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Performance Evaluation of Digital Modulation Schemes BPSK, QPSK & QAM

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Abstract:

The paper discuses about the performance of digital modulation schemes – BPSK, QPSK and QAM using MATLAB. The performance of these schemes is evaluated by finding the bit error rate (BER) on AWGN and Rayleigh channels. Initially a MATLAB code is generated and the performance of these modulation schemes BPSK,QPSK and QAM is evaluated by finding BER and signal to noise ratio over AWGN and Rayleigh fading channels. Later a simulation model is created using Simulink for these modulation schemes and its performance is evaluated on AWGN channel.

Keywords — **AWGN, BER, BPSK, QPSK, QAM, Rayleigh fading.**

I. INTRODUCTION

In Digital modulation [1], a digital bit stream is transmitted over analog bandpass channel. Here an analog carrier signal is modulated by a discrete signal. Most fundamental digital modulation schemes are based on keying. These are Phase shift keying (PSK), Frequency shift keying (FSK), Amplitude shift Keying (ASK) and Quadrature amplitude modulation (QAM). The choice of digital modulation scheme [1],[5] is very important as it significantly affects the performance of a communication system.

Any real time communication system contains noise. This noise results in some probability of error at the demodulator. Also as different communication system have different sensitivities to errors, there exists different ways to correct them.

Radio communication systems come in a variety of forms and will have different channel characteristics while designing a communication system. Some of these include Fading, Shadowing, Interference Propagation path-loss etc.

This paper reviews the key characteristics [2]-[6] of communication channel in Rayleigh fading and compares the performance of the digital modulation schemes BPSK, QPSK and QAM BER in presence of Additive White Gaussian Noise and Rayleigh fading. Simulations are carried out in MATLAB [7] and a real-time simulation model is created using Simulink.

The rest of the paper is organised as follows: Section II talks about each of the digital modulation scheme BPSK, QPSK and QAM. Section III describes the performance evaluation parameters. Section IV gives the simulation results and Section V concludes the paper.

II. DIGITAL MODULATION SCHEMES

In keying schemes either amplitude, frequency or phase of carrier signal is keyed in response to the patterns of 1's and for 0's

A Phase shift keying(PSK)

It is the basic digital modulation scheme in which the phases are switched in response to the input bits 1's and 0's. In binary phase shift keying also called 2PSK or phase reversal keying, the phases are separated by 180 and the maximum rate of modulation is 1 bit/symbol.

B Quadrature Phase Shift Keying (QPSK)

It is a form of PSK which uses a combination of two bits (00,01,10&11). Each of this bit combination is represented by four possible carrier phase shifts (0,90,180 & 270). With QPSK twice as much information as ordinary PSK can be transmitted using the same bandwidth. This scheme is useful for high data rate applications like video conferencing, cellular phone systems etc. It is also known as Quaternary PSK, Quadriphase PSK or 4PSK. With four phases, two bits per symbol can be encoded.

C Quadrature Amplitude Modulation(QAM)

It is both an analog and digital modulation scheme which transmits two message signals by changing the amplitude of two carrier waves using AM analog modulation scheme or using ASK digital modulation scheme. The two carrier waves with the same frequency are out of phase with each other by 90 degree and are thus called quadrature of carriers or quadrature components. These two modulated waves are summed and the final waveform is a combination of both PSK in digital case and ASK or PM and AM in analog case.

III. PERFORMANCE PARAMETERS

A Bit Error Rate

Bit error gives the number of bits in error per unit time. In digital communication, the number of bits in error are the number of bits received in a data stream over a communication channel that are altered either due to noise, interference, distortion or bit synchronisation, attenuation, wireless multipath fading etc.

Bit error probability P_e is defined as the expectation value of the bit error ratio i.e. the number of bit errors divided by the total number of transferred bit during a defined time interval. It is desirable to improve by choosing a strong signal strength and by choosing a robust modulation technique.

In a noisy channel the BER [1], [5] may be expressed as a function of signal to noise ratio denoted as E_b/N_o and is given by $BER = 1/2\, erfc\sqrt{Eb/No}$

B AWGN

It is one of the channel model in which the only impairment to communication is a linear addition of white noise with a constant spectral density and a Gaussian distribution function of amplitude. This model does not account fading, interference, non linearity or dispersion but produces simple and tractable mathematical models which are very useful to gain the insight into the underlying behaviour of a system.

