

Agenda item: 5.1.2.4.3
Source: LG Electronics
Title: On DL DMRS Design
Document for: Discussion and Decision

1 Introduction

In the previous RAN1 #89 meeting, we discussed front-load DMRS design for NR and two DMRS configurations for UL/DL CP-OFDM were defined in working assumption as follows [1]:

Working assumption:

- UEs in a cell are higher layer configured with 2 DMRS configurations for the front-load DMRS for UL/DL CP-OFDM
 - Front-load DMRS Configuration 1: Supports up to 8 ports
 - IFDM based pattern with Comb [2] and/or [4] w cyclic shifts (CS)
 - One OFDM symbol:
 - To be down selected to 1 Alt:
 - Alt 1: Comb 2 + 2 CS, up to 4 ports
 - Alt 2: Comb 4 + 2 CS, up to 8 ports
 - Two OFDM symbols:
 - To be down selected to 2 Alts:
 - Alt. 1: Comb 2 + 2 CS + TD-OCC ($\{1\ 1\}$ and $\{1\ -1\}$), up to 8 ports
 - Alt. 2: Comb 2 + 4 CS + TD-OCC ($\{1\ 1\}$), up to 8 ports
 - Alt. 3: Comb 4 + 2 CS + TD-OCC ($\{1\ 1\}$), up to 8 ports
 - Front-load DMRS Configuration 2: Supports up to 12 ports
 - FD-OCC pattern with adjacent REs in the frequency domain
 - One OFDM symbol:
 - To be down selected to 1 Alt:
 - Alt. 1: 2-FD-OCC across adjacent REs in the frequency domain up to 6 ports
 - Alt. 2: 2-FD-OCC across adjacent REs in the frequency domain up to 4 ports
 - Alt. 3: 2-FD-OCC across adjacent REs in the frequency domain up to 2 ports
 - Two OFDM symbols:
 - 2-FD-OCC across adjacent REs in the frequency domain + TDM up to 12 ports
 - 2-FD-OCC across adjacent REs in the frequency domain + TD-OCC (both $\{1,1\}$ and $\{1,-1\}$) up to 12 ports
 - FFS: DMRS pattern before configuration, e.g., SIB1

Important decisions to design the front-load DMRS were made in the previous meeting. However, some alternatives have to be down selected to complete the front-load DMRS design. Also, there are some issues on DL DMRS design. In this contribution, we share LG's views on DL DMRS design.

2 Discussion

In the previous meeting, two DMRS configurations for UL/DL CP-OFDM were defined in working assumption. Configuration 1 is based on IFDM pattern with Comb and with cyclic shift. And Configuration 2 is based on FD-OCC pattern with adjacent REs in the frequency domain. Although two configurations were defined, there are some alternatives that have to be down selected in each configuration. In this section, we provide our views on these alternatives.

■ Configuration 1

There are three alternatives in two OFDM symbols of front-load DMRS Configuration 1. These alternatives have advantages in different case. Alt. 1 can be more robust to frequency selectivity because its CDM length in frequency domain is shorter than other alternatives. However, time domain OCC used in Alt. 1 can cause performance degradation especially in mmWave application because of phase rotation between adjacent OFDM symbols caused by phase noise [2]. Alt. 2 and Alt. 3 that are repeated in time domain can be used to estimate the phase rotation between two DMRS symbols and improve channel estimation performance by compensating this phase rotation and providing more RS energy. Based on these observations, Alt. 1 can be used in low frequency band, and one of Alt. 2 and Alt. 3 can be used for high frequency band.

Alt. 2 and Alt. 3 use different Comb types, i.e. Comb 2 for Alt. 2 and Comb 4 for Alt. 3. These different Comb types need different signaling method, so that signaling overhead can be differed according to Comb type. For example, Comb 2 with CS 4 can multiplex 4 DMRS ports in same REs in frequency domain. However, Comb 4 with CS 2 can multiplex 2 DMRS ports. As large Comb size is used, the number of multiplexed ports in the same REs becomes smaller, so that more FDMed REs are required to support maximum port number. When transparent MU-MIMO is considered, a lot of FDMed ports number would require more DCI overhead, e.g. for indicating ZP DMRS subcarrier.

From performance of channel estimation perspective, DMRS pattern with Comb 4 could cause performance degradation in large delay spread because of less RS density in frequency domain. Figure 1 shows SE performances of 4 layers transmission about DMRS pattern with Comb 2 with CS 2 and Comb 4. The detailed simulation assumptions and DMRS patterns for simulation are provided in Appendix. Delay spread and MCS are demonstrated in Figure 1. From Figure 1, we can observe that Comb 4 based DMRS pattern for 4 layers transmission has lower SE performance than DMRS pattern based on Comb 2 with CS 2 in large delay spread channel where DS=1000ns.

