**3GPP TSG RAN WG1 Meeting #109-e R1-2205424**

**e-Meeting, May 9th – 20th, 2022**

**Source: Moderator (NTT DOCOMO)**

**Title: FL summary on DMRS#3**

**Agenda item: 9.1.3.1**

**Document for: Discussion and Decision**

# Introduction

In RAN#94-e meeting, a new Rel-18 WID on MIMO [1] was agreed. From 7 objectives, there are two objectives for DMRS enhancements, as shown below.

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| 1. Study, and if justified, specify larger number of orthogonal DMRS ports for downlink and uplink MU-MIMO (without increasing the DM-RS overhead), only for CP-OFDM,  * Striving for a common design between DL and UL DMRS * Up to 24 orthogonal DM-RS ports, where for each applicable DMRS type, the maximum number of orthogonal ports is doubled for both single- and double-symbol DMRS   […]   1. Study, and if justified, specify UL DMRS, SRS, SRI, and TPMI (including codebook) enhancements to enable 8 Tx UL operation to support 4 and more layers per UE in UL targeting CPE/FWA/vehicle/Industrial devices  * Note: Potential restrictions on the scope of this objective (including coherence assumption, full/non-full power modes) will be identified as part of the study. |

The agreements in the 1st round are listed in sect. 6 in [28]. This document contains summary of the company’s proposal and FL proposals for round 2 discussion.

# Evaluation methodology (EVM)

EVM for LLS and SLS is agreed by email on May 13. However, there is FFS of precoding assumption of PDSCH/PUSCH in LLS. We should resolve this within RAN1#109e. There was a proposal of simulation method for MU-MIMO LLS, and it would impact on the following FFS, FL suggestion is to discuss FL proposal#2-1-6 in sect. 2.1 first.

**Agreement: (RAN1#109e)**

* **Following evaluation assumptions are used for LLS for increasing DMRS ports in AI 9.1.3.1 in Rel.18.**

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| **Parameter** | **Value** |
| Precoding and precoding granularity | For PDSCH: Companies can select and need to report which option(s) are used between   * [ZF or SVD] based sub-band precoding (with 4PRB precoding granularity) on ideal channel knowledge * CSI codebook based sub-band precoding (with 4PRB precoding granularity) on ideal CSI feedback.   For PUSCH: Companies can select and need to report which option(s) are used between   * [ZF or SVD] based wide-band precoding on ideal channel knowledge * Codebook based wide-band precoding on ideal CSI feedback. |

## Simulation method for MU-MIMO LLS

### Round3

On GTW discussion Monday 2nd week, FL proposal#2-1-6a was discussed, and Alt.1 was majority view because it can calculate interference more accurate. On the other hand, some companies showed concern to make Alt.1 as mandatory. It was also commented by Mr. Chairman that it is better to align the evaluation assumption, to compare the evaluation results fairly between companies. From FL perspective, it is preferable to select one option. Statistically, I assume there is not much difference between Alt.1 and Alt.2. Hence, I’d like to propose Alt.2.

**FL proposal#2-1-6a (pre-coding assumption of interference of co-schedules UEs):**

**For MU-MIMO LLS of PDSCH, the pre-coding assumption of interference of co-scheduled UEs is Alt.2.**

* **~~Alt.1: calculated by pre-coder of channel of each co-scheduled UE.~~**
* **Alt.2: calculated by random pre-coder (i.e. precoder selected randomly** **from a predefined set of precoders).**
* **~~Alt.3: the same pre-coder as scheduled UE.~~**

**FL proposal#2-1-6b (power ratio):**

**For MU-MIMO LLS of PDSCH, assuming transmit power of the scheduled (target) UE is 1, transmit power of other co-scheduled UE(s) is:**

* **Alt.1: Selected as one value from {0dB, -3dB, -6dB} as fixed evaluation parameter.**

Please provide your views:

