College of Engineering Attingal

Instructor : Dr. Sunil T T

Lesson 3

Building FM transmitters and Receivers in GNU radio

Review of theory.

Assume that your carrier frequency is fc an modulating signal frequency is fm
FM can be generated by changing the phase of carrier

Recall that for a sinusoidal modulating wave,

$$m(t) = A_m cos\left(2\pi f_m t\right)$$

the FM wave can be written as:

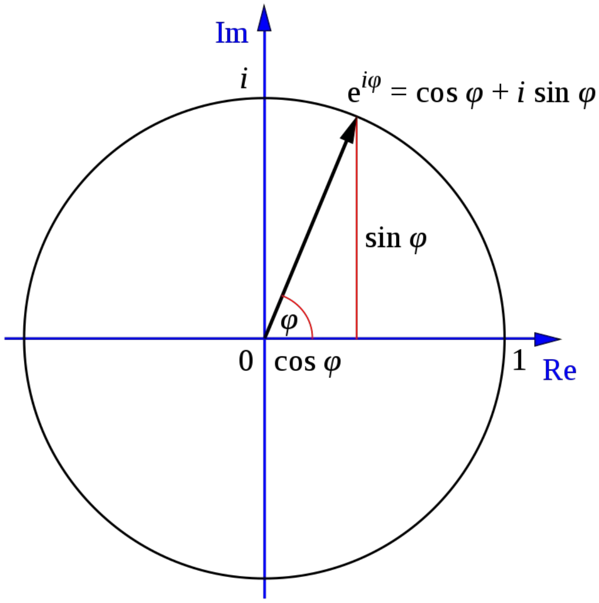
$$\begin{aligned} s(t) &= A_c cos\left(2\pi f_c t + \beta sin\left(2\pi f_m t\right)\right) \\ &= Re\{A_c e^{j(2\pi f_c t + \beta sin(2\pi f_m t))}\} \\ &= Re\{A_c e^{j\beta sin(2\pi f_m t)} e^{j2\pi f_c t}\} \end{aligned}$$

(Please learn your theory :D)

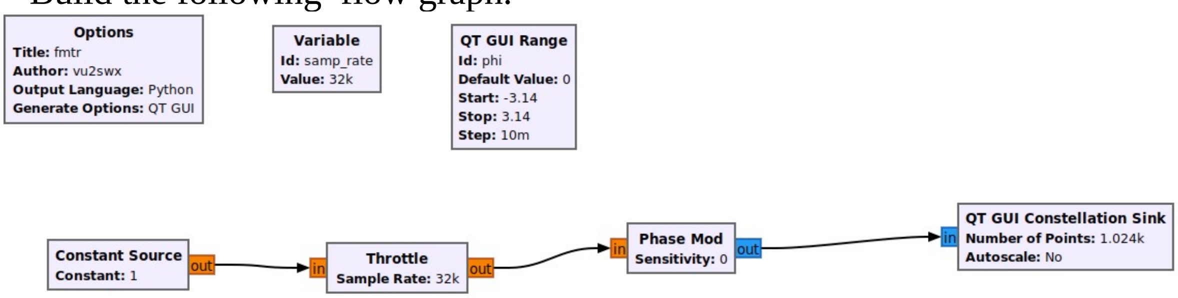
You can build the above exponential very easily in GRC and generate fm

Phase modulation

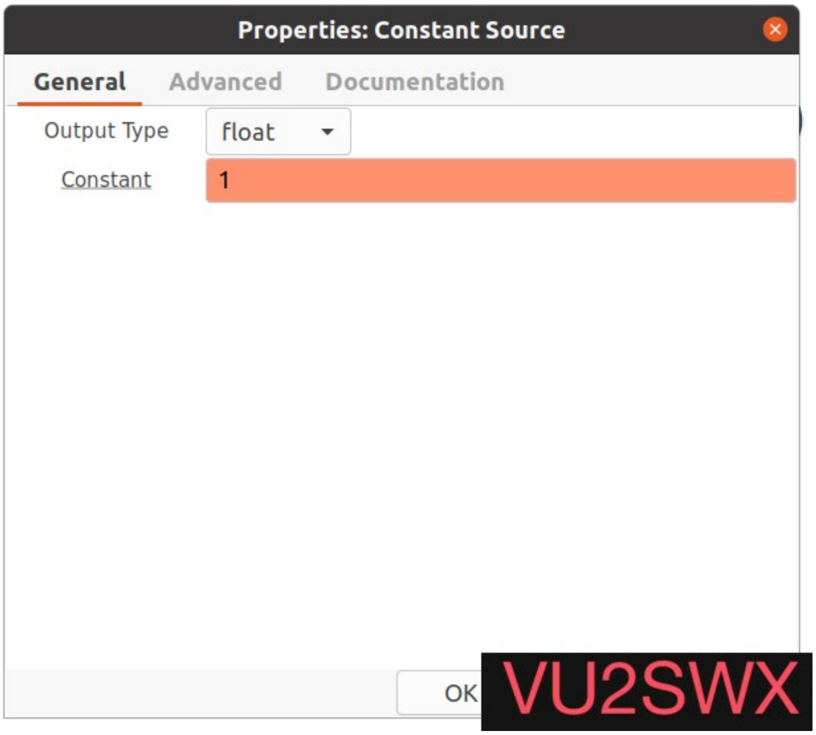
Let us first explore Phase modulation.



