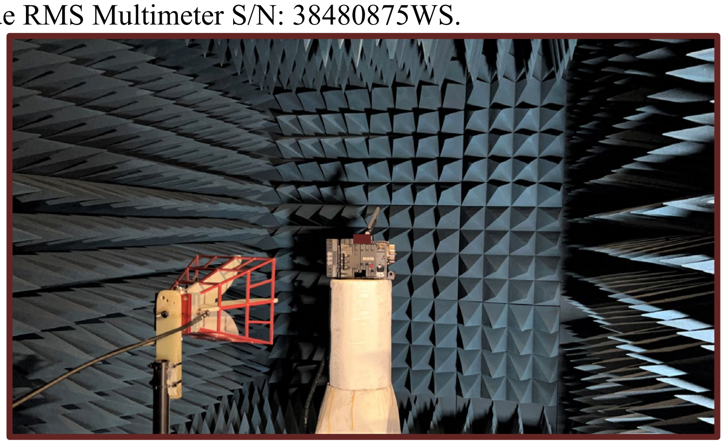
Train Sensor Unit (TSU) MIST Antenna Analysis CIA (09/24/2024)

1 Introduction

The data presented below represents the measured data for the TSU 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.
- Bosch Professional Laser Level Model GLL 1P 3 601 K66 C10, S/N: 327005416
- 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 were used in the closed system setup, as well as Teledyne Model: "CCR33S80T" SPDT coaxial switches.
- Calibrated 100 mm 0.86 mm semi rigid DUT test coaxial cable with SMA connector.
- Precision SMA female to SMA female,18 GHz "bullet" adapters, Pasternack P/N: PE 9695.
- Precision SMA male to SMA female 27 GHz mitered right angle adapter, Pasternack P/N: PE91504
- Various small power and hand tools required for antenna design and testing.
- Two Teledyne CCR33S80T coaxial switches, Lot #: TR 109-71-M.
- Two TrackLife Model MDC01 Variable Regulated (0 – 30 V / 5 A max) power supply.
- Omano 7x to 45 x trinocular microscope, with Hayear Model: HY-5099 (no S/N) Industrial Inspection Camera 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
- 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.



