Design and Applied an Ordered Scheme for Orthogonal MIMO Multipath Channel

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Abstract - In this paper we propose an ordered scheme for designing or maintaining orthogonal property in MIMO multipath channel. This scheme is applicable for an arbitrary number of transmitting and receiving antennas and also uses to design channel matrix, retaining the orthogonal property and to keep the channel uncorrelated consequently this helps to improve the performance and to reduce the effect of fading in multiple antenna systems. Such systems are utilized to improve the bit error rate (BER) performance of wireless communication systems and counter the destructive effects of channel attenuation and alternative distortion phenomena due to this condition, interference do not occurs between the data transmitted through the channels and thus performance improvement is achieved, which is evaluated through simulation.

Keywords - MIMO, BER, STBC, orthogonal.

I. INTRODUCTION

During early days, in wireless communication system a sender uses a single antenna to transmit a signal, which after undergoing modification effects in the communication channel, is received by a single antenna at the receiver. In a Multiple Input and Multiple Output (MIMO) scheme, as the name suggests, the sender uses multiple antennas for transmission and the receiver uses multiple antennas for reception, thus making available multiple communication paths or channels between the sender and receiver. These multiple channels can be used to increase the data rate by sending different data streams on the different channels [3]. But another perhaps a better way is to transmit different blocks, containing encoded data, in different channels. This procedure known as Space Time Block Coding (STBC) the bit error rate (BER) performance at lower SNR at the receiver can be improved. Error performance gets adversely effected at higher data rates, an additional study is been made to analyze the amount of degradation in BER at higher data rates (QAM) with respect to lower data rates (BPSK) [2]. In this paper we focus on the use of MIMO systems to improve the BER performance of wireless communication systems in fading channels as well as in channels based on actual field measurements. In a fading channel, the transmitted signal is reflected, diffracted or scattered in the channel, and, as a consequence, attenuated "versions" of the symbol arrive at the receiver via multiple paths and at varying times, causing unpredictable time-varying changes in the magnitude and phase of the arriving received signal. Real-world channels will also exhibit Doppler spread and co-channel interference as well.

We propose a systematic method for designing multi antenna system. The biggest challenge is to create orthogonal behaviour between the channels, so that no correlation may exist between the channels. A manuscript work presented by Alamouti [1] proposed a method to maintain orthogonal behaviour, which is known as space time block coding. In multi antenna system, the number of independent channels that a signal passes through, from the sender to the receiver is termed diversity gain. The maximum diversity gain is the product of the number of transmitting antennas and the number of receiving antennas; with assumption that all signal paths are orthogonal (independent) due to use of STBC [4][9]. We study the effect of various diversity gain Thus we also discuss orthogonal behaviour in detail. The performance of digital system is primarily measured by Power efficiency, Bandwidth efficiency and the error performance of the system [10]. This paper studies the performance of a variety of MIMO schemes in channels exhibiting fading and other distortion phenomena. We show that by properly designing the system to meet orthogonality conditions, a system employing multiple antennas can achieve a markedly improved bit error rate. We propose a systematic process for designing a MIMO system with an arbitrary number of transmitting antennas and receiving antennas, and evaluate (through simulation) the performance improvements that can be attained by employing our design approach [7].

- **Three Transmitters-one Receiver scheme**

In this scheme three transmitting and one receiving antennas are present three symbols can be sent at each time interval. To maintain orthogonality, the input signals are combined in different compositions (polarity and conjugate).

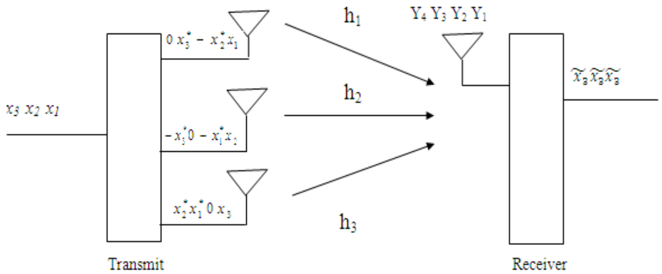

Fig 1: Three transmitter-one receiver scheme

First antenna transmits signal x_1, second antenna transmit signal $x_2$and third antenna transmit x_3 during the first interval of time. During second interval of time signals $-x_2^*$, $-x_1^*$and 0 are transmitted by the antennas 1, 2 and 3 respectively, as in this scheme three sending and one receiving antenna are available.

