Antenna Pattern Measurement System

DESIGN DOCUMENT

Team 23
Dr. Al Qaseer
Jonathan Insyxiengmay - Leader / Firmware Engineer 1
Aaron Barvincak - Hardware Engineer 1
Alec Gilroy - Hardware Engineer 2
Aryan Prajapati - Software Engineer 1
Hamza Shahid - Software Engineer 2
Brock Veatch - Firmware Engineer 2
Team Email : sdmay23-23@iastate.edu
Team Website : https://sdmay23-23.sd.ece.iastate.ed
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Executive Summary

Development Standards & Practices Used

List all standard circuit, hardware, software practices used in this project. List all the Engineering standards that apply to this project that were considered.

Summary of Requirements

- Application to run scans
    - Shows polar plots generated from scanned data.
    - Allow user to run scan scripts and manually move the antenna.
    - Must be able to export and import data gathered from a scan.
- Antenna mount on transmitting side of anechoic chamber that must be able to rotate about two axes, at least 60 degrees for each axis
- Antenna mount on receiving side of anechoic chamber

Applicable Courses from Iowa State University Curriculum

- SE 309: Software Development Practices
- SE 319: Construction of User Interfaces
- COMS 363: Introduction to Database Management Systems
- EE 311: Electromagnetic Fields and Waves
- EE 414: Microwave Engineering
- EE 417: Electromagnetic Radiation, Antennas, and Propagation

New Skills/Knowledge acquired that was not taught in courses

- We had to learn PyQt6 and more about Python as that's what we are using for the application.
- 3D CAD modeling is not taught in the EE or SE curriculum and is necessary for the project
- 3D printing is not taught in the EE or SE curriculum and is necessary for the project

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1 Team

1.1 TEAM MEMBERS
Jonathan Insyxiengmay
Aaron Barvincak
Alec Gilroy
Brock Veatch
Aryan Prajapati
Hamza Shahid

1.2 REQUIRED SKILL SETS FOR YOUR PROJECT

Hardware:

1. 3D CAD modeling skills used to design physical components specific to the project, such as the cover plates for both entrances to the anechoic chamber and the antenna mounts
2. 3D printing skills used to create the modeled components
3. Basic mechanical/electrical hardware design and troubleshooting skills for assembling and testing the physical components of the system

Software:

1. Experience with software design tools
2. Knowledge of good software design choices
3. Knowledge of developing desktop applications using PyQt6

1.3 SKILL SETS COVERED BY THE TEAM

Hardware:

1. Alec, Aaron, Jon
2. Alec, Aaron, Jon
3. Alec, Aaron, Jon

Software:

1. Brock, Aryan, Hamza
2. Brock, Aryan, Hamza
3. Brock, Aryan, Hamza

1.4 PROJECT MANAGEMENT STYLE ADOPTED BY THE TEAM

We have divided the project into three rough subgroups, Hardware, Software, and Firmware. Jonathan is our designated leader when it comes to meetings and updates.

1.5 Initial Project Management Roles

(Enumerate which team member plays what role)

Jonathan Insyxiengmay	Leader / Firmware Engineer 2
Aaron Barvincak	Hardware Engineer 1
Alec Gilroy	Hardware Engineer 2
Brock Veatch	Firmware Engineer 1
Aryan Prajapati	Software Engineer 1
Hamza Shahid	Software Engineer 2

2 Introduction

2.1 Problem Statement

We are trying to solve the problem of measuring and modeling an Antenna's Radiation pattern. We are confined to a small space and strict design requirements due to our product having a specific, non-modifiable, special requirement.

2.2 Intended Users and Uses

The main customer for our product is researchers at a NDE lab here at Iowa State. They will benefit from this project because they will be able to have a more verifiable result for antennas used in the lab. They will also be able to prove or acknowledge antenna design deficiencies or efficiencies. The individuals who care that the product exists are firstly the researchers in the lab. It is also the 3rd party entities who use the lab to be able to perform their research through the lab.

Undergraduate Student Researcher

Key Characteristics:

Learning about antennas, minimal amount of time to configure, lacks complete understanding of how the system is intended to work.

Needs:

They need the system to be simple to use, provide easy to obtain, justifiable results.

Benefits:

They will benefit from the product by being able to perform experiments on antennas and gain an understanding on different types of antennas and their radiation patterns

Graduate Student Researcher

Key Characteristics:

Fleshed out understanding of antennas, they have an idea of the expected results, they also may know more about the experiment environment.

Needs:

They need the system to be simple to use, provide an abundance of information in regards to the radiation pattern of the antenna. (I.e S-Parameter information at a specific angle) It will also need to be radar absorbent so that possibility of the antenna rotating assembly does not provide any additional erroneous information that skews results.

Benefits:

They will benefit from this product by being able to analyze and experiment with differing type of antennas and their radiation patterns. They will be able to duplicate and change specific measuring methods to ensure reliability of information.

2.3 REQUIREMENTS & CONSTRAINTS

Mechanical Requirements:

Design of both the antenna rotating device and the antenna receiving device must not exceed the opening on the side of the anechoic chamber. This opening has a constraint of 3.5 in x 3.5 in. We also need the device to be able to house 2 motors (used for rotation), a motor controller, and it needs to have a device to hold a specific waveguide. The waveguide holding device may need to be interchangeable to expand how many waveguides or antennas can be used with the design.

The device also needs to be able to support anechoic cones that will be attached onto the face of the device so it does not supply any unwanted or negligent reflections into the system, these may skew the intended testing.

Functional requirements:

- The application must be able to receive and parse binary file data to be able to interpret antenna angels, radiation patterns, movement in x and y directions, ect.
- This software must also plot points and model the pattern on a 2d or 3d plane and interpolate/extrapolate data between angles to correctly model the pattern.
- This application shall also be able to control the motors to move the antenna on certain paths to collect data.

Non functional requirements:

- The application should be able to run for multiple hours to collect adequate amounts of data
- The application should plot data to multiple decimal points of accuracy
- The application should be able to download a pdf to a host users hard drive within 1 minute

UI requirements:

- The application must have a button to download data as a pdf for a given testing cycle.
- The application shall also have a display of the model in a 2d or 3d plane.

IEEE Std. 488.1-1987 Standard Digital Interface for Programmable Instrumentation - We will need to use SCPI commands to communicate with various components and subsystems involved in this project, these include the Vector Network Analyzer and Motor controller.

IEEE Std. 488.2-1987 Codes, Formats and Common Commands For Use With IEEE Std. 488.1-1987. - Similarly to the use of 488.1, we will need to be familiar with this engineering standard to be able to communicate with the various test equipment involved with this project.

3 Project Plan

3.1 PROJECT MANAGEMENT/TRACKING PROCEDURES

This would allow us to go for an agile project management to continually update project requirements as needed and show bits of the project to our client to make sure he accepts the design. We chose this because we anticipate that requirements might change or design aspects of the project might be different than currently thought. We will also be using GitLab to store anycode for the application and Discord for any communication we need to do outside of class.

