Monte Carlo Simulation in Communication System

Mazlina Binti Poniran

Faculty of Electrical Engineering,
MARA University of Technology,
40450 Shah Alam, Selangor Darul Ehsan
mp_nyna@yahoo.com

Abstract – In this research, Monte Carlo simulations were used to evaluate the bit error rate (BER) due to the degrading effects in a communication system. The communication system under study consists of a binary PSK modulator/demodulator with both signal points in the signal constellation lying in the direct (in-phase) channel. The filter at the output of the modulator is a third-order Butterworth filter with a bandwidth equal to the bit rate (BW = rb), leads to intersymbol interference (ISI). Simulation results were compared with the ideal (zero ISI) result in order to determine the increase in BER resulting from the filter - induced ISI. The evaluations demonstrate that the increase in the BER resulting from the ISI caused by the filter is evident.

Keywords: Bit error Rate (BER), Intersymbols Interference (ISI), Binary Phase Shift Keying (BPSK), Monte Carlo

1. Introduction

In the development, deployment, and operation of signal transmission systems, instruments are needed which will display signal quality, and assist the operator in identifying problems in the system. This is particularly true of digital systems. In systems using Phase Shift Keying (PSK), data is encoded by varying carrier phase and magnitude. Commonly, PSK schemes are identified by the number of different phase angles used in transmission. A scheme such as 8-PSK uses 8 equally spaced carrier phase angles. Each of these individual phase angles is called a symbol, and the set of symbols taken together is called a constellation. In an ideal PSK transmission and reception system, a graphical display of symbols in I-Q space would show a discrete set of points on a circle. In such a display, it is easy to observe transmitter problems such as gain imbalance, phase noise, or the presence of spurious tones. When transmitting symbol streams on the crowded radio spectrum, filters are commonly used to limit the bandwidth of the transmitted signal. A side effect of these filters is that in limiting or shaping signal bandwidth, the signal is distorted. The nature of the distortion depends on the particular sequence of symbols in decoding a particular symbol. The signal representing that symbol is distorted by the effect of the filter on the symbol and the symbols which surround it. Because this distortion is symbol dependent, it is called inter-symbol interference (ISI). In many systems, ISI introduced by a transmit filter is removed by a receive filter. However, ISI cannot be practically removed because the bandwidth of the signal is too narrow to allow for zero ISI conditions [1]. Some studies relate to the effect of filter at front end of the receiver or in the channel. However, more attention should be paid to the effects of filtering in the transmitters. Based on related literature, inter-symbol interference is a worst case because it is regarded as a degradation of the signal amplitude, and the resulting error probability [2]. Figure 1 shows a single pulse is passed though a channel having a first-order impulse response inducing a significant spillover of one bit-interval's energy into succeeding ones [3].

Figure 1: Intersymbol Interference

According to the research of Tetsushi Ikegami; the bit error performance degrades because the correlation peak output to the desired input signal decrease due to the filter at the transmitters. Furthermore, the performance degrades as the correlation output to the undesired input signal increase. Computer simulation was used to evaluate the effect of Butterworth filters [4].

The bit error rate (BER) of a communication system is defined as the ratio of the number of error bits to the total number of bits transmitted during a specific period. It is the likelihood that a single error bit will occur within received bits, independent of the rate of transmission [5]. The error rate was evaluated by using the Monte Carlo technique. Based on related literatures, Monte Carlo simulation is easy to learn and quick to implement [6]. The technique use random numbers and probability to solve problems. This method was also used for iteratively evaluating a deterministic model using sets of random numbers as inputs. Besides that, it is often used when the model is complex, nonlinear, or involves more than just a couple uncertain parameters. Figure 1 shows the steps that involved in the Monte Carlo Method.

