

EE 304 COMMUNICATION THEORY

FINAL PROJECT REPORT

TITLE: COOPERATIVE RELAYING USING USRP AND GNU RADIO

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Abstract

This article will encourage the readers to apply new ideas for cooperative communication. From last few decades the largest development occurs in wireless communication. Every day new technology or approach is developing. With the help of current technology (Smartphone, Webcam, Radio etc) or hardware based devices we can contact with anyone from one corner of world to the other corner. Now a days user wants better quality of received signal with maximum rate so as to full fill these requirement researches going on. The cooperative communication using Relay or Mediator is also such type of technique that is growing at very fast rate. In traditional networks, direct communication is done between two nodes. In cooperative communication, communication is done by using relay between source and destination. It improves the system efficiency and performance significantly. It is one of the fastest growing technology and reliable network. We have implemented this technique using GNU Radio software it is open source software, and three USRPs(Universal Software Radio Peripheral) acting as transmitter, relay and receiver. In this type of communication receiver can be a more number of users with one transmitter. We have also verified the direct communication between source and destination. In cooperative communication between transmitter and receiver we used relay as amplify and forward as well as decode and forward. In this article an overview on cooperative communication has been presented. We have used GMSK(Gaussian Minimum Shift keying) modulation and demodulation technique.

1 Introduction

In today's world users of wireless devices expect high data rates without any possible distortion in transmitted signal. This expectation is not an easy thing to implement because the radio frequency signal propagating through environment get distorted due to diffraction, interference and transmission through materials. The signals received by receiver is from the multipath the phases and amplitude is different and when combination and alignment occurs the same phase signals produce strong signal and different phases produce weak signals and there is more chance to get different phases. SO to avoid this problem scientists developed MIMO technique that is multiple input multiple output in this the signal is transmitted on independent path that is distributed in frequency time and space and combine at receiver end. But this approach is also less feasible due to less size of antenna of mobile devices. SO a new technique is originated in which without the use of multiple

antennas we use relay in between the transmitter and Receiver as a mediator to enhance the signal quality.

2 Problem statement

Our main objective in this project is to hands on experiment the Cooperative Communication Using USRP and GNU Radio which is most commonly used software based platform.

- 1. Direct Link Transmission*
- 2. Then introduce a relay in between transmitter and receiver using GMSK modulation technique.*

3 Deliverables

Here are the list of things which has to be demonstrated after this project done

- How file transfer taken place using a Relay inserted in between Tx and Rx*
- Why decode and forward method is better then amplify and forward as implementation of relay*
- GMSK Modulation and Demodulation*

4 Equipments required for this project

To implement Cooperative Communication using relay we require the following equipments.

- 1. NI USRP-2920 (Qty:03)*
- 2. Ac/DC Power Supply Adapter for USRP*
- 3. PC with GNU Radio Installed*
- 4. Gigabit Ethernet Cable*
- 5. Vert 400 Antenna(Qty:04)*

5 Block diagram of the experimental setup

Here is the block diagram for experimental setup in this each block will be represented by one PC connected with USRP.

Block 1 : USRP1 will be used as transmitter which will modulate the message signal and transmit it at 915 MHz centre frequency.

Block 2 : USRP 2 will act as relay. It will demodulate the signal coming from USRP1 amplify and then it will encode to modulate again the signal and forward it to the receiver.

Block 3 : USRP 3 will be used as receiver. It will first demodulate the signal coming from both channels.

In this project the main part is making GRC files on gnu radio open software. We have to understand

