Part 15 Antenna Gains Test Report

Model 2037

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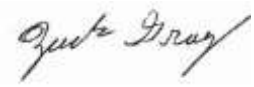
Microsoft

Authorizing Party:

Zack Gray, Microsoft



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.

2037 Gains Bands	Frequency (MHz)	Left Antenna Peak Gain (Chain A) (dBi)	Right Antenna Peak Gain (Chain B) (dBi)	Uncorrelated Directional MIMO Gain (dBi)	Correlated Directional MIMO Gain (dBi)
2.4GHz	2400-2483.5	5.69	4.66	3.91	6.74
UNII-1	5150-5250	8.11	5.35	5.78	8.51
UNII-2A	5250-5350	8.11	6.07	5.82	8.83
UNII-2C	5470-5725	7.21	5.36	5.70	8.52
UNII-3	5725-5850	6.00	5.35	4.15	6.87
UNII-4	5850-5895	6.00	5.35	3.83	6.84
UNII-5	5925-6425	7.60	5.35	4.80	6.86
UNII-6	6425-6525	6.89	2.92	4.23	6.60
UNII-7	6525-6875	7.95	3.80	5.50	7.72
UNII-8	6875-7125	7.69	3.64	5.28	7.54

2. Test Method and Test Setup

- Measurement Facility: Microsoft Antenna Lab
- Dates of Testing: 09/01/2023 – 09/30/2023
- 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.

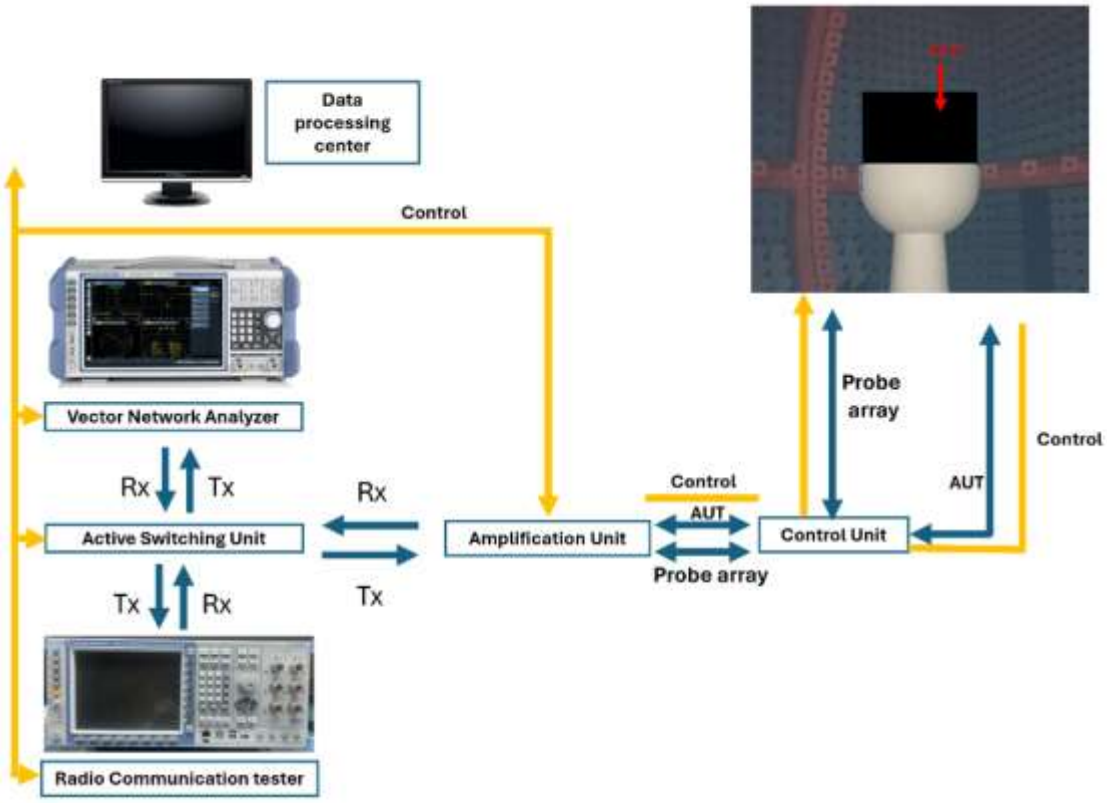
Item	Equipment	Manufacturer	Model	Calibration / Validation Due
1	SATIMO chamber	MVG	Satimo star gate	August 2024
2	Network Analyzer	Keysight	PNA-L N5232A	April 2024
3	Validation Dipole	MVG	WD3000	May 2024
4	Validation Dipole	MVG	WD6000	May 2024

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.


Data processing center
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Vector Network Analyzer
Rx
Tx
Active Switching Unit
Rx
Tx
Tx
Rx
Radio Communication tester
Amplification Unit
Control
AUT
Probe array
Control Unit
Probe array
AUT
Control

3. Antenna Manufacturer and Gains

Antenna Part Number	Antenna Type	Manufacturer	Cable Assembly Part Number	Freq range MHz	Peak Gain W Cable Loss	Peak Gain W/O Cable Loss	Max VSWR	Cable Loss
M1292891-001 Left Antenna (Chain A)	PIFA	Amphenol (Shanghai Amphenol Airwave Communication Electronics Co Ltd)	Connector Type: IPEX MHF4-L 20565-001R-13 Cable Type: Shenyu, 50 Ohm, Coaxial cable Length 60.7 mm, diameter 1.13 mm	2400-2483.5	5.69	5.99	2.6	0.3
				5150-5250	8.11	8.61	1.6	0.5
				5250-5350	8.11	8.61	1.9	0.5
				5470-5725	7.21	7.71	2.6	0.5
				5725-5850	6.00	6.50	2.3	0.5
				5850-5895	6.00	6.50	2.3	0.5
				5925-6425	7.60	8.10	2.3	0.5
				6425-6525	6.89	7.49	2.3	0.6
				6525-6875	7.95	8.55	2.3	0.6
				6875-7125	7.69	8.29	2.3	0.6
M1292892-001 Right Antenna (Chain B)	PIFA	Amphenol (Shanghai Amphenol Airwave Communication Electronics Co Ltd)	Connector Type: IPEX MHF4-L 20565-001R-13 Cable Type: Shenyu, 50 Ohm, Coaxial cable Length 206.6 mm Diameter 1.13 mm	2400-2483.5	4.66	5.36	3	0.7
				5150-5250	5.35	6.35	3	1.0
				5250-5350	6.07	7.07	3	1.0
				5470-5725	5.36	6.46	2.3	1.1
				5725-5850	5.35	6.45	1.8	1.1
				5850-5895	5.35	6.45	2.1	1.1
				5925-6425	5.35	6.45	3	1.1
				6425-6525	2.92	4.02	3	1.1
				6525-6875	3.80	5.00	3	1.2
				6875-7125	3.64	4.84	3	1.2

