**3GPP TSG RAN WG1 Meeting #102-e R1-** **2007268**

**E-meeting, August 17th – 28th, 2020**

**Agenda Item: 8.1.4**

**Source: Huawei, HiSilicon**

**Title: Technical Categorization for CSI enhancements MTRP and FR1 FDD reciprocity**

**Document for: Discussion and Decision**

# Proposals

***Proposal 6: Taking Type II port selection codebook enhancement (based on Rel.15/16 Type II port selection) as a starting point, study following aspects, taking into account trade-off among UE complexity, performance and reporting/RS overhead:***

* *Alt1: separate port selection (based on R16 Type II PS CB type structure)*
  + *Enhancements on quantization, e.g.,* 
    - *With free port selection in*
    - *With modified value range of taking into account beamforming mechanism for CSI-RS;*
  + *Enhancements on quantization, e.g.,*
    - *With a smaller value of*
    - *With a modified value range of R;*
  + *Restrictions/Relaxation, e.g.* 
    - *for the size of the PMI indicators for SD basis, FD basis and bitmap.*
    - *How UE distinguishes SD basis and FD basis or in a pre-defined set*
* *Alt2: joint port selection (based on R15 Type II PS CB type structure)*
  + *: out of SD-FD pairs are selected jointly* 
    - *(if polarization independent) or (if polarization common)*
    - *How to map P SD-FD pairs into CSI-RS ports and inform to UE*
  + *: coefficients for the selected pairs*
* *Enhancements on reporting mechanism, e.g.:* 
  + *Separate triggering for reporting of and (for Alt 1) or reporting of and the rest of the PMI components (for Alt 2)*
  + *Report only a subset of PMI components*
  + *SD/FD pairs indication/selection/reporting*
  + *UE reporting to support gNB calibration including UL/DL time difference;*
* *Enhancements on RS triggering/signaling/transmission mechanism, e.g. for SRS and/or CSI-RS, CSI-RS utilization conveying one or more SD-FD pairs per port*
* *Other enhancement are not excluded.*

