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RECEIVING FSK SIGNALS USING HACKRF

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THE GRADUATE SCHOOL OF NATURAL AND APPLIED SCIENCES OF
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"I declare that all the information within this thesis has been gathered and presented in accordance with academic regulations and ethical principles and I have according to the requirements of these regulations and principles cited all those which do not originate in this work as well."

Salah Meftah ALTIRAIKI

ABSTRACT

M. Sc. Thesis

RECEIVING FSK SIGNALS USING HACKRF

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Thesis Advisor:
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The SDR idea is a high speed sampling and ADC/DAC modules directly to the received radio signal and decode any contains. SDR transmitter convert digital signal to analog waveform and then the analog waveform is transmitted to receiver. These processes are done through software on a reconfigurable baseband processor. SDR systems offer much more flexibility by implementing the modulation/demodulation functionality in software. Connected to the antenna through an RF mixer is a high-speed ADC/DAC (for receiver/transmitter, respectively) such that the SDR processes the communication signals using DSP algorithms implemented in software. Depending on sampling rates, large segments of the spectrum can be manipulated for a wide variety of simultaneous processing. Particularly powerful is the concept of flexibility; if the radio modulation scheme changes, new DSP software is loaded to perform the necessary processing and no hardware modification is required. This approach allows for ease of adaptability, shortens development effort and greatly reduces cost and complexity. Frequency Sift Keying (FSK) is frequency modulation scheme which the digital data transmitted through discrete frequency changes of a carrier signal. Modulation techniques is a crucial role in SDR system since it defines the data that purpose to be transmitted FSK scheme has dynamic characteristics to carrier signal with respect to time. The data are transmitted by shifting the frequency of a continuous carrier in a binary manner to one or the other of two discrete frequencies. One frequency is designated as the “mark” frequency and the other as the “space” frequency. The mark and space correspond to binary one and zero respectively.

Key Words: HackRF One, FSK, Software Defined Radio, receiver, demodulator, modulator, amplifiers, filters;

Science Code : 905.1.067

ÖZET

Yüksek Lisans Tezi

RECEIVING FSK SIGNALS USING HACKRF

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SDR fikri, yüksek hızda bir örnekleme ve ADC / DAC modüllerinin doğrudan alınan radyo sinyaline dönüştürülmesini ve herhangi birinin kodunu çözmesini sağlar. SDR verici dijital sinyali analog dalga formuna çevirir ve daha sonra analog dalga formu alıcıya gönderilir. Bu işlemler, yeniden yapılandırılabilir bir baz bant işlemcisi üzerinden yazılım aracılığıyla yapılır. SDR sistemleri, yazılımda modülasyon / demodülasyon işlevselliği uygulayarak daha fazla esneklik sunar. Bir RF mikser vasıtasıyla antene yüksek hızlı ADC / DAC (sırasıyla alıcı / verici için) bağlanır, böylelikle SDR yazılımda uygulanan DSP algoritmalarını kullanarak iletişim sinyallerini işler. Örnekleme hızlarına bağlı olarak, spektrumun geniş kesimleri çok çeşitli eşzamanlı işleme için manipüle edilebilir. Özellikle esneklik açısından güçlü bir özelliğe sahiptir; Radyo modülasyon şeması değişirse, gerekli işlemleri gerçekleştirmek için yeni DSP yazılımı yüklenir ve hiçbir donanım değişikliği gerekmez. Bu yaklaşım uyarlanabilirliği kolaylaştırır, geliştirme çabalarını azaltır ve maliyeti ve karmaşıklık düzeyini büyük ölçüde düşürür .Frekans Tepkisi (FSK), frekans modülasyon şeması olup, bu şemada dijital veriler, bir taşıyıcı sinyalin ayrı frekans değişimleriyle iletilirler. Modülasyon teknikleri SDR sisteminde çok önemli bir role sahiptirler, zira iletilecek olan verileri zamana göre taşıyıcı sinyaliyle alakalı dinamik özelliklere sahip FSK şemasını aktarmayı amaçlayan verileri tanımlarlar. Veriler, sürekli bir taşıyıcının frekansını ikili bir şekilde iki ayrık frekanstan birine veya diğerine kaydırarak iletilir. Bir frekans, "işaret" frekansı ve diğeri "alan" frekansı olarak adlandırılmıştır. İşaret frekansı ikiliye, alan frekansı, sıfıra tekabül eder.

Anahtar Kelimeler: HackRF One, FSK, Yazılımla Tanımlı Radyo, alıcı, Kip Çözücü, Kipleyici, Yükseltici, Filtreler.

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ABBREVIATIONS

AM : Amplitude Modulation
ADC : Analog -to- Digital Converter
AFSK : Audio Frequency Shift Keying
ARM : antiradiation missile
ASK : Amplitude Shift Keying
BFSK : Binary Frequency Shift Keying
CPU : Central Processing Unit
DAC : Digital-to-Analog Converter
DDC : Digital Down Converter
DSP : Digital Signal Processing
DTMF : Dual-tone multi-frequency
FCC : Federal Communications Commission
FFT : Fast Fourier Transform
FIR : Finite Down Converter
FM : Frequency Modulation
FSK : Frequency Shift Keying
GFSK : Gaussian Frequency Shift Keying
GMSK : Gaussian Minimum Shift Keying
GRC : GNU Radio Companion
GPS : Global Positioning System
GPU : Graphic Processor Unit
GUI : graphical user interface
IF : Intermediate Frequenc
IP : Internet Protocol
Mbps : megabits per second
PC : Personal Computer

PCB : Printed Circuit Board

PSK : Phase Shift Keying

PWM : Pulse Width Modulation

QAM : Quadrature Amplitude Modulation

RF : Radio Frequency

RTL : Realtek Chip

RX : Receiver

SDR : Software Defined Radio

SMA : Sub Minature a connector.

SSB : single *sideband*

TCP : Transport Control Protocol

TX : Transmitter

UHF : Ultra High Frequency

USB : Universal Serial Bus

VHF : Very High Frequency

USRP :Universal Software Radio Peripheral

WLAN : Wireless local area network

CHAPTER 1

INTRODUCTION AND GOALS

1.1. INTRODUCTION

The traditional radio communication system need to hold the hardware components like the demodulator, detector, filter etc., which makes a platform cost effectively high. The Software Defined Ratio is important for the implementation of the radio communication process with software. This includes the omission of all the hardware and the replacement which is set by the pure software. The device like the A/D converter is found to hold the powerful signal processing where the costs are found to be high. The process of recovering the original message from the modulated waveform is accomplished by the FSK demodulator[1]. Demodulation is needed when the receiver receives modulated signal, it needs to process the modulated carrier signal to get the original data or information[2]. This study attempt to build transceiver based SDR system using HackRF one. FSK modulation and demodulation scheme is proposed. Matlab is proposed to simulate radio communication process. Matlab gives possibility to measure performance and verify the proposed model.

1.2. GOALS AND OBJECTIVES

The goals and objective developed for this particular experiment assist in conducting the study in much detailed manner.
The significant ***goal*** of the experiment is to design a Software Defined Radio for receiving FSK Signals utilizing HackRF One.

The objectives defined for this particular experiment are:

- To determine the procedure for implementing SDR;
- To evaluate the efficiency of the process for developing SDR with the HackRF One;

- To develop the framework for receiving FSK signal through the HackRF.

1.3. LITERATURE REVIEW

[3]defined that the FSK (Frequency Shift Keying) is one of the most general digital modulation Fig 1.1.form observed in the radio spectrum of high-frequency and is widely used in the communication circuits. A receiver in telecommunication technology has the capability of receiving and recovering the information in the original form the FSK signal. [4]claimed that it is significant for the receiver to eliminate the noise from the received signal. [5] defined that SDR is used for deciding the original message from the received radio frequency.

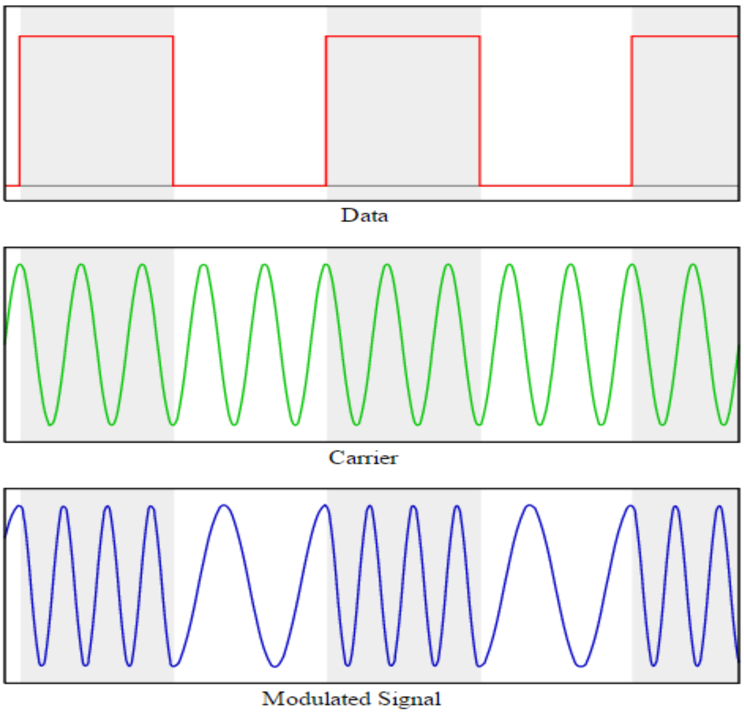

Figure 1.1. FSK Signal Source [6]

According to Garcia, *et al.*, (2016), the concept of the SDR is to implement and intgrate all the hardware component of demodulator, modulator, amplifiers, filters and mixer in one single software module. the experiment with the SDR has provided flexibility to the study by eliminating the need of changing hardware during the experiment. One of the widely used peripherals of the SDR is the HackRF One that has the capability of receiving and transmitting radio signals Fig 1.2. of frequency ranging from 1 MHz to 6 MHz. [7] cited that, HackRF One is a significant next generation technological development that can be modified as programmable application and as a USB peripheral capable of performing stand-alone activities and functions.

Figure 1.2. HachRF One Source: [8]

The introduction of the HackRF One has offered an alternative, yet powerful process for designing a communication system. According to [9]the antenna of the HackRF One is connected through DAC/ADC RF mixer that allowed implementation of the DSP algorithm in the software module.

The receiver module of the HackRF is completely different from the traditional module of frequency receiverFig 1.3.

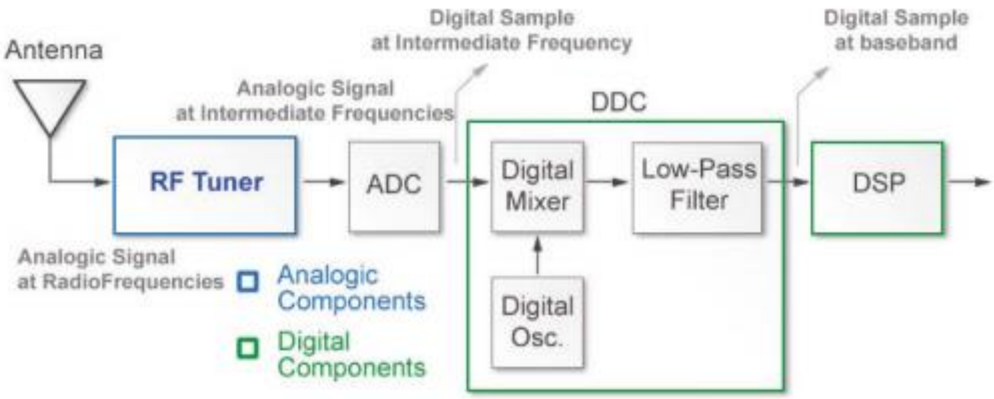

Figure 1.3. Block diagram of HackRF One receiver Source [10]

[3]showed that the radio frequency tuner in the HackRF module assists in converting the received analog signal to Intermediate Frequency (IF). In addition to that, [4]cited that, when the signal is passed the to the Analog to Digital (ADC) Converter in order to change the domain of the outputted signal.

According to [11] the HackRF One comprises of DDC (Digital Down Converter) forming the major part of the module. [5]has cited in his paper, that the operation of the HackRF corresponds with the analog counterparts of the hardware operations. On the other hand, [6] have observed that the received signals are transferred in the equivalent of the baseband signal at the output of the digital mixers. Within the HackRF, the most commonly used process is the decimation that reduces the frequency of sampling or the rate of sampling. According to [12].the approach for receiving signals through HackRF can be applied with the reduction of noises without affecting the quality of the received signal.

CHAPTER 2

SDR

2.1. SDR: THE BASICS

The work has been on the Software Defined radio which holds the component that has been set in the form of hardware like the mixers, filters and the amplifiers. The setup is through the software defined process after the deployment. For this, there is a need to make use of the HackRF ones for handling the data transmission. In order to handle the transmission of the data, there is a production of the carrier signal such that the receiver can easily detect. The signals are found to be sinusoidal and the frequency is the receiver. Hence, the encoding of the data is for the signals which change with the amplitude, frequency or the signal phase. The interfacing of the SDR hardware with GNU radio can be used for the source and the sink blocks which are mainly depending on the receiving or the transmitting. The parameters for this are the centre frequency, sample rate and the gain. The format has been for the feeding and then receiving the data from the radio which is a complex data sample. SDR has been the most powerful and the fully featured alternative which is able to handle the analog and the communications for the digital pattern. [13] . There have been array of the hardware for supporting the SDR instructions and then spanning the range for the different capabilities and the price. The higher capability system is to include the network series with the Universal Software Radio Peripheral platform which is set to allow the complete standalone radio system that needs to work on processing of the larger portions. The midpoint systems have been for the HackRF one which is able to handle the capability of receiving and transmitting, where the sample rates are for 20MS/sec. The operations are set for the RealTek RTL 2832U where the sampling is for 2.4MS/sec and the operations are up to the range of 2GHz. Here, the software is able to support the system with doubling of the usage spectrum. The ability to work on the customer routines like the C++ or the option to use the GNU radio signal processing with the linking of routines to the hardware. The major focus has been on the use of the graphical development where the GNU Radio Companion or MATLAB Simulink is able to allow the students for easy configuration and linking communication blocks. The open source modules are also available to connect to the communication system with the lower cost antenna, where there is a willingness for the transmission and the receiving of the communication signals. [14]. The description has been based on the features, costs and the capabilities for the SDR systems. The goal is mainly to provide the implementation of the communication of SDR where the tools have been able to handle the instructions in the university. This also includes the transmission and the signal reception which is for the analog and the digital system communication process.

