**3GPP TSG RAN WG1 Meeting #105-e R1-210xxxx**

**e-Meeting, May 10th – 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*

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

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

In RAN1 104e, basic codebook structure for Rel-17 Type II port selection codebook enhancement was agreed. For Multi-TRP CSI enhancement in Rel-17, further basic design targets were agreed for CSI measurement setting and also for two options for CSI reporting setting.

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

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

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

# Summary of CSI enhancement for FDD

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

### 2.1.1 Remain issues of codebook structure for

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

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

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

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

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

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

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

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

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

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

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

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

|  |  |
| --- | --- |
| Company | Comments |
| Mod | Strive to make a decision in RAN1 105 based on the majority |
|  |  |

**Issue 2 – Values of K1**

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

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

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

For values of for :

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

The values of depends on CSI-RS ports P:

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

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

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

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

|  |  |
| --- | --- |
| Company | Comments |
| Mod | Strive to make a decision in RAN1 105 based on the majority.  |
|  |  |

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

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

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

Base on above views, following conclusion is suggested:

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

|  |  |
| --- | --- |
| Company | Comments |
| Mod | This can be simple conclusion if there is no further design/enhancement required.  |
|  |  |

### 2.1.2 Remain issues of codebook structure for

**Issue 1 - Values of**

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

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

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

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

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

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

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

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

|  |  |
| --- | --- |
| Company | Comments |
| Mod | Strive to make a decision in RAN1 105 based on the majority.  |
|  |  |

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

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

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

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

Companies support Alt1 with the following consideration:

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

Companies support Alt2 with the following consideration:

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

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

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

|  |  |
| --- | --- |
| Company | Comments |
| Mod | Strive to make a decision in RAN1 105 based on the majority. |
|  |  |

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

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

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

Companies preferring fixed have the following considerations.

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

Companies preferring configurable have the following considerations:

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

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

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

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

|  |  |
| --- | --- |
| Company | Comments |
| Mod | Strive to make a decision in RAN1 105 based on the majority. |
|  |  |

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

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

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

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

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

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

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

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

*• Alt 1: N= Mv always*

*• Alt 2: N >= Mv*

|  |  |
| --- | --- |
| Company | Comments |
| Mod | Strive to make a decision in RAN1 105 based on the majority, i.e. do we need N>M?  |
|  |  |

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

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

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

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

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

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

|  |  |
| --- | --- |
| Company | Comments |
| Mod | It seems that Proposal 7 may depend on the outcome of Proposal 6.  |
|  |  |

**Issue 4 - Values of R**

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

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

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

For R<1, companies have the following reviews.

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

Companies preferring only R =1 have the following considerations.

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

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

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

Companies preferring to supported R= have the following considerations.

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

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

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

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

|  |  |
| --- | --- |
| Company | Comments |
| Mod | For simplicity of configuration and also potential compromise, it is suggested to choose only two values as 1 (the smallest), and another one from another camp (the largest).  |
|  |  |

**Issue 5 - Clarifying on turn off**

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

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

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

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

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

|  |  |
| --- | --- |
| Company | Comments |
| Mod  | The proposal intends to align RAN1 understanding further for the agreement, as much as possible.  |
|  |  |

### 2.1.3 Remain issues of codebook structure for

**Issue 1 – Value(s) of**

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

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

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

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

Based on above views, the following proposal is suggested:

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

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

|  |  |
| --- | --- |
| Company | Comments |
| Mod | Some values are still in bracket in order to keep candidate values as less as possible. We may strive to make a decision in RAN1 105 based on the majority.  |
|  |  |

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

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

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

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

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

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

Based on above views, the following proposal is suggested:

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

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

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

|  |  |
| --- | --- |
| Company | Comments |
| Mod | The proposal intends to down select to one Alt in order to save UCI overhead, if the bitmap is absent |
|  |  |

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

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

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

Based on above views, the following proposal is suggested:

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

|  |  |
| --- | --- |
| Company | Comments |
| Mod | Strive to make a decision in RAN1 105 based on the majority. |
|  |  |

**Issue 3 – SCI**

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

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

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

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

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

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

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

|  |  |
| --- | --- |
| Company | Comments |
| Mod | The proposal intends to study/clarify the issue of SCI, for further decision in August Meeting by RAN1 106 |
|  |  |

**Issue 4 - Quantization of coefficients**

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

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

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

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

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

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

|  |  |
| --- | --- |
| Company | Comments |
| Mod | For W2, the majority companies prefer to reuse so that above proposal is to clarify which design are to be reused, for the sake of discussion. If possible, down-selection from Alt1~3 is preferred this meeting.  |
|  |  |

### 2.1.4 Others

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

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

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

## Analysing mechanisms to improve utilization of CSI-RS

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

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

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

Companies preferring Option 0 have the following considerations.

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

Companies preferring Option 1 have the following considerations.

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

Companies preferring Option 3 have the following considerations.

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

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

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

|  |  |
| --- | --- |
| Company | Comments |
| Mod | From FL perspective, companies’ preference are almost the same as the last time.  |
|  |  |

## Others

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

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

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

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

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

# Summary of CSI enhancement for Multi-TRP

## CSI Measurement Enhancements for Multi-TRP

### 3.1.1 Resource setting for CMR

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

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

Based on the above view, following proposal is suggested:

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

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

|  |  |
| --- | --- |
| Company | Comments |
| Mod | Strive to make a decision in RAN1 105 based on the majority  |
| ZTE | We support Alt 1, and also accept Alt 3 |

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

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

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

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

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

The companies’ views can be summarized as:

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

Based on above views, following proposal is suggested:

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

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

|  |  |
| --- | --- |
| Company | Comments |
| Mod | From FL perspective, above proposal intends to make agreed “study” a little more concrete in terms of what we shall do next at high level. However it does not mean that companies supporting individual Alt may have same understanding or preference of details. Therefore in order to move forward, some RAN1 discussion/decision may be required to research a certain compromise.  |
| ZTE | Support Alt 2Alt 1 is not preferred. The current CSI framework is flexible enough to use DCI/MACCE for selection from RRC configured CSI reportings, e.g. two CSI reportings can be configured by RRC with the same CMR configuration but with different NCJT/STRP hypotheses, then DCI or MACCE is used to select one. It is equivalent with Alt1 which needs much more spec effort. Alt 3 is a compromised solution of Alt 2, the benefit is just to save RRC overhead compared with Alt2, but the flexibility is sacrificed.  |

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

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

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

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

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

|  |  |
| --- | --- |
| Company | Comments |
| Mod | Strive to make a decision in RAN1 105 based on the majority  |
| ZTE | Support Alt 1We don’t think the UE capability of three receive beams should be discussed in Rel-17. Even in MTRP beam manage agenda, it is not discussed. This is a Rel-18 or 19 issues.  |

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

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

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

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

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

|  |  |
| --- | --- |
| Company | Comments |
| Mod | Strive to make a decision in RAN1 105 based on the majority  |
| ZTE | Support Alt 2. Alt 2 is a clean solution for CSI measurement which can avoid the misalignment between STRP and MTRP CSI measurement. |

### 3.1.2 Resource setting for IMR

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

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

The companies’ views can be summarized as:

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

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

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

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

|  |  |
| --- | --- |
| Company | Comments |
| Mod | Depending on companies’ feedback, we will strive at least to polish Alts to be clearer at least this meeting for future discussion and decision. Otherwise CSI-IM related configuration are missing.  |
| ZTE | Support Alt 2. We don’t know how to use two IMRs for NCJT CSI if Alt 1 is supported. It is noted that Alt 1 just saves RRC signalling rather than IMR resources. |

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

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

The companies’ views can be summarized as:

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

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

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

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

|  |  |
| --- | --- |
| Company | Comments |
| Mod | Strive to make a decision in RAN1 105 based on the majority  |
| ZTE | Support Alt 1. We are fine with the limitation of the example. Please noted that NZP CSI-RS can be used for interference measurement other than MU-MIMO |

## 3.2 CSI Reporting Enhancements for Multi-TRP

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

The companies’ views can be summarized as:

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

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

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

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

|  |  |
| --- | --- |
| Company | Comments |
| Mod | Strive to make a decision in RAN1 105 based on the majority, at least high level decision for yes or no. If yes, a certain details of elaboration may be required.  |
| ZTE | We prefer down-prioritize this discussion. If we get conclusion for CSI enhancement on MDCI based MTRP, e.g. if we agree option 2, i.e. the UE can be expected to report one RI, one PMI, one LI and one CQI per TRP, up to 2 TRPs, for Multi-DCI based NCJT, then the RI/PMI sharing will be unnecessary since only two RI/PMI/CQIs can be sharing for MTRP and STRP in such case.  |

## 3.3 CSI processing criteria

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

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

*Whereas i=0, 1, 2*

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

|  |  |
| --- | --- |
| Company | Comments |
| Mod | Strive to make a decision in RAN1 105 based on the majority  |
| ZTE | Support  |

