Design Analysis of Digital Modulation Schemes with GNU Radio

Conference Paper · May 2015

Khyati P Vachhani
The MathWorks, Inc

Design Analysis of Digital Modulation Schemes with GNU Radio

Jay Kumar Lunagariya
Student, Electronics and Communication
Institute of Technology, Nirma University
Ahmedabad, India
11bec037@nirmauni.ac.in

Kenil Gokhruwala
Student, Electronics and Communication
Institute of Technology, Nirma University
Ahmedabad, India
11bec026@nirmauni.ac.in

Khyati Vachhani
Assistant Professor, Electronics and Communication
Institute of Technology, Nirma University
Ahmedabad, India
khyati.vachhani@nirmauni.ac.in

Abstract— **In this paper we represent the basic idea about the Software Defined Radio (SDR) and have demonstrated the fundamental digital modulation schemes like Amplitude Shift Keying (ASK), Frequency Shift Keying (FSK), and Phase Shift Keying (PSK) using GNU Radio Companion. Gnu Radio can also be used in real time communication with the help USPR or RTL-SDR which are composed of FPGA. Combination of GNU Radio Companion and USRP can be used to replace the traditional hardware radios.**

Keywords—GNU Radio, SDR, RTL-SDR

I. Introduction

In today's world all the communication processes are done on hardware but the assembly of the proper hardware can many times cause errors in the processing of signals. The hardware is very costly moreover it is many times used only for a specific process. The hardware is also not easily portable, as a result to get away with all this problems researchers have come up with Software Defined Radio or SDR [1] a complete software implementation of hardware processes. SDR with its dynamic nature of modifying the system parameters without actually changing the hardware part is very effectively used today. So SDR proves to be an effective solution to the very high cost and limited flexibility of hardware based radios. We have implemented some modulation scheme just to show the effectiveness of SDR Communication concepts are based on the mathematical models. Students can explore the communication concepts by modelling the circuits in SDR and observing the behaviour of the circuit. SDR provides the flexibility of wide range of parameters so students can observe the effect of change of parameters and observe the corresponding waveform. Thus SDR proves to be a good source of learning for students also.

The paper starts with basic introduction to some important concepts that are related to Software Defined Radio. The second part includes the demonstration of the various schemes. The final part contains of conclusions and some description of the hardware implantation of the said modulation scheme.

II. SOFTWARE DEFINED RADIO

Software Defined Radio is a technique of turning the hardware problems faced in communication into software problems and getting the code as close to the antenna as possible. The software defined radio consist of a specific software which is GNU Radio [2] and hardware as USRP [3]. The basic block diagram of software defined radio is given as follows. Accordingly, the Software Defined Radio is divided into 3 blocks, starting with the RF frontend we have an antenna for the reception of RF signals and USRP daughter boards which serves as an interface to the analog RF domain. The second block contains the main hardware part which consists of USRP motherboard and does the conversion from the analog to the digital domain. The last block is the software part which is done completely on PC.

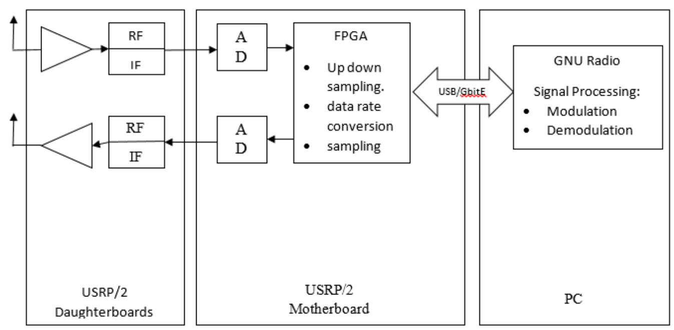

Figure 1. SDR Block Diagram

A. *Universal Software Radio Peripheral (USRP)*

The hardware part of Software Defined Radios is known as Universal Software Radio Peripheral (USRP) and was developed by Matt Ettus. The current scenario of USRP is that it is being developed by Ettus Research as open source hardware and is being used in research labs and universities for educational purpose. The USRP is usually used as 'Transceiver' and is powered with 6 VDC adapter and can be connected to the computer using a USB 2.0 interface. The USRP mainly consists of a Motherboard that can support up to 4 Daughterboard which can be tuned at different frequencies which is generally from 0 to 2.9GHz. The Daughterboards represent the tuner component as an interchangeable component which in contrast to the analog receiver are generally hardwired. Different daughterboards can be combined to obtain a wide range of frequencies. Some of the daughterboards are transceiver whereas some of them are only transmit or receive only. The basic block diagram is represented as follows.

