Comparative BER Performance of M-ary QAM-OFDM System in AWGN & Multipath Fading Channel

Abhijyoti Ghosh
Department of Electronics & Communication Engineering, Mizoram University,
Tanhril, Aizawl, Mizoram-796004, India
E-mail:-abhijyoti_engineer@yahoo.co.in

Bhaswati. Majumder
Department of Electronics & Communication Engineering, Siliguri Institute of Technology,
Sukna, Darjeeling, W.B.-734009, India
bhaswati.sit2008@gmail.com

Parijat Paul
Department of Electronics & Communication Engineering, Siliguri Institute of Technology,
Sukna, Darjeeling, W.B.-734009, India
parijatpl42@gmail.com

Pinky Mullick
Department of Electronics & Communication Engineering, Siliguri Institute of Technology,
Sukna, Darjeeling, W.B.-734009, India
pinkyatsit@gmail.com

Ishita Guha Thakurta
Department of Electronics & Communication Engineering, Siliguri Institute of Technology,
Sukna, Darjeeling, W.B.-734009, India
dats.ish26@gmail.com

Sudip Kumar Ghosh
Department of Electronics & Communication Engineering, Siliguri Institute of Technology,
Sukna, Darjeeling, W.B.-734009, India
sdpghsh@gmail.com

Abstract- **OFDM (Orthogonal Frequency Division Multiplexing) is a multicarrier technique where linearly modulated data streams are divided into number of substreams each occupying a bandwidth less than the total bandwidth of the signal. However, full justice was done in proper utilization of bandwidth in OFDM where subcarriers overlap orthogonally. M-ary modulation schemes are preferred because in these schemes more than one bit can be grouped & transmit at a time which is very effective for band limited channels. MQAM (M-ary Quadrature Amplitude Modulation) is the most effective digital modulation technique as it is more power efficient for larger values of M. The basic idea of M-ary QAM & OFDM has been discussed in the paper. The Simulink based model of the MQAM-OFDM system with normal AWGN channel and Rayleigh fading channel has been made for study error performance under different channel conditions. Lastly a comparative study of BER performance of 64QAM-OFDM & 128QAM-OFDM under AWGN channel & Rayleigh fading channel has been given.**

Keywords: OFDM; MQAM; AWGN channel; Multipath fading channel, Bit Error Rate

I. INTRODUCTION

Wireless services have been growing rapidly with each passing year. Present telecommunication system provides a more flexible data rate, a higher capacity and a tightly integrated service. Modern wireless communication adopts digital modulation techniques instead of analog modulation as digital modulation has several advantages over analog modulation [1]. Digital modulation techniques offer higher data rates, powerful error correction techniques and better security, efficient multiple access process and more resistivity. Different modulation techniques support different bits per modulation techniques and achieve different throughput and efficiencies. As the order of the modulation technique increased, spectral efficiency also increases [2].

Adaptive modulation is a special type of modulation techniques which provides robust & spectral efficient transmission over time varying channels. In adaptive modulation the channel condition is estimated at the receiver end & this estimate is fed back to the transmitter so that proper transmission mechanism can be adopted depending on the characteristics & condition of the channel [3].

In wireless communication networks high bit rate data transmission is required for video, high quality audio and mobile ISDN services. This can be achieved but the limitation of spectrum is an important restriction to it. The use of M-ary Quadrature Amplitude Modulation (M-QAM) is an attractive method to overcome this problem because of its high spectral efficiency [4]. In wireless communications received signal is heavily distorted when the transmission rate is high due to frequency selective fading. Multicarrier transmission like OFDM can offer immunity against frequency selective fading.

II. QUADRATURE AMPLITUDE MODULATION (QAM) AND M-QAM

QAM can be considered as both analog and digital modulation scheme. In QAM two analog message signals or two digital bit streams is conveyed by changing the amplitude of two carrier waves. As the two signals are combined into a single channel, the effective bandwidth becomes double. The two carrier waves used are usually sinusoids, and are out of phase with each other by 90^0. Mathematically, one of the signals can be represented by a sine wave and the other by a cosine wave. The transmitted signal is thus given by,

$$s(t) = x_1(t)A\cos(2\pi f_c t) + x_2(t)A\sin(2\pi f_c t) \qquad (1)$$

The signal $s(t)$ consists of two phase-quadrature carriers with each one being modulated by a set of discrete amplitudes, hence the name Quadrature Amplitude Modulation (QAM). The two modulated carriers are combined at source and are separated at the receiver to extract the original signal. The resulting output waveform is the combination of both phase shift keying and amplitude shift keying. In the digital QAM case, a finite number of at least two phases and two amplitudes are used [4].

