

Agenda Item: 5.1.3.1.1.2

Source: MediaTek Inc.

Title: RS structures for NR-PDCCH

Document for: Discussion

1 Introduction

In this paper, the following aspects about the DMRS for NR-PDCCH are discussed.

- DMRS structure
- DMRS density

2 Discussions

2.1 DMRS structure

One open issue in the RS structure is whether to support front-loaded DMRS structure when the CORESET has more than one symbol in time domain. In this section, we provide simulation results for following DMRS structures.

- Case #1: Front-loaded DMRS structure. The DMRS is located on the first symbol of the CORESET.
- Case #2: The DMRS is located on the first and the last symbols of the CORESET.
 - If the CORESET has 2 symbols in time, then Case #2 is equivalent to Case #3.
 - If the CORESET has 3 symbols in time, then the DMRS is located on the first and the third symbols of the CORESET.
- Case #3: per-symbol DMRS structure. The DMRS is located on each symbol of the CORESET.

In general, the front-loaded DMRS structure (Case #1) provides the benefit of lower code rate due to less DMRS overhead. Moreover, the front-loaded DMRS structure helps to relax the UE processing latency because the UE only has to perform channel estimation (CE) on the first symbol of the CORESET. And there is no need for the UE to wait for more symbols for CE process. However, the price for less DMRS overhead is the worse CE accuracy. If the channel varies fast in time, the front-loaded DMRS structure may lead to significant performance loss. For the per-symbol DMRS structure (Case #3), each symbol has its own DMRS. It has the advantage of better CE performance. But the penalties are longer processing latency and higher code rate. For the Case #2, it strikes a balance between the code rate and CE accuracy.

First, we provide the evaluation results for the 2-symbol CORESET. Figure 1 and 2 present the performances when the UE mobility is 3 km/hr and 500 km/hr, respectively. In this section, the simulations are evaluated based on the REG-to-CCE mapping with non-interleaving. And the DCI size is 60 bits. DMRS density is fixed to be 33%. More simulation results for REG-to-CCE mapping with interleaving are provided in Appendix A.2. The simulation assumptions are listed in Table A.1.1 in Appendix A.1.

In each subfigure, the red and green curves are the performances for the Case #1 and Case #3 (equivalent to Case #2), respectively. From the results, we can observe that the gain of the Case #1 over the Case #3 is about 0.5~1.5 dB for UE mobility 3 km/hr. The gain for the Case #1 is from the benefit of lower code rate. Therefore, the gain is especially obvious in low aggregation levels (ALs). However, from the Figure 2, we can also observe that the worse CE accuracy for the Case #1 leads to significant performance loss when UE mobility is 500 km/hr. The additional DMRS on the second symbol of the CORESET is required to improve the CE accuracy. Based on the results, we have the observations for the 2-symbol CORESET as below.

Observation #1: When the CORESET time duration is 2 symbols and UE mobility is low, the front-loaded DMRS structure has better performance than the per-symbol DMRS structure.

Observation #2: When the CORESET time duration is 2 symbols, The front-loaded DMRS structure has significant performance loss when the UE mobility is 500 km/hr.

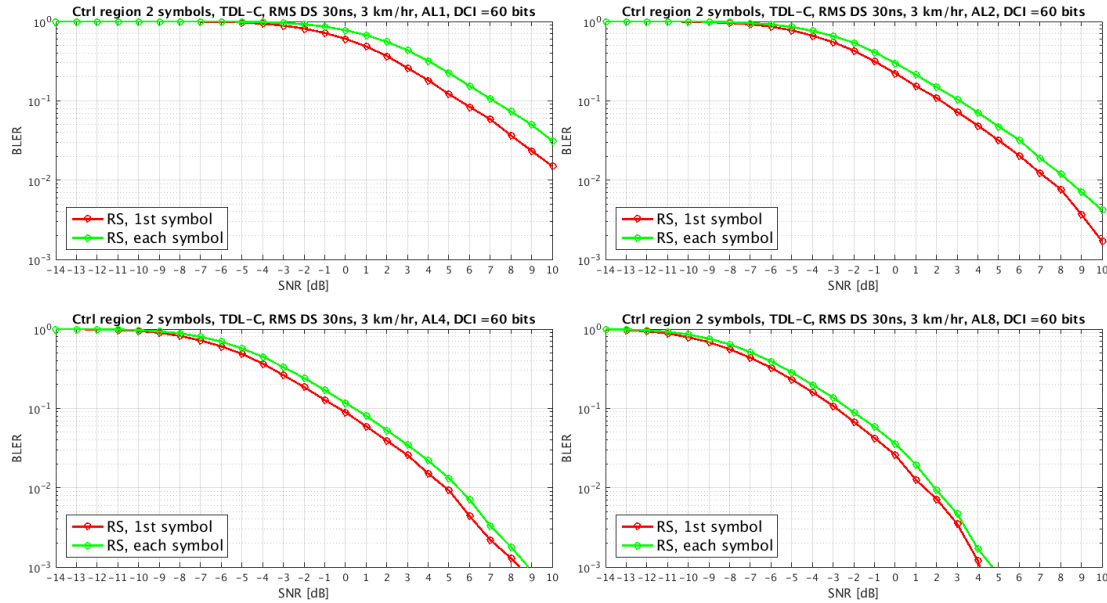


Figure 1. Evaluation results for DMRS structure with 2-symbol CORESET, UE mobility is 3 km/hr

