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Performance Analysis of BPSK, QPSK & QAM over AWGN Channel

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Abstract

Digital modulation schemes provide more information carrying capacity, better quality communication, data security and RF spectrum sharing to accommodate more services. The goal of designer is to create a communications system that transport a message signal from a source across a Noisy channel to the user both efficiently and reliably, submit to certain design restrictions: Permissible transmit power, available bandwidth channel, and low cost of building the system. The data is first convoluted, and then transmitted into a noisy channel. This convolution process encodes some redundant bits into the transmitted signal, thereby improving the data capacity of the system channel. This paper reviews the key characteristics of communication channel and compares the performance of the digital modulation schemes BPSK, QPSK and QAM BER in presence of Additive White Gaussian Noise (AWGN). Simulations are carried out in MATLAB

Keywords: Convolution, BPSK, QPSK, QAM, BER, AWGN .

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I. Introduction

In Digital modulation, a digital bit stream is transmitted over analog band-pass channel. Here an analog carrier signal is modulated by a discrete signal. Most fundamental digital modulation schemes are based on keying. The choice of digital modulation scheme 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.

II. Digital Modulation Techniques

QPSK QPSK uses four points on the constellation diagram, equi spaced around a circle. With four phases, QPSK can encode two bits per symbol, to minimize the bit error rate (BER) [7] [8]

BPSK BPSK is the simplest form of phase shift keying (PSK). It uses two phases which are separated by 180° and so can also be termed 2-PSK. It does not particularly matter exactly where the constellation points are positioned, Therefore, it handles the highest noise level or distortion before the demodulator reaches an incorrect decision. That makes it the most robust of all the PSKs. It is, however, only able to modulate at 1 bit/symbol (as seen in the figure) and so is unsuitable for high data-rate applications. [7] [8]

QAM In QAM, the constellation points are usually arranged in a square grid with equal vertical and horizontal spacing, although other configurations are possible . The simplest and most commonly used QAM constellations consist of points arranged in a square, i.e. 16-QAM, 64-QAM and 256-QAM . Non-square constellations, such as Cross-QAM, can offer greater efficiency but are rarely used because of the cost of increased modem complexity.[7][8]

III. Convolution Codes

In telecommunication, a convolution code is a type of error-correcting code that generates parity symbols via the sliding application of a Boolean polynomial function to a data stream. The sliding nature of the convolution codes facilitates trellis decoding using a time-invariant trellis. Time invariant trellis decoding allows convolution codes to be maximum-likelihood soft-decision decoded with reasonable complexity.[2] [3] Convolution codes are often characterized by the base code rate and the depth (or memory) of the encoder. The memory is often called the "constraint length" K, where the output is a function of the current input as well as the previous inputs. The depth may also be given as the number of memory elements v in the polynomial or the maximum possible number of states of the encoder.

IV. Performance Parameters

Code Rate (r)

The code rate (or information rate) is a fractional number that expresses what part of the redundant message is actually meaningful. For instance an encoder with 1/3 rate will output 3 bits of message for each bit of data. Therefore, bigger code rates produce stronger codes. [3] [4]

$$\mathbf{r = k/n}$$

Bit Error Rate (BER)

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 synchronization, attenuation, wireless multipath fading etc. [4] [5]

BER = Number of errors / total message length.

Bit error Probability (Pe)

Bit error probability Pe 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. [5] [6]

Signal to Noise Ratio (SNR)

Signal to noise ratios and Eb/No figures are parameters that are more associated with radio links and radio communications systems. In terms of this, the bit error rate, BER, can also be defined in terms of the probability of error or POE. The determine this, three other variables are used. They are the error function, erf, the energy in one bit, Eb, and the noise power spectral density . It should be noted that each different type of modulation has its own value for the error function. This is because each type of modulation performs differently in the presence of noise

Additive white Gaussian noise

Additive white Gaussian noise (AWGN) is a basic noise model used in information theory to mimic the effect of many random processes that occur in nature. [1] The modifiers denote specific characteristics like

- ***Additive*** because it is added to any noise that might be intrinsic to the information system
- ***White*** refers to the idea that it has uniform power across the frequency band for the information system. It is an analogy to the color white which has uniform emissions at all frequencies in the visible spectrum.
- ***Gaussian*** because it has a normal distribution in the time domain with an average time domain value of zero.

