**3GPP TSG RAN WG1 Meeting #109-e R1-2205208**

**e-Meeting, May 9th – 20th, 2022**

**Source: Moderator (NTT DOCOMO)**

**Title: FL summary on DMRS**

**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. |

This document contains summary of the company’s proposal and FL proposals.

# Evaluation methodology (EVM)

In this AI, objective #3 (increasing DMRS ports for MU-MIMO) and objective #5 (>4 layers PUSCH DMRS) are to be discussed. 11 companies show evaluation results or propose EVM for objective #3 (increasing DMRS ports for MU-MIMO) to understand the benefit of increasing DMRS ports and to compare the performance of different schemes. 3 companies show evaluation results to show the benefit of supporting more than 4 layers PUSCH.

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| **Objective** | **Companies show evaluation result or propose EVM** |
| **#3 (increasing DMRS ports for MU-MIMO)** | **LLS:** Huawei/HiSilicon, ZTE, vivo, Xiaomi, Samsung, OPPO, Nokia, Qualcomm, Ericsson (9)  **SLS:** Huawei/HiSilicon, Nokia/NSB, MediaTek (3) |
| **#5 (>4 layers PUSCH DMRS)** | **LLS:** OPPO (1)  **SLS:** Huawei/HiSilicon, MediaTek (2) |

**For objective #3 (increasing DMRS ports for MU-MIMO)**

9 companies show evaluation result/assumption for LLS. One of the target for LLS is to compare the different schemes (e.g. FD-OCC, TD-OCC, FDM, etc.) for increasing the number of DMRS ports and to see the performance difference from Rel.15 DMRS. Meanwhile, 3 (Huawei/HiSilicon, Nokia/NSB, MediaTek) show evaluation result/assumption for SLS. One of the target for SLS is to understand the benefit to specify increasing the number of DMRS ports. Since the most of companies think LLS is enough, the following is suggested.

**FL proposal#2a:**

* **LLS is used for objective #3 (increasing DMRS ports for MU-MIMO) in Rel.18 MIMO, while SLS can be used optionally.**

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| **Company** | **Comment** |
| OPPO | Support. For evaluation of different DMRS enhancement schemes, LLS with realistic channel estimation is necessary. |
| Samsung | Support the proposal. |
| Lenovo | Support the proposal. |
| CMCC | Support the proposal |
| IDC | Support the proposal |
| Futurewei | Support the proposal |
| Intel | Support the proposal |
| CATT | Support the proposal. |
| Nokia/NSB | We support FL’s proposal.  Furthermore, we would like to highlight the importance of SLSs in the following two aspects:1) To study the need for >12 DMRS APs in DL MU-MIMO 2) Since LLSs are not able to capture properly inter- and intra-cell MU-MIMO interference, SLSs are needed to evaluate the performance of different antenna port multiplexing options at the system level. |
| Xiaomi | Support proposal#2a |
| Fraunhofer IIS/HHI | Support FL’s proposal in principle. We tend to agree with Nokia’s view that SLS may be required to capture the interference aspects better in the case of MU-MIMO. |
| Spreadtrum | Support the proposal. |
| Docomo | Support. |
| Moderator | No update. |
| Huawei, HiSilicon | Support FL’s proposal. |
| ZTE | Agree with FL’s proposal.  If majority companies agree that LLS simulation on MU-MIMO DMRS, we think the simulation results can help to decide the details of Rel.18 DMRS, and then SLS may be treated as low priority. |
| MediaTek | Support. |
| LGE | Support the proposal. |
| vivo | Support. |

**For objective #5 (>4 layers PUSCH DMRS)**

For objective #5 (>4 layers PUSCH DMRS), the target of evaluation is to observe the benefits of supporting more than 4 layers PUSCH. However, 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). Once agreement is made to support more than 4 layers PUSCH in AI 9.1.4.2, necessary DMRS enhancements (e.g. Antenna ports indication, and DMRS to PTRS mapping, etc.) can be discussed without evaluation in this AI.

**FL proposal#2b:**

* **No EVM discussion is needed for objective #5 (>4 layers PUSCH DMRS) in AI 9.1.3.1 (DMRS) in Rel.18.**

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| **Company** | **Comment** |
| OPPO | Support to discuss it in 9.1.4.2. |
| Samsung | We are fine with this FL proposal. |
| Lenovo | Support the proposal and also fine to discuss it in 9.1.4.2. |
| CMCC | Prefer to discuss it in 9.1.4.2. |
| IDC | Support the proposal. |
| Futurewei | To discuss it in 9.1.4.2 |
| Intel | Fine with FL proposal |
| QC | Support FL proposal. Actually, before 9.1.4.2 deciding to support >4 layer PUSCH, we don’t see objective #5 (>4 layers PUSCH DMRS) needs to be discussed. |
| CATT | Support FL’s proposal. |
| Nokia/NSB | We are fine with FL’s proposal. |
| Fraunhofer IIS/HHI | OK with FL’s proposal |
| Docomo | Support. |
| Moderator | No update. |
| Huawei, HiSilicon | Support the proposal. |
| ZTE | Agree with FL’s proposal to discuss in AI 9.1.4.2. |
| MediaTek | We agree with FL that evaluations for >4 layers PUSCH DMRS should be considered in AI 9.1.4.2, and *only* if >4 layers is agreed there, should this AI proceed with related DMRS enhancements. |
| LGE | Support the proposal. |
| vivo | Support |

## EVM for LLS for objective #3 (increasing DMRS ports)

### 2.1.1 Evaluation metric and baseline.

For the evaluation comparison with Rel.15 DMRS, it is expected that performance of new Rel.18 DMRS configurations can be worse than legacy Rel.15 DMRS configurations. This is because the number of supported ports is larger, allowing for gains using MU-MIMO. We can select the new DMRS configuration that gives the smallest degradation relative to legacy configurations, while taking also backwards compatibility and complexity into account.

Please provide your views on the evaluation metric and baseline.

**FL proposal#2-1-1:**

* **LLS for increasing DMRS ports in AI 9.1.3.1 in Rel.18:**
  + **Evaluated channel: PDSCH as baseline (Companies can additionally submit evaluation results of PUSCH).**
  + **Evaluation metric:** 
    - **BLER for fixed MCS and rank as baseline**
    - **User throughput for adaptive MCS and rank as optional**
    - **MSE or NMSE of DMRS as optional**
  + **Evaluation baseline (i.e. compared with):** 
    - **For evaluation of enhanced single-symbol DMRS, baseline refers to Rel.15 single-symbol DMRS or Rel.15 double-symbol DMRS.**
    - **For evaluation of enhanced double-symbol DMRS, baseline refers to Rel.15 double-symbol DMRS.**

