



Bosch BRP HUB3-10 Antenna

Measurement

ID: SCDC-1050199185-134720

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1 Introduction

At the request of Bosch, the Combo WIFI antenna matching component were optimized. The antenna was then (re)characterized. Antenna efficiency and maximum gain for the four antennas characterized in the Satimo chamber are presented.

2 Test Equipment

The following test equipment was used:

Description	Manufacturer	Model	Serial Number
Vector Network Analyzer	Agilent Technologies	E5071C	MY46212807
SG24 Multi-probe Antenna Measurement System	MVG Industries	SG24L	PAR2899S

3 Test Object

Antenna Measurement were performed on a prototype labelled “#D301-C3.1 SAMPLE, ANTENNA TUNED #2”.

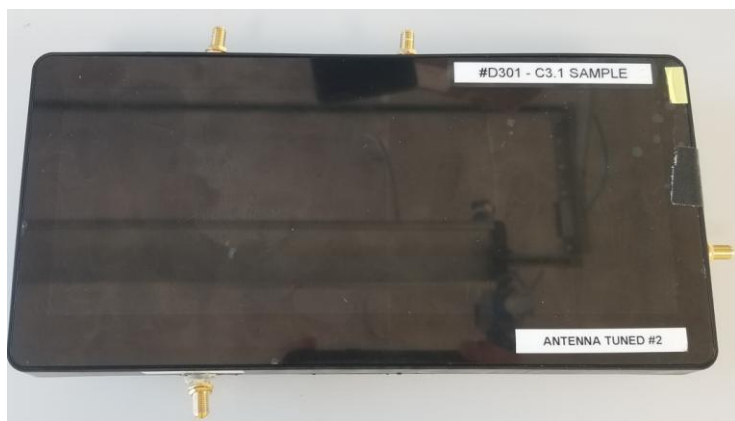


Figure 1 - DUT, Top View



Figure 2 - DUT, Bottom View



Figure 3 - GNSS connector



Figure 4 - BT_COMBO connector



Figure 5 - WIFI_COMBO and BT_ONLY connectors

The prototype has four antenna ports labelled as follows:

- 1) GNSS

- 2) BT_COMBO
- 3) BT_ONLY
- 4) WIFI_COMBO

The test scope was defined as follows:

Table 1 – Test Scope

Antenna	Start Frequency (MHz)	Stop Frequency (MHz)
BT-only	2400	2483
BT COMBO	2400	2483
WIFI COMBO*	2400	2500
WIFI COMBO*	5000	5895
GNSS antenna	1559	1610

*WIFI antenna is a dual-band antenna

The antennas were tested on numerous frequencies across their operational bands including the following key frequencies:

Table 2 – Important Antenna Test Frequencies

Antenna	Description	F1	F2	F3	F4	F5	F6	F7
GNSS	GNSS antenna	1559	1585	1610				
BT-ONLY	BT-only	2400	2442	2483				
BT COMBO	BT	2400	2442	2483				
Combo WIFI	WIFI 2.4 & 5 GHz	2400	2450	2500	5170	5735	5755	5895

NOTE: Per a conversation with Bosch (2025.11.20), the 5 GHz antenna is only used between the frequencies of 5.735 and 5.755 GHz. Accordingly, matching was optimized for these frequencies in spite of the fact that the 5 GHz band covers a much wider bandwidth.

4 Antenna Matching – WIFI COMBO

At the request of Bosch, the matching for the Combo WIFI antenna was updated. This was done after a preliminary measurement showed poor performance in the 5.735-5.755 GHz band.

The original matching circuit is shown in Figure 6.

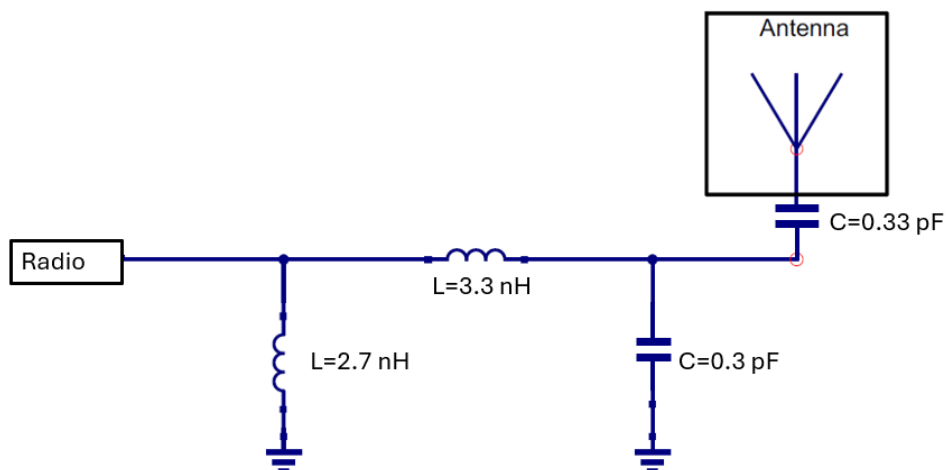


Figure 6 - Matching as provided by Bosch

The updated matching circuit is shown in Figure 7.

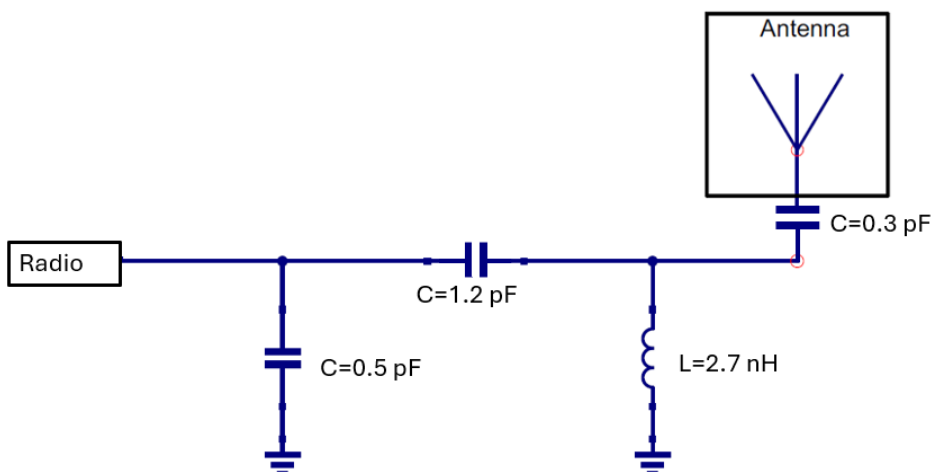


Figure 7 - Updated matching circuit used in measurements

The VSWR (old vs. new) is shown below. Note, for many consumer applications, a VSWR of lower than 3:1 is required.



Figure 8 - VSWR Comparison (original vs. updated WIFI COMBO antenna matching)

A rough comparison of the radiated efficiency of the two matching networks as measured in a reverb chamber is shown below:

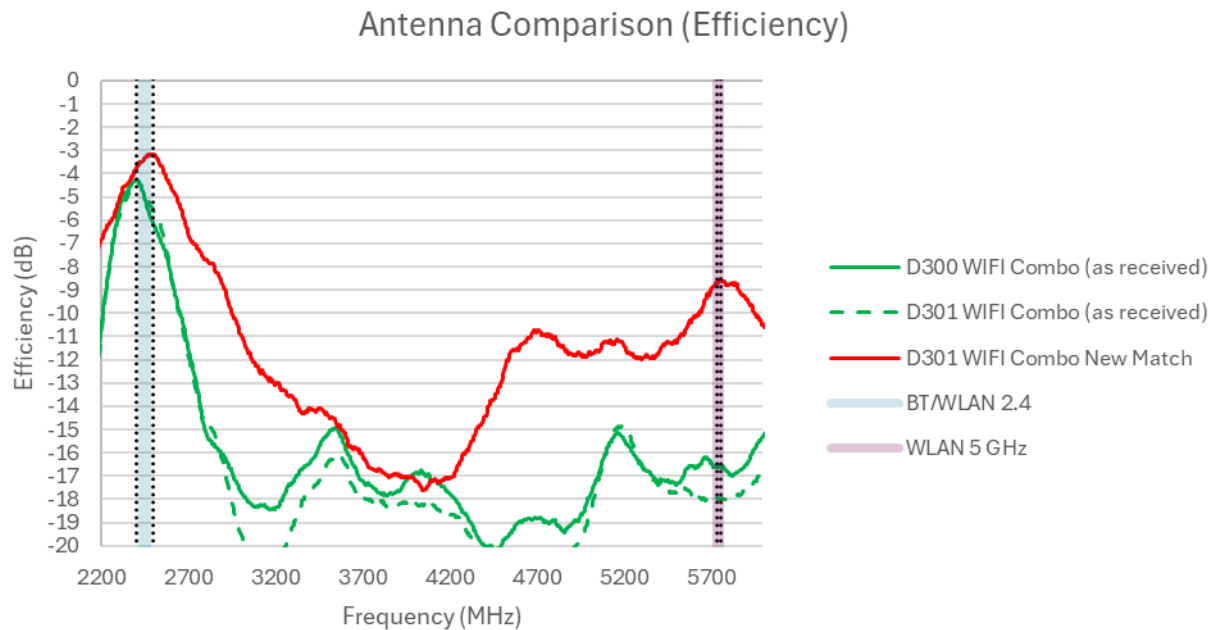


Figure 9 - Comparison of the WIFI COMBO antenna matching: Sample as received vs. with the updated matching network.

The updated matching results in an improvement to the 2.4 and 5.74 GHz bands of approximately 1.5 dB and 9 dB respectively.

5 Measurement Setup

The DUT was placed so that the display is facing Z direction, sides are along the X axis and the top/bottom along the Y axis (Figure 10). Coordinate system of SG24 is shown in Figure 11. Vertical cuts at $\Phi=0^\circ$ and $\Phi=90^\circ$ and horizontal cut at $\Theta=90^\circ$ are shown on Figure 11 as well.

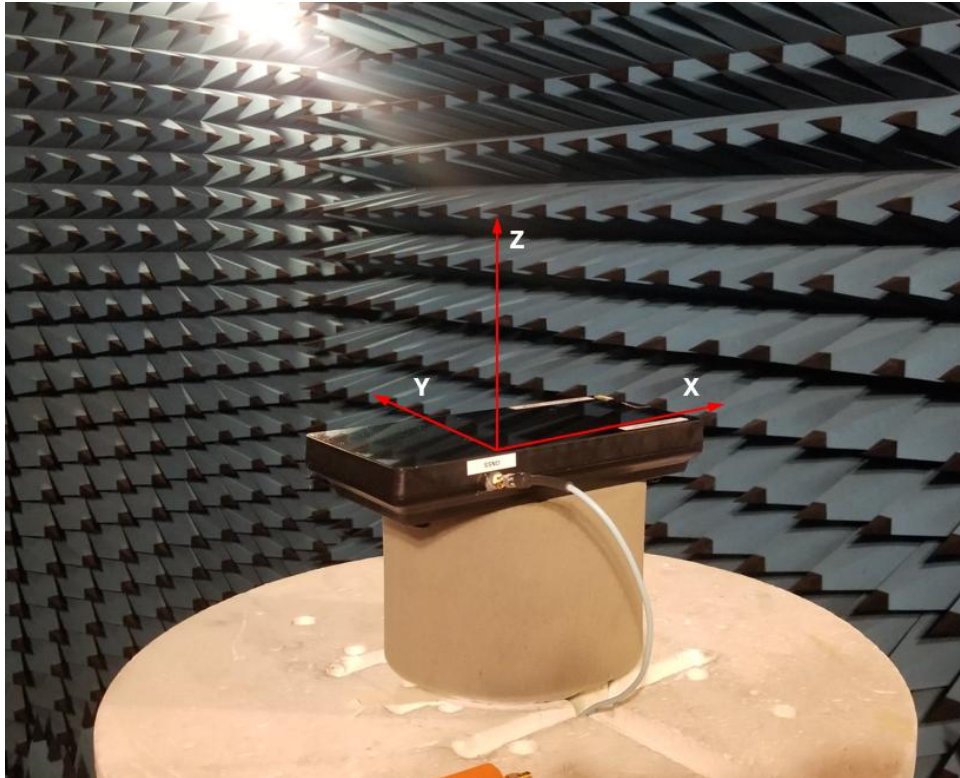


Figure 10 - Positioning of the DUT in the chamber and associated coordinate system for measurements

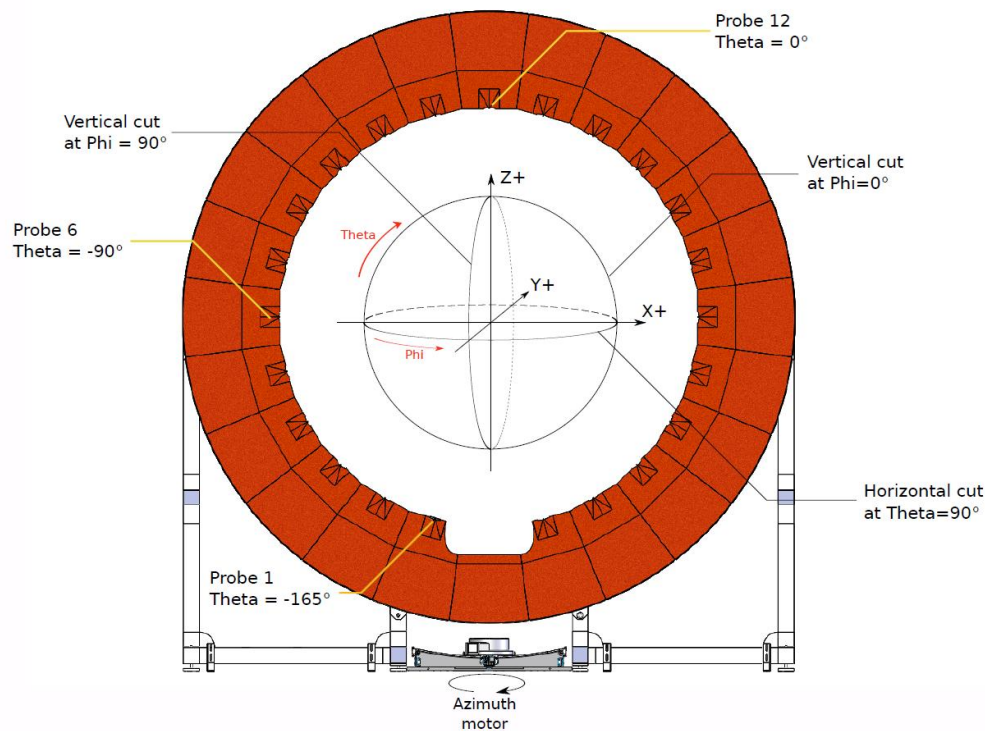


Figure 11: SG24 coordinate system

Coordinate system is given for a fixed antenna under test (AUT) i.e. it is the measurement system which moves around the AUT. The azimuth scan (Phi) and the elevation scan (Theta) are done by rotating of the AUT (goniometer and mast rotation). The direction of rotation of the mast is reversed compared the coordinate system.

$\Phi \in [0^\circ, 180^\circ]$ and $\Theta \in [-180^\circ, 180^\circ]$.

6 Measurement Results

6.1 Efficiency

The efficiency of the antennas was measured as follows. Frequencies where the device is operational are highlighted in blue.

Table 3: Efficiency for all DUT antennas

Frequency	GNSS	BT Combo	WIFI COMBO	BT ONLY
1550	-3,9	-18,1	-36,4	-25,3
1559	-3,5	-18,4	-35,9	-24,9
1560	-3,5	-18,4	-35,9	-24,9
1570	-3,2	-18,8	-35,4	-24,4
1575	-3,0	-19,0	-35,0	-24,2
1580	-3,0	-19,2	-34,7	-24,1
1585	-2,9	-19,3	-34,4	-23,8
1590	-2,9	-19,5	-34,2	-23,7
1600	-2,8	-19,8	-33,5	-23,5
1610	-3,1	-20,3	-33,2	-23,2
1620	-3,4	-20,7	-32,7	-23,1
2380	-16,1	-5,9	-4,7	-3,5
2390	-16,0	-5,7	-4,5	-3,4
2400	-16,0	-5,5	-4,5	-3,4
2410	-16,0	-5,3	-4,3	-3,4
2420	-15,9	-5,1	-4,1	-3,2
2430	-15,7	-4,9	-4,0	-3,1
2440	-15,7	-5,0	-4,0	-3,2
2442	-15,7	-5,0	-4,0	-3,2
2450	-15,8	-4,9	-3,9	-3,2
2460	-15,6	-4,7	-3,7	-3,0
2470	-15,6	-4,7	-3,6	-3,1
2480	-15,7	-4,8	-3,7	-3,2
2483	-15,7	-4,8	-3,7	-3,2
2490	-15,6	-4,9	-3,7	-3,3
2500	-15,4	-4,9	-3,6	-3,3
2510	-15,5	-5,2	-3,8	-3,6
2520	-15,6	-5,4	-4,0	-3,8
4900	-5,2	-23,6	-12,4	-16,3
5000	-5,7	-20,3	-11,2	-15,4
5100	-6,6	-17,2	-11,2	-15,6
5170			-11,5	
5200	-7,9	-14,3	-11,6	-17,1
5300	-9,8	-14,3	-11,7	-19,3
5400	-10,6	-18,0	-11,2	-19,7
5450	-10,8	-19,7	-10,6	-20,2
5500	-11,4	-21,1	-10,6	-20,8
5600	-10,3	-21,0	-9,0	-19,5
5700	-11,2	-21,3	-9,1	-20,3
5735	-10,5	-20,6	-8,8	-19,4
5745	-10,3	-20,5	-9,0	-19,3
5755	-10,2	-20,5	-9,2	-19,4
5800	-10,3	-21,1	-9,8	-20,2
5895	-10,6	-22,2	-10,6	-20,0
5900	-10,5	-22,2	-10,7	-19,9
6000	-10,6	-25,0	-12,0	-21,2

6.2 Gain

The peak gain of the antennas was measured as follows. Frequencies where the device is operational are highlighted in blue.

