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MIMO SPACE-TIME BLOCK CODING

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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 beamforming), 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 transmit 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 transmit range without requiring additional bandwidth or transmit 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.

Keywords: *MIMO, STBC, BER, BPSK, QPSK, 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:

Beamforming - A transmitter receiver pair can perform beamforming 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).

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's STBC as well as other othogonal STBC for 3 and 4 transmit antennas and finally show simulation results and analysis.

1.2 Problem statement

Original transmit diversity using STBC requires the channel to be flat and static over the coding block period that is two symbols long [3]. Lindskog and Paulraj [4] extended this scheme for time-dispersive channel. According to their scheme, the space-time coding is done over two large blocks of data symbols instead of just two symbols as in originally proposed scheme. At the receiver, space-time decoding involves convolution with channel responses and combining, followed by a maximum-likelihood sequence estimator (MLSE) with an Euclidean metric. Consequently, the front-end convolution almost doubles the overall system channel response, thus increases the complexity of the MLSE detector. Also, the noise gets colored by the channel response filters that make the MLSE based detector a sub-optimal. Kambiz et. al. [5] have identified the above issues, and proposed a whitening filter followed by a Decision Feedback Sequence Estimation (DFSE) detector for lower complexity.

The above solutions for time-dispersive channels increase the complexity of the receiver due to increase in channel response by the front-end convolution. More importantly, these schemes assume the channel to be static over large block of data, usually one burst period, compared to just two symbol periods in the original scheme. Constant channel assumption over the whole burst is not valid for the high speed mobile terminals, even for GSM burst. Due to the above reasons, this paper proposes transmitter with original space-time coding that is over every two-symbol blocks. For time-dispersive channels, an MLSE with Euclidean metric type receiver is shown for joint space-time decoding and symbol detection for maximum diversity gain. MLSE detector for SISO system can be extended for this DISO system with no or some complexity increase based on system requirements.

1.3 Proposed system

1.3.1 Overview of 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.

1.3.2. Frequency Division Multiple Access:

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.

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.

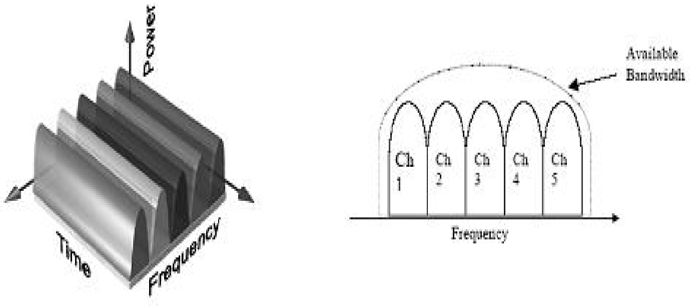

Fig.1.2 FDMA showing that the each narrow band channel is allocated to a single user.

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

Fig1.3.1. show the allocation of the available bandwidth into several channels.

1.3.1.2 Time Division Multiple Access:

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. 1.4 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.

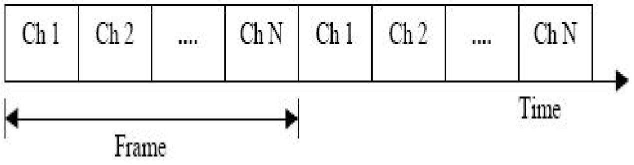

Fig 1.3.2 TDMA scheme, where each user is allocated a small time slot

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. 1.5 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. 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.

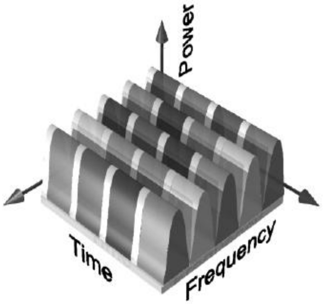

Fig 1.3.3. TDMA/FDMA hybrid, showing that the bandwidth is split into frequency channels and time slots.

1.3.1.3 Code Division Multiple Access:

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. 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.

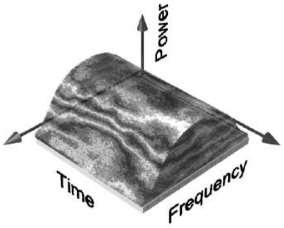

Fig 1.3.4. Code Division Multiple Access (CDMA)

Fig 1.3.4 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.

