Project 07076-10

FreeFlight Systems
RA4000E Radio Altimeter

Certification
Electromagnetic Compatibility Test Report

Prepared for:

FreeFlight Systems

3700 Interstate 35 S.
Waco, Texas 76706

By

Professional Testing (EMI), Inc.
1601 FM 1460, Suite B
Round Rock, Texas 78664

23 April 2007

Reviewed by	Written by
Jason Anderson Regulatory Department Manager	Eric Lifsey Test Engineer

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FIGURES

NOTICE: (1) This Report must not be used to claim product endorsement, by NVLAP, NIST, the FCC or any other Agency. (2) This report also does not warrant certification by NVLAP or NIST. This report shall not be reproduced except in full, without the written approval of Professional Testing (EMI), Inc. The significance of this report is dependent on the representative character of the test sample submitted for evaluation and the results apply only in reference to the sample tested. The manufacturer must continuously implement the changes shown herein to attain and maintain the required degree of compliance.

Certificate Of Compliance

Applicant: FreeFlight Systems

Applicant's Address: 3700 Interstate 35 S.
Waco, Texas 76706

Project Number: 07076-10

Test Dates: 30 Aug 2006 to 6 Sep 2006

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

The **FreeFlight Systems, RA4000E Radio Altimeter** was tested to and found to be in compliance with FCC Part 15 Subpart C and FCC Part 87 for an Intentional Radiator.

The highest emissions generated by the above equipment are listed below:

	Frequency (MHz)	Level	Limit	Margin (dB)
Fundamental	2300	20.7 dBm (117.5 mW)	None	-
Spurious Harmonics	8500	-15.3 dBm (pk)	-13 dBm	-2.3
Spurious < 1 GHz	199.9	46.5 (Class B)*	43.5	3.0

*All other sub 1 GHz radiated spurious emissions were below the Class B limits.

Occupied Bandwidth 102.6 MHz
Fastest Observed F(o) Sweep Interval 4.34 ms
Transmit Duty Cycle 100 % (While powered.)

Jason Anderson
Regulatory Department Manager

This report has been reviewed and accepted by **FreeFlight Systems**. The undersigned is responsible for ensuring that the device named above will continue to comply with the FCC rules.

1.0 EUT Description

The RA4000E Radio Altimeter (EUT) detects altitude by transmitting a RF signal downward from the aircraft and receiving the reflected signal from ground objects.

The EUT transmits a slowly swept RF carrier while also sampling a portion of the signal from the source for the receiver mixer. The sampled transmit signal is mixed with the received signal using a direct conversion (AKA homodyne) method, and passed through a limiting amplifier. The limiting amplifier produces digital pulses resulting from the beating of the source and delayed-reflected received signal; this is then applied to a frequency counter to derive an altitude value. Altitude data is then read via a RS-422/232 port by other instruments.

The EUT is powered by 28 VDC. The transmitter operates continually while powered. A detailed tune up and service procedure sets the sweep start/stop frequencies and width. The procedure also validates calibration at temperature extremes as part of the production process. Thermal frequency stability is assisted by thermistor ovens in the EUT. The sweep speed is a slow 100 Hz, which results a signal nearly devoid of sidebands.

The system tested consisted of the following:

Manufacturer	Description	FCC ID
FreeFlight Systems	4300 MHz Transceiver	T7YRA4000E

1.1 Modifications to Equipment

Initial measurements of harmonics failed the limits. The manufacturer eliminated a superfluous production-line tune up procedure that effectively de-tuned the transmitter output stage. This improved linearity and reduced the harmonic emissions sufficiently to pass the limit.

1.2 Applicable Documents

The following guidelines apply to the operation of the EUT:

Guidelines	FCC Rule Parts
Transmitter Characteristics	87.147, 2.1055
Spurious Radiated Power	15.209 < 1 GHz 87.139 > 1 GHz
Occupied Bandwidth	Part 2 allocated 4200 to 4400 MHz.
Antenna Requirements	N/A

1.3 EUT Operation

The EUT was operated in continuous transmit mode at a fixed and maximum power.

1.4 Test Site

Emission measurements below 1 GHz were made at the PTI open area test site designated Site 3, located in Round Rock, Texas. This site is registered with the FCC under Section 2.948 and is subsequently confirmed by laboratory accreditation (NVLAP). Emission measurements above 1 GHz were made either by conduction or by radiated fields measured indoors at 1 meter distance and limits were adjusted accordingly.

2.0 Electromagnetic Emissions Testing

Professional Testing (EMI), Inc. (PTI), follows the guidelines of NIST for all uncertainty calculations, estimates and expressions thereof for EMC testing. See Appendix B for details.

2.1 Radiated Emissions Measurements

Radiated emission measurements were made of the spurious emissions below 1 GHz. Above 1 GHz the fundamental and spurious emissions of the device were measured directly conducted at the antenna port.

2.1.1 Test Procedure

The EUT was placed at the center of a non-conductive remotely-rotated table 0.8 meters above the ground plane. Below 1 GHz the measurement antenna was placed at a distance of 3 meters as measured from the closest point of the EUT. Above 1 GHz radiated emissions are measured indoors under controlled conditions and the antenna is placed at 1 meter distance. The radiated emissions were maximized by rotating the EUT. Transmitter harmonics are measured up to the 10^{th} harmonic. A drawing showing the test setup is given as Figure 1.

