Certification CTIA Authorized Test Lab
Lab Code: 20020328- 00

ilac-MRA ACCREDITED TESTING LABORATORY Certificate #2135.01

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Total Radiated Power and Total Isotropic Sensitivity Spherical Pattern Measurement.

TESLA WiFi#4 Antenna REPORT

Date of Report: 2022-12-01
Date of issue: 2022-12-01
Report Copy No.: 1.0

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Manufacturer	Tesla
Model	WiFi Antenna #4
CTIA Request #	N/A
Wi-Fi Alliance CID #	N/A
EUT ID / SN / IMEI	N/A
FCC ID Number	N/A
Hardware Version	N/A
Software Version	N/A
Configuration of Primary Mechanical Mode	Unit in Freespace position
Test Plan Revision	N/A
Test date	11/18/2022
Temperature / Humidity	72.7^{0}F / 47.1%

Applicant's Name:	TESLA INC
Address:	3500 Deer Creek Rd, Palo Alto, CA 94304
Contact Person:	Peng Zhang
Phone No.	510-213-1367
Fax:	N/A
e-mail:	pengzhang@tesla.com

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EUTs used for each test

EUT #	EUT ID	CATL/CHAMBER USED	Radio Modes	Band(s)	Test Types(s)	Test Conditions
1	WiFi #4	CETECOM/OTA5	Passive antenna	2.4 GHz / 5 Ghz	Gain	FS

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1 SUMMATION TEST REPORT – Gain measurements

Frequency (MHz)	2400	2410	2420	2430	2440	2450	2460	2470	2480
Gain (dBi)	6.10	6.10	6.07	6.25	6.26	6.22	6.22	6.23	6.03
Frequency (MHz)	2490	2500	5100	5130	5160	5190	5220	5250	5280
Gain (dBi)	6.08	5.90	3.94	4.00	4.28	4.87	4.99	5.26	5.08
Frequency (MHz)	5310	5340	5370	5400	5430	5460	5490	5520	5550
Gain (dBi)	4.99	4.95	5.18	4.72	4.70	4.76	5.09	4.89	4.80
Frequency (MHz)	5580	5610	5640	5670	5700	5730	5760	5790	5820
Gain (dBi)	5.10	5.28	4.93	4.68	4.95	5.06	5.10	5.24	4.96
Frequency (MHz)	5850	5880	5910	5940	5970	6000			
Gain (dBi)	4.80	4.86	4.97	5.23	5.20	5.17			

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FS = Free Space
BHHL = Beside Head and Hand Left Side (Head & Hand Phantom)
BHHR = Beside Head and Hand Right Side (Head & Hand Phantom)
HL = Hand Left (Hand Phantom Only)
HR = Hand Right (Hand Phantom Only)
* Mark values exceeding pass/fail limits in RED.

Milpitas 2022-12-01

Technical responsibility for area of testing:

12/01/22	OTA	Nicolas Stamber (Director of OTA)	Nicolas Stamber Digitally signed by: Nicolas Stamber DN: CN = Nicolas Stamber email = Nicolas.Stamber@cetecom.com C = AD O = CETECOM Inc. OU = OTA Date: 2022.12.01 14:31:47 -08'00'
Date	Section	Name	Signature

This report is reviewed by:

12/01/22	OTA	Chin Ming Lui (OTA Test Engineer)	chinming.lui@cetecom.com Digitally signed by: chinming.lui@cetecom.com DN: CN = chinming.lui@cetecom.com Date: 2022.12.01 14:57:00 -08'00'
Date	Section	Name	Signature

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2 Physical Layout and Site Description

2.1 Wireless Test Facility

All tests were performed in CETECOM's state-of-the-art Wireless Test Facility consisting of a fully anechoic rectangular chamber equipped with a Phi Axis Positioner & Theta Axis Scanner with a measurement antenna, Wrist-Worn Forearm Phantom, a dual polarized quad-ridge wave guide horn, and a circularly polarized communication antenna. A base station simulator is use to establish communication with the EUT and place it in the proper mode. A power meter and RF switch combination is used for measuring the signal from the EUT at each position and polarization. Rohde & Schwarz's proprietary AMS32 Pattern Measurement Software is used for data acquisition, post-processing and generation of the required output.

2.2 Anechoic Chamber

The 310cm x 340cm x 335cm in rectangular chamber consists of a shielded enclosure constructed of shielded modular panel sections that are assembled with a clamping system. The panels are joined together to provide uniform and consistent pressure contacts against the shielded panel mating surfaces. The chamber is treated with Hybrid Ferro Sorb absorbers, including both FT-1500 ferrite tiles and FAA polyurethane absorbers. Lighting in the chamber consists of fiber optic lights mounted in the chamber ceiling. The chamber is forced air ventilated to maintain it at the same ambient as the surrounding facility. A single leaf swing type shielded door is provided for equipment and personal access into the chamber. The Anechoic Chamber is capable of meeting RF attenuation level of over 100dB throughout the frequency range of 700 MHz to 6 GHz, so that testing performed within the chamber does not interfere with other testing activities at the facility and vice versa. Power is supplied on separate circuits to the chamber and control area. All power filters provide a minimum of 100dB attenuation over a frequency range of 14 kHz to 18 GHz when tested per Mil Std 220A.

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2.3 Phi Axis Positioner & Theta Axis Scanner

The Phi Axis Positioner is capable of rotating the Equipment Under Test (EUT) in the Phi axes with full 360 degrees angular range. The Theta Axis Scanner with a measurement antenna revolves around the EUT in the Theta axes from 0 degrees to 165 degrees. Under normal conditions it provides 0.1 degree positioning accuracy. In conjunction with the AMS32 Software, it can perform positioning for data acquisition in both continuous and stepped movement modes.

A DUT and SAM head is place on the pedestal to minimize the effect of the support on the measurement. The electrically driven Phi Axis Positioner does not introduce conducted or radiated electrical noise above the ambient levels existing within the chamber.

