Performance Analysis of Adaptive MIMO OFDM System over Adaptive SISO OFDM System

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Abstract:— *The* need of any communication system is high data speed with higher accuracy and reliability. Orthogonal Frequency Division Multiplexing (OFDM) provides optimistic solution for achieving high data rates in wireless environment. Orthogonal frequency division multiplexing (OFDM) is one of the multicarrier modulations, in which all of the sub channels are dedicated to a single data source In an OFDM transmission system, each subcarrier is attenuated individually under the frequency-selective and fast fading channel. If the same fixed transmission scheme is used for all OFDM subcarriers, it results in high attenuation and hence poor performance. Multiple input multiple output (MIMO) communication systems when integrated with the OFDM system can obtain high data rate transmission over broadband wireless channels. The purpose of this paper is to compare adaptive single input single output (ASISO) -OFDM with adaptive multiple input multiple output(AMIMO) -OFDM system and why MIMO is better than SISO is stated. Based on calculated average instantaneous signal to noise (SNR) same modulation scheme is applied to all subcarriers of same block. Average bit error rate (BER) performance of MIMO-OFDM system under fixed modulation and adaptive modulation is observed. The simulation results show that BER performance of MIMO-OFDM system using adaptive modulation is better than fixed modulation.

Keywords: **-** OFDM, BER, *QAM,ASISO, A*MIMO, SNR.

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I. INTRODUCTION

OFDM is a Multi-Carrier Modulation (MCM) scheme which converts a broadband frequency-selective channel into parallel flat-fading narrowband sub-channels. In a multipath environment, a transmitted symbol takes different time to reach the receiver through different propagation paths. From the receiver's point of view, the channel introduces time dispersion in which the duration of the received symbol is stretched. Extending the symbol duration causes the current received symbol to overlap previous received symbols and results in inter symbol interference (ISI). Cyclic Prefix (CP) is added to each symbol to mitigate the ISI (inter-symbol interference) caused by multipath wireless channel [1], and hence leads to spectral inefficiency. Cyclic prefix also causes ripples in the power spectral density (PSD) of the UWB (Ultra-Wideband) signal thus resulting in a transmit power back-off.

The implementation of Multiple-Input and Multiple-Output (MIMO) has dramatically improved the channel capacity performance of wireless communication system. MIMO systems are equipped with multiple number of antennas at both transmitter and receiver side to improve communication performance. MIMO offers a significant improvement in data throughput without additional bandwidth requirement. This is achieved by higher spectral efficiency and link diversity by reducing fading [8, 11].

Multiple Input Multiple Output (MIMO) and Orthogonal Frequency Division Multiplexing (OFDM) are the two assuring technologies that offers high data rate as required for the 4G wireless systems. Conventionally OFDM is Fast Fourier Transform (FFT) based system. It uses IFFT (Inverse FFT) blocks in the transmitter and FFT blocks in the receiver. OFDM combined with MIMO gives increased throughput and better system performance and hence FFT based MIMO OFDM systems are widely used in 4G wireless schemes.

In a MIMO-OFDM transmission system, each subcarrier is attenuated individually under the frequency-selective and fast fading channel. The channel performance may be highly fluctuating across the subcarriers and varies from symbol to symbol [2]. If the same fixed transmission scheme is used for all MIMO-OFDM subcarriers, the error probability is dominated by the MIMO-OFDM Subcarriers with highest attenuation resulting in a poor performance. Therefore, in case of frequency selective fading the error probability decreases very slowly with increasing average signal-to-noise ratio (SNR) [3].

This problem can be mitigated if different modulation schemes are employed for the individual

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MIMO-OFDM subcarriers. Unlike adaptive serial systems, which employ the same set of parameters for all data symbols in a transmission frame, adaptive MIMO-OFDM schemes have to be adapted to the SNR of the individual subcarriers. This will substantially improve the performance of bit error rate and data throughput of an MIMO-OFDM system.

This paper focuses on performance improvement of MIMO-OFDM system and how adaptive MIMO OFDM system give better performance than SISO OFDM system ,with antenna configuration of 2x2.

