3GPP TSG RAN WG1 Meeting #104-e R1-210xxxx

**E-meeting, January 25th – February 5th, 2021**

**Agenda Item: 8.1.4**

**Source: Moderator (Huawei, HiSilicon)**

**Title: Summary of CSI enhancements for MTRP and FDD (Round 3)**

**Document for: Discussion and Decision**

# Summary of CSI enhancement for FDD

***Proposal 2:*** *For PS codebook enhancements utilization DL/UL reciprocity of angle and/or delay, down-select codebook structure W=W1W2 WfH with*

* *Alt 3-0, i.e. W1 ∈ N^{PCSI-RS × K1} (K1 ≤ PCSI-RS ) is a port selection matrix*
	+ *Lenono/MotM, Oppo, Ericsson, Intel, Vivo, Sony*
* *Alt 5, i.e. W1∈ N^{PSD-FD × K2} (K2 ≤ PSD-FD=Of PCSI-RS) is a SD-FD basis selection matrix*
	+ *ZTE,*
* *Note that PCSI-RS is the number of CSI-RS ports.*

***Proposal 3:*** *For PS codebook enhancements utilization DL/UL reciprocity of angle and/or delay, support one or a combination of following options for CSI-RS configurations associated with Rel-17 PS codebook and to be decided in RAN1 104bis:*

* + *Option 1: Support configuring a lower CSI-RS density per CSI-RS resource, e.g. 0.25*
		- *Nokia/NSB, Apple, Sony*
	+ *Option 2:Support configuring one or multiple CSI-RS patterns per CSI-RS resource associated with Rel-17 PS codebook*
		- *Nokia/NSB*
	+ *Option 3:*$ $*Support configuring multiple CSI-RS resources per CSI reporting configuration associated with Rel-17 PS codebook*
		- *ZTE, Ericsson, Sony*
	+ *Option 4:*
		- *W1∈ N^{PSD-FD × K2} (K2 ≤ PSD-FD=Of PCSI-RS), single CSI-RS resource with single CSI-RS pattern per resource and normal CSI-RS density*
			* *Vivo,Nokia/NSB, Spreadtrum, DOCOMO, ZTE*
		- *W1 ∈ N^{PCSI-RS × K1} (K1 ≤ PCSI-RS )and Wf ∈ C^{N3 × Mv} (PSD-FD=Of PCSI-RS, Mv ≤ Of ), single CSI-RS resource with single CSI-RS pattern per resource and normal CSI-RS density.*

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| Company | Comments |
| Huawei (Moderator) | Some companies have commented that it is preferred to discuss P3 firstly before P2, or vice versa. On the other hand, Alt 3-0 seems to be the majority view. To provide a better picture, I just put them together, by removing Alt 5 in Proposal 2. However Lenovo/MotM, Intel and Samsung have concerns about Proposal 3. Therefore, from Moderator perspective, P3 may be needed to be studied firstly. Please share your view, if we jointly consider both proposals.   |
| Qualcomm | Support Alt3-0. P3 can be discussed/studied after P2. We prefer to add the default option (no enhancement) in P3. |
| ZTE | We still support Alt 5 in P2. We think P3 should be studied and discussed before P2. The reason why we choose Alt 3-0 or Alt 5 should depend on whether we consider or which solution we consider in P3. Otherwise, we perform down-selection in P2 based on what? In terms of supporting companies, it is clear the companies supporting Option 4 in P3 should support Alt 5 in P2.Another way to move forward can be to discuss P2 and P3 together. These two are trying to solve a common issue in W1 design essentially.  |

***Proposal 5:*** *Study following mechanisms,*

* *With regarding to mechanism of configuring/indicating Wf to the UE (if supported)*
	+ *Option 1: The FD bases used for Wf quantitation are limited within a single window with size N and initial point Minitial, which can be fixed/configured/indicated by gNB.*
		- *FFS: whether/how to support more than one windows*
		- *FFS: candidate values and value ranges for N, Minitial, includingwhether Minitial can be fixed to be, e.g. 0*
		- *FFS: signaling mechanism by MAC-CE or RRC or hybrid*
		- *FFS: The number of CSI-RS ports and the value of Mv is jointly configured per codebook parameter combination*
		- *Other enhancements are not excluded.*
* *With regarding to mechanism of selecting/reporting Wf to the gNB (if supported)*
	+ *Option 1: UE selects all FD components configured/indicated by the NW without reporting them*
	+ *Option 2: UE selects and reports the index of* $M\_{ν}$ *components within a window of size N*
	+ *Other enhancements are not excluded.*

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| Huawei (Moderator) | The intention of P5 is to provide high level description to clarify the FFS in the agreement so that we can see any solutions/variations on the table, to help companies to understand each other. After checking comments, it seems that most of companies refer to the same thing, at least conceptually. @All: It seems that most companies think that the motivation of K windows/sets is unclear, so I use Fraunhofer words so that proponent company may elaborate more. Also, I have taken a few comments to make proposals to be less “aggressive”. @Vivo: I add a FFS for K windows, but please strive to explain to RAN1 that it is a valid/good option to try. @QC: add M\_initial to be fixed as FFS@Spreadtrum: FFS is required by QC. Let’s keep it as it is. @Apple @ SS: “other enhancements” are limited to the discussion of Wf here. I have no intention to across proposals. @Intel, @Ericsson: I have used Nokia’s wording. It seems to be in your preference/thinking I assume.  |
| Nokia/NSB | We support the FL’s proposal to provide sufficiently high-level description to identify more precise alternatives at the next meeting.Some comments below in response to questions from other companies and suggestions that may help clarify the wording furtherRegarding gNB’s configuration/indication of $W\_{f}$* We also don’t see the need to configure multiple windows, so $K=1$. In our view, configuring a single window per UE is sufficient, whereas configuring multiple windows per port increases indication overhead in the PDCCH and makes UE’s complexity similar to that of Rel-16 PS. However, we are not against keeping it there for study, as we are not downselecting yet.
* Regarding $M\_{initial}$, to simplify things, this would be applicable, in our view, only for a single window per UE. The reason for considering $M\_{initial}$ in this study is the possibility for the NW to configure two UEs in the same port on two windows well separated in the delay domain. For example, if R=4, the delay domain is 4 times wider than for R=1, and two UEs may be configured, for example, with $M\_{initial}=0,N\_{3}/2$, respectively, if the two channels are well separated in the delay domain.

@QC: this operation is part of the FD precoding, which applies different weights for different PMI subbands and is separate from the cover code in CSI-RS design which applies different coefficient per RB, regardless of the PMI subband size.Regarding UE’s selection/reporting of $W\_{f}$* We think the understanding of the two options is clear, as explained by Ericsson, for example. Maybe the wording can be improved. In our view Option 1 is for $W\_{f}$ what Alt 0 is for $W\_{1}$, i.e., the UE selects all the FD components configured by the NW without explicit reporting of the $M\_{ν}$ components. A possible rewording may be along these lines
	+ *Option 1: UE selects all FD components configured/indicated by the NW without reporting them*
	+ *Option 2: UE selects and reports the index of* $\_{}$ *components within a window of size* $N$

@ZTE: “*If Wf is to be reported by UE, and gNB does not turn it off, UE should report the index of Wf.*” As elaborated above, if $W\_{f}$ is configured, option 1 means that the UE selects all components and does not need to report their indices explicitly. |
| Lenovo/MotM | We appreciate Nokia’s detailed comments which provide more clarity to the proposal bullet points. We are generally fine with the proposal, however we suggest the following minor wording changes for consistency, as follows ***Proposal 5:*** *Study following mechanisms for downselection in RAN1#104bis-e,**With regarding to mechanism of configuring/indicating Wf to the UE (if supported)** + *Option 1: The FD bases used for Wf quantitation are limited within a single window with size N and initial point Minitial, which can be fixed/configured/indicated by gNB.*
		- *FFS: whether/how to support more than one windows*
		- *FFS: candidate values and value ranges for N, Minitial, includingwhether Minitial can be fixed to be, e.g. 0*
		- *FFS: signaling mechanism by MAC-CE or RRC or hybrid*
		- *FFS: The number of CSI-RS ports and the value of Mv is jointly configured per codebook parameter combination*
		- *Other enhancements are not excluded.*
* *With regarding to mechanism of selecting/reporting Wf to the gNB (if supported)*
	+ *Option 1: UE selects all FD components configured/indicated by the NW without reporting them*
	+ *Option 2: UE selects and reports ~~the index of~~* $M\_{ν}$ *FD components within a window of size N*

*Other enhancements are not excluded* |
| Qualcomm | @Nokia, thanks for the reply. I understand the intention is to use FD precoding to multiplex ports intended for different UEs. But if not clarified in CSI-RS pattern, the UE will see two ports (intended for itself and another UE) mixing together, and will misunderstand it as the channel of its own. Mini and Wf is about the reported PMI, not related to CSI-RS estimation and CSI measurement. Not sure this proposal is essentially needed. Interested companies can provide more concrete proposals in their contribution next meeting. |
| ZTE | We are okay to discuss this issue. This formulation is more clear than last version. We thank FL for the effort.But still, there is one unclear part for us, which is Option 1 under UE reporting bullet. If UE uses all the Wf vectors configured by NW, it should be same as Option 1 in the NW configuration bullet. It’s not clear to us why we need to have this option 1 under UE reporting while there is no UE reporting at all. |

