PURDUE UNIVERSITY | Elmore Family School of Electrical and Computer Engineering

ARES GROUP

Automated Radio Evaluation Suite
Antenna Measurement Tutorial

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1. Accessing the Antenna Tab

Upon launching the Automated Radio Evaluation Suite (ARES), you will be presented with the main interface. In the top-left corner, you will find three key tabs: **Info**, **Power Amplifier**, and **Antenna**. These tabs allow you to navigate between the different functionalities of the application. At the bottom of the screen, there are four useful hyperlinks:

- The **GitHub repository** for accessing the source code and contributing to the project.
- The **ReadMe file** provides detailed instructions and information about the application.
- The **Power Amplifier measurement tutorial**, offering step-by-step instructions for antenna testing.
- The **Antenna measurement tutorial**, offering step-by-step instructions for antenna testing.

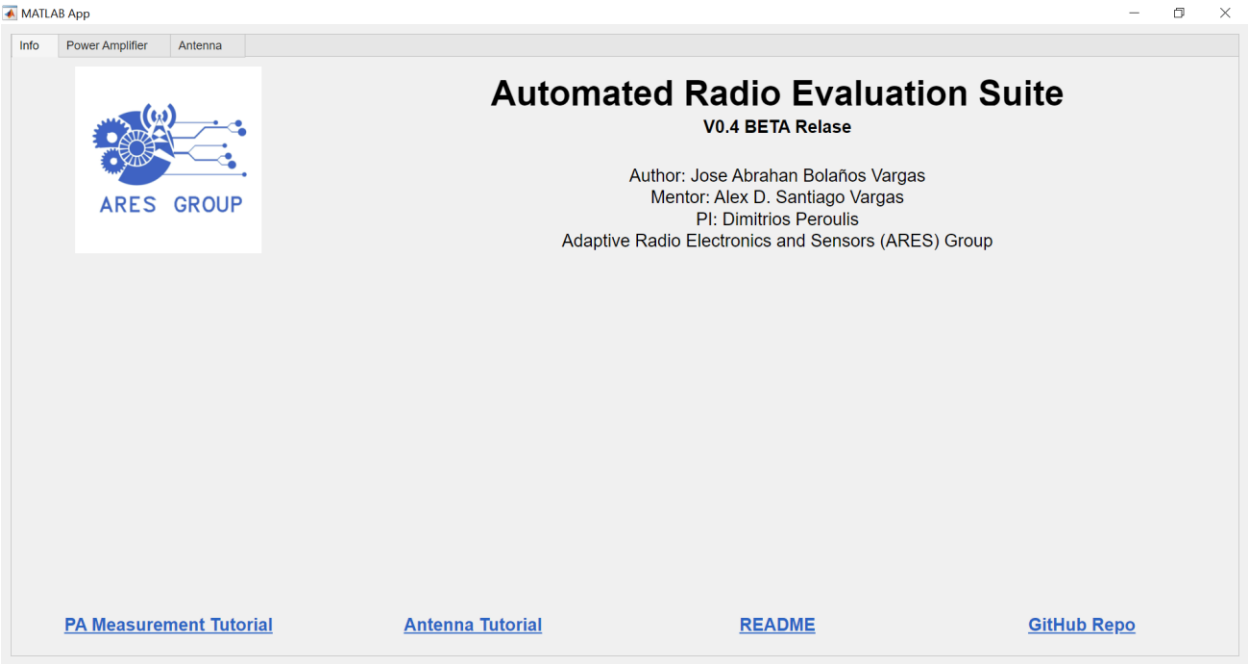

Figure 1: ARES Main Interface

To get started, navigate to the **Antenna** tab in the application. Upon opening, you will see the screen shown in **Figure 2.**