This paper is organized as follows. Section 2 describes OFDM System and section 3 describes MIMO System. The adaptive procedure and switching thresholds used in simulation are presented in section 4, the system model is presented in section 5,and section 6 presents results and discussions. Finally conclusion is made in section 7.

II. OFDM SYSTEM

Orthogonal frequency division multiplexing is a multicarrier transmission based on the principle of transmitting data by dividing the stream into several parallel bit streams, each of which has a lower bit rate, and by using several carriers, called also subcarriers, to modulate these sub streams. This avoids the need to have non-overlapping subcarrier channels to eliminate inter-carrier interference. OFDM is being used in a number of wired and wireless voice and data application due to its flexible system architecture. The basic idea behind multi-tone modulation is to replace one wideband signal with many simultaneously transmitted narrowband signals with the same overall bandwidth as the original signal. In principle, the two schemes are equivalent in an AWGN channel. To implement OFDM transmitters and receivers in discrete time, Inverse fast Fourier transform (IFFT) and Fast Fourier transform (FFT) are used respectively.

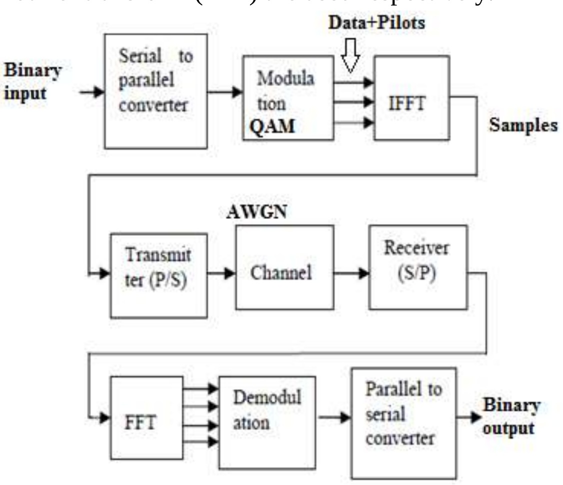

Figure 1. Basic OFDM system

Fig. 1 shows the basic block diagram of an OFDM system. The main concept of OFDM is the Orthogonality of subcarriers. OFDM transmits symbols that have long time duration, which is less or equal to the maximum delay spread. To eliminate ISI, guard intervals are used between OFDM symbols.

III. Comparison of SISO and MIMO SYSTEM

The simplest form of radio link can be defined as SISO - Single Input Single Output as shown in figure 2. This is effectively a standard radio channel - this transmitter operates with one antenna as does the receiver.

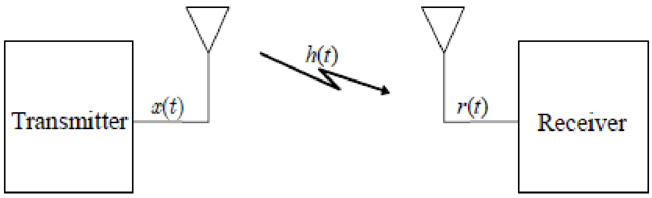

Figure 2. SISO SYSTEM

The advantage of a SISO system is its simplicity. The SISO channel is limited in its performance. Interference and fading will impact the system more than a MIMO system using some form of diversity, and the channel bandwidth is limited by Shannon's law the throughput being dependent upon the channel bandwidth and the signal to noise ratio.

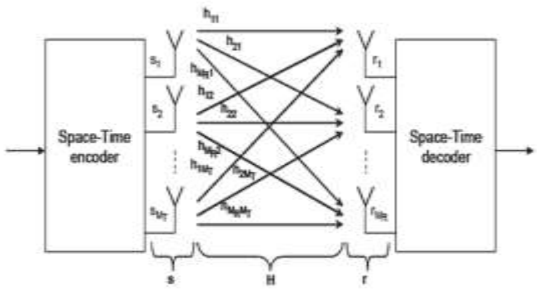

Figure 3. MIMO system

Figure 3 show block diagram of the MIMO system which consists of space time block code and spatial multiplexing which are explained as follows.

