International Journal of Engineering & Technology, 7 (3.29) (2018) 487-494

International Journal of Engineering & Technology

Website: www.sciencepubco.com/index.php/IJET

Research paper

Performance analysis of BER and channel capacity of MIMO-OSTBC using adaptive modulation techniques

Sudha Arvind [1] *, Dr. S. Arvind [2]

[1] *Assoc. Professor, ECE Department, CMR Technical Campus, Hyderabad*
[2] *Professor, CSE Dept., CMRIT, Hyderabad*
**Corresponding author E-mail: sudharvind99@gmail.com*

Abstract

As per today's scenario the information transmission is needed with highly effective communication in terms of greater speeds of data transmission, more accuracy and high reliability. Multiple-Input Multiple-Output (MIMO) Communication System is more suitable for ro-bust and secure communication with high speed data transmission. Here in this paper how MIMO is more suitable than SISO, SI-MO (Single-Input Multiple-output) and MISO(Multiple-input single-output) is shown in terms of better Channel Capacity and less BER (Bit Error Rate). OSTBC Encoder and Decoders are used for secure communication is estimated and analyzed for BPSK, QPSK with SISO and MIMO(3 outputs and two inputs-3x2 fading channel) Communication System for ½ and ¾ coding rates with AWGN Channel as transmis-sion. Adaptive Quadrature Modulation technique (QAM) is used with M-ary values of 16,24 and 256 for ½ and ¾ coding rates for both SISO and MIMO (3x2 Fading Channel) Communication System. As per the Simulation results BER and Channel capacity per-formances for MIMO are better compared with SISO with Adaptive Modulation Techniques.

Keywords: *Component; SISO; AMUD; MIMO; BER; Channel Capacity; MIMO-QAM.*

1. Introduction

For, communication only one pair of transmitting and receiving antennas called as single input single output (SISO) is used. It cannot serve for high data rate services because of single antenna at both ends of link. To mitigate this, MIMO system is used. In MIMO, array of multiple antennas are used at both the ends, which operates at same frequency and at same time. Using MIMO channel capacity can be increased by availing extra spatial channels with increase spectral efficiency. In order to satisfy the growing demand in terms of high spectral efficiency, high speed data transmission and reliability MIMO concept in terms of multiple antennas at both transmitter and receiver end. MIMO Is one of the technology which suits for next generation networks.

Advanced MIMO Technology is AMUD where adaptive filters are used to have better performance for BER and channel capacity with QAM for Single Input Single Output (SISO) Communication System and MIMO and Adaptive MIMO with 16-QAM, 64-QAM, 256-QAM.

ISSUES: The advances in wireless technology lead to the simultaneous growth in the field of communication by increasing the data speed with high accuracy. It is a very complex task to increase the requirements of a data rate.

So in order to meet these requirements Multiple-Input-Multiple -Output (MIMO) system has been developed.

Adaptive MIMO system uses an adaption algorithm. The number of transmit and receive antennas will change depending on this algorithm and it uses an Orthogonal Space Time Block Codes (OSTBC).These codes using different adaptive modulation techniques in improving channel capacity & reduces the BER.

2. Literature survey

1) MIMO system are established due to the concept of diversity in which information signal transmitted over independent fading path using multiple antenna at transmitted side and same information signal received by multiple antenna at receiver side. In this paper have evaluated the channel capacity of SISO and MIMO system with respect to Rayleigh fading channel.
2) Multiple Input Multiple Output (MIMO) estimates the channel using one antenna at a time for sequence transmission and the other antenna has been kept idle. This present the enhanced adaptive channel estimation technique. Here the simulations are carried out for the performance measure of the adaptive channel estimation technique of the MIMO system for wireless fading channel like Rayleigh channel, AWGN Channel etc.
3) The communication takes place when the receiver identifies the particular message sent by the transmitter. In this era, the wireless communication systems get the request for higher data rates, larger carrier frequencies, greater mobility and better link reliability. The data transmission over wireless channels is possible by finding the BER, which is function of SNR at the receiver side.
4) The transmitter is a 4x4 MIMO antenna mode with Quadrature Amplitude Modulation (QAM) scheme is used to increase the SNR and to decrease the BER of the system. Here channel coefficient is evaluated and BER, FER (Frame Error Rate) and capacity of the channel is improved. Here

10000 bits are given as input. As this whole system operates under scheme, various sub-carriers are allocated in the range of 8, 16 or 32.

5) Normally, for communication one pair of transmitting and receiving antenna called as single input single output (SISO) is used. It cannot serve for high data rate services because of single antenna at both ends of the link. Different QAM techniques are applied to the OFDM system which enhances the BER performance of the OFDM. This improves the system efficiency and reliability. Maximum throughput can be achieved by combining MIMO and OFDM, combination of these two techniques compliments each other for improving system performance.

3. Theoretical back ground

i) Single Input Single Output (Siso)

SISO refers to the regular and wireless configuration both at the transmitter and receiver having single antenna. It is less complex and easier to make. [5]

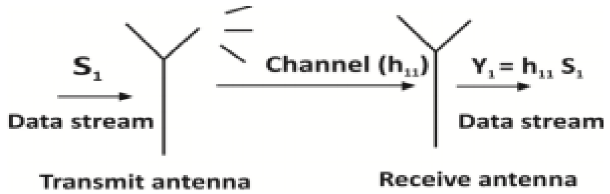

Fig. 1: Single Input-Single Output (SISO) when the Signal is Propagating through an Environment, the Signal Undergoes Fading. the Single Input Single Output (SISO) is Illustrated in Fig.1.

ii) Single Input Multi Outputs (Simo) Simo

Refers to single antenna at the transmitter and Multiple at receiver side. Single Input Multi Output (SIMO) system is shown in fig. 2.For two receiving antennas [3], there will be two received signals y1 and y2 with different fading coefficients h1 and h2. The effect upon the signal s for a given path (from a transmit antenna to a receive antenna) is called a channel.

