

CIA Lab Notes: RSAE-TGU Antenna Analysis (10/09/2024)**1 Introduction**

The data presented below represents the measured data for the TGU as it will be delivered to the end customer, i.e., completely assembled with all production components as intended for production manufacturing.

2 Equipment Used

 Vector Network Analyzer “VNA” used was a CMT (Copper Mountain Technologies) Model: S5085; a 50 Ohm, 2-Port, 2-Path, 9 kHz to 8.5 GHz, S/N: 20107496 (Calibration Date 08.13/2024)

 A CIA custom designed and built, 13 ft. x 9 ft. x 9 ft. anechoic antenna measurement chamber fully lined with Cumming Microwave “C-RAM SFC-18”, 18 in. deep pyramidal absorber and associated Cumming Microwave corner and walkway absorber treatments, see image below.

 The anechoic chamber’s source antenna is a RF Spin Model: QRH11, Quad Ridged Horn Antenna, S/N: 200721Q11.

 Green Heron Engineering Model RT-21D-v4 Deluxe Rotator Controller, S/N: 06152.

 AlfaSpid RAK-1, double worm gear, 550 lb. load capacity, 1 degree/pulse precision, rotator.

 CIA custom designed and built floor level turntable with passthrough coaxial cable and multi-section conical Styrofoam pedestal, customizable to align varied Device Under Test (DUT) sizes.

 The pedestal can be removed to accommodate human test subject with wearable DUT.

 Bosch Professional Laser Level Model GLL 1P 3 601 K66 C10, S/N: 327005416, for Source/DUT alignment.

 CMT (Copper Mountain Technologies) Model: TW-SMA Torque Wrench (no S/N).

 CMT (Copper Mountain Technologies) Model: S911T 3.5 mm Calibration Kit, SN: A266049.

 Various Mini-Circuits “Flex Test” test cables and Precision Pasternack connectors and adapters.

 Precision SMA male to SMA female 27 GHz mitered right angle adapters, Pasternack P/N: PE91504

 Calibrated 170 mm RG-178 DUT coaxial test cable with MMCX male connector.

 Two Teledyne CCR33S80T coaxial switches, for polarization switching, Lot #: TR 109-71-M.

 Two TrackLife Model MDC01 Variable Regulated (0 – 30 V / 5 A max) power supply.

 Various small hand and power tools required for day-to-day antenna design and testing.

 Omano 7x to 45 x trinocular microscope, with Hayear Model: HY-5099 54 MP Industrial Inspection Camera (no S/N) and SW.

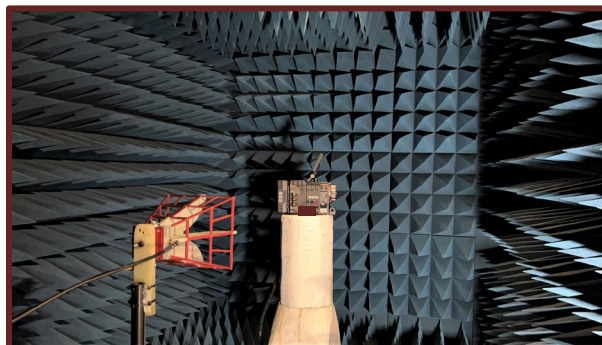
 Mitutoyo, 6 in. ± 0.001 in., Digital Caliper, Model: CD-6 CS, S/N: 0422822.

 L. S. Starrett, 12 inch ± 0.001 in. Precision Caliper, Model 122-12, S/N: QG-1014-1

 HP 50g, Scientific and engineering Graphing Calculator, S/N: CNA3131R9M.

 Canon EOS 5D Camera, with numerous lenses, ranging from MP-E 65 extreme macro to EF 100 – 400 mm Zoom (as needed), numerous flash and lighting solutions, tripods, and numerous other accessories (as needed).

 Fluke 177 True RMS Multimeter S/N: 38480875WS.