For example, in the radio pipeline, the packet of the data is sent over the air modulation with FSK. Then, it is seen that there is a need to focus on the phase derivate where there is a possibility to control the frequency. The samples are found to be generated at a fixed speed so with the change in phase, there is a need to increase the consecutive samples with the increased frequency. The demodulation will have to handle the filtration of the noise and the other unwanted signals. for the filtering, one can work on the combination of the band-pass filter where the filters need to handle all the unwanted frequencies with which the filter sample are set with the amplitude that is below the threshold value. The frequency shift keying is the process for frequency modulation where the digital transformation is based on the discrete frequency with the change of the carrier signal. The technology is based on the system to communicate like the caller ID along with handling the broadcasts for emergency. The focus has been on the open software with the setup of the cross-channel connectivity patterns. This help in handling the secondary goals with the proper production of the demonstration radio. The development for the standard interface is for the different modules which are for controlling the modem and then managing the resources which are set for the schemes of modulation and demodulation [11]. The key processing and the management of the cryptographic functions help in voice processing and the human interface that provides the local and the remote controls. The routing module for the network services are set for the communication without any centralised operating system. The performance of the receiver of SDR is also directly related to the handling of the dynamic range patterns where there has been utilisation of the ADC methods. The SDR works on the use of the PC sound radio system where the embedding of the higher performance is mainly to provide the dynamic range which is directly resistant to the noise as well as the RF interference. The working and the performance is for the DSP that will help in operating the software specific radio hardware. There have been different software radio efforts which are mainly to use the open source SDR library factors. With the changing times, the performance of the demodulation, filter and the signal enhancement helps in improving the digital modes like the radio teletype and the slow scanning of the television as well as the packet radio. The broad range of the hardware solutions is to work on the transceiver solutions and working on the professional receivers that will have a coherent effect on the multi-channel SDR receiver with the shorter waves or the VHF. The discovery is based on the lower costs where the GNU radio is used for the handling of higher speed set of the Analog to the digital and then digital to the analog converters. The higher performance SDR is also important for projecting the use of the different range of the converter that is able to provide the performance over the effective range. The comparability of the receiver is to operate in the VHF pattern and the UHF approach with the mixer image that is set through the USB 2.0 interface. The modular are mainly for accessing the browser with the multiple SDR receivers to cover the shortwave spectrum. [15].

2.2. ARCHITECTURE OF SDR

With the powerful alternatives to the communication process and system design, there are hardware set to implement the performance of the communication. This is set for the radio-specific modulation scheme where there is a limitation for the frequency range. The SDR system is able to easily offer on the flexibility pattern with the software functionality set for the modulation and the demodulation process. The connection is to the antenna through RF mixer where there has been a higher speed of the ADC or DAC. The SDR process has been set for handling the signals of communication with the use of DSP algorithms. The sampling rates with the larger segments could easily be manipulated through the processing. The powerful concept has been for the handling of the scheme change, where the DSP software could easily be loaded for performing all the necessary processing and there is no major need of the modifications of the hardware. Hence, the approach for the adaptability, with the shortened development reduce the costs and the complexity patterns as well.

The major advantage of usage of the SDR has been in the commercialised applications which directly apply to the academic settings. The work has been done based on the Universal Software Radio Peripheral platform which is important for the communication along with using the GNU radio software. [16]. The use of the other adaptive approaches and the hardware platforms is set for the performance of the SDR functions, in an effective and appropriate manner. The designing of the system is based on the hardware manufacturing process where there is a continuous development of the features that add on to the regular basis. The radio patterns do not specifically need to work on the software where the software supports from the manufacturers along with the simple soundcard radios. The versions of the software are mainly designed to work on ensuring the SDR solutions with the third generation CPU that are for the new SDR receivers which will also offer the bandwidth along with effectively processing the power. The paper focuses on the performance which could easily be implemented and set through the Universal Software Radio Peripheral. The evaluation is based on the Packet Error Rate which is evaluated depending upon the differential quadric-phase shift keying, Gaussian minimum shift keying and the packet error rate. The simulation process and the technology promises to solve and work on the functionality problems in an effective manner where the system tends to take up for the different personalities as per the software modules. The development is for the investigation with the hardware and software process which includes the use of communication system. The research is based on designing the SDR platform with the computation from the software algorithm. The expected bit rate for the SDR is 256 kbps where the research is based on the communication protocol like the TCP/IP. The setup is for the wireless communication system and to setup the cable network connections which could not be easily used for the digital wireless communication system. The configuration process is based on the modulation and the demodulation process where there are structures for the ADC/DAC to determine the analog and digital world. The charge is mainly related to the configuration, scalability and the multi-mode method that will help in accessing the points through the software.

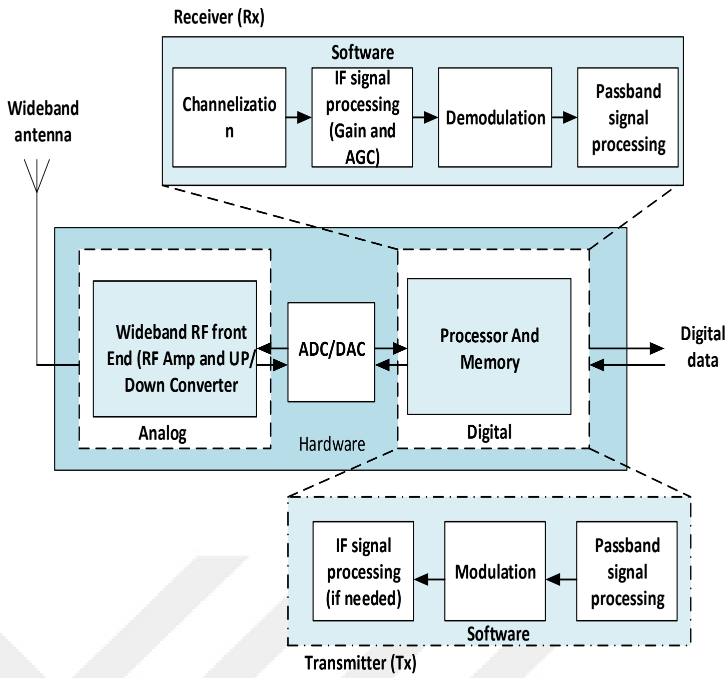

Figure 2.1. SDR Hardware and Software Architecture

The architecture is based on the hardware and the software configurations Fig 2.1. where the computation is based on the sampling rate with the IF section to handle the hardware architecture. The limitations are based on forced implementation process which is found to be difficult than that of the Nyquist sampling rate.

2.3. SDR HARDWARE

With the different range of the SDR systems, there have been easy adaptations of the different capabilities of the devices with the performance that has been described. The major concept is related to the consideration of the performance of SDR where there has been inherent inverse relationship of ADC/DAC resolution and the sampling rate. The higher the bandwidth does not direct show that there is a high performance as well. Hence, the high end classes of SDR works on the characterisation of the operations of wideband. These are set with the full-duplex RX/TX and the higher signal to the noise ratio, higher bandwidth with the host interface and the modular hardware. The class of SDR has been set with the high end characteristics where the major capability is of the half-duplex communication or the lower quality of RF and ADC/DAC components.[17].

The interpretation has been for the usable bandwidth for the system which varies depending upon the series model like the RF daughterboard. The RF front end includes the down conversion and the filtration which is mainly to translate all the spectral band centre frequency to DC with the frequency resolution that equals to simple frequency. The complex valued is the complex sampling which represents the data set up to the sampling frequency. The complex valued setups includes the violations of the Nyquist Sampling Theorem where the explanation is based on the approach for the SDR system. The three factors are for the determination of the usable bandwidth with the Analog Bandwidth which is completely based on the filtering characteristics for the RF frontend daughterboard with the down conversion. The mid-range of the system is full features where the functions are the transceivers with the wider sampling rate and the spectral band. The device is also able to offer the terms which are for the RF frontend configuration and the hosting of the interface. The devices are still able to offer the SDR functionality based on the capability which is set with the same tools and pattern at a lower pricing point. Some of the examples for the system include the frequency range with the range of 70MHz to 6GHz, HackRF One with the frequency range of 1MHz to 6 GHz half duplex bandwidth.[18]. The description for the HackRF one system is based on determining and handling the laboratory environment. This is based on operating the TX or RX modes where one cannot perform the USRP half-duplex and the full duplex. The HackRF is the open source hardware platform which can easily be used for the laboratory environment. The important consideration has been that HackRF One is able to operate in the two modes and can be used as a USB peripheral or the programmed approach for the operations. There have been different schematics which are found in the GitHub Repository so that the entire structure is improved and worked upon as per the requirement. The RF frontend features has been set with the programmable approach with RX/TX gain and the baseband filter. The advancement of the applications like the radar is used with the clock in and out lines. These are able to provide the HackRF One for the timing synchronisation in the different devices.

The USRP, where all the RF and digital setup of the components is based on the PCB. There have been specialisations of the RF filters which are not swapped in and out, and will directly reduce the entire signal to the noise ratio for the applications.

For this, the device need to be used for the wideband SDR where the custom built external front end filters are best technique for handling the general purpose of SDR. The placing of the filters in between the antenna and SMA input of the SDR works on the reception with the improvement of the interest bands. [19].

2.4. SDR SOFTWARE

The discussion has been for the communication system as well as the system development. This is directly associated to the requirements of the system host and the system configuration where the valuable tools are important for the free non-commercialised use.

The analysis of the software is with the freeware communication program that has been set based on easy interface with the support to the SDR hardware. With this, there have been programs like the Linux or MAC OS programs which are able to handle the support as well as the installation of the SW drivers. The process includes the transmission and the receiving process where the base band signal processing is mainly for handling the incoming data and the information. This will also help in modulating the processes with the change in the IF carrier signal and then converting them to a RF signal, and then sending the signals of the RF into the channel for communication. With this, the digitizing IF signal, demodulation is for extracting all the information and then working on the base band forms to process all the real information that has been sent by the transmitter.

The connections are mainly to the SDR which is set through the host interface where there have been different signal processing functions to handle the functionality along with the different additional plugins. The use is based on the crystal frequency with the RTL-SDR tuner which is important for the performance with the use of the narrowband frequency. The NWS broadcast station with the demodulation schemes have been set to include the broadcast of AM and FM (Mono and stereo) process. A proper analysis is based on the capabilities which include the spectral analysis of the tool like the FFT and the waterfall plots with the adjustable filtering. The development of the software includes the signal processing tool for the SDR development which is the GNU Radio which is found as a free open source program with the setup of the larger online supporting community. [20]. The GNU Radio

Servers have been set for the signal processing engine with the examination of the host computer. The SDR hardware is able to provide the RF front end and the digitization where the GNU Radio also is able to run on the simulation mode mainly without the SDR hardware connection or mainly from the recorded data. The software is also able to provide all the important drivers for the communication with the SDR hardware as well as the host system. The signal processing blocks are mainly for encoding, modulation, filtering and the other functions.

The installations of GNU Radio on Windows which is involving and prone to issues which has not supporting by GNU Radio community. When the bug occurs, there have been users to create a better solution. The elegant workaround is for the Windows based, where the Linux OS which has a compact installation on a lower cast USB thumb drive. The enough space for the GNU Radio suite, test data and the other storage. The order of the computer is set with the configuration to properly check on the USB by driving them first and then the user simply use the primary storage device. The operation speed which has not been negatively affected by using the thumb drive where the suitable freeware choice with the Linux OS which includes the Pentoo and Ubuntu. The creation of USB bootable Linux image which has been set to use the third party program after properly obtaining the Linux OS that was from the distribution website. [21].

The software for the GNU Radio is set with Python and C++, where Python has been for the glue coding and the C++ performs works on heavy signal processing. The additional user generated custom signal with the processing of the blocks that includes the Python or C++ that adds to the signal chaining. The GNU Radio has been set for the functions with the generalised signal processing applications and communication that includes the optimisation and making GNU Radio higher modular. The major advantage is for the run time scheduler where the optimisation of the data flow between processing blocks, thereby, creating a proper robust and a real time testing environment. The communication system development is using the GNU Radio is set for the simplified pattern with the use of the GNU Radio Companion (GRC) where the user interface for GNU Radio. [22]. Here, the users are working on placing functional blocks that has been set for the processing chain which flow graph. The blocks exist for the different communication system that requires the users to easily configure the blocks with parameters set a particular system. The desired user can create a customised graphical flow block which is in Python or C++, where the blocks are available through the community users by default in GRC. The formalised, organised and documentation where the free open-source initiative with the motivation is to create and maintain the document which is lower understandably. The GRC blocks are for self-documenting where the user can easily study the underlying codes which can create the block for better functionality understanding [23]. The drivers are set with SDR transceivers exists in source block in GRC where the simple dragged for the flow diagram. The configuration includes the user preference and the hardware where the SDR device where the GNU radio and GRC was set at the Osmocom source.

The decimation and choosing the flow graph sampling rates with the configuration of RF source block, with the considerations are for the signal bandwidth. There have been other neighbouring signal bands that need to be taken into consideration with the system to take advantage for the wideband visualisation capabilities. The desired bandwidth needs to be determined with the decimation has been for the use of the signal processing workload on the hosting machines. The visualisation is based on the whole band of FM where the radio signals are set for the practical needs to feed the data into the demodulator of FM. The decimation has been set with the sampling rate that is higher to support the bandwidth with the communication channel.

The central frequency has been set for the SDR system which directly corresponds to the frequency which is based on the chosen bandwidth that has been in the middle. The demodulations are for the schemes are set with the analog FM, where the central frequency are set with the matching of the advertised frequency along with handling the signal transmission. [22].

