Small Rotor-Craft Obstacle Avoidance System

Senior Design Team: SDMAY21-07

Team Members: Matthew Bahr, Joshua Welton, Michael Ostrow, Felipe Varela Carvalho, Leonardo Bertoncello Machado, Matthew McDermott

Team email: *sdmay21-07@iastate.edu*

Advisor: *Dr. Mohammad Tayeb Al Qaseer*

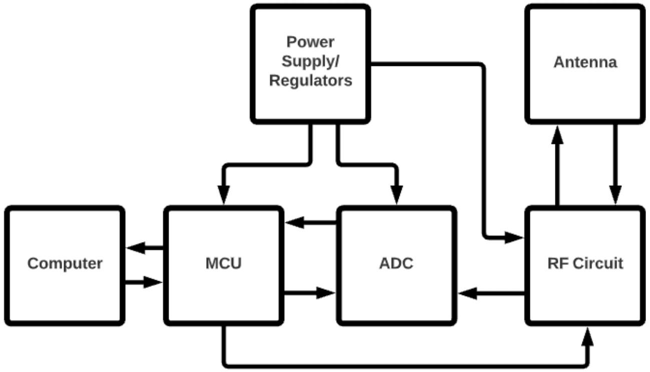
IOWA STATE UNIVERSITY

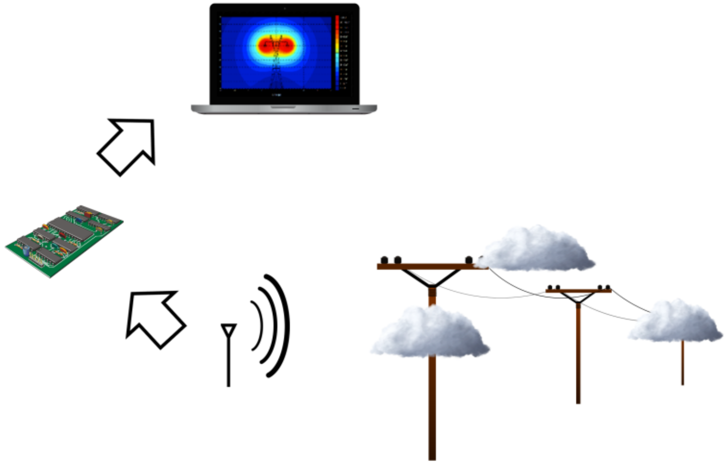
Problem Statement

- When operating a rotorcraft, small obstacles, such as power lines, can be difficult to spot.
- Rotorcraft collisions can be costly and dangerous

Solution

- Design proof-of-concept radar system to detect objects for users
- Incorporate array of modified horn antennas
- Send data from antenna to PC for signal processing





Functional Requirements

- Functional Requirements:
  - System must detect object's distance, size, and orientation
  - Range: 10-100 meters
  - Generate a visual recreation of obstacle (size and orientation)
  - Operation must be within ISM band

Non-Functional Requirements

- Non-Functional Requirements:
  - Multiple antennas used for triangulation
  - Independent Polarization for obstacle orientation
  - Antennas interface with RF PCB
  - Unique circuitry for Tx and for Rx
  - PCBs integrate with computer software

Technical Constraints

- Physical layout limitations for PCB
- Antenna machining limitations
- Limited access to testing equipment
- Coaxial connectors that operate in frequency range

