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Performance Evaluation of MIMO system in mm wave based on Space Time Block Code and Different Modulation techniques

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KEYWORDS:
mmWave, MIMO System, space-time block code (STBC), Fading, Modulation.

***Abstract*—Multiple input multiple output (MIMO) system with millimeter wave frequency is one of the most important technologies in fifth generation of wireless communication systems. This paper presents the performance evaluation for the MIMO system based on Space time block code (STBC) in millimeter Wave frequency range. MIMO-STBC is an efficient technique to solve problems in 5G due to increasing the density of transmitted information and obtain higher data rates with limited bandwidth and power This technique is applied under different modulation schemes (Binary Phase Shift keying (BPSK), Quadrature Phase Shift keying (QPSK), Quadrature Amplitude Modulation(M-QAM) and Trellis Modulation Code (TCM) to improve the capacity, reliability and moreover minimize BER with limited bandwidth and transmit power.**

Moreover, the method is verified using Adaptive white Gaussian Noise (AWGN), Rayleigh and Rician fading channel to prove its effectiveness, with different number of antennas at transmitter and receiver sides(2×2), (3×3), (4×4) MIMO-STBC. The presented method has been applied using MIMO system in MATLAB simulation program. The results of simulation show that (4×4) STBC MIMO system has been better performance than (2×2) and (3×3) STBC MIMO system. also, BPSK can be minimize the BER than QPSK, M-QAM, TCM. and the Rician fading distribution give slowest BER than Rayleigh fading distribution.

I. INTRODUCTION

THE fifth generation (5G) of wireless communication systems needs to be supported by large user base and high-speed links. Accordingly, the Millimeter-Wave (mmWave) technology is considered promising solution because it is operated in range between 30-300GHz in which the small wavelength allows modest size antennas to have a small beam width [1]. In addition, 28 GHz considered as mmWave due to its proximity to the 30 GHz spectrum. which has many advantages such the output speeds required for high-definition (HD) video, low latency content, and high data rate transfer among data centers and virtual interaction between people and machines. The vast spectrum at frequencies more than28 GHz offers wide channel bandwidths which support high peak data rates of several Gigabits per second.

The most simple and easy to fabricate using photolithography process are printed circuit antennas. These antennas which include microstrip patch or dipole arrays are

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low profile, light weight and can be used in small handheld planar devices

Different MIMO antennas have been proposed for mmWave spectrum, most of them use antenna arrays to achieve high gain.

Two and four element MIMO antennas at 28 GHz having reasonably good gain and isolation between the ports [2]

Wireless communication systems are divided into four types according to the number of antennas at the sending and receiving sides These types are single input single out (SISO), single input multiple output (SIMO), multiple input single output (MISO), multiple input multiple output (MIMO) [3]. MIMO systems with an operating frequency 28 GHz "in terms of mmWave" have a lot of advantages such as supporting higher data rates, low BER, wide coverage, higher link reliability in comparison to the other types SISO, SIMO, MISO communication systems [4]. In addition, studies have been carried out regarding the space-time block code which uses for enhancing the reliability by sending different duplicates of an information stream to the receiver. At the receiver side, waiting to arrive the signals, firstly they are combined then to be sent to the maximum likelihood detector where the decision rules are applied. [5].

Previous studies give a basic overview on STBC for wireless network [6]. [7] present Alamouti Coding Scheme with Rayleigh fading but not considered the effect of Rician fading. [8], [9], uses TCM combination for the same system, author in [10] uses STBC with MIMO at BPSK, QPSK,16-QAM, 64-QAM. All the authors in previous studies consider the frequency range in 4G.

This paper considered the advantages of mmwave frequency ranges at fifth generation technology. and present the MIMO- STBC with uniform linear array at mmwave frequency ranges to calculate the performance parameter and comparison between different modulation schemes BPSK, QPSK, 4-QAM ,16-QAM, 64-QAM, 256-QAM, TCM convolutional code for AWGN, Rayleigh and Rician channel fading at different number of transmit and receive antennas. Considering at the both transmit and receive side, will use two- element resonant dipole array and the spacing between two dipoles is half-wavelength.

This paper is organized as follows; section II introduces System Model, section III introduces Modulation Techniques, section IV presents System Parameters, section V presents Simulation Results, and section VI concludes this paper

II. SYSTEM MODEL

In MIMO System Consider N_t and N_r antennas at the both transmitter and receiver arrays, and h channel fading, the magnitude of h can be defined in [12]as:

$$|h| = \sqrt{x^2 + y^2} \qquad (1)$$

Where x and y are independent and identically distributed (IID) Gaussian random Variables that have zero mean and equal variance (σ^2),

Rayleigh fading is non line of sight path (NLOS), at that case P.D.F of Rayleigh random variable |h(x)| in [12] is:

$$h(x) = \frac{x}{\sigma^2} e^{\frac{-x^2}{2\sigma^2}} \qquad (2)$$

Where, $\sigma^2$is the variance.

If there is a clear line of sight path (Los) the Rician fading occurs. at that case P.D.F of Rician random variable |h(x)| in [16]is:

$$h(x) = \frac{2x(k+1)}{G} e^{\left(\frac{-K-(K+1)X^2}{G}\right)} I_0(2X\sqrt{\frac{K(K+1)}{G}} X > 0 \qquad (3)$$

Where, the first kind and zero order of the modified Bessel function defined as I_0. K is Rician factor, the value of 'k' can be determined using the relation in [16] by:

$$k = \frac{specular\ power\ (s^2)}{scattered\ power\ (2b_0)}$$

Envelope average power $E\ [a^2]$ =G =$S^2 + 2b_0$

A. *Space Time Block Code (STBC).*

Data input is modulated and then encoded by STBC and sending via Numbers of antennas, fading supposed as (Rayleigh - Rician) channel with effect of additive white gaussian noise (AWGN), then the received signal decoded and demodulated. The Block diagram of methodology transfer data in MIMO system as shown in Figure 1

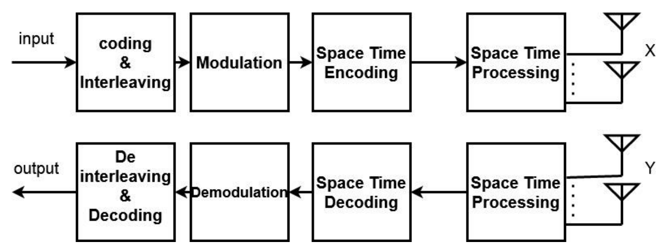

Fig (1): block diagram for MIMO system [6]

Space-time block codes were designed to achieve the maximum diversity order for the given number of transmit and receive antennas subject to the constraint of having a simple linear decoding algorithm. This has made STBC a very poplar schemes and most widely used., because it encodes in sender side by create the data as a matrix that has columns similar to number of transmitting antenna and rows similar to number of slots required to transmit the data, and decoding in receiver side by combined the received signals and then sent to maximum probability detector where the decision rules are applied [6]. Figure 2 show the encoder and decoder by STBC in MIMO system.

