Performance Analysis of Various Modulation Techniques using GNU Radio

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ABSTRACT
This paper analyzes the performances of QPSK, GMSK and QAM modulation techniques using the GNU Radio software. These modulation techniques are used in most communications systems like cable modems, DSL modems, CDMA, 4G, Wi-Fi and WIMAX. A basic idea about Software Defined Radio (SDR) is also represented. SDR has the nature of modifying the system parameters without actually changing the hardware part and is very effectively used today. The implementation is done on the GNU Radio Companion. QPSK is very spectrally efficient and is used in various cellular wireless standards such as GSM, CDMA, LTE, 802.11 WLAN, 802.16, WIMAX, Satellite and Cable TV applications. QPSK is noted for its power efficiency and robustness against phase noise. It is popular for both its easy implementation and resilience to noise. GMSK has high bandwidth efficiency and is also used for GSM. It is immune to amplitude variations and therefore more resilient to noise. QAM is used extensively as a modulation scheme for digital telecommunication systems. High spectral efficiencies for QAM are achieved by setting a suitable size for the constellation, limited only by the noise level and linearity of the communications channel. The various performances for these modulation schemes are observed based on their constellation plots and also on their waveforms.

Keywords
SDR, GNU Radio, QPSK, GMSK, QAM

1. INTRODUCTION
Nowadays, all the communication processes are done on hardware but the combination of the proper hardware can cause errors in various signal processing. The hardware is of very high cost and also not easily portable. So SDR is the effective solution for the high cost and hardware based radios that are less flexible. The modulation schemes are implemented to show the effectiveness of SDR based on mathematical models [1]. Good performance has been achieved in wireless communication through the combination of USRP and GNU Radio. Many researchers are also widely implementing digital communications using GNU Radio and USRP [2]. The modulation and demodulation techniques in digital signal processing have been the key technology of the SDR implementation [7].

In this paper, the performances of QPSK, GMSK and QAM modulation techniques are analyzed using the GNU Radio software. The various constellation plots of these modulation techniques are observed and their time domain waveforms are also obtained.

The rest of the paper is organized as follows. First, a description of SDR and GNU Radio is given. Then the proposed modulation techniques, that is, QPSK, GMSK and QAM are discussed in detail. Second, the implementations of these modulation techniques are performed on the GNU Radio Companion (GRC). Third, the experimental results and analysis are discussed. Lastly, the conclusion of the experiment is explained.

2. SOFTWARE DEFINED RADIO
Software defined radio turns the hardware problems faced in communication into software problems and get the code as close to the antenna as possible [1]. In SDR, the hardware such as mixers, filters, amplifiers, modulators and demodulators can be transformed as software in a PC or on embedded systems. SDR can be used with a variety of communication modes or waveforms and can allow the same hardware to be operated with any type of waveform [2]. Thus, the hardware complexity is reduced [5]. The hardware part of SDR is Universal Software Radio Peripheral (USRP) and was developed by Matt Ettus. The USRP is used as a transceiver and can be connected to the computer using a USB 2.0 interface [1]. The SDR systems are low cost and flexible and it is possible to implement various radios using the same hardware just by changing the software parameters [6].

3. GNU RADIO
GNU Radio was developed by Eric Blossom and is a most important toolkit for software defined radios [1]. It is an open source software for digital signal processing functions that was developed using C++ and Python programming languages [2]. The C++ language is used for writing the low level codes and comprises of small signal processing. The high level codes are written in Python and it connects the various signal blocks to make a flowgraph [1]. The blocks are integrated into the GNU Radio Companion (GRC) [5]. GRC provides a graphical user interface and any hardware functions like mixers, oscillators, etc. can be implemented as a block and can be executed [5]. The SDR developed using GNU Radio can transmit or receive real signals using an RF interface [6].

4. DIGITAL MODULATION TECHNIQUES
4.1 QPSK modulation
QPSK is the Quadrature Phase Shift Keying modulation. It is an extension of the phase shift keying (PSK) digital modulation technique in which the division of the phase of the carrier signals takes place and four equally spaced values are allotted for the phase angle [4]. The term quadrature means that the phase of a signal is in quadrature or 90 degrees to another one. In QPSK, two successive bits are combined and this combination of two bits forms four distinct symbols [9]. This reduces the bit rate and hence reduces the bandwidth of the channel [9]. The phase shift of analog carrier can be any one of the four values such as 90o, 180o, 270o and 360o to represent four different input symbols (00, 01, 10 and 11) [7].