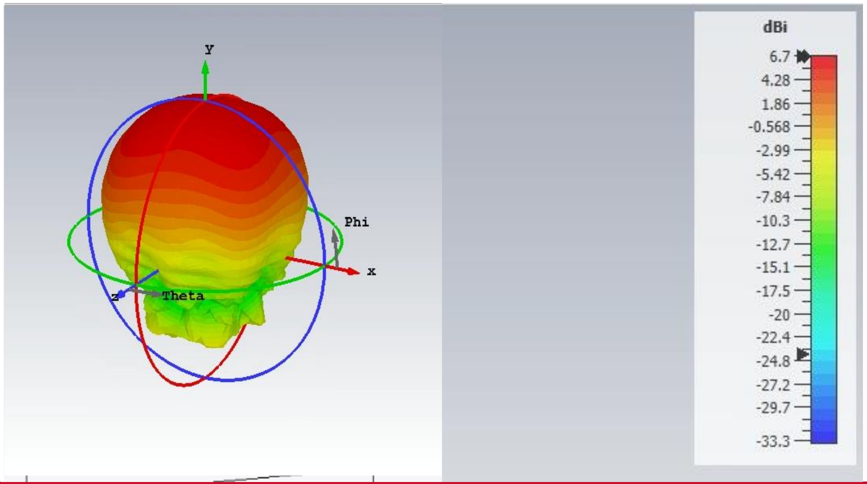
Engineering Standards

- IEEE 370
  - Practices for ensuring the quality of measured data for high-frequency electrical interconnect
  - Best practices for component layout on board
- IEEE 145
  - Established definitions for systems incorporating antennas into their design.
  - Useful for easy understanding of EM terminology

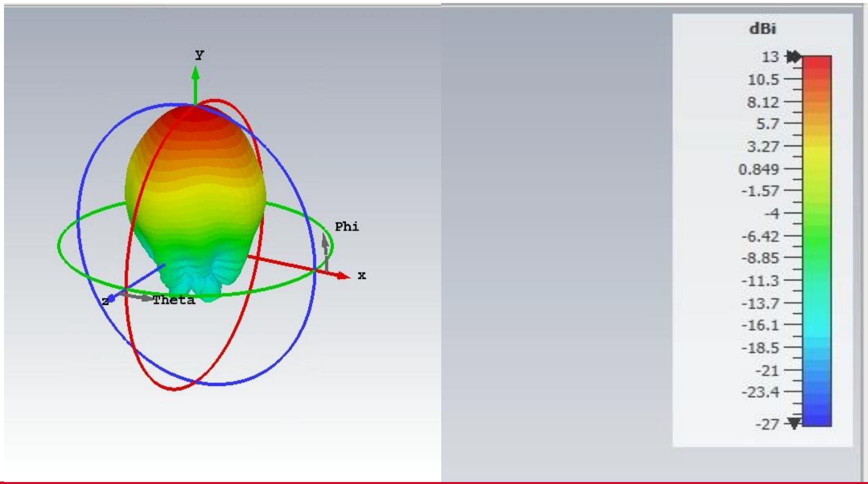
Antenna – Model Design

- Model designed in CST Studio
  - Simulations conducted
  - Changed to horn antenna
  - Created access for coaxial cable

