DESIGN OF FM SYSTEM IN COGNITIVE ENVIRONMENT

Electronics & Communication
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ABSTRACT

As communication technology continues its rapid transition, from analog to digital, more functions of modern radio systems are implemented in software, rather than hardware, leading towards the software defined radio architecture. Software defined radio (SDR) is a promising technique for multi-type, high speed wireless communication system with low requirements on capability of hardware devices, low development cost and facilitation of the development process.

In this project, a SDR testbed has been built to compare the performance of two systems which are narrow band frequency modulation (NBFM) and wide band frequency modulation (WBFM) by changing different parameters and also hardware implementation of narrow band frequency modulation has been done. In particular, the testbed has been built based on the GNU Radio software platform

The main difference between NBFM and WBFM is modulation index which depends on frequency deviation. This parameter was studied in this project. The systems were configured and results were observed. The hardware implementation was done using SDR and the GRC files that we designed for the system. Various concepts related to in phase and quadrature phase components, Field programmable gate arrays (FPGA), homodyne and heterodyne receiver were studied and conclusions have been obtained.

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ABBREVIATIONS

3GPP 3rd Generation Partnership Project
ADC Analog-to-digital converter
AM Amplitude Modulation
BER Bit Error Rate
CR Cognitive Radio
DAC Digital-to-analog converter
DDC Digital down converter
DUC Digital up converter
DUT Device under test
FFT Fast Fourier Transform
FM Frequency Modulation
FPGA Field-programmable gate array
GNU GNU's Not UNIX
GRC GNU Radio Companion
GUI Graphical User Interface
I/Q Inphase& Quadrature
IDFT Inverse Discrete Fourier Transform
IF Intermediate Frequency
JTRS Joint Tactical Radio System
LTE Long Term Evolution
NBFM Narrow Band Frequency Modulation
OFDM Orthogonal Frequency Division Multiplexing
PLL Phase-locked loop
RF Radio Frequency
Rfid radio frequency identification
Sdr software defined radio
Snr signal-to-noise ratio
Usrp universal software radio peripheral
Wbfm wide band frequency modulation

Chapter 1-
BASIC DEFINITIONS & KEY CONCEPTS

Communication:

Communication is the act of conveying intended meaning to another entity through the use of mutually understood signs and semiotic rules. The basic steps of communication are the forming of communicative intent, message composition, message encoding, transmission of signal, reception of signal, message decoding and finally interpretation of the message by the recipient.

Signal:

Signal:

A signal as referred to in communication systems, signal processing, and electrical engineering is a function that "conveys information about the behaviour or attributes of some phenomenon". In the physical world, any quantity exhibiting variation in time or variation in space (such as an image) is potentially a signal that might provide information on the status of a physical system, or convey a message between observers, among other possibilities. The *IEEE Transactions on Signal Processing* states that the term "signal" includes audio, video, speech, image, communication, geophysical, sonar, radar, medical and musical signals .There are two types of signal – Analog Signal & Digital Signal.

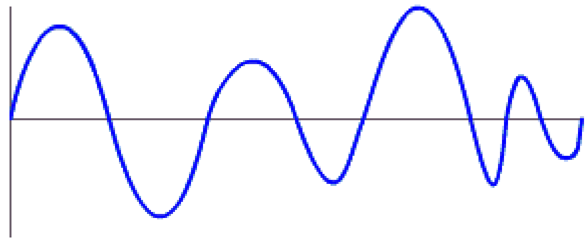
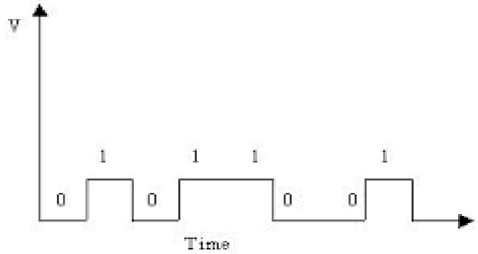


Figure1.1 Analog Signal

Figure1.2 Digital Signal



Bandwidth:

Bandwidth is defined as a range within a band of frequencies or wavelengths. Bandwidth is also defined as the amount of data that can be transmitted in a fixed amount of time. For digital devices, the bandwidth is usually expressed in bits per second (bps) or bytes per second. For analog devices, the bandwidth is expressed in cycles per second, or Hertz (Hz).

Channel:

In telecommunications and computer networking, a communication 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. 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*. These pathways, called communication channels, use two types of media: cable (twisted-pair wire, cable, and fiber-optic cable) and broadcast (microwave, satellite, radio, and infrared).

Modes of channel operation-

- *Simplex Channel*: Data in a simplex channel is always one way. Simplex channels are not often used because it is not possible to send back error or control signals to the transmit end.

- *Half Duplex Channel*: A half-duplex channel can send and receive, but not at the same time. Only one end transmits at a time, the other end receives. In addition, it is possible to perform error detection and request the sender to retransmit information that arrived corrupted.

- *Full Duplex Channel*: Data can travel in both directions simultaneously. There is no need to switch from transmit to receive mode like in half-duplex.

Noise:

In communication systems, noise is an error or undesired random disturbance of a useful information signal in a communication channel. The noise is a summation of unwanted or disturbing energy from natural and sometimes man-made sources.

Signal to Noise Ratio (SNR):

Signal-to-noise ratio (abbreviated SNR) is a measure used in science and engineering that compares the level of a desired signal to the level of background noise. It is defined as the ratio of signal power to the noise power, often expressed in decibels. A ratio higher than 1:1 (greater than 0 db) indicates more signal than noise.

$S(dB) = 10\log10(PsignalPnoise)$

Where, SNR is signal-to- noise ratio

Psignal is the power of signal

Pnoise is power of noise

Channel Capacity:
For a given specified channel, the channel capacity is defined as the maximum rate at which information can be transmitted over a communications channel of a specified bandwidth in the presence of noise.
According to Shannon–Hartley theorem, the channel capacity is given by

$$C=B\log2(1+SN)$$

Where, C is the channel capacity
B is the bandwidth of channel
S is the average received power over the bandwidth
N is the average power of interfering noise

Bit Error Rate (BER):
In digital transmission, the number of bit errors is the number of received bits of a data stream over a communication channel that have been altered due to noise, interference, distortion or bit synchronization errors.
The bit error rate (BER) is the number of bit errors per unit time. The bit error ratio (also BER) is the number of bit errors divided by the total number of transferred bits during a studied time interval. BER is a unit less performance measure, often expressed as a percentage.
The bit error probability *pe*is the expectation value of the bit error ratio. The bit error ratio can be considered as an approximate estimate of the bit error probability. This estimate is accurate for a long time interval and a high number of bit errors.

