd port indices, 3rd FD basis indices with the order of FD basis by index size** | CATT |
| **Prioritization within Polarizations** | Fraunhofer IIS, Fraunhofer HHI |

* Qualcomm proposes to support mapping coefficients firstly across port indices, secondly across FD basis indices, and thirdly across layers because such an order of mapping coefficients can keep full precoder of the 1st layer as being complete as possible.
* CATT propose to support mapping coefficients firstly across layers, secondly across port indices, and thirdly across FD basis indices same as Rel-16 except permuting the index of FD basis by index size. Hence, the priority value Pri(l,i,f)=K\_1⋅υ⋅f+υ⋅i+l should be used to omit CSI for Rel-17 port selection codebook.
* Fraunhofer IIS, Fraunhofer HHI propose to support grouping of non-zero coefficients into two coefficient subsets, where each coefficient subset comprises the precoder coefficients associated with K\_1/4 ports of the first polarization and K\_1/4 ports of the second polarization and coefficient ordering in each coefficient subset follows the coefficient ordering of Rel.16, because that the precoder coefficients associated with the second polarization are more likely to be dropped in the event of UCI omission due to the high number of selected ports.

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

***Proposal 11:*** *Support one or more from following alternatives for the priority of mapping coefficients:*

* *Alt 1: Support mapping coefficients firstly across port indices, secondly across FD basis indices, and thirdly across layers, i.e. priority value is given by the priority value Pri(l,i,f)=K1\*Mυ\*l+ K1\*f+i*
* *Alt 2: Support mapping coefficients firstly across layers, secondly across port indices, and thirdly across FD basis indices, i.e., the priority value is given by Pri(l,i,f)= υ\*K1\*f+υ\*i+l.*
* *Alt 3: Support grouping of non-zero coefficients into two coefficient subsets, where each coefficient subset comprises the precoder coefficients associated with K1/4 ports of the first polarization and K1/4 ports of the second polarization.*
  + *Coefficient ordering in each coefficient subset follows the coefficient ordering of Rel. 16.*

|  |  |
| --- | --- |
| Company | Comments |
| Mod | Proposal 11 is suggested based on existing views. It is recommended to take the majority later. |
| Alt1 | Alt1 is preferred with the following reason:   1. Simplest method for coefficient packing and omission, as per-layer ordering is the most natural order. For UCI omission and packing, complexity should be considered as the 1st criteria, as it rarely happens in real-world. 2. When omit UCI by layer, all coefficients of layer 1 and layer 2 can be kept with large probability. These layer(s) can still be used by gNB for MU scheduling. However, Alt2 cannot have all coefficients for any layers. 3. When omit UCI by layer, the CQI can still be used by gNB pass the 10% BLER test as the CQI for a higher rank is underestimated for a lower rank. E.g., Let say UE report rank-2 and omit layer-2 (layer-1 is kept), in this case, the reported CQI is based on rank-2 hypothesis, gNB can use the CQI to schedule PDSCH with <10% BLER with the precoding vector of layer-1. |
| Lenovo/Mot | Support Alt2 |
| ZTE | We support Alt 2. Alt 2 is based on the Rel-16 design. The prioritization of layers, FD basis and ports has been discussed a lot in Rel-16, with the outcome as in Alt 2. We think layers should have highest priority. The correct number of layers is more crucial for NW to achieve high performance. |
| Ericsson | Okay to support Alt 1, but as in the previous proposal, we need more discussions. First priority is to finalize codebook parameters. |
| Samsung | Support prefer Alt2, but can be OK to discuss Alt1 |
| Nokia/NSB | Support Alt2. This is the same as in Rel-16 where replaces and yields the same ordering for .  We don’t see any strong reason for changing Rel-16 order. |

In RAN1#106e, it was agreed that when Mv=2, in addition to N=2, one value from {3, 4, 5} should be selected for N by RAN1 in RAN1 106bis-e. More than 15 companies provide their views on this issues, which is summarized as Table 13.

**Table 13 Summary of Companies’ Views on value of N**

|  |  |
| --- | --- |
| **Views** | **Companies** |
| **N = 3 (4)** | OPPO(1st), Samsung, QC, Ericsson |
| **N = 4 (10)** | Huawei, HiSilicon, ZTE, vivo, OPPO(2nd), Fraunhofer IIS, Fraunhofer HHI, MTK, Intel, DoCoMo |
| **N = 5 (5)** | CATT, Samsung, DoCoMo, Nokia, Nokia Shanghai Bell |

Most companies prefer N=4 due to better trade-off among reporting overhead, performance robustness and UE complexity. Some companies prefer N=3 due to lower UE complexity and avoid N3 < N. Companies preferring N=5 may have advantage over smaller window size in term of performance, especially for non-ideal reciprocity caused by some implementation limitations. In addition, vivo gives simulation results for different value of N, in which the performance gain between N = 4 and N = 5 is marginal while the gain among N = 2, 3, 4 is more evident.

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

***Proposal 12: In addition to N=2, N=4 can be supported when =2***

|  |  |
| --- | --- |
| Company | Comments |
| Mod | Proposal 12 is suggested based on the majority. |
| Lenovo/Mot | Support |
| ZTE | We support the proposal. |
| vivo | Support |
| Ericsson | It’s ok to agree on the proposal but then we need to handle N3=3 case |
| Samsung | Suggest to discuss Proposal 13 first. If Proposal 13 is agreed, then we support N-1 = 2 or 4 depending on 1 or 2 bits for Wf reporting. Implying N = 3 or 5.  Between N=4 and 5, there is no difference in reporting payload (both require 2 bits), but N=5 allows one more candidate for reporting for free. |
| Nokia/NSB | Prefer to discuss after the reporting mechanism is agreed, i.e. after P13-14 |

With regarding to report Wf in terms of reporting mechanism and associated bits when Mv=2 and N=one value from {3, 4, 5} is another issue for Rel-17. About 17 companies provide their views, which is shown in Table 14.

**Table 14 Summary of Companies’ Views on Report of Wf**

|  |  |
| --- | --- |
| **Views** | **Companies** |
| use bits to report Wf (4) | ZTE, vivo, DoCoMo, Ericsson |
| use bits to report Wf  (13) | Huawei, HiSilicon, Spreadtrum, vivo, OPPO, CATT, Fraunhofer IIS, Fraunhofer HHI, Samsung, MTK, Nokia, Nokia Shanghai Bell, QC |

Some companies propose to use bits to report Wf, wherein a code point corresponds to pair selected from FD basis 0 to N-1. On the other hand, companies propose to use bits to report Wf, which equals to bits when Mv = 2. Similar to Rel-16 codebook, the UE can apply a rotation to the FD basis vectors without any loss in performance since the same phase shifting on PMI calculation for each subband does not have impact on system performance. Therefore, in this approach, FD basis 0 (all-1 vector) will be selected by default, and UE only needs to report the other FD basis from FD basis 1 to N-1. Compared with bits, fewer bits can be saved.

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

***Proposal 13: If =2 and N>Mv, bits are used to report the second FD basis of Wf,***

|  |  |
| --- | --- |
| Company | Comments |
| Mod | Proposal 13 is suggested based on the majority. |
| Qualcomm | Support |
| Lenovo/Mot | Support proposal |
| ZTE | We are wondering whether such proposal means the specification is going to specify the CS operation. If not, we are okay with this proposal. Hence we suggest to add a note saying “The phase shift/remapping is up to UE implementation.” |
| vivo | Support |
| Ericsson | Support |
| Samsung | OK with the clarification that   * FD index 0 is always reported and remaining Mv-1=1 FD index is reported via  ***bits*** |
| Nokia/NSB | Proposal 13 and 14 are linked and we suggest discussing them together, for example as follows  ***Proposal 13-14: If =2 and N>Mv, support one of the alternatives:***  ***Alt 1. bits are used to report the second FD basis of Wf, after remapping***  ***Alt 2. bits are used to report the second FD basis of Wf without remapping***  ***Alt 3. bits are used to report the two components, without remapping***  W support Alt 1 (first choice) or Alt 3 (second choice), but not Alt 2. With the current proposal 13 and without remapping, a UE may wrongly assume that component 0 is fixed and only one component is selected. |

About 8 companies have shared their views on the issue whether to support FD basis remapping. The views are listed in the following tables.

**Table 10 Summary of Companies’ Views on** **FD basis remapping**

|  |  |
| --- | --- |
| **Views** | **Companies** |
| **Don’t support (7)** | Spreadtrum, Samsung, Qualcomm, Huawei, HiSilicon, ZTE, CATT |
| **Support (2)** | Nokia, Nokia Shanghai Bell |

Companies not supporting FD basis remapping have the following considerations:

* Spreadtrum considers that since FD basis reporting is layer-common and Mv>2 is not supported, remapping is no longer needed and whether FD basis 0 is selected by remapping can be UE implementation.
* Qualcomm, Huawei, HiSilicon and ZTE prefer not support FD basis remapping because that the saved overhead from this remapping is very small but implementation complexity is increased.
* Samsung thinks shift/remapping for UCI omission is merely an optimization of a rare-event, hence doesn’t have any benefits.

On the other hand, companies proposing to FD basis remappinghave the following considerations:

* Nokia, Nokia Shanghai Bell consider that if the remapping operation is not specified for , and only one FD basis is reported, a UE may assume that component 0 is fixed by gNB configuration. Hence, the gNB would align the start of the window with the peak of a delay estimate resulting in a less robust FD precoding against imperfect delay reciprocity and timing offsets..

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

***Proposal 14: For Rel-17 PS codebook, whether remapping FD basis is needed***

* ***Alt1: it is needed***
* ***Alt2: it is not needed***

|  |  |
| --- | --- |
| Company | Comments |
| Mod | Proposal 14 is suggested based on existing views. It is recommended to take the majority later. |
| Qualcomm | Alt2. |
| ZTE | We support Alt 2. |
| vivo | Support Alt2 |
| Ericsson | Alt 2, the marginal saving in overhead does not pay off the complexity increase. |
| Samsung | Support Alt2 |
| Nokia/NSB | We prefer to discuss this proposal jointly with P13 as suggested in our previous comment.  Note that Alt 1 is not proposed for saving one bit. The main reason to specify remapping, similarly to Rel-16, is to ensure that a UE can freely select both FD bases. Without remapping, if only one component is reported, a UE may assume that component 0 is fixed and only the second component is selected |

Regarding the value of R, R=1 and at most one value (can be none) from {2, D\*} are supported according to the agreements of RAN1 #106e. About 15 companies have shared their views on the value of R. The views are listed in the following table.

**Table 15 Summary of Companies’ Views on R for**

|  |  |
| --- | --- |
| **Views** | **Companies** |
| **R = 2 (3)** | Lenovo, Motorola Mobility, LG |
| **R =** **D\* (9)** | ZTE, HW, HiSilicon(for Mv=2), vivo (for Mv>1), CATT(R is not needed for Mv=1), Intel, Nokia, Nokia Shanghai Bell, Ericsson(2nd, R is not applicable for Mv=1) |
| **Neither above (4)** | MTK, Apple, QC, Ericsson(1st, R is not applicable for Mv=1) |

Companies preferring only R =1 have the following considerations.

* QC and MTK think that R value impacts CQI calculation, but the benefit might not be sufficient considering increased complexity in PMI construction with R>1. The network can obtain same precoder with R=1 and R > 1 via implementation, i.e., RB-level CSI-RS precoding and/or PMI interpolation. Therefore, no need to define R in the spec or only support R=1 PMI per CQI subband.

Companies preferring R = {1, 2} have the following considerations.

* LG considers that for values exceeding 2, it is not clear how much performance gain can be obtained compared to an increase in UE complexity.

Companies preferring R = {*1, D\**} have the following considerations.

* Nokia, Nokia Shanghai Bell, vivo, Intel and Ericsson support since the best performance is observed for from simulation results.
* ZTE and CATT believe that to increase R is beneficial to achieve higher performance for UE throughput without increasing feedback overhead.
* HW and HiSilicon consider that from spec view, different values of R means different length of FD bases in , which can be used by gNB to indicate UEs for the appropriate FD bases in order to match with the precoding granularity of beamformed CSI-RS when UEs calculate the coefficients.

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

***Proposal 15: For Rel-17 PS codebook, support R=* D\* NPRBSB *when Mv=2***

* **Note that this R is optional**

|  |  |
| --- | --- |
| Company | Comments |
| Mod | Proposal 15 is suggested based on existing views. It is recommended to take the majority later. |
| Qualcomm | Cannot accept this R. Still prefer R=1 only. |
| ZTE | Support this proposal. |
| vivo | Support |
| Ericsson | Prefer R=1 only |
| Samsung | Since it is optional, we can live with R=2 or **D\* NPRBSB** as long as it is configured only when Mv=2 |
| Nokia/NSB | Support |

With regarding to the relationship between turn off and discussed in RAN1#105e:

* Alt 1: OFF and ON with =1 are same, and is an all-one vector of length N3. as an all-one vector of length 1 is not needed
* Alt 2: OFF and ON with =1 are same, and is an all-one vector of length 1, i.e., a scalar. as an all-one vector of length N3 is not needed.
* Alt 3: Keep both OFF and ON with =1.
  + If PMI format is SB, is an all-one vector of length N3
    - Informative note: this case is considered as “ ON with =1” in the agreement in RAN1 104e
  + If PMI format is WB, is an all-one vector of length 1, i.e., a scalar
    - Informative note: this case is considered as “ OFF” in the agreement in RAN1 104e

Companies provide views shown as following table.

**Table 16 Summary of Companies’ Views on**  **off**

|  |  |
| --- | --- |
| **Views** | **Companies** |
| **Alt 1 (11)** | Spreadtrum, Fraunhofer IIS, Fraunhofer HHI, Samsung[?], DOCOM, Sony, Nokia, Nokia Shanghai Bell, LG, Lenovo, Motorola Mobility |
| **Alt 2 (3)** | ZTE(1st), DOCOMO，CATT |
| **Alt 3 (1)** | ZTE (2nd), |

Companies preferring Alt 1 have the following considerations:

* Companies (e.g. Lenovo, Motorola Mobility, Fraunhofer IIS, Fraunhofer HHI, LG) think Alt1 has the advantage that the codebook can still be configured with >1 without the need to redefine the codebook.

Companies preferring Alt 2 have the following considerations:

* ZTE prefers Alt2 because introducing a DFT vector in frequency domain could complicate the codebook design and restricts the UE behaviour to calculate PMI when off and =1.
* DoCoMo shows that UE implementation would be the same for three alternatives and Alt3 seems to be redundant, so prefers Alt1 or Alt2.

Other companies preferring Alt 3 have the following considerations:

* ZTE supports Alt 3 to use PMI format in the CSI reporting configuration to configure whether it is off (=1, WB) or on (=2, SB) so that WB PMI in Rel-17 can be used to reduce UE complexity.

