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Analysis of Multiple Antenna System using OFDM in term of SNR and BER

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Abstract—

Multiple Input and Multiple Output communication system(MIMO) architecture is the current trends in the wireless communication technology. Unlike the single input single output system(SISO), MIMO has advantage of providing higher capacity, bit rate and reliability. Spatial diversity, spatial multiplexing and beam forming are the three different classes of the MIMO system architecture.

This paper present a analysis carried out for OFDM based wireless communication architecture using space time block code (STBC) at the transmitter side. Analysis is carried out to see the effect of delay spread and fading. An expression is designed and developed for computing the bit error rate with STBC and timing error. Signal to noise ratio calculation is also carried out.

Keywords— SISO (Single input single output), MIMO(Multiple input Multiple output), ML(Maximum Likelihood), STC (Space Time Coding)

I. INTRODUCTION

Next generation wireless communication aim to achieve high data rate while acquiring the low bandwidth. Along with this power efficient method of wireless communication is the goal of the modern wireless communication technology. Due to the bandwidth efficiency of the orthogonal frequency division multiplexing (OFDM), this scheme of modulation is widely used now a days.

Orthogonal characteristics of the different channel in this scheme makes it suitable for transmitting more data at limited bandwidth as compared to the older system of communication. The performance of this system can be improved further by increasing the diversity gain. Space time code (STBC) is the one of the way to increase the diversity gain of the antenna. This paper presents an OFDM system with almouti's code and STBC code is used to improve the performance of the wireless communication. For this signal to noise ratio and Bit error rate has been computed and analyzed for different combination of MIMO

Increasing the diversity gain is another way to improve the performance of the system. By using Space Time Block Code the antenna diversity gain can be increased. In this paper shows the analysis of STBC-OFDM. At the end of the paper equations have been derived analytically for Signal to Noise Ratio (SNR) and Bit Error Rate (BER) using 4 transmitting antennas and one receiving antenna. Another is 6 transmitting antennas and one receiving antenna.

Various advantages of MIMO system makes it ideal for the current technology like 3G [1][2], 4G[3], WIMAX and IEEE 802.11 specification [4]. Higher capacity, higher data bit rate, small value of bit error rate, better spectral efficiency are some of the advantages of MIMO over SISO[1][2]. There are three categories of the MIMO system e.g. Space diversity, space multiplexing and beam forming technique [6]. In beam forming technique forming beam size and its width decided by considering the receiver position and variation in environment.

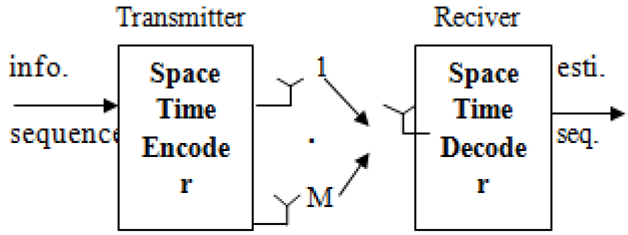

Figure 1 Basic Structure of Space time Coding

Figure 1 Basic Structure of Space time Coding

In spatial multiplexing technique, input bit stream of transmitter is divided in to a N-different sub-straem. Here N is the total number of transmitting antenna[5].

Spatial diversity scheme, on the other hand generate N-copies of the generated signal with each signal is assigned to indivisual antenna[4].

Two dimension coding in space and time which is known as the space time coding is used in MIMO for transmitting the redundant signal. At the receiver side various combining techniques are used for combining both space and time coding[7]. In the past various spatial diversity techniques has been used which can be found in paper [8],[9],[10], [11],[12]. Orthogonal STBC[13] is another scheme of achieving the full diversity. Selection of antenna at the receiver side also play very important role in communication. In [14] and [15] this aspect of communication is analyzed and examined. Space time trellis code is another variants of the STBC which provides maximum diversity. In literature [16] ,[17],[18] and [19] [20], STTC and OSTBS has been discussed vastly. In paper [21] STBC with ML detector has been investigated while in paper [22], Diagonal algaibric STBC was discussed.

