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Interference Cancellation Techniques in Multiuser MIMO

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Abstract— In multi-user multiple input multiple output (MU-MIMO) system; the main difficulty in data transmission in broadcast channel is that the desired signal is affected by other user signal. So, interference cancellation at the base station is required. In this paper, two methods channel inversion and block diagonalization are used to cancel interference. First the channel inversion method is used to cancel inference due to other signals and minimizes noise enhancement and second Block Diagonalization (BD) method eliminates or minimizes the multi-user interference. This paper discusses the performance of channel inversion and Block Diagonalization (BD) in term of bit error rate (BER)

Key words: Multi-User MIMO, Bit Error Rate (BER), Broadcast channels (BC), Interference, Channel Inversion

I. INTRODUCTION

multi-Input multi output (MIMO) systems is more popular in the past few years due to their great potential to achieve high throughput in a wireless communication system [1][2]. Wireless communication technology has increased widespread acceptance in recent years [3].

More recently, the research of the capacity region has been of concern in multi-user MIMO broadcast channels [4]. In multiple antenna broadcast channels, transmit antenna arrays can be used to simultaneously transmit data streams to receivers and thereby significantly increase throughput. The transmitter and receiver of uth user are respectively equipped with NT and NR antenna elements [5].

In multiple antennas at both the base station and mobile station operating in space, time have been proposed and demonstrated to significantly increase system performance as well as capacity. The main advantage of using multiple antennas is that no bandwidth expansion is required for capacity and performance improvement. This paper focused on multi user MIMO broadcast channel because the main difficulty in broadcast channel is that the desired signal is affected by other user's signals [6].

This paper, channel inversion is used to cancel interference due to other users and block diagonalization method eliminates or minimize the multi-user interference and give the performance of both methods in terms of BER [7].

II. SYSTEM MODEL

A. *Communication Schemes for Multiuser- MIMO Systems:*

Communication schemes for MU-MIMO systems include both uplink MU-MIMO and downlink MU-MIMO. In uplink communication user transmit signal to the base station [8]. In the case of downlink communication, base station transmits signals to users. For uplink MU-MIMO Xk the transmit signal of uth user; k=1, 2, K. The received signal at the base station y is given as below,

$$y_k = \sum_{k=1}^{K} H_k.X_k + B_k \qquad (1.1)$$

In the above equation (1) Hk is the channel matrix between the user and base station and b is the noise. For downlink MU-MIMO assumes K user is simultaneously receiving signals from the base station.

The transmitted signal is expressed as the sum of signals to users u=1, 2,.. K.

$$\mathrm{x} = \sum_{\mathrm{k}=1}^{\mathrm{k}} \mathrm{H}_{\mathrm{k}} \qquad (1.2)$$

The received signal y is given as below,

$$y_k = H_k.x + B_k$$

$$y_k = H_k.X_k + \sum_{j \neq k}^{K} (H_k.X_j) + B_k \qquad (1.3)$$

In the above Equation (1.3) Bk is the noise.

B. *Channel Inversion:*

In channel inversion method, we assume NM=1 for all users and K=NB. Let Xu stand for the uth users signal and the H_u^DL Stand for the channel matrix between base station and the uth user u=1, 2…K.

The received signal of uth user can be expressed as,

$$y_u = H_u^{DL} \begin{bmatrix} x_1 \\ x_2 \\ \cdot \\ \cdot \\ x_K \end{bmatrix} + b_u \qquad (2.1)$$

Where, *u*=1, 2... *K*.

The received signals of all, users can be represented as,

$$\begin{bmatrix} y_1 \\ y_2 \\ \cdot \\ \cdot \\ y_K \end{bmatrix} = \begin{bmatrix} H_1^{DL} \\ H_2^{DL} \\ \cdot \\ \cdot \\ H_K^{DL} \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \\ \cdot \\ \cdot \\ x_K \end{bmatrix} + \begin{bmatrix} b_1 \\ b_2 \\ \cdot \\ \cdot \\ b_K \end{bmatrix} \qquad (2.2)$$

Above Equation (2.2) is received signal at each individual user terminal. Since each user is equipped with a single antenna, interferences due to other signals cannot be canceled.

Channel inversion is the same processing as the ZF pre-equalization.

