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Performance Evaluation Of Digital Modulation Techniques In Awgn Communication Channel

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Abstract

The paper investigates the performance of different digital modulation techniques in Additive White Gaussian Noise (AWGN) Channel. It reviews digital modulation techniques. The AWGN channel was modeled and simulated in MATLAB Environment. The evaluation of the different modulation techniques was carried on the modeled channel. The BER for simulated modeled channel agreed with the theoretical results. The effect of multipath channels on bandpass modulation was also investigated by simulating a selective frequency fading channel with 6 rays in MATLAB Environment for up to 20MHz bandwidth. This was carried out to understand the contributions of channel characteristics to effective wireless communication. It was observed that the BER is higher in frequency selective channel as compared with the AWGN channel. It was also observed that the performance of 64QAM is better compared with other bandpass modulation in AWGN Channel

Key words: BER**,** communication channels, modulation and Noise

1. Introduction

Wireless communication is enjoying a fast growth period in history which is coupled with technology improvements that permit its widespread deployment. Such is the cellular concept developed by Bell Laboratories [1]. Mobile communication offers a full duplex communication using a radio to connect portable device to a dedicated Base station, which is then connected to a switching network. Microwave communication for line of sight propagation deployed for transmission between one station and the other. In a rapidly growing environment, overall system performance will depend on the ability to provide power and spectrum efficiency, adaptive to wireless fading and channel characteristics and support to changing UE traffics. This work is investigating the channel impairment to wireless communication as it affects increasing the data rate. Because of the growing trend in Mobile communication, the work focuses on this area. The effect of increasing the bandwidth to 20MHz was investigated.

2. Wireless Channel Characteristics

Wireless channel is an unguided channel and signals not only contain the direct Line of Sight LOS waves; but also a number of signals as a result of diffraction, reflection and scattering. This propagation type is termed Multipath [2] degrades the performance of the channel. Similarly, the channel may introduce Doppler effect when the transmitter or receiver moves

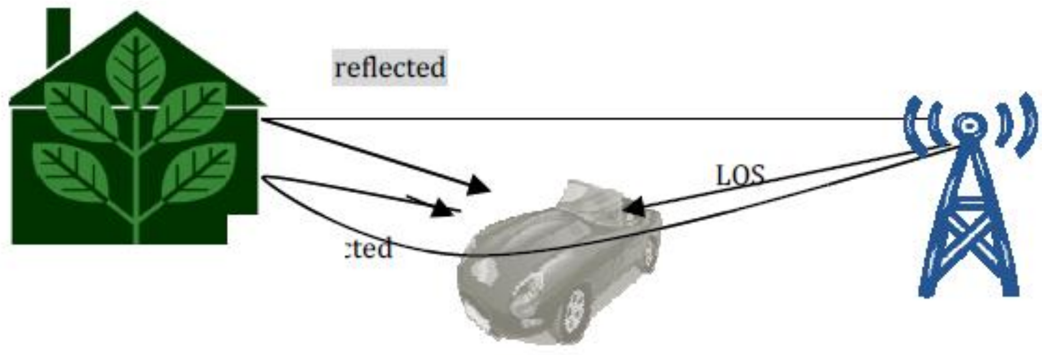

Figure 1: Multipath Signal reception of a moving receiver

2.1 Additive White Gaussian Noise Channel

Additive White Gaussian Noise (AWGN) channel is a good model for the physical reality of channel, as long as the thermal noise at the receiver is the only source of disturbance [3]. The impairment this channel caused to signal is the addition of Gaussian distributed noise. Mathematically, it can be illustrated as:

$$r(t) = s(t) + n(t) \dots\dots\dots\dots\dots\dots\dots\dots\dots 1$$

Where r(t) is the received signal, s(t) is the transmitted signal and n(t) is the noise.

