Project 22523-15

FreeFlight

RA-6500

Radar Altimeter

Wireless Certification Report

Prepared for:

FreeFlight Systems
7333 Interstate 35 South
Robinson, TX 76706

By

Professional Testing (EMI), Inc.
1601 North A.W. Grimes Blvd., Suite B
Round Rock, Texas 78665

8 February 2022

Reviewed by

Larry Finn
CTO

Written by

Shakil Murad
EMC Engineer

Revision History

Revision Number	Description	Date
Draft 01	For review and comment	12/20/2021
Final 01	Release to agency	1/10/2022
Final 02	Removed setup photos; clarified calculations	1/28/2022
Final 03	Correct calculations	2/8/2022
Final 04	Corrected Power Values	2/8/2022

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Certificate of Compliance

FCC MRA Designation Number: US5270
NVLAP Accreditation Number: 200062-0

Applicant	EUT Identification	
FreeFlight Systems 7333 Interstate 35 South Robinson, TX 76706	Model #: Part #: Serial #: FCC ID:	RA-6500 87990-11 2142X005 T7YRA6XXX

The EUT model(s) listed above were tested utilizing the following documents and found to be in compliance with the required criteria.

47 CFR, FCC, Part 87 and Part 2	
Section	**Description**
87.131; 2.1046	Conducted output power
87.135; 2.1049	Occupied bandwidth
87.139; 2.1047	Modulation characteristics
87.139; 2.1051	Conducted Spurious Emissions
87.139; 2.1053	Radiated Spurious Emissions
87.133; 2.1055	Frequency stability

I, Shakil Murad, for Professional Testing (EMI), Inc., being familiar with the above rules and test procedures have reviewed the test setup, measured data, and this report. I believe them to be true and accurate.

TESTING
NVLAP LAB CODE 200062-0

Shakil Murad
EMC Engineer

This report has been reviewed and accepted by the Applicant**.** The undersigned is responsible for ensuring that this device will continue to comply with the requirements listed above.

_____
Representative of Applicant

1.0 Introduction

1.1 Scope

This report describes the extent to which the equipment under test (EUT) conformed to the intentional radiator requirements of the United States.

1.2 EUT Description

Table 1.2.1: Equipment Under Test

Manufacturer	Part	Model #	Serial #	FCC ID
FreeFlight Systems	Radar Altimeter	RA-6500	1948X016	T7YRA6XXX
Frequency Range (MHz): 4200 - 4400				
Modulation Methods: FMCW				
Operating Voltage: 28 VDC				

Table 1.2.2: Support Equipment

Manufacturer	Part	Model #	Serial #	FCC ID
N/A	N/A	N/A	N/A	N/A

Table 1.2.3: EUT Options

Description	Gain	Notes
N/A	N/A	N/A

1.3 Modifications to EUT

None.

1.4 Measurement Correction Methods

Table 1.4.1: Measurement Corrections

Parameter	From Sums Of
Radiated Field Strength	Raw Measured Level + Antenna Factor + Cable Losses – Amplifier Gain
Conducted Antenna Port	Raw Measured Level + Attenuator Factor + Cable Losses

Additionally, measurement distance extrapolation factors (such as 1/d above 30 MHz) are applied and documented where used.

1.5 Test Site

Measurements were made at the PTI semi-anechoic facility designated Site 45 (FCC 776781, IC 3036B-1) in Austin, Texas. The site is registered with the FCC under Section 2.948 and Industry Canada per RSS-GEN, and is subsequently confirmed by laboratory accreditation (NVLAP). The test site is located at 11400 Burnet Road, Austin, Texas 78758, while the main office is located at 1601 North A.W. Grimes Boulevard, Suite B, Round Rock, Texas, 78665. CAB Identifier: US 0123.

Professional Testing (EMI), Inc., (PTI) follows the guidelines of National Institute of Standards and Technology (NIST) for all uncertainty calculations, estimates, and expressions thereof for electromagnetic compatibility testing.

2.0 Applicable Documents

Table 2.1.1: Applicable standards

Document #	Title/Description
ANSI C63.26-2015	American National Standard for Compliance Testing of Transmitters Used in Licensed Radio Services
47 CFR	FCC Part 87 – Subpart D – Technical requirements FCC Part 2 – Subpart J – Equipment authorization procedures

3.0 Summary of Test Results

Test	Test Reference Section	Result
Conduced Output Power	2.1046/87.131	Pass
Occupied Bandwidth	2.1049/87.135	Pass
Modulation characteristics	2.1047/87.139	NA
Frequency Stability	2.1055/87.133	Pass
Conducted Spurious Emissions	2.1051/87.139	Pass
Radiated Spurious Emissions	2.1053/87.139	Pass

4.0 Conducted Output Power at Antenna Terminal

4.1 Test Procedure

The output of the EUT was connected directly to an attenuator and then to the spectrum analyzer. A peak detector was used for the measurement. The transmitter was switched on, and the measurement receiver was tuned to the frequency of the transmitter under test. The loss of the attenuator and cable were compensated by adding an offset to the analyzer amplitude. Power was measured directly with the spectrum analyzer using a resolution bandwidth greater than the occupied bandwidth of the transmitter.

4.2 Test Result

Table 4.2.1: Peak Output Power - Conducted

Environmental Conditions:	Temperature		25.1	°C	Humidity	51	RH	Barometric Pressure		29.98	in Hg
Measurement Parameters:	RBW	3	MHz	VBW	50	MHz	Span	125	MHz	Detector	Peak
Frequency	Measured Power	Attenuator+Cable Loss		Corrected Power			Power		Power		
(GHz)	(dBm)	(dB)		(dBm)			(mW)		(Watts)		
4.25-2.35	-6.35	32.68		26.33			430		0.43		

4.3 Test Equipment List

Asset#	Manufacturer	Model	Equipment Nomenclature	Serial Number	Calibration Due Date
2262	Keysight	E4440A	Spectrum Analyzer, 3 Hz - 26.5 GHz	MY42510155	11/8/2023
A122	JFW	50HF-030-25/18	Attenuator, N, 30dB 25W, DC-18GHz	None	6/25/2022
C118	Harbour Industries	MIL-C-17/60C-RB142	Cable, RF, SMA-TNC, 1.52m, Brown	None	6/2/2022
PTI55	Bracke Manufacturing	BM11074	Termination, 50Ω, 5W, 18 GHz	None	N/A

5.0 Occupied Bandwidth

5.1 Test Procedure

The output of the EUT was connected to an attenuator and then to the spectrum analyzer. The spectrum analyzer was tuned to the frequency of the transceiver under test and the EUT activated in continuous transmit mode. Bandwidth is measured relative to the peak power measurement measured separately in full bandwidth.