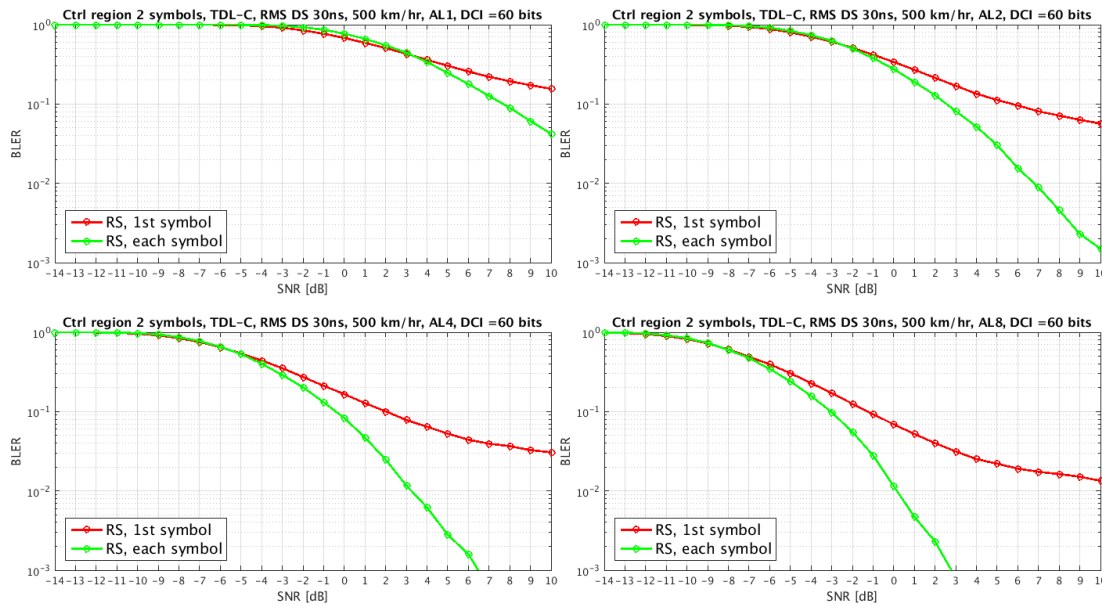


Figure 2. Evaluation results for DMRS structure with 2-symbol CORESET, UE mobility is 500 km/hr

More simulation results for the 3-symbol CORESET are further provided in Figures 3 and 4 for the UE mobility 3 km/hr and 500 km/hr, respectively. In each subfigure, the red, blue and green curves are represented for the Case #1, Case #2 and Case #3, respectively. When the UE mobility is low, the Case #3 has the worst performance due to the highest code rate. The Case #1 and Case #2 have similar performances in most of the ALs. The performance of Case #1 is slightly better than the performance of Case #2 in AL1 because of lower code rate. When the UE mobility is high, the Case #2 and Case #3 can achieve similar performance when the AL is high, e.g., 4 and 8. But when the AL is one and the code rate becomes large enough, the Case #2 has better performance. The gain of the Case #2 over Case #3 in AL1 is larger than 1 dB. The front-loaded DMRS structure cannot achieve acceptable performance when the UE mobility is 500 km/hr. According the results, we have following observations for the 3-symbol CORESET:

Observation #3: When the CORESET duration is 3 OFDM symbols in time domain, the DMRS structure of “DMRS located on the first and the last symbols of the CORESET” has the similar performance of front-loaded DMRS structures in low UE mobility and has the best performance in high UE mobility.

Observation #4: When the CORESET duration is 3 OFDM symbols in time and UE mobility is 500 km/hr, the front-loaded DMRS structure is not appropriate.

Considering the observations in 2-symbol and 3-symbol CORESETs, we propose:

Proposal 1#: Front-loaded DMRS structure is supported in default. The network can indicate additional DMRS on the last symbol of the CORESET via the CORESET configuration if needed.

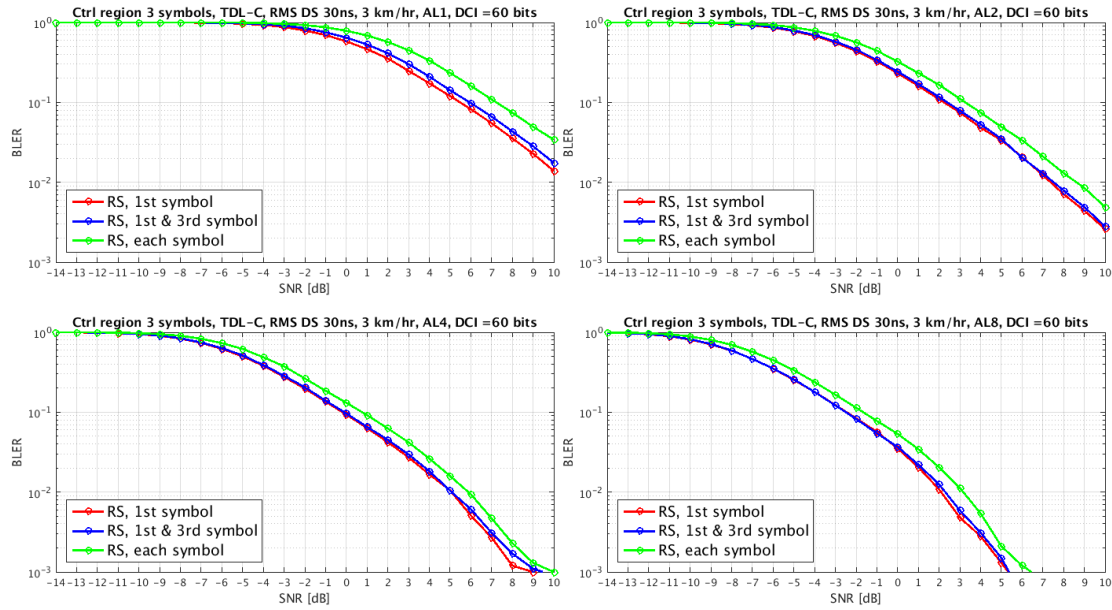


Figure 3. Evaluation results for DMRS structure with 3-symbol CORESET, UE mobility is 3 km/hr

