



Part 15 Antenna Gains Test Report

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Authorizing Party:

Zack Gray, Microsoft

A handwritten signature in black ink that appears to read "Zack Gray".

1. Antenna Gains Summary

The purpose of this report is to explain how the antenna gains for the unlicensed transmitters of the given device were measured and evaluated.

The device has two antennas which are used for WLAN / Bluetooth Tx / Rx.

- The peak gains of each antenna were measured separately. These peak gains are used in any SISO evaluations in the unlicensed test reports.
- Additionally, the directional MIMO gains of the two-antenna system were evaluated as allowed by **KDB 662911 D03 MIMO Antenna Gain Measurement v01** and confirmed through Inquiry. The following directional MIMO gains were determined:
 - Uncorrelated Directional MIMO Gains. These gains are used in the unlicensed test reports for power measurements of all WLAN modes and power spectral density (PSD) measurements of WLAN operating modes with uncorrelated signals, as per ANSI C63.10.
 - Correlated Directional MIMO Gains. These gains are used in unlicensed test reports for PSD measurements of WLAN operating modes with correlated signals, such as cyclic delay diversity (CDD.)

The summary of the Peak Gains and Directional MIMO Gains are given below.

Gains	Frequency (MHz)	Left Antenna Peak Gain (Chain 2) (dB _i)	Right Antenna Peak Gain (Chain 1) (dB _i)	MIMO Uncorrelated Directional Gain (dB _i)	MIMO Correlated Directional Gain (dB _i)
Bands					
2.4GHz	2400-2483.5	1.50	1.02	1.11	4.11
UNII-1	5150-5250	4.12	3.42	2.25	5.25
UNII-2A	5250-5350	3.37	3.42	1.58	4.50
UNII-2C	5470-5725	6.95	4.34	4.02	6.08
UNII-3	5725-5850	6.95	4.34	4.02	6.08
UNII-4	5850-5895	6.24	3.92	3.48	5.27
UNII-5	5925-6425	5.87	4.94	4.07	7.08
UNII-6	6425-6525	3.93	4.35	4.07	7.08
UNII-7	6525-6875	3.78	3.92	3.54	6.55
UNII-8	6875-7125	2.74	3.78	2.90	5.91

2. Test Method and Test Setup

- Measurement Facility: Microsoft Antenna Lab
- Dates of Testing: 12/12/2024 to 12/14/2024
- Equipment: MVG Starlab (formerly known as Satimo)
- Calibration Verification: A reference calibration dipole was measured before the device was tested and compared to the reported values of the manufacturer to verify that the chamber calibration is within measurement uncertainty and in good standing.

Item	Equipment	Manufacturer	Model	Calibration / Validation Due
1	SATIMO chamber	MVG	StarGate	02/12/2025
2	NPAC (New Probe Array Controller)	MVG	N/A	03/29/2025
3	Network Analyzer	Keysight	PNA-L N5232A	April 2025
4	Validation Dipole	MVG	WD3000	1/12/2025
5	Validation Dipole	MVG	WD6000	1/12/2025

i. Passive Gain Calibration and Test Method

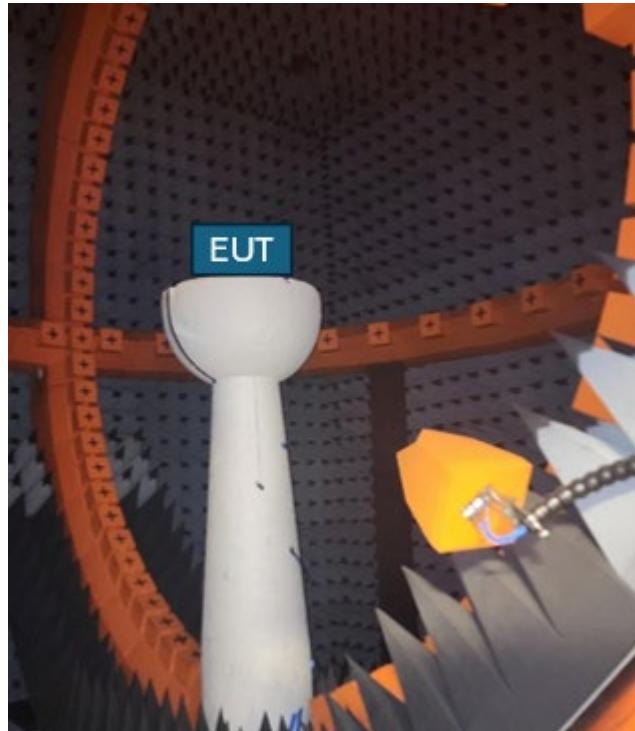
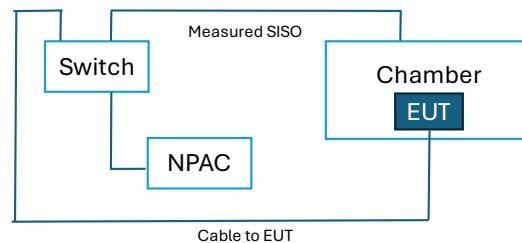
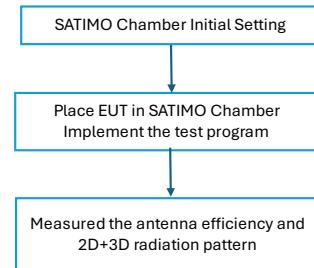
The calibration of the chamber is performed using gain by substitution method. A reference calibration dipole with known antenna gain and efficiency connected in the middle of the chamber in the quiet zone is measured and a calibration file that includes offset values for each frequency to adjust the losses of the system is generated. The device under test was tested the same way as the calibration dipoles and the calibration file described above is used to calculate the gain of each embedded antenna.

ii. Radiation Pattern and Gain Measurement

The radiation pattern and gain measurements were done in the MVG Starlab fully anechoic chamber. The antenna gain reported is the maximum measured in both horizontal and vertical polarizations. The measurement step size in both the Phi (Φ) and Theta (Θ) measurement axes was 3 degrees, meeting the requirements to use Directional MIMO Gains evaluation method.

