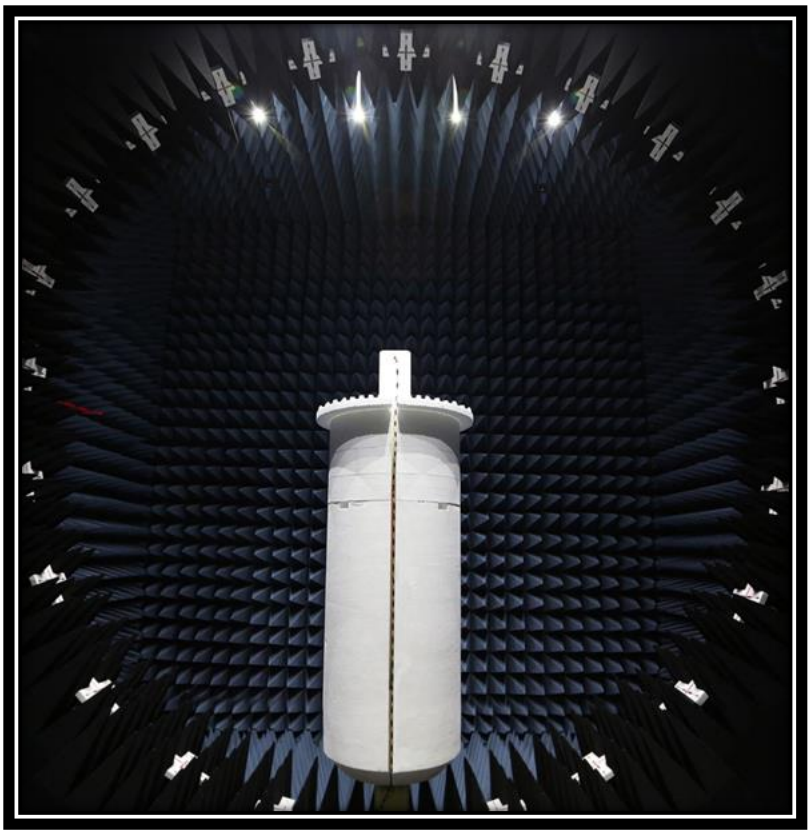
IrriGreen, Inc.

Sprinkler

Antenna Pattern Measurements

Report: IRRI0015.1 Rev. 1, Issue Date: January 25, 2024



Approved by:

Eric Brandon, Department Manager

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REVISION HISTORY

Revision Number	Description	Date (yyyy-mm-dd)	Page Number
00	None		
01	Antenna info from the BLE report was added. EUT photo added.	2024-01-25	6
	Added 3D plot at 2402, where max gain exists.	2024-01-25	11

ACCREDITATIONS AND AUTHORIZATIONS

element
2021.09.01

United States

FCC - Designated by the FCC as a Telecommunications Certification Body (TCB). Certification chambers, Open Area Test Sites, and conducted measurement facilities are listed with the FCC.

A2LA - Each laboratory is accredited by A2LA to ISO / IEC 17025, and as a product certifier to ISO / IEC 17065 which allows Element to certify transmitters to FCC and IC specifications.

Canada

ISED - Recognized by Innovation, Science and Economic Development Canada as a Certification Body (CB) and as a CAB for the acceptance of test data.

European Union

European Commission – Recognized as an EU Notified Body validated for the EMCD and RED Directives.

United Kingdom

BEIS – Recognized by the UK as an Approved Body under the UK Radio Equipment and UK EMC Regulations.

Australia/New Zealand

ACMA - Recognized by ACMA as a CAB for the acceptance of test data.

Korea

MSIT / RRA - Recognized by KCC's RRA as a CAB for the acceptance of test data.

Japan

VCCI - Associate Member of the VCCI. Conducted and radiated measurement facilities are registered.

Taiwan

BSMI – Recognized by BSMI as a CAB for the acceptance of test data.

NCC - Recognized by NCC as a CAB for the acceptance of test data.

Singapore

IDA – Recognized by IDA as a CAB for the acceptance of test data.

Israel

MOC – Recognized by MOC as a CAB for the acceptance of test data.

Hong Kong

OFCA – Recognized by OFCA as a CAB for the acceptance of test data.

Vietnam

MIC – Recognized by MIC as a CAB for the acceptance of test data.