2.1.2 Test Criteria

Relevant FCC & CISPR emission limits are listed below. The lower limit shall apply at the transition frequency.

FCC			
Frequency MHz	**Test Distance (Meters)**	**Field Strength Limit**	
		Distance 3 m (µV/m)	**At Test Distance (dB µV/m)**
Fundamental (peak)	3	50000	94.0
Harmonics (average)	1	500	63.5
Harmonics (peak)	1	-	83.5

FCC		
Frequency (MHz)	**Test Distance (Meters)**	**Field Strength Limit (dB µV/m)**
30 to 88	3	40.0
88 to 216	3	43.5
216 to 960	3	46.0
960 and above	3	54.0

CISPR		
Frequency (MHz)	**Test Distance (Meters)**	**Field Strength Limit (dB µV/m)**
30 to 230	3	40.5
230 to 1000	3	47.5

2.1.3 Radiated Emissions Test Equipment < 1 GHz

Asset #	Manufacturer	Model #	Description	Calibration Due
C005	None	None	Underground Coaxial Cable	March 17, 2007
1494	EMCO	3110B	Biconical Antenna	April 20, 2007
0746	Tek	2706	RF Preselector	October 27, 2006
0084	HP	8566B	Spectrum Analyzer	March 13, 2007
0084	HP	8566B	Spectrum Analyzer Display	March 13, 2007
0085	HP	85650A	Quasi-peak Adapter	September 26, 2006
0483	HP	8447D	RF Preamplifier	January 12, 2007
0290	EMCO	3146	Log Periodic Dipole Array Antenna	May 22, 2007

2.1.4 Radiated Emissions Test Equipment > 1 GHz

Asset #	Manufacturer	Model #	Description	Calibration Due
C031	None	None	1.5 meter Coaxial RF Cable	November 23, 2006
0267	EMCO	3115	Ridge Guide Antenna	July 21, 2007
0950	HP	8566B	Spectrum Analyzer	March 13, 2007
0949	HP	8566B	Spectrum Analyzer Display	March 13, 2007
0897	Miteq	None	Microwave Preamplifier	May 16, 2007
A026	HP	None	10 dB Attenuator	CBU
1527	Micro-Tronics	HPM501121	High-Pass Filter 6.4 GHz	CBU

3.0 Occupied Bandwidth Measurements

Measurements of the occupied bandwidth were made in a controlled indoor environment in a configuration which did not present measurement distortion or ambient interference.

3.1 Test Procedure

The EUT was placed on a non-conductive table 0.8 meters above the floor. The table was rotated to an angle which presented the highest signal level. The occupied bandwidth of the swept signal is measured by max hold of the sweep until a stable profile is obtained, then plotted. A drawing showing the test setup is given as Figure 1.

3.2 Test Criteria

The fundamental emission must remain in the allocated band.

4.0 Temperature Extremes

Measurements of operating frequency were made for selected temperatures and DC power input voltages (22.8 V, 32.2 V) in a temperature-controlled environment.

4.1 Test Procedure

The EUT was placed temperature chamber and normal operation was verified. Selected operating temperatures were applied and measurements were taken of frequency with sweeping halted.

Frequency measurements at temperature and DC power extremes are performed and for each 10 degree increment.

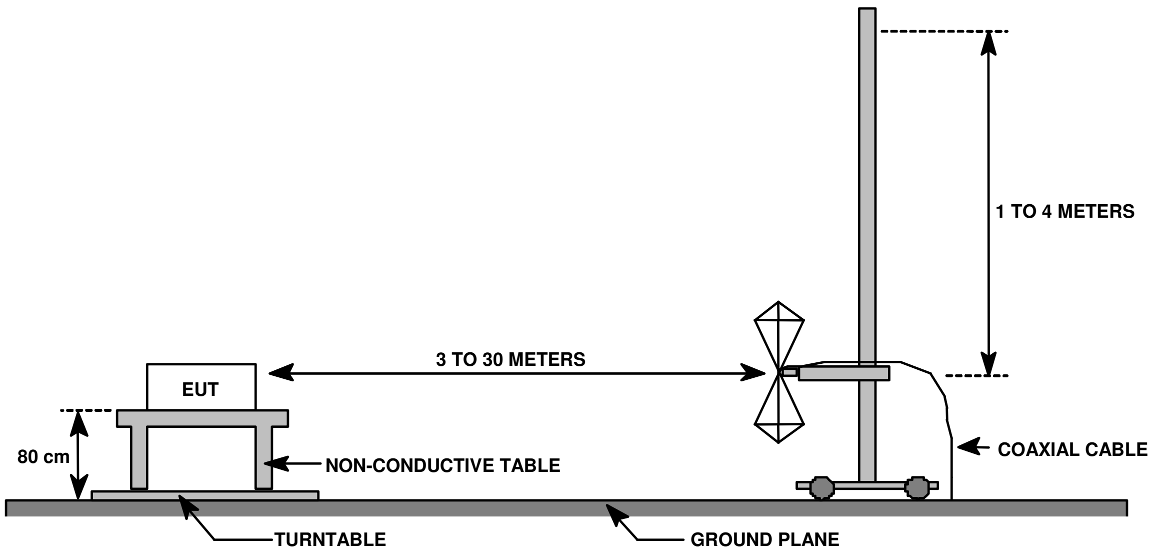
4.2 Test Criteria

The fundamental emission must remain in the allocated band and transmit power should not deviate from manufacturer's specifications.

