

Analysis and Simulation of Space Time Block Code with Linear Receiver for QAM and PSK as Modulation Techniques

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ABSTRACT

In Space-Time Coding (STC) systems, the same information symbol stream is transmitted from different transmit antennas in appropriate manner to obtain transmit diversity. The structure of the signal enables us to exploit diversity in the spatial and temporal dimensions in order to obtain improved bit error performance and higher data rates without bandwidth expansion. The objective of this paper is to provide the description of different type of space time block codes and to provide the analysis of these codes without channel knowledge at the transmitter with different modulation schemes for four transmit and one receive antenna. We propose a new space time block code and compare it with other codes.

Keywords

Wireless communication, MIMO systems, diversity, bit error rate, OSTBC, Q-OSTBC.

1. INTRODUCTION

Multiple-input multiple-output (MIMO) communication technology has received significant recent attention due to the rapid development of high-speed broadband wireless communication systems. In wireless communications, one main challenge is the transmission over channels that experience time-variant multipath fading. Such detrimental effects in wireless channels can be combated using space-time block coding (STBC), an efficient transmit diversity scheme with exploitation of the diversity advantage of multi-antenna systems.

Deploying multiple antennas at the transmitter and receiver creates a multiple-input multiple-output (MIMO) channel that not only offers higher transmission rates, but it can also decrease error rates that improve the system's reliability and robustness to noise compared to single antenna systems. In addition to this, multiple antennas can also be utilized in order to mitigate co-channel interference, which is another major source of disruption in (cellular) wireless communication systems.

At the receiver due to multipath fading, the receiver cannot correctly detect the transmitted signal unless some less attenuated replica of the signal is provided to the receiver, this technique is called diversity.

2. DIVERSITY

Depending on surrounding environment, a transmitted radio signal propagates through several different paths. This phenomenon is often referred as multipath propagation. The signal received by the receiver antenna consists of the superposition of various multipaths. If there is

Non-Line of Sight components between the transmitter and receiver, the attenuation coefficients corresponding to different paths are assumed to be independent and identically distributed. Signal power in a wireless system fluctuates. When this signal power drops significantly, the channel is said to be in fade. Diversity is used in wireless channels to combat the fading.

The main idea behind diversity is to provide different replicas of the transmitted signal to the receiver. If these different replicas fade independently, it is less probable to have all copies of the transmitted signal in deep fade simultaneously. Therefore, the receiver can reliably decode the transmitted signal using these received signals. Diversity techniques can be implemented into different ways.

In time diversity different time slots are used to achieve diversity. In frequency diversity different frequency bands are used to achieve diversity. In space diversity multiple antennas are deployed at either the transmitting end or the receiving end to achieve diversity.

Space diversity can further be divided into receive and transmit diversity. Receive diversity and transmit diversity mitigate fading and significantly improve link quality. *Receive diversity* is achieved using multiple antennas on the receiving end of the communication link. The basic idea is to have multiple signals with different degree of fading or different channel transfer function 'h'. The signals are then appropriately combined with the help of diversity combining techniques. The major problem with using the receive diversity approach is the cost, size, and power of the remote units. *Transmit diversity* is achieved using multiple antennas on the transmitting end of the communication link. The transmit diversity is far more advantageous in comparison to the receive diversity. This is due to the fact that with transmit diversity, multiple antennas transmit delayed versions of a signal, creating frequency-selective fading, which is equalized at the receiver to provide diversity gain. A base station often serves hundreds to thousands of remote units. It is therefore more economical to add equipment to base stations rather than the remote units. For this reason, transmit diversity [1] schemes are very attractive.

2.1 Space Time Coding

An effective and practical way to approaching the capacity of MIMO wireless channels is to employ Space-Time Coding (STC). STC is a coding technique designed to be used with multiple transmit antennas. Coding is performed in both spatial and temporal domains to introduce correlation between signals transmitted for various

antennas at various time periods. Space-Time coding can achieve transmit diversity and power gain over spatially uncoded systems without sacrificing the bandwidth.

2.2 Focus and Outline of the paper

The objective of this paper is to provide the basics of space time block codes and propose a new scheme. This paper is organized as follows. In Section III, we describe the model of space time block codes. In Section IV, we present the different type of space time block codes and their property. In section V, We give the simulation result and performance comparison of different space time block codes with different modulation techniques. In Section VI, Some conclusions are offered. Although the list of references is not intended to be exhaustive, the cited papers (as well as the references therein) will serve as a good starting point for further reading.

3. SPACE TIME BLOCK CODES

STBC is defined by a code matrix with orthogonal columns. A simple linear receiver is also obtained due to the orthogonality of the columns of the code matrix. In general, an STBC is defined by a $(p \times n_T)$ matrix G . The entries of the matrix G are linear (possibly complex) combinations of the variables $x_1; x_2; \dots; x_k$ (representing symbols). The columns of the matrix represent antennas and the rows time slots. Therefore, p time slots are needed to transmit k symbols, resulting in a code rate $R = k/p$.

