Performance Analysis of MIMO-STBC Adopting Different Variable Conditions of Channel and Modulations

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Abstract:-Wireless networks have quickly become part of everyday life. Wireless LANs, cell phone networks, and personal area networks are just a few examples of widely used wireless networks. However, wireless devices are range and data rate limited. The research community has spent a great deal of effort on finding ways to overcome these limitations. One method is to use Multiple-Input Multiple-Output (MIMO) links. The multiple antennas allow MIMO systems to perform precoding (multi-layer beam forming), diversity coding (space-time coding), and spatial multiplexing. Beam forming consists of transmitting the same signal with different gain and phase (called weights) over all transmits antennas such that the receiver signal is maximized. Diversity consists of transmitting a single space-time coded stream through all antennas. Spatial multiplexing increases network capacity by splitting a high rate signal into multiple lower rate streams and transmitting them through the different antennas. In spatial multiplexing, the receiver can successfully decode each stream given that the received signals have sufficient spatial signatures and that the receiver has enough antennas to separate the streams. The result of using these MIMO techniques is higher data rate or longer transmits range without requiring additional bandwidth or transmits power. This paper presents a detailed study of diversity coding for MIMO systems. Different space-time block coding (STBC) schemes including Alamouti's STBC for 2 transmit antennas as well as orthogonal STBC for 3 and 4 transmit antennas are explored. Finally, these STBC techniques are implemented in MATLAB and analyzed for performance according to their bit-error rates using BPSK, QPSK, 16-QAM, and 64-QAM modulation schemes.

Index words: MIMO, space-time block coding (STBC), BPSK, QPSK, Wireless LANs, SNR, 16-QAM, 64-QAM.

I. INTRODUCTION

It has come a long way since Tesla, using Maxwell and Hertz's work on transmission of electromagnetic waves, demonstrated the transmission of information through a wireless medium using such waves . The Second World War lead to much interest in this area, giving way to many of the theoretical foundations of communications. Claude Shannon's work in 1948, which provided an upper bond to the error free data rate under the signal-to-noise ratio (SNR) constraint, appeared during that time.

Wireless networks widely used today include: cellular networks, wireless mesh networks (WMNs), wireless Local Area Networks (WLANs), personal area networks (PANs), and wireless sensor networks (WSNs). The increasing demand for these networks has turned spectrum into a precious resource. For this reason, there is always a need for methods to pack more bits per Hz. A particular solution that has caught researcher's attention is the use of multiple antennas at both transmitter (TX) and receiver (RX). The use of MIMO for increasing capacity dates back to winters. Such a system is called a Multiple-Input Multiple-Output (MIMO) system. Advantages of MIMO systems include:

- **Beam forming** - A transmitter receiver pair can perform beam forming and direct their main beams at each other, thereby increasing the receiver's received power and consequently the SNR.
- **Spatial diversity** - A signal can be coded through the transmit antennas, creating redundancy, which reduces the outage probability.
- **Spatial multiplexing** - A set of streams can be transmitted in parallel, each using a different transmit antenna element. The receiver can then perform the appropriate signal processing to separate the signals. It is important to note that each antenna element on a MIMO system operates on the same frequency and therefore does not require extra bandwidth. Also, for fair comparison, the total power through all antenna elements is less than or equal to that of a single antenna system, i.e.

$$\sum_{K=1}^{N} p_k \leq P \qquad 1$$

Where N is the total number of antenna elements, pk is the power allocated through the kth antenna element, and P is the power if the system had a single antenna element. Effectively, (1) ensures that a MIMO system consumes no extra power due to its multiple antenna elements. As a consequence of their advantages, MIMO wireless systems have captured the attention of international standard organizations. The use of MIMO has been proposed multiple times for use in the high-speed packet data mode of third generation cellular systems (3G) as well as the fourth generation cellular systems (4G).

