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Measured Radio Frequency Emissions
From

Raven Industries Transceiver
FCC ID: KSME1008500
IC: 2004A-E1008500

Test Report No. 417124-563
March 28, 2010

For:
Raven Industries
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Measurements made by: Valdis V. Liepa   Report Approved by:________________
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Summary

Tests for compliance with FCC Regulations, CFR 47, Part 15 and with Industry Canada RSS-210/Gen, were performed on a Raven, Model/FCC ID: KSME1008500, IC: 2004A-E1008500. This device under test (DUT) is subject to the rules and regulations as a Transceiver.

In testing completed on March 25, 2010, the DUT tested met the allowed specifications for radiated emissions by more than 7.9 dB. AC Mains conducted emissions meet the allowed specifications by more than 5.0 dB.

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1. Introduction

This Raven Transceiver was tested for compliance with FCC Regulations, Part 15, adopted under Docket 87-389, April 18, 1989 as subsequently amended, and with Industry Canada RSS-210/Gen, Issue 7, June 2007. Tests were performed at the University of Michigan Radiation Laboratory Willow Run Test Range following the procedures described in ANSI C63.4-2003 "Methods of Measurement of Radio-Noise Emissions from Low-Voltage Electrical and Electronic Equipment in the Range of 9 kHz to 40 GHz". The Site description and attenuation characteristics of the Open Site facility are on file with FCC Laboratory, Columbia, Maryland (FCC Reg. No: 91050) and with Industry Canada, Ottawa, ON (File Ref. No: IC 2057A-1).

2. Equipment Used

The pertinent test equipment commonly used in our facility for measurements is listed in Table 2.1 below. The middle column identifies the specific equipment used in these tests. The quality system employed at the University of Michigan Radiation Laboratory Willow Run Test Range has been established to ensure all equipment has a clearly identifiable classification, calibration expiry date, and that all calibrations are traceable to national standards.

Table 2.1 Test Equipment.

Test Instrument	Used	Manufacturer/Model	Q Number
Spectrum Analyzer (9kHz-26GHz)	X	Hewlett-Packard 8593E, SN: 3412A01131	HP8593E1
Spectrum Analyzer (9kHz-6.5GHz)	X	Hewlett-Packard 8595E, SN: 3543A01546	JDB8595E
Power Meter		Hewlett-Packard, 432A	HP432A1
Harmonic Mixer (26-40 GHz)		Hewlett-Packard 11970A, SN: 3003A08327	HP11970A1
Harmonic Mixer (40-60 GHz)		Hewlett-Packard 11970U, SN: 2332A00500	HP11970U1
Harmonic Mixer (75-110 GHz)		Hewlett-Packard 11970W, SN: 2521A00179	HP11970W1
Harmonic Mixer (140-220 GHz)		Pacific Millimeter Prod., GMA, SN: 26	PMPGMA1
S-Band Std. Gain Horn	X	S/A, Model SGH-2.6	SBAND1
C-Band Std. Gain Horn	X	University of Michigan, NRL design	CBAND1
XN-Band Std. Gain Horn	X	University of Michigan, NRL design	XNBAND1
X-Band Std. Gain Horn		S/A, Model 12-8.2	XBAND1
X-band horn (8.2- 12.4 GHz)		Narda 640	XBAND2
X-band horn (8.2- 12.4 GHz)	X	Scientific Atlanta , 12-8.2, SN: 730	XBAND3
K-band horn (18-26.5 GHz)	X	FXR, Inc., K638KF	KBAND1
Ka-band horn (26.5-40 GHz)		FXR, Inc., U638A	KABAND1
U-band horn (40-60 GHz)		Custom Microwave, HO19	UBAND1
W-band horn(75-110 GHz)		Custom Microwave, HO10	WBAND1
G-band horn (140-220 GHz)		Custom Microwave, HO5R	GBAND1
Bicone Antenna (30-250 MHz)	X	University of Michigan, RLBC-1	LBBIC1
Bicone Antenna (200-1000 MHz)	X	University of Michigan, RLBC-2	HBBIC1
Dipole Antenna Set (30-1000 MHz)	X	University of Michigan, RLDP-1,-2,-3	UMDIP1
Dipole Antenna Set (30-1000 MHz)		EMCO 3121C, SN: 992 (Ref. Antennas)	EMDIP1
Active Rod Antenna (30 Hz-50 MHz)		EMCO 3301B, SN: 3223	EMROD1
Active Loop Antenna (30 Hz-50 MHz)		EMCO 6502, SN:2855	EMLOOP1
Ridge-horn Antenna (300-5000 MHz)	X	University of Michigan	UMRH1
Amplifier (5-1000 MHz)	X	Avantek, A11-1, A25-1S	AVAMP1
Amplifier (5-4500 MHz)	X	Avantek	AVAMP2
Amplifier (4.5-13 GHz)	X	Avantek, AFT-12665	AVAMP3
Amplifier (6-16 GHz)		Trek	TRAMP1
Amplifier (16-26 GHz)	X	Avantek	AVAMP4
LISN Box	X	University of Michigan	UMLISN1
Signal Generator		Hewlett-Packard 8657B	HPSG1