3.2 TASK DECOMPOSITION

Hardware:

1) Find dimensions of the openings of the anechoic chamber
    a) measure both the width and depth of the chamber openings
2) Using Fusion 360, create a design for a piece to attach to the anechoic chamber
    a) We will need two sides, one side for the stationary horn antenna, and the other will be for the rotating horn antenna and a hole for the RF cable and other power cables
3) Using Fusion 360, Create a design for a piece to attach to the previously designed piece
    a) This piece will contain the motors, gears, horn antenna, and the motor controller and raspberry pi
4) Using Cura slicer, create .stl files to be able to 3d print the parts
5) 3D print the parts
    a) We will be using ABS as our filament
6) Test fit assembly
    a) Test fit the assembly on all components, ensuring that all fit and operate as intended
7) Develop firmware for motors to be able to rotate
    a) There will be two motors controlling different angles of measurement of the horn antenna, they will need to obtain a resolution of 1.8 degrees.
8) Add miscellaneous components
    a) The design will consist of various fasteners, such as heat set threads and radar absorbing foam. Once we know all pieces will sit correctly, we will add the finishing parts.

Software:

1) Simulate dummy data and convert file type to binary file to hold a lot of information

   a) convert file types to binary files
   b) convert binary files back to viable readings to plot
2) Start design of desktop application that will allow you to run scripts to run the hardware and have plotting data for the radiation patterns of the antenna
   a) UI design of application with button layouts and formatting
   b) develop applications plotting UI and script running capability
3) Use the dummy data and pythons extensive libraries to plot data points on a polar plot
   a) send it dummy data
   b) plot the data with python libraries on a polar plot
4) Allow downloadable pdf of plots and data that goes along with the polar grid
   a) develop button on UI
   b) button allows download to host computer's hard drive
5) Run multiple tests of multiple sets of dummy data.
6) Integrate firmware with software to test real time data plotting
   a) test and verify correct data is sent
   b) monitor UI for correct plotting of data

3.3 PROJECT PROPOSED MILESTONES, METRICS, AND EVALUATION CRITERIA

Hardware:

1) Obtain measurements of anechoic chamber
   a) All measurements obtained should be within $\pm$ 1 mm
2) Create Fusion 3D schematic for mounting assembly
   a) Less than $\pm$ 1 mm of interior dimension of anechoic chamber openings
3) Create Fusion 3D schematic for receive side aft piece
   a) Less than $\pm$ 1 mm of interior dimension of anechoic chamber openings
4) Create Fusion 3D schematic for transmit side aft piece
   a) Less than $\pm$ 1 mm of interior dimension of anechoic chamber openings
5) Mount parts inside of printed pieces ensuring that things are working correctly
   a) Less than $\pm$ 1 mm of exterior dimension of components
   b) Face should be $\pm$ 1 mm flush with interior of chamber
   c) Cables should have $\pm$ 1 mm of clearance into the printed assembly
6) Check compatibility of parts inside of printed assembly
   a) Motors should move gears with a resolution of 1.8○
   b) Horn antenna should have 60○ of rotation direction in both rho and phi directions
   c) Response time should be < 1ms

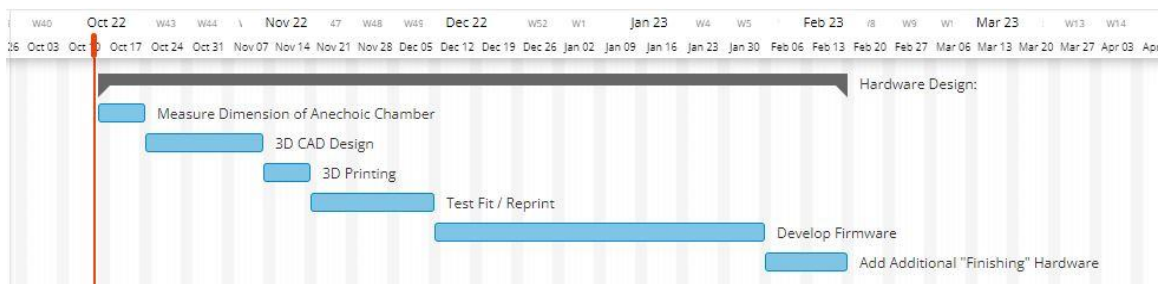**Software:**
1) Simulate dummy data and convert file type to binary file to hold a lot of information
   a) Convert file types to binary files.
    - Need to be converted within 1 minute
    - Needs to include 100% of previous data
2) Start design of desktop application that will allow you to run scripts to run the hardware and have plotting data for the radiation patterns of the antenna.
   a) UI design of application with button layouts and formatting
    - A user should be able to navigate and understand the layout within first time of use
    - In this sprint client should like and approve of design
   b) Develop applications plotting UI and script running capability
    - Needs to be able to run a script within 3o seconds of button click
3) Use the dummy data and pythons extensive libraries to plot data points on a polar plot.
   a) Send it dummy data
   -Needs to be able to handle 10 mb of binary file size with dummy data

b) Plot the data with python libraries on a polar plot
   -Acceptance test the polar plotting of radiation data. This data should be correct and verifiable
   -10 degree of rotation for the antenna should be handled and plotted correctly with data precise to the tenth decimal spot
4) Allow downloadable pdf of plots and data that goes along with the polar grid
   a) Button allows download to host computer's hard drive
      -This file needs to download to host computer within 1 minute of pressing button

3.4 PROJECT TIMELINE/SCHEDULE

Hardware:

Software:
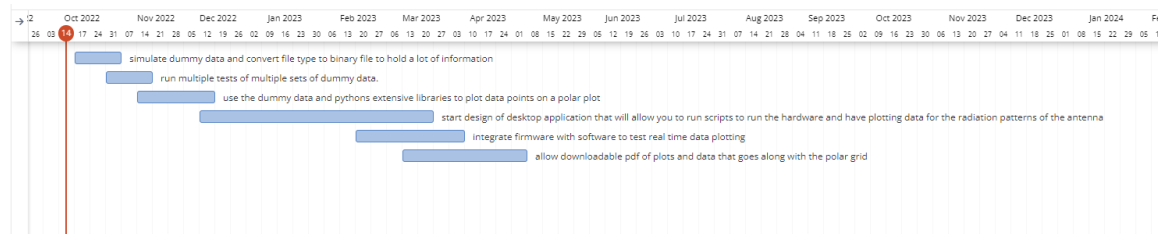
3.5 RISKS AND RISK MANAGEMENT/MITIGATION

Hardware:
1) Find dimensions of the openings of the anechoic chamber
   Risk Rating = - .1
2) Using Fusion 360, create a design for a piece to attach to the anechoic chamber
   Risk Rating = -.4
3) Using Fusion 360, Create a design for a piece to attach to the previously designed piece
   Risk Rating = -.3
4) Using Cura slicer, create .stl files to be able to 3d print the parts
   Risk Rating = - .1
5) 3D print the parts
   Risk Rating = -.3
6) Test fit assembly
   Risk Rating = - .3
7) Develop firmware for motors to be able to rotate
   Risk Rating = -.6

Firmware must be compatible with software for the system to provide usable results. This risk can not be mitigated, thus, we must plan accordingly to have time to develop robust firmware

8) Add miscellaneous components
   Risk Rating = -.2

Software:

1) Simulate dummy data and convert file type to binary file to hold a lot of information
   Risk Rating = - .2
2) Start design of desktop application that will allow you to run scripts to run the hardware and have plotting data for the radiation patterns of the antenna
   Risk Rating = - .3
3) Use the dummy data and pythons extensive libraries to plot data points on a polar plot
   Risk Rating = -.1
4) Allow downloadable pdf of plots and data that goes along with the polar grid
   Risk Rating = -.1
5) Run multiple tests of multiple sets of dummy data.
   Risk Rating = -.1
6) Integrate firmware with software to test real time data plotting
   Risk Rating =-.6

3.6 PERSONNEL EFFORT REQUIREMENTS

Hardware:

Task 1 hours: 3
Task 2 hours: 10
Task 3 hours: 20
Task 4 hours: 4
Task 5 hours: 10
Task 6 hours: 15
Task 7 hours: 50
Task 8 hours: 5

Software:

Hours:	Task 1:	Task 1a:	Task 1b:
20	20	15	5
Hours: 20	Task 2: 20	Task 2a: 10	Task 2b: 10
Hours: 16	Task 3: 16	Task 3a: 1	Task 3b: 15
Hours: 4	Task 4: 4	Task 4a: 2	Task 4b: 2
Hours: 2	Task 5: 2		
Hours: 30	Task 6: 40	Task 6a: 15	Task 6b: 15

3.7 OTHER RESOURCE REQUIREMENTS

We will need and have access to a 3d printer to build components to stabilize and mount certain parts that we need to take measurements from. We will also need access to a VM to build our desktop application. We also might need a server for our application if we want to store the results of the scan. Also, we will need access to a VNA or signal generator to be able to use the system as intended.

