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COMPARISON BETWEEN MLD AND ZF ALGORITHMS FOR MIMO WIRELESS SYSTEM AT RAYLEIGH CHANNEL

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ABSTRACT

In this paper, the performance of the Multiple Input Multiple Output (MIMO) technique evaluated in term of Bit Error Rate (BER) with respect to Signal to Noise Ratio (SNR) by using Binary Phase Shift Keying (BPSK) modulation for two algorithms Maximum Likelihood (MLD) and Zero-Forcing (ZF) with different configurations of antennas array in Rayleigh and Additive White Gaussian Noise (AWGN) channels. The results were compared between them to determine which of the numbers antenna elements are suitable in the transmitter and receiver of each algorithm. The results of MLD offers a better configuration when 4×4 and 3×4 antennas array were used, while the ZF remains the same performance for the 2×2, 3×3 and 4×4 configurations. In different numbers of antennas, the best performance of ZF is got when the number of transmitter and receiver antennas are equal to 2×4 respectively. Also, the last one is better than the 4×4 and 3×4 configurations of MLD algorithm.

KEYWORDS: Multiple Input Multiple Output (MIMO); Zero Forcing (ZF); Maximum Likelihood (ML).

1. INTRODUCTION

One of the technologies that have made a significant advance in wireless communications is the MIMO technology. In fact, MIMO has been used to increase the capacity of wireless communications as a result of increasing demand at present (Samundiswary and Rav, 2013). This technology offers high throughput, enhance link reliability, and wide system coverage area by applying multiple antenna elements at the source and destination sides (Rohit and Amit, 2012). As an example of techniques that supports data transfer speed is Orthogonal Frequency Division Multiplexing (OFDM), MIMO and Adaptive Modulation (AM) (Ming and Lajos, 2007). Because the weakness of the path between the source and the destination as a result of fading, the received signal will have higher BER. MIMO used to transfer more data, because the data signals separated equally between each antenna element and transmitted at the same time and frequency domain to the receiver, thereby increasing channel capacity and eliminates the problem caused by multipath wave propagation. MIMO makes antennas operate intelligently by collecting of the transmitted signal incoming from various paths and different times to raise the effectiveness of the receiver signal. It provides the highest capacity, and productivity while improving Quality of Service (QoS) without increasing in the transmitted power (Kirthiga and Jayakumar, 2012). In this paper, the MIMO technique algorithms were investigated to test their performance in the different number of antennas in the transmitter and receiving sides and to give the suitable antennas in terms of performance for each algorithm. This paper is organized as follows:

In section 2, gives the overview of the MIMO transmitter and receiver system description. Section 3, discusses the Rayleigh channel. Section 4, discusses the algorithms of the MIMO Systems. Section 5, simulation results and discussion. Section 6, conclusion and Section 7, Reference.

2. MULTIPLE INPUT MULTIPLE OUTPUT TECHNIQUE

It has been demonstrated that: by utilizing MIMO is possible to boost the ability to a high extent. In the MIMO system, different signals are sent from each transmit element through the Rayleigh channel to be collected at receiver’s elements cumulatively from all transmitter elements. Independent information signals are divided into equal sections which have the same number of the transmitted elements. At the receiver, each received signal separated from each other by solving a linear equation system as shown in Fig. 1. The receiver uses two algorithms (MLD and ZF) to recover the information signal (Ali and et.al. 2013). In this model, the modulation BPSK will be used with the Rayleigh fading channel. The demonstration of the general equation of 2×2 MIMO transmission in the presence of the channel model and the noise is represented as follows:

$$y_1 = h_{11}x_1 + h_{12}x_2 + n_1 \qquad 1$$

$$y_2 = h_{21}x_1 + h_{22}x_2 + n_2 \qquad 2$$

$$\begin{bmatrix} \mathrm{y}_1 \\ \mathrm{y}_2 \end{bmatrix} = \begin{bmatrix} \mathrm{h}_{1,1} & \mathrm{h}_{1,2} \\ \mathrm{h}_{2,1} & \mathrm{h}_{2,2} \end{bmatrix} \begin{bmatrix} \mathrm{x}_1 \\ \mathrm{x}_2 \end{bmatrix} + \begin{bmatrix} \mathrm{n}_1 \\ \mathrm{n}_2 \end{bmatrix} \qquad 3$$

Eq. 3 represents a matrix notation for the Eqs. 1 and 2. Where the received signal on the first and second element represented by y_1, y_2, $h_{i,j}$ is the coefficient of the channel path from ith radiated antenna element to jth collected antenna element, and the second term 'n' is the AWGN term in the receiving antenna.