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| --- | --- |
| **Company** | **Comment** |
| DOCOMO | FL proposal#2-1-6a: Support.  FL proposal#2-1-6b: Support Alt.1 for simplicity. |
| CATT | Regarding FL proposal 2-1-6a, based on Jianwei’s explanation in FL summary v23, I think the wording “**same pre-coder as scheduled UE**” is somewhat misleading.  Actually from my reading, “same precoder” means the ith port is precoded with its corresponding precoding vector Wi, and the precoder for all the ports being transmitted is composed of this set of precoding vectors, each for a layer/port. That is, W=[ W1,…, WN] is precoder for all the N ports.    Intuitively, “same precoder” sounds like that the same Wi applies to all the layers/ports being co-scheduled. However, based on Jianwei’s description, that is not the case.  So, if my understanding is correct, compared with Alt-1, Alt-3 is more suitable for modeling of MU-MIMO.    With Alt-1, the channels from all the potentially co-scheduled users need to be modeled. Given that full CSI at gNB side is already modeled, if the goal of such complicated modeling is to reflect the performance of MU more accurately, why not to calculate the precoding vector for each layer/port based on all the channels of co-scheduled uses?  The precoding scheme proposed in Alt-1 is acrually single-user precoding rather than multi-user precoding. In practice, such kind of precoding cannot work for MU transmission at all.  In addition, if the channel and noise are randomly generated in each simulation, the precoder for co-scheduled user and consequently the inter-user interference are all randomly distributed. In such case, what’s the difference between Alt-1 and 2?  If there is no fundamental difference, why do we need to take the cost of such complicated modeling with Alt-1?    As discussed above, with Alt-1, the lever of residual inter-user interference is already distributed randomly. And why do we still need to model a randomly distributed power of co-scheduled UEs as in Alt.2 of FL proposal 2-1-6b?  l  **Alt.2: Decided by random distribution with the following probability.**  -            **Alt. 2-1: the probability of each value of {0dB, -3 dB, -6dB} is the same.**  -            **Alt. 2-2: the probability of each value of {0dB, -3 dB, -6dB} can be different. The higher CQI, the lager power ratio (FFS: details).** |
| Moderator | FL proposal#2-1-6a, let’s try to agree on Alt.2.  For FL proposal#2-1-6b, I agree with CATT that Alt.1 should be enough. |
| OPPO | For proposal#2-1-6a, we think precoder generated by random channel is equivalent to a random precoder but with significantly higher evaluation complexity. We think Alt.2 or Alt.3 are better way than Alt.1. We are fine with the compromise that companies report the applied interference precoder modelling among Alt.1-3.  For proposal#2-1-6b, we agree with CATT that Alt.2 is redundant and Alt.1 should be used. |
| Samsung | We are generally fine with FL proposal#2-1-6a. Also, we have similar view with FL and Chair that aligning simulation assumption is definitely beneficial. BTW, we would like to ask FL about what the difference between Alt1 and Alt2. Our understanding is that since there is no MU scheduling procedure in LLS, although we consider Alt1, all the channels of co-scheduled UEs are anyway generated randomly (i.e., random dropping of UEs multiple times). Hence, we are not sure what the difference between Alt1 and Alt2.  Regarding FL proposal#2-1-6b, either way is fine but Alt1 seems enough as FL and CATT mentioned. |
| QC | For proposal #2-1-6a,  We still support Alt 1, as that is what MU-MIMO means – use different precoders to boost the SNR of target UE while supress the interference from other UEs.  @OPPO, regarding “we think precoder generated by random channel is equivalent to a random precoder” – we think these two are very different. The former is selecting precoder matching random realization of the channel, while the latter is just blindly select a random precoder ignoring what the channel is. The former is closed-loop MU-MIMO while the later is open loop MU-MIMO. They are very different. I think we need model closed loop MIMO, i.e., Alt 1.  As for Alt 3, sorry I still don’t understand it, even after CATT’s further clarification. In MU scenario, each UE has different channel, how to determine a precoding vector for each DMRS port? The determination is with respect to which UE’s channel?  For proposal#2-1-6b, we support Alt 1. |
| CATT2 | Based on current revision of FL proposal#2-1-6a, seems we still need to generate random channel of each of the N users. If so, we would like to understand the difference between Alt-1 and 2. As OPPO mentioned, **pre-coder generated by random channel** is equivalent to random precoder.   * **~~Alt.1: calculated by pre-coder of channel of each co-scheduled UE.~~** * **Alt.2: calculated by pre-coder generated by random channel.**   Regarding FL proposal#2-1-6b, as we commented before, Alt.1 is sufficient. |
| vivo | For proposal#2-1-6a, we are ok with Alt 2. It seems there is no difference between Alt 1 and Alt 2, since they both depend on the channel generated randomly for each UE. Then precoders can be calculated for each UE by joint precoding across all users for PDSCH, and precoders can be calculated for each UE by separate precoding for PUSCH.  However, the distribution of the randomness should be further defined, e.g.,  AoD is uniformly distributed within [-60,60] degrees;  ZoD is uniformly distributed within [90,135] degrees;  AoA is uniformly distributed within [-180,180] degrees;  ZoA is uniformly distributed within [45,90] degrees;  Additionally, multiple drops can be simulated for more randomness, and the number of drops can be provided by companies.  For proposal#2-1-6b, we prefer Alt 1. |
| Moderator | For “random precoder”, sorry for ambiguity. Let’s categorize with the following.   * “precoder generated by random channel” is selecting precoder matching random realization of the channel. This would be equivalent to Alt.1. * “random precoder” is randomly selecting a precoder regardless of the channel is. Now this is Alt.2. |
| CATT3 | Thanks moderator for the clarification.  Regarding the update of FL proposal #2-1-6, we support the following alternatives   * Updated Alt.2 of FL proposal #2-1-6a * Alt.1 of FL proposal #2-1-6b |
| Ericsson | I moved our late comment for last round here, which is still valid and helps to explain why Alt-1 and Alt-2 may not work.  We’d like to further share our view on the LLS assumptions.  In Alt proposal#2-1-6a Alt-1/2 that channel parameters should be dropped randomly. If each company does this independently, results from different companies will not be comparable. To allow comparisons all parameters would instead have to be agreed upon rather than dropped randomly.  To use one specific drop of multiple Ues and channels will not make it possible to evaluate cross UE interference in a systematic way. That would require averaging over **a large number of drops**, but then we are doing system level simulations and **not link level simulations**.  **Cross UE interference** **should instead be emulated by transmitting other UE DMRS’s over the same precoder and channel as used for the studied UE but with a variable power ratio**. Note that any drop of Ues and channels would give equivalent results as such a simple emulation model, for correctly selected power ratios.  **To emulate cross UE interference for single layer transmission**, the received signal can be written as  where H is the channel, W is the single precoder, and is the one port DMRS signal for the studied UE, while are the one port DMRS signals emulating the interference from other Ues and are the corresponding power ratios. Note that any UE and channel drop can be emulated in this way. For the study we think it’s sufficient to set all to the same value, e.g. 0dB, -3dB, -6dB.  This emulation scheme is easily generalized to multi-layer transmission. For n layers the received signal can be written as  where H is the channel, is the precoder used for layer i, and are the n single port DMRS signals for the studied UE, while are the m single port DMRS signals emulating the interference from the DMRS of other Ues and are the corresponding power ratios. Note that any UE and channel drop can be emulated in this way. For the study we think it’s sufficient to set all to the same value, e.g. 0dB, -3dB, -6dB.  On FL proposal#2-1-6b (power ratio) we note that if alt. 2-1 is agreed, the result for any probability distribution as discussed in alt. 2-2 can be very simply calculated based on the alt. 1 results. We therefore propose that alt. 2-1 is agreed.  In general, we think one should avoid averaging link level results over various parameters. Link level results should be kept elementary to allow flexible utilization of the results depending on what scenario one wants to study. This also makes it easier to compare results from different companies.  We note also that when NR Rel. 15 DMRS was designed no ‘MU MIMO link simulations’ were done. We find this whole idea strange and fear it will just lead to a lot of wasted time.  Another point to make regarding Alt-1 in #2-1-6a is that channel estimation needs to be done for each UE Rx antenna individually before any type of receiver either non-MIMO or MIMO (i.e., channel information is needed for receiver calculation), therefore talking about UE possibly rejecting/suppressing other UE's DMRS interference is non-sense, which can only be done after channel estimation.  Regarding Alt-2 in #2-1-6a, we don't think it's clear what is meant by ”Alt.2: calculated by pre-coder generated by random channel."  Please describe exactly what this means. What is randomized in the channel? UE position? Clusters? Angular spreads?? Are the link simulations support to be averaged over the random channel?  If the link simulations are averaged over 'random channels' they are not really link simulations. If, on the other, one channel is used it's not really a random channel but some channel that needs to be agreed upon.  Regarding updated Alt-2:  Q1: What set of precoders? Needs to be defined.  Q2: Are linksimulations supposed to be averaged over these precoders? |
| Huawei, HiSilicon | Considering that companies’ directions are very divergent, we here first clarify our understanding and then show our position.  The most concrete MU-MIMO modelling should be done by generating different channels for different UEs and the MU precoder (e.g., ZF based on eigenvectors) which is able to supress the interference from co-scheduled UEs should be utilized. In real MU-MIMO scenario, since the channel information is non-ideal, there still exists some interference between co-scheduled UEs after MU-MIMO precoding.  If companies consider this to be over-complicated for modelling and the MU-MIMO precoding algorithm to be hard to align, we can also live with the following simplified modelling method:  1. The channel between each UE and gNB should be generated independently (e.g., as ZTE suggested in round 1);  2. The precoding of each UE is conducted individually (e.g., SVD based on each UE’s own channel), the large-scale fading difference and the interference suppression effect brought by MU-MIMO precoding are reflected by the power ratio.  Based on the analysis above, regarding FL proposal#2-1-6a, we support Alt.1; regarding FL proposal#2-1-6b, we support Alt.2-1 with detailed probability modelling. |
