**3GPP TSG RAN WG1 Meeting #110 R1-2207715**

**Toulouse, France, August 22nd – 26th, 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.
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For objective#3 (increased DMRS ports), in RAN1#109-e meeting, the following agreement was made. From FL perspective, the highest priority in RAN1#110 is to down select from the agreed 5 options.

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

# Summary of evaluation results for objective#3

Multiple companies (FUTUREWEI, Huawei/HiSilicon, ZTE, vivo, Lenovo, OPPO, CATT, Xiaomi, Samsung, Fraunhofer IIS/HHI MediaTek , Ericsson, Qualcomm, Nokia) show evaluation results to compare the 5 options. Evaluation results are summarized in “Summary of evaluation results” in

[https://www.3gpp.org/ftp/tsg\_ran/WG1\_RL1/TSGR1\_110/Inbox/drafts/9.1(NR\_MIMO\_evo\_DL\_UL)/9.1.3.1%20-%20DMRS/Round0](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_110/Inbox/drafts/9.1%28NR_MIMO_evo_DL_UL%29/9.1.3.1%20-%20DMRS/Round0)

# Objective #3 (increasing DMRS ports)

## Down-selection of 5 options

Based on reviewing companies’ tdocs, Pros. and Cons. of each option are summarized in the following table.

Table 3.1-1: Companies views on the 5 options.

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|  | **Pros.** | **Cons.** | **Support/Concern** |
| **Opt.1 (FD-OCC)** | * HW: Good Backward compatibility.
* Small spec. impact.
* No performance degradation in high UE velocity
 | * ZTE: Performance degradation in large delay spread.
* LGE: Not possible to multiplex with legacy UE in the same CDM group.
 | **Support/Fine (21):**Huawei/HiSilicon (length 4), ZTE (length 4), Spreadtrum, vivo (length 4), New H3C Technolog, Google (length 4), Lenovo (length 4), OPPO (length 4), CATT (length 4), NEC, Intel (length 6 for type 1, length 4 for type 2), Xiaomi, , Samsung, CMCC, Fraunhofer IIS/HHI, MediaTek (length 4), Qualcomm (length 4), Apple (2nd pref., length 4), DOCOMO (length 4) Sharp(length 4), Nokia**Concern:** |
| **Opt.2 (TD-OCC)** | * No performance degradation in large delay spread.
* LGE: MU-MIMO targets low mobility UEs.
 | * HW, DCM: Limitation on applicable scenarios (must be with additional DMRS symbols)
* HW, DCM: Performance degradation in high UE velocity
* HW: Affecting the capability of the Doppler or frequency shift estimation
* Spreadtrum: Further enhancements needed due to frequency hopping
* Xiaomi, Samsung, HW: The front-DMRS is specified to support faster demodulation of PDSCH/PUSCH. It causes additional latency for channel estimation.
* LGE: Not possible to multiplex with legacy UE in the same CDM group
* Nokia: Confliction with WID restriction of “without increasing DM-RS overhead”
 | **Support/Fine (3):**InterDigital, ZTE, DOCOMO (in addition to Opt.1)**Concern:**Xiaomi, Ericsson |
| **Opt.3 (FDM)** | * No performance degradation in high UE velocity.
 | * + HW, Sharp: Compatibility between Rel.15 and Rel.18 DMRS ports
	+ HW, ZTE: Power boosting design
	+ HW: Low PAPR DMRS sequence design
	+ HW PXSCH rate matching design
	+ ZTE: More interference
	+ Performance degradation in large delay spread.
	+ Sharp: Channel estimation accuracy is degraded
 | **Support/Fine (10):**FUTUREWEI, Spreadtrum New H3C Technolog, Google, Lenovo, OPPO, CATT, Samsung, CMCC, Apple**Concern:** |
| **Opt.4 (TDM)** | * No performance degradation in large delay spread.
* LGE: MU-MIMO targets low mobility UEs.
 | * HW, DCM: Limitation on applicable scenarios (must be with additional DMRS symbols)
* HW, DCM: Performance degradation in high UE velocity
* HW: Affecting the capability of the Doppler or frequency shift estimation
* Sharp, Samsung, Xiaomi: The front-DMRS is specified to support faster demodulation of PDSCH/PUSCH. It cause additional latency for channel estimation.
* HW: Compatibility between Rel.15 and Rel.18 DMRS ports
* ZTE: More impact on legacy DMRS estimation
* MediaTek: PAPR will be too large (some OFDM symbols may have zero power)
* Qualcomm: Not able to maintenance the phase continuity of PUSCH.
* Nokia, ZTE, MediaTek: confliction with WID restriction of “without increasing DM-RS overhead”
* Nokia: cause UL coverage problem.
 | **Support/Fine (3):**InterDigital, New H3C Technolog, LGE**Concern:** Xiaomi, Ericsson |
| **Opt.5 (TD-OCC over FD OCC/FDM)** | * Ericsson: Better performance than Opt.1 with large delay spread (300ns). There is no performance loss.
 | * Limitation on applicable scenarios (must be with additional DMRS symbols)
 | **Support/Fine (1):**Ericsson**Concern:**  |

