**3GPP TSG RAN WG1 #110bis-e R1-2210263**

**e-Meeting, October 10th – 19th, 2022**

**Source: Moderator (NTT DOCOMO)**

**Title: FL summary on DMRS#1**

**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.

# Objective #3 (increasing DMRS ports)

## Confirm WA

In RAN1#110 meeting, the following working assumption was made.

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| Working Assumption   * To increase the number of DMRS ports for PDSCH/PUSCH, support at least Opt.1 (introduce larger FD-OCC length than Rel.15 (e.g. 4 or 6)).   + FFS: FD-OCC length for Rel.18 DMRS type 1 and type 2.   + FFS: Whether it is needed to handle potential performance issues of Opt 1. For example, study if there is performance loss in case of large delay spread scenario. If needed, how (e.g. additionally support other options). |

18 companies propose to confirm the WA. Based on tdoc reviewing, there is no critical concern to confirm the WA. Hence, FL proposal is to confirm the WA. FFS for FD-OCC length can be removed, because it is covered in other agreement.

FL notes:

* Ericsson shows evaluation result that Opt.5 outperforms Opt.1 in case of the large delay spread.
* ZTE, NTT DOCOMO propose to consider TD-OCC enhancement across non-consecutive symbols as an additional option. While, Intel, NEC, Samsung, Qualcomm, Nokia/NSB propose to consider Opt.1 only.
* Huawei/HiSilicon propose to enhance TD-OCC between double symbols in Opt.1. From FL perspective, Opt.1 does not preclude possibility of such enhancement in future.

**FL proposal#3.1:**

* **Confirm the WA in RAN1#110 with the following update:**
  + ***To increase the number of DMRS ports for PDSCH/PUSCH, support at least Opt.1 (introduce larger FD-OCC length than Rel.15 (e.g. 4 or 6)).***
    - ***~~FFS: FD-OCC length for Rel.18 DMRS type 1 and type 2.~~***
    - ***FFS: Whether it is needed to handle potential performance issues of Opt 1. For example, study if there is performance loss in case of large delay spread scenario. If needed, how (e.g. additionally support other options).***

**Support/fine (18): Huawei/HiSilicon, ZTE, Spreadtrum (remove FFS), vivo, OPPO, Google, CATT, Intel (Only Opt.1), NEC (Opt.1 only), Xiaomi, Fraunhofer IIS/HHI, Samsung (Opt.1 only), NTT DOCOMO, Qualcomm (Opt.1 only), Nokia/NSB (Opt.1 only)**

**No (1?): Ericsson?**

Please provide your views.

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| **Company** | **Comment** |
| DOCOMO | Support |
| Apple | We are fine. But does the modification help anything. We anyhow need to discuss whether FD-OCC 4 and/or FD-OCC 6 should be supported. |
| InterDigital | Support FL proposal. |
| Futurewei | Support |
| Google | Support |
| OPPO | Support |
| Ericsson | We need to acknowledge the performance issue with FD-OCC 4/6 first. Several companies have shown in their simulation with 300ns/1000ns delay spread there’s certain level of performance degradation being observed with FD-OCC 4/6 compare with FD-OCC 2.  Ericsson, HW, Intel, Lenovo, InterDigital, ZTE …  Once we acknowledge the performance issue, we can further discuss if there’s need to resolve the issue in Rel-18 DMRS design, either support enhancement on top of Opt1(e.g. FAT-OCC) or other options (e.g. TD-OCC) or dynamic switching between Rel15/Rel-18 DMRS type.  Proposal 1:  ***RAN1 acknowledge that for large delay spread scenario there is performance degradation with FD-OCC4/6 (compare with Rel-15 FD-OCC2)***  Proposal 2:   * + ***To increase the number of DMRS ports for PDSCH/PUSCH, support at least Opt.1 (introduce larger FD-OCC length than Rel.15 (e.g. 4 or 6)).***     - ***FFS: FD-OCC length4/6 combined with TD-OCC length 2 on additional DMRS symbols (FAT-OCC)***     - ***FFS: other options***   Note: FAT-OCC or dynamic switching between Rel18/Rel-15 DMRS can mitigate the observed performance issue with large delay spread for Opt1. |
| ZTE | Support in principle.  Regarding the FFS part, simulation results provided by several companies have already shown that FD-OCC-M (M>2) will cause sever performance loss in case of large delay spread. For MU-MIMO scenario, this case should also be enhanced with increase DMRS ports anyways. Ericsson’s proposals can be used to capture the above.  **FL proposal#3.1:**   * **Confirm the WA in RAN1#110 with the following update:**   + ***To increase the number of DMRS ports for PDSCH/PUSCH, support at least Opt.1 (introduce larger FD-OCC length than Rel.15 (e.g. 4 or 6)).***   + ***RAN1 acknowledge that for large delay spread scenario there is performance degradation with FD-OCC4/6 (compare with Rel-15 FD-OCC2), and RAN1 shall strive to further study the solution (e.g., TD-OCC) to increase the number of orthogonal DMRS ports in this scenario.***     - ***~~FFS: FD-OCC length for Rel.18 DMRS type 1 and type 2.~~*** |
| Lenovo | We are fine with the proposal. In addition to Opt.1, we also prefer to Opt.3 since it can provide performance gain relative to Opt.1 in case of large delay spread scenario, especially in high SNR region. Furthermore, the scheduling is more flexible for multiplexing more users on account of introducing more CDM groups. |
| Huawei, HiSilicon | Support. |
| NEC | Support. |
| Xiaomi | Support FL proposal#3. |
| MediaTek | Support |
| Spreadtrum | Support. Considering the potential work load and UE complexity. We don’t prefer additional schemes other than Opt.1. |
| Ericsson | FD-OCC combined with TD-OCC on additional DMRS symbols (FAT-OCC) is based on FD-OCC length 4 or 6, only if additional DMRS symbol is configured, you swap the sign on additional symbols, i.e. apply TD-OCC length 2. When additional symbol is not configured, only FD-OCC is applied. Please also note that TD-OCC on additional DMRS symbol is not new, it is **already used in LTE** uplink.    The receiver side can decide whether to utilize FD-OCC or TD-OCC to decode based on the channel knowledge from receiver side. Considering the complexity for UE, if the **UE** side receiver chooses to **always use FD-OCC**, it works fine too.  More important is that **gNB can utilized FAT-OCC**. We think FAT-OCC is very useful for improving uplink performance. In our simulation we’ve shown that the performance of FAT-OCC is on par with FD-OCC length 2, i.e. the Rel-15 DMRS when there’s large delay spread.  We still believe FAT-OCC is a simple and effective design for Rel-18 DMRS, and it can be considered as an extension based on option1.  **FL proposal#3.1:**   * **Confirm the WA in RAN1#110 with the following update:**   + ***To increase the number of DMRS ports for PDSCH/PUSCH, support ~~at least~~ Opt.1 (introduce larger FD-OCC length than Rel.15 (e.g. 4 or 6)).***   + ***RAN1 acknowledge that for large delay spread scenario there is performance degradation with FD-OCC4/6 (compare with Rel-15 FD-OCC2), ~~and RAN1 shall strive to further study the solution (e.g., TD-OCC) to increase the number of orthogonal DMRS ports in this scenario.~~***     - ***~~FFS: FD-OCC length for Rel.18 DMRS type 1 and type 2.~~*** |
| vivo | Support the proposal, and fine with removing ‘at least’. |
| Samsung | Support the proposal to confirm the working assumption, and we are fine with removing “at least” to have Opt. 1 only for supporting Rel-18 DMRS. |
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## Details on Opt.1 (FD-OCC)

### 2.2.1 FD-OCC length.

For FD-OCC length for Rel.18 DMRS type 1, we will down FD-OCC length in RAN1#110bis-e.

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| Agreement   * For enhanced FD-OCC length for DMRS of PDSCH/PUSCH, support the following FD-OCC length:   + For Rel.18 DMRS type 1, down select from the following in RAN1#110bis-e:     - Opt.1-1: Length 6 FD-OCC is applied to 6 REs of DMRS within a PRB within an CDM group     - Opt.1-2: Length 4 FD-OCC is applied to 4 REs of DMRS within a PRB or across consecutive PRBs within an CDM group   + For Rel.18 DMRS type 2:     - Length 4 FD-OCC is applied to 4 REs of DMRS within a PRB within an CDM group     - FFS: Support of length 6 FD-OCC |

Majority companies propose FD-OCC length 4, while some other companies propose FD-OCC length 6.

FD-OCC length 4 has the following benefits:

* Better performance especially for large delay spread.
* Common FD-OCC design between DMRS type 1/2 (i.e. Simplify the specification work, and reduce UE/gNB implementation complexity).
* FD-OCC length 4 can be the same sequence as duplication of Rel.15 FD-OCC length 2 ([+1 +1] and [+1 -1]).

On the other hand, FD-OCC length 4 has the following drawbacks:

* FD-OCC can be applied across two consecutive PRBs, which causes orphan RE problem in sect. 2.2.2.



Figure 2-1. Extension of FD-OCC for DMRS type 1 (CDM group 0) [24].

From performance perspective, multiple companies show evaluation results to compare FD-OCC length 4 and 6 as following.

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| Qualcomm [24]  Chart, line chart  Description automatically generated  **Fig 10: Peak throughput (at 40dB SNIR) comparison between size 4 and size 6 FD-OCC** |

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| Intel [13]    Figure : DM-RS Channel Estimation Performance for 2 UE MU-MIMO at varying delay spread with MMSE before and after channel de-spreading   1. **At high delay spread, receiver implementation for channel estimation can avoid performance difference between length-4 vs. length-6 FD-OCC, especially at high SNRs.** |

**FL proposal#2.2.1:**

* **For enhanced FD-OCC length for DMRS of PDSCH/PUSCH for Rel.18 DMRS type 1, support**
  + **Opt.1-2: Length 4 FD-OCC is applied to 4 REs of DMRS within a PRB or across consecutive PRBs within an CDM group**

**Support/fine (19): FUTUREWEI, ZTE, New H3C, Spreadtrum, Lenovo, OPPO, Google, CATT, Xiaomi, Sharp,** **MediaTek, Fraunhofer IIS/HHI, Apple, Samsung, NTT DOCOMO, Qualcomm, Nokia/NSB (either 4/6)**

**No (4): [Ericsson(orphan REs)], [LGE (orphan REs)], [Intel], [NEC]**

Please provide your views.

