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

**e-Meeting, August 16th – 27th, 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 FDD

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

### 2.1.1 Remain issues of codebook structure for

There is a working assumption in RAN1 #105e, which is related to a single window with size N configured to the UE to limit FD bases used for quantization, which is shown as following.

**Working Assumption**

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

* FFS: Further dependence/restriction, e.g. conditioned on N3 or the number of CSI-RS ports, can be applied to above design. If does, how to support a non-consecutive FD bases used for quantization
* FFS: Whether to introduce thresholds for N3 and/or P

For this issue, about 19 companies propose the candidate value, which are shown as Table 1.

**Table 1 Summary of Companies’ Views on whether to confirm WA for**

|  |  |
| --- | --- |
| **Views** | **Companies** |
| **Confirm WA without any restriction**  **(17)** | ZTE, Spreadtrum, CATT, Lenovo, Motorola Mobility, OPPO, QC, Fraunhofer IIS, Fraunhofer HHI, MTK, Intel, DoCoMo, Huawei, HiSilicon, Nokia, Nokia Shanghai Bell, Ericsson |
| **Confirm WA with restriction**  **(2)** | vivo (configured as consecutive or non-consecutive)  Samsung(Confirm for N3 > t) |

Companies preferring to confirm WA without any restriction have the following considerations:

* ZTE, Spreadtrum, OPPO, Fraunhofer IIS and Fraunhofer HHI) propose that a small window size suffices to achieve a good performance since the dominant channel tap locations of the uplink and the downlink channel may differ by a small number of taps.
* CATT, QC, Intel, Nokia and Nokia Shanghai Bell prefer to confirm WA without any restriction because non-consecutive set leads to larger downlink signalling overhead.
* Huawei and HiSilicon support to confirm WA without any restriction since gNB can shift discretely distributed delays in delay domain, to align the same/single FD base window across CSI-RS ports.

On the other hand, Samsung thinks that for small N3 values, all FD components can be comparable. Hence, limiting to a single window may incur performance loss, and a free selection in that case may be beneficial. And vivo proposes that the window/set can be configured as consecutive or non-consecutive since the performance of non-consecutive delay window/set is better than the consecutive one, e.g., at most 3% gain for N=4 and at most 1.8% for N=2.

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

***Proposal 1: Following working assumption is confirmed:***

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

|  |  |
| --- | --- |
| Company | Comments |
| Mod | Proposal 1 is suggested based on the majority. |
| Apple | We are fine with FL proposal |
| Nokia/NSB | Support this proposal |
| Lenovo/Mot | Support |
| vivo | We think non-consecutive window is also needed especially for smaller number of CSI-RS ports. We think smaller number of CSI-RS ports configured for each UE is an common scenario for MU-MIMO. In Rel-17 enhanced codebook, CSI-RS is precoded in a UE-specific way, meaning that the CSI-RS ports configured for one UE can be hardly shared with other UEs because they have different SD-FD bases. Thus we see the needs for small number of CSI-RS ports, e.g, 4, to save the system overall overhead caused by CSI-RS for multiple UEs. To improve the total throughput with finite resources, only a few CSI-RS ports can be allocated to each UE.  Compared to Rel-16, the enhancement of Rel-17 is the FD information obtained by gNB. Without limited number CSI-RS ports, not all selected FD bases can be precoded in CSI-RS ports. Therefore, gNB needs to convey the selected FD bases from configuration. The window length may be too long because the intervals among the selected FD bases may be very large. However, if a longer window is configured, many useless delay locations will be included. Therefore, we think a non-consecutive window is better to convey the selected FD bases.  We compare the performance of consecutive window and non-consecutive window with Mv = 2 for limited number of CSI-RS ports, 4. According to our simulation results, there are about 3% gain for window size N = 4 and 2% for N = 2.  Therefore, we’d like to update the proposal 1 as:  ***Proposal 1: Following working assumption is confirmed:***   * ***At least for rank 1 and the number of ports larger than X, FD bases used for Wf quantization are limited within a single window with size N configured to the UE whereas FD bases in the window must be consecutive from an orthogonal DFT matrix, i.e. Alt 1.***   + ***FFS: for rank 1 and the number of ports larger than X, whether non-consecutive windows is needed.*** |
| Qualcomm | Support |
| ZTE | We support to confirm the WA. |
| DOCOMO | Support the proposal. |
| OPPO | support |
| Intel | Support to confirm the WA without restrictions |
| Fraunhofer IIS/HHI | Support |
| Samsung | Support the proposal for large N3 values. For small N3 values, e.g. N3=3,4,.., since N value is comparable to the N3 value, we don’t need any window.  ***Proposal 1: Following working assumption is confirmed:***   * ***At least for rank 1 and N3>t, FD bases used for Wf quantization are limited within a single window with size N configured to the UE whereas FD bases in the window must be consecutive from an orthogonal DFT matrix, i.e. Alt 1.*** * ***N=N3 for N3<=t*** * ***FFS: t*** |

There is a FFS in RAN1 #105e: whether further dependence/restriction, i.e. conditioned on the number of CSI-RS ports, can be applied to . About 8 companies have shared their views on whether further dependence/restriction for Mv=2 for . The views are listed in the following table.

**Table 2 Summary of Companies’ Views on whether** **further dependence/restriction for Mv=2 for**

|  |  |
| --- | --- |
| **Views** | **Companies** |
| **No Restriction (6)** | CATT, Lenovo, Motorola Mobility, Huawei, HiSilicon, Intel |
| **With Restriction (2)** | Samsung (UE capable to support Mv=2 for P > 12)  MTK (*Restrict Mv=2 to P≤16*) |

Six companies preferring nofurther dependence/restriction for =2 for have the following considerations:

* Companies (e.g. CATT, Lenovo, Motorola Mobility, Intel) think that the main benefit of M = 2 is the robustness against FDD delay reciprocity errors. Therefore, =2 is applicable for any CSI-RS port configuration. And Huawei and HiSilicon provides the simulation to show that compared with , has the 3.58% performance gain with 12 CSI-RS ports, 3.21% performance gain with 16 CSI-RS ports, 1.88% performance gain with 24 CSI-RS ports and 1.32% performance gain with 32 CSI-RS ports.

Some companies preferring further dependence/restriction for =2 for have the following considerations:

* Samsung proposes the UE capable reporting of =2 for P > 12 CSI-RS ports because =2 has no evident performance gain for high CSI-RS ports. MTK’s simulations results show that the performance gain of =2 over =1 is diminishing as the number of CSI-RS ports increases (3~4 % with 8 ports to ~1% with 12 ports to none with 16 ports) and the incremental performance gain is obtained at the cost of a large feedback overhead. Therefore, MTK supports to restrict the configuration of =2 to number of CSI-RS ports P≤16.

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

***Proposal 2:*** **With regarding to supported *Mv=2 for Wf, no further dependence/restriction is applied to Mv=2.***

|  |  |
| --- | --- |
| Company | Comments |
| Mod | Proposal 2 is suggested based on slight majority so far. |
| Apple | We are fine with FL proposal |
| Nokia/NSB | Support this proposal.  In our view there are two main use cases for the gNB to configure , applicable for any CSI-RS configuration:   1. Robustness against nonideal UL-DL reciprocity for channel delays 2. gNB implementations with lower delay resolution, due for example to limited SRS bandwidth. In this case, allows to increase the delay resolution   As shown in simulation results in our previous tdoc ([R1-2105277](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_105-e/Docs/R1-2105277.zip), sec 2.2), the gain of over for use case 2 is up to ~21% for rank 1 and ~32% for max rank 2 |
| Lenovo/Mot | Support proposal |
| Qualcomm | Ok |
| DOCOMO | Support the proposal. |
| OPPO | support |
| vivo | Support. |
| Intel | We support the proposal |
| Fraunhofer IIS/HHI | Support |
| Samsung | The proposal is unclear, what does “no further dependence/restriction” mean? In our view, the restriction based on UE capability is still possible. For example, the support of Mv=2 for large number of ports (e.g. >= 16) can be subject to UE capability since it may not always be beneficial. |

In addition to whether further dependence/restriction for Mv=2 for , some companies provide their view on whether support Mv=4 for , which are summarized as following.

**Table 3 Summary of Companies’ Views on whether support Mv>2 for**

|  |  |
| --- | --- |
| **Views** | **Companies** |
| **Support** |  |
| **Not Support (4)** | Samsung, Ericsson, MTK, Intel |

Some companies’ simulation results show that there is no benefits for Mv =4 compared with Mv=2. For example in Ericsson’s simulation results, no performance gain can be observed for Mv = 4 compared with Mv = 2 and in MTK’s simulation results, the performance gain for is modest in comparison to the feedback overhead and UE computational complexity. In addition, Samsung and Intel think that the need for Mv>2 is not clear.

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

***Proposal 3: For Rel-17 PS codebook, Mv>2 is not supported for Wf*.**

|  |  |
| --- | --- |
| Company | Comments |
| Mod | Proposal 3 is suggested on companies’ feedback so far. |
| Apple | We are fine with FL proposal |
| Nokia/NSB | Support this proposal.  In our view, the increase in feedback overhead and complexity is not justified by the modest throughput gain observed |
| Lenovo/Mot | Support the proposal |
| vivo | We don’t support.  For limited number of CSI-RS ports like 4, Mv>2 is beneficial.  Different from large number of CSI-RS ports, where sufficient SD-FD pairs can be precoded on CSI-RS ports, Mv>2 is necessary to provide more SD-FD pairs with smaller number of CSI-RS ports. For the case of 4 CSI-RS ports, if Mv=2, only up to 8 SD-FD bases can be selected which may be far from the required number of bases to achieve good performance.  Our simulation results show that about 2.5% gain of Mv = 4 over Mv = 2. When the number of CSI-RS ports is 4, the average throughput is low and the upper bound of the throughput is also limited. The throughput upper bound cannot be improved with a small window size M. Therefore, we think M = 4 should be supported for the number of CSI-RS ports less than 8. |
| Qualcomm | Support |
| DOCOMO | Support the proposal. |
| OPPO | Support |
| Intel | Support the proposal |
| Fraunhofer IIS/HHI | Fine with the proposal |
| Samsung | Support |

For , about 15 companies give proposal on value(s) of R. The main preference can be summarized as follows：

**Table 4 Summary of Companies’ Views on R for**

|  |  |
| --- | --- |
| **Views** | **Companies** |
| **R < 1 (1)** | Samsung(R=1/4) |
| **Only R=1 (4)** | Lenovo, Motorola Mobility, QC, Apple, |
| **R > 1 (10)** | ZTE (*{1, 2, …, }*), HW, HiSilicon (D\* ), CATT(*{1, 2, …, }* ), Fraunhofer IIS, Fraunhofer HHI (1,2), Intel (D\* ), Nokia, Nokia Shanghai Bell (D\* ), Ericsson(Only 1 or D\* ) |

For R<1, companies have the following considerations:

* Samsung thinks when CSI-RS beamforming is the same for different R values, R=1/4 achieves the best performance among R=1/4,1/2, 1, and 4.
* Fraunhofer IIS and Fraunhofer HHI don’t support R<1. They observed that compared to R=1, there has a loss for R<1, e.g. 0.4% performance loss for R=1/4.

Companies preferring only R =1 have the following considerations.

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

Companies preferring to support R>1 have the following considerations.

* Fraunhofer IIS, Fraunhofer HHI, Nokia, Nokia Shanghai Bell and Ericsson support R>1 because compared to R=1, a reasonable performance gain is observed for R>1 from simulation results.
* ZTE and CATT believe that to increase R is beneficial to achieve higher performance for UE throughput without increasing feedback overhead.
* HW and HiSilicon thinks that from spec view, different values of R means different length of FD bases in , which can be used by gNB to indicate UEs for the appropriate FD bases in order to match with the precoding granularity of beamformed CSI-RS when UEs calculate the coefficients.

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

***Proposal 4: For Rel-17 PS codebook, following values of R are supported:***

* ***R = 1 and***
* ***One value from {2, D\* NPRBSB}***
  + ***D is the density of CSI-RS in frequency domain and NPRBSB is the CQI subband size in PRBs***
  + ***Note that this R is optional***

|  |  |
| --- | --- |
| Company | Comments |
| Mod | Proposal 4 is suggested based on slight majority so far, starting from the proposal left from RAN1 105e. |
| Apple | We are open for discussing the additional R, however, we prefer to limit R=1 |
| Nokia/NSB | Support this proposal |
| Lenovo/Mot | OK with proposal. As agreed in previous meeting, only R=1 should be supported if no consensus on the R≠1 value |
| Qualcomm | We don’t think additional R value is needed. Can live with “At most ***One value from {2, D\* NPRBSB}***”. |
| ZTE | We are okay with the current formulation from FL. We think to include ***D\* NPRBSB*** is helpful to align gNB and UE’s assumption of precoding granularity. |
| OPPO | Support |
| vivo | Support this proposal |
| Intel | Our preference is R = D \* N\_PRB\_SB   * For M = 1 there is no additional complexity to support R = D \* N\_PRB\_SB comparing to R = 1 * For M = 2 additional complexity is minor since it has impact only for product of channel matrix and 2 DFT vectors |
| Fraunhofer IIS/HHI | Support |
| Samsung | We don’t think R>1 is needed/beneficial since gNB beamforming (if performed PRB level) can reduce the frequency selectivity of the channel to “almost flat” so that there is no or tiny gain, at the cost of UE complexity. So, for progress, we prefer a simple solution by fixing R=1.  ***Proposal 4: For Rel-17 PS codebook, following value~~s~~ of R is~~are~~ supported:***   * ***R = 1 ~~and~~*** * ***~~One value from {2, D\* N~~~~PRB~~~~SB~~~~}~~***   + ***~~D is the density of CSI-RS in frequency domain and N~~~~PRB~~~~SB~~ ~~is the CQI subband size in PRBs~~***   ***~~Note that this R is optional~~*** |

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

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

Companies provide views shown as following table.

**Table 5 Summary of Companies’ Views on**  **off**

|  |  |
| --- | --- |
| **Views** | **Companies** |
| **Alt 1 (12)** | vivo(no need to configure subband or wideband), Spreadtrum, Sony, Samsung(N3 = 1 when CSI is WB, and N3 >1 when CSI is SB), Lenovo, Motorola Mobility, Fraunhofer IIS, Fraunhofer HHI, Intel(RRC parameter pmi-FormatIndicator is ignored), LG, DoCoMo, Nokia, Nokia Shanghai Bell(no further changes are needed to support Rel-17 CB for such small BWPs) |
| **Alt 2 (2)** | ZTE(1st, Use PMI format to configure off or on with =2), DoCoMo |
| **Alt 3 (2)** | ZTE (2nd, Use PMI format to configure off or on with =2), CATT (OFF and ON with =1 are distinguished by PMI format) |

Most companies preferring Alt 1 have the following considerations:

* Some companies (e.g. vivo, Apple, and Spreadtrum) support Alt1 because that codebook structure with Alt1 is similar to Rel-16 without any new RRC configuration. Other companies (e.g. Sony, Lenovo, Motorola Mobility, Fraunhofer IIS, Fraunhofer HHI, Intel, LG, Nokia Shanghai Bell) think Alt1 has the advantage that the codebook can still be configured with >1 without the need to redefine the codebook.

Some companies preferring Alt 2 have the following considerations:

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

Other companies preferring Alt 3 have the following considerations:

* Some companies (e.g. ZTE, Samsung) support Alt 3 to use PMI format in the CSI reporting configuration to configure whether it is off (=1, WB) or on (=2, SB). CATT thinks that OFF is different from ON because or the window size N does not need to be configured when is turned off. Therefore, Alt3 makes OFF and ON be independent by parameter pmi-FormatIndicator configuration.

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

***Proposal 5: For Rel-17 PS codebook, following Alt is supported.***

* ***Wf OFF and Wf ON with Mv=1 are same, and Wf is an all-one vector of length N3***
* ***FFS whether to support wideband report for Rel-17 PS codebook additionally, i.e. for a BWP size < 24 PRBs with N3=1 in this case.***

|  |  |
| --- | --- |
| Company | Comments |
| Mod | Proposal 5 is suggested based on majority so far. FFS is to have a clear spec and support Alt 2 or 3 partially as a compromise if possible. |
| Apple | We support FL proposal |
| Nokia/NSB | Support this proposal.  Regarding the FFS, the use of PMI format indicator to configure WB reporting would need to be restricted to BWP<24 where subband size is not defined, i.e. csi-ReportingBand is not configurable. For BWPs where the subband size is defined, a UE’s behaviour, when , is the same regardless of the value of PMI format indicator. However, if subband size is extended also to BWP<24, as proposed for example in the RedCap WI, to support SB reporting for Type I, then WB reporting for Rel-17 CB would naturally be supported, by configuring without need of PMI format indicator. |
| Lenovo/Mot | Support the proposal. Agree with Nokia’s comment |
| Qualcomm | We don’t think whether BWP < 24 is supported is coupled with discussion here (even if RedCap agreed on subband size for BWP < 24). For instance, both wideband and subband are defined for Rel-15 Type II, but it is not supported for BWP < 24. The reason is that the benefit of Type II CSI is not significant for BWP < 24 considering the main usage of small BWP. So, it is natural that Rel-17 CB is not supported for BWP < 24.  We suggest to revise as “***FFS whether to support wideband report for Rel-17 PS codebook additionally~~, i.e. for a BWP size < 24 PRBs~~ with N3=1 ~~in this case~~.***” |
| ZTE | We are okay for the sake of progress in general. We support the revision from QC instead of the original wording of the FFS point. |
| DOCOMO | Generally support the proposal and okay with QC’s revision. |
| OPPO | Support |
| vivo | Support the proposal and okay with QC’s revision.  In our opinion, Wf off, Mv = 1 and wideband are the same. They all mean that UE do not select FD bases and only report one coefficient for all the subbands corresponding to a single CSI-RS port selected.  In Rel-16 spec, “UE is not expected to be configured with pmi-FormatIndicator” for TypeII CSI feedback. And we think it can be kept in Rel-17. Also, Mv configuration is necessary to indicate UE whether to select or not and the number to select. Therefore, we think Mv configuration is enough to implicitly indicate wideband/subband and Wf off/on. |
| Intel | OK with the proposal provided by the Moderator. Changes proposed by Qualcomm are also acceptable for us. |
| Fraunhofer IIS/HHI | Support the proposal and fine with QC’s revision. |
| Samsung | We think BWP size < 24 should be discussed here since only WB CSI can be configured for it, and hence N3>1 is not possible. So, any alt which requires N3>1 can’t be used for BWP < 24.  Re the argument that Type II is not supported for BWP < 24, we all know the history, this issue (CSI for BWP < 24) was identified very late (in Rel.16 maintenance). We did discuss both Type I and Type II codebooks for it, but unfortunately, companies could not agree to supporting Type II codebook or/and SB CSI for BWP < 24. We therefore don’t understand the logic - since T2 and eT2 codebook are not supported for BWP < 24, hence R17 codebook is not supported. There is clear performance gain, and there is a use case, i.e., when gNB beamforming reduces frequency selectivity of the channel so that the channel is ‘almost flat’. In short, Rel.17 codebook is not the same as R15 and R16 Type II, and in particular, it targets scenarios in which gNB can reduce channel frequency selectivity via CSI-RS beamforming, hence making channel ‘almost flat’ which makes WB CSI is useful configuration.  So, we suggest the following:  ***Proposal 5: For Rel-17 PS codebook, following Alt is supported.***   * ***Wf OFF and Wf ON with Mv=1 are same, and Wf is an all-one vector of length N3 where N3>1 when SB size is configured (i.e. SB CSI) and N3=1 when SB size is not configured (e.g. WB CSI)***   ***WB CSI is support for BWP size < 24.***  ***FFS whether WB CSI is supported for BWP >=24***  ***~~FFS whether to support wideband report for Rel-17 PS codebook additionally, i.e. for a BWP size < 24 PRBs with N~~~~3~~~~=1 in this case~~*** |

### 2.1.2 Remain issues of codebook structure for

There is a FFS in RAN1 #105e, which is for the reserved state for reference amplitude, down-select one Alt from the following candidate Alts.

* Alt 1: it is kept to be reserved
* Alt 2: it is replaced as (1/2) ^ (15/4)
* Alt 3: it is replaced as (1/2) ^ (3/8)

For this issue, about 16 companies give proposal, which are shown as Table 6.

