

# BER Performance Comparison of Channel Inversion and Regularized Channel Inversion Methods for Multi-user MIMO System

<sup>1</sup>Dalveer Kaur, <sup>2</sup>Neeraj Kumar

Assistant Professor, Electronics and Communication Engineering,

<sup>1</sup>Punjab Technical University, Jalandhar, <sup>2</sup>Meerut Institute of Engineering and Technology, Meerut

<sup>1</sup>dr\_dogra@rediffmail.com, <sup>2</sup>iet\_neeraj@yahoo.com

**Abstract**— In multi-user multiple input multiple output (MU-MIMO) system, the main difficulty in data transmission in broadcast channel (BC) is that the desired signal is affected by other user signals. So, interference cancellation at base station (BS) is required. In this paper, channel inversion and regularized channel inversion techniques are considered to cancel inference due to other signals. This paper discusses the performance comparison of channel inversion and regularized channel inversion in term of bit error rate (BER).

**Keywords**—Multiuser MIMO, BER, Interference, Broadcast channel (BC), Multiple access channel (MAC)

## I. INTRODUCTION

Multi-Input multi output (MIMO) systems have drawn a lot of attention in the past few years due to achieve high throughput in wireless communication system. Antenna systems which employ multiple antennas at both the base station (BS) and mobile station (MS), operating in space time, have been proposed and demonstrated to significantly increase system performance as well as capacity. The most important advantage of using multiple antennas or space diversity is that no bandwidth expansion or increase in transmitted power is required for capacity and performance improvement. The research on MIMO systems are extended to multiuser MIMO systems which can be classified as multi user MIMO broadcast channel and multi user MIMO multiple access channel(MAC).This paper focused only on multi user MIMO broadcast channel because the main difficulty in BC is that the desired signal is effected by other users signals. This paper, channel inversion and regularized channel inversion methods are used to cancel interference due to other users and give the performance comparison of both method in terms of BER [1].

## II. MULTI USER MIMO COMMUNICATION SYSTEM

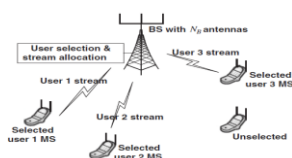


Fig. 1. Multi-user MIMO communication system: K= 4

Fig. 1 shows a typical multi-user communication environment in which the multiple mobile stations are served by a single base station in the cellular system. Three out of four users are selected and allocated communication resource such as time, frequency, and spatial stream. Suppose that the base station and each mobile station are equipped with  $N_B$  and  $N_M$  antennas, respectively. As  $K$  independent users form a virtual set of  $K \cdot N_M$  antennas which communicate with a single BS with  $N_B$  antennas, the end-to-end configuration can be considered as a  $(K \cdot N_M) \cdot N_B$  MIMO system for downlink, or  $N_B (K \cdot N_M)$  MIMO system for uplink. In this multi-user communication system, multiple antennas allow the independent users to transmit their own data stream in the uplink (many-to-one) at the same time or the base station to transmit the multiple user data streams to be decoded by each user in the downlink (one-to-many). This is attributed to the increase in degrees of freedom with multiple antennas as in the single-user MIMO system. In the multi-user MIMO system, downlink and uplink channels are referred to as broadcast channel (BC) and multiple access channel (MAC), respectively. Since all data streams of  $K$  independent users are available for a single receiver of the base station in the multiple access channels, the multi-user MIMO system is equivalent to a single user  $(K \cdot N_M) \cdot N_B$  MIMO system in the uplink. Similar to the single-user MIMO system, therefore, it can be shown that the uplink capacity of multi-user MIMO system is proportional to  $\min(N_B, K \cdot N_M)$  [2].

