Development of RTL-SDR Signal Monitoring System

GUIDE AIR LABS

Motivations and Objective

Signals traveling through Earth's Ionosphere can be delayed, refracted, and attenuated.

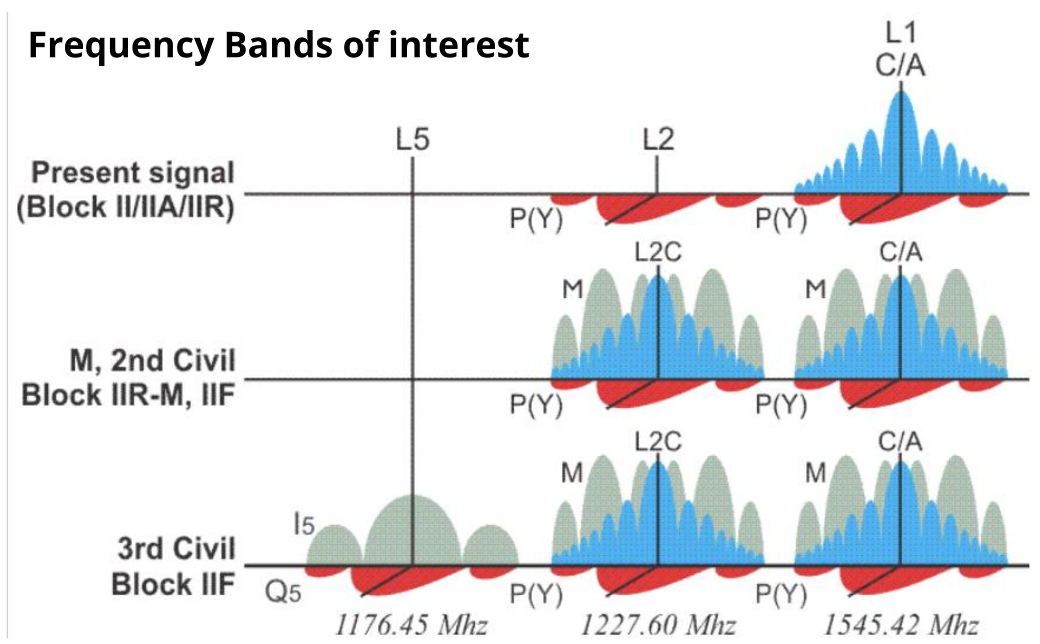
Current methods of identifying and mitigating signal errors require multiple pieces of large equipment that cost thousands of dollars each.

Keysight signal analyzer listed for $205,000 [1]

Our objective for this project was to build an affordable portable signal monitoring system that collects, stores, and demodulates GPS data.

Requirements

Need data of effects of ionosphere on satellite communication



[2]

Access all 3 frequency bands

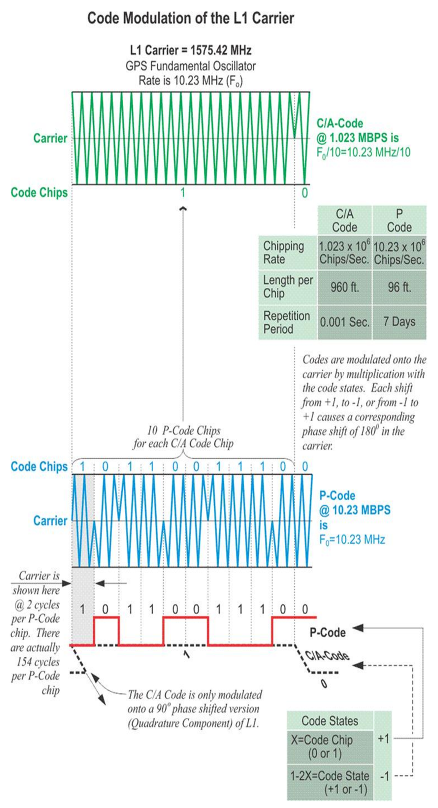
- L1 and L2 bands simply BPSK demodulation
- L5 is more complicated
  - Demodulation technique not yet readily available
- Bandwidth of 56Mhz requires high end AD9361 chip

