Comparative Performance of BER in the Simulation of Digital Communication Systems using Raised Cosine Filter

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Comparative Performance of BER in the Simulation of Digital Communication Systems using Raised Cosine Filter

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Abstract - The robustness of the digital communication system is illustrated by comparing the BER and SER with and without filter. This research entails the development of a digital communication model that transmits base band data over an additive white Gaussian noise channel (AWGN). The performance of this model is enhanced by employing raised cosine filter which reduce the BER and SER compared to model without filter. The results show that the performance of the system improves when filter is implemented. The performance of 16-QAM is found to be better than that of 32-QAM and 64-QAM, which means that there must be a tradeoff between BER and energy efficiency of Modulation schemes of QAM. In this paper inter symbol interference (ISI) is examined and It is seen that ISI place an important role in digital communication systems. This paper also observed that overall transmission errors are less while increasing the ratio of bit energy per symbol (E_b/N_0). Matlab communication tool box has been used for simulation.

Keywords - BER, SER, Raised Cosine filter, tradeoff, QAM, ISI, AWGN.

I. Introduction

The history of communication gives us insight into the way it influenced the development of civilization and still exerts an influence on modern societies. Communication can be defined simply as ‘sending and receiving messages’, or ‘the transmission of messages from one person to another’. Effective communication occurs only when the receiver understands the exact message sent by the transmitter [1].

Although digital communication is much better than the analog communication, still it has certain issues that need to be addressed. Especially when it comes to wireless communication, one of the major research considerations becomes the effect of multipath propagation. A thorough analysis is necessary for strategic planning of any system design by doing comparative study of different modulation techniques via different multipath communication channels. To study and draw the graph in terms BER versus Eb/No in AWGN channel for various QAM modulation schemes in digital communication system. Therefore, understand the system could go for more suitable modulation technique to suit the channel quality and can suggest better modulation schemes [2].

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Since information transmitted are sometimes or mostly corrupted by noise and other interferences, Quadrature amplitude modulation (QAM) as a means of modulation ensures effective transmission of information. In this way there is a balance between obtaining the higher data rates and maintaining an acceptable bit error rate for any radio communications system [3]. The Quadrature amplitude modulation (QAM) has become common place in bandwidth efficient digital communication systems. It conveys two analog message signals, or two digital bit streams, by changing (modulating) the amplitudes of two carrier waves, using the amplitude-shift keying (ASK) digital modulation scheme or amplitude modulation (AM) analog modulation scheme [11].

This paper aids an educational purpose for researchers in the digital communication field or related topics by illustrating a step-by-step approach to build the model and simulate the system using Matlab. The research paper portrays implementation of raised cosine filter in a digital communication system which improves the overall performance of the BER and symbol error rate (SER). In contrary higher BER decreases average energy (Es) of the symbol.

The remaining paper is organized as follows. In section II, Modulation Techniques are described. In section III, Raised cosine filter is given. In section IV Additive White Gaussian Noise (AWGN) is explained and simulation results are given in section V. The paper is concluded in section VI.

II. Modulation Techniques

One way to communicate a message signal whose frequency spectrum does not fall within that fixed frequency range, or one that is unsuitable for the channel, is to change a transmittable signal according to the information in the message signal. This alteration is called *modulation*, and it is the modulated signal that is transmitted. The receiver then recovers the original signal through a process called *demodulation*.

A. Digital Modulation

Digital modulation schemes transform digital signals into waveform that are compatible with the nature of the communications channel. One category uses a constant amplitude carrier and the other carries the information in phase or frequency variations (FSK, PSK). A major transition from the simple amplitude modulation (AM) and frequency modulation (FM) to digital techniques such as Quadrature Phase Shift Keying (QPSK), Frequency Shift Keying (FSK), Minimum Shift Keying (MSK) and Quadrate Amplitude

Modulation (QAM) [4].

B. M-Quadrature Amplitude Modulation

QAM is the encoding of the information into a carrier wave by variation of the amplitude of both the carrier wave and a Quadrature carrier that is 90^0 out of phase with the main carrier in accordance with two input signals. That is, the amplitude and the phase of the carrier wave are simultaneously changed according to the information we want to transmit.

In M=16-in 16-state Quadrature Amplitude Modulation (16-QAM), there are four I values and four Q values. This results in a total of 16 possible states for the signal. It can transition from any state to any other state at every symbol time. Since $M=16 = 2^4$, four bits per symbol can be sent. This consists of two bits for I and two bits for Q. The symbol rate is one fourth of the bit rate. So this modulation format produces a more spectrally efficient transmission. It is more efficient than BPSK, QPSK or 8PSK. Note that QPSK is the same as 4-QAM [12].

