# Generic IoT Device

# Antenna Characterization

Prepared for Generic Co.

# Revision History

| Rev. | Author | Revision Changes | Date |
|---|---|---|---|
| 1.0 | CAE Team | Initial release. | 18 March 2026 |
| | | | |
| | | | |
| | | | |

# Table of Contents

**1. Conclusion and Recommendations.... 4**
1.1 2.4GHz - Frequency Band Analysis.... 4
1.1.1 Analysis & Antenna Performance Results.... 4
1.1.2 Conclusion.... 4
1.2 5GHz Band Analysis.... 4
1.2.1 Analysis & Antenna Performance Results.... 5
1.2.2 Conclusion.... 5
1.3 915MHz - Frequency Band Analysis.... 6
1.3.1 Analysis & Antenna Performance Results.... 6
1.3.2 Conclusion.... 6
1.4 Recommendations.... 7
**2. Methodology.... 8**
2.1 Test Chamber.... 8
2.2 Actions Taken.... 8
2.3 How Test Results were Calculated.... 8
2.3.1 Explanation of Antenna Gain Measurements.... 9
2.3.2 Antenna Average Measured Gain.... 9
2.3.3 Antenna Peak Measured Gain.... 9
2.3.4 Antenna Efficiency.... 10
**3. Return Loss Measurement.... 11**
3.1 How Return Loss is Calculated.... 11
3.2 Test Results.... 12
**4. RF Radiation Patterns.... 15**
4.1 Device Under Test Setup & Orientation.... 15
4.2 Polarized Average and Peak Gain Measurements.... 16
4.2.1 Measured Gain Values.... 16
4.2.2 2D Gain Plots.... 18
4.2.3 Vertical Polarization Gain Plots — 2.4GHz Band.... 21
4.2.4 Horizontal Polarization Gain Plots — 2.4GHz Band.... 24
4.2.5 Vertical Polarization Gain Plots — 5GHz Band.... 26
4.2.6 Horizontal Polarization Gain Plots — 5GHz Band.... 30
4.2.7 Vertical Polarization Gain Plots — 915MHz Band.... 33
4.2.8 Horizontal Polarization Gain Plots — 915MHz Band.... 34
4.3 RF Pattern - Conclusions.... 35
**Appendix 1: Brief Explanation of Piper Chamber.... 36**
**Appendix 2: Brief Description of RF Polarization.... 39**

# 1. Conclusion and Recommendations

## 1.1 2.4GHz - Frequency Band Analysis

### 1.1.1 Analysis & Antenna Performance Results

Table 1.1.1 provides a summary of several key Generic IoT Device antenna performance measurements in the 2.4GHz band:

Table 1.1.1

| **Antenna Performance Measurements** | | | | | | |
|---|---|---|---|---|---|---|
| **Antenna Type** | Dipole | | | | | |
| | **Measured Values** | | | | | |
| | **2412 MHz** | | **2442 MHz** | | **2472 MHz** | |
| **Parameter** | **Value** | **Unit** | **Value** | **Unit** | **Value** | **Unit** |
| Average Gain | -2.113 | dBi | -1.946 | dBi | -1.841 | dBi |
| Peak Gain | 5.78 | dBi | 5.69 | dBi | 6.02 | dBi |
| Antenna Efficiency | 63.83 | % | 69.526 | % | 76.74 | % |
| Return Loss | 14.315 | dB | 10.909 | dB | 8.321 | dB |

**Note:** Gain measurements are within ±1 dB.

### 1.1.2 Conclusion

The 2.4 GHz dipole antenna efficiency is excellent. The return loss is good to acceptable across the band up to the higher channels, where the return loss is considered acceptable.

## 1.2 5GHz Band Analysis

### 1.2.1 Analysis & Antenna Performance Results

Table 1.2.1 provides a summary of several key EverScent antenna performance measurements:

Table 1.2.1

| **Antenna Type** | Dipole | | | | | |
|---|---|---|---|---|---|---|
| | **Measured Values** | | | | | |
| | **5170 MHz** | | **5500 MHz** | | **5875 MHz** | |
| **Parameter** | **Value** | **Unit** | **Value** | **Unit** | **Value** | **Unit** |
| Average Gain | -1.14 | dBi | -2.00 | dBi | -1.30 | dBi |
| Peak Gain | 6.84 | dBi | 6.03 | dBi | 7.29 | dBi |
| Antenna Efficiency | 77.2 | % | 65.8 | % | 77 | % |
| Return Loss | 25.1 | dB | 13.9 | dB | 15.0 | dB |

**Note:** Gain measurements are within ±1 dB.

### 1.2.2 Conclusion

The 5GHz dipole antenna efficiency is excellent. The return loss is good to acceptable across the band up to the higher channels, where the return loss is considered acceptable.

## 1.3 915MHz - Frequency Band Analysis

### 1.3.1 Analysis & Antenna Performance Results

Table 1.2.1 provides a summary of several key Generic IoT Device antenna performance measurements in the 915MHz band:

Table 1.3.1

| **Antenna Type** | Dipole | | | | | |
|---|---|---|---|---|---|---|
| | **Measured Values** | | | | | |
| | **-** | | **915 MHz** | | **-** | |
| **Parameter** | **Value** | **Unit** | **Value** | **Unit** | **Value** | **Unit** |
| Average Gain | - | dBi | -8.112 | dBi | - | dBi |
| Peak Gain | - | dBi | -2.71 | dBi | - | dBi |
| Antenna Efficiency | - | % | 23.255 | % | - | % |
| Return Loss | - | dB | 4.739 | dB | - | dB |

**Note:** Gain measurements are within ±1 dB.

### 1.3.2 Conclusion

The 900 MHz dipole antenna efficiency at the higher frequencies of the band is very poor and the return loss at the higher frequencies of the band is poor.

## 1.4 Recommendations

Recommendations for the 2.4GHz/5GHz antenna are minimal. Shortening the dipole antenna could tune the antenna to have a return loss of 10 dB or more across the whole band. This would give the antenna 90% or more of the radio power across the whole band.

The 900 MHz antenna recommendations are based on the assumption that this is a Z-Wave radio, and depends on the countries in which this product is being sold. If this device is being sold in the United States, we recommend shortening the antenna to tune it for United States frequencies. If this device is being sold in Asia or Europe, we recommend tuning the antenna by lengthening it. If this device is being sold worldwide, we recommend using a wider band antenna.

Because both radios are modules, it is not possible to tune the antennas with lumped elements. The only options, therefore, are to find different antennas or to length match the antennas for the frequencies of interest.

# 2. Methodology

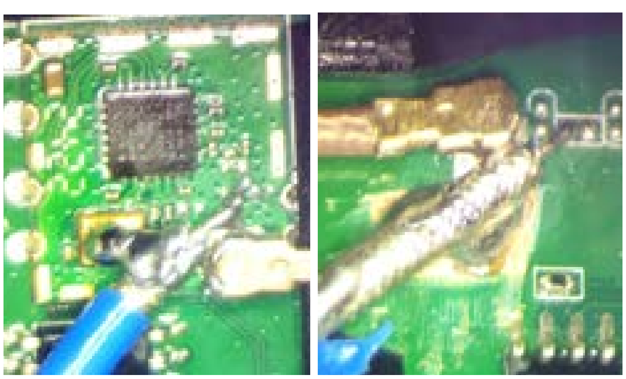
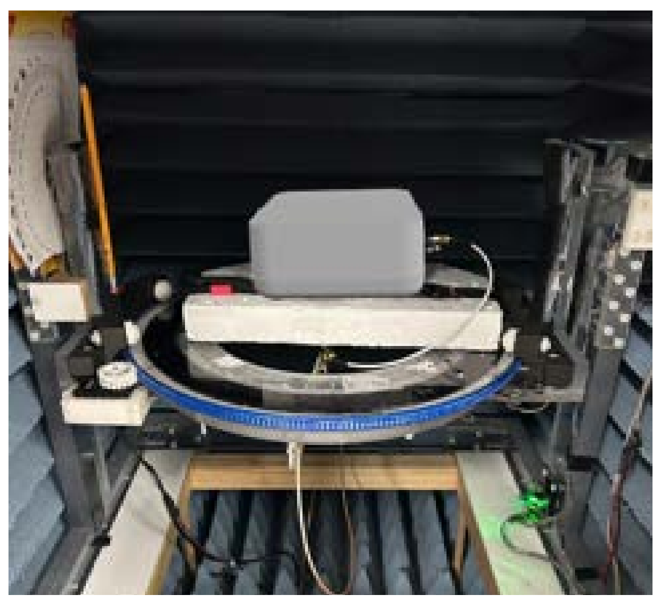
## 2.1 Test Chamber

All of the testing was performed in CAE's custom anechoic chamber (the "Piper Chamber"). Please see Appendix 1 for a description of this chamber and generally how it works.

## 2.2 Actions Taken

The Generic IoT Device device was prepared for testing, and was tested, as follows:

1. The Generic IoT Device device was partially disassembled and the antennas were disconnected from the radio.
2. A U.FL-to-SMA adapter was connected directly to the antenna, as shown in Fig. 2-1.
3. The Generic IoT Device device was placed on its side in the Piper Chamber, strapped down, and supported, as shown in Fig. 2-2.
4. The antenna was connected to the output of the Piper Chamber's signal generator, which provided the RF signal for testing.
5. The antennas were tested at 2412 MHz, 2442 MHz, 2472 MHz, 5170 MHz, 5500 MHz, and 5875 MHz and 915MHz for both vertical and horizontal polarization power.

|  |  |
|---|---|
| **Fig. 2-1 Generic IoT Device antenna connections** | **Fig. 2-2 Generic IoT Device placement in chamber** |

## 2.3 How Test Results were Calculated

The results described in this report were obtained and calculated as follows:

### 2.3.1 Explanation of Antenna Gain Measurements

Each scan in the Piper Chamber produces the gain of the tested antenna, in dBi, for 1000 points equally distributed around a sphere. The gain in dBi at each point is how much power is transmitted in that direction relative to a perfect isotropic antenna. An isotropic antenna is a theoretical antenna that radiates power equally in every direction. A measured gain of 0 dBi means that the measured antenna radiated the same amount of power in the measured direction as an isotropic antenna would have. A negative dBi value indicates the measured antenna radiated less than an isotropic antenna would have radiated, and a positive value indicates the measured antenna radiated more than an isotropic antenna would have radiated.

### 2.3.2 Antenna Average Measured Gain

To calculate the average measured gain, each measurement is converted to a linear gain factor using the equation:

$$Gain\ (linear)\ =\ 10^{(Gain\ (dBi)/10)}$$

Next, the average of the linear gain factors is calculated. This average is then converted back into a logarithmic gain factor using the equation:

$$Average\ Gain\ (dBi)\ =\ 10\ \cdot\ log_{10}(Average\ Gain\ (linear))$$

### 2.3.3 Antenna Peak Measured Gain

The peak antenna gain is measured in both the horizontal and vertical planes. Each plane will have an angle with the highest amount of power in that plane. The plane with the highest amount of power at any angle will be the peak gain of the antenna.

### 2.3.4 Antenna Efficiency

Antenna efficiency is the ratio between power delivered to the antenna and power radiated from the antenna, expressed as a percentage. The Piper Chamber spectrum analyzer transmits a 0 dBm (1 mW) signal to the antenna. Using return loss, we can calculate how much of this power makes it to the antenna. The total power radiated is equal to the average measured gain. With all of these values, efficiency can be calculated as follows:

$$Efficiency\ (\%) \ = \ 100 \cdot \frac{Average\ Gain\ (linear)}{(1-(10^{-Return\ Loss\ (dB)/10})) * Total\ Transmit\ Power\ (1\ mW)}$$

As a general rule, antenna efficiency values are rated as described in Table 2.3.4a.

Table 2.3.4a. Antenna Efficiency Values and What They Mean

| Antenna Efficiency (%) | General "Rating" |
|---|---|
| below 30% | Very Poor |
| 30% | Poor |
| 40% | Good |
| 50%+ | Excellent |

Table 2.3.4b shows where the test results for the GenericIoT Device device's 2.4 GHz and 915 MHz antennas appear relative to those ratings.

Table 2.3.4b. Frequency Related - Tested Antenna Efficiency Values

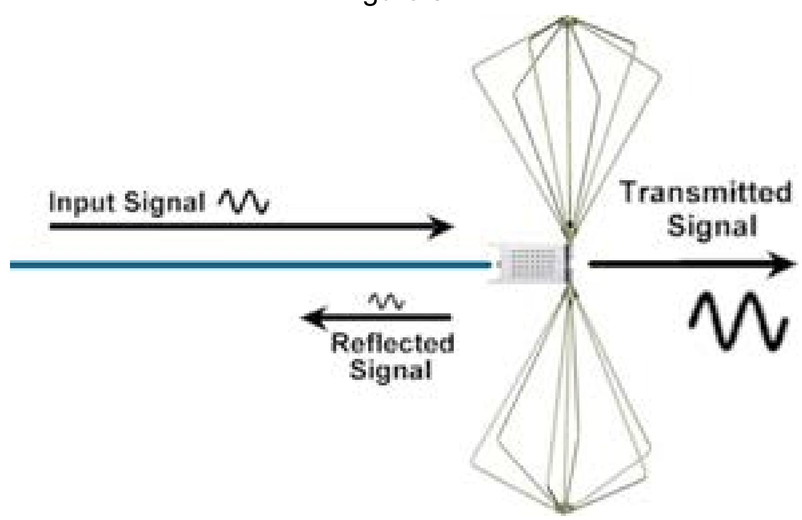
| **Frequency (MHz)** | **Antenna Efficiency (%)** | **General Rating** |
|---|---|---|
| 2412 | 63.838 | Excellent |
| 2442 | 69.526 | Excellent |
| 2472 | 76.748 | Excellent |
| 5170 | 77.2% | Excellent |
| 5500 | 65.8% | Excellent |
| 5875 | 77.0% | Excellent |
| 915 | 23.255 | Poor |

# 3. Return Loss Measurement

## 3.1 How Return Loss is Calculated

A return loss measurement shows how much power is reflected back from the antenna. See Figure 3.1.

Figure 3.1




The greater the value of return loss, the less reflected power. See Table 3.1.

