MIMO PERFORMANCE ANALYSIS WITH ALAMOUTI STBC CODE and V-BLAST DETECTION SCHEME

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Abstract—**An analysis of the performance of Multiple Input Multiple Output (MIMO) antenna systems has been carried out by determining the transmit diversity using Alamouti Space Time Block Coding (STBC) techniques. In this paper our purpose is that, peformance analysis of Alamouti STBC and also comparing with SISO performance. It includes definition of SISO system,STBC, after that Alamouti STBC theory and its mathematical expressions. Also we define process of project and lastly we give our results for each of SISO, 2x1 and 2x2 Alamouti STBC. This paper also includes study of VBLAST technique, many algorithms have been proposed to reduce the interference in the received signals caused by other transmitters in the system. Also, they aim achieve closer values to the Shannon capacity limit. D-BLAST (Diagonal Bell Labs Layered Space Time) and V-BLAST (Vertical Bell Labs Layered Space Time) are such schemes used for detection and suppression the interference in MIMO systems. D-Blast, which was proposed by Gerard J. Foschini, applies a diagonal space time coding on the data. By applying this algorithm, it could achieve 90% of Shannon capacity rates as well as high spectral efficiency. However, due to complexity of implementing the algorithm, V-Blast algorithm was proposed. It was established in 1996 at Bell Labs. It demultiplexes the transmitted signal and then maps bit to symbol independently for each substream.**

Index Terms:MIMO ,SISO,STBC,VBLAST.

1. INTRODUCTION OF SPACE-TIME BLOCK CODING

One of the methodologies for exploiting the capacity in MIMO system consists of using the additional diversity of MIMO systems, namely spatial diversity, to combat channel fading. This can be achieved by transmitting several replicas of the same information through each antenna. By doing this, the probability of losing the information decreases exponentially [1]. The antennas in a MIMO system are used for supporting a transmission of a SISO system since the targeted rate of is that of a SISO system. The diversity order or diversity gain of a MIMO system is defined as the number of independent receptions of the same signal. A MIMO system with N_t transmit antennas and N_r receive antennas has potentially full diversity (i.e. maximum diversity) gain equal to N_tN_r. The different replicas sent for exploiting diversity are generated by a space-time encoder which encodes a single stream through space using all the transmit antennas and through time by sending each symbol at different times. This form of coding is called Space-Time Coding (STC). Due to their decoding simplicity, the most dominant form of STCs are space-time block codes (STBC).

2. SYSTEM MODEL

MIMO systems are composed of three main elements, namely the transmitter (TX), the channel (H), and the receiver (RX). In this paper, N_t is denoted as the number of antenna elements at the transmitter, and N_r is denoted as the number of elements at the receiver. Figure 1 depicts such MIMO system block diagram. It is worth noting that system is described in terms of the channel. For example, the Multiple-Inputs are located at the output of the TX (the input to the channel), and similarly, the Multiple-Outputs are located at the input of the RX (the output of the channel).[3]

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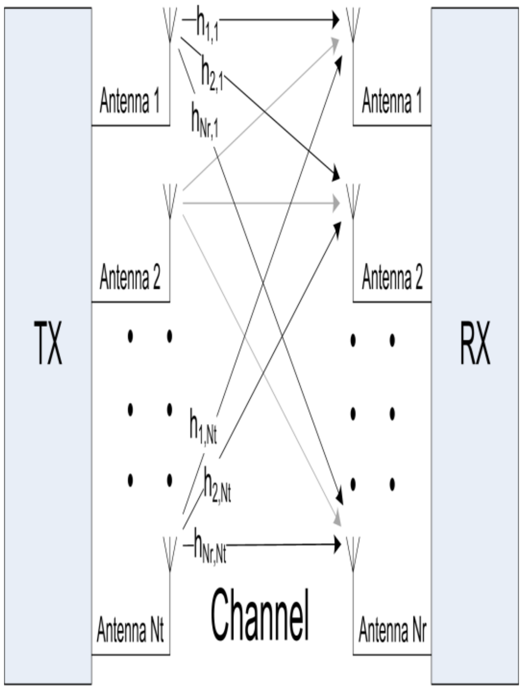

