PERFORMANCE ANALYSIS OF TRANSMIT DIVERSITY CONFIGURATIONS BASED ON OSTBC ALAMOUTI'S EXTENSION

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Keywords: –

Alamouti's Scheme
Diversity Technique
OSTBC
MRC
Transmit Diversity

Article History: –

Received: January, 2021.
Reviewed: January, 2021
Accepted: February, 2021
Published: March, 2021

ABSTRACT

One of the diversity configurations is transmit diversity. It is employed to mitigate multipath fading channel in a time varying channels to improve wireless communication system and make it more reliable. This paper presents a review of diversity techniques and configurations with various signal processing techniques and space time coding system that are mostly employed, diversity combining schemes and analysis of diversity schemes is also exploited. We also proposed a robust space time coding scheme based on orthogonal design by extending the Alamouti's space time block coding to a higher order diversity and evaluates its performance based on signal to noise ratio (SNR) and bit error rate (BER). The advantage of this transmit diversity is to simplify the hardware requirement by providing a cost effective solution in broadband wireless system with eliminating the need for adopting many antennas at the receiver side.

1. INTRODUCTION

Wireless communication system suffers from multipath fading in a time varying channels which seriously affects the channel capacity and degrades the system throughput. This effect becomes a serious challenge for overcoming recent user's expectation and demands with the recent migration of mobile communication into new generations to enable the users to enjoy high quality services such as qualitative multimedia services, easy and high internet accessibility, among others [1-4]. Various improvements in signal processing techniques, multiple access techniques, channel coding, and other enhance services techniques have been explored and studied over the years. One of these technique is to employ multiple antenna at either transmitting and/or receiving end or both. This is called a diversity system, it is one of the efficient and effective technique of improving channel capacity, system throughput and mitigate fading [5-8]. The diversity system configuration can be transmit diversity with multiple input single output (MISO), receive diversity with single input multiple output (SIMO) and multiple input multiple output (MIMO) diversity. Figure 1 shows different types of diversity configurations. Various forms of diversity approaches developed in the literature are; diversity in terms of time, space, frequency, polarization and angle [9-12].

A lot of works have been proposed to improve the wireless communication links throughput and capacity by adopting diversity techniques such as in [13,14]. Early works suggests the used of antenna array at one end, mostly at the receiver. Authors in [15,16] shows that by using antenna arrays at both ends capacity gain would be improved in scattering wireless links. Receive diversity have been proposed in [17-19]. In a similar manner, reference [20,21] have 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 [11,22,23]. [24] proposed an efficient, simple and low in computation transmit diversity with two antennas. As detection techniques, other works include the proposed spatial multiplexing technique and the vertical bell labs space time architecture (V-BLAST) technique [25]. Alamouti STBC performance using theoretical values [26,27] was compared. Other works in literature include [28-31]. 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 [32-34].

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 [27] proposed a scheme using STBC with M=2, and N=1, the term 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 [35-41] that 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.

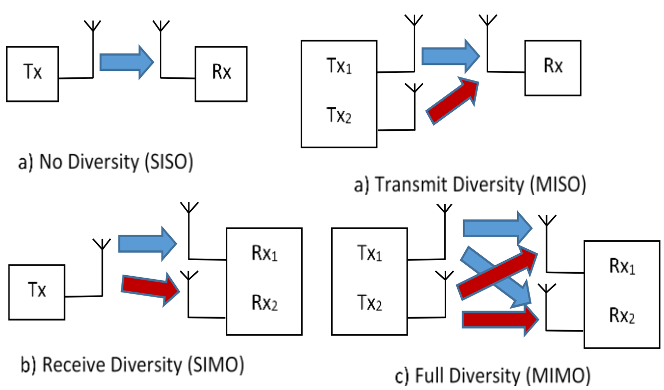

Fig. 1. Diversity techniques configurations

The majority of the published works have a limitation in that channel information is needed at the receiver end. This study proposed a new extended Alamouti's scheme, the scheme uses OSTBC to encode the data.

This paper is an extended version of the paper presented at International Conference on Electrical Engineering Applications (ICEEA'2020), Department of Electrical Engineering, Ahmadu Bello University, Zaria, Nigeria [42]. This paper highlights some of the transmit diversity configuration theories and other diversity coding such as popular Alamouti's space time coding, we then proposed the extended version of Alamouti's scheme based on OFDM.