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| **Company** | **Comment** |
| OPPO | 1. To compare channel estimation performance of different schemes, we propose MSE of DMRS as a metric (maybe optional), which can straightforwardly show the performance in a large SINR range. 2. For THP, we think rank adaption can be optional. The target scenario is mTRP transmission with MU-MIMO, but LLS with rank adaptation may result in high rank without scheduling. Also, THP with rank and MCS adaption is difficult to show slight performance difference among different schemes. |
| Samsung | We are fine with the evaluation assumption for LLS in principle. We think both PDSCH and PUSCH can be a baseline. |
| Lenovo | We think both PDSCH and PUSCH can serve baseline since the DMRS enhancement is made for both DL and UL DMRS. Furthermore, we have similar view as Oppo that MSE can also serve as a direct evaluation metric on top of user throughput and BLER. |
| CMCC | Support the proposal. |
| IDC | Support the proposal. |
| Futurewei | Support LLS evaluations for both PDSCH and PUSCH, prefer CE MSE and BLER with fixed MCS and rank |
| Intel | OK with PDSCH with PUSCH as optional. For metric, BLER for fixed MCS and rank should be baseline and adaptive rank and MCS should be optional. |
| CATT | Support in principle. For evaluation metric, we think BLER for fixed MCS and rank is enough. This metric can show the comparison of performance directly, and it is relatively easy to align simulation results among companies. |
| Nokia/NSB | We are fine to use both PDSCH and PUSCH as a baseline. Otherwise, we support FL’s proposal. |
| Xiaomi | Support proposal#2-1-1. |
| Fraunhofer IIS/HHI | Support FL proposal |
| Spreadtrum | Support the proposal. |
| Docomo | Support. |
| Moderator | Based on the companies’ inputs, MSE of DMRS is added as optional and BLER of fixed MCS/rank is set as baseline. Samsung, Lenovo, Futurewei, Nokia/NSB commented that both PDSCH and PUSCH can be a baseline. However, all companies submitted LLS results only for PDSCH in RAN1#109e. Moderator’s concern is companies’ workload to evaluate both PDSCH and PUSCH, if we set both as baseline. Hence, the moderator suggestion is to set PDSCH as baseline, and companies can submit evaluation results of PUSCH additionally. |
| Ericsson | Support the proposal. |
| Huawei, HiSilicon | For the **Evaluated channel** part, although we still think PUSCH should also be treated as baseline, considering the Moderator’s concern, we can live with the current version.  For the **Evaluation metric** part, generally we’re OK, but one thing should be considered is that whether the adaptive rank is suitable to be the metric. Since different companies may have different rank adaptation algorithms, and aligning the rank is necessary for comparing the performance of different scheme, we think ‘User throughput for adaptive MCS as optional’ may be more appropriate.  For the **Evaluation baseline** part, we think the wording ‘Rel.15 DMRS’ need to be further clarified. For single-symbol based DMRS expansion, this wording may refers to non-orthogonal single-symbol legacy DMRS or orthogonal double-symbol legacy DMRS; for double-symbol based DMRS expansion, this wording may only refers to non-orthogonal double-symbol legacy DMRS. |
| ZTE | Agree with updated FL’s proposal. |
| MediaTek | We are okay with PDSCH channel being the baseline and PUSCH to be optional.  For performance metrics, we think (1) Normalized Mean Square Error (NMSE), and (2) BLER with fixed MCS and rank should be considered as baseline. NMSE is a straightforward metric that is directly related to channel estimation performance. Adding normalization to MSE makes comparison between different companies’ results more convenient. We prefer not to have adaptive MCS/rank in evaluation. |
| Moderator | I updated evaluation baseline, based on Huawei’s comment. I didn’t capture “orthogonal” or “non-orthogonal”. I understand Huawei’s SLS results shows the performance improvement of increased DMRS ports compared to non-orthogonal ports by gNB implementation (i.e. by using the for DMRS sequence generation). But, other companies compares the performance degradation from Rel.15 DMRS in LLS with different number of orthogonal DMRS ports (e.g. x-ports in Rel.15 DMRS vs. 2x-ports in Rel.18). I think both methods can be considered.  For evaluation metric, at least “BLER for fixed MCS and rank as baseline”, can be used for fair comparison. I added “or NMSE” based on MediaTek’s comment. |
| LGE | Support the proposal. |
| New H3C | Support this proposal. |
| vivo | Support |
| Samsung | Support the updated proposal. |

### 2.1.2 System setting

Please provide your views on the general system setting, with the following as a start point (Table A.1.6-1 in TR38.802 can be a reference).

**FL proposal#2-1-2:**

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| **Parameter** | **Value** |
| Duplex, Waveform | TDD, OFDM |
| Carrier Frequency | 4 GHz |
| Subcarrier spacing | 30kHz |
| Channel Model | CDL-B or CDL-C in TR 38.901 with 30ns or 300ns delay spread as baseline for MU-MIMO and SU-MIMO  Note: Other delay spread is not precluded.  Note: Simulation using TDL-A with 30ns or 300ns for MU-MIMO is not precluded. |
| Delay spread | Baseline: 30ns, 300ns  Optional: 1000ns |
| UE velocity | Baseline: 3km/h, 30km/h  Optional: 60km/h, 120km/h |
| Allocation bandwidth | 20MHz  Note: Other bandwidth smaller than 20MHz is not precluded |

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| **Company** | **Comment** |
| OPPO | 1. CDL-B/C is used for evaluation of SRS enhancement in Rel-17. Can you clarify why CDL-A is prioritized for DMRS enhancement?  2. 120km/h can be optional. We don’t think it is the target scenario for DMRS enhancement to support more than 12/16 ports. |
| Samsung | Support the proposed system setting in principle, and we also have similar question with OPPO about the prioritization on CDL-A/TDL-A rather than other channel models. |
| Lenovo | We also have the similar view to further check whether other channel models are needed for evaluation. For UE velocity, we also prefer 120kmp/h as optional on account typical application scenario. |
| CMCC | We agree with Lenovo to include 120km/h as an optional UE velocity. |
| InterDigital | Since the scope of DMRS port enhancements is primarily for MU-MIMO and 8TX UEs, it is not clear to us if inclusion of 120Km/h is needed. |
| Futurewei | We also think 120Km/h can be optional. |
| Intel | OK with assumptions. Agree that scope of enhancement mostly targets MU-MIMO performance and 120km/hr can be optional. |
| QC | 120km/hr seems not typical case for heavy MU packing in scheduling. So we don’t prefer to evaluate it.  Similar comment as some companies above: TDL/CDL B/C channel are more widely used in previous RAN1 studies. We think the same should be applied for this study. |
| CATT | Support. Regarding velocity, we have similar view with many other companies that 120km/h is not practical for MU-MIMO operation. However, in addition to 3 and 30km/h, scenarios with medium velocity, e.g. 60km/h, can be included for evaluation. |
| Nokia/NSB | Share the same views as OPPO that whether support for 120km/h is primary use case for >12 APs and could be considered as optional. Regarding to channel mode, we prefer to use TDL based channel models. Otherwise, we are fine with FL’s proposed system settings. |
| Xiaomi | For delay spread, should we still consider other larger than 300ns case? Because the joint channel may have large delay spread for CJT. |
| Fraunhofer IIS/HHI | We prefer TDL based channel models to CDL in FR1, but OK to evaluate both. And, as several companies have mentioned, 120 kmph does not seem to be a useful scenario for MU-MIMO deployments. Hence, it can be kept as optional or removed altogether. |
| Spreadtrum | Share the same views as OPPO. |
| Docomo | Support. |
| Moderator | For channel model, the above proposal was based on companies’ tdoc. But, I updated it to the agreed EVM in Rel.17 SRS.  UE velocity is updated that 60/120km/h are optional. |
| Ericsson | Include also 1000ns. This is one of the proposed valued in 38.901 and isn’t unusual in reality.  We have no strong opinion on whether to choose TDL-A and CDL-A or TDL-B and CDL-B as first priority. Good to select one model as first priority to simplify comparison of results from different companies. |
| Huawei, HiSilicon | For the **Delay spread** part, although Moderator have already listed a relevant note, we think paying more attention on larger delay spread (e.g., 1000ns) is worthy, since the main challenge faced by both FD-OCC and FDM is large delay spread, the performance under which should be fully investigated and considered.  For the **Allocation bandwidth** part, taking the actual scheduling situation into consideration, bandwidth smaller than 20MHz should not be precluded. |
| ZTE | Agree with updated FL’s proposal. |
| Moderator | I added 1000ns as optional. I also noted “Other bandwidth smaller than 20MHz is not precluded” |
| LGE | Support the updated proposal. |
| New H3C | Support this revised proposal. |
| vivo | Support the updated proposal. |
| Samsung | Support in principle, and we would like to ask moderator about duplex scheme. We think FDD is not precluded since CSI codebook based precoding scheme is listed in 2.1.3 MIMO setting. |