Rayleigh Fading Channel

Rayleigh fading is a statistical model for the effect of a propagation environment on a radio signal, such as that used by wireless devices. Rayleigh fading models assume that the magnitude of a signal that has passed through such a transmission medium will vary randomly, or fade, according to a Rayleigh distribution — the radial component of the sum of two uncorrelated Gaussian random variables. [1]

V. Flow Chart of the Proposed Model

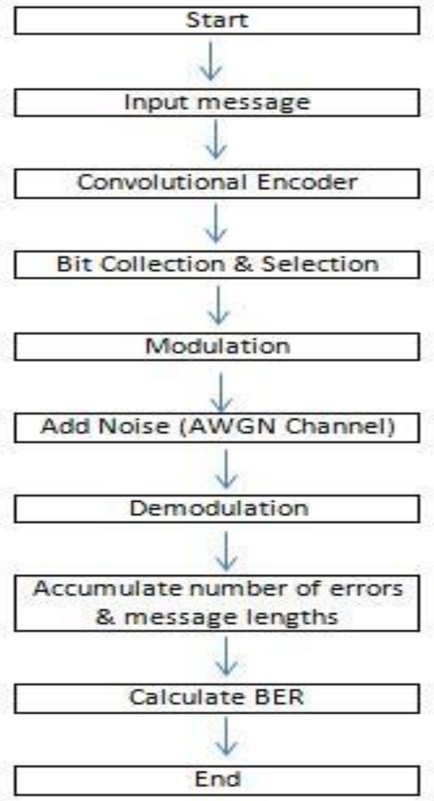

Figure 1: Flow Chart of the Proposed Model

VI. Results

The Performance of the QPSK System is measured using the BER vs SNR simulation Graphs, the Bit error rate value should approach zero as SNR Value increases for an efficient Modulation System.

VI a. Simulation Results for QPSK Modulation (BER vs SNR)