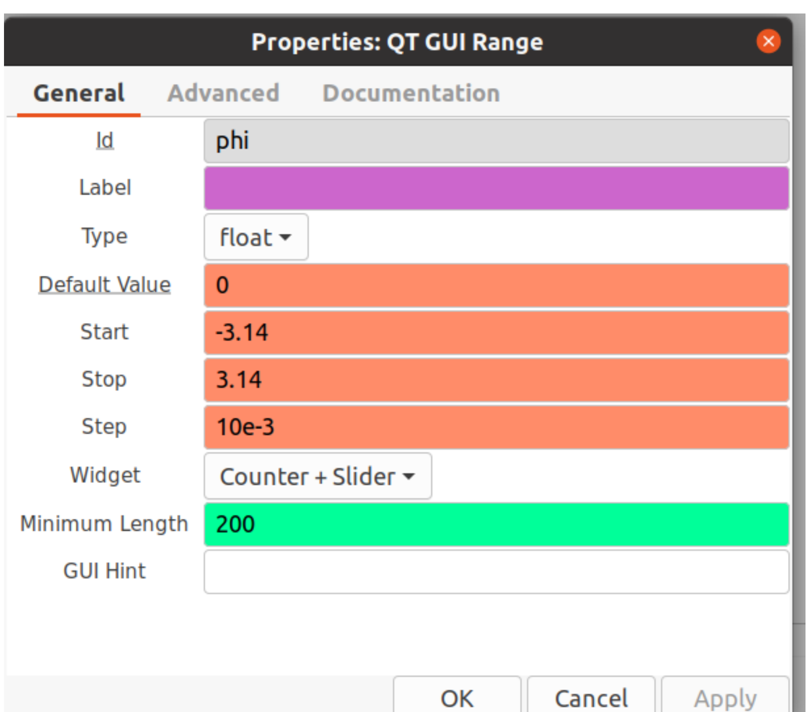
Build the following flow graph.



The first block is a constant source . It produces some constant value. It is followed by throttle and phase modulation. The throttle block is used to remove some samples . Otherwise our CPU will be overloaded.



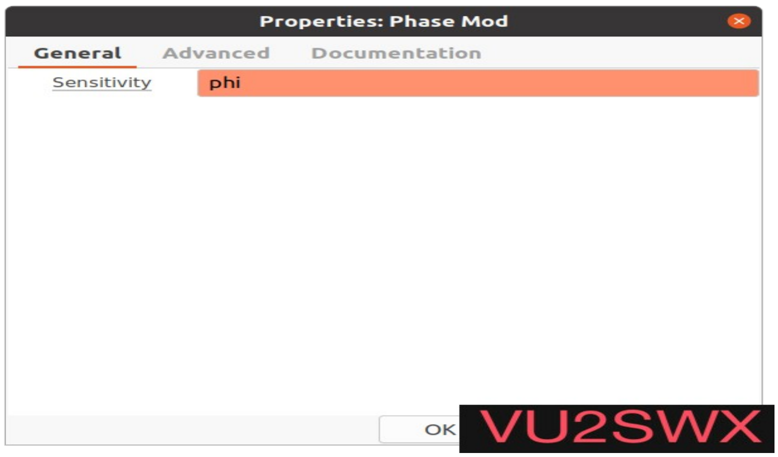
We will input a constant value and change the sensitivity and observe the phasor output. Set constant block to 1



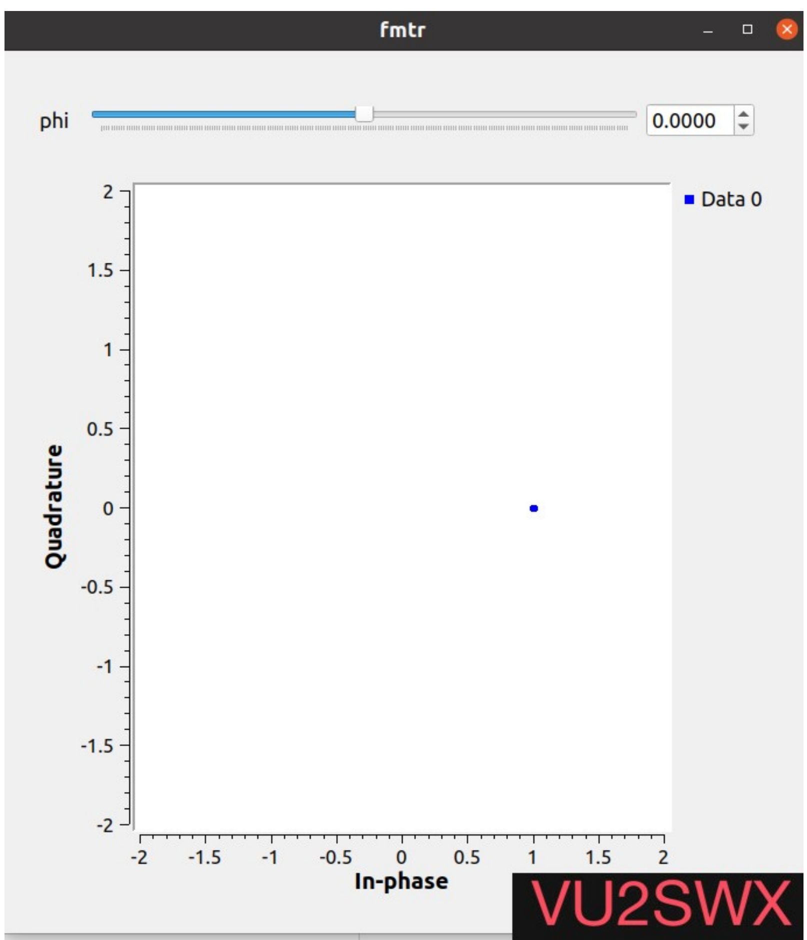
The QT range block controls the variable phi.   Set its value to change between -pi and pi.

We will send the constant signal to a phase modulation block and see how the I and Q values change as we vary phase.

You can set sensitivity to phi. Look at the data type colors.