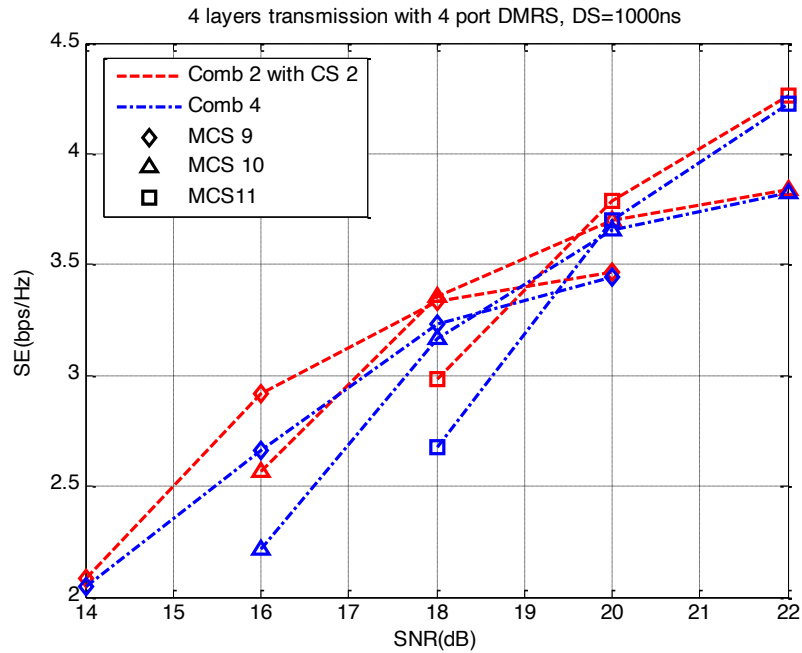


Figure 1. SE performance for 4 layers transmission with 4 port DMRS

Observation #1: *Comb 4 based design would require more DCI overhead than Comb 2 with CS 2, e.g. for indication ZP DMRS subcarrier. And SE performance of Comb 4 for 4 layers transmission is also lower than Comb 2 with CS 2 because of lower RS density in frequency domain.*

In one OFDM symbol of front-load DMRS Configuration 1, two alternatives have different maximum number of supported ports, i.e. 4 ports for Alt. 1 and 8 ports for Alt. 2. When we consider 8 layers transmission with orthogonal 8 port DMRS, one OFDM symbol DMRS causes performance degradation [3]. Figure 2 shows SE performances about one OFDM symbol DMRS and two symbol DMRS. The detailed simulation assumptions and DMRS patterns for simulation are provided in Appendix. Delay spread and MCS are demonstrated in Figure 2.

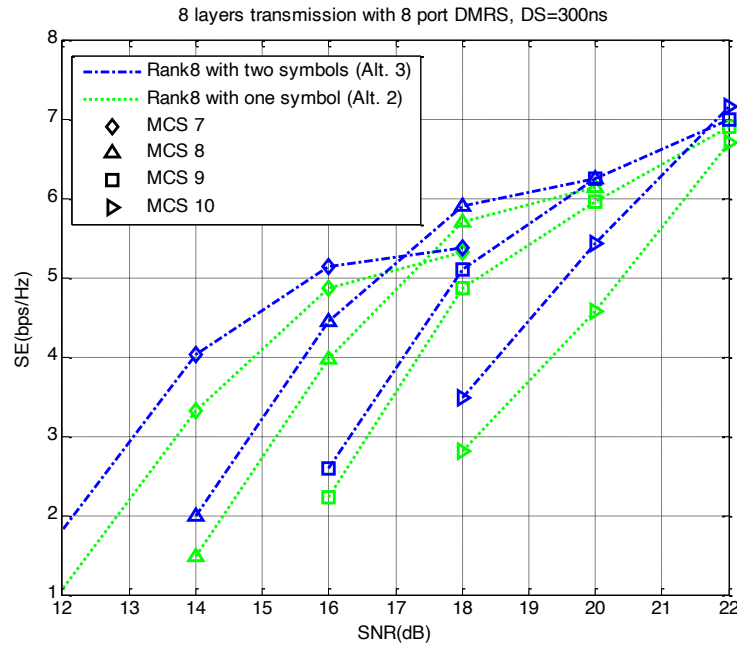


Figure 2. SE performance for 8 layers transmission with 8 port DMRS

From Figure 2, we can observe that DMRS with two OFDM symbols has better SE than DMRS with one OFDM symbol. This is due to the fact that DMRS with two OFDM symbols can obtain more RS energy that can improve channel estimation performance. And this can reduce inter-layer interference caused by channel estimation error. As a result, SE is increased in spite of more RS overhead.

