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Bit Error Rate Analysis in Simulation of Digital Communication Systems with Different Modulation Schemes

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Abstract

With the increasing demand in communication, it has become necessary to give better and efficient service to users by using better technique. This paper analyse the bit error rate, for different modulation schemes such as Binary Phase Shift Keying (BPSK), Quadrature Phase Shift Keying (QPSK. By Choosing a reliable modulation scheme and better coding technique the enhancement of the performance can be obtained in transmitter and receiver of the system. Simulated result is shown to analyse and compare the performance of these systems by using additive white Gaussian noise channel (AWGN). Finally the different modulation schemes are compared on the basis of BER and best modulation scheme is determined. From analysis of two modulation techniques, the system could use more appropriate modulation technique to suit the channel quality, thus we can deliver the optimum and efficient system parameters. LabVIEW has been used for simulation.

Keywords: *LabVIEW, BER, AWGN*

1. 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. **[17]**

A communication system is made up of devices that employ one of two communication methods (wireless or wired), different types of equipment (portable radios, mobile radios, base/fixed station radios, and repeaters), and various accessories (examples include speaker microphones, battery eliminators, and carrying cases) and/or enhancements (encryption, digital communications, security measures, and interoperability/networking) to meet the user needs.

In the series of communication methods, one of them is Wireless communications. It has become one of the fastest growing areas in our modern life and creates enormous impact on nearly every feature of our daily life. A tremendous technological transformation during the last two decades has provided a potential growth in the area of digital communication.

Living in the era of communication everything may be video, audio or any information in the form of electrical signal is termed as data and there is an enormous requirement of data transfer between two or more point through the world wide web, every moment of the clock, which is a big threaten to the existing communication systems because of the problems like spectral congestion, severe adjacent & co-channel interference problems and noise corrupted data reception etc. This has resulted in serious need for the research work all around the world for the development of the communication systems which can handle the above said problems, where each aspect of the communication systems is dealt with the development of new encoding techniques, modulation techniques, possibilities for newer transmission channels and off course the demodulation and decoding techniques. **[7]**

The next generation of wireless communication systems faces the demand for increased data rates, higher mobility, larger carrier frequencies, and more link reliability. Wireless channels are characterized by fading, multipath, limited bandwidth, and frequency and time selectivity which make system design a challenge. It is therefore crucial to have an understanding of the behavior of wireless channels in order to know their performance limits and to be able to design efficient communication systems for them. This dissertation considers the analysis of the performance of digital communication systems with different coding and modulation schemes.

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 multipath communication channels for modulation schemes. Therefore, understand the system could go for more suitable modulation technique to suit the channel quality and can suggest better modulation schemes. **[3]**

2. Modulation and Channel Schemes

The purpose of any digital communication system is to transmit data from an information source to an information sink. At a minimum, a baseband waveform must be constructed from the symbols making up the information. Some media, such as coaxial cable, can propagate baseband waveforms with

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no further manipulation required. For wireless transmission, on the other hand, baseband waveforms are impractical for several reasons. First, the antenna size necessary to transmit an electromagnetic wave is inversely proportional to the wave's frequency. Therefore, shifting the baseband waveform to a higher frequency allows for a smaller antenna. For many mobile devices, this results in a carrier frequency on the order of 1 GHz. Second, multiple transmitters operating at the same frequency generally interfere with each other. By assigning each transmitter a unique portion of the electromagnetic spectrum, multiple transmitters can operate without interference. This is called frequency-division multiple access.

The translation of a baseband waveform to a higher frequency is accomplished by manipulating the features of a sinusoidal wave at that frequency. This process is called bandpass modulation. In general the four different modulation schemes: amplitude, frequency, phase and code modulation are possible. Well known examples of high frequency carrier signals are: AM radio is 550-1600 KHz, FM radio is 88 MHz-108 MHz, TV is 52-88 MHz (channels 1-6), 174-216 MHz (channels 7-12) and 470-900 MHz (UHF) microwave and satellite signals are of the order of several GHz infra red fiber optic signals are of the order of 200-300 THz.