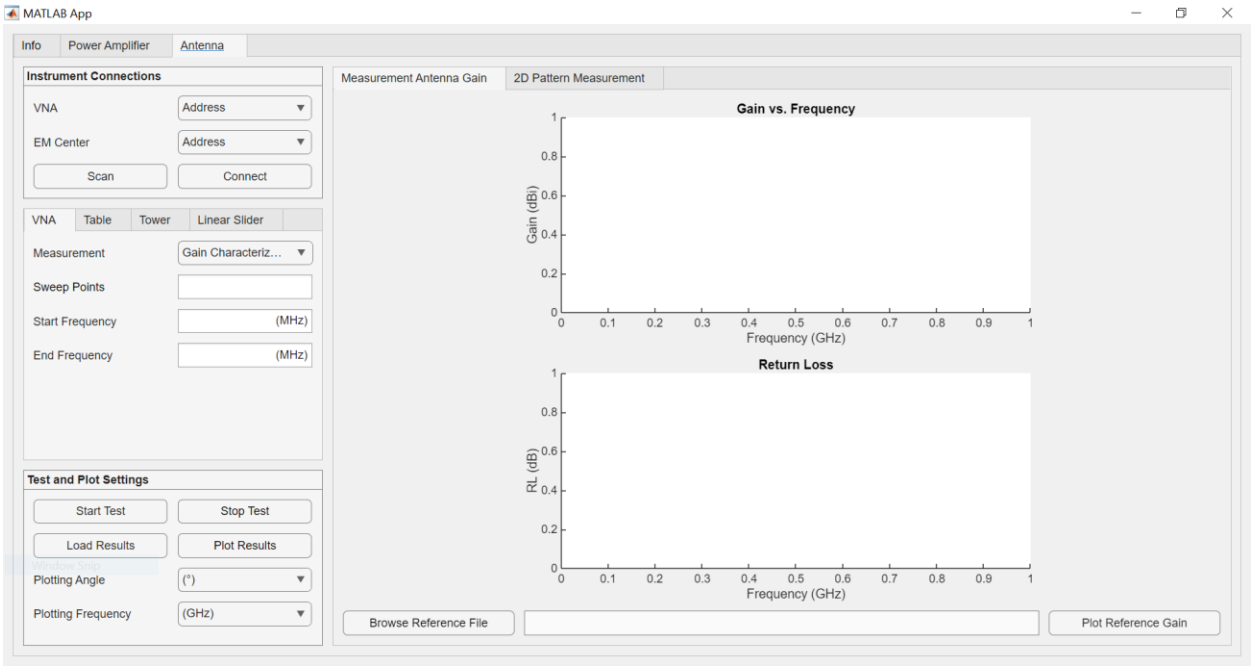

Figure 2: Antenna Measurement Tab

2. Establishing Instrument Connections

Scan Instrument Addresses:

- Click the **Scan** button to detect available VISA instrument addresses.
- The scan process takes approximately **30–60 seconds**.
- Once complete, the **Address** dropdown menu will be populated with detected instrument addresses, as shown in **Figure 3**.

Select Instrument Addresses:

- For each instrument (Vector Network Analyzer and EM Center), choose the correct address from the dropdown menu.
- To determine the correct address for your instrument, you can either check it in the Keysight Connection Expert software or find it displayed directly on the device's interface.

Connect to Instruments:

- After selecting the appropriate addresses, click the **Connect** button.
- The connection process is quick, and upon success:
  - The dropdown menus will become greyed out, as shown in **Figure 4**, indicating a successful connection.
  - The instruments are now ready to communicate with the application.

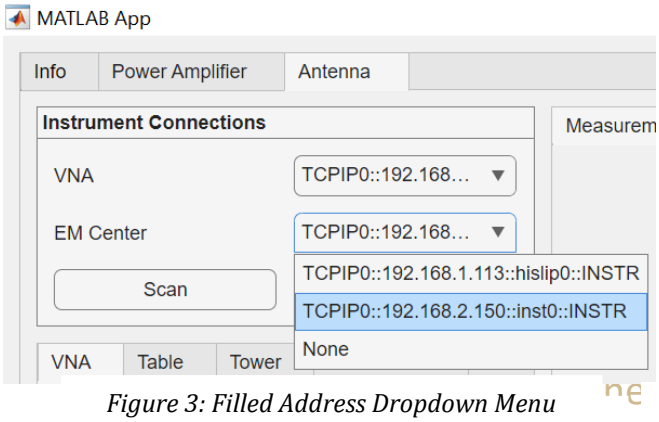

Figure 3: Filled Address Dropdown Menu

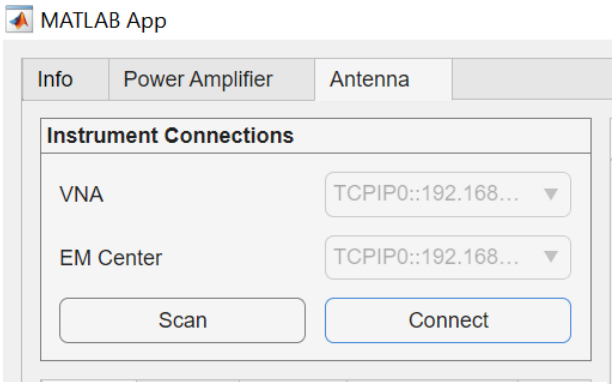

Figure 4: Successful Instrument Connection

Access the Linear Slider Tab:

Switch to the **Linear Slider** tab in the application below the Instrument Connections panel. Upon opening, you will see the interface shown in **Figure 5**.