5.0 Burst Length, Pulse Width, Pulse Repetition Rate and Duty Cycle

The EUT transmitter operates continuously whenever power is applied and does not burst data. Therefore these measurements are not applicable and the duty cycle is reported as 100 %.

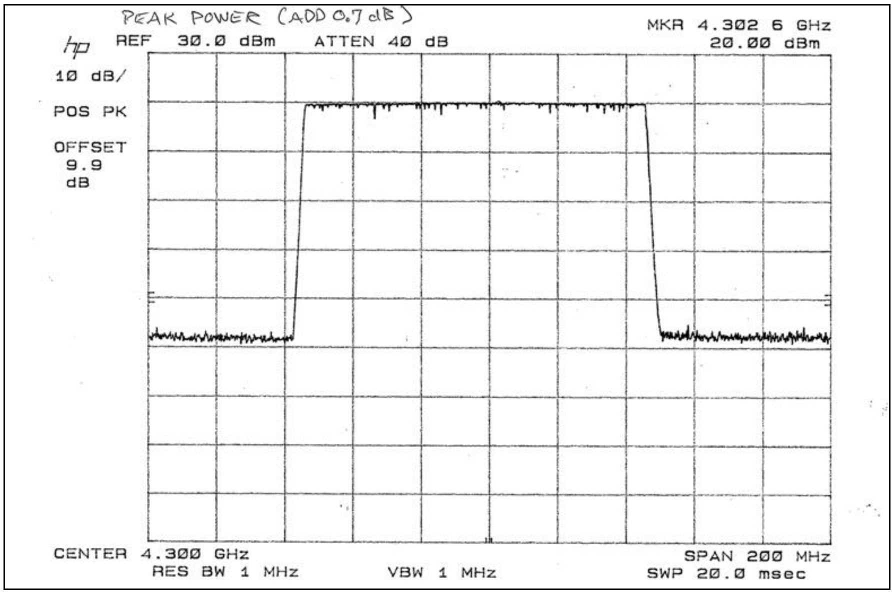
FIGURE 1: Radiated Emissions Test Setup < 1 GHz



Fundamental Radiated Emissions
4.3 GHz Carrier

PROJECT #	DATE	CLASS	RBW	VBW	DETECTOR
07076-10	30 Aug 2006	(Part 87)	1 MHz	1 MHz	Peak

COMMENT	CW carrier sweep rate is very low, virtually no sidebands. 1 MHz RBW is sufficient to measure peak power. 10 dB fixed attenuator employed to prevent any possible measurement receiver overload.



Frequency (MHz)	Recorded Level (dBm)	Cable Loss (dB)	Corrected Level (dBm)	Transmit Power (mW)
4300	20	0.7	20.7	117

Manufacturer transmit power specification: 100 mW

Fundamental emissions were measured directly conducted from the EUT.