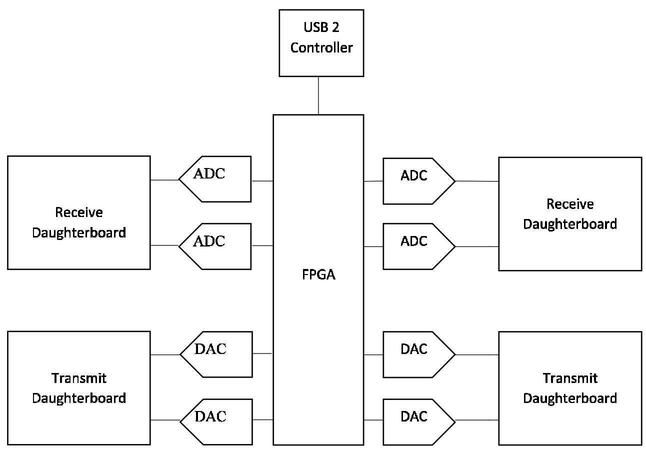

Figure 2. USRP Architecture

B. RTL-SDR

The drawback of USRP is that its cost is way high so a company called OsmoSDR [5] came up with a low cost hardware known as the RTL-SDR. The RTL-SDR uses DVB-T TV tuner dongle based on the RTL2832U chipset. The RTL-SDR is often called as the DVB-T SDR, RTL dongle, RTL2832U or the “$20 Software Defined Radio”. The RTL-SDR is based on the Realtek RTL2832U which acts as a demodulator and USB interface plus a tuner IC such as the R820T developed by Rafael Micro. The DVB-T demodulator gives raw samples in place of demodulated signals and as the chip is able to transmit raw I/Q samples to the host, as a result the DVB-T dongle proves efficient for software defined purpose. The operating frequency of the RTL2832U is from 64 to 1700MHz, with a sample rate of 3.2MS/sec. This RTL2832U hardware when used with GNU Radio Software requires a block in the GRC.

C. GNU RADIO

GNU Radio is a free and an open source software toolkit which is used to implement real time signal processing and also provides signal blocks to implement a particular scheme. The software environment when used with low cost external RF hardware such as the RTL-SDR gives us software defined radios. Developed by Eric Blossom, GNU Radio today is a basic and most important toolkit for software defined radios. The main application of GNU Radio includes educational purpose, wireless communication and real time radio systems. GNU Radio is available as licensed version under the GNU General Public License (GPL) version 3.

The GNU Radio applications themselves are generally known as 'flowgraphs', which are a series of signal processing blocks connected together, describing a data flow. The flowgraphs are written in C++ or Python. The GNU Radio when implemented on an operating system is installed as GNU Radio Companion (GRC).

The basic flow structure of GNU Radio is shown as follows, accordingly the GNU Radio has two major layers that are used one is C++ and the other is Python. Low level codes are written in C++ and consists of small signal processing. The high level codes are written in Python which is an interpretable language, it mainly does the work of connecting the various signal blocks into what is known as ‘Flowgraphs’. Python doesn’t require any additional compilation time so it is mainly used for the rapid functioning of the flowgraphs.

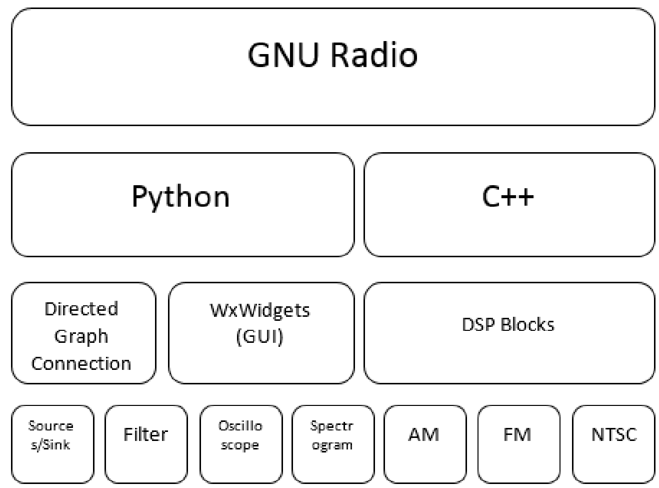

Figure 3.GNU Radio Architecture [6]

II. DIGITAL MODULATION SCHEME

The modulation scheme that are being discussed here are digital modulation schemes mainly Shift Keying in which the phase, amplitude or frequency of the signal is varied keeping the other two constants. Starting with ASK we will be describing FSK and PSK.

