



ANTENNA TEST REPORT

for the

**EATON ENERGY – MD
FCC ID: P9X-GA3BLE
IC ID: 6766A-GA3BLE**

WLL REPORT# 18976-01 REV 0

Prepared for:

**Eaton's Cooper Power Systems
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Rockville, Maryland 20878**

Prepared By:

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4840 Winchester Boulevard
Frederick, Maryland 21703**



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WLL Report# 18976-01 Rev 0

October 8, 2024

Prepared by:

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Reviewed by:

Samuel Violette
Vice President



Abstract

This report has been prepared on behalf of Eaton Energy – MD to document the testing results of the Bluetooth Antenna that is contained as part of the applicant’s transmitter assembly, seeking authorization under FCC ID: P9X-GA3BLE. The information provided within this report is only applicable to the device herein documented as the EUT.

Testing was performed in the Free-space Anechoic Chamber Test-site (FACT) 3m chamber of Washington Laboratories, Ltd., located at: 4840 Winchester Boulevard, Suite #5., Frederick, MD 21703.

Revision History	Description of Change	Date
Rev 0	Initial Release	October 11, 2024



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1 Introduction

1.1 Test Scope

Testing was to determine the isotropic gain of the PCB BT antenna.

1.2 Contract Information

Customer:	Eaton Energy – MD
Purchase Order Number:	6500149029
Quotation Number:	74939

1.3 Test and Support Personnel

Washington Laboratories, LTD	Randon McIlwain
Customer Representative	Steven Seymour

1.4 Test Location

All measurements herein were performed at Washington Laboratories, Ltd. test center in Frederick, MD. Site description and site attenuation data have been placed on file with the FCC's Sampling and Measurements Branch at the FCC laboratory in Columbia, MD. Washington Laboratories, Ltd. has been accepted by the FCC and approved by ANAB under Testing Certificate AT-1448 as an independent FCC test laboratory (ISED Canada Number 3035A).

1.5 Environmental Conditions

Environmental conditions during all testing	
Ambient Temperature:	17.2 °C ($\pm 3^\circ$)
Relative Humidity:	49 % ($\pm 8.5\%$)



2 Equipment Under Test, Antenna

2.1 EUT Identification & Description

The results obtained relate only to the item(s) tested.

Table 1: Antenna Summary

EUT Name, Model(s) Tested:	Grid Advisor 3 (GA3) BLE
Manufacturer:	Eaton Energy – MD
Antenna Type:	Printed Circuit (PCB Embedded F-Type)
Antenna Gain:	-1.97 dBi
Testing Date(s):	10/3/2024

The Eaton Energy, FCC ID: P9X-GA3BLE is a powerline sensor, detecting current on the powerline on which it is installed. It is equipped with an energy harvesting system that uses the powerline itself to generate its operating power and charge its internal battery.

The EUT is equipped with a BLE transceiver.

The BLE portion employs a PCB trace antenna with -1.97 dBi of gain.

The final test data is provided below.

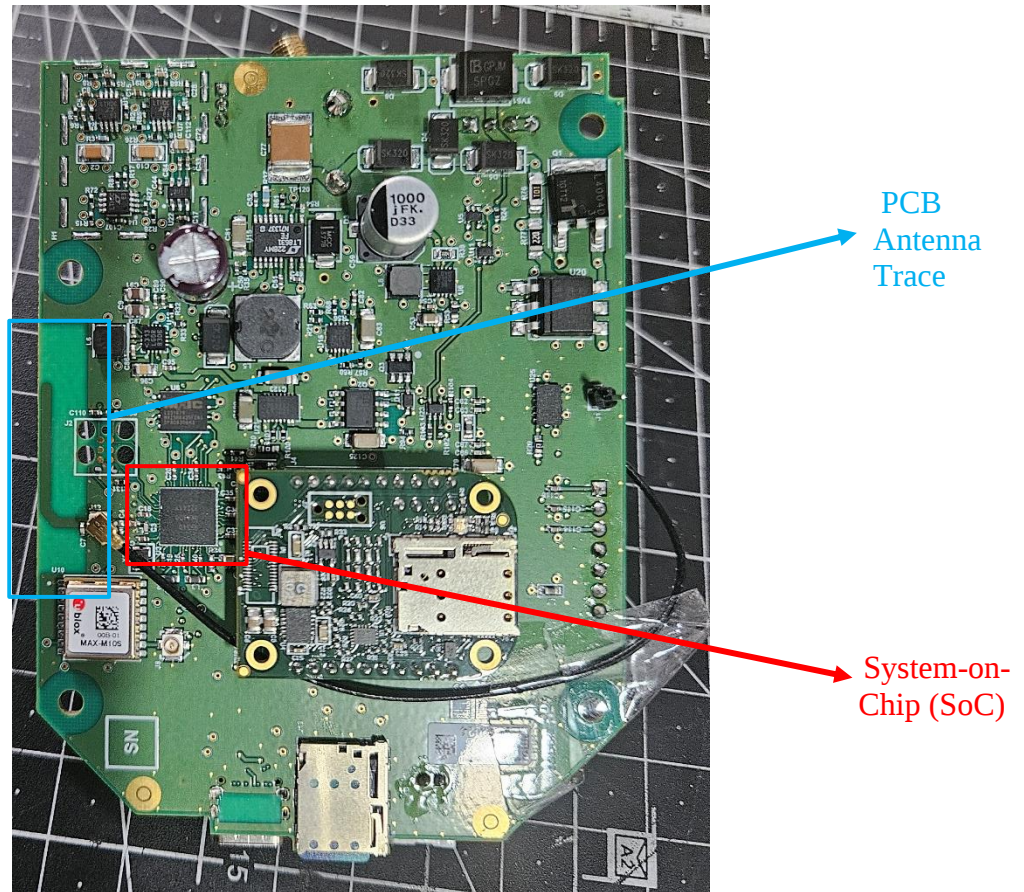


Figure 1: Antenna and PCB Photograph, As Tested (View #1)



* photo taken by WLL on 10/3/2024.

