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GNU Radio-USRP-MATLAB based Laboratory set-up for Digital Modulation Schemes

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Abstract: **- The process of changing some characteristics of waveform with respect to the characteristics of other waveform is called modulation. To reduce practical antenna length, improve radiation efficiency of an antenna and to increase the operating range this process is needed. In digital modulation techniques there are different schemes such as BPSK, QPSK, QAM, PAM etc. The study, analysis, simulation and implementation of these techniques on different platforms are necessary such as MATLAB/SIMULINK, GNU radio and hardware platform like USRP. In this paper we have discussed about two basic techniques BPSK & QPSK and evaluated their parameters like constellation plot and BER using GNU radio on USRP and compared it with MATLAB results.**

Keywords: **- Modulation, GNU Radio, USRP, BER.**

I. INTRODUCTION

Background/Motivation

As every modulation techniques has their specific set of kits on which they can be performed i.e. each technique will require different kit. This is not very convenient, so to make things easy there is a platform on which we can perform Multiple modulation schemes. SDR platform is much more convenient to use. SDR is a radio communication system in which the components (mixer, oscillator, filter etc.) that are implemented in hardware are instead implemented on software. It is flexible, adaptive and programmable.
Study and performance analysis of different modulation techniques like BPSK, QPSK, QAM, PAM, GMSK, OFDM has been done in this field based on parameters like channel capacity, power efficiency, symbol error rate, BER on different platform such as Matlab/ Simulink and GNU radio. Simulation has been performed on this platform for the same [1] [9] [12].

Contribution of our work

We studied the basics of modulation schemes, their performance analysis, and their specifications. The modulation schemes which we studied were BPSK and QPSK. To be specific, we did the study of their bit error rate, constellation diagram and their power spectral density. Further we studied the GNU radio, how it is used and how the simulation of the different techniques are performed on a single platform.
Problem definition
To analyze BPSK and QPSK modulation technique & studying their performance parameters then implementing the same on GNU radio & USRP and on MATLAB.

Solution approach/ Outline

This paper provides the study of BPSK and QPSK modulation schemes and comparison of its parameter, in different simulation environment such as in MATLAB and GNU radio in terms of bit error rate, constellation diagram, and Power Spectral density.
The Software used are MATLAB and GNU radio.
GNU radio provides set of signal processing blocks that can be used to make the flow graphs. The blocks are written in C++ language and are run in python. Some of the blocks are readily available with the environment, also new blocks according to the requirement can be created in C++ .There are several advantages such as it is easy to use like its instantiation, joining the existing blocks and easy graphical user interface(GUI).
The existing blocks of GNU radio covers simple operations, filter, modulation / demodulation and many more others. UHD (USRP hardware driver) blocks and audio blocks are used to create real world interface. To transmit or receive signal from wireless medium UHD blocks are added to the flow graphs to use the USRP [2].
The better technique is decided based on the results of simulation.

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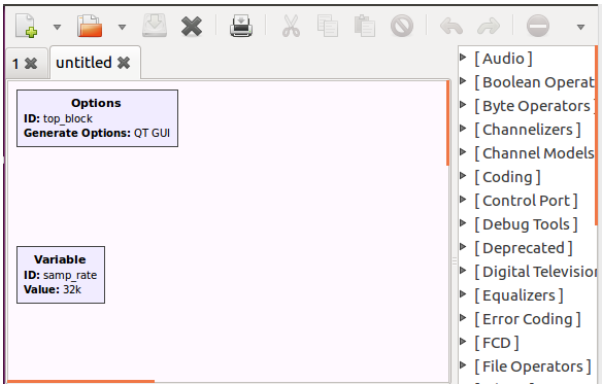

Fig. 1 Graphical User Interface of GNU radio

MATLAB is another simulation environment used. The coding is done in MATLAB R2015a version for BPSK and QPSK's performance parameters. Master code is then called by the several functions of modulation technique. A window is created in which options for various techniques of modulation are available [1].