Table 3.1. Sample Return Loss Values and What They Mean

| Return Loss (dB) | % Power Reflected (approximate) | General “Rating” |
|---|---|---|
| 20 dB | 1% | Excellent |
| 15 dB | 3% | Good |
| 10 dB | 10% | Acceptable |
| 6 dB | 25% | Poor |
| 3 dB | 50% | Very Poor |

## 3.2 Test Results

Table 3.2.1 Generic IoT Device VNA Measurements (2.4GHz Band)

| Frequency (MHz) | Return Loss (dB) | % Power Reflected | General Rating |
|---|---|---|---|
| 2412 | 14.315 | 3.70 | Good |
| 2442 | 10.909 | 8.11 | Acceptable |
| 2472 | 8.321 | 14.72 | Acceptable |

Figure 3.2.1 provides a graph of the return loss parameters across the band. Please note that the values are inversed–that is:

Return Loss (dB) = –Reflection Coefficient (dB)

**Figure 3.2.1 Generic IoT Device Reflection Coefficient in dB**

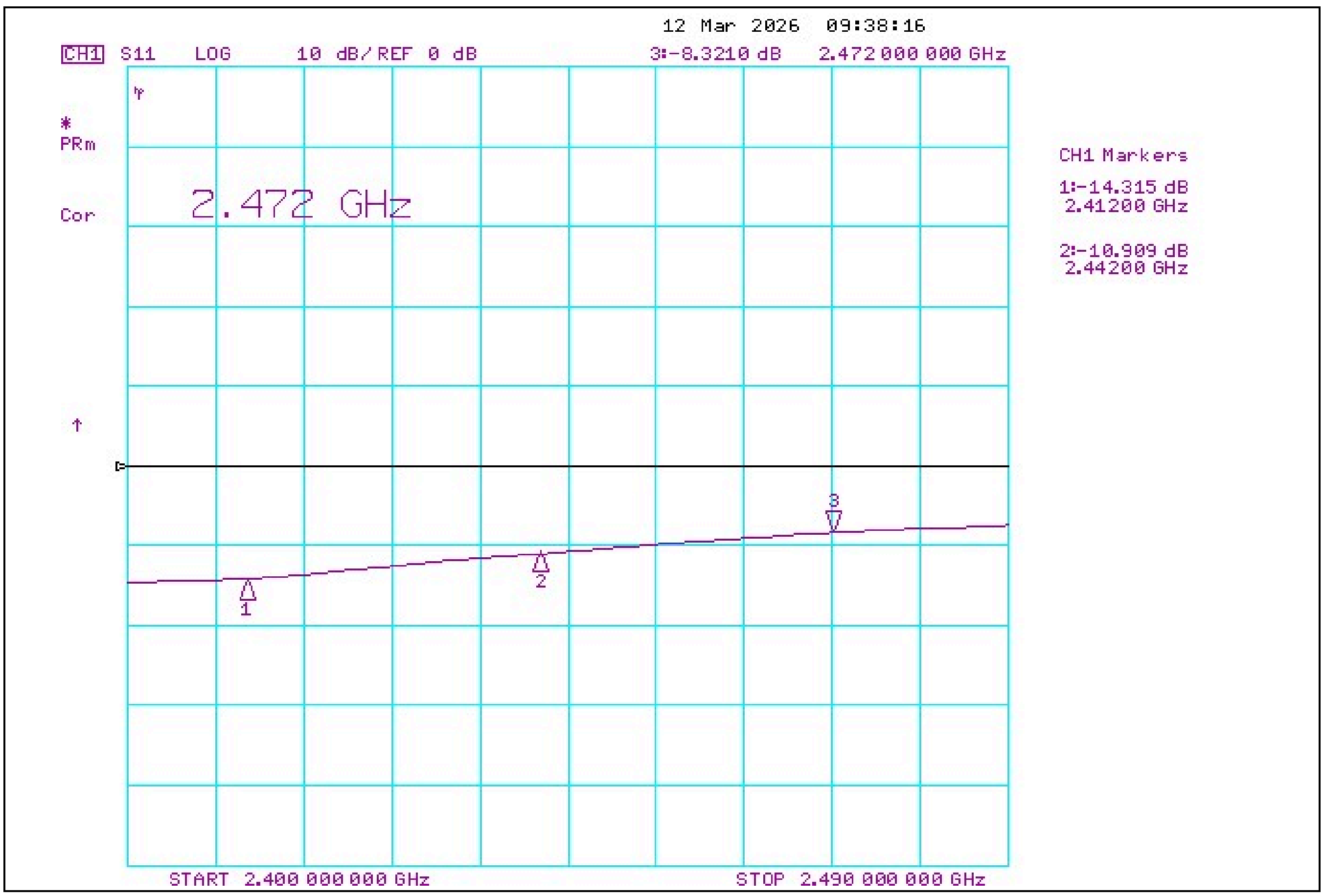


Table 3.2.2 Generic IoT Device VNA Measurements (5 GHz Band)

| **Frequency (MHz)** | **Return Loss (dB)** | **% Power Reflected** | **General Rating** |
|---:|---:|---:|---:|
| 5170 | 25.08 | 0.31% | Excellent |
| 5500 | 13.88 | 4.09% | Very Good |
| 5875 | 14.97 | 3.18% | Very Good |

Figure 3.2.2 provides a graph of the return loss parameters across the band. Please note that the values are inversed–that is:

Return Loss (dB) = –Reflection Coefficient (dB)

**Figure 3.2.2 Generic IoT Device Reflection Coefficient in dB**

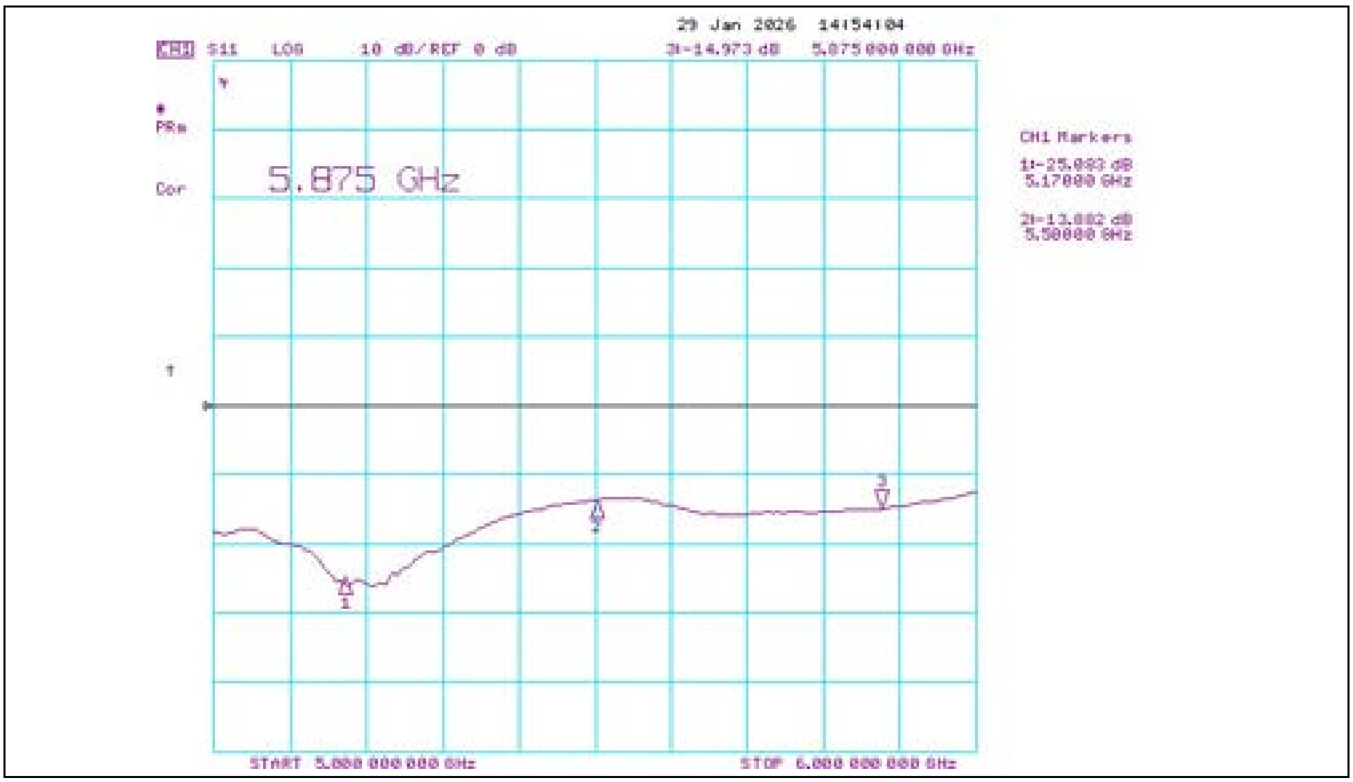


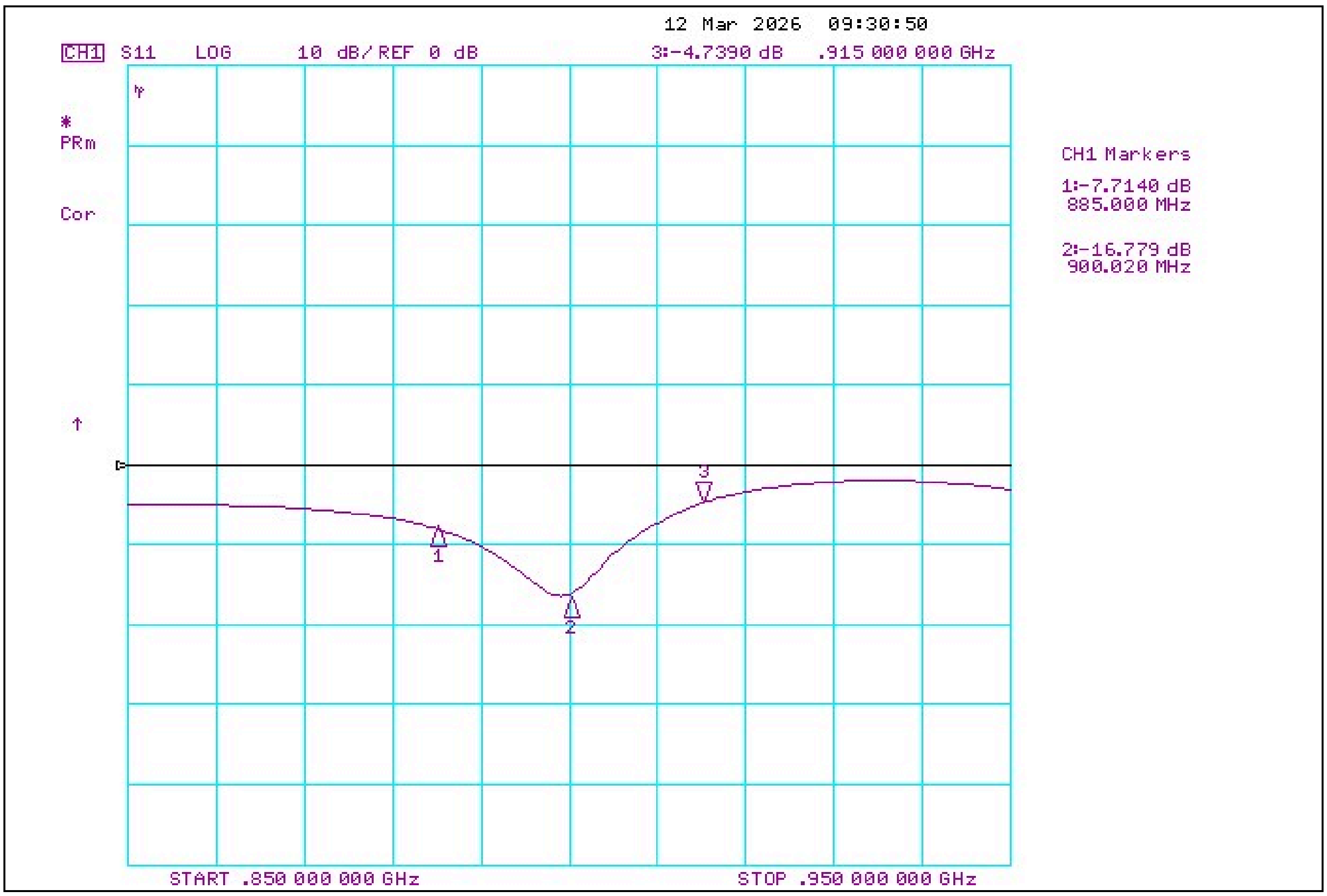
Table 3.2.2 Generic IoT Device VNA Measurements (915MHz Band)

| **Frequency (MHz)** | **Return Loss (dB)** | **% Power Reflected** | **General Rating** |
|---:|---:|---:|---|
| 885 | 7.714 | 16.93 | Acceptable |
| 900 | 16.779 | 2 | Excellent |
| 915 | 4.739 | 33.57 | Very Poor |

Figure 3.2.2 provides a graph of the return loss parameters across the band. Please note that the values are inversed–that is:

Return Loss (dB) = –Reflection Coefficient (dB)

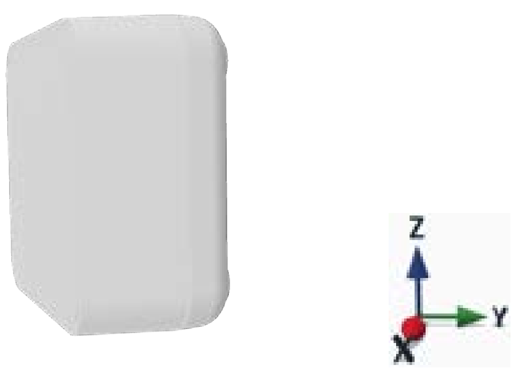
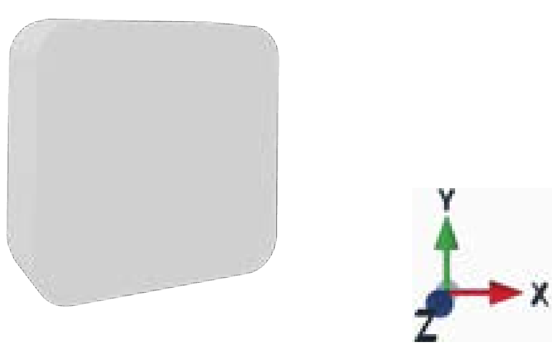
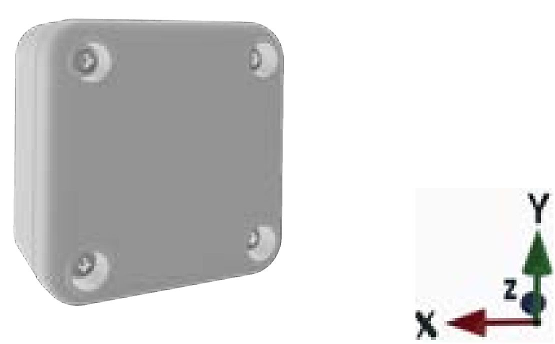
**Figure 3.2.2 Generic IoT Device Reflection Coefficient in dB**



# 4. RF Radiation Patterns

## 4.1 Device Under Test Setup & Orientation

The six principal orientations for the Generic IoT Device device are: Front, Back, Left, Right, Top and Bottom all corresponding to the placement of the device under test as shown in the following photographs:

| **Figure 4-1. Orientation from Front** | **Figure 4-2. Orientation from Back** |
|---|---|
|  |  |
| **Figure 4-3. Orientation from Right** | **Figure 4-4. Orientation from Left** |
|  |  |
| **Figure 4-5. Orientation from Top** | **Figure 4-6. Orientation from Bottom** |
|  |  |

## 4.2 Polarized Average and Peak Gain Measurements

The RF radiation patterns presented below show antenna gain (dBi) performance with:

(i) The antenna of the Generic IoT Device device in six principal orientations; and

(ii) The receiving horn antenna positioned for vertically polarized RF waves and then for horizontally polarized RF waves.

*(please see Appendix 2 for a brief description of radio wave polarization)*

### 4.2.1 Measured Gain Values

Table 4.2.1a

| Polarized Average and Peak Gain Measurements - 2.4GHz Band | | | | | | |
|---|---|---|---|---|---|---|
| | **Measured Values** | | | | | |
| | **2412 MHz** | | **2442 MHz** | | **2472 MHz** | |
| **Parameter** | **Value** | **Unit** | **Value** | **Unit** | **Value** | **Unit** |
| Average Gain (Vertical) | -7.37 | dBi | -7.33 | dBi | -7.14 | dBi |
| Peak Gain (Vertical) | 4.11 | dBi | 4.80 | dBi | 6.02 | dBi |
| Average Gain (Horizontal) | -3.65 | dBi | -3.43 | dBi | -3.36 | dBi |
| Peak Gain (Horizontal) | 5.78 | dBi | 5.69 | dBi | 5.72 | dBi |

**Note:** Gain measurements are within ±1 dB.

Table 4.2.1b

| Polarized Average and Peak Gain Measurements - 5GHz Band | | | | | | |
|---|---|---|---|---|---|---|
| | **Measured Values** | | | | | |
| | **5170 MHz** | | **5500 MHz** | | **5875 MHz** | |
| **Parameter** | **Value** | **Unit** | **Value** | **Unit** | **Value** | **Unit** |
| Average Gain (Vertical) | -6.13 | dBi | -7.16 | dBi | -6.33 | dBi |
| Peak Gain (Vertical) | 5.59 | dBi | 4.14 | dBi | 3.22 | dBi |
| Average Gain (Horizontal) | -2.79 | dBi | -3.58 | dBi | -2.94 | dBi |
| Peak Gain (Horizontal) | 6.84 | dBi | 6.03 | dBi | 7.29 | dBi |

**Note:** Gain measurements are within ±1 dB.

Table 4.2.1c

| Polarized Average and Peak Gain Measurements - 915MHz Band | | | | | | |
|---|---|---|---|---|---|---|
| | **Measured Values** | | | | | |
| | **-** | | **915 MHz** | | **-** | |
| **Parameter** | **Value** | **Unit** | **Value** | **Unit** | **Value** | **Unit** |
| Average Gain (Vertical) | - | dBi | -11.96 | dBi | - | dBi |
| Peak Gain (Vertical) | - | dBi | -2.71 | dBi | - | dBi |
| Average Gain (Horizontal) | - | dBi | -10.42 | dBi | - | dBi |
| Peak Gain (Horizontal) | - | dBi | -3.63 | dBi | - | dBi |

