

## Free Writing Assistant

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Universal Software Radio Peripheral (USRP)

The USRP is developed by Ettus Research LLC. who are involved in developing of SDR platform form general purpose computers. The USRP we use here knows as USRP 1 in which motherboard consist of four ADCs/DACs which are capable for fast and effective performance these are connected to radio front end daughterboard. There is programmable FPGA Chip on motherboard which is connected to PC through USB. Figure 2 show USRP's motherboard and daughterboard which are used in our project also there are other list of daughterboard that are used for different frequency band.

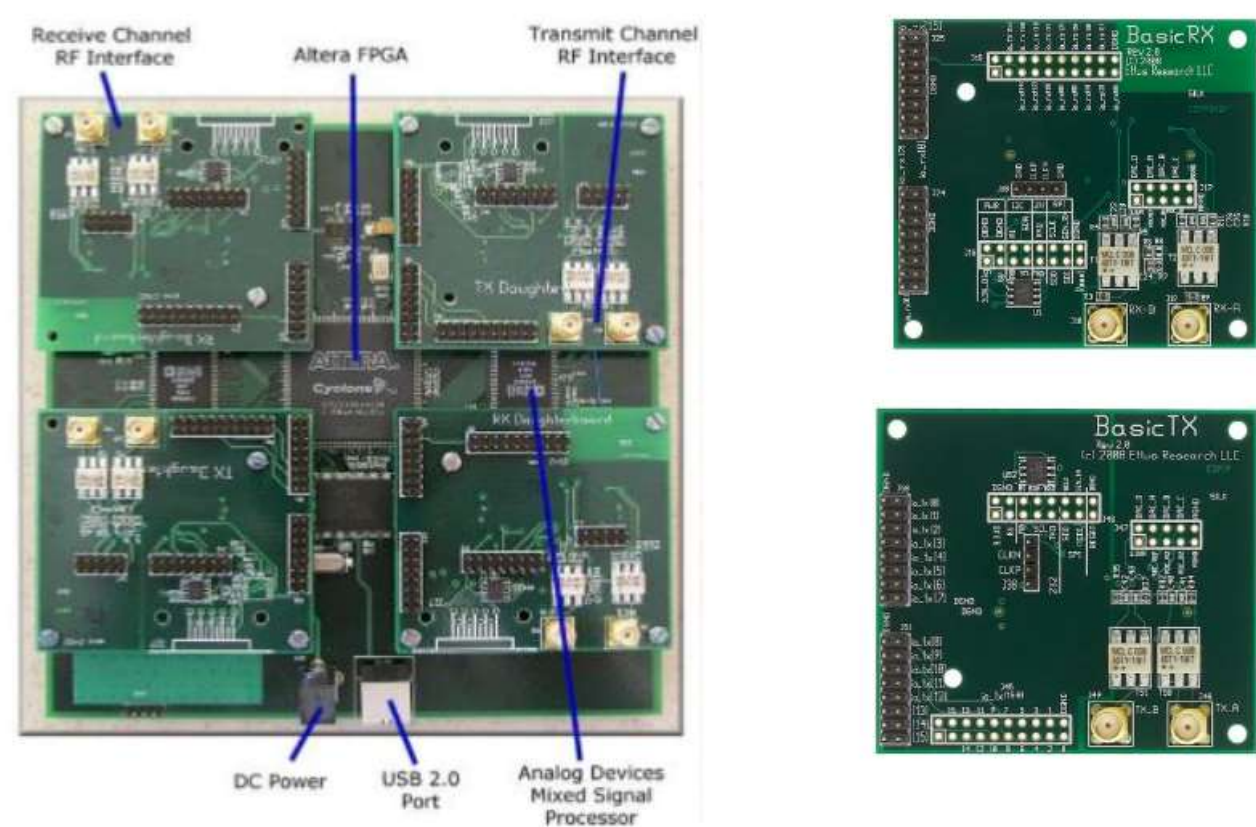


Figure 2. USRP Main Board and Basic TX and Basic RX Daughterboard 1-250 MHz Tx/Rx

Types of Daughterboard.