Test Method, Setup, Block Diagram

- This test report is prepared for host antenna testing under a Full Anechoic Chamber (MVG StarGate64 SISO).
- Test Date(s):
12/12/2024 to 12/14/2024
- Test Engineer: Chulmin Han



3. Antenna Manufacturer

Antenna manufacturer 1	Lanto Electronic Limited
Antenna Part number	Main: 1415-0AW80QS Aux: 1415-0AW70QS
Antenna type	PIFA

Antenna manufacturer 2	(AWAN) ADVANCED WIRELESS & ANTENNA INC.
Antenna Part number	Main: 1415-0AW00QS Aux: 1415-0AW30QS
Antenna type	PIFA

i. Peak Gain Details

Peak Gains	Frequency (MHz)	Left Antenna Peak Gain (Chain 2)			Right Antenna Peak Gain (Chain 1)		
		Peak Gain (dBi)	Phi (°)	Theta (°)	Peak Gain (dBi)	Phi (°)	Theta (°)
2.4GHz	2400-2483.5	1.50	96	-123	1.02	81	-126
UNII-1	5150-5250	4.12	135	-129	3.42	36	-129
UNII-2A	5250-5350	3.37	138	-126	3.42	36	-126
UNII-2C	5470-5725	6.95	135	-129	4.34	36	-129
UNII-3	5725-5850	6.95	135	-129	4.34	36	-129
UNII-4	5850-5895	6.24	132	-129	3.92	36	-129
UNII-5	5925-6425	5.87	132	-129	4.94	42	-129
UNII-6	6425-6525	3.93	42	-126	4.35	45	-129
UNII-7	6525-6875	3.78	45	-123	3.92	135	-102
UNII-8	6875-7125	2.74	48	-129	3.78	138	-105

ii. Directional MIMO Gain Details

The Directional MIMO Gains were determined computationally from the standalone antenna gains. For each point in space, the Directional MIMO Gains were calculated by performing both the Uncorrelated and Correlated Gain calculations on the gain values from each antenna at that point in space. The highest results calculation results in each band are used as the Directional gains. Note that in some cases the highest uncorrelated and correlated values occur at different points in space.

These are the directional Gain equations used from KDB 662911 D01 (Section F.2.d), for this case where number of antennas N=2:

$$\text{Uncorrelated Gain} = 10 * \log \frac{\frac{G_1}{10^{10}} + \frac{G_2}{10^{10}} + \dots + \frac{G_N}{10^{10}}}{N_{ANT}} \text{ dBi}$$

$$\text{Correlated Gain} = 10 * \log \frac{\left(\frac{G_1}{10^{20}} + \frac{G_2}{10^{20}} + \dots + \frac{G_N}{10^{20}} \right)^2}{N_{ANT}} \text{ dBi}$$

These equations were applied at all measurement points for the two antennas, at all frequencies. The highest Uncorrelated and Correlated Directional MIMO Gains values with their locations in space are as follows:

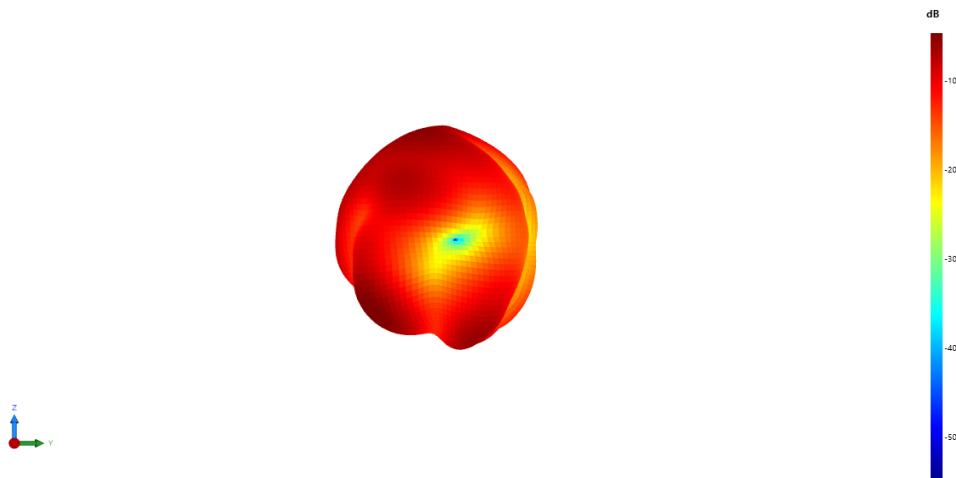
Directional MIMO Gains	Frequency (MHz)	Uncorrelated Directional MIMO Gain						Correlated Directional MIMO Gain					
		Uncorr. Gain (dBi)	ϕ (°)	θ (°)	Left Gain (dBi)	Right Gain (dBi)	Corr. Gain (dBi)	ϕ (°)	θ (°)	Left Gain (dBi)	Right Gain (dBi)		
2.4GHz	2400-2483.5	1.11	90	-123	1.41	0.78	4.11	90	-123	1.41	0.78		
UNII-1	5150-5250	2.25	75	-138	2.6	1.86	5.25	111	-135	2.66	0.13		
UNII-2A	5250-5350	1.58	108	-132	2.79	-0.11	4.50	111	-135	2.66	0.13		
UNII-2C	5470-5725	4.02	135	-129	6.95	-10.2	6.08	105	-135	3.33	2.8		
UNII-3	5725-5850	4.02	135	-129	6.95	-10.2	6.08	105	-135	3.33	2.8		
UNII-4	5850-5895	3.48	132	-129	6.24	-6.06	5.27	132	-126	5.79	-3.77		
UNII-5	5925-6425	4.07	45	-126	3.79	4.34	7.08	45	-126	3.79	4.34		
UNII-6	6425-6525	4.07	45	-126	3.79	4.34	7.08	45	-126	3.79	4.34		
UNII-7	6525-6875	3.54	45	-126	3.78	3.28	6.55	45	-126	3.78	3.28		
UNII-8	6875-7125	2.90	141	-117	2.61	3.18	5.91	141	-117	2.61	3.18		

4. Radiated Characteristics of Antennas in Host Platform

Main (Left) Antenna

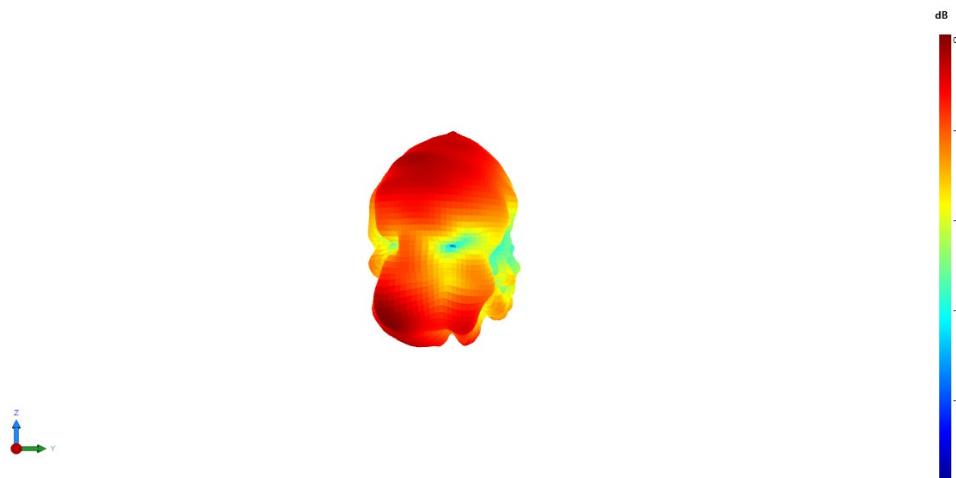
Max Antenna 3D Radiation Pattern 2400 – 2483.5 MHz

