Software Defined Radio Synthetic Aperture Radar

Final Senior Design Presentation

Team 301 Members:
Marius Urdareanu
Grant Steans
Tyree Lewis
Nathaniel Henry

Team Introductions

Team Manager and Hardware/Power Analyst
Responsible for RF Front End design to the SDR, as well as power management of the overall project.

Software Engineer
Responsible for designing the SDR analysis code, including programmatic responses to receiving and transmission of signals.

Simulation Analyst and Data Collection
Responsible for utilizing MATLAB to model the project specifications and establish a baseline of theoretical data for real world implementation.

Front-to-Back End Integration
Responsible for ensuring communication between the front end and back end components of the project.

Marius Urdareanu

Sponsor

NORTHROP GRUMMAN

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Background

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What is the SDR-SAR?

The Software Defined Radio Synthetic Aperture Radar, or SDR-SAR, is an ongoing project sponsored by Northrop Grumman. The purpose of the project is to design a low-cost imaging system that can provide a low, but academically useful, imaging resolution.

Marius Urdareanu

What is the SDR-SAR?

Possible use cases for a SAR imager include airport security, government offices, and even the battlefield.

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What is the SDR-SAR?

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How does it work?

Fundamentally, the SDR-SAR utilizes two techniques:

- Beamforming
- Pulse Compression

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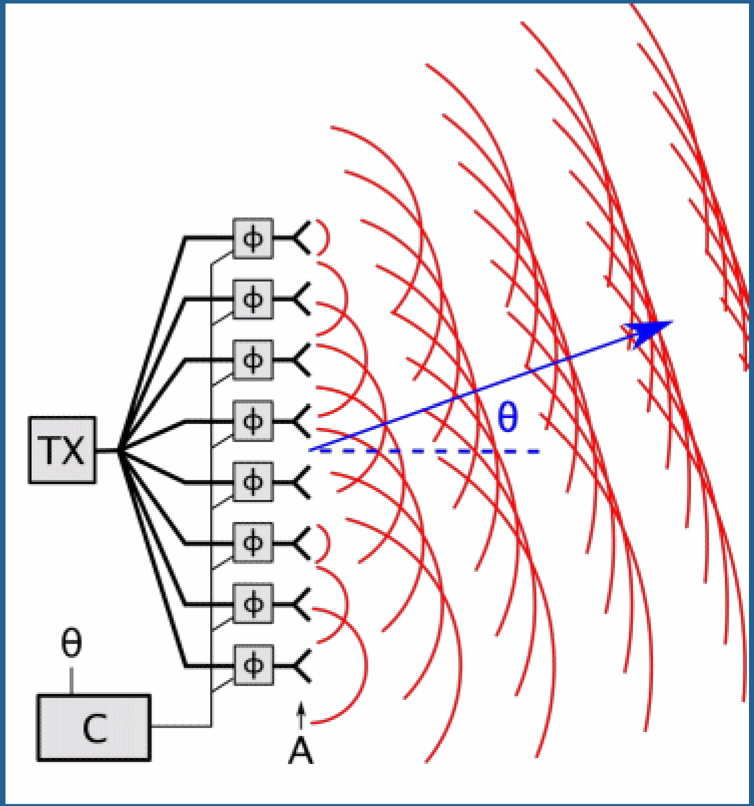
How does it work?

Beamforming is a signal processing technique where signals in an antenna array experience constructive interference at particular angles, and destructive interference at other angles.



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How does it work?

Pulse compression is a technique where both desirable range resolution and signal to noise ratio (SNR) can be achieved by compressing a long signal with good SNR to a shorter signal with adequate range resolution.

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Identifying the Problem

The main issue that previous iterations of the project had was leakage noise between the transmit horns and adjacent receive horns.

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Goals and Objectives

Tyree Lewis

Implementing a Solution

Software tools such as digital filters implemented in MATLAB could minimize leakage noise between the horns in a way that that the hardware-only implementation of previous years could not.

Our team’s goal is to redesign the SAR to use a software defined radio that will allow for the collection and processing of data digitally with the intent of reducing leakage noise between the transmit and receive horns.

Tyree Lewis

Implementing a Solution

Requirements

- Redesign the radar system to utilize a software defined radio instead of the previous team's FPGA-based design
- Identify metal objects at a minimum range of 40 feet
- Reduce noise leakage between transmit and adjacent receive horns

Tyree Lewis

Implementing a Solution

Concept Generation

The team went through multiple concept generation activities and created several possible solutions to the design problems.

Tyree Lewis

Concept Generation

Reduce Leakage Noise	• Use signal normalization to ignore leakage noise • Use MATLAB filters to remove leakage noise • Place panels between horns to limit leakage noise
Purchase Radio	• USRP N210 • B200 • Build our own radio
Detect Metal Objects	• Generate a signal short enough to give desired resolution • Use a pulse compression technique to give desired resolution

Tyree Lewis

Concept Selection

Reduce Leakage Noise	• Use MATLAB filters to remove leakage noise
Purchase Radio	• B200
Detect Metal Objects	• Use a pulse compression technique to give desired resolution

Tyree Lewis

Implementing a Solution

Our team came up with a three-phase plan to complete the project.

Phase I

- Acquire necessary components

Phase II

- Modify electronics box

Phase III

- Test the system

Tyree Lewis

Phase I – Setup and Part Acquisition

The following goals were set and met in our Phase I outline:

- Install necessary software on Ubuntu OS
- Validation of GNU Radio transmitting a simple sine wave to USRP B200
- Validation of receive signal on GNU Radio
- Validation of radar functionality
- Purchasing of components needed for Phase II

Nathaniel Henry

Phase II - Modifying the Systems Box

The following goals were set and met in our Phase II outline:

- Create a multiple pulse waveform in Simulink for the source file
- Finish VHDL code that generates timing reference for the system
- Add existing VHDL for switching between TR paths
- Get the voltage-controlled oscillator (VCO) source board from TI programmed with the needed frequency
- Mechanize the RF components in the system box

Nathaniel Henry

Phase III - Validating the System

The following goals were set and met in our Phase III outline :

- Test FPGA code that does transitions between pulses
- Order detectors and replacement amplifier to replace damaged one
- Attach components and standoffs to component plate
- Understand the image formation document and implement in testing

