



Performance Comparison of Transmit and Receive Diversity under Rayleigh Faded Channel Using Extended Alamouti's Scheme

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ABSTRACT

Diversity techniques have been used over the years to improve the wireless communication links, mitigate fading, achieve higher data rates, and improve channel capacity gains. This paper presents the comparative analysis of transmitting and receive diversity techniques with our proposed extended Alamouti's scheme using orthogonal space-time block codes (OSTBC) under the Rayleigh faded channel. In this paper, three possible diversity configurations have been considered: multiple-input multiple-output (MIMO), single-input multiple outputs (SIMO), and multiple-input single-output (MISO). The model was developed in a Matlab environment and performance comparison was carried out using BER vs SNR. Our proposed model proved that the MIMO system is highly efficient in improving wireless communication links. Also, our proposed transmit diversity scheme with a higher number of antenna arrays achieves full diversity as in receive combining schemes.

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INTRODUCTION

The highly increasing demands in today's wireless communication system and migration of new generations in mobile networks coupled with the integration of internet and multimedia applications such as high-quality multimedia services, easy and efficient internet accessibility, and 3D qualitative animation games among others posed several challenges in the wireless communication system. Satisfying these ever-increasing demands within the limited radio spectrum, multipath fading channels, and interference is a great challenge and difficult task [1]. Therefore, over the years modern wireless communication has been passing through

several improvements with the addition of more new services that changes and improves our lifestyle.

Several works have been carried out by researchers on diversity techniques by using an array of smart antennas at the receiver and/or the transmitter. This technique proved to be effective and one of the efficient methods for improving the efficiency of the wireless system in multipath fading channels. Diversity can be achieved either at the receiver termed as receive diversity or at transmitter known as transmit diversity. If the array of antennas were deployed at the receiver while a single antenna is used at the transmitter, the configuration is known as single input multiple outputs (SIMO). With

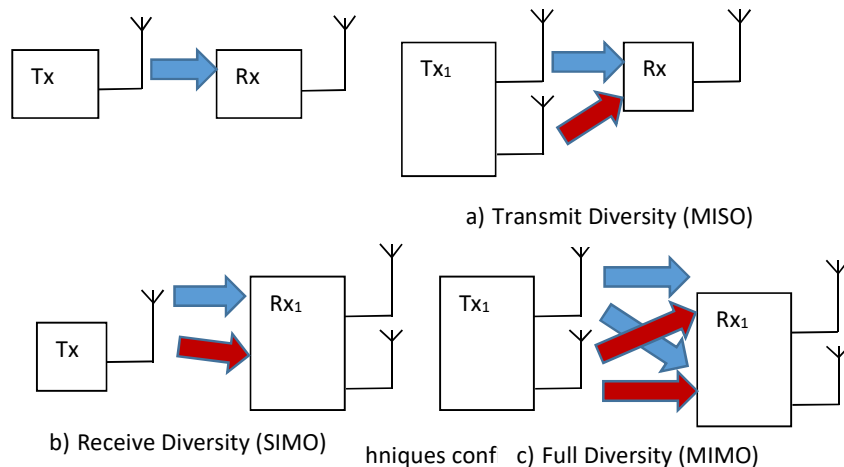
multiple antennas at the transmitting end while a single antenna at the receiving end, the system is known as multiple-input single-output (MISO). If the configuration consists of multiple arrays of antennas at both ends, then the configuration is called multiple-input multiple-output (MIMO) [2,3]. Fig. 1 depicts a different form of diversity configurations. Various forms of diversity approaches have been reported such as time diversity, space diversity, angle diversity, among others.

Traditionally, several receive combining diversity techniques have been proposed such as equal gain combining (EGC), selection combining (SC), and maximum ratio combining (MRC). MRC scheme which uses a maximum likelihood detector is the most effective and widely used method of simple receive diversity. To achieve a full transmit diversity and improve diversity gains, space-time block codes were developed based on a space-time coding system to achieve full diversity as in receive diversity techniques [4]. Alamouti's coding scheme was proposed by Alamouti using space-time block codes (STBC) with $M=2$ and $N=1$, with M and N be the number of transmitting and receiving antennas respectively. The scheme is low in computational complexity, does not require bandwidth

expansion, and without any feedback to the transmitter, can be generalized to a diversity of order $2M$ [5].

Many researchers have explored the benefit of using an array of antennas at one side, such as at the receiver end as reported in [4], while [6] proposed the use of the array of antennas at both ends and the capacity gains were greatly improved. Other researchers believe that the benefits of receive diversity can also be obtained in transmit diversity as reported in [7-9]. Transmit diversity with two antennas was proposed by [10]. Alamouti's scheme performance was also theoretically analyzed and compared in [11,12]. Beam former design for the 2×2 MIMO system was proposed in [13]. MIMO system has been extensively studied with STBC coding system to enhance data rates (bit/sec) and bit error rate (BER) [14-24].

To study the effect and performance of STBC in diversity techniques, this work proposed an extended version of Alamouti's code scheme with higher diversity order than other reported studies using orthogonal STBC (OSTBC) encode data. Performance comparison of diversity techniques was carried out to evaluate the efficacy of our proposed scheme.



SYSTEM EXPERIMENTS AND DESIGN

Maximum Ratio Combining (MRC) Scheme

MRC is a receive diversity method which is also a linear combining scheme. The output signal is obtained when the different receive signals are weighted and combined. Consider a receive diversity

$$h_1 = \alpha_1 e^{j\theta_1} \quad (1)$$

$$h_2 = \alpha_2 e^{j\theta_2} \quad (2)$$

α is the magnitude response and ϑ is the phase response.

