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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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Release	
Patent Policy	

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, 2×2 is baseline and the extended downlink requirement 4×2, 4×4 antenna mode is also considered in 16m downlink MIMO, which is also compatible with 4×2 mode. According to different demand for control, broadcast, synchronization and data channel, we describe the transmission methods in different MIMO scheme. A general transmitter architecture supporting the downlink MIMO can be illustrated in Figure 1.

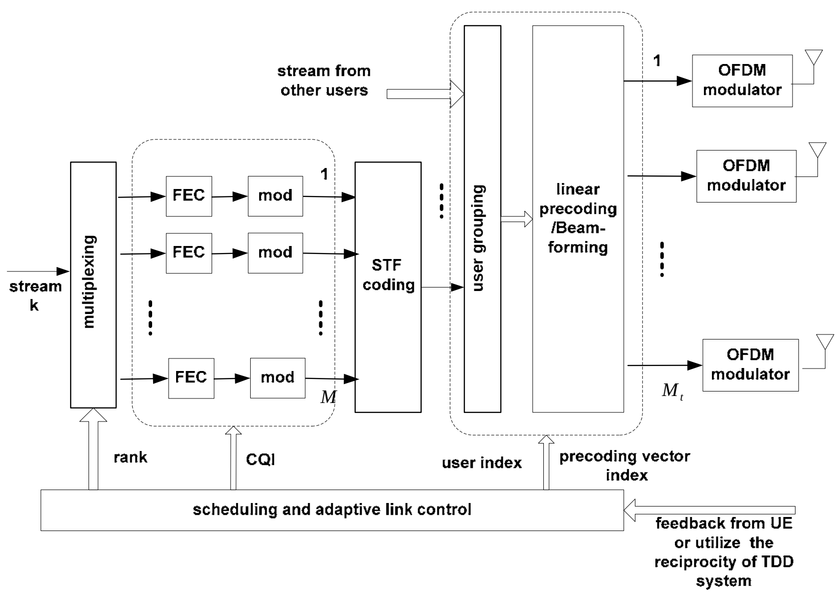

Figure 1 General MIMO structure in 16m

2 Downlink MIMO Schemes

2.1 DL MIMO Scheme for data channel

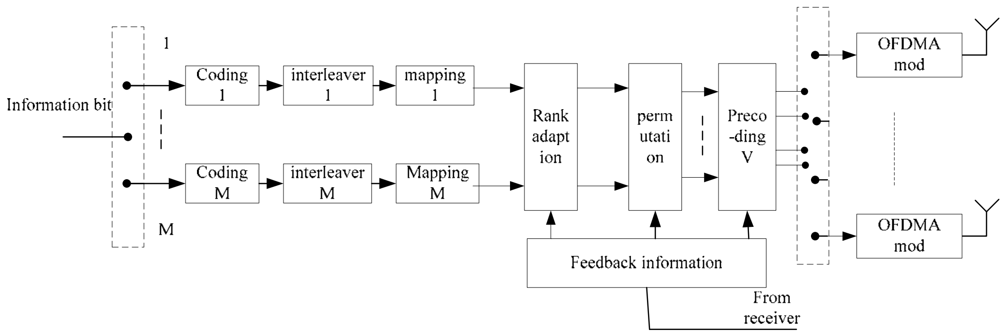

Fig 2 transmitter block diagram for data channel MIMO

Fig2 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 rank adaptation 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 2×2 MIMO mode, we recommended 1 stream. Both 4×4 and 4×2 antenna mode, number of stream is choosed among 1, 2, 3 and 4.Typical value 2 in 4×4 mode and 1 in 4×2 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 follow in detail:

- 2Tx：

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

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

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

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

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

- 3Tx：

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

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

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

- 4Tx：

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

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

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

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

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 SFBC schemes for 2Tx, and the coding matrix is described as follow:

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

Or its transform matrix $A=\begin{bmatrix} s_1 & s_2 \\ -s_2^* & s_1^* \end{bmatrix}$

2） 4Tx：

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

Option1:

Combing SFBC and frequency switched transmit diversity:

- When the pilot density is same for data transmitted on four antennas, matrix (2） is considered：

$$A=\begin{bmatrix} s_1 & -s_2^* & 0 & 0 \\ s_2 & s_1^* & 0 & 0 \\ 0 & 0 & s_3 & -s_4^* \\ 0 & 0 & s_4 & s_3^* \end{bmatrix} \quad (2)$$

Or its other transform as described in 16e.