A. AMPLITUDE SHIFT KEYING (ASK)

Amplitude Shift Keying (ASK) is a digital modulation scheme where the amplitude of the carrier wave is changed with respect to the amplitude of the message signal keeping the phase and frequency of the signal as constant. Here we have used Binary Amplitude Shift Keying (BASK) which is similar to on-off keying. ASK is defined using the following equation [7]:

$$S(t) = Am(t)\cos\omega t \tag{1}$$

As shown in the GRC block diagram of ASK, here we have multiplied the message signal i.e. square wave in our case as our data is binary with the cosine wave i.e. carrier wave. The multiplied signal is observed on the scope sink. The scope sink output shown below is the ASK modulated wave. Demodulation of this ASK signal can be done similar to Demodulation of AM.

As shown in the scope plot when the input data signal is 1 then output obtained is the cosine wave and when the input signal is 0 the output is also 0. Here our data signal is a square wave of frequency 1000 hertz and peak amplitude of 1. The carrier signal used is cosine wave of frequency 10000 hertz and peak amplitude of 1. The sampling frequency here should be greater than twice the maximum frequency of the data signal which in our case will be more than 2000 hertz. Here we have used the sampling frequency of 64000 hertz.

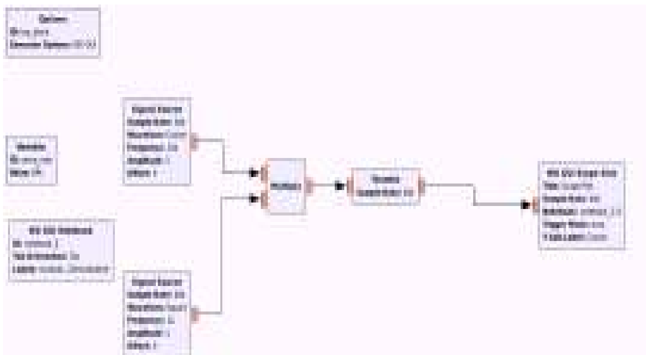

Figure 4. GRC Block Diagram of ASK

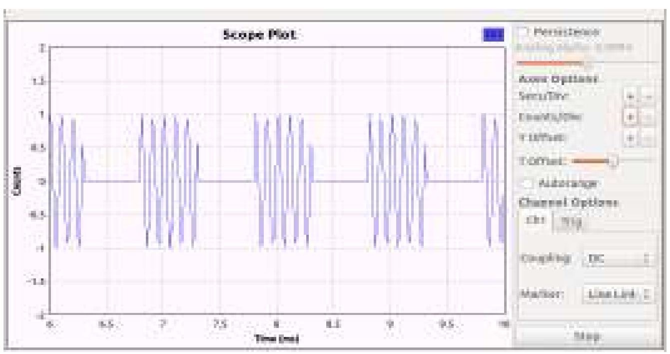

Figure 5. Modulated Signal of ASK

B. FREQUENCY SHIFT KEYING (FSK)

Frequency Shift Keying is the Digital modulation key technique where different frequencies are used to transmit the data. For Binary Frequency Shift Keying (BFSK) two different frequencies are used to transmit two different signal i.e. 0 and 1 as shown below

$$s1(t) = A\cos\omega 1t \quad (2)$$
$$s2(t) = A\cos\omega 2t \quad (3)$$

In our case we have used one carrier as a cosine wave of frequency 1000 hertz and peak amplitude of 1 and another as cosine wave of frequency 10000 hertz and peak amplitude of 1. The signal 1 is represented by a square wave and signal 0 an be obtained by subtracting the same square wave from 1.After multiplying both the carrier frequency with the message signal they are added and the resultant signal is observed on the scope sink.

As shown in the scope plot output of FSK we receive cosine wave of frequency 1000 when the data signal is 1 and cosine wave of frequency 10000 when data signal is 0. Here the sampling frequency used is 128000 hertz. The GRC Block diagram of BFSK and the scope sink output is shown below.