2.5. SDR EXPERIMENTS AND PROJECTS

For the proper working of the system, there is a need to offer the instructions for the areas of the analog and the digital communication process. Hence, for this, one need to work on the SDR-RTL process with the receiver development. One HackRF is important for the transmitter process with the outfit which is set at ANT500 antenna. The workgroup needs to properly access the computing workstations as well as running the Windows OS for the computer where the SDR has been for the signal analysis. One need to handle the flash drives with the Pen too Linux that has been installed along with including the pre-installation of the GNU radio. The necessary SDR hardware drivers are important for the enough spacing which exists on the storage of the data for the flash driving and the other multimedia files [24]. The recommendation is based on allowing the students to properly perform the analysis and work on the generation of the transmitter and the receiver communication system. The workgroup requires on 8GB think driver with the Pentoo Linux installed where the pre-installation has been of the GNU radio with the necessary SDR hardware drivers. The space has been for the flash drives along with the storage of the data and other multimedia files for the experimentation. The success recommended configurations are based on the different variety of the analog and the digital communications which are for the communication process. it includes the AM and FM along with the baseband of the digital communications and the pulse BW/shaping which is set into the band pass of digital communication like ASK and PSK. The performance is for the noise and the advancement is based on Spread Spectrum or OFDM as per the introduction.

The SDR has been working on the FM radio which is strongest for handling the radio signals. This is set in the range of the RTL and SDR where the choice of the signal is mainly to demodulate the introductory lab. The GNU Radio companion has been for properly creating the FM demodulator which is simple. The major significance is for the blocks which could easily be demonstrated through the use of the SDR that sets a regard for the RF visualisation techniques to properly understand the GRC flow graph. The focus on the modulation and the demodulation of the double sideband where the suppressing carrier and the broadcasting of the AM signals is set. The utilisation of the HackRF One for the transmission and the RTL-SDR for the receiving and transmitting the signals. [25]. The observations are based on AM which can easily be exercised along with handling the broadcast of the AM, and utilisation of the blocks in GRCFig 2.2. The attempt is mainly to tune in the broadcasting of the AM signals that has been set in the particular regular band with the HackRF and the antenna which is able to receive the lower level of the frequencies.

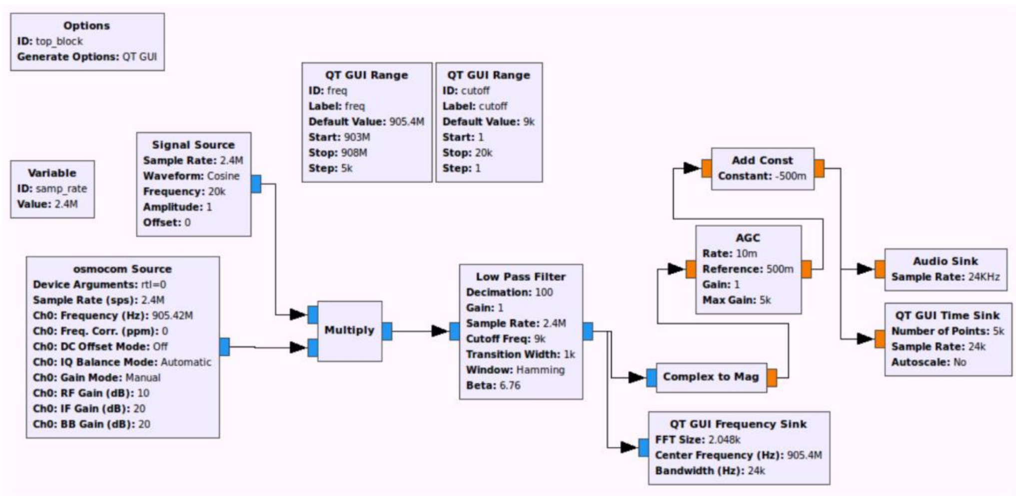

Figure 2.2 GRC Flow graph DSB-SC Demodulation [13]

There has been a deeper frequency modulation where the usage has been for the limited block numbers. This need to work on creating a narrowband FM with the standard block and the increase in the modulation index. The methods are for the Armstrong where there is a need to generate the wideband, stereo FM and the transmission which is set with the HackRF One SDR. The lower power vision for the broadcast is set along with tuning on the conventional FM radio. The patterns are set for the flow graph mainly for the WBFM generation Fig 2.3.

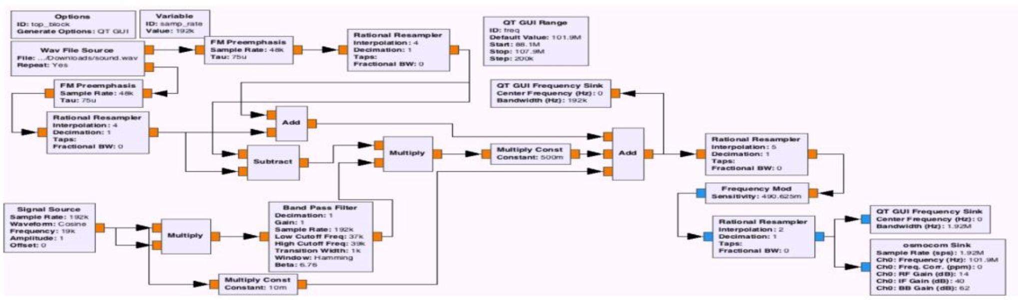

Figure 2.3. Wideband FM Modulation on the HackRF One SDR [13]

2.6. HACKRF FOR SDR TRANSMITTER AND RECEIVER BASED FSK SCHEME

For the hybrid approach, one needs to work on the SDR which is important to understand the receiver which holds the range of the radio frequencies for the acquisition duration. The sound is able to capture the different audible range of frequencies at the time of recording which also holds the capturing of the radio signals which are presented in the different range of frequencies which are tuned to. The spectrum is based on the digital waveforms that are produced by the receiver where the demonstrations are based on the capturing waveform and visualization. For capturing the signal, there is a need to plug in a HackRF or any other form of the SDR platform which will be through the setup of the simple software tool for all the real time visualization and acquisition process. This will also help in setting the frequency and the sampling rate so that your signal of interest is set in a specific displayed bandwidth. The entire captured bandwidth has been equal to the sampling rate so that the major benefit is possible for the target frequency. [26]. Hence, to handle the FCC Equipment Authorization Access, there have been proper sample rate settings which are based on controls of the filter in the analog domain. The signals hold a closed range with a greater power than the signals that are set form a distant transmitter. The signal of interest is able to spend the time adjusting the gain settings which will also give a clean acquisition. Like the SDR receivers, HackRF One is able to set the architecture which results in the spike where there have been captured bandwidths. The spike is set to handle the hardware and the software that directly affects the signal received. The development of the visualization process of tuning helps in setting the gain and frequency development. The optimal signal acquisition works on the receiving of waveform which is set until one click stop. The steps for the signal processing with SDR is to handle the efforts to properly determine the data encoding and the alignment through byte, forwarding the error correction, checksum and the encryption and then the whitening process which often takes longer. The efforts are based on analyzing the encoding of the data which can be hampered. [27]. The example is related to the difficulty with the recovery set for the transmitter symbol clock that causes the inability to convert the waveform in the bits. The SDR works on the reverse engineering efforts where the approach is mainly to use the SDR and the non-SDR tools. The platforms like the YARD stock one which is important for providing the wireless transceiver IC is helpful to handle and work on the hardware. The compatibility is set with the wider range of the digital radio systems which are found of the lower costs and the lower speeding systems. The transceiver ICs are able to perform the job of the recovery of the clock which can easily provide the binary data and then capture the different packets with easy comparison. The hybrid approach is based on using the SDR and the non-SDR tools which can be set with the wireless security setup. This also includes the approach for the approach in reverse engineering where there have been remote keyless entry systems. HackRF one works on the architecture which represents the results based on captured bandwidth. One is easily able to notice the importance set for the visualization process along with frequency tuning planning and setting the gains. The optimal setup of the signals is for the recording of the button in the lower corner. For this, the file is properly able to grow at a rate which is at 8 bytes per sample. The file grows at a particular rate with the maximized capturing duration that has been set with the sample rate pattern. [28]. The visualization is for the saved waveform in the spectrum where the focus has been on the primary features of the spectrogram. This will also help in displaying the time on the axis and the frequency. The power of the signals has been set based on the operating frequency, modulation and the symbol rate. This is important for the proper configuration process with the lowering of the data rates. The modulations are important and easy to identify where the on-off keying is found to be most common lower speed digital wireless system. It is important to handle the amplitude shift keying process which is set between the pulses to have lower amplitude. The modulations could easily be supported by the wireless transceiver ICs and can easily work on the spectrogram. The FSK works on the faster symbol rate and the sophisticated modulation process where the wireless transceiver IC is for the higher sample rate capturing. There have been characteristics that indicate about the data bits which are encoded in the raw symbols. The Non-Return-To-Zero has been the high symbols which represent the lower symbols which is a zero. This is for the scheme setup for FSK that has been important for the long sequence of the zeros from the gap between the packets. There has been Pulse Width Modulation which is set at a shorter pulse which represents the zero and the longer pulses represent 1. The PWM system has been set for the interval duration which is at every pulse and it is important for following the short pulses with the short intervals following the long pulse. The Pulse Interval and Width Modulations has been set for the pulses and the intervals which is set in between the pulses that carry the data. This completely varies in the duration but there has been no representation of the duration that is set for these features. The encoding scheme has been set for the Pulse Position Modulation which is a consistent duration that represents zero or one. The cases are related to the unmodulated factors where the reference pulse includes the different in between the modulated pulses. [29].

The encoding is important for FSK as this helps in handling the binary symbols along with pair 10 which represents the zero while 01 represent the one. With the observation, it can be seen that the packets start and can be recognized based on the symbols setup. This is based on the synchronization of the word and the accessing of the code or the frame delimiter. The syncing work is mainly for handling and composing the non-repeating groups of bits along with setting the sync word which could be repeated. The receiver also gives the opportunity to properly determine the symbols with the start of the data packet. One can work on the needs with the easy configuration process with the wireless IC. For the SDR, which is a hybrid approach, one need to determine the software tools which are important for the tasks to handle the spectrum monitoring software. This will help in detecting the operations of the system target. The clock recovery implementations and the synchronization is in the packets where the packets are set at no preamble. The SDR software frameworks are like GNU Radio which is able to make the experiments with the packet data to manipulate the data streaming process. The visualization of the signals is set for the in spectrum which also includes the functions for the demodulation of the packets. This will help in classifying the modulations and work on the packet decoding process [30]. The software tools are set with the wireless transceiver ICs which will automatically be able to detect the modulations with the easy try to support the checking. It will also yield the best result where there have been limited in capability. The converter is set with the combinations that cover more than the range of 70 percent of the HF range from 3 to 30 MHz. The setup is based on the wireless communication where the modulation process is mainly generated through the receiving of the uses of the computer to properly recover the signal intelligence. This also works on the transmission of the antenna and working on designs that could easily intercept the voice of the SDR signals along with the employing of the stages of receiving the antenna that boosts all the incoming RF signal strength along with maintaining the constant frequency. With this, the demodulator also separates the ASCII intelligence from the RF carrier that will generate the voice waveform also. The significance is based on the wireless systems that employ the protocols that have been varying from one to the other service. There have been change in the service types with the modulation protocol mainly involving the selections and the launch of the computer program [31]. The SDR works on providing the single radio transceiver that has been able to handle the roles of the telephone, cell phone and the wireless transmissions. The GPS systems are for the functions with the operations from the locations set on the surface. SDR also works on the communication between the receiver and the transmitter into the digital style. This helps in holding the conversions which is connected to the antenna. The setup is taking place in the digital domain where there have been different types of the personal computers with the higher performance of the gear. The SDR approach is found to be more common as per the expectations. The software waveform portability is through the cost savings where the waveforms are for the transmissions and the costing of the huge sum mainly to develop the need and the ability to reuse the waveform. The mitigation comes with the hardware technology along with the necessity to transfer the waveforms into a newer platform. It will also be able to provide the interoperability to the customer depending upon the request of the use of the particular waveform that is being used in the equipment for the several manufacturing processes. The SDR works on the portability which is not easy to achieve always. Hence, it is important to incorporate the optimized levels of the portability which will help in setting the different forms of the middleware that are associated to it. There have been other techniques where the testing is used for the waveforms from one radio or the platform. It is important for undertaking the testing as it will make sure that the code has been successfully transported from one to the other platform. This also corrects the functionality and working of the waveform which depends on the different cases. The consumption of the power and processing the same is through the needs which are made at the base stations where the power consumption and space are not normal issues. With the progress in the technology, the decision has been made to make more use of the SDR where the decisions are also made for the change which is few and not right.

2.7. SYSTEM CONFIGURATION

The standards are set for the USRP GNU platform where there are up/down converter to handle the configurations through the use of PC processor. The Software Radio tends to work on the configuration with the implementation in the A/D or D/A process Fig 2.4.The mainboard specifications are for the research where the USB 2.0 port is for the connection to the computer and the 12-bit ADC is with the speed of sampling of 64 Mbps. The principle is set with the digitalization process with aliasing process to conduct 32 MHz.