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

***Proposal 16: For Rel-17 PS codebook***

* ***Wf OFF and Wf ON with Mv=1 are same, and Wf is an all-one vector of length N3***

|  |  |
| --- | --- |
| Company | Comments |
| Mod | Proposal 16 is suggested based on existing views. It is recommended to take the majority later.  Although many companies have shared views for this particular matter, it has been sufficiently discussed for two meetings now. Also Proposal 8 has similar/related discussion of RRC which needs to be decided this way or another.  So my recommendation is to address Proposal 16 later. The table is to collect more comments from companies in case that I miss something or you prefer to add more details to remind MIMO colleagues here. |
| Qualcomm | Support |
| Lenovo/Mot | Support the proposal |
| ZTE | Do not support this proposal. We support Alt 2 or Alt 3. |
| vivo | Support |
| Ericsson | Support |
| Samsung | Do not support. Suggest to discuss Proposal 8 first, or Proposal 8 and 16 together.  Also, re the length of all-one vector, we suggest the following:   * + *Alt1: N3 = 1*   + *Alt2: one of the following is included in the codebook description*     - *Alt2-1: a single precoding matrix is indicated by the PMI*     - *Alt2-2: N3 precoding matrices indicated by the PMI, but they are the same when Mv=1* |
| Nokia/NSB | Support |

## Others

Besides the above issues, some companies provide some proposals related to Rel-17 Port Selection Codebook, which is summarized as following.

|  |  |
| --- | --- |
| **Company** | **View** |
| **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.* |
| **Sony** | * *Free selection of by the UEs, e.g., , or for some , should be supported.* * *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** | * *R17 codebook is supported for BWP size < 24 PRBs* |
| **Samsung** | * *when N>N3, window size = N3* |
| **Samsung** | * *P=2 is supported for R17 codebook* |

|  |  |
| --- | --- |
| Company | Comments |
| Samsung | Added some proposals from our side in the table |
|  |  |

# Summary of CSI enhancement for Multi-TRP

## CSI Measurement Enhancement and CSI framework for Multi-TRP

In the last meeting, the issue of undesired phase rotation at receiver was raised and possible restrictions over CMR configurations are agreed for further study as following:

For CSI measurement associated with a *CSI-ReportingConfig* for NC-JT, study following restriction(s) for two CMRs within the same CMR pair configured for NCJT measurement hypothesis:

* Alt1: two resources are restricted within the same DL slot
* Alt2: two resources are restricted with the same CDRX active time

Companies’ views over Alt 1 can be summarized as following:

|  |  |
| --- | --- |
| **Views** | **Companies** |
| **Same/neighbouring DL slots (8)** | Futurewei, OPPO (in the same DL slot or in neighboring DL slot), MediaTek, Lenovo, Motorola Mobility, Qualcomm, Huawei, HiSilicon |
| **No uplink symbol (1)** | Vivo |
| **No need (5)** | ZTE, Samsung, Intel, DoCoMo, Ericsson |

Companies preferring Alt1 have the following considerations:

* Huawei, HiSilicon, Futurewei and Lenovo support Alt 1 since that the random phase rotation at receiver caused by DL/UL switching as well as different power compensation steps in AGC will impact the estimation of the inter-TRP interference so as to cause the mismatch between reported CQI and proper MCS in NCJT scheduling.
* Qualcomm supports Alt1 from both accuracy of CSI point of view as well as UE implementation considerations. Furthermore, there is no use case/benefit for two CMRs in a CMR pair located in different slots.
* MediaTek supports Alt1 in order to reduce the overall CSI latency, ensure reduced impact of time-varying interference and guarantee high coherency.
* OPPO proposes two CMRs are located in the same DL slot, or in some case, in neighbouring DL slots, to reduce unnecessary memory occupation and improve the CSI accuracy for NCJT.
* Vivo proposes that Alt1 is too restrictive and propose that avoiding uplink symbols between two CMRs within the same CMR pair can be enforced by network.

On the other hand, companies who do not support Alt1 have the following considerations:

* ZTE proposes that it is unclear how much impact that the receiver side phase rotation can cause when there are uplink symbols between two CMRs within the same CMR pair. ZTE proposes to avoid the DL/UL switching between two CMRs by gNB implementation rather than restricting two CMRs within the same slot or the same CDRX active time.
* Samsung and Ericsson proposes a common phase rotation across all Rx antenna elements due to a time delay will not impact the estimation of inter-TRP interference. Consequently, the restriction of two CMRs within the CMR pair for NCJT located in the same DL slot is not necessary. Furthermore, Ericsson prefers network to decide whether two CMRs are configured in the same slot or different slots.
* DoCoMo proposes that since CMR and IMR for the same CSI measurement can come from different slots in existing specification, restricting two CMRs within the same DL slot is not needed.

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

***Proposal 17:*** *For CSI measurement associated with a CSI-ReportingConfig for NCJT,*

* *Alt 1:* *two CMRs within the same CMR pair configured for NCJT measurement hypothesis are restricted within the same DL slot*
* *Alt 2: UE does not expect uplink symbols between two CMRs within the same CMR pair.*
  + *FFS which two CMRs for P/SP CMRs*
* *Alt 3: Neither restriction from above is needed.*

|  |  |
| --- | --- |
| Company | Comments |
| Mod | Starting from previous agreement in RAN1 106 to study possible restrictions to address with UE implementation issues. |
| Lenovo/Mot | Support Alt1 |
| vivo | Slightly prefer Alt2.  We think Alt.1 is too restrictive so that the network has to configure the slot as a DL slot before it transmits CSI-RS for enhanced MTRP CSI feedback in dynamic TDD systems. Actually, avoiding uplink symbols between two CMRs within the same CMR pair can be assured and implemented by network and thus a relaxed restriction can be made, i.e. Alt.2. For the FFS, we think it is unclear and may be applied to both Alt.1 and Alt.2.  Further evaluation may be needed to see how much performance impact this issue will have. Not only on PMI selection but also the CQI results and throughput. |
| Samsung | Support Alt 3. Alt 1 is too restrictive. |
| QC | We think Alt1 is a natural choice. What is the use case to send the two CMRs of a pair in different slots? How this flexibility would be useful for network? |
| Nokia/NSB | Alt 3 is preferred.  This time restriction can already be achieved by network scheduler implementation. However, in some limited cases, e.g. large number of users in the cell and multiple CCs, this may not be possible. Hence, enforcing this requirement may be too restrictive. |
| Futurewei | Support FL’s proposal and we prefer Alt 1. |
| InterDigital | Support Alt 3. |

Companies’ views over Alt2 is summarized as following:

|  |  |
| --- | --- |
| **Views** | **Companies** |
| **Same CDRX active time (4)** | Futurewei, Vivo, Intel, DoCoMo |
| **No need (1)** | ZTE |

Companies supporting Alt2 have the following considerations:

* Intel proposes that it is beneficial to constraint the CMRs for NCJT to be in the same CDRX active time to avoid unnecessary complications at the UE.
* DoCoMo proposes that restricting two CMR resources within the same CMR pair within the same CDRX active time can avoid UE memory increase.

On the other hand, ZTE proposes to avoid the DL/UL switching between two CMRs by gNB implementation rather than restricting two CMRs within the same slot or the same CDRX active time.

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

***Proposal 18:*** *For CSI measurement associated with a CSI-ReportingConfig for NCJT,*

* *Alt 1: two CMRs within the same CMR pair configured for NCJT measurement hypothesis are restricted within the same CDRX active time*
* *Alt 2: Above restriction is not needed*

|  |  |
| --- | --- |
| Company | Comments |
| Mod | Starting from previous agreement in RAN1 106 to study possible restrictions to address with UE implementation issues. |
| Lenovo/Mot | Are we supposed to select between Proposal 17/18? I think this should be merged with Proposal 17 |
| vivo | Support Alt.1. |
| Samsung | We support Alt 1. It is reasonable to restrict two CMRs of a CMR pair to be in the same CDRX active time considering the memory requirement for joint NCJT CSI computation as well as from the CSI latency and accuracy viewpoints. |
| QC | Support Alt1. |
| Nokia/NSB | Alt 2 is preferred, for similar reasons as P17. |
| Futurewei | Support FL’s proposal and we prefer Alt 1. |
| InterDigital | Support Alt. 1. |

With regarding to *powerControlOffset*, three alternatives were suggested in RAN1 106e as following:

* Alt 1: a separate *powerControlOffset* (Pc ratio) shall be configured for the NCJT measurement hypothesis by re-defining such Pc ratio as 10log10(P\_PDSCH/P\_CSIRS) dB, whereas
  + P\_PDSCH is the energy of PDSCH ports with a same TCI state as the CMR on one subcarrier of one OFDM symbol
  + P\_CSIRS is the energy of all CSI-RS ports of the CMR multiplexed on one subcarrier of one OFDM symbol
* Alt 2: re-interpret two Pc ratios configured for the CMR pair for the NCJT measurement hypothesis, FFS detailed impact of specification
* Alt 3: No change to definition or configuration of Pc ratio

Companies’ view on *powerControlOffset* is summarized as following:

|  |  |
| --- | --- |
| **Views** | **Companies** |
| **Alt 1 (6)** | CATT, MediaTek, Intel, Nokia, Nokia Shanghai Bell, Qualcomm |
| **Alt 2 (2)** | ZTE, Ericsson |
| **Alt 3 (6)** | Vivo, OPPO, Fraunhofer IIS, Fraunhofer HHI, DoCoMo, LGE |

Companies supporting Alt1 have the following considerations:

* CATT proposes that the definition of CSI-RS ports and PDSCH ports is consistent in Alt1 when the CMR is from one TRP and PDSCH ports are also from that same TRP.
* MTK prefers to Alt1 to keep the consistency of the *powerControlOffset* definition when applying to NCJT scenario.
* Intel thinks that Alt1 allows flexible Tx power configuration for each TRP for PDSCH transmission.
* Nokia proposes it can be beneficial to introduce a separate ratio for NCJT hypotheses, powerControlOffsetNCJT, defined as the ratio between the PDSCH EPRE of the PDSCH ports transmitted from one of the two TRPs and the CSI-RS EPRE of all CSI-RS ports multiplexed on one subcarrier.
* Qualcomm points out that Alt3 may not work. With Rel. 15 definition, PPDSCH= Pc,1\*PCSIRS,1= Pc,2 \* PCSIRS,2. Since PCSIRS,1 and PCSIRS,2 are the measured energy at the UE corresponding to two CMRs, there is no way for gNB to configure Pc,1 and Pc,2 such that the equation above is satisfied. In addition, Qualcomm proposes that Alt 1 can achieve the fairness among single-TRP CSI hypotheses versus NCJT CSI hypotheses in terms of power-gain versus reuse-loss trade off.

Companies supporting Alt2 have the following considerations:

* ZTE thinks the existing Pc ratio should be sufficient for both sTRP and NCJT CSI calculation and one Pc ratio is shared for both STRP and NCJT for each CMR.
* Ericsson proposes that it is enough to re-interpret two Pc ratios (P\_PDSCH/P\_CSIRS) configured for CMR pair for the NCJT measurement hypothesis as per TRP, i.e., PDSCH ports is related to CSI-RS ports from the same TRP.

Companies supporting Alt3 have the following considerations:

* Vivo proposes since in NCJT transmission, layers cannot be mapped across different TRPs due to non-coherent transmission between TRPs, it implies that the “corresponding PDSCH signals” transmitted on antenna ports [3000,…,3000 + *P* - 1] doesn’t mean all layers of the PDSCH but the TRP-specific layers of the PDSCH mapped to CSI-RS ports within CMR of each TRP. Therefore, at least for NCJT, Vivo think the current description in subclause 5.2.2 of TS 38.214 is clear and flexible enough and different *powerControlOffset* values can be configured to CMRs from two TRPs.
* OPPO proposes gNB can determine a reasonable value of Pc based on the EPRE ratio between PDSCH and CSI-RS in each TRP and therefore the definition or configuration of Pc ratio doesn’t need to be changed.
* Fraunhofer IIS and Fraunhofer HHI propose that since each CMR within a CMR pair for a NCJT hypothesis is associated with a TRP, it is clear from the current definition of *powerControlOffset* in 38.214 that the mapping is specific with respect to the CSI-RS ports of each CMR.
* DoCoMo proposes that since for a CMR pair configured for NCJT measurement hypothesis, the power of CSI-RS for single-TRP measurement and that for NCJT measurement can be the same, there is no issue on Pc for CSI-RS.
* LGE proposes NCJT CSI can also be calculated by UE implementation based on the current definition on Pc.

Based on above company’s views, the following issue is suggested to be discussed:

***Proposal 19:*** *For a CMR pair configured for a NCJT measurement hypothesis, downselect one alternative from the following in RAN1 106bis:*

* *Alt 1: a separate powerControlOffset (Pc ratio) shall be configured for the NCJT measurement hypothesis by re-defining such Pc ratio as 10log10(P\_PDSCH/P\_CSIRS) dB, whereas*
  + *P\_PDSCH is the energy of PDSCH ports with a same TCI state as the CMR on one subcarrier of one OFDM symbol*
  + *P\_CSIRS is the energy of all CSI-RS ports of the CMR multiplexed on one subcarrier of one OFDM symbol*
* *Alt 2: re-interpret two Pc ratios configured for the CMR pair for the NCJT measurement hypothesis, FFS detailed impact of specification*
* *Alt 3: No change to definition or configuration of Pc ratio*

|  |  |
| --- | --- |
| Company | Comments |
| Mod | Starting from previous agreement in RAN1 106 to study possible issues of Pc, the target is to make a decision this way or another this meeting, due to potential RAN2 impact, e.g. if we need a new RRC parameter. |
| Vivo | Support Alt.3.  We think it is clear and still works according to the current description that the corresponding PDSCH signals transmitted on antenna ports [3000,…,3000 + P - 1] would have a ratio of EPRE to CSI-RS EPRE equal to the ratio given in Clause 5.2.2.3.1. For NCJT transmission, layers can not be mapped across different TRPs due to non-coherent transmission between TRPs. Therefore, it implies that the “corresponding PDSCH signals” transmitted on antenna ports [3000,…,3000 + P - 1] doesn’t mean all layers of the PDSCH but the TRP-specific layers of the PDSCH mapped to CSI-RS ports within CMR of each TRP, as illustrated in following figure. Therefore, at least for NCJT, we think the current description in subclause 5.2.2 of TS 38.214 is clear and flexible enough and different powerControlOffset values can be configured to CMRs from two TRPs.    With such understanding, our interpretation according to current spec for the relationship between PPDSCH, PCSIRS, and Pc is PPDSCH,1= Pc,1\*PCSIRS,1, and PPDSCH,2= Pc,2 \* PCSIRS,2 |
| Samsung | We support Alt2. Reinterpreting the Pc ratio is sufficient. |
| QC | Support Alt1.  Alt3 should be removed as it does not work. How can network ensure P\_PDSCH= Pc,1 \* P\_CSIRS,1= Pc,2 \* P\_CSIRS,2?  For Alt2, while it can work, it removes the possibility for network to control fairness among sTRP versus NCJT hypotheses. This is because UE always assumes larger power (3dB in case of equal power) for NCJT CSI hypothesis compared to sTRP CSI hypothesis, but the impact of reuse loss (more resources) cannot be taken into account for a fair comparison. |
| Nokia/NSB | Support Alt 1  We suggest a modification in the definition of P\_PDSCH in Alt1 because The CMR Group associated with a CMR is enough to identify which of the two TRPs in the NCJT hypothesis transmits the PDSCH ports.   * + *P\_PDSCH is the energy of PDSCH ports transmitted from one TRP in the CMR Group associated with the CMR, on one subcarrier of one OFDM symbol*   Agree with QC that Alt 3 does not work |
| Futurewei | Support FL’s proposal and we prefer Alt 1. |

With regarding to whether introducing new/relaxed values on CSI computation delay requirement associated with a *CSI-ReportingConfig* for a NCJT measurement hypothesis:

* Alt1: introducing new/relaxed values on Z and Z’, FFS exact values or other conditions
* Alt2: No changes of values on Z and Z’

Companies’ view on *powerControlOffset* is summarized as following:

|  |  |
| --- | --- |
| **Views** | **Companies** |
| **Alt 1 (7)** | Spreadtrum, OPPO, MediaTek, Lenovo, Motorola Mobility, LGE, Ericsson |
| **Alt 2 (4)** | ZTE, Intel, Nokia, Nokia Shanghai Bell |

Companies supporting Alt1 have the following considerations:

* To fully take advantage of NCJT, the inter-layer interference should be considered in the calculation of 2 PMIs for NCJT measurement hypothesis. It means that 2 PMIs should be calculated jointly rather than be calculated independently through parallel computing. Joint PMI calculation sequentially requires higher complexity as well as higher latency. Consequently, seven companies (Spreadtrum, OPPO, MediaTek, Lenovo, Motorola Mobility, LGE, and Ericsson) propose to relax delay requirement for NCJT CSI calculation.

