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Performance Analysis of 2x2 and 3x3 MIMO with QPSK in Rayleigh Fading Channel

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Abstract: A promising approach to improve the performance of wireless communication is multiple input multiple output (MIMO) system. MIMO can achieve high data rate without extra bandwidth. Space-Time Block Coding (STBC) is an emerging concept in MIMO which provides efficient performance in case of Bit Error Rate (BER) and diversity gain. In this paper, mathematical equations of channel capacity and Bit Error Rate (BER) for 3x3 MIMO system has been derived and simulation has been done to compare the performance of Average Channel Capacity vs. SNR and BER vs. SNR for 2X2 and 3X3 antennas. By varying the SNR value we observe the channel capacity and BER of the proposed system. In case of probability of error it is decreased when SNR value is increased but not tends to zero. But in case of channel capacity, it is increased with the increased value of SNR. By comparing these two relations we see that channel capacity is increasing without extra band-width and offers faster communication. Then a comparison among the existing MIMO system with the proposed system has been done. The result shows 3x3 MIMO system gives better performance for channel capacity compared to 2X2 MIMO.
Keywords: MIMO, SNR, Chanel Capacity, Bit error rate, Wireless Communication.

I. INTRODUCTION

This document is a template. For questions on paper guidelines, please contact us via e-mail. With the availability and enhancement of wireless communication technologies, people can contact with each other whenever and wherever they want. However, rapidly varying propagation environment, limited resources, lack of storage, heterogeneous technologies, limited speeds, high latency etc. are key challenges for a trustworthy communication system. According to the record of ITU, immense users are using the Internet to transmit the electronic information. Though, they are using high speed band, but the amount is not adequate to faster transmission for the rapidly growing users. However, as researchers are working on 5th generation communication standard like 5G or 6G, significant improved solution is required [1]. In [2] Arvind et al. provide a review of performance of various MIMO system with TCM, OSTBC and OSTBC-TCM in terms of FER, for Rician and Rayleigh fading channels. Using Matlab-Simulink tool, authors predicts that 4×2, 4×4, 3×4 MIMO channels would provide better performance in wireless communication. Algorithms of coded and uncoded STBC using 2x2, 3x3 and 4x4 MIMO system concatenated with MPSK is observed in [3]. Here authors found that coded 4x4 system is improved over uncoded system by 88% at low SNR (<5dB) and 96% at high SNR (>10dB) in Rayleigh channel in data communication systems such as 4G, LTE, WLAN and WiMAX. Saminu et al. proposed an orthogonal extended Alamouti's STBC scheme and analyzed the performance of Orthogonal Space Time Block Codes on Multiple Input Multiple Output (OSTBC-MIMO) system in [4]. Modulation schemes such as BPSK, QPSK, 8-PSK, and 16-PSK with various antenna configurations are analyzed under Rayleigh faded channel where BPSK provides the best result in terms of BER for the proposed model. One of the key challenges of wireless communication is multiple antennas at user ends. MIMO is a cognitive concept where multiple antennas are employed in sender and receiver end. The emerging MIMO technology has introduced a breakthrough for reliable communication. Precoding, diversity coding and spatial multiplexing are main functionalities which is allowed by MIMO techniques [5]. MIMO provides efficient data rate or longer transmission range without requiring additional bandwidth or transmit power. In the last couple of years, immense works have been done on the performance analysis of STBC. Liu et al. [6] proposed a class of full space diversity full rate space-time turbo codes. The work analyzed various implementation of STBC and shows the efficiency over fading channel. Jafarkhani et al. [7] provided a perplex orthogonal framework of STBC which showed that full diversity and full transmission rate for a space-time block code is impossible in case of more than two antennas. However, Weinrichter and Rupp [8] proposed a novel multi antenna system using STBC. Stefanov and Erkip [9] showed an analysis and design of space–time codes that are capable of achieving the full diversity provided by user co-operation. Goyal and Khanna shows about the Performance analysis of differential detection transmit diversity [10].