Table 4: Gain for all DUT antennas

Frequency	GNSS	BT Combo	WIFI COMBO	BT ONLY
1550	3,7	-13,8	-28,8	-18,5
1559	4,1	-14,2	-28,4	-18,4
1560	4,1	-14,3	-28,5	-18,4
1570	4,3	-14,6	-27,9	-17,9
1575	4,4	-14,8	-27,5	-17,8
1580	4,3	-15,1	-27,3	-17,9
1585	4,3	-15,1	-27,3	-17,5
1590	4,3	-15,4	-27,1	-17,5
1600	4,3	-15,9	-27,0	-17,4
1610	4,0	-16,1	-27,4	-17,2
1620	3,5	-16,3	-27,4	-17,4
2380	-10,0	0,4	1,3	2,5
2390	-9,9	0,8	1,5	2,7
2400	-9,9	1,2	1,7	2,8
2410	-10,0	1,6	1,8	3,0
2420	-9,9	1,9	1,9	3,2
2430	-9,7	1,8	1,8	3,2
2440	-9,8	1,7	1,7	3,1
2442	-9,7	1,7	1,7	3,1
2450	-9,8	1,8	1,9	3,3
2460	-9,5	2,1	2,1	3,4
2470	-9,7	2,2	2,0	3,2
2480	-9,8	2,4	2,0	3,1
2483	-9,8	2,3	2,0	3,2
2490	-9,6	2,5	2,1	3,3
2500	-9,5	2,4	2,2	3,1
2510	-9,8	2,1	2,0	2,7
2520	-9,7	1,9	2,1	2,6
4900	2,9	-16,1	-4,8	-9,6
5000	2,3	-13,2	-4,2	-8,0
5100	1,4	-9,1	-3,5	-8,6
5170			-3,4	
5200	-0,3	-6,2	-3,5	-10,4
5300	-1,8	-6,2	-4,3	-13,0
5400	-2,4	-10,1	-3,8	-13,3
5450	-2,6	-11,4	-3,2	-13,8
5500	-3,3	-12,5	-3,1	-14,2
5600	-2,8	-11,1	-0,7	-12,5
5700	-3,6	-10,7	-0,3	-13,2
5735	-2,6	-10,1	0,0	-12,5
5745	-2,6	-9,9	-0,3	-12,2
5755	-2,3	-10,1	-0,5	-12,3
5800	-2,3	-10,9	-1,3	-12,9
5895	-2,7	-13,0	-2,4	-12,6
5900	-2,7	-13,1	-2,5	-12,5
6000	-3,0	-17,1	-3,8	-13,0

6.3 Directivity

The directivity of the antennas was measured as follows:

Table 5: Directivity for all DUT antennas

Frequency	GNSS	BT Combo	WIFI COMBO	BT ONLY
1550	7,6	4,2	7,5	6,7
1559	7,6	4,2	7,5	6,6
1560	7,6	4,2	7,4	6,6
1570	7,5	4,1	7,5	6,5
1575	7,4	4,2	7,5	6,5
1580	7,3	4,1	7,4	6,3
1585	7,2	4,1	7,2	6,3
1590	7,2	4,1	7,1	6,2
1600	7,1	4,0	6,5	6,1
1610	7,1	4,2	5,8	6,0
1620	6,9	4,4	5,3	5,7
2380	6,1	6,3	6,0	6,0
2390	6,2	6,5	6,1	6,1
2400	6,1	6,7	6,1	6,2
2410	6,1	6,9	6,2	6,4
2420	6,0	7,0	6,0	6,4
2430	6,0	6,7	5,7	6,3
2440	5,9	6,6	5,8	6,3
2442	6,0	6,7	5,7	6,3
2450	6,0	6,7	5,8	6,5
2460	6,1	6,8	5,8	6,5
2470	6,0	6,9	5,6	6,3
2480	5,9	7,2	5,7	6,3
2483	5,9	7,2	5,7	6,4
2490	6,0	7,3	5,8	6,5
2500	5,9	7,3	5,8	6,4
2510	5,7	7,2	5,9	6,2
2520	5,8	7,4	6,0	6,4
4900	8,2	7,5	7,7	6,7
5000	8,0	7,1	7,0	7,4
5100	8,0	8,0	7,6	7,0
5170			8,0	
5200	7,6	8,1	8,0	6,7
5300	7,9	8,1	7,4	6,3
5400	8,2	7,8	7,4	6,3
5450	8,2	8,3	7,5	6,4
5500	8,1	8,6	7,4	6,7
5600	7,5	9,9	8,3	7,0
5700	7,6	10,6	8,8	7,1
5735	7,8	10,5	8,8	7,0
5745	7,7	10,6	8,8	7,1
5755	7,9	10,4	8,7	7,1
5800	8,0	10,2	8,5	7,3
5895	7,8	9,2	8,2	7,4
5900	7,8	9,1	8,2	7,4
6000	7,6	7,9	8,2	8,2

7 Pattern Data

7.1 GNSS Antenna

7.1.1 2D Cuts

7.1.1.1 Elevation Cut (Azimuth = 0)

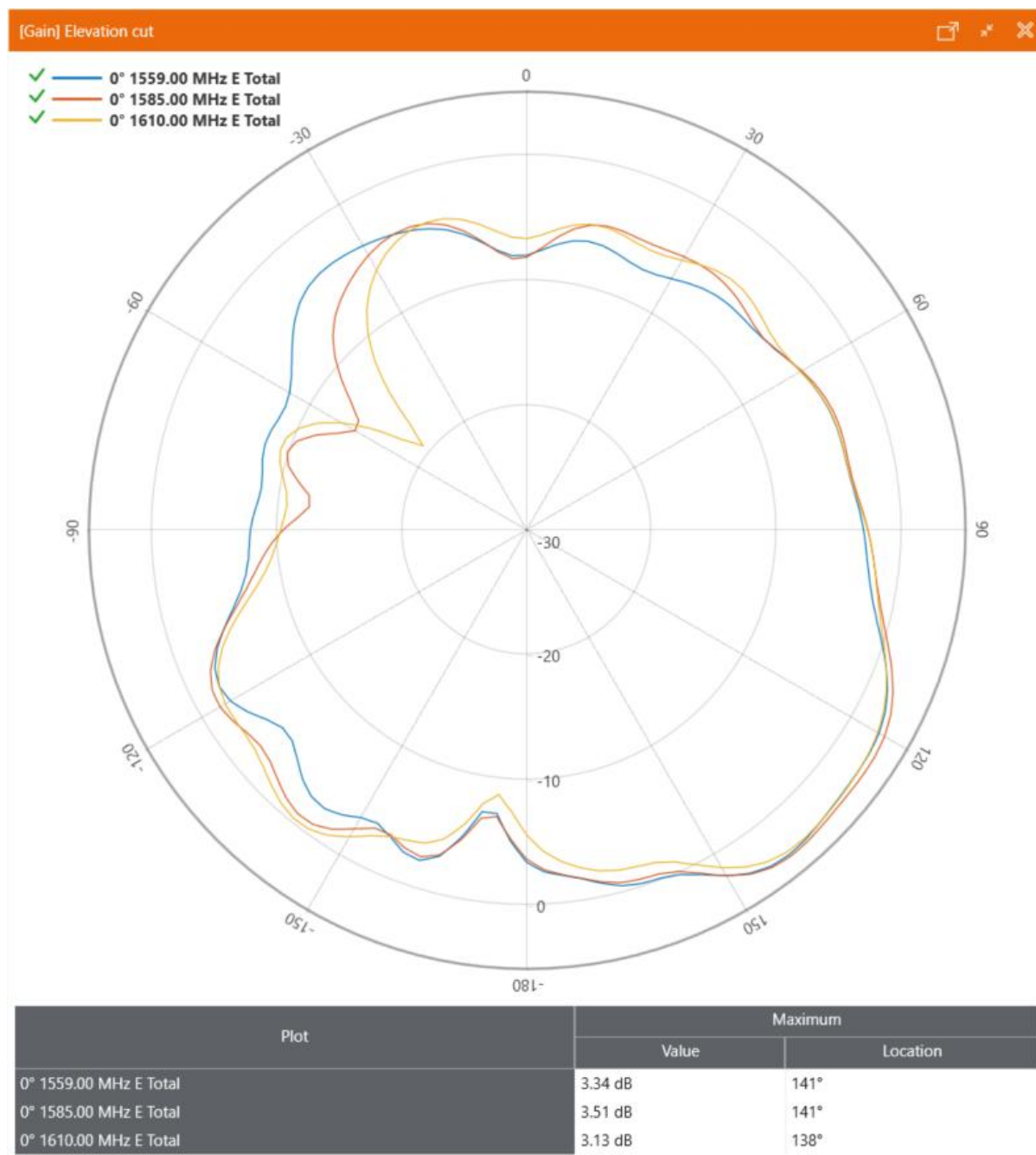


Figure 12: GNSS antenna Elevation Cut (Azimuth = 0)

7.1.1.2 Elevation Cut (Azimuth = 90)

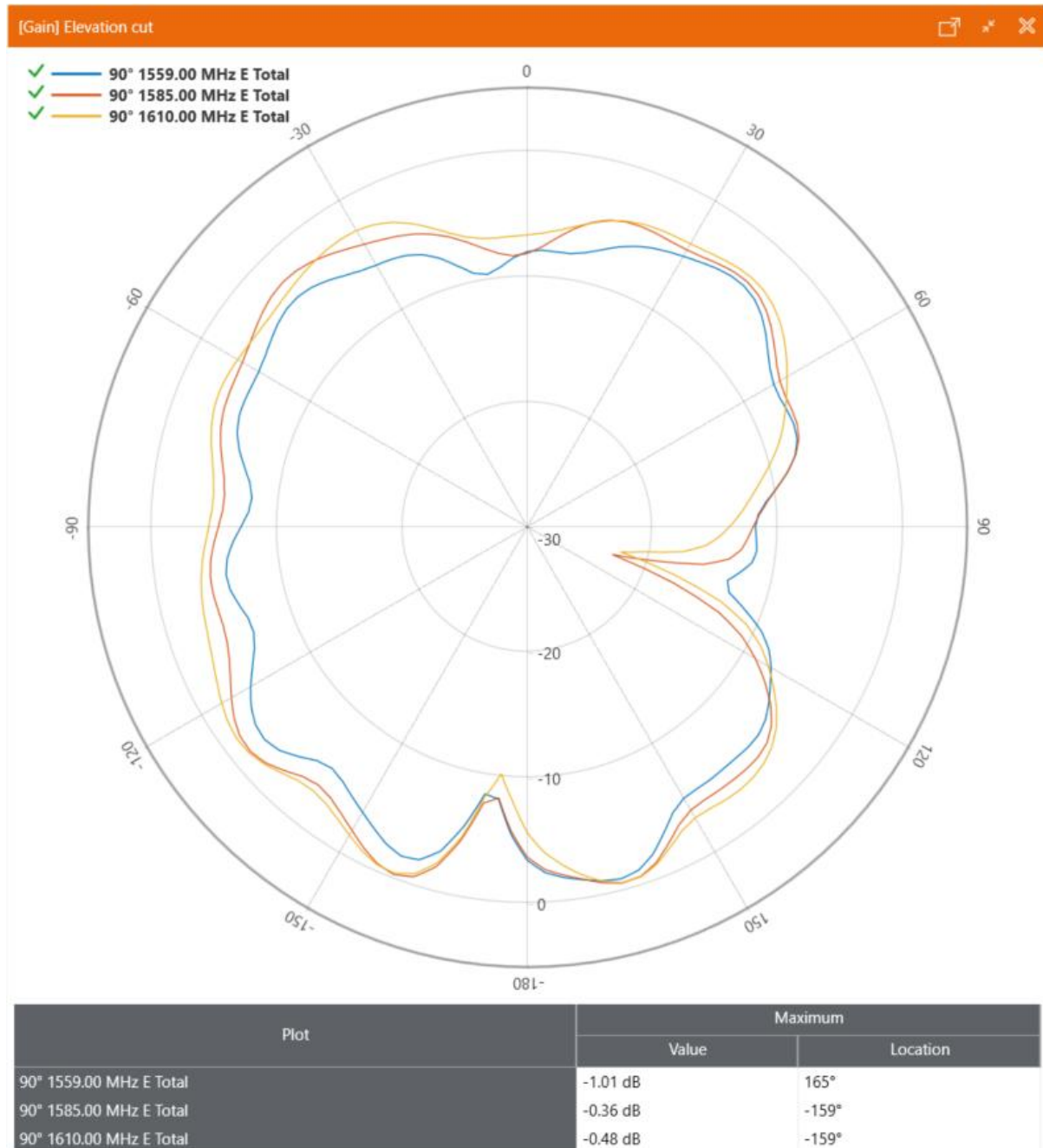


Figure 13: GNSS antenna Elevation Cut (Azimuth = 90)

7.1.1.3 Azimuth Cut (Elevation = 90 degrees)

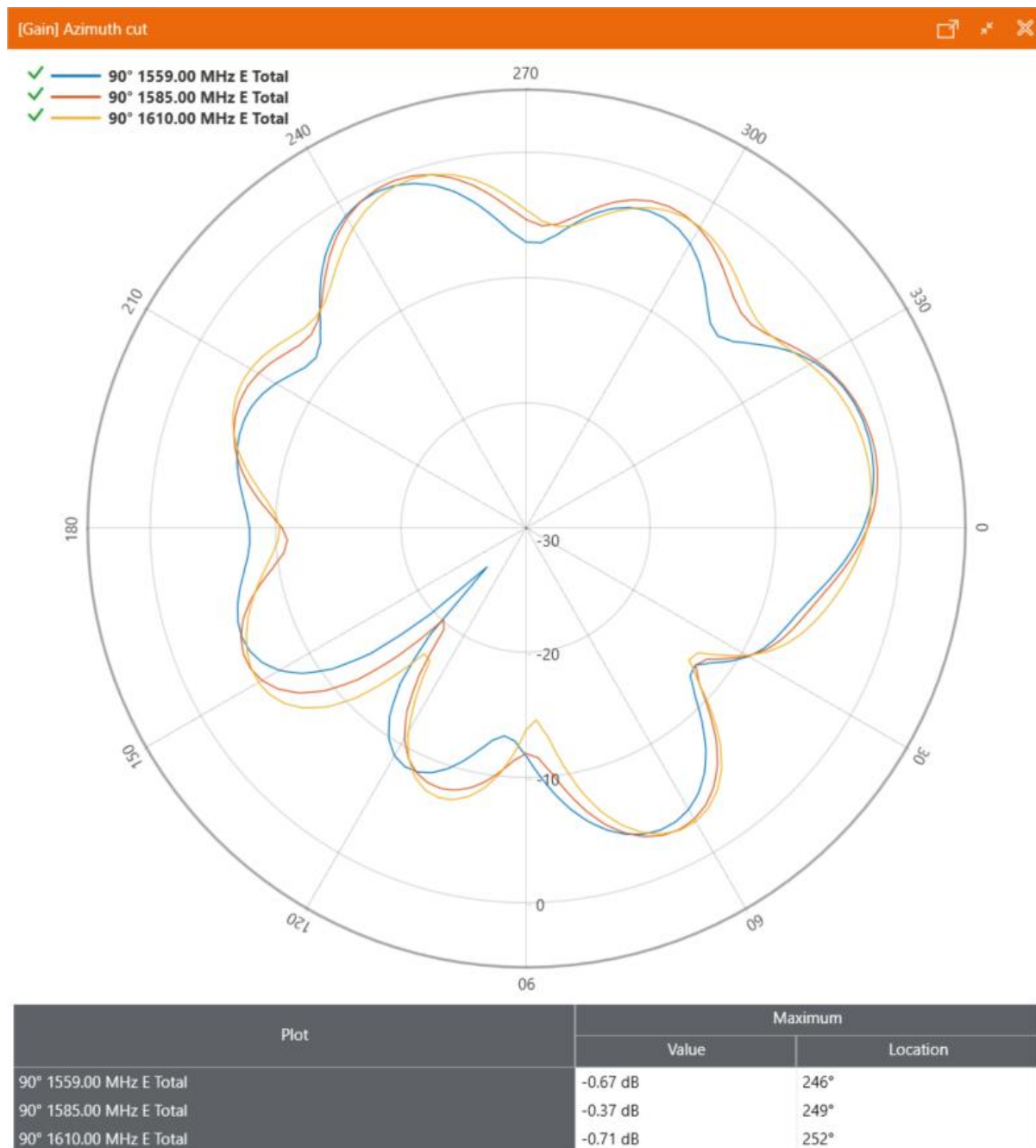


Figure 14: GNSS antenna Azimuth Cut (Elevation =90)