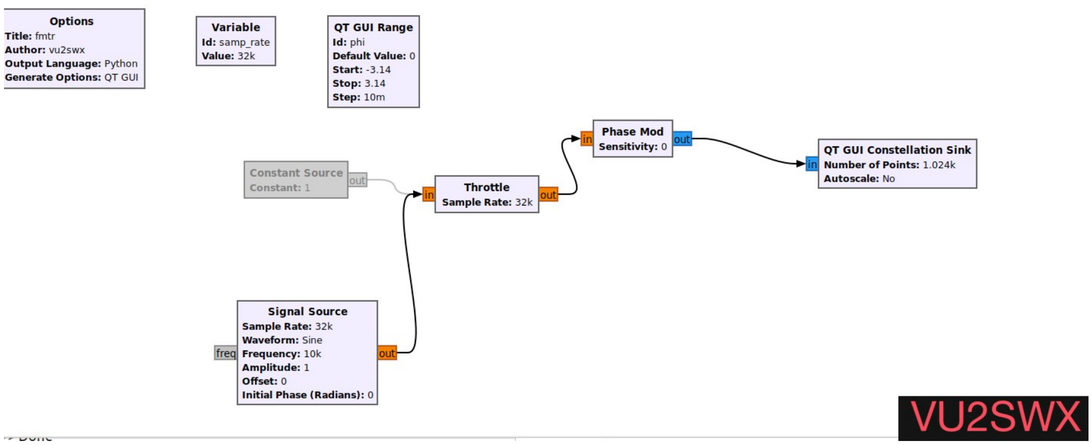


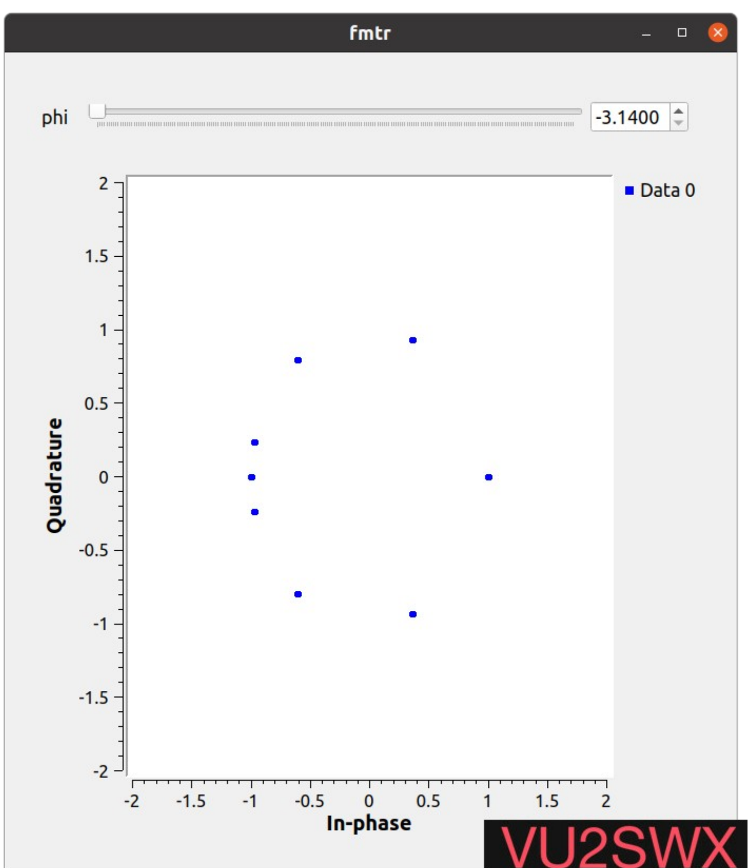
Instead of sensitivity you can vary input and obtain a rotating phasor.



The constellation diagram looks as shown below. Vary the phase and see how I and Q changes.

We will experiment with the above flow graph. Change the constant input source to a signal source.





Vary the phase and see the change of phasor in constellation output

Try changing the signal source to triangular or square and try to explain the diagram.

Frequency modulation.