# Summary of CSI enhancement for Multi-TRP

***Proposal 6:*** *For CSI measurement associated to a reporting setting CSI-ReportConfig for NCJT, the UE can be configured with Ks ≥ 2 NZP CSI-RS resources in a CSI-RS resource set for CMR and N ≥ 1 NZP CSI-RS resource pairs whereas each pair is used for a NCJT measurement hypothesis, support one CMR pairing mechanism by down-selecting from following in RAN1 104e:*

* *Alt.1: Configure UE with N NZP CSI-RS resource pairs within a CMR resource set explicitly, whereas the first Ks-2N CMRs are for single-TRP measurement hypotheses and the remaining 2N CMRs in consecutive N CMR pairs are for N NCJT hypotheses.*
	+ *Note: Network can reuse CMRs of single-TRP hypotheses for NCJT hypotheses at least in FR1 (by configuring the same CSI-RS resource ID of any of the first Ks-2N CMRs for any of the remaining 2N CMRs in the resource set)*
* *Alt.3: Configure UE with two CMR groups with Ks = K1+K2 CMRs, whereas each CMR group corresponds to one out of two TRPs. CMR pairs are determined from two CMR groups by following method(s).*
	+ *K1 and K2 are the number of CMRs in two groups respectively. FFS K1=K2 or different K1/K2.*
	+ *Note that the first M1 (or M2) CMRs in each CMR group can be used for both NCJT and Single-TRP measurement hypotheses, the remaining CMRs are only used for single-TRP measurement hypotheses*
	+ *FFS. Option 1: N NZP CSI-RS resource within a group can be one-to-one mapping with the N NZP CSI-RS resource in the other group*
		- *N= M1=M2, signalling mechanism can be discussed further*
	+ *FFS Option 1.5: N CMR pairs are RRC configured and/or indicated (by MAC-CE) by selecting from all possible pairs*
		- *K1=M1, K2=M2, signalling mechanism can be discussed further, e.g. using a bitmap*
	+ *FFS Option 2: UE freely select CMR pairs from two groups (without one-to-one mapping)*
		- *N= M1M2*
	+ *Starting from M1=M2=1*
	+ *Further down-selection and/or consolidation above options will be done in RAN1 104bis*
* *Support N=1 and Ks =2, FFS other maximal values of N>1 and Ks*>2

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| Huawei (Moderator) | Alt 1 (3): QC (1st), ZTE, Intel (1st), Alt 3 (16): Vivo, CATT, Oppo, NEC, Intel(2nd), MediaTek, LG, Lenovo/MoM, Ericsson (2nd), Futurewei (2nd), Fraunhofer IIS/Fraunhofer HHI, Nokia/NSB (2nd), CMCC (option 2) Either Alt 1 or Alt 3: Apple, Docomo, Samsung@QC @ZTE: From Feature lead perspective, companies are converging to Alt3 and they are willing to leave difference of signaling later. It is just a matter that how signaling is designed to form N pairs from groups in the same set. Option 1 and 2 can be two ends of option 1.5, in my view, e.g. TRP1 {1, 2}, TRP {3,4} can form {1,2}{1,3}{2,3}{2,4} so that RRC can select {1,3}{2,4} as Option 1, or 4 pairs if N=4 and M=2, as Option 2. Of cause if companies may have different understanding or minor variations of signaling design, it is always possible to be clarified, justified and unified thereafter. @DC: Let us keep existing wording. Actually current wording in Alt 3 seems to include Alt 1 already except that we have re-arranged/saved some CSI-RS resource ID with implicit two groups, in a different manner. @Intel @Ericsson: let us start from simple examples, with small candidate values at first, as red part. FL recommendation is to agree with Alt 3. However RAN1 will discuss further until Tuesday GTW: * Whether there is any issue to support FR2 from Alt3 by comparing to Alt 1
* Whether/how to support more than 2 TRPs?
* Design pros/cons in terms of singling overhead

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| QC | Note sure why we need to agree with Alt3 before it is clarified wrt basic questions asked before. At the very least, the change suggested by Docomo (no mandating to use NCJT CMR pairs for sTRP hypotheses) and vivo (extend it to G groups rather than 2 groups) are needed to adress the FR2 issue and FR1 issue (more than 2 TRPs), respectively.In our view, Alt1 adresses all the issues above, is simple/clean, and has minimal specification impact. |
| Nokia/NSB | We support the FL’s proposal and have a preference for Alt 3 – Option 1.5@Moderator, all: we suggest adding the corresponding definition of $M\_{1}$,$M\_{2}$ for Option 1.5 as follows* + ***FFS Option 1.5: N CMR pairs are RRC configured and/or indicated (by MAC-CE) by selecting from all possible pairs***
		- $\_{}\_{}\_{}\_{}$***, signalling mechanism can be discussed further, e.g. using a bitmap***

Note that, in Alt 1 the total number of CPU calculations, $O$, for sTRP and NCJT is assumed to be $O=K\_{s}$, so under the combination $N=1$, $K\_{s}=2$, no sTRP measurement can be configured.Similar assumptions can be made with Alt 3, by fixing $O$ with respect to $K\_{s}$. For example, for Option 1.5, we can fix $O$, such that $O-2N$ is the number of sTRP measurements (FFS: if the same definition applies in FR2 and FR1)@ QC: regarding your question “*Is it correct to say that if M>0, we always reuse the first M CMRs for both NCJT and sTRP hypotheses?*”. The answer is no, at least for Option 1.5, because the NW may configure different CMR resources for NCJT than those used for sTRP measurement. The case with only NCJT can be supported in Alt 3, at least for Option 1.5 without need for X=0 in P8. In fact, if $N\_{CPU}$ is the UE’s CPU capability, then $N\_{CPU}-2N$ is the number of sTRP measurements the UE can calculate. So, if $2N\geq N\_{CPU}$, the NW can configure only NCJT measurement, without need for X=0 in P8.@ QC, @Intel: Regarding the support of more than 2 TRPs in the cluster, Alt 3 does not imply any TRP association to the CMR groups. These groups are only for pairing purpose, so a NW can associate CMRs from more than 2 TRPs in each of the two groups.@QC: regarding RRC configuration overhead, in Alt 3, at least for Option 1.5, the CMR grouping can be assumed fixed, so the only overhead compared to a Rel-16 CSI Reporting Setting is the CMR pairing, which only needs $K\_{1}K\_{2}$ bits for the possible pairs.@QC: regarding the NW signalling mechanism via MAC-CE to indicate the CMR pairs for NCJT, this is not mandated in Alt 3 - Option 1.5, as it is assumed there is a default configuration for NCJT pairs in the Reporting Setting. However, whilst Alt 3 – Option 1.5 allows for the NW to dynamically override the configuration with $K\_{1}K\_{2}$-bit indication, Alt 1 does not have this flexibility and a change of NCJT pairs would require an RRC reconfiguration. |
| ZTE | We still support Alt.1.* **Comment for option 2:**

Here, we would clarify one import thing is**Observation:** One CMR cannot be configured/assumed within two or more CMR pairs in FR2For instance, UE has to use two simultaneous receive beam r1, r3 to measure CMR pair {1, 3} , meanwhile, UE has to use two simultaneous receive beam r1, r4 to measure CMR pair {1, 4}. So to measure CMR1, how could UE simultaneously use both r1, r3 and r1, r4? In such case, option 2 of alt.3 will not work. If companies don’t agree with the observation above, please share your views.* **Comment for option 1.5:**

MACCE cannot be used for periodic CSI since UE will average measurement instances. If only RRC configuration is used, there is no much difference between Alt.1 and option 1.5. @Nokia, for the comment ‘Note that, in Alt 1 the total number of CPU calculations, $O$, for sTRP and NCJT is assumed to be $O=K\_{s}$, so under the combination $N=1$, $K\_{s}=2$, no sTRP measurement can be configured’, for sTRP, why doesn’t gNB configure Ks =3 ?For CPU assumption, in the case CPU is over occupied, you actually prioritize NCJT CSI than sTRP which may not be reasonable. * **Comment on the last bullet:**

Regarding the last bullet ‘Support N=1 and Ks =2, FFS other maximal values of N>1 and Ks>2’, we have strong concern since Ks can even be 8 in Rel-15. We can not accept a backward design in Rel-17. We are fine with either removing the bullet or following revision*- Maximum Ks value should not be smaller than Rel-15/16, the maximum N is equal to or smaller than Ks/2** **General comment:**

