Analysis and Parametric Characterization of Space Time Block Code over Various Fading Channels

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***Abstract* - Now-a-days a speedy and more reliable communication links along with Multiple-input-multiple-output (MIMO) systems has become a prime concern in the field of Communication systems. As MIMO systems utilizes multiple number of antennas both at the transmitter and receiver, the necessary requirement to reduce the fading resulting from signal fluctuations in the channel is Diversity. In this paper the analysis of MIMO systems using STBC codes and OSTBC codes and measured the BER vs. Eb/N0 values have been carried out. The performance analysis of space–time block-coded multiple-input–multiple-output (STBC-MIMO) systems in different fading channels such as Rayleigh channel and Additive White Gaussian Channel (AWGN) channel is presented in this paper. Comparative analysis of average bit error rate (BER) of STBC-MIMO for binary phase-shift keying (BPSK), quadrature phase shift keying (QPSK) and Quadrature amplitude modulation (QAM) – both 8-QAM and 16-QAM are derived. Based on asymptotic analysis for both these fading channels, closed-form expressions of approximate average BER is obtained for different Eb/N0.**

***Index Terms* - Bit error rate (BER), Additive White Gaussian Channel (AWGN), Quadrature Amplitude Modulation (QAM), multiple input–multiple output (MIMO), space–time block coding (STBC)**

I. INTRODUCTION

The diversity gain property of Transmit diversity technique has recently received considerable attention in multiple-input multiple-output (MIMO) communication systems.

The capacity and error probability performance of STBC-MIMO have been extensively studied for different fading channels [1]. Based on the smallest distance of the constellation, an expression of the bit error rate (BER) of the STBC with m-bit Quadrature amplitude modulation (QAM) and various shift keying techniques in slow Rayleigh fading channel is derived [2]. By using the bit log-likelihood ratio, an analytical expression of the bit error rate (BER) of the STBC with QAM over Rayleigh fading channels is obtained [3]. In [4], closed-form expressions of BER of the Alamouti scheme with binary phase-shift keying (BPSK) over flat Rayleigh fading channels are derived, but the analysis is complicated for large constellation size. The closed-form exact BER expressions of the orthogonal STBCs for QAM and phase-shift keying (PSK) in both spatially white and correlated Rayleigh MIMO channels are presented in [5].

Most of the existing work in this area assumes that the antenna elements at the transmitter and the receiver of the MIMO system are placed far enough (spatially)such that the effect of the channel at a particular antenna element is different from the effect at all other antenna elements. This implies independent or spatially uncorrelated fading. This holds true only if spacing between transmit antennas or receive antennas is of the order of several wavelengths. However, if antenna spacing is not enough, the fading channel from multiple antennas might be correlated, and the performance will be degraded. Similarly, few of the previous works assume quasi-static fading in which the channel characteristic remain constant over one frame period, while some others assume. (fully interleaved) fading in which channel varies from one symbol to another independently. However, it is not possible to interleave code words due to delays involved in interleaving. In that case, the channel will have temporal correlation.

A code is mapping from the input bits to the transmitted symbols. Here, we assume that symbols are transmitted simultaneously from different antennas. Here, we study the performance of different codes by deriving some bounds on them. Then, we use the bounds to provide some guidance to design codes with “good” performance. Such guidance is called the design criterion. Most of the analyses in this paper are asymptotic analysis. Therefore, different asymptotic assumptions may result in different code criteria. We concentrate on a quasi-static Rayleigh fading wireless channel and some of the important design criteria that result in achieving maximum diversity and good performance at high SNRs. A good code follows a design criterion that adds some notion of optimality to the code. In fact, the goal of defining a design criterion is to have a guideline for designing good codes. For example let us consider transmission over a binary symmetric channel using a linear binary block channel code. The bit error rate of the system depends on the Hamming distances of the codeword pairs. Defining the set of all possible codeword pairs and the corresponding set of Hamming distances, we denote the minimum Hamming distance by dmin. It can be shown that a code with minimum Hamming distance dmin can correct all error patterns of weight less than or equal to _(dmin − 1)/2_, where _x_ is the largest integer less than or equal to x. Therefore, for a given redundancy, a “good” code has a high minimum Hamming distance. The design criterion for such a code is to maximize the minimum possible Hamming distance among the codeword pairs. To compare two codes with similar redundancies, the one with higher Hamming distance is preferable. Similarly for an additive white Gaussian noise (AWGN) channel, a good design criterion is to maximize the minimum Euclidean distance among all possible codeword.

