Performance of BER Analysis of MIMO System using BPSK Modulation under Different Channel with STBC, ML and MRC

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ABSTRACT: Higher data rate and easier communication is required for commercial wireless communication system. System design in the multipath fading is channelled in wireless communication system because which gives weak signal strength and enhance the bit error rate of communication system. Multi input- multi output (MIMO) system is used to overcome this drawback. Multiple antennas are used to gives higher data rate, higher transmit and receive diversity through spatial multiplexing in wireless communication system. This paper presents a detail study of bit error rate(BER) analysis of multi input- multi output(MIMO) system under AWGN(additive white Gaussian noise) and Rayleigh fading communication channel. It is used maximum like hood detector and maximal ratio combining at the receiver side and encoded by Almouti space time block code at the transmitter sides. Almouti space time block code (STBC) gives the transmit diversity. System result is observed by BPSK modulation technique using MATLAB. Simulation result gives the comparison between two channels, AWGN channel has better achievement.

KEYWORDS: MIMO, BER, AWGN, ML, Rayleigh, MRC

I.   INTRODUCTION

By increasing the demand of high speed of multimedia wireless services is achieved by modern communication system. There are different type of aspect which decreases the performance of the communication system such as interference and noise, loss and propagation, limitation of bandwidth and fading due to multipath [1]. There are different type of antenna which is used at the transmitter and receiver section. To slash the fading and enhance the capacity with the help of spatial diversity or spatial multiplexing [1] .Multi input multi output is one of the most important techniques which is used in wireless system that desire high data rates and transmit diversity. There are different parameters such as selections of modulation technique, signal processing chains, and supplementary antennas are critical in multi input multi output system, it gives the restriction of antenna size mainly for mobile. Advantage of MIMO technique depends on multiplicity of receiver and coding scheme so in performance of wireless communication system multi input multi output play important role.[3].

In a now days, requirement of wireless machinery is very high STBC play important role for study purpose in various modulation technology. There are four procedures such as simulation of the Almouti STBC transmission system, digital transmission system, modelling and commutation and relation of bit error rate. [4]

In this paper, its evaluate bit error rate of MIMO system in AWGN and Rayleigh fading channel, where at the transmitter section Almouti STBC is used for encoding the information and the receiver side maximal ratio combining (MRC) and Maximum Likehood (ML) is used for decoding purpose. Modulation scheme BPSK is used for modulate the encoded signal. This paper qualified as followed in section II, the MIMO system model is described. Section III, encoder and decoder. In Section IV, modulation scheme. Section V, discuss the AWGN and Rayleigh fading channel. In Section VI, bit error is discussed. In Section VII, numerical results are obtained and Section VIII gives the final conclusion.

II. SYSTEM MODEL

There is suppose that a MIMO system transmit section consist of M_T antenna and receive section consist of M_R antenna [5].Fig.1 shows the block diagram of MIMO system.
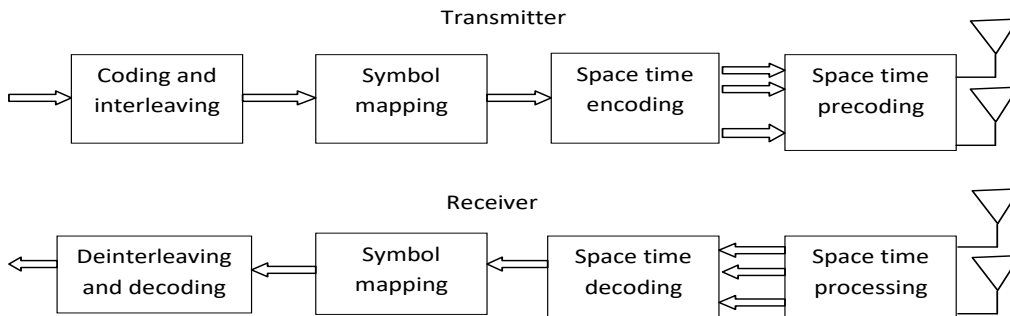
Figure1. Block Diagram of MIMO System

In transmitter section is the transmitted matrix S is column matrix. It is denoted by M_T*1 where S, denotes the ith component transmitted of transmit antenna. Alamouti STBC used in transmitted section, advantage of this STBC code channel state information is not required for transmit the data. It is used Gaussian channel the component S are independent identically distribution Gaussian variable. If the channel information not known the transmitter side then signal power transmitted of single antenna is equal to $\frac{P_S}{M_T}$. Covariance matrix R_{SS} of transmitted signal can be written as equation (1)

$$R_{SS} = \frac{P_S}{M_T} * I_{MT} \qquad (1)$$

Where P_s represents the total transmit power of transmitter and I_{MT} represent the identity matrix. The channel matrix H for M_T transmit antenna and M_R receive antenna is M_R*M_T complex matrix. H_{ij} represent the component of channel matrix H for j^{th} transmit antenna and i^{th} received antenna.[6] In receiver section the received matrix Y is column matrix. It is denoted by M_R*1. It is consider that transmit and received power of transmitter and receiver section is equal than the SNR can be written as in equation (2)

$$\gamma = \frac{P_S}{N_0} \qquad (2)$$

Where P_s and N_0 represent signal and noise power.