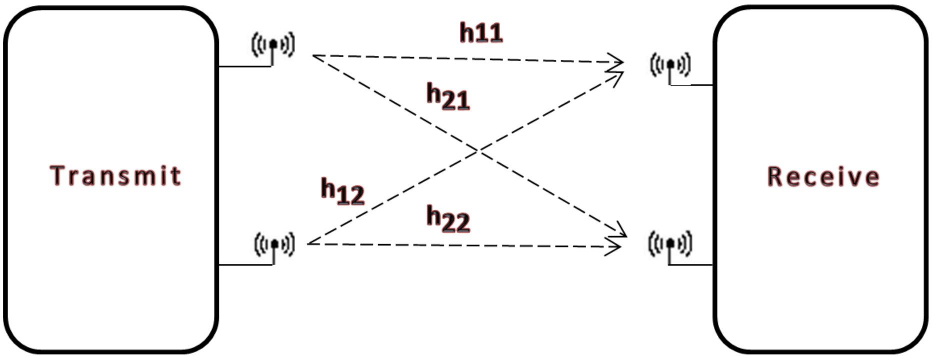

Fig. 1. MIMO 2×2 configuration and channel model.

3. RAYLEIGH CHANNEL

A small-scale fading that produced by multiple signal paths between the sender and the destination is discussed in this section. When the transmitted is a Single Input Single Output (SISO) wireless channel, the signal will be affected by the impediments of the surrounding environment to produce multiple time and amplitude versions of the signal in the receiving stage as shown in Fig. 2 (Thrimurthulu and Murti, 2017), where x(t) is the input and r(t) is the output from the Linear Time Varying (LTV) channel. The final result of the received signal can be described by the Eq. 4.

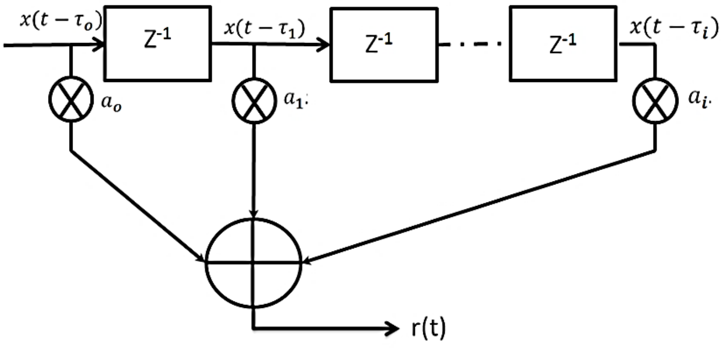

Fig. 2. Impulse response of the wireless channel.

$$r(t) = Re\left\{\sum_{i=0}^{N-1} a_i s(t-\tau_i)\, e^{-j2\pi f_c \tau_0} e^{j2\pi f_c t}\right\} \qquad 4$$

Where the r(t) is the received signal, a_i is an attenuation coefficients of each path, s(t) is the baseband transmitted data, τ_i is the delay time of each path, $e^{j2\pi f_c t}$ is the modulation carrier frequency.

If assuming the data rate (f_b) is much smaller than carrier frequency (f_c) then $s(t) \cong s(t-\tau_i)$. Thus, the Eq. 4 can be written as in the following:

$$r(t) = Re\left\{s(t) \sum_{i=0}^{N-1} a_i\, e^{-j2\pi f_c \tau_0} e^{j2\pi f_c t}\right\} \qquad 5$$

After a demodulation process, the demodulated signal $(Z(t))$ will become as in Eq. 6.

$$Z(t) = s(t) \sum_{i=0}^{N-1} a_i\, e^{-j2\pi f_c \tau_0} \qquad 6$$

From Eq. 6 the term $\sum_{i=0}^{N-1} a_i\, e^{-j2\pi f_c \tau_0}$ will represent the response of the wireless channel and denoted by term (h). So that if the signal transmitted from multiple antennas then each signal will has its channel response in respect of each receiver antenna.

