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Title:	Down link rank adaptation with 4 transmit antennas for open loop MIMO at High Doppler
Agenda Item:	6.4.5
Document for:	Discussion and Decision

I. INTRODUCTION

Closed loop spatial multiplexing in the downlink (such as SU-MIMO) is aided by rank and PMI¹ feedback from the UE to eNodeB [1]. Closed loop transmission should switch to open loop mode when the reliability of the rank/PMI feedback is degraded, which can occur at high vehicular speeds.

The working assumption currently specifies two modes for open loop transmission with 4 Tx antennas: (a) rank-2² spatial multiplexing (SM) with a randomly chosen precoding matrix, or (b) rank-1 transmit diversity, SFBC-FSTD [2]. However, based on simulation results, we observe that under most operating scenarios of interest, SFBC-FSTD outperforms open-loop SM, thus implying that the open-loop SM mode may never be invoked for DL transmissions.

Moreover, we show that SFBC-SM, a new open loop scheme, outperforms SM in all cases we investigated, and outperforms SFBC-FSTD under certain operating conditions. [Therefore, we recommend the adoption of SFBC-SM as an open-loop scheme, with the possibility to perform rank adaptation between SFBC-FSTD and SFBC-SM.](#)

The mechanism for rank adaptation between rank-1 SFBC-FSTD and rank-2 SFBC-SM can be considered for further study (FFS).

II. CODE DESCRIPTIONS

SFBC-FSTD is a rank-1 transmission, whose code matrix (antenna index \times subcarrier index) is given by [2]:

$$\begin{bmatrix} s_1 & s_2 & 0 & 0 \\ 0 & 0 & s_3 & s_4 \\ -s_2^* & s_1^* & 0 & 0 \\ 0 & 0 & -s_4^* & s_3^* \end{bmatrix} \quad (1)$$

Note that the structure in (1) achieves better averaging of channel estimates (since RS on antennas 3 and 4 are weaker than those on antennas 1 and 2).

SM is a rank-2 transmission (when the UE has 2 receive antennas). We select one of the precoding matrices from the set specified in [2]:

¹ PMI = Pre-coding Matrix Indicator

² The maximum rank for SM in the DL is limited by the number of Rx antennas at the UE, which is assumed to be 2 for purposes of this discussion.

$$\frac{1}{2} \begin{bmatrix} 1 & -1 \\ 1 & 1 \\ 1 & 1 \\ -1 & 1 \end{bmatrix} \begin{bmatrix} s_1 \\ s_2 \end{bmatrix} \quad (2)$$

SFBC-SM is a rank-2 transmission, whose code matrix is given by [3]:

$$\begin{bmatrix} s_1 & -s_2^* \\ s_3 & -s_4^* \\ s_2 & s_1^* \\ s_4 & s_3^* \end{bmatrix} \quad (3)$$

For the same modulation and coding scheme, it can be readily seen that the transmission rate of rank-2 schemes is twice that of rank-1 schemes.

III. PERFORMANCE COMPARISON

From an information theory perspective, a useful criterion for benchmarking the performance of a coding scheme is to compute its mutual information, which is a measure of the maximum data rate the code will support at an arbitrarily low BER. By this measure, good codes are those whose mutual information is as close as possible to the capacity of the channel. Figure 1 plots the mutual information as a function of SNR in an i.i.d. Rayleigh fading channel for four space-frequency codes — SFBC-FSTD, SFBC-SM, SM, and QO-SFBC-CR³ (which was presented in an earlier contribution [4]).