**Table 6 Summary of Companies’ Views on Reserved code point for**

|  |  |
| --- | --- |
| **Views** | **Companies** |
| **Alt 1 (15)** | vivo, Spreadtrum, Sony, CATT, Lenovo, Motorola Mobility, OPPO, Fraunhofer IIS, Fraunhofer HHI, Intel, Nokia, Nokia Shanghai Bell, HW, HiSilicon, Ericsson |
| **Alt 2** |  |
| **Alt 3 (1)** | Samsung |

It was proposed to replace this reserved value with an additional level at -1.5dB lower than the current lowest level, *i.e.*, at -22.5dB in Alt 2 or with a value obtained by some further optimisation based on simulation-based distribution of the coefficient amplitudes such as Alt 3. Whilst Alt 2 provides negligible performance improvement because of the very low quantisation value, Alt 3 depends on the assumed distribution of the coefficient amplitudes and achieve negligible performance gain in 7 companies’ simulation (CATT, OPPO, vivo, Fraunhofer IIS, Fraunhofer HHI, and HW, HiSilicon).

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

***Proposal 6: For Rel-17 PS codebook, the reserved state for reference amplitude is to be reserved as Rel-16 PS codebook.***

|  |  |
| --- | --- |
| Company | Comments |
| Mod | Proposal 6 is suggested based on the majority. |
| Apple | We are fine with the FL proposal. |
| Nokia/NSB | Support this proposal |
| Lenovo/Mot | Support |
| Qualcomm | Support |
| ZTE | We are fine with the proposal. |
| DOCOMO | Support |
| OPPO | Support |
| vivo | support |
| Intel | Support |
| Fraunhofer IIS/HHI | Support |
| Samsung | For progress, we can accept the majority view. |

In RAN1#105e, it was agreed that whether/how the NZC bitmap can be absent from the CSI reporting would be discussed in RAN1#106e. About 15 companies have shared their views on the bitmap absent issue, which are listed in the table below.

**Table 7 Summary of Companies’ Views on whether/how the bitmap can be absent**

|  |  |  |
| --- | --- | --- |
| **Views** | | **Companies** |
| **Can’t Absent/No need (2)** | | vivo, QC |
| **Absent** | **Alt 1 (5)** | Lenovo, Motorola Mobility, Intel, DoCoMo, Ericsson |
| **Alt 2 (4)** | ZTE, Samsung, Nokia, Nokia Shanghai Bell |
| **Alt 3 (3)** | CATT, Huawei, HiSilicon |
| **Alt 4 (2)** | Lenovo, Motorola Mobility |
| **Alt 5 (1)** | Spreadtrum Communications |

Most companies (Spreadtrum, Lenovo, Motorola Mobility, Intel, DoCoMo, Ericsson, ZTE, Samsung, Nokia, Nokia Shanghai Bell, CATT, Huawei, and HiSilicon) think the bitmap for indicating non-zero coefficients for can be absent in Rel-17 to reduce the CSI feedback overhead in some cases thanks to angle and delay pre-compensation and efficient CSI-RS precoding. And companies (vivo and QC) prefer that the bitmap for indicating non-zero coefficients always exists because the bitmap being absent is a corner case.

Among companies who support bitmap can be absent in Rel-17, the following Alts are proposed by different companies.

* Five companies (Lenovo, Motorola Mobility, Intel, DoCoMo, and Ericsson) prefer Alt 1, in this Alt, the bitmap for indication non-zero coefficient can be absent when and for rank 1.
* Four companies (ZTE, Samsung, Nokia, and Nokia Shanghai Bell) prefer Alt 2. These companies think UE still can select and report a subset of NZ coefficients even when and . Hence it is not sufficient to omit the bitmap just in the condition of having beta = 1, otherwise it restricts the flexibility of UE implementation. In Alt 2, if β=1 and UE reports () nonzero coefficients, the bitmap for indication non-zero coefficient can be absent.
* Three companies (CATT, Huawei, and HiSilicon) prefer Alt 3. These companies think Alt 2 shall be applied for both layers’ bitmaps being absent or not simultaneously, which introduce a significant limitation on the scenarios that the bitmap can be absent. So they propose based on Alt 2, additionally the bitmap for layer I alone can be absent, only if reported real number of NZC for layer I is equal to corresponding maximal number of NZC for layer i.
* Except Alt 1, Lenovo, Motorola Mobility also proposed Alt 4, in which the bitmap for indication non-zero coefficient can be absent when the number of coefficients is small, e.g., K1Mv ≤ δ, FFS: value of δ.
* In addition, Spreadtrum Communications proposed Alt 5, in which the bitmap for indication non-zero coefficient can be absent depends on the number of non-zero coefficients, e.g. />2/3

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

***Proposal 7-1: For Rel-17 PS codebook, whether the bitmap for indicating non-zero coefficients can be absent***

* ***Yes : Spreadtrum, Lenovo, Motorola Mobility, Intel, DoCoMo, Ericsson, ZTE, Samsung, Nokia, Nokia Shanghai Bell, CATT, Huawei, HiSilicon***
* ***No: vivo, QC***

***Proposal 7-2: If a bitmap for indicating non-zero coefficients can be absent, down-select one Alt from the following for Rel-17 PS codebook:***

* ***Alt 1: For rank 1 PMI, the bitmap of indicating non-zero coefficients is not needed if and .***
* ***Alt 2: For rank ½ PMI, the bitmap(s) of indicating non-zero coefficients for corresponding layer(s) is absent if reported KNZ=K1\*Mv\*rank***
* ***Alt 3: In addition to Alt 2, additional field is reported by UE to inform whether the bitmap of indicating non-zero coefficients for specific layer is absent if rank>1.***
* ***Alt 4: The bitmap of indicating non-zero coefficients is not needed if the number of coefficients is sufficiently small, i.e. K1Mv ≤ δ***
* ***Alt 5: The bitmap for indication non-zero coefficient can be absent depends on the number of non-zero coefficients, e.g. />2/3***

|  |  |
| --- | --- |
| Company | Comments |
| Mod | Proposal 7 is suggested based on the majority, starting from Proposal 7-1 to determine whether we shall go ahead. For Proposal 7-2, Alt 1 has slight majority and can be discussed thereafter once Proposal 7-1 have been determined, also to be polished with more inputs/preferences. |
| Apple | We think it might be better to first discuss whether we adopt the similar Rel-16 design principle, i.e., is the upper limit of the number of NZP coefficients and UE can report less number, or, we change the design such that indicates the exact number of NZP coefficients that UE needs to report. |
| Nokia/NSB | On Proposal 7-2: Alt 1, 4 and 5 limit the choice of NZC by a UE and force the reporting of coefficients that may be zero with nonzero values. Alt 2 and 3 optimise the overhead without affecting the quantisation and reporting of NZCs. Alt 3 requires an additional field in part 1 to indicate for which layer the bitmap is absent. This field needs to be present in all cases (also for ) because part 1 has fixed length.  Therefore, our preference is Alt 2 because it does not affect the quantisation and reporting of NZCs and is a simple optimisation that does not require additional signalling |
| Lenovo/Mot | Support Alt 1, 4 of Proposal 7-2. For Alt 1, can we generalize to “at least for Rank 1 PMI”, since details of Rank>1 are not yet discussed?  ***Revised Proposal 7-2: If a bitmap for indicating non-zero coefficients can be absent, down-select one Alt from the following for Rel-17 PS codebook:***   * ***Alt 1: At least For rank 1 PMI, the bitmap of indicating non-zero coefficients is not needed if and .*** * ***Alt 2: For rank ½ PMI, the bitmap(s) of indicating non-zero coefficients for corresponding layer(s) is absent if reported KNZ=K1\*Mv\*rank*** * ***Alt 3: In addition to Alt 2, additional field is reported by UE to inform whether the bitmap of indicating non-zero coefficients for specific layer is absent if rank>1.*** * ***Alt 4: The bitmap of indicating non-zero coefficients is not needed if the number of coefficients is sufficiently small, i.e. K1Mv ≤ δ*** * ***Alt 5: The bitmap for indication non-zero coefficient can be absent depends on the number of non-zero coefficients, e.g. />2/3*** |
| Qualcomm | Do not support either of them. We think bitmap being absent is over-design for corner case but complicate UE and BS implementation. Unified framework is preferred. Also, UE reporting of actual NNZC should be discussed first.  For Alt2/3, it introduces additional reporting of per-layer NNZC. Besides, the max payload should be clear for each para-combo so that gNB would know how much UL resource should be allocated. If the bitmap is absent by opportunistic, it seems the max payload is unclear.  For Alt1/4/5, UE has to quantize zeros to the lowest quantization level, whether the payload can be saved needs further evaluation. Also, quantizing zeros to lowest level may have impact on performance. |
| ZTE | The Rel-15/16 principle of determining and reporting the real number of NZC shall not be changed, i.e., the number of NZC is always reported in Part 1. Hence any further optimization should not challenge this principle. We can accept to optimize the overhead when this principle is not impacted, but if this principle is impacted, bitmap shall not be absent.  On the alternatives, Alt 2 is the only one which does not break such principle, while the other alternatives do break this principle in different cases. Further, Alt 2 does not require any additional enhancement on reported parameters, i.e., no need to introduce per layer NNZC. Hence our position is that Alt 2 is the only option to omit bitmap, otherwise, bitmap cannot be absent. |
| DOCOMO | Even though we support Alt.1, we can also accept Alt.2. |
| OPPO | Alt 2 is clear. |
| vivo | We think the bitmap cannot be absent. The case of absent bitmap is not common. And in the case that Mv = 1, the overhead saved by absent bitmap is not evident. |
| Intel | In accordance with analysis (including SLS results) from our tdoc our first preference is Alt.1 with the following comments.   * In our view Alt. 1 is applicable for rank 1-2 * For Alt. 1 the smallest amplitude value shall be equal to 0   Our second preference is Alt. 2 since it is simple and straightforward. |
| Fraunhofer IIS/HHI | We think absence of a bitmap is a corner case and overhead saving is not that high. It is better to discuss this issue once the parameter combinations for all ranks are decided. |
| Samsung | We prefer Alt2 since it doesn’t require any change in UE behaviour, and the overhead saving can be large, up to 64 bits. |

In RAN1#105-e, these has many discussion on how the strongest coefficient indicator (SCI) is reported. In the previous discussions, the following alternatives are discussed.

* Alt 0 : Reporting of the position, [il\*, fl\*], of the strongest coefficient of layer l using ceil(log2(K0)) bits, where K0=Beta\*K1\*Mv
* Alt 1-1: Reporting of the position, [il\*, fl\*], of the strongest coefficient of layer l, using ceil(log2(K1\*Mv)) or ceil(log2(K1))+ceil(log2(Mv)) bits
* Alt 1-2: Reporting of the position, [il\*, fl\*], of the strongest coefficient of layer l, using ceil(log2(K1\*Mv)) or ceil(log2(K1))+ceil(log2(Mv)) bits, and shifting of the strongest coefficient to position fl\*=0
* Alt 2: shifting the strongest coefficient to fl\* = 0, and using ceil(log2(N)) bits to indicate the shift quantity for l-th layer. The strongest coefficient is indicated by il\*, using ceil (log2(K1)) for l-th layer.
* Alt 3: SCI is not needed so that the SCI in R16 codebook is replaced with a strongest polarization indicator (1 bit)

In this meeting about 16 companies have shared their views on the above Alts for the SCI design, which are listed in the table below.

**Table 8 Summary of Companies’ Views on SCI**

|  |  |
| --- | --- |
| **Views** | **Companies** |
| ***Alt 0 (3)*** | ZTE, Samsung(1st), QC |
| ***Alt 1 (14)*** | QC(Alt 1-1), Huawei, HiSilicon (Alt 1-1), CATT(Alt 1-2), Lenovo, Motorola Mobility, OPPO, Fraunhofer IIS, Fraunhofer HHI, MTK(Alt 1-2), Apple (Alt 1-1), Nokia, Nokia Shanghai Bell(Alt 1-2), Ericsson(Alt 1-1) |
| ***Alt 2*** |  |
| ***Alt 3 (1)*** | Samsung(2nd) |

* Three companies (ZTE, Samsung, QC) prefer Alt0 because this Alt explicitly reports the location of the strongest coefficient among non-zero coefficients, compared with other Alts, Alt 0 can save some bits when .
* Many companies (QC, Huawei, HiSilicon, CATT, Lenovo, Motorola Mobility, OPPO, Fraunhofer IIS, Fraunhofer HHI, MTK, Apple, Nokia, Nokia Shanghai Bell, and Ericsson) prefer Alt 1 because compare with Alt 1, Alt 0 could have larger impact of UCI design, which means that the SCI and bitmap may need to be grouped together in G0 or G1 because the SCI depends on the bitmap. There have two different views in the companies who support Alt 1.
  + Some companies (CATT, Nokia, Nokia Shanghai Bell and MTK) prefer Alt 1-2 because this Alt has shifting operation to move the strongest coefficient within the zeroth FD basis. It can help to have a robust CSI report when UCI of FD indicator is omitted.
  + Some companies (QC, Huawei, HiSilicon, Apple, and Ericsson) prefer Alt 1-1 due to its simplicity. The shifting operation complicates the spec and implementation but the benefits is unclear.
* Except Alt0, Samsung also take Alt3 as the second preference.

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

***Proposal 8: For Rel-17 PS codebook, support reporting of the position, [il\*, fl\*], of the strongest coefficient (SCI) of layer l, using ceil(log2(K1\*Mv)) bits***

* ***FFS whether shifting/remapping the strongest coefficient to position fl\*=0 is needed***

|  |  |
| --- | --- |
| Company | Comments |
| Mod | Proposal 8 is suggested based on the majority since most companies preferring either Alt 1-1 or Alt 1-2. To clarify/make a decision between Alt 1-1 or Alt 1-2, a FFS is added temporally as a placeholder to have further clarification and discussion. |
| Apple | We are fine with the FL proposal. |
| Nokia/NSB | Support this proposal.  Regarding the FFS, the shift of the strongest coefficient to position is also related to the reporting of . In case is agreed in P10 and is reported, it is not clear if under Alt 1-1 a shift is needed to remap the FD bases such that , or (in case of layer-common ) and only bases are reported, or whether no shift is needed and all FD bases are reported.  On the other hand, Alt 1-2 would follow Rel-16 in this case and reports only bases, after remapping (in case of layer-common ) and . |
| Lenovo/Mot | Support the proposal |
| Qualcomm | Ok, and we cannot accept the shifting/remapping operation. |
| ZTE | We are okay with Alt 1-1 as well. We don’t think any shift or remapping is needed. It does not reduce any overhead but just increases UE processing complexity.  It seems Alt 1-1 stands for the majority view. We suggest to agree on this Alt, and clarify the subbullet as a note that shift/remapping is not supported. |
| DOCOMO | Support the proposal. |
| OPPO | Support |
| vivo | Support. |
| Intel | Support the proposal |
| Fraunhofer IIS/HHI | Support the proposal. |
| Samsung | We also think shift/remapping is not necessary, and adds to UE side operations without any benefits. So, prefer Alt0, but can live with Alt1-1 for progress. |

## Rank 2 for Rel-17 PS Codebook Design

About 10 companies have shared their views on the issue whether port selection is layer-common or layer-specific for rank 2. The views are listed in the following tables.

Table 9 Port selection for rank2

|  |  |
| --- | --- |
| **Views** | **Companies** |
| **Layer-common(9)** | Huawei, HiSilicon, CATT (at least for Mv=1), OPPO (all RI), Fraunhofer IIS, Fraunhofer HHI, Intel (all RI), Apple(all RI), Ericsson |
| **Layer-specific(1)** | Samsung |

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

* Companies provide simulation results (e.g. Huawei, HiSilicon, CATT, Fraunhofer IIS, and Fraunhofer HHI) show that the performance of layer-common for port selection is similar to that of layer-specific with the same overhead for different configurations of number of CSI-RS ports. Furthermore, many companies (e.g. Huawei, HiSilicon, Intel, and OPPO) view that port selection for rank2 for R17 Type II codebook should be the same with R16 Type II codebook, which help to reduce the PMI search complexity. Companies (e.g. Fraunhofer IIS, Fraunhofer HHI) point out that layer-specific port selection indication results in a high feedback overhead as the maximum number of supported ports as well as the maximum number of selected ports are as high as 32.

On the other hand, Samsung prefers port selection is layer-specific. In Samsung’s simulation result, layer-specific PS (W1) performs better than layer-common PS (W1) up to ~2-3%, especially in medium-high overhead regime (beta =0.75,1). Meanwhile, Samsung consider that this issue is related to whether PS is implemented before or after SVD operation to extract layers. If it is done after SVD, then layer-specific PS may be needed.

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

***Proposal 9: For Rel-17 PS codebook, support layer-common port selection for rank 2.***

|  |  |
| --- | --- |
| Company | Comments |
| Mod | Proposal 9 is suggested based on the majority. |
| Apple | We are fine with the FL proposal |
| Nokia/NSB | Support |
| Qualcomm | Support |
| ZTE | We are okay with the proposal. |
| DOCOMO | Support the proposal |
| OPPO | Support |
| vivo | Support. |
| Intel | Support |
| Fraunhofer IIS/HHI | Support |
| Samsung | In our view, for some parameter values, e.g. K1=P/2, layer-specific can be beneficial since the selected ports are likely to be different for different layers. Also, for rank 3-4, K1 value can be smaller than that for rank 1-2 (we haven’t this yet), hence layer-specific port selection may also be needed/beneficial for rank 3-4. So, we prefer to discuss this issue when we discuss parameter combinations (supported K1 values and rank 3-4). |

With regarding to the relationship between N and Mv, and FD basis selection is layer-common or layer-specific for rank 2, companies’ views are listed in the following table.

Table 10 The relationship between N and Mv, and FD basis selection

|  |  |
| --- | --- |
| **Views** | **Companies** |
| **Alt 1: N= Mv always, no UE reporting of Wf . (5)** | OPPO, Qualcomm, Samsung(rank1-2, N=Mv), MTK(1st), Intel(1st) |
| **Alt 2-1: N >= Mv, Wf is layer-common and reported by UE for N>Mv. (9)** | Hua Wei, HiSilicon, MTK(2nd), Intel(2nd), NTT, DOCOMO, Nokia, Nokia Shanghai Bell，Ericsson({N=1,2,Mv=1}) |
| **Alt 2-2: N >= Mv, Wf is layer-specific and reported by UE for N>Mv. (4)** | ZTE, Samsung(FFS: rank>2, N>=Mv), CATT(P=4,N>Mv), Apple |

Companies preferring Alt 1 have the following considerations:

* Simulation Performance: Some companies (e.g. Samsung, Qualcomm, MTK, CATT) provide simulation results show that when rank<=2, Alt1 and Alt2-1 achieve almost same performance; OPPO also consider the performance of Alt1 and Alt2-1 are similar, there is no need to support both schemes. Moreover, simulation results provided by Qualcomm show that Alt2-2 is worse than Alt1 and Alt2-1, since the FD-basis pair selection is performed after SVD operation, which may not beneficial for the orthogonality among layers.
* UE complexity: Some companies (e.g. Samsung, Qualcomm, OPPO, ZTE) consider Alt 1(N=Mv) is simple, and no configuration and reporting are needed for . Furthermore, Qualcomm believes that Alt 2-1 requires additional complexity in PMI searching and SVD operation.

Companies preferring Alt 2-1 have the following considerations:

* Simulation Performance: Some Companies (e.g. Ericsson (1.5%)) provide simulations result to show that compared with Alt1, Alt2-1 provides about 1.5% performance gain.
* Robustness: Many Companies (e.g. NTT, DOCOMO, Ericsson, Huawei, HiSilicon, Nokia and Nokia Shanghai Bell) consider when there is non-ideal delay reciprocity or timing offset between UL and DL receivers, configuring N slightly larger than Mv provides additional robustness. Moreover, Ericsson believes that UL/DL timing offset are most likely common across all antennas, therefore it makes more sense to have layer-common .
* UE complexity: some companies (e.g. Intel，Ericsson, Huawei, and HiSilicon) view that FD basis layer-common help to maintain low PMI search complexity and UE computation complexity.

Companies preferring Alt 2-2 have the following considerations:

* Performance improvement: Some companies (e.g. ZTE, Samsung (rank>2)) view that to support N>Mv with layer-specific is better for higher ranks since different layers most likely will experience different delay profiles. CATT believe that  with layer-specific should improve performance compared to with layer-common, and there are no much indication overhead increased even though UE reports the selected FD bases to gNB.
* Simulation Performance: Some companies (e.g. CATT (3%),) provide simulations result to show that N>Mv can bring performance improvement compare with N = Mv when P=4. However, the performance gain for N>Mv is still limited when P=8.