The matrix X (Transmitting matrix) is

$$X=\begin{bmatrix} x_1 & -x_2^* & x_3^* & 0 \\ x_2 & x_1^* & 0 & -x_3^* \\ x_3 & 0 & x_1^* & x_2^* \end{bmatrix} \quad (1)$$

The received signal will be

$$Y_1=h_1x_1+h_2x_2+h_3x_3+n_1 \quad ...(2)$$

$$Y_2=h_1(-x_2^*)+h_2x_1^*+h_3(0)+n_2 \quad ...(3)$$

$$Y_3=h_1(-x_3^*)+h_2(0)+h_3(x_1^*)+n_3 \quad ...(4)$$

$$Y_4=h_1(0)+h_2(-x_3^*)+h_3(x_2^*)+n_4 \quad ...(5)$$

Complementing the required equations

$$Y_1=h_1x_1+h_2x_2+h_3x_3+n_1 \quad ...(6)$$

$$Y_2^*=(-h_1^*)x_2+h_2^*x_1+0+n_2^* \quad ...(7)$$

$$Y_3^*= (-h_1^*)x_3+ h_3^* (x_1)+n_3^* \quad ...(8)$$

$$Y_4^*= (-h_2^*)x_3+h_3^*x_2+n_4^* \quad ...(9)$$

Rearranging the order of equations

$$Y_1=h_1x_1+h_2x_2+h_3x_3+n_1 \quad ...(10)$$

$$Y_2^*=(-h_2^*)\ x_1-h_1^*x_2+0\ x_3+n_2^* \quad ...(11)$$

$$Y_3^*= (-h_3^*)\ x_1+0\ x_2-h_1^*x_3+n_3^* \quad ...(12)$$

$$Y_4^*= 0\ x_1+(h_3^*)\ x_2-h_2^*x_3+n_4^* \quad ...(13)$$

Writing in Matrix form

$$\begin{bmatrix} y_1 \\ y_2^* \\ y_3^* \\ y_4^* \end{bmatrix}=\begin{bmatrix} h_1 & h_2 & h_3 \\ h_2^* & -h_1^* & 0 \\ h_3^* & 0 & -h_1^* \\ 0 & h_3^* & -h_2^* \end{bmatrix}\begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix}+\begin{bmatrix} n_1 \\ n_2^* \\ n_3^* \\ n_4^* \end{bmatrix} \quad ...(14)$$

The design of H matrix should satisfy orthogonal condition.

$$H^H H = (\sum_{l=1}^{3}|h_l|^2)\, I_3 \quad ...(15)$$

WhereI_3 is Identity matrix

$$I_3 = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix} \quad ...(16)$$

The number of transmitting antenna can be increased which increases the transmission diversity. In order to maintain orthogonally, Three bits requires four time slots thus can achieve maximum rate of ¾. The design process maintains orthogonal relationship between the channels by properly designing the channel matrix. At the receiver estimated symbol vectors is given by $\tilde{x} = H^H y$

... (17)