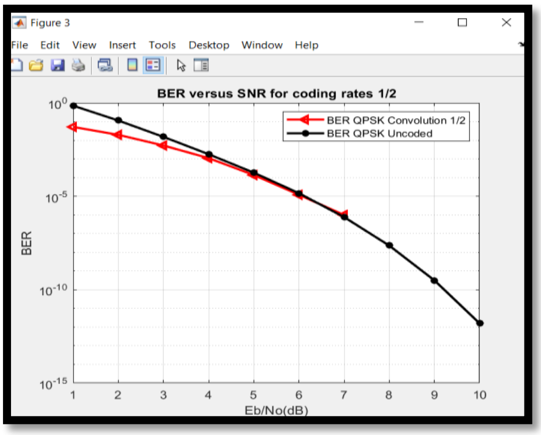

Figure 2: BER vs SNR for Coding Rate 1/2

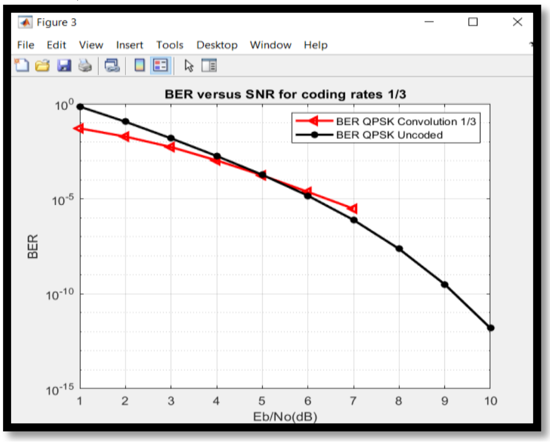

Figure 3: BER vs SNR for Coding Rate 1/3

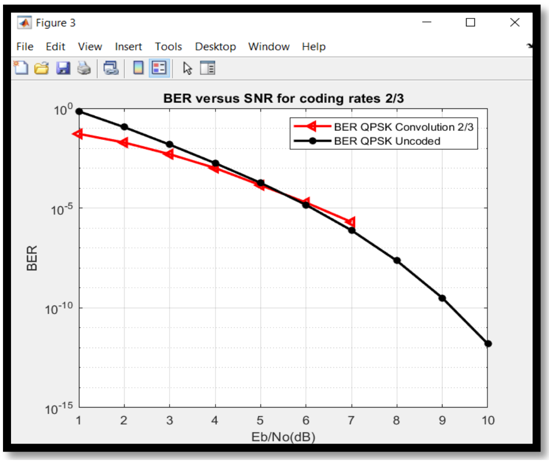

Figure 4 : BER vs SNR for Coding Rate 2/3

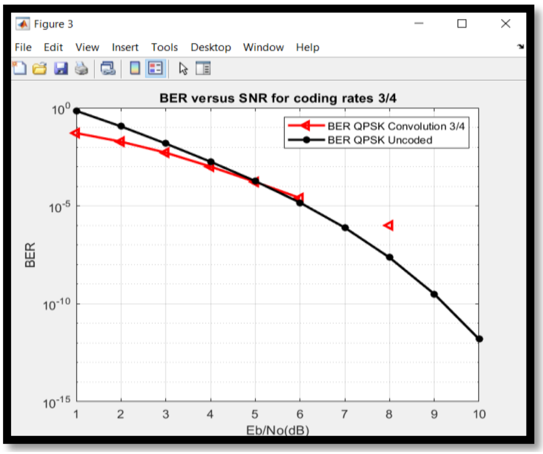

Figure 5 : BER vs SNR for Coding Rate ¾

Table 1 : BER vs SNR for QPSK Modulation system at different Code Rates

Sno	SNR (db)	Code Rate (1/2)	Code Rate (1/3)	Code Rate (2/3)	Code Rate (3/4)
1	1	10^{-1}	$10^{-1.3}$	$10^{-1.3}$	$10^{-1.3}$
2	3	$10^{-2.2}$	$10^{-2.2}$	$10^{-2.2}$	$10^{-2.2}$
3	5	$10^{-3.9}$	$10^{-3.9}$	$10^{-3.9}$	$10^{-3.9}$
4	7	10^{-6}	$10^{-5.5}$	$10^{-5.5}$	$10^{-5.5}$

VI b. Simulation Results for BPSK Modulation (BER vs SNR)