In M-QAM scheme two or more bits are grouped together to form symbols and one of the M possible signals is transmitted during each symbol period of duration T_s.

The number of possible signals $M = 2^n$ where n is an integer. The general form of an M-ary QAM signal can be defined as [2]

$$S_i(t) = \sqrt{\frac{2E_{min}}{T_s}}\, a_i cos(2\pi f_c t) + \sqrt{\frac{2E_{min}}{T_s}}\, b_i sin(2\pi f_c t) \qquad 0 \le t \le T, \quad i = 1,2,3,\ldots\ldots,M \qquad (2)$$

where E_{min} is the energy of the signal with lowest amplitude and a_i and b_i are a pair of independent integers chosen according to the location of the particular signal point.

QAM is widely used in many digital data radio communication and data communications. A variety of forms of QAM are available such as 16-QAM, 32-QAM, 64- QAM, 128-QAM and 256-QAM [2]. The constellation diagram is a very useful representation in digital modulation techniques which provides graphical representation of complex envelop of each possible symbol states. The constellation diagram for 16-QAM, 32-QAM, 64- QAM, 128-QAM and 256-QAM is shown in figure 1.

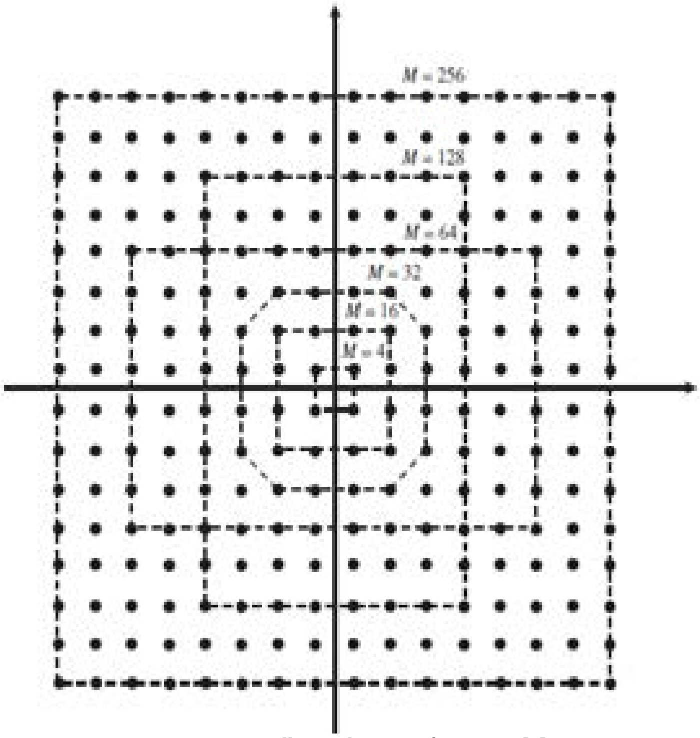

Figure 1: Constellation diagram of M-QAM [1]

III. ORTHOGONAL FREQUENCY DIVISION MULTIPLEXING (OFDM)

Orthogonal Frequency Division Multiplexing (OFDM) is a special type of multicarrier modulation with densely spaced sub carriers and overlapping spectra. The basic principles of OFDM are to split a high rate data stream into a number of lower rate streams that are transmitted simultaneously over a number of subcarriers. In OFDM the subcarriers are spaced as closed as is theoretically possible maintaining orthogonality between them [5] [6].

