

Agenda Item: 11.2
Source: Huawei
Title: Comparison of precoding impact on CM between OFDMA and SC-FDMA
Document for: Discussion and decision

1 Introduction

Uplink MIMO is an important technology to attain the target uplink spectral efficiency for LTE-advanced [1]. Precoding will be an essential component for uplink MIMO and it will have an important impact on the cubic metric (CM), an important measurement for uplink transmission. In this contribution, we provide simulation results of CM for UL precoding based on SC-FDMA and OFDMA and discuss MA scheme with precoding for Uplink MIMO.

2 CM characteristics of UL precoding

A general uplink transmission structure based on SC-FDMA/OFDMA can be given in Fig. 1, where Q, P, U and M are the number of code words, the number of antenna ports, the number of layers and the number of modulation symbols per layer, respectively. For OFDMA, M-DFT modules are removed in Fig.1.

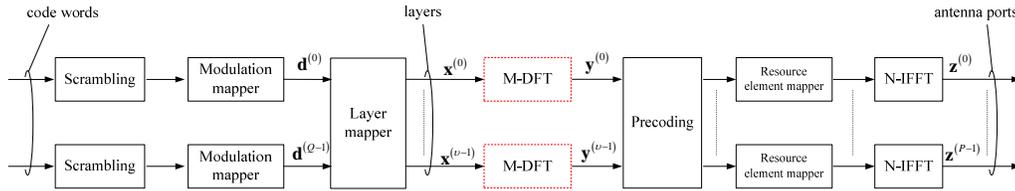


Fig.1 the general uplink transmission structure based on SC-FDMA/OFDMA

2.1 CM Analysis of precoding

If the complex modulation symbol sequence after layer mapping at layer ζ is denoted by $\mathbf{x}^{(\zeta)}$, $\zeta = 0, \dots, U-1$, and M-DFT for each layer and a common precoding at all sub-bands allocated to UE are performed, the block of complex-value symbols after IFFT to be transmitted at antenna port p can be given by

$$\mathbf{z}^{(p)} = \sum_{\zeta=0}^{U-1} w_{p\zeta} (\mathbf{s}^{(\zeta)})^T, p = 0, \dots, P-1, \mathbf{s}^{(\zeta)} = \mathbf{F}_N^H \mathbf{T}_{N,M} \mathbf{F}_M \mathbf{x}^{(\zeta)}, \zeta = 0, \dots, U-1$$

where \mathbf{F}_M is the M-point DFT matrix, $\mathbf{T}_{N,M}$ is an N by M binary matrix representing the resource element mapper. The above formulas show that $\mathbf{s}^{(\zeta)}$ is a single carrier signal and $\mathbf{z}^{(p)}$ is the superposition of U single carrier signals. Hence, for a common precoding matrix with rank 1 (i.e. $U=1$), single carrier characteristic will be preserved, otherwise, in the case of multiple layer spatial multiplexing, CM will increase due to destroying single carrier property.

2.2 Simulation results

To verify the above analysis and compare the precoding impact on CM for SC-FDMA/OFDMA by **reusing downlink precoding schemes in LTE**, Monte Carlo simulation were performed and CM was

calculated according to the method in [2]. The simulation assumptions are given in Table 1 and results are presented and discussed as follows.

Table 1 simulation assumptions

Occupied subcarriers	300
IFFT size	512
Number of RBs per Subband	4
Number of subcarriers per RB	12

2.2.1 Close-loop precoding for 2Tx/4Tx

a) Common precoding

For common precoding across all sub-band allocated to UE, it can be observed in simulation that CM values are almost same at all antenna ports (including the cases of 2Tx and 4Tx), which means that power balance is kept among difference antenna ports, so average CMs over all antenna ports are plotted for SC-FDMA in Fig.2 and 3 and for OFDM in Fig.4 and 5, respectively.