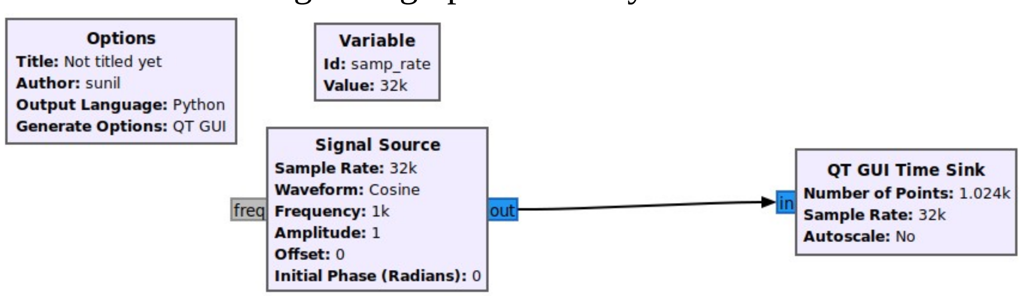
We will implement

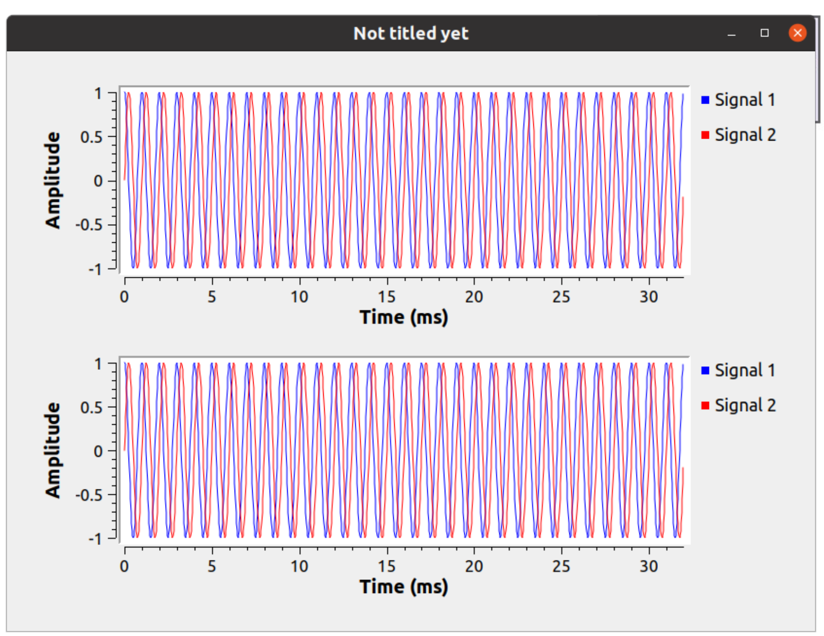
$$Re\{A_c e^{j\beta sin(2\pi f_m t)} e^{j2\pi f_c t}\}$$

We have constructed the first part above of the above equation using phase mod block above. Multiply the above with a phasor with frequency fc.

Complex sine and Complex cosine signals are nothing but phasors.

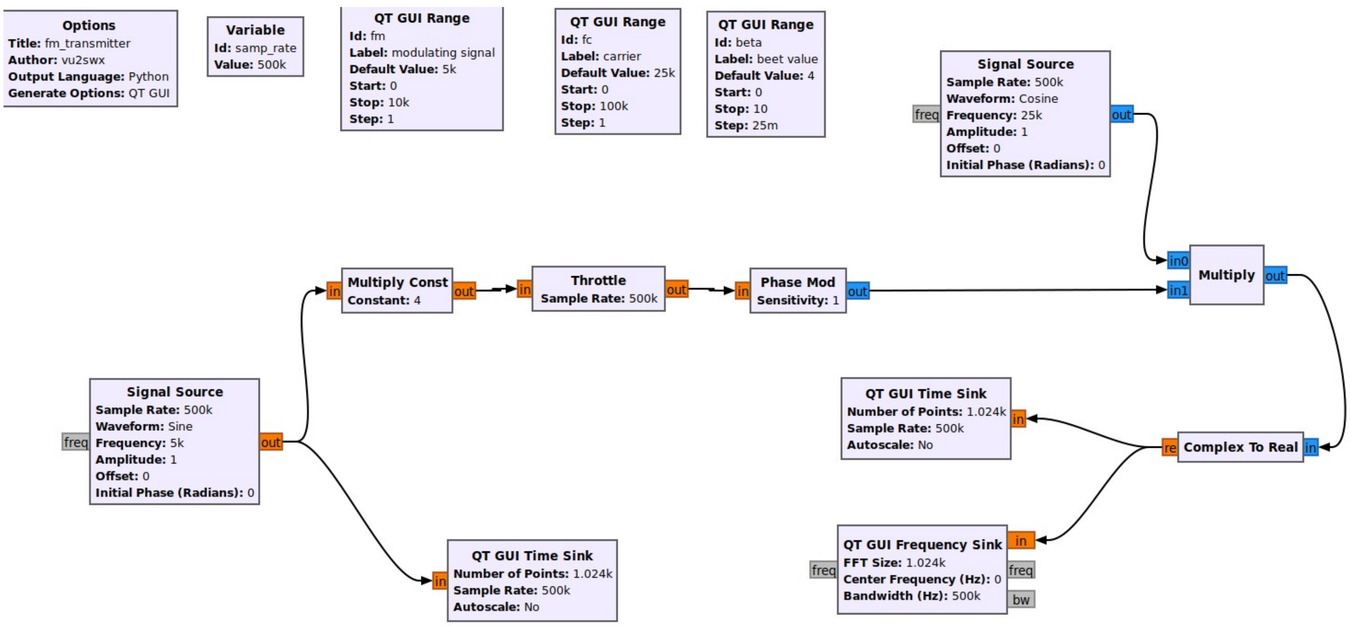
Implement the following flow graph and verify.





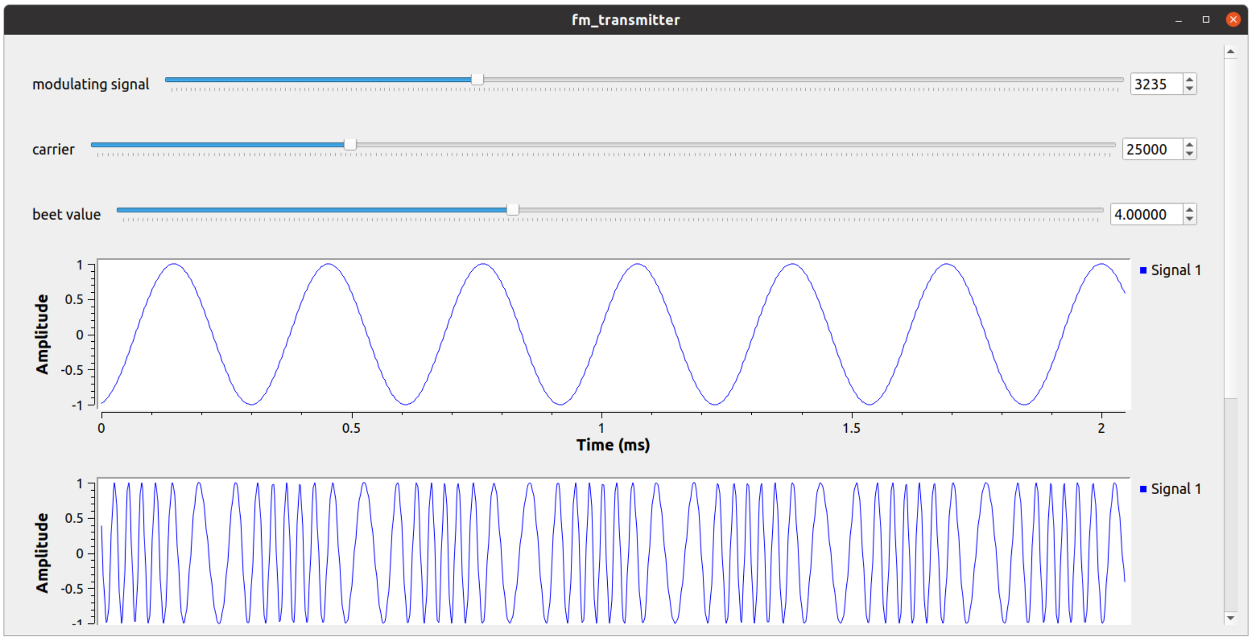
Closely examine the phase of I and Q in both cases above.

