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Re:	IEEE 802.16m-08/016r1 –Call for Contributions on Project 802.16m System Description Document (SDD); Downlink MIMO schemes	
Abstract	The contribution presents DL MIMO consideration for 802.16m system.	
Purpose	To be discussed and adopted by TGM for use in the IEEE 802.16m SDD	
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Downlink MIMO Schemes for 16m

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1 Introduction

According to the requirements for IEEE 802.16m, throughput and spectral efficiency are main factors to improve the performance. This facilitates the use of multi-input multi-output (MIMO) techniques. The IEEE 802.16m standard shall define minimum antenna requirements for the BS and MS. For the BS, a minimum of two transmit and two receive antennas shall be supported. For the MS, a minimum of one transmit and two received antennas shall be supported. This minimum is consistent with a 2x2 downlink configuration and a 1x2 uplink configuration. In this contribution, 2x2 is baseline and the extended downlink requirement 4x2, 4x4 antenna mode is also considered in 16m downlink MIMO, which is also compatible with 4x2 mode. According to different demand for control, broadcast, synchronization and data channel, we describe the transmission methods in different MIMO schemes.

2 Downlink MIMO Schemes

2.1 DL MIMO Scheme for data channel

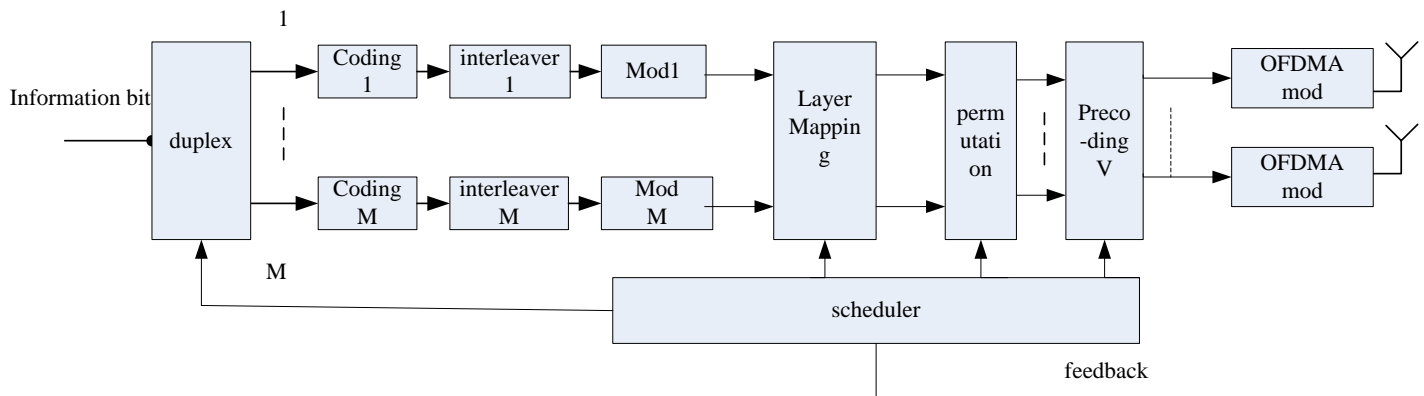


Fig 1 transmitter block diagram for data channel MIMO

Fig1 shows the basic transmitter structure, assumed M streams are sent, which is coded and modulated separately and is not more than rank number. M codewords are sent to layer mapping unit, rank number is less than or equal to transmit antenna numbers. Next is layer permutation unit, which is cyclically shifted. According to different channel conditions, this unit is optional. In baseline 2x2 MIMO mode, we recommended 1 stream. Both 4x4 and 4x2 antenna mode, number of stream is chosen among 1, 2, 3 and 4. Typical value 2 in 4x4 mode and 1 in 4x2 mode, it has a good trade-off between complexity and overhead.

Generally, SM is recommended to adopt, in addition, diversity or combination of SM and diversity is also should be considered.

Coding matrix is described as follows in detail:

- 2Tx:

In 2Tx, According to different channel conditions, matrix A, B and C is applied in data channel MIMO transmission.

$$A = \begin{bmatrix} s_1 & -s_2^* \\ s_2 & s_1^* \end{bmatrix} \quad (1)$$

$$B = \begin{bmatrix} s_1 & s_3 & -s_4^* & s_5 \\ s_2 & s_4 & s_3^* & s_6 \end{bmatrix} \quad (2)$$

$$C = \begin{bmatrix} s_1 \\ s_2 \end{bmatrix} \quad (3)$$

Where the coding rate of these matrix is 1, 1.5 and 2 for matrix A, B and C as above.