- When the pilot density for data tansmitted 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(3),which antenna (1,3) and (2,4) paring is combined to encode. $A=\begin{bmatrix} s_1 & -s_2^* & 0 & 0 \\ 0 & 0 & s_3 & -s_4^* \\ s_2 & s_1^* & 0 & 0 \\ 0 & 0 & s_4 & s_3^* \end{bmatrix}$ (3)

Or its transform $\begin{bmatrix} 0 & 0 & s_3 & -s_4^* \\ s_1 & -s_2^* & 0 & 0 \\ 0 & 0 & s_4 & s_3^* \\ s_2 & s_1^* & 0 & 0 \end{bmatrix}$ etc.

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

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

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 (5） is considered：

$$A=\begin{array}{l} OFDM1\rightarrow\begin{bmatrix} s_1 & -s_2^* & 0 & 0 \\ s_2 & s_1^* & 0 & 0 \\ 0 & 0 & s_3 & -s_4^* \\ 0 & 0 & s_4 & s_3^* \end{bmatrix} \\ OFDM2\rightarrow\begin{bmatrix} 0 & 0 & ss_3 & -ss_4^* \\ 0 & 0 & ss_4 & ss_3^* \\ ss_1 & -ss_2^* & 0 & 0 \\ ss_2 & ss_1^* & 0 & 0 \end{bmatrix} \end{array} \quad (5)$$

As formula(5), 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 in antenna is different between two groups (1,2) and (3,4), the coding matrix is considered as follow (6)：

$$A=\begin{array}{l} OFDM1\rightarrow\begin{bmatrix} s_1 & -s_2^* & 0 & 0 \\ 0 & 0 & s_3 & -s_4^* \\ s_2 & s_1^* & 0 & 0 \\ 0 & 0 & s_4 & s_3^* \end{bmatrix} \\ OFDM2\rightarrow\begin{bmatrix} 0 & 0 & ss_3 & -ss_4^* \\ ss_1 & -ss_2^* & 0 & 0 \\ 0 & 0 & ss_4 & ss_3^* \\ ss_2 & ss_1^* & 0 & 0 \end{bmatrix} \end{array} \quad (6)$$

As above formula (6), antenna (1,3) and (2,4) paring is combined separately. In addition, Principle of formula (6) is the same as above (5) formula.

- When the pilot density is all different in 1,2,3and 4 antenna, assuming the pilot density sorted ascending from 4 to 1,then matrix (7) is considered：

$$A=\begin{array}{l} OFDM1\rightarrow\begin{bmatrix} s_1 & 0 & s_3 & 0 \\ 0 & -s_2^* & 0 & -s_4^* \\ s_2 & 0 & s_4 & 0 \\ 0 & s_1^* & 0 & s_3^* \end{bmatrix} \\ OFDM2\rightarrow\begin{bmatrix} 0 & -ss_2^* & 0 & -ss_4^* \\ ss_1 & 0 & ss_3 & 0 \\ 0 & ss_1^* & 0 & ss_3^* \\ ss_2 & 0 & ss_4 & 0 \end{bmatrix} \end{array} \quad (7)$$

One of the most important issues for DL control channel transmission is the reliability and coverage extension.

MIMO schemes are shown an effective for this requirement. Transmit diversity is best choice for the DL control transmission. In this contribution, we proposal some consideration for MIMO transmission in DL control channel.

