COMPARATIVE STUDY OF BIT ERROR RATE (BER) FOR MPSK-OFDM IN MULTIPATH FADING CHANNEL

Abhijyoti Ghosh[1], Bhaswati Majumder[2], Parijat Paul[2], Pinky Mullick[2], Ishita Guha Thakurta[2] and Sudip Kumar Ghosh[2]
[1]Department of Electronics & Communication Engineering, Mizoram University, Tanhril, Aizawl, Mizoram, India
[2]Department of Electronics & Communication Engineering, Siliguri Institute of Technology, Sukna, Darjeeling, West Bengal, India

ABSTRACT

Orthogonal frequency Division Multiplexing (OFDM) is a multicarrier modulation technique where high rate data stream is divided into a number of lower rate data streams and transmitted over a number of subcarriers. Quadrature Phase Shift Keying (QPSK) & MPSK (M-ary phase shift keying) can be combined with OFDM for better data transmission taking the advantage of both OFDM & the different high rate modulation techniques. This paper discussed M-PSK- OFDM system where the information bits are already modulated using QPSK and M-PSK process. A comparative study of bit error rate (BER) vs. SNR under normal AWGN & multipath fading channel has been done between different M-PSK OFDM techniques using MATLAB Simulink model.

KEYWORDS: *OFDM, QPSK, MPSK, MPSK-OFDM, BER, AWGN channel, Multipath fading channel*

I. INTRODUCTION

In wireless industry a major evaluation is occurring from narrowband, circuit-switched network to broadband, IP centric network. OFDM is the most exciting development in the period of this evaluation. Multicarrier transmission or multiplexing like frequency division multiplexing (FDM) has come into technology in 1950s. But high spectral efficiency and low cost implementation of FDM has been possible in 1970s and 1980s with the aid of Digital Fourier Transform (DFT) [1]. OFDM is special type of multicarrier transmission where the total information bit stream is transmitted using several lower rate subcarriers which are orthogonal in nature in order to avoid inter carrier interference. In a single carrier system, a single fade can fail the entire link. But in multi carrier system, the effect of noise on a particular frequency affects only a small percentage of the total information. Also ‘orthogonal’ implies an interesting mathematical relation between multiple sub carriers for which although the sidebands of the subcarriers overlap, the signal can be received without adjacent carrier interference [2]. OFDM found a wide range of application in modern communication systems like Digital Subscriber Lines (DSL), Wireless LANs (802.11a/g/n), WIMAX, Digital Video Broadcasting etc [3].

The rest of the paper is organized as follows. In section II the requirements of evaluating the error rate of OFDM-MPSK has been presented. Section III presents a brief background of OFDM process with its advantages & disadvantages. Section IV gives the overview of QPSK & M-PSK modulation process. The concept of multipath fading channel has been discussed in section V. Section VI presents the MATLAB SIMULINK model of OFDM-MPSK and the section VII provides the performance evaluation of OFDM-MPSK system under AWGN & multipath fading channel in terms of their bit error rate. Finally conclusion & future works are discussed in section VIII & section IX respectively.

II. RELATED WORKS

Orthogonal frequency Division Multiplexing (OFDM) with different base band modulation techniques like BPSK, QPSK, MPSK, MQAM have been proposed for modern wireless communication systems like WRAN (IEEE 802.22), 4G LTE, IEEE 802.11a, IEEE 802.16e etc [3]. Non-Contiguous Orthogonal Frequency Division Multiplexing (NC-OFDM), new variation of present OFDM has been proposed in [4]. The NC-OFDM is very useful to determine the presence of secondary user in Cognitive Radio (CR) application [4]. So the performance of OFDM with different base band modulation techniques in wireless channel is very important for implementing the modern wireless communication system. The error performance of MPSK, MFSK in AWGN channel has been discussed in [5] [6]. The performance of base band modulation process in AWGN channel can be further improved by incorporating the channel coding process like Reed-Solomon code [7], Gray Code [8] before transmitting the modulated signal in the channel . But the wireless channel is fading in nature, so the performance of the different modulation techniques should be studied under mobile fading channel. The application like Cognitive Radio (CR) needs to sense the presence of licensed user in a particular spectrum band and if found then shifting the operating frequency of the secondary user efficiently without any data loss and connection failure [9] which is known as Simultaneous Sensing and Data Transmission (SSDT) [10] . NC-OFDM is one solution for Simultaneous Sensing and Data Transmission (SSDT). All these applications use OFDM technique for smooth operation. So in this paper the error performance of OFDM process with MPSK (M = 4, 16 and 64) modulation has been studied under both normal AWGN channel and multipath fading channel.

