

New Mexico

SUPERCOMPUTING CHALLENGE

**AVALANCHERS: Detection Device**

**For Finding People After An**

**Avalanche**

**Capital High School**

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## Executive Summary

Every year, around 150 lives are taken by avalanches worldwide. (NWS) Two causes contribute towards this high count: Improper examination of the snow (“Avalanche Safety”), which could inadvertently misguide traveller(s) into clustering up in an unsafe area, and ineffective methods for locating lost individuals (“Avalanche problems”), which could mark the difference between life and death for an individual. This project explores the idea of locating individuals after a snowpack falls on them, in turn, creating a device that could detect individuals under snow. This device was built using affordable – but effective components, with the ultimate goal of saving the lives of skiers and townsfolk that can unknowingly fall under an avalanche.

This project began with the construction of a Yagi-Uda antenna – which directionally sends and receives signals – using a Yagi-Uda calculator, which allowed the antennas to be fine tuned to work with our project's specific frequency of 885MHz. In general, antennas often lose signal when changing their location, travelling, or having a large bubble in which nearby objects can interfere with the antenna signal. (“Yagi-Uda Antenna”) To compensate for this loss, we used two amplifiers with a +50dB gain respectively, which consequently added enough gain for the system to be detected.

After the development of this project, the team came up with the conclusion that the existing system is a work in progress, and will require more research and development to further refine. The tests that we have conducted indicate that the detection of individuals is possible, the antennas are too close in range – which causes unwanted interference between communication channels, or crosstalk. Along with this, the creation of program code to analyze data and plot collected by a vector network analyzer (VNA) proved to be a challenging task for our team. As a whole, the team has acknowledged the current limitations of this project and plan on further developing this project and acquiring reliable, final data.

## Literature review

Through the years many lives have been taken by avalanches. Although the number is not large, around 150 people yearly according to the National Weather Service. Some of the most deadliest avalanches are the Huascarán avalanche in Peru with a death toll of ~30,000 people (1970), the “White Friday” avalanche in Italy with a death toll of 2,000-10,000 people (1916), and the Huascarán avalanche (1962) with a death toll of ~4000 people. Many of these numbers are startling to look at with such high values. It was important to understand the death tolls this natural disaster has taken to see what stopped people from being saved.

The idea for this project first began when our team member was talking about skiing but had to worry about avalanches. This simple statement had us thinking about how maybe we could create a device to save people's lives or to lower the death toll of avalanches. While researching avalanches we realized that many of the deaths are caused not by people dying on impact but getting lost underneath the snow. This led to our idea to create something to detect people under snow. Another thing we encountered when researching how to do this was a group called RECCO. RECCO is a company that creates tags to place on helmets that when hit with one of the RECCO detectors will signal there is a person in the general area it is pointed at (assuming they have a RECCO tag).

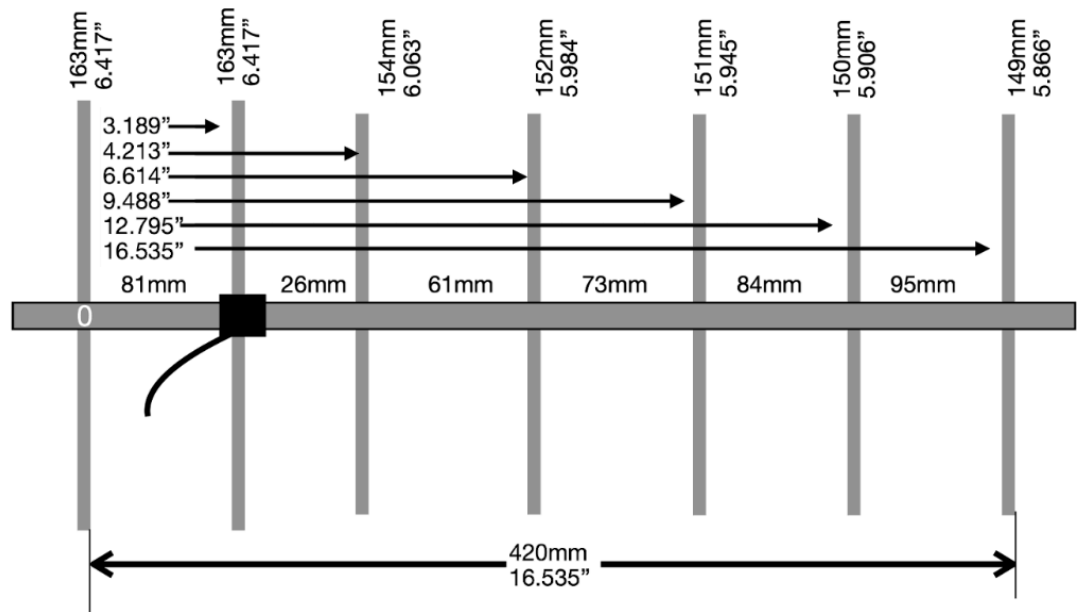
When we eventually finished our preliminary research we started to look into how exactly we are going to do this with no harm to the environment or individuals. We wanted to create something sort of like GPR (ground penetrating radar) that used radio waves to detect people under the snow. The very first thing we had to find was what type of antennas we would have to utilize to detect people under snow. We ultimately found Yagi antennas to be the most effective form of antenna because of their wide band ability and cheap/simple design. To calculate the length of the elements we used an online Yagi calculator to fine tune the antenna to 885MHz