i. Peak Gain Details

2037 Peak Gains	Frequency (MHz)	Left Antenna Peak Gain (Chain A)			Right Antenna Peak Gain (Chain B)		
Bands		**Peak Gain (dBi)**	**Phi (°)**	**Theta (°)**	**Peak Gain (dBi)**	**Phi (°)**	**Theta (°)**
2.4GHz	2400-2483.5	**5.69**	96	-54	**4.66**	24	-33
UNII-1	5150-5250	**8.11**	177	-30	**5.35**	174	-6
UNII-2A	5250-5350	**8.11**	177	-30	**6.07**	153	-6
UNII-2C	5470-5725	**7.21**	177	-21	**5.36**	126	-6
UNII-3	5725-5850	**6.00**	153	-171	**5.35**	0	-27
UNII-4	5850-5895	**6.00**	153	-171	**5.35**	0	-27
UNII-5	5925-6425	**7.60**	153	-171	**5.35**	0	-27
UNII-6	6425-6525	**6.89**	153	-171	**2.92**	168	21
UNII-7	6525-6875	**7.95**	153	-171	**3.80**	3	150
UNII-8	6875-7125	**7.69**	153	-171	**3.64**	9	153

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:

$$\text{Uncorrelated Gain} = 10 * \log \frac{10^{\frac{G1}{10}} + 10^{\frac{G2}{10}} + \cdots + 10^{\frac{GN}{10}}}{NANT} \text{ dBi}$$

$$\text{Correlated Gain} = 10 * \log \frac{(10^{\frac{G1}{20}} + 10^{\frac{G2}{20}} + \cdots + 10^{\frac{GN}{20}})\text{^}2}{NANT} \text{ dBi}$$

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:

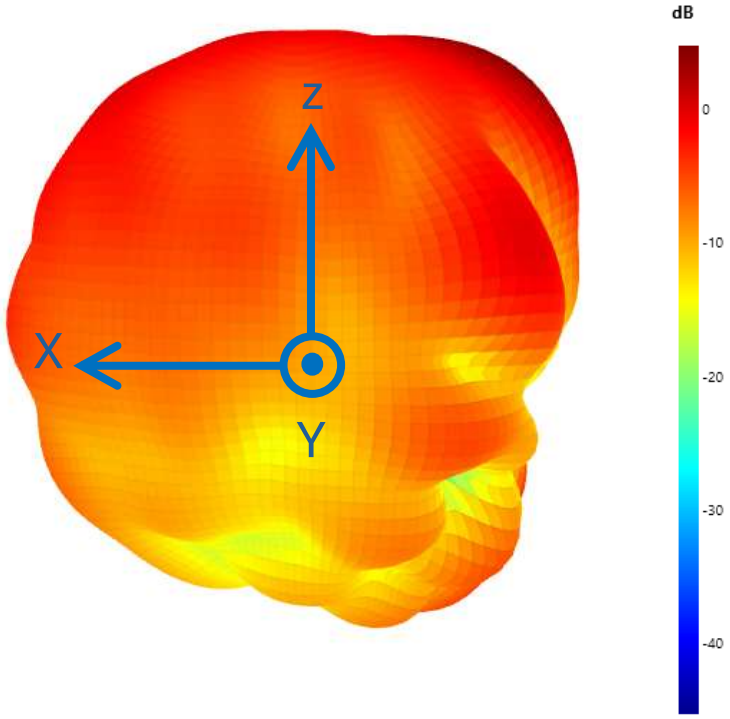
2037 Directional MIMO Gains	Frequency (MHz)	Uncorrelated Directional MIMO Gain					Correlated Directional MIMO Gain				
Bands		**Uncorr. Gain (dBi)**	**ϕ(°)**	**θ (°)**	**Ant A Gain (dBi)**	**Ant B Gain (dBi)**	**Corr. Gain (dBi)**	**ϕ(°)**	**θ (°)**	**Ant A Gain (dBi)**	**Ant B Gain (dBi)**
2.4GHz	2400-2483.5	**3.91**	99	-54	5.37	1.69	**6.74**	99	-54	5.37	1.69
UNII-1	5150-5250	**5.78**	177	-21	7.51	2.88	**8.51**	177	-21	7.51	2.88
UNII-2A	5250-5350	**5.82**	159	-9	5.77	5.86	**8.83**	159	-9	5.77	5.86
UNII-2C	5470-5725	**5.70**	171	-18	7.15	3.49	**8.52**	171	-18	7.15	3.49
UNII-3	5725-5850	**4.15**	177	-21	5.91	1.17	**6.87**	177	-21	5.91	1.17
UNII-4	5850-5895	**3.83**	15	9	4.09	3.56	**6.84**	15	9	4.09	3.56
UNII-5	5925-6425	**4.80**	153	-171	7.38	-2.44	**6.86**	159	-168	7.16	-1.56
UNII-6	6425-6525	**4.23**	153	-171	6.64	-1.67	**6.60**	15	168	6.20	-0.16
UNII-7	6525-6875	**5.50**	153	-171	7.92	-0.43	**7.72**	153	-171	7.92	-0.43
UNII-8	6875-7125	**5.28**	153	-171	7.69	-0.58	**7.54**	18	168	6.30	2.30