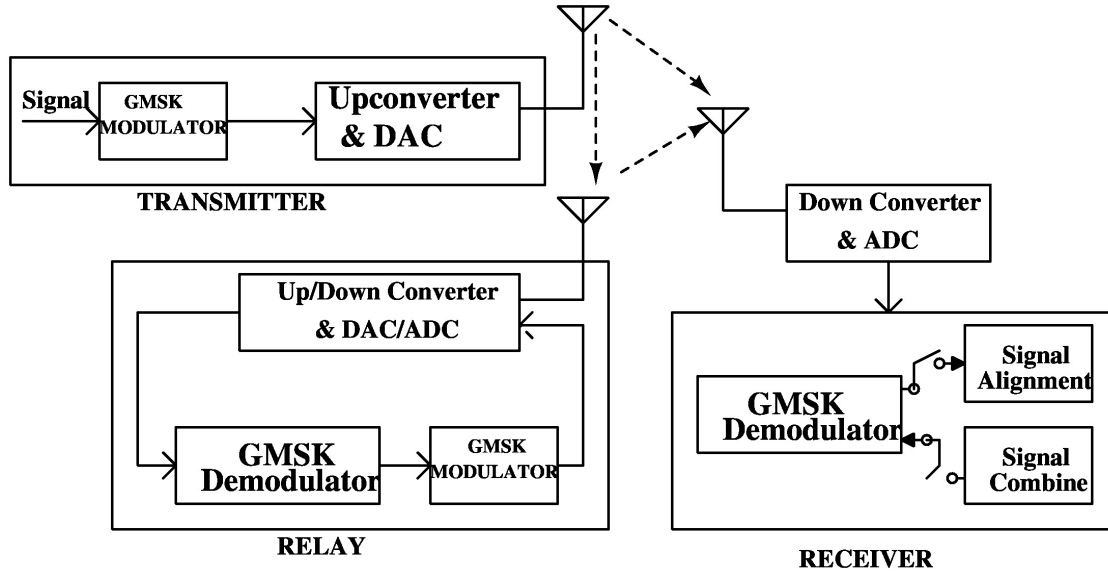


Figure 1: Block Diagram For Experimental Setup

each GRC block's functionality to come up with an efficient transmitter and receiver part.

6 Theory

Basic Principle: With the help of transmitter grc flow graph the message signal given to the GMSK modulator and then the modulated signal is transmitted by upconverter and DAC.

Then the transmitted signal can be received by Relay USRP and receiver USRP setup. In relay, before decoding the signal noise is removed from it. Using Cyclic Redundancy Check method the

altered bits is measured. Now, the signal is encoded and transmitted to the receiver USRP setup. The receiver USRP receives the signal from two paths i.e. from transmitter and relay so we do signal alignment and signal combination after demodulation to get maximum quality of signal. Here in this Project implementation we will use GMSK modulation technique which is Gaussian Minimum Shift Keying. Here are two ways to implement GMSK modulation.

After transmission done, the GMSK modulated signal is demodulated using Differential Phase Detection (DPD) in this technique we are basically decoding the transmitted signal on the basis of some mathematical calculation of phase.

It computes the multiplication of one symbol with the conjugation of its previous symbol as follows.

$$Z = X(kT+T)X^*(kT) = A_z \exp(jp).$$

where $X(kT)$ is the transmitted signal corresponding to the k th symbol. Now in our case assume that two signals received as one from transmitter which is X_1 and one from relay which is X_2 at the receiver end so by DPD we have

$$D = X_1(kT+T)X^*(kT) + X_2(kT+T)X^*(kT) = A_d \exp(jPd)$$

The decoding is done in this manner. when Pd is greater than or equal to $=0$ then $A_k=1$ when Pd is less than 0 then $A_k=0$ this decoding helps us to reduce the complexity of demodulation.

7 Division of work

Main challenge in our project to make 3 USRP devices to act as transmitter, relay and receiver.

We will use decode and forward technique for communication between USRPs.

Lokesh Bairwa: He will be mainly working on GMSK modulation and differential phase detection technique.

Shrawan Kumar : He will work on GMSK demodulation and to check error in received signal and transmitted signal(CRC Method).

We will both work together on making GRC flowgraph and implementation to get better performance.

