**3GPP TSG RAN WG1 Meeting #107-e R1-210xxxx**

**e-Meeting, November 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*

# Summary of CSI enhancement for Rel-17 port selection codebook

## Remaining issues of Rel-17 Port-Selection Codebook

According to the agreement on Rel-17 PS codebook, N = 2 or 4 is supported when M = 2. One remaining issue is for the value of N when N3 = 3. Several companies have shared their views on this issue as shown in the following table.

**Table 1 Summary of Companies’ Views on how to configure the value of N when N3 = 3**

|  |  |
| --- | --- |
| **Views** | **Companies** |
| **Alt1: N = 2 or 4 can be configured. The windows size for Wf quantization is min(N,3)** **(10)** | CATT, Huawei, HiSilicon, Intel, Samsung, DOCOMO, Nokia, Nokia Shanghai Bell, Ericsson, Spreadtrum(2nd) |
| **Alt2: Only N=2 is configured** **(1)** | Spreadtrum (1st) |
| **Alt3: When N3 = 3 and N = 4, there is no specification impact** **(1)** | vivo |

CATT, Huawei, HiSilicon, Intel, Samsung, DOCOMO, Nokia, Nokia Shanghai Bell and Ericsson prefer Alt1 because compared with Alt2, Alt1 can allow UE selects FD basis freely from more candidate FD bases when N=4. Spreadtrum are OK with Alt1 or Alt2 and slightly prefer Alt2.

Vivo supports Alt3. If N3 = 3 and N = 4, the window covers the all candidate FD bases and it is up to UE implementation to perform FD bases selection.

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

***Proposal 1:*** *When N3 = 3, the window size is .*

* *Note: the UCI payload of i1,6 is bits regardless of values of N3*

|  |  |
| --- | --- |
| Company | Comments |
| **Mod** | Proposal 1 is suggested based on the majority.  |
| vivo | Support. |
| Intel | OK |
| ZTE | OK |
| Samsung | We don’t need to say “when N3=3”, we can just say that the window size is min(N3,N), which applies to all N and N3 values.***Proposal 1:*** *~~When N~~~~3~~ ~~= 3,~~ the window size is .** *Note: the UCI payload of i1,6 is bits regardless of values of N3*
 |
| OPPO | OK |
| Qualcomm | No need of this proposal, it can be handled by UE implementation by not reporting i\_{1,6}=2 when N3=3 and N=4 since the payload is not changed. |
| Ericsson | Support |
| Nokia/NSB | OK |

About 20 companies have shared their views over Part II for UCI groups, which are listed in the table below.

**Agreement**

For UCI part II of Rel-17 PS codebook, **study the following** alternatives and down-select one or more alternatives in RAN1 107

* 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 Rel-17 PS codebook enhancement except that the starting position of the FD basis window is not needed

**Note that other solutions of UCI part II design are not excluded.**

**Table 2 Summary of Companies’ Views on** **the design of three groups of Part II**

|  |  |
| --- | --- |
| **Views** | **Companies** |
| **Alt 1****(13)** | Huawei, HiSilicon, CATT, OPPO, Intel, Samsung, Lenovo, Motorola Mobility, DOCOMO, Nokia, Nokia Shanghai Bell, MTK, Ericsson |
| **Alt 2****(4)** | Intel, Samsung, Lenovo, Motorola Mobility |
| **Alt 3** **(7)** | ZTE, Spreadtrum Communications, Fraunhofer IIS, Fraunhofer HHI, LG Electronics, Apple, Qualcomm |

* 13 companies (Huawei, HiSilicon, CATT, OPPO, Intel, Samsung, Lenovo, Motorola Mobility, DOCOMO, Nokia, Nokia Shanghai Bell, MTK and Ericsson) support to report FD indicator in Group 0. If Group 1 and Group 2 are dropped when CSI omission is applied, the incomplete CSI report from Group 0 without FD indicator for SCI cannot be used for obtaining any meaningful DL CSI. Moreover, FD indicator with 2 bits in Group 0 does not increase its size significantly. Some companies (Huawei, HiSilicon and CATT) also think reported bitmap in Alt 2 is less useful if the corresponding NZCs are dropped.
* 4 companies (Intel, Samsung, Lenovo, and Motorola Mobility) support to report a whole bitmap in Group 0 or Group 1 considering that the bitmap size of Rel-17 PS codebook is much smaller than that of Rel.16 PS codebook. Some companies (Lenovo, Motorola Mobility) think that with reciprocity-based port selection codebook, the network may be able to reconstruct a rough estimate of the precoder based on the bitmap(s) even if corresponding coefficient values are not reported due to omission of Group 2 of CSI Part 2.
* 7 companies (ZTE, Spreadtrum Communications, Fraunhofer IIS, Fraunhofer HHI, LG Electronics, Apple and Qualcomm) thinks there is no obvious benefit to make any changes as Alt 1 or Alt 2 with respect to Rel. 16 design principles.

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

***Proposal 2:*** *Support Alt 1, i.e. report Port indicator, SCI, and FD indicator in Group 0*

|  |  |
| --- | --- |
| Company | Comments |
| **Mod** | Proposal 2 is suggested based on the majority. |
| vivo | We are fine with the majority view. |
| Qualcomm | Still prefer Alt3. Moving FD indicator to Group 0 is not essential, but UE has to change the implementation in UCI grouping.Besides, we think it is essential to clarify the coefficient partition. As we proposed for Rel-16 maintenance, when KNZ < 2\*v, the value ceil(KNZ/2-v) would be negative. To solve this issue, we propose ceil((KNZ-v)/2) coefficients are in Group 1, while floor((KNZ-v)/2) coefficients are in Group 2. |
| Intel | OK with the proposal.On top of it Alt 2 can be supported; i.e. bitmap can be fully reported in G0/G1. |
| ZTE | We still prefer Alt 3 rather than Alt 1. We don’t see strong motivation to change the Rel-16 UCI mapping. |
| Samsung | SupportBesides, same view as Intel regarding this bitmap. Unlike R16, the bitmap size is small in R17, and bitmap can provide useful information about NZ coefs in case of UCI omission. Plus, it simplifies the UCI packing for the UE. |
| OPPO | Support. |
| Ericsson | Support FL Proposal. Note that Alt.2 may imply additional gNB complexity and Alt.3 have critical performance drawback for this feature, which were not present in Rel.16 design. |
| Nokia/NSB | Support. |

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

**Agreement**

For the priority of mapping coefficients for Rel17 PS codebook, study the following alternatives and down-select one or more alternatives in RAN1#107-e:

* 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
* 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
* Alt 3: Support mapping coefficients firstly across layers, secondly across port indices, and thirdly across FD basis indices, i.e., the priority value is given by
	+ FFS port permutation function

Note that other solutions are not excluded.

**Table 3 Summary of Companies’ Views on** **the priority of mapping coefficients**

|  |  |
| --- | --- |
| **Views** | **Companies** |
| **Alt 1 (3)** | Qualcomm, MTK, Ericsson |
| **Alt 2 (10)** | Huawei, HiSilicon, ZTE, vivo, Spreadtrum Communications, LG Electronics, intel, Samsung (1st), Apple, DOCOMO |
| **Alt3** | **Alt 3-1****(*****interleave between polarization per port subset with size of , start from index 0*) (2)** | Fraunhofer IIS, Fraunhofer HHI |
| **Alt 3-2****(*****interleave between polarization per port, start from index 0*) (3)** | CATT, Lenovo, Motorola Mobility, |
| **Alt 3-3****(*****interleave between polarization per port, start from index of the strongest coefficient* ) (2)** | Nokia, Nokia Shanghai Bell, |
| **Others (*No specific preference)* (5)** | OPPO, Sony, Intel, Samsung (2nd), MTK |
| **Alt4 (*1st port indices, 2nd******layers, 3rd FD basis indice*****) (1)** | CATT |

* 3 companies (Qualcomm, MTK and Ericsson) support Alt 1 considering that such ordering of coefficients in Alt1 will reduce UE complexity. The precoders for dominant layer(s) with subband granularity will be given more opportunity due to MU-MIMO and frequency domain scheduling. In addition, Ericsson thinks that prioritize more layers over more accurate PMI per layer as Alt 2 or Alt 3 may lose the orthogonality of PMIs for different layers.
* 10 companies (Huawei, HiSilicon, ZTE, vivo, Spreadtrum Communications, LG Electronics, Intel, Samsung, Apple, DOCOMO) support Alt 2 and think it’s better to let gNB reconstruct the channel vectors for all the layers, thus can provide better rank information. In addition, some companies (Huawei, HiSilicon, Samsung, LG Electronics and DoCoMo) don’t see the benefit to redefine port permutation as Alt 3.
* 12 companies (Fraunhofer IIS, Fraunhofer HHI, CATT, OPPO, Sony, Intel, Samsung, Lenovo, Motorola Mobility, Nokia, Nokia Shanghai Bell and MTK) support Alt 3 because that port permutation can give equal priority to port indices from both polarizations with increased maximum number of selected ports. However, different companies have subtle difference for design principle and associated permutation functions for Alt 3 as following:
	+ Fraunhofer IIS, Fraunhofer HHI support port permutation function which interleave between polarization per port and start from index 0, i.e., the first port of the first polarization and the first port indices of the second polarization ordered sequentially, followed by the remaining port as the same order, wherein
	+ CATT, Lenovo, Motorola Mobility support port permutation function which interleave between polarization per port and start from index 0, i.e., the order as {0, L,1,1+L,2,2+L,…}, wherein
	+ Nokia, Nokia Shanghai Bell support port permutation function which interleave between polarization per port and start from index of the strongest coefficient , i.e., the order as {},

In addition, OPPO also provide simulations showing that the power distribution of ports can be similar over two polarizations. Sony thinks accurate polarization of CSI is important to enable the transmission of multiple layers and to extract channel diversity for single layer transmission.

* Besides, CATT propose to mapping coefficients firstly across port indices, secondly across layers, and thirdly across FD basis indices with )and point out that Alt 4 is same with Alt1 when *M* = 1, and for *M* = 2, this method will guarantee reporting the NZCs of all layers for the 1st FD basis and ignore unimportant NZCs for the 2nd FD basis.

