HP WLAN 2.4/5 GHz PCB Trace Antenna performance for the Snowy Module

V1.0

Antenna Report Model: SNPRC- 2450

26 JULY 2024

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5) Antenna System Features:

- Dual 2.4/5 GHz PCB Trace Antennas
- Orthogonal antenna orientation for optimal coverage (Diversity)
- 2.4 GHz:
  - 2.4-2.5 GHz Frequency Range
  - VSWR Better than 2.5:1 across Frequency Range
  - Typical Gain: 3 DBI across the 2.4-2.5 GHz Frequency Range

- 5 GHz:
  - 5.1-5.9 GHz Frequency Range
  - VSWR Better than 2.5:1 across Frequency Range
  - Typical Gain: 3.8 DBI across the 5.1-5.9 GHz Frequency Range

---

6) Date of Test:
February 9th, 2024

7) Location of Test:
MVG, Inc
SATIMO SG64 Chamber
Attn: Jim Acree
450 Franklin Gateway SE
Suite 100
Marietta, GA 30067
USA

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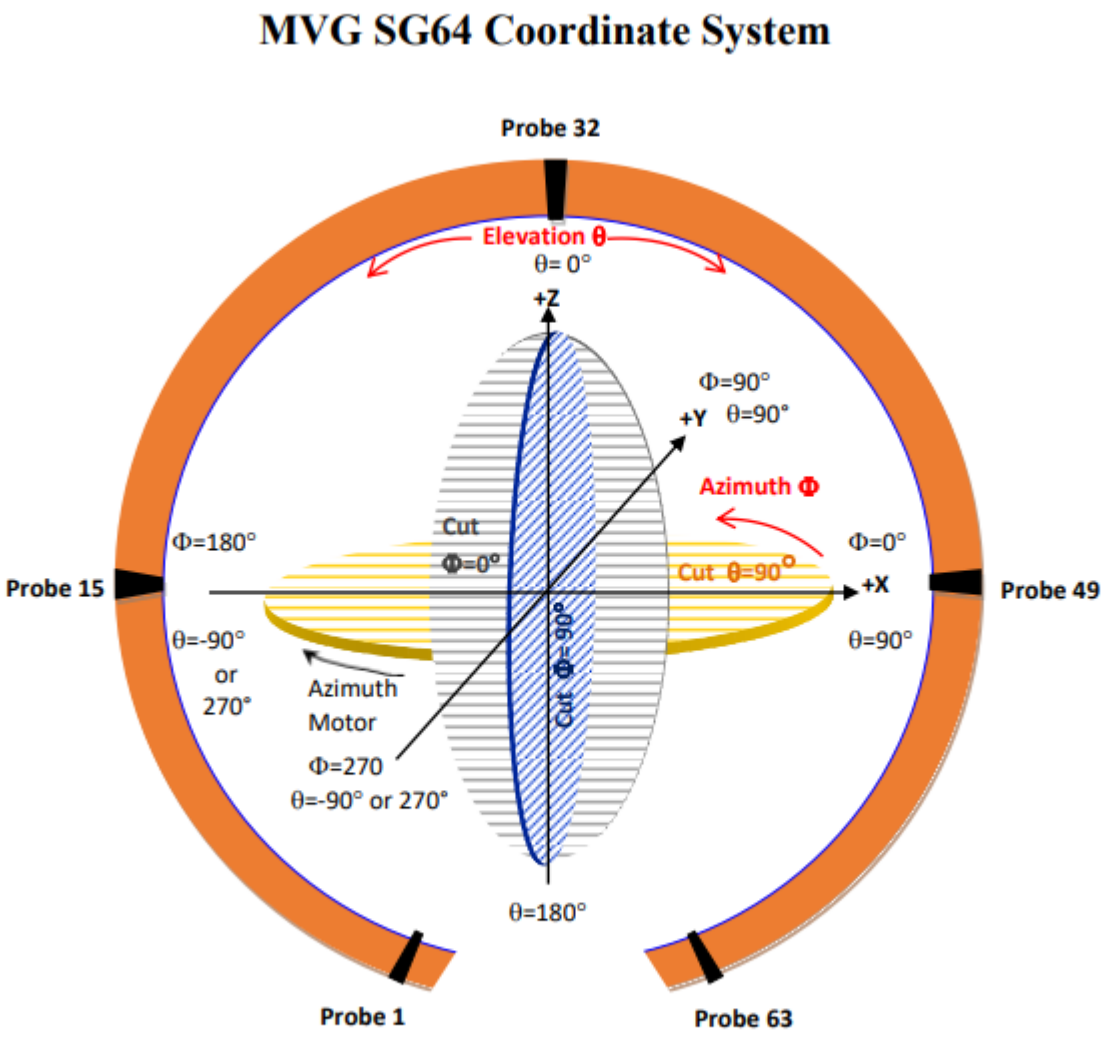
8) SG64 Chamber Coordinate System



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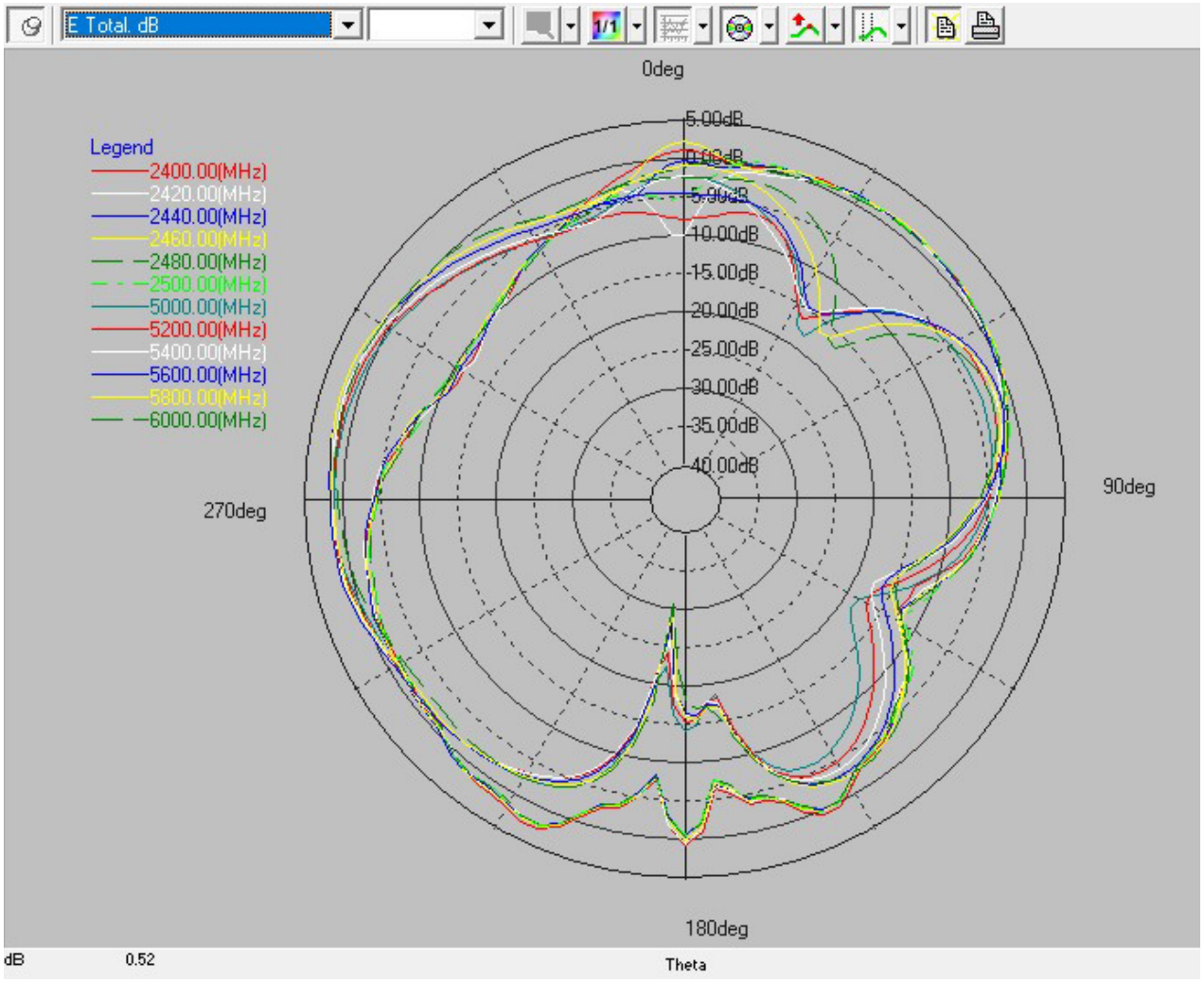
10) SNOWY Module Antenna Report (09FEB24)

1) SNOWY Antenna 1 (MAIN) 2.4-6.0 GHz

a)Phi=0.00deg

E Total. dB



Average

- 1:- 2.534 dB
- 2:0 dB
- 3:0 dB
- 4:- 2.534 dB

Layer	Max value	Position	Min value	Position	Beam Width	Max/Min	Average	Standard Deviation	Marker 1 pos	Marker 1 value	Marker 2 pos	Marker 2 value