2.3 MIMO Transmission for Preamble

Based on the baseline in 16m requirement,we recommend MIMO transmission in preamble transmit. In this section, we assume switching interval index in frequency domain is 0,1,2…7 and index in time is 1,2.Figure3 shows the MIMO transmission method with 2Tx and Figure4 is MIMO mode with 4Tx.

In 2Tx, the odd bit of preamble sequence is transmitted in odd sub-carrier by antenna 1 and the even bit is transmitted in even sub-carrier by antenna 2. In next preamble, MIMO mode will be switched as inverse as aforementioned. Operation in detail is described as figure3. As the same principle, figure 4 shows the MIMO mode for Preamble in 4Tx.

interval index in frequency domain	Tx 1	Tx2	Tx 1	Tx2
0	a1	0	0	a2
1	0	b1	b2	0
2	c1	0	0	c2
3	0	d1	d2	0
4	e1	0	0	e2
5	0	f1	f2	0
6	g1	0	0	g2
7	0	h1	h2	0
interval index in time domain	1		2	

Figure 3 MIMO transmission for preamble in 2Tx

interval index in frequency domain	Tx 1	Tx2	Tx 3	Tx 4	Tx 1	Tx2	Tx 3	Tx 4
0	a1	0	0	0	0	0	0	a2
1	0	b1	0	0	0	0	b2	0
2	0	0	c1	0	0	c2	0	0
3	0	0	0	d1	d2	0	0	0
4	e1	0	0	0	0	0	0	e2
5	0	f1	0	0	0	0	f2	0
6	0	0	g1	0	0	g2	0	0
7	0	0	0	h1	h2	0	0	0
interval index in time domain	1				2			

Figure 4 MIMO transmission for preamble in 4Tx

From fig3 and fig4, diversity gain is obtained from the switched 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, in 2Tx, its STC matrix is described as equation (1).

3 Adaptive MIMO

3.1 Adaptive switching and Multi-antenna mode control

The adaptive MIMO mode as the figure5 shows, 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. In the later, there is some suggestion to assigning control signaling about the various MIMO mode. 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