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

***Proposal 3:*** *In Rel-17, the priority value is given by whereas for , down-select one alternative from the following:*

* *Alt 2: Support non-interleaving between polarization, i*
* *Alt 3-1: Support interleave port subsets (with a size of per subset) across polarizations, with the port permutation function given by*
* *Alt 3-2: Support interleave ports across polarizations (starting from port index 0), with the port permutation function given by*
* *Alt 3-3: Support interleave ports across polarizations (starting from port index of the strongest coefficient ), with the port permutation function given by*

|  |  |
| --- | --- |
| Company | Comments |
| **Mod** | Proposal 3 is suggested based on Alt 2 and Alt 3 with the most supporting companies. Alt 3-1/3-2/3-3 share the common intention to re-arrange coefficients across polarizations. However there are subtle difference among these alternatives. We will decide one Alternative this way or another for this matter in RAN1 107.  |
| vivo | Support Alt 2. In our opinion, the port permutation can be realized by permutation of the selected ports, e.g., interleaving the selected ports, before mapping to UCI with little change in UCI mapping by replacing 2L with K1 in the formula.For Alt 3-1, is always zero?We propose to add one more alternative* *Alt 2-1: Support non-interleaving between polarization, i, with permutation of the selected ports before mapping to UCI*
 |
| Fraunhofer IIS/ Fraunhofer HHI | For Alt 3-1, the correct permutation function in terms of L is given as follows: As explained in our Tdoc and during the last meeting, equal priority should be given to the port indices from both polarizations as the number of selected ports in Rel. 17 PS CB can be 4 times higher than the number of port indices selected for Rel. 16 PS CB. Giving equal priority to both polarizations results in a performance gain e.g., 9% for rank 1 and 27% for rank 2 compared to Alt 2 as shown in our Tdoc. Therefore, port permutation is needed to capture port indices of both polarizations in group 1 which cannot be achieved with Alt 2 i.e., **.**Alt 3-1 proposes a simple permutation scheme, where L/2 port indices from the first polarization and L/2 port indices from the second polarization are ordered sequentially followed by the remaining L/2 port indices from the first polarization and remaining L/2 port indices from the second polarization 🡪 for L = 4 🡪 {0,1, **0+L,1+L**, 2,3, **2+L,3+L**}.For Alt 3-2 and Alt 3-3, the number of alternations between the polarizations is dependent on the number of selected ports i.e., 2L and the UE alternates between the two polarizations by 2L-1 times 🡪 for L = 4 🡪 {0, **0+L**, 1, **1+L**, 2, **2+L**, 3, **3+L**}.In contrast, Alt 3-1 is simple in a way that the number of alternations between the polarizations is always 3 (3 << 2L-1) and the number of alternations is not dependent on the number of selected ports i.e., 2L. @vivo – Could you elaborate more on how interleaving of the selected port indices be achieved by simply replacing 2L with K1? |
| Qualcomm | Cannot accept this proposal. Alt1 should be included because Alt1 has larger number of supporters than Alt 3-1, 3-2 and 3-3.  |
| Intel | Support the proposal. Particular permutation function (if supported) can be discussed further.  |
| ZTE | Support Alt 2. We don’t see the need to over-optimize the coefficient priority. The benefit of alternatives other than Alt 2 is unclear. Further, it seems companies’ views are quite divergent on Alt 3 series. It’s not clear to us whether we can select one in this meeting (which is the last meeting of this release) given the divergent preferences.  |
| Samsung | Our 1st preference is R16 design (Alt2). But, we can be open to a simple port permutation. For example, we can just say even-numbered indices have higher priority than odd-numbered. We don’t need to over-design for a rare-event (i.e. UCI omission), and specify complicated math formulae. So, we suggest add a simpler alt without any math formulae. Alt 3-4: *Support port permutation such that even-numbered ports (0,2,…) have higher priorities than odd-numbered ports (1,3,…)* |
| OPPO | Support the proposal.  |
| Ericsson | Support Alt.2 |
| Nokia/NSB | Support the proposal.We are also ok to add that if we cannot reach an agreement, Rel-16 design, i.e. Alt 2 is reused@Samsung: in Alt 3-4 if the starting point is port index 0, it sounds the same as Alt 3-2. Alt 3-3 can also be described in plain text without formulae in a similar fashion  |

In RAN1#106e, it was agreed that 8 parameter combinations are supported in Rel-17 PS codebook, and whether further restrictions for given parameter combinations should be further study. More than 10 companies provide their opinions on this issue, which is summarized as Table 4.

**Table 4 Summary of Companies’ Views on the restrictions for parameter combination**

|  |  |
| --- | --- |
| **Views** | **Companies** |
| **No restrictions (1)** | vivo |
|  **for 4 and 12 ports (5)** | Samsung, Huawei, HiSilicon (*not applicable to 4 and 12 ports*)CATT, MTK, ZTE (K1=⌈α×P/2⌉\*2) |
| **Overhead (5)** | Nokia，Nokia Shanghai Bell, CATT(P<=24)); MTK, Qualcomm (P<=16){2,1,1/2}: Qualcomm(P<=24), MTK (P<=16)Qualcomm(P<=24)  |

Five companies provide their view on addressing potential issue of for cases of 4 and 12 CSI-RS ports, which are summarized as following.

* Samsung, Huawei, and HiSilicon point out that causes and for 4 ports and 12 ports CSI-RS, respectively. This makes it impossible to select the ports for each polarization. Furthermore, Samsung propose that when , the value of implying that only rank 1~2 CSI can be reported for . Therefore, allowed rank can’t be 3 or 4 when and .
* CATT and MTK propose that to accommodate parameter combinations with for 4 and 12 CSI-RS ports, the port selection may be slightly modified to select ports out of ports for each polarization. ZTE propose that refine the definition of K1 as K1=⌈α×P/2⌉\*2 to ensure K1 are even integers.

Considering high overhead for parameter combinations, companies’ views are mainly focused on {M, alpha, beta} = {2, 1, 3/4} (Nokia, Nokia, Nokia Shanghai Bell, CATT, Qualcomm and MTK), which are summarized as following.

* {M, alpha, beta} = {2, 1, 3/4} is onlyapplied to .

Nokia, Nokia Shanghai Bell, and CATT simulation results show that when , the parameter combination {M, alpha, beta} = {2, 1, 3/4} provide slightly performance gains, compared with {M, alpha, beta} = {2, 1, 1/2}, but the overhead of the former is significantly larger.

* {M, alpha, beta} = {2, 1, 3/4} is onlyapplied to .

Qualcomm and MTK view that the maximum feedback overhead of Rel-17 PS CB should be comparable to Rel-16 eTypeII. Meanwhile, Qualcomm and MTK think that if , extra non-zero-coefficient increase the UE complexity significantly.

Except {M, alpha, beta} = {2, 1, 3/4}, QC also proposes {M, alpha, beta} = {1, 1, 1} and {M, alpha, beta} = {2, 1, 1/2} are only applied to <= 24 ports, and MTK proposes {M, alpha, beta} = {2, 1, 1/2} is only applied to <= 16 ports.

On the other hand, vivo prefers no further restrictions should be add to parameter combinations, since the restrictions can be determined by gNB if needed.

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

***Proposal 4-1:*** *Regarding to codebook parameters for Rel-17 PS codebook, down-select one from the following:*

* *Alt1: is not applicable to 4 and 12 CSI-RS ports*
* *Alt2: Same ports out of PCSI-RS/2 ports are selected for both polarizations, i.e. L=* and K1=αPCSI-RS
* *Alt 3: Neither above Alt is needed.*

|  |  |
| --- | --- |
| Company | Comments |
| **Mod** | Alt 4-1 is suggested based on the latest companies’ view.  |
| Vivo | Support Alt1. |
| Qualcomm | Ok with Alt1. |
| Intel | Of with Alt 1 |
| ZTE | We support Alt 2. Alt 2 is just a simple round operation which is typically used, e.g., to derive Mv and K0 in Rel-16. Further, the variable L already exists in the specification. Alt 2 just adds a round operation to L in the current spec. It is not clear to us why to leave a hole in the spec as Alt 1 is better than a simple round operation in Alt 2. |
| Samsung | Support Alt1 |
| OPPO | Ok with Alt 1 |
| Ericsson | Support Alt.2 |
| Nokia/NSB | Support Alt 1With Alt 2, needs to be replaced by in 212 and 214 otherwise the bitwidth of some indicators and the definition of would be incorrect/inconsistent |

***Proposal 4-2:*** *Regarding to the restriction applying to parameter combination for Rel-17 PS codebook, down-select one from the following:*

* *Alt 1: {M, alpha, beta}={2,1,3/4} is only applicable to P <= [16 or 24] ports*
* *Alt 2: Above restriction is not needed.*

|  |  |
| --- | --- |
| Company | Comments |
| **Mod** | Alt 4-2 is suggested based on the latest companies’ views which mostly focus on the parameter combination of {2, 1, ¾}. If Alt 1 is preferred by the group, we also need to decide whether it is up to P<=16 or P<=24 as well.  |
| Vivo | Support Alt 2. |
| Qualcomm | We think restrictions {1,1,1} and {2,1,1/2} are also needed considering the overhead, Alt1 is already our compromise. |
| Intel | Support Alt 2. Restriction is not needed. |
| ZTE | Support Alt 2. |
| Samsung | Support Alt2. There is no need for any restrictions. The parameter combinations apply to all number of CSI-RS ports. So, the NW is free to configure a smaller number of CSI-RS ports, to reduce payload. |
| Ericsson | Support Alt.2 |
| Nokia/NSB | Support Alt 1. We are also fine with majority view on this proposal |

## Others

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

|  |  |
| --- | --- |
| **Company** | **View** |
| **Samsung** | ***Proposal 8****: When M=1, the description on includes one of the following:** *Alt1: a single precoding matrix is indicated by the PMI*
* *Alt2: N3 precoding matrices indicated by the PMI, but they are the same when M=1*

