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Simulink Based Comparative Analysis of M-ary Phase Shift Keying Modulation Schemes

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Abstract: *This paper focuses mainly on Bit Error Rate(BER) and Signal to Noise Ratio(SNR).To analyse the system's performance probability of error plays a major role. Each modulation technique has its own performance while dealing with signals corrupted with noise. This paper describes the comparative analysis of basic M-ary Phase Shift Keying modulation schemes like BPSK, QPSK,8-PSK and 16-PSK. It gives that increasing of M results in increase of Bit Error Rate. Here BER and SNR are the key factors to evaluate the performance of M-ary PSK modulation system. The BER curves for MPSK modulation obtained after simulation are compared with theoretical curves for M=2,4,8, and 16.*

Index Terms: *Bit error Rate (BER), Additive White Gaussian Noise (AWGN), Octa Phase Shift Keying (OPSK), Hexa Phase Shift Keying (HPSK), Signal-to Noise Ratio (SNR).*

1. INTRODUCTION

In digital communications industry the latest mathematical softwares can be used to increase the performance of digital system with different digital modulation techniques. These are Amplitude Shift Keying (ASK), FrequencyShift Keying (FSK), Phase Shift Keying (PSK) and Quadrature Amplitude Modulation (QAM) techniques. In ASK modulation the analog carriers are amplitude modulated to transport digital information and it has low quality, low cost and is seldom used except for very low speed telemetry circuits.FSK error performance is very poor than PSK or QAM and is used for high-performance digital radio systems. So, PSK is the widely used digital modulation technique. These modulation schemes have constant envelope but discontinuous phase transitions from symbol to symbol. The applications of M-ary PSK schemes are compressed Image communication in mobile fading channel[2], Tracking and Data RelaySatellite System (TDRSS),quasi-optical wireless array applications [1], space applications.BER has been analyzed for different values of M=2, 4, 8 and 16. This paper presents the comparative analysis of various MPSK modulation techniques in terms of their error probability. In general Matlab software offers a simplified environment for the simulation of communication systems. The performance analysis of each modulation is calculated by measuring its probability of error with assumption with additive white Gaussian Noise and the performance of modulation techniques can be compared with theoretical values.

1.1 Bit Error Rate (BER)

In Digital transmission scheme the number of bit errors is the number of received bits of a data stream over a communication channel that has been altered due to noise, distortion, interference, or bit synchronization errors. The bit error rate (BER) is the number of bits in error divided by the total number of transferred bits during a studied time interval. BER is a unit less performance measure and expressed as a percentage. The bit error probability Pb is the expectation value of the BER.

$$Bit\ Error\ Rate(P_b) = \frac{Number\ of\ bits\ in\ error}{Total\ number\ of\ transfered\ bits} \tag{1}$$

The probability of error is used to measure the performance of each modulation scheme with assumption that systems are operating with additive white gaussian noise. High data rate like 16-PSK can transmit 4 bits per symbol. It is easy to reduce the bandwidth of a modulation scheme with a large amount of power, similarly high power is not required to achieve a low BER if a wide bandwidth can be tapped.In communication system Modulation schemes are capable of delivering more bits per symbol are more immune to errors caused by noise and interference in the channel. Errors can be easily produced due to the increase of number of users, then the mobile terminal is subjected to mobility.Thus, it has driven many researches into the application of higher order modulations.

1.2 Additive White Gaussian Noise

Generally noise is an unwanted electrical signal presents in electrical systems and the term additive means the noise is added or superimposed to the signal that tends to mask the signal where it will limit the rate of information transmission and limit the receiver ability to make correct symbol decisions [1].The received signal is the combination of transmitted and AWGN noise. The term white indicates the spectrum of the noise is flat for all frequencies and Gaussian represents the values of the noise 'n' follow the Gaussian probability distribution function p(z), where σ is the variance

$$p(z) = \frac{1}{\sigma\sqrt{2\pi}} \exp\left[-\frac{1}{2}\left(\frac{z-a}{\sigma}\right)^2\right] \tag{2}$$

Thus, AWGN is generated by thermal motion of electron in all dissipative electrical components like resistors, wires and so on. Mathematically, this noise is described by a zero-mean Gaussian random process where the r andom signal (z) is a sum of Gaussian noise random variable (n) and a dc signal (a) that is

$$z = a + n \tag{3}$$

Thermal noise Power Spectral Density (PSD) is flat for all frequencies and is represented as

$$G_n(f) = \frac{N_0}{2} \tag{4}$$

Equation (4) gives two sided power spectral density and indicates that half the power is associated with positive frequencies and half with negative frequencies [1]. When noise power has a uniform spectral density, then it is called as white noise. Since thermal noise is present in all communication systems with additive, white and Gaussian characteristics to model the noise in communication systems.