III. OFDM BASIC

OFDM is basically a multicarrier modulation process where the bit stream that is linearly modulated using PSK or QAM technique is divided into a number of substerams each occupying a bandwidth less than the total signal bandwidth. Orthogonality between the subcarriers is obtained by IDFT process that implements a very easy computational method called Inverse Fast Fourier Transform (IFFT). Orthogonality is a mathematical relation between two subcarriers that ensures zero cross correlation between them ensuring zero inter carrier interference (ICI). Thus during extracting information from one subcarrier, the effect of the adjacent subcarriers are null although the subcarriers are overlapping. Thus the total bandwidth requirement is also less for an OFDM system. The number of substreams is chosen in such a manner so that each subchannel has a bandwidth less than the coherence bandwidth of the channel. As a result the subchannels experience flat fading. Thus inter symbol interference (ISI) on each sub-channel is small.ISI can be completely eliminated using the concept of cyclic prefix [3] [11].

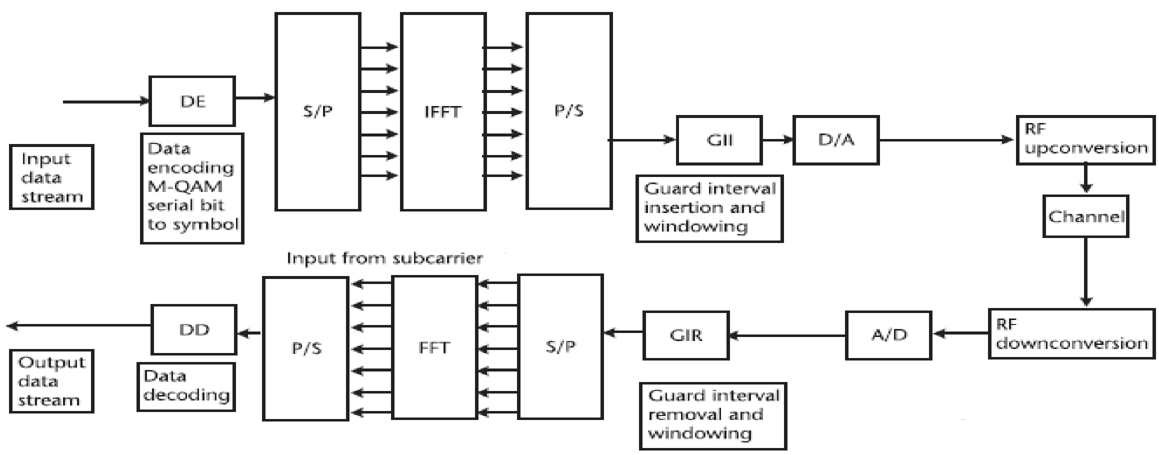


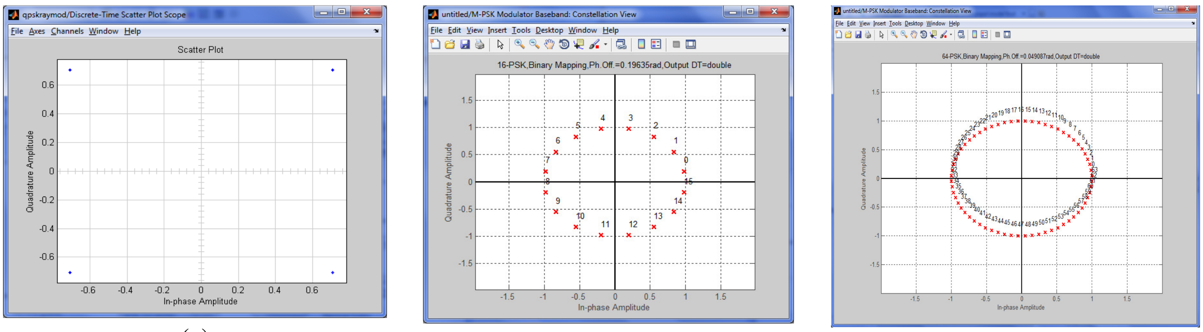
Figure 1. OFDM transmitter & receiver [12]