This can be expanded into

$$\tilde{x}_1 = h_1^* y_1 + h_2 y_2^* + h_3 y_3^* \quad (18)$$

$$\tilde{x}_2 = h_2^* y_1 - h_1 y_2^* + h_3 y_4^* \quad ...(19)$$

$$\tilde{x}_3 = h_3^* y_1 - h_1 y_3^* - h_2 y_4^* \quad ...(20)$$

$$\tilde{x}_1 = (\sum_{l=1}^{3}|h_l|^2) x_1 + \eta_1 \quad ...(21)$$

$$\tilde{x}_2 = (\sum_{l=1}^{3}|h_l|^2) x_2 + \eta_2 \quad ...(22)$$

$$\tilde{x}_3 = (\sum_{l=1}^{3}|h_l|^2) x_3 + \eta_3 \quad ...(23)$$

Noise terms are given by

$$\eta_1 = h_1^* n_1 + h_2 n_2^* + h_3 n_3^* \quad ...(24)$$

$$\eta_2 = h_2^* n_1 - h_1 n_2^* + h_3 n_4^* \quad ...(25)$$

$$\eta_3 = h_3^* n_1 - h_1 n_2^* - h_2 n_4^* \quad ...(26)$$

Since the magnitude of estimated signals is now greater, it is reasonable to conclude that the bit error rate (BER) performance will be enhanced over the two transmit antenna system. The results presented for the diversity gain, rate, and recovered signals. Further system can be extended to 3transmitters and two receiving antenna system. Designing process shown below

- **Three Transmitters-two Receiver Scheme**

In this scheme three transmitting and two receiving antennas are present three symbols can be sent at each time interval. To maintain orthogonality, the input signals are combined in different compositions (polarity and conjugate).

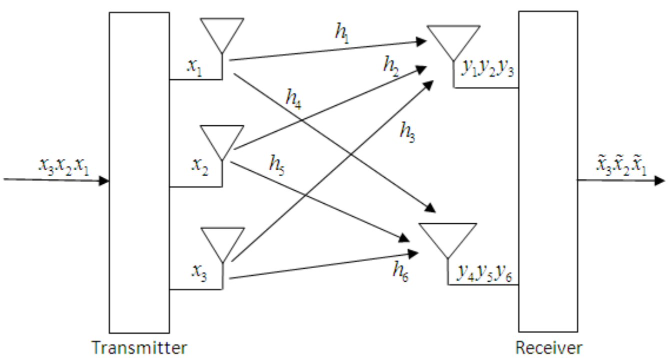

Fig. 2: Three transmitter-two receiver scheme

The matrix X (Transmitting matrix) is same as 3x1 antenna system

$$X=\begin{bmatrix} x_1 & -x_2^* & x_3^* & 0 \\ x_2 & x_1^* & 0 & -x_3^* \\ x_3 & 0 & x_1^* & x_2^* \end{bmatrix} \quad \text{... (27)}$$

Similarly as above writing in Matrix form

$$\begin{bmatrix} y_1 \\ y_2^* \\ y_3^* \\ y_4^* \\ y_5 \\ y_6^* \\ y_7^* \\ y_8^* \end{bmatrix} = \begin{bmatrix} h_1 & h_2 & h_3 \\ h_2^* & -h_1^* & 0 \\ h_3^* & 0 & -h_1^* \\ 0 & h_3^* & -h_2^* \\ h_4 & h_5 & h_6 \\ h_5^* & -h_4^* & 0 \\ h_6^* & 0 & -h_4^* \\ 0 & h_6^* & -h_5^* \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix} + \begin{bmatrix} n_1 \\ n_2^* \\ n_3^* \\ n_4^* \\ n_5 \\ n_6^* \\ n_7^* \\ n_8^* \end{bmatrix} \quad \text{... (28)}$$

The design of H matrix should satisfy orthogonal condition.

$$H^H H = (\sum_{l=1}^{6} |h_l|^2) \mathrm{I}_6 \quad \text{... (29)}$$

The design process maintains orthogonal relationship between the channels by properly designing the channel matrix. At the receiver estimated symbol vectors is given by

$$\tilde{x} = H^H y \quad \text{... (30)}$$

This can be expanded into

$$\tilde{x}_1 = h_1^* y_1 + h_2 y_2^* + h_3 y_3^* + h_4^* y_5 + h_5 y_6^* + h_6 y_7^* \quad \text{... (31)}$$

$$\tilde{x}_2 = h_2^* y_1 - h_1 y_2^* + h_3 y_4^* + h_2^* y_1 - h_5^* y_5^* - h_4 y_6^* + h_6 y_8^* \quad \text{... (32)}$$

$$\tilde{x}_3 = h_3^* y_1 - h_1 y_3^* - h_2 y_4^* + h_6^* y_5 - h_4 y_7^* - h_5 y_8^* \quad \text{... (33)}$$