***Proposal 9****: support Rel.17 codebook for BWP size < 24 PRBs with the current restriction in the specification, i.e. support only WB CSI implying M=1****Proposal 10****: Regarding M = 2, UE reporting its capability to support M = 2 shall also report whether it supports M=2 for P > 12 CSI-RS ports****Proposal 12****: Regarding Rel.17 codebook parameters,** *support*
* *specify the following restrictions on the parameter combinations*
	+ *can’t be configured when or 12*
	+ *allowed rank can’t be 3 or 4 when and*
 |
| **Lenovo&, Motorola Mobility** | * The parameter *paramCombination-r17* configures the supported parameter combination values of the parameters (α, *Mv*, *β*, *R*)

we prefer including the parameter *R* to set of parameters of the parameter combination, as shown in Table 3, as follows

|  |  |  |  |
| --- | --- | --- | --- |
| **M** | **Alpha** | **Beta** | **R** |
| 1 | 1 | 1 | 1 |
| 1 | 1 | 3/4 | 1 |
| 1 | 1 | 1/2 | 1 |
| 1 | 3/4 | 1/2 | 1 |
| 2 | 1 | 3/4 | 1 |
| 2 | 1 | 1/2 | 1 |
| 2 | 3/4 | 1/2 | 2 |
| 2 | 1/2 | 1/2 | 2 |

 |
| **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*
 |
| **Intel** | 24 PRB BWP is not supported for new Rel-17 Type II PMI codebook |
| **vivo** | **Proposal 14:*** *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.*
 |
| **Qualcomm** | **Proposal 7:** For Rel-17 Type II port-selection codebook, only CSI reporting on PUSCH is supported. |

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| --- | --- |
| Company | Comments |
| **Mod** | The table is to check whether there is any essential issue for Rel-17 PS codebook.  |
| Vivo | Proposal: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, e.g., when alpha = 3/4.Our reasoning is as follows:When the number of selected ports is larger than half of the number of candidate ports, the combinatorial coefficients of non-selected ports can be reported to derive the selected ports, resulting in less calculation complexity than that of to be reported port, given that both gNB and UE know the number of reported ports K1 and the number of candidate ports, i.e., N CSI-RS ports. In this way the computation iteration number will never be more than N/2 for any cases. Meanwhile the combinatorial coefficients table can just reuse part of Table 5.2.2.2.4-4 in TR 38.214.For example, when the number of CSI-RS ports is 32 and K1 is 24, it means the combinatorial coefficients is calculated by with 12 iterations. By the approach of reporting non-selected beams, there are only 4 non-selected beams and thus only 4 iterations are enough for the combinatorial coefficients . |
| Qualcomm | We think it is worthy to point out that CSI on PUCCH is not reported for FeType II CSI.Besides, it seems that we need an agreement on reusing UCI omission table as Rel-16 eType II codebook, and UE is not expected to recalculate CQI if UCI omission occurs. |
| Samsung | The issue of alpha = ½ and 4 CSI-RS ports **is critical**, since it is not feasible to support rank 3 or 4 with only 2 ports (after port selection).Besides, it is beneficial to support R17 CB for 2 CSI-RS ports (similar to R14 Class B, K=1 codebook in LTE). This is relevant for scenarios in which the channel has no spread after beamforming. So, we suggest to include this a possible configuration. |
| Ericsson | We don’t see anything on this list that is essential. On alpha=1/2 issue pointed out by Samsung, there is no spec impact.  |
| Qualcomm2 | We would like to repeat and emphasize our point on coefficient partitioning (also mentioned it in P2). We think KNZ/2 – v being negative is a critical issue to be fixed. The reason is that KNZ value is determined by UE based on measurement of the DL channel. Even if gNB configure K0 large enough, KNZ can be small (e.g., in LOS case). If grouping KNZ/2 – v into Group 1, it implies that UE will have to always report at least 2v coefficients, which was not agreed in either R16 or R17. If not changed, this means that UE is forced to quantize zeros to some non-zero values when actual KNZ < 2v. This may cause issues in real-world deployment. So, this issue should be fixed, it is not optimization or any further enhancement. |

# Summary of CSI enhancement for Multi-TRP

## Remaining issues for Multi-TRP CSI

Regarding of CBSR for NCJT measurement hypothesis, it is agreed to down select one alternative from the following in RAN1 #107e:

**Agreement**

**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 in RAN1 107:**

* **Alt 1: One CBSR can be configured per *CodebookConfig*, whereas CBSR is applied to all CMRs regardless measurement hypotheses or CMR groups.**
* **Alt 2: 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.**

Companies’ views can be summarized as following:

|  |  |
| --- | --- |
| **Views** | **Companies** |
| **Alt 1** |  |
| **Alt 2 (17)** | Huawei, HiSilcon, ZTE, Vivo, SpreadTrum, CATT, LGE, Intel, NEC, Samsung, Lenovo, MotM, DoCoMo, Nokia, NSB, MTK, Ericsson |

Companies preferring Alt2 have the following considerations:

* ZTE, Intel, CMCC, Lenovo, and Ericsson propose that if **only one CBSR is configured per *CodebookConfig*, where single CBSR is applied to all CMRs regardless of measurement hypotheses or CMR groups,** the optimal precoders may be restricted, due to different channel conditions between two **CMR groups.** Ift**wo CBSRs are configured per *CodebookConfig*, described as Alt2, where two CBSRs are applied to two CMR group (two TRPs) in a CMR resource set respectively,** the strong interference may be avoided and the optimal precoders can be selected.
* Vivo, CATT, and DoCoMo think CBSR should be TRP-specific according to different channel conditions or beam directions per TRP, and the same CBSR for a TRP can be applied to both STRP CSI and NCJT CSI from the same TRP.
* Spreadtrum prefer Alt 2, because it can avoid possibly strong cross-correlation in spatial domain.
* LGE proposes that different TRPs can have different antenna structures, i.e., different value of (N1, N2), and single CBSR cannot support such deployment..

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

***Proposal 5:*** *For a CSI report associated with a Multi-TRP/panel NCJT measurement hypothesis configured by single CSI reporting setting:*

* ***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.***

|  |  |
| --- | --- |
| Company | Comments |
| **Mod** | The proposal is suggested based on the majority view.  |
| QC | Even though we think Alt2 is effectively an enhancement to DPS (not specific to NCJT), we can accept it given the majority view. |
| ZTE | Support |
| vivo | Support |
| Intel | Support |
| CATT | Support |
| MediaTek | Support |
| CMCC | Support |
| Samsung | Support |
| OPPO | Support |
| Nokia/NSB | Support |

In Rel-15/16, wideband CSI is conveyed by 1-part UCI on PUCCH. If 1-part wideband CSI on PUCCH is also supported for Rel-17 Multi-TRP CSI, the payload size variation for different ranks can be enormous, especially under reporting Mode 2. Vivo and Nokia propose to enhance NCJT CSI reporting on PUCCH when PMI and CQI granularity are set to be wideband. In addition, Nokia proposes that wideband reporting of NCJT CSI on PUCCH is only supported with reporting Mode 1 with X = 0 or Mode 2, such that the report consists of a single CSI with either one or two WB PMIs.

Companies’ views can be summarized as following:

|  |  |
| --- | --- |
| **Views** | **Companies** |
| **Support wideband reporting of MTRP CSI on PUCCH** | Vivo, Nokia, NSB (Mode 1 with X=0 or Mode 2) |

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

***Proposal 6:*** *For a CSI report associated with a Multi-TRP/panel NCJT measurement hypothesis configured by single CSI reporting setting,*

* ***Alt 1: the UE can be configured with pmi-FormatIndicator=widebandPMI and cqi-FormatIndicator=widebandCQI.***
* ***Alt 2: the UE cannot be configured with pmi-FormatIndicator=widebandPMI and cqi-FormatIndicator=widebandCQI simultanously.***

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| Company | Comments |
| **Mod** | The proposal is to address whether RAN1 shall support wideband reporting of MTRP CSI on PUCCH. If does, Table 6.3.1.1.2-7 in 38.212 and 38.214 shall be extended accordingly, subject to restrictions (if any). |
| QC | Do not support wideband PMI. The agreements so far are based on 2-part CSI. It is not appropriate to introduce additional solutions in the last meeting. As FL pointed out, 1-part UCI does not make sense due to large payload size of NCJT and the need for many zero-padding due to large payload variations. In addition, the benefit of wideband reporting for NCJT is questionable given that the goal of this item is more accurate CSI for NCJT scheme. |
| ZTE | Don’t support this proposal in the last meeting. The performance benefit is not justified. Agree with QC, wideband PMI is not desired to achieve accurate CSI estimation.  |
| vivo | Support to enhance wideband reporting of MTRP CSI with some restrictions if payload size is concerned by companies.For example, for PUCCH formats 3 or 4, or Mode 1 with X=0 or Mode 2. |
| Intel | We are open to consider the wideband PMI/CQI for MTRP assuming fixed payload size without any additional features.  |
| CATT | Agree with QC and ZTE. Do not support wideband PMI. |
| MediaTek | We are open to consider wideband PMI/CQI for NCJT CSI. |
| Samsung | We are also open to consider 1-part CSI but limiting the scope to Mode 1 with X=0 and Mode 2 may not be necessary.  |
| OPPO | Agree with QC and ZTE. We don’t think there would be benefit to support wideband reporting for NC-JT. |
| Nokia/NSB | We think there is an important use case for configuring WB periodic reporting on PUCCH with only one CSI per report.We are also fine with Samsung’s suggestion to limit this case to Mode 1, X=0, in which case padding is limited |

For UCI payload construction for CSI reporting option 1 with X=1/2, the following 3 alternatives were agreed for further study:

* 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.

Companies’ views on UCI payload construction can be summarized as following:

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| **Views** | **Companies** |
| **Alt 1 (9)** | InterDigital, Qualcomm, CATT, Intel, Samsung, Lenovo, MotM, DoCoMo, MediaTek |
| **Alt 2+ Alt 4 (9)** | ZTE, Vivo, Spreadtrum, LGE, DoCoMo, CMCC, Nokia, NSB, Ericsson |
| **Alt 4 (1)** | OPPO |

Companies preferring Alt1 have the following considerations:

* InterDigital think Alt 1 is more straightforward to assign a different priority number for the CSI corresponding to a different measurement hypothesis.
* Qualcomm proposes that Alt 2 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. This leads to large specification efforts and unnecessary discussions. In addition, Alt1 can also address the issues of CSI omission for CSI part 2 as well as CPU occupation in a consistent and unified way.
* CATT think if one CSI reporting setting corresponds to one CSI report that contains all measurement results of all hypotheses, one CSI report would include 4 PMI, 4 RI, 4 LI, 3 CQI, **modifying mapping order of CSI fields of one CSI report (i.e., Alt 4)** is unavoidable which leads to significant impact on T**able 6.3.2.1.2-3/4/5 in TS38.212**
* Samsung prefer to Alt 1 because the UCI payloads for NCJT and sTRP CSI reports are different.
* CATT, Lenovo and MediaTek think Alt 1 is more straightforward and would cause less specification impact, compared with Alt4.