II. DETAILS OF EXPERIMENT

Digital Communication System

A system in which the input analog signal is converted into digital signal by a analog to digital converter and then modulated through a modulator which is passed through a channel and demodulated through a demodulator and is regained by digital to analog converter, which is to be received at the destination.

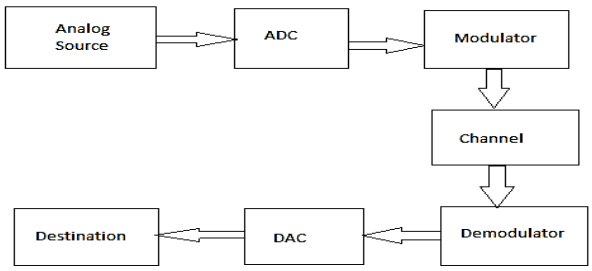

Fig.2. Block diagram of digital communication

Digital modulation process involves switching or keying of different parameters such as amplitude, phase and frequency of the carrier data with respect to the input data [9]. There exist many different digital modulation techniques that can be employed for electronic communication. In this paper, we have implemented only two techniques within the simulation environment.

The techniques are:

1) Binary Phase Shift Keying (BPSK)
2) Quadrature Phase Shift Keying (QPSK)

Binary Phase Shift Keying

In digital modulation techniques binary phase shift keying is one of the simplest form of techniques. In BPSK, for a single carrier frequency two phases of output are possible. The phase of the carrier is modulated by the binary symbols '1' and '0' [9]. Corresponding to binary '1' and '0', the phase of the constant amplitude carrier is switched between two values. BPSK takes the highest level of noise or distortion which makes the demodulator reach an incorrect decision which makes it robust of all the PSK's. [6].

Binary 0:

$$S_1(t) = A_c\cos(2\pi f_c t), \qquad 0 \le t \le T_b \quad (1)$$

Binary 1:

$$S_2(t) = A_c\cos(2\pi f_c t + \pi) = -A_c\cos(2\pi f_c t) \quad (2)$$

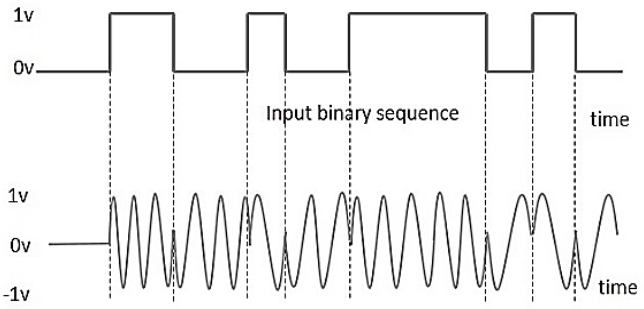

Fig. 3. BPSK Modulated Signal

Quadrature Phase Shift Keying

It is a form of phase shift keying in which two bits are modulated at once, selecting one of four possible carrier phase shifts (0, 90, 180, 270 degrees). QPSK allows a signal to carry twice as much as information as ordinary PSK using the same bandwidth. The phase of the carrier is modulated by binary symbols '00', '01', '10' and '11'.

$$\emptyset_1(t) = \sqrt{\frac{2}{T}}\cos(2\pi f_c t), \qquad 0 \le t \le T \quad (3)$$

$$\emptyset_2(t) = \sqrt{\frac{2}{T}}\sin(2\pi f_c t), \qquad 0 \le t \le T \quad (4)$$

$$s_i = \begin{bmatrix} \sqrt{E}\cos[(2i-1)\frac{\pi}{4}] \\ \sqrt{E}\sin[(2i-1)\frac{\pi}{4}] \end{bmatrix}, \qquad i = 1, 2, 3, 4 \quad (5)$$

Performance parameters

1) Constellation diagram:

A constellation diagram is a representation of a signal modulated by a digital modulation scheme such as quadrature amplitude modulation or phase shift keying. It displays the signal as a two dimensional X-Y plane scattered diagram in the complex plane at symbol sampling instants. In a more abstract sense, it represents

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the possible symbols that may be selected by a given modulation scheme as a points in the complex plane. Measure constellation diagrams can be used to recognize the type of interference and distortion in a signal.