CIA's Anechoic Chamber

Custom Integrated Antennas Proprietary Document

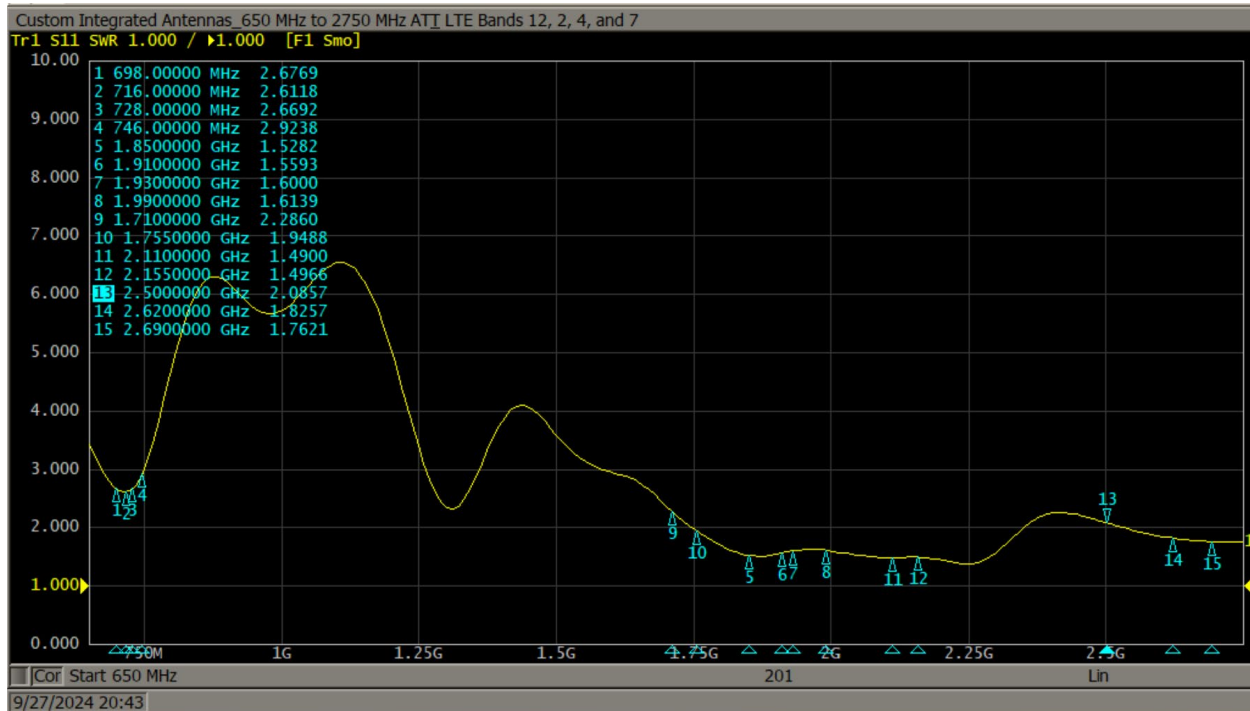
3 DUT As Measured

DUT images have been provided in separate a Device Photos document.

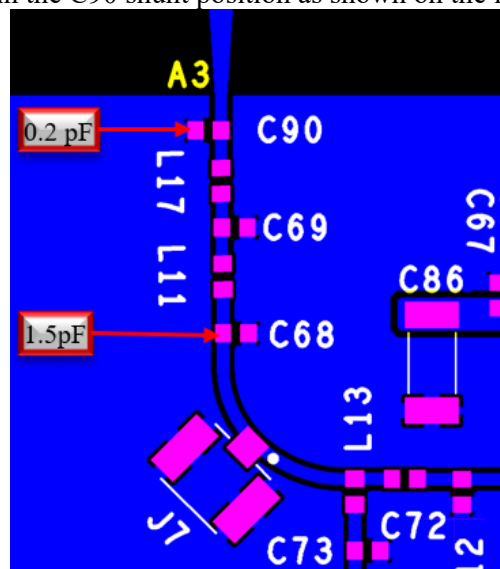
4 TGU Antenna Measurement Data

VSWR indicates peak frequency resonance and impedance match (low values, i.e., closer to 1:1 is better). Other impedance measurement methods are available if desired.