Modulation:
Modulation is the process of varying one or more properties of a periodic waveform, called the carrier signal, with a modulating signal that typically contains information to be transmitted. Modulation is the process of conveying a message signal, for example a digital bit stream or an analog audio signal, inside another signal that can be physically transmitted. Modulation of a sine waveform transforms a baseband message signal into a passband signal.
A modulator is a device that performs modulation. A demodulator (sometimes detector or demod) is a device that performs demodulation, the inverse of modulation. A modem (from modulator-demodulator) performs both operations.

There are basically two types of modulation techniques-

- *Analog-Modulation*: The aim of analog modulation is to transfer an analog baseband (or lowpass) signal, for example an audio signal or TV signal, over an analogbandpass channel at a different frequency, for example over a limited radio frequency band or a cable TV network channel. Examples of analog modulation techniques are- Amplitude Modulation (AM), Frequency Modulation (FM), Phase Modulation (PM) and etc.

Digital Modulation: The aim of digital modulation is to transfer a digital bit stream over an analogbandpass channel, for example over the public switched telephone network (where a bandpass filter limits the frequency range to 300–3400 Hz) or over a limited radio frequency band. Examples of digital modulation techniques are- Amplitude Shift Keying (ASK), Frequency Shift Keying (FSK), M-ary Phase Shift Keying (M-PSK) and etc.

Need for Modulation:

(I) To separate signal from different transmitters:-

Audio frequencies are within the range of 20 Hz to 20 khz. Without modulation all signals at same frequencies from different transmitters would be mixed up. There by giving impossible situation to tune to any one of them. In order to separate the various signals, radio stations must broadcast at different frequencies.

Each radio station must be given its own frequency band. This is achieved by frequency translation as a result of modulation process.

(II) Size of the antenna: –

For efficient transmission the transmitting antennas should have length at least equal to a quarter of the wavelength of the signal to be transmitted. For an electromagnetic wave of frequency 15 khz, the wavelength λ is 20 km and one-quarter of this will be equal to 5 km. Obviously, a vertical antenna of this size is impractical. On the other hand, for a frequency of 1 mhz, this height is reduced to 75m.

Also, the power radiated by an antenna of length *l* is proportional to (l/λ)2. This shows that for the same antenna length, power radiated is large for shorter wavelength. Thus, our signal which is of low frequency must be translated to the high frequency spectrum of the electromagnetic wave. This is achieved by the process of modulation.

Radio Frequency:

Radio frequency (RF) is any of the electromagnetic wave frequencies that lie in the range extending from around 3 khzto 300 ghz, which include those frequencies used for communications or radar signals.

FREQUENCY	WAVELENGTH	DESIGNATION	ABBREVIATION
3–30 Hz	105–104 km	Extremely low frequency	ELF
30–300 Hz	104–103 km	Super low frequency	SLF
300–3000 Hz	103–100 km	Ultralow frequency	ULF
3–30 khz	100–10 km	Very low frequency	VLF
30–300 khz	10–1 km	Low frequency	LF
300 khz– 3 mhz	1 km – 100 m	Medium frequency	MF
3–30 mhz	100–10 m	High frequency	HF
30–300 mhz	10–1 m	Very high frequency	VHF
300 mhz– 3 ghz	1 m – 10 cm	Ultra-high frequency	UHF
3–30 ghz	10–1 cm	Super high frequency	SHF
30–300 ghz	1 cm – 1 mm	Extremely high frequency	EHF
300 ghz– 3000 ghz	1 mm – 0.1 mm	Tremendously high frequency	THF

Radio:

Radio is the use of radio waves to carry information, such as sound, by systematically modulating some property of electromagnetic energy waves transmitted through space, such as their amplitude, frequency, phase, or pulse width. When radio waves strike an electrical conductor, the oscillating fields induce an alternating current in the conductor. The information in the waves can be extracted and transformed back into its original form.

A radio communication system sends signals by radio.[4] The radio equipment involved in communication systems includes a transmitter and a receiver, each having an antenna and appropriate terminal equipment such as a microphone at the transmitter and a loudspeaker at the receiver in the case of a voice-communication system.

Antenna:
An antenna (or aerial) is an electrical device which converts electric currents into radio waves, and vice versa. It is usually used with a radio transmitter or radio receiver. In transmission, a radio transmitter supplies an electric current oscillating at radio frequency (i.e. High frequency AC) to the antenna's terminals, and the antenna radiates the energy from the current as electromagnetic waves (radio waves). In reception, an antenna intercepts some of the power of an electromagnetic wave in order to produce a tiny voltage at its terminals, which is applied to a receiver to be amplified. Some antennas can be used for both transmitting and receiving, even simultaneously, depending on the connected equipment.

Latency:
It is defined as time elapsed between a message inputted to an encoder and a coded output being produced by the encoder. At receiver side, it is in terms of decoder.

Energy/bit:
It is the amount of energy contained in 1 information bit. It is related to transmission power and bit rate.

Sampling &Nyquist Criterion:
Sampling is a process of converting a signal (for example, a function of continuous time and/or space) into a numeric sequence (a function of discrete time and/or space).
According to Nyquist Criterion:
If the frequency of signal to be sampled is fs, then the sampling rate must be equal to or greater than 2fs for perfect reconstruction of the signal.

Coding gain:
The difference in dbin the required signal to noise ratio (SNR) to maintain reliable communication after coding is employed and its values before coding is called as coding gain

Code rate:
Consider an encoder takes ‘k’ information bits and add ‘r’ redundant bits to produce ‘n’ bit code word. So the code rate is the fraction k/n.

CHAPTER 2-INTRODUCTION TO SDR AND COGNITIVE RADIO

2.1 SDR:

Introduction:

A radio in which the RF operating parameters including, but not limited to, frequency range, modulation type, or output power can be set or altered by software, and/or the technique by which this is achieved.

Radio: It is a device that can be used for transmission, receiver and trans-receiver applications using radio waves.

FIGURE- CONVENTIONAL RADIO

Conventional Hardwired Radios: All the working of a radio is defined on hardware. It has fixed set of characteristics.

Issues with conventional radios:

- Not flexible
- Limited encryption capabilities.
- One receiver is designed for one communication system
- Different set of hardware for different types of radio communication system.

Today's radio:

Software defined radio(SDR) is a radio communication system where components that have been typically implemented in hardware are implemented by means of software on a personal computer or embedded system.

Standardization of SDR has, up to now, not really taken off, as SDR is about implementation technology (which, principally, shouldn't be standardized)

For specific sectors, as Public Safety and Defence, there has been customer demand on SDR, usually to achieve extended interoperability. Still, in spite of intensive funding, no real results in these sectors.

