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Study and Analysis in MIMO Wireless Channel for STBC and Equalization Techniques by Using Matlab

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Abstract: **The proposed research study analyzes several methods to achieve a higher data rate by using past wireless technologies and also enhancing the past technology by working on them and modifying them for achieving a better data flowing rate. This research work is focusing more on the multiple-inputs multiple-outputs(MIMO) system, and by using this system this research study aims to produce a higher data rate, higher data flowing channels by using multiplexing and diversity. Nowadays, wireless technology is on growing so for the future point of view, it is highly required to improve the current data flowing rate properties on the transceiver side. Here, by using both ends of the nodes, a higher data flowing capacity of the wireless system can be achieved with very negligible losses along with consistent quality performance while transporting the data packets from one door to another and getting a quick response through the channel that is modified by using spatial multiplexing and increasing it higher-level up. This spatial multiplexing help undamaged data packets to arrive at the link target as quickly as possible while transmission and due to this the higher data flowing rate can be achieved with a higher data gaining rate by only using the MIMO system. Based on past communication technologies, this study has have determined that Alamouti STBC and ZF equalizer is the best remedy for the analysis of MIMO system to calculate communication diversity including the helping hands of BPSK modulation technique for achieving a better quality result. The Alamouti STBC and ZF equalization technique is used to calculate the BER result and this would be the linear equalization technique that is used to find the receiver nodes on the transceivers. The most important key point is that, all the operations are performing on MATLAB.**

Keywords: STBC, ZFE, MMSE, MMSE-SIC, MMSE-SIC Sort, ZF-SIC, ZF-SIC Sort

I. INTRODUCTION

This paper is based on enhancing the wireless technology for the better achievement of a higher data transmitting rate or gaining rate. This study utilizes the MIMO system, which is the key system for this method. Also, this research work considers some important merits that are essential to include while doing this operation on the MIMO system. We are performing analysis on the MIMO system by using the Matlab simulation tool, which is considered as an analytic tool for this whole process of observing the data flowing rate with calculating the BER result of the MIMO system. How we can calculate this, let see. We need to collect better resources for the higher spectrum size but the problem is only with fading and interference. So we need to fulfil this problem for this our wireless technology is proposed a new technique to achieve the higher data transmission and gaining the data using MIMO system this is the new key system that used to achieve this higher data rate.

This new MIMO system has attracted the wireless industry to gain all possible permutation and combination of this useful system and build wireless technology that will fulfil the future need of human lives. So let see how this MIMO system is designed to achieve this higher amount of data rate. In this system, a transceiver can bind both transmitter and receiver with the multiple numbers of the node for both transmitter and receiver. According to a theoretical examination of this system, it allows for linear link capacity expansion and is exactly proportional to the rank of each channel in the system. As we are mentioned above there is one very important factor is the top peek spectral efficiency which is obtained using spatial multiplexing which helps to improve signal quality network quality also reducing data loss rate which is nearly negligible and converged can be achieved by spatial diversity. For dividing the data packets into multiple parallel sets we are using orthogonal frequency division multiplexing and this also helps to transmit separate subcarrier in reducing the data flowing and gaining rate this OFDM technique is also known by multiple carrier digital communication method.

We are also using the Alamouti STBC technique for analysis performance of the memory system this can be a remote advancement for digital modulation. Along with Alamouti STBC, we also are using three-technique for this whole analysis performance operation which is zero forcing equalizer, BPSK modulation. These three-technique also demonstrating the simulation of this Alamouti STBC for data transmission and estimating the result of bit error rate (BER). So the whole operation and process are to gain the BER for digital modulation of the MIMO using Matlab and also examine the analysis result by changing the numerical values of the important parameters of the MIMO system.

II. APPROACH TO METHODOLOGY

This proposed methodology utilizing BPSK modulation techniques for analyzing the Alamouti STBC scheme. As we can see the proposed methodology for Alamouti STBC in form of a block diagram. In this method, we have to produce a range of 31bit random binary packets.

To produce the data packets we have to use some random data sources which have a different kind of series of ones and zeros. The symbol mapping is a destination where these random data packets are going. This whole operation is done using on sequence technique.

Now in the next steps, we have to modulate the incoming data sources and this can be done by using the technique which is called digital modulation technique. As we already know that in wireless data transferring systems that is BPSK modulation techniques are very essential for better operation analysis.

In this proposed methodology, we have to create a data flowing diversity for the transmitter and receiver which means when the upcoming data packets are coming towards transceivers we have to make them diverse and this can be done by Alamouti STBC. The output signal of the data flowing stream is passed through the Rayleigh multipath fading channels.