2. SYSTEM THEORETICAL MODEL

2.1 Alamouti's Space Time Transmit Diversity

Alamouti's scheme is an efficient and simple transmit diversity, the diversity has been achieved using space time coding to achieve a full diversity in a wireless flat fading channels. Alamouti's proposes a 2 x 1 configuration scheme and 2 x 2 MIMO scheme. M-array modulation scheme modulates the transmitted symbol and transmitted via each antenna. The transmitted symbols are encoded using Space time block coded (STBC) scheme. To model the flat-frequency-fading channel with signal bandwidth as B, channel delay spread as T_m, T_z is the time it takes for the signal to travel from the transmit antenna to the receive antenna. For this channel $BT_m \ll 1$ while $BT_z \ll 1$. The symbols can be transmitted from M number of transmit antennas and also received by N number of receive antennas as depicted in Figure 2.

To modeled the channel, the channel coefficients and the received signal at time k are given in Equation (1) and (2) respectively [8].

$$h = [h_o \quad h_1 \quad \dots . h_{N-1}] \tag{1}$$

$$y[k] = \sqrt{\frac{E_s}{N}} hx[k] + n[k] \tag{2}$$

Where $x[k] = [x_o\,[k], \quad x_1\,[k], \dots\, x_{N-1}\,[k]]^{\mathrm{T}}$ is the vector of transmitted signal, while $n[k]$ is the additive noise.

From Figure 3, the scheme is employed to perform certain functions such as 1. Encoding the symbols at the transmitter and transmitting the sequence of information symbols 2. Combining these symbols at the receiver side and 3. Carried out the decision rule by maximum likelihood detector [6].

2.2 Encoding and Transmission Symbols

For simple Alamouti's scheme with 2 x 1 antenna configuration based on space time coding, the pairs of symbols are transmitted in even and odd numbered interval. Odd-numbered symbols are transmitted in complex conjugate and inverted form, as shown in Equations (3) and (4), whereas even-numbered symbols are transmitted unchanged by two antennas.

Let's denote the symbol as s_n, $x_0[k]]$ is the transmitted symbol by antenna zero, while $x_1[k]$ is for antenna one.

$$\begin{cases} x_0[k] = s_n \\ x_1[k] = s_{n+1} \end{cases} \tag{3}$$

$$\begin{cases} x_0[k+1] = -s_{n+1}^* \\ x_1[k+1] = s_n^* \end{cases} \tag{4}$$

Complex multiplicative distortions are used in modelling the channel with the assumption that the channel fading is flat as seen in equation (5), over two consecutive symbol intervals [5].

$$\begin{cases} h_0[k+1] = h_0[k] = h_0 = a_0 e^{j\varphi_0} \\ h_1[k+1] = h_1[k] = h_1 = a_0 e^{j\varphi_1} \end{cases} \tag{5}$$

At the receiver side, the received signal can be defined as in (6) when the reception delay between $x_0[k]$ and $x_1[k]$ is negligible.

$$y[k] = h_0 x_0[k] = h_1 x_1[k] + n[k] \tag{6}$$

2.3 Combining Scheme

As can be seen in Figure 4, across two consecutive symbol instant the received signals are combined at the receiver's side with the assumption that the channel information is known at the receiver.

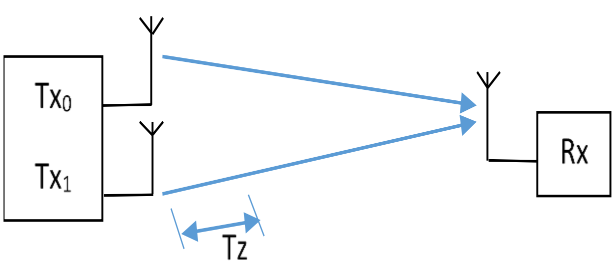

Fig. 2. Time Transmit Across Antenna Array

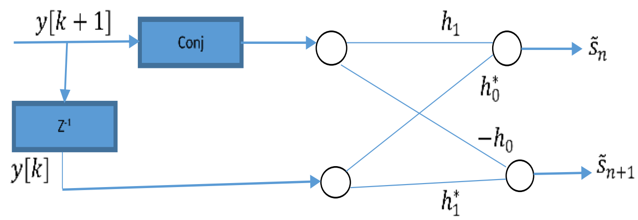

Fig. 3. Combining Scheme based on Alamouti's Technique

The channel estimator estimated $h_{0,1}$ which is the channel complex multiplicative factors and provide these channel coefficient at the receiver side as in (7).

$$\begin{cases} \tilde{s}_n = h_0^* y[k] + h_1^* y[k+1] \\ \tilde{s}_{n+1} = h_1^* y[k] - h_0^* y[k+1] \end{cases} \tag{7}$$

$$\begin{cases} \tilde{s}_n = (\alpha_0^2 + \alpha_1^2) s_n + h_0^* n[k] + h_1 n^*[k+1] \\ \tilde{s}_{n+1} = (\alpha_0^2 + \alpha_1^2) s_{n+1} + h_1^* n[k] - h_0 n^*[k+1] \end{cases} \tag{8}$$

Equation (8) confirm that the combined symbols are transmitted signals received in additive noise and have been in scaled version.