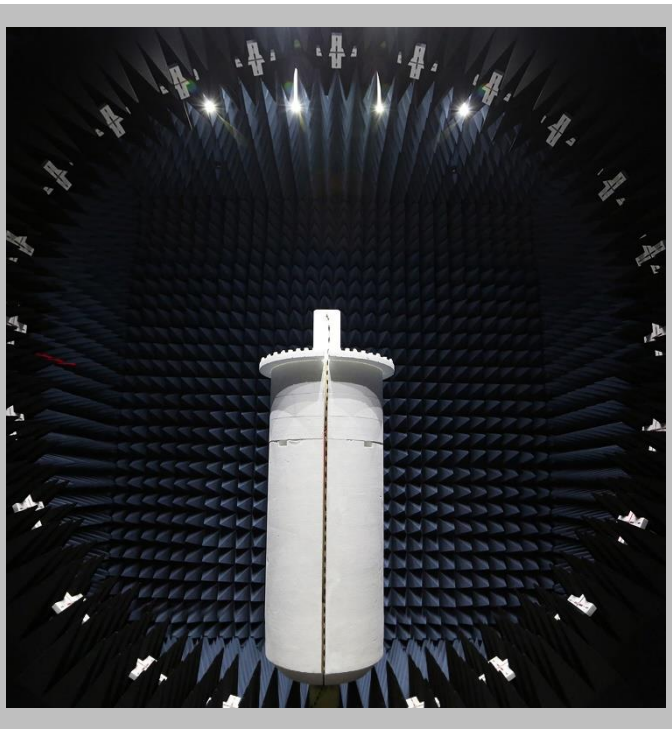
SCOPE

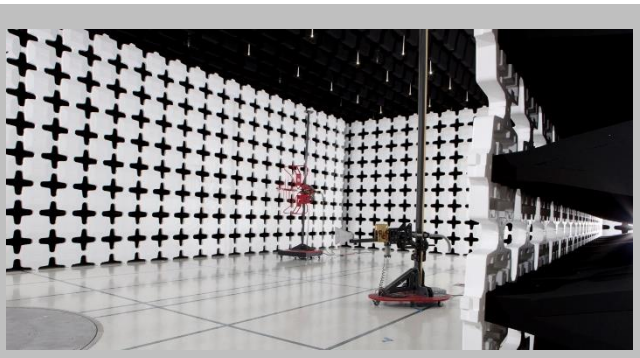
For details on the Scopes of our Accreditations, please visit:

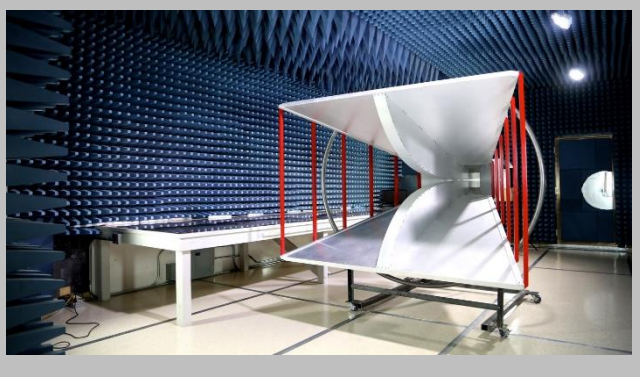
California Minnesota Oregon Texas Washington

FACILITIES

California	Minnesota	Oregon	Texas	Washington
Labs OC01-17 41 Tesla Irvine, CA 92618 (949) 861-8918	Labs MN01-11 9349 W Broadway Ave. Brooklyn Park, MN 55445 (612) 638-5136	Labs EV01-12 6775 NE Evergreen Pkwy #400 Hillsboro, OR 97124 (503) 844-4066	Labs TX01-09 3801 E Plano Pkwy Plano, TX 75074 (469) 304-5255	Labs NC01-05 19201 120th Ave NE Bothell, WA 98011 (425) 984-6600
A2LA				
Lab Code: 3310.04	Lab Code: 3310.05	Lab Code: 3310.02	Lab Code: 3310.03	Lab Code: 3310.06
Innovation, Science and Economic Development Canada				
2834B-1, 2834B-3	2834E-1, 2834E-3	2834D-1	2834G-1	2834F-1
BSMI				
SL2-IN-E-1154R	SL2-IN-E-1152R	SL2-IN-E-1017	SL2-IN-E-1158R	SL2-IN-E-1153R
VCCI				
A-0029	A-0109	A-0108	A-0201	A-0110
Recognized Phase I CAB for ISED, ACMA, BSMI, IDA, KCC/RRA, MIC, MOC, NCC, OFCA				
US0158	US0175	US0017	US0191	US0157