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| Company | Comments |
| FUTUREWEI | As we raised in the previous round of comments, we would like to point out that enhancement on SRS frequency hopping transmission to improve UL delay estimation performance should also be studied. Therefore we propose the following modifications on the 6th bullet:   * ***Enhancements on RS triggering/signaling/transmission mechanism, e.g. for SRS and/or CSI-RS*** |
| Samsung | 1st comment: 2nd and 3rd bullets assume R16 CB structure wherein the SD and FD port (or basis) selection is decoupled. But, as pointed out in our contribution, their selection can be joint. So, we suggest to add two separate alternatives:  Alt1: separate port selection (assuming R16 CB structure)   * ***Enhancements on quantization, e.g., free port selection in and/or modified value range of taking into account beamforming mechanism for CSI-RS;*** * ***Enhancements on quantization, e.g., smaller and/or modified value range of R;***   Alt2: joint port selection (assuming R15 CB type structure)   * : out of ports are selected jointly across SD and FD   + (if polarization independent) or (if polarization common) * : coefficients for the selected ports   2nd comment: 4th bullet is applicable to Alt 1 above, so, we can add “for Alt1,..” in the beginning of the 4th bullet, as shown below.   * ***For Alt1, Restrictions/Relaxation, e.g. in the size of the PMI indicators for SD basis, FD basis and bitmap.***   3rd comment: 5th bullet can be revised accordingly as follows. For clarity, we can add examples in separate sub-bullets   * ***Enhancements on reporting mechanism,***    + ***e.g., separate triggering for reporting of and (for Alt1), or W1 (for Alt2) from the rest of the PMI components,***   + ***e.g. reporting only a subset of PMI components,***   + ***e.g. SD/FD pairs indication/selection/reporting ,***   + ***e.g. UE reporting to support gNB calibration including UL/DL time difference;***     **[SS2]** Reply to QCM’s comments are below.   1. Are they different by R15 or R16 structure, or by how to select ports? In our view, port-selection (no matter freely, separately, jointly) refers to the design of W1 matrix, which shall be applied to both R15 and R16 CB types.   [SS]: No, the high level structure is the same as R15/16, i.e. W1W2 for Alt2 and W1W2Wf^H for Alt1. The exact content can of course be different. Re port selection, we have a different view. For Alt1, it can be in SD or/and FD (W1 or/and Wf). For Alt2, since the SD-FD ports are selected jointly, there is no need for Wf (since it can be combined in W1), and the port selection is jointly in SD and FD.   1. What is the difference between the description of W1 in Alt2 (i.e., “jointly”) and Alt1 (i.e., “freely”)   [SS]: In Alt2, W1 selected SD-FD port pairs, whereas for Alt1, W1 selects SD ports only.   1. What is the difference in CSI-RS beamforming in Alt1 and Alt2? Alt1 seems only based on SD basis, Alt2 seems based on SD-FD pair?   [SS]: In Alt1, the number of beamformed ports = 2LM (2L in SD and M in FD), whereas in Alt2, it is X. The difference is how the beamforming weights are derived.   1. In Alt2, the wording “SD-FD pair” is misleading. If a port is precoded based on SD-FD pair, then it is slection of X out of P ports, right?   [SS]: We can replace it with “SD-FD port pairs” since with joint selection, we essentially select port pairs. Yes, the selection is X out of P ports. |
| ZTE | Support the categorization of alternatives from SS. But we would like to suggest the following revisions marked in blue.  **1.** We suggest to revise “assume” to “based on”, since we think the exact codebook structure can be different with either R15 or R16 due to port selection in delay domain.  Alt1: separate port selection (based on R16 CB type structure)  Alt2: joint port selection (based on R15 CB type structure)  **2.** For Alt 1   * Alt 1 seems to indicate UE will select SD and FD basis independently using W1 and Wf in the codebook matrix. Then there should be some mechanism for UE to distinguish the SD and FD vectors in CSI-RS precoded by gNB, or in a pre-defined set. We think how it is done needs to be further studied.   Alt1: separate port selection (based on R16 CB type structure)   * ***Enhancements on quantization, e.g., free port selection in and/or modified value range of taking into account beamforming mechanism for CSI-RS;*** * ***Enhancements on quantization, e.g., smaller and/or modified value range of R;*** * ***Study further on how UE distinguishes SD basis and FD basis***   **3.** For Alt2   * We think it is too restricted if we just select X from the configured CSI-RS ports. In our simulation observation, the number of SD-FD pairs gNB precodes in CSI-RS needs to be larger than 32 in most cases, otherwise there is large performance loss. Further, if we have to configure 32 ports in order not to lose performance, large CSI-RS overhead occurs for UE-specific CSI-RS. Hence we think we need to study how to map the SD-FD pairs to the configured CSI-RS ports, in order to facilitate gNB selects more than 32 SD-FD pairs and to reduce CSI-RS overhead. * X=P or P/2 seems to be typo? P or P/2 should be maximum value.   Alt2: joint port selection (based on R15 CB type structure)   * : out of SD-FD pairs are selected jointly   + (if polarization independent) or (if polarization common)   + Study further on how to map the SD-FD pairs to configured CSI-RS ports * : coefficients for the selected pairs   **[ZTE2]**  Thanks Qualcomm for the questions. Indeed, it should be good to clarify and align the understanding on different alternatives.  Our understanding on Alt 1 and Alt 2 are differentiated by codebook structure. Codebook in Alt 1 will distinguish SD and FD vectors, while codebook in Alt 2 does not distinguish SD and FD vectors.  For Alt 1, two sub-options can be included. The first is CSI-RS is precoded with only SD vectors, and the second is CSI-RS is precoded with both SD and FD vectors. Then in order not to preclude options for evaluation, we should add one more sub-bullet in Min’s current version as follows.   * *Alt1: separate port selection (based on R16 Type II PS CB type structure)*   + *Enhancements on quantization, e.g.,*      - *With free port selection in*     - *With modified value range of taking into account beamforming mechanism for CSI-RS;*   + *Enhancements on quantization, e.g.,*     - *With a smaller value of*     - *With a modified value range of R*     - *With port selection in Wf;*   + *Restrictions/Relaxation, e.g.*      - *for the size of the PMI indicators for SD basis, FD basis and bitmap.*     - *How UE distinguishes SD basis and FD basis or in a pre-defined set*   For Alt 2, codebook will select SD-FD pairs in one selection vector, and CSI-RS is precoded with both SD and FD vectors. But X may not just select SD-FD pairs from the configured P\_CSI-RS ports. How to map the SD-FD pairs and P\_CSI-RS ports is a key point here as given in Min’s current proposal. |
| Fraunhofer IIS/ Fraunhofer HHI | Before discussing further details of the codebook in bullet points 2 and 3, we suggest to have some discussion on the usage/utilization of the resources of the CSI-RS ports. For example, the CSI-RS resources of a single port can be associated with a single or with multiple beam, delay or beam-delay pairs. This association may have an effect on the structure of the codebook. We therefore suggest to add “Utilization of CSI-RS resources” to the proposal. |
| InterDigital | Support FL proposal. First bullet seems redundant, suggest removing it. |
| Lenovo/MotM | - We do not see clear advantage of considering R15 Type-II PS codebook (Alt 2), since R16 PS codebook is more generic (setting M=1, NSB can recover R15 PS WB, SB performance, respectively). I suggest removing this Alternative (unless some companies prefer to keep)  - We would like to propose the following modifications to the first bullet in Alt 1   * *Alt1: separate port selection (based on R16 Type II PS CB type structure)*   + *Enhancements on quantization, e.g.,*      - *With free port selection in*     - *With modified value range of taking into account beamforming mechanism for CSI-RS;*     - *With layer-specific port selection, i.e., for layer l*   - For the 4th bullet, we suggest the following modification   * *Enhancements on RS triggering/signaling/transmission mechanism, e.g. for SRS and/or CSI-RS, timing restrictions between SRS and CSI-RS transmission, and CSI-RS utilization conveying one or more SD-FD pairs per port*   - We suggest adding one bullet on CQI enhancements for reciprocity codebook, as follows   * *CQI enhancements, e.g., CQI format and/or CQI reporting mechanism* |
