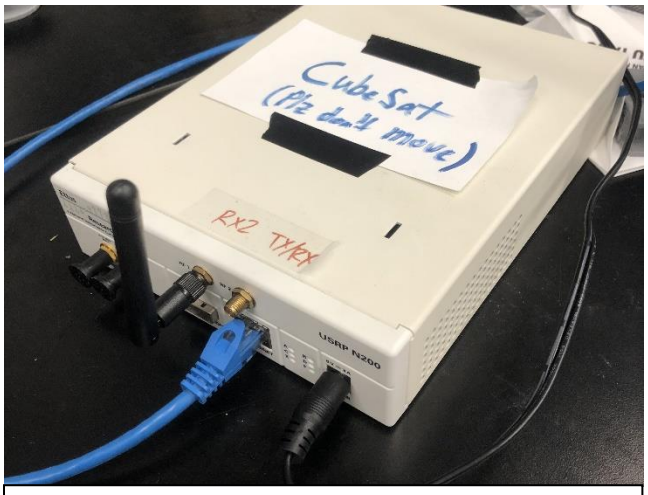
FM Reception and Demodulation with USRP N200 and GNU Radio

As a small test to work up to satellite reception, our SDR was tested to receive FM radio stations local to the NYC area. This was also used as an introductory learning experience to block coding in GNU Radio.

This first test will prove useful working up to amateur radio satellite reception, as near in the future, practice with NOAA weather satellite reception will be performed, which also uses FM, to produce a picture of the Earth. For this however, the full antenna will have to be built.

1) Initial Verification of Working Equipment

After installation of the UBX-40 daughterboard into the SDR and establishing a connection (detailed in SDRSetup docs), the software GQRX was used to check if the equipment was still working.



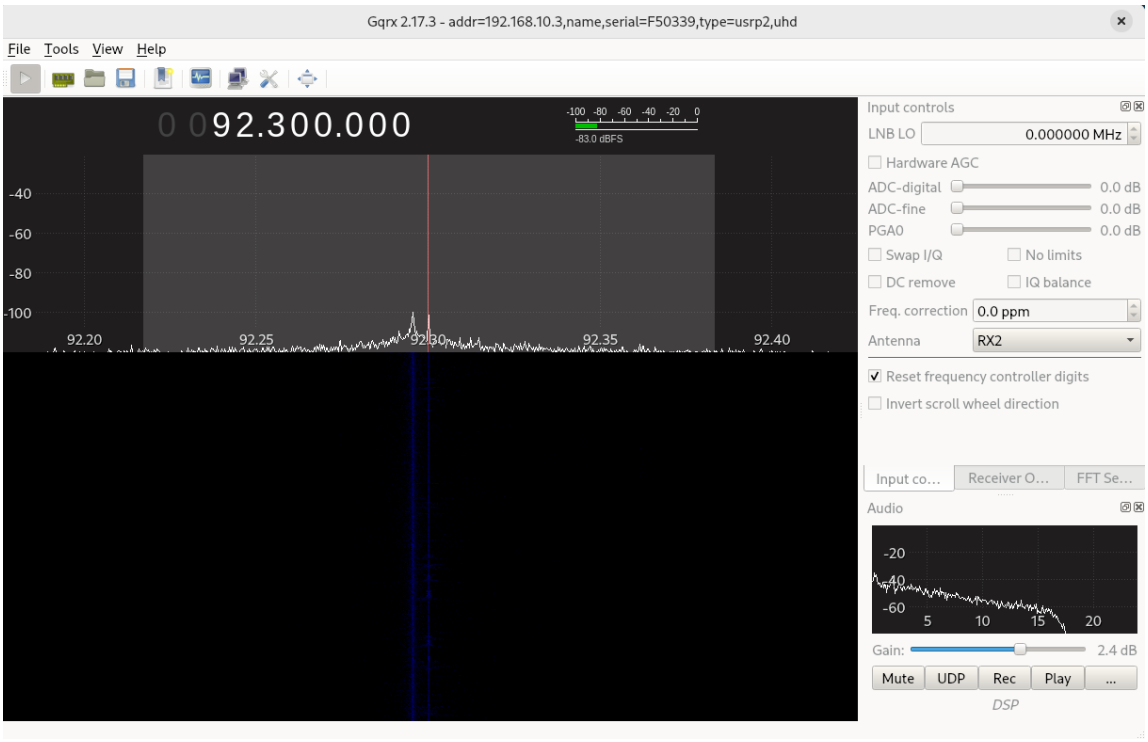
USRP N200 with necessary connections

To the left is the setup used for testing. In the RX2 port, a 2.4GHz rated Wi-Fi antenna is used. There is an ethernet connection to the host laptop, and the power supply.