2.4 Wrist-Worn Forearm Phantom

A Wrist-Worn Forearm Phantom meeting the requirement for CTIA Certification Program Test Plan revision 3.9.5 is used for the phantom head testing.

2.5 Quiet Zone

A 50 cm diameter by 30 cm tall cylindrical quiet zone volume was qualified for each axis of the Phi Axis Positioner and polarization of the receive antenna per Howland Co. with test plan that encompasses the requirements of the CTIA test plan for Wireless Device Over the Air Performance, September 2022, Revision 3.9.5. The associated effects are included in the measurement uncertainty reported for the Total Isotropic Sensitivity.

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2.6 Howland Company Model QR-4 Quad Ridge Horn Antenna

The Model QR-4 is a broad bandwidth, dual polarized horn antenna designed for wireless device measurements. It can be used as the measurement antenna in all Howland Wireless Test Labs. The QR-4 is designed with a minimum overall length in order to maximize the range length in the wireless test lab.

2.7 Circularly Polarized Communication Antenna

The top of the Phi Axis Positioner below the EUT is fitted with a broadband circularly polarized communication antenna (R&S 3102 Circular Polarized Antennal) to provide a relatively low loss link to the base station simulator in any position. An RF switch allows selection of either antenna so that lost calls may be avoided when the phantom is in between the antenna and the EUT.

2.8 Test Equipment

The test was performed using the following additional test equipment:

Rohde & Schwarz ZNB8 Vector Network Analyzer
Howland Company Motion Control Unit
Rohde & Schwarz OSP RF Switch

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2.9 AMS32 Software

Rohde & Schwarz's AMS32 proprietary pattern measurement software is used to automate the data acquisition process and provides all post-processing calculations and data output required by the CTIA. Its parameterized test configuration system and conscientiously validated design helps to insure repeatable and correct results.

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3 Test Method

3.1 Total Radiated Power

The Total Radiated Power (TRP) test is performed according to the CTIA Test Plan for Wireless Device Over the Air Performance, September 2022, Revision 3.9.5, using the conical cut data acquisition order.
The call is established using the communication antenna and the EUT is positioned in the center of the quiet zone, either on the pedestal mount (FS), Forearm phantom Wrist-Worn Left (WL), or Forearm phantom Wrist-Worn Right (WR). The call parameters are adjusted on the base station simulator to bring the EUT to the required traffic channel and output power level. The EUT is then stepped between 0 and 165 degrees along the theta axis in 15-degree increments. At each theta position, the phi axis is stepped from 0-345 degrees or from 345-0 degrees, alternating to minimize test time in 15-degree increments. Data is recorded using the power meter with two independent power sensors to measure both theta and phi polarization at each position simultaneously. Upon completion of the test, the net power (Angular dependent EIRP) is calculated at each measurement point and the required values of TRP and Near Horizon Partial Radiated Power (NHPRP) are automatically calculated. This test procedure is repeated for each channel, band, and configuration as required.
GPRS and EGPRS, respectively 1xRTT and 1xEV-DO are calculated through CTIA's single point offset test.

3.2 Total Isotropic Sensitivity

The Total Isotropic Sensitivity (TIS) test is performed according to the CTIA Test Plan for Wireless Device Over the Air Performance, September 2022, Revision 3.9.5, using the conical cut data acquisition order. The call is established using the horn antenna for the downlink and the communication antenna for the uplink. The EUT is positioned in the center of the quiet zone, either on the pedestal mount (FS), Forearm phantom Wrist-Worn Left (WL), or Forearm phantom Wrist-Worn Right (WR). The call parameters are adjusted on the base station simulator to bring the EUT to the required traffic channel and ensuring the receive signal at the position of the EUT is high enough to provide a stable connection. The EUT is then stepped between 0 and 150 degrees along the theta axis in 30-degree increments. At each theta position, the phi axis is stepped from 0-330 degrees or from 330-0 degrees, alternating to minimize the test time in 30-degree increments. At each spherical point and on each polarization the base station emulator lowers the downlink power until a certain BER/BLER limit is exceeded. The chamber path loss will then be subtracted from the base station output power to calculate the receive signal strength at the

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position of the EUT. These values are recorded by the AMS32 software and later used to calculate the TIS and NHPIS according to the formula specified in Appendix E of the CTIA Test Plan. This test procedure is repeated for each channel, band and configuration as required. GPRS and EGPRS respectively 1xRTT and 1xEV-DO are calculated through CTIA's single point offset test.

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4 Measurement Uncertainty OTA 5 Chamber

4.1 TRP uncertainty standard

Free Space	LTE700 699-798 MHz	Cellular 824-894 MHz	AWS-1 Tx 1710-1755 MHz	PCS 1850-1995 MHz	LTE/WLAN 2300-2800 MHz	
Standard Uncertainty, u	0.81	0.75	0.75	0.76	0.73	
Expanded Uncertainty, U, with 95% Confidence Interval	1.62	1.49	1.50	1.51	1.45	

Phantom Head and Hand	LTE700 699-798 MHz	Cellular 824-894 MHz	AWS-1 Tx 1710-1755 MHz	PCS 1850-1995 MHz	LTE/WLAN 2300-2800 MHz	
Standard Uncertainty, u	0.86	0.80	0.80	0.80	0.78	
Expanded Uncertainty, U, with 95% Confidence Interval	1.71	1.59	1.60	1.61	1.55	

Phantom Hand Only	LTE700 699-798 MHz	Cellular 824-894 MHz	AWS-1 Tx 1710-1755 MHz	PCS 1850-1995 MHz	LTE/WLAN 2300-2800 MHz	
Standard Uncertainty, u	0.82	0.76	0.76	0.76	0.74	
Expanded Uncertainty, U, with 95% Confidence Interval	1.64	1.51	1.52	1.53	1.47	

Laptops over 30 cm	LTE700 699-798 MHz	Cellular 824-894 MHz	AWS-1 Tx 1710-1755 MHz	PCS 1850-1995 MHz	LTE/WLAN 2300-2800 MHz	
Standard Uncertainty, u	0.82	0.75	0.76	0.79	0.91	
Expanded Uncertainty, U, with 95% Confidence Interval	1.63	1.50	1.51	1.58	1.82	