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Embodiment and Validation

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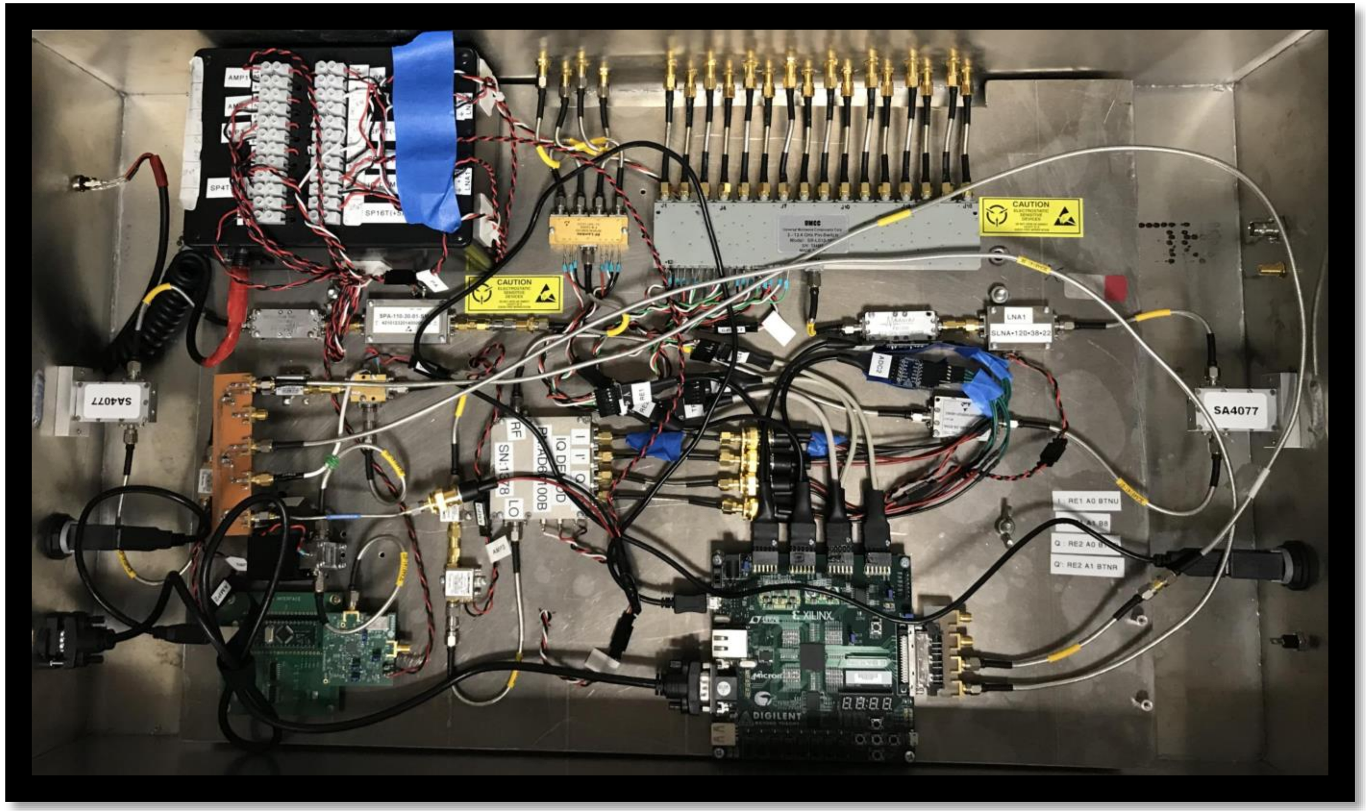
Embodiment

Image 1 – The previous electronics box.



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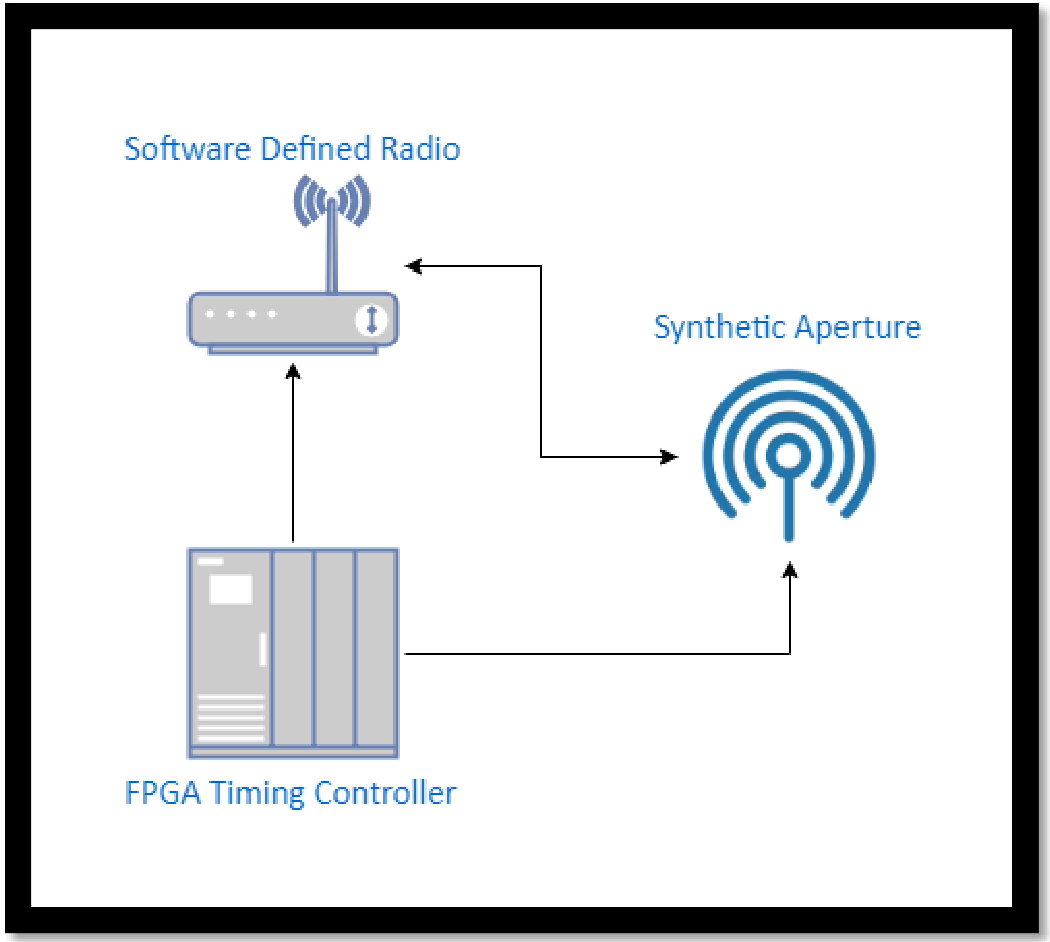
Embodiment

Image 2 – High-level block diagram of the project, showing communication between the SDR, aperture, and FPGA.