II. METHODOLOGY

Severe attenuation is one of the major problem in a multipath wireless communication environment. Due to this severe attenuation it become very difficult for the receiver to determine the actual transmitted signal until, unless some form of diversity is provided to the receiver i.e. less attenuated version of the transmitted signal. Setting up multiple antenna system at the transmitter side as well as at the receiver side is the only practical solution of this problem. Since next generation wireless communication system demands highly power efficient and bandwidth efficient algorithm, current system of multiple antenna not only increase the capacity of the system but also provides higher data rate than the single antenna system. One of the power efficient and bandwidth efficient method of communication is space time coding which is designed for multiple antenna system.

The block diagram of proposed methodology is shown in the figure 2. This block diagram represents the MIMO system with four transmitters and one receiver. For the two transmitters and single receiver and for the six transmitters and the single receiver is same with only change in the transmitter section where number of transmitter antenna will be 2 and 6 for 2:1 MIMO system and 6:1 MIMO system.

In the proposed methodology, there are four different module i.e transmitter module, Channel module, noise module and then last is receiver module.

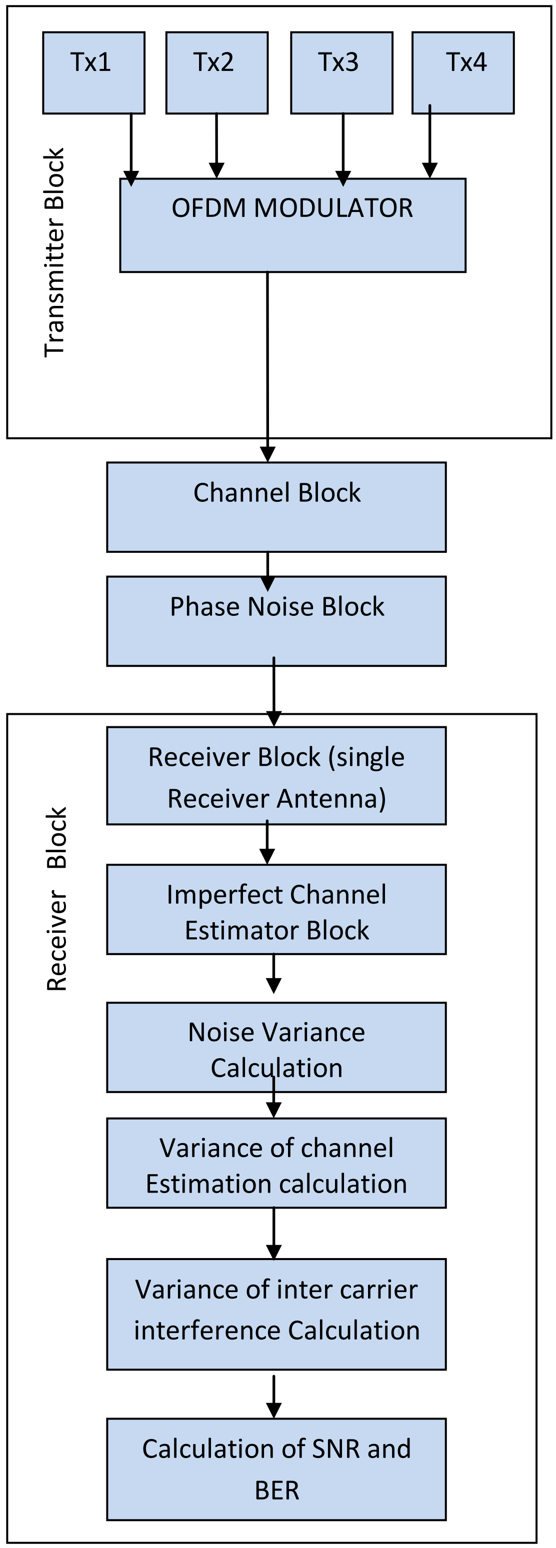

Figure 2 Block Diagram of overall Methodology

A. Transmitter Module

Transmitter module or block consists of four number of antenna and the OFDM modulator. In the first time instant symbol[Xo, X1, X2, X3] are transmitted simultaneously from four transmitting antenna with X0 is transmitted through antenna1, X1 symbol is transmitted through antenna 2 and so on. In the second time slot, symbols [-X1*, X0*,-X3*, X2*] are transmitted. Similarly symbols [-X2*, -X3*, X0*, X1*] and [X3, -X2, -X1, X0] are transmitted during the third and fourth time slots respectively.