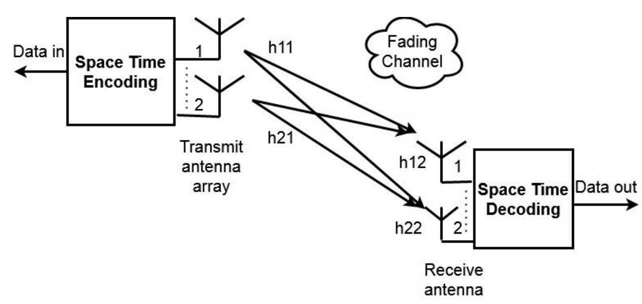

Fig (2): MIMO System using STBC

B. Equations of STBC

In transmitter side, z_1 and $z_2$symbols are transmitted by Tx1 and Tx2 antennas at time= t_1 and then at time = $t_1 + T$, $-Z_2^*$ and Z_1^*symbols are transmitted by T_{x1} and T_{x2} antennas. Transmission symbols for 2*2 MIMO STBC are shown in Table (1).

TABLE (1)
EXPLANATION OF TRANSMISSION SYMBOLS FOR 2*2 MIMO STBC [8]

Antenna	**Time t_1**	**Time t_1+ T**
Transmission1	Z_1	$-Z_2^*$
Transmission 2	Z_2	Z_1^*

The received signal$y$ can be discussed in [7]by:

$$y = h\,x + n \tag{4}$$

Where, x is transmitted signal, h is channel matrix, n is noise And, can be analyzed as follows [11]:

$$\begin{bmatrix} y_{11} & y_{12} \\ y_{21} & y_{22} \end{bmatrix} = \begin{bmatrix} h_{11} & h_{12} \\ h_{21} & h_{22} \end{bmatrix} \begin{bmatrix} z_1 & -z_2^* \\ z_2 & z_1^* \end{bmatrix} + \begin{bmatrix} n_{11} & n_{12} \\ n_{21} & n_{22} \end{bmatrix} \tag{5}$$

Where,y_{11} and y_{21} is received data at first time slot and y_{12} ,y_{22} are received data at second time slot.h $\in C^{Nr\times Nt}$ is the channel matrix,$z\in C^{Nr\times Nt}$ is the transmitted signal matrix, N$\in C^{Nr\times Nt}$is the additive white Gaussian noise matrix. Combine signals that are sent to decoding in [6] is:

$$\begin{bmatrix} \tilde{z}_1 \\ \tilde{z}_2 \end{bmatrix} = \begin{bmatrix} h_1^* & h_2 \\ h_2^* & -h_1 \end{bmatrix} \begin{bmatrix} y_1 \\ y_2^* \end{bmatrix} = \begin{bmatrix} h_1^* y_1 + h_2 y_2^* \\ h_2 y_1^* - h_1 y_2^* \end{bmatrix} \tag{6}$$

Can be obtained: [19]

$$\hat{z}_1 = \arg min_{(z_1, z_2)\in c} \left(|h_{11}|^2 + |h_{12}|^2 + |h_{21}|^2 + |h_{22}|^2 - 1\right)|\hat{z}_1|^2 + d^2(\tilde{z}_1, \hat{z}_2) \tag{7}$$

$$\hat{z}_2 = arg\, min_{(z_1, z_2)\in c} \left(|h_{11}|^2 + |h_{12}|^2 + |h_{21}|^2 + |h_{22}|^2 - 1\right)|\hat{z}_2|^2 + d^2(\tilde{z}_1, \hat{z}_2) \tag{8}$$

For 3*3 MIMO system, the transmission symbols are shown in Table (2):

TABLE (2)
EXPLANATION OF TRANSMISSION SYMBOLS FOR 3*3 MIMO STBC [8]

	Time							
Space	z_1	$-z_2$	$-z_3$	$-z_4$	z_1^*	$-z_2^*$	$-z_3^*$	$-z_4^*$
	z_2	z_1	z_4	z_3	z_2^*	z_1^*	z_4^*	z_3^*
	z_3	$-z_4$	z_1	z_2	z_3^*	$-z_4^*$	z_1^*	z_2^*

For 4*4 MIMO system, the transmission symbols are shown in Table (3):

TABLE (3)
EXPLANATION OF TRANSMISSION SYMBOLS FOR 4*4 MIMO S TBC [8]

	Time							
Space	z_1	$-z_2$	$-z_3$	$-z_4$	z_1^*	$-z_2^*$	$-z_3^*$	$-z_4^*$
	z_2	z_1	z_4	z_3	z_2^*	z_1^*	z_4^*	z_3^*
	z_3	$-z_4$	z_1	z_2	z_3^*	$-z_4^*$	z_1^*	z_2^*
	z_4	z_3	$-z_2$	z_1	z_4^*	z_3^*	$-z_2^*$	z_1^*

In general, the space-time decoder decision metric for $N \times N$ system in [8] is:

$$\hat{z}_l = \sum_{t=1}^{l} \sum_{j=1}^{nr} \left| y_{j,t} - \sum_{i=1}^{nt} h_{i,j}\, x_{i,t} \right|^2 \tag{9}$$

$l = 1, 2, \dots\dots, n$ for n possible symbols

III. MODULATION TECHNIQUES

Binary phase shift keying (BPSK), quadrature phase shift keying (QPSK), Quadrature amplitude modulation (QAM), and trellis modulation code (TCM) are some of different modulation techniques available to use [12].