2) Bit error rate:

In a digital transmission BER is the percentage of bits with errors divided by the total number of bits that have been transmitted, received or processed over given time period. The rate is typically expressed as 10 to the negative power. BER is a digital equivalent to signal-to-noise ratio in an analog system.

3) Power spectral density:

Power spectral density is the frequency response of a random or periodic signal. It tells us where the average power is distributed as a function of frequency. The PSD is deterministic, and for certain types of random signals is independent on time.

III. BLOCK DIAGRAM

Methodology/Setup

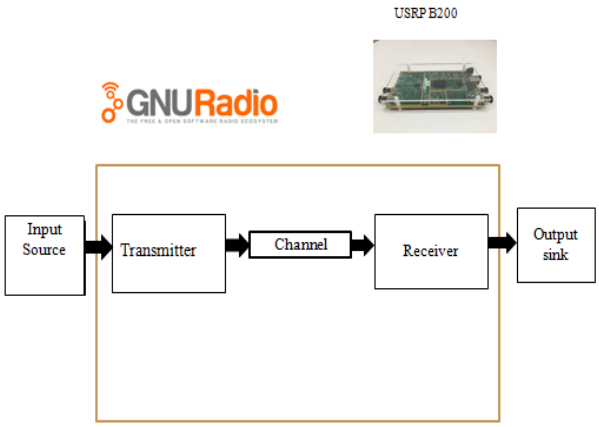

Fig.4. Block Diagram

Input Source: The input source block is the very first block in the block diagram. The input of this block can be of any form whether it may be a text file, image, music or video. The output of this input source block is given to the next block which is the transmitter block. Transmitter: In electronics and telecommunications a transmitter or radio transmitter is an electronic device which produces radio waves with an antenna. The transmitter itself generates a radio frequency alternating current, which is applied to the antenna. When excited by this alternating current the antenna radiates radio waves. The term transmitter is usually limited to equipment that generates radio waves for communication purposes; or radiolocation, such as radar and navigational transmitters.

Channel: A communication channel or simply channel refers either to a physical transmission medium such as a wire, or to a logical connection over a multiplexed medium such as a radio channel in telecommunications and computer networking. A channel is used to convey an information signal, for example a digital bit stream, from one or several senders (or transmitters) to one or several receivers. A channel has a certain capacity for transmitting information, often measured by its bandwidth in Hz or its data rate in bits per second.

Receiver: In radio communications, a radio receiver (radio) is an electronic device that receives radio waves and converts the information carried by them to a usable form. It is used with an antenna. The antenna intercepts radio waves (electromagnetic waves) and converts them to tiny alternating currents which are applied to the receiver, and the receiver extracts the desired information. The receiver uses electronic filters to separate the desired radio frequency signal from all the other signals picked up by the antenna, an electronic amplifier to increase the power of the signal for further processing, and finally recovers the desired information through demodulation.

IV. SIMULATION ENVIRONMENT

Constellation Analysis

The phase of the analog signal is shifted in binary phase shift keying to represent the digital signal. Each symbol represent one bit which can be seen from the IQ diagram below:

In GNU:

BPSK constellation flow graph-

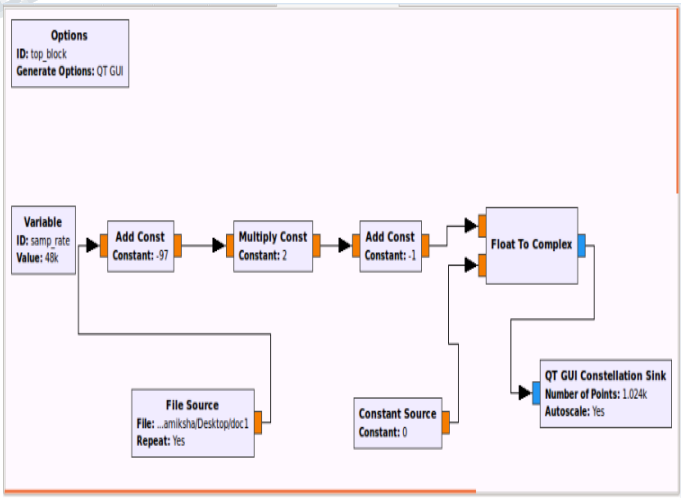

Fig.5. BPSK constellation flow graph

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BPSK constellation diagram

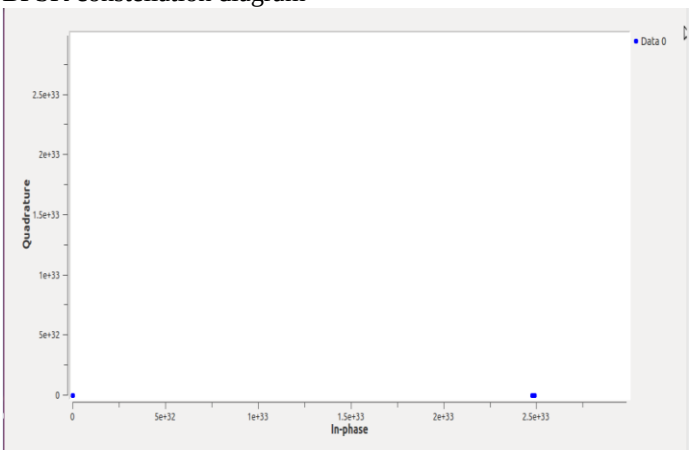

Fig.6. BPSK constellation diagram

QPSK constellation flow graph:

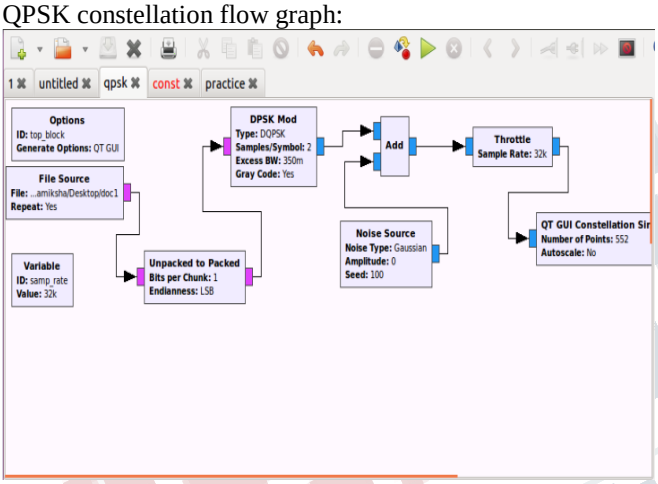

Fig.7. Constellation flow-graph

QPSK constellation diagram

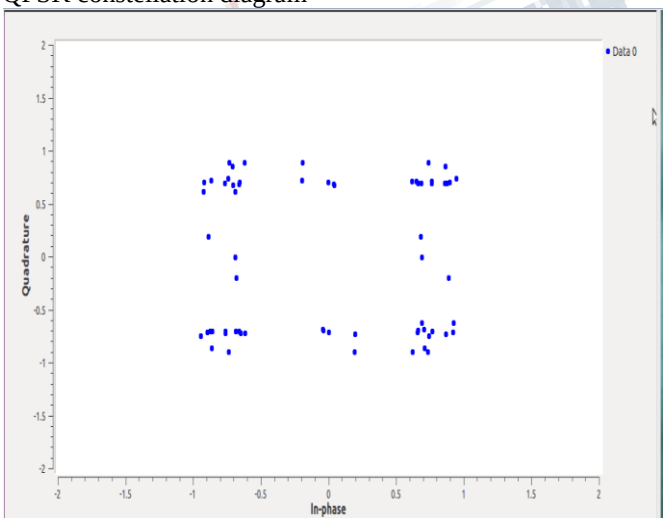

Fig.8. constellation diagram

Above Figure is the implementation of QPSK on GNU radio (Fig.4). Fig.5 is the simulated output of constellation diagram for QPSK. The simulated result is distorted due to effect of noise. The phase shift of the wave can be any of the four values $\pi/4$, $3\pi/4$, $5\pi/4$ or $7\pi/4$ to represent four different input symbols (00, 01, 10 and 11).