Companies supporting Alt2 have the following considerations:

* Since it has been agreed that two CPUs are occupied for NCJT CSI computation where the extra complexity has been considered, four companies (ZTE, Intel, Nokia, Nokia Shanghai Bell) suggest that there is no need to relax computation delay requirement, i.e., Z and Z’.

Based on above companies’ views, the following issue is suggested to be discussed:

***Proposal 20:*** *For CSI computation delay requirement associated with a CSI-ReportingConfig for a NCJT measurement hypothesis, down-select one alternative from the following:*

* *Alt1: introducing new/relaxed values on Z and Z’, FFS exact values or other conditions*
* *Alt2: No changes of values on Z and Z’*

|  |  |
| --- | --- |
| Company | Comments |
| Mod | Starting from previous agreement in RAN1 106 to study possible relaxation of CSI delay requirement, the target is to make a decision this way or another. Exact values may be decided later, but RAN1 needs one meeting (e,g. RAN1 107) to consolidate values/spec changes if we decide to go to Alt 1. |
| Lenovo/Mot | Support Alt1 |
| QC | No strong opinion either way. For us, the more important issue is to design the UE capabilities for NCJT CSI in way that is both consistent with Rel-15 and also allows the UE to signal its true capability taking into account the complexity of NCJT CSI calculation. |

In RAN1#106-e, whether to support non-PMI CSI reporting with *reportQuantity* set to "CRI-RI-CQI" in Rel-17 is discussed. Companies are encouraged to share details and related specification impact if support. Seven companies provide their views on this topic as following:

|  |  |
| --- | --- |
| **Views** | **Companies** |
| Support non-PMI CSI reporting for NCJT measurement hypothesis in Rel-17 (4) | Samsung, CATT, MediaTek, Intel, Nokia/NSB |
| Non-PMI CSI reporting for NCJT measurement hypothesis is not supported in Rel-17 (3) | Lenovo, Motorola Mobility, Ericsson |

Companies preferring non-PMI based CSI reporting for NCJT measurement have the following considerations:

* Samsung proposes that by non-PMI based port-selection, the calculation complexity of precoders can be avoided.
* Intel proposes that non-PMI based CSI reporting is important for TDD deployments.
* CATT proposes that to enhance the CSI feedback for M-TRP in Rel-17, it’s natural to extend non-PMI based feedback mechanism to the case with more than one TRP.
* CATT and MediaTek propose that at least for TDD system, NCJT can benefit from channel reciprocity by non-PMI based port-selection due to accurate CSI feedback and lower feedback overhead.

On the other hand, companies not preferring non-PMI based CSI reporting for NCJT measurement have the following considerations:

* Lenovo proposes that the benefit of non-PMI based CSI reporting for NCJT hypothesis is not clear, especially that performance gains of non-PMI based port-selection over conventional codebooks are yet to be justified.
* Ericsson proposes to de-prioritize this for Rel-17 since only two RAN1 meetings left for Rel-17 and no evaluation results have been seen so far.

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

***Proposal 21:*** *For CSI measurement associated to a reporting setting CSI-ReportConfig for measurement hypothesis, down-select one alternative from the following:*

* *Alt 1:* *Non-PMI CSI reporting with reportQuantity set to "CRI-RI-CQI" is supported in Rel-17.*
  + *If the UE is not configured with higher layer parameter non-PMI-PortIndication, for two CMRs configured in a CMR pair as an NCJT measurement hypothesis, the CSI-RS port indices of the first CMR and the CSI-RS port indices of the second CMR are associated with the rank combination reported for the first and second CMRs respectively.*
  + *FFS whether/how the UE is configured with high layer parameter non-PMI-PortIndication*
* *Alt 2:* *Non-PMI CSI reporting with reportQuantity set to "CRI-RI-CQI" is not supported in Rel-17.*

|  |  |
| --- | --- |
| Company | Comments |
| Mod | Starting from previous agreement in RAN1 106 to study possible support of non-PMI CSI reporting in Rel-17, I am striving to provide slightly more details of specification impact, starting from a design raised by proponents, as simple as possible.  Instead of going too far with more complicated design with “non-PMI-PortIndication”, I would suggest to start from the simple one firstly. Hopefully companies can be more open for non-PMI reporting with less concerns about Rel-17 time and complexity of RAN1 design. |
| vivo | We support non-PMI CSI reporting for NCJT measurement hypothesis in Rel-17, if a simple solution is designed.  In our opinion, how to indicate selected ports for shared CMR between NCJT and STRP should be studied and clarified. When CMR sharing is enabled, which means that a CMR is used for both STRP hypothesis and NCJT hypothesis, the selected ports/ranks for STRP hypothesis may be different from those for NCJT hypothesis due to different interference assumptions between two hypotheses.  Therefore, we update the Proposal as follows.  ***Proposal 21:*** *For CSI measurement associated to a reporting setting CSI-ReportConfig for measurement hypothesis, down-select one alternative from the following:*   * *Alt 1:* *Non-PMI CSI reporting with reportQuantity set to "CRI-RI-CQI" is supported in Rel-17.*   + *If the UE is not configured with higher layer parameter non-PMI-PortIndication, for two CMRs configured in a CMR pair as an NCJT measurement hypothesis, the CSI-RS port indices of the first CMR and the CSI-RS port indices of the second CMR are associated with the rank combination reported for the first and second CMRs respectively.*   + *FFS whether/how the UE is configured with high layer parameter non-PMI-PortIndication*   + *FFS: Port indication when CMR sharing is enabled.* * *Alt 2:* *Non-PMI CSI reporting with reportQuantity set to "CRI-RI-CQI" is not supported in Rel-17.* |
| Samsung | We support Alt1. |
| QC | We did not see any performance evaluation from supporting companies to justify this proposal. Support Alt2. |
| Nokia/NSB | Support Alt 1.  As argued in our tdoc, we think ‘cri-RI-CQI’ reporting for MTRP CSI reporting can be supported with minimal specification impact.  We also support ‘non-PMI-PortIndication’ with a single port indication list for single-TRP and NCJT hypotheses and the reuse of Rel-16 related UE capabilities, 22-11 (cri-RI-CQI-WithoutNon-PMI-PortInd-r16) and 2-38 (csi-ReportWithoutPMI) to indicate support of non-PMI reporting with or without port indication.  The use case for ‘cri-RI-CQI’ reporting quantity is when the gNB can achieve enough spatial separation between the CSI-RS ports, for example by calculating the precoders from SRS measurement. Amongst the advantages of this report quantity are the lower feedback overhead and reduced UE’s complexity, as the PMI calculation is avoided at the UE side. |
| InterDigital | Support Alt1, this can be beneficial for TDD case to reduce PMI calculation complexity. |

## CSI Reporting Enhancements for Multi-TRP

**In RAN1#106-e, how to support RI restriction for a CSI report associated with a Multi-TRP/panel NCJT measurement hypothesis configured by single CSI reporting setting has been discussed. The following six alternatives are agreed for down-selecting at most one in RAN1#106bis-e:**

* **Alt 1: One RI restriction is configured per *CodebookConfig*, whereas the RI restriction is applied to both Single-TRP and NCJT measurement hypotheses.** 
  + **If rank restriction of X is configured, reported rank is X for a Single-TRP measurement hypothesis and sum of two reported ranks is X for a Multi-TRP measurement hypothesis.**
* **Alt 2: Two RI restrictions can be configured per *CodebookConfig*, whereas one RI restriction is applied to one CMR group in a CMR resource set respectively, i.e. per TRP.** 
  + **If rank restriction of (X, Y) is configured, reported rank is X for the CMR in the first CMR group and Y for the CMR in the second CMR group, regardless single-TRP and NCJT measurement hypotheses.**
* **Alt 3: Multiple RI restrictions can be configured per *CodebookConfig*, whereas RI restriction is applied to per each CMR in CMR pair for NCJT and per each CMR for Single-TRP.**
* **Alt 4: Two RI restrictions can be configured per CodebookConfig, whereas one RI restriction is applied to all Single-TRP measurement hypotheses, and another one is applied to all NCJT measurement hypotheses.** 
  + **If rank restriction of (X, Y) is configured, reported rank is X for all single-TRP measurement hypotheses and reported rank (1 out of 4 possible rank combinations) is Y for all NCJT measurement hypotheses.**
* **Alt 5: Three RI restrictions can be configured per *CodebookConfig*, whereas two RI restrictions are applied to two CMR groups in a CMR resource set respectively for Single-TRP measurement hypothesis, and the third one is applied to all NCJT measurement hypotheses.** 
  + **If rank restriction of (X1, X2, Y) is configured, reported rank is X1, X2 for each CMR group respectively for single-TRP measurement hypotheses and reported rank (1 out of 4 possible rank combinations) is Y for all NCJT measurement hypotheses.**
* **Alt 6: Switch between Alt 4 and Alt 5 where gNB can configure via RRC signaling which alternative to use**

**Note that if none of above Alternatives is agreed in Rel-17, RI restriction is only applied for Single-TRP measurement hypotheses and no RI restriction is applied for Multi-TRP measurement hypotheses.**

Companies’ view is summarized as following:

|  |  |
| --- | --- |
| **Views** | **Companies** |
| **Alt 1 (7)** | OPPO, CMCC, Fraunhofer IIS, Fraunhofer HHI, Docomo, Lenovo, Motorola Mobility |
| **Alt 2 (1)** | MediaTek |
| **Alt 3 (1)** | LGE, |
| **Alt 4 (8)** | InterDigital (2nd preference), Spreadtrum, CATT, Qualcomm, Lenovo, Motorola Mobility(2nd preference), Huawei, HiSilicon |
| **Alt 5 (5)** | Vivo, NEC, CATT, Nokia, Nokia Shanghai Bell |
| **Alt 6 (1)** | Vivo |
| **None of above alts (3)** | InterDigital (1st preference), ZTE, Samsung |

Companies preferring Alt 1 have the following considerations:

* OPPO proposes that the same RI restriction for S-TRP and NC-JT is the simplest solution and the same maximal rank for S-TRP and NC-JT is beneficial for UE implementation.
* CMCC proposes that one RI restriction is already enough and with a high RI restriction, the network is still able to configure proper RI for Single-TRP or NC-JT transmission anyway even if only one RI restriction can be configured.
* Fraunhofer IIS, Fraunhofer HHI, Lenovo, and Motorola Mobility propose that a RI restriction for S-TRP and NC-JT is simple.
* DoCoMo proposes that in NCJT transmission, it is highly possible that two TRPs have the same configuration and support the same max number of DL transmission layers for UEs with single-TRP transmission. Hence, there is no need to configure different RI restrictions for single-TRP measurement for different TRPs.

Companies preferring Alt 2 have the following considerations:

* MediaTek proposes joint RI restriction is unnecessary.

Companies preferring Alt 3 have the following considerations:

* LGE proposes that Alt 3 can be the most flexible configuration method for RI restriction.

Companies preferring Alt 4 have the following considerations:

* Huawei and HiSilicon propose that two RI restrictions should be configured where one is for NCJT measurement hypothesis and the other is for Single-TRP measurement hypothesis, since the candidates of RI restriction for different measurement hypothesis are different and hence to use two different RI restrictions is more straightforward.
* Spreadtrum proposes that for Rel-17 CSI enhancement, one RI restriction is enough for all single TRP measurement hypotheses. Considering two TRPs are involved for NCJT measurement hypotheses and should be considered together, it is preferred to configure another RI restriction for NCJT measurement hypotheses.
* Qualcomm proposes that in Alt4, RI restriction is based on CSI report type and also does not change Rel-15 behavior for sTRP CSI reporting.

Companies preferring Alt 5 have the following considerations:

* Vivo proposes that since different report configurations across TRPs should be considered at least for cases like TRPs in heterogeneous deployment, TRP-specific RI restriction should be considered from the perspective of flexibility.
* NEC and CATT propose that for single TRP hypothesis, precoders and ranks can be different for different TRPs, and for NCJT hypothesis, it’s typical that precoders and ranks are different from single TRP hypothesis. Alt5 can achieve the flexibility and UE complexity reduction.
* Nokia proposes that Alt5 is the combination of Alt 2 and 4 and provides maximum configuration flexibility.

Company preferring Alt 6 have the following considerations:

* Vivo proposes that switching between Alt 4 and Alt 5 can be realized by configuring one or two RI restriction for STRP hypothesis besides the RI restriction for NCJT hypothesis.

Companies preferring **no RI restriction have the following considerations:**

* InterDigital and ZTE proposes that it has been agreed that the RI combinations are indicated by a joint RI field for a NCJT measurement hypothesis with a limited set of layer pairs that allow a maximum of 2 layers per TRP.
* Samsung points out two purposes of RI restriction are to limit a cell-edge UE to report the low rank and to give the gNB flexibility in terms of managing the transmission layers in MU-MIMO scenario. Considering the possible rank pairs for NCJT are already for low ranks per each TRP and owing to the common understanding that simultaneous occurrence of NCJT and MU-MIMO operations is not supported, Samsung prefer to configure RI restriction only for sTRP measurement hypotheses.