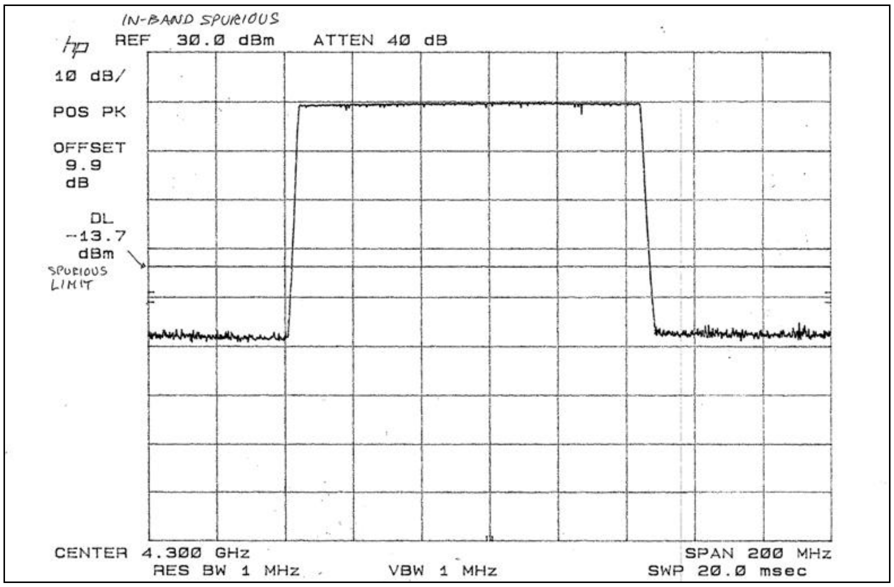
Conclusion: Pass

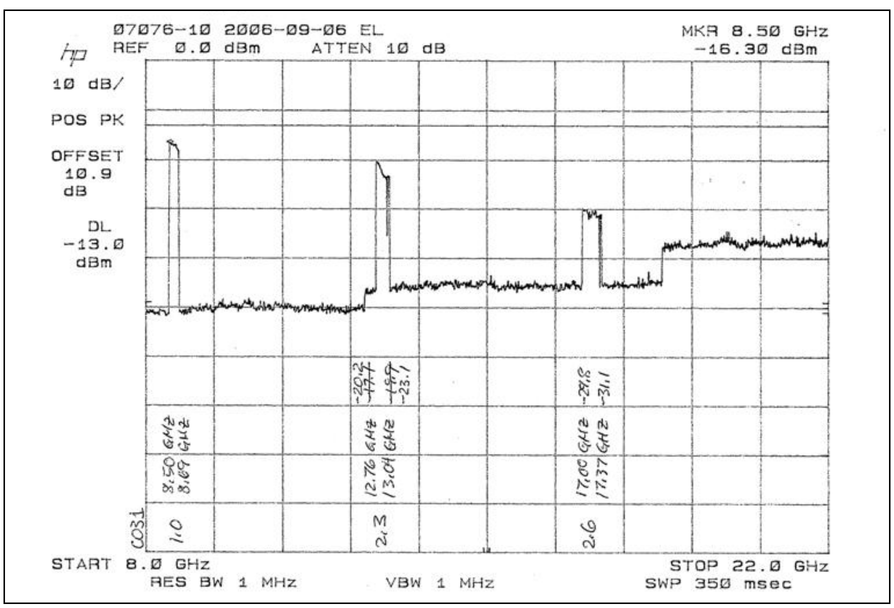
Test Engineer: Eric Lifsey

Radiated Emissions
Harmonics & Spurious – Transmit Port
1 GHz ≤ f ≤ 40.0 GHz

PROJECT #	DATE	CLASS	RBW	VBW	DETECTOR
07076-10	6 Sep 2006	FCC B	1 MHz	1 MHz	Peak

COMMENT	Measured directly at transmit antenna port





Highest harmonic emission was measured as: -16.3 dBm + 1.0 dB = -15.3 dBm @ 8.5 GHz

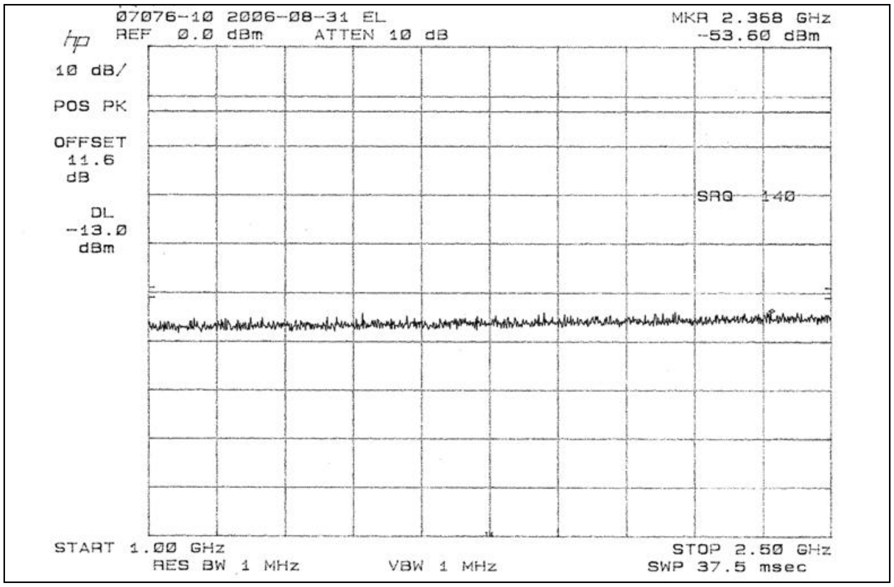
Emissions above 22 GHz and from 1 to 4.2 GHz were at the noise floor or lower.