4. ALGORITHMS

The mathematical model of the algorithms that used to build the MIMO technique will be presented in this section.

4.1. Zero Forcing Algorithm

The ZF equalizer easy and always considered as a reference with other equalizers. In this algorithm, the main drawback is a noise enhancement during interference rejection process (Cheng Wang and Edward, 2007). The ZF response for meeting linear detection constraint is given by:

$$\mathrm{W_{ZF}} = (\mathrm{H^H H})^{-1}\mathrm{H^H} \qquad 7$$

Where $\mathrm{W_{ZF}}$ is the equalization coefficient of the wireless channel.

4.2. Maximum likelihood Algorithm

The MLD algorithm is an optimum equalizer with a high complexity and high error reduction because it compares the received signal with all the potential vectors that are transmitted. The ML algorithm computes the Euclidean distance between the received symbol and all probable transmitted symbols to get an approximation of the symbol (Mayank, et. al., 2012). The Euclidean distance can be calculated to each sample in sample space as following (Xu, 2017):

$$\mathrm{J} = |y - Hx|^2 \tag{8}$$

$$\mathrm{J} = \left|\begin{bmatrix} y1 \\ y2 \end{bmatrix} - \begin{bmatrix} h1{,}1 & h1{,}2 \\ h2{,}1 & h2{,}1 \end{bmatrix} \begin{bmatrix} \hat{x} \\ \hat{x} \end{bmatrix}\right|^2 \tag{9}$$

$$\mathrm{J}_{+1,+1} = \left|\begin{bmatrix} y1 \\ y2 \end{bmatrix} - \begin{bmatrix} h1{,}1 & h1{,}2 \\ h2{,}1 & h2{,}1 \end{bmatrix} \begin{bmatrix} +1 \\ +1 \end{bmatrix}\right|^2 \tag{10}$$

$$\mathrm{J}_{+1,-1} = \left|\begin{bmatrix} y1 \\ y2 \end{bmatrix} - \begin{bmatrix} h1{,}1 & h1{,}2 \\ h2{,}1 & h2{,}1 \end{bmatrix} \begin{bmatrix} +1 \\ -1 \end{bmatrix}\right|^2 \tag{11}$$

$$\mathrm{J}_{-1,+1} = \left|\begin{bmatrix} y1 \\ y2 \end{bmatrix} - \begin{bmatrix} h1{,}1 & h1{,}2 \\ h2{,}1 & h2{,}1 \end{bmatrix} \begin{bmatrix} -1 \\ +1 \end{bmatrix}\right|^2 \tag{12}$$

$$\mathrm{J}_{-1,-1} = \left|\begin{bmatrix} y1 \\ y2 \end{bmatrix} - \begin{bmatrix} h1{,}1 & h1{,}2 \\ h2{,}1 & h2{,}1 \end{bmatrix} \begin{bmatrix} -1 \\ -1 \end{bmatrix}\right|^2 \tag{13}$$

Where Eqs. 8 and 9 represent the distance of received sample point in constellation from each element in sample space and Eqs. 10 to 13 represent the Euclidean distance for each individual possible sample $(+1, +1,\ +1, -1,\ -1, +1,\ +1, -1)$.

5. RESULTS AND DISCUSSION

In simulation of MIMO antenna system, the BPSK modulation is used for data transfer in Rayleigh channel. In the receiver, MLD and ZF algorithms are used for data detection. Different and equal numbers of antenna elements at transmitter and receiver have been investigated for each algorithm. . The two algorithms had simulated by using MATLAB. From Fig. 3, the evaluation of the MLD algorithm in Rayleigh channel was compared using equal antenna elements. When the number of antenna elements on both sides is equal, we find the performance of 4×4 giving the best performance at Eb/No <15dB with a maximum data rate and the performance of 2×2 giving the best performance at Eb/No >15dB but it will give a low data rate.

