Drone Locating and Jamming Assembly

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Today's Presentation

The Problem and Solution

Technical Background

The Methodology

Conclusions and Recommendations

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The Problem and Our Solution

Why there is a need and how our project fills it

Drones in Restricted Airspace Cause Harm

Financial Damage

- Gatwick Airport 2018
  - 700 Grounded Flights
  - 100,000 Changed Passenger Plans
  - Over $1,800,000 in damages to the airport alone

Safety Implications

- Jean Lesage International Airport
  - Drone & Airplane Collision
- Could Potentially Cause Deadly Crashes [1]

1. https://www.cnbc.com/2018/10/17/drone-hits-plane-wing-shears-off-video.html

Drone Locating and Jamming Assembly

Location

- Find coordinates of drone and its controller using SDR signal strength
- Estimating the possible amount of error in the location

Jamming

- Process received signals to identify any threats
- Jam unwanted signals within the area of interest

Importance in an Airfield

Locating

- Finding the person responsible for the disturbance
- Finding the drone to avoid collisions and make sure jamming will be safe

Jamming

- Eliminating the security threat
- Avoiding potential collisions with aircraft

Broad Overview of the System

Receive and Process the Drone Signal

Locate the Source of the Signal

Generate and Output Jamming Signal

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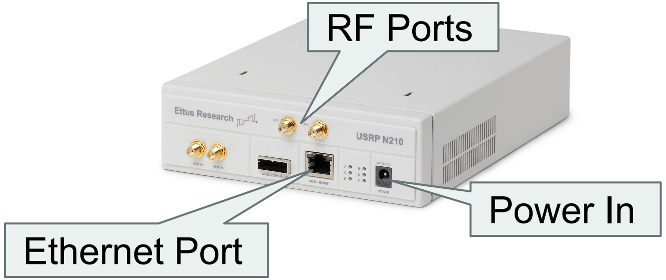
Technical Background

What we used to create our solution

How We Receive and Process the Signal

Software-Defined Radios (SDRs)

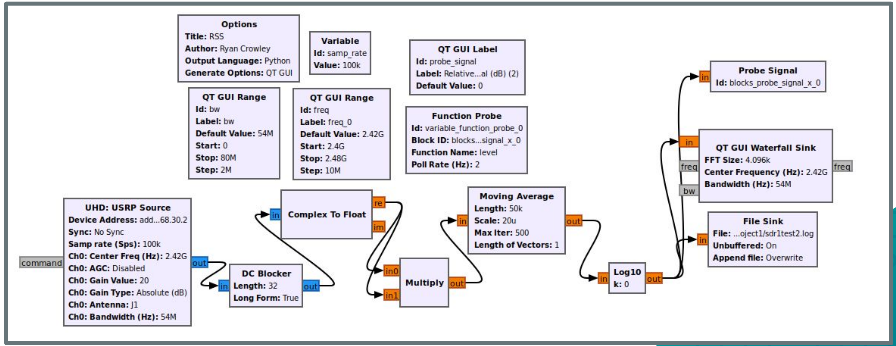
- Able to receive the signals
  - Unable to process the signals itself



SDR[1,2]

GNU Radio

- Able to process the signals
  - Runs on a laptop that is connected to the SDR(s)



Example GNU Radio Flowgraph

1. Image courtesy of Ettus Research, https://www.ettus.com/all-products/un210-kit/
2. SDR pictured is updated version of the ones used in this project