- 4Tx:

$$A = \begin{bmatrix} s_1 & -s_2^* & 0 & 0 \\ s_2 & s_1^* & 0 & 0 \\ 0 & 0 & s_3 & -s_4^* \\ 0 & 0 & s_4 & s_3^* \end{bmatrix} \quad (4)$$

$$B^{R=2} = \begin{bmatrix} s_1 & -s_2^* & s_5 & -s_6^* \\ s_2 & s_1^* & s_6 & s_5^* \\ s_3 & -s_4^* & s_7 & -s_8^* \\ s_4 & s_3^* & s_8 & s_7^* \end{bmatrix} \quad (R=2) \quad (5)$$

$$B^{R=3} = \begin{bmatrix} s_1 & -s_2^* & s_7 & -s_8^* \\ s_2 & s_1^* & s_8 & s_7^* \\ s_3 & s_4 & s_9 & s_{10} \\ s_5 & s_6 & s_{11} & s_{12} \end{bmatrix} \quad (R=3) \quad (6)$$

$$C = \begin{bmatrix} s_1 \\ s_2 \\ s_3 \\ s_4 \end{bmatrix} \quad (7)$$

As above described, matrix A, B and C with different coding rate is proposed in 4Tx mode to be applied to various situations.

2.2 DL MIMO Scheme for control channel

Alamouti schemes for 2Tx and SFBC-based schemes for 4Tx is consideration in this contribution.

1) 2Tx:

We advise to apply Alamouti schemes for 2Tx, and the coding matrix is described as follows:

$$A = \begin{bmatrix} s_1 & -s_2^* \\ s_2 & s_1^* \end{bmatrix} \quad (8)$$

2) 4Tx:

SFBC-based structure is considered, two options are shown as follows:

Option1:

Combing SFBC and frequency switched transmit diversity:

- When the pilot density is same for data transmitted on four antennas, matrix (9) is considered:

$$A = \begin{bmatrix} s_1 & -s_2^* & 0 & 0 \\ s_2 & s_1^* & 0 & 0 \\ 0 & 0 & s_3 & -s_4^* \\ 0 & 0 & s_4 & s_3^* \end{bmatrix} \quad (9)$$

Or its other transform as described in 16e.

- When the pilot density for data transmitted on different antennas is not same, e.g. pilot density on group 1(antenna 1 and 2) is not same with that on group 2(antenna 3 and 4), we advise to adapt the coding matrix as formula(10),which antenna (1,3) and (2,4) are combined to encode.

$$A = \begin{bmatrix} s_1 & -s_2^* & 0 & 0 \\ 0 & 0 & s_3 & -s_4^* \\ s_2 & s_1^* & 0 & 0 \\ 0 & 0 & s_4 & s_3^* \end{bmatrix} \quad (10)$$

- When the pilot density is totally different on 1,2,3 and 4 antenna, assuming the pilot density is sorted in ascending order from 4 to 1, then matrix (11) is considered:

$$A = \begin{bmatrix} s_1 & 0 & s_3 & 0 \\ 0 & -s_2^* & 0 & -s_4^* \\ s_2 & 0 & s_4 & 0 \\ 0 & s_1^* & 0 & s_3^* \end{bmatrix} \quad (\text{uniform}) (11)$$

Option2:

To further improve the performance, a method which combining SFBC and frequency time switched transmit diversity is proposal as below:

- When the pilot density is uniform in four antennas, matrix (12) is considered:

$$\begin{aligned}
 A = & \begin{aligned}
 & \text{OFDM1} \rightarrow \begin{bmatrix} s_1 & -s_2^* & 0 & 0 \\ s_2 & s_1^* & 0 & 0 \\ 0 & 0 & s_3 & -s_4^* \\ 0 & 0 & s_4 & s_3^* \end{bmatrix} \\
 & \text{OFDM2} \rightarrow \begin{bmatrix} 0 & 0 & ss_3 & -ss_4^* \\ 0 & 0 & ss_4 & ss_3^* \\ ss_1 & -ss_2^* & 0 & 0 \\ ss_2 & ss_1^* & 0 & 0 \end{bmatrix}
 \end{aligned} \quad (12)
 \end{aligned}$$

As formula(12), In first OFDM symbol OFDM1, symbol S_1 and S_2 in 1 and 2 sub-carrier is transmitted by antenna 1 and 2, while symbol S_3 and S_4 in 3 and 4 sub-carrier is transmitted by antenna 3 and 4. In second OFDM symbol OFDM2, coding matrix is switched as OFDM2 point in (5) formula. When the next OFDM symbol come, the coding matrix is the same as OFDM1, and so on. Frequency diversity is obtained in one OFDM symbol, space diversity is from different antennas.