There is also another element that is more important in this methodology which Maximum- Likelihood (ML) detector. This Maximum- Likelihood (ML) detector is used to detect the data signal which decodes by the STBC. When the digital modulation technique begins this process creates multiple waveforms which are converted by the demodulation technique into real transform bits.

The important role of the modulator is that it has some rules which are used to decide on sending which bit has to be sent whether it is “zero” or “one”.

Multiple-Input Multiple-Output technology has gained popularity in telecommunications due to its ability to improve data connectivity and link range without requiring additional bandwidth or transmit signals. MIMO achieves this through improved link reliability and spectral efficiency or diversity. MIMO is a crucial component of current wireless communication technologies including WIMAX, LTE, 4G and IEEE 802.11n (Wi-Fi).

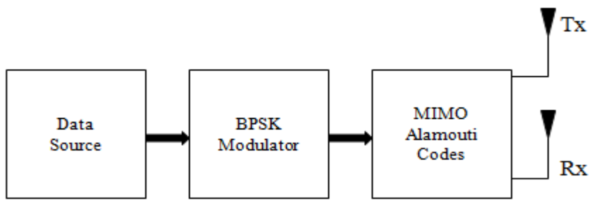

Fig. 1: Block diagram of Alamouti STBC

III. MIMO SYSTEM

This MIMO technology has developed as a sophisticated and technically significant approach in modern wireless communication. This cutting-edge technology might potentially aid in the resolution of traffic capacity issues in future internet-accelerated wireless networks. In addition to evolving as an advanced system, it aids in areas such as broadband wireless access systems, third-generation (3G) networks and wireless local area networks (WLAN).

A wireless communication system's sending and receiving ends are equipped with several antenna elements, as illustrated in figure (2). The key premise behind an advanced MIMO system is that the transmitting and receiving antennas at opposite ends are merged to increase the wireless communication system's bit error rate (BER) or data rates (bits/sec).It may be a big benefit since it may be utilized to improve network service quality (QoS).

The MIMO system's fundamental principle is space-time signal processing, which involves the addition of time to the spatial dimension. The utilization of many dispersed antennas entails these unique dimensions. This sophisticated MIMO system, which replaces smart antennas, may be a huge assist and can continue to aid for decades if the technology is improved. Each antenna element of the MIMO system does not require any extra bandwidth as it operates on the same frequency.

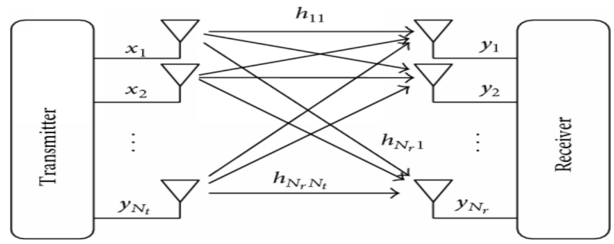

Fig. 2: Multiple Input Multiple Output System

In above Fig 1.shows the structure of M x N in the MIMO system this system has the matrix which has the parameter M x N and these are the sub channel of this system we can also call it multiple-beam transmit formers [1]. As we all know the MIMO system is the best remedy to increase the capacity of the system and channel.

M_T = Number of transmitting antennas

M_R= Number of receiving antennas

$x_j(t), j = 1,2, \ldots, M_T$= Transmitted signal

$y_i(t), i = 1,2, \ldots, M_R$= Received signal

The relation between transmitting signals and receiving signals looks like [4]

$$yi(t) = \sum_{j=1}^{M_T} h_{i,j}(t) * x_j(t) + n_i(t),\ i = 0,1, \ldots \ldots M_R \quad (1)$$

Where, = $h_{i,j}(t)$ is the channel in the centre of transmitting antenna j and receiving antenna number i's impulse response. A matrix can express the MIMO system channel [4]:

$$H(t) = \begin{bmatrix} h_{1,1}(t)\, h_{1,2}(t) & \cdots & h_{1,M_T}(t) \\ \vdots & \cdots & \vdots \\ h_{M_R,1}(t)\, h_{M_R,2}(t) & \cdots & h_{M_R,M_T}(t) \end{bmatrix} \quad (2)$$

The MIMO system has the capacity which is given as follows [4]

$$C = \log_2[\det(I_N + \rho h h^H)] \quad (3)$$

Where
I_N = identity matrix,
Vector h = between the single transmitter antenna and the reception antenna array, the Hermitian transpose of h is the transfer function or channel gain.
Where H is the N x M MIMO channel matrix.