4.1 TGU LTE VSWR



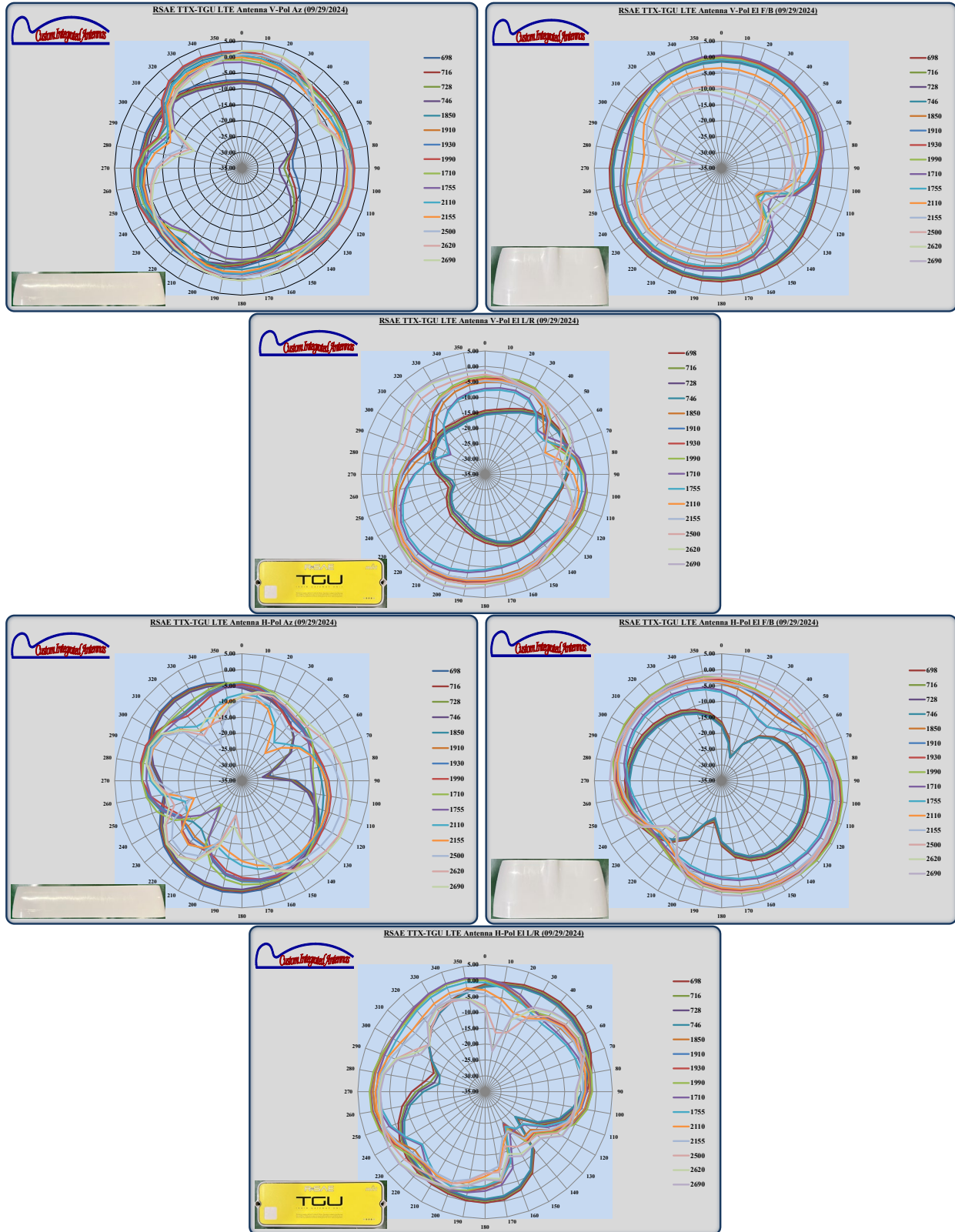
VSWR of the TGU fully assembled TGU in free space, after the SMT matching. The SMT components used were a 1.5 pF muRata P/N: GJM1555C1H1R5BB01 in the C68 shunt position and a 0.2 pF muRata P/N: GJM1555C1HR20BB01 in the C90 shunt position as shown on the image below.