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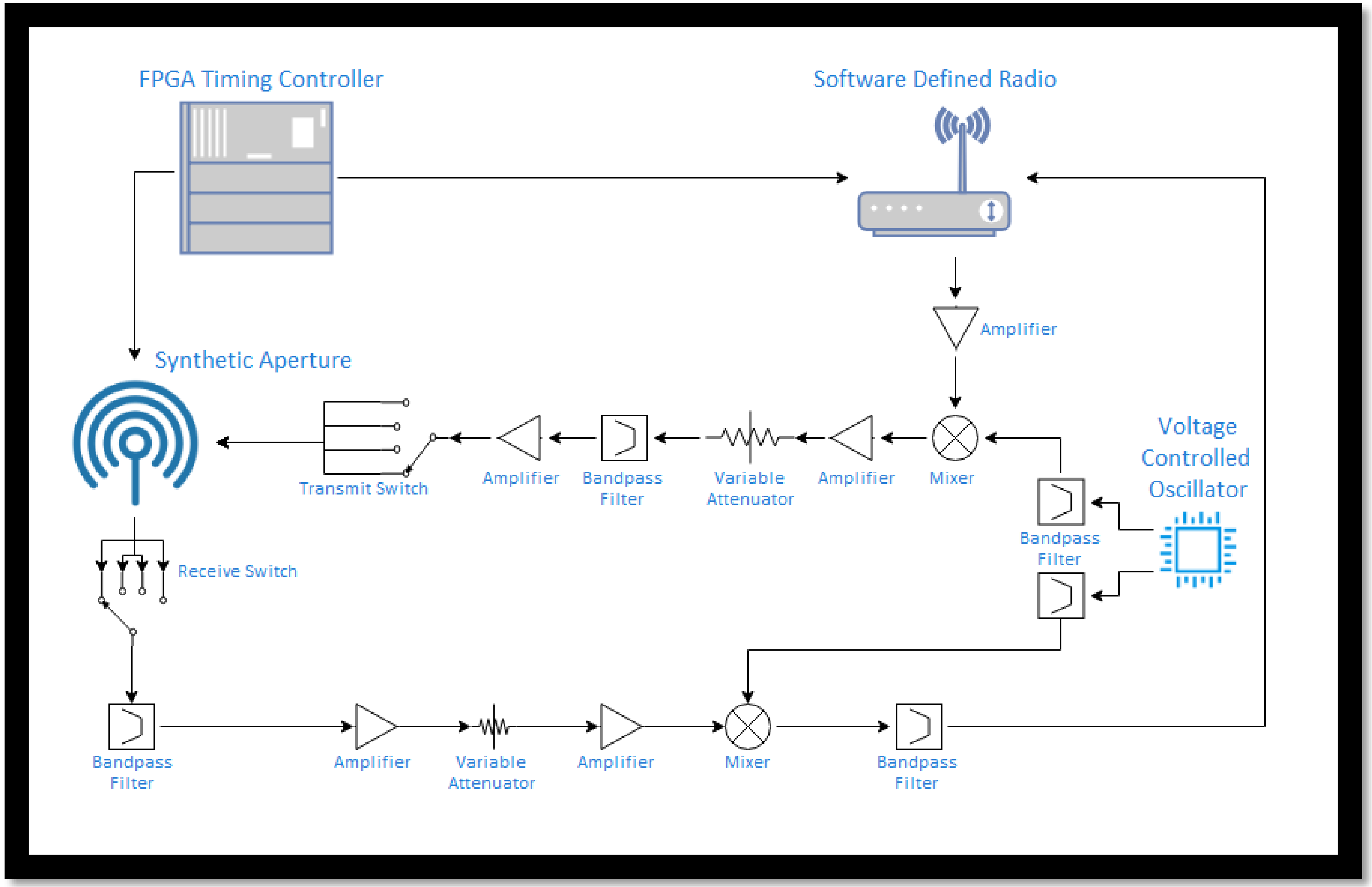
Embodiment

Image 3 – Block diagram of the finished system.



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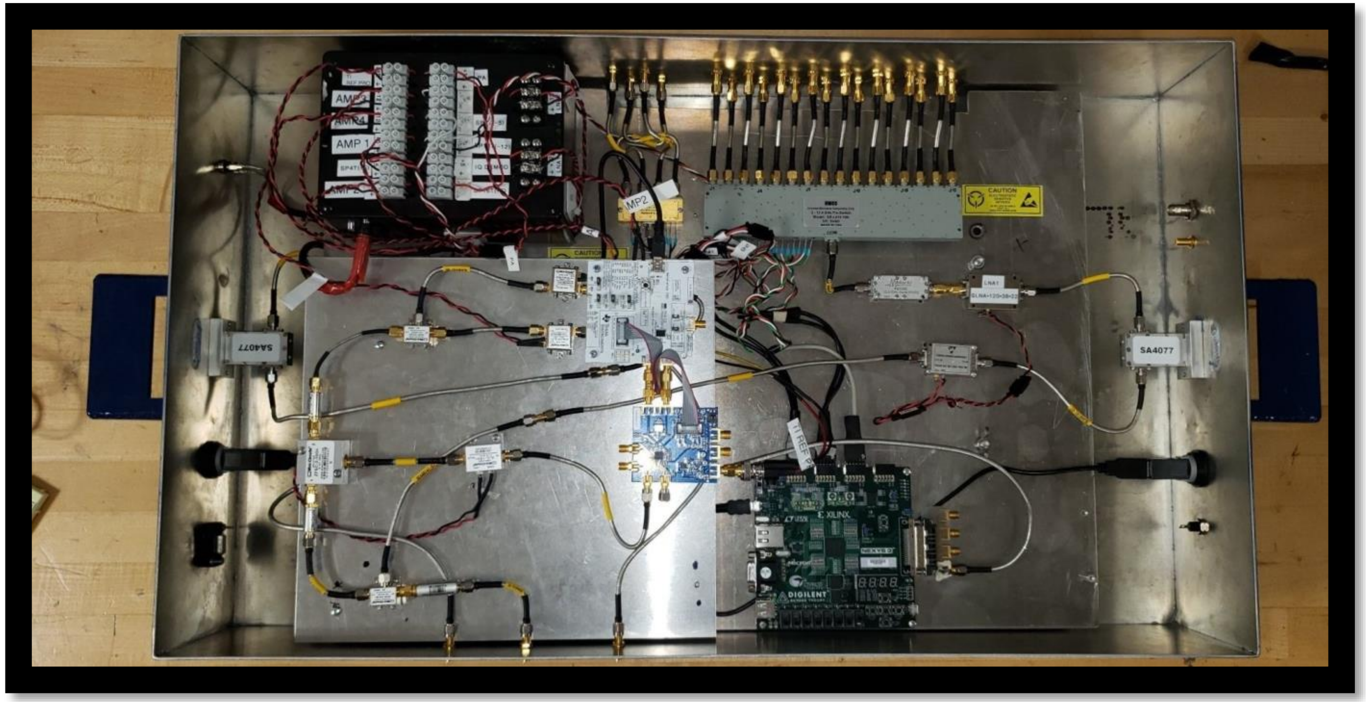
Embodiment