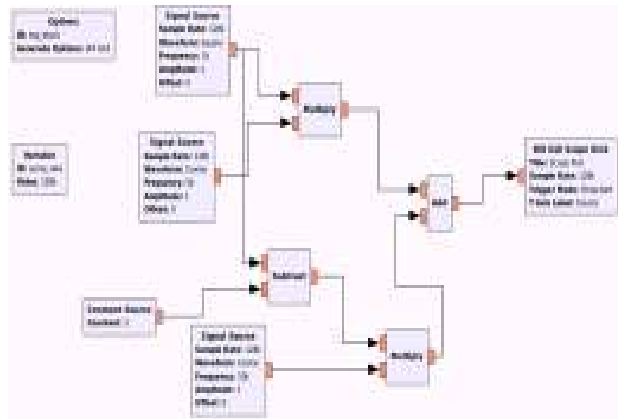

Figure 6. GRC Block Diagram of FSK

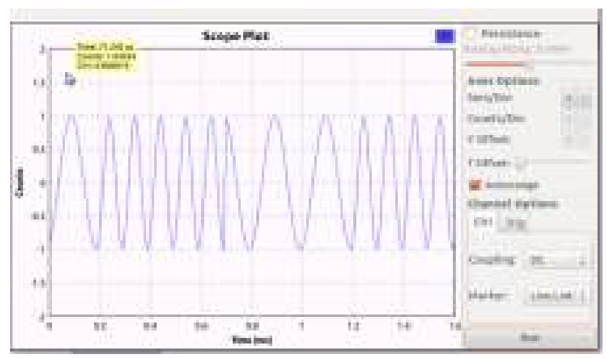

Figure 7. Modulated Output of FSK

C. PHASE SHIFT KEYING (PSK)

Phase Shift Keying is a Digital modulation scheme where the phase of the signal is varied, keeping the frequency and the amplitude constant. In Binary Phase Shift Keying (BPSK) both the carrier signal are out of phase with each other. The carrier wave used here is cosine wave of 50000 hertz and peak amplitude of 1 and other is sine wave of 50000 hertz and peak amplitude of 1. Similar to BFSK here we represent signal 1 with a square wave of frequency 5000 hertz and signal 0 by subtracting the same square wave from 1. Here as shown in the GRC block diagram below we have multiplied the carrier signals with the signal 0 and 1 and observed the resultant output on the scope sink.

$$s1(t) = A\cos\omega t \quad (4)$$
$$s2(t) = -A\sin\omega t \quad (5)$$

Here symbol 1 will be represented by s1(t) and symbol 0 will be represented by s2(t) as shown below in figure 9:

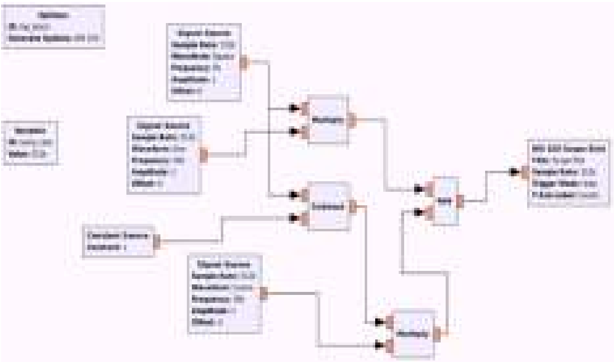

Figure 8. GRC Block Diagram of PSK

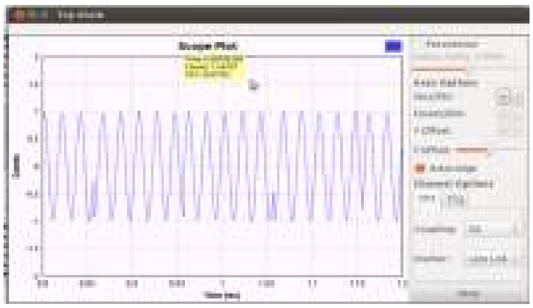

Figure 9. Modulated Output of PSK

IV. CONCLUSION

SDR is a technique which can be used to replace the current hardware when used along with USRP. Since USRP being costly, RTL-SDR seems to be a more efficient option. This concept of SDR using GNU Radio and RTL-SDR also proves to be helpful for students for learning the concepts practically. Here we have used SDR (Software Defined Radio) as a platform to implement Communication circuits by demonstrating fundamental digital modulation schemes like ASK, FSK and PSK and observed the corresponding waveform on time domain.

V. REFERENCES

[1] Bard, John and Kovarik, Vincent, “Software Defined Radio: The Software Communications Architecture,” Wiley Series in Software Radio, 2007

[2] E.Blossom, ”GNU radio: tools for exploring the radio frequency spectrum”, Linux Journal, vol. 2004, no. 122, June 2004.

[3] Ettus Research, LLC, http://www.ettus.com/, Available Online Retrieved 2008-10-21.

[4] http://sdr.osmocom.org, Available Online

[5] D. Casey Tucker, Gene A. Tagliarini, ‘Prototyping with GNU Radio and the USRP – Where to begin’, Southeastcon’09, pp. 50-54, March 2009.

[6] R P Singh, S D Sapre, ‘Communication System – Analog and Digital’, Tata McGraw Hill, Second Edition, 2008