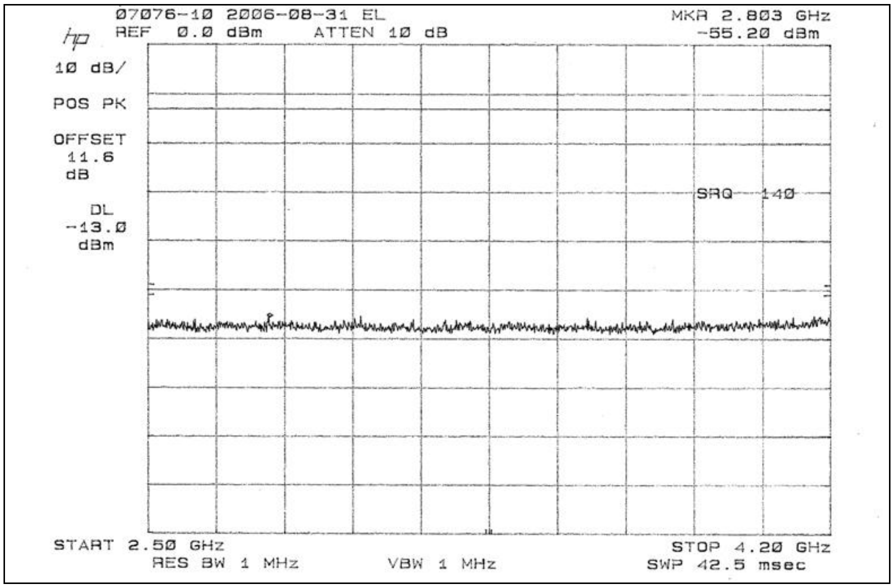
Test Engineer: Eric Lifsey

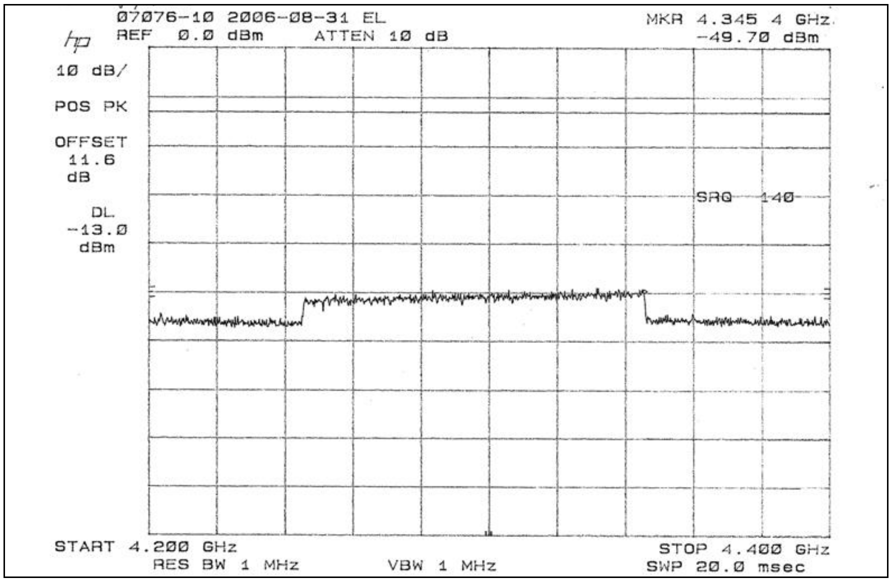
Radiated Emissions
Harmonics & Spurious – Receive Port
1 GHz ≤ f ≤ 22.0 GHz

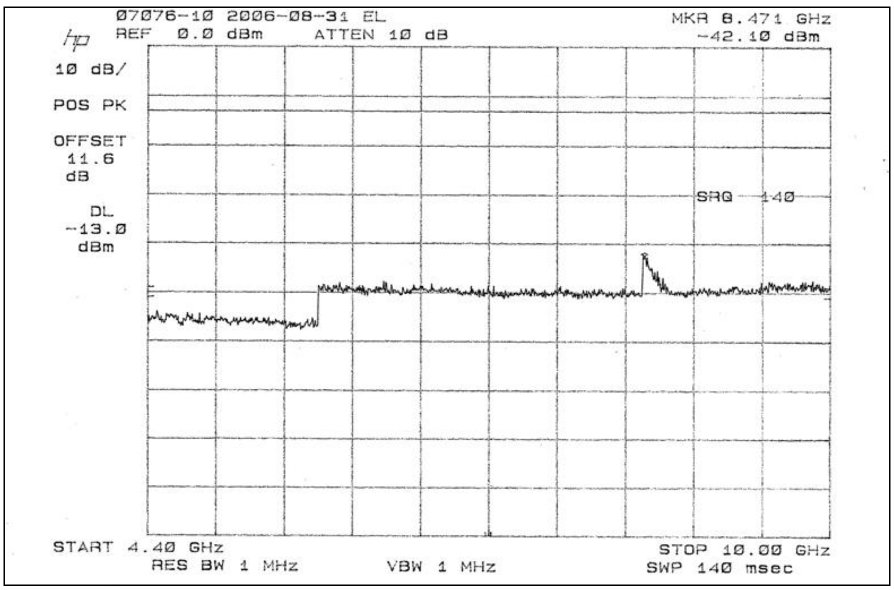
PROJECT #	DATE	CLASS	RBW	VBW	DETECTOR
07076-10	31 Aug 2006	FCC B	1 MHz	1 MHz	Peak

COMMENT	Measured directly at receive antenna port.









All spurious and harmonic emissions measured to be well below limits.

Test Engineer: Eric Lifsey

Spurious Radiated Emissions
30 MHz ≤ f ≤ 1 GHz

PROJECT #	DATE	CLASS	DISTANCE	ANTENNA	RBW	VBW	DETECTOR
07076-10	30 Aug 2006	FCC B	3 m	Bicon | Log	CISPR 120 kHz	1 MHz	QP | Peak

COMMENT	Emissions compared to FCC Class B though not required. One deviation above Class B limits recorded at 200 MHz by 3.0 dB.