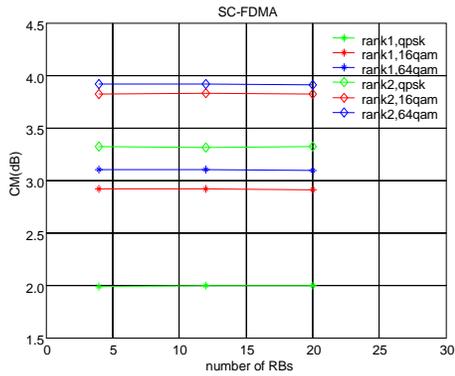


Fig. 2 CM v.s. number of RB for 2Tx based on SC-FDMA

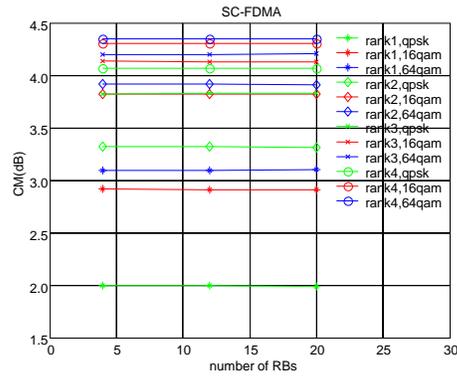


Fig. 3 CM v.s. number of RBs for 4Tx based on SC-FDMA

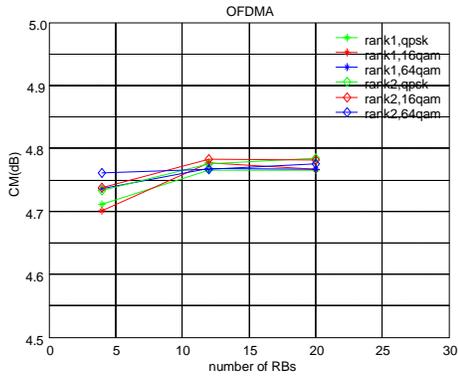


Fig. 4 CM v.s. number of RB for 2Tx based on OFDM

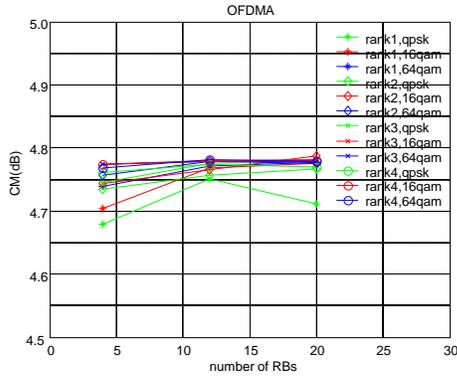


Fig. 5 CM v.s. number of RBs for 4Tx based on OFDM

From Fig.2 and Fig.3, CM is insensitive to bandwidth allocated to UE but it will increase with rank and modulation order. Moreover, for the common rank 1 precoding across all allocated sub-bands, the single carrier characteristic can be preserved for SC-FDMA. However, for multi-layer precoding, the single carrier characteristic will be destroyed, especially for the case of rank 4. From Fig.4 and Fig.5, CM of OFDMA stays between 4.7dB and 4.8dB, larger than that of SC-FDMA. The increments of OFDMA over SC-FDMA are shown in Table 2.

Table 2. CM increment of OFDMA over SC-FDMA

	QPSK	16QAM	64QAM
Rank 1	2.7	1.8	1.6
Rank 2	1.4	0.9	0.8
Rank 3	0.9	0.6	0.6
Rank 4	0.7	0.5	0.4

b) Frequency selective precoding

Simulation results for SC-FDMA based frequency selective precoding are given in Fig.6- Fig.11 and those for OFDM in Fig.12 - Fig.17, where PMI is randomly selected in simulation,.

