

BER Performance Analysis of Pre-MMSE Equalizer for MIMO System

Shivkaran Meghwal

Lecturer(ECE Department), Government Polytechnic College, Dungarpur, Rajasthan, India

Abstract: This paper investigates the performance analysis of linear ZF/MMSE and pre-minimum mean square error (MMSE) applied to wireless multi-input multi-output (MIMO) system. Here the numbers of transmitters are equal to receivers [1]. Fading and interference effects can be combated with equalizers. The bit error rate characteristics for different MIMO matrices are simulated. Channel state information for the spatial-multiplexing system is used. Paper is focused on linear pre-equalization method. It demonstrates that pre-MMSE equalizer improves the BER performances.

Keywords: Multi-Input Multi-Output (MIMO), Minimum Mean Square Error (MMSE), Zero-Forcing(ZF), Bit Error Rate (BER), Inter Symbol Interference(ISI), Channel State Information(CSI)

1. Introduction

Wireless is an emerging field, which has been enormous growth in last several years. The frequency spectrum is the scarce resource for wireless communication system and the rapid increase of wireless application has demanded the new techniques to achieve high spectral efficiency [2]. The multiple-input multiple-output (MIMO) system utilizes the spectral diversity to increase the data rate and spectral efficiency. The multiple-input multiple-output (MIMO) system improves the performances in terms of capacity and bit error rate (BER) [3]. The major challenge to design the system is the high complexity in data detection at the receiver.

The knowledge of channel state information (CSI) is an important factor for acceptable system operation. Transmitter and Receiver Channel state information (CSI) can be used at the transmitter, receiver or both sides, depending upon MIMO architecture [4]. In the literature, there are various MIMO detection techniques. The linear equalization –based MIMO detection includes the zero-forcing (ZF) and minimum–mean square error (MMSE). The main advantage of linear detection is its low complexity and simplicity. This paper is focus on linear receiver scheme. Among these schemes, the MMSE receiver is a good choice. It offers better performance than zero forcing. The main feature of MMSE equalizer is that it does not eliminate ISI completely but, minimizes the total power of the noise and ISI components in the output. A transmitter does not have direct access to its own channel state information. Therefore, some indirect means are required for the transmitter. In time division duplexing (TDD) system, it can exploit the channel reciprocity between opposite links (downlink and uplink). Based on the signal received from the opposite direction, it follows for indirect channel estimation In frequency division duplexing (FDD) system, which usually does not have reciprocity between opposite directions, the transmitter relies on the channel feedback information a from the receiver. In other words, CSI must be estimated at the receiver side and then, fed back to the transmitter side.

2. Mathematical Model For Linear Pre-Equalization [5]

CSI can be exploited at the transmitter for spatial-multiplexing MIMO system. For exploiting CSI, the number of receiver must be equal or greater than number of transmitter. There are various possible methods that use CSI for the spatial-multiplexing system, this paper focus on linear pre-equalization method. As shown in figure 1, it employs pre-equalization on the transmitter side, which is equivalent to pre-coding.

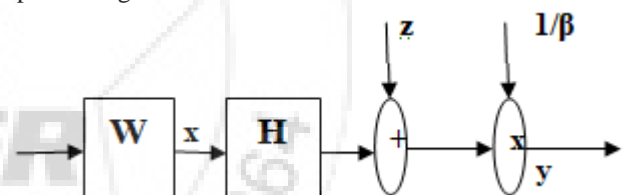


Figure 1: Pre-equalization [5]

In figure 1. The pre-coded symbol can be expressed as

$$x = W\tilde{x} \quad (1)$$

Where \tilde{x} is the original vector for transmission. If the zero-forcing (ZF) equalization is employed, the corresponding weight matrix is given as

$$W_{ZF} = \beta H^{-1} \quad (2)$$

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

$$\beta = \sqrt{\frac{N_T}{\text{Tr}(H^{-1}(H^{-1})^H)}} \quad (3)$$

To compensate for the effect of amplification by a factor of β at the transmitter, the received signal must be divided by β via automatic gain control (AGC) at the receiver as shown in figure 1. The received signal y is given by

$$\begin{aligned} y &= 1/\beta(HW_{ZF}\tilde{x} + z) \\ &= \frac{1}{\beta}(H\beta H^{-1}\tilde{x} + z) \\ &= \tilde{x} + \frac{1}{\beta}z \\ &= \tilde{x} + \tilde{z} \end{aligned} \quad (4)$$

Equation (4) is the output of ZF pre-equalization.

The weight matrix for MMSE pre-equalization is given by[6]

$$W_{MMSE} = \beta \times \arg_w \min E\{\|\beta^{-1}(HW\tilde{x} + z) - \tilde{x}\|^2\}$$

$$= \beta \times H^H \left(HH^H + \frac{\sigma_z^2}{\sigma_x^2} \right)^{-1} \quad (5)$$

Where the constant is used again to meet the total transmitted power constraints. It is calculated by equation (3). It is observed that pre-equalization scheme on the transmitter side outperforms the receiver side equalization. It is also observed that the receiver side equalization suffers from noise enhancement in the course of equalization.

Simulations And Design (A) for linear-ZF, linear-MMSE and PRE-MMSE

For simulations, matrix is taken with perfect channel state information at the receiver [6]. QPSK modulation scheme is used for transmission. Equal power allocation is considered for all antennas at the transmitter.

