**3GPP TSG RAN WG1 Meeting #109-e R1-200xxxx**

**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. |
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**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. |
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## 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 (Optional for PUSCH).**
  + **Evaluation metric:** 
    - **User throughput for adaptive MCS and rank**
    - **BLER for fixed MCS and rank**
  + **Evaluation baseline (i.e. compared with): Rel.15 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. |
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### 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).

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| **Parameter** | **Value** |
| Duplex, Waveform | TDD, OFDM |
| Carrier Frequency | 4 GHz |
| Subcarrier spacing | 30kHz |
| Channel Model | Alt. 1: CDL channels with first priority on CDL-A, while the use of other CDL channels isn’t precluded  Alt. 2: TDL channels with uncorrelated antenna elements with first priority on TDL-A, while the use of other TDL channels isn’t precluded |
| Delay spread | 30ns, 300ns |
| UE velocity | 3km/h, 30km/h, 120kmp/h |
| Allocation bandwidth | 20MHz |

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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. |
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### 2.1.3 MIMO setting

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

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| **Parameter** | **Value** |
| MIMO scheme | MU-MIMO / SU-MIMO |
| BS antenna configuration | Companies need to report which option(s) are used between  - 32 ports: (8,8,2,1,1,2,8), (dH,dV) = (0.5, 0.8)λ  - 16 ports: (8,4,2,1,1,2,4), (dH,dV) = (0.5, 0.8)λ  Other configurations are not precluded. |
| UE antenna configuration | 4RX: (1,2,2,1,1,1,2), (dH,dV) = (0.5, 0.5)λ for rank > 2  2RX: (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, or 4 |
| Precoding | Alt. 1: SVD based sub-band precoding on ideal channel knowledge  Alt. 2: CSI codebook based sub-band precoding on ideal CSI feedback. |
| Precoding granularity | 4 PRB |

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| **Company** | **Comment** |
| OPPO | It needs to be clarified that the configuration is only applied to DL DMRS evaluation. |
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### 2.1.4 DMRS setting

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

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| **Parameter** | **Value** |
| **DMRS type** | Type 1 and/or Type 2 |
| **DMRS configurations** | Single symbol DMRS with 1 additional DMRS symbols.  Double symbol DMRS with 1 additional DMRS symbols |
| **DMRS mapping type** | Mapping type A (slot based) |

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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. |
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### 2.1.5 Transmitter and receiver setting

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

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| **Parameter** | **Value** |
| **Link adaptation** | * Fixed modulation, coding and rank for BLER evaluation. * Adaptation of both MCS and rank for throughput evaluation. |
| **HARQ** | Off |
| **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 |

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| **Company** | **Comment** |
| OPPO | 1. As mentioned before, for THP, rank adaption can be optional.  2. For TPH evaluation, HARQ can be ON. |
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### 2.1.6 Other comments

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

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| **Company** | **Comment** |
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## 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.**

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| **Company** | **Comment** |
| OPPO | Fine. |
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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.

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| **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: (8,8,2,1,1,2,8), (dH,dV) = (0.5, 0.5)λ * 16 ports: (8,4,2,1,1,2,4), (dH,dV) = (0.5, 0.5)λ   Other configurations are not precluded. |
| **Antenna setup and port layouts at UE** | | 4RX: (1,2,2,1,1,1,2), (dH,dV) = (0.5, 0.5)λ for rank > 2  2RX: (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 |

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| **Company** | **Comment** |
| OPPO | For LLS, dv=0.8λ for gNB, while for SLS, dv=0.5λ. It would be better to align them. |
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### 2.2.1 Other comments

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

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| **Company** | **Comment** |
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# 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]).

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| **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.**

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| **Company** | **Comment** |
| OPPO | We are fine to this enhancement if majority companies think it is beneficial. |
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## 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.

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|  | **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.**

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| **Company** | **Comment** |
| OPPO | Support. |
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## 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.

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| **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**.
  + **The same option can be applied to both single symbol DMRS and double symbol DMRS.**

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| **Company** | **Comment** |
| OPPO | Support. |
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## 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 and Rel.18 DMRS in the same or different CDM group.**

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| **Company** | **Comment** |
| OPPO | Support. |
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## 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. |
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# 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.**

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| **Company** | **Comment** |
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# Other issues

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

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# References

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| [17] | R1-2204232 | Views on supporting increased number of orthogonal DMRS ports | Apple |
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