- Most options will be greyed out, indicating that the instrument is not yet connected.

Establish the Connection:

- Click the **Connect** button.
- Upon successful connection:
    - The greyed-out options will become available for usage, the updated interface is shown in **Figure 6.**
    - The **Current Position** of the linear slider is displayed, the **Current Spacing** value is calculated and updated based on the slider's position.

Available Features After Connection:

- **Speed Preset Dropdown Menu:** Allows you to select the speed for slider movement, with the following options:
    - 1: Slowest speed
    - 8: Fastest speed
- **Current Position Field**: Displays the real-time position of the slider.
- **New Position Field**: Lets you enter a target position for the slider to move to, to use this feature:
    - Enter a target position within the range of 0 – 200 cm.
    - Press the **Move to Position Button**, making the slider seek the entered position.
    - As the slider moves to the target position, the Current Spacing will be adjusted and displayed to you in real-time.
- **Stop Button**: Allows you to stop the linear slider movement at any moment.

Setting the Antenna Offset Parameter:

- **The Antenna Offset Field** allows the user to enter the physical dimensions of the reference antenna. This value is essential to account for the additional spacing introduced by the reference antenna.
- **The Current Spacing** value is crucial for calculating the antenna gain. It is calculated by the application using the following formula:

$$\textbf{Current Spacing} = \textbf{LS Max Position} - \textbf{LS Current Position} + \textbf{Table Offset} + \textbf{Antenna Offset}$$

Where:

- **LS Max Position** is 2 meters (maximum position of the linear slider).
- **LS Current Position** is the actual position of the linear slider.
- **Table Offset** is a fixed value of 0.8062 meters, as measured in the chamber.
- **Antenna Offset** is the physical offset distance of the reference antenna, entered by the user.

It's important to accurately enter the **Antenna Offset** value because it directly influences the **Current Spacing**, which in turn is used in the antenna gain calculation. Proper use of this parameter ensures the accuracy of your antenna measurements.

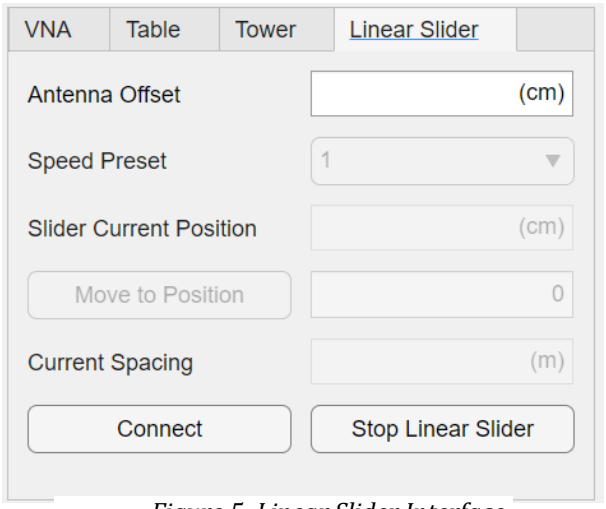

Figure 5: Linear Slider Interface

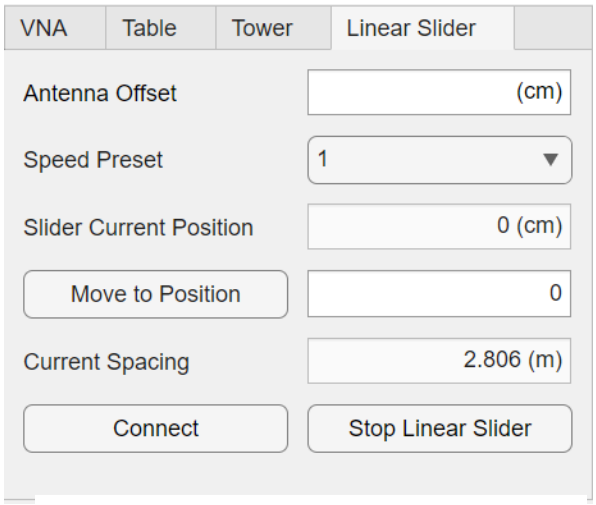

Figure 6: Successful Linear Slider Connection

4. Configure the EMCenter

Access the Turntable Tab:

- Navigate to the **Table Tab** in the application, located below the Instrument Connections panel.
- Upon opening, you will see the interface shown in **Figure 7**, which provides six configurable settings for the turntable.

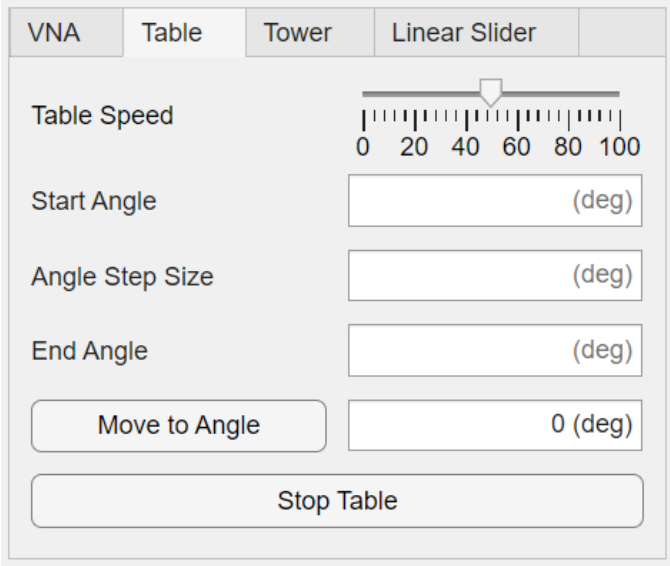

Figure 7: Turntable Interface

Adjust the Turntable Speed:

- Use the **Speed Slider** to control the rotation speed of the turntable.
    - The default speed is 50.
    - The speed range is 1 (slowest) to 100 (fastest).

Note: A slower speed is recommended for more precise measurements, while faster speeds can be used for initial testing or less sensitive patterns.

Manual Movement Controls:

- The application also allows manual movement of the turntable.
- **Move to Angle Field**: Enter a target angle to position the turntable without performing a measurement. To use this feature:
    - Enter the desired angle in the field.
    - Press the **Move to Angle Button**, making the turntable seek the specified angle.
- **Stop Button**: Press this button to halt the turntable immediately in case of an error or other issues.

Set Measurement Angles:

- **Use the following fields to configure the measurement angles for pattern tests:**
    - **Start Angle Field**: Enter the starting angle for the turntable. Acceptable values range from **-180° to +180°**.
    - **Angle Step Size Field:** Enter the step size for each angular increment.
    - **End Angle Field:** Enter the ending angle for the turntable. Acceptable values range from **-180° to +180°.**

Important:

1. The application was designed to work with angles in the range **-180° to +180°** for convenience.
2. Internally, the turntable operates using positive angles, so when a user enters **-180°**, the application automatically instructs the turntable to rotate to **+180°**.
3. For a full rotation pattern measurement, set the **Start Angle** to **-180°** and the **End Angle** to **+180°**. The turntable will complete a **0° to 360°** rotation, but the data will be saved with angles in **-180° to +180°** format for consistency.

Accessing and Utilizing the Tower Tab:

- Navigate to the **Tower Tab** in the application, located below the Instrument Connections panel.
- Upon opening, you will see an interface like the Turntable interface, as shown in **Figure 8.**