| ZTE | For proposal#2-1-6-a (precoding assumption), we prefer Alt.1. For the sake of progress, we can live with Alt 2 by stating the correlation coefficient between target channel and other co-scheduled channels is mandatory to a allowable range, i.e. [0 0.5]. Otherwise, randomly generate channels may lead to spatial multiplexing become marginal like Alt 3, which is very far away the real channel propagation in MU-MIMO scenario.  **FL proposal#2-1-6a (pre-coding assumption of interference of co-schedules UEs):**  **For MU-MIMO LLS of PDSCH, the pre-coding assumption of interference of co-scheduled UEs is Alt.2.**   * **~~Alt.1: calculated by pre-coder of channel of each co-scheduled UE.~~** * **Alt.2: calculated by random pre-coder (i.e. precoder selected randomly** **from a predefined set of precoders), where the correlation coefficient between any two pre-coders in the range of [0 0.5]..** * **~~Alt.3: the same pre-coder as scheduled UE.~~**   For proposal#2-6-1-b, our initial Alt. 2-1 is to set the same transmitting power among channels of target UE and other co-scheduled UEs, which is similar to Alt.1 (when the fixed value is 0dB) in fact. Regarding our Alt. 2-2, it is Alt. 2-2 in proposal#2-6-1. As we ventilated in Round-2, our preference is Alt.1 to simply the simulation complex. To avoid any ambiguous, we noticed that the term of “the power” should be clarified as “the transmitting power”. Besides, due to this proposal aims to calibrate power ratio assumption, we suggest to state “power ratio” in this proposal.  **FL proposal#2-1-6b (power ratio):**  **For MU-MIMO LLS of PDSCH, the transmitting power ratios of the scheduled (target) UE and other co-scheduled UE(s) are:**   * **One fixed value as evaluation parameter.**   **Note: The fixed value is optionally determined by companies.** |
| Lenovo | Support updated FL proposal#2-1-6a. We think the preconfigured set can control MU-user interference to avoid unnecessary large interference by random precoder, where the cases with large interference can be avoided by actual MU scheduling/pair algorithms.  We are fine with Alt.1 of FL proposal#2-1-6b on account of simplicity. |
| Spreadtrum | For proposal#2-1-6a, we support Alt2. There’s balance between realistic and low complexity. For any of these 3 alternatives, there’s no MU pairing procedure, so we can only compare with the performance under the same interference assumption.  For Alt3, our understanding is that the residual interference transmitted with the actual precoder for interference UE observed by the target UE is treated as the signal transmitted by the ‘same precoder as scheduled UE’ with scaled power. We are not clear if our understanding is correct. And if yes, Alt3 is not complete since we will need to have another round of discussion to define the power distribution of interference which we haven’t studied.  For Alt1 and Alt2, Alt1 may have the issue that the interference UE should not be co-scheduled in practice, while Alt2 may have similar issue that some precoders may point to a direction where UE may never be located. Considering that the simulation complexity for Alt2 is much lower than Alt1, Alt2 is preferred.  For proposal#2-1-6b, support Alt1 for simplicity. |
| Moderator | For FL proposal#2-6-1a, I’m not sure “*, where the correlation coefficient between any two pre-coders in the range of [0 0.5]*” from ZTE is acceptable. It becomes not “random” precoder anymore. But, more companies’ inputs are appreciated.  Regarding to Ericsson’s question to Alt.2,   |  | | --- | | Q1: What set of precoders? Needs to be defined.  [Moderator] Companies can define it.  Q2: Are linksimulations supposed to be averaged over these precoders?  [Moderator] Please see the latest version. Random pre-coder is clarified as “precoder selected randomly from a predefined set of precoders”. |   For FL proposal#2-6-1b, ZTE’s suggestion has no difference from the current proposal (actually, the current value means the power ratio). Also, I prefer to have common value set of power ratio, rather than letting companies to decide. Hence, no update is made. |
| Ericsson | @Spreadtrum: I think the interpretation you have on Alt3 is correct. And the power distribution is the same as being discussed in #2-1-6b Alt1. So, we don’t need another round of discussion.  Alt3 is simpler and make the results **comparable** cross the companies.  If it is up to companies to define their own set of precoders, it is completely impossible to compare the results. It is still unclear to us if companies are going to make multiple drops of the random precoder and average the result over the drops. |
| Fraunhofer IIS/HHI | Proposal #2-1-6a: Fine with the revised Alt. 2 (OK with the constraint on low correlation by ZTE as well)  Proposal #2-1-6b: Support the fixed power difference as in Alt. 1 |
| Nokia/NSB | First, we think the power offset is valid only with Alt 3, which emulating MAI. For Alt1 and Alt 2, we don’t see any reason to take such power offset. (We don’t use DL dynamic power control, only channel precoders are different.  Second, we are sympathy with Ericsson view. We don’t think Alt 1 and Alt 2 are realistic condition for LLS. Such MU pairing has much implementation aspect, and this can be evaluated by SLS with the consideration of scheduling, geometry etc.  At least for LLS, it is intended for the performance evaluation when certain level of interference comes. In addition, we believe that the main motivation of this agenda is to increase the orthogonal DMRS ports when higher interference is expected. We can use non-orthogonal DMRS for spatial multiplexing by using ZF or MMSE precoder. So, at least we have to see the pure performance with new DMRS pattern assuming higher/medium/low interference. But, evaluation result with the alt1 or alt2 should be highly impacted by precoder configuration, and possibly almost impossible to emulating all different cases. We have too much randomness of time-frequency channel, UE paring.  We don’t object to perform evaluation with Alt 1 or Alt 2. Instead, we think at least the evaluation independent from percoding configuration should be performed.  In that sense, we support following proposal.  **FL proposal#2-1-6a (pre-coding assumption of interference of co-schedules UEs):**  **For MU-MIMO LLS of PDSCH, companies report the pre-coding assumption of interference of co-scheduled UEs between two options below.**   * **~~Alt.1: calculated by pre-coder of channel of each co-scheduled UE.~~** * **Option 1: calculated by random pre-coder (i.e. precoder selected randomly** **from a predefined set of precoders).** * **Option 2: the same pre-coder as scheduled UE.**   **Power offset of the co-scheduled UE is used in {0dB, -3dB, -6dB}** |
| LGE | For proposal #2-1-6a,  In our understanding, Alt1 is aligned with practical scheduling on MU-MIMO. However, LLS simulation for MU scheduling is not possible, and I think the simplification of the simulation is also necessary for simulation accuracy and result comparison. Therefore, Alt2 can also be supported if make sure what the difference between Alt1 and Alt2.  For proposal#2-1-6b, we support Alt 1. |
| Ericsson | We would like to make some general comments.  We all agree that the main use case for increasing the number of DMRS ports is MU-MIMO. However, this doesn’t mean that the evaluation of the new DMRS ports have to be done based on MU-MIMO. The properties of new DMRS ports can be studied on a general level without the complexity of MU-MIMO. This was how it was done for NR Rel. 15 and there are good reasons why this is the case. To simulate MU-MIMO will bring no new understanding of DMRS port design. It will rather complicate the analysis.  In our view, **the main things** that need to be evaluated for the new DMRS design are:   1. **Channel estimation accuracy due to the reduced DMRS density to support more DMRS ports under realistic channel conditions with delay spread and Doppler spread**  * This can be evaluated with LLS with a single UE  1. **Inter-DMRS ports interference due to, e.g., increased OCC length, under realistic channel conditions with delay spread and Doppler spread**  * This is applicable to both SU-MIMO and MU-MIMO, the only difference for MU-MIMO is that some interference reduction can achieved by precoding in DL  1. **The new DMRS design should be good for both DL and UL**   Given the above, the new DMRS designs can be most efficiently studied using a single UE with rank 1 with  1**. No cross UE interference**: this can be used **to evaluate #1** above  or  2**. Cross UE interference** emulated by transmitting the DMRS ports not used for the UE on the same precoder as is used for the studied UE with a power ratio, e.g. 0dB, -3dB, -6dB,…. This can be used to **evaluate #2**. Keep in mind that the new DMRS designs need to be good in both DL and UL and there is no cross DMRS ports interference reduction in MU-MIMO in UL, i.e., each Rx antenna receives all DMRS ports in roughly the same power level under ideal power control, which corresponding to 0dB power offset.  **We should not turn the link level simulations into system level simulations.** To specifically study MU-MIMO gains it’s perfectly fine for companies to perform SLS.  To address ZTEs concern about spatial multiplexing we note that this can be addressed by simply having a bigger power offset for the emulated interference, say -20dB. Alternatively, one may perform LLS without cross UE interference. Such simulations were used a lot in for the Rel. 15 DMRS evaluations and do show the degradations due to delay spread and Doppler spread that we are interested in investigating.  Therefore, we think **Alt.3 is the most effective and efficient way for the new DMRS evaluations**. |
| MediaTek | Proposal #2-1-6a: We prefer Alt. 3 as proposed by Ericsson, we believe this option will lead to more reproducible and unified simulation results. Furthermore, it is less complex to simulate without loss of ability to model the impact of new DMRS designs on MU-MIMO performance.  Proposal #2-1-6b: We support Alt. 1. |
| Ericsson | We would like to clarify one more thing about Alt.3.  In Alt.3 only PDSCH intended to the target UE is transmitted. For other UEs, only DMRS are transmitted. In this way, the robustness of DMRS design is evaluated, which is decoupled from MU-MIMO receiver for PDSCH. In our view, LLS should be used to evaluate DMRS design, hence interference on DMRS should be efficient. |