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| **Company** | **Comment** |
| DOCOMO | Support |
| Apple | Support. |
| InterDigital | Support FL proposal. |
| Futurewei | Support |
| Google | Support |
| OPPO | Support |
| Ericsson | We support length 6 FD-OCC. Length 6 FD-OCC naturally fits in the RB structure and doesn’t have orphan RB issue. We can consider support length 4 only if there’s no scheduling restriction and it’s assumed that the UE utilize the DMRS at scheduling edge for an extra raw channel estimate. |
| ZTE | Support |
| Lenovo | Support |
| Huawei, HiSilicon | Under mix or large delay spread scenario, either advanced sequence design for length-4 FD-OCC (e.g., DFT-vector like FD-OCC) or adopting different FD-OCC length for different CDM groups (multiplexing less DMRS ports experiencing large channel delay spread within one CDM group with shorter-length FD-OCC, while multiplexing more DMRS ports experiencing small channel delay spread within one CDM group with longer-length FD-OCC) should be considered.  Thus we’d like the following version:  **FL proposal#2.2.1:**   * **For enhanced FD-OCC length for DMRS of PDSCH/PUSCH for Rel.18 DMRS type 1, support**   + **Opt.1-2: Length 4 FD-OCC is applied to 4 REs of DMRS within a PRB or across consecutive PRBs within an CDM group**   **Opt.2: Length 2 and length 6 FD-OCC are applied to 2 and 6 REs of DMRS within a PRB for different CDM groups, respectively** |
| NEC | We prefer length-6, while if majority companies support length 4, and if this is combined with section 2.2.3 (common RB index is applied for FD-OCC mapping), we can be fine. Otherwise, if there is any orphan RE issue, length-6 FD-OCC may still be revisited. |
| Xiaomi | Actually, both length 6 OCC and length 4 are acceptable to us. If most companies prefer length 4 OCC, we are fine with it. And the decision of this issue should be considered together with the issue in section 2.2.3. |
| MediaTek | Support length 4 FD-OCC. |
| Spreadtrum | Support. |
| vivo | Support |
| Samsung | Support for length 4 FD-OCC. |
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### 2.2.2 FD-OCC design

For the details of FD-OCC code, following FD-OCC codes are proposed for length 4 and 6.

**For length 4:**

* **Opt.1-1: Walsh matrix (Hadamard code):**

Supported by: Lenovo, OPPO, CATT?, NTT DOCOMO (1st pref), MediaTek?, Fraunhofer IIS/HHI, Qualcomm (robust to TLL residual timing error)

* **Opt.1-2: Cyclic shift** **with {0, π, π/2, 3π/2}**

Supported by: Ericsson (FFT based decoding), DOCOMO (2nd pref)

* **Opt.1-3: Inner cover codes + outer cover codes**

Supported by: HW

**For length 6:**

* **Opt.2-1: size 6 DFT-based sequence**:

Supported by: Fraunhofer IIS/HHI, Intel.

Since FD-OCC length 4 is already agreed for DMRS type 2, we can discuss FD-OCC length 4 at least for DMRS type 2. FL proposal is to propose Opt.1-1, because it is the majority views based on reviewing tdocs.

**FL proposal#2.2.2:**

* **For FD-OCC length 4 for DMRS of PDSCH/PUSCH for Rel.18 DMRS type 2 and for Rel.18 DMRS type 1 (if supported), support the following FD-OCC:**

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| **OCC index** | **wf(0)** | **wf(1)** | **wf(2)** | **wf(3)** |
| 0 | +1 | +1 | +1 | +1 |
| 1 | +1 | -1 | +1 | -1 |
| 2 | +1 | +1 | -1 | -1 |
| 3 | +1 | -1 | -1 | +1 |

Please provide your views.

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| **Company** | **Comment** |
| DOCOMO | Support. |
| Apple | Support |
| InterDigital | Support FL proposal. |
| Futurewei | Support |
| Google | Support |
| OPPO | Support |
| Ericsson | Do not support. We support cyclic code with FD-OCC length 6. For length 4, we only support cyclic code. It is essential for us that the FFT based decoding can be used. |
| ZTE | Support |
| Lenovo | Support |
| Huawei, HiSilicon | Not Support.  We support DFT-based sequence (i.e., Opt.1-2 for length-4 and option.2-1 for length-6), which is more friendly to the DFT-based channel estimation.  Opt.1-3 itself is only a framework of Rel.18 DMRS design, it does not imply the detailed sequence design and can be deleted.  Moreover, as FL claimed in section 2.1, **TD-OCC design of 2-symbol DMRS is not precluded**. Candidate designs can be:  **For TD-OCC of 2-symbol DMRS:**   * + **Alt.1:**   + **Alt.2:**   As discussed in our contribution, the combination of FD-OCC Opt.1-2 and TD-OCC Alt.2 can ensure fixed cross-correlation between the inner cover code (formed by the Kronecker product of the length-2 subsequence of the length-4 FD-OCC and the length-2 TD-OCC) of Rel.18 expanded DMRS ports and that of Rel.15 DMRS ports, which can achieve balanced performance when the orthogonality between DMRS ports is destroyed due to large delay spread or compatibility issue. |
| NEC | Further discuss after section 2.2.1 is settled. |
| Xiaomi | If length 6 OCC is not precluded, Opt.2-1 should be included in this proposal. |
| MediaTek | Support. |
| Spreadtrum | Support. |
| vivo | Support |
| Samsung | Support the proposal. |
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### 2.2.3 Orphan REs in length 4 FD-OCC in DMRS type 1

If FD-OCC length 4 is supported in sect. 2.2.1, FD-OCC length 4 can be applied across consecutive PRBs. If the number of PRBs is odd, there is orphan REs. How to deal with the orphan REs should be discussed.

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**Figure 12. Example of orphan RB/REs of Type1 DMRS [26]**

Following options can be considered.

* **If FD-OCC length 4 is supported in DMRS type 1, down select from the following to handle orphan REs:**
  + **Alt.1: Introduce scheduling restriction (e.g. gNB always schedules PDSCH/PUSCH with even number of PRBs).**
    - **FFS: details.**
  + **Alt.2: Not introducing scheduling restriction (i.e. gNB can schedules PDSCH/PUSCH with any number of PRBs).**
    - **Alt.2-1: FD-OCC length 4 can be decoded per a PRB at a receiver.**
    - **Alt 2-2: DMRS is not transmitted in the last 2 REs corresponding to the DMRS port in the orphan RB.**

Alt.2-1 is illustrated in figure below, RE#4 and RE#6 are used twice for FD-OCC decoding on CE window 1 and 2.

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Alt.1: Channel estimation across two RBs[7]  Alt.2-1: Two channel estimations based on FD-OCC=4 in one RB [7]

ZTE shows evaluations result to compare performance between Alt.2-1 (purple), and Alt.2-2 (red). Based on the result, Alt.2-2 has slightly better performance than Alt.2-1.

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| ZTE [4]    **Figure 1** Performance comparison of different schemes of frequency domain multiplexing  ***Observation 1:*** *For DMRS type 1, DMRS with PRB bundling without mapping the last two REs in the last PRBs performs a little better than two CE windows when the number of scheduled DMRS port in one PRG is odd.* |

Vivo shows evaluations result to compare performance between Alt.1 (red with square), and Alt.2-1 (red with circle). Based on the result, both performances are almost the same.

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| In vivo [6]    d) 64QAM, DS=300   1. For DMRS type 1, FD-OCC=4 with two channel estimations in one RB has a similar performance to FD-OCC=4 with 2RB as scheduling granularity. |

Multiple companies mention the scheduling restriction of Alt.1 is not preferred. For Alt.2, Alt.2-1 requires additional receiver complexity. Some companies mention Alt.2-2 would degrade performance significantly, however, based on ZTE’s evaluation result, the performance degradation is not observed. Hence, FL proposal is to select Alt.2-2, which neither introduce additional scheduling restriction nor increase large receiver complexity.

**FL proposal#2.2.3:**

* **If FD-OCC length 4 is supported in DMRS type 1, select the following to handle orphan REs:**
  + **Alt.2: Not introducing scheduling restriction (i.e. gNB can schedules PDSCH/PUSCH with any number of PRBs).**
    - **Alt 2-2: DMRS is not transmitted in the last 2 REs corresponding to the DMRS port in the orphan RB.**

Apple [21] makes a good point that it is important to align CDM group index from common freq. resource (e.g. Point A). MU-MIMO is also not possible in case of figure 2.2.3. Also, Apple shows assessment that only limited scenario, the orphan RE issue happens.

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| Next, we need to handle the orphan CDM group issue for DRMS Type I for both the FDRA type 0 and FDRA type 1. The following facts of the current NR specification need to be taken into considering when designing the restriction   * PRG (Precoding Resource Block Group) is configured with reference to Point A (common resource block 0)   + PRG can be configured to contain 2 PRB, or 4 PRB, or wideband * For FDRA type 0,   + The frequency resource allocation is bitmap with unit of RBG (Resource Block Group)   + RBG is counted with reference to Point A (common resource block 0)   + RBG is always even number * For FDRA type 1,   + The frequency resource allocation is a set of contiguously allocated PRB indicated by the starting PRB, and a number of contiguously allocated PRBs   To avoid orphan CDM group across PRG boundary, one principle is to start CDM group from Point A (common resource 0) which aligns with the PRG. Since PRG is always even number of PRBs, i.e., 2 or 4, this ensure that there is no orphan CDM group issue for almost all the PDSCH PRBs, except under certain condition, the first and the last PRB of the scheduled PDSCH  ***Proposal 1.2, When FD-OCC length 4 is used to double the number of DMRS port for CP-OFDM, for DMRS Type 1, to avoid orphan CDM group issue, start CDM group operation from Point A (common resource block 0)***   * ***Consider the restriction, e.g., no DMRS, only for the following cases***    + ***For FDRA type 0***     - ***The first PRB of the scheduled PDSCH, when the first indicated RBG contains odd number of PRBs***     - ***The last PRB of the scheduled PDSCH, when the last indicated RBG contains odd number of PRBs***   + ***For FDRA type 1***     - ***The first PRB of the scheduled PDSCH, when it is located at odd number of PRBs from Point A***     - ***The last PRB of the scheduled PDSCH, when it is located at odd number of PRBs from Point A*** |



**Figure 2.2.3. MU-MIMO is impossible if different starting PRB of FD-OCC for Type1 DMRS with length 4 FD-OCC for different UEs.**

Please provide your views for FL proposal 2.2.3 and Apple’s proposal.