The channel capacity C for AWGN channel is given by

$$C = Blog2(1 + S/N)\ bits/sec$$

where B is bandwidth in Hz, S/N is Signal-to-Noise ratio and is measured in bits per second.

C Rayleigh Fading

It is a statistical model which assumes that the magnitude of a signal that has passed through a transmission medium or communication channel varies randomly or fade according to a Rayleigh distribution.

It is mostly applicable to channels where there is no dominant propagation along a line of sight between a transmitter and receiver.

IV. SIMULATION RESULTS

In this paper, MATLAB [7] is used to simulate the performance of the digital modulation scheme-BPSK, QPSK & QAM and their performance is evaluated by finding BER over AWGN and Rayleigh fading channels. Model is also created using Simulink with the help of communication tool box. Matlab 15 version is used for this.

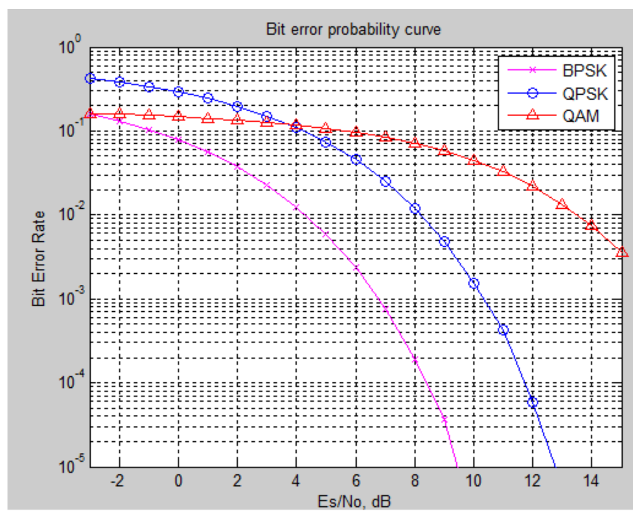

Fig. 1 BER Performance of BPSK, QPSK & QAM in AWGN channel using MATLAB code

Fig1. above shows BER versus SNR (E_b/N_o in dB) performance analysis of BPSK, QPSK & QAM modulation techniques over Additive White Gaussian Noise channel using MATLAB code. From figure 1 it is clear that BPSK has lower BER than QPSK & QAM. For example at E_b/N_o of 4dB, BER in BPSK is around 0.01 whereas QPSK and QAM is around 0.1. At SNR= 10 BER for BPSK is 0 but for QPSK and QAM it is greater than 10^{-3}. If we compare BER among QPSK and QAM then at SNR 10, BER for QPSK is approximately 10^{-3} where as QAM it is around 10^{-1}.Therefore QPSK performs better than QAM. Also at SNR=14, BER for QPSK is 0 where as for QAM it is approximately 10^{-2}.

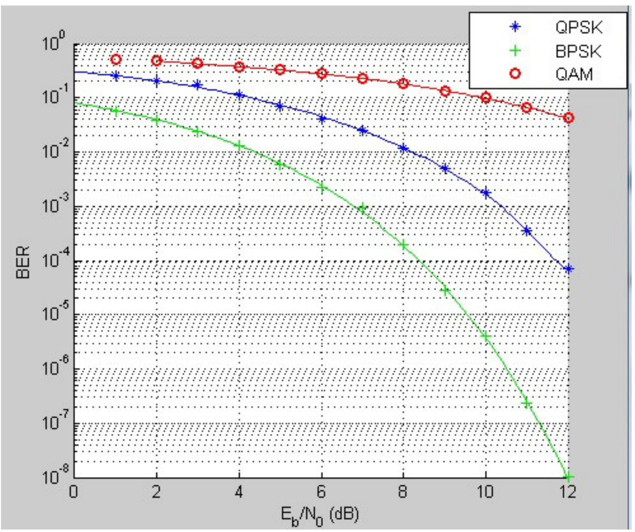

Fig. 2 BER Performance of BPSK, QPSK & QAM in Rayleigh channel using MATLAB code

Figure2.shows BER vs SNR plot for BPSK, QPSK & QAM modulation schemes in Rayleigh fading channel with MATLAB. From figure 2. it is clear that BPSK has lower BER than QPSK and QAM. For example at SNR=5, BER for BPSK is less than 0.1 whereas for QPSK and QAM it is around 0.2. Similarly at SNR=15 dB, BPSK has BER less than 0.01 whereas QPSK has above 0.01 and QAM around 0.1.