8 Timeline

Here is given a Timeline described in Gantt Chart which showing the flow of working on project as duration (Days) vs Tasks. This project is estimated to evaluate on 9th May 2017

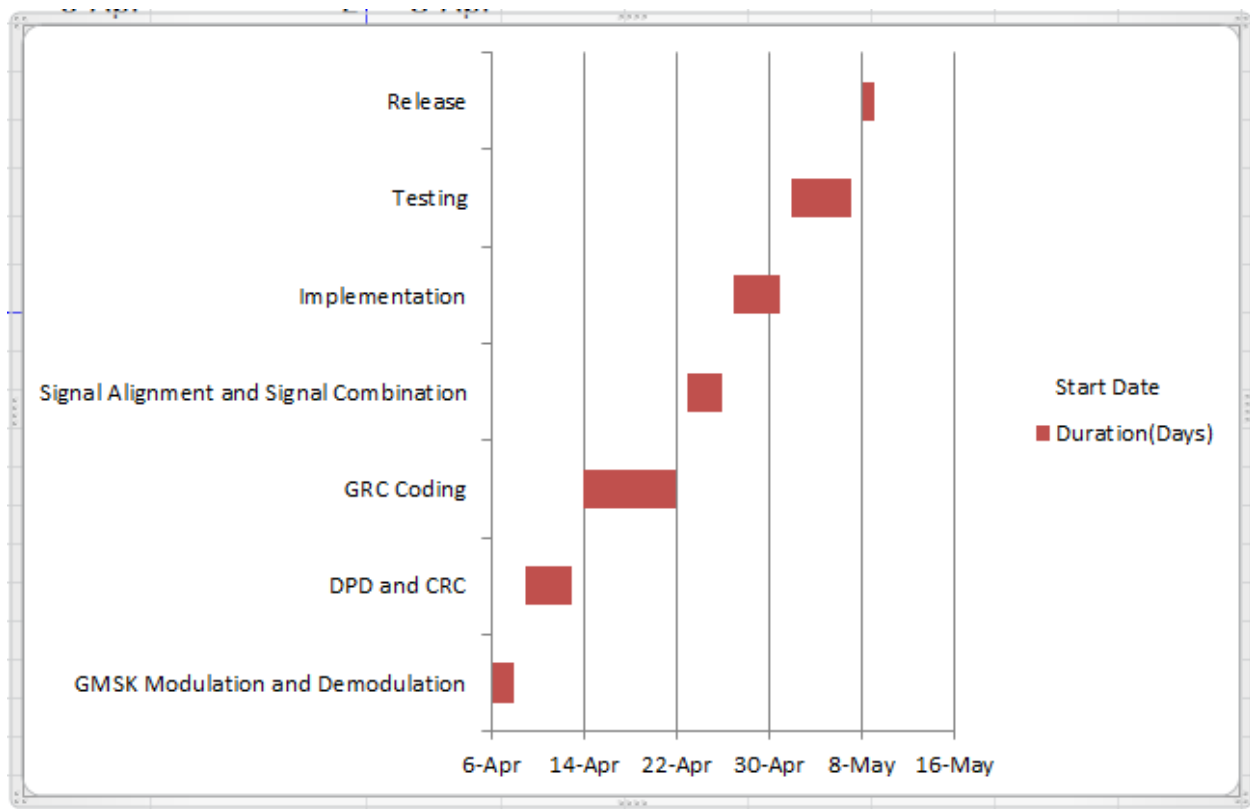


Figure 2: Gauntt Chart for Timeline

9 Interfacing With USRPs

Connecting USRP to GRC

- Connect Gigabit ethernet and set Internet protocol IPv4 manual to ip address as 192.168.10.1 and netmask as 255.255.255.0 and save.
- Open terminal and type the following commands one by one.

```
$ ping 192.168.10.2
$ find_uhd_devices
$ find_usrp_probe
```

Figure 3: Setting USRP with GNURadio

- While running grc file if terminal shows like install ABI compatibility or the uhd images does not matching then uninstall the current GNURadio and update pc then reinstall by link provided by Ettus Research.

After successfully connected USRP we first demonstrate direct transmission of a .text file using a simple transmitter and simple receiver with one channel. The figure 4 shows the transmitter.