## 3.4 CSI measurement for multi-DCI based NCJT

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

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

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

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

The companies’ views can be summarized as:

|  |  |
| --- | --- |
| **Views** | **Companies** |
| Option 1 (6) | ZTE, Vivo, Spreadtrum, Samsung, Nokia/NSB |
| Option 2 (3) | Qualcomm, MediaTek, DoCoMo(second preference), ZTE |

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

* *Option 1: Confirm the Working Assumption from RAN1 103e*
* *Option 2: The UE can be expected to report one RI, one PMI, one LI and one CQI per TRP, up to 2 TRPs, for Multi-DCI based NCJT*

|  |  |
| --- | --- |
| Company | Comments |
| Mod | Strive to make a decision in RAN1 105 based on the majority  |
| ZTE | We are also fine to support Option 2 after thinking because of less spec impact and unified framework. |

## 3.5 Others

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

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

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

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

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

# Proposals for Online/Offline Discussion

TBD

# Work Plan

TBD

# References

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

# Appendix

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

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

|  |  |
| --- | --- |
| **Companies** | **Proposals** |
| **Huawei, HiSilicon** | ***Proposal 1: For R17 port selection codebook, the maximal value of CSI-RS port number P as Pmax is 32.******Proposal 2: 4, 8, 12, 16, 24 and 32 can be supported for candidate values of K1 (K1 <= P) for port selection matrix.******Proposal 3: For R17 port selection codebook, should be supported.******Proposal 4: At least for rank 1, support FD bases used for Wf quantitation limited within a single window with size N configured to the UE whereas FD bases in the window must be consecutive from an orthogonal DFT matrix, i.e. Alt 1.*** ***Proposal 5: For relationship between N and , support Alt 2**** ***N= if***
* ***N with N=2,4 if***

***Proposal 6: Support Alt 4, i.e. R= {1, 2, …, } whereas D is the density of CSI-RS in frequency domain), for R17 port selection codebook.******Proposal 7: Polarization-common based bitmap for should be supported for R17 PS CB.******Proposal 8: Considering that gNB can implement compression implicitly, β = 1 should be supported for R17 and other smaller candidate values can be considered as well.******Proposal 9: Option 1, i.e. with a lower CSI-RS density as 0.25, should be supported to improve utilization of CSI-RS for Rel-17 PS codebook.*** |
| **vivo** | **Proposal 19:***No restriction of the number of CSI-RS ports for polarization-common report.**K1 in {2,4,8,12,16,24,32} with K1 <= P and the maximal value of P is 32.***Proposal 20:***When Wf is turned off, the non-zero coefficients bitmap can be absent and beta value can be 1;**When Wf is turned on, beta values can be 1/4, 1/2 and 3/4 can be supported and additional beta value of 1/8 can be supported for the case of large number of CSI-RS ports.***Proposal 21:***At least for rank1, the window/set can be consecutive/non-consecutive, and FD bases are selected freely by gNB from an orthogonal DFT matrix.**At least for rank1, N ≥ Mv.**The candidate values of N can be 2, 4, [6]. The candidate values of Mv can be 1, 2, 3, 4.***Proposal 22:** *UE can use partial CSI-RS ports to search target tap 0 to reduce the complexity.**gNB can map SD-FD bases to CSI-RS ports with a predetermined order or indicating the ports for timing calibration.* |
| **Spreadtrum Communications** | ***Proposal 13: Support Alt 1: FD bases in the window must be consecutive from an orthogonal DFT matrix.******Proposal 14: for the window is fixed to be 0.******Proposal 15:*** ***the*** ***bitmap for indication non-zero coefficients can be absent, depending on the value of beta.******Proposal 16: Support Alt1: Reusing Rel-16 quantization mechanism at least for Rank 1.******Proposal 17: Support Option 0: No further CSI-RS enhancement as the baseline.*** |
| **CATT** | **Proposal-1:** * *When is turned off or, the bitmap for indicating non-zero coefficients should be polarization-common.*

**Proposal-2:** * *The values of can be configured to 1/8, 1/4, 1/2, 3/4 and 1.*

**Proposal-3:** * *When is turned off or, the bitmap for indicating non-zero coefficients can be absent.*

**Proposal-4:*** *The strongest coefficient should be indicated to save feedback overhead.*

**Proposal-5:*** *Alt1 is supported for coefficient quantization.*

**Proposal-6:*** *should be reported to network with any value up to P.*

**Proposal-7:*** *Port selection should be indicated via combinatorial coefficients when is turned off or on.*

**Proposal-8:** * *The maximal value of P should be equal to 48.*

**Proposal-9:*** *Consecutive FD bases from an orthogonal DFT matrix should be configured to UE via a window.*

**Proposal-10:*** *Dynamic indication of should be considered in order to flexibly shift the delay position.*

**Proposal-11:*** *is supported.*

**Proposa-12:*** *The number of FD bases and/or the selected FD bases should be allowed to report by UE.*

**Proposa-13:** * *R= {1, 2,…, D\*NPRBSB} whereas D is the density of CSI-RS in frequency domain should be supported.*
* *R is applied when is turned on.*
* *R is not applied when is turned off.*

**Proposal-14:*** *Opiton3 or the combination of both Option1 and Option3 is supported.*

**Proposal-15:*** *For Rel-17 port selection codebook, high rank transmission, e.g., 4 layers, should be supported.*

**Proposal-16:*** *Port selection can be layer-independent.*

**Proposal-17:*** *When is turned on and the number of selected FD bases is different for all layers, FD bases selection should be layer-independent.*

**Proposal-18:*** *In order to save indication overhead, the port selection can be indicated by using two parts: the first part is used to indicate the ports common to all layers, the second part is used to indicate the remaining selected ports for each layer.*

**Proposal-19:*** *Phase shift can be adopted at UE side. Then, and bits are used to indicate the selected FD bases by UE for the l-th layer.*

**Proposal-20:** * *The strongest coefficient is indicated by using for l-th layer.*
 |
| **ZTE** | **Proposal 7:*** *Support polarization-common W1 for all the ranks and CSI-RS ports in Rel-17 PS codebook.*

**Proposal 8:*** *All the values in {4, 8, 12, 16, 24, 32} can be supported for K1 where K1<=P.*

**Proposal 9:** * *Reuse the Rel-16 non-zero coefficient quantization approach for the amplitudes and phases in W2 of Rel-17 PS codebook.*
* *The reserved state for reference amplitude in Rel-16 can be replaced with a smaller value following 1.5 dB step size, i.e., .*

**Proposal 10:** * *On Wf in Rel-17 PS codebook*
* *The set of N candidate vectors of Wf is a consecutive window configured by gNB, where both the window size and the start position M\_initial are configured (e.g., window size N = 2 or 4 for Mv = 1 or 2), and N>Mv.*
* *UE selects and reports Mv Wf vectors within the window configured by gNB.*
* *Support having smaller Mv values for higher numbers of CSI-RS ports (e.g., Mv = 1 only for 24/32 ports)*
* *Support R=1 and 2.*

**Proposal 11:** * *Support configuring multiple CSI-RS resources per CSI reporting configuration associated with Rel-17 PS codebook.*
 |
| **Qualcomm Incorporated** | **Proposal 11:*** *For Rel-17 FDD CSI, clarify that Wf OFF and Wf ON with M=1 are same.*

**Proposal 12:*** *For Rel-17 FDD CSI, support window-based intermediate set for Wf quantization.*
	+ *Note: the window does not imply any specific UE implementation in PMI calculation*

**Proposal 13:*** *For Rel-17 FDD CSI, support window size equal to the number of FD bases in Wf quantization, i.e., N=M. No UE reporting of Wf is needed.*
	+ *For M=1, the FD basis in Wf is DFT basis 0;*
	+ *For M=2, the FD bases in Wf are DFT basis 0 and FD basis 1.*

**Proposal 14:*** *For Rel-17 FDD CSI, no need to define R in the spec or only support R=1 PMI per CQI subband.*

**Proposal 15:*** *For Rel-17 FDD CSI, support 1 value of K1 for number of CSI-RS ports <=12, and upto 2 values of K1 (number of selected ports) per number of CSI-RS ports, e.g., K1={16,32} for 32-port.*

**Proposal 16:*** *Support parameter combinations of {K1, beta, M}, and total number of different combinations should not exceed Rel-16 eType II codebook.*

**Proposal 17:*** *For Rel-17 FDD CSI, support following for linear combination coefficient reporting.*
	+ *Up to 2 values for*
	+ *max number of non-zero coefficients per layer is*
	+ *max number of non-zero coefficients across all layers is .*
	+ *UE reporting of actual number of non-zero coefficients.*

**Proposal 18:** *For Rel-17 FDD CSI, no CSI-RS enhancement is needed.* |
| **OPPO** | **Proposal 1:*** *Support K1 = {8, 16, 24} and Pmax = 32 for Rel-17 codebook.*