Frequency (MHz)	Peak Gain w/ Cable Loss (dBi)
2400-2483.5	1.5



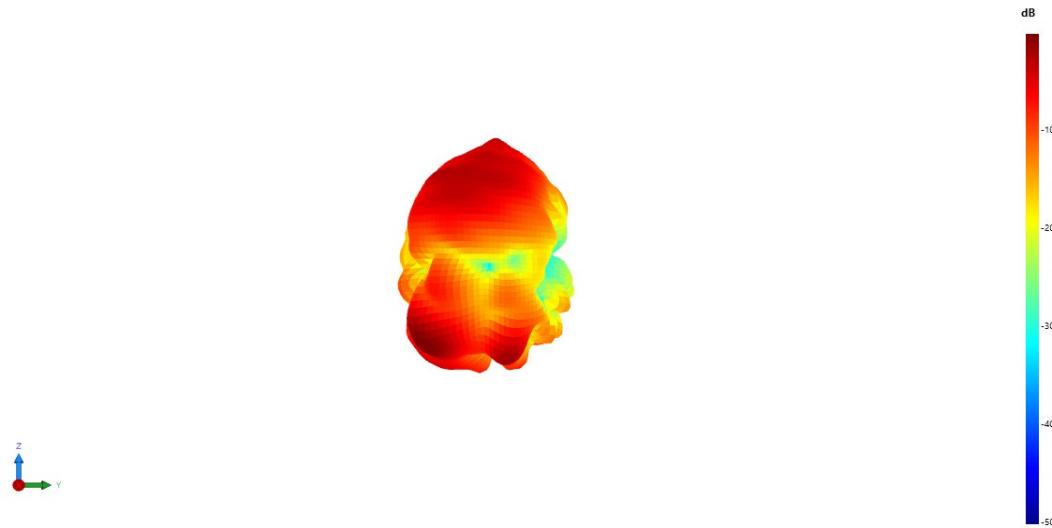
Max Antenna 3D Radiation Pattern 5150-5250 MHz

Frequency (MHz)	Peak Gain w/ Cable Loss (dBi)
5150-5250	4.12



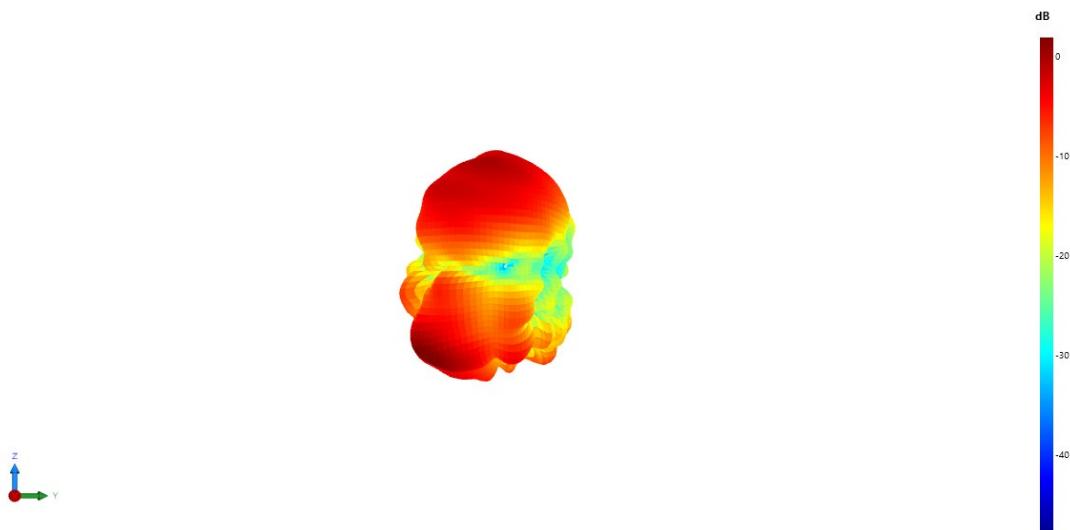
Max Antenna 3D Radiation Pattern 5250-5350 MHz

Frequency (MHz)	Peak Gain w/ Cable Loss (dBi)
5250-5350	3.37



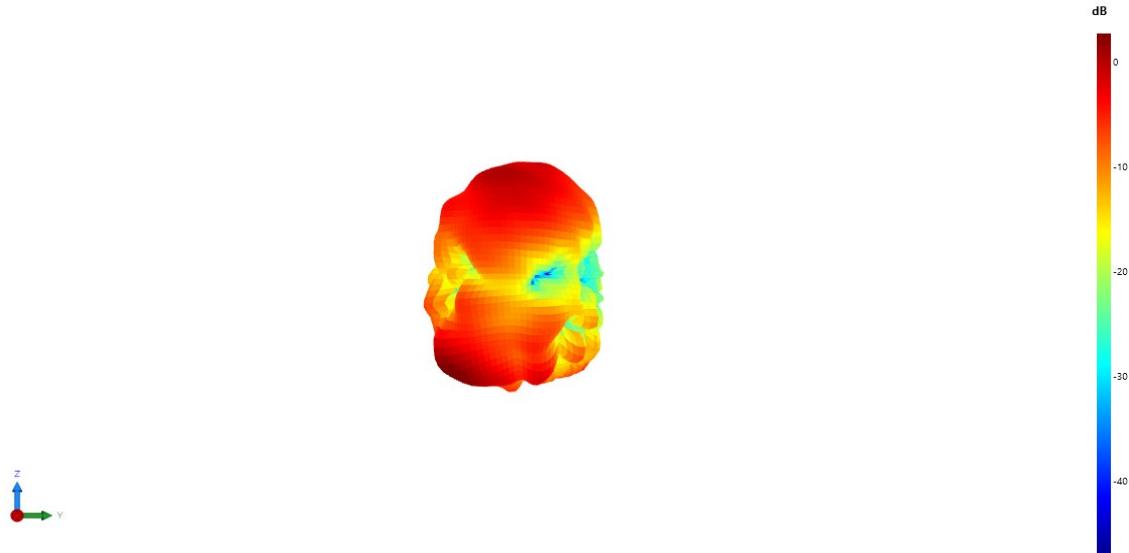
Max Antenna 3D Radiation Pattern 5470-5725 MHz