4 Design

4.1 DESIGN CONTEXT

4.1.1 Broader Context

We are enabling the lab to have a device that will be able to test an assortment of different antennas. It will provide insight into how some of the antennas that they have work in a controlled environment. The researchers in the CNDE lab will be affected by the design, and to address their needs we need to develop a reliable system to enable them to be able to test a multitude of different antennas.

Area	Description	Examples
Public health, safety, and welfare	Our project will allow the researchers in the lab to gain insight into how a desired antenna under test operates. Allowing them to make enhanced decisions when it comes to guaranteeing the results of their desired experiments.	Increasing the knowledge of the antenna pattern, Decreasing the amount of guesswork regarding antenna performance.
Global, cultural, and social	In the scientific community it is of the utmost importance that experimental results are guaranteed and performed with precision. The use of this antenna pattern measuring device will allow the CNDE lab to be able to guarantee experiments made with antennas.	Without being able to guarantee experiment results from antenna based experiments. The lab can not guarantee that their results are perfect, as they need to be.
Environmental	The environmental impact of this device allows for the re-use and re-purpose of different types of antennas for different applications. Our system may prove that an antenna may be able to be used for an unintended application, therefore making the procurement of a new antenna not necessary and the recycling of an already obtained antenna possible.	Decreasing the amount of unused or single use antennas.
Economic	Similarly to the environment consideration, having the ability to characterize different antennas and storing that information, the lab will not need to purchase more antennas if antennas can work for multiple applications.	Decreasing the amount of antennas required to be purchased for future experiments.

4.1.2 Prior Work/Solutions

MilliBox - It is a nearly identical system. The main difference is that the antennas sit inside of the anechoic chamber while ours will sit on the side of the anechoic chamber. Their system also rolls out with a proprietary UI that we will have to create ourselves.

Advantages:

- MilliBox already has an established procedure for manufacturing the antenna measuring device.
- MilliBox has a Phd working on their team, his knowledge gives them an advantage because there are many things that we will have to learn on our own.

Disadvantages:

- MilliBox is not a perfect faraday chamber, its walls, whilst lined with radar absorbent foam, is not metal backed.
- MilliBox is expensive, they do not list their price on their website. Our antennas movement design will be roughly 150 to 200 dollars.

4.1.3 Technical Complexity

<u>Hardware:</u>

- This system needs to have an antenna rotating device. To provide a resolution that allows an antenna to be accurately modeled a study must be performed for appropriating the proper gearing ratios for the motor to move the antenna in specific, minute, steps. 3D printed parts will also be used, so the various stresses that will come with mounting with the system will need to be studied.
- The mechanical portion of this project will consist of 2 motors, a pulley or gearing ratio, a power supply, a raspberry pi and a motor controller. The challenge of having all of these components operate simultaneously with our UI will be immense. Time will need to be taken to be able to ensure that the data that we are receiving from the antennas is correct.

<u>Software:</u>

- This system will also use a UI that will need to simultaneously map a 3D projection of magnitude and phase at a specific angle in relation to the receiving antenna. With that being said, the antenna movement and timing that the software will take measurements will need to be thoroughly investigated.

4.2 DESIGN EXPLORATION

4.2.1 Design Decisions

<u>Hardware:</u>

1. We had to make a design decision about the motor size we will need, we decided to go for a smaller motor due to a larger motor being less practical and more power consuming than a smaller one.
2. We decided to use 3d printing as opposed to other methods, such as wood construction, to manufacture our antenna measuring devices hardware. We plan on creating both the box the system will sit in and also the gears that will help control the movement of the system using a 3d printer.

<u>Software:</u>

1. Desktop Application
2. 2D/3D modeling UI
3. Feature to run scripts to interact with the hardware through the UI.

The desktop application is important because we want to be able to get as low as possible to interact with the computers hardware components and run scripts through a corded device. The 2d and 3d model is important because modeling the pattern is a major functional requirement and needs to be done through a modeling library and seen on a UI to be able to be analyzed.

4.2.2 Ideation

The desktop application was a design decision. We were contemplating these options. Android app and Ios app because of the GUI being really easy to learn and maneuver. Web application because of the experience we had with building that. And a 3rd party so we could use a modeling service much easier than creating it from scratch.

Our final decision was a desktop application because of the experience we had and the amount of control to being closer to the computer's resources the application gave us and the fact the program only needs to be able to run locally and output locally gives more security benefits and no need for a server and database.

1) Web application
2) Android application
3) Ios application
4) Desktop application
5) 3rd party software

4.2.3 Decision-Making and Trade-Off

Software:

We chose desktop application because in the most important area which was being able to be locally run it had led and in other important areas like GUI design it was still top 2 of the list. So considering the weights we put on the categories, desktop applications made the most sense.

WEIGHTED DECISION MATRIX TEMPLATE

| Prioratization Criteria	Value	desktop	Score	web app	Score	mobile app	Score	3rd party	Score
locally run	.5	4	2	2	1	3	1.5	1	.5
GUI function	.3	3	.9	2	.6	4	1.2	1	.3
low level interaction	.05	4	.02	1	.05	3	.15	2	.1
data storing	.15	3	.45	4	.6	2	.3	1	.15
Total	1	12	3.37	9	2.25	12	3.15	5	1.05

4.3.1 Overview

The antenna measuring device will be able to measure and characterize different types of Antenna. To do this the device will be attached to an radar absorbent chamber and will be able to rotate in 2 directions, vertically and horizontally. The device will utilize stepper motors, a controller, a VNA, and a software graphical user interface to be able to perform its operations. To be able to implement all of the above functions there will also need to be some connections to a power supply and also a USB interface between the controller and a computer.