At the receiver, the complex noise is added as n_1 and n_2 and assume to be Gaussian distributed. Therefore, the

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

$$r_2 = h_2 s_2 + n_2 \quad (4)$$

Assuming n_1 and n_2 are Gaussian distributed, the maximum likelihood decision rule at the receiver for these

$$d^2(r_1, h_1 s_i) + d^2(r_2, h_2 s_i) \leq d^2(r_1, h_1 s_k) + d^2(r_2, h_2 s_k), \forall i \neq k \quad (5)$$

$d^2(x, y)$ is the squared Euclidean distance between signals x and y calculated in Eq. (6)

$$d^2(x, y) = (x, y)(x^* - y^*) \quad (6)$$

The receiver combining scheme for two-branch MRC is shown in Eq. (7):

$$\hat{s}_1 = h_1^* r_1 + h_2^* r_2 = h_1^*(h_1 s_1 + n_1) + h_2^*(h_2 s_1 + n_2) = (\alpha_1^2 + \alpha_2^2) s_1 + h_1^* n_1 + h_2^* n_2 \quad (7)$$

Expanding (5) and using (6) and (7) we get eqs. (8) and (9)

Choose s_i iff

$$(\alpha_1^2 + \alpha_2^2) |s_i|^2 - \hat{s}_1 s_i^* - \hat{s}_1^* s_i \leq (\alpha_1^2 + \alpha_2^2) |s_k|^2 - \hat{s}_1 s_k^* - \hat{s}_1^* s_i \quad \forall i \neq k \quad (8)$$

Or equivalently

Choose s_i iff

$$(\alpha_1^2 + \alpha_2^2 - 1) |s_i|^2 + d^2(\hat{s}_1, s_i) \leq (\alpha_1^2 + \alpha_2^2 - 1) |s_k|^2 + d^2(\hat{s}_1, s_k), \quad \forall i \neq k \quad (9)$$

For PSK signals (equal energy constellations), the energy of the signal E_s is expressed in Eq. (10)

$$|s_i|^2 = |s_k|^2 = E_s \quad \forall i \neq k \quad (10)$$

Therefore, for PSK signals, the decision rule in (9) may be simplified to Eq. (11)

Choose s_i iff

$$d^2(\hat{s}_1, s_i) \leq d^2(\hat{s}_1, s_k), \quad \forall i \neq k \quad (11)$$

The maximal-ratio combiner may then construct the signal \hat{S}_1 , so that the maximum likelihood detector may produce \hat{S}_1 , which is a maximum likelihood estimate of S_1 [25, 26].

STBC for the extended Alamouti's scheme based on orthogonal design

The Space-time block codes (STBC) is a generalized version of Alamouti's scheme. These codes have the same key features. That is, they are orthogonal and can achieve full transmit diversity specified by the number of

with two antennas Rx_1 and Rx_2 at the receiving end. The signal S_1 is sent from transmitter Tx . While the channel between Tx and Rx_1 is denoted as h_1 and that of Tx and Rx_2 is denoted as h_2 as shown in Eqs. (1) and (2).

received baseband signals r_1 and r_2 are expressed in Eqs. (3) and (4) as:

received signals is to choose s_i signal if and only if (iff) Eq. (5) is satisfied.

transmit antennas. In other words, STBC is 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 data are constructed as a transmission matrix S which has its rows equal to the number of the transmit antennas n_{Tx} and its columns equal to the number of the time slots required to transmit the data p . At the receiver side, when signals are received, they are first combined and then sent to the maximum likelihood detector where the decision rules are applied.

Examples of Alamoutis STBC decoder and encoder are shown in Fig. 2 and Fig. 3 respectively.

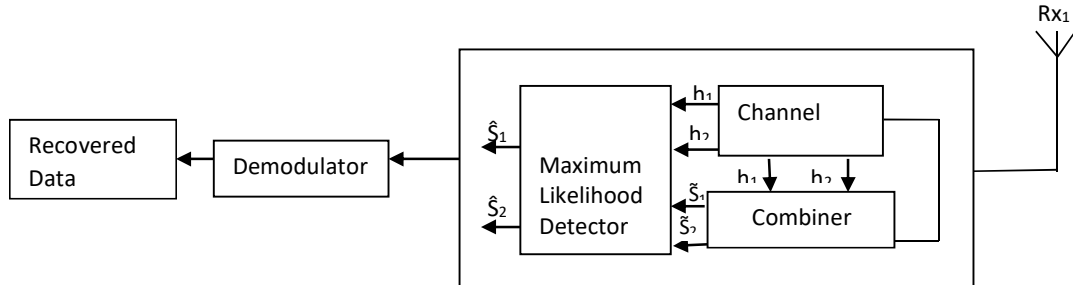


Fig. 2. Alamouti Space-Time Decoder.

Two Transmit and Two Receive Antennas
 The encoding for all STBC that uses two transmit antennas is the same

as the encoding for Alamouti space-time code.

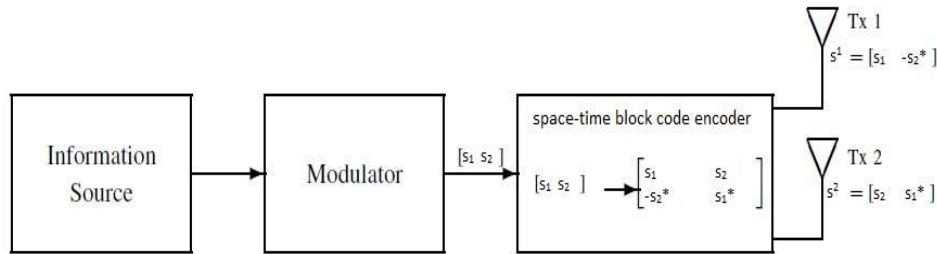


Fig. 3: Space-Time Block Encoder

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.

