

Performance of Extended Alamouti's Scheme Using Orthogonal Space Time Block Codes

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Abstract—In today's communication system, satisfying users demand is very challenging and difficult due to the increase in multimedia and internet applications requirement within the limited radio spectrum coupled with multipath fading and interference. Signaling techniques that are robust and efficient need to be investigated and developed. Diversity techniques that used multiple antennas such as space time wireless technology has been proposed to improve the wireless communication in a multipath fading, interference, and signal scattering wireless links. This paper proposed an extended Alamouti's scheme based on orthogonal space time block code (OSTBC). This proposed scheme is aimed to improve the wireless system efficiency in multipath fading links technique, also it improves the Multiple input multiple output (MIMO) Raleigh fading channel, and minimizes the bit error ratio (BER). The model is developed in MATLAB environment and performance of the model is analyzed in terms of BER vs Signal to Noise Ratio (SNR).

Keywords—STBC, Alamouti's Code, Diversity Technique, MIMO.

I. INTRODUCTION

Modern wireless communication has been going into tremendous improvement over the years and it continuously improves and changes the lifestyle with constant addition of various improved new services such as high speed data transmission and increased data rates. These improvements enable the user to enjoy quality services such as easy internet accessibility, high quality multimedia services, 3D graphic animation games etc. However, to effectively satisfy ever increasing users demand and expectation in a multipath wireless links and limited radio spectrum, signaling techniques that are robust and efficient need to be developed [1-3]. Several works have been reported to mitigate the ever-increasing challenges in wireless communication system. Space time wireless technique enables using multiple antennas in transmission and receiving ends known as

diversity techniques [4]. It is one of the powerful methods for improving the wireless system efficiency in multipath fading links. Various forms of diversity include; time diversity, frequency diversity, space diversity, angle diversity, and polarization diversity. The diversity can be implemented at either transmitter or receiver. If the diversity is implemented at the receiver side with multiple antenna at receiving end while a single antenna at transmitting, the configuration is known as Multiple input single output (MISO). For the configuration with multiple antenna at the transmitter and single antenna at receiver is called single input multiple output (SIMO). Meanwhile, if the diversity is implemented at both ends then the system is known as multiple input multiple output (MIMO) [5]. Example of MIMO configuration system is shown in fig 1.

several works have proposed the used of antenna array at one end, mostly at the receiver. Authors in [6] shows that by using antenna arrays at both ends capacity gain would be improved in scattering wireless links. Receive diversity have been proposed in [7]. In similar manner, reference [8] has analyzed the used of receive diversity in cellular system. Recently, researchers have explored that the benefits of receive diversity can be fully achieved by transmit diversity [9,10,11]. [12] proposed an efficient, simple and low in computation transmit diversity with two antennas. Other works include proposed vertical bell labs space time architecture (V-BLAST) and spatial multiplexing as a detection technique [13]. Alamouti SBTC performance using theoretical values [14,11] was compared. Other works in literature include [15,16,17]. MIMO have been explored and implemented to enhance data rate (bit/sec) and bit error rate (BER) quality by employing suitable coding techniques. It

also maximizes the efficient bandwidth use as well as to mitigate random fading [18,19].

Space time block coding (STBC) was developed and used to improve the efficiency of diversity gains of space time coding (ST) system. Its advantage is to possibly combine time, spatial diversity, and also it is easier to develop which draws the attention of researchers in investigating its efficacy to provide diversity and full rate. Alamouti [20] proposed a scheme using STBC with $M=2$, and $N=1$, where M and N are the number of transmit and receive antenna elements respectively. This scheme is simple transmit diversity and is equal to maximal-ratio receiver combining (MRRC). The scheme has low computational complexity and easily be generalized to diversity of order $2M$ without any feed back to the transmitter as well as no bandwidth expansion. Several works have focused on improvement of STBC scheme such as in [11,18,21] proposed extension of Alamouti's scheme for $M=2$, but these codes are non-square, loss in bandwidth efficiency, and complex orthogonal only in time domain.

Most of the reported works limitation is that the knowledge of the channel at receiver end is required. This work proposed a new extended Alamouti's scheme, the scheme uses OSTBC to encode the data.

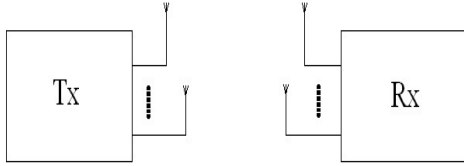


Fig. 1. MIMO Communication System

II. MATHEMATICAL MODELING OF OSTBC WITH MIMO

In this stage, space time block codes for extended Alamouti's scheme based on complex constellation and orthogonal design will be developed and analyzed. The encoding for space time block codes, transmission matrices, channel configurations and the combiner will be described mathematically.