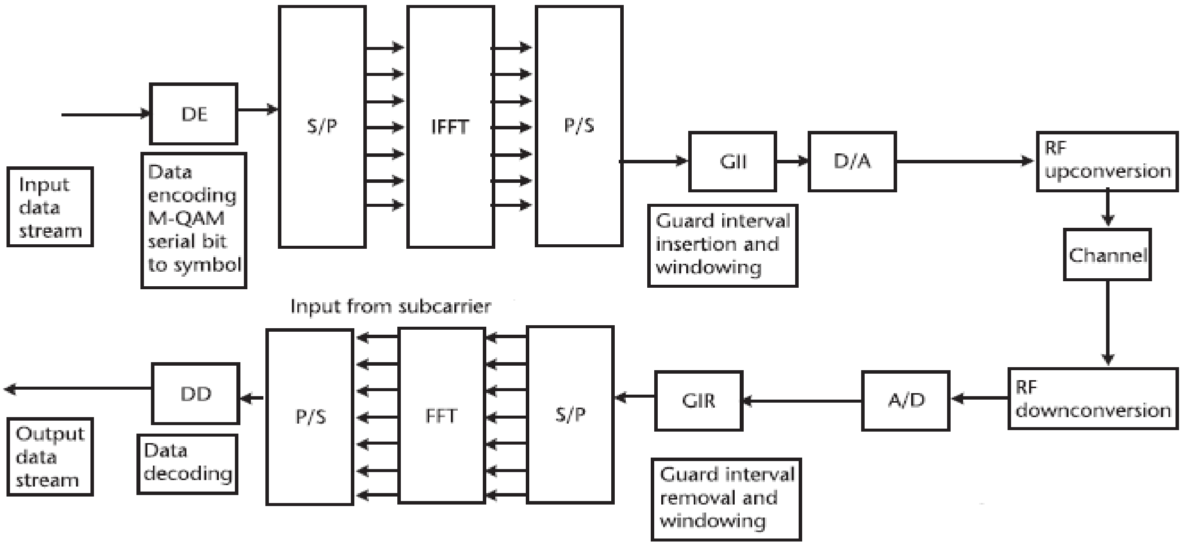

Figure 2: OFDM transmitter & receiver [5]

In multi-carrier digital modulation scheme, one user's information streamed or frame is split up in multiple symbols and each symbol or a group of symbols will be assigned a separate sub-carrier. Thus it is a block modulation scheme where each block contains a group of symbols. The resulting signals are transmitted together in the same band. Thus if a particular frequency is affected by noise in the channel, then a particular part of the information will be lost, not the total information of that user. One of the main reasons to use multicarrier modulation is to increase the robustness against frequency selective fading and narrow band interference. In contrast to conventional frequency division multiplexing the spectral overlapping of the subcarriers and orthogonality between them in OFDM will ensure the subcarrier separation at the receiver providing better spectral efficiency [5]. The OFDM transmitter & receiver block diagram has been shown in figure 2.

The orthogonality of subchannels in OFDM can be maintained and individual subchannels can completely separated by the FFT at the receiver when there are no intersymbol interference (ISI) and intercarrier interference(ICI) introduced by the transmission channel distortion [6].

IV. MULTIPATH FADING CHANNEL

In wireless communication, radio propagation refers to the behavior of radio waves when they are propagated from transmitter to receiver. In the course of propagation, radio waves are mainly affected by three different modes of physical phenomena: reflection, diffraction, and scattering. Due to reflections from buildings, ground, and other obstacles with vast surfaces, as well as scatters from trees and other scatter-objects, a multitude of partial waves arrive at the receiver antenna from different directions [4]. This effect is known as multipath propagation. The multiple paths causes time delay spread on the received signal. This delay spread is the time difference between the arrival of first received component and the last received components of the same transmitted signal.

Another unique characteristic in a wireless channel is a phenomenon called 'fading' which is the variation of the signal amplitude over time and frequency. In contrast with the additive noise as the most fading common source of signal degradation, fading is another source of signal degradation that is non-additive signal disturbance in the wireless channel. Fading may either be due to multipath propagation, referred to as multi-path (induced) fading, or to shadowing from obstacles that affect the propagation of a radio wave, referred to as shadow fading [7].

The multipath copies of the received signal may be combined to give rise to received signal whose envelope can be described by Rayleigh fading process or a Rice fading process or Nakagami fading process [1].