Companies preferring Alt 2+ Alt 4 have the following considerations:

* ZTE, and CMCC proposes the X+1 CSI hypotheses per CSI Reporting Setting should be mapped to a single CSI report from RRC structure perspective.

In addition, ZTE, CMCC and LGE proposes a finer granularity for CSI omission in NCJT by modifying priority reporting levels for Part 2 CSI in case that the MTRP CSI report is overkilled due to X+1 sets CSI in the single CSI report.

* Vivo proposes that Alt 1 contradicts some restrictions in the current specification, e.g. a UE configured with DCI format 0\_1 or 0\_2 does not expect to be triggered with multiple CSI reports with the same CSI-ReportConfigId, etc. And whether or how to support CSI part2 omission priority level to prioritize STRP or NCJT measurement hypothesis is a key factor for defining a UCI mapping rule.
* Spreadtrum proposes that the priority equation in **Section 5.2.5 of 38.214 reflects the priority value of one CSI report, which is not based on the assumed transmission scheme. Thus, Alt 1 should not be considered for UCI payload construction.**
* Nokia and Ericsson propose that all CSIs of all measurement hypotheses should be mapped to one CSI report and the omission rule for Part 2 CSI should be enhanced to support partial omission.

Companies preferring Alt4 have the following considerations:

* OPPO think Alt 1 have the significant specification impact. In addition, the reported CSI may not be better than the dropped CSI because the priority is pre-defined. Therefore 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.

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

***Proposal 7:*** To confirm the order of UCI payload construction for reported CSIs, down-select one from the following:

* Alt 1: modify priority equation, i.e., Section 5.2.5 in 38.214 by introducing priority index corresponding to single-TRP or NCJT measurement hypothesis type
	+ It also implies that one CSI reporting setting for NCJT measurement reporting can contain multiple CSI reports each of which corresponds to one single-TRP or NCJT measurement hypothesis
* Alt2+Alt 4:
	+ 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.
	+ Alt 2: modifying the table of priority reporting levels for Part 2 CSI for prioritized single-TRP or NCJT measurement hypothesis type, i.e., Table 5.2.3-1 in 38.214
		- introducing the priority reporting level for Part 2 CSI associated with single-TRP or NCJT measurement hypothesis type in the order of:
			* Alt 2-1:
				+ Part 2 wideband CSI for CSI reports 1 to N;
				+ Part 2 subband CSI for report 1 to N: in the order of MTRP CSI, the first TRP CSI, and the second TRP CSI within each report
			* Alt 2-2:
				+ Part 2 wideband CSI for CSI reports 1 to N;
				+ Part 2 subband CSI for report 1 to N: even subbands associated with all measurement hypotheses and then odd subbands associated with all measurement hypotheses within each report
	+ It also implies that one CSI reporting setting for NCJT measurement reporting contains single CSI report which corresponds multiple single-TRP and/or NCJT measurement hypotheses.

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| Company | Comments |
| **Mod** | It is the leftover of RAN1 106bis discussion. However it seems that more companies are willing to support Alt 2 + Alt 4 as a compromise to address both issues of CSI omission with certain priorities and CSI payload construction together. Alt 2 has some subtle difference about whether UCI is arranged per hypothesis firstly or per even/odd subband firstly.  |
| QC | We support Alt1 only. As it is clear from the proposal itself, Alt1 can address all issues with minimum spec change. In our contributions, we explained the details of why Alt1 has much less spec impact compared to the combination of Alt2+Alt4. We also explained why the claim from some companies that changing priority formula has many impacts is not accurate.In addition, we believe treating each reported CSI hypothesis as a “CSI report” is more friendly to UE implementation since logically UE can treat this as if different “CSI report settings” are configured and the rest follows legacy from processing / implementation point of view.  |
| ZTE | We will be flexible for the options as all of them works well, the difference is just spec change. Our first preference is still that, one CSI report corresponds to one CSI report config. Otherwise, if we use Alt 1, linking among multiple CSI reports should be set up. One question for Alt 2-2, can someone clarify what kind of change is needed for the omission table in 38.214? If not, it will conflict with main bullet of Alt 2.  |
| vivo | Support Alt2+Alt4. We can concentrate on UCI mapping table in 38.212 and/or part 2 CSI omission table as it is clear and simple to be based on the CSI design principle as Rel-15/16 that one CSI reporting setting for NCJT measurement reporting contains single CSI report which corresponds multiple single-TRP and/or NCJT measurement hypotheses.It is too risky to deal with Alt 1 which may impact many places scattering in different specs. |
| CATT | Support Alt 1 for less specs impact. |
| MediaTek | Our preference is Alt 1. We share a similar view as QC that treating each reported CSI hypothesis as a distinct CSI report is friendly to UE implementation. In our tdoc, we identify the required changes of Alt 1 in TS 38.212, 38.213, and 38.214, which are clearly manageable.  |
| Samsung | Slightly prefer Alt1.  |
| OPPO | We are flexible to both alternatives. However, for Alt 2, if we go with Alt 2-2, what is the impact to the table of priority reporting levels for Part 2 CSI? We think it is actually Alt 4 only. |
| Nokia/NSB | Prefer Alt 2+4 to keep the rule that 1 CSI report config corresponds to 1 CSI report and avoid unnecessary spec changes, such as those on overlapping CSI reports (213) and others that may be needed after a deeper scrutiny. For example, the description of CSI-ReportConfig IE in 331 would also need to be changed:*CSI-ReportConfig*The IE *CSI-ReportConfig* is used to configure a periodic or semi-persistent report sent on PUCCH on the cell in which the *CSI-ReportConfig* is included, or to configure a semipersistentor aperiodic report sent on PUSCH triggered by DCI received on the cell in which the *CSI-ReportConfig* is included (in this case, the cell on which the report is sent isdetermined by the received DCI). See TS 38.214 [19], clause 5.2.1.@ZTE: regarding Alt 2-2, the changes to Table 5.2.3-1 are minimal, as follows:

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| Priority 0:For CSI reports 1 to , Group 0 CSI for CSI reports configured as 'typeII-r16' or 'typeII-PortSelection-r16'; Part 2 wideband CSI for all CSIs in all CSI reports configured otherwise |
| Priority 1:Group 1 CSI for CSI report 1, if configured as 'typeII-r16' or 'typeII-PortSelection-r16'; Part 2 subband CSI of even subbands for all CSIs in CSI report 1, if configured otherwise |
| Priority 2:Group 2 CSI for CSI report 1, if configured as 'typeII-r16' or 'typeII-PortSelection-r16'; Part 2 subband CSI of odd subbands for all CSIs in CSI report 1, if configured otherwise |
| Priority 3:Group 1 CSI for CSI report 2, if configured as 'typeII-r16' or 'typeII-PortSelection-r16'; Part 2 subband CSI of even subbands for all CSIs in CSI report 2, if configured otherwise |
| Priority 4:Group 2 CSI for CSI report 2, if configured as 'typeII-r16' or 'typeII-PortSelection-r16'. Part 2 subband CSI of odd subbands for all CSIs in CSI report 2, if configured otherwise |
| ⁞ |
| Priority :Group 1 CSI for CSI report , if configured as 'typeII-r16' or 'typeII-PortSelection-r16'; Part 2 subband CSI of even subbands for all CSIs in CSI report , if configured otherwise |
| Priority :Group 2 CSI for CSI report , if configured as 'typeII-r16' or 'typeII-PortSelection-r16'; Part 2 subband CSI of odd subbands for all CSIs in CSI report , if configured otherwise |

 |

It has been agreed that the calculation of a CSI associated with NCJT measurement hypothesis occupies 2 CPUs. For CSI reporting Mode 1 with X=1/2 or Mode 2, the number of required CPUs is very large and may be beyond the number of CPUs supported by the typical commercial chipset. Hence Qualcomm, Nokia, and LGE propose to enhance the CPU occupation rules.

***Proposal 8-1:*** For CSI measurement associated with a *CSI-ReportingConfig* for NCJT, down-select one alternative from the following:

* Alt 1: Support enhanced CPU occupancy, e.g. to prioritize given measurement hypothesis or CSI(s) in a CSI report
* Alt 2: Enhancement on the CPU occupancy for NCJT is not supported in Rel-17

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| Company | Comments |
| **Mod** | Enhancement of CPU occupancy has been discussed before. In RAN1 107, Proposal 8-1 and associated 8-2 can be further confirmed after Proposal 7 since detailed solution of 8-2 seems to be still diverse.  |
| QC | We want to point out that the proposal should be only relevant for Option 1 with X=1 or 2. In the case of Option 2, we do not have separate groups of hypotheses (all CSI hypotheses are evaluated together), and the CPU occupation cannot be separated. Under this assumption, we support Alt1. |
| ZTE | We prefer Alt 2 for simplicity. Also agree with QC, the discussion is only for Option 1 with X=1 or 2. |
| vivo | Support Alt2.According to current spec 38.214, if the number of unoccupied CPUs is smaller than the number of required CPUs of N CSI reports, the UE is not required to update the N-M requested CSI reports with lowest priority. In our view, it is just "not required" but the UE can do whatever to update partial CSI hypotheses in the enhanced CSI report. |
| Intel | Prefer Alt 2. |
| CATT | Prefer Alt 2. |
| MediaTek | Support Alt 1. Agree with FL that Proposal 8-1 can be deferred after we have an outcome from Proposal 7.  |
| CMCC | Prefer Alt 2. |
| Samsung | We are open for discussion. We would like to ask QC what the assumptions are for Option 2. For Option 2, is it assumed that the CPU occupancy is based on the total CPU requirement of all measurement hypotheses, i.e., 2*N*+*M*?  |
| OPPO | Prefer Alt 2. Furthermore, if we agree on Alt 1 for proposal 7, we don’t need this proposal at all. |
| Nokia/NSB | Agree with QC and ZTE that this discussion is limited to Mode 1 for X=1,2. We are open to discuss different solutions. The one we proposed introduces X+1 separate CPU occupations.In case we cannot reach agreement, we are also fine with Alt 2. |

***Proposal 8-2:*** To confirm the CPU occupancy rule for CSI measurement associated with a *CSI-ReportingConfig* for NCJT, down-select one from the following:

* Alt 1: if CSI report is associated with a *CSI-ReportingConfig* with reporting 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. The definition of can be:
	+ Alt 1-1: , with , alongside the legacy such that
		- , , for
		- , , , for ,
	+ Alt 1-2: , with , alongside the legacy such that
		- , , for or 2
* Alt 2: 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 to CPU occupation.

