



OSTBC-MIMO Performance Evaluation Using Different Modulation Schemes

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ABSTRACT

This paper presents the performance evaluation of Orthogonal Space Time Block Codes on Multiple Input Multiple Output (OSTBC-MIMO) system using our proposed extended Alamouti's STBC scheme based on Orthogonal design. The model was evaluated with different modulation schemes such as BPSK, QPSK, 8-PSK, and 16-PSK for different antenna configurations. From our results, BPSK outperforms other modulations scheme. The system model was developed in Matlab environment and Bit error rate against signal to noise ratio was used to evaluate the performance under Rayleigh faded channel. Our proposed scheme improves the channel capacity gains, data throughput, and mitigate fading and interference.

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INTRODUCTION

Wireless communication system suffers from wave attenuation, delay, and phase shift as a result of interaction of wave with objects which causes replicas of transmit signal at the receiving end superimposed with noise and interference. This is called Fading in communication system, this phenomenon degraded the signal quality and reduce data throughput [1]. As modern wireless communication undergoes several improvements such as migration of new generations in mobile communication, efficient signal processing techniques, improved voice and channel coding, and advanced multiple access techniques due to the ever increase in user's demand, limited radio spectrum, and multipath fading channels. Diversity technique is one of the useful method in mitigating fading problems and improve channel capacity in communication system.

Several diversity techniques have been reported in literature such as receive and transmit diversity, multiple input multiple output (MIMO) is the best diversity configuration as it consists of array of smart antennas at both transmitter and receiver ends [2, 3]. Example of 2x2 MIMO configuration is shown in Figure 1.

MIMO system improves bit error rate (BER) as transmission quality, higher capability (bits/s/Hz), and increased faster and higher data rates. MIMO utilized space time code in its implementation. Alamouti [4] proposed a simple transmit diversity based on space time coding with 2x1 multiple input single output (MISO) and 2x2 MIMO system configuration, the scheme is low in computational complexity, does not require bandwidth expansion, and without any feedback to the transmitter, can be generalized to diversity of order $2M$ with M been the number of transmit antennas. Using

M -array modulation technique, each antenna transmitted a symbols while space time block codes (STBC) is used to encode the symbols [3, 5]. Consider a MIMO system with $M \times N$ configuration, the possible propagation paths between transmitting antennas M and receiving antenna N is MN . For many modulation scheme in a Rayleigh faded channel, the MIMO general property is that $G_d = O_d = MN$ is to hold true. Where, G_d is the diversity gain and O_d is the diversity order.

The performance of STBC codes depends on the type of modulation scheme and the type of MIMO configuration used (number of transmit and receive antennas). Therefore, this

work investigates the efficacy of our proposed extended version of Alamouti's scheme based on orthogonal design by evaluating the performance of the technique with different modulation scheme such as BPSK, QPSK, 8PSK and 16PSK under Rayleigh faded channel with Additive white Gaussian Noise (AWGN).

The rest of this paper is organised as follows: section two highlighted some of the previous works in literature, while section three presents our experimental and model design of the proposed method, result and discussion will be presented in section four. Finally, section five presents the conclusion of the paper.

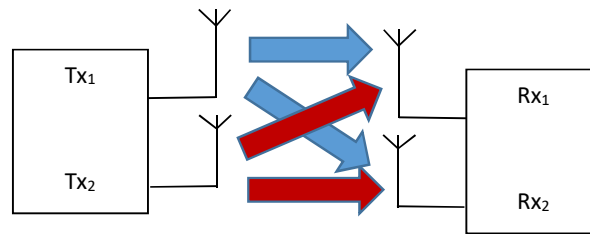


Figure 1: Example of 2x2 MIMO configuration

RELATED WORKS

Several researchers have proposed and explored the performance evaluation of MIMO system in wireless communication. [6] Provides the performance of MIMO-STBC with different modulation schemes using Alamouti's 2x1 and 2x2 configurations. Performance analysis of differential STBC (DSTBC) with different modulation was conducted in [7]. Also, Semiblind channel estimation method was employed by [8] to evaluate the MIMO-STBC scheme and simulated with different modulation scheme. [9] and [10] have used Hamming channel coding in evaluating the performance of MIMO-STBC and demonstrated its benefit in improving the system performance. Using STBC the performance of MIMO was also evaluated with discrete cosine transform in QAM and QPSK modulation techniques [11].

