

Lab 4 - Analog Modulation with SDR



ECE531 – Software Defined Radio

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Daniel Gallagher, danielgallagher@arizona.edu
Department of Electrical & Computer Engineering
University of Arizona, Tucson AZ 85721

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1 Overview and Objectives

This laboratory looks at Analog Modulation with SDR; primarily using frequency modulation (FM). The FM radio receiver is often considered the “Hello World!” introduction to SDR. For this reason, it is very common to find many tutorials and examples online. Analog Devices has published examples using gr-iio and the PlutoSDR on their github [1] under the examples folder. More detailed examples are available on websites such as Instructables [2].

In Lab 3, you may have decided to listen to FM broadcast signals using gqrx or SDR#. In this lab, we will demodulate these signals using blocks in GNU Radio. During this process, it is important to pay careful attention to sample rates and filter widths.

1.1 Amplitude Modulation – AM

Amplitude modulation, or AM, was the first method developed for making audio radio transmissions and is still widely used today. Tuning these signals with certain SDR hardware can require external upconversion hardware, such as the Nooelec “Ham It Up”, or other hardware tweaks. Air traffic control communication uses higher frequency AM, which is possible to receive directly with the PlutoSDR.

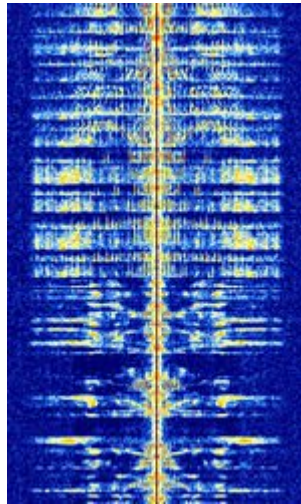


Figure 1: AM Radio Waterfall of ATC from SigIDWiki.

In class, we discussed envelope detectors for AM demodulation. The complex envelope detector can be implemented in GNU Radio using the “Complex to Mag” block. This is useful for demodulating ASK signals as well as AM.

You can try tuning AM signals using the University of Twente’s WebSDR at:

<http://websdr.ewi.utwente.nl:8901/?tune=198AM>

1.2 Angle Modulation – PM & FM

Another common analog modulation standard is FM. This is a modulation scheme where a carrier wave is modulated with an information signal in a way that causes the frequency to fluctuate as the amplitude of the information signal changes. Unlike AM, the amplitude of the modulated carrier remains constant. The modulation standard is commonly used for commercial radio stations due to its high resilience to additive noise.

Broadcast FM radio stations typically range from 88 MHz to 108 MHz bands. FM is also widely used for other applications, such as FRS handheld radios, HAM radio, and others. Additionally, NOAA National Weather Radio (NWR) broadcasts occur on seven dedicated radio frequencies; 162.400, 162.425, 162.450, 162.475, 162.500, 162.525, and 162.550 MHz. The NWR broadcast can be found at 162.400 MHz in the Tucson area.

2 FM Demodulation with GNU Radio

Figure 2 shows a simple FM receiver flowgraph in GNU Radio companion.

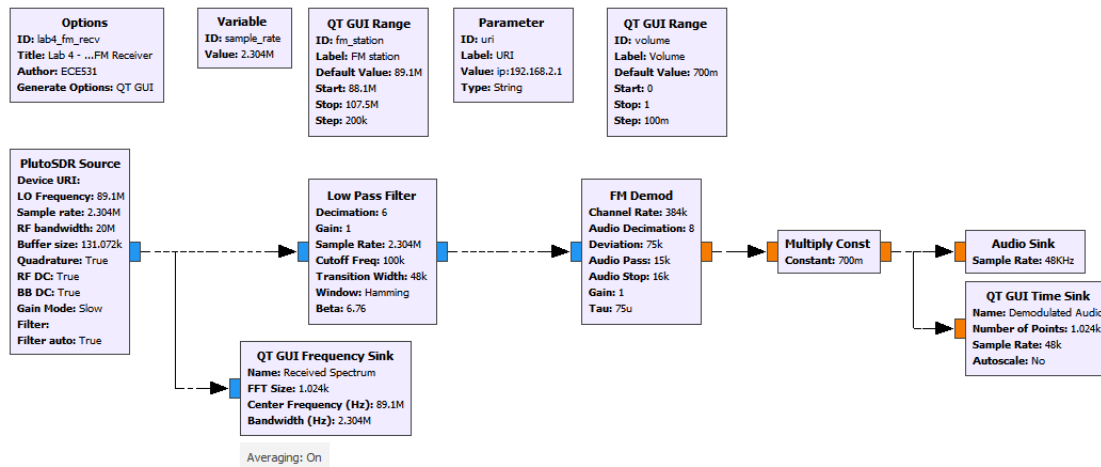


Figure 2: FM Radio flowgraph.