IV. FRAMEWORK OF CHANNEL

A. Rayleigh Fading Channel:

A Rayleigh fading channel is defined as a channel with a large number of reflective paths but no line of sight signal component. Reflection, diffraction, and scattering are the three basic methods that influence signal propagation. When a propagating electromagnetic wave collides with a smooth surface, reflection occurs. Diffraction happens when there is an obstacle between the transmitter and the receiver. Diffraction accounts for RF energy moving from transmitter to receiver without a line of sight path.

When a wave passes through a radio medium that contains tiny things, it scatters. Rough surfaces are the most common source of scattered waves. A statistical model is the Rayleigh Fading Channel. The strength of a radio signal varies as it travels over a communication channel owing to Rayleigh dispersion. The Rayleigh distribution illustrates how the received envelope of a flat fading signal changes statistically over time.

The troposphere and ionosphere signal propagation are supported by the Rayleigh fading model. It's most useful when there's no clear dominating path between the transmitter and receiver along the LOS. Jakes proposed a summing sinusoids-based Rayleigh fading model in this regard. Jakes model performs as well when modeling a single path channel or a multipath frequency-selective channel. The Jakes model popularized the Doppler spectrum, which is sometimes referred to as the Jakes spectrum since it is connected with Rayleigh fading.

B. Additive White Gaussian Noise (AWGN):

Substitute a typical channel representation for studying all modulation schemes is the White Gaussian Noise (AWGN) channel. Because it is known that white Gaussian noise to signal travelling all the way through it has uniform power across the frequency range for the entire information system, it is used in this channel. It's employed in information theory to simulate the outcome of a variety of random events that occur in nature. A procedure known as equalization can be used to mitigate the effects of Multipath, fading, ISI, and fading in a certain type of environment.

V. EXCEUTION OF MODEL

A. Tool used:

In this project, we are using Matlab Simulink, we are using this platform for our project analysis because this tool is very simple and having many features for many technical fields and this tool is easy to understand the operations and mathematical operations if someone is new with this tool they can easily understand the process and working of the projects. In this project, we have done simulation using the Matlab R2016a version which is easily available for the users and this version is very stable as compared to previous versions of Matlab also there are a lot of Simulink components are added in this version which fulfills the need of every field whether you are formed medical background or you are doing mathematical operations.

We are analyzing the performance of the MIMO system with Alamouti STBC using BPSK and zero-forcing modulation technique for the better BER value and with negligible latency of the network. The key element of our projects is the MIMO system why we are using this as the key component for the performance analysis. The most important benefits of this system that for the better strength of the internet and data connectivity and getting the good BER for the wireless connectivity this system multiplying the capacity of all the propagative signals which are transmitting a data packet from one point to another point and this can only happen using multiple transceivers. This can be the better practice of using this system to gain the maximum potential of MIMO and make a new advanced system for future benefits.

B. Binary Phase Shift Keying (BPSK):

When compared to alternative modulation techniques, the system using BPSK modulation gives a superior BER result.
Benefits of BPSK Modulation are as follows:

i. Binary bits 1 and 0 are separated by a 180 degree phase shift of the carrier; it is the most resilient modulation method. BPSK modulated data can travel greater distances when sent from base stations or subscriber stations because of this characteristic.

ii. Cellular towers employ BPSK modulation for long-distance communication or data transfer.

iii. To retrieve original binary information, the BPSK demodulator simply has to make two judgments. As a result, compared to other modulation schemes, the BPSK receiver is relatively simple.

iv. BPSK is a power-efficient modulation technology since it requires less power to transmit the carrier with fewer bits.

The criterion for transmission of BPSK. BPSK transmits signals through modulation and demodulation techniques. The simplest version of PSK, i.e. phase shift keying, is binary phase shift keying. It is also known as 2-PSK since it employs two phases separated by 180°. The constellation points are depicted on the real axis, at 0° and 180°, and it makes no difference where they are placed. As a result, it can withstand the maximum degree of noise or distortion before the demodulator makes a bad choice. As a result, it is the most durable PSK.

C. ZF-Equalizer:

The zero forcing technique is a time-saving method for creating an inverse filter. An impulse is formed by transmitting a training signal over a channel to produce a set of FIR inverse filter coefficients. A set of coefficients is found from the received sample after solving the set of a simultaneous equation which are determined to force all filtered responses to zero to accept the center tap filter response. Since the N-1 samples are forced to become zero so these samples will not contribute to ISI. Solution of the set equations are reduced to a simple matrix inverse thus this technique proves to be of great advantages.