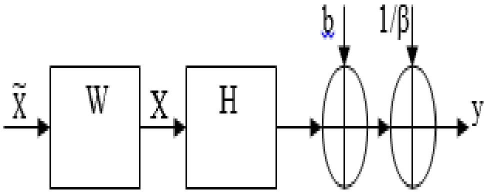

Fig. 1: Pre-equalization process

Fig.1 shows the pre-equalization on the transmission side. The pre-equalization can be represented by a pre-equalizer weight matrix W and precoded symbol vector X can be expressed as,

$$X = W\tilde{X} \qquad (2.3)$$

In the above Equation (2.3), X˜ is the original symbol for transmission. The zero-forcing equalization in use the corresponding weight matrix is given as below,

$$W_{ZF} = \beta H^{-1} \qquad (2.4)$$

In the above Equation (2.4), β is a constant total transmitted power after pre-equalization and it is given as below,

$$\beta = \sqrt{\frac{N_T}{T_r(H^{-1}(H^{-1})^H)}} \qquad (2.5)$$

To balance the effect of amplification by a factor of β at the transmitter, the received signal must be divided by β via automatic gain control of the receiver. The received signal y is given by,

$$y = \frac{1}{\beta}\left(HW_{ZF}\tilde{X} + b\right) \qquad (2.6)$$

$$= \frac{1}{\beta}\left(H\beta H^{-1}\tilde{X} + b\right)$$

$$= \tilde{X} + \frac{1}{\beta} b$$

$$= \tilde{X} + \tilde{b} \qquad (2.7)$$

C. Block Diagonalization:

In Block Diagonalization (BD), technique the multi user interference can be cancelled in the process of precoding. The MIMO channel of each user is assumed to BS has NT transmitter antennas, and each user has NR receiver antennas.

Let XK show the transmit signal of uth user and bu is the noise vector. The signal of each user preprocessed at the transmitter by precoding matrix. At mobile station the received signal of uth user signal X̃_u is given as,

$$y_u = H_u^{DL} \sum_{k=1}^{K} W_k \tilde{X}_k + b_u$$

$$= H_u^{DL} W_u \tilde{X}_u + \sum_{\substack{k=1 \\ k \neq u}}^{K} H_u^{DL} W_k \tilde{X}_K + b_u$$

(3.1)

In the above Equation (3.1), H_u^DL is the channel matrix between base station and the uth user, Wu is the precoding matrix for the uth user. The second part of the equation (3.1) on the right side is an interference result from messages belongs to other users. Consider the received signals for the three-user case (i.e. K=3),

$$\begin{bmatrix} y_1 \\ y_2 \\ y_3 \end{bmatrix} = \begin{bmatrix} H_1^{DL} & H_1^{DL} & H_1^{DL} \\ H_2^{DL} & H_2^{DL} & H_2^{DL} \\ H_3^{DL} & H_3^{DL} & H_3^{DL} \end{bmatrix} \begin{bmatrix} W_1\tilde{X}_1 \\ W_2\tilde{X}_2 \\ W_3\tilde{X}_3 \end{bmatrix} + \begin{bmatrix} b_1 \\ b_2 \\ b_3 \end{bmatrix} \qquad (3.2)$$

$$= \begin{bmatrix} H_1^{DL}W_1 & H_1^{DL}W_2 & H_1^{DL}W_3 \\ H_2^{DL}W_1 & H_2^{DL}W_2 & H_2^{DL}W_3 \\ H_3^{DL}W_1 & H_3^{DL}W_2 & H_3^{DL}W_3 \end{bmatrix} \begin{bmatrix} \tilde{X}_1 \\ \tilde{X}_2 \\ \tilde{X}_3 \end{bmatrix} + \begin{bmatrix} b_1 \\ b_2 \\ b_3 \end{bmatrix} \qquad (3.3)$$

Where H_u^DL W_k is useful channel matrix for the uth user receiver and kth user transmit signal (u, k=1, 2,..K). In Block Diagonalization precoding matrix is use to cancel or minimize the multi-user interference [9]. To reduce all multi-user interference the useful channel matrix is given as [10].

$$H_u^{DL} W_k = 0 \qquad u \neq k \qquad (3.4)$$

Now, the received signal of uth user is interference free, that is,

$$y_u = H_u^{DL} W_u \tilde{X}_u + b_u \qquad (3.5)$$

$\widetilde{H}_u^{DL}$ is indicated as the channel matrix for all users other than the user *k*.

$$\widetilde{H}_u^{DL} = [(H_1^{DL})^H \dots (H_{u-1}^{DL})^H \ (H_{u+1}^{DL})^H \dots (H_K^{DL})^H]^H$$

(3.6)

So we should have H_u^DL W_k= 0 for u≠k. This means the interference of other users is totally eliminated for the uth user. Let us denote singular value decomposition of matrix H̃_u^DL .

$$\widetilde{H}_u^{DL} = \widetilde{U}_u \tilde{\Lambda}_u [\widetilde{V}_u^{\text{non-zero}} \ \widetilde{V}_u^{\text{zero}}]^H \qquad (3.7)$$

Where $\widetilde{U}_u$ is the left singular matrix of $\widetilde{H}_u^{DL}$ and $\tilde{\Lambda}_u$ is a diagonal matrix whose diagonal elements are the singular values of $\widetilde{H}_u^{DL}$ [11]. Sub-matrices $\widetilde{V}_u^{non-zero}$ and $\widetilde{V}_u^{zero}$ are the right singular matrices corresponding to non-zero singular values and zero singular values of $\widetilde{H}_u^{DL}$ respectively.