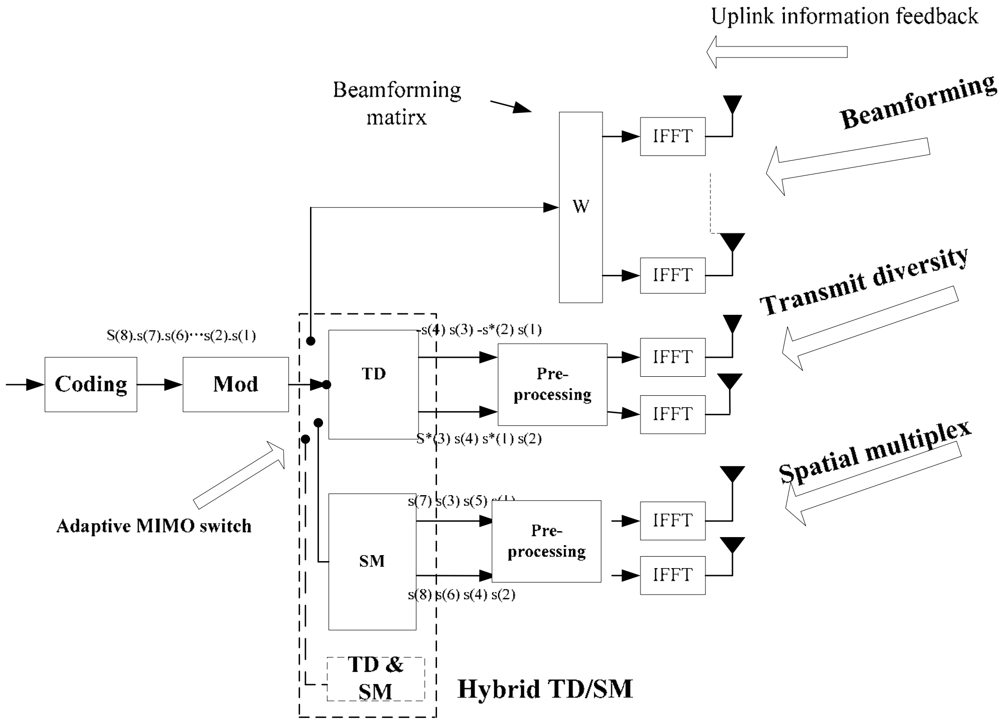

Figure5 Adaptive switching among Multi-antenna mode

Some Multi-antenna mode control signalling in the upper layer, some control information has the tigh 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.

3.2 Adaptive HARQ with MIMO

MIMO is a key technology for 16m system. MIMO combined with HARQ can enhance the retransmission gain of 16m system. For MIMO mode multi-stream can simultaneously transmit from various TX antennas and each independent data stream has its own independent HARQ process in order to implement AMC conveniently.

Except for IR combing, STFD(Space time frequency diversity) -HARQ should be supported.

The basic concept of STFD-HARQ is that the initial transmission multi stream can adopt spatial multiplexing. When at least one data stream transmission failed, failed transmission stream can adopt diversity to be transmitted from multi antennas, including spatial diversity, frequency diversity and time diversity so as to enhance HARQ gain in high speed and reduce number of retransmission.

According different channel conditions, method like CC,IR or STFD-HARQ should be switched adaptively . Control signaling related with HARQ will be further considered.

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

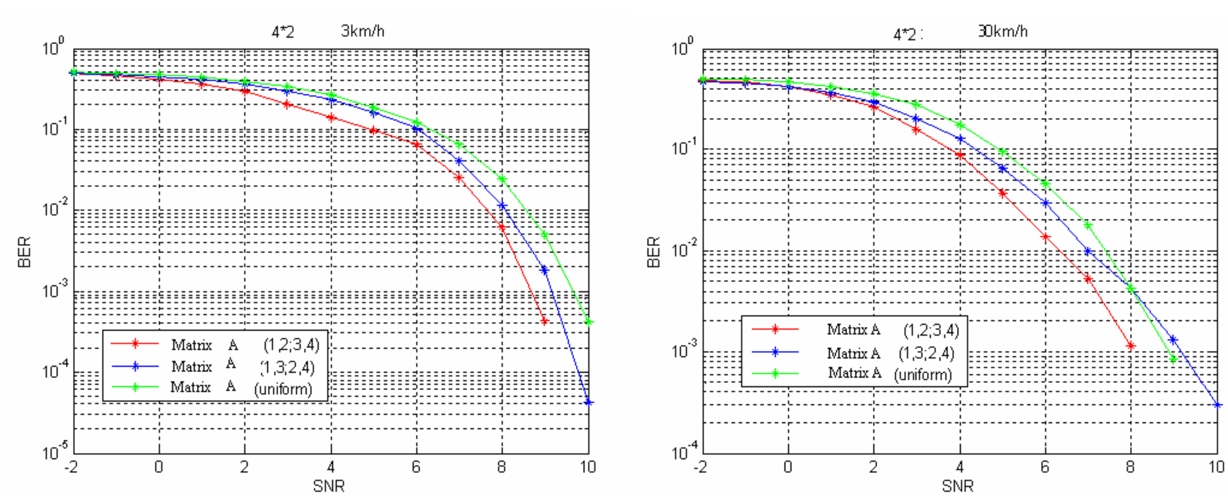

Figure6 Performance comparsion in 4*2 mode

Figure 6 shows the performance results in 3km/h and 30km/h, pilot density is uniform in each antenna. Performance of formula (2) is shown by red curve, formula (3) is shown by blue color and formula (4) is in green one. In this case,we can see that formula (2) encoding matrix is better than other two matrix.

The performance of different STC matrix schemes is simulated here to make a comparison when the transmit antenna number is two. The simulation bandwidth is 5MHz, and 300 subcarriers are used for data allocation and FFT size is 512. The TU channel model with the speed 3km/h is used and ideal channel estimation is assumed. Simulation result is shown as Fig7.