**Proposal 2:** * *Support beta=3/4 for Rel-17 codebook.*

**Proposal 3:*** *Support polarization-specific bitmap for Rel-17 codebook.*

Proposal 4: * *Reuse Rel-16 W2 quantization for Rel-17 PS.*

Proposal 5: * *Support R = 1 and R = 2 as baseline for Mv>1.*

 **Proposal 6:*** *Support Wf:*
	+ *FD basis in the window are consecutive (Alt.1)*
	+ *N=Mv always (Alt.1)*
 |
| **Intel** | ***Proposal 6***: * *Support polarization-common CSI-RS port selection for all the supported number of ports for rank 1-4*

***Proposal 7***: * *Support combinatorial coefficient reporting for CSI-RS port selection for rank 1-4 including the case with one vector in* ***W****f matrix M = 1*

***Proposal 8***: * *Support M = 2 for all the supported number of ports as for M = 1*

***Proposal 9***: * *Support consecutive window for FD vector selection with the window size N = 4 for M = 2*
	+ *Selection and reporting of M FD vectors among N FD vectors is layer-common*

***Proposal 10***: * *Reuse Rel-16 coefficient quantization design for Rel. 17 (Alt1)*

One more feature which can be reused for Rel. 17 codebook from Rel. 16 codebook is partial CSI omission. Since the PMI has similar structure the same partial CSI omission design can be reused.***Proposal 11***: * *Reuse Rel-16 partial CSI omission design for Rel. 17*

***Proposal 12***: * *Support 0.25 CSI-RS density in Rel. 17*

***Proposal 13***: * *Support R = D\*NPRBSB whereas D is the density of CSI-RS in frequency domain*
 |
| **Apple** | ***Proposal 4 For potential CSI-RS enhancement for port selection codebook enhancement,**** ***Do not introduce SD-FD pairing***
* ***Do not introduce CSI-RS with more than 32 ports***
* ***No CSI-RS enhancement in Rel-17***

***Proposal 5 For port selection codebook enhancement, more flexible wideband and subband CSI reporting configuration can be considered******Proposal 6 For W1 design for port selection codebook enhancement, W1 is polarization common and combinatorial coefficient is used for port selection for W1 for RI>1******Proposal 7 For Wf design for port selection codebook enhancement,*** * ***UE always selects the DC frequency basis, i.e., frequency basis with all entries equal to 1.***

***Do not support R>1*** |
| **Sony** | **Proposal 1. If further CSI-RS enhancements are needed for CSI-RS associated with Rel-17 PS codebook, then prefer Option 1.****Proposal 2. For minimum specification impact, maintain the polarization-common base selection and reporting mechanism of Rel-15/16. A polarization-specific mechanism should only be introduced if it can be shown that, at least for some scenarios of interest, it provides substantial advantage over polarization-common.****Proposal 3: Based on UL CSI, further restrict the set of CSI-RS ports eligible by the UE to those compatible with UL signal angles. By reducing the number of choices, less bits are needed to encode the DL CSI feedback reports by the UE.****Proposal 4: Introduce an FD sampling size parameter . Based on UL CSI, further restrictions to can be applied in order to limit the set of FD DFT vectors eligible by the UE.****Proposal 5: At least for rank 1, the FD bases used for quantization must be consecutive vectors from an orthogonal DFT matrix.****Proposal 6: At least for rank 1, support .** |
| **Fraunhofer IIS, Fraunhofer HHI** | ***Proposal: Support for all supported number of CSI-RS ports, i.e., no restriction of the number of CSI-RS ports for .*** ***Proposal: The number of selected ports is less than or equal to 3/4 of the total number of CSI-RS ports (i.e., ).*** ***Proposal: Considering UE complexity, for the Rel. 17 PS CB the size of the window can be fixed to the number of delays .*** ***Proposal: Support fixing or configuring the starting index of window to zero.*** ***Proposal: Do not support R < 1 for Rel. 17 PS CB. Support and .******Proposal: For simplicity, support the Rel. 16 quantization scheme for the R17 codebook.*** ***Proposal: Support option 0 – no further CSI-RS enhancements.***  |
| **Nokia, Nokia Shanghai Bell** | **Proposal 1 Support rank 1,2 and further evaluate support for rank 3 and 4 under the assumption that CSI overhead for rank>2 should be comparable to that of rank 2.****Proposal 2 Regarding the gNB configuration of a single measurement window for , support Alt 1, *i.e.*, a window formed by consecutive DFT components.****Proposal 3 Regarding the relationship between parameters and , support Alt 2, *i.e.*, .****Proposal 4 Support . Consider possible restrictions in relation to other parameters, such as , and , in the discussion on supported parameter combinations and UE capabilities.****Proposal 5 Support reporting of nonzero components of using a combinatorial indicator of bits for . For and/or , is not reported.****Proposal 6 Regarding the values of , support Alt4. In particular, support the configuration with . Consider limiting configurations for for .****Proposal 7 Regarding the quantisation of , support the baseline Alt 1, *i.e.*, reuse Rel-16 quantisation scheme at least up to rank 2.****Proposal 8 Regarding the maximum number of NZC per layer, , reuse the definition from Rel-16, such that .****Proposal 9 Regarding the bitmap and SCI reporting, support:*** **Reporting of the position, [, ], of the strongest coefficient of layer , for , using bits.**
* **Reporting of the bitmap after remapping the index of the strongest coefficient to .**

**Proposal 10 Regarding the candidate values for , consider for and for . Consider further down-selection in the discussion for supported parameter combinations: . For , the bitmap does not need reporting.****Proposal 11 Support polarisation-specific bitmap.****Proposal 12 Support polarisation-common based free port selection for at least up to rank 2 and for .****Proposal 13 Support the use of combinatorial indication for at least up to rank 2.****Proposal 14 Regarding the candidate values for , consider, at least with and for . Consider further down-selection in the discussion for supported parameter combinations: . For , does not need reporting.****Proposal 15 Regarding CSI-RS enhancement, support Option 1 (lower density) or Option 3 (multiple resources).** |
| **Samsung** | ***Proposal 7****: Regarding turning Wf ON/OFF,** *support an explicit RRC parameter for turning Wf ON/OFF*
* *the length of the all-one vector is 1, when Wf is turned OFF*

***Proposal 8****: support R17 codebook for BWP size < 24 PRBs with the current restriction in the specification, i.e. support only WB CSI implying Wf is turned OFF****Proposal 9****:* **At least for rank 1, r***egarding R value(s),** *support Alt0 (R=1/4) and Alt1 (R=1), and*
* *value(s) R>1 requires more study considering*
	+ *the impact of same or different CSI-RS beamforming (depending on R value(s)); and*
	+ *tradeoff among UE complexity, CSI overhead, potential-specification impact, and the UPT performance*

***Proposal 10****: Regarding Mv value(s),* * *support Mv=2 for #CSI-RS ports <= 12*
* *do not support Mv>2*

***Proposal 11****:* **At least for rank 1, r***egarding Wf configuration, support Alt1 (window-based) when N3 > t and Alt1 (free selection) when N3 <= t, where t is threshold (e.g. t=19).****Proposal 12****:* **At least for rank 1,** *for relationship between N and Mv, support Alt1 (N=Mv)****Proposal 13****: For W2 quantization,* * *support R16 based scheme, and replace the reserved reference amplitude = 0 with a new value*
* *Regarding the strongest polarization indicator for one of the two reference amplitudes, down-select from*
	+ *Alt1-1: based on SCI; details FFS*
	+ *Alt2-1: based on 1-bit strongest polarization indicator*

***Proposal 14****: Regarding Rel. 17 codebook parameters,** *The maximal value of P is discussed together with the CSI-RS related study*
* *Similar to R16, support a joint optimization based on the supported parameter values in order to reduce the #supported combinations, where the supported parameter values are given by:*
	+ *P from {2,4,8,12,16,24,32}*
	+ *K1 from {2,4,8,12,16,24,32}*
	+ *beta from {1,3/4,1/2}*

***Proposal 15:*** *Regarding CSI-RS related enhancement,* * *Support option 0 (no enhancement) as baseline*
* *Down-select to Option 3 for further study, and the study should consider aspects in Observation 8*