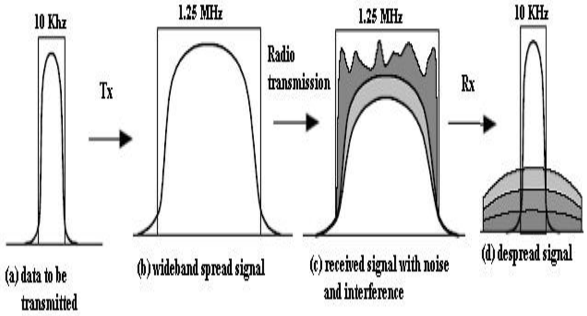

Fig1.3.5. Basic CDMA Generation.

CDMA Generation:

CDMA is achieved by modulating the data signal by a pseudo random noise sequence (PN code), which has a chip rate higher then the bit rate of the data. The PN code sequence is a sequence of ones and zeros (called chips), which alternate in a random fashion. The data is modulated by modular-2 adding the data with the PN code sequence. This can also be done by multiplying the signals, provided the data and PN code is represented by 1 and -1 instead of 1 and 0.the below**.** shows a basic CDMA transmitter.

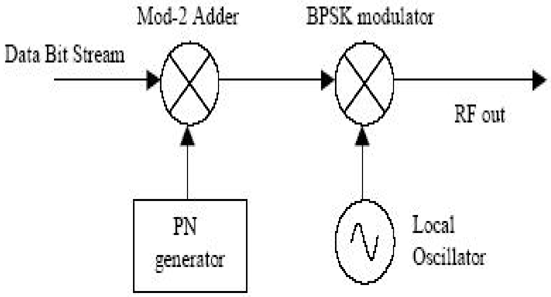

Fig 1.3.6. Simple direct sequence modulator

The PN code used to spread the data can be of two main types. A short PN code
(Typically 10-128 chips in length), can be used to modulate each data bit. The short PN code is then repeated for every data bit allowing for quick and simple synchronization of the receiver. **Fig1.3.7.** shows the generation of a CDMA signal using a 10-chip length short code. Alternatively a long PN code can be used. Long codes are generally thousands to millions of chips in length, thus are only repeated infrequently. Because of this they are useful for added security as they are more difficult to decode.

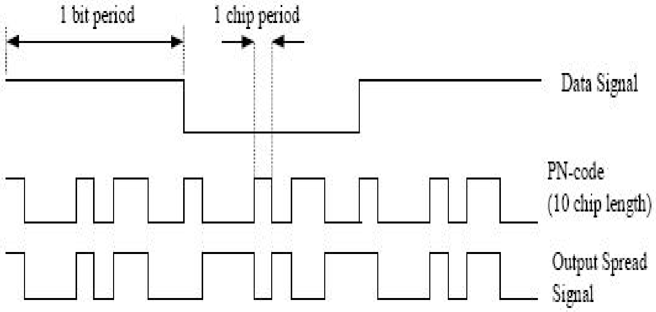

Fig 1.3.7. Direct sequence signals

1.3.2 Beam forming: Beam forming is the combination of radio signals from a set of small non-directional antennas to simulate a large directional antenna. The simulated antenna can be pointed electronically, although the antenna does not physically move. In communications, beam forming is used to point an antenna at the signal source to reduce interference and improve communication quality. In direction finding applications, beam forming can be used to steer an antenna to determine the direction of the signal source.

1.3.2.1 Antenna Radiation Patterns: A transmitting antenna generates stronger electromagnetic waves in some directions than others. A plot of field strength vs. direction is called the antenna's **"**radiation pattern**."** It's always the same for receiving as for transmitting. An electromagnetic wave measured at a point far from the antenna is the sum of the radiation from all parts of the antenna. Each small part of the antenna is radiating waves of a different amplitude and phase, and each of these waves travels a different distance to the point where a receiver is located. In some directions, these waves add constructively to give a gain. In some directions they add destructively to give a loss.A half-wave dipole is a simple antenna that consists of a half wavelength of wire, cut in the center for connection of the cable. The following figure shows its radiation pattern.