Following are list of Daughterboard with its band range and cost

- 1. Basic TX and Basic RX Daughterboard 1-250 MHz Tx/Rx - \$140
- 2. LFTX -- DC-30 MHz Transmitter and Receiver - \$154
- 3. TVRX2 50-860 MHz Rx x 2 - \$205
- 4. DBSRX -- 800 MHz to 2.4 GHz Receiver - \$155
- 5. RFX400 -- 400-500 MHz Transceiver - \$275
- 6. RFX900 -- 800-1000MHz Transceiver - \$275
- 7. RFX1200 -- 1150 MHz - 1450 MHz Transceiver - \$275
- 8. RFX1800 -- 1.5-2.1 GHz Transceiver - \$275
- 9. RFX2400 -- 2.3-2.9 GHz Transceiver, 20+mW output - \$ 275

**GNU Radio**

GNU radio provide software environment for developing and which is open source and free of cost software and also has inbuilt signal processing blocks for implementation of software radios. For creating SDR it provides less cost RF hardware and it also provides stimulation like user interface which does not required physical hardware. It is widely used in real radio systems and for research related work for wireless communication.

**Implementation**

For implementation in GNU Radio their certain blocks which are pre-defined in gr library, this blocks are been created in C++ as low level programing while python is used to build graphs as high level programming and as interface between them (Simplified Wrapper and Implemented Generator) SWIG is used.

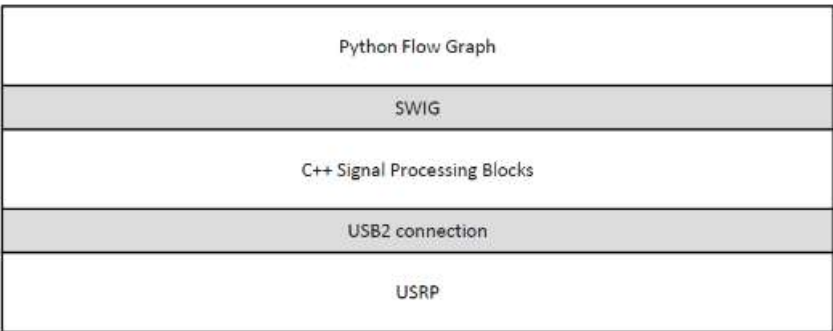


Figure 3. GNU radio framework structure

**1. Practical Implementation using WBFM Modulation/Demodulation Scheme**

**FM Transmitter**

In practical implementation the modulation technique used here is wideband frequency modulation. When the highest frequency component of a modulating signal is greater than the peak frequency deviation of modulated signal, then it is called as wide band frequency modulation.

Following are detail description for block for building WBFM

Figure 3a WBFM Transmit: The message signal is then passed through WBFM block which takes the input signal and gives the frequency modulated signal as an output. Audio rate and quadrature rate are the sampling rate of input and output signal. You can give any value to Max Deviation as long as it is greater than 20kHz (highest frequency component of a (sound) message signal). Also Figure 3b shows FFT sink properties of after WBFM block to see exactly how is signal look after Modulation.





1. Here our main aim is to transmit some audio file to the destination so we are going to use a file source (here wav file source) and not the USRP. In the Wav file source we have to choose the input file source where we store our audio file.
2. Figure-5 shows the graph for our Wav file before the WBFM block.

