Lab 2: Implementation of AM in GNU Radio

Aim of the experiment

- To understand the basics of analog communication
- Implementing modulation – demodulation flow graphs for both amplitude modulation (AM) in GNU Radio

Important Note

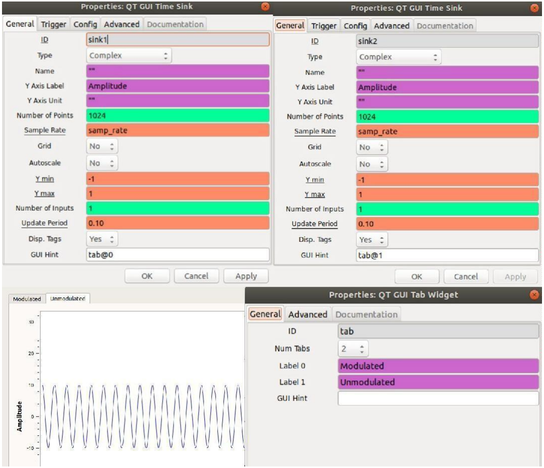
Using QT GUI Tab Widget to monitor multiple signals:-

QT GUI Tab Widget block in gnuradio can be used to monitor multiple graphs by giving a label to each graph to overcome the confusion about the source of a graph. For example, if you want to monitor two signals in the time domain, namely modulated and demodulated, then use two QT GUI time sinks e.g., sink1 and sink2.

1. Open the block ‘QT GUI Tab Widget’
2. Set the ID to ‘tab’ or any name you want to use
3. Set no. of tabs to 2 (the number of labeled graphs you want to monitor)
4. In Label 0 enter the label for first graph which is ‘Modulated’ in our example
5. In Label 1 enter the label for second graph which is ‘Demodulated’ in our example
6. Now to connect the GUI sinks to QT GUI Tab Widget, open the block of respective QT GUI Time sink (in the current example)
7. In GUI hint field of QT GUI Time sink 1 which is plotting modulated signal enter tab@0 (‘ID of GUI Tab Widget’@‘Index of tab’)
8. In GUI hint field of QT GUI Time sink 2 which is plotting demodulated signal

   enter tab@1 (‘ID of GUI Tab Widget’@‘Index of tab’)

Important Note



Properties: QT GUI Time Sink

ID	sink1
Type	Complex
Name	""
Y Axis Label	Amplitude
Y Axis Unit	""
Number of Points	1024
Sample Rate	samp_rate
Grid	No
Autoscale	No
Y min	-1
Y max	1
Number of Inputs	1
Update Period	0.10
Disp. Tags	Yes
GUI Hint	tab@0

Properties: QT GUI Time Sink

ID	sink2
Type	Complex
Name	""
Y Axis Label	Amplitude
Y Axis Unit	""
Number of Points	1024
Sample Rate	samp_rate
Grid	No
Autoscale	No
Y min	-1
Y max	1
Number of Inputs	1
Update Period	0.10
Disp. Tags	Yes
GUI Hint	tab@1

Properties: QT GUI Tab Widget

ID	tab
Num Tabs	2
Label 0	Modulated
Label 1	Unmodulated
GUI Hint	

Figure: Using QT GUI Tab Widget to monitor multiple signals

Important Note

- Use the sample rate of 48KHz for all un-modulated signals (this sample rate is termed as *Audio Rate* in FM blocks-however, you don't have to use the ready made blocks)
- Use the sample rate of 960kHz for all the frequency or phase modulated signals in GNU-Radio (this rate is termed as Quadrature Rate in GNU radio FM blocks)
- Debugging steps:
  - If something is not working, trace the point of failure(by checking the signal at various nodes)
  - If you're not able to get the display after a new GNU-Radio block was added in the schematic,most likely you have entered wrong parameters in the new block (check carefully!)
  - **Make sure that you are consistently accounting for the sample rate whenever decimation (for downsampling) and interpolation (for upsampling) are used.**
- IIR filter block implementation:
  - FF coefficients=[b_0,b_1];FB coefficients=[a_0,a_1];Old Style of Taps=True, implements the discrete time filter:

$$\frac{Y(z)}{X(z)} = \frac{b_0 + b_1 z^{-1}}{a_0 - a_1 z^{-1}}$$

  - A bug in implementation always sets the value of $a_0 = 1$. Therefore, you must use $a_0 = 1$ in all your calculations for filter coefficients.