4. Radiated Characteristics of Antennas in Host Platform

A. Left Antenna (Chain A)

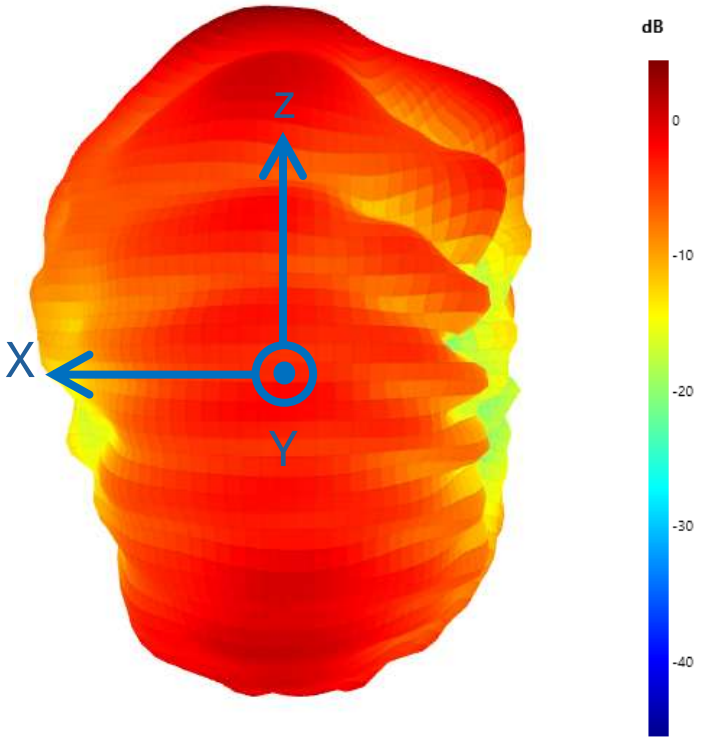
3D radiation Pattern over 2400-2483.5 MHz