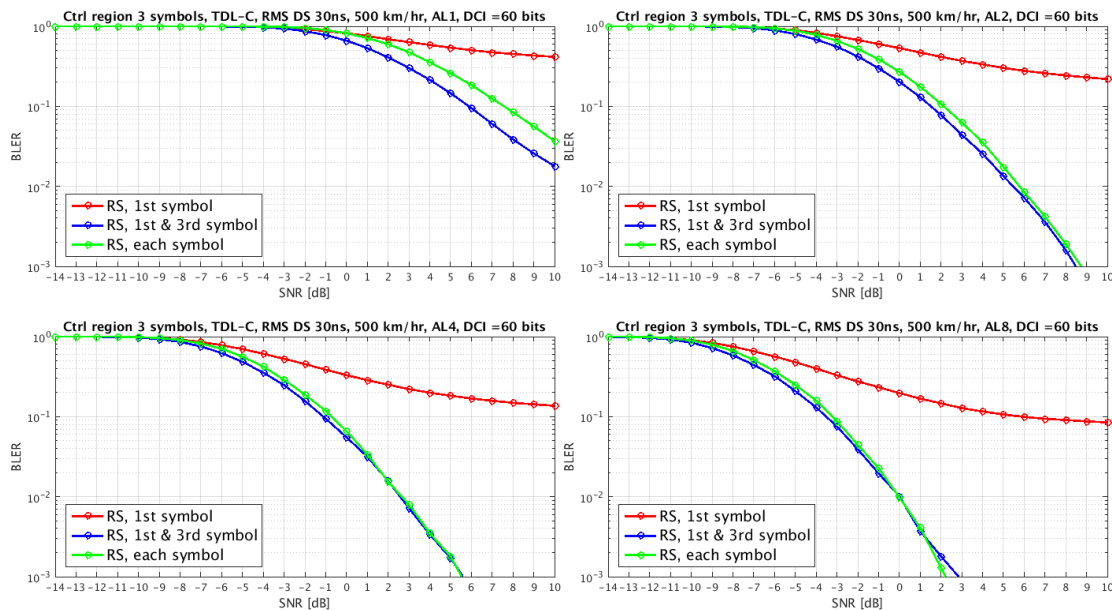


Figure 4. Evaluation results for DMRS structure with 3-symbol CORESET, UE mobility is 500 km/hr

2.2 DMRS density

Another open issue about the DMRS structure is its density. In this paper, we evaluate the PDCCH performance with following DMRS densities.

- Case #1: DMRS density 1/6 as shown in Figure 5(a)
- Case #2: DMRS density 1/4 as shown in Figure 5(b)
- Case #3: DMRS density 1/3 as shown in Figure 5(c)

The Case #1 has the advantage of the lower code rate than other two cases, but the price is the worse CE performance. The Case #2 is used to strike a balance between the code rate and the CE accuracy. The DMRS overhead is largest in the Case #3. In Case #3, the CDM with orthogonal cover code (OCC) $\{1, 1\}$ is used for DMRS port-0, therefore, the CE performance can be improved due to halved noise power. If orthogonal MU is supported, another DMRS port, e.g., DMRS port-1, can be multiplexed with DMRS port-0 with OCC $\{1, -1\}$. However, for the Case #1 and Case #2, the extra REs in FDM with DMRS port-0 are required to support orthogonal MU. And this may lead to very large DMRS overhead, i.e., $\frac{1}{2}$, in the Case #2. Another benefit for the Case #3 is that the DMRS pilots always occupies the same REs no matter orthogonal MU is supported or not.

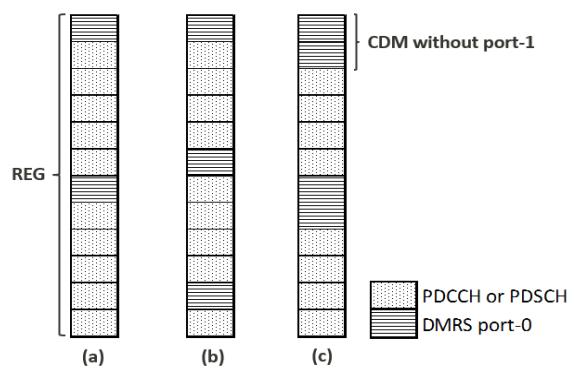


Figure 5. DMRS patterns

Figures 6-9 show the results for the DMRS density evaluations in 3-symbol CORESET. The REG-to-CCE mapping is non-interleaving. More results for interleaving REG-to-CCE mapping are provided in Appendix A.3. In the following evaluations, the front-loaded DMRS structure is used. Since the REG bundle is fixed to 6, the bundle size in frequency domain is 2 REGs.

Figures 6 and 7 provide the results for DCI 20 bits in RMS delay spread 30 ns and 1000 ns, respectively. And the Figures 8 and 9 show the results for DCI 60 bits in RMS delay spread 30 ns and 1000 ns, respectively. It can be observed that the DMRS densities 1/4 and 1/3 have close performances in low ALs. In high ALs, the DMRS density 1/3 has a slightly better performance than DMRS density 1/4 due to more accurate CE. In addition, the DMRS density 1/6 has the worst performance in all scenarios. We also can note that the loss for DMRS density 1/6 decreases with the increase of DCI payload size. When the code rate is high, e.g., DCI bits 60 or low AL, the benefit of less DMRS overhead for DMRS density 1/6 provides gain and thus the loss is reduced. Based on the results, we have following observations and proposals.

Observation #5: *DMRS density 1/6 has the worst performance in simulated scenarios. DMRS density 1/4 and 1/3 have similar performances in low ALs. But DMRS density 1/3 has slightly better performance than DMRS density 1/3 in high AL due to more accurate CE.*

Observation #6: *DMRS density 1/4 may lead to very large DMRS overhead in a REG containing DMRS if the orthogonal MU is supported.*