Based on the above observations, several concerns are observed for Opt.2 (TD-OCC) and Opt.4 (TDM). Especially, concerns on Opt.4 are critical (e.g. PAPR is too large, not able to maintain the phase continuity, UL coverage problem). Hence, FL suggestion is to preclude Opt.4 firstly. Then, among other 4 options, Opt.1 and Opt.3 have more applicable scenarios (applicable with/without additional DMRS) than Opt.2/5, and better performance except for the large delay spread. Between Opt.1 and Opt.3, not significant performance difference is observed, and Opt.1 has the largest number of supporters. Hence, FL suggestion is to agree at least on Opt.1. On the other hand, based on the evaluation results, sometimes Opt.2/3/5 has better performance than Opt.1, and later discussion is not precluded to support Opt.2/3/5 additionally. Note that some companies (e.g. Samsung, Qualcomm, etc) believe single solution is enough to complete the WID, on the other hand, other some companies (e.g. ZTE, DOCOMO, etc) think multiple options can be considered. This can be discussed as part of FFS later.

**FL proposal#3.1:**

* **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 to support additional option(s) from Opt.2/3/5.**
	+ **Opt.4 (TDMed DMRS symbol) is precluded.**

Please provide your views. If you prefer other option(s), please check the concerns for other options in the above table.

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| **Company** | **Comment** |
| OPPO | Fine with the proposal. |
| Ericsson | Not ok. We think option 5, i.e. FD-OCC combined with TD-OCC over additional DMRS symbols should be selected. Note that option 5 means that the receiver side can choose whether to use longer length FD-OCC or TD-OCC over additional DMRS symbols for decoding and channel estimation. The same DMRS signal is always transmitted independently of delay spread and Doppler spread. If the RX decides to us longer length FD-OCC then the performance is identical to option 1 FD-OCC. In case of low doppler spread and high delay spread the RX may decide to use TD-OCC instead to achieve better performance. Note, that it doesn’t make sense to select option 5 ***and*** option 1 since option 5 in itself allows for everything that can be achieved with option 1. The only difference between an option 1 and an option 5 DMRS port is that there may (depending on the TD-OCC code) be an ***overall*** sign difference between different non-contiguous DMRS symbols. Clearly, this doesn’t preclude the UE from decoding the port using FD-OCC in the same way as for option 1.In the case of zero additional DMRS signals, option 5 and option 1 are obviously identical.Note, that if option 5 is adopted UE/NW manufacturers may very well implement a channel estimator which always uses longer length FD-OCC. This will then give the same performance as option 1. In order to improve performance, UE/NW manufacturers may, however, implement a channel estimator which decides on whether to use longer length FD-OCC or TD-OCC over additional DMRS signals based on estimated Doppler spread and delay spread.This method (option 5) has previously been used for the LTE uplink with good result. |
| Apple | Even though our first preference is to have sparse frequency domain allocation by doubling the amount of CDM groups (Option 3), we are fine to downselect to option 1 |
| Google | Support the proposal.  |
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## Details on Opt.1 (FD-OCC)

If Opt.1 (FD-OCC) is agreed, details of FD-OCC should be discussed.