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| **Company** | **Comment** |
| NTT DOCOMO | Support FL proposal 2.2.3. We think it is good to start PRB index of FD-OCC for Type1 DMRS with length 4 FD-OCC from Point A. |
| Apple | Proposal 2.2.3 may still have some issue.  The true issue is CDM group cross PRG boundary.  In the current specification, PRG starts from point A and PRG is either wideband or always even (2 or 4). So if we start the CDM group also from point A, we remove almost all the issue since CDM will advance synchronously with PRG.  The only issue is that for the first and last PRB of the FDRA, it might have problem, which is only for the first few RE for the first PRB and last few RE for the last PRB. We can discuss this further. |
| InterDigital | Support Alt 2, but for the sub-bullet we prefer DMRS to be still transmitted in the scheduled RB, but it would be left to UE as how to use it. |
| Futurewei | Support FL proposal 2.2.3. We are ok that for supporting MU-MIMO with Type 1 DMRS, the starting PRB of length-4 FD-OCC of different UEs should be aligned. |
| Google | Support proposal 2.2.3, but we think it is better to have a clear definition on orphan RE, as this could have spec impact.  We are also open to study Apple’s proposal. |
| OPPO | Support Alt 2. For the sub-bullet, we prefer no restriction on the transmission of DMRS in the last two REs at least for PUSCH. For example, if MU-MIMO is not scheduled for uplink, the two REs can still be used for channel estimation at gNB. |
| Ericsson | We support length 6 FD-OCC. We can consider support length 4 only if there’s no scheduling restriction and it’s assumed that the UE utilize the DMRS at scheduling edge for an extra raw channel estimate. |
| ZTE | Support FL proposal#2.2.3  Regarding case of figure 2.2.3, it seems as long as the CDM group index of UE#2 starting from PRB#1 or PRB#3, inter-UE orthogonality can be guaranteed for MU-MIMO scenario. Apparently, it can be up to gNB implementation. |
| Lenovo | Support FL proposal 2.2.3. We are open for more discussion on orphan CDM group issue. |
| Huawei, HiSilicon | Support Alt.2. How to perform channel estimation can be left for implementation. |
| NEC | We support Apple’s proposal in general. While only starting from point A seems not enough, common RB index should be applied for FD-OCC mapping. Or in other words, if common RB index (point A already applied) is applied for FD-OCC mapping, we don’t need to say point A again. |
| Xiaomi | We are not sure whether the simulation results of vivo where the performance of length 4 OCC is better than length 6 OCC is still valid when Alt 2-2 is supported. If this is how we solve the Orphan REs problem, we would rather support length 6 OCC than length 4 OCC. |
| Spreadtrum | Our first preference is Alt.1. We are fine with FL proposal 2.2.3 if there’s majority view. |
| vivo | Support Alt 2-1, which doesn’t require any spec effort. We would like to mention that   1. It is up to receiver implementation whether to perform two channel estimations for FD-OCC=4 decoding in each RB or just in the orphan RB. When only performing two channel estimations in the orphan RB, its performance would be almost the same as FD-OCC=4 with 2RB granularity as shown below.      1. After two FD-OCC=4 decoding, only one MMSE filtering operation would be performed to complete the channel estimation in each PRG (2/4/wideband). Therefore, the receiver complexity is acceptable, just with more additive operations when performing the FD-OCC=4 decoding.   Regarding Alt 2-2, if DMRS is not transmitted in the last 2 REs, there are three key points should be noticed.   1. It changes the pattern of DMRS, which would lead to many additional issues, such as power boosting, channel estimation accuracy 2. The last 2 REs can be still transmitted, UE can determine whether to use them for eatimation. 3. Additional MMSE filtering matrix should be calculated for the last PRG containing the orphan RB due to the different number of REs occupied by DMRS from other PRGs, which would increase the UE complexity   Moreover, regarding Alt 1, we would like to clarify that it is not enough to just introduce the restriction on the number of scheduled RB as even. For FD-OCC=4 decoding, it is also necessary to align the offset of the start RB of each UE in MU-MIMO as even. As shown in the figure below, if two UEs in MU-MIMO don’t align the offset of the start RB as even (offset=1 RB in the figure below), FD-OCC=4 decoding in the red box can’t be performed correctly for UE 1. Therefore, Alt 2 is a better way without any restriction.    Regarding Apple’s proposal, in the current TS 38.211, it has been specified that the reference point for DMRS mapping is subcarrier 0 in common resource block 0 (Point A). That implies that FD-OCC=4 would be mapped from point A. Based on this principle, we find there is a mistake of FD-OCC mapping for UE#2 from PRB#2 in Figure 2.2.3, where the OCC value of one port should be the same on the same subcarrier for all UEs. Therefore, we think it’s unnecessary to discuss starting CDM group operation from Point A again.  According the above analysis, we prefer to modify the proposal as follow.  **FL proposal#2.2.3:**   * **If FD-OCC length 4 is supported in DMRS type 1, select the following to handle orphan REs:**   + **Alt.2: Not introducing scheduling restriction (i.e. gNB can schedules PDSCH/PUSCH with any number of PRBs).**     - **Up to the receiver how to implement DMRS channel estimation.** |
| Samsung | Support original Alt.1 which can be the simplest solution. Actually scheduling restriction on even number of RBs is not a big restriction, since the smallest unit of FDRA type 0 and PRG is 2 PRBs. If Alt2-2 (DMRS is not transmitted in the last 2 REs) is adopted, then channel estimation on the last RB may be degraded, and power boosting for the DMRS symbol would be complicated. |
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## DCI-based dynamic switching between FD-OCC length 2 and 4/6

15 companies (FUTUREWEI, Huawei/HiSilicon, InterDigital, Spreadtrum, vivo, Lenovo, CATT, NEC, Sharp, Samsung?, Ericsson, NTT DOCOMO, Nokia/NSB) mentioned it is beneficial to support dynamic switching between FD-OCC length 2 and M (M = 4 or 6) due to the following reasons:

* It enables to MU-MIMO with Rel.15-17 UEs within a CDM group.
* If the large MU-MIMO capacity is not required, gNB can dynamically indicate DMRS with FD-OCC length 2 because it has better performance than FD OCC length4/6 in case of large delay spread.

On the other hand, 8 companies (OPPO, Google, Xiaomi, MediaTek, Fraunhofer IIS/HHI, Apple, Qualcomm) think the dynamic switching is not needed due to the following reasons:

* It increases UE complexity
* Performance difference between FD-OCC length 2 and 4/6 is not significant.

Regarding to the UE complexity,

* Ericsson [25] says: Dynamic fallback is already supported by using different DL DCI format (DCI format 1\_0 is Rel.15 DMRS, and DCI format 1\_1 can be configured with Rel.18 DMRS).
* Samsung [22] says: In current specification, dynamic switching between DMRS type 1 and type 2 can be done by TDRA field in DCI. To be specific, different DMRS type can be configured with different PDSCH/PUSCH mapping type, and each TDRA entry can indicate different PDSCH/PUSCH mapping type. Similarly, switching between current DMRS type 1 (or 2) and new DMRS type 1 (or 2) can be studied and supported if justified.

Regarding to the performance difference between FD-OCC length 2 and 4/6, multiple companies show the results.



d) 64QAM, DS=300

The BLER performance of R18 DMRS type 2 in MU-MIMO with 2 UEs [7]

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Fig.3 Comparison of MSE performance of enhanced DMRS pattern and R15 legacy DMRS pattern for type 1 DMRS [8].

Chart, line chart

Description automatically generated

**Fig 13: Performance comparison between assuming FD-OCC 2 vs FD-OCC 4 with joint MMSE channel estimation [24]**

Considering that majority companies think it is beneficial to support the dynamic switching, FL suggestion is to agree the dynamic switching, but this feature can be optional UE capability. Also, the intention of the proposal is to support the dynamic switching within/using a DCI format. Nokia/NSB and vivo mention detail on how to enable the dynamic switching (e.g. new DCI field, use existing TDRA field, etc.), which can be discussed later.

**FL proposal#2.3:**

* **For increased DMRS ports for enhanced FD-OCC, support DCI based dynamic switching between DMRS port(s) associated with length 2 FD-OCC and DMRS port(s) associated with length M FD-OCC (where M > 2), within a DCI format 1\_1/1\_2/0\_1/0\_2.**
  + **This feature is optional UE feature of Rel.18 DMRS port(s).**

**Support/fine ():**

**No ():**

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| --- | --- |
| **Company** | **Comment** |
| DOCOMO | Support. |
| Apple | We still have concern on this proposal |
| InterDigital | Support FL proposal. |
| Futurewei | Support in principle. We suggest removing the term “within a DCI format 1\_1/1\_2/0\_1/0\_2” from the proposal as this term may imply that the existing DCI is to be used without introducing a new DCI field, which is still to be discussed. |
| Google | We would like to clarify the DMRS ports associated with FD-OCC-2 and FD-OCC-M, does it mean to use different FD-OCC sequence or just to provide some reference for the UE to identify the FD-OCC despreading length? In our view, it is sufficient to keep the same FD-OCC-M sequence, but the gNB only needs to tell UE some co-scheduled UE info to identify the FD-OCC despreading length. |
| OPPO | We think the dynamic switching is not needed. No matter the switching is implemented via a new DCI field or a current field, it would lead to larger DCI overhead and/or loss of flexibility. The benefit doesn’t deserve the cost. |
| Ericsson | This can be one of the solutions to mitigate the performance issue with FD-OCC 4/6. We are open for discussion. |
| ZTE | Support |
| Lenovo | Support |
| Huawei, HiSilicon | Can be postponed after 2.2 is decided. |
| NEC | Support |
| Xiaomi | From our understanding, this is actually a DMRS type switching problem about how to support the switching of R18 DMRS type and legacy DMRS type. FD-OCC length 2 is legacy DMRS type and length 4/6 is R18 DMRS type. We are OK to discuss how to support the switching between R18 DMRS and legacy DMRS. While, we don’t see any convincing reason that the switching has to be dynamic yet. More discussion is needed and we think RRC based switching can be the base line because the DMRS type is indicated/updated by RRC signalling in current specification. |
| MediaTek | Not support. As mentioned by OPPO and Xiaomi we don’t believe such dynamic switching is needed. |
| Spreadtrum | Support the proposal. Besides, as mentioned by FL in section 2.5, this feature can avoid the need of MU-MIMO between Rel.15 DMRS ports and Rel.18 DMRS ports. |
| vivo | Support in principle.  Regarding the sub-bullet, i.e., as an optional feature, we wonder why UE can’t support the dynamic switching. In our understanding, R18 UE would prepare for FD-OCC=2 decoding for fallback DCI format, while preparing for FD-OCC=4 or 6 decoding for DCI format 1\_1/1\_2/0\_1/0\_2. In other words, anyway R18 UE would prepare two FD-OCC decoding process for different FD-OCC length, so why can not support dynamic switching in the same DCI format? |
| Samsung | Support in principle and similar view with vivo. |
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## Definition of Rel.18 DMRS ports

In RAN1#110, definition of Rel.15/18 DMRS ports was discussed. Different companies had different interpretation of Rel.15/18 DMRS ports. To avoid confusion, it is better to clarify the definition for future discussion purpose. There are two possible interpretations. Figure 2-2 [23] illustrates them for DMRS type 1.