Proposal #2: *The DMRS RE density for the REG containing DMRS is 1/3.*

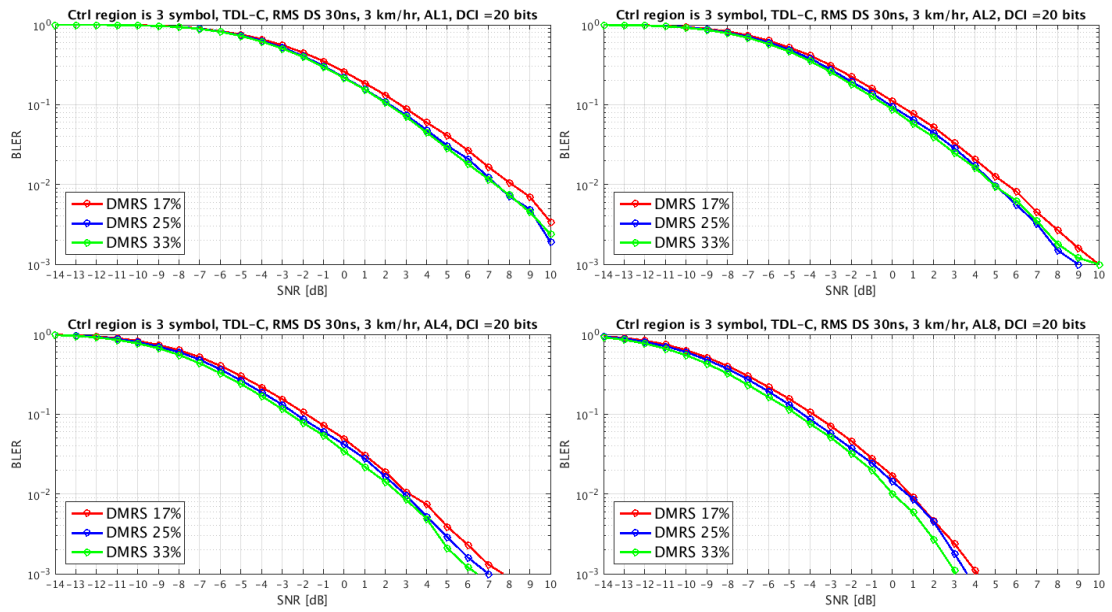


Figure 6. Evaluation results for DMRS densities for DCI 20 bits in TDL-C RMS DS 30 ns

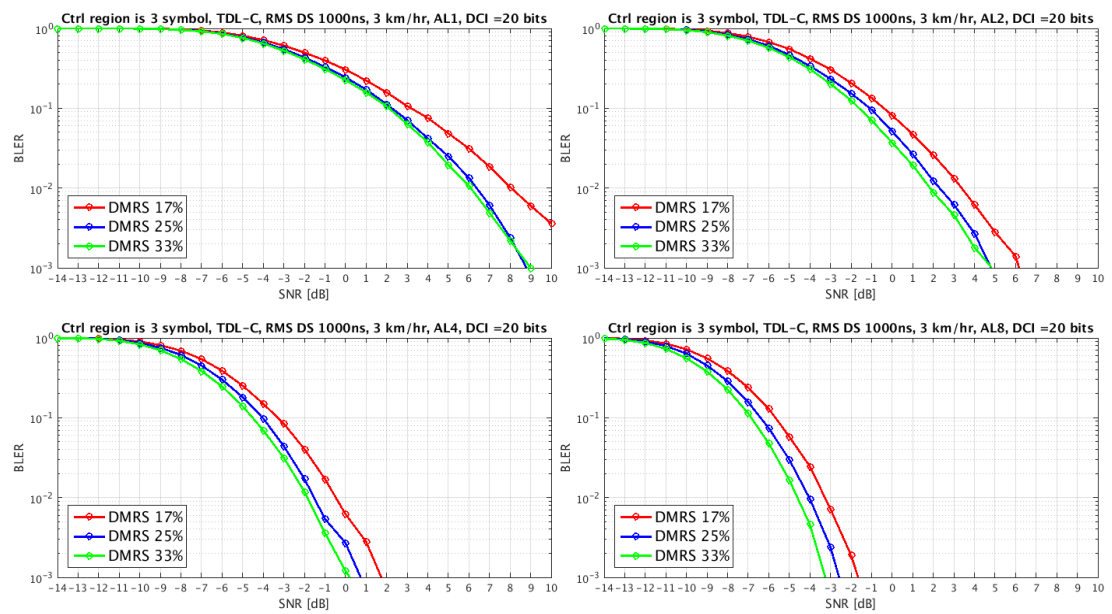


Figure 7. Evaluation results for DMRS densities for DCI 20 bits in TDL-C RMS DS 1000 ns

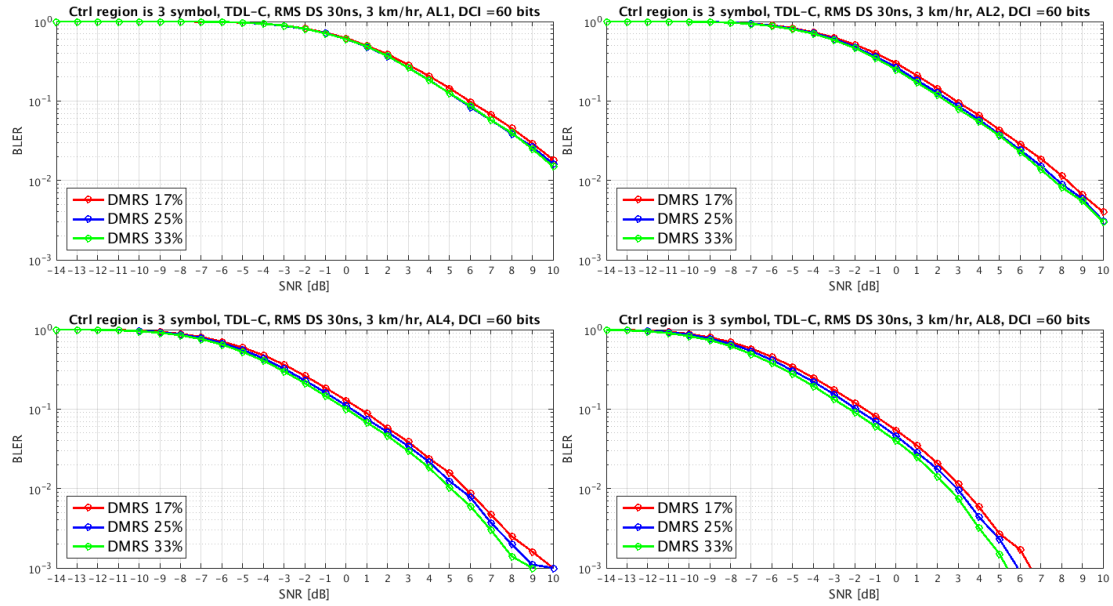


Figure 8. Evaluation results for DMRS densities for DCI 60 bits in TDL-C RMS DS 30 ns