### 3.2.1 FD-OCC length.

For the FD-OCC length, we can discuss the following options. Based on reviewing tdocs, for DMRS type 2, all companies assume length 4 FD-OCC in their tdocs. For DMRS type 1, Opt.1-2 is the majority view for DMRS type 1. For Opt.1-2, FD-OCC can be applied across different PRBs. How to handle the issue (orphan RE/RB) in Opt.1-2 can be discussed in sect. 3.2.2.

* + **For Rel.18 DMRS type 1:**
		- **Opt.1-1: length 6 is applied to 6 REs of DMRS within a PRB**
		- **Opt.1-2: length 4 is applied to nearby 4 REs of DMRS within a PRB or across consecutive PRBs**
	+ **For Rel.18 DMRS type 2:**
		- **length 4 is applied to 4 REs of DMRS within a PRB**



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



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

For the details of FD-OCC code, following FD-OCC codes are proposed.

* **Length 4: Walsh matrix** (Fraunhofer, Qualcomm, DOCOMO, etc.):

$$W\_{Hadamard}^{4}=\left[\begin{matrix}\begin{matrix}1&1\\1&-1\end{matrix}&\begin{matrix}1&1\\1&-1\end{matrix}\\\begin{matrix}1&1\\1&-1\end{matrix}&\begin{matrix}-1&-1\\-1&1\end{matrix}\end{matrix}\right]$$

* **Length 6: FFT-based sequence** (Fraunhofer, Intel):

$$W\_{FFT}^{6}=\left[\begin{matrix}\begin{matrix}1&1\\1&e^{-jπ/3}\end{matrix}&\begin{matrix}1&1\\e^{-j2π/3}&-1\end{matrix}&\begin{matrix}1&1\\e^{j2π/3}&e^{jπ/3}\end{matrix}\\\begin{matrix}1&e^{-j2π/3}\\1&-1\end{matrix}&\begin{matrix}e^{-j2π/3}&1\\1&-1\end{matrix}&\begin{matrix}e^{j4π/3}&e^{j2π/3}\\1&-1\end{matrix}\\\begin{matrix}1&e^{-j4π/3}\\1&e^{-j5π/3}\end{matrix}&\begin{matrix}e^{-j8π/3}&1\\e^{-j10π/3}&-1\end{matrix}&\begin{matrix}e^{j8π/3}&e^{j4π/3}\\e^{j10π/3}&e^{j5π/3}\end{matrix}\end{matrix}\right]$$

Multiple companies show performance comparison between length 4 FD-OCC and length 6 FD-OCC in DMRS type 1. Based on the evaluation results, length 4 FD-OCC has better performance in large delay spread.



**Fig 12: Peak throughput (at 40dB SNIR) comparison between size 4 and size 6 FD-OCC [22]**

Based on reviewing tdocs, majority supports Opt.1-2:

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| **Options** | **Support** |
| Opt.1-1 (length 6 FD-OCC) | Intel, Fraunhofer  |
| Opt.1-2 (length 4 FD-OCC) | Huawei/HiSilicon, ZTE, vivo, Google, Lenovo, OPPO, CATT, MediaTek, Qualcomm, Apple, DOCOMO, Sharp |

Hence, FL proposal is to agree on Opt.1-2.