Locating the Drone

Path Loss Model

RLS Algorithm

Error Analysis with CRLB

Path Loss Model

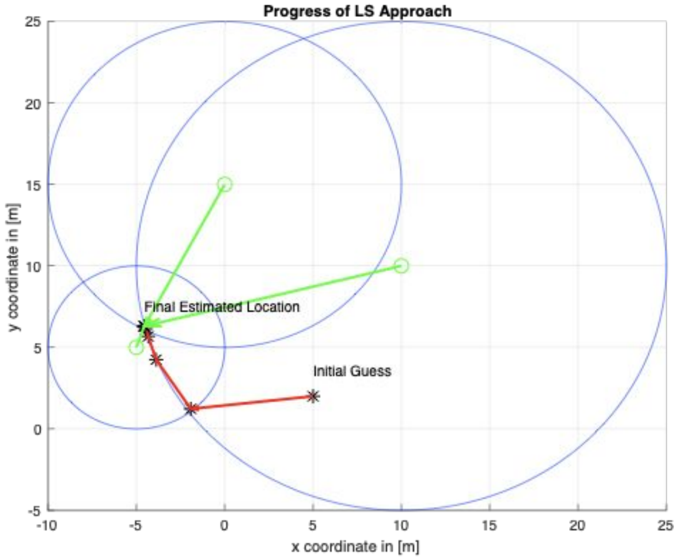
- How to convert RSS (Received Signal Strength) into distance

$$P_r = P_0 - 10\alpha\log_{10}(r/r_0) + X(\sigma)$$

$$r = 10^{(P0-Pr)/10\alpha}$$

RLS Algorithm

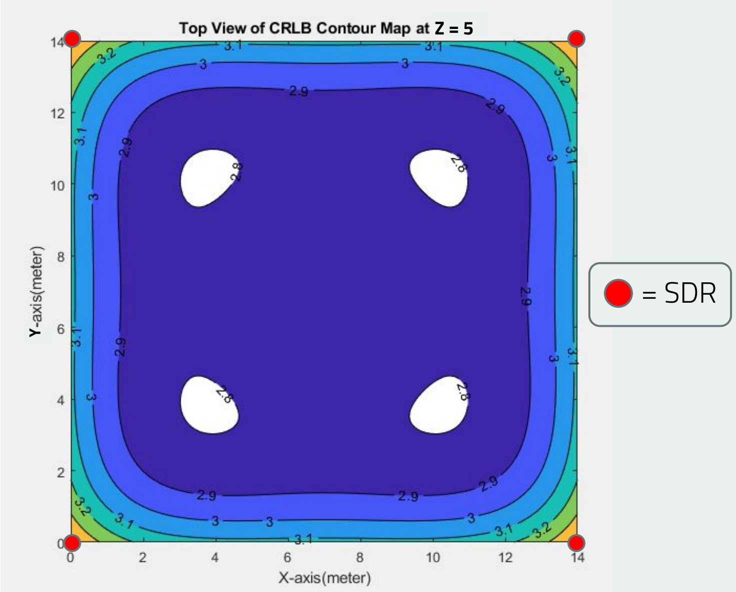
- Using the distance from SDR to drone
- How to find intersection of circles or spheres
- Recursive Least Squares Algorithm
- How much error will this produce?



Simulated Error Analysis of Localization

- Cramer Rao Lower Bound (CRLB)
  - Estimates the standard deviation of the localization error at a point

- Equations used in the MATLAB script for 3D space[1]
  - $r_p = \mathrm{sqrt}((pD_1 - apD_1)^2 + (pD_2 - apD_2)^2 + \ldots)$
  - $H[D] = -10 * \alpha * (pD - apD) / r_p^{\,2}$
  - $Cov = \sigma^2 * (H' * H)^{-1}$



Example CRLB Contour Map (SDRs at Z = 0)

1. The 3D script is based off of a 2D script found in the book "Indoor Geolocation Science and Technology: At the Emergence of Smart World and IoT", 2019, by Kaveh Pahlavan