3.1 Transmission Model

We consider a wireless communication system with N antennas at the base station and M antennas at the remote. At each time slot t , signals, C_t^i $i=1,2,\dots,N$ are transmitted Simultaneously from the N transmit antennas. The channel is assumed to be a flat fading channel and the path gain from transmit antenna i to receive antenna j is defined to be α_{ij} . The path gains are modeled as samples of independent complex Gaussian random variables with variance 0.5 per real dimension. This assumption can be relaxed without any change to the method of encoding and decoding [2]. The wireless channel is assumed to be quasi-static i.e the path gains are constant over a frame of length and vary from one frame to another. At time t the signal r_t^j , received at antenna j , is given by

$$r_t^j = \sum_{i=1}^n \alpha_{ij} c_t^i + n_t^j \dots (1) \text{ where the noise samples}$$

n_t^j are independent samples of a zero-mean complex Gaussian random variable with variance $n/(2 \text{ SNR})$ per complex dimension. The average energy of the symbols transmitted from each antenna is normalized to be one, so that the average power of the received signal at each receive antenna is n and the signal-to-noise ratio is SNR.

Assuming perfect channel state information is available, the receiver computes the decision metric

$$\sum_t \sum_j^{n_r} \left| r_t^j - \sum_{i=1}^n \alpha_{ij} c_t^i + n_t^j \right|^2 \dots (2)$$

over all codeword

$$c_1^1 c_1^2 \dots c_1^n c_2^1 c_2^2 \dots c_2^n c_1^1 c_1^2 \dots c_1^n$$

and decides in favor of the code word that minimizes the sum.

4. TYPES OF SPACE TIME BLOCK CODES

4.1 The Alamouti Scheme

The Alamouti scheme is a simple transmit diversity[10] scheme suitable for two transmit antennas. The ALAMOUTI code is the first STBC that provides full diversity at full data rate for two transmit antennas [3]. At a given symbol period, two signals are simultaneously transmitted from the two antennas. Two symbols are considered at a time, say x_1 and x_2 , and they are transmitted in two consecutive time slots. In the first time slot, x_1 is transmitted from the first antenna and x_2 is transmitted from the second one. In the second time slot, $-x_2^*$ is transmitted from the first antenna, while x_1^* is transmitted from the second antenna. The signals x_1 and x_2 are picked from an arbitrary (M -ary) constellation. Since two symbols are transmitted in two time slots, the overall transmission rate is 1 symbol per channel use, or $\log_2 M$ bits per channel use.

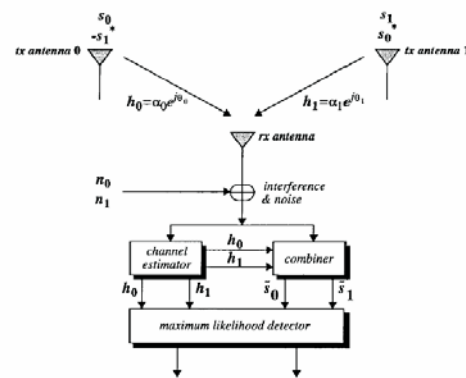


Fig 1: The Alamouti Scheme

The encoding, however, may also be done in space and frequency. Instead of two adjacent symbol periods, two adjacent carriers may be used (spacefrequency coding).

4.2 Orthogonal space time block code

In this section, we describe what is known as the general space-time block codes based on the theory of orthogonal designs[5]. Consider a system with N_t transmit antennas. The objective is to design a set of $N_t \times N_t$ matrices with elements from a desired signal constellation whose columns are orthogonal to each other. The latter property is required to make sure that a linear receiver is still optimal and the decoding complexity is still kept at a minimum. It is not always possible to find full-rate, full-diversity space-time block codes using (square) orthogonal designs. For real constellations, such a design is possible if the number of antennas is two, four or eight. If the square orthogonal design condition is relaxed, then it is possible to find other full-rate full-diversity code examples. On the other hand, for complex signal constellations full-rate designs exist if and only if $N_t = 2$, that is, the Alamouti code is the only full-rate, full-diversity space-time block code when the signal constellation is complex.

