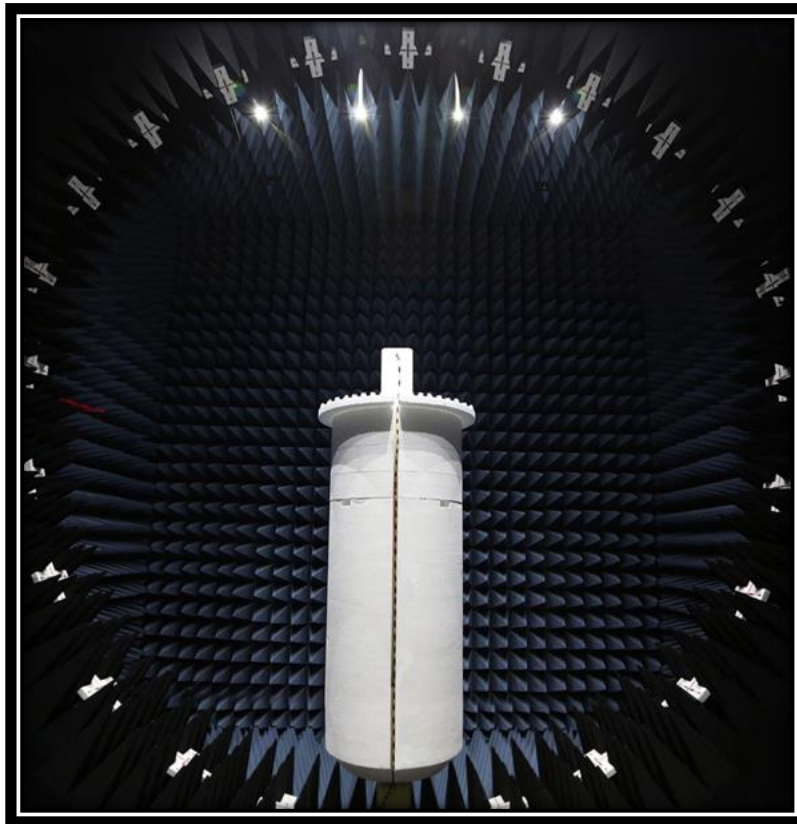




element

MSA Innovation, LLC
SCBA G1 Beacon
Antenna Pattern Measurements

Report: F3EN0295.0 Rev. 0, Issue Date: May 12, 2026



Approved by:

Trevor Buls

Trevor Buls, Principal EMC Test Engineer
Signed for and on behalf of Element

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REVISION HISTORY



Revision Number		Description	Date (yyyy-mm-dd)	Page Number
00	None			

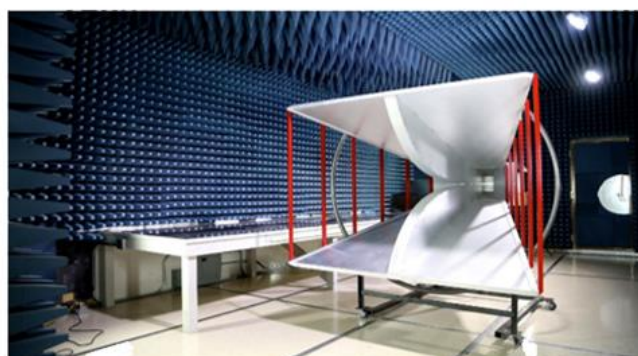
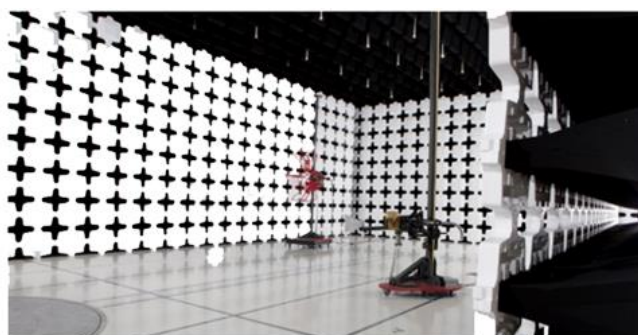
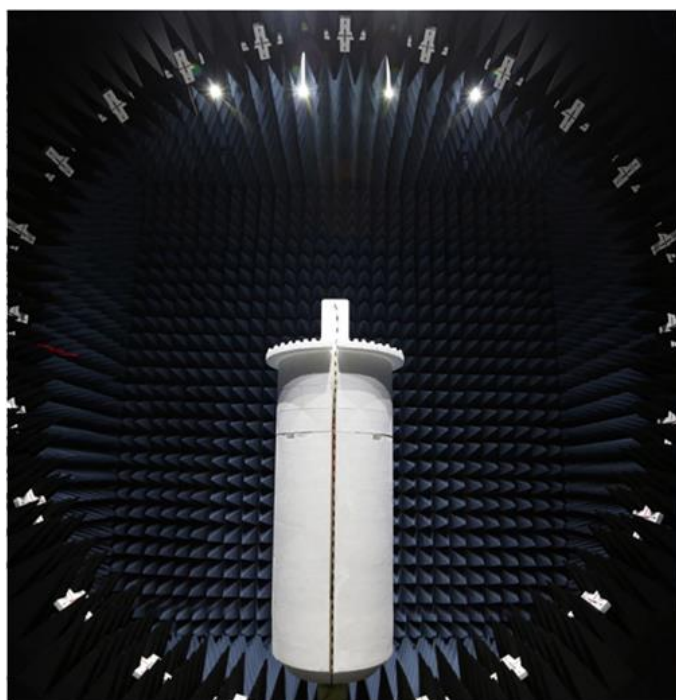
FACILITIES