ANTENNA POLARIZATION: Horizontal

Frequency (MHz)	EUT Direction (degrees)	Antenna Elevation (Meters)	Recorded Level (dBμV)	Amplifier Gain (dB)	Antenna Factor (dB/m)	Cable Loss (dB)	Corrected Level (dBμV/m)	Limit (dBμV/m)	Margin (dB)	Detector Function
50	0	3	48.7	26.7	11.3	2.4	35.7	40	-4.3	pk
50	0	3	47.3	26.7	11.3	2.4	34.3	40	-5.7	qp
73.5	180	3	49.7	26.7	6.8	2.9	32.7	40	-7.3	qp
86	135	3.5	43.3	26.6	8.5	3.0	28.2	40	-11.8	qp
199.9	135	1.5	52.5	26.9	16.2	4.7	46.5	43.5	3.0	qp bicon
200	135	2	55.2	26.9	12.9	4.7	45.9	43.5	2.4	qp log
250	45	1	44.1	27.1	13.5	5.8	36.3	46	-9.7	qp
264	45	1	37	27.0	13.8	5.7	29.5	46	-16.5	qp
275	135	1	45.1	26.9	14.0	5.6	37.8	46	-8.2	qp
300	45	1	46.7	27.1	14.8	5.8	40.2	46	-5.8	qp
325	45	1	44.5	27.1	15.4	6.3	39.1	46	-6.9	qp
350	0	1	43.8	27.3	15.1	6.6	38.3	46	-7.7	qp
375	270	1	41	27.2	16.8	6.7	37.3	46	-8.7	qp
400	315	1	40.6	27.4	17.2	6.7	37.1	46	-8.9	qp
425	135	1	36.2	27.5	17.5	7.1	33.4	46	-12.6	qp
450	3	1	42.7	27.3	18.2	7.2	40.8	46	-5.2	qp

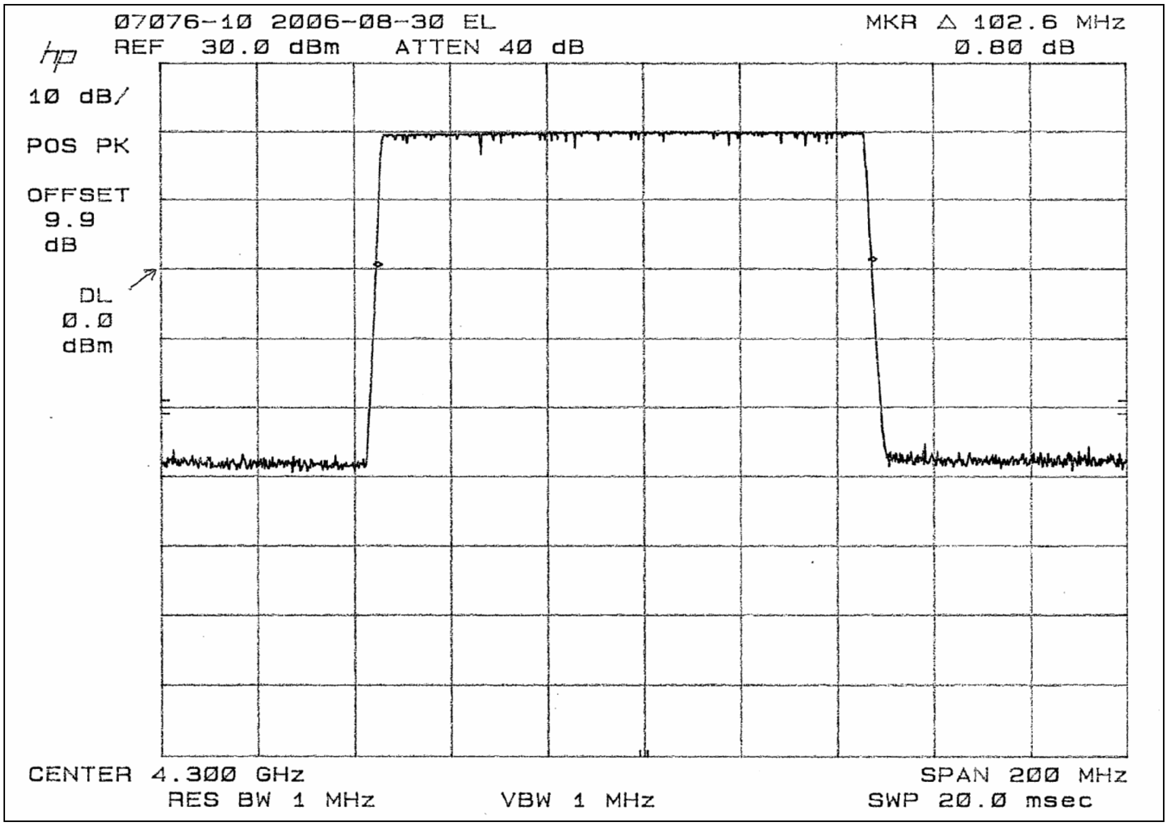
ANTENNA POLARIZATION: Vertical

Frequency (MHz)	EUT Direction (degrees)	Antenna Elevation (Meters)	Recorded Level (dBμV)	Amplifier Gain (dB)	Antenna Factor (dB/m)	Cable Loss (dB)	Corrected Level (dBμV/m)	Limit (dBμV/m)	Margin (dB)	Detector Function
86	180	1	43.6	26.6	8.5	3.0	28.5	40	-11.5	qp
123	135	1	48.2	26.7	11.9	3.7	37.1	40	-2.9	qp
199.9	0	1	45.6	26.9	16.2	4.7	39.6	43.5	-3.9	qp bicon
200	0	1	47.7	26.9	12.9	4.7	38.4	43.5	-5.1	qp log
225	270	1	39.2	26.8	12.1	5.3	29.7	46	-16.3	qp
250	0	1.5	34.9	27.1	13.5	5.8	27.1	46	-18.9	qp
300	0	3	41.9	27.1	14.8	5.8	35.4	46	-10.6	qp
375	0	3	38.6	27.2	16.8	6.7	34.9	46	-11.1	qp

Conclusion: Pass FCC Class A, exceeds FCC Class B at one emission frequency.