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2400(MHz)	2.58 dB	-153.00 deg	-13.13 dB	117.00 deg	25.95 deg	15.71 dB	-2.53 dB	4.14	----	----	----	----
2420(MHz)	2.04 dB	-153.00 deg	-12.52 dB	117.00 deg	29.22 deg	14.55 dB	-3.06 dB	4.00	----	----	----	----
2440(MHz)	2.14 dB	-153.00 deg	-12.81 dB	117.00 deg	31.23 deg	14.95 dB	-2.80 dB	3.87	----	----	----	----
2460(MHz)	2.27 dB	-156.00 deg	-12.22 dB	117.00 deg	28.30 deg	14.49 dB	-2.57 dB	3.92	----	----	----	----
2480(MHz)	2.08 dB	-156.00 deg	-12.71 dB	117.00 deg	27.97 deg	14.79 dB	-2.90 dB	3.80	----	----	----	----
2500(MHz)	2.13 dB	-153.00 deg	-11.76 dB	117.00 deg	28.80 deg	13.89 dB	-2.91 dB	3.72	----	----	----	----
5000(MHz)	1.24 dB	-90.00 deg	-22.58 dB	-174.00 deg	87.21 deg	23.83 dB	-4.71 dB	5.76	----	----	----	----
5200(MHz)	1.52 dB	-93.00 deg	-24.38 dB	-174.00 deg	84.27 deg	25.90 dB	-4.75 dB	5.79	----	----	----	----
5400(MHz)	1.84 dB	-75.00 deg	-26.22 dB	-174.00 deg	73.74 deg	28.06 dB	-4.24 dB	5.99	----	----	----	----
5600(MHz)	2.34 dB	-75.00 deg	-28.15 dB	-174.00 deg	68.92 deg	30.49 dB	-3.89 dB	5.99	----	----	----	----
5800(MHz)	2.26 dB	-72.00 deg	-30.58 dB	-174.00 deg	70.20 deg	32.85 dB	-3.58 dB	5.96	----	----	----	----

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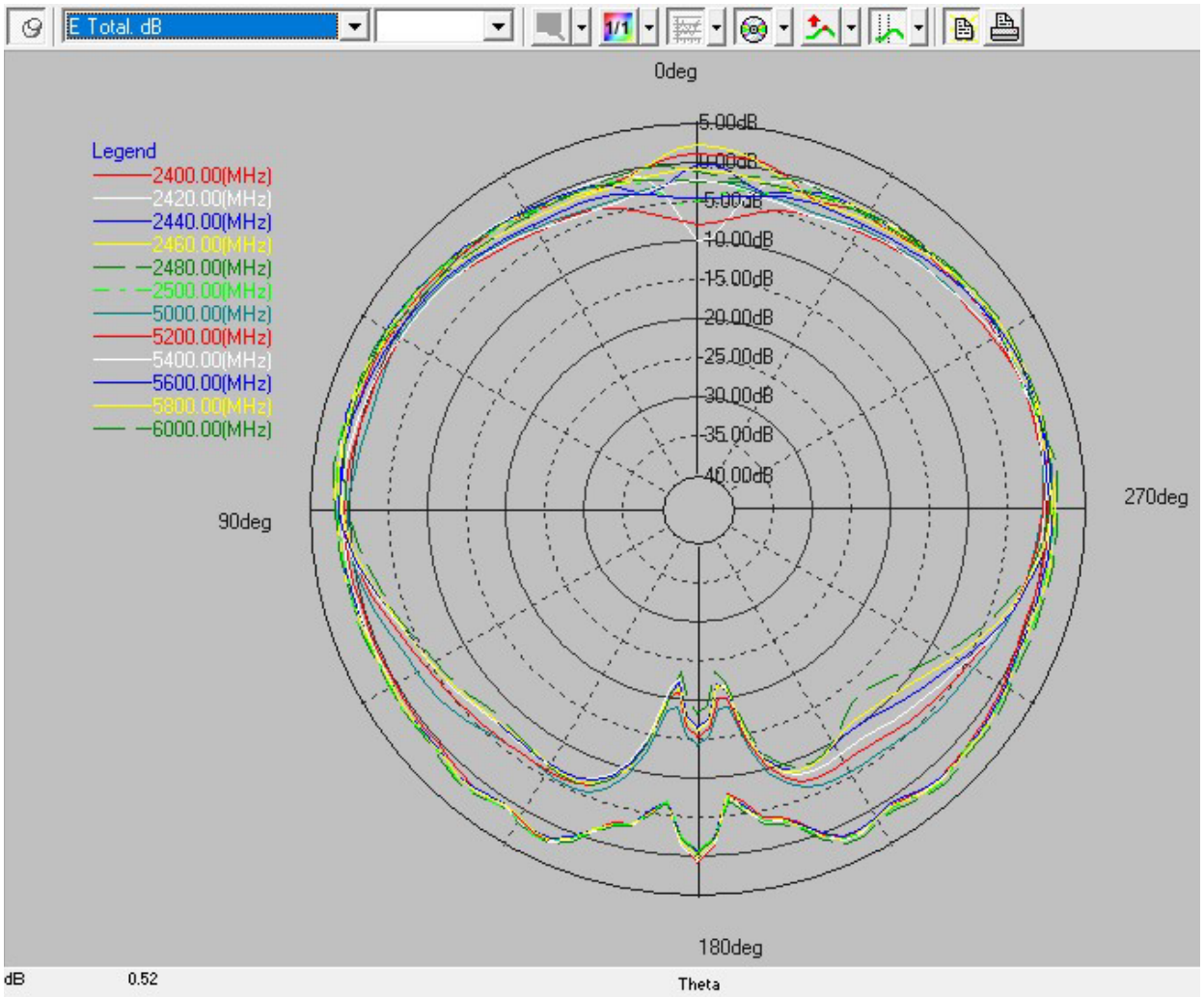
6000(MHz)	1.67 dB	-72.00 deg	-30.74 dB	-174.00 deg	75.88 deg	32.41 dB	-3.81 dB	5.85	----	----	----	----

b)Phi=90.00deg

E Total. dB



Average

- 1:-0.05923 dB
- 2:0 dB
- 3:0 dB
- 4:-0.05923 dB

Layer	Max value	Position	Min value	Position	Beam Width	Max/Min	Average	Standard Deviation	Marker 1 pos	Marker 1 value	Marker 2 pos	Marker 2 value
2400(MHz)	1.91 dB	153.00 deg	-7.8	-174.	133.71 deg	9.73 dB	-0.06 dB	1.65	----	----	----	----

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			2 dB	00 deg								
2420(MHz)	2.08 dB	78.00 deg	-10.19 dB	0.00 deg	149.94 deg	12.27 dB	-0.02 dB	2.33	----	----	----	----
2440(MHz)	1.97 dB	75.00 deg	-7.69 dB	-174.00 deg	143.55 deg	9.66 dB	0.00 dB	1.81	----	----	----	----
2460(MHz)	2.05 dB	-138.00 deg	-7.77 dB	-174.00 deg	134.23 deg	9.82 dB	0.34 dB	1.76	----	----	----	----
2480(MHz)	2.64 dB	-138.00 deg	-7.09 dB	-174.00 deg	121.58 deg	9.73 dB	0.50 dB	1.78	----	----	----	----
2500(MHz)	2.27 dB	-138.00 deg	-7.39 dB	-174.00 deg	120.89 deg	9.66 dB	0.06 dB	2.05	----	----	----	----
5000(MHz)	0.35 dB	93.00 deg	-19.15 dB	174.00 deg	83.53 deg	19.49 dB	-3.09 dB	4.28	----	----	----	----
5200(MHz)	0.62 dB	90.00 deg	-21.15 dB	174.00 deg	68.36 deg	21.77 dB	-3.67 dB	4.70	----	----	----	----
5400(MHz)	1.11 dB	87.00 deg	-22.72 dB	174.00 deg	62.88 deg	23.83 dB	-3.51 dB	5.16	----	----	----	----
5600(MHz)	1.52 dB	84.00 deg	-22.31 dB	174.00 deg	62.23 deg	23.82 dB	-3.21 dB	5.42	----	----	----	----
5800(MHz)	1.63 dB	78.00 deg	-21.91 dB	-174.00 deg	65.83 deg	23.54 dB	-2.81 dB	5.57	----	----	----	----