### 2.1.3 MIMO setting

Please provide your views on the MIMO parameter setting, with the following as a start point.

**FL proposal#2-1-3:**

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| **Parameter** | **Value** |
| MIMO scheme | Baseline: MU-MIMO  Optional: SU-MIMO |
| BS antenna configuration | Companies can select and need to report which option(s) are used between  - 32 ports: (M, N, P, Mg, Ng, Mp, Np) = (8,8,2,1,1,2,8), (dH,dV) = (0.5, 0.8)λ  - 16 ports: (M, N, P, Mg, Ng, Mp, Np) = (8,4,2,1,1,2,4), (dH,dV) = (0.5, 0.8)λ  Other configurations are not precluded. |
| UE antenna configuration | Companies can select and need to report which option(s) are used between  4RX: (M, N, P, Mg, Ng, Mp, Np) = (1,2,2,1,1,1,2), (dH,dV) = (0.5, 0.5)λ for rank > 2  2RX: (M, N, P, Mg, Ng, Mp, Np) = (1,1,2,1,1,1,1), (dH,dV) = (0.5, 0.5)λ for (rank 1,2)  Other configuration is not precluded. |
| MIMO Rank | 1, 2, or 4 per UE (rank fixed or rank adaptation) |
| UE number for MU-MIMO | 1, 2, 4, 8, or 12 |
| 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. |
| Feedback delay for precoding | 5ms |

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| **Company** | **Comment** |
| OPPO | It needs to be clarified that the configuration is only applied to DL DMRS evaluation. |
| Samsung | We think that wideband precoding granularity for PUSCH can be also considered. Regarding MIMO rank, 1 or 2 seems enough. |
| Lenovo | Support in principle. |
| CMCC | Support. |
| InterDigital | Support |
| Futurewei | Support |
| Intel | OK |
| CATT | Support. |
| Nokia/NSB | Share the same view Samsung that wideband precoding granularity for PUSCH can also be considered. Support FL’s MIMO settings. |
| Xiaomi | Support |
| Fraunhofer IIS/HHI | Support in principle. |
| Spreadtrum | Support |
| Docomo | Support |
| Moderator | The proposal is updated. Precoding assumption for PUSCH is also included. |
| Ericsson | Support the updated proposal. |
| Huawei, HiSilicon | For the **MIMO scheme** part, we think SU-MIMO shouldn’t be listed here.  For the **BS antenna configuration** part, we think larger number of BS antennas (e.g., 64 ports: (8, 8, 2, 1, 1, 4, 8), (dH, dV) = (0.5, 0.8)λ) is also widely used and should be added.  For the **UE number for MU-MIMO** part, since the rank per UE during MU-paring is relatively low, 8 or 12 UE should be supported to achieve 24 layers in WID.  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. |
| ZTE | 1. We think rank 1 or 2 is preferred in this simulation. 2. For SVD based sub-band precoding, a feedback delay should be clarified, e.g. 5ms. 3. The large delay spread is an important simulation case for FD-OCC/FDM, and different precoding granularity may introduce some simulation difference, so we think other precoding granularity should also be considered, i.e. 2 PRB. 4. 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: 5. 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; 6. Different PDSCH/DMRS ports for different UEs associated with different channels, and independent PMI calculation based on different channel for each UEs. 7. 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. 8. 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. |
| QC | For BS antenna configurations, my understanding of the proposal is that one could choose to simulate any one of the two configurations. It is not mandatory to simulate both configurations. If so, maybe it is better to add a note make this point clear. Similar note can be add for UE antenna configurations.  For precoding, is it similar situation that one could choose to simulate any one of the two alternatives and it is not mandatory to simulate both? Or we are doing a down-selection between Alt 1 and Alt 2. We prefer Alt 1 for down-selection. |
| MediaTek | We support the modified proposal. |
| Moderator | For MIMO scheme part, I clarified MU-MIMO as baseline.  For the BS/UE antenna configuration part, companies can select one or multiple options. For 64 BS antenna ports, it is already noted that “Other configurations are not precluded”.  For the number of UEs, I added “8 or 12”.  For precoding, I clarified companies can select one of the options. I updated from SVD to ZF for PDSCH.  I added feedback delay = 5ms, based on ZTE’s comment.  @ZTE, for precoding granularity, since the purpose of EVM discussion is to align evaluation assumption, evaluation deference is not welcomed. I prefer to have one value as much as possible.  @ZTE, for the simulation method for MU-MIMO LLS, let’s discuss on sect. 2.1.7 |
| New H3C | Support |
| ZTE2 | @FL: Thanks for FL’s clarification. For precoding granularity and simulation method, we tend to agree with your assessment.For MU-MIMO LLS, we agree to discuss it in FL’s proposal#2-6-1.  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. Hence it may be proper to handle this proposal with proposal#2-6-1 together. If it will impact the progress of this discussion, one alternative way can be FFS the part of “ZF” until the outcome of proposal#2-6-1 in this meeting. |
| vivo | Support the updated proposal in principle.   * For BS/UE antenna configuration, it is better to add the description of (M, N, P, Mg, Ng, Mp, Np) to avoid the confusion about the meaning of the mentioned values. * For precoding, it is better to align the same non-codebook precoder for PDSCH and PUSCH, i.e., both using ZF or SVD. * Additionally, the transmission scheme needs also be clarified for evaluation. For instance, CJT is a potential scenario to achieve more DMRS ports or UEs in MU-MIMO, we prefer to clarify the PDSCH transmission scheme for MU-MIMO, i.e., STRP-based can be mandatory and MTRP-based (e.g., CJT) can be optional. |
| Moderator | For precoding method of PDSCH/PUSCH, I set both [ZF or SVD] as FFS. But, we need to resolve it within this meeting.  @vivo, thank you for your suggestion of BS/UE antenna configuration. For your last comment of M-TRP or S-TRP, this proposal is for LLS, and I couldn’t catch your point why we should consider M-TRP or S-TRP in LLS. If you are talking about SLS assumption, FL proposal#2-2 intends S-TRP, because there is no TRP assumptions. |
| Ericsson | 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)    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 | Support the updated proposal. Regarding Ericsson’s comment on the proposal to emulate MU MIMO with N channels, 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. |

### 2.1.4 DMRS setting

Please provide your views on DMRS setting, with the following as a start point.