This is done with the help of encoding matrix as shown in the figure-

$$\begin{bmatrix} H0 & H1 & H2 & H3 \\ -H1* & H0* & -H3* & H2* \\ -H2* & -H3* & H3* & H1* \\ H3 & H2 & -H1 & -H0 \end{bmatrix}$$

For each transmit antenna, a block of *N* complex-valued data symbols **{X(*k*)} *for k=0 to N-1*** are grouped and converted into a parallel set to form the input to the OFDM modulator, where *k* is the sub carrier index and *N* is the number of sub carriers. The modulator consists of an Inverse Fast Fourier transform (IFFT) block. The output of the IFFT at each transmitter is the complex baseband modulated OFDM symbol in discrete time domain and is computed by using below mention formula

$$x(n) = \frac{1}{\sqrt{N}} \sum_{k=0}^{N-1} X(k) e^{\frac{j2\pi kn}{N}}; \quad 0 \le n \le N-1$$

B. Channel Module

Channel for this project is modelled by a tapped delay line. Channel coefficients in the tapped delay lines are so selected that it is assumed to be slowly varying and hence can be considered as constant over the transmission instant. In the channel module, channel frequency response for kth subcarrier is given by

$$\mathbf{H}(k) = \sum_{p=0}^{L-1} h(p) e^{\frac{j2\pi pk}{N}}$$

Here h(p) represent the complex channel gain of p^{th} multipath component.

C. Phase Noise Module

This module is designed to simulate the effect of phase noise. Phase noise θ(n) is modelled as the zero mean continuous Brownian motion with variance $\sigma^2{}_\theta$. Winner process is used for incremental steps of phase noise.

D. Receiver Module

Receiver module takes the received signal and performs the channel estimation and variance of noise, variance of channel estimation and variance of inter-carrier interference. In the receiver block, time domain received signal for the corresponding input signal is represented by

y0(n)= (h0(n)◊x0 (n)+h1(n) ◊x1 (n)+h2(n) ◊x2 (n)+h3(n) ◊x3 (n)+w(n)0)ejθ(n)

y1(n) = (-h0(n)◊x1* (n)+h1(n) ◊x0* (n)-h2(n) ◊x3* (n)+h3(n) ◊x2* (n)+w(n)1)ejθ(n)

y2(n) = (-h0(n)◊x2* (n)-h1(n) ◊x3* (n)+h2(n) ◊x0* (n)+h3(n) ◊x2* (n)+w(n)2)ejθ(n)

y3(n) = (h0(n)◊x3 (n)-h1(n) ◊x2 (n)-h2(n) ◊x1 (n)+h3(n) ◊x0 (n)+w(n)3)ejθ(n)

In the above equation symbol ◊ represent linear convolution operation. Antenna index is represented by subscript and superscript represents the instant of transmission. Variable w(n) here represent the AWGN(Additive white Gaussian noise) with $\sigma_w{}^2 = E[|w(n)|^2].\theta_n$ represent the phase noise.

E. Imperfect channel estimator module

Main function of this module is to estimate the channel response H' of the true channel response in presence of imperfect channel. Channel response H' is given by

$$\begin{bmatrix} H_0 & H_1 & H_2 & H_3 \\ -H_1{}^* & H_0{}^* & -H_3{}^* & H_2{}^* \\ -H_2{}^* & -H_3{}^* & H_0{}^* & H_1{}^* \\ H_3 & H_2 & -H_1 & -H_0 \end{bmatrix}$$

=

$$\begin{bmatrix} H_0+\varepsilon_0 & H_1+\varepsilon_1 & H_2+\varepsilon_2 & H_3+\varepsilon_3 \\ -H_1{}^*+\varepsilon_0{}^* & H_0{}^*+\varepsilon_0{}^* & -H_3{}^*-\varepsilon_0{}^* & H_2{}^*+\varepsilon_0{}^* \\ -H_2{}^*-\varepsilon_2 & -H_3{}^*-\varepsilon_3 & H_0{}^*+\varepsilon_0{}^* & H_1{}^*+\varepsilon_1{}^* \\ H_3+\varepsilon_3 & H_2+\varepsilon_2 & -H_1-\varepsilon_1 & -H_0-\varepsilon_0 \end{bmatrix}$$

Here $\varepsilon_0, \varepsilon_1, \varepsilon_2, \varepsilon_3$ are error in channel estimate from first, second, third and fourth transmit antenne. These are modelled as complex Gaussian random variables with zero mean and variance $2\sigma\varepsilon_0$, $2\sigma\varepsilon_1$, $2\sigma\varepsilon_2$, $2\sigma\varepsilon_3$ respectively.

