Project	**IEEE 802.16 Broadband Wireless Access Working Group** <http://ieee802.org/16>
Title	**Precoding Scheme for Downlink MU-MIMO**
Date Submitted	**2008-05-05**
Source(s)	Hao Donglai, Liu min, Wang Wenhuan,Wei hui, Fang huiying,Qu hongyun ZTE Corporation Voice: [Telephone Number (optional)]] E-mail: hao.donglai@zte.com.cn *<http://standards.ieee.org/faqs/affiliationFAQ.html>
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
Notice	*This document does not represent the agreed views of the IEEE 802.16 Working Group or any of its subgroups*. It represents only the views of the participants listed in the “Source(s)” field above. It is offered as a basis for discussion. It is not binding on the contributor(s), who reserve(s) the right to add, amend or withdraw material contained herein.
Release	The contributor grants a free, irrevocable license to the IEEE to incorporate material contained in this contribution, and any modifications thereof, in the creation of an IEEE Standards publication; to copyright in the IEEE’s name any IEEE Standards publication even though it may include portions of this contribution; and at the IEEE’s sole discretion to permit others to reproduce in whole or in part the resulting IEEE Standards publication. The contributor also acknowledges and accepts that this contribution may be made public by IEEE 802.16.
Patent Policy	The contributor is familiar with the IEEE-SA Patent Policy and Procedures: <http://standards.ieee.org/guides/bylaws/sect6-7.html#6> and <http://standards.ieee.org/guides/opman/sect6.html#6.3>. Further information is located at <http://standards.ieee.org/board/pat/pat-material.html> and <http://standards.ieee.org/board/pat>.

Precoding Scheme for Downlink MU MIMO

Hao Donglai, Liu min, Wang Wenhuan,Wei hui, Fang huiying, Qu hongyun

ZTE Corporation

1 Introduction

In Multi-user MIMO, multiplexed users on the same RBs can be separated in the spatial dimension by designing appropriate transmit and receive antenna weight vectors. Receiver processing and complexity, closed loop mechanism and feedback should be considered as main aspects for MU-MIMO schemes. There are basically two ways of implementing MU-MIMO, the difference being in how the separation of the spatial streams is achieved.
Based on the analysis of several interference elimination methods, This contribution proposed zero-forcing(ZF) vector feedback method , which is a low feedback overhead comparing with traditional method.

2 Precoding Schemes for DL MU-MIMO

Figure1 shows a DL MU-MIMO diagram, precoding unit is very important for eliminating interference. In this Section, several precoding methods will be discussed. One stream for a user is suggested in baseline research.

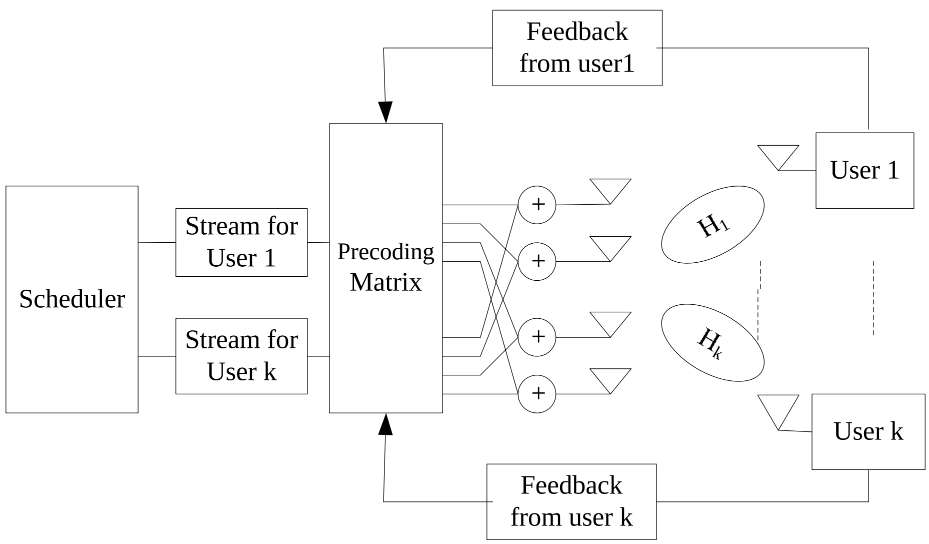


Figure1 DL MU-MIMO diagram

2.1 Block Diagonalize (BD)

Block Diagonalize (BD) algorithm is a traditional algorithm to eliminate interference completely in MU-MIMO. Define