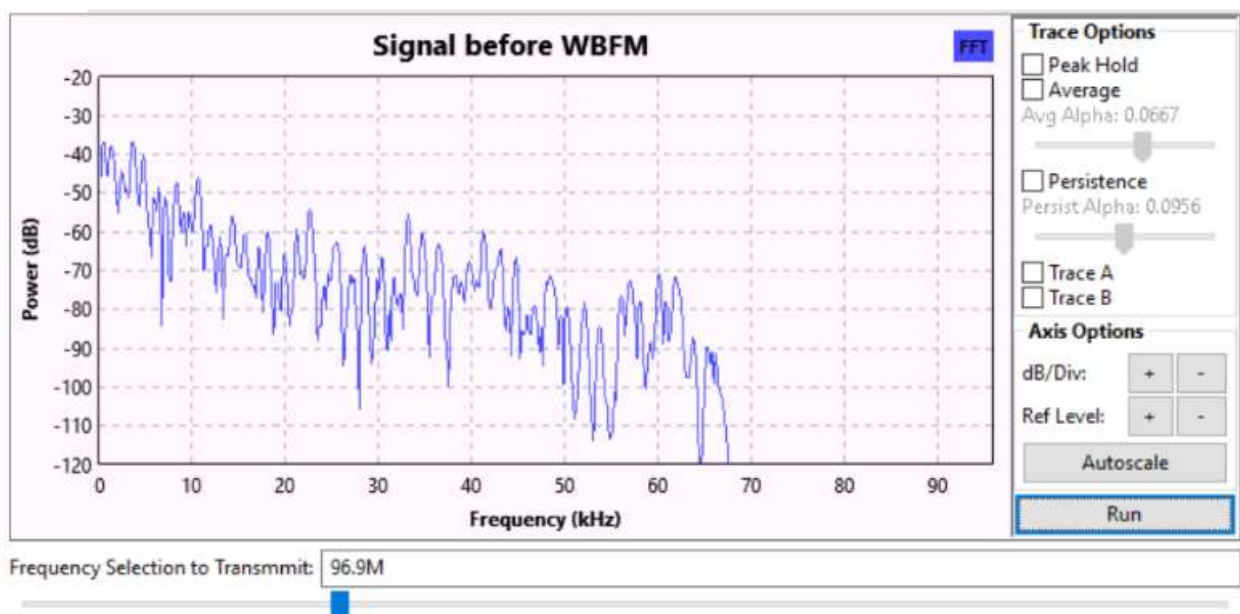


Figure 5. Original Wav file signal

3. Then this input file is sent the WBFM block where audio rate is predefined. Here quadrature rate is set in the multiple of 48 and this rate is the outgoing sample rate whereas 48kHz is incoming sample rate. The modulated signal is shown in Figure-6 below.  
Audio rate: 48 kHz  
Quadrature Rate:  $48 \text{ kHz} * 4 = 192 \text{ kHz}$   
Tua: 75u