PRODUCT DESCRIPTION

Client and Equipment under Test (EUT) Information

Company Name:	IrriGreen, Inc.
Address:	5250 West 73rd Street Suite I
City, State, Zip:	Edina, MN 55439
Test Requested By:	Gary Klinefelter
EUT:	Sprinkler
First Date of Test:	March 10, 2023
Last Date of Test:	March 10, 2023
Receipt Date of Samples:	March 10, 2023
Equipment Design Stage:	Prototype
Equipment Condition:	No Damage
Purchase Authorization:	Verified

Information Provided by the Party Requesting the Test

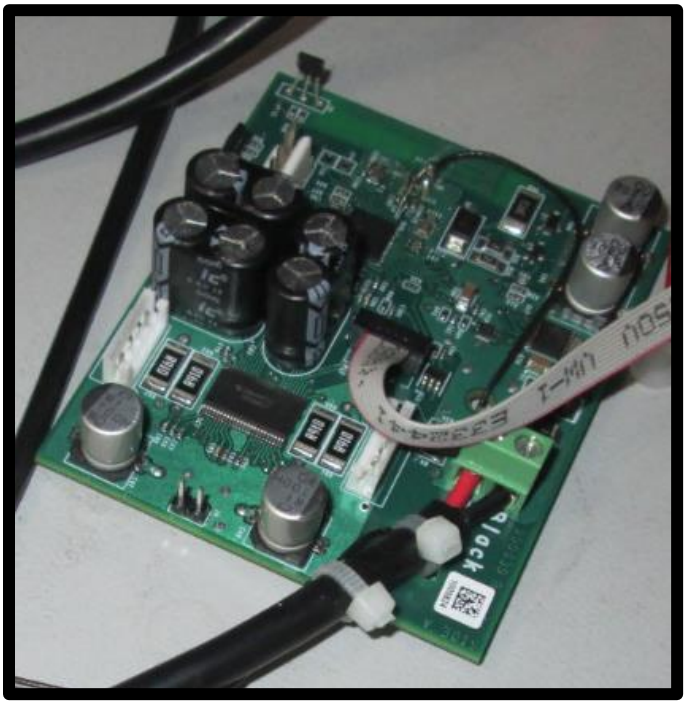
Functional Description of the EUT:
Irrigation Sprinkler with a Bluetooth Low Energy radio

Antenna

Type	Provided by:	Frequency Range (MHz)
PCB Trace	IrriGreen, Inc	2400-2483.5

Testing Objective:
To obtain 3D antenna pattern measurements and calculated antenna performance values.

EUT Photo:



MODIFICATIONS

Equipment Modifications

Item	Date	Test	Modification	Note	Disposition of EUT
1	2023-03-10	Passive 3D Antenna Pattern Measurements	Tested as delivered to Test Station.	No EMI suppression devices were added or modified during this test.	Scheduled testing was completed.

PASSIVE 3D ANTENNA PATTERN MEASUREMENTS

OTA 2018.01.04

Testing was performed using the mode(s) of operation and configuration(s) noted within the report. The individuals and/or the organization requesting the test provided the modes, configurations and settings used to complete the evaluation. The actual test parameters are specified in the test data, this includes items such as investigated frequency range (scanned) and test levels. The testing methods and performance specifications, as well as the test site used for the evaluation are indicated in the test data. The test data represents the configuration / operating mode/ model that produced the highest emission levels as compared to the specification limit.

TEST EQUIPMENT

Description	Manufacturer	Model	ID	Last Cal.	Interval
Antenna - Dipole	ETS Lindgren	3126-2450	OTF2	4/8/2021	36 mo
Analyzer - Network Analyzer	Agilent	E5071C	NAM	11/19/2022	36 mo
Chamber - OTA	ETS Lindgren	AMS-8923-195	OTA	4/19/2021	36 mo

TEST DESCRIPTION

Using the modes of operation and configurations noted within this report, a radiated pattern measurement test was performed. The frequency ranges investigated (scanned), are also noted in this report.

The EUT was placed on a low dielectric constant support structure (Phi Axis Positioner) in the 3D center of the measurement zone using a laser alignment system. The antenna port of the EUT is connected to an RF feed cable which is connected to a Vector Network Analyzer (VNA) at its opposite end.