FYI, companies’ inputs in the 2nd round is in the following table:

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| **Company** | **Comment** |
| ZTE (round1) | For MU-MIMO link level simulation, the simulation method should be decided first for the results alignment in the later simulation. So we give our suggestion as follows:   1. Generate N channels associated with N UE, each channel with a number of random parameters and one set of cluster angle, i.e. ZOA,ZOD,AOA,AOD; 2. Different PDSCH/DMRS ports for different Ues associated with different channels, and independent PMI calculation based on different channel for each Ues. 3. For UE1, other PDSCH with respective precoding is treated as interference, a power ratio P can be considered, e.g. 0dB, 3dB, 6dB or other values. 4. The PDSCH received by UE1 is , MMSE or other receiver types can be adopted, and the BLER or throughput is performed based on PDSCH of UE1.   It will be appreciated if other companies shares the MU simulation method for the results alignment. |
| ZTE2(round1) | We would like to ventilate that this setting aims for controllable interference leakage between multiple channels when MU-MIMO, so it is closer to the real scenario when compared ZF. In additional, as we mentioned in section 2.1.3, the outcome of this proposal should be taken into consideration of PDSCH precoding method in proposal#2-1-3. |
| Ericsson(round1) | Regarding the proposal to emulate MU MIMO with N channels, so in our view, this is not needed. Because we only concerned about interference at one UE, and all the interference should go through the same channel associated with the desired UE. (As illustrated below in the Figure)  グラフ, レーダー チャート  自動的に生成された説明  Therefore, only the channel for the desired UE needs to be generated. And the interference from other UEs can be emulated by transmitting different DMRS ports intended for other UEs on the same single channel with different precoders. It is not trivia to specify different precoder for different UEs because depend on the UE location and other factors. The end effect of different precoders is the power leakage between UE channels. Therefore, in our view, this can be achieved by using a same precoder with different power ratios for different UE. We think this is much simpler and easier to setup and compare between companies. |
| Samsung(round1) | We are fine with having detailed MU-MIMO simulation set-up since MU-MIMO simulation is baseline in 2.1.3 MIMO setting. We would like to recall our comment to Ericsson in 2.1.3 MIMO setting. Since the other UE’s precoders can be decided by other UE’s channel (i.e., N-1 channels), it would be generated. Same precoders for UEs scheduled by MU-MIMO seems not appropriate. We would like to see other companies’ view on this. |
| Ericsson 1 | Maybe there’s some miss understanding on precoder setting. The UEs are using different precoder, as in the figure, w1 , w2 , w3 are the different precoders for each UE, but for the targeting UE we are interested, we are evaluating the interference caused by co-scheduled UEs. At the target UE, the effective interference is caused by leakage from the co-scheduled UE, though the UE uses different precoder, has different channels, the interfering part relevant to **the target UE** can be modeled as different power ration using same precoder and same channel.  With such approach we could compare companies MU-MIMO result by using same setting of power ratios as the interference from co-scheduled UEs.  Hope this explains better our proposal. |
| ZTE | In principle, the interference caused by around UEs should be reflected as real as possible.  By comparing ZF and SVD, our proposed method aims for evaluating the realistic MU-MIMO by taking independent PMI as well as power ratio of other channels into account of SVD. Given that CSI codebook on ideal CSI feedback has already been one endorsed option, interference from other UEs in MU-MIMO will be marginal when taking ZF as another option. Hence the meaning of the MU-MIMO evaluation results will be agnostic if both CSI codebook on ideal CSI feedback and ZF are to be optional simultaneously.  W.r.t the precoders of UE1 and its co-scheduled UEs, we think it should be independent/different. In addition of power leakage from other channels, spatial diversity is another critical aspect which should be considered for interference in MU-MIMO scenario. That is, if precoders of UE1 and its co-scheduled UEs is mandatory to be the same, UE1 cannot be able to identify the spatial filter/beam of its channel-1, and then the interference from other UEs will be inevitable even taking larger DMRS ports. Thus, both PMI and power ratio of each channel should be independent for MU-MIMO simulation to approach the real MU-MIMO. |
| OPPO | We also think modeling of N channels are not mandatory. In LLS, it is difficult to model the practical MU-MIMO scheduling as in SLS. Even when N independent channels are generated, the orthogonality among UEs cannot be guaranteed. The precoders derived from N channels with random parameters and random angles are similar to random precoders actually. Hence, we propose to use random precoders for co-scheduled UEs instead of N random channels. |
| Lenovo | We think it is not easy to make refined simulation for MU-MIMO interference since the MU pairing/scheduling algorithm, UE dropping may be not realized in LLS. So we prefer Ericsson’s proposal for further discussing since it can reduce simulation realization complexity and be beneficial for calibrating the simulation results between companies. In detail, the inter-user interference is reflected by power ratio and precoder. To reflect interference with precoding, we prefer random precoding for interference (i.e. random precoding for w2, w3 for Ericsson’s example) as OPPO’s suggestion. Furthermore, we have a detail question on modelling for the power ratio (i.e. what’s the distribution for power ratio?). |
| vivo | According to the antenna setup and port layouts at gNB agreed, it implies that there would be an analog beam from the gNB side. Therefore, it is more appropriate to generate the different channel corresponding to different UEs with the same set of cluster angle, i.e. ZOA, ZOD, AOA, AOD in LLS evaluation. We would like to clarify that different channel corresponding to different UEs can be generated simultaneously as a full channel with all DMRS ports. Regarding the precoding, we support to generate N different precoders to reflect the realness as much as possible. Finally, the interference from other UEs on the target UE would be naturally modeled after precoding. The only issue is that how to determine the power ratio P of different UEs, we suggest that the P of the target UE is 1, and P of other UEs can be selected from a set, e.g., {0dB, 1dB, 2dB, 3dB, 6dB}. |
| Xiaomi | Support to model the interference as different power ration using same precoder and same channel, as proposed by Ericsson, for the sake of reducing simulation realization complexity. |
| Ericsson 2 | Regarding ZTE’s comment: “… our proposed method aims for evaluating the realistic MU-MIMO by taking independent PMI as well as power ratio of other channels into account of SVD …”, we would like to point out that ZTE’s intention is good, however, even N independent channels are used, they only correspond to Ues at one set of locations associated with the configured AOAs/DOAs etc. The resulted cross UE interference by the PMIs are just due to one drop of Ues. It is a bit of stretch to say it is more realistic. As for ZTE’s comment “ … UE1 cannot be able to identify the spatial filter/beam of its channel-1… “, our understanding is that the DMRS design should work for Ues without beamforming capability, simulating UE’s with beamforming capability in rejecting other Ues’ DMRS interference should not be part of the study in our view as it can vary depending on UE beamforming capability, number of layers allocated to the UE, etc.  Regarding Lenovo’s question on the distribution for power ration, we think one simple setup is to configure the same power for all Ues, or same power for all interfering Ues, e.g., -3dB with respect to the desired UE. |
| ZTE2 | Regarding the setup of power ratio (denoted as “*p*i”), we would like to further share our opinions by the following two alternatives:  **Alt. 1:** *p*1 = *p*2 = ... = *p*N  **Alt. 2:** the power ratio of each co-scheduled UE depends on its CQI. In other words, the higher CQI, the lager power ratio.  For Alt. 1, that means the power ratio of each co-scheduled UE is to be equal from the perspective of NW scheduling, which is straight and simple. For Alt. 2, power ratio is distributed proportionally by CQI, it requests CQI of each co-scheduled UE should be calculated and compared. To make simulation easier, we prefer Alt. 1.  In addition, it should be noted that due to the power ratio determination above, independent precoding is needed for power leakage from other Ues. |
| CATT | Agree with Ericsson and OPPO, the channel of the target UE is mandatorily modelled in MU-MIMO LLS. Modeling of all the other N-1 channels of co-scheduled Ues is not necessary.  If our goal is just to improve the accuracy of evaluation and to reflect the performance in practical MU-MIMO operation, generating N channels associated with N UE in LLS may not be the right choice. The reasons lie in several aspects:  1. The performance of MU-MIMO depends largely on the strategy of scheduling which is barely modeled in LLS. In practical system, depending on the scheduling algorithm, the N Ues may not even be scheduled together. Therefore, without the modeling of scheduling, modeling of N Ues’ channels solely is still not meaningful to the improvement of evaluation accuracy.  2. To our understanding, “**independent PMI calculation based on different channel for each UE**” implies single-user precoding rather than multi-user precoding. If that is the case, the residual inter-user interference after MU precoding is never reflected in the whole simulation.  Based on the analysis above, seems the outcome of the modeling of N channels in LLS is just higher complexity in generating more channels in simulation, rather than accuracy improvement. If so, we would rather use SLS to model the whole procedure of MU scheduling and MU precoding than using such kind of complicated but inaccurate LLS. However, the operation of channel estimation is not modeled in SLS usually. And as there are many other factors having impact on the final performance, we may not deduce the reason for influencing the performance of different DMRS patterns easily from SLS.  So, the main reason for using LLS rather than SLS is to help us to focus on the impact of directional or spatial selective inter-user interference with different leakage levels on the performance of channel estimation of DMRS in MU-MIMO. To achieve that, no fundamental difference between 1-channel and N-channel modeling can be foreseen. Therefore, to better trade off the accuracy against complexity, modeling of the channel of one target user is sufficient to us.  If only the channel of the target UE is modeled, random precoding is preferred for other co-scheduled Ues. With regard to power ratio, we support to introduce a fixed power ratio (e.g. 0dB, 3dB, 6dB or other values) for other co-scheduled Ues in the simulation. |
| Moderator | Thank you for the inputs. We have two discussion points for MU-MIMO PDSCH LLS assumption   1. How to calculate the precoder of interference of co-schedules Ues 2. How to assume power ratio between scheduled UE and co-scheduled UE(s).   I propose two following proposals for GTW discussion on Monday 2nd week.  **FL proposal#2-1-6a (pre-coding assumption of interference of co-schedules Ues):**  **For MU-MIMO LLS of PDSCH, the pre-coding assumption of interference of co-schedules Ues is**   * **Alt.1: calculated by pre-coder of channel of each co-scheduled UE.**   + Supported by: ZTE, QC, Samsung?, vivo * **Alt.2: random pre-coder.**   + Supported by: OPPO * **Alt.3: the same pre-coder as scheduled UE.**   + Supported by: Ericsson, Xiaomi, Nokia   **FL proposal#2-1-6b (power ratio):**  **For MU-MIMO LLS of PDSCH, assuming the power of the scheduled (target) UE is 1, the power of other co-scheduled UE(s) is:**   * **Alt.1: Selected as one value from {0dB, -3dB, -6dB} as fixed evaluation parameter.**   + Supported by: vivo, Ericsson, Nokia * **Alt.2: Decided by random distribution with the following probability.** * **Alt. 2-1: the probability of each value of {0dB, -3 dB, -6dB} is the same.** * **Alt. 2-2: the probability of each value of {0dB, -3 dB, -6dB} can be different. The higher CQI, the lager power ratio (FFS: details).**   + Supported by: ZTE |
| Nokia/NSB | We have similar view with Ericsson, so no detail simulation assumption is needed for MU-MIMO.  Assuming the same precoder across different Ues should be one scenario and it can be used as a starting point. We cannot emulate all cases with MU-MIMO channel conditions. The main motivation of orthogonal DMRS ports is for overcoming the multi-user interference when sufficient spatial separation is difficult toobtain. Also, even though we are assuming TDD, we think that FDD is also very important when considering MU-MIMO. Then, we cannot fully utilize channel state information other than PMI reported. So, we prefer the same precoder as a baseline, and each company can additionally provide the result with further advanced assumption.  Regarding to value “N”, at least in DL, we can assume number of layers per UE is to be large. (e.g. 4 or higher), In this case, if we only focus on DMRS based channel estimation, interference only related to the Ues sharing same DMRS RE can be considered. |
| Ericsson 3 | We’d like to further share our view on the LLS assumptions.  ZTE writes that channel parameters should be dropped randomly. If each company does this independently, results from different companies will not be comparable. To allow comparisons all parameters would instead have to be agreed upon rather than dropped randomly.  To use one specific drop of multiple Ues and channels will not make it possible to evaluate cross UE interference in a systematic way. That would require averaging over a large number of drops, but then we are doing system level simulations and not link level simulations.  Cross UE interference should instead be emulated by transmitting other UE DMRS’s over the same precoder and channel as used for the studied UE but with a variable power ratio. Note that any drop of Ues and channels would give equivalent results as such a simple emulation model, for correctly selected power ratios.  To emulate cross UE interference for single layer transmission, the received signal can be written as  where H is the channel, W is the single precoder, and is the one port DMRS signal for the studied UE, while are the one port DMRS signals emulating the interference from other Ues and are the corresponding power ratios. Note that any UE and channel drop can be emulated in this way. For the study we think it’s sufficient to set all to the same value, e.g. 0dB, -3dB, -6dB.  This emulation scheme is easily generalized to multi-layer transmission. For n layers the received signal can be written as  where H is the channel, is the precoder used for layer I, and are the n single port DMRS signals for the studied UE, while are the m single port DMRS signals emulating the interference from the DMRS of other Ues and are the corresponding power ratios. Note that any UE and channel drop can be emulated in this way. For the study we think it’s sufficient to set all to the same value, e.g. 0dB, -3dB, -6dB. |

## Remaining issue of EVM for LLS

### Round3

We need to resolve the FFS in EVM for LLS in RAN1#109e agreement. Alt.2-3 was added by Ericsson in round2, but from FL perspective, I have some questions to Alt.2-3 (please see in the table).

