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?

The FM broadcast band in the U.S. is 88MHz – 108MHz. The lowest center frequency is 88.1MHz and the highest center Frequency is 107.9MHz, with station spacing being 200kHz (or 0.2MHz). This is considered in the Very High Frequency range. FM uses a nonlinear angle modulation technique:

$$s(t) = A_C Cos(2\pi f_C t) + 2\pi k_f \int_0^t m(\tau) d\tau$$

And the resulting bandwidth (Carson's Rule):

$$B_T \cong 2(\Delta f + f_m)$$

From the figure below, captured in SDR++, we can analyze several aspects of the FM modulation equation. A_C represents the carrier amplitude, which determines the transmitted signal strength and appears as the consistent brightness (amplitude band) in the spectrogram. f_c is the carrier frequency - the central frequency that the receiver locks onto, which is shown here at 100.9 MHz. m(t) is the message (audio) signal containing the transmitted information. This can be observed in the spectrogram as variations in the signal's structure: when music is playing, the signal spreads more widely due to higher frequency and amplitude variation, whereas during speech between songs, the pattern narrows and becomes more defined. Finally, k_f is the frequency sensitivity of the modulator, which controls how far the instantaneous frequency swings around the carrier, corresponding to the observed spread of the signal's bandwidth.

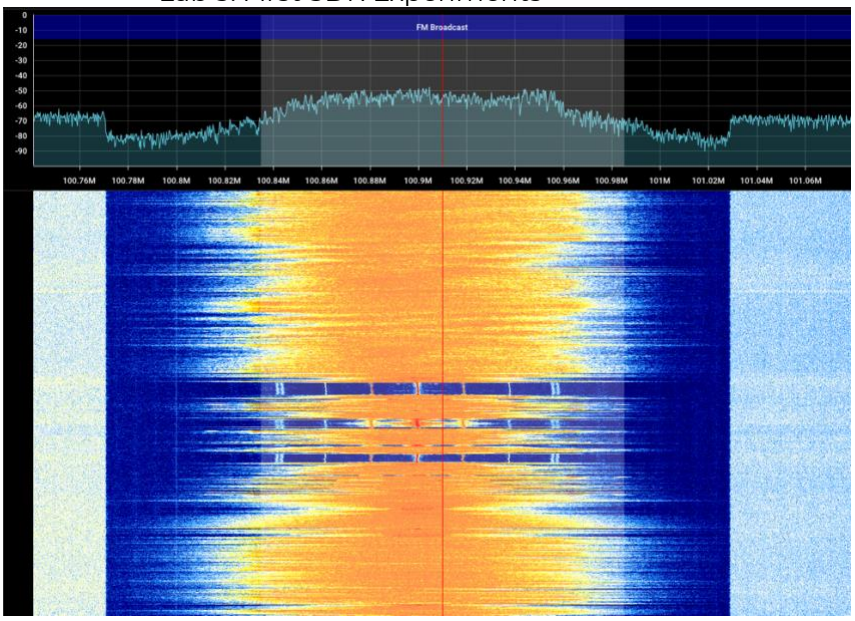


Figure 1: Power vs. frequency and Waterfall plot at 100.9 MHz

2. Determine what center frequency WSKY-FM "The Sky" broadcasts on.

WSKY-FM locks on at 97.3MHz. This can be observed in the figure below.

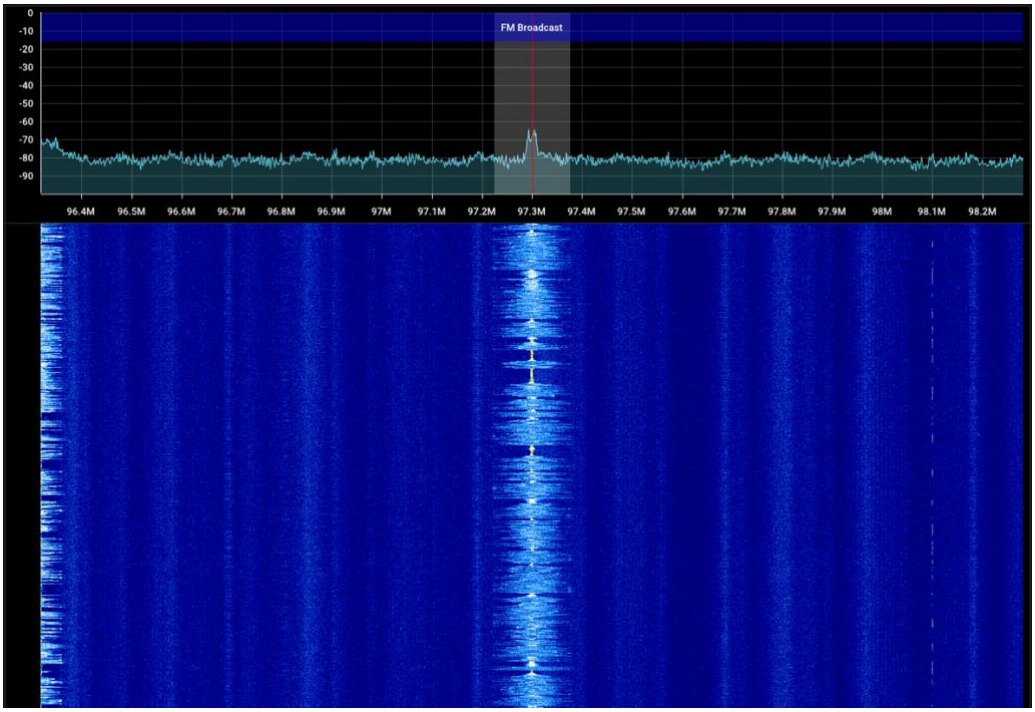


Figure 2: WSKY-FM power spectrum plot and spectrogram

3. What is the wavelength for the WSKY-FM signal?

For 97.3MHz the wavelength is as follows:

$$\lambda = \frac{c}{f} = \frac{3 * 10^8 \frac{m}{s}}{97.3 * 10^6\ s^{-1}} = 3.083\ meters$$