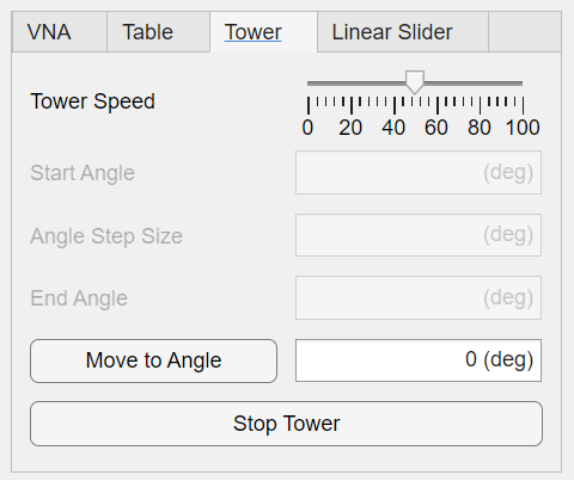

Figure 8: Tower Interface

Note: To adjust the tower speed or manually control the tower movement, refer to the previous instructions from step 4, as the functionality is identical. While most features in the **Tower Tab** mirror those in the **Table Tab**, please note that the measurement angles fields (**Start Angle**, **Angle Step Size**, and **End Angle**) are currently not implemented and will appear greyed out to indicate they are unavailable for configuration. The current version of the application supports manual movement only.

5. Configure the VNA and Select Type of Measurement

Access the VNA Tab:

- Navigate to the **VNA Tab** in the application, located below the Instrument Connections panel.
- Upon opening, you will see an interface with four configurable fields, as shown in **Figure 9.**

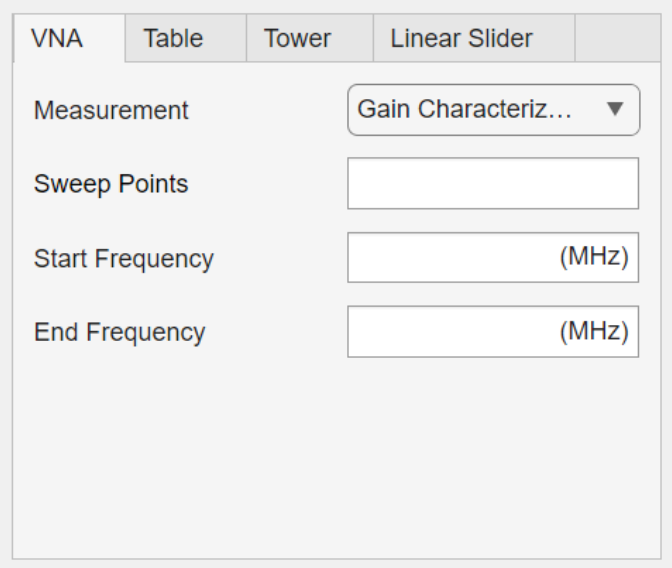

Figure 9: VNA Interface

Input VNA Settings:

- In the VNA Tab, configure the following fields to set up the Vector Network Analyzer:
    - **Sweep Points**: Enter the desired number of frequency sweep points.
    - **Starting Frequency:** Specify the lowest frequency in the sweep (in MHz).
    - **Ending Frequency:** Specify the highest frequency in the sweep (in MHz).
- Ensure that the chosen frequency range and number of sweep points align with what you want and what the VNA shows you if you first manually set up the VNA, as the code will overwrite with the values fed to it.

Select the Antenna Measurement Type:

- In the **Measurement Dropdown Menu**, choose on the following measurement options based on your testing requirements:
    1. **Gain Characterization:**
        - Use this option to measure **boresight gain**.
        - This measurement requires configuring both the VNA and Linear Slider settings and does not involve the EM Center.
    2. **Pattern Measurement**
        - Use this option to measure the full **radiation pattern** of the antenna.
        - This measurement requires configuring the VNA, the Linear Slider, and the EM Center settings (as detailed in step 4).

Configure the Reference Antenna:

For cases where the reference antenna is different from the test antenna, the application supports uploading a reference gain file specific to your reference antenna. This file provides the gain and frequency data required for the **Comparison Antenna Method** of calculating antenna gain. If the reference antenna and test antenna are identical, this step can be skipped, and the gain will be calculated using the **Two-Antenna Method (Friis Equation).**

Uploading the Reference Gain File:

- Navigate to the **Measurement Antenna Tab**, and locate the **Browse Reference File Button**, as shown in **Figure 10**.
- Click the button to open a file selection dialog box and choose the reference gain file from your device.
- After you have selected your file:

    1. The path and filename will appear in the adjacent field, allowing you to verify the correct file has been loaded. This file will automatically be used in the gain calculation.

    2. To visualize the reference gain data, click the **Plot Reference Gain Button** next to the file path field. This plots the gain vs. frequency, and the return loss data, as shown in **Figure 11**.