Test Engineer: Eric Lifsey

Occupied Bandwidth
20 dB



Bandwidth measured with direct conducted connection to EUT.

Measured bandwidth 102.6 MHz

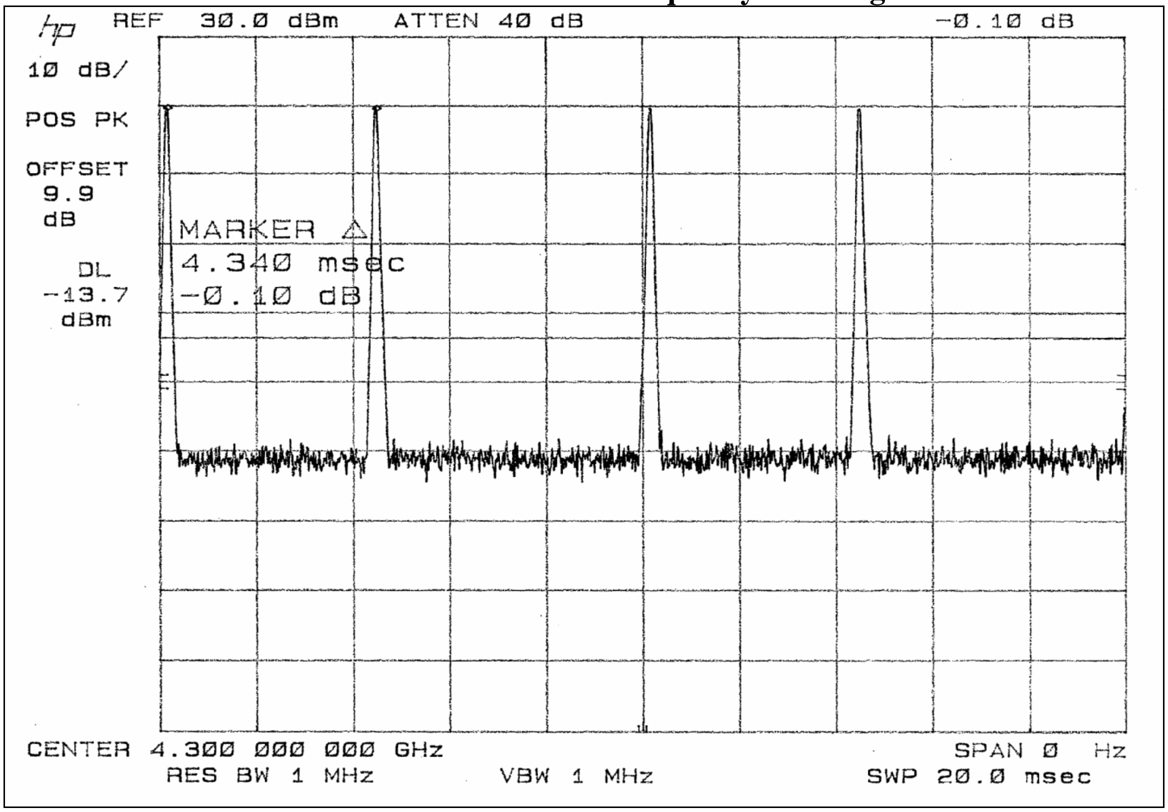
Test Engineer: Eric Lifsey

Band Edge

Reference the bandwidth plot on this page showing the entire allocated band. The emissions at band edges are clearly more than 45 dB below the carrier and below -25 dBm.

Test Engineer: Eric Lifsey

Time Interval on Center Frequency Crossings



This measurement is for reference to document the VCO sweep timings. There are no criteria for this measurement.

Fastest VCO sweep interval 4.34 ms

Test Engineer: Eric Lifsey

Temperature Extremes Data Sheet
Frequency & Bandwidth
-20°C to 50°C (Per 87.147)
10°C Increments (Per 2.1055)

DC power extreme operating voltages: 23.8 and 32.2 VDC. DC extremes were applied at highest and lowest temperatures in steps 5 and 8.

VCO tested with sweep voltage source in normal configuration (sweeping, internal source) and with fixed external DC reference (9.3 VDC, not subject to temperatures) conditions.