| OPPO | We are fine with FL proposal. Re the comments from InterDigital, we suggest to keep the first bullet. It provides necessary clarification. |
| Qualcomm | First, as FL mentioned earlier, this meeting targets on listing potential study aspects. Companies are encouraged to prepare detailed proposal next meeting and the alternative list for down-selection should be made next meeting. More importantly, unlike mTRP CSI which was studied and specified in Rel-14 FeCoMP, FDD reciprocity has never been studied before, companies should focus on aligning the SLS performance based on the EVM agreed in this meeting. So, we are not sure listing Alt1/2 is really helpful at this stage, and previous FL proposal 6 already captures all elements in Alt1/2.  Second, the categorization of Alt1/2 is unclear to us in following aspects:   1. Are they different by R15 or R16 structure, or by how to select ports? In our view, port-selection (no matter freely, separately, jointly) refers to the design of W1 matrix, which shall be applied to both R15 and R16 CB types. 2. What is the difference between the description of W1 in Alt2 (i.e., “jointly”) and the (i.e., “freely”) 3. What is the difference in CSI-RS beamforming in Alt1 and Alt2? Alt1 seems only based on SD basis, Alt2 seems based on SD-FD pair? 4. In Alt2, the wording “SD-FD pair” is misleading. If a port is precoded based on SD-FD pair, then it is slection of X out of P ports, right?   Third (if we are the only one not preferring this proposal), Alt1/2 does not seem to be in the same level as other bullets in terms of details. So, we suggest to use a bullet as “Enhancement on codebook structure”, and making Alt1/2 as examples as  ***Proposal 6: Taking Type II port selection codebook enhancement (based on Rel.15/16 Type II port selection) as a starting point, study following aspects, taking into account trade-off among UE complexity, performance and reporting/RS overhead***   * ***Enhancement on codebook structure, e.g.,***   + ***Alt1:***   + ***Alt2:*** * …   **Qualcomm2:**  Based on SS’s reply to question 2/3, we have two further questions and some comments:  Question 1: in Alt1, there are 2LxM ports, if the structure is W1\*W2\*Wf, then the number of rows of W1 should be 2LM, then how Wf would take in part in the port-selection? It seems a Kronecker of W1 and Wf is more proper, kron(W1,Wf)\*W2. If yes, it seems that this is not R16 CB type.  Question 2: still “joint” and “free” are not clear. In Alt1, 2L x M ports are well organized as 2L SD and M FD, but free-selection seems meaning that UE can select any ports from the 2LM, which should be same as “joint” in Alt2, but it is not same as “separate”.  Comment:   1. Based on SS’s reply, we think the essential difference of Alt1/Alt2 lying in the CSI-RS beamforming and port-selection indication, i.e.,    1. Alt1: 2L x M ports are organized/beamformed such that there are 2L SD precoders and each of them is associated with M FD bases; UE will do two-part port selection, W1 selection of ports with different SD bases, Wf selects ports with different FD bases.    2. Alt2: X ports are beamformed with SD-FD bases, UE can do free selection out of the X ports. 2. If my understanding above is correct, then there seems other alternatives as mentioned by proponents of Rel-16 CB type structure in their tdoc, e.g., Huawei and Lenovo/MotM. It seems Wf is still used for bases reporting in their tdoc rather than for port-selection. 3. If all my understandings above are correct, it seems difficult to do categorization in this meeting. We should be clear the alternatives are differed by how CSI-RS beamformed, or which codebook structure is based on, or whether Wf is used and is used for port-selection and FD basis selection. These are kind of low-level details. We appreciate the clarification, but seems not the high priority in this meeting.   Vivo’s suggestion seems capturing all things discussed herein. Besides, in order to give more room to companies to refine their proposals, we suggest to add “etc” at the end of each “eg”. |
| vivo | We also have similar view as QC that it is too early to limit the alternatives before all companies disclose their solutions and we should try to agree on all possible study aspect. For example, Alt1 and Alt2 in current proposal are based on port selection only. As QC’s comment, Alt1/2 are not on the same level as other sub-bullets. We recommend to revert to the original version of the FL’s proposal 6 without list any specific alternative in this meeting. Of course, other companies can still comment based on the original version. In our understanding, Samsung’s concern on joint SD/FD basis selection can be included in the updated 5th sub-bullet as follows  ***Proposal 6: Taking Type II port selection codebook enhancement (based on Rel.15/16 Type II port selection) as a starting point, study following aspects, taking into account trade-off among UE complexity, performance and reporting/RS overhead:***   * ***Basic codebook structure ~~based on Rel.15/16 Type II port selection~~*** * ***Enhancements on quantization, e.g., free port selection in and/or modified value range of taking into account beamforming mechanism for CSI-RS;*** * ***Enhancements on quantization, e.g., smaller and/or modified value range of R;*** * ***Restrictions/Relaxation, e.g. in the size of the PMI indicators for SD basis, FD basis and bitmap.*** * ***Enhancements on SD/FD pairs indication/selection and reporting mechanism, e.g., SD/FD basis indication based on precoded CSI-RS or signaling, separate/joint SD/FD basis selection, separate triggering for reporting of and , and/or reporting only a subset of PMI components, ~~SD/FD pairs indication/selection/reporting ,~~ UE reporting to support gNB calibration including UL/DL time difference;*** * ***Enhancements on RS triggering/signaling mechanism, e.g. for SRS and/or CSI-RS*** * ***Other enhancement are not excluded.*** |
| CATT | Comment#1:  We have several questions regarding Alt1.   1. Separate port selection means separate port selection for W1 and Wf. Is that the intention of this wording? If that is true, we’d better capture something like ‘With port selection in Wf’ as proposed by ZTE. 2. Are Ports for W1 and ports for Wf selected from the same set of CSI-RS ports or different sets of CSI-RS ports?     Comment#2:  The following seems to be a typo:   * + - *How to map P SD-FD pairs into CSI-RS ports and inform to UE* |
| LG | We are generally fine with FL proposal. Our additional comments are as follows.  Comment 1: Regarding the main bullet of Alt1/2, we have the similar view with QC. The meaning of ‘separate’/’joint’ is also somewhat unclear to us. In addition to QC’s suggestion, the following modification seems better to us.  Alt1: ~~separate port selection between SD and FD basis (~~Enhancement based on R16 Type II PS CB type structure~~)~~  Alt2: ~~joint port selection (~~Enhancement based on R15 Type II PS CB type structure)  Comment 2: Regarding the second sub-bullet of Alt1, we would like to propose the following for potential study aspects.   * + *Enhancements on quantization, e.g.,*     - *With a smaller value of*     - *With a modified value range of R;*     - *With multiple values of for different SD bases* |
| Intel | Agree with Qualcomm and LG that some aspects for Alt 1/2 are not clear. Terms “joint port selection” and “separate port selection” require clarification. If these terms indicate only codebook structure (i.e. W1W2 or W1W2Wf) then it is better to delete them. We are also fine to keep the current wording if terms “joint port selection” and “separate port selection” are clarified in the proposal. |
| Ericsson | Agree with Qualcomm |