Image 4 – The revamped electronics box.



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Embodiment

Image 5 – The finalized electronics box with the software defined radio and necessary laptop connected.

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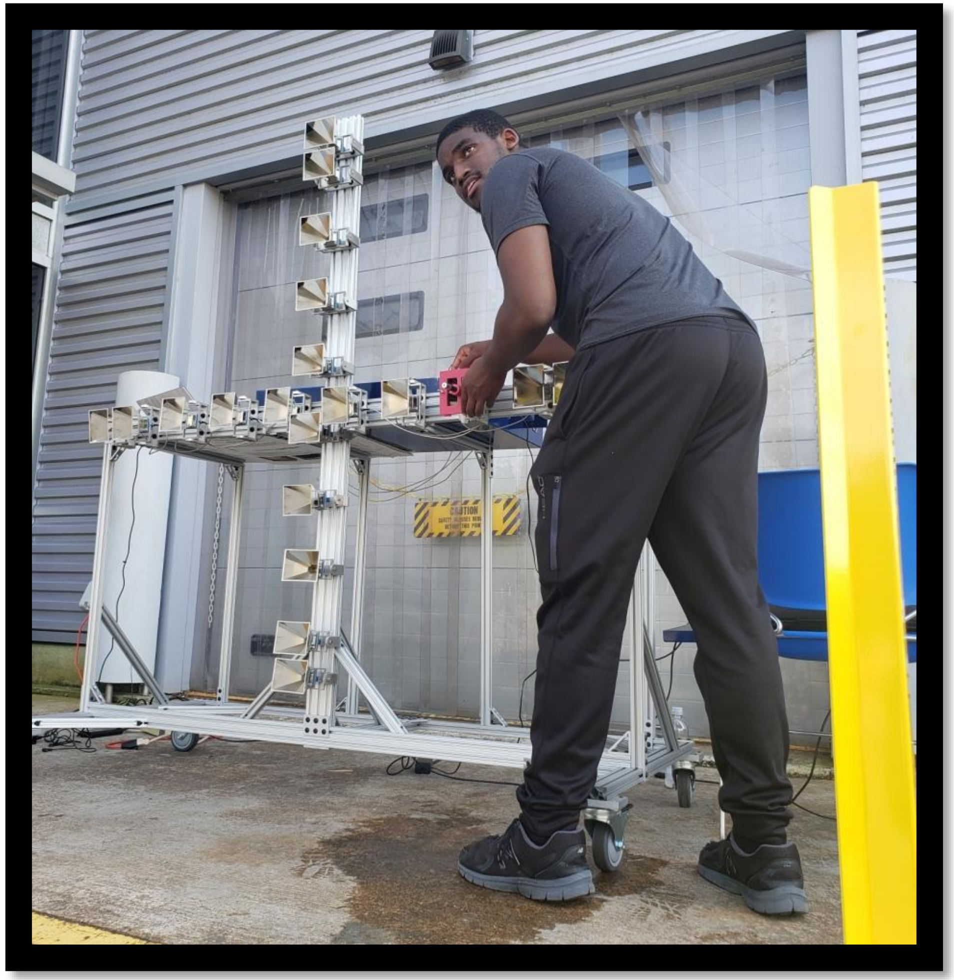
Validation

Image 6 – Grant calibrating the SAR to the scene we were testing with.



Grant Steans

Validation

- Pulse calibration and integration MATLAB script complete

1. Pull the .bin file from GRC, convert to complex domain
2. Reshape the result to 16 individual pulses
3. Normalize pulse amplitudes at frequency of interest
4. Calculate phase difference using the first pulse as a reference

Grant Steans

Validation

- How is this file used in the project?