2. DIGITAL MODULATION TECHNIQUES

Modulation is defined as the process by which a carrier wave is able to carry the message or digital signal (series of ones and zeroes) [4]. Basically there are three major classes of digital modulation techniques (i) Amplitude Shift Keying (ASK), (ii) Frequency Shift Keying (FSK), (iii) Phase Shift Keying (PSK) used for transmission of digitally represented data. For ASK, FSK and PSK, the amplitude, frequency and phase are changed with respect to the message signal. In case of FSK and PSK modulation it provides constant amplitude envelope, so the effect of non-linearity and noise interference is minimum than ASK. Due to low quality, and low cost this modulation is used for very low speed telemetry circuits. BFSK generation is easier but its BW is almost double the BW of BPSK. Also, PSK error performance is better than FSK and is used for high performance digital radio systems. It is has low cost, low performance, asynchronous data modems which are used for data communications over analog voice band telephone lines[3]. Therefore, M-ary PSK is the most commonly used digital modulation technique.

In this scheme we may send one of M possible signals $s_1(t),\ s_2(t),\ s_3(t)\ .....\ s_M(t).$ during each signaling interval of duration T. For almost all applications, the numbers of possible signals are $M = 2^m$, where m is an integer. The symbol duration $T = mT_b$, where T_b is the bit duration.

In this paper the BER of all modulation Techniques will be discussed and analyzed using graphical plots[3]. In digital communication systems PSK is widely used modulation scheme like military, deep space telemetry, commercial applications. The bandwidth efficiency of the PSK modulation scheme is increased by using M-PSK modulation [3]. This paper describes the comparision between Binary Phase ShiftKeying (BPSK), Quadrature Phase ShiftKeying (QPSK/4PSK), OctalPhaseshiftKeying (OPSK/8PSK), and HexaPhaseShift Keying

(HPSK). However, increasing the bandwidth efficiency in this way usually increases the bit error rate. This paper considers M-PSK modulation types where M = 2, 4,8 and 16 which corresponds to m = 1, 2 , 3 and 4 data bits. The general expression for a M-PSK signal set is given by

$$s_i(t) = V\cos[\,2\pi f_c t - \frac{(i-1)2\pi}{M}]\,,\, i = 1,2,\ldots\ldots\ M\,. \tag{5}$$

Where V is the signal Amplitude, Here M defines the number of constellation points in the constellation diagram, and fc is the carrier frequency. For example M = 4 implies 4-PSK or QPSK, M = 8 implies 8-PSK. The value of M depends on a parameter ‘k’ – the number of bits we wish to squeeze into a single M-PSK symbol. For example if we wish to squeeze in 3 bits (k = 3) in one transmit symbol, M = 2^K = 23 = 8. This gives us 8-PSK configuration. The previous equation can be separated into cosine and sine basis terms as follows

$$s_i(t) = V\cos\left[\frac{(i-1)2\pi}{M}\right]\cos(2\pi f_c t) + V\sin\left[\frac{(i-1)2\pi}{M}\right]\sin(2\pi f_c t) \tag{6}$$

This can be written as,

$$s_i(t) = s_{i1}(t)\,\varphi_1(t) + s_{i2}(t)\,\varphi_2(t) \tag{7}$$

Where $s_{i1}(t) = \sqrt{E_s}\cos\left[\frac{(i-1)2\pi}{M}\right]$, $s_{i2}(t) = \sqrt{E_s}\sin\left[\frac{(i-1)2\pi}{M}\right]$ (8)

$$\phi_1(t) = \frac{V\ \cos(\,2\pi f_c t)}{\sqrt{E_s}}\ ,\quad \varphi_2(t) = \frac{V\ \sin(\,2\pi f_c t)}{\sqrt{E_s}} \tag{9}$$

Here $\phi_1(t)$ and $\phi_2(t)$ are the orthonormal basis functions that follows from Gram-Schmidt orthogonalization procedure and $s_{i1}(t)$, $s_{i2}(t)$ are the coefficients of each signaling point in the M-PSK constellation. E_s is the symbol energy usually normalized to $1/\sqrt{2}$.