C. Average energy of an M-QAM constellation

In a general M-QAM constellation where $M= 2^b$ and b the number of bits in each constellation is even, the alphabets used are:

$$\alpha_{MQAM} = \{\pm(2m-1) \pm (2m-1)j\} where\ m \leftarrow \{ l, \ldots, -\frac{\sqrt{M}}{2}\} \qquad (1)$$

For computing the average energy of the M-QAM constellation, let us proceed as follows:

(a) Find the sum of energy of the individual alphabets:

$$E_\alpha = \sum_{m=1}^{\frac{\sqrt{M}}{2}} |(2m-1) + j(2m-1)|^2$$

$$= \frac{\sqrt{M}}{3}(M-1) \qquad (2)$$

(b) Each alphabet is used $2\sqrt{M}$M times in the M-QAM constellation.

(c) So, to find the average energy from M constellation symbols, divide the product of (a) and (b) by M. Plugging in the number for 16-QAM, 64-QAM:

$$E_{16QAM} = 2/3(16-1) = 10$$

$$E_{64QAM} = 2/3(64-1) = 42$$

From the above explanations, it is reasonably intuitive to guess that the scaling factor of $1/\sqrt{E_\alpha}E_\alpha$ which is seen along with M-QAM constellations respectively is for normalizing the average transmits power to unity.

D. Bit Error Rate (BER)

The BER, or quality of the digital link, is calculated from the number of bits received in error divided by the number of bits transmitted.

BER= (Bits in Error) / (Total bits received)

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 BER is the number of bit errors divided by the total number of transferred bits during a particular time interval. BER is a unit less performance measure, often expressed as a percentage [10].

BER can also be defined in terms of the probability of error (POE) [13] and represented in (3).

$$\text{POE} = \frac{1}{2}\,(1 - erf)\sqrt{\frac{E_b}{N_0}} \qquad (3)$$

Here, 'erf 'is the error function, E_b is the energy in one bit and N_0 is the noise power spectral density (noise power in a 1Hz bandwidth). The error function is different for the each of the various modulation methods. The POE is a proportional to E_b/ N_0, which is a form of signal-to-noise ratio. The energy per bit, E_b, can be determined by dividing the carrier power by the bit rate. As an energy measure, E_b has the unit of joules. N0 is in power that is joules per second, so, E_b/ N_0 is a dimensionless term, or is a numerical ratio.

E. Signal to Noise Ratio (SNR)

SNR is the ratio of the received signal strength over the noise strength in the frequency range of the operation. It is an important parameter of the physical layer of Local Area Wireless Network (LAWN). Noise strength, in general, can include the noise in the environment and other unwanted signals (interference). BER is inversely related to SNR, that is high BER causes low SNR. High BER causes increases packet loss, increase in delay and decreases throughput [9]. The exact relation between the SNR and the BER is not easy to determine in the multi channel environment. Signal to noise ratio (SNR) is an indicator commonly used to evaluate the quality of a communication link and measured in decibels and represented by (4).

$$SNR = 10log10(Signal\ Power/Noise\ Power)dB \qquad (4)$$

F. E_b/N_0 (Energy per bit to Noise power spectral density ratio)

E_b/N_0 is an important parameter in digital communication or data transmission. It is a normalized signal-to- noise ratio (SNR) measure, also known as the "SNR per bit". It is especially useful when comparing the bit error rate (BER) performance of different digital modulation schemes without Taking bandwidth into account. *E_b/N_0* is equal to the SNR divided by the "gross" link spectral efficiency in (bit/s)/Hz, where the bits in this context are transmitted data bits, inclusive of error correction information and other protocol overhead.

III . Raised Cosine Filter

In modern data transmission systems, bits or groups of bits (symbols) are typically transmitted in the form of individual pulses of energy. Sometimes Rectangular pulse is probably the most fundamental. It is easy to implement in a real-world system because it can be directly compared to opening and closing a switch, which is synonymous with the concept of binary information Pulses are sent by the transmitter are detected by the receiver in any data transmission system. At the receiver, the goal is to sample the received signal at an optimal point in the pulse interval by the matched filter to maximize the probability of correct decision. This implies that the fundamental shapes of the pulses be such that they do not interfere with one another at the optimal sampling point. There are two criteria that ensure non-interference.

i. The pulse shape exhibits a zero crossing at the sampling point of all pulse intervals except its own. That is Minimized inter symbol interferences (ISI).