Figure1 : Multiple-input Mutilpe –output system block diagram

The channel with N_r outputs and N_t inputs is denoted as a N_r X N_t matrix:

$$H = \begin{pmatrix} h_{1,1} & h_{1,2} & \cdots & h_{1,N_t} \\ h_{2,1} & h_{2,2} & \cdots & h_{2,N_t} \\ \vdots & \vdots & \ddots & \vdots \\ h_{N_r,1} & h_{N_r,2} & \cdots & h_{N_r,N_t} \end{pmatrix}$$

where each entry $h_{i;j}$ denotes the attenuation and phase shift (transfer function) between the j^{th} transmitter and the i^{th} receiver. It is assumed in this paper that the MIMO channel behaves in a "quasi-static" fashion, i.e. the channel varies randomly between burst to burst, but fixed within a transmission. This is a reasonable and commonly used assumption as it represents an indoor channel where the time of change is constant and negligible compared to the time of a burst of data .[3]

The MIMO signal model is described as

$\vec{r} = H\vec{s} + \vec{n}$

where $\vec{r}$ is the received vector of size N_r x 1, H is the channel matrix of size N_r x N_t , $\vec{s}$ is the transmitted vector of size N_t x 1, and $\vec{n}$is the noise vector of size Nr x1. Each noise element is typically modeled as independent identically distributed (i.i.d.) white Gaussian noise ,with variance N_t/(2 ▪SNR) .An explanation for this model is as follows. The transmitted signals are mixed in the channel since they use the same carrier frequency. At the receiver side,the received signal is composed of a linear combination of each transmitted signal plus noise. If the channel H is correlated, the system of linear equations will have more unknowns than equations. One reason correlation between signals can occur is due to the spacing between antennas. To prevent correlation due to the spacing, they are typically spaced at least λ_c /2, where λ_c is the wavelength of the carrier frequency . The second reason correlation can occur is due to lack of multipath components. It is for this reason that rich multipath is desirable in MIMO systems. The multipath effect can be interpreted by each receive antenna being in a different channel. For this reason, the rank of a MIMO channel is defined as the number of independent equations offered. It is important to note that

$\mathrm{rank}(H) \leq \min(N_r,N_t)$

and therefore the maximum number of streams that a MIMO system can support is upper-bounded by $\min(N_r,N_t)$.Since the performance of MIMO systems depends highly on the channel matrix, it is important to model the channel matrix realistically.

3. **Single Input Single Output (SISO)**

It is a traditional model in wireless system which uses one antenna at transmitter and one antenna at receiver. Its overall performance largely dependent on channel behavior and environment .It is used in radio and TV broadcast and our personal wireless technologies such us wi-fi and Bluetooth

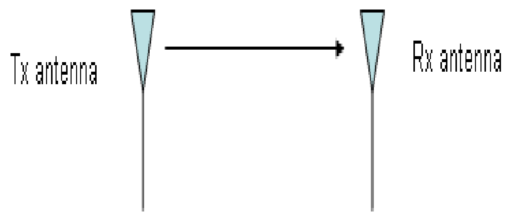

Figure2 : SISO MODEL

It can be represented by $\vec{r} = H\vec{s} + \vec{n}$ defined above

4. Alamouti's STBC

In Alamouti published his technique on transmit diversity.Historically, Alamouti's scheme was the first STBC .The simplicity and structure of the Alamouti STBC

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has placed the scheme in both the W-CDMA and CDMA-2000 standards. The Alamouti STBC scheme uses two transmit antennas and Nr receive antennas and can accomplish a maximum diversity order of $2N_r$. Moreover, the Alamouti scheme has full rate (i.e. a rate of 1) since it transmits 2 symbols every 2 time intervals. Next, a description of the Alamouti scheme is provided for both 1 and 2 receive antennas, followed by a general expression for the decoding mechanism for the case of N_r receive antennas.[2][3]