Portable and Cost Effective

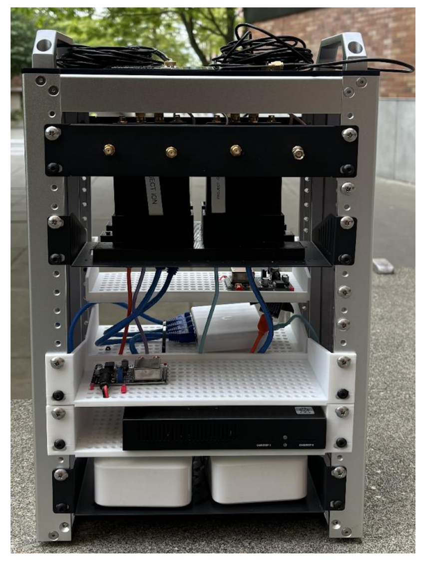
- Light and durable
- Battery powered

Large Amounts of Data Collected and Stored

- All connections must use ethernet
- Data must be stored



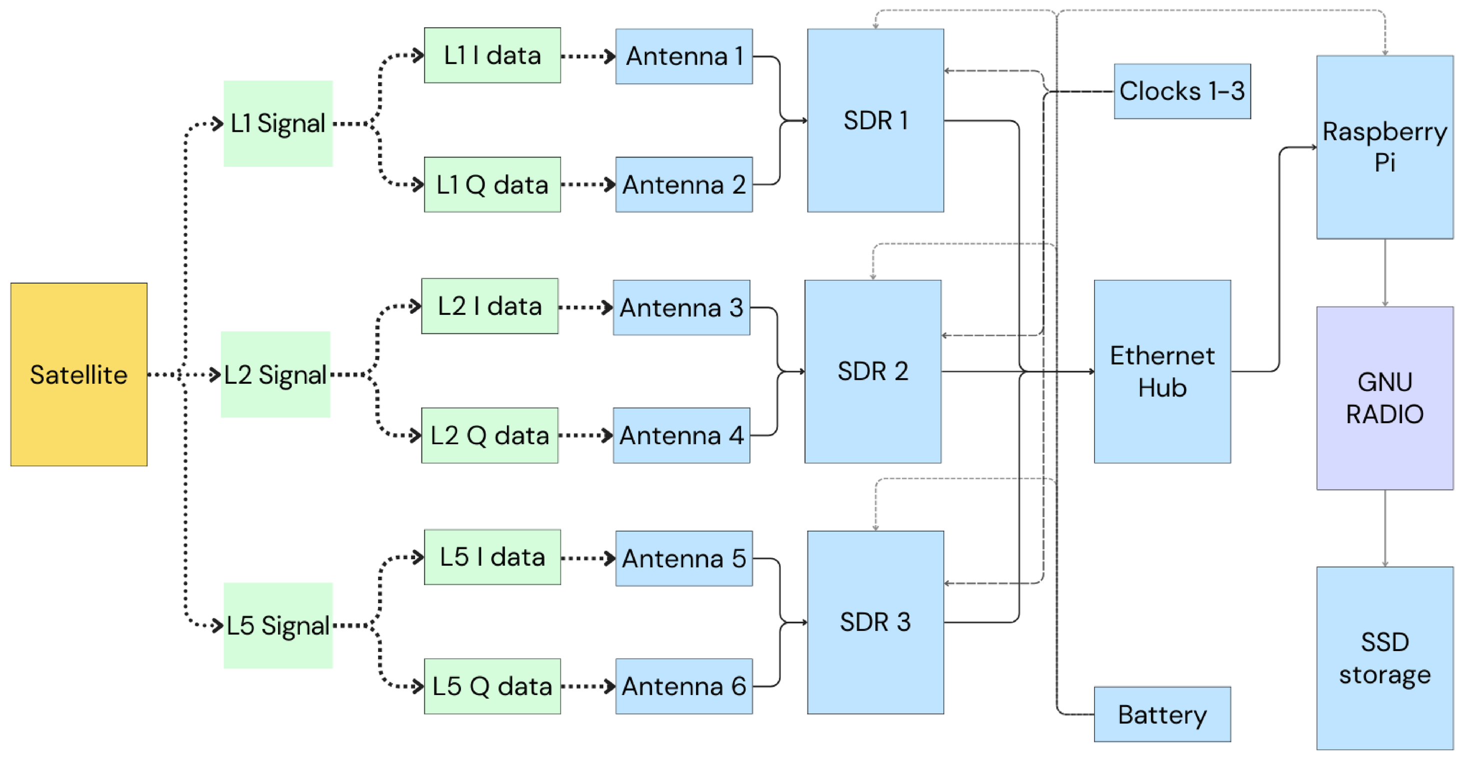
Hardware Implementation



Improvements over the past decades in RF chips have made software defined radios (SDRs) cheaper and more practical.