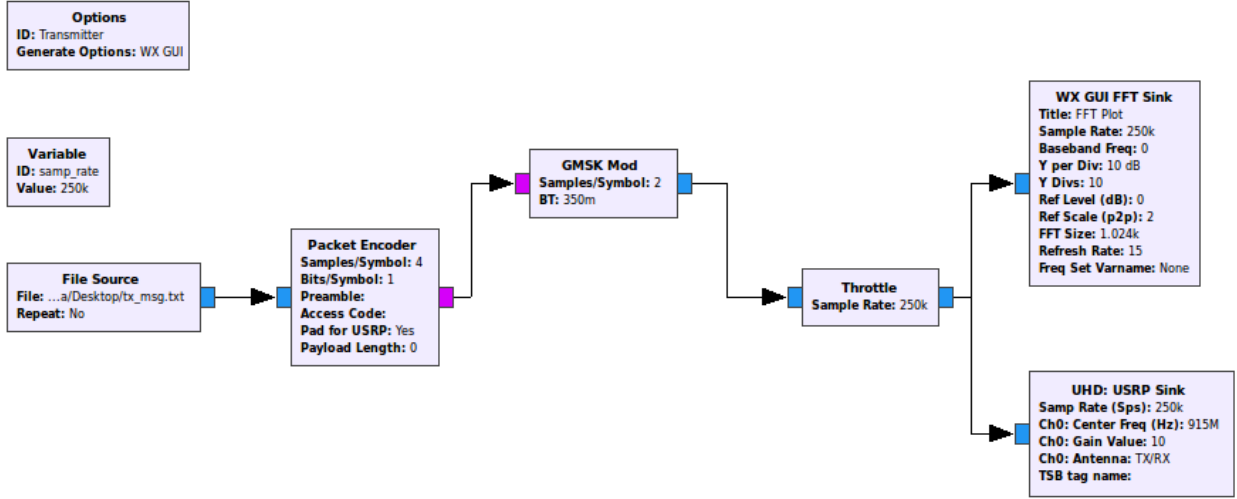


Figure 4: GRC Flow graph for Transmitter

The waveform generated by fft sink at transmitter is shown in Figure 5.