Multipath Rayleigh fading channels are described by the Rayleigh distribution. In mobile radio channels, the Rayleigh distribution is commonly used to describe the statistical time varying nature of the received envelope of a flat fading signal, or the envelope of an individual multipath component [2].

For mobile-radio applications, the channel is time-variant because motion between the transmitter and the receiver results in propagation path changes. It is well-known that the envelope of the sum of two Quadrature Gaussian noise signals obeys a Rayleigh distribution. The Rayleigh distribution has a probability density function (PDF) given by [2]

$$\begin{aligned} p(r) &= \frac{r}{\sigma^2} exp\left(-\frac{r^2}{2\sigma^2}\right) \quad (0 \le r \le \infty) \\ &= 0 \qquad (r < 0) \end{aligned} \tag{3}$$

where σ is the rms value of the received voltage signal before envelope detection and σ^2 is the time-average power of the received signal before envelope detection.

V. MQAM-OFDM SIMULATION MODEL

Simulink is an environment for multi-domain simulation and Model Based Design for dynamic and embedded systems. It helps us to design various model based structure for communication, DSP etc. The simulation of model of 64QAM along with AWGN and Rayleigh fading channel is shown in the figure 3. The binary signal is generated by the random integer generator source. Then the data is modulated by either 64QAM or 128QAM and OFDM operation has been performed over this modulated data. After passing through either by only AWGN channel and

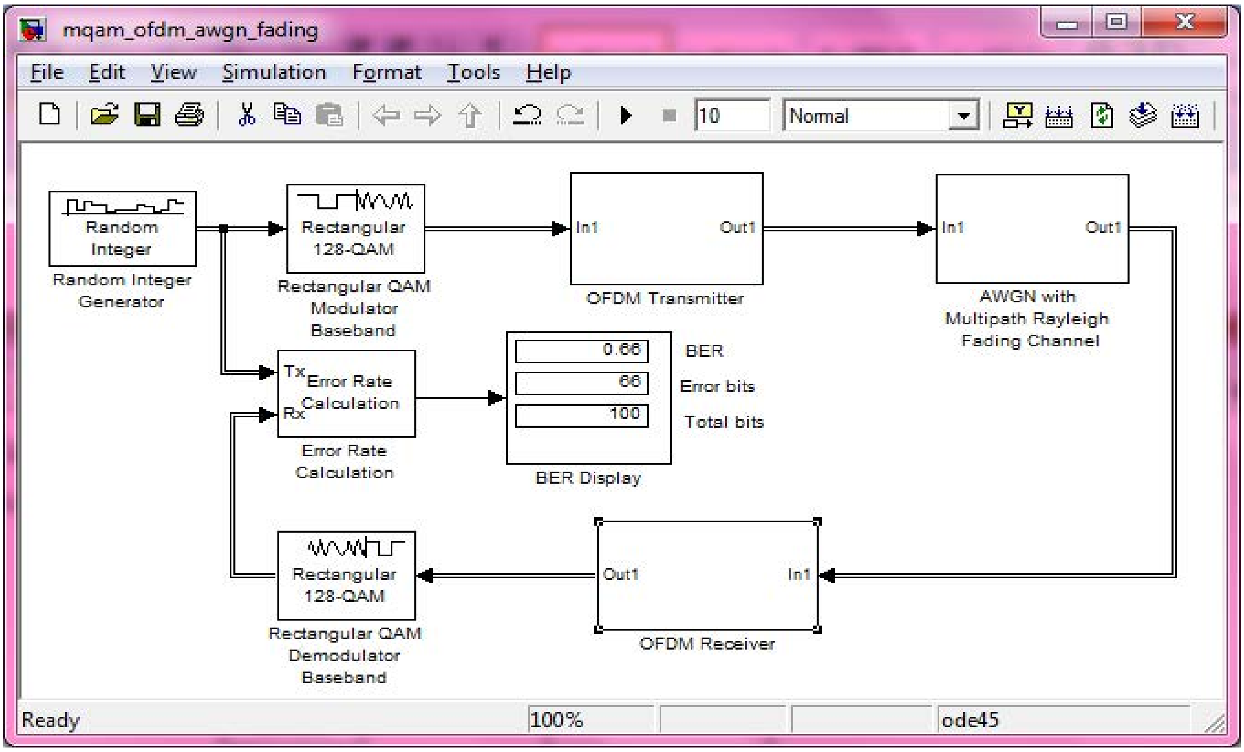

Figure 3: MQAM-OFDM Simulink model

multipath Rayleigh fading channel, the signal is received either by 64QAM or 128QAM demodulator. The bit error rate has been calculated over the received data by error rate calculation block.