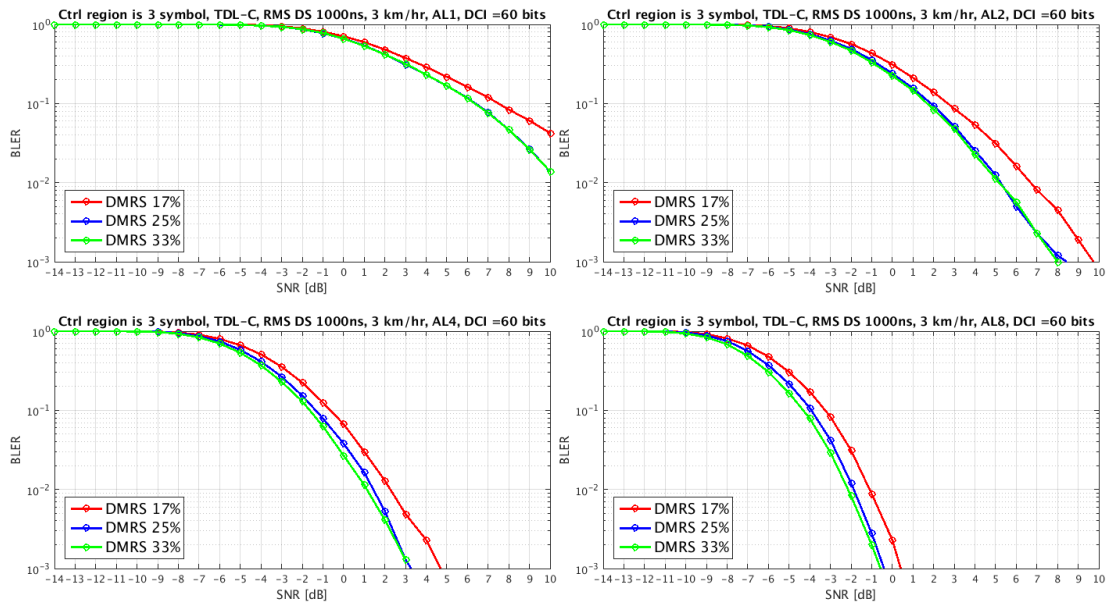


Figure 9. Evaluation results for DMRS densities for DCI 60 bits in TDL-C RMS DS 1000 ns

3 Conclusions

In this paper, we provide evaluation results for the DMRS structure and density of PDCCH in different scenarios. Based on the simulation results, we have the following observations and proposal for the DMRS structure:

Observation #1: When the CORESET time duration is 2 symbols and UE mobility is low, the front-loaded DMRS structure has better performance than the per-symbol DMRS structure.

Observation #2: When the CORESET time duration is 2 symbols, The front-loaded DMRS structure has significant performance loss when the UE mobility is 500 km/hr.

Observation #3: When the CORESET duration is 3 OFDM symbols in time domain, the DMRS structure of “DMRS located on the first and the last symbols of the CORESET” has the similar performance of front-loaded DMRS structures in low UE mobility and has the best performance in high UE mobility.

Observation #4: When the CORESET duration is 3 OFDM symbols in time and UE mobility is 500 km/hr, the front-loaded DMRS structure is not appropriate.

Proposal 1#: Front-loaded DMRS structure is supported in default. The network can indicate additional DMRS on the last symbol of the CORESET via the CORESET configuration if needed.

And according to the analysis on the DMRS density, we have observations and proposal as below.

Observation #5: DMRS density 1/6 has the worst performance in simulated scenarios. DMRS density 1/4 and 1/3 have similar performances in low ALs. But DMRS density 1/3 has slightly better performance than DMRS density 1/3 in high AL due to more accurate CE.

Observation #6: DMRS density 1/4 may lead to very large DMRS overhead in a REG containing DMRS if the orthogonal MU is supported.

Proposal #2: The DMRS RE density for the REG containing DMRS is 1/3.

4 Reference

[1] “Chairman’s Notes,” RAN1 #89, June, 2017.

Appendix

A.1 Simulation settings

Table A.1.1 Simulation assumptions

Parameters	Values
Duplexing mode	FDD
Duration of simulation	10000 subframes
Channel bandwidth	10 MHz
Carrier frequency	4 GHz
Subcarrier spacing	15 kHz
BS antenna configuration	4 TX
UE antenna configuration	2 RX
Channel type	TDL-C
RMS delay spread (DS)	30 ns, 1000 ns
UE speed	3 km/hr, 500 km/hr
Transmission scheme	The fixed precoder and the precoder-cycling scheme are used for non-interleaving and interleaving mappings, respectively.
DCI size	20/60 bits
CRC size	16 bits
Modulation order	QPSK
Number of REGs per CCE	6
CCE aggregation level	1, 2, 4, 8
REG bundle size	6 The REG bundle sizes in frequency domain are 3 and 2 for 2-symbol and 3-symbol CORESETs, respectively.
Signal generation flow	LTE PDCCH-like

Channel encoding	TBCC
Channel estimation	MMSE based method
DMRS density	33 %

A.2 More evaluation results for DMRS structure - REG-to-CCE mapping with interleaving

This section provides more results for the DMRS structure evaluations with interleaving REG-to-CCE mapping. The simulation settings are provided in Appendix A.1. The DCI payload size is 20 bits and the REG bundle size is 6. The performance trend for interleaving mapping is similar as which of non-interleaving mapping. The observations and conclusions can be found in Section 2.1.