1. Opt. 1: For FD-OCC length >2, Rel.15 DMRS ports are DMRS ports with FD-OCC index = 0/1, and Rel.18 DMRS ports are DMRS ports with FD-OCC index = 2/3.



1. Opt.2: For FD-OCC length >2, all DMRS ports are Rel.18 DMRS ports.

Figure 2-2. Definition of DMRS ports for DMRS type 1 [23].

Based on reviewing companies tdocs, it seems most of companies assume Opt.2. Hence, FL proposal is to agree Opt.2.

**FL proposal#2.4:**

* **For discussion purpose, definition of Rel.15DMRS ports and 18 DMRS ports are:**
  + **Rel.15 DMRS ports: DMRS ports with FD-OCC length =2.**
  + **Rel.18 DMRS ports: DMRS ports with FD-OCC length >2.**

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| --- | --- |
| **Company** | **Comment** |
| DOCOMO | Support. |
| Apple | We are fine with this definition |
| InterDigital | Support FL proposal. |
| Futurewei | Support. |
| Google | We think it is better to use a term like eType1/eType2 for Rel-18 DMRS. |
| OPPO | Fine. Also fine with Google’s proposal. |
| Ericsson | Support. Note that FD-OCC length 6 is also included in this proposal. We think Google’s suggestion on the terms can also be fine to better identify the enhancement for each type. |
| ZTE | Support |
| Lenovo | Support |
| Huawei, HiSilicon | Support. |
| NEC | Fine with the proposal. |
| Xiaomi | Fine. |
| MediaTek | Fine |
| Spreadtrum | Support. |
| vivo | Support |
| Samsung | Support the definition. |
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## MU-MIMO between Rel.15 DMRS ports and Rel.18 DMRS ports

4 companies (e.g. ZTE, Samsung, NTT DOCOMO, Sharp) support MU-MIMO between Rel.15 DMRS ports and Rel.18 DMRS ports. Note that FL proposal#2.4 is assumed as definition of Rel.18 DMRS ports, that is

* + **Rel.15 DMRS ports: All DMRS ports with FD-OCC length =2.**
  + **Rel.18 DMRS ports: All DMRS ports with FD-OCC length >2.**

Spreadtrum [6] mentioned spec. enhancement is not needed to multiplex Rel.15 DMRS ports and Rel.18 DMRS ports if gNB indicates only FD-OCC sequence of either [+1 +1 +1 +1] or [+1 -1 +1 -1] for Rel.18 DMRS ports, gNB can also indicate FD-OCC of [+1 +1] or [+1 -1] for Rel.15 DMRS ports for another UE.

FUTUREWEI mention that if DCI-level dynamic switching of FD-OCC length is supported, MU-MIMO between Rel.15 DMRS ports and Rel.18 DMRS ports is not needed. Huawei/HiSilicon mentions that this can be discussed later.

**From FL perspective, if dynamic switching is supported in sect. 2.3, MU-MIMO between Rel.15 DMRS ports and Rel.18 DMRS ports are not needed. Hence, I suggest to discuss this later.**

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| FL proposal#3.5 (may be discussed later):   * Support MU-MIMO between Rel.15 DMRS ports and Rel.18 DMRS ports within a CDM group for PDSCH.   + - Note: the study includes MU-MIMO between Rel.15 UE and Rel.18 UE, and between Rel.18 UEs.   Companies views based on tdocs:  Support/fine ():ZTE, Samsung, NTT DOCOMO, Sharp (only between Rel.18 or later UEs)  No (): FUTUREWEI, vivo (up to gNB implementation), Xiaomi (there is no solution), MediaTek, Nokia/NSB,  Discuss later: HW |

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| **Company** | **Comment** |
| DOCOMO | Agree with FUTUREWEI. Whether MU-MIMO between Rel.15 DMRS ports and Rel.18 DMRS ports is needed or not depends on whether DCI-level dynamic switching of FD-OCC length is supported. |
| Apple | Do not fully understand this.  The issue is more from the UE interference cancellation perspective in case UE may need to assume what DMRS is used for the co-scheduled UE. In this case, irrespective of whether dynamic switch is supported, the problem is that a UE might be co-scheduled with legacy or Rel-18 UE. |
| InterDigital | We have a similar view as Spreadtrum that this could be potentially done without any enhancement. But we need to wait for the outcome of the FL Proposal #2.2.2. |
| Futurewei | As pointed out by FL, our view is that MU-MIMO between Rel.15 DMRS ports and Rel.18 DMRS ports is not needed if dynamic switching between FD-OCC length 2 and M is supported. So we are fine to discuss and make decision on dynamic switching in Section 2.3 first and then come back to this topic. |
| Google | OK to postpone the discussion. |
| OPPO | We think the multiplexing is beneficial without specification impact. |
| Ericsson | We are OK to postpone the discussion. |
| ZTE | Our understanding is different from FL’s assessment. Support of dynamic switching between FD-OCC-2 and FD-OCC-M does not mean MU-MIMO between Rel.15 DMRS ports and Rel.18 DMRS ports is not needed. Even though Rel-18 UE could dynamically switch to Rel-15 FD-OCC sequence to keep the orthogonality, however, it results in fewer DMRS ports available. For example, Rel-18 UE with FD-OCC [+1 -1 +1 -1] switch to [+1 -1] when co-scheduled with Rel-15 UE with FD-OCC [+1 +1], the available DMRS ports of Rel-18 UE will be halved in this case. It deviates from the WID that strive to larger number of orthogonal DMRS ports for DL and UL MU-MIMO.  In terms of supporting MU-MIMO between Rel.15 DMRS ports and Rel.18 DMRS ports, it should specify the principle that the OCC sequence of Rel-18 DMRS ports should be orthogonal with Rel-15 DMRS ports. |
| Lenovo | We also think the discussion is related with conclusion of whether DCI-based dynamic switching between FD-OCC length 2 and 4/6 is supported and FD-OCC design (e.g. OCC sequence). So we prefer to discuss this issue later. |
| Huawei, HiSilicon | OK to postpone. |
| NEC | OK to postpone. |
| Xiaomi | For clarification, all we said in our contribution is that there is no such a length 4/6 OCC can be orthogonal to length 2 OCC used in legacy DMRS as shown below.   |  | | --- | | Let’s assume that one of the length 4 OCC is , like or when the length 4 OCC is Walsh sequence. In order to support the multiplexing of R18 DMRS and legacy DMRS, is supposed to be orthogonal to and . Then we have the following equation:    Apparently, there is no non-zero solution for this equation. Hence, there is no such a length 4/6 OCC which is used in frequency to support larger number of DMRS ports can be orthogonal to length 2 OCC used in legacy DMRS.  ***Observation 1:*** ***There is no such a length 4/6 OCC which is used in frequency to support larger number of DMRS ports can be orthogonal to length 2 OCC used in legacy DMRS*** |   We do not know whether there is solution to support the multiplexing between legacy DMRS and R18 DMRS in MU-MIMO. And if there is way to support the multiplexing, we will support it. |
| MediaTek | We believe MU-MIMO scheduling of R15 and R18 is independent to whether DCI based switching of R15 and R18 is supported. As pointed out by Apple scheduling R15 and R18 in the same CDM group impact the interference cancellation performed at the UE. Nevertheless, we do not support scheduling of R15 and R18 ports within the same CDM group. |
| Spreadtrum | We are OK to postpone the discussion. |
| vivo | Support MU-MIMO between Rel.15 DMRS ports and Rel.18 DMRS ports within a CDM group for PDSCH. However, we think it is unnecessary to introduce any specification for it, since there is no any restriction on indicated DMRS port in one CDM group for MU-MIMO in the current TS 38.214.  It is up to the network to ensure the DMRS ports indicated to UEs are orthogonal as much as possible in MU-MIMO. Due to the limited number of orthogonal DMRS port, the network can even configure different *scramblingID* of DMRS to UEs in MU-MIMO, which would lead to non-orthogonal MU-MIMIO scheduling in the current network. |
| Samsung | Support the proposal, and it can be discussed later after finalizing which option, length, and OCC are utilized. |

## Rel.18 DMRS Ports Indication and Signaling

In TS38.212, antenna port(s) field in DCI format 0\_1/0\_2/1\_1/1\_2 indicates DMRS port index(es) of PDSCH/PUSCH. The current antenna port(s) table only captures DMRS port indexes of Rel.15 DMRS port(s) (p=#1000~1007 for type1 and p=#1000~1011 for type2), multiple companies mention it is necessary to add at least 1-bit in DCI format 0\_1/0\_2/1\_1/1\_2 to indicate Rel.18 DMRS ports in Rel.18, because total number of DMRS ports is doubled in Rel.18.

FUTUREWEI [1] proposes two possible options:

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| --- |
| * Scheme A: Generate new tables similar to Tables 7.3.1.2.2-1/2/3/4 and Tables 7.3.1.2.2-1A/2A/3A/4A in [4]. To accommodate larger number of orthogonal DMRS ports, these new tables will in general have more entries/rows than its legacy counterparts. Therefore, it requires larger size of Antenna port(s) field in DCI to indicate one of the entries in the table. For example, the size of the Antenna port(s) field is increased from 4, 5, or 6 bits to 5, 6, or 7 bits, respectively. * Scheme B: Reuse the existing Tables 7.3.1.2.2-1/2/3/4 and Tables 7.3.1.2.2-1A/2A/3A/4A in [4] and keep the size of the Antenna port(s) field in DCI unchanged. To accommodate larger number of orthogonal DMRS ports, introduce a new bit to the existing DCI message to indicate the DMRS port indexing offset. For example, if this bit is set to “0”, the Antenna port(s) field in DCI refer to one row in the existing tables to indicate the number of CDM groups without data, DMRS port(s), and number of front-load symbols. In this case, the operation is similar to that in legacy mode. On the other hand, if this bit is set to “1”, the Antenna port(s) field in DCI refers to one row in the legacy tables to indicate the number of CDM groups without data and the number of front-load symbols, while the real DMRS port(s) indexes is the ones read from the existing table plus an offset value, which is 8 for DMRS Type 1 and 12 for DMRS Type 2, respectively. |

Following illustrates examples of extension of Table 7.3.1.2.2-1 in TS38.212.



a) Scheme A b) Scheme B

Figure 2.6. Examples of extension of Table 7.3.1.2.2-1 in TS38.212.

