# A COMPREHENSIVE REVIEW OF PASSBAND DIGITAL MODULATION TECHNIQUES AND ITS PERFORMANCE ANALYSIS

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***Abstract*— A very important objective for selection of particular schemes depends upon the techniques, which plays a vital role for the implementation of any algorithm or schemes that needs to be analyzed and evaluated for understanding their performances. This paper presents an overview of the various modern digital modulation techniques such as BPSK, QPSK, and QAM emphasizing their performances on the various parameters such as BER, AWGN, SNR, MSE etc. The modulation techniques are simulated using MATLAB software and compared.**

***Keywords*— Binary Phase Shift Keying (BPSK); Quadrature Phase Shift Keying(QPSK); Quadrature Amplitude Modulation (QAM); Bit Error Rate (BER); Signal To Noise Ratio (SNR); AWGN Channel**

## I. INTRODUCTION

In the past few years, a tremendous transformation from analog communication to digital communication has taken place. Moreover, while communication systems were initially established as voice networks, they now have to accommodate computer data as well as multimedia content. And, as more and more users join the communication network the need for efficient use of available bandwidth in the RF spectrum becomes even more important.

Digital modulation techniques provide more information carrying capacity, better quality communication, data security and RF spectrum sharing to accommodate more services when compared to analog modulation.

The history of communication focuses the way it influenced the development of civilization and its impact on modern societies. Communication stands in simple words as ‘sending and receiving messages’, or ‘the transmission of messages from one person to another’. Effective communication happens only when the receiver understands the exact message sent by the transmitter.

### *A. Literature Survey*

Reference [1] presents performance evaluation of the different Modulation Schemes (BPSK, QPSK, GMSK) in of BER in cellular mobile environment with GSM standard parameters. The main objective of this paper is to investigate the factors that go into selection of the particular modulation scheme in the wireless environment.

Reference [2] describes the performance of OFDM-BPSK,-QPSK and -QAM system by using forward error correcting codes ( convolution, reed Solomon as well as concatenated coding) schemes in wireless communications AWGN channel. Various simulations performed to find out the best BER performance among each codes and used these best outcomes to model the RS-CC concatenated codes.

Reference [3] discusses the basic criteria for best modulation scheme depends on BER, SNR, Available Bandwidth, Power efficiency, better Quality of Service, cost effectiveness. The performance of each modulation scheme is measured by estimating its probability of error produced by noise and interference induced in the channel. The research has been performed by evaluation of BER and SNR for OFDM system models using MATLAB SIMULINK Tool.

Reference [4] analyses the BER, for different modulation techniques known to be BPSK, QPSK. After performing various simulations it is observed that by choosing a reliable modulation scheme and better coding technique can enhance the performance of transmitter and receiver system. Simulated result is analyzed and compared the performance of these systems through Lab VIEW software.

### *B. Organization of the paper*

The paper has been organized into six sections. Section I gives the brief introduction about the digital communication and some of the previous works related to this paper.

Section II gives an idea about each schemes in digital communication. Section III focuses on details about the types of communication channel and its characteristics. Section IV is a more complex one deals with various parameters for comparison of the different digital modulation schemes. Section V shown the simulated results for previous researches. In section VI, based on the above discussions, what can be inferred is described and conclusions drawn based on them.

## II. DIGITAL MODULATION SCHEMES

### *A. Definition*

The process of varying a property of message signal with respect to carrier is termed as Modulation. The property may be any parameter of the waveform i.e. amplitude, phase or frequency. Modulation plays a vital role in the long distance communication.

### *B. Classification*

Modulation is classified in two categories Baseband and Bandpass referred as :

- Line coding which deals with short distances uses Baseband modulation for transmission.
- Carrier modulation is the for long distance transmission uses Bandpass modulation

### *C. Passband digital modulation techniques*

M-ary modulation consists of two or more bits which are grouped together to form symbols and signals, and one of the possible signals obtained is transmitted. All the techniques in the Modulation are basically known as M-ary modulations. There are 3 basic modulation techniques via Amplitude Shift Keying (ASK), Frequency Shift Keying (FSK), Phase Shift Keying (PSK).

