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MIMO-OFDM SYSTEM PERFORMANCE ANALYSIS USING QUADRATURE AMPLITUDE MODULATION TECHNIQUE

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ABSTRACT

In the present scenario, with the rapid growth of digital communication technology, the demand of wireless technology increases. For fulfill of these demands, new innovative ideas are coming into existence which needs to be implemented. The main need of any communication system is basically high speeds of data transmission with higher accuracy and reliability. Multiple input multiple output (MIMO) provides high-rate transmission through expended channels by multiple array antennas on both sender and receiver side. Also orthogonal frequency division multiplexing (OFDM) is well-known as the most appropriate technique for high data rate transmission. Adaptive modulation and coding (AMC) changes a modulation order and coding rate according to channel conditions, so it is possible that the spectral efficiency is improved at the fixed error performance. Cyclic prefix (CP) is one of the most important techniques in OFDM system and is reducing inter-symbol interference (ISI) effects in high speed wireless mobile communication system. In this paper, a model of MIMO-OFDM system with AMC stated to improve system capacity by reducing error rate has been proposed and QAM is used as AMC technique.

KEYWORDS- *MIMO, OFDM, Adaptive Modulation technique, Quadrature Amplitude Modulation, Inter-Symbol interference*

I. INTRODUCTION

One of the major challenges that modern communication systems are facing today is to cope up with the ever increasing demand for high speed reliable communication with very limited frequency spectrum and power available. High data rate channels are required to fulfill data services in wireless communication. The requirement for high data rate is also increasing nowadays with increasing popularity of fourth generation mobile telephony. Within the power and frequency limits, wireless communication devices should be able to achieve the required reliability to serve at such a high data rate overcoming signal scattering and multipath effects in metropolitan areas. Since this reduces spectral efficiency, multicarrier transmissions wherein several carriers are used to carry the information signal.

In Single Input Single Output (SISO) systems, a pair of transmitting and receiving antenna can't fulfill the demand of higher bandwidth and hence cannot be implemented at higher data rate application over wired and wireless links as only one transmitter and receiver is present. To mitigate this problem Multiple Input Multiple Output (MIMO) system was introduced. MIMO systems are arrays of multiple antennas both at the transmitting and receiving end of the communication link, operating simultaneously at the same frequency. Multiple antennas introduce additional spatial channels on account of which the capacity of the channel increases. Hence increased spectral efficiency without additional bandwidth or transmitter power is achieved.

The Quality of Service (QoS) monitoring at higher data rates is difficult due to limitations of OFDM, such as sensitivity to carrier frequency offset, large Peak Power to Average Power Ratio (PAPR) and fixed modulation scheme leading to poor BER performance. To improve the BER performance, modulation scheme like Adaptive Modulation can be used. To reduce the PAPR most common technique is to adaptively manage transmission parameters such as constellation size and type of error control coding depending on the quality of data received and sent back to the transmitter. This is a way to reduce errors in advance and hence mean throughput increases thereby enhancing the performance.

Adaptive Modulation Coding (AMC) in addition with MIMO-OFDM helps in achieving large amount of spectral efficiency along with reliable communication over fading channel. According to Shannon's formula this leads to an increase in throughput as the Signal to Noise Interference Noise ratio (SNR) increases. AMC in MIMO-OFDM can be used in several ways, one such method is the use of close loop technique that here it is implemented in this work. Adaptive MIMO-OFDM system can be implemented to optimize performance by implying frequency diversity, spatial diversity and spatial multiplexing. At the receiver no specific algorithm is required and hence communication engineers can use their own innovative procedure.

In the context of this paper, the performance of adaptive MIMO-OFDM system has been established through analytical approach. Moreover, the results presented in this work can be a benchmark for performance analysis of different adaptive algorithms. In AMC, most difficult part is to control transmit power, transmit and coding rate, though there are many techniques defined to control the same. But the available techniques do not consider the mathematical properties of MIMO-OFDM channel completely and hence, this thesis aims at presenting statistical analysis of MIMO-OFDM channel and system performance.