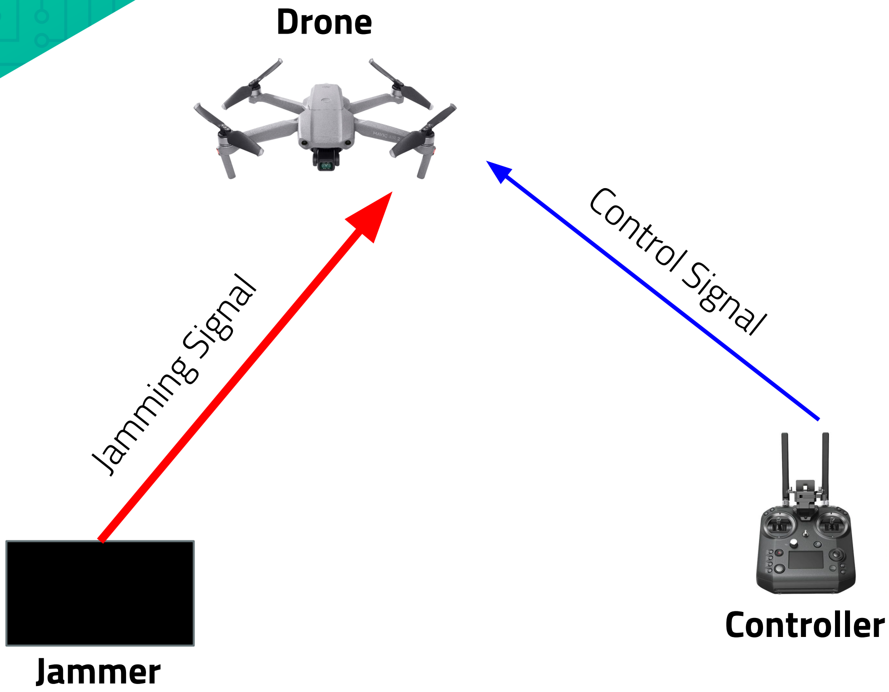
Jamming the Drone

Receive RF Signals in the Area

Ascertain Unwanted Signals

Transmit Jamming Signal

Jamming Scenario



- J/S @ drone > 0dB: should disable drone, but as you approach 0dB jamming probability decreases
- **J/S @ drone > 6dB**: desired ratio, extremely high jamming probability
- Barrage jamming technique used

Frequency Considerations

- Most commercial drones operate within the 2.4 GHz and 5.8 GHZ bands
- Due to budget constraints, our assembly jams signals within the 2.4 GHz band
  - Tinyhawk II used for testing; 2.4 - 2.48 GHz communication frequency

Brand	Frequency
DJI Phantom	2.4 / 5.8 GHz
Futaba	2.4 GHz
Spektrum	2.4 GHz
JR	2.4 GHz
Hitec	2.4 GHz
Graupner	2.4 GHz
Yuneec	2.4 GHz
Parrot AR2	2.4 GHz
Immersion	433 MHz

Common Drone Frequencies of Operation

1. Phuc Nguyen, Hoang Truong, Mahesh Ravindranathan, Anh Nguyen, Richard Han and Tam Vu, "Drone Presence Detection by Identifying Physical Signatures in the Drone's RF Communication"

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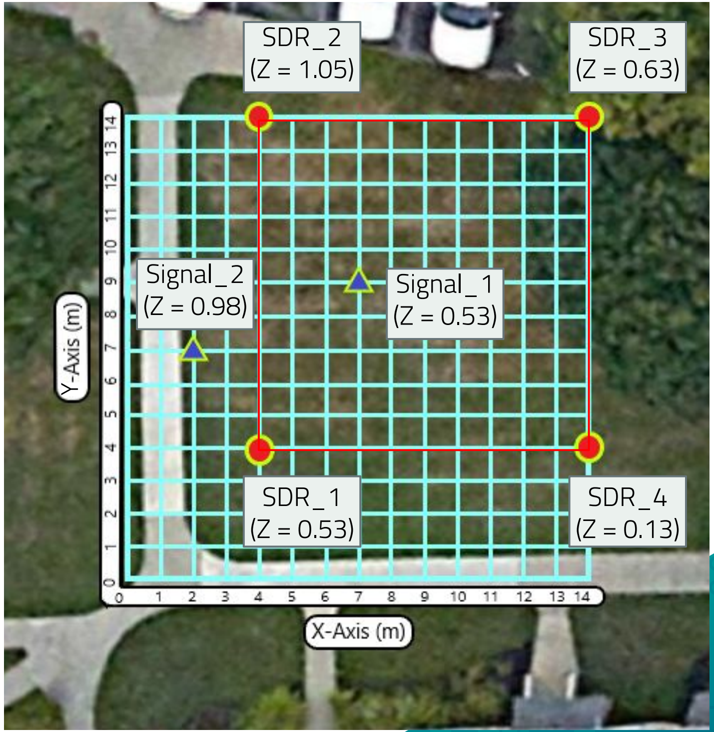
The Methodology