Alt 3 is getting more complicate and hard understandable. Option 1 actually has no much difference with Alt.1. Option 2 is completely different with Option 1.5. In Option 1.5, only NCJT is allowed, but Option 2 cannot. In option 1.5, MACCE may be used, but option 2 will not. In option 1.5, K1, K2 seem fixed as Nokia clarified, but Option 2 is unclear. Based on the above, we propose to split Alt.3 into some parallel alternatives.  |
| Lenovo/MotM | We support Alt 3, Option 2.@ZTE: In our view, Alt3 is more flexible for FR1, since flexible CMR pairing (i.e., different CMR group sizes and free CMR pairing) is allowed. In our opinion Alt1 is too restrictive for FR1. We have previously suggested adding FFS under Alt3 to address whether special FR2 considerations are needed (e.g., one-to-one CMR pairing in FR2), which we are still fine with to address ZTE’s concerns on Alt3 under FR2. Also, we believe it is important to set upper limits for supported *N*, *Ks* values for better comparison of the different alternatives and easier assessment of overall complexity/overhead. |
| NTT DOCOMO | We understand the concerns from QC and ZTE on CMR pairing in FR2. But Alt.3 – Option1 can achieve the similar CMR pairing as Alt.1 for FR2, and ZTE also agreed on it. Can we assume ZTE is also okay with Alt.3 – Option1 (if FFS to use NCJT CMRs for sTRP hypotheses)? For Alt.3-Option2, it is more suitable for FR1, considering CMR pairing restrictions in FR2. However, on the other hand, it also requires further study whether such flexibility on CMR pairing is necessary or not. Because before CSI reporting configurations, gNB already obtains several good beam pairs from UE based on beam measurement/reporting. Hence, gNB just needs to configure a limited number of beam pairs for CSI measurement/reporting, which means that such flexibility on CMR pairing in Alt.3-Option2 may be not needed.In MTRP BM, enhancement on group-based beam reporting is also discussed. No matter which grouping method is supported in MTRP BM, grouping of CSI-RS resources and association with each TRP is needed. To make the CSI signaling framework consistent, we slightly prefer Alt.3 even though we think Alt.1 and Alt.3-Option1 can achieve similar configuration results. For the options in Alt.3, Option1 can be considered at least for FR2. |

***Proposal 8:*** *For a CSI report associated with a Multi-TRP/panel NCJT measurement hypothesis configured by single CSI reporting setting, support following two options:*

* *Option 1: the UE can be configured to report X CSIs associated with single-TRP measurement hypotheses and one CSI associated with NCJT measurement hypothesis*
	+ *Alt. 3: X = 1, 2*
	+ *FFS omission of CSI associated with NCJT measurement hypothesis*
* *Option 2: the UE can be configured to report one CSI associated with the best one among NCJT and single-TRP measurement hypotheses*
	+ *FFS how to report recommended measurement hypothesis associated with that CSI report*

***Proposal 8’:*** *For a CSI report associated with a Multi-TRP/panel NCJT measurement hypothesis configured by single CSI reporting setting, support following option:*

* *Option 1: the UE can be configured to report X CSIs associated with single-TRP measurement hypotheses and one CSI associated with NCJT measurement hypothesis*
	+ *Alt. 1: X = 1*
	+ *FFS omission of CSI associated with NCJT measurement hypothesis*

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| Huawei (Moderator) | Option 1 only (12): QC (1st), Lenono/MotM (X=0/1/2), CMCC, CATT, Ericsson, DOCOMO (1st), MediaTek (1st), Futurewei, Intel, Nokia/NSB Option 2 only (7): ZTE, Samsung, Oppo, LG (1st), Spreadtrum (1st) , Fraunhofer IISFraunhofer HHIOptions 1+2: Vivo, QC (2nd) , DOCOMO (2nd) , MediaTek (2nd) , LG (2nd), Spreadtrum (2nd), Oppo (X=1 only), ZTE (X=1 only)* There are a few companies, e.g. QC, Oppo, ZTE, raising concerns that even if we can compromise to Options 1+2, we shall simplify specification, i.e. single value of X
* Also ZTE raised a question whether X=0 is needed due to the discussion of Proposal 6 by which at least one CSI reporting based on single-TRP measurement hypothesis is reported.
* A few companies, e.g. Ericsson, has some strong concern over Option 2, which is insufficient to gNB.

FL recommendation is to either * Compromised Proposal 8: Support Option 1 (with X=1 and 2) and Option 2, by removing X=0, with the maximal flexibility but also with a higher spec cost. Option 2 can be considered as a subset of Option 1. The UE will determine one of two hypotheses (if following option 2), or report both (if following option 1) whereas NW will determine X=1 or 2 by RRC configuration for required reports. It is a kind of middle point so that each company may step ahead one feet.
* Compromised Proposal 8’: Support Option 1 (with X=1 only) to simplify specification changes. It seems to be another kind of middle point so that each company may have to step back one feet.

If we cannot reach a consensus for Proposal 8, likely I would suggest Propose 8’ for Tuesday GTW, at least it looks simpler, spec wise. Any comments are welcome.  |
| QC | We support Proposal 8’. Another proposal, which may be worth trying is in between proposal 8 and 8’, which is Alt1 of Option1 + Option 2, which may have higher chance. |
| Nokia/NSB | We support proposal 8 |
| ZTE | We still have concern to support X=2. We are fine with proposal 8 with X=1. Note that, option 2 has been adopted in LTE FeCoMP where only one best CSI among sTRP and NCJT is selected.Further, the current wording of proposal 8 with X=2 is more high level than previous agreement. Why two single TRP CSI is needed for sDCI based MTRP in which there is no TRP differentiation.  |
| Lenovo/MotM | We support Proposal 8. We further elaborate on the motivation to support X=2 as follows.For a UE configured with NCJT CSI from TRP1 and TRP2, the network may need to fall back to single-TRP transmission due to change in traffic demands, e.g., falling back from NCJT to single-TRP transmission with TRP2 in case TRP1 needs to be scheduled with other UE(s). A UE configured with X=1 that reports single-TRP CSI for TRP1 along with NCJT CSI fails to support such fallback scenario. Supporting X=2 would resolve this issue, regardless of whether TRP1 or TRP2 has higher traffic, which cannot be fully predicted when configuring/reporting CSI. In light of that, we think Proposal 8 provides a good compromise by addressing network flexibility concerns (via supporting X=2), as well as overhead concerns (via supporting Option2 in Proposal 8).  |
| NTT DOCOMO | First preference: support Proposal 8’.Second preference: support Proposal 8. |

***Conclusion:***

* Strive to mitigate the spec impact by supporting at most one of the following options
	+ Option 1: 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
	+ Option 2: The design was agreed by Working Assumption in RAN1 103e.
* The time of decision is RAN1 106e (August 2021)

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| Huawei (Moderator) | Option 1: WA (if confirmed) is sufficient in Rel-17 so that new solution is not needed.[QC], Lenono/MotM, CMCC, Samsung, Ericsson, Vivo, Nokia, CATTOption 2: a new solution, as above, is needed in Rel-17. DOCOMO, MediaTek, LG, Intel, Spreadtrum, I don’t see there is strong chance to agree with Proposal 9 or confirm WA this meeting. But since Proposal 9 has been proposed by more than 4 companies this time and WA is to address similar issue, at least we can conclude to mitigate concerns of time line and high level scope. Here I don’t talk about priority here but just be clear that they will be discussed in RAN1 106e, assuming that basic design are stable enough.  |
| QC | Support the conclusion with the following suggestion:***Conclusion:*** * Strive to mitigate the spec impact by ~~discussing~~ supporting at most one of the following options
	+ Option 1: 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
	+ Option 2: The design was agreed by Working Assumption in RAN1 103e.
* The time of decision is RAN1 106e (August 2021)
 |
| Nokia/NSB | Support the FL’s conclusion and QC’s revision. |
| Lenovo/MotM | We are fine with the FL version of the conclusion |
| NTT DOCOMO | Based on Moderator’s comments, Option 1 is to confirm WA, and Option 2 is to enhance single CSI reporting. It seems not consistent with the Option1/2 in Conclusion. Better to exchange Option1/2 in Moderator’s comments.For the conclusion, we are supportive of FL’s conclusion. |

**Appendix**

# Summary of CSI enhancement for FDD

**Possible Agreement**

*For PS codebook enhancements utilization DL/UL reciprocity of angle and/or delay, support codebook structure* ***W=W1W2 WfH****where*

* ***W1****is a free selection matrix, with identity matrix as special configuration*
	+ *FFS polarization-common/specific selection*
* ***Wf****is a DFT based compression matrix in which N3 = NCQISubband\*R and Mv>=1*
	+ *At least one value of Mv>1 is supported*
		- *Decide on the value of Mv, e.g. Mv=2,  in RAN1# 104bis-e*
	+ *Working assumption:  Support of Mv>1 is a UE optional feature if the UE supports Rel-17 PS codebook enhancement, taking into account UE complexity related to codebook parameters*
	+ *FFS other candidate values of R, mechanism for configuring/indicating to the UE and/or mechanism for selecting/reporting by UE for* ***Wf***
* ***Wf*** *can be turned off by gNB. When turned off,* ***Wf****is an all-one vector (FFS; the length of all-one vector)*
* *FFS other signaling/CSI reporting mechanism for trade-off among signaling overhead, UE complexity and UPT gain*