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

***Proposal 10:*** ***At least for rank ½ and Mv > 1, for relationship between N and Mv, support following alternative***

* + ***Alt 2-1: N >= Mv, Wf is layer-common and reported by UE for N>Mv.***
  + ***Note: Wf is layer-common for N=Mv***
  + ***Note: For all alternatives, a layer-common window/set of size N is configured.***

|  |  |
| --- | --- |
| Company | Comments |
| Mod | Proposal 10 is suggested based on slight majority so far, starting from the agreement left from RAN1 105e. |
| Apple | 1. In Rel-16, Wf is layer independent. So we are suggesting that we change our design principle after one release? 2. We think this is also connected to the potential value of N when N>Mv, for example limit N=2\*Mv |
| Nokia/NSB | Support |
| Qualcomm | We don’t see clear benefit of Alt2-1 over Alt1 based on our simulation. Alt2-2 has performance loss with the CSI algos mentioned by most companies, and it increases the complexity of SVD operation significantly. If the majority view lies in Alt2-1, we can live with it, but cannot accept Alt2-2. |
| ZTE | We support Alt 2-1 as our second preference. We are fine with the FL proposal. |
| DOCOMO | Support the proposal. |
| OPPO | We have similar view as QC. |
| vivo | Support. |
| Intel | OK |
| Fraunhofer IIS/HHI | Our first preference is Alt1. Second preference is Alt2-1. |
| Samsung | We support only Alt1 for rank 1-2 since there is no performance gain with Wf reporting for rank 1-2. We can be open to discuss Alt2 for rank 3-4 since for high rank, the delay profiles for multiple layers may require a larger window. |

About 8 companies have shared their views on the issue that non-zero coefficient selection is layer-Common or layer-specific for rank 2. Their views are listed as following table.

Table 11 non-zero coefficient selection for rank2: summary of companies’ proposals

|  |  |
| --- | --- |
| **Views** | **Companies** |
| **Layer-specific（8）** | Huawei, HiSilicon ,Samsung, CATT,OPPO, Intel, Apple, Ericsson |
| **Layer-common** |  |

Companies (e.g. Samsung (2-3%), Huawei, HiSilicon (12% low/medium overhead regime)) provide simulations result to show that the performance of layer-specific for non-zero coefficient selection is better than that of layer-specific assuming with the same overhead. Companies (e.g. CATT, Huawei, and HiSilicon) prefer that the locations of NZC selected by UE for different layers can be different.

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

***Proposal 11: For Rel-17 PS codebook Rank 2 at least, support layer-specific non-zero coefficient selection of W2.***

|  |  |
| --- | --- |
| Company | Comments |
| Mod | Proposal 11 is suggested based on the majority so far. |
| Apple | We are fine with FL proposal |
| Nokia/NSB | Support |
| Lenovo/Mot | Support |
| Qualcomm | Support |
| ZTE | Support |
| DOCOMO | Support |
| OPPO | Support |
| vivo | Support |
| Intel | Support |
| Fraunhofer IIS/HHI | Support |
| Samsung | Support with the clarification in red  ***Proposal 11: For Rel-17 PS codebook and Rank 2 ~~at least~~, support layer-specific bitmap for non-zero coefficient selection of W2.*** |

## Rank 3 and 4 for Rel-17 PS Codebook

About 12 companies have shared their views on the issue that whether support rank 3~4 for R17 port selection codebook, and the design principles for rank 3~4. The views are listed in the following table.

Table 12 RI=3-4 extension: summary of companies’ proposals

|  |  |
| --- | --- |
| **Views** | **Companies** |
| **Support (9)** | Huawei, HiSilicon, CATT, Lenovo, Motorola Mobility, Intel, Nokia, Nokia Shanghai Bell, OPPO |
| **Study(2)** | ZTE(smaller beta), Samsung (UE capability, only Mv=1 for rank3-4), |
| **Others(1)** | Ericsson(low priority), |

The view from different companies and available SLS results to support rank 3~4 for R17 Type II codebook can be summarized as follows：

Companies that support rank3-4 have the following considerations:

* Some companies (Huawei, HiSilicon) provide simulation results show that compared with R16, R17 can provide about 4% performance gain at medium CSI feedback overhead and 8% performance gain at low CSI feedback overhead for SU-MIMO with dynamic rank adaptation. Moreover, in the case of 32 ports CSI-RS, both R17 and R16 are near the saturated performance, but compared with R16 PS CB, Rel-17 PS CB enhancement can save significantly CSI overhead at the saturated performance, e.g. up to 45%.
* Companies (Huawei, HiSilicon, CATT, Lenovo, Motorola Mobility, and Intel) consider higher system performance can be achieved with the same overhead compared with Rel-16 Type II port selection codebook. The UE complexity of Rel-17 port selection codebook is less than that of Rel-16 Type II port selection codebook. Therefore, Rel-17 port selection codebook should also support high rank transmission.
* Companies (Huawei, HiSilicon, ZTE, and Intel) consider to decrease beta for rank3-4 comparing to beta used for rank1-2. Intel also consider to limit the maximum number of non-zero coefficients across all layers to 2∙K0 with the same Beta for rank 1-4. Nokia consider that feedback overhead of rank 3-4 is comparable to that of rank 2.

Companies that support to study rank3-4 have the following considerations:

* Samsung propose that if rank3-4 is supported, it should be optional by separate UE capability, similar to Rel.16. Also, it is desired to keep the UE complexity CSI payload of rank 3-4 CSI reporting reasonable, if possible, comparable to rank 2 CSI reporting. ZTE considers that if Rank 3 and 4 are supported, use a smaller beta value for Rank 3 and 4 compared with beta value configured for Rank 1 and 2, e.g., .

In additional, Ericsson considers that the overhead for rank 3 and 4 transmissions can be much higher than that of rank 1 and 2 transmission, unless some further optimization is considered for rank 3-4 design. Related effort should be deprioritized given limited 3GPP time budget and Ericsson prefers a straightforward extension.

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

***Propose 12: Support rank 3 and 4 for Rel-17 PS codebook with following:***

* ***Supporting rank 3 and 4 is optional (as Rel-16 PS codebook)***
* ***The maximal CSI overhead of rank 3 and 4 is comparable to rank 2*** 
  + ***FFS: use a smaller beta for rank ¾, or limit the maximum number of non-zero coefficients across all layers to 2K0 with the same beta***
* ***FFS: limit Mv=1 for rank ¾ PMI***

|  |  |
| --- | --- |
| Company | Comments |
| Mod | Proposal 12 is suggested based on the majority so far. Rank 3 and 4 are likely to reuse rank 2 design, if possible. |
| Apple | We are supportive  If this codebook is ever deployed, we think it is more likely to be deployed first in the TDD band. In new NR TDD band, UE is mandated to support 4 Rx, i.e., 4 layers. It will be an artificial handicap if we limit the codebook to RI<=2 |
| Nokia/NSB | Support this proposal |
| Lenovo/Mot | Support |
| Qualcomm | We think rank > 2 should be optional same as Rel-16 PS codebook. |
| DOCOMO | Support |
| OPPO | Support |
| vivo | Support |
| Intel | Support |
| Fraunhofer IIS/HHI | Support |
| Samsung | OK as long as it is optional with separate UE capability (same as Rel16). Plus some clarifications as shown below.  ***Propose 12: Support rank 3 and 4 for Rel-17 PS codebook with following:***   * ***Supporting rank 3 and 4 is optional with separate UE capability (as Rel-16 PS codebook)*** * ***The maximal CSI overhead of rank 3 and 4 is comparable to rank 2***    + ***FFS: use a smaller K1 (or alpha) or beta for rank ¾, or limit the maximum number of non-zero coefficients across all layers to 2K0 and per layer to K0 with the same beta*** * ***FFS: limit Mv=1 for rank ¾ PMI*** |

## Others

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

|  |  |
| --- | --- |
| **Company** | **View** |
| **Sony** | * Free selection of by the UEs, e.g., , or for some , should be supported * *Based on UL CSI, further restrict the set of CSI-RS ports eligible by the UE to those compatible with UL signal angles. By reducing the number of choices, less bits are needed to encode the DL CSI feedback reports by the UE.* |
| **Samsung** | * simplify Rel.16 UCI omission mechanism and consider the following potential simplifications   + no FD permutation   + no bitmap partition   + no FD basis indicator, at least for rank 1 and 2 |
| **CATT** | * The CSI reporting design of Rel-16 Type II port selection codebook should be regarded as a starting point * The design principle of CSI omission for Rel-16 Type II port should be applied to CSI omission design of Rel-17 port selection codebook * The priority order of Rel-16 Type II port selection codebook for omitting CSI Part 2 should be regarded as a starting points |
| **Lenovo** | * Study PUCCH reporting of CSI feedback corresponding to Rel. 17 port-selection codebook for some codebook parameter combinations that yield low CSI feedback overhead   + FFS: codebook parameter combination values that support PUCCH reporting |
| **QC** | * For Rel-17 FDD CSI, the pre-configured window does not imply any specific UE implementation in PMI calculation. * 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. |
| **DoCoMo** | * Consider dynamic configuration of turning on/off implicitly using DCI. |
| **Nokia, Nokia Shanghai Bell** | * For , support reporting of nonzero components of using a combinatorial indicator of bits. |
| **vivo** | * UE can use partial CSI-RS ports to search target tap 0 to reduce the complexity. * gNB can map SD-FD bases to CSI-RS ports with a predetermined order or indicating the ports for timing calibration. |

Moreover, about 9 companies give their views on the codebook parameter combinations for Rel-17 PS CB, which is summarized as following.

|  |  |
| --- | --- |
| **Company** | **View** |
| **ZTE** | * All the values in {4, 8, 12, 16, 24, 32} can be supported for K1 where K1<=P |
| **vivo** | * At least 8 parameter combinations of (K1,Mv, Beta) can be supported as (4,2,0.5), (8,2,0.25), (8,1,1), (12,1,0.5), (8,2,0.5), (12,1,0.75), (12,2,0.5), (16,2,0.75). * K1 can be limited to no more than half of the number of CSI-RS ports. |
| **Samsung** | * Regarding Rel. 17 codebook parameters,   + support P from {2,4,8,12,16,24,32}   + parameterize K\_1 as K\_1=αP\_CSIRS   + parameter combinations correspond to triples (α,Mυ,β), where the candidate values for down-selection are as follows:     - α=1,3/4,1/2     - β=1,3/4,1/2     - Mυ=1, 2 |
| **CATT** | * A new parameter for determining the number of port selection K1 is introduced to limit the number of parameter combinations. * For =1, when ，1/2, 3/4 and can be considered, and when , is configured as 3/4 and 1. * When , the following parameter combinations can be considered.  |  |  | | --- | --- | |  |  | | ***1/2*** | ***1*** | | ***3/4*** | | ***1*** | | ***Note:***   * ***When P=4, is not supported.*** * ***is selected as the largest value in {2, 4, 8, 12, 16, 24, 32} and.*** | |  * When, the following parameter combinations can be considered.  |  |  | | --- | --- | | **1** |  | | ***1*** | ***1/2*** | | ***3/4*** | | ***1*** | | ***Note: the following combinations is not supported***   * ***P,*1, *.*** * ***P32,* 1,** | | |
| **OPPO** | * Support K1 = {8, 16, 24} for Rel-17 codebook. * Support beta=3/4 for Rel-17 codebook. |
| **MTK** | * β=1/4 can be supported when the number of CSI-RS ports P (or number of selected ports K1) is equal to or more than 16 or when Mv=1. * Parameterize K1 as K1=αP, and support candidate values of α={[1/2],3/4,1}. * Support a triplet of parameters (α, β, Mv) for the Rel-17 PS CB. |
| **QC** | * Support parameter combinations of {K1, beta, M}, and total number of different combinations should not exceed Rel-16 eType II codebook (regardless of number of CSI-RS ports). |
| **Nokia, Nokia Shanghai Bell** | * Regarding the port selection parameter , consider the parameter formula: , with for and for . |

|  |  |
| --- | --- |
| Company | Comments |
| Mod | The discussion/design of parameter combinations will be kicked off in RAN1 106bis, starting from general considerations of parameter combinations and companies interests, once overall design is roughly complete. Final design will be made in RAN1 107. It is highly welcome to consider them right now. |
| Samsung | It seems that a good number of companies are proposing *,* with . We suggest to agree to the following so that companies can study for parameter combinations:  **Proposal**: parameterize as for parameter combinations   * The candidate values of are . |

# Summary of CSI enhancement for Multi-TRP

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

For a CSI-RS resource set with Ks NZP CSI-RS resources configured for CMR and N NZP CSI-RS resource pairs configured for NCJT measurement hypotheses, the default value of *Ks, max* can be one of the following 3 Alts:

* Alt 1: *Ks, max* = 4
* Alt 2: *Ks, max* = 2
* Alt 3: *Ks, max* = 4 for FR2, and *Ks, max* = 2 for FR1

|  |  |
| --- | --- |
| **Views** | **Companies** |
| **Alt 1** (8) | Vivo, CMCC, Fraunhofer IIS, Fraunhofer HHI, DoCoMo, Nokia, NSB, Ericsson |
| **Alt 2** (5) | InterDigital, Spreadtrum, OPPO, Qualcomm, MediaTek, |
| **Alt 3** (5) | ZTE, Spreadtrum, Lenovo, MotM, CMCC |

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

***Conclusion #1: Given that there is no clear majority and urgency to make an immediate decision in RAN1 106e, default value of Ks, max  can be discussed later with Rel-17 MIMO UE capability.***

|  |  |
| --- | --- |
| Company | Comments |
| Mod | Related discussion seems not be urgent and clearly companies have diverse views. |
| MediaTek | Fine with the conclusion. |
| Vivo | Fine to delay the issue to UE capability. |
| QC | Ok to delay. We do not see the logic of Alt1/3 when NCJT CSI can still be supported with 2 CMRs. |
| Nokia/NSB | Ok with the proposed conclusion |
| Lenovo/Mot | Support the conclusion |
| Futurewei | Ok with the conclusion. |
| DOCOMO | Ok with the conclusion. |
| OPPO | Fine with the conclusion. |
| Intel | OK |
| ZTE | OK |
| Fraunhofer IIS/HHI | Support the conclusion. |
| NEC | Fine with the conclusion. |
| InterDigital | Ok with the conclusion. |
| Samsung | Fine with treating this issue later. |

For CSI measurement associated with a CSI-ReportingConfig for NC-JT, the methods of the CMR sharing between single-TRP and NCJT measurement hypotheses are agreed in RAN1 #105e:

**Agreement**

For CSI measurement associated with a CSI-ReportConfig for NC-JT, down-select one or more Alts in RAN1#106-e:

* Alt 2: additional RRC signalling is needed to configure M (M≤ Ks) CMRs from the CSI-RS resource set for CMR for Single-TRP measurement hypotheses
  + Example: For a given set of {{#0, #1}, {#2, #3}} with N=1, {#0, #2} are for NCJT measurement hypothesis. Additional RRC signalling may select {#0,#3} (if sharing is allowed), or {#1, #3} (if not allowed), or select any from the set for single-TRP measurement hypotheses.
* Alt 3: For CMRs configured in the CSI-RS resource set, support RRC signalling to enable/disable single-TRP measurement hypothesis using CMR configured within CMR pairs for NCJT measurement hypothesis
  + Example: For a given set of {{#0, #1}, {#2, #3}} with N=1, {#0, #2} are for NCJT measurement hypothesis. If gNB enables the sharing, {#0, #1, #2, #3} are for single-TRP measurement. If gNB disable the sharing, {#1, #3} are for single-TRP measurement hypotheses.
* Alt 4: CMR sharing between single-TRP measurement hypothesis and NCJT measurement hypothesis is realized by configuring the same value of CMR ID for single-TRP CMR and NCJT CMR pair.
  + Example: When the UE supports sharing, for a given set of {{#0, #0}, {#2, #3}} with N=1, {#0, #2} are for NCJT measurement hypotheses, the rest {#0, #3} are for single-TRP measurement hypotheses. The CMRs for STRP can be updated by re-configuring the CSI resource set.

Note that above examples are only for the purpose of illustrating/discussing Alternatives.

In RAN1 106e, companies’ preferences for CMR sharing mechanism is summarized as following:

|  |  |
| --- | --- |
| **Views** | **Companies** |
| **Alt 2** (8) | ZTE, InterDigital, CMCC, Intel, LGE, DoCoMo, Nokia, NSB, |
| **Alt 3** (10) | Spreadtrum, Samsung, CATT, Futurewei, Lenovo, MotM, OPPO, Qualcomm, MediaTek, Ericsson |
| **Alt 4** (3) | Vivo, Fraunhofer IIS, Fraunhofer HHI |

Companies supporting Alt 2 have the following considerations:

* ZTE proposes that not all resources in resource group 0 and group1 can always be used for STRP measurements in some case, especially when some transmitted beams may only be suitable for MTRP transmission according to group based beam reporting. gNB may use some dedicated beams only used for group based beam reporting, while each individual ones of these beams may not be the strongest ones for STRP transmission. Thus, it is better and more flexible to introduce two independent bitmaps for MTRP CSI and STRP CSI respectively.
* Some companies (CMCC, Intel, DoCoMo) propose that due to inter-beam interference, the CMRs for single-TRP might not be suitable to be used for NC-JT. On the contrary, the CMR pairs for NCJT maybe not proper to be used for single-TRP as well. In such case subset of CMRs is used for NCJT only and other subset of CMRs is used for STRP only.
* Some companies (Intel and LGE) propose that selection of *M* CMRs for STRP can be used in order to reduce the complexity of CSI calculation and achieve more efficient CSI calculation at the UE side.
* Nokia proposes that by Alt 3, if CMR sharing is disabled, determining the value of is more complicated as it depends on whether some CMRs are referred to by two NCJT pairs, which is feasible in FR1. In this case, one has to count the unique CMR IDs that are configured in the NCJT pairs, say , and the number of single-TRP hypotheses is given by .