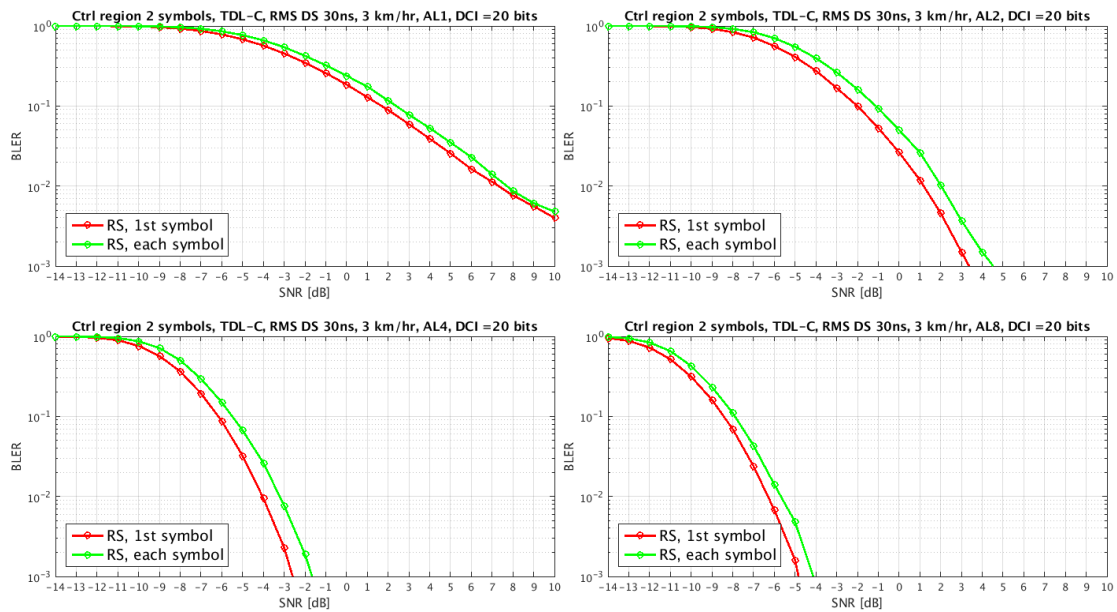


Figure A.2.1. Evaluation results for DMRS structure with 2-symbol CORESET, UE mobility is 3 km/hr

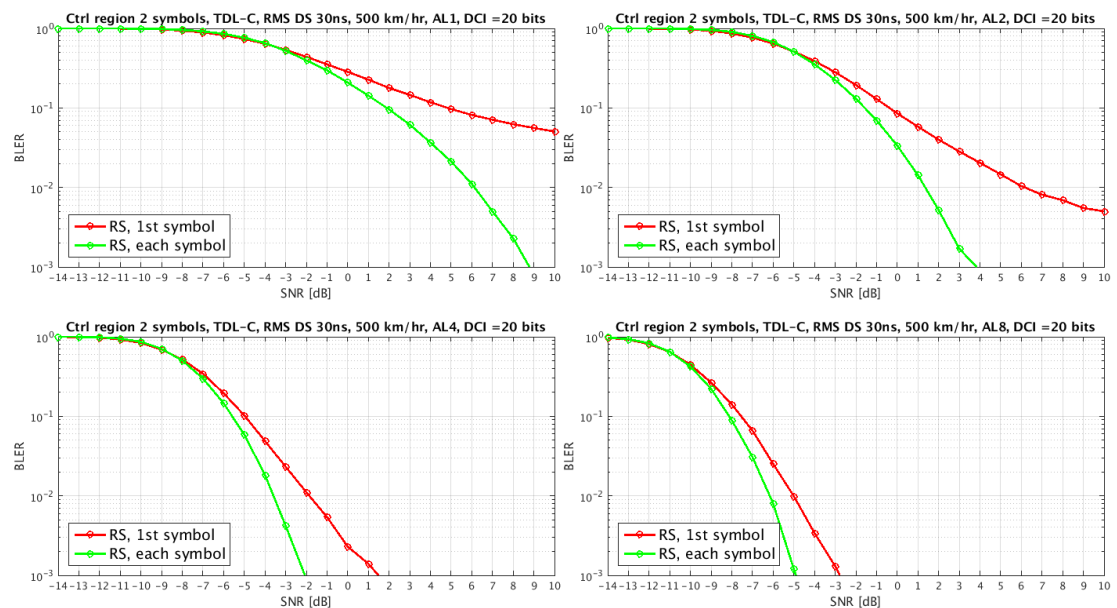


Figure A.2.2. Evaluation results for DMRS structure with 2-symbol CORESET, UE mobility is 500 km/hr

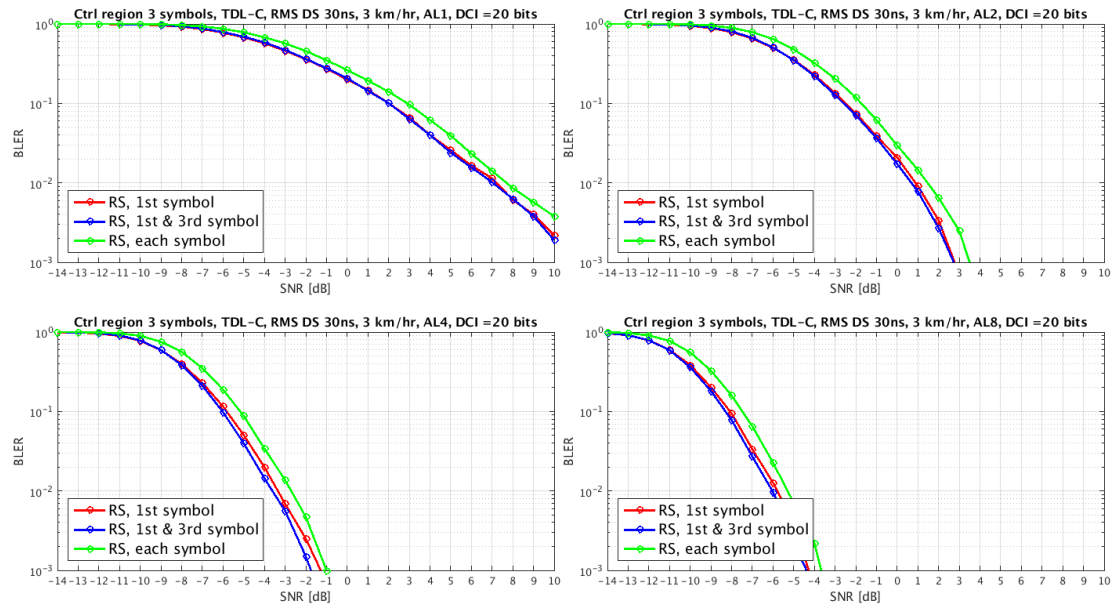


Figure A.2.3. Evaluation results for DMRS structure with 3-symbol CORESET, UE mobility is 3 km/hr