**Note:** Gain measurements are within ±1 dB.

### 4.2.2 2D Gain Plots

Table 4.2.2a

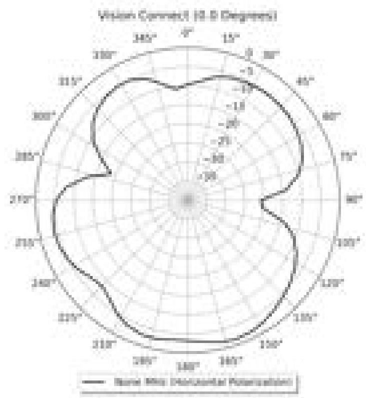
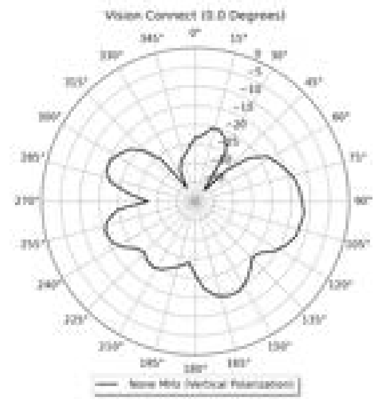
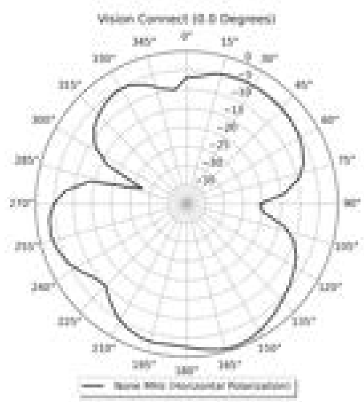
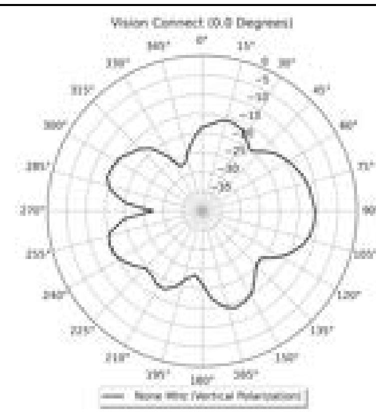
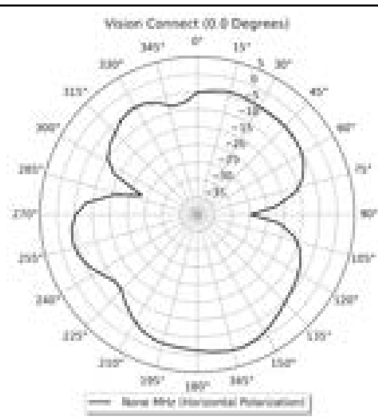
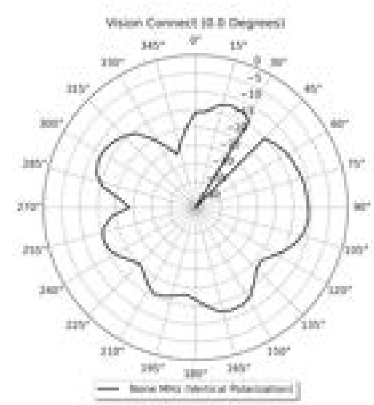
| 2.4GHz Band - 2D Gain Plots | | |
|---|---|---|
| | Horizontal Polarization | Vertical Polarization |
| **2412MHz** |  |  |
| **2442MHz** |  |  |
| **2472MHz** |  |  |

Table 4.2.2b

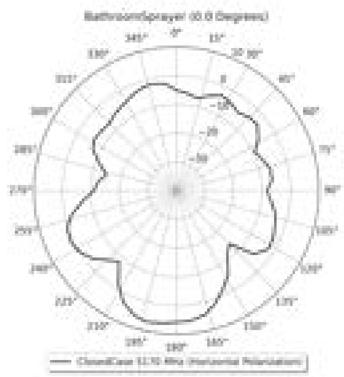
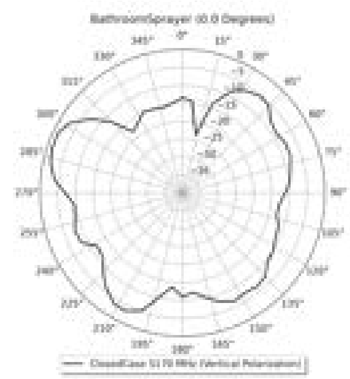
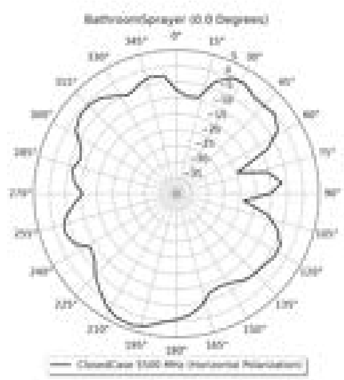
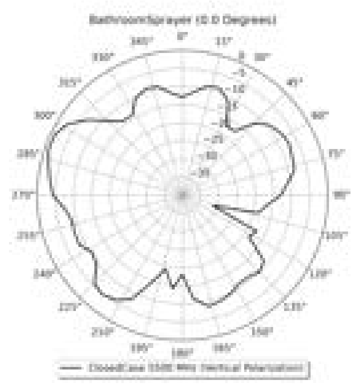
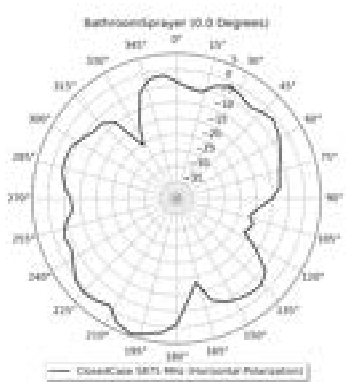
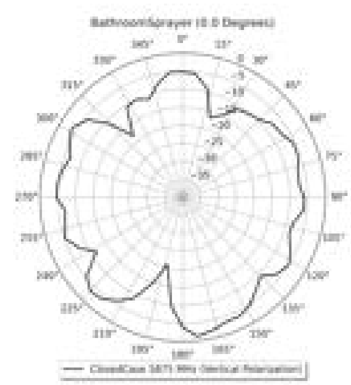
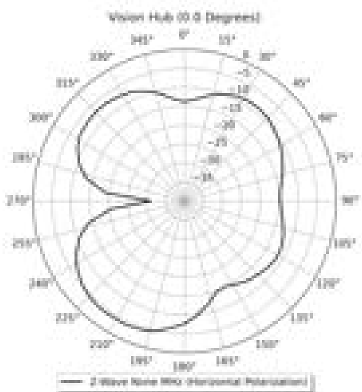
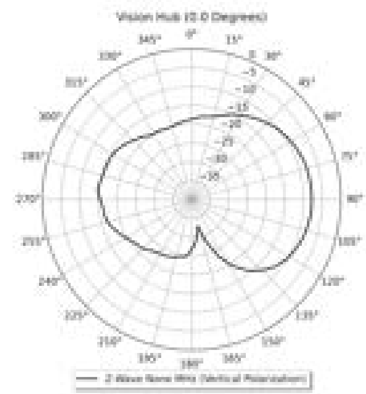
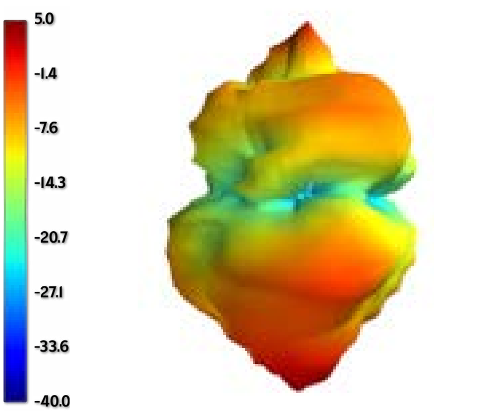
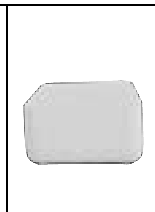
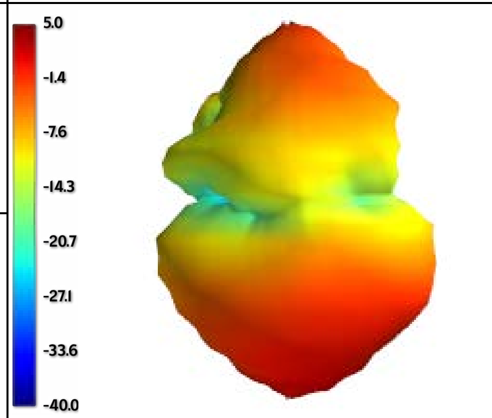
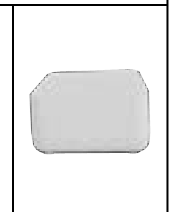
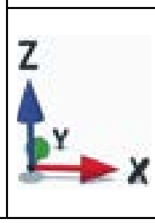
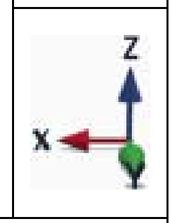
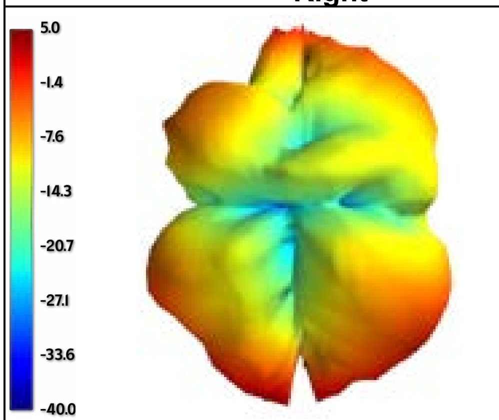
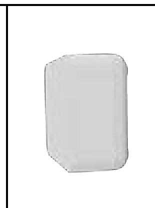
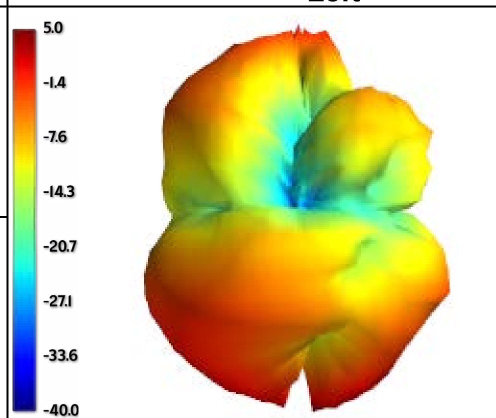
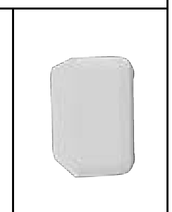
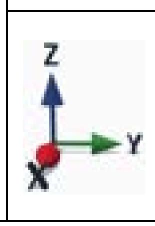
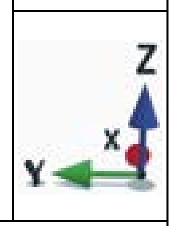
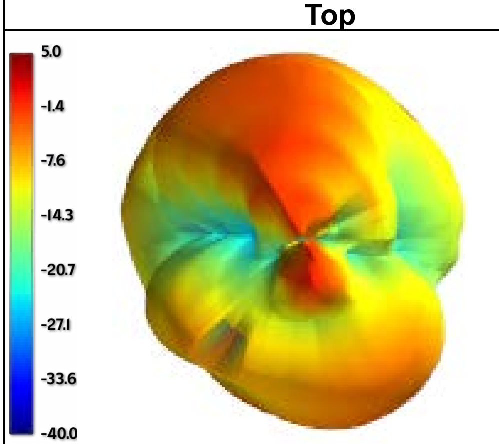
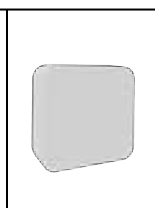
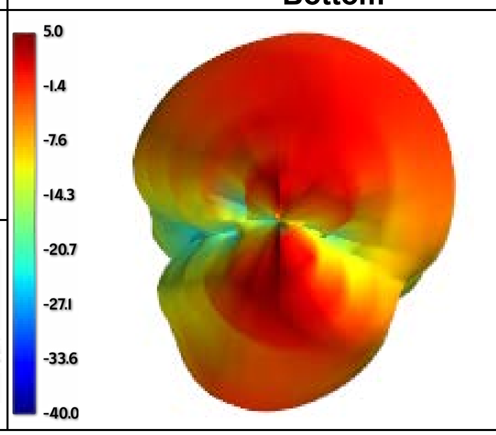
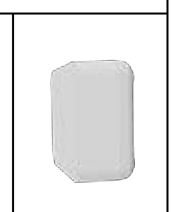
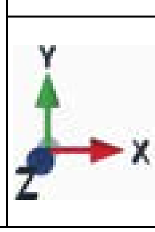
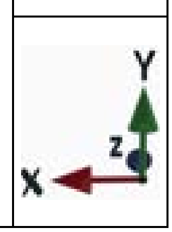
| 5GHz Band - 2D Gain Plots | | |
|---|---|---|
| | Horizontal Polarization | Vertical Polarization |
| 5170MHz |  |  |
| 5500MHz |  |  |
| 5875MHz |  |  |

Table 4.2.2c

| **915 MHz - 2D Gain Plots** | | |
|---|---|---|
| | Horizontal Polarization | Vertical Polarization |
| **915MHz** |  |  |

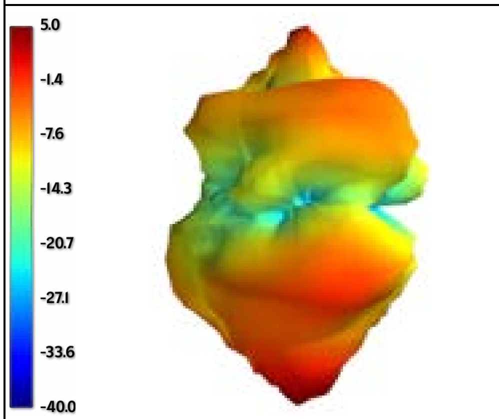
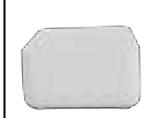
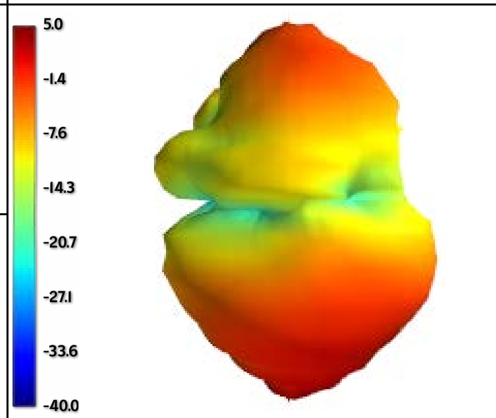
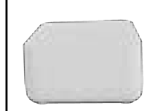
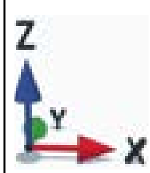
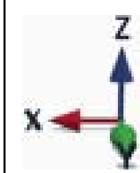
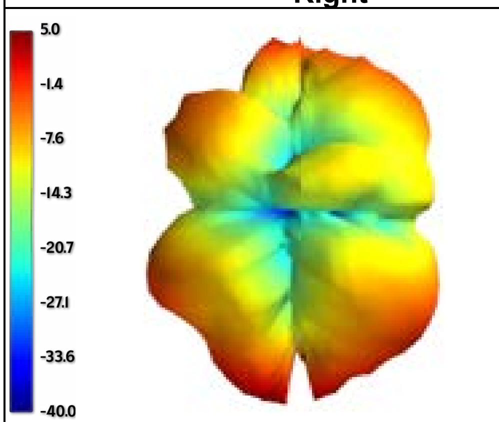
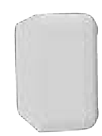
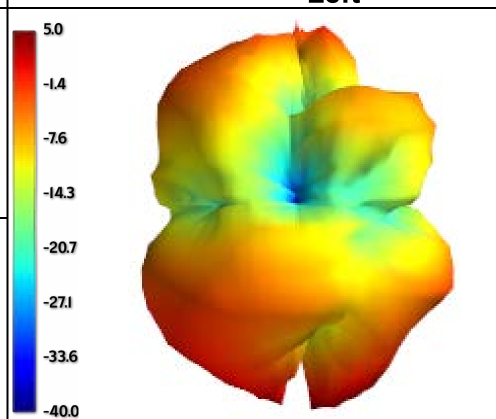
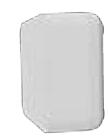
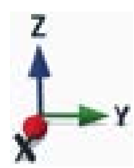
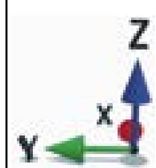
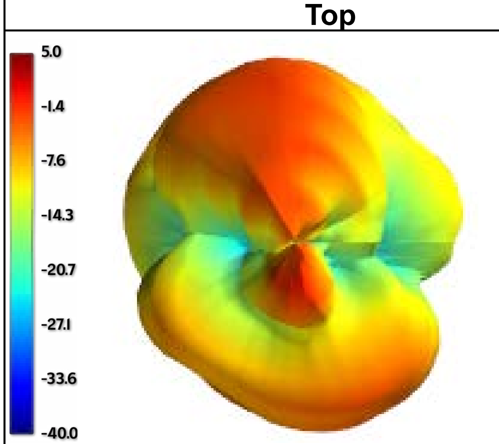
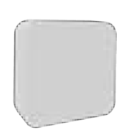
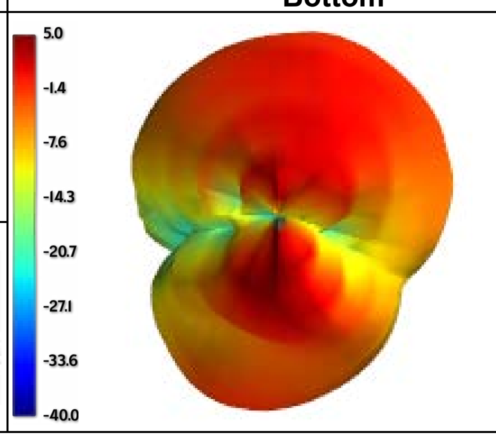
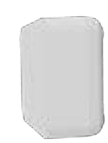
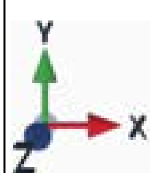
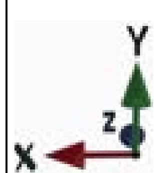
### 4.2.3 Vertical Polarization Gain Plots — 2.4GHz Band