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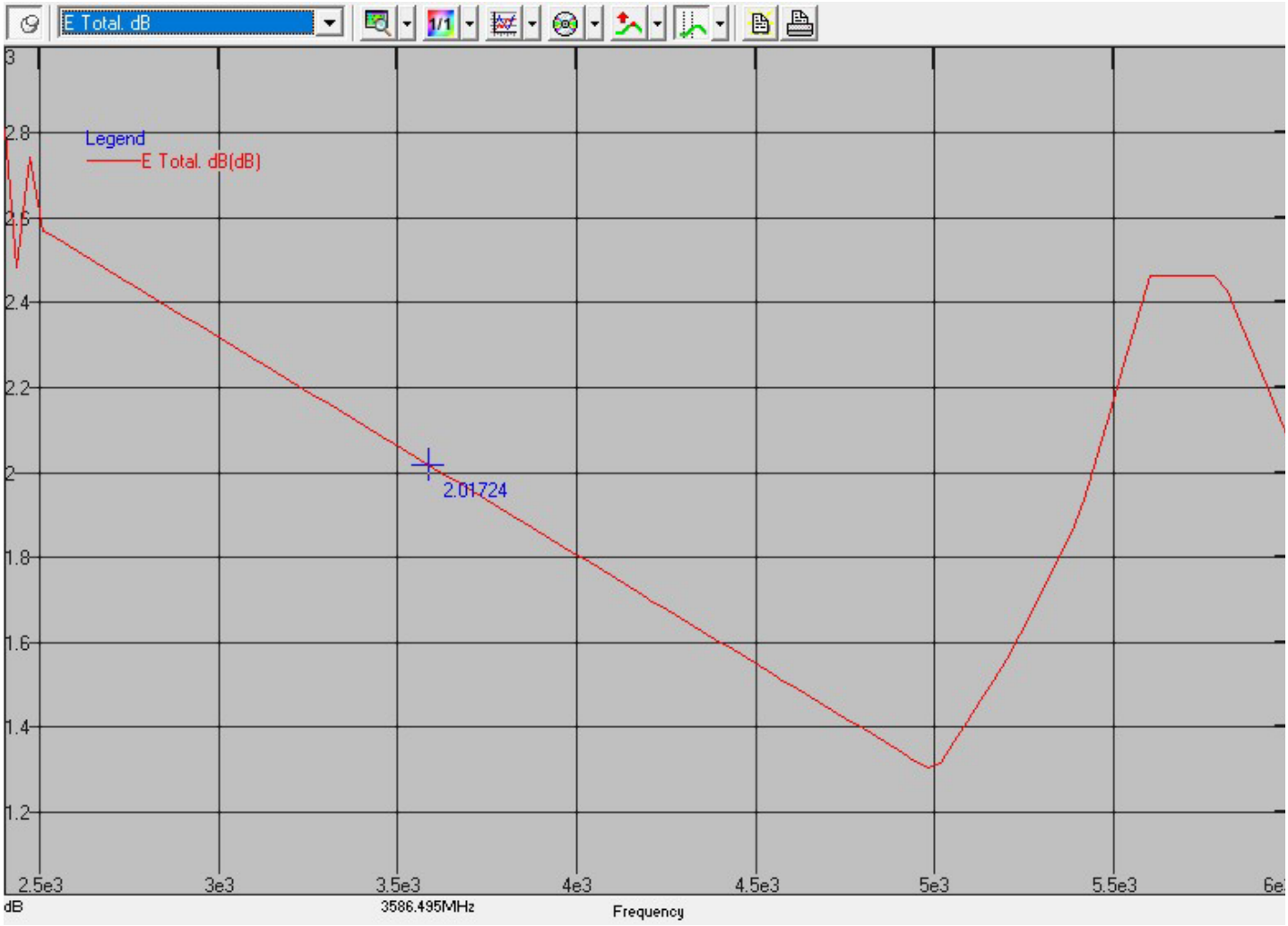
6000(MHz)	1.49 dB	72.00 deg	-23.68 dB	174.00 deg	85.82 deg	25.17 dB	-2.97 dB	6.06	----	----	----	----

c) NF to FF transform Maximum Maximum

E Total. dB



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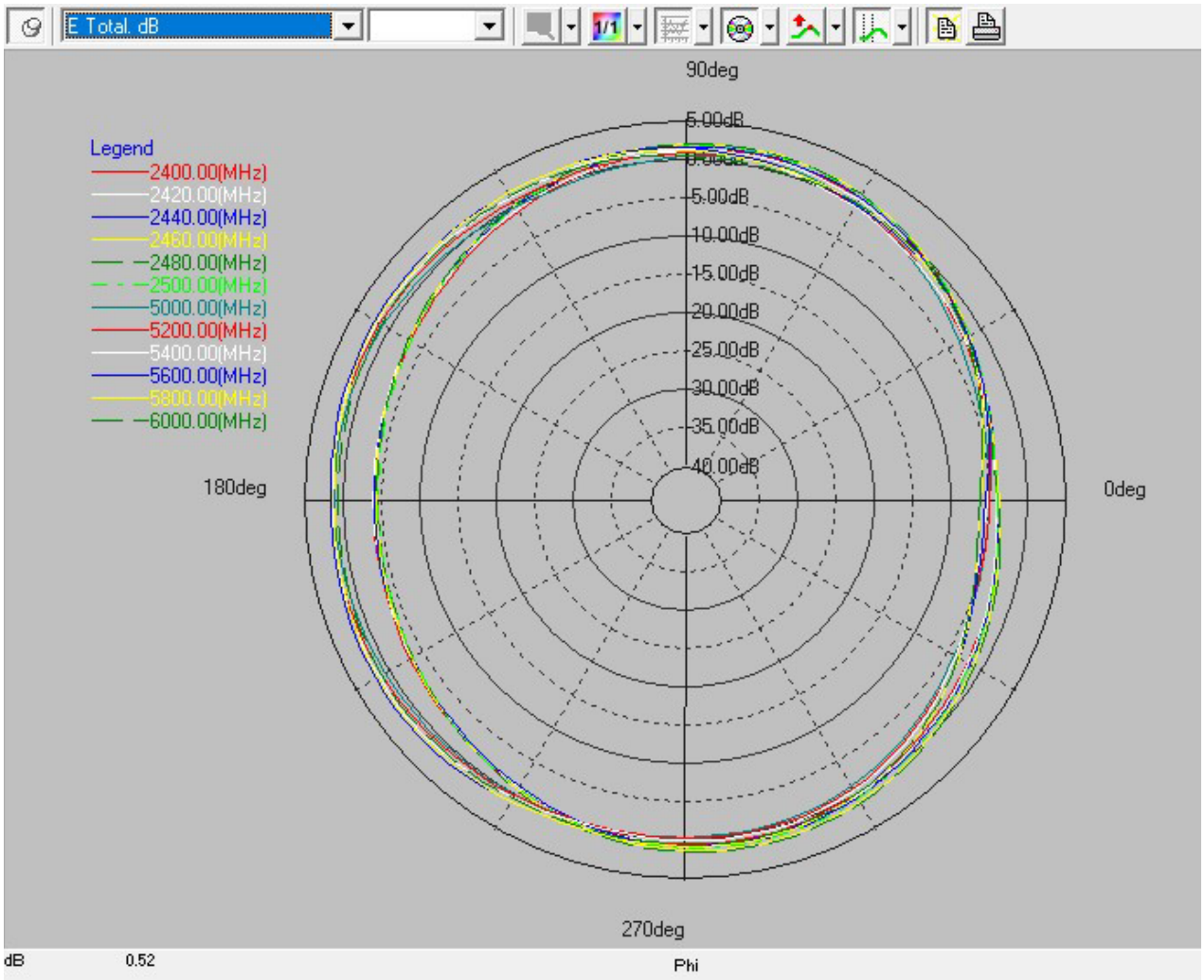
d)Theta=90.00deg

E Total. dB



Average

- 1:-1.369 dB
- 2:0 dB
- 3:0 dB
- 4:-1.369 dB

Layer	Max value	Position	Min value	Position	Beam Width	Max/Min	Average	Standard Deviation	Marker 1 pos	Marker 1 value	Marker 2 pos	Marker 2 value
2400(MHz)	1.28 dB	75.00 deg	-4.0	3.00 deg	95.82 deg	5.31 dB	-1.37 dB	1.72	----	----	----	----

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			3 dB									
2420(MHz)	1.15 dB	78.00 deg	-4.11 dB	6.00 deg	98.69 deg	5.26 dB	-1.37 dB	1.74	----	----	----	----
2440(MHz)	1.57 dB	81.00 deg	-4.04 dB	180.00 deg	95.82 deg	5.61 dB	-1.17 dB	1.86	----	----	----	----
2460(MHz)	2.01 dB	81.00 deg	-4.25 dB	183.00 deg	91.54 deg	6.25 dB	-0.85 dB	2.06	----	----	----	----
2480(MHz)	1.97 dB	78.00 deg	-4.44 dB	186.00 deg	90.95 deg	6.41 dB	-0.83 dB	2.14	----	----	----	----
2500(MHz)	1.76 dB	78.00 deg	-4.50 dB	180.00 deg	93.69 deg	6.26 dB	-1.10 dB	2.02	----	----	----	----
5000(MHz)	1.28 dB	174.00 deg	-5.00 dB	354.00 deg	260.96 deg	6.28 dB	-0.79 dB	1.94	----	----	----	----
5200(MHz)	1.56 dB	168.00 deg	-5.02 dB	351.00 deg	261.66 deg	6.58 dB	-0.47 dB	1.97	----	----	----	----
5400(MHz)	1.78 dB	156.00 deg	-5.50 dB	351.00 deg	258.38 deg	7.28 dB	-0.22 dB	2.16	----	----	----	----
5600(MHz)	2.17 dB	150.00 deg	-5.54 dB	354.00 deg	264.13 deg	7.70 dB	0.21 dB	2.25	----	----	----	----
5800(MHz)	1.85 dB	144.00 deg	-6.16 dB	357.00 deg	273.16 deg	8.01 dB	0.06 dB	2.33	----	----	----	----