The test begins with a measurement path configured (via ETS-Lindgren EMQuest Data Acquisition and Analysis Software) such that an electrical path is present from the Theta polarization element of the -165° detector antenna, to port 2 of the VNA. The VNA drives the EUT through the desired frequency range at the desired IFBW and an insertion loss measurement is obtained. The measurement path is then reconfigured (again via EMQuest) such that an electrical path is present from the Phi polarization element of the -165° detector antenna, to port 2 of the VNA. The VNA drives the EUT through the desired frequency range at the desired IFBW and an insertion loss measurement is obtained. This process is repeated at each of the 23 detector antennas in turn. This process is repeated for every rotation of the Phi Axis Positioner up to 180° - Phi Axis Resolution. When this process is complete, EMQuest applies factors from a Range Calibration and Normalization to produce a final data set with 1D/2D/3D patterns and tabular values such as antenna efficiency, Equivalent Isotropic Radiated Power (EIRP), Total Radiated Power (TRP), etc.

A measurement uncertainty estimation has been performed for this testing. When a measurement is made, the result will be different from the true or theoretically correct value. The difference is the result of tolerances in the measurement system that cannot be completely eliminated. To the extent that technology allows us, it has been our aim to minimize this error. Measurement uncertainty is a statistical expression of measurement error qualified by a probability distribution. The expanded measurement uncertainty, 95% confidence level (K=2), for Maximum Gain / Efficiency for 2400-2483.5 MHz on active measurements is +/-1.08 dB. The expanded measurement uncertainty, 95% confidence level (K=2), for Maximum Gain / Efficiency for 2400-2483.5 MHz on passive measurements is +/-1.29. The calculations for estimating measurement uncertainty are available upon request.

PASSIVE 3D ANTENNA PATTERN MEASUREMENTS

OTA 2018.01.04

EUT:	Sprinkler
Serial Number:	1000823
Customer:	IrriGreen, Inc.
Attendees:	Gary Klinefelter
Customer Project:	None
Tested By:	Christopher Heintzelman
Test Run Description:	Passive_Run1

Work Order:	IRRI0015
Date:	3/10/2023
Temperature:	22.7 °C
Relative Humidity:	25.5% RH
Bar. Pressure:	1026 mbar
Job Site:	MN10

COMMENTS

Maximum gain is 1.5 dBi at 2402-2404 MHz.

3D PATTERN DATA

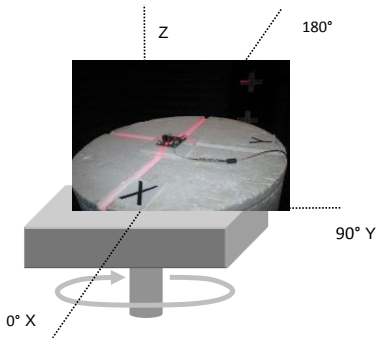
Frequency (MHz)	2400	2402	2404	2406	2408	2410	2412	2414	2416	2418	2420	2422
Ant. Port Input Pwr. (dBm)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Tot. Rad. Pwr. (dBm)	-6.21	-6.21	-6.23	-6.24	-6.26	-6.27	-6.29	-6.32	-6.33	-6.34	-6.34	-6.36
Peak EIRP (dBm)	1.46	1.50	1.50	1.47	1.47	1.40	1.36	1.33	1.30	1.23	1.24	1.19
Directivity (dBi)	7.68	7.71	7.73	7.70	7.73	7.67	7.65	7.64	7.64	7.58	7.58	7.55
Efficiency (dB)	-6.21	-6.21	-6.23	-6.24	-6.26	-6.27	-6.29	-6.32	-6.33	-6.34	-6.34	-6.36
Efficiency (%)	23.92	23.93	23.83	23.79	23.66	23.60	23.49	23.35	23.26	23.21	23.22	23.12
Gain (dBi)	1.46	1.50	1.50	1.47	1.47	1.40	1.36	1.33	1.30	1.23	1.24	1.19
Average Gain (dB)	-6.21	-6.21	-6.23	-6.24	-6.26	-6.27	-6.29	-6.32	-6.33	-6.34	-6.34	-6.36
E-Plane 3 dB BW (°)	22.00	21.00	21.00	22.00	22.00	22.00	22.00	22.00	23.00	22.00	22.00	22.00