Table 4.2.3a

<table>
<tr><th colspan="4">Vertical Polarization - Gain @ 2412MHz - Radiation Pattern Plots</th></tr>
<tr><th colspan="2">Front</th><th colspan="2">Back</th></tr>
<tr><td rowspan="2"></td><td></td><td rowspan="2"></td><td></td></tr>
<tr><td></td><td></td></tr>
<tr><th colspan="2">Right</th><th colspan="2">Left</th></tr>
<tr><td rowspan="2"></td><td></td><td rowspan="2"></td><td></td></tr>
<tr><td></td><td></td></tr>
<tr><th colspan="2">Top</th><th colspan="2">Bottom</th></tr>
<tr><td rowspan="2"></td><td></td><td rowspan="2"></td><td></td></tr>
<tr><td></td><td></td></tr>
</table>

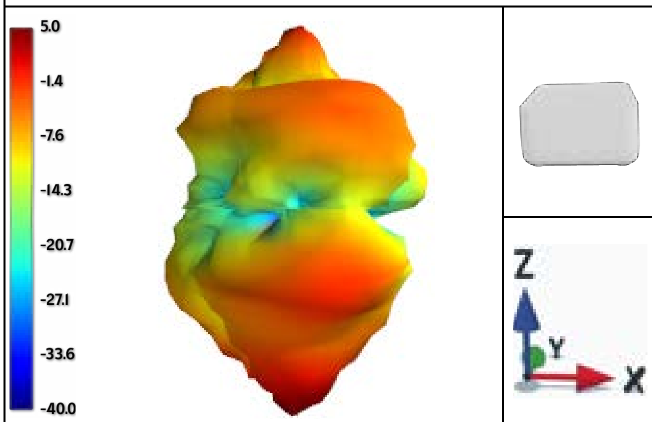
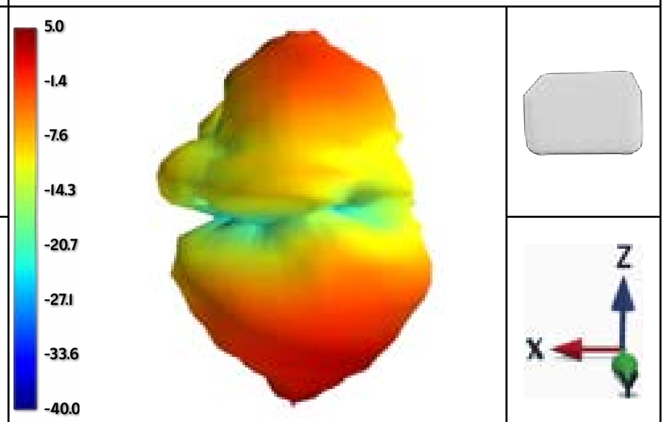
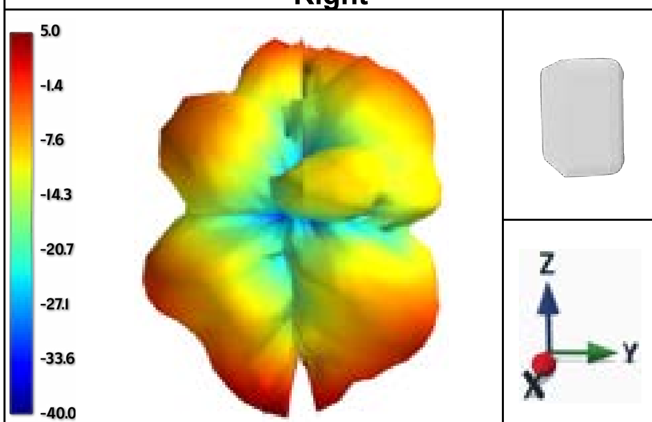
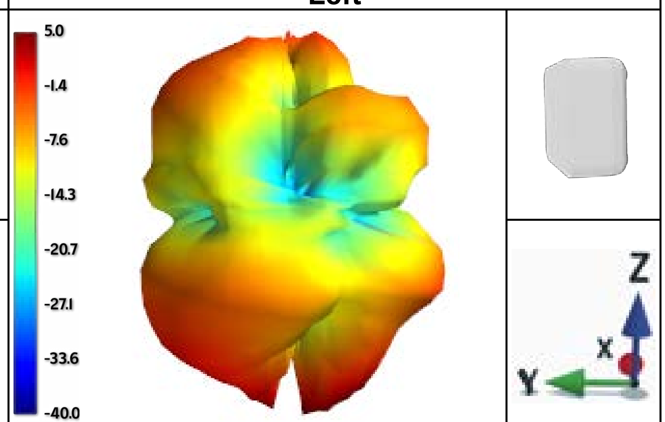
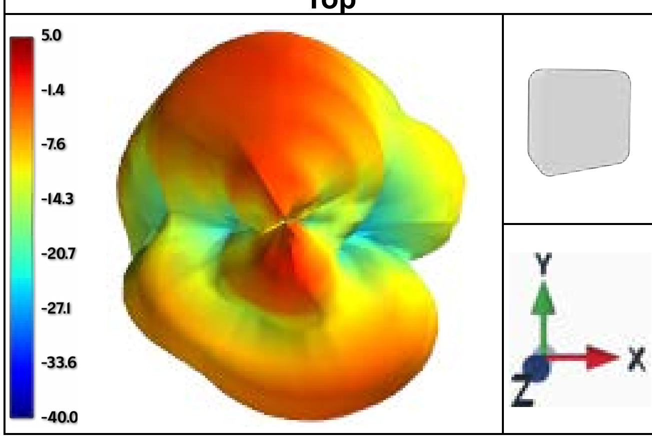
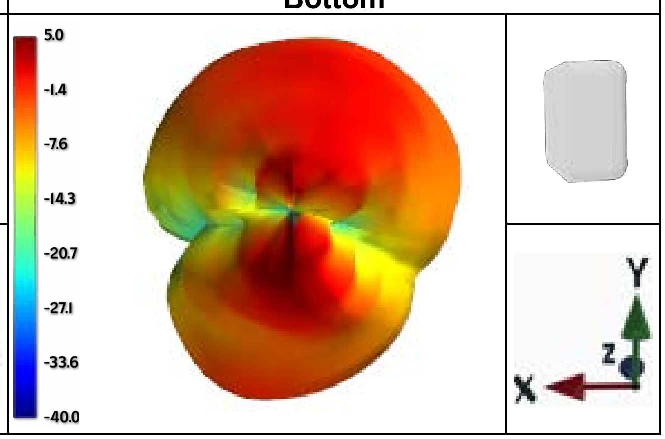
**Note: The Device's antenna is located directly in the center of the 3D plot.*

Table 4.2.3b

<table>
<tr><th colspan="4">Vertical Polarization - Gain @ 2442MHz - Radiation Pattern Plots</th></tr>
<tr><th colspan="2">Front</th><th colspan="2">Back</th></tr>
<tr>
<td rowspan="2">
</td>
<td></td>
<td rowspan="2">
</td>
<td></td>
</tr>
<tr>
<td>
</td>
<td>
</td>
</tr>
<tr><th colspan="2">Right</th><th colspan="2">Left</th></tr>
<tr>
<td rowspan="2">
</td>
<td></td>
<td rowspan="2">
</td>
<td></td>
</tr>
<tr>
<td>
</td>
<td>
</td>
</tr>
<tr><th colspan="2">Top</th><th colspan="2">Bottom</th></tr>
<tr>
<td rowspan="2">
</td>
<td></td>
<td rowspan="2">
</td>
<td></td>
</tr>
<tr>
<td>
</td>
<td>
</td>
</tr>
</table>

**Note: The Device's antenna is located directly in the center of the 3D plot.*

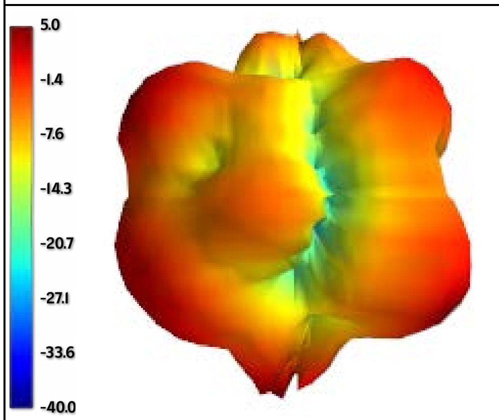
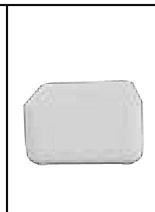
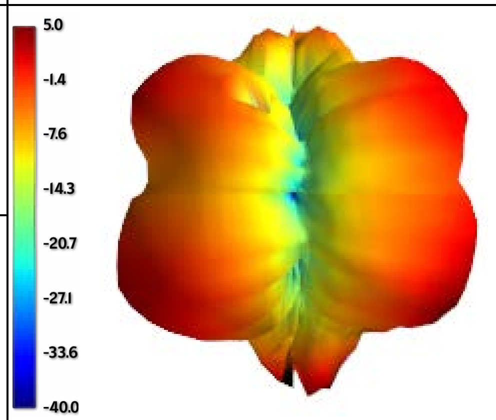
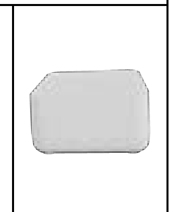
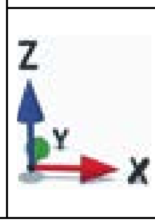
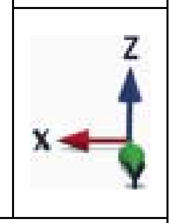
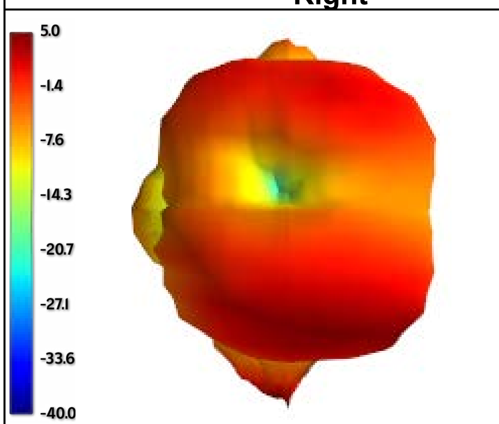
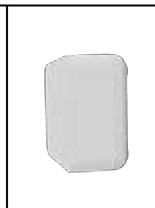
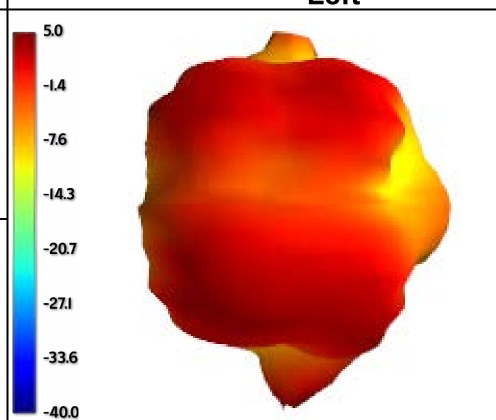
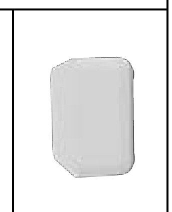
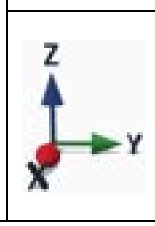
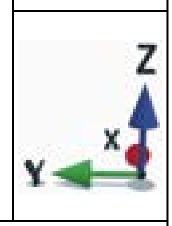
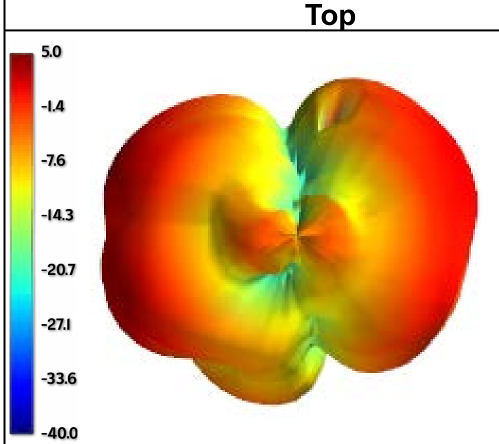
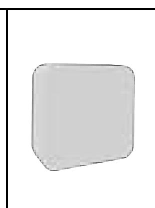
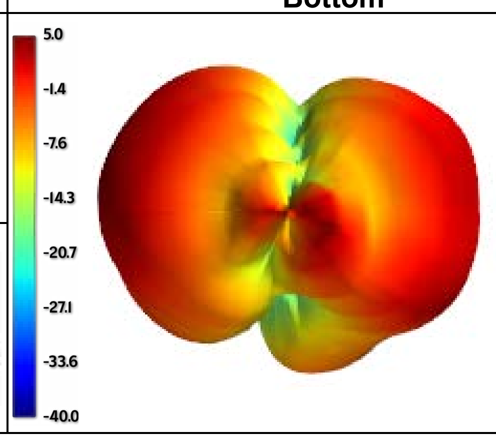
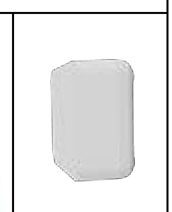
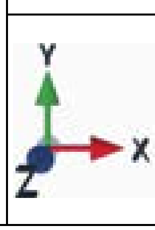
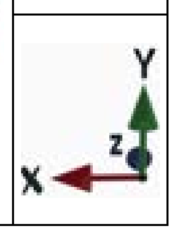
Table 4.2.3c

<table>
<tr><th colspan="2">Vertical Polarization - Gain @ 2472MHz - Radiation Pattern Plots</th></tr>
<tr><th>Front</th><th>Back</th></tr>
<tr><td>
</td><td>
</td></tr>
<tr><th>Right</th><th>Left</th></tr>
<tr><td>
</td><td>
</td></tr>
<tr><th>Top</th><th>Bottom</th></tr>
<tr><td>
</td><td>
</td></tr>
</table>