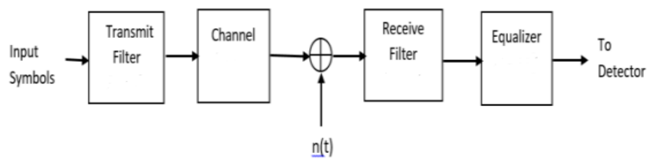

Fig. 3: Block diagram of a communication system (with equalizer)

In the first scheduled opening, the receiver antenna has its first received signal as [5]

$$y_1 = h_{1,1}x_1 + h_{1,2}x_2 + n_1 = \begin{bmatrix} h_{1,1}h_{1,2} \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \end{bmatrix} + n_1 \qquad (4)$$

The signal received on the second receiver antenna will be [5],

$$y_2 = h_{2,1}x_1 + h_{2,2}x_2 + 2 = \begin{bmatrix} h_{2,1}h_{2,2} \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \end{bmatrix} + n_2 \qquad (5)$$

Where

The received signal on the first and second antennas is represented by y_1, y_2

$h_{1,1}$: First sending antenna to first receiving antenna channel

$h_{1,2}$: Transmission channel from the second transmitting antenna to the first receiving antenna.

$h_{2,1}$: Transmission channel from the first sending antenna to the second receiving antenna.

$h_{2,2}$: Transmission channel from the second sending antenna to the second receiving antenna.

Where,
Signals sent from the transmitter, x_1, x_2 .

n_1, n_2 : Noise signal received by the first and second antennas, respectively

We accepted values which the receiver knows are $h_{1,1}, h_{1,2}, h_{2,1}$ and $h_{2,2}$. In addition to this it also knows y_1 and y_2 .And the only unknown are are x_1 and x_2. For better understanding, we can also write above equation in below matrix format [5]:

$$\begin{bmatrix} y_1 \\ y_2 \end{bmatrix} = \begin{bmatrix} h_{1,1} & h_{1,2} \\ h_{2,1} & h_{2,2} \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \end{bmatrix} + \begin{bmatrix} n_1 \\ n_2 \end{bmatrix} \qquad (6)$$

Proportionally [5],

$$y = Hx + n \qquad (7)$$

To satisfies $WH = I$ a matrix is needed to find W for which we to solve x

To meet the imperative linear detector of zero forcing equalizer is given by [5],

$$W = (H^H H)^{-1} H^H \qquad (8)$$

The pseudo inverse of the following n x m matrix is also known as

The term [5],

$$H^H H = \begin{bmatrix} h_{1,1}^* & h_{2,1}^* \\ h_{1,2}^* & h_{2,2}^* \end{bmatrix} \begin{bmatrix} h_{1,1} & h_{1,2} \\ h_{2,1} & h_{2,1} \end{bmatrix}$$
$$= \begin{bmatrix} |h_{1,1}|^2 + |h_{2,1}|^2 & h_{1,1}^* h_{1,2} + h_{2,1}^* h_{2,2} \\ h_{1,2}^* h_{1,1} + h_{2,2}^* h_{2,1} & |h_{1,2}|^2 + |h_{2,2}|^2 \end{bmatrix} \qquad (9)$$

D. Space Time Code:

Tarokh at el. [3] was the first to develop space-time coding (STC), a scheme in which the number of sent code symbols per time slot equals the number of transmit antennas. A space-time encoder is used to construct the code symbol, resulting in diversity gain, coding gain, and good spectrum efficiency. Space-time coding is utilized in cellular communications and wireless local area networks because it has the potential to improve data transmission dependability. Some of the coding methods accessible include layered space-time (LST) codes, space-time turbo trellis codes, space-time block codes (STBC) and space-time trellis codes (STTC). In all of these designs, using redundancy to achieve high reliability, spectrum efficiency, and performance increase is a major problem. To create STC, you must first identify a code matrix that meets specific optimality requirements. It also enables the achievement of the objectives of retaining a simple decoding method, minimizing error probability, and increasing information rate.

E. STBC Prototype:

The Alamouti system has the same key characteristic as space-time block coding. The various transmit antennas define the degree of diversity at which the orthogonal codes may accomplish full transmission. On both the transmitter and receiver sides, the method of encoding and decoding the space-time block codes, which are believed to be a complicated variation of the Alamouti space time code, is comparable. The signals on the receiver side are combined first and then sent to the detector, where the decision is generally made. These space-time block codes are built with a certain number of transmitter and receiver antennas to assist achieve optimum variety. The widespread use of these space-time block codes has demonstrated their appeal.