The fm transmitter implementation is shown below.



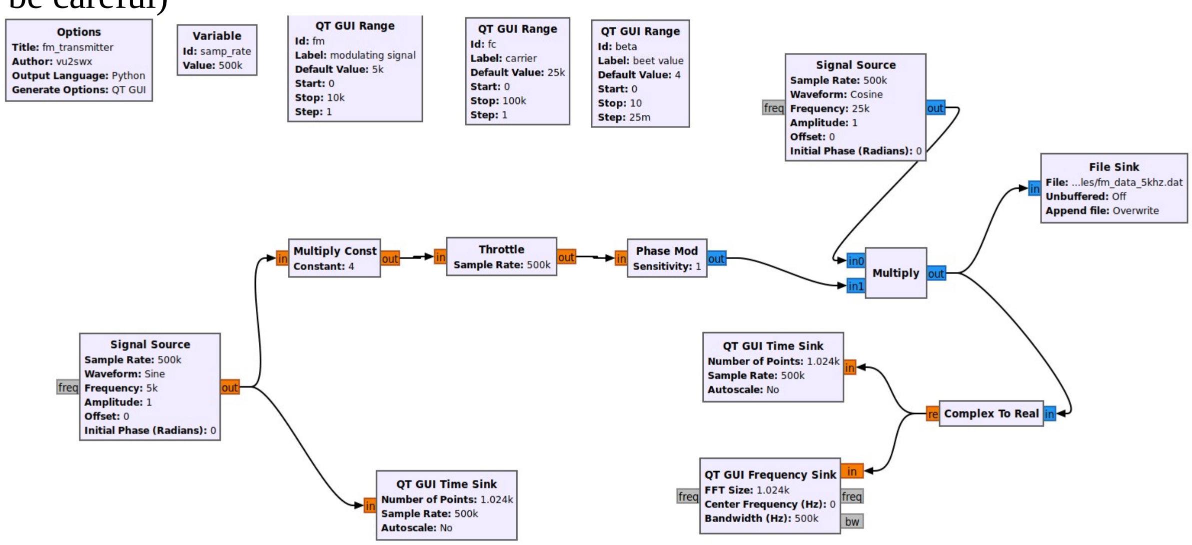
Look at the various QT widgets. We can control fm,fc and Beta with them. Complex to real extracts the real part.

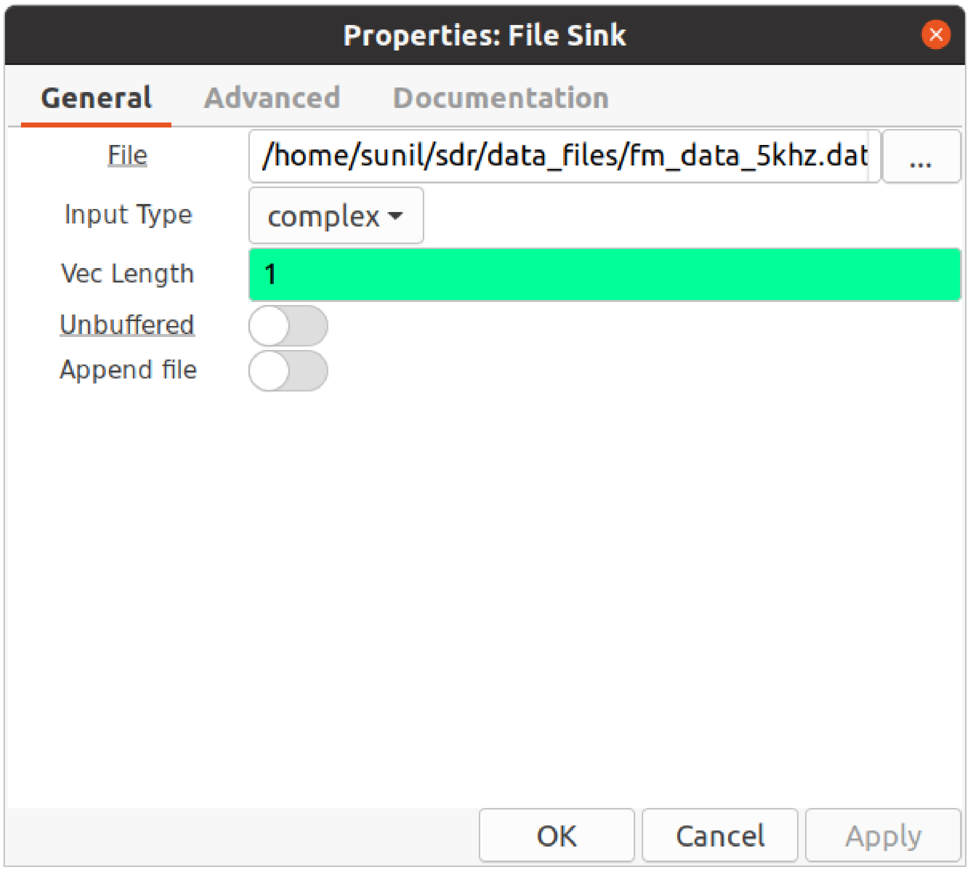
Carefully look at the colors of various outputs. The complex ones are shown in blue and real ones are shown as saffron. The output of the above flow graph is shown below.