## III. MATHEMATICAL MODEL FOR MULTI USER MIMO SYSTEM

Consider  $K$  Independent users in the multi-user MIMO system. We assume that the BS and each MS are equipped with  $N_B$  and  $N_M$  antennas, respectively. Figure 2 shows the uplink channel, known as a multiple access channel (MAC) for  $K$  independent users. Let  $x_u$  and  $y_{MAC}$  denote the transmit signal from the  $u^{\text{th}}$  user,  $u = 1, 2, \dots, K$ , and the received signal at the BS, respectively. The channel gain between the  $u^{\text{th}}$  user MS and BS is represented by  $H_u^{UL}$ ,  $u = 1, 2, \dots, K$ . The received signal is expressed as

$$y_{MAC} = H_1^{UL} x_1 + H_2^{UL} x_2 + \dots + H_K^{UL} x_K + z \quad (1)$$

$$(2) \quad = \begin{bmatrix} H_1^{UL} + H_2^{UL} + \dots \dots \dots H_K^{UL} \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \\ \vdots \\ x_K \end{bmatrix} + z$$

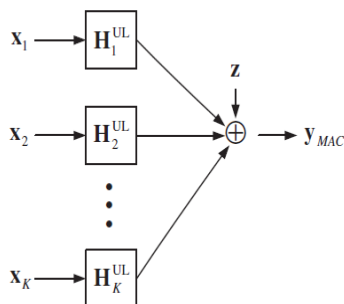


Fig. 2. Uplink channel model for multiuser MIMO system

Where  $z$  is the additive noise in the receiver and it is modeled as a zero-mean circular symmetric complex Gaussian (ZMCSCG) random vector.

On the other hand, Fig. 3 shows the downlink channel, known as a broadcast channel (BC) in which  $x$  is the transmit signal from the BS and  $y_u$  is the received signal at the  $u^{\text{th}}$  user,  $u = 1, 2, \dots, K$ . Let  $H_u^{\text{DL}}$  represents the channel gain between BS and the  $u^{\text{th}}$  user. In MAC, the received signal at the  $u^{\text{th}}$  user is expressed as

$$(3) \quad y_u = H_u^{\text{DL}} x + z_u \quad u = 1, 2, 3, \dots, K$$

where  $z_u$  is the additive ZMCSCG noise at the  $u^{\text{th}}$  user. Representing all user signals by a single vector, the overall system can be represented as [5].

$$(4) \quad \begin{bmatrix} y_1 \\ y_2 \\ \vdots \\ y_K \end{bmatrix} = \begin{bmatrix} H_1^{\text{DL}} \\ H_2^{\text{DL}} \\ \vdots \\ H_K^{\text{DL}} \end{bmatrix} x + \begin{bmatrix} z_1 \\ z_2 \\ \vdots \\ z_K \end{bmatrix}$$

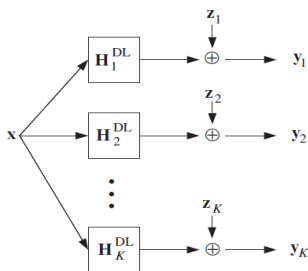


Fig. 3. Downlink channel model for multiuser MIMO system

#### IV. TRANSMISSION MODELS FOR BROADCAST CHANNEL

The main difficulty in data transmission in BC is that the coordinated signal detection on the receiver side is not straightforward, and thus, interference cancellation at BS is required. In this paper, we consider two transmission methods: channel inversion and regularized channel inversion.

##### A. Channel Inversion

In this section, we assume  $N_M = 1$  for all users and  $K = N_B$ . Let  $\tilde{x}_u$  note the  $u^{\text{th}}$  user signal while  $H_u^{\text{DL}}$  denotes the channel gain between BS and the  $u$  user,  $u = 1, 2, \dots, K$ . The received signal of the  $u^{\text{th}}$  user can be expressed as

$$(5) \quad y_u = H_u^{\text{DL}} \begin{bmatrix} \tilde{x}_1 \\ \tilde{x}_2 \\ \vdots \\ \tilde{x}_K \end{bmatrix} + z_u, \quad u = 1, 2, \dots, K$$

The received signals of all users can be represented as

$$(6) \quad \begin{bmatrix} y_1 \\ y_2 \\ \vdots \\ y_K \end{bmatrix} = \begin{bmatrix} H_1^{\text{DL}} \\ H_2^{\text{DL}} \\ \vdots \\ H_K^{\text{DL}} \end{bmatrix} \begin{bmatrix} \tilde{x}_1 \\ \tilde{x}_2 \\ \vdots \\ \tilde{x}_K \end{bmatrix} + \begin{bmatrix} z_1 \\ z_2 \\ \vdots \\ z_K \end{bmatrix}$$

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 techniques such as channel inversion and regularized channel inversion can be considered.