4.3.2 Detailed Design and Visual(s)Hardware:
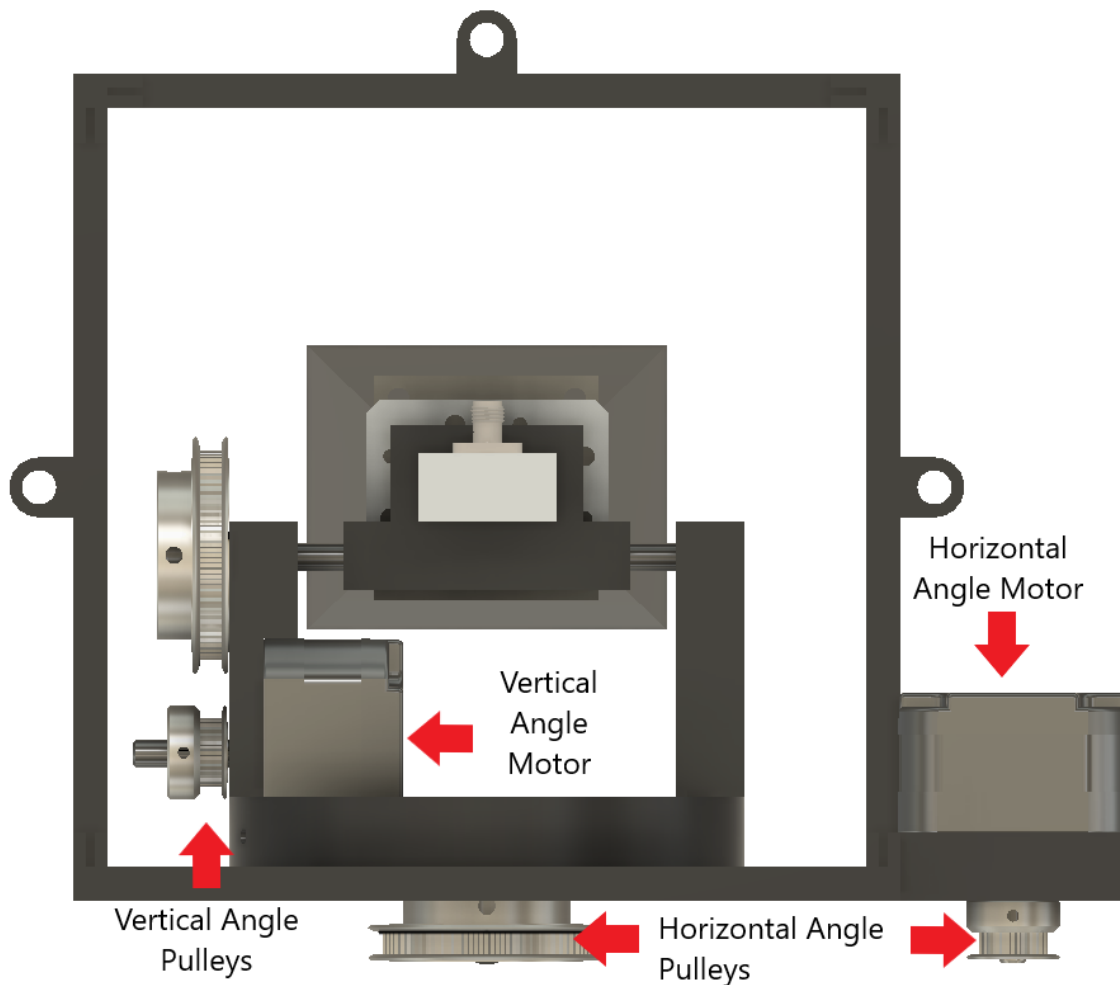
The hardware component of this project will require some tuning, but as it stands, the design that can be anticipated is shown below.

Side View

Mount to
Anechoic
Chamber Inlet

X-Band
Waveguide
Adapter

Drive Shaft
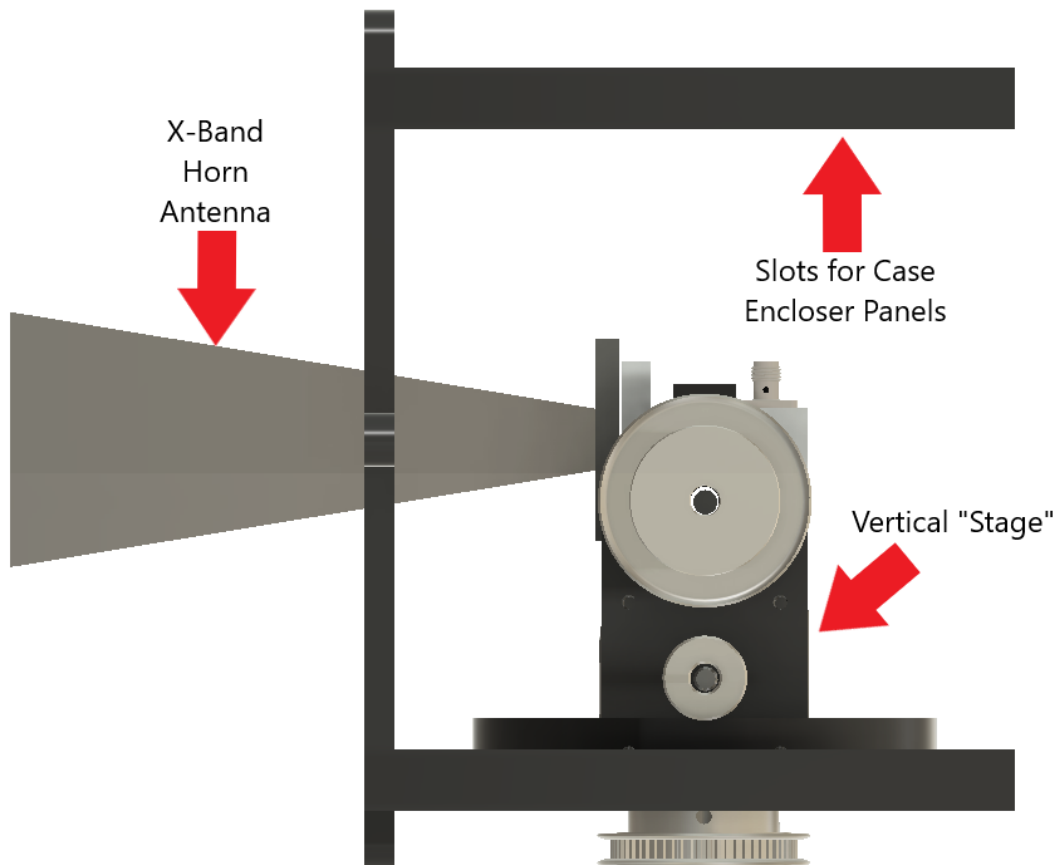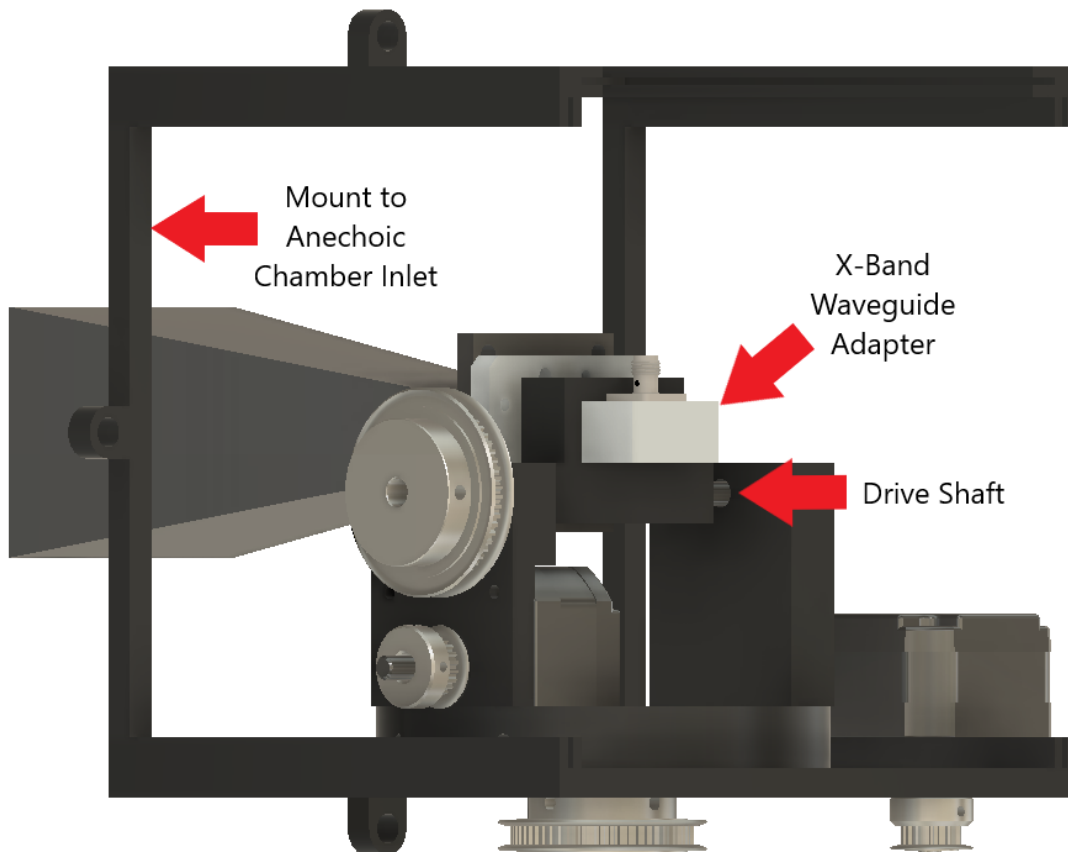
Side (Angled) View