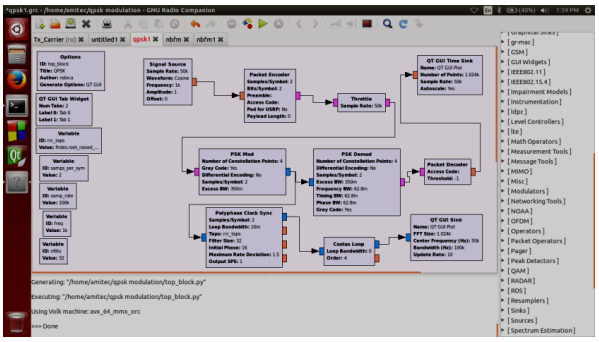

Fig 1: GRC block diagram of QPSK

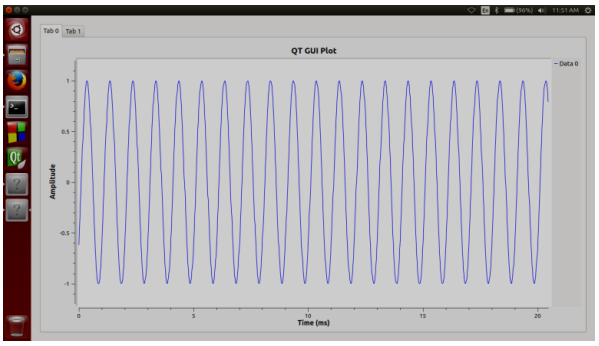

Fig 2: Modulated output of QPSK

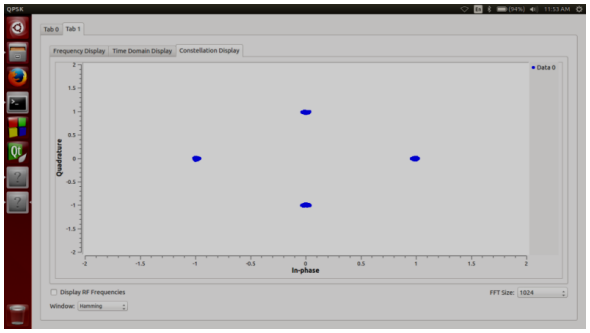

Fig 3: Constellation plot of QPSK

The modulation scheme is implemented on the GNU Radio Companion by executing the flowgraph as shown in the figure and observes the time domain waveform and constellation plot. The output modulated waveform is a constant envelope. QPSK uses four points on the constellation diagram, equispaced around a circle. With the four phases, QPSK is encoded with two bits per symbol, [7] given with gray coding to minimize the bit error rate.

4.2 GMSK modulation

It is called the Gaussian Minimum Shift Keying modulation technique. It has no phase discontinuities and provides data transmission with efficient spectrum usage. The main advantage of GMSK modulation is the improved spectral efficiency. It can also be amplified by a nonlinear amplifier and remain undistorted.

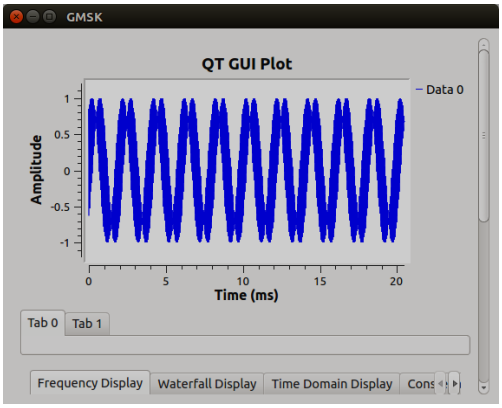

Fig 4: Modulated output of GMSK

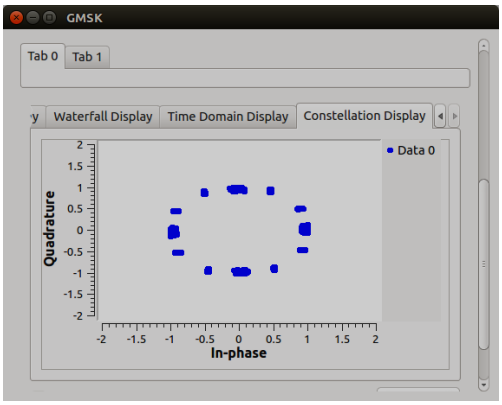

Fig 5: Constellation plot of GMSK

The GMSK modulation technique is implemented on the GNU Radio companion with the same method as QPSK. The output waveform is also a constant envelope and the points on the constellation diagram are in a circular shape due to non-coherent single frequency interference on the signal.

