BER Analysis of STBC ALAMOUTI's Code for MIMO System

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***Abstract*—** *In this paper we are studying about the different transmit diversity techniques and different algorithms used for MRC technique in MIMO system to enhance diversity gain. Multiple-Input-Multiple-Output (MIMO) systems, which uses many antennas at the transmitter and receiver ends of a wireless communication system. MIMO systems are adopted increasingly in communication systems for the potential gains in capacity they realize when using many antennas. To transmit diversity we use space time block coding scheme that will yields the similar diversity advantage as maximal ratio combining. In space time block coding we use Alamouti's code. The Alamouti's scheme is historically the first Space-Time Block Code (STBC) to give full transmit diversity for systems with two transmit antennas. It is worthwhile to advert that delay diversity schemes can also meet a full diversity, but they introduce interference between symbols and complex detectors are required at the receiver.*

Keywords— *Alamouti's Code, Diversity Techniques, MIMO Systems, Space Time Block Coding.*

I. INTRODUCTION

In recent years, multiple-input multiple-output (MIMO) signal processing has been investigated for wireless communication applications. By applying multiple antennas at the transmitter or receiver, it can offer spatial multiplexing gains and spatial diversity gains. Therefore, MIMO techniques become more and more attractive in current and future wireless communication standards. A wide variety of spatial diversity techniques have been proposed in the past decade. In general, spatial diversity techniques for MIMO communication mainly classified into three categories: space-time codes, transmit-receive beam-forming and limited feedback. Spatial diversity exploits multiple antennas either separated in space or differently polarized in different antennas have different multi path characteristics or different fading characteristic and this can be used to generate a stronger signal. Spatial diversity techniques have no drawbacks associated with time diversity and frequency diversity techniques. In traditional space-time codes, channel state information is required at the receiver side but not at the transmitter. Many kinds of space-time codes have been designed to offer spatial diversity gains. Space time block coding is a technique used to send multiple copies of a data stream across a number of antennas and to exploit the various received version of the observations to improve the reliability of data transfer.

A. **Diversity Concept**

The reception of a signal in a channel transmitted through any type of fading channel degrades in quality if the signal level attenuation is below the expected operation region of the receiver. In this situation, the received signal power is not expectedly enough comparing with signal noise and interference power for reliable reception. The solution to overcome the channel attenuation because of fading problem in channel is to increase the transmitted power adjusted to the attenuation which is called power control (PC). On the other hand, there are two primary problems with this power control (PC) system.

One of the problems is that the range of the transmitter and the required transmitting power is extremely high if it is intended to fully compensate the fading. This is impossible because of the radiation power limitations, cost and the size of the amplifiers, and the limited battery power in the portable unit. Moreover, excess transmitted power increases the interference level at the other channels and users in the system unit. Another problem in power control (PC) approach is that a feedback link is needed for the channel unless the operation of the radio channel is in time division duplex (TDD) mode. In a TDD system, the same frequency band is used for the downlink transmission from the base station to mobile unit and for the uplink transmission from the mobile unit to the base station. As a result, the transmitted signal undergoes the fading as the received signal due to its reciprocal characteristic of the channel, the transmitted power of transmitter is adjusted according to the received signal power. The feedback information usage decreases throughout the channel and increases the complexity in the system [4]. Even an appropriate feedback link may not available in some application.

Using PC the fading can't be overcome completely but the attenuation may be compensated considerably. It can be mentioned that large-scale fading can be compensated as well in the uplink of a system, such as CDMA. But stringent power control is required in preventing near-far problem in the system. The rate of large-scale fading is simply slow, as a result it can be tracked well and the delay in the feedback of the power control commands can be neglected comparing with the rapid fading. On the other hand, small-scale fading can result in such rapid variations in the signal power that even the power control can't follow them.