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| --- | --- |
| Company | Comments |
| **Mod** | Enhancement of CPU occupancy has been discussed before. In RAN1 107, Proposal 8-1 and associated 8-2 can be further confirmed after Proposal 7 since detailed solution of 8-2 seems to be still diverse. The main difference of Alt 1-1 and Alt 1-2 in Proposal 8-2 is that Alt 1-2 is to prioritize single-TRP CSI with O(A,0), whereas Alt 1-1 is to prioritize CSI in a finer order of NCJT CSI with O(A,0), the first Single-TRP CSI with O(A,1) and the second Single-TRP CSI with O(A,2).  |
| QC | We support Alt2 as it can address this issue as well as the issue of Proposal 7. Similar to our comment in Proposal 8-1, it should be clarified that the proposal is applicable only to Option 1 with X=1 or 2. |
| ZTE | It is related with proposal 7. For example, if Alt 2-2 in proposal 7 is supported, we don’t see the necessity to optimize CPU occupancy within one CSI report as CSI omission granularity is CSI report level.  |
| vivo | Not needed.Agree with ZTE that Proposal 8-2is related with proposal 7 and Proposal 8-1. For Proposal 8-1, we agree with Alt2. |
| Intel | Same view as ZTE. |
| CATT | Support Alt 2. |
| MediaTek | We support Alt 2. |
| CMCC | Not support.We have same view as ZTE. |
| Samsung | We have clarification question. For Alt 1-2, shouldn’t it be , , for or 2. |
| OPPO | Not support. Furthermore, if we agree on Alt 1 for proposal 7, we don’t need this proposal at all. |
| Nokia/NSB | Alt 1 is our first preference. We can discuss this proposal, if needed, after P7 so a decision on Alt 2 will be already made |

## 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:



Nokia points out that the parameter *sharedCMR* is missing in the latest vesion of RRC parameters, i.e., R1-2110573. In addition, Nokia proposes to define the new NCJT RI restriction parameter as a bitmap of size 4 and add the corresponding description in 38.214.

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| Company | Comments |
| **Mod** | This table is to address any RRC related comments or potential issues that may need RAN1’s confirmation, if there is any other outstanding. We may NOT need official RAN1 agreementsif it is common understanding so that this section can be served as reminding points for next round of RRC/specification update. Some notes in my understanding are * Note 1: Capture *sharedCMR* in next round of RRC update
	+ [FL]: It was postponed due to an error/typo.
* Note 2: How to design NCJT RI restriction parameter is up to RAN2 and how to capture associated description in 38.214 is up to 38.214 editor thereafter.
	+ [FL]: this might be a maintenance issue.
 |
| ZTE | Support two notes from FL. |
| CATT | Support. |
| Samsung | Support |
| Nokia/NSB | Support FL’s notes |

## Others

Besides above issues, some companies provide additional proposals related to Rel-17 Multi-TRP CSI enhancement, which are summarized as following. The most proposals have been widely discussed before. Alternatively the proposal can be discussed in UE capability session or maintenance.

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| **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. |
| 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 |
| 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.
 |
| CSI computation delay | ZTE | No changes of value on Z and Z’ |
| Spreadtrum | Support to introduce new CSI computation delay requirement for NC-JT CSI. |
| OPPO | For CSI computation delay requirement associated with a CSI-ReportingConfig for a NCJT measurement hypothesis, consider to introduce relaxed values on Z and Z’. |
| LGE | Support relaxed values on Z and Z’ for CSI computation delay requirement associated with a CSI-ReportingConfig for a NCJT measurement hypothesis. |
| Lenovo, MotM | CSI computation delay relaxation is supported for multi-TRP CSI reporting |
| One or multiple allowed RI combinations indicated by RI restriction for NCJT | ZTE | Support multiple candidate values of X and Y for rank restriction. |
| Vivo | Support multiple candidate values of X and Y, i.e. multiple rank values can be reported for all single-TRP measurement hypotheses and multiple rank groups can be reported for all NCJT measurement hypotheses |
| Samsung | For a CSI report associated with a Multi-TRP/panel NCJT measurement hypothesis configured by single CSI reporting settings support multiple RI candidate values X and Y for Single-TRP and Multi-TRP measurement hypotheses, respectively. |
| Lenovo, MotM | For CSI reporting Mode 1, X=0, support one RI restriction with 4 bits corresponding to all possible RI pairs of NCJT hypothesis. Otherwise, support two RI restrictions with 4 bits, 8 bits, respectively, corresponding to all possible RI pairs for NCJT hypothesis, and all possible RI for single-TRP transmission hypothesis, respectively |
| CSI enhancement for M-DCI based M-TRP transmission  | 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.
 |
| CATT | For CSI enhancement on M-DCI for NCJT, 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).
 |
| Non-PMI based feedback for MTRP  | CATT | For CSI measurement associated to a reporting setting CSI-ReportConfig for NCJT measurement hypothesis, non-PMI based feedback should be supported in Rel-17. |
| Intel | 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 |
| Samsung | For NC-JT CSI reporting enhancement, support following* Non-PMI CSI reporting
* Minimize the remaining specification work by adopting Non-PMI CSI without non-PMI-PortIndication configuration.
 |
| Levono, MotM | Non-PMI CSI reporting is not supported for multi-TRP CSI framework |
| Ericsson | Non-PMI CSI reporting for NCJT measurement hypothesis is not supported in Rel-17. |
| UE capability of X=2 | Samsung | For two CMRs within a same CMR pair configured for NCJT measurement hypothesis to be restricted within X continuous slot(s) without DL/UL switch between two CMRs:* Do not support UE capability for X=2
 |
| DoCoMo | For CSI measurement associated with a CSI-ReportingConfig for NC-JT, two CMRs within the same CMR pair are restricted within X continuous slot(s) without DL/UL switch between two CMRs. No need to define UE capability for X. |
| Ericsson | Support two CMRs within the same CMR pair configured for NCJT measurement hypothesis to be restricted within X continuous slot(s) without DL/UL switch between two CMRs, where X can be either 1 or 2, and where X=2 is not a separate UE capability. |
| 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 |
| Additional restriction on CMRs for NCJT | MediaTek | **For CSI measurement associated with a *CSI-ReportingConfig* for NCJT,** the UE expects that the two CSI-RS resources for channel measurement in a Resource Pair and any DL signal in a time interval between the two CSI-RS resources are resource-wise QCLed with respect to 'typeD'. |
| Normalization for two PMIs of NCJT CSI | MediaTek | For an NCJT measurement hypothesis, decide the normalization for its two precoders and :* Alt 1: (no specification change)
* Alt 2:
* Alt 3: The power of each column in and is normalized to .
* is the Frobenius norm
 |

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| Company | Comments |
| **Mod** | The table is to check whether there is any essential issue for Rel-17 Multi-TRP CSI enhancement.  |
| CATT | We sincerely suggest non-PMI CSI reporting for Rel-17 MTRP CSI enhancement. At least for TDD system, the system can benefit from accurate CSI feedback and lower feedback overhead. Meanwhile, the complexity with precoder selection at UE side can be avoided.For less specs impact at this stage of Rel-17, the legacy RRC parameter *non-PMI-PortIndication* can be reused, and the only two enhancements that impact the current specs might be CSI-RS port indication and reference resource for CQI calculation. * For CSI-RS port indication without *non-PMI-PortIndication*, we can accept the following proposal in last meeting for less specs impact.
	+ Alt 1: 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.
* For reference resource for CQI calculation with or without non-PMI-PortIndication, the similar modifying as Rel-17 MTRP based PMI feedback can be used that the ports of PDSCH is still divided into two sets and each set of PDSCH ports can be corresponding to the sets of CSI-RS ports from the two paired CMRs respectively.
 |
| MediaTek | Additional restriction on the two CMRs is needed in FR2 as a different “QCL-TypeD” usually triggers gain change in the AGC module and thus incurs random phase rotation. If the UE disallows any gain change between the two CMRs, then the reception performance of the DL signal in between can be degraded. Our proposed restriction can be slightly relaxed as the following:“**For CSI measurement associated with a *CSI-ReportingConfig* for NCJT,** the UE expects that any DL signal in a time interval between the two CSI-RS resources for channel measurement in a Resource Pair are resource-wise QCLed with respect to 'typeD' with at least one of the two CSI-RS resources.” |