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 in Eqs. (12) – (15):

$$r_1 = h_1 s_1 + h_2 s_2 + n_1 \quad (12)$$

$$r_2 = -h_1 s_2^* + h_2 s_1^* + n_2 \quad (13)$$

$$r_3 = h_3 s_1 + h_4 s_2 + n_3 \quad (14)$$

$$r_4 = -h_3 s_2^* + h_4 s_1^* + n_4 \quad (15)$$

The combiner builds the following two combined signals that are

$$\hat{s}_1 = h_1^* r_1 + h_2 r_2^* + h_3^* r_3 + h_4 r_4^* \quad (16)$$

$$\hat{s}_2 = h_2^* r_1 - h_1 r_2^* + h_4^* r_3 - h_3 r_4^* \quad (17)$$

Four Transmit and One 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 Eq. (18) is transmitted.

$$G_4 = \begin{bmatrix} s_1 & s_2 & s_3 & s_4 \\ -s_2 & s_1 & -s_4 & s_3 \\ -s_3 & s_4 & s_1 & -s_2 \\ -s_4 & -s_3 & s_2 & s_1 \\ s_1^* & s_2^* & s_3^* & s_4^* \\ -s_2^* & s_1^* & -s_4^* & s_3^* \\ -s_3^* & s_4^* & s_1^* & -s_2^* \\ -s_4^* & -s_3^* & s_2^* & s_1^* \end{bmatrix} \quad (18)$$

The matrix in Eq. (18) has a rate of half and is used as an STBC encoder to transmit any complex signal constellations.

For four transmit and one receive antenna system, the channel coefficients are modelled 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 in Eqs. (19) – (22). Fig. 4. shows the four transmit and one receive antenna scheme.

$$h_1(t) = h_1(t + T) = h_1 = |h_1|e^{j\theta} \quad (19)$$

$$h_2(t) = h_2(t + T) = h_2 = |h_2|e^{j\theta^2} \quad (20)$$

$$h_3(t) = h_3(t + T) = h_3 = |h_3|e^{j\theta^3} \quad (21)$$

$$h_4(t) = h_4(t + T) = h_4 = |h_4|e^{j\theta} \quad (22)$$

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 receiver in this case will receive eight different signals in eight different time slots. The received signals can be represented as in Eqs. (23) – (30):

$$r_1 = h_1s_1 + h_2s_2 + h_3s_3 + h_4s_4 + n_1 \quad (23)$$

$$r_2 = -h_1s_2 + h_2s_1 - h_3s_4 + h_4s_3 + n_2 \quad (24)$$

$$r_3 = -h_1s_3 + h_2s_4 + h_3s_1 - h_4s_2 + n_3 \quad (25)$$

$$r_4 = -h_1s_4 - h_2s_3 + h_3s_2 + h_4s_1 + n_4 \quad (26)$$

$$r_5 = h_1s_1^* + h_2s_2^* + h_3s_3^* + h_4s_4^* + n_5 \quad (27)$$

$$r_6 = -h_1s_2^* + h_2s_1^* - h_3s_4^* + h_4s_3^* + n_6 \quad (28)$$

$$r_7 = -h_1s_3^* + h_2s_4^* + h_3s_1^* - h_4s_2^* + n_7 \quad (29)$$

$$r_8 = -h_1s_4^* - h_2s_3^* + h_3s_2^* + h_4s_1^* + n_8 \quad (30)$$

The combiner builds the following four combined signals as shown in Eqs. (31) – (34)

$$\tilde{s}_1 = h_1^*r_1 + h_2^*r_2 + h_3^*r_3 + h_4^*r_4 + h_1r_5^* + h_2r_6^* + h_3r_7^* + h_4r_8^* \quad (31)$$

$$\tilde{s}_2 = h_2^*r_1 - h_1^*r_2 - h_4^*r_3 + h_3^*r_4 + h_2r_5^* - h_1r_6^* - h_4r_7^* + h_3r_8^* \quad (32)$$

$$\tilde{s}_3 = h_3^*r_1 + h_4^*r_2 - h_1^*r_3 - h_2^*r_4 + h_3r_5^* + h_4r_6^* - h_1r_7^* - h_2r_8^* \quad (33)$$

$$\tilde{s}_4 = h_4^*r_1 - h_3^*r_2 + h_2^*r_3 - h_1^*r_4 + h_4r_5^* - h_3r_6^* + h_2r_7^* - h_1r_8^* \quad (34)$$