Alamouti's scheme performance was also theoretically analyzed and compared in [12, 13, 14]. MIMO system have been extensively studied with STBC coding system to enhance data rates (bit/sec) and bit error rate (BER) as reported in [15,16,17,18,19,20,21].

EXPERIMENTAL AND SYSTEM DESIGN

STBC for the Extended Alamouti's Scheme Based on Orthogonal Design

The aim of this code design is to develop high-rate complex transmission matrices that have a low decoding complexity for higher number of antennas that can achieve full diversity. STBC are generalized and complex version of Alamouti's scheme with the same encoding and decoding scheme at both ends. The matrix is constructed consisting of number of transmit antennas and the number of time slots as rows and

columns respectively. The block diagram of proposed model is shown in Figure 2.

Four Transmit and Two Receive Antennas

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 (1) is transmitted.

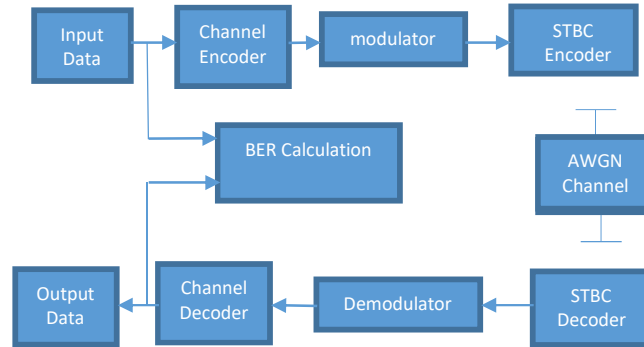


Figure 2: Block diagram of proposed model

$$G_4 = \begin{bmatrix} s_1 & s_2 & s_3 & s_4 \\ -s_2 & s_1 & -s_4 & s_3 \\ -s_3 & s_4 & s_1 & -s_2 \\ -s_4 & -s_3 & s_2 & s_1 \\ s_1^* & s_2^* & s_3^* & s_4^* \\ s_2^* & s_1^* & -s_4^* & s_3^* \\ -s_3^* & s_4^* & s_1^* & -s_2^* \\ -s_4^* & -s_3^* & s_2^* & s_1^* \end{bmatrix} \quad (1)$$

The matrix in equation (1) 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 Table 1.

Table 1: Encoding and mapping of STBC for four transmit antennas using complex signals.

	Rx_1	Rx_2
Tx_1	h_1	h_5
Tx_2	h_2	h_6
Tx_3	h_3	h_7
Tx_4	h_4	h_8

For four transmit and two receive antenna system, the channel coefficients are modeled by complex multiplicative distortions, h_1 for the first transmit antenna, h_2 for the second transmit antenna, h_3 for the third transmit antenna

$$h_1(t) = h_1(t + T) = h_1 = |h_1|e^{j\theta_1} \quad (2)$$

$$h_2(t) = h_2(t + T) = h_2 = |h_2|e^{j\theta_2} \quad (3)$$

$$h_3(t) = h_3(t + T) = h_3 = |h_3|e^{j\theta_3} \quad (4)$$

$$h_4(t) = h_4(t + T) = h_4 = |h_4|e^{j\theta_4} \quad (5)$$

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 . In the implementation of four transmit and two receive antennas, each antenna receives eight different

and h_4 for the fourth transmit antenna. Assuming the fading is constant across four consecutive symbols, then channel coefficients can be represented as given in equation (2)-(5).

signals that come through four different channels. Table 2 shows the channel coefficients for space-time block codes with four transmit and two receive antennas.

	Tx₁	Tx₂	Tx₃	Tx₄
t	S ₁	S ₂	S ₃	S ₄
t + T	-S ₂	S ₁	-S ₄	S ₃
t + 2T	-S ₃	S ₄	S ₁	-S ₂
t + 3T	-S ₄	-S ₃	S ₂	S ₁
t + 4T	S ₁ *	S ₂ *	S ₃ *	S ₄ *
t + 5T	-S ₂ *	S ₁ *	-S ₄ *	S ₃ *
t + 6T	-S ₃ *	S ₄ *	S ₁ *	-S ₂ *
t + 7T	-S ₄ *	-S ₃ *	S ₂ *	S ₁ *

Table 2: Four transmit and two receive antenna channel coefficients

Figure 3 shows the diagram of space-time block codes system with four transmit and two receive antennas.