In this paper Section-II gives the details on STBC, the proposed design technique is described in Section-III, results and discussion is carried out in Section-IV, Section-V concludes the paper with references mentioned in Section-VI.

II. SPACE-TIME BLOCK CODING

A. Introduction

Optimal design and successful deployment of high performance wireless networks present a number of technical challenges. These include regulatory limits on usable radio frequency spectrum and a complex time-varying propagation environment affected by fading and multi-path. In order to meet the growing demand for higher data rates at better quality of service (QoS) with fewer dropped connections, boldly innovative techniques that improve both spectral efficiency and link reliability are called for. Use of multiple antennas at the receiver and transmitter in a wireless network is a rapidly emerging technology that promises higher data rates at longer ranges without consuming extra bandwidth or transmits power. This technology, popularly known as smart antenna technology, offers a variety of leverages which if exploited correctly can enable multiplicative gains in network performance [6].

Smart antenna technology provides a wide variety of options, ranging from single-input, multiple-output (SIMO) architectures that collect more energy to improve the signal to noise ratio (SNR) at the receiver, to multiple-input, multiple-output (MIMO) architectures that open up multiple data pipes over a link. The number of inputs and outputs here refers to the number of antennas used at the transmitter and receiver, respectively. The space-time (S-T) modem at the transmitter (Tx) encodes and modulates the information bits to be conveyed to the receiver and maps the signals to be transmitted across space (Mt transmit antennas) and time. The S-T modem at the receiver (Rx) processes the signals received on each of the Mr receive antennas according to the transmitter's signaling strategy and demodulates and decodes the received signal.

Different smart antenna architectures provide different benefits which can be broadly classified as array gain, diversity gain, multiplexing gain and interference reduction. The signaling strategy at the transmitter and the corresponding processing at the receiver are designed based on link requirements (data rate, range, reliability etc.). For example, if we want to improve the point-to-point spectral efficiency (in bits/sec/Hz) between a transmitter and receiver, multiplexing gain is required. And it is provided by the MIMO architecture. The signaling strategy also depends on the availability of channel information at the transmitter. For example, MIMO does not require channel knowledge at the transmitter, although it enjoys improved performance if channel information is available. On the other hand, spatial division multiple access (SDMA) does re-quire channel information at the transmitter which is used to increase the network throughput at the media access (MAC) layer. The advantage of point-to-multipoint SDMA over point-to-point MIMO is that SDMA deploys multiple antennas only at the cellular base station or wireless local area network (LAN) access point, thus reducing cost of the cell phone or network interface card (NIC).

B. OSTBC

1. *Introduction*

Recent information theoretic results have demonstrated that the ability of a system to support a high link quality and higher data rates in the presence of Rayleigh fading improves significantly with the use of multiple transmit and receive antennas. Since then there has been considerable work on a variety of schemes which exploit multiple antennas at both the transmitter and receiver in order to either obtain transmit and receive diversity and therefore increase the reliability of the system, e.g., orthogonal space-time block codes (OSTBC) and space-time trellis codes or achieve the theoretical bounds. The performance of OSTBC with respect to mutual information has been analyzed and it was shown that the capacity is achieved only in the case of nT = 2 transmit, the well known Alamouti scheme, and nR = 1 receive antennas due to the rate loss inherent in OSTBC with higher number of transmit antennas. Recently, it was shown that due to this rate loss, OSTBC with odd number of antennas are always outperformed by OSTBC with even number of antennas, restricting even more the deployment of OSTBC. On the one hand, we have the OSTBC with low complexity and low rates [7]. On the other hand, we have the space-time trellis codes, which achieve higher spectral efficiency in addition to high performance with respect to frame error rates. However, the decoding complexity of space-time trellis codes is increasing exponentially with the number of transmit antennas and the transmission rate. In order to achieve higher spectral efficiency combined with low complexity maximum likelihood detectors, a quasi-orthogonal space-time block codes (QSTBC) with transmission rate one for more than two transmit antennas was designed.