F. Alamouti STBC:

In the early days, STBC was considered to be the Alamouti scheme. W-CDMA and CDMA were the standards in which the Alamouti STBC system was implemented. When the Alamouti STBC system comprises of two broadcast antennas and Nr receiving antennas, the maximum diversity order of 2Nr may be attained. To reach a rate of 1, the Alamouti method must transmit two symbols per two-time interval. The Alamouti technique is given with receiver antennas 1 and 2 in the decoding process so that the general expression can be deciphered for Nr receiver antennas.

1. In the case of one receiving antennas:

The number of receiver antennas available signifies the reception and decoding process [2].

$$r_1^{(1)} = r_1(t) = h_{1,1}s_1 + h_{1,2}s_2 + n_1^{(1)}$$
$$r_1^{(2)} = r_1(t+T) = -h_{1,1}s_2^* + h_{1,2}s_2^* + n_1^{(2)} \quad (10)$$

Where,
r_1= received signal at antenna 1
The channel of transfer function hij is comprised of the jth transmit antenna and the ith reception antenna.
n_1= Antenna 1 noise is represented by a complex random variable.
$x^{(k)}$ = at time t + (K-1) T, x at a time instant of k.

The received signal is initially mixed before being sent to the decoder. [2]

$$\bar{s}_1 = h_{1,1}^* r_1^{(1)} + h_{1,2} r_1^{*(2)}$$
$$\bar{s}_2 = h_{1,2}^* r_1^{(1)} + h_{1,1} r_1^{*(2)} \quad (11)$$

And substituting (10) in (11) yields [2]:

$$\bar{s}_1 = (\alpha_{1,1}^2 + \alpha_{1,2}^2)s_1 + h_{1,1}^* n_1^{(1)} + h_{1,2} n_1^{*(2)}$$

$$\bar{s}_2 = (\alpha_{1,1}^2 + \alpha_{1,2}^2)s_2 - h_{1,1} n_1^{*(2)} + h_{1,2}^* n_1^{(1)} \quad (12)$$

Where αij^2= the channel transfer function's squared magnitude hij. The calculated $\bar{s}_1$ *and* $\bar{s}_2$ are then sent to a Maximun Likelihood (ML) decoder to estimate the transmitted symbols s_1 and s_2 respectively [2].

2. In the case of two receiving antennas:

The received symbols for to receiver antennas are given as follows [2]

$$r_1^{(1)} = h_{1,1}s_1 + h_{1,2}s_2 + n_1^{(1)}$$
$$r_1^{(2)} = -h_{1,1}s_2^* + h_{1,2}s_1^* + n_1^{(2)}$$
$$r_2^{(1)} = h_{2,1}s_1 + h_{2,2}s_2 + n_2^{(1)}$$
$$r_2^{(2)} = -h_{2,1}s_2^* + h_{2,2}s_1^* + n_2^{(2)} \quad (13)$$

The combined signals are [2]:

$$\bar{s}_1 = h_{1,1}^* r_1^{(1)} + h_{1,2} r_1^{*(2)} + h_{2,1}^* r_2^{(1)} + h_{2,2} r_2^{*(2)}$$
$$\bar{s}_2 = h_{1,2}^* r_1^{(1)} + h_{1,1} r_1^{*(2)} + h_{2,2}^* r_2^{(1)} + h_{1,1} r_2^{*(2)} \quad (14)$$

This, after substituting (13) becomes:

$$\bar{s}_1 = (\alpha_{1,1}^2 + \alpha_{1,2}^2 + \alpha_{2,1}^2 + \alpha_{2,2}^2)s_1 + h_{1,1}^* n_1^{(1)} + h_{1,2} n_1^{*(2)} + h_{2,1}^* n_2^{(1)} + h_{2,2} n_2^{*(2)}$$
$$\bar{s}_2 = (\alpha_{1,1}^2 + \alpha_{1,2}^2 + \alpha_{2,1}^2 + \alpha_{2,2}^2)s_2 - h_{1,1} n_1^{*(2)} + h_{1,2}^* n_1^{(1)} - h_{2,1} n_2^{*(2)} + h_{2,2}^* n_2^{(1)}$$
$$(15)$$