From FL perspective, both Scheme A/B have not much difference. One thing we should carefully consider is that it seems Scheme B cannot indicate 3 or 4 DMRS ports within a CDM group (e.g. DMRS port index = 0,1,8,9 in DMRS type 1). This may be problem especially for >4 ranks, because in the current spec., in case of two CWs, all remaining DMRS ports are not used to other UEs. If UE#1 cannot use all of 4 DMRS ports within a CDM group, some of DMRS ports are wasted, which cannot not increase the max number of DMRS ports in MU-MIMO.

**FL proposal#2.6:**

* **If Rel.18 DMRS is configured, increase/add at least 1-bit in DCI format 0\_1/0\_2/1\_1/1\_2 to indicate Rel.18 DMRS port(s).**
* **Down select one of the following on how to enhance TS38.212.**
  + **Scheme A: Specify new antenna port(s) tables similar to Tables 7.3.1.2.2-1/2/3/4 and Tables 7.3.1.2.2-1A/2A/3A/4A in TS38.212. The size of the Antenna port(s) field is increased from 4, 5, or 6 bits to 5, 6, or 7 bits, respectively.**
    - **Existing rows in Tables 7.3.1.2.2-1/2/3/4 and Tables 7.3.1.2.2-1A/2A/3A/4A in TS38.212 are copied to the new tables except for “Reserved” row.** 
      * **FFS for other rows in the new tables.**
  + **Scheme B: Reuse the existing Tables 7.3.1.2.2-1/2/3/4 and Tables 7.3.1.2.2-1A/2A/3A/4A in TS38.212 and keep the size of the Antenna port(s) field in DCI unchanged. Introduce new 1-bit DCI field of “DMRS port(s) offset indicator” to indicate Rel.18 DMRS ports.**
    - **If “DMRS port(s) offset indicator” field is set “0”, DMRS port(s) are the same as indicated by antenna port(s) field in DCI format 0\_1/0\_2/1\_1/1\_2.**
    - **If “DMRS port(s) offset indicator” field is set “1”, DMRS port(s) are incremented with X from the indicated DMRS port(s) by antenna port(s) field in DCI format 0\_1/0\_2/1\_1/1\_2.**
      * **Value of X is 8 for DMRS type 1 and 12 for DMRS type 2.**

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| **Company** | **Comment** |
| NTT DOCOMO | Support in principle. We believe it is important to enable to indicate 3 or 4 DMRS ports within a CDM group to a UE to minimize DMRS overhead (e.g. DMRS port index = 0,1,8,9 in DMRS type 1). However, Scheme B seems not possible such operation. If we add new DMRS port combination in reserved bit, it may be possible. |
| Apple | The issue of Scheme B is that it will limit the DMRS port selection, i.e., either all selected from the first half of DMRS ports or the second half of DMRS ports.  Maybe we first agree on OCC length, finalized the DMRS port pattern table similar as Table 7.4.1.1.2-1/2 in 38.211, and then discuss the antenna port indication table since we may also need to discuss for UL which is even harder since we need to discuss more than 4 layers |
| InterDigital | Don’t agree with the first bullet that requires addition of a new bit. We could simply use one of the reserved codepoint to indicate whether the indicated DMRS ports are for Rel-18 DMRS.  We are OK with scheme B, if the first bullet is corrected. |
| Futurewei | Support FL’s proposal. We are open to both schemes with a slight preference on Scheme B as it requires less specification effort. Our understanding is that the main goal for increased DMRS ports in this WI is to support pairing more users in MU-MIMO. In this case, supporting rank up to 2 per user within a CDM group is sufficient. In the case that it is really needed to support higher rank (e.g., 3 or 4) for a UE within a CDM group, the tables with maxLength = 2 can be used. |
| Google | We think new table should be needed (Scheme A), but the first main bullet seems unnecessary. |
| OPPO | For the first bullet, we don’t think it is needed. RRC based table switching is sufficient. With Scheme A, Rel-15 and Rel-18 DMRS can use different tables with different size. Furthermore, more antenna port combinations should be supported for Rel-18 DMRS, e.g. 4 ports within one CDM group with only one CDM group without data, which is not supported in Rel-15. |
| Ericsson | Fine with the proposal. |
| ZTE | First things first, RAN shall clarify whether the first half of Rel-18 DMRS ports and the second half of Rel-18 DMRS ports can be allocated in one CDM group, e,g,. port 0, port 1, port 8 and port 9 are allocated in CDM group 0 when DMRS type 1 with single-symbol. The above can be supported by Scheme A in principle, but Scheme B seems to completely preclude this point. Besides, the first main bullet is not needed in the current phase and should be removed.  **FL proposal#2.6:**   * **Down select one of the following on how to enhance TS38.212.**   + **Scheme A: Specify new antenna port(s) tables similar to Tables 7.3.1.2.2-1/2/3/4 and Tables 7.3.1.2.2-1A/2A/3A/4A in TS38.212.**     - **Existing rows in Tables 7.3.1.2.2-1/2/3/4 and Tables 7.3.1.2.2-1A/2A/3A/4A in TS38.212 can be copied to the new tables except for “Reserved” row at least.**        * **FFS for other rows in the new tables.**   + **Scheme B: Reuse the existing Tables 7.3.1.2.2-1/2/3/4 and Tables 7.3.1.2.2-1A/2A/3A/4A in TS38.212 and keep the size of the Antenna port(s) field in DCI unchanged. Introduce new 1-bit DCI field of “DMRS port(s) offset indicator” to indicate Rel.18 DMRS ports.**     - **If “DMRS port(s) offset indicator” field is set “0”, DMRS port(s) are the same as indicated by antenna port(s) field in DCI format 0\_1/0\_2/1\_1/1\_2.**     - **If “DMRS port(s) offset indicator” field is set “1”, DMRS port(s) are incremented with X from the indicated DMRS port(s) by antenna port(s) field in DCI format 0\_1/0\_2/1\_1/1\_2.**       * **Value of X is 8 for DMRS type 1 and 12 for DMRS type 2.** |
| Lenovo | Support FL’s proposal. We are open for more discussion on scheme A and scheme B. In general, scheme B reuses existed DMRS port indication table as much as possible and the standard effort is lower although some flexibility may be lost such as supporting DMRS port index = 0,1,8,9 in DMRS type 1. For scheme A, it need clarify on details and have more discussion on necessity for new entries/rows different from legacy antenna port table. |
| Huawei, HiSilicon | Current version precludes some candidate options and further study is needed. Suggest to postpone after 2.2 is decided. |
| NEC | We also think the first bullet is not needed. And we prefer scheme A in principle. While we think it’s not needed to copy each exiting row for Rel-18 DMRS ports. For example, the row “number of CDM group without data = 1, DMRS port = 8”, what’s the use case? Taking “DMRS type 1” “maxlength =1” for example, with number of CDM group without data =1, the maximum number of DMRS ports available is 4 (with doubled DMRS ports), while legacy Rel-15 configuration can support this already.  So in our understanding, the additional DMRS ports (8,9,10,11,12,13,14,15) is only needed when legacy DMRS ports (0,1,2,3,4,5,6,7) are all allocated. In this case, the number of CDM group without data =2 for DMRS port 8 is sufficient.  **FL proposal#2.6:**   * **Down select one of the following on how to enhance TS38.212.**   + **Scheme A: Specify new antenna port(s) tables similar to Tables 7.3.1.2.2-1/2/3/4 and Tables 7.3.1.2.2-1A/2A/3A/4A in TS38.212.**     - **At least some existing rows in Tables 7.3.1.2.2-1/2/3/4 and Tables 7.3.1.2.2-1A/2A/3A/4A in TS38.212 are copied to the new tables except for “Reserved” row.**        * **FFS for the copied rows. For example, whether all existing rows are needed to be copied.**       * **FFS for other rows in the new tables.**   + **Scheme B: Reuse the existing Tables 7.3.1.2.2-1/2/3/4 and Tables 7.3.1.2.2-1A/2A/3A/4A in TS38.212 and keep the size of the Antenna port(s) field in DCI unchanged. Introduce new 1-bit DCI field of “DMRS port(s) offset indicator” to indicate Rel.18 DMRS ports.**     - **If “DMRS port(s) offset indicator” field is set “0”, DMRS port(s) are the same as indicated by antenna port(s) field in DCI format 0\_1/0\_2/1\_1/1\_2.**     - **If “DMRS port(s) offset indicator” field is set “1”, DMRS port(s) are incremented with X from the indicated DMRS port(s) by antenna port(s) field in DCI format 0\_1/0\_2/1\_1/1\_2.**       * **Value of X is 8 for DMRS type 1 and 12 for DMRS type 2.** |
| Xiaomi | Support FL proposal#2.6 with less details.  **FL proposal#2.6:**   * **Down select one of the following on how to enhance TS38.212.**   + **Scheme A: Specify new antenna port(s) tables similar to Tables 7.3.1.2.2-1/2/3/4 and Tables 7.3.1.2.2-1A/2A/3A/4A in TS38.212.**   + **Scheme B: Reuse the existing Tables 7.3.1.2.2-1/2/3/4 and Tables 7.3.1.2.2-1A/2A/3A/4A in TS38.212 and keep the size of the Antenna port(s) field in DCI unchanged.**   The details of DMRS ports indication can be discussed later. |
| MediaTek | Fine. We are open to discussing both Scheme A and B further. |
| Spreadtrum | Support the proposal. Specifying new antenna port(s) tables is a more clear solution, and the additional port combinations can be further discussed. |
| vivo | In additional to scheme A and B, another potential solution could also be considered, i.e., specifying a new antenna port table only containing the rows for new DMRS port index, e.g., 8/9/10/11… for type 1.  **FL proposal#2.6:**   * **Down select one of the following on how to enhance TS38.212.**   + **Scheme A: Specify new antenna port(s) tables similar to Tables 7.3.1.2.2-1/2/3/4 and Tables 7.3.1.2.2-1A/2A/3A/4A in TS38.212.**     - **Alt 1: Existing rows in Tables 7.3.1.2.2-1/2/3/4 and Tables 7.3.1.2.2-1A/2A/3A/4A in TS38.212 are copied to the new tables except for “Reserved” row.**        * **Existing other rows for new DMRS port index in the new tables.**     - **Alt 2: Not existing rows in Tables 7.3.1.2.2-1/2/3/4 and Tables 7.3.1.2.2-1A/2A/3A/4A in TS38.212 are copied to the new tables except for “Reserved” row.**        * + **Existing other rows for new DMRS port index in the new tables.**   + **Scheme B: Reuse the existing Tables 7.3.1.2.2-1/2/3/4 and Tables 7.3.1.2.2-1A/2A/3A/4A in TS38.212 and keep the size of the Antenna port(s) field in DCI unchanged. Introduce new 1-bit DCI field of “DMRS port(s) offset indicator” to indicate Rel.18 DMRS ports.**     - **If “DMRS port(s) offset indicator” field is set “0”, DMRS port(s) are the same as indicated by antenna port(s) field in DCI format 0\_1/0\_2/1\_1/1\_2.**     - **If “DMRS port(s) offset indicator” field is set “1”, DMRS port(s) are incremented with X from the indicated DMRS port(s) by antenna port(s) field in DCI format 0\_1/0\_2/1\_1/1\_2.**       * **Value of X is 8 for DMRS type 1 and 12 for DMRS type 2.** |
| Samsung | Support in principle. |
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## MU-MIMO scheduling restriction within a CDM group

In section 5.1.6 in TS38.214, MU-MIMO scheduling restriction is specified as following.

