BER Analysis of Digital Modulation Schemes using LabVIEW

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Abstract: **Since the last few decades there has been an abrupt rise in technology and all the communication devices of the new generation mostly rely on digital transmission of information. Thus, it has become necessary to give better and efficient services to users by employing better digital modulation techniques. This paper analyses the Bit Error Rate (BER) performance of different digital modulation schemes such as Binary Phase Shift Keying (BPSK), Quadrature Phase Shift Keying (QPSK) and Quadrature Amplitude Modulation (QAM) using LabVIEW. The Additive White Gaussian Noise (AWGN) channel is used for analysis and modulation. As LabVIEW is a graphical programming environment it gives good visualization of the results and it also allows us to design systems in an intuitive block based manner in short time as compared to other commonly used text based programming languages. Thus, it is concluded from the simulation results that BPSK outperforms QPSK and QAM in terms of BER.**

Index Terms**: AWGN, BPSK, QAM, QPSK**

I. INTRODUCTION

Communication is the process of conveying information from one entity to another in sending or receiving information between two or more people. The one who sends the information is called sender or source of information and the one for whom the information is destined is called the receiver or user. A Simple communication system consists of a transmitter, a channel and a receiver.

Conventional methods of communication use analog signals for long distance communication. But these systems suffer many losses such as interference, distortion, attenuation as well as other losses including security. To overcome these problems, the analog signals are digitized which allow the communication to be more clear and accurate without losses. Not only this, the digital system is more reliable, easy to design, cheap but also can be saved and retrieved more conveniently and above all the capacity of the channel is effectively utilized.

The process of digitization [1], [3] involves steps such as Sampling, Quantizing and Encoding which are performed in analog to digital convertor section. The receiver performs the reverse operations like decoding and reconstruction of the quantized pulse train which is then given to reconstruction filter to get the original signal.

Digital modulation [1] techniques provide more information capacity, high data security and fast system availability with a great quality of communication.

With tremendous development in digital communication systems it is very important to ensure the quality of service for real time transmission of video applications and provide user with more powerful and efficient services by using better modulation techniques.

The most commonly used digital modulation schemes are BPSK, QPSK & QAM as they offer the lowest bit error rate as compared to other digital modulation techniques like ASK, FSK, DPSK and other M-ary techniques.

In this paper BER [2] analysis is performed under AWGN channel using LabVIEW for modulation techniques i.e. BPSK, QPSK and QAM [10].

The paper is organized as follows:

- Section II discusses about the digital modulation schemes, BER and AWGN channel in detail.
- Section III describes the LabVIEW simulation and implementation of the generalized block diagram.
- Section IV gives the simulation results.
- Section V concludes the paper.

II. DIGITAL MODULATION SCHEMES

A. BPSK

It is one of the most commonly used digital modulation technique where in the phase of the carrier signal is varied according to the input bits at a particular time.

In this technique , the sine wave carrier usually takes two phase values such as 0^0 and 180^0.

B. QPSK

It is a variation of BPSK which sends two bits of digital information at a time. This results in the bit rate to half and allows space for other users. Since it transmits a combination of 1's and 0's, the generated bits are 00, 01, 10 and 11. Each of this combination of 2 bits is represented by a phase reversal such as 45^0, 135^0, 225^0 and 315^0.

C. QAM

It is a combination of both analog and digital schemes. It actually conveys two message signals or two digital streams by changing the amplitudes of two carrier waves using amplitude shift keying or amplitude modulation. These two carrier waves of the same frequency are out of phase with each other by 90^0 and are called as quadrature carrier or quadrature components.

D. BER

It defines the number of bits that are in error out of the total number of transferrable bits during an observation period. BER is evaluated using simulations assuming simple channel models usually AWGN channel without fading. If E_b is the energy of a bit and N_o is the noise power then BER is taken as a function of E_b/N_o and is expressed as

$$BER= \frac{1}{2} \operatorname{erfc}\sqrt{(E_b/N_0)} \quad (1)$$

where erfc is the complementary error function of argument E_b/N_0. Plot of BER curves are used to describe the performance of a digital communication system.