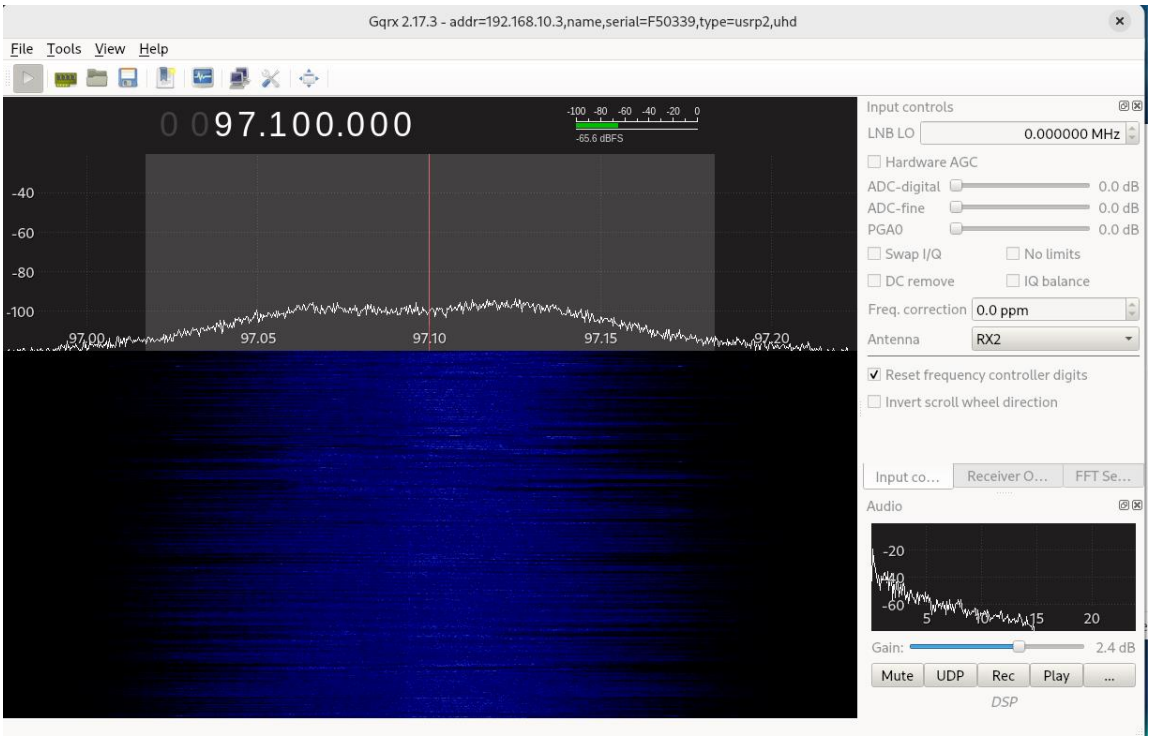
For those using this doc as a guide, please plug the power supply into the wall before connecting it to the radio. Also, please avoid touching any of the RF ports to avoid ESD and potentially damaging the device. The SDR may also randomly disconnect a few times after setting the static IP address, just continue setting it and it should stabilize.

When starting GQRX and hitting the play button (Start DSP), you should just see noise, depending on what frequency you are tuned to. Because the antenna used was designed for Wi-Fi in the 2.4GHz range, we can tune to a frequency somewhere between 2.4 and 2.48GHz to try to find a signal. When writing this, I am listening to music through my Bluetooth headset, which should show up somewhere on this bandwidth, and it does show up, at 2.433 GHz. This could also be other internet traffic, but interesting, nonetheless.