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

***Proposal 22-1: For a CSI report associated with a Multi-TRP/panel NCJT measurement hypothesis configured by single CSI reporting setting, support configuring RI restriction for Multi-TRP measurement hypothesis.***

* *FFS detailed solution in RAN1 106bis.*

|  |  |
| --- | --- |
| Company | Comments |
| Mod | Starting from previous agreement in RAN1 106 with listed Alternatives, the target is to make a decision this way or another this meeting, due to potential RAN2 impact, e.g. if we need a related RRC parameter.  **Therefore, i**n my understanding unless X-6-1 can be confirmed firstly, there is no need to discuss detailed preference of Proposal X-6-2 yet. |
| Lenovo/Mot | Support |
| vivo | Support |
| QC | Support |
| Nokia/NSB | Support |
| Futurewei | Support |
| InterDigital | We can support FL’s proposal as second preference. |

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

***Proposal 22-2: For a CSI report associated with a Multi-TRP/panel NCJT measurement hypothesis configured by single CSI reporting setting, down-select one alternative from the following:***

* ***Alt 1: One RI restriction is configured per CodebookConfig, whereas the RI restriction is applied to both Single-TRP and NCJT measurement hypotheses.*** 
  + ***If rank restriction of X is configured, reported rank is X for a Single-TRP measurement hypothesis and sum of two reported ranks is X for a Multi-TRP measurement hypothesis.***
* ***Alt 2: Two RI restrictions can be configured per CodebookConfig, whereas one RI restriction is applied to one CMR group in a CMR resource set respectively, i.e. per TRP.*** 
  + ***If rank restriction of (X, Y) is configured, reported rank is X for the CMR in the first CMR group and Y for the CMR in the second CMR group, regardless single-TRP and NCJT measurement hypotheses.***
* ***Alt 3: Multiple RI restrictions can be configured per CodebookConfig, whereas RI restriction is applied to per each CMR in CMR pair for NCJT and per each CMR for Single-TRP.***
* ***Alt 4: Two RI restrictions can be configured per CodebookConfig, whereas one RI restriction is applied to all Single-TRP measurement hypotheses, and another one is applied to all NCJT measurement hypotheses.*** 
  + ***If rank restriction of (X, Y) is configured, reported rank is X for all single-TRP measurement hypotheses and reported rank (1 out of 4 possible rank combinations) is Y for all NCJT measurement hypotheses.***
* ***Alt 5: Three RI restrictions can be configured per CodebookConfig, whereas two RI restrictions are applied to two CMR groups in a CMR resource set respectively for Single-TRP measurement hypothesis, and the third one is applied to all NCJT measurement hypotheses.*** 
  + ***If rank restriction of (X1, X2, Y) is configured, reported rank is X1, X2 for each CMR group respectively for single-TRP measurement hypotheses and reported rank (1 out of 4 possible rank combinations) is Y for all NCJT measurement hypotheses.***
* ***Alt 6: Switch between Alt 4 and Alt 5 where gNB can configure via RRC signaling which alternative to use***

|  |  |
| --- | --- |
| Company | Comments |
| Mod | This table is mainly to collect more views of preference, in case that your views are not included or I may miss something.  In my understanding unless X-6-1 can be confirmed firstly, there is no need to discuss detailed preference of Proposal X-6-2 yet. |
| Lenovo/Mot | Our suggestion is to omit alternatives with a single company support, i.e., limit to Alt1, Alt4, Alt 5 for a more constructive discussion. We support either Alt1 or Alt4 |
| vivo | Support Alt 5 or Alt 6. In our opinion, different report configurations across TRPs should be considered at least for cases like TRPs in heterogeneous deployment. Therefore, we think TRP-specific RI restriction should be considered from the perspective of flexibility. |
| QC | Support Alt4.  We do not think sTRP RI restriction needs a change compared to Rel-15. |
| Nokia/NSB | If we agree P22-1, we suggest agreeing the NCJT RI restriction filed of 4 bits applies to each of the four possible NCJT rank combinations, for all alternatives.  If the sum of two reported ranks is used instead, as in Alt 1, what is the consequence for NCJT RI restriction of setting the rank restriction field to 0001, i.e. only rank 1 is allowed for single-TRP RI? It seems no NCJT transmission is allowed |
| Futurewei | Support FL’s proposal and we prefer Alt 4. |
| InterDigital | Support Alt4 as a second preference. sTRP doesn’t need to be changed, and we don’t see the need to have multiple restrictions for the different pairs. |

**In addition, five companies provide their views on CBSR for a CSI report associated with a Multi-TRP/panel NCJT measurement hypothesis configured by single CSI reporting setting. Based on their views, two main alternatives for two CBSRs for a CSI report associated with a NCJT measurement hypothesis can be summarized:**

* **Alt 1: per TRP or per CMR group**
* **Alt 2: per measurement hypothesis type**

|  |  |
| --- | --- |
| **Views** | **Companies** |
| **Alt 1 (4)** | Vivo, Fraunhofer IIS, Fraunhofer HHI, DoCoMo, |
| **Alt 2 (1)** | NEC |

Companies preferring Alt 1 have the following considerations:

* Vivo proposes that since different report configurations across TRPs should be considered at least for cases like TRPs in heterogeneous deployment, TRP-specific RI restriction should be considered for better flexibility.
* Fraunhofer IIS and Fraunhofer HHI proposes that as the channel conditions for the UE-TRP links can be different for two TRPs, there should be one CBSR configuration per TRP.
* DoCoMo proposes that considering that beam conditions from two TRPs are different, separate CBSR configurations for each TRP can be supported with each CBSR configuration applied to a CMR group.

On the other hand, NEC preferring Alt 2. For single TRP hypothesis, precoders and ranks can be different for different TRPs. For NCJT hypothesis, it’s typical that precoders and ranks are different from single TRP hypothesis.

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

***Proposal 23-1:*** *For a CSI report associated with a Multi-TRP/panel NCJT measurement hypothesis configured by single CSI reporting setting,*

* *Alt 1: CBSR is supported.*
* *Alt 2: CBSR is only applied for single-TRP measurement hypotheses and CBSR for Multi-TRP measurement hypotheses is not needed/applied.*

***Proposal 23-2:******For a CSI report associated with a Multi-TRP/panel NCJT measurement hypothesis configured by single CSI reporting setting, down-select one alternative from the following:***

* ***Alt 1: Two CBSRs can be configured per CodebookConfig, whereas one CBSR is applied to one CMR group in a CMR resource set respectively, i.e. per TRP.***
* ***Alt 2: Two CBSRs can be configured per CodebookConfig, whereas one CBSR is applied to all Single-TRP measurement hypotheses, and another one is applied to all NCJT measurement hypotheses.***

|  |  |
| --- | --- |
| Company | Comments |
| Mod | There are a few companies proposing to support CBSR. Therefore it may be worth considering whether it is needed in Rel-17, due to potential RAN2 impact, e.g. if we need a related RRC parameter.  **Therefore, i**n my understanding unless 23-1 can be confirmed firstly, similar with handling RI restriction, there is no need to discuss detailed preference of Proposal 23-2 yet. |
| Lenovo/Mot | Support Alt1. CBSR is needed to avoid interference from “each TRP” on other UEs. Restriction should be TRP specific, i.e., per CMR group |
| vivo | Support Alt1. |
| QC | Proposal 23-1: We think a more natural choice is  Alt3: CBSR configuration is same as legacy: Once CBSR configuration is applied to a PMI for sTRP hypotheses, and to each PMI of a pair of PMI for NCJT hypotheses. |
| Nokia/NSB | We don’t think CBSR is needed. The network has already the flexibility to configure resources that minimise interference and it can do so separately for single-TRP and NCJT hypotheses. |
| InterDigital | For Proposal 23-1, support Alt1.  For Proposal 23-2, support Alt1. |

## CSI Processing Criteria

For the order of UCI payload construction for reported CSIs, the following alternatives are agreed in last meeting:

* **Alt 1: modify priority equation, i.e., Section 5.2.5 in 38.214.**
* **Alt 2: modify the table of priority reporting levels for Part 2 CSI, i.e., Table 5.2.3-1 in 38.214.**
* **Alt 4: modify mapping order of CSI fields of one CSI report, i.e., Table 6.3.2.1.2-3/4/5 in 38.212**

For Rel-17 NCJT CSI enhancement related to CSI processing, companies’ views are summarized as following:

|  |  |
| --- | --- |
| **Views** | **Companies** |
| **Alt 1 (7)** | InterDigital, Samsung, MediaTek, DoCoMo, Lenovo, Motorola Mobility, Qualcomm |
| **Alt 2 (4)** | ZTE, CMCC, LGE, Ericsson, Nokia, Nokia Shanghai Bell |
| **Alt 4 (6)** | ZTE, CMCC, DoCoMo, Ericsson |

Companies preferring Alt 1 have the following considerations:

* **InterDigital proposes that to enable the UE determine the payload to include based on the hypothesis with the lowest priority, each measurement hypothesis should been assigned a priority level. It is more straightforward to accomplish this using a modified priority equation.**
* **Samsung proposes that** since the UCI payloads for NCJT and sTRP CSI reports are different, it is preferable if the CSI for NCJT and sTRP are reported separately as distinct reports.
* **MediaTek, DoCoMo, Lenovo, Motorola Mobility, and DoCoMo propose that** each CSI measurement hypothesis is mapped to a distinct CSI report to achieve finer granularity for CSI omission and minimum specification impact.
* Qualcomm proposes that Alt1 does not require to add separate tables (Table 6.3.2.1.2-3/4/5) for each of X=1 and X=2 in Option 1 and can also address the issues of CSI omission for CSI part 2 as well as CPU occupation in a consistent and unified way.

Companies preferring Alt 2 have the following considerations:

* **ZTE, CMCC and LG propose that** the CSI omission priority table, i.e., Table 5.2.3-1 in TS38.214, should be modified, otherwise such rough granularity, i.e. grouping X+1 sets CSI in the single CSI report, may jeopardize the MTRP CSI report.

Companies preferring Alt 4 have the following considerations:

* **ZTE, CMCC, DoCoMo and Nokia propose that in Rel-17 UE needs to report X+1 sets of CSI part 1 and X+1 sets of CSI part 2 in a single CSI report. The mapping order of CSI fields, i.e., Table 6.3.2.1.2-3/4/5 in TS38.212 should be specified accordingly.**

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

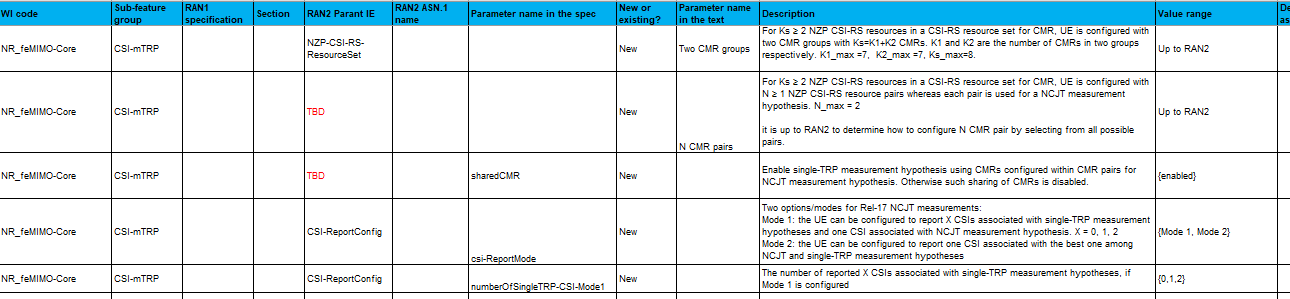
***Proposal 24: To confirm the order of UCI payload construction for reported CSIs, down-select one or more alternatives from the following:***

* ***Alt 1: modify priority equation, i.e., Section 5.2.5 in 38.214.***
  + ***i.e. introducing priority index corresponding to single-TRP or NCJT measurement hypothesis type***
* ***Alt 2: modify the table of priority reporting levels for Part 2 CSI, i.e., Table 5.2.3-1 in 38.214.***
  + ***i.e. introducing different priority levels corresponding to single-TRP or NCJT measurement hypothesis type for Part 2 CSI within a subband CSI***
* ***Alt 4: modify mapping order of CSI fields of one CSI report, i.e., Table 6.3.2.1.2-3/4/5 in 38.212***
  + ***i.e. introducing mapping order of CSI fields in the order of MTRP CSI, the first TRP CSI, and the second TRP CSI***
* ***Note that details are up to 38.212 and 38.214 editors.***

|  |  |
| --- | --- |
| Company | Comments |
| Mod | Starting from previous agreement in RAN1 106, I am striving to provide slightly more details of specification impact, for each Alt, at high level, which can be polished further.  However it is up to RAN1 to debate which one(s) is preferred and sufficient enough to address the order of UCI payload construction. Looking at companies arguments, it seems to me that there are still some thoughts beyond that. |
| Lenovo/Mot | Support Alt1. In our understanding, the implicit question here is whether to (Alt1) map one hypothesis to a CSI report, i.e., X+1 reports for Option 1 reporting, or (Alt2) map one *CSI-ReportConfig* to one CSI report, e.g., for Option 1 X=2, one CSI report would contain 4 PMI, 4 RI, 3 CQI, which would significantly complicate the T**able 6.3.2.1.2-3/4/5 in TS38.212, and would require new CSI omission rules with >2 parts, or >3 groups per part, which would also require significant work** |
| vivo | We think it is more important to discuss the following viewpoints firstly.   * Viewpoint1: One CSI reporting setting contains multiple CSI reports, each CSI report corresponding to a hypothesis. * Viewpoint2: One CSI reporting setting corresponds to one CSI report that contains all measurement results of all hypotheses.   If Viewpoint1 is agreed, it implies that the priority rule decides the mapping order among multiple measurement hypotheses. Modify the priority equation in Section 5.2.5 in 38.214 is needed because the current equation cannot distinguish the priority of the measurement hypothesis. However, the equation may also invoke elsewhere in current specification such as CPU occupation, UE procedure for transmitting multiple CSI reports on PUCCHs in a slot, and so on.  Viewpoint1 is at the risk of invoking other places in the spec. Therefore, we support Viewpoint2 that a CSI reporting setting configured with enhanced MTRP CSI reporting corresponds to a CSI report.  **In our view, Alt.1 and Alt.4 have similar specification work.** For ***Table 6.3.2.1.2-3/4/5 in 38.212*, if taking Alt.1, i.e., Viewpoint1, adding a table for NCJT CSI is unavoidable. While employing Alt.4, i.e., Viewpoint2 also needs to update the table.**  **For *Table 5.2.3-1 in 38.214*, the legacy omission rule can be reused and it still works, if we do not want to support an enhanced omission rule for smaller granularity. Or the table can be updated to support omission with finer granularity, but without any change on the priority equation.** |
| Samsung | We support Alt 1 and Alt 4. |
| QC | Support Alt1. With Alt1, both functionalities of Alt2 and Alt4 is achieved w/o further spec change.  Alt2 and Alt4 will lead to significant spec impact and a lot of discussions about the construction of theses new tables. |
| Nokia/NSB | Support Alt 2.  For an M-TRP CSI report n, assign reporting priority level 0 to all WB PMIs, priority 2n-1 to all even SB PMIs and priority level 2n to all odd SB PMIs. The mapping order of the PMIs in each priority level is the same as the order used in Part 1. Note that with this solution the order of CSIs does not impact the omission rules.  T**able 6.3.2.1.2-3/4/5 of 212 still apply to each CSI in the report with no change.**  No need to modify the priority equation to assign a different priority to each CSI in the report. |
| InterDigital | Support Alt1, we agree with QC’s comments. |

## Discussion related to RRC parameters

The draft version on RRC parameters related to CSI enhancement for Multi-TRP in Rel-17 is shown as following:



Two companies (Samsung and Nokia) provide views over RRC parameters for mTRP CSI enhancement. To have more flexible CSI framework for NCJT measurement, Samsung prefers to configure the CMR pairs for NCJT measurement hypothesis and the CMR sharing in *CSI-ReportConfig*. Moreover Nokia prefer to configure all 3 CMR-related parameters, i.e., N CMR pairs, Two CMR groups, and sharedCMR within the same IE.