The block diagram of OFDM system has been shown in Figure 1. The input to the system is serial data stream with a rate of (1/T) bits/s. This data is encoded using suitable data stream to convert it into

multilevel data stream. Then this multilevel data stream is demultiplexed into N parallel streams using serial-to-parallel converter. Each parallel data stream has a rate of (1/NT) bits/s and each will modulates one of the N orthogonal subcarriers. As the parallel datas are narrowband data they experience only flat fading. This is the greatest advantage of OFDM technique. IFFT operation is performed over this parallel data and then it is summed. After the OFDM modulation the task is to remove ISI within each OFDM symbol and that is achieved by inserting a guard interval. This guard interval is also known as cyclic prefix which is basically a copy of the last part of OFDM symbol which is prepended to the transmitted symbol. This way the transmitted symbols are made periodic, which plays an important role in identifying frames correctly and also helps to avoid ISI & ICI. This guard interval allows the multipath signal to die before the information from the current symbol is gathered. If the delay spread of the channel is larger than the guard interval then ISI occurs. The signal then converted to analog baseband signal, unconverted to RF and transmitted. The reception process is just reverse of the transmission process [3] [12].
The advantages of OFDM system are high spectral efficiency, resistance to fading and interference and simple implementation due to the use of DSP tool. But OFDM is suffering from disadvantages like sensitivity to frequency offset and high peak-to-average power ratio [1] [3].

IV. QPSK AND M-PSK

QPSK is basically a digital modulation technique where the information or the modulating signal is in the form of a binary data stream and the phase of an sinusoidal signal known as the carrier signal is modulated according to the incoming binary symbols '0' and '1'. In QPSK two successive bits are combined reducing the bit rate or signaling rate and also bandwidth of the channel which is a main resource of communication system. Combination of two bits creates for distinct symbols. When a symbol makes a change to the next symbol, the phase of the carrier signal is shifted by 45° (π/4 radians). Constellation diagram of QPSK is shown in Figure 2(a).



(a) (b) (c)

Figure 2. Constellation diagram of (a) QPSK (B) 16PSK (c) 64PSK.

In M-ary signaling process symbols are made by grouping two or more bits and one of the M possible signals are transmitted during one symbol duration (T_s). The number of possible signals is $M = 2^k$, where k is the number of bits in one symbol. Binary PSK or BPSK is a special type of M-PSK where k = 1. QPSK is a type of M-ary PSK with k = 2. In M-ary PSK (MPSK) the carrier phase takes one of the M possible values i.e. $\theta_i = \frac{2(i-1)\pi}{M}$, where i = 1, 2, 3 …. M. The modulated wave form is given by [13]

$$S_i\,(t) = \sqrt{\frac{2E_s}{T_s}} \cos\left(2\pi f_c + \frac{2\pi}{M}(i-1)\right) \dots \dots (i)$$

where E_s is the signal energy per symbol & T_s is the symbol period [13]. Bandwidth efficiency is increased as the value of M increases because as M increases implying number of bits per symbol k is increasing, we are therefore raising the data rate within the previous available bandwidth. But at the same time BER performance degrades as signals are more closely packed in constellation [14].