**FL proposal#3.2.1:**

* **If Opt.1 (enhanced FD-OCC) is supported, for enhanced FD-OCC length for DMRS of PDSCH/PUSCH, support the following FD-OCC length:**
	+ **For Rel.18 DMRS type 1:**
		- **Opt.1-2: Length 4 FD-OCC is applied to nearby 4 REs of DMRS within a PRB or across consecutive PRBs**
	+ **For Rel.18 DMRS type 2:**
		- **Length 4 FD-OCC is applied to 4 REs of DMRS within a PRB**

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| **Company** | **Comment** |
| OPPO | Support the proposal.  |
| Ericsson | Not ok. We think option 5 FD-OCC combined with TD-OCC over additional DMRS symbols should be adopted. Also, we think more studies are needed to decide on whether length 4 or length 6 FD-OCC should be used. The performance differences between length 4 and length 6 are very small for the case when there are only new UEs in the network. Therefore, differences in backwards compatibility are important. Length 6 FD-OCC has very good backwards compatibility properties, since the two legacy ports ‘exist as 2 of the 6 length 6 codes’ but these two ports are not used for the new UEs. In the uplink the gNB can use length 6 decoding both for legacy and new UEs. Thus, legacy UEs and new UEs can be fully co-scheduled without any restrictions on what ports that can be used. |
| Apple | We are fine with the proposal  |
| Google | Support the proposal |
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### 3.2.2 How to handle orphan RE/RB in length 4 FD-OCC in DMRS type 1

Since length 4 FD-OCC can be applied across different PRBs, there is orphan RE/RB. How to deal with the orphan RE/RB should be discussed. Based on reviewing tdocs, following options are proposed.

* + **Alt.1: Scheduling restriction (i.e. gNB always schedules PDSCH/PUSCH with even number of PRBs): CATT, DOCOMO, MediaTek, etc.**
	+ **Alt.2: No scheduling restriction (i.e. gNB can schedules PDSCH/PUSCH with any number of PRBs).**
		- **Length 4 FD-OCC can be decoded per a PRB at a receiver: vivo, Huawei**

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

 

Alt.1: Channel estimation across two RBs[6]  Alt.2-1: Two channel estimations based on FD-OCC=4 in one RB [6]

It is pointed out by Huawei that performance loss due to the orphan RE is not significant.

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| グラフ  自動的に生成された説明**Figure 12. Example of orphan RB/REs of Type1 DMRS [3]**For example, the scheduling bandwidth is 13 RBs, and the proportion of orphan REs is only 2.56%. Therefore, the overall performance loss caused by orphan REs is not significant. |

Two companies (vivo, Huawei) show the performance loss due to Alt.2 is small.

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| In vivo [6]d) 64QAM, DS=3001. For DMRS type 1 enhancement, FD-OCC=4 with two channel estimations in each RB has a similar performance to FD-OCC=4 with 2RB as scheduling granularity in the case of large delay spread.
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| In Huawei [3]**A. OCC decoding is performed three times in 2RBs based on length-4 FD-OCC.****B. Each RB performs decoding of the length-4 FD-OCC twice according to the method proposed above.****C. Non-orthogonal DMRS ports** C:\Users\g00435124\AppData\Roaming\eSpace_Desktop\UserData\g00435124\imagefiles\107CD0FD-67DB-46E1-B121-6089E9A6370C.png**Figure 13. NMSE performance of orphan RB/REs of Type1 DMRS*****Observation 10: Through appropriate channel estimation algorithm, orphan RB/REs only introduces negligible performance loss.*** |

**FL proposal#3.2.2:**

* **If Opt.1 (enhanced FD-OCC) is supported, for orphan RE/RB for Rel.18 DMRS type 1 with length 4 FD-OCC, down select from the following:**
	+ **Alt.1: Scheduling restriction (i.e. gNB always schedules PDSCH/PUSCH with even number of PRBs).**
	+ **Alt.2: No scheduling restriction (i.e. gNB can schedules PDSCH/PUSCH with any number of PRBs).**
		- **Length 4 FD-OCC can be decoded per a PRB at a receiver.**