**FL proposal#2-1-3a (2nd round):**

* **For LLS assumptions for increasing DMRS ports in AI 9.1.3.1 in Rel.18:**
  + **Precoding assumption of PDSCH, “**[ZF or SVD]**” in RAN1#109e agreement is updated by**
    - **~~Alt.1-1: ZF~~**
    - **Alt.1-2: SVD**
      * **Only the channel of one desired UE, i.e. Hd, needs to be modelled. SVD is performed based on Hd to obtain the precoder for this UE only. The interference from co-scheduled Ues can be modelled as , wherein can be randomly selected from a predefined set of precoders (Based on random pre-coder in FL proposal#2-1-6a)**
    - **~~Alt.1-3: SVD based independent pre-coding for each UE (in FL proposal#2-1-6)~~**
  + **Precoding assumption of PUSCH, “**[ZF or SVD]**” in RAN1#109e agreement is updated by**
    - **~~Alt.2-1: ZF~~**
    - **Alt.2-2: SVD**

Please provide your views:

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| --- | --- |
| **Company** | **Comment** |
| Moderator | **For Alt. 2-3:**  **@Ericsson,** I’m not sure why we need to clarify “single layer” here? As we agreed, rank = 1/2/4 can be considered. Also, what is pre-coding assumption in Alt.2-3? If you are talking about CSI-codebook based, it is already agreed. We are now discussing on [ZF or SVD] based precoding.  (Agreements in RAN1#109e)  MIMO Rank: 1, 2, or 4 per UE (rank fixed or rank adaptation)  For PUSCH: Companies can select and need to report which option(s) are used between   * [ZF or SVD] based wide-band precoding on ideal channel knowledge * Codebook based wide-band precoding on ideal CSI feedback.   **For other alternatives**  Since some companies showed concern on ZF, hence Alt.1-1/1-2 are deleted.  Since Alt.2 is proposed in FL proposal#2-1-6a, Alt.1-2 is also proposed for PDSCH in the above.  Between Alt.2-2/2-3, since Alt.2-3 is not clear, FL suggestion is to take Alt.2-2. |
| DOCOMO | Support Alt.1-2 and Alt.2-2. |
| OPPO | We prefer Alt.1-2 and Alt.2-2. |
| Samsung | Support Alt1-2 and Alt2-2. We are also not sure what the intention of Alt2-3 is, since the number of layers and precoding granularity of frequency domain was already agreed. |
| QC | For “Alt.1-2: SVD”, we have a question for clarification: Does Alt.1-2 mean joint SVD cross all users in MU-MIMO scenario? If yes, then it is conflicting with proposal in Section 2.1. If no, then what is the difference between Alt 1-2 and Alt 1-3?  We support Alt. 2-2. |
| CATT | @QC: regarding the question from QC, our understanding is that **if we agree on using random precoders for co-scheduled Ues** (noted as for the ith co-scheduled UE), only the channel of one desired UE, i.e. Hd, needs to be modelled. And then, SVD is performed based on Hd to obtain the precoder for this UE only. The interference from co-scheduled Ues can be modelled as , wherein can be randomly chosen from a predefined set of precoders.  We know this is not perfect from accuracy point of view, as MU precoding and scheduling are not actually modelled. However, compared with the approach requiring the modelling of all the N channels in LLS, the complexity is drastically lower.  Regarding Alt.1-3, since the precoder for each user is calculated independently, it doesn’t mean joint SVD cross all users in MU-MIMO scenario. So, similar accuracy as that of random precoder can be foreseen for Alt.1-3. The only difference seems to be the unnecessary complexity with N-fold channel generation and SVD for each of all the N channels. |
| Vivo | Support Alt.1-2 and Alt.2-2 in principle.  In our understanding, joint SVD would be applied across all users, after the channel is generated for each UE in proposal#2-1-6a, since joint precoding across all users would be applied for PDSCH at the gNB side in practice. For clarification, we can modify “Alt.1-2: SVD” as “Alt.1-2: joint SVD across all users” |
| Moderator | I updated based on CATT’s input. Please check. |
| Ericsson | @Moderator Thanks for pointing out Alt 2-3 has already been agreed.  We would like to emphasize that we are interested in an MU-MIMO DMRS shortage issue in real eployment for midband, where most deployed Ues have single Tx, so for us, the rank 1 per UE (and many Ues) is the most interesting case to provide and enhancement for.  We can remove the Alt 2-3 as it is already agreed by “Codebook based wide-band precoding on ideal CSI feedback.”  We support the FL proposal, SVD for PDSCH and PUSCH. |
| Huawei, HiSilicon | Based on the discussion in section 2.1, we support Alt.1-3 and Alt.2-2. |
| ZTE | According to our suggested proposal#2-6-1a, we can live with Alt.1-2 by adding the same clarification in proposal#2-6-1a:   * + - **Alt.1-2: SVD**       * **Only the channel of one desired UE, i.e. Hd, needs to be modelled. SVD is performed based on Hd to obtain the precoder for this UE only. The interference from co-scheduled Ues can be modelled as , wherein can be randomly selected from a predefined set of precoders, where the correlation coefficient between any two pre-coders in the range of [0 0.5] (Based on random pre-coder in FL proposal#2-1-6a)** |
| Lenovo | Support updated Alt.1-2 and Alt.2-2. |
| Spreadtrum | Support Alt.1-2 and Alt.2-2. |
| Moderator | I removed Alt 2-3. |
| Fraunhofer IIS/HHI | Support SVD for both PDSCH and PUSCH (Alt. 1-2 and Alt. 2-2) |
| Nokia/NSB | We are fine with Alt 1-2, and Alt 2-2. |
| LGE | Support Alt.1-2 and Alt.2-2. |
| MediaTek | Support Alt.1-2 and Alt.2-2. |
| Ericsson | The sub-bullet under Alt.1-2 is needed for **2-1-6a** Alt2, not for **2-1-6a** Alt3. |

FYI, companies’ inputs in 2nd round are in the following table.

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| **Company** | **Comment** |
| Huawei, HiSilicon (round1) | For the **Precoding and precoding granularity** part, considering the practical scenario, ‘practical channel knowledge with real channel estimation’ rather than ‘ideal channel knowledge’ may be more appropriate. Furthermore, for PDSCH Alt.1, we think ZF-based rather than SVD-based precoding should be considered. |
| ZTE2(round1) | For precoding method of PDSCH, it should be noted that if proposal#2-6-1 (unified simulation method) can be acceptable to companies as a consensus, it should be used to replace ZF here for companies’ alignment. |
| Vivo(round1) | For precoding, it is better to align the same non-codebook precoder for PDSCH and PUSCH, i.e., both using ZF or SVD. |
| Samsung | We are fine with either methods but prefer down-selecting one precoding assumption to reduce simulation effort. |
| ZTE | According to our previous elaborations of FL’s proposal#2-6-1, due to ZF algorithm is too ideal and far away the real-field deployment, we support Alt.1-3 for PDSCH and Alt.2-2 for PUSCH to approach the real MU-MIMO. |
| OPPO | We prefer Alt 1-2 for PDSCH to be compared with the results based on codebook.  For PUSCH, SVD should be applied and how to apply ZF at UE side needs further clarification. |
| Lenovo | In principle, either ZF or SVD can be used for precoding assumption of PDSCH and PUSCH. For ZF schemes, it is a realistic MU-MIMO precoding scheme and the inter-user interference is modelled accurately. But the simulation realization complexity is high (such as MU-MIMO UE selection/paring based on interference if considered) and more alignment may be needed since there may be different realization schemes, such as, ZF scheme, regular ZF scheme, etc. For SVD scheme, it is simple but the inter-user interference needs further considered for modeling such as schemes discussed in section 2.1. If the inter-user interference modeling can be accepted by companies, we prefer SVD scheme to save simulation effort and easy calibrating simulation results between companies. |
| QC | For DL, we prefer Alt 1-3. Just an editorial comment: It seems the following is more accurate to capture the intention of Alt 1-3?  **Alt.1-3: SVD based ~~on~~ independent PMI calculation for each UE (in FL proposal#2-1-6)**  For UL, we prefer Alt.2-2.  In our understanding, ZF precoder would amplify noise which will degrade performance. We are not sure what is the benefit of using ZF precoder. Can proponents of ZF precoder please clarify? |
| Moderator | Updated by QC’s input. |
| Vivo | We are confused about the Alt 1-3. Since we have agreed “CSI codebook based sub-band precoding (with 4PRB precoding granularity) on ideal CSI feedback”, why we need Alt 1-3 which is based on codebook (PMI)?  Regarding ZF, SVD precoding, both are ok for us. If to choose one as the unique assumption, we slightly prefer SVD precoding which can provide better performance than ZF generally. |
| Xiaomi | Both ZF and SVD are acceptable for us. |
| Ericsson | On PUSCH, we would like to add Alt.2-3 for PUSCH and prefer Alt.2-3, because the other alternatives assume reciprocity based schemes which are optional UE features, we should base on realistic schemes.   * + **Precoding assumption of PUSCH, “**[ZF or SVD]**” in RAN1#109e agreement is updated by**     - **Alt.2-2: ZF**     - **Alt.2-2: SVD**     - **Alt.2-3: Single layer PUSCH with non-coherent codebook based wide-band precoding on ideal CSI feedback**   For PDSCH we prefer Alt.1-2 based on ideal channel knowledge. |
| CATT | Support the proposal, and SVD based precoding for only one target user is preferred for DL. If random precoding is agreed for co-scheduled Ues in FL proposal#2-1-6, Alt.1-3 can be removed.  For UL, Alt.2-2 is preferred. |
| Moderator | “PMI calculation” is updated to “pre-coding”, based on vivo’s comment.  @Ericsson, we have agreed codebook based already. We are discussing now for ZF or SVD based PUSCH precoder.  Agreement  For PUSCH: Companies can select and need to report which option(s) are used between   * [ZF or SVD] based wide-band precoding on ideal channel knowledge * Codebook based wide-band precoding on ideal CSI feedback. |
| Nokia, NSB | We need first resolve proposal #2-1-6. We don’t think this MU-MIMO precoding algorithm to be agreed for simulation. |
| Ericsson | @Moderator. We are adding the one for PUSCH.   * + - **Alt.2-3: Single layer PUSCH with non-coherent codebook with wide-band precoding** |

# Specifying objective #3 (increasing DMRS ports)

## Other proposals in the 1st round

Companies’ inputs in the 1st round are summarized in the following table. It is observed that most popular proposals are proposal 1 and proposal 4. Meanwhile, some companies mentioned it is better to discuss after RAN1 decides how to increase the DMRS ports. For the proposal 4, it is pointed out that it is premature to decide to re-use the existing table before deciding how to increase the DMRS ports. Hence, the scope of this discussion is to agree on “study”.

For proposal 2) and 3), the proposals are only valid, if Opt.1/Opt.5 using FD-OCC is agreed.