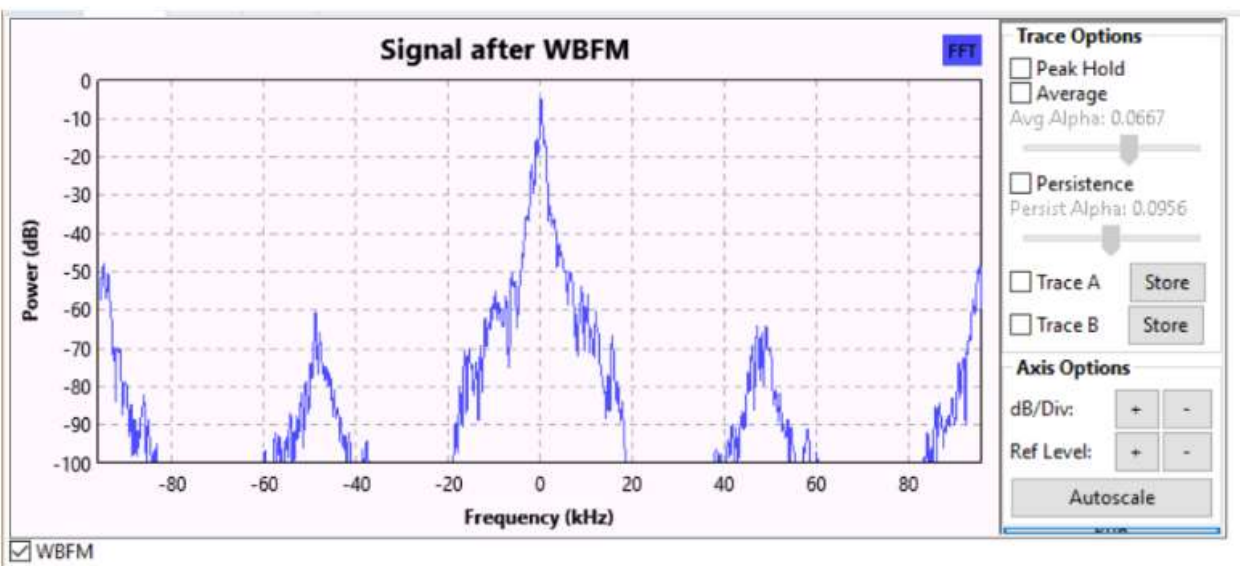


Figure 6. Signal after modulation



- 4. After that this sampled signal is sent to the rational Resampler. Where we are doing some frequency conversion. For example, the Audio Sink needs lower frequency and USRP block need higher then this block converts the frequency by doing some interpolation or decimation as per the requirements.
- 5. Now output of the rational resampler is feed to one of the input of the Multiply block. Second input of the multiply block is Cosine signal with the 192 kHz sample rate. Here this carrier signal is used for proper transmission.
- 6. Figure-7 shows resulting signal after multiplier.

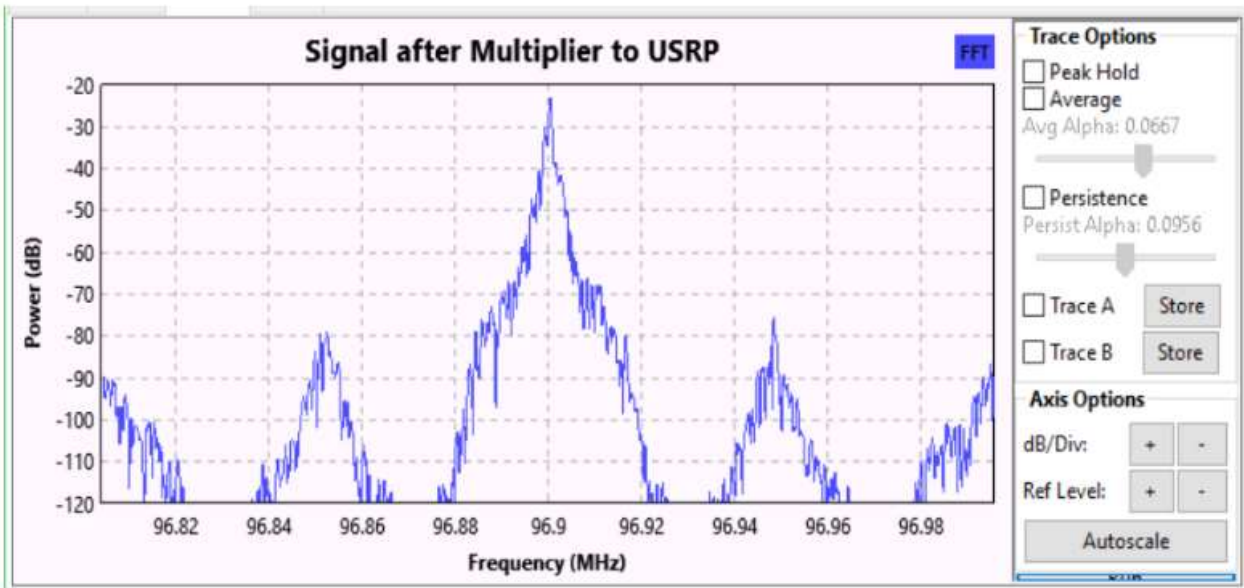


Figure 7. Multiplication of carrier signal and modulated signal

- 7. Now these multiplied signal is sent to the USRP sink from there signal is send to the destination using wireless medium. Here we use 96.9 MHz as center frequency but it can change using freq\_selection slider and antenna is connected to TX/RX daughterboard.