Observation #2: For 8 port, DMRS pattern with two OFDM symbols achieves better SE performance than DMRS pattern with one OFDM symbol.

Proposal #1: For front-load DMRS Configuration 1, following design should be supported.

- For one OFDM symbol, Alt. 1 is supported.
- For two OFDM symbols, Alt. 1 and Alt. 2 are supported.

■ Configuration 2

There are three alternatives in one OFDM symbol of front-load DMRS Configuration 2. The alternatives have different maximum number of supported ports, i.e. 6 ports for Alt. 1, 4 ports for Alt. 2 and 2 ports for Alt. 3. Figure 2 shows port mapping examples for three alternatives in one OFDM symbol and TDM pattern in two OFDM symbols.

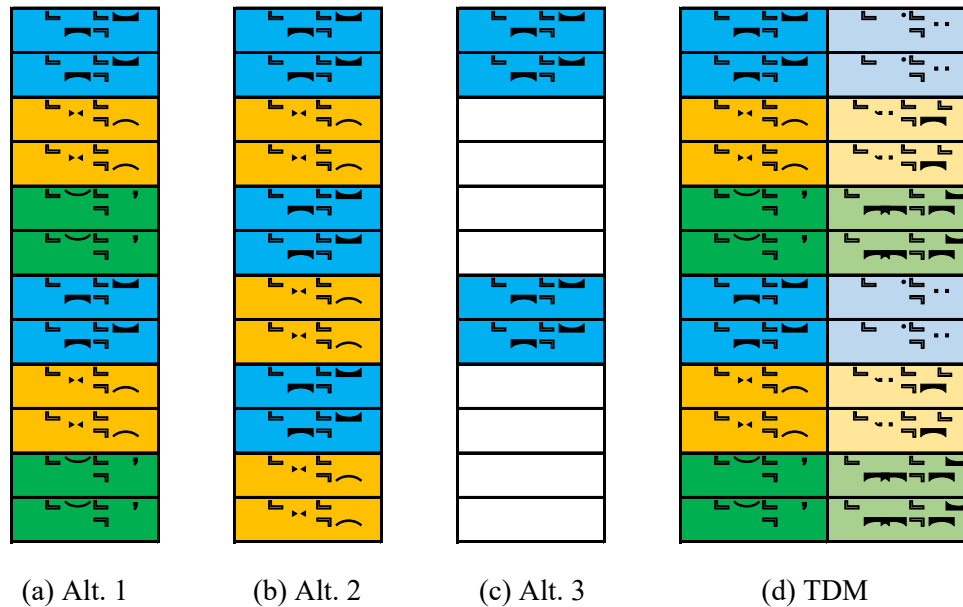


Figure 3. Port mapping examples

As shown in Figure 3, Alt. 1 and Alt. 3 can be subsets of TDM pattern in two OFDM symbols, so that it is natural that one of these alternatives can be supported in one OFDM symbol. From maximum supported port number perspective, Alt. 1 and Alt. 3 can support 6 ports and 2 ports respectively. Front-load DMRS pattern for maximum 2 ranks might be considered in case of SU-MIMO for high frequency band, however, maximum rank 2 isn't enough when MU-MIMO is considered. As a result, Alt. 1 would be preferred in one OFDM symbol of front-load DMRS Configuration 2.

Considering robustness to frequency selectivity, Alt. 1 could cause performance degradation because of its RS density in frequency domain lower than Alt. 2 in high delay spread channel. However, if Configuration 2 is mainly used for mmWave applications, Alt. 1 is appropriate because high delay spread channel is not common in mmWave band. MmWave suffers from weak diffraction and high blockage loss. And narrow beam is also used to focusing energy on the dominant propagation paths. These characteristics cause sparsity of mmWave channels. As a result, high delay spread channel is not common in mmWave band, so that RS density of Alt. 1 is sufficient in this case.

Proposal #2: For one OFDM symbol of front-load DMRS Configuration 2, Alt. 1 is supported.