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| For DM-RS configuration type 1,  - if a UE is scheduled with one codeword and assigned with the antenna port mapping with indices of {2, 9, 10, 11 or 30} in Table 7.3.1.2.2-1 and Table 7.3.1.2.2-2 of Subclause 7.3.1.2 of [5, TS 38.212], or  - if a UE is scheduled with two codewords,  the UE may assume that all the remaining orthogonal antenna ports are not associated with transmission of PDSCH to another UE.  For DM-RS configuration type 2,  - if a UE is scheduled with one codeword and assigned with the antenna port mapping with indices of {2, 10 or 23} in Table 7.3.1.2.2-3 and Table 7.3.1.2.2-4 of Subclause 7.3.1.2 of [5, TS38.212], or  - if a UE is scheduled with two codewords,  the UE may assume that all the remaining orthogonal antenna ports are not associated with transmission of PDSCH to another UE. |

In Qualcomm [24], following was proposed.

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| **Observation 4: To avoid co-scheduled SU+MU DMRS ports exceeding the total number of DMRS ports that a UE can support, certain restrictions are needed on co-scheduled MU ports.**  **Proposal 6: Adopt Option 1 (for both type-1 and type-2 DMRS) to increase number of orthogonal DMRS ports for PDSCH and PUSCH, with restrictions as listed below**   * **For single symbol DMRS, if the DMRS ports of a UE are in two or more CDM groups, the UE does not expect DMRS ports from a co-scheduled UE in a same CDM group as the UE.** * **For double symbol DMRS, a UE does not expect DMRS ports from a co-scheduled UE in a same CDM group as the UE, unless the UE and the co-scheduled UE each associated with a distinct TD-OCC for their DMRS ports respectively.** |

Considering that MU-MIMO scheduling restriction is specified in Rel.15, Rel.18 DMRS ports also needs the scheduling restriction of MU-MIMO.

**FL proposal#2.7:**

* **For Rel.18 DMRS ports associated with FD-OCC length 4/6 for PDSCH/PUSCH, following MU-MIMO scheduling restriction is specified.**
  + **For single symbol DMRS, if the DMRS ports of a UE are in two or more CDM groups, the UE does not expect DMRS ports from a co-scheduled UE in a same CDM group as the UE.**
  + **For double symbol DMRS, a UE does not expect DMRS ports from a co-scheduled UE in a same CDM group as the UE, unless the UE and the co-scheduled UE each associated with a distinct TD-OCC for their DMRS ports respectively.**

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| **Company** | **Comment** |
| NTT DOCOMO | We’d like to postpone the discussion until antenna port(s) indication in sect. 2.6. Firstly, we’d like to see whether 4 DMRS ports within a CDM group can be allocated to a UE in R18. If not, we would have concern on the proposal, because some DMRS ports cannot be allocated for anybody, especially for > 4 ranks (i.e. two CWs). |
| Apple | We are open to discuss the restriction. But we also prefer to delay it since the DMRS port design is clearer. |
| InterDigital | Same view as Apple; this can be discussed later. |
| Futurewei | This proposal can be discussed later. |
| Google | We think it can be decided after a DMRS ports indication table is agreed. |
| OPPO | Support to discuss later. |
| Ericsson | In principle fine with the proposal. |
| ZTE | Share the view with companies to discuss this later. |
| Lenovo | Same view and this proposal can be discussed later. |
| Huawei, HiSilicon | Can be postponed after 2.2 is decided. |
| NEC | Open to discuss later. |
| Xiaomi | Agree with NTT DOCOMO. |
| MediaTek | We also like to postpone this discussion to later. |
| Spreadtrum | Share the view with companies to discuss this later. |
| vivo | Discuss it later. |
| Samsung | We are fine with discussion what is needed for MU-MIMO within CDM group, which can be discussed later. |
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## Other proposals

Following proposals are also proposed.

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| **Proposals** | **Companies** |
| 1. **PTRS-DMRS association for Rel.18 DMRS ports** | Lenovo |
| 1. **Study how to support dynamic switching between different number of additional DMRS symbols in Rel-18** | Ericsson |
| 1. **Sequence mapping equation needs to be modified to ensure that Rel.18 DMRS and Rel.15 DMRS have the same DMRS pattern** | Lenovo |
| 1. **Study on OCC disabling scheme for new DMRS type (Rel.17 feature in above 52.6GHz).** | 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** |
| Google | We think new PT-RS RE offset table is needed, since there are more DMRS ports. |
| Ericsson | We hope companies can consider to discuss Proposal 2). |
| Lenovo | For proposal 1, we have similar view as Google.  For proposal 3, we agree to discuss sequence mapping equation for R18 DMRS pattern. But we prefer to discuss it later after the details on R18 DMRS pattern are agreed. |
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# Specifying objective #5 (>4 layers PUSCH DMRS)

## Rel.15/18 DMRS ports for >4 layers PUSCH

Multiple companies (e.g. Huawei/HiSilicon, ZTE, Lenovo, OPPO, CATT, Intel, DOCOMO, Nokia/NSB, etc.) think it is beneficial to use Rel.18 DMRS ports to support >4 layer PUSCH. In Rel.15 DMRS ports, double symbol DMRS is needed to support >4 ranks for type 1 and > 6 ranks for type 2, which increases DMRS overhead. Since Rel.18 UE may support Rel.18 DMRS ports, it is natural to use Rel.18 DMRS ports to support >4 ranks PUSCH, if the UE supports. The benefit is it enables to use single symbol DMRS to support >4 ranks, or it requires smaller number of CDM groups to support > 4 ranks, which can also reduce DMRS overhead.

In RAN1#110, following proposal was discussed. However, due to lack of clear definition of Rel.15/18 DMRS ports, we could not reach consensus.

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| * **If AI 9.1.4.2 agree to specify > 4 layers PUSCH, support one option from the following to support >4 layers SU-MIMO for PUSCH.**   + **Alt.1: utilize Rel.15 DMRS ports only.**   + **Alt.2: utilize Rel.18 enhanced DMRS ports only.**   + **Alt.3: utilize Rel.15 DMRS ports or Rel.18 enhanced DMRS ports, depending on RRC-configuration, DCI-indication, and/or UE capability.**     - **FFS: indication between Rel.15 DMRS ports and Rel.18 DMRS ports are done by RRC and/or DCI.**   + **Note: this does not impact the discussion whether to specify > 4 layers PUSCH in AI 9.1.4.2.** |

Considering that majority supports Alt.3, and there is no critical concern to take Alt.3, FL proposal is to agree on Alt.3. Also, definition of Rel.15/18 DMRS ports are clarified.

**FL proposal#3.1:**

* **For more than 4 layers SU-MIMO PUSCH, support**
  + **Alt.3: both Rel.15 DMRS ports and Rel.18 enhanced DMRS ports.** 
    - **For UE supporting Rel.18 DMRS ports, UE can be indicated with either of Rel.15 DMRS ports or Rel.18 DMRS ports.**
    - **For UE not supporting Rel.18 DMRS ports, UE can be indicated with Rel.15 DMRS ports only.**
  + **Note: definition of Rel.15/18 DMRS ports is**
    - **Rel.15 DMRS ports: DMRS ports with FD-OCC length =2.**
    - **Rel.18 DMRS ports: DMRS ports with FD-OCC length >2.**

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| **Company** | **Comment** |
| NTT DOCOMO | Support. |
| Apple | We are fine with the proposal |
| InterDigital | Support FL proposal. |
| Google | Support, but we think it is better to call R18 DMRS ports as eType1/eType2 DMRS |
| OPPO | Fine with the proposal. |
| Ericsson | It is not clear to us if we need the sub bullets. The Rel-15 DMRS ports will be a subset of Rel-18 DMRS ports, and for UL, what is difference between Rel-15/Rel-18 for the OCC codes that are the same? So the sub bullets are only needed if some of the Rel-18 DMRS ports design is not compatible with Rel-15 DMRS ports design. |
| ZTE | Support |
| Lenovo | Support |
| Huawei, HiSilicon | Support. |
| NEC | Support |
| Xiaomi | Fine with the proposal |
| MediaTek | Support |
| Spreadtrum | Support |
| vivo | Support |
| Samsung | Support in principle and we have a question on the sub-bullets under Alt.3. “**UE can be indicated with either of Rel.15 DMRS ports or Rel.18 DMRS ports**” means that Rel-15 DMRS ports and Rel-18 DMRS ports can be dynamically switched by DCI, for supporting SU-MIMO PUSCH more than 4 layers? If so, we think that the switching between Rel-15 DMRS ports and Rel-18 DMRS ports can be further discussed (e.g., RRC, DCI), and our view is that RRC is enough. |
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## PTRS-DMRS association

Multiple companies (e.g. Huawei/HiSilicon, Lenovo?, LGE, CATT, Sharp?, Apple, Samsung, NTT DOCOMO, Qualcomm, etc.) propose to increase the size of PTRS-DMRS association filed in DCI format 0\_1/0\_2 to 4-bit for PUSCH > 4 ranks.