1) Space-Time Block Codes: Space-Time Block Codes (STBCs)[8] are the simplest of spatial temporal codes that exploit the diversity offered in systems with several transmit antennas. The transmit diversity technique proposed by Alamouti was the first STBC [7]. The encoding and decoding operation is carried out in sets of two modulated symbols. They are S_1 and S_2 the two modulated symbols that enter the space-time encoder. In the Alamouti[8-11]scheme, during the first time instance t, the symbols S_1 and S_2 are transmitted by the first and the second antenna element, respectively. During the second time instance t_1, the negative of the conjugate of the second symbol, i. e. -S_1^* is sent to the first antenna while the conjugate of the first constellation point. i. e. S_2^* is transmitted from the second antenna. The transmission rate is equal to the transmission rate of a SISO system. The space-time encoding mapping of Alamouti 2x2 can be represented by the coding matrix:

$$S = \begin{bmatrix} S_1 & -S_2^* \\ S_2 & S_1^* \end{bmatrix} \quad (6)$$

The received signals at the time t and t + T can then be expressed as:

$$\begin{aligned} r_1 &= r_1(t) = h_{11}s_1 + h_{21}s_2 + n_1 \\ r_2 &= r_1(t+T) = -h_{11}s_2^* + h_{21}s_2^* + n_2 \\ r_3 &= r_2(t) = h_{12}s_1 + h_{22}s_2 + n_3 \quad (7) \\ r_4 &= r_2(t+T) = -h_{12}s_2^* + h_{22}s_2^* + n_4 \end{aligned}$$

Where r_1, r_3 are the received signals at time t and r_2, r_4 are the received signals at time $t+T$, $n_1, n_{2,} n_3$ and n_4 are complex random variables representing receiver noise and interference. This can be written in matrix form as:

$$r = HS + n \quad (8)$$

where H is the complex channel vector and n is the noise vector at the receiver.

2) Spatial Multiplexing: In spatial multiplexing, a signal is divided into different streams and each stream is transmitted from a different transmit antenna in the same frequency channel. If these signals arrive at the receiver antenna array with sufficiently different spatial signatures, the receiver can separate these streams, creating parallel channels for free. Spatial multiplexing is very powerful technique for increasing channel capacity at higher Signal to Noise Ratio (SNR). It can be used with or without transmit channel knowledge. Consider that we have a transmission sequence, for example S_1, S_2,….., S_n. For 2 transmit antennas, the symbols are group into groups of two. In the first time slot, Signal S_1 and S_2 from the first and second antenna are send . In second time slot, signal S_3 and S_4 from the first and second antenna are send. Two symbols are grouped together and send them in one time slot, but only n /2 time slots to complete the transmission, so data is doubled. Transmission for 2 x 2 MIMO systems can be represented in matrix notation as follows:

$$\begin{bmatrix} r_1 \\ r_2 \end{bmatrix} = \begin{bmatrix} h_{11} & h_{12} \\ h_{21} & h_{22} \end{bmatrix} \begin{bmatrix} s_1 \\ s_2 \end{bmatrix} + \begin{bmatrix} n_1 \\ n_2 \end{bmatrix} \quad \text{………} (8)$$

Where, r_1, r_2 are the received symbol on the first and second antenna respectively, h_{ij} is the channel from i^{th} transmit antenna to j^{th} receive antenna, S_1, S_2 are the transmitted symbols that use first and second constellation mapped respectively and $n_{1,} n_2$ is the noise on 1^{th}, 2^{nd} receive antennas.

IV. ADAPTIVE MODULATION ALGORITHM

In this paper, subband adaptive transmission schemes are employed to reduce the complexity. In this simulation the instantaneous SNR of the subcarrier is measured at the receiver. The channels quality varies across the different subcarriers for frequency selective channels. The received signal at any subcarrier can be expressed as:

$$R_n = H_n X_n + W_n \quad (10)$$

Where $R_n$the channel coefficient at any subcarrier is, X_n is the transmitted symbol and W_n is the Gaussian noise sample. So the instantaneous SNR can be calculated using

$$SNR_n = \frac{H_n^2}{N_0} \quad (11)$$

Where N_0 is the noise variance [7].