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| Company | Comments |
| Huawei (Moderator) | Please comment by RAN1 reflector. Here is just for a reference of final outcome (if any) |
| Apple | We are fine with this FL proposal  |
| Samsung | OK, with two additional clarifications in blue**Possible Agreement***For PS codebook enhancements utilization DL/UL reciprocity of angle and/or delay, support codebook structure* ***W=W1W2 WfH****where ~~whereas~~** ***W1****is a free selection matrix, with identity matrix as special configuration*
	+ *FFS polarization-common/specific selection*
* ***Wf****is a DFT based compression matrix in which N3 = NCQISubband\*R and Mv>=1*
	+ *At least one value of Mv>1 is supported*
		- *Decide on the ~~value~~ value(s) of Mv, e.g. Mv=2,  in RAN1# 104bis-e*
	+ *Working assumption:  Support of Mv>1 is a UE optional feature if the UE supports Rel-17 PS codebook enhancement, taking into account UE complexity related to codebook parameters*
	+ *FFS ~~other~~ candidate ~~values~~ value(s) of R, mechanism for configuring/indicating ~~of Configured/indicated~~ to the UE and/or mechanism for selecting/reporting ~~of selected/reported~~ by UE for* ***Wf***
* ***Wf*** *can be turned off by gNB. When turned off,* ***Wf****is an all-one vector (FFS; the length of all-one vector)*
* *FFS other signaling/CSI reporting mechanism for trade-off among signaling overhead, UE complexity and ~~performance~~ UPT gain*
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***Proposal 5:*** *Study following mechanisms, which are to be decided in RAN1 104bis-e:*

* *If configuring/indicating Wf to the UE*
	+ *Option 1: The FD bases used for Wf quantitation is limited within K windows/sets, with size Nk and initial point Minitial,k, which can be fixed/configured/indicated by gNB.*
		- *FFS: candidate values and value ranges for K, Nk, Minitial,k*
		- *FFS: signaling mechanism by MAC-CE or RRC or hybrid*
	+ *FFS: The number of CSI-RS ports and the value of Mv is jointly configured per codebook parameter combination*
* *If selecting/reporting Wf to the gNB*
	+ *Option 1: UE is not required to report the index of Wf*  *(which is equivalent to UCI reporting with 0 bit), e.g. if some codebook parameters are configured/indicated by the NW*
	+ *Option 2: UE is required to report the index of Wf**within a window of size Nk*

*Other enhancements are not excluded.*

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| --- | --- |
| Huawei (Moderator) | Thanks for the feedback. I intent to make proposal 5 at high level so that we can have more information about how to use Wf here, which may be different from Rel-16 PS. Of cause companies are encouraged to show your understanding in more details. If you prefer to list more options, please suggest. Note the discussion here is not to intent to exclude solutions but to elaborate concepts to help further evaluation/simulations. @CATT @Vivo: update accordingly. @LG: update accordingly@SS: Understand. Let us have one round comment to see whether you can change minds later. Of cause you have all right saying no, even if it is proposed later. @QC: OK to keep FFS |
| Apple | We do not see a strong need to make an agreement on this study since it is at very high level anyway.Furthermore, in Rel-16, we have frequency basis selection design especially when the number of subbands is large. It is mainly because potential large value of C(N3-1, Mv-1). However, in Rel-17, it is not even clear about the condition we should discuss the frequency basis selection * We have not decided on the value of Mv, some proponent wants Mv =2 which is already much smaller than what Rel-17 allows
* We have not decided on the R and N3, in general, the larger N3 and R=2 do not seem to be necessary

Without a clear direction of the subband size and the potential value of Mv, it is hard to make an agreement on the study. But companies can still study, there is just no need to make an agreement on this.  |
| Samsung3 | In addition to my earlier comments, we also have concern about his statement “*Other enhancements are not excluded*” Our concern is about the potential scope expansion. So far the scope of FDD CSI keeps expanding (we already expanded the scope by moving away from angle and delay reciprocity based design, by accommodating Wf in the CB design, for weak reciprocity scenarios). Not to mention that we have mTRP CSI, in this to FDD CSI.Also, based on the replies from companies in the appendix, it is clear that companies have different understanding about these options. This is perhaps due to the lack of time spent on studying this. Besides, this issue is about signaling of a codebook component (Wf), which we have not designed yet. We are puzzled what is the point of discussing something which we have not designed and agreed on yet.  |
| CATT | We havn’t agreed to support gNB indicating Wf or UE reporting Wf for Rel-17 PS codebook. Current formulation of Proposal 5 seems to imply that both of them are supported. We can add ‘(if supported)’ in the two bullets to make it clear that gNB indicating or UE reporting are still undecided.For the FFS part of the first bullet, as we commented earlier, it is not necessary to be part of this proposal. The codebook parameter combination is further detail and can be discusssed after the mechanism of configuring/indicating Wf is agreed. On Option 1 of the first bullet, if UE is not required to report, why it is listed as one option under ‘if selecting/reporting to gNB’? This option can be removed.On Option 2 of the second bullet, the value of Nk is not defined. Is it the same definitiona as that of the first bullet? |
| Lenovo/MotM | The merit of using *K*>1 windows is not justified, or at least the proposal is not clear to us. Initially, our understanding is that the window location (parametrized by *M*initial) approach would be UE indicated to correct misalignments in case of imperfect reciprocity, especially that indicating Minitial by the UE requires very few bits. One window should be enough with a few bits to report window location similar to Rel. 16 CB, no need to unnecessarily complicate the design  |
| Qualcomm | We think the discussion go way further and people start to mix CSI-RS channel estimation, CSI calculation and PMI reporting. In our view, UE is only provided with a CSI-RS pattern, and a PMI codebook. Only these two issues can be discussed in the air-interface level, what left in the middle, including how to perform channel estimation and how to calculate PMI, are UE implementation. We should not touch it.Going back to the topic of this proposal, we think it is just a component in PMI codebook. It has nothing to do with channel estimation and PMI calculation. Even though network configure Wf being 1 and 2, it does not mean UE only needs to measure these two taps in channel estimation, and also does not mean UE only needs to calculate CSI on these two taps. * For channel estimation, UE tries best effort to estimate all taps on each port, so as to support better CSI calculation including PMI RI and CQI.
* For CSI calculation, UE tries best to optimize its CSI algos. Even with timing misalignment, there are many ways to solve it in implementation. One way is to find the best tap(s) to calculate the PMI. Specifically, UE may find the best taps being FD bases 3 and 4 in PMI calculation, but can associate the PMI calculation results with FD bases 1 and 2 in the reporting – there is no difference in reported PMI and CQI, as FD bases 3/4 are just cyclic shift to FD bases 1/2. Another way is to follow similar algo of Rel-16 CB, UE may calculate subband SVD, and find the best FD bases for compression. These best FD bases could be FD bases 3 and 4, but UE can associate PMI calculation results with FD bases 1 and 2 in the reporting.

So, from these perspectives, we don’t see the need of Mini (or it should be fixed to zero). The only reason that R16 CB needs Mini is that UE needs to keep the strongest coefficient in the PMI (please note that it is PMI, not the channel) at FD bases zero. Regarding multiplexing multiple UEs on the same CSI-RS resource but in delay domain, we think it is related to CSI-RS design with a new cover code. Without clarifying in CSI-RS pattern, UE will consider all the taps in the delay domain are associated to its own channel rather than as stated by Nokia. Wf and Mini do not achieve the goal, as it is just a component in the PMI codebook and not related to specific CSI algo. So, we suggest it to be discussed in options of P3. |
| Fraunhofer IIS,Fraunhofer HHI | We think that the specific design depends on the agreed value(s) of $M\_{ν}$ which have not yet been agreed. If the agreed value(s) of $M\_{ν}$ are rather small, the specific design can be very simple at the end. We prefer to decide at first if the gNB indicates $W\_{f}$, or the UE reports $W\_{f}$. The detailed design can be either FFS or to be discussed at a later stage. If the FL decides to list possible options, we would like to add Option 2 below the first main bullet which can be considered as a variant of Option 1. *Option 2:* *The FD bases used for Wf quantitation are limited within a single window with size N and initial point Minitial, which can be fixed/configured/indicated by gNB. FFS: value(s) of N and Minit* |
| NTT DOCOMO | As pointed out by Lenovo/MotM, we are also not clear about the requirement of having *K*>1windows/sets. It is appreciated if a proper justification can be provided. Regarding the two (broad) options proposed for identifying $W\_{f}$ which are, 1) indicated by gNB, and 2) reported by UE, we think that there should be sufficient flexibility at the UE side to select and report $W\_{f}$. We do acknowledge that the indication of $W\_{f}$ by gNB can reduce CSI reporting overhead. However, this comes with the underlying assumption that the gNB is accurately estimating delay(s) associated with a particular DL port considering UL RS transmission. This is not always true especially given the fact that the effective antenna-spacing is different in two bands for FDD. Hence, we prefer to let UE to select *Mv* FD bases either freely or from a preconfigured window of size *N*  |
| ZTE | Share similar view as Qualcomm. The timing misalignment between UE and gNB can be solved by UE implementation.* We are not sure about the need of M\_initial.
* We don’t see the need of multiple windows either.

