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Performance of Linear Precoding for Broadcast Channels for Multi- User MIMO System

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Abstract:
In this paper performance of Multi-user (MU) multiple input multiple output (MIMO) systems are analyzed. MIMO system is one of the significant emerging technologies on today. It is used to achieve high data rates and capacity in transmission medium. In Multi-user MIMO, downlink and uplink channels are referred to as broadcast (BC) channel and multiple accesses channel (MAC). In Broad-Cast channel data transmission application, the coordinated signal detection on the receiver side is mixed with interference. There are four transmission methods at downlink are Channel Inversion (CI), Block Diagonalization (BD), Dirty Paper Coding (DPC) and Tomlinson Harashima pre-coding (THP). In this paper bit error rate (BER) and signal to noise ratio (SNR) are compared. Channel Inversion, Block Diaonalization are linear pre-coding while Dirty Paper Coding, Tomlinson Harashima are non linear pre-coding. Linear pre-coding schemes have low complexity and can achieve a reasonable capacity.

Keywords: Multi-Input Multi-Output (MIMO), Dirty Paper Coding (DPC), Tomlinson Harashima Precoding (THP), Block Diagonalization (BD), Zero-Forcing (ZF), Bit Error Rate (BER), Inter Symbol Interference (ISI), Channel State Information (CSI).

I. INTRODUCTION

Wireless is an emerging field, which has been enormous growth in last several years. The need for achieving better spectral efficiency, high data rate and high throughput with low latency in the transmission medium is very challenging task. All the above requirements in the field of Cellular technology are difficult [1].To mitigate this situation; new emerging technique like MIMO system can be considered [2].

In an ideal multipath channel, the MIMO capacity is approximately N times the capacity of a single system, where N is the smaller size of transmits or receives antenna element [3]. For enjoying applications such as Wireless LAN, Cellular telephony, and single base station must communicate with many users simultaneously.

Therefore the study of Multi-User MIMO systems has emerged as an important research topic recently. [4]. Multi-User MIMO can be classified as Multiple Access Channel (MAC) and Broad-Cast Channel (BS) [5]. In this paper certain linear precoding technique has been analyzed. Channel inversion (CI) is linear precoding technique which impose the constraint that all the interference terms as zeros. It is suitable for high power and low noise conditions. The Block Diagonalization (BD) precoding can avoid the interference between different users in multi antenna scheme [6].

II. MATHEMATICAL MODEL OF MULTI-USER (MU) MIMO [6]

We assume that Base stations (BS) and mobile station (MS) are equipped with N_B and N_M. The Received signal is given by

$$y_{MAC} = [H_1^{UL} \quad H_2^{UL} \ldots\ldots \quad H_{KL}^{UL}] \begin{bmatrix} X_1 \\ \cdot \\ \vdots \\ X_K \end{bmatrix} + z \qquad \ldots(1)$$

$$y_{MAC} = H_1^{UL} x_1 + H_2^{UL} x_2 + \ldots\ldots + H_K^{UL} x_K + z$$

$$= H^{UL} \begin{bmatrix} X_1 \\ \cdot \\ \vdots \\ X_K \end{bmatrix} + Z \qquad (2)$$

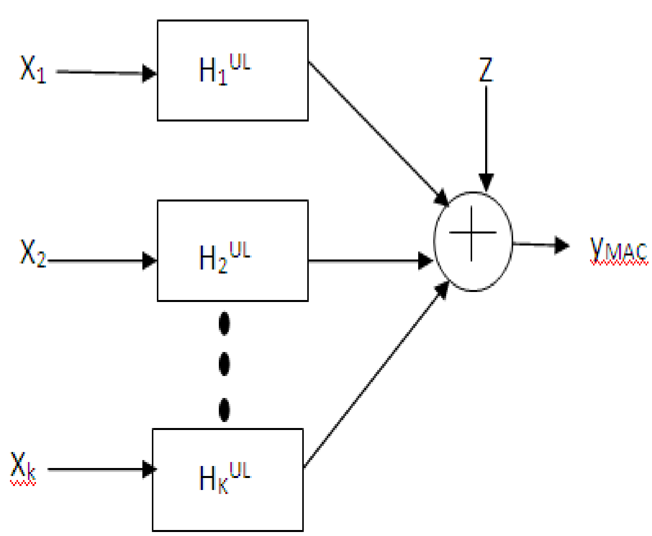

Figure.1. Uplink channel model for MU-MIMO [6]