In wireless communications, BER (dB) versus SNR (dB) is generally used.

E. AWGN chnnel

AWGN channel is one of the wireless communication [4], [7] channel model which considers a linear addition of white noise with a constant spectral density and a Gaussian distribution function of amplitude. It is a simple and tractable mathematical model which does not take into account fading interference, non linearity or dispersion but gives a useful insight to gain the underlying behavior of the system.

For AWGN channel model the channel capacity is given by the equation

$$C=B\log_2(1+S/N) \text{ bits/sec} \quad (2)$$

where B is channel bandwidth in Hz, S/N is Signal to Noise ratio in bits/sec

III. LabVIEW Implementation

LabVIEW (Laboratory Virtual Instrument Engineering Workbench) [5], [6], [8] is a graphical programming environment and has become prevalent not only in research labs but also in industries as well as in academia. It gives a powerful and versatile analysis for measurement and automation. The LabVIEW graphical programming language is called Programming and is performed using a graphical block diagram which compiles into machine code and eliminates many syntactical details. Since it is software based, it offers much flexibility than the standard laboratory instruments. It is possible to view and modify data and/or control inputs easily using LabVIEW.

As the appearance and operation imitate physical instruments like oscilloscope, the programs of LabVIEW are called Virtual Instruments (VI's). LabVIEW offers various display options and is designed to facilitate data collection and analysis.

LabVIEW contains with it the tools to help in troubleshooting the code and a comprehensive set of VIs and functions for acquiring, analyzing, displaying and storing data. LabVIEW has many built in features and may be used as a tool for simulation and control. It can be implemented on any of the platforms including Microsoft Windows, UNIX and LINUX. Other advantages of using LabVIEW is that it is possible to vary the input parameters and the corresponding results by making a change in the appropriate block in the front panel.

LabVIEW has built in analysis capability with functions to generate signals, analysis, visualization, and processing of standard and custom digital and analog modulation formats. All these are possible using the Modulation Toolkit which is available as a built-in with LabVIEW. The Toolkit helps to rapidly develop custom applications for research, design, characterization, validation, and test of communications systems and components that are used to modulate and demodulate signals. The various Modulation Toolkit applications include analog and digital modulation schemes like AM, FM, PM, ASK, FSK, MSK, GMSK, PSK, QPSK, PAM, and QAM. These modulation schemes are the foundation of many digital communication standards found in 802.11a/b/g/n, ZigBee (802.15.4), WiMAX (802.16), RFID, satellite communications, and commercial broadcast among others.

To work with RF signals, the Modulation Toolkit (MT) complements the PXI-5660 RF vector signal analyzer and the PXI-5671 RF vector signal generator. For low frequency signals like baseband and IF signals the Modulation Toolkit works with the 100 MHz mixed-signal test platform with digitizer, analog waveform generator, and digital waveform I/O products.

Figure.1 gives the block diagram of a digital communication system generated using LabVIEW. As shown in figure 1, all the three modulation techniques BPSK, QPSK & QAM are implemented in a single system. The system uses a PN sequence generator which generates a random signal and is applied to BPSK, QPSK and QAM blocks. Each of the blocks internally has its own communication system i.e. Modulator, AWGN channel and a Demodulator. The bits are modulated and demodulated in their respective blocks. The output from each block is given to respective constellation graphs as shown and is also applied as inputs to a single BER block which generates the BER plot for the three modulation schemes.