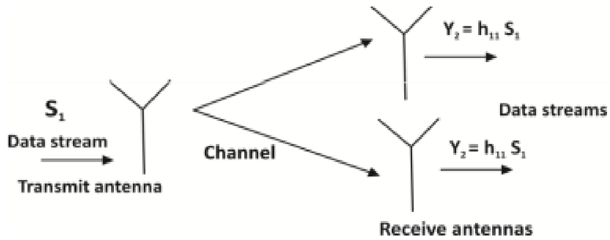

Fig. 2: Single Input Multiple Output.

iii) Multiple Inputs Single Output (Miso) Miso refers to multiple antennas at the transmitter and a single antenna at receiver side [3], as in fig.3.

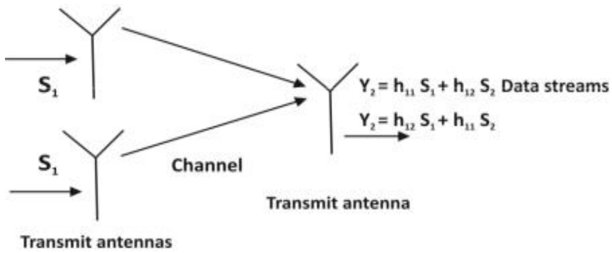

Fig. 3: Multiple Input-Single Output Assume [2] Transmitting Antennas and [1] Receive Antenna. There Will Be One Received Signal.

[3]. In order to separate s1 and s2 we will need to also transmit at different transmit antennas. (iv) MIMO Antenna Configuration (MIMO) MIMO antenna configuration describes that use of multiple transmit and multiple receive antennas [3] for a single user produces higher spectral efficiency and more data rates, as shown in Fig.4. Spatial multiplexing technique, different data streams are transmitted from the different antenna elements, Interference can be reduced easily in the wireless system.

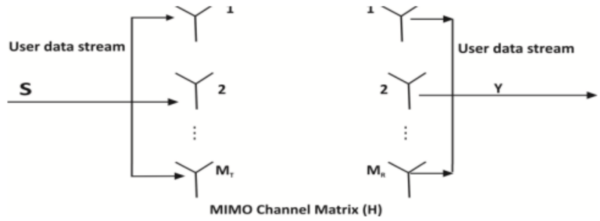

Fig. 4: MIMO Antenna Configuration.

4. Implementation of proposed work

i) Mimo Technology

In MIMO technology multiple antennas are available at transmitter and multiple at receiver side to improve communication system shown in Fig 5. MIMO antenna is regarded as efficient solution to meet the needs of high capacity, assisting fading, improving link reliable without sacrificing bandwidth efficiency.

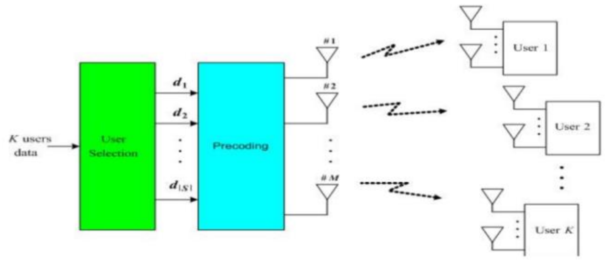

Fig. 5: MIMO System.

ii) Bit Error Rate

In the transmission of digital signal, the BER is the defined as the ratio of number of bits in errors to the total number of transferred bits during certain duration of time interval.

iii) System Model For Siso

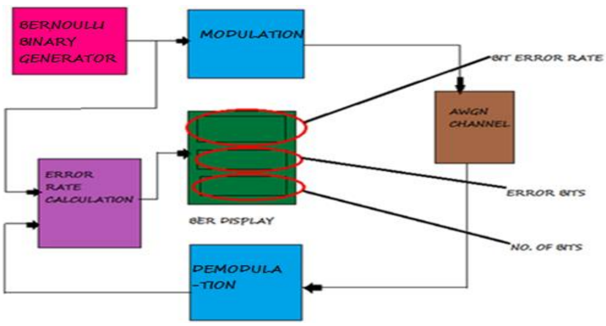

Fig. 6: Simulink Block Diagram for Single Input and Single Output.

iv) System Model For MIMO

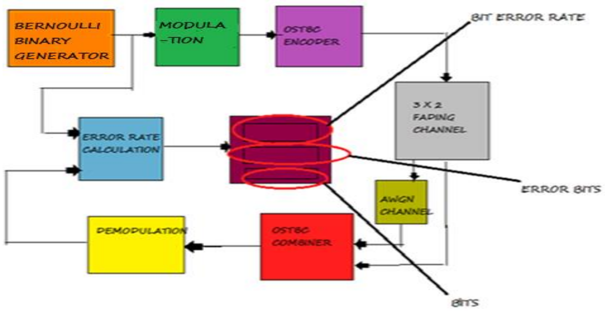

Fig. 7: Designing Block Diagram for Multiple Input and Multiple Output.