OFDM is a multicarrier transmission which works on the principle of data transmission by splitting data into multiple parallel bit streams, each with lower bit rate and with the help of several carriers also called as subcarrier. This eliminates the requirement of non-overlapping subcarrier channel for reducing inter-carrier interference. In addition to this, due of the flexibility of OFDM system architecture, it finds application in several wired and wireless system. Discrete multi-tone modulation is based on OFDM in which original signal is replaced with many simultaneously transmitted narrowband signals. For implementation of OFDM in discrete time, Inverse Fast Fourier Transform at transmitter and Fast Fourier Transform at receiver is used. The symbol which OFDM transmits has long duration and is less than or equal to maximum delay spread. For reduction of inter symbol interference, guard intervals are placed between OFDM symbols. Figure 1 below shows the block schematic of OFDM system architecture.

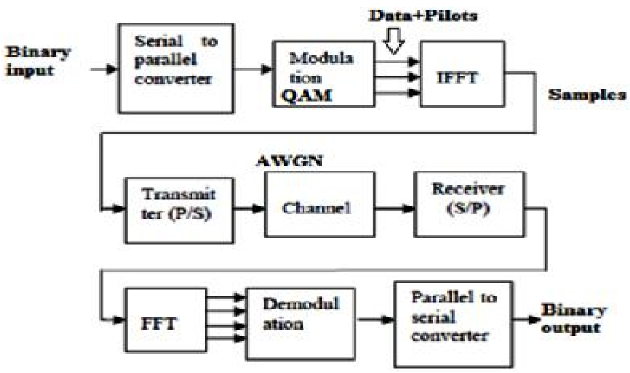

Fig. 1: OFDM system

In the figure1 shown above, binary input is given to the serial to parallel converter which converts the serial data stream into block of data so that it is modulated in orthogonal form. Quadrature modulator selects modulation on the basis of input SNR value. The output signal of QAM modulator is in the form of several parallel bit streams. IFFT converts the signal from time domain to frequency domain. Then the signal travels through the AWGN channel and at the receiver end FFT for converting back the signal to time domain is used. Parallel to serial converter is used for binary output.

In wireless communication signals travel through multiple path which are destructive in nature. This effect is responsible for signal degradation at receiver also called as fading. By using properties of MIMO, capacity of the channel can be increased and the fading of signal is reduced significantly. The capacity of single transmitting antenna increases logarithmically by placing multiple antennas at the receiving end. In MIMO capacity increases linearly with increasing no of antenna at both end of communication channel. MIMO helps in reducing BER of the channel and is most effective way to achieve reliable communication over wireless channel, where receiver is getting multiple replicas of transmitted signal. Within the spectral and power limitations of channel this is achieved with the help of MIMO.

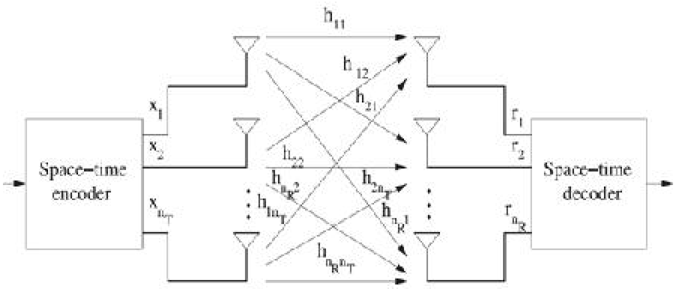

Fig.2 MIMO system

As shown above each transmitting antenna T sending a copy of signal h_{ij} to all R receiving antenna which can be mathematically written as follows.

$$\gamma = \sum_{i=1}^{N}\sum_{j=1}^{M} |h_{ij}|^2 \frac{\varepsilon_x}{\sigma^2 N}$$

Where: γ – Received signal to noise ratio; N – Number of transmitting antennas; σ^2 – Noise variance.

II. RELATED WORK

Yang discussed about wireless access MIMO-OFDM system based on air interface [30] for providing secure communication with bandwidth efficiency and high data rate but it is very much sensitive towards channel estimation error, so at the time of pilots and cyclic prefix insertion precautions is must.

Masayuki Miyashita, Manabu Mikami and Hitoshi Yoshino [31] suggested about Channel Quality Indicator (CQI) generation scheme based on Man Machine Interface (MMI) for cooperative MIMO with AMC in frequency-selective channels but problem was that the CQI generation scheme designed for non-cooperative MIMO scheme may not obtain the optimum CQI value since the transmission signals from adjacent base station are regarded as interference signals. The CQI feedback scheme needs to be enhanced so that transmission signals from adjacent BSs in cooperative MIMO are regarded as desired signals.