But we are open to further discuss these issues.Another question for the current FL proposal:For the UE reporting part, the two options are not clear to us.* + *Option 1: UE is not required to report the index of Wf*  *(which is equivalent to UCI reporting with 0 bit), e.g. if some codebook parameters are configured/indicated by the NW*
	+ *Option 2: UE is required to report the index of Wf**within a window of size Nk*

We have (almost) agreed in proposal 1 that gNB can turn off Wf. In this case, there should not be any reporting for Wf, which is Option 1. If Wf is to be reported by UE, and gNB does not turn it off, UE should report the index of Wf. Hence we are not sure about the point of discussing Option 1 and Option 2. The discussion point should be whether UE reporting is supported or not. |
| OPPO | The use case of multiple windows is unclear to us now. With delay reciprocity we don’t see channel will be more spread. At least single window size 2M as in Rel-16 is enough. Agree with Qualcomm that Wf in Rel-16 reflects relative delays, but to support UE measurement in option 2 an absolute delay window indication may be needed. We are open for further discussion. |
| Spreadtrum | We don’t have strong concern on each options since they’re high level. But we are not sure what we should decide in next meeting. Are we going to decide whether supporting configuring/indicating Wf to the UE and/or selecting/reporting Wf to the gNB? Are we going to further down select between different options?Regarding the FFS on ‘The number of CSI-RS ports and the value of Mv is jointly configured per codebook parameter combination’, since it’s not an option comparing with the parallel bullet, it seems not related to this proposal and should be removed. |
| Intel | We have concerns on opening this high-level discussion by agreeing to the proposal. In our view the options presented in the proposal are too broad and such agreement is not useful at all. In our understanding it is clear for all the interested companies that there are three main approaches how to deal with Wf. * Wf fixed in the specification
* Wf indicated by the gNB
* Wf selected by the UE

There are a variety of combinations and detailed design for the above approaches and our work in RAN1 is to select the best one for scenario with FDD reciprocity (simulation assumptions are already agreed). So, proponents of particular solution can directly propose it in the next RAN1 meeting without any high-level agreement now.In our view codebook design with Mv = 1 is already very good option, it is challenging to outperform it in the simulations. For Mv > 1 we may consider two corner cases: Wf fixed in specification and Wf indicated by the gNB. |
| LG | We think this proposal can provide discussion point for the next meeting. Actually, high level description for this proposal has already been captured in the agreement as follows, so more details can help further discussion. o   *FFS candidate value(s)  of R, mechanism for configuring/indicating to the UE and/or mechanism for selecting/reporting by UE for* ***Wf***However, regarding multiple windows/sets, we think single window/set will be enough for a UE. If multiple windows/sets are for supporting multiplexing multiple UEs, then supporting of multiple windows/sets should be discussed separately from this proposal. |
| Ericsson | Some comments on this proposal:* **If gNB indicating Wf:**
* We don't see the need of configuring/indicating multiple windows to UE. A single window, i.e., K=1, is sufficient for the UE. To be more specific, note that the gNB uses multiple windows for CSI-RS precoding. However, due to delay pre-compensation, the windows for CSI-RS precoding are aligned, so that UE only needs a single window for PMI calculation.
* The need for initial point, M\_init, needs to be justified. Fixing M\_init to 0 (i.e., DC component) is sufficient in our opinion.
* **If UE reporting Wf:**
* UE should not freely select Wf., UE should be configured/indicated to select Wf within a window. Within this window, UE can either select all and no need to report (which corresponds to Opt 1), or the UE can freely choose a subset within the window and report (Opt 2). Some further study is needed on these options.
* We don’t understand why Option.1 us under this category since no Wf is reported by the UE ??
 |
| vivo | Support.Let me explain the details of “K windows/sets, with size Nk and initial point Minitial,k, which can be fixed/configured/indicated by gNB”.In our understanding, compared with R16, the improvement of R17 is SD, FD information measured by gNB based on angular and delay reciprocity. The FD information can be conveyed to UE by CSI-RS ports or signaling indication. Considering the flexibility and CSI-RS port consumption, gNB can indicate partial or all FD information to UE. In enhanced Type II codebook in R16, K FD bases are selected from a window of size N starting from Minitial. If the gNB is able to measure the delay and indicate the exact K delay taps to the UE, the FD bases searching at UE will not be needed with the benefit of lower UE complexity and reduce feedback overhead. What’s more, R can be larger than that in R16 with finer granularity. Furthermore, for each tap indicated by gNB, to counteract the non-ideal FDD reciprocity and timing mismatch, each tap can be expanded to a window of size Nk around the k-th delay location starting from Minital, k, enabling precise FD basis selection within a limited window. In a word, K windows corresponding to each CSI-RS port are for K FD bases indication and UE can obtain K times SD-FD bases.Anyway, this is a general model to accommodate all options. When K=1, N=1, Minital=0, then it turns out to be the case of Mv=1. If the overhead of CSI-RS ports is more essential, K>1 can be indicated for UE to measure. The candidate values and value ranges for K, Nk, Minitial,k are FFS. |
| Nokia/NSB | We support the FL’s intention to provide sufficiently high-level description to identify more precise alternatives at the next meeting. We have some comments to help improve the scope of this studyRegarding gNB’s configuration/indication of $W\_{f}$* We also don’t see the need to configure multiple windows, so $K=1$. In our view, configuring a single window per UE is sufficient. However, we understand this is a company’s proposal, so we are not against keeping it there for study, as we are not downselecting yet.
* Regarding $M\_{initial}$, to simplify things, this would be applicable, in our view, only for a single window per UE. The reason for considering $M\_{initial}$ in this study is the possibility for the NW to configure two UEs in the same port on two windows well separated in the delay domain. For example, if R=4, the delay domain is 4 times wider than for R=1, and two UEs may be configured, for example, with $M\_{initial}=0,N\_{3}/2$, respectively, if the two channels are well separated in the delay domain.

@QC: this operation is part of the FD precoding, which applies different weights for different PMI subbands and is separate from the cover code in CSI-RS design which applies different coefficient per RB, regardless of the PMI subband size.Regarding UE’s selection/reporting of $W\_{f}$* We think the understanding of the two options is clear, as explained by Ericsson, for example. Maybe the wording can be improved. In our view Option 1 is for $W\_{f}$ what Alt 0 is for $W\_{1}$, i.e., the UE selects all the FD components configured by the NW without explicit reporting of the $M\_{ν}$ components. A possible rewording may be along these lines
	+ *Option 1: UE selects all FD components configured/indicated by the NW without reporting them*
	+ *Option 2: UE selects and reports the index of* $\_{}$ *components within a window of size* $N$

@ZTE: “*If Wf is to be reported by UE, and gNB does not turn it off, UE should report the index of Wf.*” As elaborated above, if $W\_{f}$ is configured, option 1 means that the UE selects all components and does not need to report their indices explicitly. |

# Summary of CSI enhancement for Multi-TRP

***Proposal 6:*** *For CSI measurement associated to a reporting setting CSI-ReportConfig for NCJT, the UE can be configured with Ks ≥ 2 NZP CSI-RS resources in a CSI-RS resource set for CMR and N ≥ 1 NZP CSI-RS resource pairs whereas each pair is used for a NCJT measurement hypothesis, support ~~at least~~ one CMR pairing mechanism by down-selecting from following in RAN1 104e:*

* *Alt.1: Configure UE with N NZP CSI-RS resource pairs within a CMR resource set explicitly, whereas the first Ks-2N CMRs are for single-TRP measurement hypotheses and the remaining 2N CMRs in consecutive N CMR pairs are for N NCJT hypotheses.*
	+ *Note: Network can reuse CMRs of single-TRP hypotheses for NCJT hypotheses at least in FR1 (by configuring the same CSI-RS resource ID of any of the first Ks-2N CMRs for any of the remaining 2N CMRs in the resource set)*
* *Alt.2: N CMR pairs are RRC configured and/or indicated (by MAC-CE) explicitly by a bitmap.*
	+ *Note: the first Ks-2N CMRs in the set are for single-TRP measurement hypotheses.*
* *Alt.3: Configure UE with two CMR groups with Ks = K1+K2 (≥ 2N) CMRs, whereas each CMR group corresponds to one out of two TRPs. N CMR pairs are [explicitly/implicitly] determined from two CMR groups by following method(s)*
	+ *K1 and K2 are the number of CMRs in two groups respectively. FFS K1=K2 or different K1/K2.*
	+ *Note that the first M CMRs in each CMR group can be used for both NCJT and Single-TRP measurement hypotheses, the remaining CMRs are only used for single-TRP measurement hypotheses*
	+ *FFS. Option 1: N NZP CSI-RS resource within a group can be explicitly/implicitly determined for NCJT measurement hypothesis with one-to-one mapping with the N NZP CSI-RS resource in the other group*
		- *N=M, signalling mechanism can be discussed further*
	+ *FFS Option 1.5: N CMR pairs are RRC configured and/or indicated (by MAC-CE) by selecting from all possible pairs*
		- *signalling mechanism can be discussed further, e.g. using a bitmap*
	+ *FFS Option 2: UE freely select CMR pairs from two groups (without one-to-one mapping)*
		- *N=M^2*
* *Alt.4: N ≥ 1 NZP CSI-RS resource pairs are determined and reported by UE*
* *Alt.5: N= Ks(Ks-1)/2 pairs for all possible pairing from the set*
	+ *Note that CMRs in the set can also be used for single-TRP measurement hypotheses*
* *FFS maximal values of N and Ks*