2.4 Maximum Likelihood Decision Rule

Euclidean distance is used in the detector to make a decision of which symbol is transmitted as in Equation (9)

$$\hat{s}_n = s_j, j = \arg\min|\tilde{s}_n - s_i| \tag{9}$$

3. EXTENSION TO *M* RECEIVE ANTENNAS

3.1. STBC for the extended Alamouti's scheme based on Orthogonal design,

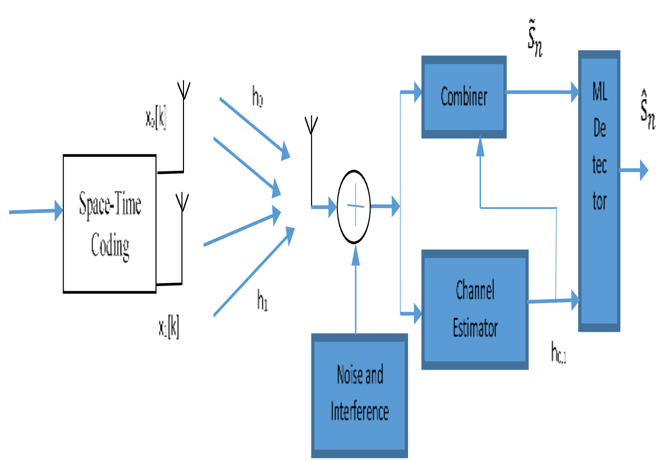

Fig. 4. Simple transmit Alamouti's diversity scheme

To provide diversity of order *2N*, Alamouti's simple transmit diversity scheme can be applied to a MIMO system with two transmit antennas and *N* number of receive antennas. In this paper, we have proposed the extended version of Alamouti's scheme with *M* number of transmit antennas and *N* number of receive antennas with transmission matrix remain the same as in equation (5). Equation (10) is the channel matrix with channel coefficients.

$$H = \begin{bmatrix} h_{0,0} & \cdots & h_{0,1} \\ \vdots & \ddots & \vdots \\ h_{M-1,0} & \cdots & h_{M-1,1} \end{bmatrix} \qquad (10)$$

where h (l,m) is the complex scalar corresponding to the transmission path between the transmit and receive antennas.$l, l \in \{0,1\}$ and receive antenna m, $m, m \in \{0,1,\ldots,M-1\}$. The received signals are in (11) and (12).

$$y(k) = \begin{bmatrix} y_0[k] \\ \vdots \\ y_{M-1}[k] \end{bmatrix} = H \begin{bmatrix} x_0[k] \\ x_1[k] \end{bmatrix} + \begin{bmatrix} n_0[k] \\ \vdots \\ n_{M-1}[k] \end{bmatrix} \qquad (11)$$

$$\begin{cases} \tilde{s}_n = [h_{0,0} \ldots h_{M-1,0}]^* \boldsymbol{y}[k] + [h_{0,1} \ldots h_{M-1,1}] \boldsymbol{y}^*[k+1] \\ \tilde{s}_{n+1} = [h_{0,1} \ldots h_{M-1,1}]^* \boldsymbol{y}[k] + [h_{0,0} \ldots h_{M-1,0}] \boldsymbol{y}^*[k+1][k+1] \end{cases} \qquad (12)$$

Replacing Eqs. (11) and (12) into Eq. (7) yields Equation (13)

$$\begin{cases} \tilde{s}_n = s_n \sum_{M=0}^{M-1} (\alpha_{m,0}^2 + \alpha_{m,1}^2) + \sum_{M=0}^{M-1} (h_{m,0}^* n_m[k] + (h_{m,1}^* n_m^*[k+1]) \\ \tilde{s}_{n+1} = s_{n+1} \sum_{M=0}^{M-1} (\alpha_{m,0}^2 + \alpha_{m,1}^2) + \sum_{M=0}^{M-1} (h_{m,1}^* n_m[k] + (h_{m,0}^* n_m^*[k+1]) \end{cases} \qquad (13)$$