The constellation points on the M-PSK constellation lie 2π/ M radians apart and are placed on a circle of radius. The co-efficient $s_{i1}(t)$ and $s_{i2}(t)$ are termed as in phase (I) and quadrature-phase (Q) components respectively. The ideal constellation diagram for M-PSK contains M equally spaced signaling points that are located at the distance from the origin. The following figure illustrates the ideal constellation diagram for 8-PSK constellation.

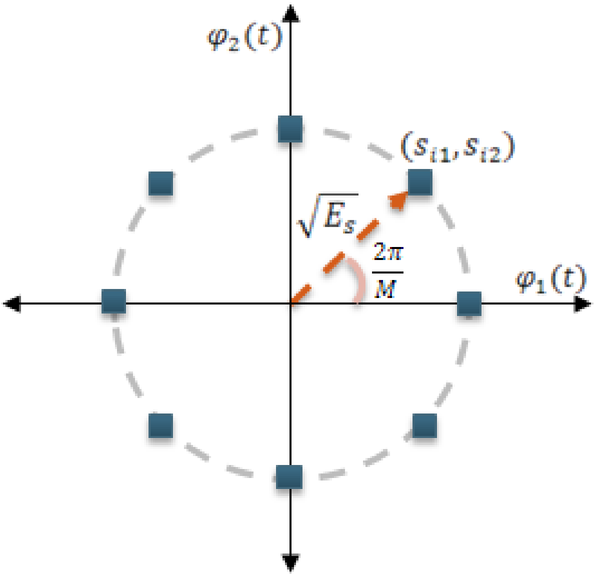

Fig.1. *Constellation Diagram for 8-PSK*

The generated I and Q components are then added with AWGN noise of required variance depending on the required E_s/N_0 . In effect, the received signal’s constellation is corrupted with noise and the detection is based on comparing the received symbols with the ideal signaling points and making a decision based on the minimum distance. Finally the simulated and theoretical symbol error rates are computed. The theoretical symbol error rate for M-PSK modulation is given by

$$P_s = 2Q\left[\sqrt{2E_s}\,\sin(\frac{\pi}{M})\right]$$

$$= erfc\left[\sqrt{E_s}\,\sin(\frac{\pi}{M})\right] \qquad (10)$$

Bit Error Rate of BPSK is same as that of QPSK, but

QPSK utilizes half of the channel bandwidth. If we increase the order of PSK, the performance will be degraded since the order of constellation is more susceptible to noise [1].

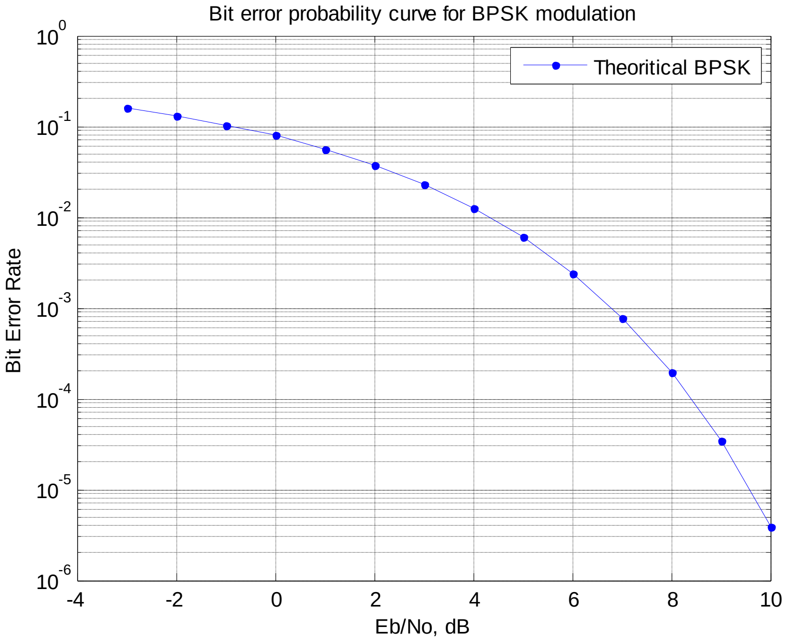

Fig. 2. *Bit error rate probability for BPSK over AWGN*

Figure 2 shows the Bit error rate for BPSK modulation over Additive White Gaussian Noise channel.