The downlink model is shown in Figure 2. The received signal is given by

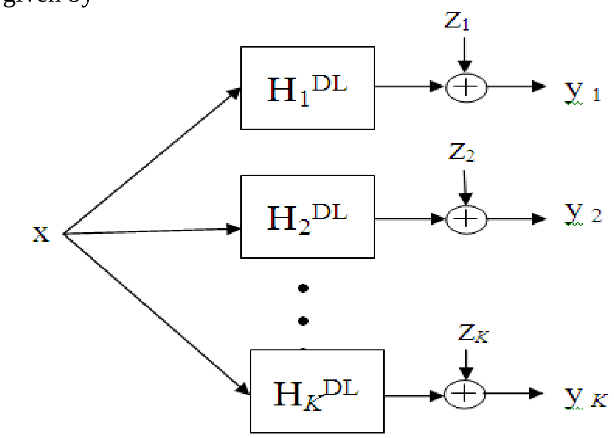

Figure.2. Downlink channel model for MU-MIMO

$$y_u = H_U^{DL} X + z_u \quad \ldots(3)$$

Where u=1, 2, 3……..K

The overall system can be represented by following equations

$$\begin{bmatrix} y_1 \\ y_2 \\ \vdots \\ y_k \end{bmatrix} = \begin{bmatrix} H_1^{DL} \\ H_2^{DL} \\ \vdots \\ H_K^{DL} \end{bmatrix} X + \begin{bmatrix} Z_1 \\ Z_2 \\ \vdots \\ Z_K \end{bmatrix} \quad (4)$$

III. MULTI-USER TRANSMISSION VIA LINEAR PROCESSING

There are two types of linear precoding which are used in multi-user MIMO system.

(A).Channel Inversion Precoding [6]

Channel Inversion is a linear precoding where the interference occurs in transmitted signal can be mitigated by considering all the interference terms is zero. Let $\widetilde{x_u}$ denotes the u[th] user signal while $H_u^{DL} \in C^{1\times K}$ denotes the channel matrix between BS and the u[th] user u=1,2,….K. The received signal of the user can be expressed as

$$y_u = H_u^{DL} \begin{bmatrix} \widetilde{x_1} \\ \widetilde{x_2} \\ \vdots \\ \widetilde{x_K} \end{bmatrix} + z_u \quad (5)$$

The received signals of all users can be represented

$$\begin{bmatrix} y_1 \\ y_2 \\ y_3 \\ \vdots \\ y_K \end{bmatrix} = \begin{bmatrix} H_1^{DL} \\ H_2^{DL} \\ H_3^{DL} \\ \vdots \\ H_K^{DL} \end{bmatrix} \begin{bmatrix} \widetilde{x_1} \\ \widetilde{x_2} \\ \widetilde{x_3} \\ \vdots \\ \widetilde{x_K} \end{bmatrix} + \begin{bmatrix} z_1 \\ z_2 \\ z_3 \\ \vdots \\ z_K \end{bmatrix} \quad (6)$$

The received signal at each user terminal in equation (6) is a scalar while each user's received signal in equation (3) is a vector. Since each user is equipped with a single antenna, interferences due to other signals cannot be canceled. Instead, precoding technique such as channel inversion can be considered.

(B) Block-Diagonalization Precoding [6]

Block Diagonalization (BD) is a linear precoding technique used at transmitter side of MIMO system to achieve maximum diversity gain. During signal transmission all the intended users are considered as the interference for that particular used. Let $N_{M,u}$ denotes the number of antennas for the u[th] user. For the u th user signal $\widetilde{x}_u \in C^{N_{M,u}} \times 1$, the received signal $y_u \in C^{N_{M,u \times 1}}$ is given as

$$y_u = H_u^{DL} \sum_{k=1}^{K} W_k \widetilde{X_{k+}} Z_u \quad (7)$$

$$= H_u^{DL} W_u \widetilde{X_u} + \sum_{k=1, k\neq u}^{K} H_u^{DL} W_k \widetilde{X_k} + z_u \quad (8)$$