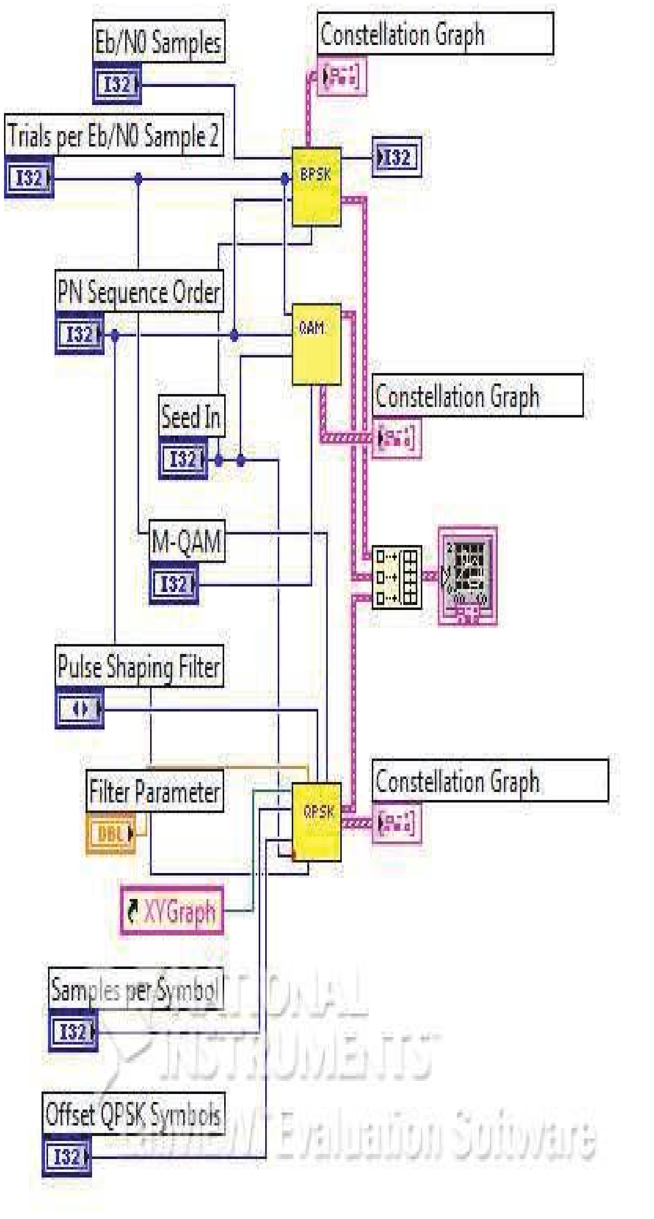

Figure 1. Block Diagram of a Digital Communication System generated using LabVIEW

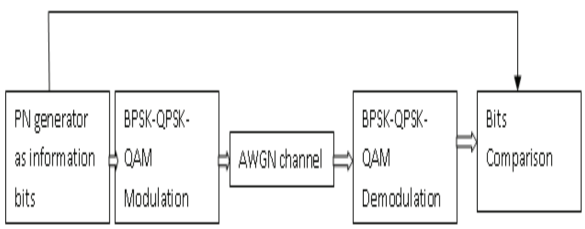

Figure 2. Communication System using LabVIEW

A. PN Sequence Generator

The PN sequence generator generates Galois pseudonoise (PN) bit sequences. The selected pattern is repeated unless the total number of bits that is specified is generated. Use this node to specify the primitive polynomial that determines the connection structure of the linear feedback shift register (LFSR).

The generated bits are applied as inputs to the modulator block. Figure 2 shows the block diagram of a communication system which implements all the three modulation schemes.

B. Modulator

The input bits from the sequence generator are mapped to symbols. Number of symbols indicates M-ary of the modulation scheme.

$$\text{Bits per Symbol} = \log_2(M) \qquad (3)$$

For example, 16QAM has sixteen different combinations of amplitude and phase. Each is assigned a 4 bit sequence. These symbols are then passed through an AWGN channel.

C. AWGN Channel

The AWGN channel generates a complex Additive White Gaussian Noise (AWGN) with uniform power spectral density with zero mean and adds it to the complex baseband modulated waveform from the modulator block. The AWGN channel gives a signal-plus-noise waveform with E_b/N_0, where E_b represents the energy per bit, and N_0 is the noise variance.