Figure 2: Antenna and PCB Photograph, As Tested (View #2)

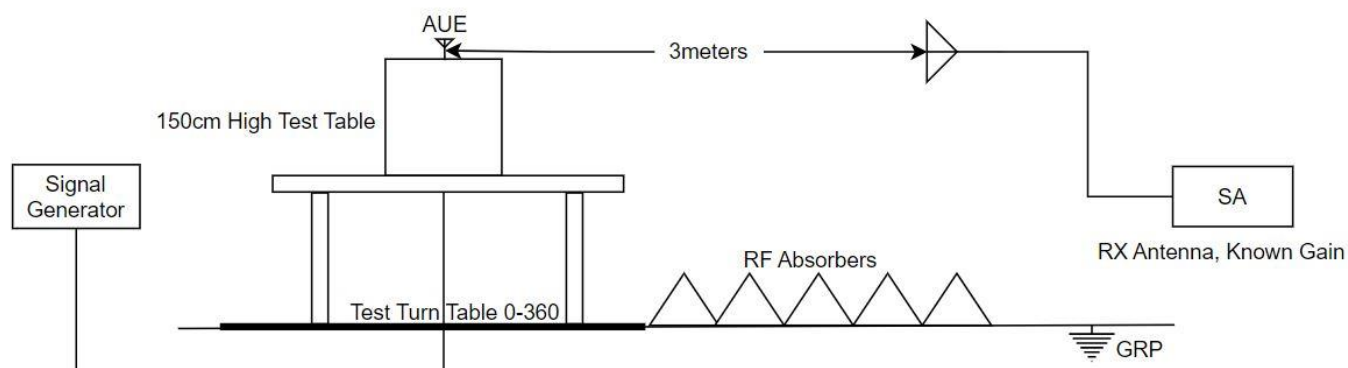


* photo taken by WLL on 10/3/2024.



2.2 Test Configuration

Figure 3: EUT Test Configuration



2.2.1 Test Equipment Used

Table 2: Test Equipment List and Calibration Due Dates

Test Name: Antenna Gain Testing		Test Date: 10/3/2024	
Asset #	Manufacturer/Model	Description	Cal. Due
00626	ARA, DRG-118/A	HORN ANTENNA	6/19/2025
00605	AGILENT, N1911A	POWER METER	6/21/2025
00992	KEYSIGHT, N5173B	SIGNAL GENERATOR	11/27/2024
00942	AGILENT, MXA-N9020A	SPECTRUM ANALYZER	12/19/2024
00825	CABLE ASSOCIATES, MTC1010	SMA, COAXIAL CABLE	6/19/2025
00806	MINI-CIRCUITS, 3061	COAXIAL CABLE, SMA	12/26/2024
00731	NARDA 4779-3	2W, 3DB ATTENUATOR	6/20/2025



3 Test Results

3.1 Antenna Pattern

3.1.1 Test Procedure Summary

Antenna gain testing was performed on the Bluetooth antenna. The test frequency was chosen in the center of the 2.4GHz unlicensed ISM band. A CW at 2440.0 MHz was supplied to the transmit path of the PCB trace. All measurement system losses and attenuations are accounted for. A verification/investigation was performed to determine the orientation of the PCB that produced the worst-case emissions. The worst-case orthogonal position was maintained for the remainder of the testing. The spectrum analyzer was placed in max hold mode, and the turn table was set to rotate at an RPM setting of 12%. The turn-table was rotated from 0 to 360 degrees, in 2-degree steps.

3.1.2 Radiated Data Reduction and Reporting

The following formula is a widely accepted link budget for calculating power received at the receiver:

$$P_{RX} = P_{TX} + G_{TX} - L_{TX} - FSPL - G_{RX} - L_{RX}$$

where,

P_{RX} = measured by the receive spectrum analyzer, in dBm

P_{TX} = transmit power (or drive level into the antenna feed), in dBm

G_{TX} = the final peak gain of the AUT, in dBi

L_{TX} = cable loss on the transmit side, in dB

G_{RX} = the known gain of the receive antenna, in dBi

L_{RX} = cable loss on the receive side, in dB

$$FSPL = 20 \log_{10}(d) + 20 \log_{10}(f) + 20 \log_{10} \left(\frac{4\pi}{c} \right) - G_{Tx} - G_{Rx} *$$

* *FSPL is a factor of frequency and distance only, provided the gain at either end is ignored.*



This link budget formula can be rearranged and used to calculate the gain of an unknown transmitting antenna, provided the remaining values are known.