BER is a unit less performance measure, mainly expressed in percentage [1]. The bit error probability is the expected value of the BER in any communication system, where there are chances of error due to addition of noise. The BER can be considered as an approximate estimate of the bit error probability. This estimate is accurate for a long time interval and a high number of bit errors. In a communication system, mainly we have two blocks, transmitter and receiver linked through channel. Then at the receiver side BER may be affected by transmission channel noise, interference, distortion, bit synchronization problems, attenuation, wireless The definition of bit error rate[6] can be translated into a simple formula: BER = number of errors / total number of bits sent .If the medium between the transmitter and receiver is good and the signal to noise ratio is high, then the bit error rate will be very small - possibly insignificant and having no noticeable effect on the overall system However if noise can be detected, then there is chance that the bit error rate will need be considered. multipath fading, etc.

v) Channel Capacity:

Channel capacity is the maximum upper limit on the rate of information that can be reliably transmitted over a communications channel [1]. Channel capacity can be affected by the noisy-channel coding theorem, the channel capacity of a given channel is the limited information rate (in units of information per unit time) that can be achieved with arbitrarily small error probability. Here in the paper we tried to improve Channel capacity with M-QAM. The unit of channel capacity is bits/sec/Hz.

Channel is a medium to forward information from source to destination. During this process, the information at destination may be distributed by noise as well as channel distortion [7]. Here the two parameters are different in nature because channel distortions are fixed function while the noise is statistical and unpredictable in nature. Here, we are considering discrete time additive white Gaussian noise (AWGN) channel [4]. Here, g (t) is input and w (t) is output signal. [1] The relation between input and output signal after transmitting through the channel is given by, w (t) = g (t) + N (t) Channel Capacity formula can be given as: $C = B \log_2(1+SNR)$ This is for SISO System. Where, C = channel capacity SNR = Signal to Noise Ratio,B = Bandwidth in Hzs[5]. For the SIMO system, we have M antennas at the receiver end. Suppose the signals received on the antennas have the same amplitude on average. Then they can be added coherently to produce M^2 times increase in the signal power. Hence, the channel capacity becomes, $C = B \log_2 (1+ M \cdot SNR)$ For the MISO system, we have N transmitting antennas. The total transmitted power is divided into N branches. There is only one receiving antenna and the noise level is the same s in the SISO case.Thus channel capacity for this case is $C = B \log_2 (1+ N \cdot SNR)$. By analysing the above equation, it can be concluded that the channel capacity for the MIMO system is higher.

5. Results and discussions

5.1. Roposed method results

In the block diagram shows that data is generated from Bernoulli Binary Generator, and Bernoulli Binary will generates 192 samples per frame. Also modulation techniques i.e., BPSK will be generated here, Then this will map the signal according to M-ary number. Then the signal will be given to the AWGN channel and demodulation techniques i.e., BPSK, will be generated and error bits are calculated and displayed. Hence the values are tabulated in table 2.

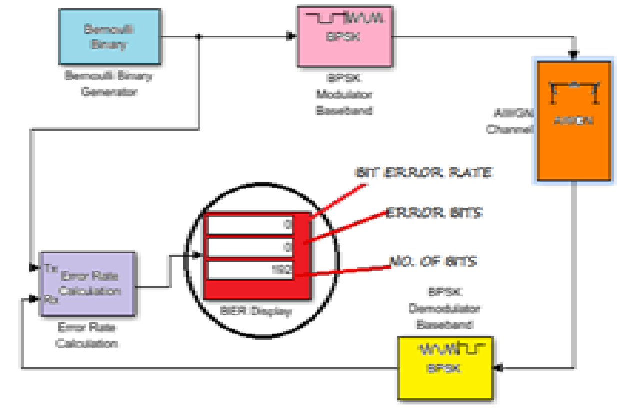

Fig. 8: BPSK with SISO.

In the block diagram shows that data is generated from Bernoulli Binary Generator, and Bernoulli Binary will generates 192 samples per frame. Also modulation techniques i.e., QPSK generation takes place, Based on M-ary number signal will be mapped Then the signal will be given to the AWGN channel and demodulation techniques i.e., QPSK, will be generated and error bits are calculated and displayed. Hence the values are tabulated in table 1

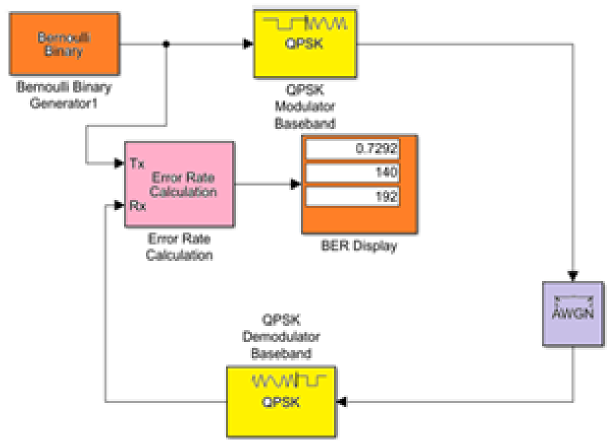

Fig. 9: QPSK with SISO.

Table 1: Simulink Values for QPSK with SISO

Snr	Ber	Fault Bits	No.Of Bits
-10	0.7509	7641	1.018e+04
-8	0.7503	7635	1.018e+04
-6	0.7486	7618	1.018e+04
-4	0.7464	7595	1.018e+04
-2	0.745	7581	1.018e+04
0	0.7429	7560	1.018e+04
2	0.7409	7539	1.018e+04
4	0.7351	7480	1.018e+04
6	0.7301	7429	1.018e+04
8	0.7219	7346	1.018e+04
10	0.7131	7257	1.018e+04

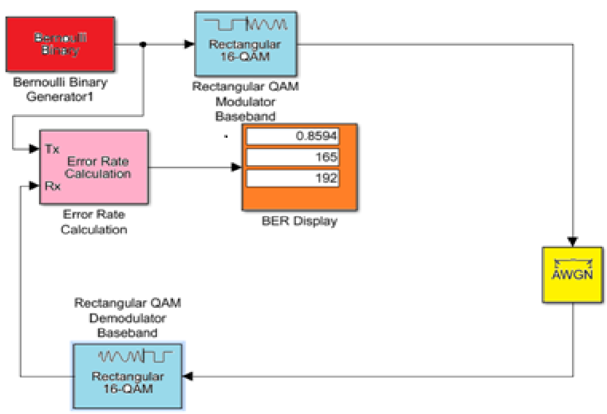

Fig. 10: 16-QAM with SISO.