2.1 Classification of Modulation Schemes

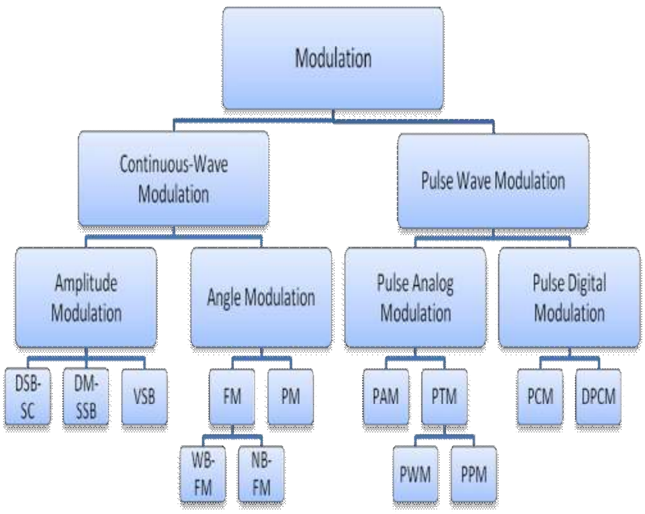

Fig. 1 Hierarchy of Modulation Scheme [12]

2.1.1 Analog Modulation

Analog or Continuous Wave modulation schemes are basically of two types: the amplitude modulation and the angle modulation. Angle modulation deals with two: frequency and phase modulation schemes which have in turn lot of class, subclass or derivatives. In case of the Amplitude Modulation there are several derivatives and it is found that the Single Side Band Suppressed Carrier (SSS-SC) has smaller bandwidth and power requirements in contrast with Double Side Band Suppressed Carrier (DSB SC) and Double Side Band Full Carrier (DSB FC) and Single Side Band Full Carrier (SSB FC) but for detection of this signal, it is require sharp cut-off Low Pass Filter (LPF) which is not practically viable **[12]**. Using the Vestigial Side Band (VSB) technique in place of (SSB SC), it can be achieve a low pass filter with a gradual cut off but it requires more BW and power than SSB-SC and less then the DSBSC and DSB-FC and hence ideally SSB-SC is proves to be better than other AM schemes but practically, VSB proves to be a much better candidate then the other amplitude modulation techniques.

The Amplitude modulated signals require nonlinear amplifiers which generate spurious out-of-band spectral components which are filtered out with a great difficulty. Frequency Modulation proves to be better in comparison to amplitude modulation and phase modulation, and the derivative of frequency modulation, narrow band FM (NBFM) is usually employed to overcome above mentioned problems in the communication system. The great merit of FM over AM is that FM allows us to suppress the effects of noise at the expense of bandwidth. The major limitation of the analog modulation systems for communicating over long channels is that once noise has been introduced at any place along the channel, then it is carried out till the end. Because the analog modulation system (AM, FM and PM) are extremely sensitive to the noise present at the receiver end in contrast to this if a digital signal is modulated and transmitted the received signal is far less sensitive to receiver.**[12]**

2.1.2 Digital Modulation

After the conversion of an Analog signal to digital by sampling, different types of digital modulation schemes can be achieved by the variation of different parameter of the carrier signal. For example the Amplitude variation gives BASK, Frequency variation gives BFSK and the Phase variation gives BPSK. Also sometimes a combinational variation of this parameter is done to generate the hybrid modulation technique viz. a combinational variation of Amplitude and Phase Shift Keying (APSK). Many more digital modulation techniques are available and can also be designed depending upon the type of signal and the application. Thus a better digital modulation technique is to be thought over by the designer which has an ability of exploiting the available transmitted power and the bandwidth to its full extent. **[8]**

The choice of digital modulation scheme will significantly affect the characteristics, performance and resulting physical realization of a communication system. There is no universal 'best' choice of scheme, but depending on the physical characteristics of the channel, required levels of performance and target hardware trade-offs, some will prove a better fit than others. Consideration must be given to the required data rate, acceptable level of latency, available bandwidth, anticipated link budget and target hardware cost, size and current consumption.

In digital communications, the modulation process corresponds to switching or keying the amplitude, frequency,

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or phase of the carrier in accordance with the incoming digital data.

Three basic digital modulation techniques are:

- Amplitude-shift keying (ASK) - special case of AM
- Frequency-shift keying (FSK) - special case of FM
- Phase-shift keying (PSK) - special case of PM

In binary signaling, the modulator produces one of two distinct signals in response to 1 bit of source data at a time. If all the above used as in form of Binary then it will be called BASK, BFSK and BPSK.