1 — **Repeat FFT reshaping code and align any new data to a zero phase**

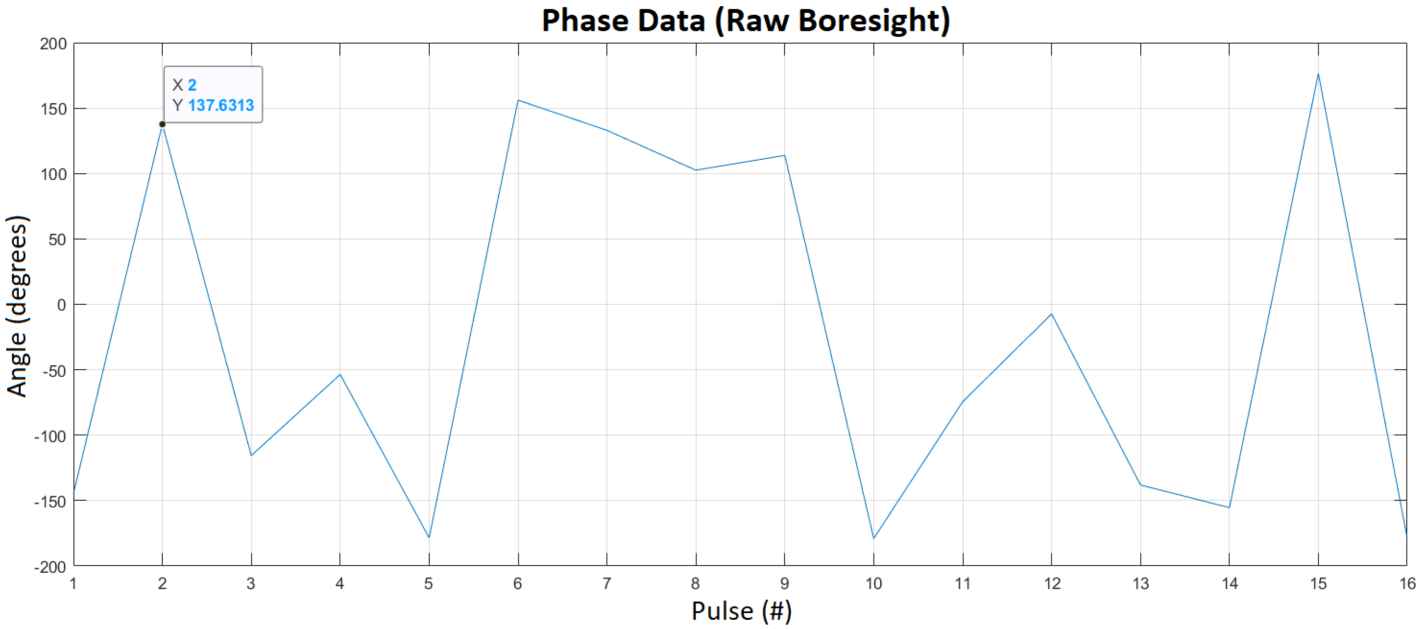
2 — **Shift data by calibrated phase difference**

3 — **Sum pulses together to increase signal strength**

Grant Steans

Data Collection

Figure 1 – Phase data from a data collection run.



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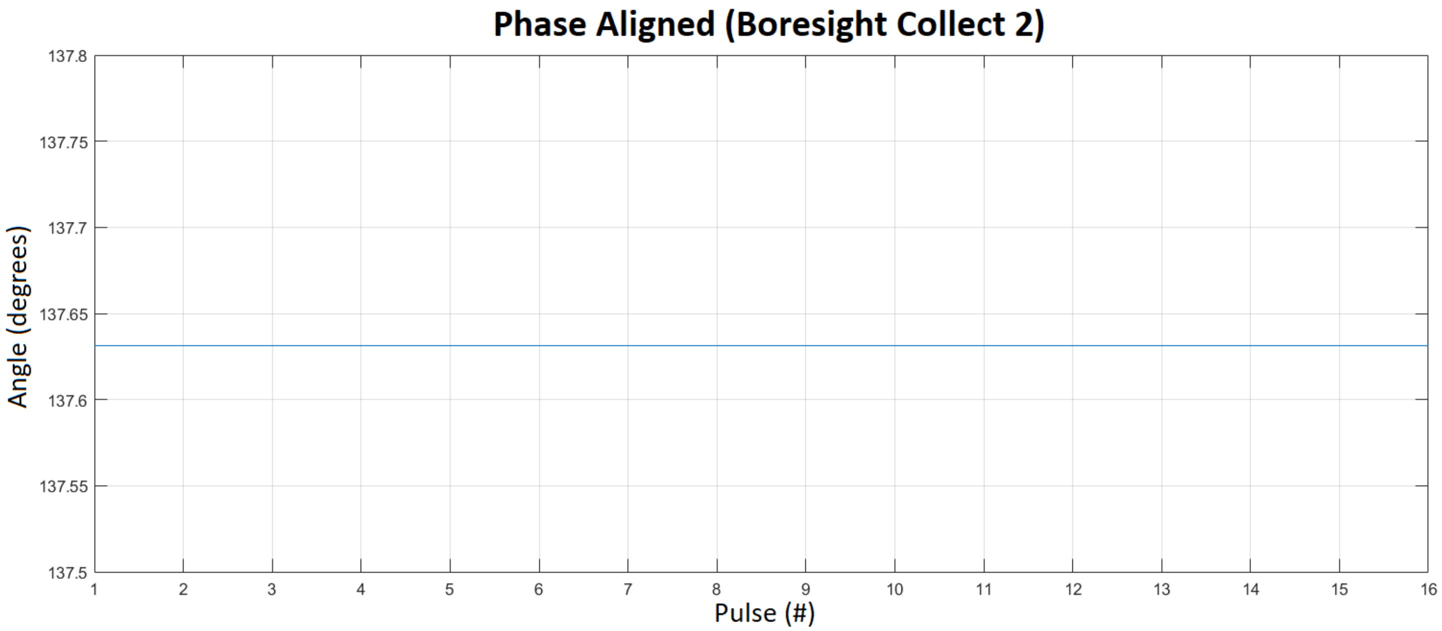
Data Collection

Figure 2 – Aligned phase data to the first second received pulse.



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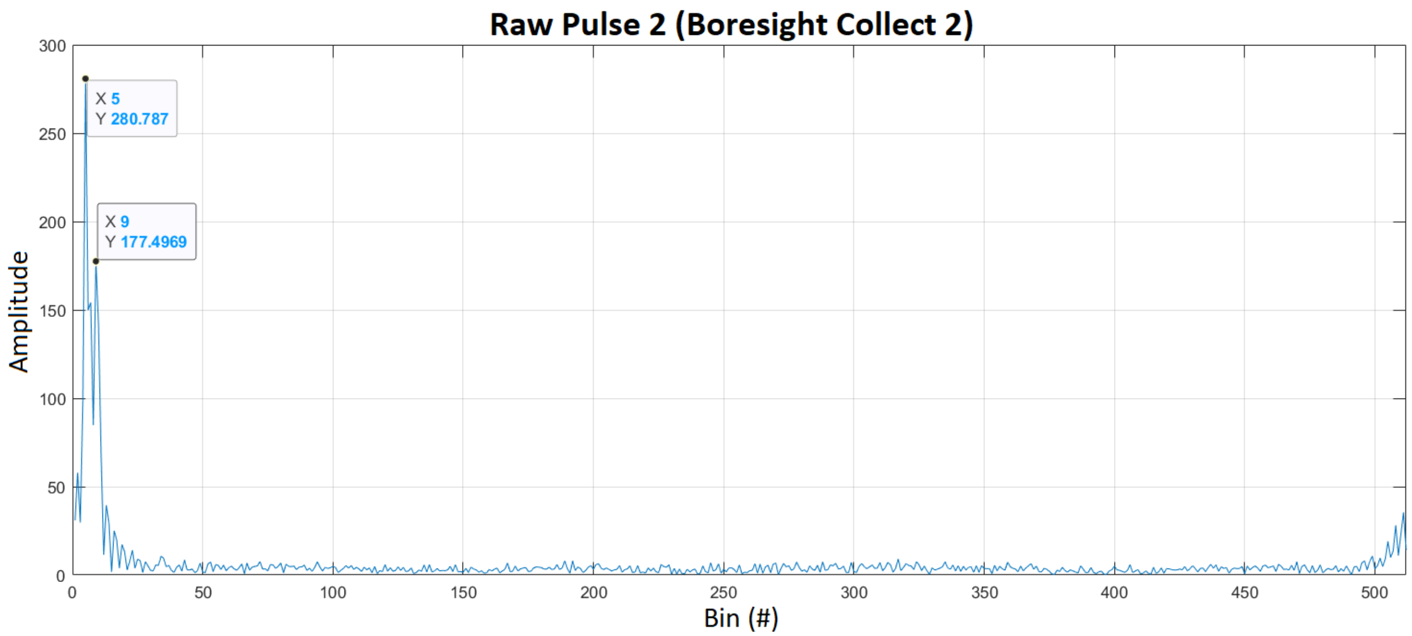
Data Collection