F. Noise Variance Module

Since noise contain both positive and negative values therefore it is squared and then mean has been computed which is called variance. Variance of noise is then calculated. After some tricky mathematical manipulation, the variance of noise W can be given as

$$\sigma^2{}_w = E[|W|^2]$$

$$= \sigma^2{}_w * \begin{bmatrix} \sum_{i=0}^{3}(\sigma^2{}_{Hi}+\sigma^2{}_{\varepsilon i}) & 0 \\ 0 & \sum_{i=0}^{3}(\sigma^2{}_{Hi}+\sigma^2{}_{\varepsilon i}) \end{bmatrix}$$

G. Variance of Channel estimation error Module

This module is used for calculating the variance of channel estimation error(φ) which is given by the following formula-

$$\sigma^2{}_{\varphi} = E[|\varphi|^2] = \sigma^2{}_{H_0} * E_g * \begin{bmatrix} \sum_{i=0}^{3}(\sigma\varepsilon_i{}^2) & 0 \\ 0 & \sum_{i=0}^{3}(\sigma\varepsilon_i{}^2) \end{bmatrix}$$

$$+ \sigma^2{}_{H_1} * E_g * \begin{bmatrix} \sum_{i=0}^{3}(\sigma\varepsilon_i{}^2) & 0 \\ 0 & \sum_{i=0}^{3}(\sigma\varepsilon_i{}^2) \end{bmatrix}$$

$$+ \sigma^2{}_{H_2} * E_g * \begin{bmatrix} \sum_{i=0}^{3}(\sigma\varepsilon_i{}^2) & 0 \\ 0 & \sum_{i=0}^{3}(\sigma\varepsilon_i{}^2) \end{bmatrix}$$

$$+ \sigma^2{}_{H_3} * E_g * \begin{bmatrix} \sum_{i=0}^{3}(\sigma\varepsilon_i{}^2) & 0 \\ 0 & \sum_{i=0}^{3}(\sigma\varepsilon_i{}^2) \end{bmatrix}$$

H. Variance of Inter-carrier interference Module

This module compute the variance of (ICI)inter-carrier interference(β) error by applying the below mentioned formula-

$$\sigma^2{}_{\beta} = E[|\beta|^2] = E_g * \begin{bmatrix} \sum_{i=0}^{3}(\sigma H_i{}^2) & 0 \\ 0 & \sum_{i=0}^{3}(\sigma H_i{}^2) \end{bmatrix}$$

I. SNR and BER Computation Module

Once all the bits of the transmitted signal have been estimated then signal to noise ration and Bit error rate has been computed to check the performance of the proposed methodology. This module is designed to perform this function. In this paper, 16 QAM modulation is used with gray code mapping for the signal (b0b1b2b3). It is to be noted that though this work uses 16 QAM for modulation, nevertheless this analysis is valid for all type of square QAM constellations. Conditional Bit error rate for bit b1 when condition H0, H1, H2, H3 is given by

$$P_1(b1|H0, H1, H2, H3) = \frac{1}{2} * \left[Q\left(\sqrt{\frac{\left(2 * \frac{Eg}{5}\right)(|H0|^2 + |H1|^2 + |H2|^2 + |H3|^2)}{6\varphi^2 + 6\beta^2 + 6w^2}} \right) + Q\left(\sqrt{\frac{\left(2 * \frac{Eg}{5}\right)(|H0|^2 + |H1|^2 + |H2|^2 + |H3|^2)}{6\varphi^2 + 6\beta^2 + 6w^2}} \right) \right]$$