***Proposal 16****: for R17 codebook,** *support polarization-specific bitmap*
* *support rank 2, and study rank 3-4 after rank 1-2 design matures*
* *study the following regarding the SCI*
	+ *Alt1: SCI is reported, e.g. SCI is reported via one joint indicator, e.g. using -bits.*
	+ *Alt2: SCI is not reported, and the role of SCI in R16 quantization scheme is replaced with a 1-bit strongest coefficient indicator*
* *reuse UCI omission mechanism and study the following potential simplifications*
	+ *replacing SCI with the 1-bit strongest polarization indicator*
	+ *no FD permutation*
	+ *no bitmap partition*
	+ *no FD basis indicator*
 |
| **MTK** | **Proposal 13**: Combinatorial coefficients should be used to convey free port selection using .**Proposal 14:**  turned off is the same as , in which the UE uses the FD basis 0 (all-ones vector of length ) for PMI reporting.**Proposal 15:** Configuration of FD basis vectors is not needed when is turned off (equivalently ).**Proposal 16:** Configuration of FD basis vectors is needed only when is turned on (equivalently ). For the relation between and , prefer .**Proposal 17**: The FD bases configured to the UE can be consecutive/non-consecutive, and are selected freely by the gNB from an orthogonal DFT matrix of size .**Proposal 18**: Due to increase in UE complexity with higher values of prefer as mandatory and as optional to the UE.**Proposal 19**: Prefer Option 0, no further CSI-RS enhancements. As a second preference, support Option 1, lower density CSI-RS, with the minimum density configured jointly with the value of as . |
| **DoCoMo** | **Proposal 11*** *Support at least beta=1.*
* *A bitmap for indication non-zero coefficient is not needed if Mv is small. All the non-zero LC coefficients within W2 can be reported.*

**Proposal 12*** *At least for rank 1,*
	+ *on the FD bases, support Alt.1: FD bases in the window must be consecutive from an orthogonal DFT matrix.*
	+ *on the relationship between N and Mv, support Alt.2: N >= Mv and FFS candidate value(s) of N, e.g. 2, 4.*
	+ *Above applies when Wf is turned ON*

**Proposal 13*** *Consider dynamic configuration of turning on/off*  *using DCI.*

**Proposal 14*** *For CSI-RS configurations associated with Rel-17 PS codebook, support Option 1 (i.e. lower CSI-RS density).*
 |
| **Lenovo, Motorola Mobility** | 1. No further modification is necessary on the Rel. 17 codebook structure
2. Support *M*=1, 2 for frequency compression parameter values for Rel. 17 Type-II port-selection codebook
3. Do not further restrict the supported number of CSI-RS ports for the Rel. 17 port-selection codebook configured with *M*=2
4. A layer-common, window-based approach is used to configure the FD basis indices for all layers, where the set of FD basis indices is contiguous, and whose location and size are higher-layer configured
5. Support UE-assisted FD basis indices selection for each layer from a layer-common network-configured window
6. Support Option 0: No further CSI-RS enhancement as the baseline
7. Reuse the Rel-16 coefficient quantization approach for the amplitudes and phases of the Rel. 17 port-selection codebook
* FFS: whether modified amplitude quantization values and/or bitwidth are considered
1. A bitmap is not reported for Rel. 17 port selection codebook when most coefficients are quantized, i.e., β=1, or the number of coefficients is small, e.g., *M*=1
2. Polarization-common port selection and polarization-specific coefficient quantization should be supported for Rel. 17 Reciprocity-based Port Selection codebook
3. Study PUCCH reporting of CSI feedback corresponding to Rel. 17 port-selection codebook for some codebook parameter combinations that yield low CSI feedback overhead
* FFS: codebook parameter combination values that support PUCCH reporting
 |
| **LG Electronics** | **Proposal #6: FD bases are selected freely by gNB from an orthogonal DFT matrix.****Proposal #7: N is always equal to Mv.****Proposal #8: For the quantization of W2 coefficient, support Alt1, i.e., reusing Rel-16 quantization mechanism.** **Proposal #9: If enhancement is needed, consider option 1(a lower CSI-RS density per CSI-RS resource) for lower CSI-RS overhead in Rel-17.** |
| **Ericsson** | [**Proposal 1** **Support up to 16.**](#_Toc71667623)[**Proposal 2** **Use a proportion factor to determine the value , where . Candidate values can be 0.75 and 1.**](#_Toc71667624)[**Proposal 3** **An RRC parameter controls the number of FD bases (e.g. =2), and the default value is a single basis (=1). In this default case, Wf is an all-one vector of length N3.**](#_Toc71667625)[**Proposal 4** **Support Alt.1: FD bases in the window must be consecutive from an orthogonal DFT matrix**](#_Toc71667626)[**Proposal 5** **Support Alt.2: N >= Mv and furthermore, support for and for**](#_Toc71667627) [**Proposal 6** **Support Alt 2: Minit for the window is fixed to be 0.**](#_Toc71667628)[**Proposal 7** **Support and , larger value of is not needed.**](#_Toc71667629) **Support and .**[**Proposal 9** **For rank 1 transmission, when is configured, then UE reports all coefficients and the resulting NZC bitmap is all ones and is therefore not reported.**](#_Toc71667631)[**Proposal 10** **Support polarization-specific bitmap, when bitmap is reported.**](#_Toc71667632)[**Proposal 11** **Support a single and large value, for example , where is the CQI subband size.**](#_Toc71667633)[**Proposal 12** **Support polarization-common based free selection for all supported number of CSI-RS ports and ranks.**](#_Toc71667634)[**Proposal 13** **Support combinatorial coefficient for reporting the port selection matrix for all supported codebook configurations.**](#_Toc71667635)[**Proposal 14** **Support Alt 1, i.e., reuse the Rel-16 quantization mechanism.**](#_Toc71667636)[**Proposal 15** **Prioritize rank 1 and 2 in RAN1 work on FDD CSI feature**](#_Toc71667637)[**Proposal 16** **Do not support lower CSI-RS density, e.g., .**](#_Toc71667638) |

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

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

|  |  |
| --- | --- |
| **Companies** | **Proposals** |
| **Futurewei** | ***Proposal 1: Regarding whether a NZP CSI-RS resource m can be referred by two CMR pairs (m, a) and (m, b) configured for NCJT measurement hypotheses, FeMIMO supports Alt 2: It is feasible for both FR1 and FR2 but subject to further UE capability for FR2.*** ***Proposal 2: Regarding whether a NZP CSI-RS resource can be referred by both a CMR pair configured for NCJT measurement hypothesis and a CMR configured for Single-TRP measurement hypothesis, FeMIMO supports Alt 3: It is feasible in both FR1 and FR2 but subject to UE capability for FR2. If a UE supports and the sharing is also enabled by gNB, two CMRs from a CMR pair configured for a NCJT measurement hypothesis can be used for Single-TRP measurement hypotheses, otherwise they cannot.******Proposal 3: Regarding whether a CSI-IM can be referred by both NCJT and Single-TRP measurement hypotheses, FeMIMO supports Alt 1: CSI-IM can be shared by both NCJT and Single-TRP measurement hypotheses.*** |
| **Huawei, HiSilicon** | ***Proposal 10: For CSI measurement associated with a CSI-ReportConfig for NC-JT, support M (M ≤ Ks) CMRs from the CSI-RS resource set for CMR to be configured for Single-TRP measurement hypotheses by additional RRC signaling.******Proposal 11: For FR1, a NZP CSI-RS resource m can be referred by:**** ***Two CMR pairs (m, a) and (m, b) configured for NCJT measurement hypotheses***
* ***Both a CMR pair configured for NCJT measurement hypothesis and a CMR configured for Single-TRP measurement hypothesis.***

***Proposal 12:* For FR2, a NZP CSI-RS resource *m* cannot be referred simultaneously by:*** ***Two CMR pairs (m, a) and (m, b) configured for NCJT measurement hypotheses***
* ***Both a CMR pair configured for NCJT measurement hypothesis and a CMR configured for Single-TRP measurement hypothesis.***

***Proposal 13: A NZP CSI-RS resource set configured with M CMRs for single-TRP measurement hypotheses and N CMR pairs for NCJT measurement hypotheses is associated to a CSI-IM resource set configured with M+N CSI-IM resources,*** * ***Whereas the first M CSI-IM resources are associated with M CMRs one-by-one and remaining N CSI-IM resources are associated with N selected CMR pairs one-by-one.***

***Proposal 14: For a CMR in a CMR pair, another CMR in the same pair is considered as NZP IMR for that CMR.******Proposal 15: The report quantity is either ‘cri-RI-PMI-CQI’ or ‘cri-RI-LI-PMI-CQI’ if a CSI-ReportConfig is associated with NCJT measurement hypothesis in Rel-17.*** ***Proposal 16:* When one UE is is configured with CSI Option 1,** * **A CRI with a bitwidth of is used to determine one CMR pair within *N* CMR pairs configured for NCJT measurement hypothesis;**
* **A CRI with a bitwidth of is used to determine one CMR within *M* CMRs configured for Single-TRP measurement hypothesis.**

***Proposal 17:* For CSI measurement associated to a reporting setting *CSI-ReportConfig* for NCJT, two RI restrictions are configured for a given reporting setting, whereas:*** **One RI restriction corresponds to *M* CMRs for Single-TRP measurement hypothesis.**
* **Another RI restriction corresponds to *N* CMR pairs for NCJT measurement hypothesis.**