In MATLAB:

QPSK constellation

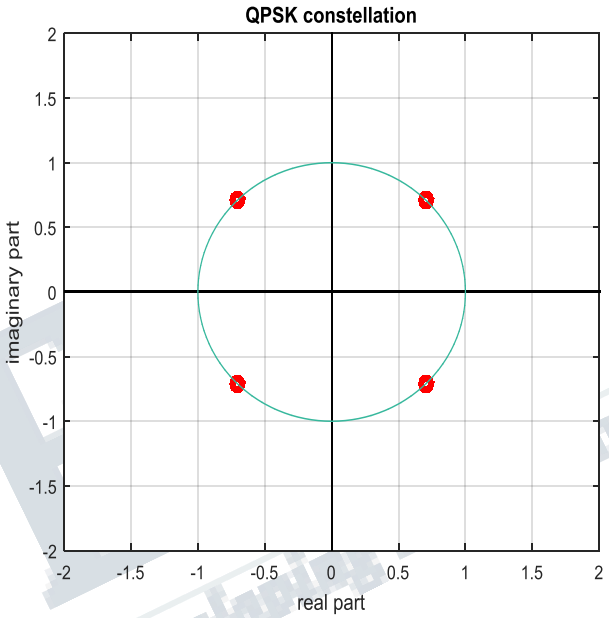

Fig.9 QPSK constellation diagram

Above is the constellation diagram for QPSK modulation technique in Matlab. In QPSK there is 1-symbol and 2-bit composition. There are 4 status corresponding to the phases $\pi/4$, $3\pi/4$, $5\pi/4$, $7\pi/4$.

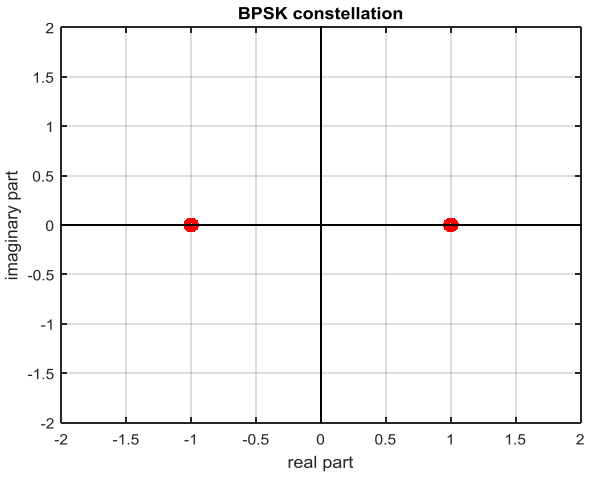

Fig.10 BPSK constellation diagram

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In the above implementation a text file is transmitted as a file source in both BPSK and QPSK. The above diagram Fig.9 shows the constellation diagram of BPSK in Matlab.
There are only two status in BPSK and hence the phases of the wave are corresponding to 0 or π.

Bit Error Rate Analysis
In GNU:

BPSK BER flow graph
The BER results Obtained using Matlab simulation scripts shows good agreement with the derived theoretical results.