***Proposal 25:*** *Parent IE of RRC parameters configuring “N CMR pairs”, “Two CMR groups” and RRC parameter “sharedCMR” is*

* ***Alt 1:*** *CSI-ReportConfig*
* ***Alt 2:*** *NZP-CSI-RS-ResourceSet*

|  |  |
| --- | --- |
| Company | Comments |
| Mod | Parent IE may have different specification impact, and of cause flexibility and restrictions, in my understanding. Therefore let us have some discussion to see whether there are any different views. |
| Lenovo/Mot | Support Alt1 |
| vivo | Support Alt2.  In our opinion, CMR-related parameters should be configured in the CSI-RS resource set and the reporting-related parameters should be configured in the reporting setting. If “SharingCMR” and “N CMR pairs” are under CSI-ReportConfig, it means that all CSI-RS resource sets associated with the CSI report have the same “SharingCMR” and “N CMR pairs”, which have some risks. For example, for aperiodic CSI resource setting where the number of CSI-RS resource sets configured is not limited to S=1, configuring “SharingCMR” and “N CMR pairs” in CSI-ReportConfig means that multiple CSI-RS resource sets are configured with same configurations of “SharingCMR” and “N CMR pairs”, which has lower flexibility.  Regarding the comments that a NZP-CSI-RS-ResourceSet can be referred by two CSI-ReportConfigs with different CMR pair configurations, we think a NZP-CSI-RS-Resource can be referred by two CSI-ResourceConfigs with different CMR pairs configurations, which is allowed and flexible enough in the current specification. |
| Samsung | We support Alt1 |
| QC | Support Alt1 |
| Nokia/NSB | Slight preference for Alt 1  It’s more flexible to assign these parameters to a higher level IE, such as *CSI-ReportConfig*, rather than a lower level IE, so the same Resource Setting can be reused in different MTRP CSI Reporting Setting, e.g. for different NCJT pairing |
| Futurewei | Support FL’s proposal and we prefer Alt 1. |
| InterDigital | Support Alt1. |

In case that there may have more comments for RRC parameters of Rel-17 NCJT measurement enhancements, following table is added for additional comments, if any.

|  |  |
| --- | --- |
| Company | Comments |
| Mod | This table is to address additional comments, if any, for text updating or ambiguity. |
|  |  |

## 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** |
| RI/PMI sharing between sTRP and NCJT CSI | InterDigital | Support sharing of RI/PMI for sTRP and NCJT CSI. The sharing can be RRC configured on/off. |
| CATT | RI/PMI sharing between single-TRP and NCJT measurement hypotheses can be supported for Option 1 with X={1, 2}. RI/PMI sharing can be enabled or disabled by the gNB. |
| Samsung | * 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. |
| Intel | 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 |
| CSI enhancement for other scenarios | Spreadtrum | * For CSI enhancement on M-TRP operation, M-DCI based M-TRP operation should also be supported. * Support option 2, i.e., for a CSI report associated with a Multi-TRP/panel NCJT measurement hypothesis configured by single CSI reporting setting, the UE is expected to report two Ris, two PMIs, two Lis and two CQIs. |
| Vivo | Support to confirm the work assumption in RAN1#103-e, i.e., Option1.   * Support to specify rules on how to divide and map the generated UCI into two associated reports in Cat2. * “SharingCMR” and “N CMR pairs” should be configured in NZP-CSI-RS-ResourceSet. |
| CATT | Option 1, i.e, to confirm the work assumption in RAN1#103-e is slightly preferred for CSI enhancement on M-TRP operation. |
| Docomo | For a CSI report associated with a Multi-TRP/panel NCJT measurement hypothesis configured by single CSI reporting setting for single-DCI based NCJT, support CSI enhancement for URLLC schemes and HST-SFN scheme. |
| Wideband CSI report for M-TRP | Vivo | Support to enhance the CSI reporting mechanism when PMI and CQI granularity are wideband. |
| Enhancement on CPU Occupation rule | Nokia, Nokia Shanghai Bell | Support the following additional “soft” formula for CSI updates at the end of the first paragraph of Sec 5.2.1.6 in 38.214. |
| Qualcomm | The CSI priority corresponding to single-TRP CSI(s) and NCJT CSI is for CPU occupation priority. |
| Samsung | Design new CPU occupation rule for dynamic NC-JT CSI report |
| The number of CSI-IM resources in one set | OPPO | The number of CSI-IM resources depends on whether CMR sharing between S-TRP and NC-JT measurement hypotheses is enabled.   * If CMR sharing between NC-JT and S-TRP measurement is enabled, M=Ks CSI-IM resources with one-to-one mapping with M CMRSs for S-TRP, and N CSI-IM resources with one-to-one mapping with N CMR pairs for NC-JT can be configured. * If CMR sharing between NC-JT and S-TRP measurement is not enabled, M=Ks-2N CSI-IM resources with one-to-one mapping with M CMRs for S-TRP, and N CSI-IM resources with one-to-one mapping with N CMR pairs for NC-JT can be configured. |
| Vivo | For the number of CSI-IM resources in one set   * *M* is equal to *Ks* when the CMR sharing is enabled. * *M* is equal to *Ks* – 2*N* when the CMR sharing is disabled. |
| The default value of Ks,max | Spreadtrum | *Ks,max* =4 shall be not supported |
| Vivo | *Ks,max* =2 with Rel-17 MIMO UE capability for MTRP CSI measurement |
| Ericsson | *Ks,max* =4 for both FR1 and FR2 |

|  |  |
| --- | --- |
| Company | Comments |
| Samsung | We encourage companies to consider PMI/RI sharing among NCJT and sTRP measurement hypotheses. The advantage in terms of CSI overhead reduction is clear. |
| QC | Do we also need a rule for “the first RI/PMI/LI”? Which one is first, which one is second? |
| Nokia/NSB | Regarding CPU overbooking, we support improved handling of CPU calculations for MTRP CSI reports with multiple CSIs without impacting the rules for legacy CSI reports.  The following TP can be added at the end of the first paragraph of Sec 5.2.1.6 in 38.214:  *If CSI report is an MTRP CSI report configured with Mode 1 and or , where CSI corresponds to , and CPUs are unoccupied, the UE is expected to update the first CSIs and is not required to update the last CSIs, according to their UCI mapping order, where is the largest value such that holds.* |

# Proposals for Online/Offline Discussion

TBD

# Work Plan

TBD

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22. 3GPP R1-2110291, CSI enhancements for Multi-TRP and FR1 FDD reciprocity, Ericsson, RAN1#106bis-e, October 11th – 19th, 2021.