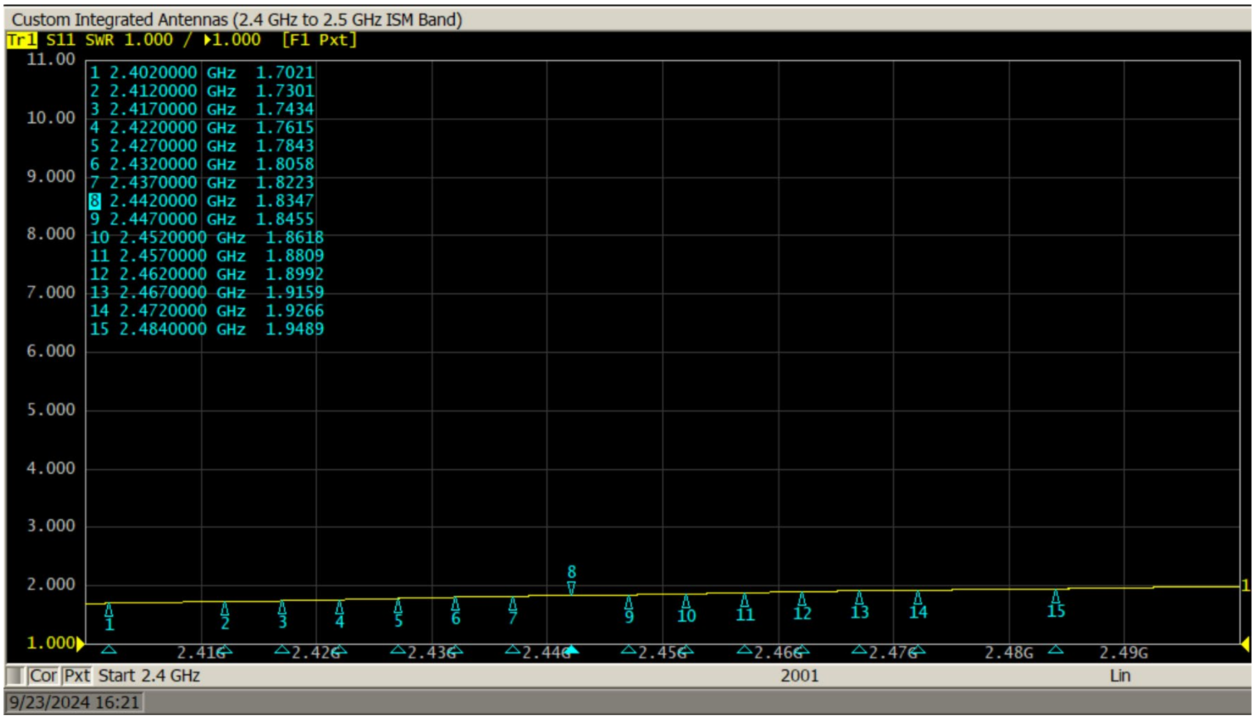
CIA's Anechoic Chamber

3 DUT As Measured

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

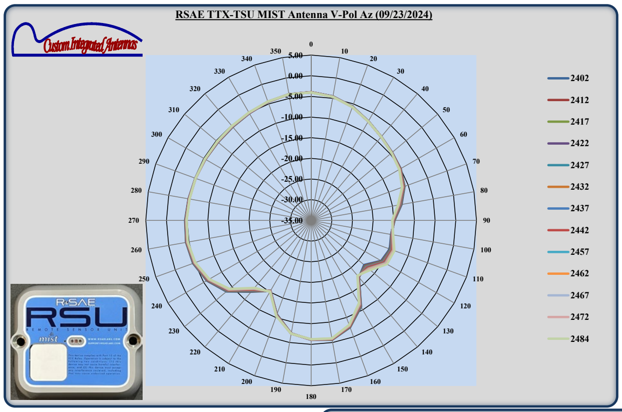
4 TSU Antenna Measurement Data

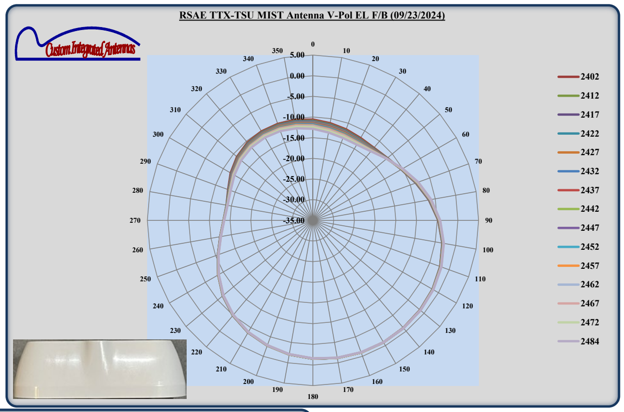
4.1 MIST VSWR

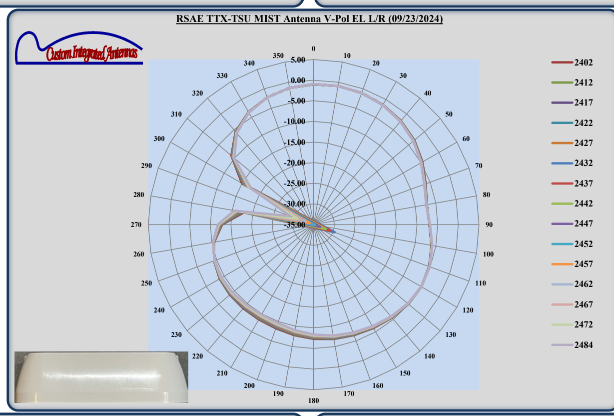


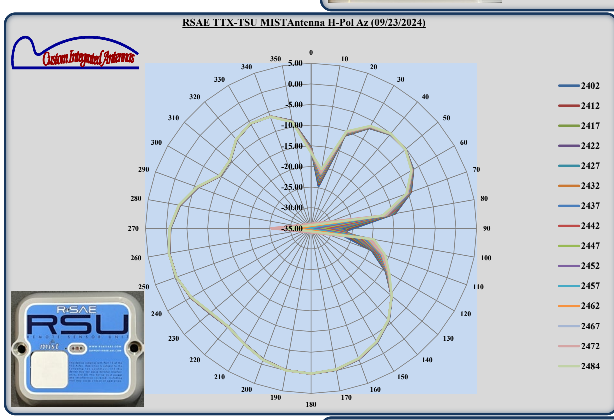
VSWR shown here was after a 3.0 nH inductor (TDK MLG1005S3N0CT000) was placed in the C14 shunt position and a 0.8 pF capacitor (muRata GJM1555C1HR80BB01) was placed in the C15 shunt position. The series L4 position was left alone as a 0 Ohm jumper.