The Adaptive algorithm used in this paper is used to provide a better trade off between throughput and overall BER by choosing a more suitable scheme for both sub band. Instead of using the lowest SNR in both sub band, the average value of the SNR of the subcarriers in the sub band is going to be used.

The Figure 4 shows instantaneous SNR of received symbol for fixed MQAM techniques . It shows that when fixed 64QAM is applied to system the instantaneous SNR is less than 8 dB. Similarly when fixed 32QAM is applied to system the instantaneous SNR is in the range 6.5dB to 7.5dB. Also for 16QAM instantaneous SNR is in the range 5.75dB to 6.5dB and for 8QAM instantaneous SNR is in the range 4.5 dB to 5.75dB. For fixed 4QAM ,system response shows that , instantaneous SNR is less than 4.5dB. Hence, it is clear that for higher modulation instantaneous SNR is less as compared to lower modulation and therefore 64QAM is utilized when instantaneous SNR is greater. Hence, from these instantaneous SNR values switching threshold are made for adaptive modulation as shown in Table 1. When instantaneous SNR is good then higher modulation scheme is applied and vice versa.

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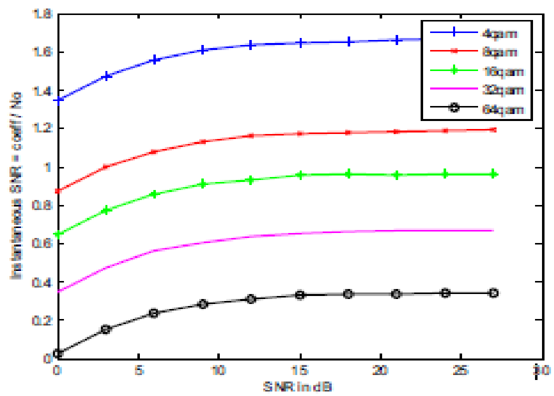

Figure. 4. Instantaneous SNR of fixed modulation[13]

V. SYSTEM MODEL

Figure 5 demonstrates the implementation of MIMO in OFDM system, data is generated from random generator, and random generator will produce 192 samples per frame. Also modulation i.e M-ary number will be generated here, then this signal will go to integer to bit convertor which will convert continues signal into discrete signal. Then this signal will send to Rectangular QAM Modulator which will map the signal according to M ary number. This signal will go to OFDM block, here subcarrier signal ,cyclic prefix, pilots, null vector,FFT size all this parameter calculated here, then this signal will give to OSTBC Encoder, here Number of transmit antennas will be decided , also in no of antennas are more than 2 then code rate is also decided here.

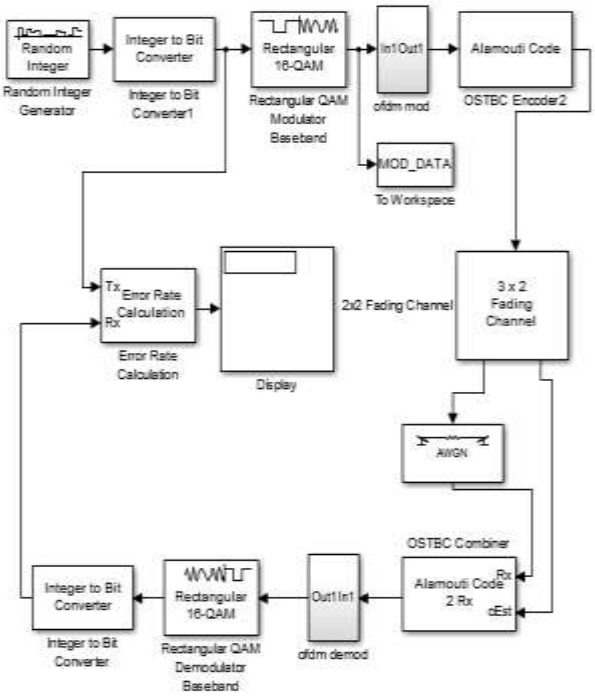

FIGURE 5 .MIMO-OFDM SYSTEM

This total process is nothing but transmitting process, noise will be added to this signal and receiver will receive this signal and then removal of cyclic prefix, null vector and integer to bit convertor all this process will occurs at receiver end.