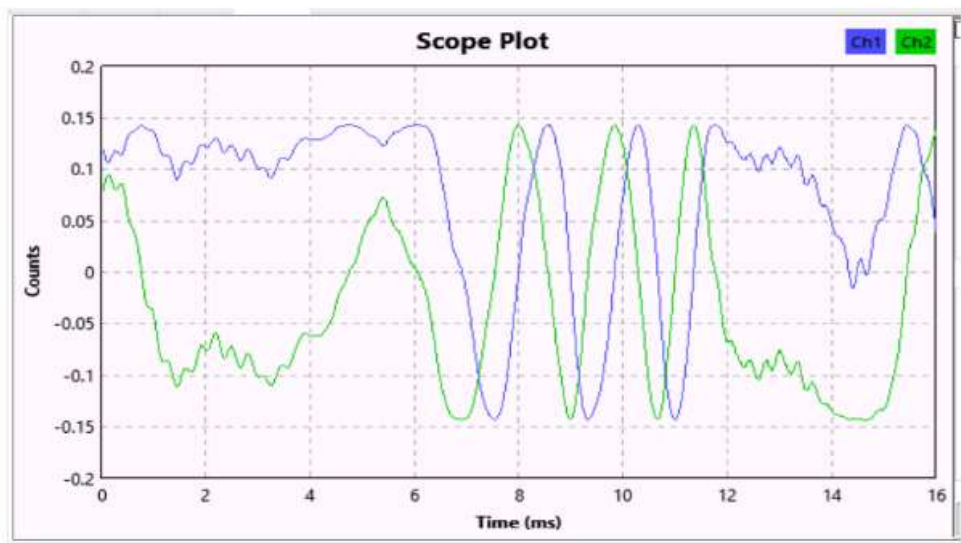


Figure 8. Multiplication of carrier signal and modulated signal in time domain

FM Receiver

- 1. Here we are trying to receive FM channels using USRP that is why our input source is going to be USRP block with centre frequency of 106.7MHz which can be adjusted with the help of Text Box. Here sampling rate is 4MHz and other properties are as below:  
Gain Value: It is managed by rf\_gain slider with min=0 and max=30.  
Antenna: Connected to TX/RX in daughter board

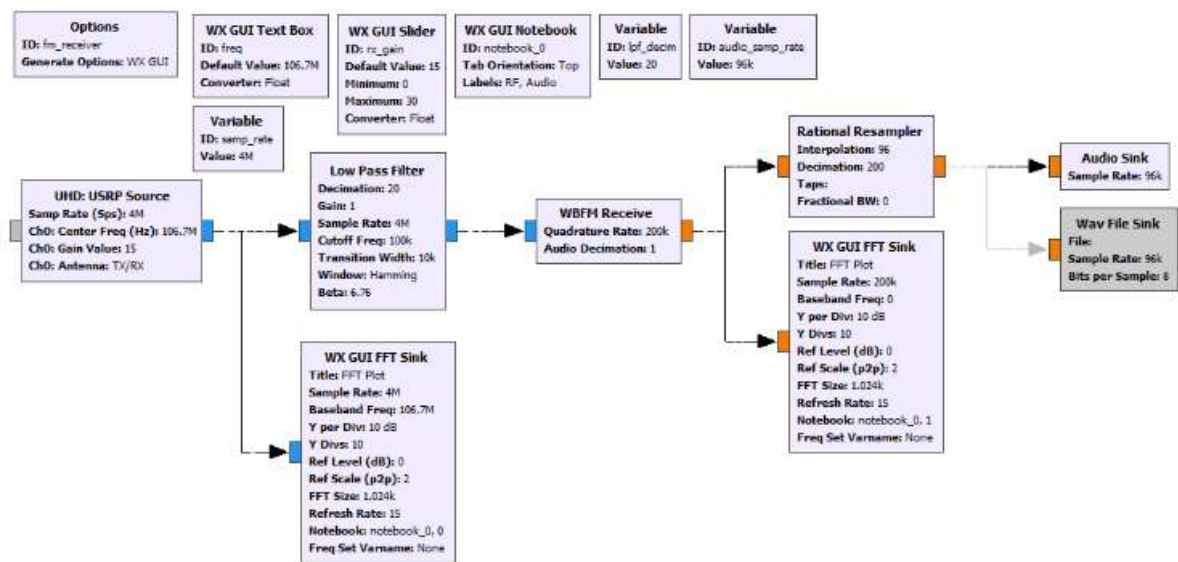


Figure 9. Modified FM Receiver

- 2. Now the output of the USRP block is going to the low pass filter. Here filter passes the signal whose frequency is below the cutoff frequency (here it is 100kHz) and also it deduces the signal with higher frequency.
- 3. Figure 10 shows the graph of the received signal at the input of USRP.