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

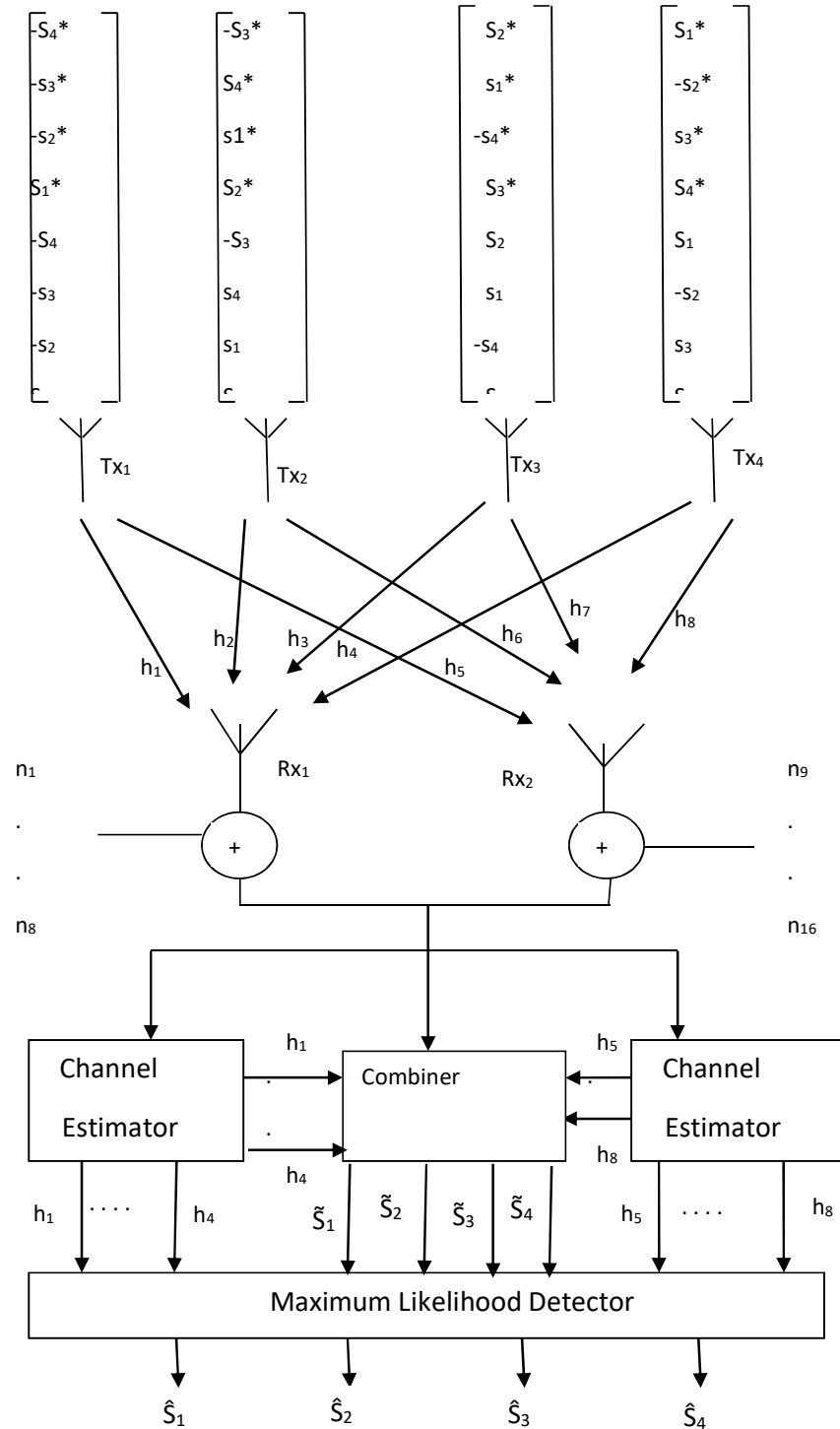


Fig. 4: Space-Time Block Code Scheme with Four Transmit and One Receive Antennas.

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Eight Transmit and One Receive Antennas

Section The space-time block code transmission matrix for eight transmit antennas is given in Eq. (35).

$$G_8 = \begin{bmatrix} S_1 & S_2 & S_3 & S_4 & S_5 & S_6 & S_7 & S_8 \\ -S_2 & S_1 & S_4 & -S_3 & S_6 & -S_5 & -S_8 & S_7 \\ -S_3 & -S_4 & S_1 & S_2 & S_7 & S_8 & -S_5 & -S_6 \\ -S_4 & S_3 & -S_2 & S_1 & S_8 & -S_7 & S_6 & -S_5 \\ -S_5 & -S_6 & -S_7 & -S_8 & S_1 & S_2 & S_3 & S_4 \\ -S_6 & S_5 & -S_8 & S_7 & -S_2 & S_1 & -S_4 & S_3 \\ -S_7 & S_8 & S_5 & -S_6 & -S_3 & S_4 & S_1 & -S_2 \\ -S_8 & -S_7 & S_6 & S_5 & -S_4 & -S_3 & S_2 & S_1 \\ S_1^* & S_2^* & S_3^* & S_4^* & S_5^* & S_6^* & S_7^* & S_8^* \\ -S_2^* & S_1^* & S_4^* & -S_3^* & S_6^* & -S_5^* & -S_8^* & S_7^* \\ -S_3^* & -S_4^* & S_1^* & S_2^* & S_7^* & S_8^* & -S_5^* & -S_6^* \\ -S_4^* & S_3^* & -S_2^* & S_1^* & S_8^* & -S_7^* & S_6^* & -S_5^* \\ -S_5^* & -S_6^* & -S_7^* & -S_8^* & S_1^* & S_2^* & S_3^* & S_4^* \\ -S_6^* & S_5^* & -S_8^* & S_7^* & -S_2^* & S_1^* & -S_4^* & S_3^* \\ -S_7^* & S_8^* & S_5^* & -S_6^* & -S_3^* & S_4^* & S_1^* & -S_2^* \\ -S_8^* & -S_7^* & S_6^* & S_5^* & -S_4^* & -S_3^* & S_2^* & S_1^* \end{bmatrix} \quad (35)$$

The matrix in Eq. (35) 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 the Table 1.