Companies supporting Alt 3 have the following considerations:

* Some companies (Spreadtrum, Futurewei, Lenovo, OPPO, Qualcomm, MediaTek, and Ericsson) prefer the simplicity of signalling and consistency with existing UE capability agreement.
* Some companies (Samsung, CATT, Futurewei) proposes that by Alt 4, the number of CSI-RS resources for sTRP measurement hypotheses is limited when sharing is enabled. Futurewei proposes that Alt 4 cannot work for small Ks when the sharing is enabled, e.g., when Ks = 2.
* Samsung proposes that the gNB can achieve the effect of Alt 2 by Alt 3 by properly configuring the number of CSI-RS resources in the set.
* Qualcomm has concern that CMR(s) may be not used for either Single-TRP measurement hypothesis or NCJT measurement hypothesis in Alt 2

Companies supporting Alt 4 have the following considerations:

* Vivo proposes that Alt 4 with higher configuration flexibility needs no additional RRC signalling with repeated CMR IDs are in the configuration. Vivo has concern that CMR(s) may be not used for either Single-TRP measurement hypothesis or NCJT measurement hypothesis

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

***Proposal 13: For CSI measurement associated with a CSI-ReportingConfig for NC-JT, down-select one from the following Alts:***

* ***Alt 2: additional RRC signalling is needed to configure M (M≤ Ks) CMRs from the CSI-RS resource set for CMR for Single-TRP measurement hypotheses***
* ***Alt 3: For CMRs configured in the CSI-RS resource set, support RRC signalling to enable/disable single-TRP measurement hypothesis using CMR configured within CMR pairs for NCJT measurement hypothesis***

|  |  |
| --- | --- |
| Company | Comments |
| Mod | Proposal 13 is suggested based on the majority of Alt 2 and Alt 3 so far, although Alt 2 and Alt 3 does not have a clear winner. Given potential RRC impact and it has been discussed for a few meetings, we need to make a decision this meeting, either this way or another. |
| MediaTek | We support Alt. 3 in Proposal 13.  gNB can configure multiple CSI reporting settings to realize Alt. 2. |
| Apple | Slightly prefer Alt 2. |
| Vivo | We don’t support the proposal. We’d like to reconsider Alt 4.  The benefit of Alt 4 is very obvious and clear.   * Alt 4 can achieve exactly same CMR configuration results as Alt 2, i.e., achieve the functionality of fully/partially/non-CMR sharing between NCJT and STRP * Alt 4 can exactly reuse Rel-15/16 CMR configuration with CMR group concept without introducing any new RRC signalling, which is has least spec efforts. * Alt 4 is inline with the legacy CPU occupation rule in the sense that the required number of CPUs for the CSI report is the number of CMRs, Ks. For the example given in Alt 4, a given set of {{#0, #0}, {#2, #3}} with N=1, {#0, #2} are for NCJT measurement hypotheses, the rest {#0, #3} are for single-TRP measurement hypotheses. Then the number of CPUs needed for the CSI report is 4 (2 for NCJT and 2 for STRP), which is the number of Ks in the resource set.   What we need to do is to re-interpret the Ks CMRs in the set into two groups and determine the CMP pairs for NJCT hypos.  For the concerns on Alt 4 raised by some companies, our reply is as follows:   1. The number of CSI-RS resources for sTRP measurement hypotheses is limited when sharing is enabled   [vivo] The issue is not a REAL issue at all. The sum number of CSI-RS resources for STRP and the number of CSI-RS resources for NCJT cannot exceed the number of CPUs which is up to 8, which is the maximum Ks in Rel-15/16. If N=2 CMR pairs are configured for NCJT, then at least 4 CPUs should be occupied for the CSI report and at most another 4 CMRs can be configured for the STRP. The number of CSI-RS resources for sTRP measurement hypotheses is limited by the number of CPUs–2\*N.   1. Alt 4 cannot work for small Ks when the sharing is enabled, e.g., when Ks = 2   [vivo] Alt 4 can work for Option 1 with X=0 when Ks=2. For Option 1 with X=1 and Option 2, at least Ks=3; for Option 1 with X=2, at least Ks=4. We can’t see any problem to configure Ks>2 CMRs.  The proponents on either side of Alt 2 and Alt 3 have pointed out the problems of the other alternative. In our view,  Alt 2 requires additional signaling to configure M (M≤ Ks) CMRs from the CSI-RS resource set for CMR for Single-TRP measurement hypotheses, which will require much more spec efforts to decide on the signaling details.  Alt 3 is lack of flexibility by restricting that all CMRs for NCJT should be shared for STRP if sharing is enabled, otherwise none of the CMRs for NCJT can be used for STRP. |
| QC | Prefer Alt3. Our second preference is Alt4. The use case for configuring a CMR but not using it at all is not clear. So, we think the flexibility of Alt3 is enough. At the end, all alternatives can work, and we prefer to go with the majority view as there is no big difference among the Alts technically. |
| Nokia/NSB | Support this down-selection  We still prefer Alt 2 because it’s more flexible (partial sharing of some of the NCJT CMRs is not possible with Alt 3) and easier to determine the value of (for CRI definition, CPU count, etc.) |
| Lenovo/Mot | OK to down select. Prefer Alt3 |
| Futurewei | Support Proposal 13 and we prefer Alt 3. |
| DOCOMO | Support the proposal. Prefer Alt2. |
| OPPO | Support the proposal and agree with QC for Alt.3. |
| Intel | Support the proposal. Our first preference is Alt. 2. |
| ZTE | Slightly prefer Alt2. Also fine to go for majority |
| Fraunhofer IIS/HHI | Prefer Alt4. Second preference is Alt3. |
| NEC | Support the proposal, and prefer Alt 3. |
| InterDigital | Support FL’s proposal. Our preference is Alt2. |
| Samsung | We support the down selection. Our preference is Alt 3. |

For CSI measurement associated with a CSI-ReportConfig for NC-JT, it is agreed in RAN1 105e to study whether/how to support following dynamic updating on, e.g. by MAC-CE

* Alt 1: CMR pairs for NCJT measurement hypotheses
* Alt 2: CMRs for Single-TRP measurement hypotheses
* Alt 3: TCI states in CMRs
* Alt 4: the number of single-TRP CSIs (i.e. X=0/1/2) in a NCJT CSI report

In RAN1 106e, companies’ preferences for dynamic updating are summarized as following:

|  |  |
| --- | --- |
| **Views** | **Companies** |
| **Alt 1** (6) | InterDigital, CATT, Intel, Nokia, NSB, Ericsson |
| **Alt 2** (4) | InterDigital, Intel, Nokia, NSB |
| **Alt 3** (1) | Vivo |
| **Alt 4** (4) | CMCC, DoCoMo, Nokia, NSB |
| **Alt 5: dynamic change between Option 1 and Option 2 (1)** | DoCoMo |
| **No need** | ZTE, MediaTek |

Companies preferring Alt 1 have the following considerations:

* InterDigital, CATT, Intel, Nokia and Ericsson propose that due to UE movement or channel variation, there is a need to dynamically update the CMR pairs for NC-JT measurement hypothesis.
* Nokia proposes the issue of CPU overbooking can be solved by removing some CMR pairs.

Companies preferring Alt 2 have the following considerations:

* InterDigital proposes that in FR2 the narrower beams may cover smaller portions of the cell so that the CMRs for the Single-TRP measurement hypothesis may need to be updated.
* Nokia proposes the issue of CPU overbooking can be solved by reducing the CMRs for Single-TRP measurement hypothesis.
* Intel proposes to relax the implementation complexity by dynamic updating of CMRs for Single-TRP measurement hypothesis.

Companies preferring Alt 3 have the following considerations:

* Vivo prefers Alt 3 because dynamic TCI updating of CMRs by MAC-CE is beneficial for FR2 in order to update possible beams. Alt 3 can avoid frequently reconfiguring the TCI states in CSI resource settings or preconfiguring too many CSI-resource settings with all possible TCI states for CMR pairs and CMRs for STRP hypotheses.

Companies preferring Alt 4 have the following considerations:

* Nokia proposes that being able to dynamically adjust the number of single-TRP CSIs allowing the gNB to better control the feedback overhead and avoid partial omission of part 2 of the CSI report, if the resources available on PUSCH are limited.
* DoCoMo proposes that to facilitate the change of gNB scheduling, the number of single-TRP CSIs (i.e. X=0/1/2) for Option1 can be dynamic updated by MAC CE.
* CMCC proposes that if the number of single-TRP CSIs in a NCJT CSI report need to be updated, since the basic CSI report framework, like CMR/IMR configuration, have already be configured in RRC, MAC CE only updating the number could take the place of RRC re-configuration and the switching latency could be reduced effectively.

Companies preferring Alt 5 have the following considerations:

* DoCoMo proposes to facilitate the change of gNB scheduling, the change between Option1 and Option2 for a NCJT CSI report can be dynamically updated by MAC CE.

On the other hand, companies (ZTE/MediaTek) have concerns of supporting above dynamic updating:

* ZTE and MediaTek proposes the current CSI framework is very flexible so that gNB can configure different CMR pair(s) for NCJT, CMR(s) for single-TRP, and different values of *X* for each CSI reporting setting and use the current MAC-CE or DCI to activate or trigger the desired CSI report setting. It is up to gNB implementation to consider trade-off between scheduling flexibility and RRC signalling overhead.
* MediaTek proposes in R15/R16, there is no MAC-CE update within a CSI reporting setting. Instead, gNB can configure multiple CSI reporting settings to allow different configurations for CMRs or for their TCI states. For aperiodic CSI, the aperiodic CSI trigger state can be used to indicate a desired parameter setting and the trigger states can already be updated by MAC-CE in R15. For semi-persistent CSI, the desired parameter setting can be activated by DCI scrambled by SP-CSI-RNTI. Besides, TCI states for semi-persistent CMRs can already be updated using MAC-CE in R15.

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

***Proposal 14-1: For CSI measurement associated with a CSI-ReportConfig for NC-JT, with regarding to dynamically update (e.g. by MAC-CE) a certain configuration parameter(s) of CSI-ReportConfig***

* ***Alt 1: Dynamic updating is needed, FFS conditions***
* ***Alt 2: Dynamic updating is not needed***

***Proposal 14-2: For CSI measurement associated with a CSI-ReportConfig for NC-JT, support one or more from the following Alts, which can be dynamically updated, e.g. by MAC-CE***

* ***Alt 1: CMR pairs for NCJT measurement hypotheses***
* ***Alt 2: CMRs for Single-TRP measurement hypotheses***
* ***Alt 4: the number of single-TRP CSIs (i.e. X=0/1/2) in a NCJT CSI report***

|  |  |
| --- | --- |
| Company | Comments |
| Mod | Although there is sufficient interest, related enhancements have been discussed for several meetings. Proposal 14 will start from the basic question of need/no need in Rel-17, as Proposal 14-1. It is understandable that companies can be hesitating due to uncertainty and potential spec impact, so that FFS is added just in case. We may need a decision this meeting.  If need, we will discuss alternatives to understand each other better in Proposal 14-2. Temporally Alt 3 and Alt 5 are removed due to the least support based on Tdoc review. |
| MediaTek | Support Alt. 2 in Proposal 14-1. |
| Apple | Proposal 14-1: Prefer Alt 2  Proposal 14-2: We do not see strong need to use MAC-CE to update the CMR configuration. |
| QC | Support Alt. 2 in Proposal 14-1. |
| Nokia/NSB | P 14-1: prefer Alt 1  P 14-2: support all three Alt. Alt 1 and 2 allow the gNB to reduce the number of CSI calculations and avoid CPU overbooking. Alt 3 allows to reduce the UCI payload and avoid omissions |
| Lenovo/Mot | Support Alt 2 of Proposal 14-1 |
| Futurewei | Support Alt 2 in Proposal 14-1. |
| DOCOMO | Proposal 14-1: Prefer Alt 1.  Proposal 14-2: we can accept all three alts. |
| OPPO | Support Alt. 2 in Proposal 14-1. |
| vivo | Our preference is original Alt3 in Proposal 14-2. For Alt3, we see the need for dynamic TCI updating of CMRs by MAC-CE, which is beneficial for FR2 to update the possible beams to avoid frequently reconfiguring the TCI states in CSI resource settings or preconfiguring too many configurations of *csi-ReportConfig, csi-ResourceConfig* or *CSI-AssociatedReportConfigInfo*.  Firstly, it is known that the number of measurement combinations that can be composed by the reporting mechanism (Option1 with X=0/1/2 and Option2), the number of NCJT measurement hypotheses (N), the number of STRP measurement hypotheses (Ks-2N), and the number of beam pairs that can be received by the UE at the same time is in the form of a product, and it therefore may have a significant configuration overhead. For example, when a UE reports 4 beam pairs, the network may configure 6 CSI reporting settings to include all possible CMR pair combinations for Option1 with X=0 and N=2 CMR pairs. While only 1 CSI-reporting setting is needed in Alt 3.  Secondly, when a UE moves through an area deployed with multiple TRPs, TRP switching will happen frequently. The network is not able to predict the TRP switching route and hardly to pre-configure all CSI-reporting settings associated with the CMR pairs of different coordinating TRPs.  Alt3 can effectively and directly solve the above problem of large signaling overhead and unpredictable CMR pair configuration due to dynamic changing measurement beams. Therefore, we modify Proposal 14-2 as follows.  ***Proposal 14-2: For CSI measurement associated with a CSI-ReportConfig for NC-JT, support one or more from the following Alts, which can be dynamically updated, e.g. by MAC-CE***   * ***Alt 1: CMR pairs for NCJT measurement hypotheses*** * ***Alt 2: CMRs for Single-TRP measurement hypotheses*** * ***Alt 3: TCI states in CMRs*** * ***Alt 4: the number of single-TRP CSIs (i.e. X=0/1/2) in a NCJT CSI report*** |
| Intel | Support Alt 1 for Proposal 14.1.  Support Alt. 1 and Alt. 2 for Proposal 14.2. |
| ZTE | Support Alt. 2 in Proposal 14-1. |
| Fraunhofer IIS/HHI | Support Alt2 in Proposal 14-1. |
| InterDigital | Support Alt 1 for Proposal 14.1.  Support Alt. 1 and Alt. 2 for Proposal 14.2. |
| Samsung | Support Alt 2 in Proposal 14-1. |

Huawei/HiSilicon raises an issue that the undesired phase rotation at a practical receiver caused by DL/UL switching impacts the estimation of the inter-TRP interference. On the contrary, random phase rotation does not exist in NCJT scheduling itself, because the transmission of two cooperative TRPs are SDM-based and the same slot is used. The inter-TRP interference in CQI calculation may be too conservative or too aggressive comparing the inter-TRP interference in NCJT scheduling PDSCH experienced by UE. Consequently, above random phase rotation leads to the mismatch between the reported CQI and the proper MCS in NCJT scheduling. It means that the gNB cannot derive the proper MCS relying on the reported CQI. The reported NCJT CSI may be useless for NCJT scheduling.

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

***Proposal 15: For CSI measurement associated with a CSI-ReportingConfig for NC-JT,***

* ***whether two CMRs within the same CMR pair configured for NCJT measurement hypothesis shall be further constrained, e.g. within the same DL slot***

|  |  |
| --- | --- |
| Company | Comments |
| Mod | Due to potential UE implementation impact for CSI measurement, above issue is suggested to be discussed in RAN1. |
| MediaTek | We are open to study the issue until the next meeting. |
| Apple | We are open and supportive to discuss, other restriction can be that they are within the same CDRX active time. |
| QC | We support the proposal, and agree with the motivation mentioned by Huawei. |
| Nokia/NSB | Ok with discussing this issue |
| Lenovo/MotM | OK to discuss |
| Futurewei | Support Proposal 15 to discuss the issue. |
| DOCOMO | Ok to discuss this issue. |
| OPPO | Support to discuss. |
| ZTE | We are OK to discuss it. |
| Fraunhofer IIS/HHI | Support. |
| NEC | OK to further discuss. |
| InterDigital | Support FL’s proposal to further discuss this issue. |
| Samsung | Ok to discuss |

Qualcomm proposes to clarify the *powerControlOffset* for a CMR configured in a CMR pair for a NCJT CSI hypothesis. In Rel-15, *powerControlOffset* or “Pc ratio” is configured per NZP CSI-RS resource and is defined as ratio of PDSCH EPRE to NZP CSI-RS EPRE when UE derives CSI feedback. More accurate definition of Pc ratio for Rel. 15 was concluded as below:

**Conclusion (RAN1 #96bis)**

It is common understanding in RAN1 that:

* The *powerControlOffset* (“Pc”) ratio is defined as  dB
* Where
  + *PPDSCH* is the energy of total PDSCH ports multiplexed on one subcarrier of one OFDM symbol
  + *PCSIRS* is the energy of all CSI-RS ports multiplexed on one subcarrier of one OFDM symbol

In Rel-17, when CMR is used in a CMR pair for a NCJT hypothesis, then the CMR is from one TRP while “total PDSCH ports” are from both TRPs since layers have the first TCI state and another layers have the second TCI state in SDM scheme. In addition, in Option 2, UE evaluates all NCJT and single-TRP hypotheses and reports only the best one. This Pc ratio assumption and definition plays an important role for UE to determine the best CSI hypothesis.

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

***Proposal 16: For a CMR pair configured for a NCJT measurement hypothesis,***

* ***whether a separate powerControlOffset (Pc ratio) shall be configured for NCJT measurement hypothesis***
* ***whether re-define Pc ratio: For a NCJT measurement hypothesis, the Pc ratio is defined as dB, whereas*** 
  + ***PPDSCH is the energy of PDSCH ports with a same TCI state as the CMR on one subcarrier of one OFDM symbol***
  + ***PCSIRS is the energy of all CSI-RS ports of the CMR multiplexed on one subcarrier of one OFDM symbol.***

|  |  |
| --- | --- |
| Company | Comments |
| Mod | Due to potential UE implementation impact for CSI measurement, above issue is suggested to be discussed in RAN1. |
| MediaTek | We are open to study the issue until the next meeting. |
| Apple | We are open to discuss. In our understanding, powerControlOffset is configured per CSI-RS resource, so it seems that there is no issue. |
| QC | Support the proposal.  @Apple: With Rel. 15 definition, we are not sure how it can work. The numerator will be the power across both TRPs while the denominator is the power per TRP. In addition, with this definition, how can a CMR be used for both sTRP hypothesis and NCJT hypothesis in a consistent way? |
| Nokia/NSB | Ok to discuss this issue.  It seems that with the old definition of Pc ratio, as long as the same CDM factor is used for CMRs of both TRPs, the CQI calculation would be correct for both S-TRP and NCJT hypotheses based on the equation |
| Lenovo/Mot | OK to discuss the issue |
| Futurewei | We are open to discuss the issue. |
| DOCOMO | Ok to discuss this issue. |
| OPPO | Fine to discuss the issue. However, gNB can adjust the value of *powerControlOffset* according to the number of multiplexing layers between TRPs. It may be solved by implementation. |
| vivo | We are OK to discuss this issue. |
| Intel | OK to discuss |
| ZTE | OK to discuss. However, we don’t think a new Pc is needed for NCJT. For different layers of PDSCH, the power may be different. It is hard to associate power offset with partial PDSCH DMRS ports. Furthermore, for CSI calculation, Pc is just for the assumption, not real transmission. gNB can recalculate if needed. |
| Fraunhofer IIS/HHI | We are open to discuss this issue. |
| NEC | OK to further discuss. |
| Samsung | We are ok to discuss. |

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

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

***Proposal 17: For CSI calculation associated to a NCJT measurement hypothesis,***

* ***Whether CSI computation delay requirement shall be relaxed. FFS details***

|  |  |
| --- | --- |
| Company | Comments |
| Mod | Due to potential UE implementation impact for CSI measurement, above issue is suggested to be discussed in RAN1. |
| Apple | We are open for discussion especially the Z and Z’ |
| Nokia/NSB | Ok to discuss this issue |
| Lenovo/Mot | OK to discuss |
| Futurewei | Ok to discuss the issue. |
| OPPO | Fine to discuss. |
| vivo | OK to discuss |
| ZTE | No.  So the complexity has been considered as more CPUs are occupied for those CMRs. |
| Fraunhofer IIS/HHI | OK to discuss. |
| NEC | OK to discuss. |
| Samsung | Ok to discuss. |

With regarding to non-PMI based port selection, companies’ views are summarized as following:

|  |  |
| --- | --- |
| **Views** | **Companies** |
| Support non-PMI based port-selection in Rel-17 | Samsung, CATT, MediaTek |

Companies preferring non-PMI based port-selection for NCJT measurement have the following considerations:

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

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

***Proposal 18: For CSI measurement associated to a reporting setting CSI-ReportConfig for NCJT,***

* ***whether non-PMI based port-selection is needed for NCJT measurement hypothesis in Rel-17***

|  |  |
| --- | --- |
| Company | Comments |
| Mod | Probably we can make a conclusion this meeting, for potential impact of UCI design, if we decide to go ahead with more support. |
| MediaTek | We support non-PMI based port-selection because the precoders may be calculated by gNB using SRS measurement. |
| Apple | We are open for discussion, i.e., which codebook we support for the CSI enhancement for mTRP |
| QC | We are open to discuss, but this is not high priority in our view. There is already an FFS in the earlier agreements on this, and seems not enough interest. |
| Nokia/NSB | Ok to discuss this issue |
| Futurewei | We are open to discuss this issue. |
| DOCOMO | Ok to discuss this issue. |
| OPPO | We are fine to discuss it with low priority. |
| vivo | Agree with QC. |
| Intel | OK to discuss |
| ZTE | OK to discuss it with low priority |
| Fraunhofer IIS/HHI | We are open to discuss this issue. |
| NEC | Open to discuss. |
| Samsung | We support non-PMI-based NCJT considering the CPU requirements and the related limitations of PMI-based NCJT. |

Whether the maximum number of transmission layers for a NCJT measurement hypothesis equals to 4 or can be larger than 4 is still open. Therefore companies’ views are summarized as following:

|  |  |
| --- | --- |
| **Views** | **Companies** |
| Up to 4 layers in Rel-17 | Vivo, Ericsson |
| Up to 8 layers in Rel-17 | CATT, DoCoMo |

Companies preferring up to 4 layers have considered that single-DCI based NC-JT only supports up to 4 layers in Rel-16. On the other hand, companies (CATT, DoCoMo) have considered NCJT CSI enhancements in order to support the maximal transmission layer larger than 4

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

***Proposal 19: For CSI measurement associated to a NCJT measurement hypothesis in Rel-17, the maximal number of transmission layers is***

* ***Alt 1: up to 4 layers***
* ***Alt 2: up to 8 layers***

|  |  |
| --- | --- |
| Company | Comments |
| Mod | Probably we can make a conclusion this meeting, for potential impact of UCI, if we decide to go ahead with more support for 8 layers. |
| MediaTek | Support Alt. 1. |
| Apple | Prefer Alt 1 |
| QC | Prefer Alt1. |
| Nokia/NSB | Support Alt 1  Extension to the max. number of layers currently supported by single-DCI NCJT transmission has lower priority for this release in our view. |
| Lenovo/Mot | Support Alt 1 |
| Futurewei | Prefer Alt 1. |
| DOCOMO | We support Alt2. But we can also accept Alt1. |
| OPPO | Support Alt.1 |
| vivo | Support Alt. 1. |
| Intel | Prefer Alt 1 |
| ZTE | Support Alt 2 for more forward compatibility. |
| Fraunhofer IIS/HHI | Support Alt1. |
| NEC | Prefer Alt 1. |
| Samsung | Support Alt 1. |

## CSI Reporting Enhancements for Multi-TRP

Some companies (OPPO, Qualcomm, Nokia, and NSB) provide further considerations/clarifications over the bitwidth of CRI for Option 1, starting from following agreement:

**Agreement**

For the UE configured to report X CSIs associated with single-TRP measurement hypotheses and one CSI associated with NCJT measurement hypothesis (i.e. Option 1),

* Alt 1: X+1 CRIs are reported, whereas X CRIs are for single-TRP measurement hypotheses and one CRI is for NCJT measurement hypothesis.  Each CRI bit size depends on the corresponding number of either valid CMR pairs for NCJT measurement hypothesis or valid CMRs for single-TRP measurement hypotheses

FFS: Whether the X+1 CRIs are reported jointly as one CSI report or as separate CSI reports.