Original Antenna



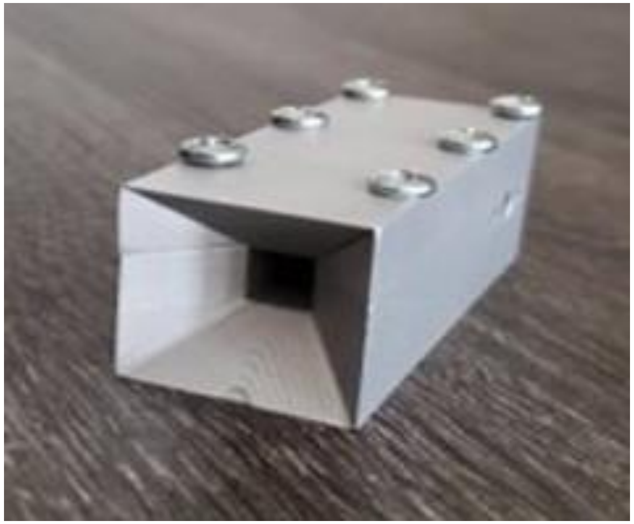
New Antenna

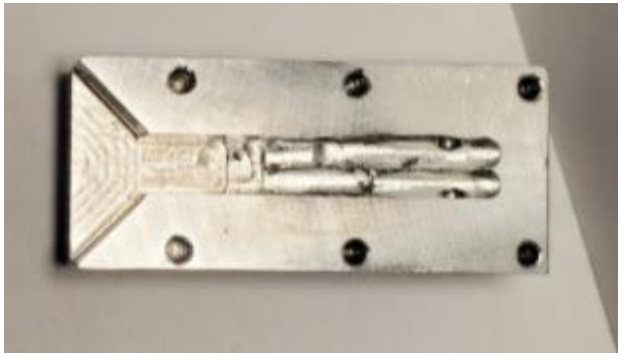


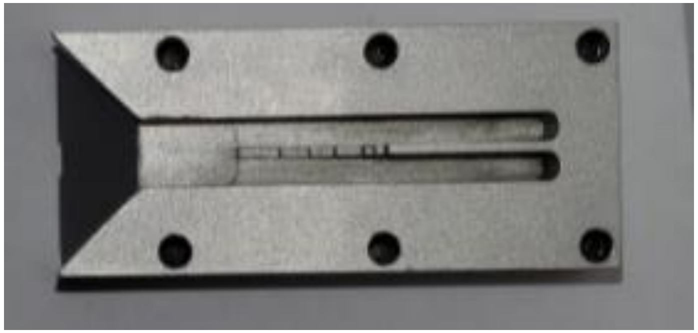
Antenna – Fabrication

- Fabricated using Coover's CNC machine

- Modified design to suit creation process