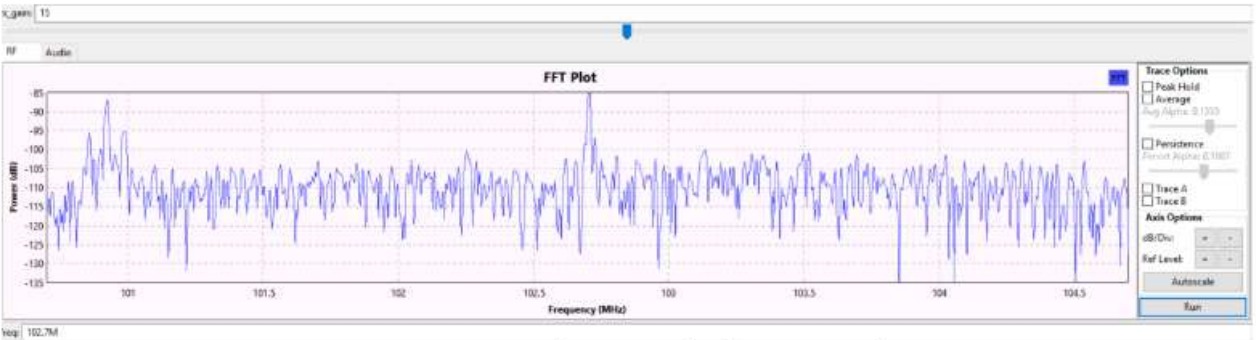


Figure 10. Resulting Graph of Input Signal

- 4. Now filtered signal is given to the wide band FM block. This block demodulates the wide band frequency signal from data stream. So at the output we get the original data stream which sent by the sender.
- 5. Output of the WBFM block sent to the Rational Resampler. Here we decimate or interpolate the data stream according to the application to the desire rate. For example, the Audio Sink needs lower frequency and USRP block need higher then this block converts the frequency by doing some interpolation or decimation as per the requirements.



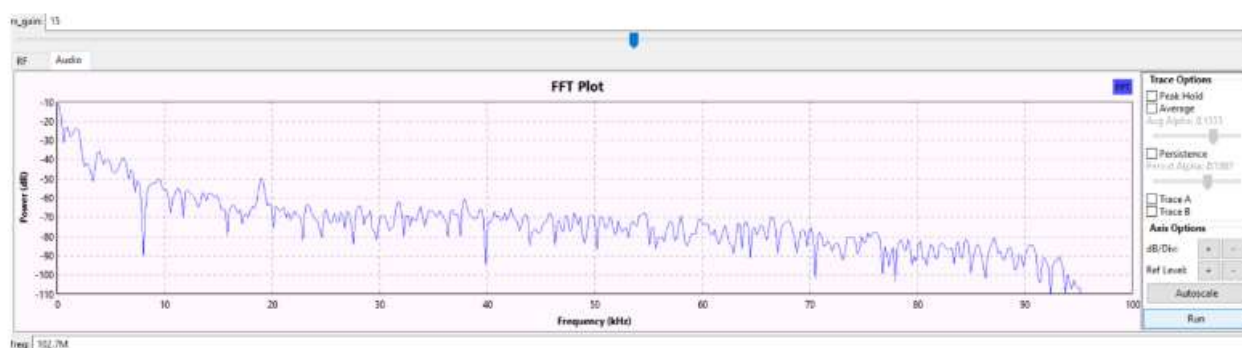


Figure 11. Resulting Graph of Low Passed Signal

6. Figure 11 is the graph of demodulated data stream in frequency domain.
7. Finally, Audio sink block is used to listen the sound of the received channel.