Change the signal source waveform type and see the waveforms.

Next add a file sink block and save the output to a file. The file can grow very huge. (be careful)





Record the fm data for 1 minute . Locate the file and examine the content using od command. (od is available on terminal)

FM Receiver

FM reception is very easy.
Consider the FM signal

$$Re\{A_c e^{j\beta sin(2\pi f_m t)} e^{j2\pi f_c t}\}$$

If we multiply as shown below you can recover the original signal

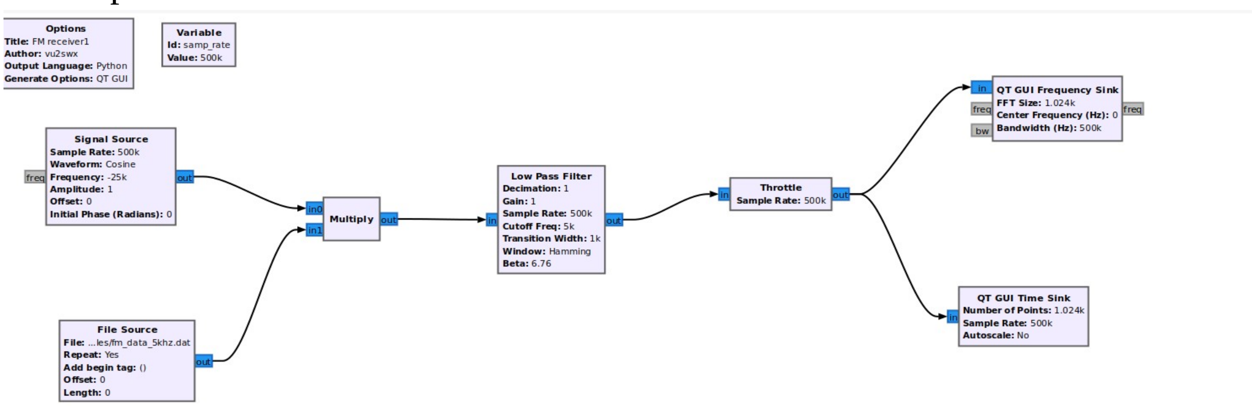
$$A_C e^{jBsin(2\pi f_m t)} e^{j2\pi f_c t)} \bigstar e^{-j2\pi f_c t)}$$

This will cancel out the carrier

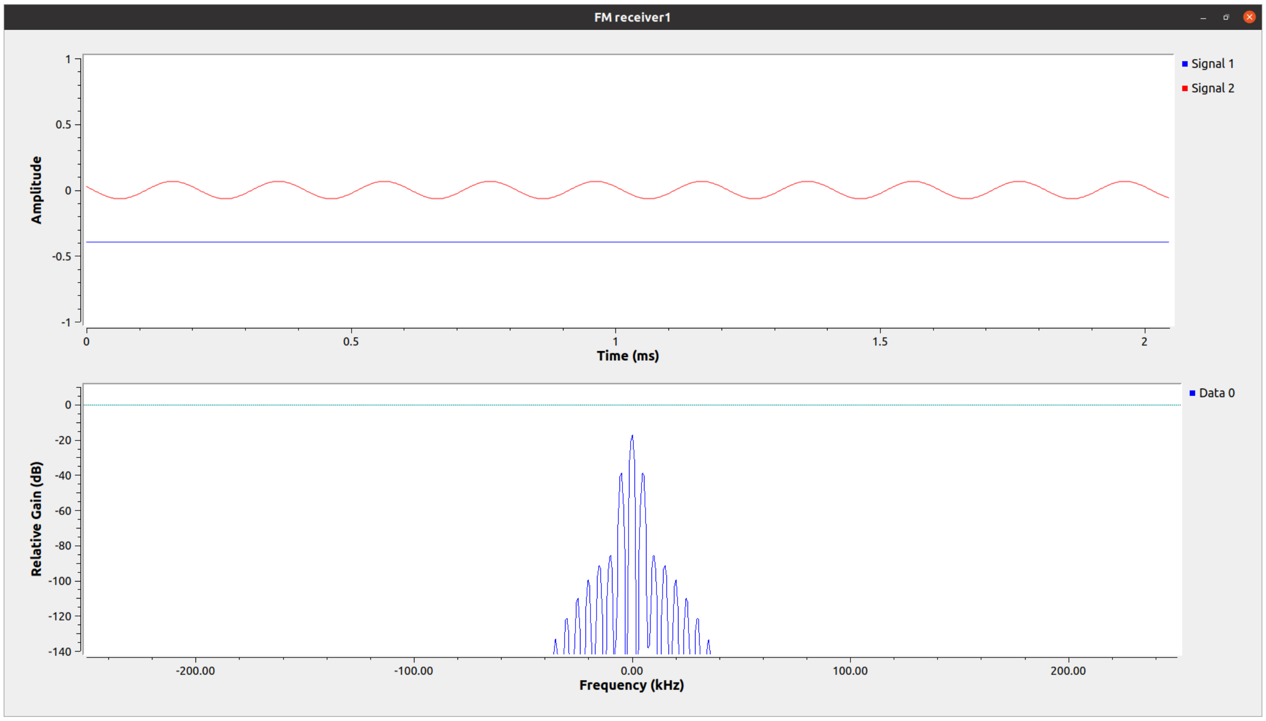
$$A_C e^{(jBsin(2\pi f_m t)+j2\pi f_c t+-j2\pi f_c t)}$$

Let us build receiver.