A. BPSK

The transmitted signal can be written as [18]:

$$S(t) = m(t)c(t) \tag{10}$$

Where,$m(t)$ is modulated signal has a phase result either 0 or π radians,$c(t)$is sinusoidal carrier signal with amplitude A. Then the transmission power$P_S = \frac{1}{2}A^2$, $A = \sqrt{2\,P_S}\, s(t)$ is given in [14] by

$$S(t) = m(t)\sqrt{2\,P_S}\cos\omega_0\, t \tag{11}$$

Where, $\omega_0 = 2\pi\, f_c$ and f_c is carrier frequency

Then, the probability of error in [14] defined as:

$$p_b = \frac{erfc}{2}\sqrt{\frac{E_b}{N_O}} \tag{12}$$

Where, Erfc is the complementary error function,
$\frac{E_b}{N}$ = ratio of signal energy per bit to noise spectral density.

B. QPSK

In order to deliver the same transmission rate at the same bit error performance, QPSK it will reduce the transmission bandwidth to half of that required by BPSK. accordingly, this is the advantage of QPSK over BPSK. [14]

$$s(t) = \sqrt{2\,P_S}\cos\left[\omega_0\, t + (2\,m + 1)\frac{\Pi}{4}\right] \quad m = 0,1,2,3. \tag{13}$$

The error probability is [14]:

$$P_{b=}erfc\sqrt{\frac{E_b}{N_O}} \tag{14}$$

Where,p_s is transmission power
Erfc is the complementary error function
$\frac{E_b}{N}$ = ratio of signal energy per bit to noise spectral density.

C. M-QAM

The signal vectors can be different in amplitudes not in their phase only by using QAM which improves the noise immunity of the system. Two DSB signals can be permitted to occupy the same frequency band by carrier phase shifting and synchronous detection.

The error probability is given by: [14]

$$P_b = 2\left(1 - \frac{1}{\sqrt{M}}\right)\frac{1}{2} erfc \sqrt{\frac{E_b}{N_0}} \quad (15)$$

D. TCM

Trellis Coded Modulation was invented as a mixing of both convolutional coding and M-PSK modulation technique, this mixing can improve the performances and reliability of a digital transmission system without increase the bandwidth or data rate reduced as shown in fig (3)

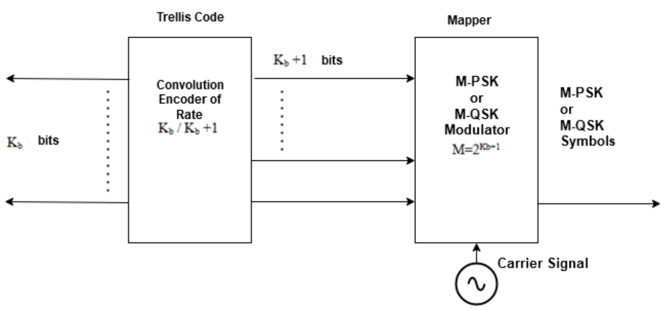

Fig (3): A simple Trellis Code Modulation

The upper bound on error probability denoted by $P(e)$ for TCM [13]:

$$\mathrm{P(e)} \leq \mathrm{N}(\delta_{free})\frac{1}{2} erfc\left(\frac{\delta_{free}}{2\sqrt{N_O}}\right) \quad (16)$$

Where; $\mathrm{N}(\delta_{free})$ is error coefficient, N_O is complex noise power spectral density. In addition, the lower bound of the error probability denoted by [13]:

$$\mathrm{P(e)} \geq \frac{1}{2} erfc\left(\frac{\delta_{free}}{2\sqrt{N_O}}\right) \quad (17)$$

IV. SYSTEM PARAMETER

A. Bit Error Rate (BER)

Bit error rate is measure as percentage of the number of error bits divided by the total transmitted bits in interval time [11].

$$\text{Bit error rate } (P_b) = \frac{\text{Number of bits in error}}{\text{Total no. of transmitted bits}} \quad (18)$$

SNR is the ratio between signal power to noise power in disciple (dB) [11].

$$\mathrm{SNR} = 10 \log \frac{signalpower}{noisepower} \mathrm{dB} \quad (19)$$

Relation between Eb/No and SNR in [14] by equation (20)

$$\frac{E_b}{N_0} = \frac{ST_b}{N/W} = \frac{S/R_b}{N/W} \quad (20)$$

Eb/No ratio is used in digital communication, this ratio is a normalized version from SNR where Eb is bit energy equal to signal power S times multiplied by the bit time Tb and N0 is noise power spectral density equal to noise power (N) divide by bandwidth (W). Since it can be replaced Tb with 1/ bit rate (Rb). [14]

B. Capacity

Channel capacity for MIMO wireless communication system is better than (SISO, SIMO, MISO). Where the number of antennas in transmitter and receiver side increase, the capacity is grown more or less logarithmically with SNR. The channel capacity of the SISO system is given as [15]:

$$C_{SISO} = \log_2(1 + SNR|h|^2)\, bits/S/HZ \quad (21)$$

The channel capacity of the SIMO system is given as [15]:

$$C_{SIMO} = \log_2\left(1 + SNR\sum_{i=1}^{Nr_x}|h|^2\right) bits/S/HZ \quad (22)$$

The channel capacity of the MISO system is given as [15]:

$$C_{MISO} = \log_2\left(1 + \frac{SNR}{Nt_x}\sum_{i=1}^{Nt_x}|h|^2\right) bits/S/HZ \quad (23)$$

Channel capacity for MIMO is [15]:

$$C_{MIMO} = \log_2\left[det\left(I_{Nrx} + \frac{SNR}{Ntx}HH^H\right)\right] bits/S/HZ \quad (24)$$

Where, SNR is the signal to noise ratio,N_{RX} is number of an antenna at receiving part,N_{TX} is number of an antenna in transmission part,$|h|$ is channel normalized complex gain matrix,det(k) is determinate of matrix (k).$I_{Nrx}$is the identity of matrix with dimension of Nr_x, H is channel matrix and H^H is Hermitian transpose [17].

$$C_{MIMO} = \log_2 det\left(I_{nr} + \frac{E_s}{n_t N_0}HH^H\right) \quad (25)$$

For $n_t = n_r$ and $HH^H = VDV^H$ (eigen value decomposition theorem) [17],

$$C_{MIMO} = \log_2 det\left(I_{nr} + \frac{E_s}{n_r N_0}VDV^H\right) \quad (26)$$

$V^H V = VV^H = I_{nr}$, and $D = diag\{\lambda_1, \lambda_2, \ldots \lambda_i\}\lambda_i > 0$