2.2 Multi Path Fading Channels

An alternative class of channel used to model communication system is fading channels because mobile reception is harshly affected by multipath propagation which results in Fading or Inter-symbol Interference (ISI). This can be mathematically expressed as

$$r(t) = s(t) * h(t) + n(t) \dots\dots\dots..\dots.2$$

2.2.1 Flat and Frequency Selective Fading Channel

Time disperse signal are often affected by the delay spread. If the delay spread is less than the symbol period *Ts*, the signal channel is categorised as *Flat fading* which preserves of the spectral characteristics of the signal at the receiver [2]. In contrast, if signal bandwidth is more than the coherence bandwidth or delay spread is more than the symbol period, then the channel is categorised as *Frequency Selective fading* and leads to ISI which degrades the channel

3. Channel Models

Andrea stated in [4] that deterministic channel models are rarely available. But to evaluate the performance of signals properly in fading channels, this work considered Flat and Frequency Selective fading channel and few of the models.

3.1. *Rayleigh and Rician Fading Model*

Rayleigh distribution model is often used for fading signal with infinite or large number of arrival paths at the same time whose gain are statistically independent and no dominant path[4]. The phase component of the channel gain is Gaussian distributed and equation 2.8 is its probability density function (PDF) as stated by Rappaport[5] :

$$(r) = \begin{pmatrix} \frac{r}{\sigma^2} e^{\left(-\frac{r^2}{2\sigma^2}\right)} & 0 \le r \le \infty \\ 0 & r < 0 \end{pmatrix} \dots\dots 3$$

Where, σ is the RMS value of received signal before detection. And according to [2], the average channel power is given by:

$$E[r] = 2\sigma^2 \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots.4$$

Similar to the distribution properties of Rayleigh is the *Rician Distribution* model except for the presence of a dominant path with numerous weak paths. Inclusive in its pdf (equation 5 [2]) is the peak amplitude *A* of dominant signal and zero-order Bessel function I, of the first kind

$$p(r) = \begin{pmatrix} \frac{r}{\sigma^2} e^{\left(-\frac{r^2+A^2}{2\sigma^2}\right)} I_0\left(\frac{Ar}{\sigma^2}\right) & A \ge 0, r \ge 0 \\ 0 & r < 0 \end{pmatrix} ..5$$

3.2 Clarkes' Fading Model

The model assumes all multipath signals arrive at the same time in horizontal direction and when the mobile user moves, each path will experience a different Doppler shift. Hence, a uniform probability density function (PDF) of the rays is assumed and a Doppler effect is introduced [6].

3.3. ITU Model

International Telecommunications Union published some generic test models that are commonly used in the communication industry. Depicted in [2] is the three common cases of the model- Indoor, Pedestrian and Vehicular. But in this work, the interest is in the Channel B type of the Pedestrian model with 6 rays, median delay spread (750 *ns*) and 55% probability of occurrence in an outdoor to indoor environment. Each tap is modelled using Rayleigh fading distribution characterised by Clarkes' model to incorporate a model of the Doppler spectrum. From table 1, the rays are Rayleigh distributed with Classic Doppler spectrum defined [7] as:

$$S(f) \propto \frac{1}{\sqrt{1-\left(\frac{f}{f_d}\right)^2}} \qquad for\ f \epsilon - f_d, \ldots \ldots \ldots \ldots .6$$

Assuming all the paths arrives at the same time and are uniformly distributed, the PSD is modelled as [4]:

$$\tilde{a}(t) = \sum_{i=0}^{N-1} a_i\, e^{j(2\pi f_i} t + \theta_i) \quad \ldots \ldots \ldots \ldots \ldots \ldots .7$$

$$f\ or\ f_i = f_d \cos\theta_i \qquad 0 \ldots\ldots\ldots\ldots\ldots\ldots...8$$

$$S_h(f) = \mathcal{F}\{R_h(\Delta t;\tau)\} = \left\{\begin{matrix} \dfrac{P_{av}}{\sqrt{1-\left(\dfrac{f}{f_d}\right)^2}} & |f| < f_d \\ 0 & |f| > f_d \end{matrix}\right\} \ldots..9$$

Where R_h is channel autocorrelation function, P_{av} is the average channel power, F_i is the Doppler shift in direction of travel for path θ_i and ã is the channel response in relation to Doppler shift

Table1: ITU Pedestrian Model [4]

	Channel A		Channel B		Doppler Spectrum
Tap	Relative Delay (ns)	Average Power (dB)	Relative Delay (ns)	Average Power (dB)	
1	0	0	0	0	Classic
2	110	-9.7	200	-0.9	Classic
3	190	-19.2	800	-4.9	Classic
4	410	-22.8	1200	-8.0	Classic
5			2300	-7.8	Classic
6			3700	-23.9	Classic