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| Huawei (Moderator) | Thanks all for valuable input. After reviewing all preference, it seems to be quite clear that the most popular ones are Alt 1 and Alt 3. So Let us more discussion between Alt 1 and Alt 3 firstly. My general plan is to strive to make a decision between Alt 1 and Alt3, until next GTW session (Tuesday). Based on explanation from Nokia and other companies, I have updated some text for Alt 3 which seems to have more details now. I reformat Nokia’s preference as Option 1.5 (^-^) for which I, personally, think that it is something between option 1 and 2 and can be interesting. If any text polish is required, please be free to comment. Alt 1: QC (1st), ZTE, Docomo, Intel, CMCC, SamsungAlt 2: Nokia, QC (2nd)Alt 3: Vivo, CATT, Oppo, NEC, Intel, Docomo, MediaTek, LG, Lenovo/MoM, CMCC, Samsung, Ericsson (2nd), Futurewei (2nd), Fraunhofer IIS/Fraunhofer HHI, Nokia (2nd) Alt 4: Futurewei (1st)Alt 5: Ericsson (1st)  |
| Apple | We are fine with either alternative 1 or 3 |
| Lenovo/MotM | Support Alt3 |
| QC | We are fine with the direction of FL proposal to focus on Alt 1 and Alt3.It seems that Alt3 still does not provide the flexibility that for some of the CMR pairs, they are not also used for sTRP hypotheses. Is it correct to say that if M>0, we always reuse the first M CMRs for both NCJT and sTRP hypotheses?If yes, then it is not clear how Case 3 in Nokia’s examples in the previous round can be supported with this unless if we consider this together with X=0 of Proposal 8. As mentioned before, Alt1 allows for this (only NCJT hypotheses) w/o requiring additional reporting configuration enhancements (i.e., w/o requiring configuring X=0 in Proposal 8). With respect to reusing sTRP CMR for NCJT hypotheses in FR2: This depends on multi-panel implementation. Here is one example for illustration (whether this implementation will be used in practice is a different story): When receiving CMR0 that is configured for sTRP hypothesis, UE may select to use both panels simultaneously to receive the same Tx beam (using two Rx beams or one effective Rx beam). However, if this CMR0 is also used together with CMR1 for NCJT hypothesis, UE has to use panel 0 to receive CMR0 and panel 1 to receive CMR1. In this case, the Rx beam on panel 0 cannot be optimized for the one effective Rx beam in the former case, which may be slightly different than this case that only panel 0 is used to receive CMR0. There could be other examples depending on specific multi-panel implementation.In addition, Alt3 in its current format assumes 2 TRPs. It is not clear where this is coming from. Single-DCI based mTRP is not designed for only 2 TRPs in the cluster. For example, when MAC-CE maps each of the 8 TCI codepoints to one or two TCI states, there is no grouping of TCI states. Alt3 cannot support FR1 use case where {TRP1,TRP2}, {TRP2,TRP3}, and {TRP1,TRP3} are 3 different NCJT hypotheses while Alt1 can support this.With respect to overhead of Alt1 when sTRP CMRs are reused for NCJT hypotheses, we would like to point out that this is only about configuring the same CSI-RS resource ID two times in the resource set. This is not about actual CSI-RS overhead. Furthermore, depending on the signaling details of Alt3, the RRC overhead of Alt3 can be even larger and more complicated than Alt1 (e.g. bitmap, configurations related to grouping the resources into two groups, etc.). One last point: When it comes to down-selection, we think i) signaling mechanisms of Option 1 and Option 1.5 should be first clarified ii) down-selection should not be based on Alt1 and Alt3, but should be based on {Alt1, Alt3-Option1, Alt3-Option1.5, Alt3-Option2}. This is because Alt1 is already clear, but Alt3 have different variants and some FFS for signaling aspects. |
| OPPO | Support to further discuss between Alt.1 and Alt.3. |
| ZTE | We are fine to focus on Alt 1 and Alt 3. However, in the next round discussion, the following issues should be clarified.* CPU occupation for CSI calcaultion. For Atl. 1, the number of CPUs O is the same as Rel-15/16 where O is equal to the number of CMRs Ks within the set. For NCJT, one pair CMR needs two CPUs. However, what is the number of O for Alt 3?
* The down-selection should be based on {Alt1, Alt3-Option1, Alt3-Option1.5, Alt3-Option2} as QC mentioned. All the signaling details should be clear for each sub-options of Alt 3.

As QC mentioned in FR2, for STRP, UE can use the same two receiving beams on two panels. However, for NCJT, UE will use different receive beams. If one CMR can be configured for both STRP and MTRP, UE can only use single panel for STRP. The CSI estimation accuracy will be impacted for STRP.  |
| CATT | In FR2, if we assume that a CMR for sTRP hypothesis is receive with two panels jointly while single panel is assumed in receiving the same CMR for mTRP hypothesis, different measurements will be obtained in the two cases. In such sense, one may argue that a resource for sTRP measurement cannot be used for mTRP hypothesis. Even in Alt.1, if the same resource is configured for both sTRP and mTRP hypotheses, the same issue as illustrated above exists in both Alt.1 and 3.Furthermore, to address the concerns to Alt 3 from some companies, one solution could be to configure a subset of resources for sTRP hypothesis only.  |
| NEC | We are fine with the proposal, and support Alt 3. |
| DOCOMO | Fine to further discuss Alt.1 and Alt.3.In Alt.3, we suggest following revision for the ‘Note’ since we have not fully discussed it.* + *Note that the first M CMRs in each CMR group can be used for ~~both~~ NCJT ~~and Single-TRP~~ measurement hypotheses, the remaining CMRs are only used for single-TRP measurement hypotheses.*
		- *FFS whether the first M CMRs in each CMR group can be also used for single-TRP measurement hypotheses.*

With above revision, we think Alt1 and Alt3-Option1 can achieve the similar configuration results. The only differences are signalling format and grouping in Alt3 to distinguish the CMR from each TRP for single-TRP measurement hypotheses. |
| Intel | At this stage it seems for us that it is hard to understand pros and cons for Alt 1 and Alt 3. The alternatives are very flexible and support a variety of use cases. Our first preference is Alt. 1 for the following reasons* Alt 1 support >2 TRP in coordination for the CSI
	+ It is explicitly stated that 2 TRP are supported for Alt 3 in the proposal
* Alt 1 is clean and clear without multiple options and FFS

For Alt 3 there are more supporters but it is more fragmented (i.e. multiple options), it requires more RAN1 efforts and discussions comparing to Alt 1. |
| LG | We are fine with FL’s suggestion, and support Alt3. Regarding Alt3, if my understanding is correct, the main motivation of Alt3 is to support CMR grouping in the same resource set, and it seems that majority wants to support it. We think options for signalling mechanism can be discussed further if we decide to support Alt3. And different options can also be supported together (e.g., Option 1 + Option 1.5, etc) instead of selecting only one option according to discussion. And to support only NCJT hypotheses in Alt3, disabling/enabling CMR(s) for STRP hypothesis can be considered together with disabling/enabling CMR pair(s) for NCJT hypothesis(i.e., Option 1.5). |
| CMCC | We are fine with this proposal. And we prefer Alt 3-Option2, which has more flexibility than other Options. Furthermore, if the number of CMRs in each CMR group is limited to a low value, like 4, the overhead of CRI is also acceptable. |
| Ericsson | Regarding the proposal, it seems there is so much emphasis on optimizing the measurement for both FR1 and FR2. In order to optimize for FR2, we would like to understand what value of Ks and N companies have in mind. To flexibly support FR2, we may need a large value of Ks. But then there would be too many NC-JT hypothesis which would not be practical. Our preference is to first agree on the simple case where Ks=2 and N=1. Note that for Ks=2 and N=1, FR2 can still be supported. The best beams can be acquired via L1-RSRP/L1-SINR reports (e.g., group based beam reports that is expected to be enhanced in Rel-17). Before discussing Ks>1 and N>1, we should first decide the value of Ks. After this, further discussion of the alternatives can take place.Note that configuring separate resources for NC-JT measurement hypothesis and single-TRP hypothesis will increase CSI feedback. Hence, reusing same resource for NC-JT hypothesis and single-TRP hypothesis is desirable from CSI-RS overhead perspective. |
| vivo | We first preference is Alt3. If we cannot down-select between Alt1 and Alt3, we support to further study between Alt.1 and Alt.3.Besides, we show some understanding about Proposal 6 as follows:1. Firstly, we think grouping CMRs is necessary for UE to tell which TRP that a CMR belongs to, which is the same as in MTRP beam reporting.
2. Proposal 6 and Proposal 8 are related and Proposal 6 should work for the CSI hypotheses reporting alternatives considered in Proposal 8
	1. when option1 and X = 0 enabled, the CMR pairs in different groups are measured for NCJT hypothesis.
	2. When X=2, the UE cannot tell which TRP the CMR for two single-TRP CSI measurement belongs to and may report two STRP CSIs corresponding to one TRP if Alt1 is assumed. While this can’t happen with Alt3.
3. On reusing CMR for NCJT for STRP,
	1. First of all, the CMR for NCJT hypothesis can also be used for STRP hypothesis at least FR1.
	2. In FR2, we agree with QC’s comment that it depends on multi-panel implementation. In Alt3, it is also possible to configure dedicated CMRs only for STRP measurement. Even if the CMR for NCJT is also used for STRP CSI calculation where one of the Rx panel using the beam for another TRP, in our opinion performance loss may not be very large. Evaluations can be conducted and can be FFS.
4. As for current Alt3 assuming 2 TRPs, we think Alt3 also can support more than 2 TRPs joint transmission by grouping more than 2 CMR groups. Alt3 can be extended to consider more groups within a cluster.

