Mini-Project 2: FSK Modulation and Demodulation in GNURadio

In this mini-project module, you will learn how to create your own GNURadio flowgraph to transmit and receive Frequency Shift Keying (FSK) modulation. FSK modulates bits onto tones at different frequencies. For example, 2-FSK (simplest) modulates 1 as a tone at fc + fd/2 and 0 at fc - fd/2. More on theoretical analysis of FSK will come in Pre-Lab3 to be released this week.

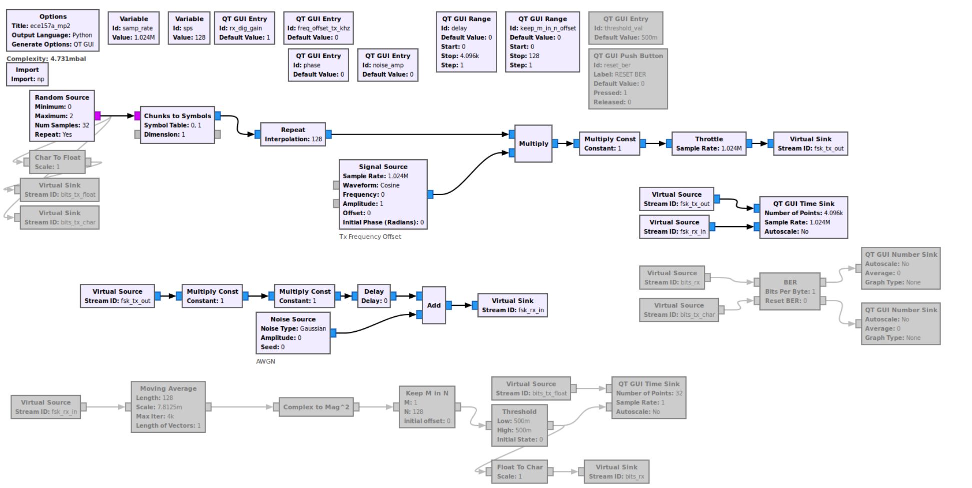
At the end of this module, you will:

1. Make a simple FSK Modulator and Demodulator Flowgraph
2. Understand two different kinds of demodulation schemes:
    a. Match Filtering + Envelope Detection
    b. Quadrature Demodulation
3. Comment on noise performance characteristics of the demodulators.

Overall Description:
1. There are a total of five tasks (two for FSK Modulation and three for FSK Demodulation).
2. Some tasks require you to take a screenshot and/or write a very short answer to a question.
3. Submission format: upload the following as a .zip to Gradescope
    a. PDF containing screenshots and short answers
    b. Final GNURadio .grc file that you create.
4. Tips on working as a team:
    a. You can choose to divide the tasks among yourselves. Note that they have to be done in the order they are described.
    b. Include a note on each person's contribution on the pdf.
5. You do not need an SDR for this mini-project.

Walkthrough:

Jump Off Point

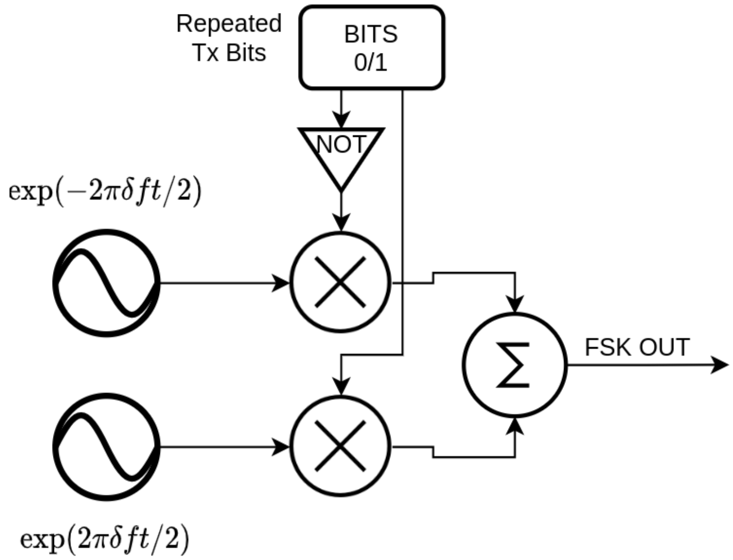
1. You will start with the following reference flowgraph (incomplete and incorrect):
    a. 

    b. This flowgraph should be familiar to you as it is very similar to the OOK flowgraph.
    c. Make sure you have cloned the latest version of the course git repository. **https://github.com/ucsdwcsng/ece157A**
    d. You can open this flowgraph by:
        cd ece157A/grc/miniproj/
        gnuradio-companion ece157a_mp2_0_reference.grc
    e. Use the "Save As" option to save your modified flowgraph in a different location, name it **ece157a_w21_mp2_<teamidx>.grc**
    f. Some of the modules appear grey because they are disabled. To enable a block, you need to highlight it and press 'E'. To disable a block, press 'D'.
2. The flowgraph has three parts:
    a. FSK Modulator (top)
    b. Channel/Impairments (middle)
    c. FSK Demodulator (bottom)
3. When the reference flowgraph is run, it will open a GUI:
    a. The GUI plots the Tx Signal and RX Signal (Tx Signal + Impairments)
    b. You can phase rotate the received signal using the 'phase' entry box.
    c. You can delay the received signal using the delay slider
4. The goal of the rest of this mini-project is to complete the flowgraph and understand it.