# Appendix

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

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

|  |  |
| --- | --- |
|  |  |
| **ZTE** | ***Proposal 8:*** *Support polarization-common W1 for all the ranks (up to rank 4) and CSI-RS ports in Rel-17 PS codebook.*  ***Proposal 9:*** *Refine the definition of K1 as to ensure K1 are even integers.*  ***Proposal 10:*** *On Wf in Rel-17 PS codebook*   * *Support the following (N, Mv) values*   + *N = {2, 4} for Mv=2*   + *N=1 for Mv=1* * *For N>Mv, use bits to report Wf.* * *For rank 3-4, use the same design of length-N window for UE reporting as rank 1/2. The supported values of Mv and N are same as rank 1/2.* * *Support R from the set {1, }.*   ***Proposal 11:*** *For Wf off vs Mv=1*   * *Support Alt 2: Wf OFF and Wf ON with Mv=1 are same, and Wf is an all-one vector of length 1, i.e., a scalar. Wf as an all-one vector of length N3 is not needed.*   + *Use PMI format to configure Wf off or Wf on with Mv=2. If PMI format is configured as WB, Wf is off; otherwise Wf is on with Mv=2.* * *Alt 3 can be supported if Alt 2 is not supported.*   ***Proposal 12:*** *Support UE reporting the total number of non-zero coefficients in CSI Part 1.*   * *The bitmap for indicating non-zero coefficients in W2 can be absent when Beta = 1 and the total number of NZ coefficients reported in Part 1 equals to Rank\*K1\*Mv.*   ***Proposal 13:*** *On Rank 3 and 4 for Rel-17 PS codebook, use a smaller beta value for Rank 3 and 4 compared with beta value configured for Rank 1 and 2, e.g., .* |
| **Spreadtrum** | ***Proposal 9: Regarding the reporting of Wf when Mv=2, FD basis 0 is selected but not reported, another FD basis is selected freely with reporting bit width of .***  ***Proposal 10: FD basis remapping is not specified in Rel-17.***  ***Proposal 11: For NZC reporting without bitmap, Alt 1 is our first preference, and Alt 2 is our second preference.***  ***Proposal 12: For Rel-17 PS codebook***  ***• Wf OFF and Wf ON with Mv=1 are same, and Wf is an all-one vector of length N3***  ***~~• Support pmiReportingFormat = WB [if N3=1]~~***  ***~~• FFS: the case when no SB size is configured (from RAN1#105-e agreement)~~*** |
| **vivo** | **Proposal 14:**  *UE reports the combinatorial coefficients of non-selected beams when the number of selected beams is larger than half of the number of candidate beams.*  **Proposal 15:**  *Always keep the bitmap for indicating non-zero coefficients for W2 for CSI reporting.*  **Proposal 16:**  *The FD bases in the window can be consecutive or non-consecutive when the number of CSI-RS ports is less than 8.*  *The actually used N should be min{N, N3} for the case of small N3.*  **Proposal 17:**  *Support N = 4.*  *Wf can be reported with a 2-bit or 3-bit combinatorial coefficient.*  **Proposal 18:**  *Slightly prefer R =* ***D\* NPRBSB for Mv > 1.***  **Proposal 19:**  *The minimum of alpha increases with decreasing number of CSI-RS ports and the maximum of beta decreases with increasing number of CSI-RS ports.*  **Proposal 20:**  *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.* |
| **OPPO** | **Proposal 1:**  *Support , ,, for Rel-17 codebook.*  **Proposal 2:**  *For Rel-17 PS N> Mv=2:*   * *N=3 is slightly preferred.* * *UE report non-zero FD basis with log(N-1) bits.*   **Proposal 3:**  *Reuse Rel-16 number of NZC for rank 3/4, i.e., and* |
| **CATT** | **Proposal-1:**   * *R D\*NPRBSB} should be supported in addition to R=1 when , where D and NPRBSB respectively denote the density of CSI-RS in frequency domain and the number of PRB in a CQI subband.* * *R is configured as D\*NPRBSB if , where denotes the number of CQI subbands. Otherwise, R=1. can be FFS.*   **Proposal-2:**   * *When = 1, the length N3 is predefined as 1.* * *pmi-FormatIndicator is used to indicate whether PMI is wideband for Rel-17 port selection codebook when Wf is turned OFF.*   **Proposal-3:**   * *N=5 is supported in addition to N=2.* * *The first FD basis is always selected and the other FD basis is indicated through bits if N> .*   **Proposal-4:**  *Existence of the bitmap depends on the reported number of non-zero coefficients and additional indication information if rank>1, i.e., Alt3.*  **Proposal-5:**  *Port selection is layer-common for rank 3 or 4.*  **Proposal-6:**  *is layer-common for rank 3 or 4 and selected from the configured FD basis with window size N if N>.*  **Proposal-7:**  *The indication of non-zero coefficients for rank 3 or 4 should be layer-specific.*  **Proposal-8:**   * *The following parameter combinations can be considered for Rel-17 port selection codebook when*  |  |  |  | | --- | --- | --- | |  |  |  | | ***1*** | ***1/2*** | ***1*** | | ***1*** | ***3/4*** | | ***1*** | ***1*** | | ***Note:***   * ***is selected as the largest value in {2, 4, 8, 12, 16, 24, 32} and.*** * ***P=2 is not supported when.*** | | |  * *When, the maximum number of non-zero coefficients per layer and across all layers are respectively limited to and 2 for rank 2, 3 and 4, where.*   **Proposal-9:**   * *The following parameter combinations can be considered for Rel-17 port selection codebook when.*  |  |  |  | | --- | --- | --- | |  |  |  | | ***2*** | ***1*** | ***1/2*** | | ***2*** | ***3/4*** | | ***2*** | ***1*** | | ***Note: the following combinations is not supported***   * ***P,1, .*** * ***P32, 1,*** * ***P=2 is not supported when*** | | |  * *When, the maximum number of non-zero coefficients per layer and across all layers are respectively limited to and 2 for rank 2, 3 and 4, where.*   **Proposal-10:**  *The CSI report comprises of Part 1 and Part 2 for of Rel-17 port selection codebook as shown in the table.*   |  |  |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | --- | --- | | ***Two parts of CSI reporting*** | ***The content of each part*** | | | | | | | | ***Part 1*** | ***RI*** | ***CQI*** | ***the overall number of NZC across layers*** | | | | | | ***Part 2*** | ***The indication of port selection*** | ***The indication of the strongest coefficients*** | ***The indication of the selected FD basis*** | ***The reference amplitude*** | ***The indication of NZC*** | ***The amplitude of NZC*** | ***The phase of NZC*** |   **Proposal-11:**   * *Three groups of Part 2 for CSI Omission for Rel-16 Type II port selection codebook is reused for Rel-17 port selection codebook.* * *The priority value = is used to omit CSI for Rel-17 port selection codebook.*   **Proposal-12:**  *Rank restriction is supported forRel-17 port selection codebook.* |
| **Fraunhofer IIS, Fraunhofer HHI** | ***Proposal: Considering feedback overhead, the size of the window can be fixed to the number of delays for ranks 3 and 4, i.e., .***  ***Proposal: Support coefficient ordering such that the coefficients associated with the FD component of the strongest coefficient are placed in group 1.***  ***Proposal: For Rel-17 PS codebook***  **·        *Wf OFF and Wf ON with Mv=1 are same, and Wf is an all-one vector of length N3.***  ***Observation: Due to the high number of selected ports, the precoder coefficients associated with the second polarization are more likely to be dropped in the event of UCI omission when Rel. 16 coefficient ordering is re-used for the Rel. 17 PS CB.***  ***Proposal: Equal priority shall be given to the precoder coefficients of both polarizations.***  ***Proposal: Support grouping of non-zero coefficients into two coefficient subsets, where each coefficient subset comprises the precoder coefficients associated with ports of the first polarization and ports of the second polarization***   * ***Proposal: Coefficient ordering in each coefficient subset follows the coefficient ordering of Rel. 16.*** |
| **Samsung** | ***Proposal 10****: Regarding turning Wf OFF,*   * *Wf OFF and Wf ON with Mv=1 are the same, and Wf is an all-one vector of length N3.* * *pmiReportingFormat = WB* * *support one of the following*   + *Alt1: N3 = 1*   + *Alt2: one of the following is included in the codebook description*     - *Alt2-1: a single precoding matrix is indicated by the PMI*     - *Alt2-2: N3 precoding matrices indicated by the PMI, but they are the same when Mv=1*   ***Proposal 11****: support Rel.17 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 12****: shift/remapping operations are not supported in Rel. 17 codebook.*  ***Proposal 13****: R>1, if supported, is configured only when Mv=2.*  ***Proposal 14****: Regarding Mv = 2,*   * *UE reporting its capability to support Mv = 2 shall also report whether it supports Mv=2 for P > 12 CSI-RS ports*   ***Proposal 15****: when N>Mv=2,*   * *window-size = N3 if the configured N>N3* * *the reported FD indices include FD index 0* * *Support N=3 or 5*   ***Proposal 16****: for bitmap being absent, support Alt 2 (whether bitmap is absent is determined by the UE, e.g., based on value in UCI part 1).*  ***Proposal 17****: For rank 3-4, support*   * *Mv=1 only* * *reuse Rel.16 design: and* * *at least layer-pair-specific : one for layer 1-2 and another for layer 3-4* * *:*    + *layer-specific bitmap, SCI, and amplitude/phase of NZ coefficients*   + *same quantization scheme for all layers*   ***Proposal 18****: Regarding Rel. 17 codebook parameters,*   * *support P from {2,4,8,12,16,24,32}* * *parameter combinations correspond to triples , where*   + .   ***Proposal 19****: for Rel.17 codebook,*   * *Support RI restriction: reuse Rel.16 design* * *simplify Rel.16 UCI omission mechanism and consider the following potential simplifications*   + *no shifting/remapping operations in frequency domain*   + *no FD permutation*   + *no bitmap partition, i.e. bitmap is included in G0 or G1*   *no FD basis indicator for rank 3-4* |
| **MTK** | **Proposal 11:** For and rank 1,2, support the parameter combinations shown in Table 1, i.e., .  **Proposal 12:** For and rank 1,2, support the parameter combinations shown in Table 2, i.e., .  **Proposal 13:** For the Rel-17 codebook extension to rank 3,4, the port selection coefficient should be kept the same as that for rank 1,2.  **Proposal 14:** For the Rel-17 codebook extension to rank 3,4, the compression coefficient should be halved compared to that for rank 1,2.  **Proposal 15:** For Rel-17 PS codebook, need not be supported for rank 3,4.  **Proposal 16:** For the Rel-17 PS codebook, support the 8 parameter combinations in Table 3.  **Proposal 17:** RAN1 should further discuss the applicability of for and 12 CSI-RS ports.  **Proposal 18:** There is no need of specifying for the Rel-17 codebook to increase PMI granularity.  **Proposal 19**: should not be supported for Rel-17 codebook.  **Proposal 20:** is enough for all configurable CSI-RS ports and ranks (including rank 3 and 4).  **Proposal 21:** Support layer common selection of out of FD bases for rank 3 and 4.  **Proposal 22:** To report out of FD bases, the UE only needs to report one among combinations using bits.  **Proposal 23:** For the Rel-17 PS codebook, port selection indicator of bits, SCI of bits, and FD indicator of bits should be made part of UCI Group 0. |
| **Intel** | ***Proposal 1****:*   * *RRC parameter pmi-FormatIndicator is ignored for Rel. 17 codebook*   + *It is assumed that pmi-FormatIndicator is always set to subbandPMI* * *Configuration with BWP size < 24 PRB is not considered for Rel. 17 codebook*   ***Proposal 2****:*   * *For Beta = 1, consider the below solutions with the corresponding priority*   + *Priority 1: Bitmap for coefficient selection is not reported for rank 1 and rank 2*     - *Amplitude and phase for coefficients which are equal to zero are reported by the UE*     - *Change the value corresponding to the last amplitude codepoint to 0*   + *Priority 2: Bitmap is not reported if all coefficients are non-zero (KNZ = K1∙M∙RI)*   ***Proposal 3***:   * *Support N = 4 for the case with M = 2*   ***Proposal 4:***   * *For M = 1 and M = 2, support R = D\*N\_PRB\_SB, where D is the density of CSI-RS in frequency domain, N\_PRB\_SB is the number of PRB in a subband for CQI*   ***Proposal 5***:   * *Consider support the following codebook parameters combinations (alpha, M, beta)*   + *(0.5, 1, 0.5), (0.75, 1, 0.5), (1.0, 1, 0.5)*   + *(0.5, 2, 0.25), (0.75, 2, 0.25), (1.0, 2, 0.25)*   ***Proposal 6****:*   * *Parameters K1, N and M should be the same for rank 1-4* * *Support the following solution to decrease overhead for rank 3-4*   + *Limit the maximum number of non-zero coefficients across all layers to 2∙K0 with the same Beta for rank 1-4*   ***Proposal 7****:*   * *Selection of K1 CSI-RS ports in* ***W****1 is layer-common for rank 1-4* * *Selection of M FD vectors in* ***W****f is layer-common for rank 1-4*   *Selection of K0 coefficients in* ***W****2 is layer-specific for rank 1-4* |
| **NTT DOCOMO** | **Proposal 7**  *Support the bitmap for indication non-zero coefficient can be absent. Either Alt 1 or Alt 2 can be supported.*  **Proposal 8**  *For FD bases for Wf, there is no need to add restrictions on value of N or the number of CSI-RS port.*  *For N > Mv =2, either N=4 or N=5 is supported. And Mv is reported with bit number of .*  **Proposal 9**  *Regarding Wf OFF and Wf ON with Mv=1, support either Alt.1 or Alt.2.*   * + *Alt 1: Wf OFF and Wf ON with Mv=1 are same, and Wf is an all-one vector of length N3. Wf as an all-one vector of length 1 is not needed.*   + *Alt 2: Wf OFF and Wf ON with Mv=1 are same, and Wf is an all-one vector of length 1, i.e., a scalar. Wf as an all-one vector of length N3 is not needed.*   **Proposal 10**  *For rank 3 and 4 for Rel-17 PS codebook, support to limit the maximum number of non-zero coefficients across all layers to 2K0 and per layer to K0 with the same beta.* |
| **Sony** | **Proposal 1. Support proposal 5-1 from RAN1#106-e, but only the first bullet, i.e., “** OFF and ON with are same, and is an all-one vector of length .**” The second and third bullet are not needed and should be dropped. Instead, amend 38.214 to declare *pmi-FormatIndicator* not applicable to Rel-17 PS CB, i.e., “**a UE is not expected to be configured with *pmi-FormatIndicator* if *codebookType* is set to 'typeII-r16' or 'typeII-PortSelection-r16' or 'typeII-PortSelection-r17'**”.**  **Proposal 2. The terminology**  **ON/OFF is not needed for Rel-17 PS CB and can be abandoned.**  **Proposal 3. Free selection of by the UEs, e.g., , or for some , should be supported.**  **Proposal 4. Support Alt 2, “For rank 1/2 PMI, the bitmap(s) of indicating non-zero coefficients for corresponding layer(s) is absent if reported , where is the number of non-zero coefficients.”**  **Proposal 5. 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.** |
| **Nokia, Nokia Shanghai Bell** | **Proposal 1 Extend support for polarisation- and layer-common free port selection also for rank 3 and 4.**  **Proposal 2 Regarding the absence of the bitmap, support Alt 2, *i.e.*, if and a UE reports nonzero coefficients for rank , the bitmap is absent from the CSI report. In all other cases the bitmap is reported.**  **Proposal 3 Extend support of layer-common and layer-common window configuration also to rank 3 and 4.**  **Proposal 4 Regarding the reporting mechanism of for , support specifying the remapping of the two components, with either of the following two alternatives and reporting the nonzero component after remapping, using bits:**   * **Alt 1: remap with respect to the component of lower index, , as , for , or** * **Alt 2: remap with respect to the component of the strongest coefficient for layer 1, , as , for .**   **Proposal 5 Support the value for the window size with 2-bit reporting of the nonzero component of , after remapping.**  **Proposal 6 For the configuration , if the number of PMI subbands is small such that , a UE is expected to select the two FD bases from the unrestricted set . The reporting mechanism is the same as for the case .**  **Proposal 7 On the issue of OFF and ON with , support the following conclusion**   * **OFF and ON with are the same and is the all-1 vector of length .**   **Note: the frequency granularity of Rel-17 PS is wideband if and subband if . For , the precoding matrices indicated by the PMI are the same.**  **Proposal 8 Regarding a possible extension to support Rel-17 CB to BWP<24 PRB, consider this as lower priority. The outcome of the discussion in RedCap WI regarding the extension of the subband definition to BWP<24 PRB should also be considered. If the subband definition is extended to BWP<24 PRB, no further changes are needed to support Rel-17 CB for such small BWPs.**  **Proposal 9 Regarding the values of , support the two values .**  **Proposal 10 For Rel-17 PS, parameter does not need to be rank-dependent and can be replaced by .**  **Proposal 11 Regarding the port selection parameter , in a parameter combination support for and one value for .**  **Proposal 12 For , support parameter combinations with . For , support parameter combinations with .**  **Proposal 13 For Rel-17 PS codebook, support the following parameter combinations**   |  |  |  |  |  | | --- | --- | --- | --- | --- | | *paramCombination-r17* |  | |  |  | |  |  | | 1 | 1 | 1 | 1 | ½ | | 2 | 1 | ½ | 1 | ¾ | | 3 | 1 | 1 | 1 | 1 | | 4 | 1 | 1 | 2 | ½ | | 5 | 1 | ½ | 2 | ½ | | 6 | 1 | ½ | 2 | ¾ | |
| **Lenovo, Motorola Mobility** | 1. Support rank-dependent configuration for the value of *K*1,*v* for Rel. 17 PS codebook 2. For Rank 3,4, support a layer-common, window-based approach to configure the FD basis indices for all layers, where the set of FD basis indices is contiguous, and whose size is higher-layer configured 3. For Rel. 17 PS codebook with Rank 3,4, support the following  * A polarization-specific bitmap is reported for each layer * Reuse the Rank 1 quantization/reporting mechanism for up to Rank 4, with layer-specific non-zero coefficients quantized/reported * A strongest coefficient indicator is reported for each layer, with a feedback mechanism similar to that for Rank 1 design  1. Support Alt1: *Wf* OFF and *Wf* ON with *M*=1 are same, and *Wf* is an all-one vector of length *N*3. *Wf* as an all-one vector of length 1 is not needed 2. 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., *K*1*M* ≤ δ, FFS: value of δ 3. Support *R*=1,2 with R=2 being optionally supported 4. The RAN2 parent IE for each of the RRC parameters corresponding to “Two CMR groups” and “CMR sharing” is set to “CSI-ReportConfig” 5. The field “paramCombination-r17” configures the supported parameter combination values of the parameters (α, *Mv*, *β*, *R*), where *K*1 = *α*.*P* |
| **Apple** | ***Proposal 3 For W2 coefficients reporting for port selection codebook enhancement***   * ***NW can configure the maximum number of reported NZC (non-zero coefficients)*** * ***UE selects and reports the actual number of reported NZC (non-zero coefficients) as long as the number is less than or equal to the maximum number configured by the NW***   ***Proposal 4 For Wf frequency basis reporting for port selection codebook enhancement, UE reports WB (wideband) PMI under either of the following two conditions***   * ***Mv=1*** * ***Wf not configured***   ***Proposal 5 For Wf frequency basis reporting 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*** |
| **LG Electronics** | **Proposal #6: Support Alt 1 for meaning of Wf OFF.**   * **Alt 1: Wf OFF and Wf ON with Mv=1 are same, and Wf is an all-one vector of length N3. Wf as an all-one vector of length 1 is not needed**   **Proposal #7: The bitmap for indicating non-zero coefficients for W2 is always present.**  **Proposal #8: Support R=2 for R value greater than 1 considering trade-off between UE complexity and performance gain.** |
| **QC** | **Proposal 8: For Rel-17 FDD CSI, support following for rank 3 and 4:**   * **Same value of K1 (or alpha) compared to rank 1 and 2, and layer-common port-selection** * **Same value of Mv compared to rank 1 and 2, and layer-common FD basis selection** * **Same value of beta compared to rank 1 and 2, but total number of non-zero coefficients is limited to 2K0. Coefficients selection and quantization are layer-specific.**   **Proposal 9: For Rel-17 FDD CSI, the pre-configured window does not imply any specific UE implementation in PMI calculation.**  **Proposal 10: For Rel-17 FDD CSI, no need to define R in the spec or only support R=1 PMI per CQI subband.**  **Proposal 11: Total number of different combinations should not exceed Rel-16 eType I codebook, and the payload of the combinations should be separated away from each other.**  **Proposal 12: For Rel-17 port-selection type II codebook, support N=3 as additional value for the window size.**  **Proposal 13: For Wf reporting in Rel-17 port-selection Type II codebook, support using bits (which is actually bits since M=2), and each codepoint maps to one FD basis index in increasing order with codepoint ‘0’ mapped to FD basis 1.**  **Proposal 14: For Rel-17 FDD CSI, support UE reporting of actual number of non-zero coefficients, and the bitmap for reporting location of non-zero coefficients always exists.**  **Proposal 15: For Rel-17 FDD CSI, do not support FD permutation in UCI packing and omission, and support mapping coefficients first across port indices, secondly across FD basis indices, and thirdly across layers** |
| **Ericsson** | [**Proposal 1 Support 8 parameter combinations for the Rel-17 Type II codebook, as summarized in Table 1.**](#_Toc84019113)  [**Proposal 2 For rank 3 and 4, the same is used as for rank 2. The total number of non-zero coefficients across all layers are limited to 2, where is the maximum number of non-zero coefficients for each layer.**](#_Toc84019114)  [**Proposal 3 The bitmap for indicating non-zero coefficients is always present.**](#_Toc84019115)  [**Proposal 4 Support for . When , is not reported; when , bits are used for reporting .**](#_Toc84019116)  [**Proposal 5 R is not applicable for Mv=1**](#_Toc84019117)  [**Proposal 6 Our first preference is to only support R=1. Our second preference is to also support R= *D\*NPRBSB***](#_Toc84019118)  [**Proposal 7 Study methods to make CSI omission robust for Rel-17 Type II, e.g., report in Group 0.**](#_Toc84019119)  [**Proposal 8 Discuss whether/how to support CBSR for Rel.17 Type II codebook.**](#_Toc84019120) |