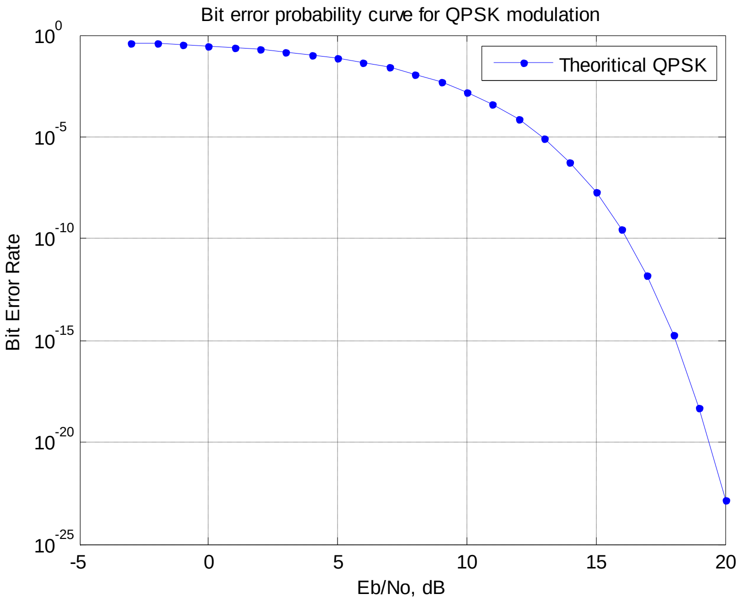

Fig. 3. *Bit error rate probability for QPSK over AWGN*

By substituting m=2 in equation (10) we obtain the value of P_s for QPSK. BER for BPSK is same as that of QPSK except channel bandwidth. It uses only half of the channel bandwidth and it transmits information at twice the bit rate of a BPSK system [5]. So it is mostly used in practice. The advantage of QPSK modulation is reduced bandwidth with increase in number of bits per symbol and disadvantage is that BER increases with increase in number of bits per symbol.

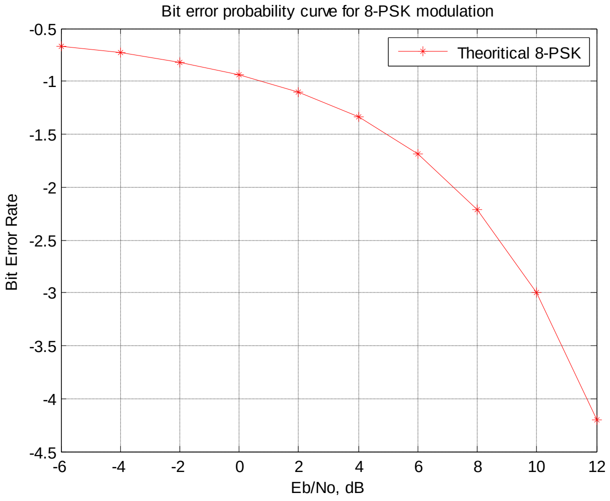

Fig. 4. *Bit error rate probability for 8PSK over AWGN*

The 8-PSK is also known as octa phase shift keying. The Bandwidth for 8- PSK is fb/3.Fig.3 shows the probability of error Vs Eb/No for OPSK.

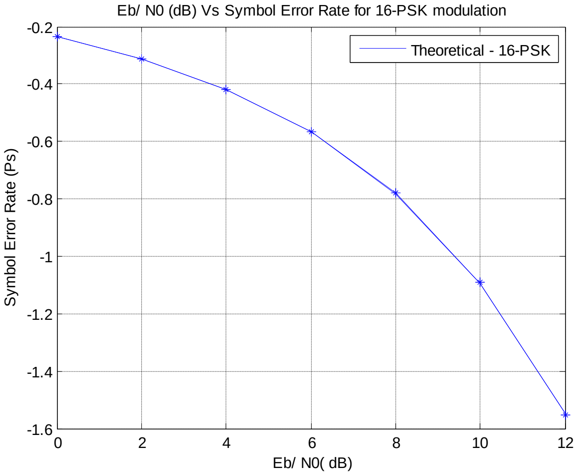

Fig. 5. *Bit error rate probability for 16PSK over AWGN*

The 16-PSK is also known as Hexa phase shift keying. The Bandwidth for 16- PSK is fb/4. In this modulation the probability of errors and number of bits per symbols increases with the value of M. The constellation points come closer as the distance between them decreases.Fig.4 shows the probability of error Vs Eb/No for HPSK.