When the above formula is rearranged to solve for the gain of the transmitter antenna:

$$G_{TX} = P_{RX} + L_{RX} - G_{RX} + FSPL - P_{TX} + L_{TX}$$

where,

G_{TX} = the final peak gain of the AUT, in dBi

P_{RX} = measured by the receive spectrum analyzer, in dBm

P_{TX} = transmit power (or drive level into the antenna feed), in dBm

G_{RX} = the known gain of the receive antenna, in dBi

L_{TX} = cable loss on the transmit side, in dB

L_{RX} = cable loss on the receive side, in dB

$$FSPL = 20 \log_{10}(d) + 20 \log_{10}(f) + 20 \log_{10}\left(\frac{4\pi}{c}\right) - G_{Tx} - G_{Rx} *$$

** FSPL is a factor of frequency and distance only, provided the gain at either end is ignored.*

Therefore,

$$G_{TX} = -46.842 + 0.55 - 9.5 + 49.74 - 0.0 + 4.08 = -1.97$$



Table 3: Worst Case Orientation(s) Test Data

RX Antenna Polarity	EUT Axis	SA Level P _{RX} (dBm)	P _{TX} (dBm)	G _{RX} (dB)	L _{TX} (dB)	FSPL (dB)	L _{RX} (dB)	Final G _{TX} (dBi)	Turn Table (Degrees)	SA Trace	Turn Table RPM (%)
V	Vert.	-46.951	0	9.50	0.55	49.74	4.08	-2.08	0-360	Max Hold	12
V	Vert.	-47.713	0	9.50	0.55	49.74	4.08	-2.84	0-360	Max Hold	12
V	Vert.	-56.592	0	9.50	0.55	49.74	4.08	-11.72	0-360	Max Hold	12
H	X	-46.842	0	9.50	0.55	49.74	4.08	-1.97	0-360	Max Hold	12
H	Y	-48.996	0	9.50	0.55	49.74	4.08	-4.13	0-360	Max Hold	12
H	Z	-46.988	0	9.50	0.55	49.74	4.08	-2.12	0-360	Max Hold	12

Please note that the highest EUT gain was recorded as -1.97 dBi. The orientation that produced this gain shall be employed for the final antenna pattern plot, which is provided on the next page. The following settings were employed:

RX Antenna = Vertical

EUT Axis = Y

SA, RBW = 1MHz

SA, VBW = 3 MHz

Detector = Peak

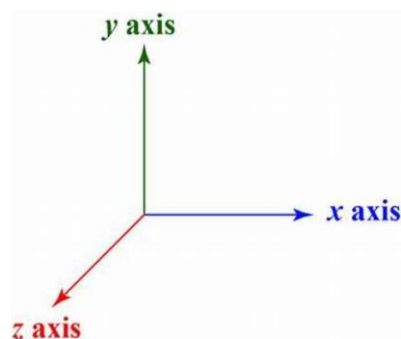
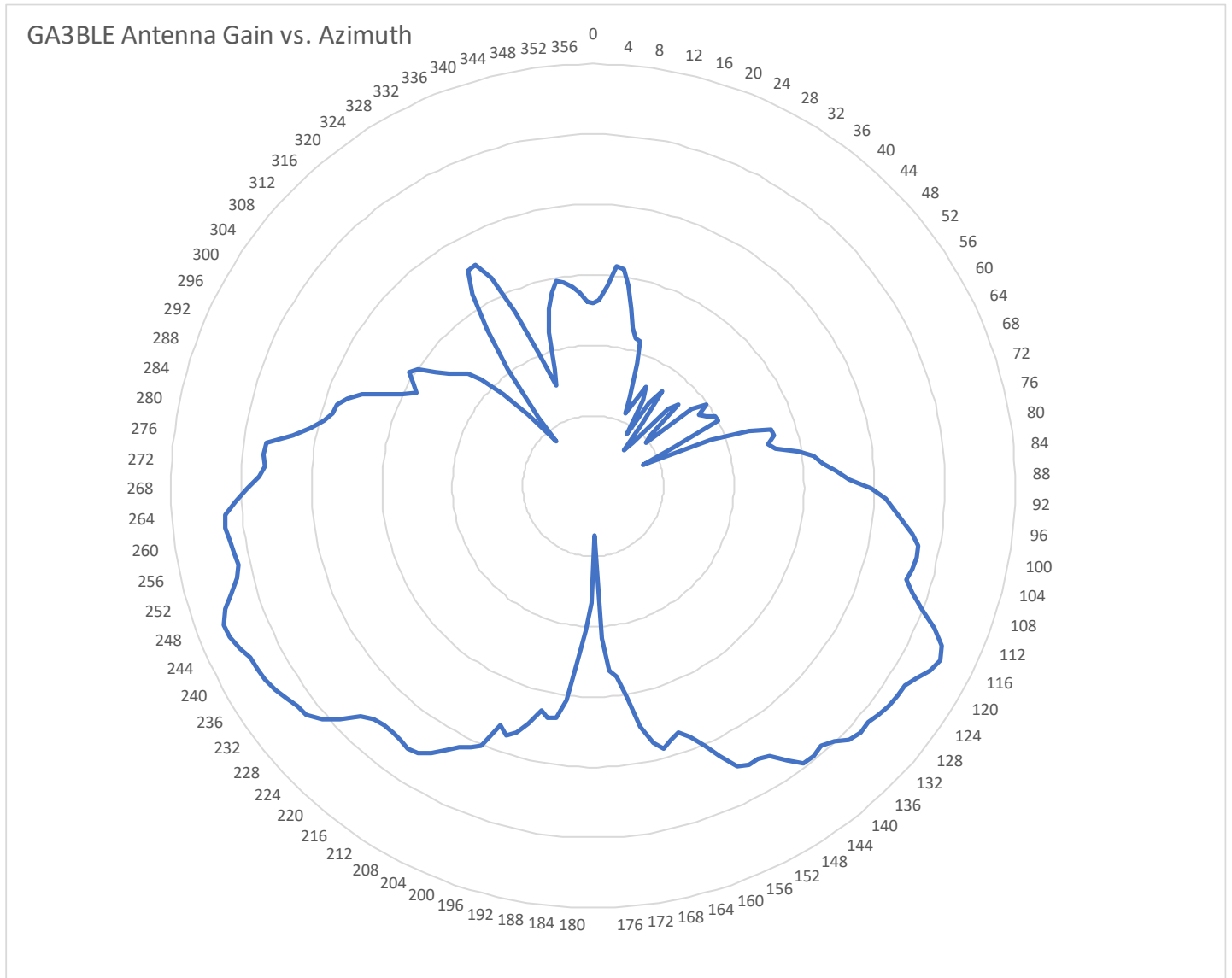