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Vidhya and Dananjayan [11] analyzed Cooperative STBC MIMO Transmissions in WSN using Threshold Based MAC Protocol. Li et al. [12] utilized robust linear receiver for multi-access STBC MIMO system. The simulated result showed that the proposed receiver model is more effective than existing popular receivers. Wei et al. [13] employed the orthogonal STBC (OSTBC) in multi-cluster scattering MIMO channels where an integrated and closed form estimation of the channel outage capacity has been derived over Rayleigh fading MIMO channels. Garg et al. [14], introduced non-OSTBC in 2X1 MIMO using diagonal weighting technique to take advantage of quantized one bit feedback without delay. The simulation of the article showed that like OSTBC, non-OSTBC can deal with error performance to develop the introduced diagonal precoding technique. Wang et al. [15] focused on massive MIMO environment where, OSTBC is considered to accelerate the diversity gain performance for uplink nodes and get apex rate with full diversity. Vakilian and Mehrpouyan [16] proposed a novel 2X2 MIMO framework which is used rate-two STBC and low convoluted maximum-likelihood detector to increase bit-error-rate outcomes of millimeter-wave techniques. The result showed the efficiency of proposed model compared to the conventional existed models. On the other hand, Hairi et al. [17] implemented OSTBC in a MIMO system which is able to connect 32 transmit ans 32 receive antennas. The work demonstrated that the outcomes of the model mostly depends on transmission matrix code rate. Chinh et al. [18] used OSTBC to measure the performance of MIMO architecture over Nakagami-m fading channel. Therefore, in MIMO, number of antennas and the quality of encoding techniques have a great impact on the performance of channel capacity. To address the previous research gap, this paper represents the performance of space-time block codes in Rayleigh fading channels for various number of antennas and different level of SNR values. This work also studies the diversity advantages through space-time block codes and the effect of the probability of error against different SNR. The key contribution of this work is listed below:

1) Mathematically analyze the probability of error for 3X3 (three transmit and three receive antenna) MIMO framework.
2) Mathematical representation of the channel capacity for 3X3 MIMO environment.
3) Comprehensive analysis of 2X2 and 3X3 to compare the performance of channel capacity and probability of error over various SNR levels.

Rest of the sections are organized as- section 2 provides the existing work review. Section 3 represents system model for three antennas in the sender and receiver end. Section 4 shows the outcomes of the proposed model and compares the channel performance in various number of antennas over different SNR.

II. SYSTEM MODEL

The performance criteria of diversity gain uses code design assuming the entire channel follows Rayleigh fading. The whole system for 3X3 diversity is illustrated in the fig. 1.

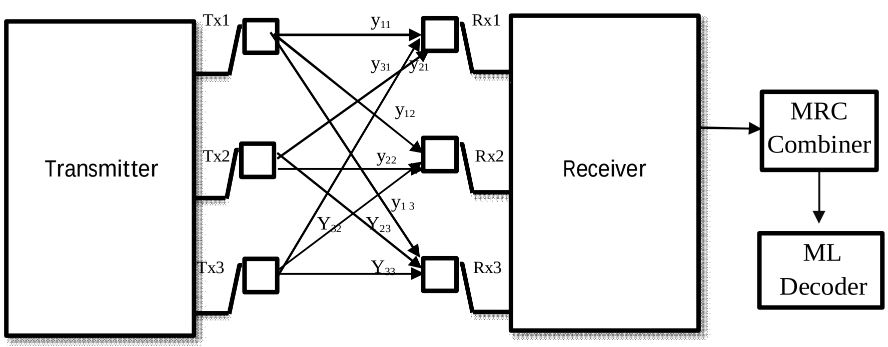

Fig. 1. The whole system for 3X3 diversity

The received signals y_{11}, y_{12}, y_{13}, y_{21}, y_{22}, y_{23}, y_{31}, y_{32} and y_{33} are the combination of the signals from antennas 1, 2 and 3, plus additive noise. The transmitting Matrix is

$$X=\begin{bmatrix} x_1 & x_2 & x_3 \\ -x_2^* & x_1^* & x_3 \\ x_3^* & -x_1^* & x_2 \end{bmatrix} \quad (1)$$

