Problem Set 3: HackRF One

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The purpose of this problem set was to work with the HackRF One to send and receive wireless signals and interact with signal encoding.

Problem 1: SDR Platform Setup

Problem 1 involved the setup process of the HackRF One and associated tools. Overall, this part was not very complicated. Other than some minor issues resolving dependencies, the installation process was relatively straight-forward.

To confirm that we had connected the HackRF One correctly, we ran `hackrf_info` which responded with information about the attached HackRF such as the serial number and firmware version.

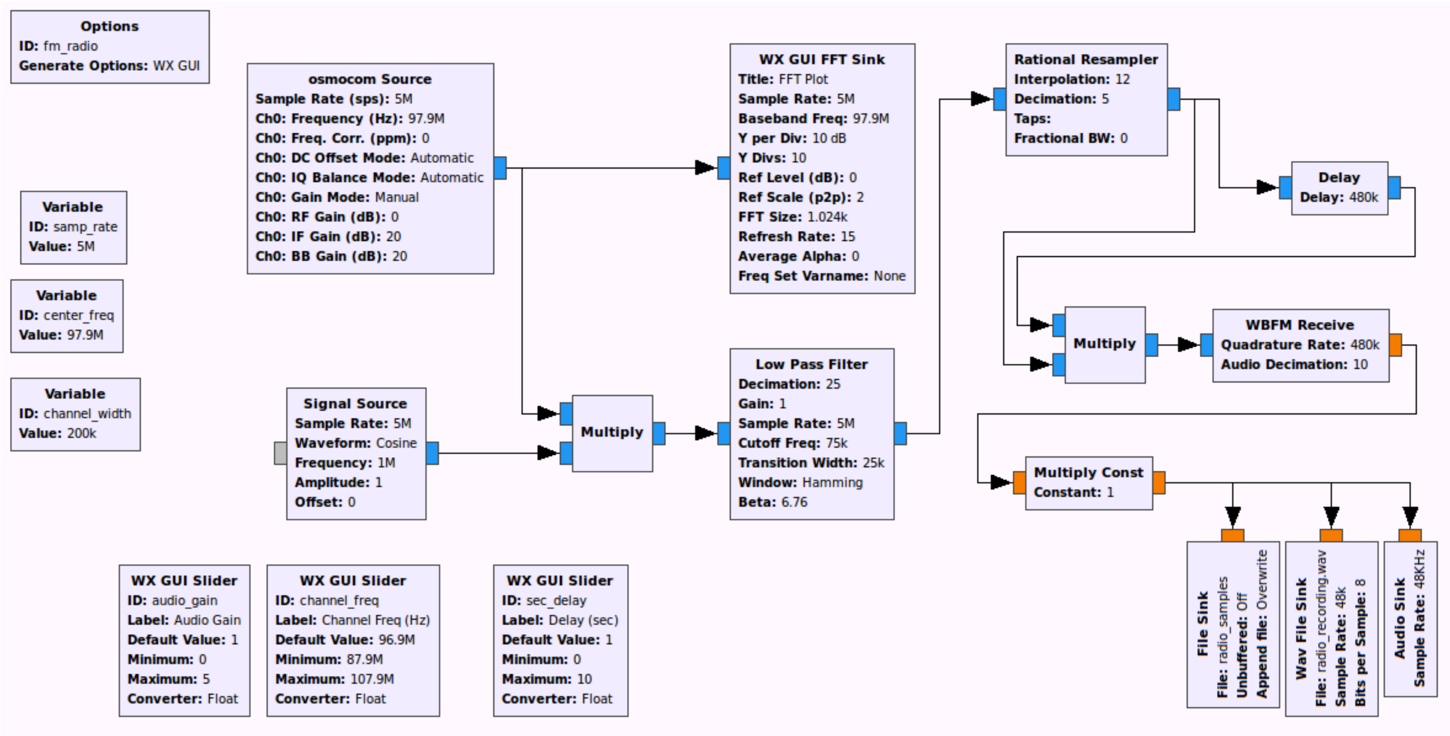
```
$ hackrf_info
Found HackRF board 0:
Board ID Number: 2 (HackRF One)
Firmware Version: 2014.08.1
Part ID Number: 0xa000cb3c 0x00534751
Serial Number: 0x00000000 0x00000000 0x406464c8 0x235e484b
```

After this we checked that we could interact with the HackRF by running osmocom_fft from the gr-osmosdr module. We looked up the frequency for 802.11 2.4 Ghz channel 1, which was 2.412 Ghz. We centered the chart on this frequency and observed fluctuations in the wireless signal strength.

