mmWave Channel Analysis Campaign

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Meet the team

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Overview

Explore and understand the behaviors of the FR2 range (24.25 - 52.6 GHz) to model impacts on adjacent frequency ranges.

Experiment 1

Measuring the Power Distance Relationship of a Signal

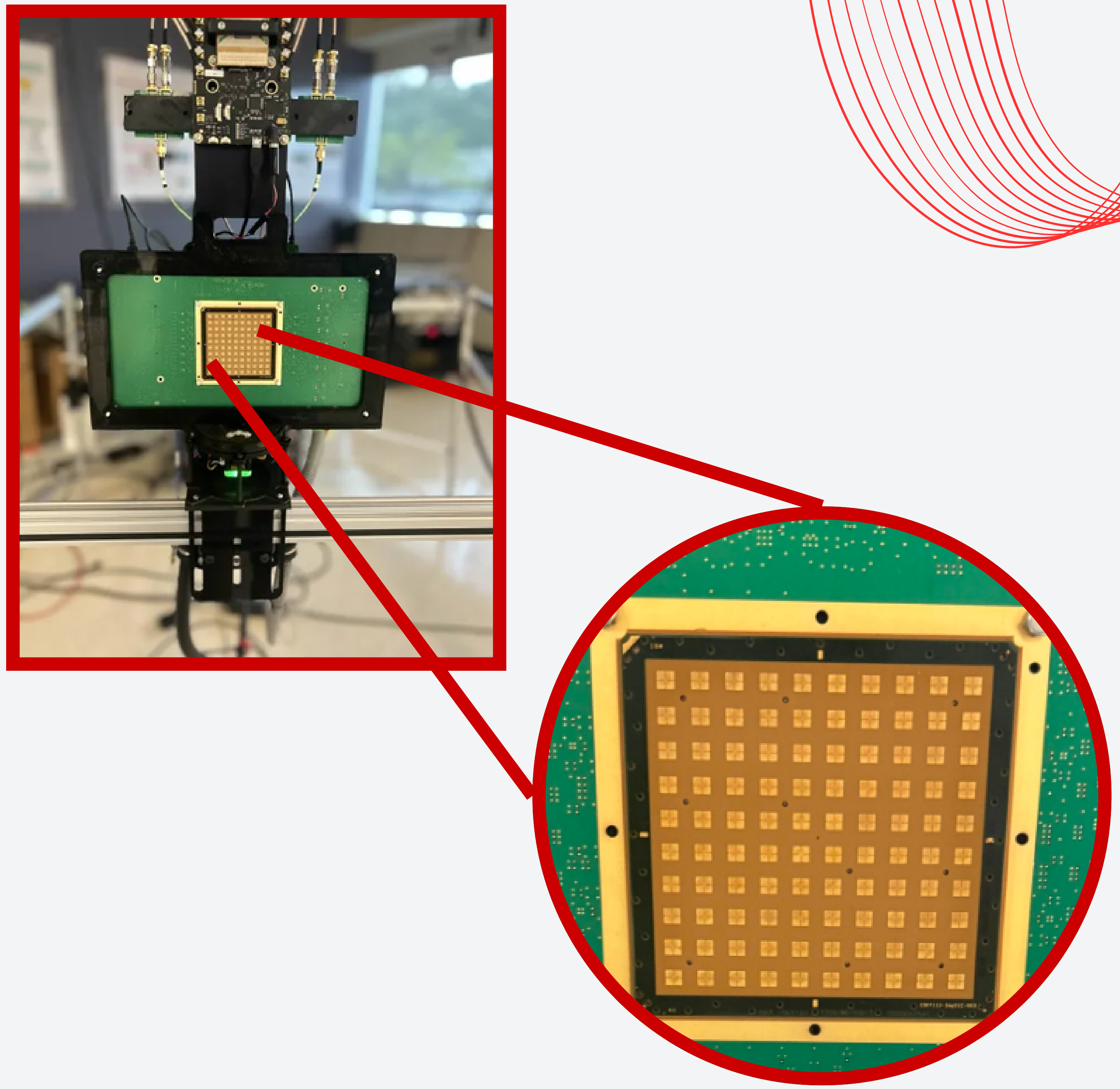
Experiment 2

ML Model to Detect Water Obstruction of OFDM Signals

Hardware

Phased-Array Antenna Module (PAAM)

- Adjusts the phase of signals transmitted by an array of antennas to achieve rapid beamforming to enhance signal strength
- Can change direction of signal transmission very rapidly, on the order of the speed of the internal computer clock