# Proposals for Online/Offline Discussion

TBD

# Work Plan

TBD

# References

1. 3GPP R1-2110787, CSI enhancements on MTRP and FDD in Rel-17, Huawei, HiSilicon, RAN1#107e, E-meeting, November 11th –19th, 2021.
2. 3GPP R1-2110954, CSI enhancements for Multi-TRP and FR1 FDD reciprocity, ZTE, RAN1#107e, E-meeting, November 11th –19th, 2021.
3. 3GPP R1-2110996, Remaining issues on MTRP CSI and partial reciprocity, vivo, RAN1#107e, E-meeting, November 11th –19th, 2021.
4. 3GPP R1-2110767, Remaining Details on CSI Enhancements for NCJT MTRP, InterDigital, Inc., RAN1#107e, E-meeting, November 11th –19th, 2021.
5. 3GPP R1-2111090, Discussion on CSI enhancements for M-TRP and FR1 FDD reciprocity, Spreadtrum Communications, RAN1#107e, E-meeting, November 11th –19th, 2021.
6. 3GPP R1-2111171, CSI enhancements on Type II PS codebook and multi-TRP, Fraunhofer IIS, Fraunhofer HHI, RAN1#107e, E-meeting, November 11th –19th, 2021.
7. 3GPP R1-2111227, Remaining issues on CSI enhancement, CATT, RAN1#107e, E-meeting, November 11th –19th, 2021.
8. 3GPP R1-2111285, CSI enhancements for M-TRP and FR1 FDD reciprocity, OPPO, RAN1#107e, E-meeting, November 11th –19th, 2021.
9. 3GPP R1-2111384, Views on CSI enhancements, Sony, RAN1#107e, E-meeting, November 11th –19th, 2021.
10. 3GPP R1-2111459, CSI enhancements for Rel-17, LG Electronics, RAN1#107e, E-meeting, November 11th –19th, 2021.
11. 3GPP R1-2111482, Remaining issues on CSI for MTRP and FDD, Intel, RAN1#107e, E-meeting, November 11th – 19th, 2021.
12. 3GPP R1-2111603, Enhancements on CSI reporting for Multi-TRP, CMCC, RAN1#107e, E-meeting, November 11th – 19th, 2021.
13. 3GPP R1-2111689, Discussion on CSI enhancement for multi-TRP transmission, NEC, RAN1#107e, E-meeting, November 11th – 19th, 2021.
14. 3GPP R1-2111723, Views on Rel-17 CSI enhancements, Samsung, RAN1#107e, E-meeting, November 11th – 19th, 2021.
15. 3GPP R1-2111859, Views on Rel. 17 CSI enhancements, Apple, RAN1#107e, E-meeting, November 11th –19th, 2021.
16. 3GPP R1-2111941, CSI enhancements for multi-TRP and FDD reciprocity, Lenovo, Motorola Mobility, RAN1#107e, E-meeting, November 11th –19th, 2021.
17. 3GPP R1-2112095, Discussion on CSI enhancements, NTT DOCOMO, INC., RAN1#107e, E-meeting, November 11th –19th, 2021.
18. 3GPP R1-2112182, Enhancement on CSI measurement and reporting, Nokia, Nokia Shanghai Bell, RAN1#107e, E-meeting, November 11th –19th, 2021.
19. 3GPP R1-2112202, CSI enhancements: MTRP and FR1 FDD reciprocity, Qualcomm Incorporated, RAN1#107e, E-meeting, November 11th –19th, 2021.
20. 3GPP R1-2112281, CSI enhancement for NCJT and FR1 FDD reciprocity, MediaTek Inc, RAN1#107e, E-meeting, November 11th –19th, 2021.
21. 3GPP R1-2112322, CSI enhancements for Multi-TRP and FR1 FDD reciprocity, Ericsson, RAN1#107e, E-meeting, November 11th –19th, 2021.

# Appendix

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

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

|  |  |
| --- | --- |
| **Companies** | **Proposals** |
| **Huawei, HiSilicon** | ***Proposal 1: For N3=3, FD bases used for quantization is limited within a window with size .******Proposal 2: The parameter combinations with =0.75 (i.e. and ) should not be applied to and .******Proposal 3: Support Alt1, report Port indicator, SCI, and FD indicator in Group 0.******Proposal 4: Support Alt2 with mapping coefficients firstly across layers, secondly across port indices, and thirdly across FD basis indices, i.e., the priority value is given by .*** |
| **ZTE** | ***Proposal 6:*** *Refine the definition of K1 as to ensure K1 are even integers.****Proposal 7:*** *For UCI design of FeType II PS codebook, support the following** *For UCI grouping, support Alt 3: Three groups of UCI Part 2 for Rel-16 PS codebook is reused for Rel-17 PS codebook enhancement except that the starting position of the FD basis window is not needed.*

*For mapping order of coefficients, support 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 .* |
| **vivo** | Proposal 10:* *There is no need for further restrictions/dependences for parameter combinations.*

Proposal 11:* *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, e.g., when alpha = 3/4.*

**Proposal 12:*** *Support Alt2 and a remapping of the selected ports, e.g., interlacing the selected ports, can be applied before mapping to UCI.*

**Proposal 13:*** *When N3 = 3 and N = 4, it is up to UE implementation to perform FD bases selection without specification impact.*

**Proposal 14:*** *UE can use partial CSI-RS ports to search target tap 0 to reduce the complexity.*
	+ gNB can map SD-FD bases to CSI-RS ports with a predetermined order or indicating the ports for timing calibration.
 |
| **Spreadtrum Communications** | ***Proposal 9: Support Alt 3, i.e. three groups of UCI Part 2 for Rel-16 PS codebook is reused for Rel-17 PS codebook enhancement except that the starting position of the FD basis window is not needed.******Proposal 10: Support Alt2, i.e. support mapping coefficients firstly across layers, secondly across port indices, and thirdly across FD basis indices.******Proposal 11: Regarding the case when N3=3, only N=2 is supported.*** |
| **Fraunhofer IIS, Fraunhofer HHI** | ***Proposal 1: Support mapping coefficients firstly across layers, secondly across port indices, and thirdly across FD basis indices, i.e., the priority value is given by .*** ***Proposal 2: Port permutation with respect to the strongest coefficient shall not be supported.*** ***Proposal 3: The port permuation function for Rel. 17 PS CB is given by*** ***Proposal 4: Prefer Alt 3 i.e., three groups of UCI Part 2 for Rel-16 PS codebook is reused for Rel-17 PS codebook enhancement except that the starting position of the FD basis window is not needed.*** |
| **CATT** | ***Proposal 1:*** * ***The parameter combination, and should be not applicable to P = 32.***
* ***The same ports out of P/2 ports for both polarizations are selected.***

***Proposal 2: When N3 = 3, N = 2 or 4 can be configured, and the last FD basis in the window is not used by UE for N=4.******Proposal 3: The contents of Part 1 for Rel-17 PS codebook are same with that of Part 1 for Rel-16 Type II PS codebook.******Proposal 4: Alt 1, i.e., report port indicator, SCI, and FD indicator in Group 0, is support for UCI part II design, and the other contents of Part 2 is same to Rel-16 Type II port selection codebook except that starting position of the FD basis window is not needed***.***Proposal 5: The following two alternatives can be considered for the priority of mapping coefficients:**** ***Alt 3: Support mapping coefficients firstly across layers, secondly across port indices, and thirdly across FD basis indices, i.e., the priority value is given by , where , and .***
* ***Alt 4: Support mapping coefficients firstly across port indices, secondly across layers, and thirdly across FD basis indices, i.e., the priority value is given by , where , and .***
 |
| **OPPO** | ***Proposal 1: For Rel-17 PS codebook, Group 0 includes port indicator, SCI and FD indicator******Proposal 2: Support SD permutation for Rel-17 PS codebook*** |
| **Sony** | ***Proposal 1: Support Alt 3, i.e., “Alt 3: Support mapping coefficients firstly across layers, secondly across port indices, and thirdly across FD basis indices, i.e., the priority value is given by ”, when the permutation function is designed so as to minimize the possibility of omitting all coefficients of a single polarization.***  |
| **LG Electronics** | ***Proposal 5: Support Alt 3 for UCI part II of Rel-17 PS codebook.******- Alt 3: Three groups of UCI Part 2 for Rel-16 PS codebook is reused for Rel-17 PS codebook enhancement except that the starting position of the FD basis window is not needed******Proposal 6: Support Alt 2 for the priority of mapping coefficients for Rel-17 PS codebook.******- 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***  |
| **Intel** | ***Proposal 1:*** * *Support the following groups for partial UCI omission for Rel-17 PMI codebook*
	+ *Group 0: Port indicator, SCI, FD indicator, bitmap*
	+ *Group 1: ceil(KNZ/2) higher priority coefficients*
	+ *Group 2: floor(KNZ/2) lower priority coefficients*

***Proposal 2****:* * *Support mapping coefficients firstly across layers, secondly across port indices, and thirdly across FD basis indices*
	+ *Permutation of port indexes can be considered to avoid omission of all coefficients per polarization*

***Proposal 3****:* * *If RRC parameter corresponding to N is configured as 4 with N3 = 3 then N is equal to 3*

***Proposal 4****:* *24 PRB BWP is not supported for new Rel-17 Type II PMI codebook* |
| **Samsung** | ***Proposal 8****: When M=1, the description on includes one of the following:** *Alt1: a single precoding matrix is indicated by the PMI*
* *Alt2: N3 precoding matrices indicated by the PMI, but they are the same when M=1*

***Proposal 9****: support Rel.17 codebook for BWP size < 24 PRBs with the current restriction in the specification, i.e. support only WB CSI implying M=1****Proposal 10****: Regarding M = 2, UE reporting its capability to support M = 2 shall also report whether it supports M=2 for P > 12 CSI-RS ports****Proposal 11****: when , the value of N>2 is N=3, which is achieved by setting the window size as* ***Proposal 12****: Regarding Rel.17 codebook parameters,** *support*
* *specify the following restrictions on the parameter combinations*
	+ *can’t be configured when or 12*
	+ *allowed rank can’t be 3 or 4 when and*

***Proposal 13****: for Rel.17 codebook, reuse two-part UCI comprising part 1 and part 2** *UCI part 1 is the same as in Rel. 16*
* *For UCI part II,*
	+ *support Alt 1 and Alt 2 following from RAN1#106b-e:*
		- *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*
	+ *Re coefficient mapping, support the following from RAN1#106b-e:*
		- *1st preference (Rel. 16): Alt 2*
			* mapping coefficients firstly across layers, secondly across port indices, and thirdly across FD basis indices, i.e., the priority value is given by
		- *2nd preference (if need and benefit can be justified): Alt 3*
			* mapping coefficients firstly across layers, secondly across port indices, and thirdly across FD basis indices, i.e., the priority value is given by *, where the SD permutation is based on even and odd SD indices, i.e. 0, 2, 4, ….., 1, 3, 5,.*
 |
| **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 the UCI part II of Rel-17 PS codebook, in terms of how to define the three groups for CSI omission, support to reuse the similar design as Rel-16 Type II PS codebook*** * ***Three groups of UCI Part 2 for Rel-16 PS codebook is reused for Rel-17 PS codebook enhancement except that the starting position of the FD basis window is not needed***
* ***Support mapping coefficients firstly across layers, secondly across port indices, and thirdly across FD basis indices, i.e., the priority value is given by , where is the layer index, is the port index, is the FD basis index, is the RI (number of layers), and is the number of selected ports.***
 |
| **NTT DOCOMO, INC.** | **Proposal 5*** When M=2, following two options can be considered for N3=3 case. Option 2 is preferred.
	+ Option 1: UE is not expected to be configured with a N larger than N3.
	+ Option 2: When configured N is larger than N3=3, the N actually used is min{N, N3}.

**Proposal 6*** Regarding Wf OFF and Wf ON with Mv=1, support Alt.1.
	+ 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*** For UCI part II of Rel-17 PS codebook, support Alt 1 and Alt 3.
	+ Alt 1: Report Port indicator, SCI, and FD indicator in Group 0.
	+ Alt 3: Three groups of UCI Part 2 for Rel-16 PS codebook is reused for Rel-17 PS codebook enhancement except that the starting position of the FD basis window is not needed.