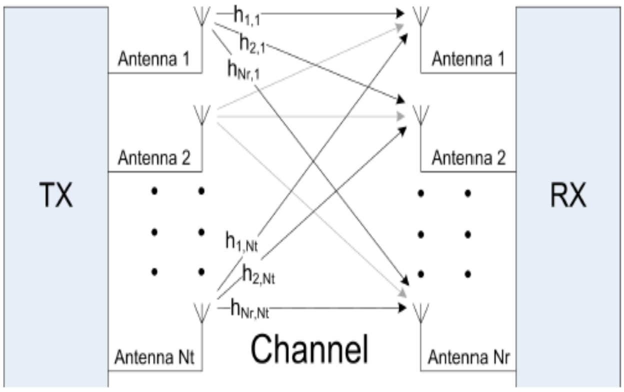

Figure.1.1: Block Diagram of Multiple-Input Multiple-Output System

MIMO has also influenced wireless local area networks (WLANs) as the IEEE 802.11n standard exploits the use of MIMO systems to acquire throughputs as high as 600Mbps. This paper provides a brief background on MIMO systems including the system model, capacity analysis, and channel models. Focus is then given to spatial diversity, specifically to space time block codes (STBC). We discuss Alamouti STBC as well as other orthogonal STBC for 3 and 4 transmit antennas and finally show simulation results and analysis.

II. MULTIPLE ACCESS TECHNIQUES:

Multiple access schemes are used to allow many simultaneous users to use the same fixed bandwidth radio spectrum. In any radio system, the bandwidth, which is allocated to it, is always limited. For mobile phone systems the total bandwidth is typically 50 MHz, which is split in half to provide the forward and reverse links of the system. Sharing of the spectrum is required in order increase the user capacity of any wireless network. FDMA, TDMA and CDMA are the three major methods of sharing the available bandwidth to multiple users in wireless system. There are many extensions, and hybrid techniques for these methods, such as OFDM, and hybrid TDMA and FDMA systems. However, an understanding of the three major methods is required for understanding of any extensions to these methods.

A. Frequency Division Multiple Accesses (FDMA): In Frequency Division Multiple Access (FDMA), the available bandwidth is subdivided into a number of narrower band channels. Each user is allocated a unique frequency band in which to transmit and receive on. During a call, no other user can use the same frequency band.

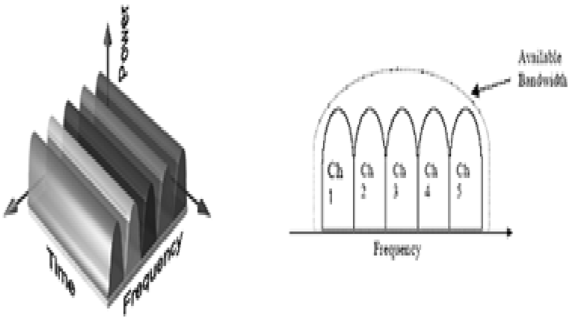

Fig.1.2 FDMA showing that the each narrow band channel is allocated to a single user.

Fig.1.3 FDMA spectrum, where the available band width is sub-divided into narrow band channels.

Figure.2.1: Show the allocation of the available Bandwidth into Several Channels

Each user is allocated a forward link channel (from the base station to the mobile phone) and a reverse channel (back to the base station), each being a single way link. The transmitted signal on each of the channels is continuous allowing analog transmissions. The bandwidths of FDMA channels are generally low (30 kHz) as each channel only supports one user. FDMA is used as the primary breakup of large allocated frequency bands and is used as part of most multi-channel systems.

B. Time Division Multiple Accesses (TDMA): Time Division Multiple Access (TDMA) divides the available spectrum into multiple time slots, by giving each user a time slot in which they can transmit or receive. Fig. shows how the time slots are provided to users in a round robin fashion, with each user being allotted one time slot per frame. TDMA systems transmit data in a buffer and burst method, thus the transmission of each channel is non-continuous.