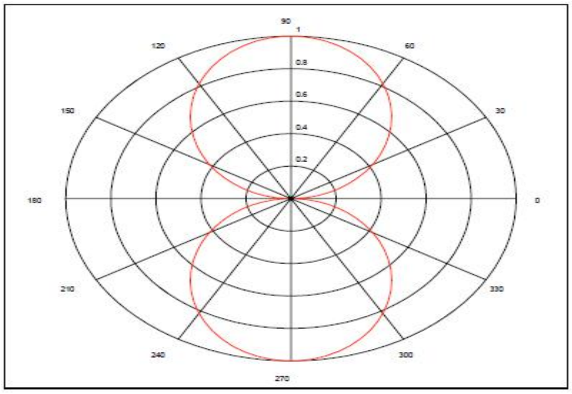

Fig 1.3.8 Half wave dipole directional antenna

1.3.2.2 Directional Antennas:

A directional antenna is one designed to have a gain in one direction and a loss in others. An antenna is made directional by increasing its size. This spreads the radiating conductors of the antenna over a larger distance, so that the constructive and destructive interference can be better controlled to give a directional radiation pattern. A satellite dish antenna can, simplistically, be considered a circular surface that radiates electromagnetic waves equally from all parts. It has a narrow central "beam" of high gain, as shown in the following figure, that is aimed at the satellite. As the dish diameter, in wavelengths, is increased the central beam gets narrower. Notice the smaller beams, called "side lobes", on either side of the central beam. Directions in which the signal strength is zero are called **"**nulls**."**

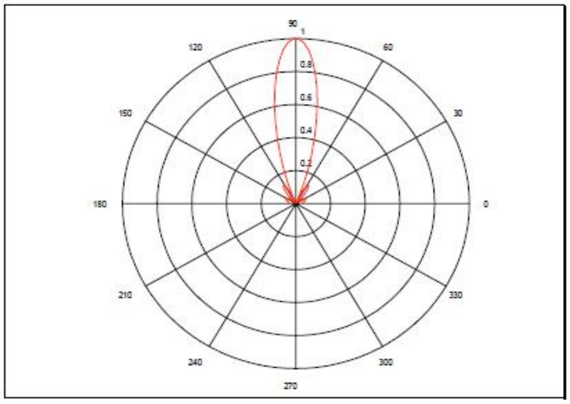

Fig 1.3.9 Central beam formation

In beamforming, both the amplitude and phase of each antenna element are controlled. Combined amplitude and phase control can be used to adjust side lobe levels and steer nulls better than can be achieved by phase control alone. The combined relative amplitude **ak** and phase shift **k** for each antenna is called a "complex weight" and is represented by a complex constant **wk** (for the kth antenna).A beamformer for a radio transmitter applies the complex weight to the transmit signal (shifts the phase and sets the amplitude) for each element of the antenna array. And Precoding is a generalization of beamforming to support multi-layer transmission in multi-antenna wireless communications.

In conventional single-layer beamforming, the same signal is emitted from each of the transmit antennas with appropriate weighting such that the signal power is maximized at the receiver output. When the receiver has multiple antennas, single-layer beamforming cannot simultaneously maximize the signal level at all of the receive antennas. Thus, in order to maximize the throughput in multiple receive antenna systems, multi-layer beamforming is required.

1.3.2.3 System Models:

Traditional wireless systems are affected by multipath propagation. In MIMO systems, however, this multipath effect is exploited to benefit the user. In fact, the separability of parallel streams depend on the presence of rich multipath. The reason for this effect will become apparent as the System Model is described in Section II-A below. A. System Model MIMO systems are composed of three main elements, namely the transmitter (TX), the channel (H), and the receiver (RX).

In this project, Nt is denoted as the number of antenna elements at the transmitter, and Nr is denoted as the number of elements at the receiver. Figure 1 depicts such MIMO system block diagram. It is worth noting that system is described in terms of the channel. For example, the Multiple-Inputs are located at the output of the TX (the input to the channel), and similarly, the Multiple-Outputs are located at the input of the RX (the output of the channel).

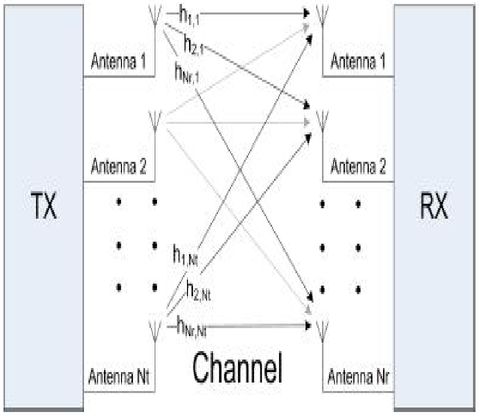

Fig 1.3.10 Multiple-Input Multiple-Output system block diagram.

