**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.

|  |
| --- |
| 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 |

**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. |
|  |  |

## 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.
 |
| 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. |
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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).

|  |  |
| --- | --- |
| **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 precludedAlt. 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 |

|  |  |
| --- | --- |
| **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. |

### 2.1.3 MIMO setting

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

|  |  |
| --- | --- |
| **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)λOther configurations are not precluded. |
| UE antenna configuration | 4RX: (1,2,2,1,1,1,2), (dH,dV) = (0.5, 0.5)λ for rank > 22RX: (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 knowledgeAlt. 2: CSI codebook based sub-band precoding on ideal CSI feedback. |
| Precoding granularity | 4 PRB |

|  |  |
| --- | --- |
| **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 |
|  |  |

### 2.1.4 DMRS setting

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

|  |  |
| --- | --- |
| **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) |

|  |  |
| --- | --- |
| **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. |
|  |  |

### 2.1.5 Transmitter and receiver setting

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

|  |  |
| --- | --- |
| **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  |

|  |  |
| --- | --- |
| **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 |
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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.**

|  |  |
| --- | --- |
| **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 |
|  |  |

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: (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 > 22RX: (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** | LDPCMax 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 schemeCSI 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. |
| 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 |
|  |  |

### 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 $n\_{SCID}\in \left\{0, 1\right\}$ 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.  |
| 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. |
|  |  |

## 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.**

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| --- | --- |
| **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 |

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

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| **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. |
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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.  |
| 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 |

## 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. |
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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, IntelAlt.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** |
| 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. |
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# 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

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| --- | --- | --- | --- |
| [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 |