$$\tilde{x}_4 = (\sum_{l=1}^{4} |h_l|^2) x_4 + \eta_4 \quad \text{... (34)}$$

$$\tilde{x}_2 = (\sum_{l=1}^{6} |h_l|^2) x_2 + \eta_2 \quad \text{... (35)}$$

$$\tilde{x}_3 = (\sum_{l=1}^{6} |h_l|^2) x_3 + \eta_3 \quad \text{... (36)}$$

Noise terms is given by:

$$\eta_1 = h_1^* n_1 + h_2 n_2^* + h_3 n_3^* + h_4^* n_5 + h_5 n_6^* + h_6 n_7^* \quad \text{... (37)}$$

$$\eta_2 = h_2^* n_1 - h_1 n_2^* + h_3 n_4^* + h_2^* n_1 - h_5^* n_5^* - h_4 n_6^* + h_6 n_8^* \quad \text{... (38)}$$

$$\eta_3 = h_3^* n_1 - h_1 n_3^* - h_2 n_4^* + h_6^* n_5 - h_4 n_7^* - h_5 n_8^* \quad \text{... (39)}$$

The results presented for the diversity gain, rate, and recovered signals can be extended to 3×M Systems by using the same steps shown in the previous section.

The rate will remain constant (maximum rate =1) if the no. of transmitting antennas are fixed at two. As two time slots are required to send two bits. Thus full rate is achieved. The number of transmitting antenna can be increased which increases the transmission diversity. In order to maintain orthoganality, Three bits requires four time slots thus can achieve maximum rate of ¾. The design process maintains orthogonal relationship between the channels by properly designing the channel matrix.

- **Orthogonal Requirement and Satisfaction**

This process satisfies the orthogonality requirements for H matrix (channel matrix) the no. of rows provides the no. of time intervals needed to transmit p no. of symbols. Now, starting with the first row, add (k-1) rows so that the first column is orthogonal to column 2, then we add (k-2) rows, so that the 2nd column is orthogonal to column 3 and so on.

Therefore, entire number of rows present in the MIMO channel matrix

$$1+\sum_{k=1}^{p-1} k = 1+\frac{p(p-1)}{2} = \frac{p^2-p+2}{2} \quad \text{...(40)}$$

- **Step 1**: The equation relating input and output by involving H matrix is given by
$Y = Hx + \eta$ ...(41)

$$\begin{bmatrix} y_1 \\ y_2^* \\ y_3^* \\ y_4^* \\ y_5^* \\ \vdots \\ \vdots \\ y^*_{(\frac{p^2-p+2}{2})} \end{bmatrix} = \begin{bmatrix} h_{11} & h_{12} & h_{13} & h_{14} & \dots & h_{1Xp-1} & h_{1Xp} \\ -h_{12}^* & h_{11}^* & 0 & 0 & \dots & 0 & 0 \\ -h_{13}^* & 0 & h_{11}^* & 0 & \dots & 0 & 0 \\ -h_{14}^* & 0 & 0 & h_{11}^* & \dots & 0 & 0 \\ \vdots & \vdots & \vdots & \vdots & \vdots & 0 & 0 \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ 0 & 0 & 0 & 0 & \dots & -h_{1Xp}^* & h_{1Xp-1}^* \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \\ x_3 \\ x_4 \\ \vdots \\ x_p \end{bmatrix} + \begin{bmatrix} n_1 \\ n_2^* \\ n_3^* \\ n_4^* \\ n_5^* \\ \vdots \\ \vdots \\ n^*_{(\frac{p^2-p+2}{2})} \end{bmatrix} \quad \text{..(42)}$$