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4.2 TRP uncertainty alternate methods (worst case)

Free Space	LTE700 699-798 MHz	Cellular 824-894 MHz	AWS-1 Tx 1710-1755 MHz	PCS 1850-1995 MHz	LTE/WLAN 2300-2800 MHz	
Standard Uncertainty, u	0.83	0.76	0.77	0.77	0.75	
Expanded Uncertainty, U, with 95% Confidence Interval	1.65	1.53	1.54	1.55	1.49	

Phantom Head and Hand	LTE700 699-798 MHz	Cellular 824-894 MHz	AWS-1 Tx 1710-1755 MHz	PCS 1850-1995 MHz	LTE/WLAN 2300-2800 MHz	
Standard Uncertainty, u	0.87	0.81	0.82	0.82	0.79	
Expanded Uncertainty, U, with 95% Confidence Interval	1.74	1.62	1.63	1.64	1.59	

Phantom Hand Only	LTE700 699-798 MHz	Cellular 824-894 MHz	AWS-1 Tx 1710-1755 MHz	PCS 1850-1995 MHz	LTE/WLAN 2300-2800 MHz	
Standard Uncertainty, u	0.84	0.77	0.78	0.78	0.75	
Expanded Uncertainty, U, with 95% Confidence Interval	1.67	1.55	1.56	1.56	1.51	

Laptops over 30 cm	LTE700 699-798 MHz	Cellular 824-894 MHz	AWS-1 Tx 1710-1755 MHz	PCS 1850-1995 MHz	LTE/WLAN 2300-2800 MHz	
Standard Uncertainty, u	0.83	0.77	0.77	0.80	0.92	
Expanded Uncertainty, U, with 95% Confidence Interval	1.66	1.54	1.55	1.61	1.85	

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4.3 TIS uncertainty

Free Space	LTE700 699-798 MHz	Cellular 824-894 MHz	PCS 1850-1990 MHz	AWS-1 Rx 2110-2155 MHz	LTE/WLAN 2300-2800 MHz	
Standard Uncertainty, u	0.86	0.80	0.81	0.80	0.78	
Expanded Uncertainty, U, with 95% Confidence Interval	1.72	1.60	1.62	1.59	1.57	

Phantom Head and Hand	LTE700 699-798 MHz	Cellular 824-894 MHz	PCS 1850-1990 MHz	AWS-1 Rx 2110-2155 MHz	LTE/WLAN 2300-2800 MHz	
Standard Uncertainty, u	0.92	0.87	0.88	0.86	0.85	
Expanded Uncertainty, U, with 95% Confidence Interval	1.85	1.74	1.75	1.73	1.70	

Phantom Hand Only	LTE700 699-798 MHz	Cellular 824-894 MHz	PCS 1850-1990 MHz	AWS-1 Rx 2110-2155 MHz	LTE/WLAN 2300-2800 MHz	
Standard Uncertainty, u	0.88	0.83	0.83	0.82	0.81	
Expanded Uncertainty, U, with 95% Confidence Interval	1.77	1.65	1.67	1.64	1.62	

Laptops over 30 cm	LTE700 699-798 MHz	Cellular 824-894 MHz	PCS 1850-1990 MHz	AWS-1 Rx 2110-2155 MHz	LTE/WLAN 2300-2800 MHz	
Standard Uncertainty, u	0.87	0.81	0.84	0.81	0.95	
Expanded Uncertainty, U, with 95% Confidence Interval	1.73	1.61	1.68	1.62	1.91	

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4.4 TIS uncertainty RSS based

Free Space	LTE700 699-798 MHz	Cellular 824-894 MHz	PCS 1850-1990 MHz	AWS-1 Rx 2110-2155 MHz	LTE/WLAN 2300-2800 MHz	
Standard Uncertainty, u	0.93	0.88	0.88	0.87	0.86	
Expanded Uncertainty, U, with 95% Confidence Interval	1.86	1.75	1.77	1.74	1.72	

Phantom Head and Hand	LTE700 699-798 MHz	Cellular 824-894 MHz	PCS 1850-1990 MHz	AWS-1 Rx 2110-2155 MHz	LTE/WLAN 2300-2800 MHz	
Standard Uncertainty, u	0.99	0.94	0.95	0.93	0.92	
Expanded Uncertainty, U, with 95% Confidence Interval	1.98	1.88	1.89	1.87	1.85	

Phantom Hand Only	LTE700 699-798 MHz	Cellular 824-894 MHz	PCS 1850-1990 MHz	AWS-1 Rx 2110-2155 MHz	LTE/WLAN 2300-2800 MHz	
Standard Uncertainty, u	0.95	0.90	0.91	0.89	0.88	
Expanded Uncertainty, U, with 95% Confidence Interval	1.91	1.80	1.81	1.79	1.76	

Laptops over 30 cm	LTE700 699-798 MHz	Cellular 824-894 MHz	PCS 1850-1990 MHz	AWS-1 Rx 2110-2155 MHz	LTE/WLAN 2300-2800 MHz	
Standard Uncertainty, u	0.94	0.88	0.91	0.89	1.02	
Expanded Uncertainty, U, with 95% Confidence Interval	1.87	1.76	1.83	1.77	2.04	

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4.5 TIS uncertainty alternate methods (worst case)

Free Space	LTE700 699-798 MHz	Cellular 824-894 MHz	PCS 1850-1990 MHz	AWS-1 Rx 2110-2155 MHz	LTE/WLAN 2300-2800 MHz	
Standard Uncertainty, u	0.95	0.90	0.90	0.89	0.88	
Expanded Uncertainty, U, with 95% Confidence Interval	1.90	1.80	1.81	1.78	1.76	

Phantom Head and Hand	LTE700 699-798 MHz	Cellular 824-894 MHz	PCS 1850-1990 MHz	AWS-1 Rx 2110-2155 MHz	LTE/WLAN 2300-2800 MHz	
Standard Uncertainty, u	1.01	0.96	0.96	0.95	0.94	
Expanded Uncertainty, U, with 95% Confidence Interval	2.02	1.92	1.93	1.90	1.89	