4. BAND PASS MODULATION

Modulation is a process of transforming signal into waveforms that are compatible with the channel properties [8] and this is necessary in wireless communication where the antenna diameter must be at least equal to the wavelength of the carrier [9]. Advances in technology over the last decades have made digital transmission a widely acceptable and significant mode over the Analog transmission. A digital data is usually in the sequence of 0s and 1s, regardless of their generic source, i.e either it is inherently digital or a result of analog-to-digital conversion [0]. To transmit such data over the channel, a signal that represents the data and matches the channel property is generated. Since, there is a limitation in antenna size that can meet efficient signal transmission, data signal are super imposed on carrier-wave by shifting the information bearing signal to the frequency band of the channel [11]. Baseband signals can be translated to higher frequency range. This technique is known as *bandpass modulation* and they are used in wireless and mobile communication, supporting small size antenna design for mobile equipments. Three main parameters-amplitude, phase, frequency can be exploited to produce a modulated signal[9], which leads to three generic modulation scheme namely Amplitude Shift Keying (ASK), Phase Shift Keying (PSK) and Frequency Shift Keying (FSK).

For a given digital data of finite bit sequence to be transmitted over a channel by a bandpass filtered signal s(t), a mapping process known as digital modulation is required between the bit sequence and possible signals [2,10]. The mapping rule is also needed for proper demodulation and detection at the receiver. Also, signals can consider information bits in groups known as *symbols* and generate one wave form for each group. That is, transmitted data can have *M* numbers of symbols in a signal constellation or word length and *k* numbers of bit within each symbol. The k numbers of bits contained per symbol is guided by

$$k = \log_2(M) \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots 10$$

And M ε [2, 4, 8……M]. The general form of modulated signal s(t) is

$$s(t) = A(t)\cos[w(t)t + \emptyset(t)] \ldots \ldots \ldots .11$$

Where A is the amplitude, w is the frequency and ∅ is the phase of the signal

3.1 Phase Shift Keying

This is the modulation mode of where the phase Ø(t) parameter of the signal is varied.

The transmitted information is contained in *M* possible phase values. The values are also represented on the constellation maps. Hence for every phase value, *k* numbers of bit is represented. Increase in symbol rate gives a corresponding increase in bit rate and offers an advantage that while the symbol period remains constant, the bandwidth remains unchanged. The BER equation of M-PSK modulated signal in an AWGN channel [9] can be expressed as:

$$P_b = \left(\frac{1}{k}\right) erfc\left(\sqrt{\frac{kE_b}{N_0}} \sin\left(\frac{\pi}{M}\right)\right) \ldots . \ldots . .12$$

Where E_b is the signal energy, N_0 is the noise power, M is the number of phase carrying data and k is the number of bit per symbol

3.2. Quadrature Amplitude Modulation

QAM is a hybrid modulation technique that takes its implementation from combining variations of both the amplitude A(t) and phase Ø(t) of the signal. The structure is similar to that of PSK, but the amplitude takes on a different range of value pairs [9]. Which means it uses the amplitude of the quadrature carrier signal to carry the data. QAM produce a better distribution of signal states in the signal constellation and variety of shape can be achieved. Data is stored in *M* possible symbols that can be located at any amplitude and phase dimension. It can also achieve increase in bit rate without bandwidth expansion. However, due to its superior bit packing structure, it has a lower probability of error performance than PSK when *M* possible values are more than 8. Alsusa in [14] stated the bit error probability as shown below:

$$P_b = \left(\frac{1}{k}\right) erfc\left(\sqrt{\frac{3kE_b}{2(M-1)N_0}}\right) \ldots \ldots \ldots .13$$

3.2. Error Probability

A key performance metric of digital information transmission over a channel in communication system is the measure of errors in the transmitted bits or symbols. This is the amount of information error that is experienced when transmitting over a channel at certain Signal energy to Noise power Ratio (SNR), depending on the modulation scheme. It follows a simple statistical grading of the numbers of error and often referred to as Bit Error Rate (BER) or Symbol Error Rate (SER) [9].