2.2 APPLICATIONS OF SDR

SDR has a wide range of applications:

Military-

The Joint Tactical Radio System (JTRS) was a program of the US military to produce radios that provide flexible and interoperable communications. Examples of radio terminals that require support include hand-held, vehicular, airborne and dismounted radios, as well as base-stations (fixed and maritime). This goal is achieved through the use of SDR systems based on an internationally endorsed open Software Communications Architecture (SCA). This standard uses CORBA on POSIX operating systems to coordinate various software modules.

Emergency communication systems -

During natural calamities, the communication systems in the particular area is destroyed, due to which there is difficulty in communicating to emergency services like the police force, or the hospital or the rescue team. At this time, this communication is achieved by Software Defined Radios, we can set these at any point, and communication can be done easily.

RFID Applications-

This concept is similar to the internet of things. RFID stand for radio frequency id. For example, if we assign a RFID to a car, and it passes through a toll area, it won’t have to stop to pay. An SDR will simply detect its RFID number, and automatically money will be deducted from the car owner’s credit card. This application is also used in banks and offices.

2.3 Cognitive radio

Wireless technology is proliferating rapidly, and the vision of pervasive wireless computing and communications offers the promise of many societal and individual benefits. While consumer devices such as cell phones, pads and laptops receive a lot of attention, the impact of wireless technology is much broader, e.g., through sensor networks for safety applications and home automation, smart grid control, medical wearable and embedded wireless devices, and entertainment systems. This explosion of wireless applications creates an ever-increasing demand for more radio spectrum. However, most easily usable spectrum bands have been allocated, although many studies have shown that these bands are significantly underutilized. These considerations have motivated the search for breakthrough radio technologies that can scale to meet future demands both in terms of spectrum efficiency and application performance. Cognitive radios offer the promise of being a disruptive technology innovation that will enable the future wireless world. Cognitive radios are fully programmable wireless devices that can sense their environment and dynamically adapt their transmission waveform, channel access method, spectrum use, and networking protocols as needed for good network and application performance. There is however a big gap between having a flexible cognitive radio, effectively a building block, and the large-scale deployment of cognitive radio networks that dynamically optimize spectrum use. Building and deploying a network of cognitive radios is a complex task. But continuous research is being done.

Future applications of Cognitive Radio

Cognitive radio has a very bright future in wireless technology.

- Radio technology will be at the very heart of the future computing world - one in which billions of communicators, mobile devices and sensors/actuators are connected to the global Internet and serve as the foundation for many exciting new classes of applications.
- One of the anticipated benefits of CR technology is that it will enable lower cost Internet access by reducing the substantial cost component associated with the purchase of spectrum.
- CR networks is in the application to assistive technology for the physical handicap. There is an effort currently underway to deploy personal wireless networks for enabling muscle activation in paraplegics. Through this technology it is thought that victims of crippling spinal accidents may be able to walk again through cyberphysical systems operating over wireless systems.

2.4 SDR HARDWARE

Software Defined Radio performs the majority of signal processing in the digital domain using programmable dspsand hardware support, but some signal processing is still done in the analog domain, such as in the RF and IF circuits.

Software-Defined Radio (SDR) structure is divided into three blocks. The left one builds the RF frontend of the hardware which serves as interface to the analog RF domain. In the second block, the intelligence of the hardware part is implemented, forming the interface between the digital and the analog world. In the third block, the whole signal processing is done - fully designed in software.

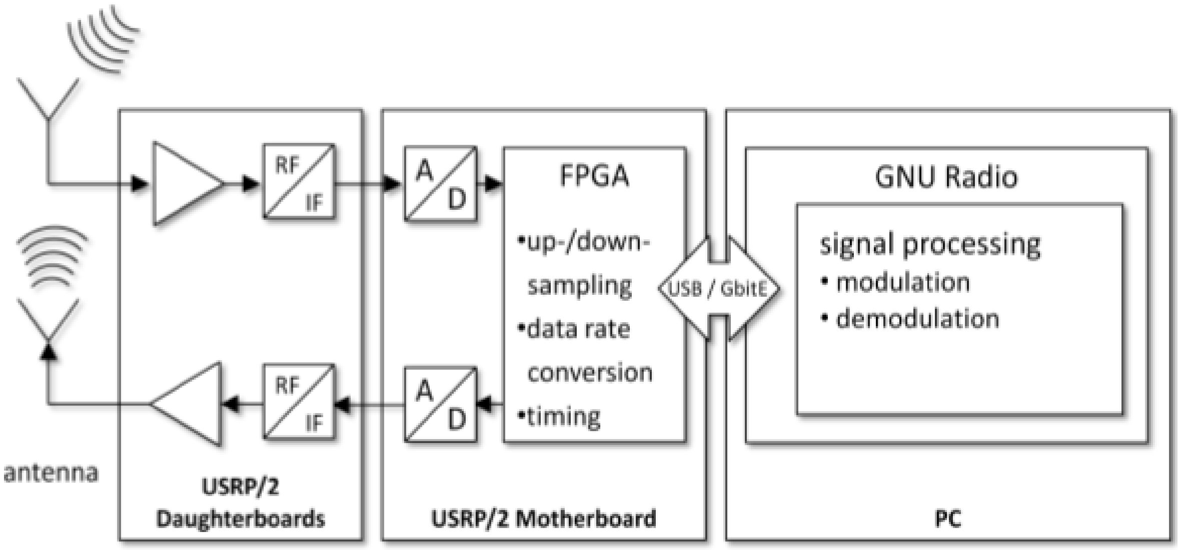


Fig. Software Defined Radio Block Diagram

Universal Software Radio Peripheral (USRP):

GNU Radio together with USRP hardware proved to be a valuable lab platform for implementing complex radio system prototypes in a short time.USRP uses a different FPGA, faster adcsand dacswith a higher dynamic range and a Gbit-Ethernet connection. In USRP motherboard, an analog to digital converter (ADC) samples the received signal and converts it to digital values depending on the adcsdynamic range of bit. How many times per second the analog signal can be measured is defined by the sampling rate of used adcs- yielding in 100e6 results per second at a sampling rate of 100 mega samples per second (MS/s) for USRP.The digital sample values are transferred to the FPGA and Software-Defined Radio with GNU Radio and USRP processed with digital down converters (DDC) to meet exactly the requested output frequency and sample rate.