Multiplying $\widetilde{H}_u^{DL}$ with $\widetilde{V}_u^{zero}$, we have the following relationship,

$$\widetilde{H}_u^{DL} \widetilde{V}_u^{(0)} = 0 \qquad (3.8)$$

From equation (3.8) it can be seen that Ṽ_u^zero is in the null space of H̃_u^DL, that is, when a signal is transmitted in the direction of Ṽ_u^zero, all but the uth user receives no signal at all. Thus Wu = Ṽ_u can be used for precoding the uth user signal.

Let us take an example of *NB*=4, *K*=2, and $N_{M,1}=N_{M,2}=2$,

$$\widetilde{H}_1^{DL} = \widetilde{U}_1 \tilde{\Lambda}_1 [\widetilde{V}_1^{non-zero} \ \widetilde{V}_1^{zero}]^H$$

$$= [\tilde{u}_{11} \ \ \tilde{u}_{12}] \begin{bmatrix} \tilde{\lambda}_{11} & 0 & 0 & 0 \\ 0 & \tilde{\lambda}_{12} & 0 & 0 \end{bmatrix} [\tilde{v}_{11} \ \ \tilde{v}_{12} \ \ \tilde{v}_{13} \ \ \tilde{v}_{14}]^H$$

(3.9)

$$\widetilde{H}_2^{DL} = \widetilde{U}_2 \tilde{\Lambda}_2 [\widetilde{V}_2^{non-zero} \ \widetilde{V}_2^{zero}]^H$$

$$= [\tilde{u}_{21} \ \ \tilde{u}_{22}] \begin{bmatrix} \tilde{\lambda}_{21} & 0 & 0 & 0 \\ 0 & \tilde{\lambda}_{22} & 0 & 0 \end{bmatrix} [\tilde{v}_{21} \ \ \tilde{v}_{22} \ \ \tilde{v}_{23} \ \ \tilde{v}_{24}]^H$$

(3.10)

The precoding matrices W_u for $u = 1, 2$.

$$W_1 = \widetilde{V}_1^{zero} = [\tilde{v}_{13} \ \tilde{v}_{14}]$$

$$W_2 = \widetilde{V}_2^{zero} = [\tilde{v}_{23} \ \tilde{v}_{24}] \qquad (3.11)$$

The transmitted signal *s* is given as,

$$x = W_1\tilde{x}_1 + W_2\tilde{x}_2 \qquad (3.12)$$

Where $\tilde{x}_u$ is the u^{th} user signal *u*=1, 2. Then the received signal of the first user is given as,

$$y_1 = H_1^{DL} x + b_1$$

$$= H_1^{DL}(W_1\tilde{x}_1 + W_2\tilde{x}_2) + b_1$$

$$= \widetilde{H}_2^{DL}\left(\widetilde{V}_1^{zero}\,\tilde{x}_1 + \widetilde{V}_2^{zero}\tilde{x}_2\right)$$

$$+ \qquad b_1 \qquad (3.13)$$

$$= \widetilde{H}_2^{DL}\left(\widetilde{V}_1^{zero}\,\tilde{x}_1\right) + b_1$$

$$= \widetilde{H}_1^{DL}\left(\widetilde{V}_1^{zero}\,\tilde{x}_1\right) + b_1$$

In Equation (3.13), we have used the fact that $H_1^{DL} = \widetilde{H}_2^{DL}$ and $H_2^{DL} = \widetilde{H}_1^{DL}$. In equation (3.13), we can see that the received signal is collected of the preferred signal only. The received signal of the second user is found in a similar way.

III. SIMULATION RESULTS

Fig.2 shows that the BER performance of channel inversion method for NB=4, and NM=1 in which four users with the highest channel norm values are selected out of K = 20.