III. ENCODER AND DECODER

A. Alamouti Space Time Block Code

The Alamouti STBC is a well known diversity technique which uses the information increase multiple antennas at the transmitter. The Alamouti STBC is basically provide transmits complex space-time diversity. It is used spread the information at the transmitter end. It is classified as two modes (2*1 MISO mode or 2*2 MIMO mode). It gives full diversity gain without need to loss its data rate. The advantage of Alamuoti STBC it gives better bit error rate as compared to oldest STBC [7].

1. 2*1 Alamouti STBC

Table 1: 2*1 Alamouti STBC

Time	Transmitter 1	Transmitter 2
Time t	X_1	X_2
Time t+T	$-X_2^*$	X_1^*

Where X_1 and X_2 are the modulated signal. The received vector can be written as from Table 1

$$Y_1 = h_1(X_1) + h_2(X_2) + n_1 \qquad \text{(first time slot)} \qquad\qquad (3)$$

$$Y_2 = h_1(-X_2^*) + h_2(X_1^*) + n_2 \qquad \text{(second time slot)} \qquad\qquad (4)$$

Where: X_1 and X_2 modulated symbol, Y_1 and Y_2 Received vectors, h_1 and h_2 impulse response of Rayleigh channel ,n_1 and n_2 AWGN channel Equation (3) and equation (4) can be written in matrix equation from as

$$\begin{bmatrix} Y_1 \\ Y_2 \end{bmatrix} = \begin{bmatrix} X_1 & X_2 \\ -X_2^* & X_1^* \end{bmatrix} \begin{bmatrix} h_1 \\ h_2 \end{bmatrix} + \begin{bmatrix} n_1 \\ n_2 \end{bmatrix} \qquad\qquad (5)$$

$$H = \begin{bmatrix} h_1 & h_2 \\ h_2^* & -h_1^* \end{bmatrix}$$

Where H is a 2*2 channel matrix, a^* represents the complex conjugate of a

$$Y = H\, X + N \qquad\qquad (6)$$

Where H is an orthogonal matrix

(2) 2*2 Alamouti STBC

2*2 alamouti STBC 2 transmit and 2 receive antenna consist. Working principle same as 2*1 alamouti STBC but it consist one extra received antenna. It gives better bit error rate performance as compare to 2*1 alamouti STBC. We assume that the channel parameter remains constant during the two time slot.

$$Y_{11} = h_{11}(X_1) + h_{12}(X_2) + n_{11} \qquad \text{(first time slot receive data in } R_{X1}) \qquad\qquad (7)$$

$$Y_{12} = h_{21}(X_1) + h_{22}(X_2) + n_{12} \qquad \text{(first time slot receive data in } R_{X2}) \qquad\qquad (8)$$

$$Y_{21} = h_{11}(-X_2^*) + h_{12}(X_1^*) + n_{21} \qquad \text{(second time slot receive data in } R_{X1}) \qquad\qquad (9)$$

$$Y_{22} = h_{21}(-X_2^*) + h_{22}(X_1^*) + n_{22} \qquad \text{(second time slot receive data in } R_{X2}) \qquad\qquad (10)$$

Equation (7), (8), (, 9) and (10) can also be written as matrix form the received vector in first time slot is

$$\begin{bmatrix} Y_{11} \\ Y_{12} \end{bmatrix} = \begin{bmatrix} h_{11} & h_{12} \\ h_{21} & h_{22} \end{bmatrix} \begin{bmatrix} X_1 \\ X_2 \end{bmatrix} + \begin{bmatrix} n_{11} \\ n_{12} \end{bmatrix} \qquad\qquad (11)$$

The received vector in second time slot is

$$\begin{bmatrix} Y_{21} \\ Y_{22} \end{bmatrix} = \begin{bmatrix} h_{11} & h_{12} \\ h_{21} & h_{22} \end{bmatrix} \begin{bmatrix} -X_2^* \\ X_1^* \end{bmatrix} + \begin{bmatrix} n_{21} \\ n_{22} \end{bmatrix} \qquad\qquad (12)$$