Note that the FM band is 88-108MHz which corresponds to wavelengths of 3.41-2.78 meters. Since 97.3 is near the middle we could estimate around 3.1 meters from that.

4. How long would a ½ wave monopole be for the WSKY-FM signal?

$$\lambda = \frac{c}{f} = \frac{3 * 10^8 \frac{m}{s}}{97.3 * 10^6\ s^{-1}} = 3.083 \rightarrow \frac{\lambda}{2} = 1.54\ meters$$

5. 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.

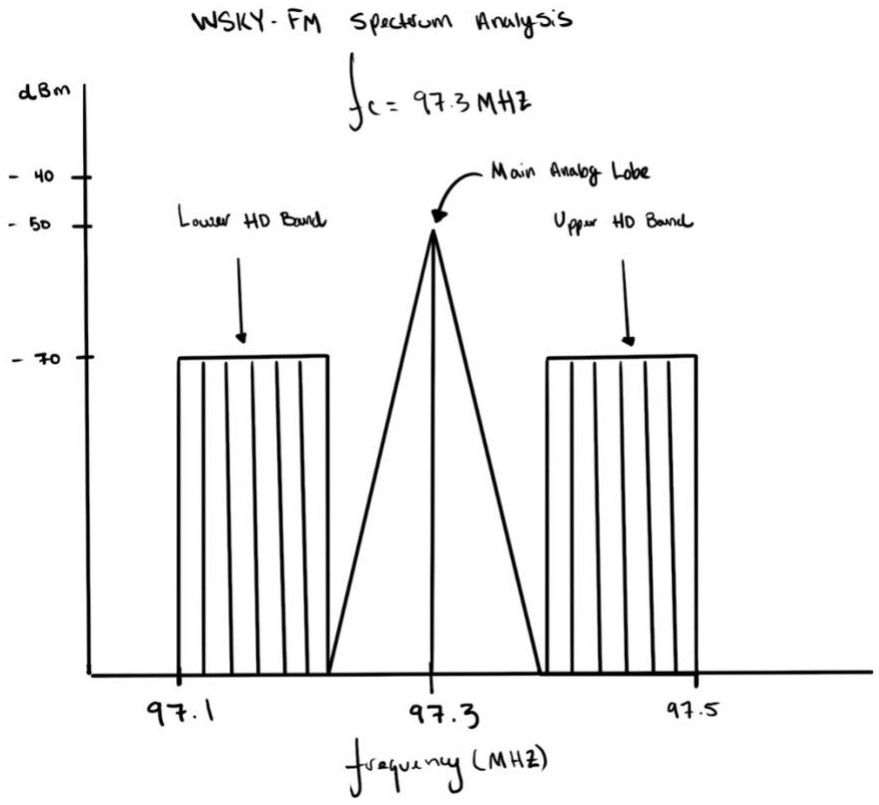


Figure 3: Sketch of WSKY-FM plot with HD sidebands

6. , 7. & 8. Determine all the center frequencies used by NOAA Weather Radio transmitters. 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? Look up and record the NOAA Weather Radio frequency for Gainesville

NOAA Weather Radio (NWR) uses seven VHF center frequencies that are spaced 25kHz apart from 162.4MHz to 162.550MHz.

- 162.400 MHz
- 162.425 MHz
- 162.450 MHz
- 162.475 MHz
- 162.500 MHz
- 162.525 MHz
- 162.550 MHz

NOAA Weather Radio is on Narrowband FM for voice / alerts. The audio frequency is approximately 3kHZ with around a 5kHz deviation.

Going back to Carson's rule -

$$B_T \cong 2(\Delta f + f_m) = 2(5 + 3) = 16kHz$$

With overhead, 25kHz spacing is efficient given NWR only has a 150kHz wide slice. This allows each channel to have the necessary bandwidth while having 7 nationwide channels available.

For Gainesville NWR is on channel 162.475MHz – this is verified in figure 4 below.