5.2 Test Criteria

Table 5.2.1: Authorized Allocated Bandwidth, 87.135; 87.137; 2.1049

4.2 GHz to 4.4 GHz (200 MHz)

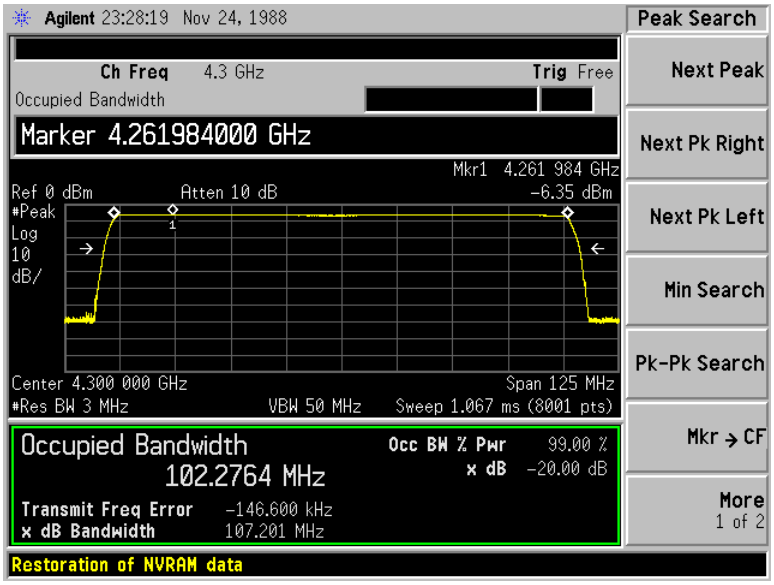
5.3 Test Results

Table 5.3.1: Occupied Bandwidth - Conducted

Environmental Conditions:	Temperature	25.1 °C	Humidity	51 RH	Barometric Pressure	29.98 in Hg
Measurement Parameters:	RBW	3 MHz	VBW	50 MHz	Span	125 MHz
Measurement Bandwidth:	99 %					

Frequency (GHz)	Measured Bandwidth (MHz)
4.25 - 4.35	102.2764

Conclusion: The occupied bandwidth is within the 200 MHz authorized bandwidth, therefore, the EUT satisfied the requirements. Results appear below.



Bandwidth 99%

5.4 Test Equipment List

Asset#	Manufacturer	Model	Equipment Nomenclature	Serial Number	Calibration Due Date
2262	Keysight	E4440A	Spectrum Analyzer, 3 Hz - 26.5 GHz	MY42510155	11/8/2023
A122	JFW	50HF-030-25/18	Attenuator, N, 30dB 25W, DC-18GHz	None	6/25/2022
C118	Harbour Industries	MIL-C-17/60C-RB142	Cable, RF, SMA-TNC, 1.52m, Brown	None	6/2/2022
PTI55	Bracke Manufacturing	BM11074	Termination, 50Ω, 5W, 18 GHz	None	N/A

6.0 Modulation Characteristics

The EUT is a Frequency-Modulated Continuous-wave (FMCW) radar device that transmits no message and utilizes no modulation. Therefore, no modulation curves are available or required.

7.0 Spurious Emissions at Antenna Terminals

7.1 Test Procedure

The output of the EUT was connected directly to an attenuator and then to the spectrum analyzer. A peak detector was used for the measurement. The EUT was switched on and the transmitter was transmitting continuously. Spurious power was then measured directly with the spectrum analyzer.

7.2 Test Criteria

Table 7.2.1: Spurious Limit, 2.1051/87.139

Limit:	***40 dBc***

7.3 Test Results

Table 7.3.1.1: Conducted Spurious Emissions Test Results Summary:

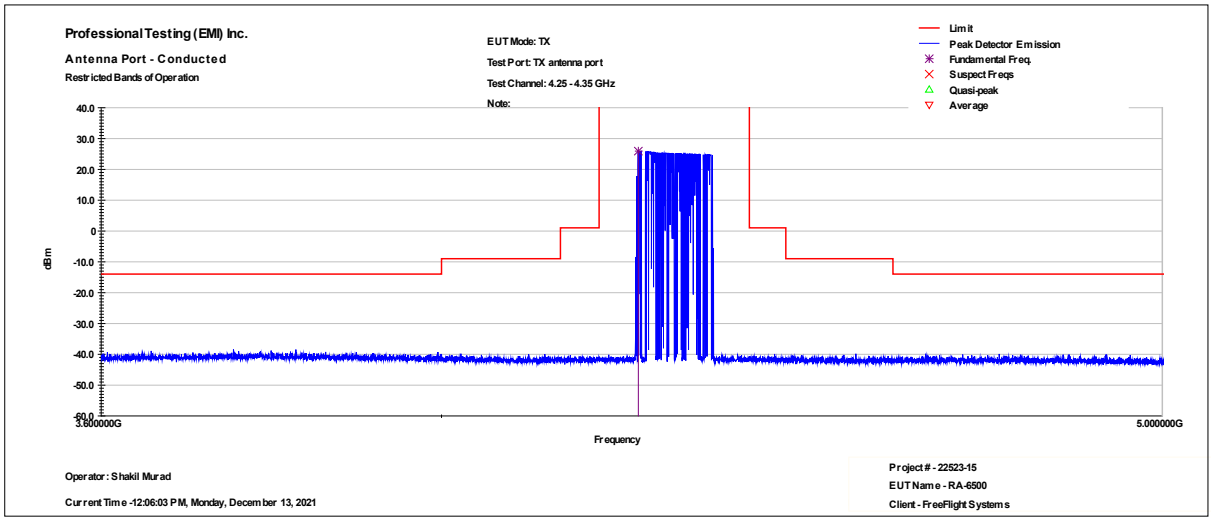
EUT Name	**RA-6500**		**Model or Serial #**	2142X005	
EUT Line Voltage	**28**	**VDC**	**Frequency**		Hz
Frequency Range			**Test Results**		
9kHz to 30MHz			**Pass**		
30MHz to 26.5GHz			**Pass**		
26.5GHz to 40GHz			**Pass**		
Notes:					

7.4 Test Data

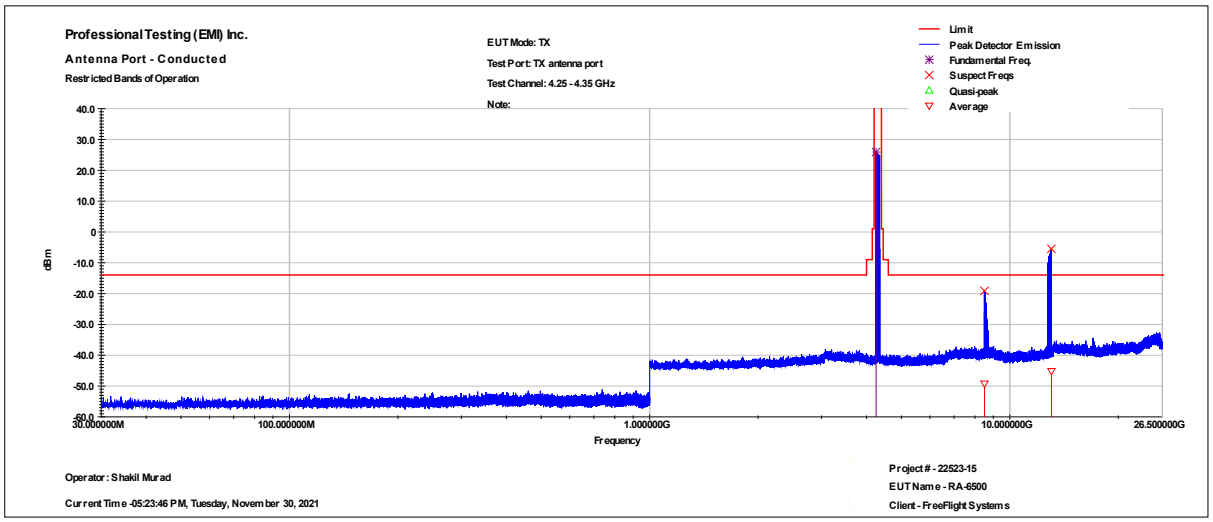
9kHz – 30MHz Conduced Spurious Emissions Data