The two receivers in this case receive eight different signals in eight

$$r_1 = h_1s_1 + h_2s_2 + h_3s_3 + h_4s_4 + n_1 \quad (6)$$

$$r_2 = -h_1s_2 + h_2s_1 - h_3s_4 + h_4s_3 + n_2 \quad (7)$$

$$r_3 = -h_1s_3 + h_2s_4 + h_3s_1 - h_4s_2 + n_3 \quad (8)$$

$$r_4 = -h_1s_4 - h_2s_3 + h_3s_2 + h_4s_1 + n_4 \quad (9)$$

$$r_5 = h_1s_1^* + h_2s_2^* + h_3s_3^* + h_4s_4^* + n_5 \quad (10)$$

$$r_6 = -h_1s_2^* + h_2s_1^* - h_3s_4^* + h_4s_3^* + n_6 \quad (11)$$

$$r_7 = -h_1s_3^* + h_2s_4^* + h_3s_1^* - h_4s_2^* + n_7 \quad (12)$$

$$r_8 = -h_1s_4^* - h_2s_3^* + h_3s_2^* + h_4s_1^* + n_8 \quad (13)$$

$$r_9 = h_5s_1 + h_6s_2 + h_7s_3 + h_8s_4 + n_9 \quad (14)$$

$$r_{10} = -h_5s_2 + h_6s_1 - h_7s_4 + h_8s_3 + n_{10} \quad (15)$$

different time slots. These received signals can be presented as in equation (6)-(21):

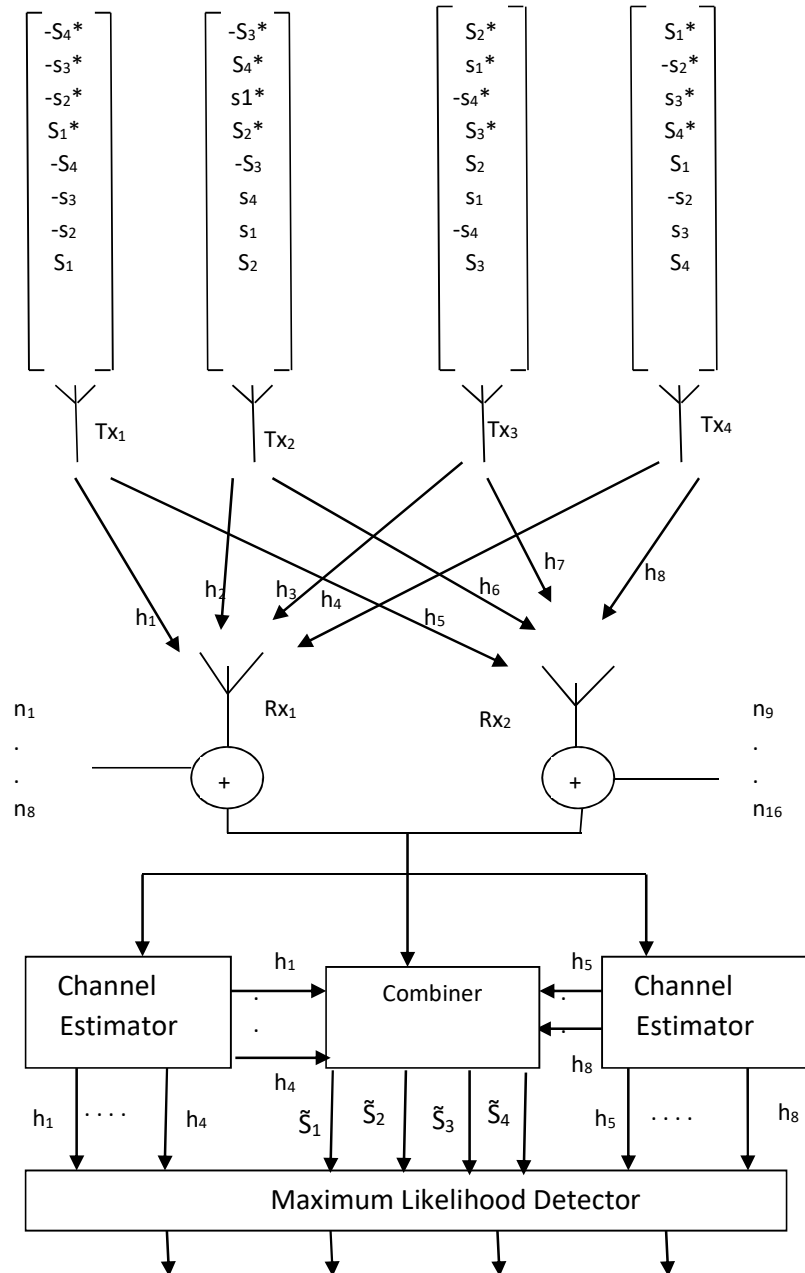


Figure 3. Space-Time Code (STC) with Four Transmit and Two Receive Antennas.