A. Space-time block code for the extended Alamouti's scheme based on orthogonal design

The goal of STBC code is to design and construct higher number of transmission matrices with low complexity in decoding and at the same time attain a full diversity when the number of transmit antennas is greater than two. These proposed codes are also generalized version of Alamouti's scheme with the same features of orthogonality and with specified number of transmit antennas they achieved full diversity. In other words, space-time block codes are a

complex version of Alamouti's space-time code, where the encoding and decoding schemes are the same as in both the transmitter and receiver sides. the matrix which consist of data is constructed with the columns as a number of the time slots required to transmit the data, while the rows are equal to the number of transmit antennas. The signals at the receiver sides are combined first and then to the maximum likelihood detector to apply the decision rules.

In general, space-time block code is defined by $nTx \times p$ transmission matrix S , where nTx represents the number of transmit antennas and p represents the number of time periods needed to transmit one block of coded symbols. The rate of the space-time block code is defined as the ratio of the number of input (k) which represents the number of symbols taken by space-time block encoder and the number of space-time block coded symbols transmitted from each antenna. For the rate of any space-time block codes with two transmit antennas is equal to one. The rate of a space-time block code can be calculated by (1):

$$R = k/p \quad (1)$$

B. Two Transmit and Two Receive Antennas

The encoding for all space-time block codes that uses two transmit antennas is exactly the same as the encoding for Alamouti space-time code. The transmission matrix used is the same as in Equation (2). Fig. 2 shows the Encoder block diagram.

$$G_2 = \begin{bmatrix} s_1 & s_2 \\ -s_2^* & s_1^* \end{bmatrix} \quad (2)$$

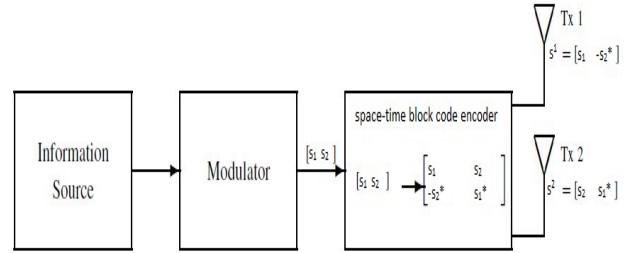


Fig. 2. Space-Time Block Encoder

Although the transmission sides are the same, the receiver sides are quite different. The receiver in this case has two receive antennas instead of one, which increases the receive diversity compared with a system with one receive antenna. Table 1 shows the channel coefficients for the space-time system with two transmit and two receive antennas.

The received signals at the two receive antennas denoted by r_1 , r_2 , r_3 and r_4 for t and $t + T$, respectively, can be expressed as (3)-(6):

$$r_1 = h_1 s_1 + h_2 s_2 + n_1 \quad (3)$$

$$r_2 = -h_1 s_2^* + h_2 s_1^* + n_2 \quad (4)$$

$$r_3 = h_3 s_1 + h_4 s_2 + n_3 \quad (5)$$

$$r_4 = -h_3 s_2^* + h_4 s_1^* + n_4 \quad (6)$$

The combiner builds the following two combined signals that are sent to the maximum likelihood detector.

$$\tilde{s}_1 = h_1^* r_1 + h_2^* r_2 + h_3^* r_3 + h_4^* r_4 \quad (7)$$

$$\tilde{s}_2 = h_2^* r_1 - h_1^* r_2 + h_4^* r_3 - h_3^* r_4 \quad (8)$$

These two combined signals are then sent to the maximum likelihood detector.

Table 1: Channel configurations for two transmit and two receive antennas.

	Rx1	Rx2
Tx1	h_1	h_3
Tx2	h_2	h_4

C. Four Transmit and One Receive Antenna

At a given symbol period, four signals are transmitted simultaneously from four transmit antennas. The signal transmitted from antenna one is denoted by s_1 , the signal from antenna two by s_2 , the signal from antenna three by s_3 and the signal from antenna four by s_4 . This process will go on in the same manner until transmitting the last column of the G_4 transmission matrix as given in Equation (9).

$$G_4 = \begin{bmatrix} s_1 & s_2 & s_3 & s_4 \\ -s_2^* & s_1^* & -s_4^* & s_3^* \\ -s_3 & s_4 & s_1 & -s_2 \\ -s_4^* & -s_3^* & s_2^* & s_1^* \\ s_1^* & s_2^* & s_3^* & s_4^* \\ -s_2^* & s_1^* & -s_4^* & s_3^* \\ -s_3 & s_4 & s_1 & -s_2 \\ -s_4^* & -s_3^* & s_2^* & s_1^* \end{bmatrix} \quad (9)$$

The matrix in Equation (9) has a rate of half and is used as STBC encoder to transmit any complex signal constellations. The encoding, mapping and transmission of the STBC can be summarized in fig. 3.