7.1.2 3D patterns at 1.585 GHz

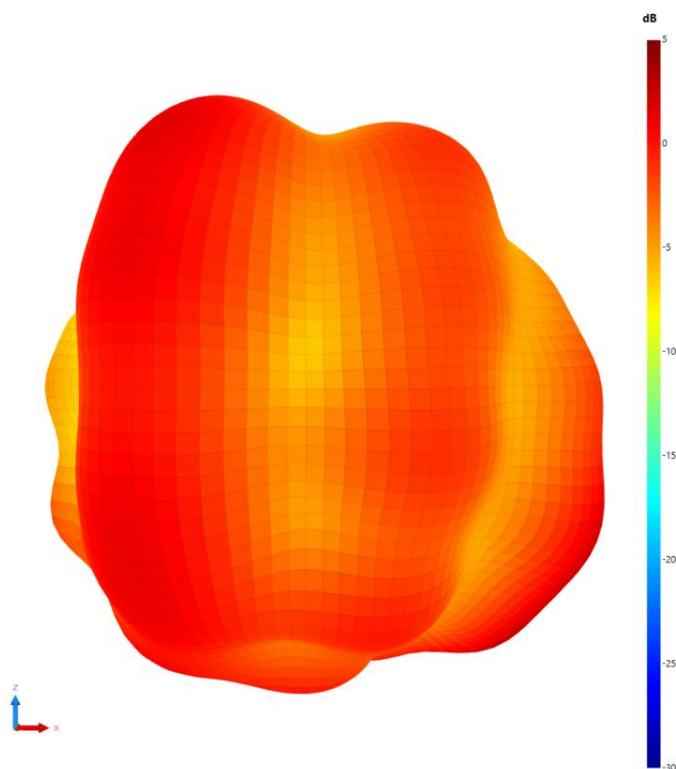


Figure 15: GNSS 3D pattern, XZ plane

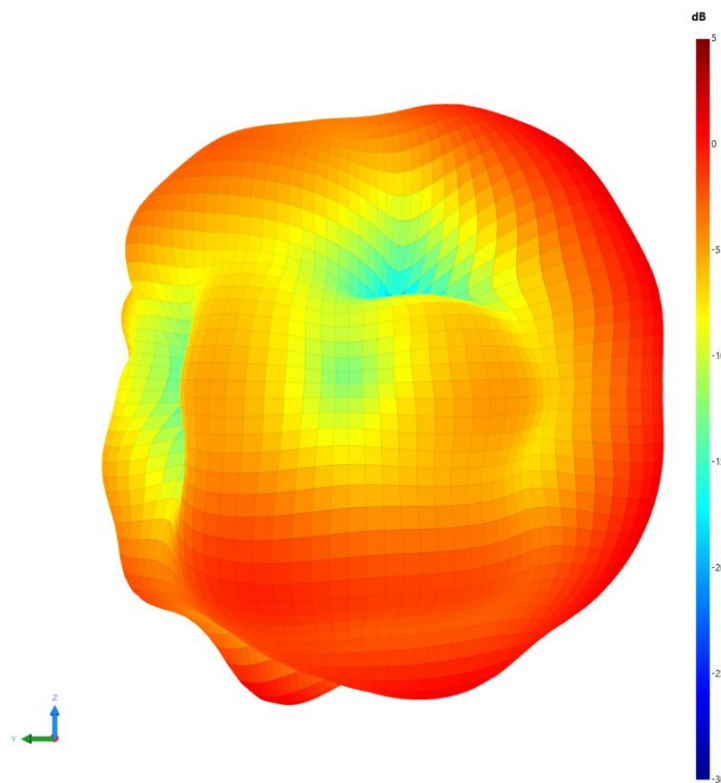


Figure 16: GNSS 3D pattern, ZY plane

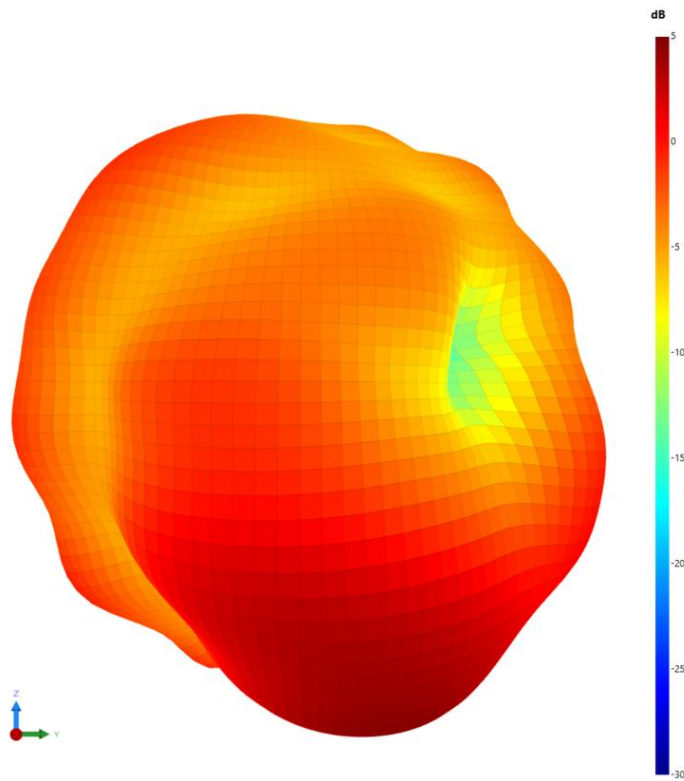


Figure 17: GNSS 3D pattern, YZ plane

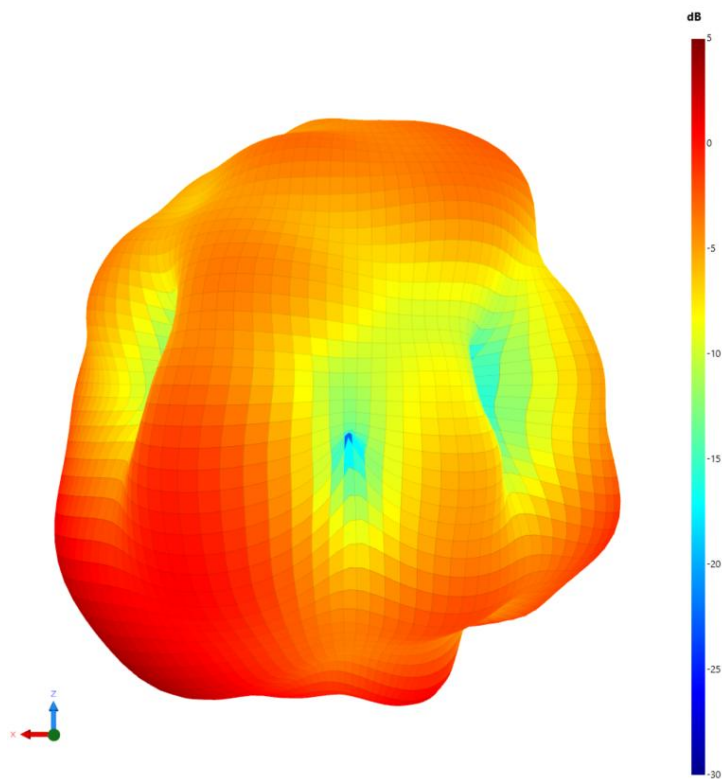


Figure 18: GNSS 3D pattern, ZX plane

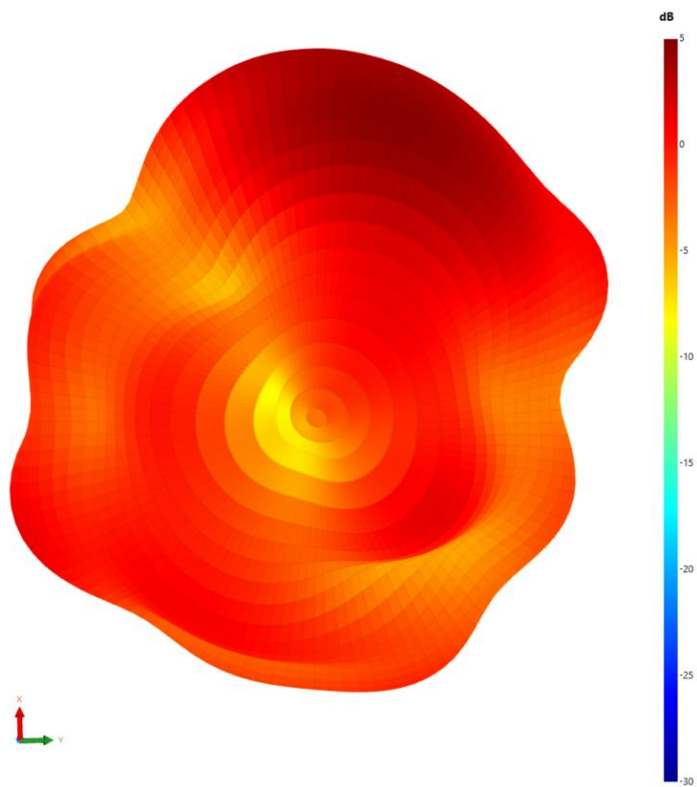


Figure 19: GNSS 3D pattern, YX plane

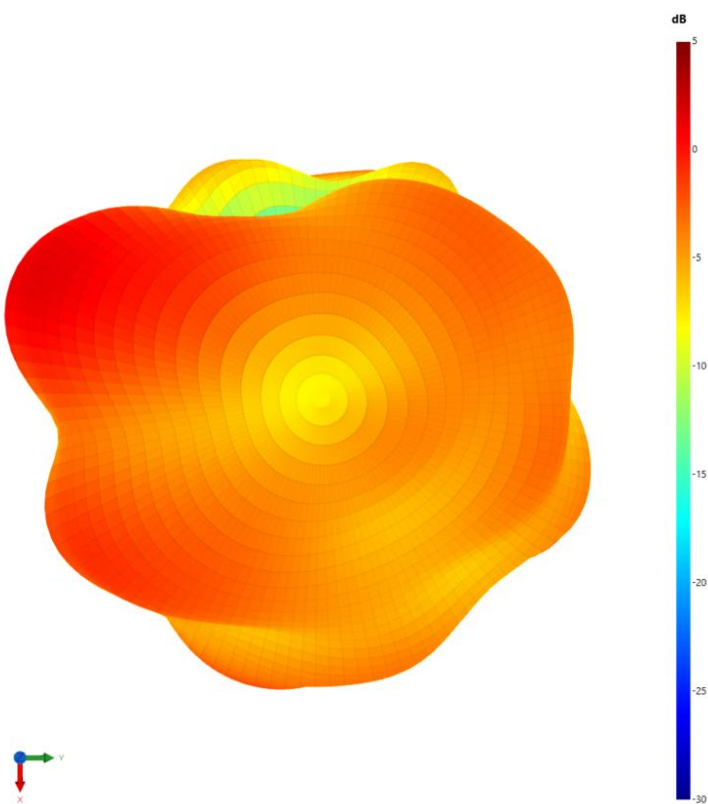


Figure 20: GNSS 3D pattern, XY plane

7.2 Bluetooth ONLY

7.2.1 2D Cuts

7.2.1.1 Elevation Cut (Azimuth = 0)

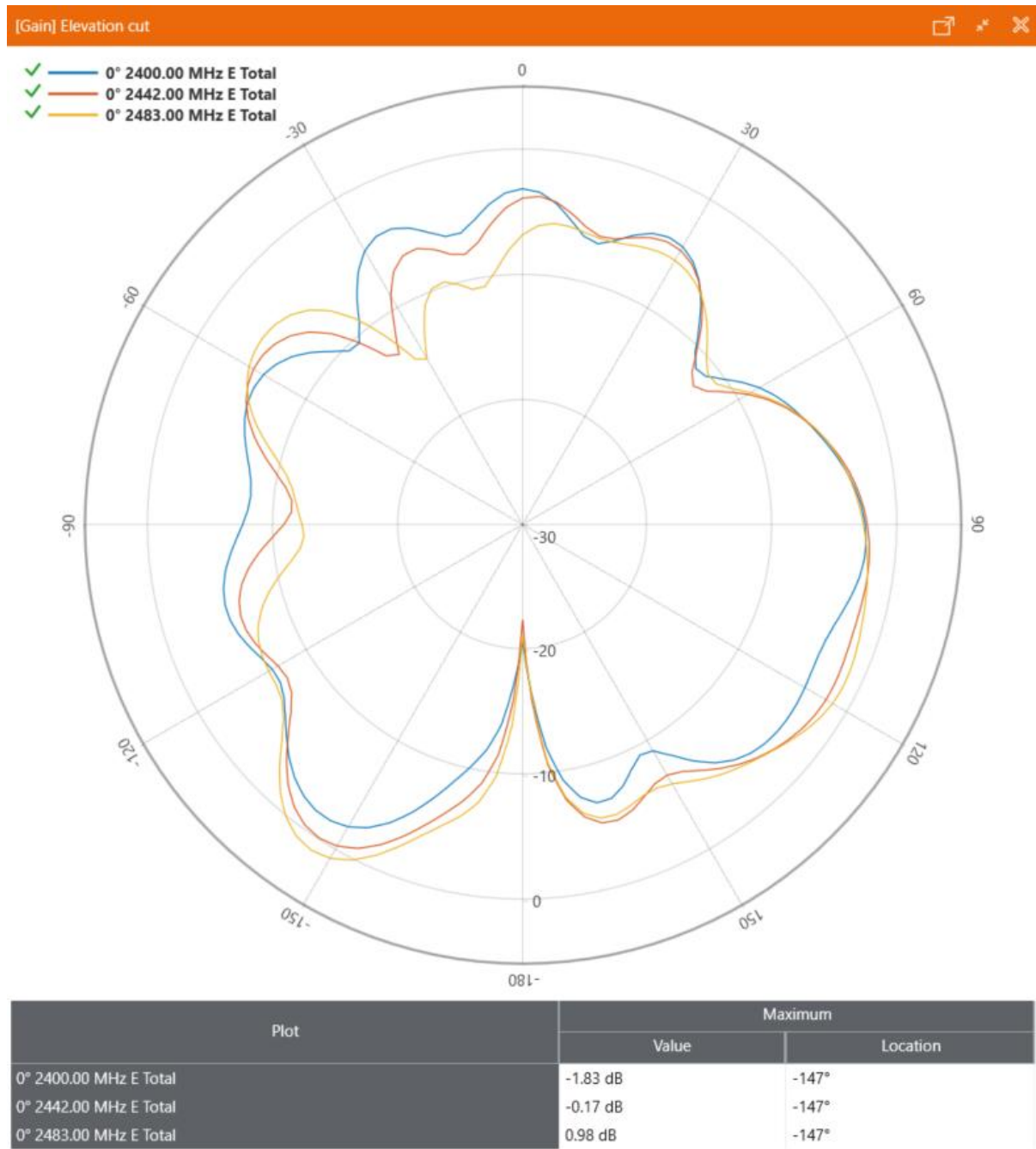


Figure 21: BLE Antenna Elevation Cut (Azimuth = 0)

7.2.1.2 Elevation Cut (Azimuth = 90)

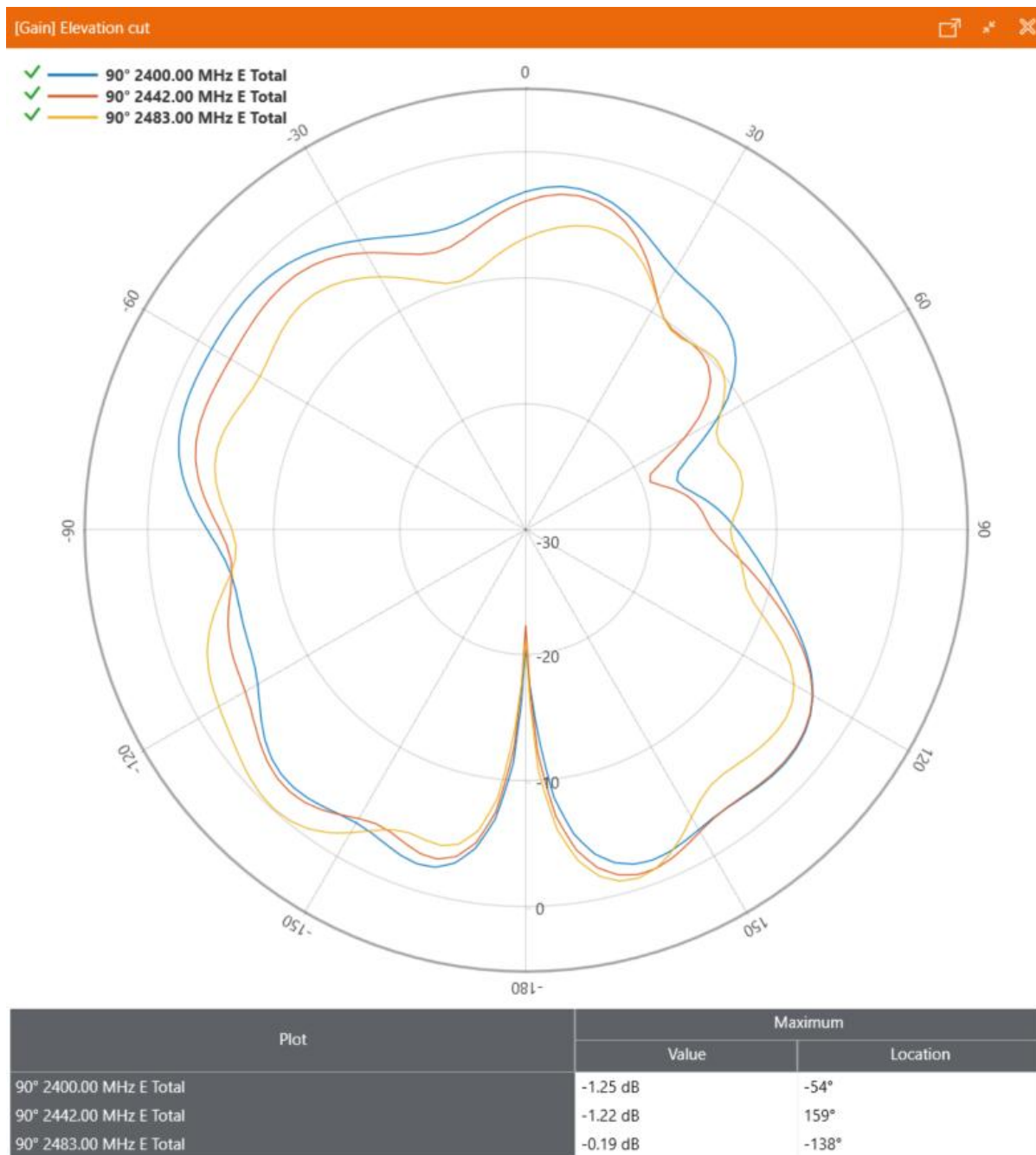


Figure 22: BLE Antenna Elevation Cut (Azimuth = 90)