Frequency (MHz)	2424	2426	2428	2430	2432	2434	2436	2438	2440	2442	2444	2446
Ant. Port Input Pwr. (dBm)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Tot. Rad. Pwr. (dBm)	-6.36	-6.37	-6.38	-6.39	-6.40	-6.41	-6.41	-6.41	-6.43	-6.45	-6.46	-6.48
Peak EIRP (dBm)	1.17	1.13	1.04	1.05	1.00	0.94	0.93	0.90	0.87	0.82	0.80	0.65
Directivity (dBi)	7.54	7.50	7.42	7.44	7.40	7.35	7.34	7.32	7.30	7.27	7.26	7.14
Efficiency (dB)	-6.36	-6.37	-6.38	-6.39	-6.40	-6.41	-6.41	-6.41	-6.43	-6.45	-6.46	-6.48
Efficiency (%)	23.11	23.09	23.02	22.97	22.89	22.87	22.85	22.84	22.77	22.65	22.59	22.48
Gain (dBi)	1.17	1.13	1.04	1.05	1.00	0.94	0.93	0.90	0.87	0.82	0.80	0.65
Average Gain (dB)	-6.36	-6.37	-6.38	-6.39	-6.40	-6.41	-6.41	-6.41	-6.43	-6.45	-6.46	-6.48
E-Plane 3 dB BW (°)	23.00	22.00	23.00	22.00	23.00	22.00	22.00	23.00	22.00	23.00	23.00	23.00

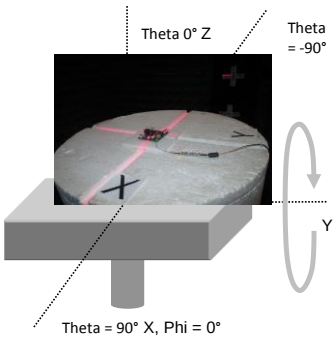
Frequency (MHz)	2448	2450	2452	2454	2456	2458	2460	2462	2464	2466	2468	2470
Ant. Port Input Pwr. (dBm)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Tot. Rad. Pwr. (dBm)	-6.50	-6.52	-6.54	-6.57	-6.59	-6.63	-6.66	-6.71	-6.77	-6.82	-6.87	-6.92
Peak EIRP (dBm)	0.70	0.61	0.54	0.54	0.51	0.46	0.40	0.34	0.28	0.21	0.13	0.09
Directivity (dBi)	7.19	7.13	7.08	7.11	7.11	7.08	7.07	7.05	7.05	7.03	7.00	7.01
Efficiency (dB)	-6.50	-6.52	-6.54	-6.57	-6.59	-6.63	-6.66	-6.71	-6.77	-6.82	-6.87	-6.92
Efficiency (%)	22.41	22.27	22.19	22.02	21.92	21.73	21.56	21.34	21.04	20.81	20.58	20.33
Gain (dBi)	0.70	0.61	0.54	0.54	0.51	0.46	0.40	0.34	0.28	0.21	0.13	0.09
Average Gain (dB)	-6.50	-6.52	-6.54	-6.57	-6.59	-6.63	-6.66	-6.71	-6.77	-6.82	-6.87	-6.92
E-Plane 3 dB BW (°)	23.00	23.00	24.00	24.00	24.00	23.00	24.00	24.00	24.00	25.00	25.00	25.00

Frequency (MHz)	2472	2474	2476	2478	2480	2482	2484	2486	2488	2490
Ant. Port Input Pwr. (dBm)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Tot. Rad. Pwr. (dBm)	-6.96	-7.01	-7.08	-7.14	-7.20	-7.26	-7.31	-7.35	-7.38	-7.37
Peak EIRP (dBm)	0.00	-0.01	-0.14	-0.15	-0.28	-0.32	-0.43	-0.43	-0.44	-0.53
Directivity (dBi)	6.97	7.00	6.94	6.99	6.92	6.94	6.89	6.93	6.94	6.84
Efficiency (dB)	-6.96	-7.01	-7.08	-7.14	-7.20	-7.26	-7.31	-7.35	-7.38	-7.37
Efficiency (%)	20.13	19.90	19.60	19.31	19.03	18.79	18.56	18.39	18.28	18.32
Gain (dBi)	0.00	-0.01	-0.14	-0.15	-0.28	-0.32	-0.43	-0.43	-0.44	-0.53
Average Gain (dB)	-6.96	-7.01	-7.08	-7.14	-7.20	-7.26	-7.31	-7.35	-7.38	-7.37
E-Plane 3 dB BW (°)	25.00	25.00	25.00	25.00	25.00	25.00	26.00	25.00	26.00	26.00