Table 2: Simulink Values for BPSK with SISO

Snr	Ber	Fault Bits	No.of Bits
-10	0.3125	60	192
-8	0.2604	50	192
-6	0.2604	50	192
-4	0.1823	35	192
-2	0.1354	26	192
0	0.06731	13	192
2	0.04688	9	192
4	0.005208	1	192
6	0	0	192
8	0	0	192
10	0	0	192

In the block diagram of fig.10 shows that data is obtained from Bernoulli Binary Generator, and Bernoulli Binary will generates 192 samples per frame. Also modulation techniques i.e., 16-QAM will be generated here, then signal will be mapped based on M-ary number. Then the signal will be given to the AWGN channel and demodulation techniques i.e., 16-QAM, will be generated and error bits are calculated and displayed. Hence the values are tabulated in table 3.

Table 3: Simulink Values for 16-QAM WITH SISO

SNR	BER	FAULT BITS	NO.OF BITS
-10	0.8634	8786	1.018e+04
-8	0.8615	8767	1.018e+04
-6	0.8601	8752	1.018e+04
-4	0.8573	8724	1.018e+04
-2	0.8543	8693	1.018e+04
0	0.851	8660	1.018e+04
2	0.8475	8624	1.018e+04
4	0.8414	8562	1.018e+04
6	0.328	8475	1.018e+04
8	0.8216	8361	1.018e+04
10	0.8108	8251	1.018e+04

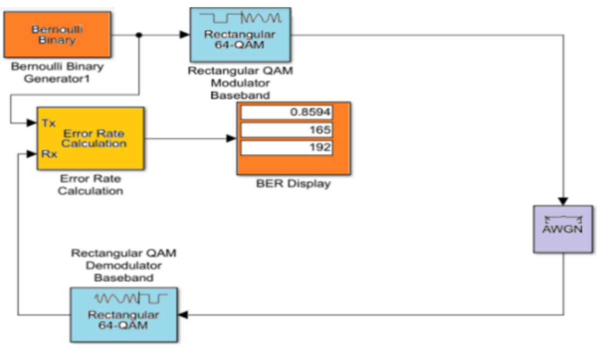

Fig. 11: 64-QAM with SISO.

In the block diagram shows that data is generated from Bernoulli Binary Generator, and Bernoulli Binary will generates 192 samples per frame. Also modulation techniques i.e., 64-QAM will be generated here, then this will map the signal according to M-ary number. Then the signal will be given to the AWGN channel and demodulation techniques i.e., 64-QAM, will be generated and error bits are calculated and displayed. Hence the values are tabulated in table 4.

Table 4: Simulink Values for 64-QAM WITH SISO

SNR	BER	FAULT BITS	NO.OF BITS
-10	0.8634	8786	1.018e+04
-8	0.8615	8767	1.018e+04
-6	0.8601	8752	1.018e+04
-4	0.8573	8724	1.018e+04
-2	0.8543	8693	1.018e+04
0	0.851	8660	1.018e+04
2	0.8475	8624	1.018e+04
4	0.8414	8562	1.018e+04
6	0.328	8475	1.018e+04
8	0.8216	8361	1.018e+04
10	0.8108	8251	1.018e+04

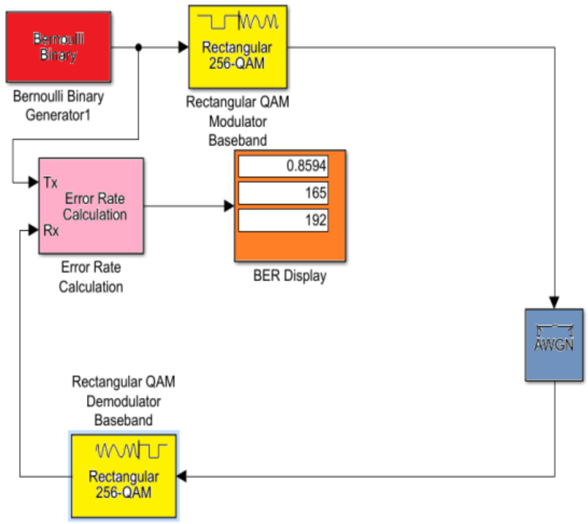

Fig. 12: 256-QAM with SISO.

In the block diagram shows that data is generated from Bernoulli Binary Generator, and Bernoulli Binary will generates 192 samples per frame. Also modulation techniques i.e., 256-QAM will be generated here, then this the signal will be mapped based on M-ary number. Then the signal will be given to the AWGN channel and demodulation techniques i.e., 256-QAM, will be generated and error bits are calculated and displayed. Hence the values are tabulated in table 5.