Figure 4: GA3, BLE, Final Antenna Pattern vs Azimuth (Worst-Case Data)





3.1.3 Complete Test Data

Table 4: GA3BLE Antenna (2.44GHz) vs. Azimuth, Final Test Data

SA Level P _{RX} (dBm)	P _{TX} (dBm)	G _{RX} (dB)	L _{TX} (dB)	FSPL (dB)	L _{RX} (dB)	Final Gain (dBi)	Turn Table (Degrees)
-61.839	0	9.50	-0.55	-49.74	4.08	-16.97	0
-61.665	0	9.50	-0.55	-49.74	4.08	-16.80	2
-60.577	0	9.50	-0.55	-49.74	4.08	-15.71	4
-59.168	0	9.50	-0.55	-49.74	4.08	-14.30	6
-59.271	0	9.50	-0.55	-49.74	4.08	-14.40	8
-60.359	0	9.50	-0.55	-49.74	4.08	-15.49	10
-62.016	0	9.50	-0.55	-49.74	4.08	-17.15	12
-63.309	0	9.50	-0.55	-49.74	4.08	-18.44	14
-63.899	0	9.50	-0.55	-49.74	4.08	-19.03	16
-64.05	0	9.50	-0.55	-49.74	4.08	-19.18	18
-65.615	0	9.50	-0.55	-49.74	4.08	-20.75	20
-68.055	0	9.50	-0.55	-49.74	4.08	-23.19	22
-69.255	0	9.50	-0.55	-49.74	4.08	-24.39	24
-68.066	0	9.50	-0.55	-49.74	4.08	-23.20	26
-66.904	0	9.50	-0.55	-49.74	4.08	-22.03	28
-67.798	0	9.50	-0.55	-49.74	4.08	-22.93	30
-70.458	0	9.50	-0.55	-49.74	4.08	-25.59	32
-67.788	0	9.50	-0.55	-49.74	4.08	-22.92	34
-66.562	0	9.50	-0.55	-49.74	4.08	-21.69	36
-69.164	0	9.50	-0.55	-49.74	4.08	-24.29	38
-71.487	0	9.50	-0.55	-49.74	4.08	-26.62	40
-70.701	0	9.50	-0.55	-49.74	4.08	-25.83	42
-67.205	0	9.50	-0.55	-49.74	4.08	-22.34	44
-66.555	0	9.50	-0.55	-49.74	4.08	-21.69	46
-69.414	0	9.50	-0.55	-49.74	4.08	-24.54	48
-70.043	0	9.50	-0.55	-49.74	4.08	-25.17	50
-65.978	0	9.50	-0.55	-49.74	4.08	-21.11	52
-65.019	0	9.50	-0.55	-49.74	4.08	-20.15	54
-65.775	0	9.50	-0.55	-49.74	4.08	-20.91	56
-65.468	0	9.50	-0.55	-49.74	4.08	-20.60	58