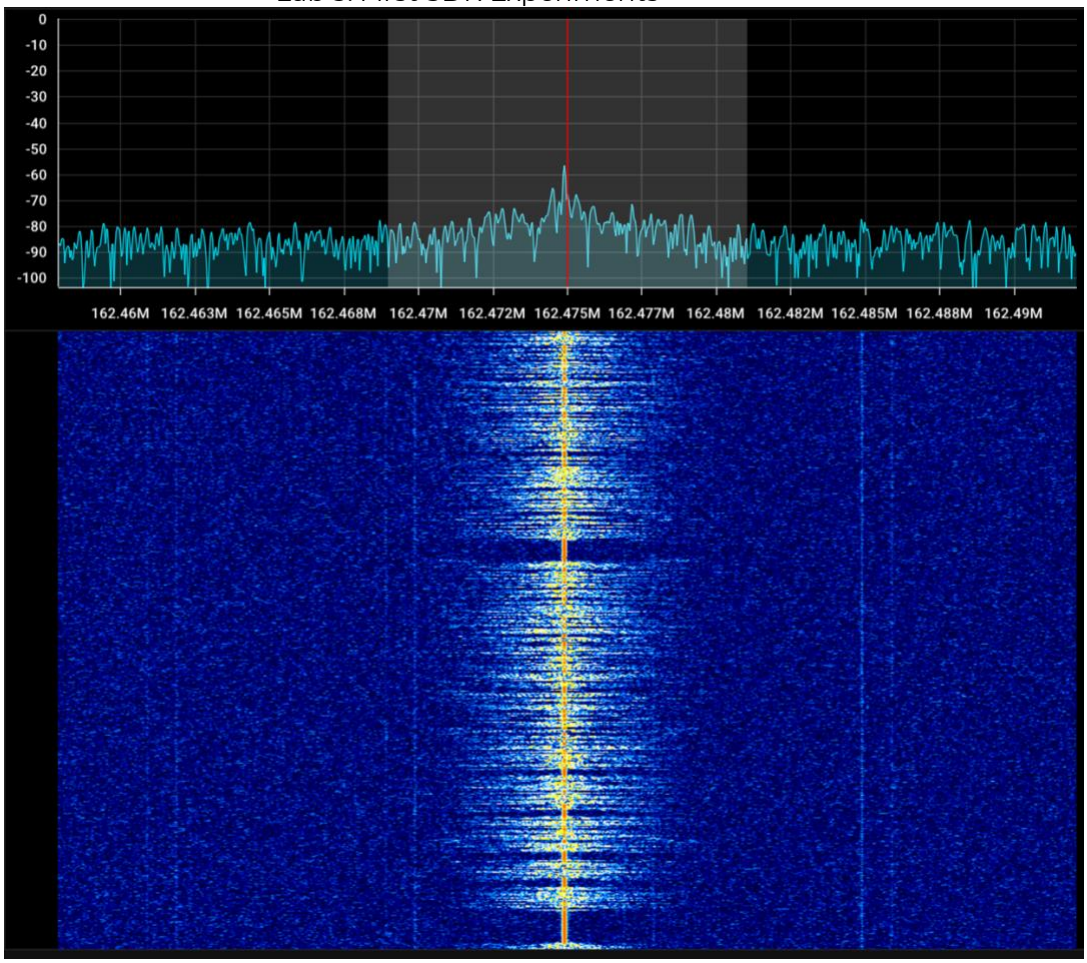


Figure 4: Spectrogram of NWR at 162.475 MHz

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

In this section I created a spectrum analyzer in GNU Radio using a Soapy RTL-SDR Source, rational resampler, QT Time/Frequency Sinks chain with complex samples. Run-time controls are handled by the QT range and chooser where I set the center frequency across the FM band 88–108 MHz. The sample rate can be toggled between 0.250, 1, 2, or 3 MS/s, where 2MS/s was generally the most reliable. RF gain range was between 0-50dB where 20dB was reliable. The Frequency Sink bandwidth is tied to the post-resample rate, so increasing decimation narrows the span for and resolution, however a decimation factor of 1 was effective for finding radio channels. Using this setup made it possible to find multiple stations. For instance, WUFT-FM at 89.1 MHz, where the analog FM hump was visible with symmetric HD sidebands were clearly visible. The plots for the channels are analyzed in more depth below. The Time Sink displays the in-phase and quadrature components centered near zero.