Description: As mentioned earlier, Alamouti STBC uses two transmit antennas regardless of the number of receive antennas. The Alamouti scheme encoding operation is given by (1). In this paper, the rows of each coding scheme represents a different time instant, while the columns represent the transmitted symbol through each different antenna. In this case, the first and second row represent the transmission at the first and second time instant respectively. At a time t,the symbol s_1 and symbol s_2 are transmitted from antenna 1 and antenna 2 respectively. Assuming that each symbol has duration T, then at time t + T, the symbols $-s^*_2$ and s^*_1 where $(.)^*$ denotes the complex conjugate, are transmitted from antenna 1 and antenna 2 respectively.[2]

$$\mathcal{G}_2 = \begin{pmatrix} s_1 & s_2 \\ -s_2^* & s_1^* \end{pmatrix} \quad (1)$$

In this paper we discuss 2 transmitters-1receiver system(2x1) and 2transmitters-2receivers system(2x2).

A) Case of 1 Receive Antenna: The reception and decoding of the signal depends on the number of receive antennasavailable. For the case of one receive antenna, the receive signals are [3]

$$r_1^{(1)} = r_1(t) = h_{1,1}s_1 + h_{1,2}s_2 + n_1^{(1)}$$

$$r_1^{(2)} = r_1(t+T) = -h_{1,1}\, s^*_2 + h_{1,2}s^*_1 + n_1^{(2)} \quad (2)$$

where r_1 is the received signal at antenna 1, $h_{i;j}$ is the channel transfer function from the jth transmit antenna and the ith receive antenna ,n_1 is a complex random variable representing noise at antenna 1, and $x^{(k)}$ denotes x at time instant k(i.e at time t+ (k-1)T).

Before the received signals are sent to the decoder, they are

combined as follows[3]:

$$\tilde{s}_1 = h^*_{1,1}r_1^{(1)} + h_{1,2}r_1^{*(2)}$$

$$\tilde{s} = h^*_{1,2}r_1^{(1)} + h_{1,1}r_1^{*(2)} \quad (3)$$

And substituting (2) in (3) yields

$$\tilde{s}_1 = (a^2_{1,1} + a^2_{1,2})s_1 + h^*_{1,1}n_1^{(1)} + h_{1,2}n_1^{*(2)}$$

$$\tilde{s}_2 = (a^2_{1,1} + a^2_{1,2})s_2 - h^*_{1,1}n_1^{(2)} + h_{1,2}n_1^{*(1)} \quad (4)$$

B) Case of 2 Receive Antennas**:** For the case of two receive antennas, the received symbols are[3];

$$r_1^{(1)} = h_{1,1}s_1 + h_{1,2}s_2 + n_1^{(1)}$$

$$r_1^{(2)} = -h_{1,1}s_2^* + h_{1,2}s_1^* + n_1^{(2)}$$

$$r_2^{(1)} = h_{2,1}s_1 + h_{2,2}s_2 + n_2^{(1)}$$

$$r_2^{(2)} = -h_{2,1}s_2^* + h_{2,2}s_1^* + n_2^{(2)} \quad (5)$$

and the combined signals are [3];

$$\tilde{s}_1 = h^*_{1,1}r_1^{(1)} + h^*_{1,2}r_1^{*(2)} + h^*_{2,1}r_2^{(1)} + h_{2,2}r_2^{*(2)}$$

$$\tilde{s}_2 = h^*_{1,2}r_1^{(1)} + h^*_{1,1}r_1^{*(2)} + h^*_{2,2}r_2^{(1)} + h_{1,1}r_2^{*(2)} \quad (6)$$

Which after substituting in (5) becomes:

$$\tilde{s}_1 = (a^2_{1,1} + a^2_{1,2} + a^2_{2,1} + a^2_{2,2})s_1 + h^*_{1,1}n_1^{(1)} + h_{1,2}n_1^{*(2)} + h^*_{2,1}n_2^{(1)} + h_{2,2}n_2^{*(2)}$$

$$\tilde{s}_2 = (a^2_{1,1} + a^2_{1,2} + a^2_{2,1} + a^2_{2,2})s_2 - h_{1,1}n_1^{*(2)} + h^*_{1,2}n_1^{(1)} - h^*_{2,1}n_2^{*(2)} + h^*_{2,2}n_2^{(1)}$$