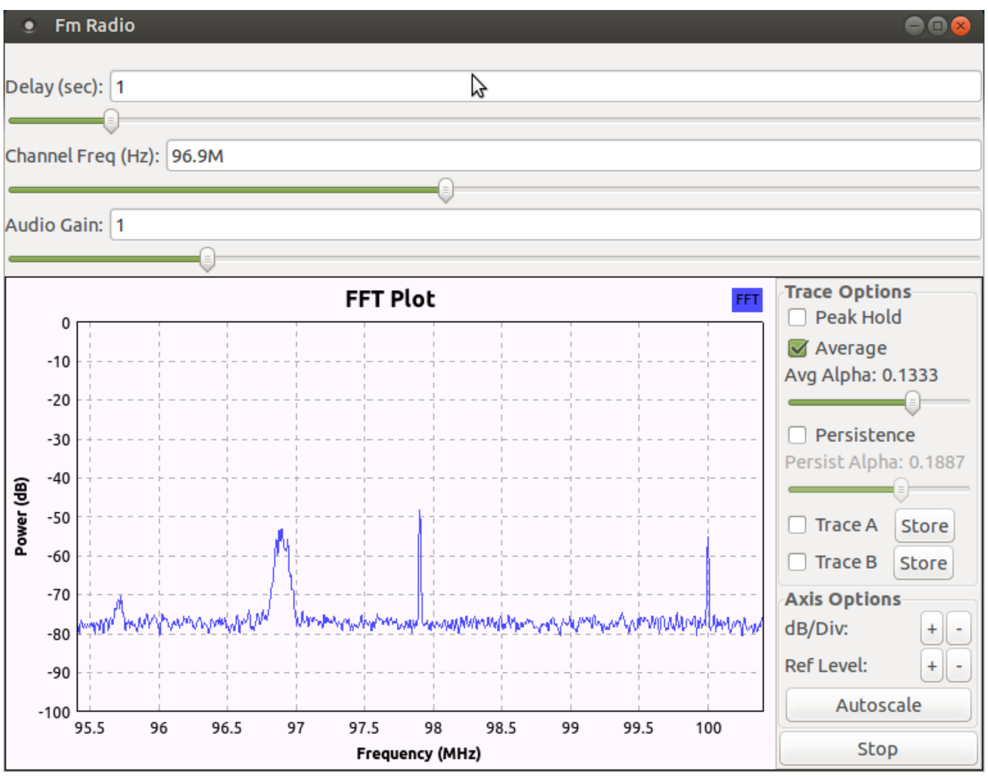
Problem 2: Building FM Radio Receiver

Part 2 involved creating a FM radio receiver and a tool to play recorded audio at different speeds.

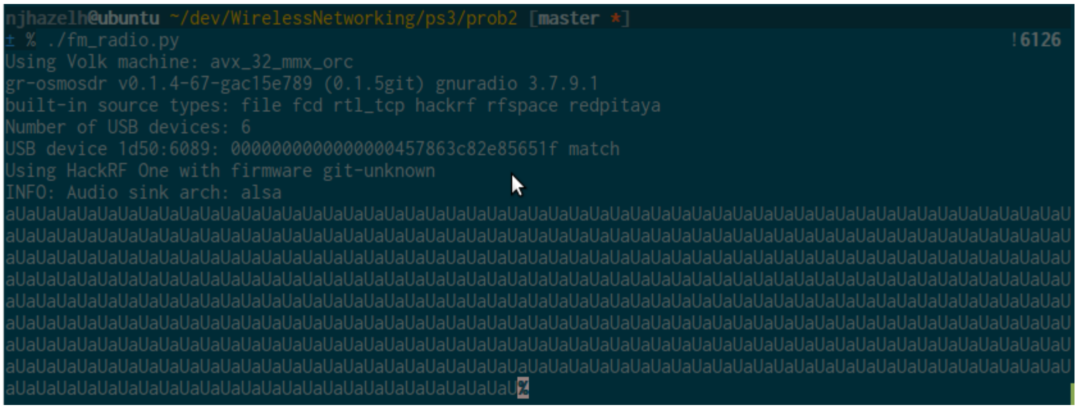
For part2, we configured the flowchart using gnuradio-companion as the instructions directed us to.



We encountered a few problems with this part. Although we could see one or two radio stations, there weren't nearly as many as we were expecting. There were some very strong signals around 96.9 and 100.2, but other than this, we couldn't see much else. This may be due to our antenna being too short. We tried compensating by increasing the RX gain in the osmocom source, but it didn't seem to have much effect.