### Combined Implementation

Figure 12 below shows the combine receiver and transmitter flow graph where we tune into our FM channel using GUI Text Box which is used to receive the FM channels. The USRP block takes this frequency as its center Frequency and shifts it to origin to make it a baseband signal. Thus changing the center frequency of the USRP, we can tune to various channels. In this implementation we use basic Rx so it can work only in certain frequency range i.e. 1-250MHz. Also the antenna has to be in the frequency range in which you want to receive the signal, so in the beginning, reception was not at all audible. After successfully receive the FM channel it is feedback to transmitter portion. Now with the use of this transmitter we transmit that channel to the another frequency (here it is 106.9 MHz). So, in general we receive an audio from one channel then play from laptop's soundcard and broadcast it from transmitter and listen to another channel using mobile phone.

1. Here we are trying to receive FM channels using USRP that is why our input source is going to be USRP block with center frequency of 91.1 MHz which can be adjusted with the help of Text Box. Here sampling rate is 4MHz and other properties are as below:  
Gain Value: It is managed by rf\_gain slider with min=0 and max=30.  
Antenna: Connected to TX/RX in daughter board
2. Now the output of the USRP block is going to the low pass filter. Here filter passes the signal whose frequency is below the cutoff frequency (here it is 100kHz) and also it deduces the signal with higher frequency.
3. Now filtered signal is given to the wide band FM block. This block demodulates the wide band frequency signal from data stream. So at the output we get the original data stream which sent by the sender.
4. Output of the WBFM block sent to the Rational Resampler. Here we decimate or interpolate the data stream according to the application to the desire rate. For example, the Audio Sink needs lower frequency and USRP block need higher then this block converts the frequency by doing some interpolation or decimation as per the requirements.