$$\tilde{H}_j = [H_1^T \cdots H_{j-1}^T \quad H_{j+1}^T \cdots H_K^T]^T \qquad (1)$$

where $H_1, \cdots, H_K$ is the channel matrix of each user respectively. Singular value decomposing (SVD) the channel matrix $\tilde{H}_j$,formula (2) is obtained:

$$\tilde{H}_j = \tilde{U}_j \tilde{\Sigma}_j \left[\tilde{V}_j^{(1)} \quad \tilde{V}_j^{(0)} \right]^* \qquad (2)$$

where $\tilde{V}_j^{(1)}$ is the first column vector of V that is the right singular matrix of $\tilde{H}_j$, and $\tilde{V}_j^{(0)}$ is the matrix that is consisted of the rest column vectors of V. Then for user j, equations (3) can be obtained as follows:

$$H_j \tilde{V}_j^{(0)} = U_j \begin{bmatrix} \Sigma_j & 0 \\ 0 & 0 \end{bmatrix} \begin{bmatrix} V_j^{(1)} & V_j^{(0)} \end{bmatrix}^* \qquad (3)$$

$\tilde{V}_j^{(0)} V_j^{(1)}$ and U_j are the weight matrices used at transmit and receive side respectively.

Comparing with other interference cancellation method, the condition to implement BD algorithm is looser than implement ZF method. Because the request of dimension for BD is that the number of transmit antenna is not less than the sum number of receive antenna of any K-1 users. That is described as formula (4):

$$N_{RX} * (K-1) \le N_{TX} \qquad (4)$$

where N_{RX} is the number of antennas in MS,K is the number of users, N_{TX} is antennas in BS.

2.2 Matrix Inversion method

Assuming MU-MIMO system with K users, channel matrix is $H_1, \cdots, H_K$. Let $H_S = [H_1^T \quad H_2^T \quad \cdots \quad H_K^T]^T$,then

$$M_s = H_s^{\dagger} \qquad (5)$$

where $M_S = [M_1 \quad M_2 \quad \cdots \quad M_K]$, precoding weight vector for each user is contained in M_S .Matrix inversion method requires the number of transmit antenna is not less than the sum number of receive antenna of K users . That is described as formula (6):

$$N_{\mathrm{RX}} * \mathrm{K} \le N_{TX} \qquad (6)$$

where N_{RX} is the number of antennas in MS, K is the number of users, N_{TX} is antennas in BS.

2.3 Zero-Forcing （ZF） method

Assuming MU-MIMO system with K users, channel matrix is $H_1, \cdots, H_K$ .For each user,

$$[U_j, D_j, V_j] = svd(H_j) \qquad (7)$$

where D_j is a diagonal matrix, V_j is the precoding weight vector and U_j is the weight vector in receiver for the jth user. $U_j H_j$ is $(D_j \times V_j^H)^T$ ， $U_j H_j$ is required to feedback to BS. Let

$$H_{MU} = [U_1 H_1 \quad \cdots \quad U_j H_j \quad \cdots \quad U_k H_k]^T \qquad (8)$$

Then

$$W = H_{MU}^{\dagger} \qquad (9)$$

ZF method requires the number of transmit antenna is not less than the sum number of receive antenna of k users .Detail describe is as mention as Matrix inversion method.