For four transmit and one receive antenna system, the channel coefficients are modeled by a complex multiplicative distortion, h_1 for the first transmit antenna, h_2 for the second transmit antenna, h_3 for the third transmit antenna and h_4 for the fourth transmit antenna.

Assuming the fading is constant across four consecutive symbols then channel coefficients can be represented as (10)- (13):

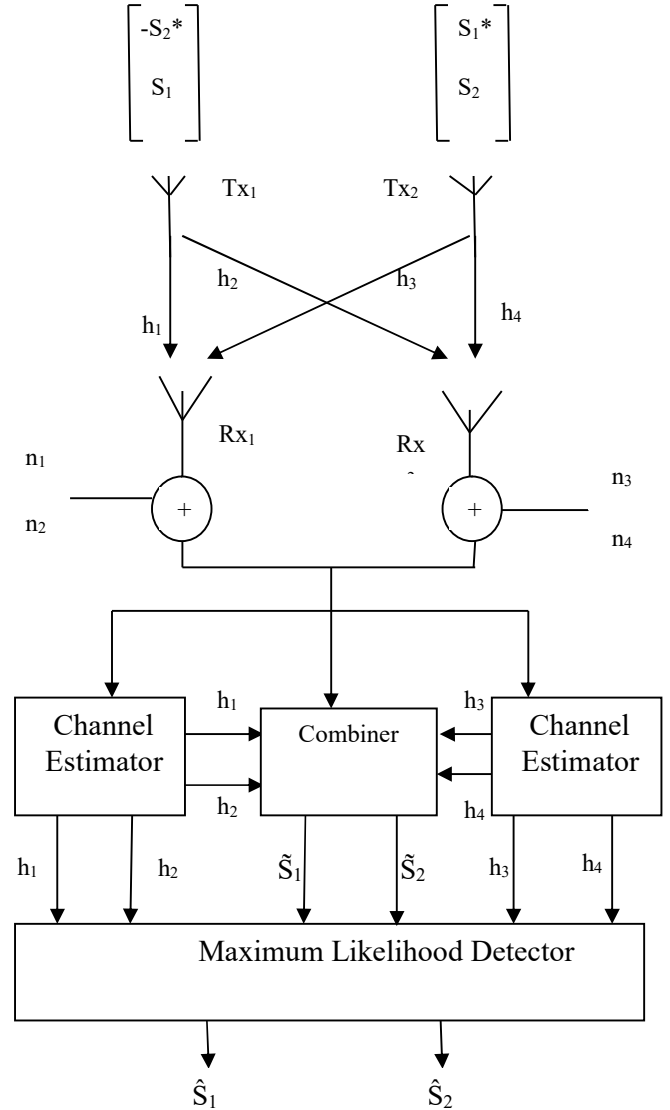


Fig. 3. Space-Time Block Code Scheme with Two Transmit and Two Receive Antennas.

$$h_1(t) = h_1(t + T) = h_1 = |h_1|e^{j\theta_1} \quad (10)$$

$$h_2(t) = h_2(t + T) = h_2 = |h_2|e^{j\theta_2} \quad (11)$$

$$h_3(t) = h_3(t + T) = h_3 = |h_3|e^{j\theta_3} \quad (12)$$

$$h_4(t) = h_4(t + T) = h_4 = |h_4|e^{j\theta_4} \quad (13)$$

where $|h_i|$ and θ_i , $i = 1, 2, 3$ and 4 are the amplitude and phase shift for the path from transmit antenna i to receive antenna j . The channel coefficients for space-time block codes with four transmit and one receive antenna is shown in Table 2.

The receiver in this case will receive eight different signals in eight different time slots. The received signals can be represented as equation (14)-(21):

Table 2: Four transmit and one receive antenna channel coefficients.