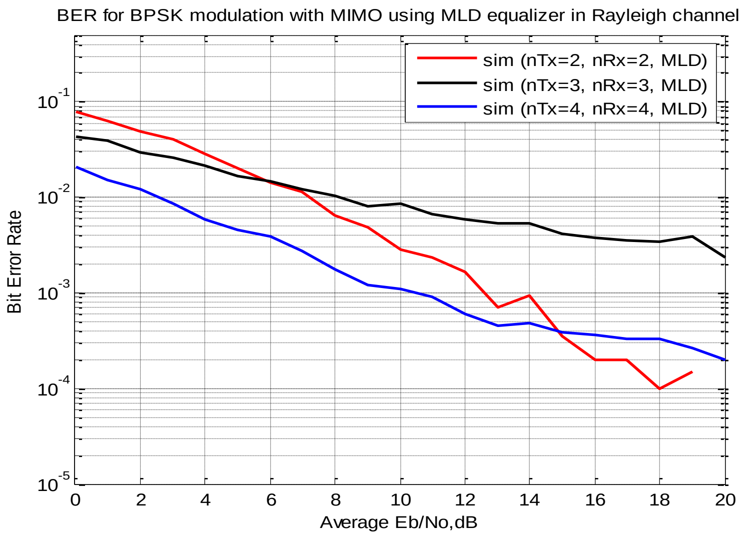

Fig. 3. The BER performance of MLD algorithm for equal number of antenna elements.

From Fig. 4, the evaluation of the MLD algorithm in Rayleigh channel was compared using different antenna elements. When the number of antenna elements on both sides is different, we find the performance of 3×4 and 2×4 giving the best performance with the same performance approximately. The 3x4 MIMO has the best performance and data rate.

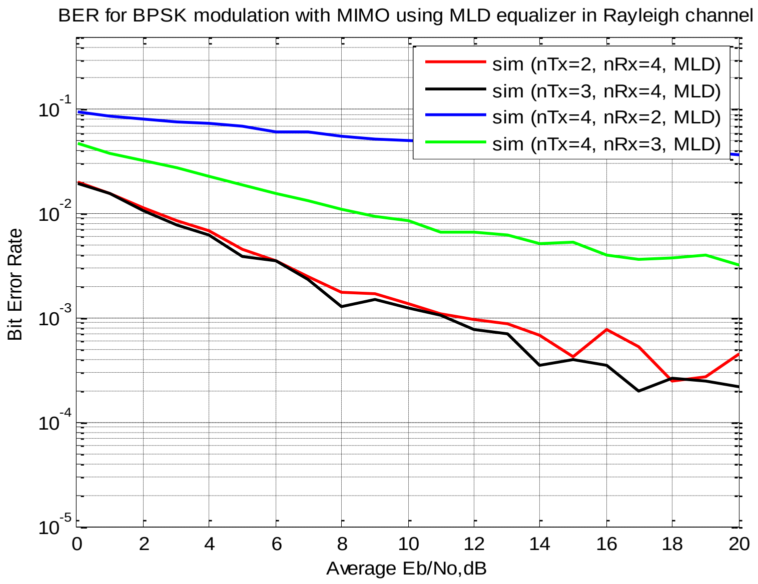

Fig. 4. The BER performance of MLD algorithm for different number of antenna elements.

From Fig. 5, provides the evaluation of the ZF algorithm in Rayleigh channel using equal antenna elements (2x2, 3x3 and 4x4). Each of them has the same performance. It is apparent that the 4x4 MIMO network has the best data rate but it has a lower performance than (4×4, 3×4 and 2×4) configurations of the MLD algorithm.