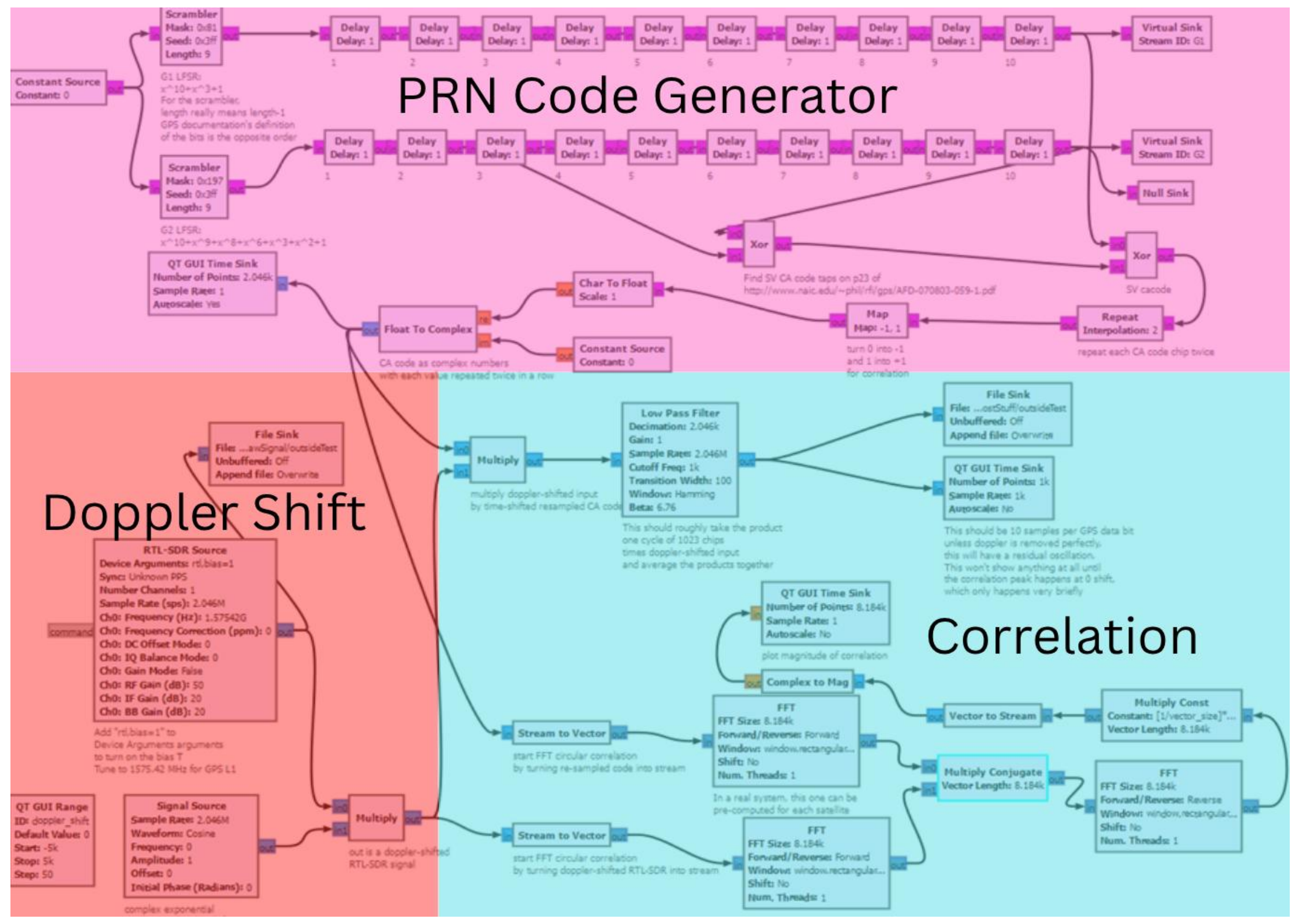
SDRs implement many of the functions of prior mentions devices, digitally on an embedded system.

- Hamgeek e310 SDRs output raw data via ethernet to Raspberry Pi [3,4]
- Demodulation is done onboard the Pi and stored
- Components attached to 2 power banks with ~16 hrs of battery life.

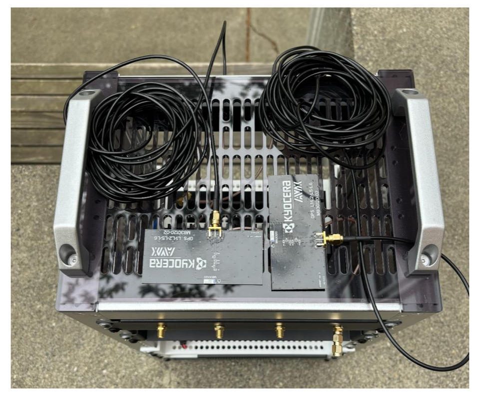


Software implementation

Current GNURadio flowgraph for collecting, demodulating, storing GPS Signal [5, 6]