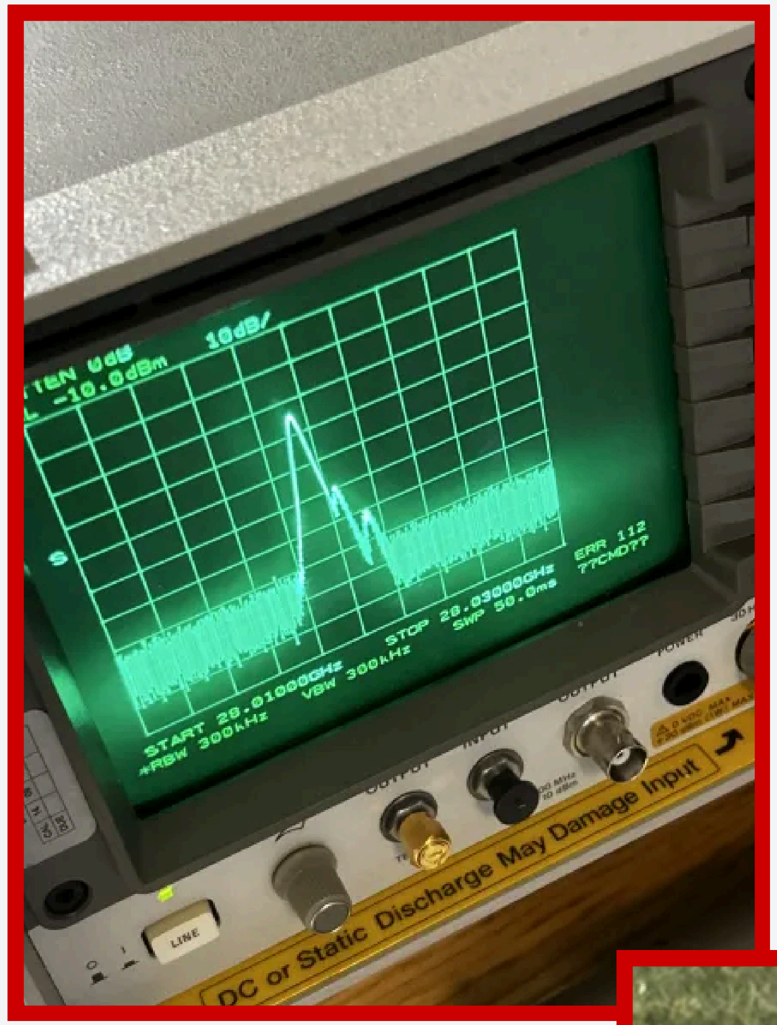


Hardware

Spectrum Analyzer (SA)

- Used for frequency-domain analysis of a received signal

- Crucial for detecting signal interference, bandwidth, and assessing signal quality



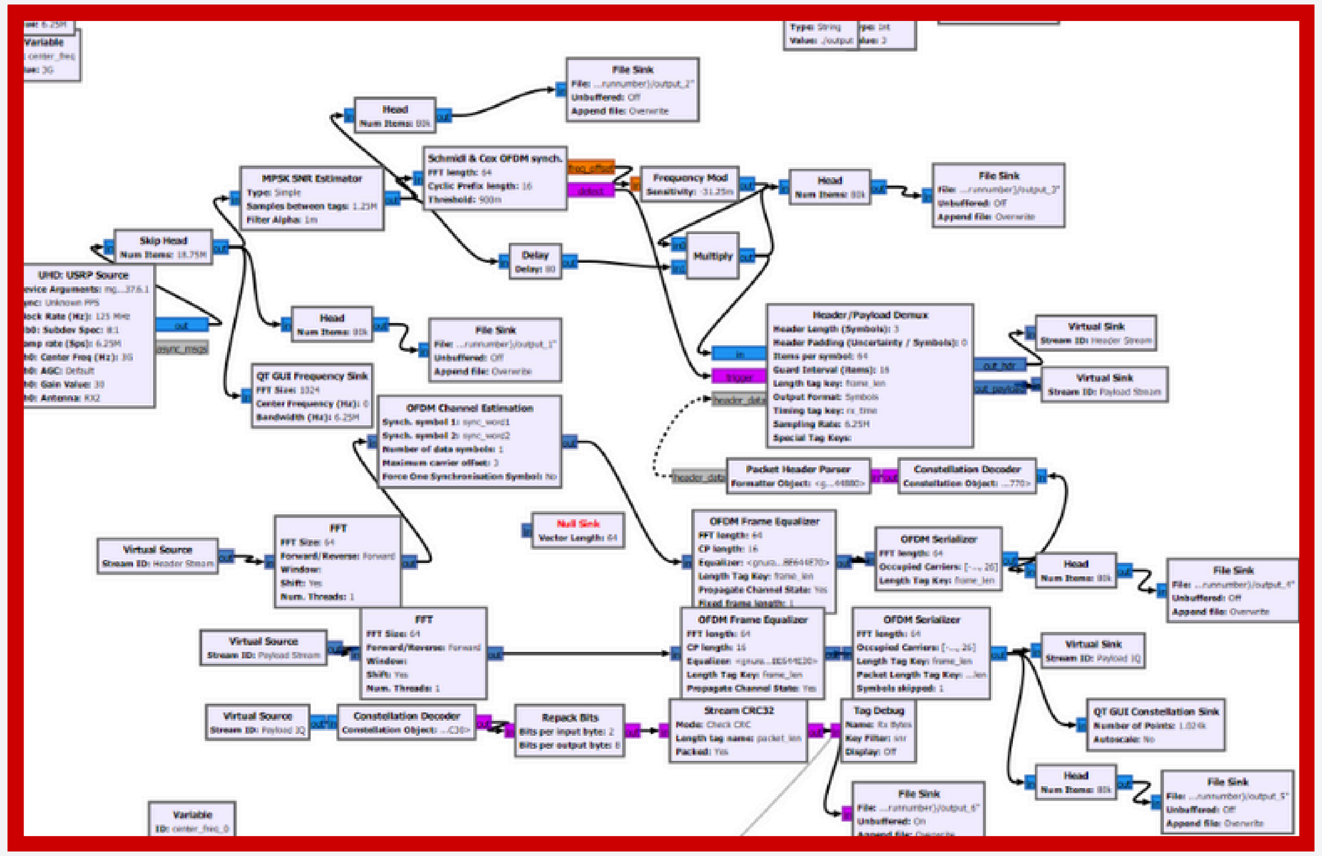
Software

GNU Radio

- GNU Radio is an open-source software development toolkit for implementing and simulating software-defined radios (SDRs)

- Allows for the creation of reconfigurable radio systems for a variety of applications