2. *System Modeling*

We consider a system with nT transmit and nR receive antennas. Our system model is defined by

$$Y = G_{nT} H^T + N$$

where G_{nT} is the (T × nT) transmit matrix, Y = [y1 ,...,y_{nR}] is the (T × nR) receive matrix, H = [h1 ,...,h_{nT}] is a (nR × nT) matrix characterizing the coherent channel, and N = [n1,...,n_{nR}] is the complex (T × nR) white Gaussian noise (AWGN) matrix, where an entry { n_{ti} } of N ($1 \le i \le n_R$) denotes the complex noise at the ith receiver for a given time t($1 \le t \le T$). The real and imaginary parts of n_{ti} are independent and N (0,n_T /(2SNR)) distributed. An entry of the channel matrix is denoted by { h_{ij} } [8]. This represents the complex gain of the channel between the jth transmit ($1 \le j \le nT$) and the ith receive ($1 \le i \le nR$) antenna, where the real and imaginary parts of the channel gains are independent and normal distributed random variables with N (0,1/2) per dimension. The channel matrix is assumed to be constant for a block of T symbols and changes independently from block to block. The average power of the symbols transmitted from each antenna is normalized to be $1/n_T$, so that the average power of the received signal at each receive antenna is one and the signal-to-noise ratio (SNR) is ρ. It is further assumed that the transmitter has no channel state information (CSI) and the receiver has perfect CSI.

III. PROPOSED DESIGN TECHNIQUE

In order to analyze the Bit Error Rate of a system, it is important to consider all the factors such as which channel is being used, which modulation technique is carried out and for which MIMO system, i.e., how many number of input and output antennas are being used. Below shown are steps deriving the calculation of BER.

A. Main steps in coding algorithm

In order to analyze the BER, the following steps are required:

1. *The MATLAB code begins by the input data i.e, a stream of digital data is to be considered*
2. *This data was modulated by BPSK/QPSK/QAM modulator*
3. *Then data was encoded by using OSTBC encoder for 3x2 and rate 3/4 systems And is forwarded through AWGN channel*
4. *At the receiver MRC is used for 3x2 MIMO system and for and ML detector is used and BER is compared*

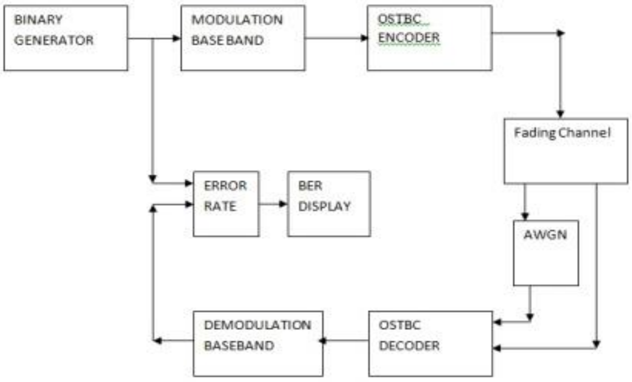
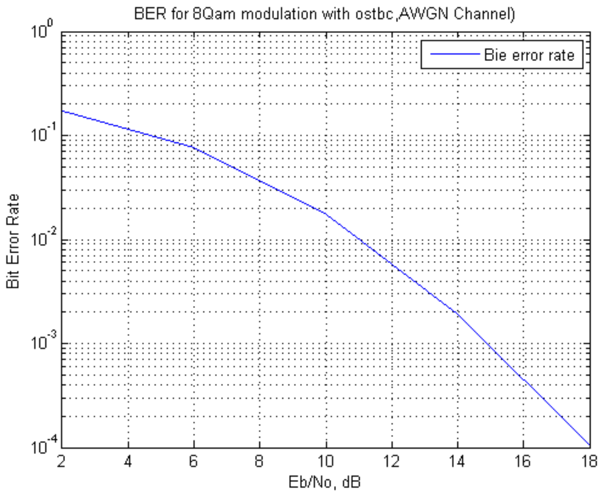
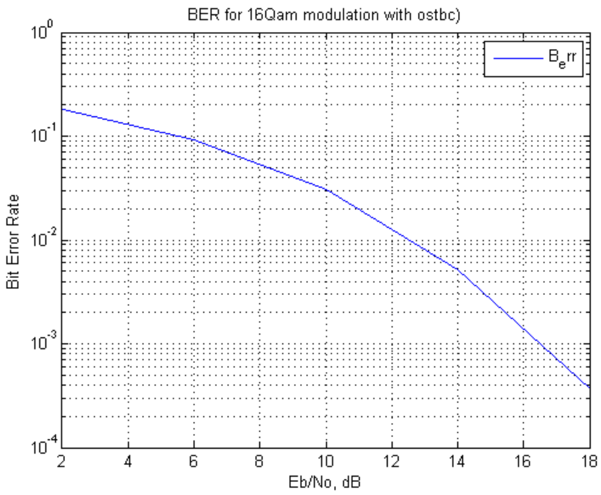