Based on parameters like amplitude, phase or frequency variations in the transmitted signals, the modulation is referred to as M-ary modulation.

### *D. Binary Phase Shift Keying (BPSK)*

Binary Phase Shift Keying (BPSK) is a two phase modulation scheme in which the 0’s and 1’s in a binary message are represented by two different phase states in the carrier signal: θ=0∘ for binary 1 and θ=180∘ for binary 0.

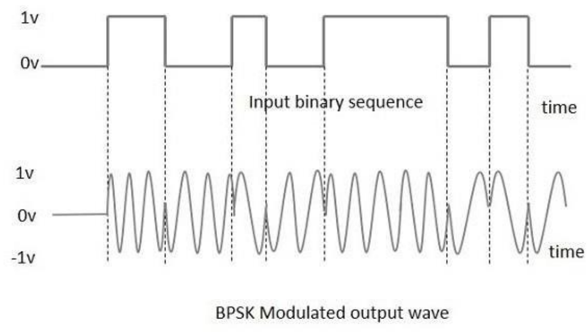


Figure 1 : Waveform Diagram of BPSK Modulation

### *E. Quadrature Phase Shift Keying (QPSK)*

A four-level (4-ary) PSK is called Quaternary Phase Shift Keying (QPSK), and uses four points on the constellation.The QPSK can transmit 2 bits/symbol and shifts the phase of the signal to one of four states as clearly mentioned in figure 2.

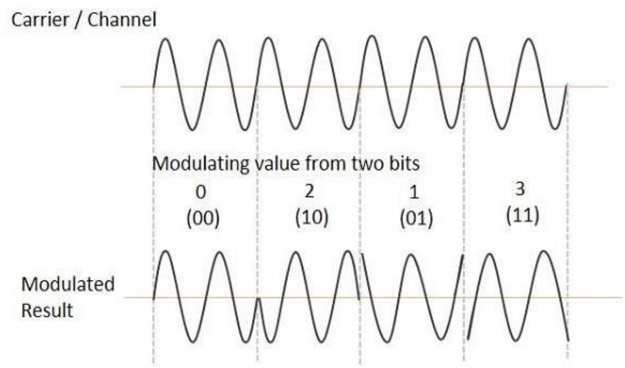


Figure 2 : Waveform Diagram of QPSK Modulation

### *F. Quadrature Amplitude Modulation (QAM)*

QAM (quadrature amplitude modulation) is a termed as combination of two amplitude-modulated (AM) signals into a single channel, which doubles the effective bandwidth. This technique is used with pulse amplitude modulation (PAM) in digital systems, especially in wireless applications.

M-QAM constellations involve two orthonormal basis functions and are two-dimensional. An important configuration of signal points is rectangular QAM, the signal points are placed on a rectangular grid spaced equally in amplitude in each direction. Fig. 3 shows rectangular QAM signal constellations for M = 4, 8, 16, 32, 64.

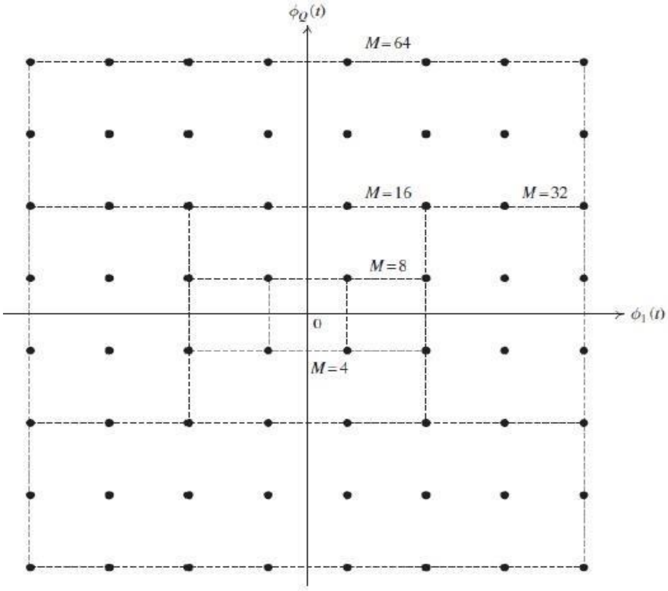


Figure 3 : Constellation Diagram of QAM Modulation

## III. COMMUNICATION CHANNEL

Communication channels are basically of three types based on the classifications in terms of their characteristics as Additive White Gaussian Noise Channel (AWGN), Bandlimited Channel and Fading channel. These characteristics play a vital role in the design and selection of the schemes. A detailed explanation about the AWGN channel is given below based on the analysis.