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| **Company** | **Comment** |
| OPPO | For Alt.2, even when odd number of PRBs are scheduled, gNB can still decode FD-OCC4 every two PRBs expect for the last PRB. We suggest to delete “Length 4 FD-OCC can be decoded per a PRB at a receiver” which may limit the gNB implementation.  |
| Ericsson | We think this is pre-mature to agree upon before we have decided what FD-OCC length to use.If length-4 FD-OCC would be selected, we think Alt. 2, no scheduling restrictions (i.e. gNB can schedules PDSCH/PUSCH with any number of PRBs) should be adopted. As shown by Huawei, the orphan issue for odd numbers of RBs can be handled by the receiver. |
| Apple | We are fine with the proposal, we think Alt 1 is needed. We think it is better to remove the content in (), for example “**(i.e. gNB always schedules PDSCH/PUSCH with even number of PRBs)”** may not be the sufficient condition to avoid the issue.  |
| Google | Agree with Ericsson that this can be decided later. For current proposal, we suggest removing “i.e.” for each alternative or changing “i.e.” into “e.g.” as there could be some other ways. Meanwhile, the “i.e….” for Alt1 does not seem to be sufficient as Apple pointed out. |
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## Dynamic indication of Rel.15 DMRS ports and Rel.18 DMRS ports

Multiple companies (e.g. Spreadtrum, Lenovo, CATT, NEC, Samsung, Sharip, ZTE, Fraunhofer, DOCOMO, etc.) mentioned it is beneficial to support dynamic indication of Rel.15 DMRS ports and Rel.18 DMRS ports. One use-case is that gNB can dynamically indicate Rel.15 DMRS ports, if not large number of DMRS ports are required for the scheduled PDSCH/PUSCH. Another use-case is that gNB can find good MU-MIMO UE pairing if dynamic switching is supported.

FL suggestion is to discuss the following proposal. Note that Nokia and NEC mentioned that we should strive not to increase the size of DCI for the dynamic indication. This option is included in Alt.2, and whether to increase the size of the existing DCI field is a part of the study in next step.

**FL proposal#3.3:**

* **For increased DMRS ports, support DCI-based dynamic antenna ports indication between Rel.15 DMRS ports and Rel.18 DMRS ports, and down select from the following:**
	+ **Alt.1: Introduce new DCI field for dynamic switching between Rel.15 DMRS ports and Rel.18 DMRS ports.**
	+ **Alt.2: No new DCI field is introduced. Existing DCI field (e.g. antenna port indication field, or TDRA field) can be used for indication between Rel.15 DMRS ports and Rel.18 DMRS ports.**
		- **FFS: whether to increase the DCI size of the existing DCI field.**

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| **Company** | **Comment** |
| OPPO | Fine with the proposal.  |
| Ericsson | Support.  |
| Apple | We think it is too early to have such an agreement. We should first agree on the DMRS design and what the new “antenna port” field looks like, before we commit to dynamic switching between legacy and enhanced DMRS mode.  |
| Google | We also think it is too early for this agreement. Whether dynamic switching is possible or not depends on the outcome of 3.1. |
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## MU-MIMO between Rel.15 DMRS ports and Rel.18 DMRS ports

Multiple companies (e.g. Spreadtrum, Lenovo, Xiaomi, DOCOMO, CMCC, Nokia, Ericsson, etc.) support MU-MIMO between Rel.15 DMRS ports and Rel.18 DMRS ports. For multiplexing with different CDM groups, it should be no problem to support MU-MIMO between Rel.15 DMRS ports and Rel.18 DMRS ports. For multiplexing within a CDM group, whether/how to multiplex R15 DMRS ports and Rel.18 DMRS ports depends on which option is selected.