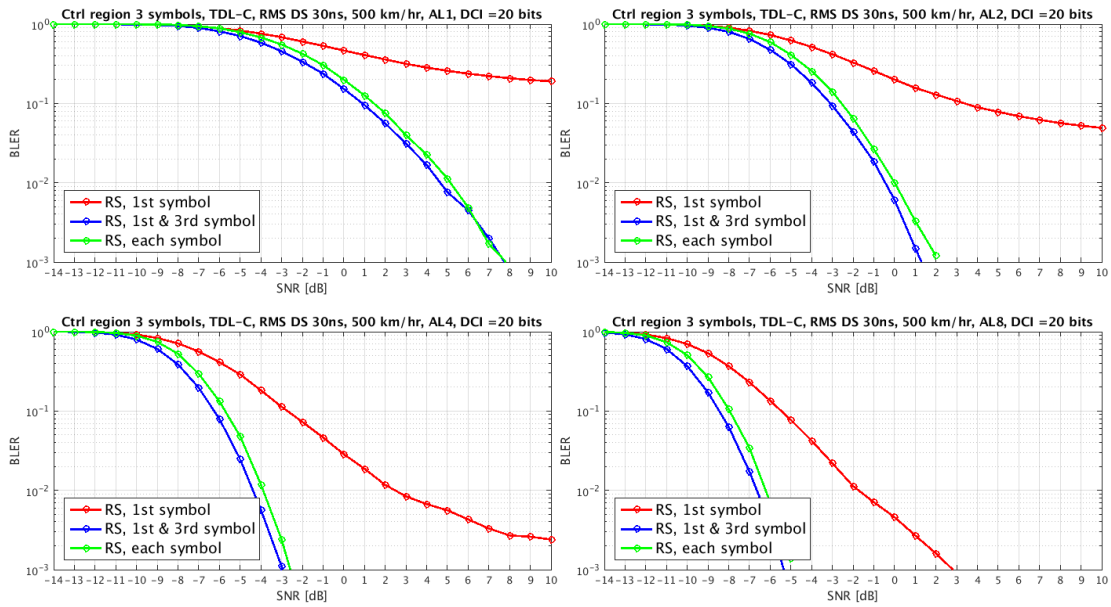


Figure A.2.4. Evaluation results for DMRS structure with 3-symbol CORESET, UE mobility is 500 km/hr

A.3 More evaluation results for DMRS structure - REG-to-CCE mapping with interleaving

This section provides more results for the DMRS density evaluations with interleaving REG-to-CCE mapping. The simulation settings are provided in Appendix A.1. The DCI payload size is 20 bits and the REG bundle size is 6. The performance trend for interleaving mapping is similar as which of non-interleaving mapping. The observations and conclusions can be found in Section 2.2.

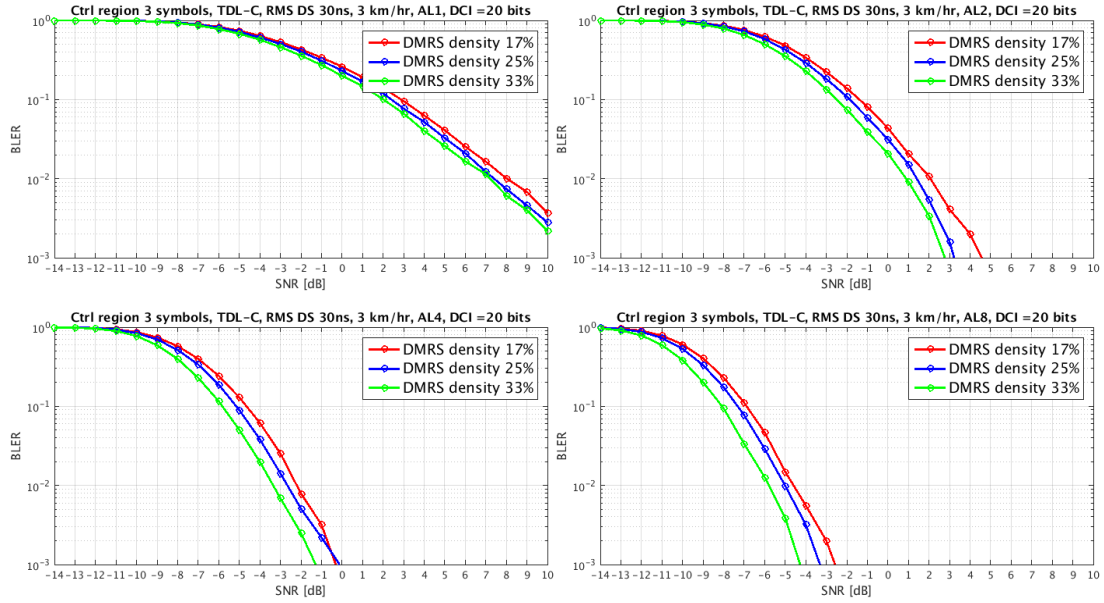


Figure A.3.1. Evaluation results for DMRS densities for DCI 20 bits in TDL-C RMS DS 30 ns