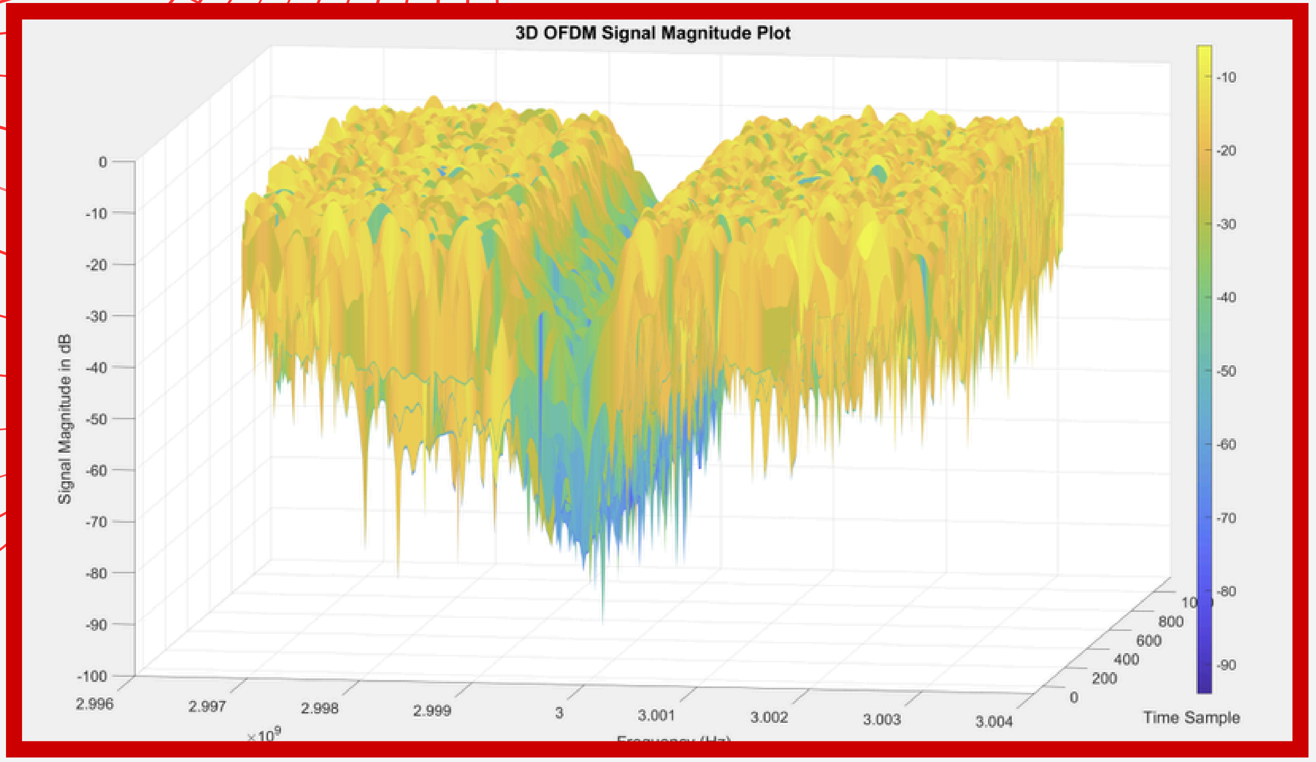
- For our purposes, we created flowgraphs for the RX(Receiver) and TX(Transmitter) operations of the PAAMs.

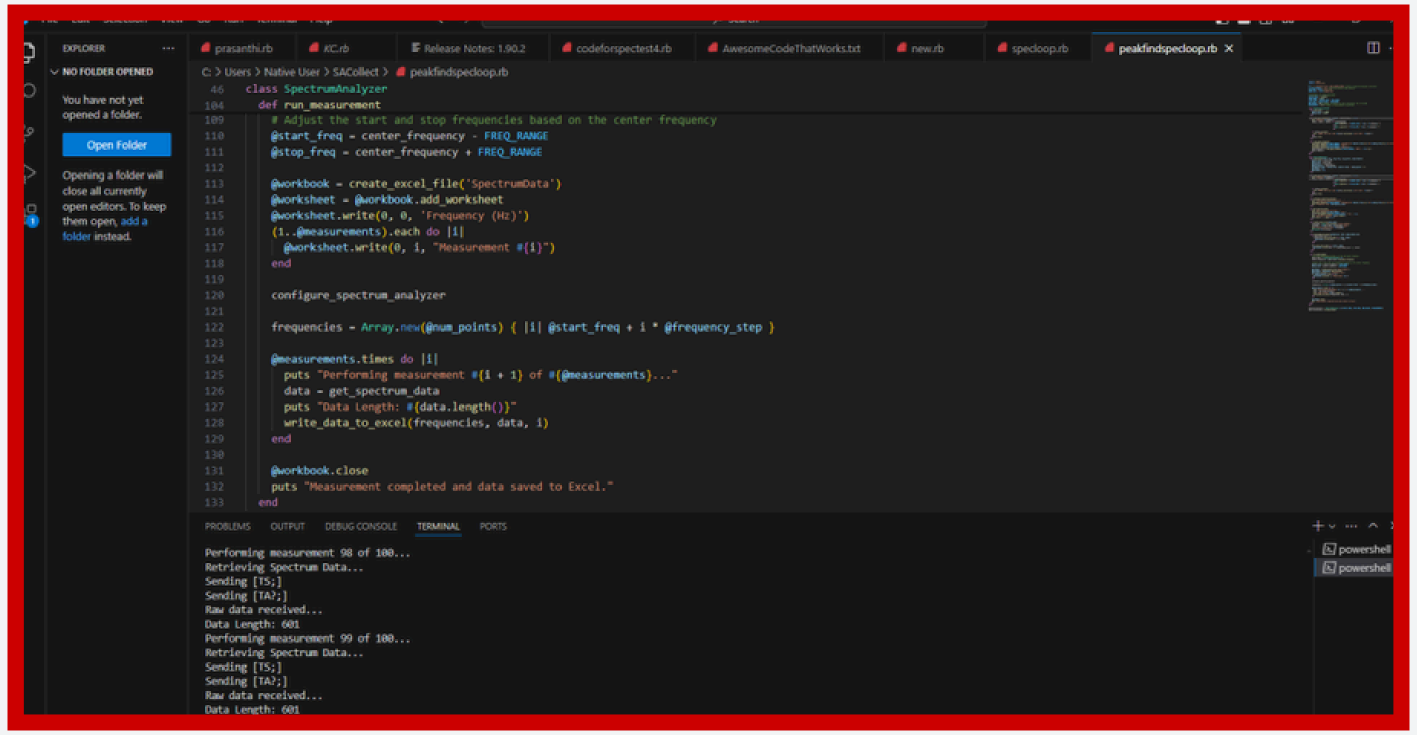


Software

Ruby & Matlab

- “Screenshot” information from the Spectrum Analyzer
  - Visualizing on computer
  - Collecting points of data to compare different powers at different distances
  - Create graphs to see key features of the data (peaks, skirts, etc.)
- Run mathematical analysis to come to conclusive results