Similarly for bit bit3, it is given by

$$P_1(b1|H0,H1,H2,H3) = \frac{1}{2} * \left[Q\left(\sqrt{\frac{9*\left(2*\frac{Eg}{5}\right)(|H0|^2+|H1|^2+|H2|^2+|H3|^2)}{6\varphi^2+6\beta^2+6w^2}}\right) + Q\left(\sqrt{\frac{\left(2*\frac{Eg}{5}\right)(|H0|^2+|H1|^2+|H2|^2+|H3|^2)}{6\varphi^2+6\beta^2+6w^2}}\right) + Q\left(\sqrt{\frac{\left(2*\frac{Eg}{5}\right)(|H0|^2+|H1|^2+|H2|^2+|H3|^2)}{6\varphi^2+6\beta^2+6w^2}}\right) + Q\left(\sqrt{\frac{\left(25*\frac{Eg}{5}\right)(|H0|^2+|H1|^2+|H2|^2+|H3|^2)}{6\varphi^2+6\beta^2+6w^2}}\right)\right]$$

Signal to noise ratio is given by

$$\gamma = \frac{(|H0|^2+|H1|^2+|H2|^2+|H3|^2)}{6\varphi^2+6\beta^2+6w^2} * 2 * \frac{Eg}{5}$$

The above mentioned signal to noise ration follows the Chi-square distribution with PDF (probability density function)

$$P(\gamma) = \frac{1}{2*6\gamma^2} * e^{\left[-\frac{\gamma}{2*6*\gamma^2}\right]}$$

Symmetrical nature of the M-QAM constellations, the BER for in-phase and quadrature bits are same or equal in such a way that *Pe (b*1) = *Pe (b2)* and *Pe (b3)= Pe (b4*). So average bit error rate(BER) is obtained by taking the average of the conditional bit error rate(BER) of bit b1 and b3 over the PDF of SNR γ . This is given by

$$p_e = \frac{1}{2} * \int_0^X [p_e(b1|H0,H1,H2,H3) + p_e(b3|H0,H1,H2,H3)] P(\gamma)\, d(\gamma)$$

Similarly for 6:1 transmission, signal to noise ratio (γ)is given by

$$\gamma = \frac{(|H0|^2+|H1|^2+|H2|^2+|H3|^2+|H4|^2+|H5|^2)}{6\varphi^2+6\beta^2+6w^2} * 2 * \frac{Eg}{5}$$

And Bit error rate is given by

$$p_e = \frac{1}{2} * \int_0^X [p_e(b1|H0,H1,H2,H3,H4,H5) + p_e(b3|H0,H1,H2,H3,H4,H5)] P(\gamma)\, d(\gamma)$$

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III. RESULTS

Following are the parameters values which has been used for calculation

Table 2 : System Parameters

Parameters	Values
σh^2	0.1 0.2 0.02 0.4
$\sigma \varepsilon^2$	0.1 0.04 0.06
Subcarriers(N)	64
Channel path gains	-9.7 -0.9 -8.5 -0.5

In order to check the validity of the above mentioned calculation and to see the performance of different MIMO combination.

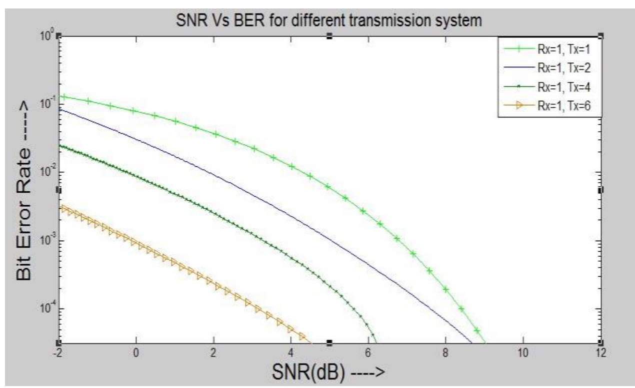

Figure 3 SNR Vs BER graph for different MIMO combination (1:1, 2:1, 4:1, 6:1)

A simulation program was designed for different combination of antenna system by incorporating the STBC code. Output of the simulation program is shown in the figure 3, figure 4, figure 5 and figure 6.