Reference File Requirements:

- The reference gain file must follow the application's required format, with the following column headers:
    1. Frequency (Hz)
    2. Gain (dBi)
    3. Return Loss (dB)
- If any of these fields are missing, the application will raise an error listing the missing fields. Ensure the file adheres to this format before uploading.

How Gain is Calculated:
The gain calculation depends on whether the antennas are identical or not.

- **Identical Antennas (Two-Antenna Method):**

- If no reference file is uploaded, the application assumes both antennas are identical and calculates gain using the **Friis Equation**:

$$Gain\ (dBi) = \frac{S21(dB) - Free\ Space\ Path\ Loss\ (dB)}{2}$$

- **Non-Identical Antennas (Comparison Antenna Method):**
  - If a reference file is uploaded, the gain is calculated by interpolating the reference antenna's gain data and subtracting it from the measured S21 and Free Space Path Loss:

$$Gain(dBi) = S21(dB) - Free\ Space\ Path\ Loss\ (dB) - Interpolated\ Reference\ Gain\ (dBi)$$

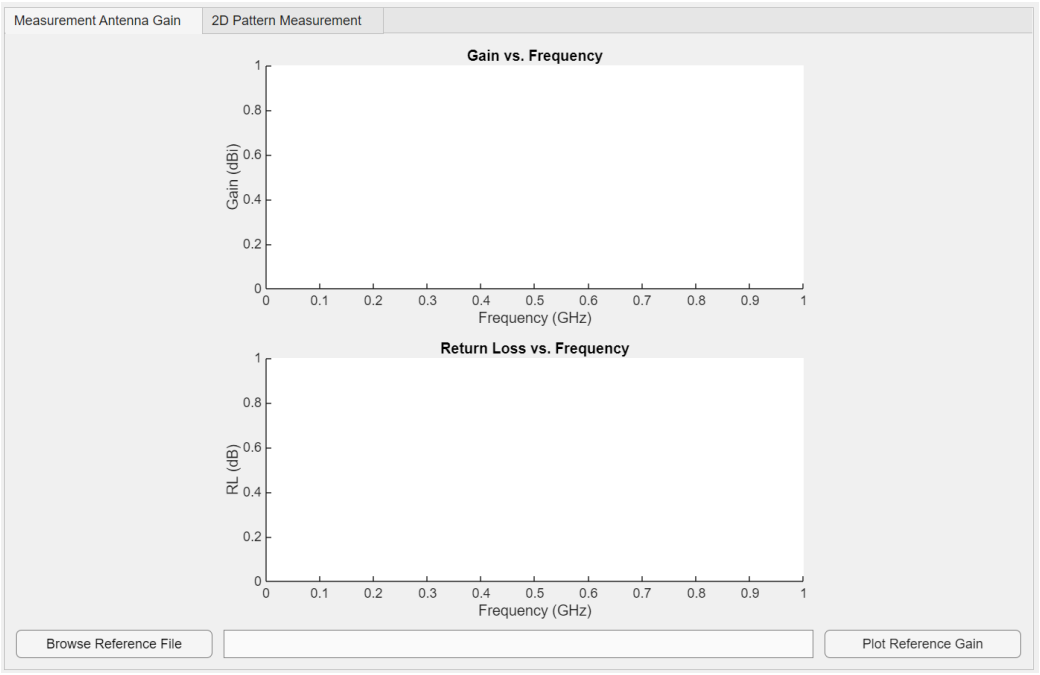

Figure 10: Measurement Antenna Tab

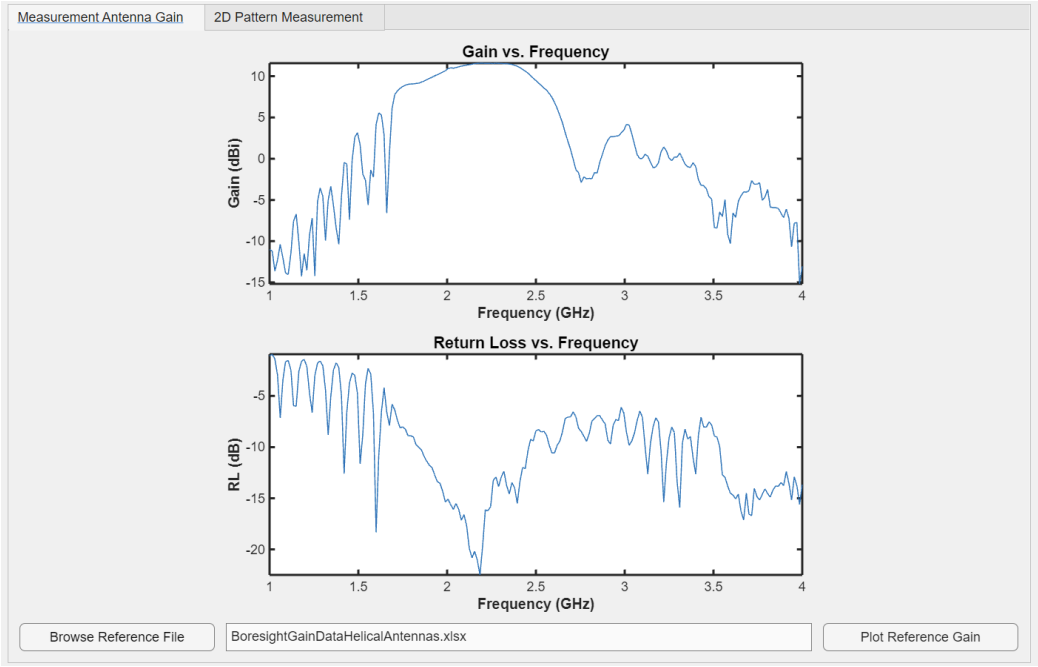

Figure 11: Example Reference File Successfully Uploaded and Plotted

6. Starting your Measurement, Saving, and Plotting the Results

Access the Test and Plot Settings Panel:

- Navigate to the **Test and Plot Settings Panel**, located in the bottom left of the application.
- This panel contains four buttons and two dropdown menus, as shown in **Figure 12.**

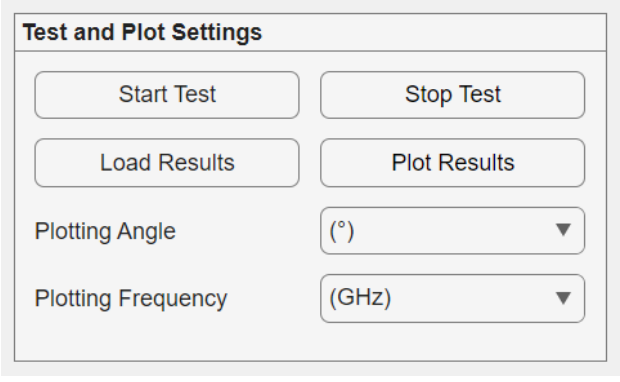

Figure 12: Test and Plot Settings

Starting and Stopping the Selected Measurement:

- **Starting the Measurement:**
    - Click the **Start Test Button** to initiate the selected test.
    - The test will run until it is manually stopped or until successful completion.
- **Stopping the Measurement:**