***Proposal 18:* For CSI measurement associated to a reporting setting *CSI-ReportConfig* for NCJT, two CBSRs are configured for a given reporting setting whereas each of them corresponds to one CMR group in a CMR set, i.e. per TRP.*****Proposal 19:* For a given NCJT report with Option 1, priority reporting levels for Part 2 CSI in the report are defined as following orders, if configured*** **Part 2 subband CSI of even subbands of NCJT measurement hypothesis**
* **Part 2 subband CSI of odd subbands of NCJT measurement hypothesis**
* **Part 2 subband CSI of even subbands of the first Single-TRP measurement hypothesis**
* **Part 2 subband CSI of odd subbands of the first Single-TRP measurement hypothesis**
* **Part 2 subband CSI of even subbands of the second Single-TRP measurement hypothesis**
* **Part 2 subband CSI of odd subbands of the second Single-TRP measurement hypothesis**

***Proposal 20:* For a CSI report associated with both Single-TRP and NCJT measurement hypotheses, the UE is required to update the CSI associated with NCJT measurement hypothesis in the CSI report, if , where *N* is the number of CMR pairs associated with the CSI report, denotes the number of available CPUs on a given OFDM symbol, and is the number of CPUs required to update whole CSI report*.*** |
| **InterDigital, Inc.** | ***Proposal 1:*** *Ks,max=2, Nmax=1 should be considered as the default values.* ***Proposal 2:*** *There should not be any restriction on pairing of Ks* *and* *N values, and MAC-CE can be used to indicate a preferred pairing.*  ***Proposal 3:*** *CRIs for NCJT can be ordered after the CRIs for single-TRP.* ***Proposal 4:*** *For option 1 with X reports, prioritize single-TRP CSIs over NCJT measurement hypothesis when X=1, however for 2 ensure that at least one of the CSIs corresponds to the NCJT hypothesis.* ***Proposal 5****: Support Alt. 1* *to support interference measurement based on NZP CSI-RS.* ***Proposal 6****: Study two-step CSI-RS measurement reporting for NCJT where** *NZP CSI-RS is configured per TRP,*
* *in the first step, a PMI corresponding to the first TRP, and in the second step a PMI corresponding to the second TRP is determined and reported.*

***Proposal 7****: Study a two-step SRS plus CSI-RS measurement/reporting for NCJT where** *NZP CSI-RS is configured per TRP,*
* *in the first step UE transmits an SRS, and in the second step based on the received precoded CSI-RS from each TRP, UE estimates and report the CSI*
 |
| **vivo** | **Proposal 1:***The default values of Nmax, Ks\_max are 1 and 4, respectively, and other values of N>1 and Ks>4 can be a UE optional feature.***Proposal 2:***N CMR pairs are formed by one-to-one mapping of the first N CMRs between two CMR groups.**The CMRs other than the CMRs in the CMR pair(s) in each CMR group are used for SINGLE-TRP hypothesis measurement.***Proposal 3:***It is feasible for both FR1 and FR2 but subject to further UE capability for FR2 that a NZP CSI-RS resource m can be referred by two CMR pairs (m, a) and (m, b) configured for NC-JT measurement hypotheses.***Proposal 4:***It is feasible in both FR1 and FR2 but subject to UE capability for FR2 that a NZP CSI-RS resource can be referred by both a CMR pair configured for NC-JT measurement hypothesis and a CMR configured for Single-TRP measurement hypothesis.***Proposal 5:***Support to configure CMRs with same CSI-RS resource ID in one resource set for different measurement hypotheses,** + *the CMR with same CSI-RS resource ID is referred by two CMR pairs configured for NC-JT measurement hypotheses, or*
	+ *the CMR with same CSI-RS resource ID is referred by both a CMR pair configured for NC-JT measurement hypothesis and a CMR configured for Single-TRP measurement hypothesis.*

**Proposal 6:***Support dynamic updating TCI states of CMRs by MAC-CE for periodic CSI-RS and aperiodic CSI-RS.***Proposal 7:***There is no need to introduce high layer signaling to configure M (M≤ Ks) CMRs from the CSI-RS resource set for CMR for Single-TRP measurement hypotheses, or to enable/disable Single-TRP measurement hypothesis using CMR configured within CMR pairs for NC-JT measurement hypothesis.***Proposal 8:***CSI-IM can be shared by both NC-JT and Single-TRP measurement hypotheses for FR1 and FR2.***Proposal 9:***Support to configure CSI-IM resources with same CSI-RS resource ID in one CSI-IM resource set for different measurement hypotheses, e.g., NC-JT measurement hypothesis and Single-TRP measurement hypothesis.***Proposal 10:***For CRI reporting in Option1, support separate CRI reporting.***Proposal 11:***For CRI reporting in Option2, the first N codepoints are corresponding to N CMR pairs and the remaining codepoints are corresponding to the remaining CMRs.***Proposal 12:***Support to add the priority between Single-TRP report and Multi-TRP report and to use legacy omission rule.***Proposal 13:***Support enhancing the CSI reporting mechanism when PMI and CQI granularity are wideband.***Proposal 14:** *Consider different configurations of RI restrictions, codebook subset restriction across TRPs.***Proposal 15:***Total number of layers of NC-JT reception is no more than 4 for NC-JT CSI reporting.***Proposal 16:***Support to confirm the work assumption in RAN1#103-e, i.e., Option1.***Proposal 17:***Support to associate two CSI reporting settings with CMRs configuration same as Cat1 for Cat2 configuration.***Proposal 18:***Support to specify rules on how to divide and map the generated UCI into two associated reports in Cat2.* |
| **Spreadtrum Communications** | ***Proposal 1: Support to introduce additional high layer signaling to configure M (M<=Ks) CMRs for single TRP measurement hypotheses.******Proposal 2: For whether a NZP CSI-RS resource can be referred by two CMR pairs, support Alt1.******Proposal 3: For whether a NZP CSI-RS resource can be referred by both a CMR pair and a CMR for single-TRP, support Alt2.******Proposal 4: Not support interference measurement based on NZP CSI-RS outside the CMR pair configured for NCJT measurement hypothesis, in addition to CSI-IM.******Proposal 5: For whether a CSI-IM resource can be referred by both NCJT and single-TRP, support Alt2.******Proposal 6: Support to introduce new CSI computation delay requirement for NC-JT CSI.******Proposal 7:******For option 1 with X=0, for UCI composition and structure,*** * ***2RI or joint RI, 1 or 2 CQI(s) should be include into Part1;***
* ***2 PMIs (if required) should be include into Part2;***

***Proposal 8:******For option 1 with X=1 or X=2, for UCI composition and structure,**** ***Some CSI information for single TRP, e.g., CRI/RI/CQI for the first CW, should be placed into Part 1;***
* ***Some CSI information for single TRP, e.g.,PMI, CQI for the second CW(if reported), and CSI information for NCJT should be placed into Part 2;***

***Proposal 9:******For option 2 for UCI composition and structure,*** * ***CRI, RI or joint RI, 1 CQI for the first CW should be include into Part1;***
* ***2 PMIs (if required) for NCJT, or CQI for the second CW (if required) for single TRP and/or 1 PMI (if required) for single TRP transmission should be include into Part2.***

***Proposal 10: For CSI enhancement on M-TRP operation, M-DCI based M-TRP operation should also be supported.******Proposal 11: For CSI enhancement on M-DCI based M-TRP operation, support option 1, i.e., Confirm the Working Assumption from RAN1 103e.******Proposal 12: For CSI enhancement on M-DCI based M-TRP operation, support to explicitly link two report settings.*** |
| **CATT** | ***Proposal-21: Non-PMI based feedback can be supported for CSI enhancement for M-TRP.******Proposal-22: For CSI reporting based on single report setting, two associated CMR resources in the same resource set are used for channel measurement of two TRPs. In CSI calculation, the UE assumes that in PDSCH transmission, PMI-1/RI-1 and PMI-2/RI-2 are applied to the channel of TRP 1 and 2 respectively. By doing so, inter-TRP interference measurement can be achieved without introducing non-precoded IMR.******Proposal-23: Considering the impacts of the two options on spec, option 1 is slightly preferred.**** ***Option 1 (Explicit): CMRs corresponding to different TRPs can be associated with different reporting settings respectively, with the same configurations between two settings except for PUCCH/PUSCH resources and CMR/IMR resources setting(s)***

***Proposal-24: CSI feedback enhancements for transmission scheme 2a, 2b, 3 and 4 are supported.******Proposal-25: Further discuss the following alternatives for CSI reporting of M-DCI based NC-JT.**** ***Alt-1(separate feedback): Two independent reports, for different TRPs respectively***
* ***Alt-2(joint feedback): One set of report quantities can be reported to any of the two TRPs***
* ***Alt-3: Separate reports (i.e., Alt-1) can be used if the resources for CSI reporting towards different TRPs are different. If resources for CSI reporting towards different TRPs are overlapped, joint CSI reporting (i.e., Alt-2) can be used.***