3. Number of receiving antennas decoding decision statistic:

Over all potential values of s1 and s2, the ML decoder decision statistic decodes in favour of s1 and s2 such that (16) and (17) are minimised, where is provided by (18) for Nt = 2. [2]

$$\left|\left[\sum_{i=1}^{Nr}(r_i^{(1)} h_{i,1}^* + r_i^{*(2)} h_{i,2})\right] - s_1\right|^2 + \varphi|s_1|^2 \quad (16)$$

$$\left|\left[\sum_{i=1}^{Nr}(r_i^{(1)} h_{i,2}^* + r_i^{*(2)} h_{i,1})\right] - s_2\right|^2 + \varphi|s_2|^2 \quad (17)$$

$$\varphi = \left(-1 + \sum_{i=1}^{Nr}\sum_{j=1}^{Nt}\left|h_{i,j}\right|^2\right) \quad (18)$$

Diversity of 2 the Alamouti STBC needs to transmit as well as 1 receiver antenna. Using Alamouti STBC, we can employ an additional antenna at a base station to mitigate the fading impact at a mobile station instead of multiple antennae at the receiver. If there is no problem having more antenna at receivers are to Nr full diversity can be accomplish using to transmitter antenna and Nr receiver antenna.

In conclusion, we have utilized Alamouti STBC, which can provide a low bit error rate followed by higher data quality and can be used in WIMAX, LTE, 4G and IEEE 802.11n (Wi-Fi) models for better data rate performance, therefore Alamouti STBC used in this project may assist in delivering better data quality with similar models.

VI. NOVELY OF THE PROJECT

In Alamouti STBC the transmission is through two independent antennas and at the receiving end we get signals similar to the transmitted signal which may have some variations but the quality of the signal is good as bit error rate is low while in ZF equalizer the transmission technique used is inverse of frequency response to restore the signal at the channel end but the quality of the signal at channel end is not as good as in Alamouti STBC because here the bit error rate is high in comparison to Alamouti STBC. Therefore, Alamouti STBC is a novel approach in this project as the existing projects does not use Alamouti STBC for lower bit error rate consideration.

VII. SIMULATION RESULTS AND DISCUSSIONS

A simulation is created in MATLAB ver.2016A to compare the performance of all six equalizers. In a 2x2 MIMO system, this simulation accepts the binary values +1 and -1 as input and performs BPSK modulation. Multipath effect and noise may also be produced using the Rayleigh channel model and the AWGN noise model. After that, the modulated signal is sent across these models. Demodulation and BER performance are performed on the receiver side.

A. MIMO System for Alamouti STBC:

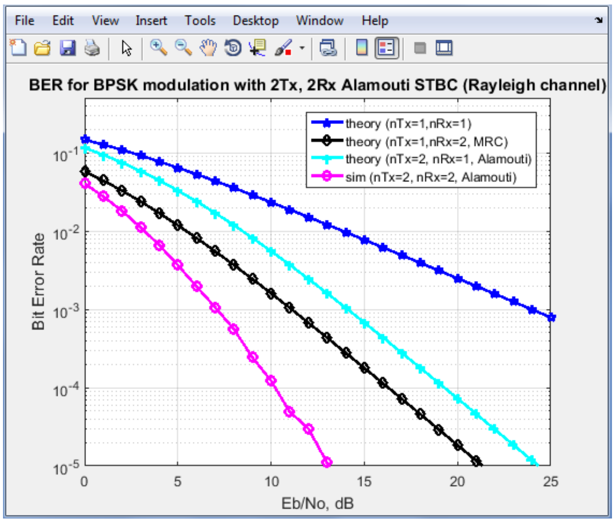

Fig. 4: Performance of BER for Alamouti STBC with BPSK Modulation

Figure 4 shows the Alamouti STBC's BER performance in a 2x2 MIMO system versus a 2x1 Alamouti STBC system, indicating that the Alamouti STBC's performance in a 2x2 MIMO system differs from that of a 2x1 Alamouti STBC system, and that the 2x2 Alamouti system gives us better BER performance than the 2x1 Alamouti system.