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

***Proposal 20: For the UE configured to report X CSIs associated with single-TRP measurement hypotheses and one CSI associated with NCJT measurement hypothesis (i.e. Option 1), the bitwidth associated to X+1 CRI(s) are given as following:***

* ***for X=0***
* ***in CSI associated with NCJT measurement hypothesis and in CSI associated with Single-TRP measurement hypothesis for X=1***
* ***in CSI associated with NCJT measurement hypothesis and and in CSI associated with Single-TRP measurement hypothesis for X=2***
* ***Note that (M1<=K1) and (M2<=K2) is the number of CMRs configured for Single-TRP measurement hypothesis in the first and second CMR groups respectively in a CMR measurement set.***

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| Company | Comments |
| Mod | Proposal 20 is to clarify payload of CRI. In my understanding, Proposals 13 and 14 may impact the final value ranges but this proposal seems be stand-alone enough, from spec point of view. |
| MediaTek | Support Proposal 20. |
| Apple | We are fine with FL proposal |
| QC | Support. |
| Nokia/NSB | Support this proposal and agree with FL’s assessment |
| Lenovo/Mot | Support |
| Futurewei | Support Proposal 20. |
| DOCOMO | Support |
| OPPO | Support. |
| Vivo | Support |
| Intel | Support |
| ZTE | Support |
| Fraunhofer IIS/HHI | Support. |
| NEC | Support. |
| InterDigital | Support FL’s proposal. |
| Samsung | Support the proposal. |

Some companies (Vivo, CATT, Qualcomm, Fraunhofer IIS, Fraunhofer HHI, DoCoMo, Nokia) have provided the consideration of CRI codepoints mapping order for Option 2, starting from following agreement:

**Agreement**

For the UE be configured to report one CSI associated with the best one among NCJT and single-TRP measurement hypotheses (i.e. Option 2),

* Alt 1: Single CRI is reported whereas CRI bit size depends on total number of valid CMR pairs for NCJT measurement hypothesis and valid CMRs for single-TRP measurement hypotheses.
  + FFS further mapping mechanism between each CRI codepoint and Single-TRP/NCJT measurement hypothesis.

Some companies (DoCoMo, Qualcomm) support the CRI codepoint mapping to Single-TRP measurement hypothesis first, then to NC-JT measurement hypothesis. Some companies (Vivo, CATT, Fraunhofer IIS, Fraunhofer HHI, Nokia) support the CRI codepoint mapping to NC-JT measurement hypothesis first, then to Single-TRP measurement hypothesis.

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

***Proposal 21: For the UE be configured to report one CSI associated with the best one among NCJT and single-TRP measurement hypotheses (i.e. Option 2), down-select one Alt:***

* ***Alt 1: the first M1+M2 codepoints of CRI corresponds to M1+M2 CMRs for Single-TRP measurement hypothesis and the second N codepoints corresponds to N CMR pairs for NC-JT measurement hypothesis.***
* ***Alt 2: the first N codepoints of CRI corresponds to N CMR pairs for NC-JT measurement hypothesis and the second M1+M2 codepoints corresponds to M1+M2 CMRs for Single-TRP measurement hypothesis.***
* ***Note that (M1<=K1) and (M2<=K2) is the number of CMRs configured for Single-TRP measurement hypothesis in the first and second CMR groups respectively in a CMR measurement set.***

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| Company | Comments |
| Mod | Proposal 21 is to make a decision of codepoint mapping, based on the majority assuming that there is no clear pros and cons. |
| MediaTek | Slightly prefer Alt. 2, but Alt. 1 is also fine. |
| Apple | Alt 1 and 2 look the same to us |
| QC | Both Alts work, but Alt1 seems more natural (sTRP hypos are same as legacy, NCJT hypos are added at the end) |
| Nokia/NSB | Preference for Alt2 because it allows to use the same mapping of the NCJT codepoints for Option 2 and Option 1 and for any value of . |
| Lenovo/Mot | Prefer Alt 1, agree with QC |
| Futurewei | Ok with both Alt 1 and Alt 2. |
| DOCOMO | Slightly prefer Alt.1. But also okay with Alt.2. |
| OPPO | We cannot find any difference. Both are fine. |
| vivo | We think the choice may depend on the CMR configuration, i.e., whether CMR pairs for NCJT measurement hypotheses are arranged firstly in each CMR group. |
| Intel | We don’t have preference. Both Alt 1 and Alt 2 are OK. |
| ZTE | Alt 2 is slightly preferred as the same view as Nokia. |
| Fraunhofer IIS/HHI | Alt1 and Alt2 are fine. |
| NEC | Prefer Alt 2, with same view as Nokia and ZTE. |
| InterDigital | Both Alts are OK, although we slightly prefer Alt1 to keep the new NCJT codepoints at the end. |
| Samsung | Support Alt 1. |

In Rel-15, a UE can be configured with a *CSI-ReportingConfig* containing *CodebookConfig* configured with one RI restriction. The single RI restriction with a bitmap is used to indicate allowed rank indicator for all Single-TRP measurement hypotheses configured by *CSI-ReportingConfig*. In Rel-17, Single-TRP and NCJT measurement hypotheses are configured by single CSI reporting setting*.* Therefore remaining issue, related to RI restriction, is whether/how to configure RI restriction(s) associated with single-TRP/NCJT measurement hypotheses configured by single CSI reporting setting in both Options 1 and 2. Therefore companies’ views are summarized as following:

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| --- | --- |
| **Views** | **Companies** |
| **Alt 1: One RI restriction is for both Single-TRP and NCJT measurement hypotheses** | Lenovo, DoCoMo |
| **Alt 2: Two RI restrictions, each RI restriction is applied to one TRP** | Vivo, LGE, Nokia, NSB |
| **Alt 3: Multiple RI restrictions, each RI restriction is applied to one CMR** | Intel |
| **Alt 4: Two RI restrictions, one is applied to NCJT and another is applied to Single-TRP** | Huawei, HiSilicon |
| **No need** | Ericsson |

Companies preferring Alt 1 have the following considerations:

* Lenovo proposes that the total number of layers for NC-JT is limited to 4, such that the difference between numbers of layers corresponding to two NCJT PMIs is no larger than one.
* DoCoMo proposes that a single RI restriction is sufficient which can be applied to both single-TRP measurement, and total rank of NCJT measurement.

Companies preferring Alt 2 have the following considerations:

* Vivo, LGE propose different report configurations across TRPs should be considered at least for cases e.g. like TRPs in heterogeneous deployment or TRPs having different antenna structures.

Companies preferring Alt 3 have the following considerations:

* Intel proposes that RI restriction should be configured per each CMR in CMR pair for NCJT and per each CMR for STRP because maximum rank may be different for NCJT and STRP.

Companies preferring Alt 4 have the following considerations:

* Huawei and HiSilicon propose that two RI restrictions should be configured where one is for NCJT measurement hypothesis and the other is for Single-TRP measurement hypothesis, since the candidates of RI restriction for different measurement hypothesis are different and hence to use two different RI restrictions is more straightforward.

On the other hand, Ericsson prefers that RI restriction is not supported in Rel-17, since a maximum of 2 layers can be supported per TRP, and hence the rank per TRP can be either 1 or 2.

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

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

* ***Alt 1: RI restriction is needed.***
* ***Alt 2: RI restriction is not needed, at least not for NCJT measurement hypotheses***

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

* ***Alt 1: One RI restriction is configured, whereas the RI restriction is applied to both Single-TRP and NCJT measurement hypotheses***
* ***Alt 2: Two RI restrictions can be configured, whereas one RI restriction is applied to one CMR group in a CMR resource set respectively, i.e., per TRP.***
* ***Alt 3: Multiple RI restrictions can be configured, whereas each RI restriction is applied to one CMR in a CMR resource set respectively***
* ***Alt 4: Two RI restrictions can be configured, whereas one RI restriction is applied to all Single-TRP measurement hypotheses, and another one is applied to all NCJT measurement hypotheses.***

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| Company | Comments |
| Mod | Proposal 22 will start from the basic question of need/no need in Rel-17, as Proposal 22-1. If need, we will discuss alternatives to understand each other better and we may need to make final decision no later than RAN1 106bis (next meeting). |
| MediaTek | Support Alt. 1 in Proposal 22-1.  Support Alt. 4 in Proposal 22-2. |
| Apple | First preference, Alt 2 in Proposal 22-1  Second preference, Alt 1 in Proposal 22-2 |
| QC | Support Alt1 in Proposal 22-1. In Alt 2, we suggest to remove the “at least not”. Why should we remove the existing RI restriction for sTRP?  On Proposal 22-2: First preference: Alt4. Second preference: Alt1. We do not think RI restriction per CMR group or per CMR pair or per CMR is needed, as RI restriction is a property of codebook and not measurement resource. |
| Nokia/NSB | Support discussing this issue.  P 22-1: preference for Alt 1  P 22-2: preference for Alt 2 as it gives the network the possibility to control the transmission rank from each TRP separately, with a simple configuration |
| Lenovo/Mot | Support Alt 1 in Proposal 22-1  Support Alt 1 in Proposal 22-2 |
| Futurewei | Proposal 22-1: Support Alt 1.  Proposal 22-2: Support Alt 4. |
| DOCOMO | Proposal 22-1: Support Alt 1.  Proposal 22-2: Support Alt. 1. Can also accept Alt.4. |
| OPPO | Proposal 22-1: Alt.2 without “at least not”.  Proposal 22-2: Support Alt.1 |
| vivo | Proposal 22-1: Support Alt 1.  Regarding Proposal 22-2, we’d like to add another alternative which is TRP-specific RI restriction and one RI restriction for NCJT can be configured.   * ***Alt 5: Multiple RI restrictions can be configured, whereas each RI restriction is applied to each Single-TRP measurement hypothesis, and one is applied to all NCJT measurement hypotheses.*** |
| Intel | Support Alt. 1 in Proposal 22-1.  For Alt 4 we prefer the following alternative.  ***Alt 6: Multiple RI restrictions can be configured, whereas RI restriction is configured per each CMR in CMR pair for NCJT and per each CMR for STRP*** |
| ZTE | New RI restriction for NCJT is not needed. The legacy RI restriction is for STRP. |
| Fraunhofer IIS/HHI | Proposal 22-1: Support Alt 1.  Proposal 22-2: Support Alt 1. |
| NEC | Proposal 22-1: Support Alt 1.  Proposal 22-2: Support Alt 5 from vivo.  In addition, we think multiple CBSRs should also be supported. |

With regarding to the discussion of PMI/RI sharing mechanisms between NCJT CSI and single-TRP CSI(s), as following:

* For Option 1 CSI reporting associated with NCJT and X single-TRP measurement hypotheses, study whether to support following PMI/RI sharing mechanisms between NCJT CSI and single-TRP CSI(s):
  + Enabling/Disabling PMI, RI sharing via higher-layer configuration
  + Dynamic indication of PMI, RI sharing in the CSI report
  + FFS: other details
  + FFS: applicable conditions/restrictions of CMR sharing among Single-TRP and NCJT hypotheses, if above PMI/RI sharing mechanism can be applied

Companies (Vivo and Ericsson) have provided simulation results on the PMI/RI sharing mechanisms between NCJT CSI and Single-TRP CSI(s):

* Simulation results provided by Ericsson show that for a scenario with 2TX TRPs (which is the typical scenario where NCJT provides gains over single-TRP scheduling for UEs equipped with 4 Rx antennas), there is very little difference in performance when reusing RI/PMIs between NC-JT CSI and single-TRP CSI.
* Simulation results provided by Vivo further show that the PMIs of NC-JT CSI are always the same as the PMIs of Single-TRP CSI will result in performance loss and nearly half of the Ues have an identical PMI ratio less than 60%, when Single-TRP CSI and NC-JT CSI calculate separately.

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| **Views** | **Companies** |
| **Alt 1+Alt2: Support PMI/RI sharing by both network configuration and UE dynamic indication** | Vivo, ZTE |
| **Alt 2: Support PMI/RI via higher-layer configuration** | Intel, Ericsson |

Companies preferring Alt 1 +Alt 2 have the following considerations:

* Some companies (Vivo, ZTE) proposes that to support PMI/RI sharing relies on only on network configuration is not a good solution and results in some performance loss. Based on the configuration of enabling/disabling PMI/RI sharing, UE can further report an indicator within Part 1 to indicate whether PMI/RI sharing is performed in CSI report.

Companies preferring Alt 2 have the following considerations:

* Intel proposes that sharing of RI and PMI values may lead to degradation of system performance due to different optimal RI value for NCJT and STRP especially for scenarios were number of Tx antennas at the gNB is equal or higher comparing to the number of Rx antennas at the UE. For such a scenario, RI for STRP may be higher comparing to the number of layers transmitted from the same TRP in NCJT. Thus, if sharing of RI and PMI for NCJT CSI and STRP CSI is supported, enabling/disabling of this feature shall be considered.

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

***Proposal 23-1: For Option 1 CSI reporting associate`ed with NCJT and X single-TRP measurement hypotheses, with regarding to PMI/RI sharing mechanisms between NCJT CSI and single-TRP CSI(s), support one of following Alts***

* ***Alt 1: PMI/RI sharing mechanism is needed, FFS conditions***
* ***Alt 2: PMI/RI sharing mechanism is not needed***

***Proposal 23-2: For Option 1 CSI reporting associated with NCJT and X single-TRP measurement hypotheses, with regarding to PMI/RI sharing mechanisms between NCJT CSI and single-TRP CSI(s), support one or more Alts from the following:***

* ***Alt 1: Enabling/Disabling PMI, RI sharing via higher-layer configuration that corresponding PMI/RI for Single-TRP measurement hypothesis will not be reported by UE as well as dynamic indication of PMI, RI sharing in the CSI report by adding indicator(s) in CSI Part 1 to inform which PMI/RI are to be shared and omitted.***
  + ***FFS details***
* ***Alt 2: Enabling/Disabling PMI, RI sharing via higher-layer configuration that corresponding PMI/RI for Single-TRP measurement hypothesis will not be reported by UE.*** 
  + ***FFS details***

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| Company | Comments |
| Mod | Proposal 23 will start from the basic question of need/no need in Rel-17, as Proposal 23-1. It is understandable that companies can be hesitating due to uncertainty and potential spec impact, so that FFS is added just in case.  If need, we will discuss available Alternatives to understand each other better in Proposal 23-2. |
| MediaTek | Support Alt. 1 in Proposal 23-1.  Support Alt. 2 in Proposal 23-2.  About UE’s dynamic indication of PMI/RI sharing, from UE’s perspective there seems to be no merit of using PMI/RI sharing. If UE determines whether to perform PMI/RI sharing before any PMI calculation, the CSI accuracy may be degraded. On the other hand, UE cannot save any PMI calculation if it decides whether to perform PMI/RI sharing at the very end. Considering CSI accuracy and implementation complexity, UE may just disable PMI/RI sharing all the time. |
| Apple | We do not support Alt 2 in proposal 23-2  NW should not be the entity that determines the CSI, for example, whether UE prefers RI/PMI sharing. It is based on the UE CSI measurement. |
| QC | We do not support Alt1 in proposal 23-2. We agree with MediaTek. If it is left to the UE, we are not sure why it makes sense to introduce this feature. With Alt1, we introduce all theses complicated conditions and new UCI field but at the end UE may never indicate sharing or may always assume sharing. |
| Nokia/NSB | In our view this discussion has lower priority.  The primary objective of this optimisation seems to reduce UCI payload for Option 1 and X>0. An easier way to address this problem is for example, by dynamic update of (P 14-2, Alt 4)  P 23-1: preference for Alt 2 |
| Lenovo/Mot | Support Alt 2 of Proposal 23-2. The main advantage of PMI/RI sharing is reducing the CSI feedback overhead. Given that the network needs to allocate UCI bits for CSI feedback prior to UE feedback, depending the PMI/RI sharing based on CSI feedback would not be very helpful |
| Futurewei | We shared the same view as Nokia/NSB that discussion of this topic should have lower priority. |
| DOCOMO | Agree with Nokia/NSB and Futurewei to have low priority for this issue.  And we do not support Alt 2 of Proposal 23-2. The enabling ignalling can be configured by NW, but UE should further determine whether PMI/RI can be shared based on CSI measurement. |
| Vivo | Support Alt 1 of Proposal 23-1. Alt 1 in Proposal 23-2 is preferred. |
| Intel | Support Alt 1 of Proposal 23-1.  Prefer Alt 2 in Proposal 23-2. Alt. 1 also can be considered as a second preference. |
| ZTE | We do not support Alt 2 in proposal 23-2  It is unclear how gNB can know whether PMI sharing is feasible or not. PMI sharing or not should be reported by UE based on comparison between STRP CSI and NCJT CSI. This feature is to save UCI overhead rather than UE calculation complexity. |
| Fraunhofer IIS/HHI | Agree with Nokia that this issue should have lower priority. |
| InterDigital | Postpone the discussion. |
| Samsung | We support Alt 1 in both Proposal 23-1 and 23-2. We believe dynamic indication of PMI sharing allows the UE to decide on PMI sharing based on its observation of the channel. This resolves the observed performance degradation due to fixed (RRC configured) sharing in the simulation results provided by Vivo.  Contrary to Nokia/NSB’s proposal, the channel observation is not available at the network prior to CSI feedback, hence, dynamic update of *X* may not lead to the same advantages as dynamic PMI sharing.  We agree with Lenovo/Mot that PMI/RI sharing has impact on UCI overhead. Even though the UCI bits for CSI feedback are allocated in priori to UE’s CSI feedback, such PMI/RI sharing affects the CSI omission based on prioritization. In other words, more CSI parts for single report or more CSI reports (hypotheses) can be included, if sharing is available. |

## CSI processing criteria

In Rel-15/16, each CSI report associated with the *CSI*-*ReportConfig* is assigned a priority for:

* UCI payload construction
* CSI part 2 omission
* CPU occupation.

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

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| **Views** | **Companies** |
| **Purpose 1: the order of UCI payload construction of reported CSIs** | Lenovo, DoCoMo, Qualcomm |
| **Purpose 2: CSI part 2 omission** | ZTE, Qualcomm, MediaTek, Lenovo, MotM, Huawei, HiSilicon |
| **Purpose 3: CPU occupancy** | Huawei, HiSilicon, Spreadtrum |

Companies preferring purpose 1 have the following considerations:

* Some companies (Qualcomm, Lenovo) propose that each CSI for each individual measurement hypothesis is assigned a priority for payload construction.

Companies preferring purpose 2 have the following consideration:

* Some companies (ZTE, Qualcomm, MediaTek, Lenovo, MotM, Huawei, HiSilicon) proposes to define the new priority formula which is mainly used for determining the omission of part 2 CSI. UL resource of PUSCH may not be enough to carry a CSI report conveying all X+1 CSIs for multiple measurement hypotheses.

Companies preferring purpose 3 have the following considerations:

* Some companies (Huawei, HiSilicon, Spreadtrum) propose that because the minimal number of required CPUs for a NCJT report in Rel-17 is larger than the typical commercial chipset, the new CPU occupancy rule should be defined to solve the issue of CPU overbooking in Rel-17.