■ **Issues on additional DMRS**

When slot contains 14 OFDM symbol and 1 additional DMRS is introduced for high mobility UE, the location of additional DMRS has several alternatives. One of them is to locate the DMRS around a last OFDM symbol, i.e., back-loaded DMRS and another one is to locate the DMRS around a middle OFDM symbol, i.e., center-loaded DMRS. In case of back-loaded DMRS, channel estimation performance may be improved with channel interpolation using front-loaded DMRS and back-loaded DMRS. However, the gain should be sufficient considering the penalty of decoding delay. If UE mobility is very high, channel estimation accuracy using back-loaded DMRS probably increases but in this case more additional DMRS such as 3 additional DMRS OFDM symbols will be used, so that the gain is not meaningful.

Observation #3: Back-loaded additional DMRS results in decoding latency and for high mobility case, in which back-loaded additional DMRS may achieve higher performance than center-loaded additional DMRS, more than 1 additional DMRS OFDM symbols will be configured by gNB, instead of 1 additional DMRS OFDM symbol.

Another issue is density reduction in frequency domain when additional DMRS is configured. Since additional DMRS is mainly used for high velocity UE, it is questionable to support high rank transmission due to unstable link adaptation resulting from CSI mismatch. Therefore, rank restriction such as maximum rank 2 limitation naturally conducts density control. However, more than 1 additional DMRS can be configured and high RS overhead can be caused even with rank restriction. So, if additional DMRS causes high RS overhead even with rank restriction, density reduction may be considered but if not, it is not necessary.

Observation #4: Rank restriction such as maximum rank 2 limitation naturally conducts DMRS density control when additional DMRS is used.

Observation #5: Depending on final front-loaded DMRS pattern, configurable front-loaded density may or may not be needed.

■ **Signaling issues on front-load DMRS configuration and the number of DMRS OFDM symbols**

Regarding configuration method for front-load DMRS, both high layer signaling and dynamic signaling should be supported. In our view, selection between front-load DMRS Configuration 1 and Configuration 2 is configured by high layer signaling because switching between Configuration 1 and Configuration 2 would be rarely triggered.

On the other hands, dynamic switching on the number of OFDM symbols for front-load DMRS should be supported because of dynamic switching between SU/MU-MIMO. Even though per UE rank is equal or less than 4, total transmission rank can be more than rank 4 considering MU-MIMO scheduling. Therefore, even though a UE receives rank N ($N < 5$) PDSCH using N DMRS ports, it should be supported that front-loaded DMRS is transmitted using 2 OFDM symbols, taking into account MU-MIMO possibility with total transmission rank more than 4. If a UE is scheduled with SU-MIMO or MU-MIMO with total transmission rank less than 5, it is desirable to use one OFDM symbol DMRS considering the benefits of 1 OFDM symbol DMRS such as low DMRS overhead, early decoding and no phase noise impact. Therefore, the number of front-loaded DMRS OFDM symbol should be dynamically configured either 1 or 2 when per UE rank is less than 5.

Proposal #3: Selection between front-load DMRS Configuration 1 and Configuration 2 should be configured by high layer signaling and the number of front-load DMRS OFDM symbol should be dynamically configured either 1 or 2 when per UE rank is less than 5.

■ **DMRS for broadcast PDSCH**

- i) Front-load DMRS configuration

For the case of broadcast PDSCH transmission, e.g. SIB and paging, only single port is used. So, one OFDM symbol is sufficient for front-load DMRS in this case. And considering robustness to frequency selectivity, Alt. 1 of one OFDM symbol in front-load DMRS Configuration 1 should be preferred because of its high RS density in frequency domain.

Proposal #4: Alt. 1 of one OFDM symbol in front-load DMRS Configuration 1 is used for the broadcast PDSCH transmission.

ii) Additional DMRS configuration

About the presence of and the number of additional DMRS, following two options can be considered.

- Option 1: Additional DMRS is always on and the number of additional DMRS is fixed as maximum number for high speed UEs.

- Option 2: Presence of and the number of additional DMRS are configured by gNB.

Option 1 ensures channel estimation performance for all UEs in the coverage of gNB regardless of UE speed and SINR at the cost of large DMRS overhead. On the other hands, option 2 can configure the number of additional DMRS, so that it can prevent unnecessary transmission of additional DMRS if specific scenarios such as indoor cell guarantees DMRS performance without additional DMRS or with low density DMRS. In this case, the presence and the number of additional DMRS can be configured through MIB in PBCH or DCI that is CRC masked by SI RNTI or P (paging) RNTI. In order to reduce control overhead, it does not need to support all possible DMRS configuration designed for unicast PDSCH. Taking into account the robust DMRS performance for broadcast PDSCH and no signaling overhead using PBCH or common DCI, we slightly more prefer Option 1.

Proposal #5: Taking into account the robust DMRS performance for broadcast PDSCH and no signaling overhead using PBCH or common DCI, following could be considered.