Capacity equation can be reducing to [17]:

$$C_{MIMO} = \sum_{i=1}^{r} \log_2 \left[1 + \frac{E_s}{n_t N_0} \lambda_i\right] \qquad (27)$$

Where $r = rank(HH^H) = \min[n_r, n_t]$
Channel capacity with STBC [15]:

$$C_{STBC} = E\left[BR \log_2 \left[1 + \frac{E_s}{n_t R N_0} Q\right]\right] \qquad (28)$$

Where; $E[\ \ ]$ is expectancy operator; B is Bandwidth, R is Code rate [15].

$$C_{STBC} = E[BR \log_2[1 + \Upsilon_S]] \qquad (30)$$

Υ_s is efficient instant SNR per symbol at the recipient can be expressed in equation [15]:

$$\Upsilon_S = \frac{E_S}{N_T R N_0} \|H\|_F^2 \qquad (31)$$

$$\|H\|_F^2 = \sum_{i=1}^{N_T} \sum_{i=1}^{N_R} \left\|\boldsymbol{h}_{ij}\right\|^2 \qquad (32)$$

V. SIMULATION RESULTS

In this section can be study the capacity and BER for different number of antennas in MIMO system with and without STBC using the simulation parameter as a shown in table (4).

TABLE (4)
SET UP SIMULATION PARAMETER

f_c	28 GHZ
N_T	2 , 3 ,4
N_R	2 , 3 ,4
SNR	0:10
Maximum number of errors	300
Symbol rate of STBC	N_T=2 Symbol rate =1 $N_T > 2$ symbol rate =3/4
Maximum number of bits	50000
Fading	Rayleigh , Rician with k =3
Modulation types	BPSK , QPSK ,M-QAM , TCM

A. Channel Capacity

Using equations (21-24) to calculate the channel capacity with different number of antenna at transmit and receive side (SISO), (SIMO), (MISO), (MIMO) without STBC as shown in fig (4.a)

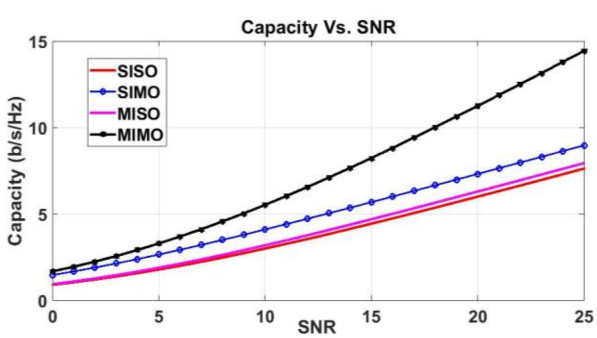

Fig (4.a): comparison capacity between SISO, SIMO, MISO, MIMO.

TABLE (5)
CAPACITY RESULTS AT DIFFERENT VALUES OF SNR AND DIFFERENT NUMBER OF ANTENNAS

SNR (dB)	**Capacity(b/s/Hz)**			
	SISO (1×1)	MISO (2×1)	SIMO (1×2)	MIMO (2×2)
Low SNR =0(dB)	0.93	0.93	1.463	1.673
High SNR=25(dB)	7.6	7.9	8.96	14.44

TABLE (6)
PERCENTAGE IMPROVEMENT IN CAPACITY OF MIMO OVER THAN SISO, MISO, AND SIMO

SNR (dB)	**Percentage improvement in capacity of MIMO over than**		
	SISO	MISO	SIMO
At low SNR =0(dB)	44.4%	44.4%	12.5%
At high SNR =25(dB)	47.2%	45%	37.8%

It can be noticed the numerical results and percentage improvement of channel capacity with minimum and maximum SNR in table (5), (6).

The capacity of MIMO reaches to 44,4% improvement percentage over SISO, MISO system and up to 12,5% over SIMO system at minimum SNR =0(dB)

While, at high SNR =25(dB), the channel capacity arrives to 47.2% over SISO system, 45% over MISO system and 37.8% improved by SIMO system.

It means the MIMO system gives high results; therefore, it can be studied it in details.

Using equations (24 -27) to simulate the channel capacity for MIMO system at different numbers of transmitter and receiver antennas without STBC in fig (4.b)

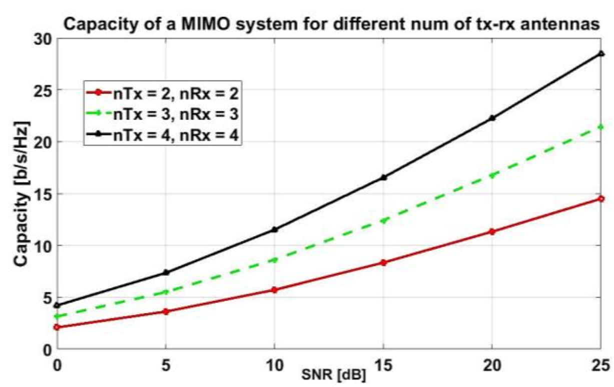

Fig (4.b): capacity for various number of antenna VS SNR without STBC.

TABLE (7)
CAPACITY RESULTS AT DIFFERENT VALUES OF SNR AND DIFFERENT MIMO SYSTEM WITHOUT STBC

SNR (dB)	**ChannelCapacity (b/s/Hz)**		
	(2×2) MIMO	(3×3) MIMO	(4×4) MIMO
At low SNR =0 (dB)	2.0932	3.1474	4.2137
At high SNR=25(dB)	14.497	21.4455	28.496

TABLE (8)
PERCENTAGE IMPROVEMENT ON CAPACITY OF (4×4) MIMO SYSTEM OVER OTHER SYSTEMS (2×2), (3×3) MIMO.

SNR (dB)	**Percentage improvement on capacity of (4×4) MIMO over than**	
	(2×2) MIMO	(3×3) MIMO
low SNR =0 (dB)	50%	25%
high SNR =25 (dB)	49,1%	24.7%

From fig (4.b) and tables (7), (8), it can be observed the numerical results and percentage improvement in capacity for (4×4) MIMO system by 50% than (2×2) MIMO system and 25% than (3×3) MIMO system at low SNR.

However, at high value of SNR the improvement for (4×4) MIMO reaches to 25% than (2×2) MIMO system and over (3×3) MIMO system by 24.7%.