For three received antennas, the received symbols are given below [7].

$$
\begin{aligned}
y_{11} &= h_{11}x_1 + h_{12}x_2 + h_{13}x_3 + n_{11} \\
y_{12} &= -h_{11}x_2^* + h_{12}x_1^* + h_{13}x_3 + n_{12} \\
y_{13} &= h_{11}x_3^* + -h_{12}x_1^* + h_{13}x_2 + n_{13} \\
y_{21} &= h_{21}x_1 + h_{22}x_2 + h_{23}x_3 + n_{21} \\
y_{22} &= -h_{21}x_2^* + h_{22}x_1^* + h_{23}x_3 + n_{22} \\
y_{23} &= h_{21}x_3^* + -h_{22}x_1^* + h_{23}x_2 + n_{23} \\
y_{31} &= h_{31}x_1 + h_{32}x_2 + h_{33}x_3 + n_{31} \\
y_{32} &= -h_{31}x_2^* + h_{32}x_1^* + h_{33}x_3 + n_{32} \\
y_{33} &= h_{31}x_3^* + -h_{32}x_1^* + h_{33}x_2 + n_{33}
\end{aligned}
$$

Where *ij* is the path gain between the *i*th transmit antenna and *j*th receive antenna. The term n_{ij} is the additive noise modeled as independent complex Gaussian random variables with zero-mean and variance 1/(2SNR) per complex dimension, where SNR is the signal to noise ratio of the channel [9].

If the symbols y_{11}, y_{12}, y_{13}, y_{21}, y_{22}, y_{23}, y_{31}, y_{32} and y_{33} are considered as complex conjugated then we have,

$$
\begin{aligned}
y_{11} &= h_{11}x_1 + h_{12}x_2 + h_{13}x_3 + n_{11}^* \\
y_{21} &= h_{21}x_1 + h_{22}x_2 + h_{13}x_3 + n_{21}^* \\
y_{31} &= h_{31}x_1 + h_{32}x_2 + h_{33}x_3 + n_{31}^* \\
y_{12}^* &= h_{12}^*x_2 - h_{11}^*x_2 + h_{13}x_3 + n_{12}^* \\
y_{22}^* &= h_{22}^*x_1 - h_{21}^*x_2 + h_{23}x_3 + n_{22}^* \\
y_{23}^* &= -h_{22}^*x_1 + h_{23}x_2 + h_{21}^*x_3 + n_{23}^* \\
y_{32}^* &= h_{32}^*x_1 - h_{31}^*x_2 + h_{33}x_3 + n_{32}^* \\
y_{33}^* &= -h_{32}^*x_1 + h_{32}x_2 + h_{31}^*x_2 + n_{33}^*
\end{aligned}
$$

Matrix representation of the received signal for each channels can be written as,

$$
\begin{bmatrix} y_{11} \\ y_{21} \\ y_{31} \\ y_{12}^* \\ y_{13}^* \\ y_{22}^* \\ y_{23}^* \\ y_{32}^* \\ y_{33}^* \end{bmatrix}
=
\begin{bmatrix}
h_{11} & h_{12} & h_{13} \\
h_{21} & h_{22} & h_{23} \\
h_{31} & h_{32} & h_{33} \\
h_{12}^* & -h_{11}^* & h_{13} \\
-h_{12}^* & h_{13} & h_{11}^* \\
h_{22}^* & -h_{21}^* & h_{23} \\
-h_{22}^* & h_{23} & h_{21}^* \\
h_{32}^* & -h_{31}^* & h_{33} \\
-h_{32}^* & h_{33} & h_{31}^*
\end{bmatrix}
\begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix}
+
\begin{bmatrix} n_{11} \\ n_{21} \\ n_{31} \\ n_{12} \\ n_{13} \\ n_{22} \\ n_{23} \\ n_{32} \\ n_{33} \end{bmatrix}
$$

So the general formation of received signals can be determined as,

$$\mathbf{Y} = \mathbf{H}x + n \qquad (2)$$

Where, **H** is the channel matrix. It is easy to check that the matrix displays the property of orthogonality by computing [14]

$$\mathbf{H}^{\mathbf{H}}\mathbf{H} = (|h_1|^2 + (|h_2|^2 + (|h_3|^2)\ \mathbf{I}_3 \qquad (3)$$

where $\mathbf{I}_3$ is a 3×3 identity matrix.