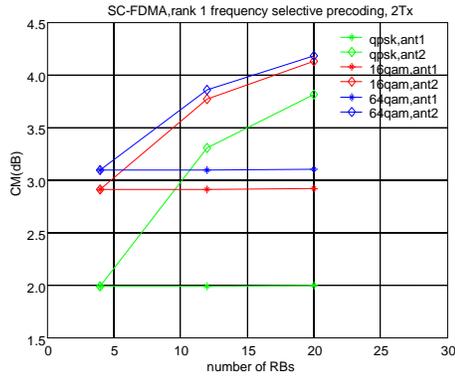


Fig. 6 CM of SC-FDMA v.s. number of subbands for 2Tx with rank 1 precoding

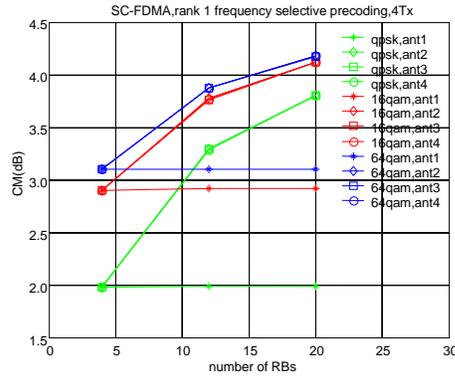


Fig. 7 CM of SC-FDMA v.s. number of subbands for 4Tx with rank 1 precoding

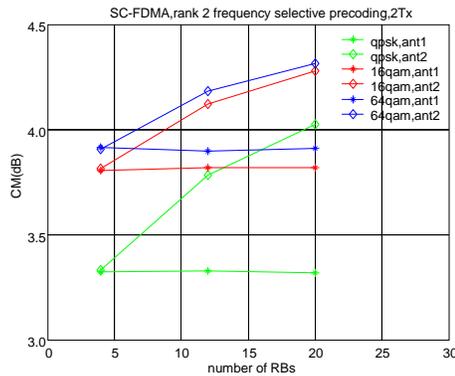


Fig. 8 CM of SC-FDMA v.s. number of subbands for 2Tx with rank 2 precoding

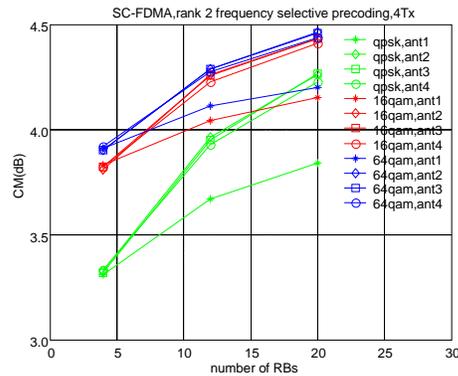


Fig. 9 CM of SC-FDMA v.s. number of subbands for 4Tx with rank 2 precoding

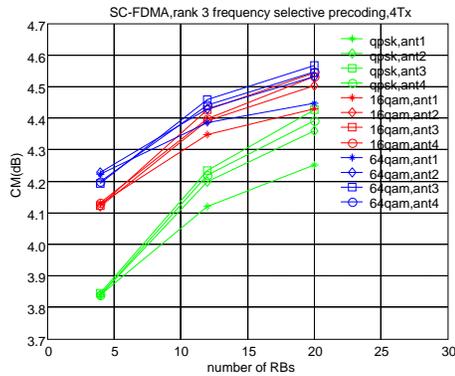


Fig. 10 CM of SC-FDMA v.s. number of subbands for 4x with rank 3 precoding

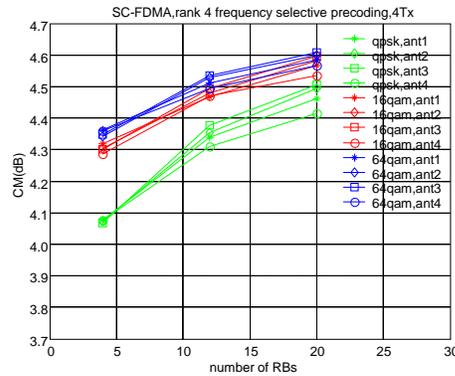


Fig. 11 CM of SC-FDMA v.s. number of subbands for 4x with rank 4 precoding

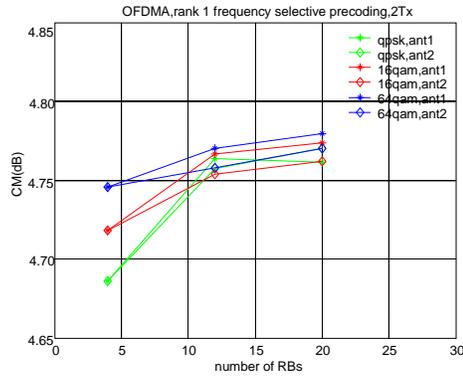


Fig. 12 CM of OFDM v.s. number of subbands for 2Tx with rank 1 precoding

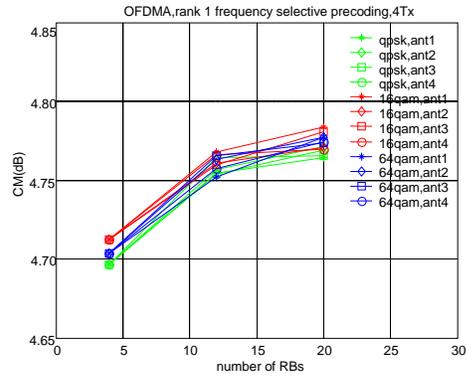


Fig. 13 CM of OFDM v.s. number of subbands for 4Tx with rank 1 precoding

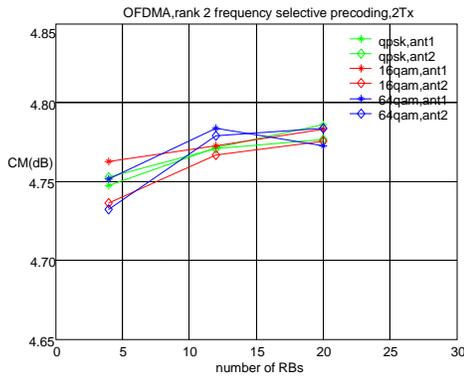


Fig. 14 CM of OFDM v.s. number of subbands for 2Tx with rank 2 precoding

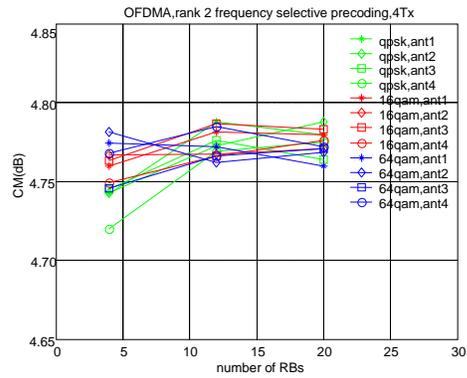


Fig. 15 CM of OFDM v.s. number of subbands for 4Tx with rank 2 precoding

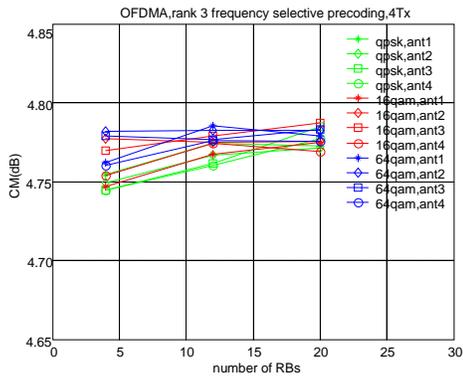


Fig. 16 CM of OFDM v.s. number of subbands for 4Tx with rank 3 precoding

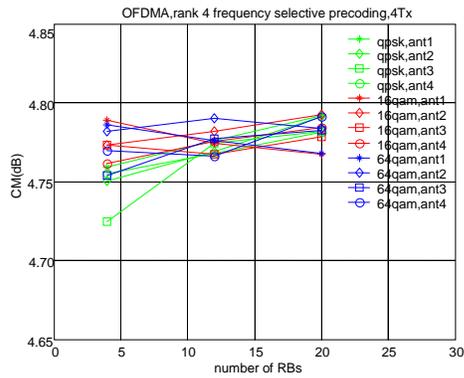