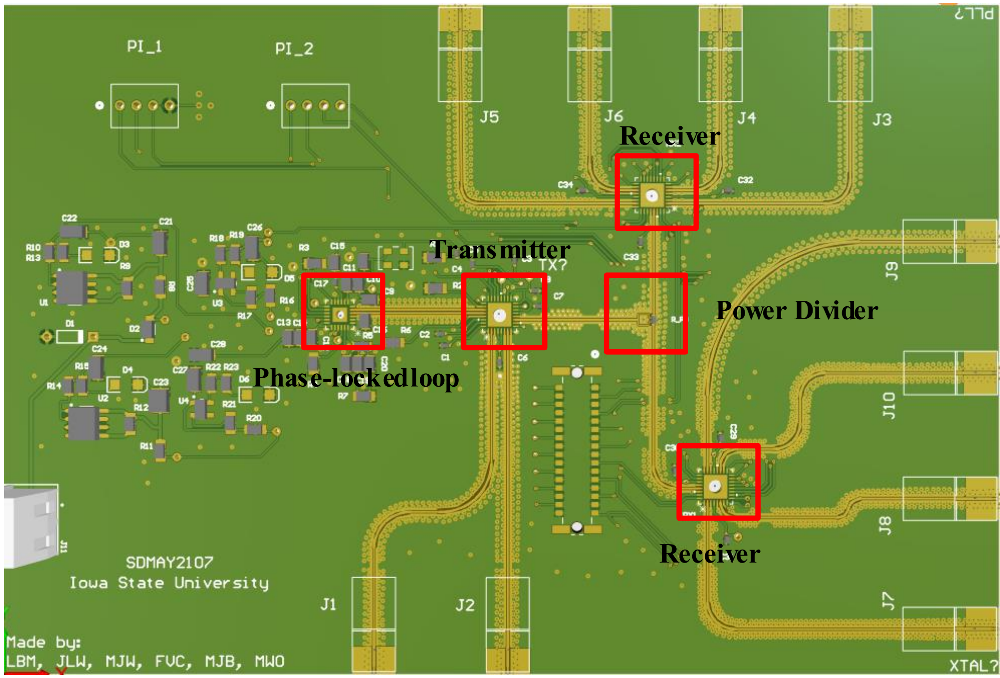


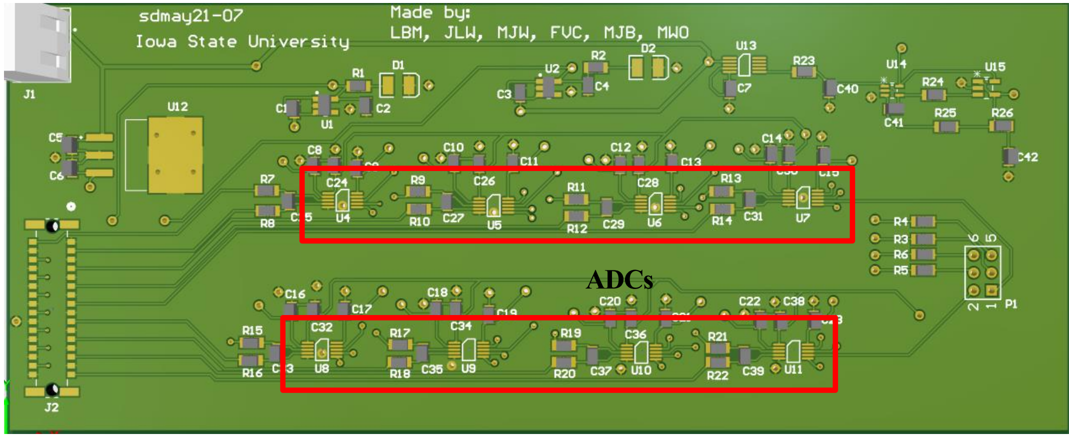




PCB - Design

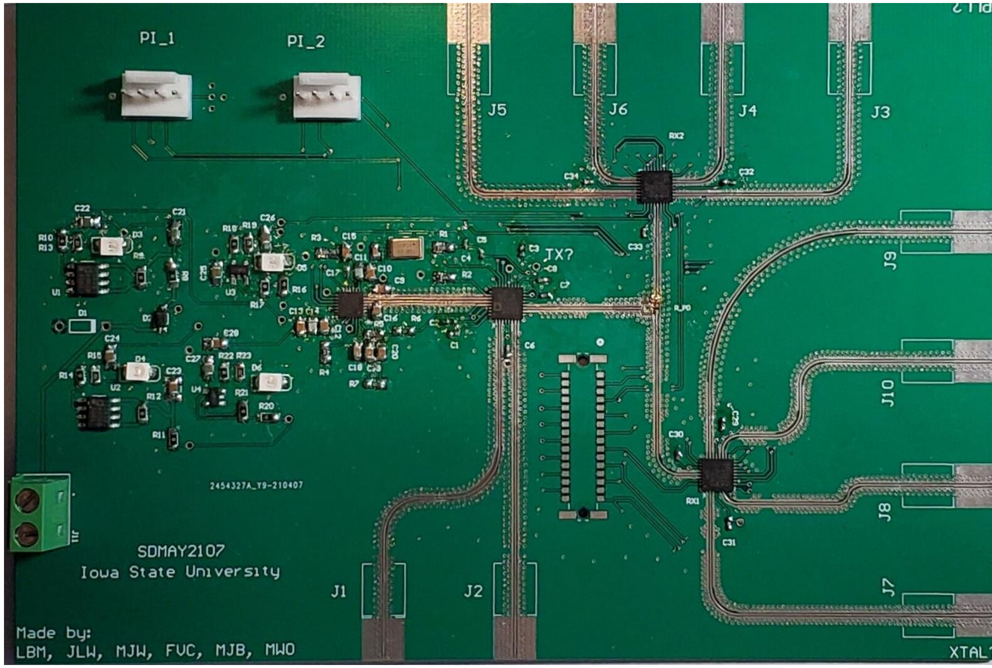
- 2 boards; 1 for each main circuit
- Utilized Altium to design both ADC & RF boards
- Designed around ICs that were pre-determined