VI. SIMULATION RESULTS

In this paper the error performance of 64QAM-OFDM and 128QAM-OFDM is studied under both AWGN and Rayleigh fading channel using Matlab Simulink model. The Bit Error Rate (BER) performance against signal to noise ratio (Eb/No) of 64QAM-OFDM & 128QAM-OFDM in both AWGN channel & multipath fading channel has been shown in figure 4 & figure 5 respectively. The BER decreases sharply with the increase in the signal to noise ratio in both AWGN channel & multipath fading channel but the bit error rate in multipath fading channel is higher than normal AWGN channel.

Figure 6 summarizes the error rate performance of 64QAM-OFDM & 128QAM-OFDM system in AWGN channel only. As the value of M i.e. the number of bits in a symbol increases i.e. from 64 to 128, the error rate also increases though the signal is passes through same channel. The same effect can be seen when the different modulated signals are pass through the multipath fading channel but the error rate in multipath fading channel is much higher than the error rate in the AWGN channel. The Eb/No vs. BER performance of 64QAM-OFDM & 128QAM-OFDM system in multipath Rayleigh fading channel is shown in figure 7.

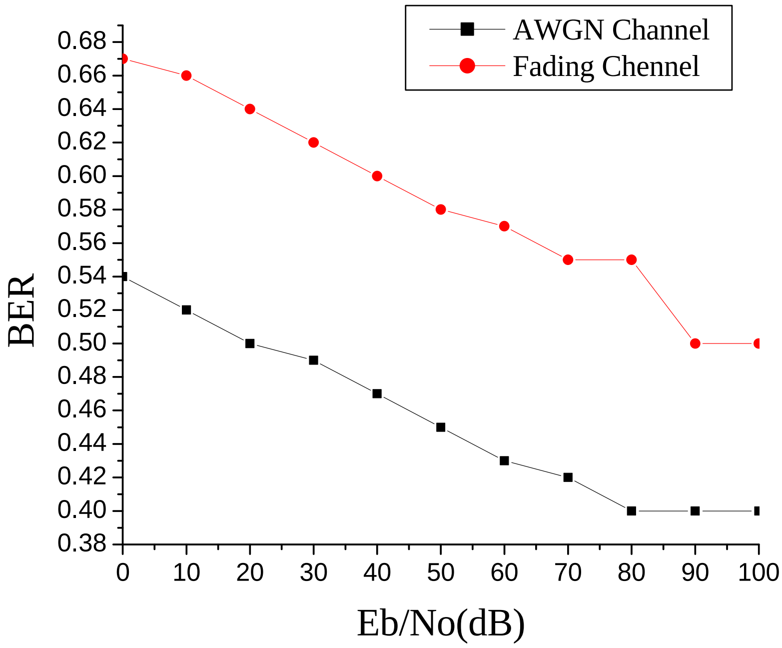

Figure. 4: Eb/No vs. BER for 64QAM-OFDM system in AWGN channel & Multipath fading channel