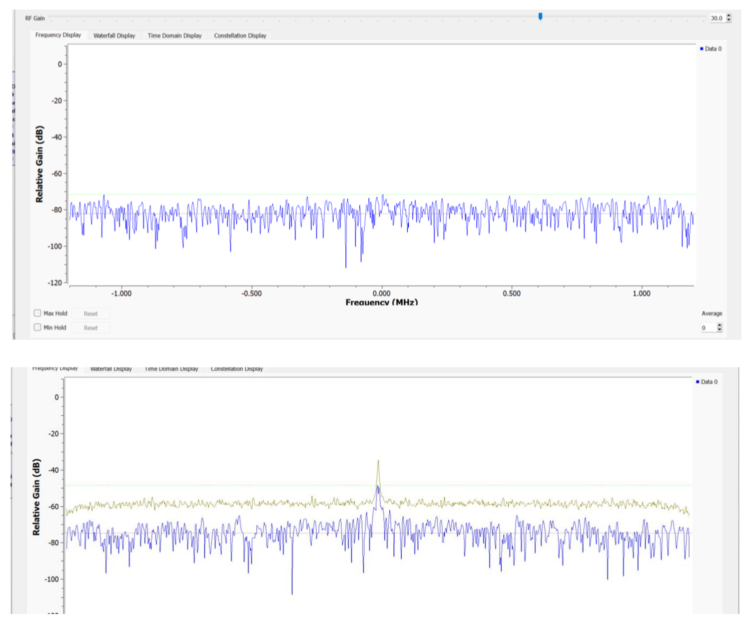


Testing and Results

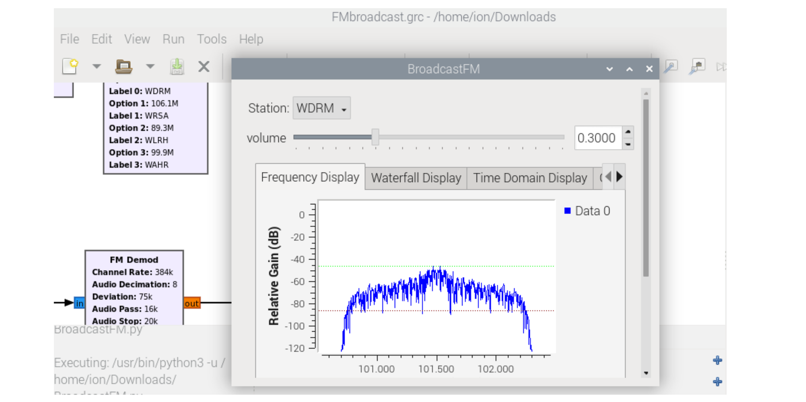


Testing setup:

- System was taken outdoors to an area with no above interference
- Antennas placed perpendicular to each other for I and Q data collection
- Data taken in 25 min intervals where it is saved onto Pi for later viewing and processing



Unfiltered frequency data from SDR taken from inside a building (top) and outside (bottom)



Initial test with FM receiver to verify real signal detection and not just noise (above)

Data collection is currently ongoing and we are continuously looking for ways to improve.

Future Works

Goals for the Future :

- Replace current off-the-shelf components with ones designed by students
  - Power bank
  - Antennas
- Faraday Enclosure
- Test external clocks
- Collection and processing of L5 signals
- Data analysis and application

References

[1]"Keysight N9030B-550 Spectrum Analyzers 2 Hz to 50 GHz," *Keysight.com*, 2025. https://www.keysight.com/used/us/en/spectrum-signal-analyzers/n9030b-550-p08-100458 (accessed May 15, 2025)..

[2]"Summary of C/A, L2C, and L5 | GEOG 862: GPS and GNSS for Geospatial Professionals," *Psu.edu*, 2023. https://www.e-education.psu.edu/geog862/node/1867 (accessed May 15, 2025).

[3]"HAMGEEK E310 70MHz-6GHz SDR Software Defined Radio AD9361 ZYNQ7020 for Openwifi DragonOS Open5G-PHY," *HAMGEEK Official Store*, 2025. https://www.hgeek.com/products/hamgeek-e310-70mhz-6ghz-sdr-software-defined-radio-ad9361-zynq7020-for-openwifi-dragonos-open5g-phy (accessed May 15, 2025).

[4] Raspberry Pi Ltd, "Buy a Raspberry Pi Development Kit for Compute Module 5 – Raspberry Pi," *Raspberry Pi*, 2025. https://www.raspberrypi.com/products/cm5-dev-kit/ (accessed May 15, 2025).

[5] "RTL-SDR FM Receiver - GNU Radio," *Gnuradio.org*, 2022. https://wiki.gnuradio.org/index.php?title=RTL-SDR_FM_Receiver

[6]gallicchio, "learnSDR/lesson23_GPS_RTL_SDR_calculateCA_simplified.grc at main · gallicchio/learnSDR," GitHub, 2021. https://github.com/gallicchio/learnSDR/blob/main/lesson23_GPS_RTL_SDR_calculateCA_simplified.grc (accessed May 15, 2025).

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