J.Faezah, K.Sabira discussed about the enhancement of the OFDM system using Adaptive Modulation for OFDM Systems [32]. He employed convolutional coding to OFDM system and applied adaptive modulation. First, they reviewed performance of OFDM system by analyzing 12 uncoded adaptive modulation techniques using quadrature amplitude modulation (QAM) and phase shift keying (PSK). Then, its BER performance is compared with adaptive modulation and convolution encoding. After implementation of OFDM system improvement in BER was observed.

From the above study it can be concluded that the OFDM system with MIMO along with adaptive coding will give better performance than other individual system.

III. PROPOSED ALGORITHM

Adaptive modulation uses the channel more efficiently as compared with fixed modulation technique. Specifically, change in bit error rate performance will be improved while using adaptive modulation scheme with channel conditions being varied. The first challenge for adaptive modulation is how to change the modulation scheme that is, decision making sense to select particular modulation scheme. At the receiver end for switching, BER can be a potential factor for decision making [27], but in this paper, SNR is used as the metric for switching. Deciding BER value for short duration pulse is not easy and hence to decide which range of SNR is suitable for particular modulation lies in AWGN channel performance of that particular modulation scheme. Hence received signal can be modeled as follows.

$$y(t) = c(t).x(t) + n(t)$$

Where c(t) is the channel coefficients , x(t) is the transmitted signal, and n(t) is the noise signal. In the proposed scheme BER curves for various QAM techniques are considered, and on the basis of that adaptive rules are formulated consisting of data rates, transmitter power and modulation index for various ranges of SNR of the system. The proposed scheme improves BER performance of the OFDM system.

IV. EXPERIMENTAL RESULTS

In this paper, performance of different QAM techniques for MIMO-OFDM systems using the BER analysis tool is measured. Analysis results are compared with each other and then compared with Adaptive QAM methodology. Additionally, the data rates achievable for a required BER are evaluated for all modulation schemes. Finally, it is shown that adaptive methodology applied on MIMO-OFDM system reduces the average BER and also improves overall data rate of the system. The table I contains system parameters required for simulations. BER required for computing minimum performance of adaptive MIMO OFDM system and the BER required for audio communication is same as 10^{-3}. This value is computed by analyzing tabulated simulation results.

The time domain representation of transmitted signal without noise and with addition of noise is shown in figure 3 and figure 4 respectively. The effect of noise on the signal can be observed from these two figures.

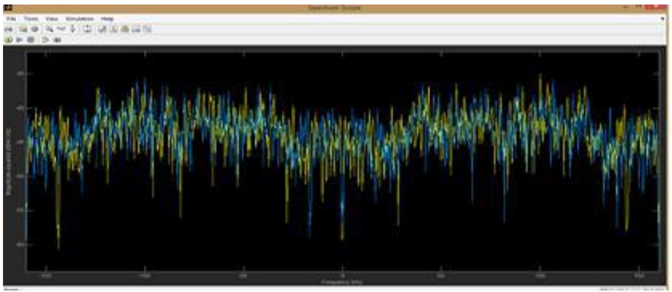

Fig.3 Frequency domain signal (original signal)

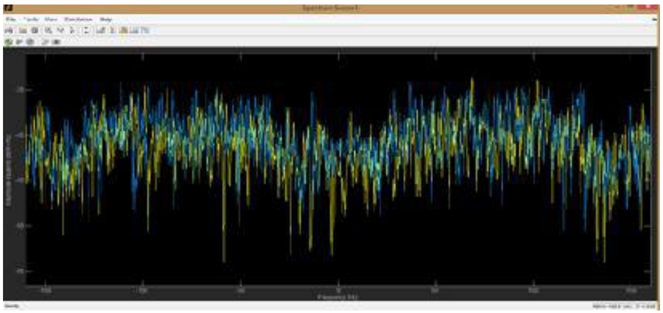

Fig.4 Frequency domain signal (with noise)

Channel performance with different modulation techniques such as 4 QAM, 8 QAM, 16 QAM with AWGN is shown in figures 5(a), 6(a), 7(a) whereas 5(b), 6(b), 7(b) are the constellation diagram of modulation after addition of noise in the signal. In this case OFDM is not minimizing the effect of AWGN channel on the signal. OFDM is reducing the possibility of complete signal loss which can occur due to burst error. With the help of parallel data transfer many parallel data streams are transmitted instead of single data steam of complete signal. Forward Error Correction (FEC) method helps in detecting and correcting error in the signal.