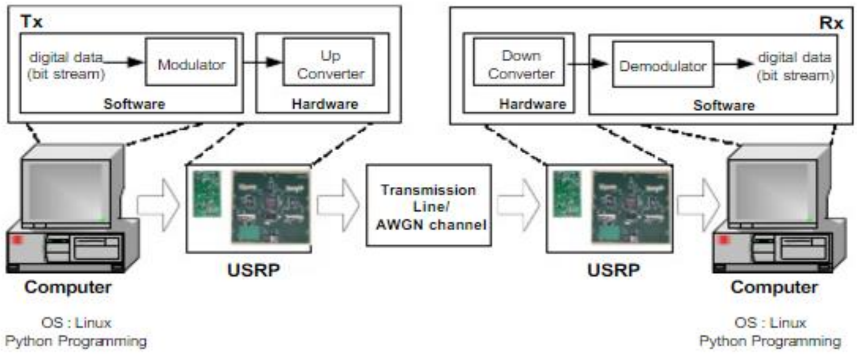

Figure 2.4. System configuration of SDR platform

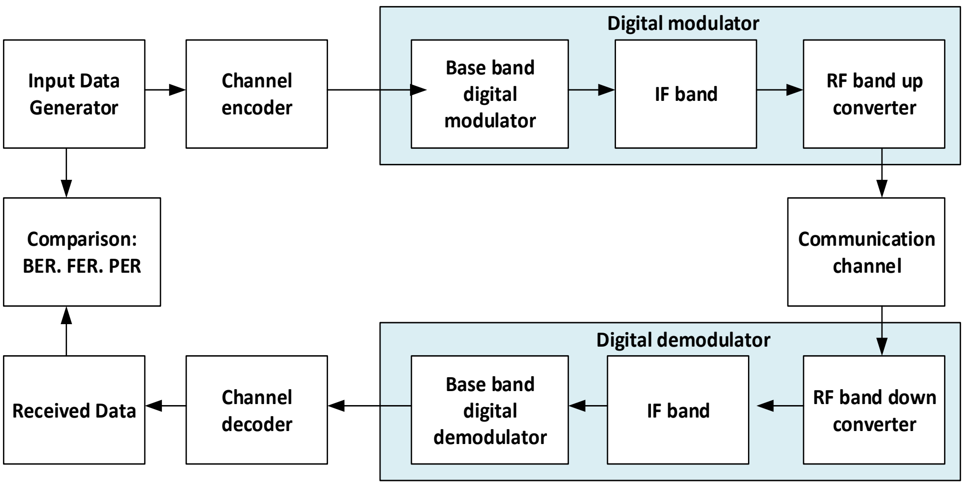

Figure 2.5. Method of performance measurement

The implementation of the research is based on the Packet Error Rate scheme where the data tends to work on the integration mainly with the TCP/IP protocol for a better development. The digital processing is mainly to execute the implementation and facilitate the SDR software integration with the TCP/IP for the proper development of the nodes. The experiments are set for the performance through using the USRP digital communication with the coaxial cable that has been used to connect the transmitter with the receiver Fig 2.5. The experiments are carried out mainly to observe the Packet Error Rate which is stated under the change of the bit rate and the frequency process, filter coefficient and the gain size.

2.8. RADIO FREQUENCY

It is for handling the electromagnetic wave frequency which mainly lie in the range that has been set in the range which mainly extends from 3KHz to 300 GHz. It includes the frequencies which are for the communication and the setup of the radar signals. The mechanical system is set for handling the rate of oscillations with the radio frequency. It mainly described the communication as opposed to the communication through the electric wires. The electric currents are set to oscillate at the radio frequency which has a special property that is not shared by the direct current or any alternating current factor which is set at the lower frequency. The energy in RF has been set for radiating off the conductor which is set into the space for the electromagnetic waves. The RF technology does not penetrate into the electrical conductor but it mainly tends to flow along with surface. Hence, for this, the RF currents are mainly applied to the body which does not cause it to be a painful sensation of the electrical shock. The RF works on the ionization of the air with the creation of the conductive path that is set through it. The high frequency units are mainly for the electric arc. The radio communications are for receiving the radio signals and working on the use of the antenna. The antenna is able to pick up the signals and work according to the tuning effect as per the necessary pattern. This is through the resonator which is considered to be the simplest form where the circuit has been set with the capacitor and the inductor. The resonator is able to amplify the oscillations and work on the frequency band. The distance which is set over the communications of radio is depending upon the wavelength like the transmitter or the receiving of the quality, type or the size. [32]. There have been setup of the ground waves and the sky waves which can be able to achieve the greater ranges than the line-of-sight. There have been greater ranges which are found to be useful.

The radio frequency measurements are for the electric and the magnetic component which is set to properly express the radiation intensity field. There have been other characterizing factors for RF Fig 2.6. which are set under the power density which are found to handle the accurate point of measurements which are far from the RF emitter to be located in the far field zone. The relationship is based on the field strength units as per the discussion. It is considered to be the smaller electronic device which has been for the transmission or the receiving of the radio signals. This has been mainly important for the communication with the devices that have been set in a wireless connection. The communication is mainly important for the applications where the medium of choice is RF as it does not need any line of sight. With the setup of the RF modules which are used for the proper radio designing. The components and the layouts are set mainly to achieve the operations which are of a specific frequency and for the careful monitoring process. The radio frequency modules have been mainly used for the electronic designs that owes to the difficulty range of the designing of the radio circuit. The performance is based on the usage of the medium with the lower volume of the products for the consumers. The replacement of the older infrared communication designs without light-of-sight operation. The transmitter, receiver, transceiver and the system on the chip module is important for the huge functionality and the capability. This is important for handling the transmission or the receiving of the circuit based on the hosting processor. The transmitter modules are set which are able to handle the radio waves and then modulating the same for carrying the data forward. The modules are implemented with the micro controller which also helps in the data that could easily be transmitted forward. The transmitter modules are set with the capability to wave the carrying of the data, where the modules are also set for the performance over the super-regenerative part with increased accuracy and stability. The modules incorporate the transmitter and the receiver where the signals are half-duplex operations and the full-duplex are also available with the higher costs patterns. [33].

The RF device has been set to handle the performance which depends on the different factors which include the increasing power of the transmitter and the larger communication distance which can easily be achieved. The higher electrical power drain is set on the device of the transmitter with the use of the power which will make the system more prone to the interference. The increasing sensitivity will also help in increasing the effective range of communication that directly causes malfunctioning mainly due to the interference with the other devices and RF.

The performance of the system can have a major impact on the labelled remote distances with the connection set through the whole technology. The module allows insetting and removing the setup which is attached to the PCB without any assembly step. The RF module has been mainly to operate the radio frequency where the corresponding frequency range varies and the representation of RF is better than from the IR. The signals are easy to travel through the larger distance which is important for the longer range of the applications. The operations are set in the line-of-sight mode with the RF signals that can even travel without the obstruction between the receiver and the transmitter. The communication also consists of the frequency which is set to use the pair of the encoder and the decoder (Table 1 and 2). The encoder is for the parallel data where the reception is mainly decoded by the decoder [34].

Pin Diagram:

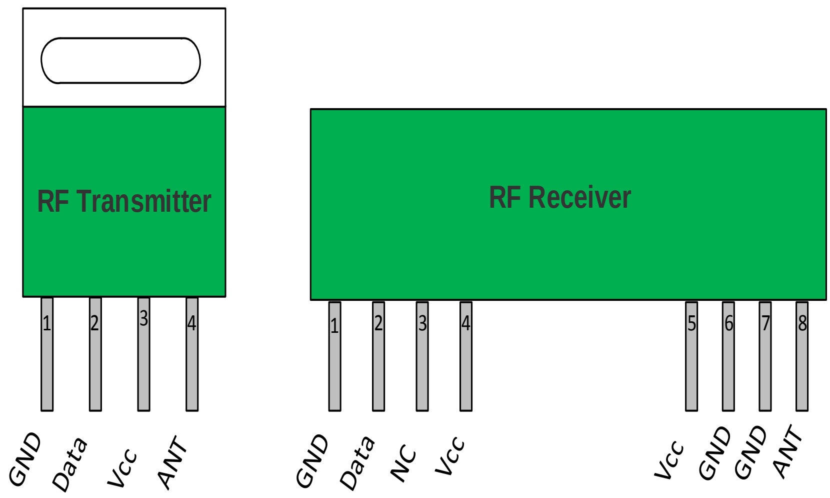

Figure 2.6. RF Transmitter and RF Receiver

Pin Description:

RF Transmitter

Pin No	Function	Name
1	Ground (0V)	Ground
2	Serial data input pin	Data
3	Supply voltage; 5V	Vcc
4	Antenna output pin	ANT

Table 2.1. Pin Description of RF transmetter

RF Receiver

Pin No	Function	Name
1	Ground (0V)	Ground
2	Serial data output pin	Data
3	Linear output pin; not connected	NC
4	Supply voltage; 5V	Vcc
5	Supply voltage; 5V	Vcc
6	Ground (0V)	Ground
7	Ground (0V)	Ground
8	Antenna input pin	ANT

Table 2.2. Pin Description of RF Receiver

The wireless system has been working on the operation of the certain distance and then transferring the amount of the information which is set at a particular data rate. The RF modules have the transmitter which has no power when there is a zero transmitting logic. This has been set for handling the data which is sent in the serial form mainly from the transmitter which is then received by the receiver.

CHAPTER 3

FSK

The frequency shift keying process is mainly to set the transmission of the digital signals. This is mainly in the analog waveform which is important for the specific frequency range. The modem is able to convert the binary data to FSK for handling the transmission over the telephone lines or the wireless media.

3.1. CONTINUOUS PHASE FREQUENCY SHIFT KEYING

With the changing principles of FSK, the implementation is based on the free running oscillators where the switching is mainly set at the beginning time. Hence, with this, the FSK transmitters are for the single oscillator to handle the switching process for the different frequency. The elimination in the phase completely reduce the power of the sideband and there is a reduction of the interference that has been set with the neighboring channels. The modulations are based on the digital transformation where the changes are for the carrier signal. The technology is also used for the amateur radio with the broadcasting frequencies to transmit all the 0s and the 1s information. The principle setup is for the free running of the oscillators and then switching them in between for the particular symbol. There have been switch over the instant that cause the discontinuity over the signal set over the transmission. The FSK works on the use of single oscillator and then processing the switches for the beginning with periodic preserves of the phases. It will also reduce the sideband power, and then reduce the interference that comes with the other neighboring channels.

3.2. GAUSSIAN FREQUENCY SHIFT KEYING

With the change in the setup of the GFSK, the filters are set for the data pulse with the filter of Gaussian to handle the transitions in a smooth manner. It also encourages the sideband power with the reduction based on the neighboring channels. The costs are set to handle the inter-symbol interference. For the modulator, the GFSK has been set from the simple frequency shift keying which is at a baseband waveform at -1 and +1 level. It passes mainly through the Gaussian filter to handle the transitions which are smoother to work on the spectral width. The ordinary setup of the non-filtered FSK has been for the modulated waveform change with the introduction of the larger out-of-band spectrum. The Gaussian filter is set with the digital data that is for changing the frequency and to handle the symbol periods. The data pulses are holding the transitions in a smooth manner with the reduced sideband power and reducing the interference with other neighboring channels. The setup is based on the modulated waveform change which will also introduce a larger out-of-band spectrum.

3.3. MINIMUM SHIFT KEYING

This is considered to be efficient for the coherent FSK where the minimum shift key process has been set with the difference between the higher and lower frequency which is identical to half the bit rate. The waveforms are representing the 0 and 1 bit which differ by half the carrier period. The audio FSK has been set as the modulation technique which is able to handle the modulation by which the digital data could easily be presented with the change in frequency. The audio alternates in between the tones and the mark clearly represent the binary one. The AFSK has been differing mainly from the other regular shift of frequency where the performance is set at the baseband level. For the radio applications, the use is mainly for the modulation of the RF carrier like the AM or FM for handling transmission. It is not for the higher speed of the data communication as it is found to be less effective for the power and the bandwidth. The AFSK has a major advantage that is able to encode the signals along with passing mainly through the settled AC Coupled links. The system is based on the emergency alert system for the notification of the different emergency types and the locations, with time of issue.

The major applications have been set for the arc converter where the compensation wave was not mainly used at the end of the receiver. The telephone line modems have been set to use the audio frequency shift key for sending and receiving the data as per the rates. The specification of the AFSK modulation is mainly to store the data and then use it to allow the easy transmission through the unmodified voice bands.

There have been certain devices for the discrete selection sampling rates where the instance has been for the sound cards which are based on the operations for the sampling rates which range from 8 KHz and above. The connection stage is based on the Software Defined Radio with the sampling rating that is set at a consistent level. The rate is found to be completely different from the output where the device is different to the input which is set for the other, where the errors generally occur. The system is based on the two-step process where the signal chain needs to work on the sampling rates with the interpolation. The assembling of the system is to match with the speed up or the slowdown audio. The system has not been interfacing with the rate that is set for the limited hardware. [35]The CPU can easily work on the acceleration of the samples which is through the signal chain processing. It is found to be faster than the sample rate of the incoming pattern. In the GNU radio, there is a need to control the situations where the throttle block is able to work on the sample rate parameter where the limits are set based on the sample passing through the blocks. The specifications of the rate blocks are there that do not check for the sample as per the correct time ordering. The throttle block can easily be able to handle the higher usage of the CPU and then the results are found to take place depending upon the system requirement set under the unbounded rate.

The complex sampling is important for describing the maximum sampling which is directly associated to the bandwidth. The maximization of the bandwidth and the higher frequency is available for the device. This is important for the employing of the complex sampling where the concepts of the SSB-AM are set based on the one sideband with the sample spectrum to maintain and so the aliasing factors can be avoided [36].

$$f_{max} < f_{samp} \tag{3.1}$$

For this, the maximum frequency of the signal is found to be less than the sampling frequency. Hence, the chosen rate of the sample is set for the maximised single bandwidth. Here, the arrangements are based on creating a proper I/Q presentation with the real valued setup of x(t)

$$x_{IQ}(t) = x(t) + x_h(t) \tag{3.2}$$

Here, the signal has been the imaginably valued signal which is known as the Hilbert Transform.

$$H(\omega) = -jsgn(w) = \begin{cases} e^{-j\pi/2} & \omega \geq 0 \\ e^{\,j\pi/2} & \omega < 0 \end{cases}; \quad (3.3)$$

The $H(\omega)$ introduce the 90 phase shift over the frequencies, where the possibility is based on the narrowband sampling schemes. The note is about the handling of the discrete time with the digital filters but would be needing a temporary doubled sampling rate [37].