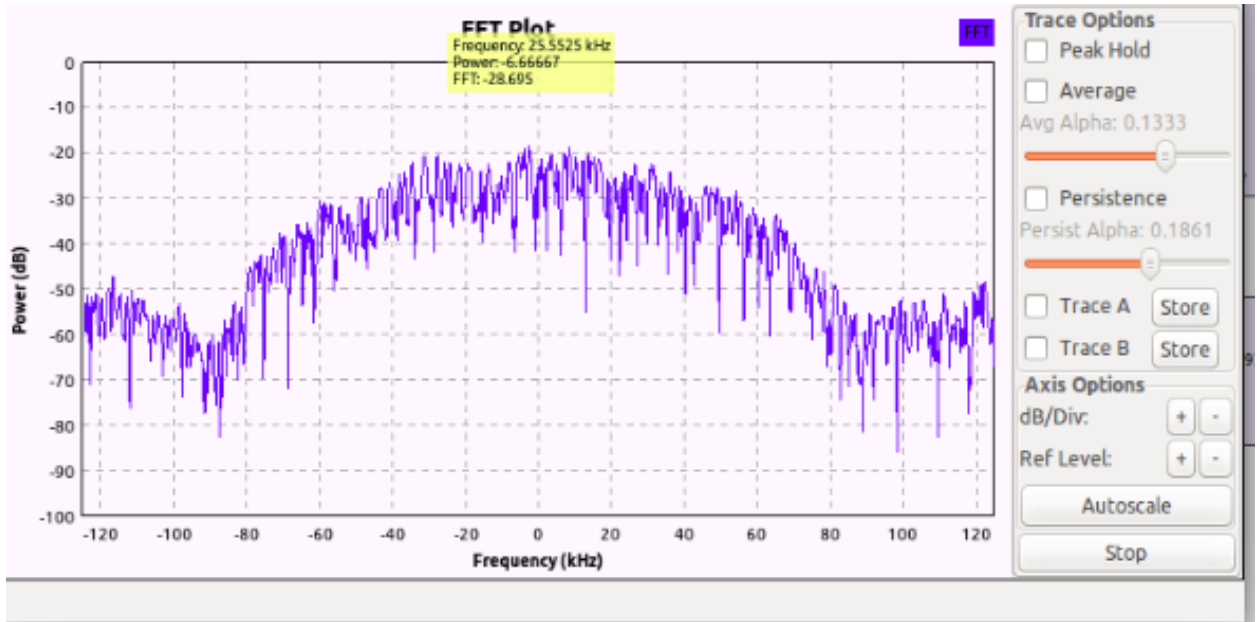


Figure 5: GRC Flow graph for FFT sink when Transmit message signal

In transmitter flow graph several blocks are used for transmitting message signal using USRP. The description of these blocks are as follows.

- **File Source:** This block is uploading text file which we want to transmit over channel. It is a bit stream file.
- **Packet Encoder:** This is converting the bit stream file into packets and producing symbols.
- **GMSK Modulator:** This block performs 3 tasks: first it will convert all 0 and 1 to ± 1 . Second, there is a Gaussian Filter, and finally it will do modulation.
- **Throttle:** This prevents GRC software from consuming all CPU resources when the flowgraph is not using any hardware block like USRP source, sink, etc.
- **USRP Sink:** This block does the task for transmitting the signal at centre frequency (in our case 915 MHz).

Figure 6 shows the grc flowgraph of receiver for direct transmission

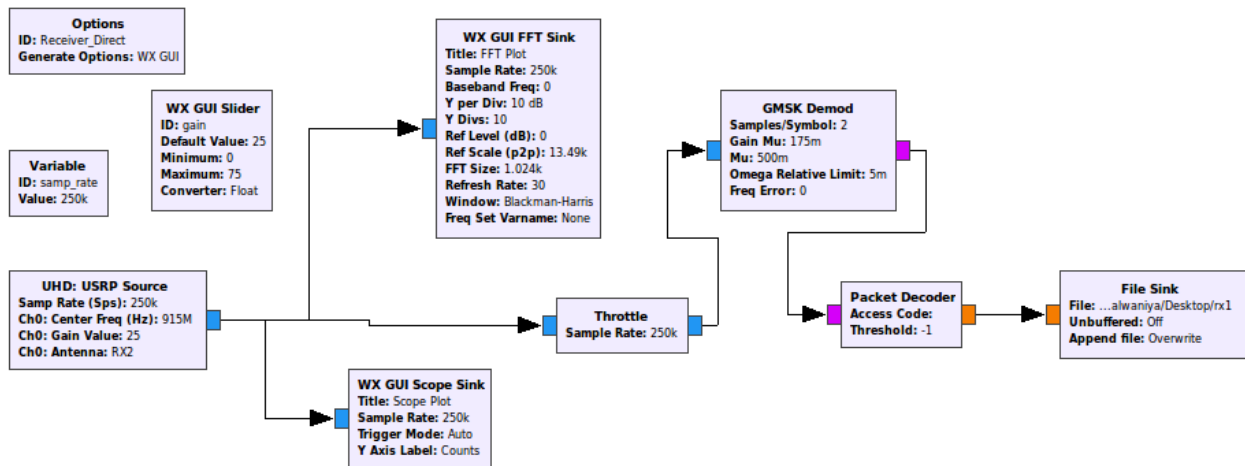


Figure 6: GRC Flow graph of Receiver for Direct Communication

- **USRP Source:** In this, the transmitted signal is received in analog form.
- **WX GUI FFT:** It is used to see the Fourier transform of the received signal.
- **Throttle:** It is used to give required amount of memory to run the program so that the computer doesn't freeze.

- **GMSK Demodulator:** It collects the phase information of incoming packets. B) Clock Recovery : It synchronize the symbols. C) Slicer It is used for symbol decision. Packet Decoder: In this, Data are extracted from the packet.
- **Packet Decoder:**In this, Data are extracted from the packet.
- **File Sink:**The extracted data are sent into a file where they are saved.