2.4 Vector Zero-Forcing （ZF） method

Assuming MU-MIMO system with K users, channel matrix is $H_1, \cdots, H_K$. For reducing feedback information, Matrix $U_j H_j$ mentioned in section 2.3 is not fed back to BS completely. Only first N_S vectors of each user is required feedback to BS, where N_S is rank number for each user. H_{MU} is modified as formula (10):

$$H_{MU} = [U_1 H_1(:,1:N_S) \quad \cdots \quad U_j H_j(:,1:N_S) \quad \cdots \quad U_K H_K(:,1:N_S)]^T \qquad (10)$$

W is also obtained by formula (9).

Premise Conditions of this method to eliminate the interference among users is formula (11)

$$N_S \times \mathrm{K} \le N_{TX} \quad (11)$$

where N_S is rank number for each user, K is the number of users, N_{TX} is antennas in BS.

2.5 Comparsion for interference elimination methods

BD algorithm has advantage for overcoming interference between users, which interference is eliminated only $N_{RX} \times (K-1) \le N_{TX}$ satisfied. Shortcoming of this method is its overhead in feedback. With channel reciprocity, this method is suitable for TDD mode. From constrain conditions as this method, two users in 4x4 mode can be separated completely.

Matrix inversion and ZF method also have large feedback overhead, from its constrain condition, two users in 4x4 mode can not be separated completely, in 4x2 mode, two users can be separated completely.

As for vector ZF method mentioned as above, its constrain condition is $N_S \times \mathrm{K} \le N_{TX}$,which is only related to rank number. Four users will be separated completely in 4x4 mode.

3 Proposal

Based on the analysis of precoding method for MU-MIMO, Vector ZF has a good trade-off between performance and overhead. This method is recommended in MU-MIMO, one stream for a user is also suggested in this method. For reducing overhead as possible, the number of rank is suggested one for each user, $N_{TX} \times 1$ vector need to be feedback in this case.

Codebook is considered for feedback, for improving performance in limited feedback, codebook matrix pair is advised to adopted in feedback. Correlation between codebook Matrix should be as lower as possible in a Codebook pair.

4 Simulation Results

In this section, we evaluate the link performance with two scheduled users under 4x4 antenna configuration. Table 1 lists the simulation parameters assumed in the evaluations.

Table 1 Simulation parameters

System bandwidth	10 MHz
Data modulation	QPSK
Channel coding rate	R = 1/3
Channel coding / decoding	Turbo coding (K = 4) / Max-Log-MAP decoding
Number of antennas	4-by-4 MIMO
Channel model	SCME
Maximum Doppler frequency	f_D = 5.55 Hz (v = 3 km/h)
Channel estimation	Real
Signal detection	MMSE-SIC
Control delay in AMC and pre-coding matrix update	1 TTI (= 1 msec)
Hybrid-ARQ	None

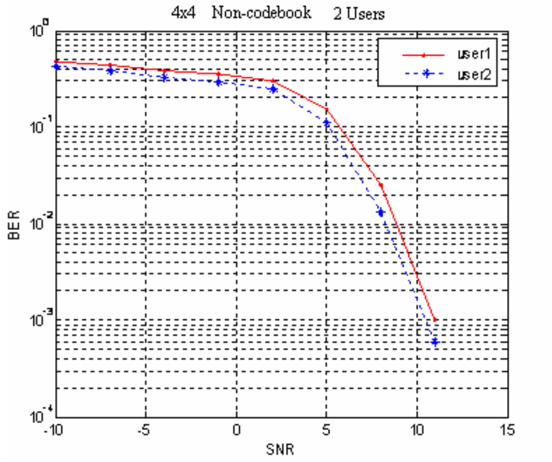


Figure 2 BER of two scheduled Users (channel information ideal feedback)

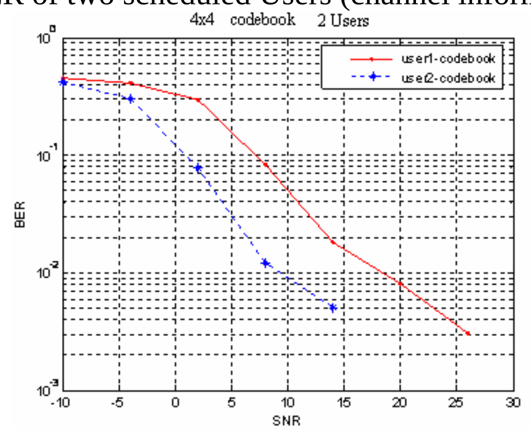


Figure 3 BER of two scheduled Users (channel information feedback base on codebook)