*Alt.3: Configure UE with ~~two~~ G(G>1) CMR groups with Ks = K1+K2+…+KG (≥ 2N) CMRs, whereas each CMR group corresponds to one out of ~~two~~the TRPs. N CMR pairs are [explicitly/implicitly] determined from the CMR groups by following method(s)** 1. *Kg (g=1, 2, …, G) ~~and K2 are~~ is the number of CMRs in ~~two~~ G groups respectively. FFS K1=K2=…=KG or different Kg~~1~~~~/K~~~~2~~.*
	2. *Note that the first M CMRs in each CMR group can be used for both NCJT and Single-TRP measurement hypotheses, the remaining CMRs are only used for single-TRP measurement hypotheses*
	3. *FFS. Option 1: N NZP CSI-RS resource within a group can be explicitly/implicitly determined for NCJT measurement hypothesis with one-to-one mapping with the N NZP CSI-RS resource in the other group*
		1. *N=M, signalling mechanism can be discussed further*
	4. *FFS Option 1.5: N CMR pairs are RRC configured and/or indicated (by MAC-CE) by selecting from all possible pairs*
		1. *signalling mechanism can be discussed further, e.g. using a bitmap*
	5. *FFS Option 2: UE freely select CMR pairs from two groups (without one-to-one mapping)*
		1. *N=M^2*
1. *Alt.4: N ≥ 1 NZP CSI-RS resource pairs are determined and reported by UE*
2. *Alt.5: N= Ks(Ks-1)/2 pairs for all possible pairing from the set*
	1. *Note that CMRs in the set can also be used for single-TRP measurement hypotheses*

*FFS maximal values of N and Ks* |
| Nokia/NSB | We support the FL’s proposal and have a preference for Alt 3 – Option 1.5@Moderator, @ZTE: In Alt 3, we suggest differentiating the note on “M” for the different options, because the definition of “M” according to DOCOMO’s comment, is different for Option 1.5. In fact, to allow for odd total number of CMR resources, $K\_{s}$, and/or an odd number of CPUs, $O$, we suggest replacing $M$ with $M\_{1}\leq K\_{1},M\_{2}\leq K\_{2}$ for each respective CMR group.In practice, for Option 1.5, the total number of CPUs is, for example (FFS: if the same definition applies in FR2 and FR1): $M\_{1}+M\_{2}+2N=O\leq N\_{CPU}$, so $M\_{1}=min\left\{K\_{1},\left⌈\frac{N\_{CPU}-2N}{2}\right⌉\right\}$ and $M\_{2}=min\left\{K\_{2},\left⌊\frac{N\_{CPU}-2N}{2}\right⌋\right\}$. Note that, in case $M\_{1}<K\_{1}$ and/or $M\_{2}<K\_{2}$, the remaining CMR resources are not used for sTRP measurement as they would exceed the CPU capability. We suggest to modify the note for Option 1.5 as follows: * + ***Note that the first*** $\_{}\_{}\_{}\_{}$ ***CMRs in each respective CMR group can be used for both NCJT and Single-TRP measurement hypotheses.***

@ QC: regarding your question “*Is it correct to say that if M>0, we always reuse the first M CMRs for both NCJT and sTRP hypotheses?*”. The answer is no, at least for Option 1.5, because the NW may configure different CMR resources for NCJT than those used for sTRP measurement. The case with only NCJT can be supported in Alt 3, at least for Option 1.5 without need for X=0 in P8. In fact, if $N\_{CPU}$ is the UE’s CPU capability, then $N\_{CPU}-2N$ is the number of sTRP measurements the UE can calculate. So, if $2N\geq N\_{CPU}$, the NW can configure only NCJT measurement, without need for X=0 in P8.@ QC, @Intel: Regarding the support of more than 2 TRPs in the cluster, Alt 3 does not imply any TRP association to the CMR groups. These groups are only for pairing purpose, so a NW could, in principle, associate CMRs from multiple TRPs in the same group.@QC: regarding RRC configuration overhead, in Alt 3, at least for Option 1.5, the CMR grouping can be assumed fixed, so the only overhead compared to a Rel-16 CSI Reporting Setting is the CMR pairing, which only needs $K\_{1}K\_{2}$ bits for the possible pairs.@QC: regarding the NW signalling mechanism via MAC-CE to indicate the CMR pairs for NCJT, this is not mandated in Alt 3 - Option 1.5, as it is assumed there is a default configuration for NCJT pairs in the Reporting Setting. However, whilst Alt 3 – Option 1.5 allows for the NW to dynamically override the configuration with $K\_{1}K\_{2}$-bit indication, Alt 1 does not have this flexibility and a change of NCJT pairs would require an RRC reconfiguration. |

***Proposal 8:*** *For a CSI report associated with a Multi-TRP/panel NCJT measurement hypothesis configured by single CSI reporting setting, downselect between the following two options:*

* *Option 1: the UE can be configured to report X CSIs associated with single-TRP measurement hypotheses and one CSI associated with NCJT measurement hypothesis*
	+ *Alt. 0: X = 0*
		- *Yes:*
		- *No: QC, ZTE*
	+ *Alt. 1: X = 1*
		- *Yes: QC, MediaTek OPPO(if Option 1 is supported)*
		- *No:*
	+ *Alt. 2: X=0, 1*
		- *Yes:CATT, DOCOMO, MediaTek*
		- *No: OPPO, ZTE*
	+ *Alt. 3: X = 0, 1, 2*
		- *Yes: CATT, Ericsson, Futurewei*
		- *No:QC OPPO,ZTE*
	+ *FFS omission of CSI associated with NCJT measurement hypothesis*
* *Option 2: the UE can be configured to report one CSI associated with the best one among NCJT and single-TRP measurement hypotheses*
	+ *FFS how to report recommended measurement hypothesis associated with that CSI report*

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| Huawei (Moderator) | Option 1 only (12): QC (1st), Lenono/MotM, CMCC, CATT, Ericsson, DOCOMO (1st), MediaTek (1st), Futurewei, Intel, Nokia/NSB Option 2 only (7): ZTE, Samsung, Oppo, LG (1st), Spreadtrum (1st) , Fraunhofer IISFraunhofer HHIOptions 1+2: Vivo, QC (2nd) , DOCOMO (2nd) , MediaTek (2nd) , LG (2nd), Spreadtrum (2nd) Based on above review, from Moderator perspective, 7 companies plus Vivo have very strong preference over Option 2 only. So it is hardly to see a majority view. Therefore, I would recommend to support both. However if the group disagree the assessment, we will continue discussing until next GTW session (Tuesday) to make final decision.  |
| Apple | Fine with the FL proposal |
| Lenovo/MotM | Support Option 1, Alt 3 |
| QC | We are fine with FL proposal to support both Option 1 and Option 2. But then, we should try to also select one simple/meaningful Alt in Option 1. |
| OPPO | We prefer Option 2. If Option 1 is agreed by most companies, we prefer X=2 for Option 1. We don’t think it is needed to support X=2 considering legacy CSI report can be adopted to acquire the CSIs for S-TRP. |
| ZTE | Support Option 2. We can accept with option 2 + option 1 with X = 1. However, if people can only accept one option, the down selection should be based on {option 2, option 1+ alt.0, option 1+ alt.1, option 1+alt 2, option 1+alt 3} for fairness.  |
| CATT | Option 1+Alt. 2/3 is supported.Even though CSI for sTRP is always available by configuring additional CSI report setting, the overhead of signaling should be considered. Instead, with Option 1+Alt. 2/3, the CSI for all the possible hypotheses can be obtained within one report setting. If the feedback overhead is a concern, the value of X can still be adjustable. Consequently, this gives network the flexibility to choose suitable transmission scheme and making better decision on scheduling.  |
| NEC | Support Option 1, and fine with either Alt 2 or Alt 3. |
| DOCOMO | We prefer Option1. But we can also accept the FL proposal. |
| Intel | Support of Option 1 and Option 2 may be a good compromise, we support it. Our preference is Option 1, but we are fine to compromise and support option 1+2. |
| LG | We prefer Option 2, but we are fine with FL’s suggestion for the progress.  |
| CMCC | Our preference is Option 1 and we are fine with Alt 1 or Alt 2.But we can support Option 1+2 as a compromise. |
| Ericsson | We have some strong concerns over agreeing to Option 2. As mentioned in our previous reply, one risk is that the UE may keep reporting single-TRP CSI since the choice of reporting single-TRP CSI vs multi-TRP CSI is up to the UE. Hence, there is no guarantee for the network side to receive an NC-JT CSI from the UE. We prefer Option 1 Alt 3 as it provides the maximum scheduling flexibility as discussed in our previous reply. Overall, agreeing to multiple options at this time is not preferable as it would involve a lot of spec impact and UE cap discussions in the future. Hence, some more discussion before we downselect to one option is beneficial. |
| vivo | We agree to support both Option 1 and Option 2. In our view, Option1 and Option2 both are useful and suitable to various scenarios. The Network can configure multiple reporting hypotheses to increase the flexibility for scheduler. For Option1, we prefer Alt.3, i.e., X=0,1,2 to leave the flexibility to the network. |
| Nokia/NSB | Our preference is for Option 1 – Alt 3 or 2. We are ok with FL’s proposal of supporting both Options |

***Proposal 9:*** *For a CSI report associated with a Multi-TRP/panel NCJT measurement hypothesis configured by 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, for Multi-DCI based NCJT when the maximal transmission layers is less than or equal to 4.*