**FL proposal#3.4:**

* **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 PUSCH/PDSCH.**
		- **Note: the study includes MU-MIMO between Rel.15 UE and Rel.18 UE, and between Rel.18 UEs.**

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| **Company** | **Comment** |
| OPPO | Support the proposal.  |
| Ericsson | Support. |
| Apple | We are fine with the proposal  |
| Google | Support the proposal in principle. But we think it could be better to clarify such MU-MIMO for PUSCH is for CP-OFDM waveform. |
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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. **If Opt.3 (FDM) is supported, study the following issues**
* **DMRS power boosting**
* **DMRS sequence generation**
* **Frequency domain subsampling at CDM group level or PRB level**
 | Lenovo, CATT, LGE, CMCC, Apple |
| 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** |
| Ericsson | On dynamic switching between different number of additional DMRS symbols, we would like to point out that the performance gain one can achieve with switching between different additional DMRS symbols is much larger than switching between Rel-15 and Rel-18 DMRS ports.In addition, in Rel-15 the switching between double/single symbol DMRS has already been supported. This means the functionality for dynamic switching between different number of DMRS symbols may have been implemented in UE chipset. However, as the overhead for double symbol DMRS is too large and impacts the throughput, double symbol DMRS is not a practical configuration in a commercial network. The Rel-18 enhancement on dynamic switching shall include switching between different number of additional DMRS symbols for a single symbol DMRS, which will improve both MU-MIMO and SU-MIMO performance in a commercial network. |
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# Specifying objective #5 (>4 layers PUSCH DMRS)

Based on reviewing the companies’ tdocs, the following DMRS enhancements for >4 layers PUSCH are proposed to support more than 4 layers PUSCH. Whether to support >4 layers PUSCH is discussed under AI 9.1.4.2, but we can start technical discussion for potential DMRS enhancement, in case AI 9.1.4.2 agrees to support >4 layers PUSCH.

## PTRS-DMRS association

Multiple companies (e.g. Huawei/HiSilicon, CMCC, ZTE, Xiaomi, Sharp, DOCOMO, Samsung, LGE, Ericsson, etc.) mentioned study/specify enhancement of PTRS-DMRS association is needed. On the other hand, OPPO thinks this should be FFS because whether > 4 layer PUSCH is supported in FR2 is not clear. From FL perspective, it is beneficial to clarify what aspects need to be studied for PTRS-DMRS association.

**FL proposal#4.1:**

* **For potential support of more than 4 layers SU-MIMO PUSCH, study the following potential enhancements for PTRS-DMRS association.**
	+ **1) Whether to support more than 2-port UL PTRS.**
	+ **2) Whether to increase the DCI size of PTRS-DMRS association field in DCI format 0\_1/0\_2.**

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| **Company** | **Comment** |
| OPPO | Fine to study. |
| Ericsson | Support to study. |
| Apple | Support to study.But more fundamentally, we need to agree on the antenna architecture that we are going to support, especially in terms of how many independent phase noise sources, (e.g., antenna port groups or panels). We need to check the agreement reached in the last RAN1 meeting regarding the new antenna architecture for 8Tx in 8 Tx UL agenda.  |
| Google | Support, but this may depend on the outcome of antenna layout assumption in 8Tx. |
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## Rel.15/18 DMRS ports for >4 layers PUSCH

Multiple companies (e.g. Huawei/HiSilicon, ZTE, DOCOMO, Lenovo, Intel, Nokia/NSB, etc.) think it is beneficial to use Rel.18 DMRS ports to support >4 layer PUSCH. Advantage is to avoid using Rel.15 double symbol DMRS, for example, to support 8-port, Rel.15 DMRS requires double symbol DMRS, however, Rel.18 DMRS can support 8-port with single symbol DMRS, if Opt.1 or Opt.3 is supported. On the other hand, Spreadtrum says there is no need to mandate UE with > 4 layers PUSCH to support Rel.18 DMRS ports. hence, Alt.3 is also added.