	Rx1
Tx1	h_1
Tx2	h_2
Tx3	h_3
Tx4	h_4

$$r_1 = h_1 s_1 + h_2 s_1 + h_3 s_1 + h_4 s_1 + n_1 \quad (14)$$

$$r_2 = -h_1 s_2 + h_2 s_1 - h_3 s_4 + h_4 s_3 + n_2 \quad (15)$$

$$r_3 = -h_1 s_3 + h_2 s_4 + h_3 s_1 - h_4 s_2 + n_3 \quad (16)$$

$$r_4 = -h_1 s_4 - h_2 s_3 + h_3 s_2 + h_4 s_1 + n_4 \quad (17)$$

$$r_5 = h_1 s_1^* + h_2 s_2^* + h_3 s_3^* + h_4 s_4^* + n_5 \quad (18)$$

$$r_6 = -h_1 s_2^* + h_2 s_1^* - h_3 s_4^* + h_4 s_3^* + n_6 \quad (19)$$

$$r_7 = -h_1 s_3^* + h_2 s_4^* + h_3 s_1^* - h_4 s_2^* + n_7 \quad (20)$$

$$r_8 = -h_1 s_4^* - h_2 s_3^* + h_3 s_2^* + h_4 s_1^* + n_8 \quad (21)$$

The combiner builds the following four combined signals:

$$\tilde{s}_1 = h_1^* r_1 + h_2^* r_2 + h_3^* r_3 + h_4^* r_4 + h_1^* r_5 + h_2^* r_6 + h_3^* r_7 + h_4^* r_8 \quad (22)$$

$$\tilde{s}_2 = h_2^* r_1 - h_1^* r_2 - h_4^* r_3 + h_3^* r_4 + h_2^* r_5 - h_1^* r_6 - h_4^* r_7 + h_3^* r_8 \quad (23)$$

$$\tilde{s}_3 = h_3^* r_1 + h_4^* r_2 - h_1^* r_3 - h_2^* r_4 + h_3^* r_5 + h_4^* r_6 - h_1^* r_7 - h_2^* r_8 \quad (24)$$

$$\tilde{s}_4 = h_4^* r_1 - h_3^* r_2 + h_2^* r_3 - h_1^* r_4 + h_4^* r_5 - h_3^* r_6 + h_2^* r_7 - h_1^* r_8 \quad (25)$$

These four combined signals equations (22)-(25) are then sent to the maximum likelihood detector.

III. RESULTS AND DISCUSSION

To evaluate the performance of developed model, random bit stream is generated, power level is defined, and the symbols that are transmitted are also generated using the encoding scheme. The encoded symbols are transmitted through a multipath fading channel which is assumed to be flat faded and channel distortion is assumed to be multipath.

A. Performance of Alamouti's scheme

The performance of Alamouti transmit diversity and maximum ratio combining schemes in slow fading channels is evaluated using BER verses SNR in dB. In the simulation, it is assumed that the fading is mutually independent from each transmit antenna to each receive antenna and the total transmit power is the same for all cases. Fig. 4 shows the Alamouti scheme BER versus SNR performance with coherent BPSK modulation. From the simulation result, it is very clear to see that Alamouti scheme has the same diversity as the two-branch maximal ratio combining (MRC). However, from Fig. 4, it is seen that Alamouti scheme performance is worse than the two-branch MRC by 3 dB and that is because the energy radiated from the single antenna in the MRC is the double of what radiates from each transmit antenna in the Alamouti scheme. To reach the same results, the total transmit power from each transmit antenna in the Alamouti scheme has to be equal to the transmit power of the MRC.

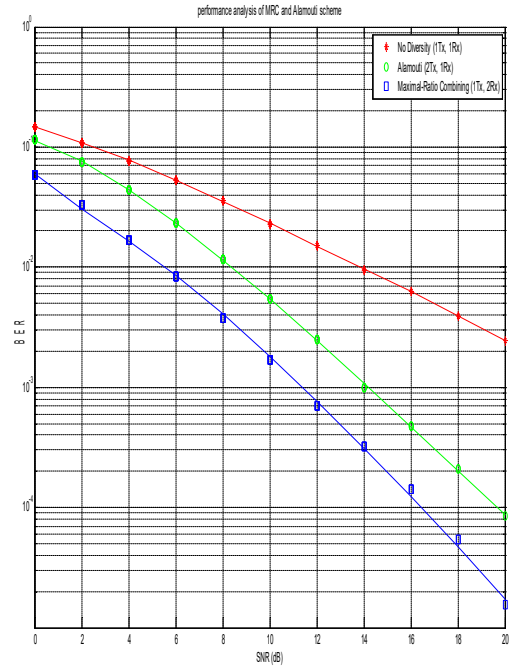


Fig. 4. Performance Analysis of MRC and Alamouti Scheme

B. Performance of extended Alamouti and maximum ratio combining for higher order diversity

Fig. 5 shows the performance results for Alamouti OSTBC with two transmit and one receive antenna and maximum ratio combining with one transmit and two receive antenna that is a diversity of order two. From this figure, it is shown that the slopes of both curves are the same. However, though the curves enjoy the same diversity, the 2x1 Alamouti scheme appears to have less gain than a 1x2 MRC. This is because the power

from the Alamouti scheme is divided between the antennas (i.e. approximately 3dB less per antenna than the power from the MRC scheme, which has only one antenna).