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

	TX ₁	TX ₂	TX ₃	TX ₄	TX ₅	TX ₆	TX ₇	TX ₈
T	S ₁	S ₂	S ₃	S ₄	S ₅	S ₆	S ₇	S ₈
t + 1T	-S ₂	S ₁	S ₄	-S ₃	S ₆	-S ₅	-S ₈	S ₇
t + 2T	-S ₃	-S ₄	S ₁	S ₂	S ₇	S ₈	-S ₅	-S ₆
t + 3T	-S ₄	S ₃	-S ₂	S ₁	S ₈	-S ₇	S ₆	-S ₅
t + 4T	-S ₅	-S ₆	-S ₇	-S ₈	S ₁	S ₂	S ₃	S ₄
t + 5T	-S ₆	S ₅	-S ₈	S ₇	-S ₂	S ₁	-S ₄	S ₃
t + 6T	-S ₇	S ₈	S ₅	-S ₆	-S ₃	S ₄	S ₁	-S ₂
t + 7T	-S ₈	-S ₇	S ₆	S ₅	-S ₄	-S ₃	S ₂	S ₁
t + 8T	S ₁ [*]	S ₂ [*]	S ₃ [*]	S ₄ [*]	S ₅ [*]	S ₆ [*]	S ₇ [*]	S ₈ [*]
t + 9T	-S ₂ [*]	S ₁ [*]	S ₄ [*]	-S ₃ [*]	S ₆ [*]	-S ₅ [*]	-S ₈ [*]	S ₇ [*]
t + 10T	-S ₃ [*]	-S ₄ [*]	S ₁ [*]	S ₂ [*]	S ₇ [*]	S ₈ [*]	-S ₅ [*]	-S ₆ [*]
t + 11T	-S ₄ [*]	S ₃ [*]	-S ₂ [*]	S ₁ [*]	S ₈ [*]	-S ₇ [*]	S ₆ [*]	-S ₅ [*]
t + 12T	-S ₅ [*]	-S ₆ [*]	-S ₇ [*]	-S ₈ [*]	S ₁ [*]	S ₂ [*]	S ₃ [*]	S ₄ [*]
t + 13T	-S ₆ [*]	S ₅ [*]	-S ₈ [*]	S ₇ [*]	-S ₂ [*]	S ₁ [*]	-S ₄ [*]	S ₃ [*]
t + 14T	-S ₇ [*]	S ₈ [*]	S ₅ [*]	-S ₆ [*]	-S ₃ [*]	S ₄ [*]	S ₁ [*]	-S ₂ [*]
t + 15T	-S ₈ [*]	-S ₇ [*]	S ₆ [*]	S ₅ [*]	-S ₄ [*]	-S ₃ [*]	S ₂ [*]	S ₁ [*]

The channel coefficients for space-time block codes with eight transmit

and one receive antenna is shown in Table 2.

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

	Rx ₁
Tx ₁	h ₁
Tx ₂	h ₂
Tx ₃	h ₃
Tx ₄	h ₄
Tx ₅	h ₅
Tx ₆	h ₆
Tx ₇	h ₇
Tx ₈	h ₈

The receiver in this case will receive sixteen different signals in sixteen different time slots. The received signals can be represented as in Eqs. (36) - (51).

$$r_1 = h_1s_1 + h_2s_2 + h_3s_3 + h_4s_4 + h_5s_5 + h_6s_6 + h_7s_7 + h_8s_8 + n_1 \quad (36)$$

$$r_2 = -h_1s_2 + h_2s_1 + h_3s_4 - h_4s_3 + h_5s_6 - h_6s_5 - h_7s_8 + h_8s_7 + n_2 \quad (37)$$

$$r_3 = -h_1s_3 - h_2s_4 + h_3s_1 + h_4s_2 + h_5s_7 + h_6s_8 - h_7s_5 - h_8s_6 + n_3 \quad (38)$$

$$r_4 = -h_1s_4 + h_2s_3 - h_3s_2 + h_4s_1 + h_5s_8 - h_6s_7 + h_7s_6 - h_8s_5 + n_4 \quad (39)$$

$$r_5 = -h_1s_5 - h_2s_6 - h_3s_7 - h_4s_8 + h_5s_1 + h_6s_2 + h_7s_3 + h_8s_4 + n_5 \quad (40)$$

$$r_6 = -h_1s_6 + h_2s_5 - h_3s_8 + h_4s_7 - h_5s_2 + h_6s_1 - h_7s_4 + h_8s_3 + n_6 \quad (41)$$

$$r_7 = -h_1s_7 + h_2s_8 + h_3s_5 - h_4s_6 - h_5s_3 + h_6s_4 + h_7s_1 + h_8s_2 + n_7 \quad (42)$$

$$r_8 = -h_1s_8 - h_2s_7 + h_3s_6 + h_4s_5 - h_5s_4 - h_6s_3 + h_7s_2 + h_8s_1 + n_8 \quad (43)$$

$$r_9 = h_1s_1^* + h_2s_2^* + h_3s_3^* + h_4s_4^* + h_5s_5^* + h_6s_6^* + h_7s_7^* + h_8s_8^* + n_9 \quad (44)$$

$$r_{10} = -h_1s_2^* + h_2s_1^* + h_3s_4^* - h_4s_3^* + h_5s_6^* - h_6s_5^* - h_7s_8^* + h_8s_7^* + n_{10} \quad (45)$$

$$r_{11} = -h_1s_3^* - h_2s_4^* + h_3s_1^* + h_4s_2^* + h_5s_7^* + h_6s_8^* - h_7s_5^* - h_8s_6^* + n_{11} \quad (46)$$