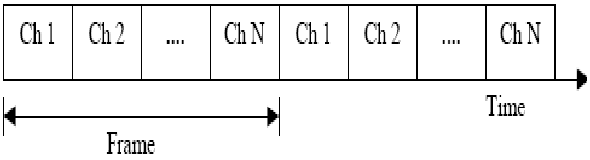

Figure.2.2: TDMA scheme, where each user is allocated a small time slot

The input data to be transmitted is buffered over the previous frame and burst transmitted at a higher rate during the time slot for the channel. TDMA cannot send analog signals directly due to the buffering required, thus are only used for transmitting digital data. TDMA can suffer from multipath effects, as the transmission rate is generally very high. This leads the multipath signals causing inter-symbol interference. TDMA is normally used in conjunction with FDMA to subdivide the total available bandwidth into several channels. This is done to reduce the number of users per channel allowing a lower data rate to be used. This helps reduce the effect of delay spread on the transmission. Fig. 2.3 shows the use of TDMA with FDMA. Each channel based on FDMA, is further subdivided using TDMA, so that several users can transmit of the one channel.

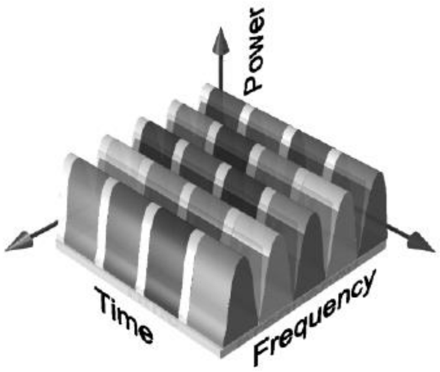

Figure.2.3: TDMA/FDMA hybrid, showing that the bandwidth is split into frequency channels and time slots.

This type of transmission technique is used by most digital second generation mobile phone systems. For GSM, the total allocated bandwidth of 25MHz is divided into 125, 200 kHz channels using FDMA. These channels are then subdivided further by using TDMA so that each 200 kHz channel allows 8-16 users.

C. Code Division Multiple Accesses (CDMA): Code Division Multiple Access (CDMA) is a spread spectrum technique that uses neither frequency channels nor time slots. In CDMA, the narrow band message (typically digitized voice data) is multiplied by a large bandwidth signal, which is a pseudo random noise code (PN code). All users in a CDMA system use the same frequency band and transmit simultaneously. The transmitted signal is recovered by correlating the received signal with the PN code used by the transmitter. Fig. 1.6 shows the general use of the spectrum using CDMA. Some of the properties that have made CDMA useful are: Signal hiding and non-interference with existing systems, Anti-jam and interference rejection, Information security, Accurate Ranging, Multiple User Access, Multipath tolerance.

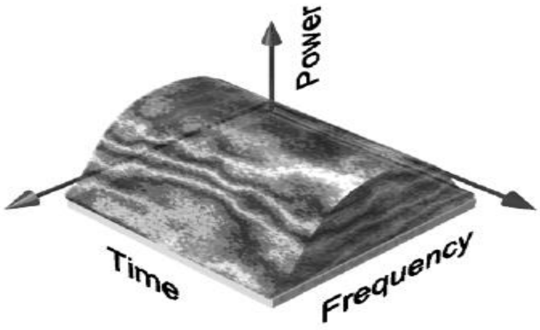

Figure.2.4: Code Division Multiple Access (CDMA)

Fig. shows the process of a CDMA transmission. The data to be transmitted (a) is spread before transmission by modulating the data using a PN code. This broadens the spectrum as shown in (b). In this example the process gain is 125 as the spread spectrum bandwidth is 125 times greater the data bandwidth. Part (c) shows the received signal. This consists of the required signal, plus background noise, and any interference from other CDMA users or radio sources. The received signal is recovered by multiplying the signal by the original spreading code. This process causes the wanted received signal to be dispread back to the original transmitted data. However, all other signals, which are uncorrelated to the PN spreading code used, become more spread. The wanted signal in (d) is then filtered removing the wide spread interference and noise signals.