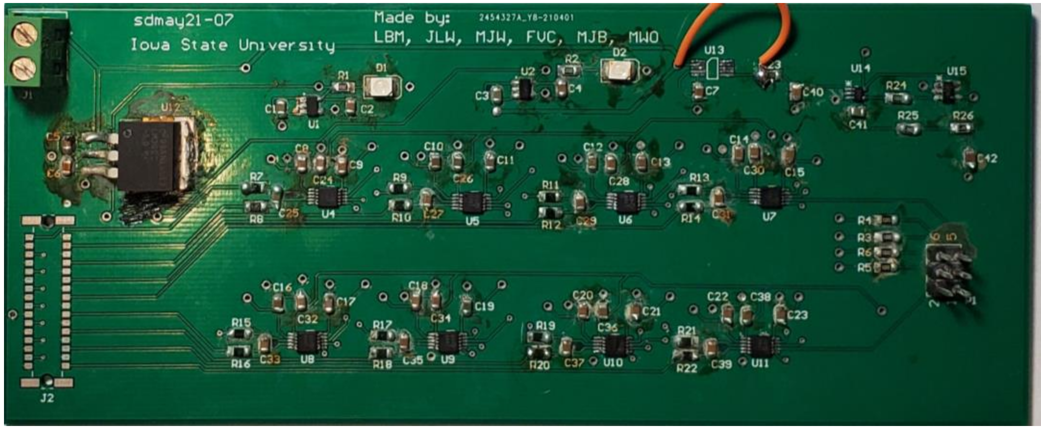




PCB - Fabrication

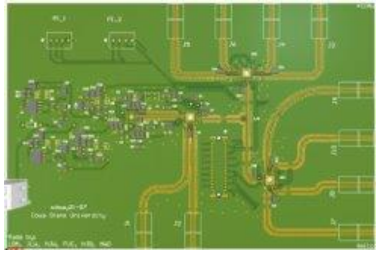
- Utilized JLCPCB to manufacture boards
- Soldered larger SMT components by hand
- Used oven for smaller SMT components





Microcontroller Design

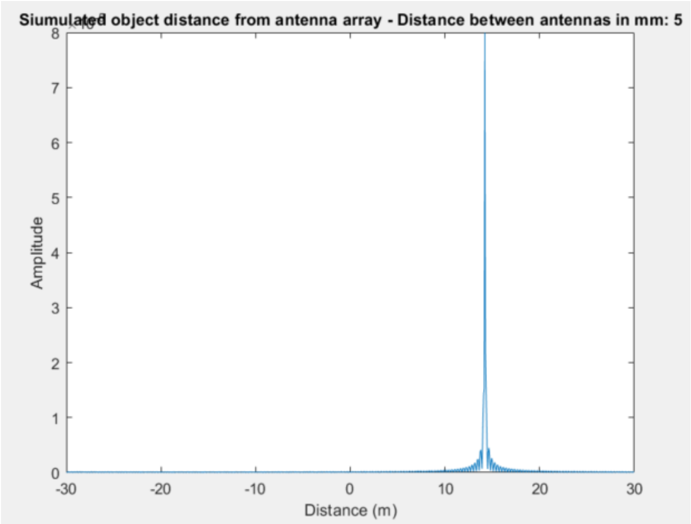
- Microcontroller to control the PCB and collect the data
  - Utilize SPI serial communication to set register values for ICs
  - Package data into a readable format and hand to the PC