$$r_{12} = -h_1s_4^* + h_2s_3^* - h_3s_2^* + h_4s_1^* + h_5s_8^* - h_6s_7^* + h_7s_6^* - h_8s_5^* + n_{12} \quad (47)$$

$$r_{13} = -h_1s_5^* - h_2s_6^* - h_3s_7^* - h_4s_8^* + h_5s_1^* + h_6s_2^* + h_7s_3^* + h_8s_4^* + n_{13} \quad (48)$$

$$r_{14} = -h_1s_6^* + h_2s_5^* - h_3s_8^* + h_4s_7^* - h_5s_2^* + h_6s_1^* - h_7s_4^* + h_8s_3^* + n_{14} \quad (49)$$

$$r_{15} = -h_1s_7^* + h_2s_8^* + h_3s_5^* - h_4s_6^* - h_5s_3^* + h_6s_4^* + h_7s_1^* + h_8s_2^* + n_{15} \quad (50)$$

$$r_{16} = -h_1s_8^* - h_2s_7^* + h_3s_6^* + h_4s_5^* - h_5s_4^* - h_6s_3^* + h_7s_2^* + h_8s_1^* + n_{16} \quad (51)$$

The combiner builds the following eight combined signals as expressed in Eqs. (52)- (59):

$$\{\tilde{s}_1 = h_1^*r_1 + h_2^*r_2 + h_3^*r_3 + h_4^*r_4 + h_5^*r_5 + h_6^*r_6 + h_7^*r_7 + h_8^*r_8 + h_1r_9^* + h_2r_{10}^* + h_3r_{11}^* + h_4r_{12}^* + h_5r_{13}^* + h_6r_{14}^* + h_7r_{15}^* + h_8r_{16}^*\} \quad (52)$$

$$\{\tilde{s}_2 = h_2^*r_1 - h_1^*r_2 + h_4^*r_3 - h_3^*r_4 + h_6^*r_5 - h_5^*r_6 - h_8^*r_7 + h_7^*r_8 + h_2r_9^* - h_1r_{10}^* + h_4r_{11}^* - h_3r_{12}^* + h_6r_{13}^* - h_5r_{14}^* - h_8r_{15}^* + h_7r_{16}^*\} \quad (53)$$

$$\{\tilde{s}_3 = h_3^*r_1 - h_4^*r_2 - h_1^*r_3 + h_2^*r_4 + h_7^*r_5 + h_8^*r_6 - h_5^*r_7 - h_6^*r_8 + h_3r_9^* - h_4r_{10}^* - h_1r_{11}^* + h_2r_{12}^* + h_7r_{13}^* + h_8r_{14}^* - h_5r_{15}^* - h_6r_{16}^*\} \quad (54)$$

$$\{\tilde{s}_4 = h_4^*r_1 + h_3^*r_2 - h_2^*r_3 - h_1^*r_4 + h_8^*r_5 - h_7^*r_6 + h_6^*r_7 - h_5^*r_8 + h_4r_9^* + h_3r_{10}^* - h_2r_{11}^* - h_1r_{12}^* + h_8r_{13}^* - h_7r_{14}^* + h_6r_{15}^* - h_5r_{16}^*\} \quad (55)$$

$$\{\tilde{s}_5 = h_5^*r_1 - h_6^*r_2 - h_7^*r_3 - h_8^*r_4 - h_1^*r_5 + h_2^*r_6 + h_3^*r_7 + h_4^*r_8 + h_5r_9^* - h_6r_{10}^* - h_7r_{11}^* - h_8r_{12}^* - h_1r_{13}^* + h_2r_{14}^* + h_3r_{15}^* + h_4r_{16}^*\} \quad (56)$$

$$\{\tilde{s}_6 = h_6^*r_1 + h_5^*r_2 - h_8^*r_3 + h_7^*r_4 - h_2^*r_5 - h_1^*r_6 - h_4^*r_7 + h_3^*r_8 + h_6r_9^* + h_5r_{10}^* - h_8r_{11}^* + h_7r_{12}^* - h_2r_{13}^* - h_1r_{14}^* - h_4r_{15}^* + h_3r_{16}^*\} \quad (57)$$

$$\{\tilde{s}_7 = h_7^*r_1 + h_8^*r_2 + h_5^*r_3 - h_6^*r_4 - h_3^*r_5 + h_4^*r_6 - h_1^*r_7 - h_2^*r_8 + h_7r_9^* + h_8r_{10}^* + h_5r_{11}^* - h_6r_{12}^* - h_3r_{13}^* + h_4r_{14}^* - h_1r_{15}^* - h_2r_{16}^*\} \quad (58)$$

$$\{\tilde{s}_8 = h_8^*r_1 - h_7^*r_2 + h_6^*r_3 + h_5^*r_4 - h_4^*r_5 - h_3^*r_6 + h_2^*r_7 - h_1^*r_8 + h_8r_9^* - h_7r_{10}^* + h_6r_{11}^* + h_5r_{12}^* - h_4r_{13}^* - h_3r_{14}^* + h_2r_{15}^* - h_1r_{16}^*\} \quad (59)$$

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

RESULTS AND DISCUSSION

Simulation results of the performance of the proposed mathematical model were analyzed and evaluated in the Matlab environment. In the simulation, we generate a random bit stream first, define a signal power level, and symbols that are transmitted are generated using the encoding scheme. The encoded symbols are transmitted through a multipath faded channel. The channel is assumed to be flat faded and channel distortion is assumed to be multipath. The BER vs SNR was calculated and the performance of MRC receive diversity and

our proposed transmit diversity based on extended Alamouti's OSTBC scheme was evaluated.