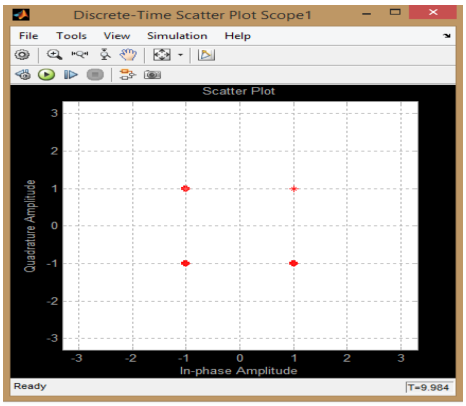

Fig.5 (a): Constellation Diagram of 4QAM

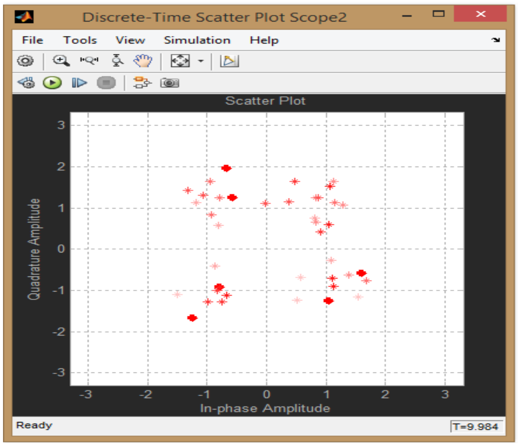

Fig.5 (b): Constellation Diagram of 4 QAM with noise

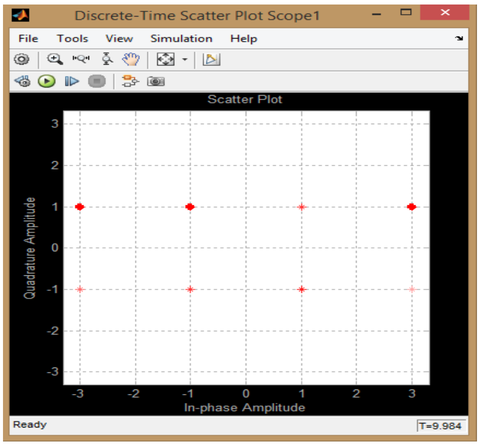

Fig.6 (a): Constellation Diagram of 8 QAM

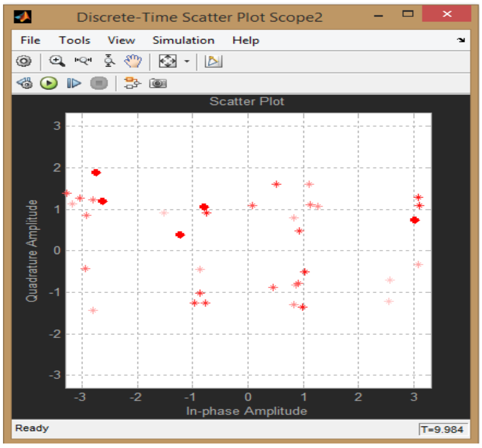

Fig.6 (b): Constellation Diagram of 8 QAM with noise

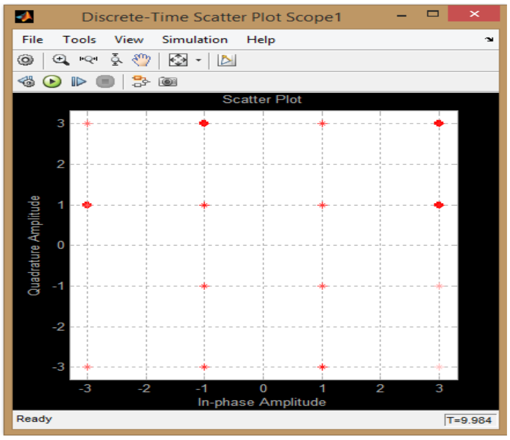

Fig.7 (a): Constellation Diagram of 16 QAM

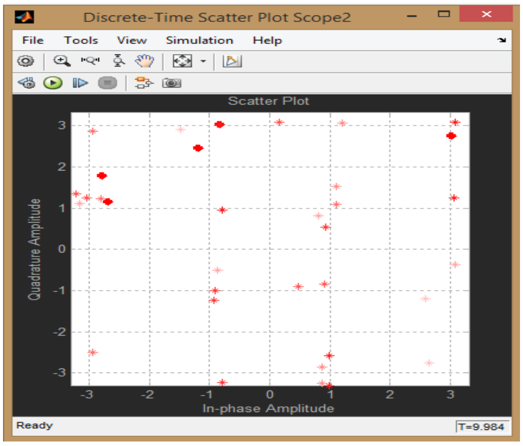

Fig.7 (b): Constellation Diagram of 16 QAM with noise

Constellation diagrams for various M-QAM techniques are shown above in figures 5 to 7 where values of 'M' taken are 4, 8 and 16. As the value of M increases the SNR required also increases to reduce BER for that modulation technique. Hence as M increases, cluster in constellation diagram becomes more concentrated. From figures 5(b), 6(b) and 7(b), it is clear that as value of M increases SNR required also increases which reduces noise and hence BER.

As the signal travels through different paths in fading channel and arrive at receiver following distinct path lengths. Their amplitude and phase are also different. When the signal travels through multipath