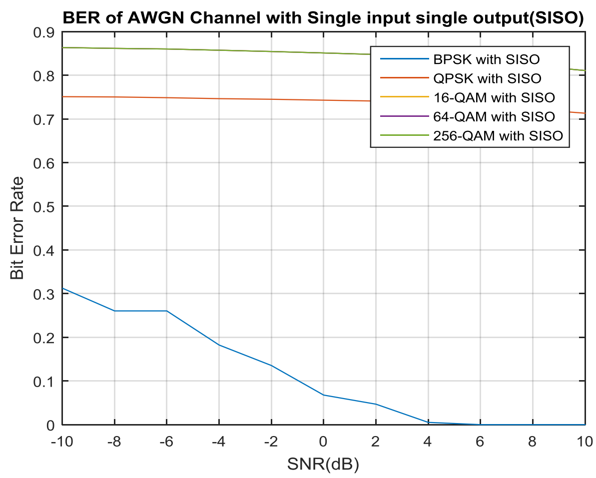

Fig. 13: BER of AWGN Channel with SISO by Using BPSK, QPSK, 16, 64,256-QAM

Table 5: Simulink Values for 256-QAM with SISO

SNR	BER	FAULT BITS	NO.OF BITS
-10	0.4401	384	169
-8	0.3906	384	150
-6	0.3438	384	132
-4	0.2682	576	103
-2	0.2222	576	128
0	0.1753	576	101
2	0.1042	960	100
4	0.0447	2304	103
6	0.2208	4800	106
8	0.008485	1.19e+04	101
10	0.002644	3.782e+04	100

Hence in above graph shows the comparison between the BER of AWGN channel with SISO by using BPSK,QPSK,QAM-16,64,256.we observe that 64-QAM and 256-QAM graph is overlapping because there is a same Bit Error Rate.

5.2. Proposed results for MIMO

In the block diagram shown in fig.14 consists of MIMO (3X2 fading channel) shows that data is generated from Bernoulli Binary Generator, and Bernoulli Binary will produce 192 samples per frame with modulation techniques BPSK will be generated here. Then the signal will be given to the Encoder of OSTBC, transmit antennas number will be decided and also more than 2 then number of antennas code rate is also decided here (i.e., 1/2,3/4). Error rate calculation block calculates the error bits and BER Display is used to display the Bit error rate, Error bits and Number of bits. Hence values are tabulated in table 6.

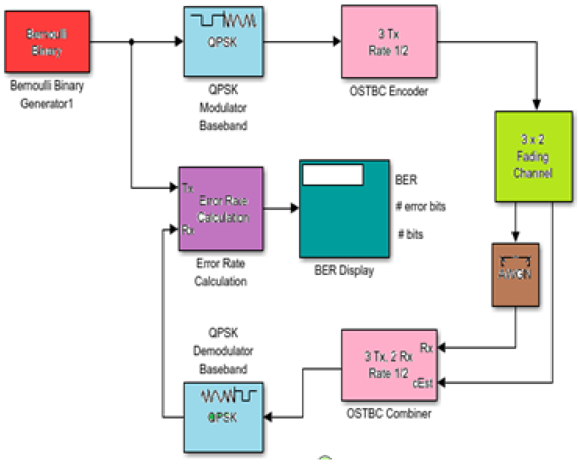

Fig. 14: BPSK with MIMO (½ Coding Rate).

Table 6: Simulink Values for BPSK with MIMO (Coding Rate-1/2)

SNR	BER	FAULT BITS	NO.OF BITS
-10	0.8634	8786	1.018e+04
-8	0.8615	8767	1.018e+04
-6	0.8601	8752	1.018e+04
-4	0.8573	8724	1.018e+04
-2	0.8543	8693	1.018e+04
0	0.851	8660	1.018e+04
2	0.8475	8624	1.018e+04
4	0.8414	8562	1.018e+04
6	0.328	8475	1.018e+04
8	0.8216	8361	1.018e+04
10	0.8108	8251	1.018e+04

In the block diagram shown in fig.15consists of MIMO (3X2 fading channel) shows that data is generated from Bernoulli Binary Generator, and Bernoulli Binary will produce 192 samples per frame with modulation techniques BPSK will be generated and in OSTBC Encoder using with 3/4 coding rate. BER Display is used to display the Bit error rate, Error bits and Number of bits. Hence values are tabulated in table 7.

Table 7: Simulink Values for BPSK with MIMO (Coding Rate-3/4)

SNR	BER	FAULT BITS	NO.OF BITS
-10	0.3411	384	131
-8	0.3073	384	118
-6	0.2682	384	103
-4	0.1823	576	105
-2	0.1341	768	103
0	0.1753	576	101
2	0.1042	960	100
4	0.2251	4608	104
6	0.01042	9792	102
8	0.0029	3.45e+04	103
10	0.000643	1.55e+05	100

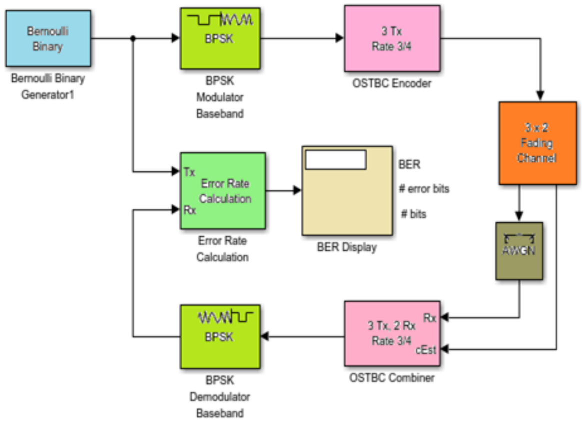

Fig. 15: BPSK with MIMO (3/4 Coding Rate).