Considering that the study of 1) and 4) would be useful, irrespective of which option to increase the DMRS ports is to be supported, FL suggestion is to focus on 1) and 4).

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| **Proposals** | **Companies** |
| 1. **Support dynamic indication between Rel.18 DMRS ports and Rel.15 DMRS ports** | **Support:** Futurewei, ZTE, vivo, Samsung, Fraunhofer IIS/HHI(after down selection), OPPO, Lenovo, NEC, CMCC, Intel, Huawei/HiSilicon, QC (but later), Docomo (13), Samsung (after finalizing FL proposal 3.3), CATT (after down selection)  **Not support:** Spreadtrum (depends on performance different b/w R15 and R18), New H3C(after finalizing FL proposal 3.3) (4) |
| 1. **DM-RS EPRE enhancement in case of Sparser frequency allocation (increase the number of CDM groups)** | **Support:**CATT, Xiaomi, Fraunhofer (after down selection), ZTE(if FDM is agreed), LGE, Docomo(if FDM is agreed) (6)  **Not support:** CATT (after down selection), Xiaomi (after down selection), New H3C(after finalizing FL proposal 3.3) (3) |
| 1. **Study whether to indicate the length of FD-OCC to Ues** | **Support:**NEC, Lenovo, Huawei/HiSilicon, ZTE(if FDM is agreed) , Docomo(if FDM is agreed) (5), Samsung  **Not support:** CATT (after down selection), New H3C(after finalizing FL proposal 3.3) (3) |
| 1. **Reuse the antenna port indication table in 38.212 as much as possible for both PDSCH and PUSCH** | **Support:**Apple, Samsung, Futurewei, Intel (But, later), Huawei/HiSilicon, ZTE, LGE (7)  **Not support:** CATT (after down selection), New H3C(after finalizing FL proposal 3.3) (2) |
| 1. **Study on designing DMRS table entries focusing on utilizing MU-MIMO** | **Support:**Samsung, ZTE (2)  **Not support:** CATT (after down selection), New H3C(after finalizing FL proposal 3.3) (2) |

**1st round (by May 13)**

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| **Company** | **Comment** |
| OPPO | We think further study is needed for dynamic indication between Rel.18 DMRS and Rel.15 DMRS. The required max DMRS ports number doesn’t seem to change dynamically. |
| Samsung | Regarding 1), we are fine to study a dynamic indication between Rel-15 and Rel-18 DMRS types since Rel-18 DMRS type may have degraded performance when it is used for SU due to a sparser DMRS REs or larger length of OCC. Hence, fallback operation into Rel-15 from Rel-18 DMRS should be studied and supported.  Regarding 2), if we consider the direction #2 (increase the number of CDM groups) in section 3.3 above, it would be natural extension to be considered. Hence, it can be discussed after finalizing FL proposal 3.3.  Regarding 3), it seems a specific way to indicate dynamically between Rel-15 and Rel-18 DMRS.  Regarding 4), we tend to agree with reusing existing tables as much as possible.  Regarding 5), since Rel-18 DMRS is mainly used for MU-MIMO and the number of DMRS ports indicated by tables would be much larger than those of Rel-15, deleting some table entries which may not be used for MU-MIMO can be deleted. |
| Lenovo | We also support to make study on proposal 1 and 3. |
| NEC | We support to study 1). And Regarding 3), we share similar view with Samsung that 3) is a way to indicate dynamic switching between Rel-15 and Rel-18. So we think 1) and 3) can be jointly discussed. |
| CMCC | We support to study 1). |
| Futurewei | We support to study 1) and 4) |
| Intel | 1 and 4 can be further considered but only after Options in 3.2 are more mature. Without detailed design it’s premature to re-use legacy design fully. |
| CATT | Next-level details can be further studied after down-selection among options listed in FL proposal#3-3. |
| Xiaomi | Proposal 2) can be discussed after the DMRS patterns to support lager number of DMRS ports are decided. |
| Fraunhofer IIS/HHI | Support further studying (1) and/or (2) after down-selection of options in Proposal#3-3 |
| Spreadtrum | For proposal 1, the support of dynamic indication may also depends on the performance difference of channel estimation between Rel.18 DMRS ports and Rel.15 DMRS ports. |
| Ericsson | Agree with Samsung on 1). This is beneficial since there is a channel estimation performance loss with Rel.18 DMRS and it is unfortunate if the UE needs to take the hit of this loss in every slot. |
| Huawei, HiSilicon | Support to study 1), 3) and 4). |
| ZTE | 1. Considering the DMRS ports are indicated in the DCI field, different DMRS pattern may have different performance in different scenarios, so it is better to support indicate the DMRS port are Rel.18 DMRS or Rel.15 by DCI signaling. 2. Can be discussed if FDM is agreed in section 3.3. 3. Can be discussed when FD-OCC is agreed in section 3.3. 4. Antenna port indication table in 38.212 should be a baseline. 5. Agree to study. |
| QC | Comment on Proposal 1: is the intention of proposal 1 to allow dynamic switch between Rel-15 and Rel-18 ports via “antenna ports” field in DCI? If so, we support this intention in general. But we think this is signaling detail and it can be discussed after the scheme to double # antenna ports is finalized.  Mod: Yes, I think it is the intention. |
| LGE | We support to study 2) and 4) |
| New H3C | Those 5 proposals should be treated after the design direction on increasing DMRS ports is decided. |
| Vivo | Support to study 1).  The dynamic indication is important when the traffic or the number of Ues in MU-MIMO is changed dynamically, which would affect the performance of channel estimation based on DMRS. |
| Docomo | Support 1) to study.  Support 2) and 3) to study, but it should be discussed after RAN1 agree to support FD-OCC. |

**2nd round (by Monday GTW in 2nd week)**

For FL proposal#3.1.1, dynamic indication is clarified as DCI-based dynamic antenna port indication.

**FL proposal#3.1.1:**

* **To increase the max. number of DMRS ports for PDSCH/PUSCH larger than Rel.15,** 
  + **Study whether/how to support DCI-based dynamic antenna ports indication of Rel.18 DMRS ports and/or Rel.15 DMRS ports.**

**FL proposal#3.1.4:**

* **To increase the max. number of DMRS ports for PDSCH/PUSCH larger than Rel.15,** 
  + **Study whether/how to reuse the antenna port indication table in 38.212 as much as possible for both PDSCH and PUSCH**
  + **Study the potential need for MU scheduling restrictions in the design of the enhanced antenna port indication table in 38.212 for DL PDSCH.**

Please provide your views on the above FL proposals.

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| **Company** | **Comment** |
| Docomo | Support both proposals to study. |
| Apple | We are fine with both proposal to study |
| Samsung | Support to study both proposals. Btw, our position of original 1) and 3) in Round 1 are both supportive. We think that original 3) can be one way of achieving 1). |
| ZTE | Support both proposals. |
| OPPO | Support both proposals. |
| Lenovo | Support both proposals. |
| QC | The original wording of proposal#3.1.1 can be interpreted as the dynamic indication is indicating either Rel-15 (old) ports or Rel-18 (new) ports, while not both. I assume the intention is to enhance Rel-15 antenna port indication to indicate all the following: Rel-15 ports, or Rel-18 ports, or Rel-15 + Rel-18 ports? If so, I suggest the following editorial change.  **FL proposal#3.1.1:**   * **To increase the max. number of DMRS ports for PDSCH/PUSCH larger than Rel.15,**    + **Study whether/how to support DCI-based dynamic antenna port indication ~~between~~ Rel.18 DMRS ports and/or Rel.15 DMRS ports.**   **For proposal #3.1.4, when we design the new antenna port indication table, we need consider the MU scheduling restriction, as we agreed in previous round. The table is where we capture the MU scheduling restrictions. So I suggest the following update. The reason that “restriction” is put in square bracket is because I am not sure if everyone prefers to call this a “restriction”. To us, it is a restriction. But we are open to discuss other wording.**  **FL proposal#3.1.4:**   * **To increase the max. number of DMRS ports for PDSCH/PUSCH larger than Rel.15,**    + **Study whether/how to reuse the antenna port indication table in 38.212 as much as possible for both PDSCH and PUSCH**   + **The design of the enhanced antenna port indication table in 38.212 take MU scheduling [restrictions] into account. FFS details on MU scheduling [restrictions].** |
| NEC | Support the proposals. |
| CMCC | Support FL‘s proposal. |
| Moderator | FL proposals are updated by QC’s suggestion. I removed [ ] in QC’s suggestion because “MU-scheduling restriction” itself is FFS. |
| Spreadtrum | Support the updated FL proposals. |
| Vivo | Support the updated proposal. |
| Sharp | Support both updated proposals. |
| Xiaomi | Support FL proposal#3.1.1 and proposal#3.1.4. |
| Ericsson | On the updated proposal, we prefer to use “Study”, and this restriction is for downlink.  **Study the potential need for MU scheduling restrictions in the ~~The~~ design of the enhanced antenna port indication table in 38.212 for DL PDSCH ~~take MU scheduling [restrictions] into account. FFS details on MU scheduling [restrictions]~~.**  Another comment is on the main bullet, we propose to remove the “To increase the max. number of DMRS ports for PDSCH/PUSCH larger than Rel.15”, we have agreement already on the number of DMRS ports in Round 1. |
| CATT | Support both proposals in principle. The intention and the meaning of DCI-based dynamic antenna port indication between Rel.18 DMRS ports and Rel.15 DMRS ports in FL proposal#3.1.1 should be further clarified. One understanding is that antenna ports (e.g., ports 11-23 or ports 0-11) can be indicated dynamically. Another understanding is that DMRS table of Rel.15 and Rel.18 can be indicated dynamically. |
| Moderator | Updated by Ericsson’s suggestion on FL proposal#3.1.4.  @CATT, for FL proposal#3.1.4, I think both options are not precluded. We can discuss more details on next meetings.  @Ericsson, for FL proposal#3.1.4, the main bullet is to clarify the purpose of the proposal (for objective#3). I think keeping it has no issue. |
| Nokia, NSB | We are fine with the proposal. |

### Round3

No update on FL proposals from round2. I’ll propose them for email endorsement on this week.