Fig. 17 CM of OFDM v.s. number of subbands for 4Tx with rank 4 precoding

From Fig.6- Fig.9, it can be observed that power balance is broken between the 1st antenna port and the other(s). However, for the case of 4Tx, all antenna ports except the 1st one are almost power balanced. From Fig.6 and 8, the case of 2Tx, the single carrier characteristic at the 1st antenna port is maintained and insensitive to number of subbands, which is just due to codebook structure. For 4Tx, the same conclusion only holds for rank 1. All the other cases of SC-FDMA, the single carrier characteristic can not be preserved and CM tends to increase with bandwidth allocated to UE. Furthermore, it can also be seen that CMs increase with modulation order and rank but impact of rank on CM is larger for lower order modulation. From Fig.12 - Fig.17, CM of OFDM ranges from 4.7dB to 4.8dB, larger than that of SC-FDMA.

2.2.2 Open-loop precoding for 4Tx

For open loop precoding, only the average CM over four antenna ports are given in Fig.8, because of the almost same CM at four antenna ports.

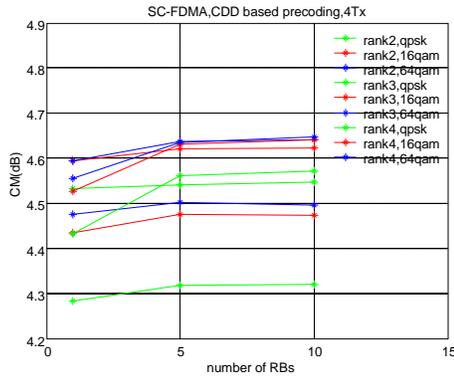


Fig. 18 CM of SC-FDMA v.s. number of RBs for 4Tx with CDD-based precoding

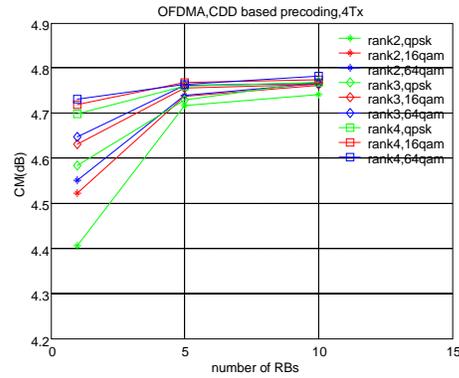


Fig. 19 CM of OFDMA v.s. number of RBs for 4Tx with CDD-based precoding