channel a train of pulses having different amplitude and phase arrives at the receiver. This is shown in below figure 8 and figure 9. Due to multipath effect on transmitted signal all replicas of transmitted signal has different amplitude and phase and their spectral components are also affected because of multipath fading channel.

BER vs SNR comparison for Fading channel and Normal channel for OFDM Using QAM Modulation is shown below.

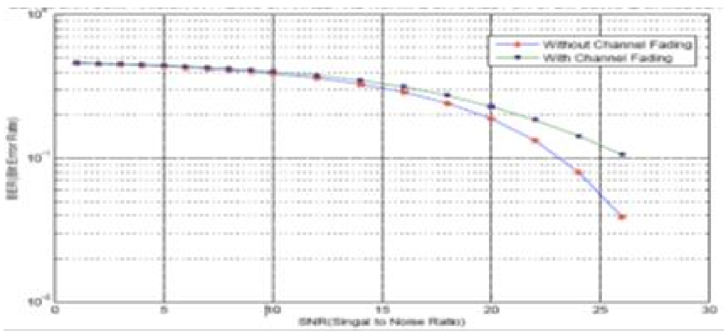

Fig.8 BER v/s SNR in Fading Channel

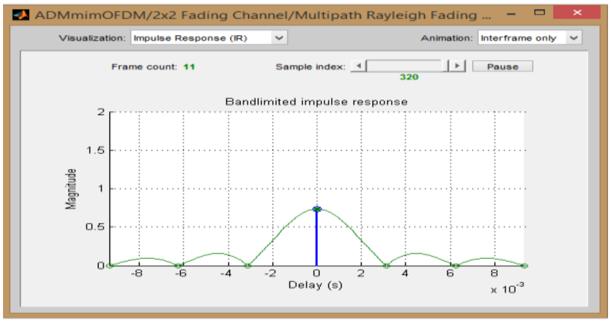

Fig.9 The Channel Visualization of fading channel

Figure 8 above depicts the difference between performance of MIMO-OFDM signal in fading channel and that of AWGN channel. Here Rayleigh fading channel is used as fading channel and QAM as modulation technique. From figure 8, it is clear that OFDM is very much immune to fading effect over the channel. In the fading channel to attain a BER of 10^{-3} value of SNR required is 8dB which is almost 4dB in normal channel. From above discussion it is clear that for drastic changes in channel characteristic slight change in SNR is enough which proves OFDM is more robust to fading channel effects.