Also, from fig. 6 all the three curves have the same diversity of order four (implied by the same slope of the BER curves). 1x4 MRC outperforms 2x2 Alamouti by 3dB gain and 2x2 Alamouti outperforms 4x1 Alamouti based on the same reason as above.

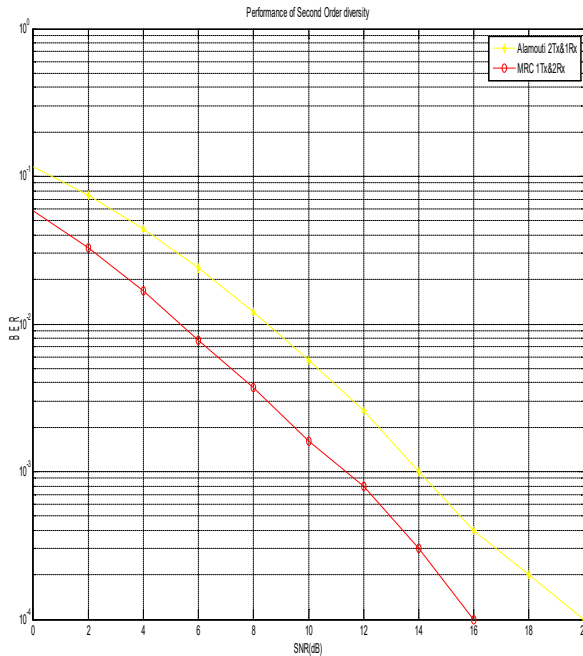


Fig. 5. BER performance of second order diversity.

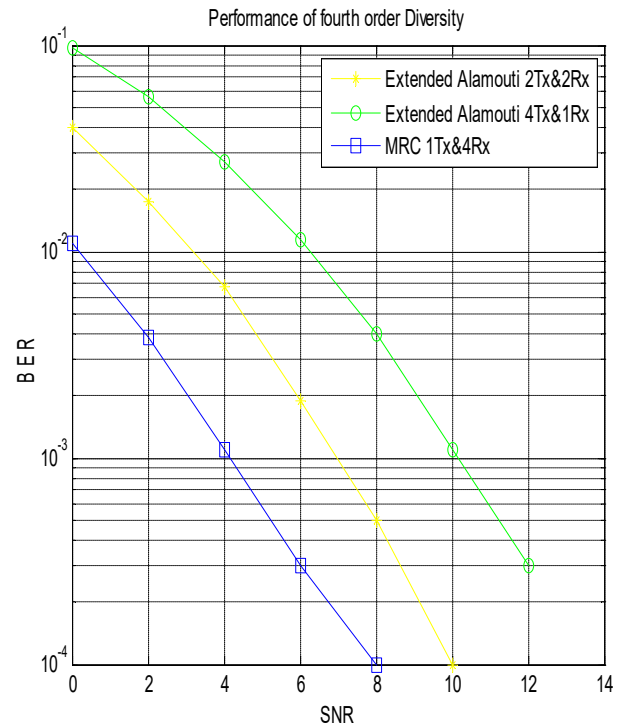


Fig. 6. BER Performance of Fourth Order Diversity

IV. CONCLUSIONS

This paper proposed the extended Alamouti's scheme using OSTBC coding scheme. The scheme is simple yet ingenious transmit diversity technique in MIMO technology. The performance of higher order diversity system involving a larger number of antennas, but whose basic approach is derived from the method proposed by Alamouti was analyzed and evaluated. It is concluded that space-time block codes with large number of transmit antennas always give better performance than that of lower number of transmit antennas. In order to transmit more data, it is clearly evident that higher number of transmit antennas need to be implemented with the receiver ability to recover the transmitted data. Also, at the receiving end, higher number of received antennas will receive the same number of transmitted data. This is an advantage because if one receives antenna did not recover the transmitted data correctly, the second antenna could. The chance that at least one out of two or more receive antennas would receive the transmitted data uncorrupted is always higher than if there is only one receive antenna. The proposed scheme also minimizes the multipath effect and maximize the information

rate. MIMO-STBC with channel estimation scheme need to be further investigated.

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