3. Device Under Test

3.1 Description & Block Diagram

The DUT is a 2405-2480 MHz Transceiver designed for motorized bed applications. It is powered by a 120 VAC power adapter and is housed in a plastic case approximately 13 x 7 x 4.5 cm in dimension. For testing, a generic harness was provided by the manufacturer. The DUT is designed and manufactured by Raven Industries, 4372 Green Ash Drive, Earth City, MO 63045.

Equipment Used

Device	**[Make], Model**	**[S/N],P/N**	**EMC Consideration**
EUT	[Raven], KSME1008500	[70000007]	

3.2 Variants & Samples

There is only a single variant of the device, as tested and employs only one antenna built into the PCB. The sample supplied was setup with custom test software to control channel selection and to enable/disable hopping for testing purposes.

3.3 Modes of Operation

This device only operates in a single mode, a customized hopping IEEE 802.15.4 transceiver, as tested. Also included within the device is a fully modular WLAN transceiver, FCC ID: XM5-SM2144N2, IC: 8516A-SM2144N2 that is separately certified by module manufacturer.

3.4 Exemptions

None.

3.5 EMC Relevant Modifications

No EMI Relevant Modifications were performed by this test laboratory.

4. Emissions Limits

4.1 Radiated Emissions Limits

The DUT tested falls under the category of an Intentional Radiator. The applicable testing frequencies and corresponding emission limits set by both the FCC and IC are given in Tables 4.1 and 4.2 below.

Table 4.1. TX Emission Limits (FCC: 15.249; IC: RSS-210e A2.9).

Frequency (MHz)	Field Strength of Fundamental (mV/m)	Field Strength of Harmonics (μV/m)
902.0 – 928.0	50	500
2400 - 2483.5	50	500
5725.0 – 5875.0	50	500
24000.0 – 24250.0	250	2500

1) Field strength limits are specified at a distance of 3 meters.
2) Emissions radiated outside of the specified frequency bands, except for harmonics, shall be attenuated by at least 50 dB below the level of the fundamental or to the general radiated emission limits in Section 15.209 (Class B), whichever is the lesser attenuation.
3) Peak field strength of any emission above 1GHz shall not exceed the maximum permitted average limits specified above by more than 20 dB under any condition of modulation. (15.35)

Table 4.2. Spurious Emission Limits (FCC: 15.33, .35, .109/209; IC: RSS-210 2.7, T2)

Freq. (MHz)	E_{lim} (3m) μV/m	E_{lim} dB(μV/m)
30-88	100	40.0
88-216	150	43.5
216-960	200	46.0
960-2000	500	54.0

Note: Average readings apply above 1000 MHz (1 MHz BW), Quasi-Peak readings apply to 1000 MHz (120 kHz RBW), PRF of intentional emissions > 20 Hz for QPK to apply.

Power Line Conducted Emissions Limits

Table 4.3 Emission Limits (FCC:15.107 (CISPR); IC: RSS-Gen, 7.2.2 T2).