Here simulation results are shown for analyzing the performance of various QAM techniques applied on OFDM system and compared these with the proposed adaptive methodology. Table 1 depicts all the parameters required and their values for simulations. Figure 10 to figure 14 shows the BER curve for MQAM techniques (M=4, 8, 16, 32, 64) applied on an OFDM system with 96 number of sub-carriers (i.e. N = 200). SNR values in terms dB are plotted on X and BER is plotted on Y axis. From the graph it is clear that as SNR increases BER reduces substantially.

Table I. Parameter value

parameter	value
FFT size	256
No. of nulls	56
No. of pilots	8
No. of data	192
Cyclic prefix length	64
M-QAM	4,8,16,32,64
Channel bandwidth	1.25 MHz
Baseband Modulation	M-QAM (M=4, 8, 16, 32…)
Antenna no (Nt, Nr)	2x2
Noise	AWGN
Channel model	Rayleigh fading

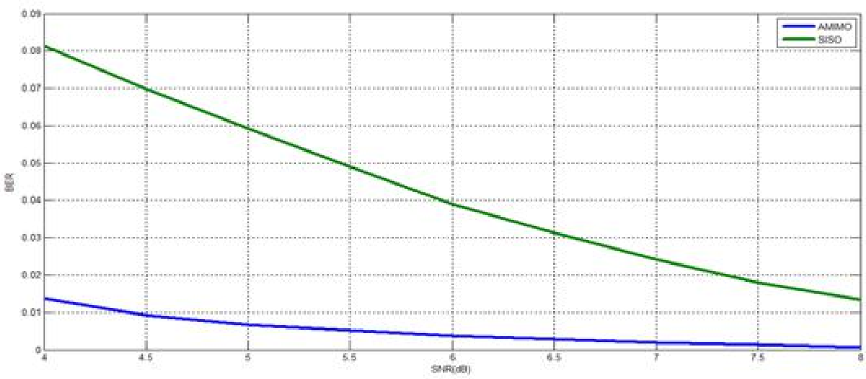

Fig.10 BER Comparison for A SISO-OFDM, A MIMO-OFDM and with (Nt=Nr=2) 4 ary QAM

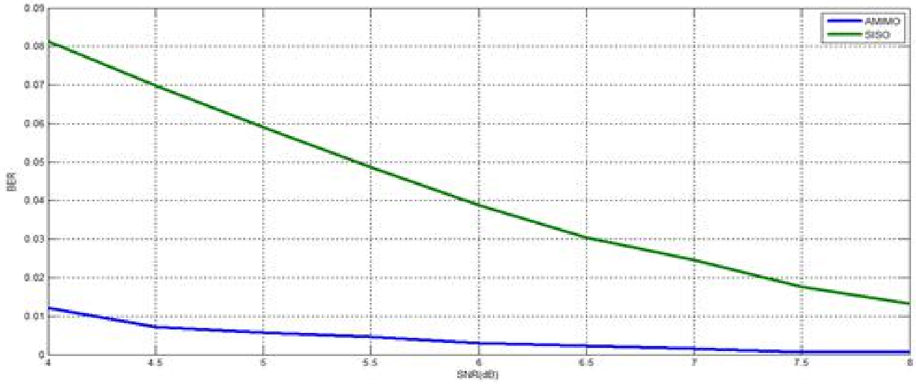

Fig.11 BER Comparison for SISO-OFDM, AMIMO-OFDM And with (Nt=Nr=2) 8 ary QAM

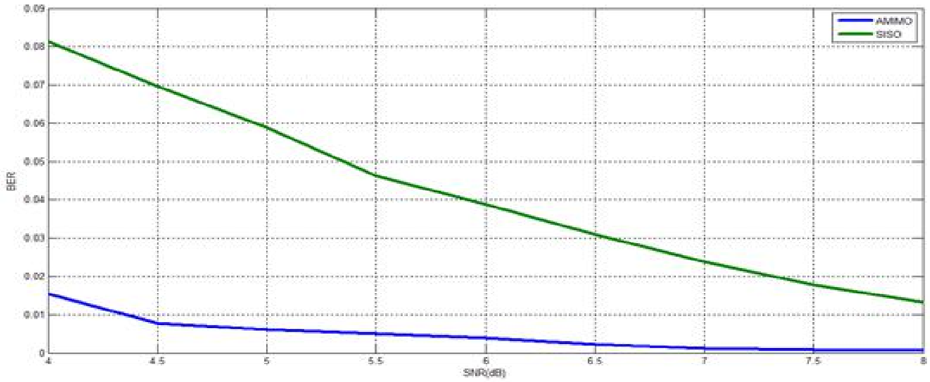