Frequency Range (MHz)	Peak Gain W Cable Loss
2400-2483.5	5.69



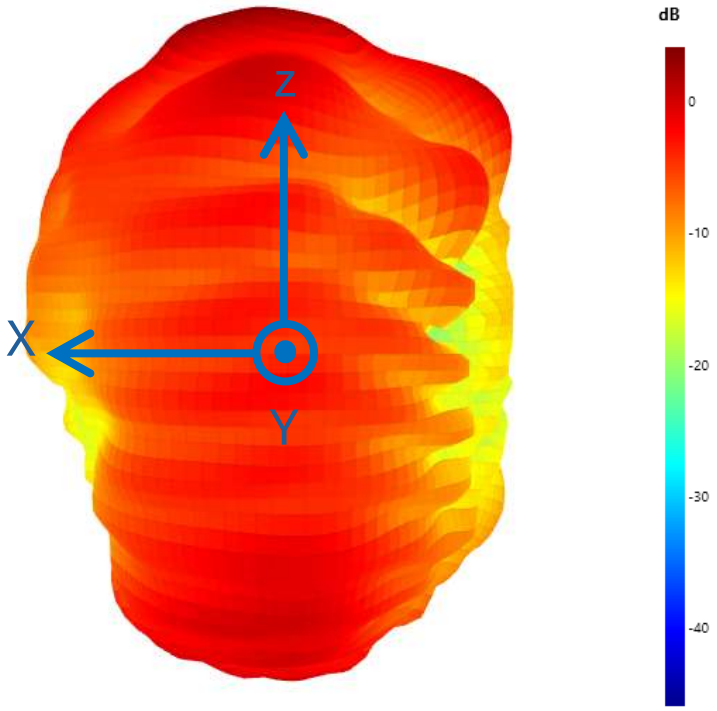
3D radiation Pattern over 5150-5250 MHz

Frequency Range (MHz)	Peak Gain W Cable Loss
5150-5250	8.11



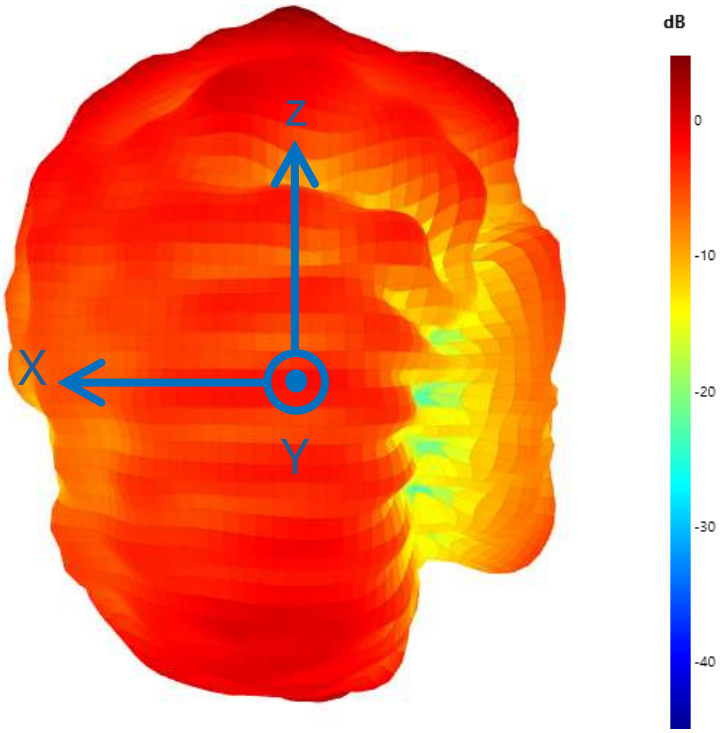
3D radiation Pattern over 5250-5350 MHz

Frequency Range (MHz)	Peak Gain W Cable Loss
5250-5350	8.11



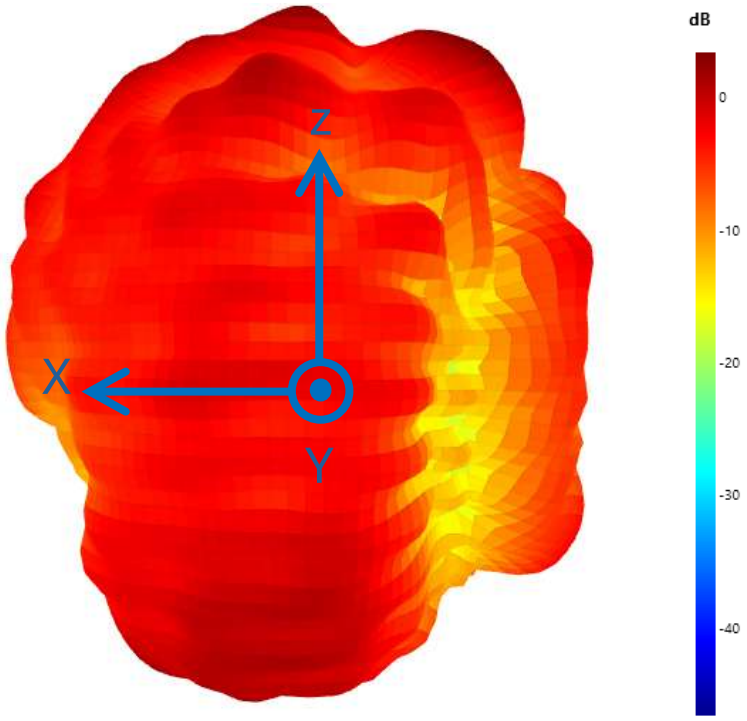
3D radiation Pattern over 5470-5725 MHz

Frequency Range (MHz)	Peak Gain W Cable Loss
5470-5725	7.21



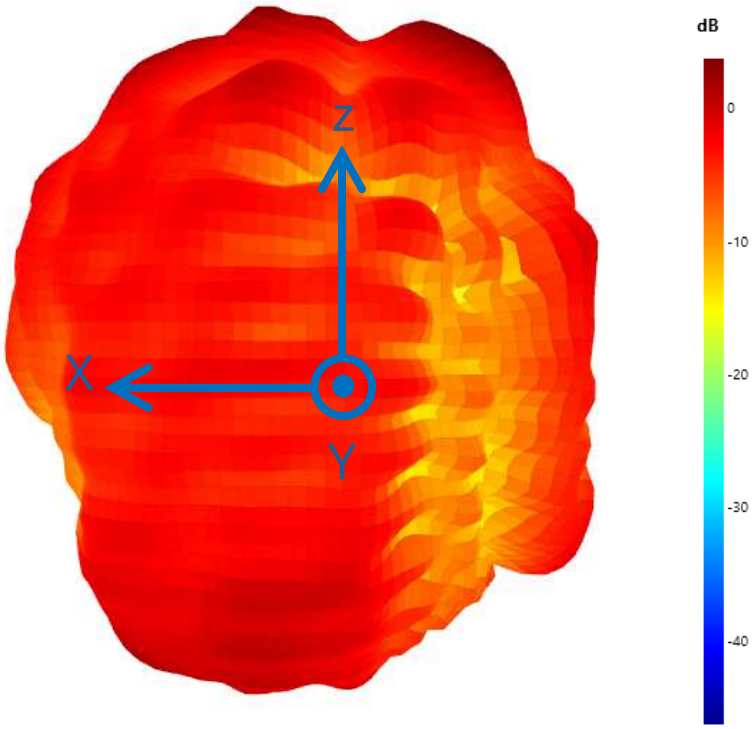
3D radiation Pattern over 5725-5850 MHz

Frequency Range (MHz)	Peak Gain W Cable Loss
5725-5850	6.00



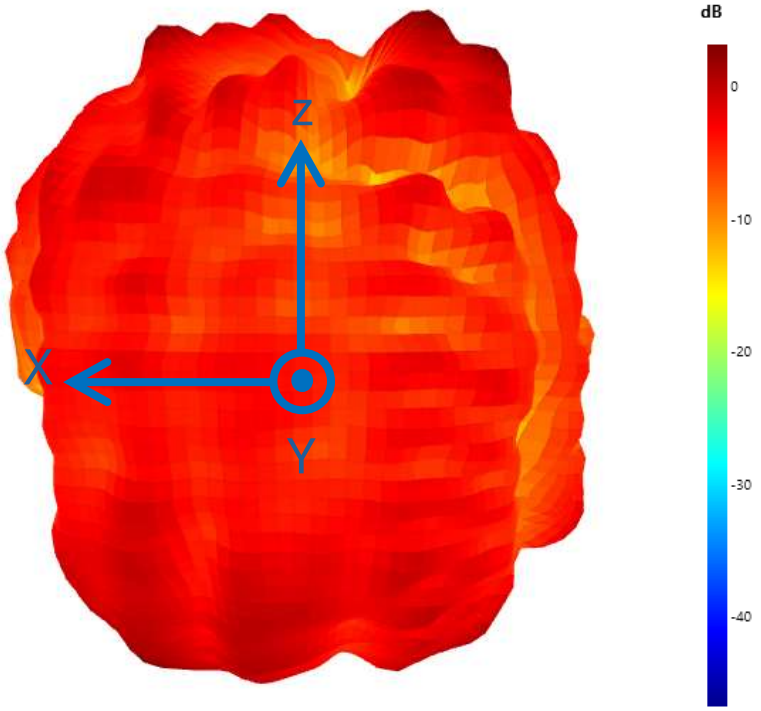