V. MULTIPATH FADING CHANNEL

When a signal flows from transmitter to receiver, it is received via multiple paths. These multiple path arises due to scattering of the signal from obstacles like trees, lamp post, vehicles etc or may be due to reflections from ground, buildings, hills etc or sometimes due to diffraction of signal. So the signal received at the receiver ends is the attenuated, delayed, phase shifted version of the original signal. Such channels are called multipath fading channels. The modified form of signal that is received after fading process in the channel; if received via no line of sight then the channel is called Rayleigh fading channel and if via line of sight then channel is called Ricean fading channel[12][15].

Propagation of signal when characterized by large separation of transmitter and receiver usually few kilometers are described by large scale propagation model and fading is called large scale or macroscopic fading. Few examples of large scale fading are of satellite communication system and microwave radio links. When there is rapid variation of the signal over a short distance between the transmitter and the receiver; distance is of few wavelengths; such fading is called small scale fading or microscopic fading [12].

Microscopic fading comprises of rapid fluctuation of signal in space, time and frequency due to scattering objects in the channel. The scattered components when collected at the receiver end is described by the Rayleigh distributed function and is given by [12]

$$f(x) = \frac{2\pi}{\Omega} e^{-\frac{x^2}{\Omega}} u(x) \ldots\ldots\ldots.(ii)$$

where Ω is average received power and $u(x)$ is the unit step function. Microscopic or small scale fading is mainly affected by the following factors [12]:

- Angle spread at the receiver end that is Angle of Arrival (AOA) of the multipath component at the receiver and Angle of Departure (AOD) of the signal from the transmitter.
- Delay spread due to time varying response of the mobile radio channel.
- Doppler spread due to motion of the transmitter, receiver, and scattered.

VI. SIMULATION MODEL

Simulation model of OFDM system using MPSK (where M is 4, 16, 64) as baseband modulation along with AWGN and Rayleigh fading channel is shown in Figure 3.