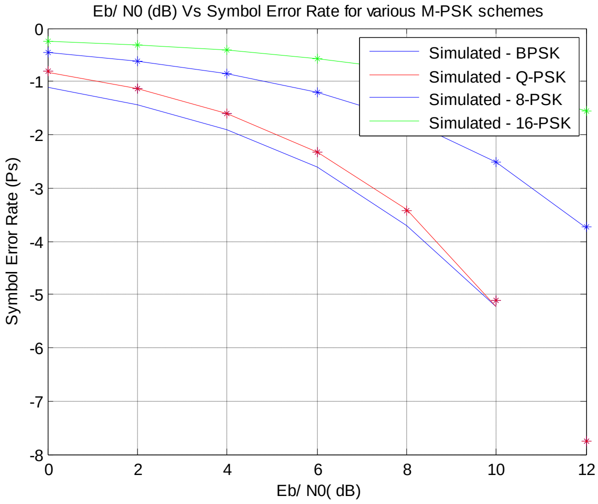

Fig.6 : *Comparative performance analysis of bit error rate probability for MPSK for M= 2, 4, 8 and 16 over AWGN.*

Fig.6 shows the comparison between BPSK, QPSK, 8-PSK and 16-PSK modulation schemes. The probability of error Vs Eb/No for BPSK, QPSK, OPSK/8PSK and HPSK/16PSK are obtained graphically by using MATLAB simulation.16-PSK gives better results than previous modulation techniques.

3. PERFORMANCE ANALYSIS OF MPSK USING MATLAB SIMULINK

Simulink, developed by The Math Works, is an environment used for multi-domain simulation design for dynamic and embedded systems. It provides a graphical environment and a set of block libraries that let you design, simulate, implement, and test a variety of time varying systems, including various fields like communications, controls, signal processing, video and image processing. The baseband simulation models of M-ary PSK for M=2, 4, 8 i.e. for BPSK, QPSK and OPSK are given in Fig. 7,8,9 and 10. Table.1. shows the parameter settings for each block .

Table 1. *Parameter settings for BPSK, QPSK, OPSK/8PSK and HPSK/16PSK*

Name of the Block	Name of the Parameter	BPSK/QPSK/ 8PSK/16PSK
1.Bernouli Binary Generator	Probability of a Zero Initial Seed Sample Time Samples per Frame Output Data Type	0.5 Any positive integer 1/symbol rate 1000 Double
2.Modulator	Phase Offset Constellation Ordering Input Type Output Type	(pi/2)/(pi/4)/(pi/8)/ (pi/16) Binary Integer Double
3.AWGN Channel	Initial Seed Mode E_b/N_0 (dB) No.of Bits per Symbol Input signal Power(watts) Symbol period(s)	Any positive integer SNR(E_b/N_0) Constant or variable 1/2/3/4 1 1 1
4.Demodulator	M-ary number Phase offset(rad) Constellation Ordering Output Type	2/4/8/16 0/pi/4/pi/8/pi/16 Binary Integer
5.Error rateCalculation	Receive delay Computation Delay Computation Mode OutputData Target No.of Errors	0 0 Entire Frame Port 100
6.Display	Format Decimation Floating display	Short 1 Unchecked