From Fig.18, it can be observed that CMs of SC-FDMA are almost stable, ranging from 4.25dB to 4.65dB. The single carrier characteristic is severely destroyed just due to the cyclic precoding among sub-carriers. Hence, UL open-loop precoding needs to be further investigated. From Fig.19, CMs of OFDMA are slightly larger than those of SC-FDMA.

3 Conclusion

Based on the CM evaluation results in this document, some observations are,

- The advantages of SC-FDMA based common precoding :
 - CM is insensitive to bandwidth allocated to UE
 - Power balance among antenna ports.
- Both Multiple-layer common precoding and frequency selective precoding have high CM regardless of OFDMA or SC-FDMA and should be further considered
 - The performance and complexity of SC-FDMA and OFDMA should be evaluated
- Uplink open-loop precoding has high CM
- SC-FDMA has only obvious CM advantage over OFDMA in the case of rank 1 common precoding, and in other cases, SC-FDMA has almost similar CM with OFDMA.

From CM perspective, it is preferred to using SC-FDMA in the case of rank-1 common precoding, and it should be careful to reuse LTE downlink precoding for LTE-A uplink.

References

- [1] 3GPP TR 36.913, "Requirements for further advancement for EUTRA," V1.0.0, May 2008.
- [2] R1-060023, Motorola, Cubic Metric in 3GPP-LTE, 3GPP RAN 1 LTE Ad hoc.