CH 3-INTRODUCTION AND INSTALLATION OF GNU RADIO SOFTWARE

3.1 GNU Radio:

GNU Radio is a collection of software that when combined with minimal hardware, allows the construction of radios where the actual waveforms transmitted and received are defined by software: it turns the digital modulation schemes used in high performance wireless devices into software problems. Waveforms are generated as sampled digital signals, converted from digital to analog via a wideband DAC and then possibly upconverted from IF to RF. The receiver uses a wideband Analog to Digital Converter (ADC) that captures all the channels of the software radio node. The receiver then extracts, downconverts and demodulates the channel waveform using software on a general purpose processor.

The GNU Radio applications themselves are generally known as 'flow graphs', which are a series of signal processing blocks connected together, thus describing a data flow. As with all software-defined radio systems, configurability is a key feature. Instead of using different radios designed for specific but disparate purposes, a single, general-purpose, radio can be used as the radio front-end, and the signal-processing software (here, GNU Radio), handles the processing specific to the radio application.

These flowgraphs can be written in either C++ or the Python programming language. The GNU Radio infrastructure is written entirely in C++, and many of the user tools are written in Python.

GNU radio provides:

- Basic data structure, the flow graphs to build streaming signal processing systems
- Connections to and from hardware systems
- A framework of programming tools and examples

3.2 Installation

 GNU Radio runs under several operating systems like Linux, Mac OS X, netbsd.

 Installation on LINUX:

-download GNU Radio Packages from standard Repository
-run:
$apt-get install gnuradio (on Ubuntu and Debian)
$yum install gnuradio
 For Windows User, First Install VMWARE , then LINUX Virtual Machine and run above commands on terminal .Refer www.gnuradio.org/

3.3 GNU Radio Companion:

The GNU Radio Companion is a graphical UI used to develop GNU Radio applications. This is the front-end to the GNU Radio libraries for signal processing. GRC was developed by Josh Blum during his studies at Johns Hopkins

University (2006-2007), then distributed as free software for the October 2009 Hackfest. Starting with the 3.2.0 release, GRC was officially bundled with the GNU Radio software distribution.
GRC is effectively a Python code-generation tool. When a flow graph is 'compiled' in GRC, it generates Python code that creates the desired GUI windows and widgets, and creates and connects the blocks in the flow graph.
GRC currently supports GUI creation with wxwidgetsor the Qt toolkit.

GRC Processing Blocks

 Basic mathematical and logical operations

 Large library of filter design and processing algorithms

 Narrowband and OFDM digital modulation capabilities

 Type conversions

 Analog (AM/FM) processing techniques

 Trellis, convolutional coding

 Graphical visualization tools

Plotting and displays:
GNU Radio provides many common plotting and data visualization data sinks, including FFT displays, symbol constellation diagrams, and scope displays. These are commonly used both for debugging radio applications and as the user-interface to a final application.