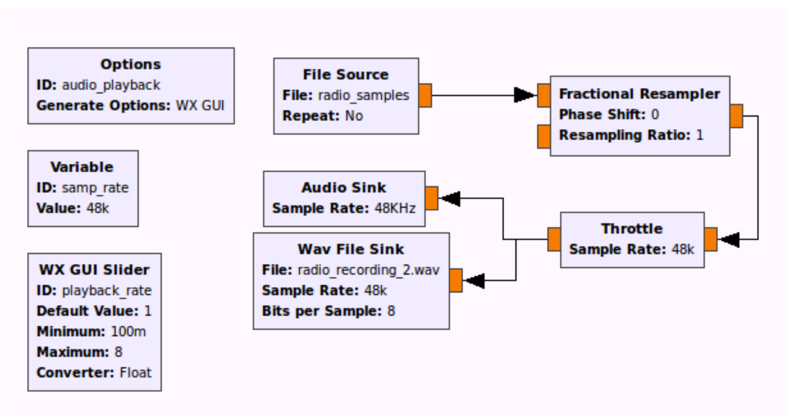
We also encountered issues with audio underrun. Because we were running the environment in a virtual machine, this resulted in issues with the audio sink output due to clock syncing issues. Although we processed the FM signal correctly, the audio was clipped and warped. At first we thought that this was some kind of processing issue, but after dumping the audio to a wav file and playing it back, we realized that the signal was fine. According to the GNU radiocompanion documentation, there is no simple solution to this problem. It recommended a quick hack of supplying information to the audio sink at a slightly faster rate than it expects, but this did not seem to work when we tried.



Each aU is an audio underrun error

To create the delay effect, we added a delay block and a WX Slider. We fed the output from the rational resampler into the delay block which we configured with the sample rate times the value of the slider (seconds). We then multiplied the output of the delay block with the original signal. This created resulted in overlapping audio signals. One consequence of this is that when the delay is still filling its buffer, the output is zero, which zeros the original output.

To create the playback script, we stored the signal from the FM receiver to a file (not wav). We then read this file and throttled the data to the default rate. We then took this data and fractionally resampled it at a ratio defined using a WX slider. This resulted in the signal playing faster or slower than normal.

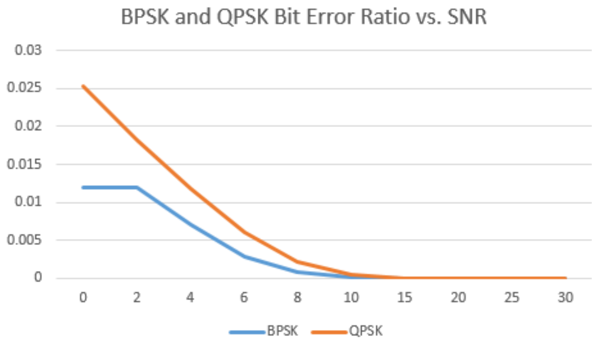


Problem 3: BPSK/QPSK Transmission Simulation

Problem 3 involved creating flowgraphs to represent BPSK and QPSK modulators and demodulators. Additionally, we needed to write Python scripts to read gnuradio file outputs and determine bit error ratios between two files.

BSPK was relatively straightforward to encode by following the instructions; changing the flowgraph to accomodate QPSK required some better understanding of gnuradio and how to use the constellation object. Ultimately, though, the differences between the two flowgraphs were minor. In addition, the python scripts to process them are essentially the same -- they just use different file parameters and were split so that the two encodings could be analyzed more quickly. Calculating the BER was as simple as reading in the files for pre- and post-modulated bits, putting them into arrays of binary, and then checking the number of differences between the two.