Fig.12 BER Comparison for ASISO-OFDM, AMIMO-OFDM and with (Nt=Nr=2) 16 ary QAM

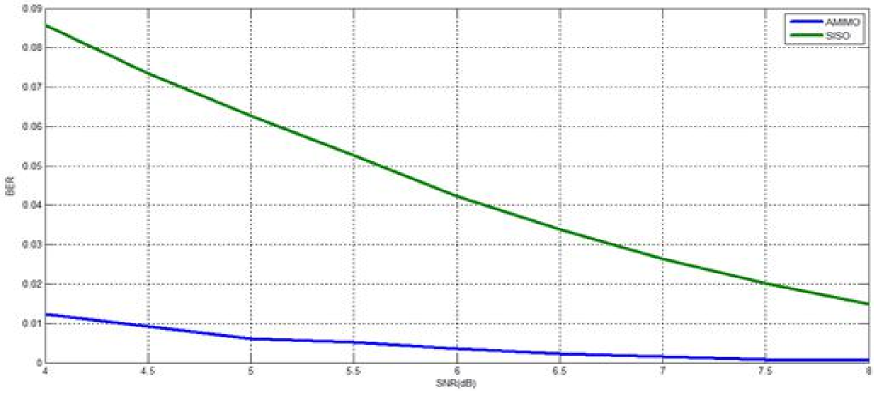

Fig.13 BER Comparison for SISO-OFDM, AMIMO-OFDM and with (Nt=Nr=2) 32 ary QAM

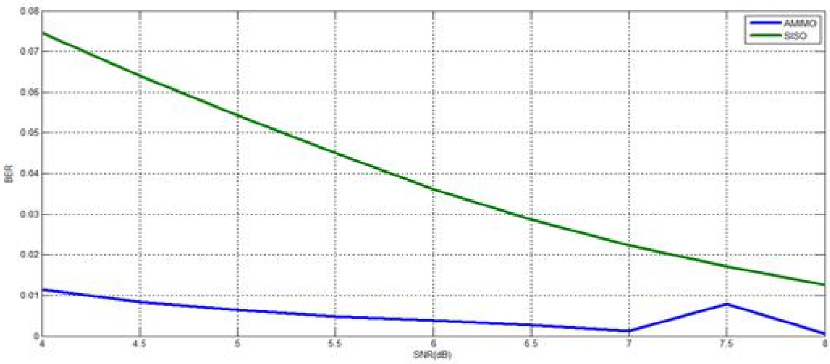

Fig.14 BER Comparison for SISO-OFDM, AMIMO-OFDM and with (Nt=Nr=2) 64 ary QAM

Figures 10 to figures 14 demonstrate the correlation of 4 QAM to 64 QAM modulations. With increment in estimation of SNR, BER value diminishes .This can be distinguish in above figure where green line represents BER of SISO framework and blue line represents AMIMO framework. This distinction is because of fading, in SISO only one signal is get transmitted, if that signal fades a lot, then signal data will be lost however in AMIMO numerous copies of signal are send, so the lightest influenced signal will be utilized for transmission, this is the essential explanation for BER of AMIMO. In 4 QAM just 2 bit get transmitted while in 8 QAM 3 bit get transmitted. So because of this, noise rate gets increased in small bit value transmission though in large bits value transmission noise gets disseminated hence BER is less. In above all figures same phenomenon is explained.