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

***Proposal 24: To clarify purposes of discussing CSI priority among multiple CSI measurement hypotheses configured by a single CSI reporting setting for Option 1, following issues need to be addressed:***

* ***Issue 1: to confirm the order of UCI payload construction for reported CSIs***
* ***Issue 2: to enhance CSI part 2 omission rules for prioritized CSI measurement hypotheses and associated CSIs***
* ***Issue 3: to enhance CPU occupancy rules for prioritized CSI measurement hypotheses and associated CSIs***

***Proposal 25: To address with issues in Proposal 24, down-select one or more Alternative from the following:***

* ***Alt 1: modify priority equation to address individual single-TRP or NCJT measurement hypothesis in a CSI report***
* ***Alt 2: modify the table of priority reporting levels for Part 2 CSI***
* ***Alt 3: modify CPU occupy rules/descriptions***

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| Company | Comments |
| Mod | Proposal 24 is to start from discussing general purposes for related discussion in Rel-17. If RAN1 considers that all are needed, for example, it seems to be easier to treat each CSI hypothesis as a CSI report. If nothing is needed, perhaps only thing left is UCI design by following a simple/natural order of CSIs.  Proposal 25 is a placeholder once we can agree with or understand better purposes in Proposal 24. |
| MediaTek | As we support partial CSI feedback, not only for Part 2 CSI but also for Part 1 CSI and single-part CSI, all issues in Proposal 24 need to be addressed.  For Alt. 1 in Proposal 25, we suggest to revise it as   * ***Alt 1: Each single-TRP/NCJT measurement hypothesis in mapped to a distinct CSI report and modify the priority equation accordingly.***   We support the revised Alt. 1. |
| Apple | We only support to address the issue 1 in Proposal 24  We do not support to enhance the CSI omission rule, it is already unnecessarily complicated for UE to implement  We do not support to enhance CPU occupancy rule which is anyway meaningless in the real deployment since UE has to have some proprietary solution to handle CPU overbooking as UE CSI processing timeline and capability cannot be fully standardized |
| QC | For proposal 24, we support issue 1 and issue 2.  For proposal 25, our preference is Alt1 as we think it is the simplest implementation in the spec. Alternatively, we can let the editor to capture whatever priority we agree on.  For us, we hear a lot of proposals / arguments on the need to reduce UCI overhead (e.g. PMI/RI sharing). CSI part 2 omission is the natural way to do this (i.e. whenever resources are not enough, less important parts of UCI are dropped), and the framework is already in the spec. |
| Nokia/NSB | We think that only Alt 2 in P25 is needed to address Issue 1. Issue 2 and 3 seem more like optimisations that can be very complex from specs perspective |
| Lenovo/Mot | Support Issue 1 of Proposal 24, and Alt 1 of Proposal 25. Also agree with MediaTek’s revised Alt 1. If not agreed, one CSI report under Option 1, X=2 would have up to 4 PMI, 4 RI, 3 CQI. This would significantly increase the complexity of updating the table of priority reporting levels for Part 2 CSI |
| DOCOMO | For proposal 24, we support issue1.  For proposal 25, we support Alt1. And we can also accept MTK’s revision. |
| O**PPO** | Support only issue 1 in proposal 24.  For proposal 25, we don’t any of alternatives is needed to solve issue 1 including modifying the priority formula, which will introduce significant specification impact. The X+1 CSIs can be simply treated as one CSI report. |
| vivo | For Proposal 24, if one issue must be selected, we prefer issue2. We can also live with no agreement on Proposal 24.  For proposal 25, if we agree with issue2 in Proposal 24, we only support Alt2. |
| Intel | Ok to discuss issues in proposal 24. However, agreement is not necessary.  For Proposal 25 support Alt. 1. |
| ZTE | First, we think the first thing should be discussed is: **Whether each single-TRP/NCJT measurement hypothesis maps to a distinct CSI report or a subset of a CSI report?**  Our view is each single-TRP/NCJT measurement hypothesis should map to a subset of a CSI report rather than a separate CSI report. That is because a CSI report including all STRP and NCJT CSI should correspond to one CSI report setting.  Second, we think the mapping order of CSI fields of one CSI report #n (38.212 section 6.3) should be discussed for both CSI part 1 and 2. So we support issue 1 in proposal 24.  We are ok to discuss Alt 1 and Alt 2 in proposal 25. |
| Fraunhofer IIS/HHI | Support issue 1 of Proposal 24. |
| InterDigital | For Proposal 25, we support Alt1. |
| Samsung | We support Proposal 24 and Alt 2 and 3 in Proposal 25. |

## Others

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

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| **Issues** | **Companies** | **Views** |
| Support of wideband CSI reporting | Vivo | Support enhancing the CSI reporting mechanism when PMI and CQI granularity are wideband |
| MediaTek | Wideband CSI reporting on PUSCH and on PUCCH formats 2, 3, 4 are supported for NCJT CSI measurement. |
| CSI enhancement for M-DCI M-TRP | Vivo | Support to confirm the working assumption in RAN1#103-e. |
| CATT | Further discuss the following alternatives for CSI reporting of M-DCI based NC-JT.   * Alt-1(separate feedback): Two independent reports, for different TRPs respectively * Alt-2(joint feedback): One set of report quantities can be reported to any of the two TRPs * Alt-3: Separate reports (i.e., Alt-1) can be used if the resources for CSI reporting towards different TRPs are different. If resources for CSI reporting towards different TRPs are overlapped, joint CSI reporting (i.e., Alt-2) can be used. |
| 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. |
| Value/definition of M of IMR | OPPO | If CMR sharing between NC-JT and S-TRP measurement is enabled, M=Ks.  If CMR sharing between NC-JT and S-TRP measurement is not enabled, M=Ks-2N. |
| LI reporting for NC-JT CSI | Qualcomm | For indicating the 2 LI’s, 0/1/2 bits are required depending on the indicated rank combination in CSI part 1. If the indicated rank combination is 2+2, then 2 bits are needed; if the indicated rank combination is 1+2 or 2+1, only 1 bit is needed; if the indicated rank combination is 1+1, no LI is required. |

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| Company | Comments |
| Intel | We propose to support NCJT CSI omission at least for cases where NCJT and STRP CSI measurement hypothesis are reported with X = 1, 2.   * *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* |

# Proposals for Online/Offline Discussion

TBD

# Work Plan

TBD

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14. 3GPP R1-2107396, Enhancements on CSI reporting for Multi-TRP, CMCC, RAN1#106e, E-meeting, August 16th –27th, 2021.
15. 3GPP R1-2107466, CSI enhancements on Type II PS codebook and multi-TRP, Fraunhofer IIS, Fraunhofer HHI, RAN1#106e, E-meeting, August 16th –27th, 2021.
16. 3GPP R1-2107490, CSI Enhancement for NCJT and FR1 FDD reciprocity, MediaTek Inc. , RAN1#106e, E-meeting, August 16th –27th, 2021.
17. 3GPP R1-2107576, On CSI enhancements for MTRP and FDD, Intel Corporation, RAN1#106e, E-meeting, August 16th –27th, 2021.
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19. 3GPP R1-2107820, CSI enhancements for Rel-17, LG Electronics, RAN1#106e, E-meeting, August 16th –27th, 2021.
20. 3GPP R1-2107844, Discussion on CSI enhancements, NTT DOCOMO, INC., RAN1#106e, E-meeting, August 16th – 27th, 2021
21. 3GPP R1- 2108058, Enhancement on CSI measurement and reporting, Nokia, Nokia Shanghai Bell, E-meeting, August 16th – 27th, 2021
22. 3GPP R1-2108071, CSI enhancements for Multi-TRP and FR1 FDD reciprocity, Ericsson, E-meeting, August 16th – 27th, 2021

# Appendix

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

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

|  |  |
| --- | --- |
| **Company** | **Proposals** |
| **Huawei, HiSilicon** | *Proposal 1: Confirm the working assumption that at least for rank 1, FD bases used for quantization are limited within a single window with size N configured to the UE whereas FD bases in the window must be consecutive from an orthogonal DFT matrix.*  *Proposal 2: At least for rank 1 of R17 port selection codebook, no further restriction or condition is applied for . Further reduction of parameter combinations including Mv and other CB codebook parameters are feasible and can be discussed jointly.*  *Proposal 3: R= D\* should be supported for Rel-17 PS codebook.*  *Proposal 4: Considering similarity of performance gain, it is preferred to keep the reserved state for reference amplitude.*  *Proposal 5: The bitmap for indicating non-zero coefficients for W2 is absent when the reported total number of NZC is equal to the maximum number of NZC for Rank 1 and 2, if β = 1 is configured. Additionally the bitmap for layer 1 alone can be absent, only if reported real number of NZC for layer 1 is equal to corresponding maximal number of NZC for layer 1.*  *Proposal 6: For SCI reporting in R17 PS CB, support the reporting of the position, [il\*, fl\*], of the strongest coefficient of layer l, using ceil(log2(K1\*Mv)) or ceil(log2(K1))+ceil(log2(Mv)) bits.*  *Proposal 7: For Rel-17 PS CB for Rank 2, support layer-specific quantization/non-zero coefficient selection of W2, assuming layer-common port selection/FD basis subset and the same maximum number of non-zero coefficients per layer.*  *Proposal 8: Support layer-common port selection and FD basis selection for rank 2.*  *Proposal 9: For rank 1 and 2 PMI for Rel-17 PS CB, Wf is layer-common and reported by UE if N>Mv, i.e. Alt 2-1.*  *Proposal 10: Support Rel-17 PS codebook design with rank ¾ by keeping CSI feedback overhead comparable to rank 2 and also reusing rank ½ CB design as much as possible for higher rank.* |
| **ZTE** | *Proposal 8: Support polarization-common W1 for all the ranks and CSI-RS ports in Rel-17 PS codebook.*  *For the candidate values for K1, it is okay to support all the values in {4, 8, 12, 16, 24, 32} where K1<=P.*  *Proposal 9: All the values in {4, 8, 12, 16, 24, 32} can be supported for K1 where K1<=P.*  *Proposal 10: On Wf in Rel-17 PS codebook*   * *The set of N candidate vectors of Wf is a consecutive window configured by gNB, where the window size N is configured (e.g., window size N = 2 or 4 for Mv = 1 or 2), and support N>Mv.* * *UE selects and reports layer-specific Wf vectors within the window configured by gNB.* * *Support R from the set {1, 2, …, }.*   *Proposal 11: For Wf off vs Mv=1*   * *Support Alt 2: Wf OFF and Wf ON with Mv=1 are same, and Wf is an all-one vector of length 1, i.e., a scalar. Wf as an all-one vector of length N3 is not needed.*   + *Use PMI format to configure Wf off or Wf on with Mv=2. If PMI format is configured as WB, Wf is off; otherwise Wf is on with Mv=2.* * *Alt 3 can be supported if Alt 2 is not supported.*   *Proposal 12: The bitmap for indicating non-zero coefficients in W2 can be absent when Beta = 1 and the total number of NZ coefficients reported in Part 1 equals to Rank\*K1\*Mv.*  *Proposal 13: For SCI reporting in Rel-17 PS codebook, support Alt 0: Reporting of the position, [il\*, fl\*], of the strongest coefficient of layer l using ceil(log2(K0)) bits, where K0=Beta\*K1\*Mv.*  *Proposal 14: Study whether to support Rank 3 and 4 for Rel-17 PS codebook.*   * *If Rank 3 and 4 are supported, use a smaller beta value for Rank 3 and 4 compared with beta value configured for Rank 1 and 2, e.g., .* |
| **vivo** | *Proposal 16:*   * *Support Alt1: the reserved state for reference amplitude is kept to be reserved for the quantization of W2 coefficients.*   *Proposal 17:*   * *Keep the bitmap for indicating non-zero coefficients for W2 for CSI reporting.*   *Proposal 18:*   * *At least for rank1, the window/set can be configured as consecutive or non-consecutive.* * *The non-consecutive window can be configured with an extra starting point. The length of both separate parts is half the overall window length.*   *Proposal 19:*   * *Support Alt 2-1: N >= Mv, Wf is layer-common and reported by UE for N>Mv.*   *Proposal 20:*   * *Support Alt 1: Wf OFF and Wf ON with Mv=1 are same, and Wf is an all-one vector of length N3.* * *There is no need to configure subband or wideband for PMI in Rel-17 codebook.*   *Proposal 21:*   * *At least 8 parameter combinations of (K1,Mv, Beta) can be supported as (4,2,0.5), (8,2,0.25), (8,1,1), (12,1,0.5), (8,2,0.5), (12,1,0.75), (12,2,0.5), (16,2,0.75).* * *K1 can be limited to no more than half of the number of CSI-RS ports.*   *Proposal 22:*   * *UE can use partial CSI-RS ports to search target tap 0 to reduce the complexity.*   + *gNB can map SD-FD bases to CSI-RS ports with a predetermined order or indicating the ports for timing calibration.* |
| **Spreadtrum Communications** | *Proposal 10: Support Alt 1, Wf OFF and Wf ON with Mv=1 are same, and Wf is an all-one vector of length N3.*  *Proposal 11: Support Alt 1, the reserved state for reference amplitude is kept to be reserved.*  *Proposal 12:* *The* *bitmap for indication non-zero coefficients can be absent, depending on the value of beta.*  *Proposal 13: Confirm the Working Assumption that FD bases used for Wf quantization are limited within a single window with size N configured to the UE whereas FD bases in the window must be consecutive from an orthogonal DFT matrix.* |
| **Lenovo, Motorola Mobility** | 1. *Do not further restrict the supported number of CSI-RS ports for the Rel. 17 port-selection codebook configured with M=2* 2. *Confirm the working assumption on window design: a layer-common, window-based approach is used to configure the FD basis indices for all layers, where the set of FD basis indices is contiguous, and whose size are higher-layer configured* 3. *Support UE-selected FD basis indices that are reported for each layer from a layer-common network-configured window* 4. *Support Alt1: Wf OFF and Wf ON with M=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* 5. *The strongest coefficient indicator is based on the order of coefficients (whether zero or non-zero) in the bitmap, using log2(K1M) bits per layer* 6. *Support Alt1 for reserved state of reference amplitude quantization values* 7. *A bitmap is not reported for Rel. 17 port selection codebook when most coefficients are quantized, i.e., β=1, or the number of coefficients is small, e.g., K1M ≤ δ, FFS: value of δ* 8. *Support up to Rank 4 for Rel. 17 Type-II port-selection codebook* 9. *Limit the support of R, i.e., the number of PMI sub-bands per CQI sub-band to one* 10. *Study whether rank-dependent K1 is supported for Rel. 17 port-selection codebook* 11. *Study PUCCH reporting of CSI feedback corresponding to Rel. 17 port-selection codebook for some codebook parameter combinations that yield low CSI feedback overhead*     * *FFS: codebook parameter combination values that support PUCCH reporting* |
| **Fraunhofer IIS, Fraunhofer HHI** | *Proposal: The default Ks,max should be given by a value of 4.*  *Proposal: For the CRI mapping, a set of N CMR pairs (representing the N NCJT measurement hypotheses) from the two groups is mapped to N first CRI codepoints and the remaining CMRs (representing single-TRP measurement hypotheses) in a group are mapped to additional CRI codepoints.*  *Proposal: For CMR sharing between single-TRP measurement hypothesis and NCJT measurement hypothesis support ALT 4, i.e., allow to configure the same value of CMR ID for a single-TRP CMR and a NCJT CMR pair in a resource set.* |
| **OPPO** | *Proposal 1: Support K1 = {8, 16, 24} for Rel-17 codebook.*  *Proposal 2: Support beta=3/4 for Rel-17 codebook.*  *Proposal 3: Reuse Rel-16 reserved code-point.*  *Proposal 4: For Rel-17 PS, support :*   * *FD basis in the window are consecutive (Alt.1)* * *N=Mv always (Alt.1)*   *Proposal 5: support SCI, bit-width is and (term is applicable to M>1).*  *Proposal 6: Support up to rank 4 codebook for Rel-17 PS*   * *Support layer-common port selection for rank >1* * *Support layer-specific NZC selection, the number of NZC* * *Reuse Rel-16 CSI omission* |