Figure 3 – Response of the second pulse received. Each bin corresponds to roughly 10 feet of distance. Bin 5 (leakage noise) is higher than bin 9 (metal reflector 40 feet away).



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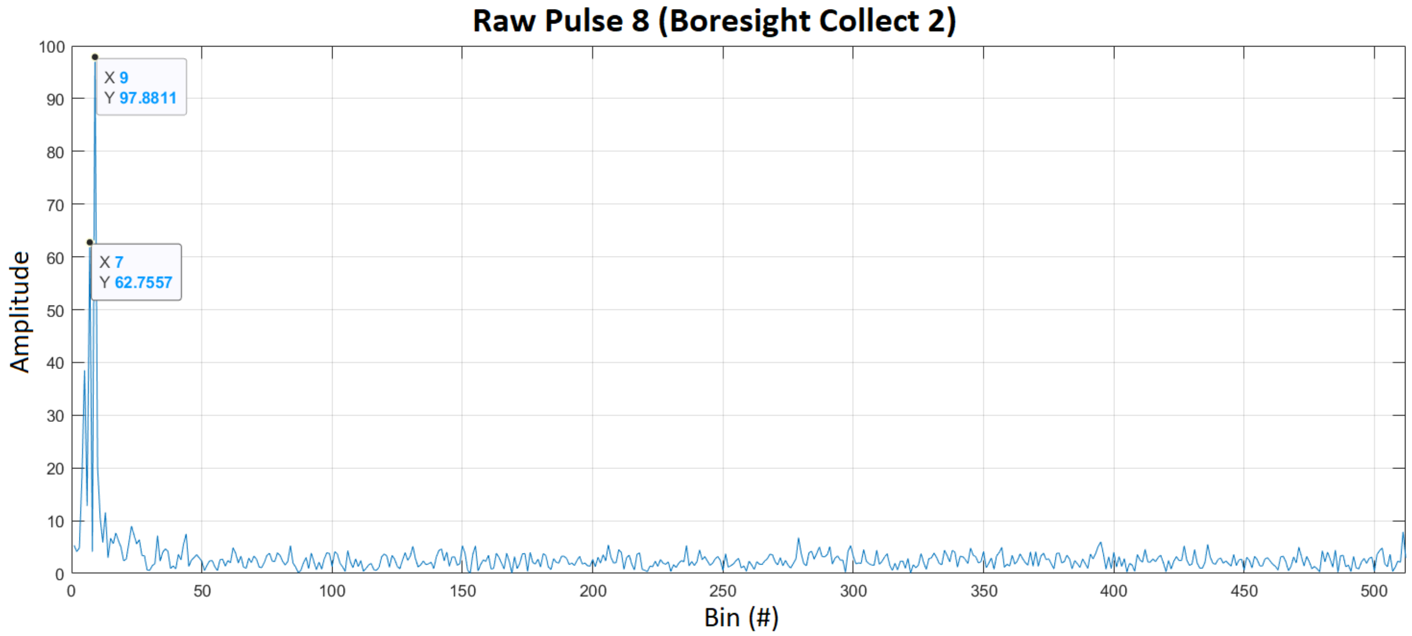
Data Collection

Figure 4 – Response of the eight pulse received. As this receive horn is further away from the transmit horn on the aperture, amplitude of response at 40 feet away is slightly higher than leakage noise.



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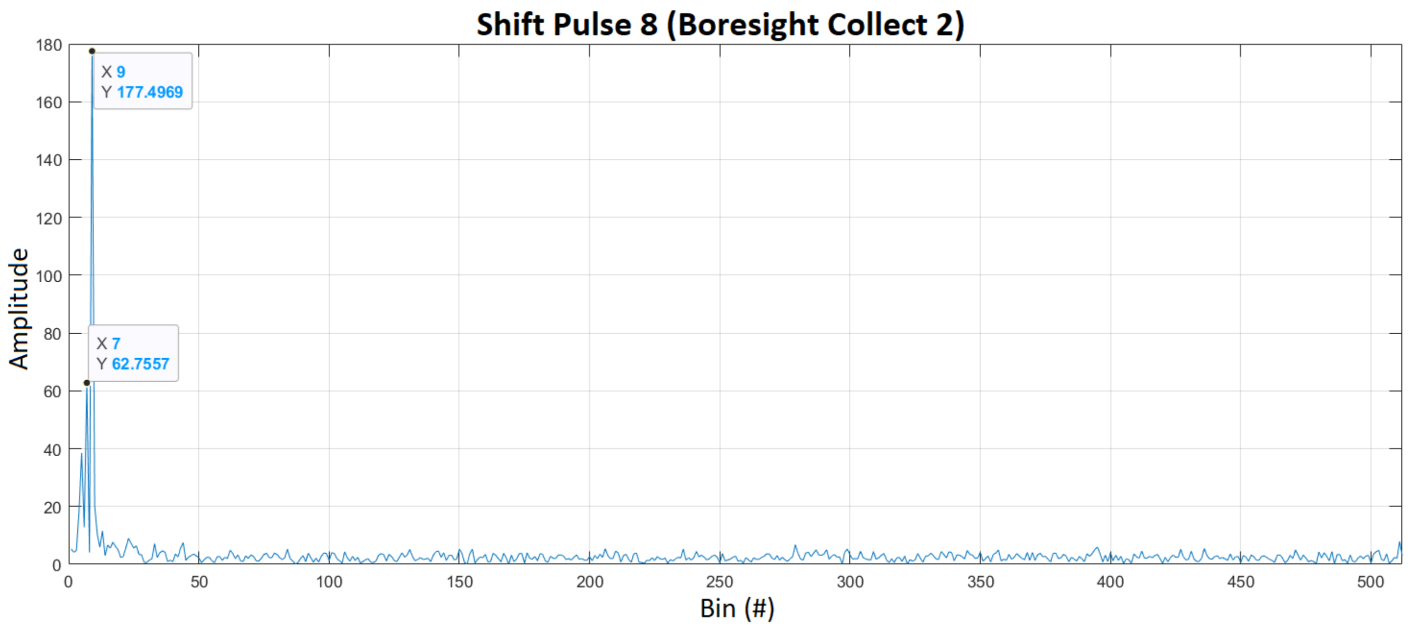
Data Collection