**FL proposal#2-1-4:**

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| **Parameter** | **Value** |
| **DMRS type** | Type 1E and/or Type 2E, which are enhanced DMRS that are based on the legacy RE mappings of DMRS Type 1/2, where the enhanced DMRS support larger DMRS ports.  Note: The terminology of Type 1E and/or Type 2E is for discussion purpose. |
| **DMRS configurations** | Single symbol DMRS and Double symbol DMRS without additional DMRS symbols are baseline.  Note: evaluation of Single symbol DMRS and Double symbol DMRS with 1 additional DMRS symbol is not precluded. |
| **DMRS mapping type** | Mapping type A (slot based) for PDSCH.  Mapping type A (slot based) for PUSCH. |

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| **Company** | **Comment** |
| OPPO | We think additional DMRS should be optional. High mobility is not a typical scenario for this DMRS enhancement. The DMRS enhancement should be applicable to the case without additional DMRS. |
| Samsung | Support both DMRS types, but 1 additional DMRS symbol can be optional which is similar view with OPPO. Also, the last row on the table above seems PDSCH mapping type and we think mapping type B is also considered. |
| Lenovo | We share same view with Oppo and Samsung and prefer DMRS without additional DMRS symbols as baseline and DMRS with additional DMRS symbols as optional. |
| CMCC | We think whether additional DMRS symbols should be used is related to UE velocity. For high or medium UE velocity, additional DMRS symbols can be used |
| InterDigital | Support |
| Futurewei | We share the same view to make additional DMRS symbols case as optional |
| Intel | Agree that additional DM-RS can be optional and can be evaluated for higher UE velocity |
| QC | Agree with many companies that additional DMRS should be optional. |
| CATT | Share similar view with OPPO and Samsung, additional DMRS should be optional. |
| Nokia/NSB | Agree with Oppo and Samsung that front-loaded single/double symbol option without 1 additional DMRS symbols should be used as baseline. |
| Xiaomi | Additional DMRS should be optional. |
| Fraunhofer IIS/HHI | Support |
| Spreadtrum | Share similar view with OPPO. |
| Docomo | Support |
| Moderator | The proposal is updated. No additional DMRS symbol is a baseline, and Mapping type B is used for PUSCH evaluation. |
| Ericsson | We think 1 additional DMRS symbol is important (i.e 1+1) . It’s often used in reality. We think 2 or 3 additional DMRS could be optional. The single front loaded DMRS configuration is very rare. |
| Huawei, HiSilicon | For the **DMRS mapping type** part, we think ‘Mapping type A (slot based) for PUSCH’ should be treated as the baseline. |
| ZTE | Both types are supported. For Type 1 DMRS, more details need to be decided, e.g. OCC length and DMRS pattern. |
| MediaTek | * For DMRS Types 1 and 2, we assume the FL refers to ***new*** DMRS patterns that are based on the legacy RE mappings, where the new patterns support more DMRS ports. If our understanding is correct, we prefer to give a new name to those new DMRS patterns, where the new names: (1) distinguish those new DMRS patterns from the legacy ones, and (2) infer which legacy RE mapping is the new pattern derived from. For example, Type 1E and Type 2E. * If additional DMRS symbols is to be considered, it should be paired with scenarios of at least medium UE speed since this is the main use case of additional symbols. Otherwise, we risk violating the “without increasing the DM-RS overhead” requirement.   We prefer mapping Type A as baseline. |
| DOCOMO | We agree with Ericsson. 1 additional DMRS symbol is widely used in practical, regardless of UE velocity. |
| Moderator | For DMRS Types 1 and 2, although we will create new terminology of DMRS type 1E/2E should be discussed later, I clarified that evaluated DMRS types are new Rel.18 DMRS.  I updated that PUSCH mapping type A from type B.  For additional DMRS, most of companies think no additional DMRS should be baseline. Thus, no update. |
| LGE | Support the updated proposal. |
| New H3C | Support the revised proposal. |
| ZTE2 | From the perspective of infra vendor, we do believe “with 1 addition DMRS symbol” is commonly needed. After confirm with our product team, “with 1 addition DMRS symbol” is even required for medium UE velocity in reality, e.g. 30km/h, which is baseline setting on UE velocity in proposal#2-1-2. Seriously, we think larger DMRS enhancement will be very useful in the forthcoming market, so the realistic requirement should be taken into consideration. According to the above as well as majority preference, it should be fairly treat the cases of w/ and w/o addition DMRS symbol at least. |
| vivo | Support the updated proposal. |
| Moderator | Although, 3 companies (Ericsson, Docomo, ZTE) suggest to consider “1 additional DMRS” as baseline, most of companies think no-additional DMRS should be baseline. Considering that, all I can do is to set no additional DMRS is a baseline and evaluation of 1 additional DMRS symbol is not precluded. |
| Ericsson | We know more companies prefer DMRS without additional DMRS symbol as baseline. However, as pointed out by ZTE and DOCOMO, one additional DMRS symbol is widely used in a real network deployment, even at low UE velocity. Therefore, we think it is important to simulate this scenario. So we just wonder if the following proposal is acceptable to the group.  **Proposal:**  Single symbol DMRS without additional DMRS, single symbol DMRS with one additional DMRS  and Double symbol DMRS without additional DMRS symbols are baseline.  2 or 3 additional DMRS symbols are not precluded |
| Samsung | Support the updated proposal. We prefer to consider additional DMRS symbols as optional. |

### 2.1.5 Transmitter and receiver setting

Please provide your views on transmitter and receiver setting, with the following as a start point.

**FL proposal#2-1-5:**

|  |  |
| --- | --- |
| **Parameter** | **Value** |
| **Link adaptation** | * Fixed modulation, coding and rank for BLER evaluation as baseline. * Adaptation of both MCS and rank for throughput evaluation as optional. |
| **HARQ** | Baseline: Off  Optional: On (HARQ with max. 4 re-transmissions) for throughput evaluation |
| **Channel estimation** | Realistic channel estimation with ideal info of frequency sync, SNR, doppler and delay spread |
| **Receiver type** | MMSE as baseline |
| **EVM** | No radio impairments |

|  |  |
| --- | --- |
| **Company** | **Comment** |
| OPPO | 1. As mentioned before, for THP, rank adaption can be optional.  2. For TPH evaluation, HARQ can be ON. |
| Samsung | Support in principle. |
| Lenovo | Support in principle. |
| CMCC | Support in principle. |
| InterDigital | Support |
| Futurewei | Support in principle |
| Intel | Second sub-bullet for link adaption can be optional for LLS |
| CATT | As mentioned above, for performance comparison purpose, it’s sufficient to adopt fixed modulation, coding and rank in BLER evaluation. Adaptation of both MCS and rank for throughput evaluation can be optional. |
| Nokia/NSB | We are fine with proposed settings. Additionally, we are fine to enable also HARQ with max. 4 re-transmissions. |
| Xiaomi | OK |
| Fraunhofer IIS/HHI | Support |
| Spreadtrum | Support |
| Docomo | Support. |
| Moderator | FL proposal is updated for link adaptation (fixed MCS/rank is baseline) and HARQ on for throughput evaluation. |
| Ericsson | Support. |
| Huawei, HiSilicon | As discussed above, the adaptive rank may not be suitable to be considered. |
| ZTE | Support updated FL’s proposal. |
| QC | We think both HARQ on and off can be simulated. HARQ OFF should be baseline. And HARQ ON can be optional. |
| MediaTek | Okay with modified FL’s proposal. |
| Moderator | For HARQ, I set HARQ off as baseline and HARQ ON as optional, based on Qualcomm’s comment. |
| LGE | Support |
| vivo | Support the updated proposal. |

### 2.1.6 Simulation method for MU-MIMO LLS

ZTE commented in sect. 2.1.3 that simulation method should be aligned for MU-MIMO LLS. Please provide your views on simulation method for MU-MIMO LLS, with the following as a start point.