Frequency (MHz)	Peak Gain w/ Cable Loss (dBi)
5470-5725	6.95



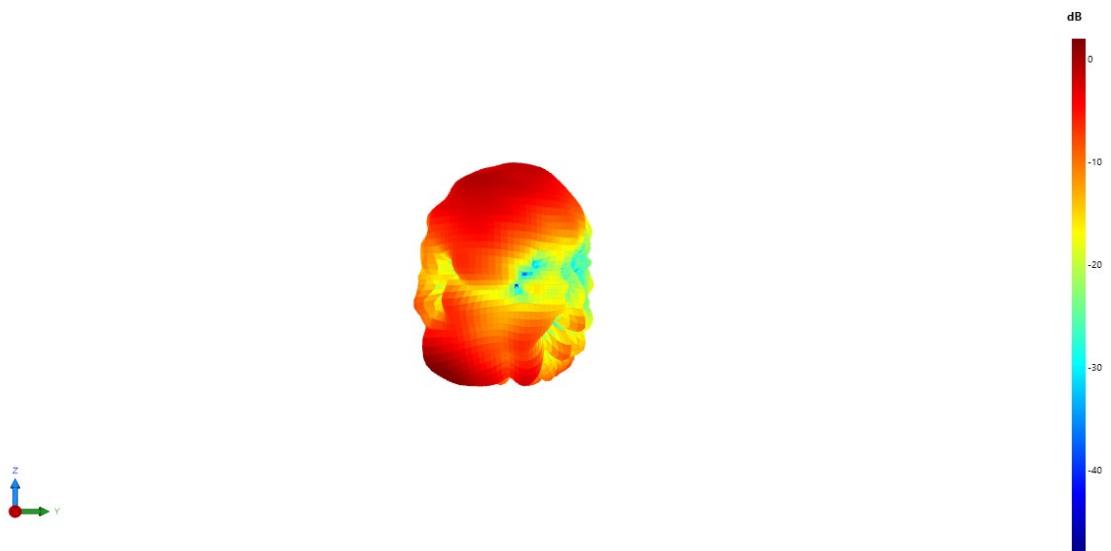
Max Antenna 3D Radiation Pattern 5725-5850 MHz

Frequency (MHz)	Peak Gain w/ Cable Loss (dBi)
5725-5850	6.95



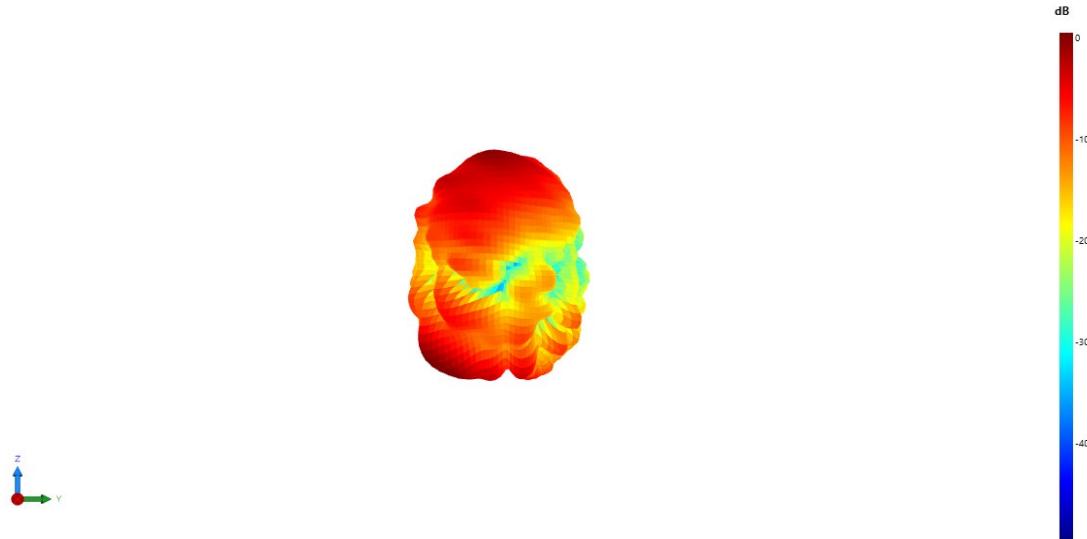
Max Antenna 3D Radiation Pattern 5850-5895 MHz

Frequency (MHz)	Peak Gain w/ Cable Loss (dBi)
5850-5895	6.24



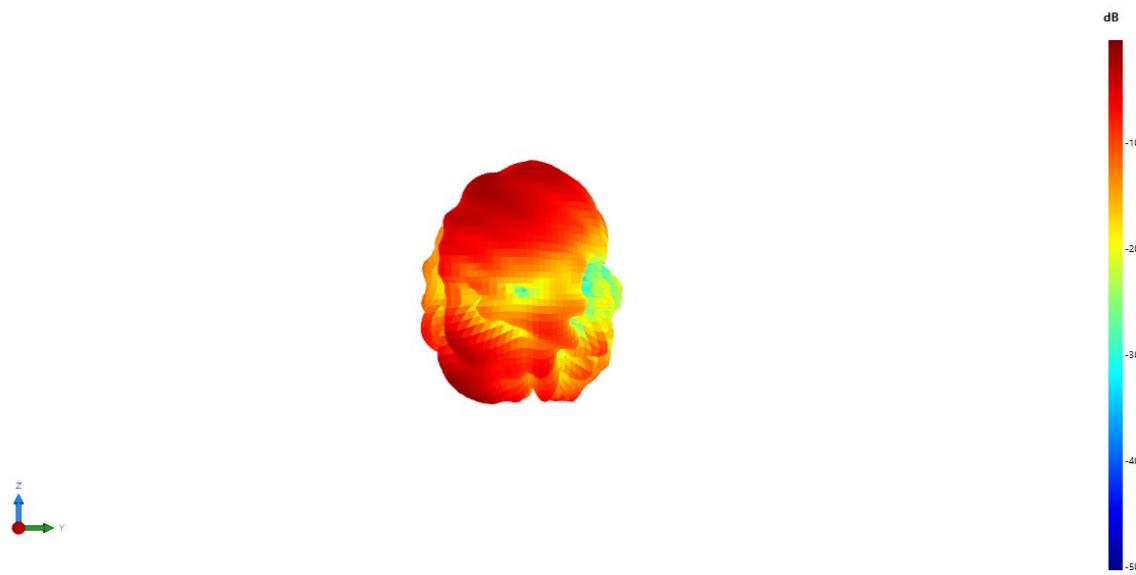
Max Antenna 3D Radiation Pattern 5925-6425 MHz