B. MIMO System for Zero Forcing Equalizer:

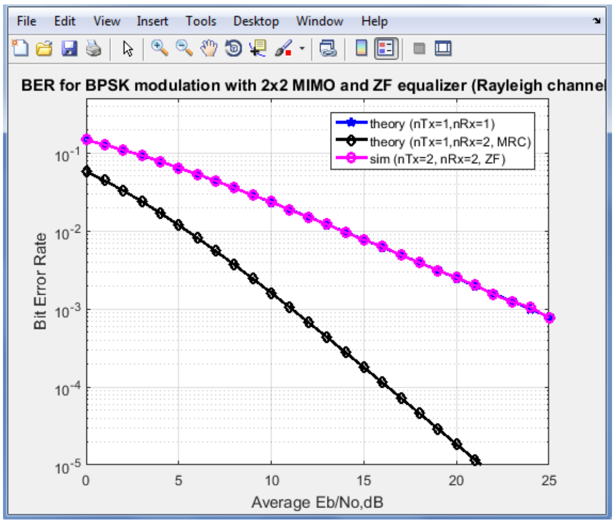

Fig. 5: Performance of BER for Zero Forcing Equalizer with BPSK Modulation

Figure 5 shows the ZF equalizer's BER performance, which reveals that the ZF equalizer's performance in a 2x2 MIMO system is equivalent to that of a 1x1 BPSK system.

C. MIMO System for MMSE equalizer:

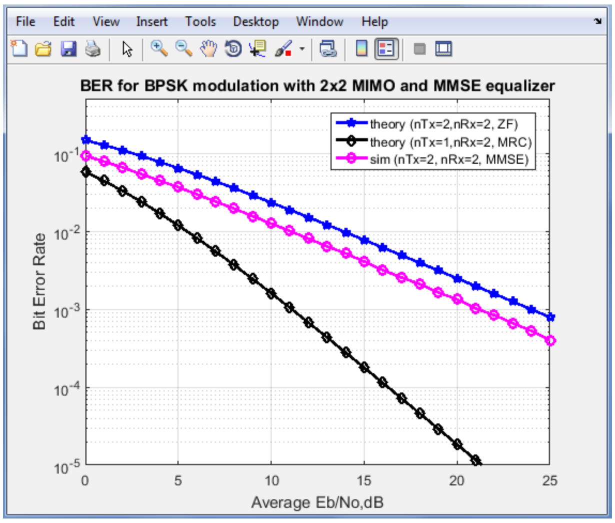

Fig. 6: Performance of BER for MMSE equalizer with BPSK Modulation

Figure 6 shows the MMSE equalization's BER performance in a 2x2 MIMO system, which shows that the MMSE equalizer's performance in a 2x2 MIMO system differs from that of a 2x2 ZF equalizer system, and that the 2x2 MMSE equalizer system offers us superior BER performance than the 2x2 ZF equalizer system.

D. MIMO System for MMSE-SIC equalizer:

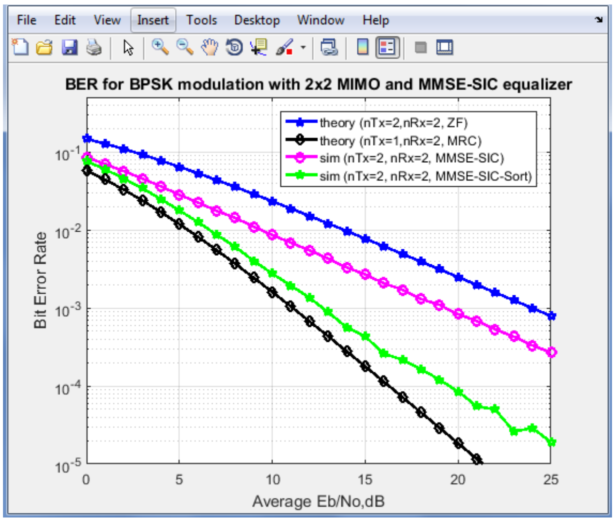

Fig. 7: Performance of BER for MMSE-SIC equalizer with BPSK Modulation

Figure 7 compares the BER performance of the MMSE-SIC equalizer and the MMSE-SIC Sort equalizer in a 2x2 MIMO system, indicating that the MMSE-SIC equalizer performs differently in a 2x2 MIMO system than a 2x2 MMSE-SIC Sort equalizer, and that MMSE-SIC Sort gives us better BER performance than the 2x2 MMSE-SIC equalizer.