**FL proposal#2-1-6:**

Following simulation method for MU-MIMO LLS of PDSCH can be considered:

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.

|  |  |
| --- | --- |
| **Company** | **Comment** |
| ZTE | 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. |
| Moderator | Let’s hear companies’ views. |
| ZTE2 | 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 | 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)    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 | 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. |

### 2.1.7 Other comments

Please provide your views on other aspects which are not included in the above.

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

## EVM for SLS for objective #3 (increasing DMRS ports)

For SLS, Huawei/HiSilicon evaluated the benefit of supporting increased DMRS ports on Uma with 200m ISD @3.5GHz. Nokia/NSB also shows evaluation result on Uma with 200m ISD @3.5GHz, and proposes Dense Urban (Macro only) as a baseline of EVM. MediaTek proposes to consider both Dense Urban (macro only) with 200 m ISD and Uma with 500m ISD.

**FL proposal#2-2:**

* **For SLS assumption for increasing DMRS ports in AI 9.1.3.1 in Rel.18,**
  + **Scenario: Dense Urban (Macro only) at 4GHz is a baseline. Other scenarios (e.g. Umi, Uma) are not precluded.**

|  |  |
| --- | --- |
| **Company** | **Comment** |
| OPPO | Fine. |
| Samsung | Support in principle. |
| Lenovo | Support in principle. |
| CMCC | Support in principle. |
| InterDigital | Support |
| Futurewei | Support in principle. |
| Intel | OK |
| CATT | Support. |
| Nokia/NSBN | Support FL’s proposal. |
| Xiaomi | OK |
| Spreadtrum | Support |
| Docomo | OK |
| Moderator | No update. |
| Huawei, HiSilicon | Support FL’s proposal. |
| ZTE | As our comment of FL proposal#2a, SLS should be low priority. |
| QC | SLS for this study should be low priority. |
| LGE | Support |
| New H3C | Support |
| ZTE | We still fail to see the strong motivation of SLS for this agenda. To avoid any ambiguous efforts for companies, updating proposal#2-2 as follows.  **FL proposal#2-2:**   * **For SLS (which is optional) assumption for increasing DMRS ports in AI 9.1.3.1 in Rel.18,**   + **Scenario: Dense Urban (Macro only) at 4GHz is a baseline. Other scenarios (e.g. Umi, Uma) are not precluded.** |
| Vivo | Support and fine with ZTE’s revision. |
| Moderator | @ZTE, vivo, FL proposal#2a already clarifies SLS is optional. No need to repeat the same description again. Hence, no update is made. |

Please provide your views on more details on SLS, with the following as a start point. The difference from Rel-16/17 MIMO EVM is marked in red.

|  |  |  |
| --- | --- | --- |
| **Parameter** | | **Value** |
| **Scenario** | | Dense Urban (macro only) |
| **Carrier frequency** | | 4GHz |
| **Duplex, Waveform** | | TDD, OFDM |
| **Multiple access** | | OFDMA |
| **Frequency Range** | | FR1 only. |
| **Inter-BS distance** | | 200 m |
| **Channel model** | | According to the TR 38.901 |
| **Antenna setup and port layouts at gNB** | | Companies need to report which option(s) are used between   * 32 ports: (M, N, P, Mg, Ng, Mp, Np) = (8,8,2,1,1,2,8), (dH,dV) = (0.5, 0.8)λ * 16 ports: (M, N, P, Mg, Ng, Mp, Np) = (8,4,2,1,1,2,4), (dH,dV) = (0.5, 0.8)λ   Other configurations are not precluded. |
| **Antenna setup and port layouts at UE** | | 4RX: (M, N, P, Mg, Ng, Mp, Np) = (1,2,2,1,1,1,2), (dH,dV) = (0.5, 0.5)λ for rank > 2  2RX: (M, N, P, Mg, Ng, Mp, Np) = (1,1,2,1,1,1,1), (dH,dV) = (0.5, 0.5)λ for (rank 1,2)  Other configurations are not precluded. |
| **BS Tx power** | | 41 dBm for 10MHz, 44dBm for 20MHz, 47dBm for 40MHz |
| **BS antenna height** | | 25 m |
| **BS noise figure** | | 5 dB |
| **UE noise figure** | | 9 dB |
| **UE antenna height & gain** | | Follow TR36.873 |
| **Modulation** | | Up to 256 QAM |
| **Coding on PDSCH** | | LDPC  Max code-block size=8448bit |
| **Numerology** | **Slot/non-slot** | 14 OFDM symbols per slot |
| **SCS** | 30 kHz |
| **Simulation bandwidth** | | 20 MHz |
| **Number of RBs** | | 52 for 30 kHz SCS |
| **Frame structure** | | Slot Format 0 (all downlink) for all slots |
| **MIMO scheme** | | SU/MU-MIMO with rank adaptation is a baseline  For low RU, SU-MIMO or SU/MU-MIMO with rank adaptation are assumed  For medium/high RU, SU/MU-MIMO with rank adaptation is assumed |
| **MIMO layers** | | For all evaluation, companies to provide the assumption on the maximum MU layers (e.g. 8 or 12) |
| **CSI feedback** | | Feedback assumption at least for baseline scheme  CSI feedback periodicity (full CSI feedback): 5 ms,  Scheduling delay (from CSI feedback to time to apply in scheduling): 4 ms |
| **Overhead** | | Companies shall provide the downlink overhead assumption |
| **Traffic model** | | Full-buffer, or FTP1 with 50% Resource Utilization |
| **UE distribution** | | [80%] indoor (3km/h),  [20%] outdoor (30km/h) |
| **UE receiver** | | MMSE-IRC as the baseline receiver |
| **Feedback assumption** | | Realistic |
| **Channel estimation** | | Realistic |