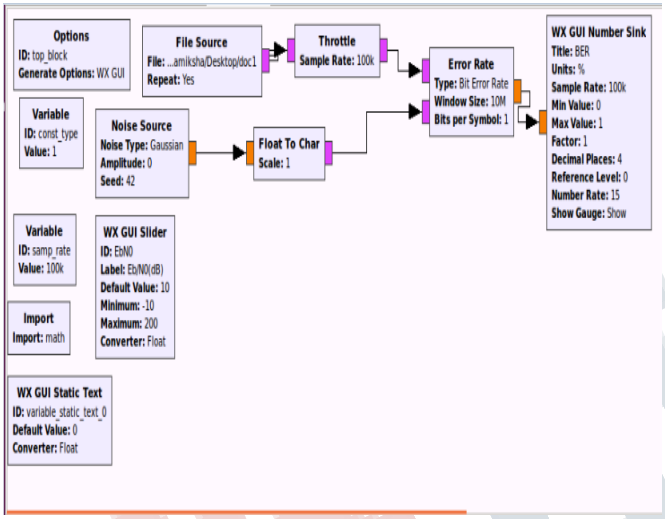

Fig.11 BPSK BER flow graph

BPSK BER output

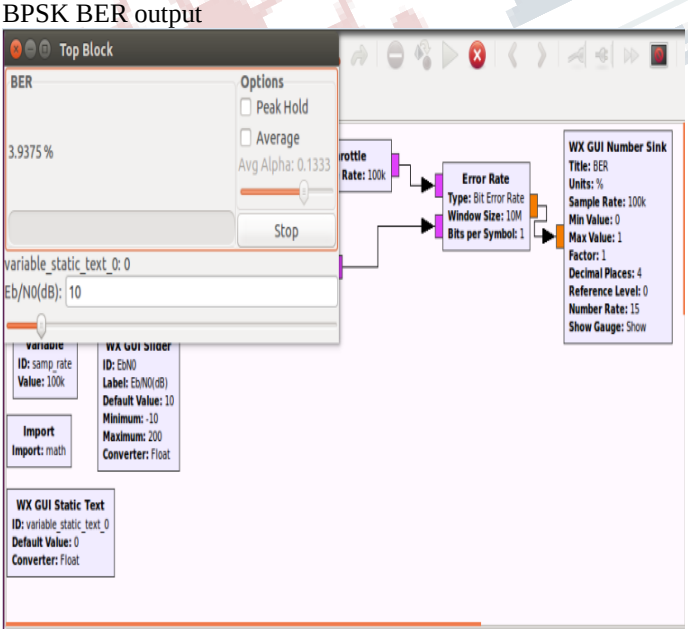

Fig.12 BPSK BER output

QPSK BER flow graph

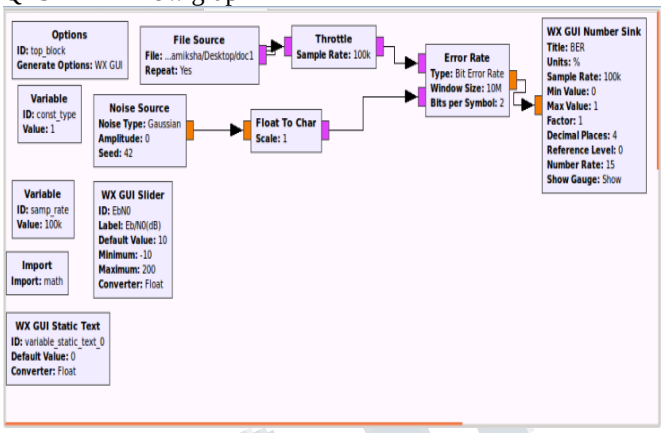

Fig.13 QPSK BER flow graph

QPSK BER output-

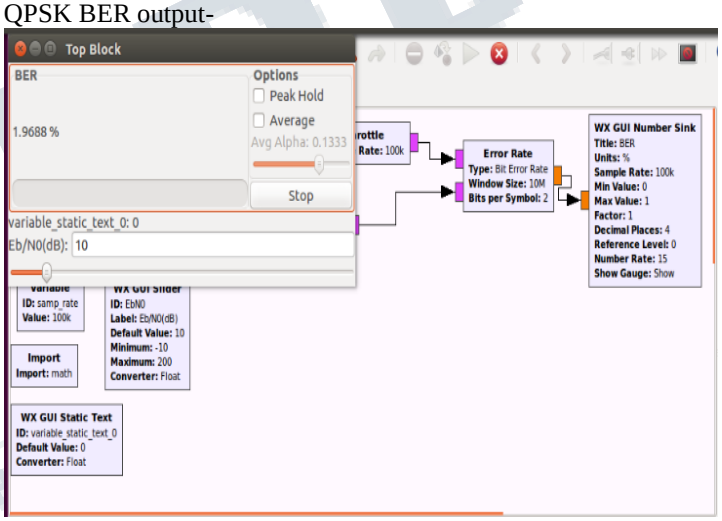

Fig.14. QPSK BER output

In MATLAB:
BPSK BER

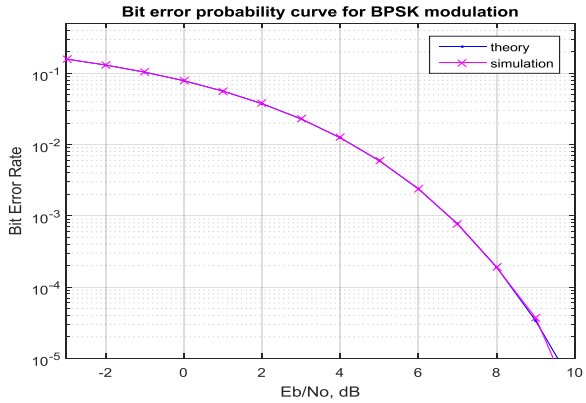

Fig.15. BPSK BER

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The above fig. shows the comparison of theoretical and simulated value of BER of BPSK. Till 8dB both the theoretical and simulated values match but after 8dB there is a slight change in the value.

QPSK BER

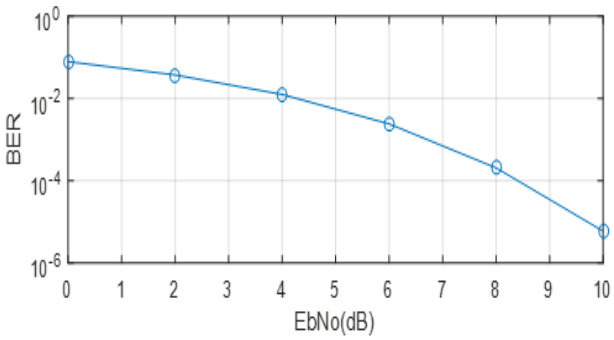

Fig.16. QPSK BER

From the above Simulation we can say that QPSK system has double the throughout as that of for BPSK system.
The selection of digital modulation system is affected mainly by three factors namely:
Bandwidth efficiency
Error performance: the probability of making an bit error as a function of signal-to-noise ratio, at the receiver.
Complexity of equipment [9].