Where X_1 and X_2 are modulated symbol, Y_{11} and Y_{12} are received vectors (first time slot), Y_{21} and Y_{22} are received vectors (second time slot) ,h_{11}, h_{12} , h_{21} and h_{22} are impulse response of Rayleigh fading channel,n_{11}, n_{12} AWGN noise (first time slot) ,n_{21} and n_{22} AWGN noise (second time slot)

B.Maximum Likehood Decoder

For decoding of alamouti STBC there are different method like ZF (zero forcing), minimum mean square estimation (MMSE), Brut Force ML decoding etc. In above method Maximum Likehood decoding gives better performance. The ML receiver tries to find $\hat{X}$ which minimize $J = |Y - H\hat{X}|^2$ for the BPSK modulation. The possible value of X_1 is +1 and -1 and X_2 is also lies between 1 and -1. So find the minimum value of J all four possible combinations in the ML decoder for below equation (13)

$$J = |\begin{bmatrix} Y_1 \\ Y_2 \end{bmatrix} - \begin{bmatrix} h_{11} & h_{12} \\ h_{21} & h_{22} \end{bmatrix} \begin{bmatrix} \widehat{X_1} \\ \hat{X}_2 \end{bmatrix}|^2 \tag{13}$$

The estimate of the transmit symbol is chosen best on the minimum value from the above four values If the minimum is $J_{+1,+1}$= [1 1], If the minimum is $J_{+1,-1}$= [1 0], If the minimum is $J_{-1,+1}$ = [0 1] and If the minimum $J_{-1,-1}$= [0 0]

C .Maximal Ratio Combining

In telecommunication different method is use to combine the signal. MRC is as method of diversity combining. MRC multiplied the all branches signal. MRC amplified higher amplitude signal but shrink the low amplitude signals. It is also add the signal from each channel and gain of each channel is made directly proportional to the RMS signal value and inversely proportional to the mean square noise value in that channel. Each channel is different. It is known as RSC (ratio-squared-combining) and PC (prediction combining). MRC is also known as optimum combiner and it is independent of AWGN channels. It can achieved high bit error rate when MRC is used in multi input multi output receiver. The least square solution in this case is also known as maximal ratio combining. In the case of two antennas the least square solution can be written as equation (14)

$$\hat{X} = \frac{h_1^* * Y_1 + h_2^* Y_2}{|h_1^2| + |h_2^2|} \tag{14}$$

IV. MODULATION

If the digital modulation modulates the incoming data BPSK (Binary phase shift keying) modulation is used. Encoding of M massage bits single pulse transmit 2M possible time shifts. Transmit bit rate M/T (bit per second) is replicate after every T second. This paper BPSK modulation scheme is used.

V. COMMUNICATION CHANNEL

Communication channel is medium to transmit the information from source to destination. It can be classified as two type wired and wireless. In wired channel physically connected to source and destination but wireless channel not connected physically from source to destination. Wireless communication channel classified as slow and fast fading channel. The fast fading channel impulse response is changed while slow fading channel impulse response is constant from many symbols. This paper study the performance of bit error rate of MIMO system under AWGN and Rayleigh fading channel using Alamouti STBC encoders, ML and MRC receivers.

(A) AWGN

AWGN channel add White Gaussian noise when signal pass through it. Noise add in AWGN depends only what is the input signal is applied where the input is complex the add complex Gaussian noise and output is also complex in nature. When the inputs signal is used real output is also real and add real Gaussian noise. Gaussian means normal distribution in time domain with an average time domain value only. It is used only impairment to communication is a continuous addition of white band or white noise with stable spectral density and Gaussian distribution of amplitudes. Modulation signals pass through AWGN channel amplitude and phase distortion not loss only change in phase. This model does not tell for fading, frequency selectivity, interference and nonlinearity. Only distortion is introduced in equation (15) the received signal y (t) is simplified to equation (15)

Y(t) = X(t) + n(t) $\tag{15}$

Where n(t) denotes AWGN Gaussian noise. The probability density function can be expressed as equation (16)

$$P(n) = \frac{1}{2}\sqrt{2\pi\sigma^2}e^{\frac{-(n-\mu)^2}{2\sigma^2}} \tag{16}$$

For AWGN channel $\mu = 0$ where μ represents Gaussian means and $\sigma^2 = \frac{N_0}{2}$.