Phantom Hand Only	LTE700 699-798 MHz	Cellular 824-894 MHz	PCS 1850-1990 MHz	AWS-1 Rx 2110-2155 MHz	LTE/WLAN 2300-2800 MHz	
Standard Uncertainty, u	0.97	0.92	0.93	0.91	0.90	
Expanded Uncertainty, U, with 95% Confidence Interval	1.94	1.84	1.85	1.83	1.81	

Laptops over 30 cm	LTE700 699-798 MHz	Cellular 824-894 MHz	PCS 1850-1990 MHz	AWS-1 Rx 2110-2155 MHz	LTE/WLAN 2300-2800 MHz	
Standard Uncertainty, u	0.96	0.90	0.93	0.91	1.04	
Expanded Uncertainty, U, with 95% Confidence Interval	1.91	1.80	1.86	1.81	2.07	

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5 Test Equipment List

a. Table 1. Test equipment used for measuring OTA performance

TYPE OF EQUIPMENT	MODEL NUMBER	MANUFACTURER	SN	CALIBRATION DUE DATE
Rectangular Anechoic Chamber	3500	Howland Company	N/A	April 2023
Quad-Ridge Horn Antenna 400MHz-6GHz	QR-4	Howland Company	1010	N/R
Circularly Polarized Communication Antenna	3102	Rohde & Schwarz	408211-0001	N/A
Antenna Position Controller	Motion Control Unit	Howland Company	143	N/A
Dual Axis Positioner	None	Howland Company	Az 1019 E1	N/A
Low loss RF Cables	UFA210B	Microcoax	N/A	N/R
Desktop Computer	Workstation	Dell Computer	N/A	N/A
Pattern Measurement Software	AMS32	Rohde & Schwarz	101154	N/A
Vector Network Analyzer	ZNB8	Rohde & Schwarz	101659	September 2023
RF Switch	OSP 130	Rohde & Schwarz	100186	N/R

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Power Meters	NRP 2	Rohde & Schwarz	101712	September 2023
Power Sensors	NRP Z-11 (H)	Rohde & Schwarz	110121	September 2023
Power Sensors	NRP Z-11 (V)	Rohde & Schwarz	110122	September 2023

Note: **N/A** = Equipment does not need to be calibrated.
N/R = Equipment is not required to be calibrated, due to the fact that it is included in the chamber calibration.

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6 Setup Photos

a. Test Chamber

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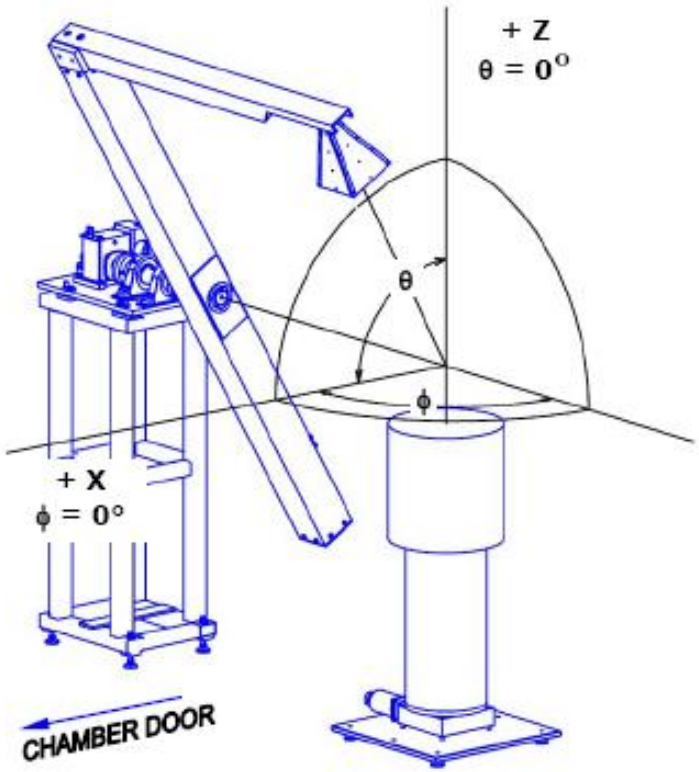