Using equations (28 -32) to simulate the channel capacity for MIMO system at different numbers of transmitter and receiver antennas with STBC in fig (4.c)

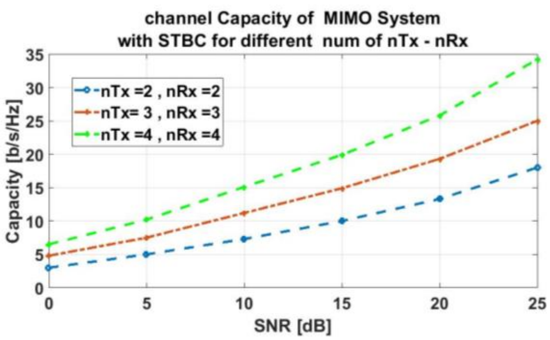

Fig (4.c): capacity for various number of antenna VS SNR with STBC.

TABLE (9)
CAPACITY RESULTS AT DIFFERENT VALUES OF SNR AND DIFFERENT MIMO SYSTEM WITH STBC

SNR (dB)	**Channel Capacity (b/s/Hz)**		
	(2×2) MIMO	(3×3) MIMO	(4×4) MIMO
low SNR =0 (dB)	3.03	4.8	6.5
high SNR=25(dB)	18.0134	24.965	34.2

TABLE (10)
PERCENTAGE IMPROVEMENT ON CAPACITY WITH STBC IN MIMO SYSTEM OVER WITHOUT

SNR (dB)	**Percentage improvement on capacity with STBC over without**		
	(2×2) MIMO	(3×3) MIMO	(4×4) MIMO
low SNR =0 (dB)	30.9%	34.4%	35%
high SNR =25 (dB)	19.5%	14.1%	16.67%

The figure (4.c) and tables (9), (10) can be explained that channel capacity with STBC at low value of SNR =0 (dB) for (2×2) MIMO system is about 3.03 (b/s/HZ). but the channel capacity without STBC at the same SNR and number of transmit- receive antennas equal to 2.09 (b/s/Hz)

At high SNR =25 (dB) in the same number of antennas, the capacity value with STBC is 18.0134 (b/s/Hz) and the capacity value without STBC is 14.497 (b/s/Hz). it means the capacity improved by 19.5% when using STBC

In (3*3) MIMO system at low SNR (dB), the value of channel capacity with STBC is 4.8 (b/s/Hz), while when using without STBC the value of capacity at the same conditions is 3.1474(b/s/Hz).

At high SNR (dB) the capacity with STBC is 24.965 (b/s/Hz), and the numerical value of capacity without STBC reaches to 21.4455 (b/s/Hz), this means the percentage improvement up to 14%.

In (4×4) MIMO system at low SNR (dB) the capacity with STBC is 6.5 (b/s/Hz) and the capacity without STBC is 4.2137 (b/s/Hz). while, the capacity with STBC at high SNR (dB) is 34.2 (b/s/Hz), and value of capacity without STBC is 28.496 (b/s/Hz), this means the percentage improvement arrives to 16.67%.

In general, the capacity improved by increasing numbers of antennas.

In addition, the capacity improved by using STBC under the same number of antenna (2×2), (3×3), (4×4). and the same range of SNR with Rayleigh fading channel.

B. Bit Error Rate

In this section, the results have been simulated using MATLAB to describe and analysis the performance of wireless MIMO system over mmWave frequency. Also, comparison between the simulation results for the implemented MIMO Wireless system using STBC over flat Rayleigh fading channels, and Rician with operating frequency as 28 GHZ. A two-element resonant dipole array is used at both transmit (Tx) and receive (Rx) side. with half-wavelength spacing. Over different modulation techniques (BPSK, QPSK, 4-QAM ,16-QAM ,64-QAM ,256-QAM and TCM).

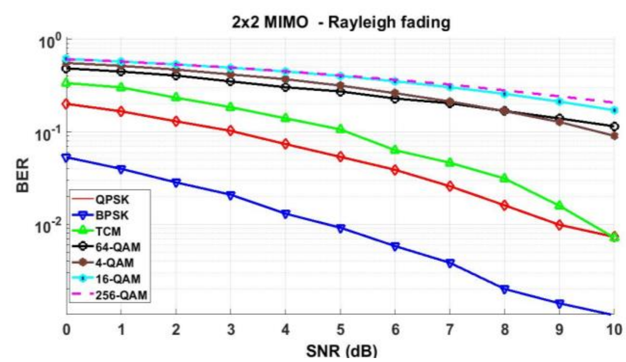

Fig (5.a): BER VS SNR for 2×2 MIMO system over (BPSK-QPSK-M-QAM-TCM)

Bit error rate values is found to be very low for a BPSK modulation scheme compares with other modulation schemes as shown in fig (5.a).

It is observed that for an SNR= 0 dB with (2×2) MIMO - STBC over Rayleigh fading. BPSK results in an BER is 0.0531, QPSK gives max BER equal to 0.2, while other modulation techniques like (TCM - M-QAM) gives results above 0.3, this means BPSK better than other modulation techniques.

Figure (5.b) describes the relation between BER and SNR at Rayleigh fading for (3×3) MIMO- STBC over different modulation techniques.

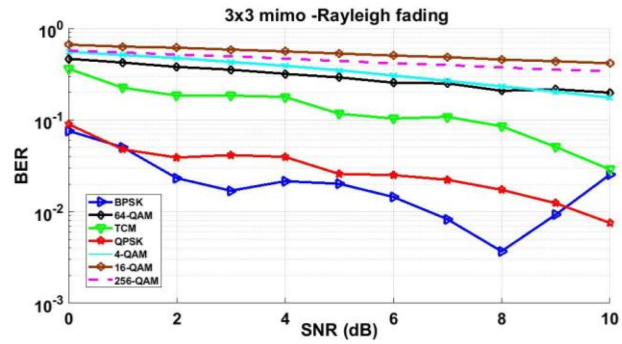

Fig (5.b): BER VS SNR for 3*3 MIMO system over (BPSK-QPSK-M-QAM-TCM)

In figure (5.b) shows the maximum BER for BPSK is 0.0763, QPSK gives maximum BER equal to 0.09, the next in maximum BER is TCM with 0.36. but M-QAM gives results above 0.466 so, BPSK is gives lowest values of BER compared with other modulation techniques.

Figure (5.c) describes the relation between BER and SNR at Rayleigh fading for (4×4) MIMO- STBC over different modulation techniques.