Frequency (MHz)	Class A (dBμV)		Class B (dBμV)	
	Quasi-peak	Average	Quasi-peak	Average
.150 - 0.50	79	66	66 - 56*	56 - 46*
0.50 - 5	73	60	56	46
5 - 30	73	60	60	50

Notes:
1. The lower limit shall apply at the transition frequency
2. The limit decreases linearly with the logarithm of the frequency in the range 0.15-0.50 MHz:
   *Class B Quasi-peak: dBμV = 50.25 - 19.12*log(f)
   *Class B Average: dBμV = 40.25 - 19.12*log(f)
3. 9 kHz RBW

5. Measurement Procedures

5.1 Semi-Anechoic Chamber Radiated Emissions

To become familiar with the radiated emission behavior of the DUT, the device is first studied and measured in our shielded semi-anechoic chamber. In the chamber there is a set-up similar to that of an outdoor 3-meter site, with a turntable, an antenna mast, and a ground plane. Instrumentation includes spectrum analyzers and other equipment as needed.

The DUT is laid on the test table as shown in the included block diagram and/or photographs. A shielded loop antenna is employed when studying emissions from 9 kHz to 30 MHz. Above 30 MHz and below 250 MHz a biconical antenna is employed. Above 250 MHz a ridge or and standard gain horn antennas are used. The spectrum analyzer resolution and video bandwidths are set so as to measure the DUT emission without decreasing the emission bandwidth (EBW) of the device. Emissions are studied for all orientations (3-axes) of the DUT and all test antenna polarizations. In the chamber, spectrum and modulation characteristics of intentional carriers are recorded. Receiver spurious emissions are measured with an appropriate carrier signal applied. Associated test data is presented in subsequent sections.

5.2 Outdoor Radiated Emissions

After measurements are performed indoors, emissions on our outdoor 3-meter Open Area Test Site (OATS) are made, when applicable. If the DUT connects to auxiliary equipment and is table or floor standing, the configurations prescribed in ANSI C63.4 are employed. Alternatively, an on-table layout more representative of actual use may be employed if the resulting emissions appear to be worst-case in such a configuration. Any intentionally radiating elements are placed on the test table flat, on their side, and on their end (3-axes) and worst case emissions are recorded. For each configuration the DUT is rotated 360 degrees about its azimuth and the receive antenna is raised and lowered between 1 and 4 meters to maximize radiated emissions from the device. Receiver spurious emissions are measured with an appropriate carrier signal applied. For devices with intentional emissions below 30 MHz, our shielded loop antenna at a 1 meter receive height is used. Low frequency field extrapolation to the regulatory limit distance is employed as needed. Emissions between 30 MHz and 1 GHz are measured using tuned dipoles and/or biconical antennas. Care is taken to ensure that the RBW and VBW used meet the regulatory requirements, and that the EBW of the DUT is not reduced. The Photographs included in this report show the Test Setup.

5.3 Radiated Field Computations

To convert the dBm values measured on the spectrum analyzer to dB(μV/m), we use expression

$$E3(dB\mu V/m) = 107 + PR + KA - KG + KE - CF$$

where
- PR = power recorded on spectrum analyzer, dBm, measured at 3 m
- KA = antenna factor, dB/m
- KG = pre-amplifier gain, including cable loss, dB
- KE = duty correction factor, dB
- CF = distance conversion (employed only if limits are specified at alternate distance), dB

When presenting the data at each frequency, the highest measured emission under all of the possible DUT orientations (3-axes) is given.

5.4 Indoor Power Line Conducted Emissions

When applicable, power line conducted emissions are measured in our semi-anechoic chamber. If the DUT connects to auxiliary equipment and is table or floor standing, the configurations prescribed in ANSI C63.4 are employed. Alternatively, an on-table layout more representative of actual use may be employed if the resulting emissions appear to be worst-case in such a configuration.

The conducted emissions measured with the spectrum analyzer and recorded (in dBµV) from 0-2 MHz and 2-30 MHz for both the ungrounded (Hi) and grounded (Lo) conductors. The spectrum analyzer is set to peak-hold mode in order to record the highest peak throughout the course of functional operation. Only when the emission exceeds or is near the limit are quasi-peak and average detection used.