- When the pilot density for data transmitted on different antennas is not same, e.g. pilot density on group 1(antenna 1 and 2) is not same with that on group 2(antenna 3 and 4), the coding matrix is considered as follows (13):

$$\begin{aligned}
 A = & \begin{aligned}
 & \text{OFDM1} \rightarrow \begin{bmatrix} s_1 & -s_2^* & 0 & 0 \\ 0 & 0 & s_3 & -s_4^* \\ s_2 & s_1^* & 0 & 0 \\ 0 & 0 & s_4 & s_3^* \end{bmatrix} \\
 & \text{OFDM2} \rightarrow \begin{bmatrix} 0 & 0 & ss_3 & -ss_4^* \\ ss_1 & -ss_2^* & 0 & 0 \\ 0 & 0 & ss_4 & ss_3^* \\ ss_2 & ss_1^* & 0 & 0 \end{bmatrix}
 \end{aligned} \quad (13)
 \end{aligned}$$

As shown in formula (13), antenna (1,3) and (2,4) pairing is combined separately. In addition, Principle of formula (13) is the same with formula (12).

- When the pilot density is all different on 1,2,3and 4 antenna, assuming the pilot density is sorted in ascending order from 4 to 1,,then matrix (14) is considered:

$$\begin{aligned}
 A = & \begin{aligned}
 & \text{OFDM1} \rightarrow \begin{bmatrix} s_1 & 0 & s_3 & 0 \\ 0 & -s_2^* & 0 & -s_4^* \\ s_2 & 0 & s_4 & 0 \\ 0 & s_1^* & 0 & s_3^* \end{bmatrix} \\
 & \text{OFDM2} \rightarrow \begin{bmatrix} 0 & -ss_2^* & 0 & -ss_4^* \\ ss_1 & 0 & ss_3 & 0 \\ 0 & ss_1^* & 0 & ss_3^* \\ ss_2 & 0 & ss_4 & 0 \end{bmatrix}
 \end{aligned} \quad (14)
 \end{aligned}$$

Some of the most important issues for DL control channel transmission are the reliability and coverage extension. MIMO schemes are effective solutions for the requirements. Transmit diversity is the best choice for the DL control transmission. In this contribution, we provide some considerations for MIMO transmission in DL control channel.

2.3 MIMO Transmission for Preamble

Based on the baseline in 16m requirement, we recommend MIMO scheme used in preamble transmission. In this section, we assume switching interval index in frequency domain is 0,1,2...7 and index in time is 1,2. Figure2 shows the MIMO transmission method with 2Tx and Figure3 is MIMO mode with 4Tx.

In 2Tx, the odd bits of preamble sequence are transmitted in odd sub-carriers by antenna 1 and the even bits are transmitted in even sub-carriers by antenna 2. For the next preamble transmission, MIMO mode will be switched as inverse as aforementioned. Operation in detail is described in figure2. According to the same principle, figure3 shows the MIMO mode for Preamble transmission in 4Tx.