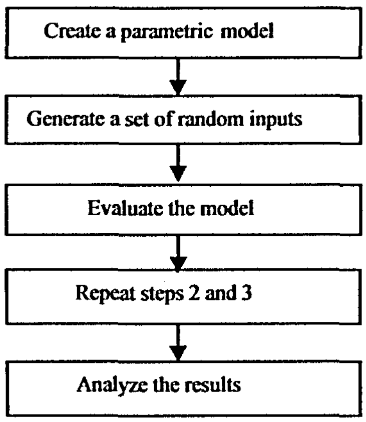

Figure 2: Step in Monte Carlo Method

The most commonly used channel: the Additive White Gaussian Noise (AWGN) channel has been considered where the noise gets spread over the whole spectrum of frequencies.

2. Methodology

BER has been measured by comparing the transmitted signal with the received signal and computing the error count over the total number of bits. For any given modulation, the BER is normally expressed in terms of signal to noise ratio (SNR). In Matlab, it is focused only on the BER performance in terms of signal to noise ratio per bit for PSK, considering AWGN.

Because of the space limitations, only the bit error rate (BER) will be considered. The BER of the simulation is calculated and plotted. For comparison, the theoretical BER is also plotted.

The performance of the simulator is first studied under ideal conditions, to make it possible to observe how varying algorithm parameters will affect performance [7].
The simulation has been divided into two parts:

2.1 Construction of a Simple Communication System Simulator (without transmitter filter)

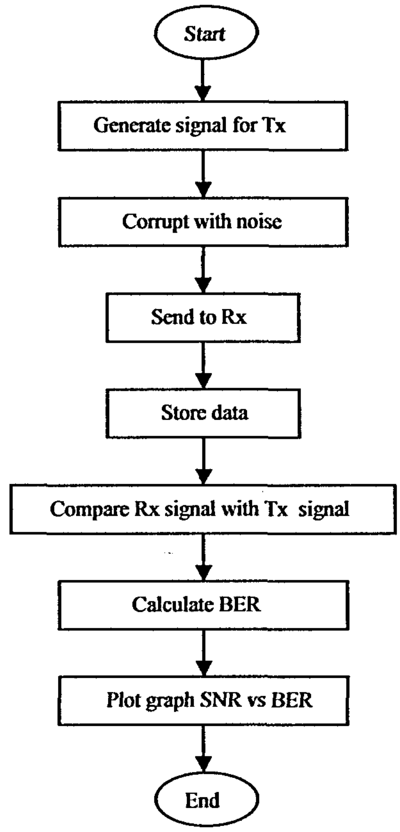

Figure 3: Flow chart of simple simulator (without transmitter filter)

In this part, an assumption has been made where there is no pulse shaping performed at the transmitter, and there is no filtering within the system. Monte Carlo technique is implemented by passing the N data symbols through a simulation model of the system and counting the number of error (N_e) that occur.
Assuming the estimate of the BER is,

$$BER = N_e/N_o$$

For the theoretical, BER is obtained using the Q-function of,

$$BER = sqrt(2\ E_b/\ N_0)$$

2.2 Construction of a simple communication System Simulator (with transmitter filter)

The second part of the simulation involves the incorporation of the transmitter filter within the system. The first problem is to determine the value of the delay. Delay is used to line up or synchronize corresponding symbols, prior to comparing the transmitted symbol and the received symbol [8]. Figure 3 shows the block diagram for constructing a simulator for a basic communication system with a transmitter filter.