Testing was performed at the following location(s)

	Location	Labs ⁽¹⁾	Address	A2LA ⁽²⁾	ISED ⁽³⁾	BSMI ⁽⁴⁾	VCCI ⁽⁵⁾	CAB	FDA ⁽⁶⁾
☐	California	OC01-17	41 Tesla Irvine, CA 92618 (949) 861-8918	3310.04	2834B	SL2-IN-E-1154R	A-0029	US0158	TL-55
☒	Minnesota	MN01-11	9349 W Broadway Ave. Brooklyn Park, MN 55445 (612) 638-5136	3310.05	2834E	SL2-IN-E-1152R	A-0109	US0175	TL-57
☐	Oregon	EV01-12	6775 NE Evergreen Pkwy #400 Hillsboro, OR 97124 (503) 844-4066	3310.02	2834D	SL2-IN-E-1017	A-0108	US0017	TL-56
☐	Washington	NC01-05	19201 120th Ave NE Bothell, WA 98011 (425) 984-6600	3310.06	2834F	SL2-IN-E-1153R	A-0110	US0157	TL-67
☐	Offsite	N/A	See Product Description	N/A	N/A	N/A	N/A	N/A	N/A

See data sheets for specific labs

- (1) The lab designations denote individual rooms within each location. (OC01, OC02, OC03, etc.)
- (2) A2LA Certificate No.
- (3) ISED Company No.
- (4) BSMI No.
- (5) VCCI Site Filing No.
- (6) FDA ASCA No.



PRODUCT DESCRIPTION



Client and Equipment under Test (EUT) Information

Company Name:	MSA Innovation, LLC
Address:	1000 Cranberry Woods Drive
City, State, Zip:	Cranberry Township, PA 16066
Test Requested By:	Dustin Morris
EUT:	CBA G1 Beacon
First Date of Test:	February 24, 2025
Last Date of Test:	February 24, 2025
Receipt Date of Samples:	February 24, 2025
Equipment Design Stage:	Production
Equipment Condition:	No Damage
Purchase Authorization:	Verified

Information Provided by the Party Requesting the Test

Functional Description of the EUT:
Inverted F PCB Trace Antennas
Testing Objective:
To obtain 3D antenna pattern measurements and calculated antenna performance values (gain, efficiency, TRP, etc.)

MODIFICATIONS



Equipment Modifications

Item	Date	Test	Modification	Note	Disposition of EUT
1	2025-02-25	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.

OTA MEASUREMENT SUMMARY



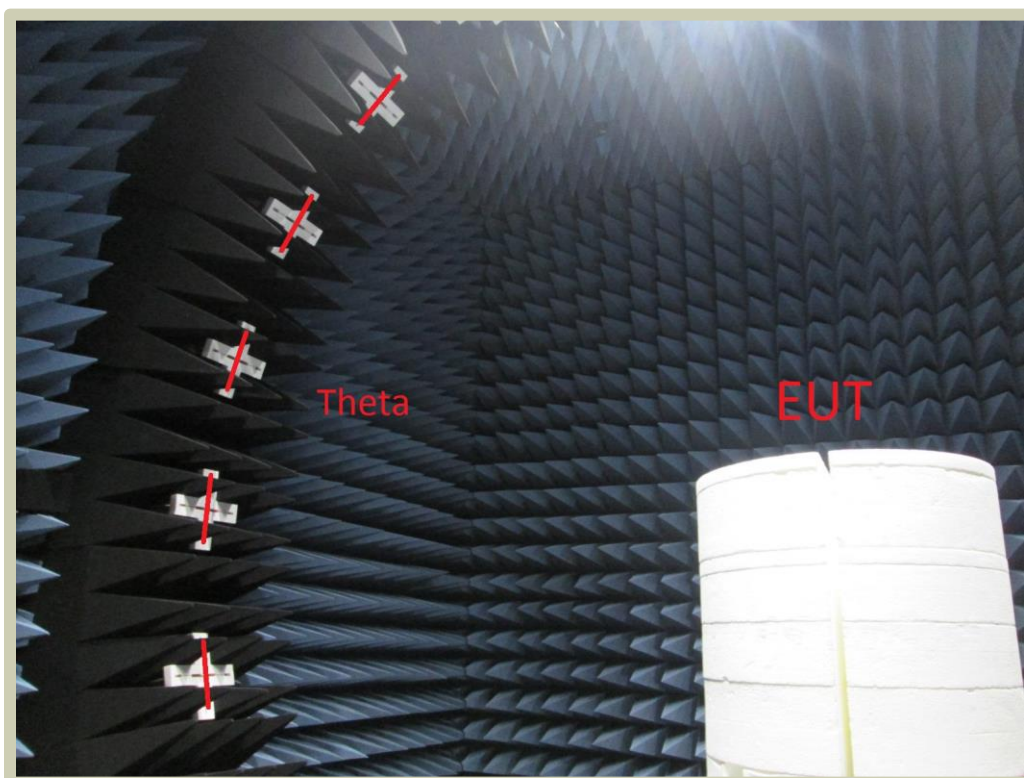
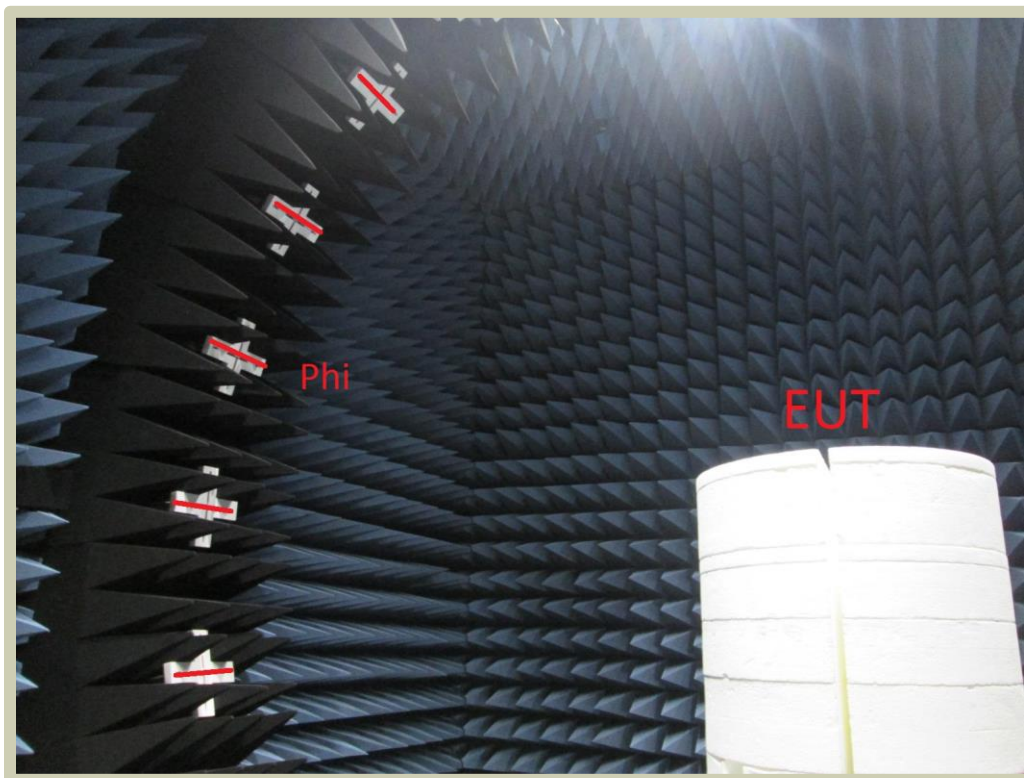
TEST DEFINITIONS