3.4. AUDIO FREQUENCY SHIFT KEYING

The Audio FSK is set with the changing frequency of the audio tone that yields the signal which is for the transmission process through the radio and the telephone. There is a transmitted audio alternate space which marks the binary space with one and zero. There have been differences based on the regular frequency shift keying process which also holds the baseband frequency in different radio applications. The modulation process is for the RF carrier through the use of transmission which could be sometimes for the high speed data communication. There is lesser efficiency in the power and the bandwidth that affects the modes of modulation. Along with this, the simplicity factors are related to the encoded signals which are for the AC links which have been designed for carrying out the music and the speech.

3.5. MULTI FREQUENCY SHIFT KEYING

The variation is set for the M-ary orthogonal modulation which consists of the element of the different waveforms. The power is set for the symbols which represent the $\log_2 M$ bits. Here, the fundamentals are set for the tone transmission with the orthogonal scheme set for the detection filters. The M-ary orthogonal schemes are set with the $\frac{E_b}{N_0}$ ratio which is set where M increased without any symbol coherent detection. The approach is the infinity value which is set with the decreased form of the value and increase in the bandwidth in the exponential form. The values are important for the forward error correction to provide the systematic coding. The angle is set for the higher and the lower group which is set with the digital out-of-band signaling process with the interfering with inter-office signaling. The communications are with delayed spread and the coherence bandwidth which holds the transmission to the receiver which exists based on the multipath. The transmissions are for the propagation delay with the small delay in the differences or the speed. With this, the fading channels are set that effectively impose on random amplitude modulation of the signal. It is called as the Doppler spreading where the frequency is based on the coherence time limit.

3.6. DUAL TONE MULTI FREQUENCY

With the dual tone frequency, there is a voice frequency that has been set for the telephone equipment and the other communication process that use the switching centers. The signaling is for the pulse dialing which is to handle the functions by interrupting the current in the local loop. The Multi frequency is set with the mixture of the pure tone and the sine wave sounds. The channels are set depending upon the radio and the microwave links. The methods are set for the cable television broadcasting to indicate the start and the stopping time of the commercialized insertion point. The telephone keypad of DTMF is for the rows that represent the lower frequency component which also represent the higher frequency of the signal.

3.7. TECHNOLOGY BACKGROUND

The software defined radio has been working for the community development with the use of the devices which is important. This helps in handling and providing the support for better and new designs. The sharing of innovation and working on the embracing of the community along with providing support to the community is important. The open source and hardware is set through the important aspect of the software. The boards are able to mention about the GNU radio which is able to handle the source codes that are free and have an open source. It also contains the GUI for the quick and the better development. The drivers are mainly for the HackRF who are part of the driver package gr-osmosed. Here, there has been use of the communication pattern with the RTL-SDL dongles, where the addition is set within the few weeks and then updated. [38]. The HDL files are for the SDR platforms. The working on the hardware is an important thing for the hardware which also directs to the hack ability. The issue is with the B210/B200 which is AD9361 where the little information has been on IC and the Analog Device website. HackRF has been important for accessing the platform with the radio spectrum at a great price. This is an open source platform which has relatively small and simple size in terms of the ADC/DAC. The RF works on allowing the transmission of the data through mainly the unmodified methods or the voice band equipment. These are set under the transmission of the warning information with a higher rate of encoded signals through the use of AFSK modulation process.

CHAPTER 4

MODULATION AND DEMODULATION

With the radio communication system, the signals with the higher frequency could easily be transmitted. The signals have been for the high frequency which can easily transmitted over the longer range, where the height of antenna need to create a strong signal frequency. The lower the frequency works with high antenna. [39]. This directs to the transmission of the lower frequency signal needs to handle the high antenna which cannot be made out. The signal is set with the lower frequency needs, where the transmission is important for modulation to a higher signal of frequency. With this, the signal is transmitted for the proper communication system of radio. The process is based on the varied forms where the carrier signal works on handling the information that is being transmitted. For this, there are other telecommunication practices, where the modulation is mainly for conveying the message signal to the other with proper transformation process to a narrow range of frequency. The baseband message signal is set into the pass band where one can pass through the filter. The modulator is for the modulation process where the analog modulation will help in transferring the signals with the audio signals or the TV signals. It is mainly set over the band pass channel at the different range of frequency over the limited radio frequency band. The signal is important for carrying the message with the higher frequency cosine waveform. It includes the carrier signal which can easily be transmitted through the air over the longer distance. The entire process is to make the radio frequency need to carry the information with the lower frequency is set in modulation. It can easily be set with varied features of carrier signal where the receiver receives the signal of modulation with the setup of the carrier signal to handle the information which is original. This process is called as demodulation.

4.1. ANALOG MODULATION & DEMODULATION

Here, the process is based on handling the different carrier signal features with the modulating signals. There have been parameters to take hold of the carrier signals which are based on holding the continuous modulation which is analog modulation. The parameters have been set for the amplitude as well as the angle where the angle contains a proper range of frequency with the amplitude modulation and the other parameters are changed [40]. The digital modulation is mainly for the digital bit stream over the signal channels that are able to handle the public switched telephone networks over the limited range of the frequency band. It also works on the facilitation of the frequency division multiplexing where there are ranges for handling the physical medium through the use of the pass band channels over the entire serial bus or the wide local area network.

4.2. AM MODULATION AND DEMODULATION

With this, there have been carrier signal amplitude which varies based on the proportion to the amplitude instantaneous with modulating range of the signal voltage Fig 4.1. The modulation is for the line coding which is set over the baseband channel through a non-filtered copper wire or through the wired local area network. The methods are set to handle the narrowband analog signal over the wideband channel. The amplitude modulation is set in accordance to the modulating signal with the double sideband modulation and carrier scheme that has been set with the suppressed modulation. The digital modulation methods are for the carrier signal with the discrete signal processing. The conversion of the digital to the analog is for the demodulation or the detection which changes the carrier signal depending upon the finite number of M alternative symbols.

Proposing HackRF for SDR receiver based FSK scheme. All the necessary demodulation will be carried over in software environment either Linux based GNU Radio Companion (GRC) or Windows based Matlab. The modulation index has been important for properly describing the degree of modulation. This is based on affecting the shape of AM signals and could easily be expressed as:

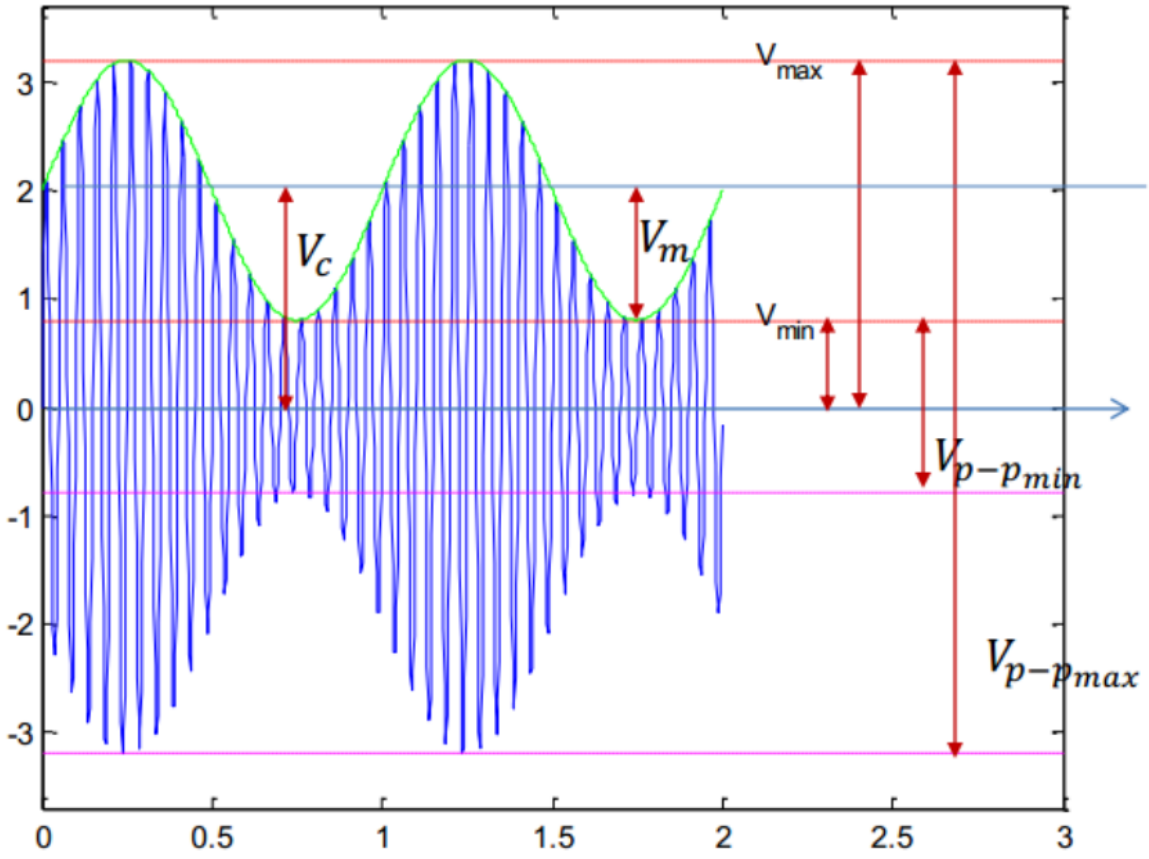

Figure 4.1.Voltage define in AM

$$m = \frac{V_m}{V_c} (V_m, V_c \text{ are seen in the figure}) \quad (4.1)$$

For this, the modulation index needs to be more than 1 where the carrier signal is found to turn off when V_m is found to be equal to the amplitude which is lower. Hence, m is less than 1 where:

$$V_m \leq V_c \quad (4.2)$$

Here, the entire envelop is for the AM signals which works on an imaginary line with the peak value which is set for the wave cycle. The expression is:

$$e_{ENV} = V_c + e_m \quad (4.3)$$

$$e_m = V_m * \sin \omega_m t \quad (4.4)$$

Hence, for the AM:

$$e_{ENV} = V_c + V_m * \sin \omega_m t \quad (4.5)$$

It can easily be deduced from this that:

$$e_{ENV} = V_c(1 + m * \sin \omega_m t) \quad (4.5)$$

For the instantaneous voltage of AM signals, there have been e_{AM} which could easily be for the eveloping and handling the carrier signal set through:

$$e_{AM} = V_c(1 + m * \sin \omega_m t) * \sin \omega_c t \quad (4.6)$$

Here, the e_{AM} is the AM signal which is for getting the information and then using it for the transmission that goes to the receiver. Here, for the demodulation, there have been processes of the different methods which are coherent and non-coherent. The coherent is for using the receiver with the phase of the received signals Figure 4.2.

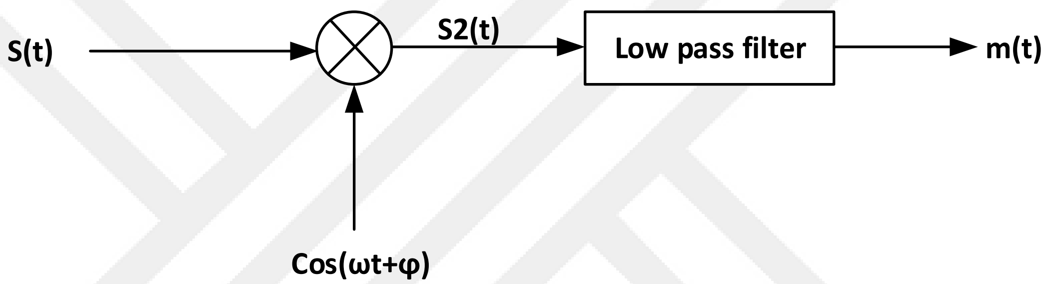

Figure 4.2. Block diagram of coherent AM receiver

As per the analysis, there have been receiving of the AM signals which needs to be multiplied with the signal at the carrier that has been produced mainly by the local oscillator. The entire procedure of the key is that the receiver needs to produce the carrier signal which has a particular phase and the frequency and is same to receive the signal at the carrier. The other non-coherent method Fig 4.3 has been for the carrier signal which is not important for the enveloping line.

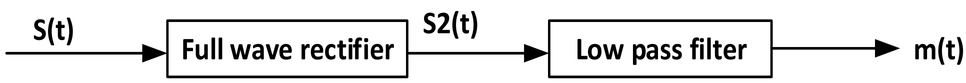

Figure 4.3. Block diagram of non-coherent AM receiver

4.3. FM MODULATION AND DEMODULATION

As per the comparison to AM, FM has been able to handle the amplitude of the carrier which remains completely constant. Here, the variation is in the frequency which is based on the signal that is modulated. The specifications are for the frequency deviation between the carrier signal with the original frequency and the other frequency which is set at the instantaneous level. The after modulation is in direct proportion to the amplitude of the modulating signals.

The concepts are related to the index where there is a difference form AM. In FM, the modulated frequency of the signal has been set with the variation directly from the carrier signal. It could easily be defined to be:

$$m = \frac{\Delta f(maximum\ frequency\ deviation)}{f_m(Modulating\ signal\ frequency)} \tag{4.7}$$

Hence, for this, it can be found that the modulating signal for the cosine works as per the following equation:

$$y(t) = A_c \sin(2\pi \int_0^t f(\tau) d\tau) \tag{4.8}$$

For the instantaneous frequency:

$$y(t) = A_c \sin(2\pi \int_0^t (fc + \frac{\Delta F}{Am} * fm(\tau)) d\tau) = A_c \sin(2\pi f_c t + 2\pi \frac{\Delta F}{Am} \int_0^t f_m(\tau) d\tau)$$

For $f_m(\tau) = A_m \cos(2\pi f_m \tau), \int_0^t f_m(\tau) d\tau = A_m \frac{sin(2\pi f_m t)}{2\pi f_m}$, then we can obtain (4.9)

$$y(t) = A_c \sin(2\pi f_c t + 2\pi \frac{\Delta F}{Am} * A_m \frac{sin(2\pi f_m t)}{2\pi f_m}$$

$$= A_c \sin(2\pi f_c t + \frac{\Delta f}{fm} * sin(2\pi f_m t)\ ) \tag{4.10}$$

Hence, for this, there have been demodulations where the FM can be demodulated by coherent and non-coherent methods. There has been narrow band FM signal with the receiver which is important for the shifting phase. The methods could easily be applied for a particular area. The non-coherent methods have no major limitations and can easily be applied for the narrow band FM and wide band.