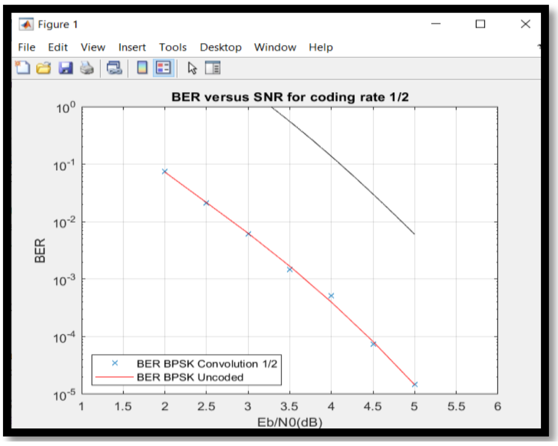

Figure 6 : BER vs SNR for Coding Rate 1/2

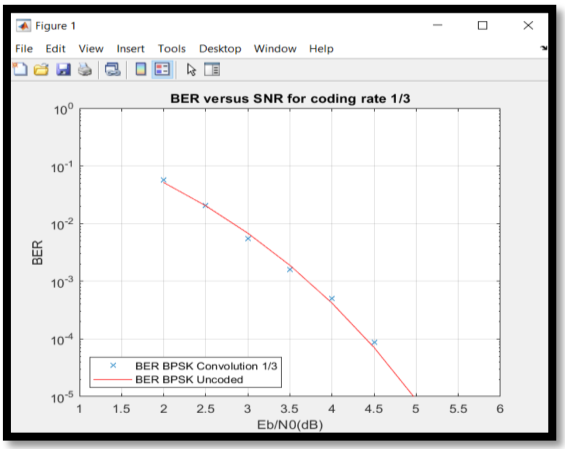

Figure 7 : BER vs SNR for Coding Rate 1/3

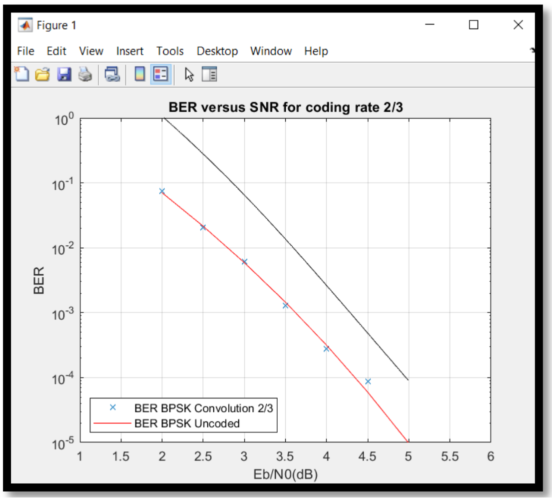

Figure 8 : BER vs SNR for Coding Rate 2/3

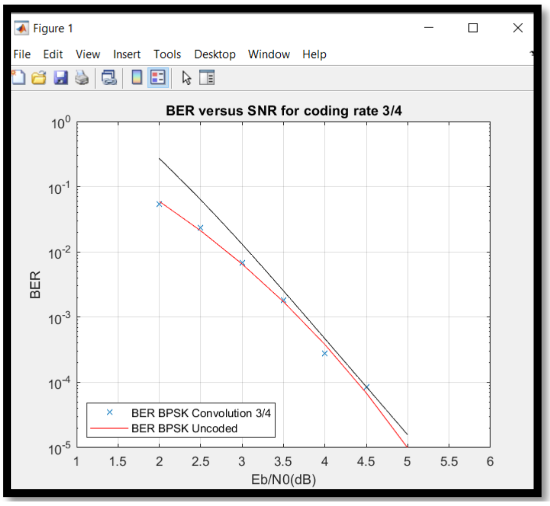

Figure 9 : BER vs SNR for Coding Rate ¾

Table 2 : Comparison of BER vs SNR for BPSK Modulation system at different Code Rates

Sno	SNR (db)	Code Rate (1/2)	Code Rate (1/3)	Code Rate (2/3)	Code Rate (3/4)
1	2	$10^{-1.1}$	$10^{-1.1}$	$10^{-1.1}$	$10^{-1.1}$
2	3	$10^{-2.2}$	$10^{-2.2}$	$10^{-2.2}$	$10^{-2.2}$
3	4	$10^{-3.3}$	$10^{-3.3}$	$10^{-3.6}$	$10^{-3.6}$
4	5	$10^{-4.9}$	10^{-5}	10^{-5}	10^{-5}

VI C. Simulation Results for QAM Modulation (BER vs SNR)

