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Optimization Method for Analysis of Bit Error Rate with BPSK Modulation Technique

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Abstract— In this paper the bit error rate (BER) analysis of binary phase shift keying (BPSK) modulated signal detection is performed in presence of additive white Gaussian noise. Through this technique we have analyzed and calculated probability of error with systems operating with the additive white Gaussian noise and by doing so the performance of modulation techniques can be compared with theoretical values.

Keywords— Additive Gaussian Noise, Bit error Rate, M-ary Phase Shift Keying, Signal-to-Noise Ratio.

1. Introduction

IN digital communication system design, the main objective is to receive data as similar as the data sent from the transmitter. It is important to analyze the system in term of probability of error to view the system's performance. Each modulation technique has different performance while dealing with signals, which normally are affected with noise. [1] [2] General explanation for probability of error is explained and simulated in this paper. It focuses on comparative performance analysis of basic M-ary PSK modulation schemes like BPSK (M=2). To better understand the M-ary PSK system, a Simulink-based simulation system is designed for M-ary PSK for M=2, 4 and 8 using communication toolbox in Simulink. This paper indicates that increasing of M results in increase of BER. Error rates of M-ary PSK system versus the signal-to-noise ratio (SNR) are used to evaluate the performance of M-ary PSK system. The BER curves for MPSK obtained after simulation are compared with theoretical curves.

2 Bit Error Rate

In Digital transmission 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, interference, distortion or bit synchronization errors. The bit error rate or bit error ratio (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; often expressed as a percentage. The bit error probability Pb is the expectation value of the BER [3].

$$\text{Bit Error Rate (Pb)} = \frac{\text{Number of bit in error}}{\text{Total number of transferred bits}}$$

The performance of each modulation is measured by calculating its probability of error with assumption that systems are operating with additive white Gaussian noise. High data rate like 8-PSK can transmit 3 bits per symbol. When a large amount of power is available, it is easy to reduce the bandwidth of a modulation scheme; similarly high power is not needed to achieve a low BER if a wide bandwidth can be tapped [4]. Modulation schemes which are capable of delivering more bits per symbol are more immune to errors caused by noise and interference in the channel. Moreover, errors can be easily produced as the number of users is increased and the mobile terminal is subjected to mobility. Thus, it has driven many researches into the application of higher order modulations.

3 Additive White Gaussian Noise

The term noise refers to unwanted electrical signals that are always present in electrical systems [5] and the term additive means the noise is superimposed or added to the signal that tends to obscure or mask the signal where it will limit the receiver ability to make correct symbol decisions and limit the rate of information transmission. The transmitted waveform gets corrupted by noise 'n', typically referred to an Additive White Gaussian Noise (AWGN) [8], illustrated as - Additive: As the noise gets 'added' (and not multiplied) to the received signal, White: The spectrum of the noise is flat for all frequencies Gaussian: The values of the noise 'n' follow the Gaussian probability distribution function p(z), where is the variance

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

Thus, AWGN is the effect of thermal noise generated by thermal motion of electron in all dissipative electrical components i.e. resistors, wires and so on.

4 DIGITAL MODULATION TECHNIQUES

The technique of superimposing the ***message signal*** on the ***carrier*** is known as ***modulation***. The process by which a carrier wave is able to carry the message or digital signal (series of ones and zeroes). ***Modulation*** is performed at the transmitter and the reverse operation (***demodulation/detection***) is performed at the receiving end. Different Classes of digital modulation techniques as shown in figure 4.1 used for transmission of digitally represented data (i) Amplitude Shift Keying (ASK), (ii) Frequency Shift Keying (FSK), (iii) Phase Shift Keying (PSK) and (iv) QAM [3].