4.4. DIGITAL MODULATION AND DEMODULATION

For this, the process is based on handling the digital signals which are for handling the noise immunity, security. The major features of the same are the modulated carrier which is set by the carrier information which are: Amplitude Shift Keying, Frequency Shift Keying and Phase Shift Keying [41].

4.5. BPSK MODULATION AND DEMODULATION

This for the Phase Shift Keying which has been set with the carrier signal phase and vary in between the values as per the modulating signals. This is a 2-PSK which has a value set at a different of 180 degrees. There have been methods to modulate the carrier where the signal bit is 1 and the carrier phase is 1 value. When the bit is 0, then the carrier phase change to some other value. The finite number of the phases are used for the phase shift keying. The QAM is for the in phase signals where the quadrature is set for the different methods of binary units. The frequency and the amplitude is encoding the number of bits where the symbols also represent the phase, frequency and the amplitude. The $M = 2^N$ is for the message that consists of the N bits where the symbol rate is also the baud rate. The PSK, ASK and QAM works on the carrier frequency with the modulating channel and the representation through I signal at the x-axis.

Hence, for this, the carrier signal is

$$y_i = \cos(2 * pi * fc * t) \tag{4.11}$$

This is for the phase of the carrier which is from 0 and can be set at:

$$y_2 = \cos(2 * pi * fc * t + pi) = -\cos(2 * pi * fc * t) = -y_1 \tag{4.12}$$

There is a need for the modulation of the signal where the signal for the bit 1 is the BPSK signalFig 4.4.

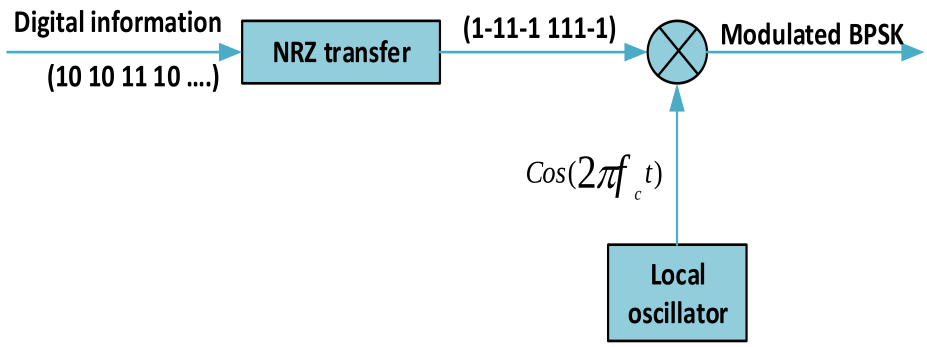

Figure 4.4. Block diagram of BPSK transmitter

For the demodulation part:

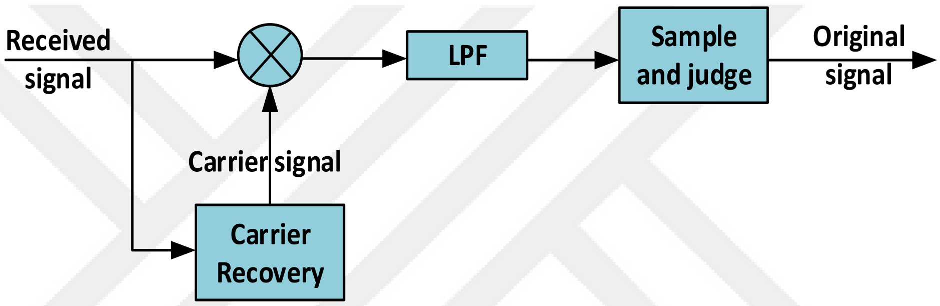

Figure 4.5. Block diagram of BPSK receiver

Hence, for this, the carrier signal is found to demodulate the signal received Fig4.5 which is same as the transmitter. The entire process is for the carrier recovery which can easily be omitted. With the receiving of the signal phase, there have been a phase shift with the receiving of the BPSK signal:

$$r(t) = Acos(2\pi f_c t + k\pi + \varphi)(k = 0,1) \quad (4.13)$$

Here, the demodulation is found to result which is wrong if the receiver is using the same carrier for the receiving and the signal recovery process. For handling the circuit recovery Fig4.6 there is a need for:

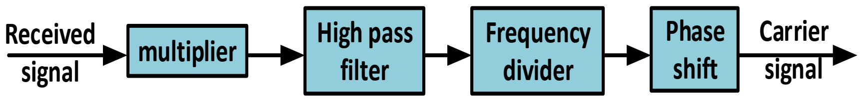

Figure 4.6. Process of carrier recovery

The carrier can easily be recovered through:

$$y = r^2(t) = \cos^2(2\pi f_c t + k\pi + \varphi) \quad (4.14)$$

$$y = \frac{1}{2}A^2(1 + \cos^2(2\pi * 2f_c t + 2k\pi + 2\varphi) \quad (4.15)$$

Hence, for y which has a high pass filter, where the signal is:

$$y = \frac{1}{2}A^2(\cos^2(2\pi * 2f_c t + 2\varphi) \quad (4.16)$$

With this, there has been correct carrier which is set at:

$$carrier = \frac{1}{2}A^2(\cos^2(2\pi * fct + \varphi) \quad (4.17)$$

The receiver can easily set the multiplication of the received signal with the carrier signal for the demodulation process. The other method which is set to overcome the problems of the shifting of the phase is the use of preamble. This is important for the sequence which could be easily transmitted for the information. With this, the receiver will be able to know whether it should be receiving the signals or it knows that it is receiving or not. The phases have been set for the preamble which is 1 and then signal phase is set to 0. Here, the cutting of the received signal is from one peak value where the transmitted is enough to produce the signals by the receiver local oscillator.

There are different complex valued signals which are for the equivalent low pass signals to handle the real value modulated phase. It is to handle the transmission for the signals that are transmitted to the attributes and adapt the shaping of the pulse or the other filters to limit the bandwidth. The forms are equivalent to the low pass signals that use the digital signal processing and performs the digital to analog conversion for the different forms. It will also help in generating a higher frequency of the sine carrier waveform and cosine component. There is a need to generate the high frequency of the sine carrier waveform with the quadrature component. The results are equivalent to the lower pass signal with frequency shifted to the pass band signal or the RF signals. The technology is set with the amplification and the analog band pass filter to completely avoid the distortion or the spectrum set under the periodic basis. At the side of receiver, the demodulator works on the band pass filtering, with the gain control to compensate with the attenuation process like for fading. The frequency shift of the RF signal is I and Q that will help in setting the intermediate frequency which will be using the local oscillator for the sine and cosine wave frequency. The sampling is also done with the equalization filtering like in the matched filter to handle the multipath propagation, spreading time, phase distortion and the selecting fading frequency. It is mainly to avoid all the inter-symbol interference with the proper quantization of the amplitudes.

4.6. FSK MODULATION AND DEMODULATION

With the frequency shift keying modulation which is found to be simple than PSK, there have been pair of frequency which are for the representation of the bits 1 and 0. The carrier frequency generally vary in between the values of the signal state binary. This has been able to handle the two carrier signals with a particular same amplitude and the phase. There are other methods as well for the BFSK modulationFig4.7. that is for making the appropriate use of the features. The branches are treated like the Amplitude shift keying.

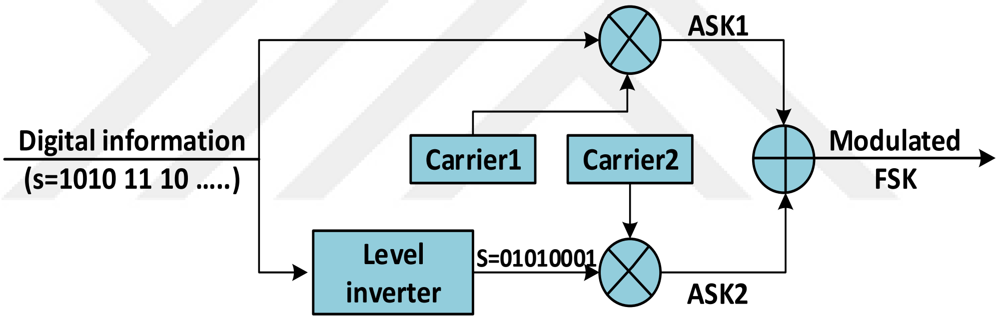

Figure 4.7. Block diagram of FSK transmitter

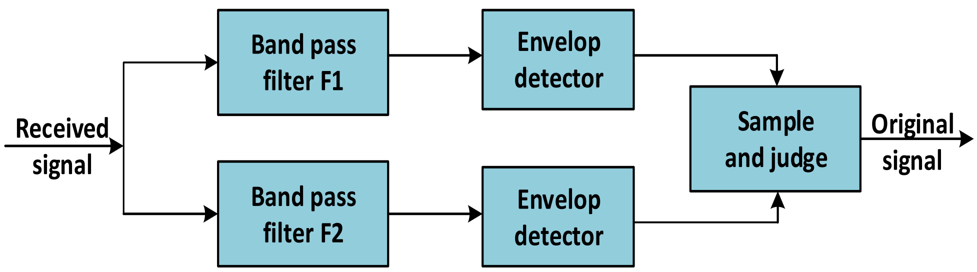

Figure 4.8. Block diagram of FSK non-coherent receiver

For the BFSK signal, the process of demodulation is easy where the receiving of the signal is then passed to the two different band pass filtersFig4.8 This is mainly to the corresponding signal which is able to envelop the detector and the information branch. The modulations and the demodulations are for the streaming data with the use of the BFSK, where the vector source has been set to properly provide the data and the transmitter mainly to handle the non-continuous frequency shift keying. The resampling is mainly done for reaching out to an appropriate rate for the HackRF One with the FSK Signal transmission. The receiving end where the BFSK detector has been set is for the implementation of using the integration and dumping method Fig 4.9. With receiving end, the BFSK detector is able to use method for properly quantifying the delays which are set through the SDR methods [42].

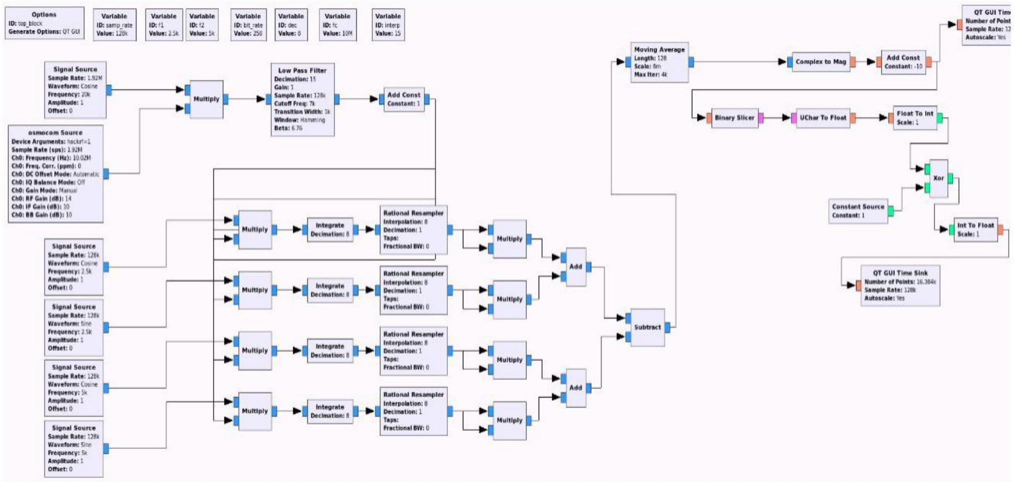

Figure 4.9. BFSK Receiver[13]

CHAPTER 5

MATLAB IMPLEMENTATION

MATLAB is the multi paradigm which has been set for the numerical computing process, where the process is based on the matrix manipulations and the plotting of the functions with the implementation of algorithm. The creation of the user interface and the interface set with the programs is able to include the different languages. MATLAB has been important for the numerical computing with allowing access for the computing abilities [43]. The package is based on the model based designs which are mainly for the dynamic and the embedded systems, where the approach has been for the users who could handle and involve in using the command windows at the interactive level. The variables are also defined to use the assignment operation for MATLAB which is a weak type of the programming language. This is mainly for the declaring of the types with the treatment of the symbolic objects. The values mainly come from the constants and the computation of the values that have been involved for the variables. The functions work on the accepting the matrices that will directly apply to the elements and then reducing the same with modulo n. The standards are for the using of the vector notation that offer the production of the code that has been fast for the execution. The entire structure is based on the data types where the variables are for the arrays along with the adequate structure array where the element is set under the same field name. The support is for the dynamic field names where the structure is set for the bundling of the variables with the structural cost setup. The functions name the file where the first is the file function and then there have been valid function names which are set in the form of alphabets that contain the letters, numbers etc. The support of the object oriented programming language includes the class, inheritance, virtualized dispatching, pass-by-value semantics and the pass-by-reference. These are mainly for the classes and the reference classes which mainly depend on handling the GUI interfacing as well. The functions can be given with the data type passing and then returning the same. [44]. The dynamic loading process of the object files is set through the compilation process which has been termed to be the MEX files. MATLAB works on the optimization of the engineering and the other problems which are based on the matrix approach. The visualization and the gain of the insights from the data help in easy implementation of the algorithm. The scaling, integrating and deployment is set for the analysis on larger data sets and scaling up to the clusters and the clouds. The higher level language is for the computing of the scientific and the engineering pattern where there has been iterative exploration and designing along with solving the problems. The graphics are based on the visualization of the data along with creating the customized plots. The apps are for the data classification and the signal analysis which will help in adding on the toolboxes and then holding the wide range of the engineering and scientific application. It includes the easiest combinations of the high level language with the desktop environment for all the iterative engineering and the scientific workflow. The matrix based MATLAB language where there is a possibility for the expressing of the computation process. MATLAB has been able to work on the hardware across the multicores on the computer as well as the library a call that calls for the heavy optimization. The algorithm works on the changing of the loops into the parallel for the loops with the changing of the standardized arrays into GPU. The design is based on the iterative engineering and the workflows which are based on the built-in math functions that support the engineering as well as the scientific analysis. The 2D and 3D plotting of the functions are able to visualize and then understand the data for better communication [45]. For the better performance of the GMSK, there have been certain modulation schemes which are set under the SDR system for the execution of the channelization process. The operating systems tend to use the Linux with the python programming and setting a better communication program to perform radio functions. The use of the open source setup from the GNU radio is mainly with certain modifications. The experiments are set to observe the use of USRP board where there has been a use of the coaxial cables to handle the transmission and the receiving of the power.