Figure A-2

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OTA Test(7) 5 / 5

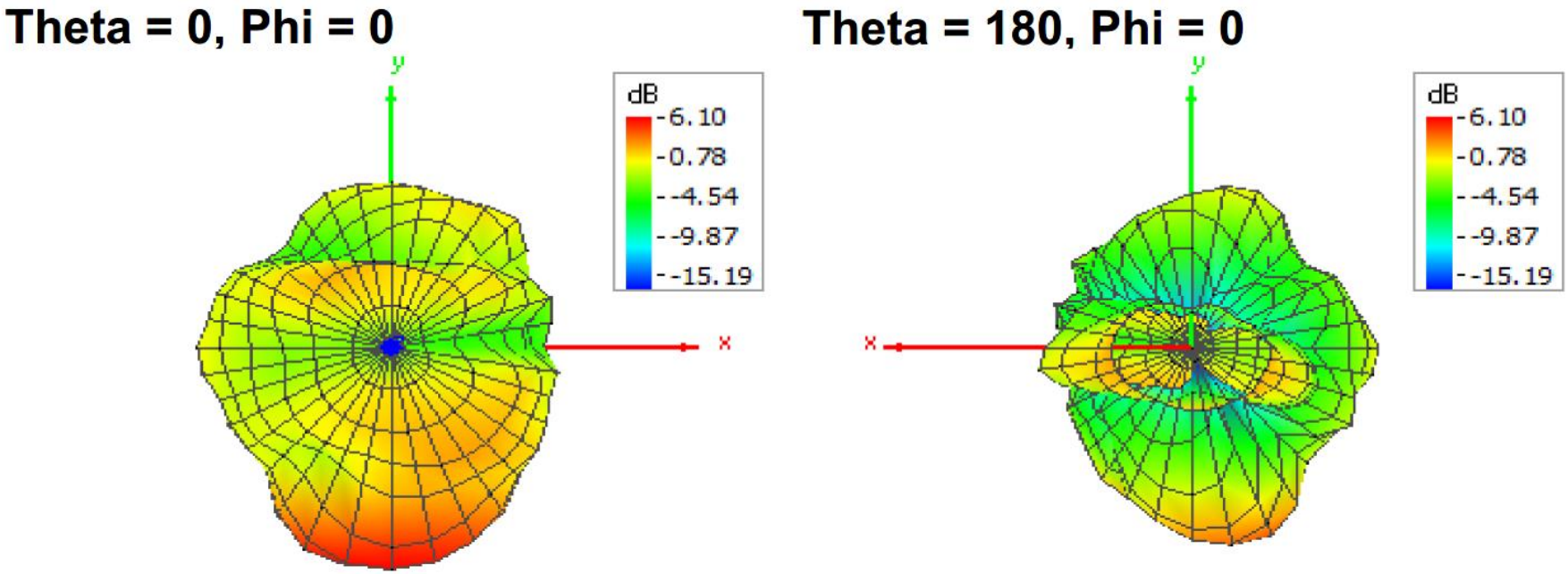

Figure A-3 Pattern at 2400 MHz

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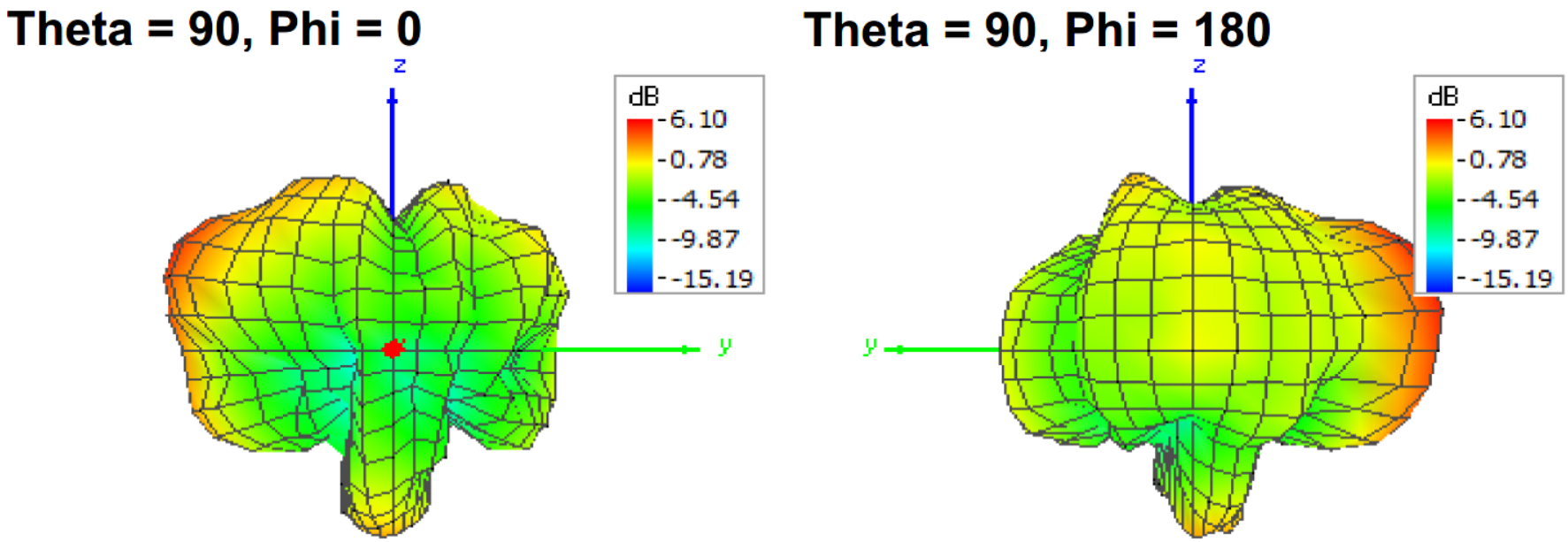

Figure A-4 Pattern at 2400 MHz

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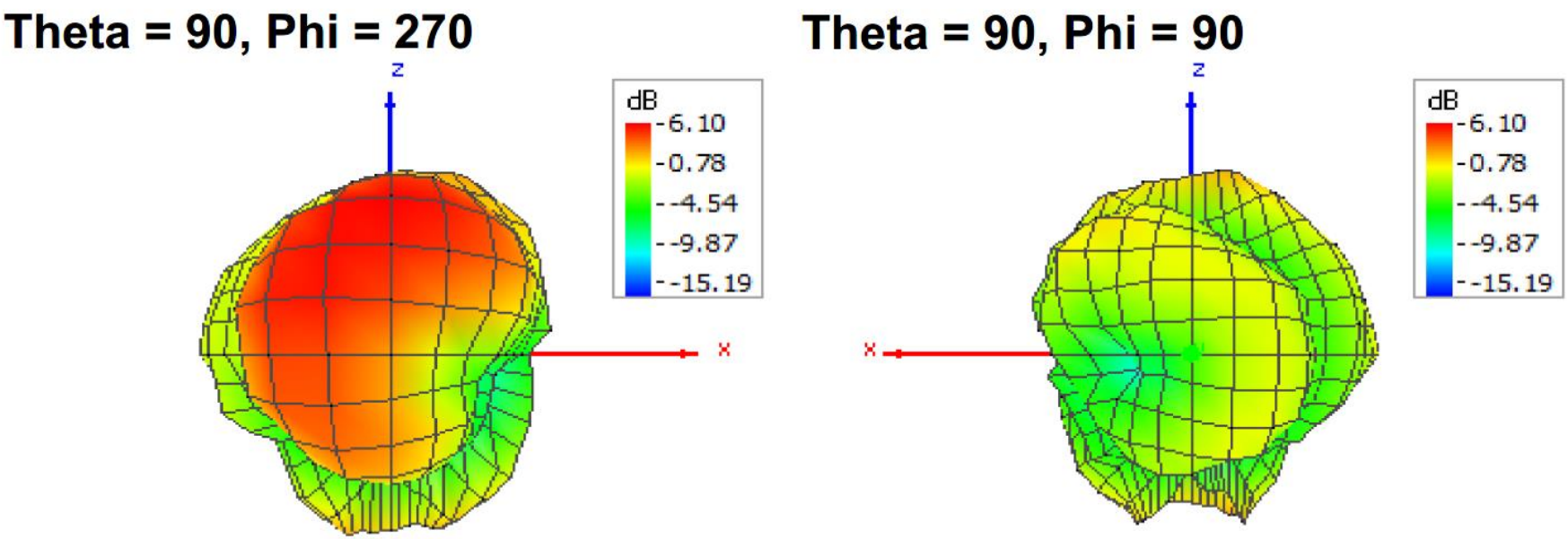