Phi Polarity	The detector antennas that are pointing in the same direction as the phi axis positioner rotates. See following page for photos.
Theta Polarity	The detector antennas that are pointing in the same direction as when the ring of detector antennas. See following page for photos.
Phi Angle	The position of the phi axis positioner, usually between 0° and 180°
Theta Angle	The position of the detector antenna, usually between -165° and 165°
Antenna Port Input Power (APIP)	The absolute power going into the antenna. This is used to calculate Efficiency and Gain.
Effective Isotropic Radiated Power (EIRP)	After combining phi and theta polarity measurements, the highest reading seen at any phi and theta angle during the measurement is the Effective Isotropic Radiated Power.
Total Radiated Power (TRP)	The sum of the power seen at all measuring antennas at all Theta and Phi angles and at both polarities. Represented in equation form by: $TRP = \frac{1}{4\pi} \int_0^{2\pi} \int_0^{\pi} (EIRP_{\theta}(\theta, \phi) + EIRP_{\phi}(\theta, \phi)) * \sin(\theta) d\theta d\phi$ Where θ is the theta angle of the measurement, ϕ is the phi angle of the measurement, $EIRP_{\theta}(\theta, \phi)$ is the reading on the theta polarity at a given theta and phi angle, and $EIRP_{\phi}(\theta, \phi)$ is the reading on the phi polarity at a given theta and phi angle.
Minimum Effective Isotropic Sensitivity (Min. EIS)	After finding the inverse of the sum of the inverses of the phi and theta polarity measurements for each single phi and theta angle, the lowest value is the Min. EIS. EIS is represented in equation form as: $EIS = (EIS_{\theta}(\theta_n, \phi_n)^{-1} + EIS_{\phi}(\theta_n, \phi_n)^{-1})^{-1}$ Where θ is the theta angle of the measurement, ϕ is the phi angle of the measurement, $EIS_{\theta}(\theta, \phi)$ is the reading on the theta polarity at a given theta and phi angle, and $EIS_{\phi}(\theta, \phi)$ is the reading on the phi polarity at a given theta and phi angle. The lowest value found across all EIS values is the Minimum Effective Isotropic Sensitivity.
Total Isotropic Sensitivity (TIS)	The inverse of the sum of the inverses of all the individual EIS readings. Represented in equation form as: $TIS = \frac{4\pi}{\int_0^{2\pi} \int_0^{\pi} (EIS_{\theta}(\theta, \phi)^{-1} + EIS_{\phi}(\theta, \phi)^{-1}) * \sin(\theta) d\theta d\phi}$ Where θ is the theta angle of the measurement, ϕ is the phi angle of the measurement, $EIS_{\theta}(\theta, \phi)$ is the reading on the theta polarity at a given theta and phi angle, and $EIS_{\phi}(\theta, \phi)$ is the reading on the phi polarity at a given theta and phi angle.
Directivity	The difference between the EIRP and the TRP or the Min. EIS and the TIS.
Efficiency	The difference between the TRP and the APIP.
Gain (also called Peak Gain)	The difference between the EIRP and the APIP.
3 dB Beamwidth	The angle between the locations of the half-power (3 dB down) points referenced against the location of the highest EIRP of the azimuth cut.