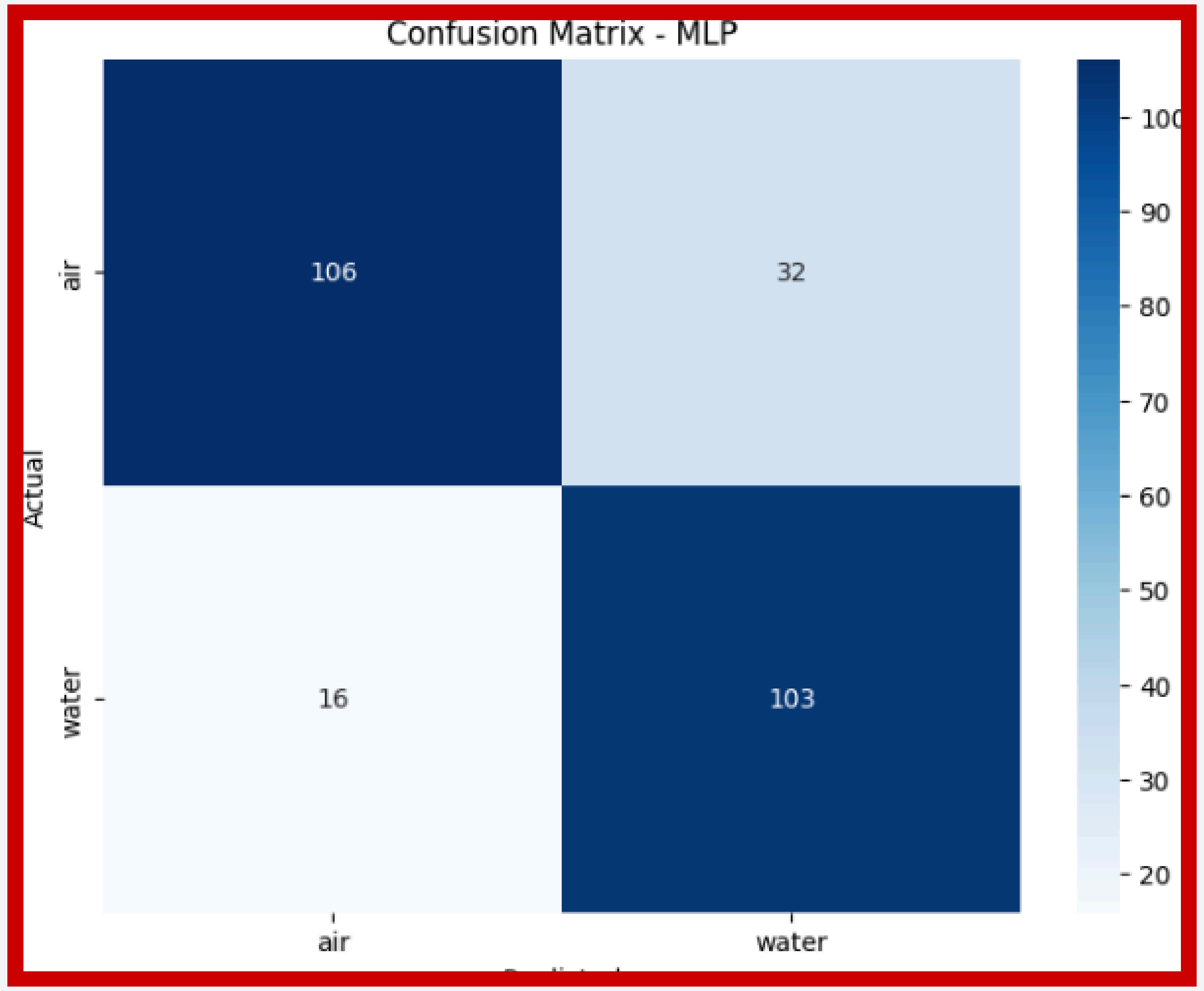


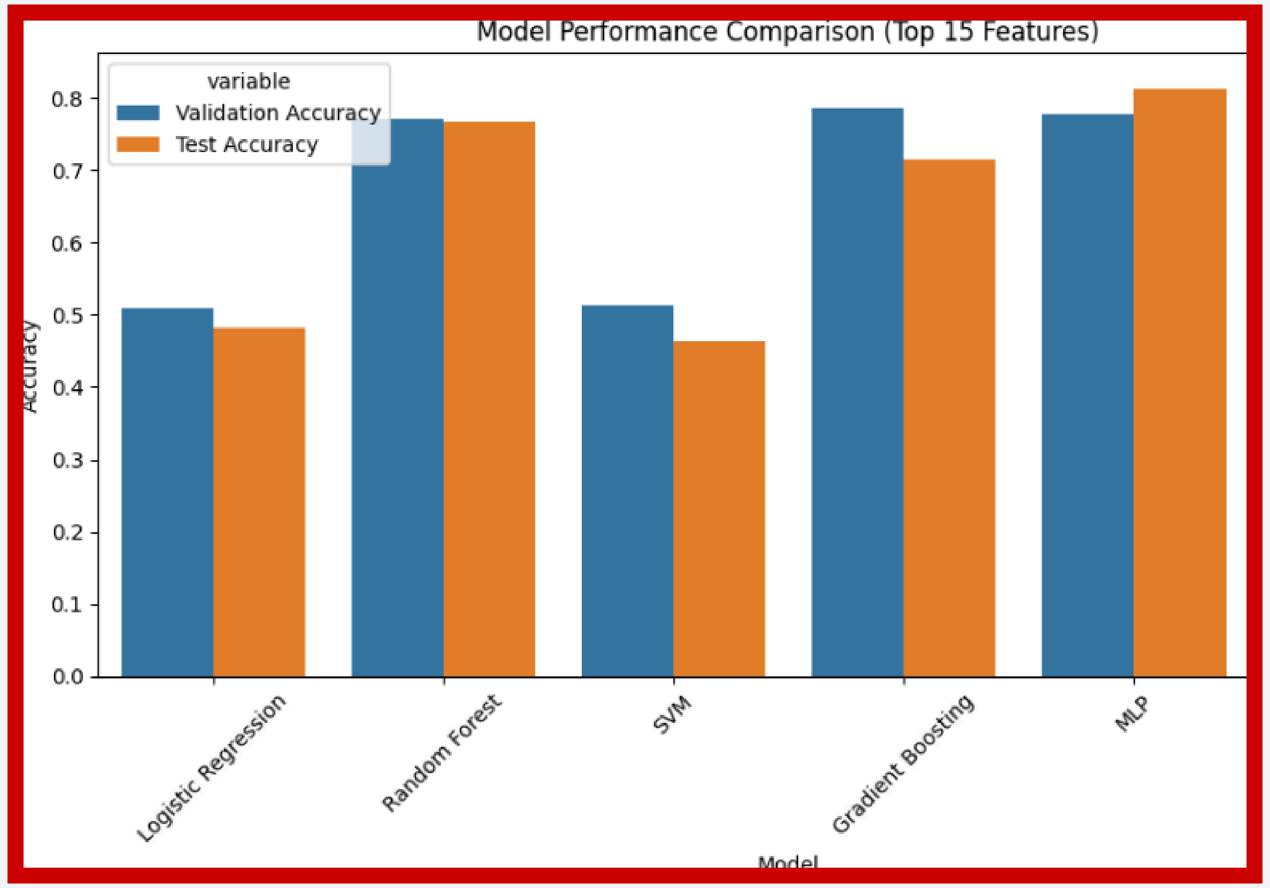


Software

Python

- Script used to extract data from the flowgraph made in GNURadio
- SKLearn helps build representation of the data that was used
- ML(juggernaut) and training models





Experiment 1

Power Loss over Distance

Capture data on spectrum analyzer

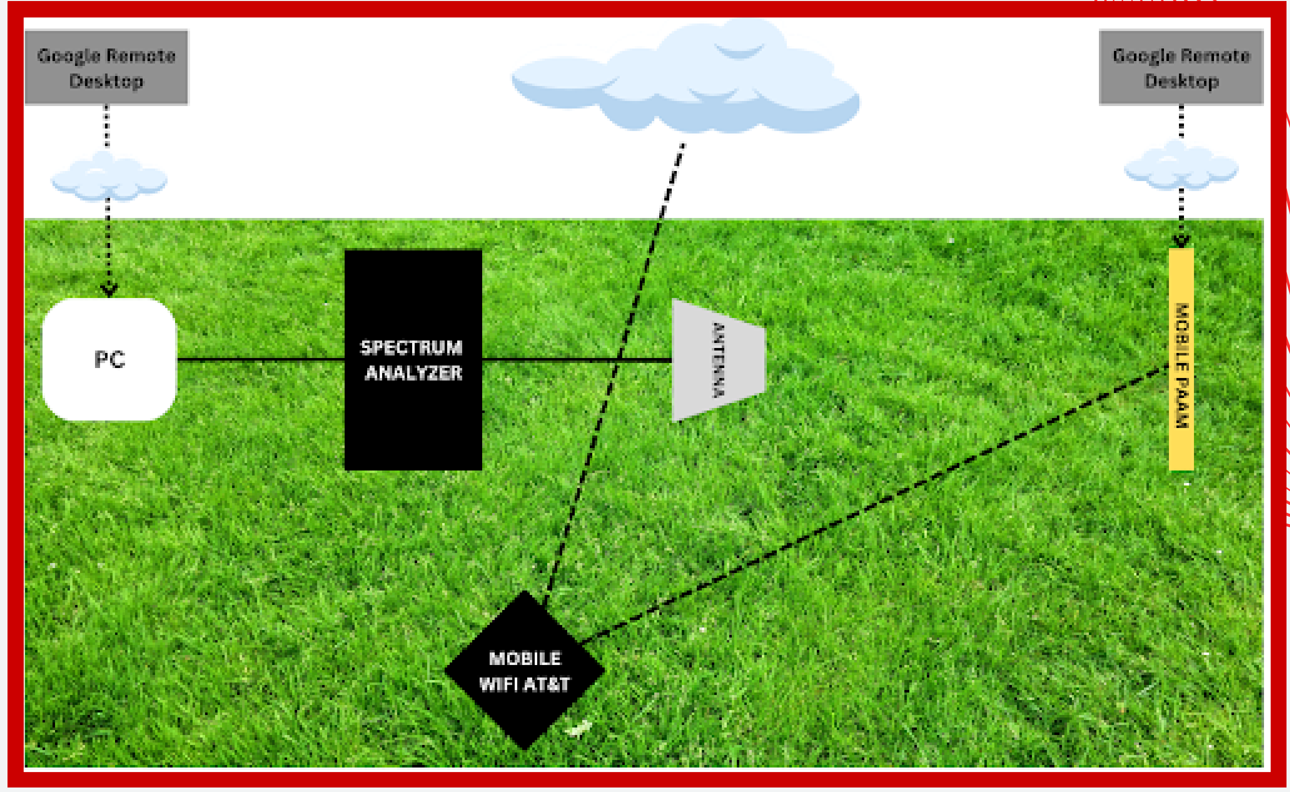
Process and visualize with MATLAB

Transmitter: Mobile PAAM (OFDM signal at 28 GHz)
Receiver: Antenna attached to Spectrum Analyzer
Variable: Distance between PAAM and SA

Automate data collection with Ruby

Experiment 1: Procedures

- Conducted our experiment on grassy field outside of WINLAB. Figure 1
- Transmitted signals from GNU Radio and used a Ruby script to record frequency samples 100s of times.
- In between each transmission, mobile PAAM was moved further away from spectrum analyzer and temperature was recorded.