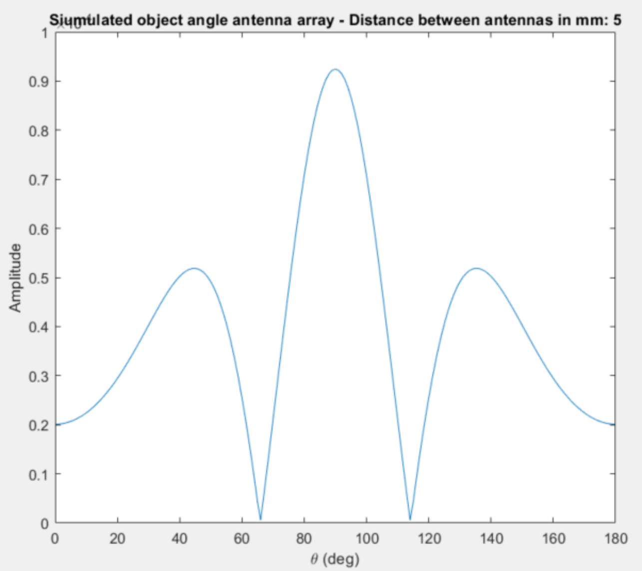


Code Design

- Gets code from microcontroller through application like PuTTy

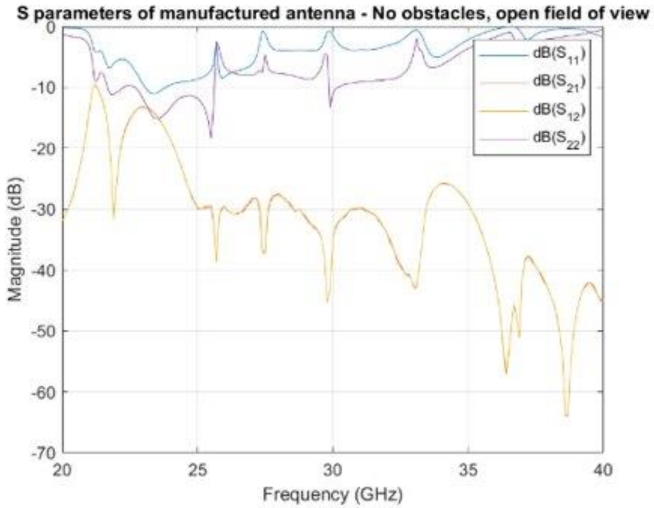
- Use Matlab Script to process data and return position and orientation





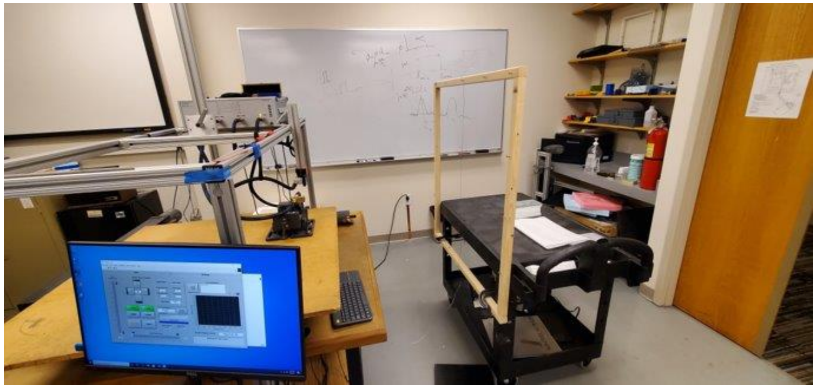
Antenna Test

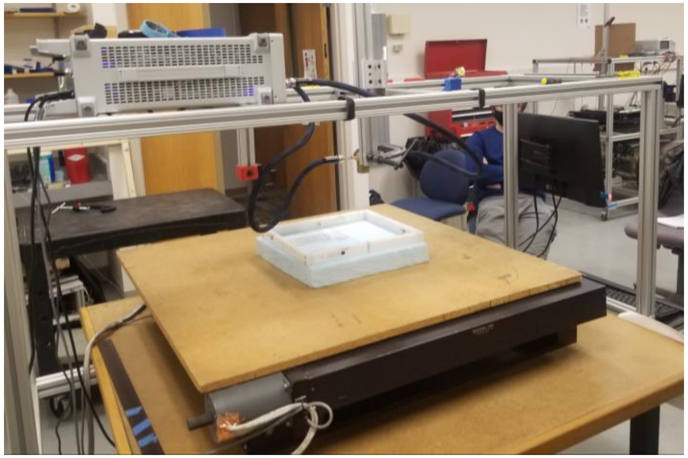
- **Setup**:
  - Vector Network Analyzer
  - Controlled environment
  - First day: Operation check.
  - Second day: Dynamic test.
- **Results**:
  - Consistent readings
  - Flaws in antenna and methods.
    - Power loss and coupling
- **Conclusion**:
  - Acquired acceptable S-parameters
  - Familiarized with hardware



Antenna Test (cont.)