Another approach to minimize fading effect in a system is to supply multiple replicas of the transmitted signal to the receiver which have already been passed through different fading channels. The result of this approach is that the probability that all replicas of the signal fading simultaneously is reduced [1]. This is called diversity and it is effectively and commonly used to overcome degradation in performance due to interference and fading. If there is D number of fading channels and the probability of any one channel may fade under some threshold is P, then the probability of all D signals which fade below the threshold is. The number of diversity channel D is called diversity order in the system.

B. **Diversity Branches**

Diversity in wireless radio communication is originated at various sources and this diversity can be achieved by several techniques. Moreover, several methods can be combined to get higher diversity and its advantages. A diversity technique needs a number of transmitted signal paths which are called diversity branches. These diversity branches carry the same information with uncorrelated multi-path fading. A circuit is also needed to combine the received signals and needed to select one of them. There are a number of methods to construct a diversity branches depending on the land mobile radio propagation characteristics.

C. **Diversity Techniques:**

Diversity technique is used to decrease the fading effect and improve system performance in fading channels. In this method, we obtain L copies of desired signal through M different channels instead of transmitting and receiving the desired signal through one channel. The main idea here is that some of the signals may undergo fading channel but some other signals may not. While some signal might undergo deep fade, we may still be able to obtain enough energy to make right decision on the transmitted symbol from other signals. There are a number of different diversity techniques which can be commonly employed in wireless communication systems. Some of them are following:

- Multi path/frequency diversity
- Spatial/space diversity
- Temporal/time diversity
- Polarization diversity
- Angle diversity
- Antenna diversity

1) Frequency diversity: It is used to provide the multi path structure in different frequency bands is different. This fact can be exploited to mitigate the effect of fading. But, the positive effects of frequency diversity are limited due to bandwidth limitation. Wireless communication uses the radio spectrum technique which is a resource i.e. finite. This limits the number of wireless users and the amount of spectrum available to any user at any moment in time.

2) Spatial diversity: It exploits multiple antennas either separated in space or differently polarized in different antennas have a different multipath characteristics or different fading characteristics and this can be used to generate a stronger signal. Spatial diversity techniques do not have the drawbacks associated with time diversity and frequency diversity techniques. The main drawback of spatial diversity is that it involves deployment of multiple antennas at the transmitter and the receiver which is not always feasible.

3) Time diversity: It makes use of the fact that fading over different time intervals is different. By using channel coding the effect of bad fading intervals can be mitigated by good fading intervals. However, due to delay constraints time diversity is difficult to exploit.

4) Polarization diversity: It makes the use of transmitted signals having uncorrelated fading statistics in VHF and VHF land mobile radio system when signals should be transmitted through two orthogonally propagations paths [6]. The polarization diversity may obtain in dense scattering environments when there is line of sight (LOS) and non-line of sight (non-LOS) situations.

5) Angle diversity: Equal data traffic is used on the both uplink (reverse link) and downlink (forward link) in digital cellular communication but the system requires better reverse link performance because of the limitation of mobile terminal transmit power. There is uplink capacity deployed in CDMA system due to synchronize operation on forward link and asynchronize operation on reverse link [6] [7]. If we need to achieve better uplink reliability then we can use space diversity or polarization diversity. On the other hand, there is a huge demand of data applications on downlink capacity comparing to the uplink capacity.

6) Antenna diversity is a popular and extensively used technique to improve performance in wireless communication systems. This technique reduces fast fading and inter-channel interference effects in the wireless system. In this system, two or many more antennas that are used in this technology are used and are fixed in their respective positions which will provide uncorrelated signals with the same power level. The generated signals are collected and then from those signals an enhanced signal is created. This common method of this diversity is that the antennas experiences different kind of signals because of individual channel conditions and the signals are correlated partially.

D. **Concepts of Diversity Combining Techniques:**

It is important to combine the uncorrelated faded signals which were obtained from the diversity branches to get similar diversity profit. This combing system should be in such a way that improves the performance of the communication system. Diversity combing also increases the signal-to-noise ratio (SNR) or the power of the signal that is received. Mainly, the combinatorial should be applied into the reception; however it is also possible to apply at the transmitter end. There are many diversity combining methods available but only three of them are going to be discussed here.