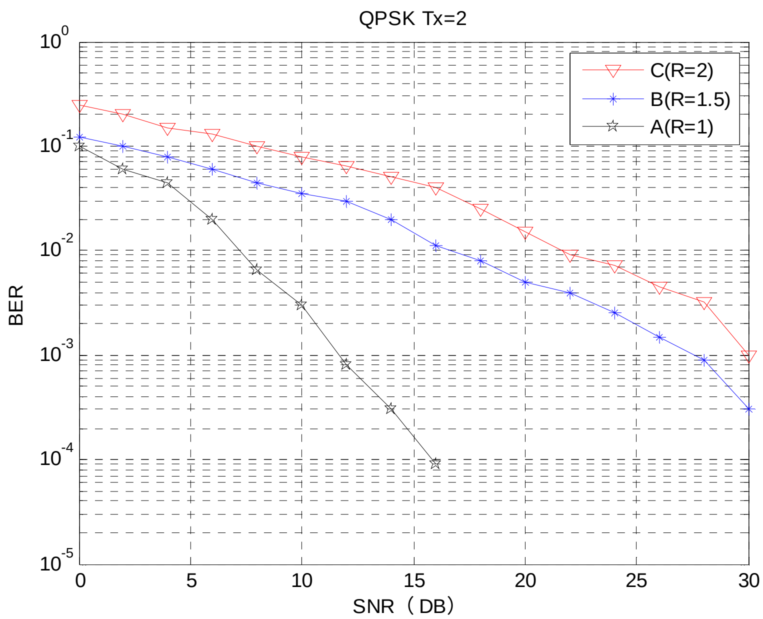

Figure7 A,B,C performance with 2Tx

5 Conclusion

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

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6 Proposed Text for SDD

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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. A general transmitter architecture supporting the downlink MIMO can be illustrated in Figure x.1.

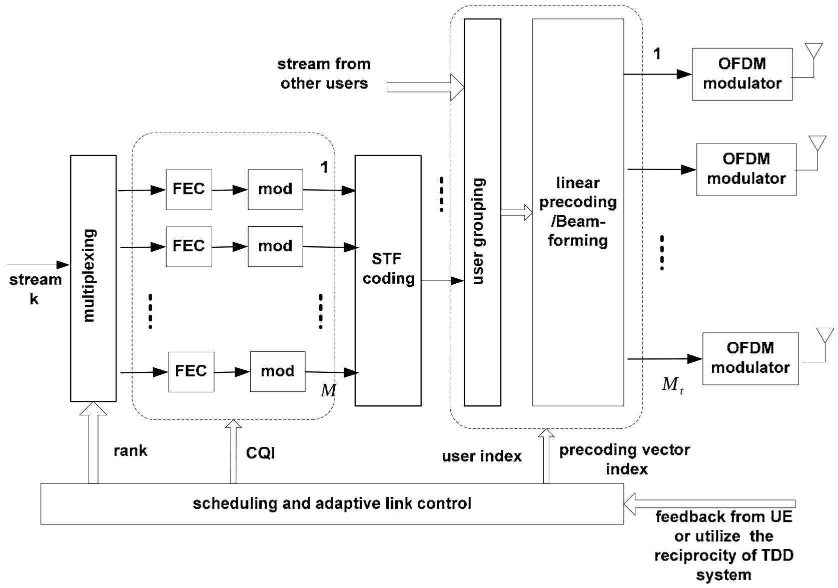

Figure x.1 General MIMO structure in 16m

- **DL MIMO Scheme for data channel**

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, C,B,A matrix is applied in data channel MIMO transmission.