OTA MEASUREMENT SUMMARY

PHI POLARITY AND THETA POLARITY VISUALIZATION



OTA TEST DESCRIPTION



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	4/18/2024	36 mo
Antenna - Dipole	ETS Lindgren	3126-2150	OTG	3/6/2023	36 mo
Chamber - OTA	ETS Lindgren	AMS-8923-195	OTA	10/8/2024	36 mo
Analyzer - Network Analyzer	Agilent	E5071C	NAM	11/9/2022	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 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:	SCBA G1 Beacon
Serial Number:	DUT 1
Customer:	MSA Innovation, LLC
Attendees:	Charlie
Customer Project:	None
Tested By:	Christopher Heintzelman
Test Run Description:	DUT_1_ANT1 BEAC_Free

Work Order:	F3EN0255
Date:	2/24/2025
Temperature:	22.5 °C
Relative Humidity:	26.7% RH
Bar. Pressure:	1005 mbar
Job Site:	MN10

COMMENTS

Beacon antenna 1 in free space. The maximum measured gain is 3.22 dBi at 2440 MHz.

3D PATTERN DATA

Frequency (MHz)	2200	2220	2240	2260	2280	2300	2320	2340	2360	2380	2400
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
Tot. Rad. Pwr. (dBm)	-3.05	-2.63	-2.33	-2.15	-1.76	-1.65	-1.48	-1.47	-1.47	-1.47	-1.60
Peak EIRP (dBm)	0.84	1.26	1.51	1.58	2.03	2.19	2.45	2.57	2.81	3.12	3.08
Directivity (dBi)	3.88	3.89	3.84	3.73	3.79	3.84	3.93	4.05	4.27	4.59	4.69
Efficiency (dB)	-3.05	-2.63	-2.33	-2.15	-1.76	-1.65	-1.48	-1.47	-1.47	-1.47	-1.60
Efficiency (%)	49.60	54.58	58.42	60.99	66.64	68.45	71.12	71.22	71.30	71.26	69.16
Gain (dBi)	0.84	1.26	1.51	1.58	2.03	2.19	2.45	2.57	2.81	3.12	3.08
Average Gain (dB)	-3.05	-2.63	-2.33	-2.15	-1.76	-1.65	-1.48	-1.47	-1.47	-1.47	-1.60
E-Plane 3 dB BW (°)	77.00	79.00	80.00	84.00	83.00	82.00	82.00	79.00	78.00	82.00	77.00

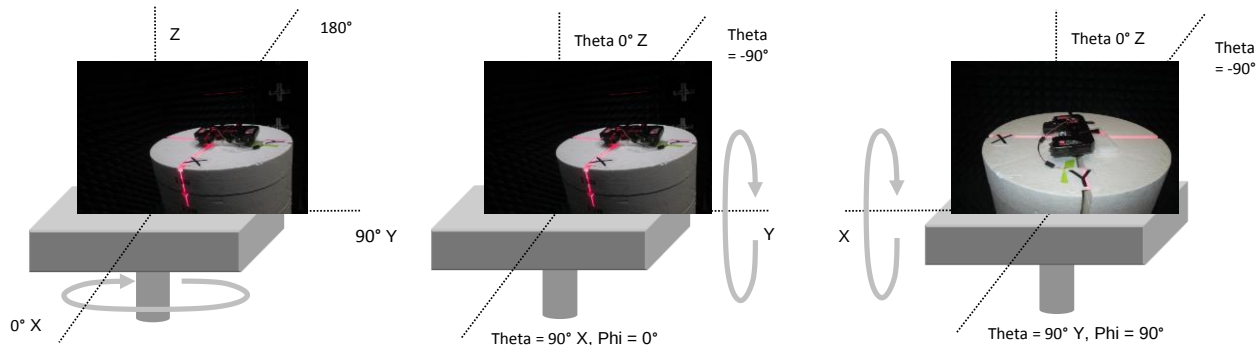
Frequency (MHz)	2420	2440	2460	2480	2500	2520	2540	2560	2580	2600	2620
Ant. Port Input Pwr. (dBm)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Tot. Rad. Pwr. (dBm)	-1.39	-1.36	-1.40	-1.69	-1.65	-1.52	-1.93	-1.97	-1.97	-2.22	-2.46
Peak EIRP (dBm)	3.18	3.22	2.94	2.50	2.68	2.82	2.09	2.09	2.10	2.00	1.77
Directivity (dBi)	4.57	4.58	4.34	4.19	4.33	4.33	4.02	4.07	4.08	4.22	4.23
Efficiency (dB)	-1.39	-1.36	-1.40	-1.69	-1.65	-1.52	-1.93	-1.97	-1.97	-2.22	-2.46
Efficiency (%)	72.59	73.14	72.50	67.80	68.41	70.52	64.09	63.47	63.49	59.92	56.72
Gain (dBi)	3.18	3.22	2.94	2.50	2.68	2.82	2.09	2.09	2.10	2.00	1.77
Average Gain (dB)	-1.39	-1.36	-1.40	-1.69	-1.65	-1.52	-1.93	-1.97	-1.97	-2.22	-2.46
E-Plane 3 dB BW (°)	89.00	89.00	90.00	88.00	84.00	80.00	89.00	97.00	98.00	97.00	95.00