- Maximal ratio combining (MRC)
- Equalized gain combining (EGC)
- Selection combining (SC)

The combining processes which are used to combine multiple diversity branches in the reception, has two classes such as post-detection combing and pre-detection combining. The signals from diversity branches are combined coherently before detection in pre-detection combining. However, signals are detected individually before combining in post-detection. The performance of communication system is the same for both combining techniques for coherent detection. However, the performance of communication system gets better by using pre-detection combining for non-coherent detection. It does mean that there is no effect in performance by the type of combining procedure for the coherent modulation case. The post-detection combining is not complex in non-coherent detection. There is a difference in system performance when we use pre-detection combining and post-detection combining for non-coherent detection such as frequency modulation (FM) discriminator or differential detection schemes. Moreover, the terms pre-detection and post-detection also indicates the time of combining means when the combining is performed, before or after the hard decision.

Square-law non-coherent combining is employed frequently in diversity reception when non-coherent modulation methods are used. The demodulator outputs of all diversity branches are squared and summed to form a decision variable when we use square-law pre-detection combining. The system performance is decreased in non-coherent combining compared to coherent combining and the degradation obtained is called combining loss.

Maximal Ratio Combining (MRC)

This is a very useful combining process to combat channel fading. This is the best combinatorial process in which achieves the best performance improvement as compared to other methods. The MRC is basically used for combinatorial method to improve performance in a noise limited communication systems where the AWGN and the fading are independent amongst the diversity branches. But the MRC employment needs summing circuits, weighting and co-phasing. In the MRC combining technique, the signals from different diversity branches are co-phased and weighted before summing or connecting as shown in Fig. 1. These weights will have to be chosen as equal to the respective signals level for maximizing the combined carrier-to-noise ratio (CNR). The applied weights to the diversity branches have to be adjusted in accordance to the SNR. For enlarging the SNR and diminishing the probability of error at the output combiner, signals of diversity branch are weighted before making sum with others by a factor, . Here is noise variance of diversity branch and is the complex conjugate of channel gain [1]. As a result the phase-shifts are compensated in the diversity channels and the signals coming from strong diversity branches which have the low triggered noise, that are weighted as more as correlating to the signals from the weak branches with high level of noise. The term in weighting can be neglected conditioning that has equal values for all the values of d. Then this awareness of the connector needs the estimation of gains in complex channel and it does not need any estimation of the power of noise.

It is feasible to employ MRC in transmission process of transmit diversity. But in this case the transmitter should get proper feedback information about the sub-channels state between single receive antenna and multiple transmit antennas. However, it is not feasible to weight transmissions from multiple antennas optimally for every receiving antenna, in a combined transmit-receive diversity channel. Moreover, if interference is limited in a communication system, then there is a scheme which combines the diversity branches in order to maximize the signal-to-interference-plus-noise ratio which may allow much better performance than MRC provides. This assumption is valid for spatially white Gaussian noise if we can observe noise power at the receiver where just thermal noise is taken into consideration. If we use the same type of antenna elements then the thermal noise power is uncorrelated
and equal for each branch.

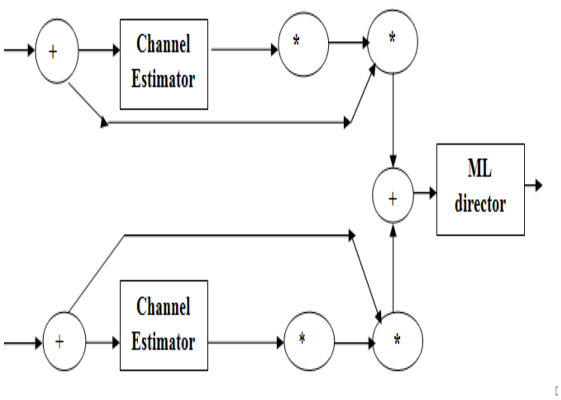

Fig.1. Maximal Ratio Combining(MRC)

II. Space Time Block Code (STBC)

Space Time Block Coding is a low complexity coding scheme that transmits diversity scheme that will yields the similar diversity advantage as maximal ratio combining. Originally proposed by Alamouti, as a full rate code for two transmit antennas, STBC now extends to an arbitrary number of transmit antennas and varying code rates. Fig. 2 shows the system diagram for the original Alamouti STBC with two transmits antennas and one receive antenna. Additional receive antennas allow the system to benefit from receive diversity.