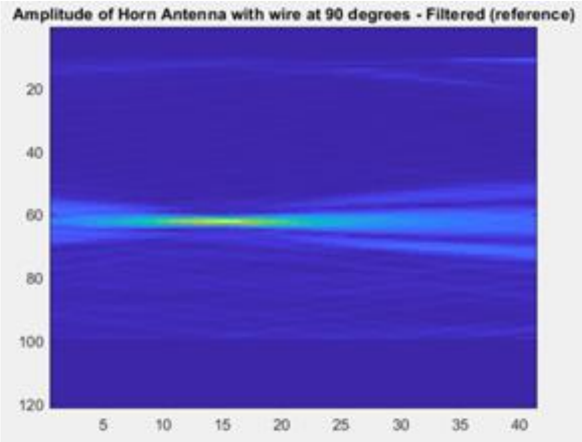
- Third day of testing:
  - Used a single antenna to test array
  - Moved obstacle instead of antenna to generate array.

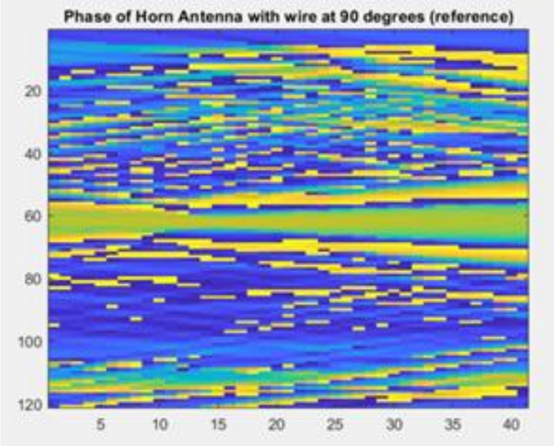


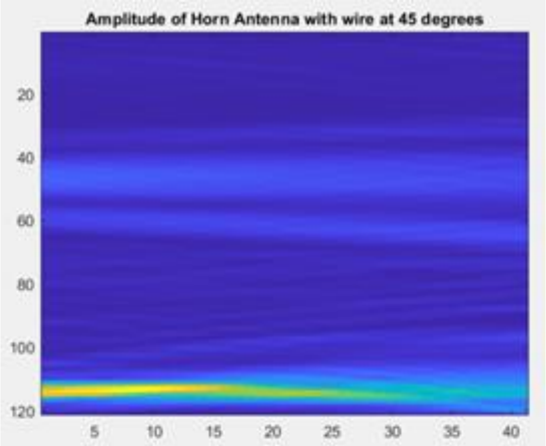


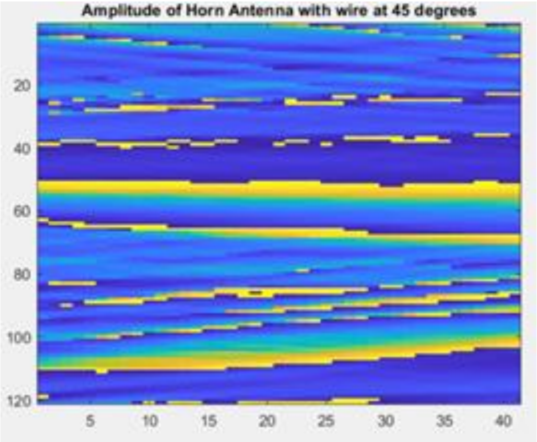
Radar Data Processing Test

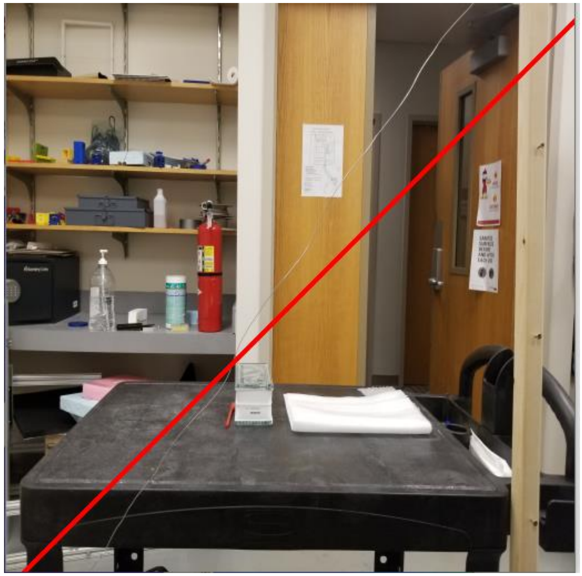
- Used provided code with modification to interpret data.
- Spectrums were used to calculate phase difference





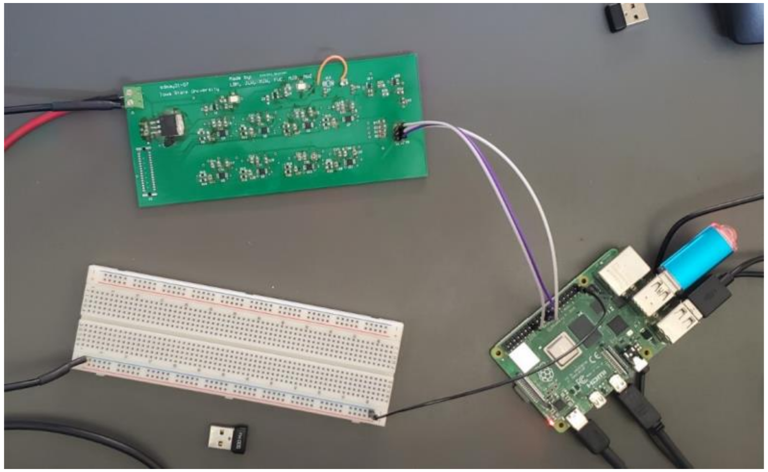






ADC PCB Test

- **Setup**: Hooked up the ADCs to the raspberry pi and to a function generator, and tried to get readings.
- **Results**: Serial communication worked, but the output showed the input voltage is equal to the reference voltage regardless of the input voltages value.
- **Conclusion**: Likely a short between the reference and input voltages



Challenges

- PCB Design
- Antenna Design
- Data Processing
- Manufacturing and Ordering
- Implementation

What we learned

- Design (PCB + Antenna)
- Manufacturing (PCB + Antenna)
- Datasheet Interpretation