    - Click the **Stop Test Button** to stop the measurement and turntable movement.
    - Upon stopping the measurement, if data has already been collected, the application will prompt you asking to save or discard the partially collected data.

Common Test Times

- Test times will depend on the speed of the turntable and the total movement range of the test. The following are sample times of various measurement step sizes all measured with the default speed (50/100).
- **1-degree step size:** ~16 minutes
- **3-degree step size:** ~8 minutes
- **5-degree step size:** ~6 minutes

Saving the Test Results:

- After completing the measurement, the application will pop up a file save menu prompting the user to choose where to save the data, to specify the file format (CSV or Excel), and the filename.
- The application automatically checks if the data size is too big and will only allow you to save the data as a CSV file.
- The data will be saved with the following default column headers: **Azimuth Angles (deg)**, **Frequency (Hz)**, **Gain (dBi)**, and **Return Loss (dB)**.

Loading the Pattern Measurement Data:

- To plot the measured data, use the **Load Results Button** to upload the file containing the pattern measurement data.
- Upon clicking the button, a file selection dialog box will appear prompting you to choose the data file from your device.
- After you have selected the file and upon successful upload, the application will extract the angles and frequencies and populate the **Plotting Angle** and **Plotting Frequency** dropdown menus as shown in **Figure 13.**

Pattern Measurement Data File Requirements:

- The pattern measurement data file must follow the application's required format, with the following column headers:
    1. Azimuth Angles (deg)
    2. Frequency (Hz)
    3. Gain (dBi)
    4. Return Loss (dB)