keeping it within the 900MHz range

# Yagi Antenna Construction

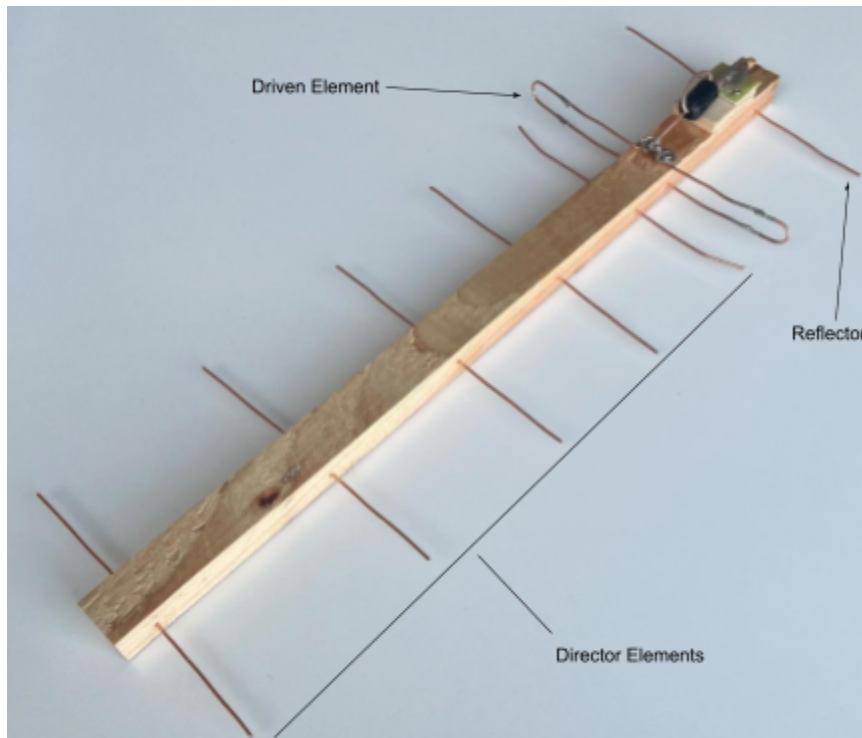
| Element Lengths (inches) |          |           |
|--------------------------|----------|-----------|
| Decimal                  | Whole    | 32nds     |
| <b>6.417</b>             | <b>6</b> | <b>13</b> |
| 6.417                    | 6        | 13        |
| 6.063                    | 6        | 2         |
| 5.984                    | 5        | 31        |
| 5.945                    | 5        | 30        |
| 5.906                    | 5        | 28        |
| 5.866                    | 5        | 27        |

| Element Positions (inches) |          |          |
|----------------------------|----------|----------|
| Decimal                    | Whole    | 32nds    |
| <b>0.000</b>               | <b>0</b> | <b>0</b> |
| 3.189                      | 3        | 6        |
| 4.213                      | 4        | 6        |
| 6.614                      | 6        | 19       |
| 9.488                      | 9        | 15       |
| 12.795                     | 12       | 25       |
| 16.535                     | 16       | 17       |

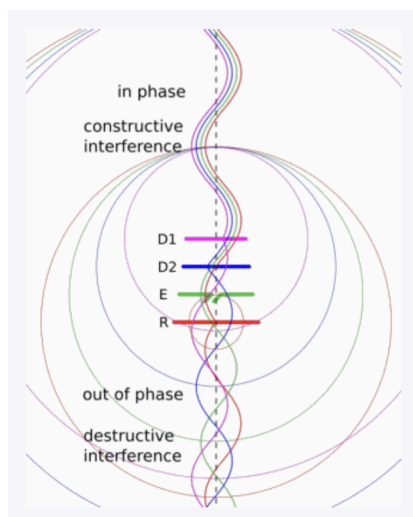


This diagram that the calculator pumped out gave us exact measurements for how to construct our Yagi antenna. It is also worth mentioning that to test the Yagi antenna we used a wide band frequency yagi antenna from amazon.