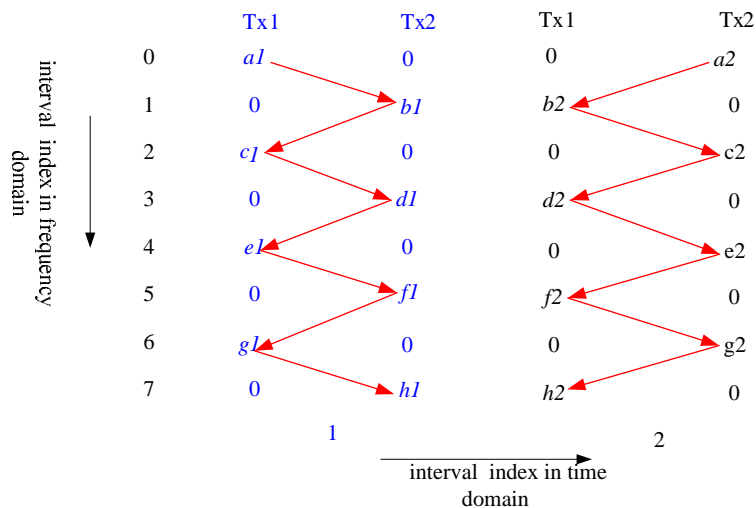


Figure 2 MIMO transmission for preamble in 2Tx

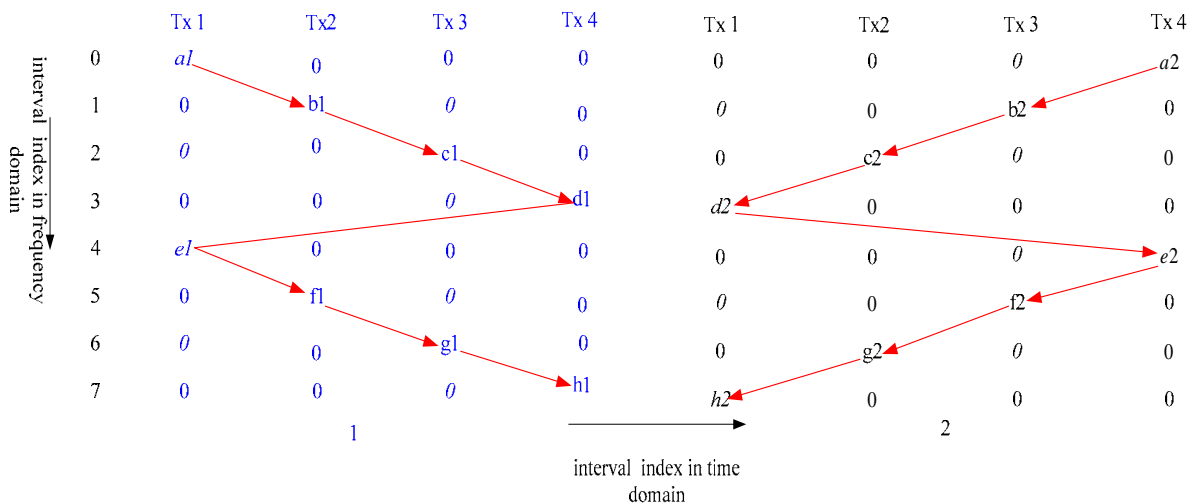


Figure 3 MIMO transmission for preamble in 4Tx (option 1)

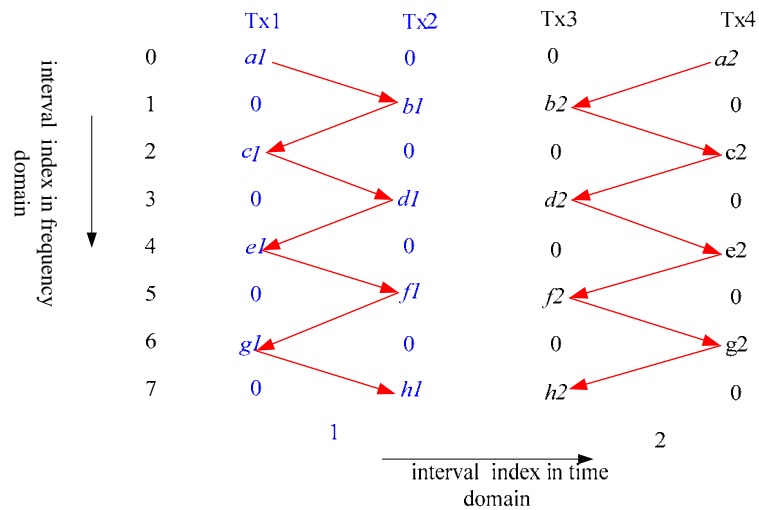


Figure 4 MIMO transmission for preamble in 4Tx (option 2)

From figure2, figure 3 and figure 4, diversity gain is obtained from the switching among two or four antennas in time and frequency domain.

2.4 MIMO Transmission for other channel

In broadcast or MBS channel, open loop diversity MIMO scheme is recommended, for 2Tx, its STC matrix is described in equation (1).

3 Adaptive MIMO

3.1 Adaptive switching and Multi-antenna mode control

The adaptive MIMO mode is shown in figure4. The MIMO mode contains transmit diversity, spatial multiplex, hybrid SM/TD(spatial multiplex/transmit diversity) and beamforming which are related with the channel information, MS speed and average SINR. The design of control signaling about switching among various MIMO modes is under consideration. The class as below:

- SU-MIMO

Open loop/Close loop

Transmit Diversity/ Spatial Multiplex/ TD&SM/ Beamforming

- MU-MIMO

Open loop/Close loop

Transmit Diversity/ Spatial Multiplex/ TD&SM/ Beamforming

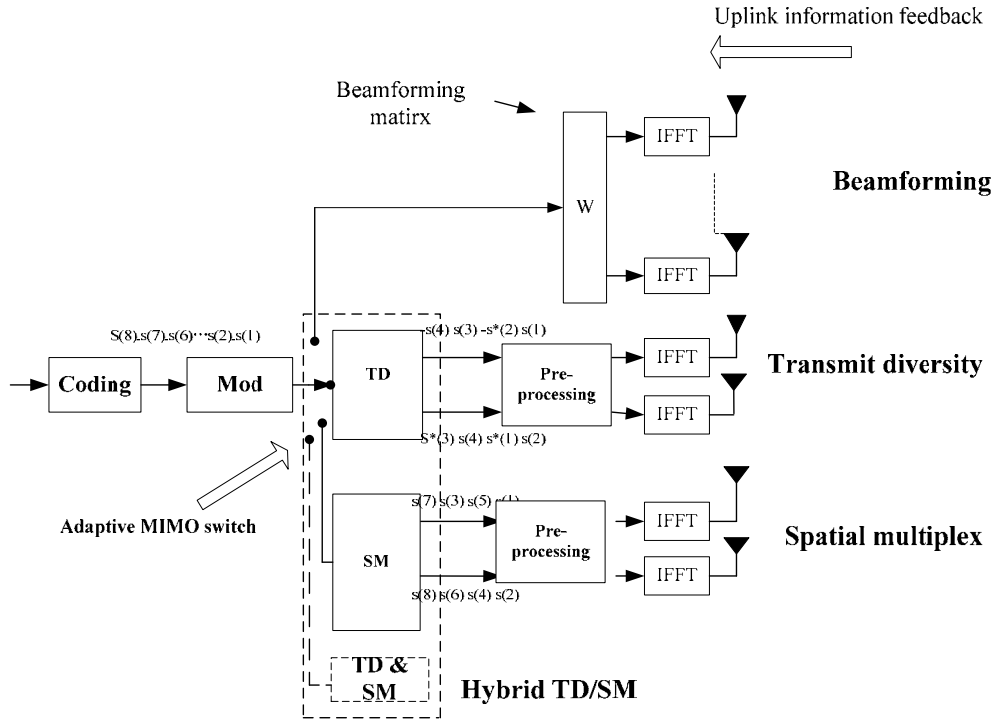


Figure4 Adaptive switching among Multi-antenna mode

Some Multi-antenna mode control signalling in the upper layer, some control information has the tight relations with MS in the lower layer, the particular information to MS in the downlink control channel.

SU and MU-MIMO mode is scheduled by layer3. In SU-MIMO mode, the open loop/close loop, SM, TD, SM&TD and beamforming control in the MAC, the other multi-antenna related parameters, such as Rank indication, MCS Modulation & payload size, HARQ process, redundancy version, in the downlink control channel, each different mode should have it's corresponding format.

In the MU-MIMO mode, BS inform each paired user with different precoding matrix index(PMI) and the user with the PMI corresponding matrix to detect the data stream. Except the PMI, the other information is same as the single stream, each paired MS is assigned rank 1.

As to beamforming (BF), diversity, and spatial multiplexing (SM), the requirements of correlation among antennas are different. Both beamforming and diversity are the single stream systems. Spatial multiplexing is the multiple stream system.

All the transmit antennas can be classified into several groups according to some parameters. The antenna mode in a certain group and the mode between groups may set to be different. SM, TD, SM&TD and beamforming should be considered to be switched adaptively by feedback information.

4 Simulation results

Table 1 Simulation Parameters

System bandwidth	10 MHz
Number of IFFT point	1024

Data modulation	QPSK
Channel coding	1/3 CC
Number of Tx antennas	4
Number of Rx antennas	2
Channel model	SCME
Mobile Speed	3 Km/H , 30 Km/H
Signal detection	Maximum likelihood
Pilot density	Uniform in each antenna