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

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

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| --- | --- |
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| **Huawei, HiSilicon** | ***Proposal 13*: *Two CMRs within the same CMR pair configured for NCJT measurement hypothesis are within the same DL slot.***  ***Proposal 14: For a CSI report associated with a Multi-TRP/panel NCJT measurement hypothesis configured by single CSI reporting setting****,* ***two RI restrictions can be configured per CodebookConfig whereas:***   * ***One RI restriction is applied to all Single-TRP measurement hypotheses*** * ***Another RI restriction is applied to all NCJT measurement hypotheses.***   ***Proposal 15: Support more candidate values with {2, 4, 8, 12, 16, 24, 32} ports in FG 23-7-2 for better flexibility of UE implementation.***  ***Proposal 16: Combine FG23-7-2 and FG23-7-3 as one FG with pairs of UE capability parameters to reduce fragmentation and simplify gNB/UE implementation.***  ***Proposal 17: Changes/updates for FG23-7 family for Rel-17 MTRP CSI enhancement are suggested as following:***   |  |  |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | --- | --- | | **Features** | **Index** | **Feature group** | **Components** | **Prerequisite feature groups** | **Need of FR1/FR2 differentiation** | **Note** | **Mandatory/Optional** | | 23. NR\_FeMIMO | 23-7-1 | Basic Features of CSI Enhancement for Multi-TRP | 1. Support of Nmax=1 2. FFS others |  |  | {Support, Not support} | Optional | | 23. NR\_FeMIMO | 23-7-2 | Support of max # Tx ports per source and max # resources | 1. A list of supported combinations, each combination is {max # of Tx ports per source in a resource set for Multi-TRP CSI, max # resources in a resource set for Multi-TRP CSI} | 23-7-1 |  | Maximum size of the list is 4.  The candidate values for max # of Tx ports per source in a resource set for Multi-TRP CSI is  {2, 4, 8, 12, 16, 24, 32}  The candidate values for max # resources in a resource set for Multi-TRP CSI is {2, 3, 4, 5, 6, 7, 8} | Optional | | ~~23. NR\_FeMIMO~~ | ~~23-7-3~~ | ~~Support of max # resources in a resource set for Multi-TRP CSI~~ | ~~FFS exact candidate values, Ks,max is up to 8~~ |  |  | ~~{Support, Not support}~~ | ~~Optional~~ | | 23. NR\_FeMIMO | 23-7-4 | Support of Nmax=2 | 1. Support of Nmax=2 for Multi-TRP CSI | 23-7-1 |  | {Support, Not support} | Optional | | 23. NR\_FeMIMO | 23-7-5 | Reuse two CMRs of NCJT for single-TRP measurement | 1. Whether two CMRs from a CMR pair configured for a NCJT measurement hypothesis can be used for Single-TRP measurement hypotheses | 23-7-1 | Applicable only to FR2 | {Support, Not support} | Optional |   **Proposal 18: Clarify whether FG 16-2c in Rel-16 can apply to both CS-RS and CSI-IM at least. If FG 16-2c cannot cover, e.g. CSI-IM configured for NCJT measurement hypothesis, a new/dedicated *FG is needed to indicate whether UE supports simultaneous reception with different QCL-TypeD for CSI-IM resource associated with NCJT measurement hypothesis.*** |
| **Futurewei** | ***Proposal 1: For CSI measurement associated with a CSI-ReportingConfig for NC-JT, two CMRs within the same CMR pair configured for NCJT measurement hypothesis should be restricted within the same DL slot and with the same CDRX active time.*** |
| **InterDigital, Inc.** | ***Proposal 1****: Support sharing of RI/PMI for sTRP and NCJT CSI. The sharing can be RRC configured on/off.*  ***Proposal 2****: Don’t support introducing a new RI restriction in the CSI reporting setting.*  ***Proposal 3****: Support Alt 1: modify priority equation, i.e., Section 5.2.5 in 38.214.* |
| **ZTE** | ***Proposal 1:*** *Do NOT support any time domain restriction of CMRs for NCJT CSI measurement hypothesis from RAN1 specification perspective.*  ***Proposal 2:*** *For a CMR pair configured for a NCJT measurement hypothesis, support Alt 2, re-interpret two Pc ratios configured for the CMR pair for the NCJT measurement hypothesis*   * *Antenna ports [3000,…, 3000+P-1], set [1000,…, 1000+ν-1] for ν layers, Pc ratio are associated with each resource of the CMR pair.* * *For CQI derivation assumption, the associated PDSCH layers transmitted on antenna ports [3000,…,3000 + P - 1] of the corresponding CSI-RS resource in the selected CSI-RS resource pair would have a ratio of EPRE to CSI-RS EPRE equal to the ratio given in Clause 5.2.2.3.1.*   ***Proposal 3:*** *For CSI computation delay requirement associated with a CSI-ReportingConfig for a NCJT measurement hypothesis, support Alt 2*   * *No changes of values on Z and Z’* * of table 5.4-2 in 38.214 is used   ***Proposal 4: The existing RI restriction is only applied for Single-TRP measurement hypotheses and no RI restriction is applied for NCJT measurement hypotheses in Rel-17.***  ***Proposal 5:*** *The X+1 CSI hypotheses per CSI Reporting Setting for NCJT and STRP are mapped to a single CSI report.*  ***Proposal 6:*** *Do NOT modify priority equation in section 5.2.5 in 38.214.*  ***Proposal 7:*** *Support to modify the table of priority levels for Part 2 CSI omission with finer granularity.*   * *MTRP CSI priority is higher than STRP CSI within a single CSI reporting when performing CSI omission.* |
| **Spreadtrum** | ***Proposal 1: For the value of Ks,max, Alt.1 shall be not supported.***  ***Proposal 2: Regarding RI restriction, support Alt 4.***  ***Proposal 3: Support to introduce new CSI computation delay requirement for NC-JT CSI.***  ***Proposal 4:******For option 1 with X=0, for UCI composition and structure,***   * ***2 RIs or joint RI, 1 or 2 CQI(s) should be include into Part 1;*** * ***2 PMIs (if required) should be include into Part 2;***   ***Proposal 5:******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 6:******For option 2 for UCI composition and structure,***   * ***CRI, RI or joint RI, CQI for the first CW should be include into Part 1;*** * ***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 Part 2.***   ***Proposal 7: For CSI enhancement on M-TRP operation, M-DCI based M-TRP operation should also be supported.***  ***Proposal 8: Support option 2, i.e., for a CSI report associated with a Multi-TRP/panel NCJT measurement hypothesis configured by single CSI reporting setting, the UE is expected to report two RIs, two PMIs, two LIs and two CQIs.*** |
| **vivo** | **Proposal 1:**  *The default maximum number of CMR is 2 with Rel-17 MIMO UE capability for MTRP CSI measurement.*  **Proposal 2:**  *For CSI measurement associated with a CSI-ReportingConfig for NCJT, following restrictions are applied for two CMRs within the same CMR pair configured for NCJT measurement hypothesis:*  *UE does not expect any uplink symbols between two CMRs within the same CMR pair.*  *Two CMRs are restricted with the same CDRX active time*  **Proposal 3:**  *For the number of CSI-IM resources*  *M is equal to Ks when the CMR sharing is enabled.*  *M is equal to Ks – 2N when the CMR sharing is disabled.*  **Proposal 4:**  *Support no change to definition or configuration of Pc\_ratio.*  **Proposal 5:**  *For non-PMI CSI feedback, when CMR sharing between NCJT hypothesis and STRP hypothesis is enabled*  *When non-PMI-PortIndication is configrued, separate non-PMI-PortIndication parameters are configured where one is for STRP hypothesis and the other is for NCJT hypothesis.*  *When non-PMI-PortIndication is not configured, an enhanced rule can be considered, e.g., the first v ports are associated with the rank v of STRP hypothesis measurement and the last k ports are associated with the rank k of NCJT hypothesis measurement.*  **Proposal 6:**  *For RI restriction, support Alt 5 or Alt 6 considering the flexibility.*  *For codebook subset restriction, support TRP-specific CBSR.*  **Proposal 7:**  *A CSI reporting setting configured with enhanced MTRP CSI reporting corresponds to a CSI report.*  **Proposal 8:**  *Slightly prefer to use legacy priority definition and omission rule with a granularity of CSI report level.*  **Proposal 9:**  *Support to enhance the CSI reporting mechanism when PMI and CQI granularity are wideband.*  **Proposal 10:**  *Support to confirm the work assumption in RAN1#103-e, i.e., Option1.*  **Proposal 11:**  *Support to associate two CSI reporting settings with CMRs configuration same as Cat1 for Cat2 configuration.*  **Proposal 12:**  *Support to specify rules on how to divide and map the generated UCI into two associated reports in Cat2.*  **Proposal 13:**  *“SharingCMR” and “N CMR pairs” should be configured in NZP-CSI-RS-ResourceSet.* |
| **OPPO** | **Proposal 4:**  *For CSI measurement associated with a CSI-ReportingConfig for NC-JT, support to restrict the two CMRs within the same CMR pair for NCJT measurement, e.g. in the same DL slot or in neighboring DL slot.*  **Proposal 5:**  *For a CMR pair for NCJT measurement, support Alt 3: No change to definition or configuration of Pc ratio.*  **Proposal 6:**  *For CSI computation delay requirement associated with a CSI-ReportingConfig for a NCJT measurement hypothesis, consider to introduce relaxed values on Z and Z’.*  **Proposal 7:**  *The number of CSI-IM resources depends on whether CMR sharing between S-TRP and NC-JT measurement hypotheses is enabled.*  *• If CMR sharing between NC-JT and S-TRP measurement is enabled, M=Ks CSI-IM resources with one-to-one mapping with M CMRSs for S-TRP, and N CSI-IM resources with one-to-one mapping with N CMR pairs for NC-JT can be configured.*  *• If CMR sharing between NC-JT and S-TRP measurement is not enabled, M=Ks-2N CSI-IM resources with one-to-one mapping with M CMRs for S-TRP, and N CSI-IM resources with one-to-one mapping with N CMR pairs for NC-JT can be configured.*  **Proposal 8:**  *For Option 2,*  *• If CMR sharing between NC-JT and S-TRP measurement is enabled, the bit number of CRI is log2(Ks+N), which indicates one of Ks S-TRP measurement hypotheses and N NC-JT measurement hypothesis.*  *• Otherwise, the bit number of CRI is log2(Ks-N), which indicates one of (Ks-2N)S-TRP measurement hypotheses and N NC-JT measurement hypothesis.*  *• One CRI, one RI and CQI for first CW are reported via CSI part 1.*  *o Depended on CRI, the RI can indicate one or two rank values.*  *• One or two PMI(s) depended on CRI, possible CQI for second CW are reported in CSI part 2.*  **Proposal 9**  *For CSI for S-TRP in the CSI report of Option 1 and type 1 codebook,*  *• The report content is the same as that of Rel-15/16.*  *• If CMR sharing between NC-JT and S-TRP measurement is enabled, the bit number of CRI is log2(Ks); Otherwise, the bit number is log2(Ks-2N).*  **Proposal 10:**  *For CSI for NC-JT hypothesis in the CSI report of Option 1 and type 1 codebook,*  *• CRI, RI and CQI for first CW are reported via CSI part 1.*  *o The RI to rank mapping can reuse that of option 2 for NC-JT hypothesis.*  *• Two PMIs, possible CQI for second CW are reported in CSI part 2.*  **Proposal 11:**  *For a CSI report associated with a NCJT measurement hypothesis configured by single CSI reporting setting, support Alt 1 for RI restriction: One RI restriction is configured per CodebookConfig, whereas the RI restriction is applied to both Single-TRP and NCJT measurement hypotheses.*  **Proposal 12:**  *For CSI priority within a CSI report configuration for Option 1*  *• The X+1 CSI hypotheses per CSI Reporting Setting are mapped to a single CSI report*  *• The CSI priority formula is not changed.*  *• The PUCCH resource determination, CSI omission for part 2 CSI and CSI dropping due to CPU occupation, which are based on the CSI priority formula, reuses that of Rel-15/16*  *• Prioritizing CSI associated with different measurement hypotheses within a CSI Reporting Setting only applies for UCI payload generation.* |
| **NEC** | **Proposal 1:**  *For RI restriction, support Alt 5 with a minor update:*  *• Alt 5: Three RI restrictions can be configured per CodebookConfig, whereas two RI restrictions are applied to two CMR groups in a CMR resource set respectively for Single-TRP measurement hypothesis, and the third one is applied to all NCJT measurement hypotheses.*  *o If rank restriction of (X1, X2, Y) is configured, reported rank is X1, X2 for each CMR group respectively for single-TRP measurement hypotheses and reported rank (1 Z out of 4 possible rank combinations, and Z can be 0, 1, 2, 3, 4) is Y for all NCJT measurement hypotheses.*  **Proposal 2:**  Similar as RI restriction, multiple CBSRs can be introduced for different measurement hypotheses, and output of RI restriction can be reused as starting point. |
| **CATT** | **Proposal-13:**  *For non-PMI based feedback, one of the following alternatives is needed.*   * *Alt 1: a sequenceof port indices are configured for each CMR used for NCJT measurement, where and  are the sets of CSI-RS port indices associated with rank=1 and 2 respectively. For each CMR in the selected CMR pair, UE reports a RI. Therefore, for NCJT hypothesis, one CRI, two RIs and one CQI are reported. In such case, up to 2 bits are needed for reporting of two RIs.* * *Alt 2: a sequenceof port indices are configured for each CMR pair used for NCJT measurement, where  are the sets of CSI-RS port indices associated with rank=v.*    + *For rank=2 (i.e., v1=1, v2=1), and are port indices from resource 1 and 2 respectively.*   + *For rank=3 while v1=2 and v2=1, and  are sets of port indices from resource 1 and 2 respectively.*   + *For rank=3 while v1=1 and v2=2,  and  are sets of port indices from resource 1 and 2 respectively.*   + *For rank=4 (i.e., v1=2, v2=2), and  are sets of port indices from resource 1 and 2 respectively.*   + *For each CMR pair, UE reports a RI wherein the set of CSI-RS port indices combined from the pair of CMRs is indicated. Therefore, for NCJT hypothesis, similar to legacy report quantities of non-PMI feedback, one CRI, one RI and one CQI are reported. In this case, up to two bits are needed for RI reporting.*   **Proposal-14:**  *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-15:**  *For power control ratio of NCJT, Alt 1 is preferred.*   * *Alt 1: a separate powerControlOffset (Pc ratio) shall be configured for the NCJT measurement hypothesis by re-defining such Pc ratio as 10log10(P\_PDSCH/P\_CSIRS) dB, whereas*   + *P\_PDSCH is the energy of PDSCH ports with a same TCI state as the CMR on one subcarrier of one OFDM symbol;*   + *P\_CSIRS is the energy of all CSI-RS ports of the CMR multiplexed on one subcarrier of one OFDM symbol.*   **Proposal-16:**  *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-17:**  *For RI restriction(s) associated with single-TRP/NCJT measurement hypotheses configured by single CSI reporting setting, Alt 4 and 5 are slightly preferred.*   * *Alt 4: Two RI restrictions can be configured per CodebookConfig, whereas one RI restriction is applied to all Single-TRP measurement hypotheses, and another one is applied to all NCJT measurement hypotheses.* * *Alt 5: Three RI restrictions can be configured per CodebookConfig, whereas two RI restrictions are applied to two CMR groups in a CMR resource set respectively for Single-TRP measurement hypothesis, and the third one is applied to all NCJT measurement hypotheses.*   **Proposal-18:**  *RI/PMI sharing between single-TRP and NCJT measurement hypotheses can be supported for Option 1 with X={1, 2}. RI/PMI sharing can be enabled or disabled by the gNB.*  **Proposal-19:**  *Further discuss the following alternatives for CSI reporting of M-DCI based NCJT.*   * *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-20:**  *For CSI reference resource definition the assumption of mapping between layers and CSI-RS ports should be specified and the rules elaborated in section 3.4 can be considered.* |
| **CMCC** | **Proposal 1:**  *Support Alt 1 about RI restriction for a CSI report associated with a Multi-TRP/panel NCJT measurement hypothesis.*   * *Alt 1: One RI restriction is configured per CodebookConfig, whereas the RI restriction is applied to both Single-TRP and NCJT measurement hypotheses.* * *If rank restriction of X is configured, reported rank is X for a Single-TRP measurement hypothesis and sum of two reported ranks is X for a Multi-TRP measurement hypothesis.*   **Proposal 2:**  *Alt 2 and 4 should be supported to confirm the order of UCI payload construction for reported CSIs.*   * *Alt 2: modify the table of priority reporting levels for Part 2 CSI, i.e., Table 5.2.3-1 in 38.214.* * *Alt 4: modify mapping order of CSI fields of one CSI report, i.e., Table 6.3.2.1.2-3/4/5 in 38.212*   **Proposal 3***:*  *The CSI associated with NCJT measurement hypotheses could be high prioritized within one single CSI report in the table of priority reporting levels for Part 2 CSI, when the UE is configured with CSI Option 1 and X=1 or 2.* |
| **Fraunhofer IIS, Fraunhofer HHI** | ***Proposal: Support Alt 3, i.e., no change to definition or configuration of Pc ratio.***  ***Proposal: Support Alt 1: One RI restriction is configured per CodebookConfig, whereas the RI restriction is applied to both Single-TRP and NCJT measurement hypotheses.***   * ***If rank restriction of X is configured, reported rank is X for a Single-TRP measurement hypothesis and sum of two reported ranks is X for a Multi-TRP measurement hypothesis.***   ***Proposal: Support CBSR configuration per TRP.*** |