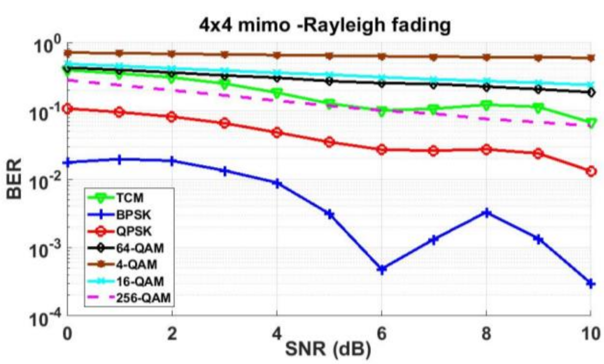

Fig (5.c): BER VS SNR for 4*4 MIMO system over (BPSK-QPSK-M-QAM-TCM)

For (4×4) MIMO-STBC, the maximum BER occurs when used BPSK where at SNR =0 the BER =0.017, and when used QPSK the BER=0.1076. the next in maximum BER is 256-QAM it gives 0.28, and other modulation gives results above to 0.3921. in general, the BPSK gives low BER compared with QPSK and TCM and M- QAM.

The numerical results and percentage improvement in table (11), (12) describe and explain the (4×4) MIMO-STBC with Rayleigh fading gives lowest values BER especially when using BPSK modulation scheme.

TABLE (11)
MAXIMUM VALUES OF BER VS SNR AT DIFFERENT MODULATION TECHNIQUES OVER RAYLEIGH CHANNEL FADING

Modulation techniques	**Maximum BER over Rayleigh fading**		
	2×2	3×3	4×4
BPSK	0.0531	0.07	0.017
QPSK	0.2005	0.09	0.1076
TCM	0.336	0.36	0.3921
4 - QAM	0.55	0.57	0.71
16 -QAM	0.6	0.66	0.482
64 - QAM	0.48	0.466	0.426
256 -QAM	0.61	0.574	0.28

TABLE (12)
PERCENTAGE IMPROVEMENT OF BPSK FOR (2×2), (3×3), (4×4) MIMO-STBC WITH RAYLEIGH FADING OVER OTHER MODULATION TECHNIQUES.

	Percentage improvement for BPSK over					
Modulation	QPSK	TCM	4-QAM	16-QAM	64-QAM	256-QAM
(2×2) MIMO	73%	84%	90%	91%	89%	91%
(3×3) MIMO	22%	80%	88%	89%	85%	88%
(4×4) MIMO	84%	95%	97%	96%	96%	93%

TABLE (13)
AVERAGE VALUES OF BER VS SNR AT DIFFERENT MODULATION TECHNIQUES OVER RAYLEIGH CHANNEL FADING

Modulation techniques	**Average values in BER over Rayleigh fading**		
	(2×2) MIMO	(3×3) MIMO	(4×4) MIMO
BPSK	0.02	0.03	0.007
QPSK	0.08	0.04	0.005
TCM	0.147	0.17	0.2
4 – QAM	0.352	0.37	0.65
16 -QAM	0.38	0.543	0.7
64 – QAM	0.291	0.318	0.298
256 -QAM	0.4225	0.457	0.152

TABLE (14)
EFFECT OF UTILIZING STBC WITH DIFFERENT MODULATION TECHNIQUES ON BER VALUES OVER RAYLEIGH FADING

	Rayleigh fading					
	2×2 MIMO System		**3×3 MIMO system**		**4×4 MIMO system**	
Modulation	**Without STBC**	**With STBC**	**Without STBC**	**With STBC**	**Without STBC**	**With STBC**
BPSK	0.5	0.053	0.415	0.07	0.1	0.017
QPSK	0.75	0.2005	0.2	0.09	0.157	0.1076
TCM	0.5	0.336	0.5	0.36	0.4	0.3921
4-QAM	0.876	0.55	0.65	0.57	0.6	0.71
16-QAM	0.78	0.6	0.78	0.66	0.8	0.482
64-QAM	0.8	0.48	0.54	0.466	0.75	0.426
256-QAM	0.78	0.61	0.7	0.574	0.7	0.28

Figure (6.a) shows the relation between BER and SNR at Rician fading for (2×2) MIMO- STBC over different modulation techniques

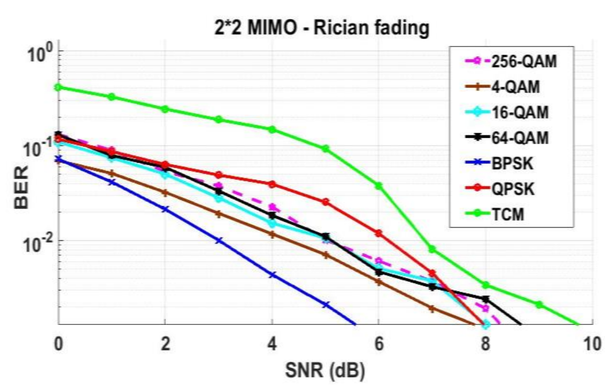

Fig (6.a): BER VS SNR for 2*2 MIMO system over (BPSK-QPSK-M-QAM-TCM)

From the figure (6.a) can be noticed that the BPSK modulation scheme gives BER = 0.07 at SNR =0 (dB)and when using QPSK, M-QAM the maximum BER is slightly around 0.13, while the TCM gives result equal to 0.4126

BPSK all the way gives lowest BER at (2×2) MIMO – STBC with Rician distribution

Figure (6.b) shows the relation between BER and SNR at Rician fading for (3×3) MIMO- STBC over different modulation techniques

It can be noticed the different values of BER between BPSK and other modulation. at SNR =0 (dB), BER with BPSK is equal to 0.01115, BER with 16-QAM is 0.042 and so on with slightly increasing until reach the BER with TCM is 0.3012. So, in (3×3) MIMO -STBC BPSK gives lowest values of BER.

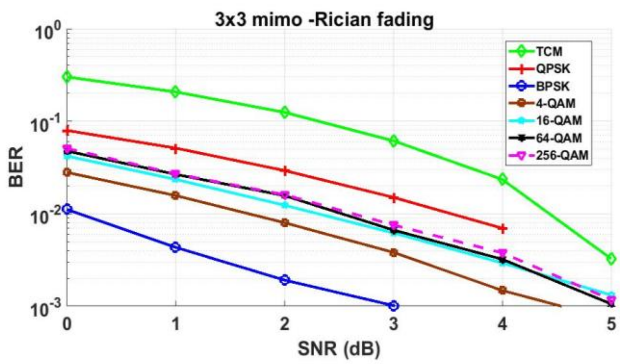

Fig (6.b): BER VS SNR for 3*3 MIMO system over (BPSK-QPSK-M-QAM-TCM)

Figure (6.c) shows the relation between BER and SNR at Rician fading for (4×4) MIMO- STBC over different modulation techniques.