Table 1. Eight transmit antennas mapping and encoding of STBC 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 proposed popular Alamouti's transmit diversity scheme is based on STBC codes and also is a generalized version of STBC with equal features. These features are the orthogonality and with defined number of transmit antennas both schemes achieved full diversity. Technically speaking, Alamouti's space time codes can be defined as a complex version of STBC in which at both transmitter and receiver ends they utilized equal encoding and decoding schemes. The transmission matrix S which consist of data to be transmitted is constructed with the number of transmit antennas nTx and the number of time slots p needed to transmit the symbols as the rows and columns, respectively. The transmitted signals are then received at receiver ends in which they were combined. When the combined signals are fed into the maximum likelihood detector, the decision rules are computed.

3.2. Eight Transmit and One Receive Antennas

To evaluate the performance of transmit diversity system configuration, extended version of Alamouti's scheme was proposed and modelled. Equation (14), gives the space-time block code transmission matrix for eight transmit antennas.

The matrix in Equation (14) serves as encoder for STBC scheme and is employed for transmitting any complex constellation signal, it has also a rate of half. Table 1 shows the mapping, encoding and transmission of STBC scheme.

$$G8=\begin{bmatrix} s_1 & s_2 & s_3 & s_4 & s_5 & s_6 & s_7 & s_8 \\ -s_2 & s_1 & s_4 & -s_3 & s_6 & -s_5 & -s_8 & s_7 \\ -s_3 & -s_4 & s_1 & s_2 & s_7 & s_8 & -s_5 & -s_6 \\ -s_4 & s_3 & -s_2 & s_1 & s_8 & -s_7 & s_6 & -s_5 \\ -s_5 & -s_6 & -s_7 & -s_8 & s_1 & s_2 & s_3 & s_4 \\ -s_6 & s_5 & -s_8 & s_7 & -s_2 & s_1 & -s_4 & s_3 \\ -s_7 & s_8 & s_5 & -s_6 & -s_3 & s_4 & s_1 & -s_2 \\ -s_8 & -s_7 & s_6 & s_5 & -s_4 & -s_3 & s_2 & s_1 \\ s_1^* & s_2^* & s_3^* & s_4^* & s_5^* & s_6^* & s_7^* & s_8^* \\ -s_2^* & s_1^* & s_4^* & -s_3^* & s_6^* & -s_5^* & -s_8^* & s_7^* \\ -s_3^* & -s_4^* & s_1^* & s_2^* & s_7^* & s_8^* & -s_5^* & -s_6^* \\ -s_4^* & s_3^* & -s_2^* & s_1^* & s_8^* & -s_7^* & s_6^* & -s_5^* \\ -s_5^* & -s_6^* & -s_7^* & -s_8^* & s_1^* & s_2^* & s_3^* & s_4^* \\ -s_6^* & s_5^* & -s_8^* & s_7^* & -s_2^* & s_1^* & -s_4^* & s_3^* \\ -s_7^* & s_8^* & s_5^* & -s_6^* & -s_3^* & s_4^* & s_1^* & -s_2^* \\ -s_8^* & -s_7^* & s_6^* & s_5^* & -s_4^* & -s_3^* & s_2^* & s_1^* \end{bmatrix} \quad (14)$$

Table 2 shows the channel coefficients for proposed STBC schemes with *8Tx* and *1Rx* antennas configurations.

Table 2. Channel coefficients for *8Tx* and *1Rx* antennas configuration.

	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

At the receiving ends, the received signals as shown in Equation (15) - (30) will be received by receiver with sixteen number of different signals with equal time slots respectively.

$$r_1 = h_1 s_1 + h_2 s_2 + h_3 s_3 + h_4 s_4 + h_5 s_5 + h_6 s_6 + h_7 s_7 + h_8 s_8 + n_1 \quad (15)$$

$$r_2 = -h_1 s_2 + h_2 s_1 + h_3 s_4 - h_4 s_3 + h_5 s_6 - h_6 s_5 - h_7 s_8 + h_8 s_7 + n_2 \quad (16)$$

$$r_3 = -h_1 s_3 - h_2 s_4 + h_3 s_1 + h_4 s_2 + h_5 s_7 + h_6 s_8 - h_7 s_5 - h_8 s_6 + n_3 \quad (17)$$

$$r_4 = -h_1 s_4 + h_2 s_3 - h_3 s_2 + h_4 s_1 + h_5 s_8 - h_6 s_7 + h_7 s_6 - h_8 s_5 + n_4 \quad (18)$$