***Proposal 8: For CSI enhancement for multi-TRP, study following aspects taking into account trade-off among UE complexity, performance and reporting/RS overhead***

* *Category 1 - For a reporting setting CSI-ReportConfig, more than one CSI-RS port groups in a resource or resources or resource sets are associated to different TRPs/UE receiving panels.* 
  + *The UE will determine CSI reporting qualities/quantities based on pre-defined/indicated (MAC-CE)/configured (RRC)/suggested (by UE) channel and interference hypotheses across TRPs/UE receiving panels*
  + *and then report one or more CSIs within a single CSI report.*
* *Category 2 – Within a implicit/explicit set of reporting settings CSI-ReportConfigs, which are associated to different TRPs/UE receiving panels,* 
  + *the UE will determine CSI reporting qualities/quantities based on pre-defined/indicated (MAC-CE)/configured (RRC)/suggested (by UE) channel and interference hypotheses*
  + *and then report multiple CSIs with multiple CSI reports.*
* *Other enhancement are not excluded.*

*Note that companies are encouraged to clarify applicable transmission schemes/scenarios and strive to unify Rel-17 MTRP CSI framework enhancements*

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| Company | Comments |
| FUTUREWEI | Support FL’s proposal. |
| InterDigital | Support for multi-panel UEs should also be considered for CSI enhancement. In a multi-TRP transmission, UE panel activation and deactivation would be driven based on some configured CSI measurement/reporting. Therefore, we would like that CSI enhancement to also consider support of multiple-panel UE operation.  One way to proceed may be   * *Category 1 - For a reporting setting CSI-ReportConfig, more than one CSI-RS port groups in a resource or resources or resource sets are associated to different TRPs* ***/UE panels****. The UE will determine CSI reporting qualities/quantities based on pre-defined/indicated (MAC-CE)/configured (RRC)/suggested (by UE) channel and interference hypotheses across TRPs* ***/UE panels*** *and report one or more CSIs within a single CSI report.* * *Category 2 – Within a implicit/explicit set of reporting settings CSI-ReportConfigs, which are associated to different TRPs* ***/UE panels****, the UE will determine CSI reporting qualities/quantities based on pre-defined/indicated (MAC-CE)/configured (RRC)/suggested (by UE) channel and interference hypotheses and reporting multiple CSIs with multiple CSI reports.* * *Other enhancement are not excluded.* |
| Lenovo/MotM | We are fine with the current bullet points. We suggest adding the following bullet   * *CQI enhancements for multi-TRP transmission, e.g., CQI format and/or CQI reporting mechanism* |
| OPPO | We are fine with the FL proposal.  We suggest not add extra items or examples. The proposal contains “Other enhancement are not excluded”, thus any other necessary enhancement are not preclude here. We do not need to list all the potentials. |
| vivo | For category 2, for the case of the CSI reporting qualities/quantities suggested by UE, we think a single DPS CSI may be suggested by the UE. Therefore, there may not always be multiple CSIs. We propose to modify the category 2 as follows:   * *Category 2 – Within an implicit/explicit set of reporting settings CSI-ReportConfigs, which are associated to different TRPs/UE receiving panels,*    + *the UE will determine CSI reporting qualities/quantities based on pre-defined/indicated (MAC-CE)/configured (RRC)/suggested (by UE) channel and interference hypotheses*   + *and then report suggested CSI/multiple CSIs with multiple CSI reports.* |
| LG | We are generally fine with the FL proposal. We are also supportive of Lenovo/MotM’s suggestion. |
| NTT DOCOMO | We are generally fine with the FL proposal.  For Category 2, suggest to further clarify ‘report multiple CSIs with multiple CSI reports’, e.g., how many CSI(s) per a single CSI report. Hence, a possible modification can be:   * + *and then report multiple CSIs with multiple CSI reports (FFS: one or more CSIs per a single CSI report).* |
| Intel | OK with the proposal. |
| Qualcomm | Support the proposal. We do not think including UE panel is necessary. Such terminology was not used / defined in Rel.16 mTRP schemes. For category 2, we do not see how one CSI can be reported if different CSI-ReportConfigs are used. |
| Ericsson | A few comments on the proposal:  - What is meant by CSI reporting quality? If we need to keep this term in the proposal, we need to clearly define what it is. Otherwise, we suggest to just keep ‘CSI reporting quantities’ and delete ‘qualities/’.  - We don’t need to include MAC CE/RRC at this point, so we suggest to remove these.  We suggest the following revisions to the proposal:  ***Proposal 8: For CSI enhancement for multi-TRP, study following aspects taking into account trade-off among UE complexity, performance and reporting/RS overhead***   * *Category 1 - For a reporting setting CSI-ReportConfig, more than one CSI-RS port groups in a resource or resources or resource sets are associated to different TRPs/UE receiving panels.*    + *The UE will determine CSI reporting ~~qualities/~~quantities based on pre-defined/indicated ~~(MAC-CE)~~/configured ~~(RRC)~~/UE-selected ~~suggested (by UE)~~ channel and interference hypotheses across TRPs/UE receiving panels*   + *and then report one or more CSIs within a single CSI report.* * *Category 2 – Within a implicit/explicit set of reporting settings CSI-ReportConfigs, which are associated to different TRPs/UE receiving panels,*    + *the UE will determine CSI reporting ~~qualities/~~quantities based on pre-defined/indicated ~~(MAC-CE)~~/configured ~~(RRC)~~/UE-selected ~~suggested (by UE)~~ channel and interference hypotheses*   + *and then report multiple CSIs with multiple CSI reports.* * *Other enhancement are not excluded.*   *Note that companies are encouraged to clarify applicable transmission schemes/scenarios and strive to unify Rel-17 MTRP CSI framework enhancements* |

# Appendix (Based on Discussion Summary of V24)

## CSI Enhancement for FDD

Eight companies have shared their views on codebook design, which can be summarized in Table 3.

**Table 3 Codebook Design Framework**

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| **Category** | **Brief description** | **Companies** |
| Alt1. Based on R16 eType II PS codebook | * Based on Rel.16 Type II PS codebook, potentially with some extensions/ modifications | Intel, Lenovo/Motorola Mobility, Samsung, Nokia/Nokia Shanghai Bell, DCM, FUTUREWEI, Huawei/HiSi |
| Alt2. Based on R15 Type II PS codebook | * W=W1W2, W1 indicate the selected ports beam, and W2 be the port combination coefficients matrix | CATT |
| Alt3. New framework for the codebook design | * New Type II PS design with potentially different codebook structure and parametrization from Rel.16 Type II PS design * Example: separate or joint port selection across SD and FD | Samsung |

Moreover, companies have shared potential codebook enhancements based on Rel.16 Type II PS codebook as following:

* **Samsung:**
  + Based on Rel.16 Type II PS codebook with small modifications
    - Example: free port selection in W1, reporting only a subset of PMI components (from Rel.16 Type II PS codebook).
  + New Type II PS design with potentially different codebook structure and parametrization from Rel.16 Type II PS design
    - Example: separate or joint port selection across SD and FD
* **Lenovo/Motorola Mobility:** Introduce additional parameter values for Rel. 16 Type-II port selection codebook, e.g., include WB reporting with M=1. Other changes to parameters, parameter values are FFS.
* **NTT DOCOMO/INC:**
* Consider separate triggering for reporting of CSI components associated with angle(s) and delay(s), i.e., and , in Type II PS codebook in addition to currently available simultaneous reporting of all the CSI components.
* Introduce larger SB sizes compared to what is already available in NR Rel-15/16, e.g. SB sizes of 12, 16 PRBs etc.
* **Nokia/Nokia Shanghai Bell:** Consider possible restrictions or reductions in size of the PMI indicators for SD basis, FD basis and bitmap to complement the reciprocity-based estimates performed by the gNB. These modifications should not change the structure of the PMI and should result in a smaller UCI overhead.
* **FUTUREWEI：**If gNB can utilize angle and delay information to generate appropriate beamformed CSI-RS ports, thus resulting in a smaller *Mv* and *L* for CSI feedback, many of the CSI feedback fields can be reduced.
* **Huawei:** The enhancements are as follows
  + is enhanced by relaxing restrictions of to improve performance, e.g. more than 4 ports can be selected freely;
  + can be limited with very few vector(s), e.g. one or two;
  + can be enabled with a larger value of R (*numberOfPMISubbandsPerCQISubband*) , e.g. R=4.
* **Apple:** For CSI enhancement utilizing partial reciprocity of DL/UL channels, more dynamic wideband and subband CSI reporting configuration can be considered.

It can be more or less pre-mature to conclude during the first Rel-17 MIMO meeting. Therefore companies are encouraged to study further, taking into account agreed EVM in RAN1 102e and following proposal.

***Proposal 6: Taking Type II port selection codebook enhancement (based on Rel.15/16 Type II port selection) as a starting point, study following aspects, taking into account trade-off among UE complexity, performance and reporting overhead:***

* ***Basic codebook structure based on Rel.15/16 Type II port selection***
* ***Enhancements on quantization, e.g., free port selection in and/or modified value range of and/or SD basis type (SVD or DFT);;***
* ***Enhancements on quantization, e.g., smaller and/or modified value range of R;***
* ***Enhancements on FD basis indication/selection/reporting;***
* ***Restrictions/Relaxation, e.g. in the size of the PMI indicators for SD basis, FD basis and bitmap.***
* ***Enhancements on reporting mechanism, e.g., separate triggering for reporting of and , and/or reporting only a subset of PMI components;***
* ***Timing calibration to address timing difference between UL and DL;***
* ***Other enhancement are not excluded.***

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| Company | | Comments |
| NTT DOCOMO | | We are fine with the FL proposal |
| CATT | | Ok with the proposal. |
| LG | | We are also fine with the proposal |
| ZTE | | Table 3 is a bit confusing to us. The mathematic formulation is not the critical issue here. The structure of W1\*W2\*Wf can also be re-written as kron(Wf,W1)\*vec(W2), which has the structure of W1\*W2. The categorization is better to be described from whether the precoding is done in compressed domain as Rel-16 or per subbband as Rel-15. Our understanding is the enhancement is based on precoding in compressed domain, i.e., there is no need to do per-subband reporting. But it is not necessary to have Wf in the final codebook as in the end UE will just select “ports” from a set of FD/SD vector pairs.  In addition, we would like to add one more study aspect. In our contribution R1-2005460 [4], we observe the number of FD/SD pairs selected by gNB in CSI-RS has significant impact on performance. If the number of FD/SD pairs in CSI-RS is not sufficient, the performance of the enhanced codebook can be worse than Rel-16 eType II port selection codebook, as in Rel-16, UE can select SD and FD vectors among a set of 2LM pairs. Hence we suggest to add the following bullet as a study aspect.   * The number of SD and FD vector pairs selected by gNB in beamformed CSI-RS |
| Samsung | | It is too early to agree to only R16-based codebook enhancements. Once the baseline EVM is agreed, companies should be allowed to simulate their proposals which may or may not be R16 codebook based. So, for this meeting, we prefer to just list or categorize proposed enhancements, and the down-selection can be done next meeting. |
| OPPO | | We are fine with the proposal to study those aspects. |
| Lenovo/MotM | | We support the FL proposal. Also, time restrictions on the SRS transmission and the corresponding beamformed CSI-RS transmission should be considered. |
| AT&T | We are fine with the proposal to study these aspects related to codebook enhancements.  In addition to the proposed enhancements, we think it is very important to study enhancements on reporting mechanism to support gNB calibration. | |
| Ericsson | Ok with FL’s proposal. | |
| FUTUREWEI | We are fine with FL’s proposal. We would also like to point out that enhancement on SRS frequency hopping transmission to improve UL delay estimation performance should also be studied. | |
| Sony | We are ok with the proposal. | |
| Intel | OK with the proposal | |
| Huawei/HiSilicon | Support this proposal to study the related codebook enhancements.  Furthermore, to enhance efficiency of CSI measurement, gNB can apply multiple angle-delay pairs on one CSI-RS port and UE can obtain M(M≥1) coefficients from the same CSI-RS port to further enhance the CSI-RS utilization, which can be achieved through codebook design of . So, the mentioned enhancements also should be considered in the codebook design. | |
| Qualcomm | We think the focus at this stage should be evaluation methodology, then the very next step should be aligning the performance across companies. Please note that there are only 3 companies providing simulation results, and the results diverge significantly. Also, as some companies already mentioned, even for the baseline scheme, i.e., port-selection (e)Type II codebook, its performance has never been studied. Per content in Proposal 5, there seems lots work to bring all companies on the same page. From these aspects, it is too early to list those alternatives, and this would distract the attention.  If an agreement is really needed to help progress, we think it should be listing the high-level aspects or metrics to be considered/studied, e.g., UPT, reporting payload, CSI-RS overhead, and UE complexity. Companies are encouraged to provide simulation results to justify their proposals.  Regarding the codebook structure, we also share similar view to ZTE and Samsung. We don’t think it is essential at this point. We should keep the door open to more possible enhancements. | |
| vivo | We think the enhancement of Type II codebook can also include following aspects to reduce CSI-RS overhead, performance improvement and timing impairment:   * CSI-RS beamforming method, e.g., SVD vs. DFT * Methods of FD basis/delay tap indication   Methods to deal with timing difference between UL and DL, e.g., timing calibration before CSI feedback | |
| Nokia/NSB | Support FL’s proposal. We suggest adding “reference signalling overhead” in the first sentence, i.e.: “...taking into account trade-off among UE complexity, performance, reporting and reference signalling overhead” | |
| InterDigital | We can support the FL proposal, but we are not sure what the agreed proposal would mean, as we find it too broad and vague at points. For example, what does the following bullet exactly entails? Are we limiting the new design or as the statement before says, it is just to take it as the starting point?   * ***Basic codebook structure based on Rel.15/16 Type II port selection***   Overall, we have a similar view as Qualcomm and Samsung that for now, the main focus should remain on EVM and calibration aspects. | |