2.1.3 Binary Phase Shift Keying (BPSK)

BPSK (also sometimes called PRK, Phase Reversal Keying, or 2PSK) is the simplest form of phase shift keying (PSK). In binary phase shift keying (BPSK) the transmitted signal is a sinusoid of fixed amplitude. It uses two phases which are separated by 180° and so can also be termed 2-PSK. **[16].** Binary Phase Shift Keying (BPSK) modulation, the simplest and most robust of all techniques, the signal shifts the phase of the waveform to one of the two states, either zero or π. Its constellation diagram is shown in figure 3.4 with in-phase and quadrature axes named as I and Q, respectively. It is only able to transmit 1 bit/symbol in this case and so this is considered to be a disadvantage when using high data-rate systems with limited bandwidth.

For transmission of '1':

$$S_1(t) = \sqrt{\frac{2E_b}{T_b}}\cos(2\pi f_c t) \qquad 3.7$$

For Transmission of '0':

$$S_2(t) = \sqrt{\frac{2E_b}{T_b}}\cos(2\pi f_c t + \pi) \qquad 3.8$$

Where, T_b is bit duration, f_c is carrier frequency, E_b is transmitted signal energy per bit.

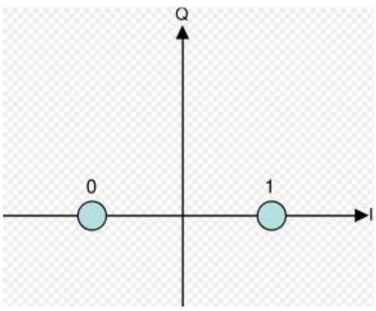

Fig. 2 Constellation diagram of BPSK [1]

In another way, it can be understood as a binary level digital modulation scheme of phase variation that has two theoretical phase angles, +90° and -90°. It is immune to noise and interference therefore it improves BER performance. Each modulation symbol represents a single phase.

The bit error rate (BER) of BPSK in AWGN can be calculated as:

$$P_b = Q\left(\sqrt{\frac{2E_b}{N_0}}\right) \qquad 3.9$$

Or

$$P_b = \frac{1}{2} erfc\left(\sqrt{\frac{2E_b}{N_0}}\right) \qquad 3.10$$

Since there is only one bit per symbol, this is also the symbol error rate. The differential phase shift keying (DPSK) is a modification of BPSK. [**1**]

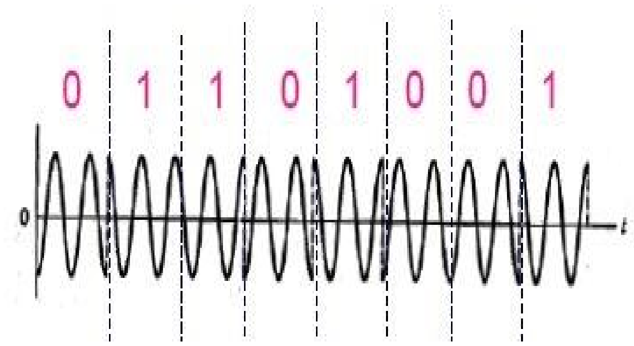

Fig. 3 BPSK Modulation [5]

2.1.4 Quadrature Phase Shift Keying (QPSK)

Quadrature Phase-shift Keying (QPSK) is a widely used method of transferring digital data by changing or modulating the phase of a carrier signal **[30].** A four-level (4-ary) PSK is called Quaternary Phase Shift Keying (QPSK), and uses four points on the constellation figure 3.6. The signal shifts the phase to one of four states and so QPSK can transmit 2 bits/symbol as we see from the diagram as well. When applying Gray coding each adjacent symbol only differs by one bit.

The QPSK uses four phases at 0°, 90°, -90° and 180 degrees. It gives high spectral efficiency and it is more efficient than BPSK because it uses two symbols at a time for modulation. Both BPSK and QPSK are power efficient in same way but QPSK is more bandwidth efficient than BPSK.

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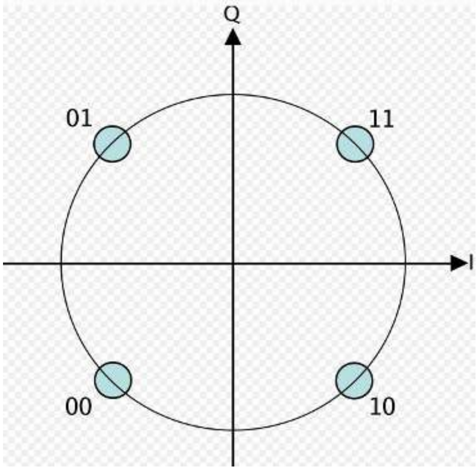

Fig. 4 Constellation diagram of QPSK [1]

The probability of bit-error for QPSK is the same as for BPSK:

$$P_b = Q\left(\sqrt{\frac{2E_b}{N_0}}\right)$$

When QPSK is compared to that of BPSK, QPSK provides twice the spectral efficiency with the same energy efficiency. However, in order to achieve the same bit-error probability as BPSK, QPSK uses twice the power (since two bits are transmitted simultaneously).