Back View

The design consists of a complex, multi- level structure that is meant to house the electrical components (not pictured) the motors, an assortment of pulleys, and the waveguide. To perform the angular movement required by this project we first needed to come up with a way to convert our motors with a resolution of 1.8°. We needed a way to convert each step to a lower resolution. We decided on using a 3:1 pulley system that will allow us to have a resolution of 0.6°, to further lower our resolution we will use some microstepping functions of the microcontroller to get a resolution of < 0.1°. You can see these pictured as "Large pulley" and "Small Pulley".

Next, to keep the waveguide level and able to move along with the motor, a drive shaft is planned to be used. This drive shaft will be connected to the large pulley and we will 3d print a clamp that will have two functions, the first to allow us to clamp around the drive shaft, and secondly it will allow us to have a modular design to be able to change out different sizes of antenna, to increase the capability of the system for future uses this portion of the design is to enable the functionality of rotating in the vertical axis.

All of these components will be mounted to a 3d printed "Vertical stage". This stage's purpose is to be able to support motor 2, connected via a pulley to the driveshaft. The mass of the

antenna also provides stability and allows motor 2 to rotate with the system, so as to not bind it up. This will allow us to have our 2 degrees of motion.

The vertical stage will then be mounted to motor 1, this motor has a similar pulley system as motor 2. This motor 2 allows our horizontal rotation of the waveguide. Thus programming this should be relatively straight forward. This portion of the design can be anticipated to be revised and improved, a study of how the 3d print holds up with the advanced level of stresses that come from the components listed above may cause the design of this portion to change dramatically.

Finally, the entirety of the moving components will be encapsulated inside of a 3d printed enclosure that will allow us to mount the system to the anechoic chamber. The enclosure and all components inside of it are required to be no more than 5.5 in x 5.5 in large.

Software:
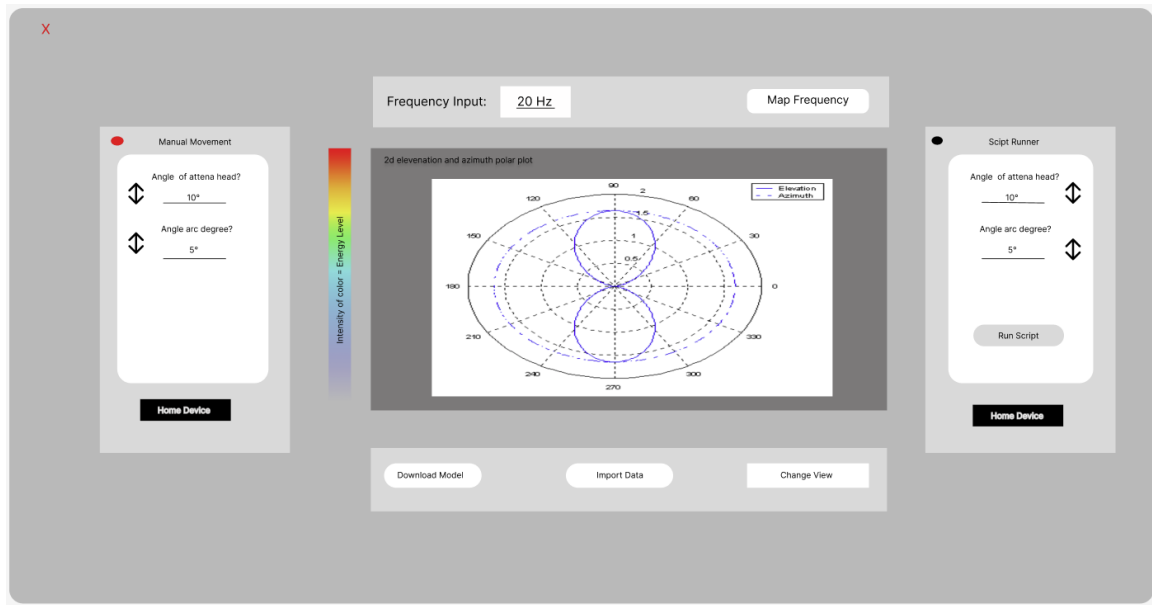
Our application will be a windows application so it doesn't need any browser or internet connection to run. In the application the user will be able to manually move the antenna or run a script with given angles. The "Home Device" button will reset the antenna back to its original or "home" position. When the antenna is scanning the application will be sending commands for movement to the motors, meanwhile the antenna will be returning scanning data. Once the scan is complete a plot will be displayed showing the data recorded, users will be able to view plots for whatever frequency they type in. The minimum viable product will contain a 2d graph, but if time arises there is a possibility of integrating a 3d graph. There is also the option to export the scan data in an Excel file that can later be imported back to view plots for already scanned data.

4.3.3 Functionality

The user should first calibrate the VNA or spectrum analyzer. Once completed the user should then be able to attach their antenna to both the receiving side and the transmitting side. Once complete, the user should then load the GUI and home the device. Once the homing is complete the user can begin with the measurement of the antenna. The process, while varying in length depending upon the selected resolution and size of the antenna, will wait until the measurement is complete. Once complete, the user will be able to see a plot of both the magnitude of the antenna depending upon angle. They should be able to check and see how well the antenna performs depending upon frequency. The user should also be able to get back a 3d plot of the antenna's radiating pattern. Finally, the user will be able to export any of the data they would like by obtaining the .scan file created by the program.

4.3.4 Areas of Concern and Development

The current design for the application meets the minimum viable product requirements. If time permits we would add the option to view the plots in 3d which would allow the user to better visualize the data recorded. If the plot is 3d we would also have to add a way to move the plot around and view it from different angles. Our biggest concern is stability with the antennas and angular resolution. To create a greater amount of angular resolution we planned to use the pulley system, this will allow us to physically have greater control over the steps of the motors. The stability of the antennas will be addressed by trying different thickness of 3D prints for our rotating device, we will start at a standard thickness and move up or down depending on if we see any flexing in the plastic.