Frequency (MHz)	2640	2660	2680	2695
Ant. Port Input Pwr. (dBm)	0.00	0.00	0.00	0.00
Tot. Rad. Pwr. (dBm)	-2.65	-2.73	-2.94	-3.13
Peak EIRP (dBm)	1.52	1.50	1.12	1.22
Directivity (dBi)	4.17	4.24	4.07	4.35
Efficiency (dB)	-2.65	-2.73	-2.94	-3.13
Efficiency (%)	54.26	53.30	50.77	48.59
Gain (dBi)	1.52	1.50	1.12	1.22
Average Gain (dB)	-2.65	-2.73	-2.94	-3.13
E-Plane 3 dB BW (°)	95.00	95.00	95.00	101.00

Azimuth Cut (Theta Axis = 90°)

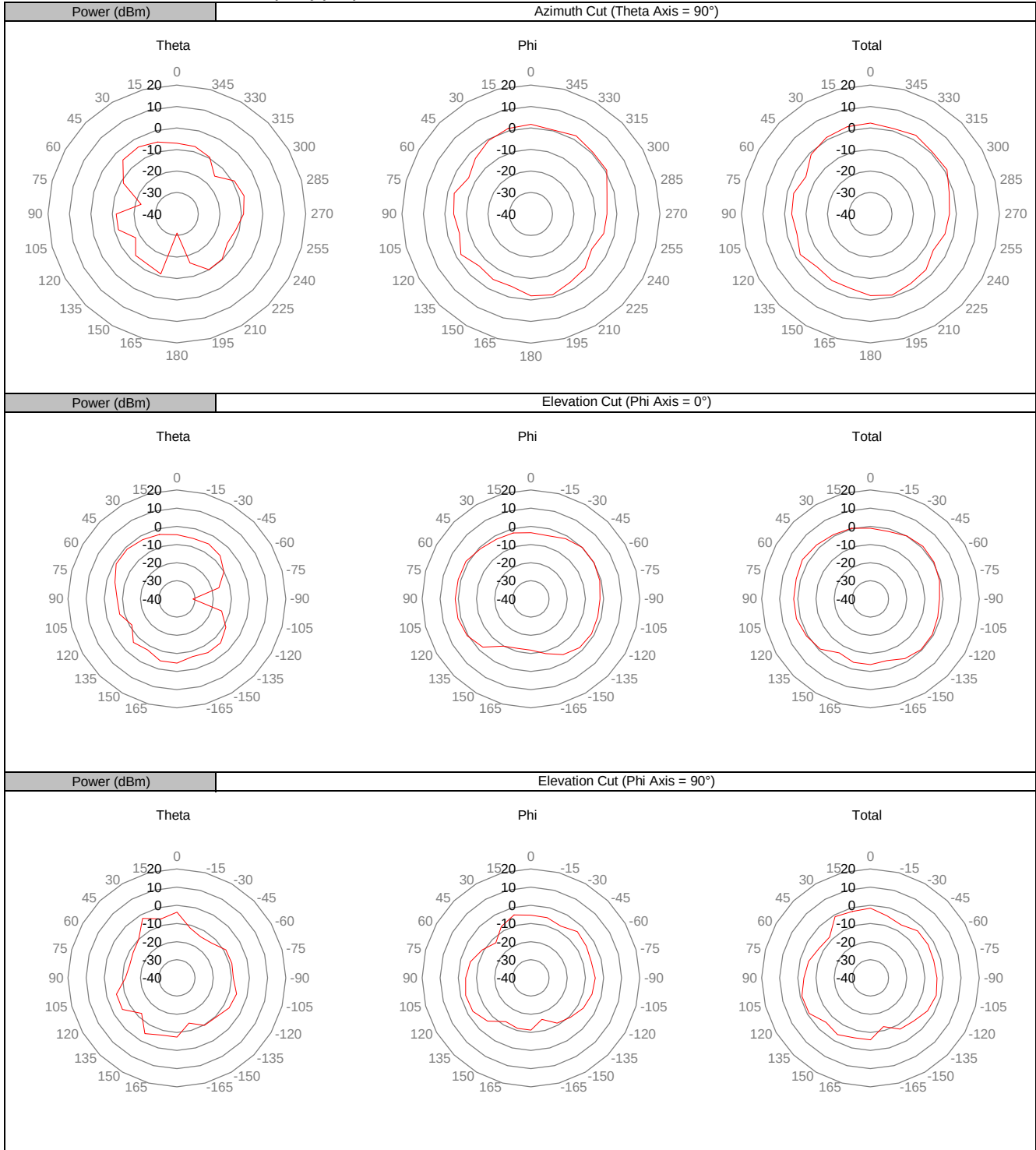
Elevation Cut (Phi Axis = 0°)