4.2 Bit-Error-Rate Analysis on MATLAB

By using QPSK Modultaion below figure shows how we do performance analysis of SISO, (2x1) and (2x2) Alamouti Space Time Coding with QPSK modulation with block diagrams step by step[10][11]

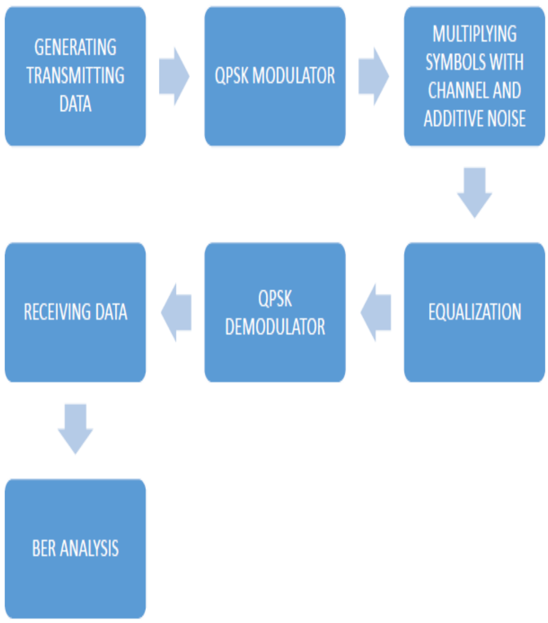

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Figure3: Proposed simulation model for Applied Alamouti's scheme

4.3 Results

As can be seen from graph 2x2 Alamouti STBC has the smallest BER values for all of SNR_dB values. This result is expected because 2x2 Alamouti system has one more receiver when compared with 2x1Alamouti system and thanks to this one more receiver it increases its diversity. Matlab simulation shown the below figure

SISO system has the highest BER values for all of SNR_dB values because of no diversity

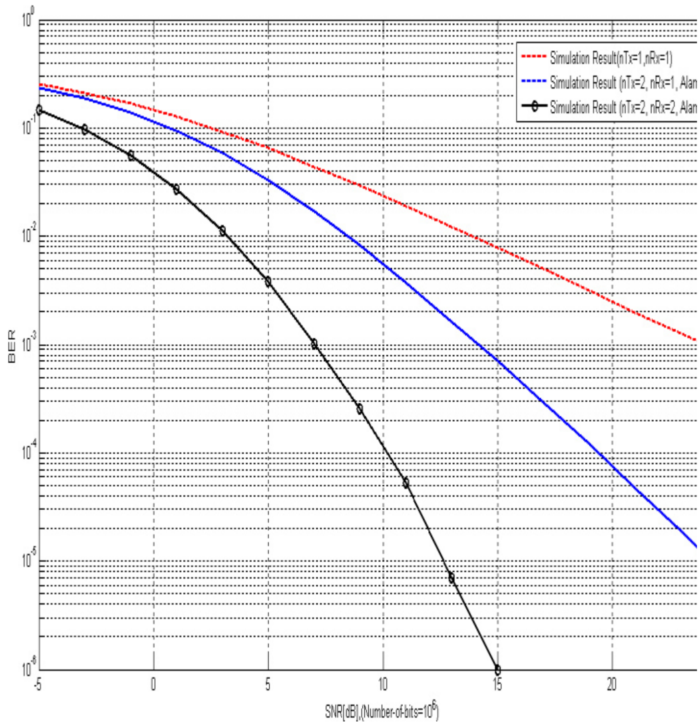

Figure4: Comparative simulation results of applied Alamouti IN QPSK modulation

5 V-Blast Theory

V-Blast is a single user scheme which has multiple transmitters. It divides the data stream into substreams and transmits them through multiple transmitters at the same time and frequency. The transmission is described as follows. A data stream is demultiplexed into M sub-streams termed layers and transmits them through multiple transmitters at the same time and frequency. This results in receiving the data at the receiver at the same time and frequency. By implementing V-BLAST algorithm, the diversity gain is increased and the bit error rate (BER) performance is improved. The MIMO system is assumed to undergoes flat fading channel. The system model of the output signal is given by:

$y = Hx + \eta$

Where y is the received signal, x is the transmitted signal, η is the added noise and H is the channel model of the system. At the receiver, as mentioned previously, the received signals at each receive antenna is a superposition of M faded symbols plus additive white Gaussian noise (AWGN). Although the layers are arranged differently for the two BLAST systems across space and time, the detection process for both systems is performed vertically for each received vector. Without loss of generality,assume that the first symbol is to be detected. The V-BLAST system[5] is simplified version of D-BLAST[6] that tries to reduce its computational complexity. But in doing so transmit diversity is loss. A high-level block diagram of a V-BLAST system is shown in Fig5. [7]

5.1 Encoder

A single data stream is de-multiplexed into m sub-streams, and each sub-stream is then encoded into symbols and fed to its respective transmitter. Transmitters 1-m operate co-channel at symbol rate 1/T symbols/sec, with synchronized symbol timing.

5.2 Decoder

The decoder needs to demodulate the symbols on the received vector. If channel encoding is used, then the demodulated symbols need to be buffered until the whole block can be decoded. Otherwise, the demodulation can be done immediately. Several decoders are possible for this architecture and these decoders are explained bellow one by one

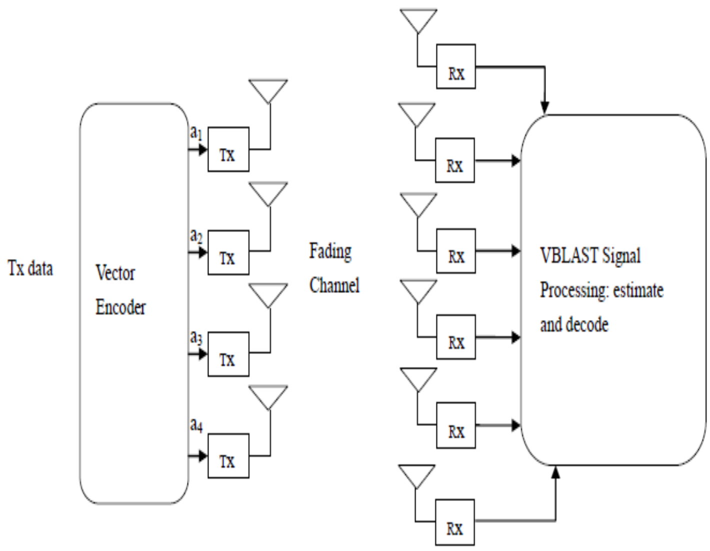

Figure5: VBLAST transceiver system

5.3 Maximum Likelihood Decoder

The ML receiver performs optimum vector decoding and is optimal in the sense of minimizing the error probability. ML receiver is a method that compares the received signals with

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all possible transmitted signal vectors which is modified by channel matrix H and estimates transmit symbol vector $\hat{C}$ according to the Maximum Likelihood principle, which is shown as:

$$\hat{C} = \text{argmin}[\![r - C'H]\!]^2_F$$

Where, $_F$ is the Frobenius norm

5.4 V-BLAST Zero Forcing (ZF)

Zero Forcing is the linear MIMO technique. The processing takes place at the receiver where, under the assumption that the channel matrix H is invertible, H is inverted and the transmitted MIMO vector 's' is estimated by

$$S_{est} = H^{-1} x$$

The solution of ZF is given by:

$$S_{est} = Wx = H^{+}x = (H^H H)^{-1} H^H x$$

Where $(\ )^{+}$ represents the pseudo-inverse.

5.5 V-BLAST Minimum Mean Square Error (MMSE)

The MMSE receiver suppresses both the interference and noise components, whereas ZF receiver removes only the interference components. This implies that the mean square error between the transmitted symbols and the estimate of the receiver is minimized. Hence MMSE is superior to ZF in the presence of noise. At low SNR, MMSE becomes matched filter and at high SNR, MMSE becomes Zero Forcing (ZF). For MMSE-V-BLAST, the nulling vector for the i^{th} layer is

$$W^i = (H_i H^*_i + \frac{1}{snr} I)^{-1} h_{i,}\ \ i = 1,2,\ldots..N$$

Where $H_i = C^{Mxi}$ consists of the first I columns of H.