This connection speaks to the exchange work between the information x of the STBC encoder and the output y of the MIMO channel, where H is the framework of the equal channel shaped by the ST encoder and the MIMO channel. Additionally H is a symmetrical grid over all channel acknowledged. At the receiver, we suppose a perfect CSIR, so we use the Maximal Ratio Combining (MRC) method, joining coefficients being ideally picked equivalently with the complex conjugated proportional channel framework [14].

$$\mathbf{X} = \mathbf{H}^{\mathbf{H}}y \qquad (4)$$

Which can be definite as:

$$\begin{bmatrix}\widetilde{x_1}\\ \widetilde{x_2}\\ \widetilde{x_3}\end{bmatrix}=\begin{bmatrix}h_{11} & h_{21} & h_{31} & h^*_{12} & -h^*_{12} & h^*_{22} & -h^*_{22} & h^*_{32} & -h^*_{32}\\ h_{12} & h_{22} & h_{32} & -h^*_{11} & h_{13} & -h^*_{21} & h_{23} & -h^*_{31} & h_{33}\\ h_{13} & h_{23} & h_{33} & h_{13} & h^*_{11} & h_{23} & h^*_{21} & h_{33} & h^*_{31}\end{bmatrix}\begin{bmatrix}y_{11}\\ y_{21}\\ y_{31}\\ y^*_{12}\\ y^*_{13}\\ y^*_{22}\\ y^*_{23}\\ y^*_{32}\\ y^*_{33}\end{bmatrix}$$

Finally, the combined symbols $\widetilde{x_1}, \widetilde{x_2}, \widetilde{x_3}$ are applied to an old style Maximum-Likelihood(ML) decoder to acquire dependable assessments of the communicated images. Regardless of whether a way is seriously blurred, we may in any case have the option to recuperate the sent images through other proliferation ways.

Here we calculated *snr* (the received signal to noise power ratio) by the formula [11]

$$snr = \mathrm{SNR}/N \sum_{n=1}^{N} |h_n|^2 \qquad (5)$$

where, SNR is the mean signal to noise power ratio.

Again, we calculated channel capacity by the formula [11]

$$C = \log_2[1+snr] \qquad (6)$$

III.SIMULATION AND RESULT

This section represents simulation results where, Receiver Operating Characteristics (ROC) are used to represent the average channel capacity and error probability against different SNR values. Each figures shows that hypothetical results are very close to simulation outcomes. Therefore, it is remarkable that more than 95% confidence level is achieved.

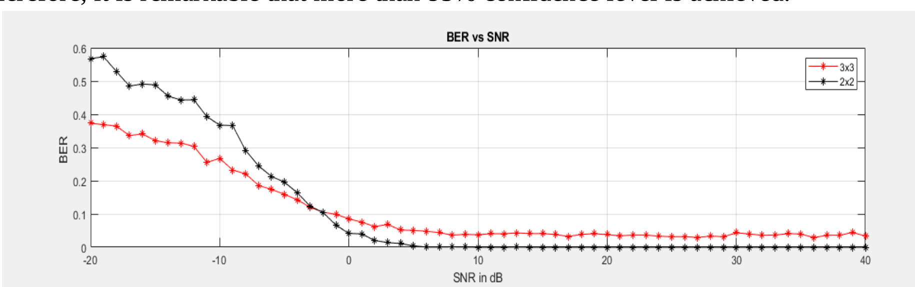

Fig. 2. : Relation between BER and SNR for 2X2 and 3X3 antennas for Alamouti code with QPSK over Rayleigh fading channel.