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

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

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

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

- 3Tx：

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

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

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

- 4Tx：

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

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

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

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

- **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 schemes is adopted for 2Tx, which coding matrix is described as follow:

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

- 4Tx

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

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

2) When the pilot density in antenna is different between two groups (1,2) and (3,4), the coding matrix is considered as follow：

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

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

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

- **DL MIMO Scheme for preamble transmission**

Assuming switching interval index in frequency domain is 0,1,2…7 and index in time is 1,2.Figurex.2 shows the preamble MIMO transmission method with 2Tx and Figurex.3 is MIMO mode with 4Tx.

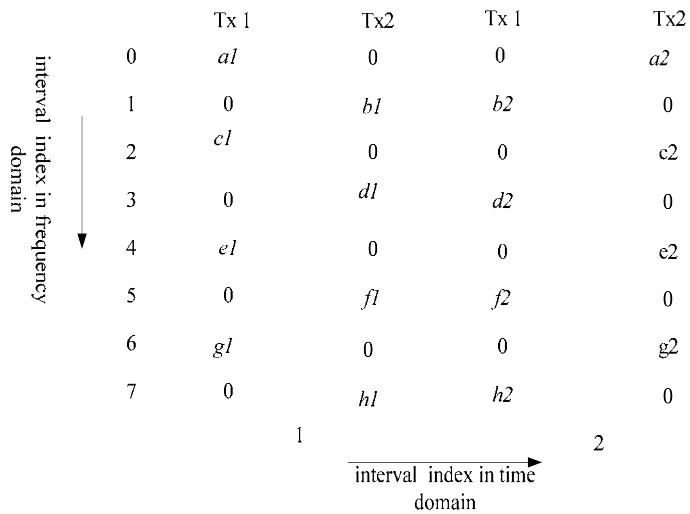

Figure x.2 MIMO transmission for preamble in 2Tx

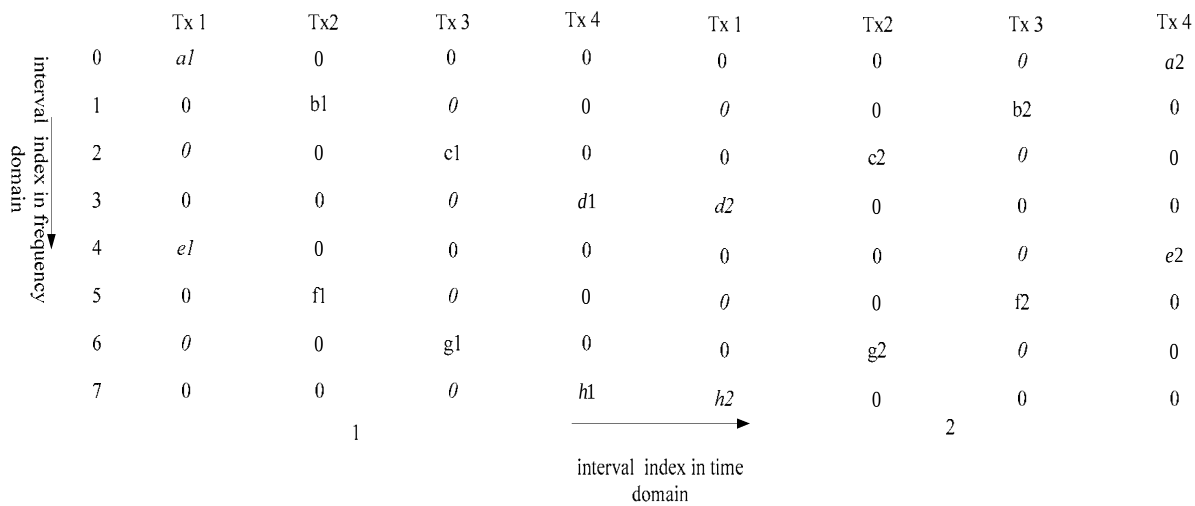

Figure x.3 MIMO transmission for preamble in 4Tx

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.. According different channel conditions, HARQ method like CC, IR or STFD-HARQ should be switched adaptively. Control signaling related with HARQ will be further considered.