**Proposal 8*** For the priority of mapping coefficients for Rel17 PS codebook, support Alt 2.
	+ 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 .
 |
| **Lenovo, Motorola Mobility** | 1. For UCI Part II content, support a three-group decomposition of UCI Part II for FeType-II codebook, where Port indicator, SCI, and FD indicator are reported in Group 0, the bitmap(s) and the first of two partitions of the coefficient information are reported in Group 1, and the second of two partitions are reported in Group 2 od UCI Part II
2. Support Alt3 mapping coefficients firstly across layers, secondly across permuted port indices, and thirdly across FD basis indices, where an example of a port indices permutation function is
3. The parameter *paramCombination-r17* configures the supported parameter combination values of the parameters (α, *Mv*, *β*, *R*)
 |
| **Nokia, Nokia Shanghai Bell** | **Proposal 1 Regarding the case , the general condition can be added in the definition of the FD basis vector , which is applicable for any value of , and . There is no need to reduce the bitwidth of the index by one bit for the special case of , when , and , as this small number of subbands is a very infrequent case.****Proposal 2 Regarding the mapping of UCI Part 1, support Alt 1 as the FD basis indicator is needed, when reported, to determine the precoder associated with the strongest coefficient.****Proposal 3 Regarding the mapping of coefficients in the UCI field, support Alt 3 by reordering the port index for each layer, starting from the index of the strongest coefficient, , and alternating between the two polarisations:** **Proposal 4 Support a restriction of parameter combination to .** |
| **Qualcomm** | **Proposal 3: Three groups of UCI Part 2 for Rel-16 PS codebook is reused for Rel-17 PS codebook enhancement except that the starting position of the FD basis window is not needed.****Proposal 4: UCI group packing order of UCI Part 2 for Rel-16 PS codebook, and the UCI omission order of UCI part 2 for Rel-16 PS codebook, are reused for Rel-17 PS codebook enhancement.****Proposal 5: 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.****Proposal 6: Parameter combinations {M,alpha,beta}={1,1,1} and{M,alpha,beta}={2,1,1/2} are only applied to <= 24 ports, while parameter combination {M,alpha,beta}={2,1,3/4} is applied to <=16 ports.****Proposal 7: For Rel-17 Type II port-selection codebook, only CSI reporting on PUSCH is supported.** |
| **MediaTek Inc** | **Proposal 6**: Parameter combinations and are not applied for CSI-RS ports .**Proposal 7**: To accommodate parameter combinations with for 4 and 12 CSI-RS ports, the port selection matrix may be slightly modified to select ports out of ports for each polarization.**Proposal 8**: 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.**Proposal 9**:For the Rel-17 codebook, Group 1 and Group 2 CSI feedback coefficients may be kept the same as Rel-16 eType II with the exception that FD indicator is placed in Group 0**Proposal 10**: For priority rule, support Alt 1, i.e., 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 **Proposal 11**: To prevent dropping of second polarization port indices, a simple grouping of port indices across polarizations may be defined such that the priority for port indices within the group is the same. Such a rule is to be applied to Alt 1. |
| **Ericsson** | [*Proposal 1* Support *Alt 1: Report Port indicator, SCI, and FD indicator in Group 0*](#_Toc87051382)[Proposal 2 Support Alt 1, the coefficients are mapped firstly across port indices, secondly across FD basis indices, and thirdly layers.](#_Toc87051383)[Proposal 3 The value of is determined via](#_Toc87051384)  |

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

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

|  |  |
| --- | --- |
| **Companies** | **Proposals** |
| **Huawei, HiSilicon** | ***Proposal 5: For a CSI report associated with a Multi-TRP/panel NCJT measurement hypothesis configured by single CSI reporting setting, 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.*** |
| **ZTE** | ***Proposal 1:*** *For CSI computation delay requirement associated with a CSI-ReportingConfig for a NCJT measurement hypothesis, support Alt 2, i.e., No changes of values on Z and Z’** of table 5.4-2 in 38.214 is used for NCJT CSI

***Proposal 2:*** *The X+1 CSI hypotheses per CSI Reporting Setting for NCJT and STRP are mapped to a single CSI report. It also implies that one CSI reporting setting for NCJT measurement reporting contains single CSI report which corresponds multiple single-TRP and/or NCJT measurement hypotheses.****Proposal 3:*** *Support Alt 4 and 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.*

***Proposal 4:*** *Support* ***multiple candidate values of X and Y for rank restriction.******Proposal 5:******For a CSI report associated with a Multi-TRP/panel NCJT measurement hypothesis configured by single CSI reporting setting, support Alt 2, i.e.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.*** |
| **vivo** | **Proposal 1:*** *The default maximum number of CMR is 2 with Rel-17 MIMO UE capability for MTRP CSI measurement.*

Proposal 2:* *For the number of CSI-IM resources M = M1+M2, where M is the number of CMRs for STRP measurement hypotheses configured in a CSI-RS resource set, M1, M2 are the numbers of CMRs for STRP measurement hypothesis in two CMR groups respectively*
	+ *For Mode 1 with X = 0, M1 =M2 = 0 and K1 = K2 = N.*
	+ *For Mode 1 with X = 1, 2 or Mode 2,*
		- *if CMR sharing is enabled, M1 = K1, M2 = K2*
		- if CMR sharing is disabled, M1 = K1–N, M2 = K2–N.

Proposal 3:* *Support multiple candidate values of X and Y, i.e. multiple rank values can be reported for all single-TRP measurement hypotheses and multiple rank groups can be reported for all NCJT measurement hypotheses.*
* *Support Alt2, i.e. two CBSRs can be configured per CodebookConfig, whereas one CBSR is applied to one CMR group in a CMR resource set respectively.*

Proposal 4:* *A CSI reporting setting configured with enhanced MTRP CSI reporting corresponds to a CSI report.*
* *Support concentrating on the UCI mapping order tables in TS 38.212 and omission table in TS 38.214 without touching any other places in the spec.*

Proposal 5:* *The part 2 omission priority (if supported) and the UCI mapping for a MTRP CSI report should have same order.*

Proposal 6:* *Support to enhance the CSI reporting mechanism when PMI and CQI granularity are wideband.*

Proposal 7:* *Support to confirm the work assumption in RAN1#103-e, i.e., Option 1.*

Proposal 8:* *Support to associate two CSI reporting settings with CMRs configuration same as Cat1 for Cat2 configuration.*

Proposal 9:* *Support to specify rules on how to divide and map the generated UCI into two associated reports in Cat2.*
 |
| **InterDigital, Inc.** | ***Proposal 1****: Support sharing of RI/PMI for sTRP and NCJT CSI. The sharing can be RRC configured on/off.* ***Proposal 2****: Support Alt 1; modify priority equation, i.e., Section 5.2.5 in 38.214.*  |
| **Spreadtrum Communications** | ***Proposal 1: Regarding CBSR, support Alt 2.******Proposal 2: Support to introduce new CSI computation delay requirement for NC-JT CSI.******Proposal 3: To confirm the order of UCI payload construction for reported CSI, support Alt4 and Alt2.******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 Part1;***
* ***2 PMIs (if required) should be include into Part2;***

***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.*** |
| **CATT** | ***Proposal 6: For CSI measurement associated to a reporting setting CSI-ReportConfig for NCJT measurement hypothesis, non-PMI based feedback should be supported in Rel-17.******Proposal 7: For non-PMI based feedback, when the UE is configured with higher layer parameter non-PMI-PortIndication, 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 total rank.***
	+ ***For total rank=2 (i.e., v1=1, v2=1), and are port indices from resource 1 and 2 respectively.***
	+ ***For total rank=3 while v1=2 and v2=1, and  are sets of port indices from resource 1 and 2 respectively.***
	+ ***For total rank=3 while v1=1 and v2=2,  and  are sets of port indices from resource 1 and 2 respectively.***
	+ ***For total 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 8: For non-PMI based feedback, when the UE is not configured with higher layer parameter non-PMI-PortIndication, one of the following alternatives is needed.**** ***Alt 1: 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.***
* ***Alt 2: The CSI-RS port indices of the CMR pair are associated with the total rank.***
	+ ***For total rank=2 (i.e., =1, =1), and are ports indices from resource 1 and 2 respectively.***
	+ ***For total rank=3 while =2, =1, and*** ***are sets of ports indices from resource 1 and 2 respectively.***
	+ ***For total rank=3 while =1, =2, and***  ***are sets of ports indices from resource 1 and 2 respectively.***
	+ ***For total rank=4 (i.e., =2, =2), and*** ***are sets of ports 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 9: For non-PMI based feedback, CSI reference resource definition the assumption of mapping between layers and CSI-RS ports should be specified and the rules elaborated in section 3.1.1 can be considered.*** ***Proposal 10: For a CSI report associated with a Multi-TRP/panel NCJT measurement hypothesis configured by single CSI reporting setting, 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.******Proposal 11: For reporting CSI of X multi-TRP/panel NCJT and one single-TRP measurement hypotheses configured by single CSI reporting setting (i.e. option 1), one CSI reporting setting contains multiple CSI reports and each CSI report corresponding to a hypothesis. Besides, modifying priority equation, i.e., Section 5.2.5 in 38.214 is preferred.******Proposal 12: 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 13: 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.***
 |
| **OPPO** | ***Proposal 3: 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 4: 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***
* ***Support Alt4: 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***
 |
| **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: Introduce additional priority rule among CPUs for NCJT CSI and STRP CSI(s), and support partial CSI update which does not exceed the number of unoccupied CPUs.******- e.g., if and , partial CSI for STRP hypothesis is updated.******Proposal #3: Support Alt2 for per-TRP CBSR configuration******- Alt 2: 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.******Proposal #4: Support relaxed values on Z and Z’ for CSI computation delay requirement associated with a CSI-ReportingConfig for a NCJT measurement hypothesis.*** |
| **Intel** | ***Proposal 5***: * *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 6***: * *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 7***: * *Support MAC-CE based update of CMRs for NCJT and STRP*

***Proposal 8****:* * *Support two CBSRs configured per CodebookConfig, whereas one CBSR is applied to one CMR group in a CMR resource set respectively*

***Proposal 9****:* * *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*
	+ *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.*