After direct transmission we have to implement it using Relay in between the transmitter and receiver. For cooperative communication using relay, the grc flow graph for relay as Amplify and Forward is shown in Figure 7.

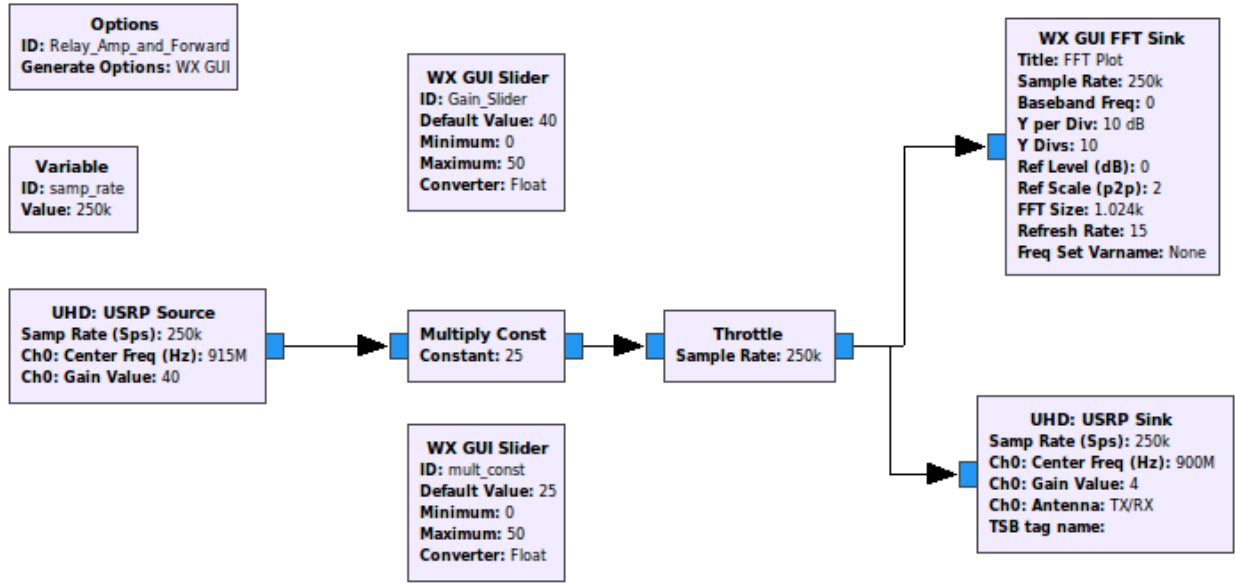


Figure 7: GRC Flow graph of Relay as Amplify And Forward

- **Sampling Rate:**The sampling rate we used in GRC flow graph is 250 KHz.
- **Center Frequency:**In the USRP sink block we have to set the transmitted frequency to transmit our message signal that we chosen 915 MHz. For Receiver we used USRP source block in that we also should use same frequency that we used for Transmitter.
- **Antenna:**For transmitter there is only one option that is RX1/TX1 but on receiver side we can choose TX1/RX1 or RX2.



Figure 8: Waveform when Realy used as Amplify and Forward

- **Packet Decoder:** In this, Data are extracted from the packet.
- **File Sink:** There we have to specify the location for received signal with extension and chose overwrite or Append option based on our requirement.
- **WX GUI Scope:** This block is used to see count vs time graph for that specified grc file.
- **GRC flowgraph for relay as Decode and Forward**