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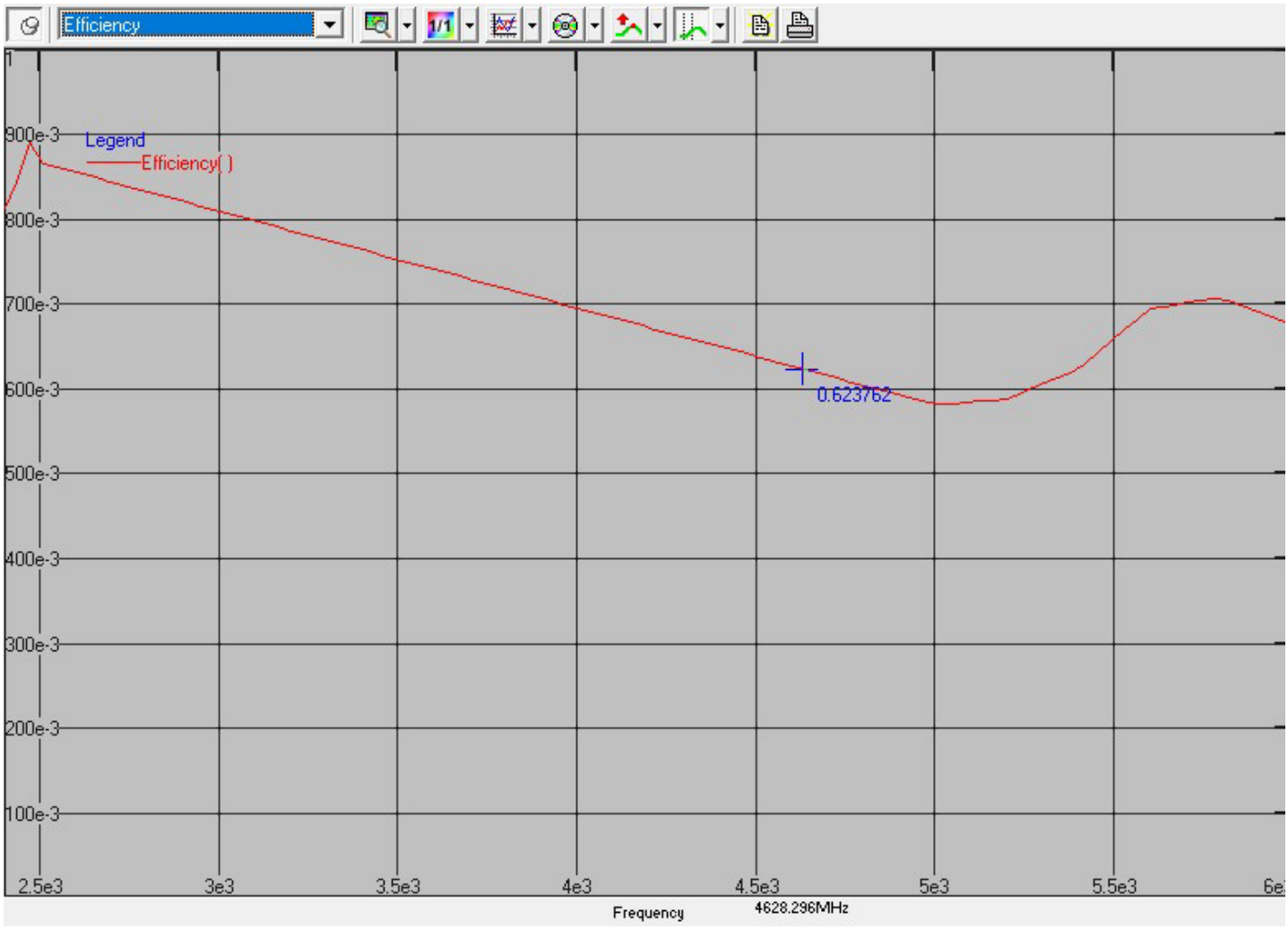
6000(MHz)	1.23 dB	141.00 deg	-6.19 dB	357.00 deg	283.51 deg	7.43 dB	-0.31 dB	2.16	----	----	----	----

e) NF to FF transform Efficiency

Efficiency



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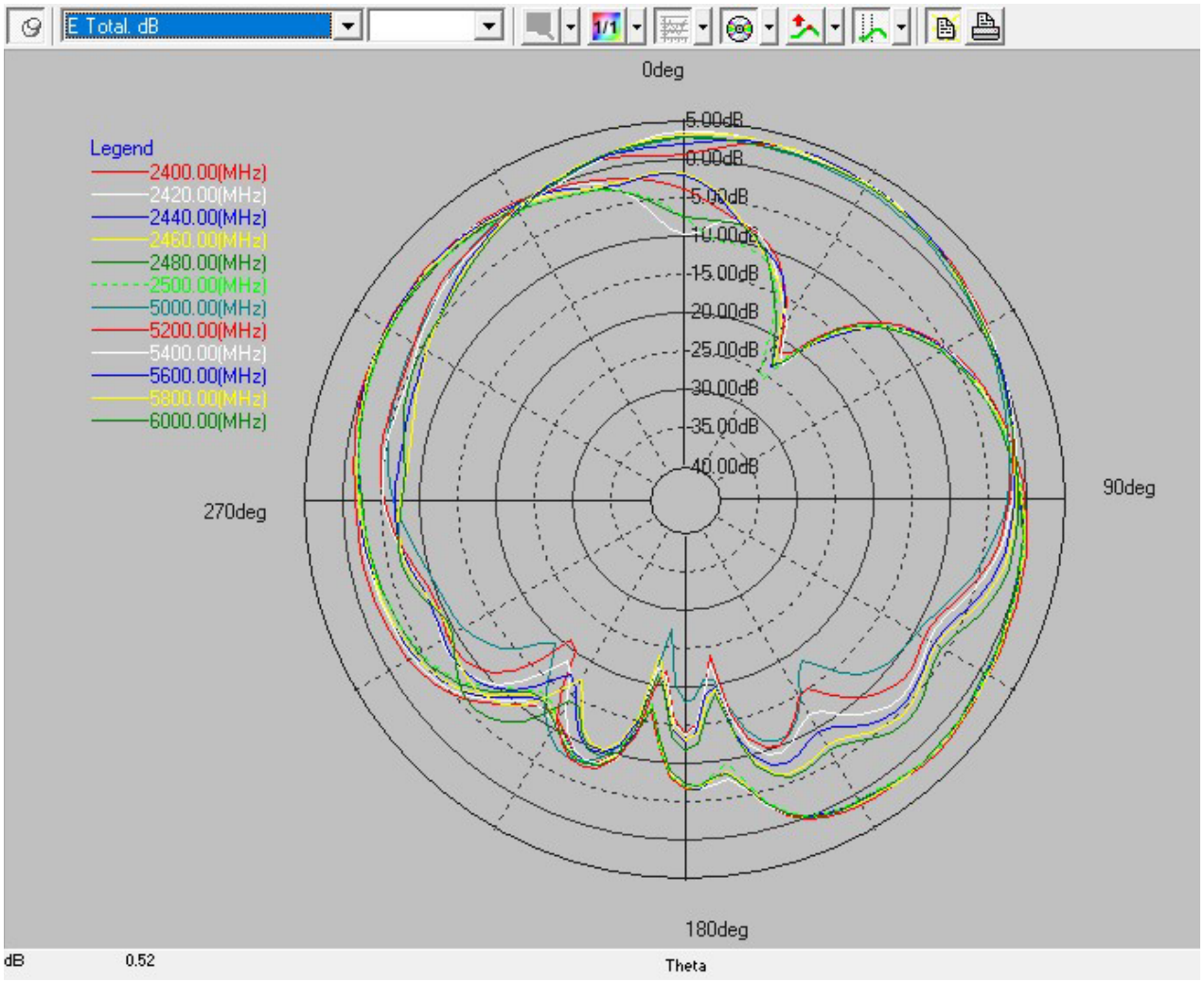
2) SNOWY Antenna 1 (AUX) 2.4-6.0 GHz

a) Phi=0.00deg



Average

- 1:- 2.675 dB
- 2:0 dB
- 3:0 dB
- 4:- 2.675 dB

Layer	Max value	Position	Min value	Position	Beam Width	Max/ Min	Average	Standard Deviation	Marker 1 pos	Marker 1 value	Marker 2 pos	Marker 2 value
2400(MHz)	2.01 dB	135.00 deg	-21.69 dB	33.00 deg	78.94 deg	23.71 dB	-2.68 dB	5.39	----	----	----	----

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2420(MHz)	1.66 dB	135.00 deg	-22.87 dB	36.00 deg	81.43 deg	24.53 dB	-3.12 dB	5.42	----	----	----	----
2440(MHz)	1.74 dB	135.00 deg	-23.91 dB	33.00 deg	78.08 deg	25.65 dB	-3.00 dB	5.52	----	----	----	----
2460(MHz)	1.81 dB	135.00 deg	-23.18 dB	33.00 deg	76.56 deg	24.98 dB	-3.00 dB	5.55	----	----	----	----
2480(MHz)	1.65 dB	135.00 deg	-23.51 dB	33.00 deg	76.80 deg	25.16 dB	-3.46 dB	5.54	----	----	----	----
2500(MHz)	1.68 dB	135.00 deg	-25.94 dB	33.00 deg	78.61 deg	27.62 dB	-3.52 dB	5.84	----	----	----	----
5000(MHz)	2.80 dB	6.00 deg	-27.43 dB	-174.00 deg	92.72 deg	30.23 dB	-3.99 dB	7.09	----	----	----	----
5200(MHz)	3.37 dB	18.00 deg	-23.96 dB	171.00 deg	68.03 deg	27.33 dB	-3.53 dB	6.47	----	----	----	----
5400(MHz)	3.61 dB	3.00 deg	-22.95 dB	171.00 deg	79.20 deg	26.56 dB	-3.20 dB	6.24	----	----	----	----
5600(MHz)	3.40 dB	18.00 deg	-23.87 dB	-171.00 deg	84.30 deg	27.27 dB	-3.34 dB	5.92	----	----	----	----
5800(MHz)	3.33 dB	12.00 deg	-23.91 dB	-171.00 deg	85.20 deg	27.24 dB	-3.16 dB	5.89	----	----	----	----
6000(MHz)	2.78 dB	21.00 deg	-21.50 dB	-171.00 deg	93.08 deg	24.28 dB	-2.99 dB	5.32	----	----	----	----