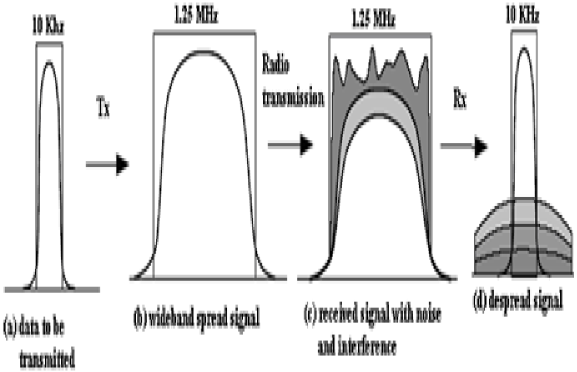

Figure.2.5: Basic CDMA Generation

III. METHODOLOGY

A. SPACE-TIME BLOCK CODING

Severe attenuation in a multipath wireless environment makes it extremely difficult for the receiver to determine the transmitted signal unless the receiver is provided with some form of diversity, i.e., some less-attenuated replica of the transmitted signal is provided to the receiver. In some applications, the only practical means of achieving diversity is deployment of antenna arrays at the transmitter and/or the receiver. However, considering the fact that receivers are typically required to be small, it may not be practical to deploy multiple receive antennas at the remote station. This motivates us to consider transmit diversity. Transmit diversity has been studied extensively as a method of combating impairments in wireless fading channels is particularly appealing because of its relative simplicity of implementation and the feasibility of multiple antennas at the base station. Moreover, in terms of economics, the cost of multiple transmit chains at the base can be amortized over numerous users.

Space–time trellis coding is a recent proposal that combines signal processing at the receiver with coding techniques appropriate to multiple transmits antennas. Specific space–time trellis codes designed for 2–4 transmit antennas perform extremely well in slow-fading environments (typical of indoor transmission) and come close to the outage capacity computed by Telatar and independently by Foschini and Gans.

However, when the number of transmit antennas is fixed, the decoding complexity of space–time trellis codes (measured by the number of trellis states in the decoder) increases exponentially with transmission rate. In addressing the issue of decoding complexity, Alamouti recently discovered a remarkable scheme for transmission using two transmits antennas. This scheme is much less complex than space–time trellis coding for two transmit antennas but there is a loss in performance compared to space–time trellis codes. Despite this performance penalty, Alamouti’s scheme is still appealing in terms of simplicity and performance and it motivates a search for similar schemes using more than two transmit antennas. It is starting points for the studies in this paper, where we apply the theory of orthogonal designs to create analogs of Alamouti’s scheme, namely, space–time block codes, for more than two transmit antennas.

The theory of orthogonal designs is an arcane branch of mathematics which was studied by several great number theorists including Radon and Hurwitz. The encyclopedic work of Geramita and Seberry is an excellent reference. A classical result in this area is due to Radon who determined the set of dimensions for which an orthogonal design exists. Radon’s results are only concerned with real square orthogonal designs. In this work, we extend the results of Radon to both non square and complex orthogonal designs and introduce a theory of generalized orthogonal designs.

Using this theory, we construct space–time block codes for any number of transmit antennas. Since we approach the theory of orthogonal designs from a communications perspective, we also study designs which correspond to combined coding and linear processing at the transmitter. Channel state information channel state information refers to known channel properties of a communication link. This information describes how a signal propagates from the transmitter to the receiver and represents the combined effect of, for example, scattering, fading, and power decay with distance. It makes it possible to adapt transmissions to current channel conditions, which is crucial for achieving reliable communication with high data rates in multi-antenna systems.

Channel state information needs to be estimated at the receiver and usually quantized and fed back to the transmitter although reverse-link estimation is possible in time division duplex systems. Therefore, the transmitter and receiver can have different CSI. The CSI at the transmitter and the CSI at the receiver are sometimes referred to as CSIT and CSIR, respectively.