Single input multiple outputs (SIMO)

In Fig. 5, a plot of the performance of the proposed scheme using BER against SNR for the various number of the receive diversity n_{Rx} is shown. From this figure, it is observed that at the BER of 10^{-4} , the error performance is improved by about 8.0dB and 4.5dB, when the receive diversity order is increased from two to four and four to eight respectively. For a large number of diversity branches, the fading channel converges towards an AWGN channel, as the error performance curve for a large n_{Rx} almost approaches the one for the AWGN channel.

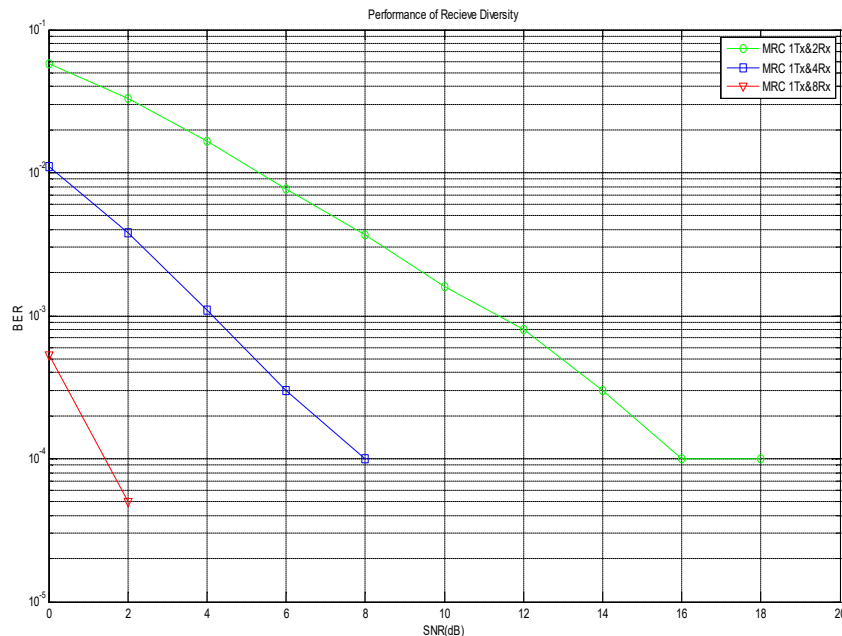


Fig. 5: Performance Comparison of Receive Diversity

Multiple input single output (MISO)

The bit error rate curves for the various number of transmit antennas n_{Tx} are depicted in Fig. 6. In particular, it is observed that the error probability decreases inversely with the n_{Tx} -th power

of the SNR. For error rate of 10^{-3} , the transmit diversity technique reduces the transmission power by about 4dB and 1.5dB, when the number of transmit diversity order increases from two to four and four to eight successively.

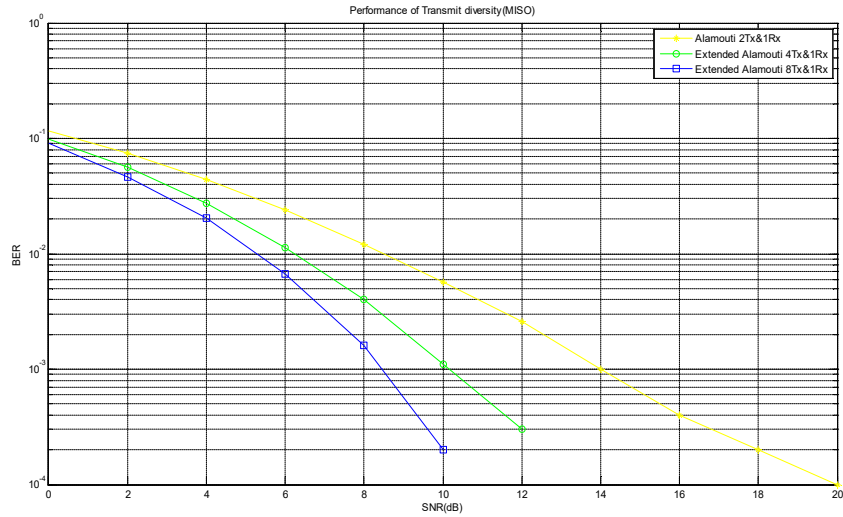


Fig. 6: Performance Comparison of Transmit Diversity

From Fig. 5, it can be seen that the receive antenna diversity dramatically improves the error performance compared to the case of transmit diversity.

Multiple input multiple output (MIMO)

Previously only transmit diversity (MISO) or receive diversity (SIMO) for a single communication model is considered. But now let's combine these both cases in the same scenario which is also known as the MIMO model. In this model, more than one antenna must exist on both sides.

Performance comparison for 2Tx: 2Rx, 3Rx, 4Rx, and 5Rx

Here, the performance of two transmit antennas and two receive antennas model, two transmit antennas and three receive antennas, two transmit antennas and four receive antennas as well as two transmit antennas and five receive antennas model have been compared in the same graph. It is clearly shown that the highest number of receiving antenna gives better performance than other models as shown in Fig. 7.