| **Qualcomm** | *Proposal 9: Confirm the working assumption that the window-based pre-configured set is applied to all codebook configurations.*  *Proposal 10: For Rel-17 FDD CSI, support window size equal to the number of FD bases in Wf quantization, i.e., N=M. No UE reporting of Wf is needed.*   * *For M=1, the FD basis in Wf is DFT basis 0;* * *For M=2, the FD bases in Wf are DFT basis 0 and FD basis 1.*   *Proposal 11: For Rel-17 FDD CSI, the pre-configured window does not imply any specific UE implementation in PMI calculation.*  *Proposal 12: For Rel-17 FDD CSI, no need to define R in the spec or only support R=1 PMI per CQI subband.*  *Proposal 13: Support parameter combinations of {K1, beta, M}, and total number of different combinations should not exceed Rel-16 eType II codebook (regardless of number of CSI-RS ports).*  *Proposal 14: Support Alt0 or Alt1-1 for SCI reporting.*  *Proposal 15: For Rel-17 FDD CSI, support UE reporting of actual number of non-zero coefficients, and the bitmap for reporting location of non-zero coefficients always exist.*  *Proposal 16: 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.* |
| **DoCoMo** | *Proposal 10*   * *For Mv=1 and Beta =1 for rank 1, the bitmap for indication non-zero coefficient can be absent.*   *Proposal 11*   * *Confirm the working assumption on FD bases for Wf and remove the FFS.* * *At least for rank 1 and 2 and Mv > 1, support Alt 2-1: N >= Mv, Wf is layer-common and reported by UE for N>Mv.*   *Proposal 12*   * *Regarding Wf OFF and Wf ON with Mv=1, support either Alt.1 or Alt.2.*   + *Alt 1: Wf OFF and Wf ON with Mv=1 are same, and Wf is an all-one vector of length N3. Wf as an all-one vector of length 1 is not needed*   + *Alt 2: Wf OFF and Wf ON with Mv=1 are same, and Wf is an all-one vector of length 1, i.e., a scalar. Wf as an all-one vector of length N3 is not needed.*   *Proposal 13*  *Consider dynamic configuration of turning on/off implicitly using DCI.* |
| **Nokia, Nokia Shanghai Bell** | *Proposal 1**Regarding the port selection parameter , consider the parameter formula: , with for and for .*  *Proposal 2 Support reporting of rank 3 and 4 by ensuring that feedback overhead is comparable to that of rank 2.*  *Proposal 3 Regarding the bitmap and SCI reporting, support:*   * *Reporting of the position, [, ], of the strongest coefficient of layer , for , using bits.* * *Remapping the strongest coefficient to as in Rel-16.*   *Proposal 4 Regarding the reporting of the bitmap, if and a UE reports nonzero coefficients for or nonzero coefficients for , the bitmap can be assumed to be absent from the CSI report. In all other cases, support reporting of the bitmap.*  *Proposal 5 Regarding the quantisation mechanism for the reference amplitude, support Alt 1, i.e., keep the codepoint ‘0’ as reserved.*  *Proposal 6 Regarding the configuration with OFF, support Alt 1, i.e., OFF and ON with are the same, and is an all-one vector of length .*  *Proposal 7 Regarding a possible extension to support Rel-17 CB to BWP<24 PRB, consider the outcome of the discussion in RedCap WI to extend the subband definition to BWP<24 PRB. If the subband definition is extended to BWP<24 PRB, no further changes are needed to support Rel-17 CB for such small BWPs.*  *Proposal 8 Regarding the choice of layer-common vs layer-specific for rank and , support layer-common .*  *Proposal 9 Regarding the relationship between and , support Alt 2-1, i.e., , with layer-common and reported by a UE for .*  *Proposal 10 For , support reporting of nonzero components of using a combinatorial indicator of bits.*  *Proposal 11 Confirm the working assumption on a single measurement window for , for all supported ranks, without further dependence/restriction on the values of and/or .*  *Proposal 12 Regarding the values of , support configurations with .* |
| **Ericsson** | [*Proposal 1 Support reuse of the Rel-16 quantization mechanism and the reserved state is kept reserved.*](#_Toc79191455)  [*Proposal 2 For rank 1 transmission, when is configured, then UE reports all coefficients and the resulting NZC bitmap is all ones and is therefore not reported.*](#_Toc79191456)  [*Proposal 3 Support Alt 1-1: Reporting of the position, [il\*, fl\*], of the strongest coefficient of layer l, using ceil(log2(K1\*Mv)) or ceil(log2(K1))+ceil(log2(Mv)) bits.*](#_Toc79191457)  [*Proposal 4 Support of is not justified.*](#_Toc79191458)  [*Proposal 5 Support Alt.2-1: N >= Mv, Wf is layer-common and reported by UE for N>Mv. Furthermore, support for and for*](#_Toc79191459)  [*Proposal 6 Support a single value to avoid unnecessary introduction of UE capabilities and fragmentation, for example or , where is the CQI subband size. is preferred.*](#_Toc79191460)  [*Proposal 7 For rank 2 transmission, the layer-common parameters include the selected SD and FD bases, and the configured FD window, while the layer-specific parameters include NZC bitmap, quantized coefficients polarization reference amplitude and SCI.*](#_Toc79191461)  [*Proposal 8 Rank 3 and 4 transmissions have lower priority for standardization.*](#_Toc79191462) |
| **CATT** | *Proposal-1: The working assumption is confirmed without any further restrictions.*   |  | | --- | | *Working Assumption*  *At least for rank 1, FD bases used for Wf quantization are limited within a single window with size N configured to the UE whereas FD bases in the window must be consecutive from an orthogonal DFT matrix, i.e. Alt 1.* |   *Proposal-2: Only is supported without restriction on the number of CSI-RS ports.*  *Proposal-3: If P=4, N can be configured as 4. Otherwise, N==2.*  *Proposal-4: Wf OFF and Wf ON with Mv=1 are distinguished by PMI format, i.e., Alt3 is supported.*  *Proposal-5: When , R can be configured as 2, …,or D\*NPRBSB. Otherwise, R=1. denotes a threshold value.*  *Proposal-6: The coefficient quantization of Rel-16 Type II codebook is reused for Rel-17 port selection codebook.*  *Proposal-7: When , the bitmap for indicating non-zero coefficients can be absent if UE reports all coefficients for one or more than one layer.*  *Proposal-8: Existence of the bitmap depends on the reported number of NZC or indication information.*  *Proposal-9: The strongest coefficient should be indicated to save feedback overhead.*  *Proposal-10: or bits with shifting the strongest coefficient to = 0 are used to indicate the strongest coefficient, i.e., Alt 1-2 is supported.*  *Proposal-11: A new parameter for determining the number of port selection K1 is introduced to limit the number of parameter combinations.*  *Proposal-12: For =1, when ，1/2, 3/4 and can be considered, and when , is configured as 3/4 and 1.*  *Proposal-13: When , the following parameter combinations can be considered.*   |  |  | | --- | --- | |  |  | | *1/2* | *1* | | *3/4* | | *1* | | *Note:*   * *When P=4, is not supported.* * *is selected as the largest value in {****2,*** *4, 8, 12, 16, 24, 32} and.* | |   *Proposal-14: When, the following parameter combinations can be considered.*   |  |  | | --- | --- | | *1* |  | | *1* | *1/2* | | *3/4* | | *1* | | *Note: the following combinations is not supported*   * *P,1, .* * *P32, 1,* | |   *Proposal-15: For Rel-17 port selection codebook, rank=3 or 4 should be supported.*  *Proposal-16: At least for, port selection for is layer-common.*  *Proposal-17:*   * *When P=4, . Otherwise, .* * *When P=4, can be layer-specific and reported by UE.*   *Proposal-18: The indication of non-zero coefficients should be layer-specific.*  *Proposal-19: The CSI reporting design of Rel-16 Type II port selection codebook should be regarded as a starting point.*  *Proposal-20:*   * *The design principle of CSI omission for Rel-16 Type II port should be applied to CSI omission design of Rel-17 port selection codebook* * *The priority order of Rel-16 Type II port selection codebook for omitting CSI Part 2 should be regarded as a starting point.* |
| **Samsung** | *Proposal 7: Regarding turning Wf OFF, support the following*   * *Wf OFF and Wf ON with Mv=1 are the same, and Wf is an all-one vector of length N3.* * *N3 = 1 when CSI is WB (i.e. when SB size is not configured), and N3 >1 when CSI is SB (i.e., when SB size is configured).*   *Proposal 8: support Rel.17 codebook for BWP size < 24 PRBs with the current restriction in the specification, i.e. support only WB CSI implying Wf is turned OFF*  *Proposal 9: regarding SCI*   * *support Alt 0*   + *The SCI of the lth layer is represented with bits*   + *The SCI and bitmap can be grouped together, e.g., in G0 or G1 of UCI part 2* * *(2nd priority) support Alt 3*   + *SCI is replaced with a strongest polarization indicator (1 bit)*   *Proposal 10:* ***r****egarding R value(s),*   * *support Alt0 (R=1/4) and Alt1 (R=1), and* * *value(s) R>1 requires more study considering*   + *the impact of same or different CSI-RS beamforming (depending on R value(s)); and*   + *trade-off among UE complexity, CSI overhead, potential-specification impact, and the UPT performance.*   *Proposal 11: Regarding Mv value(s),*   * *UE capable of supporting Mv>1 (agreement from RAN1#104bis-e) shall report whether it support Mv=2 for P > 12 CSI-RS ports* * *Mv>2 is not supported in Rel. 17*   *Proposal 12:* ***for rank 1 and rank 2, r****egarding Wf configuration,*   * *Confirm the working assumption (single window) for N3 > t* * *Support free selection for N3 <= t,*   *where t is a threshold (e.g. t=19).*  *Proposal 13: for relationship between N and Mv,*   * *For rank 1 and 2, support Alt1 (N=Mv)* * *For rank > 2, study Alt 2-2 (N>=Mv and layer-specific reporting)*   *Proposal 14: For W2 quantization,*   * *support Alt3, i.e., replace the reserved reference amplitude = 0 with a new value* * *for the strongest polarization, support Alt 0 or Alt 3 (2nd preference) in the SCI discussion*   *Proposal 15: Regarding Rel. 17 codebook parameters,*   * *support P from {2,4,8,12,16,24,32}* * *parameterize as* * *parameter combinations correspond to triples , where the candidate values for down-selection are as follows:*   *Proposal 16: whether bitmap is absent is determined by the UE, e.g., based on value in UCI part 1.*  *Proposal 17: regarding rank 2*   * *Support Rel.16 design for parameters , and*    + *layer- and RI-common , for rank 1 and rank 2*   + *layer-specific bitmap, SCI (or strongest polarization indicator), and amplitude/phase of NZ coefficients* * *Support layer-specific*   *Proposal 18: for Rel.17 codebook,*   * *study rank 3-4, and if supported,*    + *it is optional with separate UE capability (similar to Rel.16)*   + *only for rank 3-4* * *simplify Rel.16 UCI omission mechanism and consider the following potential simplifications*   + *no FD permutation*   + *no bitmap partition*   + *no FD basis indicator, at least for rank 1 and 2* |
| **Sony** | *Proposal 1. The need for Alt. 2 and Alt. 3 shall be properly motivated, and their benefits evaluated. Otherwise, select Alt. 1.*  *Proposal 2. Select Alt. 1: OFF and ON with are same, and is an all-one vector of length . as an all-one vector of length 1 is not needed. The terminology ON/OFF is not needed for Rel-17 PS CB and can be dropped.*  *Proposal 3. Free selection of by the UEs, e.g., , or for some , should be supported.*  *Proposal 4. For minimum specification impact, adopt polarization-common base selection and reporting mechanism of Rel-15/16 and rank-1 Rel-17 for rank-2 and higher Rel-17 PS CB transmissions. A polarization-specific mechanism should only be introduced if it can be shown that, at least for some scenarios of interest, it provides substantial advantage over polarization-common.*  *Proposal 5. Based on UL CSI, further restrict the set of CSI-RS ports eligible by the UE to those compatible with UL signal angles. By reducing the number of choices, less bits are needed to encode the DL CSI feedback reports by the UE.* |
| **MTK** | *Proposal 14: Restrict the configuration of to number of CSI-RS ports*  *Proposal 15: is not needed for the Rel-17 PS codebook for any number of CSI-RS ports.*  *Proposal 16: For the relation between and , support as the first preference. As a second preference, support with layer common FD bases selection. For the candidate values of , is sufficient.*  *Proposal 17: Support the confirmation of RAN1 #105-e WA that the FD bases used for quantization are limited within a single window with size configured to the UE.*  *Proposal 18: can be supported when the number of CSI-RS ports (or number of selected ports ) is equal to or more than 16 or when .*  *Proposal 19: SCI should be supported in Rel-17 PS CB and indicated using bits. Shifting of the strongest coefficient to the zeroth FD basis can be supported if is agreed.*  *Proposal 20: Parameterize as , and support candidate values of .*  *Proposal 21: Support a triplet of parameters for the Rel-17 PS CB.* |
| **Intel** | *Proposal 1:*   * *RRC parameter pmi-FormatIndicator is ignored for Rel. 17 codebook*   + *It is assumed that pmi-FormatIndicator is always set to subbandPMI*   *Proposal 2:*   * *Reserved state for reference amplitude is kept being reserved*   *Proposal 3:*   * *For Beta = 1,*    + *Bitmap for coefficient selection is not reported*   + *Amplitude and phase for coefficients which are equal to zero are reported by the UE*     - *Change the value corresponding to the last codepoint to 0*   *Proposal 4:*   * *Confirm working assumption from RAN1#105-e on FD bases used for Wf quantization* * *Consecutive window for FD bases used for Wf quantization is supported for all the codebook parameter combinations and for any number of PMI subbands N3 and CSI-RS ports P*   *Proposal 5:*   * *Support M = 2 without additional constraints on the number of CSI-RS ports*   *Proposal 6*:   * *Support N = 1 for M = 1* * *Support at least N = 2 for M = 2*   + *If N = 4 is supported, layer-common Wf should be considered*   *Proposal 7:*   * *At least for M = 1, support R = D\*N\_PRB\_SB, where D is the density of CSI-RS in frequency domain, N\_PRB\_SB is the number of PRB in a subband for CQI*   *Proposal 8:*   * *Support rank 3-4 for Rel. 17 Type II codebook*   *Proposal 9:*   * *Parameters K1, N and M should be the same for rank 1-4* * *Support one of the following solutions to decrease overhead for rank 3-4*   + *Alt. 1: Decrease Beta for rank 3 and rank 4 comparing to Beta for rank 1, 2*   + *Alt. 2: Limit the maximum number of non-zero coefficients across all layers to 2∙K0 with the same Beta for rank 1-4*   *Proposal 10:*   * *Selection of K1 CSI-RS ports in W1 is layer-common* * *Selection of M FD vectors in Wf is layer-common* * *Selection of K0 coefficients in W2 is layer-specific* |
| **Apple** | *Proposal 3 For W1 port selection reporting for port selection codebook enhancement, regardless of RI, the reporting should be*  *• Frequency basis common*  *• Polarization common*  *• Layer common*  *Proposal 4 For W2 coefficients reporting for port selection codebook enhancement, UE reports SCI freely in the frequency basis window configured*  *Proposal 5 For W2 coefficients reporting for port selection codebook enhancement, for the coefficient location reporting (both SCI and bitmap), it is*  *• Frequency basis independent*  *• Polarization independent*  *• Layer independent*  *Proposal 6 For Wf frequency basis reporting for port selection codebook enhancement, regardless of RI, the Wf is reported*  *• Polarization common*  *• Layer independent*  *Proposal 7 For Wf frequency basis reporting for port selection codebook enhancement, UE reports WB (wideband) PMI under either of the following two conditions*  *• Mv=1*  *• Wf not configured*  *Proposal 8 For Wf frequency basis reporting for port selection codebook enhancement,*  *• UE always selects the DC frequency basis, i.e., frequency basis with all entries equal to 1.*  *• Do not support R>1* |
| **LG Electronics** | *Proposal #6: Support Alt 1 for meaning of Wf OFF.*   * *Alt 1: Wf OFF and Wf ON with Mv=1 are same, and Wf is an all-one vector of length N3. Wf as an all-one vector of length 1 is not needed*   *Proposal #7: Deprioritize being absent of the bitmap for indicating non-zero coefficients for W2.* |