VI. SIMULATION RESULTS

The switching threshold for activating different modulations can be determined by extensive simulation of the fixed modulation system. The switching algorithm used for the adaptive modulation is presented in Table 1.

TABLE 1.

SWITCHING THRESHOLD FOR ADAPTIVE MODULATION

THRESHOLD	MODULATION
4dB<SNR≤4.5dB	4 QAM
4.5dB<SNR≤5.75dB	8 QAM
5.75dB<SNR≤6.5dB	16 QAM
6.5dB<SNR≤7.5dB	32 QAM
7.5dB<SNR≤8dB	64 QAM

Parameters which are used in MIMO-OFDM system are shown in Table 2. Simulation results of BER for SISO-OFDM and MIMO-OFDM with 4-QAM (2 antenna), 8-QAM(2 antenna), 16-QAM(2 antenna), 64-QAM(2 antenna) are given below, in which red line indicates BER of SISO-OFDM system and blue line indicates BER of MIMO –OFDM system.

TABLE 2 SIMULATION PARAMETER

Parameter	Value
FFT size	256
N_used	200
N_nulls	56
N_pilots	8
N_data	192
M-QAM	4,8,16,32,64
Channel B/width	1.25 MHz
Modulation	M-QAM
Antenna no(N_t,N_r)	2x2
Noise	AWGN
Channel model	Rayleigh fading

In this simulation, the performance of adaptive modulation is investigated in terms of throughput and BER performance. To highlight the advantages of adaptive modulation comparison is made with fixed modulation system

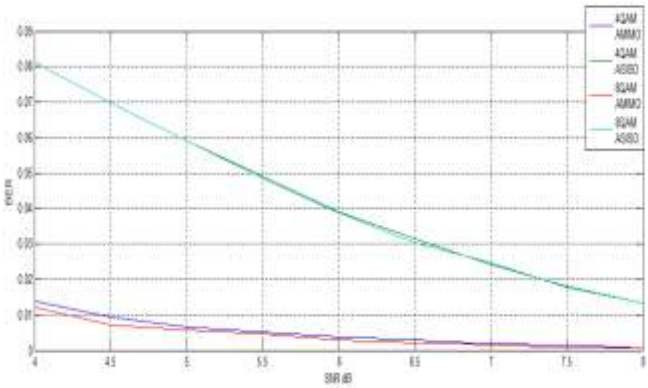

FIGURE 6. BER Comparison for ASISO-OFDM, AMIMO-OFDM and with (NT=NR=2) of 4 ary QAM& 8 ary QAM

Figure 6 demonstrates the correlation of 4QAM with 8 QAM modulations. With increment in estimation of SNR, BER value diminishes .This can be distinguish in above figure where green and light blue line spoke to BER of ASISO framework, though blue and red line speaks to AMIMO framework. This distinction is because of fading , in ASISO only one signal is get transmitted ,if that signal fades a lot, then signal data will be lost, however in AMIMO numerous signal are send , so the lightest influenced signal will be utilized for transmission, this is the essential explanation for BER of AMIMO is not exactly ASISO. BER of 8 QAM is under 4 QAM in light of the fact that when adjustment happens, in 4 QAM just 2 bit get transmitted while in 8 QAM 3 bit get transmitted. So because of this, noise rate get expanded in small bit value transmission though in large bits value transmission noise get disseminated so because of this BER is less occurs. In following all figures same phenomenon is explained.