SMT matching components used to achieve the VSWR shown above.

4.2 TGU LTE Antenna Radiation Patterns

4.2.1 Free Space



4.3 LTE Average Gain; Tabular Data

Average Gain Comparison: All data points averaged for each frequency and all angles (dBi)									
Frequency (MHz)	698	716	728	746	1850	1910	1930	1990	1710
RSAE TGU LTE Antenna V-Pol Az (09/29/2024)	-5.16	-5.77	-6.19	-6.60	-1.61	-0.94	-0.76	-0.44	-2.96
RSAE TGU LTE Antenna H-Pol Az (09/29/2024)	-3.80	-4.27	-4.59	-4.83	-5.89	-5.84	-5.85	-6.04	-5.56
RSAE TGU LTE Antenna V-Pol El F/B (09/29/2024)	-0.51	-1.00	-1.33	-1.60	-2.47	-2.60	-2.68	-3.15	-1.95
RSAE TGU LTE Antenna H-Pol El F/B (09/29/2024)	-8.30	-8.91	-9.33	-9.75	-1.64	-0.77	-0.51	-0.02	-3.49
RSAE TGU LTE Antenna V-Pol El L/R (09/29/2024)	-11.77	-12.29	-12.63	-12.92	-3.78	-3.00	-2.77	-2.33	-5.36
RSAE TGU LTE Antenna H-Pol El L/R (09/29/2024)	-2.47	-3.01	-3.38	-3.71	-2.47	-2.15	-2.07	-2.06	-2.84

Average Gain Comparison: All data points averaged for each frequency and all angles (dBi)				Avg Gain (dBi)	Avg Gain (dBi)	Avg Gain (dBi)	Peak Gain (dBi)
Frequency (MHz)	1755	2110	2155	LTE Band12	LTE Band 2	LTE Band 4	
RSAE TGU LTE Antenna V-Pol Az (09/29/2024)	-3.79	-2.10	-2.71	-5.90	-0.92	-2.85	2.30
RSAE TGU LTE Antenna H-Pol Az (09/29/2024)	-6.95	-8.34	-9.06	-4.36	-5.90	-7.27	-0.70
RSAE TGU LTE Antenna V-Pol El F/B (09/29/2024)	-3.38	-6.34	-7.49	-1.09	-2.72	-4.24	0.66
RSAE TGU LTE Antenna H-Pol El F/B (09/29/2024)	-4.15	-1.35	-1.86	-9.04	-0.69	-2.56	4.30
RSAE TGU LTE V-Pol El L/R (09/29/2024)	-6.12	-3.68	-4.16	-12.38	-2.94	-4.73	1.86
RSAE TGU LTE Antenna H-Pol El L/R (09/29/2024)	-4.00	-4.21	-4.96	-3.12	-2.18	-3.94	1.79

Peak gain of all frequencies, polarizations, and angles measured was 4.30 dBi, as indicated in the table above in **red highlight**.

Overall Average Gain of All Frequencies and Orientations Tested (dBi)			
AUT	LTE Band12	LTE Band 2	LTE Band 4
RSAE TTX-TGU LTE Antenna V-Pol Az (09/29/2024)	-4.39	-2.09	-3.86
RSAE TTX-TGU LTE Antenna H-Pol Az (09/29/2024)	-4.86	-2.43	-4.18

Overall Average Gain			
AUT	LTE Band12	LTE Band 2	LTE Band 4
RSAE TGU LTE (09/29/2024)	-4.62	-2.26	-4.02