4.4 TECHNOLOGY CONSIDERATIONS

Software:

Data visualization/Desktop application: Python

Strengths: Ease of learning, experience, extensive libraries, extensive resources to learn and python is a very popular language with many examples of use.

Weakness: code is interpreted, slow execution, not as efficient, not recommended language for a desktop application, not as experienced with python as other languages

Alternative: matlab for data visualization and c sharp, c++, or java for desktop application.

Trade off: C and java are better for desktop applications. They run faster and are compiled languages. Matlab is used extensively for data visualization but not as well known to the software team. This design would mostly look the same but with python visualization libraries it will be easier to work with a very high level language.

Hardware:

SKR Mini E3

Strength: Easy to program, user friendly, good documentation.

Weakness: Lack of current provided to motors.

Trade off: The SKR Mini E3 is an easy system to work with and is used in many 3d printers who use the same kind of motors that we will be using. What we will have to worry about is the mass of the moving parts that the motor has to rotate. To counteract this, we will design a system to have the lightest components.

NEMA 17 Stepper Motor 16N*cm

Strength: Compact, easily mounted.

Weakness: Low torque, might need to upgrade to a stronger motor. Step size of 1.8 degrees requires pulleys to reduce step size to 0.6 degrees, although this isn't a major concern because we would need some way to transfer power between motors and the antenna mount anyways.

Alternative: NEMA 17 Stepper Motor 59N*cm has a stronger torque with a slightly larger body, which is alright since it's mounted outside the chamber (no strict volume requirements).

Trade off: Higher torque generally comes with larger size and higher price. Smaller and more accurate step sizes also come with a higher cost.

Pulley System:

Strength: Allows us to house motors outside of the chamber and use belts to transfer mechanical power to the inside of the chamber, saving space. Also allows us to change the step size of our stepper motor by using a 3:1 pulley system, meaning our 1.8 degrees step will be reduced to 0.6 degrees.

Weakness: The pulleys can be finicky if the belts are not cut right or if the set screws on the pulleys to the drive shafts are not secured.

Alternative: Gear ratio system

4.5 DESIGN ANALYSIS

Hardware:

We have begun the design for the 3d model of the vertical stand, the original proposed design did not work, so we intended on reworking. We have put together a parts list to get all of the things that we will need to make this a successfully working tool for the customer. Our next step is to rework the 3d design, obtain the parts, and get to printing so we can begin assembling prior to thanksgiving break. For the future we need to think about the stability of the vertical stage, how the user will have an easy and accessible way to calibrate the VNA, how the electrical components will mount to the system, and finally how much weight can be supported with the support holes on the side of the chamber.

Software:

We have designed how the desktop application will look and what functional requirements are needed for a minimum viable product through figma. The design from 4.3 did work but had a few added functionality on top of it given by the client and a few tweaks in UI because of it. We have not yet started building out functionality so we plan on implementing that soon. We will start with UI on desktop and build functionality as we go. Feasibility of the design seems possible. As we build the application we will see what issues arise and how to deal with them.

5 Testing

5.1 UNIT TESTING

What units are being tested? How? Tools?

Software:

- Radiation Model Display
  - 2d plot of Azimuth plane and Elevation plane show correctly
  - Testing specific and known radiation patterns to make sure it has correct polar Plot
- Script Runner
  - Homing device has to be clicked before running and should go back to devices neutral spot
  - When a script is ran testing the route of the antenna to make sure it is correct
  - Input should be within a certain range
- Manual Runner
  - Homing device has to be clicked before running
  - When manual input is run antenna should run on that path
  - Manual input should be within a certain range
- Import/Export Data
  - All models form display should be able to be downloaded to host computer
  - Data plotting should be downloaded and have correct values
  - Multiple old files should be able to be uploaded and plotted together

For the software desktop application we are going to be using the framework pyqt to help organize our application. This framework has a built in QT tester that we will be using as our tool to unit test specific units of code. Testing the model will have a lot to do with finding pre disposed set models that we can compare values to our model to. Testing the script and manual runner will have a lot to do with making sure it runs in a certain path and this can be done by verifying location using python libraries. And finally testing export data will just be verifying data correctly matches up to point on the 2d plot so using standard python libraries for verification will help.

Hardware / Firmware:

- Stepper Motor Movement

  To ensure the motors are moving as intended, a test bench will need to be set up to determine the proper microstepping and pulley ratio has been programmed and calculated. The test bench will allow the user to understand the resolution that the system has.

For testing the firmware and hardware interface, the GUI will be used to move the motors in their respective directions. We can then use a mechanical test bench consisting of different angular measurements to determine and tune the movement of the motors. To be able to get the motors to ensure that the motors are properly interfaced with the GUI a sample movement script will be used and the system will be tested outside of the anechoic chamber environment. Specific angular movement requirements will be specified and annotated so the user knows if the system needs to be recalibrated or if the belts on the pulleys need to be changed.

5.2 INTERFACE TESTING
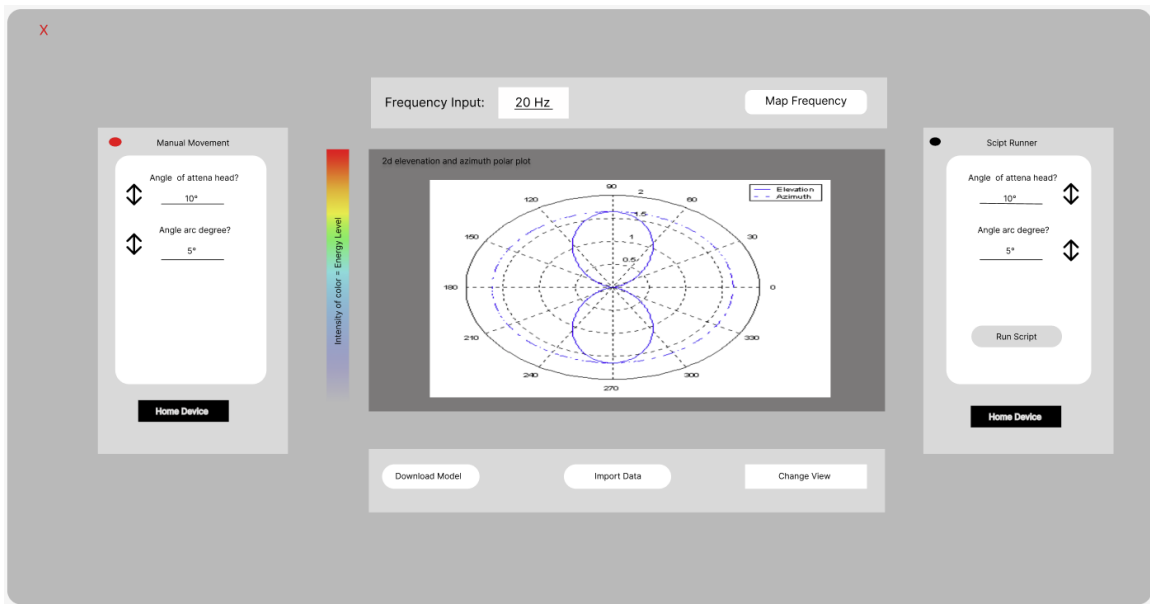
We will need to test the interface of our application. One of the main parts we will need to test is the interface for the plots. The application should display the correct plot for the frequency input provided by the user. We will test this through simulating scans through CST and comparing our plots. The rest of the testing for our interface will be done manually making sure the right prompts pop up when needed, for example the application must prompt the user to export data before starting a new scan.