B. Rayleigh

Three main mechanism of electromagnetic wave propagation are reflection, diffraction and scattering. The Rayleigh fading model combination of scatter and reflected signal. It is used for modulation the signal of troposphere and ionosphere. A case approximation of attenuation due to multi path fading wireless channel can be done by Rayleigh fading channel. There are no line of sight communication consist between transmitter and receiver. Rayleigh distribution can also be GOT by taking two identically distributed zero mean Gaussian random variable as real and imaginary part of a complex number and then taking its magnitudes this is given in equation (17)

$$h_{ij} = \frac{1}{\sqrt{2}} * (\, normal(0,1) + \sqrt{-1}\, \text{Normal}\, (0,\, 1)) \tag{17}$$

Received signal of receiver side can also be written as equation (18) $R(n) = \sum h(n, \tau) * \delta(n - m) + w(n)$ (18)

Impulse response of zero mean and unit variance can be written as equation (19)

$$h(n) = \sum \alpha(n) * e^{-j\theta(n)} \tag{19}$$

Where $\alpha(n)\ and\ \theta(n)$ attenuation and phase shift for n^{th} path. Probability density function of Rayleigh can be written as equation (20)

$$f(x) = \frac{x}{\sigma^2} e^{\frac{-x^2}{2\sigma^2}} \tag{20}$$

VI. BIT ERROR RATE ANALYSIS:

A. BER

BER is a metric which a can be implied to characterized the performance of communication system. Bit error rate is basically the average rate of bit error for particular communication

$$BER = \frac{number\ of\ bit\ in\ error}{Total\ number\ of\ bit\ transmitted}$$

Bit error rate is frequently expressed as of probability this is denoted by P_e (probability of bit error rate) the value of P_e lies between 0 to 0.5.

B. SNR

It is the ratio of received signal power into noise power. It is inversely proportional to bit error rate. SNR is measured in decibel. It is used to measure the clarity of the signal in a wired and wireless communication. In the term of diversity SNR formula can be written as in equation (21)

$$BER = \frac{1}{SNR^d} \tag{21}$$

C. Bit Error Rate of AWGN Channel

Probability of bit error rate in AWGN channel for BPSK modulation can be written as equation (22)

$$P_b = Q\left(\sqrt{\frac{E_b}{N_0}}\right) = Q(\sqrt{SNR}) \tag{22}$$

Approximate bit error rate analysis of AWGN channel can be written as equation (23)

$$P_b = \frac{1}{2}e^{\frac{-1}{2}SNR} = \frac{1}{2}erfc\sqrt{\frac{E_b}{N_0}} \tag{23}$$

D. Bit Error Rate of Wireless Rayleigh Fading Channel

In wireless communication system the received signal power in Rayleigh fading channel is equal to $|h|^2 P_T$. Where P_T denotes transmit power. SNR in Rayleigh fading channel can be written as equation (24)

$$SNR_F = |h|^2 * \frac{P}{\sigma^2} = |h|^2 * SNR \tag{24}$$ For bit

error rate derived from BPSK modulation in Rayleigh fading channel can be written as equation (25)

$$P_b = Q\sqrt{(|h|^2 * SNR)} \tag{25}$$ The

average bit error rate of this fading channel coefficient is a average of fading distribution of $|h|$. The average probability bit error of Rayleigh fading channel in BPSK modulation can be written as equation (26)

$$P_b = \frac{1}{2}(1 - \sqrt{\frac{SNR}{2+SNR}}) \tag{26}$$

E. Average BER of Alamouti-STBC

Average BER Alamouti-STBC can be written as equation (27)

$$P_b = {}^{2L-1}_L C(\frac{1}{SNR})^L \tag{27}$$

Where L = r-t+1 where r represent number of received antenna and e represent number of transmit antenna.

F. BER OF MRC

The BER of MRC can be written as equation (28)

$$\mathbf{P_b = \frac{1}{2} - \frac{1}{2}(1 + \frac{1}{SNR})^{\frac{1}{2}}} \tag{28}$$

VII. SIMULATION RESULTS

In this section the bit error rate analysis of MIMO system done AWGN and Rayleigh fading channel and Alamouti SBTC code with ML, MRC receiver in this section BPSK modulation used.

Figure 2 shows the bit error rate value of 2*1 alamouti STBC with BPSK modulation using Rayleigh fading channel. 2*1 alamouti STBC BPSK modulation the value of bit error rate is 4.34*10^-4. We get SNR value of 20db.