Frequency (MHz)	Peak Gain w/ Cable Loss (dBi)
5925-6425	5.87



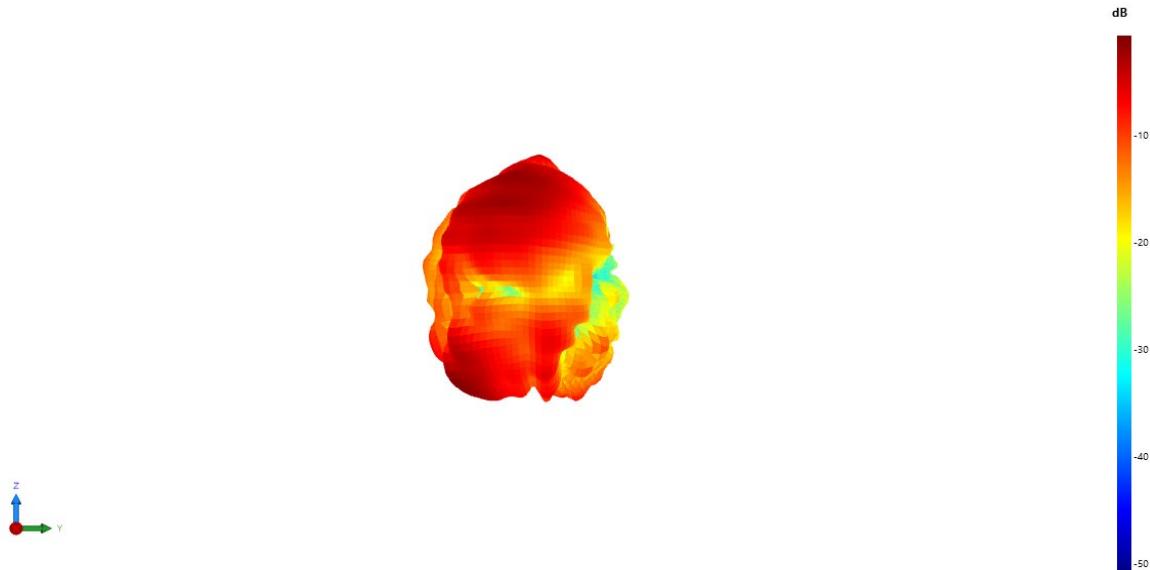
Max Antenna 3D Radiation Pattern 6425-6525 MHz

Frequency (MHz)	Peak Gain w/ Cable Loss (dBi)
6425-6525	3.93



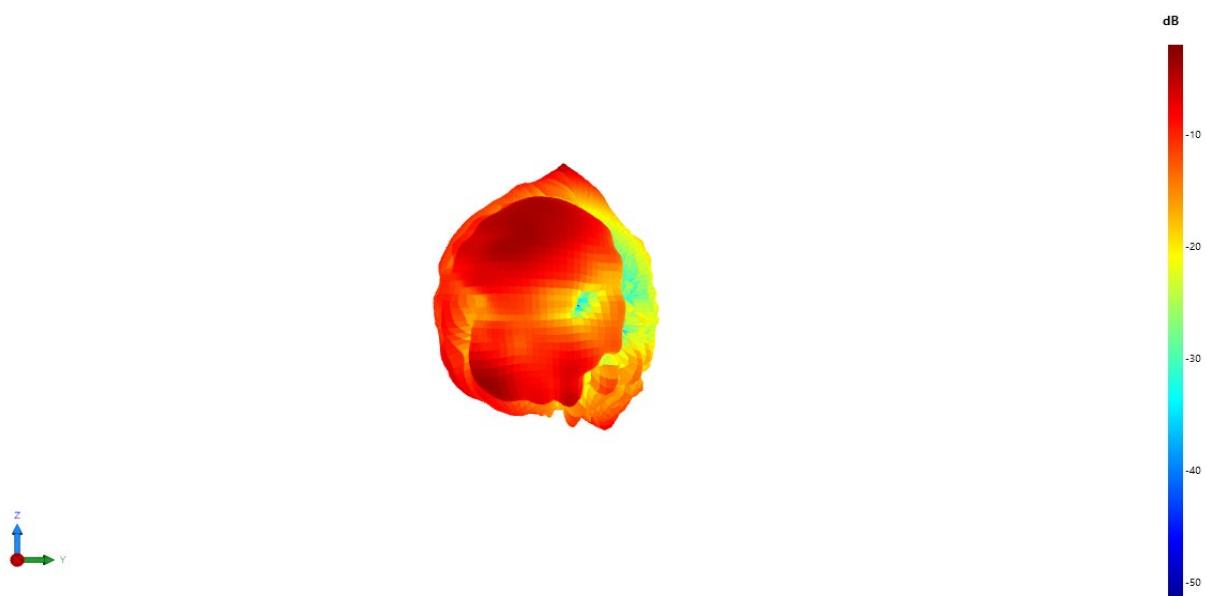
Max Antenna 3D Radiation Pattern 6525-6875 MHz

Frequency (MHz)	Peak Gain w/ Cable Loss (dBi)
6525-6875	3.78



Max Antenna 3D Radiation Pattern 6875-7125 MHz

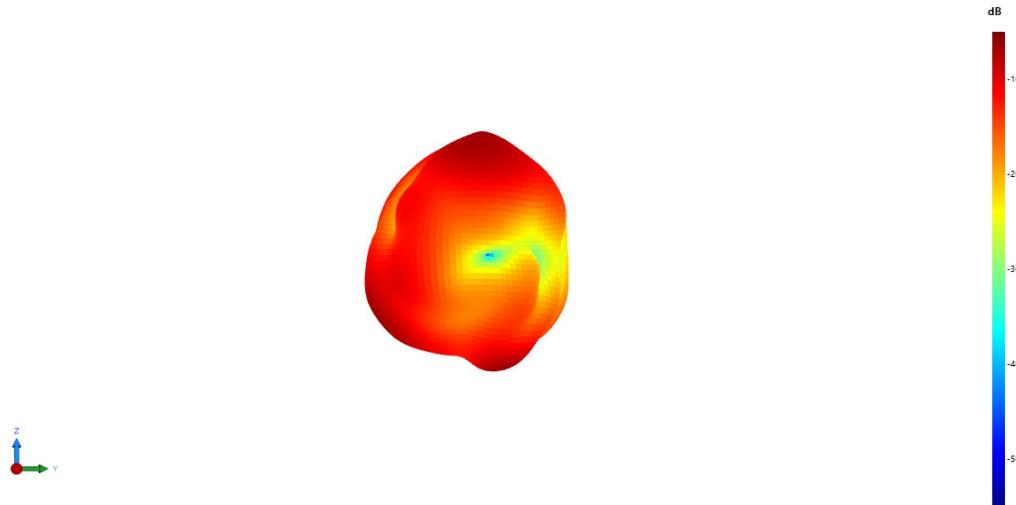
Frequency (MHz)	Peak Gain w/ Cable Loss (dBi)
6875-7125	2.74