## CSI Enhancement for Multi-TRP

Many companies, Samsung, Qualcomm, Ericsson, Nokia, MTK etc., have mentioned that CSI measurement and reporting in Rel-15/16 CSI is still insufficient to support M-TRP transmission, and concerned about the potential increase of the number of CSI reports, or signaling latency/overhead, or multiple M-TRP transmission hypotheses etc.

Based on our understanding of contributions, RAN1 proposals are extremely diverse in RAN1 102e and we hardly find any commonality among two companies’ proposals, which are usually differentiated each other for a certain details, about configurations, measurement behaver, CSI reporting mechanism etc. For the sake of discussion, RAN1 proposals can be roughly categorized as following so that companies can understand each other better (at least for what we are discussing about) and strive to find certain commonality in RAN1.

In RAN1 102e, the categorization does not intent to down-selection but provide a certain assistance what RAN1 can analyze and compare in future meetings:

* **Category 1** - *For a reporting setting CSI-ReportConfig, more than one CSI-RS port groups in a resource or resources or resource sets are associated to different TRPs. The UE will determine CSI reporting qualities based on pre-defined rule(s) across TRPs and report CSI within a single CSI report.*
* FUTUREWEI: a UE is configured with a group of NZP resources for a report configuration, and the UE decides whether each of the group of NZP resources is CM, IM, or muting
* vivo:
  + - The MTRP CSI feedback can be enhanced by associating multiple CSI ReportConfigs/CSI-ResourceConfigs/CSI Resource sets
    - increase the information element in a CSI-ReportConfig, such as increasing the amount of CSI resource settings and increasing the amount of resource sets in a CSI-ReportConfig
* Samsung: Another approach for reducing reporting overhead is to configure multiple {CMR, IMR} pairs in a CSI-RS resource set associated with a single CSI report.
* ZTE: LTE liked CSI enhancement for single-DCI based SDM MTRP.
* For one CSI reporting, support two sets of CRI/RI/PMI
* MTK: For CSI enhancement of NCJT, study the following alternatives:
* Alt. 1: One CRI can be associated with two NZP CSI-RS resources for channel measurement.
* Alt. 2: One CSI-RS resource can have two port groups, each associated with one distinct TCI state.
* CATT: To support NC-JT with single PDSCH, joint CSI measurement based on associated CSI-RS resources for coordinated TRPs/panels can be considered
* Ericsson: gNB may configure a UE with N>1 NZP CSI-RS resources in a resource setting for channel measurement where each of the N NZP CSI-RS resources may be associated with one TRP. Then, in the corresponding CSI report, the UE can select a subset M < N (e.g., 2) CRIs and report this as part of the CSI report, where M NZP CSI-RS resources are used for channel measurement.
* NTT DOCOMO/INC: For multiple CSIs in a CSI report, the inter-TRP interference can be considered by assuming the CMR of one TRP as the IMR of the other TRP
* Qualcomm: Study the pros and cons of the following two approaches to enable CSI report for SDM scheme:
* Approach 1: Support two TCI states for one CSI-RS resource for CMR, where the CSI-RS ports consists of two port groups associated with the two TCI states.
* Approach 2: Support two CMRs corresponding to two CSI-RS resources for a NCJT CSI hypothesis.
* NEC: For multi-TRP/panel transmission, inter-TRP/panel interference measurement can be based on CSI-RS resource(s) configured for channel measurement for other TRPs
* Intel: CSI design specified for NC-JT transmission in LTE FeCoMP is considered as a starting point for discussion
* CSI measurements for MTRP are configured as multiple CSI-RS resources corresponding to one CSI report settings
* Multiple transmission hypotheses are considered at the UE for CSI reporting including NC-JT and DPB/DPS
* CMCC: Two CRI and corresponding CQI, RI and/or PMI could be reported in joint CSI reporting, whether one or two CQI/RI/PMI is reported is related to the transmission scheme
* Spreadtrum: To achieve more accurate interference measurement, we prefer not to explicitly configure CMR of one TRP as IMR of another TRP. When calculating interference of one TRP, the measurement of CMR of another TRP should be additionally as the inter-layer interference
* Apple: In Rel-17 CSI enhancement for MTRP, consider the enhancement to both CSI measurement configuration and CSI report quantity configuration to reflect the reciprocal relationship between CMR and IMR, especially for NCJT
* **Category 2** – *Within a implicit/explicit set of reporting settings CSI-ReportConfigs, which are associated to different TRPs, the UE will determine CSI reporting qualities based on pre-defined rule(s) and reporting multiple CSIs with multiple CSI reports.*
* vivo: The MTRP CSI feedback can be enhanced by associating multiple CSI ReportConfigs/CSI-ResourceConfigs/CSI Resource sets. Both separate CSI reporting and joint CSI reporting should be supported.
* Lenovo/Motorola Mobility: CSI feedback corresponding to each TRP is decomposed into two CSI reports, each including information corresponding to two different sets of layers
* LG: Support enhancement for CQI reporting reflecting inter-TRP interference based on NZP CSI-RS resource for IM.
* by reporting RI/PMI/CQI for one TRP together with updated CQI for another TRP in which the RI/PMI are reflected as interference.
* by reporting RI/PMI for one TRP together with joint CQI reporting for single DCI based multi-TRP transmission
* Huawei/HiSilicon: If two CSI reporting are triggered by one trigger state, UE will do joint CSI measurement and reporting based on the CSI-RS resources related to the two CSI reporting
* NTT DOCOMO/INC: For a CSI-ReportConfig, both separate and joint CSI measurement/reporting for multiple TRPs can be considered.
* Spreadtrum: Support joint CSI feedback and separate CSI feedback for NC-JT.