We will also need to interface the GUI with the motor controllers to ensure that the automatic step cycle is working as intended. To do this, a sample "test sweep" antenna rotation pattern can be used. This pattern can have a specified maximum angle and will sweep the entire range in both the theta and phi directions. Once complete, the system should home to its original 0,0 position. This interface test will confirm that the GUI is sending movement

commands at the proper times and the measurements taken at a particular angle are the measurements that are intended to be taken.

5.3 INTEGRATION TESTING

We will be incrementally testing the modules in our design. We have 3 separate groups doing 3 different things at once so we will be testing separately and then collectively test the entire system once the incremental testing has concluded. Our path includes designing test scenarios and cases based on our clients needs and requirements. Executing those test cases and reporting the results and any defects we have. Then tracking and re testing until the individual module is found to have no defects. These last 2 steps are repeated until completion. We must design test cases and scenarios where different peripherals can be used as well as different sizes of antennas. Once the interface and desktop application has been designed and tested fully as well as the firmware we must test their integration as a module then combine that with the motor and hardware from our Hardware team to finally collectively test the entire module.

5.4 SYSTEM TESTING

The system level testing strategy is critical to the implementation of this system,To be able to perform the system test we will need to first confirm that the unit test for the Radiation Model Display, the Script Runner, the Manual Runner, the Import / Export, and the Stepper motor movement are confirmed as good. Once that is complete he interface test between the GUI and the motors as well as the interface between the GUI and the VNA. Once the interface test has been completed, an entire test scan will be performed with all systems connected. The first test will be a mechanical system test, this will allow the system to simulate that it will move in the expected pattern that we have set from the script runner. Once this is complete we can verify that the system is rotating and scanning as desired and we will be able to connect an antenna to the system. From here we can verify the results that we display from our comparison of a known antenna pattern that we have modeled in CST. Once all of these steps have been completed we will be able to confirm that the system is operating properly.

5.5 REGRESSION TESTING

1. We will need to make sure the manual movement and script runner dont interfere with each other.
    a. If the antenna is moved manually, reset to the original position before script is run.
    b. Manual movement is disabled when a script is running.
2. Data from previous scans don't interfere with new data.
    a. If running a new scan, prompt the user to save or clear old data.
    b. Make sure data imported from a previous scan doesn't overlap with new data.

Most of our regression testing will be driven by the requirements. Our client wants to be able to manually move the antenna, but it would lead to incorrect readings if it is moved manually during a scan, so we would have to disable that feature when a scan is currently running. Our client also wants to be able to export data gathered from a scan so it can later be imported and viewed again. So we need to make sure that when importing data it doesn't read any data from the most recent scan. Most of this testing will be done manually without the use of any specific tools.

5.6 ACCEPTANCE TESTING

We will be regularly consulting our client on the needs of the application throughout the design process. During the wireframe process we requested feedback from our client and he requested a manual movement feature to help with installing the antenna. We will also need to ensure that a 2D plot provides a sufficient amount of detail, if time permits we may switch to a 3d plot that will need a more advanced GUI so the user can view the 3d plot from different angles. We will need to consult with our client about this to see if he approves the 2d plots once we start generating data from actual scans.

5.7 RESULTS

To be able to confirm that the results of the testing is correct, we will heavily consider the results of CST. Some other ways that we can test if the device has the correct angular resolution is if the calculation of steps, in either the theta or phi directions are correct. For example a rotation pattern with 45 degrees of rotation should have 45 / .06 = 75 steps. To confirm this, we know that the system will take a measurement at each step, from this we know that if there are 75 different measurements the system has triggered, received data, transmitted data, and moved 75 different times. At this point we can confirm that the system is mechanically working the way that it was designed.

6 Implementation

Software:

We have started to build our application based on the design approved by our client. Moving forward we need to start communicating with the VNA and motors to have a better understanding of how to implement the scans and manual movement of the motors. Once we have built the connection between the software and hardware we can start running the scans and verify if the data being collected is correct and if the hardware is calibrated correctly.

Hardware:

Hardware has created a design in fusion 360 that is ready to be printed, we have also assembled a parts list and once ordered and printed, we are ready to begin assembly. Moving forward, as we realize the actual parts that we are able to acquire, our physical design of the system may change to benefit the measurement process to create a more reliable system for the client to be able to use and continue to use in the future. We have learned throughout the first portion of this process to stay flexible with our design, and be able to make adjustments as quickly as we can.

7 Professional Responsibility

Area of responsibility	Definition	NSPE Canon
Work Competence	Perform work of high quality, integrity, timeliness, and professional competence.	Perform services only in areas of their competence; Avoid deceptive acts.
Financial Responsibility	Deliver products and services of realizable value and at reasonable costs.	Act for each employer or client as faithful agents or trustees.
Communication Honesty	Report work truthfully, without deception, and understandable to stakeholders.	Issue public statements only in an objective and truthful manner; Avoid deceptive acts.
Health, Safety, Well-Being	Minimize risks to safety, health, and well-being of stakeholders.	Hold paramount the safety, health, and welfare of the public.
Property Ownership	Respect property, ideas, and information of clients and others.	Act for each employer or client as faithful agents or trustees.
Sustainability	Protect environment and natural resources locally and globally.	
Social Responsibility	Produce products and services that benefit society and communities.	Conduct themselves honorably, responsibly, ethically, and lawfully so as to enhance the honor, reputation, and usefulness of the profession.

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7.1 AREAS OF RESPONSIBILITY

Thoughts on Areas of Responsibility (IEEE Code of Ethics)	
Work Competence	We think that work competence is imperative in engineering, if you do not know how to do something let it be known so teammates can know that you need some time or instruction to get started.
Financial Responsibility	Working within the budget of what is agreed upon in your team is important if you would like to sustain a career in a certain company.
Communication Honesty	Communicating transparently can alleviate headache with the team, it can also ensure that everyone has complete understanding throughout the duration of a project
Health, Safety, and Well-Being	Safety is the number one priority, you the individual and the employer have invested so much time to get you to the point you are in your career that nothing is worth getting you injured or knocked out of the position.
Property Ownership	Respecting the property is extremely important. Many of us as engineers will be working with complicated, sensitive, and expensive equipment during our careers. It is of the utmost importance to not damage these pieces of equipment.
Sustainability	Creating something that is sustainable is important for all mankind, we must always try to be as frugal when using resources as we can or else there will be a point in time where we do not have any resources left.
Social Responsibility	Projects that we work as engineers may at times be good to some people and bad for others. It is up to us and our ethical center to decide if they are worth pursuing. All projects should come with a moment of reflection and consideration to all parties, not just the company or department we are working for.

7.2 PROJECT SPECIFIC PROFESSIONAL RESPONSIBILITY AREAS

Project Specific Importance (IEEE Code of Ethics)	
Work Competence	Medium - It is important to be honest about the capabilities that we have as students regarding our project, it is okay to not know anything or everything about a certain subject. It is best to be open and understand that it is okay to learn more!
Financial Responsibility	Low - The cost associated with this project is relatively low and we do not have much of a budget, or one that we are close to fulfilling. With that being said, we will not waste money or resources.
Communication Honesty	High - Similar to competence, all members must be willing to voice their concerns or reach out for help. There is no reason not to admit that they do not know how something works or that they need help or more time. We are all learning.
Health, Safety, and Well-Being	High - Safety is number one. Although there are not many hazards associated with this project, it would be foolish to get injured by becoming complacent or being careless.
Property Ownership	High - We are working with an expensive piece of equipment called a VNA, we must be cautious when using this device and ensure that we are always grounded when using it.
Sustainability	Medium - Sustainability is important for this, especially when it comes to using the 3D printer with this project, we need good designs before we just start printing random pieces.
Social Responsibility	High - Similar to Competence and Communication, we must always act with integrity and honesty. We must always respect one another and the project. Without that trust the team will fail.