All emissions from 9 kHz to 30 MHz were found to greater than 20 dB below the limit or were at the noise floor. Therefore, per 2.1057, no data is being reported.

Conducted Spurious; 87.139(a)(1-3) Mask Detail



30MHz– 26.5GHz Conduced Spurious Emissions Data



Frequency (MHz)	Average Reading (dBm)	Limit (40 dBc)	Margin (dB)	Results
8503.008	-49.242	-14	35.242	PASS
13048.45	-45.196	-14	31.196	PASS

26.5GHz - 40GHz Conduced Spurious Emissions Data

All emissions from 26.5 GHz to 40 GHz were found to greater than 20 dB below the limit, or were at the noise floor. Therefore, per 2.1057, no data is being reported.

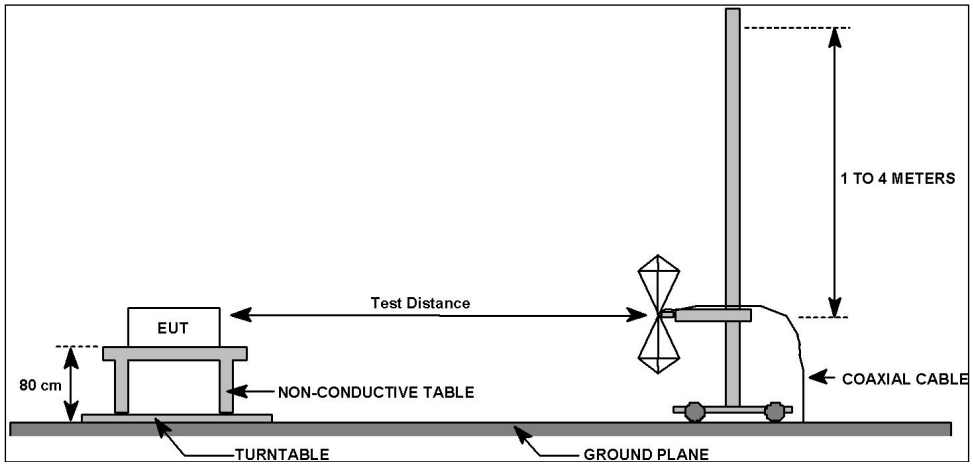
7.5 Test Equipment List

Asset#	Manufacturer	Model	Equipment Nomenclature	Serial Number	Calibration Due Date
2262	Keysight	E4440A	Spectrum Analyzer, 3 Hz - 26.5 GHz	MY42510155	11/8/2023
PTI55	Bracke Manufacturing	BM11074	Termination, 50Ω, 5W, 18 GHz	None	N/A

8.0 Field Strength of Spurious Emissions

8.1 Test Procedure

The EUT was placed on a non-conductive table 0.8 meters above the ground plane. The table was centered on a rotating turntable at a distance of 10 meters from the measurement antenna. The EUT was placed into transmit mode with the antenna removed and a resistive terminator substituted.



Field Strength of Radiated Emissions Test Setup

8.2 Test Criteria

Table 8.2.1: Radiated Spurious Limit from Calculated Power -14 dBm

Method:	$P_r = P_t + G_t + G_r + 20\log_{10}\left(\frac{\lambda}{4\pi R}\right)$, where λ = c/fMHz, c=300, f=4300 λ = 300/4300= 0.0698
Path Loss Term:	3 m: 20 $\log_{10}$ (λ/ 4πR) = 20 $\log_{10}$ (0.0698/ 4π3) = --54.6536 dB 1 m: 20 $\log_{10}$ (λ/ 4πR) = 20 $\log_{10}$ (0.0698/ 4π1) = -45.1111 dB 0.1 m: 20 $\log_{10}$ (λ/ 4πR) = 20 $\log_{10}$ (0.0698/ 4π0.1) = -25.1111 dB
Power at *R*:	3 m: -14.0 dBm + 0 dB + 0 dB + [-54.6536 dB] = -68.6536 dBm 1 m: -14.0 dBm + 0 dB + 0 dB + [-45.1111 dB] = -59.1111 dBm 0.1 m: -14.0 dBm + 0 dB + 0 dB + [-25.1111 dB] = -39.1111 dBm
Field Strength Limit Conversion Formula:	$E(dB\mu V/m) = P_{meas}(dBm) - P_{gain}(dB) + 77.2dB + 20\log(f, MHz) - G_{ant}(dB)$
Field Strength Limit Calculation, 3 m:	[-68.6536dBm] – 0 dB + 77.2 dB + 20 $\log_{10}$ (4300 MHz) - 0 dB = 81.2158 dBµV/m
Field Strength Limit Calculation, 1 m:	[-59.1111 dBm] – 0 dB + 77.2 dB + 20 log10 (4300 MHz) - 0 dB = 90.7582 dBµV/m
Field Strength Limit Calculation, 0.1 m:	[-39.1111 dBm] – 0 dB + 77.2 dB + 20 log10 (4300 MHz) - 0 dB = 110.7582 dBµV/m

Calculation Reference: Public Safety Tech Topic #17 - Propagation Characterization
https://www.fcc.gov/help/public-safety-tech-topic-17-propagation-characterization?fontsize=mediumFont

8.3 Test Results

The EUT satisfied the requirements. Plotted measurements appear below.

Emissions were below the peak/QP limits of Part 15 and are reflected in the test data section.