ii. The shape of the pulses is such that the amplitude decays rapidly outside of the pulse interval. That is high stop band attenuation

The rectangular pulse, meets first requirement because it is zero at all points outside of the present pulse interval. It cannot cause interference during the sampling time of other pulses. The trouble with the rectangular pulse, however, is that it has significant energy over a fairly large bandwidth as indicated. The unbounded frequency response of the rectangular pulse makes it unsuitable for modern transmission systems. This is where pulse shaping filters come into play. If the rectangular pulse is not the best choice for band-limited data transmission, then what pulse shape will, decay quickly, and provide zero crossings at the pulse sampling times [5]. There are several choices that have but in most systems Raised cosine filter are used to shape the input pulse.

In most cases, the square root raised cosine filter is used in the transmitter and receiver part of the system so that the overall response resembles that of a raised cosine filter. The impulse or time domain response of the raised cosine filter and the square root raised cosine filter [14] are given by (5), (6), (7) and (8).

$$h_{RC}(t) = \frac{\sin(\frac{\pi T}{T})}{(\frac{\pi T}{T})}\,\frac{\cos(\frac{\pi\alpha T}{T})}{1-(\frac{\pi T}{T})^2} \qquad (5)$$

This expression can be simplified further by introducing the sinc function (sinc $x = \frac{\mathrm{Sin}\ x}{x}$)

$$h_{RC}(t) = \mathrm{sin\,c}\,(\frac{\pi T}{T})\,\frac{\cos(\frac{\pi\alpha T}{T})}{1-(\frac{\pi T}{T})^2} \qquad (6)$$

The sinc function in the response of the filter ensures that the signal is band-limited. The time domain or impulse response of the square root raised cosine filter is given as;

$$h_{RRC}(t) = \frac{\sin[\pi(1-\alpha)t]+4\alpha(\frac{t}{T})\cos[\pi(1+\alpha)\frac{t}{T}]}{(\frac{\pi T}{T})[1-(\frac{4\alpha t}{T})^2]} \qquad (7)$$

The overall response of the system is given as;

$$h_{RC}(t)= h_{RRC}(t)h_{RRC}(t) \qquad (8)$$

IV. Additive White Gaussian Noise (AWGN)

This noise is generated through the thermal motion of electrons in all dissipative electrical elements. It is modeled as a zero-mean Gaussian random process where the random signal is the summation of the random noise variable and a direct current signal as shown in (9) [7], [8] and [15].

$$Z= \alpha + \nu \qquad (9)$$

The probability distribution function for this Gaussian noise can be represented as;

$$p(z) = \frac{1}{\sigma\sqrt{2\pi}}\exp[-\frac{1}{2}(\frac{z-a}{\sigma})^2] \qquad (10)$$

The model of this noise assumes a power spectral density $G_n(f)$ which is flat for all the frequencies denoted as;

$$G_n(f)= \frac{N_0}{2} \qquad (11)$$

The factor 2 indicates that the power spectral density is a two-sided spectrum. This type of noise is present in all communication systems and is the major noise source for most systems with characteristics of additive, white and Gaussian. It is mostly used to model noise in communication systems which are simulated to determine their performance. This noise is normally used to model digital communication systems which can be replaced with other interference schemes.

V. Simulation and Results

The following model has been simulated by using communication toolbox of MATLAB [16].

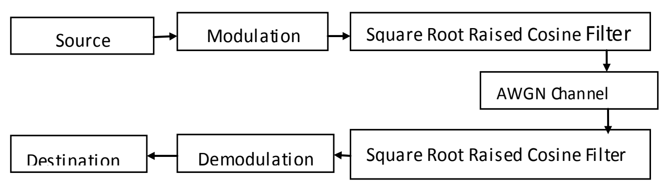

Figure1. Model of digital communication system with filter

In this simulation, $30\text{x}10^3$ information bits have been generated using '**randtint**' function to create a column vector that lists successive values of binary data stream. This binary data stream can be equivalently described by an analog signal, band limited to ½ times 1 sample per pulse. That is, if the bit rate is one bit per second and we sample it at 1 sample per second, the necessary band width is ½ Hz. That is why a raised cosine filter is used which acts as low pass filter with roll of factor 0.22. In this case square root raise cosine filter is equivalent to FIR filter.

The simulation study has been done for digital communication system with and without filter at the different QAM (M=16, 32, 64)) transmission rates in presents of AWGN. In the following shows the simulation of the model (Fig.1) with filter for M=16 sequentially in Fig.2.