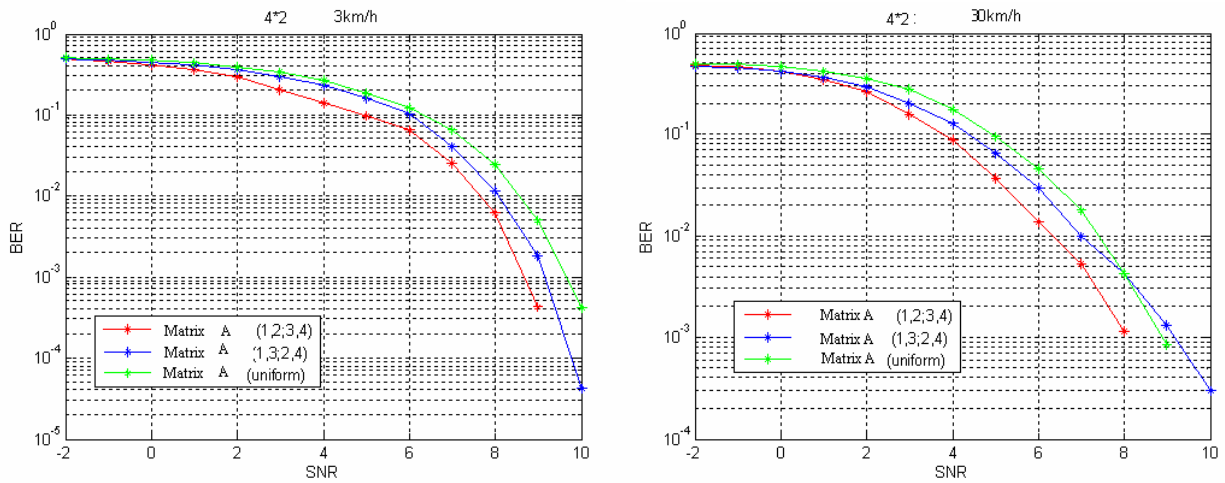


Figure5 Performance compare in 4x2 mode

Figure5 shows the performance results in 3km/h and 30km/h, pilot density is uniform in each antenna. Performance of formula (9) is shown by red curve, formula (10) is shown by blue color and formula (11) is by green one. In this case, we can see that formula (9) encoding matrix is better than other two matrix patterns.

5 Conclusion

In this contribution, Downlink MIMO schemes for 16m system is described, which including MIMO solutions for data and control channel, preamble, and adaptive MIMO considerations. Some simulation result is also given for supporting our proposal.

6 Proposed Text for SDD

----- Text Start -----

x.x Downlink MIMO schemes

According to different demand for control ,broadcast, synchronous and data channel, we suggest to describe it separately in MIMO scheme.

➤ **DL MIMO Scheme for data channel**

MIMO structure for data channel is recommended as figurex.1

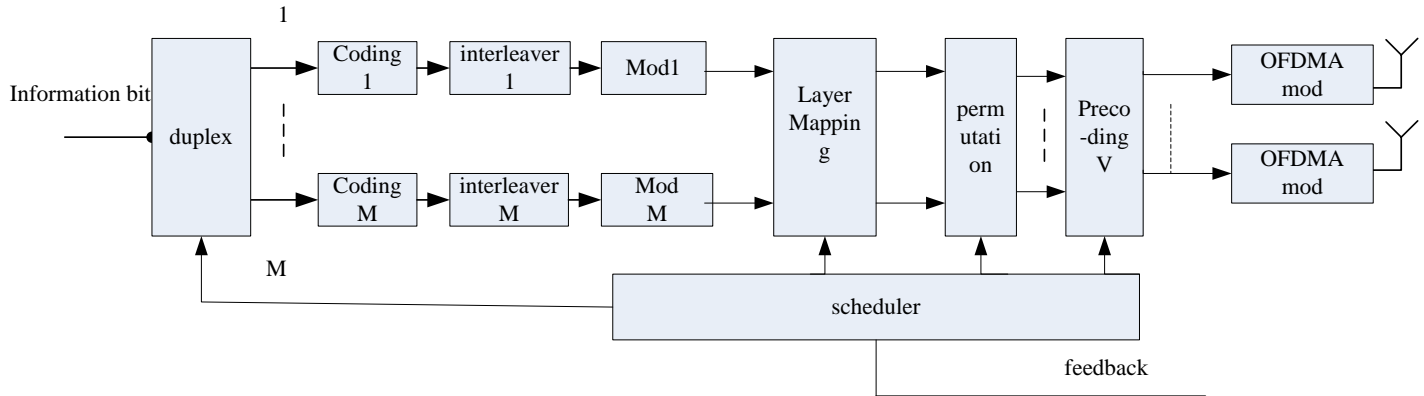


Figure x.1 transmitter block diagram for data channel MIMO

Generally, SM is recommended to adopt, in addition, diversity or combination of SM and diversity is also should be considered.

- 2Tx:

In 2Tx, According to different channel conditions, A, B, C, matrix is applied in data channel MIMO transmission.

$$A = \begin{bmatrix} s_1 & -s_2^* \\ s_2 & s_1^* \end{bmatrix}$$

$$B = \begin{bmatrix} s_1 & s_3 & -s_4^* & s_5 \\ s_2 & s_4 & s_3^* & s_6 \end{bmatrix}$$

$$C = \begin{bmatrix} s_1 \\ s_2 \end{bmatrix}$$

Where the encoding rate of these matrix is 1,1.5,2 for C,B,A matrix as above.