Aux (Right) Antenna

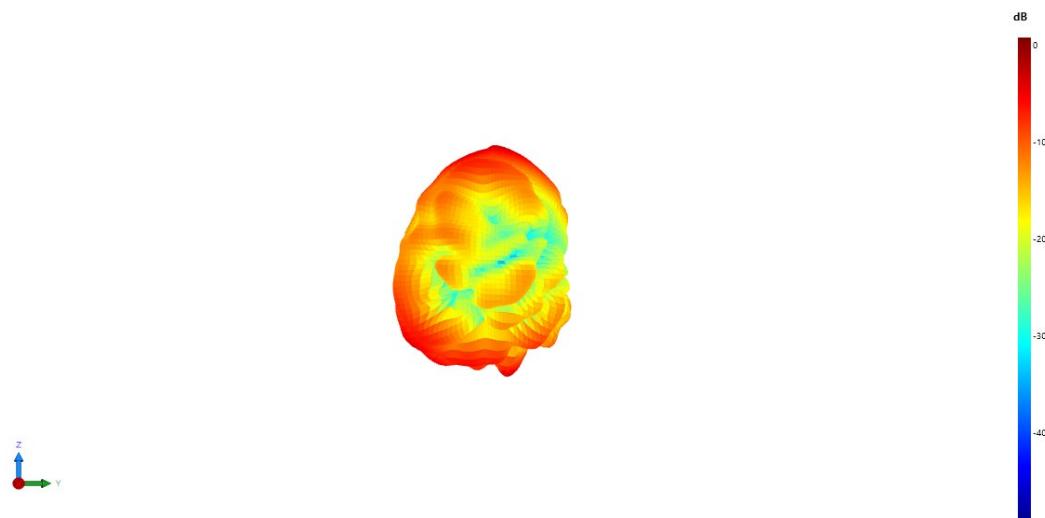
Max Antenna 3D Radiation Pattern 2400 – 2483.5 MHz

Frequency (MHz)	Peak Gain w/ Cable Loss (dBi)
2400-2483.5	1.02



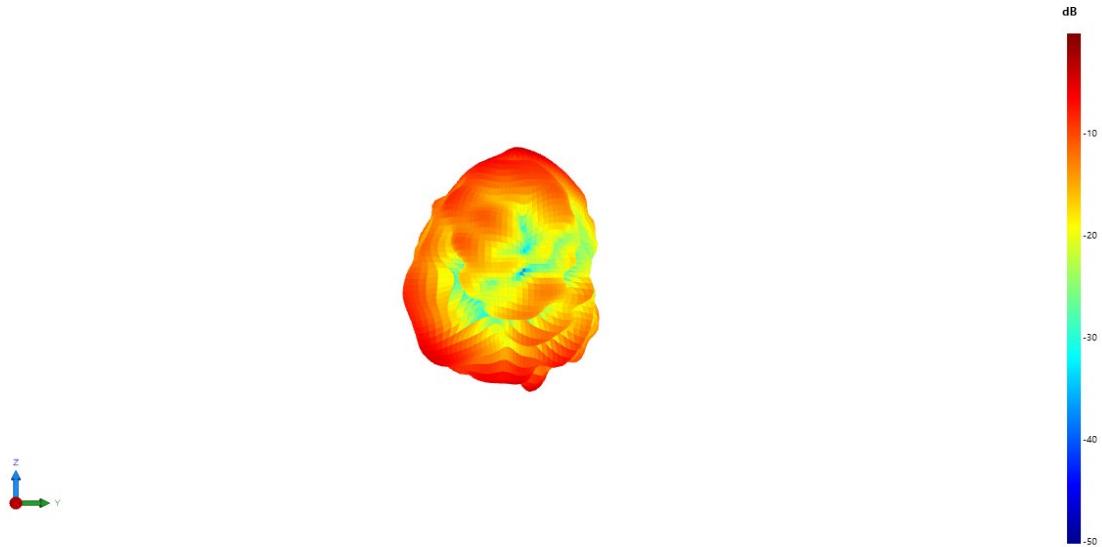
Max Antenna 3D Radiation Pattern 5150-5250 MHz

Frequency (MHz)	Peak Gain w/ Cable Loss (dBi)
5150-5250	3.42



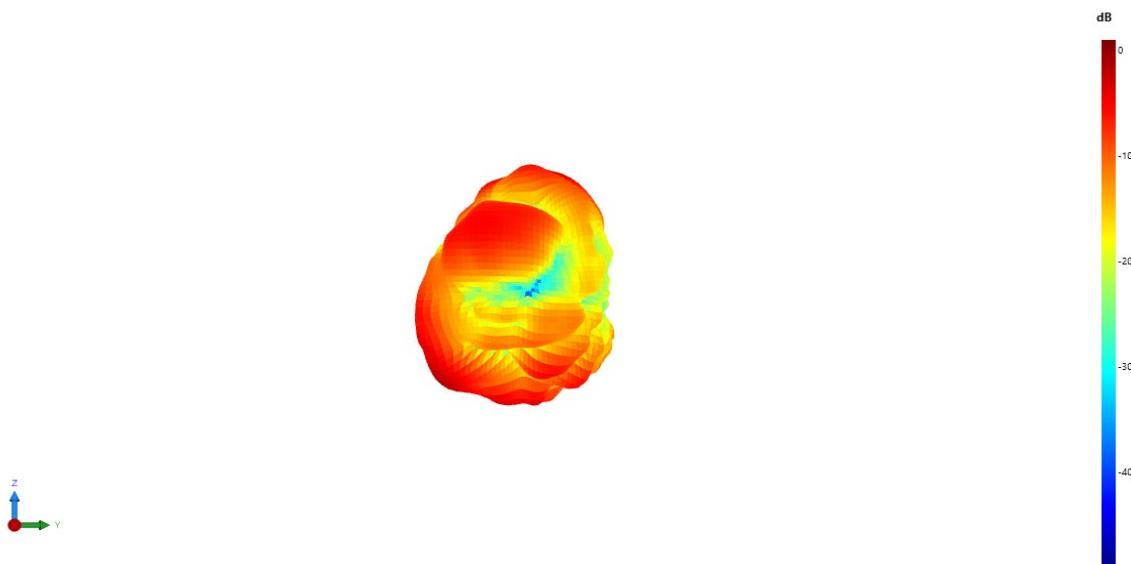
Max Antenna 3D Radiation Pattern 5250-5350 MHz