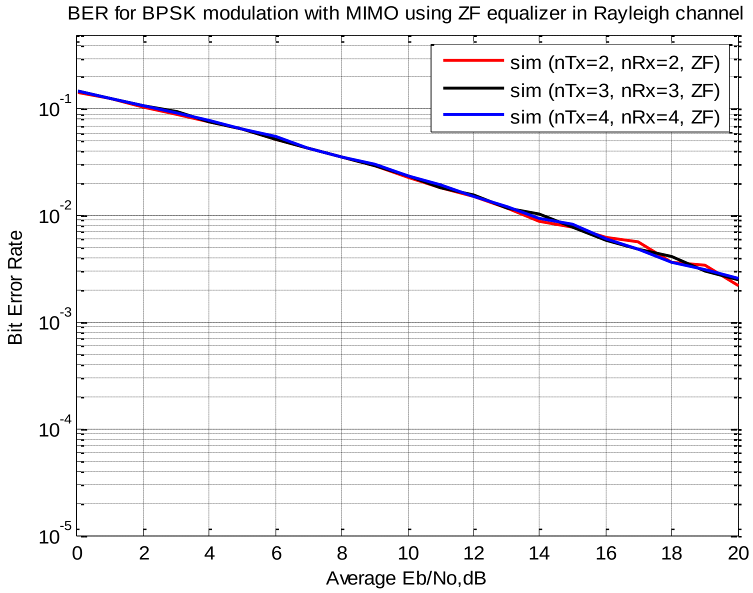

Fig. 5. The BER performance of ZF algorithm for equal number of antenna elements.

In Fig. 6, there is a significant performance of the ZF algorithm in Rayleigh channel for 2x4 MIMO network when compared with the performances of the 3x4, 4x2 and 4x3. The performance of ZF at Eb/No ≥12 dB gives error free. In the case of 4x2 and 4x3 MIMO networks, there is no acceptance in the value of their BER.

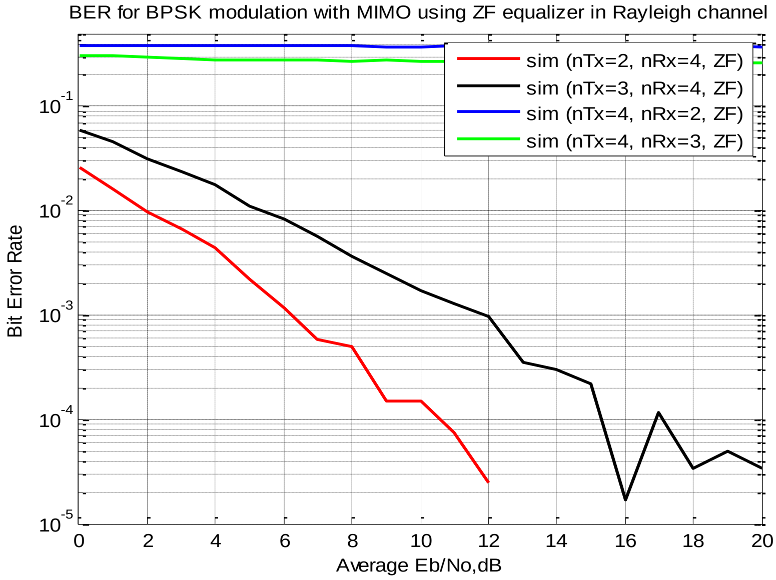

Fig. 6. The BER performance of ZF algorithm for different number of antenna elements.

In Fig. 7, the performance of the ZF and the MLD algorithms in Rayleigh channel for a different number of antennas 2x4, 3x4, 4x3 and 4x2. The graph shows that the best BER case is 2x4 for the ZF except at Eb/No =1 dB, where the best in this case is 2x4 and 3x4 for the MLD.