4.4 TGU MIST VSWR

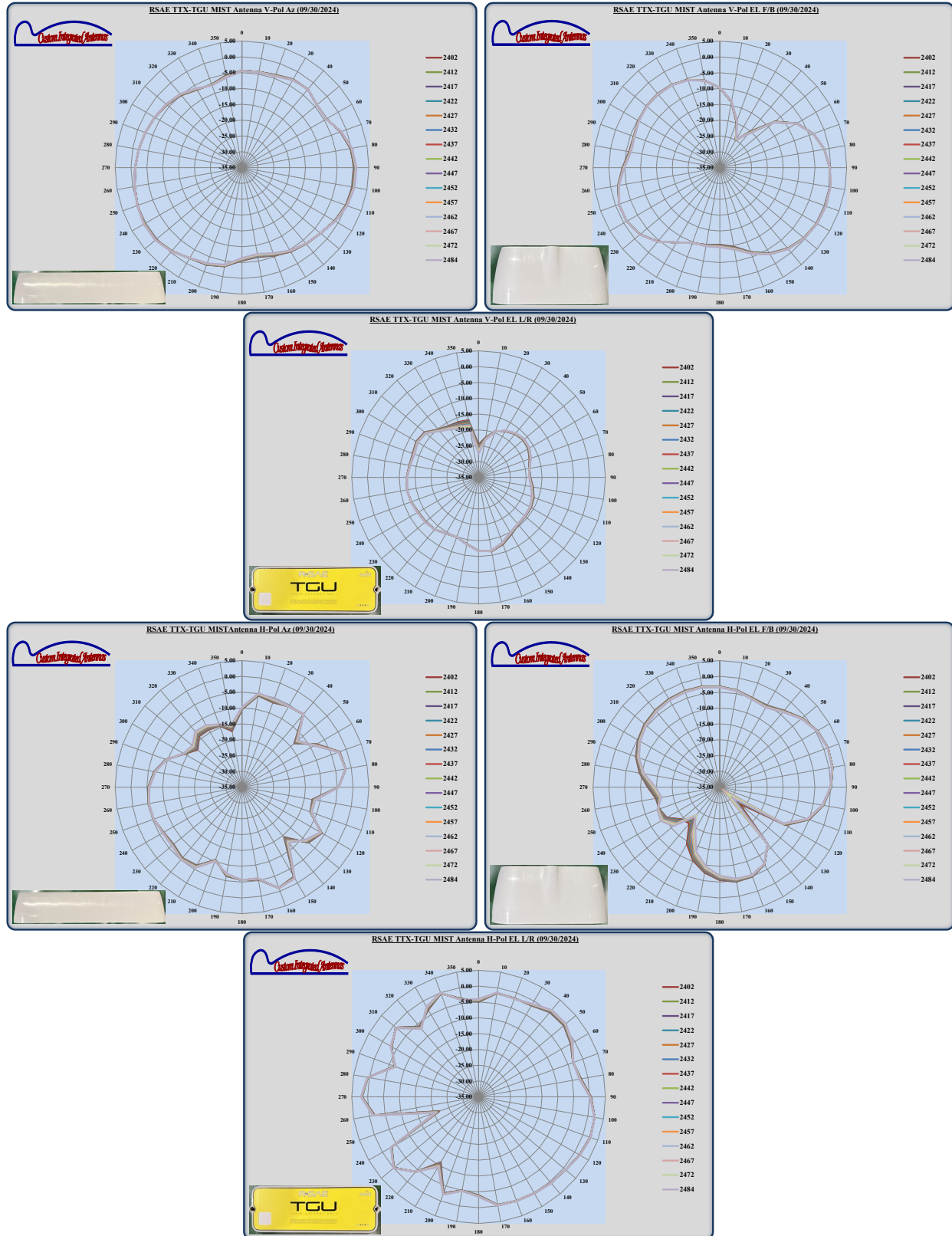


VSWR of the TGU MIST antenna as received (no SMT matching) in free space (live yellow trace) vs. fully assembled and mounted on the 23 in. x 6 in. steel TGU bracket (red memory trace).

I propose no additional SMT matching for this antenna.