**Note: The Device's antenna is located directly in the center of the 3D plot.*

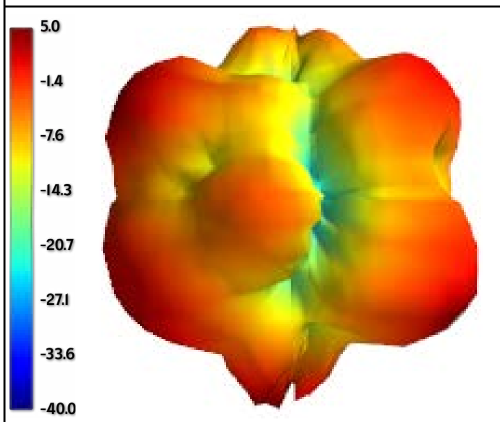
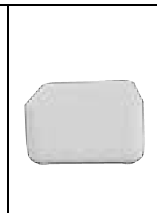
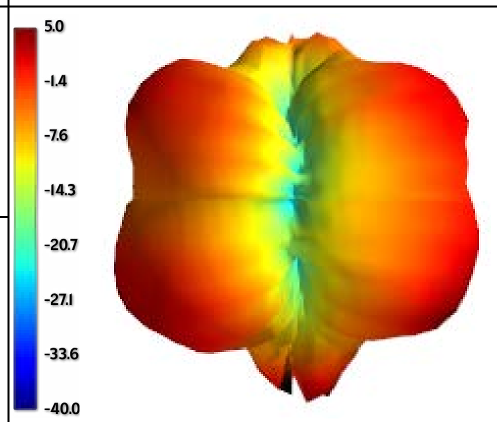
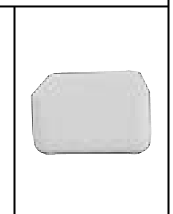
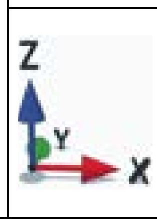
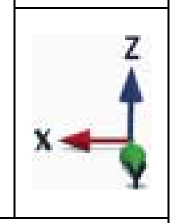
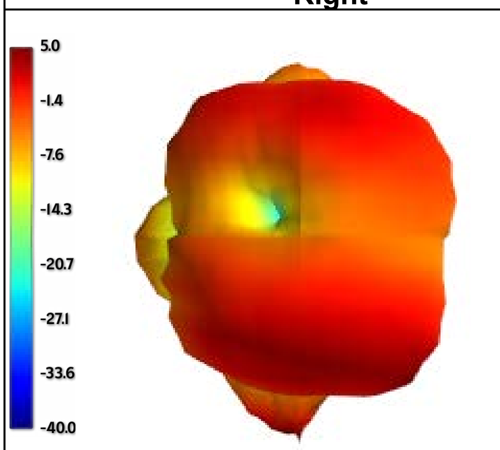
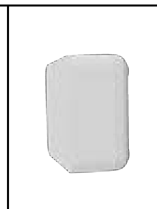
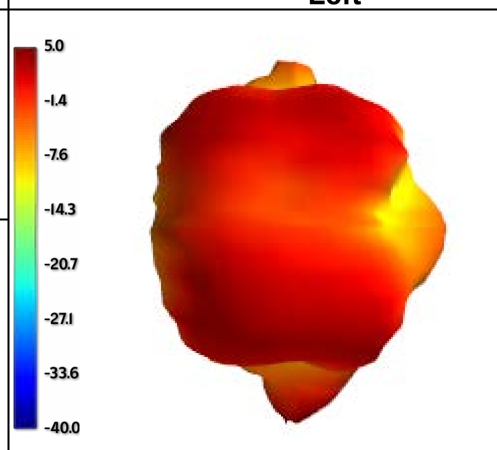
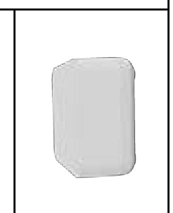
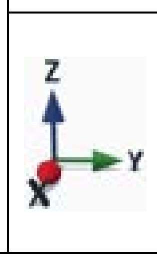
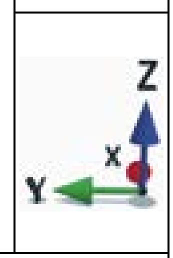
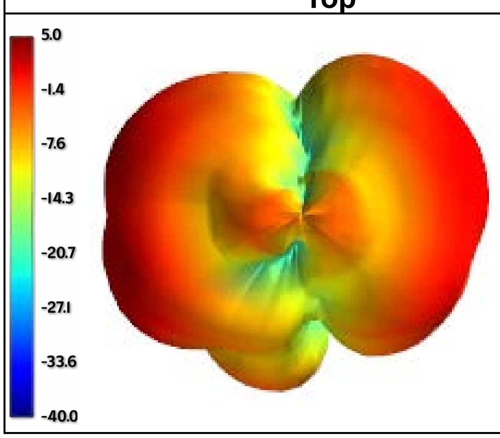
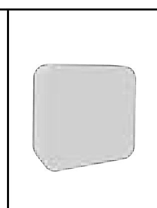
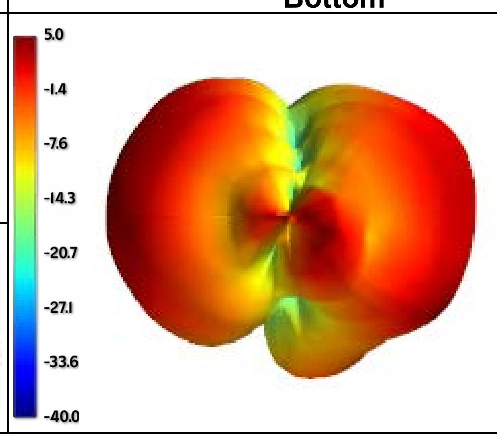
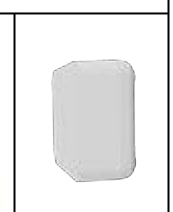
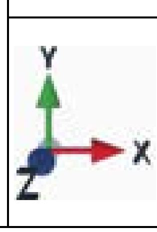
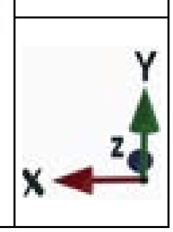
## 4.2.4 Horizontal Polarization Gain Plots — 2.4GHz Band

Table 4.2.4a

<table>
<tr><th colspan="4">Horizontal Polarization - Gain @ 2412MHz - Radiation Pattern Plots</th></tr>
<tr><th colspan="2">Front</th><th colspan="2">Back</th></tr>
<tr>
<td rowspan="2">
</td>
<td></td>
<td rowspan="2">
</td>
<td></td>
</tr>
<tr>
<td>
</td>
<td>
</td>
</tr>
<tr><th colspan="2">Right</th><th colspan="2">Left</th></tr>
<tr>
<td rowspan="2">
</td>
<td></td>
<td rowspan="2">
</td>
<td></td>
</tr>
<tr>
<td>
</td>
<td>
</td>
</tr>
<tr><th colspan="2">Top</th><th colspan="2">Bottom</th></tr>
<tr>
<td rowspan="2">
</td>
<td></td>
<td rowspan="2">
</td>
<td></td>
</tr>
<tr>
<td>
</td>
<td>
</td>
</tr>
</table>

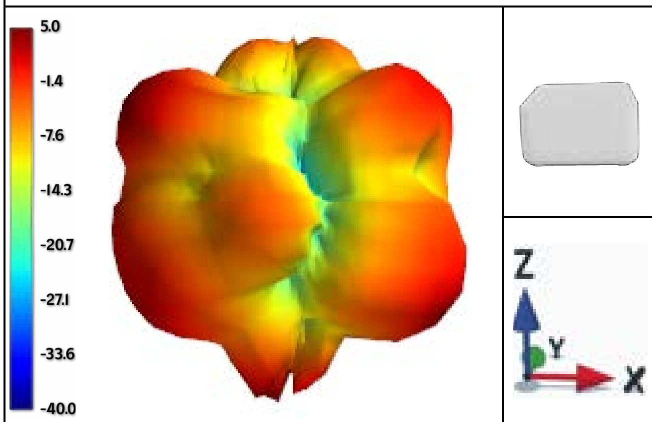
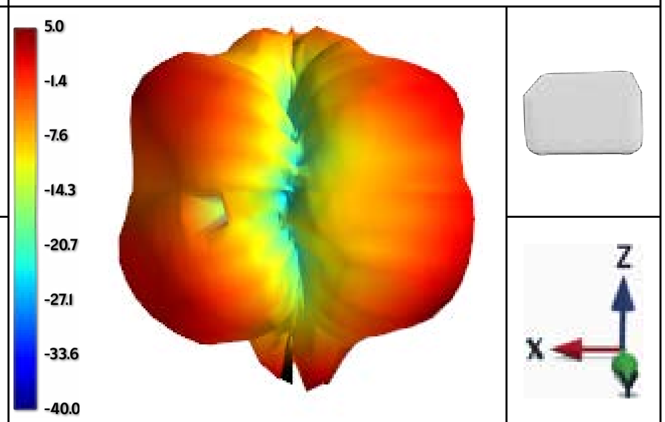
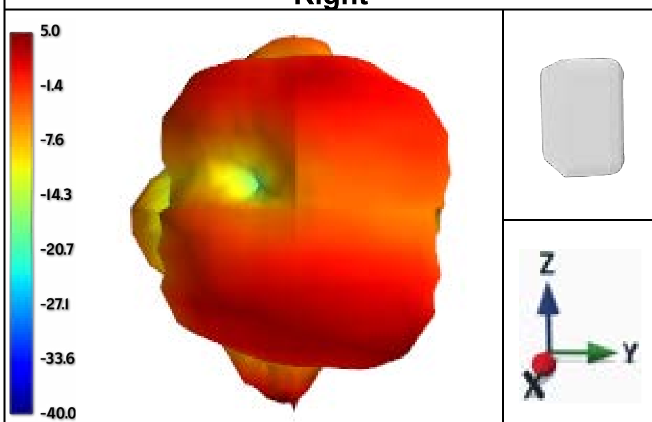
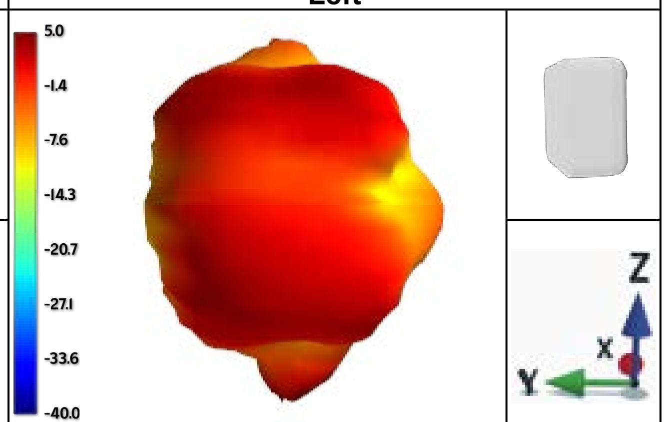
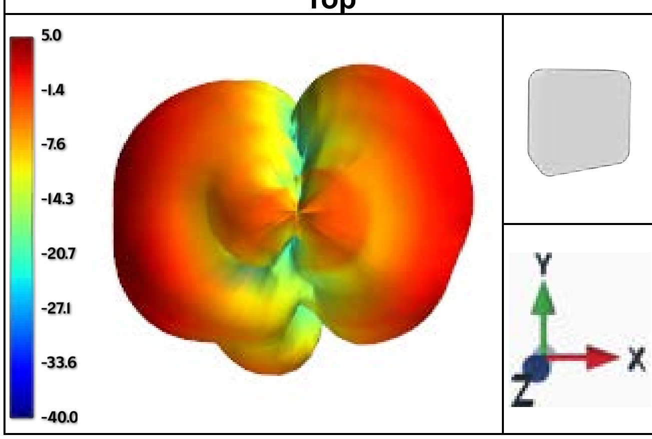
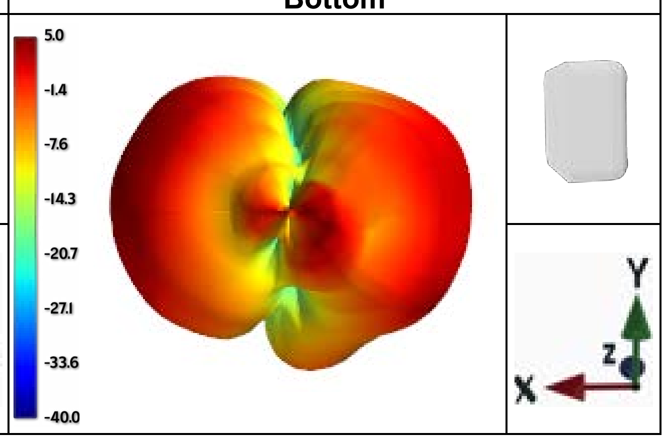
**Note: The Device's antenna is located directly in the center of the 3D plot.*

Table 4.2.4b

<table>
<tr><th colspan="4">Horizontal Polarization - Gain @ 2442MHz - Radiation Pattern Plots</th></tr>
<tr><th colspan="2">Front</th><th colspan="2">Back</th></tr>
<tr><td rowspan="2">
</td><td></td><td rowspan="2">
</td><td></td></tr>
<tr><td>
</td><td>
</td></tr>
<tr><th colspan="2">Right</th><th colspan="2">Left</th></tr>
<tr><td rowspan="2">
</td><td></td><td rowspan="2">
</td><td></td></tr>
<tr><td>
</td><td>
</td></tr>
<tr><th colspan="2">Top</th><th colspan="2">Bottom</th></tr>
<tr><td rowspan="2">
</td><td></td><td rowspan="2">
</td><td></td></tr>
<tr><td>
</td><td>
</td></tr>
</table>

**Note: The Device's antenna is located directly in the center of the 3D plot.*

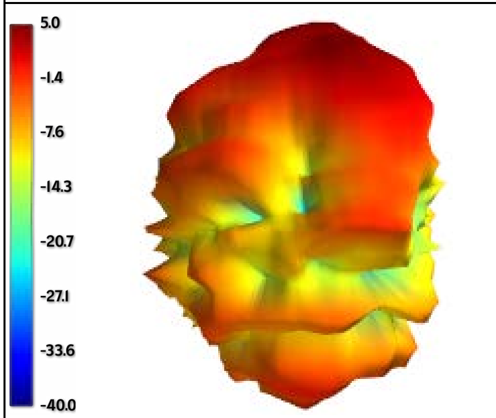
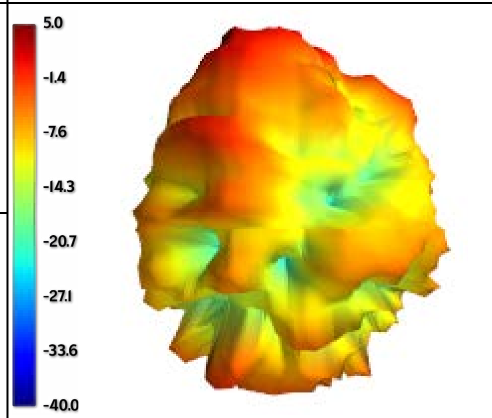
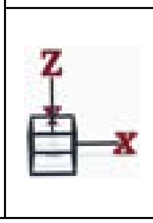
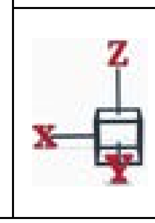
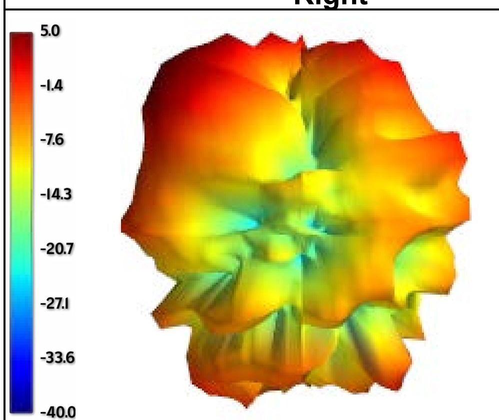
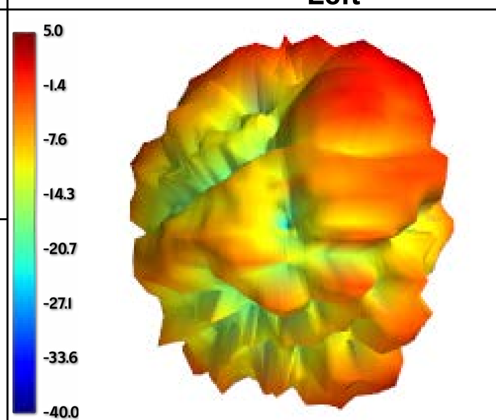
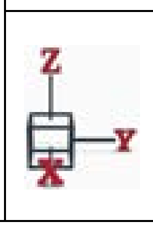
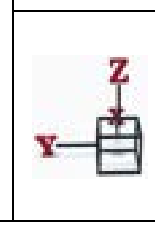
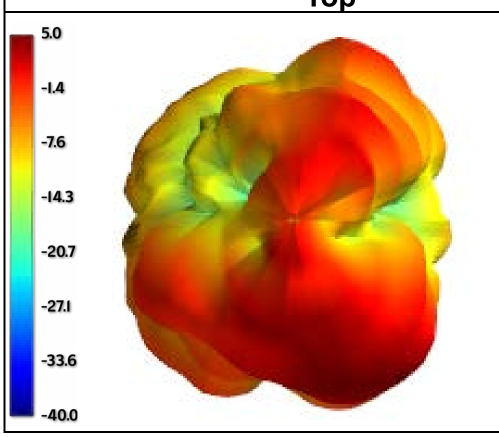
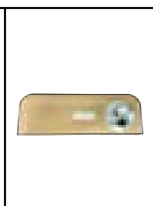
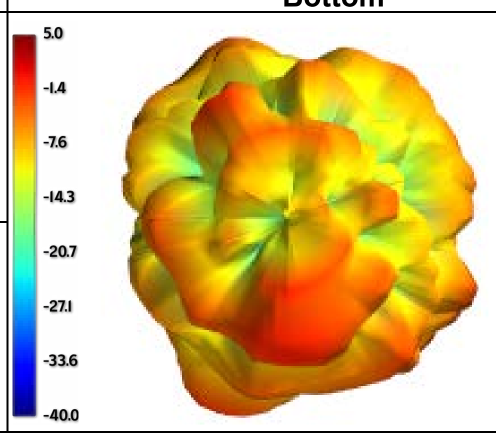
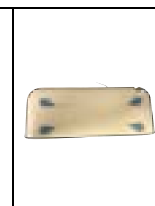
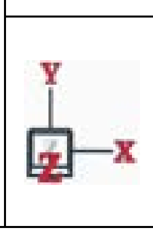
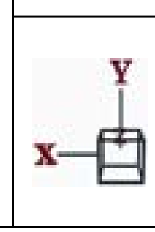
Table 4.2.4c

| Horizontal Polarization - Gain @ 2472MHz - Radiation Pattern Plots | |
|---|---|
| **Front** | **Back** |
|  |  |
| **Right** | **Left** |
|  |  |
| **Top** | **Bottom** |
|  |  |