***Proposal 10****:* * *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)* |
| **CMCC** | ***Proposal 1: Support Alt 2 for a CSI report associated with a Multi-TRP/panel NCJT measurement hypothesis configured by single CSI reporting setting.**** ***Alt 2: 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.***

***Proposal 2: Alt 4 should be supported to confirm the order of UCI payload construction for reported CSIs.**** ***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: Alt 2 can be considered to enhance the omitting rule of Part 2 CSI.******Alt 2: modify the table of priority reporting levels for Part 2 CSI, i.e., Table 5.2.3-1 in 38.214*** |
| **NEC** | ***Proposal: Considering CBSR, support Alt 2 to reduce UE complexity:******• Alt 2: 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.*** |
| **Samsung** | ***Proposal 1****: For a CSI report associated with a Multi-TRP/panel NCJT measurement hypothesis configured by single CSI reporting settings support multiple RI candidate values X and Y for Single-TRP and Multi-TRP measurement hypotheses, respectively.****Proposal 2****: For a CSI report associated with a Multi-TRP/panel NCJT measurement hypothesis configured by single CSI reporting settings support two CBSRs to be configured per CodebookConfig, whereas one CBSR is applied to one CMR group in a CMR resource set respectively, i.e. per TRP.****Proposal 3****: For two CMRs within a same CMR pair configured for NCJT measurement hypothesis to be restricted within X continuous slot(s) without DL/UL switch between two CMRs:** *Do not support UE capability for X=2*

***Proposal 4****: Support full and/or partial compression/omission/Sharing of PMI among single-TRP and NCJT hypotheses.****Proposal 5****: 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 6****: Report NCJT and sTRP CSIs as separate reports.** *Modify priority equation in Section 5.2.5 in 38.214 by giving the CSI report for NCJT a higher priority.*
* *Include an indication for sharing of CRI, RI and PMI with sTRP measurement hypotheses in CSI part 1 for NCJT.*

***Proposal 7:*** *For NC-JT CSI reporting enhancement, support following** *Non-PMI CSI reporting*
* *Minimize the remaining specification work by adopting Non-PMI CSI without* non-PMI-PortIndication configuration.
 |
| **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***  |
| **NTT DOCOMO** | **Proposal 1*** For CSI measurement associated with a CSI-ReportingConfig for NC-JT, two CMRs within the same CMR pair are restricted within X continuous slot(s) without DL/UL switch between two CMRs. No need to define UE capability for X.

**Proposal 2*** For CBSR configuration for NCJT, support Alt 2.
	+ Alt 2: 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.

**Proposal 3*** For the order of UCI payload construction for reported CSIs for NCJT, either Option1 or Option2 can be supported.
	+ Option1: support both Alt 1 and Alt 4.
		- Alt1: modify priority equation.
			* *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 CSI report #n with a CSI priority value corresponds to a single-TRP measurement hypothesis (TRP#0 or TRP#1), or a NCJT measurement hypothesis.*
		- Alt4: modify mapping order of CSI fields of one CSI report
			* *For a CSI report #n corresponding to a NCJT measurement hypothesis, the mapping order of CSI fields of one CSI report should consider two LIs and two PMIs. For a CSI report #n corresponding to a single-TRP measurement hypothesis, the mapping order of CSI fields of one CSI report is the same as Rel-15/16.*
	+ Option2: support Alt 4 only.
		- Alt4: modify mapping order of CSI fields of one CSI report
			* *For a CSI report #n corresponding to a NCJT measurement hypothesis and X (X=0/1/2) single-TRP measurement hypothesis, the mapping order of CSI fields of one CSI report should consider two LIs and two PMIs for NCJT CSI, and X sets of one LI and one PMI for single-TRP CSI.*

**Proposal 4*** + 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.
 |
| **Lenovo, Motorola Mobility** | 1. A CSI report is defined for each CSI hypothesis, i.e., X+1 CSI reports are defined for CSI reporting Mode 1 with X single-TRP CSI reports
2. Support Alt1 with two CBSRs configured per codebook configuration
3. For CSI reporting Mode 1, X=0, support one RI restriction with 4 bits corresponding to all possible RI pairs of NCJT hypothesis. Otherwise, support two RI restrictions with 4 bits, 8 bits, respectively, corresponding to all possible RI pairs for NCJT hypothesis, and all possible RI for single-TRP transmission hypothesis, respectively
4. Non-PMI CSI reporting is not supported for multi-TRP CSI framework
5. CSI computation delay relaxation is supported for multi-TRP CSI reporting
 |
| **Nokia, Nokia Shanghai Bell** | **Confirm the order of payload construction for reported CSIs by supporting Proposal 24 from RAN1#106bis-e:*** **modify mapping order of CSI fields of one CSI report, i.e., Table 6.3.1.1.2-[7]/9/10/11 for PUCCH and Table 6.3.2.1.2-3/4/5 for PUSCH in 38.212**
	+ **Introduce mapping order of CSI fields in the order of NCJT CSI, the first TRP CSI, and the second TRP CSI. It also implies that one CSI reporting setting for NCJT measurement reporting contains single CSI report which may corresponds multiple single-TRP and/or NCJT measurement hypotheses**

**Proposal 6 Support wideband reporting of MTRP CSI on PUCCH, but only for reporting Mode 1, with or Mode 2, by modifying the mapping order of CSI fields of Table 6.3.1.1.2-7 of 38.212.****Proposal 7 Regarding Issue 2, *i.e.*, whether a prioritisation between the CSIs is needed to enhance omission rules, no prioritisation between CSIs is needed because the 3 reporting priority levels for WB CSI, even SB and odd SB CSI can be assigned to each CSI in the report.****Proposal 8 Regarding Issue 3, i.e., whether any enhancement to the CPU occupation rules is needed, support improved handling of CPU calculations for Mode 1 and , without impacting the rules for legacy CSI reports. This can be done by*** **introducing separate CPU occupations for an MTRP CSI report configured with Mode 1 and or : , with , alongside the legacy such that , , for and , , , for , 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 is an MTRP CSI report configured with Mode 1 and or .**

**Proposal 9 Text proposal for the 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 the first CSI report exceeding the CPU count and it is configured with Mode 1 and or , where each CSI occupies CPUs, for , and CPUs are unoccupied, the UE is expected to update the first CSIs and is not required to update the last CSIs, where is the largest value such that holds.****Proposal 10 Regarding the RI restriction parameters, follow legacy design for Type I reporting and allow multiple candidate values. For the NCJT RI restriction parameter use a four-bit sequence as per legacy design.****Proposal 11 Regarding CBSR, support Alt 2, i.e., two CBSRs, one for each CMR group.****Proposal 12 Reintroduce the parameter *sharedCMR* in the RRC parameter list, as defined in R1-2108676, because it seems left out from R1-2110573.****Proposal 13 Clarify that there are two RI restriction parameters, one for single-TRP, which can reuse the Rel-15/16 name *typeISinglePanel-ri‑Restriction* and the new one for NCJT. Change the description for the new parameter to: “RI restriction applicable to all NCJT measurement hypotheses (up to 4 rank combinations)”.****Proposal 14 For the new NCJT RI restriction parameter, add in the description or in value range that it is a bit sequence of length 4, so the relative description can be added to 38.214 as for the legacy Type I RI restriction.** |
| **Qualcomm** | **Proposal 1: For a CSI report setting with Option 1 with X=1 or 2 and *reportConfigID*=s, CSI priority is , where is the hypothesis group index within the CSI report setting with *reportConfigID*=s.*** **correspond to single-TRP hypothesis group(s) and NCJT CSI hypothesis group, respectively**
* **This ordering is for the purpose of UCI payload construction, CSI omission for CSI part 2, and CPU occupation priority.**

**Proposal 2: 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.**
 |
| **MediaTek Inc** | **Proposal 1**: **For CSI measurement associated with a *CSI-ReportingConfig* for NCJT,** the UE expects that the two CSI-RS resources for channel measurement in a Resource Pair and any DL signal in a time interval between the two CSI-RS resources are resource-wise QCLed with respect to 'typeD'.**Proposal 2**: For Option 1 with *X* = 1, 2, each CSI measurement hypothesis is mapped to a distinct CSI report.**Proposal 3**: 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 4**: **For a CSI report associated with a Multi-TRP/panel NCJT measurement hypothesis configured by single CSI reporting setting, support 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.****Proposal 5**: For an NCJT measurement hypothesis, decide the normalization for its two precoders and :* Alt 1: (no specification change)
* Alt 2:
* Alt 3: The power of each column in and is normalized to .
* is the Frobenius norm
 |
| **Ericsson** | [Proposal 4 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.](#_Toc87051385)[Proposal 5 For multi-TRP CSI Option 1, for UCI payload construction, support the following:](#_Toc87051386)[-> modify mapping order of CSI fields of one CSI report (i.e., Table 6.3.1.1.2-[7]/9/10/11 for PUCCH and Table 6.3.2.1.2-3/4/5 for PUSCH in 38.212)](#_Toc87051387)[-> Introduce mapping order of CSI fields in the order of MTRP NCJT CSI, the first TRP CSI, and the second TRP CSI.](#_Toc87051388)[Proposal 6 For multi-TRP CSI Option 1 with X=1 and X=2, specify CSI part 2 omission priority levels to define priorities for single-TRP and/or NCJT measurement hypotheses.](#_Toc87051389)[Proposal 7 For NCJT rank restriction, support configuring a rank restriction bitmap in CodebookConfig specific to NCJT measurement hypoetheses.](#_Toc87051390)[-> Note that more than one rank can be restricted by setting the corresponding bits in the bitmap.](#_Toc87051391)[Proposal 8 Non-PMI CSI reporting for NCJT measurement hypothesis is not supported in Rel-17.](#_Toc87051392)[Proposal 9 Support two CMRs within the same CMR pair configured for NCJT measurement hypothesis to be restricted within X continuous slot(s) without DL/UL switch between two CMRs, where X can be either 1 or 2, and where X=2 is not a separate UE capability](#_Toc87051393)[Proposal 10 Support one CSI report for reporting X CSIs associated with single-TRP measurement hypotheses and one CSI associated with NCJT measurement hypothesis.](#_Toc87051394)[Proposal 11 Support Alt 2, where two CBSRs can be configured per CodebookConfig, and one CBSR is applied to one CMR group in a CMR resource set, i.e. per TRP CBSR.](#_Toc87051395) |