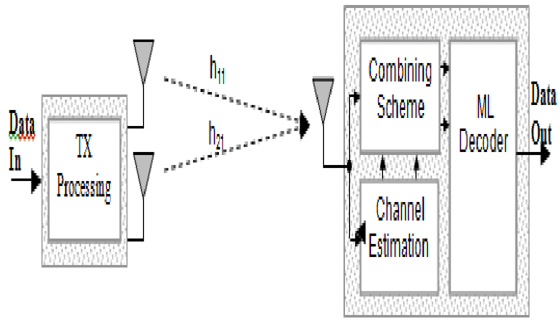

Fig. 2. Alamouti's STBC System

ALAMOUTI SYSTEM

The Alamouti's scheme is the first space-time block code to provide full transmit diversity for systems with two transmit antennas. It is worthwhile to advert that delay diversity schemes can also achieve a full diversity, but they introduce interference between symbols. Thus complex detectors are required at the receiver as shown in Fig. 3. In this section, Alamouti's transmit diversity technique algorithms have being represented including encoding and decoding.

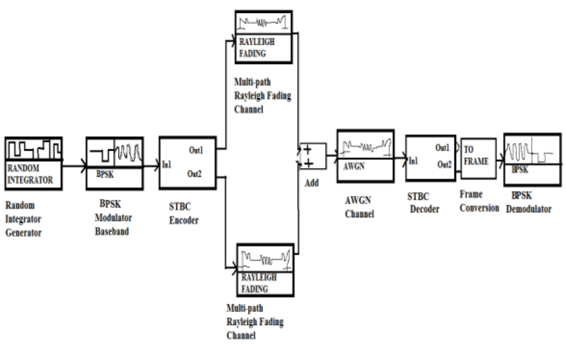

Fig. 3. Alamouti's System

A) Random Integer Generator: - This form allows you to calculate the integers randomly. The randomness comes out from the atmospheric noise, which is better than the pseudo-randomly number algorithms in many ways which otherwise used in computer programs.

B) BPSK Modulator Baseband: - The BPSK Modulator Baseband block modulates using the binary phase shift keying method. The output is a representation of the modulated signal that is baseband. This block accepts a column vector as an input signal. The input must be a binary-valued signal which is discrete-time in nature. If the input bit is 0 or 1, then the modulated symbol is exp (jθ) or -exp (jθ), respectively, where θ represents the Phase offset parameter.

STBC Encoder: - It is used to encode the data generated from BPSK Modulator baseband block. The output can be send to Rayleigh fading channel. There are multipath Rayleigh fading channel.

Rayleigh fading channel:- The delays associated with different signal paths in a multipath fading channel change in an unpredictable manner and can only be characterized .When there are a large number of available paths, then the central limit theorem can be given to model the time-variant impulse response of the channel as a complex-valued Gaussian random process. When the response is set as a zero mean complex-valued, the channel is known to be a Rayleigh fading channel. This model is assumed to have only two multipath components X (t) and Y (t). Rayleigh Fading can be get from the zero-mean complex Gaussian processes (X (t) and Y (t)). By adding two Gaussian Random variables and taking the square root (envelope) gives a Rayleigh distributed process .The phase follows uniform distribution.