This is a photograph of our first prototype which consisted of only one single frequency Yagi antenna we made using the diagram above for reference.



Our first prototype shown used a woodstock base, copper wire for the elements, and a balun converter. Yagi antennas work by connecting a signal to the balun of the system which connects ultimately to the driven element of the antenna. From here the signal travels down the director elements in sine and cosine waves. The reflector on the back acts as a stopper for the frequency bouncing part of the frequency back towards the front of the system.



This is a very great diagram from wikipedia depicting how exactly wave frequencies move on the antenna. The driven element is shown sending the signal to which the director elements of the system reinforce the signal.

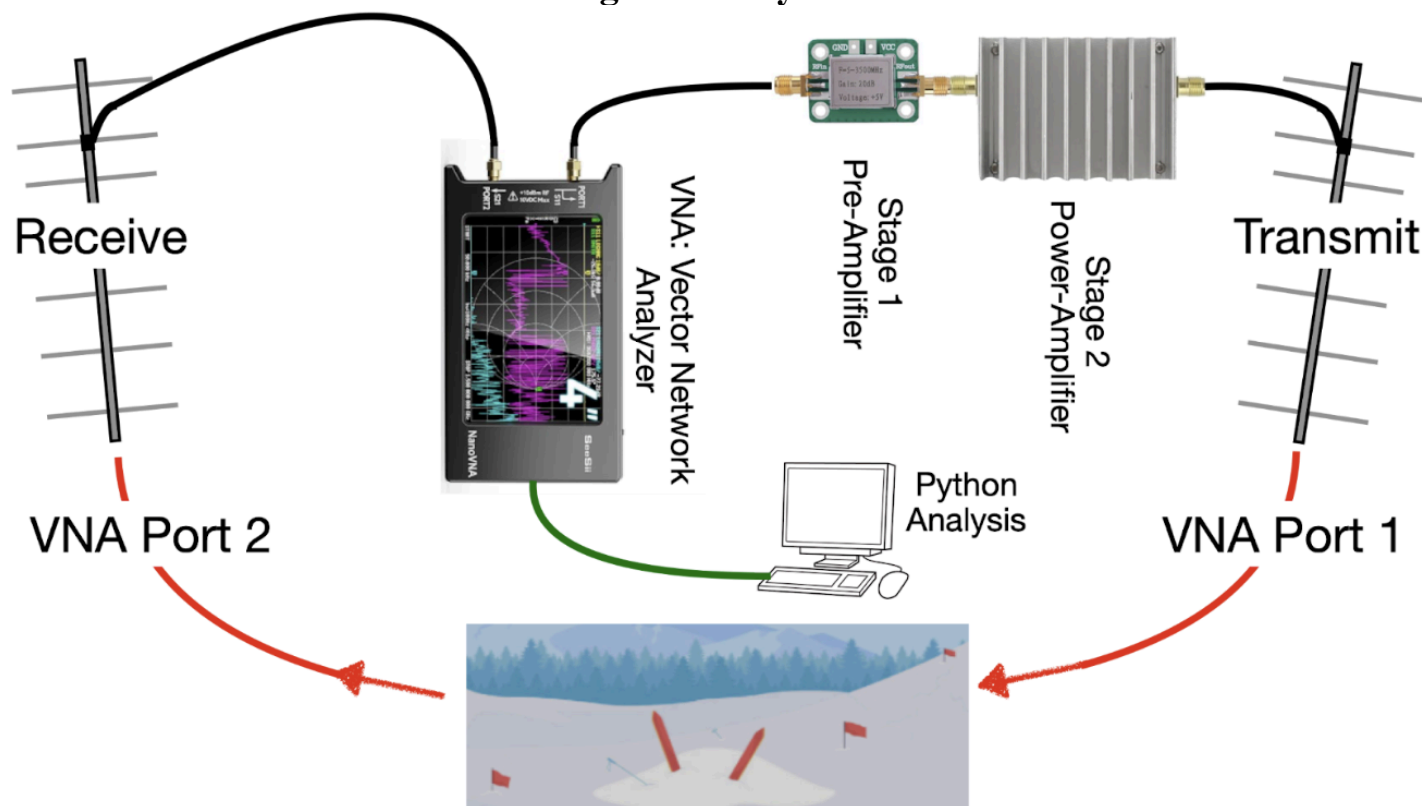
## Physical Characteristics

Lambda (wavelength): 0.339m => 13.35 inches  
Frequency: 885MHz - Old UHF channel 83  
Boom length: 407mm => 16.02 inches  
Practical construction will make this longer  
Number of elements: 7  
Gain: 10dB  
Front to Back ratio: 25dB  
Main Lobe angle width:  
Horizontal (H plane (magnetic field) ): ~45 to 60 degrees  
Vertical ( E plane (electric field) ): 35 to 45 degrees  
Element Spacing is 26mm to 95mm