Channel inversion is the same processing as the ZF pre-equalization, the only difference is that  $H$  in equation (8) is replaced with  $H^{\text{DL}}$  [3, 4].

##### 1) Pre-equalization:

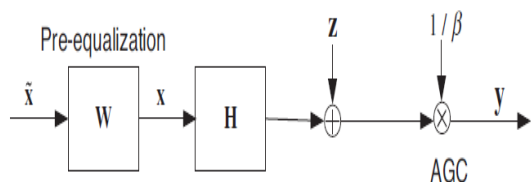


Fig. 4. Pre-equalization process

The pre-equalization can be represented by a pre-equalizer weight matrix  $W$  and thus, the precoded symbol vector  $x$  can be expressed as

$$X = W \tilde{x} \quad (7)$$

where  $\tilde{x}$  is the original symbol vector for transmission. In case where the zero-forcing (ZF) equalization is employed, the corresponding weight matrix (assuming that the channel matrix is square) is given as

$$W_{ZF} = \beta H^{-1} \quad (8)$$

Where  $\beta$  is a constant to meet the total transmitted power constraint after pre-equalization and it is given as

$$\beta = \sqrt{\frac{N_T}{\text{Tr}(H^{-1}(H^{-1})^H)}}$$

To compensate for the effect of amplification by a factor of  $\beta$  at the transmitter, the received signal must be divided by  $\beta$  via automatic gain control (AGC) at the receiver. The received signal  $y$  is given by [4].

$$\begin{aligned} y &= \frac{1}{\beta} (HW_{ZF} \tilde{x} + z) \\ &= \frac{1}{\beta} (H\beta H^{-1} \tilde{x} + z) \\ &= \tilde{x} + \frac{1}{\beta} z \end{aligned} \quad (9)$$

### B. Regularized Channel Inversion

Other than ZF pre-equalization, MMSE pre-equalization can also be used. In this case, the weight matrix is given as

$$\begin{aligned} W_{MMSE} &= \beta \times \arg \min_W E \left\{ \|\beta^{-1}(HW\tilde{x} + z) - \tilde{x}\|^2 \right\} \\ &= \beta \times H^H \{HH^H + (\sigma_z^2 / \sigma_x^2) I\}^{-1} \end{aligned} \quad (10)$$

where the constant  $\beta$  is used again to meet the total transmitted power constraint.  $W_{MMSE}$  can find by replacing  $H^{-1}$  with  $H^H \{HH^H + (\sigma_z^2 / \sigma_x^2) I\}^{-1}$ .

Regularized channel inversion is the same processing as the MMSE pre-equalization, the only difference is that  $H$  in equation (10) is replaced with  $[6 H^{DL}]$ . Fig.4. shows that the BER performance of channel inversion method for  $N_B = 4$ ,  $N_M = 1$ , in which four users with highest channel norm values are selected out of  $K=20$ .

## V. SIMULATION RESULTS

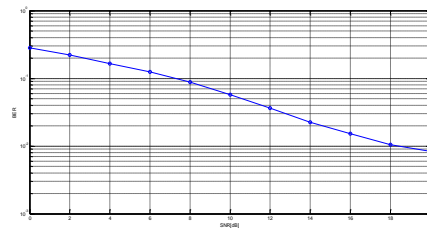


Fig.5. BER performance of channel inversion method

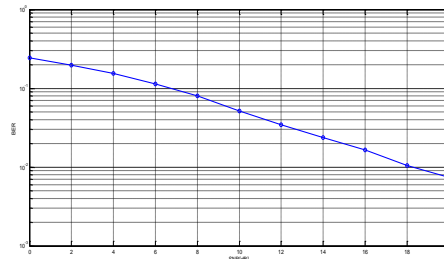


Fig.6. BER performance of regularized channel inversion method

Fig.6 shows that the BER performance of regularized channel inversion method for  $N_B = 4$ ,  $N_M = 1$ , in which four users with highest channel norm values are selected out of  $K=20$ .

## VI. CONCLUSION

The presented results show that the regularized channel inversion achieves better BER performance than the channel inversion method.

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