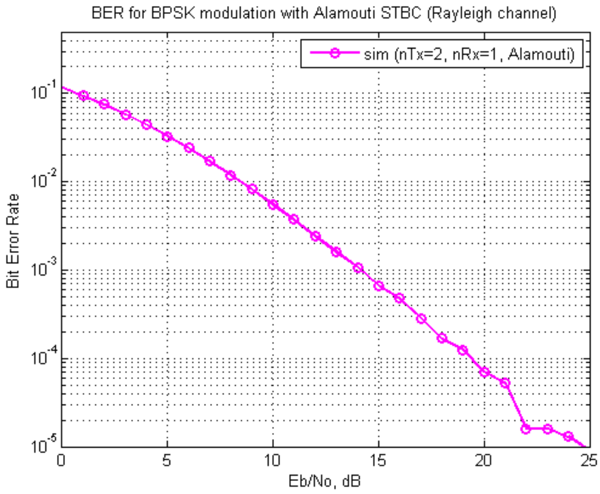
Fig. 1 OSTBC over Rayleigh fading channel

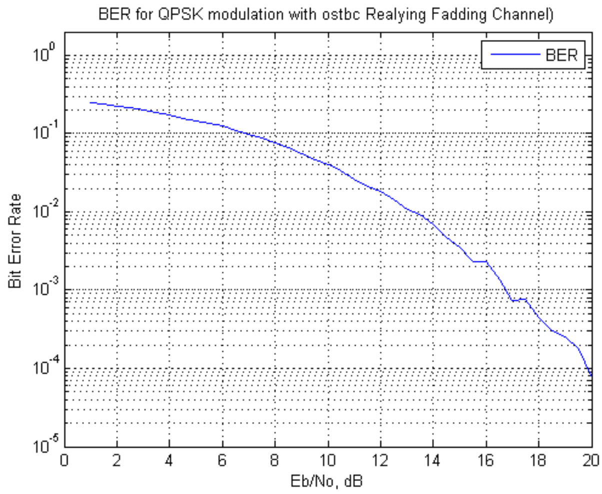
IV. RESULTS AND DISCUSSION

BER analysis for different modulation techniques is presented and the simulation results obtained are shown in here.









Furthermore, the performance analysis of bit error rate for 4 different values of Eb/N0 is carried out for two channels, AWGN and Rayleigh and is as shown below.

Table 1 BER Comparison for 16-QAM Modulation

Eb/N0	BER (AWGN)	BER (Rayleigh)
4	0.1334	0.1299
8	0.0577	0.0491
12	0.0176	0.0108
16	0.0020	0.0004

Table 2 BER Comparison for 8-QAM Modulation

Eb/N0	BER (AWGN)	BER (Rayleigh)
4	0.1202	0.1088
8	0.0764	0.0217
12	0.0176	0.0064
16	0.0020	0.0016

Table 3 BER Comparison for QPSK Modulation

Eb/N0	BER (AWGN)	BER (Rayleigh)
4	0.1050	0.0587
8	0.0674	0.0170
12	0.0034	0.0037
16	0.0010	0.0001

Table 4 BER Comparison for BPSK Modulation

Eb/N0	BER (AWGN)	BER (Rayleigh)
4	0.1050	0.0587
8	0.0674	0.0170
12	0.0034	0.0037
16	0.0010	0.0001

V. CONCLUSION

In this paper a comparative study of different modulation techniques with 2:2 MIMO system under various fading environments is done. In Rayleigh fading channel, the Bit error rate (BER) is least i.e. 0.0587 at 4dB for BPSK modulation technique as compared to the other three modulation techniques i.e. BPSK, QPSK, 8/16-QAM. Hence the performance of the Binary phase shift keying is best when Rayleigh fading is present in 2:2MIMO, OSTBC system.

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