Shown in the figure to the left are the physical characteristics of our antennas. This was also from the Yagi calculator we used. The data gathered from this helped us overall calculate different things such as how far we had to place the antennas and how far approximately we would need to stand in order to be noticed by the antenna.

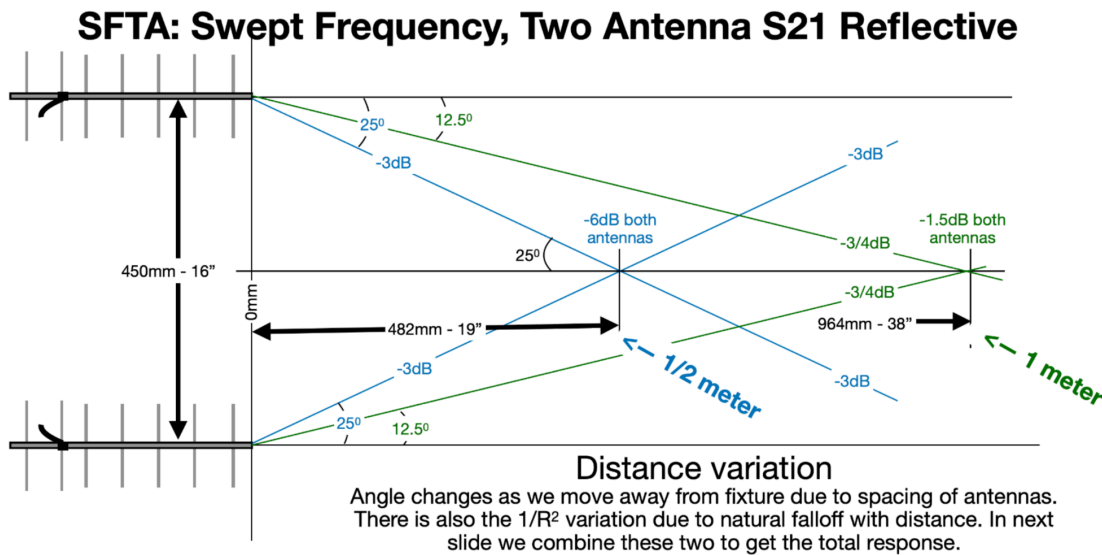
The next steps we took towards trying to detect people was making a system with a transmitting antenna and a receiving antenna.

### Diagram Of System

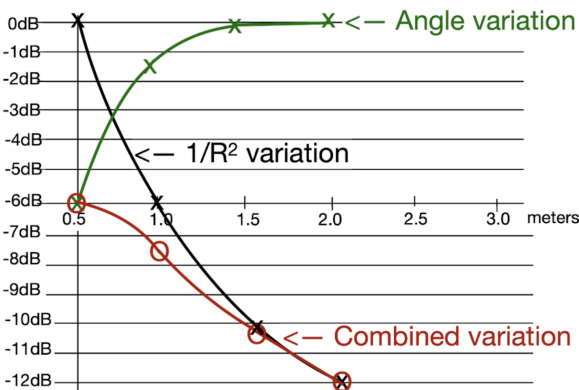


This diagram here is the basic idea of how we went about making the system. The signal first travels from the VNA (Vector Network Analyzer), moves through the first amplifier (+20db) and through the second amplifier (+30db) leading the signal to gain +50db. This decision was made to make sure the signal would hit the person and reflect back with no significant loss. Continuing through the system the signal would then travel through the transmitting antenna and reflect off of the person in the snow and come back to the receiving end of the system. The signal would then travel back to the VNA where our python code would end the sweep and tell us if there was a significant change in signal indicating a person was underneath the snow.