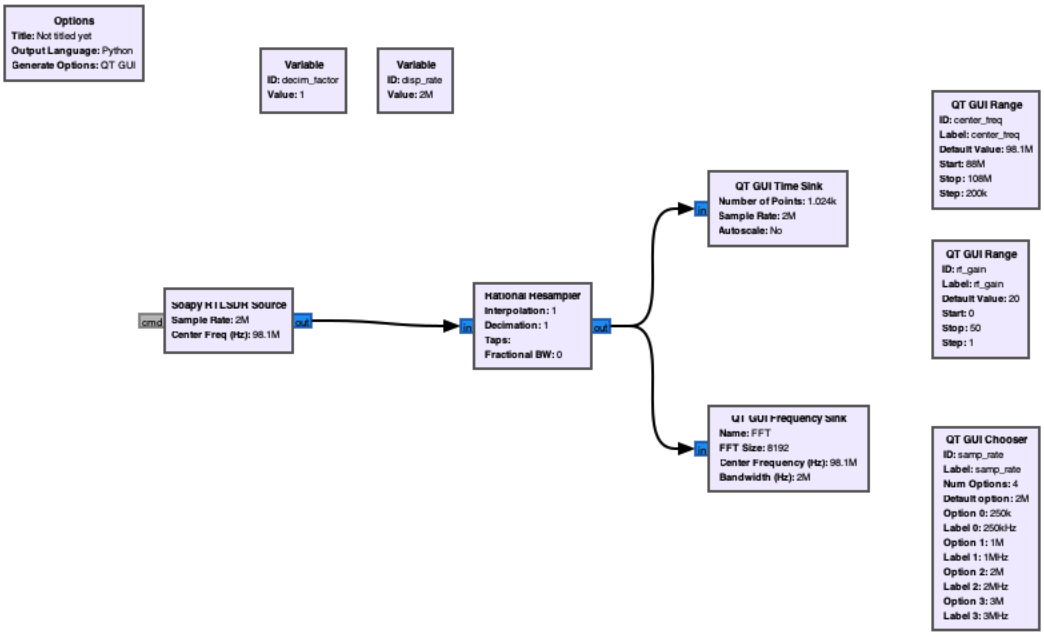


Figure 5: Block diagram of spectrum analyzer

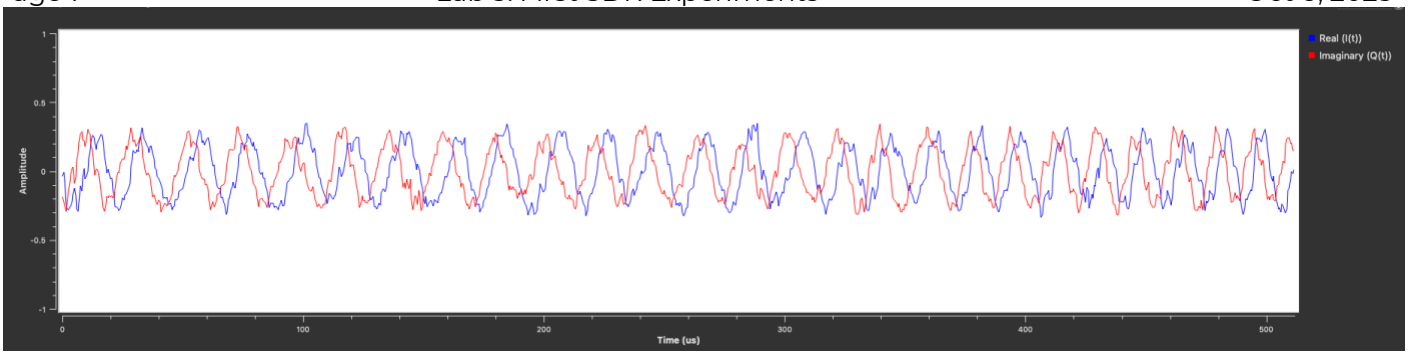
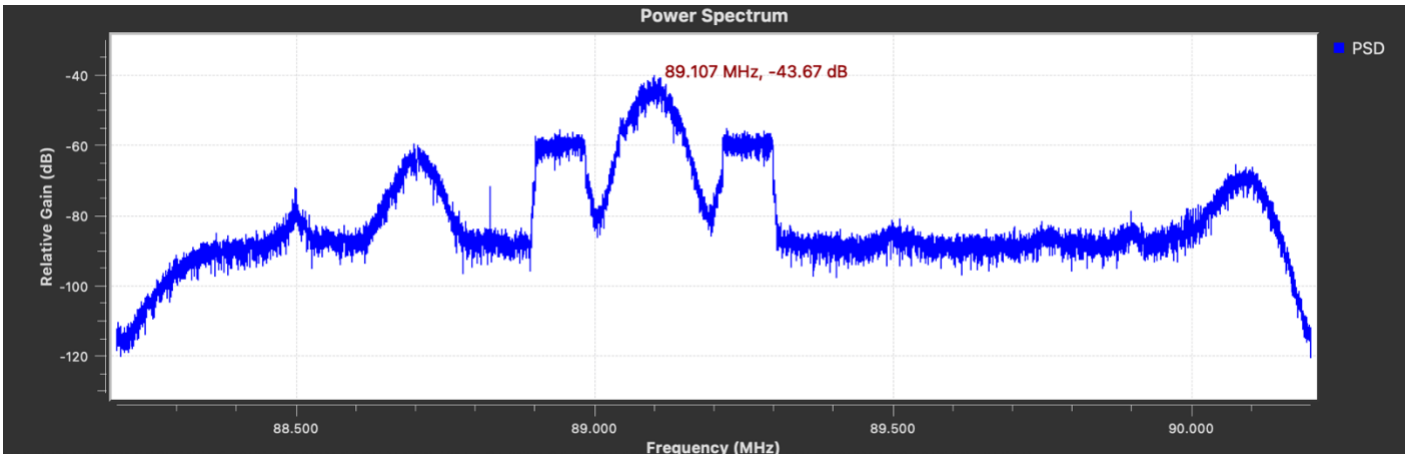
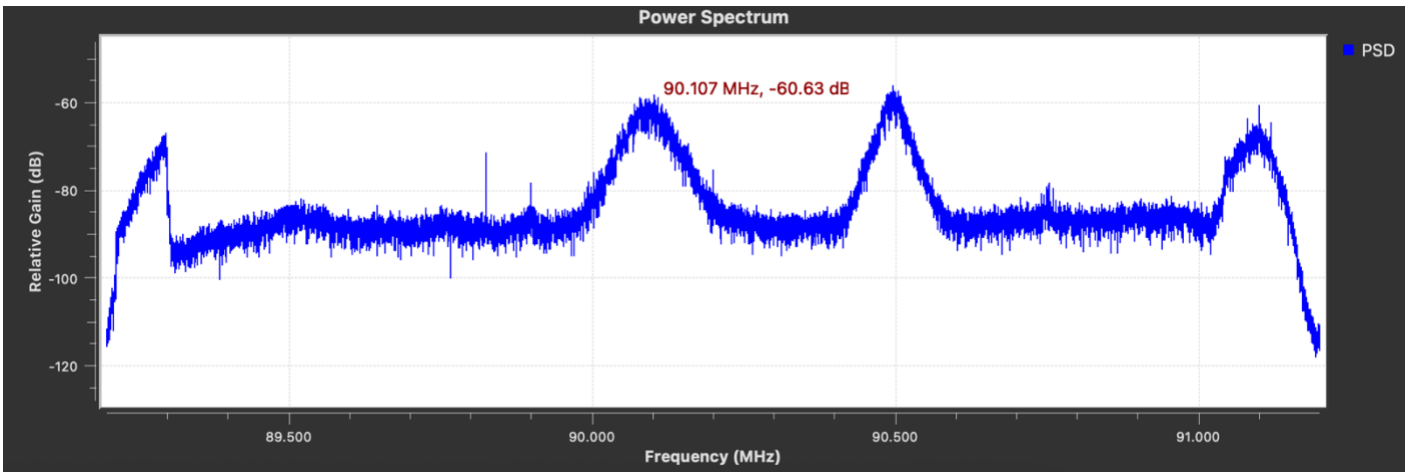