In Figure 2 the CSI is ideal, in Figure 3 the CSI feedback based on codebook method. Note that the multi-user simulation has some randomness, the performance depends on the channel correlation among each user. From Figure 2 and Figure 3, it can be observed that when 2 users are scheduled simultaneously, multi-user interference can be eliminated completely, the proposed Vector ZF scheme can work well. For the codebook based case, the BER performance degrades but can converge, it can be concluded that the codebook-based design can satisfy the requirement of multi-user system.

5 Conclusion

Based on the analysis of precoding method for MU-MIMO, this contribution proposal a vector ZF MU-MIMO precoding scheme.

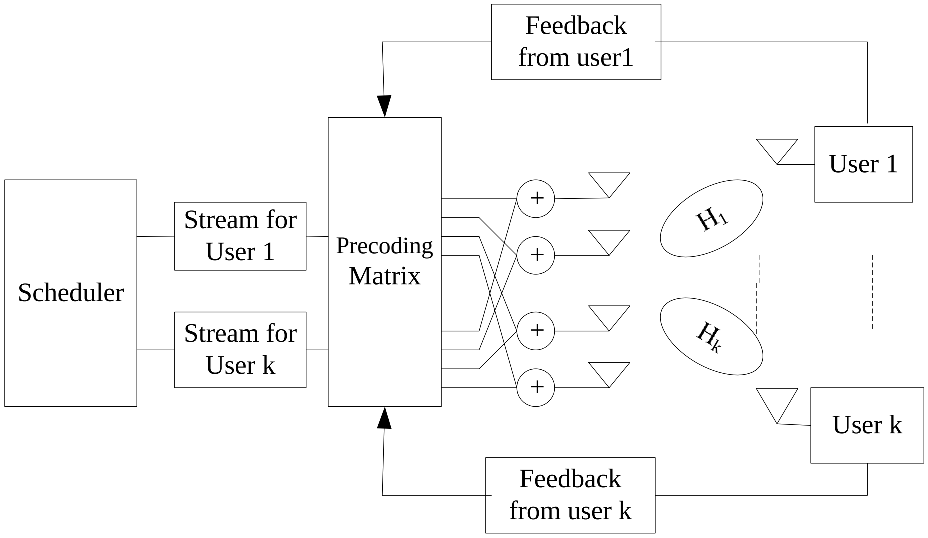
Text Proposal for the 802.16m SDD

===================*Start of Proposed Text* ================================

Section x.x: MU-MIMO

x.x.**1 DL MU-MIMO diagram**

Figure x.1 shows a DL MU-MIMO diagram, precoding unit is very important for eliminating interference. One stream for a user is suggested in baseline research.



Figurex.1 DL MU-MIMO diagram

x.x.2 Precoding scheme for DL MU-MIMO

Assuming MU-MIMO system with K users, channel matrix is $H_1,\cdots,H_K$ .For each user,

$$[U_j, D_j, V_j] = svd(H_j)$$

where D_j is a diagonal matrix, V_j is the precoding weight vector and U_j is the weight vector in receiver for the jth user. Information of $U_j H_j$ is required to feedback to BS. Let

$$H_{MU} = [U_1 H_1(:,1:N_S) \quad \cdots \quad U_j H_j(:,1:N_S) \quad \cdots \quad U_K H_K(:,1:N_S)]^T$$

Then

$$W = H_{MU}{}^{\dagger}$$

Premise Conditions of this method to eliminate the interference among users is $N_S \times \mathrm{K} \le N_{TX}$, where N_s is rank number for each user, K is the number of users, N_{TX} is antenna number in BS.

Codebook is considered for feedback, for improving performance in limited feedback, codebook matrix pair is advised to adopted in feedback. Correlation between codebook Matrix should be as lower as possible in a Codebook pair.