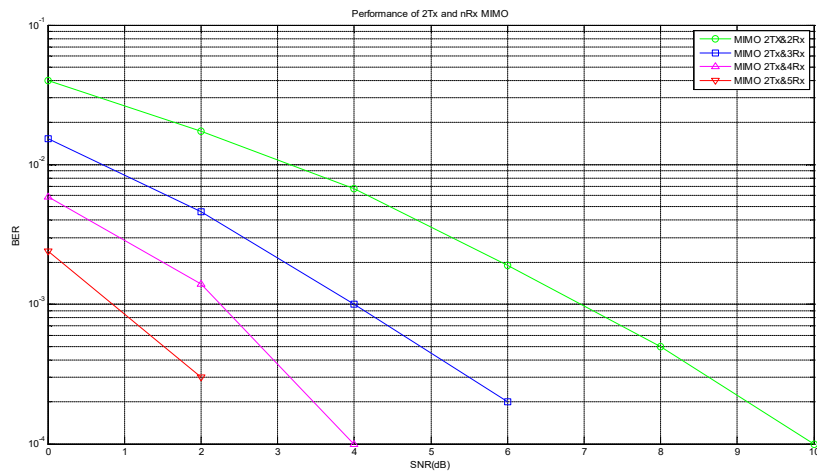


Fig. 7: BER Performance of 2xn MIMO

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Performance comparison for 4Tx: 2Rx, 3Rx, 4Rx, and 5Rx

Here, the performance of four transmit antennas and two receive antennas model, four transmit antennas and three receive antennas, four transmit antennas and four receive antennas as

well as four transmit antennas and five receive antennas have been compared in the same graph. We see that the highest number of receiving antennas gives better performance than other models as shown in Fig. 8.

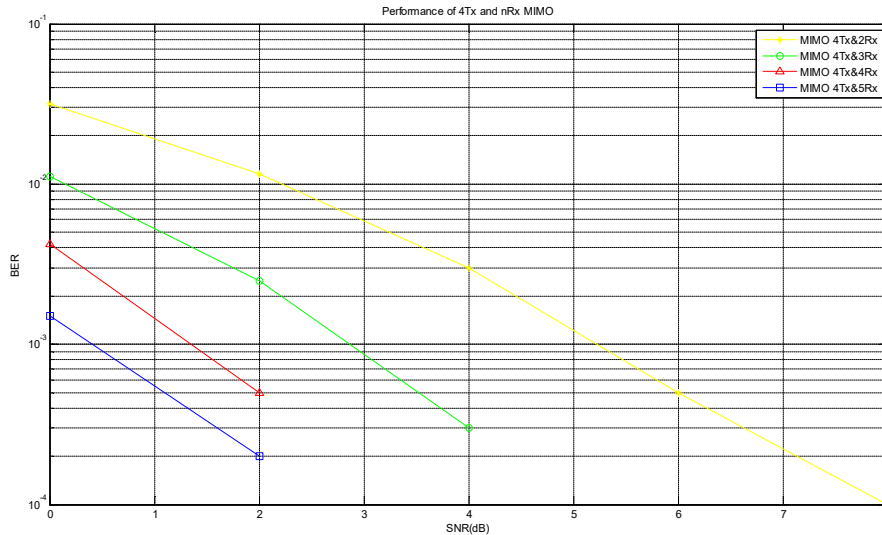


Fig. 8: BER Performance of 4xn MIMO

Performance comparison for 8Tx: 2Rx, 3Rx, 4Rx, and 5Rx

The performance of eight transmits antennas (8Tx) and n number of receive antennas (nRx) have been compared in the same graph. The number of receive

antennas model are two, three, four, and five. It is seen that the highest number of receiving antennas gives better performance than lower receive antennas models as shown in Fig. 9.

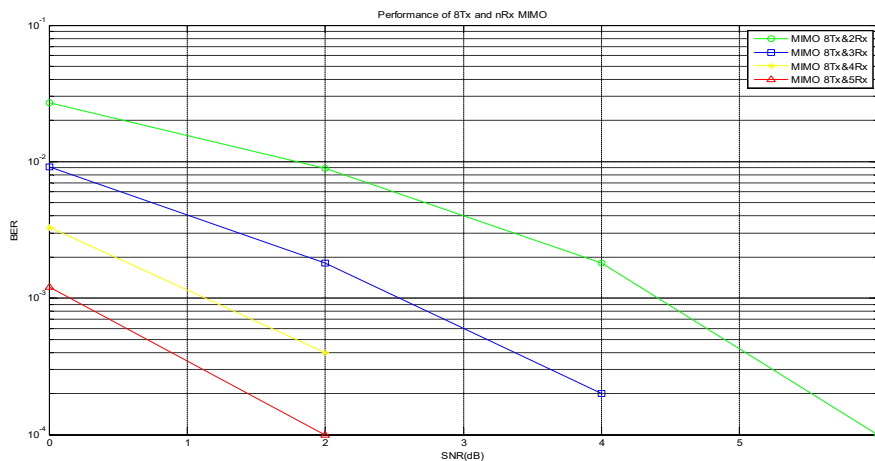


Fig. 9: BER Performance of 8xn MIMO



CONCLUSIONS

This paper presents the performance comparison analysis of different diversity techniques using our proposed extended Alamouti's code scheme based on orthogonal design using STBC to improve the wireless communication links by improving channel gains, high data throughput, mitigate fading and improve SNR. The performance was evaluated in terms of BER vs SNR. Among the diversity techniques, the MIMO system shows a promising result with an array of smart antennas at both transmission and receiving ends. Our proposed model proved that the MIMO technique is a good candidate for an enriched and robust wireless communication system, also the higher number of antenna arrays performs better than the lower number of antennas. Future work will consider investigating our model with different types of modulation schemes and other diversity decoding techniques.

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