4.5 TGU MIST Antenna Radiation Patterns

4.5.1 Free Space



4.6 MIST Average and Peak Gain; Tabular Data

Average Gain Comparison: All data points averaged for each frequency and all angles (dBi)									
Frequency (MHz)	2402	2412	2417	2422	2427	2432	2437	2442	2447
RSAE TTX-TGU MIST Antenna V-Pol Az (09/30/2024)	-2.33	-2.32	-2.31	-2.30	-2.30	-2.29	-2.28	-2.28	-2.27
RSAE TTX-TGU MIST Antenna H-Pol Az (09/30/2024)	-6.44	-6.43	-6.43	-6.42	-6.41	-6.41	-6.40	-6.39	-6.38
RSAE TTX-TGU MIST Antenna V-Pol EL F/B (09/30/2024)	-4.02	-4.01	-4.01	-4.01	-4.00	-4.00	-4.00	-3.99	-3.99
RSAE TTX-TGU MIST Antenna H-Pol EL F/B (09/30/2024)	-4.28	-4.33	-4.36	-4.38	-4.41	-4.44	-4.46	-4.49	-4.52
RSAE TTX-TGU MIST Antenna V-Pol EL L/R (09/30/2024)	-14.64	-14.67	-14.68	-14.70	-14.71	-14.73	-14.74	-14.76	-14.77
RSAE TTX-TGU MIST Antenna H-Pol EL L/R (09/30/2024)	-1.19	-1.16	-1.14	-1.13	-1.11	-1.10	-1.09	-1.07	-1.06

Average Gain Comparison: All data points averaged for each frequency and all angles (dBi)							Avg Gain (dBi)	Max Gain (dBi)
Frequency (MHz)	2452	2457	2462	2467	2472	2484	2.4 GHz ISM Band	
RSAE TTX-TGU MIST Antenna V-Pol Az (09/30/2024)	-2.26	-2.26	-2.25	-2.25	-2.24	-2.23	-2.28	1.06
RSAE TTX-TGU MIST Antenna H-Pol Az (09/30/2024)	-6.37	-6.36	-6.35	-6.34	-6.33	-6.30	-6.39	-1.00
RSAE TTX-TGU MIST Antenna V-Pol EL F/B (09/30/2024)	-3.99	-3.99	-3.98	-3.98	-3.98	-3.97	-4.00	0.60
RSAE TTX-TGU MIST Antenna H-Pol EL F/B (09/30/2024)	-4.55	-4.58	-4.61	-4.64	-4.67	-4.75	-4.50	1.32
RSAE TTX-TGU MIST Antenna V-Pol EL L/R (09/30/2024)	-14.79	-14.80	-14.82	-14.83	-14.85	-14.88	-14.76	-11.27
RSAE TTX-TGU MIST Antenna H-Pol EL L/R (09/30/2024)	-1.04	-1.03	-1.02	-1.01	-0.99	-0.97	-1.07	2.62

Peak gain of all frequencies, polarizations, and angles measured was 2.62 dBi, as indicated in the table above in **red highlight**.

Overall Average Gain of All Frequencies and Orientations Tested (dBi)	
AUT	MIST Band
RSAE TTX-TGU MIST Antenna V-Pol (09/30/2024)	-4.67
RSAE TTX-TGU MIST Antenna H-Pol (09/30/2024)	-3.42

Overall Average Gain	
AUT	MIST Band
RSAE TTX-TGU MIST Antenna (09/30/2024)	-4.00

5 LTE-MIST Isolation

Isolation Between the RSAE-TGU LTE and MIST Antennas (dB)															
Frequency (MHz) -->	2402	2412	2417	2422	2427	2432	2437	2442	2447	2452	2457	2462	2467	2472	2484
Narrow Band MIST Frequencies	-38.66	-38.68	-38.57	-38.53	-38.59	-38.58	-38.41	-38.04	-37.64	-37.45	-37.45	-37.62	-37.99	-38.41	-39.44
Frequency (MHz) -->	698	716	728	746	1850	1910	1930	1990	1710	1755	2110	2155			
Wide Band LTE Frequencies	-43.74	-43.29	-42.93	-42.33	-33.96	-35.59	-35.63	-32.09	-43.09	-40.04	-24.95	-22.87			

FYI: Measured on the anechoic chamber's Styrofoam pedestal to reduce reflections.

6 Conclusions

The measurement data provided by this report represents the TGU product in its very near production quality and most likely its final production form. Therefore, these measurements are very good representation of the antennas the end user will be using.