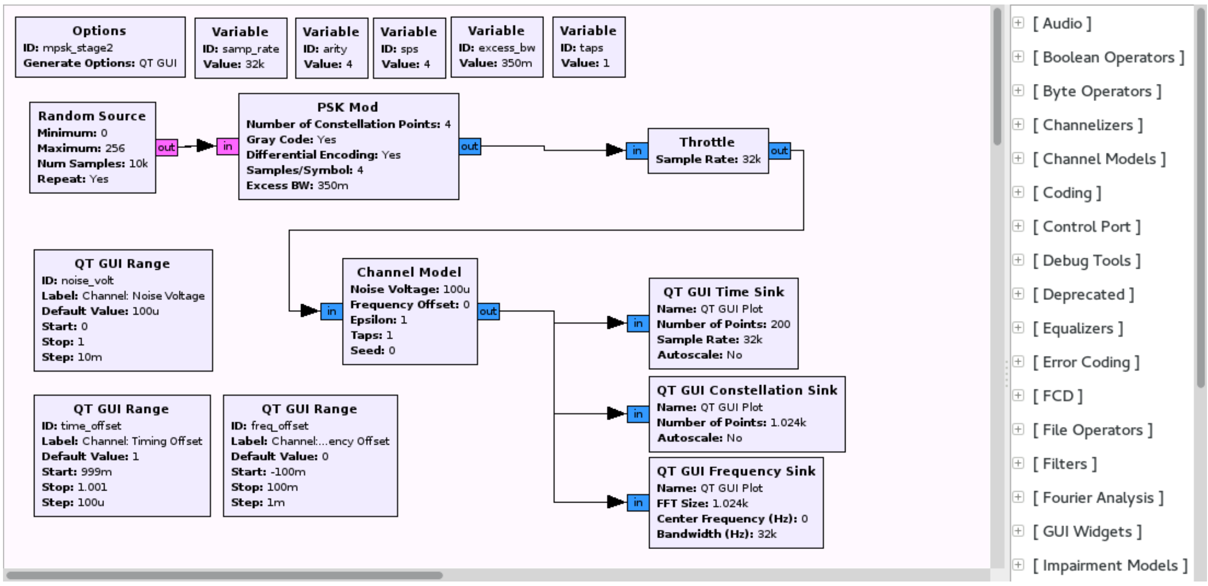


Fig. GNU Radio flow graph in GNU radio companion

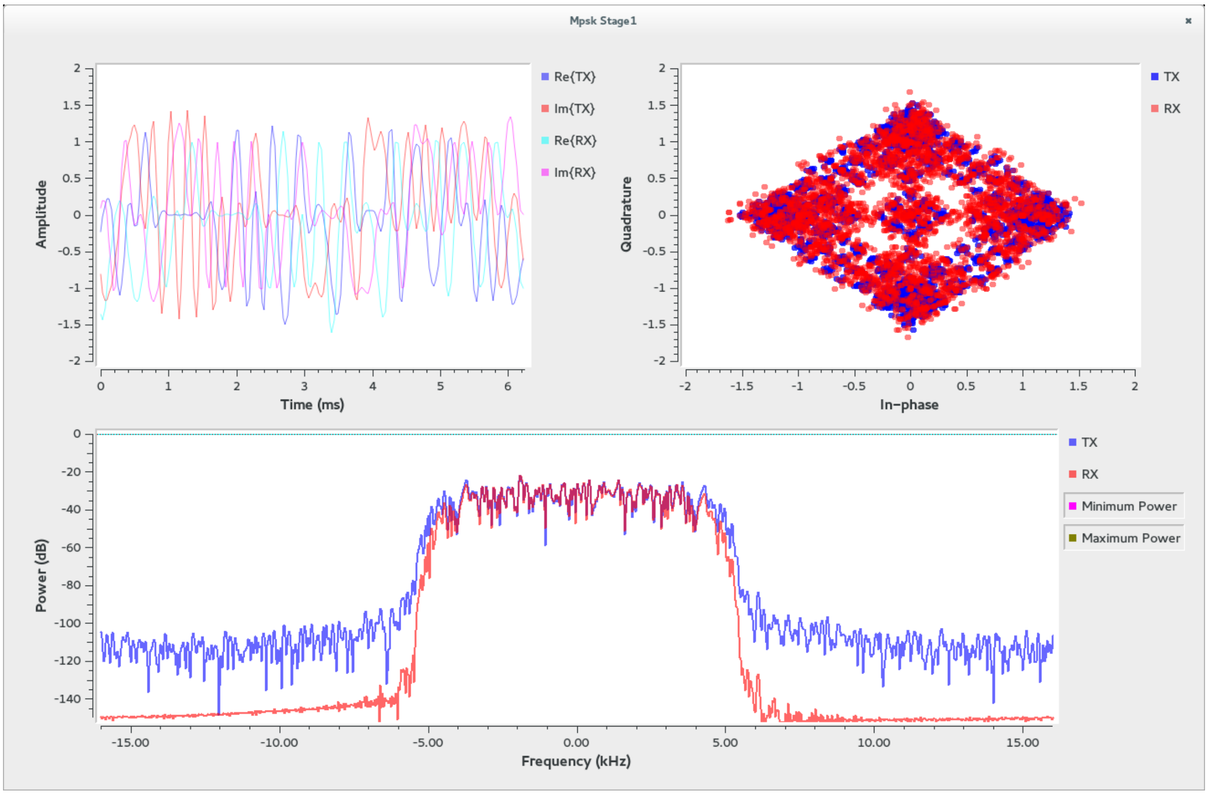


Fig-GNU radio plotting of radio samples

BLOCK IMPLEMENTATION
ON GNU RADIO

4.1 Developing and testing building blocks of communication systems

The proposed experiment gives the basic understanding of using GNU Radio Companion (GRC), which is a graphical tool for creating signal flow-graphs and
Generating flow graph source code. This particular experiment will help you to learn basic blocks that are required in communication systems and their implementation using GRC will be discussed.

Details: Steps to follow

This section describes how to start working in GNU radio platform for the beginners.
You should use the following steps as a beginner which are generally used in most of
The GRC experiments:
1: Open a terminal window using keyboard inputs: **Ctrl+Alt+T**, or by going to Dash Home on top left side and typing "Terminal" in it.
2: At the terminal prompt type: **gnuradio-companion.**
3: An untitled GRC window will open. If this
Window does not appear, then close all the windows and open a new window.

4: Save this flow-graph.
5: Double click on the Options block. This block sets some general parameters.

Leave the ID as top_block. Type in a project title (such as Experiment 1) and author. Set Generate Options to **QT GUI**, **Run** to **Autostart**, and **Realtime Scheduling** to **Off**. Then close the properties window.
6: Open the other block named Variable block present in the flow-graph. It is used
To set the sample rate. Set this equal to 32000.
7: You can find list of available blocks on the right side of the window. By Expanding any of the categories (click on triangle to the left) you can see the Available blocks.
8: Open the **Waveform Generators** category and double click on the **Signal Source**.
9: In order to view the waveform output from the source, you will have to Choose a sink. From **Instrumentation category, add QT GUI Time Sink** which is under QT category. Change the type to float.
10: In order to connect these two blocks, click once on the “out” port of the Signal
Source, and then once on the “in” port of the Time Sink.
11: Connecting source directly to sink may consumes whole of the CPU processingDueto which system may hang. Therefore, a block called **Throttle**

needs to be addedAftersource. This block limits the data rate by which data passes between the blocks.

Select this block from **Misc**category. Change the type to float.

12: Click on "Execute the flow-graph" icon. A scope plot should open displaying

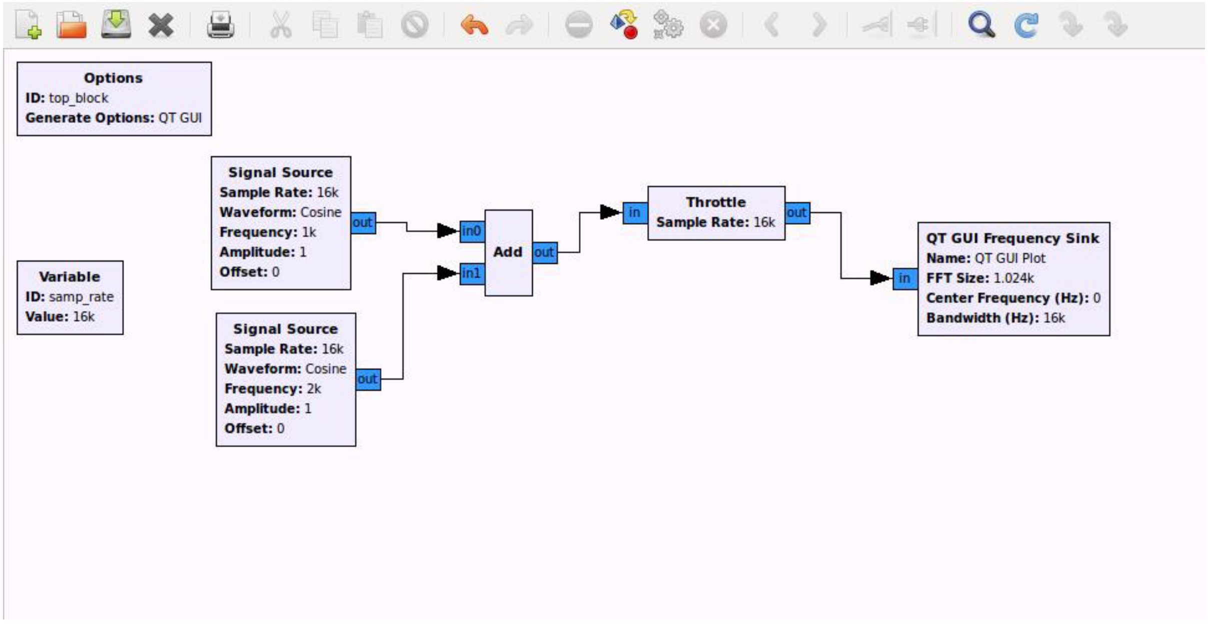
Several cycles of the sinusoid.

4.2 ADDITION OF TWO SIGNALS

Following two examples show how to develop their own flow graph, its execution and displaying various plots.