***Proposal-26: Interference measurement based on NZP CSI-RS outside the CMR pair configured for NCJT measurement hypothesis is not needed.******Proposal-27: If a UE supports and the sharing is also enabled by gNB, two CMRs from a CMR pair configured for a NCJT measurement hypothesis can be used for single-TRP measurement hypotheses, otherwise they cannot.******Proposal-28: CMR resource sharing between CMR pairs is feasible for both FR1 and FR2 but subject to further UE capability for FR2.*** |
| **ZTE** | ***Proposal 1:*** *In FR2, an NZP CSI-RS resource m cannot be referred by two CMR pairs (m, a) and (m, b) for NCJT measurement hypotheses.****Proposal 2:*** *In FR2, an NZP CSI-RS resource cannot be referred by both a CMR pair configured for NCJT measurement hypothesis and a CMR configured for Single-TRP measurement hypothesis.****Proposal 3:*** *For CSI measurement associated with a CSI-ReportConfig for NC-JT, support additional RRC signalling to configure CMRs from the CSI-RS resource set for Single-TRP measurement hypotheses.****Proposal 4:*** *CSI priority formula can be changed as**where x = 0, 1 and 2 refer to MTRP CSI, the first STRP CSI and the second STRP CSI (if any) respectively within one single CSI reporting.****Proposal 5:*** *Support a codebook subset restriction (CBSR) to determine some candidates of PMI combinations {PMI1 + PMI2} are allowed or not.****Proposal 6:*** *Confirming the working assumption or having no further CSI enhancement for multi-DCI based NJCT is slightly preferred.* |
| **CMCC** | ***Proposal 1: One NZP CSI-RS resource can’t be referred by two different CMR pairs configured for NCJT measurement hypotheses in FR2 (Alt 1).******Proposal 2: One NZP CSI-RS resource can’t be referred by both a CMR pair configured for NCJT measurement hypothesis and a CMR configured for Single-TRP measurement hypothesis in FR2 (Alt 2).******Proposal 3: Support introducing interference measurement based on NZP CSI-RS outside the CMR pair configured for NCJT measurement hypothesis (Alt 1).******Proposal 4: One CSI-IM resource can’t be shared by both NCJT and Single-TRP measurement hypotheses at least in FR2.******Proposal 5: The CSI associated with NCJT measurement hypotheses could be high prioritized within one single CSI report, when the UE is configured with CSI Option 1 with X=1 or 2.*** |
| **Qualcomm Incorporated** | **Proposal 1: With respect to CMR sharing*** **Between two pairs of CMRs corresponding to two NCJT hypotheses, support Alt2: It is feasible for both FR1 and FR2 but subject to further UE capability for FR2.**
* **Between an individual CMR (corresponding to a single-TRP hypothesis) and a pair of CMRs (corresponding to a NCJT hypothesis), support Alt3: It is feasible in both FR1 and FR2 but subject to UE capability for FR2.**

**Proposal 2: For CSI measurement associated with a CSI-ReportConfig for NC-JT:*** **The detail of RRC signalling related to configuring one or two CMR pairs for NCJT hypotheses is up to RAN2 to decide.**
* **Support RRC signalling to enable/disable single-TRP measurement hypothesis using CMR configured within CMR pairs for NCJT measurement hypothesis.**
	+ **For FR2, it can be enabled only if UE supports CMR sharing.**
	+ **If enabled, there are M=Ks single-TRP hypotheses**
	+ **If disabled, there are M≤ Ks single-TRP hypotheses corresponding to CMRs not used in a CMR pair.**
* **Additional dynamic updating by MAC-CE (to update CMR/CMR pairing/TCI state/value of X) is unnecessary.**

**Proposal 3: In a CSI report config in Option 2, CRI codepoint mapping to CSI hypotheses is based on** * **CRI codepoints are first mapped to M single-TRP hypotheses. The number of such codepoints is determined based on the number of CMRs across both CMR groups and whether the flag enables/disables individual CMRs that are used in a CMR pair.**
* **The additional CRI codepoints are mapped to N CMR pairs corresponding to N NCJT hypotheses.**

**Proposal 4: The number of *csi-IM-Resources* in the *CSI-IM-ResourceSet* configured for a *CSI-ReportConfig* is equal to** * **Ks+N, if all individual CMRs correspond to single-TRP hypotheses and UE is capable of simultaneous reception with different QCL-TypeD properties or in FR1.**
	+ **The last N CSI-IM resources are used for N NCJT hypotheses.**
* **Ks, if individual CMRs that are used in a CMR pair are disabled for single-TRP hypotheses, and UE is capable of simultaneous reception with different QCL-TypeD properties or in FR1**
	+ **For a NCJT hypothesis associated with a CMR pair, the CSI-IM resource associated with the first CMR or the second CMR is used.**
* **FFS: If UE is not capable of simultaneous reception with different QCL-TypeD properties (i.e. for CSI of TDM schemes if agreed)**

**Proposal 5: Do not support interference measurement based on NZP CSI-RS outside the CMR pair configured for NCJT measurement hypothesis.****Proposal 6: For RI and LI reporting of a NCJT CSI, the two RI’s and LI’s are based on** * **Introduce a RRC configuration for NCJT rank restriction with 4-bit bitmap, which determines the number of allowed rank pairs out of {1+1,1+2,2+1,2+2} rank pair hypotheses**
* **The size of the RI field is**
	+ **When Option 1 is configured: bits.**
	+ **When Option 2 is configured: bits.**
* **The two LI’s are reported in CSI part 2, which require 2 / 1 / 0 bits depending on the indicated rank pair.**

**Proposal 7: For Option 1 with X=1 or 2, the order of CSI reports in the UCI as well as CSI priority for CSI omission is based on an order between the two or three CSI’s associated with the *CSI-ReportConfig*. CSI priority can be expressed as , where corresponds to single-TRP CSI(s) and NCJT CSI.****Proposal 8: In the NCJT CSI, for subband part of CSI part 2, adopt one of the following alternatives for the order between even/odd subbands versus first/second PMIs:*** **Alt1: Even and odd subbands of the first PMI are placed first followed by even and odd subbands of the second PMI.**
* **Alt2: Even subbands of the first and second PMIs are placed first followed by the odd subbands of the first and second PMIs.**

**Proposal 9: For CSI measurement for multi-DCI based NCJT, support single CSI report setting. For NCJT CSI in this case, UE reports two CQIs assuming two fully overlapping PDSCHs.****Proposal 10: Multi-DCI NCJT CSI based on a pair of CMRs assumes to occupy two CPUs, and each CMR and each port of the two CMRs is counted as two times toward active NZP CSI-RS resources and active ports, respectively.** |
| **OPPO** | Proposal 7:Support Ks,max=4 up to UE capability. FFS: Ks,max=8.Proposal 8: The signaling design for indication of two CMR groups and N CMR pairs is up to RAN2. Proposal 9: A unified design for CMR reusing between different NC-JT measurement hypotheses and between NC-JT measurement hypothesis and S-TRP measurement hypothesis.Proposal 10: CMR pairs for NCJT measurement hypotheses, CMRs for Single-TRP measurement hypotheses, TCI states for CMRs and the number of single-TRP CSIs (i.e. X=0/1/2) for a CSI report are configured by RRC.Proposal 11: Additional high layer signaling to configure M (M≤ Ks) CMRs from the CSI-RS resource set for single-TRP measurement hypotheses is not needed.Proposal 12: The configuration of CSI-IM depends on whether CMR can be reused between S-TRP and NC-JT measurement hypotheses.* ***If CMR reusing for NC-JT measurement and S-TRP measurement is supported, e.g. for FR1, Ks CSI-IM resources are configured with one-to-one mapping to Ks CMRs within a CSI-RS resource set for S-TRP measurement hypothesis. Additional N CSI-IM resources are configured together with N CMR pairs with one to one mapping for NC-JT measurement hypothesis.***
* ***If CMR reusing for NC-JT measurement and S-TRP measurement is not supported, e.g. for FR2, Ks CSI-IM resources are configured with one-to-one mapping to Ks CMRs within a CSI-RS resource set similar to Rel-15/16. For each CMR pair for NC-JT measurement, the CSI-IM resource associated with the two CMRs should be the same and is used for NC-JT measurement.***

Proposal 13: Don’t support interference measurement based on NZP CSI-RS outside the CMR pair configured for NCJT measurement hypothesis.***Proposal 14: For Option 2,*** * ***If CMR reusing for NC-JT measurement and S-TRP measurement is supported, e.g. for FR1, the bit number of CRI is log2(Ks+N), which indicates Ks S-TRP measurement hypotheses and N NC-JT measurement hypothesis.***
* ***If CMR reusing for NC-JT measurement and S-TRP measurement is not supported, e.g. for FR2, the bit number of CRI is log2(Ks-N), which indicates (Ks-2N)S-TRP measurement hypotheses and N NC-JT measurement hypothesis.***
* ***CRI, two RIs and CQI for first CW are reported via CSI part 1.***
* ***One or two PMI(s) corresponding to the reported hypothesis, possible CQI for second CW are reported in CSI part 2.***

Proposal 15: For CSI for NC-JT hypothesis in the CSI report of Option 1 and type 1 codebook, * ***CRI, two RIs and CQI for first CW are reported via CSI part 1 similar to Option 2.***
* ***Two PMIs, possible CQI for second CW are reported in CSI part 2.***