# Angular Geometry Of Antennas



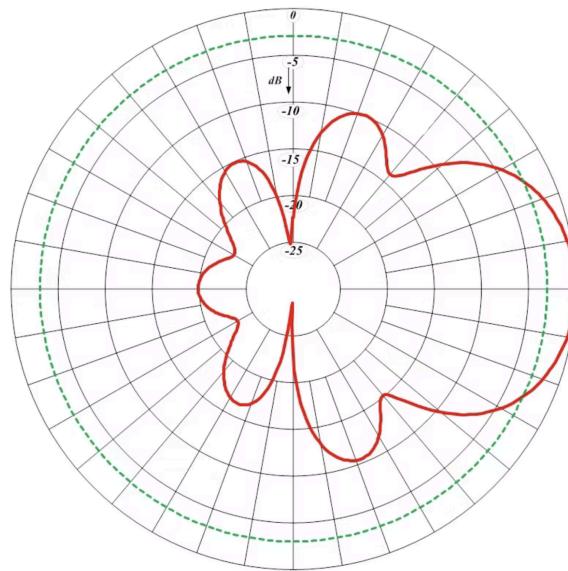
This diagram above accurately shows the dimensions in which you would get the most signal return from. We saw with the tests that we conducted that this diagram does accurately show how distance affects the signal that returns. We noticed this directly when we had our team member stand directly in front of the system and it appeared to not pick up his presence. Although when he backed up farther away from the system it appeared to pick him up better.



This graph here is what the diagram above is represented as the green line.  $1/R^2$  is the inverse square law that essentially states that the farther away you are from the antenna the more signal loss you will have. The red line on this graph is what our antenna and the inverse

square law would look like combined on the graph.

## Yagi Angular Curve



This graph here depicts the area the Yagi antenna covers. Picture this graph as sort of a top-down view of the antenna with the left being the back with the reflector elements and the right being where the signal is going through the director elements. This visual shows how the signal is mainly affected by things in front of the antenna but can still be affected by things behind it. This helped us create a plan on how to collect data without interfering with the data itself.

## Code

The code for this project aimed to plot the difference in magnitude – in decibels, of the VNA transmission coefficient (S21). This code will first initialize the necessary libraries used for communication, then require the user to create a calibration measurement – wherein the system will be cleared of any objects in its surrounding fields, which will then cause the code to start plotting out the difference in magnitude between the calibrated S21, and the most recent S21 measurement. This will also plot out the most recent S21 measurement with respect to its difference (display), its magnitude calibration, and its magnitude recent measure.

## Block I: VNA Initialization

---

```
# Import the necessary libraries
import pynanovna, math, keyboard
import numpy as np
import matplotlib.pyplot as plt

# Initialize the VNA serial link
vna = pynanovna.VNA()

#Sets frequency range and number of points to sweep
vna.set_sweep(850, 900, 101)

# set the dB calibration to  $-\infty$ 
dBCalibrate = -math.inf

# create blank arrays to differentiate the complex64 int parts
real = []
imaginary = []

# initialize VNA data stream and add condition to start
# data analysis
stream = vna.stream()
hasCalibd = False

# enable interactive plot
plt.ion()

# for all collected parameters in the VNA stream
for s11, s21, frequencies in stream:
    <continued in Block II and Block III>
```

---

## Block II: VNA Calibration

---

```
if keyboard.is_pressed('c'):
    # extract real and imaginary number parts
    real = np.real(s21)
    imaginary = np.imag(s21)

    # this is the equivalent of  $|S21| = \sqrt{\text{Re}\{S21\}^2 + \text{Im}\{S21\}^2}$ 
    # unlike a Friis gain equation, this calculates magnitude instead
    # of expected loss.
    dBCalibrate = np.sqrt(np.add(np.square(real), np.square(imaginary)))
    hasCalibd = True
```