3D radiation Pattern over 5850-5895 MHz

Frequency Range (MHz)	Peak Gain W Cable Loss
5850-5895	6.00



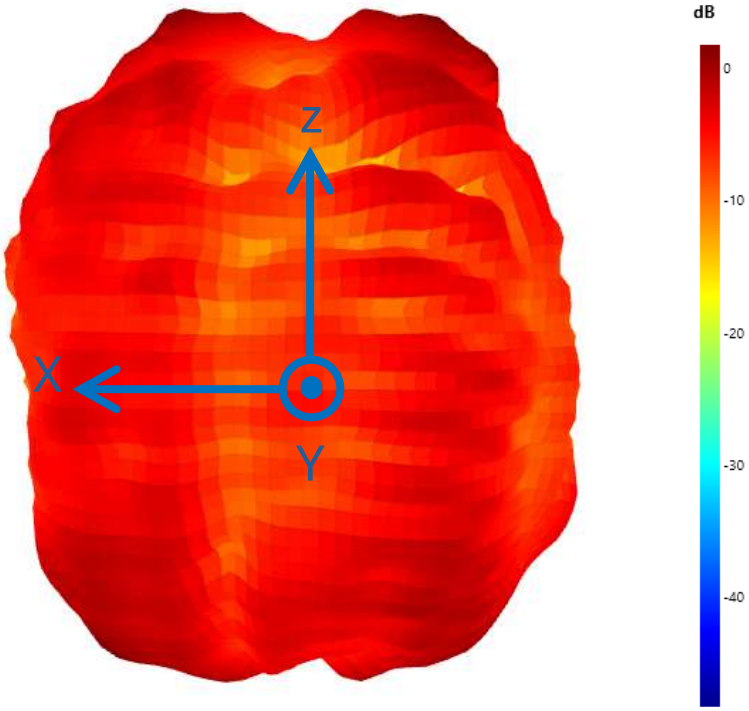
3D radiation Pattern over 5925-6425 MHz

Frequency Range (MHz)	Peak Gain W Cable Loss
5925-6425	7.60



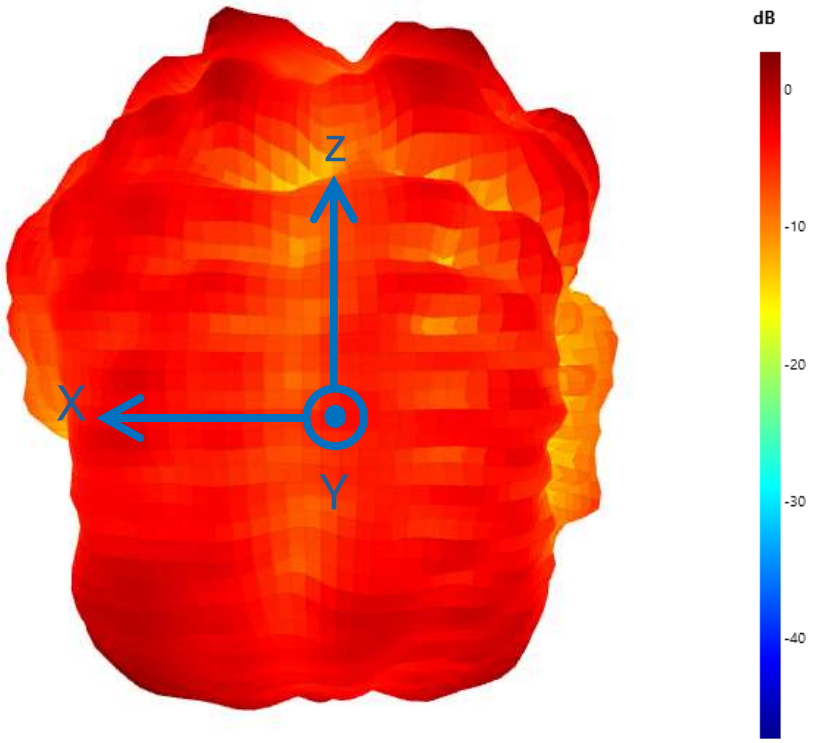
3D radiation Pattern over 6425-6525 MHz

Frequency Range (MHz)	Peak Gain W Cable Loss
6425-6525	6.89



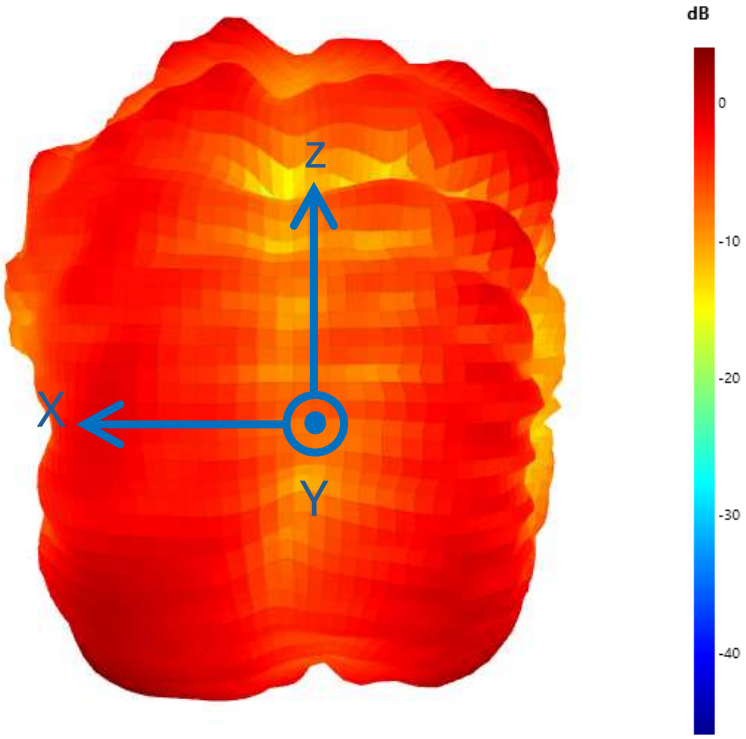
3D radiation Pattern over 6525-6875 MHz

Frequency Range (MHz)	Peak Gain W Cable Loss
6525-6875	7.95



3D radiation Pattern over 6875-7125 MHz

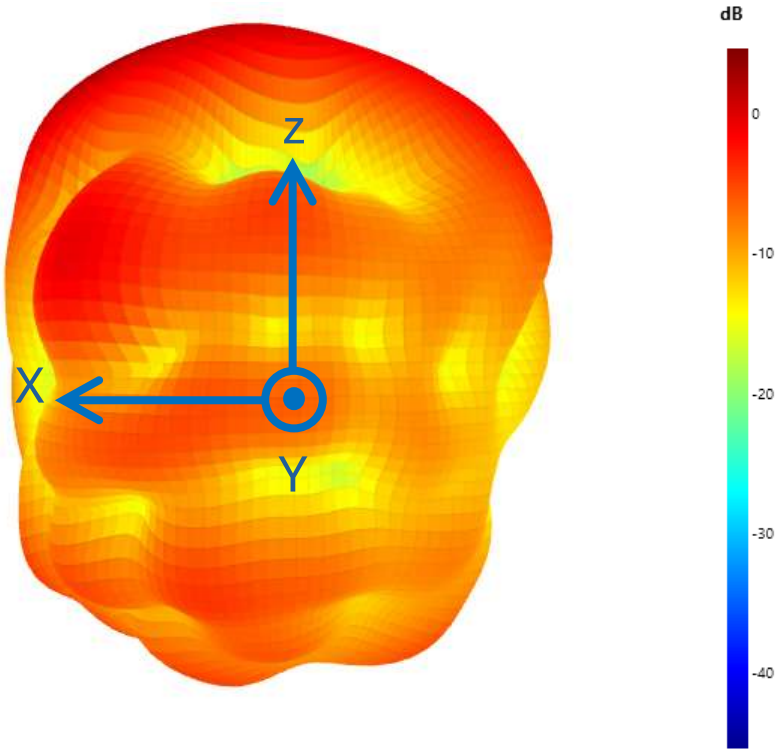
Frequency Range (MHz)	Peak Gain W Cable Loss
6875-7125	7.69