7.2.1.3 Azimuth Cut (Elevation = 90 degrees)

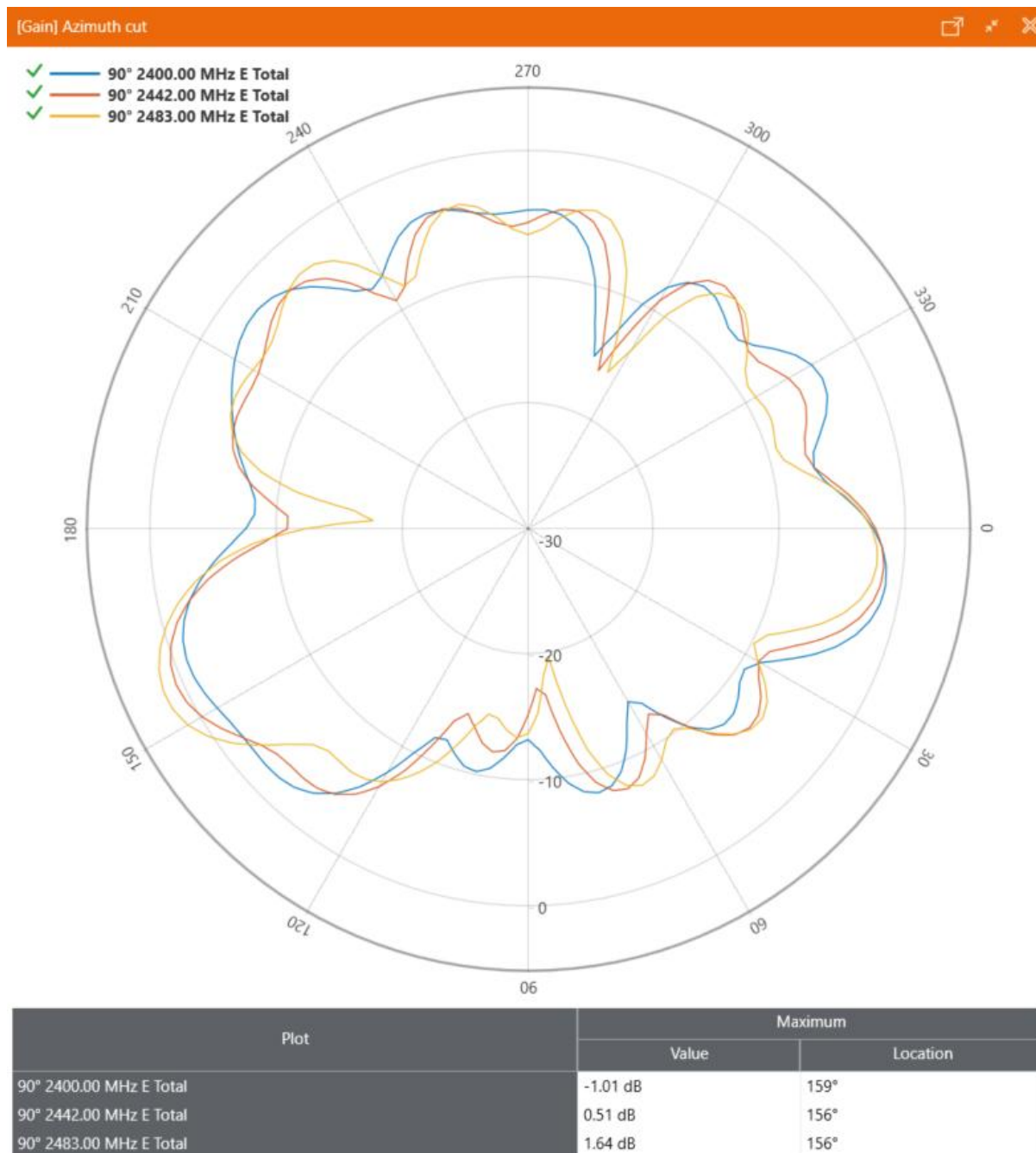


Figure 23: BLE Antenna Elevation Cut (Elevation = 90)