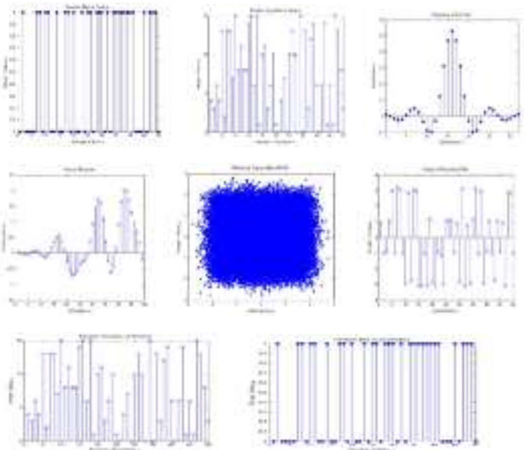

Figure 2. Simulation of the communication model with filter for

A. Simulation and discussions

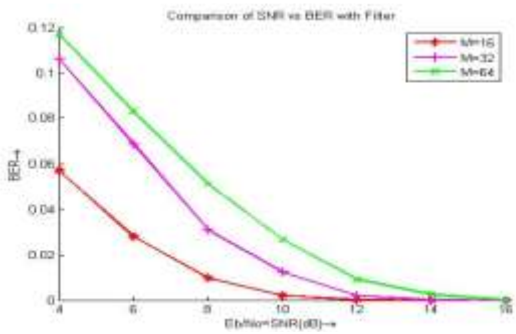

Figure 3. Comparison of SNR vs. BER with filter

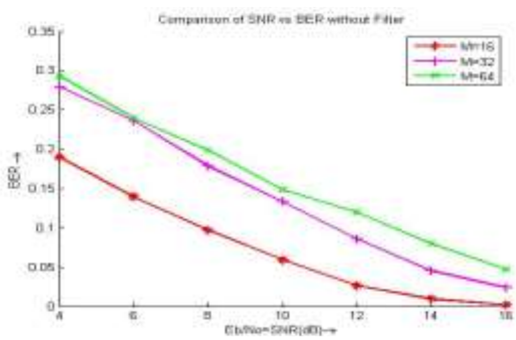

Figure 4. Comparison of SNR vs. BER without filter

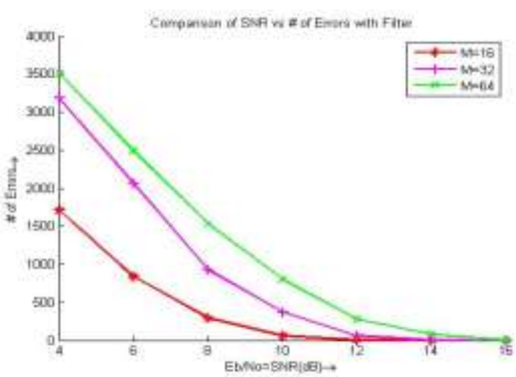

Figure 5. Number of Errors with filter

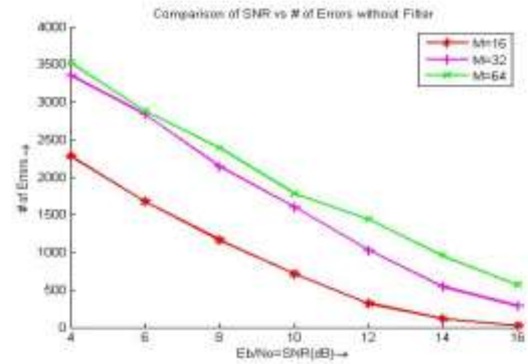

Figure 6. Number of Errors without filter

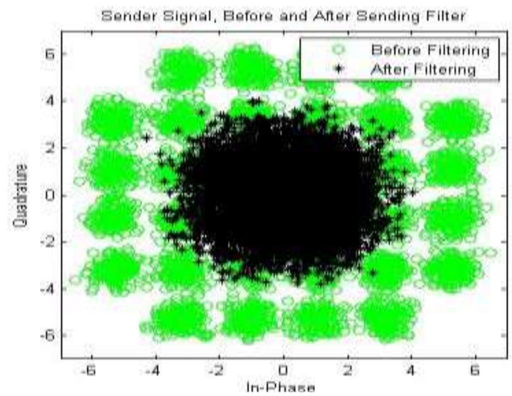

Figure 7. Scattered Plot for Sending signal before and after sending

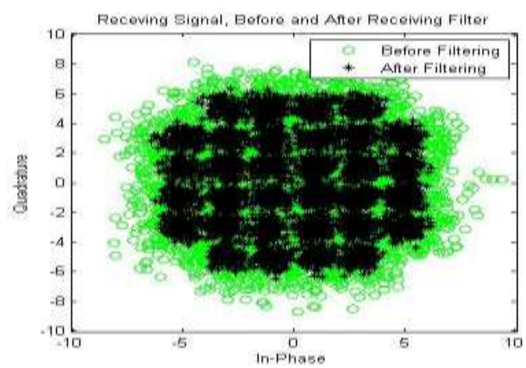

Figure 8. Scattered Plot for Sending signal before and after receiving

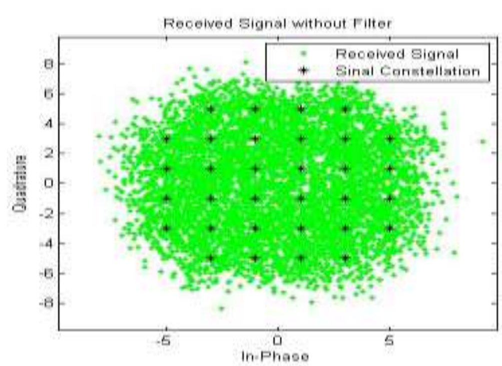

Figure 9. Scattered Plot without filter

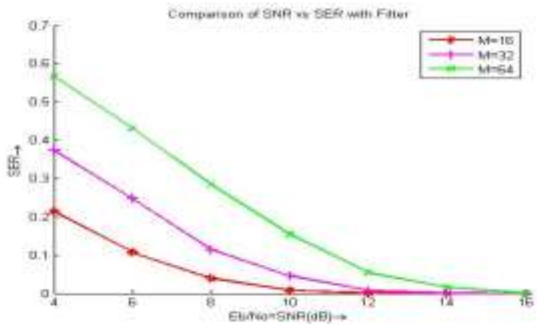

Figure 10. Comparison of SNR vs. SER with filter

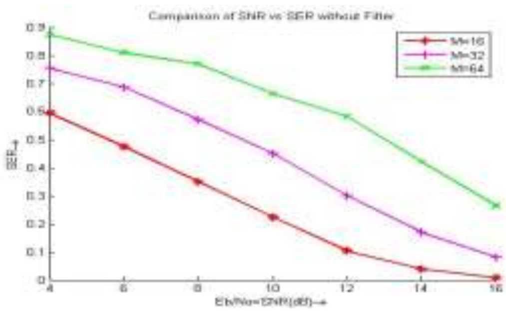

Figure 11. Comparison of SNR vs. SER without filter

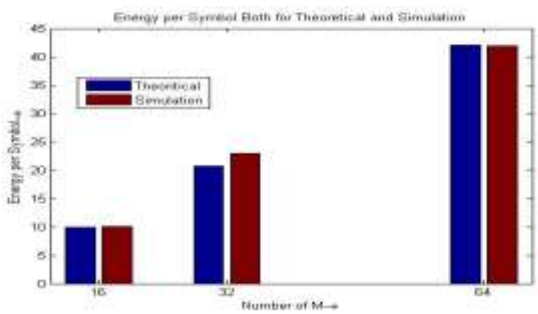

Figure 12. Energy per symbol for both theoretical and simulation

B. Discussion of results

The resulting bit error rate (BER) and Symbol error rate (SER) from the simulation for filter in Fig. 3,5,10 and without filter in Fig. 4,6,10 at different QAM transmission rates (M=16, 32, 64) show the variation of error values for each bit vs. different noise power spectral densities (E_b/No=SNR). Also the results show a comparison between the resulting errors in the receive signal at different noise levels, since (E_b/No) is defined as the ratio of bit energy per symbol to noise power spectral densities, in dB then increasing this ratio causes less overall bit errors and decreasing this ratio causes higher bit errors rate show in fig.3, 4, 5, 6, 10, 11.

It is also noted from the fig.12 showing that for higher transmission rate for QAM exhibit more energy efficient than that of less bit error rate.

VI. Conclusion

The BER and SER performance have been simulated for digital communication system with and without filter for baseband transmission where the error rate depends on the modulation technique used, the ratio (E_b/No) and channel conditions, inter symbol interference. This paper has analyzed the performance of both systems for various QAM over the AWGN. These results show that the model without filter is less efficient than that of model with filter, this analysis emphasized that ISI degrades the performance of the system if ISI is not eliminated before transmission of digital signal.

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