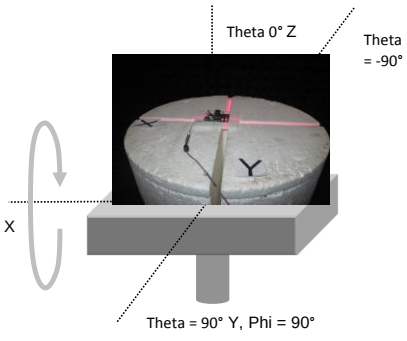
Azimuth Cut (Theta Axis = 90°)



Elevation Cut (Phi Axis = 0°)

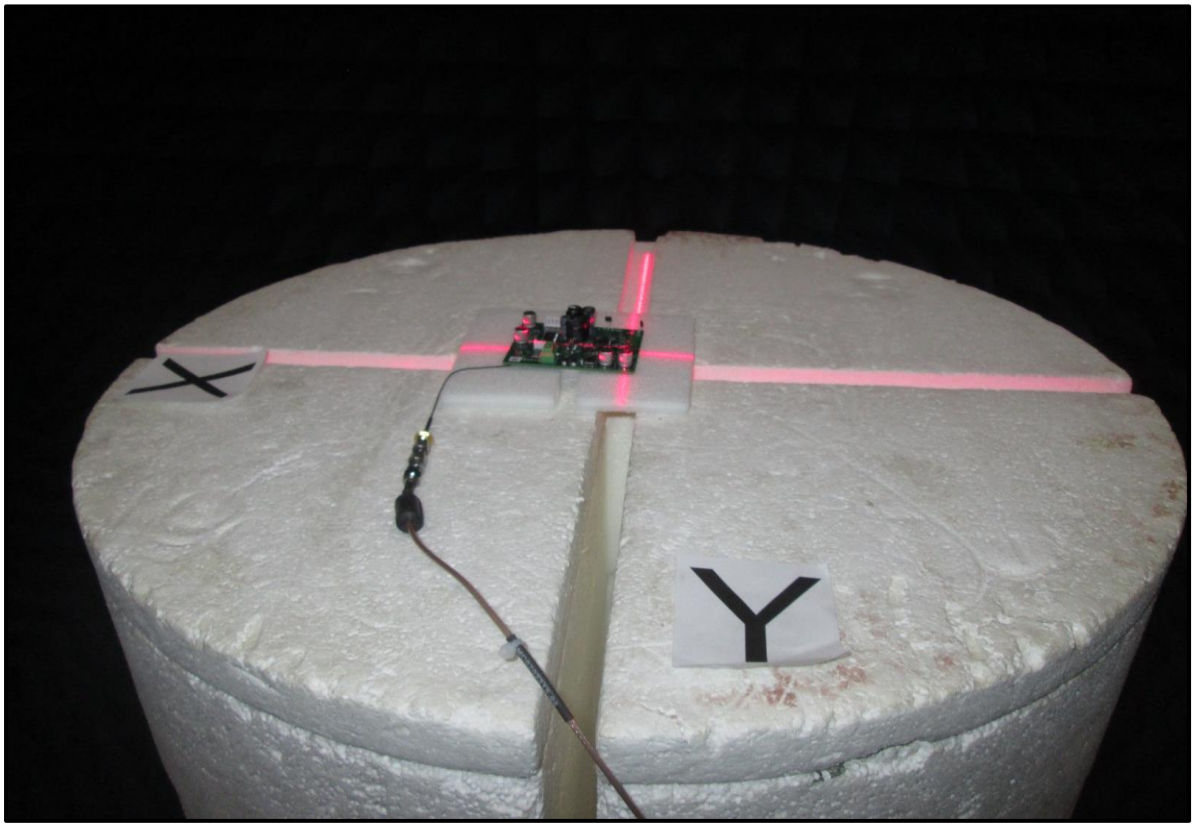


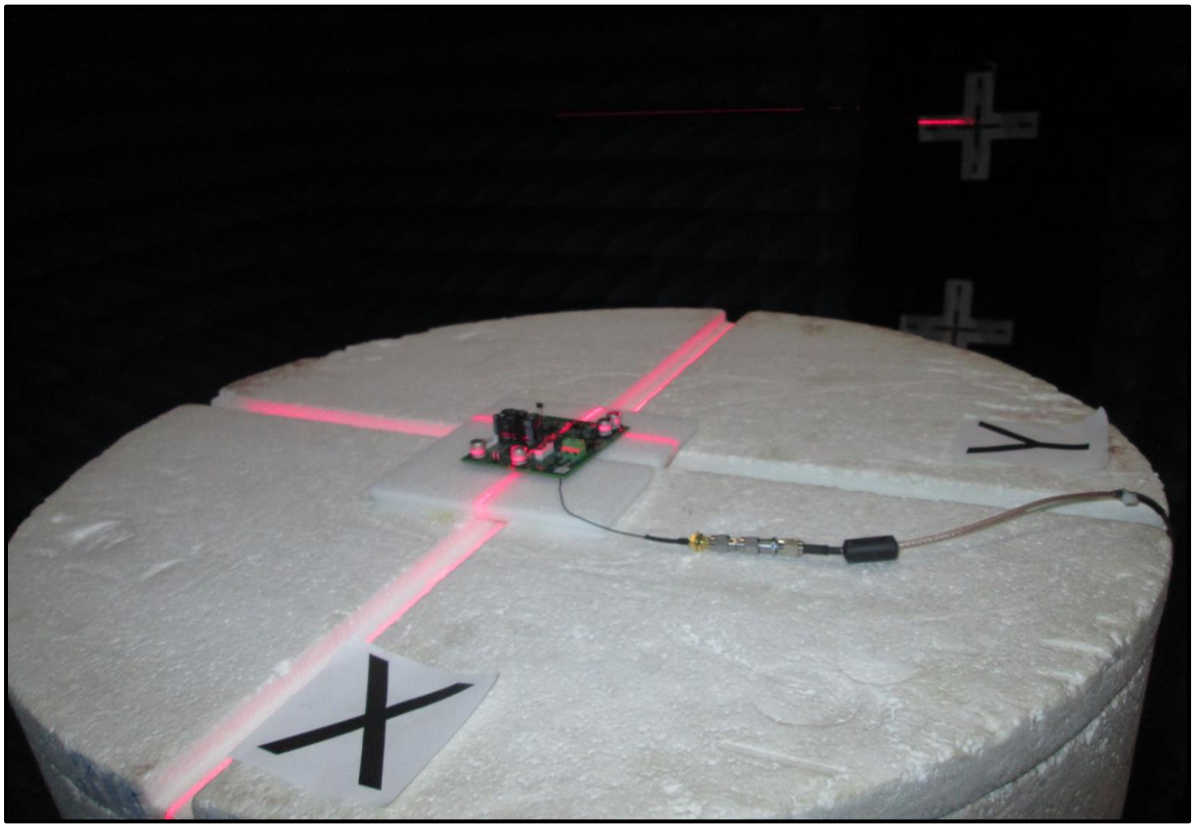
Elevation Cut (Phi Axis = 90°)