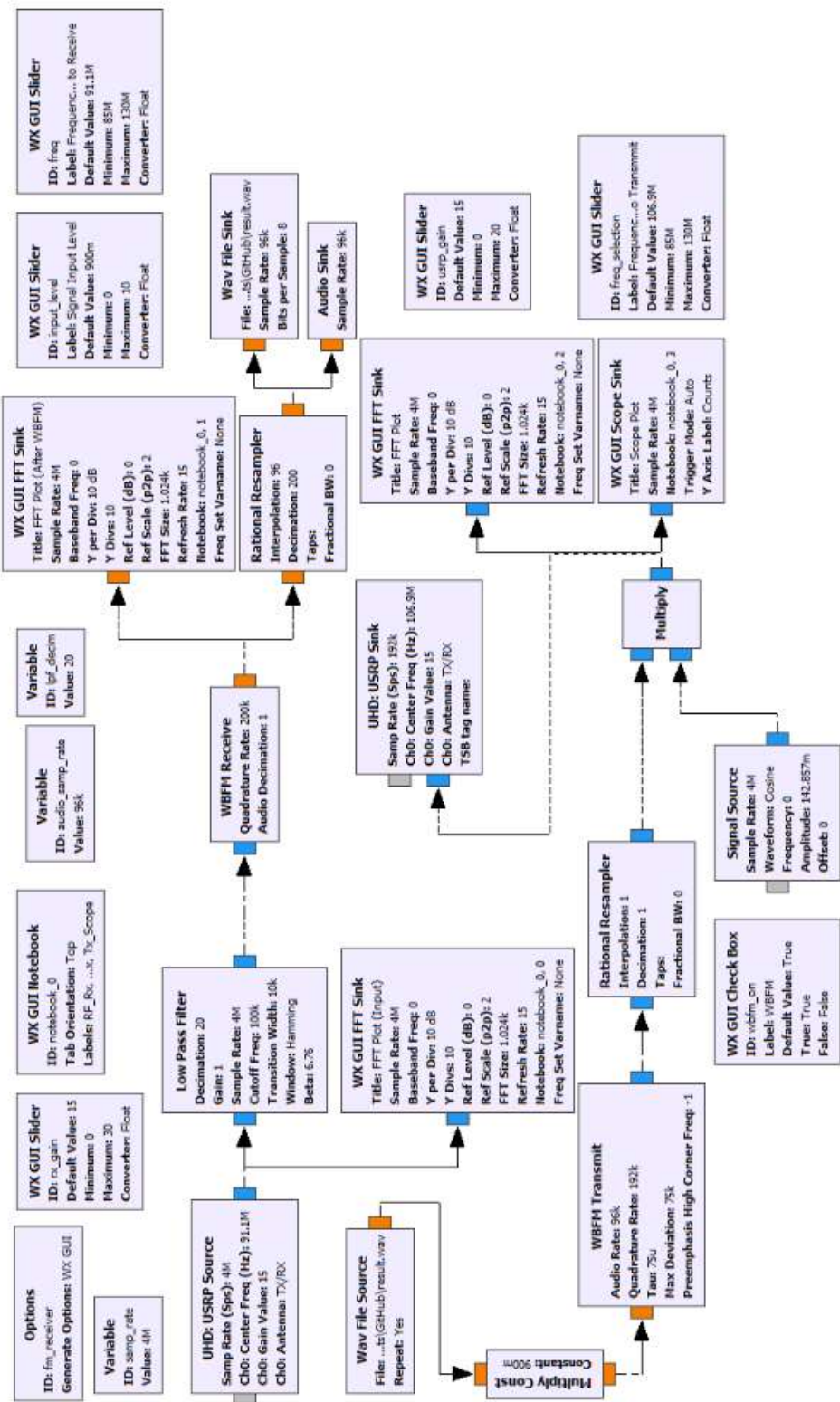


Figure 12. Architectural Flow Graph of FM Receiver and Transmitter using one USRP

5. Finally, Audio sink block is used to listen the sound of the received channel. Now as per our flow graph we are going to feed this back to transmitter for broadcasting. That's why it is used as input to the WBFM block.
6. Here in WBFM block quadrature rate is set in the multiple of 96 (i.e. 192 kHz) and this rate is the outgoing sample rate whereas 96kHz is incoming sample rate.  
 Audio rate: 96 kHz  
 Quadrature Rate:  $96 \text{ kHz} * 2 = 192 \text{ kHz}$   
 Txa: 75u
7. After that this sampled signal is sent to the rational Resampler. Where we are doing some frequency conversion again.
8. Now output of the rational resampler is feed to one of the input of the Multiply block. Second input of the multiply block is Cosine signal with the 192 kHz sample rate. Here this carrier signal is used for proper transmission.
9. Now these multiplied signal is sent to the USRP sink from there signal is send to the destination using wireless medium. Here we use 106.9 MHz as center frequency but it can change and antenna is connected to TX/RX on daughterboard.

## 2. Implementation using GMSK Modulation/Demodulation Scheme

### What is GMSK?

Gaussian Minimum Shift Keying (GMSK)

When we use half sinusoidal pulse instead of rectangular pulse then it creates the MSK (Minimum Shift Keying) signal. But when we use Gaussian Pulse shape rather than rectangular pulse then that type of modulation scheme is known as Gaussian Minimum Shift Keying (GMSK). Many studies states that GMSK digital modulation technique is revised adaptation of Minimum Shift Keying (MSK) in terms of bandwidth and spectral efficiency. In addition to that, GMSK has comparatively curtail side lobe level than the rectangular pulse and its main lobe is also confined than the QPSK and MSK. We can consider GMSK not only frequency modulation scheme but also we can view GMSK as phase modulation. Although changing of phase is restricted because of Gaussian response but advance or delay of  $90^\circ$  over bit period is not limited so beat shaping depends on Bandwidth Time Product (BT). Here in GMSK system bandwidth is totally depends on multiplication of filter bandwidth (before modulation) B and bit period T. Because of narrow bandwidth, GMSK suffers from Inter Symbol Interference (ISI) which decrease the signal power.

### GMSK Modulation

Frequency Shift Keyed Modulation and Quadrature Phase shift keyed Modulation are the two main methods for generating the GMSK.