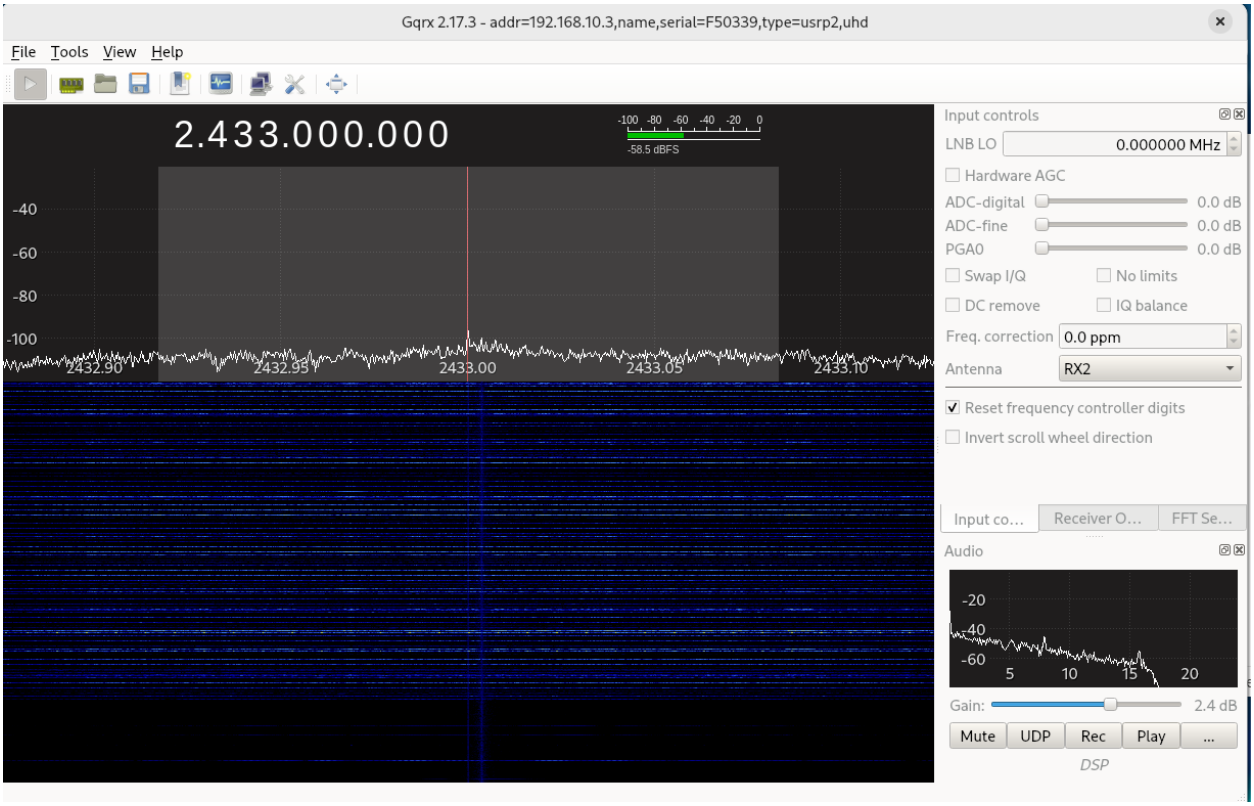
More interesting, however, is the method of reception for FM. It is odd that this was accomplished with a tiny antenna designed for a much higher frequency, as antenna length is inversely proportional to the desired frequency. The trick was to grab hold of the tiny antenna almost like it were a doorhandle, and then the signal came through very clear. Below are some pictures of the GQRX during reception. Note that the small spike in the center is leakage from the local oscillator, so it may be ignored.



Just noise. There is a tiny bit of signal visible on the spectrogram, and also audible when listening very closely.



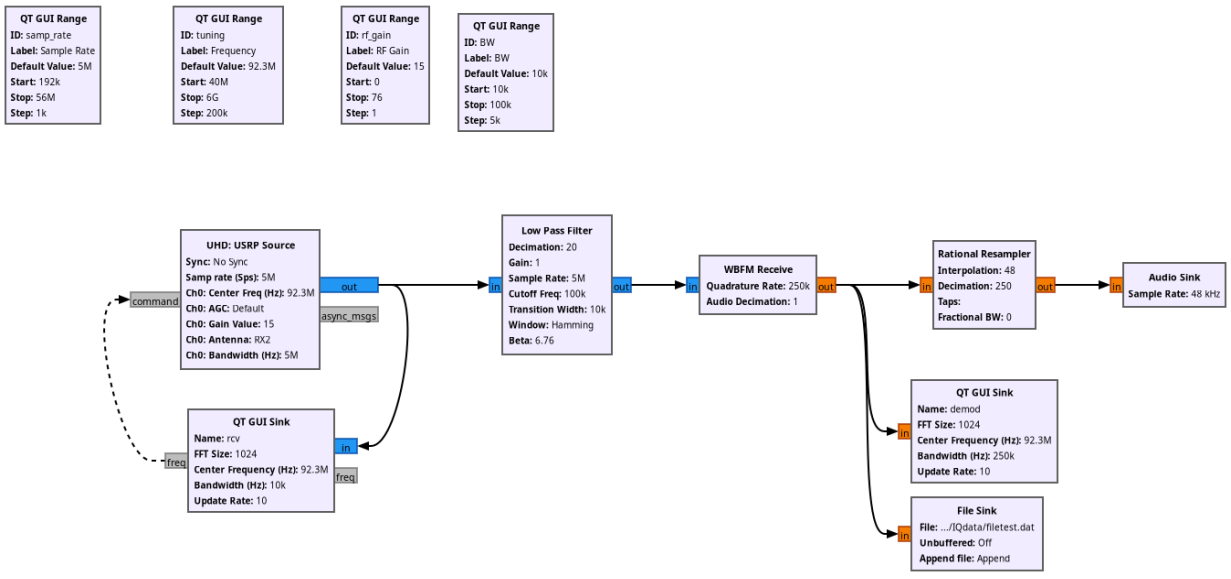
An FM signal, this one is music. Without holding on to the antenna, just noise is seen.