**Note: The Device's antenna is located directly in the center of the 3D plot.*

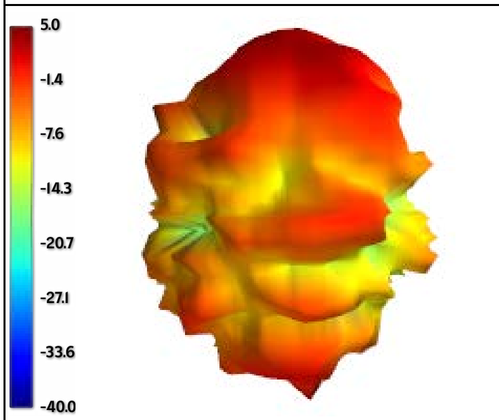
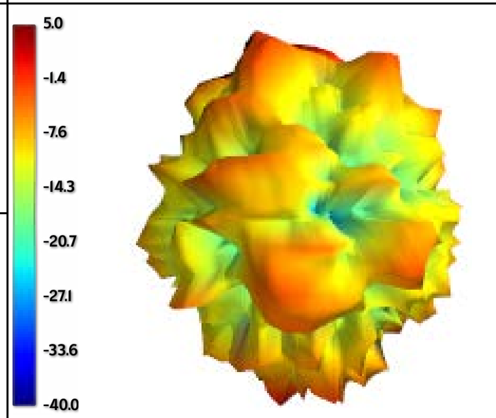
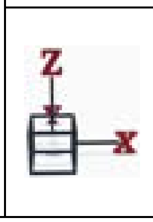
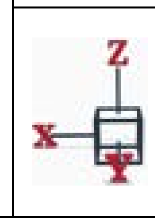
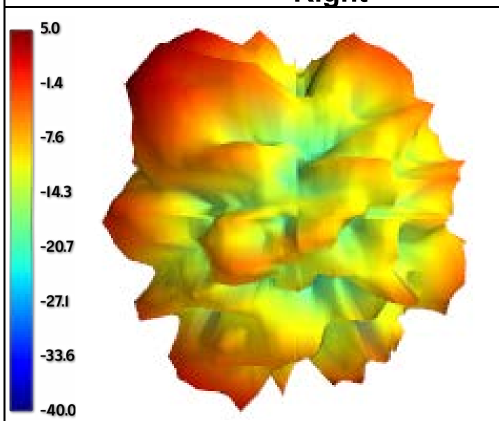
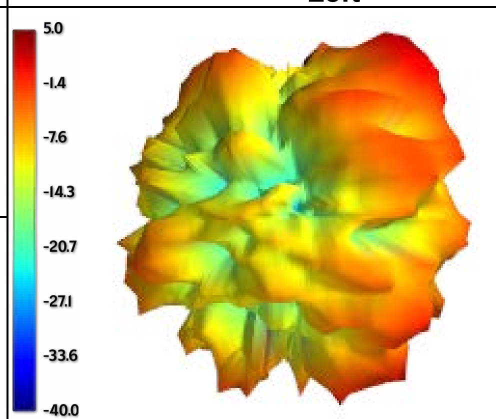
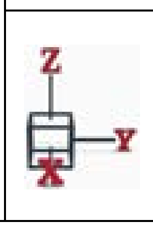
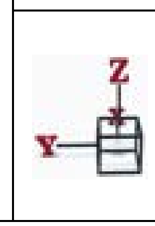
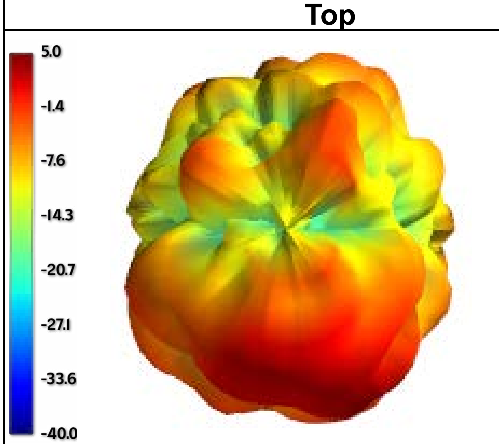
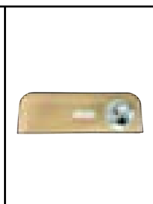
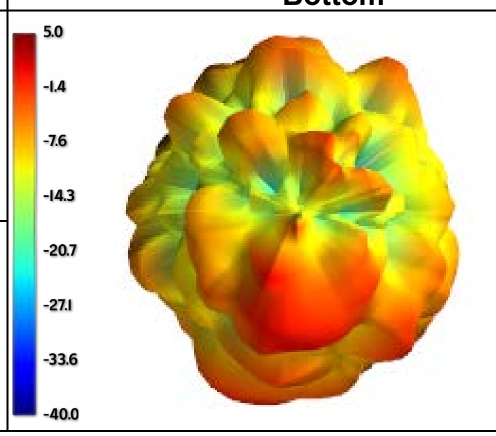
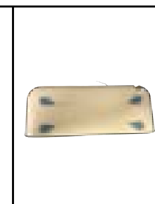
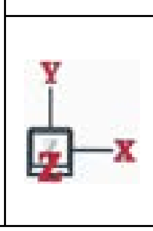
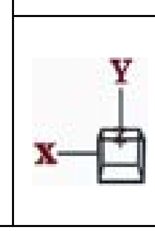
### 4.2.5 Vertical Polarization Gain Plots — 5GHz Band

Table 4.2.5a

| **Vertical Polarization - Gain @ 5170MHz - Radiation Pattern Plots** | | | |
|---|---|---|---|
| **Front** | | **Back** | |
|  |  |  |  |
| |  | |  |
| **Right** | | **Left** | |
|  |  |  |  |
| |  | |  |
| **Top** | | **Bottom** | |
|  |  |  |  |
| |  | |  |

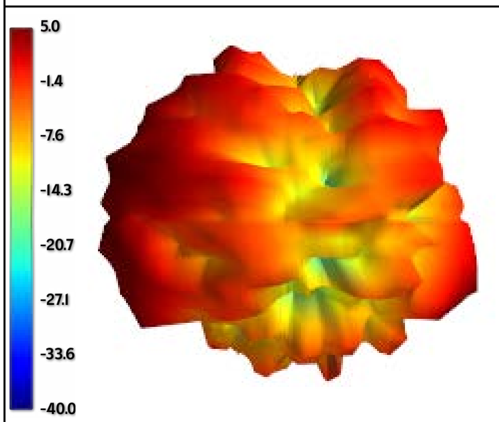
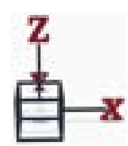
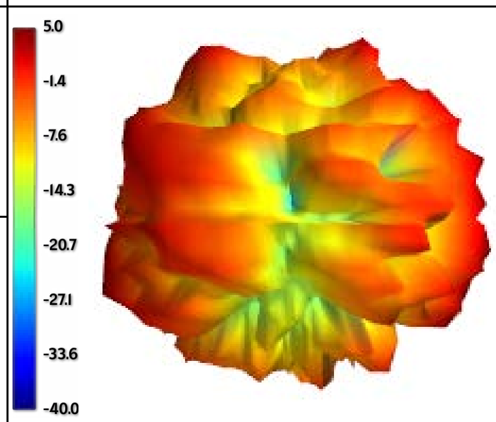
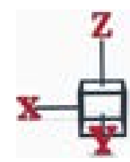
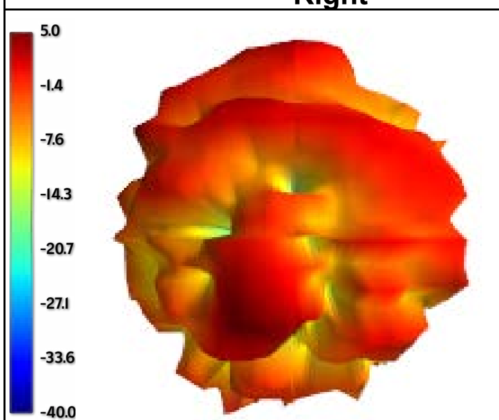
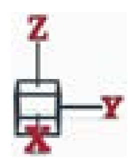
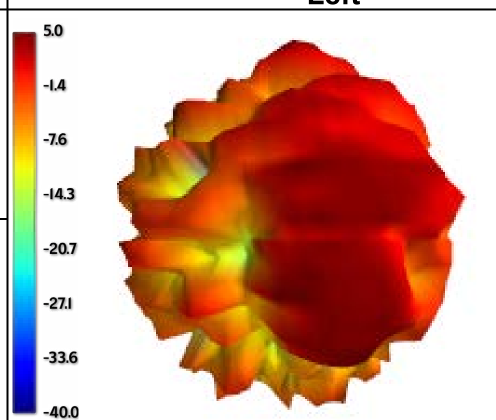
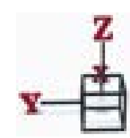
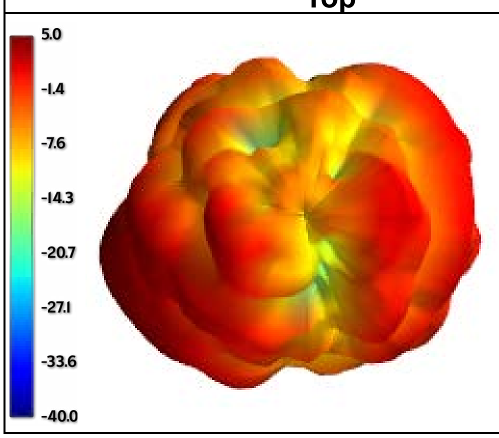
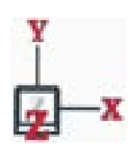
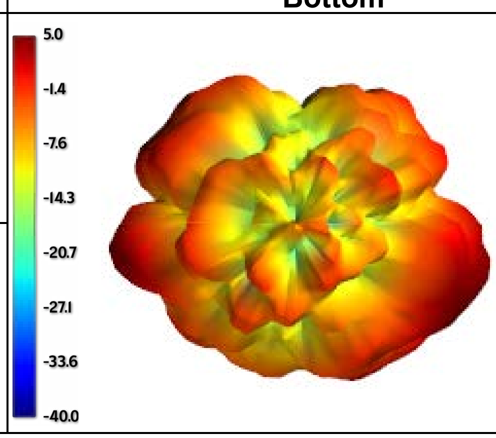
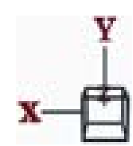
**Note: The Device's antenna is located directly in the center of the 3D plot.*

Table 4.2.5b

<table>
<tr><th colspan="4">Vertical Polarization - Gain @ 5500MHz - Radiation Pattern Plots</th></tr>
<tr><th colspan="2">Front</th><th colspan="2">Back</th></tr>
<tr><td rowspan="2"></td><td></td><td rowspan="2"></td><td></td></tr>
<tr><td></td><td></td></tr>
<tr><th colspan="2">Right</th><th colspan="2">Left</th></tr>
<tr><td rowspan="2"></td><td></td><td rowspan="2"></td><td></td></tr>
<tr><td></td><td></td></tr>
<tr><th colspan="2">Top</th><th colspan="2">Bottom</th></tr>
<tr><td rowspan="2"></td><td></td><td rowspan="2"></td><td></td></tr>
<tr><td></td><td></td></tr>
</table>