-64.891	0	9.50	-0.55	-49.74	4.08	-20.02	60
-64.879	0	9.50	-0.55	-49.74	4.08	-20.01	62
-68.549	0	9.50	-0.55	-49.74	4.08	-23.68	64
-71.005	0	9.50	-0.55	-49.74	4.08	-26.14	66
-65.838	0	9.50	-0.55	-49.74	4.08	-20.97	68
-63.091	0	9.50	-0.55	-49.74	4.08	-18.22	70
-61.632	0	9.50	-0.55	-49.74	4.08	-16.76	72
-61.514	0	9.50	-0.55	-49.74	4.08	-16.64	74
-62.030	0	9.50	-0.55	-49.74	4.08	-17.16	76
-61.605	0	9.50	-0.55	-49.74	4.08	-16.74	78
-59.996	0	9.50	-0.55	-49.74	4.08	-15.13	80
-59.007	0	9.50	-0.55	-49.74	4.08	-14.14	82
-58.468	0	9.50	-0.55	-49.74	4.08	-13.60	84
-57.617	0	9.50	-0.55	-49.74	4.08	-12.75	86
-56.661	0	9.50	-0.55	-49.74	4.08	-11.79	88
-55.168	0	9.50	-0.55	-49.74	4.08	-10.30	90
-54.068	0	9.50	-0.55	-49.74	4.08	-9.20	92
-53.419	0	9.50	-0.55	-49.74	4.08	-8.55	94
-52.671	0	9.50	-0.55	-49.74	4.08	-7.80	96
-51.93	0	9.50	-0.55	-49.74	4.08	-7.06	98
-51.42	0	9.50	-0.55	-49.74	4.08	-6.55	100
-51.304	0	9.50	-0.55	-49.74	4.08	-6.43	102
-51.479	0	9.50	-0.55	-49.74	4.08	-6.61	104
-51.6	0	9.50	-0.55	-49.74	4.08	-6.73	106
-50.955	0	9.50	-0.55	-49.74	4.08	-6.09	108
-49.823	0	9.50	-0.55	-49.74	4.08	-4.95	110
-48.582	0	9.50	-0.55	-49.74	4.08	-3.71	112
-47.614	0	9.50	-0.55	-49.74	4.08	-2.74	114
-47.312	0	9.50	-0.55	-49.74	4.08	-2.44	116
-47.569	0	9.50	-0.55	-49.74	4.08	-2.70	118
-48.168	0	9.50	-0.55	-49.74	4.08	-3.30	120
-48.565	0	9.50	-0.55	-49.74	4.08	-3.70	122
-48.579	0	9.50	-0.55	-49.74	4.08	-3.71	124
-48.699	0	9.50	-0.55	-49.74	4.08	-3.83	126
-48.884	0	9.50	-0.55	-49.74	4.08	-4.01	128
-49.067	0	9.50	-0.55	-49.74	4.08	-4.20	130
-49.028	0	9.50	-0.55	-49.74	4.08	-4.16	132
-49.275	0	9.50	-0.55	-49.74	4.08	-4.41	134
-49.919	0	9.50	-0.55	-49.74	4.08	-5.05	136
-50.265	0	9.50	-0.55	-49.74	4.08	-5.40	138



-50.158	0	9.50	-0.55	-49.74	4.08	-5.29	140
-50.157	0	9.50	-0.55	-49.74	4.08	-5.29	142
-50.932	0	9.50	-0.55	-49.74	4.08	-6.06	144
-51.883	0	9.50	-0.55	-49.74	4.08	-7.01	146
-52.215	0	9.50	-0.55	-49.74	4.08	-7.35	148
-52.192	0	9.50	-0.55	-49.74	4.08	-7.32	150
-52.452	0	9.50	-0.55	-49.74	4.08	-7.58	152
-53.681	0	9.50	-0.55	-49.74	4.08	-8.81	154
-54.772	0	9.50	-0.55	-49.74	4.08	-9.90	156
-55.791	0	9.50	-0.55	-49.74	4.08	-10.92	158
-56.304	0	9.50	-0.55	-49.74	4.08	-11.43	160
-56.024	0	9.50	-0.55	-49.74	4.08	-11.15	162
-55.538	0	9.50	-0.55	-49.74	4.08	-10.67	164
-56.109	0	9.50	-0.55	-49.74	4.08	-11.24	166
-57.426	0	9.50	-0.55	-49.74	4.08	-12.56	168
-59.716	0	9.50	-0.55	-49.74	4.08	-14.85	170
-61.256	0	9.50	-0.55	-49.74	4.08	-16.39	172
-61.699	0	9.50	-0.55	-49.74	4.08	-16.83	174
-64.027	0	9.50	-0.55	-49.74	4.08	-19.16	176
-71.4	0	9.50	-0.55	-49.74	4.08	-26.53	178
-66.578	0	9.50	-0.55	-49.74	4.08	-21.71	180
-64.566	0	9.50	-0.55	-49.74	4.08	-19.70	182
-62.249	0	9.50	-0.55	-49.74	4.08	-17.38	184
-59.491	0	9.50	-0.55	-49.74	4.08	-14.62	186
-58.141	0	9.50	-0.55	-49.74	4.08	-13.27	188
-58.072	0	9.50	-0.55	-49.74	4.08	-13.20	190
-58.446	0	9.50	-0.55	-49.74	4.08	-13.58	192
-57.374	0	9.50	-0.55	-49.74	4.08	-12.50	194
-56.522	0	9.50	-0.55	-49.74	4.08	-11.65	196
-56.133	0	9.50	-0.55	-49.74	4.08	-11.26	198
-56.687	0	9.50	-0.55	-49.74	4.08	-11.82	200
-54.734	0	9.50	-0.55	-49.74	4.08	-9.86	202
-54.408	0	9.50	-0.55	-49.74	4.08	-9.54	204
-54.058	0	9.50	-0.55	-49.74	4.08	-9.19	206
-53.383	0	9.50	-0.55	-49.74	4.08	-8.51	208
-52.738	0	9.50	-0.55	-49.74	4.08	-7.87	210
-52.121	0	9.50	-0.55	-49.74	4.08	-7.25	212
-52.045	0	9.50	-0.55	-49.74	4.08	-7.18	214
-52.233	0	9.50	-0.55	-49.74	4.08	-7.36	216
-52.303	0	9.50	-0.55	-49.74	4.08	-7.43	218