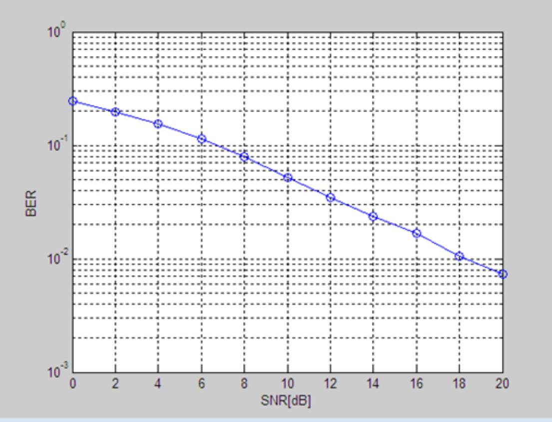

Fig. 2: BER performance of channel inversion method

Fig.3 shows that the BER performance of block diagonalization method for NB=4, and K=2 and NM,1=NM,2=2.

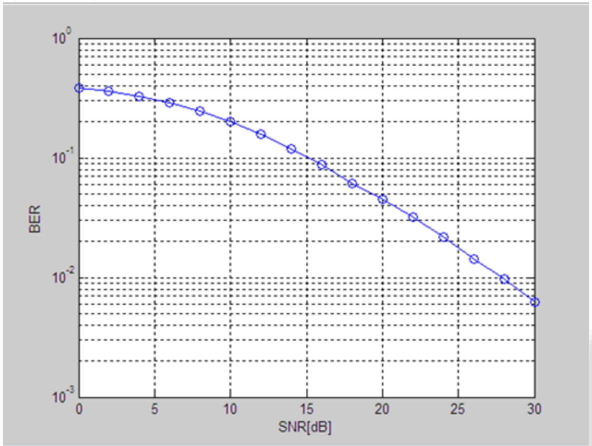

Fig. 3: BER performance block diagonalization of method

IV. CONCLUSION

Channel inversion is cancel interference due to other users and block diagonalization method eliminates or minimize the multi-user interference. The presented results show that the channel inversion and block diagonalization BER performance.

REFERENCES

[1] G. J. Foschini and M. Gans, "On limits of wireless communications in a fading environment when using multiple antennas," Wireless Personal Commun., vol. 6, pp. 311-335, Mar. 1998.

[2] I. E. Telatar, "Capacity of multi-antenna Gaussian channels," Eur. Trans. Telecommun., vol. 10, pp. 585-595, Nov. 1999.

[3] Sedrati Maamar, Maamri Ramdane, Bilami Azeddine, Benmohammed Mohamed "Contention Window Optimization: an enhancement to IEEE 802.11 DCF to improve Quality of Service" International Journal of Digital Information and Wireless Communications (IJDIWC) 1(1): 273-283.The Society of Digital Information and Wireless Communications, 2011(ISSN 2225-658X).

[4] S. Vishwanath, N. Jindal, and A. Goldsmith, "Duality, achievable rates, and sum-rate capacity of Gaussian MIMO broadcast channels," IEEE Trans. Inf. Theory, vol. 49, pp. 2658-2668, Oct. 2003.

[5] T.Taniguchi, Y.Karasawa, N.Nakajima "Simple Design Method of MIMO Multiuser Downlink System Based on Block-Diagonalization" " International Journal of Digital Information and Wireless Communications (IJDIWC) 1(1): 223-235.The Society of Digital Information and Wireless Communications, 2011(ISSN 2220-9085).

[6] Dalveer Kaur and Neeraj Kumar "BER Performance Comparison of Channel Inversion and Regularized Channel Inversion Methods for Multi-user MIMO System" International Journal of Engineering Science Invention Research & Development; Vol. I Issue II August 2014Md Hashem Ali Khan, K M Cho, Moon Ho Lee* and Jin-Gyun Chung "A simple block diagonal precoding for multi-user MIMO broadcast channels" Khan et al. EURASIP Journal on Wireless Communications and Networking 2014.

[7] C. Lim, T. Yoo, B. Clerckx, and B. Lee, "Recent trend of multiuser MIMO in LTE-Advanced," IEEE Communications Magazine, pp. 127– 135, March 2013.

[8] Ben Zid Maha and Raoof Kosai "Multi User MIMO Communication: Basic Aspects, Benefits and Challenges".

[9] Md Hashem Ali Khan, K M Cho, Moon Ho Lee* and Jin-Gyun Chung "A simple block diagonal precoding for multi-user MIMO broadcast channels" Khan et al. EURASIP Journal on Wireless Communications and Networking 2014.

[10] H. Shokri Razaghi, K. Mohamed-pour, S. M. Hosseini Andargoli, M. Hoseinzade, "Multiuser MIMO Downlink Scenario Based on Block Diagonalization Transmission" Faculty of Electrical Engineering, K. N. Toosi University of Technology, Tehran, Iran.

[11] Quentin H. Spencer, A. Lee Swindlehurst, Martin Haardt "Zero-Forcing Methods for Downlink Spatial Multiplexing in Multiuser MIMO Channels" IEEE transaction on signal processing, vol. 52, no. 2, February 2004.