The symbol error rate is given by:

$$P_s = 1 - (1 - P_b)^2$$

$$= 2Q\left(\sqrt{\frac{E_s}{N_0}}\right) - \left[Q\left(\sqrt{\frac{E_s}{N_0}}\right)\right]^2$$

If the signal-to-noise ratio is high (as is necessary for practical QPSK systems) the probability of symbol error may be approximated:

$$P_s \approx 2Q\left(\sqrt{\frac{E_s}{N_0}}\right)$$

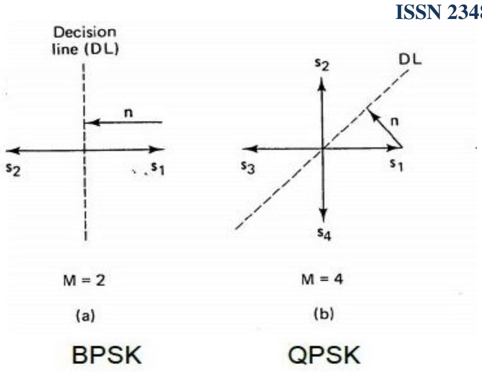

Fig. 5 MPSK Signal Constellation

The Euclidean distance between any two signal points in the constellation is:

$$d_{min} = \|s_m - s_n\| = \sqrt{2E_s\left(1 - \cos\frac{2\pi(m-n)}{M}\right)}$$

The minimum Euclidean distance is

$$d_{min} = \sqrt{2E_s\left(1 - \cos\frac{2\pi}{M}\right)} = 2\sqrt{E_s}\sin\frac{\pi}{M}$$

In the case of PSK modulation, the error probability is dominated by the erroneous selection of either one of the two signal points adjacent to the transmitted signal point. Consequently, an approximation to the symbol error probability is

$$P_{MPSK} = 2Q\left(\frac{\frac{d_{min}}{2}}{\sqrt{\frac{N_0}{2}}}\right) = 2Q\left(\sqrt{2E_s}\sin\frac{\pi}{M}\right)$$

3. Coding and Characteristics

The aim of communications is to transmit the information which is usually unknown to the receiving end in an accurate and quick manner. When data go through the communication channels, there might be the loss or some distortion of the information. Just like two speakers talking on the phone. If one does not catch the other's words, s/he may guess the ambiguous part of information by the tones and by the things talked about previously etc, or s/he could ask the other one to repeat that part. These methods to deal with uncertain words imply the human's language system of error correction in communications. In the data communications, we could also apply similar various methods of coding to solve these problems.

Coding and modulation provide the means of mapping information into waveforms such that the receiver (with an

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appropriate demodulator and decoder) can recover the information in a reliable manner. **[25]**

In wireless, satellite, and space communication systems, reducing error is critical. When a message is transmitted, it has the potential to get scrambled by noise. This is certainly true of voice messages, and is also true of the digital messages that are sent to and from computers. Now even sound and video are being transmitted in this manner. By a digital message, we mean a sequence of 0's and 1's which encodes a given message. What we will seek to do is to add more data to a given binary message that will help to detect if an error has been made in the transmission of the message; adding such data is called an **error-detecting code**. We will also try to add data to the original message so that we can detect if errors were made in transmission, and also to figure out what the original message was from the possibly corrupt message that we received. This type of code is an **error-correcting code**. High bit error rates of the wireless communication system require employing various coding methods on the data transferred.

Codes are used for data compression, cryptography, error-correction and more recently also for network coding. Error control coding theory has been the subject of intense study since the 1940s and now being widely used in communication systems. **[18]**. Codes are studied by various scientific disciplines—such as information theory, electrical engineering, mathematics, and computer science- for the purpose of designing efficient and reliable data transmission methods. This typically involves the removal of redundancy and the correction (or detection) of errors in the transmitted data.

