



# Space time Block codes for MIMO Systems

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**Abstract**—Data is encoded using a space–time block code and the encoded data is split into  $n$  streams which are simultaneously transmitted using  $n$  transmit antennas. The received signal at each receive antenna is a linear superposition of the  $n$  transmitted signals perturbed by noise. The wireless systems that is evolved the last few decades necessitates in the design and analysis of equalization techniques. Future generation of wireless system is supposed to possess very high spectral efficiency. When data is transmitted at high rates over mobile radio channels, impulse response can extend over many symbol periods which lead to Inter Symbol Interference. Space–time block codes [STBC] are designed to achieve the maximum diversity order for a given number of transmit and receive antennas subject to the constraint of having a simple decoding algorithm. In this paper, we present the performance analysis of Alamouti STBC and MIMO Equalization. Compare MIMO -STBC with SISO, MRC and 2x1 and 2x2 Alamouti STBC Systems, and also Compare MIMO –MMSE Equalization with MRC, ZF, and methods.

**KEYWORDS:** Spatial multiplexing, Spatial diversity, Space time coding, Equalization

## I. INTRODUCTION

Communication technologies have become a very important part of human life. Wireless communication systems have opened new dimensions in communications. People can be reached at any time and at any place. Over 700 million people around the world subscribe to existing second and third generation cellular systems supporting data rates of 9.6 kbps to 2 Mbps. More recently, IEEE 802.11 wireless LAN networks enable communication at rates of around 54 Mbps and have attracted more than 1.6 billion USD in equipment sales. Over the next ten years, the capabilities of these technologies are expected to move towards the 100 Mbps - 1 Gbps range and to subscriber numbers of over two billion. At the present time, the wireless communication research community and industry discuss standardizations for the fourth mobile generation (4G). The research community has generated a number of promising solutions for significant improvements in system performance. One of the most promising future technologies in mobile radio communications is multi antenna elements at the transmitter and at the receiver.

MIMO stands for multiple-input multiple-output and means multiple antennas at both ends of a communication system, i.e., at the transmit and at the receive side. The multiple-antennas at the transmitter and/or at receiver in a wireless communication link open a new dimension in reliable communication, which can improve the system performance substantially. The idea behind MIMO is that the transmit antennas at one end and the receive antennas at the other end are “connected and combined” in such a way that the quality (the bit error rate (BER), or (the data rate) for each user is improved. The core idea in MIMO transmission is space-time signal processing in which signal processing in time is complemented by signal processing in the spatial dimension by using multiple, spatially distributed antennas at both link ends. Because of the enormous capacity increase MIMO systems offer, such systems gained a lot of interest in mobile communication research. One essential problem of the wireless channel is fading, which occurs as the signal follows multiple paths between the transmit and the receive antennas. Under certain, not uncommon conditions, the arriving signals will add up destructively, reducing the received power to zero (or very near to zero). In this case no reliable communication is possible. Fading can be mitigated by diversity, which means that the information is transmitted not only once but several times, hoping that at least one of the replicas will not undergo severe fading. Diversity makes use of an important property of wireless MIMO channels: different signal paths can be often modeled as a number of separate, independent fading channels. These channels can be distinct in frequency domain or in time domain. Several transmission schemes have been proposed that utilize the MIMO channel in different ways, e.g., spatial multiplexing, space-time coding or beam forming.

Space-time coding (STC), introduced first by Tarokh et al[] is a promising method where the number of the transmitted code symbols per time slot are equal to the number of transmit antennas. These code symbols are generated by the space-time encoder in such a way that diversity gain, coding gain, as well as high spectral efficiency are achieved. Space-time coding finds its application in cellular communications as well as in wireless local area networks. There are various coding

methods such as space-time trellis codes (STTC), space-time block codes (STBC), space-time turbo trellis codes and layered space-time (LST) codes. A main issue in all these schemes is the exploitation of redundancy to achieve high reliability, high spectral efficiency and high performance gain. The design of STC amounts to find code matrices that satisfy certain optimality criteria. In particular, STC schemes optimize a trade-off between the three conflicting goals of maintaining a simple decoding algorithm, obtaining low error probability, and maximizing the information rate. In the last few years the research community has made an enormous effort to understand space-time codes, their performance and their limits. Operating in a time varying multipath fading environment is one of the biggest challenges under limited power constraints in wireless communications. The other challenge is the limited availability of the frequency spectrum. Future wireless systems will be required to support higher data rates and reliable communication under spectrum limitation and multipath fading environment.