### *A. Additive White Gaussian Noise Channel (AWGN)*

This is one of the important channel model for analyzing modulation schemes. In this model, the channel adds a white Gaussian noise to the signal passing through it which shows that the channel's amplitude frequency response is flat and phase frequency response is linear for all frequencies. This results if any modulated signals pass through it is without any amplitude loss and phase distortion of frequency components.

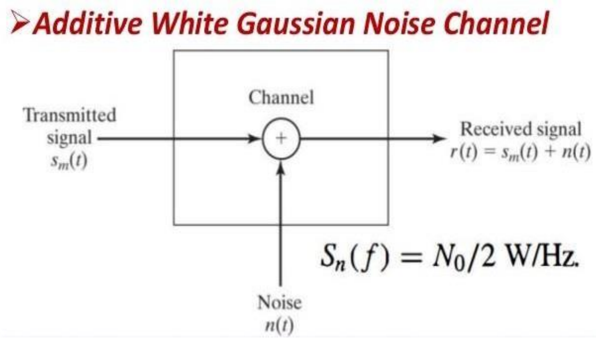


Figure 4 : AWGN Channel Model

## IV. PERFORMANCE PARAMETERS

### *A. Bit Error Rate – BER*

It is the number of bits corrupted or destroyed during the transmission of data from the source to destination. When transmitting data from one point to another, either over a radio/ wireless link or a wired telecommunications link, the key parameter is how many errors will appear in the data that appears at the remote end. Therefore, a system with low BER is required for efficient communication.

$$\text{BER} = \frac{\text{Number of bits in error (at receiver)}}{\text{Total number of bits (transmitted)}}$$

Equation 1 : BER Formula

### *B. Signal To Noise Ratio - SNR*

Signal-to-noise ratio compares a level of signal power to a level of noise power expressed in decibels. If the ratio is higher than 1:1, it shows that more signal than noise. So as long as the incoming signal is strong and well above the noise floor, then the audio will be able to maintain a higher quality. Hence it’s kind of good signal-to-noise ratio people prefer for a clear and accurate sound.

$$\text{SNR} = \frac{P_{\text{signal}}}{P_{\text{noise}}}$$

Equation 2 : SNR Formula

### *C. Mean Square Error – MSE*

The mean squared deviation of an estimator measures the average squared difference between the estimated values and what is estimated. The MSE can be written as the sum of the variance of the estimator and the squared bias of the estimator, providing a useful way to calculate the MSE and implying that in the case of unbiased estimators, the MSE and variance are equivalent.

$$MSE = \frac{1}{N}\sum_{i=0}^{N}(\hat{y}_i - y_i)^2$$

Equation 3 : MSE Formula

## V. SIMULATION RESULTS

The different modulation techniques are compared for various parameters and the performance analyzed from the above mentioned papers are presented in this section.

### *A. Reference 1 :*

In this paper the author shown the comparisons of simulated BER and theoretical probability of error (Pe ) for BPSK and QPSK in the tabulated form.

| $\frac{E_b}{N_0}$(dB) | BER | $P_e$ |
|---|---|---|
| ∞ | 0 | 0 |
| 0 | 0 | $4.05 \times 10^{-6}$ |
| 8 | $2 \times 10^{-4}$ | $2.06 \times 10^{-4}$ |
| 6 | $2.9 \times 10^{-3}$ | $2.41 \times 10^{-3}$ |
| 4 | $1.24 \times 10^{-2}$ | $1.25 \times 10^{-2}$ |
| 2 | $3.77 \times 10^{-2}$ | $3.75 \times 10^{-2}$ |
| 0 | $8.02 \times 10^{-2}$ | $7.93 \times 10^{-2}$ |