$$r_5 = -h_1 s_5 - h_2 s_6 - h_3 s_7 - h_4 s_8 + h_5 s_1 + h_6 s_2 + h_7 s_3 + h_8 s_4 + n_5 \quad (19)$$

$$r_6 = -h_1 s_6 + h_2 s_5 - h_3 s_8 + h_4 s_7 - h_5 s_2 + h_6 s_1 - h_7 s_4 + h_8 s_3 + n_6 \quad (20)$$

$$r_7 = -h_1 s_7 + h_2 s_8 + h_3 s_5 - h_4 s_6 - h_5 s_3 + h_6 s_4 + h_7 s_1 + h_8 s_2 + n_7 \quad (21)$$

$$r_8 = -h_1 s_8 - h_2 s_7 + h_3 s_6 + h_4 s_5 - h_5 s_4 - h_6 s_3 + h_7 s_2 + h_8 s_1 + n_8 \quad (22)$$

$$r_9 = h_1 s_1^* + h_2 s_2^* + h_3 s_3^* + h_4 s_4^* + h_5 s_5^* + h_6 s_6^* + h_7 s_7^* + h_8 s_8^* + n_9 \quad (23)$$

$$r_{10} = -h_1 s_2^* + h_2 s_1^* + h_3 s_4^* - h_4 s_3^* + h_5 s_6^* - h_6 s_5^* - h_7 s_8^* + h_8 s_7^* + n_{10} \quad (24)$$

$$r_{11} = -h_1 s_3^* - h_2 s_4^* + h_3 s_1^* + h_4 s_2^* + h_5 s_7^* + h_6 s_8^* - h_7 s_5^* - h_8 s_6^* + n_{11} \quad (25)$$

$$r_{12} = -h_1 s_4^* + h_2 s_3^* - h_3 s_2^* + h_4 s_1^* + h_5 s_8^* - h_6 s_7^* + h_7 s_6^* - h_8 s_5^* + n_{12} \quad (26)$$

$$r_{13} = -h_1 s_5^* - h_2 s_6^* - h_3 s_7^* - h_4 s_8^* + h_5 s_1^* + h_6 s_2^* + h_7 s_3^* + h_8 s_4^* + n_{13} \quad (27)$$

$$r_{14} = -h_1 s_6^* + h_2 s_5^* - h_3 s_8^* + h_4 s_7^* - h_5 s_2^* + h_6 s_1^* - h_7 s_4^* + h_8 s_3^* + n_{14} \quad (28)$$

$$r_{15} = -h_1 s_7^* + h_2 s_8^* + h_3 s_5^* - h_4 s_6^* - h_5 s_3^* + h_6 s_4^* + h_7 s_1^* + h_8 s_2^* + n_{15} \quad (29)$$

$$r_{16} = -h_1 s_8^* - h_2 s_7^* + h_3 s_6^* + h_4 s_5^* - h_5 s_4^* - h_6 s_3^* + h_7 s_2^* + h_8 s_1^* + n_{16} \quad (30)$$

The combiner builds the following eight combined signals as expressed in Equations (31)-(38):

$$\{\widetilde{s}_1 = h_1^* r_1 + h_2^* r_2 + h_3^* r_3 + h_4^* r_4 + h_5^* r_5 + h_6^* r_6 + h_7^* r_7 + h_8^* r_8 + h_1 r_9^* + h_2 r_{10}^* + h_3 r_{11}^* + h_4 r_{12}^* + h_5 r_{13}^* + h_6 r_{14}^* + h_7 r_{15}^* + h_8 r_{16}^*\} \quad (31)$$

$$\{\tilde{s}_2 = h_2^* r_1 - h_1^* r_2 + h_4^* r_3 - h_3^* r_4 + h_6^* r_5 - h_5^* r_6 - h_8^* r_7 + h_7^* r_8 + h_2 r_9^* - h_1 r_{10}^* + h_4 r_{11}^* - h_3 r_{12}^* + h_6 r_{13}^* - h_5 r_{14}^* - h_8 r_{15}^* + h_7 r_{16}^*\} \quad (32)$$

$$\{\tilde{s}_3 = h_3^* r_1 - h_4^* r_2 - h_1^* r_3 + h_2^* r_4 + h_7^* r_5 + h_8^* r_6 - h_5^* r_7 - h_6^* r_8 + h_3 r_9^* - h_4 r_{10}^* - h_1 r_{11}^* + h_2 r_{12}^* + h_7 r_{13}^* + h_8 r_{14}^* - h_5 r_{15}^* - h_6 r_{16}^*\} \quad (33)$$