The channel with Nr outputs and Nt inputs is denoted asa Nr x Nt matrix.

$$H = \begin{pmatrix} h_{1,1} & h_{1,2} & \cdots & h_{1,N_t} \\ h_{2,1} & h_{2,2} & \cdots & h_{2,N_t} \\ \vdots & \vdots & \ddots & \vdots \\ h_{N_r,1} & h_{N_r,2} & \cdots & h_{N_r,N_t} \end{pmatrix} \qquad (2)$$

where each entry hi;j denotes the attenuation and phase shift (transfer function) between the jth transmitter and the ith receiver. It is assumed throughout this paper that the MIMO channel behaves in a "quasi-static" fashion, i.e. the channel varies randomly between burst to burst, but fixed within a transmission. This is a reasonable and commonly used assumption as it represents an indoor channel where the time of change is constant and negligible compared to the time of a burst of data

The MIMO signal model is described as

$$\vec{r} = H\vec{s} + \vec{n} \qquad (3)$$

where $\vec{r}$ is the received vector of size Nr x 1, H is the channel matrix of size Nr x Nt , $\vec{s}$ is the transmitted vector of size Nt x1, and $\vec{n}$ is the noise vector of size Nr x1. Each noise element is typically modeled as independent identically distributed (i.i.d.) white Gaussian noise with variance Nt/(2. SNR) . An explanation for this model is as follows. The transmitted signals are mixed in the channel since they use the same carrier frequency. At the receiver side, the received signal is composed of a linear combination of each transmitted signal plus noise. The receiver can solve for the transmitted signals by treating (3) as a system of linear equations . If the channel H is correlated, the system of linear equations will have more unknowns than equations.

One reason correlation between signals can occur is due to the spacing between antennas. To prevent correlation due to the spacing, they are typically spaced at least $\lambda_c/2$, where λ_c is the wavelength of the carrier frequency . The second reason correlation can occur is due to lack of multipath components. It is for this reason that rich multipath is desirable in MIMO systems. The multipath effect can be interpreted by each receive antenna being in a different channel.

For this reason, the rank of a MIMO channel is defined as the number of independent equations offered. It is important to note that

$$rank(\boldsymbol{H}) \leq min(N_r, N_t) \qquad (4)$$

and therefore the maximum number of streams that a MIMO system can support is upper-bounded by min(Nr;Nt). Since the performance of MIMO systems depends highly on the channel matrix, it is important to model the channel matrix realistically. The following section provides an overview of typical channel models used for computer simulations.

II. 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 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 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 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 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.

III. SIMULATION RESULT

Simulations are done in MATLAB using the Rayleigh channel model described in Section II-B1. We simulate G2, G3, G4, H3, and H4, for the case of Nr = 1 up to Nr = 4. We modulate using BPSK, QPSK, 4-QAM, 16-QAM, and 64- QAM gray mapping constellations. For each sample, blocks of 104 symbols are simulated until at least 100 bit errors are obtained, or until 104 blocks are simulated. The simulation is stopped when the SNR reached 40dB or after simulating 104 blocks without errors. Consequently, each value obtained for the bit-error rate (BER) of 10^{-7} with 100 errors has a 99:9% confidence level. Both the MATLAB simulation source code and the data collected from the simulations are available .

Keeping all other variables the same, the results obtained for BPSK and QPSK are nearly identical, and we therefore present data for QPSK and omit that of BPSK. Since the data is nearly identical, the reader can safely assume that the performance of BPSK is that of QPSK. We study the performance of each block code discussed earlier for the different cases of constant Nr, Nt, rate, and diversity order .