Fig. 2 shows the impact of SNR values over Rayleigh fading channel for 2X2 and 3X3 antennas. It is observed that, the BER decreasing with increasing SNR for both scenarios but, BER for 3X3 gives better result than 2X2 for each particular point. For instance, when SNR is -10, BER for 2X2 and 3X3 are .38 and .25 respectively. Another remarkable point is, 2X2 produce zero BER for certain time which is unrealistic.

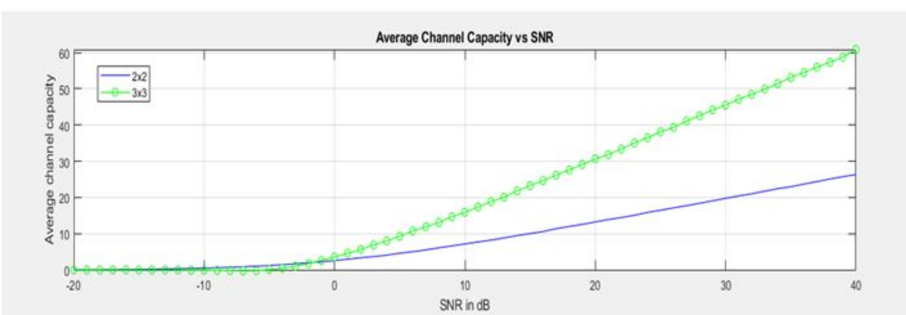

Fig. 3. Relation between average channels capacity vs. SNR over Rayleigh fading channel for 2X2 and 3X3 antennas.

Fig. 3. Represents the comparison of average channel capacity between 2X2 and 3X3 antennas over Rayleigh fading. It is witnessed that, channel capacity start increasing when SNR value is -4 and capacity reach into high level which is nearly 27 when SNR value is 40. On the other hand, 3X3 reaches average capacity at approximately 60. So from the observation, it is noteworthy that, if the number of antenna element grows the capacity will increase for MIMO technique. It increases linearly in proportion to large number of antenna elements. Table 1 and 2 show the performance analysis of 2x2 and 3x3 MIMO framework.

TABLE 1
Performance analysis of 2x2 and 3x3 MIMO framework in terms of BER.

SNR	BER for 2x2	BER for 3x3
-20	.58	.38
-15	.49	.31
-10	.38	.28
-5	.16	.15

TABLE 2
Performance analysis of 2x2 and 3x3 MIMO framework in terms of average channel capacity

SNR	Channel Capacity for 2x2	Channel Capacity for 3x3
0	3	4
10	7	17
30	20	47
40	27	60

IV. CONCLUSION

In wireless communication to transmit data with high rate we need higher bandwidth. In MIMO data can transmit with high rate without additional bandwidth. In this project mathematical equation has been derived for channel capacity and probability error and equation has been simulated by using MATLAB R2019a (version9.6) for measuring the effect of different parameter on MIMO system. The theme of this paper is on the capacity and performance analysis of MIMO antenna systems operating over general and practical propagation channels .There are primary key aspects in the paper is to give a detail investigation on the fundamental capacity limits of several important MIMO channels. Finally we see that 3x3 MIMO system gives better performance for channel capacity and probability of error compared to other systems. By using the optimized value of this parameter a system can be designed which will give better performance in wireless communication.

REFERENCES

[1] Monica Lamba, and Charanjit Singh , "Challenges and Future Direction for MIMO Communication System",SOP TRANSACTIONS ON WIRELESS COMMUNICATIONS ISSN(Print): 2373-8618 ISSN(Online): 2373-8626 Volume 1, Number 2, July 2014.

[2] Sudha Arvind, S.Arvind, Sreekanth, Ramya Smruthi, "MIMO System FER Performance Analysis in Various Fading Environments with OSTBC- TCM Combination", Solid State Technology, Volume: 63 Issue: 5, 2020, pp 4224-4237, Archives Available @ www.solidstatetechnology.us.

[3] Madhavi H. Belsare, Pradeep B. Mane, "BER Performance Evaluation of 2X2, 3X3 and 4X4 Uncoded and Coded Space Time Block Coded (STBC) MIMO System Concatenated with MPSK in Rayleigh Channel", International Journal of Applied Engineering Research ISSN 0973-4562 Volume 13, Number 1 (2018) pp. 113-117.