4.3 Quasi-orthogonal space time block code

The main characteristic of the codes designed in [5] is the orthogonality property of the codes. In Quasi orthogonal space time block code (JAFARKHANI code) [6], we propose structures that are not orthogonal designs and, therefore, at the decoder, cannot separate all transmitted symbols from each other. Instead, in Quasi OSTBC structure, the transmission matrix columns are divided into groups. While the columns within each group are not orthogonal to each other, different groups are orthogonal to each other. We call such a structure a quasi-orthogonal design. It is shown that using a quasi-orthogonal design, pairs of transmitted symbols can be decoded separately. It gives a way of obtaining full-rate (or increased-rate) space-time block coding designs using smaller designs as building blocks. The application of such a structure is in designing codes which provide higher transmission rates while sacrificing the full diversity. By using the orthogonality of the transmitted symbols, ALAMOUTI [3] first defined a space time transmission matrix as

$$A_{12} = \begin{bmatrix} X_1 & X_2 \\ -X_2^* & X_1^* \end{bmatrix} \quad .. (5)$$

Where the subscript A_{12} indicates the indeterminate X_1 and X_2 existing in the transmission matrix. Based on ALAMOUTI orthogonal STBC, JAFARKHANI [6] gave a quasi orthogonal STBC form for four transmit antennas as

$$C_J = \begin{bmatrix} A_{12} & A_{34} \\ -A_{34}^* & A_{12}^* \end{bmatrix} = \begin{bmatrix} X_1 & X_2 & X_3 & X_4 \\ -X_2^* & X_1^* & -X_4^* & X_3^* \\ -X_3^* & -X_4^* & X_1^* & X_2^* \\ X_4 & -X_3 & -X_2 & X_1 \end{bmatrix} \quad \dots\dots\dots(6)$$

Where A_{12} and A_{34} are ALAMOUTI codes. Further, different from JAFARKHANI scheme, the TBH case [7] has

$$S_{ABBA} = \begin{bmatrix} S_{12} & S_{34} \\ S_{34} & S_{12} \end{bmatrix} = \begin{bmatrix} s_1 & s_2 & s_3 & s_4 \\ -s_2^* & s_1^* & -s_4^* & s_3^* \\ s_3 & s_4 & s_1 & s_2 \\ -s_4^* & s_3^* & -s_2^* & s_1^* \end{bmatrix} \quad \dots\dots\dots(7)$$

Using a unitary pattern idea introduced in [8] to investigate the distribution of conjugates in the transmission matrices, we find that it is related to the positions of correlated values. By changing the distribution of conjugates, we can obtain matrices with different positions of correlated values.

4.3.1 JAFARKHANI Case with TBH Correlated Position

We change the conjugates' distribution of JAFARKHANI matrix, and let

$$C_{JT}^H = \begin{bmatrix} x_1 & x_2 & x_3 & x_4 \\ -x_2^* & x_1^* & -x_4^* & x_3^* \\ x_4 & -x_3 & -x_2 & x_1 \\ -x_3^* & -x_4^* & x_1^* & x_2^* \end{bmatrix} \quad \dots\dots\dots (8)$$

4.3.2 TBH case with JAFARKHANI- correlated positions

Similar to the above modification, we exchange the last row and the third row from eqn. (7) and let

$$C_{TJ}^H = \begin{bmatrix} x_1 & x_2 & x_3 & x_4 \\ x_2^* & -x_1^* & x_4^* & -x_3^* \\ x_4^* & -x_3^* & x_2^* & -x_1^* \\ x_3 & x_4 & x_1 & x_2 \end{bmatrix} \quad \dots\dots (9)$$

4.5 Proposed Code

We proposed a new space time block code matrix whose performance is better than other space time block codes. This space time block code is quasi-orthogonal in nature. We use zero-forcing technique for the analysis of this code. Channel is assumed to be quasi-static Rayleigh flat fading channel. The matrix of the proposed code is given by

$$A = \begin{bmatrix} A_{12} & A_{34} \\ A_{34} & -A_{12} \end{bmatrix} = \begin{bmatrix} x_1 & x_2 & x_3 & x_4 \\ -x_2^* & x_1^* & -x_4^* & x_3^* \\ x_3 & x_4 & -x_1 & -x_2 \\ -x_4^* & x_3^* & x_2^* & -x_1^* \end{bmatrix} \quad \dots\dots (10)$$

V. SIMULATION RESULT AND PERFORMANCE COMPARISON

In simulation result, first we give the comparison of ALAMOUTI space time block codes with 1x1 scheme. We also provide comparison with 1x2 MRC scheme. The comparison of analytical and simulation result is also given. ALAMOUTI scheme is better

than other schemes but there is 3-dB difference between ALAMOUTI scheme and (1×2) MRC scheme. Reason is that in ALAMOUTI scheme the signal power is divided in 2 antennas equally.