- 4Tx:

$$A = \begin{bmatrix} s_1 & -s_2^* & 0 & 0 \\ s_2 & s_1^* & 0 & 0 \\ 0 & 0 & s_3 & -s_4^* \\ 0 & 0 & s_4 & s_3^* \end{bmatrix}$$

$$B^{R=2} = \begin{bmatrix} s_1 & -s_2^* & s_5 & -s_6^* \\ s_2 & s_1^* & s_6 & s_5^* \\ s_3 & -s_4^* & s_7 & -s_8^* \\ s_4 & s_3^* & s_8 & s_7^* \end{bmatrix} \quad (R=2)$$

$$B^{R=3} = \begin{bmatrix} s_1 & -s_2^* & s_7 & -s_8^* \\ s_2 & s_1^* & s_8 & s_7^* \\ s_3 & s_4 & s_9 & s_{10} \\ s_5 & s_6 & s_{11} & s_{12} \end{bmatrix} \quad (R = 3)$$

$$C = \begin{bmatrix} s_1 \\ s_2 \\ s_3 \\ s_4 \end{bmatrix}$$

➤ **DL MIMO Scheme for control channel**

Open loop transmit diversity scheme is adopted in control channel. Alamouti for 2Tx and Alamouti-based schemes for 4Tx is considered.

● 2Tx

SFBC scheme is adopted for 2Tx, which coding matrix is described as follows:

$$A = \begin{bmatrix} s_1 & -s_2^* \\ s_2 & s_1^* \end{bmatrix}$$

● 4Tx

1) When the pilot density is uniform in four antennas, matrix is considered as:

$$A = \begin{matrix} OFDM1 \rightarrow \\ OFDM2 \rightarrow \end{matrix} \begin{bmatrix} s_1 & -s_2^* & 0 & 0 \\ s_2 & s_1^* & 0 & 0 \\ 0 & 0 & s_3 & -s_4^* \\ 0 & 0 & s_4 & s_3^* \\ 0 & 0 & ss_3 & -ss_4^* \\ 0 & 0 & ss_4 & ss_3^* \\ ss_1 & -ss_2^* & 0 & 0 \\ ss_2 & ss_1^* & 0 & 0 \end{bmatrix}$$

2) When the pilot density for data transmitted on different antennas is not same, e.g. pilot density on group 1(antenna 1 and 2) is not same with that on group 2(antenna 3 and 4), the coding matrix is considered as follows:

$$A = \begin{matrix} OFDM1 \rightarrow \\ OFDM2 \rightarrow \end{matrix} \begin{bmatrix} s_1 & -s_2^* & 0 & 0 \\ 0 & 0 & s_3 & -s_4^* \\ s_2 & s_1^* & 0 & 0 \\ 0 & 0 & s_4 & s_3^* \\ 0 & 0 & ss_3 & -ss_4^* \\ ss_1 & -ss_2^* & 0 & 0 \\ 0 & 0 & ss_4 & ss_3^* \\ ss_2 & ss_1^* & 0 & 0 \end{bmatrix}$$

3) When the pilot density is all different on 1,2,3and 4 antenna, assuming the pilot density is sorted in ascending order from 4 to 1,,then matrix is considered:

$$A = \begin{matrix} OFDM1 \rightarrow \\ OFDM2 \rightarrow \end{matrix} \begin{bmatrix} s_1 & 0 & s_3 & 0 \\ 0 & -s_2^* & 0 & -s_4^* \\ s_2 & 0 & s_4 & 0 \\ 0 & s_1^* & 0 & s_3^* \\ 0 & -ss_2^* & 0 & -ss_4^* \\ ss_1 & 0 & ss_3 & 0 \\ 0 & ss_1^* & 0 & ss_3^* \\ ss_2 & 0 & ss_4 & 0 \end{bmatrix}$$

➤ **DL MIMO Scheme for preamble transmission**

Based on the baseline in 16m requirement, we recommend MIMO scheme used in preamble transmission. In this section, we assume switching interval index in frequency domain is 0,1,2...7 and index in time is 1,2. Figurex.21 shows the MIMO transmission method with 2Tx and Figurex.3 and figure x.4 is MIMO mode with 4Tx.