- ***Additional DMRS is always on and the number of additional DMRS is fixed as maximum number for high speed UEs.***

3 Conclusion

In this contribution, we discuss some issues on DL DMRS design. From the discussion, we observed as follows:

Observation #1: Comb 4 based design would require more DCI overhead than Comb 2 with CS 2, e.g. for indication ZP DMRS subcarrier. And SE performance of Comb 4 for 4 layers transmission is also lower than Comb 2 with CS 2 because of lower RS density in frequency domain.

Observation #2: For 8 port, DMRS pattern with two OFDM symbols achieves better SE performance than DMRS pattern with one OFDM symbol.

Observation #3: Back-loaded additional DMRS results in decoding latency and for high mobility case, in which back-loaded additional DMRS may achieve higher performance than center-loaded additional DMRS, more than 1 additional DMRS OFDM symbols will be configured by gNB, instead of 1 additional DMRS OFDM symbol.

Observation #4: Rank restriction such as maximum rank 2 limitation naturally conducts DMRS density control when additional DMRS is used.

Observation #5: Depending on final front-loaded DMRS pattern, configurable front-loaded density may or may not be needed.

Based on above observations, we propose as follows:

Proposal #1: For front-load DMRS Configuration 1, following design should be supported.

- ***For one OFDM symbol, Alt. 1 is supported.***
- ***For two OFDM symbols, Alt. 1 and Alt. 2 are supported.***

Proposal #2: For one OFDM symbol of front-load DMRS Configuration 2, Alt. 1 is supported.

Proposal #3: Selection between front-load DMRS Configuration 1 and Configuration 2 should be configured by high layer signaling and the number of front-load DMRS OFDM symbol should be dynamically configured either 1 or 2 when per UE rank is less than 5.

Proposal #4: Alt. 1 of one OFDM symbol in front-load DMRS Configuration 1 is used for the broadcast PDSCH transmission.

Proposal #5: Taking into account the robust DMRS performance for broadcast PDSCH and no signaling overhead using PBCH or common DCI, following could be considered.

- ***Additional DMRS is always on and the number of additional DMRS is fixed as maximum number for high speed UEs.***

4 References

- [1] 3GPP, RAN1 #89, Chairman's Notes
- [2] R1-1707614, On DL DMRS Design, LGE, RAN1 #89, May, 2017.
- [3] R1-1706168, On DL DMRS Design, LGE, RAN1 #88bis, April, 2017.

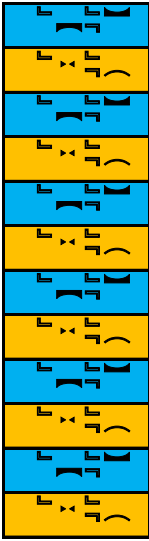
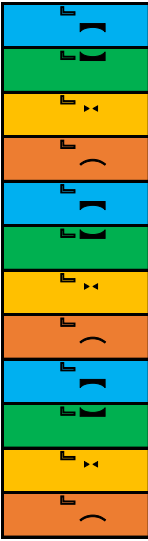
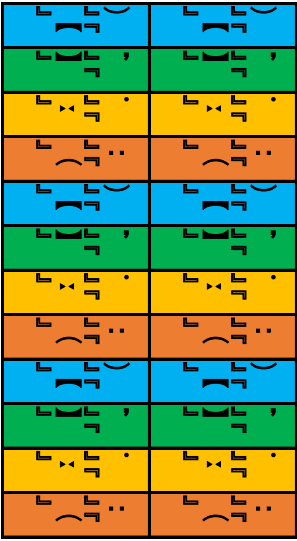
5 Appendix

Table 1. Simulation assumptions

Assumptions	Value
Carrier frequency	4GHz
Subcarrier spacing	15kHz
Transmission layers for data channel	SU-MIMO: 4/ 8 layers
Transmission scheme	- Multi-antenna port transmission schemes - Identity matrix is used for precoding matrix
Data allocation	8 PRBs
PRB bundling	2
Modulation order, Coding rate	MCS 7, MCS 8, MCS 9, MCS 10, MCS 11
Channel coding scheme	LTE turbo coding
Channel estimation	Real estimation
UE speed	3 km/h
Channel model	CDL-B with 300/ 1000 ns DS values.
TRP antenna configuration	4/ 8 with per antenna element pattern in 3GPP TR36.873
UE antenna configuration	4/ 8 with omni-directional antenna element

Table 2. DMRS patterns for simulations

4 port DMRS for 4 layers transmission		8 port DMRS for 8 layers transmission	
Comb 2 with CS 2	Comb 4	One symbol DMRS	Two symbol DMRS

			
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