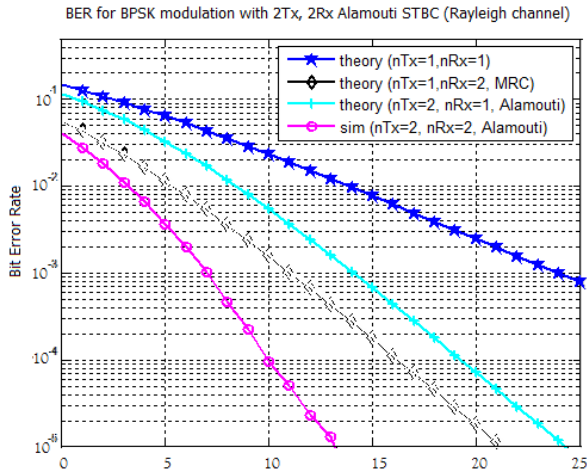


FIG 2: BER performance of ALAMOUTI STBC with different scheme

In next results, we give comparisons of all the space time block codes explained in this paper. For value of $M < 8$ M-QAM and M-PSK have same simulation results. So the codes are compared under the different modulation schemes like 8QAM, 8PSK, 16QAM, 16 PSK, 32QAM, 32 PSK. We see that the proposed code has better performance than other codes under different modulation schemes. Linear receiver techniques like zero forcing are used in simulation model. Channel is assumed to be quasi-static flat fading Rayleigh channel.

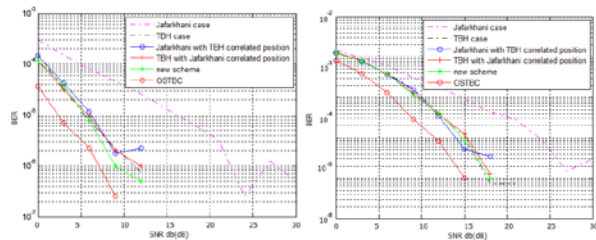


Fig 3 (a)

Fig 3 (b)

FIG 3: (a)BER performance comparisons of different STBC under 8QAM scheme (b) BER performance comparisons of different STBC under 8PSK scheme

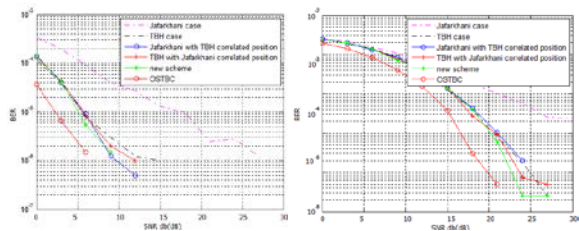


Fig 4 (a)

Fig 4 (b)

FIG 4: (a)BER performance comparisons of different STBC under 16QAM scheme (b) BER performance comparisons of different STBC under 16PSK scheme

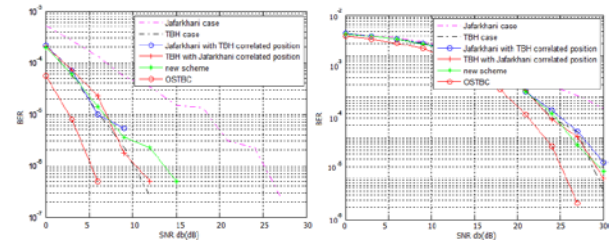


Fig 5(a)

Fig 5 (b)

FIG 5: (a)BER performance comparisons of different STBC under 32QAM scheme (b) BER performance comparisons of different STBC under 32PSK scheme

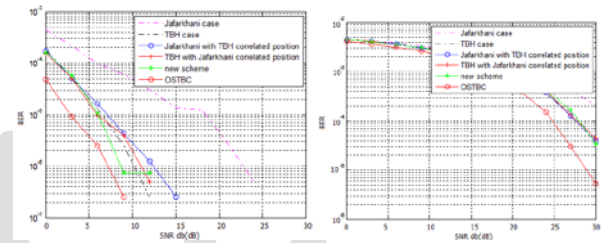


Fig 6(a)

Fig 6 (b)

FIG 6: (a)BER performance comparisons of different STBC under 64 QAM scheme (b) BER performance comparisons of different STBC under 64 PSK scheme

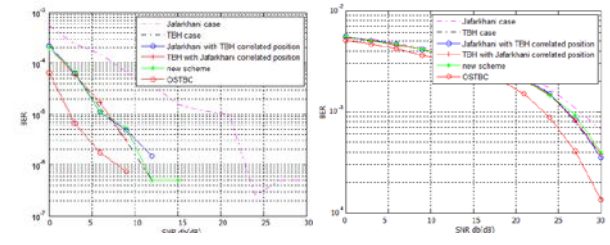


Fig 7(a)

Fig 7 (b)

FIG 7: (a)BER performance comparisons of different STBC under 128 QAM scheme (b) BER performance comparisons of different STBC under 128 PSK scheme

Analyzing all the results, we find that proposed code has better result than other space time block codes under linear receiver.

V. CONCLUSION

In this paper we give the modeling of space time block codes. ALAMOUTI space time block code is based upon this modeling. We explain different space time block codes with their code matrix. Finally we give comparisons of the different space time block codes and show that proposed space time block code is showing better

results comparing with different cases. Further, there is a scope of research in $M \times N$ space time block codes.

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