In ZTE [4]

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| One issue is when up to 8 DMRS ports are supported for UL transmission, the association between DMRS ports and PTRS ports should also be enhanced, where the PTRS-DMRS association indication field should be increased. More precisely, for the case of 8 DMRS ports share one PTRS port, 3 bits in total are needed. For case of 4 DMRS ports share one PTRS port, 4 bits (2bits + 2bits) in total are needed. For case of 2 DMRS ports share one PTRS port, 4 bits (1bit + 1bit + 1bit + 1bit) in total are needed.  ***Proposal 7:*** *More than 2 bits should be used for the DMRS port and PTRS port association indication for UL transmission with more than 4 layers.*   * *Support 3 or 4 bits of the PTRS-DMRS association field in DCI.* * *Support 2 PTRS ports for up to 8 layers transmission.* |

**FL proposal#3.2:**

* **For more than 4 layers SU-MIMO PUSCH with up to 2 ports UL PTRS, support up to 4 bits of PTRS-DMRS association field in DCI format 0\_1/0\_2.**
  + **For 1 port UL PTRS, 3bits are used for the indication of PT-RS and DMRS ports association for UL PTRS port 0.**
  + **For 2 ports UL PTRS, 4bits are used for the indication of PTRS and DMRS association when 2 PTRS ports are used, 2bits MSB are for the indication of PTRS port 0, and 2 bits LSB are for the indication of PTRS port 1.**

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| **Company** | **Comment** |
| NTT DOCOMO | Support. |
| Apple | We need to separate discussion of (1) full-coherent (2) partial-coherent (3) non-coherent, instead of the current formulation. For partial-coherent, we now have more than 1 antenna architecture agreed in 8 Tx agenda |
| InterDigital | First we need to discuss the multiplicity of the PTRS port which as Apple mentioned, for an 8TX UE, should be related to the number of antenna groups. |
| Google | We are not sure whether 2 PT-RS ports are needed or not. PT-RS port indication also depends on whether two codewords are supported. |
| OPPO | We can first agree on the number of UL PTRS ports. |
| ZTE | Support.  Basically, no matter antenna port coherency or antenna groups number of 8 Tx UE, the case of PTRS-DMRS association indication can be classified as *x* PTRS ports shared by *y* DMRS ports (where *x*=1 or 2, *y*=2 or 4 or 8, *x*<*y*). Consequently, 3 or 4 bits of the indication field are needed as elaborated in our contribution [4]. |
| Lenovo | Support |
| Huawei, HiSilicon | Not support. The overhead should strive to be minimized. |
| Xiaomi | Support the proposal targeting for 2-port PT-RS, in our view whether it is needed to support 4-port or not can be discussed further. |
| MediaTek | Agree with Oppo. We still haven’t agreed on supporting 2 ports UL PTRS ports yet. |
| Spreadtrum | We suggest to decide the maximum number of PTRS ports first. |
| vivo | Support |
| Samsung | Support the proposal, and also fine with discussion after determining the maximum number of PTRS ports. |
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## Max number of PTRS ports

In RAN1#110 meeting, in AI 9.1.4.2 (SRI/TPMI for 8Tx UL), antenna assumption of for full/partial coherent UE was agreed that the number of Ng (antenna coherent groups) is 1, 2, 4 where each group comprises coherent antennas, and antennas can be non-coherent/coherent across groups, depending on device types. From technically speaking, if different antenna groups do not share the same PA (Power Amplifier), different phase noise would be observed for different antenna groups.

Multiple companies (Lenovo, LGE, CATT, Xiaomi, Apple, NTT DOCOMO, Qualcomm) mention the max number of PTRS should be enhanced to up to 4 ports. On the other hand, some other companies ( Samsung, Nokia/NSB) think the enhancement is not needed.

A picture containing application

Description automatically generated

**Fig 15:** **Examples 8 Tx PUSCH transmission requires 4 PTRS ports [24]**

**FL proposal#3.2:**

* **For more than 4 layers SU-MIMO PUSCH, support up to 4 ports PTRS for CP-OFDM.**

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| **Company** | **Comment** |
| NTT DOCOMO | Support. |
| Apple | We think it is for 8 Tx UL operation   * **For 8 TX UL operation ~~more than 4 layers SU-MIMO PUSCH~~, support up to 4 ports PTRS for CP-OFDM.** |
| InterDigital | We are fine with Apple’s revision. |
| Google | We think 1 PT-RS port is sufficient. There seems to be no multi-panel transmission for 8Tx based on current agreement. |
| OPPO | We think two PTRS ports are sufficient. If the number of PTRS ports should be the same as the number of antenna groups, does it mean that we need 8 ports for non-coherent antenna layout? |
| ZTE | Support. In our view, Apple’s update is the same to FL proposal#3.2. |
| Lenovo | Suggest the following update:   * **For ~~more than 4 layers SU-MIMO PUSCH~~ 8Tx PUSCH, support up to 4 ports PTRS for CP-OFDM.** |
| Huawei, HiSilicon | Support. |
| NEC | We also think up to 2 PTRS ports are sufficient. |
| Xiaomi | Support the proposal |
| MediaTek | We don’t believe number of PTRS ports need to scale with number of panels. |
| vivo | Don’t support 4 PTRS ports. Up to 2 PTRS ports are sufficient, since each pair of antenna groups can be linked to the same oscillator among 4 antenna groups. |
| Samsung | Not support, we think up to 2 PTRS is enough. |
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## Antenna port(s) table for >4 layers PUSCH

Multiple companies mentioned enhancement of antenna port(s) table for rank 5/6/7/8 is needed to support >4 layers PUSCH. Some companies (e.g. Huawei/HiSilicon, vivo, OPPO, CMCC, etc) think the baseline is to reuse the same or a subset of DMRS port combination for rank 5/6/7/8 for PDSCH. On the other hand, Note/CATT pointed out that DMRS port indication mechanism is different between PUSCH and PDSCH:

* For PUSCH, DMRS is indicated from ports combinations with total ports number equals to the number of layers indicated by TPMI/SRI.
* For PDSCH, DMRS is indicated from all ports combinations.

In RAN1#110, following was proposed. However, some companies commented that it is not possible to reuse DMRS port combinations of PDSCH.

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| **FL proposal#4.3:**   * **For > 4 layers PUSCH, support new antenna port indication table for rank = 5,6,7,8 for both DMRS type 1/2, and for both single-symbol/double-symbol DMRS.**   + **For Rel.15 DMRS ports (if supported), following options can be considered**     - **Alt.1: same DMRS port combinations as that for rank = 5,6,7,8 for PDSCH are reused.**     - **Alt.2: new DMRS port combinations are used for rank = 5,6,7,8 (FFS: details).**   + **For Rel.18 DMRS ports (if supported), following options can be considered**     - **Alt.1: same DMRS port combinations as that for rank = 5,6,7,8 for PDSCH are reused.**     - **Alt.2: new DMRS port combinations are used for rank = 5,6,7,8 (FFS: details).**       * **Note: whether the DMRS port combination allows to use single symbol DMRS for rank = 5,6,7,8 should be checked.** |

From FL perspective, it is clear that we need to define new antenna port(s) table for rank = 5,6,7,8 for PUSCH. Question is either/both of Rel.15 DMRS ports or Rel.18 DMRS ports should be assumed. This will be solved after FL proposal#3.1 is agreed.

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| **Company** | **Comment** |
| Apple | We are fine with the proposal |
| InterDigital | Support FL proposal. For Alt2., we even believe that support of every combination may not be necessary, but we can discuss it later. |
| Google | Support in principle |
| OPPO | We are fine with the proposal. |
| ZTE | Support |
| Lenovo | We are fine with the proposal. The details on new DMRS port combination can be clarified and discussed later. |
| Huawei, HiSilicon | Support. |
| NEC | Fine with the proposal. |
| Xiaomi | We support the proposal in principle.  First, in our view the “Note” mentioned the issue for the single symbol DMRS should be under the bullet for Rel-15 DMRS.  Second, we think whether the DMRS table defined for RANK 5/6/7/8 separately or jointly for all RANKs similar as DL also needs to be clarified, or we agree that the details can be discussed later. |
| MediaTek | Fine |
| Spreadtrum | Support. |
| vivo | Support |
| Samsung | Fine with the proposal in principle. |
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## Other proposals

Following proposals are also proposed. Note that discussion of two CW or one CW, and CW to layer mapping is not listed because it is not related to DMRS enhancement. These proposals can be discussed in AI 9.1.4.2.

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| **Proposals** | **Companies** |
| 1. **Study power boosting of PTRS for up to 8-layer PDSCH and PUSCH transmission** | Lenovo, OPPO |
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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 PTRS power boosting needs to be discussed anyway, now or later. |
| Lenovo | We have similar view as OPPO. |
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# Conclusion

Based on the email discussion, following FL proposals are proposed.

To be updated.