**FL proposal#4.2:**

* **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 DMRS ports only.**
	+ **Alt.3: utilize Rel.15 DMRS ports or Rel.18 DMRS ports, depending on RRC-configuration, DCI-indication, and/or UE capability.**
	+ **Note: this does not impact the discussion whether to specify > 4 layers PUSCH in AI 9.1.4.2.**

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| **Company** | **Comment** |
| OPPO | If UE supports Rel-18 DMRS, whether to use Rel-18 DMRS or Rel-15 DMRS can be up to gNB configuration regardless of >4 layer or not. If UE doesn’t support Rel-18 DMRS, then only Rel-15 DMRS can be used for UE supporting >4 layer transmission. We support Alt.3 if this is the intention. |
| Apple | We are fine with the proposal.  |
| Google | We think this proposal is not urgent and may not be quite necessary. Alt2 should be precluded first. It is unreasonable to mandate UE supporting R18 DMRS ports to support >4 layers. These should be two different features. For a UE supporting R18 DMRS ports, Alt3 should be a natural choice. |
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## Antenna port indication table for >4 layers PUSCH

Multiple companies mentioned enhancement of antenna port indication table for rank 5/6/7/8 is needed to support >4 layers PUSCH. Some companies (e.g. Huawei/HiSilicon, CATT, vivo, OPPO, CMCC, LGE, etc) think the baseline is to reuse the same or a subset of DMRS port indication 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.

Whether Rel.15 DMRS ports or Rel.18 DMRS ports will be used for >4 layers PUSCH is under discussion in FL proposal#4-2. So, following proposal summarizes possible options. If Rel.18 DMRS ports are supported for > 4 layers PUSCH, we should carefully check the DMRS ports combinations for rank = 5/6/7/8 for PDSCH, whether it enables to use “single symbol DMRS” to support rank = 5/6/7/8, because it is the motivation to support Rel.18 DMRS ports for > 4 layers.

**FL proposal#4.3:**

* **If AI 9.1.4.2 agree to specify > 4 layers PUSCH, support new antenna port indication table** **for rank = 5, …, M for both DMRS type 1/2, and for both single-symbol/double-symbol DMRS.**
	+ **For Rel.15 DMRS ports (if supported),**
		- **Alt.1: same DMRS port combinations as that for rank = 5, …, M for PDSCH are reused.**
		- **Alt.2: new DMRS port combinations are used for rank = 5, …, M (FFS: details).**
	+ **For Rel.18 DMRS ports (if supported),**
		- **Alt.1: same DMRS port combinations as that for rank = 5, …, M for PDSCH are reused.**
			* **Note: whether the DMRS port combination allows to use single symbol DMRS for rank = 5, …, M should be checked.**
		- **Alt.2: new DMRS port combinations are used for rank = 5, …, M (FFS: details).**
	+ **Note: the max number of ranks M for > 4 layers PUSCH will be decided in AI 9.1.4.2.**

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| **Company** | **Comment** |
| OPPO | Though the UL DMRS is indicated per rank while DL DMRS is indicated together with rank, we can still reuse at least part of the DMRS antenna port indication from PDSCH as separate table for PUSCH. |
| Apple | In general, we are fine with the proposal since it just lists all the possibilities. But for Rel-18 DMRS, we think we should first agree on the DMRS pattern design, and antenna port to pattern (TD-OCC, FD-OCC, CDM group) mapping, before we discuss the antenna port indication design. But we also think the mapping should be backward compatible as much as possible |
| Google | This may need to wait for outcome of antenna layout from 8Tx |
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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. **Prioritize one device type for efficient study/discussion (e.g. CPE, FWA, etc.)**
 | Samsung |
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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** |
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# Other issues

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

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| Company | Comment |
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# Conclusion

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

To be updated.