Proposal 16: The benefit of CSI enhancement for multi-DCI based M-TRP transmission should be justified for different overlapping cases. |
| **Intel** | ***Proposal 1***: * *Support MAC-CE based update of CMRs for NCJT and STRP*
* *Support configuration of M < Ks CMRs for STRP*

***Proposal 2***: * *NZP CSI-RS based interference measurements is not supported for MTRP CSI in Rel. 17*

***Proposal 3***: * *Strive to minimize standardization efforts to support CSI for multi-DCI based NCJT*

***Proposal 4***: * *Enabling/disabling of sharing of RI/PMI for NCJT CSI and STRP CSI via RRC shall be considered if sharing of RI/PMI for NCJT CSI and STRP CSI is supported*

***Proposal 5***: * *Support omission of CSI for NCJT measurement hypothesis in CSI part 2*
	+ *Omission of NCJT measurement hypothesis is indicated in CSI part 1 by using CRI/RI or CQI fields*
 |
| **Apple** | ***Proposal 1 For interference measurement under NCJT, CMR, including RI/PMI decision, CMR from one TRP should be considered as the interference, i.e. IMR, to the other TRP.******Proposal 2 For reporting mechanism, regarding the following three cases**** ***Single TRP operation: Report the best TRP under the assumption that the other TRP is blanked***
* ***Single TRP operation: Report each TRP under the assumption that the other TRP is blanked***
* ***Multiple TRP operation: Report both TRP under NCJT operation***

***gNB can configure one or multiple of them*** * ***UE can independently indicate whether UE supports each reporting or not as capability***
* ***The CPU and active RS counting rule needs to be further discussed and clarified***

***Proposal 3 Regarding IMR configuration for multi-TRP CSI reporting enhancement*** * ***For CSI-IM, a CSI-IM resource is configured to be associated with either a CMR for Single-TRP measurement hypothesis or a CMR pair for NCJT measurement hypothesis with one to one mapping***
* ***For NZP-IMR, NZP-IMR cannot be configured together with multi-TRP CSI reporting enhancement***
 |
| **NEC** | ***Proposal 1: TRP specific CBSR and RI restriction can reduce the UE complexity considerably, which should be introduced at least for NCJT measurement hypothesis.******Proposal 2: The joint RI field with restricted combination of two RI values should be supported when the maximal transmission layers is larger than 4.***  |
| **Fraunhofer IIS, Fraunhofer HHI** | ***Proposal: The default value of Nmax should be 1 and the default Ks,max should be given by a value that is not larger than 4.******Proposal: For the CRI mapping, a set of N CMR pairs (representing the N NCJT measurement hypotheses) from the two groups is mapped to N CRI codepoints and the remaining CMRs (representing single-TRP measurement hypotheses) in a group are mapped to additional CRI codepoints.******Proposal: Support interference measurement based on NZP CSI-RS outside the CMR pair configured for NCJT measurement hypothesis.*** |
| **Nokia, Nokia Shanghai Bell** | **Proposal 16 Support higher-layer signalling of the number of single-TRP hypotheses, with . The first resources in the CSI-RS resource set for channel measurement are associated to the single-TRP measurement hypotheses.****Proposal 17 Support RRC and MAC-CE indication of the number of single-TRP hypotheses, , with .****Proposal 18 Support RRC and MAC-CE indication of the NCJT pairs by means of a bitmap of size .****Proposal 19 Support RRC and MAC-CE indication of the number of reported single-TRP CSIs, .****Proposal 20 Support the use of parameters and to configure Option 1/Option 2 reporting: configures Option 2 with 1 CSI (best of hypotheses); otherwise Option 1 is configured with CSI(s).****Proposal 21 For the same CMR resource to be configurable in two different NCJT measurement hypotheses, support Alt 2.****Proposal 22 For the same CMR resource to be configurable in both a single-TRP and an NCJT measurement hypothesis, support Alt 3.****Proposal 23 Support default values of and , with a maximum value for given by .****Proposal 24 For the possible combinations of and , support any value of and any value of , with .****Proposal 25 Regarding CBSR and RI restriction, support a single *CodebookConfig*** **configuration for a CSI Reporting Setting with two CMBS and RI restrictions, one for each CMR group.****Proposal 26 For Option 1, support separate CRI(s), with bit width for , and , for , and , and for , where and are the number of active single-TRP hypotheses from CMR group 1 and 2, respectively, with .****Proposal 27 For Option 2, support a CRI mapping with bits, where the first codepoints are associated to the configured NCJT hypotheses and the last codepoints are associated to the first CMR resources in the CSI-RS resource set.****Proposal 28 Regarding the split of CSI quantities between part 1 and part 2, support adding complementary information and an explicit indication in part 1 if sharing occurs.****Proposal 29 Support extending the definition of the priority function to include the CSIs reported in a single M-TRP CSI report.****Proposal 30 Regarding CSI-IM configuration for a single Reporting Setting, support Alt 2: each CSI-IM resource is configured to be associated with either a CMR for Single-TRP measurement hypothesis or a CMR pair for NCJT measurement hypothesis.** |
| **Samsung** | ***Proposal 1:*** *On CSI enhancements for multi-DCI based NC-JT, support both Category 1 and 2, and allow UE to be configured one of two Categories.****Proposal 2:*** *On CSI enhancement for multi-DCI based NC-JT, support confirming the working assumption with from RAN1#103-e.****Proposal 3:*** *On CSI enhancements for multi-TRP, support CMR to be re-used as IMR for both non pre-coded and pre-coded CSI-RS****Proposal 4:*** *For NC-JT CSI reporting enhancement, support and study followings:** *Support CRI-based dynamic reporting between NC-JT and non-NC-JT CSI*
* *Support non-PMI based port-selection*
* *Support restrictions among reported RIs or PMIs*
* *Study UCI structure optimized for dynamic NC-JT CSI report*

***Proposal 5:*** *Design new CPU occupation rule for dynamic NC-JT CSI report* ***Proposal 6****: Upon reporting of PMI for both NCJT and single-TRP hypotheses** *Support full and/or partial compression/omission/Sharing of PMI among single-TRP and NCJT hypotheses.*
* *Support the dynamic variation on the level of compression/omission/Sharing of PMI and the associated payload of PMI for single-TRP and NCJT hypotheses.*
 |
| **MTK** | **Proposal 1**: Interference measurement based on NZP CSI-RS outside the CMR pair configured for NCJT measurement hypothesis is not supported.**Proposal 2**: NZP IMR can be configured for each single-TRP measurement hypothesis in a CSI reporting setting with NCJT CSI measurement.**Proposal 3**: How to interpret the two CMRs configured for an NCJT measurement hypothesis can be up to UE implementation.**Proposal 4**: CSI-IM can be shared by both NCJT and single-TRP measurement hypotheses in both FR1 and FR2 but subject to UE capability for FR2.**Proposal 5**: If UE reports incapable of CSI-IM and/or NZP CSI-RS reference by both NCJT and single-TRP in FR2, then gNB only configures Option 1 with X = 0 for NCJT CSI.**Proposal 6**: An NZP CSI-RS resource *m* can be referred by two CMR pairs (*m, a*) and (*m, b*) configured for NCJT measurement hypotheses in FR1 but not in FR2.**Proposal 7**: An NZP CSI-RS resource can be referred by both a CMR pair configured for NCJT measurement hypothesis and a CMR configured for single-TRP measurement hypothesis in both FR1 and FR2 but subject to UE capability for FR2.**Proposal 8**: For Option 1, the X+1 CRIs are reported as separate CSI reports.**Proposal 9**: For Option 1 with X = 1, the CSI associated with the best NCJT measurement hypothesis has a lower reporting priority than the CSI associated with the best single-TRP measurement hypothesis.**Proposal 10**: For Option 1 with X = 2, the following priority order should be adopted: best single-TRP → best NCJT → 2nd best single-TRP.**Proposal** **11**: Support CSI measurement for multi-DCI based NCJT in R17, assuming the case of full overlap.**Proposal 12**: CSI measurement for multi-DCI based NCJT is configured in a single CSI reporting setting. The UE can be expected to report one RI, one PMI, one LI and one CQI per TRP, up to 2 TRPs. |
| **DOCOMO** | **Proposal 1*** *Default value of Nmax is 1. Default value of Ks,max is 4.*
* *For any value of Ks, N=1 or N=2 can be supported as long as N<=Ks/2 for FR1, and N <= min (K1, K2) for FR2.*

**Proposal 2*** *Support interference measurement based on NZP CSI-RS for NCJT measurement hypothesis with certain limitations, e.g., N=1 CMR pair and Ks=2 CMR resources.*
	+ *For Option 1 with X=1/2 and Option 2, further study whether to allow interference measurement based on NZP CSI-RS for single-TRP measurement hypothesis in the same CSI reporting setting.*