$$r_{11} = -h_5 s_3 + h_6 s_4 + h_7 s_1 - h_8 s_2 + n_{11} \quad (16)$$

$$r_{12} = -h_5 s_4 - h_6 s_3 + h_7 s_2 + h_8 s_1 + n_{12} \quad (17)$$

$$r_{13} = h_5 s_1^* + h_6 s_2^* + h_7 s_3^* + h_8 s_4^* + n_{13} \quad (18)$$

$$r_{14} = -h_5 s_2^* + h_6 s_1^* - h_7 s_4^* + h_8 s_3^* + n_{14} \quad (19)$$

$$r_{15} = -h_5 s_3^* + h_6 s_4^* + h_7 s_1^* - h_8 s_2^* + n_{15} \quad (20)$$

$$r_{16} = -h_5^*s_4^* - h_6^*s_3^* + h_7^*s_2^* + h_8^*s_1^* + n_{16} \quad (21)$$

The combiner in Figure 3 combines the eight signals arrived at each of the receiver antennas and adds them creating four new signals as shown in equation (22)-(25).

$$\{\tilde{s}_1 = h_1^*r_1 + h_2^*r_2 + h_3^*r_3 + h_4^*r_4 + h_1^*r_5^* + h_2^*r_6^* + h_3^*r_7^* + h_4^*r_8^* + h_5^*r_9 + h_6^*r_{10} + h_7^*r_{11} + h_8^*r_{12} + h_5^*r_{13}^* + h_6^*r_{14}^* + h_7^*r_{15}^* + h_8^*r_{16}^*\} \quad (22)$$

$$\{\tilde{s}_2 = h_2^*r_1 - h_1^*r_2 - h_4^*r_3 + h_3^*r_4 + h_2^*r_5^* - h_1^*r_6^* - h_4^*r_7^* + h_3^*r_8^* + h_6^*r_9 - h_5^*r_{10} - h_8^*r_{11} + h_7^*r_{12} + h_6^*r_9^* - h_5^*r_{10}^* - h_8^*r_{11}^* + h_7^*r_{12}^*\} \quad (23)$$

$$\{\tilde{s}_3 = h_3^*r_1 + h_4^*r_2 - h_1^*r_3 - h_2^*r_4 + h_3^*r_5^* + h_4^*r_6^* - h_1^*r_7^* - h_2^*r_8^* + h_7^*r_9 + h_8^*r_{10} - h_5^*r_{11} - h_6^*r_{12} + h_7^*r_{13}^* + h_8^*r_{14}^* - h_5^*r_{15}^* - h_6^*r_{16}^*\} \quad (24)$$

$$\{\tilde{s}_4 = h_4^*r_1 - h_3^*r_2 + h_2^*r_3 - h_1^*r_4 + h_4^*r_5^* - h_3^*r_6^* + h_2^*r_7^* - h_1^*r_8^* + h_8^*r_9 - h_7^*r_{10} + h_6^*r_{11} - h_5^*r_{12} + h_8^*r_{13}^* - h_7^*r_{14}^* + h_6^*r_{15}^* - h_5^*r_{16}^*\} \quad (25)$$

These four combined signals are then sent to the maximum likelihood detector to estimate the original transmitted signal.

RESULTS AND DISCUSSION

The performance of STBC depends on the type of modulation and the number of transmit and receive antennas used. Using Rayleigh faded with AWGN channel and the channel state information known only at the receiver, we evaluate the performance of OSTBC-MIMO in terms of BER with respect to SNR using different modulation schemes. The performance of BPSK, QPSK, 8-PSK, and 16-PSK for different antenna combinations was presented.