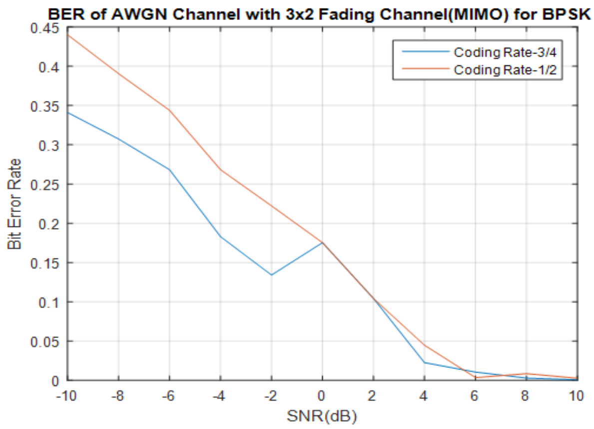

Fig. 16: BER Vs SNR for BPSK Technique Fig. 16 Gives Variation of BER for Various Values of SNR for ¾ and ½ Coding Rate.

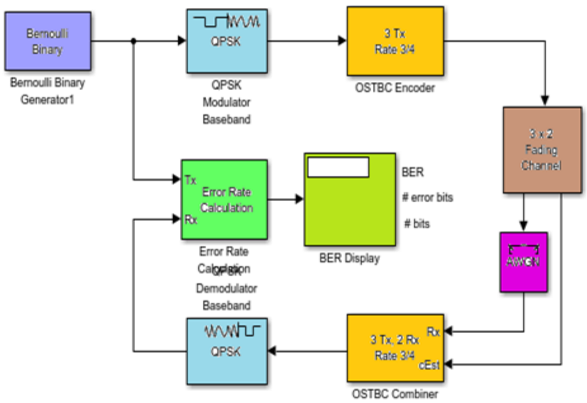

Fig. 17: QPSK with MIMO (¾ Coding Rate).

Table 8: Simulink Values for QPSK WITH MIMO (CODING RATE-3/4)

SNR (dB)	BER	FAULT BITS	NO.OF BITS
-10	0.6468	124	192
-8	0.6354	122	192
-6	0.599	115	192
-4	0.526	101	192
-2	0.4193	161	384
0	0.3229	124	384
2	0.1823	105	576
4	0.1419	109	768
6	0.6198	119	1920
8	0.02629	106	4032
10	0.00947	100	1.056e+04

In the block diagram shown in fig.17consists of MIMO (3X2 fading channel) shows that data is generated from Bernoulli Binary Generator, and Bernoulli Binary will produce 192 samples per frame with modulation techniques QPSK will be generated and in OSTBC Encoder using with 3/4 coding rate. BER Display is used to display the Bit error rate, Error bits and Number of bits. Hence values are tabulated in table 8.

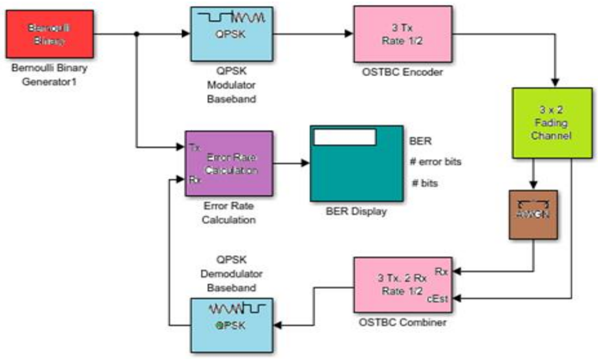

Fig. 18: QPSK with MIMO (1/2 Coding Rate).

In the block diagram shown in fig.18 consists of MIMO (3X2 fading channel) shows that data is generated from Bernoulli Binary Generator, and Bernoulli Binary will produce 192 samples per frame with modulation techniques QPSK will be generated and in OSTBC Encoder using with 1/2 coding rate. BER Display is used to display the Bit error rate, Error bits and Number of bits. Hence values are tabulated in table 9.

Table 9: Simulink Values for QPSK with MIMO (Coding Rate-1/2)

SNR	BER	FAULT BITS	NO.OF BITS
-10	0.7092	100	141
-8	0.641	100	156
-6	0.5706	101	177
-4	0.5025	101	201
-2	0.3876	100	258
0	0.2646	100	378
2	0.1182	100	846
4	0.05066	100	1974
6	0.01926	100	5193
8	0.007234	100	1.382e+04
10	0.001844	100	5.424e+04

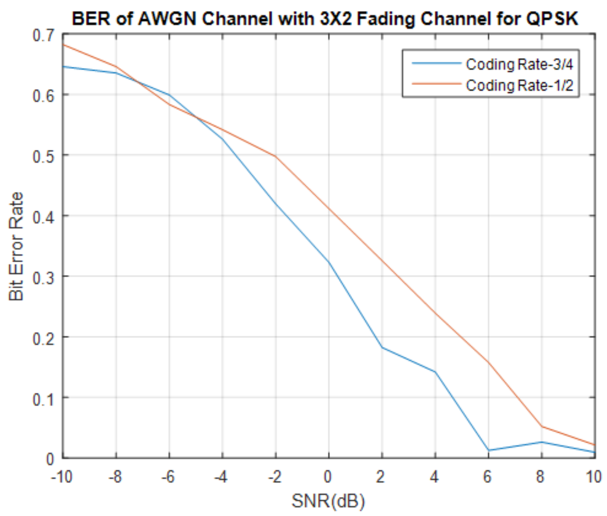

Fig. 19: BER vs SNR for QPSK.