Figure A-5 Pattern at 2400 MHz

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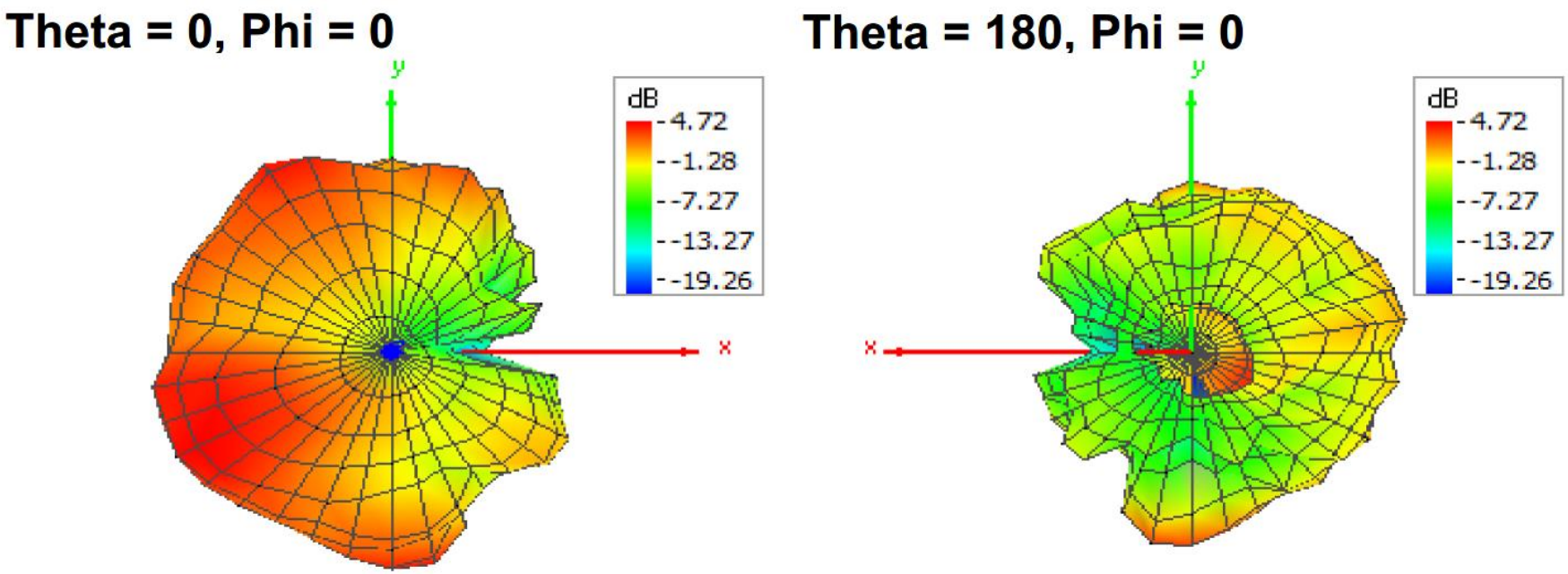

Figure A-6 Pattern at 5400 MHz

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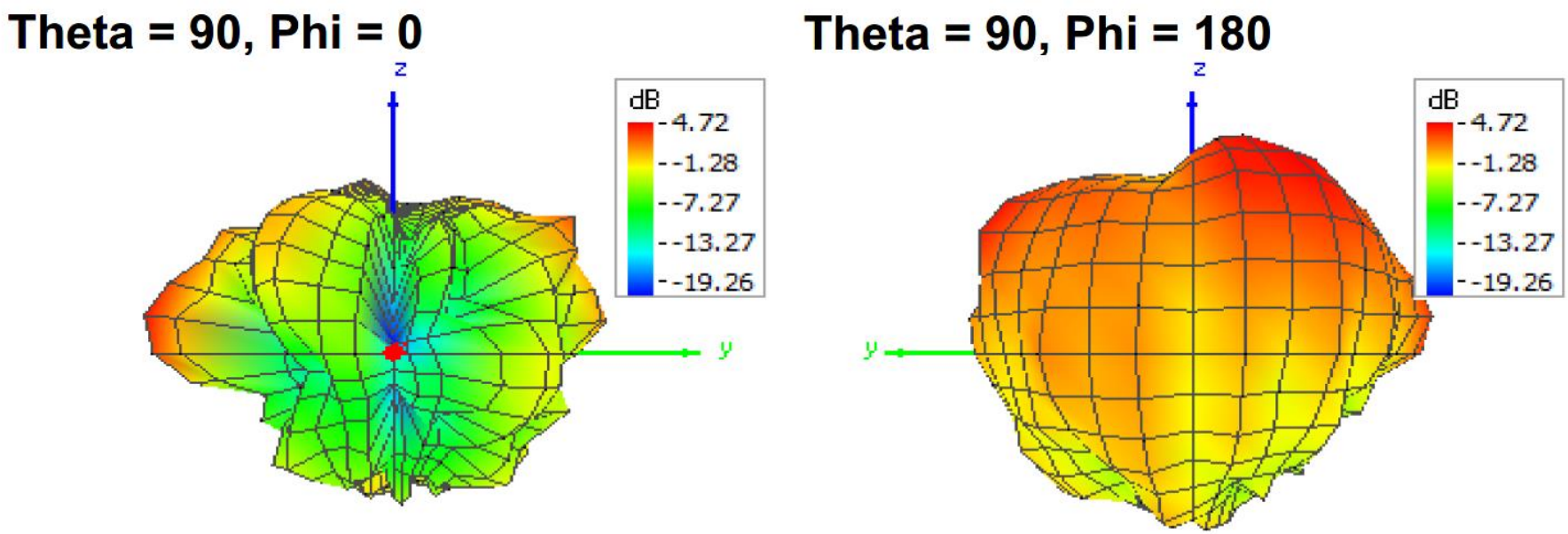