D. Demodutor

At receiver side the received signal is down converted so that a constellation graph can be plotted. The signal is then re-sampled using MT fractional re-sampler as demodulator needs integer number of samples per symbol. This sampled signal is demodulated to give the output similar to input by removing frequency and phase offsets.

E. Comparator

The comparator compares the transmitted bit stream with the received bits from the demodulation process. These bits need not be synchronized if an MT calculate BER node (block) is used. The MT Calculate is used to calculate the average bit error rate for a Galois PN sequence. The two sequences i.e the PN sequence generated by MT Generate Bits (Galois, PN Order) with a matching PN order and the received sequence must be same.

IV. SIMULATION RESULTS

In this paper, LabVIEW is used to design and implement the communication system block for modulation schemes – BPSK, QPSK & QAM and their performance is evaluated by finding BER versus SNR over AWGN channel.

Figure 3 shows BER versus SNR plot generated by the BER plot generator using LabVIEW. From figure 3 it is clear that BPSK has lowest BER compared to QPSK & QAM. For example at E_b/N_0 of 4dB, BER value in BPSK is less than 0.01 where as for QPSK it is greater than 0.01 and for QAM it is nearer to 0.1.

At SNR=6, BER value for BPSK is 0 whereas for QPSK it is 0.005 and for QAM it is 0.05.

At SNR=8, BER value for BPSK & QPSK is 0 where as QAM has a value of 0.01.

At SNR =10dB, BER value for BPSK & QPSK is 0 where as for QAM it is greater than 0.001.

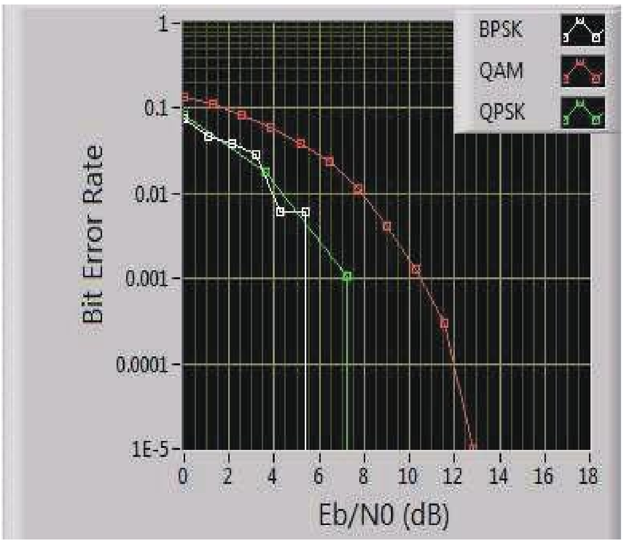

Figure 3. BER graph for BPSK, QPSK and QAM using LabVIEW

The BER value over AWGN channel for BPSK, QPSK and QAM is also given in tabular form in table1.

TABLE I.
COMPARISION OF BER VALUES

E_b/N_0 in dB	Digital Modulation Schemes		
	BPSK	QPSK	QAM
4	< 0.01	>0.01	~0.1
6	0	0.005	0.05
8	0	0	0.01
10	0	0	<0.01