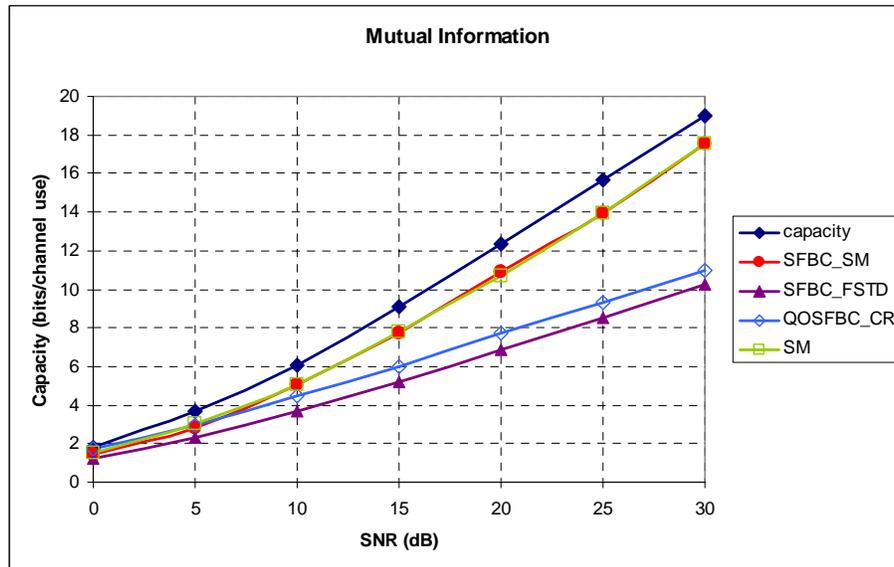


Figure 1: Mutual information for Open Loop Space-Frequency Codes in 4x2 i.i.d. Rayleigh

The capacity of a 4x2 i.i.d. Rayleigh fading channel is shown in Figure 1. It can be seen that both SFBC-SM and SM nearly achieve the capacity of the channel, whereas both SFBC-FSTD and QO-SFBC-CR are well below capacity at high SNRs. This suggests to us that at high SNRs, either SFBC-SM or SM has the potential to offer better performance than SFBC-FSTD. To explore this possibility further, we simulated the FER performance of SFBC-FSTD, SM, and SFBC-SM using the simulation setup outlined in Table 1.

³ QO-SFBC-CR is an abbreviation for quasi-orthogonal SFBC with constellation rotation.

Table 1: Simulation setup

antenna configuration	4 transmit (at eNodeB) and 2 receive (at UE)
FFT size	512 tones across 5 MHz BW
channel model	SCM-C, 30km/hr Doppler
encoding scheme	3GPP Turbo encoder/decoder
Modulation	QPSK, 16-QAM, and 64-QAM
number of RBs	1 (12 subcarriers) and 4 (48 subcarriers)
frame	1ms (14 OFDM symbols)
channel estimation	realistic (time averaging with frequency interpolation)
receiver	maximum likelihood (spherical decoder [5] for SFBC-SM and SM, linear for SFBC-FSTD)

To conduct an equitable comparison among SFBC-SM, SM and SFBC-FSTD, their respective modulation and coding schemes were chosen such that their data rate (or spectral efficiency) was identical, as shown in Table 2.

Table 2: Performance comparison among SFBC-SM, SM and SFBC-FSTD

Figure number	SFBC-SM, SM	SFBC-FSTD	Spectral Efficiency	Number of RBs
2	4/5-QPSK	4/5-16QAM	3.2 bps/Hz	1
3	1/2-QPSK	1/2-16QAM	2.0 bps/Hz	4
4	4/5-QPSK	4/5-16QAM	3.2 bps/Hz	4
5	3/5-16QAM	4/5-64QAM	4.8 bps/Hz	4

From the simulation results shown in Section IV, we can draw the following conclusions:

- At 1% FER, we can see from Figure 3, 4, and 5 that SM offers the worst performance, irrespective of the modulation and coding scheme.
- Also, we can see from Figure 3, 4, and 5 that the diversity order⁴ exhibited by SM is the lowest among the three schemes.
- We see from Figure 2 that SFBC-FSTD outperforms SFBC-SM.
- We see from Figure 4 and 5 that SFBC-SM outperforms SFBC-FSTD.
- We see from Figure 3 that the performance of SFBC-FSTD and SFBC-SM is comparable

Therefore, we can conclude that SM is not a viable mode for open-loop transmission. And, depending on the operating condition, either rank-1 SFBC-FSTD or rank-2 SFBC-SM should be chosen for open-loop transmission. The mechanism for rank adaptation between SFBC-FSTD and SFBC-SM can be considered for further study.

⁴ diversity order is given by the slope of the FER-SNR curve. Steeper curves have higher diversity order, and vice versa.