Task 1: Implementation of DSB-FC

- Implement an entire DSB-FC AM modulation-demodulation flow graph in GNU radio. Use an envelope detector for the demodulation.
  Note: You cannot use the built-in blocks for demodulation like AM-demod
- Parameters to be used:
  - ◇ Message signal (single-tone): 10 kHz
  - ◇ Carrier signal: 100 kHz
- You are allowed to use the ready-to-use Low Pass Filter block from GNU radio library
- Observe the message signal and modulated signal for DSB-FC in time and frequency domains
- Replace the tone message signal with an audio message. Can you recover the message post-demodulation?

Task 2: Implementation of DSB-SC

You now have to implement DSB-SC modulation and demodulation. Assume perfect carrier synchronisation at the receiver.

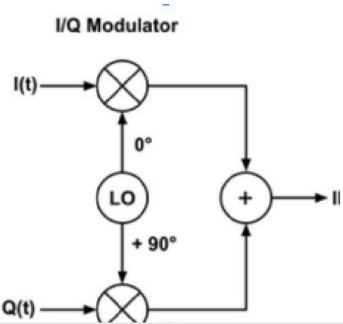
1. Implement the modulation flowgraph for DSB-SC transmission. Use a single tone at 10kHz as the message, and 100kHz as the carrier frequency.
2. Observe the spectrum of the modulated signal.
3. Implement the demodulation flowgraph.
4. Observe the spectrum of the demodulated message signal.
5. Replace the tone message signal with an audio message. Can you recover the message post-demodulation?

Q: What is the impact of a carrier frequency mismatch between the transmitter and receiver? How about a phase mismatch?

Task 3: IQ modulation and Demodulation

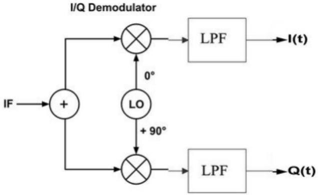
Part1: IQ Modulation

1. Implement the IQ modulation using two music files given (background.wav & vocal.wav). Treat one as the in-phase signal $I(t)$ and the other as the quadrature-phase signal $Q(t)$.
2. Set the carrier frequency as 100KHz
3. Store the modulated signal in data1.dat file in file sink



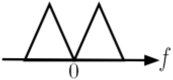
Part2: IQ Demodulation

1. Demodulate the IQ modulated signal as shown in the block diagram, from data stored in data1.dat
2. Use a low pass filter to filter higher unwanted frequencies
3. Play the demodulated audio files. Observe if you get a faithful reconstruction.

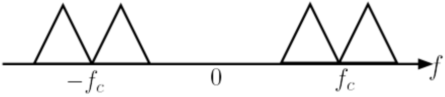


Task 4: Implementation of SSB

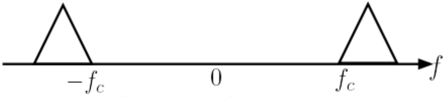
You have already implemented DSB-SC modulation. Here, only one sideband of the message is transmitted. For real messages, note that this is sufficient. This requires only half the bandwidth of DSB transmission!



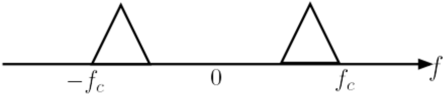
Message signal



DSB-SC transmitted signal



SSB-SC (upper sideband) transmitted signal



SSB-SC (lower sideband) transmitted signal

1. Implement the modulation flowgraph for SSB-SC (upper sideband) transmission. Use a single tone at 10kHz as the message, and 200kHz as the carrier frequency.
   Hint: Think of the transmitted (passband) signal as

   $$\begin{aligned} s_p(t) &= Re([s_I(t) + js_Q(t)]e^{j2\pi f_c t}) \\ &= s_I(t)cos(2\pi f_c t) - s_Q(t)sin(2\pi f_c t) \end{aligned}$$

   What should s_I and s_Q be for SSB transmission?
2. Observe the spectrum of the modulated signal.
3. Implement the demodulation flowgraph.
4. Observe the spectrum of the demodulated message signal.
5. Replace the tone message signal with an audio message. Can you recover the message post-demodulation?
6. Repeat the above to achieve lower sideband transmission.