Table I. below gives the comparison of different modulations over both AWGN & Rayleigh fading channels.

TABLE I
COMPARISION OF DIGITAL MODULATION SCHEMES USING MATLAB

AWGN Channel			
SNR(dB)	**BPSK BER**	**QPSK BER**	**QAM BER**
4	0.01	0.1	0.1
10	0	0.001	0.1
14	0	0	0.001
Rayleigh Fading Channel			
5	0.1	0.2	0.2
10	appr. 0.01	>0.01	0.1
15	<0.001	>0.01	>0.01

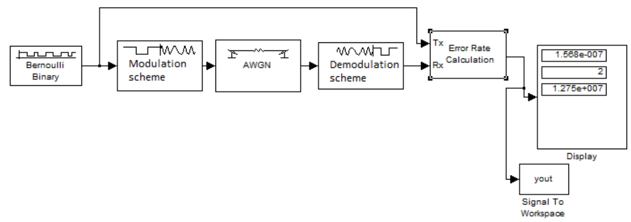

Fig.3. Digital Communication System model created using Simulink

Figure 3. shows a generalised digital communication system model with AWGN channel created using Simulink to calculate BER.

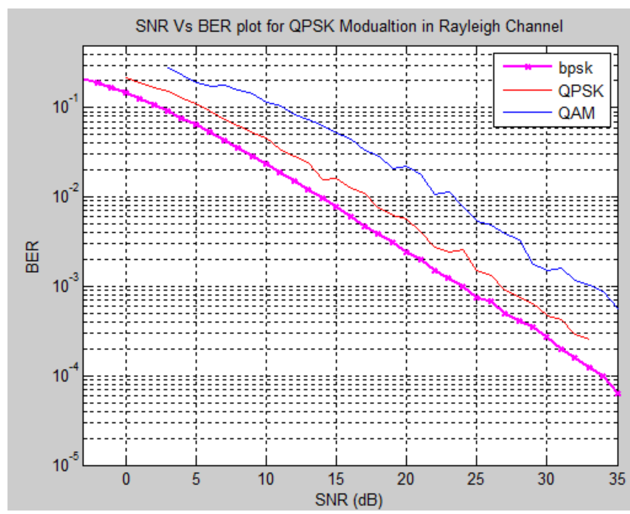

Fig. 4 BER Performance of BPSK, QPSK & QAM using simulink model

Figure 4. gives the performance analysis of BPSK, QPSK and QAM modulation schemes over AWGN channel generated through Simulink. From figure 4. it is clear that BPSK has the lowest BER values compared to QPSK and QAM. For example

at E_b/N_o or SNR=2, BER is approximately 0.005 for BPSK and above 0.1 for QPSK and QAM. For SNR =7, BPSK has BER value of 0.001 whereas QPSK has around 0.1 and QAM above0.1. For SNR =12, BER for BPSK is 0, whereas QPSK it is 0.0001 and QAM it is 0.1. Table II. below gives values of BER vs SNR over AWGN for various digital modulation schemes.

TABLE II
COMPARISION OF DIGITAL MODULATION SCHEMES USING SIMULINK

AWGN Channel			
SNR(dB)	**BPSK BER**	**QPSK BER**	**QAM BER**
2	0.05	>0.1	>0.1
7	0.001	0.1	>0.1
12	0	0.0001	0.1

V. CONCLUSIONS

Various digital modulation schemes like BPSK, QPSK & QAM are evaluated based on BER over both AWGN and Rayleigh fading channels. Through simulations using MATLAB it is concluded that BPSK performs better compared to QPSK and QAM for both the cases- using AWGN channel and Rayleigh fading channel. A simulation model is also created using Simulink and BER vs SNR plot is also generated for AWGN channel. The graph says that BPSK outperforms QPSK and QAM by giving a very low BER for a given SNR.

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