-52.322	0	9.50	-0.55	-49.74	4.08	-7.45	220
-52.139	0	9.50	-0.55	-49.74	4.08	-7.27	222
-51.564	0	9.50	-0.55	-49.74	4.08	-6.69	224
-50.442	0	9.50	-0.55	-49.74	4.08	-5.57	226
-49.462	0	9.50	-0.55	-49.74	4.08	-4.59	228
-48.78	0	9.50	-0.55	-49.74	4.08	-3.91	230
-48.631	0	9.50	-0.55	-49.74	4.08	-3.76	232
-48.391	0	9.50	-0.55	-49.74	4.08	-3.52	234
-48.063	0	9.50	-0.55	-49.74	4.08	-3.19	236
-47.822	0	9.50	-0.55	-49.74	4.08	-2.95	238
-47.741	0	9.50	-0.55	-49.74	4.08	-2.87	240
-47.602	0	9.50	-0.55	-49.74	4.08	-2.73	242
-47.236	0	9.50	-0.55	-49.74	4.08	-2.37	244
-46.874	0	9.50	-0.55	-49.74	4.08	-2.00	246
-46.842	0	9.50	-0.55	-49.74	4.08	-1.97	248
-47.333	0	9.50	-0.55	-49.74	4.08	-2.46	250
-48.077	0	9.50	-0.55	-49.74	4.08	-3.21	252
-48.725	0	9.50	-0.55	-49.74	4.08	-3.86	254
-49.039	0	9.50	-0.55	-49.74	4.08	-4.17	256
-48.883	0	9.50	-0.55	-49.74	4.08	-4.01	258
-48.76	0	9.50	-0.55	-49.74	4.08	-3.89	260
-48.569	0	9.50	-0.55	-49.74	4.08	-3.70	262
-48.656	0	9.50	-0.55	-49.74	4.08	-3.79	264
-49.392	0	9.50	-0.55	-49.74	4.08	-4.52	266
-50.339	0	9.50	-0.55	-49.74	4.08	-5.47	268
-51.151	0	9.50	-0.55	-49.74	4.08	-6.28	270
-51.461	0	9.50	-0.55	-49.74	4.08	-6.59	272
-51.37	0	9.50	-0.55	-49.74	4.08	-6.50	274
-51.494	0	9.50	-0.55	-49.74	4.08	-6.62	276
-53.257	0	9.50	-0.55	-49.74	4.08	-8.39	278
-54.395	0	9.50	-0.55	-49.74	4.08	-9.53	280
-55.178	0	9.50	-0.55	-49.74	4.08	-10.31	282
-55.618	0	9.50	-0.55	-49.74	4.08	-10.75	284
-55.824	0	9.50	-0.55	-49.74	4.08	-10.95	286
-56.33	0	9.50	-0.55	-49.74	4.08	-11.46	288
-57.191	0	9.50	-0.55	-49.74	4.08	-12.32	290
-58.562	0	9.50	-0.55	-49.74	4.08	-13.69	292
-59.749	0	9.50	-0.55	-49.74	4.08	-14.88	294
-60.697	0	9.50	-0.55	-49.74	4.08	-15.83	296
-60.176	0	9.50	-0.55	-49.74	4.08	-15.31	298



-59.492	0	9.50	-0.55	-49.74	4.08	-14.62	300
-59.942	0	9.50	-0.55	-49.74	4.08	-15.07	302
-61.042	0	9.50	-0.55	-49.74	4.08	-16.17	304
-61.902	0	9.50	-0.55	-49.74	4.08	-17.03	306
-62.42	0	9.50	-0.55	-49.74	4.08	-17.55	308
-62.915	0	9.50	-0.55	-49.74	4.08	-18.05	310
-63.905	0	9.50	-0.55	-49.74	4.08	-19.04	312
-65.759	0	9.50	-0.55	-49.74	4.08	-20.89	314
-68.043	0	9.50	-0.55	-49.74	4.08	-23.17	316
-70.777	0	9.50	-0.55	-49.74	4.08	-25.91	318
-68.69	0	9.50	-0.55	-49.74	4.08	-23.82	320
-64.549	0	9.50	-0.55	-49.74	4.08	-19.68	322
-61.376	0	9.50	-0.55	-49.74	4.08	-16.51	324
-58.813	0	9.50	-0.55	-49.74	4.08	-13.94	326
-57.142	0	9.50	-0.55	-49.74	4.08	-12.27	328
-57.07	0	9.50	-0.55	-49.74	4.08	-12.20	330
-58.381	0	9.50	-0.55	-49.74	4.08	-13.51	332
-61.349	0	9.50	-0.55	-49.74	4.08	-16.48	334
-64.713	0	9.50	-0.55	-49.74	4.08	-19.84	336
-67.283	0	9.50	-0.55	-49.74	4.08	-22.41	338
-66.105	0	9.50	-0.55	-49.74	4.08	-21.24	340
-63.497	0	9.50	-0.55	-49.74	4.08	-18.63	342
-61.868	0	9.50	-0.55	-49.74	4.08	-17.00	344
-60.791	0	9.50	-0.55	-49.74	4.08	-15.92	346
-60.085	0	9.50	-0.55	-49.74	4.08	-15.22	348
-60.239	0	9.50	-0.55	-49.74	4.08	-15.37	350
-60.617	0	9.50	-0.55	-49.74	4.08	-15.75	352
-61.085	0	9.50	-0.55	-49.74	4.08	-16.22	354
-61.769	0	9.50	-0.55	-49.74	4.08	-16.90	356



4 Test Setup Photographs

Figure 5: Antenna Gain Testing (View #1)