Figure A-7 Pattern at 5400 MHz

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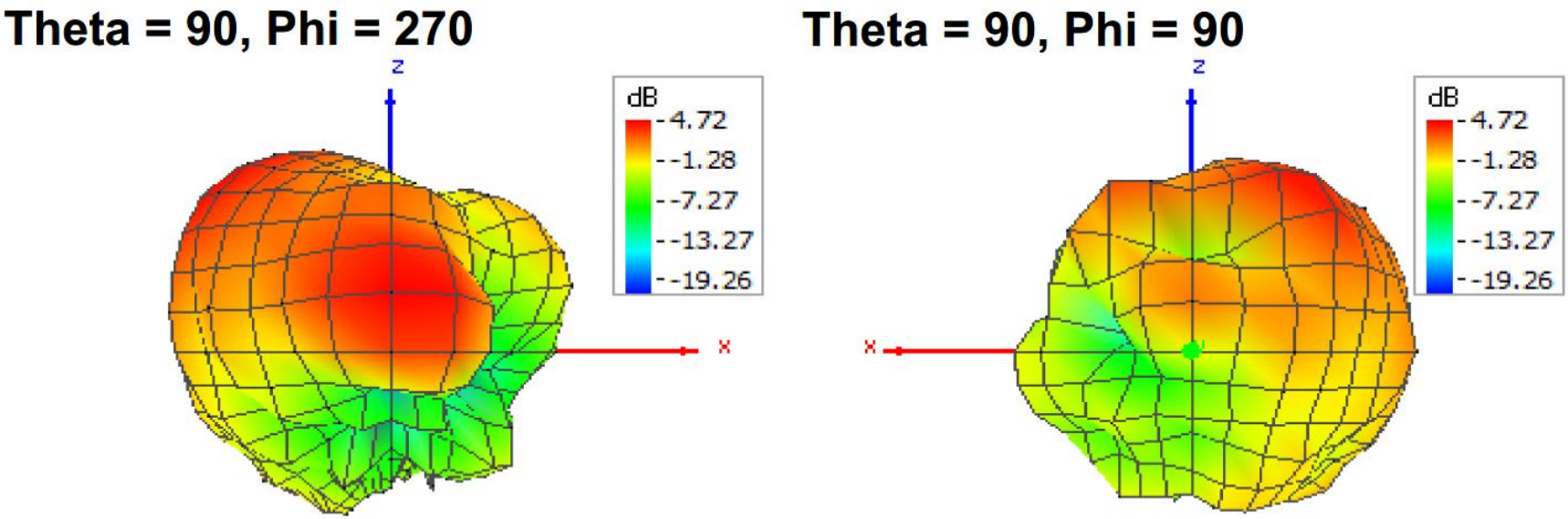

Figure A-8 Pattern at 5400 MHz

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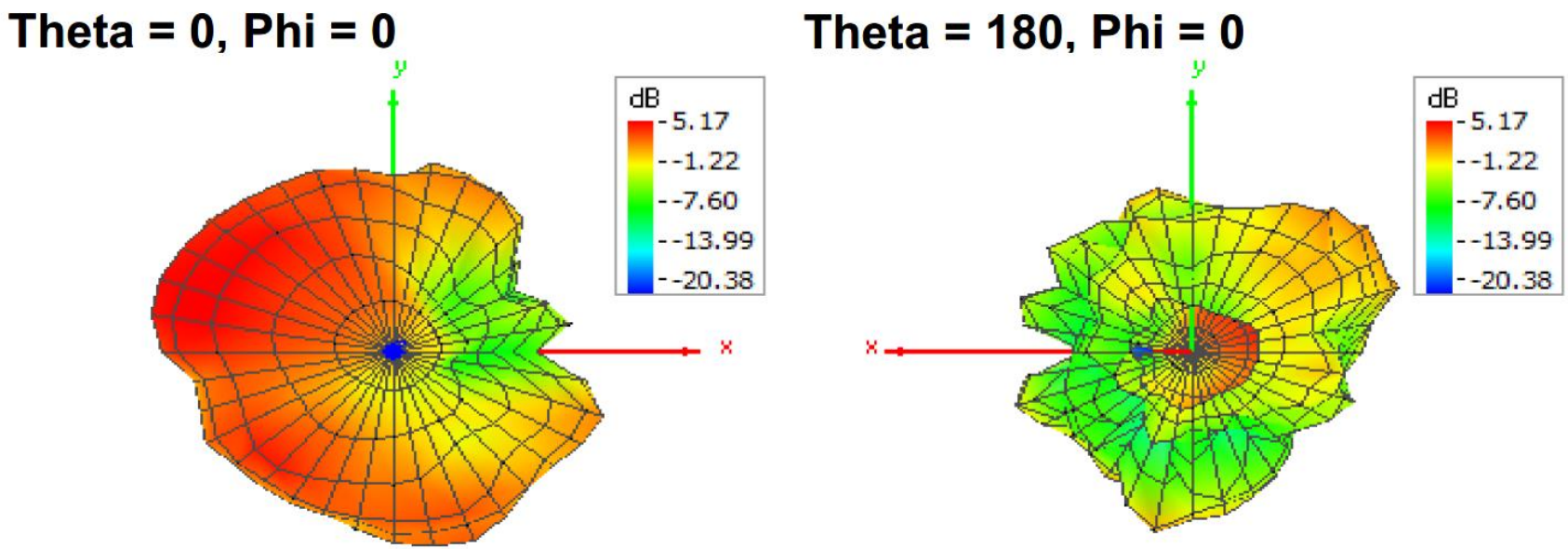