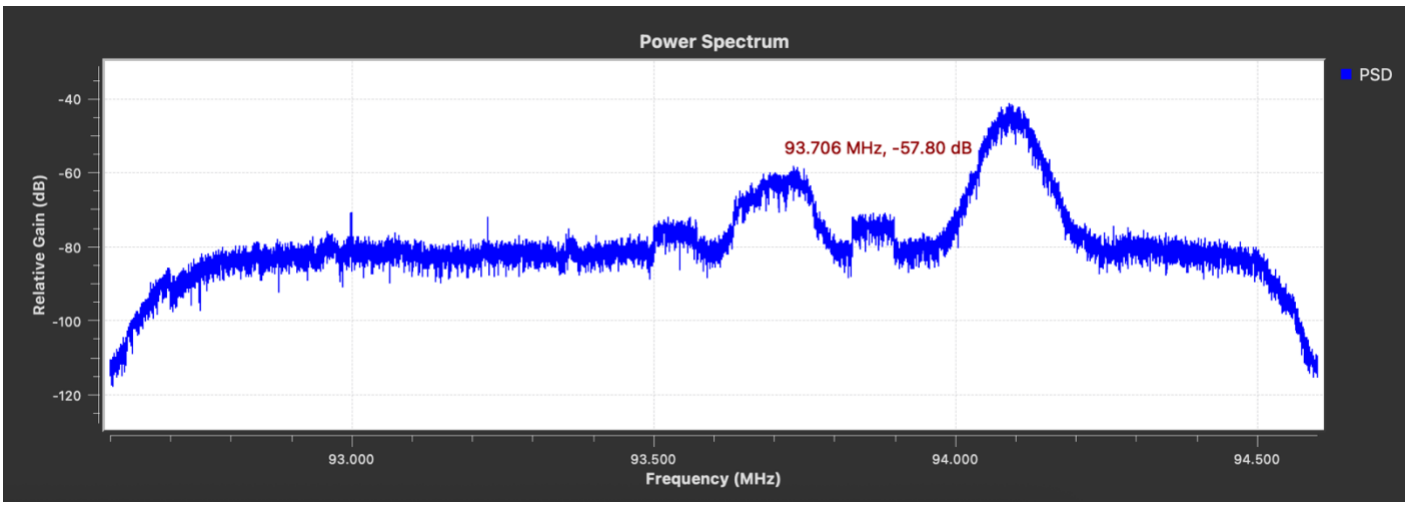
Figure 6: Time sink output

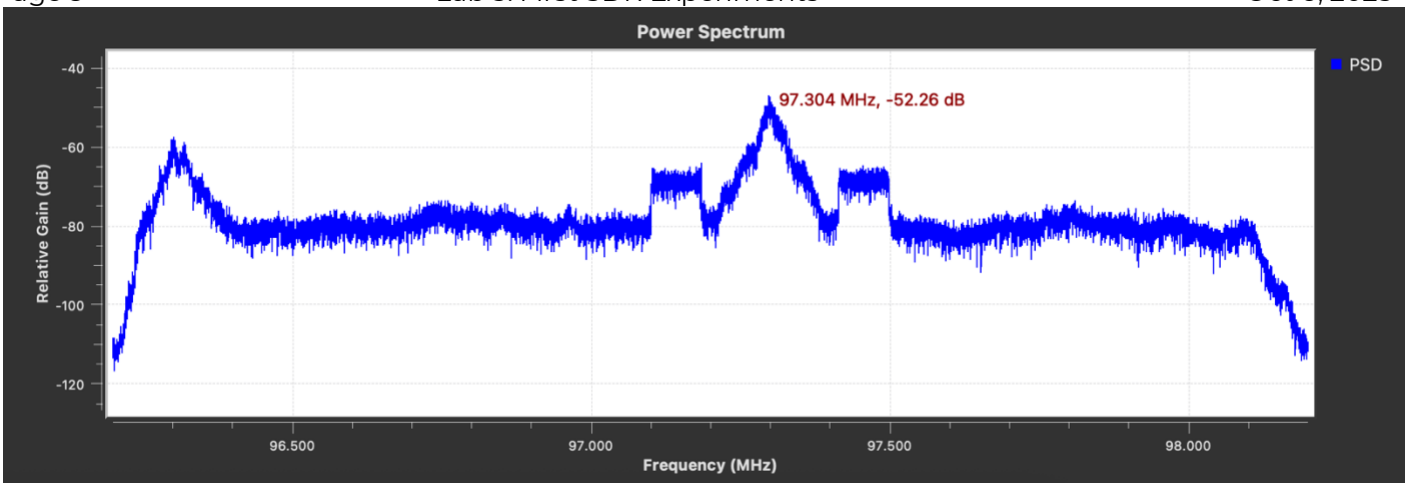
The following address's part 6-9 in part 1 of the lab. The table below provides the information for question 7. In total we have 7 channels, 5 of which had HD sidebands. In terms of the 3 stations call signs, we will use 100.9MHz WXJZ "The Beach", 103.7MHz WRUF-FM "Country 103.7 the Gator", and 98.5MHz WKTK "98.5 KTK".