E. MIMO System for ZF-SIC equalizer:

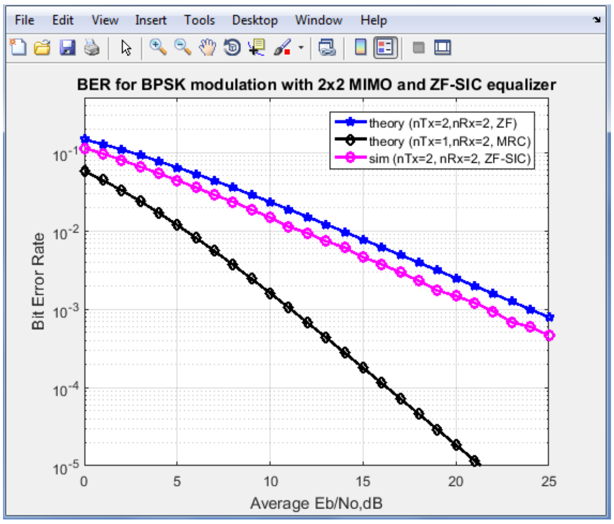

Fig. 8: Performance of BER for ZF-SIC equalizer with BPSK Modulation

Figure 8 depicts the ZF-SIC equalizer's BER performance in a 2x2 MIMO system, indicating that the ZF-SIC equalizer's performance in a 2x2 MIMO system differs from that of a 2x2 ZF equalizer system, and that the 2x2 ZF-SIC equalizer system provides better BER performance than the 2x2 ZF equalizer systems.

F. MIMO System for ZF-SIC Sorted equalizer:

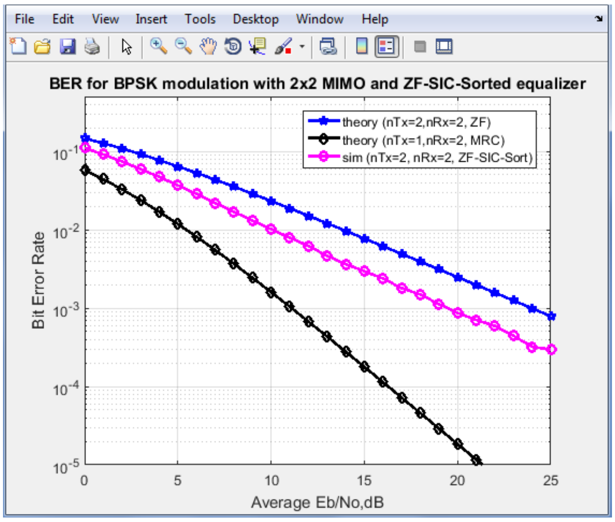

Fig. 9: Performance of BER for ZF-SIC Sorted with BPSK Modulation

Figure 9 compares the BER performance of the ZF-SIC Sort equalizer and the ZF equalizer in a 2x2 MIMO system, indicating that the ZF equalizer performs differently than a 2x2 ZF-SIC Sort equalizer in a 2x2 MIMO system and that the ZF-SIC Sort equalizer provides better BER performance than the 2x2 ZF equalizer.

VIII. RESULT AND COMPARISON

TABLE I: COMPARISON OF STBC AND EQUALIZATION TECHNIQUES

SNR (dB)	Alamouti STBC (2x2)	ZF (2x2)	MMSE (2x2)	MMSE-SIC (2x2)	MMSE-SIC Sort (2x2)	ZF-SIC (2x2)	ZF-SIC Sort (2x2)
5	0.0038	0.0642	0.0363	0.0288	0.0179	0.0441	0.0369
10	0.0001	0.0233	0.0125	0.0085	0.0028	0.0146	0.0101
20	0	0.0026	0.0013	0.0009	0.0001	0.0015	0.0009
25	0	0.0008	0.0004	0.0003	0	0.0004	0.0003

The comparison of STBC and other equalization methods is shown in table I. For a BPSK modulation scheme at a certain SNR, Table I illustrates the BER between Alamouti STBC, ZFE, MMSE, MMSE-SIC, MMSE-SIC Sort, ZF-SIC, and ZF-SIC Sort receivers.

IX. CONCLUSION

In this work, we examine the performance of six categories of equalizers for MIMO wireless receivers: ZF, MMSE, MMSE-SIC, MMSE-SIC Sort, ZF-SIC and ZF-SIC Sort or Alamouti STBC techniques. According to the results of the study, the Alamouti STBC methods are more important than any other equalization approaches in improving the performance of the MIMO system. The Signal-to-Noise Ratio (SNR) is commonly used to evaluate the quality of an analogue communication system. The signal-to-noise ratio (SNR) is defined as the ratio of signal power to noise. The better the signal quality, the greater the signal-to-noise ratio. Despite the fact that SNR is not commonly utilized in digital communication systems, there is a correlation between SNR and BER: the greater the SNR, the reduced the associated BER. Therefore, we conclude that Alamouti STBC is acquiring better data quality. An Alamouti STBC technique is different from equalizer techniques as its gives lower bit error rate than equalizer techniques.

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