5.5 Supply Voltage Variation

Measurements of the variation in the fundamental radiated emission were performed with the supply voltage varied by no less than 85% and 115% of the nominal rated value. For battery operated equipment, tests were performed using a new battery, and worst case emissions are re-checked employing a new battery.

6. Test Results

6.1 Radiated Emissions

6.1.1 Peak to Quasi-peak and Average Ratio

When the device is powered, it can, in the worst case, transmit one 0.95 ms data packet in any given 100 ms window, thus a 20 dB duty is applied throughout. See Figure 6.1. Computing the duty factor results in:

$$K_E = 0.95 \text{ ms} / 100 \text{ ms} = 0.009 < -20 \text{ dB}.$$

6.1.2 Emission Spectrum

The relative DUT emission spectrum is tabulated in Table 6.1.

6.1.3 Emission Bandwidth

The emission bandwidth of the signal is shown in Figure 6.2. Therein the worst case 99% power bandwidth is measured to be 2.425 MHz.

6.1.4 Supply Voltage and Supply Voltage Variation

The DUT has been designed to be powered by 120 VAC wall adapter. For this test, relative radiated power was measured at the fundamental as the voltage was varied from 85 to 140 volts. The emission variation is shown in Figure 6.3.

Voltage	V	=	120 VAC
Ave. current	I	=	11 mA

6.2 Conducted Emissions

AC Mains power line conducted emissions meet the Class B limits by 5.0 dB. Worst case emissions are reported in Table 6.2.

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Table 6.1(a) Highest Emissions Measured

Radiated Emissions											RAVEN WiFi Bridge; FCC/IC
#	Freq. MHz	Ant. Used	Ant. Pol.	Pr dBm	Det.* Used	Ka dB/m	Kg dB	E3** dBμV/m	E3lim dBμV/m	Pass dB	Comments
1	2405.0	R-Horn	H/V	- 8.8	Pk	23.5	26.5	75.2	94.0	18.8	Low Channel, 2405 MHz; max all
2	2445.0	R-Horn	H/V	-11.5	Pk	23.7	26.4	72.7	94.0	21.3	8th Channel, 2445 MHz; max all
3	2480.0	R-Horn	H/V	-10.0	Pk	23.8	26.4	74.4	94.0	19.6	High Channel, 2480 MHz; max all
4	4810.0	Horn C	H/V	-60.7	Pk	24.6	38.0	12.9	54.0	41.1	Low; max all
5	4890.0	Horn C	H/V	-54.4	Pk	24.6	38.0	19.2	54.0	34.8	Mid; max all