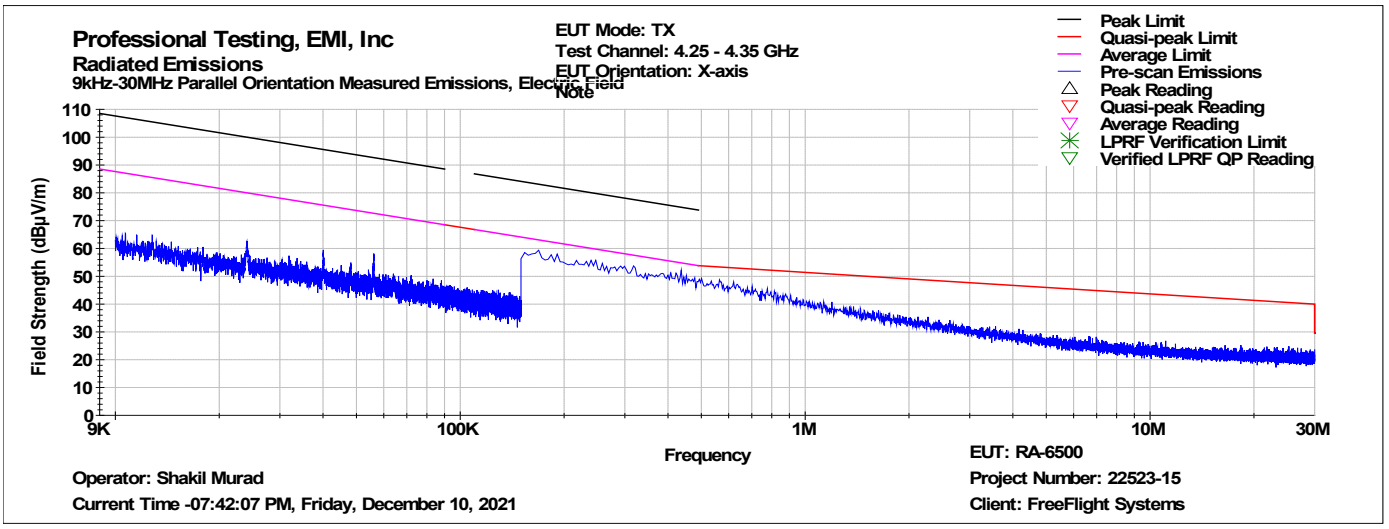
Where it applies, the 87.139 field limits calculated are included as the uppermost limit line in the plotted results.

Table 8.3.1.1: Radiated Spurious Emissions Test Results Summary:

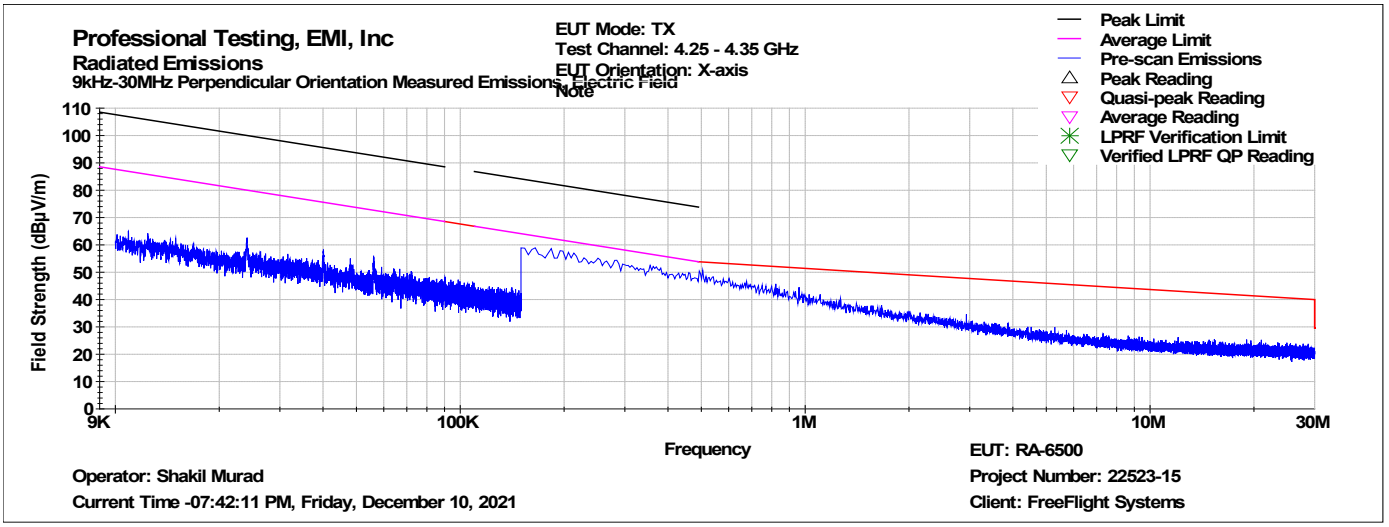
EUT Name	**RA-6500**		**Model or Serial #**	2142X005	
EUT Line Voltage	**28**	**VDC**	**Frequency**		Hz
Frequency Range	**Test Distance (Meters)**		**Antenna Polarization**	**Test Results**	
9kHz to 30MHz	**3**		**Parallel**	**Pass**	
			Perpendicular	**Pass**	
30MHz to 1GHz	**10**		**Vertical**	**Pass**	
			Horizontal	**Pass**	
1GHz to 18GHz	**3**		**Vertical**	**Pass**	
			Horizontal	**Pass**	
18GHz to 26.5GHz	**1**		**Vertical**	**Pass**	
			Horizontal	**Pass**	
26.5GHz to 50GHz	**0.01**		**Vertical**	**Pass**	
			Horizontal	**Pass**	
Notes:					

