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INVESTIGATION ON ALAMOUTI CODING TECHNIQUE ON BER PERFORMANCE TECHNIQUES

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ABSTRACT

The paper presents the analysis of Space-Time Block Codes (STBC) used in Multiple-Input Multiple-Output (MIMO) systems to assure transmit diversity. The receive diversity is resolved with a Maximum Ratio Combining technique. For a fixed number of transmit antennas, the performances of different STBC codes are analyzed in terms of Bit Error Rate (BER) and diversity gain for a quasi-static Rayleigh flat fading channel. Multiple antenna (MIMO) systems with significantly reduced complexity and (STBC) space time block coding, for communication over fading channels (Rayleigh channel is used in this paper) using multiple transmit antennas have been used. We have tested the performance of Alamouti coding technique for the Rayleigh channel. The signals on the transmitter (Tx) antennas at one end and the receiver (Rx) antennas at the other end are “combined” in such a way that the BER (quality) or the data rate (bits/sec) of the communication are improved. The simulation results are used to compare and analyze the performance.

1. INTRODUCTION

The space-time coding is a technique that provides both space and time diversity. Alamouti [1] followed by Tarokh et al [2] presented research papers in which a linear block code was designed for multi antenna system. It provides a reliable wireless communication in fading channels such as Rayleigh fading channel.[6], In Alamouti linear block code two transmit and arbitrary no of receiver antennas were used, which could achieve maximum diversity, which is possible due to orthogonal design. For decoding maximum likelyhood decoding is used. Tarokh et al [2] paper proposed orthogonal space time block code for the transmitter diversity [3]. The aim of this paper is to compare BER (bit error rate) with various SNR (signal to noise ratio) for 1 transmitter-1 receiver (SISO), 2 transmitter-1 receiver (MISO) and 2 transmitters – 2 receivers (MIMO) and compare the results. Design of different types of STC codes was done for achieving maximum diversity and full rate. But the condition of having multiple receiver antennas is very difficult to achieve. Alternate scheme [3], [4], [5] were provided. It was shown that code rate cannot be greater than one. But the biggest drawback with these codes are that during decoding, they do not perform well, when number of receiver antennas are less than transmitter antennas. Method for increasing the spectral efficiency of Alamouti code has been presented [6], [7]. But such a scheme does not contribute significant improvement in efficiency for more than two transmit antennas.

In this paper we have proposed a technique to improve the spectral efficiency of STBC for two transmit antennas retaining maximum diversity, full rate (which is equal to one) and simple (ML) maximum likelihood decoding characteristics of original code. This paper focuses on design of efficient code for two transmit antennas scenario, same idea can be used to design higher order MIMO system.

In modern wireless communication systems like 4G, WLAN and WiMAX, the multipath propagation channel is modeled as a Multiple-Input Multiple-Output (MIMO) system. In order to combat the effects of multipath fading and to increase the capacity and reliability of the

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wireless channel, a practical solution is the spatial diversity, using multiple antennas at one or both sides of the link [1]-[3]. For MIMO systems, the knowledge of the Channel State Information (CSI) at the transmitter (CSIT) and at the receiver (CSIR) is a primordial criterion for choosing a diversity technique. At the receiver, if the channel is unknown it can be estimated using different techniques so we suppose that we always have CSIR. At the transmitter, if the channel is known (with CSIT) then beamforming techniques are used to assure both the diversity gain and the array gain; if the channel is not known (without CSIT) then Space-Time (ST) codes are used to assure only the diversity gain. The ST codes are a more general class of error correcting codes, with a spatial-temporal structure, the control symbols being inserted in both spatial and temporal domains.

In [4], Foschini introduces the multi-layered space-time architecture, known as Bell Labs Layered Space-Time (BLAST). Later, in [5] are proposed the Space-Time Trellis Codes (STTrC) which provide the best tradeoff between constellation size, data rate, diversity gain and trellis complexity, but with a greater decoding complexity. Addressing the last issue, Alamouti introduced in [6] a simple diversity scheme for two transmit antennas, which provides a maximum diversity gain and no coding gain for a minimum decoding complexity. Later, the Alamouti code was generalized for an arbitrary number of transmit antennas by Tarokh et al. as the Space-Time Block Code (STBC) [7].

2. A SPACE-TIME BLOCK CODED MIMO SYSTEM

We consider a general MIMO system with *NT* transmit antennas and *NR* receive antennas, employing a space-time encoder, a MIMO channel with *NT* inputs and *NR* outputs and a space-time decoder with MRC technique and Maximum Likelihood (ML) decoding. Fig. 1 illustrates a simple example for two transmit and two receive antennas.

A. The Space-Time Encoder

The first and the simplest transmit diversity scheme for two transmit antennas is the Alamouti code [6], described by the transmission matrix:

$$\mathbf{G} = \begin{bmatrix} x_1 & x_2 \\ -x_2^* & x_1^* \end{bmatrix}.$$

To transmit *m* bits/channel use we use a modulation that maps every *m* bits to one symbol from a real or complex constellation with *M* = 2*m* symbols, for example PSK or QAM. The transmitter picks two symbols from the constellation, for example, *x*1 and *x*2. In the first time slot *t*1, the first antenna transmits the symbol *x*1 and the second antenna the symbol *x*2. Then, in the second time slot *t*2, the symbols *2 −*x* and *1 *x* are transmitted simultaneously from the two antennas. Both symbols *x*1 and *x*2 are spread over two transmit antennas and over two time slots (see Fig. 1).

At the transmitter, we do not know the channel (without CSIT), so we suppose an equal transmit power for each antenna and a unitary total transmit power.