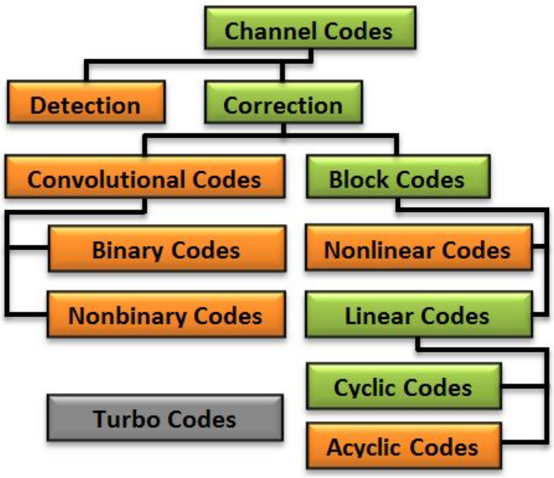

Fig. 6 Basic sorting of channel codes [13]

Burst Error (contiguous errors in the bit stream) is a common occurrence in digital communication systems, broadcasting systems and digital storage devices. Many mechanisms have devised to mitigate this problem. Forward error correction is a technique in which redundant information is added to the original message, so that some errors can be corrected at the receiver, using the added redundant information.

There are essentially two aspects to coding theory:

- Data compression (or, source coding)
- Error correction (or channel coding)

3.1 Source Coding

Whether a source is analog or digital, a digital communication system is designed to transmit information in digital form. Consequently the output of the source must be converted to a format so that it can be transmitted digitally. This conversion of the source output to a digital form is generally performed by the source encoder whose output may be assumed to be a sequence of binary digits.

Optimum coding aims to match the source and the channel for maximum reliable information transfer. The coding process involves two distinct operations namely encoding and decoding. The source encoder/decoder units match the source to the equivalent noiseless channel, provided that the source information rate falls within channel capacity. Source encoding attempts to compress the data from a source in order to transmit it more efficiently. This practice is found every day on the Internet where the common Zip data compression is used to reduce the network load and make files smaller.

3.2 Channel Coding

The aim of communications is to transmit the information which is usually unknown to the receiving end in an accurate and quick manner. When data go through the communication channels, there might be the loss or some distortion of the information. Just like two speakers talking on the phone. If one does not catch the other's words, s/he may guess the ambiguous part of information by the tones and by the things talked about previously etc, or s/he could ask the other one to repeat that part. These methods to deal with uncertain words imply the human's language system of error correction in communications. In the data communications, we could also apply similar various methods of error-correcting to solve these problems.

Channel coding refers to the class of signal transformations designed to improve communications performance by enabling the transmitted signals to better withstand the effects of various channel impairments, such as noise, interference and fading. Channel coding for error detection and correction helps the communication system designers to reduce the effects of a noisy transmission channel **[18]**. In this information age, there is an ever increasing necessity not only for speed, but also for accuracy in the storage, retrieval and transmission of data. Imperfect channels or media through which messages are transmitted cause errors in the received messages. Channel coding is a technique using which these errors can be detected or even corrected. Error correcting codes offer a kind of safety net – the mathematical insurance against the vagaries of an imperfect communication channel.

Channel encoding, adds extra data bits to make the transmission of data more robust to disturbances present on the transmission channel. A typical music CD uses the Reed-Solomon code to correct for scratches and dust. In this application the transmission channel is the CD itself. Cell phones also use coding techniques to correct for the fading and noise of high frequency radio transmission. Data modems, telephone transmissions, and NASA all employ channel coding techniques to get the bits through, for example the turbo code and LDPC codes.

The following are the important aspects of channel coding also known as error control coding making use of the structured sequences.

- It is possible to detect and correct errors by adding extra bits called error check bits or parity check bits to the message bit stream. Because of the additional bits, not all bit sequences will constitute bonafide messages.
- It is not possible to detect and correct all errors.
- Addition of extra bits reduces the effective data rate through the channel. Quantitatively, the rate efficiency of a coding scheme is defined as rb/rc.

Forward error correction (FEC) coding significantly improves the performance of communications systems. Forward Error Correction (FEC) encoding schemes can be classified into two structural types linear block codes and convolutional codes. It analyzes the following three properties of a code – mainly: Code word length, Total number of valid code words, the minimum distance between two valid code words, using mainly the Hamming distance.

Bit rate is the frequency of a system bit stream. The symbol rate is the bit rate divided by the number of bits that can be transmitted with each symbol. Symbol rate is sometimes called baud rate. Note that baud rate is not the same as= bit rate. These terms are often confused. If more bits can be sent with each symbol, then the same amount of data can be sent in a narrower spectrum. This is why modulation formats that are more complex and use a higher number of states can send the same information over a narrower piece of the RF spectrum.