Figure 5 – Normalized response of the eight pulse received. Notice how the amplitude of the detected reflector is now significantly higher than any of the leakage noise at lower bins.



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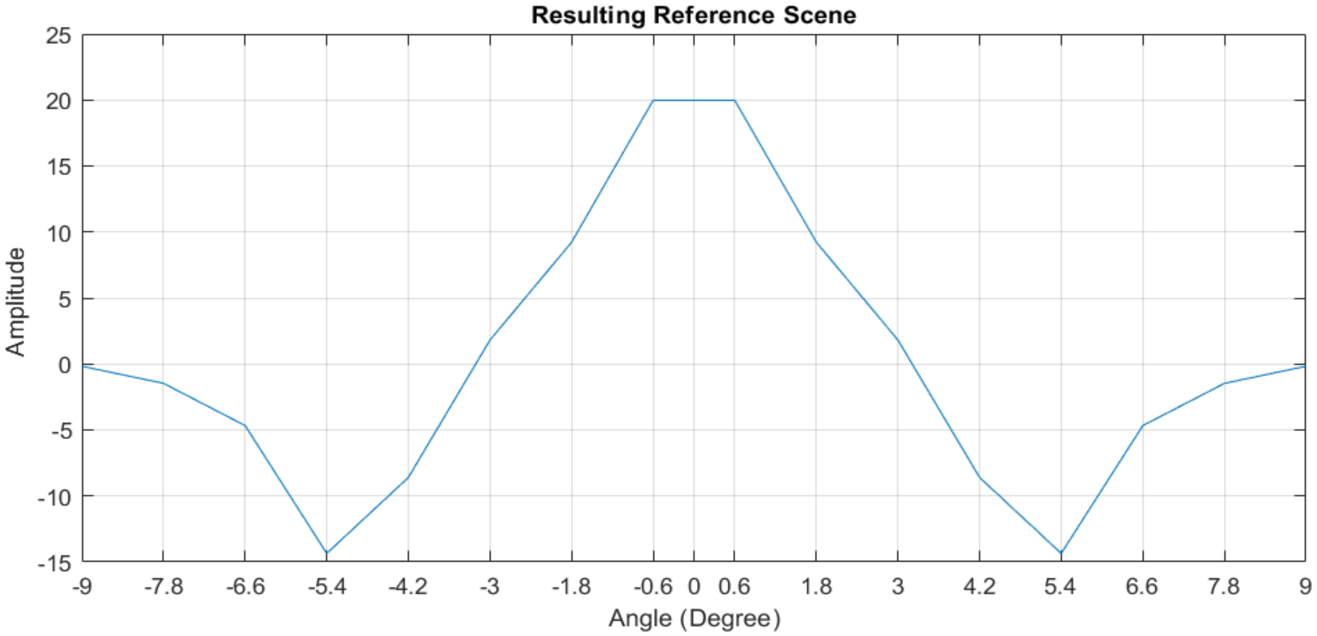
Results

Figure 6 – Calibrated scene with one metal object. Notice the symmetry at zero (0) degrees.



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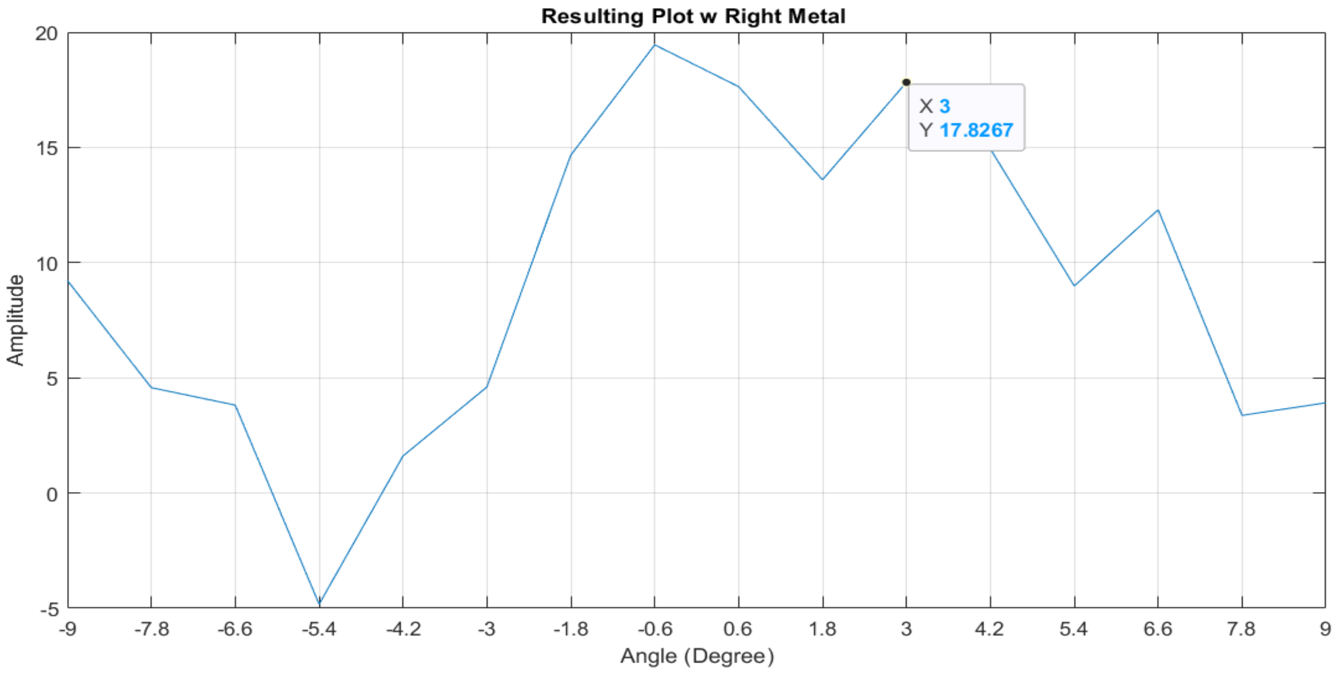
Results

Figure 7 – Scene with metal object to the right of center.