How did we create our solution

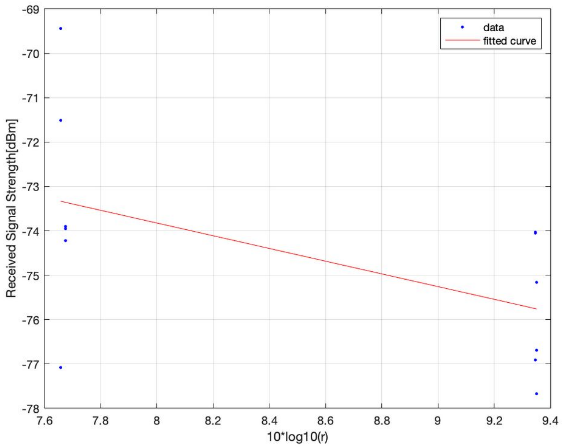
Localization Test Configuration

- 4 Software Defined Radios
  - Placed in a 10 by 10 meter square
  - Each SDR has a different height
- 2 Signal Source Positions
  - First test was in the 10 by 10 square
  - Second test was outside the square
- The goal was to measure RSS values so we can find the accuracy of our system



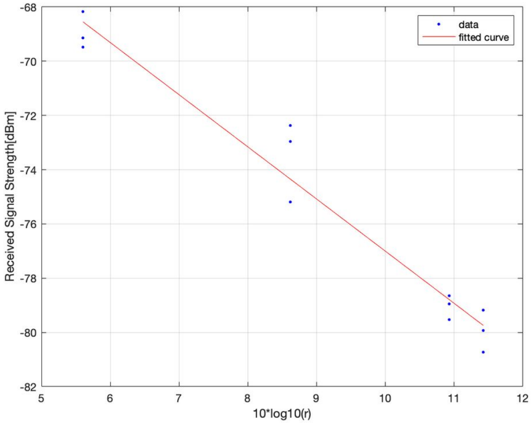
Path Loss Model

Inside Bounds



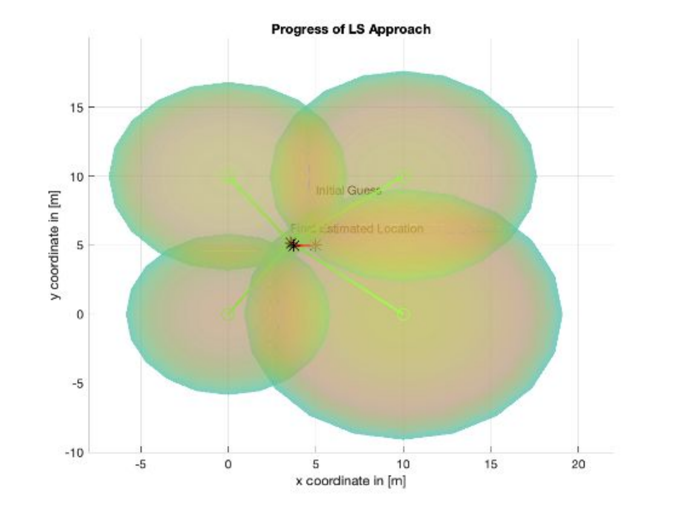

```
The Estimated Path Loss Model is:
Pr=-62.3642-14.3249*log(r)
Mean value of shadow fading is:
  -37.5362
Standard Deviation of shadow fading is:
    2.1047
```

