EEL 4514C: Communication Systems and Components (Fall 2025)

Lab 3: First SDR Experiments

Deliverables Due: At 11:59pm on October 06, 2025.

You must bring your RTL-SDR to this lab. Be sure to bring the largest antenna you have for your radio.

You will learn how to get samples from the RTL-SDR, more about QT GUI, and how to do resampling. You will also build a simple spectrum analyzer to scan all the available FM and NOAA Weather Radio stations in Gainesville. You will learn about the spectral occupancy of the analog and digital (HD) components of FM radio broadcasts, as well as the spectral occupancy of NOAA Weather Radio broadcasts.

Pre-Lab

1. Determine the frequency band used for FM Radio in the United States. What is the lowest center frequency allocated? The highest? What is the frequency spacing between stations?
2. Determine what center frequency WSKY-FM "The Sky" broadcasts on.
3. What is the wavelength for the WSKY-FM signal?
4. How long would a $\frac{1}{2}$ wave monopole be for the WSKY-FM signal?
5. Read this Wikipedia article on FM HD Radio: `https://en.wikipedia.org/wiki/HD_Radio#FM`

   Using the information and spectrum images from the Wikipedia article, draw a sketch of what you think the spectrum of WSKY-FM looks like. WSKY has HD sidebands both above and below the main analog lobe. Label the frequencies at each edge of the main lobe, as well as each edge of the HD (digital) sidebands.
6. Determine all the center frequencies used by NOAA Weather Radio transmitters.
7. What is the spacing between adjacent frequencies in NOAA Weather Radio? How does this compare to FM radio? Why do you think this might be the case?
8. Look up and record the NOAA Weather Radio frequency for Gainesville.

Lab–Part 1: First simple mixer (analog modulator) design by using GRC

GRC components:

- 1 osmocom Source block or RTL-SDR Source block
- 1 Rational Resampler block
- 1 Throttle block (optional in case your CPU is not fast enough)
- 1 QT GUI Chooser block

- 2 QT GUI Range blocks
- 1 QT GUI Time Sink block
- 1 QT GUI Frequency Sink block
- 1 Options block (by default)
- 1 Variable block (by default)

For this lab, use complex signals. The complex signal essentially captures all the signal when demodulated with both a cosine carrier and an orthogonal carrier.

Design Requirements:

1. The osmocom Source (or RTL-SDR Source) block is the GRC API to get signal samples from the SDR dongle. Learn the various parameter settings available in the osmocom Source block. The main parameters of interest here are the sampling rate, frequency, and RF gain.
2. The RTL-SDR supports a number of fixed sampling rates from about 250k to 3M samples per second. The allowable frequency range is from about 24 to 1766 MHz. The RF gain ranges from 0 to 50 dB.
3. If one wants to obtain a sampling rate that is different from the one supported by the RTL-SDR, one may connect the osmocom block to the rational resampler block to perform rate conversion. In most cases for this and the coming labs, we want to lower the sampling rate.
4. Construct a signal flow graph using the blocks above to implement a spectrum analyzer using the RTL-SDR over the FM frequency range:
   (a) You should allow users to select the center frequency from the minimum FM center frequency to the maximum FM center frequency. The step between allowed frequencies should be set according to the spacing of channels in the FM frequency band.
   (b) You should allow users to choose the sampling rate from the choices of 250 kHz, 1 MHz, 2 MHz, and 3 MHz.
   (c) You should allow users to select the RF gain from 0 to 50 dB.
   (d) Use the variable block to specify the decimation factor (by how much we lower the sampling rate). The decimation factor cannot be adjusted on the fly.
   (e) Experiment with different settings for the QT GUI Frequency Sink, including Autoscale (Yes/No) and Average.
5. Experiment with different choices of sampling rate, gain, and decimation factor.
   (a) The bandwidth of the signal going into the QT GUI Frequency Sink will vary with the sampling rate and the decimation factor. For instance, if your sampling rate is *samp_rate* and your decimation factor is down, then you can set your bandwidth to *samp_rate/down*. (The QT GUI Frequency Sink allows passing a simple formula like this.)
6. Use your spectrum analyzer to scan through the FM band and find as many radio stations as you can.
   (a) You may want to determine the best choices of the various parameters above to implement your scan.

(b) You may want to experiment with different positions for your antenna – for example, holding it up in the air. If you can find a metal surface, that can act as a ground plane that effectively doubles the length of your antenna.

(c) You can hover your cursor over points in the QT GUI display to get more accurate frequency information.

7. You should be able to find many FM stations, but if the conditions inside the lab make that hard, you can continue the search in a different location, such as at your apartment/dorm/home. For at least 5 FM stations that you find, including at least 2 with HD sidebands (using WSKY-FM for one of these is fine):
   (a) Take a screen shot while your cursor is hovering over the approximate center of the analog band.
   (b) Write down the center frequency
   (c) Set the gain to 50 dB. What is the maximum value of the "Relative Gain (dB)" (i.e., the maximum value in the frequency plot) observed?
   (d) Indicate whether the signal had visible HD sidebands.
   (e) Write down the approximate total bandwidth for the analog signal.
   (f) Write down the total bandwidth including any HD sidebands.
8. Pick 3 of the signals (other than WSKY-FM) and google their frequency and "FM Gainesville". For example, there is not a signal at 89.3 MHz, but if there were, you could google "89.3 FM Gainesville". Write down the call sign Wxxx for those stations.
9. How many stations did you find?

Lab–Part 2.

GRC components:

Same components as for Part 1.

Design Requirements:

1. Save a copy of your flowgraph and modify it to work in the NOAA Weather Radio band.
2. Allow the user to adjust from the lowest center frequency to the highest center frequency in increments corresponding to the channel spacing.
3. Tune to the frequency of the Gainesville transmitter
4. Take a screenshot of the Frequency display showing the signal from the Gainesville NOAA transmitter
5. Zoom in on the signal from the Gainesville transmitter and estimate its bandwidth.
6. Check the other NOAA frequency bands. On which channels do you see signals? Based on the information at `https://www.weather.gov/nwr/stations?State=FL`, where do you think these transmitters are located?

7. Set the gain to 50 dB. What is the maximum value of the "Relative Gain (dB)" (i.e., the maximum value in the frequency plot) observed?