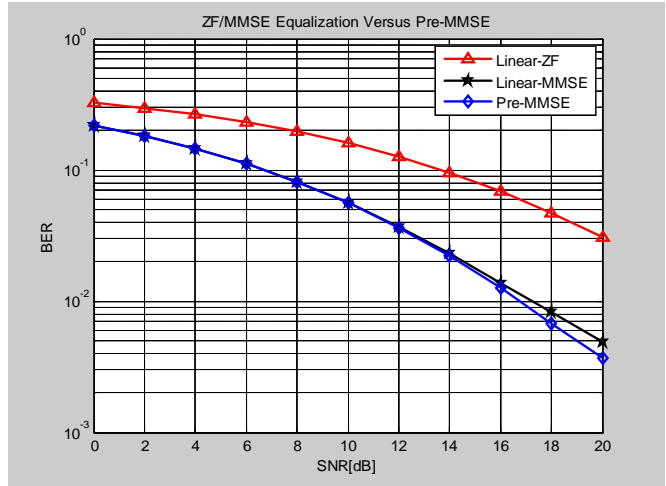


Figure 2: BER Performance at receiver side ZF/MMSE equalization vs. Pre-MMSE equalization

Table 1: Design specifications for Different pre-equalization methods

No. Of Frames	150
No. Of Packets	1500
No. Of Bits Per Symbol	2
No. Of Transmitting Antenna	4
No. Of Receiving Antenna	4

(B) For PRE-MMSE Transmission

For simulation of Pre-MMSE transmission, different matrices 4x4, 3x3 and 2x2 are taken. Matrices are taken with perfect channel information at the receiver. QPSK modulation scheme is used for transmission. Equal power allocation is considered for all antennas at the transmitter [7].

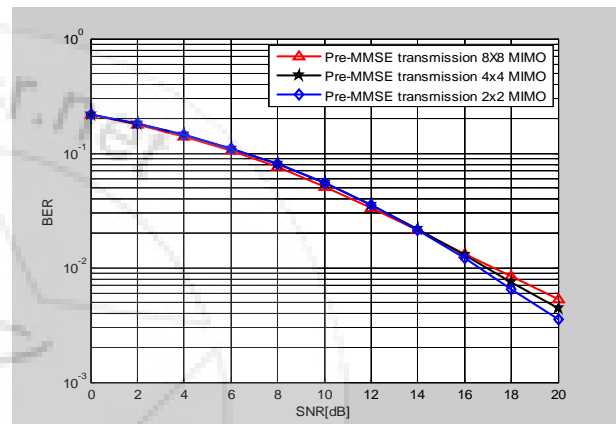


Figure 3: BER Performance of Pre-MMSE at 2 number of bits per symbol

Table 1: Design specifications for Different pre-equalization methods

No. Of Frames	150
No. Of Packets	1500
No. Of Bits Per Symbol	2,3,4
No. Of Transmitting Antenna	2,3,4
No. Of Receiving Antenna	2,3,4

3. Results

Bit error rate analysis is done for 4x4 matrix for Linear-ZF, Linear-MMSE, and Pre-MMSE. The simulation is done between 0 to 20 dB. The number of iteration is 1000. Figure 2 shows the performance comparison of receiver side ZF/MMSE equalization versus Pre-MMSE equalization at transmitter. Simulation result shows that value of BER at SNR[dB] of 18dB is .0519, .0085 and .0082 for Linear-ZF, Linear-MMSE and Pre-MMSE.

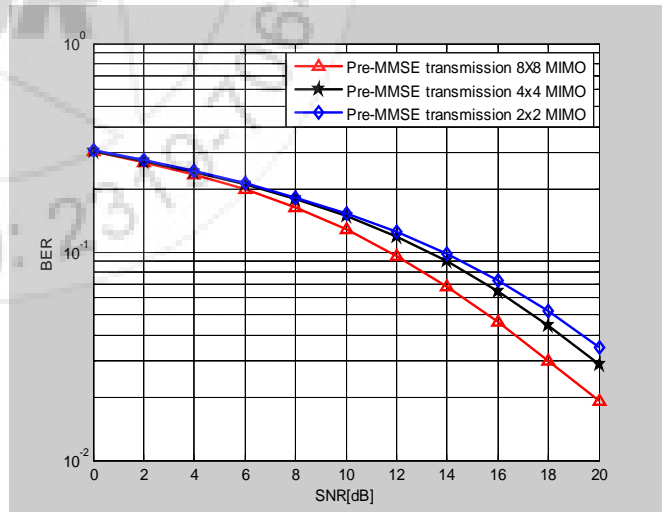


Figure 4: BER Performance of Pre-MMSE at 3 number of bits per symbol.

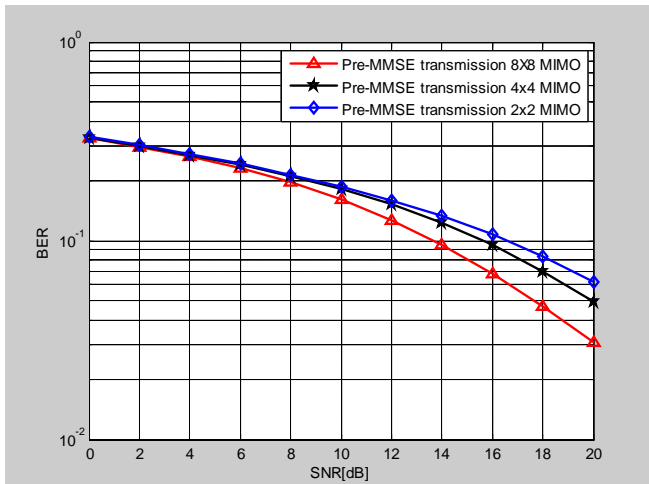


Figure 5: BER Performance of Pre-MMSE at 4 number of bits per symbol.

Analysis shows that Pre-MMSE improves the BER performance compared to Linear-ZF and Linear-MMSE.

4. Conclusion

From the analysis it is concluded that system has better bit error performances when Pre-MMSE equalization is used. Pre-equalization scheme on the transmitter side outperforms the receiver side equalization.

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