|  |  |
| --- | --- |
| **Company** | **Comment** |
| OPPO | For LLS, dv=0.8λ for gNB, while for SLS, dv=0.5λ. It would be better to align them. |
| Samsung | Support in principle. |
| Lenovo | Support in principle. |
| CMCC | Support in principle. |
| InterDigital | Support |
| Futurewei | Support in principle. |
| Intel | OK in general. OPPO’s suggestion is also OK. |
| CATT | Support. |
| Nokia/NSBN | Support FL’s proposal. |
| Xiaomi | Support |
| Fraunhofer IIS/HHI | Support |
| Spreadtrum | Support |
| Docomo | OK. |
| Moderator | Thank OPPO for pointing out. Dv for gNB is updated to 0.8λ to align with LLS. |
| Ericsson | Full buffer evaluations cannot be used to make conclusions (as usual in RAN1). |
| Huawei, HiSilicon | Similar to LLS assumptions, we think larger number of BS antennas (e.g., 64 ports: (8, 8, 2, 1, 1, 4, 8), (dH, dV) = (0.5, 0.8)λ) is also widely used and should be added. |
| ZTE | As our comment of FL proposal#2a, SLS should be low priority. |
| QC | SLS for this study should be low priority. |
| Moderator | No update. As noted, other BS antenna configuration is not precluded. |
| LGE | Support |
| New H3C | Support |
| vivo | Support in principle.  For BS/UE antenna configuration, it is better to add the description of (M, N, P, Mg, Ng, Mp, Np) to avoid the confusion about the meaning of the mentioned values. |
| Moderator | I added BS/UE antenna configuration, based on vivo’s comment. |
| Ericsson | We suggest for the traffic model to use “FTP1 with 50% resource utilization”, the “full buffer” model can be optional. |
| Samsung | Similar with 2.1.2 system setting, we think FDD is not precluded. |

### 2.2.1 Other comments

Please provide your views on other aspects which are not included in the above.

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

# Specifying objective #3 (increasing DMRS ports)

## Support of objective #3 (increasing DMRS ports) in Rel.18

Based on the companies tdocs, 20 companies support to specify objective #3 (increasing DMRS ports) in Rel.18, while 3 companies want to see SLS evaluation result to understand the benefit. OPPO mentions SLS may be needed to evaluate the required number of orthogonal DMRS ports. LGE mentions that using quasi-orthogonal ports without increasing the orthogonal DMRS ports can be another option.

Regarding to the evaluation results, Huawei/HiSilicon has SLS result that shows the benefit of supporting increased DMRS ports, compared to increasing DMRS ports by gNB implementation (i.e. by using the for DMRS sequence generation) (Figure 3 in [3]). Qualcomm has LLS results that shows increasing DMRS ports has performance gain even for SU-MIMO (Fig.2 in [26]). While, Nokia/NSB has SLS result that shows no marginal gain observed to support more than 12 UEs for MU-MIMO with rank 1 UE (Figure 1 in [21]).

|  |  |
| --- | --- |
| **Proposals** | **Companies** |
| **Alt.1: Support to specify objective #3 (increasing DMRS ports) in Rel.18** | FUTUREWEI, Huawei/HiSilicon, ZTE, Spreadtrum, InterDigital, New H3C, CATT, vivo, NEC, Xiaomi, Samsung, Lenovo, Apple, CMCC, DOCOMO, Fraunhofer IIS/ Fraunhofer HHI, MediaTek, Intel, Qualcomm, Ericsson (20) |
| **Alt.2: Need more study to see the benefit of specify objective #3 (increasing DMRS ports) in Rel.18** | OPPO, LGE, Nokia/NSB (3) |

Considering the super majority views support Alt.1, and we observe performance gain of increasing DMRS ports, FL proposal is to agree on Alt.1. Also, some companies mention it is better to strive to have common design of DMRS enhancement for PDSCH and PUSCH for a given DMRS Type, which is also noted in WID. Based on reviewing tdocs, no company propose different DMRS design for PDSCH and PUSCH.

**FL proposal#3-1:**

* **Specify to increase the max. number of DMRS ports for PDSCH/PUSCH larger than Rel.15 for CP-OFDM without increasing the DMRS overhead.**
  + **Strive to have common design of DMRS enhancement for PDSCH and PUSCH** **for a given DMRS Type.**

|  |  |
| --- | --- |
| **Company** | **Comment** |
| OPPO | We are fine to this enhancement if majority companies think it is beneficial. |
| Samsung | Support the FL proposal to specify the objective#3. |
| Lenovo | Support the FL proposal |
| NEC | Support |
| CMCC | Support |
| InterDigital | Support |
| Futurewei | Support |
| Intel | OK |
| CATT | Support the proposal. |
| Nokia/NSBN | Support FL’s proposal. |
| Xiaomi | support. |
| Fraunhofer IIS/HHI | Support |
| Spreadtrum | Support. |
| Docomo | Support |
| Moderator | Thank companies for being flexible. No update on FL proposal. |
| Ericsson | Support |
| Huawei, HiSilicon | Support FL’s proposal. |
| ZTE | Support. |
| Sharp | Support |
| LGE | We could be ok if majority support this. |
| New H3C | Support |
| vivo | Support |

## The max. number of support DMRS ports

WID for objective #3 says “*up to 24 orthogonal DMRS ports*” and “*each applicable DMRS type, the maximum number of orthogonal ports is doubled for both single- and double-symbol DMRS*”. Multiple companies mention it is better to clarify the max. number of DMRS ports for each DMRS configuration. Meanwhile, 2 companies (New H3C, OPPO) prefer to keep open for the exact number of DMRS ports for study.

Following table shows the max. number of enhanced DMRS ports in Rel.18, based on WID.

|  |  |  |
| --- | --- | --- |
|  | **Rel.15** | **Rel.18** |
| **Single symbol DMRS type 1** | 4 ports | 8 ports |
| **Double symbol DMRS type 1** | 8 ports | 16 ports |
| **Single symbol DMRS type 2** | 6 ports | 12 ports |
| **Double symbol DMRS type 2** | 12 ports | 24 ports |

**FL proposal#3-2:**

* **The max. number of enhanced DMRS ports in Rel.18 is doubled from Rel.15 DMRS ports:**
  + **For DMRS type 1, the max. number of enhanced DMRS ports in Rel.18 for PDSCH/PUSCH is**
    - **Single symbol DMRS: 8 DMRS ports.**
    - **Double symbol DMRS: 16 DMRS ports.**
  + **For DMRS type 2, the max. number of enhanced DMRS ports in Rel.18 for PDSCH/PUSCH is**
    - **Single symbol DMRS: 12 DMRS ports.**
    - **Double symbol DMRS: 24 DMRS ports.**

|  |  |
| --- | --- |
| **Company** | **Comment** |
| OPPO | Support. |
| Samsung | Support the FL proposal. |
| Lenovo | Support the FL proposal. |
| NEC | Support |
| CMCC | Support |
| InterDigital | Support |
| Futurewei | Support |
| Intel | OK |
| CATT | Support the proposal. |
| Nokia/NSB | We are fine with FL’s proposal in principle. In addition, we would like to note that type-1 is not restricted to 16 AP. In principal, type-1 with up to 24 Aps are not precluded. |
| Xiaomi | OK |
| Spreadtrum | Support. |
| Docomo | Support |
| Moderator | No update on FL proposal. |
| Ericsson | Support. This is according to WID. |
| Huawei, HiSilicon | Support FL’s proposal. |
| ZTE | Support. |
| MediaTek | Support. |
| Sharp | Support |
| LGE | We could be ok if majority support this. |
| New H3C | Support |
| vivo | Support |

## How to increase DMRS ports

To increase the number of DMRS ports, generally, we have the following two direction:

* Direction 1: Increase the number of DMRS ports within CDM group
* Direction 2: Increase the number of CDM groups