Amplitude Shift Keying (ASK):
– Change amplitude with each symbol
– Frequency constant
– Low bandwidth requirements
– Very susceptible to interference

Frequency Shift Keying (FSK):
– Change frequency with each symbol
– Needs larger bandwidth

Phase Shift Keying (PSK):
– Change phase with each symbol
– More complex
– Robust against interference

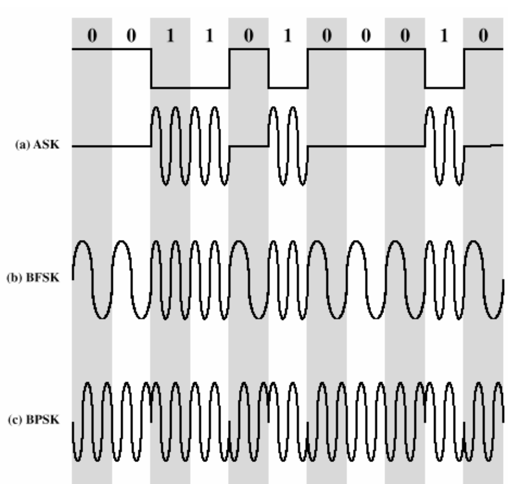

Figure: 4.1 Digital modulation Techniques

The use of amplitude modulated analog carriers to transport digital information in case of ASK is a relatively low quality, low cost type of digital modulation and therefore is seldom used except for very low speed telemetry circuits. FSK has a poorer error performance than PSK or QAM and consequently is seldom used for high-performance digital radio systems. So, PSK is the commonly used digital modulation technique. The PSK schemes have constant envelope but discontinuous phase transitions from symbol to symbol [9].

5 PERFORMANCE ANALYSIS OF PSK OVER AWGN CHANNEL

The bandwidth efficiency of the PSK modulation scheme is increased by using M-PSK modulation. A more efficient use of bandwidth is achieved when each signaling element represents more than one bit. The numbers of possible signals are $M= 2^m$. Where m is an integer. The symbol duration T =m T_b, where T_b is the bit duration. Probability of error or BER for BPSK is given by the following equation.

$$P_b = \frac{1}{2} erfc\left(\sqrt{\frac{E_b}{N_o}}\right)$$

Where Eb/No= Signal to noise ratio or ratio of signal energy per bit to noise spectral density. The BW of BPSK is fb [4]. As we increase the transmitted signal energy per bit, Eb for a specified noise spectral density No, the message points corresponding to symbols 1 and 0 move further apart and the Probability of error reduces [7]. The general formulae for probability of error or bit error rate of MPSK for AWGN channel is given as

$$P_b = \frac{1}{m} erfc\sqrt{\left(\frac{mE_b}{N_o}\right)} sin\left(\frac{\pi}{M}\right)$$

Where $M=2^m$, m = 2, 3...

6 PERFORMANCE ANALYSIS OF BPSK USING SIMULINK

Simulink, developed by The Math Works, is an environment for multi-domain simulation and Model-Based Design for dynamic and embedded systems. The baseband simulation models of M-ary PSK for M=2 i.e. for BPSK are given in Figure 6.1.

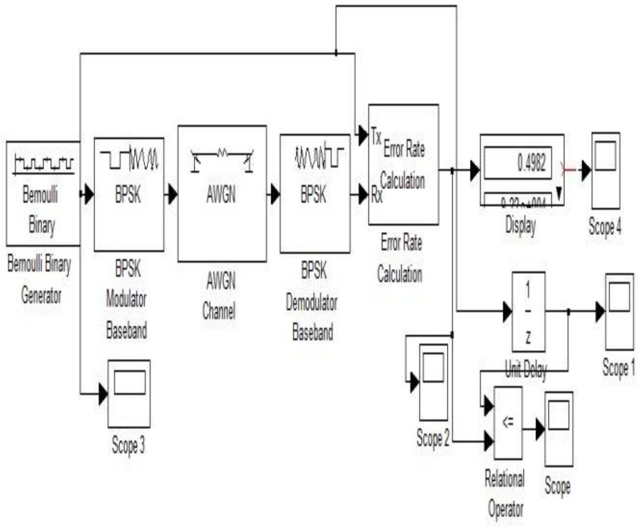

Figure: 6.1 Simulation Model for BPSK Modulation Technique.

When simulation is done by running the concerned .mdl file. Once the output values are stored in the workspace, the associated .m file is typed under the command window and it is run [6]. Finally, BER graph Vs Eb/No graphs are obtained once the simulation is completed. The AWGN Channel block adds white Gaussian noise to a real or complex input signal. The results of BER performance of Binary Phase Shift Keying for M=2 obtained using communication toolbox in SIMULINK

7 RESULTS

The results of BER performance of Binary Phase Shift Keying comparative performance analysis of simulated and theoretical curves for BER vs. Eb/ No (signal to noise ratio) for BPSK given in Figure 1, 2 and 3.