**Proposal 3*** *On whether a NZP CSI-RS resource m can be referred by two CMR pairs (m, a) and (m, b) configured for NCJT measurement hypotheses, support* *Alt.1.*
	+ *Alt.1: It is feasible for FR1 but not for FR2.*
* *On whether a NZP CSI-RS resource can be referred by both a CMR pair configured for NCJT measurement hypothesis and a CMR configured for single-TRP measurement hypothesis, prefer Alt.2 but also okay with Alt.3 considering the potential use case.*
* *On whether a CSI-IM can be referred by both NCJT and single-TRP measurement hypotheses, support Alt.2 for both FR1 and FR2.*
	+ *Alt.2: A CSI-IM resource is configured to be associated with either a CMR for single-TRP measurement hypothesis or a CMR pair for NCJT measurement hypothesis.*

**Proposal 4*** *If configured by a new RRC parameter, each CMR resource within a CMR pair should be assumed as NZP interference when deriving CSI based on the other CMR resource within the CMR pair.*

**Proposal 5*** *To indicate the valid CMR pair(s) for NCJT measurement hypothesis, higher layer signaling can explicitly indicate the ordering index(es) of one or two CMR pairs from all the possible K1\*K2 CMR pairs. The bit size of*  *is needed to indicate a CMR pair.*

**Proposal 6*** *Support additional higher-layer indication of M (M<=Ks) CMRs for single-TRP measurement hypothesis..*

**Proposal 7*** *In Option 2, on mapping between each CRI codepoint and single-TRP/NCJT measurement hypothesis, support mapping to single-TRP* *measurement hypothesis first, starting from CRI index 0, then mapping to NCJT measurement hypothesis.*
* *In Option 1, the X+1 CRIs are reported jointly in one CSI report.*
* *Do not support shared RI/PMI for single-TRP and NCJT hypotheses.*

**Proposal 8*** *On CSI priority calculation, introduce a new parameter j, where j=0 for single-TRP CSI of the first TRP, j=1 for single-TRP CSI of the other TRP, and j=2 for NCJT CSI.*

**Proposal 9*** *For a CSI report associated with a Multi-TRP/panel NCJT measurement hypothesis configured by single CSI reporting setting for single-DCI based NCJT, the UE is expected to report,*
	+ *two RIs, two PMIs, two LIs and one CQI per codeword, when the maximal transmission layer is larger than 4;*
	+ *one RI, two PMIs, one LI and one CQI, for HST-SFN.*

**Proposal 10*** *For multi-DCI based NCJT,*
	+ *first preference is to not support CSI enhancement for it,*
	+ *second preference is to support Option 2 with single CSI reporting setting for it.*
 |
| **Lenovo, Motorola Mobility** | 1. For FR2, a CMR associated with an NCJT hypothesis can be reused for a single-TRP hypothesis conditioned on an optional UE capability
2. For FR2, a CMR associated with an NCJT hypothesis can be reused for another NCJT hypothesis conditioned on an optional UE capability
3. Support the pair (*K*s, *N*) = (2,1) as mandatory parameter values for multi-TRP transmission. For UEs that do not support reusing an NCJT CMR for a single-TRP hypothesis, support the pair (*K*s, *N*) = (4,1) as mandatory parameter values for FR2
4. Study the following candidates for the parameter pair values (*K*s, *N*) = {(3,1), (4,2), (6,2), (8,2)}, where the two pair values (*K*s, *N*) = {(6,2), (8,2)} can be restricted to FR2
5. Modify the notation (*Ks*, *N*) to fit the scenario where a CMR is shared across more than one NCJT hypothesis
6. At least as a mandatory feature of multi-TRP CSI Reporting, the number of configured CMRs in the CSI Report Configuration should match that of CMRs needed for CSI reporting
7. Study dynamic signaling of *M* selected CMRs for CSI Reporting out of the *Ks* configured CMRs as an optional UE feature. Further details are FFS
8. Reuse PMI, RI across NCJT and single-TRP hypotheses for CSI reporting under Option 1 with X=1,2
9. A CSI report corresponding to single-TRP hypothesis has higher priority compared with a CSI report corresponding to NCJT hypothesis
10. For a CSI reporting configuration with X=2 single-TRP CSI reports, ties must be broken between the two single-TRP CSI reports to prioritize one CSI report over the other, e.g., based on associated CSI-RS Resource ID
11. For CSI omission based on reported CQI value, study the following aspects
* Whether Part 2 CSI is fully or partially omitted
* The rule which identifies the CSI report(s) whose Part 2 CSI is omitted
1. Reuse legacy RI restriction format for NCJT, such that an RI restriction applies to the total number of layers transmitted from the TRP(s) for a given transmission hypothesis
2. Reuse legacy CBSR format for NCJT, such that a CBSR applies to all codebooks corresponding to a given CSI reporting configuration
3. At least for single-DCI case, do not support inter-TRP interference measurement for NCJT based on NZP CSI-RS outside the CMR pair configured for NCJT measurement hypothesis
4. Configuring the UE with an NZP CSI-RS for interference measurement transmitted from a TRP outside the set of candidate TRPs for NCJT is not precluded
5. Under implicit CSI reporting for multi-DCI based NCJT, select one or more of the following alternatives
* Alt1: the CSI reporting configuration triggers the UE with either a single-DCI or a multi-DCI based NCJT CSI reporting
* Alt2: A CSI reporting configuration triggers the UE with an NCJT CSI report that includes up to three CQI values (one for single-DCI based NCJT and two for multi-DCI based NCJT)
* Alt3: A CSI reporting configuration corresponding to multi-DCI based NCJT reporting is triggered with aperiodic reporting only, where the multi-DCI based NCJT CSI report includes two CQI values, corresponding to two codeword transmissions
* Alt4: A CSI reporting configuration corresponding to multi-DCI based NCJT reporting is inferred from RI restriction, i.e., whether RI>4 is restricted

Note: RAN1 should strive to support a unified CSI reporting framework for both single-DCI and multi-DCI based multi-TRP transmission |
| **LG Electronics** | **Proposal #1: Support additional high layer signaling for configuring M CMRs for single TRP CSI from CSI-RS resource set considering the case that only one or none CMR in a CMR pair is used for single TRP CSI calculation.****Proposal #2: For the purpose of NCJT CSI calculation, support an independent ZP IMR corresponding to a CMR pair, in addition to two ZP IMRs for STRP CSI corresponding to two CMRs of the CMR pair, respectively.****Proposal #3: Interference measurement based on NZP IMR is not supported for NCJT CSI.****Proposal #4:** **A NZP CSI-RS resource can be referred by both a CMR pair configured for NCJT measurement hypothesis and a CMR configured for Single-TRP measurement hypothesis based on UE capability for FR2.** **Proposal #5: A NZP CSI-RS resource can be referred by two different CMR pairs, e.g., (m, a) and (m, b) only for FR1.**  |
| **Ericsson** | [**Proposal 17 Support Option 3: Support configuring multiple CSI-RS resources per CSI reporting configuration associated with Rel-17 PS codebook**](#_Toc71667639)[**Proposal 18 Support dynamic update of CMR pairs for NC-JT CSI measurement hypothesis using MAC-CE and/or RRC signalling**](#_Toc71667640)[**Proposal 19 Do not support higher layer signalling to dynamically update CMRs for sTRP measurement hypotheses.**](#_Toc71667641)[**Proposal 20 Support sharing a NZP CSI-RS resource m by two CMR pairs (m, a) and (m, b) configured for NCJT measurement hypotheses for FR1 and FR2 (where the support is conditioned on UE capability signalling for FR2).**](#_Toc71667642)[**Proposal 21 Support sharing a NZP CSI-RS resource configured in a CMR pair used for NCJT measurement hypothesis and a CMR configured for Single-TRP measurement hypothesis for FR1 and FR2 (where the support is conditioned on UE capability signalling for FR2).**](#_Toc71667643)[**Proposal 22 For a CSI report containing both NC-JT CSI and single-TRP CSIs (e.g., Option 1 with X =1, 2) associated with the same CMRs, support RI/PMI sharing between the NC-JT CSI and single-TRP CSIs**](#_Toc71667644)[**Proposal 23 Support NC-JT CSI omission under certain conditions when X=1 or 2 is configured with omission indicated in a CSI report.**](#_Toc71667645)[**Proposal 24 For NC-JT CSI with a single CSI reporting setting , if the NZP CSI-RS resources for channel measurement are configured without QCL-type D or with the same QCL-type D, a UE assumes that the interference on the CSI-IM resources represents two observations of a same interference.**](#_Toc71667646)[**Proposal 25 For NC-JT CSI with a single CSI reporting setting, if the NZP CSI-RS resources for channel measurement are configured with different QCL-type D source RS, a UE assumes that the interferences on different CSI-IM resources correspond to different interference sources.**](#_Toc71667647)[**Proposal 26 A CSI-IM resource can be configured for one of NC-JT and sTRP or for both NC-JT and sTRP, this should be left for gNB implementation.**](#_Toc71667648) |