Where $H_u^{DL} \in C^{N_{M,u} \times N_B}$ is the channel matrix between BS and the u th user $W_u \in C^{N_B \times N_{M,u}}$ is the precoding matrix for the uth user, and additive term is noise vector. Consider the received signals for the three-user case (i.e.,K=3)

$$\begin{bmatrix} y_1 \\ y_2 \\ y_3 \end{bmatrix} = \begin{bmatrix} H_1^{DL} & H_1^{DL} & H_1^{DL} \\ H_2^{DL} & H_2^{DL} & H_2^{DL} \\ H_3^{DL} & H_3^{DL} & H_3^{DL} \end{bmatrix} \begin{bmatrix} W_1 \widetilde{X_1} \\ W_2 \widetilde{X_2} \\ W_3 \widetilde{X_3} \end{bmatrix} + \begin{bmatrix} z_1 \\ z_2 \\ z_3 \end{bmatrix} \quad (9)$$

$$= \begin{bmatrix} H_1^{DL} W_1 & H_1^{DL} W_2 & H_1^{DL} W_3 \\ H_2^{DL} W_1 & H_2^{DL} W_2 & H_2^{DL} W_3 \\ H_3^{DL} W_1 & H_3^{DL} W_2 & H_3^{DL} W_3 \end{bmatrix} \begin{bmatrix} \widetilde{X_1} \\ \widetilde{X_2} \\ \widetilde{X_3} \end{bmatrix} + \begin{bmatrix} z_1 \\ z_2 \\ z_3 \end{bmatrix} \quad (10)$$

Where $\{H_u^{DL} W_k\}$ form an effective channel matrix for the u th user receiver and the kth user transmit signal. In other words the interference –free transmission will be warranted as long as the effective channel matrix [7] in equation (10) can be block-diagonalized that is,

$$H_u^{DL} W_k = 0_{N_{M,u \times N_{M,u}}} \quad (11)$$

In order to meet the total transmit power constraint, the precoders $W_u \in C^{N_B \times N_{M,u}}$ must be unitary, u=1, 2,…., k. Under the condition of equation (11) the received signal equation (8) is now interference-free, that is given by

$$y_u = H_u^{DL} W_u \widetilde{X_u} + z_u \quad (12)$$

Once we construct the interference-free signals in equation (12), various signal detection methods can be used to estimate the original signal [8].

IV. SIMULATION AND RESULTS

The simulation results for the linear precoding in multi-user MIMO systems are presented in this section. The plot between bit-error rate (BER) and signal to noise ratio (SNR) are simulated. QPSK modulation scheme is used for transmission.

The graph is drawn between bit error rates (BER) and signal to noise ratio (SNR) by using these parameters.

Table.1. Different parameters for performance of linear precoding

FRAMES	10
PACKETS	250
TRANSMITTING AND RECEIVING ANTENNAS	4,2
BITS PER QPSK SYMBOL	2
ACT_USER	20

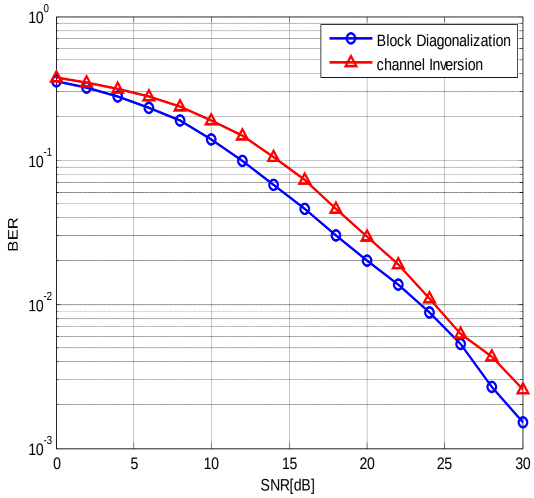

Figure.3. BER versus SNR [dB] for linear precoding

V.CONCLUSIONS

In this paper performance of channel inversion (CI) and block diagonalization (BD) are evaluated. It is observed that block diagoanalization has better performance than channel inversion. The block diagonalization (BD) method breaks down the MU-MIMO channel into multiple single-user MIMO parallel and orthogonal channels using singular value decomposition (SVD) in order to cancel interference using the null space.

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