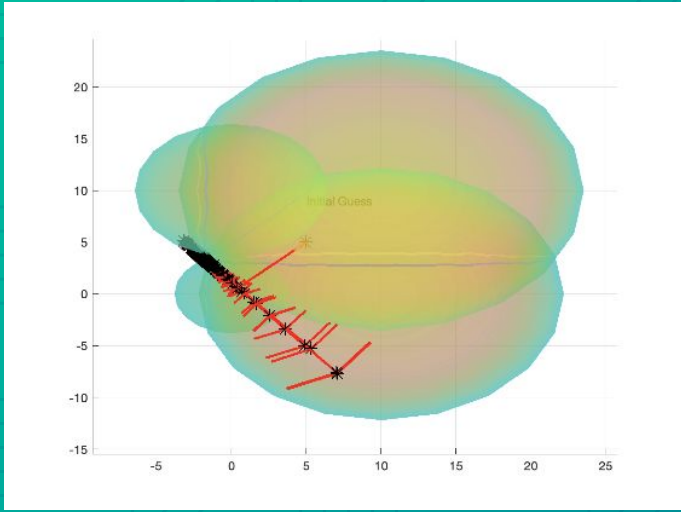
Outside Bounds




```
The Estimated Path Loss Model is:
Pr=-57.7782-19.2179*log(r)
Mean value of shadow fading is:
  -37.0628
Standard Deviation of shadow fading is:
    0.9637
```

RLS Algorithm





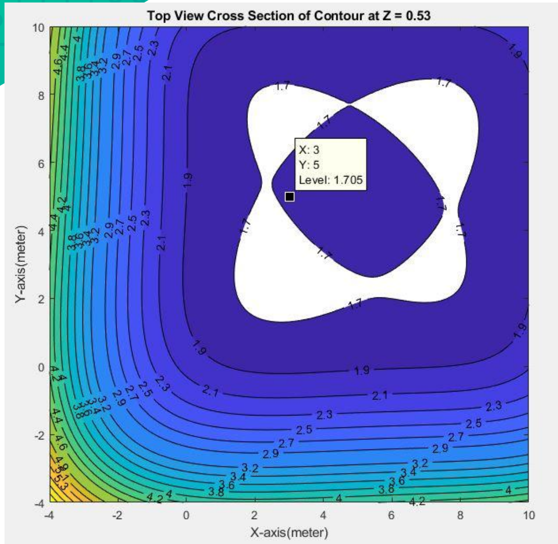
Calculated Position: (3.57,5.20,2.44)

Actual Position: (3,5,0.53)

Calculated Position: (-1.85,3.41,1.52)

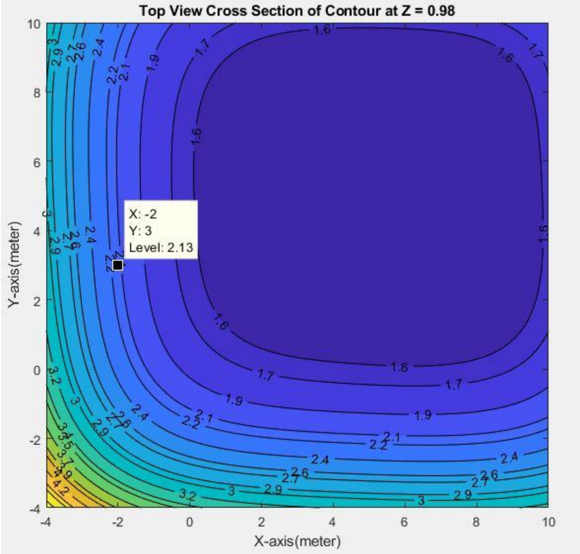
Actual Position: (-2, 3,0.98)