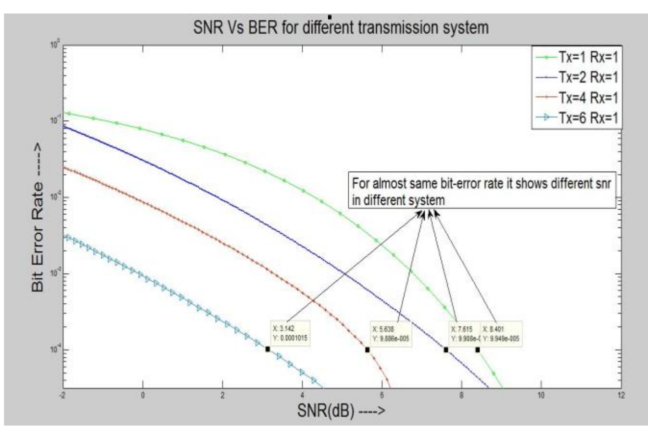

Figure 4 SNR Vs BER graph for different MIMO Combination

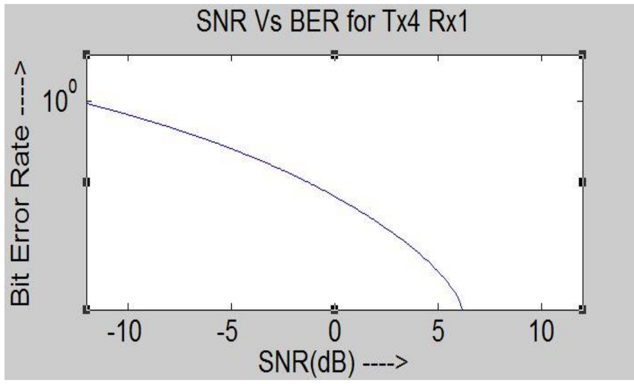

Figure 5 SNR Vs BER graph for 4:1 MIMO system

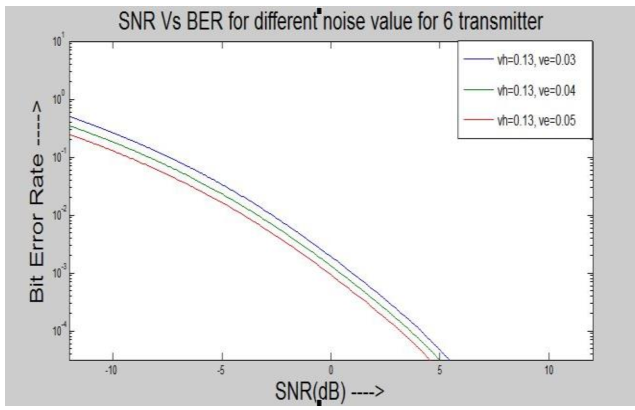

Figure 6 SNR Vs BER graph for different value of noises (Tx=6; Rx=1)

Figure 3 and figure 4 shows the SNR Vs BER plot for 1:1, 2:1,4:1,6:1 MIMO system. from this figure it is clear that as we increases the number of transmitter, SNR Vs BER graph improved e.g. in figure 3 and figure 4, graph for 6:1 MIMO system is most closer to the two axis than the other variants of MIMO system. From this graph it is also clear that as we increase the number of antenna, bit error rate start decreasing fast.

Figure 5 shows the SNR Vs BER plot for 4:1 MIMO system.

Figure 6 depicts the SNR Vs BER graph of 6:1 MIMO system for different noise values. From the SNR Vs BER curve it is clear that by increasing the diversity gain, performance of the system can be increased.

IV. CONCLUSION

In this paper, performance analysis of wireless communication system has been performed on fading channel using OFDM (Orthogonal frequency Division multiplexing) and STBC (Space Time block code).

In this paper an attempt has been made to derive the SNR (signal to noise ratio) and BER(Bit error rate) for different combination of MIMO system. What impact, a noise, Carrier interference and channel response produces on the MIMO system has been designed, developed, simulated and then analyzed. SNR Vs BER curve indicate that the performance of the MIMO system can be improved by increasing the diversity gain.

The equations for SNR and BER using 4:1 and 6:1 transmission system are derived. The effects of noise, carrier interference and channel estimator error on the system are analyzed. The SNR Vs BER curve shows that increasing the diversity gain improve the performance of the system.

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