6	4960.0	Horn C	H/V	-56.5	Pk	24.6	38.0	17.1	54.0	36.9	High; max all
7	7215.0	Horn XN	H/V	-54.1	Pk	25.1	36.8	21.2	54.0	32.8	Low, noise; max all
8	7335.0	Horn XN	H/V	-53.8	Pk	25.2	36.8	21.6	54.0	32.4	Mid, noise; max all
9	7440.0	Horn XN	H/V	-52.1	Pk	25.3	36.8	23.4	54.0	30.6	High, noise; max all
10	9620.0	Horn X	H/V	-50.3	Pk	27.8	36.8	27.7	54.0	26.3	Low, noise; max all
11	9780.0	Horn X	H/V	-50.2	Pk	27.9	36.8	27.9	54.0	26.1	Mid, noise; max all
12	9920.0	Horn X	H/V	-49.9	Pk	28.0	36.8	28.3	54.0	25.7	High, noise; max all
13	12025.0	Horn X	H/V	-49.2	Pk	31.7	35.7	33.8	54.0	20.2	Low, noise; max all
14	12225.0	Horn X	H/V	-49.8	Pk	31.8	34.0	35.1	54.0	18.9	Mid, noise; max all
15	12400.0	Horn X	H/V	-49.6	Pk	32.0	32.4	36.9	54.0	17.1	High, noise; max all
16	14430.0	Horn Ku	H/V	-59.3	Pk	33.2	16.8	44.1	54.0	9.9	Low, noise; max all
17	14670.0	Horn Ku	H/V	-60.6	Pk	33.3	16.8	42.9	54.0	11.1	Mid, noise; max all
18	14880.0	Horn Ku	H/V	-60.2	Pk	33.4	16.8	43.4	54.0	10.6	High, noise; max all
19	16835.0	Horn Ku	H/V	-60.0	Pk	34.6	16.8	44.8	54.0	9.2	Low, noise; max all
20	17115.0	Horn Ku	H/V	-60.2	Pk	34.8	16.8	44.8	54.0	9.2	Mid, noise; max all
21	17360.0	Horn Ku	H/V	-59.8	Pk	35.0	16.8	45.4	54.0	**8.6**	High, noise; max all
22	19240.0	Horn K	H/V	-56.8	Pk	32.2	32.0	30.4	54.0	23.6	Low, noise; max all
23	19560.0	Horn K	H/V	-54.1	Pk	32.3	32.0	33.2	54.0	20.8	Mid, noise; max all
24	19840.0	Horn K	H/V	-53.1	Pk	32.3	32.0	34.2	54.0	19.8	High, noise; max all
25	21645.0	Horn K	H/V	-52.1	Pk	32.7	32.0	35.6	54.0	18.4	Low, noise; max all
26	22005.0	Horn K	H/V	-51.9	Pk	32.8	32.0	35.9	54.0	18.1	Mid, noise; max all
27	22320.0	Horn K	H/V	-50.3	Pk	32.8	32.0	37.5	54.0	16.5	High, noise; max all
28	24050.0	Horn K	H/V	-50.9	Pk	33.2	32.0	37.3	54.0	16.7	Low, noise; max all
29	24450.0	Horn K	H/V	-50.5	Pk	33.3	32.0	37.8	54.0	16.2	Mid, noise; max all
30	24800.0	Horn K	H/V	-48.8	Pk	33.3	32.0	39.5	54.0	14.5	High, noise; max all
31											
32											
33	*Peak measured with 3 MHz RBW and 3 MHz VBW, Avg. more than 20 dB below Peak.										
34	** 20 dB maximum permissible duty cycle applied.										
35											
36											
37											