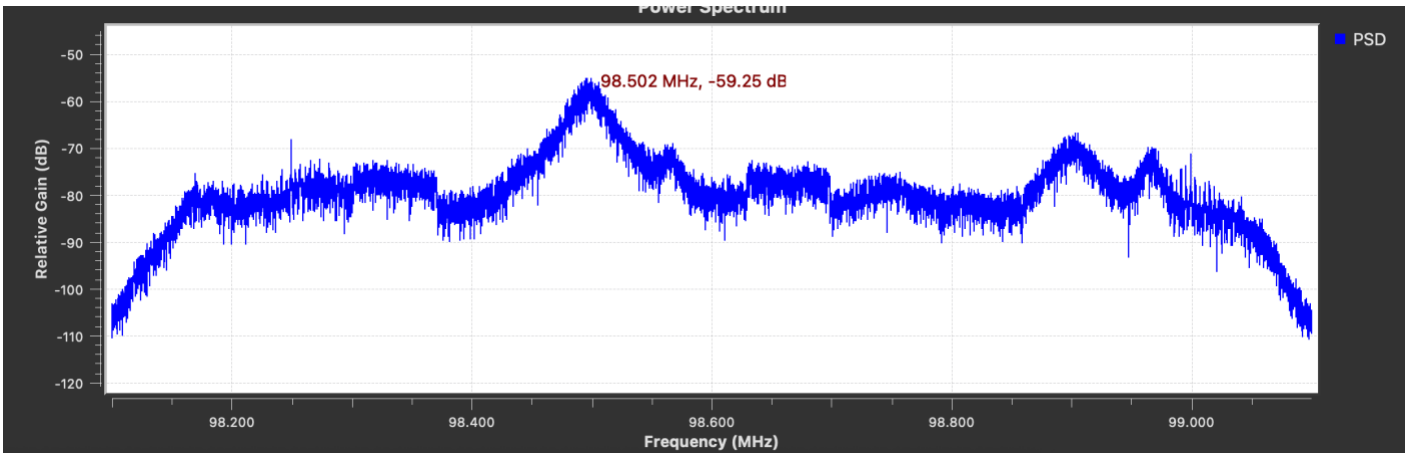
Figure	F_0 (MHz)	Gain (dB)	HD Sideband (yes / no)	Analog BW (kHz)	Total BW (kHz)
A	89.1	43.67	Yes	200	400
B	90.1	60.63	No	200	200
C	93.7	57.8	No	200	200
D	97.3	52.26	Yes	200-250	400
E	98.5	59.25	Yes	200-230	400
F	100.9	33.97	Yes	200-250	400
G	103.7	51.29	Yes	200-250	400

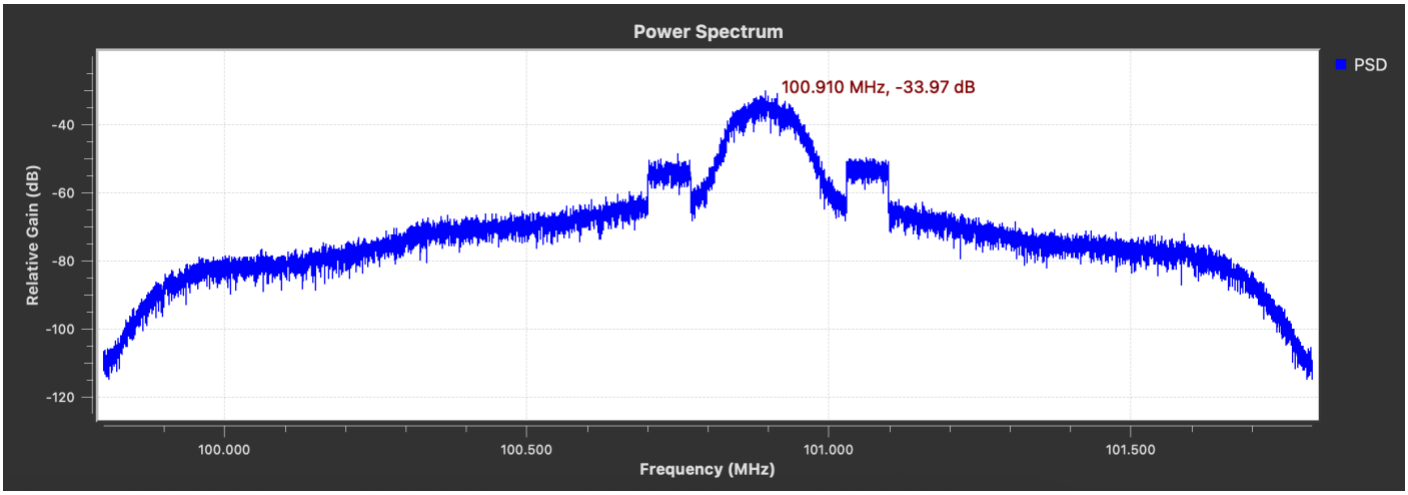

Power Spectrum
PSD
89.107 MHz, -43.67 dB
Relative Gain (dB)
-40
-60
-80
-100
-120
88.500
89.000
89.500
90.000
Frequency (MHz)