7.2.2 3D patterns at 2.44 GHz

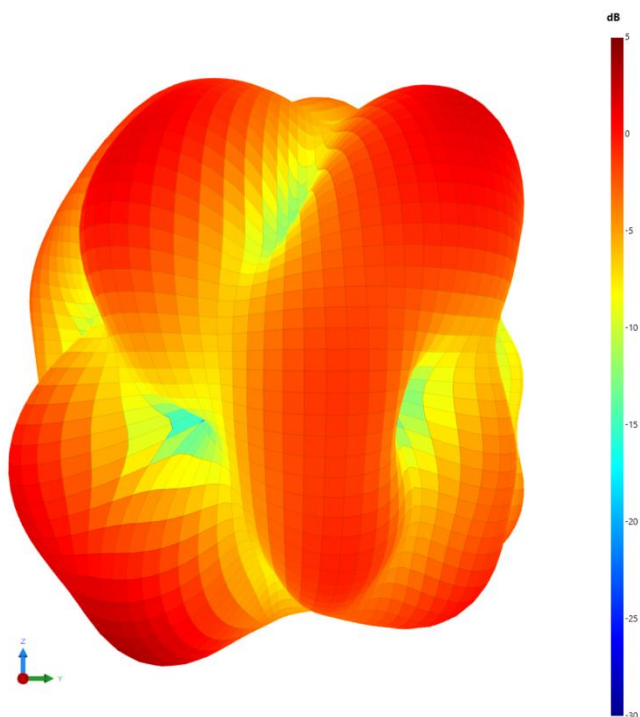


Figure 24: 3D Pattern, YZ plane

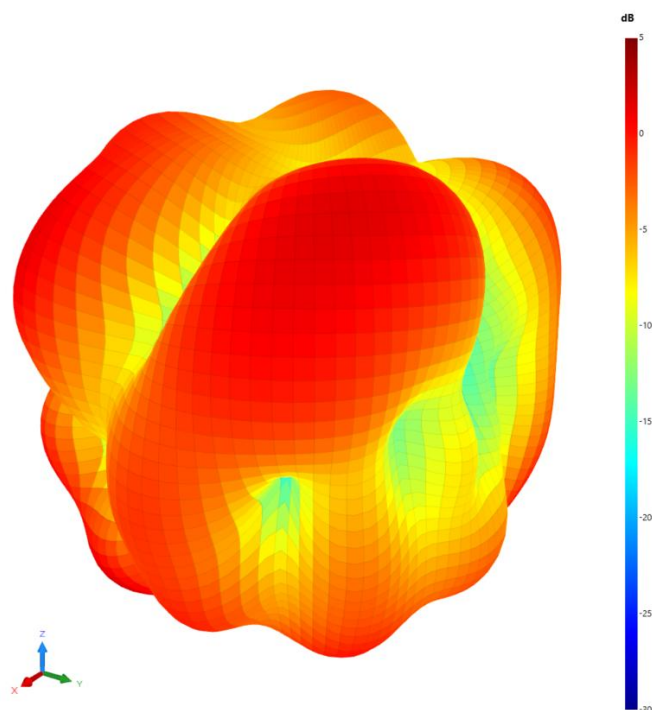


Figure 25: 3D Pattern, ISO orientation

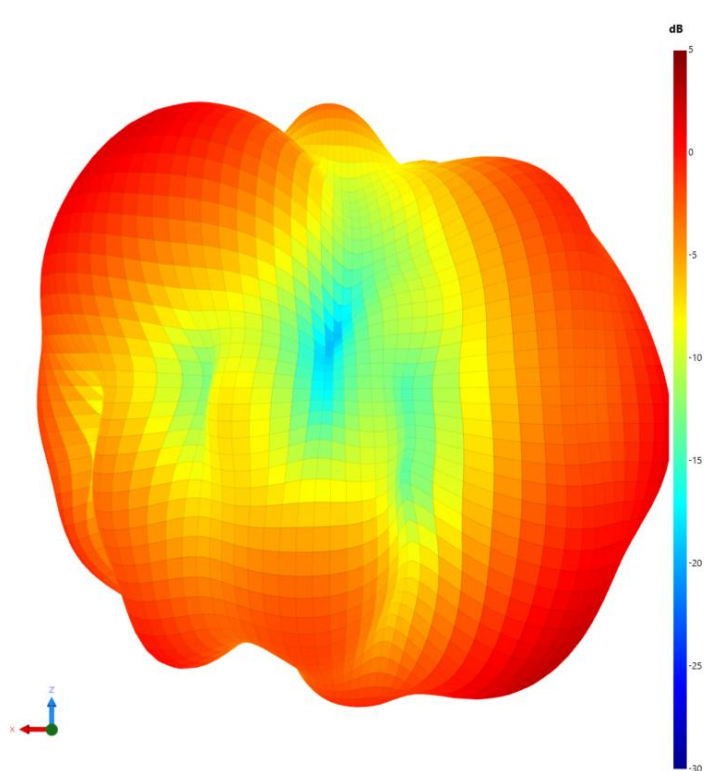


Figure 26: 3D Pattern, ZX plane

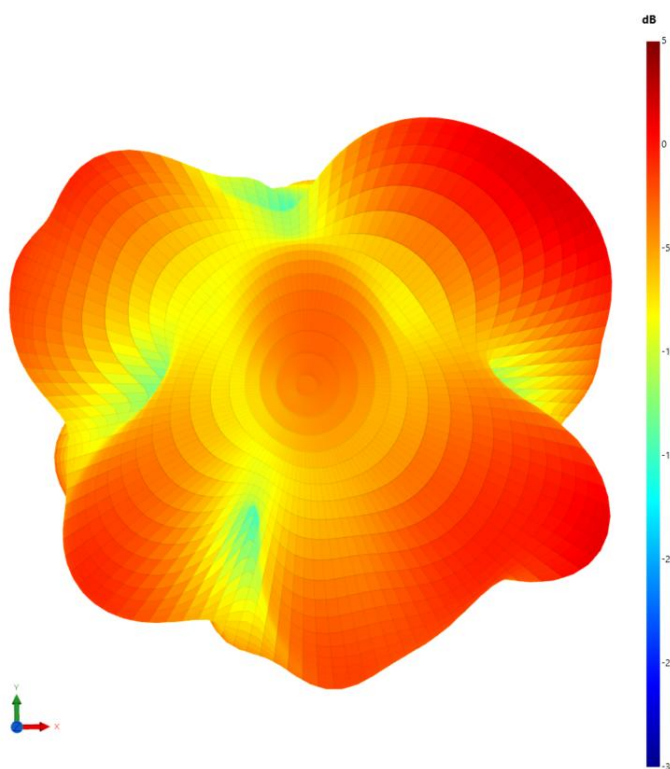


Figure 27: 3D Pattern, XY plane

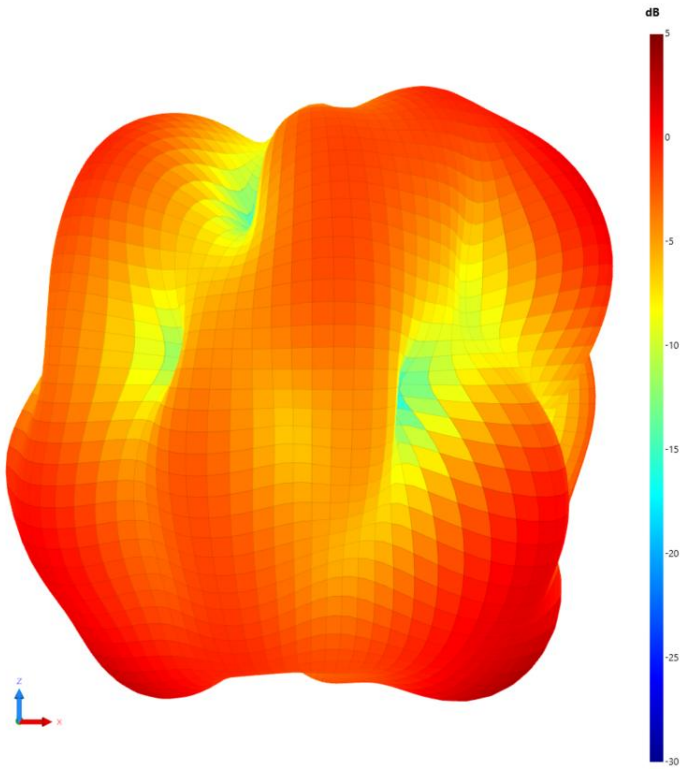


Figure 28: 3D Pattern, XZ plane

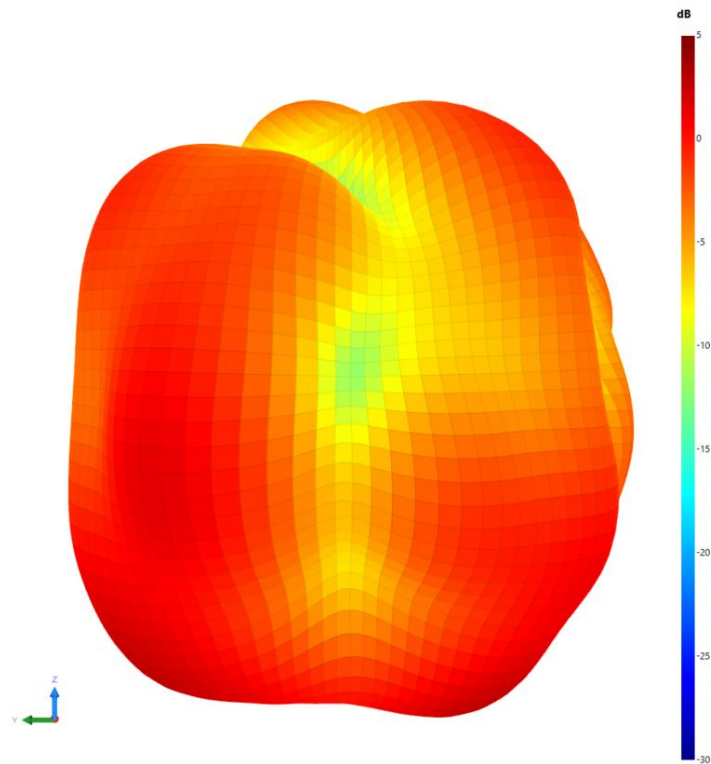


Figure 29 -3D Pattern - ZY plane

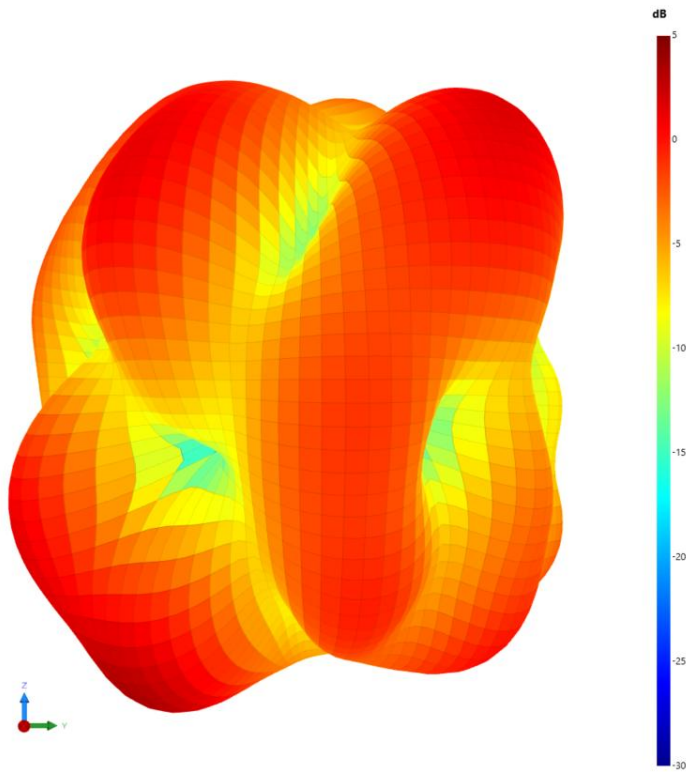


Figure 30 - 3D Pattern - YZ plane

7.3 WIFI COMBO

7.3.1 2D Cuts, 2.400 – 2.500 GHz

7.3.1.1 Elevation Cut (Azimuth = 0)

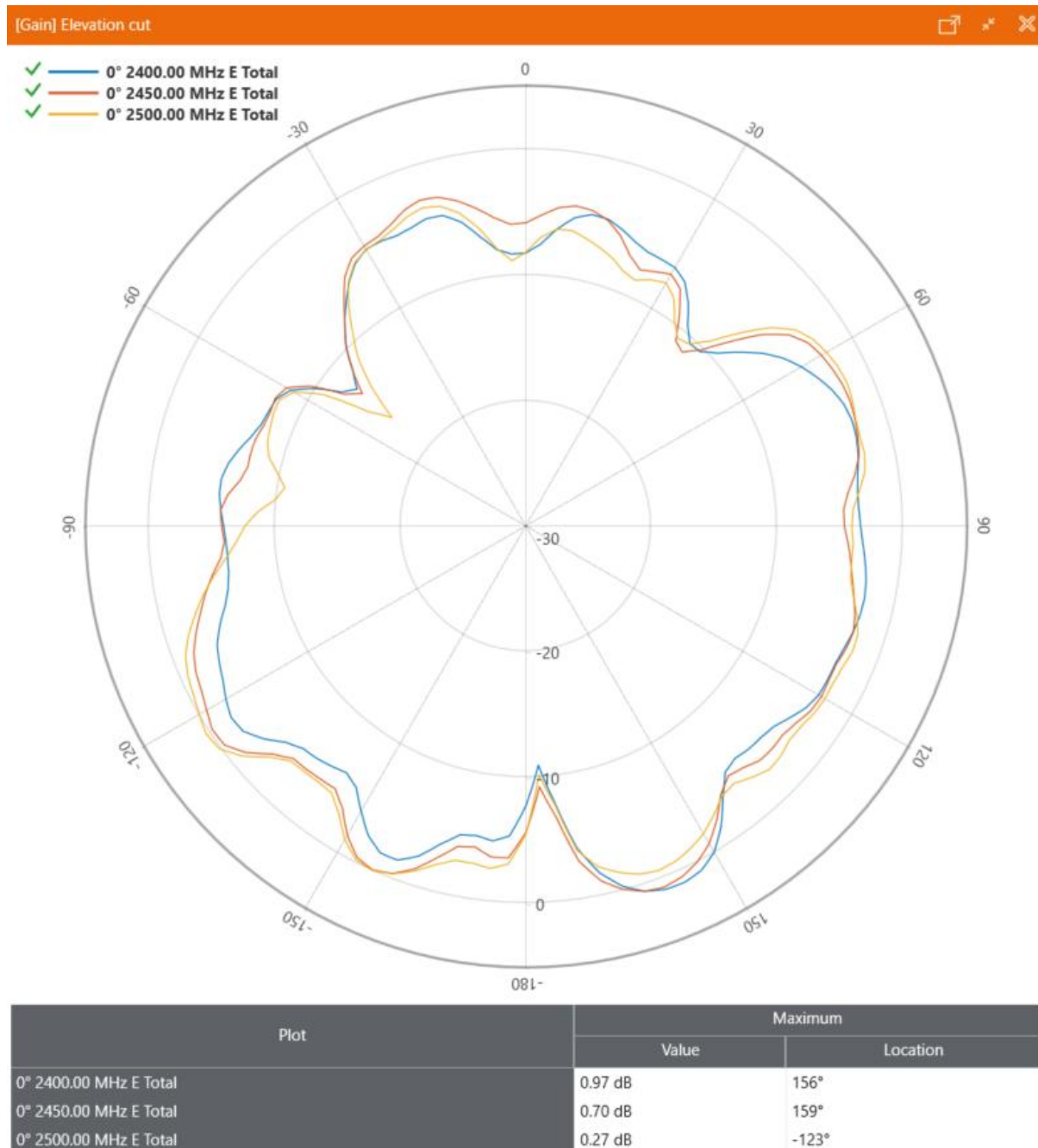


Figure 31: Combo WIFI Antenna, Elevation Cut (Azimuth = 0)

7.3.1.2 Elevation Cut (Azimuth = 90)

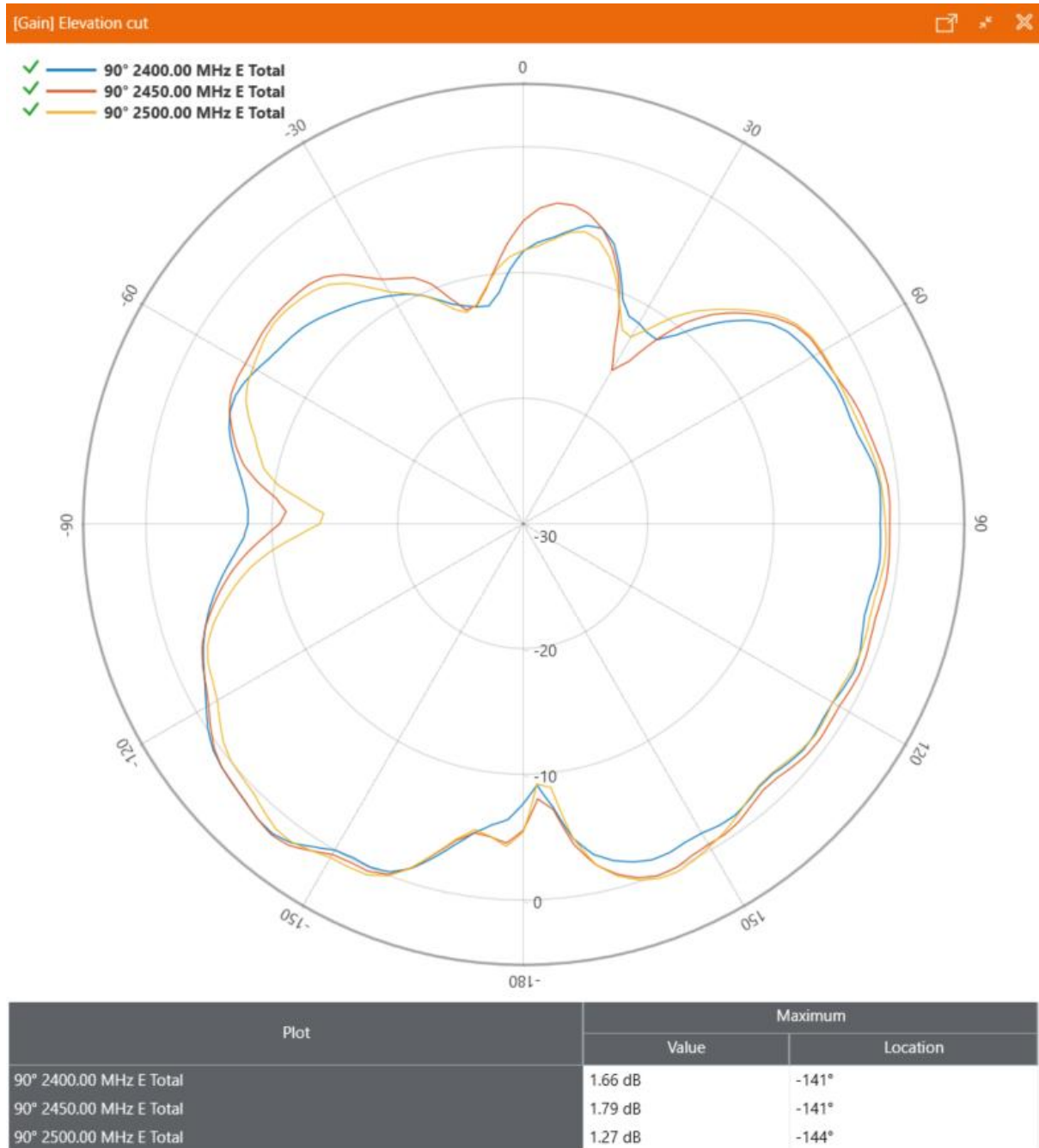


Figure 32: Combo WIFI Antenna, Elevation Cut (Azimuth = 90)

7.3.1.3 Azimuth Cut (Elevation = 90 degrees)

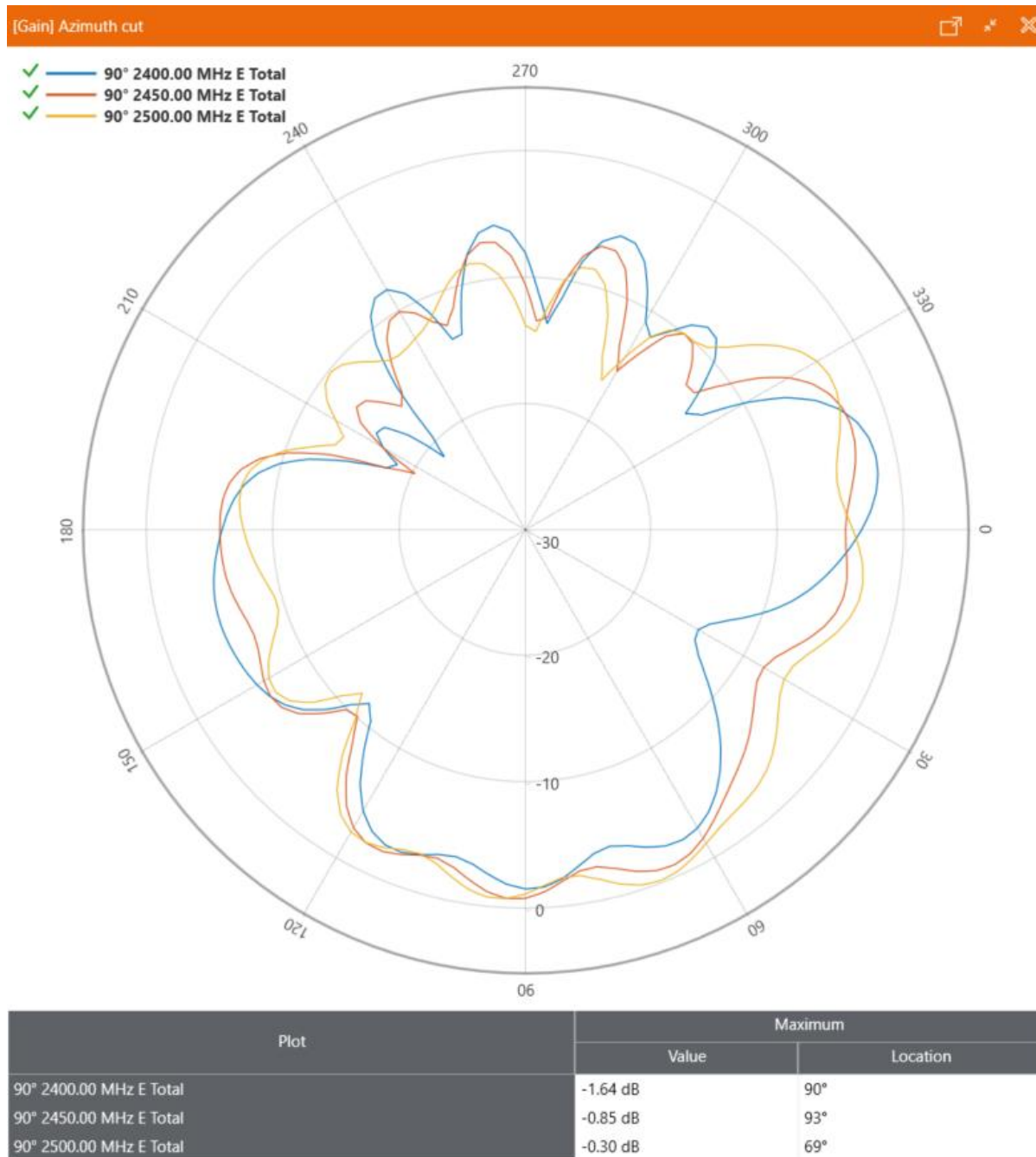


Figure 33: Combo WIFI Antenna, Azimuth Cut (Elevation = 90)

7.3.2 3D patterns at 2.45 GHz

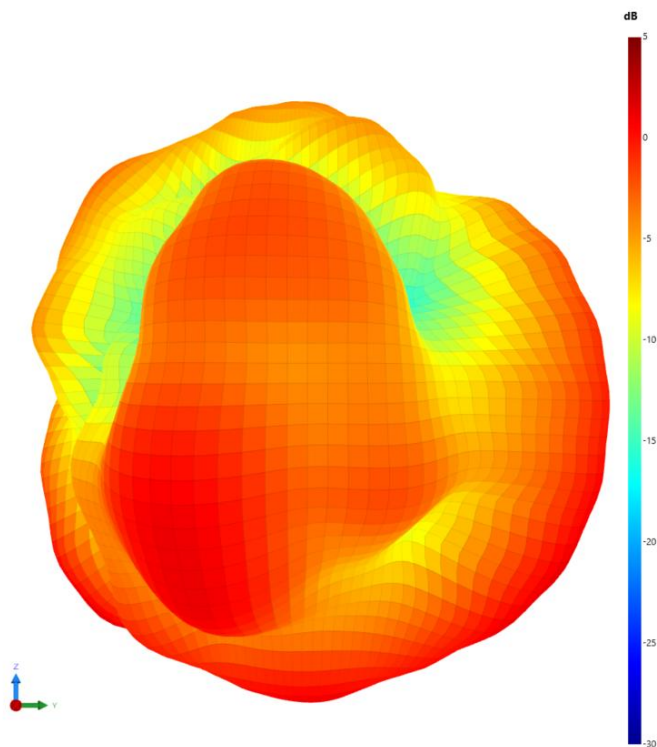


Figure 34: 3D pattern (YZ plane)

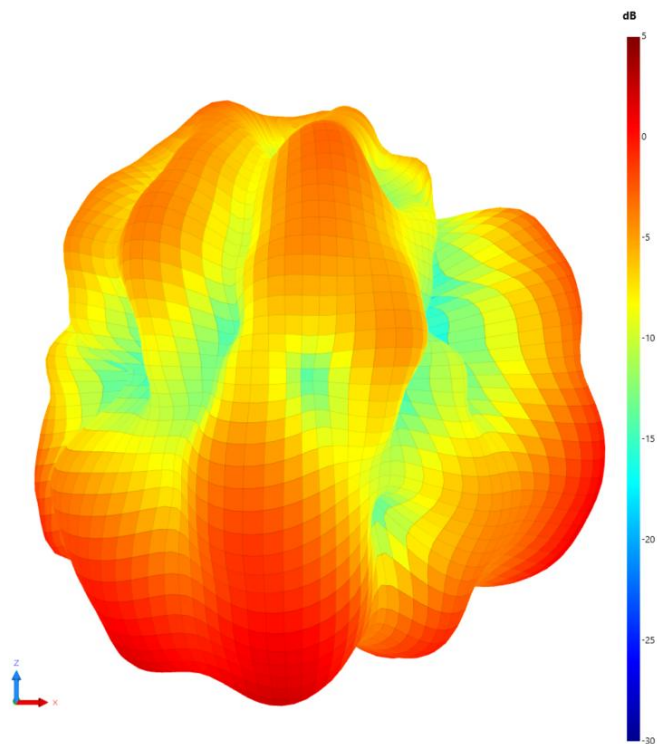


Figure 35: 3D pattern (XZ plane)

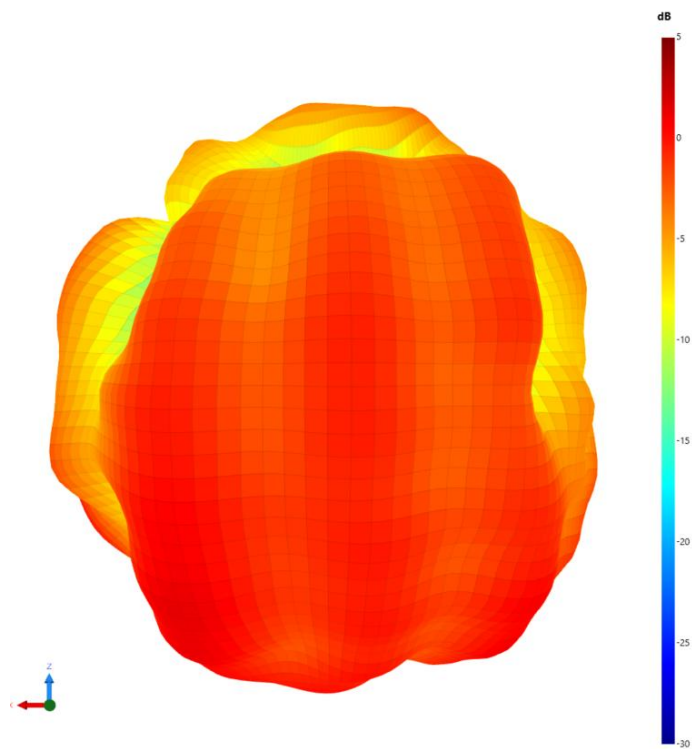


Figure 36 – 3D Pattern (ZX Plane)