# References

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| [1] | [**R1-2205749**](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_110/Docs/R1-2205749.zip) | On increasing the number of orthogonal DM-RS ports for MU-MIMO | FUTUREWEI |
| [2] | [**R1-2205819**](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_110/Docs/R1-2205819.zip) | Enhanced Capacity DMRS | InterDigital, Inc. |
| [3] | [**R1-2205882**](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_110/Docs/R1-2205882.zip) | Enhancements on DMRS in Rel-18 | Huawei, HiSilicon |
| [4] | [**R1-2205921**](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_110/Docs/R1-2205921.zip) | DMRS enhancement for UL/DL MU-MIMO and 8 Tx UL SU-MIMO | ZTE |
| [5] | [**R1-2205984**](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_110/Docs/R1-2205984.zip) | Discussion on increased number of orthogonal DMRS ports | Spreadtrum Communications |
| [6] | [**R1-2206027**](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_110/Docs/R1-2206027.zip) | Discussion on DMRS enhancements | vivo |
| [7] | [**R1-2206106**](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_110/Docs/R1-2206106.zip) | Discussions on increased number of orthogonal DMRS ports | New H3C Technologies Co., Ltd. |
| [8] | [**R1-2206190**](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_110/Docs/R1-2206190.zip) | On DMRS Enhancement | Google |
| [9] | [**R1-2206212**](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_110/Docs/R1-2206212.zip) | Discussion of increased number of orthogonal DMRS ports | Lenovo |
| [10] | [**R1-2206266**](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_110/Docs/R1-2206266.zip) | DMRS enhancement for Rel-18 MIMO | OPPO |
| [11] | [**R1-2206378**](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_110/Docs/R1-2206378.zip) | On DMRS enhancements | CATT |
| [12] | [**R1-2206460**](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_110/Docs/R1-2206460.zip) | Discussion on increased number of orthogonal DMRS ports | NEC |
| [13] | [**R1-2206573**](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_110/Docs/R1-2206573.zip) | Discussion on DMRS enhancement | Intel Corporation |
| [14] | [**R1-2206623**](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_110/Docs/R1-2206623.zip) | Discussion on DMRS enhancement | Xiaomi |
| [15] | [**R1-2206815**](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_110/Docs/R1-2206815.zip) | Views on DMRS enhancements | Samsung |
| [16] | [**R1-2206869**](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_110/Docs/R1-2206869.zip) | Increased number of orthogonal DMRS ports | LG Electronics |
| [17] | [**R1-2206897**](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_110/Docs/R1-2206897.zip) | Discussion on increased number of orthogonal DMRS ports | CMCC |
| [18] | [**R1-2206966**](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_110/Docs/R1-2206966.zip) | Increased number of orthogonal DMRS ports | Fraunhofer IIS, Fraunhofer HHI |
| [19] | [**R1-2206993**](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_110/Docs/R1-2206993.zip) | Increased number of orthogonal DMRS ports | MediaTek Inc. |
| [21] | [**R1-2207135**](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_110/Docs/R1-2207135.zip) | On DMRS enhancement in Rel-18 | Ericsson |
| [22] | [**R1-2207218**](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_110/Docs/R1-2207218.zip) | Design for increased number of orthogonal DMRS ports | Qualcomm Incorporated |
| [23] | [**R1-2207323**](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_110/Docs/R1-2207323.zip) | Views on supporting increased number of orthogonal DMRS ports | Apple |
| [24] | [**R1-2207396**](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_110/Docs/R1-2207396.zip) | Discussion on DMRS enhancements | NTT DOCOMO, INC. |
| [24] | [**R1-2207453**](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_110/Docs/R1-2207453.zip) | Increased number of orthogonal DMRS ports | Sharp |
| [25] | [**R1-2207547**](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_110/Docs/R1-2207547.zip) | Rel-18 UL and DL DMRS Enhancements | Nokia, Nokia Shanghai Bell |

# **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

AgreementFor 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, , 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 .​

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.

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| **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.
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