[4] S. Saminu, Adamu H. Jabire, A. M. Jajere, Abubakar M. Sadiq, R. Zakariyya, "OSTBC-MIMO Performance Evaluation Using Different Modulation Schemes", Journal of Science Technology and Education 8(3), September, 2020, pp 49-58.

[5] G. Fodor et al., "An Overview of Massive MIMO Technology Components in METIS," in IEEE Communications Magazine, vol. 55, no. 6, pp. 155-161, June 2017, doi: 10.1109/MCOM.2017.1600802.

[6] Youjian Liu, Michael P. Fitz and Oscar Y. Takeshita, "Full Rate Space–Time Turbo Codes", IEEE Journal On Selected Areas In Communications, vol. 19, no. 5, pp4, May 2001.

[7] Hamid Jafarkhani," A Quasi-Orthogonal Space–Time Block Code", IEEE Transactions On Communications, vol. 49, no. 1, pp7, January 2001.

[8] Univ. Prof. Dr. Johann Weinrichter and Univ. Prof. Dr. Markus Rupp," Space-Time Block Coding for Multiple Antenna Systems", pp127, November 2005.

[9] Andrej Stefanov And Elza Erkip," Cooperative Space–Time Coding For Wireless Networks", IEEE Transactions On Communications, vol. 53, no. 11, pp13, November 2005.

[10] Ankush Goyal and Rajesh Khanna," Performance analysis of differential detection transmit diversity", Thapar Institute of Engineering and Technology, pp104, June 2006.

[11] J. Vidhya and P. Dananjayan," Analysis of Cooperative STBC MIMO Transmissions in WSN using Threshold Based MAC Protocol", International Journal of Computer Applications (0975 – 8887), vol 3 – no.10, pp9, July 2010.

[12] B. Li, Y. Rong, J. Sun and K. L. Teo, "A Distributionally Robust Linear Receiver Design for Multi-Access Space-Time Block Coded MIMO Systems," in IEEE Transactions on Wireless Communications, vol. 16, no. 1, pp. 464-474, Jan. 2017, doi: 10.1109/TWC.2016.2625246.

[13] L. Wei, Z. Zheng, J. Corander and G. Taricco, "On the Outage Capacity of Orthogonal Space-Time Block Codes Over Multi-Cluster Scattering MIMO Channels," in IEEE Transactions on Communications, vol. 63, no. 5, pp. 1700-1711, May 2015, doi: 10.1109/TCOMM.2015.2419258.

[14] A. Garg, V. Venu and M. R. Bhatnagar, "One Bit Feedback Based Diagonal Precoding for Non-Orthogonal Space-Time Block Codes," in IEEE Wireless Communications Letters, vol. 4, no. 5, pp. 573-576, Oct. 2015, doi: 10.1109/LWC.2015.2464220.

[15] H. Wang, X. Yue, D. Qiao and W. Zhang, "A massive MIMO system with space-time block codes," 2016 IEEE/CIC International Conference on Communications in China (ICCC), Chengdu, 2016, pp. 1-5, doi: 10.1109/ICCChina.2016.7636853.

[16] V. Vakilian and H. Mehrpouyan, "High-Rate and Low-Complexity Space-Time Block Codes for 2X2 MIMO Systems," in IEEE Communications Letters, vol. 20, no. 6, pp. 1227-1230, June 2016, doi: 10.1109/LCOMM.2016.2545651.

[17] Thi My Chinh Chu, Hoc Phan , Hans-Jürgen Zepernick, "Performance analysis of MIMO cognitive amplify-and-forward relay networks with orthogonal space–time block codes" WIRELESS COMMUNICATIONS AND MOBILE COMPUTING Wirel. Commun. Mob. Comput. 2015; 15:1659–1679

[18] Mst Zakia Sultana Lima, Mousumi Saha, Syeda Jannatul Ferdousi, Nasrin Sultana, "Performance analysis of Space Time Block Coding on MIMO system", IJRCEE (ISSN 2319-376X, Vol 3, No 5, 2014.