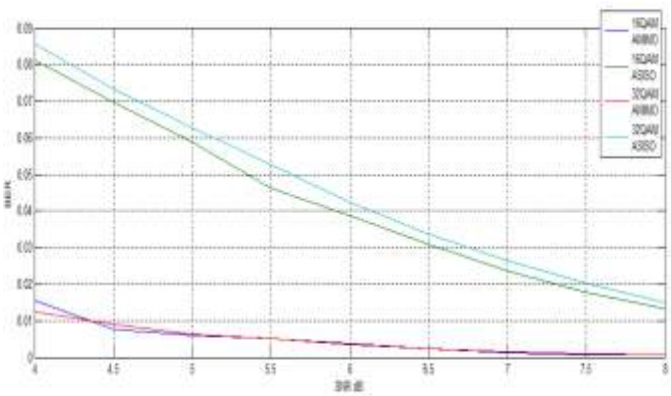

FIGURE 7. BER Comparison for ASISO-OFDM, AMIMO-OFDM and with (NT=NR=2) of 16 ary QAM&32 ary QAM

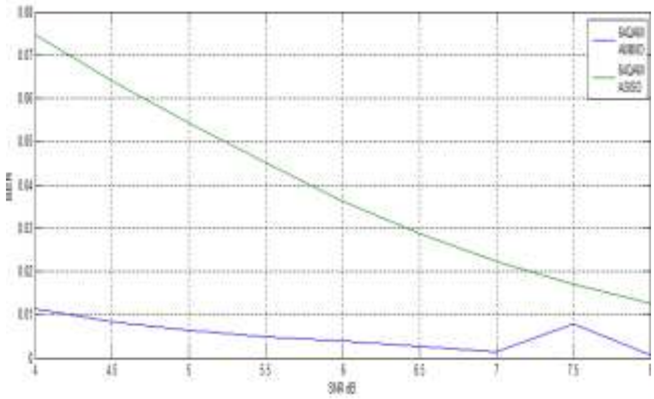

FIGURE 8. BER Comparison for ASISO-OFDM, AMIMO-OFDM and with (NT=NR=2) 64 ary QAM

From the analysis, it can be seen that the as M-ary modulation technique increases, SNR of channel also increases in all examined transmission methods in order to achieve BER target

Table 3 BER value for 4QAM & 8QAM Techniques

SNR	***4QAM AMIMO***	***4QAM ASISO***	***8QAM AMIMO***	***8QAM ASISO***
4	***0.01373***	***0.08124***	***0.01215***	***0.08131***
4.5	***0.009233***	***0.06985***	***0.00726***	***0.06982***
5	***0.006629***	***0.05923***	***0.00584***	***0.05898***
5.5	***0.005208***	***0.04896***	***0.004577***	***0.04858***
6	***0.003788***	***0.03906***	***0.002999***	***0.03881***
6.5	***0.002841***	***0.03135***	***0.00221***	***0.03046***
7	***0.001894***	***0.02416***	***0.001578***	***0.02462***
7.5	***0.00142***	***0.01805***	***0.0006313***	***0.01768***
8	***0.0007102***	***0.01336***	***0.0006313***	***0.01332***

Table 4 BER value for 16 QAM & 32QAM Techniques

SNR	***16QAM AMIMO***	***16QAM ASISO***	***32QAM AMIMO***	***32QAM ASISO***
4	***0.01155***	***0.08128***	***0.01131***	***0.08571***
4.5	***0.006813***	***0.06969***	***0.006186***	***0.07339***
5	***0.005037***	***0.05892***	***0.005155***	***0.06276***
5.5	***0.00409***	***0.0463***	***0.004114***	***0.05264***
6	***0.002906***	***0.03741***	***0.002598***	***0.04232***
6.5	***0.002367***	***0.03099***	***0.002273***	***0.03381***
7	***0.001184***	***0.02375***	***0.001161***	***0.02636***
7.5	***0.0008286***	***0.0178***	***0.0008123***	***0.02013***
8	***0.0005919***	***0.0132***	***0.0005629***	***0.01486***

Table 5 BER value for 64 QAM Techniques

SNR	*64QAM AMIMO*	*64QAM ASISO*
4	*0.01130*	*0.07456*
4.5	*0.006065*	*0.06394*
5	*0.005132*	*0.05421*
5.5	*0.004014*	*0.04501*
6	*0.002467*	*0.03603*
6.5	*0.002183*	*0.02867*
7	*0.001153*	*0.02227*
7.5	*0.007891*	*0.01704*
8	*0.0005524*	*0.01259*

Table 3 shows the comparison BER value for 4QAM & 8QAM Techniques used for adaptive scheme for both MIMO and SISO systems , in the same way Table 4 shows the comparison BER value for 16QAM & 32QAM Techniques and Table 5 shows the BER value for 64QAM Techniques. It shows that BER for adaptive scheme is very less as compared to all other QAM techniques. BER of all QAM techniques get decreased as transmitted bit get increased. From above discussion it can be understood that the proposed Adaptive methodology leads to better BER performance as well as improved Data Rates while compared to the traditional QAM techniques.