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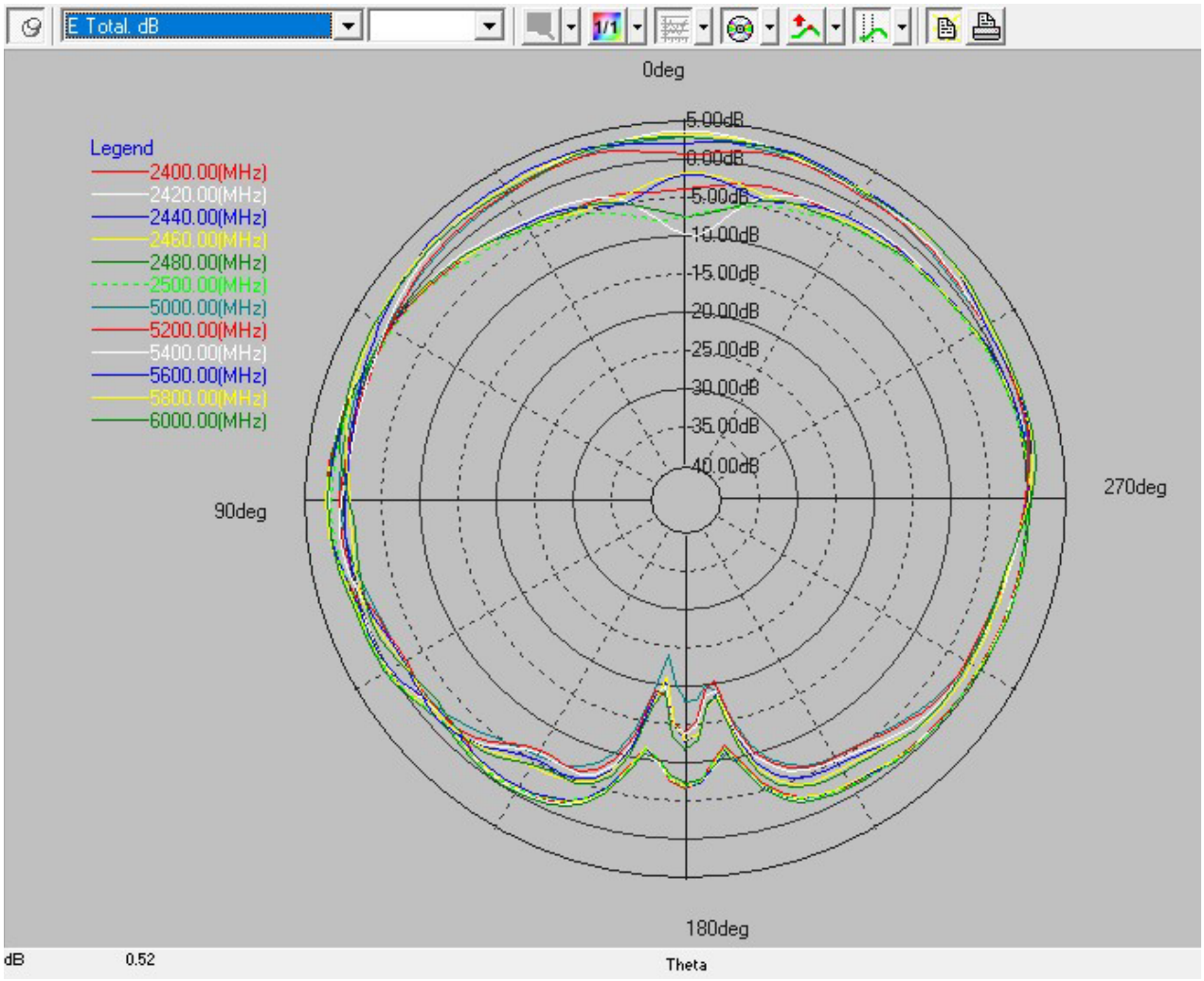
b) Phi=90.00deg

E Total. dB



Average

- 1:-1.461 dB
- 2:0 dB
- 3:0 dB
- 4:-1.461 dB

Layer	Max value	Position	Min value	Position	Beam Width	Max/Min	Average	Standard Deviation	Marker 1 pos	Marker 1 value	Marker 2 pos	Marker 2 value
2400(MHz)	2.19 dB	90.00 deg	-12.05 dB	-171.00 deg	70.79 deg	14.24 dB	-1.46 dB	2.81	----	----	----	----
2420(MHz)	1.89 dB	90.00 deg	-10.	-171.	80.53 deg	12.71 dB	-1.48 dB	3.10	----	----	----	----

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			82 dB	00 deg								
2440(MHz)	1.97 dB	93.00 deg	-11.69 dB	171.00 deg	76.83 deg	13.66 dB	-1.45 dB	2.78	----	----	----	----
2460(MHz)	2.19 dB	93.00 deg	-11.74 dB	171.00 deg	75.49 deg	13.93 dB	-1.42 dB	2.81	----	----	----	----
2480(MHz)	2.02 dB	90.00 deg	-10.99 dB	171.00 deg	80.16 deg	13.01 dB	-1.49 dB	3.04	----	----	----	----
2500(MHz)	1.61 dB	93.00 deg	-11.86 dB	-171.00 deg	81.15 deg	13.47 dB	-1.82 dB	3.09	----	----	----	----
5000(MHz)	2.67 dB	3.00 deg	-24.20 dB	174.00 deg	190.32 deg	26.87 dB	-1.21 dB	5.73	----	----	----	----
5200(MHz)	2.16 dB	18.00 deg	-20.47 dB	-171.00 deg	201.59 deg	22.63 dB	-1.27 dB	5.09	----	----	----	----
5400(MHz)	3.52 dB	0.00 deg	-19.92 dB	174.00 deg	145.97 deg	23.43 dB	-0.73 dB	5.15	----	----	----	----
5600(MHz)	3.07 dB	21.00 deg	-21.01 dB	174.00 deg	164.20 deg	24.08 dB	-0.55 dB	5.00	----	----	----	----
5800(MHz)	3.00 dB	-3.00 deg	-21.24 dB	174.00 deg	173.02 deg	24.24 dB	-0.41 dB	4.93	----	----	----	----
6000(MHz)	2.83 dB	9.00 deg	-19.30 dB	174.00 deg	180.52 deg	22.12 dB	-0.43 dB	4.71	----	----	----	----

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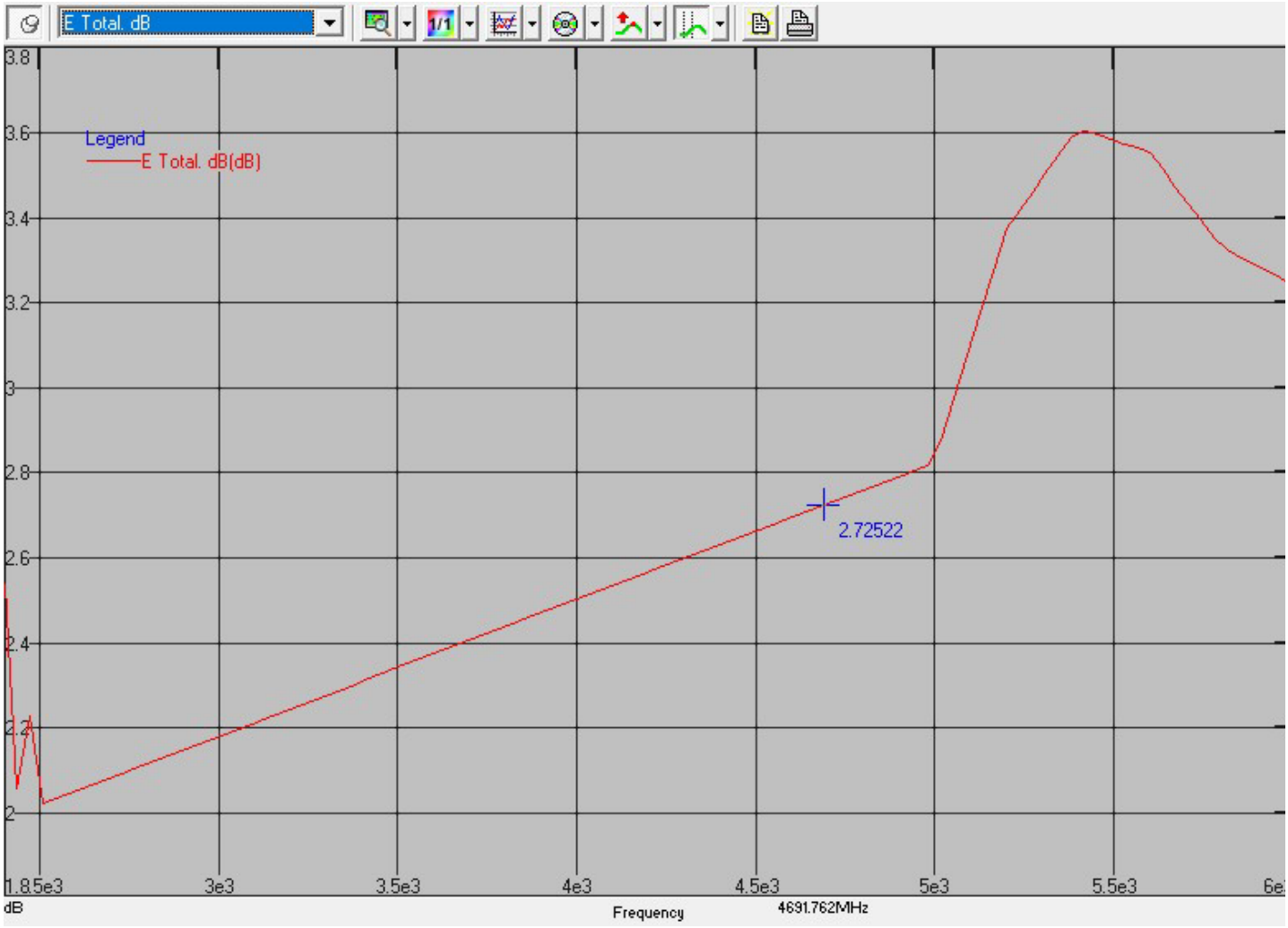
c) NF to FF transform Maximum Maximum