Figures 4, 5, 6, and 7 shows the performance of OSTBC using BPSK, QPSK, 8PSK and 16PSK modulation schemes respectively. The performance of BER using BPSK modulation is better than the performance of OSTB using QPSK and 16PSK modulations. The performance of OSTBC using QPSK modulation is better than the performance of OSTBCs using 8PSK and 16PSK modulation. This better performance is due to the number of bits that each modulated symbol can take. All BPSK modulated symbols can take only one bit at a time. However, QPSK modulated symbols take two bits, 8PSK takes three bits and 16PSK takes four bits per modulated symbol.

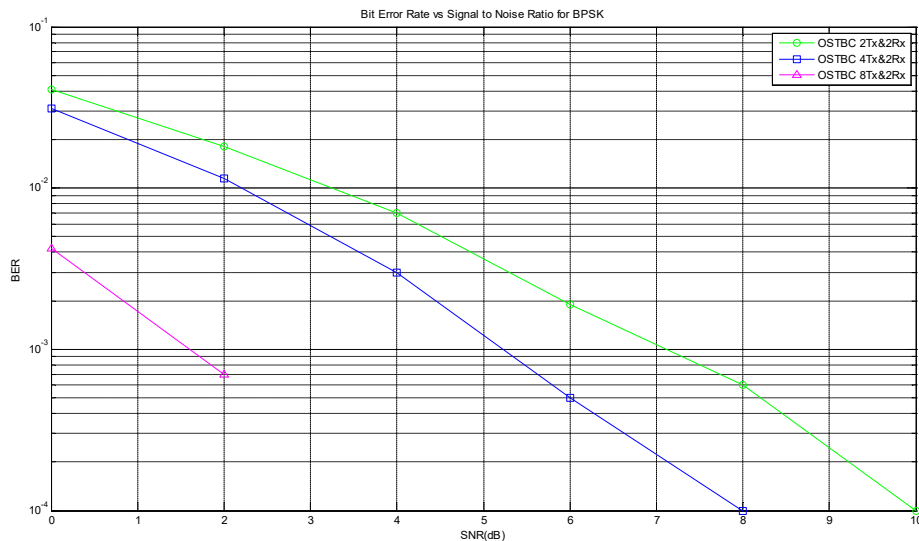


Figure 4. BER Performance of BPSK

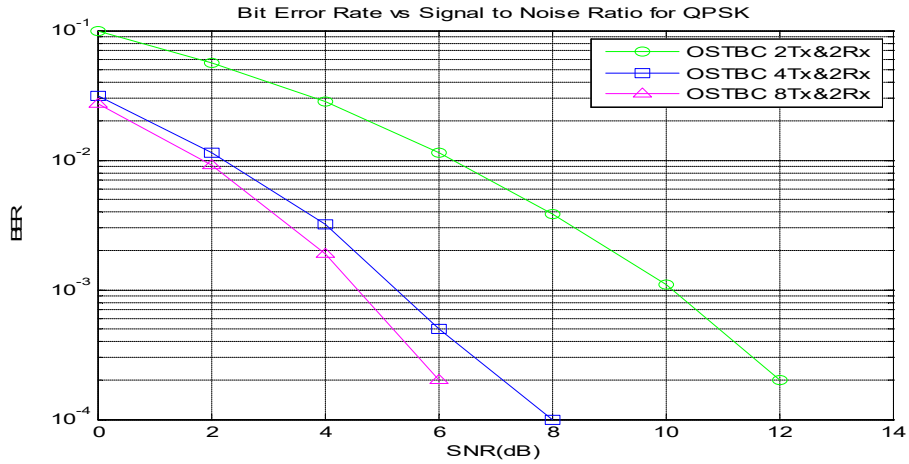


Figure 5. BER Performance of QPSK

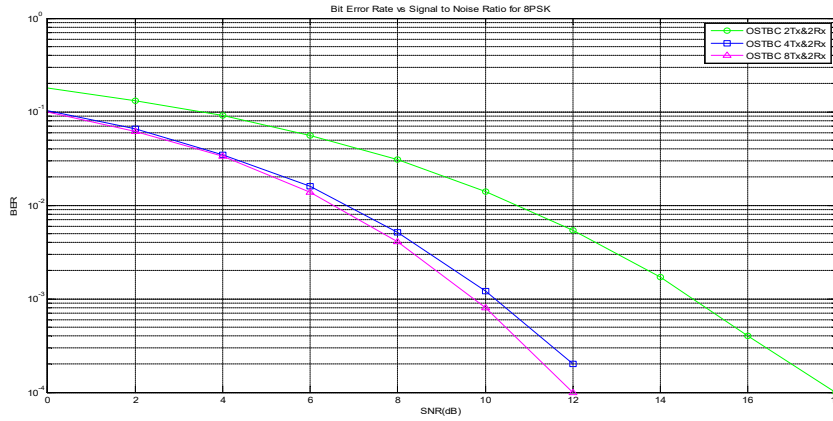


Figure 6. BER Performance of 8-PSK

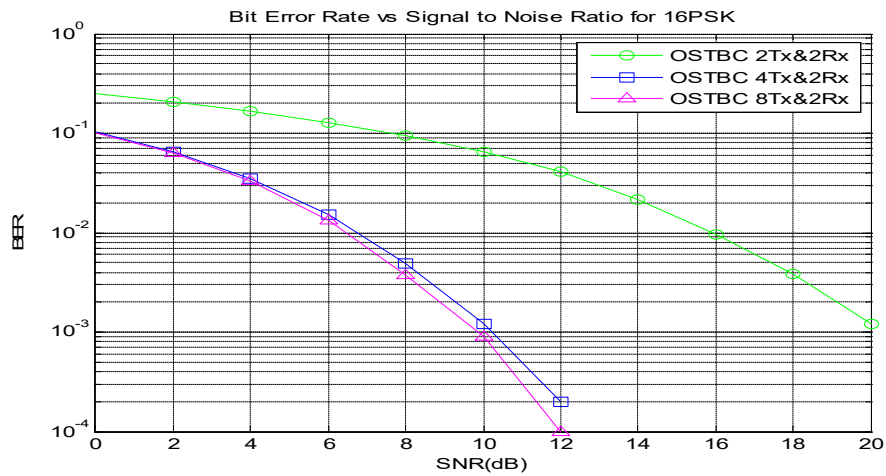


Figure 7. BER Performance of 16-PSK



Table 3 and 4 summarizes the bit-error rate performance of OSTBC using different modulation schemes.

Table 3: Performance of different modulation Schemes for 2Tx and 2Rx antennas

Modulation Scheme	Number of Tx-Rx	SNR(dB) for BER 10^{-2}	SNR(dB) for BER 10^{-3}
BPSK	2:2	3.2	7
QPSK	2:2	6	10
8PSK	2:2	11	15
16PSK	2:2	16	20

Table 4: Performance of different modulation schemes nTx and nRx antennas

Modulation Scheme	Number of Tx-Rx	BER for 2dB	BER for 4dB	BER for 6dB	BER for 8dB
BPSK	2:2	0.0181	0.0070	0.0019	0.0006
	4:2	0.0115	0.0030	0.0005	0.0001
QPSK	2:2	0.0563	0.0281	0.0114	0.0038
	4:2	0.0114	0.0032	0.0005	0.0001