Simulated Error Analysis of Our Configuration



Top-down CRLB contour map at the first signal's height

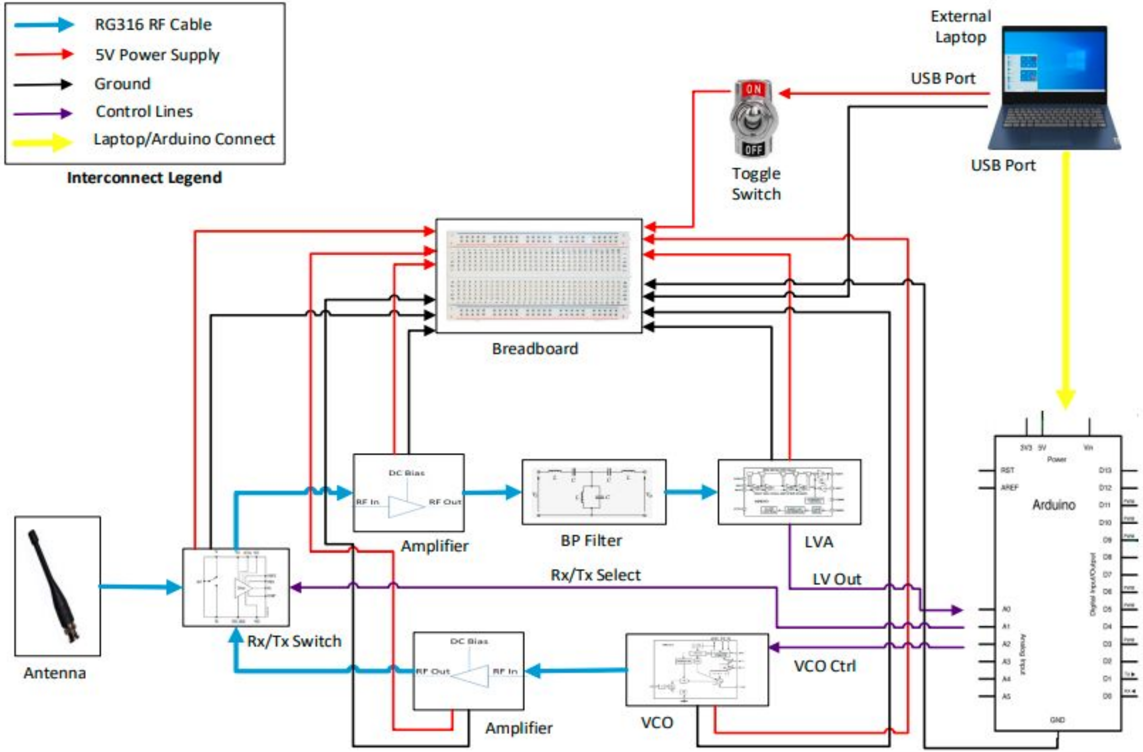
Value at Signal 1's position: 1.705 m



Top-down CRLB contour map at the second signal's height

Value at Signal 2's position: 2.13 m

Jammer Assembly Design



- Entire assembly enclosed within a bud box
- Laptop powers entire system
- Switch used as safety precaution

Signal Strength Considerations

- Controller output powered measured to be **19.4 dBm** in lab
- Calculated output power from antenna in Transmit mode is **27.1 dBm**
- ***FSPL (dB) = 20log(d)+20log(f)+20log(4pi/c)*** equation used to determine power @ drone at different distances
  - f=2.4GHz
- Jammer will be effective with high probability if same distance from drone as controller (**7.7 dB** greater strength)