8.3.2 Radiated Spurious Emissions Test Data

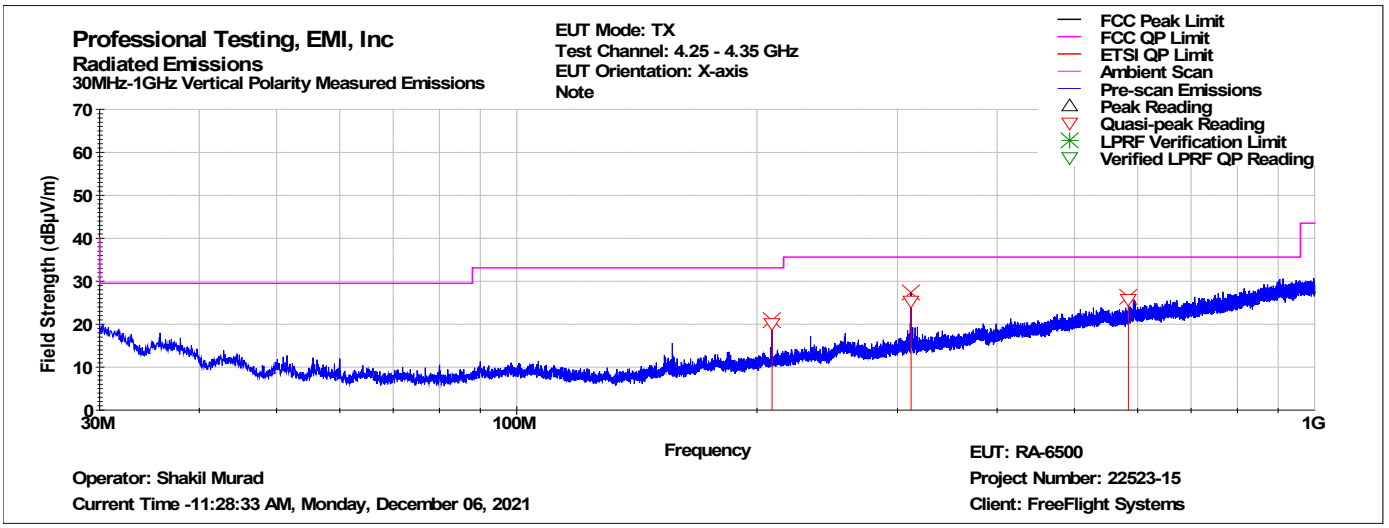
9kHz – 30MHz Emissions Data



9kHz – 30MHz Perpendicular Orientation Measured Emissions Data

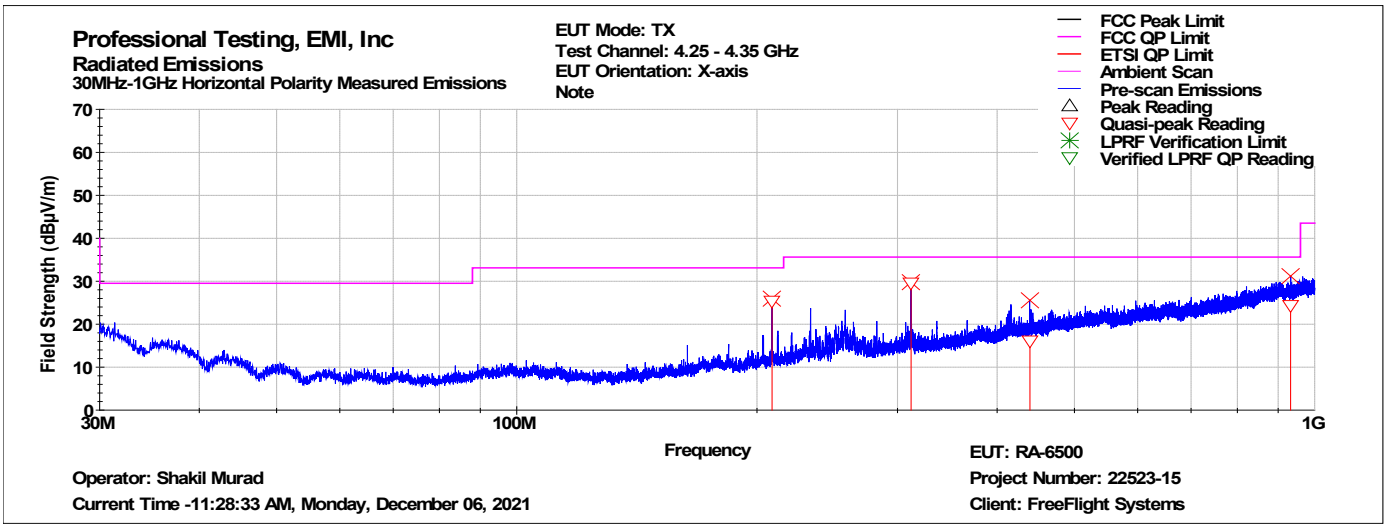


30MHz - 1GHz Vertical Polarity Measured Emissions Data



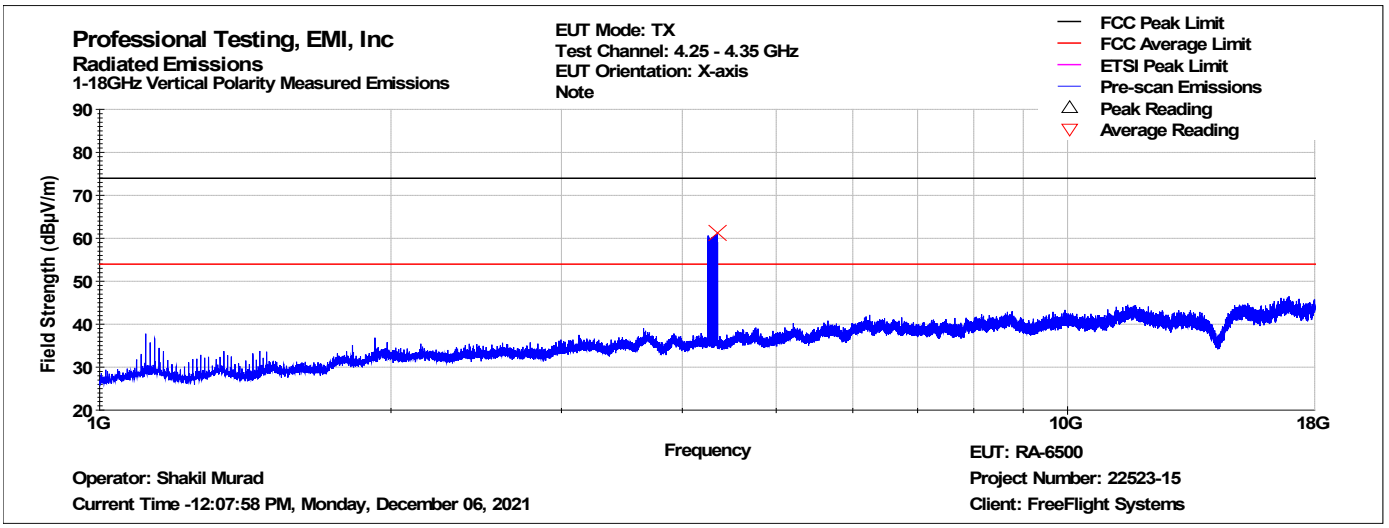
Frequency (MHz)	EUT Direction (Degrees)	Antenna Height (cm)	Quasi-peak Reading (dBµV)	Quasi-peak Limit (dBµV)	Quasi-peak Margin (dB)	Quasi-peak Results
208.891	1.000	387.000	20.059	33.100	-13.041	PASS
312.013	267.000	119.000	25.283	35.600	-10.317	PASS
584.301	148.000	412.000	25.650	35.600	-9.950	PASS