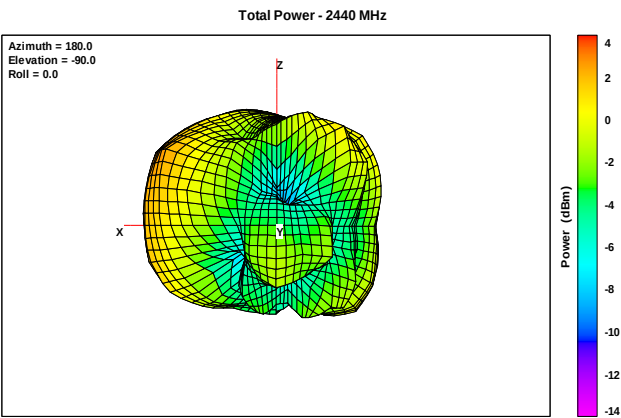
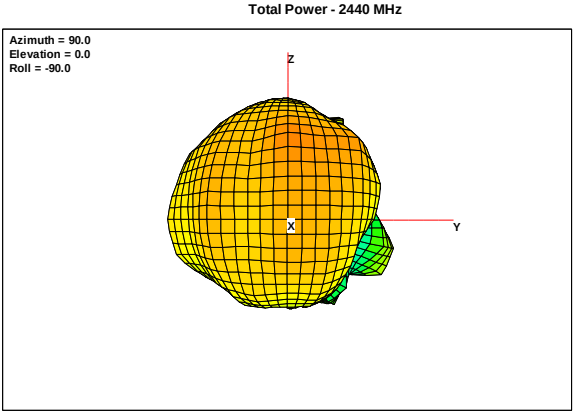
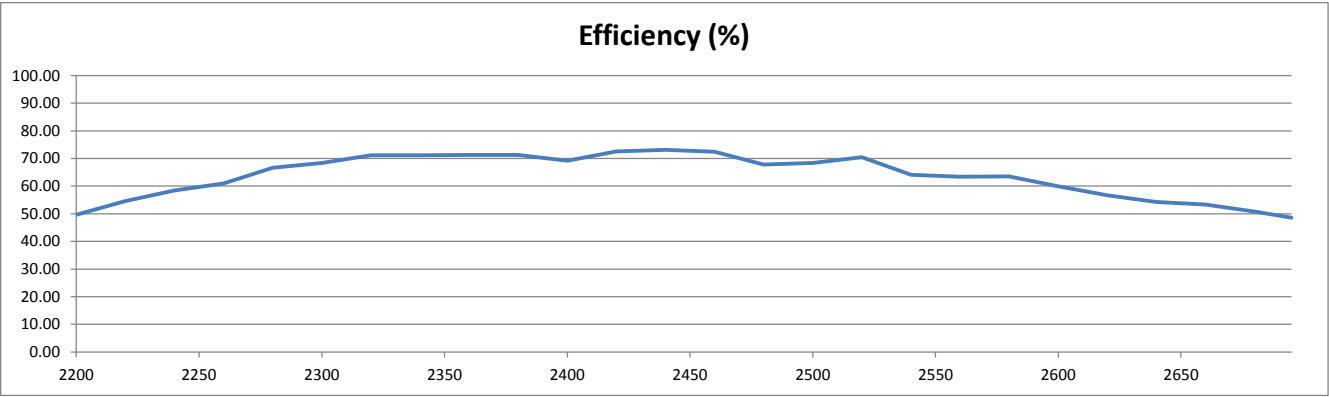
Elevation Cut (Phi Axis = 90°)



POLAR PLOTS

Frequency (MHz): 2440





PASSIVE 3D ANTENNA PATTERN MEASUREMENTS



OTA 2018.01.04

EUT:	SCBA G1 Beacon
Serial Number:	DUT 1
Customer:	MSA Innovation, LLC
Attendees:	Charlie
Customer Project:	None
Tested By:	Christopher Heintzelman
Test Run Description:	DUT_1_ANT2 BEAC_Free

Work Order:	F3EN0255
Date:	2/24/2025
Temperature:	22.5 °C
Relative Humidity:	26.7% RH
Bar. Pressure:	1005 mbar
Job Site:	MN10

COMMENTS

Beacon antenna 2 in free space. The maximum recorded gain was 4.00 dBi at 2460 MHz.

3D PATTERN DATA

Frequency (MHz)	2200	2220	2240	2260	2280	2300	2320	2340	2360	2380	2400
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
Tot. Rad. Pwr. (dBm)	-5.04	-4.44	-3.99	-3.64	-3.05	-2.72	-2.30	-2.09	-1.85	-1.71	-1.86
Peak EIRP (dBm)	-0.78	-0.06	0.62	1.14	1.94	2.43	2.94	3.22	3.50	3.53	3.34
Directivity (dBi)	4.27	4.38	4.62	4.78	4.99	5.15	5.24	5.31	5.34	5.24	5.20
Efficiency (dB)	-5.04	-4.44	-3.99	-3.64	-3.05	-2.72	-2.30	-2.09	-1.85	-1.71	-1.86
Efficiency (%)	31.33	35.93	39.88	43.24	49.53	53.48	58.87	61.75	65.36	67.48	65.22
Gain (dBi)	-0.78	-0.06	0.62	1.14	1.94	2.43	2.94	3.22	3.50	3.53	3.34
Average Gain (dB)	-5.04	-4.44	-3.99	-3.64	-3.05	-2.72	-2.30	-2.09	-1.85	-1.71	-1.86
E-Plane 3 dB BW (°)	66.00	67.00	66.00	63.00	57.00	55.00	54.00	49.00	52.00	55.00	59.00