Power Spectrum
PSD
90.107 MHz, -60.63 dB
Relative Gain (dB)
-60
-80
-100
-120
89.500
90.000
90.500
91.000
Frequency (MHz)


Power Spectrum
PSD
93.706 MHz, -57.80 dB
Relative Gain (dB)
-40
-60
-80
-100
-120
93.000
93.500
94.000
94.500
Frequency (MHz)


Power Spectrum
PSD
97.304 MHz, -52.26 dB
Relative Gain (dB)
-40
-60
-80
-100
-120
96.500
97.000
97.500
98.000
Frequency (MHz)


PSD
98.502 MHz, -59.25 dB
Relative Gain (dB)
-50
-60
-70
-80
-90
-100
-110
-120
98.200
98.400
98.600
98.800
99.000
Frequency (MHz)


Power Spectrum
PSD
100.910 MHz, -33.97 dB
Relative Gain (dB)
-40
-60
-80
-100
-120
100.000
100.500
101.000
101.500
Frequency (MHz)

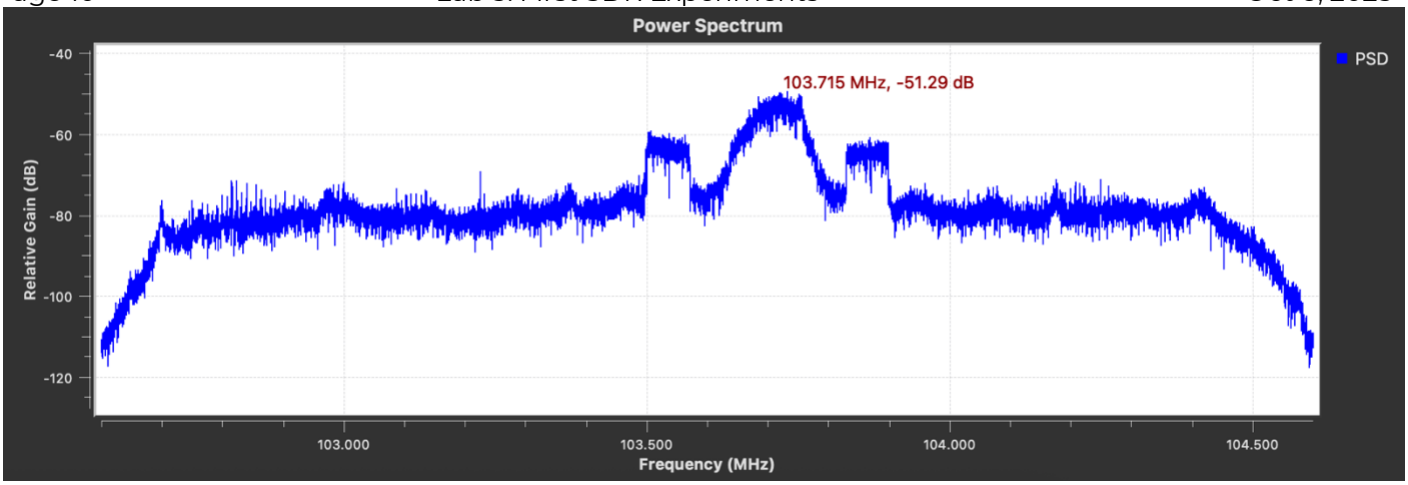


Figure 7: Various PSD plots across the FM band with their frequency and power noted

Lab–Part 2: First simple mixer (analog modulator) design by using GRC

I scanned the NOAA Weather Radio band from 162.400–162.550 MHz in 25 kHz steps. At my location the only consistently strong carrier was 162.475 MHz, which matches WXJ60 (Gainesville). The plot is shown in figure 8 (with a gain of 50). The lobe falls to the half power level at roughly + / - 8 kHz from center, making the occupied bandwidth about 16 kHz. That bandwidth aligns with what is expected of narrow-FM voice on NOAA. With the gain set to 50dB, the maximum relative gain observed at the NOAA carrier was -58.9dB.

Additionally, when using SDR++ there is a faint carrier near 162.550 MHz's Based on the Florida NWR station list this aligns with KHB39 (Jacksonville) to the northeast shown in figure 9. Other possible channels would have been 162.425 MHz (Palatka/WNG522) and 162.525 MHz (Ocala/WWF85) but they were not above the noise floor in this indoor setup. Given VHF line-of-sight propagation, indoor attenuation, and antenna height, it's reasonable that WXJ60 dominates while the more distant Jacksonville transmitter appears only weakly.