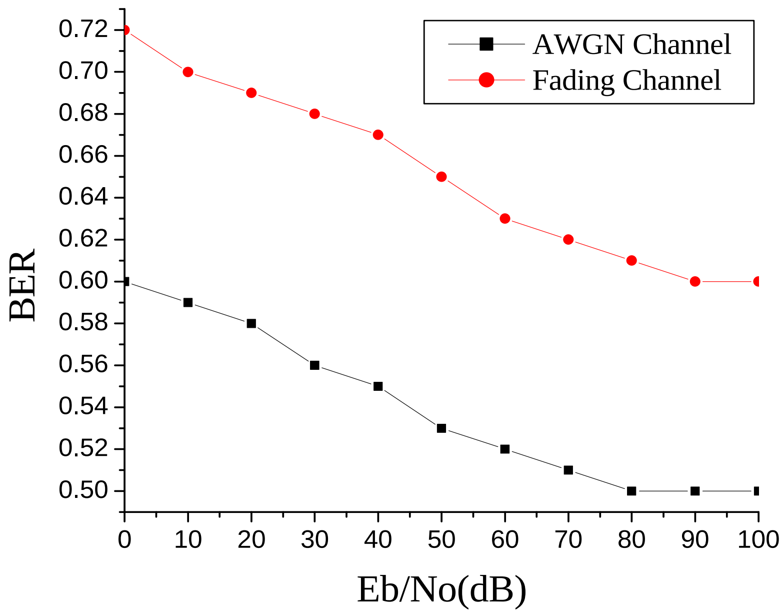

Figure. 5: Eb/No vs. BER for 128QAM-OFDM system in AWGN channel & Multipath fading channel

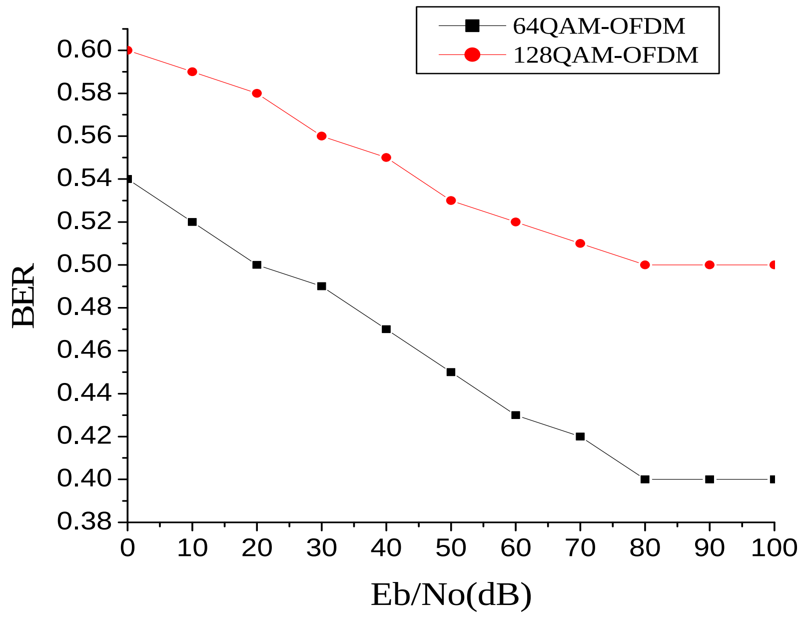

Figure. 6: Eb/No vs. BER for 64QAM-OFDM and 128QAM-OFDM under AWGN channel

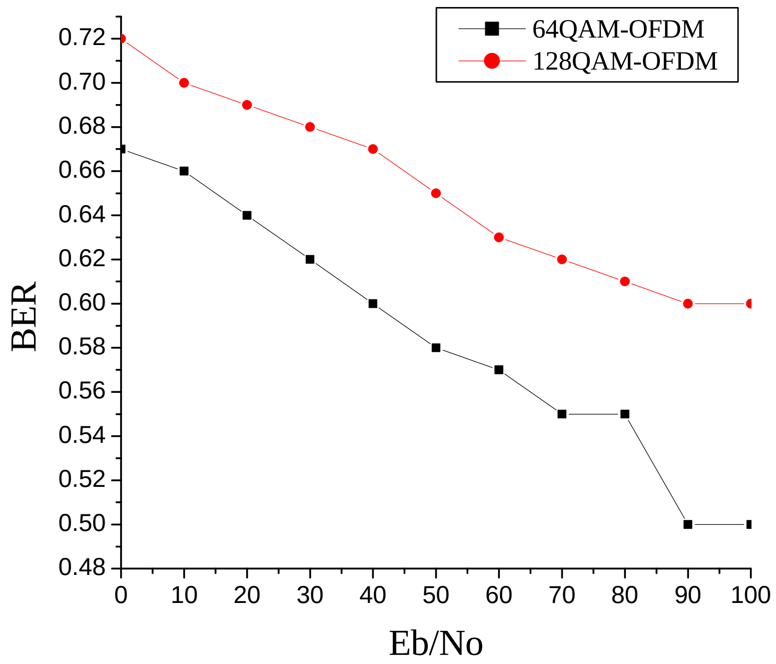

Figure. 7: Eb/No vs. BER for 64QAM-OFDM and 128QAM-OFDM under multipath Rayleigh fading channel