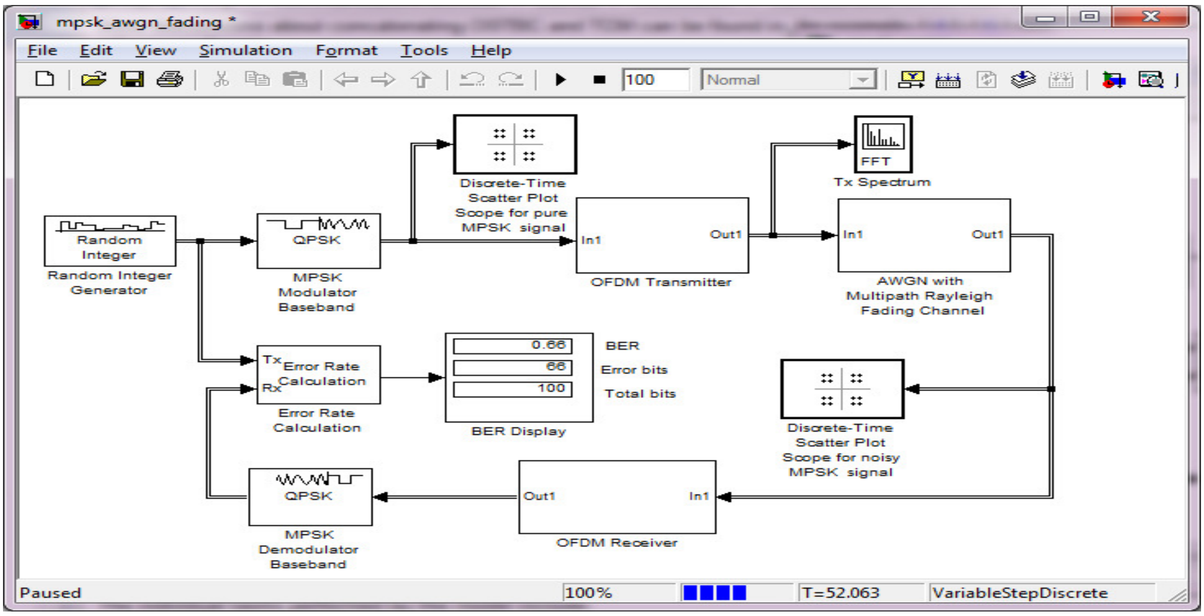


Figure 3. MPSK-OFDM Simulink model with AWGN and Rayleigh Fading Channel

All the models are of similar type for different values of M (4, 16, and 64). Data is generated by random integer source which is then fed into the MPSK modulator (M = 4, 16, 64). Pilot insertion is done for channel estimation. FFT (Fast Fourier Transform) and IFFT (Inverse Fast Fourier Transform) are the rapid mathematical method in various DFT (Discrete Fourier Transform) and IDFT (Inverse Discrete Fourier Transform) applications. Due to this technique, technology making use of it on integrated circuits is done at reasonable price helps the signal to overlap orthogonally Cyclic prefix mitigates the ISI (inter symbol interference) in a OFDM system and then signal is transmitted through the mobile fading channel having multipath Rayleigh fading channel along with AWGN channel. On the receiver end the demodulator receives the copy of the original signal, which is now affected due to ISI and noise in the channel and bit error rate is calculated. The comparative study of the BER graph is done for 4PSK-OFDM, 16PSK-OFDM, and 64PSK-OFDM Techniques along with AWGN & Rayleigh fading channel.

VII. SIMULATION RESULT

In this paper comparative study of bit error rate (BER) in different MPSK-OFDM techniques under normal AWGN channel & Rayleigh Fading channel has been presented.
The BER performance of 4PSK-OFDM (QPSK-OFDM) techniques has been shown in Figure 4. In both normal AWEGN channel & multipath fading channel BER decreases with the increase in the Eb/No value. Increasing the Eb/No value means increasing the signal power.
The error rate in fading channel is much higher than normal AWGN channel. After a particular value of Eb/No (i.e. 60dB) in normal AWGN channel the error rate becomes fixed. The error rate performance of 16PSK-OFDM & 64PSK-OFDM has been shown in Figure 5 & Figure 6. In both the cases the error rate is higher in multipath fading channel than normal AWGN channel. The error rate becoming constant after a certtain value of Eb/No in 4PSK-OFDM(QPSK), 16PSK-OFDM & 64PSK-OFDM techniques.

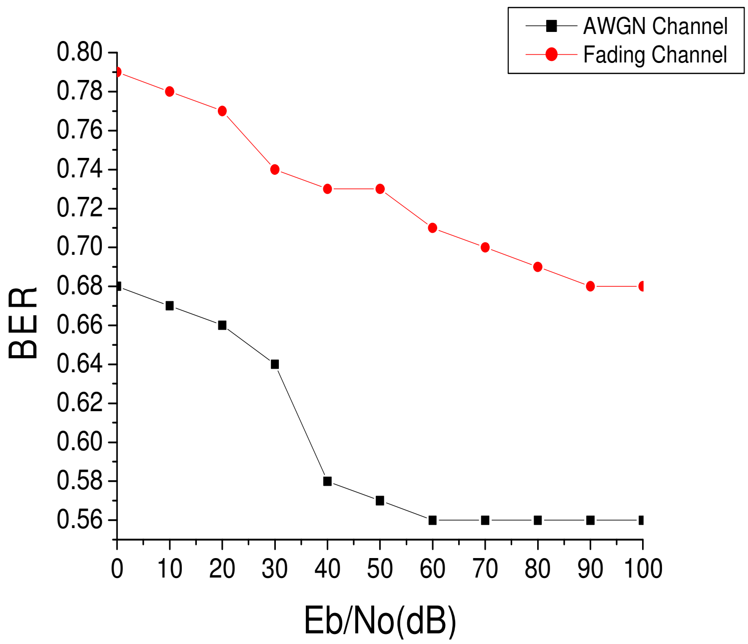


Figure 4. Eb/No Vs. BER for 4PSK-OFDM system in AWGN channel & Multipath fading channel