30MHz - 1GHz Horizontal Polarity Measured Emissions Data

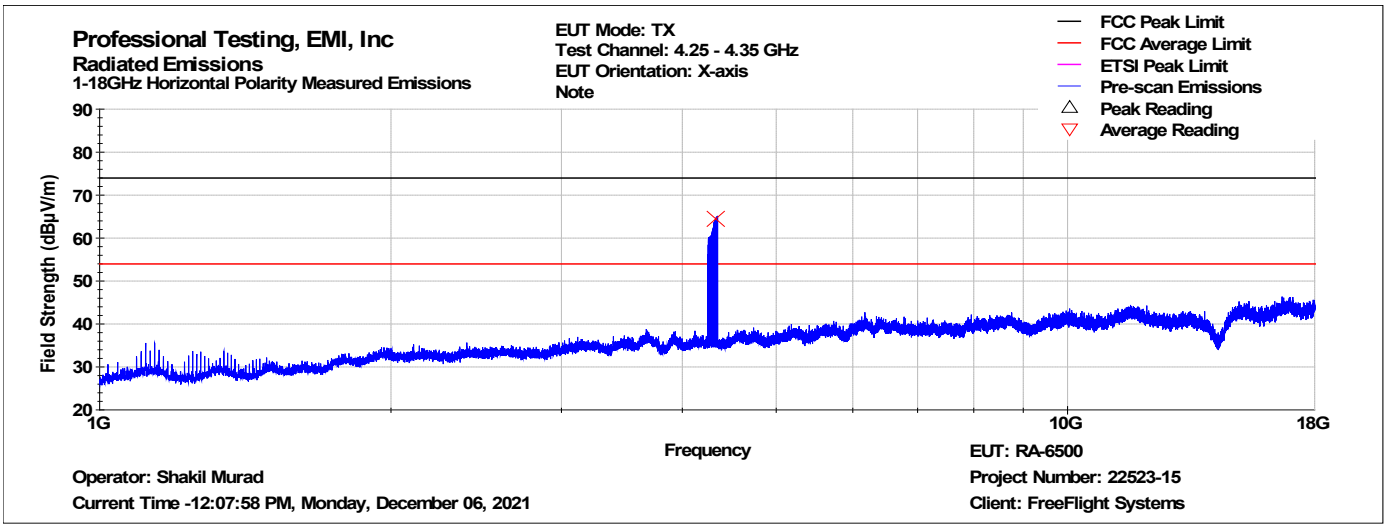


Frequency (MHz)	EUT Direction (Degrees)	Antenna Height (cm)	Quasi-peak Reading (dBµV)	Quasi-peak Limit (dBµV)	Quasi-peak Margin (dB)	Quasi-peak Results
208.882	124.000	397.000	25.391	33.100	-7.709	PASS
312.006	49.000	347.000	29.503	35.600	-6.097	PASS
439.695	112.000	176.000	16.162	35.600	-19.438	PASS
933.069	293.000	128.000	24.325	35.600	-11.275	PASS

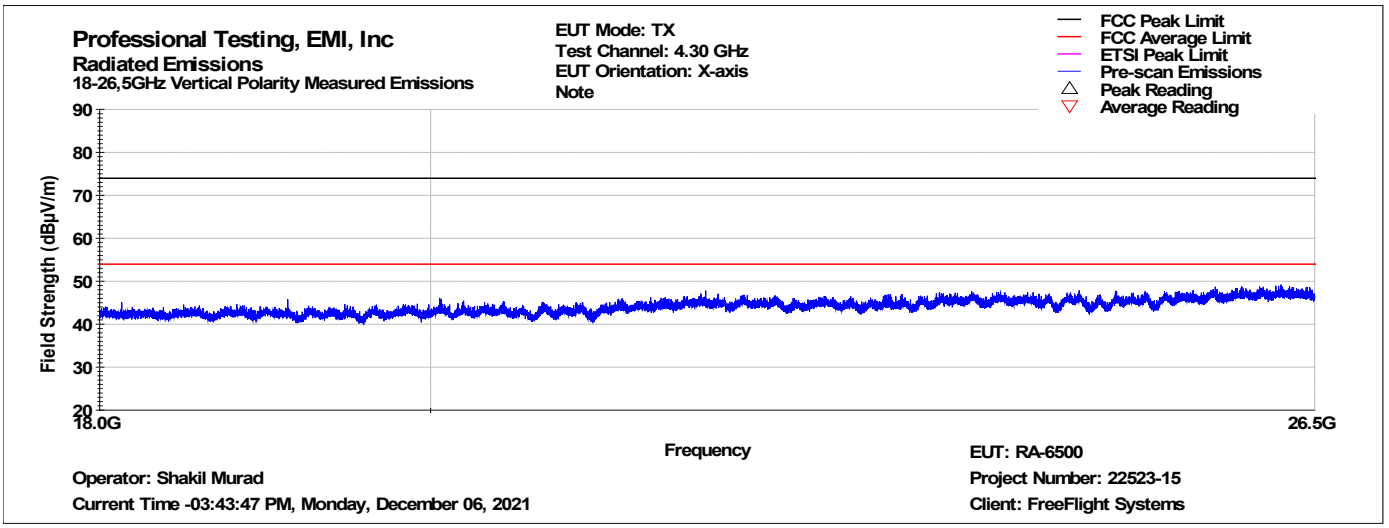
1GHz - 18GHz Vertical Polarity Measured Emissions Data



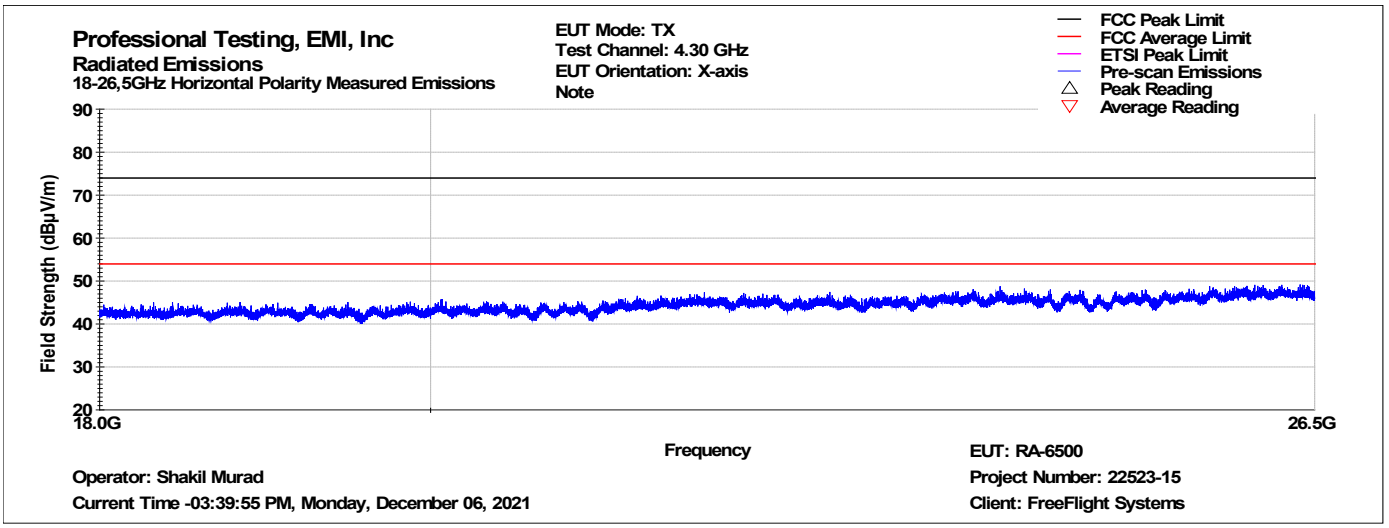
1GHz - 18GHz Horizontal Polarity Measured Emissions Data