**FL proposal#3.1.1:**

* **To increase the max. number of DMRS ports for PDSCH/PUSCH larger than Rel.15,** 
  + **Study whether/how to support DCI-based dynamic antenna ports indication of Rel.18 DMRS ports and/or Rel.15 DMRS ports.**

**FL proposal#3.1.4:**

* **To increase the max. number of DMRS ports for PDSCH/PUSCH larger than Rel.15,** 
  + **Study whether/how to reuse the antenna port indication table in 38.212 as much as possible for both PDSCH and PUSCH**
  + **Study the potential need for MU scheduling restrictions in the design of the enhanced antenna port indication table in 38.212 for DL PDSCH.**

Please provide your views if you have any concern on the above proposals:

|  |  |
| --- | --- |
| **Company** | **Comment** |
| DOCOMO | Support. |
| OPPO | Support. |
| Samsung | Support both FL proposals. |
| QC | Support |
| CATT | For the two proposals above, they have exactly the same wording for the main bullet. So, we’d prefer to merge the two proposals. |
| Vivo | Support |
| Ericsson | Support |
| ZTE | Support. |
| Lenovo | Support |
| Spreadtrum | Support |
| Fraunhofer IIS/HHI | Support both proposals |
| Nokia/NSB | Support. |
| LGE | Support the proposal. In addition, we suggest the following editorial change.  **FL proposal#3.1.1 and 3.1.4:**  **To increase the max. number of orthogonal DMRS ports for PDSCH/PUSCH larger than Rel.15,** |
| Apple | We are fine with the two proposals to study |
| MediaTek | Support. |

# Specifying objective #5 (>4 layers PUSCH DMRS)

Based on the companies tdocs, the following DMRS enhancement can be considered to support more than 4 layers PUSCH. Whether to support more than 4 layers PUSCH is to be discussed in AI 9.1.4.2 (SRI/TPMI enhancement for enabling 8 TX UL transmission), hence, the following proposals can be specified after AI 9.1.4.2 agrees to support more than 4 layers PUSCH in Rel.18.

|  |  |
| --- | --- |
| **Proposals** | **Companies** |
| 1. **Extend DMRS port allocation table** **for rank 5~8 (Note: DL DMRS table can be a reference)** | Huawei, HiSilicon, CATT, Xiaomi, Samsung, LGE, Lenovo, CMCC, DOCOMO, Intel, Ericsson |
| 1. **Enhancement for DMRS to PTRS mapping** | ZTE, Xiaomi, Samsung, OPPO, LGE, Ericsson |
| 1. **Study codeword-to-layer mapping** | Samsung, LGE |
| 1. **Alt.1: Utilize Rel.18 DMRS (or, both R15/18 DMRS)**   **Alt.2: Utilize Rel.15 DMRS only** | Alt.1: ZTE, Lenovo, DOCOMO, Intel, vivo  Alt.2: ~~vivo~~ |

After AI 9.1.4.2 agrees to support more than 4 layers PUSCH, to discuss smoothly normative work in this AI, it is good to study the potential specification impacts for DMRS.

**1st round (by May 13)**

**FL proposal#4 (1st round):**

* **Study the following potential DMRS enhancement to support more than 4 layers SU-MIMO PUSCH.**
  + **1) Extend DMRS port allocation table for rank 5~8**
    - **Note: DL DMRS table can be a reference**
  + **2) Enhancement for DMRS to PTRS mapping**
  + **3) Codeword-to-layer mapping**
* **Study whether to utilize Rel.18 DMRS ports for more than 4 layers SU-MIMO PUSCH.**

|  |  |
| --- | --- |
| **Company** | **Comment** |
| Samsung | Our view is to re-use PDSCH design for more than 4 layers as much as possible except PTRS-DMRS association. |
| Lenovo | Support the proposal |
| NEC | Regarding DMRS table, we’d like to clarify whether the extended DMRS table is similar as current UL DMRS table (i.e. per layer indication) or similar as DL DMRS table (i.e. joint indication for different number of layers)? We think this should also be studied. |
| CMCC | For 8 TX UL transmission, whether restriction on maximum number of orthogonal DMRS ports per UE in MU-MIMO is needed or not can be studied. We prefer to add a sub-bullet:   * + **4) Maximum layer per UE for MU-MIMO** |
| InterDigital | Need to wait for 9.1.4.2 |
| Futurewei | Support to reuse PDSCH design for more than 4 layers as much as possible. |
| Intel | Ok with the sub-bullet 1) and 2). For sub-bullet 3), more discussion is needed and maybe it should be discussed in AI 9.1.4.2. |
| CATT | Fine with FL’s proposal. |
| Nokia/NSB | Agree with Samsung to re-use as much as possible existing specification for this work. |
| Xiaomi | Support the proposal, but all these detailed discussions should depend the agreements made in 9.1.4.2. |
| Spreadtrum | The enhancement can be studied after more than 4 UL layers is supported. |
| Docomo | We think it is beneficial to use Rel.18 DMRS (instead of Rel.15 DMRS) for 8Tx PUSCH, because we can avoid to use double symbol DMRS, which has more DMRS overhead than single symbol DMRS. |
| Moderator | Re NEC’s question, both options can be considered for study. But, as noted, DL DMRS table can be a reference.  Re CMCC’s comment, I couldn’t understand why the number of layers per UE should be restricted in MU-MIMO scenario. In current DMRS design, I think there is no such restriction, and the number of layers per UE does not change, depending on SU-MIMO or MU-MIMO. Could you elaborate the reason? |
| Ericsson | We agree to reuse the DL DMRS design as much as possible. |
| Huawei, HiSilicon | Support to treat DL DMRS table as a reference and detailed discussions can be conducted after some agreements have been achieved in 9.1.4.2. |
| ZTE | Since Rel.18 DMRS ports may be supported in objective #3, we think Rel.18 DMRS ports with more than 4 layers SU-MIMO PUSCH should not be excluded. And the DMRS port indication and PTRS-DMRS association should be also studied. |
| QC | We think it is better to wait the decision on whether support >4 layers PUSCH in 9.1.4.2, before discuss this aspect. |
| MediaTek | For items 1) and 2), we prefer to wait for the outcome of 9.1.4.2, while for 3) we prefer to leave this codeword-to-layer mapping issue to be exclusively discussed under 9.1.4.2, not here. |
| CMCC | Re Moderator’s comment, in Rel-15, although up to 8 layers are supported for SU-MIMO in DL, it has been additionally restricted that the maximum number of orthogonal DMRS ports per UE in MU-MIMO is 4 for DL. For UL, since up to 4 layers transmission are supported in Rel-15, so no restriction is needed for MU-MIMO. However, to enable 8 TX UL operation to support up to 8 layers UL transmission, whether restriction on maximum number of orthogonal DMRS ports per UE in MU-MIMO is needed or not can be studied. |
| LGE | Support the proposal |
| New H3C | Support this proposal. |
| Vivo | Support the proposal, except 3).  Regarding 3), we think it should be discussed in 9.1.4.2. |
| CMCC | In Rel-15, we have agreements regarding maximum number of ports per UE in SU-MIMO and MU-MIMO. The restriction for MU-MIMO is specified in TS38.214 Section 5.1.6.2 DM-RS reception procedure with yellow highlight part.    We would like to clarify when enabling up to 8 layers UL transmission, whether restriction on maximum number of orthogonal DMRS ports per UE in MU-MIMO is needed or not. It is appreciated if this can be discussed in 9.1.3.1.    **Agreement: #90bis**  Any configured DMRS port indication table supports SU-MIMO scheduling.  The maximum number of ports per UE in SU-MIMO   * DMRS configuration type 1 with 1-symbol DMRS   + 4 for DL, 4 for UL * DMRS configuration type 1 with 2-symbol DMRS   + 8 for DL, 4 for UL * DMRS configuration type 2 with 1-symbol DMRS   + 6 for DL, 4 for UL * DMRS configuration type 2 with 2-symbol DMRS   + 8 for DL, 4 for UL     **Agreement: #90bis**  The maximum number of orthogonal ports per UE in MU-MIMO for   * DMRS configuration type 1 with 1-symbol DMRS   + 2 for DL * DMRS configuration type 1 with 2-symbol DMRS   + 4 for DL * DMRS configuration type 2 with 1-symbol DMRS   + 4 for DL * DMRS configuration type 2 with 2-symbol DMRS   + 4 for DL     For DM-RS configuration type 1,  -    if a UE is scheduled with one codeword and assigned with the antenna port mapping with indices of {2, 9, 10, 11 or 30} in Table 7.3.1.2.2-1 and Table 7.3.1.2.2-2 of Clause 7.3.1.2 of [5, TS 38.212], or  -    if a UE is scheduled with one codeword and assigned with the antenna port mapping with indices of {2, 9, 10, 11 or 12} in Table 7.3.1.2.2-1A and {2, 9, 10, 11, 30 or 31} in Table 7.3.1.2.2-2A of Clause 7.3.1.2 of [5, TS 38.212], or  -    if a UE is scheduled with two codewords,  the UE may assume that all the remaining orthogonal antenna ports are not associated with transmission of PDSCH to another UE.  For DM-RS configuration type 2,  -    if a UE is scheduled with one codeword and assigned with the antenna port mapping with indices of {2, 10 or 23} in Table 7.3.1.2.2-3 and Table 7.3.1.2.2-4 of Clause 7.3.1.2 of [5, TS38.212], or  -    if a UE is scheduled with one codeword and assigned with the antenna port mapping with indices of {2, 10, 23 or 24} in Table 7.3.1.2.2-3A and {2, 10, 23 or 58} in Table 7.3.1.2.2-4A of Clause 7.3.1.2 of [5, TS 38.212], or  -    if a UE is scheduled with two codewords,  the UE may assume that all the remaining orthogonal antenna ports are not associated with transmission of PDSCH to another UE. |