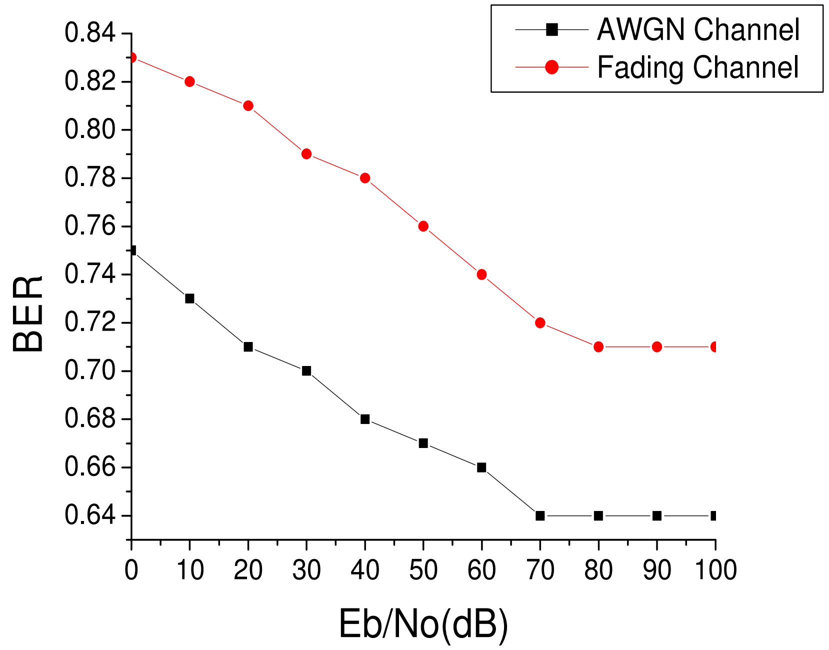


Figure 5. Eb/No Vs. BER for 16PSK-OFDM system in AWGN channel & Multipath fading channel

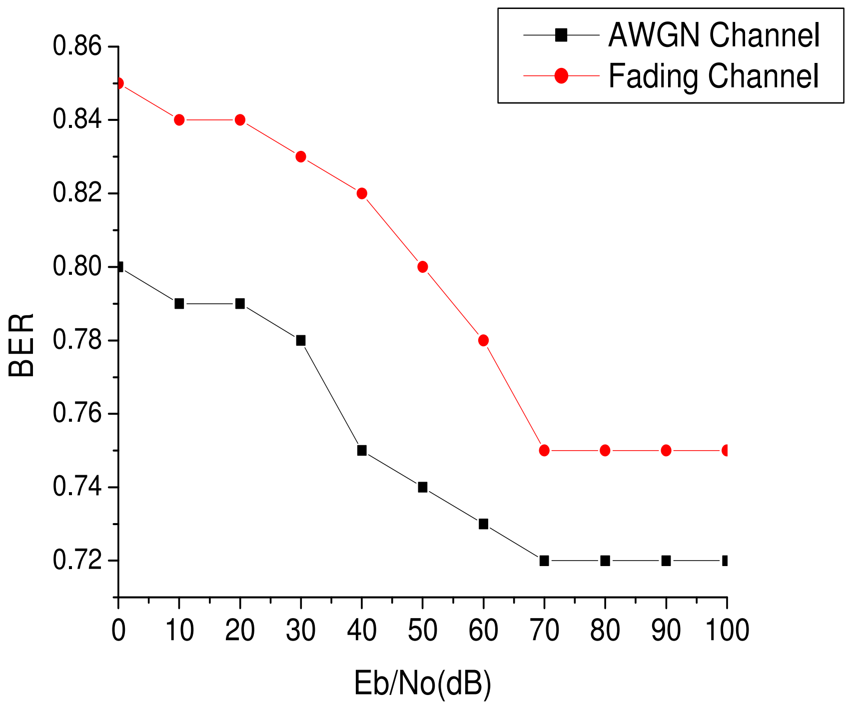


Figure 6. Eb/No Vs. BER for 64PSK-OFDM system in AWGN channel & Multipath fading channel