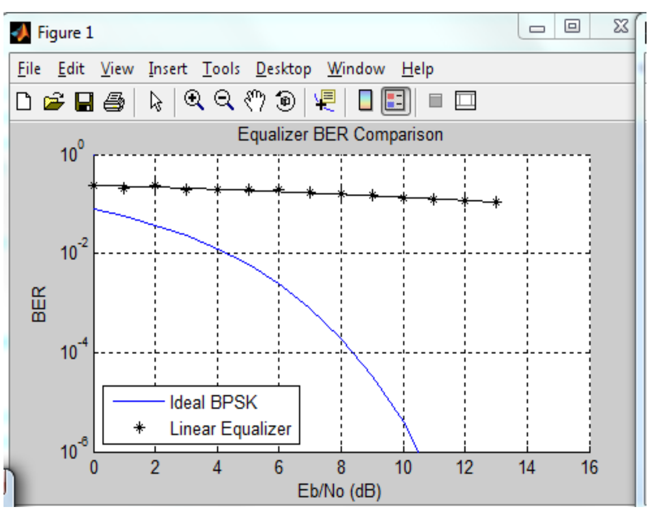

Figure: 7.1 Linear Equalizer waveform of input Signal

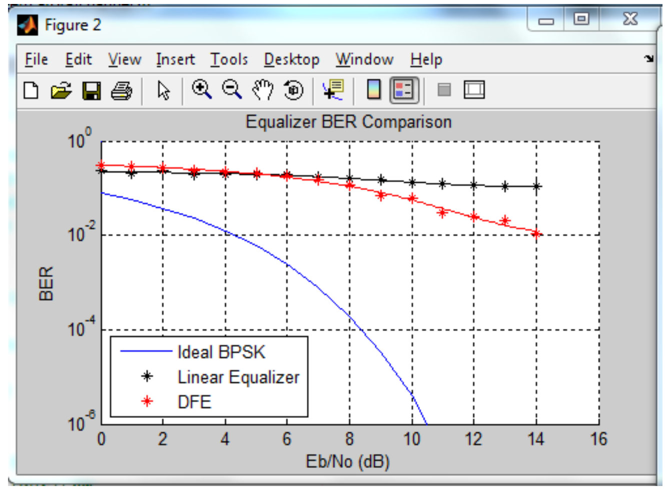

Figure : 7.2 Bit error rate probability for BPSK over AWGN channel

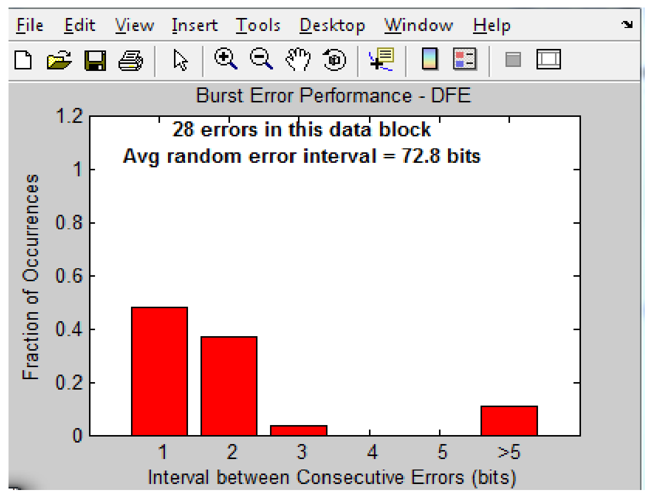

Figure: 7.3 Bit error rate Calculation

8 CONCLUSION

The mathematical analysis and simulations using SIMULINK tool shows that the BER PSK based digital modulation schemes decrease monotonically with increasing values of Eb/No. It is 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. Increasing the data rate will increase the SNR, however, increasing Rb (Bit rate in bits /second) will also cause more noise and noise term also increases.

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