E Total. dB



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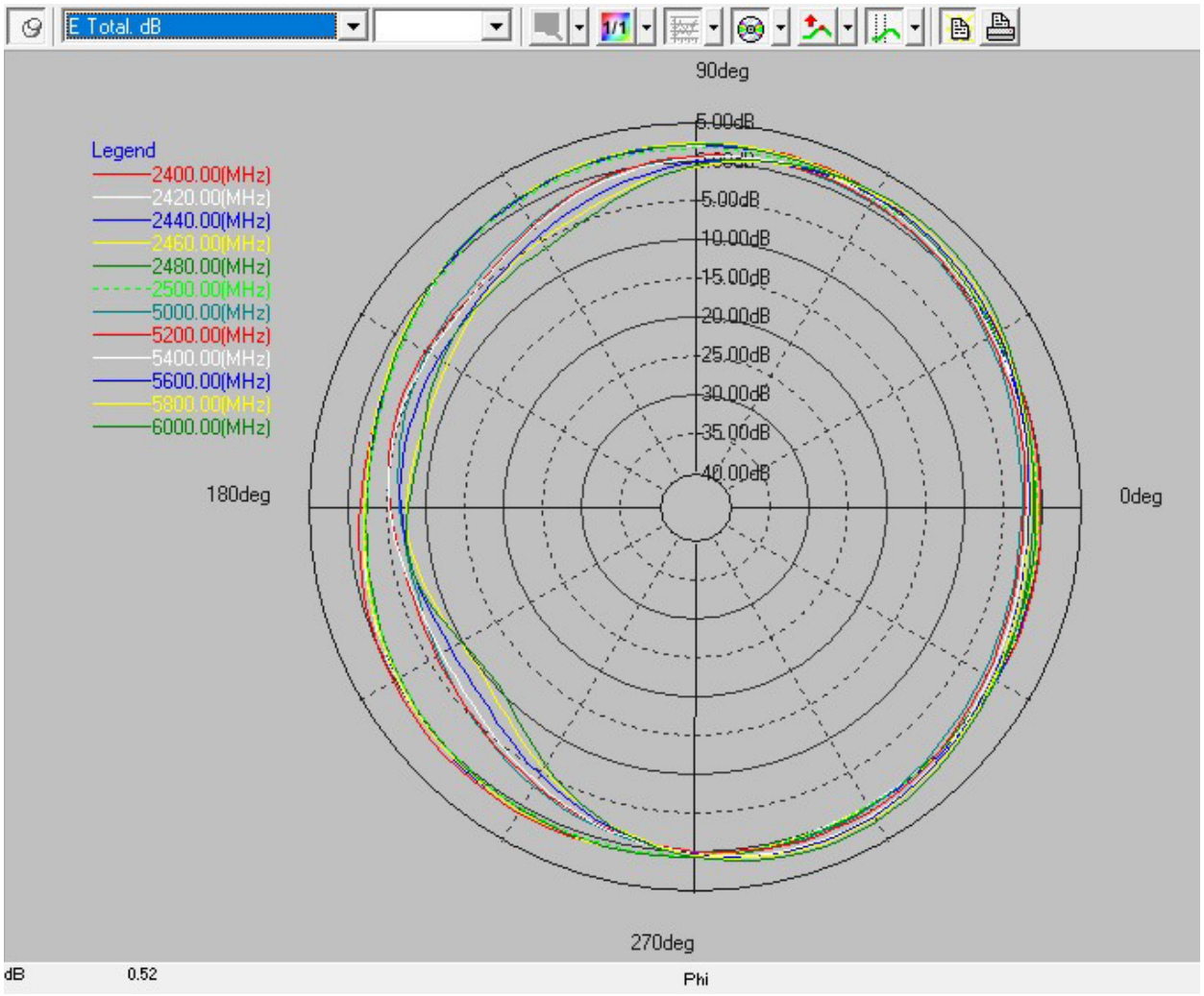
d) Theta=90.00deg

E Total. dB



Average

- 1:0.417 dB
- 2:0 dB
- 3:0 dB
- 4:0.417 dB

Layer	Max value	Position	Min value	Position	Beam Width	Max/Min	Average	Standard Deviation	Marker 1 pos	Marker 1 value	Marker 2 pos	Marker 2 value
2400(MHz)	2.26 dB	81.00 deg	-1.89 dB	168.00 deg	----	4.15 dB	0.42 dB	1.05	----	----	----	----

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2420(MHz)	1.91 dB	84.00 deg	-2.21 dB	171.00 deg	----	4.12 dB	0.10 dB	1.06	----	----	----	----
2440(MHz)	1.99 dB	84.00 deg	-2.19 dB	171.00 deg	----	4.18 dB	0.15 dB	1.07	----	----	----	----
2460(MHz)	2.23 dB	84.00 deg	-2.13 dB	174.00 deg	----	4.36 dB	0.25 dB	1.13	----	----	----	----
2480(MHz)	2.03 dB	87.00 deg	-2.46 dB	174.00 deg	----	4.49 dB	0.08 dB	1.17	----	----	----	----
2500(MHz)	1.61 dB	84.00 deg	-2.44 dB	171.00 deg	----	4.05 dB	-0.05 dB	1.02	----	----	----	----
5000(MHz)	0.80 dB	75.00 deg	-7.17 dB	195.00 deg	104.94 deg	7.97 dB	-2.02 dB	2.46	----	----	----	----
5200(MHz)	0.99 dB	72.00 deg	-6.51 dB	201.00 deg	110.01 deg	7.51 dB	-1.79 dB	2.35	----	----	----	----
5400(MHz)	1.33 dB	66.00 deg	-7.07 dB	207.00 deg	106.95 deg	8.40 dB	-1.65 dB	2.67	----	----	----	----
5600(MHz)	1.55 dB	57.00 deg	-8.32 dB	210.00 deg	93.64 deg	9.86 dB	-1.87 dB	3.32	----	----	----	----
5800(MHz)	1.89 dB	54.00 deg	-9.87 dB	213.00 deg	84.15 deg	11.76 dB	-2.03 dB	3.90	----	----	----	----
6000(MHz)	2.25 dB	51.00 deg	-10.54 dB	219.00 deg	80.07 deg	12.79 dB	-1.85 dB	4.13	----	----	----	----

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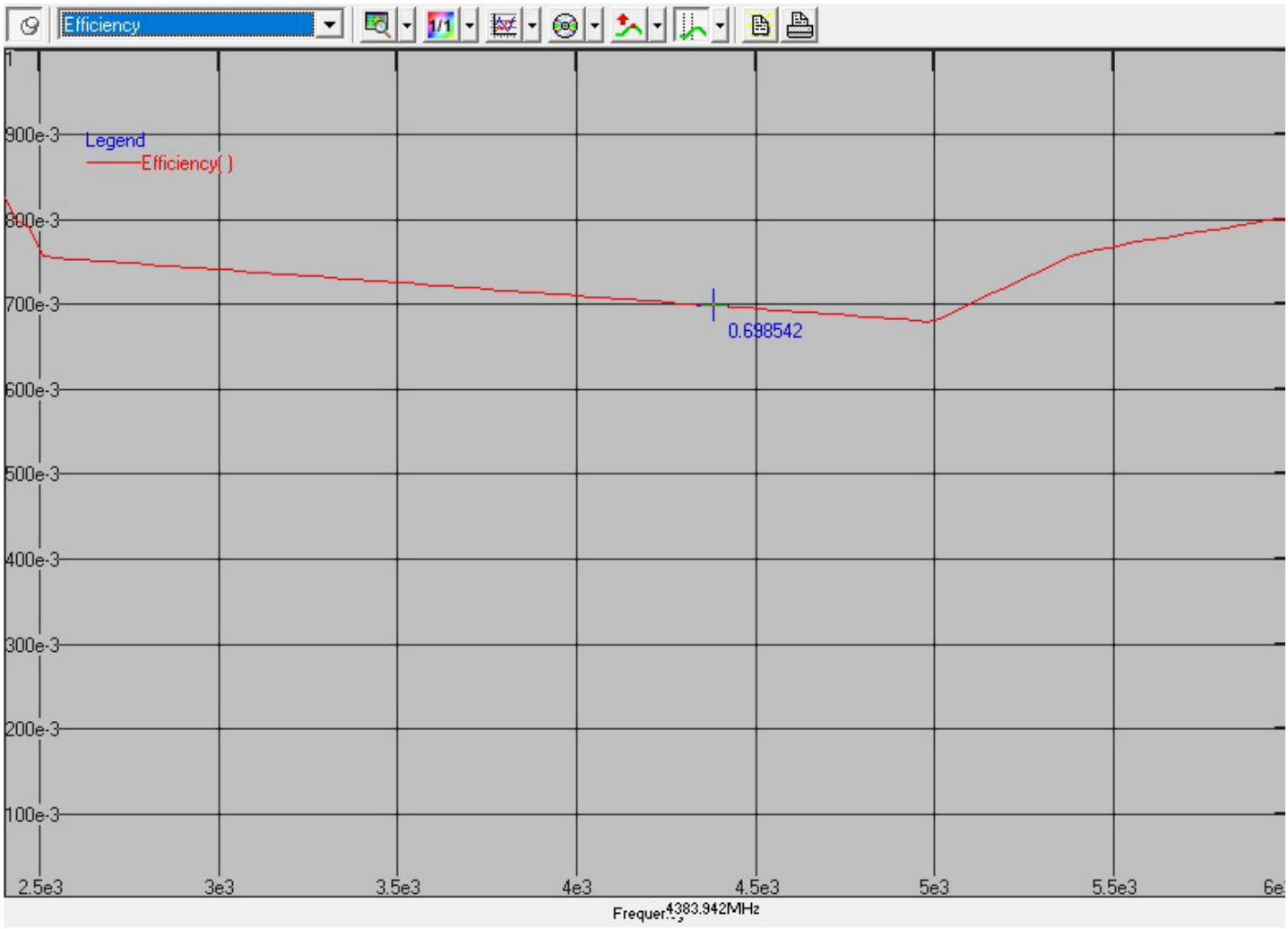
e) NF to FF transform Efficiency

Efficiency



Generated by Star Gate. 2/19/2024 1:23:36 PM. with Satenv (c) METRAWARE & SATIMO 2001. mailto:info@metraware.com

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11) MVG Antenna Test Facility Procedures and Equipment

INTRODUCTION

This document summarizes the antenna gain measurements performed at MVG Inc. The purpose of this document is to provide a summary of the measurement procedure, traceability information, expanded uncertainties and the calibration data for the Antenna Under Test (AUT).