Use a file source which contain the complex FM signal saved from previous example**.**



Note the sign of the carrier.


FM receiver1
Signal 1
Signal 2
Amplitude
Time (ms)
Data 0
Relative Gain (dB)
Frequency (kHz)

Let us improve our receiver further

Assume that we have a message m(t) encoded as FM . We have I and Q signals corresponding to this**.**

- To extract $m(t)$ from $I(t)$ and $Q(t)$, consider them as a complex signal.

$$\begin{aligned} s(t) &= Re\{a(t)e^{j\phi(t)}e^{j2\pi f_c t}\} \\ &= Re\{[I(t) + jQ(t)]e^{j2\pi f_c t}\} \\ &= Re\{\tilde{s}(t)e^{j2\pi f_c t}\} \end{aligned}$$

where,

$$\begin{aligned} \tilde{s}(t) &= I(t) + jQ(t) \\ &= a(t)e^{j\phi(t)} \end{aligned}$$

- It can be shown that $m(t)$ is obtained from the following formula:

$$m(t) = arg[\tilde{s}(t-1)\tilde{s}^*(t)]$$

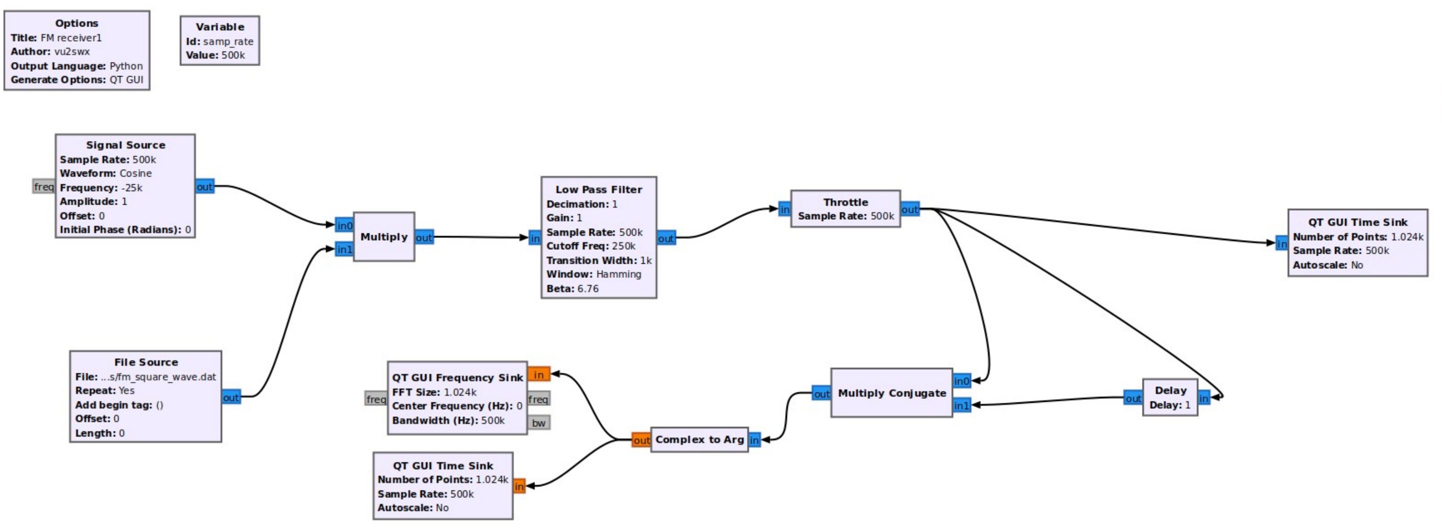
where,

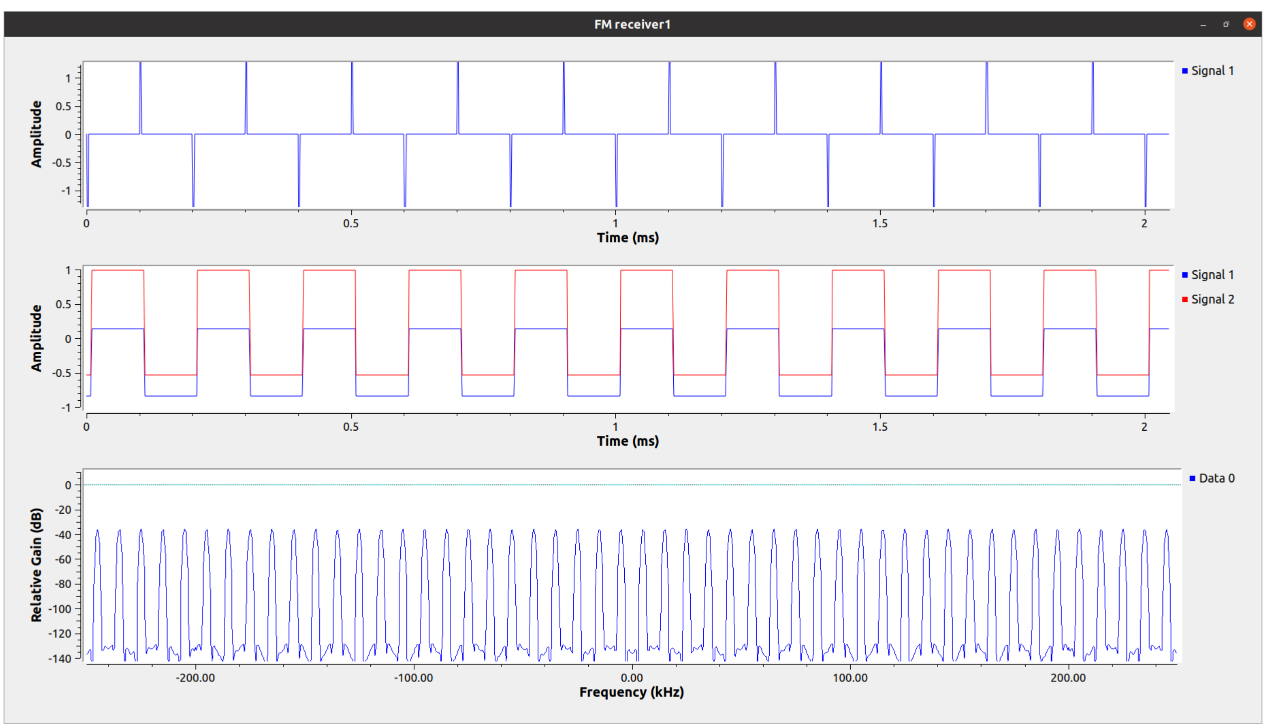
$$(t-1) \rightarrow z^{-1}$$