7.3 MOST APPLICABLE PROFESSIONAL RESPONSIBILITY AREA

The most applicable area of social responsibility for this project is communication honesty, if we are able to communicate our ideas and concerns with the client we will be able to achieve their goals. If not, the system may not work as idealized by our client. We must first try to achieve the ideal values that we were presented with and communicate our short falls. If we do not do this and antennas begin to be measured, there may be an incompleteness or incorrectness in the data that may affect the client's ability to conduct research in the future.

8 Closing Material

8.1 DISCUSSION

On the software side we want an application that communicates with the motors and VNA to scan wave data. The application runs the scans and allows the user to manually move the antenna motors. The user should also be able to import and export the data taken from a scan. We were able to incorporate all these requirements into the design of our application. One constraint we had was with the visual output of the data, a 3D graph would be better as it shows more details but it would require a more advanced GUI, so we decided to go with a 2D plot and add the ability to see it in 3D if we have extra time. Referencing the hardware portion of this project moving forward we want to tweak our design to create a more reliable system for the end user. To do this, we may have to pivot from an externally mounted design to an internally mounted design. To do this, our parts list, CAD design, and general process may change slightly, but due to the lessons we have learned during this process these design changes will be easily implemented.

8.2 CONCLUSION

So far we have been able to come up with a design for our application that our client is satisfied with and meets all the requirements. We have also started building the application using PyQt6. Moving forward we need to start looking into the motor and VNA commands to communicate with the hardware chosen by the hardware team. We will also need to communicate more with the hardware team during the build stage to ensure that the system will interface correctly. We also need to realize the real world limitations of moving the antennas, we must ensure that the antenna will be able to complete its rotation pattern with no issue or damage to the antenna.

8.3 APPENDICES

If you have any large graphs, tables, or similar data that does not directly pertain to the problem but helps support it, include it here. This would also be a good area to include hardware/software manuals used. May include CAD files, circuit schematics, layout etc,. PCB testing issues etc.Software bugs etc.

<u>Manuals:</u>

1. SKR Mini E3 V2.0
   a. https://manuals.plus/bigtreetech/skr-mini-e3-v2-0-motherboard-manual
2. NEMA 17 Stepper Motor Data Sheet
   a. https://pages.pbclinear.com/rs/909-BFY-775/images/Data-Sheet-Stepper-Motor-Support.pdf
3. FieldFox Handheld Analyzers
   a. https://www.keysight.com/zz/en/assets/9921-02561/programming-guides/FFProgrammingHelp.pdf

8.3.1 Team Contract

Team Name SDMAY 23
Team Members:

1) Jonathan Insyxiengmay   2) Aaron Barvincak
3) Alec Gilroy   4) Brock Veatch
5) Aryan Prajapati   6) Hamza Shahid

Team Procedures

- Day, time, and location (face-to-face or virtual) for regular team meetings:
    - Meetings will occur on Wednesdays from 4 until 5. They will be on either zoom or in-person, whichever is necessary for the week.
- Preferred method of communication updates, reminders, issues, and scheduling (e.g., e-mail, phone, app, face-to-face):
    - Updates will be over discord, in-person during class, and during Wednesday meetings.
- Decision-making policy (e.g., consensus, majority vote):
    - Majority vote
- Procedures for record keeping (i.e., who will keep meeting minutes, how will minutes be shared/archived):
    - Weekly meetings, recorder will write down highlights and achievements we have accomplished and set goals for the next meeting throughout our design.

Participation Expectations

- Expected individual attendance, punctuality, and participation at all team meetings:
    - Attendance to weekly class is suggested, meetings are mandatory unless they can not make it.
- Expected level of responsibility for fulfilling team assignments, timelines, and deadlines:
    - If assigned a task, or volunteering to take on a task team member should try to complete it in a timely manner
- Expected level of communication with other team members:
    - At least check in with discord once a week, answering any open questions.
- Expected level of commitment to team decisions and tasks:
    - Should have an input, or provide an alternative idea if they disagree

Leadership

- Leadership roles for each team member (e.g., team organization, client interaction, individual component design, testing, etc.):
    - Aaron B - hardware designer 1 - implementing and testing the physical antenna.
    - Alec G - hardware designer 2 - implementing and testing the physical antenna.
    - Aryan P - software designer 1 testing radiation pattern and displaying mode.l
    - Brock V - implementation of different angles of the antenna by using motor control.
    - Hamza S - software designer 2 testing radiation pattern and displaying model
    - Jonathan I - Leader - organizing team meetings, weekly updates and helper in both hardware and software.
- Strategies for supporting and guiding the work of all team members:
    - Collaboration between team members, frequent meetings to ensure goals are being met.
- Strategies for recognizing the contributions of all team members:
    - Have specific goals for each team member to achieve.

Collaboration and Inclusion

- Describe the skills, expertise, and unique perspectives each team member brings to the team.
    - Aaron B - Signal and control system processing, Circuit theory analysis
    - Alec G - Some embedded experience, some CAD, EE classes
    - Aryan P - Software applications towards data analyzing, experience in app development using android studio.
    - Brock V - C, Java, Python, Matlab and web development
    - Hamza S - Python development, Android Studio Development
    - Jonathan I - Circuit analysis and designer
- Strategies for encouraging and supporting contributions and ideas from all team members:
    - Having each team member work in a field they are comfortable with. Have open communication and be open to different ideas. Have goals but understand the way to achieve goals can be different.
- Procedures for identifying and resolving collaboration or inclusion issues (e.g., how will a team member inform the team that the team environment is obstructing their opportunity or ability to contribute?)
    - Informing team members what the issue they are having and what application they are using. Providing open communication on how we can resolve this issue. If it is outside our knowledge, we will inform our client what we are stuck with and how we can approach the problem. Writing down our error and approach when resolving issues will be critical when designing the project.

Goal-Setting, Planning, and Execution

- Team goals for this semester:
    - Get a valid prototype, have a parts list ready for assembly in the second semester
- Strategies for planning and assigning individual and team work:
    - Providing weekly plans on what we should focus on and assign team members what their positions are.
- Strategies for keeping on task:
    - Collecting information during our meetings and post them through the group chat and highlight what to keep in mind before we head to our next meeting

Consequences for Not Adhering to Team Contract to handle infractions of any of the obligations of this team contract is to contact the individual regarding their performance and contribution.If this process tends to continue, we will contact our instructor about setting up what will happen next when one of the team members violates the team contract.

****
a) *I participated in formulating the standards, roles, and procedures as stated in this contract.*
b) *I understand that I am obligated to abide by these terms and conditions.*
c) *I understand that if I do not abide by these terms and conditions, I will suffer the consequences as stated in this contract.*

1) Jonathan Insyxiengmay   Date: 09/21/2022
2) Aaron Barvincak   Date: 09/21/2022
3) Alec Gilroy   Date: 09/21/2022
4) Brock Veatch   Date: 09/21/2022
5) Aryan Prajapati   Date: 09/21/2022
6) Hamza Shahid   Date: 09/21/2022