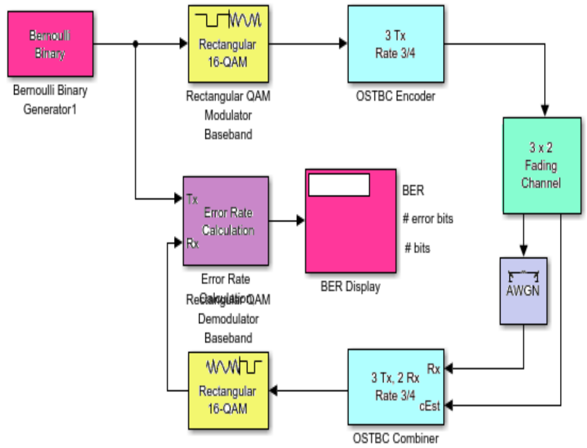

Fig. 20: 16 QAM with MIMO (¾ Coding Rate)

Table 10: Simulink Values for 16-QAM with MIMO (Coding Rate-3/4)

SNR	BER	FAULT BITS	NO.OF BITS
-10	0.6283	131	192
-8	0.6458	124	192
-6	0.5833	112	192
-4	0.5417	104	192
-2	0.4974	191	384
0	0.4115	158	384
2	0.3255	125	384
4	0.239	138	576
6	0.1576	121	768
8	0.05208	100	1920
10	0.02146	103	4800

In the block diagram as shown in fig.20 consists of MIMO (3X2 fading channel) shows that data is generated from Bernoulli Binary Generator, and Bernoulli Binary will produce 192 samples per frame with modulation techniques 16-QAM will be generated and in OSTBC Encoder using with 3/4 coding rate. BER Display is used to display the Bit error rate, Error bits and Number of bits. Hence values are tabulated in table 10.

In the block diagram as shown in fig.21consists of MIMO (3X2 fading channel) shows that data is generated from Bernoulli Binary Generator, and Bernoulli Binary will produce 192 samples per frame with modulation techniques 64-QAM will be generated and in OSTBC Encoder using with 3/4 coding rate.

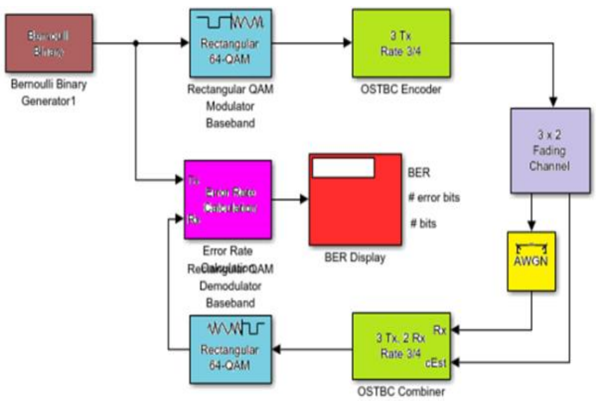

Fig. 21: 64 QAM with MIMO (3/4 Coding Rate).

BER Display is used to display the Bit error rate, Error bits and Number of bits. Hence values are tabulated in table 11.

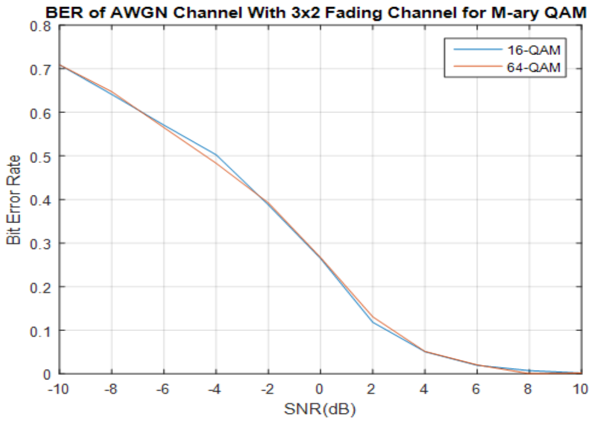

Fig. 22: BER vs. SNR for 16-QAM and 64-QAM (III) Channel Capacity.

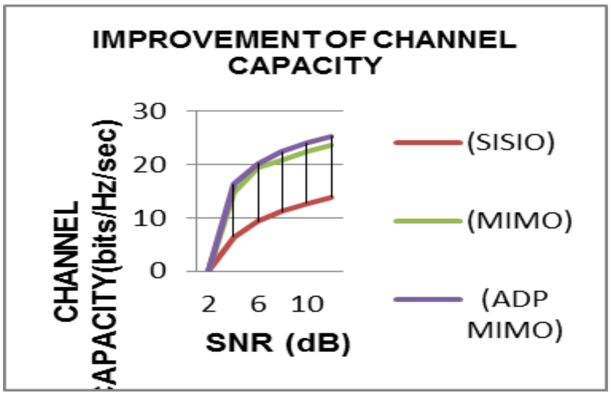

Fig. 23: Improvement of Channel Capacity for Adaptive MIMO.

Variation of Channel Capacity for SISO, MIMO and Adaptive MIMO for various SNR values is shown in Table 12 and graphs plotted as shown in figure 23.