Table 1 : Simulated BER and Pe of BPSK

| $\frac{E_b}{N_0}$(dB) | BER | $P_e$ |
|---|---|---|
| ∞ | 0 | 0 |
| 12 | 0 | $\approx 10^{-8}$ |
| 10 | $3.87 \times 10^{-6}$ | $\approx 10^{-6}$ |
| 8 | $2.9 \times 10^{-4}$ | $\approx 10^{-4}$ |
| 6 | $4.2 \times 10^{-3}$ | $2.41 \times 10^{-3}$ |
| 4 | $1.46 \times 10^{-2}$ | $1.25 \times 10^{-2}$ |
| 2 | $3.69 \times 10^{-2}$ | $3.75 \times 10^{-2}$ |
| 0 | $7.72 \times 10^{-2}$ | $7.93 \times 10^{-2}$ |

Table 2 : Simulated BER and Pe of QPSK

### *B. Reference 2 :*

In this paper the author compares the performance in terms of the BER curve using different Forward Error Correction Codes.

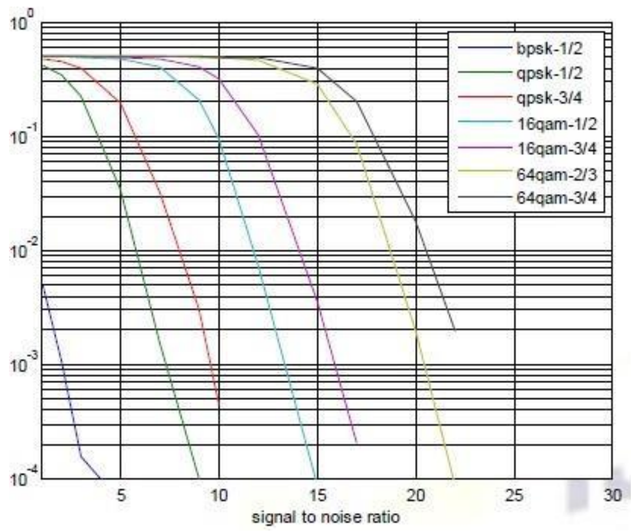


Figure 5 : BER curve using Convolution Coding

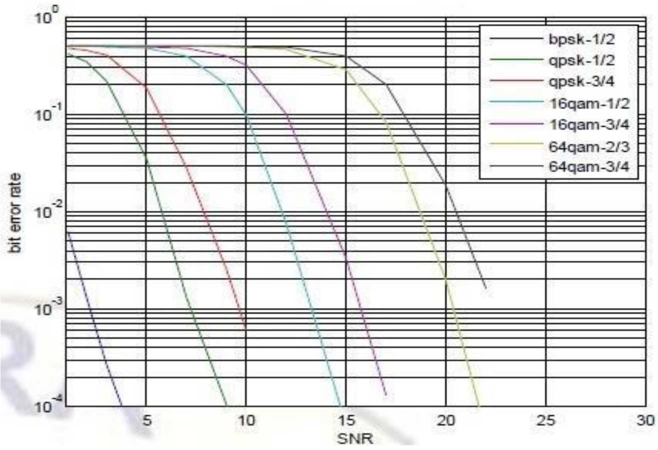


Figure 6 : BER curve using Reed-Solomon Coding

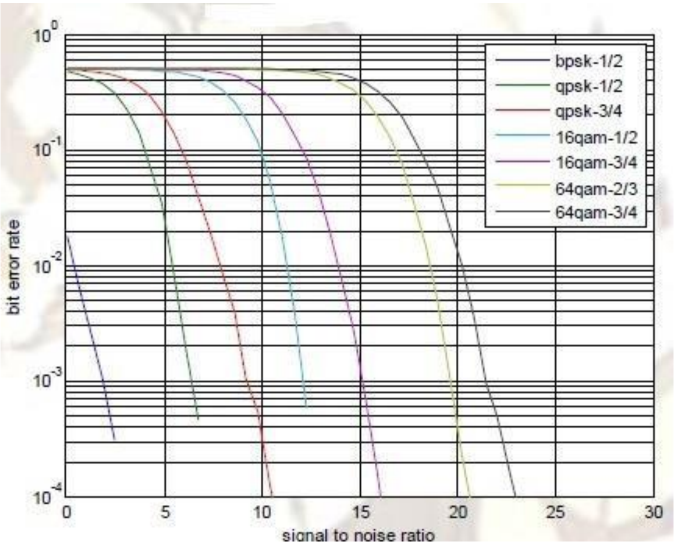


Figure 7 : BER curve using Concatenated Coding

### C. *Reference 3 :*

In this work the author analyzed BER value of different modulation techniques in two different channel bandwidth of 1.25 and 6 MHz's.

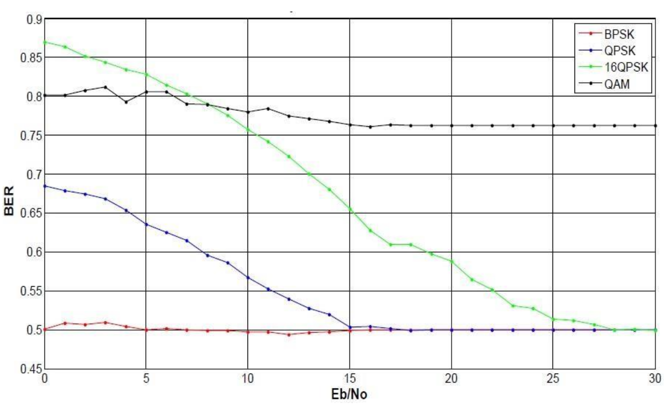


Figure 8 : BER curve at channel bandwidth 1.25 MHz

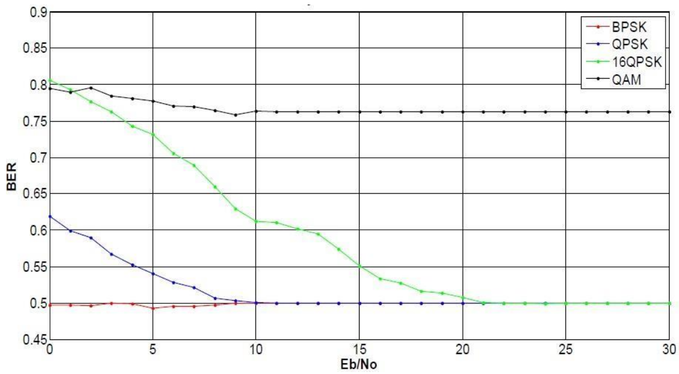


Figure 9 : BER curve at channel bandwidth 6 MHz