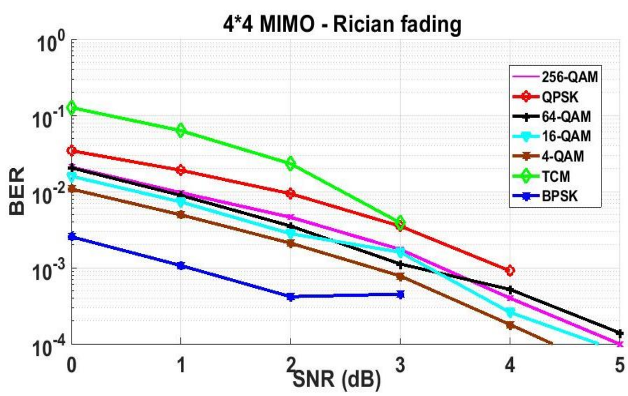

Fig (6.c): BER VS SNR for 4*4 MIMO system over (BPSK-QPSK-M-QAM-TCM)

For (4×4) MIMO -STBC in figure (6.c), it can be observed the different values between BPSK and other modulation.

At SNR =0 (dB), BER with BPSK is 0.00255, BER with 16-QAM is 0.015879 and so on with slightly increasing until reach the BER with TCM is 0.3012 So, in (4×4) MIMO -STBC BPSK gives lowest values of BER

Table (15) compare between (2×2), (3×3), (4×4) MIMO - STBC at the *Rician* channel fading and SNR over modulation techniques

TABLE (15)
MAXIMUM VALUES OF BER VS SNR AT DIFFERENT MODULATION TECHNIQUES OVER RICIAN CHANNEL FADING

Modulation Techniques	**Maximum BER over Rician fading**		
	2×2	**3×3**	**4×4**
BPSK	0.07213	0.01115	0.00255
QPSK	0.1166	0.007948	0.03433
TCM	0.4126	0.3012	0.1263
4 – QAM	0.0695	0.0279	0.010779
16 -QAM	0.1094	0.042	0.0158
64 – QAM	0.13	0.0476	0.020478
256 -QAM	0.13	0.051	0.020478

TABLE (16)
PERCENTAGE IMPROVEMENT OF BPSK FOR (2×2), (3×3), (4×4) MIMO-STBC WITH RICIAN FADING OVER OTHER MODULATION TECHNIQUES

Modulation	**Percentage improvement for BPSK over**					
	QPSK	TCM	4-QAM	16-QAM	64-QAM	256-QAM
(2×2) MIMO	38%	82%	4%	34%	45%	45%
(3×3) MIMO	3%	96%	60%	73%	76%	78%
(4×4) MIMO	92%	97%	76%	83%	87%	87%

TABLE (17)
AVERAGE VALUES OF BER VS SNR AT DIFFERENT MODULATION TECHNIQUES OVER RICIAN CHANNEL FADING

Modulation Techniques	**Average values in BER over Rician fading**		
	(2×2) MIMO	**(3×3) MIMO**	**(4×4) MIMO**
BPSK	0.03	0.00445	0.0015
QPSK	0.07	0.03856	0.015
TCM	0.27	0.149	0.074
4 – QAM	0.135	0.0124	0.006
16 -QAM	0.06	0.0191	0.006
64 – QAM	0.07	0.0223	0.008
256 -QAM	0.07	0.023	0.0084

TABLE (18)
EFFECT OF FADING ON BER USING STBC AND DIFFERENT MODULATION TECHNIQUES FOR (3×3), (4×4) MIMO.

Modulation Techniques	**Rayleigh fading**		**Rician fading**	
	(3×3) MIMO	**(4×4) MIMO**	**(3×3) MIMO**	**(4×4) MIMO**
BPSK	0.03	0.007	0.00445	0.0015
QPSK	0.04	0.05	0.03856	0.015
TCM	0.17	0.2	0.149	0.074
4 – QAM	0.37	0.65	0.0124	0.006
16-QAM	0.543	0.7	0.0191	0.006
64-QAM	0.318	0.298	0.0223	0.008
256-QAM	0.457	0.152	0.023	0.0084

TABLE (19)
EFFECT OF UTILIZING STBC WITH DIFFERENT MODULATION TECHNIQUES ON BER VALUES FOR DIFFERENT NUMBERS OF ANTENNA AND RICIAN FADINg

Rician fading

Modulation	2×2 MIMO System		3×3 MIMO system		4×4 MIMO system	
	Without STBC	With STBC	Without STBC	With STBC	Without STBC	With STBC
BPSK	0.1	0.0721	0.01	0.0111	0.012	0.0025
QPSK	0.22	0.1166	0.17	0.0079	0.1	0.0343
TCM	0.6	0.4126	0.4	0.3012	0.3	0.1263
4-QAM	0.5	0.0695	0.2	0.0279	0.2	0.0107
16-QAM	0.7	0.1094	0.6	0.042	0.25	0.0158
64-QAM	0.5	0.13	0.4	0.047	0.27	0.0204
256-QAM	0.5	0.13	0.34	0.051	0.3	0.0204

In general, the system performance improved by using STBC

Where, the channel capacity improved in MIMO -STBC by 16.67% with increasing the number of antenna (4×4) over without STBC

Also, the BER values in (4×4) MIMO-STBC decreased by 78.7% than without STBC.

The Rician fading on (4*4) MIMO-STBC with BPSK modulation gives average value of BER reach up 0.0015, while, the QPSK, TCM, M-QAM gives BER values above 0.006.