AWGN: - Additive White Gaussian Noise to input signal. The AWGN Channel block adds white Gaussian noise to a real or complex input signal. When the input signal is true, the block will add the true Gaussian noise and generates a true output signal. When the input signal is complex, this block adds complex Gaussian noise and produces a complex output signal. This block will tales its sample time from the input signal. This block can process multichannel signals. When the Input Processing parameter is set to Columns as channels, then block will accepts an M-by-N input signal. M implies the number of samples per channel and N implies the number of channels. Both M and N is equal to 1. Then the block combines frames of length-M Gaussian noise to each of the N channels, using a unique random distribution per channel.

STBC decoder: - It is used to decode the data generated from AWGN. The output can be transmitted to frame conversion.

III. RESULT AND DISCUSSION

For STBC system using Alamouti's code, Bit Error Rate (BER) is evaluated at different transmitter and receiver using different modulation schemes with respect to signal-to-noise ratio as shown in fig. 4,5,6,7.

MIMO system for MRC Diversity using ALAMOUTI algorithm

A. 16 PSK ALAMOUTI

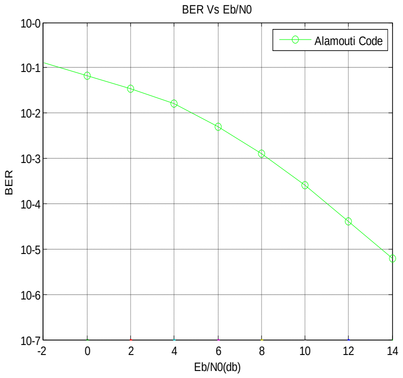

Fig. 4. 16 PSK ALAMOUTI: BER vs. EB/NO

B. 64 PSK ALAMOUTI

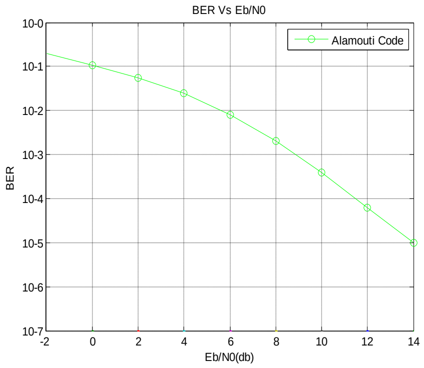

Fig. 5. 64 PSK ALAMOUTI: BER vs EB/NO

C. BPSK ALAMOUTI

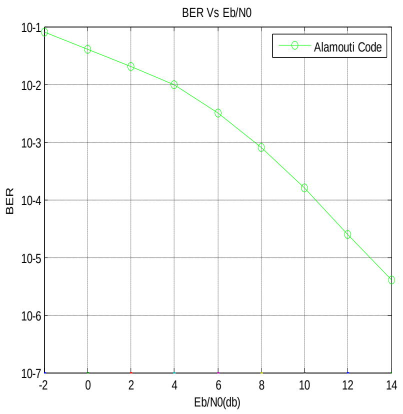

Fig. 6. BPSK ALAMOUTI: BER vs. EB/NO

D. BPSK ALAMOUTI AT DIFFERENT TRANSMITTER AND RECEIVER

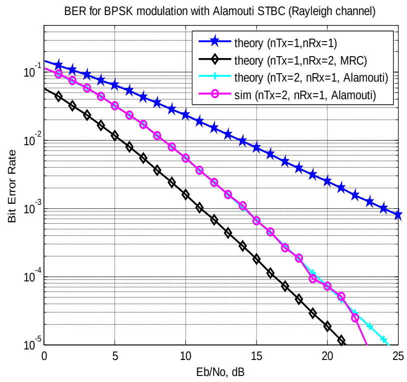

Fig. 7. BPSK ALAMOUTI at Different Transmitter and Receiver

IV. CONCLUSION

As Signal to Noise ratio is increased, Bit Error Rate (BER) decreases considerably. As the higher modulation technique is employed our overall performance degrades as BER increases significantly but a performance constraint is seen in the graphical analysis. As BER increases our performance deteriorates but system becomes bandwidth efficient. The improvement in SNR may not be achieved by higher transmit power or additional bandwidth.

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