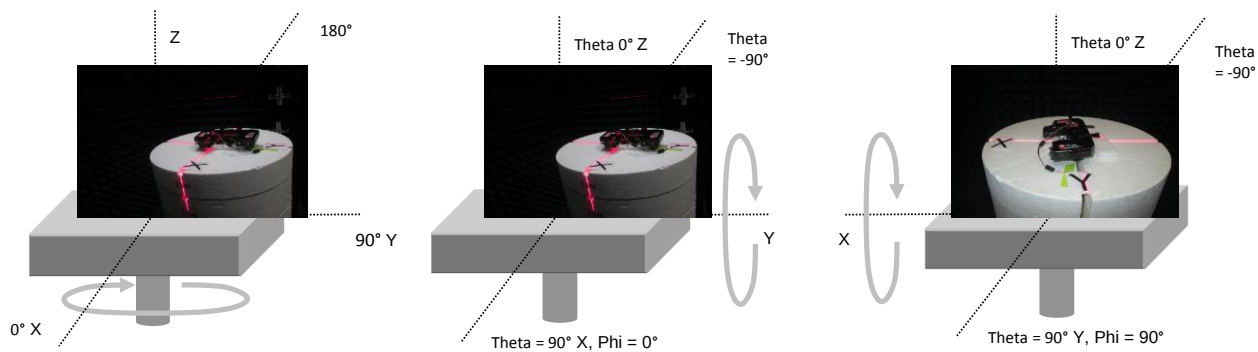
Frequency (MHz)	2420	2440	2460	2480	2500	2520	2540	2560	2580	2600	2620
Ant. Port Input Pwr. (dBm)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Tot. Rad. Pwr. (dBm)	-1.68	-1.66	-1.74	-2.09	-2.25	-2.29	-2.90	-3.11	-3.23	-3.56	-3.80
Peak EIRP (dBm)	3.53	3.76	4.00	3.91	3.92	3.69	2.88	2.57	2.37	2.15	1.74
Directivity (dBi)	5.21	5.42	5.74	6.00	6.16	5.97	5.77	5.68	5.59	5.71	5.54
Efficiency (dB)	-1.68	-1.66	-1.74	-2.09	-2.25	-2.29	-2.90	-3.11	-3.23	-3.56	-3.80
Efficiency (%)	67.98	68.21	66.96	61.78	59.63	59.08	51.31	48.90	47.58	44.10	41.66
Gain (dBi)	3.53	3.76	4.00	3.91	3.92	3.69	2.88	2.57	2.37	2.15	1.74
Average Gain (dB)	-1.68	-1.66	-1.74	-2.09	-2.25	-2.29	-2.90	-3.11	-3.23	-3.56	-3.80
E-Plane 3 dB BW (°)	60.00	55.00	41.00	39.00	40.00	43.00	45.00	44.00	45.00	45.00	46.00

Frequency (MHz)	2640	2660	2680	2695
Ant. Port Input Pwr. (dBm)	0.00	0.00	0.00	0.00
Tot. Rad. Pwr. (dBm)	-4.02	-4.14	-4.33	-4.50
Peak EIRP (dBm)	1.56	1.51	1.26	0.86
Directivity (dBi)	5.58	5.65	5.60	5.36
Efficiency (dB)	-4.02	-4.14	-4.33	-4.50
Efficiency (%)	39.63	38.55	36.86	35.52
Gain (dBi)	1.56	1.51	1.26	0.86
Average Gain (dB)	-4.02	-4.14	-4.33	-4.50
E-Plane 3 dB BW (°)	49.00	51.00	55.00	57.00

Azimuth Cut (Theta Axis = 90°)

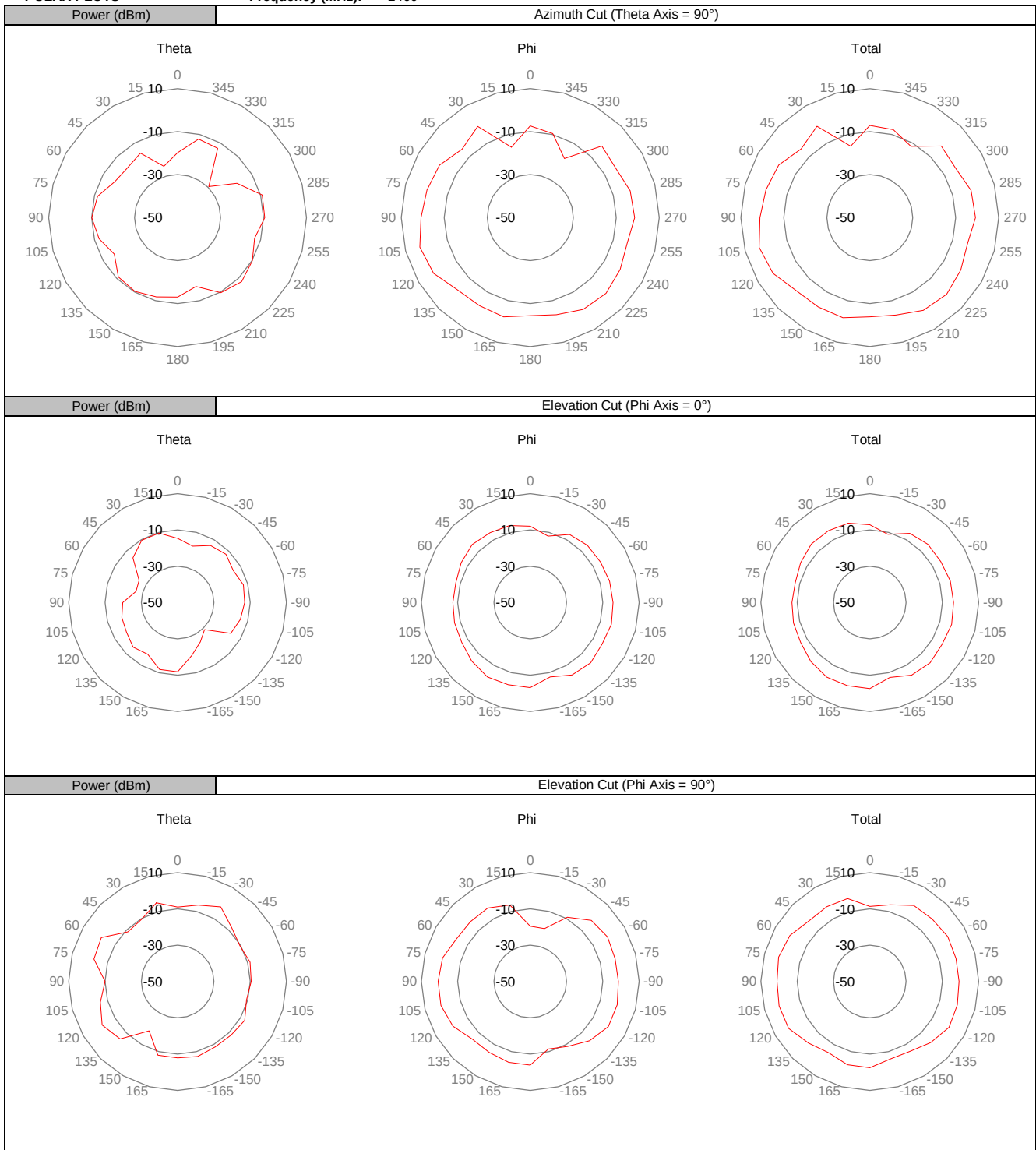
Elevation Cut (Phi Axis = 0°)