**2nd round (by Monday GTW in 2nd week)**

For 3), I discussed with FL of AI 9.1.4.2, and AI 9.1.4.2 already discusses it. Following is FL proposal in AI 9.1.4.2 for your reference. Hence, we don’t need to discuss it in this AI, and I removed 3) from FL proposal#4.

|  |
| --- |
| **FL Proposal 3.1b: For 8TX UE uplink transmission with more than 4 layers, (if supported),**   * **support 2 CW transmission** * **reuse DL CW to layer mapping** |

Meanwhile, CMCC made a good point that in Rel.15, we have agreements regarding maximum number of ports per UE in SU-MIMO and MU-MIMO. It is also beneficial to study whether such restriction is needed to support more than 4 layers (please see the CMCC’s latest comment).

**FL proposal#4:**

* **Study the following potential DMRS enhancement for potential support of more than 4 layers SU-MIMO PUSCH.**
  + **1) Extend DMRS port allocation table for rank 5~8**
    - **Note: DL DMRS table can be a reference**
  + **2) Enhancement for DMRS to PTRS mapping**
* **Study whether to utilize Rel.18 DMRS ports for more than 4 layers SU-MIMO PUSCH.**
* **Study whether restriction on max. number of orthogonal DMRS ports per UE in MU-MIMO is needed**
* Note: the above study does not imply more than 4 layers SU-MIMO PUSCH is supported.

Companies inputs in 2nd round.

|  |  |
| --- | --- |
| **Company** | **Comment** |
| Docomo | Support. |
| Apple | We are fine with the proposal to study |
| Samsung | Support the proposal. |
| ZTE | Support. |
| OPPO | Support the proposal. For UL DMRS ports with MU-MIMO, we think similar restriction to DL is needed. |
| Lenovo | Support the proposal. |
| QC | We still think it is better to wait the decision on whether support >4 layers PUSCH in 9.1.4.2, before discussing this aspect. But if majority want to perform this **study** in parallel with 9.1.4.2, we don’t object this proposal. But we request the following note to clarify this is just a study, which does not imply >4-layer PUSCH is supported already.  **FL proposal#4:**   * **Study the following potential DMRS enhancement ~~to support~~ for potential support of more than 4 layers SU-MIMO PUSCH.**   + **1) Extend DMRS port allocation table for rank 5~8**     - **Note: DL DMRS table can be a reference**   + **2) Enhancement for DMRS to PTRS mapping** * **Study whether to utilize Rel.18 DMRS ports for more than 4 layers SU-MIMO PUSCH.** * **Study whether restriction on max. number of orthogonal DMRS ports per UE in MU-MIMO is needed** * **Note: the above study does not imply more than 4 layers SU-MIMO PUSCH is supported.** |
| NEC | Support the proposal. |
| CMCC | Support the proposal. |
| Moderator | Updated by QC’s input. |
| Spreadtrum | Support the updated FL proposal. |
| Vivo | Support the proposal. |
| Sharp | Support the proposal. |
| Xiaomi | Support the updated FL proposal. |
| Ericsson | In our understanding the restriction on MU-MIMO does not apply for PUSCH, for PUSCH there’s no such restriction on co-scheduled users.   * **Study whether restriction on max. number of orthogonal DMRS ports per UE in MU-MIMO is needed for PDSCH** |
| CATT | Support FL’s proposal. |
| Moderator | @Ericsson, the proposal is for PUSCH. Whether the restriction is needed is also a part of study. Please see CMCC’s input in 1st round.  No update on FL proposal. |
| Nokia, NSB | We are fine with the proposal. |

### Round3

No update on FL proposals from round2. I’ll propose it for email endorsement on this week.

**FL proposal#4:**

* **Study the following potential DMRS enhancement for potential support of more than 4 layers SU-MIMO PUSCH.**
  + **1) Extend DMRS port allocation table for rank 5~8**
    - **Note: DL DMRS table can be a reference**
  + **2) Enhancement for DMRS to PTRS mapping**
* **Study whether to utilize Rel.18 DMRS ports for more than 4 layers SU-MIMO PUSCH.**
* **Note: the above study does not imply more than 4 layers SU-MIMO PUSCH is supported.**

Please provide your views if you have any concern on the above proposals:

|  |  |
| --- | --- |
| **Company** | **Comment** |
| DOCOMO | Support. |
| OPPO | Support. |
| Samsung | Support the FL proposal#4. |
| QC | Regarding this: “**Study whether restriction on max. number of orthogonal DMRS ports per UE in MU-MIMO is needed**”, is it possible someone could mis-interpret this as the following. RAN1 baseline is NO restriction is needed. And we are studying whether restriction is needed.  But I think Rel-15 restriction should be the baseline. We are actually studying if any NEW restriction is needed, right? If so, I suggest updated wording as below.   * **Study whether new restriction on max. number of orthogonal DMRS ports per UE in MU-MIMO is needed, on top of corresponding restrictions in Rel-15.** |
| Vivo | Support |
| Ericsson | In our understanding the restriction on MU-MIMO does not apply for PUSCH, for PUSCH there’s no such restriction on co-scheduled users.   * **Study whether restriction on max. number of orthogonal DMRS ports per UE in MU-MIMO is needed for PDSCH**   Regarding QC’s comment, on top of Rel-15 restrictions, we think it is still a bit early to include. |
| ZTE | Support FL proposal#4. |
| Lenovo | Support FL proposal#4. |
| Spreadtrum | Support |
| Moderator | For the restriction of MU-MIMO PUSCH, I agree with Ericsson that there is no such restriction on co-scheduled Ues. Rel.15 restriction on co-scheduled Ues is for PDSCH (on sect. 5.1.6.2 in TS38.214), and it is premature to discuss it for PUSCH. Hence, I removed it from the FL proposal. |
| LGE | Support the proposal |
| Apple | We are fine with FL proposal to study |
| MediaTek | Support |

# Other issues

This section contains other issues the companies want to highlight, if any.

|  |  |
| --- | --- |
| Company | Comment |
|  |  |
|  |  |
|  |  |

# Conclusion

# References

|  |  |  |  |
| --- | --- | --- | --- |
| [1] | RP-213598 | New WID: MIMO Evolution for Downlink and Uplink” | Samsung (Moderator) |
| [2] | R1-2203063 | Increased number of orthogonal DMRS ports | FUTUREWEI |
| [3] | R1-2203152 | Enhancements on DMRS in Rel-18 | Huawei, HiSilicon |
| [4] | R1-2203266 | DMRS enhancement for UL/DL MU-MIMO and 8 Tx UL SU-MIMO | ZTE |
| [5] | R1-2203323 | Discussion on increased number of orthogonal DMRS ports | Spreadtrum Communications |
| [6] | R1-2203381 | High Capacity DMRS | InterDigital, Inc. |
| [7] | R1-2203403 | Discussions on increased number of orthogonal DMRS ports | New H3C Technologies Co., Ltd. |
| [8] | R1-2203444 | On increased number of orthogonal DMRS ports | CATT |
| [9] | R1-2203544 | Views on DMRS enhancements | vivo |
| [10] | R1-2203643 | Increased number of orthogonal DMRS ports | Ericsson |
| [11] | R1-2203684 | Discussion on increased number of orthogonal DMRS ports | NEC |
| [12] | R1-2205159 | Discussion on DMRS enhancement | Xiaomi |
| [13] | R1-2203891 | Views on DMRS enhancements | Samsung |
| [14] | R1-2203956 | DMRS enhancement for Rel-18 MIMO | OPPO |
| [15] | R1-2204144 | Increased number of orthogonal DMRS ports | LG Electronics |
| [16] | R1-2204165 | Discussion of increased number of orthogonal DMRS ports | Lenovo |
| [17] | R1-2204232 | Views on supporting increased number of orthogonal DMRS ports | Apple |
| [18] | R1-2204290 | Discussion on increased number of orthogonal DMRS ports | CMCC |
| [19] | R1-2204370 | Discussion on increased number of orthogonal DMRS ports | NTT DOCOMO, INC. |
| [21] | R1-2204509 | Increased number of orthogonal DMRS ports | Sharp |
| [22] | R1-2204541 | Rel-18 UL and DL DMRS Enhancements | Nokia, Nokia Shanghai Bell |
| [23] | R1-2204677 | Increased number of orthogonal DMRS ports | Fraunhofer IIS, Fraunhofer HHI |
| [24] | R1-2204693 | Increased number of orthogonal DMRS ports | MediaTek Inc. |
| [25] | R1-2204788 | Discussion on DMRS enhancement | Intel Corporation |
| [26] | R1-2205017 | Design for increased number of orthogonal DMRS ports | Qualcomm Incorporated |
| [27] | R1-2205112 | Increased number of orthogonal DMRS ports | Ericsson |
| [28] | R1-2205208 | FL summary on DMRS | Moderator (NTT DOCOMO) |