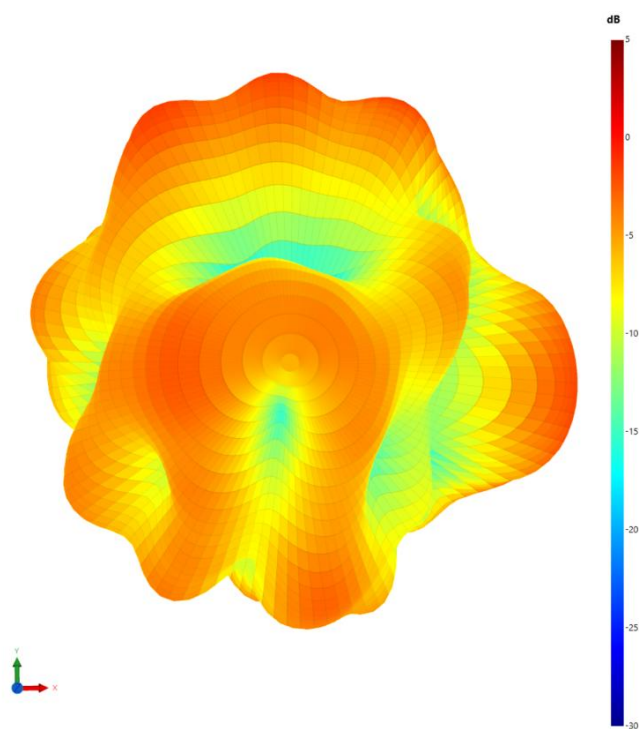


Figure 37: 3D pattern (XY plane)

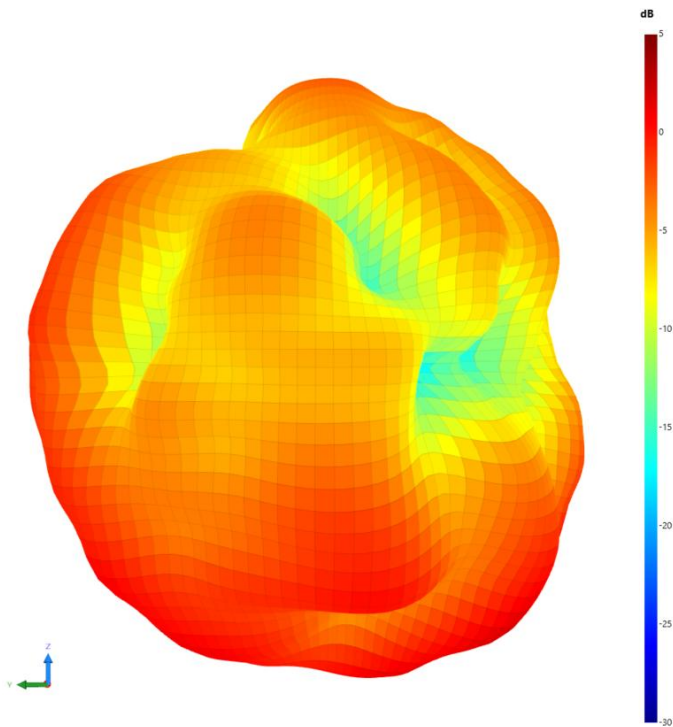


Figure 38: 3D pattern (ZY plane)

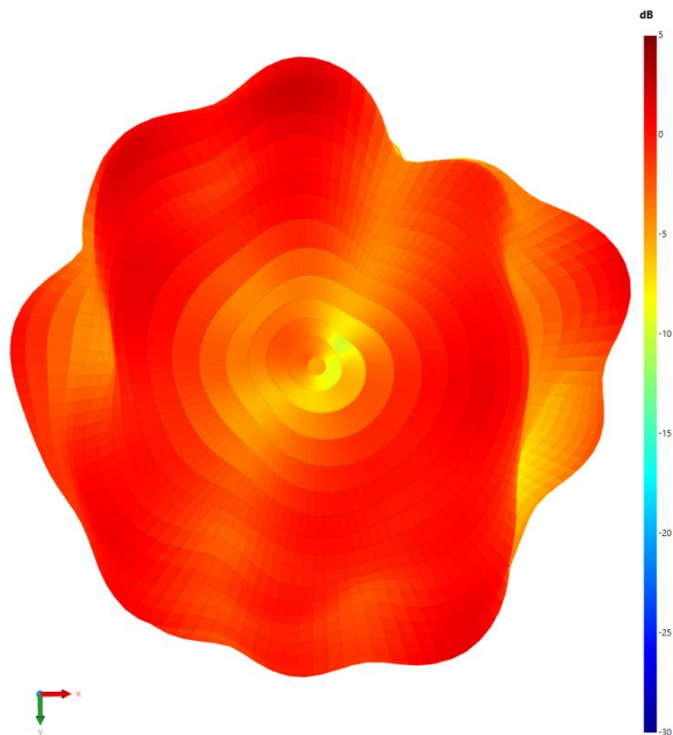
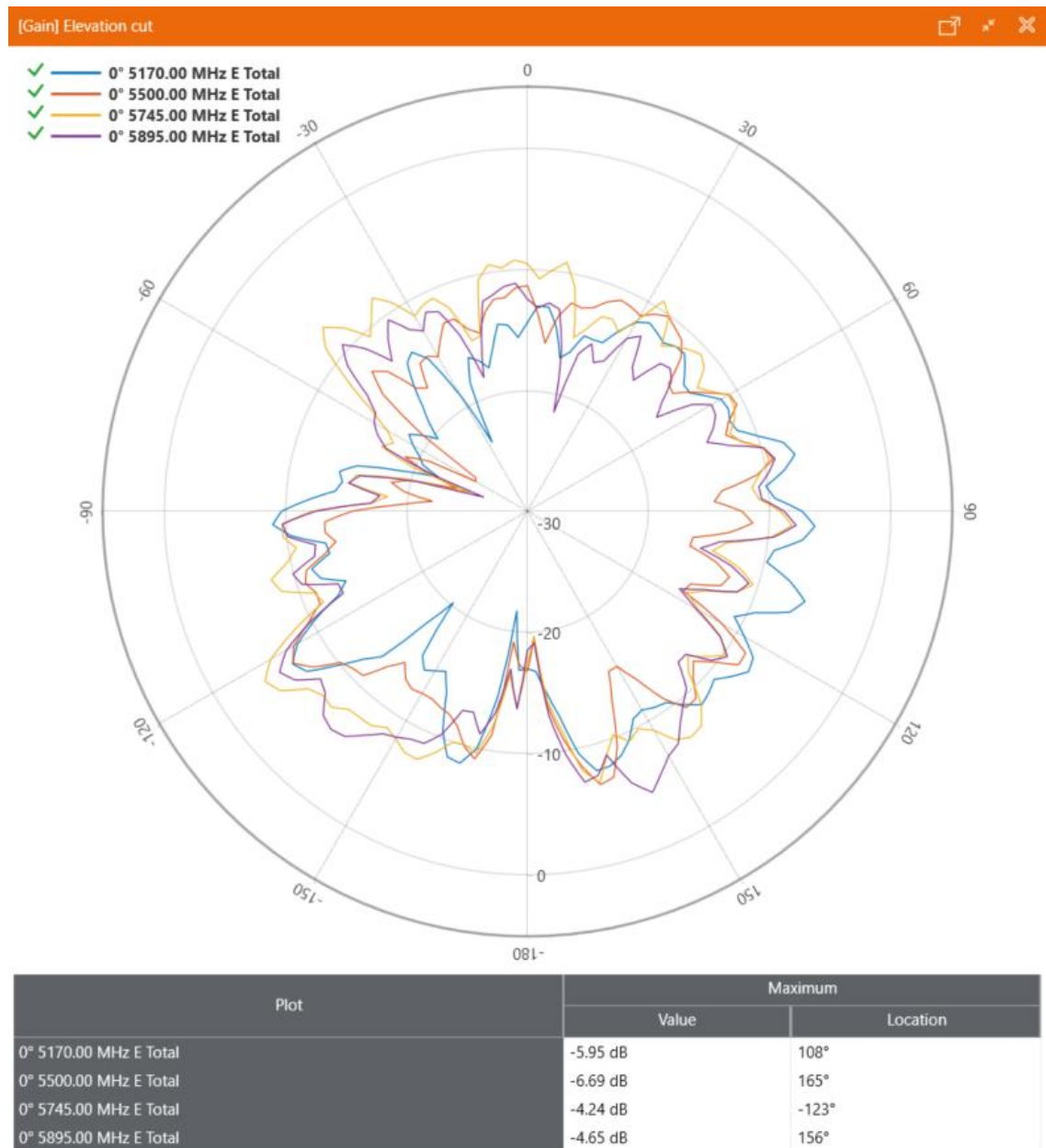


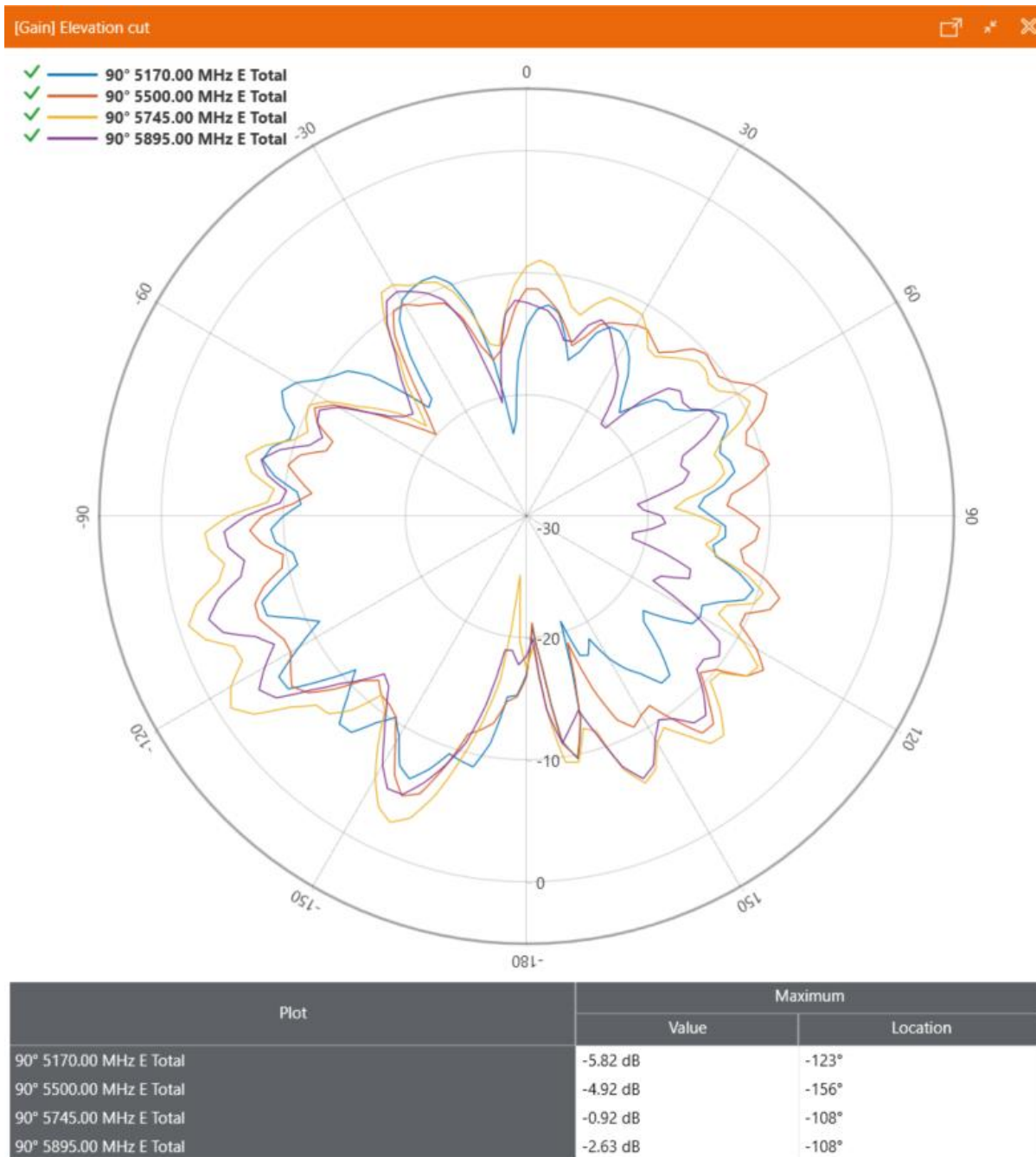
Figure 39 - 3D pattern (YX plane)

7.3.3 2D Cuts, 5170-5895 MHz

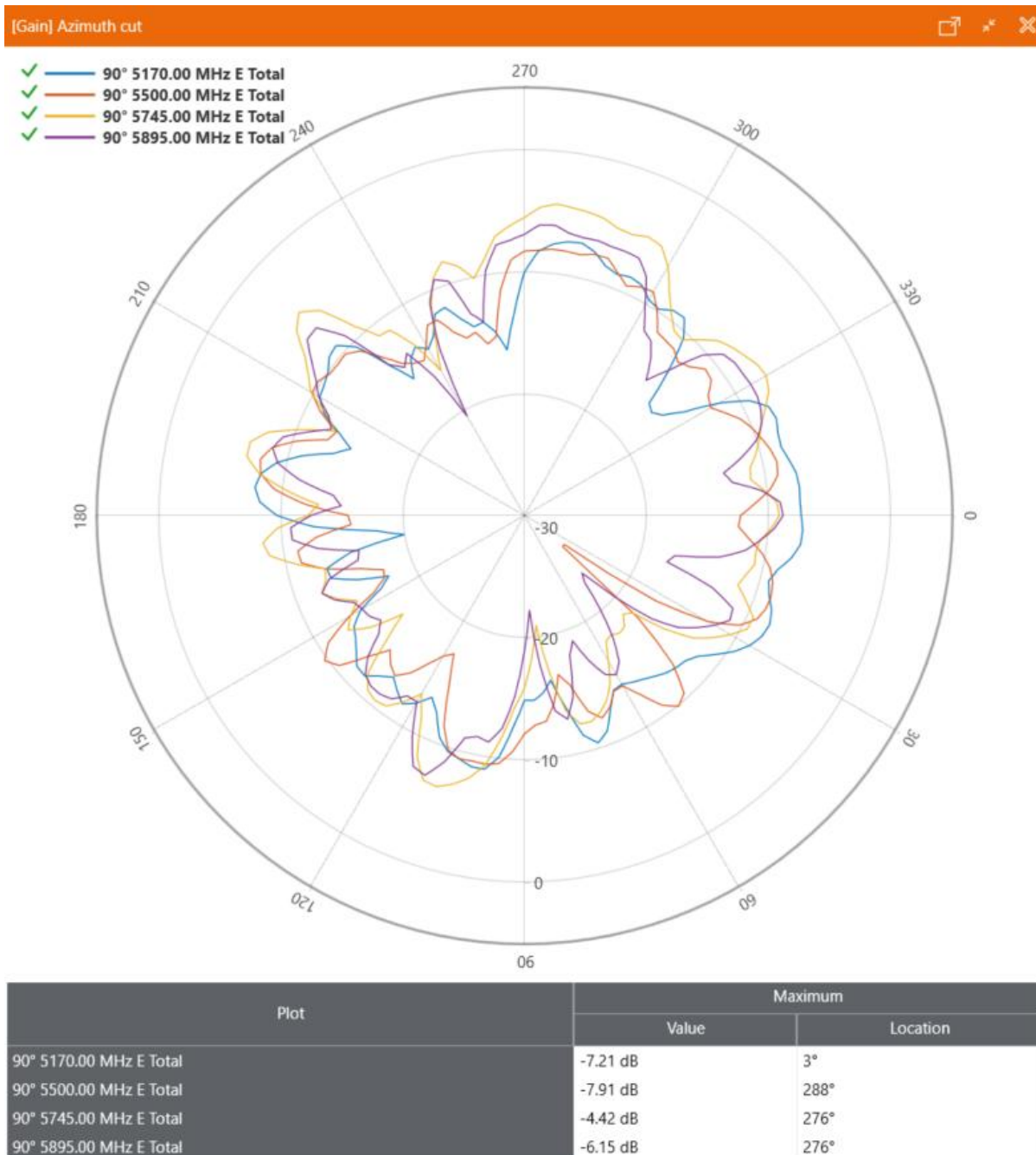
7.3.3.1 Elevation Cut (Azimuth = 0)



7.3.3.2 Elevation Cut (Azimuth = 90)



7.3.3.3 Azimuth Cut (Elevation = 90 degrees)



7.3.4 3D Patterns at 5745 MHz

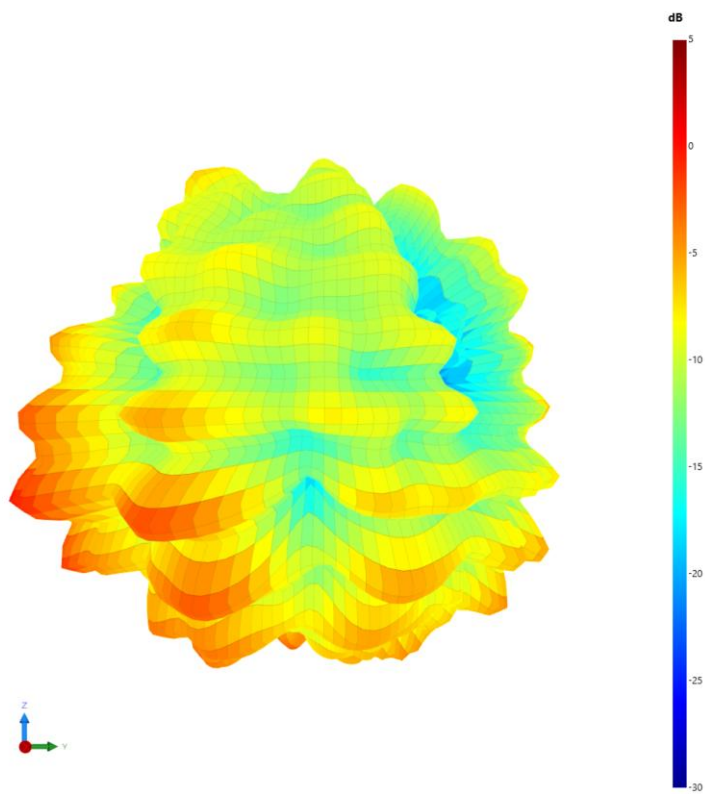


Figure 40 - 3D pattern (YZ plane)