---

## Block III: Measurement & Plotting

---

```
# start plotting data asap
if hasCalibd:
    # extract real and imaginary number parts
    realAfterCalib = np.real(s21)
    imaginaryAfterCalib = np.imag(s21)

    # equivalent of  $|S_{21}| = \sqrt{\text{Re}\{S_{21}\}^2 + \text{Im}\{S_{21}\}^2}$ 
    dBMeasure = np.sqrt(np.add(np.square(realAfterCalib), np.square(imaginaryAfterCalib)))
    dBDisplay = dBMeasure - dBCalibrate

    # this is a measure of the average amplitude (of magnitude)
    # over the dBDisplay time.
    RMSDisplay = np.sqrt(np.sum(np.square(dBDisplay)))

    # initializes plot
    plt.clf()
    plt.figure(figsize=(10, 6))

    # plots out the magnitude, raw frequency, and s21 relative to different frequencies.
    plt.plot(dBDisplay, 'r', label='|s21| magnitude')
    plt.plot(frequencies/850, 'b-', label='measured s21 (raw freq)')
    plt.plot(frequencies/850, dBDisplay, 'g-', label='measured s21 rel. to display')
    plt.plot(frequencies/850, dBCalibrate, 'y-', label='measured s21 rel. to calibrate')
    plt.plot(frequencies/850, dBMeasure, 'm-', label='measured s21 rel. to last measure')
    plt.xlabel("Frequency (MHz)")
    plt.ylabel("Magnitude (dB)")
    plt.title("Average magnitude (dB): " RMSDisplay)

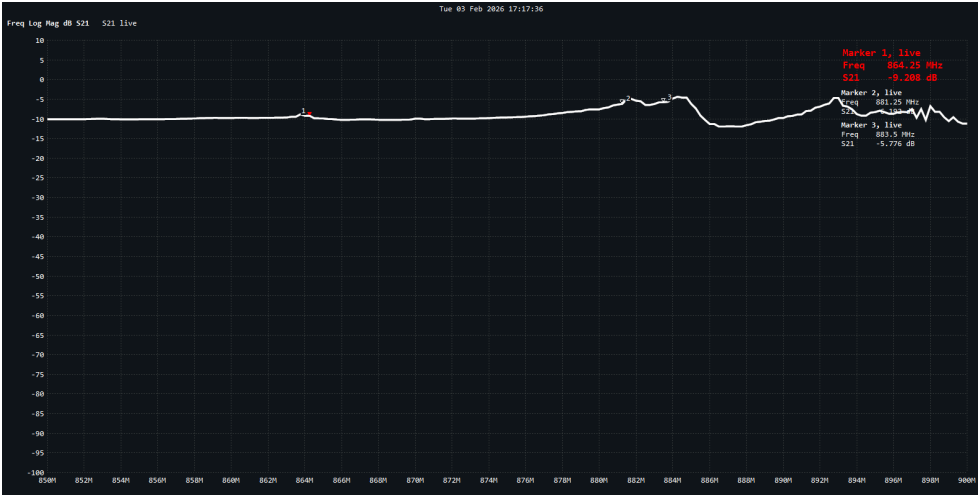
    # draws the plot
    plt.draw()
    plt.pause(0.01)
```

---

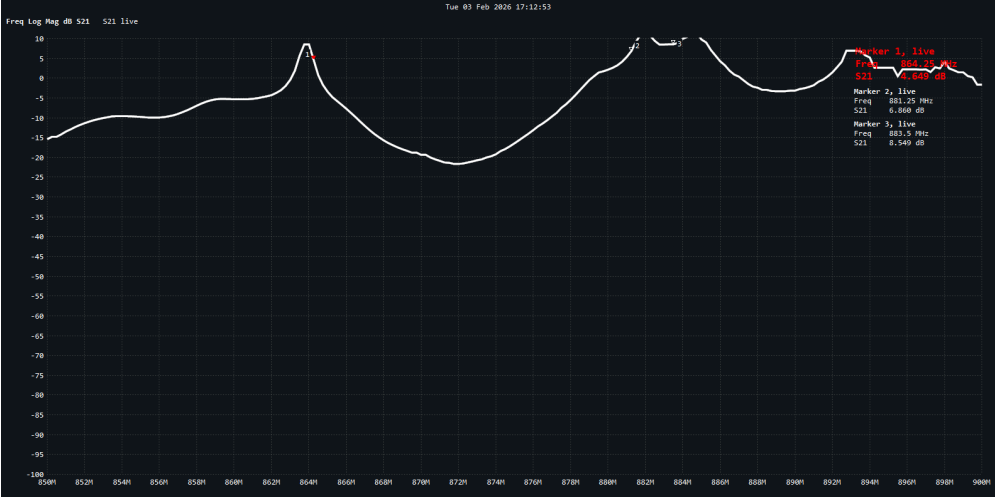
## Testing And Analysis

We conducted a number of tests during our time working on this project and many of the results we collected demonstrated that we can in fact detect people. This was aside from the idea of people under snow because we needed to first find a substitute for the snow as well as rule out any issues with our current prototype. The tests we conducted tested different environments,