$$\{\widetilde{s}_4 = h_4^* r_1 + h_3^* r_2 - h_2^* r_3 - h_1^* r_4 + h_8^* r_5 - h_7^* r_6 + h_6^* r_7 - h_5^* r_8 + h_4 r_9^* + h_3 r_{10}^* - h_2 r_{11}^* - h_1 r_{12}^* + h_8 r_{13}^* - h_7 r_{14}^* + h_6 r_{15}^* - h_5 r_{16}^*\} \quad (34)$$

$$\{\widetilde{s}_5 = h_5^* r_1 - h_6^* r_2 - h_7^* r_3 - h_8^* r_4 - h_1^* r_5 + h_2^* r_6 + h_3^* r_7 + h_4^* r_8 + h_5 r_9^* - h_6 r_{10}^* - h_7 r_{11}^* - h_8 r_{12}^* - h_1 r_{13}^* + h_2 r_{14}^* + h_3 r_{15}^* + h_4 r_{16}^*\} \quad (35)$$

$$\{\tilde{s}_6 = h_6^* r_1 + h_5^* r_2 - h_8^* r_3 + h_7^* r_4 - h_2^* r_5 - h_1^* r_6 - h_4^* r_7 + h_3^* r_8 + h_6 r_9^* + h_5 r_{10}^* - h_8 r_{11}^* + h_7 r_{12}^* - h_2 r_{13}^* - h_1 r_{14}^* - h_4 r_{15}^* + h_3 r_{16}^*\} \quad (36)$$

$$\{\tilde{s}_7 = h_7^* r_1 + h_8^* r_2 + h_5^* r_3 - h_6^* r_4 - h_3^* r_5 + h_4^* r_6 - h_1^* r_7 - h_2^* r_8 + h_7 r_9^* + h_8 r_{10}^* + h_5 r_{11}^* - h_6 r_{12}^* - h_3 r_{13}^* + h_4 r_{14}^* - h_1 r_{15}^* - h_2 r_{16}^*\} \quad (37)$$

$$\{\widetilde{s}_8 = h_8^* r_1 - h_7^* r_2 + h_6^* r_3 + h_5^* r_4 - h_4^* r_5 - h_3^* r_6 + h_2^* r_7 - h_1^* r_8 + h_8 r_9^* - h_7 r_{10}^* + h_6 r_{11}^* + h_5 r_{12}^* - h_4 r_{13}^* - h_3 r_{14}^* + h_2 r_{15}^* - h_1 r_{16}^*\} \quad (38)$$

The original transmitted signals are recovered and estimated when the combined signals from Equation (31) – (38) are fed to the maximum likelihood detector.

4. RESULTS AND DISCUSSION

To evaluate the performance of our proposed developed model, we first generated the random bit stream, then specified the power level, and then the encoding scheme is employed to generate the transmitted symbols. Some assumptions used in the study are; the channel is a multipath fading through which the symbols encoded are transmitted.

4.1. Multiple input single output (MISO)

The bit error rate curves for various numbers of transmit antennas *nTx* are shown in Figure 5. The error likelihood decreases inversely with the *nTx-th* power of the SNR, according to the results. The transmit diversity technique decreases the transmitting capacity by around 4dB and 1.5dB with a $10^{(-3)}$ error rate, when the number of transmit diversity order increases from two to four and four to eight successively.

4.2. Performance comparison of Transmit and Receive Diversity

The performance of transmit and receive diversity was evaluated and compared for different scenarios. In the simulation, coherent binary phase shift keying (BPSK) modulation was used in a flat faded channel. The model consists of two transmit antenna and one receive antenna while for receive diversity, maximum ratio combining is used with one transmit antenna and two receive antennas. As can be seen from Figure 6, both configurations have the same diversity order. Also it can be observed from the figure that the receive diversity using MRC has 3db advantage over transmit diversity, this is because our model has the same total transmitted power in both scenarios. If the transmitted power is calibrated to be the same with receive power, then their performance would be the same.