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| Huawei (Moderator) | Option 1: WA (if confirmed) is sufficient in Rel-17 so that new solution is not needed.[QC], Lenono/MotM, CMCC, Samsung, Ericsson, Vivo, NokiaOption 2: a new solution, as above, is needed in Rel-17. DOCOMO, MediaTek, LG, Intel, Spreadtrum, Based on the review, the discussion and preference are a little complicated. Clearly there is no companies suggesting that RAN1 shall support both mechanisms in Rel-17. On the other hand, the priority/preference, Proposal 9 versus WA agreed in RAN1 103, become less clear with slight favor over WA design, for example Nokia prefer WA firstly before P9, DC prefer P9 firstly before WA, Oppo prefer none of them. Therefore, from Moderator perspective, let us have further discussion for technical pros and cons, if any, until next Thursday (last MIMO session). Note that by default, neither Proposal 9 is supported, nor WA is to be confirmed this meeting.  |
| Apple | Support the proposalIt clear that we will support a solution of single CSI-ReportConfig, it is preferable to allow mDCI mTRP reporting to be supported for single CSI-ReportConfig configuration. We do not see a strong reason not allowing mDCI mTRP report to be supported for single CSI-ReportConfigOne the other side, we are not against confirming the WA. But it is irrelevant, i.e., confirming the WA does not mean that this proposal cannot be supported.CSI-ReportConfig just configures the CMR/IMR, and the association rule of CMR from different TRP, and the potential interference measurement assumption. In terms of whether it is sDCI or mDCI reporting, it is uncorrelated. In other words, we should not force NW to use one solution for sDCI and one solution for mDCI for no fundamental reason. |
| Lenovo/MotM | We do not support the proposal. Prioritizing single-DCI design should not preclude multi-DCI solution. We can discuss later but we shouldn’t favor one solution over the other based on a prioritization note. |
| QC | In our view, multi-DCI has less relevance with respect to CSI enhancements compared to single-DCI. This is because in multi-DCI, PDSCHs can be non/partially/fully overlapping. In the case of non-overlapping, no CSI enhancements are needed. In other cases, CSI enhancements only make sense if the resources are always completely (fully) overlapping. However, there is no configuration in Rel. 16 to configure the operation mode with respect to overlap in resources. Furthermore, the whole reason of these flexibilities in the case of multi-DCI was that for non-ideal backhaul, it hard for network to ensure that resources are always completely non-overlapping or completely overlapping. Now, we are not sure what has changed so that suddenly network can ensure that PDSCHs are always completely overlapping.Given this, having two solutions for multi-DCI does not make any sense to us. With respect to the choice between Proposal 9 and WA, we are flexible. But we cannot accept both. |
| OPPO | We agree with the concern from QC. Neither proposal 9 nor the WA can support different overlapping assumptions for M-DCI especially in non-ideal backhaul. We suggest discussing it later and prioritizing other proposals. |
| CATT | Option 1 is preferred. |
| NEC | We share similar view with QC and OPPO, and support Option 1. |
| DOCOMO | First, for multi-DCI based MTRP, if we do not consider the difference among non/partially/fully overlapping PDSCHs, no CSI enhancement is needed.Second, if we consider the difference among non/partially/fully overlapping PDSCHs, CSI enhancement can be considered. But it also means that the coordination among two TRPs in needed, e.g., on CMR/IMR configurations, and/or PDSCH scheduling. So that the latency for non-ideal backhaul should not be too large. In that case, enhancement on single CSI reporting is sufficient. We do not need two CSI reporting settings, which require large signaling overhead and spec. impact, for such a low latency non-ideal backhaul case. On the other hand, if the non-ideal backhaul has large latency, no CSI enhancement is needed since it is difficult for two TRPs to coordinate for partially/fully overlapping PDSCHs. |
| Intel | It seems for us that two options have fundamental difference: * WA is optimized for non-ideal backhaul while P9 is optimized for ideal backhaul.

If we need to do downselection at this stage we would prefer P9 over WA since gains from NCJT CSI are observed mainly in scenario with ideal backhaul. In scenario with non-ideal backhaul gains from NCJT-CS may be lower considering lack of coordination for joint scheduling.  |
| LG | We have similar view with Intel. If we need to do downselection, we prefer P9. |
| CMCC | We have same view with QC, OPPO and NEC, and we support the WA. |
| Ericsson | Similar view as QC. |
| vivo | First of all, we would like to confirm the work assumption. And we are also flexible to support both Proposal 9 and WA.Some observations and reasons for confirming the WA are as follows:1. We agree that the multi-DCI is mainly used for non-ideal backhaul scenario.
2. We agree that it hard for network to ensure that resources are always completely non-overlapping or completely overlapping, and, in our simulation, we also observe that. Due to overlapping uncertainty, we think the UE may assume completely overlapping when it wants to joint transmission to avoid the CQI mismatch. Besides, for lower RU case where joint transmission has a large gain, the probability of PDSCHs overlapping is obviously higher.
3. In our simulation, as shown below, Cat1 has a large performance loss than Cat2.

Some evaluation results in non-ideal backhaul scenarios (with 5ms and 50ms backhaul delay) are as following for your reference. From the results, UE recommendation of transmission scheme to different TRPs would help the different TRPs to schedule independently and make the feature more usable in real deployment.Table 1: Indoor Hotspot with non-ideal backhaul

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| --- | --- | --- | --- |
| FR1, RU for STRP (16%) | Mean UPT | 5% UPT | 50% UPT |
| STRP | -32.52% | -28.20% | -25.33% |
| DPS | -24.41% | -6.58% | -13.85% |
| Legacy CSI | -4.49% | -8.37% | -6.67% |
| Cat2 | 0.00% | 0.00% | 0.00% |
| Cat1 (5ms) | -4.69% | -6.96% | -7.57% |
| Cat1 (50ms) | -21.51% | -37.50% | -29.88% |

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| --- | --- | --- | --- |
| FR1, RU for STRP (38%) | Mean UPT | 5% UPT | 50% UPT |
| STRP | -31.63% | -35.61% | -30.45% |
| DPS | -14.43% | -13.14% | -7.06% |
| Legacy CSI | -12.31% | -13.41% | -15.24% |
| Cat2 | 0.00% | 0.00% | 0.00% |
| Cat1 (5ms) | -12.43% | -15.91% | -13.79% |
| Cat1 (50ms) | -35.44% | -45.29% | -38.42% |

Table 2: Dense Urban with non-ideal backhaul

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| --- | --- | --- | --- |
| FR1, RU for STRP (14%) | Mean UPT | 5% UPT | 50% UPT |
| STRP | -13.33% | -13.85% | -9.61% |
| DPS | -12.11% | -6.53% | -9.61% |
| Legacy CSI | -5.36% | -11.18% | -7.84% |
| Cat2 | 0.00% | 0.00% | 0.00% |
| Cat1 (5ms) | -2.52% | -5.85% | -4.08% |
| Cat1 (50ms) | -10.38% | -33.48% | -14.92% |

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| --- | --- | --- | --- |
| FR1, RU for STRP (25%) | Mean UPT | 5% UPT | 50% UPT |
| STRP | -8.53% | -13.78% | -4.05% |
| DPS | -6.51% | -7.41% | -1.22% |
| Legacy CSI | -4.66% | -11.56% | -4.05% |
| Cat2 | 0.00% | 0.00% | 0.00% |
| Cat1 (5ms) | -3.66% | -8.60% | -4.28% |
| Cat1 (50ms) | -16.34% | -36.95% | -21.17% |

Some illustration of evaluated schemes:

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| --- | --- | --- | --- |
| Scheme | CSI report | Scheduling | UE’s working mode |
| STRP | STRP CSI report to the serving TRP | UE scheduled by serving TRP | STRP |
| DPS | Cat2 framework: DPS CSI report to both TRPs | Independent scheduling | DPS |
| Legacy CSI\* | Two CSI report settings in legacy CSI framework: each with a STRP CSI report to its corresponding TRP | Independent scheduling | DPS or NCJT |
| Cat2 | Cat2 framework: UE selected NCJT CSI or DPS CSI report to both TRPs | Independent scheduling | DPS or NCJT |
| Cat1 (5ms) | Cat1 framework: UE selected NCJT CSI or DPS CSI report to a single TRP, CSI exchange with 5ms latency | Independent scheduling | DPS or NCJT |
| Cat1 (50ms) | Cat1 framework: UE selected NCJT CSI or DPS CSI report to a single TRP, CSI exchange with 50ms latency | Independent scheduling | DPS or NCJT |

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| Nokia/NSB | Our preference is to discuss P9 and the WA as two alternative solutions for m-DCI, after certain details of the s-DCI design become clear, such as the alternatives in P6. In our understanding the framework provided for s-DCI NC-JT measurement is flexible enough to be extended to the m-DCI case as well. Indeed, the only outstanding issue that may prevent extending the solution agreed for single Reporting Setting to m-DCI based NC-JT measurement is the configured uplink resources (PUCCH/PUSCH) for CSI reporting.One of the following mechanisms can provide a solution based on the agreement for single Reporting Setting: 1. two reporting settings with the same configurations except for PUCCH/PUSCH resources for CSI reporting.
2. a single reporting setting with two PUCCH/PUSCH resources for CSI reporting.

Solution 1) can be achieved starting from the WA, whereas 2) is what is proposed, in our understanding, with P9.Is it common understanding that P9 implies configuring two different PUCCH/PUSCH resources in the same Reporting Setting? |