MEASUREMENT SYSTEM INFORMATION

GENERAL INFORMATION

The antenna calibration is performed in a MVG SG-64 system with 63 probe antennas mounted with equal spacing on a circular arch. Electronic switching of the probe antennas provides outstanding measurement speed. The geometry of the setup, with only a Styrofoam column within 1.6 meters of the AUT, ensures minimum interference and low ripple on the measured radiation patterns.

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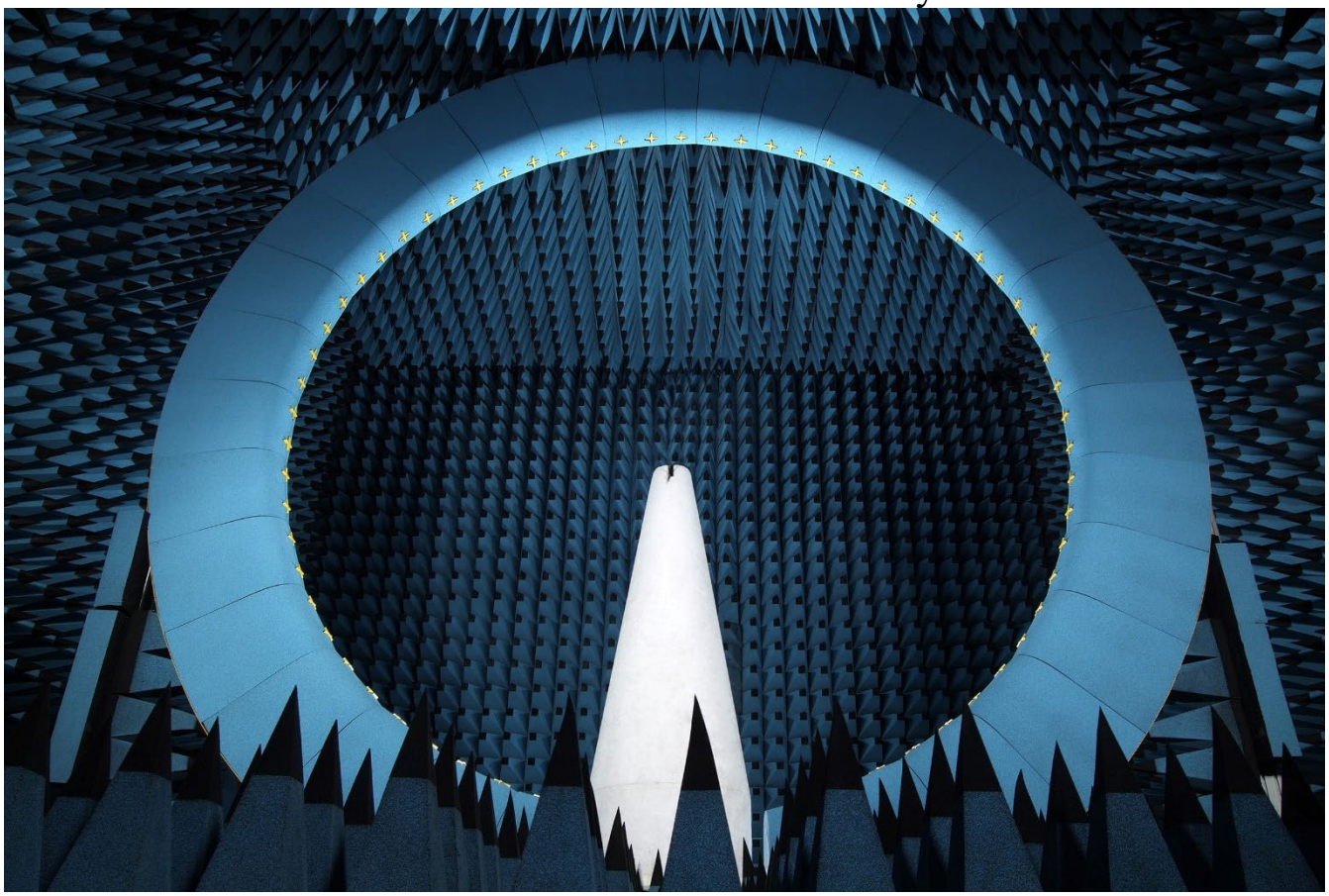

Figure 1 – *The SG-64. The AUT is placed on top of the pedestal, in the center of the system.*

LIST OF EQUIPMENT

Equipment Summary Sheet				
Equipment Description	**Manufacturer**	**Identification No.**	**Current Calibration Date**	**Next Calibration Date**
SG-64 Probe Array	MVG	1102389-0006	12/2022	12/2023
RF Transmitter/ Receiver Unit (NPAC)	MVG	1102730-9110	characterized prior to test and in annual calibration	characterized prior to test and in annual calibration
Reference Horn Antenna	MVG	SH400 sn# 0017	08/2004	Verified in monthly checks. No cal required.
Reference Horn Antenna	MVG	SH800 sn# 0025	08/2004	Verified in monthly checks. No cal required.

GAIN CALIBRATION

GAIN DEFINITION

The reported boresight antenna ***gain*** is 4π times the ratio of the power radiated per unit solid angle in that direction to the net power delivered to the antenna by a 50Ω generator. This definition is also referred to as ***realized antenna gain*** which is less than the IEEE definition [IEEE Standard Test Procedures for Antennas, ANSI/IEEE Std 149-2021] by the value of the return loss.

CALIBRATION STANDARD

The calibrated substitution antenna is a dual ridge horn as shown in Figure 2 below. This horn has been calibrated at NIST (Boulder, CO) which ensures direct traceability to a National Metrology Institute.

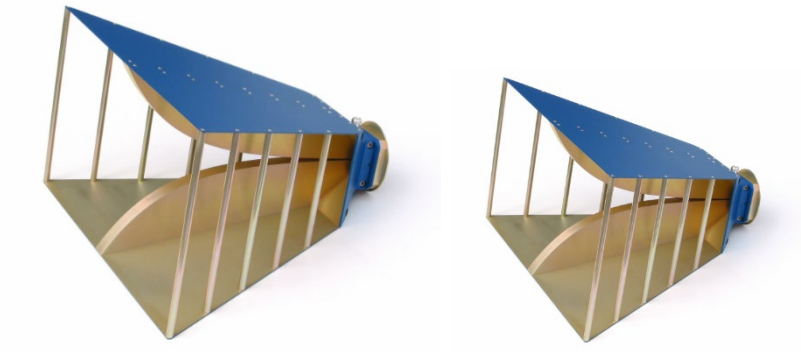

Figure 2 – MVG *SH400-SN0017 and SH800-SN0025 horns.*

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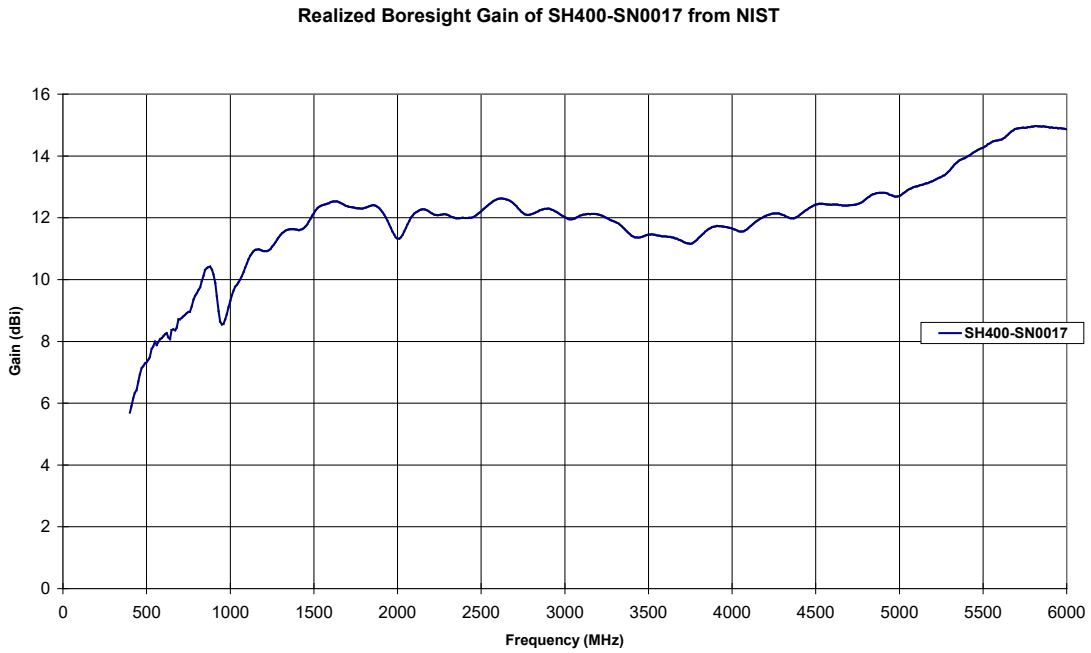

Figure 3 – *NIST calibrated boresight gain vs. frequency plot of the MVG SH400-SN0017*