Power Spectral Density Analysis
In GNU
BPSK PSD flow graph

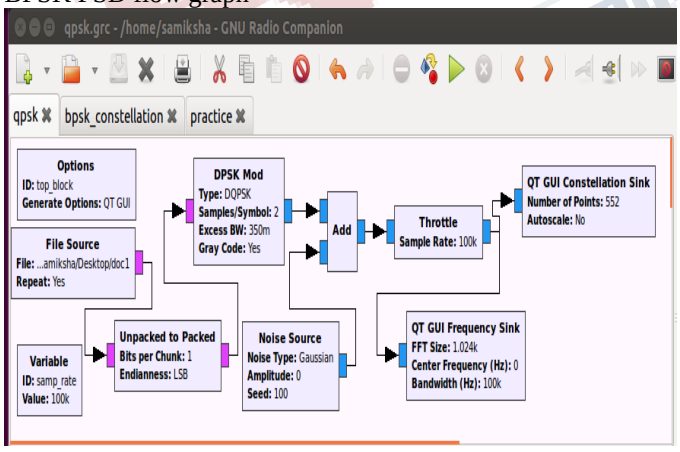

Fig.17. BPSK PSD

BSPK PSD output

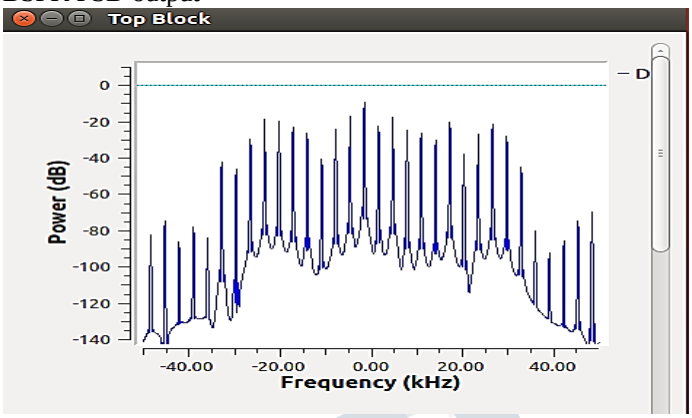

Fig.18. BPSK PSD Output

In MATLAB
BPSK PSD
The last implementation is based on Power spectral density of BPSK. Power Spectral density gives the measure of signal strength and evaluate the area of PSD to get power of signal. This Parameter is important while considering filtering in communication system. The performance of PSD for BPSK technique in GNU radio and Matlab environment is shown in Fig. 18 and 19.

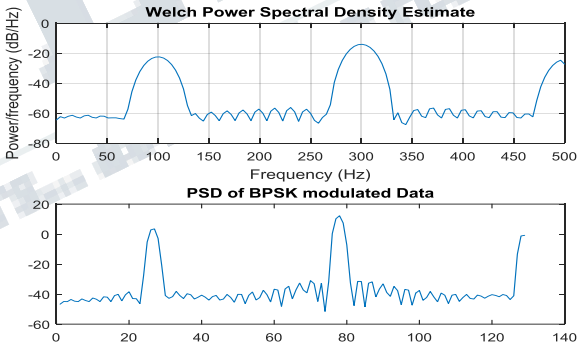

Fig.19. PSD Diagram of BPSK

V. HARDWARE ENVIRONMENT

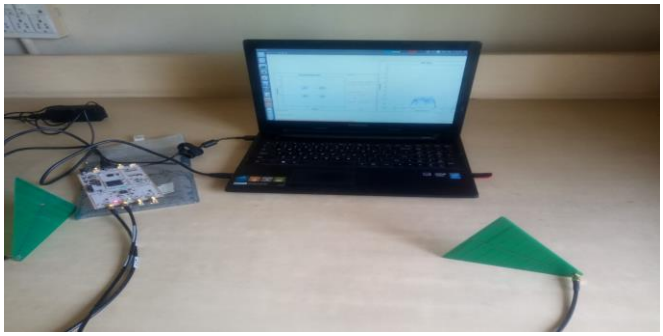

Fig.20. Hardware Set-up

Above shown is the hardware set-up for the implementation of the proposed work. In this set-up, USRP used is b210 which has two transmitter and two receiver, 3.0 USB interface and has a coverage from 70MHz-6GHz, it can be used as half duplex as well as full duplex. Antennas used are log periodic antennas. Two antennas one acts as a transmitter and the other as receiver are connected to the hardware (USRP b210), which is connected to the device. A text file is transmitted through the transmitter and received by the receiver through the same device. Along with the transmission and reception of text file its BER and PSD are also observed, with the constellation diagram of the technique used (BPSK and QPSK) for the same.

VI.CONCLUSION

The signal transmitted cannot reach the receiver without modulation, its radiate power is very less. Modulation is needed to increase the radiate power efficiency. Different techniques have different advantages and disadvantages. In this paper, the experiments using Matlab /Simulink and GNU radio has been done to see the BER, PSD and Constellation plot for a transmission using BPSK and QPSK modulation scheme and also seen the same for transmission and reception of text file through USRP hardware device. The efficiency of SDR is proved where changes are made in the modulation technique by making changes in the software without making any hardware modification. The future work of this paper could be making use of other modulation techniques like QAM, PAM, GMSK, OFDM etc. And also use of other application can be made like video streaming or image streaming can be done instead of text streaming.

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