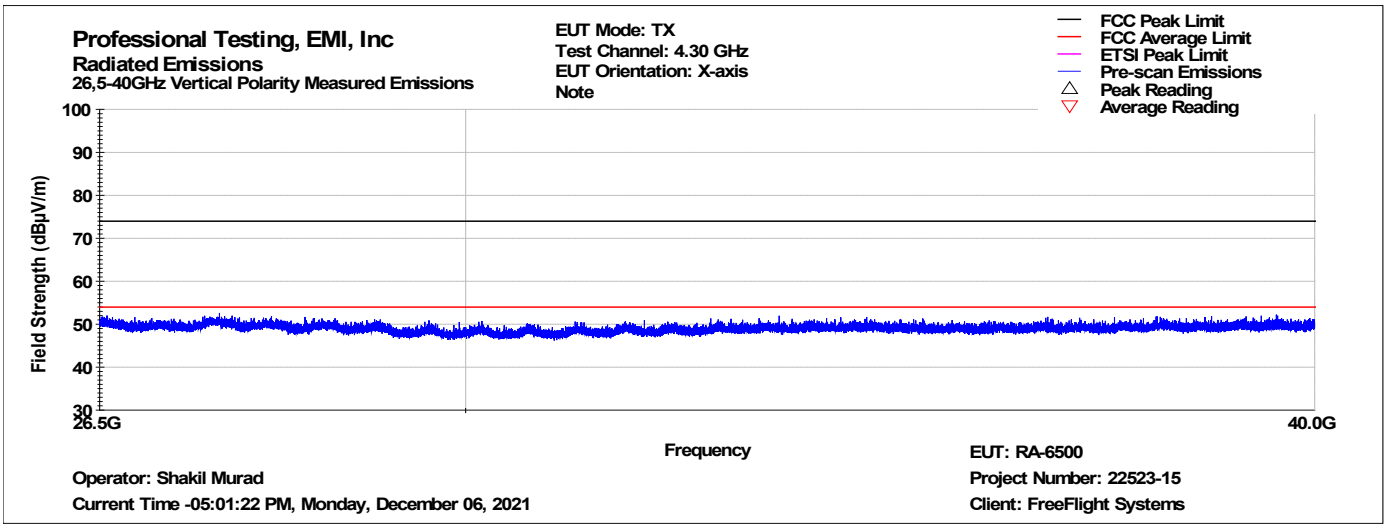
18GHz - 26.5GHz Vertical Polarity Measured Emissions Data



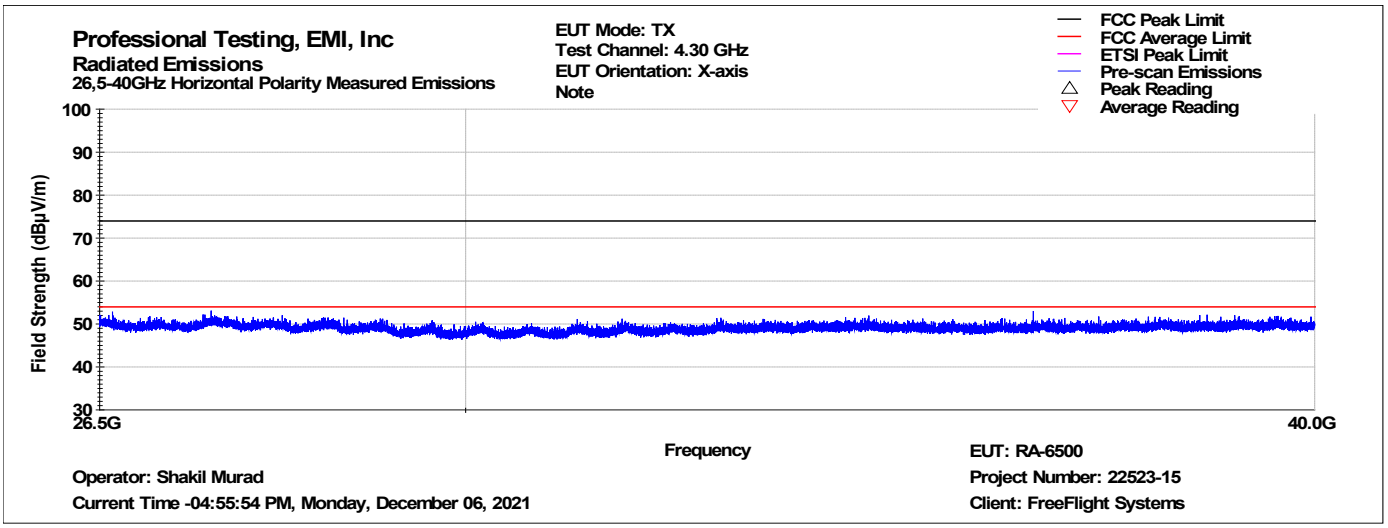
18GHz - 26.5GHz Horizontal Polarity Measured Emissions Data



26.5GHz - 40GHz Vertical Polarity Measured Emissions Data



26.5GHz - 40GHz Horizontal Polarity Measured Emissions Data



All emissions from 40 GHz to 44 GHz were found to at the noise floor. Therefore, per 2.1057, no data is being reported.

8.4 Test Equipment List

Tile! Software Version:			Version: 7.1.2.17 (Jan 08, 2016 - 02:12:48 PM) or 4.1.A.0, April 14, 2009, 11:01:00PM		
Test Profile:			2020_RE_Unintentional_TILE7_v2.7.til		
Asset #	**Manufacturer**	**Model**	**Equipment Nomenclature**	**Serial Number**	**Calibration Due Date**
1425	Electro-Metrics	BPA-1000	Preamp, Broadband 10k-1GHz	123	3/13/2022
1937	Agilent	E4440A - AYZ	PSA , 3 Hz - 26.5 GHz, Opt. AYZ	MY44808298	11/12/2022
1926	ETS-Lindgren	3142D	Antenna, Biconilog, 26 MHz - 6 GHz	135454	4/20/2022
C027	none	RG214	Cable Coax, N-N, 25m, 25MHz - 1GHz	None	9/14/2022
1327	EMCO	1050	Controller, Antenna Mast	none	N/A
942	EMCO	11968D	Turntable, 4ft.	9510-1835	N/A
1969	HP	11713A	Attenuator/Switch Driver	3748A04113	N/A
C030	none	none	Cable Coax, N-N, 30m, 1 - 18GHz	None	9/15/2022
1509B	Braden	TDK 10M	TDK 10M Chamber,sVSWR > 1 GHz	DAC-012915-005	4/9/2023
2004	Miteq	AFS44-00101800-2S-10P-44	Amplifier, 40dB, 100MHz-18GHz	None	1/9/2022
C030	none	none	Cable Coax, N-N, 30m, 1 - 18GHz	None	9/15/2022
1325	EMCO	1050	Controller, Antenna Mast	9003-1461	N/A
1780	ETS-Lindgren	3117	Antenna, Double Ridged Guide Horn, 1 - 18 GHz	110313	4/16/2023
1268	HP	6291A	Power Supply, DC, 40V 5A	1710A03515	N/A
1973	Agilent	83017A	Amplifier, Microwave 0.5-26.5 GHz	MY39500497	11/10/2022
1542	A.H. Systems	SAS-572	Antenna, Horn 18-26.5GHz, 20dB gain	225	N/A
1735	Pasternack	PE9850-20	Antenna, horn, WR28	N/A	N/A
2063	HP	11970A	Mixer, Harmonic, 26.5 - 40 GHz	3003A08717	N/A
2062	HP	11970Q	Mixer, Harmonic, 33 - 50 GHz	3003A03234	N/A
C026A	none	RG-233U	Cable Coax, N-N, 0.914m, 9 kHz - 30 MHz	None	10/21/2022
C233	Sucoflex	None	Cable, SMA-SMA, 7.62m, 9kHz - 1.5 GHz, Purple	None	10/22/2023