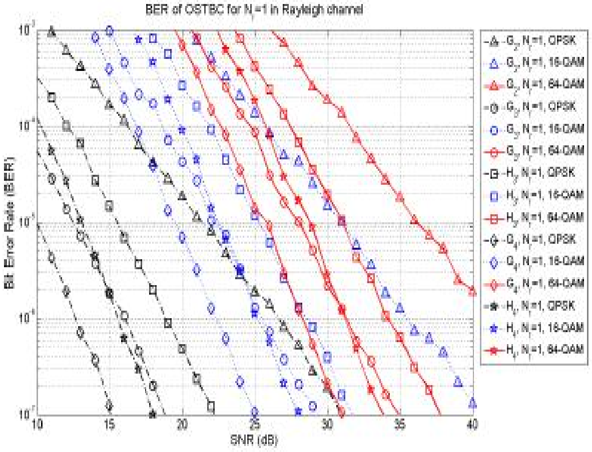

Figure 4.2.1: Bit error rate versus SNR of OSTBC for Nr = 1

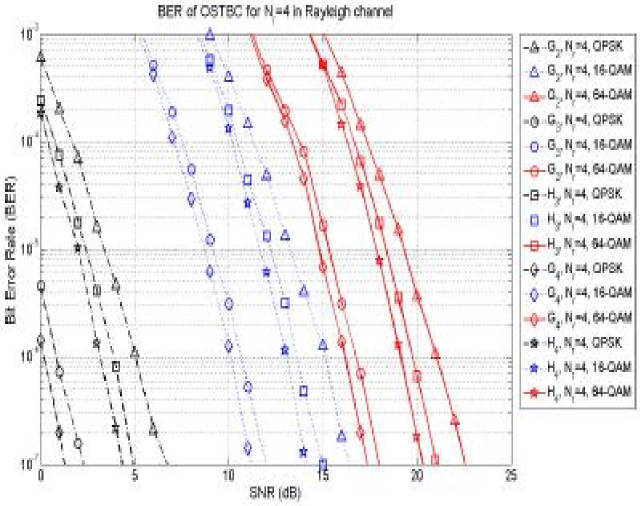

Figure 4.2.2: Bit error rate versus SNR of OSTBC for Nr = 4

For the case of Nr constant, we fix Nr = 1. The result is shown in Figure 2. As expected, for each different code blocks, the performance degrades as more bits per symbol are transmitted. It can be observed that for a particular modulation and high SNR, the best performance is obtained by 4 followed by H4, G3, H3, and G2. However, for any modulation and low SNR, G3 out performs H4 even when H4 has greater gain.

The results is that the best performance at low SNR is obtained by G4 followed by G3, H4, H3, and G2. Moreover, H4 is outperformed by G3 for the cases of Nr = 2, Nr = 3, and Nr = 4. Figure 3 shows the case where Nr is fixed to 4. As can be observed, for a particular modulation, the best performance is obtained by G4 followed by G3, H4, H3, and G2. This order is the same as for the case of Nr = 1 and low SNR where G3 outperforms H4 even with H4 having higher gain. One possible reason for this behaviour is that the higher rate of H4 causes lower channel gain per symbol and therefore higher BER for a particular SNR. The BER curve for the case of keeping Nt = 4 constant while varying Nr from 1 to 4 for different modulations is depicted in Figure 4. It can be observed that for any modulation and block code, the gain of of using 3 more antennas is approximately 14dB.

However, between Nr = 1 and Nr = 2 the gain is approximately 8dB, between Nr = 2 and Nr = 3 the gain is approximately 4dB, and between Nr = 3 and Nr = 4 the gain is approximately 2dB. This result suggest diminishing returns as Nr increases. Anothero bservation is that for any Nr and modulation scheme, G3 and G4 have a 3dB gain over H3 and H4 respectively. An interesting observation is that the performance of G4 with Nr = 2 is similar to that of H4 with Nr = 3, while G4 with Nr = 1 is outperformed by H4 with Nr = 2, and G4 with Nr = 3 outperforms H4 with Nr = 4.

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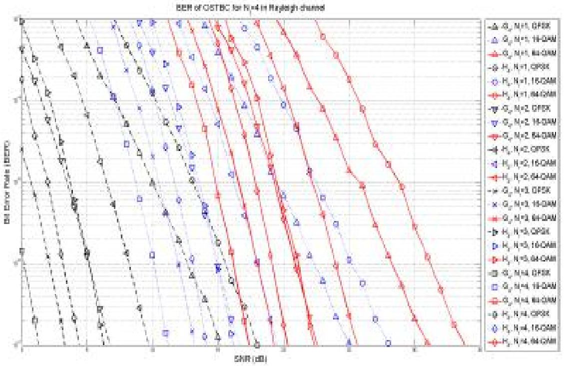