# References

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| [1] | [**R1-2208375**](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_110b-e/Docs/R1-2208375.zip) | On increasing the number of orthogonal DM-RS ports for MU-MIMO | FUTUREWEI |
| [2] | [**R1-2208442**](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_110b-e/Docs/R1-2208442.zip) | Enhancements on DMRS in Rel-18 | Huawei, HiSilicon |
| [3] | [**R1-2208496**](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_110b-e/Docs/R1-2208496.zip) | Discussion on DMRS Enhancements | InterDigital, Inc. |
| [4] | [**R1-2208505**](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_110b-e/Docs/R1-2208505.zip) | DMRS enhancement for UL/DL MU-MIMO and 8 Tx UL SU-MIMO | ZTE |
| [5] | [**R1-2208529**](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_110b-e/Docs/R1-2208529.zip) | Discussions on increased number of orthogonal DMRS ports | New H3C Technologies Co., Ltd. |
| [6] | [**R1-2208542**](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_110b-e/Docs/R1-2208542.zip) | Discussion on increased number of orthogonal DMRS ports | Spreadtrum Communications |
| [7] | [**R1-2208629**](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_110b-e/Docs/R1-2208629.zip) | Discussion on DMRS enhancements | vivo |
| [8] | [**R1-2208743**](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_110b-e/Docs/R1-2208743.zip) | Discussion of increased number of orthogonal DMRS ports | Lenovo |
| [9] | [**R1-2208795**](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_110b-e/Docs/R1-2208795.zip) | DMRS enhancement for Rel-18 MIMO | OPPO |
| [10] | [**R1-2208873**](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_110b-e/Docs/R1-2208873.zip) | On DMRS Enhancement | Google |
| [11] | [**R1-2208894**](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_110b-e/Docs/R1-2208894.zip) | Increased number of orthogonal DMRS ports | LG Electronics |
| [12] | [**R1-2208948**](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_110b-e/Docs/R1-2208948.zip) | Discussion on DMRS enhancements | CATT |
| [13] | [**R1-2209042**](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_110b-e/Docs/R1-2209042.zip) | DMRS Enhancements for Rel-18 NR | Intel Corporation |
| [14] | [**R1-2209141**](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_110b-e/Docs/R1-2209141.zip) | Discussion on increased number of orthogonal DMRS ports | NEC |
| [15] | [**R1-2209259**](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_110b-e/Docs/R1-2209259.zip) | Discussion on DMRS enhancement | xiaomi |
| [16] | [**R1-2209323**](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_110b-e/Docs/R1-2209323.zip) | Discussion on increased number of orthogonal DMRS ports | CMCC |
| [17] | [**R1-2209382**](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_110b-e/Docs/R1-2209382.zip) | Increased number of orthogonal DMRS ports | Sharp |
| [18] | [**R1-2209495**](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_110b-e/Docs/R1-2209495.zip) | Increased number of orthogonal DMRS ports | MediaTek Inc. |
| [19] | [**R1-2209544**](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_110b-e/Docs/R1-2209544.zip) | Increased number of orthogonal DMRS ports | Fraunhofer IIS, Fraunhofer HHI |
| [21] | [**R1-2209571**](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_110b-e/Docs/R1-2209571.zip) | Views on supporting increased number of orthogonal DMRS ports | Apple |
| [22] | [**R1-2209717**](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_110b-e/Docs/R1-2209717.zip) | Views on DMRS enhancements | Samsung |
| [23] | [**R1-2209891**](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_110b-e/Docs/R1-2209891.zip) | Discussion on DMRS enhancements | NTT DOCOMO, INC. |
| [24] | [**R1-2209970**](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_110b-e/Docs/R1-2209970.zip) | Design for increased number of orthogonal DMRS ports | Qualcomm Incorporated |
| [24] | [**R1-2210064**](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_110b-e/Docs/R1-2210064.zip) | Rel-18 UL and DL DMRS Enhancements | Nokia, Nokia Shanghai Bell |
| [25] | [**R1-2210078**](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_110b-e/Docs/R1-2210078.zip) | On DMRS enhancement in Rel-18 | Ericsson |
| [26] | [**R1-2205882**](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_110/Docs/R1-2205882.zip) | Enhancements on DMRS in Rel-18 (in RAN1#110) | Huawei, HiSilicon |

# **Appendix**

## **RAN1#109e agreements:**

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| **EVM**  Agreement   * LLS is used for objective #3 (increasing DMRS ports for MU-MIMO) in Rel.18 MIMO, while SLS can be used optionally.   Agreement   * No EVM discussion is needed for objective #5 (>4 layers PUSCH DMRS) in AI 9.1.3.1 (DMRS) in Rel.18.   Agreement   * 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.   Agreement   * Following evaluation assumptions are used for LLS for increasing DMRS ports in AI 9.1.3.1 in Rel.18.  |  |  | | --- | --- | | **Parameter** | **Value** | | Duplex, Waveform | TDD, OFDM  Note: FDD, OFDM is not precluded | | 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 | | 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 | | 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 | Baseline:   * Single symbol DMRS without additional DMRS symbols and 1 additional DMRS symbol * Double symbol DMRS without additional DMRS symbols.   Note: evaluation of other additional DMRS symbol(s) are not precluded. | | DMRS mapping type | Mapping type A (slot based) for PDSCH.  Mapping type A (slot based) for PUSCH. | | 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 |   Agreement   * For LLS assumptions for increasing DMRS ports in AI 9.1.3.1 in Rel.18:   + Precoding assumption of PUSCH, “[ZF or SVD]” in RAN1#109e agreement is updated by     - Alt.2-2: SVD   Agreement  For LLS assumptions for increasing DMRS ports in AI 9.1.3.1 in Rel.18:   * Precoding assumption of PDSCH, “[ZF or SVD]” in RAN1#109e agreement is updated by SVD.   Agreement   * For MU-MIMO LLS of PDSCH, for evaluation of SVD/CSI-codebook based sub-band precoding, companies shall report the pre-coding assumption of interference of co-scheduled UEs from the following:   + Alt.1: calculated by pre-coder of channel of each co-scheduled UE.     - For precoding assumption of PDSCH, precoder of target UE and precoder of co-scheduled UE are generated independently.     - Companies can report a set of azimuth and zenith angle offset used for evaluation (For example, azimuth angle offsets from [30o, 60o, 90o] and zenith angle offset from [3o, 6o] can be considered).   + Alt.2: calculated by random pre-coder (i.e. precoder selected randomly from a predefined set of precoders) which is different from the pre-coder of target UE.     - For precoding assumption of PDSCH, only the channel of one target UE, i.e. *Hd*, needs to be modelled. Precoder is generated based on *Hd* to obtain the precoder for this UE only. The interference from co-scheduled UEs can be modelled as, cid:image002.png@01D86C43.8E5DA4E0, wherein *Wi* can be randomly selected from a predefined set of precoders       * Companies shall report how to generate the predefined set of precoders for simulation.   + Alt.3: the same pre-coder as scheduled UE.     - PDSCH interference and interfering DMRS ports are emulated using the same pre-coder as for the scheduled UE.     - Power offset of the co-scheduled UE is one value from {0dB, -3dB, -6dB} as fixed evaluation parameter. Other values are not precluded.     - For precoding assumption of PDSCH, only the channel of one target UE, i.e. *Hd*, needs to be modelled. Precoder for the target UE (denoted as *Wd*) is generated based on *Hd* only. Denote the precoding matrix/vector of the ith co-scheduled UEs as *Wi*, and *Wi*=*Wd* (*Wi* for all th co-scheduled UEs are same). Then the interference from co-scheduled UEs can be modelled as cid:image003.png@01D86C43.8E5DA4E0.​   For the above Alt.1-3, only PDSCH performance of the target UE is evaluated, while interference of both PDSCH and DMRS of co-scheduled UE(s) is simulated.  Agreement   * 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.   + Following evaluation assumptions are used for SLS.  |  |  |  | | --- | --- | --- | | **Parameter** | | **Value** | | Scenario | | Dense Urban (macro only) | | Carrier frequency | | 4GHz | | Duplex, Waveform | | TDD, OFDM  Note: FDD, OFDM is not precluded | | 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 | | Baseline: FTP1 with 50% Resource Utilization  Optional: Full buffer | | UE distribution | | [80%] indoor (3km/h),  [20%] outdoor (30km/h) | | UE receiver | | MMSE-IRC as the baseline receiver | | Feedback assumption | | Realistic | | Channel estimation | | Realistic |   **For increasing orthogonal DMRS ports**  Agreement   * 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.   Agreement   * The maximum 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.   Agreement   * 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.   + Opt.5 TD-OCC over non-contiguous 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.   + The same option can be applied to both single symbol DMRS and double symbol DMRS.   Agreement   * 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.   Agreement   * To increase the max. number of orthogonal DMRS ports for PDSCH/PUSCH larger than Rel.15   + Study whether/how to support DCI-based dynamic antenna ports indication of Rel.18 DMRS ports and/or Rel.15 DMRS ports.   + Study whether/how to reuse the antenna port indication table in 38.212 as much as possible for both PDSCH and PUSCH   + Study the potential need for MU scheduling restrictions in the design of the enhanced antenna port indication table in 38.212 for DL PDSCH.   **For 8 Tx UL SU-MIMO**  Agreement   * Study the following potential DMRS enhancement for potential support of more than 4 layers SU-MIMO PUSCH.   + Extend DMRS port allocation table for rank 5~8     - Note: DL DMRS table can be a reference   + Enhancement for DMRS to PTRS mapping * Study whether to utilize Rel.18 DMRS ports for more than 4 layers SU-MIMO PUSCH. * Note: the above study does not imply more than 4 layers SU-MIMO PUSCH is supported. * Note: other study for potential DMRS enhancement for potential support of more than 4 layers SU-MIMO PUSCH is not precluded. |

## **RAN1#110bis-e agreements:**

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| **For increasing orthogonal DMRS ports**  Working Assumption   * To increase the number of DMRS ports for PDSCH/PUSCH, support at least Opt.1 (introduce larger FD-OCC length than Rel.15 (e.g. 4 or 6)).   + FFS: FD-OCC length for Rel.18 DMRS type 1 and type 2.   + FFS: Whether it is needed to handle potential performance issues of Opt 1. For example, study if there is performance loss in case of large delay spread scenario. If needed, how (e.g. additionally support other options).   Agreement   * For enhanced FD-OCC length for DMRS of PDSCH/PUSCH, support the following FD-OCC length:   + For Rel.18 DMRS type 1, down select from the following in RAN1#110bis-e:     - Opt.1-1: Length 6 FD-OCC is applied to 6 REs of DMRS within a PRB within an CDM group     - Opt.1-2: Length 4 FD-OCC is applied to 4 REs of DMRS within a PRB or across consecutive PRBs within an CDM group   + For Rel.18 DMRS type 2:     - Length 4 FD-OCC is applied to 4 REs of DMRS within a PRB within an CDM group     - FFS: Support of length 6 FD-OCC   Agreement   * Support MU-MIMO between Rel.15 DMRS ports and Rel.18 DMRS ports.   + For MU-MIMO by different CDM groups, no MU-MIMO scheduling restriction of PUSCH/PDSCH (i.e. MU-MIMO between Rel.15 UE and Rel.18 UE is allowed).   + For MU-MIMO within a CDM group, study whether and how to support MU-MIMO between Rel.15 DMRS ports and Rel.18 DMRS ports for PDSCH.     - Note: the study includes MU-MIMO between Rel.15 UE and Rel.18 UE, and between Rel.18 UEs.   + Note: PUSCH above is CP-OFDM waveform.   Agreement  For increased DMRS ports for enhanced FD-OCC, study whether/how to support DCI based switching between DMRS port(s) associated with length 2 FD-OCC and DMRS port(s) associated with length M FD-OCC (where M > 2).  **For 8 Tx UL SU-MIMO**  Agreement   * For support of more than 4 layers SU-MIMO PUSCH, study the following potential enhancements for PTRS-DMRS association.   + Whether to support more than 2-port UL PTRS.   + Whether to increase the DCI size of PTRS-DMRS association field in DCI format 0\_1/0\_2.   Agreement  For > 4 layers PUSCH, support rank = 5,6,7,8 for both DMRS type 1/2, and for both single-symbol/double-symbol DMRS. |