Four transmit antenna was experimented and evaluated using OSTBC with diversity order of four, the model is compared with 2x2 and 1x4 configurations that offer the same diversity. As shown in Figure 7, both curves have the same slope which confirm that both configuration offer the same diversity order. Also, from the figure it can be seen that the 3db disadvantage shown by 4x1 transmit diversity is due to the

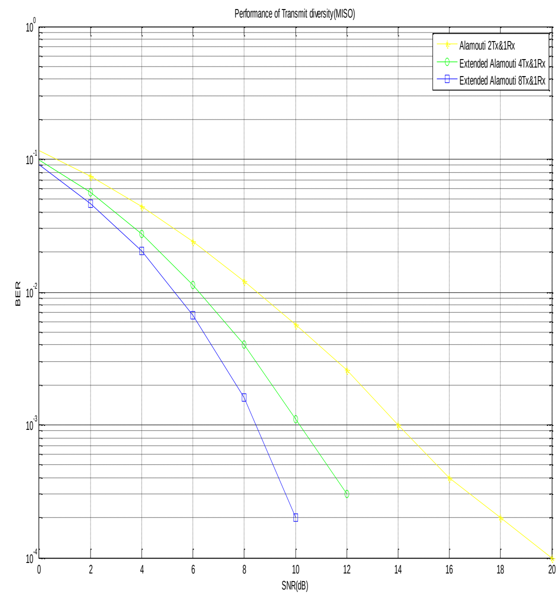

Fig. 5. Performance Comparison of Transmit Diversity

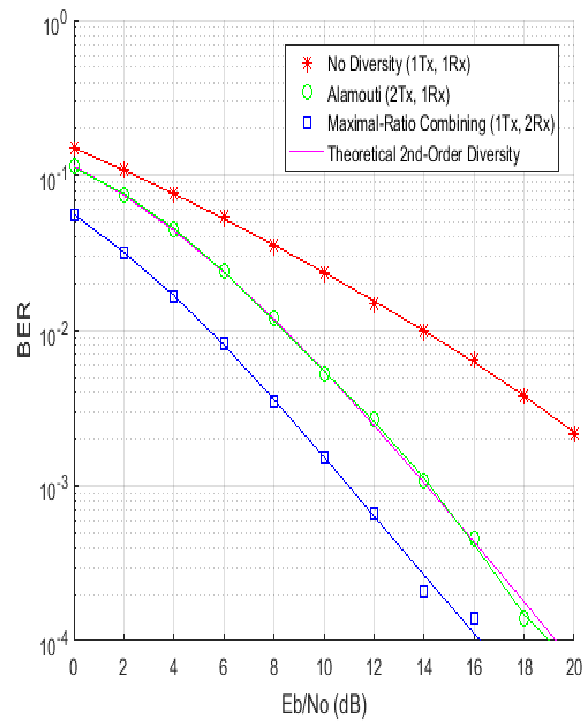

Fig. 6. Performance Comparison of second order Transmit and Receive Diversity

same reason as in second order diversity. However, the performance of simulation matches the theoretical performance of 4x1 transmit configuration.