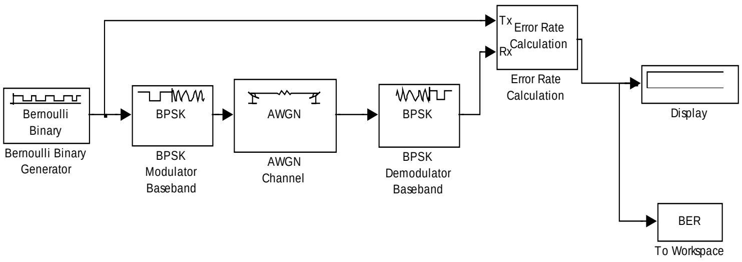

Fig. 7. *Simulation model for BPSK*

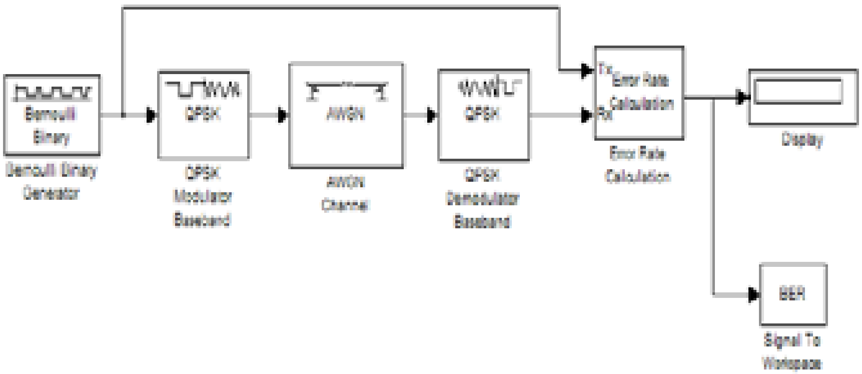

Fig. 8. *Simulation model for QPSK*

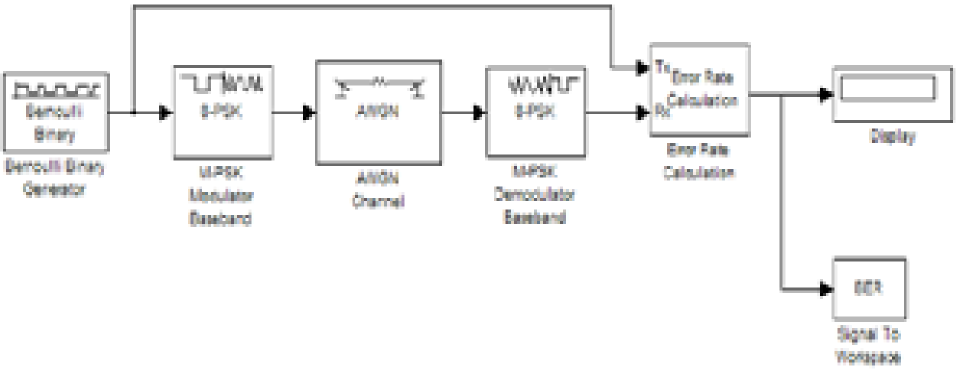

Fig. 9. *Simulation model for OPSK/8-PSK*

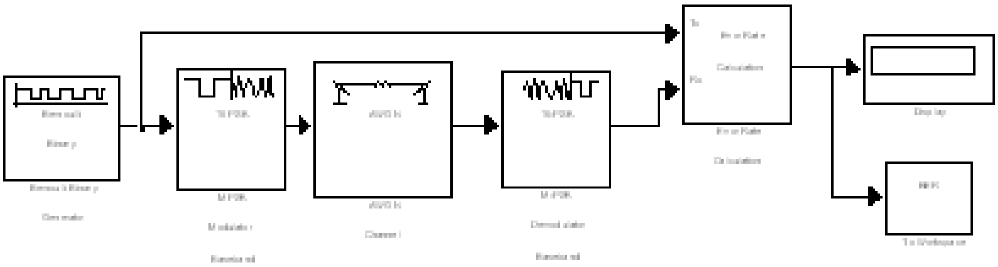

Fig.10. *Simulation model for HPSK/16-PSK*

4. SIMULATION RESULTS

The results of Bit Error Rate performance of M-ary Phase Shift Keying for M=2, 4 ,8 and 16 obtained using MATLAB SIMULINK Communication Toolbox are shown in Fig. 11,12,13 and 14.The comparative analysis of theoretical and simulated curves for BER vs Eb/ No (signal to noise ratio) for BPSK, QPSK, OPSK and HPSK over AWGN channel are given in Fig.15,16,17 and 18.