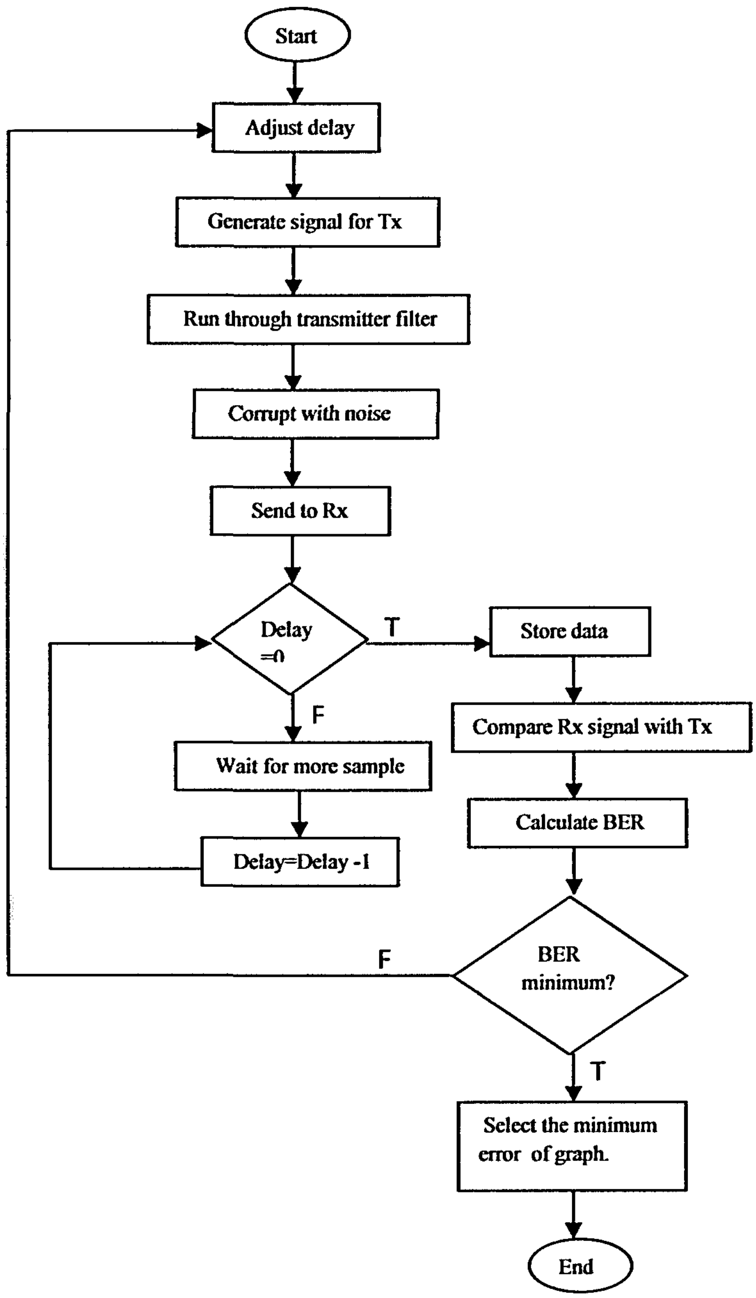

Figure 3: Flow chart of simple simulator (with Transmitter filter)

3. Results and Discussion

Figure 4 shows the BER of a basic communication system using BPSK modulator/demodulator, without the presence of a transmitter filter.

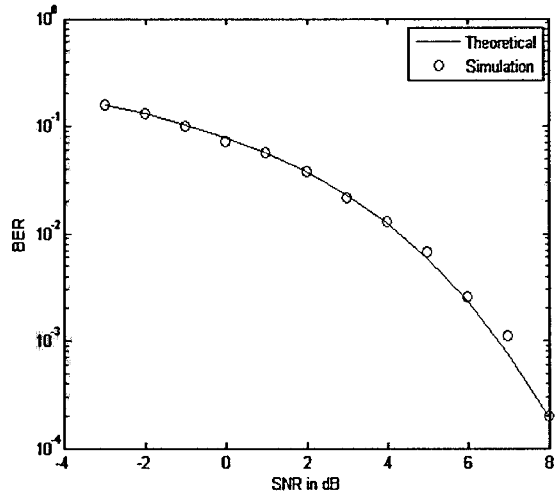

Figure 4: Bit error performance in terms of SNR per carrier for BPSK (without transmitter filter)

The execution of the program with Nsymbols for each value of SNR yields the result at Figure 4. In this figure, the performance of the simulator is compared against the theoretical probability of bit error for BPSK communication systems. Simulated results are represented by the smaller circles in the plots. It can be seen from these plots that under these conditions, there is negligible performance degradation.