- **Step 2**: The received signal $\tilde{x}$ can be determined by the equation
$\tilde{x} = H^H y = H^H[Hx + \eta]$ ...(43)

$$\begin{bmatrix} \tilde{x}_1 \\ \tilde{x}_2 \\ \tilde{x}_3 \\ \vdots \\ \tilde{x}_p \end{bmatrix} = H^H \begin{bmatrix} y_1 \\ y_2^* \\ y_3^* \\ y_4^* \\ y_5^* \\ \vdots \\ \vdots \\ y^*_{(\frac{p^2-p+2}{2})} \end{bmatrix} = \begin{bmatrix} h_{11}^* & -h_{12} & h_{13} & h_{14} & \dots & 0 & 0 \\ h_{12}^* & h_{11} & 0 & 0 & \dots & 0 & 0 \\ h_{13}^* & 0 & h_{11} & 0 & \dots & 0 & 0 \\ h_{14}^* & 0 & 0 & h_{11} & \dots & 0 & 0 \\ \vdots & \vdots & \vdots & \vdots & \vdots & 0 & 0 \\ h_{1p-1}^* & \vdots & \vdots & \vdots & \vdots & \vdots & -h_{1Xp} \\ h_{1p}^* & 0 & 0 & 0 & \dots & 0 & h_{1Xp-1} \end{bmatrix} \begin{bmatrix} y_1 \\ y_2^* \\ y_3^* \\ y_4^* \\ y_5^* \\ \vdots \\ \vdots \\ y^*_{(\frac{p^2-p+2}{2})} \end{bmatrix} + \eta \quad \text{...(44)}$$

Noise is given by the equation $\eta = H^H n$

- **Step 3**: Thus each symbol (estimated) will be given by

$$\tilde{x}_1 = (\sum_{l=1}^{p} |h_l|^2) x_1 + \eta_1 \quad \text{...(45)}$$

$$\tilde{x}_2 = (\sum_{l=1}^{p} |h_l|^2) x_2 + \eta_2 \quad \text{...(46)}$$

$$\vdots$$

$$\tilde{x}_p = (\sum_{l=1}^{p} |h_l|^2) x_p + \eta_p \quad \text{...(47)}$$

From the above equation it can be justified that as space diversity increases the amplitude of the received (estimated) signal amplitude increases thus improved BER can be achieved.

- **Four Transmitters and one receiver Antenna System**

Designing process of four transmits and one receives antenna system as per ordered designing process step wise.

Let the first row contain 4 columns.

$$H = \begin{bmatrix} h_1 & h_2 & h_3 & h_4 \end{bmatrix} \quad \text{...(48)}$$

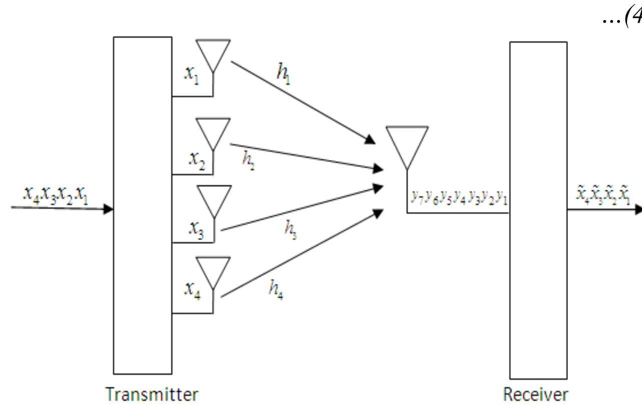

Fig. 3: Four Transmitter and One Antenna System

Rows are added in such a way that it maintain the orthogonality between all the columns. Finally, we will get 7x4 orthogonal matrix. That indicates 4 symbols are required 7 time slots.

$$H = \begin{bmatrix} h_1 & h_2 & h_3 & h_4 \\ h_2^* & -h_1^* & 0 & 0 \\ h_3^* & 0 & -h_1^* & 0 \\ h_4^* & 0 & 0 & -h_1^* \\ 0 & h_3^* & -h_2^* & 0 \\ 0 & h_4^* & 0 & -h_2^* \\ 0 & 0 & h_4^* & -h_3^* \end{bmatrix} \quad ...(49)$$

With the help of channel matrix we can relate input and output symbols.