FSK Modulation in GNURadio

1. FSK Modulation directly multiplies the carrier with the bit-stream. In this part, we deal only with the **top part of the flowgraph.**
2. **Task 1: Frequency Sources**

a. We will use two **Signal Source** blocks to generate complex sinusoidal tones at +-fd/2.



b.

c. Parameterize the signal source blocks with a variable frequency of +fd/2 and -fd/2 (fd = deltaf)

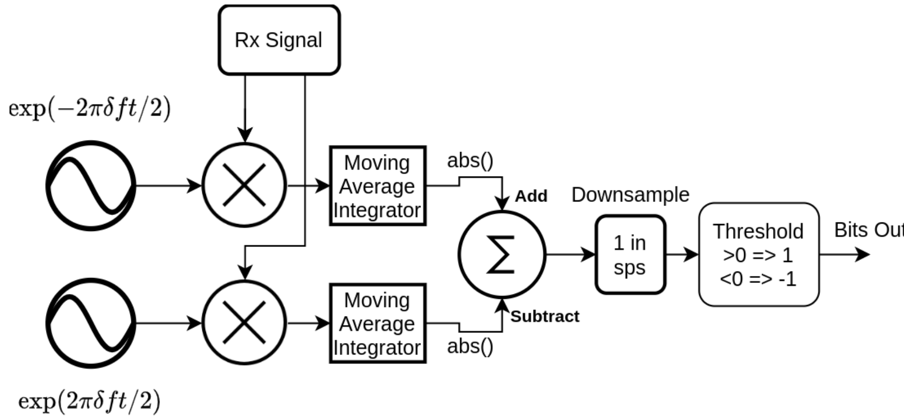
d. Implement the above diagram in GNURadio. Here are some blocks you would want to use:
   i. Multiply
   ii. Add
   iii. Subtract (NOT(BIT) = 1-BIT)

3. **Task 2: Observations and screenshots**
   a. Take a screenshot of your running flowgraph at this stage
   b. Use the following Parameters:
      i. fd = 20 kHz
      ii. sps = 128
      iii. Noise amplitude = 0
   c. Does this choice of fd and sps satisfy the orthogonality condition mentioned in Papen/Blahut Eq. 4.1.8?

FSK Demodulation in GNURadio

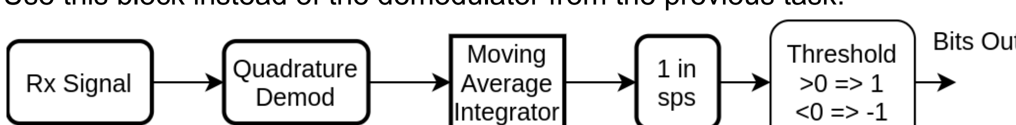
1. **Task 1: Match Filter + Envelope Detection**
   a. One way to demodulate FSK is to have two parallel “match” filters at the receiver that check for incoming frequencies
   b. These filters are essentially bandpass filters which provide large output magnitude if a particular frequency is present in the signal. For example, in this case, we will run two parallel frequency shifters to decide whether +fd/2 was sent or -fd/2 was sent

c. Block Diagram:



d. (don't miss the absolute value after the moving average integrator)
e. Set the variables to the following:
   i. fd = 20 kHz
   ii. sps = 128
   iii. Phase offset = 0
   iv. Delay = 0
   v. Choose correct offset for Keep M in N block to account for moving average filter group delay
f. Enable all the blocks so that you can note down BER.
g. Run the following experiments (collect at least 1000 errors, or run for 30 seconds, whichever is more. Don't forget to click RESET BER)
   i. Noise Amplitude 0.01
   ii. Noise Amplitude 0.1
   iii. Noise Amplitude 1
   iv. Noise Amplitude 2

2. **Task 2: Alternate Estimator -- Quadrature Demodulation**
   a. As discussed in class, there are many ways to estimate the same quantity. While it can be shown that the match-bandpass filter and envelope detection is the best estimator for non-coherent FSK demodulation in WGN, there are other simpler methods.
   b. The Quadrature Demodulation method phase change between consecutive samples to discriminate between the two frequencies +fd/2 and -fd/2
   c. A good description of how the "**Quadrature Demod**" block works is here: https://wiki.gnuradio.org/index.php/Quadrature_Demod
   d. Use this block instead of the demodulator from the previous task.
   e.



   f. Re-run the same experiments as with **Task 1** and note down the BER for various Noise Amplitudes

3. **Task 3: Discussion**

a. Compare both estimators in low noise conditions.
b. Compare both estimators in high noise conditions. Give a one sentence explanation for your conclusion.