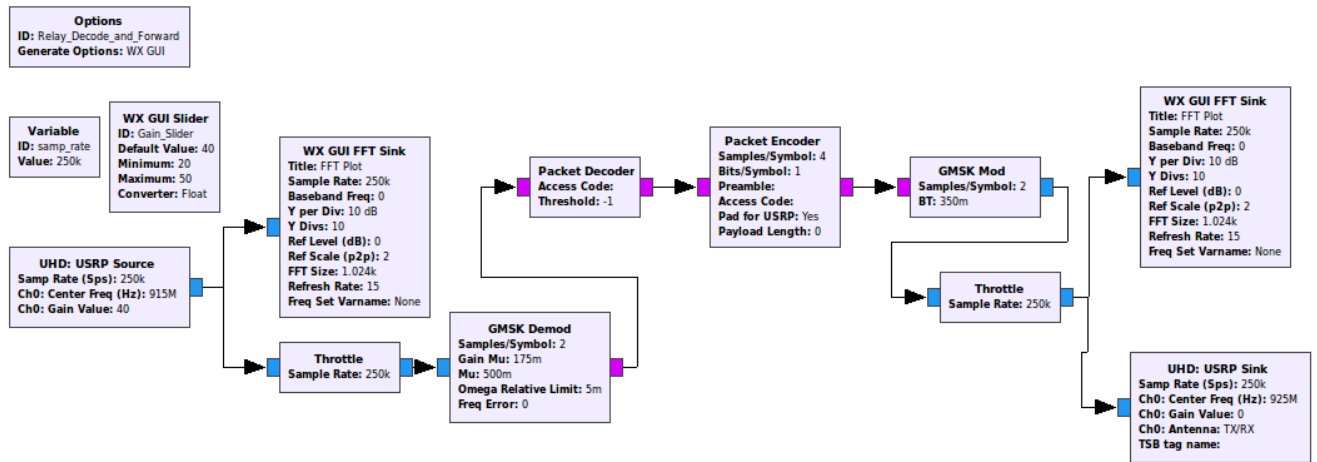


Figure 9: GRC Flow graph of Relay as Decode And Forward

In this flowgraph we are receiving the message signal at transmitted frequency(915MHz) ,de-modulate it ,amplify it and again transmit the signal at different frequency(900 MHz) after modulation.

- **FFT Sink of Relay as Decode and Forward**



Figure 10: FFT Sink when Relay used as Decode And Forward

- **Final Receiver:** This GNURadio file starts with USRP source with two channels that has different centre frequency (915,900 MHz). Then demodulate the respective signal by GMSK technique and save file as Rec-dir-msg.txt and Rec-relay-msg.txt.