$$y = \begin{bmatrix} y_1 \\ y_2^* \\ y_3^* \\ y_4^* \\ y_5^* \\ y_6^* \\ y_7^* \end{bmatrix} = Hx + n = \begin{bmatrix} h_1 & h_2 & h_3 & h_4 \\ h_2^* & -h_1^* & 0 & 0 \\ h_3^* & 0 & -h_1^* & 0 \\ h_4^* & 0 & 0 & -h_1^* \\ 0 & h_3^* & -h_2^* & 0 \\ 0 & h_4^* & 0 & -h_2^* \\ 0 & 0 & h_4^* & -h_3^* \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \\ x_3 \\ x_4 \end{bmatrix} + \begin{bmatrix} n_1 \\ n_2^* \\ n_3^* \\ n_4^* \\ n_5^* \\ n_6^* \\ n_7^* \end{bmatrix} \quad ...(50)$$

Estimated received signal is given by

$$\tilde{x} = H^H y = H^H (Hx + \eta) \quad ...(51)$$

At the receiver end estimated symbols are calculated by H^H matrix.

$$\begin{bmatrix} \tilde{x}_1 \\ \tilde{x}_2 \\ \tilde{x}_3 \\ \tilde{x}_4 \end{bmatrix} = H^H \begin{bmatrix} y_1 \\ y_2^* \\ y_3^* \\ y_4^* \\ y_5^* \\ y_6^* \\ y_7^* \end{bmatrix} = \begin{bmatrix} h_1^* & h_2 & h_3 & h_4 & 0 & 0 & 0 \\ h_2^* & -h_1 & 0 & 0 & h_3 & h_4 & 0 \\ h_3^* & 0 & -h_1 & 0 & -h_2 & 0 & h_4 \\ h_4^* & 0 & 0 & -h_1 & 0 & -h_2 & -h_3 \end{bmatrix} \begin{bmatrix} y_1 \\ y_2^* \\ y_3^* \\ y_4^* \\ y_5^* \\ y_6^* \\ y_7^* \end{bmatrix} \quad ...(51)$$

$$H^H H = (|h_1|^2 + |h_2|^2 + |h_3|^2 + |h_4|^2) I_4 \quad ...(52)$$

Where the noise terms is given by

$$\eta = H^H n \quad ...(53)$$

From the fifth step we can successfully calculate the estimated received signals

$$\tilde{x}_1 = (\sum_{l=1}^{4} |h_l|^2) x_1 + \eta_1 \quad ...(54)$$

$$\tilde{x}_2 = (\sum_{l=1}^{4} |h_l|^2) x_2 + \eta_2 \quad ...(55)$$

$$\tilde{x}_3 = (\sum_{l=1}^{4} |h_l|^2) x_3 + \eta_3 \quad ...(56)$$

$$\tilde{x}_4 = (\sum_{l=1}^{4} |h_l|^2) x_4 + \eta_4 \quad ...(57)$$

Finally we can conclude that the 4×1 system designed by using the ordered designing method which is based on orthogonal design of channel matrix with code rate 4/7.Futher we can expand 4x1 system to 4xR system where R is arbitrary of receiving antennas.

II. RESULT

This paper involves an ordered scheme to design orthogonal channel matrix for MIMO system with an STBC, the arbitrary number of transmit and receive antennas. Simulation results were used to evaluate the performance of MIMO-STBC systems designed using our approach, in Rayleigh fading channels. We presented a formula that can be readily used to determine the rate of systems that employ our design. Three criteria—the rate of the scheme, the BER and the complexity were used to analyze our scheme. Figure 1 shows BER performance comparison of two transmits MIMO system. The diversity of 2x2 antenna system just double 2x1 antenna system and to achieve BER of 10^{-4} 2x1 and 2x2 antenna systems are required 20dB and 11dB of SNR

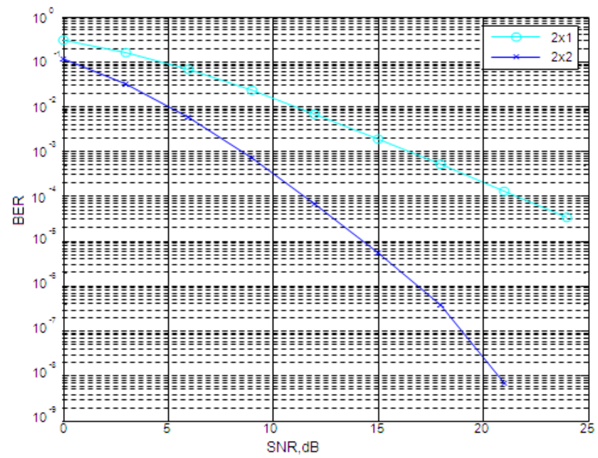

Fig. 1: BER Vs. SNR Performance of Two Transmit Antenna System

Figure2 shows that performance comparison between three transmitters and multiple antenna system over Rayleigh fading channel. The 3x3 antenna systems give improved BER performance than the 3x2 and 3x1 antenna systems