4. Implementation

The communication channel was modeled as AWGN channel. BER target performance of each digital modulation scheme in AWGN channel was determined. Provided below is the simulated BER performance of all the modulation scheme in AWGN channel and compared to their respective theoretic counterpart for correctness.

5. Results presentation

Based on the established Equations for different modulation scheme, the theoretic formulation was developed. Figure 2 shows the performance two different channels. To understand better the importance of BER measurement in different modulation, simulated BER results of some modulation scheme is provided in Fig.3 to Fig.6.

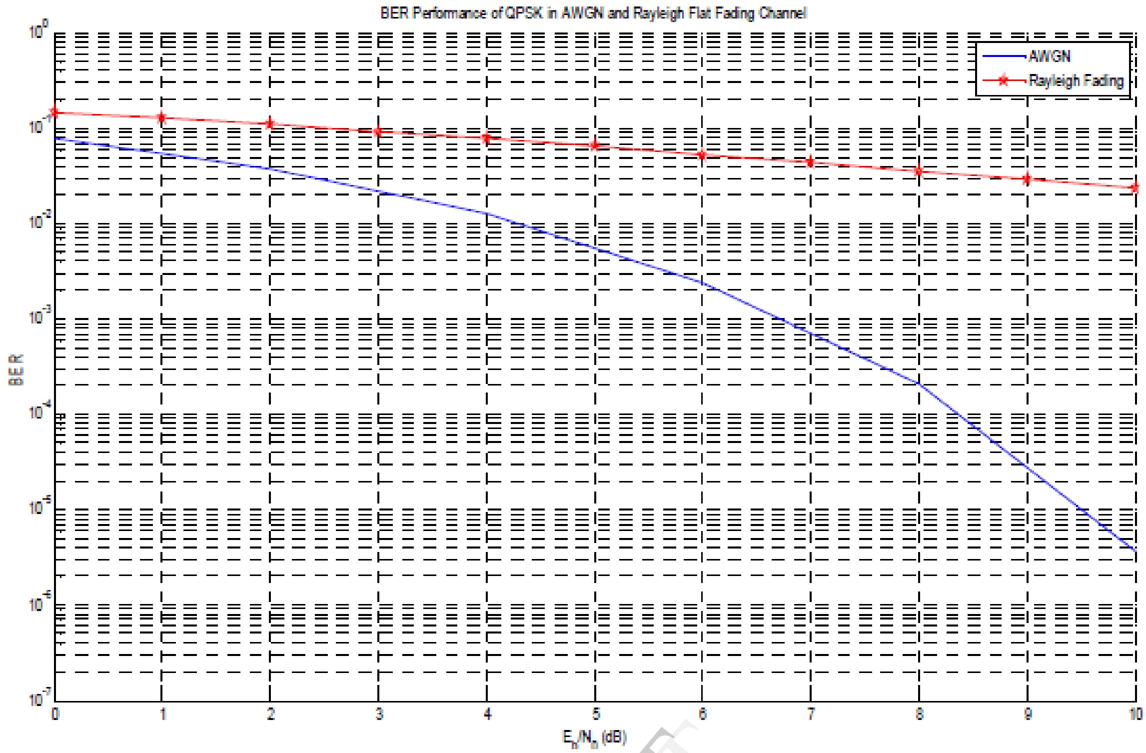

Figure 2: BER performance of QPSK in AWGN Channel and Rayleigh Fading Channel (M=4)