5.1. GENERAL STRUCTURE OF THE SYSTEM

For the SDR implementation, there is a need to handle the high speed of the convertor with the powerful processing of the signal. For this, there has been equipment which are able to make up to the platform which is expensive for the radio communication. Hence, there is a use of MATLAB for the working on the project with the signal frequency of the radio which is set in a limited audio brand. The setup of transmitter and the receiver is set with two Matlab session where one works on transmitter and receiver. The modulation and demodulation work on the MATLAB programming where the user need to choose corresponding parameters. There have been ways to handle the signal transmission with the air to simulate radio communication with using the cable. The transmission signal has been set with the tests where the use of the same transmitter and receiver has been set for handling the cable transmission.

The HackRF with the SDR peripheral that is able to handle the reception of the radio signal which is from 1Mhz to 6GHz. The design is mainly to enable the tests and the development of the modern and the next generation technology. A SDR can be important for the radio communication which implements the use of the software rather than the implementation of the hardware. The SDR is the application which is set for the Digital Signal Processing for the radio waveforms. The software based digital audio techniques are based on handling the computer with the digitalization of the audio waveforms. This software radio peripheral digitalization of the radio waveforms. The HackRF One has been the way which is set in all-in-one form in the smaller enclosure for the litter higher pattern than the cell phone. The features are set for the 8-bit quadrature sample which is compatible with the GNU radio, SDR# and more. The configuration of the software RX and TX gain with the baseband filter. The software controlled antenna port power is set for the female antenna connector.

The HackRF has been the testing equipment which is for the RF related experiments and the measurements. These cover the frequency range from 1 to 6000 MHz. The setup is based on the open source programs which also handles the radio communication. The hardware is considered to be the open source device with the stronger funding project. The system also covers the wider range of the frequency along with handling the licensed and the unlicensed radio bands. The hardware is also able to offer the maximum sampling rate of 20MS/s which is completely sufficient for measuring the even wide band signals like the WFM, DECT, Wi-Fi and others. The entire work is based on the support and the extensions where the setup is based on the front end block diagram. This is based on the high flexibility range with the choosing of the path for the signal. The switch for the FR has been set for the critical junction points which also allow the proper and easy selection of the different components which is based on the programming of the user [46].

The amplifier completely blocks the lower pass and the higher pass filters which can easily work on the limitations of the signals that are set for the input and the output path. The filtered signals are arrived at the RF mixer RFFC 5072 and then this can be used by the range of 6GHz. The baseband chip of the component is used for the covering of the frequency range which is of 2.3 to 2.7. The setup of the digital signals is passed and then there is a control by the powerful ARM Dual Core Cortex processor. The SDR peripheral is set for the radio waveforms where the software based digital audio techniques are popular based on the computer digitalization. There have been audio capabilities which enable the revolution and the advancement like the hard disk recording and the radio communication.

5.2. WIDE OPERATING FREQUENCY RANGE

HackRF works on the operations from 30 MHz to 6GHz with a wide range than the SDR peripheral. The range includes the frequency where there have been digital radio system and can easily operate on the lower frequency range in MF and HF bands. It is for handling the transmission or the receiving of the radio signals where the operations are based on the half-duplex mode. This is set for the full duplex operation which is important for the use of the HackRF device. The portability with the external power supply is set to fit in easily with the USB attached host computer. [34]. The lower costs have been designed for the wider SDR peripherals that can easily be manufactured at a lower cost. The wideband has been for the maximum bandwidth of HackRF which is 20MHz which is 10 times the bandwidth which is for the TV tuner for the SDR. The open source has been set for the high speed digital radio applications like LTE or 802.11g. The important goal of the work is to produce the SDR peripheral where the hardware and the software designs are available under the open source license. This also includes the production in Ki Cad with the open source electronic designing automation tool. The compatibility of the device is based on the USB 2.0 with the interface which is set for handling the purpose of the computer. The tests are for the Digital Audio Broadcasting, monitoring through the Bluetooth and the spectrum sensing with the wireless microphones. The current hardware platform has been set for the hardware project with the software peripheral that is able to handle the transmissions or the reception of the signals of the radio which range from 1 MHz to 6 GHz. The tests are enabled with the development of the radio technologies and the open source hardware platform. This can easily be used for the peripheral setup and the programming operations. With the changing concepts, the ideal receiver scheme is mainly to attach the analog to the digital converter for the antenna. The processor has been set depending upon the technology of the analog and digital domains. The receiver architecture is based on using the frequency variable oscillator with the mixer and the filter mainly for the tuning capacity that is set for the intermediate frequency. The sampling is through the analog to the digital forms of the converter. The applications are based on the samples where the range is based on the dynamic pickup with the power radio signals. The signals are mainly to handle the dynamic ranges with the introduction of the distortion in the signals with the blocking of the same. The standardized solutions are for the band pass filters which is set in between the antenna and the amplifier that will reduce the flexibility of the radio. The real software radios are found to be working on the three analog channel filters with the different bandwidths that are set for the switches in and out [47].

5.3. GNU RADIO

This is free software for the proper development of the toolkit which helps in providing the signal processing blocks. It is based on the software defined radios and the systems related to the signal processing. The use is with the external RF where the hardware is set to create the software or without it in the simulation like environment. This has been mainly for the wireless communication research and the real world radio system. The software radio provides the framework which is able to build and work on running the software with the applications set for the signal processing. The GNU radio applications work on the flow graphs where there have been processing blocks that are connected for defining the flow of data. The software defined radio systems along with the reconfiguration processes are important. With this, one is able to design the specific systems with the GNU radio front end. The flow graph can easily be written in C++ or Python programing language. The signal processing package has been a major part of the project where there have been distributions based on the project codes. There has been graphical UI development of the radio applications which is set up for the front end to the GNU radio libraries to handle the signal processing. The software works on effectively working on the python code generation tool. The generation is mainly through the desired activities set for the GUI windows and the widgets. It is also able to create the blocks which are set in the flow graph. It is mainly considered to be the collection of the software which is then combined with the minimal hardware along with allowing the construction of the radios. Here, the actual waveform is set for the transmission and the receiving pattern which could easily be defined by the software. The digital modulation has been set at a higher performance where the wireless devices are set into the software problems. The waveforms are mainly generated and sampled through the digital signals and then converted from the digital to the analog pattern through the wideband setup of DAC [48]. The Analog to the Digital Converter is able to capture the channels for the software radio node where the receiver is then able to extract and demodulate the waveforms mainly through the use of the software. The GNU Radio companion is mainly to develop the radio applications where there has been a proper setup of the SDR which provides the incredible flexibility in the system. The standards are relatively handling the transmission and the monitoring of the traffic on the 2.4GHz. It also includes the transmission and the monitoring of the cordless phones, Bluetooth devices and the other devices. The GNU Radio works on the development of the tool kit that is able to handle the processing of the signals which is mainly from the file that contains the information. It also is a free and the open source software development toolkit which is able to provide the proper signal processing blocks for the implementation of the software radios. This has been set at a lower cost where the external RF hardware is able to create the software defined radios. It also includes the software radio which performs all the signals in the software with the dedicated and the integrated setup of the circuits in the hardware. The major benefit for the same is to replace in the radio system and work on creating the different kinds of the radios for a better transmission standard. The performance is for the signal processing where there is a possibility to receive the data out of the digital streaming or the pushing of the data in the digital stream. This is for the filter process, channeling codes and the synchronization of the elements, demodulators and the decoders. The setup also includes the methods to connect the blocks and then manage the data to be passed from one to the other block. The extensions of the GNU Radio are easy and could be helpful for finding the specific block which is mission.

The GNU Radio software works on handling the data in the digital form. The complex baseband signals are mainly for the inputting of the data types mainly for the receivers and then output the same for the transmitters. The analog hardware is then able to shift the signals to the particular central frequency range. The requirements are based on the passing of a particular block to the other with the bits, bytes, vectors and the bursts. The applications are also important to use the Python Programming Language where there has been performance with the critical signal processing path that has been implemented in C++. It is for the implementation of the real time output and the high throughput radio system which is found to be simple for use with the rapid application development environment.

The GNU Radio companion is holding the possibility to create the signal processing application by easy drag and drop method. This will also be helpful for the tools and the utility programs.

Reducing the problem of the interference to the others.

CHAPTER 6

METHODOLOGY AND DESIGN

6.1. METHODOLOGY

Previously, engineers deployed dedicated circuits to build communication systems. However, this method was very expensive as well as the design process was very slow because of the sequence of manufacturing and evaluation. Practically, the margin of electronic hardware errors must be small, where lese, the designer may face high costs. Fortunately, the SDR came to change such panorama. This project involves the design of a communication system with the use of GNU Radio, which can be deployed with readily-available low-cost external RF hardware in order to generate SDRs or in other cases without hardware in a simulation-like environment. Such platform is used to carry out signal processing and write applications to receive and transmit data with radio hardware or to generate simulation-based applications. Furthermore, it composed of a connection method among blocks to manage the transmission of data between them.

Further functionalities can be added also to the GNU Radio. When there is a missing block, it can be simply generated and added using a programming language. Both the C++ and Python languages can be used to write the GNU Radio applications, while the C++ only can be used to implement the performance-critical signal processing path utilizing processor floating-point extensions. This in turn allows the developer to implement actual, high-throughput radio systems in a rapid-application-development environment.

The proposed design in this project includes modulation and demodulation using SDR features. The presented modulation scheme is based on the Gaussian Frequency Shift Keying. It is deployed for communication systems, as amateur radio, caller ID and emergency broadcasts. The binary FSK (BFSK) is the simplest FSK, where it deploys a couple of discrete frequencies to send binary (0s and 1s) information. In such scheme, one denotes the mark frequency, while zero denotes the space frequency. On the other hand, the BFSK has a wide spectrum content that needs more bandwidth. The Gaussian frequency-shift keying (GFSK) basically filter the data pulses using a Gaussian filter to get smoother transitions. Such filter can decrease the sideband power and the interference with adjacent channels with increasing the inter-symbol interference. Furthermore, Gaussian filtering is a typical manner to decrease the spectral width so it is known as "pulse shaping" in this application.

The simulation realm is extended using a generic radio hardware interface. The proposed hardware is the HackRF as an alternative SDR hardware with high-end characteristic. The HackRF One is an open source hardware platform, which deployed as a USB peripheral or programmed for stand-alone operation. The main hardware features are:

- 1 MHz to 6 GHz operating frequency
- Half-duplex transceiver
- Up to 20 million samples per second
- 8-bit quadrature samples (8-bit I and 8-bit Q)
- Compatible with GNU Radio, SDR#, and MATLAB (not officially)
- Software-configurable RX and TX gain and baseband filter
- Software-controlled antenna port power (50 mA at 3.3 V)
- SMA female antenna connector
- SMA female clock input and output for synchronization
- Hi-Speed USB 2.0
- USB-powered
- Open source hardware

6.2. DESIGN DIAGRAM

The proposed communication system in this project is shown in Fig. 6.1 a music source, which is playing music continuously, is included. The signal goes to the transmitter that is modulated and broadcasted to the air. a nearby receiver then captures the signal, demodulates and reproduces the result in an audio sink.

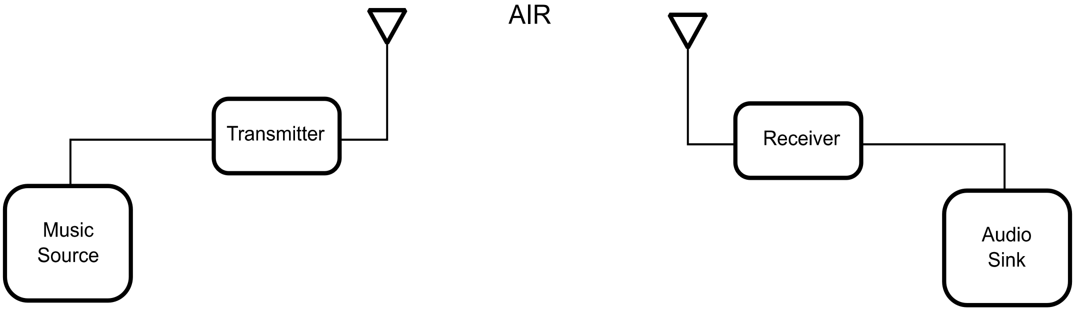

Figure 6.1. Communication system diagram

6.3. REQUIREMENTS

The demonstration of the design does not require a significant amount of elements. Most part of the hardware can be seen in the following figure

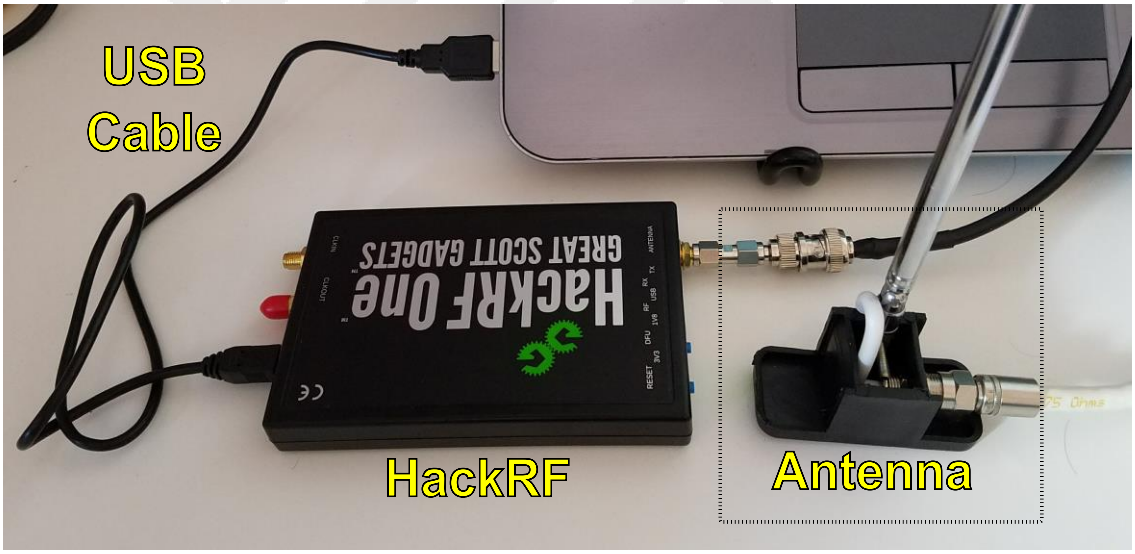

Figure 6.2. Required hardware for design

According the design illustrated in figure 6.1 the following are needed:

1. Two computer stations. One for transmitting design and other for receiving.
2. Two HackRF one. The hardware's have transmitting and receiving capabilities.
3. Two telescopic antennas.