1. Implement a GNU Radio flowgraph for receiving, demodulating, and playing the audio of frequency modulated signals. One example is shown above.
2. Capture an image of your received spectrum before and after demodulation. (Turn averaging or peak hold on to visualize FM spectrum).
3. Describe what decimation, interpolation, or other resampling was used for the blocks in your flowgraph and why.
4. When would a rational resampler block be necessary? How did I avoid using one in Figure 2?
5. How does your audio sound? What can we do to improve the quality of the audio?
6. Why was a 100 kHz cut-off frequency used for the LPF in Figure 2?

2.1 Manual RF Demodulation

The NBFM, WBFM, and FM Demod blocks in GNU Radio perform a multiple signal processing steps for you internally such as calculating frequency deviation from the carrier and filtering.

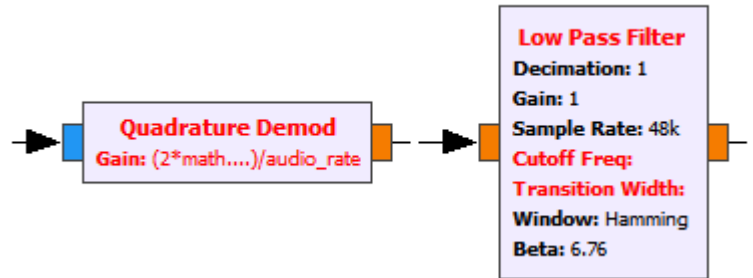


Figure 3: Manual FM Radio blocks.

1. Repeat the Narrow Band FM reception example from the section above, but perform the individual demodulation steps. This is accomplished by replacing the FM demodulator block with the quadrature demodulator and audio low-pass filter.
2. Capture an image of your received spectrum before and after demodulation. (Turn averaging or peak hold on to visualize FM spectrum).
3. Describe what decimation, interpolation, or other resampling was used for the blocks in your flowgraph and why.
4. How does your audio sound compared to the previous FM flowgraph? What can we do to improve the quality of the audio?

Tip: The “Gain” parameter in the quadrature demodulator can be defined by the function below. Since the frequency deviation is transmitter dependent, consider setting the frequency deviation value dynamically using a range slider.

Quadrature Demodulator Gain:

```
(2* $\text{math}.\pi$ *deviation)/audio_rate
```

3 Questions

1. Describe how to demodulate an amplitude modulated signal without simply using the “AM Demod” block in GNU Radio?
2. Our car stereos are able to receive broadcast AM radio signals. Why are we unable to demodulate these signals on the PlutoSDR without upconversion?

4 Lab Report Preparation & Submission Instructions

Include all your answers, results, and source code in a laboratory report formatted as follows:

- Cover page: includes course number, laboratory title, name, submission date.
- Suggested: Table of contents, list of tables, list of figures.
- Commentary on designed implementations, responses to laboratory questions, captured outputs, and explanation of observations.
- Meaningful conclusions to the lab.
- Source code (as an appendix). You may also upload source files with report submission.

Remember to write your laboratory report in a descriptive approach, explaining your experience and observations in such a way that it provides the reader with some insight as to what you have accomplished. Furthermore, please include images and outputs wherever possible in your laboratory report document.

References

- [1] Analog Devices, “GitHub: IIO blocks for GNU Radio.” [Online]. Available: <https://github.com/analogdevicesinc/gr-iio>
- [2] v3l0c1r4pt0r, “RTL-SDR FM radio receiver with GNU Radio Companion.” [Online]. Available: <https://www.instructables.com/id/RTL-SDR-FM-radio-receiver-with-GNU-Radio-Companion/>