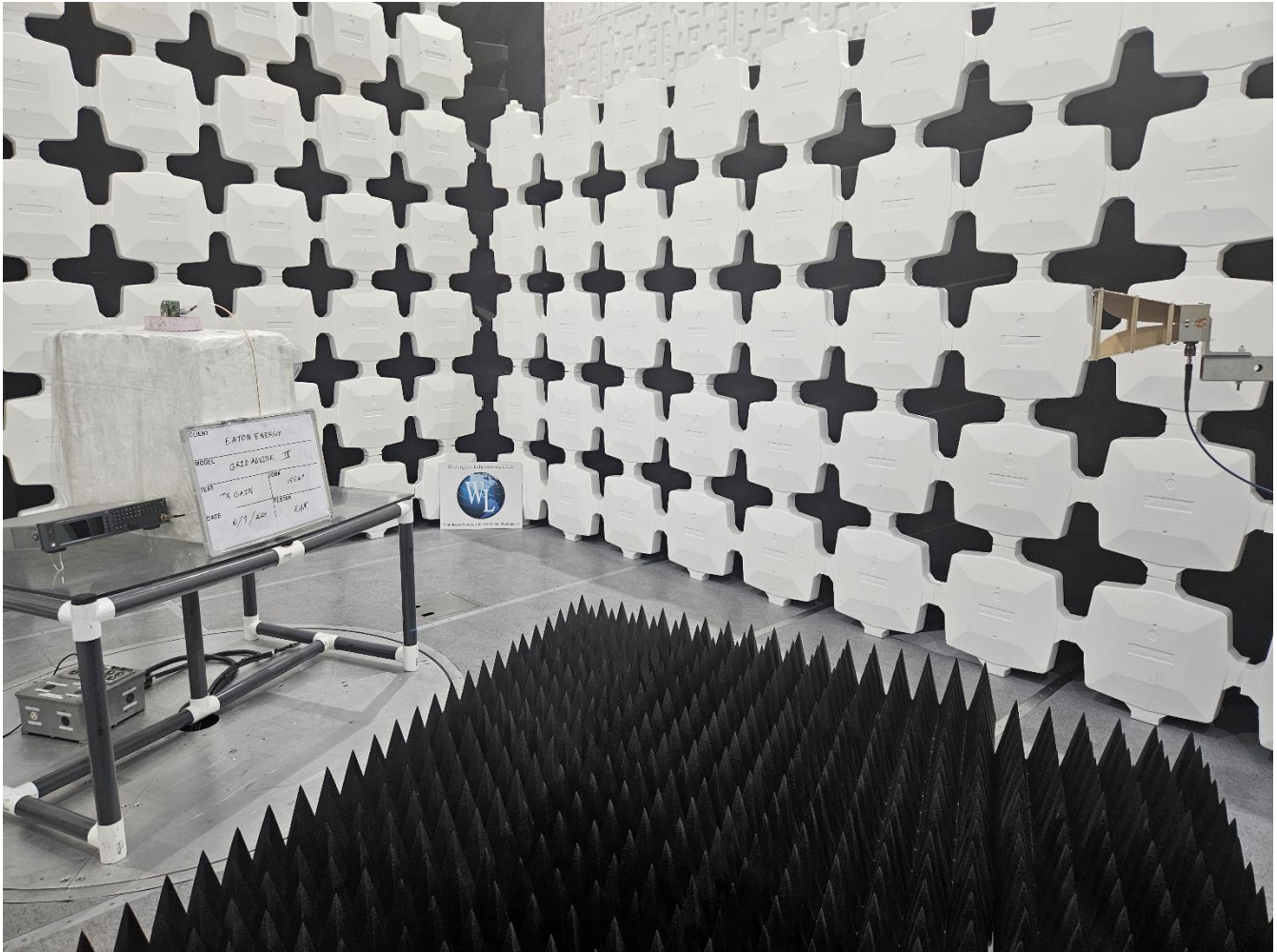




Figure 6: Antenna Gain Testing (View #2)