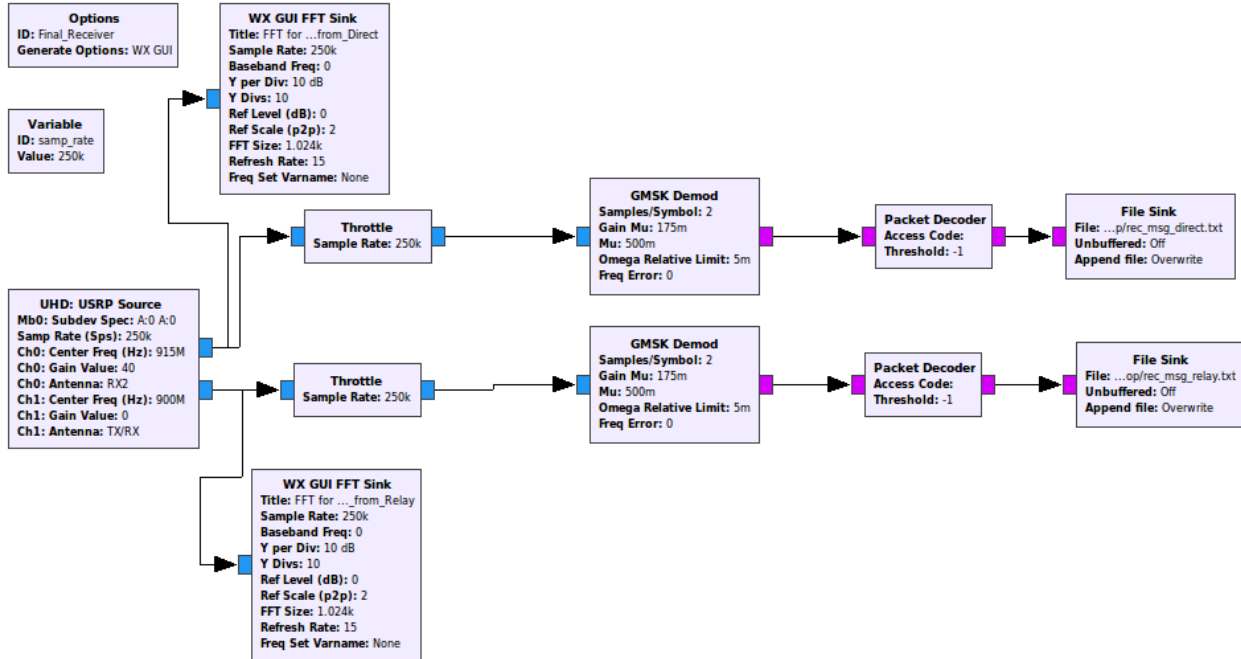


Figure 11: GRC Flow graph for Final Receiver

- **FFT Sink of Final Receiver:** In this waveform graph we will always see some waveform as of noise but some peak value obtained when we transmit message signal.

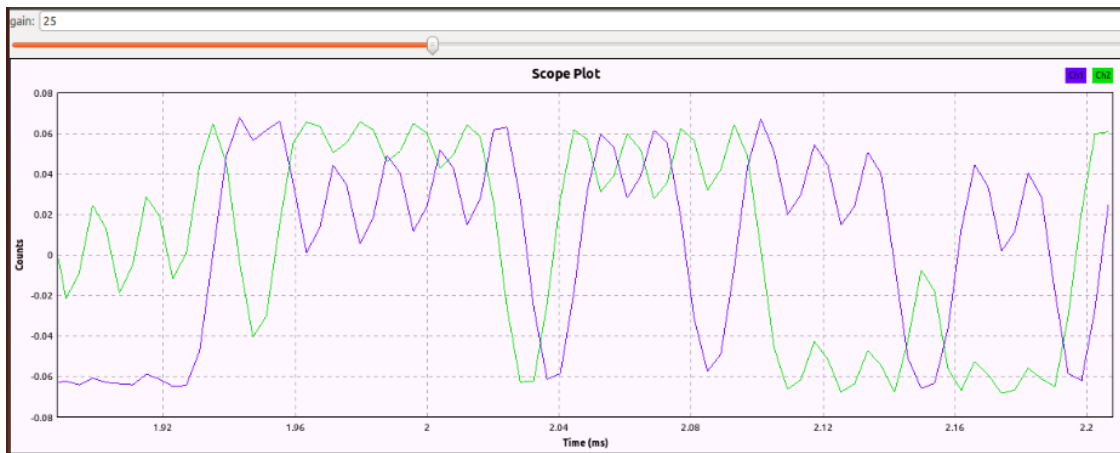


Figure 12: GRC Flow graph of Relay as Decode And Forward

10 Lessons Learned

Throughout this project we understand how to setup USRP in resective uhd device.By performing the cooperative communication using relay we understand how a file transmission takes place and at what frequency suitable for what type of message file transmission.We also learned how GMSK works.

11 Conclusion and Future scope

In this we understood that a usrp can do one thing at a time means it can not do transmission and as a reception simultaneously.For very short message signal the transmission it not taking place without repeat mode. This implementation of Cooperative communication using Relay at lab environment demonstrates basic file transmission using hardware and software based platform.

for future implementation we have to deal with more obstacle destruction so we can use multiple relays for less distortion.

we can use OFDM modulation technique for better signal quality and efficient spectrum of received signal.

References

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12 Appendices

Here is the detail of Hardware devices used for our project

1. NI USRP-2920

20 MHz Bandwidth, 50 Mhz to 2.2 GHz software Defined Radio Device.



Figure 13: NI USRP 2920

Reference of image: https://research.ece.ncsu.edu/mpact/wp-content/uploads/2016/10/IMG_2178_cropped-3.jpg

Highspeed ADC and DAC for streaming baseband signals Vert400 Antenna

Extended Receiver range 118 – 160 MHz, 250 – 290 MHz.

Maximum Power : 10 Watt

Length : 17cm

Connector : SMA