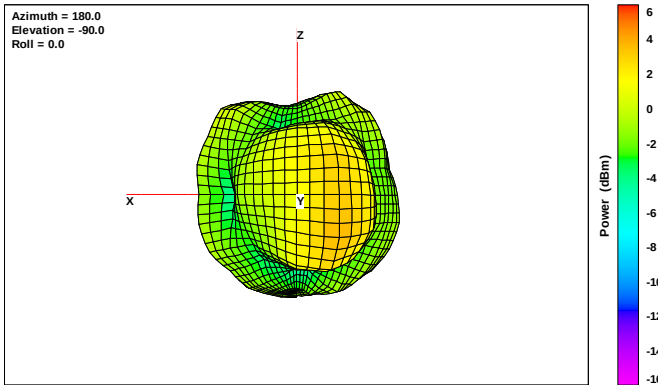
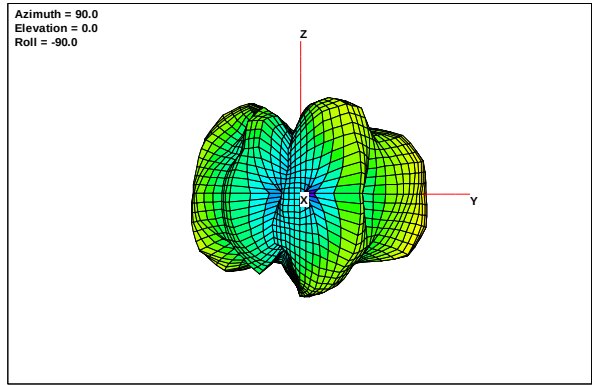
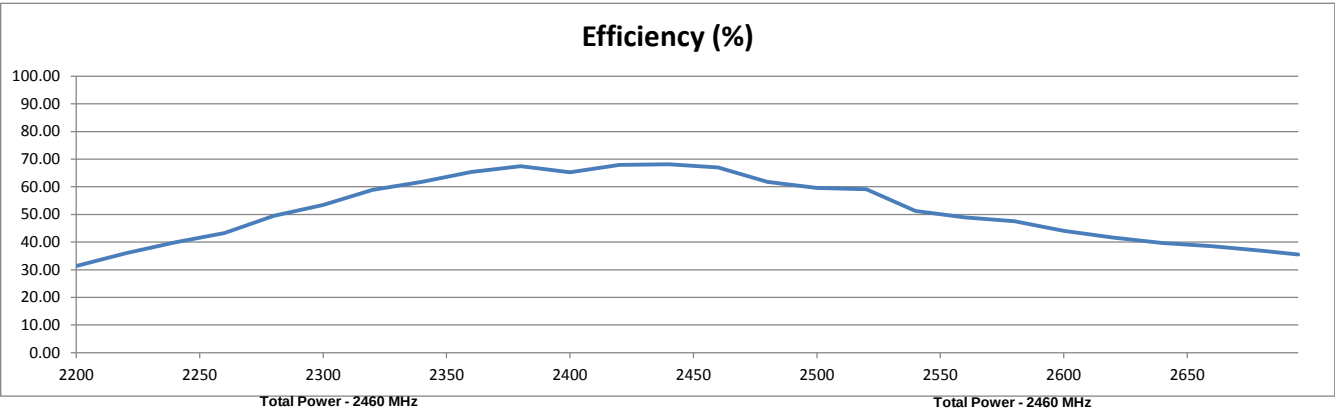
Elevation Cut (Phi Axis = 90°)



POLAR PLOTS

Frequency (MHz): 2460





End of Test Report