Figure 3 shows the bit error rate value of 2*2 alamouti STBC with BPSK modulation using Rayleigh fading channel. The bit error rate value of 2*2 alamouti STBC is 1.1*10^-5 in 21 db SNR.
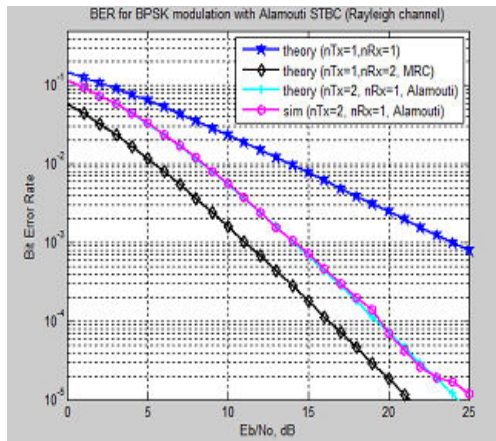
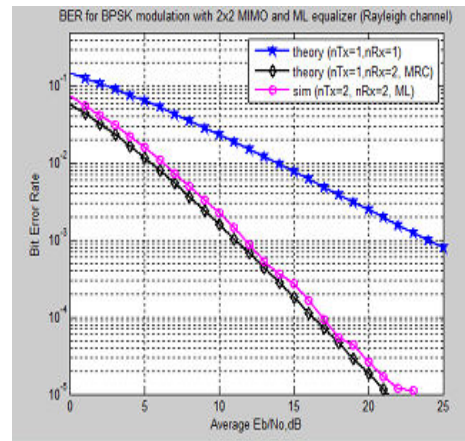Figure.2 BER of 2*1 Alamouti   STBC ML equalizer

Rayleigh fading channel

Figure.3 BER of 2*2 Alamouti STBC ML equalizer

Rayleigh fading channel

Figure 4 shows the bit error rate value of 2*1 alamouti STBC with BPSK modulation using Rayleigh fading channel and AWGN channel. The bit error rate value of 10^-3 in 6.5db SNR. For AWGN channel and the bit error rate value of 10^-3 in 14 db SNR for Rayleigh fading channel.
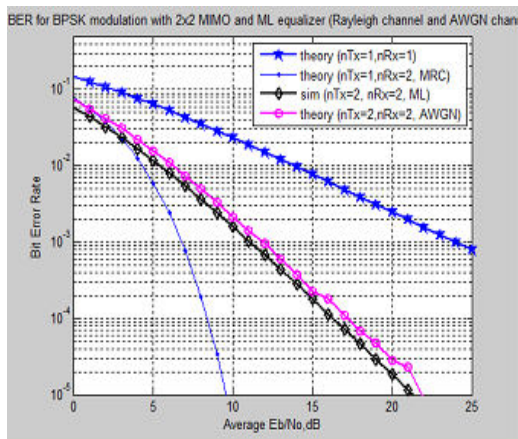

Figure.5 BER of 2*2 Alamouti   STBC ML equalizer
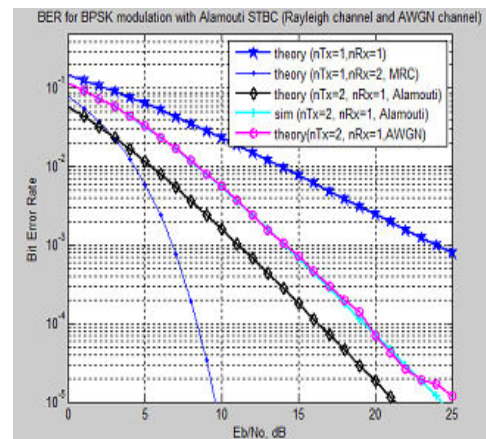
Rayleigh fading and AWGN channel

Figure.4 BER of 2*1 Alamouti STBC ML equalizer

Rayleigh fading and AWGN channel

Figure 5 shows the bit error rate value of 2*2 alamouti STBC with BPSK modulation using AWGN and Rayleigh fading channel. The bit error rate value of 10^-3 in 6.5db SNR for AWGN channel and the bit error rate value of 10^-3 in 12.5db SNR for Rayleigh fading channel. The performance of AWGN channel is better than Rayleigh channel because the bit error rate of AWGN channel is better than Rayleigh fading channel.

VIII. CONCLUSION

MIMO system performance is analyse BPSK modulation scheme in AWGN channel and Rayleigh channel. The bit error rate performance of AWGN channel is better compare to Rayleigh fading channel. In compare to the decoding technique ML decoder gives better bit error rate as compare to ZF and MMSE. The MIMO system MRC is the best equalization large bit error rate as compare to MRC but Alamouti STBC channel state information is not required. SNR of MRC is twice the SNR of Alamouti STBC. SNR is high its require large power at the transmitter side the performance of bit error rate also improve increase the number of transmit and receive antenna.

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