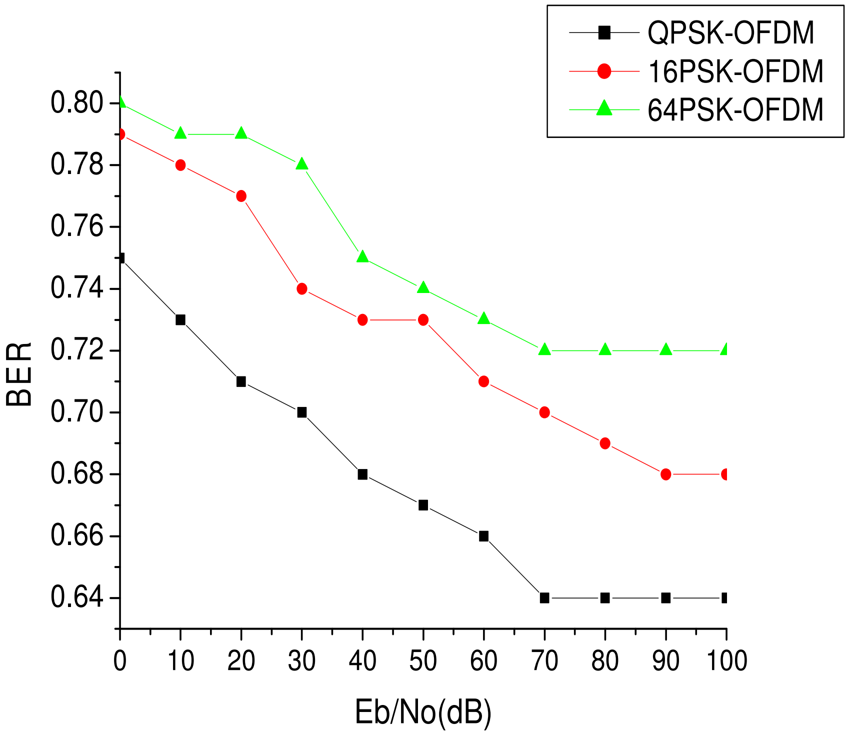


Figure 7. Eb/No Vs. BER for 4PSK-OFDM, 16PSK-OFDM & 64PSK-OFDM system under normal AWGN channel

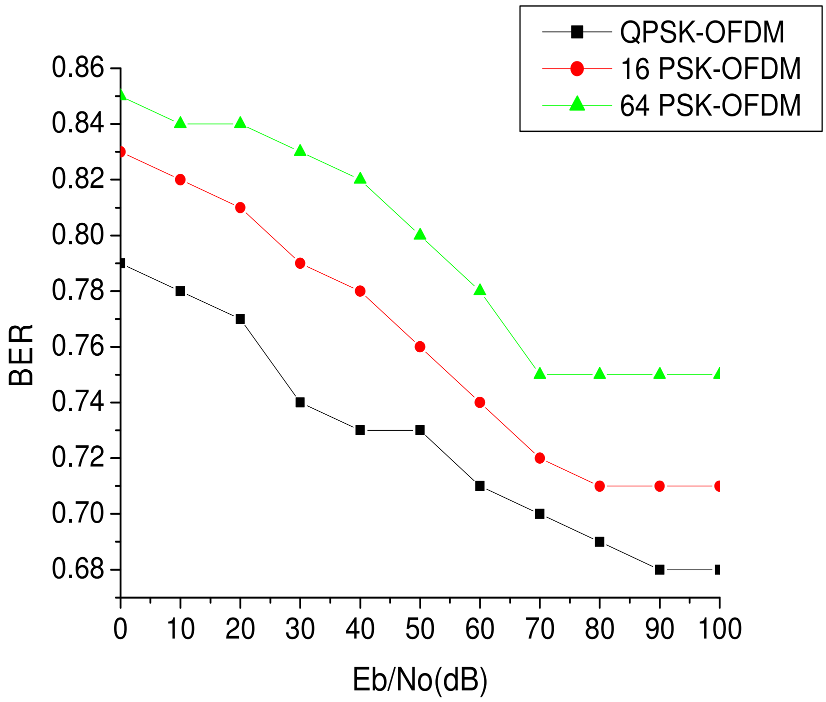


Figure 8. Eb/No Vs. BER for 4PSK-OFDM, 16PSK-OFDM & 64PSK-OFDM system under normal AWGN and Rayleigh fading channel.