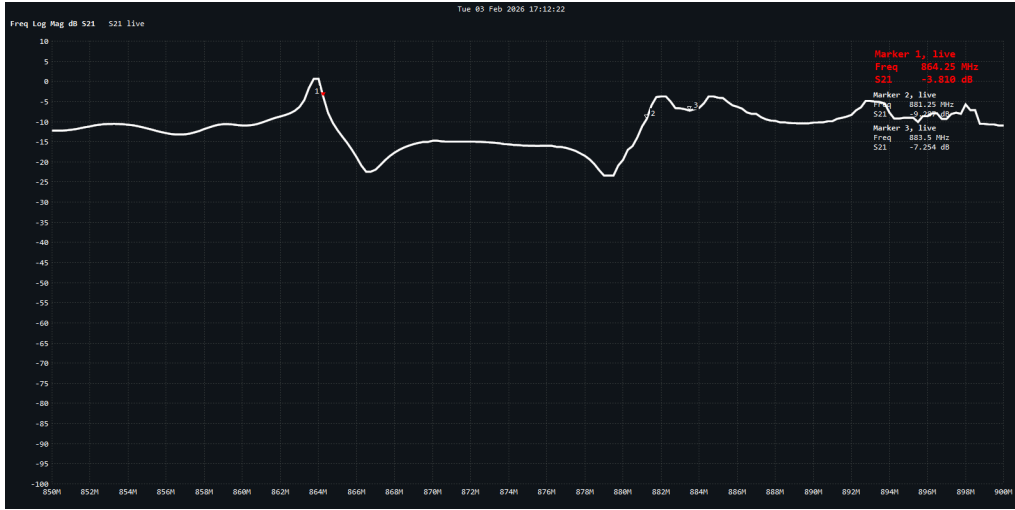
different types of Yagi antennas, and with different angles the antennas faced. The most important data we collected was on 2/3 where we tested our antenna's strength at different distances. We used one of our team members as the subject and conducted 5 tests. The first test we ran was with no subject in view. The next tests had our team member stand 1ft, 5ft, 10ft, and 15ft away. The data from our test is shown below.