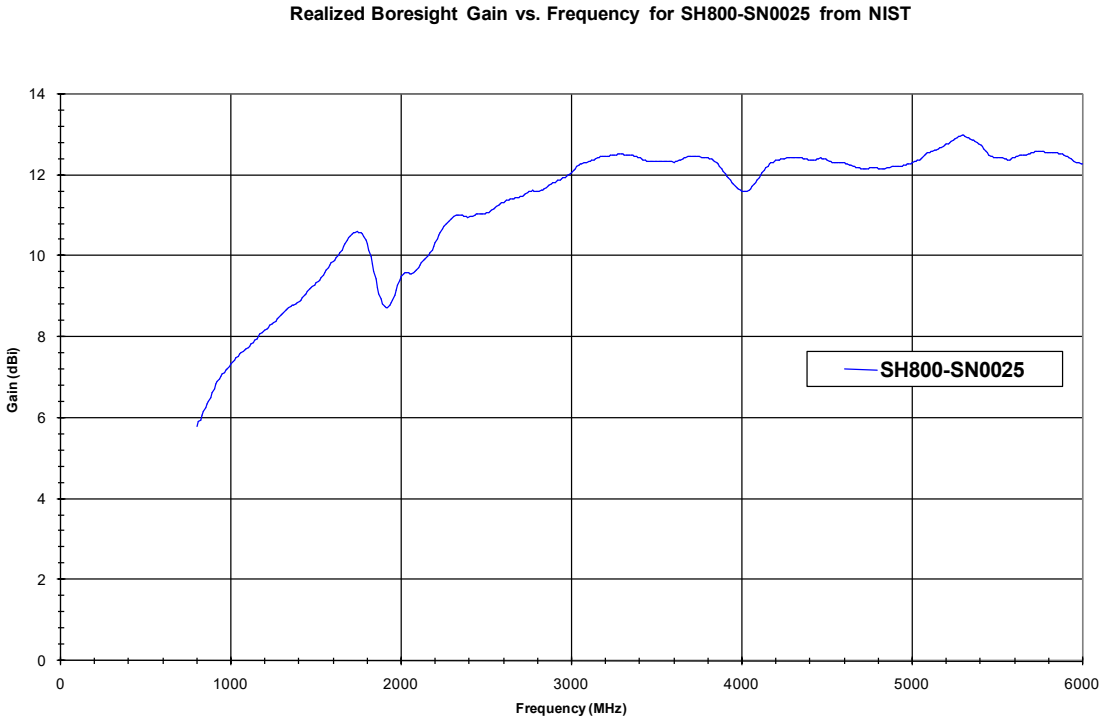

Figure 4 – *NIST calibrated boresight gain vs. frequency plot of the MVG SH800-SN0025*

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MEASUREMENT UNCERTAINTY

The following uncertainties apply to the gain measurement:

Frequency band	Expanded Uncertainty on Gain
400-800 MHz	0.89 dB
800-1000 MHz	0.84 dB
1000-6000 MHz	0.69 dB

These uncertainties represent an expanded uncertainty expressed at approximately the 95% confidence level using a coverage factor of k=2 traceable to the Internationally Accepted Guide to Measurement Uncertainty.

MEASUREMENT SETUP

The AUT is mounted on a Styrofoam column as shown in the picture below.

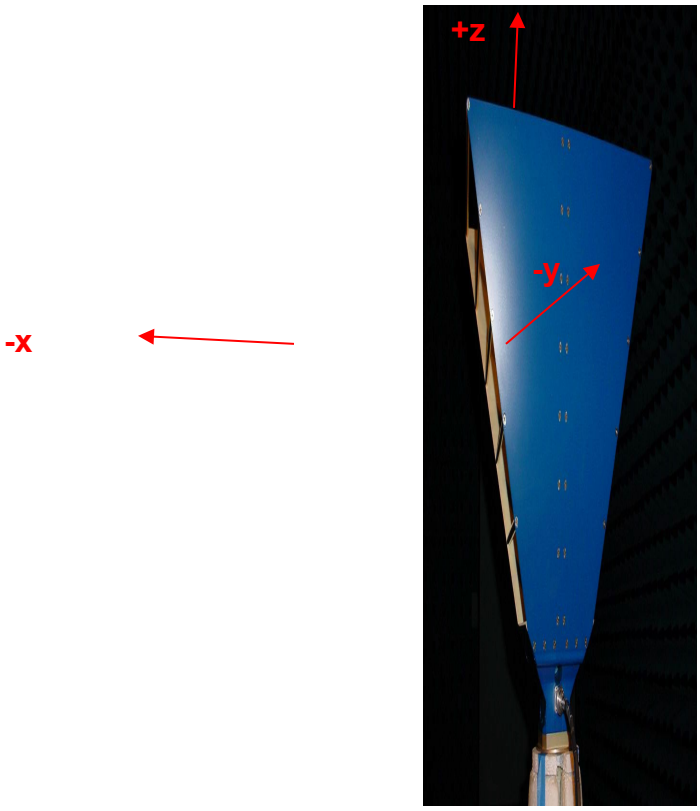

Figure 5 – *Photograph illustrating an antenna mounted in the test range. For clarity, a coordinate system has been superimposed on the picture.*

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COORDINATE SYSTEM

The system coordinate system is shown in Figure 6.

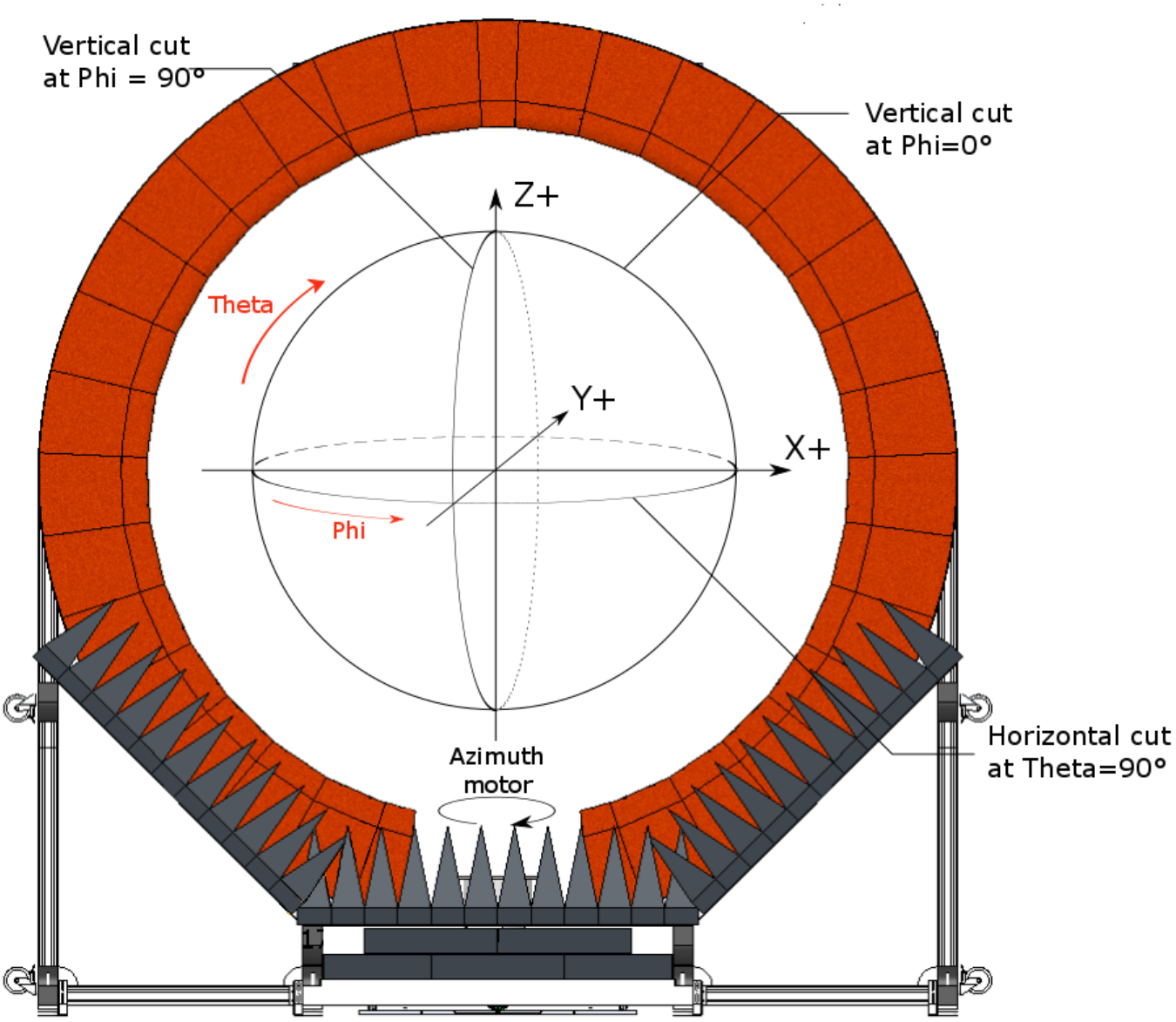

Figure 6: Coordinate System

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TEST PROCEDURES

CALIBRATION

Depending on the frequency band, either the NIST calibrated SH400-SN0017 or SH800-SN0025 antenna is first placed in the measurement system as shown in Figure 5 and, using the frequencies tabulated in the RFQ, the test engineer measures the antenna using MVG's proprietary WaveStudio software. A near-field to far-field computation is performed using SatEnv, which outputs the boresight far-field gain. The software compares these gain measurements, as a function of frequency, to the compiled NIST measured values to serve as the gain reference.

ANTENNA MEASUREMENT

The test engineer follows measures each customer antenna at the requested frequencies. SatEnv is then used to compute the far-field gain of the antenna using the reference data computed during the calibration process. Care is spent reviewing all details given in the RFQ to ensure data is output in the requested format.

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