B. Right Antenna (Chain B)

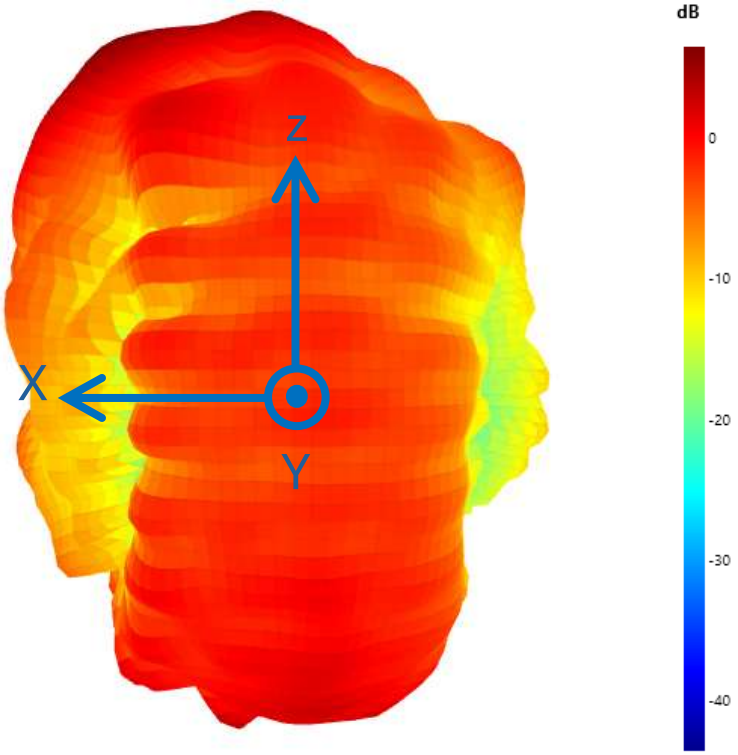
3D radiation Pattern over 2400-2483.5 MHz