| **Samsung** | ***Proposal 1:*** *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 2:*** *For NC-JT CSI reporting enhancement, support and study followings:*   * *Support non-PMI based port-selection* * *Study UCI structure optimized for dynamic NC-JT CSI report*   ***Proposal 3:*** *Support flexible RRC configuration for CSI measurement and reporting for mTRP NCJT CSI by configuring the CMR pairs for NCJT measurement hypothesis and the CMR sharing in CSI-ReportConfig.*  ***Proposal 4:*** *Design new CPU occupation rule for dynamic NC-JT CSI report.*  ***Proposal 5****: Support full and/or partial compression/omission/Sharing of PMI among single-TRP and NCJT hypotheses.*  ***Proposal 6****: 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.*   * ***Proposal 7****: For a CSI report associated with a Multi-TRP/panel NCJT measurement hypothesis configured by single CSI reporting setting, support RI restriction for single –TRP measurement hypotheses and no RI restriction is applied for Multi-TRP measurement hypothesis.* |
| **MTK** | **Proposal 1**: For CSI measurement associated with a CSI-ReportingConfig for NCJT, for two CMRs within the same CMR pair configured for NCJT measurement hypothesis two resources are restricted within the same DL slot.  **Proposal 2**: For a CMR pair configured for a NCJT measurement hypothesis a separate *powerControlOffset* (Pc ratio) shall be configured for the NCJT measurement hypothesis by re-defining such Pc ratio as 10log10(P\_PDSCH/P\_CSIRS) dB, whereas   * P\_PDSCH is the energy of PDSCH ports with a same TCI state as the CMR on one subcarrier of one OFDM symbol * P\_CSIRS is the energy of all CSI-RS ports of the CMR multiplexed on one subcarrier of one OFDM symbol   **Proposal 3**: For CSI computation delay requirement associated with a *CSI-ReportingConfig* for a NCJT measurement hypothesis, new/relaxed values on Z and Z’ should be introduced. FFS exact values or other conditions  **Proposal 4**: For Option 1 with *X* = 1, 2, each CSI measurement hypothesis is mapped to a distinct CSI report.  **Proposal 5**: The CSI priority formula is updated as: Either  ,  or  ,  where for the NCJT measurement hypothesis, for the first single-TRP measurement hypothesis, if reported, and for the second single-TRP measurement hypothesis, if reported. is the number of CSI reports in a CSI reporting setting. If UE is configured to report one single CSI report for a CSI reporting setting, then and .  **Proposal 6**: **For a CSI report associated with an NCJT measurement hypothesis configured by single CSI reporting setting, support RI restriction with Option 2, i.e., two RI restrictions can be configured per *CodebookConfig*, whereas one RI restriction is applied to one CMR group in a CMR resource set respectively.**  **Proposal 7**: Non-PMI CSI reporting with *reportQuantity* set to "CRI-RI-CQI" is supported for NCJT CSI.  **Proposal 8**: If the UE is not configured with higher layer parameter *non-PMI-PortIndication*, for two CMRs configured in a CMR pair as an NCJT measurement hypothesis, the CSI-RS port indices of the CMR in CMR group 1 and the CSI-RS port indices of the CMR in CMR group 2 are associated with rank combinations . The UE does not expect that an associated rank is larger than the number of ports of the corresponding CMR.  **Proposal 9**: If the UE is configured with higher layer parameter *non-PMI-PortIndication*, the port indication for NCJT measurement hypotheses is configured per rank combination per CMR pair. The UE shall only report RI combination corresponding to the configured fields.   * **Proposal 10**: For NCJT CSI, when calculating the CQI for a rank combination , the UE shall use the ports indicated for that rank combination for the selected CMR pair. The precoders for the indicated ports shall be assumed to be the identity matrix scaled by |
| **Intel** | ***Proposal 8****:*   * *CMR groups are configured by configuring list of CSI-RS resource indexes*   + *Value of CSI-RS resource indexes can repeat multiple times in a CMR group* * *CMR pairs for NCJT are configured by configuring indexes of CMRs inside CMR groups*   ***Proposal 9***:   * *Support MAC-CE based update of CMRs for NCJT and STRP*   ***Proposal 10***:   * *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 11***:   * *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 CQI field, i.e. if CQI for NCJT is equal to 0 NCJT CSI measurement hypothesis is not reported by the UE*   ***Proposal 12****:*   * *Different CSI measurement hypothesis are treated as separate CSI reports in TS38.212 (Table 6.3.2.1.2-6 and Table 6.3.2.1.2-7) and for CSI priority equation from TS38.214 (section 5.2.5)*   + *CSI priority equation from TS38.214 (section 5.2.5) is modified (e.g. CSI measurement hypothesis for NCJT can be prioritized over CSI measurement hypothesis for STRP)*   ***Proposal 13****:*   * *Support configuration of RI restriction per each CMR in CMR pair for NCJT and per each CMR for STRP*   ***Proposal 14***:   * *Support the following alternatives for CMR power offset configured for a NCJT measurement hypothesis*   + *Alt 1: a separate powerControlOffset (Pc ratio) shall be configured for the NCJT measurement hypothesis by re-defining such Pc ratio as 10log10(P\_PDSCH/P\_CSIRS) dB, whereas*     - *P\_PDSCH is the energy of PDSCH ports with a same TCI state as the CMR on one subcarrier of one OFDM symbol*     - *P\_CSIRS is the energy of all CSI-RS ports of the CMR multiplexed on one subcarrier of one OFDM symbol*   ***Proposal 15****:*   * *For CSI measurement associated to a reporting setting CSI-ReportConfig for NCJT measurement hypothesis, support non-PMI CSI reporting with reportQuantity set to "CRI-RI-CQI" in Rel-17*   ***Proposal 16****:*   * *Keep the same values for CSI calculation time requirements (Z, Z')*   *Two CSI-RS resources for NCJT are restricted with the same CDRX active time but no the same slot* |
| **NTT DOCOMO** | **Proposal 1**  *For CSI measurement associated with a CSI-ReportingConfig for NC-JT, two CMRs within the same CMR pair are restricted with the same CDRX active time.*  **Proposal 2**  *For Pc ratio for a CMR pair for NCJT measurement hypothesis, support Alt 3: No change to definition or configuration of Pc ratio.*  **Proposal 3**  *For RI restriction, support Alt 1: One RI restriction is configured per CodebookConfig, whereas the RI restriction is applied to both Single-TRP and NCJT measurement hypotheses.*   * + *If rank restriction of X is configured, reported rank is X for a Single-TRP measurement hypothesis and sum of two reported ranks is X for a Multi-TRP measurement hypothesis.*   **Proposal 4**  *Support to configure multiple (at least two) CBSR configurations for two CMR groups for single-TRP CSI measurement and/or NCJT CSI measurement.*  **Proposal 5**  *Support Alt 1. 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.*   * + *A new concept of CSI report #m with a CSI priority value corresponds to a single-TRP measurement hypothesis (TRP#0 or TRP#1), or a NCJT measurement hypothesis.*   *Support Alt 4. For the new CSI report #m corresponding to NCJT measurement hypothesis, the mapping order of CSI fields of one CSI report should consider two LIs and two PMIs.*  *Not support Alt 2. There is no need to modify the table of priority reporting levels for Part2 CSI.*  **Proposal 6**  *For a CSI report associated with a Multi-TRP/panel NCJT measurement hypothesis configured by single CSI reporting setting for single-DCI based NCJT, support CSI enhancement for URLLC schemes and HST-SFN scheme.* |
| **Sony** | -- |
| **Nokia, Nokia Shanghai Bell** | **Proposal 14 Regarding RI restriction for MTRP CSI Reporting Setting, support Alt 5, *i.e.*, 3 RI restriction fields of 4 bits each, one for each of the two CMR groups and one for the NCJT hypotheses, where the NCJT RI restriction applies to each of the four possible rank combinations.**  **Proposal 15 Support ‘cri-RI-CQI’ reporting for MTRP CSI reporting without additional specification impact. Rel-16 related UE capabilities, 22-11 (*cri-RI-CQI-WithoutNon-PMI-PortInd-r16*) and 2-38 (*csi-ReportWithoutPMI*) can be reused to indicate support of non-PMI reporting with or without port indication also for MTRP CSI reporting.**  **Proposal 16 Regarding the UCI mapping of the CSIs in a M-TRP CSI report , support Alt 2 by assigning reporting priority level 0 to all WB PMIs, reporting priority to all even SB PMIs and reporting priority level to all odd SB PMIs. The mapping order of the PMIs in Part 2 priorities 0, and is the same used in Part 1.**  **Proposal 17 Regarding Issue 2, *i.e.*, whether a prioritisation between the CSIs in an MTRP CSI report is needed to enhance omission rules, no prioritisation between CSIs is needed if the 3 reporting priority levels for an MTRP CSI report are assigned to all the PMIs in the report, as per our previous proposal.**  **Proposal 18 Regarding Issue 3, i.e., whether any enhancement to the CPU occupation rules is needed, support improved handling of CPU calculations for MTRP CSI reports with multiple CSIs without impacting the rules for legacy CSI reports. This can be done by:**   * **introducing separate CPU occupations, , with , alongside the legacy such that for an MTRP CSI report configured with Mode 1 and or ; and** * **adding a dedicated “soft” formula in Sec. 5.2.1.6 of 38.214 for the case when the first CSI report exceeding the CPU count, *i.e.*, CSI report , is an MTRP CSI report configured with Mode 1 and or .**   **Proposal 19 Regarding Issue 3, support the following additional “soft” formula for CSI updates at the end of the first paragraph of Sec 5.2.1.6 in 38.214:**  **If CSI report is an MTRP CSI report configured with Mode 1 and or , where each CSI, corresponds to , and CPUs are unoccupied, the UE is expected to update the first CSIs and is not required to update the last CSIs, according to their UCI mapping order, where is the largest value such that holds.**  **Proposal 20 In Alt 1, modify the definition of P\_PDSCH as the energy of PDSCH ports of the one TRP identified by the CMR Group associated with the NZP CSI-RS resource.**  **Proposal 21 Regarding the ratio definition, support Alt 1 with modification of P\_PDSCH, *i.e.*, the introduction of a *powerControlOffsetNCJT* for NCJT transmission hypotheses, defined as the ratio between the PDSCH EPRE of the PDSCH ports transmitted from one of the two TRPs and the CSI-RS EPRE of all CSI-RS ports multiplexed on one subcarrier. The CMR Group associated with a CMR resource identifies which of the two TRPs in the NCJT hypothesis transmits the PDSCH ports.**  **Proposal 22 For an NCJT CSI calculation, if the new** ***powerControlOffsetNCJT* is absent in a CMR configuration, a UE shall assume that the *powerControlOffset* is the ratio of PDSCH EPRE to NZP CSI-RS EPRE, where the PDSCH EPRE is that of all the PDSCH ports transmitted from a TRP in the CMR Group associated to the CMR resource.**  **Proposal 23 Regarding the latency requirement for NCJT CSI calculation, support Alt 2, *i.e.*, no need to relax the values of because the number of CPUs, , should already take account of the extra complexity required by an NCJT CSI calculation.**  **Proposal 24 Regarding the parent IE for the three CMR-related RRC parameters: “Two CMR groups”, “N CMR pairs” and “SharingCMR”, support the same parent IE for all three parameters, either NZP-CSI-RS-ResourceSet or CSI-ReportConfig.** |
| **Lenovo, Motorola Mobility** | 1. A CSI report corresponding to single-TRP hypothesis has higher priority compared with a CSI report corresponding to NCJT hypothesis 2. 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 3. A CSI report is defined for each CSI hypothesis, i.e., different CSI hypotheses correspond to different CSI reports 4. Support Alt1 as a first preference for RI restriction, in which the RI restriction applies to the total number of layers transmitted from the TRP(s) for all single-TRP and NCJT transmission hypotheses. Support Alt4 as a second preference 5. Support Type-II codebook for NCJT along with Type-I single-panel codebook type 6. For a UE configured with a multi-TRP CSI reporting configuration, type-II codebook can be configured with up to two CSI-RS resources for CMR 7. Non-PMI CSI reporting is not supported for multi-TRP CSI framework 8. CSI computation delay relaxation is considered for multi-TRP CSI. Details are FFS 9. For CSI-RS resource transmission under multi-TRP CSI framework, the two resources are restricted within the same DL slot |
| **Apple** | ***Proposal 1 For interference measurement under NCJT, including RI/PMI/CQI/LI decision, CMR from one TRP should be considered as the interference, i.e. IMR, to the other TRP.***  ***Proposal 2 In the same CSI-ReportConfig, when gNB configures UE to report both the single TRP measurement results and the multi-TRP measurement result, do not introduce different priority for single TRP measurement and multi-TRP measurement in the same CSI-ReportConfig, at least for CPU overbooking scenario*** |
| **LG Electronics** | **Proposal #1: Support Alt 2 to define the order of UCI payload construction for reported CSI, and for Part 2 subband CSI of even or odd subbands, STRP CSI has higher priority over NCJT CSI when UCI payload size exceeds allocated PUSCH resources.**  **- Alt 2: modify the table of priority reporting levels for Part 2 CSI, i.e., Table 5.2.3-1 in 38.214.**  **Proposal #2: Support Alt 3 for multiple RI restrictions.**  **- Alt 3: Multiple RI restrictions can be configured per CodebookConfig, whereas RI restriction is applied to per each CMR in CMR pair for NCJT and per each CMR for Single-TRP.**  **Proposal #3: Support multiple codebook subset restrictions for different TRPs.**  **Proposal #4: Support relaxed values on Z and Z’ for CSI computation delay requirement associated with a *CSI-ReportingConfig* for a NCJT measurement hypothesis.**  **Proposal #5: Support Alt 3 for definition of Pc ratio.**  **- Alt 3: No change to definition or configuration of Pc ratio** |
| **QC** | **Proposal 1: For a CSI report associated with a Multi-TRP/panel NCJT measurement hypothesis configured by single CSI reporting setting, support RI restriction by**   * **Alt 4: Two RI restrictions can be configured per CodebookConfig, whereas one RI restriction is applied to all Single-TRP measurement hypotheses, and another one is applied to all NCJT measurement hypotheses.**    + **If rank restriction of (X, Y) is configured, reported rank is X for all single-TRP measurement hypotheses and reported rank (1 out of 4 possible rank combinations) is Y for all NCJT measurement hypotheses.**   **Proposal 2: For RI and LI reporting of a NCJT CSI, the two RI’s and LI’s are based on**   * **Assuming rank pairs for NCJT CSI ( in the absence of NCJT RI restriction), 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 3: For a CSI report setting with Option 1 with X=1 or 2 and *reportConfigID*=s, CSI priority is , where corresponds to single-TRP CSI(s) and NCJT CSI within the CSI report setting, respectively.**   * **This ordering is for the purpose of UCI payload construction, CSI omission for CSI part 2, and CPU occupation priority.** * **This ordering does not impact PUCCH resource selection for UCI multiplexing.**   **Proposal 4: 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 5: For a NCJT CSI corresponding to a CMR pair, the first RI/PMI/LI is associated with the CMR in the first CMR group, and the second RI/PMI/LI is associated with the CMR in the second CMR group.**  **Proposal 6: For a CMR pair configured for a NCJT measurement hypothesis, support:**   * **Alt 1: a separate *powerControlOffset* (Pc ratio) shall be configured for the NCJT measurement hypothesis by re-defining such Pc ratio as 10log10(P\_PDSCH/P\_CSIRS) dB, whereas**   + **P\_PDSCH is the energy of PDSCH ports with a same TCI state as the CMR on one subcarrier of one OFDM symbol**   + **P\_CSIRS is the energy of all CSI-RS ports of the CMR multiplexed on one subcarrier of one OFDM symbol** |
| **Ericsson** | [**Proposal 9** **Support Alt.1, i.e. the default value (Ks,max) of the maximum number of NZP CSI-RS resources configured for CMR to be equal to 4, for both FR1 and FR2.**](#_Toc84019121)  [**Proposal 10** **For CSI measurement associated with a CSI-ReportConfig for NC-JT, support Alt.1 , i.e., dynamic update of CMR pairs for NC-JT measurement hypothesis using MAC CE.**](#_Toc84019122)  [**Proposal 11** **Do not support Alt.2, i.e. do not support higher layer signalling to dynamically update CMRs for sTRP measurement hypotheses.**](#_Toc84019123)  [**Proposal 12** **For CSI computation delay requirement associated with a CSI-ReportingConfig for a NCJT measurement hypothesis, support Alt.1, i.e. introducing new/relaxed values on Z and Z’.**](#_Toc84019124)  [**Proposal 13** **Non-PMI CSI reporting for NCJT measurement hypothesis is not supported in Rel-17.**](#_Toc84019125)  [**Proposal 14** **Support Alt 2, i.e. re-interpret two Pc ratios configured for the CMR pair for the NCJT measurement hypothesis as per TRP.**](#_Toc84019126)  [**Proposal 15** **The two CMRs belonging to the same CMR pair used for NCJT measurement hypothesis do not have to be restricted to the same slot.**](#_Toc84019127)  [**Proposal 16** **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.**](#_Toc84019128)  [**Proposal 17** **Support NC-JT CSI omission under certain conditions when X=1 or 2 is configured with omission indicated in a CSI report.**](#_Toc84019129)  [**Proposal 18** **Support one CSI report for reporting X CSIs associated with single-TRP measurement hypotheses and one CSI associated with NCJT measurement hypothesis.**](#_Toc84019130)  [**Proposal 19** **Support both Alt 2 and Alt.4 for UCI payload construction.**](#_Toc84019131) |