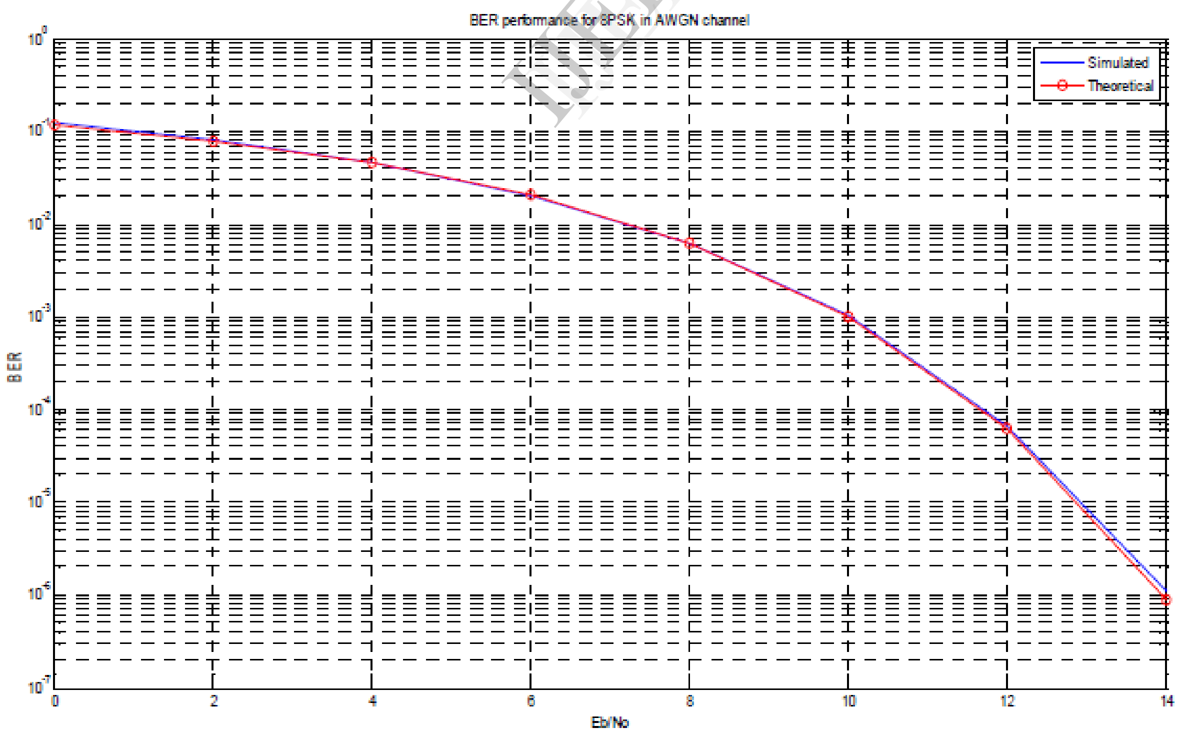

Fig 3. Simulated and Theoretical 8PSK BER Performance in AWGN Channel

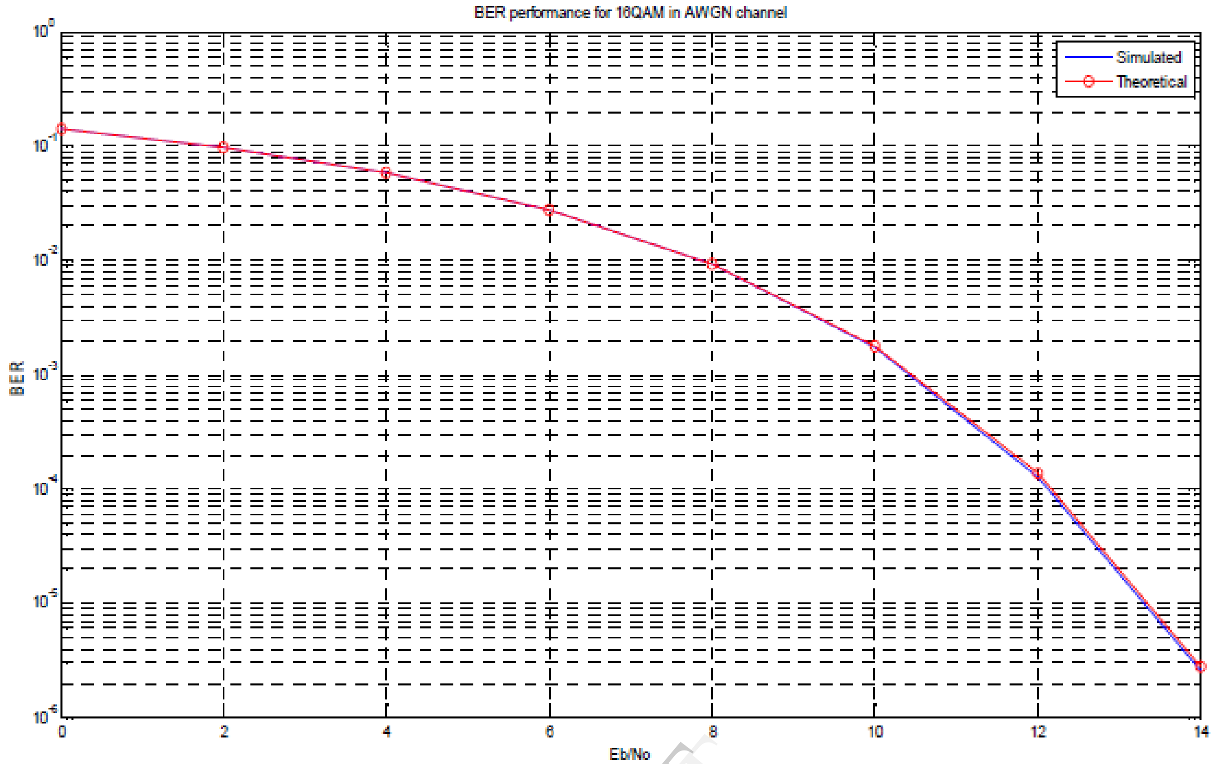

Fig.4: Simulated and Theoretical 16QAM BER Performance in AWGN Channel

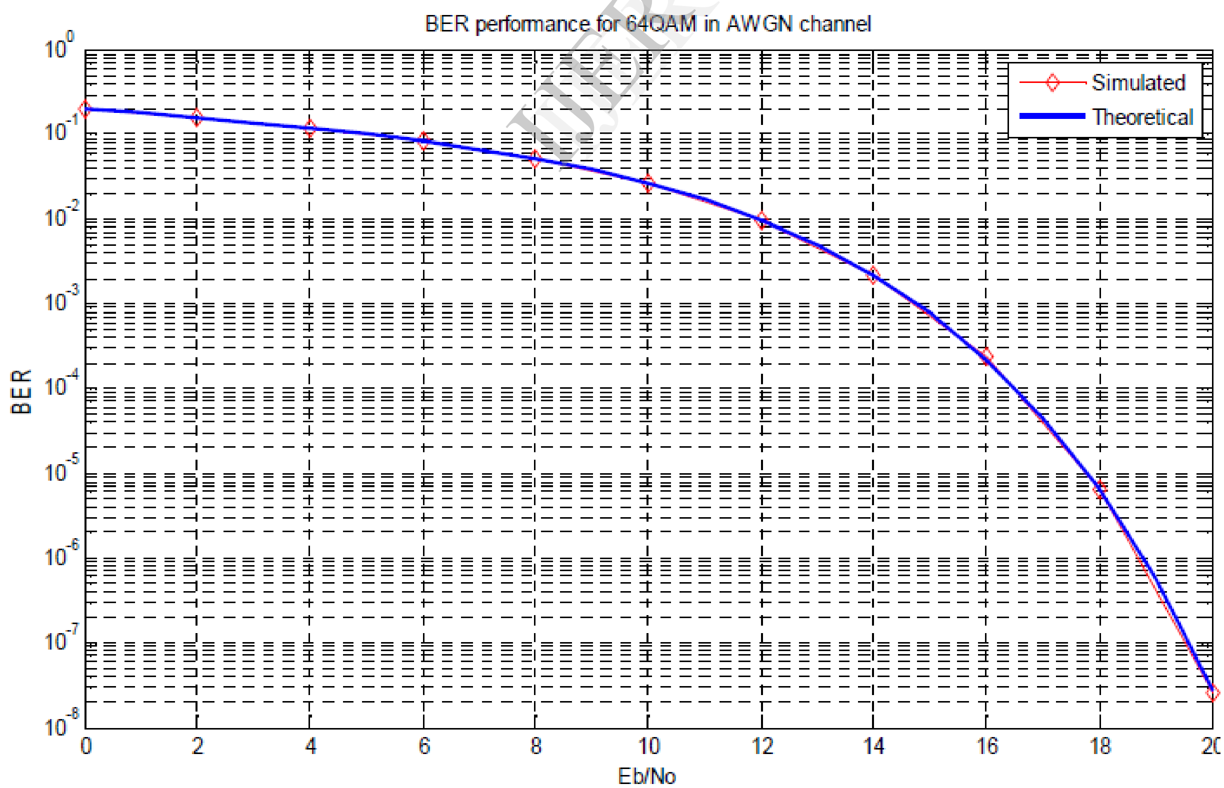

Fig. 5: Simulated and Theoretical 64QAM BER Performance in AWGN Channel

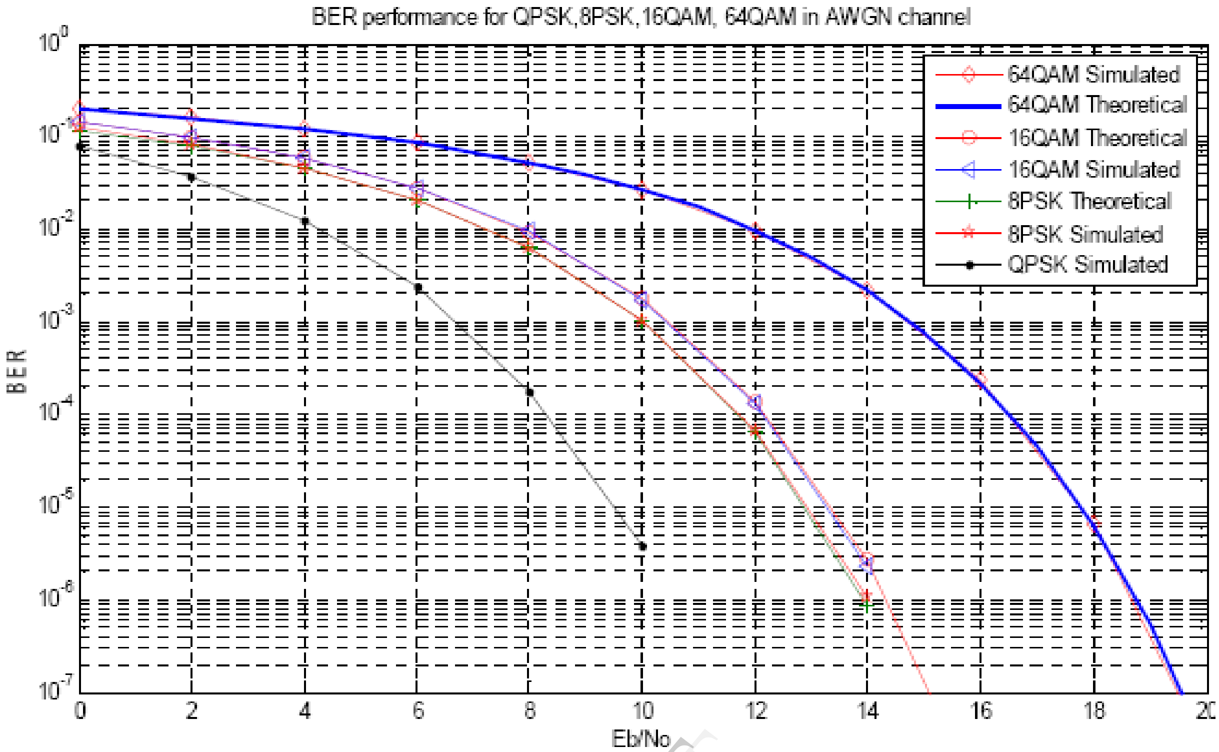

Fig.6: Combined Simulated and Theoretical QPSK, 8PSK, 16QAM AND 64QAM BER Performance in AWGN Channel

5.1 DISCUSSION

From Fig. 2, it was observed that the BER performance of AWGN channel improves rapidly and offers a better performance than Rayleigh fading channel. This is because Rayleigh fading channel is characterised by multipath signal and it is computed by average BER. The average BER is dominated by poor BER of individual path and variations in instantaneous BER. Hence, it offers a poorer performance BER Performance. The results also show that the performance of 64QAM is better compared to the other modulation scheme.

CONCLUSION

The performance of various modulation techniques in AWGN channel was investigated. The simulated results of BER agree with the theoretical values obtained for the modulation schemes. It was observed that BER performance of bandpass modulation in AWGN channel offers a

better performance than in Rayleigh fading channel. This is expected as multipath effect limits the capacity of such channel.

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