IV. PERFORMANCE CURVES

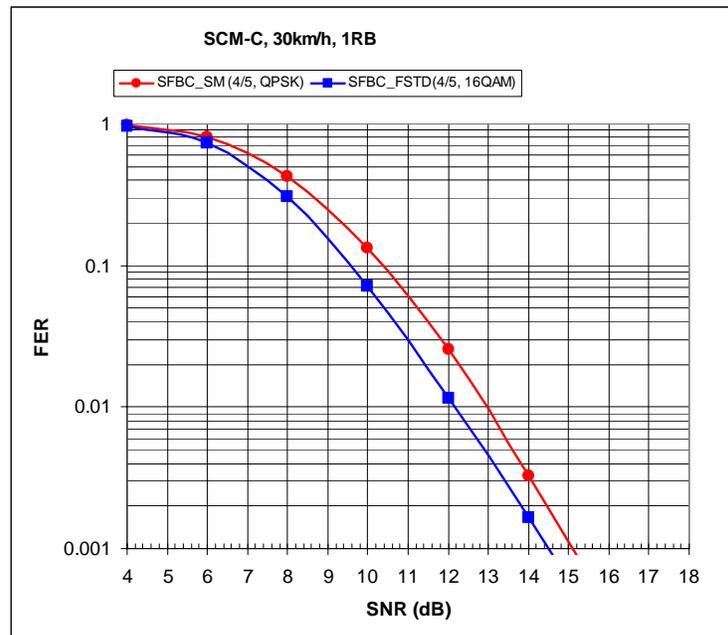


Figure 2: comparison of SFBC-SM with SFBC-FSTD at 3.2 bps/Hz

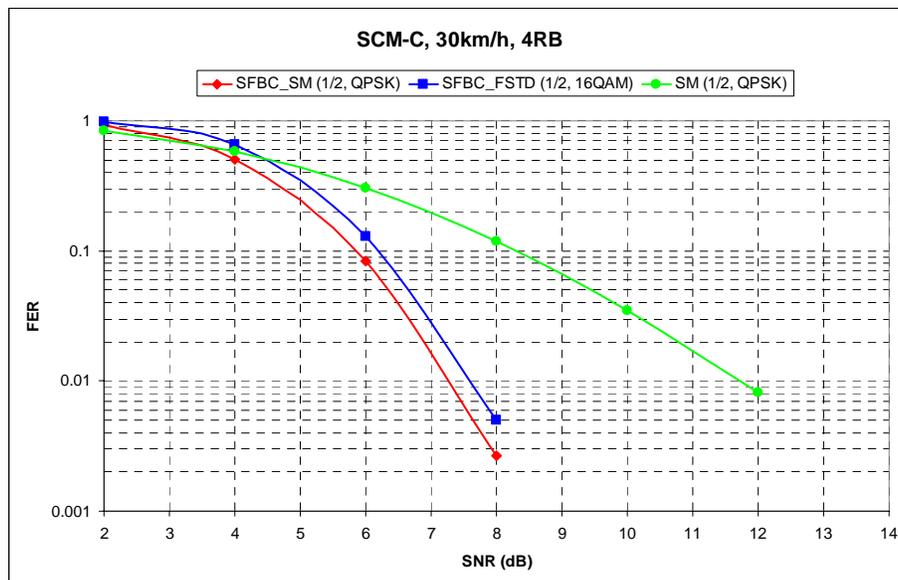


Figure 3: comparison among SFBC-SM, SM, and SFBC-FSTD at 2 bps/Hz

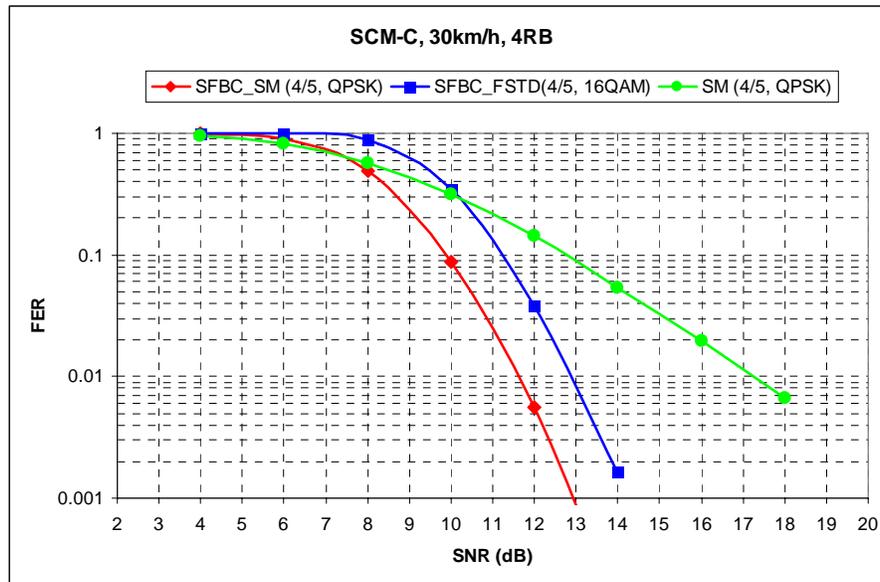


Figure 4: comparison among SFBC-SM, SM, and SFBC-FSTD at 3.2 bps/Hz

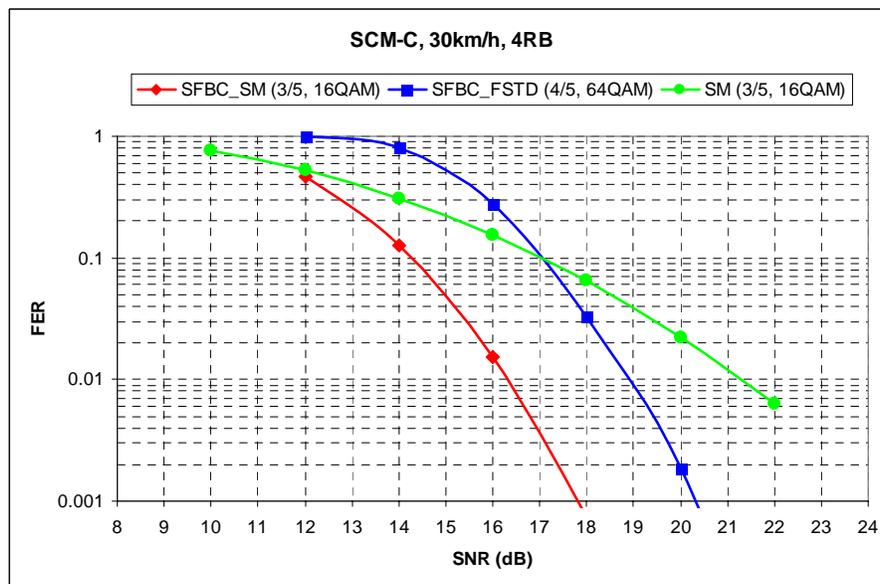


Figure 5: comparison among SFBC-SM, SM, and SFBC-FSTD for 4.8 bps/Hz

V. CONCLUSION

In this contribution, we have shown through simulations that under operating scenarios of interest, rank-1 SFBC-FSTD outperforms open-loop rank-2 SM. We've proposed a new rank-2 open loop scheme, SFBC-SM, which outperforms SM under all operating conditions. We showed that under certain operating conditions, SFBC-FSTD outperforms SFBC-SM, whereas in other operating conditions, SFBC-SM outperforms SFBC-FSTD. Therefore, open loop transmissions can entertain rank adaptation between SFBC-FSTD and SFBC-SM.

We recommend the adoption of SFBC-SM as a scheme for open loop transmission. The mechanism for rank adaptation between SFBC-FSTD and SFBC-SM can be considered for further study.

VI. REFERENCES

- [1] 3GPP TS 36.213, v8.0.0. (2007-09), E-UTRA: Physical Layer Procedures.
- [2] 3GPP TS 36.211, v8.0.0. (2007-09), E-UTRA: Physical Channels and Modulation.
- [3] R1-073318, LSI Corporation, "DL Transmit Diversity with Spatial Multiplexing for 4 Tx Antennas", 3GPP RAN1#50, Athens, August 2007.
- [4] R1-071801, Agere Systems, "Performance Comparison of Downlink Tx Diversity schemes with 4 Tx antennas for the Shared Data Channel," 3GPP RAN1 #48bis, St. Julians, Malta, March 2007.
- [5] R1-072047, LSI Corporation, "Further results on QO-SFBC as a TxD scheme for 4 transmit antennas," 3GPP RAN1 #49, Kobe, Japan, May 2007.