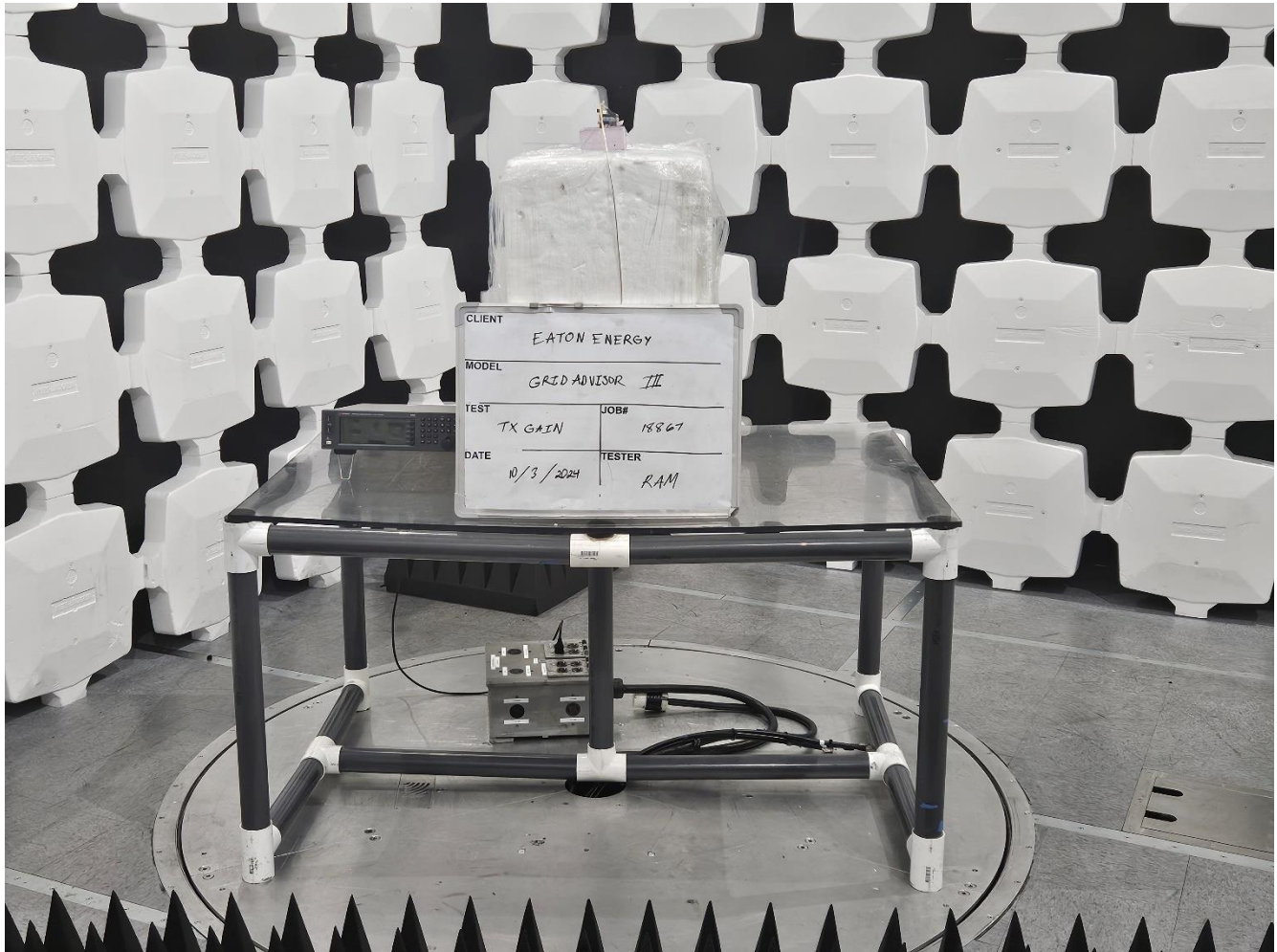
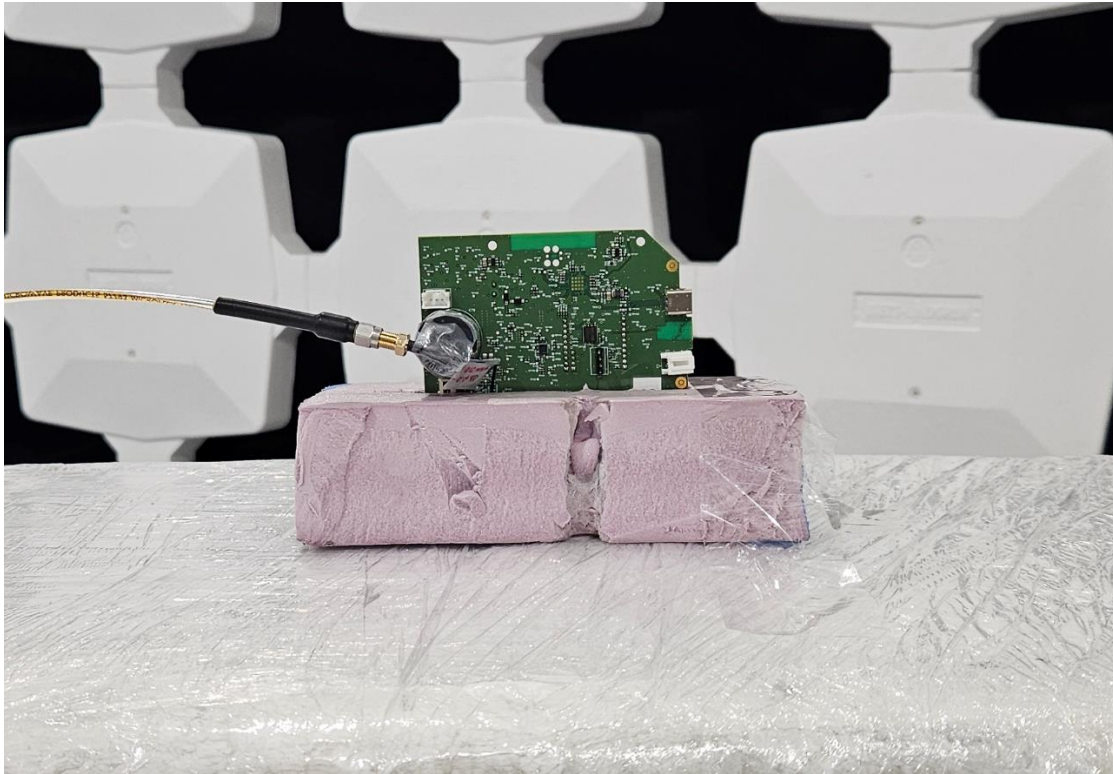




Figure 7: Antenna Gain Testing (View #3)



* X-axis, worst-case