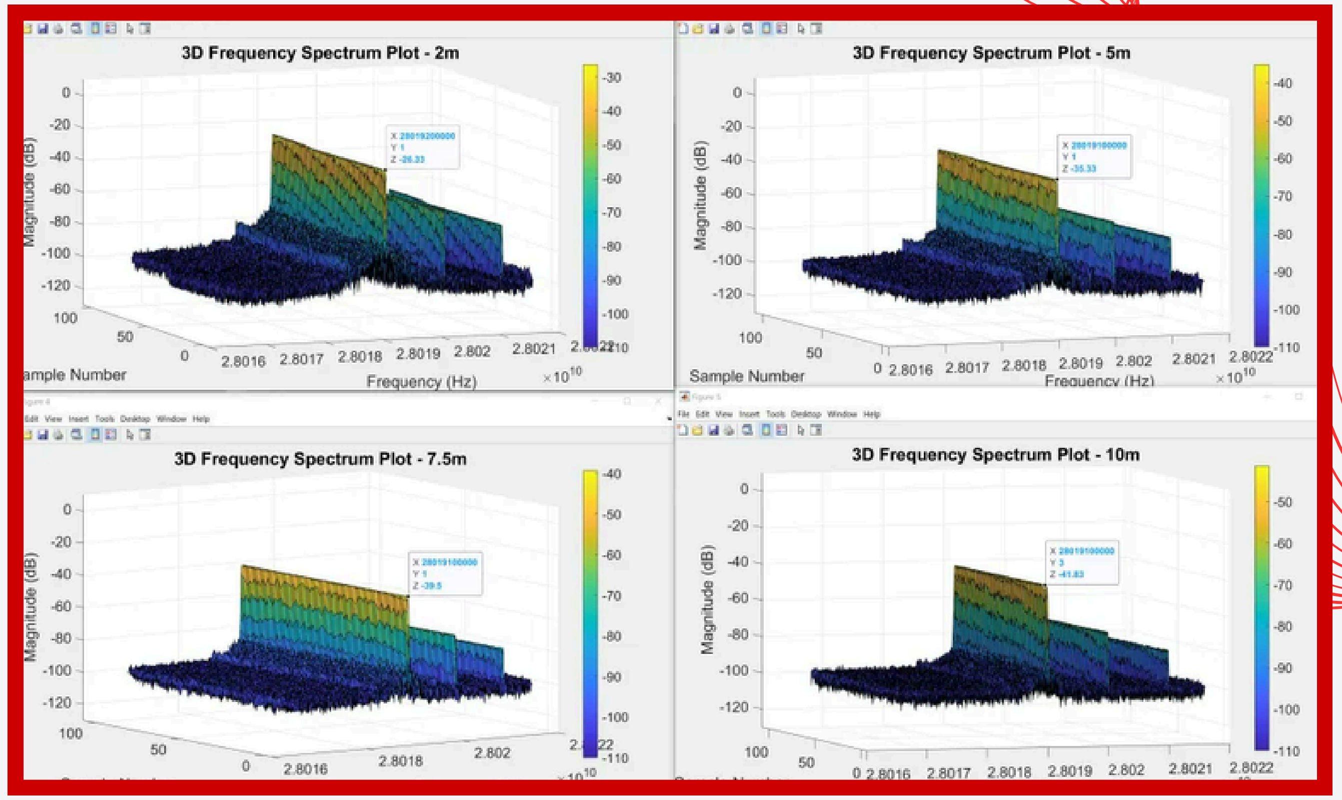
Experiment 1: Results

Results

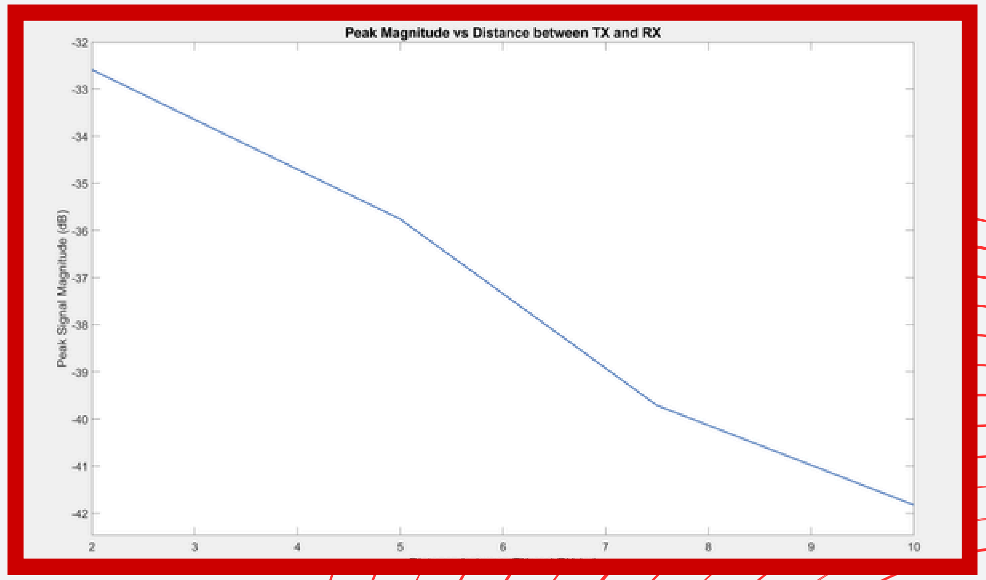
- Frequency data of transmitted signals.
- The Peak magnitude between TX and RX as data points. Figure 2
- Indicating that the Channel Path loss is 1/4πd^2 ~ matching the theoretically expected relationship.

Problems

- Wifi disconnecting leading to battery and time waste
- Mobile PAAM was not Calibrated leading to the I and Q



$$I \propto \frac{P_t}{4\pi d^2}$$



Experiment 1: Future

Future Plans

- Test this projects in various distances and frequencies such as 29 GHz, 30 GHz, and more.