4.3 QAM modulation

In Quadrature Amplitude Modulation, two amplitude modulated signals are combined into a single channel, thereby doubling the effective bandwidth. QAM is both an analog and a digital modulation scheme. It conveys two analog message signals or two digital data bit streams by varying the amplitudes of two carrier waves, using the amplitude shift keying (ASK) or amplitude modulation (AM) scheme. In digital QAM, at least two phases and at least two amplitudes of a finite number are used.

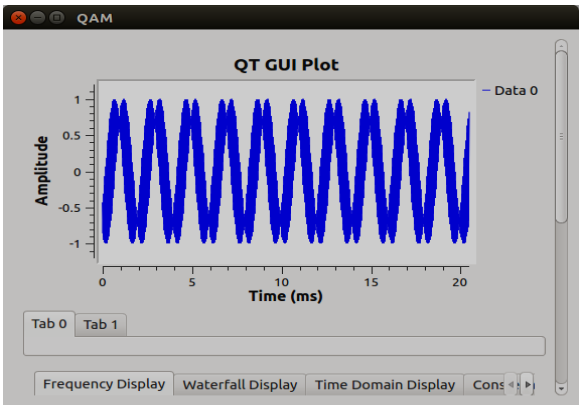

Fig 6: Modulated output of QAM

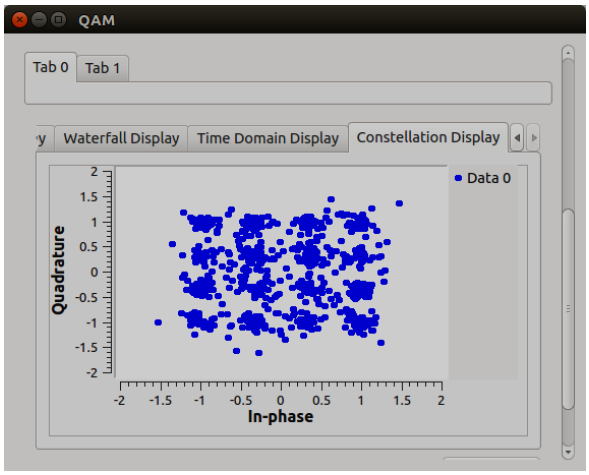

Fig 7: Constellation plot of QAM

The output modulated waveform of QAM is a non-constant envelope output waveform. In QAM, the number of constellation points increases as the order of modulation increases.

5. CONCLUSION

The performances of the modulation techniques QPSK, GMSK and QAM are analyzed using the GNU Radio software. The implementation is done on the GNU Radio Companion. GRC provides a graphical user interface and any hardware functions like mixers, oscillators, etc. can be implemented as a block and can be executed. The constellation plots and the corresponding modulated output waveforms in time domain of these modulation schemes are observed. The future work can be done on the analysis of various data transmissions using these modulation techniques and observing their performances.

6. REFERENCES

[1] Jay Kumar Lunagariya, Kenil Gokhruwala, Khyati Vachhani, Design Analysis of Digital Modulation Schemes with GNU Radio, (2015)

[2] Ahmad Zainudin, Amang Sudarsono, I Gede Puja Astawa, Reliability Analysis of Digital Communication for Various Data Types Transmission using GNU Radio and USRP, (2013)

[3] Rao Farhat Masood, Adaptive Modulation (QPSK, QAM)

[4] Rohit Garg, Er. Ankita Mittal, Design & Implementation for Combination of QPSK and BPSK Modulation Techniques, IJARECE, 3, 878-885, (2014)

[5] R. Gandhiraj, Ranjini Ram, K.P. Soman, Analog and Digital Modulation Toolkit for Software Defined Radio, Procedia Engineering, 30, 1155-1162, (2012)

[6] Aurelien Briand, Bruno B. Albert, Edmar C. Gurjao, Complete Software Defined RFID System Using GNU Radio, (2012)

[7] Archana M. Lalge, Sheetal U. Bhandari, QPSK System Implementation on FPGA, IJETT, 1, 139, (2014)

[8] T.K. Zombade, S.A. Shirsat, QPSK Modem Using FPGA, IJECCE, 5, (2014)

[9] Mandadkar Mukesh, Lokhande Abhishek, Prof. R.R. Bhambare, QPSK Modulator and Demodulator Using FPGA for SDR, IJERA, 4, 394-397, (2014)

[10] Tushar V. Kafare, Simulation and Implementation of low power QPSK on FPGA, ARDIJEET, 1, (2013)