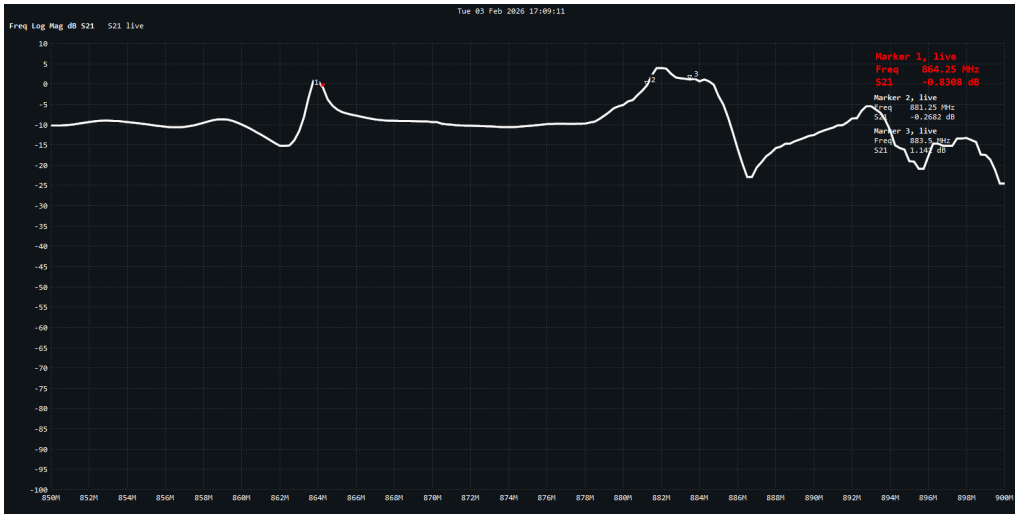
No person in sight - S21:-9.208 dB



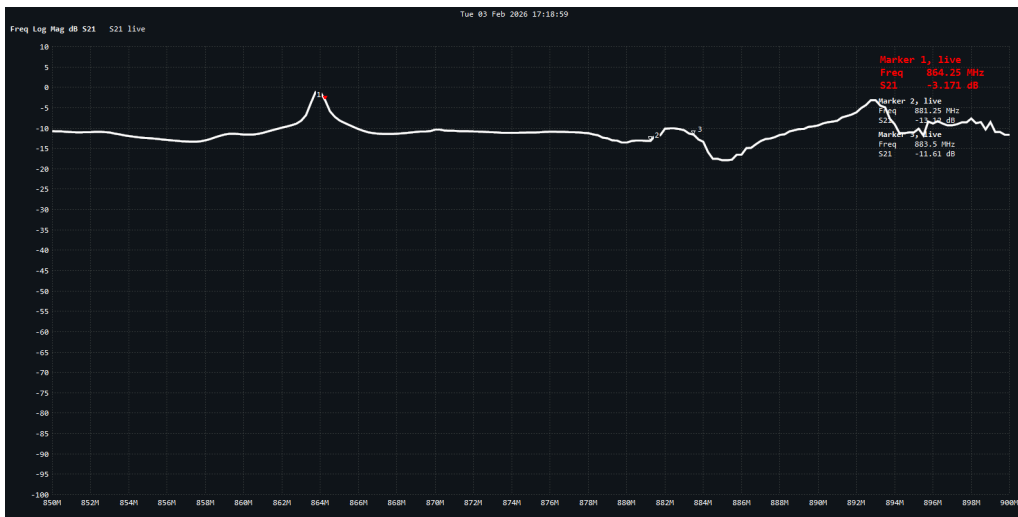
Subject 1ft away - S21: 4.649 dB



Subject 5ft away - S21: -3.810 dB



Subject 10ft away - S21: -0.8308 dB



Subject 15ft away - S21: -3.171 dB

These results showed us that our antennas did have the capabilities of detecting people but not effectively. After completing some more research after the experiment we learned that the shield we had between the antennas was not large enough to stop the cross talk between the antennas.

## **Next Steps**

The next steps for us in this project are to find a way to mitigate the amount of crosstalk between the antennas, attempt to test this using a substitute for snow, and finish creating code for the detection. We plan on making this a multi-year project and returning again next year with much more preparation and progress. Our final goal is to be able to say that we made a new device to save lives one way or another.

## **Acknowledgements**

This project would not be where it is now if it wasn't for our mentor David Ritter. Mr. David was our guide and supplied us with the materials we needed to complete this project. He had previous experience with antennas and allowed us to ask him any questions we had to understand the system that we needed to make. We would also like to thank our teacher sponsors Ms. Cislaru and Ms. Teterycz. Both teachers helped us come in contact with new team members as the time went on as well as allow us time during the day to work on our project. Lastly, we would like to thank MAKE Santa Fe for allowing us to use their makerspace to construct our antennas. They allowed us to use the tools to put together our prototype. Without any of these people we would not have such an advanced project as we do have now.

## Bibliography

Avalanche problems. Bridgeport Avalanche Center. (2022, August 25).

<https://bridgeportavalanchecenter.org/avalanche-problems/> Accessed January 12, 2026

Delgadillo, Mario, and Maringan Panggabean. EE 172 Extra Credit Project 2.4 GHz Yagi-Uda Antenna Created By Mario Delgadillo Maringan Pardamean Panggabean (pdf). Accessed March 23, 2026

Dukowitz, Z. (2025, May 6). Ground penetrating radar (GPR): An in-depth guide. MFE Inspection Solutions. <https://mfe-is.com/ground-penetrating-radar/> Accessed January 10, 2026

Pietrelli, A. (2017). Gpradar. [https://gpradar.eu/onewebmedia/TU1208\\_GPRforeducationalse November2017\\_FerraraChizhPietrelli.pdf](https://gpradar.eu/onewebmedia/TU1208_GPRforeducationalse November2017_FerraraChizhPietrelli.pdf) Accessed November 13, 2025

Technology. Recco. (2025, November 4). <https://recco.com/technology/> Accessed October 23, 2025

US Department of Commerce, NOAA, National Weather Service. "Avalanche Safety." Weather.gov, 2020, [www.weather.gov/safety/winter-avalanche](http://www.weather.gov/safety/winter-avalanche) Accessed December 16, 2026

Wikipedia Contributors. "List of Avalanches by Death Toll." Wikipedia, Wikimedia Foundation, 30 Sept. 2019, [en.wikipedia.org/wiki/List\\_of\\_avalanches\\_by\\_death\\_toll](https://en.wikipedia.org/wiki/List_of_avalanches_by_death_toll). Accessed March 23, 2026

Wikipedia Contributors. "Yagi-Uda Antenna." Wikipedia, Wikimedia Foundation, 10 Mar. 2022, [en.wikipedia.org/wiki/Yagi%E2%80%93Uda\\_antenna](https://en.wikipedia.org/wiki/Yagi%E2%80%93Uda_antenna) Accessed March 23, 2026

Zhang, M., Wang, Y., Hu, Q., Zhao, S., Liang, L., Chen, Y., Lei, Y., Qiu, C., Jia, P., Song, Y., Qin, L., & Wang, L. (2023, April 25). Phase-modulated continuous-wave coherent ranging method and anti-interference evaluation. MDPI. <https://www.mdpi.com/2076-3417/13/9/5356>

Accessed November 23, 2025