Table 11: Simulink Values for 64-QAM with MIMO (Coding Rate-3/4)

SNR	BER	FAULT BITS	NO.OF BITS
-10	0.7092	100	141
-8	0.6474	101	156
-6	0.565	100	177
-4	0.4831	100	207
-2	0.3922	100	255
0	0.2667	100	375
2	0.1307	100	765
4	0.05117	101	1974
6	0.02033	100	4920
8	0.008034	100	1.245e+04
10	0.001914	100	5.224e+04

Table 12: SNR vs Channel Capacity

SNR (dB)	Channel capacity (SISIO)	MIMO	ADP MIMO
0	0	0	0
2	6.33	14.8	16.34
4	9.28	19.43	20.17
6	11.22	20.83	22.45
8	12.679	22.45	24.08
10	13.83	23.72	25.35

6. Conclusion

Compared to SISO the Bit Error Rate in MIMO system is less. The BER performance analysis shows that Adaptive modulation technique is having better Performance. Both SISO and AMIMO are Analysed. And observed that BER performance of MIMO systems is good compared to SISO. As in SISO system only one signal is transmitted, if that signal fades too much then data from that signal will be lost. While in MIMO system multiple copies of signal are transmitted, so if one signal fades too much then another signal data will be used. So the average SNR value is calculated and that value is used for further transmission. To avoid average value of SNR, adaptive modulation is used. Adaptive modulation when used with MIMO system it gives better performance than both MIMO and SISO systems. MIMO System BER Performance is analyzed with ½ coding rate and ¾ coding rate for16-QAM, 64-QAM.

References

[1] Palak K. Patel1 , Darshankumar C. Dalwadi2 , Hiren J. Patel3 , Anita N. Bhatt4 "Channel Capacity of MIMO System in Rayleigh Fading Channel with Receiver Diversity Technique" International Conference on Research and Innovations in Science, Engineering &Technology Volume 1, Feb 2017.

[2] Milendrakumar M. Solanki and J.M. Rathod2" Performance Measures of Adaptive Channel Estimation methods for Enhanced MIMO" International Journal of Applied Engineering Research ISSN 0973-4562 Volume 12, March 2017.

[3] Vijay Prakash Singh, Anubhuti Khare and Ajay Somkunwar "To Improve the BER and Channel Capacity Through the Implementation of Differential Noise Shift Keying Using Matlab" Indian Journal of Science and Technology, Vol 10(9), March 2017.

[4] Dhanalakshmi P, Divya D, Jenny Niveditha G "BER Analysis for Quadrature Amplitude Modulation in MIMO System" Vol-3 Issue-2 2017.

[5] Lanjewar Rajesh Krushnarao1, Akhila S2 "Performance Analysis of MIMO Systems for Wireless Communication using Adaptive Modulation Technique" International Journal of Science and Research (IJSR) Volume 5 Issue 8, August 2016.

[6] Mr. Bhavesh Khasdev Mrs. Angeeta Hirwe "Performance Analysis of Adaptive MIMO OFDM System" International Journal of Advanced Research in Electronics and Communication Engineering (IJARECE) Volume 5, Issue 7, July 2016.

[7] Mohammed B. Shukur, Younis M. Abbosh "Data Throughput Maximization for Moving Receiver Using Adaptive Modulation with OFDM System" International Journal of Engineering and Innovative Technology (IJEIT) Volume 6, Issue 3, September 2016.

[8] Dr. K Padma Raju Dr. N. Bala Subrahmanyam Assistant Professor Professor & Director of DAP Professor & HOD G V P College of Engg. (A) J N T U University "Bit Error Rate Performance Analysis of Channel Estimated Adaptive OFDM System" International Journal of Computer Science and Information Security (IJCSIS), Vol. 14, No. 2, February 2016.

[9] C.Padmaja, Dr.B.L.Malleswari "Performance Analysis of Adaptive MIMO OFDM Systems" International Journal of Emerging Engineering Research and Technology Volume 3, Issue 12, December 2015.

[10] Peng Xu, Jiangzhou Wang, "Analysis and Design of Channel Estimation in Multicell Multiuser MIMO OFDM Systems", IEEE Transactions on Vehicular Technology, Vol.64, No.2, February 2015.

[11] Vishal Sharma and Gurpreet Singh "BER Analysis of MIMO-OFDM System Using Various Modulation Schemes" International Conference on Communication, Computing & Systems (ICCCS–2014).

[12] Muthanna Jaafar abbas, Mukesh Kumar & A. K. Jaiswal "Enhancement Of The Channel Capacity Using MIMO Technology For Wireless Transmission System" International Journal of Electronics, Communication ISSN(P): 2249-684X; Vol. 4, Issue 3, Jun 2014.

[13] Md. Mahmudul Hasan, "Fine-tuning of k in a K-fold Multicast Network with Finite Queue using Markovian Model", International Journal of Computer Networks and Communications (IJCNC), ISSN: 0974 - 9322; March 2013.

[14] Nazia Parveen;D.S Venkaleshwarle "Multipath Interference Cancellation in MIMO Mobile cellular System", International Journal of Distributed and parallel System vol.3,No.3 ,May2012.

[15] Shruti Trivedi, Mohd. Sarwar Raeen, Shalendra Singh pawar "BER Analysis of MIMO-OFDM System using BPSK Modulation Scheme International Journal of Advanced Computer Research Volume-2 Number-3 Issue-5 September-2012.

[16] C.Poongodi; P.Ramya; A.Shanmugam, "BER Analysis of MIMO-OFDM system using M-QAM over Rayleigh Fading Channel.", Proceedings of the international Conference on Communication and Computational Intelligence-2010 Oct.

[17] Love D.J., Heath R.W. Jr. Limited feedback unitary precoding for orthogonal space-time block codes // IEEE Trans. on Signal Processing. – 2005. – V.53. – Issue 11. – P 64.
[18] Badic B., Rupp M., Weinrichter H. Adaptive Channel – Matched Extended Alamouti Space-Time Code Exploiting Partial Feedback // ETRI Journal. – Oct. 2004. – V. 26. – № 5. – P. 443.