B. The Space-Time Coded MIMO Channel

The transmitted symbols over the MIMO channel are affected by severe magnitude fluctuations and phase rotations.

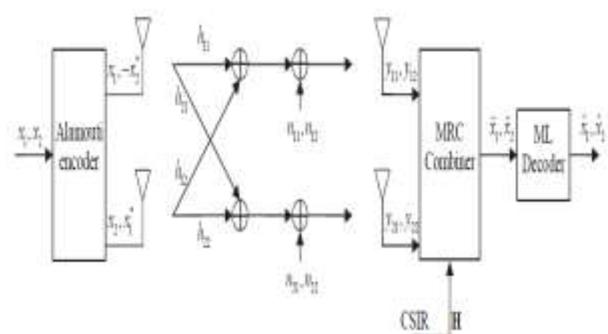

Fig. 1. A particular MIMO 2x2 system with Alamouti coding and MRC&ML decoding.

We assume a quasi-static flat fading Rayleigh channel, with coherence time *Tc*. For a flat fading channel, the fading coefficients *hij* remain constant within a frame of length *Tc* time slots and change into new ones from frame to frame. Also, we assume uncorrelated path gains (the distance between two antennas is more that

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half of the wavelength) which vary independently from one frame to another. For a quasi-static channel, the path gains are constant over a frame of length multiple of *Tc*. For a Rayleigh channel, the path gains are independent complex Gaussian random variables, with zero mean and variance 0.5 per real dimension.

3. **CHANNEL UNDER CONSIDERATION**

3.1 Rayleigh Fading Channel In mobile radio channels, the Rayleigh distribution is used to describe the time varying nature of the received envelope of a signal which is flat fading, or the envelope of an individual multipath component[6],[11]. It is well known that the envelope of the sum of two quadrature Gaussian noise signals obeys a Rayleigh distribution. The Rayleigh distribution has a probability density function which shown in Fig 2 and given by

$$P(r) = \begin{cases} \frac{r}{\sigma} e^{\frac{-r^2}{2\sigma^2}}, 0 < r < \infty \\ 0, r < 0 \end{cases}$$

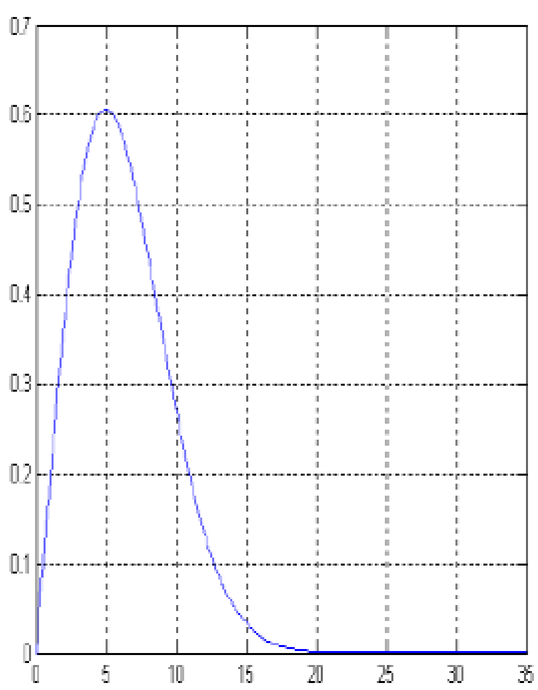

Figure 2: Rayleigh distribution

And the amount of fading is equal to 1 and typically agrees very well with experimental data for mobile systems where no LOS path exists between the transmitter and receiver antennas. It also applies to the propagation of reflected and refracted paths through the troposphere and ionosphere [9].

3.2. Channel Capacity

In MIMO system as multiple antennas are used thus space diversity increases [6],[10], some of the simulated comparison results of 1-Tx – 1-Rx, 2-Tx – 2-Rx, 3-Tx – 3-Rx are shown.

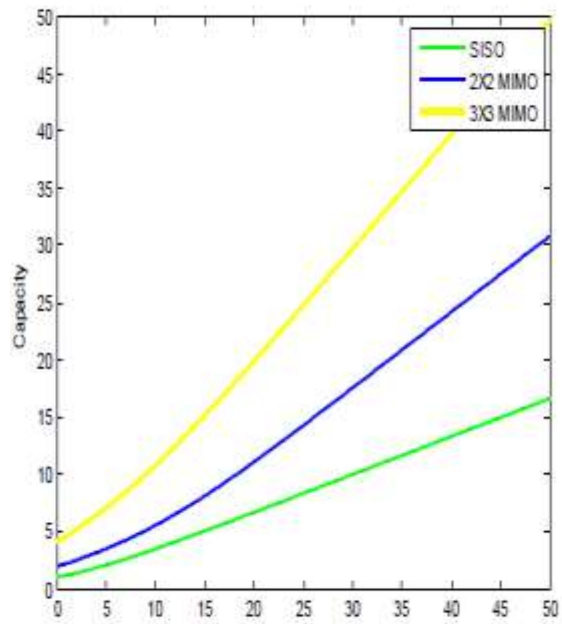

Figure 3: Channel capacity diagram

CONCLUSION

In this paper, we have reviewed the encoding and decoding process for the Alamouti code. For other nine different STBC codes from the literature, we have specified the transmission matrix and the code parameters. Then, we have provided simulation results to compare the performances of different STBC codes chosen for a fixed number of transmit antennas, specifying the best code that assures a maximum diversity gain and a minimum BER. Also, significant gains can be achieved by increasing the number of transmit antennas. However, the concatenation of STBC codes with classical

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channel codes like convolutional or turbo codes, can offer optimal diversity and coding gain, with the expense of a decreased bit rate and an increased complexity.

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