- Incorporating the water Jug in this projects and placing it at various distance as well project Juggernaut

Experiment 2

Detecting Water Interference

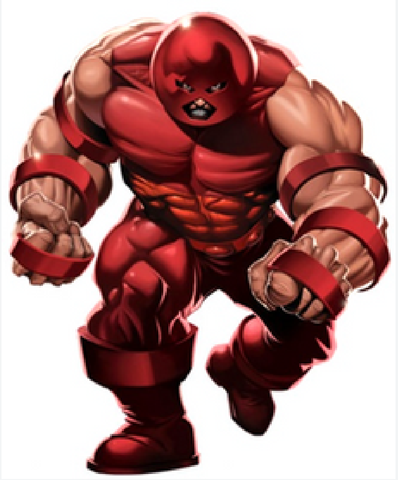
Transmitter: PAAM #2 (OFDM signal at 28 GHz)
Receiver: PAAM #1
Variable: Full water jug in front of PAAM #2

GNU Radio processing

FFT pilot and sync word data extraction

Dataset creation

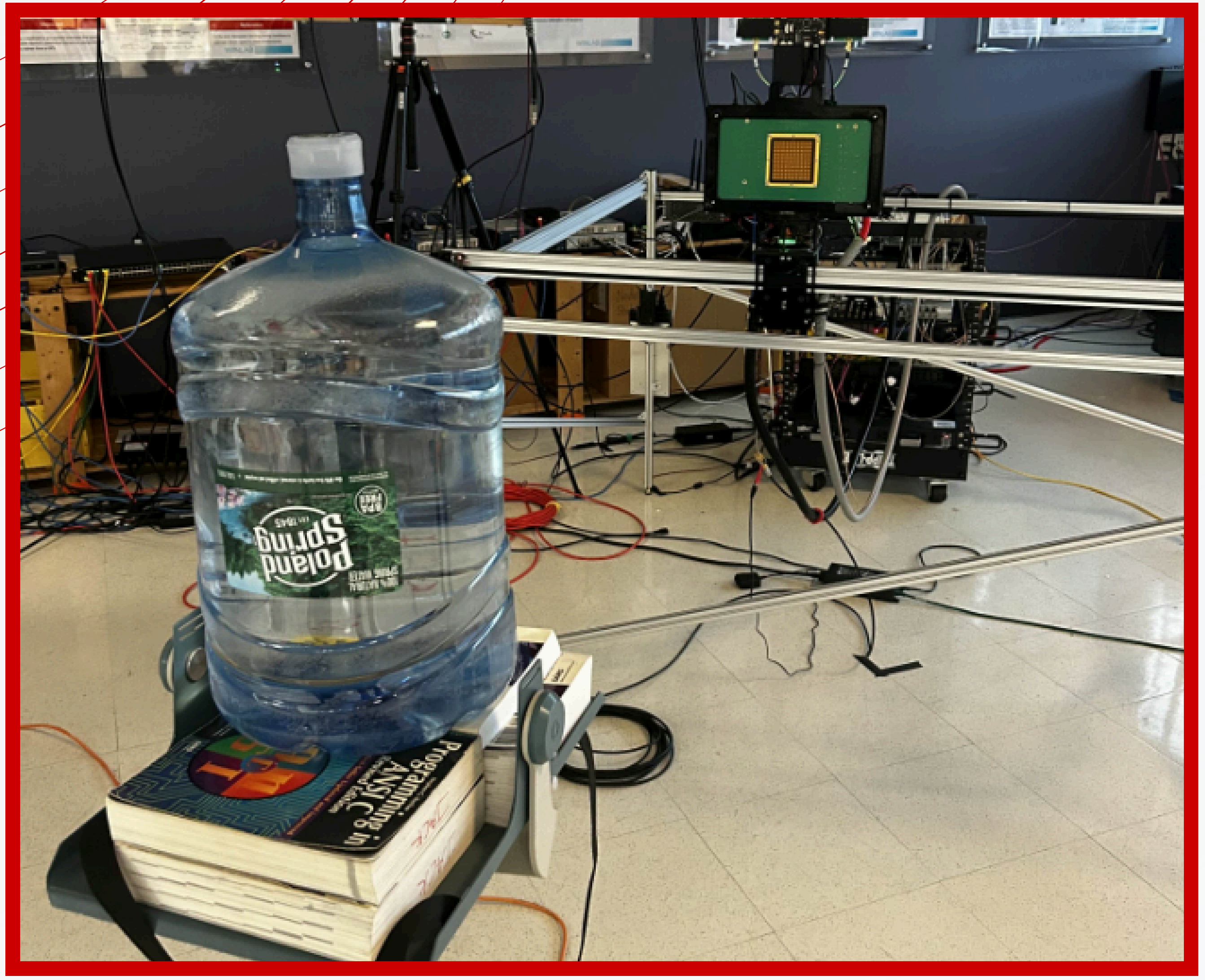
Classification



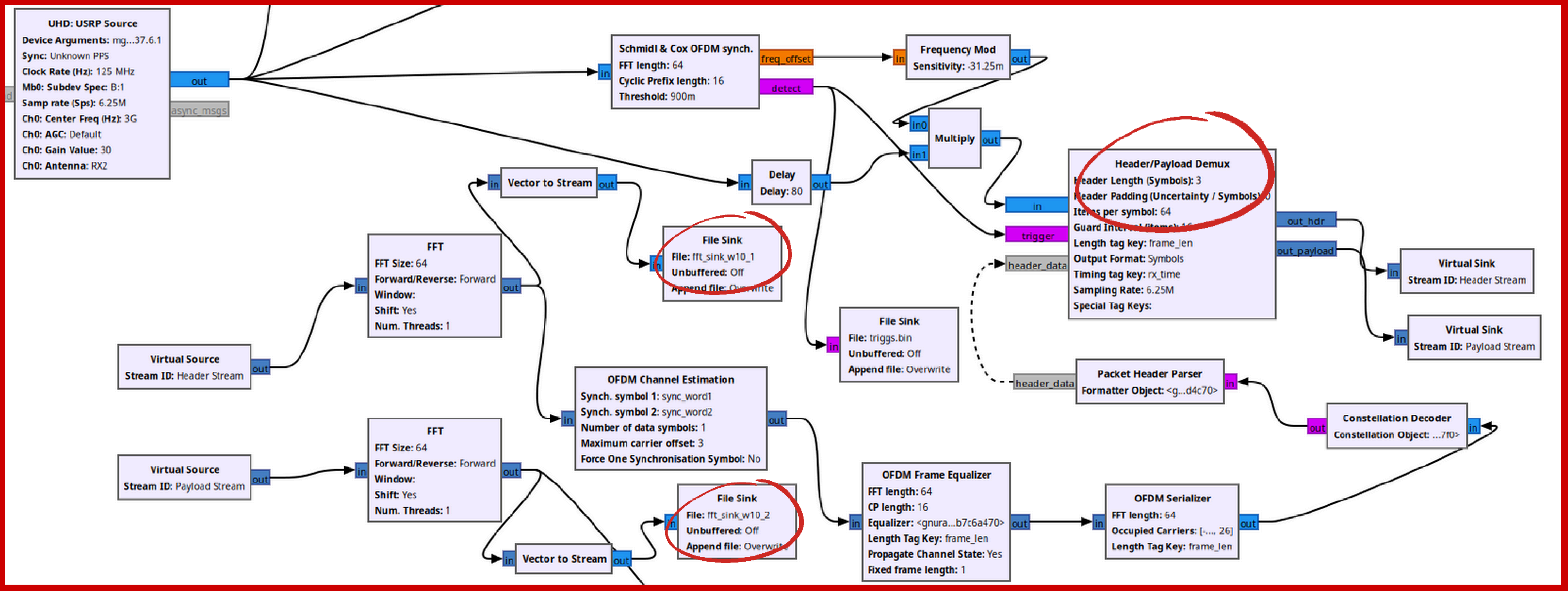
project Juggernaut

Experiment 2

Full Water Jug/ No Water Jug

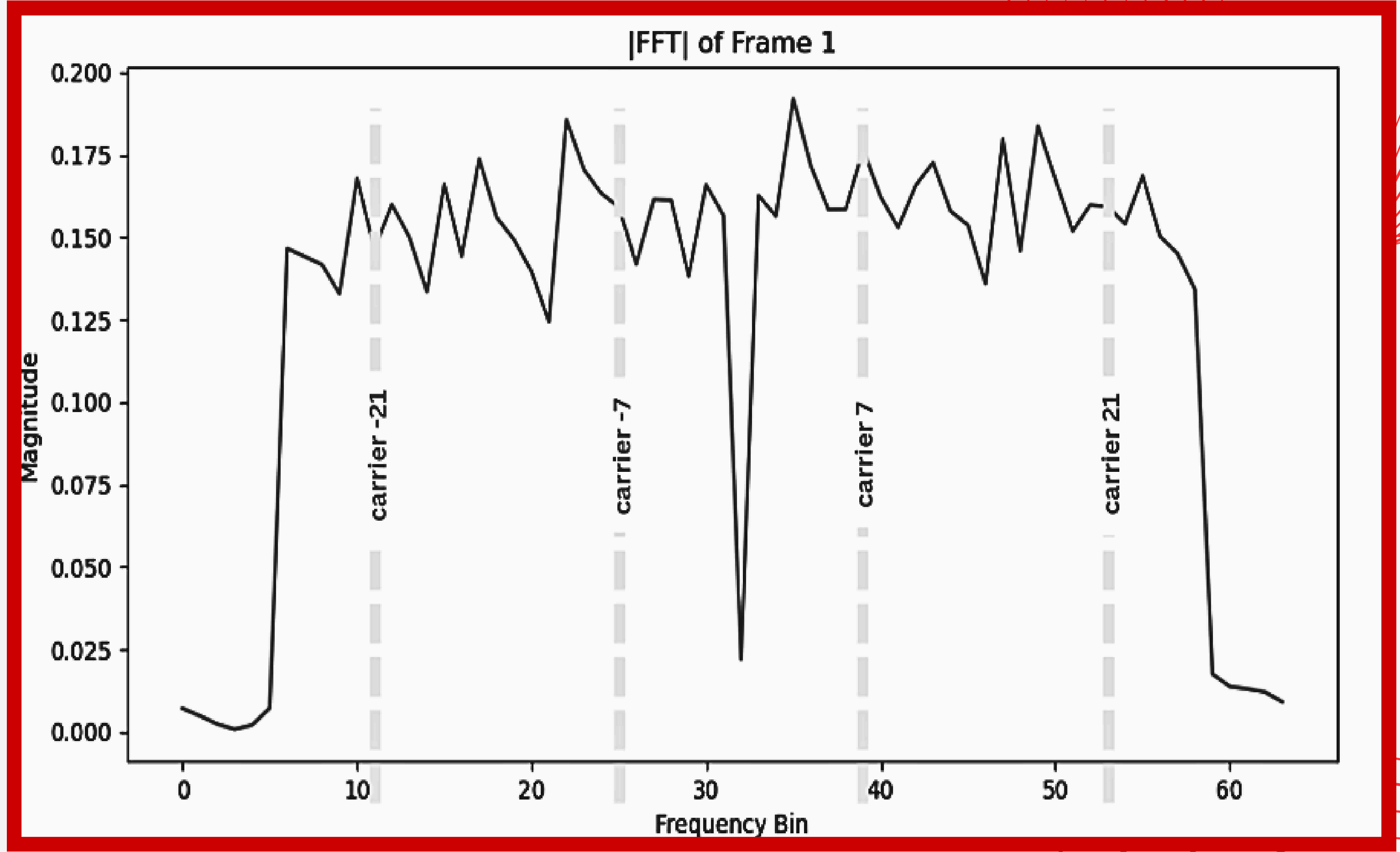


GNU Radio Receiver flowgraph



Creating the Dataset

- Extract pilot carrier data and sync word data from GNU Radio processing output
- Form dataset samples from groups of OFDM headers/payload with air/water labels
- Only keep phase information to improve model's generalization (encode into sine and cosine)



Data Processing: Probability of Accuracy

- Used a Python script to take binary RX data from GNU Radio and cross-correlate RX data with known TX message, to find a probability of accurate TX/RX of the message

- Automated the process to pipeline data from binary output to a usable format for ML models and human readability

Initial Classification Results

- Tried various models after applying PCA and keeping most important components
- Best F1-score of around 0.8: Random Forest Classifier, simple MLP, Gradient Boosting

More testing is needed
Try to reason through the classification process

Future Work

- Continue outdoor experiments
- **Diversification of Experimentation:**
  - Variable number water jugs
  - Different distances
  - Different frequencies
  - Different setting
- Refine the post-processing pipeline → more accurate classification, achieve better generalization.
- Use model for practical identification of water interference
  - Actual rain conditions (?)

THANK YOU!

ANY QUESTIONS?