Figure 7 & Figure 8 summarise the performance of 4PSK-OFDM, 16PSK-OFDM & 64PSK-OFDM in normal AWGN channel & Rayleigh multipathn fading cahnnel. When the signals of different techniques are passes through the normal AWGN channel the error rate is increases as the value of M increases. The value of M increases means more number of bits are combined to make a symbol &

these bits are packed more closely in signal constellation as shown in Figure 2(a), (b) and (c). When the same signal is transmitted through Rayleigh multipath fading channel the error rate increases in the same manner i.e. higher the value of M greater the error rate.

VIII. CONCLUSION

M-ary modulation techniques provide better bandwidth efficiency than other low level modulation techniques. As the value of M i.e. number of bits in symbol increases bandwidth utilization is increases. Also as communication range increases between a transmitter & receiver lower order modulation techniques are preferred over higher order modulation techniques [16]. In this paper we have studied the error rate performance of different MPSK modulation schemes in normal AWGN channel & multipath Rayleigh fading channel with the help of MATLAB/Simulink, the most powerful and user friendly tool for various communication systems, digital signal processing system, control systems etc which provides easy simulation and observation of the model before it is physically made. According to the various graphs provided in this paper we can conclude that error rate is much higher in fading channel than normal AWGN channel & the error rate is further increases with the value of M i.e. number of bits in symbol increases in both AWGN & multipath fading channel. High level modulation techniques are always preferred for high data rate. As error rate increases with the value of M so low level of M-ary modulation techniques should be used for data transmission over short distance and lower level of modulation technique like QPSK should be preferred over longer distance. So to provide reliable communication along with higher data rates there should be a tradeoff between error rate & data rate.

IX. FUTURE WORKS

This paper discussed the performance of Orthogonal Frequency Division Multiplexing (OFDM) process with QPSK and MPSK (M = 16 & 64) base band modulation techniques in the normal AWGN channel and multipath fading channel. Here Rayleigh fading channel has been considered as the multipath fading channel. This work can extended to

(i) Evaluate the performance of OFDM process with other adaptive modulation techniques like MQAM, GMSK etc. in fading channels like Ricean fading channel, Nakagami fading channel.
(ii) To improve the BER performance some channel coding techniques such as Reed-Solomon code, Convolution code can be used with proposed OFDM-MPSK model.
(iii) As OFDM technique is proposed for most recent wireless communication systems like 4G LTE, WRAN (IEEE 802.22), IEEE 802.16e etc. the proposed model can be extended to evaluate different requirements of modern wireless communication system s according to the specifications.

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Authors

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. He has published number of papers in journals, conferences. His research interest includes the field of Digital Communication, Wireless Communication, Networking, and Electromagnetic.

Bhaswati Majumder, currently pursuing Bachelor of Technology in Electronics and Communication Engineering from Siliguri Institute of Technology, Sukna, Darjeeling, West Bengal, India (expected 2012). Her areas of interest are Wireless communication, Digital communication.

Ishita Guha Thakurta, currently pursuing Bachelor of Technology in Electronics and Communication Engineering from Siliguri Institute of Technology, Sukna, Darjeeling, West Bengal, India (expected 2012). Her areas of interest are Wireless communication, Digital communication.

Parijat Paul, currently pursuing Bachelor of Technology in Electronics and Communication Engineering from Siliguri Institute of Technology, Sukna, Darjeeling, West Bengal, India (expected 2012). Her areas of interest are Wireless communication, Digital communication.

Pinky Mullick, currently pursuing Bachelor of Technology in Electronics and Communication Engineering from Siliguri Institute of Technology, Sukna, Darjeeling, West Bengal, India (expected 2012). Her areas of Interest are Wireless communication, Digital communication.

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. He has published number of papers in journals, conferences. His research interest includes the field of Digital Communication, Wireless Communication, Networking, and Electromagnetic.