In order to improve the reliability without increasing the emitted power, time or frequency or space diversity can be exploited. In time diversity, the received signal can be sampled at a higher rate, thus providing more than one sample per transmitted symbol. In frequency diversity, the same signal can be transmitted over a number of carriers. Both these diversity techniques require a larger bandwidth. In space diversity, the same information can be transmitted or received through multiple antennas. Employing multiple antennas at the transmitter and the receiver aggrandizes the quality of a wireless communication without increasing the bandwidth and transmitted power. Recently, multiple-input multiple-output (MIMO) systems have been under active investigation in view of their providing a more reliable reception compared to that provided by a single-input single-output (SISO) system and because of the potential for achieving higher data rates.

## II. MIMO-BASED SYSTEM ARCHITECTURE

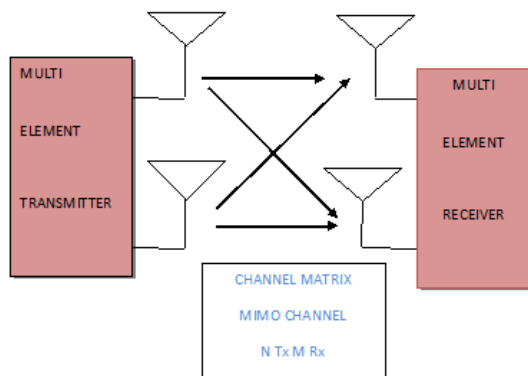


Figure 1

A. working: The MIMO systems can be represented as follows. Given an arbitrary wireless communication

system, consider a link for which the transmitting end as well as the receiving end is equipped with multiple antenna elements. Such a set-up is illustrated in fig- 1 with N transmitting and M receiving antennas. A core idea in an MIMO system is space-time signal processing in which time (the natural dimension of digital communication data) is complemented with the spatial dimension inherent in the use of multiple spatially distributed antennas. Single incoming data can be converted into parallel streams and can be processed separately. The blocks will be as usual, source coding, channel coding, modulation, and RF up-conversion blocks on the transmitter side and opposite at the receiver side but may be individual for individual antenna element, or some two-dimensional signal-processing methods may be used.

The digital signal processing is used to separate the multiple streams in MIMO at the receiving end. For example, a 2x2 MIMO system is a 'two-measurement two unknown problem'. Unless each receive antenna captures a different combination of transmitted symbols, this problem cannot be solved because the system of linear equations is dependent, the channel matrix is not full rank, and the antennas are strongly correlated to one another, which are influenced by spacing, polarization, radiation pattern, etc.

### B. Space Time Processing

The space-time processing (STP) uses the 'spatial dimension' along with the traditional temporal modulation and coding at the transmitter along with advanced decoding at the receiver making parallel transmissions possible and thus launching the concept of STP. A conceptual diagram is given in fig. The STP can improve spectral efficiency as well as coverage area. It makes better use of spectrum and allows support of multiple users and reduces power requirements (and thus PA and battery requirements). It is due to spatial multiplexing and spatial diversity in MIMO.

### C. Spatial multiplexing vs Spatial Diversity

It has already been described. In contrast to spatial multiplexing, spatial diversity is used to increase the diversity order of an MIMO link to mitigate fading by coding a signal across space and time so that a received signals constructively to achieve a diversity gain.

The trade-off exists between the spatial multiplexing and the spatial diversity. Pure spatial multiplexing allows for full independent use of the antennas. However, it gives limited diversity benefit and is rarely the best transmission scheme for a given BER target. The possibility of a linear capacity growth with a number of antennas is good, especially knowing that increasing power (SNR), coding the symbols within a block can result in additional coding and diversity gain, which can help improve the performance and robustness, even

though the data rate is kept at the same level. It is also possible to sacrifice some data rate for more diversity.

In general, it can be shown that throughput grows linearly with a number of Eigen modes of the channel and that is the fundamental for MIMO. The throughput can be improved by more spatially multiplexed channels optimally selected.