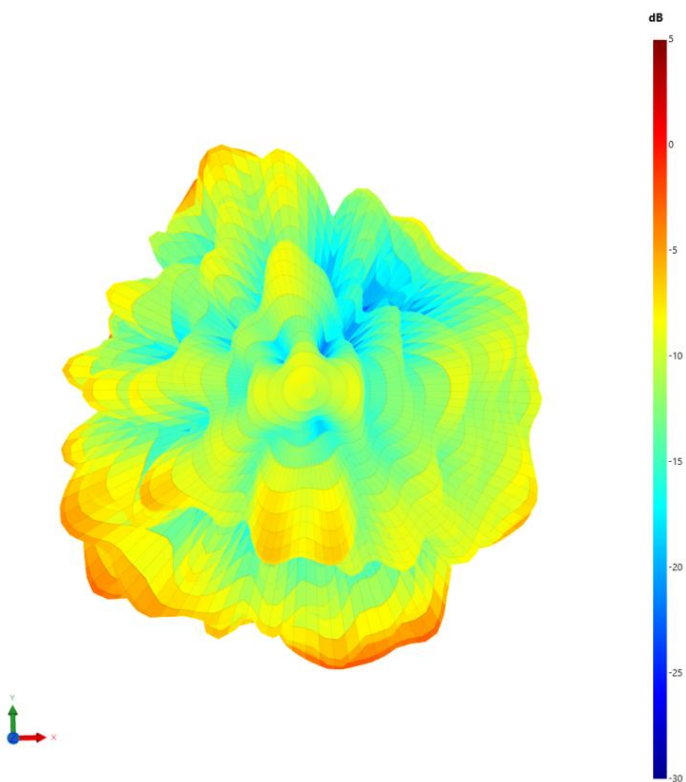


Figure 41 -3D pattern (XY plane)

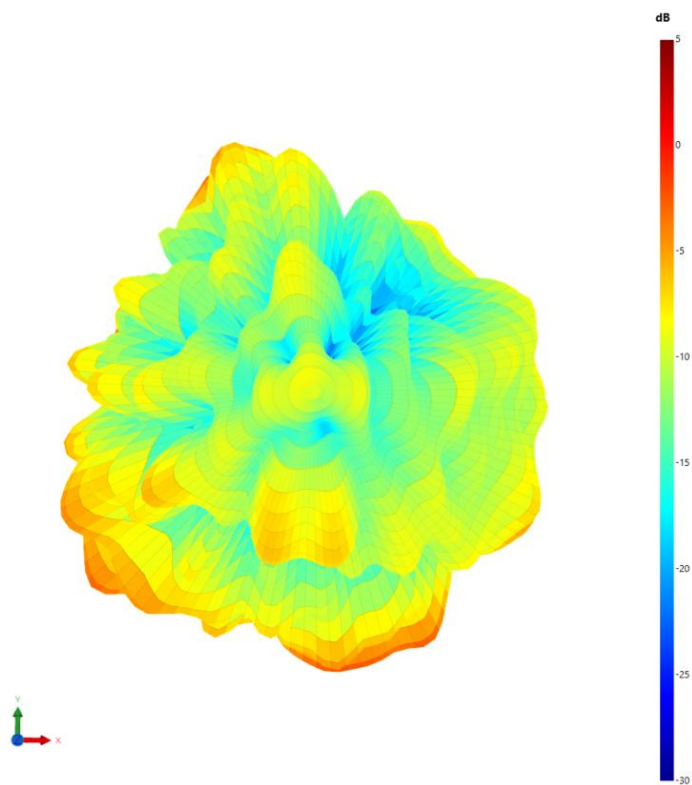


Figure 42 -3D pattern (XZ plane)

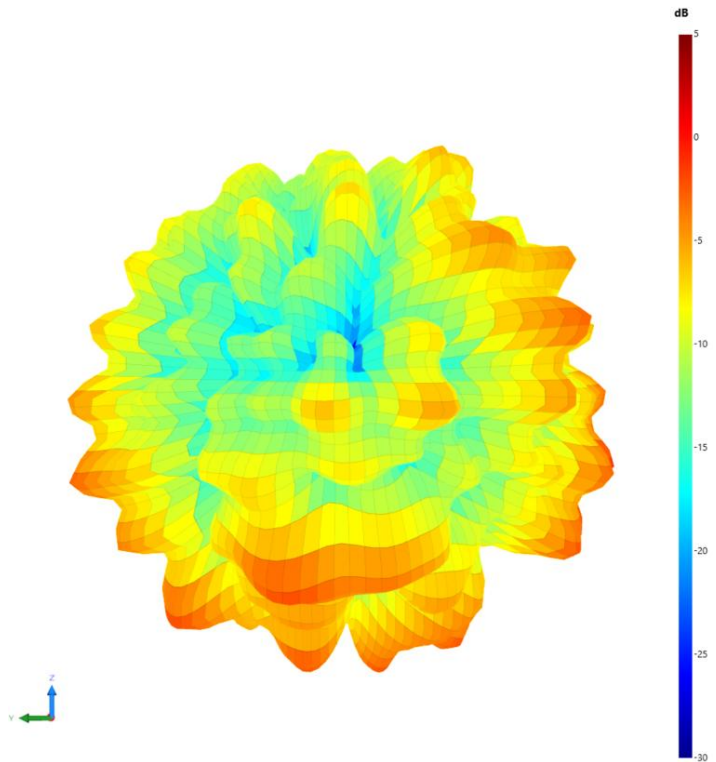


Figure 43 - 3D pattern (ZY plane)

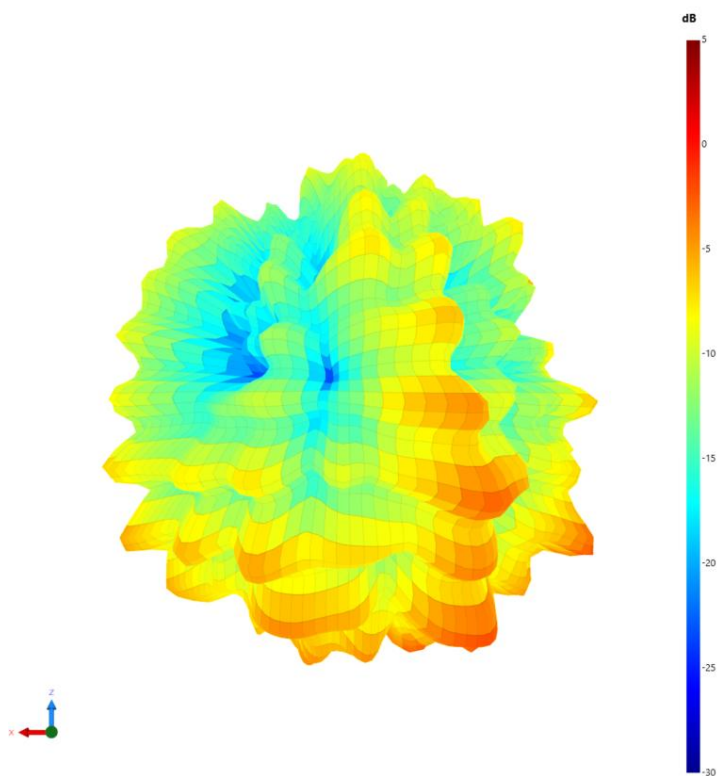


Figure 44 - 3D pattern (ZX plane)

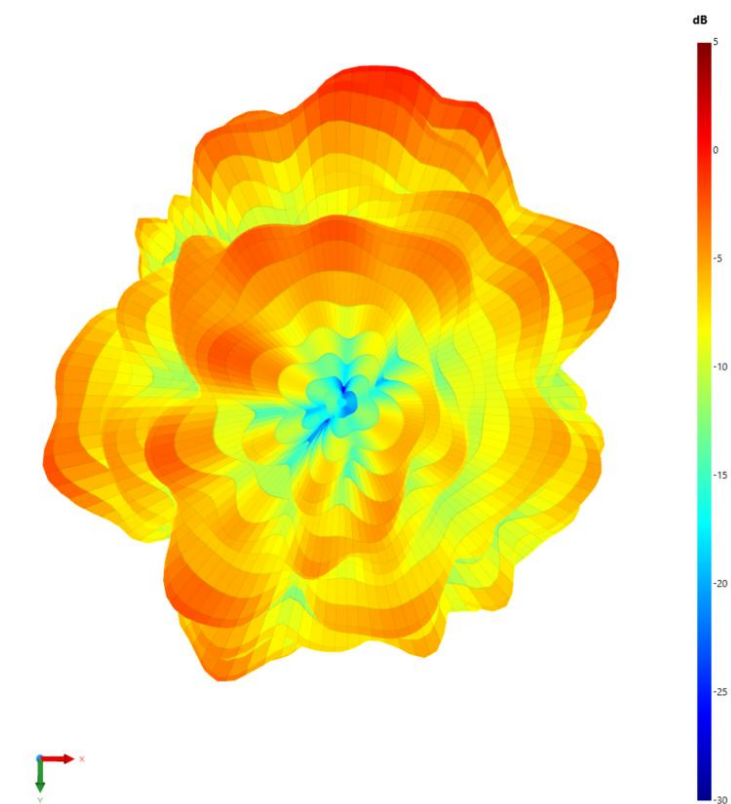


Figure 45 - 3D pattern (YX plane)

7.4 Bluetooth COMBO Antenna

7.4.1 2D Cuts, 2.4-2.5 GHz

7.4.1.1 Elevation, Azimuth = 0

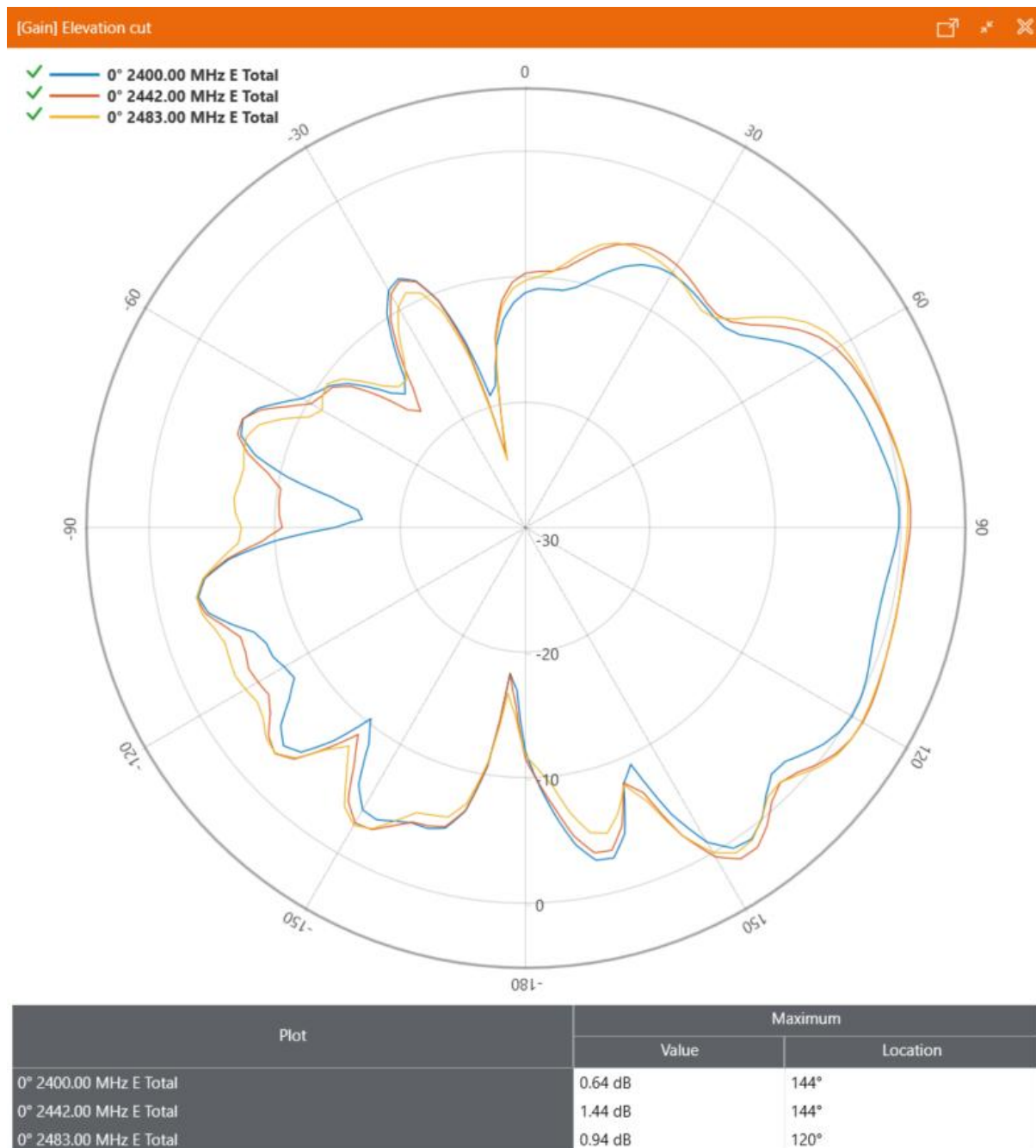


Figure 46: Combo BLE Antenna, 2.4-2.5 GHz, Elevation Cut (Azimuth = 0)

7.4.1.2 Elevation, Azimuth = 90

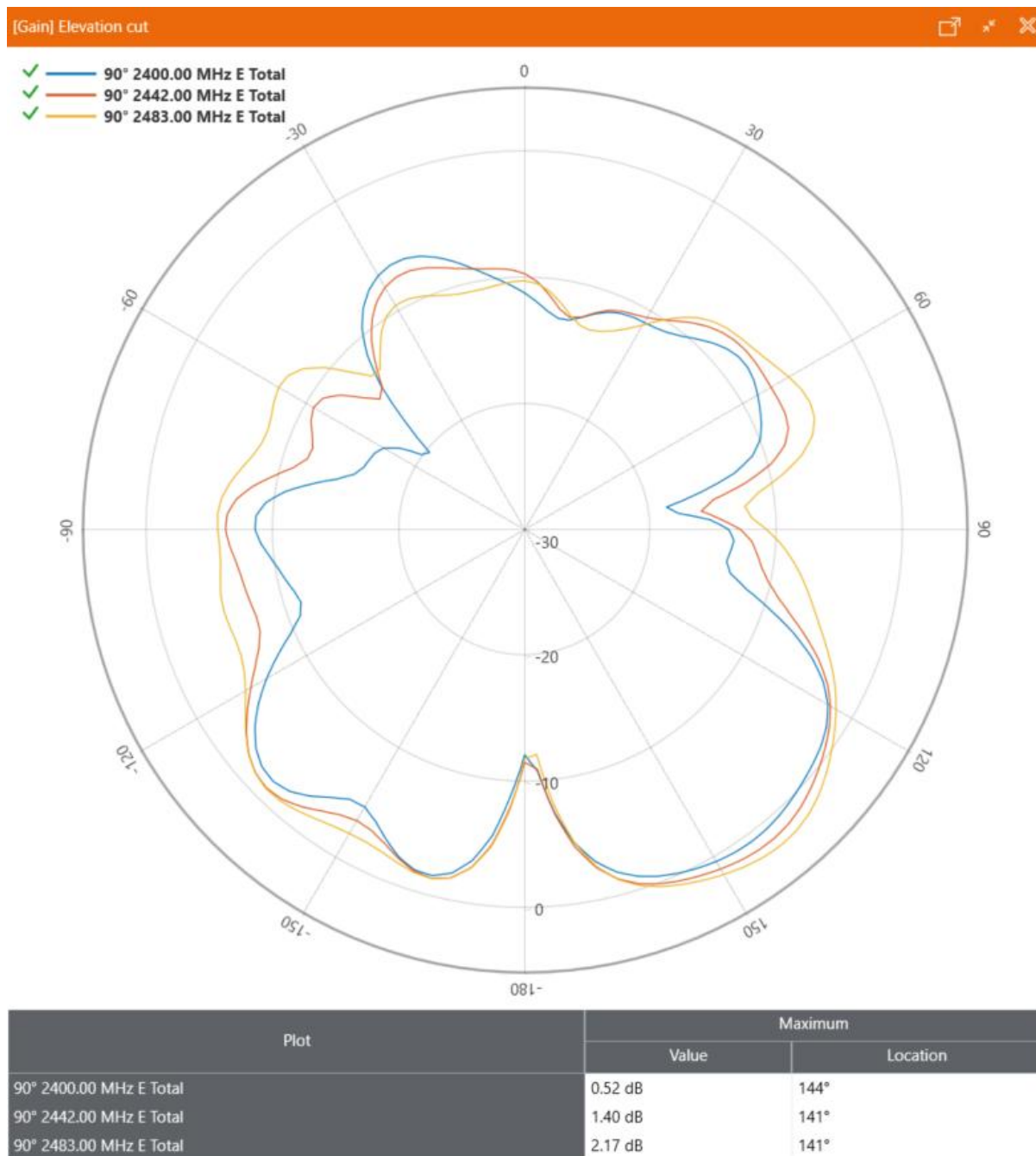


Figure 47: Combo BLE Antenna, 2.4-2.5 GHz, Elevation Cut (Azimuth = 90)