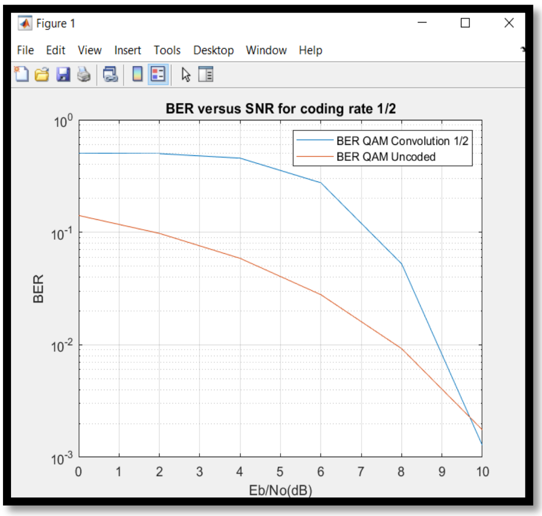

Figure 10 : BER vs SNR for Coding Rate 1/2

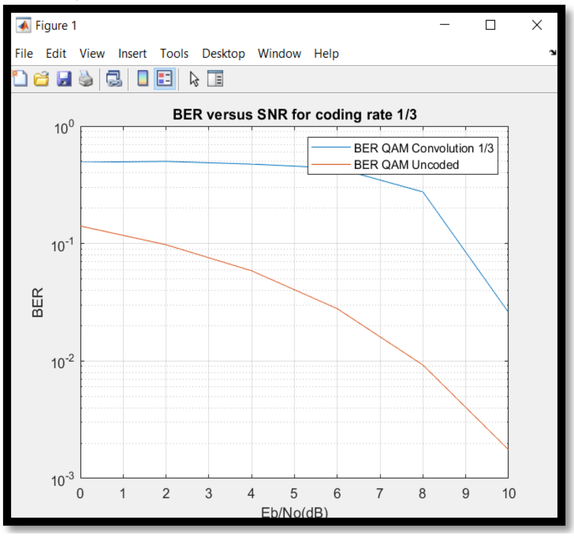

Figure 11: BER vs SNR for Coding Rate 1/3

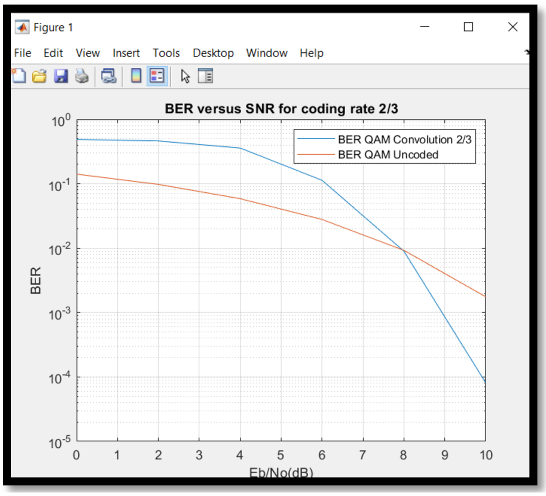

Figure 12 : BER vs SNR for Coding Rate 2/3

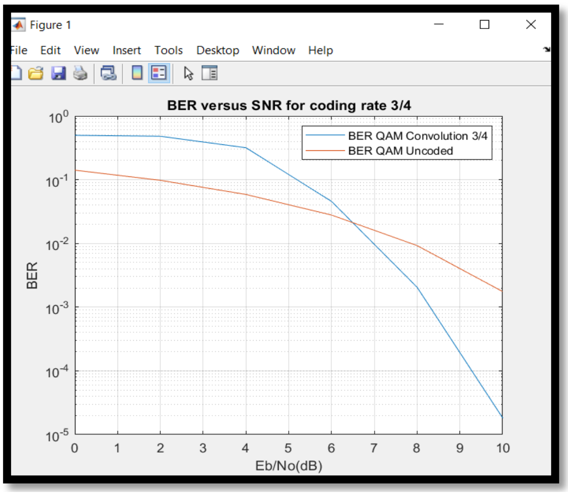

Figure 13 : BER vs SNR for Coding Rate ¾

Table 3 : Comparison of BER vs SNR for BPSK Modulation system at different Code Rates

Sno	SNR (db)	Code Rate (1/2)	Code Rate (1/3)	Code Rate (2/3)	Code Rate (3/4)
1	0	$10^{-0.3}$	$10^{-0.3}$	$10^{-0.3}$	$10^{-0.3}$
2	2	$10^{-0.3}$	$10^{-0.3}$	$10^{-0.3}$	$10^{-0.3}$
3	4	$10^{-0.33}$	$10^{-0.33}$	$10^{-0.33}$	$10^{-0.5}$
4	6	$10^{-0.66}$	$10^{-0.33}$	10^{-1}	$10^{-1.66}$
5	8	$10^{-1.33}$	$10^{-0.66}$	10^{-2}	$10^{-2.66}$
6	10	10^{-3}	$10^{-1.33}$	10^{-4}	$10^{-4.66}$

VII. Result Analysis & Conclusion

Various digital modulation schemes like BPSK, QPSK & QAM are evaluated based on BER over AWGN Channel through simulation using Matlab. The analysis is based on the study of Bit Error Rate (BER) and Signal to Noise Ratio (SNR). From the results obtained it is concluded that the BER decreases as the SNR increases. BPSK has an overall better performance as compared to QPSK & QAM techniques. That means lower order of modulation techniques is better to use in communication system if spectral efficiency is not considered or taken in an account. QPSK is not more power efficient modulation technique compare to other modulation types as more power is required to transmit two bits. QPSK is more complex compared to BPSK receiver due to four states needed to recover binary data information.

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