B. Proposed Code:

A Simple Transmit Diversity Technique for Wireless-Communication offers a simple method for achieving spatial diversity with two transmit antennas. The scheme is as follows:

1. Consider that we have a transmission sequence, for example $\{x_1, x_2, x_3, \cdots, x_n\}$

2. In normal transmission, we will be sending x_1 in the first time slot, x_2 in the second time slot, x_3 and so on.

3. However, Alamouti suggested that we group the symbols into groups of two. In the first time slot, send x_1 and x_2 from the first and second antenna. In second time slot send $-x_2^*$ and x_1^* from the first and second antenna. In the third time slot send x_3 and x_4 from the first and second antenna. In fourth time slot, send $-x_4^*$and x_3^* from the first and second antenna and so on.

4. Notice that though we are grouping two symbols, we still need two time slots to send two symbols. Hence, there is no change in the data rate.

5. This forms the simple explanation of the transmission scheme with Alamouti Space Time Block coding.

has lower interference.

The amounts of minimum determinant and minimum trace of STBC are 16 and 8, respectively, that are higher than those of the proposed code. However, our code would have has lower BER than others, at high SNRs. This is because of diagonal property of **X^XP** that is also a part of trace .Unlike our code, the other codes does not have non-vanishing property. The detection complexity of the proposed code is slightly higher.

TABLE II

MDV AND TRACE VALUE OF THE PROPOSED CODE AND Alamouti

Code	Almaouti	Proposed
MDV	5.82	7.39
Trace	4.85	5.44

IV.RESULTS AND DISCUSSION

We evaluate the performance of the proposed code in terms of BER, detection complexity, MDV, and trace criterion. In the simulations, Because of the low performance of Moreover, it has been shown hybrid STBC

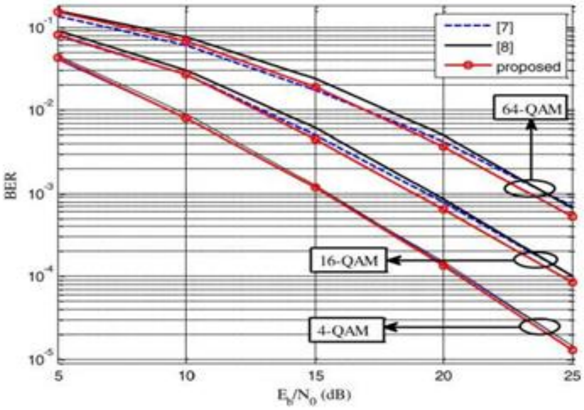

Figure.5.1: BER curves of the proposed code, SUI based STBC

TABLE I

DETECTION COMPLEXITY OF DIFFERENT CODES

Code	[7]	[8]	Propose
Complexit	O(M')	$0\ (M^{1'5})$	$0\ (M^{ls})$

Table I shows the detection complexity of different codes and Table II demonstrates the MDV and Trace for almouti

V. CONCLUSION

This project provided a basic overview of MIMO systems. We briefly discussed MIMO channel modelling techniques. A basic introduction to Space-Time Coding was provided by presenting Alamouti's scheme. We then discussed block codes schemes with different code rates for the cases of 3 and 4 transmit antennas. The encoding and decoding algorithms for each were both presented. For the case of G4, the decoding metric of s4 was corrected from the original publication presented by Tarokh et al. Simulation results were then presented. It was observed that higher diversity gain does not always imply better performance. This was observed when G3 outperformed H4 at low SNR for Nr = 1 and at any SNR for Nr = 2 up to Nr = 4.

Similarly, it was observed that equal diversity gain does not imply equal performance. This was particularly demonstrated when G3 outperformed all others for equal diversity gain. The penalty of having more transmit antennas, which consequently reduces the energy per transmit antenna was observed. Also, we observed diminishing returns for every scheme as the number of received antennas increased. It was particularly interesting to find that although H3 and H4 have higher rate than G3 and G4, the performance of G3 and G4 is greater and could therefore be preferred in some scenarios. Finally, we conclude that it is preferable to use a low constellation order with high code rate than high constellation order with low code rate.

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