Construct the flow-graph shown in Fig. Set the sample rate to 16000

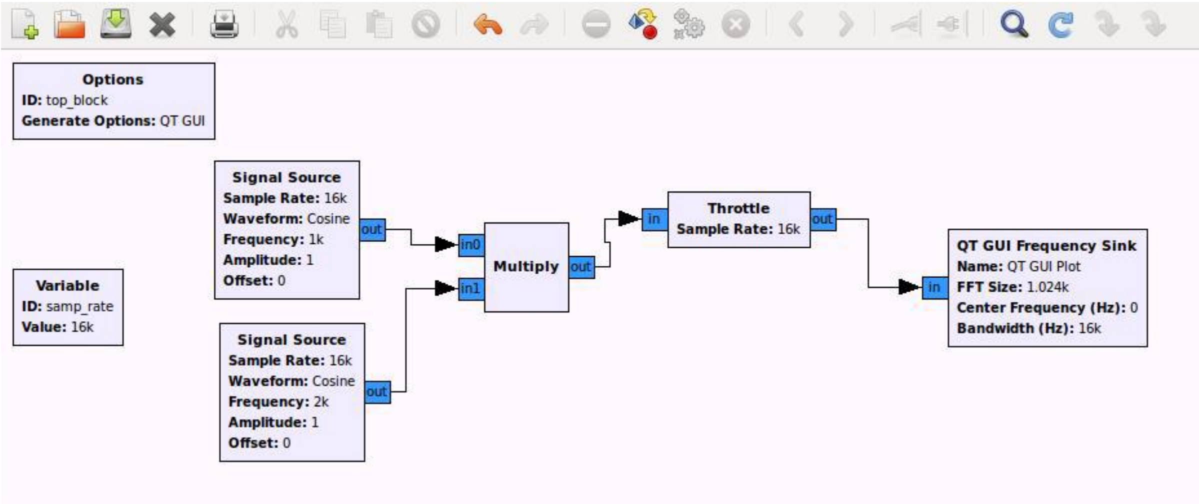
The two Signal Sources should have frequencies of 1000 and 2000 Hz, respectively. The block name Add can be found in the Operators category.



4.3 Multiplication of two signals

Replace the ADD block with MULTIPLY block. Also change the sample rate to 16 khz.

You can also change the type to float and observe the change in output.



IMPLEMENTATION OFFM SYSTEMSON GNU RADIO

5.1 THEORY

WHAT IS FREQUENCY MODULATION?

Frequency modulation (**FM**) is a method of impressing data onto an alternating-current (AC) wave by varying the instantaneous frequency of the wave. This scheme can be used with analog or digital data. In analog**FM**, the frequency of the AC signal wave, also called the carrier, varies in a continuous manner.

TYPES OF FREQUENCY MODULATION.

Depending on the value of the frequency deviated from carrier frequency, the FM types have originated. The two types of the FM are the narrow band FM known as NBFM and the wide band FM known as WBFM. Thus, the WBFM has wider bandwidth and the NBFM has narrower bandwidth.The wide band FM is good for high quality voices, because the frequencies about 15khzcan be at its spectrum but the number of stations are limited. But at narrow band we can not hear high quality voices from that but the number of stations can be higher than wide band.

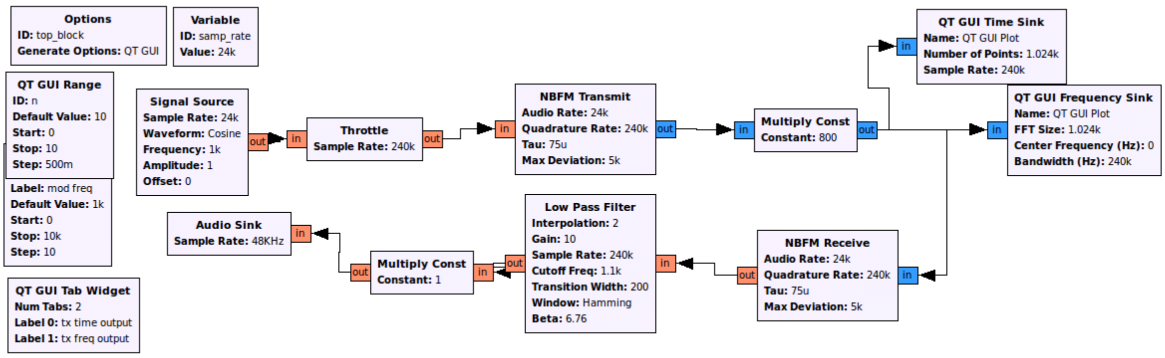


Fig. Flow graph of NBFM system

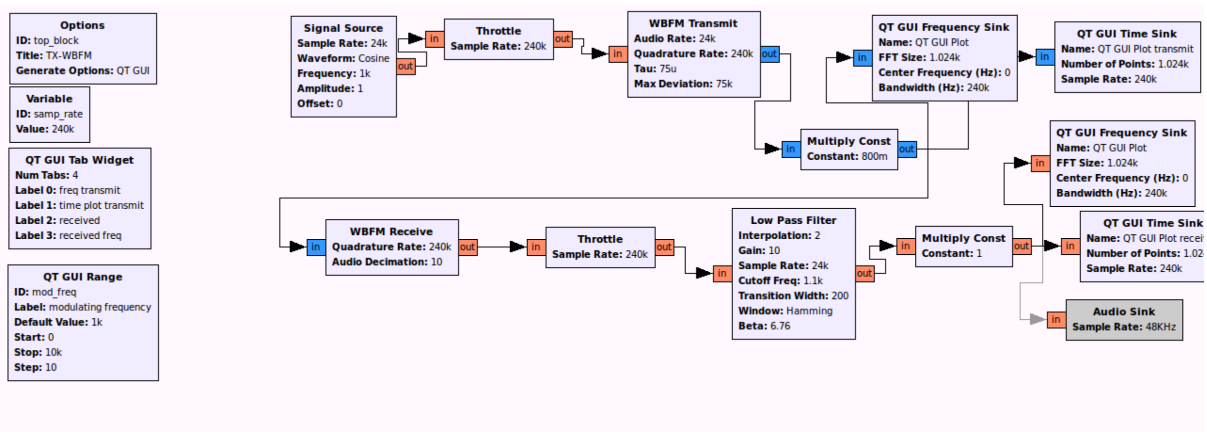


Fig- FLOW GRAPH OF WBFM system on GNU radio

Implementation of Systems on SDR at Amitec Ltd

6.1 Introduction

While working on GNU radio, we have developed all digital modulation based systems such as Narrow band frequency modulation (NBFM),Wide Band Frequency modulation (WBFM), Amplitude Modulation, OFDM, BPSK, QPSK, DBPSK, DQPSK and tested with the help of the hardware front end provided by Amitec Ltd. In educational visit to AmitecLabs . We have designed transmitter and receiver on laptop using GNU Radio Software. Laptops are connected with Software Defined radio transceiver hardware. Hardware consists of two broad band antenna one for transmission and another for reception of frequencies. Experimented all modulation techniques on hardware and observed the signals at the receiver side.