Figure A-9 Pattern at 6000 MHz

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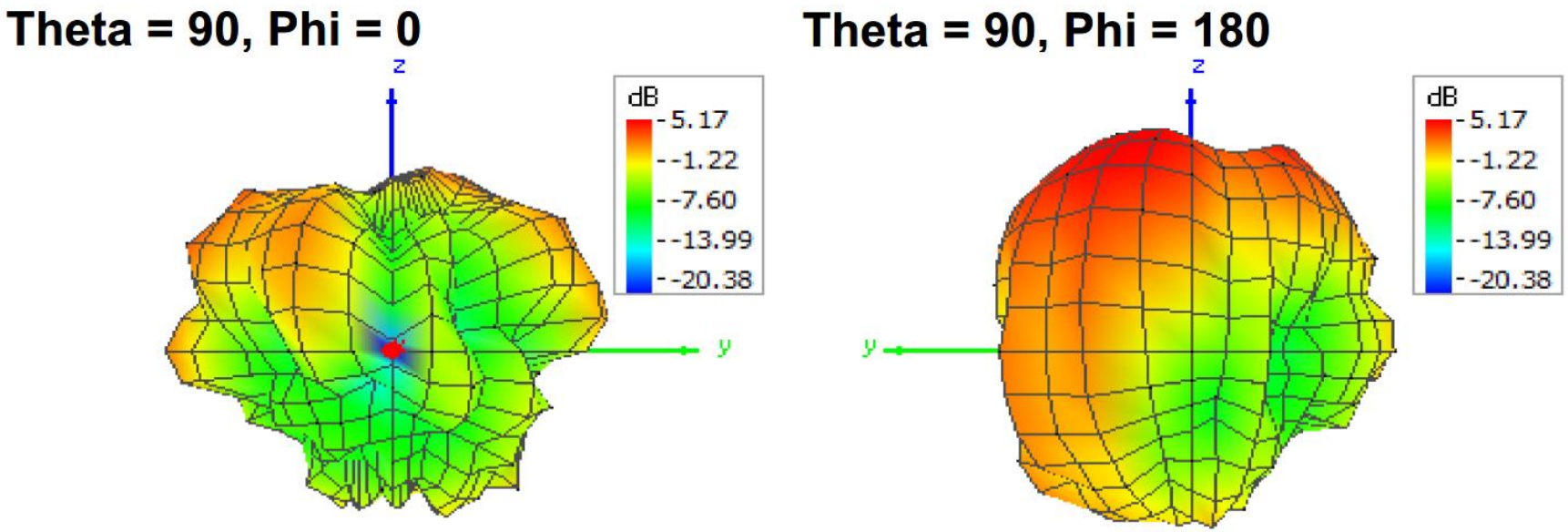

Figure A-10 Pattern at 6000 MHz

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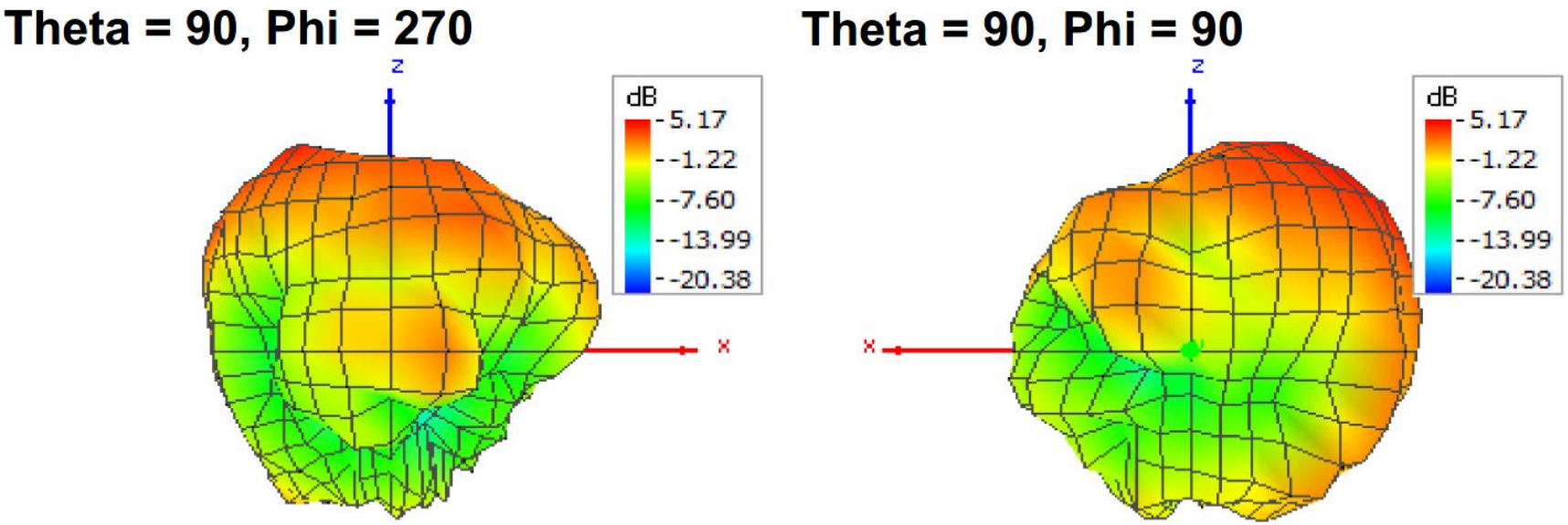

Figure A-11 Pattern at 6000 MHz

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8 Revision History

Version	Date	By	Status / changes
1.0	12/01/2022	NS	Official Report

End of Test Report !

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