2.4GHz internet traffic, perhaps from my Bluetooth headset or Wi-Fi transmissions from some other source.

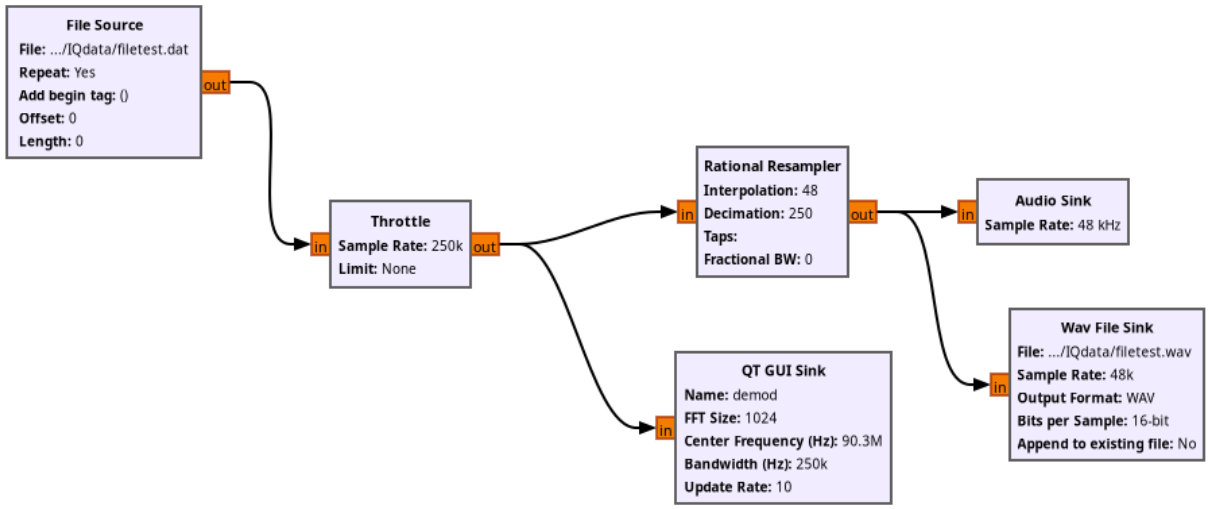
2) I/Q Data Collection and Processing to a .wav File with GNU Radio

Instead of recording this audio with a recorder in the laptop or even with a cellphone (this method still works for decoding! But it is less accurate and noisier), we can use GNU Radio to store raw I/Q data and then convert it into a much cleaner .wav file.



The block code above is in GNU Radio. This is sourced from a video from Ettus, with slight modifications. The code above stores the data after modulation, which may be undesirable for more sensitive reception like images. For NOAA reception, the file sink will be placed directly after the USRP Source block.

The collected I/Q data is stored in a binary file, which can later be passed through GNU Radio again as a file source and processed to the audio sink, which is where it can also be saved as a .wav file for listening. Below is the code.



3) Future Plans

The use of microcontrollers as the data collection hardware on the satellite payload means that data will have to be transmitted digitally, involving the use of other more involved modulation and demodulation schemes. If necessary, we may also need to employ encoding and decoding for bit error detection and correction.

So far, the modulation schemes discussed have been analog (except for the Wi-Fi one, which uses GFSK). The NOAA satellite also uses FM transmission, but there are many CubeSats trackable through N2YO which transmit in the amateur radio band, that employ digital modulation schemes. These much smaller satellites transmit with significantly lower power, which is where the RF amplifier and BPF come into play. After successful reception of the NOAA, we will find a CubeSat with its modulation scheme listed and attempt downlink. That will be our last goal for the semester. After then, transmission of data may be studied, which requires a Ham Radio License, which requires passing an exam. This should be accomplished over summer break.

Written by Jay Williams, 3/10/2024.