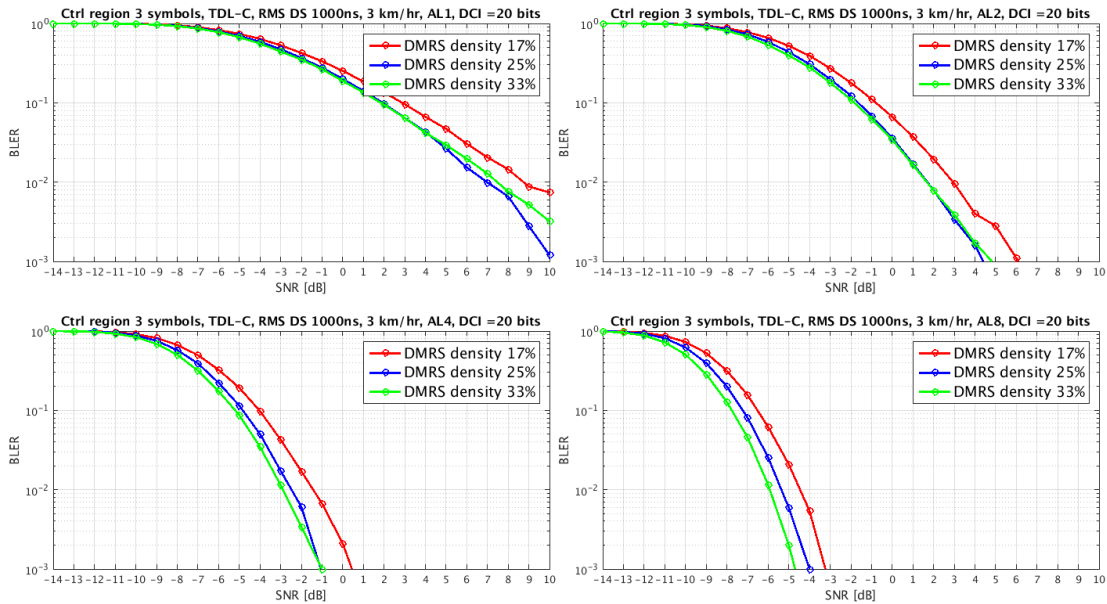


Figure A.3.2. Evaluation results for DMRS densities for DCI 20 bits in TDL-C RMS DS 1000 ns

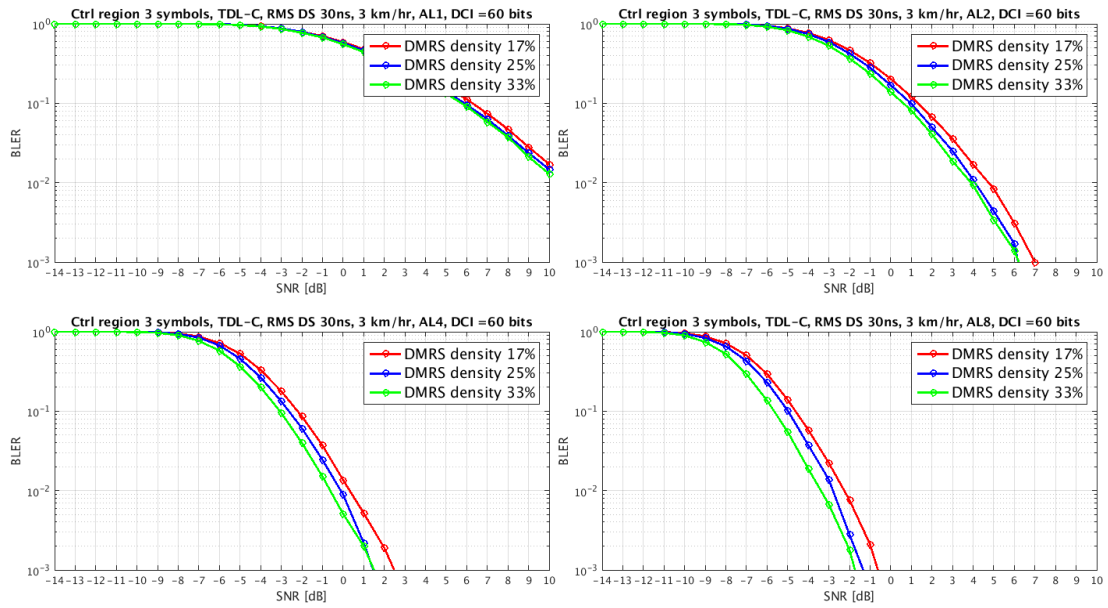


Figure A.3.3. Evaluation results for DMRS densities for DCI 60 bits in TDL-C RMS DS 30 ns

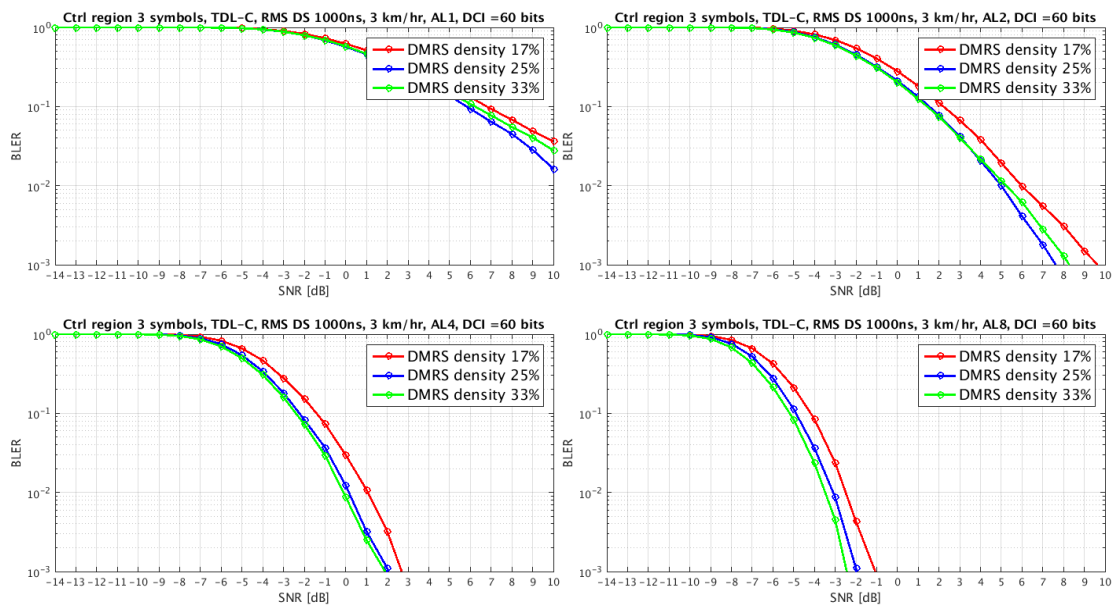


Figure A.3.4. Evaluation results for DMRS densities for DCI 60 bits in TDL-C RMS DS 1000 ns