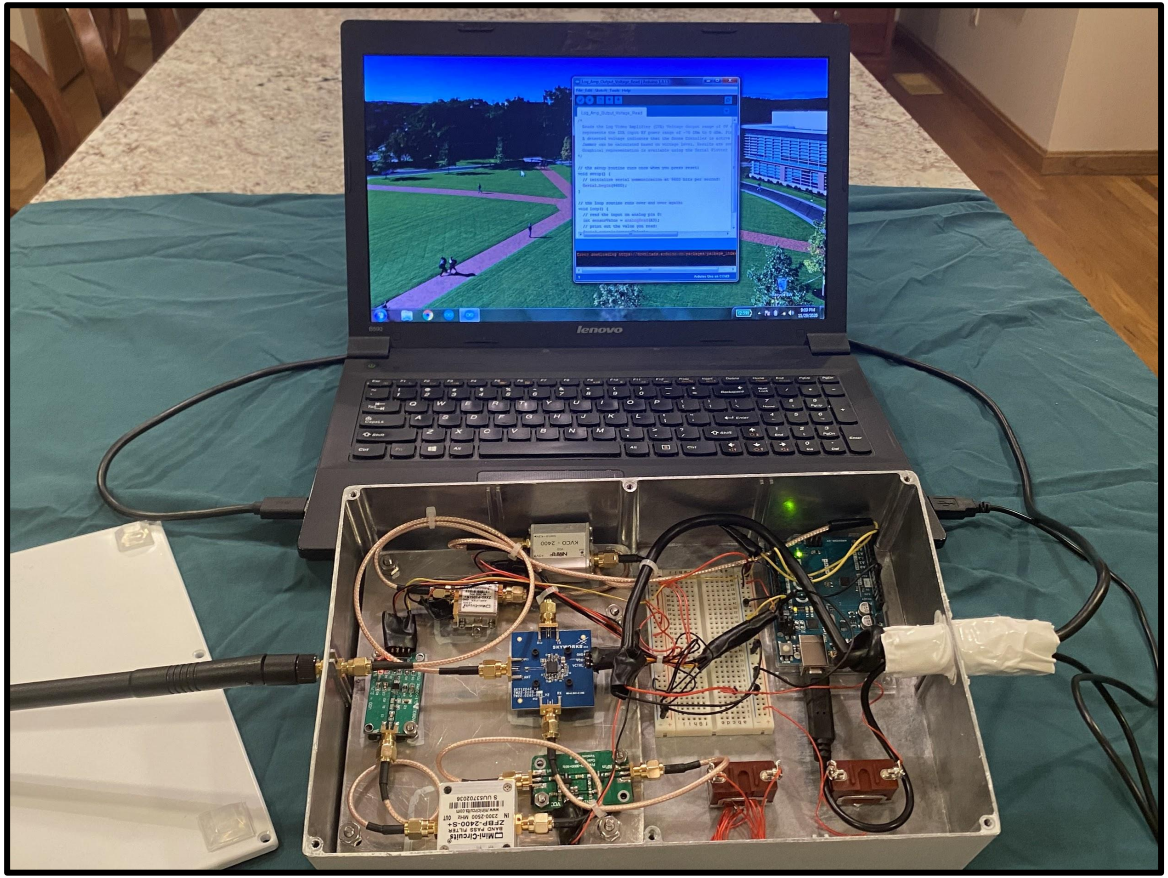
Distance (m)	Power @ Drone (dBm)
10	-40.7
20	-46.7
50	-54.6
75	-58.2
100	-60.7
200	-66.7

Controller Power at Drone vs Distance

Distance (m)	Power @ Drone (dBm)
10	-33.0
20	-39.0
50	-46.9
75	-50.5
100	-53.0
200	-59.0

Jammer Power at Drone vs Distance

Jammer Assembly Opened



Jammer Assembly Closed

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Conclusions and Recommendations

What matters from this project

Conclusions for the System

Location

- Our method is within a meter of error in the x y plane
- There needs to be greater variance in the height of the SDRs to get proper z position

Jamming

- Theoretically, the assembly will jam the signal from the controller to the drone when the jammer and controller are equidistant from the drone
- Testing of theory was hindered by WPI COVID protocols

Future Recommendations

Location

- Read the signal to determine whether they are from the controller or drone feedback
- Greater variance on z axis with SDRs

Jamming

- Design automated antenna system that focuses jamming signal in direction of drone
- Greater output jamming signal for greater jamming range