Figure 4.2.3: Bit error rate versus SNR of OSTBC for Nt = 4

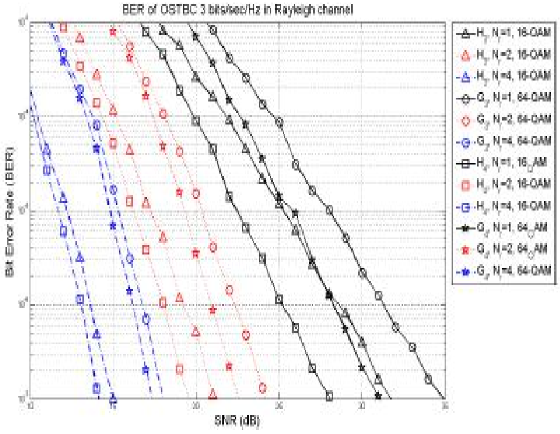

Figure 4.2.4:. Bit error rate versus SNR of OSTBC at 3 bits/sec/Hz.

In order to fairly compare all the block code schemes, a comparison with equal data rate and a comparison with equal diversity gain is needed. For the case of equal data rate, we simulate H3 and H4 with constellation 16-QAM, and G3 and G4 with constellation 64-QAM. Since H3 and H4 have code rate 3/4, using 16-QAM (4 bits/symbol) leads to 3 bits/sec/Hz. Similarly, since G3 and G4 have code rate 1/2, using 64-QAM (6 bits/symbol) leads to 3 bits/sec/Hz. The result for Nr = 1, Nr = 2, and Nr = 4 is presented in Figure 5.

As expected, having more receive diversity leads to better performance on all cases. In general, there is a 3dB gain when using the 16- QAM lower order constellations with higher code rate 3/4 over using the 64-QAM higher order constellation with lower code rate 1=2 for the same number of transmit antennas. It is particularly interesting to notice that at high SNR and Nr = 1, 64-QAM G4 outperforms 16-QAM H3 while at low SNR and Nr = 1, 16-QAM H3 outperforms 64-QAM G4.

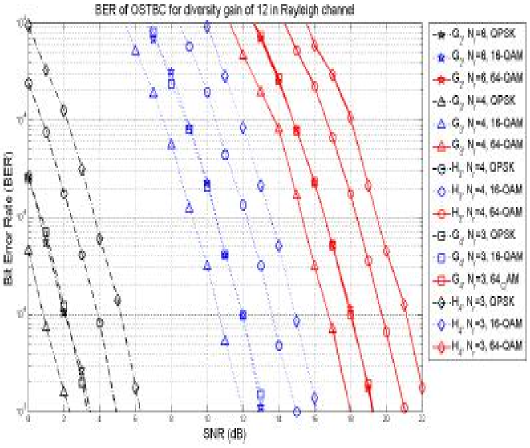

Figure 4.2.5: Bit error rate versus SNR of OSTBC with spatial diversity 12.

Figure 6 displays a BER curve for the case of equal diversity gain. To accomplish this, we simulate G2 with Nr = 6, G3 and H3 with Nr = 4, and G4 and H4 with Nr = 3. The diversity gain in each case is therefore 12. From Figure 6 we see that having fewer number of transmit antennas and more number of receive antennas results in better performance. G3 and H3 with Nr = 4 have a 2dB performance gain over G4 and G4 with Nr = 3 respectively. This result agrees with since (1) must hold true which says that as the number of transmit antennas increase, the energy per transmit antenna decreases. It is also interesting to see that G2 with Nr = 6 has similar performance as to G4 with Nr = 3. This observation suggests that there is an upper limit at which using few Nt transmit antennas and more Nr receive antennas becomes equivalent to using more Nt transmit antennas and fewer Nr receive antennas. This is important since, as previously mentioned, it is more economical to increase the number of Nt transmit antennas at the base station than increasing the number of Nr receive antennas at all mobile stations.

IV. CONCLUSION

Thus, we conclude that it is preferable to use a low constellation order with high code rate than high constellation order with low code rate. It is also observed that equal diversity gain does not imply equal performance. Diminishing returns for every scheme as the number of received antennas increased.There is a percent of error between the actual channel and the estimated one , so to reduce the error either implement a noise cancellation method as a feature inside the presented technique is to implement QO-STBC and DHSTBC over CDMA or LTE instead of OFDM.

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