PASSIVE 3D ANTENNA PATTERN MEASUREMENTS

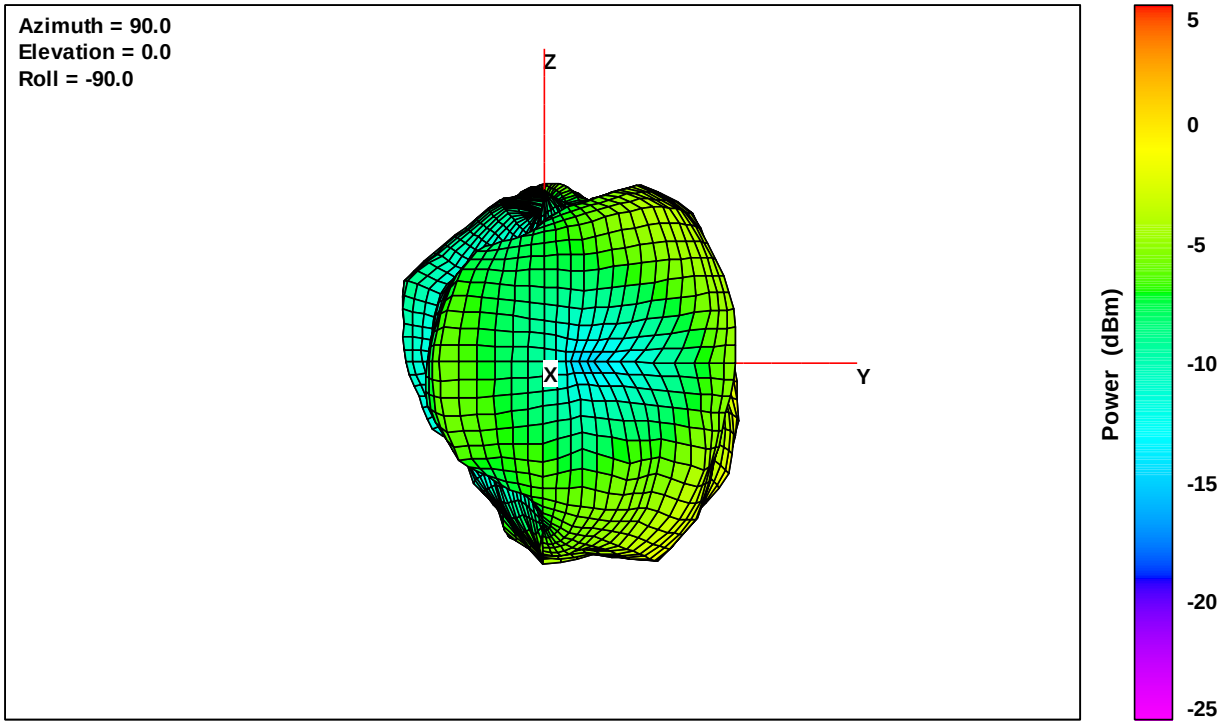
OTA 2018.01.04



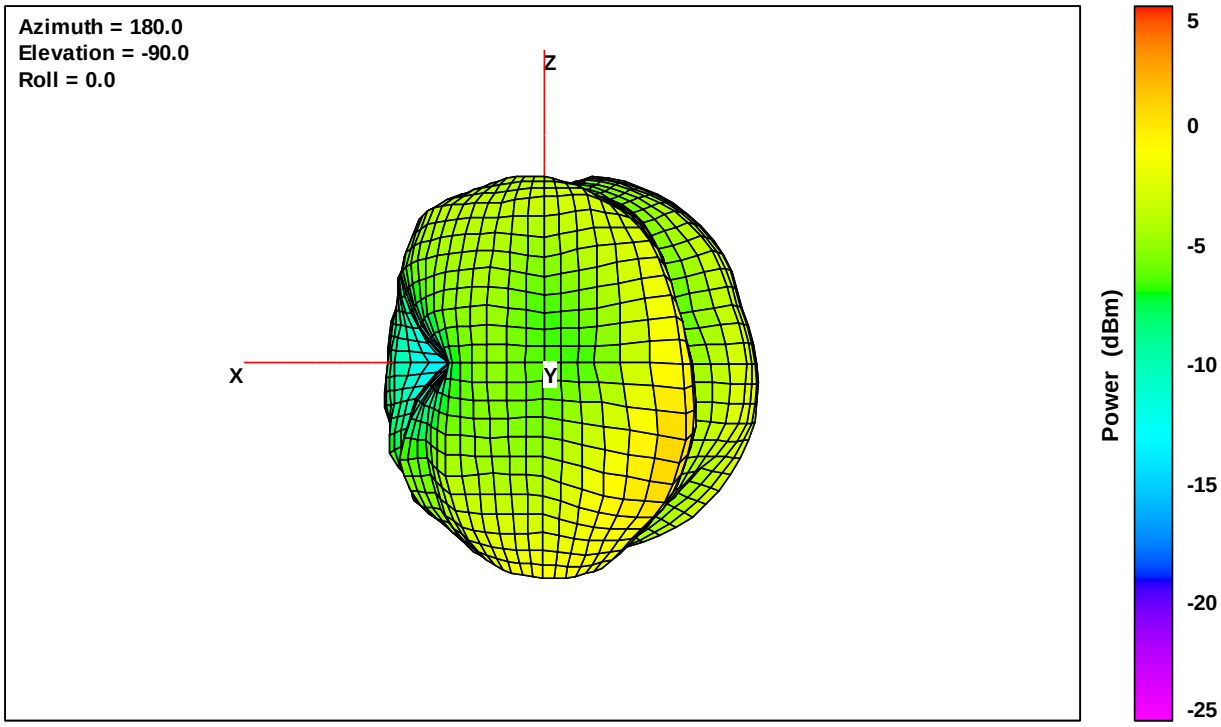


3D PLOTS

Total Power - 2402 MHz



Total Power - 2402 MHz



End of Test Report