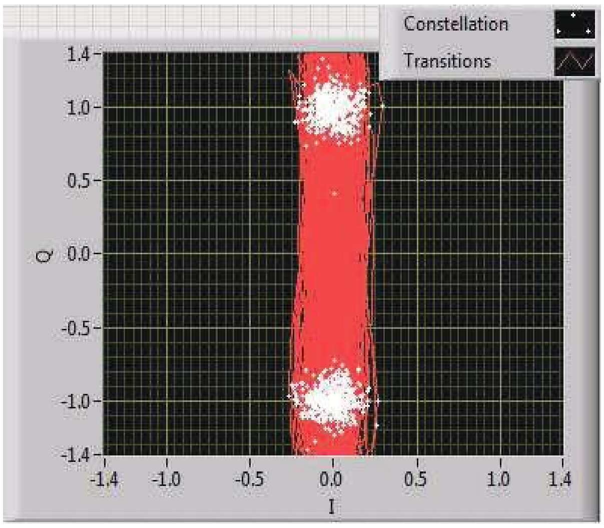

Figure 4. Constellation diagram of BPSK using LabVIEW

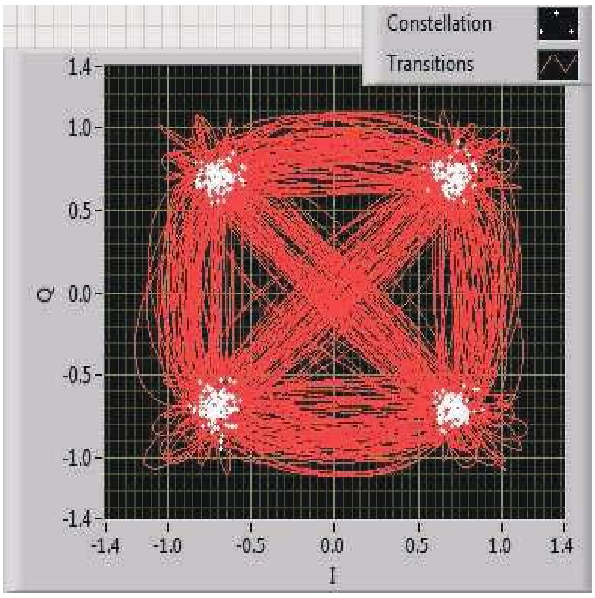

Figure 5. Constellation diagram of QPSK using LabVIEW

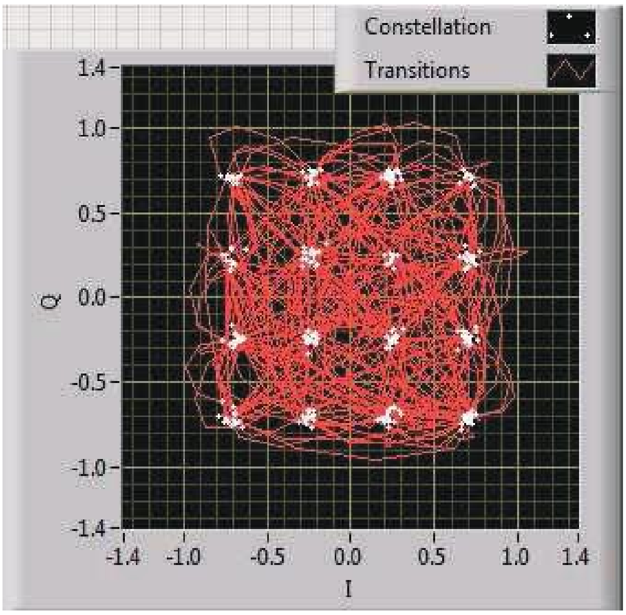

Figure 6. Constellation diagram of QAM using LabVIEW

Figure 4, 5, 6 gives constellation diagram of BPSK, QPSK and QAM as generated using LabVIEW. White dots in the constellation graph signify symbols and red lines give the transition from one symbol to another symbol. In figure 4, the constellation diagram of BPSK shows 2 bits each with a phase difference of 180^0. In figure 5, QPSK has four combinations of two bits and thereby each combination has a phase difference of 90^0. Figure 6 shows 16 QAM constellation diagram where 16 different combinations of amplitudes and phases are generated.

V. Conclusions

Commonly used digital modulation schemes like BPSK, QPSK & QAM are designed, implemented and their performance based on BER over AWGN channel is evaluated in LabVIEW. Through simulation results it is concluded that BPSK performs better compared to QPSK and QAM. The graphical environment of LabVIEW was easy to learn and simple to transform the concepts to a working program and it is also possible to continuously vary the input parameters and observe the corresponding results. In conclusion, the whole system is user friendly and BPSK gives the least number of bits in error for a given number of input bits compared to QPSK and QAM.

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