Test Step	Temperature (C)	DC Power	Measured Frequency (GHz)
1	20	Nominal	4.300291
2	10	Nominal	4.303042
3	0	Nominal	4.305440
4	-10	Nominal	4.309078
5	-20	VDC 23.8: VDC 32.2:	4.312362 4.313655
6	30	Nominal	4.298205
7	40	Nominal	4.295770
8	50	VDC 23.8: VDC 32.2:	4.290752 4.290623

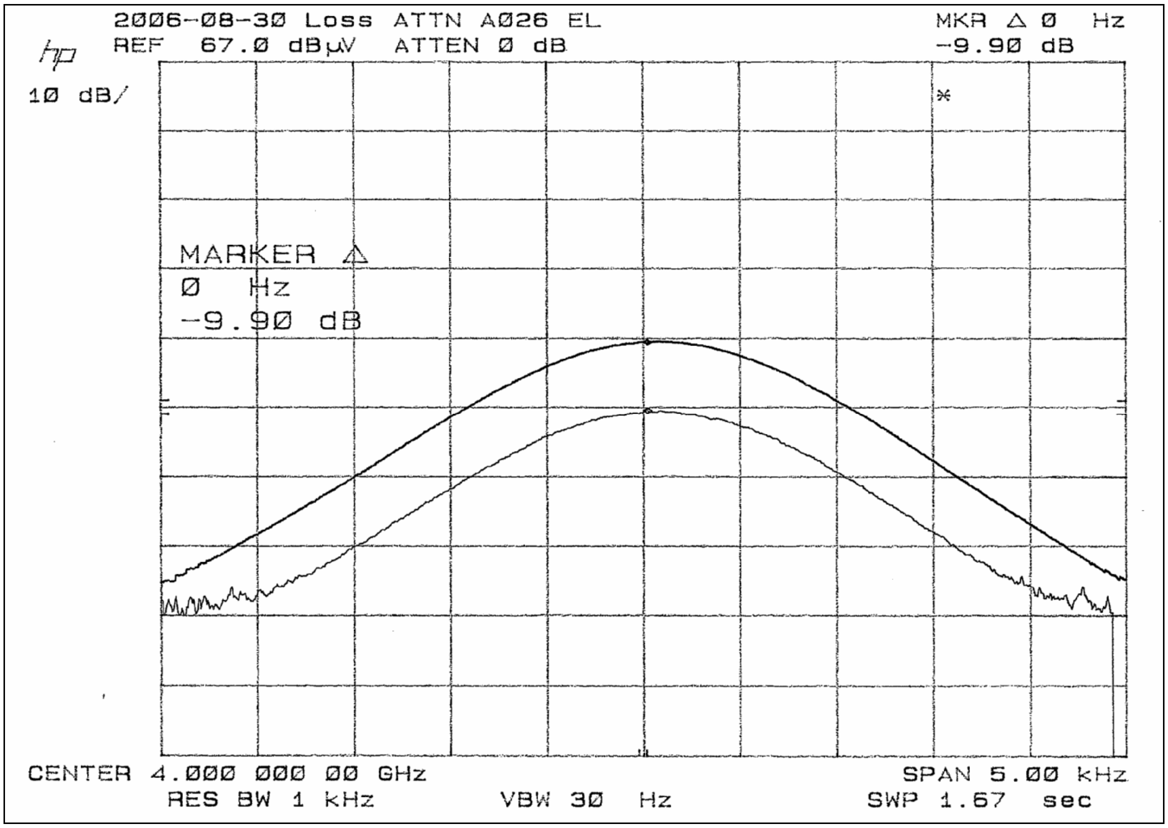
Plots were taken of fixed-reference frequency and of the normally swept mode. Fundamental signal and extreme sweep frequencies remained well within the allocated band. No undesired change in power output observed.

Conclusion: Pass

Test Engineer: Eric Lifsey

Other Supporting Information

Asset A026 10 dB Attenuator Verification



Professional Testing (EMI) Inc. (PTI) Policy, Rationale and Evaluation of EMC Measurement Uncertainty

All uncertainty calculations, estimates and expressions thereof shall be in accordance with NIST policy stated in Appendix E to NIST Technical Communications Program, Subchapter 4.09 of the Administrative Manual, as reproduced in Appendix C of NIST Technical Note (TN) 1297, 1994 Edition [1][1]. The NIST policy is based on ISO Guide to the Expression of Uncertainty in Measurement [2] (herein after called the Guide), which shall take precedence in the event of disputes. The Guide is explained in TN 1297. Other notable explanations for the Guide are NAMAS Publications NIS 80 [3] and NIS 81 [4]; the latter being specifically for EMC measurements, and the easiest to understand. Since PTI operates in accordance with NIST (NVLAP) Handbook 150-11 [5], 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.

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 manufacture’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 state 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 discussed in TN 1297, NIS 81, and the Guide. 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.

[1] Numbers in square brackets identify documents listed in the reference section.

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 if shown is Table 1. These are the worst-case uncertainties considering all operative influence factors.

Table 1-1
Summary of Measurement Uncertainties

Type of Measurement	Frequency Range	Meas. Dist.	Expanded Uncertainty U, dB (k=2)
Conducted Emissions	150 kHz to 30 MHz	N/A	2.9
Radiated Emissions, Site #1	30 to 200 MHz	3 m	4.7
		10 m	4.4
	200 to 1000 MHz	3 m	4.6
		10 m	4.0
	1 to 2.5 GHz	1 m	2.5
	2.5 to 12.5 GHz	1 m	3.6
	12.5 to 18 GHz	1 m	4.0
Radiated Emissions, Site #2	30 to 200 MHz	3 m	3.5
		10 m	3.7
	200 to 500 MHz	3 m	3.5
		10 m	3.1
	500 to 1000 MHz	3 m	4.0
		10 m	3.9
Radiated Emissions, Site #3	30 to 200 MHz	3 m	3.9
	200 to 500 MHz	3 m	4.0
	500 to 1000 MHz	3 m	4.3