Frequency Range (MHz)	Peak Gain W Cable Loss
2400-2483.5	4.66



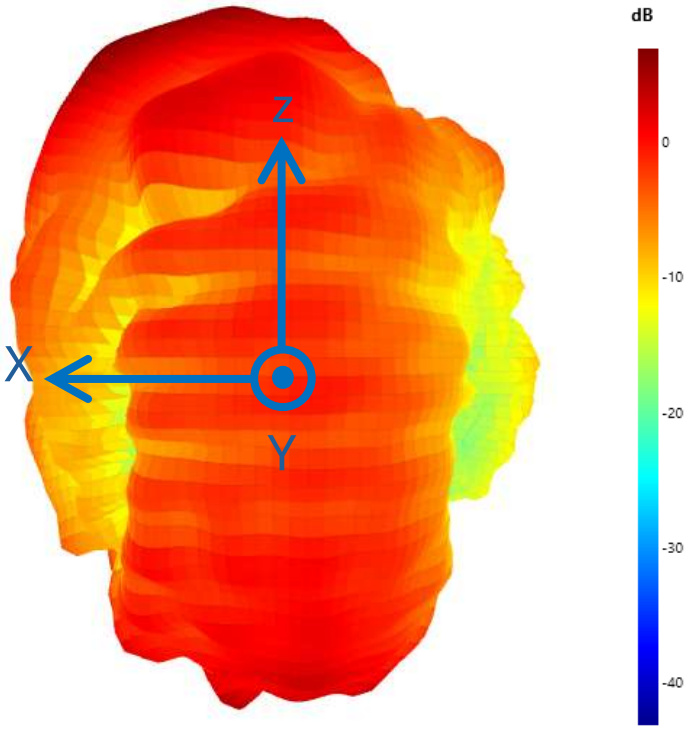
3D radiation Pattern over 5150-5250 MHz

Frequency Range (MHz)	Peak Gain W Cable Loss
5150-5250	5.35



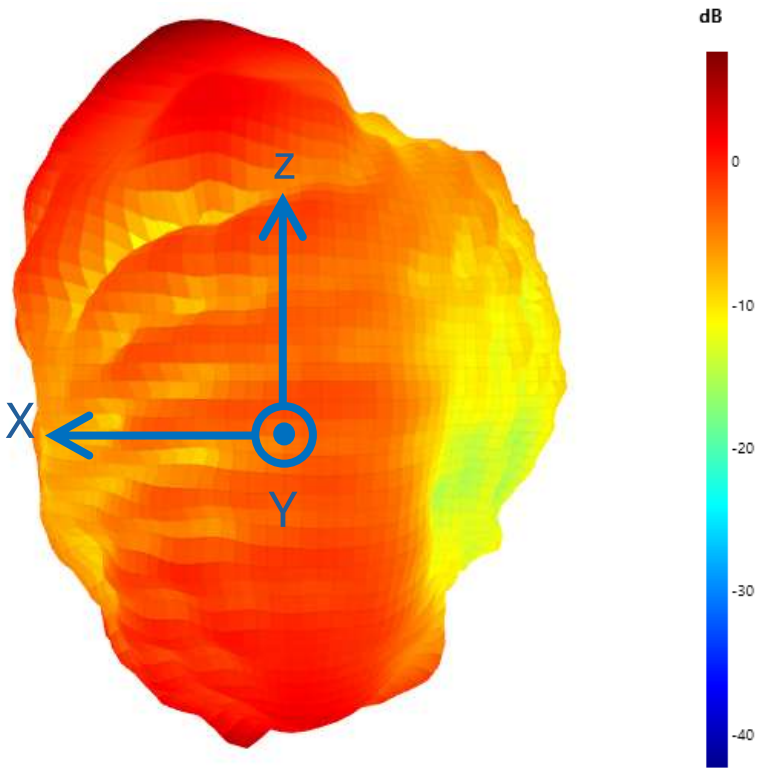
3D radiation Pattern over 5250-5350 MHz

Frequency Range (MHz)	Peak Gain W Cable Loss
5250-5350	6.07



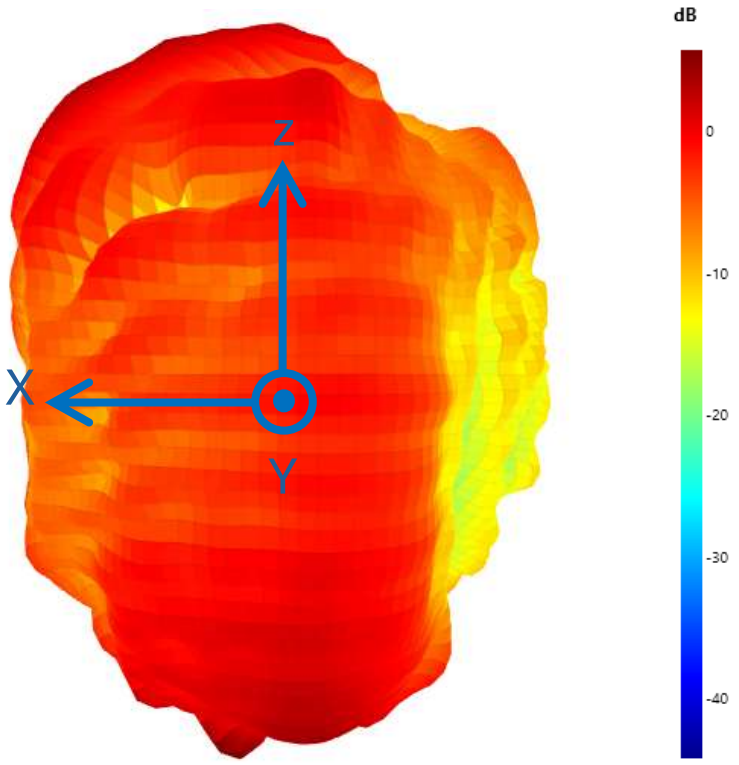
3D radiation Pattern over 5470-5725 MHz

Frequency Range (MHz)	Peak Gain W Cable Loss
5470-5725	5.36



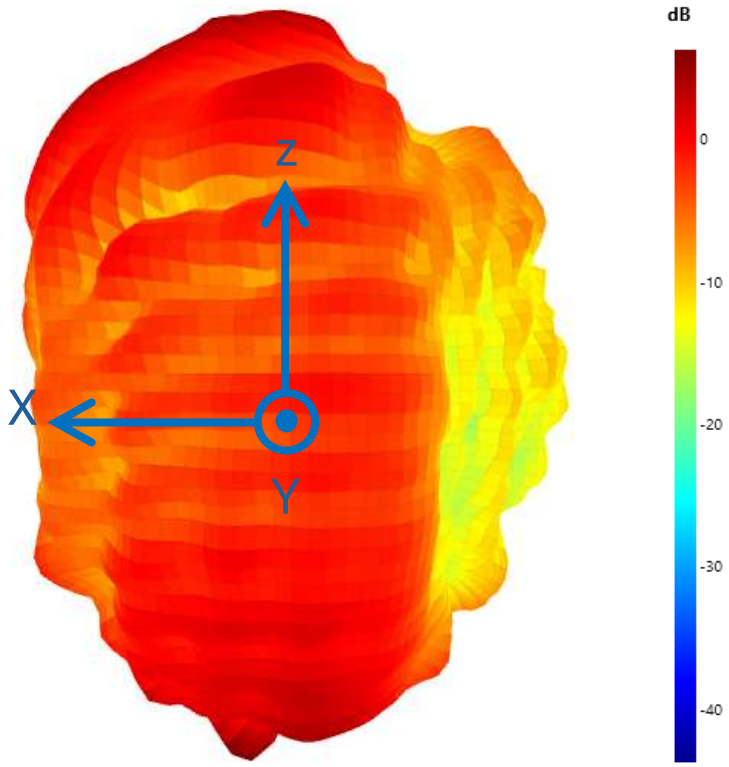
3D radiation Pattern over 5725-5850 MHz

Frequency Range (MHz)	Peak Gain W Cable Loss
5725-5850	5.35



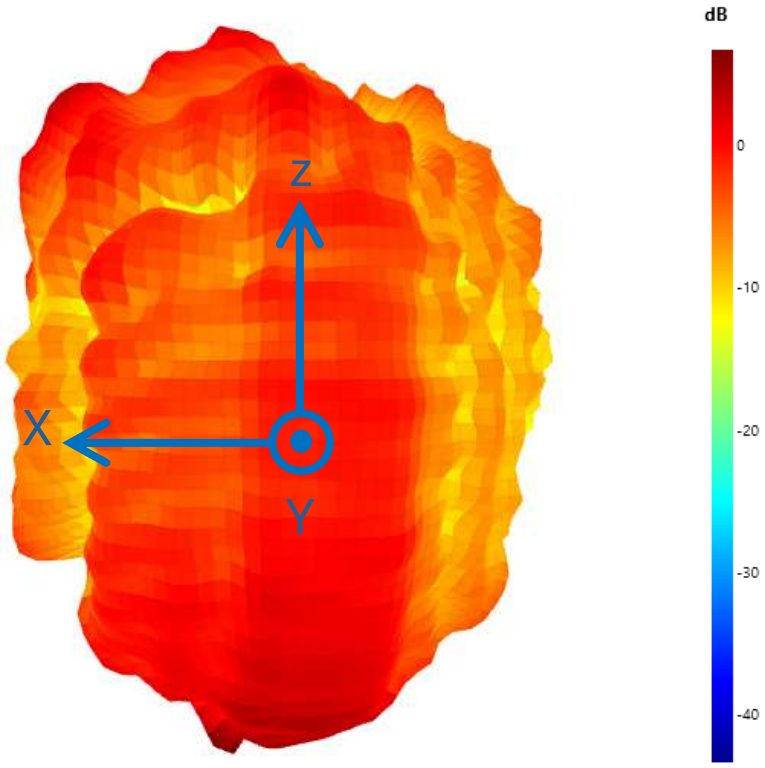
3D radiation Pattern over 5850-5895 MHz