Companies’ proposals are summarized in the following table. Between the proposals, ZTE, Vivo, Xiaomi, Nokia, etc. show evaluation results to compare the performance difference between at least two of the following options.

|  |  |  |
| --- | --- | --- |
| **Direction** | **Proposals** | **Companies** |
| **#1 (increase the number of DMRS ports within a CDM group)** | **Opt. 1 (enhance FD-OCC): Introduce larger FD-OCC length than Rel.15 (e.g. 4 or 6).** | Futurewei (length 4), Huawei/HiSilicon (2-level OCC), ZTE (length 4), Spreadtrum (length 4), InterDigital (length 4), CATT(length 4), vivo (length 4 for type 2, length 6 for type 1), NEC (length 4 for type 2, length 6 for type 1), Xiaomi (length 4 for type 2, length 6 for type 1), Samsung (length 4 for type 2, length 6 for type 1), OPPO (length 4), Lenovo (length 4), CMCC (length 4), DOCOMO (length 4 or 6), Nokia/NSB (length 4 or 6), Fraunhofer IIS/ Fraunhofer HHI (length 4 or 6), MediaTek (length 4), Intel (length 4 for type 2, length 6 for type 1), Qualcomm(length 4), Ericsson (length 4 or 6) |
| **Opt. 2 (enhance TD-OCC): Utilize TD-OCC over non-contiguous DMRS symbols (e.g. TD-OCC across front/additional DMRS symbols)** | ZTE (in addition to opt. 1-1), DOCOMO, MediaTek, Ericsson (in addition to opt. 1-1/1-2) |
| **#2 (increase the number of CDM groups)** | **Opt. 3 (Sparser frequency allocation): increase the number of CDM groups (e.g. larger number of comb/FDM)** | Futurewei, Spreadtrum, InterDigital, CATT, Samsung, OPPO (with 3 FD-OCC), Lenovo, Apple, CMCC, DOCOMO, Sharp, Nokia/NSB, MediaTek, Ericsson |

It is pointed out that each option has pros. And cons. For example, Opt.1 and Opt.3 has potential performance degradation in large delay spread. Opt.1 has potential scheduling restriction (e.g., gNB may need to schedule even number of PRBs for some case). Meanwhile, Opt.2 has potential performance degradation in high UE velocity, and it also has potential scheduling restriction (e.g. how to apply freq. hopping for PDSCH/PUSCH). Other aspect includes backward compatibility.

It is better to align the possible options, and evaluate the pros. And cons. Some companies (e.g. ZTE, Ericsson) has interest in supporting multiple options, while other companies seems to intend to down-select one option.

Most of companies think the same option can be applied to both single symbol DMRS and double symbol DMRS.

**FL proposal#3-3:**

* **To increase the number of DMRS ports for PDSCH/PUSCH, evaluate and, if needed, specify one or more from the following options:**
  + **Opt.1 (enhance FD-OCC): Introduce larger FD-OCC length than Rel.15 (e.g. 4 or 6).**
    - **Study aspect includes potential performance degradation in large delay spread, potential scheduling restriction, backward compatibility**.
  + **Opt.2 (enhance TD-OCC): Utilize TD-OCC over non-contiguous DMRS symbols (e.g. TD-OCC across front/additional DMRS symbols)**
    - **Study aspect includes potential performance degradation in high UE velocity, potential scheduling restriction (e.g. how to apply freq. hopping), potential DMRS configuration restriction (e.g. restriction of the number of additional DMRS), backward compatibility**.
  + **Opt.3 (Sparser frequency allocation): increase the number of CDM groups (e.g. larger number of comb/FDM).**
    - **Study aspect includes potential performance degradation in large delay spread, backward compatibility**.
  + **Opt.4 (using TDMed DMRS symbol): reusing additional DMRS symbols to increase orthogonal DMRS ports**
    - **Study aspect includes potential performance degradation in high UE velocity, potential DMRS configuration restriction (e.g. restriction of the number of additional DMRS), backward compatibility.**
  + **The same option can be applied to both single symbol DMRS and double symbol DMRS.**

|  |  |
| --- | --- |
| **Company** | **Comment** |
| OPPO | Support. |
| Samsung | At this early stage of Rel-18, we are fine for FL proposal 3-3 in principle. Among options, we prefer option 1 and option 3 since option 2 may have worse scheduling restriction such as frequency hopping and additional symbol, and also additional delay for a channel estimation and applying TD-OCC for non-contiguous DMRS symbols. Given the majority views on option 1 and 3, option 2 can be treated as FFS. |
| Lenovo | Support the FL proposal and prefer Opt.1 and opt.3 with high priority. |
| NEC | Support the proposal, and we support Opt.1. |
| CMCC | Support the proposal. At the early stage of R18, all the options can be considered. |
| InterDigital | Support in principle |
| Futurewei | Support the proposal with preference on Opt.1 and Opt.3. |
| Intel | Since it’s the first meeting of Release 18, OK to list all options but we prefer Options 1 and 3. |
| QC | We support the proposal in general. Similar comment as other companies: we prefer, if possible, prioritize the study on option 1 and 3, to reduce the work load of RAN1, given option 1 and 3 seem having majority support. |
| CATT | Agree with Samsung, Option 2 can be treated as FFS. If a UE is not configured with additional DMRS symbols, Option 2 is not feasible. |
| Nokia/NSB | Support Opt.1 and Opt.3. From UL perspective, TD-OCC over continuous up to 2 DMRS symbols (e.g. frontloaded DMRS symbols) should be also included as part of Opt.1 and Opt.3. However, Opt.2, may introduce a scheduling restriction which is not desirable. |
| Xiaomi | Support proposal#3-3 to list all possible schemes. And we prefer Opt.1 and Opt.3. |
| Fraunhofer IIS/HHI | Agree with the proposal in principle. Prefer to treat Opt. 1 and Opt. 3 with higher priority due to majority support. |
| Spreadtrum | Support in principle. After the evaluation, we prefer to specify only one option. |
| Docomo | Support the proposal. Between the proposals, we prefer Opt.1 as 1st priority. One concern of Opt.2 is scheduling restriction of freq. hopping and additional DMRS symbol. |
| Moderator | The proposal is “**evaluate and, if needed, specify**”. Hence, we don’t need to make some option as FFS.  This is the first meeting, it is fair to note all options for study, and we can discuss and down select in later meetings. From workload perspective, it is more important to agree FL proposal#3-3 at this meeting, so that companies can compare it. Hence, there is no update on FL proposal#3-3. |
| Ericsson | Support. Note that in our view, Option 2 is an add-on feature to Option 1 or 3. Option 2 doesn’t actually increase the number of ports, but provides the possibility to recover from the channel estimation performance loss of increasing the FD-OCC comb length or sparser frequency allocation. |
| Huawei, HiSilicon | Support FL’s proposal. Prefer to treat Opt.1 as high priority and Opt.3 can also be considered. |
| ZTE | Considering in the early stage of this objective, we are fine with the proposal. Considering FD-OCC /FDM are more sensitive with large delay spread, we prefer option 2 as one effective scheme compared with FD-OCC/FDM in the large delay spread scenario. |
| MediaTek | We prefer to focus only on options 1 and 3.  We would also like to repeat our comment for Section 2.1.4 on providing distinguishable names for Release 18 Types 1 and 2 DMRS. That is, we prefer to give a new name to new DMRS patterns such that: (1) we can distinguish those new DMRS patterns from the legacy ones, and (2) we can infer which legacy RE mapping is the new pattern derived from. For example, Type 1E and Type 2E. |
| Sharp | Support the proposal. |
| Moderator | No update. @MediaTek, thank you for your comment. I agree it is beneficial to have a common name. We can discuss it with sect. 2.1.4 or later. |
| LGE | TD-OCC, FD-OCC, FDM and TDM can provide additional orthogonal multiplexing domain. Each multiplexing method has its advantages and disadvantages. Therefore we need study about it.  Also, TDM can be considered reusing additional DMRS configuration to increase orthogonal DMRS ports. In this way, legacy DMRS symbols can be divided into two TDM groups so that the number of orthogonal ports is doubled.  In our view, MU-MIMO mainly targets low velocity UEs so that they do not require additional DMRS symbols within one slot. We suggest to add Option 4 as follow.   * + **Opt.4 (using TDMed DMRS symbol): reusing additional DMRS symbols to increase orthogonal DMRS ports**   **Study aspect includes potential performance degradation in high UE velocity, potential DMRS configuration restriction (e.g. restriction of the number of additional DMRS), backward compatibility.** |
| New H3C | Support this proposal with LGE’s update |
| vivo | Support the proposal and also ok with LGE’s update |
| Moderator | Updated by LGEs comment. Since this is the 1st meeting, it should be fine to note all possible options for study. |
| Ericsson 1 | For option 2, we prefer to study the performance of TD-OCC on top of FD-OCC (opt 1) or FDM (opt 2). As we explained in R1-2205112, the receiver can then decide, based on knowledge of statistics of the channel realization: whether it should use the frequency domain code to separate the DMRS ports, which is useful in channels with low delay spread; or if it should use the time domain code to separate the DMRS ports, which is useful in channels with low doppler spread.   * + **Opt.5 TD-OCC over non-contgeous DMRS symbols combined with FD-OCC or FDM: reusing additional DMRS symbol(s) to improve channel estimation performance.**     - **Study aspect includes potential performance degradation in high UE velocity, potential scheduling restriction (e.g. how to apply freq. hopping), potential DMRS configuration restriction (e.g. restriction of the number of additional DMRS), backward compatibility**. |
| Samsung | Since it is the first meeting, we are fine with listing options based other companies’ preference. However, due to a large number of possible options, setting a priority among options would be helpful since some options are supported by almost all of companies, but some other options are supported by few companies. |