In additional to above two categories, many companies provide further detail designs shown as Table 4, e.g. enhancement for resource configurations, enhancement for joint/separated report quantities, measurement hypotheses etc. It is unlikely to dive into very fine decision of CSI enhancement very soon in RAN1, until RAN1 has fully understood and agreed a certain measurement behavior for M-TRP/Panel based transmission. Therefore, for the sake of reference, we have summarized more proposal details from companies, and listed them in following Table as reference.

**Table 4 Summaries of Detailed Design (Next Level) for CSI Enhancement for MTRP**

|  |  |
| --- | --- |
| **Companies** | **Proposals** |
| MTK | * For joint CSI reporting of NCJT, individual PMI and RI are generated for each CMR * The allowed RI pairs can be specified for joint CSI reporting to limit signaling overhead, and it should be configurable to allow one of the RIs to be reported as 0. * For joint CSI reporting of NCJT, the number of CQI to be reported is configurable. * One CSI report can have K≥1 CRIs, where K is configurable. * If interference measurement is performed on NZP CSI-RS, there can be more than one NZP CSI-RS resource as CMR, where for each CMR there is a bitmap indicating which NZP CSI-RS resource(s) in nzp-CSI-RS-ResourcesForInterference is used as associated IMR. |
| CATT | * Indication/configuration/report on the transmission scheme assumed for CSI calculation can be considered. * A t least the following CSI feedback quantities need to be supported: * PMI/RI for each TRP/panel * CQI for each codeword or TRP |
| NEC | * Enhancement on CSI measurement and feedback for dynamic switching between single-TRP and multi-TRP transmission should be supported |
| Intel | * The following aspects are for further study * Number of CSI-RS resources corresponding to different TRP configured for one CSI report setting * CSI reporting for different MTRP transmission hypothesis including NC-JT and DPB/DPS |
| Lenovo/Motorola Mobility | * For each channel hypothesis, two CSI reports are needed to design the appropriate precoder, based on whether the hypothesis supports single TRP transmission or NCJT. * For each channel hypothesis, two CSI reports are needed to design the appropriate precoder, based on whether the hypothesis supports single TRP transmission or NCJT. * Joint CSI reporting can be considered, where each CSI report includes up to two sets of CRI, PMI, RI, and LI. The CSI resource setting and CSI reporting setting are FFS * For NCJT with transmission rank exceeding 4, the differences in the rank indicator fed back for CSI reports corresponding to two TRPs should not exceed one |
| Spreadtrum | * Support limited rank pair for NC-JT, e.g., {1,1}, {1,2}, {2,1},{2,2}. * Study how to demonstrate the validity of CSI parameters for joint reporting in NC-JT |
| QC | * Support one-to-one mapping between CSI-IM and CRI codepoint for a given CSI-ReportConfig * SDM CSI report should consist of one CRI, one CQI, two RIs, two LIs, and two PMIs. * If a CSI-ReportConfig consist of both single-TCI state and multi-TCI state hypothesis types, UE reports two CSIs corresponding to the best hypothesis within a given type and the corresponding CRIs. |
| Nokia | * For S-DCI based M-TRP operations, consider solutions to reduce the CSI reporting overhead by allowing a UE to select one or more CSI reports amongst the configured transmission/interference hypotheses * Consider solutions to optimise CSI-RS resource configurations, triggering and reporting mechanisms for S-DCI based M-TRP operations with 2 TRPs |
| Ericsson | * Evaluate UE assisted multi/single-TRP hypothesis selection feedback where the UE decides on single-TRP transmission or multi-TRP NC-JT transmission hypothesis based on its measurements and indicate the preferred hypothesis to the gNB |

***Proposal 8: For CSI enhancement for multi-TRP, study following aspects***

* ***Category 1 - For a reporting setting CSI-ReportConfig, more than one CSI-RS port groups in a resource or resources or resource sets are associated to different TRPs. The UE will determine CSI reporting qualities based on pre-defined rule(s) across TRPs and report CSI within a single CSI report.***
* ***Category 2 – Within a implicit/explicit set of reporting settings CSI-ReportConfigs, which are associated to different TRPs, the UE will determine CSI reporting qualities based on pre-defined rule(s) and reporting multiple CSIs with multiple CSI reports.***
* ***Other enhancement are not excluded.***