9.0 Frequency Stability

9.1 Test Procedure

The EUT is placed into a temperature chamber and connected by cable to a spectrum analyzer; attenuation added if needed. On reaching each set point temperature, the EUT is allowed to soak at least 15 minutes without power applied. After soak time was satisfied, the EUT is powered on in transmit mode and the frequency is observed until it becomes stable; then the measurement of frequency is taken.

Operating voltage stability was also measured for selected extremes based on operating design. This device operates over a wide voltage range greater than the FCC requirement.

The EUT is operated in FMCW mode and continuous transmit.

9.2 Test Criteria

Table 9.2.1: Frequency Stability Criteria, 87.133; 2.1055

For the type of equipment presented in this report, Part 87.133 states that the bandwidth occupied by the emissions must be maintained within the band allocated to the service (4,200 – 4,400 MHz). therefore, tolerances in the 87.133(a) table does not apply.

Table 9.2.2: Test Conditions, Temperatures

-20 C to 50 C and by 10 C steps

Table 9.2.3: Test Conditions, Voltage

Low Voltage	23.8 V
Nominal Voltage	28 VDC
High Voltage	32.2 VDC

9.3 Test Results

The EUT satisfies the requirement. As the antenna port has no effect on frequency one port was tested. Tabular results appear below.

Frequency Stability Test Data									
Environmental Conditions:	Temperature	25.2 °C	Humidity	54 RH	Barometric Pressure	29.95 in Hg			
Test Frequency (Occupied Bandwidth):			100			MHz			
Frequency Stability Under Temperature:									
Temperature (°C)	Measured Frequency (MHz)	Frequency Error (MHz)	Frequency Error (%)	Test Result					
50	100.05	0.050000	0.0500	Pass					
40	100.065	0.065000	0.0650	Pass					
30	100.095	0.095000	0.0950	Pass					
20	100.11	0.110000	0.1100	Pass					
10	100.035	0.035000	0.0350	Pass					
0	100.08	0.080000	0.0800	Pass					
-10	100.065	0.065000	0.0650	Pass					
-20	100.065	0.065000	0.0650	Pass					
-30	100.05	0.050000	0.0500	Pass					
Frequency Stability Under Voltage:									
Nominal voltage	100.047	0.047000	0.0470	Pass					
85% of nominal voltage	100.094	0.094000	0.0940	Pass					
115% of nominal voltage	100.078	0.078000	0.0780	Pass					

9.5 Test Equipment Lists

Test Equipment List					
Asset#	**Manufacturer**	**Model**	**Equipment Nomenclature**	**Serial Number**	**Calibration Due Date**
881	Thermotron	S-1.2C	Chamber, Temperature	27131	3/1/2022
2373	Agilent	E7405A	EMC Spectrum Analyzer, 9 KHz - 26.5 GHz	MY41440727	10/17/2022
A122	JFW	50HF-030-25/18	Attenuator, N, 30dB 25W, DC-18GHz	None	6/25/2022
C118	Harbour Industries	MIL-C-17/60C-RB142	Cable, RF, SMA-TNC, 1.52m, Brown	None	6/2/2022
1117	HP	6296A	Power Supply, DC, 60V 3A	1552A02489	N/A

Appendix: Policy, Rationale, and Evaluation of EMC Measurement Uncertainty

All uncertainty calculations, estimates and expressions thereof shall be in accordance with NIST policy. Since PTI operates in accordance with NIST (NVLAP) Handbook 150-11: 2007, all instrumentation having an effect on the accuracy or validity of tests shall be periodically calibrated or verified traceable to national standards by a competent calibration laboratory. The certificates of calibration or verification on this instrumentation shall include estimates of uncertainty as required by NIST Handbook 150-11.

1. Rationale and Summary of Expanded Uncertainty.

Each piece of instrumentation at PTI that is used in making measurements for determining conformance to a standard (or limit), shall be assessed to evaluate its contribution to the overall uncertainty of the measurement in which it is used. The assessment of each item will be based on either a type A evaluation or a type B evaluation. Most of the evaluations will be type B, since they will be based on the manufacturer's statements or specifications of the calibration tolerances, or uncertainty will be stated along with a brief rationale for the type of evaluation and the resulting stated uncertainties.

The individual uncertainties included in the combined standard uncertainty for a specific test result will depend on the configuration in which the item of instrumentation is used. The combination will always be based on the law of propagation of uncertainty. Any systematic effects will be accommodated by including their uncertainties, in the calculation of the combined standard uncertainty; except that if the direction and amount of the systematic effect cannot be determined and separated from its uncertainty, the whole effect will be treated as uncertainty and combined along with the other elements of the test setup.

Type A evaluations of standard uncertainty will usually be based on calculating the standard deviation of the mean of a series of independent observations, but may be based on a least-squares curve fit or the analysis of variance for unusual situations. Type B evaluations of standard uncertainty will usually be based on manufacturer's specifications, data provided in calibration reports, and experience. The type of probability distribution used (normal, rectangular, a priori, or u-shaped) will be stated for each Type B evaluation.

In the evaluation of the uncertainty of each type of measurement, the uncertainty caused by the operator will be estimated. One notable operator contribution to measurement uncertainty is the manipulation of cables to maximize the measured values of radiated emissions. The operator contribution to measurement uncertainty is evaluated by having several operators independently repeat the same test. This results in a Type A evaluation of operator-contributed measurement uncertainty.

A summary of the expanded uncertainties of PTI measurements is shown as Table 1. These are the worst-case uncertainties considering all operative influence factors.

Table 1: Summary of Measurement Uncertainties for Site 45

Type of Measurement	Frequency Range	Meas. Dist.	Expanded Uncertainty U, dB (k=2)
Mains Conducted Emissions	150 kHz to 30 MHz	N/A	2.9
Telecom Conducted Emissions	150 kHz to 30 MHz	N/A	2.8
Radiated Emissions	30 to 1,000 MHz	10 m	4.8
	1 to 18 GHz	3 m	5.7

End of Report