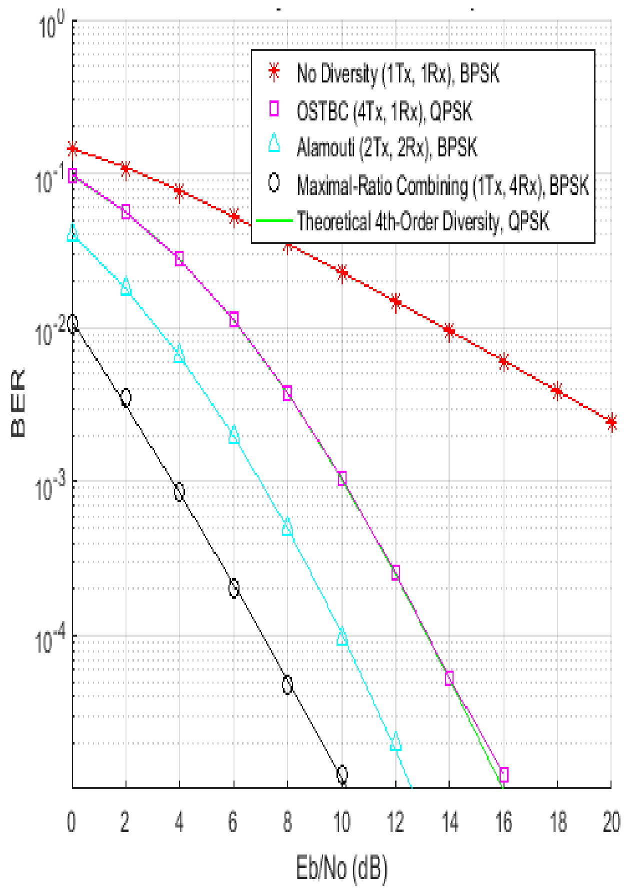

Fig. 7. Performance Comparison of Fourth Order Transmit and Receive Diversity

Table 3. Performance of different modulation schemes *nTx* and *nRx* antennas

Modulation Scheme	Number of TR-RX	BER for 2dB	BER for 4dB	BER for 6dB	BER for 8dB
BPSK	2:2	0.0182	0.0065	0.0018	0.0006
	4:2	0.0124	0.0029	0.0005	0.0002
QPSK	2:2	0.0563	0.0278	0.0096	0.0035
	4:2	0.0213	0.0031	0.0.004	0.0001
8PSK	2:2	0.1231	0.0909	0.0549	0.0289
	4:2	0.5496	0.0348	0.0160	0.0045
16PSK	2:2	0.2178	0.1590	0.1289	0.0494
	4:2	0.0597	0.0376	0.0153	0.0005

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

Figure 8 shows the performance results for Alamouti OSTBC with four transmit and one receive antenna, MIMO system with two transmit and two receive antennas and maximum ratio combining with one transmit and four receive antenna that is a diversity of order four. The slopes of both curves are the same, as can be seen in this diagram. Despite the similar diversity of the curves, the 2x2 MIMO based on Alamouti's scheme and the 4x1 Alamouti scheme tend to have less advantage than the 1x4 MRC. This is due to the fact that the Alamouti scheme's power is split between the antennas. (i.e. approximately 3dB less per antenna than the power from the MRC scheme, which has only one antenna).

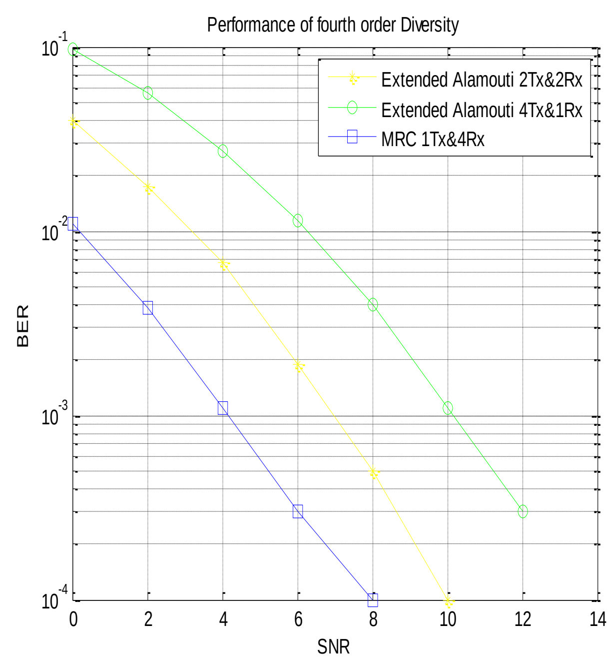

Fig. 8. BER Performance of Fourth Order Diversity

The type of modulation and the antenna configurations influence the performance of STBC. Using Rayleigh faded with an AWGN channel and only the receiver's channel state information, 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.

Also, from table 3, it is very clear to see that the performance of OSTBC with BPSK modulation is improved by approximately 3dB when compared with QPSK modulation scheme. Also, for OSTBC with QPSK modulation, the performance is improved by approximately 5dB as compared with 8PSK modulation scheme. The BER performance of OSTBC that employs 16PSK modulation scheme is less than the performance of QPSK scheme with the same OSTBC approach. The improved in performance by some modulation schemes more than the others is due to the number of bits each modulation schemes take. For example, in 16PSK modulation, the number of bits are higher than in QPSK, therefore, it's performance is higher than 16PSK. Likewise, when comparing QPSK and BPSK modulation schemes, the improved in performance in BPSK is due to lower number of bits used as compared to QPSK.

CONCLUSIONS

This paper highlights some of the theories behind transmit diversity system configuration based on Alamouti's scheme. The scheme was analysed and evaluated with the proposed extended version of Alamouti's scheme based on OSTBC scheme. It has been determined that STBC with a large number of transmit antennas often outperforms STBC with a smaller 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. The advantage of having multiple antennas is in the recovering of original transmitted signal as if one antenna fails to recover the signal correctly, the other one can correctly recover. This advantage increases the chance of receiving uncorrupted data symbols by at least one out of many antennas than if one antenna is employed. The proposed scheme also minimizes the multipath effect and maximize the information rate. MIMO-STBC with channel estimation scheme need to be further investigated.

ACKNOWLEDGEMENT

This work was supported by the Nigerian Communication Commission (NCC) under 2021 Telecommunications-Based Research Innovation from Academic in Nigeria Tertiary Institutions with grant number NCC/R&D/TSU/001.

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