5.6 Results and Discussions

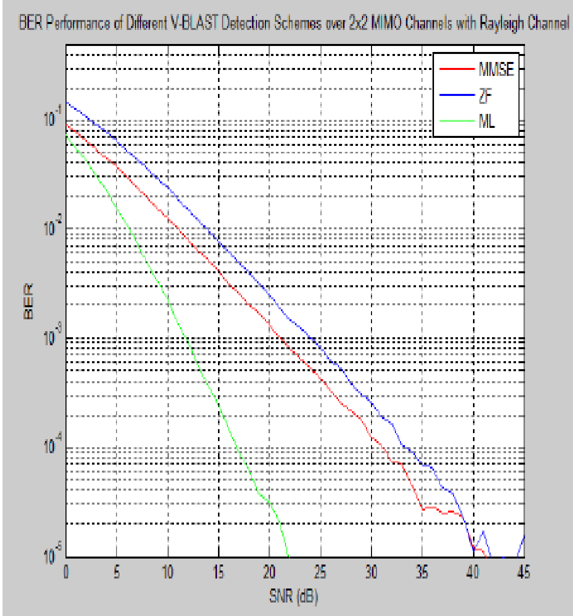

Figure6: BER Performance of different V-blast Detection scheme over 2X2 MIMO channels with Rayleigh.

At a BER of 10-4, the SNRs of ML, MMSE and ZF are 16 dB, 31 dB and 33 dB respectively. We see a huge improvement in using ML detection over MMSE and ZF detections by 15 dB. The performance of MMSE detection is better than ZF detection by 2- 3 dB. From the above results, it has been observed that the ML detection has better BER performance than the MMSE and ZF detections by 15dB. In Addition, the performance of MMSE detection is better than ZF detection by 2- 3 dB. Finally, by using the adaptive scalar recursion for fast fading, the complexity order reduces to square and the computation becomes less compared to other techniques.

REFRENCES

[1]D. Gesbert, M. Shafi, D. Shiu, P. Smith, and A. Naguib, "From theory to practice: an overview of MIMO space-time coded wireless systems," IEEE Journal on selected areas in Communications, vol. 21, no. 3, pp.281–302, 2003.

[2] STBC online Wikipedia

[3] Luis Miguel Cort´es-Pe˜na "MIMO Space-Time Block Coding (STBC):

Simulations and Results" DESIGN PROJECT: PERSONAL AND MOBILE COMMUNICATIONS, GEORGIA TECH (ECE6604), APRIL 2009.

[4] "A Simple Diversity Technique for Wireless Communication "Siavash M Alamouti, IEEE Journal on selected areas in Communication, Vol 16, No, 8, October 1998 .

[5]. G.D.Golden, G.J.Foschini, R.A. Valenzuela, and P.W.Wolniasky, "Detection algorithm and initial laboratory results using the V-BLAST space-time communication architecture," *Electron Lett*.vol.35, no.1, pp.1415, 1999

[6] G.Foschini, "Layered space-time architecture for wireless communication in a fading environment when using multiple antennas,"

ISSN: 2278 – 7798

Bell Labs, Technical Journal 2, 1996, appeared in Volume 1, number 2, pp 41-59.

[7] Sukhchain Singh, Gurpreet Singh, Amit Grover “Performance Evaluation of ML-VBLAST MIMO System using various antenna configurations with Ricean and Rayleigh Channel**”**. Innovative Systems Design and Engineering www.iiste.org ISSN 2222-1727 (Paper) ISSN 2222-2871 (Online) Vol 3, No 10, 2012.

[8] Taekyu Kim and Sin-Chong Park. “Reduced Complexity Detection for V-BLAST D Systems from Iteration Canceling”. 2008.

[9] Toshiaki. K. “ Low-Complexity Systolic V-BLAST Architecture” IEEE Transactions on Wireless Communications, 2009

[10] http://spacetimecodes.blogspot.com/p/alamouti-code.html

[11] http://nutaq.com/en/blog/alamouti-space-time-block-coding

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