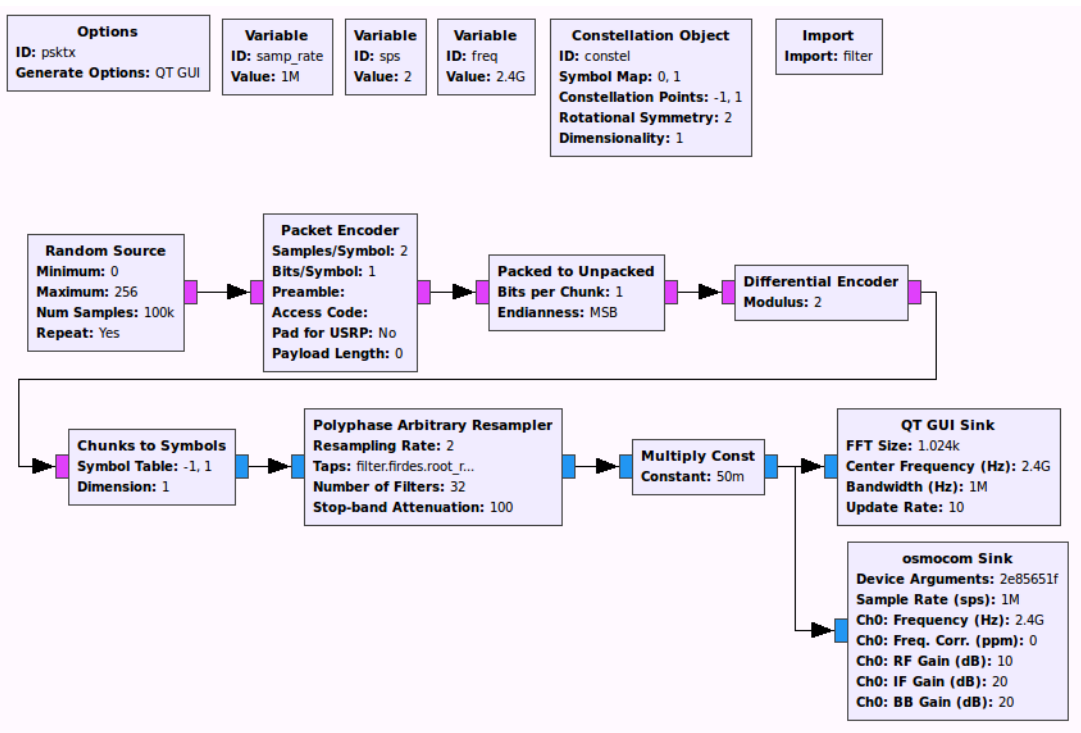
When measured against set signal-to-noise ratios, BPSK generally performed better than QPSK when the SNR was lower; however, the two eventually converged and, given higher SNRs, we expect that QPSK would outperform BPSK. Because QPSK transmits 2 bits per symbol, it would have a higher throughput overall when put against any amounts of noise.



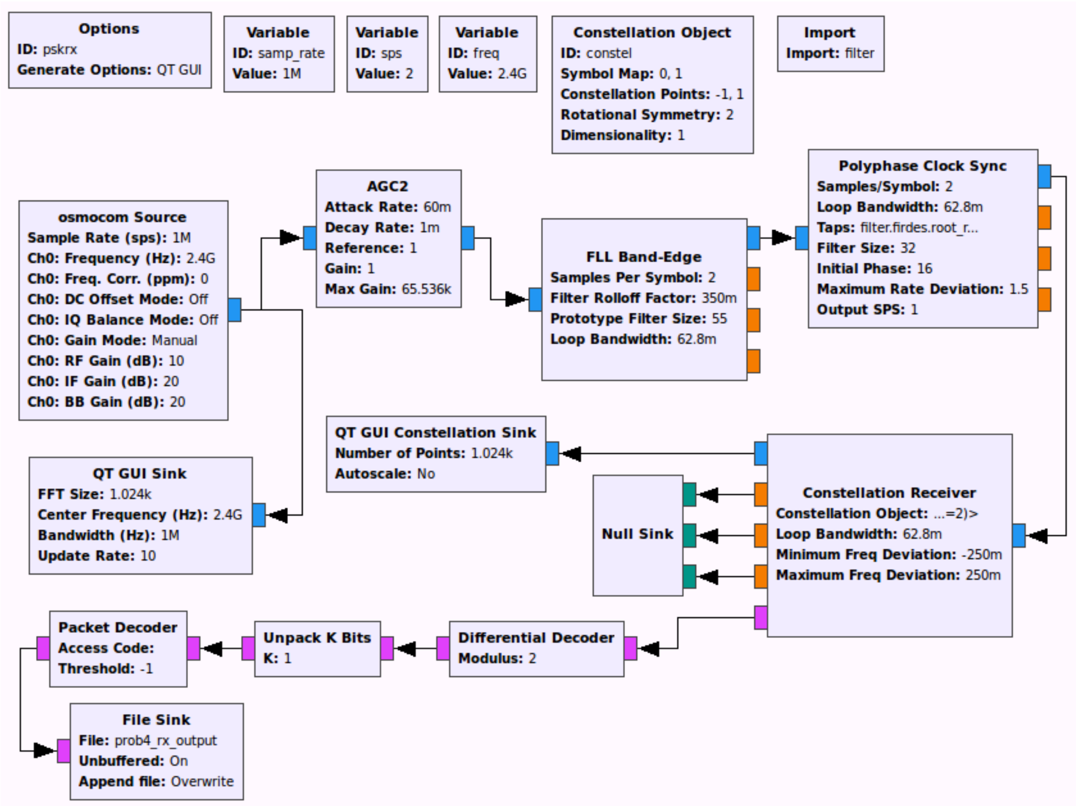
Problem 4: Real Transmission using HackRF

Problem 4 involved creating a wireless transmitter and receiver and using them to transfer a set of random data. We built these flowgraphs following the directions in the problemset.