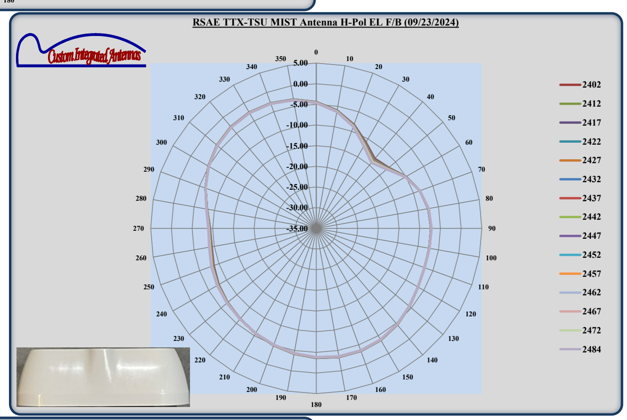
4.2 TSU MIST Antenna Radiation Patterns

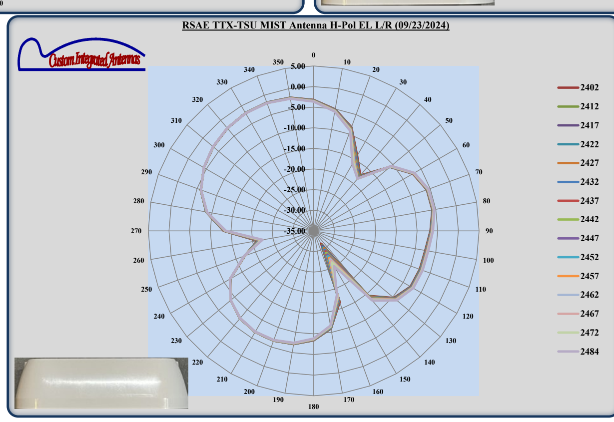












4.3 MIST Average and Peak Gain; Tabular Data

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-TSU MIST Antenna V-Pol Az (09/23/2024)	-7.10	-7.12	-7.14	-7.15	-7.16	-7.17	-7.18	-7.19	-7.19
RSAE TTX-TSU MIST Antenna H-Pol Az (09/23/2024)	-4.30	-4.30	-4.30	-4.30	-4.30	-4.30	-4.30	-4.29	-4.29
RSAE TTX-TSU MIST Antenna V-Pol EL F/B (09/23/2024)	-5.30	-5.30	-5.30	-5.30	-5.30	-5.31	-5.31	-5.31	-5.32
RSAE TTX-TSU MIST Antenna H-Pol EL F/B (09/23/2024)	-5.72	-5.73	-5.73	-5.74	-5.74	-5.75	-5.75	-5.76	-5.76
RSAE TTX-TSU MIST Antenna V-Pol EL L/R (09/23/2024)	-5.21	-5.24	-5.25	-5.27	-5.28	-5.29	-5.31	-5.32	-5.33
RSAE TTX-TSU MIST Antenna H-Pol EL L/R (09/23/2024)	-6.72	-6.72	-6.73	-6.73	-6.73	-6.73	-6.73	-6.73	-6.73

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**	**2.4 GHz ISM Band**
RSAE TTX-TSU MIST Antenna V-Pol Az (09/23/2024)	-7.20	-7.21	-7.22	-7.23	-7.23	-7.25	**-7.18**	**-3.99**
RSAE TTX-TSU MISTAntenna H-Pol Az (09/23/2024)	-4.29	-4.29	-4.29	-4.29	-4.29	-4.29	**-4.30**	**0.23**
RSAE TTX-TSU MIST Antenna V-Pol EL F/B (09/23/2024)	-5.32	-5.33	-5.33	-5.34	-5.34	-5.36	**-5.32**	**-0.90**
RSAE TTX-TSU MIST Antenna H-Pol EL F/B (09/23/2024)	-5.77	-5.78	-5.78	-5.79	-5.79	-5.81	**-5.76**	**-2.64**
RSAE TTX-TSU MIST Antenna V-Pol EL L/R (09/23/2024)	-5.35	-5.36	-5.37	-5.39	-5.40	-5.43	**-5.32**	**-0.90**
RSAE TTX-TSU MIST Antenna H-Pol EL L/R (09/23/2024)	-6.73	-6.73	-6.73	-6.73	-6.73	-6.73	**-6.73**	**-1.87**

Peak gain of all frequencies, polarizations, and angles measured was 0.23 dBi, as indicated in the table above in red highlight.

Averaged Efficiency of All Frequencies and Orientations Tested (dBi)	
AUT	**MIST Band**
RSAE TTX-TSU MIST Antenna V-Pol	0.26
RSAE TTX-TSU MIST Antenna H-Pol	0.28

Overall Average Gain	
AUT	**MIST Band**
RSAE TTX-TSU MIST Antenna	-5.66

Overall Average Efficiency (%)	
AUT	**MIST Band**
RSAE TTX-TSU MIST Antenna	27.15%

5 Conclusions

The MIST antenna did suffer from additional radiation absorption in the double walled plastic housing that has a total plastic thickness of 3.35 mm. There are also 8 screw bosses, two stainless steel bushings, and a tapered air gap in the housing design that tend to influence pattern as well as lead to more additional energy loss. These design features are necessary to protect the device from the harsh environment of high levels of vibration and impact expected for the intended use on train cars for many years, as well as to meet strict incendiary, environmental, and other rigorous product requirements. Therefore, the additional loss is unavoidable.