Frequency (MHz)	Peak Gain w/ Cable Loss (dBi)
5250-5350	3.42



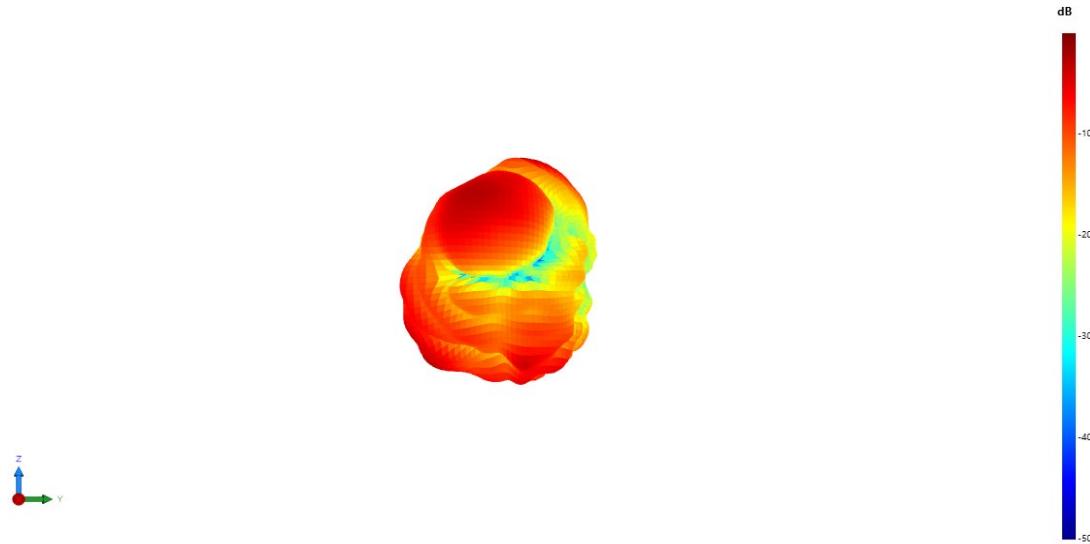
Max Antenna 3D Radiation Pattern 5470-5725 MHz

Frequency (MHz)	Peak Gain w/ Cable Loss (dBi)
5470-5725	4.34



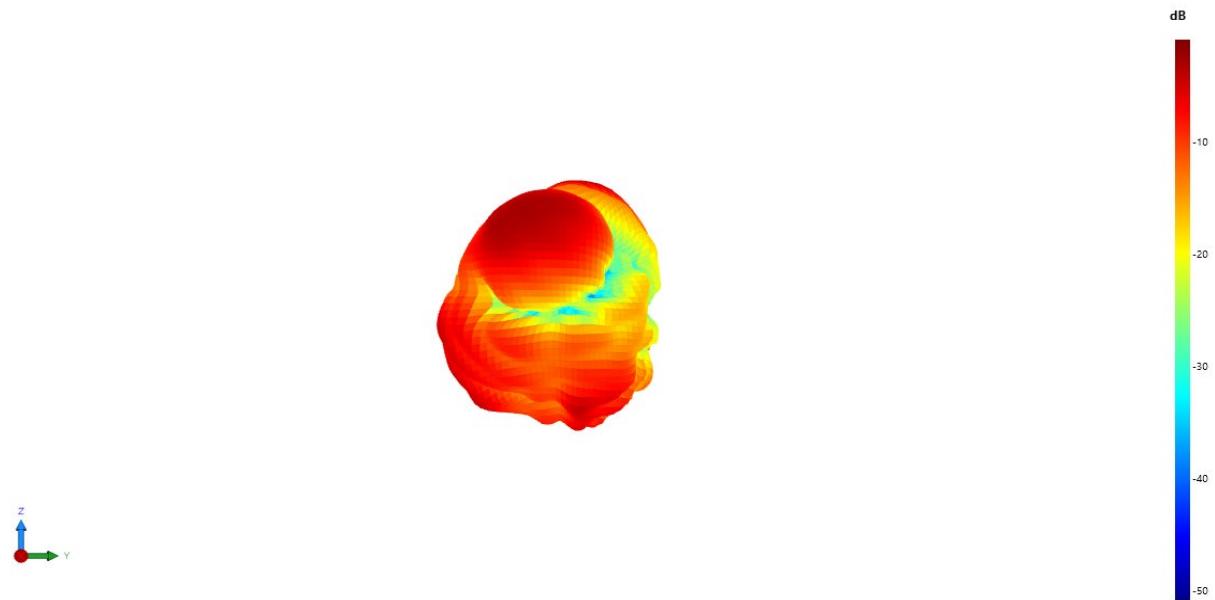
Max Antenna 3D Radiation Pattern 5725-5850 MHz

Frequency (MHz)	Peak Gain w/ Cable Loss (dBi)
5725-5850	4.34



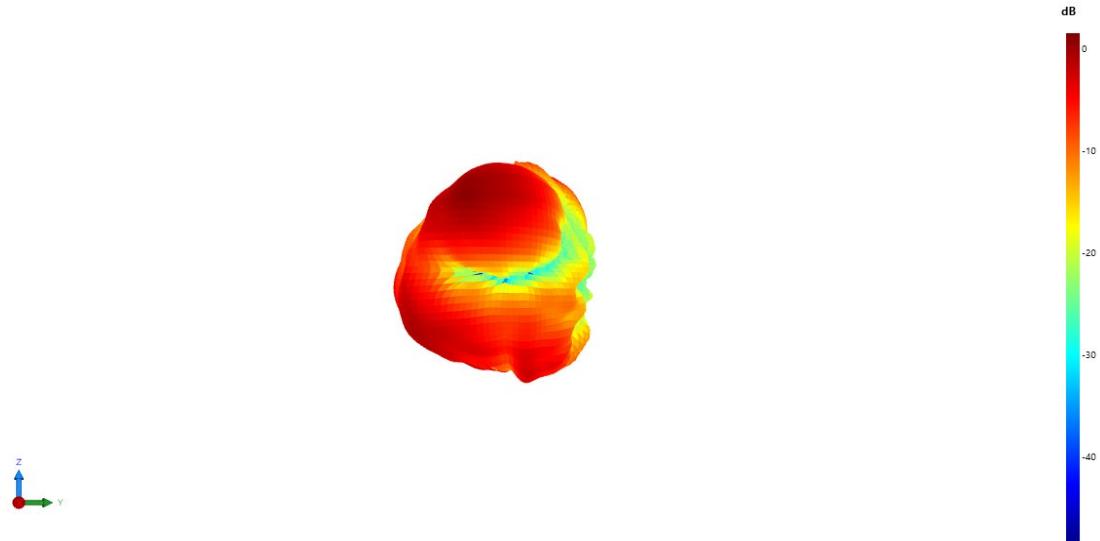
Max Antenna 3D Radiation Pattern 5850-5895 MHz