## MU-MIMO between Rel.15 DMRS ports and Rel.18 DMRS ports

Samsung, Apple, DOCOMO, MediaTek, Intel, Qualcomm mention that it is beneficial to study MU-MIMO (coexistence) between Rel.15 DMRS ports and Rel.18 DMRS ports. Qualcomm has an assessment of the issue of coexistence and proposes scheduling restriction in a same CDM group.

If we don’t update DMRS position in time/freq. domain, at least MU-MIMO with different CDM groups for Rel.15 DMRS and Rel.18 DMRS should be possible. Whether and how to enable MU-MIMO between Rel.15 DMRS and Rel.18 DMRS in the same CDM group can be studied.

**FL proposal#3-4:**

* **To increase the max. number of DMRS ports for PDSCH/PUSCH compared to Rel.15 DMRS for CP-OFDM without increasing the DMRS overhead,**
  + **Study whether/how to enable MU-MIMO between Rel.15 DMRS ports and Rel.18 DMRS ports, as well as whether/how to enable MU-MIMO among Rel.18 DMRS ports, in the same or different CDM group.**

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| **Company** | **Comment** |
| OPPO | Support. |
| Samsung | Support the FL proposal. This proposal is beneficial for increasing spectral efficiency of the whole network which serves both legacy UEs (Rel-15/16/17) and new Ues (Rel-18). We are fine for multiplexing between Rel-15 and Rel-18 DMRS ports, not only under the different CDM groups, but also under the same CDM group which orthogonality between Rel-15 DMRS ports and Rel-18 DMRS ports can be achieved. |
| Lenovo | Support the FL proposal. |
| NEC | Support |
| CMCC | Support. |
| InterDigital | Support with a lower priority |
| Futurewei | Support. |
| Intel | Support in general. But this should be discussed with the Options in 3.3 i.e., in our view backwards compatible options should be given more priority. |
| QC | We thank FL for the proposal, and we support it in general, except that we think one aspect of MU-MIMO is missing.  We need study not only MU between Rel-15 DMRS ports and Rel-18 DMRS ports, but also MU between Rel-18 DMRS ports (UE A) with Rel-18 DMRS ports (UE B). For example, in Rel-15, for type 1 DMRS, UE A on ports {0,2} with UE B on ports {1,3} is not allowed. Similarly, in Rel-18 type 1 new DMRS, UE A on ports {8,10} with UE B on ports {9, 11} should not be allowed. Of course, the details of which Rel-18 new DMRS ports can/cannot co-exist with which Rel-18 DMRS ports are to be further discussed. But we should include this aspect in the scope of study.  Therefore, we suggest the following update of FL proposal   * **To increase the max. number of DMRS ports for PDSCH/PUSCH compared to Rel.15 DMRS for CP-OFDM without increasing the DMRS overhead,**   + **Study whether/how to enable MU-MIMO between Rel.15 DMRS ports and Rel.18 DMRS ports, as well as whether/how to enable MU-MIMO among Rel.18 DMRS ports, in the same or different CDM group.** |
| CATT | Support. |
| Nokia/NSB | Support FL’s proposal. |
| Xiaomi | Support |
| Fraunhofer IIS/HHI | Support |
| Spreadtrum | Support |
| Docomo | Support |
| Moderator | FL proposal is updated based on Qualcomm’s input. |
| Ericsson | We are OK with updated FL proposal. |
| Huawei, HiSilicon | Support FL’s updated proposal. |
| ZTE | Agree to study. The main purpose of increasing the max. number of DMRS ports is to increase the spectral efficiency for the net work, we prefer to enable MU-MIMO between legacy and Rel.18 DMRS in the same and different CDM groups. |
| MediaTek | Support the updated proposal. |
| Sharp | Support |
| LGE | Support |
| New H3C | Support |
| vivo | Support |

## Other proposals

Following proposals are also proposed.

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| **Proposals** | **Companies** |
| 1. **Support dynamic indication between Rel.18 DMRS ports and Rel.15 DMRS ports** | Futurewei, ZTE, vivo, Samsung, Fraunhofer IIS/ Fraunhofer HHI |
| 1. **DM-RS EPRE enhancement in case of Sparser frequency allocation (increase the number of CDM groups)** | CATT, Xiaomi |
| 1. **Study whether to indicate the length of FD-OCC to UEs** | NEC |
| 1. **Reuse the antenna port indication table in 38.212 as much as possible or both PDSCH and PUSCH** | Apple |
| 1. **Study on designing DMRS table entries focusing on utilizing MU-MIMO** | Samsung |

Please provide your views on the above proposals, or other aspects which are not included in the summary, if any.

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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. |
| 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. |

# 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.

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| **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  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.

**FL proposal#4:**

* **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. |

# Other issues

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

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| Company | Comment |
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# 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 |