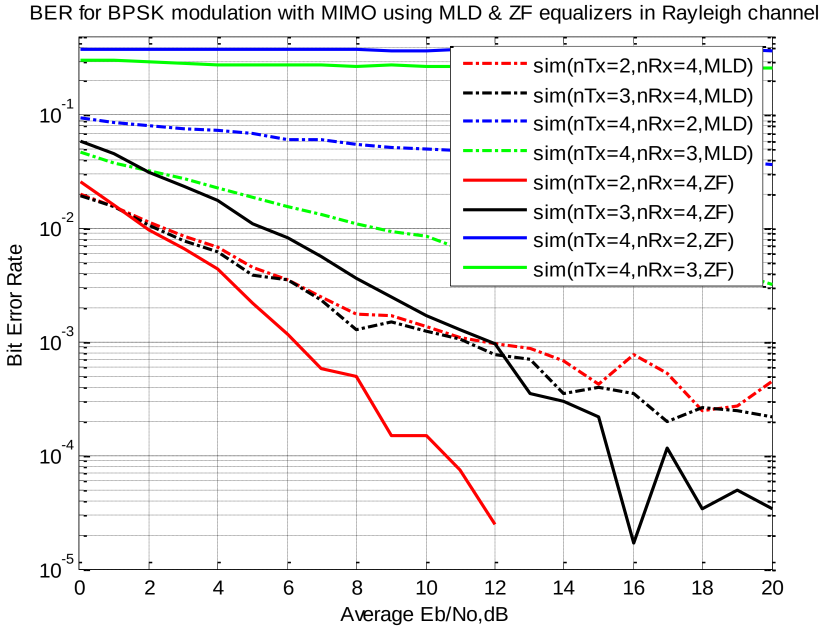

Fig. 7. The average BER performance for Comparison results between MLD and ZF algorithm in Rayleigh channel for (2x4), (3x4), (4x3) and (4x2) MIMO system.

In Fig. 8, the performance of the ZF and the MLD algorithms in Rayleigh channel for the same number of antenna elements 2x2, 3x3 and 4x4. The best BER case is 4x4 for MLD algorithm. But at Eb/No ≥15 dB the 2x2 for MLD algorithm overcome the 4x4 case.

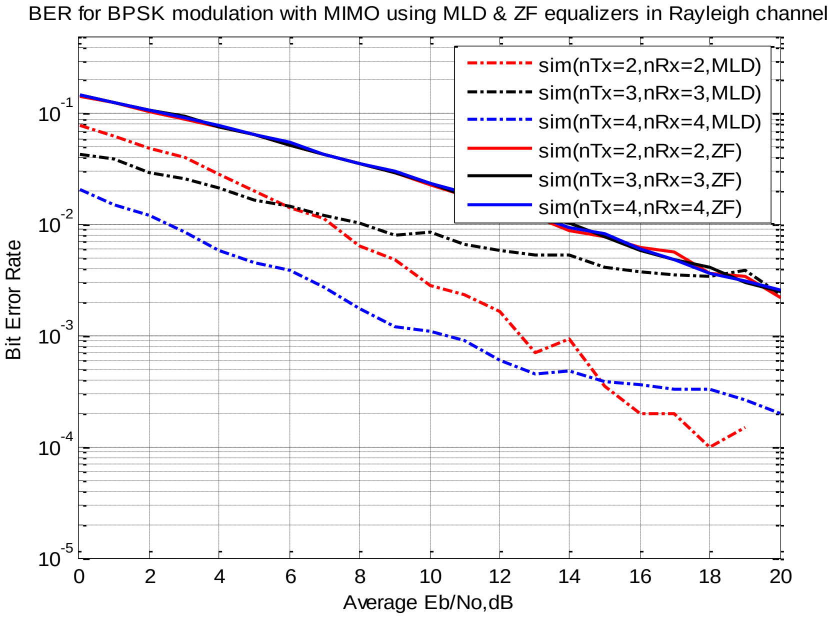

Fig. 8. The average BER performance for Comparison results between MLD and ZF algorithms in Rayleigh channel for (2x2), (3x3) and (4x4).

6. CONCLUSION

The results of this study explain the performance of the two algorithms (MLD and ZF) at a different MIMO networks. They are used to study the BER for a various MIMO structures using a Raleigh channel with BPSK modulation. The BER is calculated and compared. When the antenna configuration is different between transmitter and receiver, 2×4 ZF algorithm achieved a highest BER performance. After SNR=12 dB, the performance 3×4 ZF algorithm will exceed the performance of 2×4 and 3×4 MLD algorithm. Therefore, it seems that when the number of receiver antenna elements is increased, the BER performance will increase and verse versa. Another important result, when the antenna configuration is equal in both sides, is the ZF algorithm will give a same performance in all cases at the equal antenna configuration between transmitter and receiver, while the ML algorithm has better performance in BER than ZF algorithm especially in the case of 2×2 and 4×4 configuration. It can be concluded that the 2×4 ZF has best in reducing the probability of error, but it has a lower data rate. The feature of ZF receivers has the benefit of reducing the complexity. However, since the multipath channel coefficients are huge, the noise components will be severe for the ZF receiver. Thus, ZF receiver will provide a lower performance. Therefore, MLD algorithm has optimized to reduce the probability of error because it matches the received sample with all reference samples.

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