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

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

|  |  |
| --- | --- |
| **Company** | **Proposals** |
| **Huawei, HiSilicon** | *Proposal 11: Two CMRs within the same CMR pair configured for NCJT measurement hypothesis are within the same DL slot.*  *Proposal 12: For CSI measurement associated to a reporting setting CSI-ReportConfig for NCJT, two RI restrictions can be configured for a given reporting setting whereas:*   * *One RI restriction corresponds to M CMRs for Single-TRP measurement hypothesis* * *Another RI restriction corresponds to N CMR pairs for NCJT measurement hypothesis*   *Proposal 13: For CSI measurement associated to a reporting setting CSI-ReportConfig for NCJT, two CBSRs can be configured for a given reporting setting whereas each of them corresponds to one CMR group in a CMR set, i.e. per TRP.*  *Proposal 14: For a given NCJT report with Option 1, priority reporting levels for Part 2 CSI in the report are defined as following orders, if configured*   * *Part 2 subband CSI of even subbands of NCJT measurement hypothesis* * *Part 2 subband CSI of odd subbands of NCJT measurement hypothesis* * *Part 2 subband CSI of even subbands of the first Single-TRP measurement hypothesis* * *Part 2 subband CSI of odd subbands of the first Single-TRP measurement hypothesis* * *Part 2 subband CSI of even subbands of the second Single-TRP measurement hypothesis* * *Part 2 subband CSI of odd subbands of the second Single-TRP measurement hypothesis*   *Proposal 15: For a CSI report associated with both Single-TRP and NCJT measurement hypotheses, the UE is required to update the CSI associated with NCJT measurement hypotheses in the CSI report, if , where N is the number of CMR pairs associated with NCJT measurement hypotheses, denotes the number of available CPUs on a given OFDM symbol, and is the number of CPUs required to update whole CSI report.* |
| **ZTE** | *Proposal 1: For NCJT CSI measurement, support Alt 3: Ks,max = 4 for FR2, and Ks,max = 2 for FR1 where Ks,max is the minimum supported number of CMRs within a resource set in UE capability reporting.*  *Proposal 2: For CSI measurement associated with a CSI-ReportConfig for NC-JT, support Alt 2 in Agreement #3 : additional RRC signaling is supported to configure M (M≤ Ks) CMRs from the CSI-RS resource set for CMR for Single-TRP measurement hypotheses.*  *Proposal 3: Do NOT support dynamic updating for CSI measurement associated with a CSI-ReportConfig for NC-JT.*  *Proposal 4: Support CSI sharing indicated by UE between NCJT CSI and Single-TRP CSI(s) for CSI report Option 1. If sharing is indicated by UE in CSI part 1, the CMRs for NCJT CSI and for Single-TRP CSI should be same, and reported RI for NCJT CSI and Single-TRP CSI should also be same.*  *Proposal 5: Support reporting differential CQI of Single-TRP CSI w.r.t the CQI value of NCJT CSI.*  *Proposal 6: The X+1 CSI hypotheses per CSI Reporting Setting for NCJT and STRP are mapped to a single CSI report.*  *Proposal 7: CSI priority formula can be changed as below for determination of CSI omission rule*    *where x = 0, 1 and 2 refer to MTRP CSI, the first STRP CSI and the second STRP CSI (if any) respectively within one single CSI reporting.* |
| **vivo** | *Proposal 1:*   * *Support the default maximum number of CMR is 4 for MTRP CSI measurement.*   *Proposal 2:*   * *Support Alt.4 for measurement and framework.*   + *N CMR pairs are formed by one-to-one mapping of the first N CMRs between two CMR groups.*   + *The CMRs other than the CMRs in the CMR pair(s) in each CMR group are used for STRP hypothesis measurement.*   + *The value of M is not come from additional RRC signaling and N but from CMR configuration and N.*   *Proposal 3:*   * *Support dynamic updating TCI states of CMRs by MAC-CE for periodic CSI-RS and aperiodic CSI-RS.*   *Proposal 4:*   * *For CRI reporting in Option1, support separate CRI reporting for STRP hypotheses and NC-JT hypotheses.*   *Proposal 5:*   * *For CRI reporting in Option2, the first N codepoints are corresponding to N CMR pairs for NC-JT hypotheses and the remaining codepoints are corresponding to the remaining CMRs for STRP hypotheses.*   *Proposal 6:*   * *A CSI Reporting Setting configured with enhanced MTRP CSI reporting corresponds to a CSI report.*   *Proposal 7:*   * *Slightly prefer using legacy priority definition and omission rule.*   *Proposal 8:*   * *Support enhancing the CSI reporting mechanism when PMI and CQI granularity are wideband.*   *Proposal 9:*   * *Support the PMI sharing, considering both UE dynamic indication and RRC static configuration of sharing.*   *Proposal 10:*   * *Support adding an indicator within Part1 that indicates the information of PMI sharing to implement the dynamic PMI sharing.*   *Proposal 11:*   * *Consider different configurations of RI restrictions, codebook subset restriction across TRPs.*   *Proposal 12:*   * *A total number of layers of NC-JT reception is no more than 4 for NC-JT CSI reporting.*   *Proposal 13:*   * *Support to confirm the work assumption in RAN1#103-e, i.e., Option1.*   *Proposal 14:*   * *Support to associate two CSI reporting settings with CMRs configuration same as Cat1 for Cat2 configuration.*   *Proposal 15:*   * *Support to specify rules on how to divide and map the generated UCI into two associated reports in Cat2.* |
| **Spreadtrum Communications** | *Proposal 1: Support Alt.3 for CMR for Single-TRP measurement hypotheses.*  *Proposal 2: For the value of Ks,max, Alt.1 shall be not supported.*  *Proposal 3: Support to introduce new CSI computation delay requirement for NC-JT CSI.*  *Proposal 4: For option 1 with X=0, for UCI composition and structure,*   * *2RI 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, 1 CQI for the first CW should be include into Part1;* * *2 PMIs (if required) for NCJT, or CQI for the second CW(if required) for single TRP and/or 1 PMI (if required) for single TRP transmission should be include into Part2.*   *Proposal 7: Support to enhance on CSI report associated with NCJT for CPU overbooking case.*  *Proposal 8: For CSI enhancement on M-TRP operation, M-DCI based M-TRP operation should also be supported.*  *Proposal 9: 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.* |
| **InterDigital, Inc.** | *Proposal 1: Support Alt 2: Ks,max = 2.*  *Proposal 2: Support dynamic updating by MAC-CE of Alt 1 and Alt 2.*  *Proposal 3: Support Alt 2: additional RRC signalling is needed to configure M (M≤ Ks) CMRs from the CSI-RS resource set for CMR for Single-TRP measurement hypotheses*  *Proposal 4: For option 1 with X reports, prioritize single-TRP CSIs over NCJT measurement hypothesis when X=1, however for 2 ensure that at least one of the CSIs corresponds to the NCJT hypothesis.*  *Proposal 5: Study two-step CSI-RS measurement reporting for NCJT where*   * *NZP CSI-RS is configured per TRP,* * *in the first step, a PMI corresponding to the first TRP, and in the second step a PMI corresponding to the second TRP is determined and reported.*   *Proposal 6: Study a two-step SRS plus CSI-RS measurement/reporting for NCJT where*   * *NZP CSI-RS is configured per TRP,*   *in the first step UE transmits an SRS, and in the second step based on the received precoded CSI-RS from each TRP, UE estimates and report the CSI* |
| **Futurewei** | *Proposal 1: For CSI measurement associated with a CSI-ReportConfig for NC-JT, FeMIMO supports Alt 3: For CMRs configured in the CSI-RS resource set, support RRC signalling to enable/disable single-TRP measurement hypothesis using CMR configured within CMR pairs for NCJT measurement hypothesis.* |
| **NEC** | *Proposal 1: TRP specific CBSR and RI restriction can reduce the UE complexity considerably, which should be introduced at least for NCJT measurement hypothesis.*  *Proposal 2: The joint RI field with restricted combination of two RI values should be supported when the maximal transmission layers is larger than 4.* |
| **CMCC** | *Proposal 1: Either Alt 1 or Alt 3 (Ks,max = 4 for FR2, and Ks,max = 2/4 for FR1) could be support for default value of Ks,max.*  *Proposal 2: Alt 2 (additional RRC signaling is needed to configure M (M≤ Ks) CMRs from the CSI-RS resource set for CMR for Single-TRP measurement hypotheses) could be support.*  *Proposal 3: Support dynamic updating the number of single-TRP CSIs (i.e. X=0/1/2) in a NCJT CSI report e.g. by MAC-CE.*  Proposal 4: The CSI associated with NCJT measurement hypotheses could be high prioritized within one single CSI report, when the UE is configured with CSI Option 1 and X=1 or 2. |
| **DoCoMo** | *Proposal 1*   * *Support Alt. 1: default value of Ks,max, = 4.* * *For any value of Ks, N=1 or N=2 can be supported as long as N<=Ks/2 for FR1, and N <= min (K1, K2) for FR2.*   *Proposal 2*   * *Support Alt 2: additional RRC signalling is needed to configure M (M≤ Ks) CMRs from the CSI-RS resource set for CMR for Single-TRP measurement hypotheses.*   *Proposal 3*   * *To indicate the valid CMR pair(s) for NCJT measurement hypothesis, higher layer signaling can explicitly indicate the ordering index(es) of one or two CMR pairs from all the possible K1\*K2 CMR pairs. The bit size of is needed to indicate a CMR pair.*   *Proposal 4*   * *Support MAC CE based updating on the number of single-TRP CSIs (i.e. X=0/1/2) for Option1, as well as the change between Option1 and Option2 for a NCJT CSI report.* * *Open to support Alt. 1 and Alt. 2, which should be considered at the same time.*   *Proposal 5*   * *Support to configure a single RI restriction, which is applied to both single-TRP measurement, and the total rank of NCJT measurement.* * *Support to configure two CBSR configurations for two CMR groups for NCJT CSI measurement.*   *Proposal 6*   * *On mapping between each CRI codepoint and single-TRP/NCJT measurement hypothesis, support mapping to single-TRP measurement hypothesis first, if configured, starting from CRI index 0, then mapping to NCJT measurement hypothesis.*   *Proposal 7*   * *Do not support shared RI/PMI for single-TRP and NCJT hypotheses.*   *Proposal 8*   * *On CSI priority calculation, introduce a new parameter j, where j=0 for single-TRP CSI of the first TRP, j=1 for single-TRP CSI of the other TRP, and j=2 for NCJT CSI.*   + *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.* * *For a CSI report #n corresponding to NCJT measurement hypothesis, the mapping order of CSI fields of one CSI report should consider two LIs and two PMIs.*   *Proposal 9*   * *For a CSI report associated with a Multi-TRP/panel NCJT measurement hypothesis configured by single CSI reporting setting for single-DCI based NCJT, the UE is expected to report,*   + *two RIs, two PMIs, two LIs, and one CQI per codeword, when the maximal transmission layer is larger than 4;*   *one RI, two PMIs, one LI and one CQI per codeword, for HST-SFN.* |
| **Nokia, Nokia Shanghai Bell** | *Proposal 13 Regarding the default value of , support Alt 1, i.e., .*  *Proposal 14 Regarding the definition/value of , support Alt 2, i.e., additional RRC signalling to configure the value of .*  *Proposal 15 Regarding the definition/value of , further clarify that the CMRs for single-TRP measurement can be configured from the first CMRs in the resource set, without loss of flexibility.*  *Proposal 16 Regarding CBSR and RI restriction, support a single CodebookConfig configuration for a CSI Reporting Setting with two CMBS and RI restrictions, one for each CMR group.*  *Proposal 17 Regarding the dynamic updating of configuration parameters, support Alt 1,2 and 4, by MAC-CE indication of the NCJT pairs and/or the value of and/or the value of .*  *Proposal 18 Support the use of parameters and to configure Option 1/Option 2 reporting: configures Option 2 with 1 CSI (best of hypotheses); otherwise Option 1 is configured with CSI(s).*  *Proposal 19 For Option 1, support separate CRI(s), with bit width for , and , for , and , and for , where and are the number of active single-TRP hypotheses from CMR group 1 and 2, respectively, with .*  *Proposal 20 For Option 2, support a CRI mapping with bits, where the first codepoints are associated to the configured NCJT hypotheses and the last codepoints are associated to the first CMR resources in the CSI-RS resource set.*  *Proposal 21 Regarding the UCI mapping of the CSIs in a M-TRP CSI report , support a simple solution that assigns reporting priority 0 to the NCJT CSI, priority to the single-TRP CSI, for Option 1 with , and to the single-TRP CSI for CMR group 1, for Option 1 with , priority to the single-TRP CSI for CMR group 2, for Option 1 with .*  *Proposal 22 Regarding the study of PMI/RI sharing mechanisms, consider the completion of specifications for the already agreed Option 1, and Option 2 with higher priority.* |
| **Ericsson** | [*Proposal 9 Support Alt.1, i.e. the default value (Ks,max) of the maximum number of NZP CSI-RS resources configured for CMR is equal to 4, for both FR1 and FR2.*](#_Toc79191463)  [*Proposal 10 For CSI measurement associated with a CSI-ReportConfig for NC-JT, support Alt.1 , i.e., dynamic update of CMR pairs for NC-JT measurement hypothesis using MAC CE.*](#_Toc79191464)  [*Proposal 11 Do not support Alt.2, i.e. do not support higher layer signalling to dynamically update CMRs for sTRP measurement hypotheses.*](#_Toc79191465)  [*Proposal 12 Support Alt.3, i.e. use RRC signalling to enable/disable sharing of CMRs between single-TRP measurement hypothesis and NCJT measurement hypothesis*](#_Toc79191466)  [*Proposal 13 For a CSI report containing both NC-JT CSI and single-TRP CSIs (e.g., Option 1 with X =1, 2) associated with the same CMRs, support RI/PMI sharing between the NC-JT CSI and single-TRP CSIs*](#_Toc79191467)  [*Proposal 14 Support NC-JT CSI omission under certain conditions when X=1 or 2 is configured with omission indicated in a CSI report.*](#_Toc79191468)  [*Proposal 15 Support up to 4 transmission layers for a CSI report associated with a NCJT measurement hypothesis configured with a single CSI report setting.*](#_Toc79191469)  [*Proposal 16 CBSR and/or RI restrictions per TRP or across TRPs are not supported for NC-JT CSI report.*](#_Toc79191470)  [*Proposal 17 Support that a UE configured to report X CSIs associated with single-TRP measurement hypotheses and one CSI associated with NCJT measurement hypothesis reports the X+1 CRIs jointly as one CSI report.*](#_Toc79191471) |
| **CATT** | *Proposal-21: Non-PMI based feedback can be supported for CSI enhancement for M-TRP.*  *Proposal-22: For CSI reporting based on single report setting, two associated CMR resources in the same resource set are used for channel measurement of two TRPs. In CSI calculation, the UE assumes that in PDSCH transmission, PMI-1/RI-1 and PMI-2/RI-2 are applied to the channel of TRP 1 and 2 respectively. By doing so, inter-TRP interference measurement can be achieved without introducing non-precoded IMR.*  *Proposal-23: For dynamic updating for CMRs, support updating CMR pairs for NCJT measurement hypotheses.*  *Proposal-24: For semi-static (RRC based) updating for CMRs, support Alt 2 or Alt 3.*  *Proposal-25: 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-26: One CQI per codeword is reported even if the reported rank is more than 5 in CSI for NC-JT.*  *Proposal-27: For CRI reporting in Option1, support separate CRI reporting.*  *Proposal-28: For CRI reporting in Option2, the first N codepoints are corresponding to N CMR pairs and the remaining codepoints are corresponding to the remaining CMRs.*  *Proposal-29: CSI feedback enhancements for transmission scheme 2a, 2b, 3 and 4 are supported.*  *Proposal-30: Further discuss the following alternatives for CSI reporting of M-DCI based NC-JT.*   * *Alt-1(separate feedback): Two independent reports, for different TRPs respectively* * *Alt-2(joint feedback): One set of report quantities can be reported to any of the two TRPs* * *Alt-3: Separate reports (i.e., Alt-1) can be used if the resources for CSI reporting towards different TRPs are different. If resources for CSI reporting towards different TRPs are overlapped, joint CSI reporting (i.e., Alt-2) can be used.* |
| **Samsung** | *Proposal 1: On CSI enhancements for multi-TRP, support CMR to be re-used as IMR for both non pre-coded and pre-coded CSI-RS*  *Proposal 2: For NC-JT CSI reporting enhancement, support and study followings:*   * *Support CRI-based dynamic reporting between NC-JT and non-NC-JT CSI* * *Support non-PMI based port-selection* * *Support restrictions among reported RIs or PMIs* * *Study UCI structure optimized for dynamic NC-JT CSI report*   *Proposal 3: Design new CPU occupation rule for dynamic NC-JT CSI report*  *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: For CSI measurement associated with a CSI-ReportConfig for NC-JT, support Alt: 3:*   * *For CMRs configured in the CSI-RS resource set, support RRC signalling to enable/disable single-TRP measurement hypothesis using CMR configured within CMR pairs for NCJT measurement hypothesis.* |
| **MTK** | *Proposal 1: Support Alt. 2: for* minimal supported value in UE capability reporting.  *Proposal 2: Dynamic updating for parameters within a CSI reporting setting is not supported.*  *Proposal 3: Support Alt. 3: RRC signaling to enable/disable single-TRP measurement hypothesis using CMR configured within CMR pairs for NCJT measurement hypothesis.*  *Proposal 4: For Option 2, the RI field of a CSI report is shared by single-TRP and NCJT measurement hypotheses with a fixed payload size.*  *Proposal 5: For Option 1 with X = 1, 2, each CSI measurement hypothesis is mapped to a distinct CSI report.*  *Proposal 6: 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 7: If supported, RI restriction is applied across TRPs by enabling/disabling each supported RI combination.*  *Proposal 8: At least for Type-I single-panel codebook, CBSR configuration is not supported for NCJT CSI measurement.*  *Proposal 9: The existing R15 CSI updating rule to address CPU overbooking can be reused.*  *Proposal 10: New relaxed CSI computation delay requirement is introduced for NCJT CSI calculation.*  *Proposal 11: Wideband CSI reporting on PUSCH and on PUCCH formats 2, 3, 4 are supported for NCJT CSI measurement. For Option 2, an additional PMI field is included in the single-part CSI, which is only used by the NCJT measurement hypothesis, if reported.*  *Proposal 12: PMI/RI sharing is supported for Option 1 with . CQI for single-TRP measurement hypotheses can follow the existing R15 design for the CQI for the second codeword.*  *Proposal 13: Non-PMI based port-selection is supported when NCJT measurement hypotheses are configured in a CSI reporting setting.* |
| **Intel** | *Proposal 11*:   * *Support MAC-CE based update of CMRs for NCJT and STRP* * *Support configuration of M < Ks CMRs for STRP (Alt. 2)*   *Proposal 12*:   * *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 13*:   * *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 14:*   * *Different CSI measurement hypothesis are treated as separate CSI reports in TS38.212 (Table 6.3.2.1.2-6 and Table 6.3.2.1.2-7) and for CSI priority equation from TS38.214 (section 5.2.5)*   + *CSI priority equation from TS38.214 (section 5.2.5) is modified (e.g. CSI measurement hypothesis for NCJT can be prioritized over CSI measurement hypothesis for STRP)*   *Proposal 15:*   * *Support configuration of CBSR for PMI per each CMR* * *Support configuration of RI restriction per each CMR in CMR pair for NCJT and per each CMR for STRP* |
| **Apple** | *Proposal 1 For interference measurement under NCJT, including RI/PMI/CQI/LI decision, CMR from one TRP should be considered as the interference, i.e. IMR, to the other TRP.*  *Proposal 2 In the same CSI-ReportConfig, when gNB configures UE to report both the single TRP measurement results and the multi-TRP measurement result, do not introduce different priority for single TRP measurement and multi-TRP measurement in the same CSI-ReportConfig, at least for CPU overbooking scenario* |
| **LG Electronics** | *Proposal #1: Support Alt 2 that additional high layer signaling for configuring M CMRs for single TRP CSI from CSI-RS resource set is used for single TRP CSI calculation.*  *Proposal #2: Support Alt 1/2/4 for dynamic updating of CSI measurement associated with a CSI-ReportConfig for NCJT.*   * *Alt 1: CMR pairs for NCJT measurement hypotheses* * *Alt 2: CMRs for Single-TRP measurement hypotheses* * *Alt 4: the number of single-TRP CSIs (i.e. X=0/1/2) in a NCJT CSI report*   *Proposal #3: 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.*  *Proposal #4: Support different CodebookConfigs for different RI restrictions and CBSRs for different TRPs, i.e., different CMRs in a CMR pair.*  *Proposal #5: Deprioritize sharing of PMI/RI between NCJT CSI and STRP CSI(s).* |
| **Lenovo, Motorola Mobility** | 1. *Support Alt3 for CMR reuse, with a single configuration parameter enabling CMR reuse for single-TRP for the configured NZP CSI-RS resources* 2. *Support the pair (Ks, N) = (2,1) as mandatory parameter values for multi-TRP transmission for FR1, and support the pair (Ks, N) = (4,1) as mandatory parameter values for FR2* 3. *Study dynamic signaling of selected CMRs for CSI Reporting as an optional UE feature* 4. *Reuse PMI, RI across NCJT and single-TRP hypotheses for CSI reporting under Option 1 with X=1, 2* 5. *Support higher-layer configuration indication of PMI/RI sharing* 6. *For PMI/RI sharing, CPU occupation is similar to Option 2 with X=0 with NCJT CSI reporting* 7. *A CSI report corresponding to single-TRP hypothesis has higher priority compared with a CSI report corresponding to NCJT hypothesis* 8. *For a CSI reporting configuration with X=2 single-TRP CSI reports, ties must be broken between the two single-TRP CSI reports to prioritize one CSI report over the other, e.g., based on associated CSI-RS Resource ID* 9. *A CSI report is defined for each CSI hypothesis, i.e., different CSI hypotheses correspond to different CSI reports* 10. *Reuse legacy RI restriction format for NCJT, such that an RI restriction applies to the total number of layers transmitted from the TRP(s) for a given transmission hypothesis* 11. *Two CBSR configurations are used for NCJT, such that each CBSR configuration applies to a specific TRP* |
| **OPPO** | Proposal 7: The *minimal supported value of Ks,max  for UE capability reporting* is 2 considering FR1.  *Proposal 8: For CSI measurement associated with a CSI-ReportConfig for NC-JT, support RRC signalling to enable/disable single-TRP measurement hypothesis using CMR configured within CMR pairs for NCJT measurement hypothesis. Additional high layer signaling to configure M (M≤ Ks) CMRs from the CSI-RS resource set for single-TRP measurement hypotheses is not needed.*  Proposal 9: CMR pairs for NCJT measurement hypotheses, CMRs for Single-TRP measurement hypotheses, TCI states for CMRs and the value of X for a CSI report are configured by RRC.  Proposal 10: The number of CSI-IM resources depends on whether CMR sharing between S-TRP and NC-JT measurement hypotheses is enabled.   * *If CMR sharing between NC-JT and S-TRP measurement is enabled, M=Ks CSI-IM resources with one-to-one mapping with M CMRSs for S-TRP, and N CSI-IM resources with one-to-one mapping with N CMR pairs for NC-JT can be configured* * *If CMR sharing between NC-JT and S-TRP measurement is not enabled, M=Ks-2N CSI-IM resources with one-to-one mapping with M CMRs for S-TRP, and N CSI-IM resources with one-to-one mapping with N CMR pairs for NC-JT can be configured*   Proposal 11: For Option 2,   * *If CMR sharing between NC-JT and S-TRP measurement is enabled, the bit number of CRI is log2(Ks+N), which indicates one of Ks S-TRP measurement hypotheses and N NC-JT measurement hypothesis.* * *Otherwise, the bit number of CRI is log2(Ks-N), which indicates one of (Ks-2N)S-TRP measurement hypotheses and N NC-JT measurement hypothesis.* * *One CRI, one RI and CQI for first CW are reported via CSI part 1.*   + *Depended on CRI, the RI can indicate one or two rank values.* * *One or two PMI(s) depended on CRI, possible CQI for second CW are reported in CSI part 2.*   Proposal 12: For CSI for S-TRP in the CSI report of Option 1 and type 1 codebook,   * *The report content is the same as that of Rel-15/16.* * *If CMR sharing between NC-JT and S-TRP measurement is enabled, the bit number of CRI is log2(Ks); Otherwise, the bit number is log2(Ks-2N).*   Proposal 13: For CSI for NC-JT hypothesis in the CSI report of Option 1 and type 1 codebook,   * *CRI, RI and CQI for first CW are reported via CSI part 1.*   + *The bit number of CRI is log2(N);*   + *The RI to rank mapping can reuse that of option 2 for NC-JT hypothesis.* * *Two PMIs, possible CQI for second CW are reported in CSI part 2.*   *Proposal 14: For CSI priority within a CSI report configuration for Option 1*   * *The X+1 CSI hypotheses per CSI Reporting Setting are mapped to a single CSI report* * *The CSI priority formula is not changed.* * *The PUCCH resource determination, CSI omission for part 2 CSI and CSI dropping due to CPU occupation, which are based on the CSI priority formula, reuses that of Rel-15/16* * *Prioritizing CSI associated with different measurement hypotheses within a CSI Reporting Setting only applies for UCI payload generation.* |
| **Qualcomm** | *Proposal 1: For a CSI-RS resource set with Ks NZP CSI-RS resources configured for CMR and N NZP CSI-RS resource pairs configured for NCJT measurement hypotheses, support Alt2 for the default value of Ks,max,*   * *Alt 2: Ks,max = 2* * *Note that default value means the minimal supported value for Ks,max in UE capability reporting, if UE support this feature.*   *Proposal 2: For CSI measurement associated with a CSI-ReportConfig for NC-JT, support Alt3:*   * *Alt 3: For CMRs configured in the CSI-RS resource set, support RRC signalling to enable/disable single-TRP measurement hypothesis using CMR configured within CMR pairs for NCJT measurement hypothesis*   *Proposal 3: For a CSI report setting with K1 and K2 CMRs in the first and second CMR groups, and N CMR pair configured for NCJT CSI hypotheses*   * *M1 and M2 are the number of valid single-TRP hypotheses in the first and second CMR groups*   + *If CMR sharing is enabled: M1=K1 and M2=K2*   + *If CMR sharing is not enabled: M1 / M2 are the number of CMRs in the first / second CMR group that do not appear in a CMR pair.* * *The number of CRI points is*   + *Option 1:*      - *X=0: N*     - *X=1: N and M1+M2 for the two CRIs*     - *X=2: N, M1, and M2 for the three CRIs*   + *Option 2: M1+M2+N*     - *The first M1+M2 CRI codepoints are mapped to the single-TRP hypotheses, and the remaining N CRI codepoints are mapped to NCJT hypotheses*   *Proposal 4: For RI and LI reporting of a NCJT CSI, the two RI’s and LI’s are based on*   * *Introduce a RRC configuration for NCJT rank restriction with 4-bit bitmap, which determines the number of allowed rank pairs out of {1+1,1+2,2+1,2+2} rank pair hypotheses* * *The size of the RI field is*   + *When Option 1 is configured: bits.*   + *When Option 2 is configured: bits.* * *The two LI’s are reported in CSI part 2, which require 2 / 1 / 0 bits depending on the indicated rank pair.*   *Proposal 5: For a CSI report setting with Option 1 with X=1 or 2 and reportConfigID=s, CSI priority is , where corresponds to single-TRP CSI(s) and NCJT CSI within the CSI report setting, respectively.*   * *This ordering is for the purpose of UCI payload construction as well as CSI omission for CSI part 2.* * *This ordering does not impact PUCCH resource selection for UCI multiplexing, or CPU occupation handling.*   *Proposal 6: In the NCJT CSI, for subband part of CSI part 2, adopt one of the following alternatives for the order between even/odd subbands versus first/second PMIs:*   * *Alt1: Even and odd subbands of the first PMI are placed first followed by even and odd subbands of the second PMI.* * *Alt2: Even subbands of the first and second PMIs are placed first followed by the odd subbands of the first and second PMIs.*   *Proposal 7: For a NCJT CSI corresponding to a CMR pair, the first RI/PMI/LI is associated with the CMR in the first CMR group, and the second RI/PMI/LI is associated with the CMR in the second CMR group.*  *Proposal 8: For a CMR configured in a CMR pair for a NCJT CSI hypothesis, a separate powerControlOffset (Pc ratio) can be configured, which is defined as the energy of PDSCH ports with a same TCI state as the CMR on one subcarrier of one OFDM symbol divided by the energy of all CSI-RS ports of the CMR multiplexed on one subcarrier of one OFDM symbol.* |
| **Fraunhofer IIS, Fraunhofer HHI** | *Proposal: 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 i.e., support Alt. 1.*  *Proposal: For rank 2, support layer common port selection.*  *Proposal: The proposal on the absence of a bitmap can be discussed after deciding on the number of NZCs selection and reporting for all supported ranks for the Rel. 17 PS CB.*  *Proposal: Support cyclic shifting of the FD component associated with the SC to FD index = 0, i.e., support ALT2-1.*  *Proposal: Support Alt 1 i.e., the reserved field of the Rel. 16 4-bit amplitude set is reused for the Rel. 17 codebook.*  *Proposal: Considering feedback overhead, for the Rel. 17 PS CB the size of the window can be fixed to the number of delays for rank 1 and rank 2.*  *Proposal: Confirm the working assumption that the FD bases are consecutive within a single window of size .*  *Proposal: Do not support R < 1 for Rel. 17 PS CB. Support and .* |