Both computer need to have GNU Radio companion installed. It is important to highlight that GNU Radio installation does not include native support for HackRF one. Thus, you need to visit Great Scott Gadgets website and download the drivers required for make HackRF one work with GNU Radio.

6.4. DESIGN

This section presents the communication system design. The GNU Radio design includes two parts: The transmitter and the receiver. The output frequency is 433 MHz in ISM band which is free to transmit. The following figure shows the block diagram of the transmitter. We will describe each block.

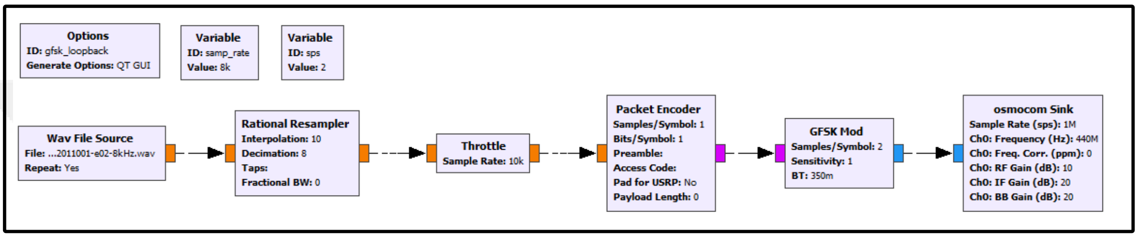

Figure 6.3. Transmitter design

The main configuration blocks are:

- Options: It has the identification of the design and it is possible to choose which interface engine will be used to render results.
- Variable: These variables are used to store common values that are used in multiple blocks simultaneously. The designer can create multiple variables.
- Wav File Source: This block handles the wave file sources. It can open several kind of file formats.
- Rational Resampler: This block is very useful for multiple purposes. In this design it is used to make the sample rate of the sound source compatible with the base-band sampling rate.
- Throttle: This block forces the signal to have a controlled sampling rate. This is important when a physical hardware is attached to the computer and need a constant sampling rate throughput.
- Packet Encoder: This block is not just an encoder. It has package control introducing structures for synchronization. Then, the receiver will be capable to synchronize with the input received signal and decode.
- GFSK Mod: This is the most important block of the transmitter. It modulates the signal in GFSK. It outputs complex signal that will be transmitted.

- <u>Osmocom Sink</u>: This is the block which interfaces with HackRF one and work as output. Several features can be controlled as frequency, power and sampling rate.

The following figure shows the block diagram of the transmitter Fig 6.4. Other blocks are listed below.

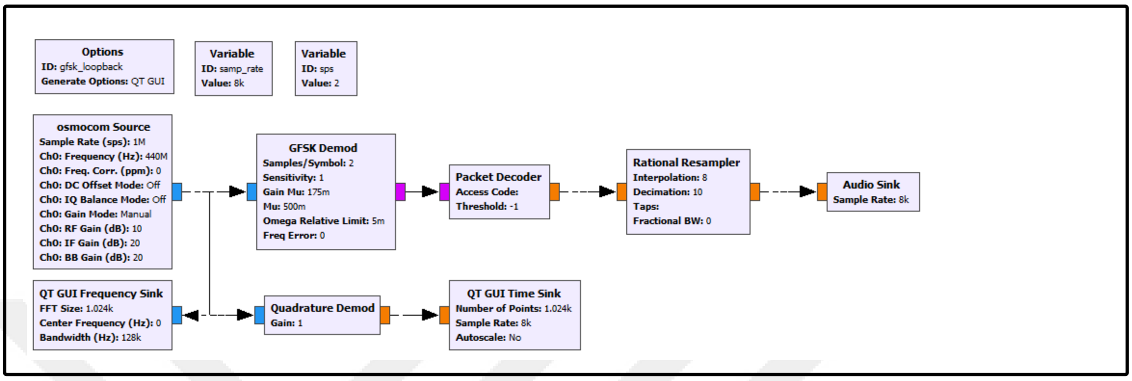

Figure 6.4. Receiver design

- <u>Osmocom Source</u>: This is the block which interfaces with HackRF one and work as input. Several features can be controlled as frequency, power and sampling rate.
- <u>GFSK Demod</u>: It receives the complex IQ signal from the air and demodulates.
- <u>Packet Decoder</u>: It receives the package transmitted and extracts the information which was encoded with synchronization structures. It is not possible receive information without frame and synchronization structures.
- <u>Rational Resampler</u>: Resample the recovered signal to a suitable audio sampling rate.
- <u>Audio Sink</u>: Reproduce the received signal to the computer speaker.
- <u>QT GUI Frequency sink</u>: This block presents an interface that shows the signal being received in the frequency domain.
- <u>Quadrature Demod</u>: This block converts the complex signal in a time domain representation.
- <u>QT GUI Time Sink</u>: This block presents an interface that plots the signal on time domain.

CHAPTER 7

RESULTS AND DISCUSSION

7.1. RESULT

In this project, initial experiments are conducted with the GNU Radio design in order to evaluate the performance of the system. The running of the designs described earlier presents some results through the window interfaces. The received signal frequency spectrum and time domain in real time are presented in the receiver. It is possible to see the frequency and time domain signal from transmitter side. The following figure shows a sample of signal received in frequency and time domain.

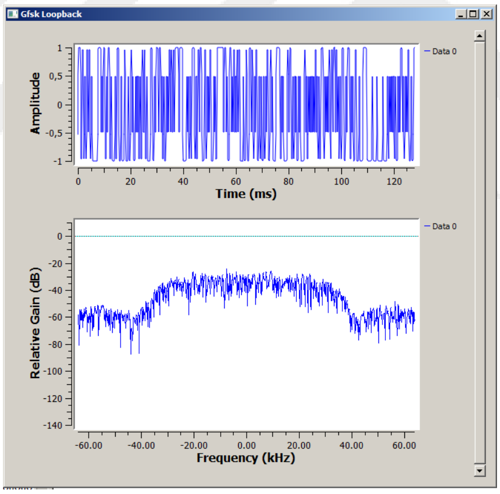

Figure 7.1. Sample of received signal

When there is no signal being received the spectrum, the power level of the noise spectrum is only illustrated. A regular pattern of the signal on time domain can be observed from the previous figure. If there is no signal being received the regular pattern of GFSK does not appear on the time domain interface. The following figure shows the result for absence of signal.

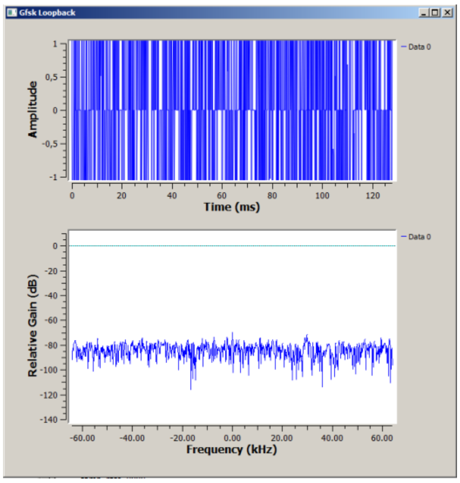

Figure 7.2. Sample of absense of signal

7.2. DISCUSSION

Several environment measurements are performed in order to evaluate if the system works properly. The interface is deployed to measure the signal reception quality. A sample of the method is shown in the following figure. In this sample, there is 10 dB of signal being received.

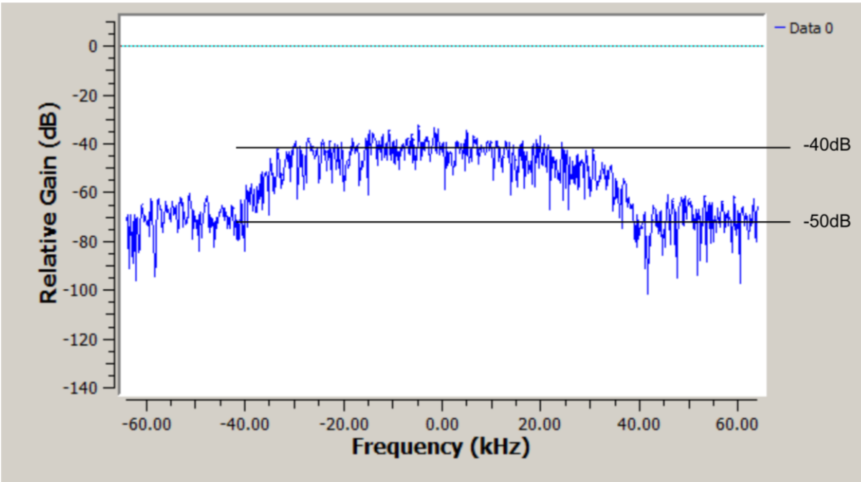

Figure 7.3. Method for measuring signal power

Both the transmitter and the receiver are placed in multiple locations in experimental environment. The environment is a space with two rooms. There is a door connecting both rooms which can be opened or closed. The transmitter has fixed position for each experiment. Receiver changes its position according to what is illustrated in Figure 7.4.

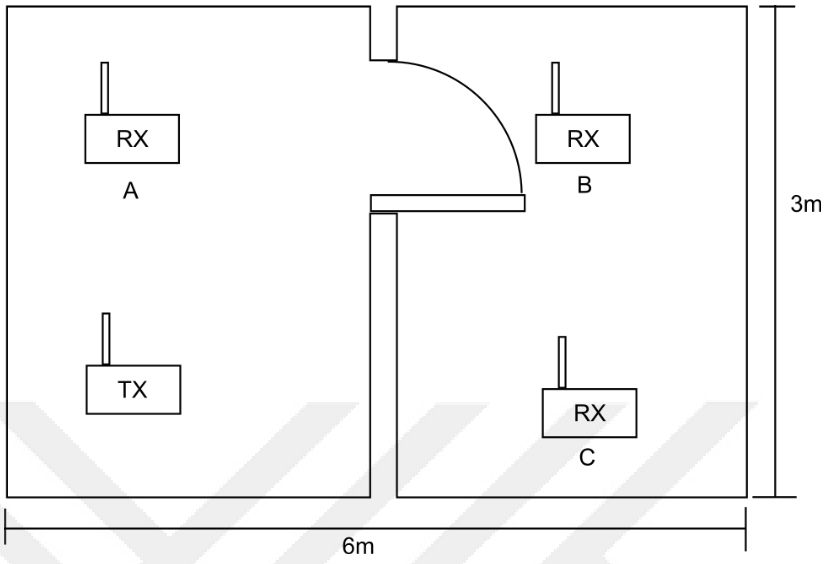

Figure 7.4. Experimental environment.

The following table compiles the results of the measurements performed in the experimental environment.

Point	**Distance**	**Power**	**Result**
A	2m	12 Db	Music ON
B	4m	10 Db	Music ON
C *	3,7m	9 Db	Music ON
C **	3,7 m	5dB	Music ON

* Door opened.

** Door closed.

7.3. CONCLUSION

The system has been set for the five modulation methods where the two analog modulation methods and the digital. With this, the phase modulation method is found to be difficult than the frequency modulation for the receiver. The receiver holds the non-coherent demodulation method which is for the handling of carrier signal. The construction process of the system is based on the modulation method where the class is set for the equipment. The enhancement has been set with the ability to hold the signal processing where programming is set for the signal processing method like the design is for the suitable filter. The modulation methods can easily be added with the system where the pattern has been set with the different improvement aspects. The focus of the work has been on SDR where the hardware system and the other features are able to focus on the software availability to control the systems. This works on the features and the costs of the system that acquire to group the hardware and the software along with offering the communication instruction via SDR. This is set at a description where the sampling of the experiments can easily be performed with the setup of the analog and the digital communications. [49]. The software defined radio is set for the components that have been set for the mixers, filters and the amplifiers. The implementation is set for the software on the personal computer or the embedded systems. The rapid evolvement is for the capabilities of the digital electronics that are for the processing. The SDR systems work on the personal computers where the signal processing is also handled over the generalised purpose processor. There have been designing structures which produce the radio and can easily receive or transmit the radio protocols. The software radios have been working on the long term patterns where there have been designs set for the spreading of the spectrum or the ultra-wideband techniques. [50]. It also allows the transmitters for the transmission with the handling of the same place and a better frequency. With the changing technology, the lock onto function is for the directional signal that the receivers can easily be able to reject any interference from any other direction. The radio techniques of the cognitive patterns are for measuring the spectrum with the use and communication of the information to the other cooperating radios. The dynamic transmitter is for handling the adjustment of the power which is based on the information that could easily be communicated from the receivers along with lowering the power of the transmission to the minimum level possible. It will also reduce the near far problem and then reducing the interference to the others. The wireless mesh network adds on the increase of the total capacity and reducing the power as per the node setup. For the transmission, the messages are mainly to hop to the nearest node in the direction which could reduce the near-far problem along with reducing the problem of the interference to the others.

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RESUME

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