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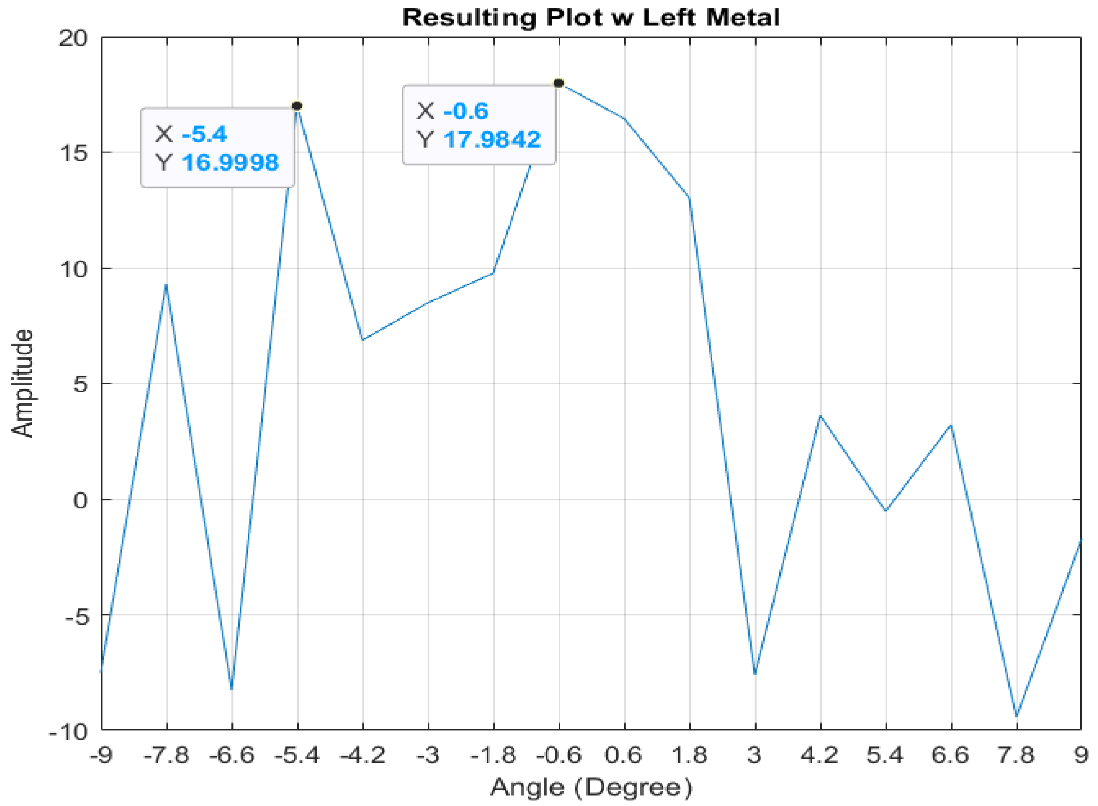
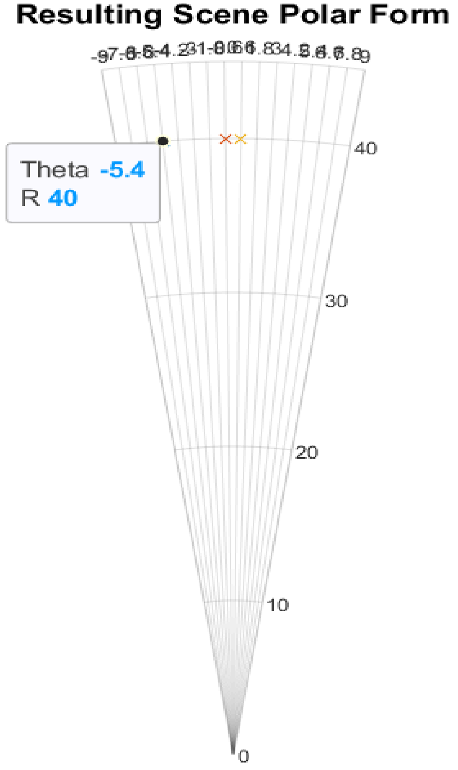
Results





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End Goals

Purchasing of parts, assembly, and field-testing is all complete. The test results are still being analyzed and analysis will be finished by this upcoming Thursday.

Nathaniel Henry

Lessons Learned

1. Designing and implementing the 2.2 GHz to 10 GHz upconverter
2. Using snapshots for SAR imaging instead of streaming
3. Using Linux instead of Windows for data acquisition
4. Perseverance

USRP N210

Nathaniel Henry

Bill of Materials

DESCRIPTION	COST ($)	UNITS	TOTAL ($)
VCO	399	2	798
B200	828	2	1656
Mixer	49	3	147
Lo Amp	108	3	324
Splitter	79	2	158
Power Detector	102	2	204
DC-DC Converter	11	1	11
RF Cables	208	2	416
Filters	40	6	240
		SUBTOTAL	3954

Nathaniel Henry

Conclusion and Future Considerations

Redesign the radar system to utilize a software defined radio instead of the previous team’s FPGA-based design

Identify metal objects at a minimum range of 40 feet

Reduce noise leakage between transmit and adjacent receive horns

Nathaniel Henry

Conclusion and Future Considerations

Future Considerations

- Radio choice
- Noise filtering choice

Nathaniel Henry

Special Thanks

We would like to thank:

- Our technical advisor, Pete Stenger
- Our instructor, Dr. Jerris Hooker
- Northrop Grumman as our sponsor and providing our budget

Nathaniel Henry

Any Questions?

Nathaniel Henry