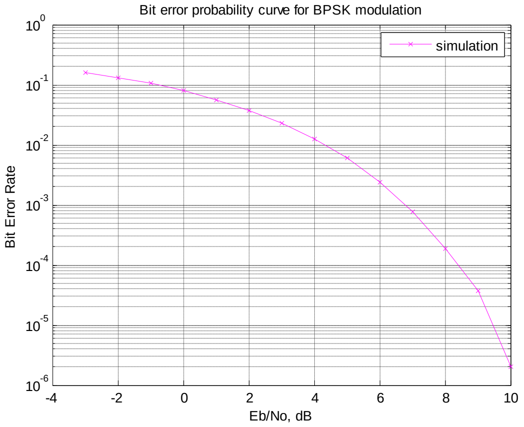

Fig. 11. *MATLAB Simulink based BER performance of BPSK over AWGN Channel*

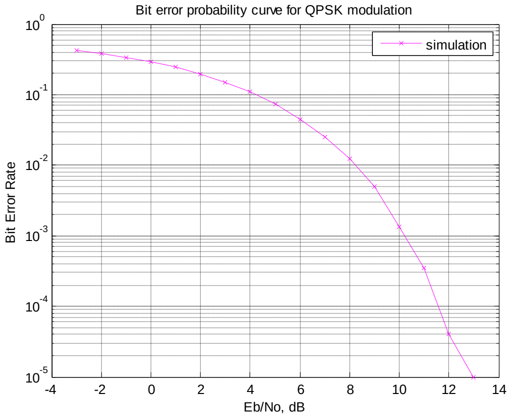

Fig. 12. *MATLAB Simulink based BER performance of QPSK over AWGN Channel*

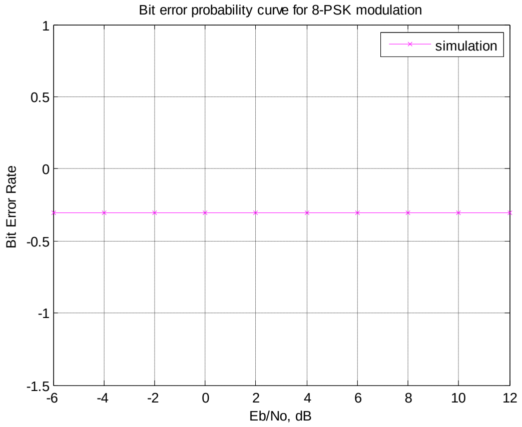

Fig. 13. *MATLAB Simulink based BER performance of 8-PSK over AWGN Channel*

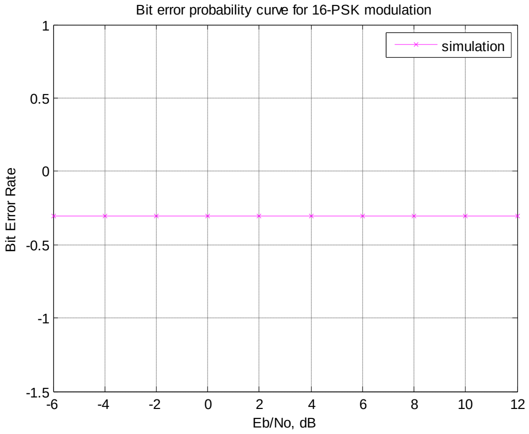

Fig. 14. *MATLAB Simulink based BER performance of 16-PSK over AWGN Channel*

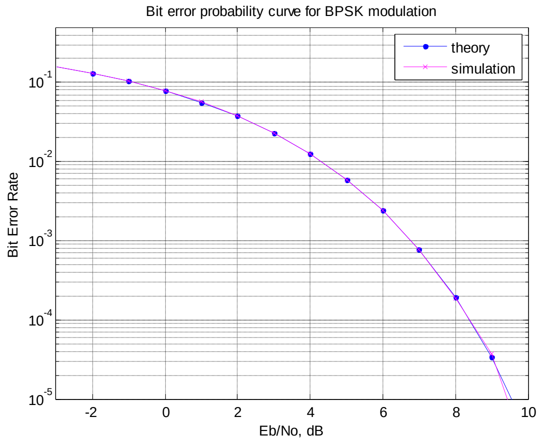

Fig.15. *Comparative analysis of BPSK over AWGN Channel using MATLAB Simulink*

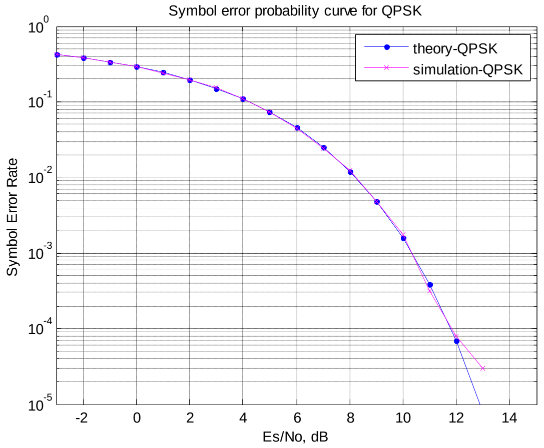

Fig.16. *Comparative analysis of QPSK over AWGN Channel using MATLAB Simulink*

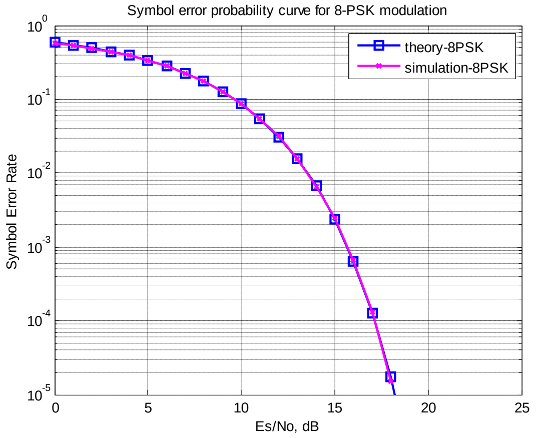

Fig.17. *Comparative analysis of 8-PSK over AWGN Channel using MATLAB Simulink*

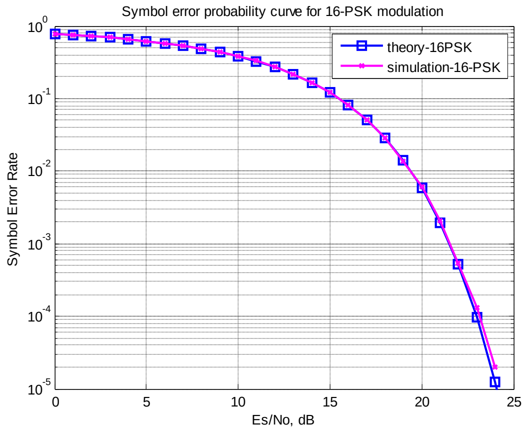

Fig.18. *Comparative analysis of 16-PSK over AWGN Channel using MATLAB Simulink*

Figure:19 shows the comparison between Theoritical and simulated M-ary PSK modulation for M=2,4,8and 16 over Additive White Gaussian Noise Channel using MATLAB Simulink.

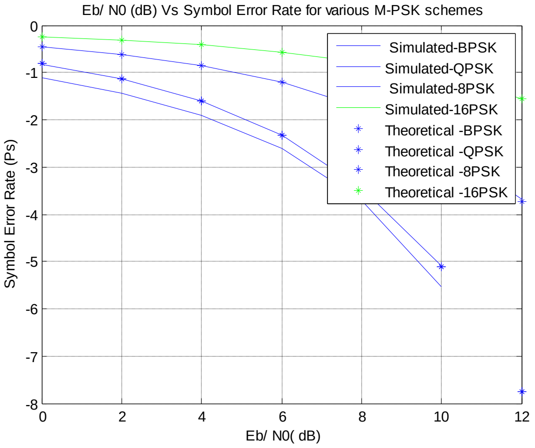

Fig.19. *Performance analysis of M-aryPSK for M=2,,4,8 and 16 over AWGN Channel using MATLAB Simulink.*

5. CONCLUSION

In this paper the mathematical analysis and simulations using Matlab shows that the Bit Error Rate for the M-ary PSK modulation techniques decrease monotonically with increasing values of SNR(Eb/N0). In QPSK system data transmission rate is twice the bit