|  |  |
| --- | --- |
| Company | Comments |
| CATT | We think the CSI enhancement for M-TRP should consider at least the following aspects:   * CSI framework: how to configure report setting/resource setting/resource set for joint/separate feedback * Report quantity: what should be reported, one or multiple sets of PMI/RI/CRI/CQI and/or recommended coordination set/transmission scheme * Assumed Tx scheme in CSI calculation: what Tx scheme is assumed in CSI calculation   So, to reflect the enhancement on assumed Tx scheme in CSI calculation, we suggest to further revise at least Category 1 of proposal 8 as follows:  ***Category 1 - For a reporting setting CSI-ReportConfig, more than one CSI-RS port groups in a resource or resources or resource sets are associated to different TRPs. The UE will determine CSI reporting qualities based on pre-defined/indicated/configured/suggested assumption(s) across TRPs and report CSI within a single CSI report.*** |
| LG | Support in principle.  Comment 1: It seems that our proposal in the above description provided by FL should be included in Category 1.  Comment 2: Regarding FL’s proposal, we think ‘CSI reporting quantities’ should also be included as well as ‘CSI reporting qualities’.  Comment 3: Support CATT’s revision, and that kind of revision can also be applied to Category 2. |
| ZTE | We are fine with the proposal  In addition, to converge the discussion, we propose to clarify the main use cases for CSI enhancement in this agenda as we discussed in GTW call, e.g. is the main enhancement for single DCI based including SDM, FDM or TDM, or is for M-DCI ? In our view, the CSI enhancement should be mainly for SDM as WID clearly say NCJT which usually points to SDM.  For other single DCI based schemes, we are also open, but the priorities should be low considering limited TUs. |
| Samsung | On the proposal and CATT’s comment, we think it is better to clarify what the rule/assumption is. In our understanding, it is on the channel and interference hypotheses as specified in WID. So, we suggest the following revision:  ***Category 1 - For a reporting setting CSI-ReportConfig, more than one CSI-RS port groups in a resource or resources or resource sets are associated to different TRPs. The UE will determine CSI reporting qualities based on pre-defined/indicated/configured/suggested channel and interference hypotheses across TRPs and report CSI within a single CSI report.***  ***Category 2 – Within a implicit/explicit set of reporting settings CSI-ReportConfigs, which are associated to different TRPs, the UE will determine CSI reporting qualities based on pre-defined/indicated/configured/suggested channel and interference hypotheses and reporting multiple CSIs with multiple CSI reports.*** |
| OPPO | We got question on the proposal: What is the difference between the Category 2 and Rel-16 CSI feedback which is also based on multiple CSI report configurations and multiple CSIs? |
| Lenovo/MotM | It may be worth clarifying that the objective of the WI is enabling more dynamic channel/ interference hypothesis for NCJT. We believe reducing the CSI feedback overhead corresponding to the different hypotheses can be pursued in two different ways:  i) CSI feedback reporting for only a subset of the hypotheses with possible UE down-selection. This fits into Category 1.  ii) Partially reusing one CSI/CSI report in more than one hypothesis, which provides freedom to the network in selecting the appropriate hypothesis based on scheduling considerations. This fits into Category 2.  We believe that both Categories are not mutually exclusive; a solution that is a combination of both should not be precluded.  @OPPO: We agree that Rel. 16 CSI feedback falls under Category 2. For NCJT with *K* candidate TRPs under Rel. 16 CSI reporting, the CSI overhead would be in order of *K2*. Other Category 2 solutions in which a portion of the CSI is reused for multiple hypotheses can help reduce the CSI feedback overhead, compared with Rel. 16 CSI reporting. |
| Ericsson | We are ok with these high level categorization. In fact, we are ok with the revisions made by Samsung.  In addition, we think it may be beneficial to consider one single CSI reporting framework that can work for single DCI based SDM, FDM or TDM. So we are positive to studying CSI feedback for single DCI based FDM and TDM schemes as well. |
| CMCC | We support the proposal.  We prefer Category 1 compared to Category 2. Firstly, we think how to configure CSI-RS resource setting/resource sets/resources for joint CSI reporting should be studied. Secondly, the CSI enhancement for M-TRP should also consider the specific report qualities under different transmission schemes, including multi-DCI based M-TRP for eMBB, single-DCI based M-TRP for eMBB, URLLC SDM/FDM/TDM. |
| FUTUREWEI | We are fine with FL’s proposal. We would also like to have clarification/confirmation that CSI enhancement for URLLC with mTRP should be discussed here, based on discussions under agenda item 8.3.1.2. |
| Sony | We are ok with the proposal. |
| Intel | We are OK with the proposal.  Regarding the transmission schemes considered for CSI enhancements we prefer to consider single-DCI and multi-DCI based schemes specified for eMBB and PDSCH repetition (FDM and TDM) specified for URLLC. The reason to consider all the schemes is to support proper link adaptation for all the supported schemes since without the optimized CSI transmission schemes might have poor performance due to MCS mismatch and wrong scheduling decisions (UE selection and number of layers). |
| Huawei, HiSilicon | Fine for the proposal. |
| Qualcomm | We are generally ok with the proposal. We have similar comment as ZTE wrt scheme. We feel it is important to have some discussions about the scheme for which the CSI enhancement is designed in this AI. Can we afford to have CSI enhancements for all schemes in this AI, or some prioritization is needed? The WID mentions NCJT explicitly, which means it would be either scheme 1a or multi-DCI. For multi-DCI, given that PDSCHs can be partially/fully/non-overlapping, the motivation is not very clear.  Agree with LG that report quantities are also an important aspect (how many PMIs/RIs/CQIs, etc. in one CSI report). |
| vivo | Support CATT's proposals.  In addition, we think following issues should also be considered/studied for CSI enhancement:   * Deployment scenarios to be considered, e.g. non-ideal backhaul, ideal backhaul, HST, URLLC for both FR1 and FR2.   CSI feedback overhead. |
| Nokia/NSB | We are fine with these two broad categories and with Samsung’s revision. We understand Category 1 comprises solutions with a single CSI Reporting Setting – single CSI report, whereas Category 2 encompass solutions with multiple CSI Reporting Settings – multiple CSI reports. To include the possibility of joint reporting of multiple CSIs in one CSI report, we suggest the following revision, where we also replaced “qualities” with “quantities”  ***Category 1 - For a reporting setting CSI-ReportConfig, more than one CSI-RS port groups in a resource or resources or resource sets are associated to different TRPs. The UE will determine CSI reporting quantities based on pre-defined/indicated/configured/suggested channel and interference hypotheses across TRPs and report one or more CSIs within a single CSI report.***  ***Category 2 – Within a implicit/explicit set of reporting settings CSI-ReportConfigs, which are associated to different TRPs, the UE will determine CSI reporting quantities based on pre-defined/indicated/configured/suggested channel and interference hypotheses and reporting multiple CSIs with multiple CSI reports.*** |
| MediaTek | Support the proposal and fine with Samsung’s revision. The current CSI reporting framework is sufficient for all multi-TRP schemes non-overlapped at least in time or in frequency. We support a unified CSI reporting framework taking all existing multi-TRP schemes into account, including DPB/DPS. However, a CSI reporting involving two TCI states should only be meant for single-DCI based SDM or multi-DCI based multi-TRP with full/partial overlap. We object any CSI reporting involving two TCI states that is specific for FDM/TDM. |
| NTT DOCOMO | We are fine with the revisions from Samsung.  And it is good to clarify/discuss the transmission schemes for CSI enhancements |