7.4.1.3 Azimuth Cut (Elevation = 90 degrees)

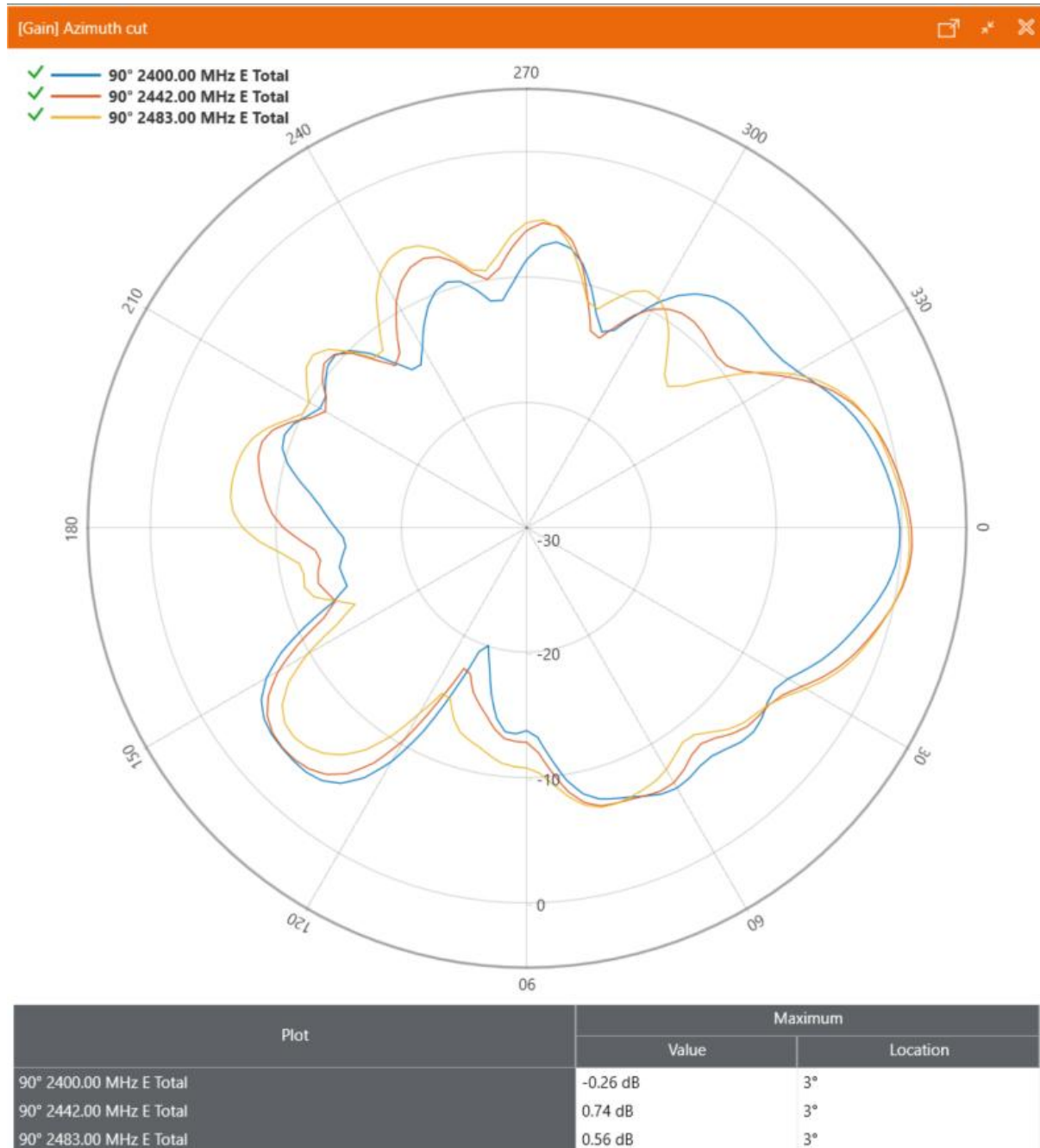


Figure 48: Combo BLE Antenna, 2.4-2.5 GHz, Azimuth Cut (Elevation = 90)

7.4.2 3D Patterns at 2.442 GHz

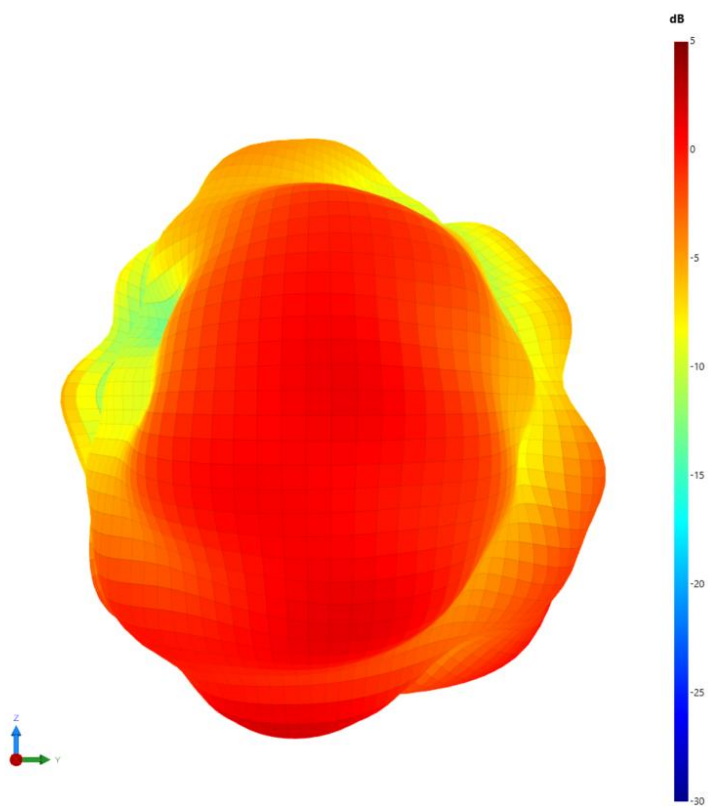


Figure 49: 3D Pattern, YZ plane

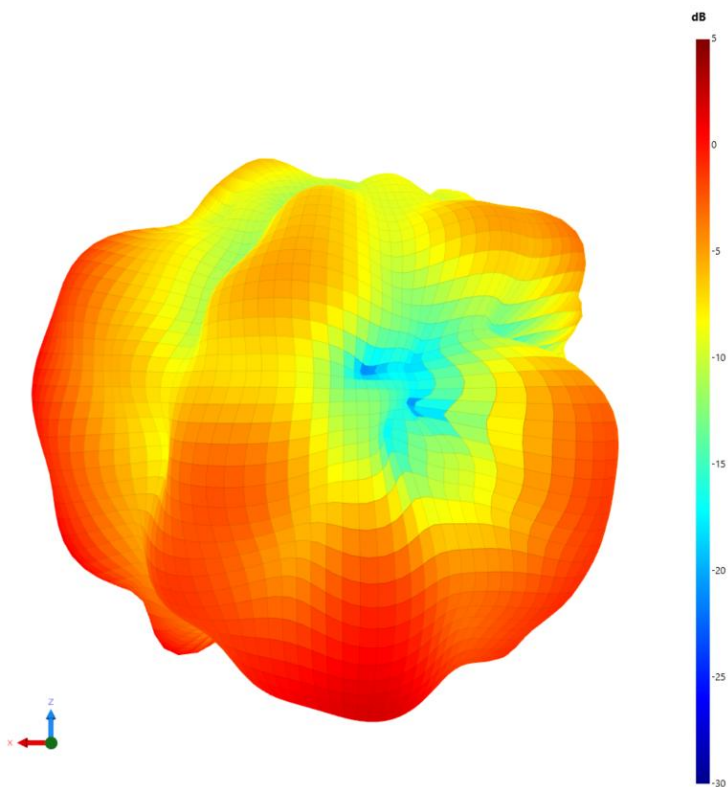


Figure 50: 3D Pattern, ZX plane

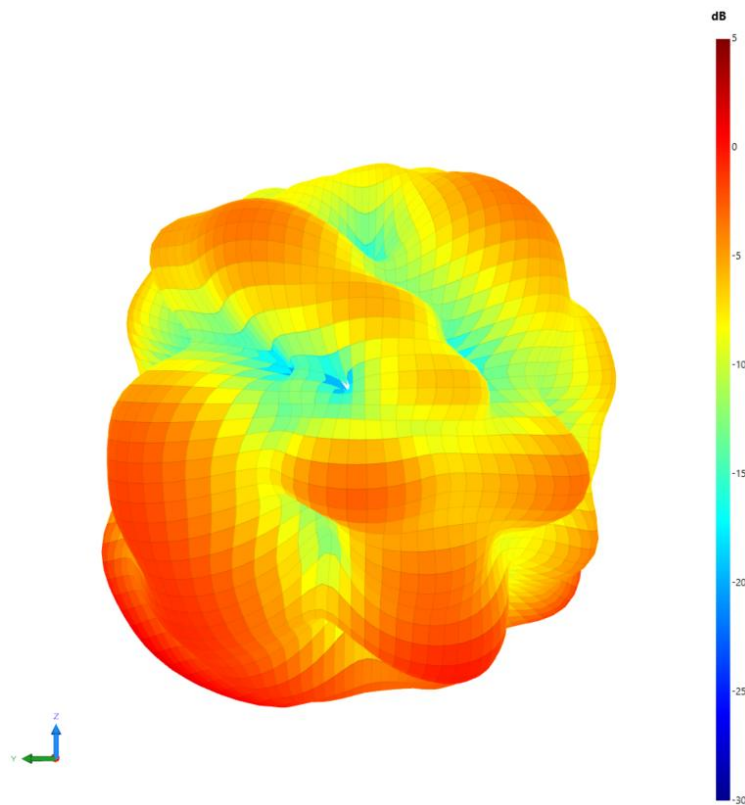


Figure 51: 3D Pattern, ZY plane

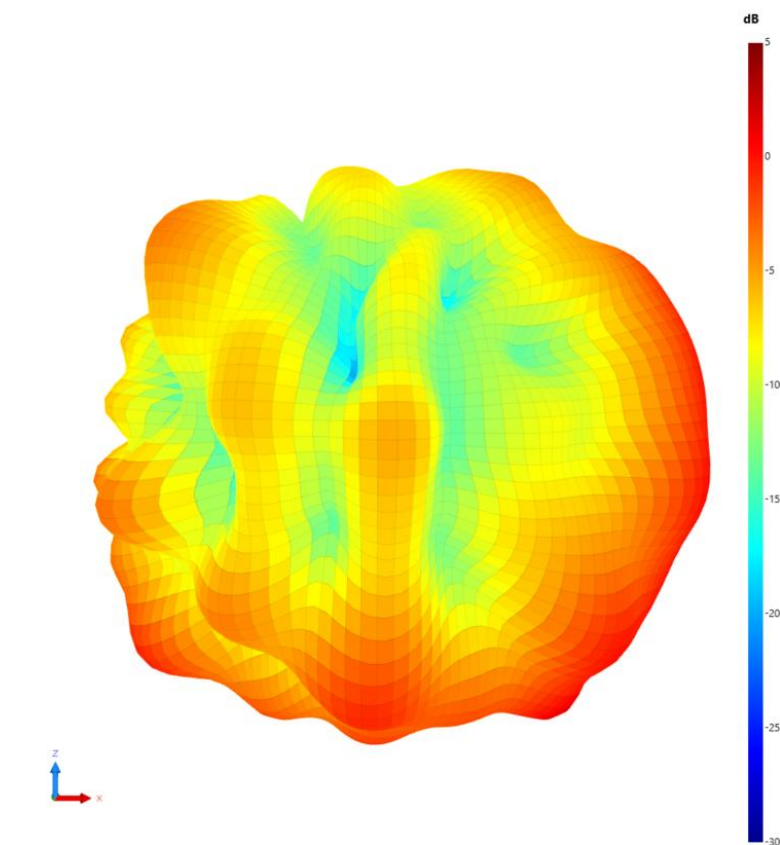


Figure 52: 3D Pattern, XZ plane

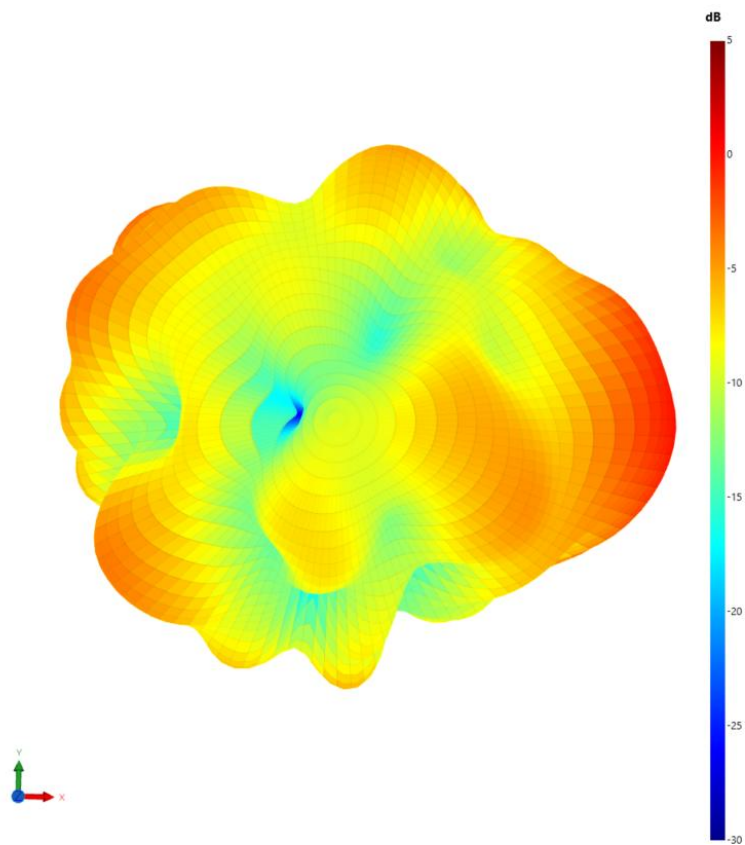


Figure 53: 3D Pattern, XY plane

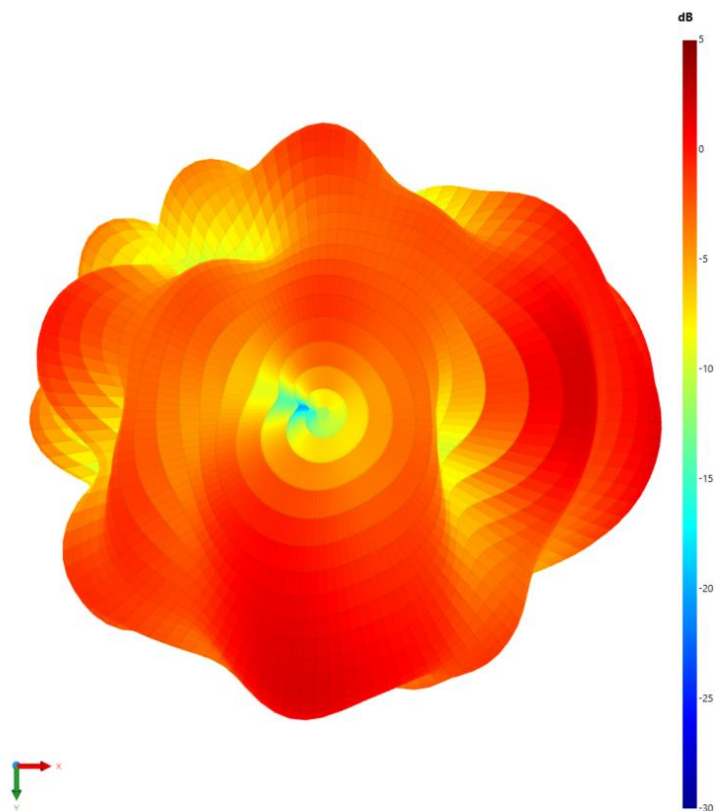


Figure 54: 3D Pattern, YX plane

8 Measurement Details

8.1 MVG SG24L CHAMBER

All of the pattern data collected and figures in this report come from measurements conducted in the MVG SG24L chamber on the premises of Sigma Connectivity in Lund, Sweden. This chamber was updated in 2018 to its current configuration (0.4 – 6 GHz). Measurements were made using WaveStudio version 25.3.0 software. The most recent calibration of the chamber prior to these measurements was conducted on Oct 2, 2025. The measurement used to measure (Keysight E5071C SN: MY46524047) was calibrated by the manufacturer in July 2025.



Figure 55 - Satimo Chamber with phantom head

Note: The phantom head shown in the figure above was not present during the current round of testing.

8.2 Reverb Chamber (SFC 1)

The reverb chamber was used for pre-measurement verification and for matching network optimization activities including data shown in Figure 8 and Figure 9. It is a custom measurement chamber developed by engineers at Ericsson, Sony Ericsson, and Sigma AB. It has undergone several improvements since it was first constructed in about 2002. It was calibrated most recently on November 24, 2025.



Figure 56 - Reverb Chamber (SFC)