**D. Generation of Alamouti code**

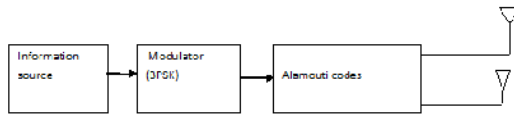


Fig 2

The block diagram of, ALAMOUTI code as shown in figure2. In ALAMOUTI codes transmission two antennas are used at the transmitter side. These two antennas are used to transmit the redundancy data. It is transmitter side. At the receiver, diversity is optional. For simplicity, this entire project is explained with a single antenna at the receiver. Here the information source gives the digital data. After modulation symbols are given to STBC encoder.

**III. SPACE TIME BLOCK CODES**

**BLOCKDIAGRAM**

In the coding theory, block codes refers to the large and important family of error-correcting codes that encode data in blocks. There is a vast number of examples for block codes, many of which have a wide range of practical applications. The main reason why the concept of block codes is so useful is that it allows coding theorists, mathematicians, and computer scientists to study the limitations of all block codes in a unified way. Such limitations often take the form of bounds that relate different parameters of the block code to each other, such as its rate and its ability to detect and correct errors.

STBC 2transmitter- 2 Receiver antennas as shown in figure3. Space-time block coding is a technique used in wireless communication used in wireless communications to transmit multiple copies of a data stream across a number of antennas and to exploit the various received versions of the data to improve the reliability of data-transfer.

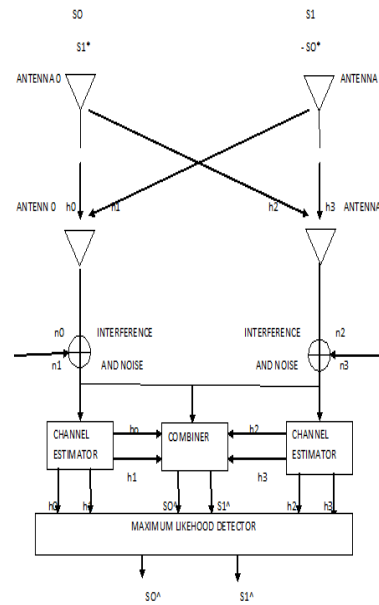


Fig 3

The fact that the transmitted signal must traverse a potentially difficult environment with scattering, reflection, refraction and so on and then be further corrupted by thermal noise in the receiver means that some of the received copies of the data will be 'better' than others. This redundancy results in higher copies to correctly decode the received signal. In fact, space-time coding combines all the copies of the received signal in an optimal way to extract as much information from each of them as possible.

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 deployed 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 the 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 transmit 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

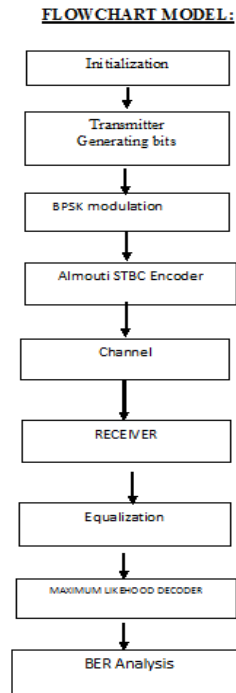
the number of transmit antennas is fixed, the decoding complexity of the space-time trellis codes (measured by the number of trellis states in the decoder) increases exponentially with transmission rate. In addressing the issue of the decoding complexity, Alamouti recently discovered a remarkable scheme for the transmission using two transmit 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 a starting point for the studies in this paper, where we apply the theory of the orthogonal designs to create analog 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 [ ] 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 introduces a theory of generalized orthogonal designs and introduces a theory of generalized orthogonal designs. Using this theory, we construct space-time block codes for any number of transmit antennas. Since approaching the theory of orthogonal designs from a communications perspective, have to study designs which correspond to combine coding and linear processing at the transmitter.