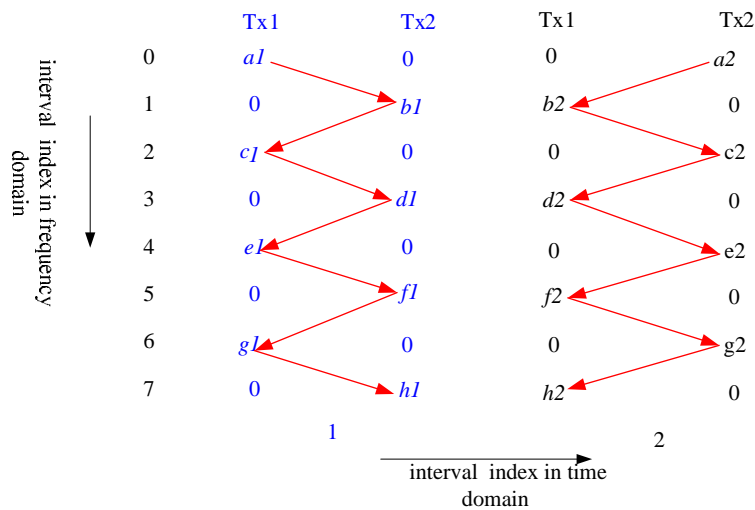


Figure x.2 MIMO transmission for preamble in 2Tx

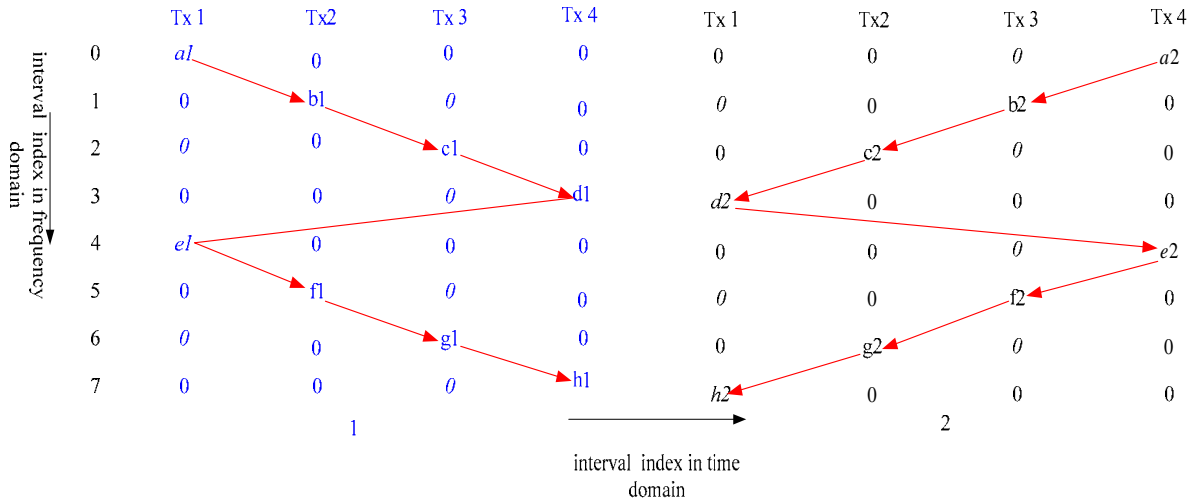


Figure x.3 MIMO transmission for preamble in 4Tx (option 1)

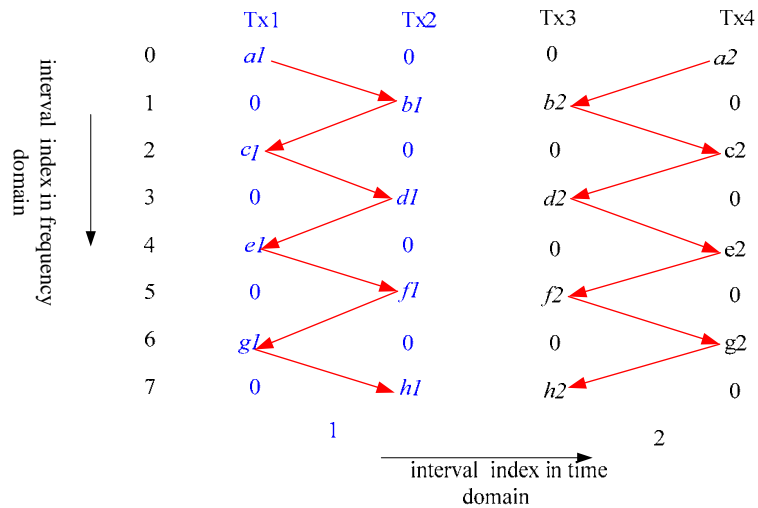


Figure x.4 MIMO transmission for preamble in 4Tx (option 2)

The adaptive MIMO mode should be also considered, the MIMO mode contain the transmit diversity, spatial multiplex, hybrid SM/TD(spatial multiplex/transmit diversity) and beamforming according the different channel information, MS speed and average SINR. Some Multi-antenna mode control signalling in the upper layer, some control information has the tight relations with MS in the lower layer, the particular information to MS in the downlink control channel should be defined. MIMO combined with HARQ can enhance the retransmission gain of 16m system.