8PSK	2:2	0.1322	0.0919	0.0556	0.0310
	4:2	0.0653	0.0349	0.0159	0.0051
16PSK	2:2	0.2089	0.1682	0.1290	0.0946
	4:2	0.0656	0.0353	0.0152	0.0049

Also, from the tables 3 and 4, it is very clear to see the performance of OSTBC with BPSK modulation is better than the performance of OSTBC with QPSK modulation by approximately 3dB. The performance of OSTBC with QPSK modulation is better than the performance of OSTBC with 8PSK modulation by approximately 5dB. The BER performance of OSTBC that employs 16PSK modulation method is worse than the BER performance of OSTBC that employs QPSK method. This worse in performance is due to the number of bit 16PSK modulation method takes when compared with the number of bits QPSK modulation method take. This is also true when the performance of OSTBC that employs QPSK modulation method is compared with the performance of OSTBC that employs BPSKs modulation method.

CONCLUSION

A noble method of MIMO diversity technique using proposed

extended Alamouti's scheme for evaluating the channel performance of mobile communication signals affected by Rayleigh multipath fading phenomena is presented. The performance of the proposed extended Alamouti's scheme is evaluated under the assumption of perfect channel knowledge at the receiver affected by reflection, diffraction and scattering environment with different modulation schemes. It is shown that this scheme can help to combat and mitigate against Rayleigh fading channel and best modulation scheme can be effectively employed.

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