SNR is defined as the ratio of a signal power to noise power and it is normally expressed in decibel (dB). The mathematical expression of SNR is

$$SNR = 10\log_{10}\left(\frac{Signal\ Power}{Noise\ Power}\right)dB$$

Performance of Error correcting codes for a complete system analysis includes finding the reliability of coding and decoding circuits as this plays a significant role in undetected errors. **[14]**. It is proved in **[10]** that for every SNR values the BER of BPSK modulation is observed to be closer to the theoretical value and hence BPSK modulation is better than QPSK modulation in both channels.

4. Simulation Platform and Result

The Simulation platform LabVIEW is chosen for the work. Some of the detail and advantages are given in this chapter to get the brief idea about the software and its advantages.

4.1 LabVIEW & Contrive

LabVIEW (**Lab**oratory **V**irtual **I**nstrument **E**ngineering **W**orkbench) is a graphical programming environment which has become prevalent throughout research labs, academia and industry. It is a powerful and versatile analysis and instrumentation software system for measurement and automation. Its graphical programming language called *G programming* is performed using a graphical block diagram that compiles into machine code and eliminates a lot of the syntactical details. LabVIEW offers more flexibility than standard laboratory instruments because it is software based. Using LabVIEW, the user can originate exactly the type of virtual instrument needed and programmers can easily view and modify data or control inputs **[12]**. The popularity of the National Instruments LabVIEW graphical dataflow software for beginners and experienced programmers in so many different engineering applications and industries can be attributed to the software's intuitive graphical programming language used for automating measurement and control systems.

LabVIEW programs are called virtual instruments (VIs), because their appearance and operation imitate physical instruments like oscilloscopes. LabVIEW is designed to facilitate data collection and analysis, as well as offers numerous display options. With data collection, analysis and display combined in a flexible programming environment, the desktop computer functions as a dedicated measurement device. LabVIEW contains a comprehensive set of VIs and functions for acquiring, analyzing, displaying, and storing data, as well as tools to help in troubleshooting the code.

4.2 Simulation Result

Table 1 Result of BPSK and QPSK with 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

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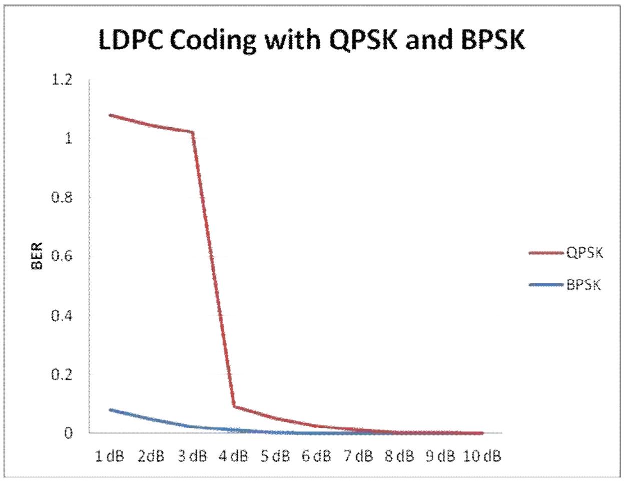

Fig. 7 BER v/s Eb/N0 for BPSK and QPSK

Result shows that BER performance analysis of LDPC coding and modulations over AWGN channel. As per figure, Performance of BPSK modulation with LDPC coding is best over AWGN channel.

5. Conclusions

The paper presents, error performance of two modulation techniques in AWGN channel are analysed and BER is calculated. Based on numerical calculation the BER of BPSK and QPSK is graphically plotted and compared. Use of the system appears to be very suitable for testing of new principles in the channel coding ambit without any need for a constant upgrading of hardware components and also without any customer-vendor cooperation in terms of software modifications. The software used is LabVIEW 2011. This software offers us various libraries which are suitable for channel coding decoding and performance analysis.

For the experiments, we have been used the BPSK, QPSK and modulation schemes that was implemented right into the assembled transmission chain with LDPC coding. The real measurements have achieved the results which have satisfied us. According to the work, a performance of different modulation techniques and channel coding is analysed on the basis of BER over AWGN channel. As per the analysis of different modulation techniques, we can say BPSK gives better performance with respect to QPSK over AWGN channel. Also we have limitation to increase E_b/N_0 ratio. Hence, for a fixed value of E_b/N_0, we have to use some kind of coding to improve quality of the transmitted signal.

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