VII. CONCLUSION

As M-ary modulation techniques provide better bandwidth utilization than other low order modulation techniques they are preferred for higher data rate applications. In M-ary modulation techniques as the value of M increases the data rate & bandwidth also increases. A 128QAM-OFDM system transmitted more bit than

64QAM-OFDM system. Along with the high data rate i.e. speed, another important parameter i.e. error rate, should be considered while choosing a particular modulation technique for communication. This paper gives a clear idea of the error performance of 64QAM-OFDM & 128QAM-OFDM system under AWGN channel & multipath Rayleigh fading channel. It is observed from the simulation results that as the signal power is increases the error rate decreases sharply in both AWGN & multipath fading channel but error rate increases as the value of M increases from 64 to 128. The error rate in multipath fading channel is also higher than the AWGN channel for same signal. So to provide a reliable communication along with the high data rate there should be a tradeoff between these two parameters.

REFERENCES

[1] Tri T.Ha,"Theory And Design Of Digital Communication System", Cambridge University Press, 2011.

[2] T.S.Rappaport,"Wireless Communication: Principles & Practice", Pearson India, 2003.

[3] X.Li,"Simulink-based Simulation of Quadrature Adaptive Modulation (QAM) System", *Proceedings of the 2008 IAJC-IJME International Conference, ISBN 978-1-60643-379-9.*

[4] Andrea Goldsmith,"Wireless Communication", Artech House, London, 2005.

[5] M.Janakiram,"Space Time Codes and MIMO System", Artech House, London, 2004.

[6] Ramjee Prasad,"OFDM for Wireless Communication System", Artech House, London, 2004.

[7] Y.S.Cho, J. Kim, W.Y.Yang & C. G. Kang,"MIMO-OFDM Wireless Communications with Matlab", John Willy & Sons(Asia) Pte. Ltd. Singapore, 2010

AUTHORS PROFILE

Mr. Abhijyoti Ghosh is currently working as an Assistant Professor in Department of Electronics & Communication Engineering, Mizoram University, Tanhril, Aizawl, Mizoram, India. He has more than 5 years of experience in teaching. His research interest includes the field of Digital Communication, Wireless Communication, Networking, and Electromagnetic.

Ms. Bhaswati. Majumder is currently pursuing B.Tech in Electronics & Communication Engineering from Siliguri Institute of Technology, Sukna, Darjeeling, West Bengal, India (expected 2012). Her areas of interest include Digital Communication, Wireless Communication.

Ms. Parijat Paul is currently pursuing B.Tech in Electronics & Communication Engineering from Siliguri Institute of Technology, Sukna, Darjeeling, West Bengal, India (expected 2012). Her areas of interest include Digital Communication, Wireless Communication.

Ms. Pinky Mullick is currently pursuing B.Tech in Electronics & Communication Engineering from Siliguri Institute of Technology, Sukna, Darjeeling, West Bengal, India (expected 2012). Her areas of interest include Digital Communication, Wireless Communication.

Ms. Ishita Guha Thakurta is currently pursuing B.Tech in Electronics & Communication Engineering from Siliguri Institute of Technology, Sukna, Darjeeling, West Bengal, India (expected 2012). Her areas of interest include Digital Communication, Wireless Communication.

Mr. Sudip Kumar Ghosh is currently working as an Assistant Professor in Department of Electronics & Communication Engineering, Siliguri Institute of Technology, Sukna, Darjeeling, West Bengal, India. He has more than 5 years of experience in teaching. His research interest includes the field of Digital Communication, Wireless Communication, Networking, and Electromagnetic.