VII. CONCLUSION

Adaptive modulation schemes for the both subcarriers in an OFDM transmission system with MIMO and SISO are describe in this paper. The bit error ratio transmitted signal in MIMO system is gradually less than SISO system. Simulations show that for a bit error ratio of 10^{-3} and a signal to noise ratio of 4 to **8** dB can be achieved

In adaptive modulation, modulation rate changes based upon value of an instantaneous SNR. The BER performance comparison between fixed and adaptive modulation shows that BER performance for Adaptive modulation techniques is better than all other modulation technique's.

For all values of IFFT sizes, average BER of Adaptive modulation using MIMO QAM technique is approximately 0.004937 and for SISO QAM technique it is approximately 0.03858 .Hence, it concludes that BER performance of adaptive modulation using MIMO is better than SISO with the cost of more execution time

VIII. REFERENCES

[1] J. A. C Bingham, "Multicarrier modulation for data transmission: An idea whose time has come", IEEE Communication Magazine, vol. 28, no. 5, **(1990)**, pp. 5-14.

[2] A.Sohail and M.N.Jafri, "Adaptive OFDM over Frequency Selective and Fast Fading Channel Using Blockwise Bit Loading Algorithm", *IEEE International Conferenece on Wireless and Optical Communication Networks*,pp. 1-4, July 2007.

[3] A.Cyzlwik, "Adaptive OFDM for wideband radio channels", *Global Telecommunications Conference*, vol 1, pp713-718, Nov 1996.

[4] A. R. Lindsey, "Generalized Orthogonally Multiplexed Communication via Wavelet Packet Bases", Ph.D. Thesis, Ohio University, (1995).

[5] Y.Lei and A.Burr "Adaptive Modulation and Code Rate for Turbo Coded OFDM Transmissions," *Vehicular Technology Conference VTC2007*, pp.2702-2706, 22-25 April 2007

[6] M.I.Rahman, S.S.Das, Y.Wang, F.B.Frederiksen and R.Prasad, "Bit and Power Loading Approach for Broadband Multi-Antenna OFDM System", *IEEE Transactions Communications*, pp. 1689-1693, 2007.

[7] D. Gesbert, M. Shafi, D. -S. Shiu, P. J. Smith and A. Naguib, "From theory to practice: an overview of MIMO space-time coded wireless systems", IEEE Journal on Selected Areas in Communications, vol. 21, Issue 3, **(2003)** April, pp. 281 -302.

[8] S. Mallat, "A Wavelet Tour of Signal Processing", ISBN: 0-12-466606-X; Academic Press, **(1999)**.

[9] R. Chen, J. G. Andrews and R. W. Heath, "Multiuser spacetime block coded MIMO system with unitary downlink precoding", in Proc. IEEE International Conference on Communications, Paris, France, **(2004)** June, pp. 2689–2693.

[10] K. K. Wong, R. D. Murch and K. B. Letaief, "Performance enhancement of multiuser MIMO wireless communication systems", IEEE Transactions on Communications, vol. 50, **(2002)** December, pp. 1960-1970.

[11] L.Hanzo, S.X.Ng, T.Keller and W.Webb. *Quadrature Amplitude Modulation: From Basics to Adaptive Trellis Coded, Turbo Equalised and Space-Time Coded OFDM, CDMA and MC-CDMA Systems*, 2nd Edition, John Wiley&Sons Ltd, 2004.

[12] Yong Soo Cho,Jaekwon Kim,Won Young Yang and Chung –Gu Kang "MIMO-OFDM Wireless Communications"

[13] J.Faezah, K.Sabira]-"Adaptive modulation with OFDM system"- International Journal of communication Networks and Information Security- Vol. 1, No. 2, August 2009.