**Note: The Device's antenna is located directly in the center of the 3D plot.*

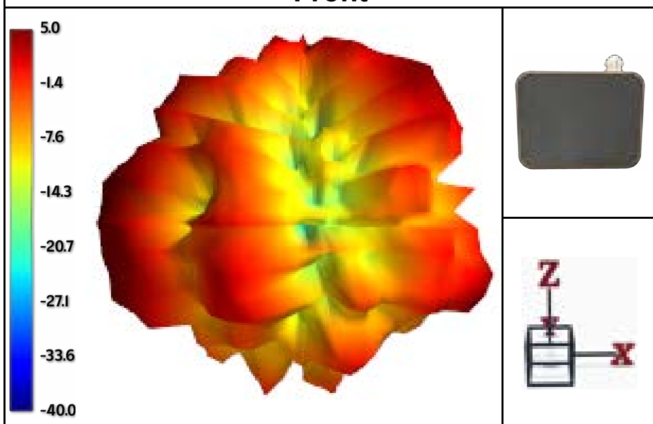
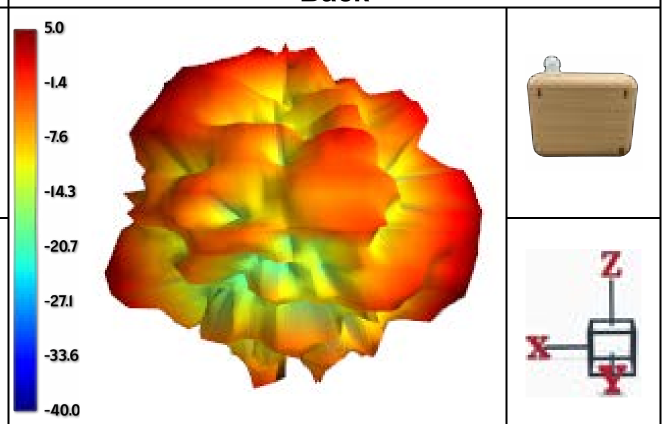
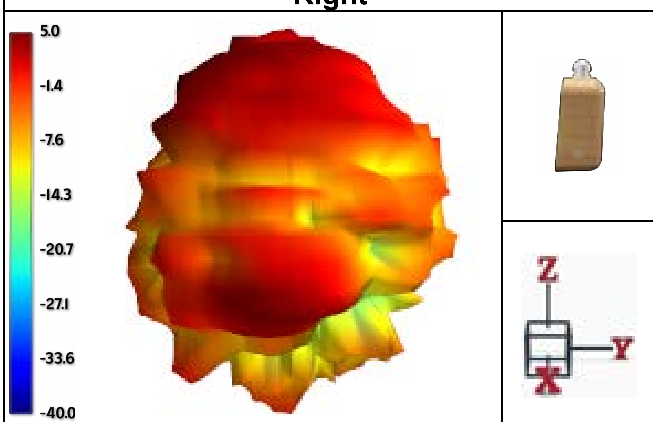
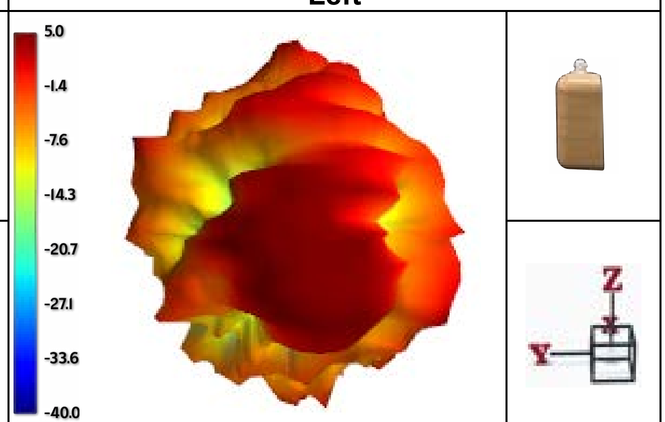
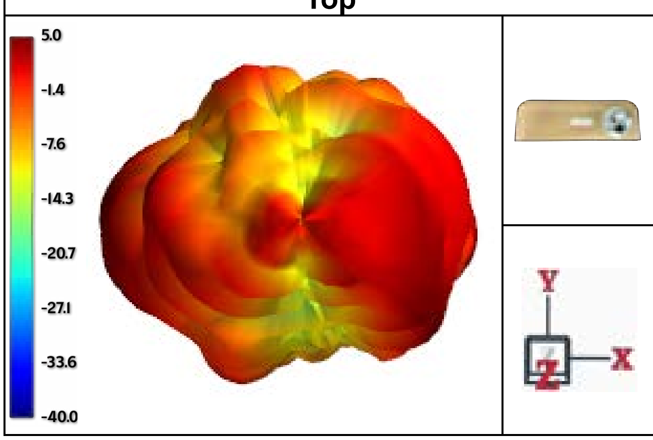
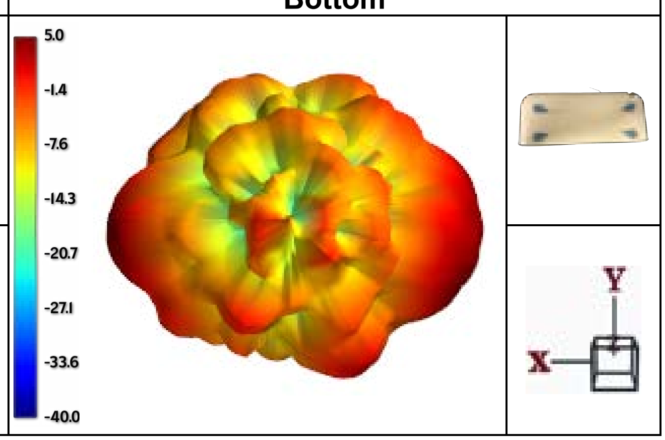
Table 4.2.5c

| Vertical Polarization - Gain @ 5875MHz - Radiation Pattern Plots | | | |
|---|---|---|---|
| **Front** | | **Back** | |
|  |  |  |  |
| **Right** | | **Left** | |
|  |  |  |  |
| **Top** | | **Bottom** | |
|  |  |  |  |

**Note: The Device's antenna is located directly in the center of the 3D plot.*

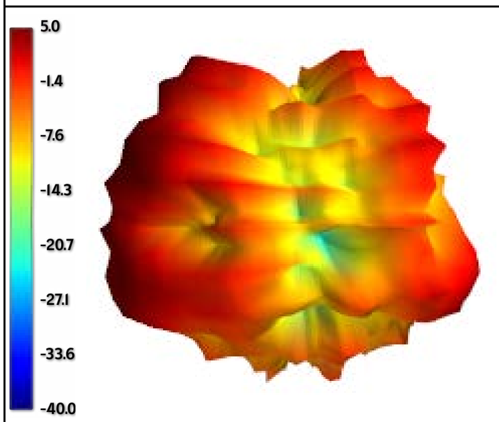
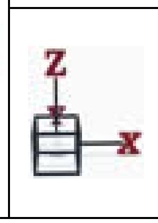
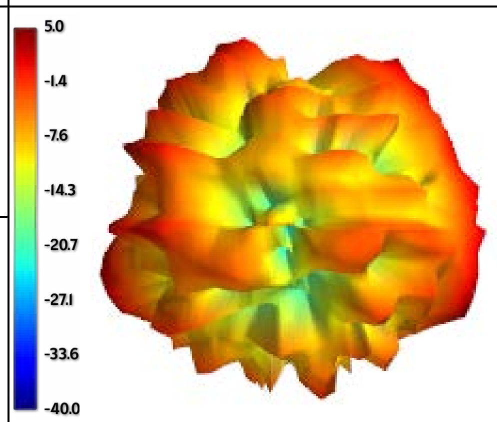
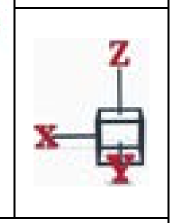
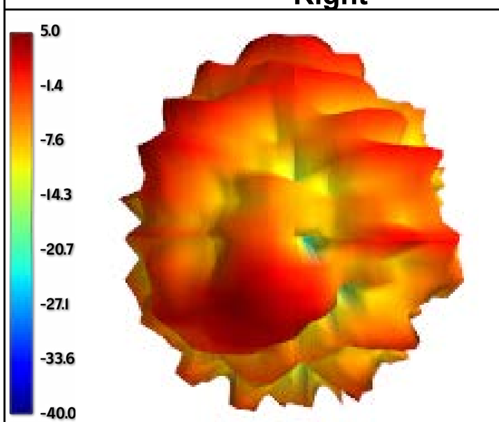
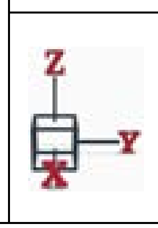
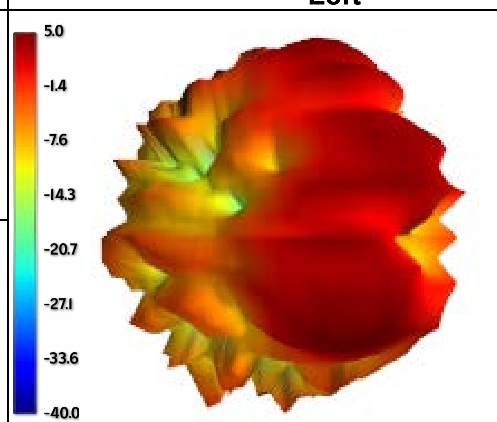
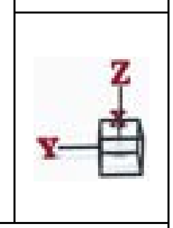
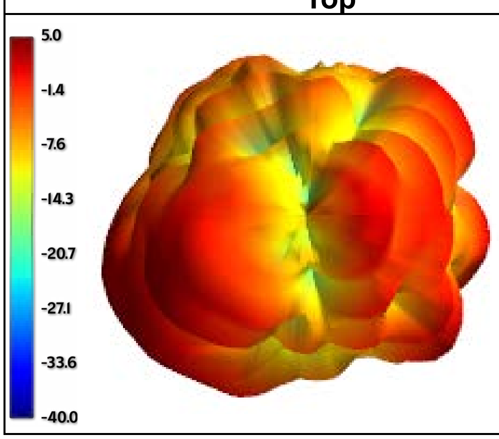
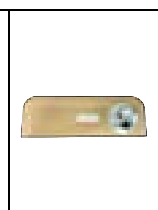
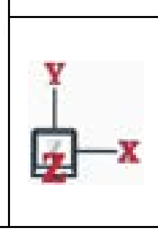
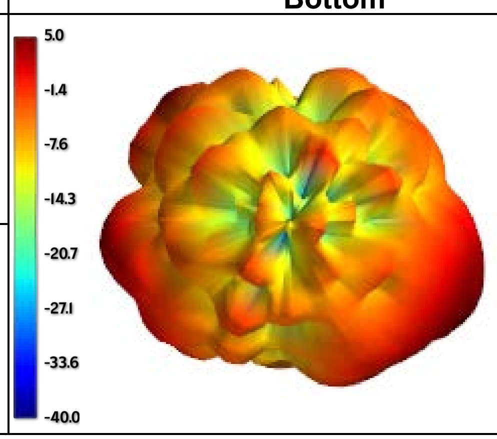
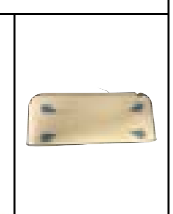
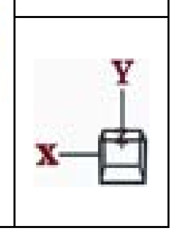
## 4.2.6 Horizontal Polarization Gain Plots — 5GHz Band

Table 4.2.6a

| Horizontal Polarization - Gain @ 5170MHz - Radiation Pattern Plots | |
|---|---|
| **Front** | **Back** |
|  |  |
| **Right** | **Left** |
|  |  |
| **Top** | **Bottom** |
|  |  |

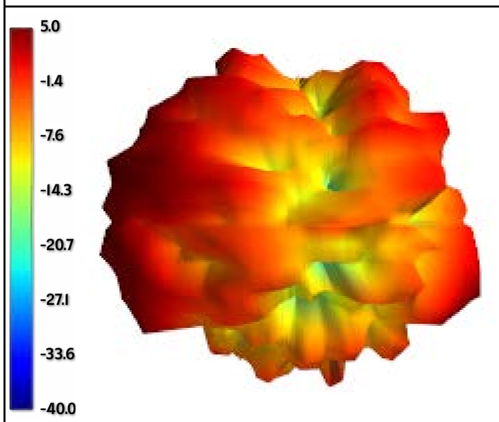
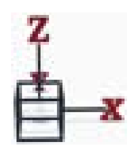
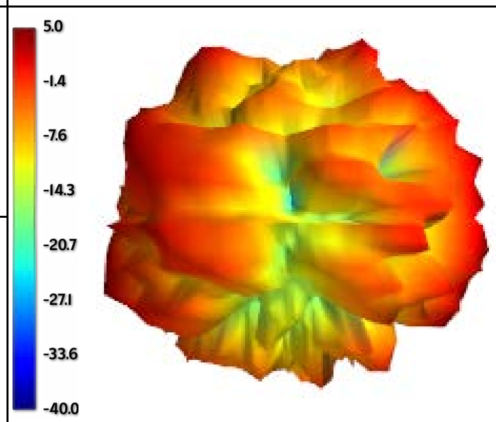
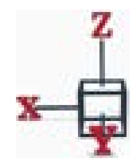
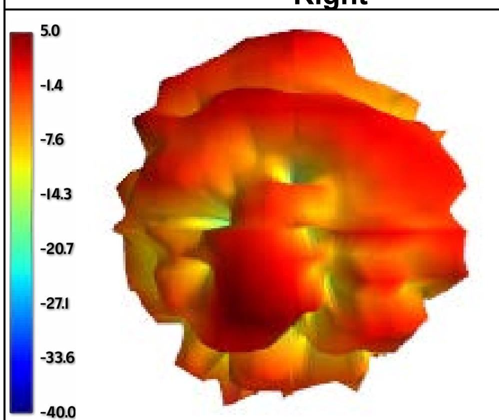
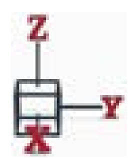
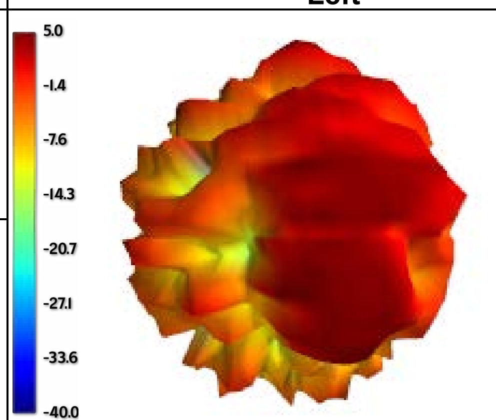
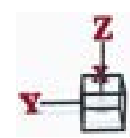
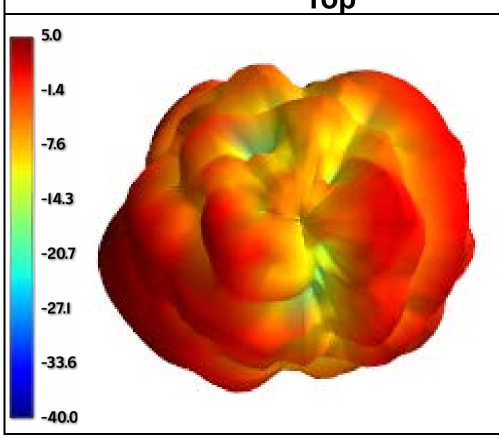
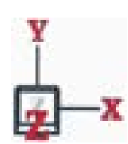
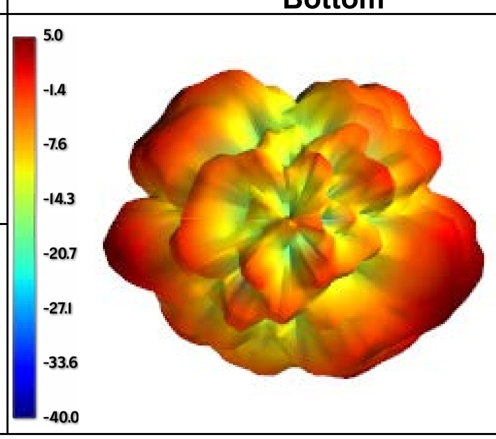
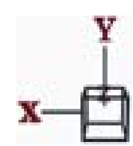
**Note: The Device's antenna is located directly in the center of the 3D plot.*

Table 4.2.6b

| Horizontal Polarization - Gain @ 5500MHz - Radiation Pattern Plots | | | |
|---|---|---|---|
| Front | | Back | |
|  | <br> |  | <br> |
| Right | | Left | |
|  | <br> |  | <br> |
| Top | | Bottom | |
|  | <br> |  | <br> |