This figure notes that the reliability of the BER become degrades as the SNR increase due to the fact that fewer errors are counted. Since the simulation is based on the processing of sequential block of samples, the Nsymbols should be more than 1000symbols (10000 samples) so that at least one complete block is processed by the simulation [8, 9]. As a conclusion, the simulator in this part is reliable and usable since the value of the theoretical and simulation is equal.

Figure 5 shows the result of the simulation to determine the value of the delay.

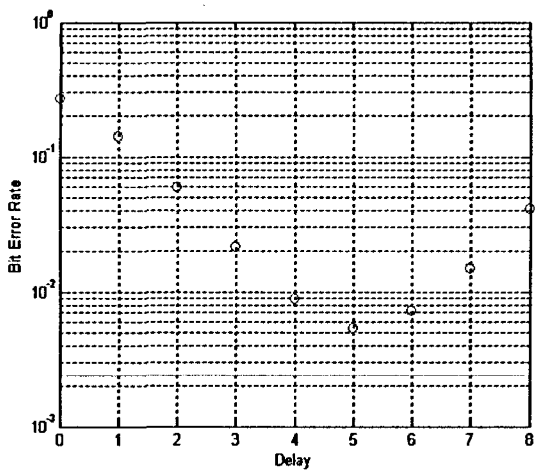

Figure 5: Preliminary simulation to determine delay

In other to illustrate the importance of choosing the value of delay correctly, the system will be simulated by using different value of delay. The delay will be iterated from 0 to 8 samples. The presence of ISI and other disturbances will of course increase the number of error. The simulated results are indicated by the small circles and the performance of the ideal (zero ISI) is given in solid line for references. The value of the BER is minimum at a delay of 5 samples. However, since the delay is quantized to an integer number of samples periods, the value of 5 may not be precisely correct. The correct value is most likely between 5 and 6 samples. A more precise estimated of the correct value of delay can be determine by executing the simulation again with the smaller sampling periods.

Based on the results in Figure 5, the value of the delay was set to 5. Next, to obtain the error rate performance of a communication system with a transmitter filter, the Monte Carlo simulation was executed and the results are illustrated in Figure 6.

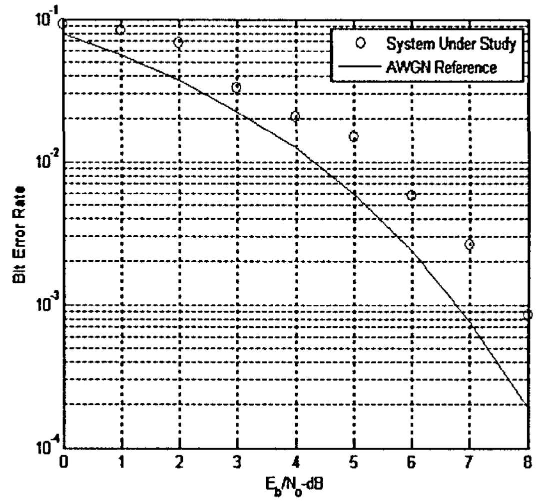

Figure 6: Bit error performance in terms of E_b / N_o for BPSK (transmitter filter)

The simulated results are given by the smaller circles, and the BER of the ideal (zero ISI) results are given by the solid line. As a conclusion in this part, the increased BER resulting from the ISI caused by the filter is evident with a maximum increase of 3.5%.

4. Conclusion

Modeling digital communication systems using MATLAB or other simulation tools is a remarkable and interesting way to gain understanding of basic communication principles and experiment with the effects of noise distortion on modulated signals. The simulation result shows that the error that was introduced by ISI substantially affected the system transmitter filter are proved. For better design of transmitter filters, we may also need some analytical performance analysis. This can be considered as an interesting topic for further research. This research can also be extended in a more complex and realistic system such as a CDMA system.

References

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