- Simulating + Testing
- Coding
- Data Processing

Thank you for your time!
Any questions?

References

[1] A. D. Inc., "EV-RADAR-MMIC2 Analog Devices Inc.: RF/IF and RFID," Digi Key, 2017. [Online]. Available: https://www.digikey.com/en/products/detail/analog-devices-inc/EV-RADARMMIC2/6072228?utm_adgroup=xGeneral. [Accessed: 15-Nov-2020].

[2] M. Dvorsky, M. T. A. Qaseer and R. Zoughi, "Detection and Orientation Estimation of Short Cracks Using Circularly Polarized Microwave SAR Imaging," in IEEE Transactions on Instrumentation and Measurement, vol. 69, no. 9, pp. 7252-7263, Sept. 2020, doi: 10.1109/TIM.2020.2978317. [Accessed: 25 – April – 2021]

[3] "IEEE Standard for Definitions of Terms for Antennas," in IEEE Std 145-2013 (Revision of IEEE Std 145-1993) , vol., no., pp.1-50, 6 March 2014, doi: 10.1109/IEEESTD.2014.6758443.

[4] "IEEE Standard for Electrical Characterization of Printed Circuit Board and Related Interconnects at Frequencies up to 50 GHz," in *IEEE Std 370-2020* , vol., no., pp.1-147, 8 Jan. 2021, doi: 10.1109/IEEESTD.2021.9316329.