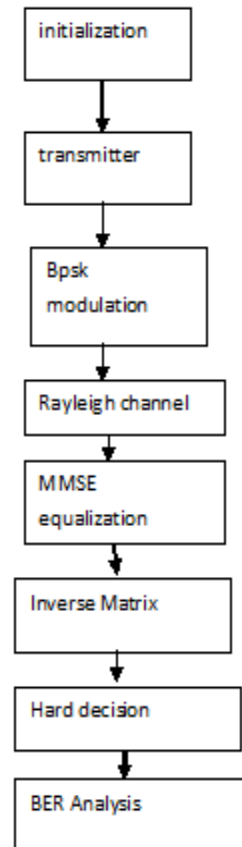
IV. EQUALIZATION TECHNIQUES

It is a method for recovery of distorted signal when it is transmitted through the channel received by convolution process. The process of recovery of a signal that is convolved with the impulse response of communication channel is known as de convolution or equalization. Design a stage in the receiver whose transfer function is exact opposite to the channel transfer function. The concept represented mathematically in discrete form  $r(n)=h(n)*s(n)+w(n)$ . Equalization problem is simple when channel response is known. The simple equalizer is matched filter correlator. The equalization error signal or convolution noise is generated due to white Gaussian noise. The equalization error is defined as difference between channel equalizer output and the desired signal. If the channel distorts the pulse shape, the matched filter no longer r matched perfectly. Inter Symbol Interference may increase system performance may degrade, hence LSE, MMSE, ZF may be used for checking the minimum error maximum matching condition, decoding quite complex.

V . A FLOW CHART MODEL FOR MIMO STBC

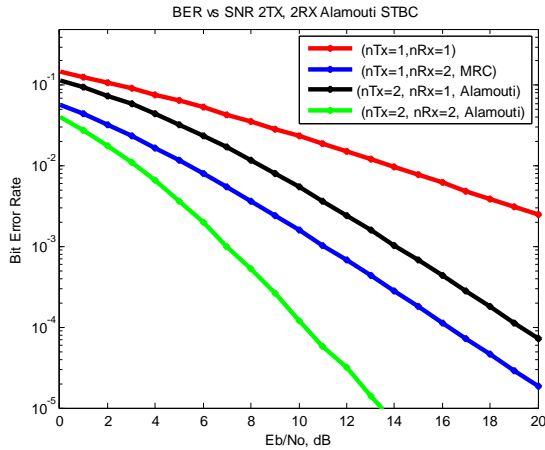


B. Flow Chart Model for MIMO Equauzation

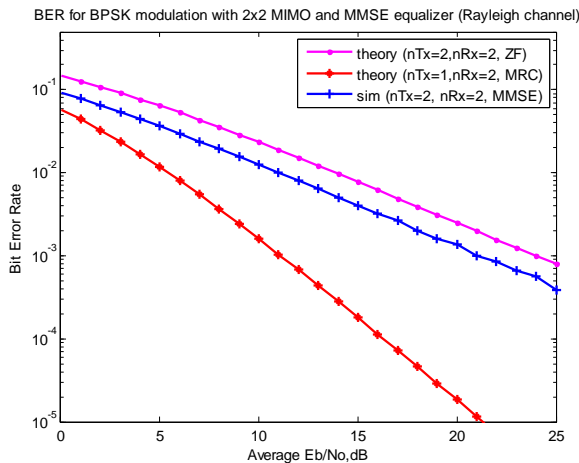


VI. RESULTS & ANALYSIS

A. FIGURE 1 shows performance of the different Diversity techniques



**B. FIGURE2:** shows the performance of MIMO Equalization techniques



**C. Trade off between Decoding Complexity and BER**

**Performance improvement for the MIMO STBC and MIMO-EQUALIZATION technique**

S.NO	SNR	DECODING COMPLEXITY	BER
MMSE - Equalization	10	More-needs inverse matrix	0.00123
MIMO STBC	10	Less-no need of inverse matrix	0.000

**VII. CONCLUSION AND FUTURE SCOPE**

The ALAMOUTI scheme has been simulated for BPSK modulation using AWGN channel. The BER VS Eb/No graph is analyzed. The performance of ALAMOUTI 2 x 1 seems to be identical to the theoretical value while the performance of 1 x 2(maximum ratio combining) is better due to the receiver diversity. In comparison with all, ALAMOUTI (2 x 2) has shown better performance. MIMO –Equalization has been simulated for BPSK modulation using AWGN channel. The BER VS Eb/No graph is analyzed. The performance of MIMO (2 x 2) MMSE is better than zero forcing and MRC methods. If more antennas are employed on receiving side, BER performance improves. From this we conclude that receive diversity contributes for the reduction of BER& hence ALAMOUTI scheme is good coding technique for the data transmission by minimizing the error. By using advanced modulation like spatial modulation , advanced channel estimation techniques MIMO systems can improve performance of BER with less decoding complexity

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