Frequency Range (MHz)	Peak Gain W Cable Loss
5850-5895	5.35



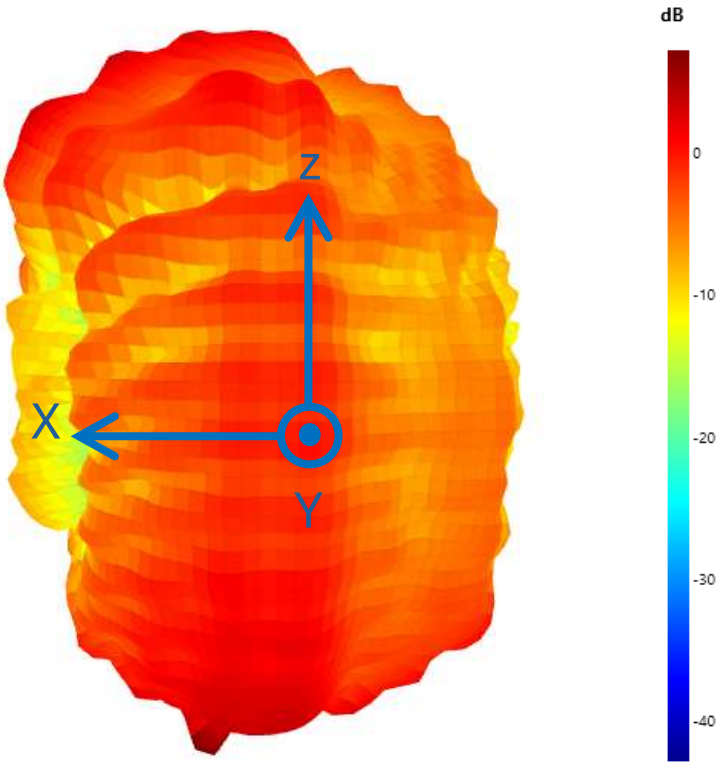
3D radiation Pattern over 5925-6425 MHz

Frequency Range (MHz)	Peak Gain W Cable Loss
5925-6425	5.35



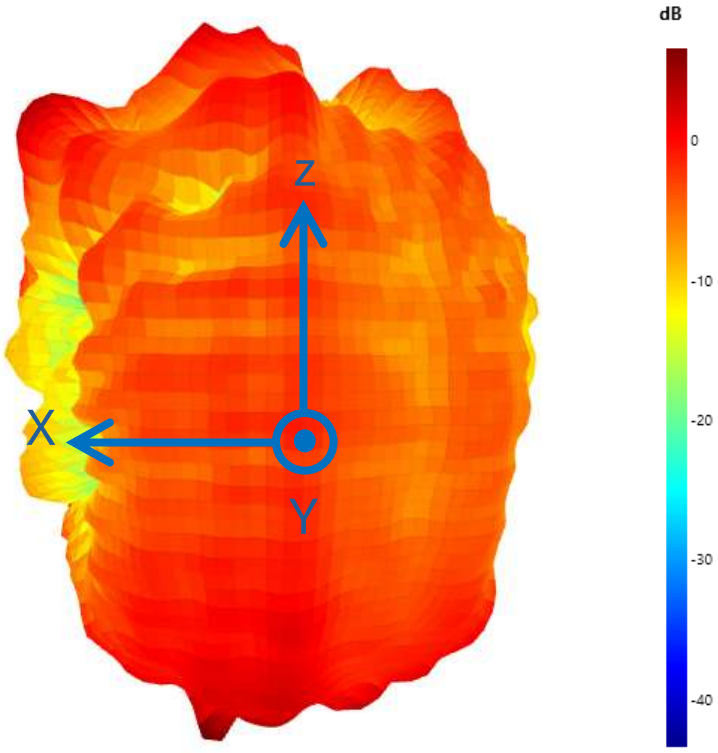
3D radiation Pattern over 6425-6525 MHz

Frequency Range (MHz)	Peak Gain W Cable Loss
6425-6525	2.92



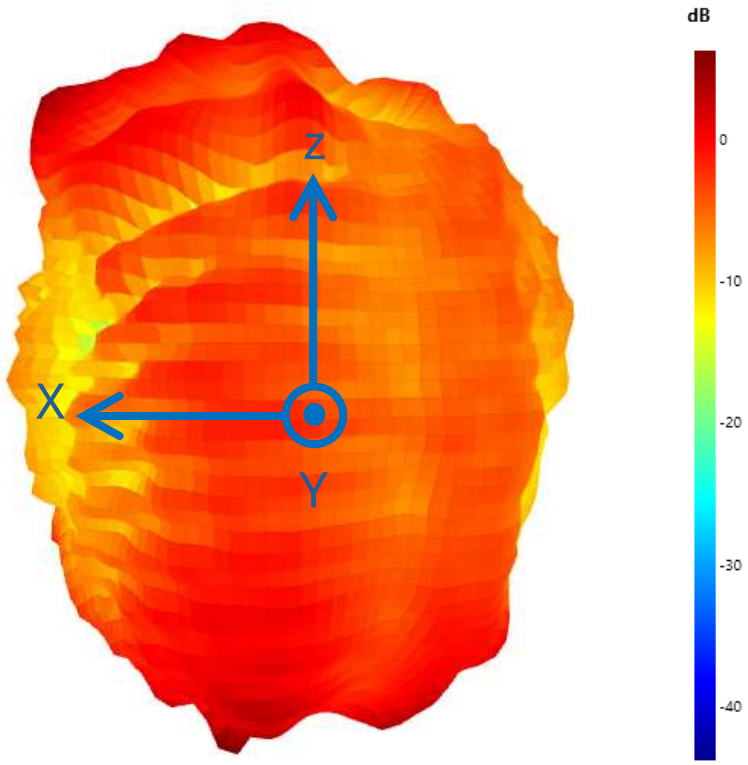
3D radiation Pattern over 6525-6875 MHz

Frequency Range (MHz)	Peak Gain W Cable Loss
6525-6875	3.80



3D radiation Pattern over 6875-7125 MHz

Frequency Range (MHz)	Peak Gain W Cable Loss
6875-7125	3.64



Record of Revisions

Revision	Date	Summary of Changes
1.0	02/28/2024	First Version
1.1	4/25/2024	Added authorizing party name, Cal. Due dates.