VI. CONCLUSION

This paper gives an evaluation to performance parameter for 2*2, 3*3, and 4*4 MIMO system based on STBC at mm wave frequency range. It concentrates on different modulation schemes and different fading channel. The simulation results show the channel capacity improved by (16.67%) using STBC with more numbers of antennas at transmitters and receivers compared it without STBC. In addition, it studied BER over Rayleigh and Rician fading at different modulation which BPSK, QPSK, TCM, M-QAM. BER performance analysis showed that 4*4 MIMO-STBC system is more reliability compared than (2×2) by 67% and then (3×3) MIMO -STBC system by 75% Rician fading submitted minimum BER than Rayleigh fading, and BPSK is given better results than TCM with 97%, 92% in QPSK and 85% for M-QAM in (4×4) MIMO –STBC

AUTHORS CONTRIBUTION

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   By Eng. Youstina Nagy Samir
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References

[1.] M. A. Almasi, R. Amiri, H.Jafarkhani , H. Mehrpouyan ,“ MmWave Lens-based MIMO System for Suppressing Small-scale Fading and Shadowing,” IEEE , vol.19, ISS.8, Aug. 2020.

[2.] S.Wani ,SH.K.Koul , “ Novel Millimeter Wave Antenna for MIMO and 5G Applications“Springer .2021.

[3.] C.R.Shan ,“Performance and Comparative Analysis of SISO, SIMO, MISO, MIMO,”International journal of wireless communication and simulation , Vol.9,2017.

[4.] J.Lota ,T.S.Rappaport , Shu Sun ,A.Demosthenous, ,“ 5G Uniform Linear Arrays With Beamforming and Spatial Multiplexing at 28, 37, 64, and 71 GHz for Outdoor Urban Communication: ATwo-Level Approach,” IEEE Transaction on Vehicular Technology , vol.66, No.11, Aug. 2017.

[5.] P.Pathak ,R.Pandey ,“ A Novel Alamouti STBC Technique for MIMO System Using 16- QAM Modulation and Moving Average Filter,” Princy Pathak Int. Journal of Engineering Research and Application , vol.4, ISS.8, PP -49 -55 ,Aug. 2014.

[6.] Santumon.S.D ,B.R.Sujatha, ,“ Space-Time Block Coding (STBC) for Wireless Networks,” International Journal of Distributed and Parallel System , vol.3, No.4, July. 2012.

[7.] D.Haider,S.A.Shah, S.I.Shah, U.Iftikhar ,“MIMO Network andtheAlamouti, STBC ,” American Journal of Electrical and Electronic Engineering , vol.5, No.1, 2017.

[8.] M.H.Belsare, P.B.Mane ,“ BER Performance Evaluation of 2X2, 3X3and 4X4 Uncoded and Coded Space Time Block Coded (STBC) MIMO System Concatenated with MPSK in Rayleigh Channel,” International Journal of Applied Engineering Research, vol.13,2018.

[9.] Sudha.Arvind, S.Arvind , S.Domakonda ,R.Smruthi ,“ MIMO System FER Performance Analysis in Various Fading Environments with OSTBC- TCM Combination,” Solis State Technology, vol.63, ISS. 5, 2020.

[10.] Ch.M.Lau ,“ Performance of MIMO System Using Space Time Block Codes [STBC].,” Open Journal of Applied Science, March.2021.

[11.] A.Mustafa ,A. Tufail ,A.Ali ,B.Haider, F.Aadil ,R.Chohan ,M.Durrani ,“ BER Reduction in QPSK.,” Journal of Applied Environmental and Biological Sciences , ISS : 2090-4274 ,April.2017.

[12.] S.Manamohan ,“ Simulation of Alamouti Coded MIMO Signals over a Nakagami Fading Channel.,”,Aug.2019.

[13.] Mei Hong, “Analysis of the Bit Error Rate of theTrellis-Coded Modulation”, Chalmers University of Technology, Goteborg, Sweden, December 2002,

[14.] J. A. Desai, S. N. Kulkarni, “Effect of Noise on BER of BPSK, QPSK, DPSK, and QAM Modulation Techniques, "International Journal of Research and Scientific Innovation (IJRSI), Vol.3, ISS.7, July. 2016..

[15.] M.S.Abed ,R.H.Thaher,“ Coding Technique Utilization to Enhance MIMO Channel Capacity,”AIP Conference Proceedings 229,Dec.2020.

[16.] Gordon L. Stüber, “Principles of Mobile Communication” (Kluwer Academic Publishers New York, 2002, 2ndedn.)

[17.] E. Mohamed, A. M, Abdualsattar, “Evaluation of MIMO system capacity over Rayleigh fading channel,“IJCSES ,vol.6 ,No.3 ,June 2015.

[18.] HAH.Nguyen, Ed.Shwedky ,“frist course in digital communication“,Cambridge University Press, 2009

[19.] M.Elzianati, “space Time Block Coding for Wireless Communication “ Augest .2008

Title Arabic:

تقييم اداء نظام متعدد المدخلات والمخرجات في نطاق الترددات المليمترية علي اساس تشفير كتلة الزمان والمكان وتقنيات التعديل المختلفة.

Arabic Abstract:

يعد نظام متعدد المدخلات والمخرجات (MIMO) باستخدام ترددات الموجات المليمترية احداهم تقنيات الجيل الخامس في انظمة الاتصالات اللاسلكية لدعمه اقصي معدل لنقل البيانات .

وتم التركيز في هذه الورقه البحثية علي تقييم اداء النظام متعدد المدخلات والمخرجات (MIMO) باستخداماحد تقنيات التشفير (STBC) وانواع مختلفة من التعديل (إزاحة الطور الثنائي(BPSK) ، إزاحة الطور التربيعي (QPSK)، تعديل السعة التربيعي (QAM) وتعديل كود التداخل(TCM)) وذلك لتحسين السعة والإتاحة والموثوقية وتقليل معدل الخطأ في نقل البيانات بالرغم من محدودية النطاق الترددي وقدرة الارسال.

بالاضافة الي ذلك ، تم التحقق من فاعلية هذه التقنية باستخدام نموذج محاكاة (MATLAB) في وجود عدد مختلف من الهوائيات في الارسال والاستقبال (2×2) ، (3×3) ، (4×4) (MIMO-STBC) في ظل ظروف مختلفة من الشوشرة (AWGN)وخفوت رايلي (Rayleigh)وريسيان (Rician).

وقد اظهرت النتائج فاعلية نظام(4MIMO-STBC× 4) في تحسين السعة وتقليل معدل الخطأ في البيانات عن انظمة (2×2) و (3×3) بالاضافة الي ان التعديل باستخدام (BPSK) له القدرة المثلي علي تقليل (BER) مقارنة ب (QPSK)، (QAM)، (TCM) كما يعطي نظام خفوت (Rician) نتائج افضل من نظام خفوت (Rayleigh)