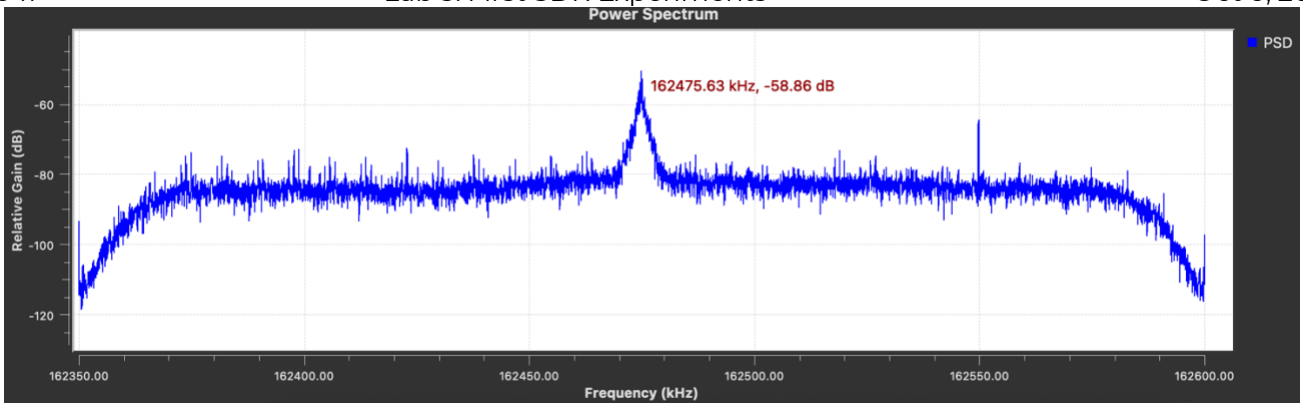


Figure 8: NOAA Gainesville at 162.475MHz

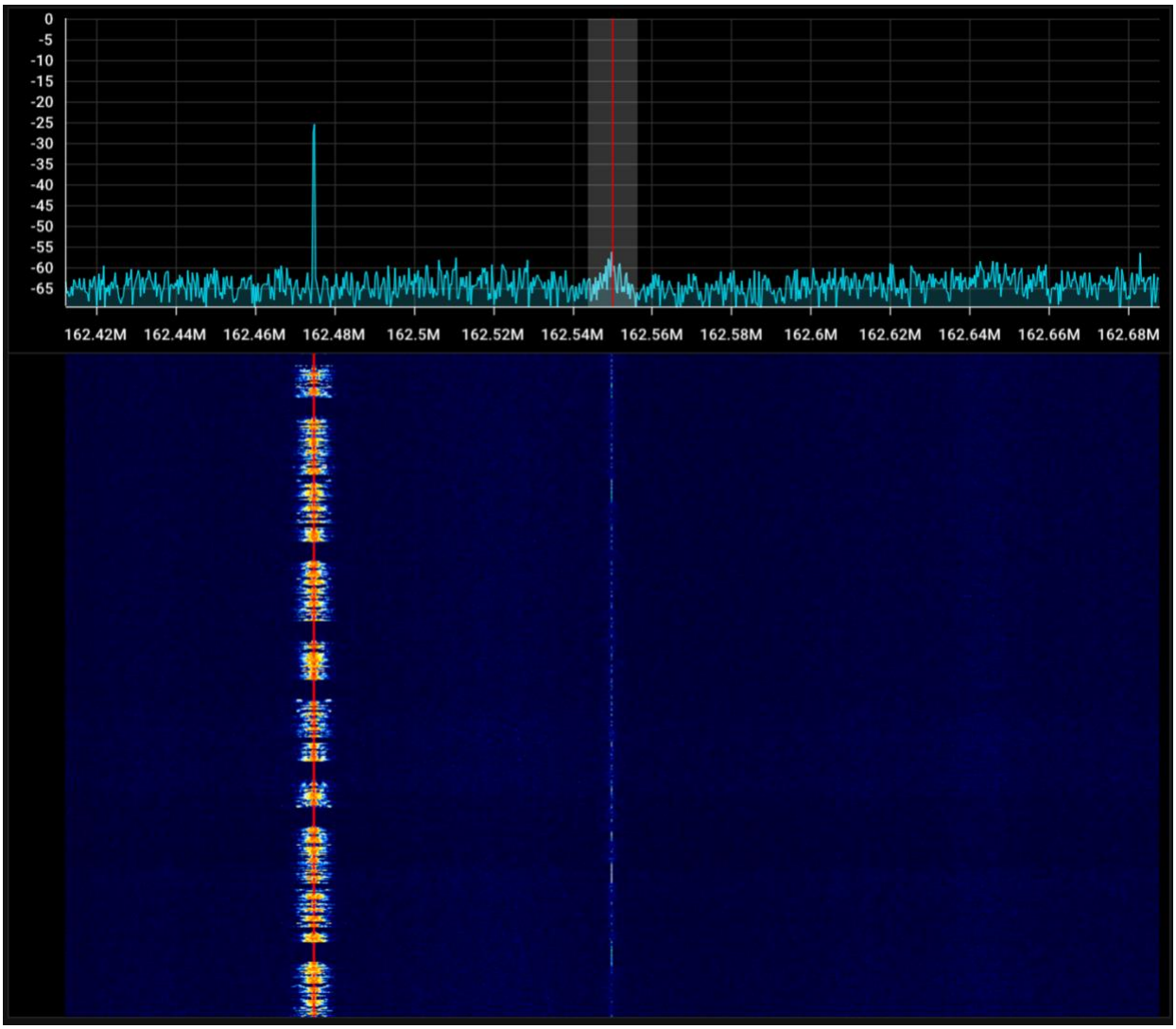


Figure 9: PSD of NOAA Jacksonville (as well as NOAA Gainesville to its left)