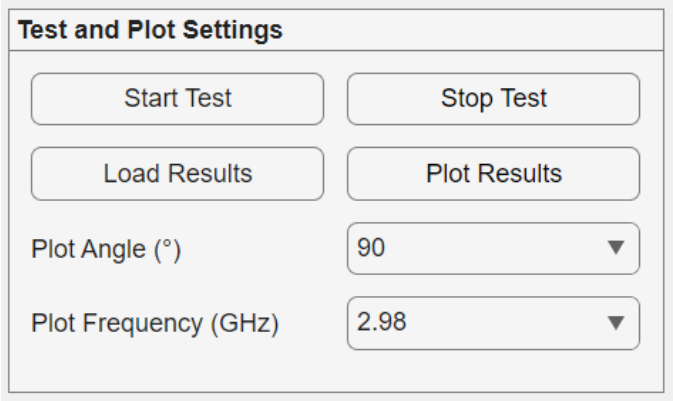

Figure 13: Test and Plot Settings with Updated Plotting Parameters

Plotting the Pattern Measurement Data:

- Navigate to the **2D Pattern Measurement Tab**.
- Once the **Plotting Angle** and **Plotting Frequency** dropdown menus are updated with the relevant data. Select an angle to visualize gain vs. frequency and select a frequency to visualize gain vs. angle.
- Use the **Plot Results Button** to generate the following plots based on the selected data:
    - Gain vs. Frequencies at the specified angle.
    - Gain vs. Angles at the specified frequency.
    - Return Loss vs. Frequencies at the specified angle.
    - 2D Radiation Pattern (Polar Plot)

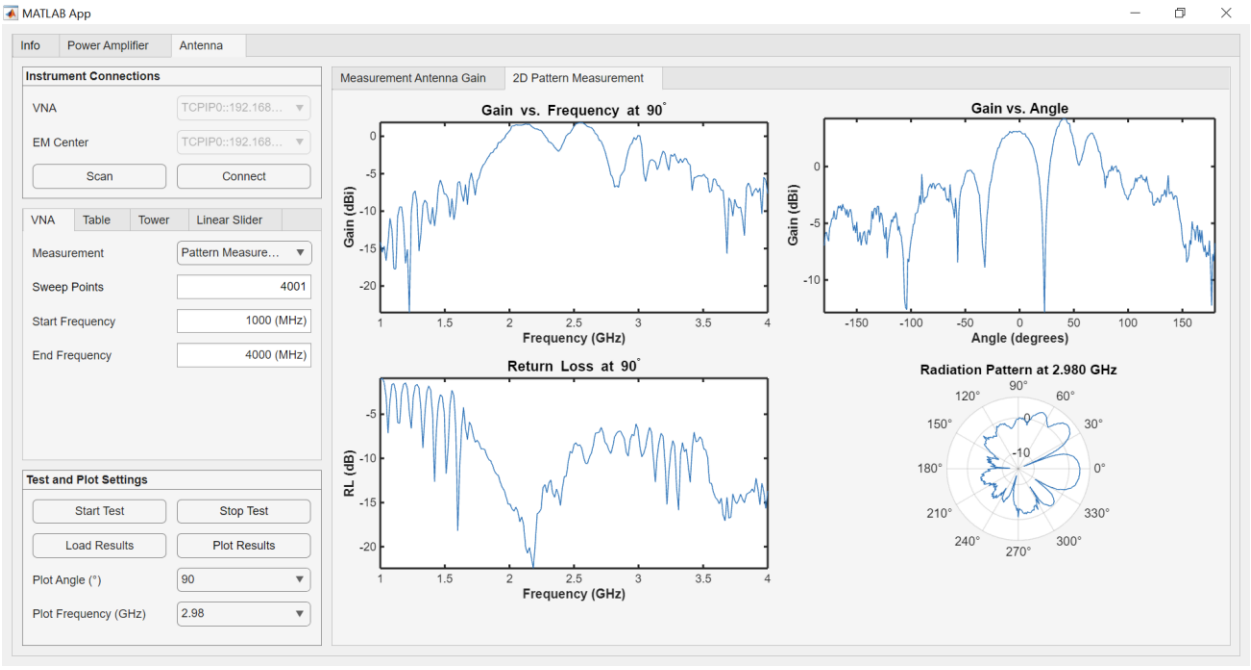

Figure 14: Antenna Tab with Populated Plots