Frequency (MHz)	Peak Gain w/ Cable Loss (dBi)
5850-5895	3.92



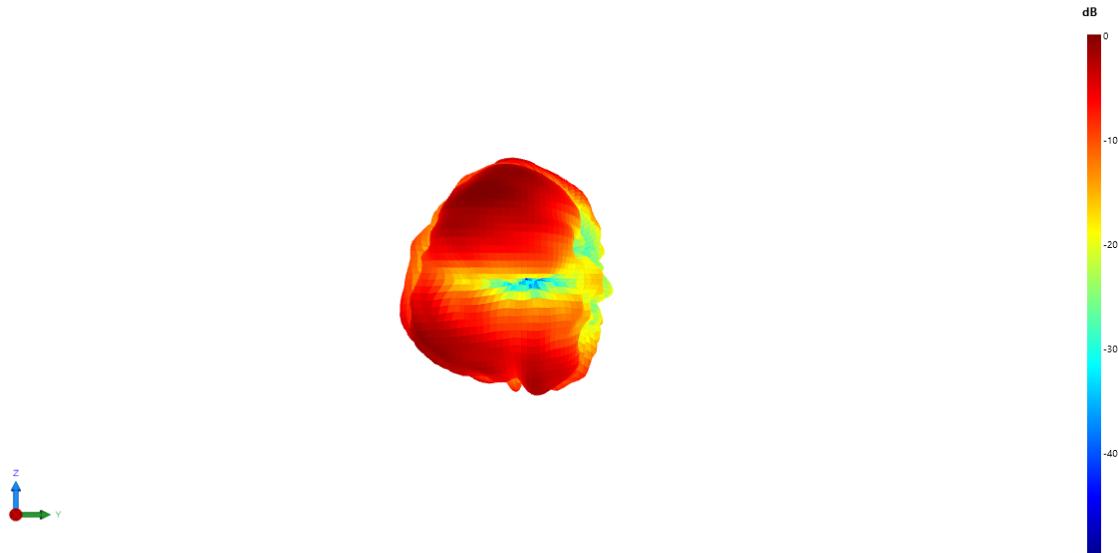
Max Antenna 3D Radiation Pattern 5925-6425 MHz

Frequency (MHz)	Peak Gain w/ Cable Loss (dBi)
5925-6425	4.94



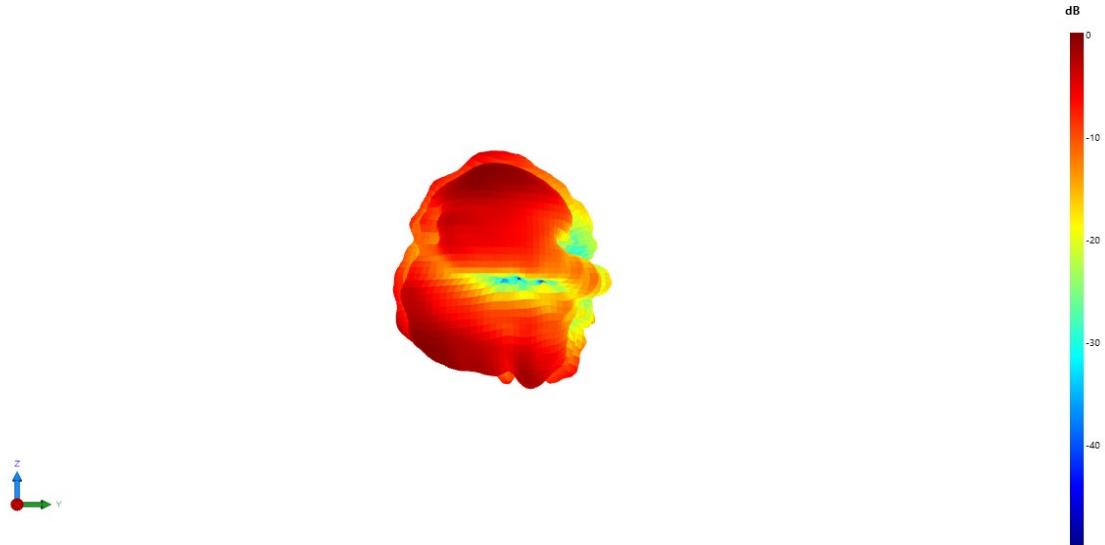
Max Antenna 3D Radiation Pattern 6425-6525 MHz

Frequency (MHz)	Peak Gain w/ Cable Loss (dBi)
6425-6525	4.35



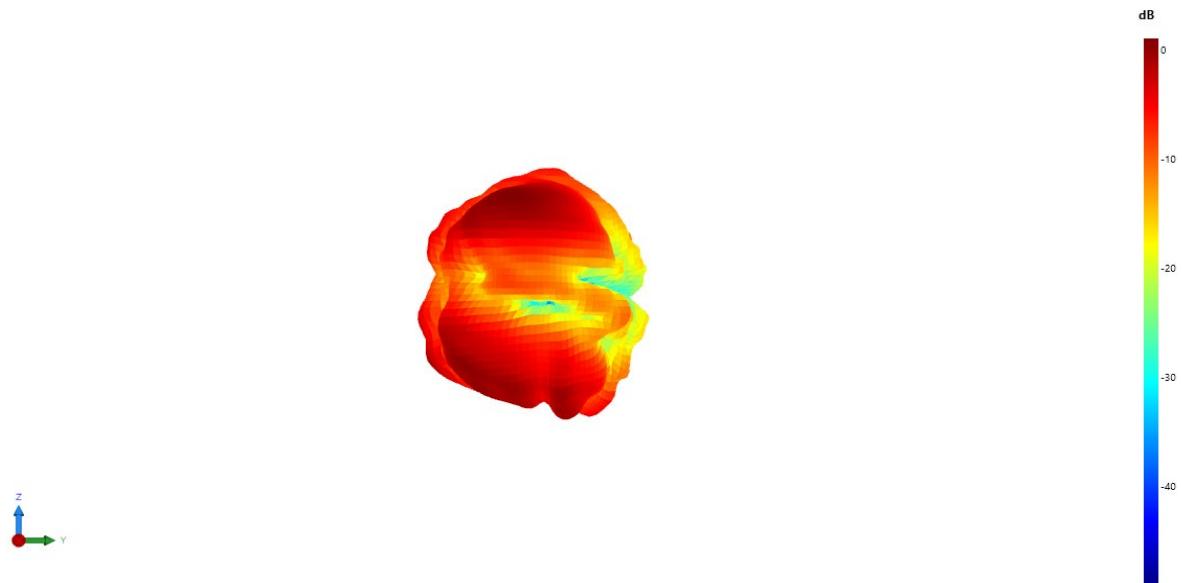
Max Antenna 3D Radiation Pattern 6525-6875 MHz

Frequency (MHz)	Peak Gain w/ Cable Loss (dBi)
6525-6875	3.92



Max Antenna 3D Radiation Pattern 6875-7125 MHz

Frequency (MHz)	Peak Gain w/ Cable Loss (dBi)
6875-7125	3.78



Record of Revisions