BER value lies below 0.005 when SNR varies from 4 to 8 dB and this value of BER is minimum as compared to all other QAM Curves. The reason is that input data rate used for 4QAM is 100bps which is minimum among all other QAM data rates, so lesser number of bit are sent while the SNR of the channel is poor. The Performance of 8QAM technique is worse than 4QAM till SNR value of 5dB is used but after that BER value of .0006 is achieved till 8 dB SNR value and becomes constant. The input data rate used for 8QAM is 1000bps, 10 times the value used in 4QAM showing that as the SNR of the channel is improved then more number of bit are sent per second. For 16 QAM 10kbps data rate is used, when SNR value from 5.75 dB to 6.5dB is achieved and BER value from .01155 to .00059 is obtained which is the better than 8QAM and 4 QAM at 10 kbps. For SNR value of greater than 7 dB BER is same for 16QAM as well as 32QAM but data rate at this SNR level is 10 times (100 kbps) better than the data rate of 16 QAM (10 kbps). Same kind of analogy can be seen for 32QAM and 64 QAM at SNR greater than 7.5dB for which same BER is achieved but at 10 times faster data rate in case of 64 QAM as compared to 32 QAM. The above analyzed data can also be understood through Table II

Table II. BER value for all QAM Techniques

SNR (dB)	4QAM AMIMO	4QAM SISO	8QAM AMIMO	8QAM SISO	16QAM AMIMO	16QAM SISO	32QAM AMIMO	32QAM SISO
4	0.01373	0.08124	0.01215	0.08131	0.01155	0.08128	0.01131	0.08571
4.5	0.009233	0.06985	0.00726	0.06982	0.006813	0.06969	0.006186	0.07339
5	0.006629	0.05923	0.00584	0.05898	0.005037	0.05892	0.005155	0.06276
5.5	0.005208	0.04896	0.004577	0.04858	0.00409	0.0463	0.004114	0.05264
6	0.003788	0.03906	0.002999	0.03881	0.002906	0.03741	0.002598	0.04232
6.5	0.002841	0.03135	0.00221	0.03046	0.002367	0.03099	0.002273	0.03381
7	0.001894	0.02416	0.001578	0.02462	0.001184	0.02375	0.001161	0.02636
7.5	0.00142	0.01805	0.0006313	0.01768	0.0008286	0.0178	0.0008123	0.02013
8	0.0007102	0.01336	0.0006313	0.01332	0.0005919	0.0132	0.0005629	0.01486

It shows that average BER for adaptive scheme is very less as compared to all other QAM techniques. The average BER is calculated by dividing the total number of error bits for all SNR values by total number of transmitted bits for all SNR values. 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.

V. CONCLUSION

This work deals with the implementation of OFDM with various QAM techniques implemented on it. The traditional fixed QAM techniques used in OFDM were studied; however the performance of the system is greatly affected by the SNR of the AWGN channel. MIMO-OFDM system give much improve average BER when compare with SISO-OFDM system. The employed Adaptive methodology offered significant improvement in average BER of the system. It can provide better BER values than that of traditional fixed QAM techniques by changing modulation index of QAM modulator depending on the SNR of the channel.

It can be seen from BER vs SNR plot that MIMO-OFDM is tolerant towards fading channel effects. Even though BER is little more for higher SNR value as compared to AWGN channel the difference is very small and hence both BER are almost equal. Hence for fading channel OFDM technique is more convenient to use.

In terms of performance AMIMO-OFDM is better than SISO system in several ways, as SNR increases system performance increases. With the application of adaptive coding system performance can be improved by nearly 10^{-1} to 10^{-2} as compared with SISO-OFDM system.

Adaptive modulation schemes used for the both subcarriers in an OFDM transmission system with MIMO and SISO are describe in this paper. The bit error ratio for transmitted signal in MIMO system is gradually less than SISO system. Simulations show that BER of the order of 10^{-3}to10^{-4} and SNR of 4 to 8 dB can be attainable. Modulation rate is totally dependent on the value of SNR in adaptive modulation. Adaptive modulation is better than all other modulation technique in terms of BER performance.

For any IFFT size, average BER for Adaptive modulation using MIMO QAM technique is approximately 0.004937 and for SISO QAM technique average value of BER is approximately 0.03858 .Hence, it can be concluded that BER performance of AMIMO OFDM is better than SISO at the cost of greater execution time.

VI. FUTURE SCOPE

A lot of research is going on in the field of wireless communication, especially in MIMO with the help of OFDM, as they give best combination for transmission. The proposed adaptive scheme can be implemented on 3x3 and 4x4 antenna pattern. Instead of the QAM modulation number, the encoding scheme can also be made adaptive in accordance with SNR of the channel.

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