Transmitter Flowchart



Receiver Flowchart

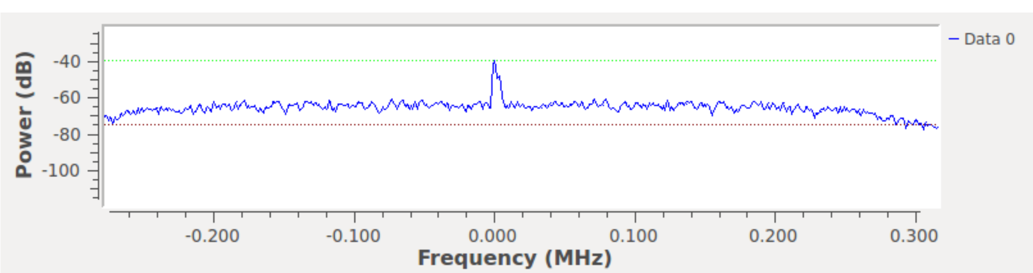


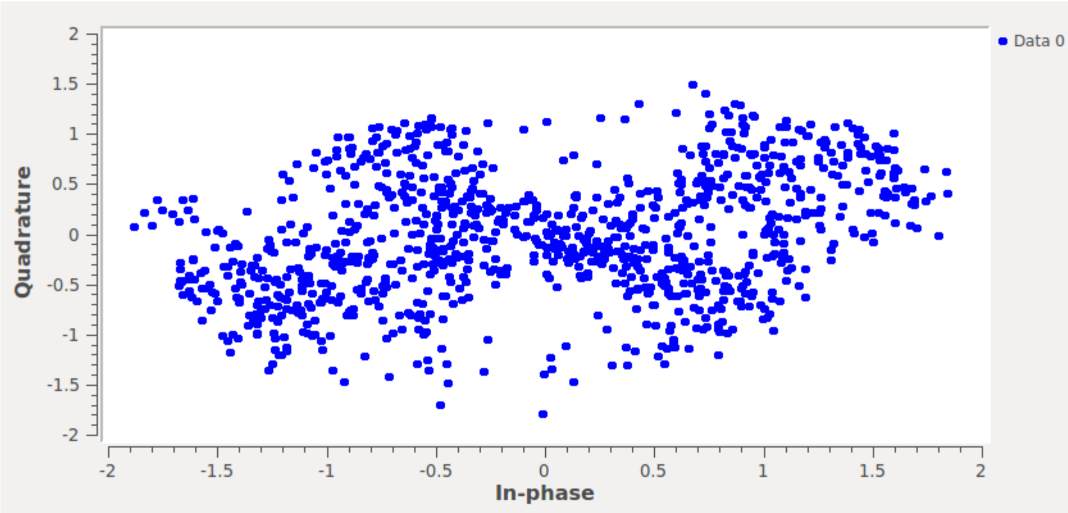
In this part, we had some minor issues getting two HackRFs to work at the same time. We expected that we would be able to specify the transmitter and receiver by changing the serial number in the osmocom source and sink. This did not work as expected. Regardless of the ordering, we couldn't get the information to transmit. The solution we came up with was to disconnect one of the HackRFs and force the receiver to start on the connected one. We then attached the second one and started the transmitter using the serial number.

The output from the receiver was stored to prob4_rx_output. After running it for a little bit, this file contained 174,592 bytes, which we counted using `wc -c`. Since we used the payload length of 0 (defaults to 512), this means that `174,592 / 512 = 341` packets were correctly received. If we ran it for a different length of time, this would obviously change.

After getting data to transmit, we ran some quick experiments regarding the effect of distance between the transmitter and receiver. We noticed that when the two two close enough to touch, the average signal strength would significantly increase but the clustering of points would get much worse. We found that the clustering became concentrated when the transmitter and receiver were about a foot apart.

Very Close Strength and Clustering





1 Foot Strength and Clustering