Amitec Ltd. Has developed one of the best Software Defined Radio hardware with which we can demonstrate the working of cognitive radio. We can opt for any digital modulation techniques like QPSK, BPSK etc. At transmitter and receiver side. One of the set of laptop with transceiver can be configured as primary (licensed) user and another can be configured as secondary (unlicensed) user. With the help of real time spectrum analyser, we can set secondary at that frequency where primary was already set. But when primary user is absent, we can set that frequency to secondary. Later we can tune primary user to its licensed frequency and demonstrate the switching of secondary user to another nearby frequency. As the purpose of Cognitive Radio is to provide Dynamic spectrum access and spectral efficiency earlier, Python code was necessary to write for every operation on GNU radio platform. But now as we set GNU radio on Linux OS, we can directly prepare the transmitter and receiver system and execute the system. Also we can develop transceiver system for simulation results. Cognitive Radio system using energy spectrum analyser can be designed. Also many other logics can be developed using software platform.

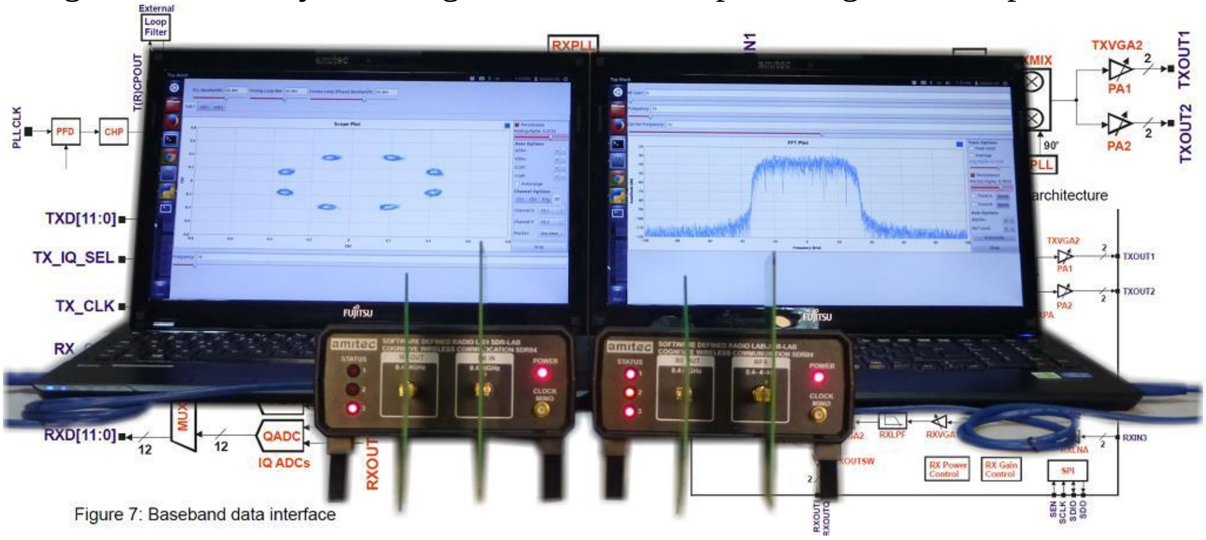


Fig.6.1 SDR Hardware Platform

The systems offers MIMO capability with high bandwidth and dynamic range. The USB 3.0 interface serves as the connection between the SDR-LAB and the host computer. This enables the user to realize 40 MS/s of real-time bandwidth in the receive and transmit directions, simultaneously (full duplex).

The Hardware Driver supports Linux, Mac OSX, Windows. Coupled with these benefits it hosts on board RF Transceiver subsystems capable of tuning frequencies from 400mhzto 4ghz. Using software addreseable down-converter and up-converters it is possible to tune from 40khzto 60ghz!

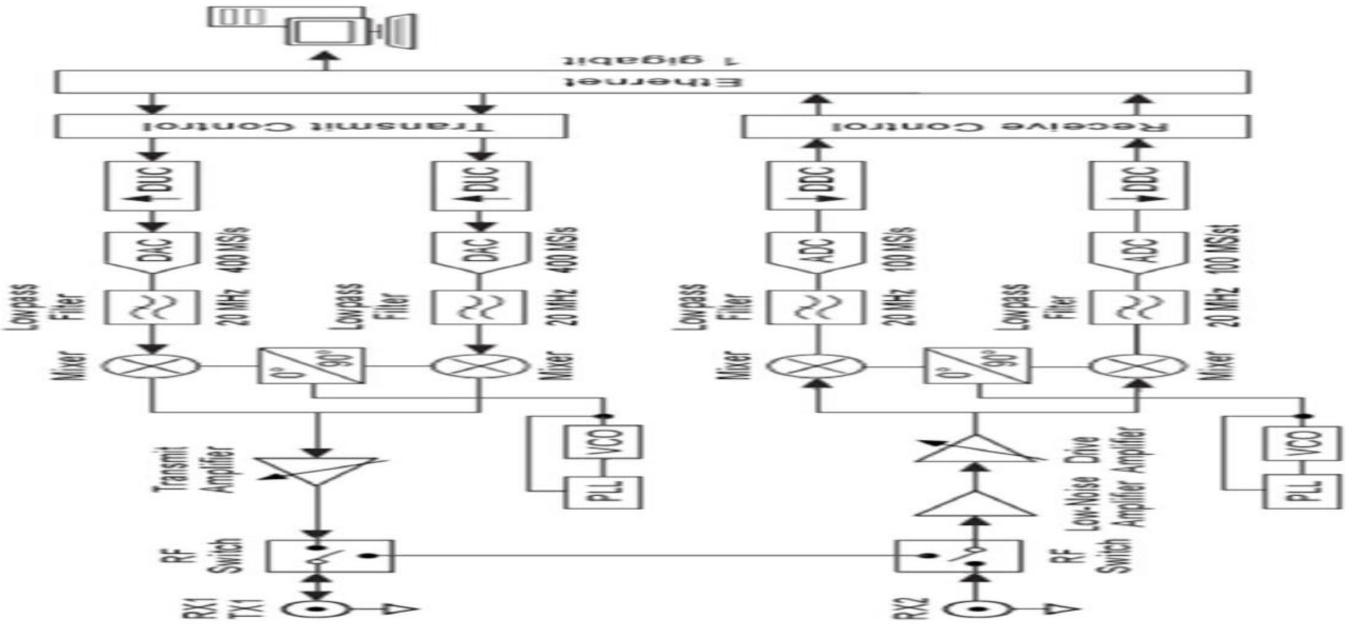


Fig- Internal block diagram of SDR

6.2 Implementation of NBFM system on SDR Hardware :

1: On GNU Radio software, replace the source and sink blocks by Amitec source and sink blocks. Amitec source and sink blocks are custom block designed on GNU Radio to interface with SDR hardware with python coding and its parameters are:

2: Connect hardware with PC through USB 3.0.
Consider a situation when the sample rate of any system be 40 MS/s. Due to I/Q channels the no. Of symbols will be doubled. If this data is passed through 14 bit ADC .
Hence, total raw data= 40×106×2×14 = 1.12 Gbits. When this data is represented in the form of packet overheads will be added. Thus, for transmission of such a huge data between pc and hardware in real time communication cannot be achieved by Ethernet LAN having maximum capacity 1 Gbits/sec or USB2.0(480 Mbits/sec). Thus, for connection to and from hardware we use USB 3.0 whose theoretical data transmission speed or throughput is around 5 Gbits/sec.
Also for real time communication at this high speed, it is not possible to read and write data at this rate. Hence, flash drives and solid state drives are used for read write operations. Cloud IQ is the latest high performance software defined receiver form RESPACE.

3: Connect Antennas at the RF in and RF out port of SDR hardware.
Antennas used here are Broadband antennas such as log-periodic or monopole antennas, planner horn antennas can also be used.Antenna range is 0.4-4 Ghz.

Fig.6.5 SDR Hardware connections

Working of SDR hardware with gnu radio:
1) Receiver antenna is connected at RF in port. When data of certain frequency is received by receiver antenna then is passed through low noise

amplifier(LNA) that amplifies a very low-power signal without significantly degrading its signal-to-noise ratio.

2) Then signal is passed through driver amplifier. VCO generates a frequency which is considered as reference frequency and PLL is used for error correction to minimize the error. The signal when passes through I/Q mixer the signal is down converted it form RF(Radio frequency) to IF (Intermediate Frequency) with certain central frequency and bandwidth. But the harmonics of signals are also present in received signal. We have filter in GNU Radio software still we need Filters in Hardware. This filter ats as Antialiasing Filter.

3) Signal at the output of the Low pass filter which acts as antialiasing bandpass filter of Quadrature phased signal is in analog domain. To convert it to digital domain for its processing in pc we use ADC. Here we used 12 Bits ADC. Next block is DDC. Digital down coverters(DDC) converts a digitized real signal centered at an Intermediate frequency(IF) to a baseband complex signal centered at zeroFrequency.In addition to downconversion, DDC's typically decimate to a lower sample rate allowing follow-on signal processing by lower speed processors.

4) Then, this digitized complex signal is given to Amitec source through USB 3.0 working in full duplex mode. And according to flow graph the processing is done.

5) This processed data is the dumped into sink which is then passed to SDR hardware through USB 3.0. This data is passed to DUC (Digital up converter) which increases the sample rate of signal.

6) Then this digitized data is converted to analog data using DAC(Digital to Analog converter). Then through low pass filter which acts as a Band limiting filter to remove harmonics. At transmitter the processing is exactly opposite to the receiver side. At I/Q mixer block the IF frequency is Converted to RF frequency.

7) This analog signal is the power amplified and transmitted for on air transmition through Antenna at port RF out.

In GNU radio implementation, no data is dumped in hardware. It's all about controlling and transmission.

FEATURES :

 Learn next generation communication & convergence technologies (Software Defined Radio, Cognitive Radio including white spaces, Cooperative Communication, Communication over Cellular Network, Wireless Network, Research in 4G/5G).

 Modulation Bandwidth Programmable upto 30 mhz

 Supports both TDD & FDD Full Duplex upto 30 mhz

 Dual 40 MS/s, 12-bit ADC

 Dual 40 MS/s, 12-bit DAC

 USB 3.0 Interface to Host Controller

200mhzARM9 with 512KB embedded SRAM

 Alterra Cyclone FPGA with single cycle access memory, 18X18 multipliers for dedicated DSP & programmable general logic elements

 2X2 MIMO Configurable, Expandable to 8X8

 Works as Spectrum Analyzer, Vector Signal Source and Vector Signal Analyzer

 No HDL Coding required

 Covers white spaces, broadcast television, public safety, land-mobile communications, low-power unlicensed devices, wireless sensor networks, cell phones, amateur radio bands.

 Future ready from simple FM to WCDMA/HSPA, 4G-LTE standard.

TECHNICAL SPECIFICATIONS:

- Tx-RX RF Frequency Range 0.4-4ghz
- 5dbm Transmiting power
- 120dbm Sensitivity receiver
- Baseband Bandwidth <1-15mhz
- Frequency Resolution <3Hz
- Maximum RF Output power +5dbm
- Receiver Sensitivity -100dbm
- Tx Output Impedance 50 Ohms SMA
- PLL Phase Noise -125dbc/Hz at 1mhz
- Transmit Gain Control Range >50db
- HOST CONTROLLER

Processor Intel Quad Core is 64 bit >2 ghz4th Generation
Onboard Graphics Intel 4600
RAM 4GB DDR3 1.6ghz
R/W Speed >150mbps

- OS Linux Ubuntu
- Ports Serial, USB 3.0 X3, HDMI, Ethernet Gigabit, VGA, Audio in/out,
- Cable: High Speed USB 3.0 Serial Cable
- Antennas: Planar Directional LPDA 0.4-4 ghzX 2,Omni Directional Antenna 0.4-4 ghz

Result, ConclusionAndFuture Scope

RESULT & CONCLUSION

The working environment of the GNU Radio was studied thoroughly and the software was installed. Various communication system were implemented on the software such as Narrow Band Frequency Modulation (NBFM), Wide Band Frequency Modulation (WBFM), which improved our understanding about the software. NBFM system was also implemented on the SDR hardware onAmitec Labs which helped us to understand how the SDR works in the real time environment.

Thus, by this project we concluded that the future of the radio is Cognitive Radio. It can be used to dynamically allocate the spectrum and for the optimal utilization of available spectrum. Also, in SDR we can vary the parameters depending on our application with minimum efforts by using the software.

FUTURE SCOPE

As we know that the traffic on the mobile communication band is increasing day by day. Cognitive radio is the best way to tackle this problem as it allows dynamic allocation of the spectrum. As SDR is the future of the wireless communication , there is tremendous scope in the future application of Radios.

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❖ Basic blocks and concepts of gnuradiofrom https://www.youtube.com/watch?V=n9slanglgqs&list=PL618122BD66C8B3C4

❖ Simulations with gnuradiofrom, https://github.com/csete/gnuradio-grc-examples/blob/master/receiver/fm_rx.grc

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