**Note: The Device's antenna is located directly in the center of the 3D plot.*

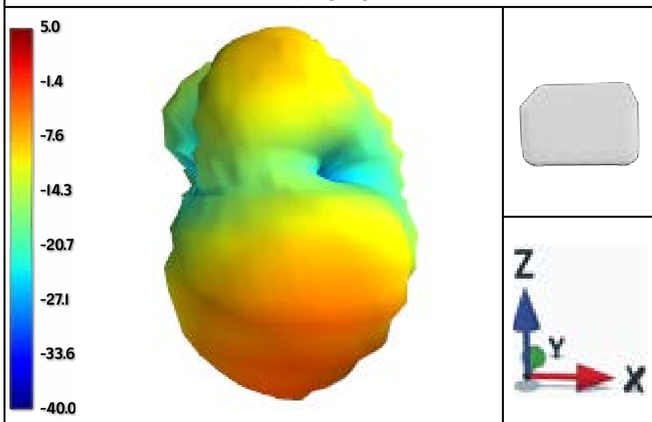
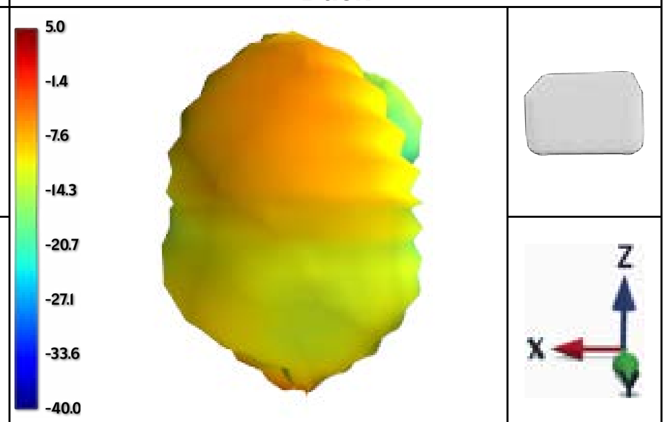
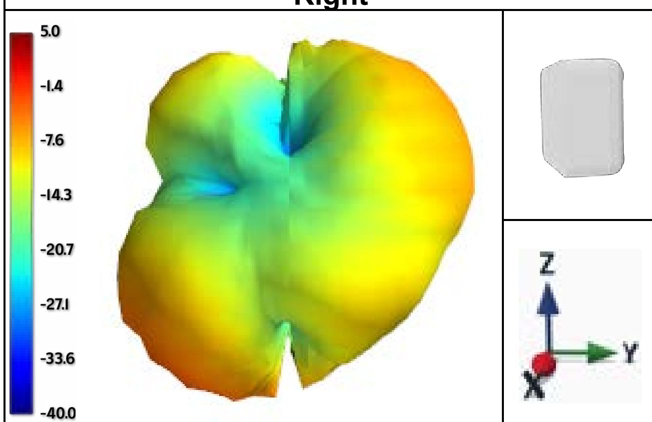
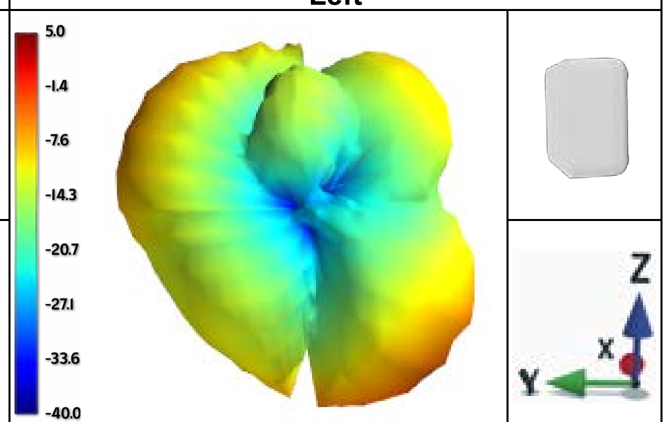
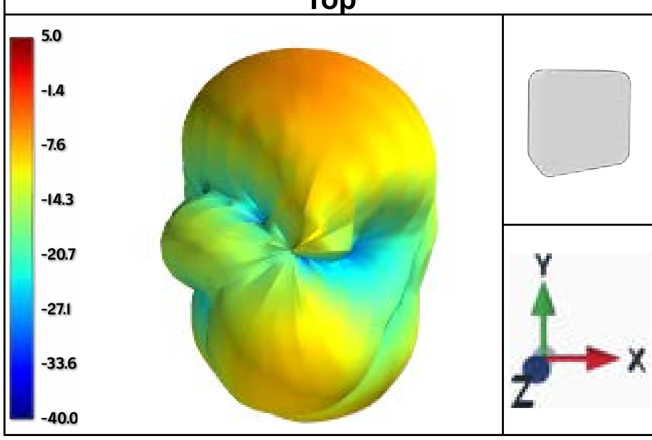
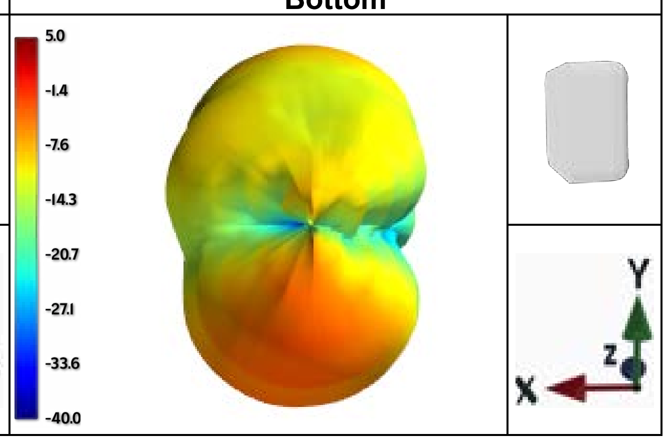
Table 4.2.6c

| **Horizontal Polarization - Gain @ 5875MHz - Radiation Pattern Plots** | | | |
|---|---|---|---|
| **Front** | | **Back** | |
|   |    |   |    |
| **Right** | | **Left** | |
|   |    |   |    |
| **Top** | | **Bottom** | |
|   |    |   |    |

**Note: The Device's antenna is located directly in the center of the 3D plot.*

## 4.2.7 Vertical Polarization Gain Plots — 915MHz Band

Table 4.2.5a

| Vertical Polarization - Gain @ 915MHz - Radiation Pattern Plots | |
|---|---|
| **Front** | **Back** |
|  |  |
| **Right** | **Left** |
|  |  |
| **Top** | **Bottom** |
|  |  |

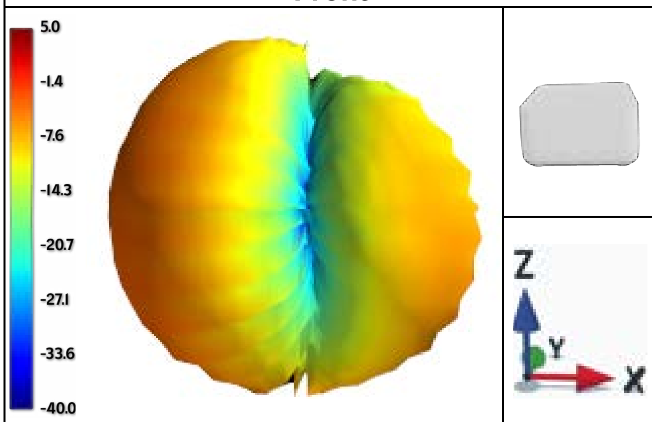
**Note: The Device's antenna is located directly in the center of the 3D plot.*

### 4.2.8 Horizontal Polarization Gain Plots — 915MHz Band

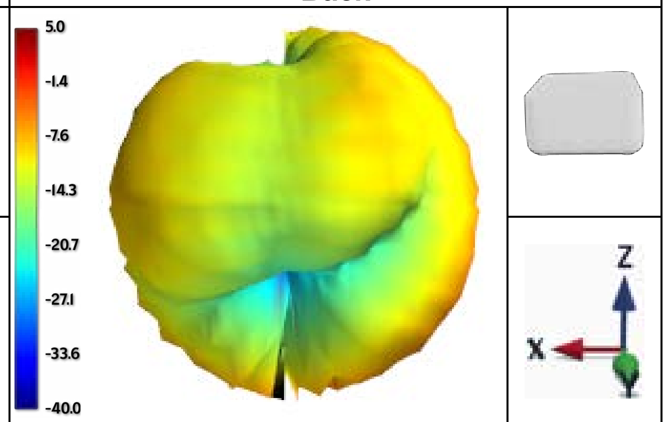
Table 4.2.6a

**Horizontal Polarization - Gain @ 915MHz - Radiation Pattern Plots**

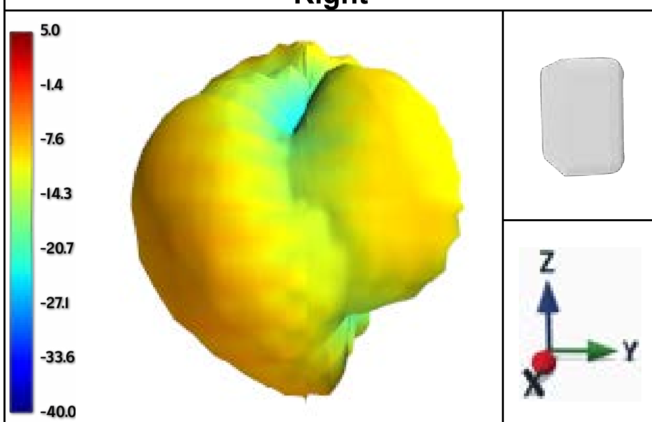
**Front**



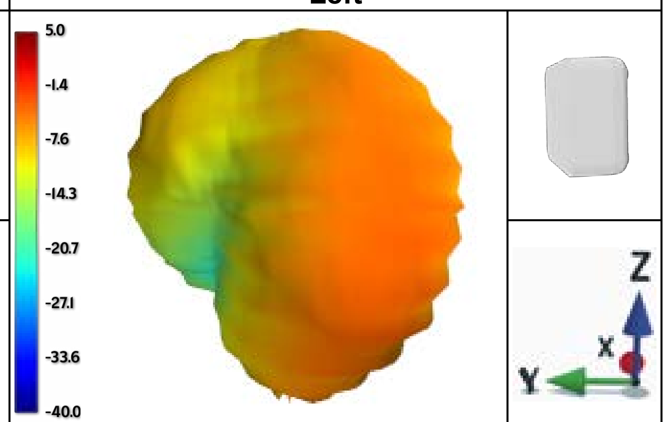

**Back**



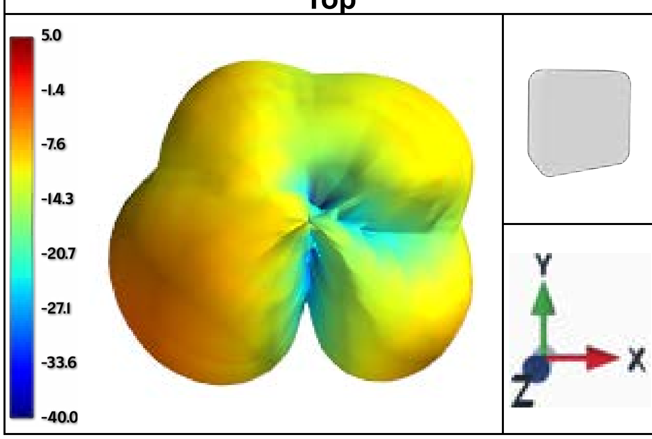

**Right**



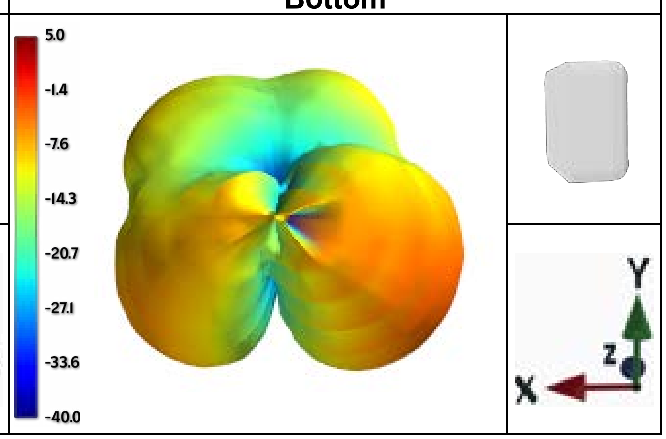

**Left**




**Top**




**Bottom**




**Note:* *The Device's antenna is located directly in the center of the 3D plot.*

## 4.3 RF Pattern - Conclusions

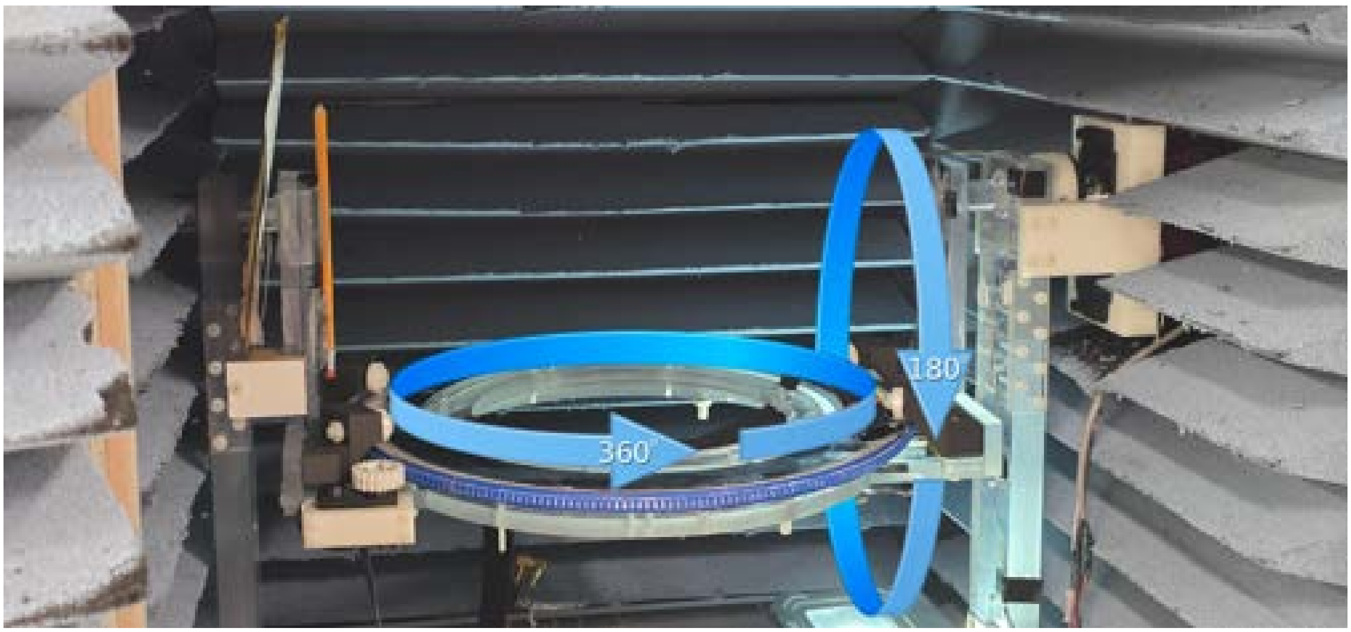
- The radiation plots for both antennas resemble a classic radiation plot for a dipole antenna. You will notice that the radiation plot for the 900 MHz antenna is not as good as the 2.4GHz/5GHz dipole antenna. Tuning the antenna for a particular frequency range for a given country should increase the power output in the radiation plot.

# Appendix 1: Brief Explanation of Piper Chamber

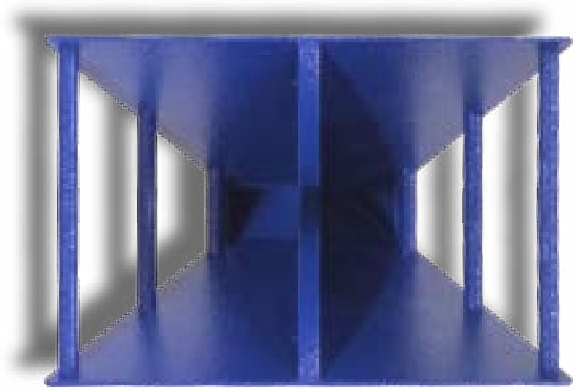
The Piper Chamber is a custom RF anechoic chamber designed and built by CAE.

It is comprised of two principal components:

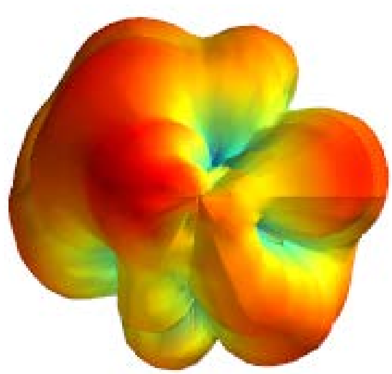
A. At the bottom, it has a mechanized platform that:
   i. Positions and powers the device under test
   ii. Rotates the device under test in a sweeping three-dimensional pattern.



B. At the top, it has a receiving horn antenna that:
   i. Receives transmissions from the device as it progresses through its movement patterns.
   ii. Digitizes and sends those transmissions to analyzers and equipment for characterization and plotting.
   iii. Rotates in 90 degree increments to allow for polarization measurements.



C. Once a device under test is properly positioned on the platform, it is placed in a constant transmit mode and stepped through its movement patterns. The transmission data received through the horn antenna is:
   i. Analyzed to generate the measurements provided in the report
   ii. Matched with the device position data captured by the platform, permitting the creation of the 3-D radiation patterns also provided in the report and shown as an example below.



# Appendix 2: Brief Description of RF Polarization

Transmitted radio waves can be compared to ripples created when a stone is dropped into a pond.

The antenna that receives these waves can similarly be compared to a rectangular box.  The amount of each wave the box will be able to capture will depend on how the box is oriented when it is placed in the water.

Since the lake is positioned, and the waves are traveling, horizontally, if the box is similarly positioned horizontally, it will capture more of each wave than if the box is positioned vertically.

Please note that the terms “horizontal” and “vertical” are relative–what we typically think of being “horizontal” in one context could be viewed as what we typically think of as being “vertical” by someone oriented differently. As such, it is not useful to place too much emphasis on, or ascribe too much meaning to, these terms, other than to recognize they are referring to relative, and differing, orientations.

The important take-away points from this explanation, then, are the following:

1. Most radio antennas transmit radio waves in a pattern.
2. That pattern is determined by how the antenna is oriented.
3. The greatest efficiency between receiving and transmitting antennas occurs when those antennas are oriented so their patterns match.