### D. *Reference 4 :*

In this paper the author showed the performance analysis of BPSK and QPSK scheme with implementation of LDPC Coding.

| SNR | LDPC Coding (BPSK) | LDPC coding(QPSK) |
|---|---|---|
| 1 dB | 0.077996 | 1 |
| 2dB | 0.0465038 | 1 |
| 3 dB | 0.0223758 | 1 |
| 4 dB | 0.00963231 | 0.0817497 |
| 5 dB | 0.00255534 | 0.0487934 |
| 6 dB | 0.000560076 | 0.0238789 |
| 7 dB | 8.00E-05 | 0.0108068 |
| 8 dB | 0 | 0.0030205 |
| 9 dB | 0 | 0.000720119 |
| 10 dB | 0 | 7.00E-05 |

Table 3 : Simulated BER with LDPC Coding

## VI. CONCLUSION

A survey on the digital modulation techniques has been presented in this document exposes that the choice of the technique of digital modulation is entirely dependent on the application necessity may be power or Available Bandwidth. This study has given the brief introduction about the type of application specific, as an application may require a greater accuracy in the receipt of data, where that the other importance of coding theory in performance improvement for digital modulation techniques. The search for a better modulation technique doesn't end here as the criterion for higher data rate communication is taking the lead in almost every area of communication and thus the ISI and BER realization become very important and crucial aspect for any future digital modulation technique.

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