represents one sample delay.

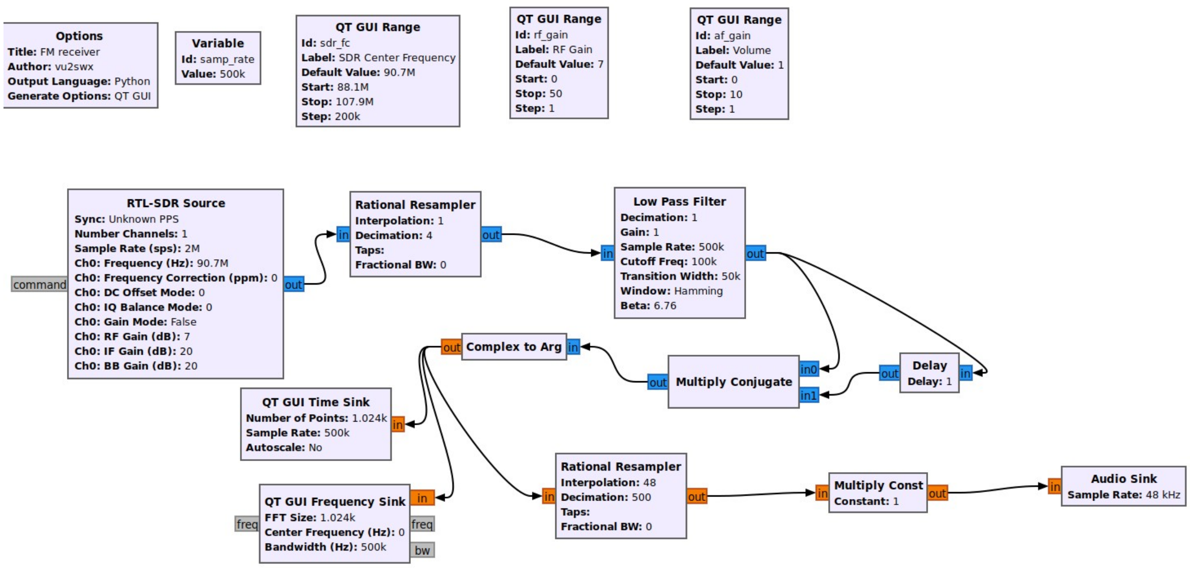
(Please look up the theory part and how to manipulate samples in z domain)

This can be implemented as shown below.





Now let us build an actual FM receiver which accepts signals from RTL SDR dongle

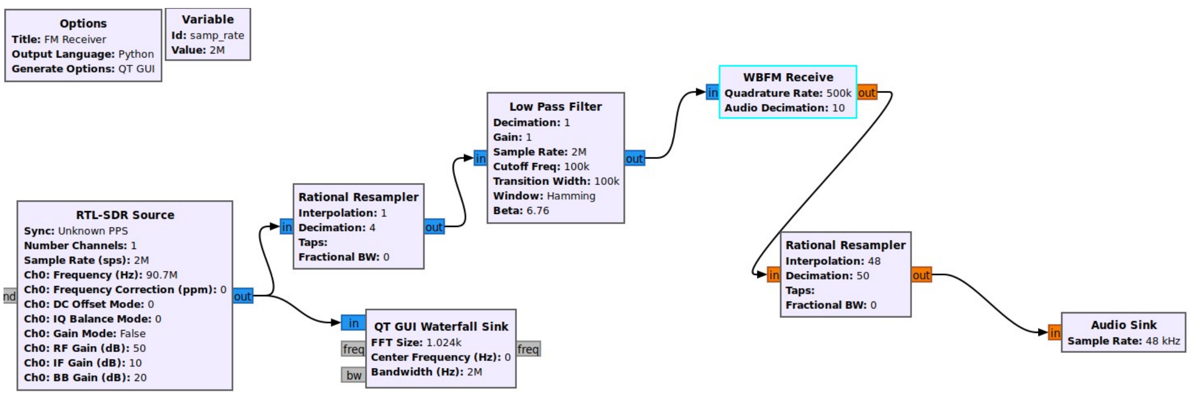


The RTL SDR source will provide I and Q signals from the FM station. We can directly recover the message using a conjugate multiplier and delay as shown above.

Complex to arg takes in a complex stream and outputs each complex value's arg (a.k.a. arctan, The output is a float.

FM with WBFM demodulation block

GNU radio provides a wide band fm receiver block which you can directly uses. See the flow graph below. It used 2Mhz sampling rate a rational re sampler converts the samples to 500khz . The demodulated out put is again re sampled to suit the audio sink which works at 48khz



FM Quadrature de modulator block