rate of a BPSK system. In of 8-PSK BW is one third of the BW of BPSK and it transmits information at thrice the bit rate of a BPSK system. It is clearly observed from the simulation curves and the mathematical analysis of the signals that as the number of signals or number of M increases, the error probability also increases over AWGN channel. Thus higher-order modulations exhibit higher error-rates; in exchange however they deliver a higher raw data-rate. Increasing the data rate will increase the SNR, however, increasing Rb (Bit rate in bits /second) will also cause more noise , since more bits are packed closer and sent through the channel. So, we cannot increase SNR by simply increasing Rb. We must strike a compromise between the data rate and the amount of noise at the receiver.

6. FUTURE WORK

The M-ary PSK can be implemented for M=32 by using five bits per symbol in both MATLAB and Simulink.

REFERENCES

[1]. Harjot Kaur,Bindiya Jain, Amit Verma.”Comparative Performance Analysis of M-ary PSK Modulation Schemes using Simulink,” IJECT Vol. 2, Issue 3, Sept. 2011.

[2]. Zhang, L.; Cao, Z., Gao, C. “Application of RS-coded MPSK Modulation scenarios to Compressed Image Communication in Mobile Fading Channel,” IEEE Vehi. Tech. C 2000, pp. 1198- 1203.

[3]. Sklar, B.“Digital Communications: Fundamentals and Applications”, Prentice-Hall, 2nd Edition, pp. 30-33, 2001.

[4]. MATLAB Help Documents, Communications Toolbox.2009.

[5]. Haykin, S.; Moher, M., “Introduction to Analog & Digital Communications”, John Wiley & Sons, Inc., 2007