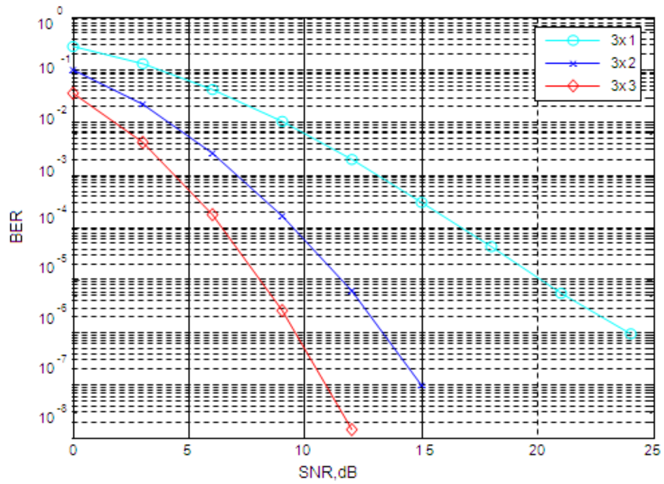

Fig. 2: BER Vs. SNR Performance of Three Transmit Antenna System

Figure 3 shows performance evaluation of a MISO system Over Rayleigh fading channel. Specifically graph shows the comparison between 1x1,2x1,3x1,and 4x1 antenna system on the of two parameter SNR and BER. From the result it is understandable that when the count of transmitted antenna increases, the performance is continuously improved. BER improvement rapidly increases after 10 dB as the system configuration changes from 1x1 to 2x1, 3x1 and 4x1.Result also justified that the estimated signal power at the receiver increases linearly with the number of transmitting antenna.

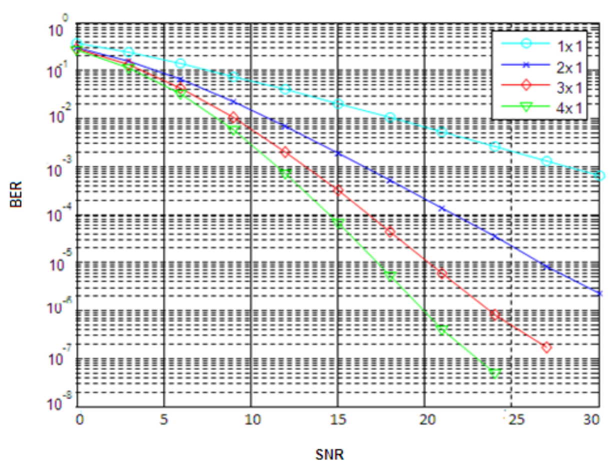

Fig. 3: BERVs. SNR Performance of Multiple input single output antenna system

III. CONCLUSION

This paper investigated the performance of MIMO systems that use STBC with the proposed ordered scheme. Such systems can be employed to improve the BER performance of wireless communication systems and can counter the detrimental effects of channel fading and other distortion phenomena. A variety of different MIMO schemes were evaluated in simulation using the MATLAB programming language. MIMO systems can also be used to counter the performance degradation that results from correlation between multipath channels at a receiver. From the above simulation graph it proves that when diversity increases performance of the system improves and also successfully implementation of extension of MISO system to MIMO system. This justified our proposed method. It is cleared that the magnitude of estimated signal at the receiver end is much greater in case of more number of antennas at both ends than the multiple transmit or single receiving antenna system. So it can conclude that MIMO system improves the system performance in multipath fading environment without any additional requirement of the bandwidth.

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