Meas. 3/16/10; U of Mich.

Table 6.1(b) Highest Emissions Measured

#	Freq. MHz	Ant. Used	Ant. Pol.	Pr dBm	Det.* Used	Ka dB/m	Kg dB	E3 dBμV/m	E3lim dBμV/m	Pass dB	Comments
Band Edge Emissions											RAVEN WiFi Bridge; FCC/IC
1	2390.0	R-Horn	H/V	-56.2	Pk	23.5	26.6	27.7	54.0	26.3	All Channels
2	2400.0	R-Horn	H/V	-49.7	Pk	23.5	26.5	34.3	54.0	19.7	All Channels
3	2483.5	R-Horn	H/V	-38.3	Pk	23.8	26.4	46.1	54.0	**7.9**	All Channels
4	* Band edge Peak measured with 1 MHz RBW, 3 MHz VBW: 20 dB duty cycle applied										
5											
Receiver Spurious Emissions											
#	Freq.** MHz	Ant. Used	Ant. Pol.	Pr dBm	Det. Used	Ka dB/m	Kg dB	E3 dBμV/m	E3lim dBμV/m	Pass dB	Comments
6	2470.0	R-Horn	H/V	-62.4	Pk	23.7	26.4	41.9	54.0	12.1	noise
7	2510.0	R-Horn	H/V	-65.0	Pk	23.8	26.3	39.5	54.0	14.5	noise
8	2545.0	R-Horn	H/V	-62.1	Pk	23.9	26.2	42.6	54.0	**11.4**	noise
9	5090.0	C-Horn	H/V	-60.9	Pk	24.7	38.0	32.8	54.0	21.2	max all channels, noise
10	7635.0	Xn-Horn	H/V	-57.9	Pk	25.5	36.8	37.8	54.0	16.2	max all channels, noise
11											
12											
13											
14	** Rx LO is fc+65 MHz.										
15											
Digital Radiated Emissions, FCC B											
#	Freq. MHz	Ant. Used	Ant. Pol.	Pr dBm	Det. Used	Ka dB/m	Kg dB	E3 dBμV/m	E3lim dBμV/m	Pass dB	Comments
16	45.1	Bic	H	-72.3	Pk	9.8	25.1	19.4	40.0	20.6	
17	45.1	Bic	V	-63.3	Pk	9.8	25.1	28.4	40.0	11.6	
18	55.1	Bic	V	-62.8	Pk	8.5	25.0	27.7	40.0	12.3	
19	68.2	Bic	V	-62.1	Pk	7.7	24.8	27.8	40.0	12.2	
20	73.8	Bic	H	-74.1	Pk	7.6	24.7	15.8	40.0	24.2	
21	73.8	Bic	V	-61.3	Pk	7.6	24.7	28.6	40.0	**11.4**	
22	84.3	Bic	H	-75.3	Pk	7.7	24.5	14.9	40.0	25.1	
23	84.3	Bic	V	-70.9	Pk	7.7	24.5	19.3	40.0	20.7	
24	119.8	Bic	H	-73.4	Pk	10.0	24.0	19.6	43.5	23.9	
25	133.9	Bic	H	-73.7	Pk	11.2	23.7	20.7	43.5	22.8	
26	148.3	Bic	H	-69.1	Pk	12.3	23.5	26.7	43.5	16.8	
27	168.6	Bic	V	-67.9	Pk	13.6	23.2	29.6	43.5	13.9	
28	208.3	Bic	H	-77.9	Pk	14.8	22.7	21.2	43.5	22.3	
29	208.3	Bic	V	-71.2	Pk	14.8	22.7	27.9	43.5	15.6	
30	222.4	Bic	V	-72.6	Pk	14.7	22.5	26.6	46.0	19.4	
31											

Meas. 1/22,3/16/2010; U of Mich.

Table 6.2 Highest Conducted Emissions Measured

RAVEN WiFi Bridge; FCC/IC

	Freq.	Line	Peak Det., dBµV		Pass	QP Det., dBµV		Pass	Ave. Det., dBµV		Pass	
#	MHz	Side	Vtest	Vlim*	dB*	Vtest	Vlim	dB	Vtest	Vlim	dB	Comments
1	0.18	Lo	48.6	54.3	5.7		64.4			54.3		
2	0.24	Lo	46.6	52.0	5.4		62.0			52.0		
3	0.30	Lo	42.5	50.1	7.6		60.2			50.1		
4	0.36	Lo	43.7	48.7	**5.0**		58.8			48.7		
5	0.48	Lo	38.9	46.3	7.4		56.4			46.3		
6	0.60	Lo	39.9	46.0	6.1		56.0			46.0		
7	0.89	Lo	39.3	46.0	6.7		56.0			46.0		
8	0.95	Lo	40.6	46.0	5.4		56.0			46.0		
9	1.01	Lo	39.6	46.0	6.4		56.0			46.0		
10	1.36	Lo	39.0	46.0	7.0		56.0			46.0		
11	2.91	Lo	35.4	46.0	10.6		56.0			46.0		
12												
13												
14												
15												
16	0.19	Hi	48.4	54.0	5.6		64.1			54.0		
17	0.24	Hi	46.3	52.0	5.7		62.0			52.0		
18	0.30	Hi	39.6	50.2	10.6		60.3			50.2		
19	0.36	Hi	42.2	48.7	6.5		58.8			48.7		
20	0.54	Hi	39.5	46.0	6.5		56.0			46.0		
21	0.60	Hi	39.8	46.0	6.2		56.0			46.0		
22	0.89	Hi	39.2	46.0	6.8		56.0			46.0		
23	0.95	Hi	40.9	46.0	**5.1**		56.0			46.0		
24	1.01	Hi	39.6	46.0	6.4		56.0			46.0		
25	1.36	Hi	38.5	46.0	7.5		56.0			46.0		
26	3.26	Hi	35.5	46.0	10.5		56.0			46.0		
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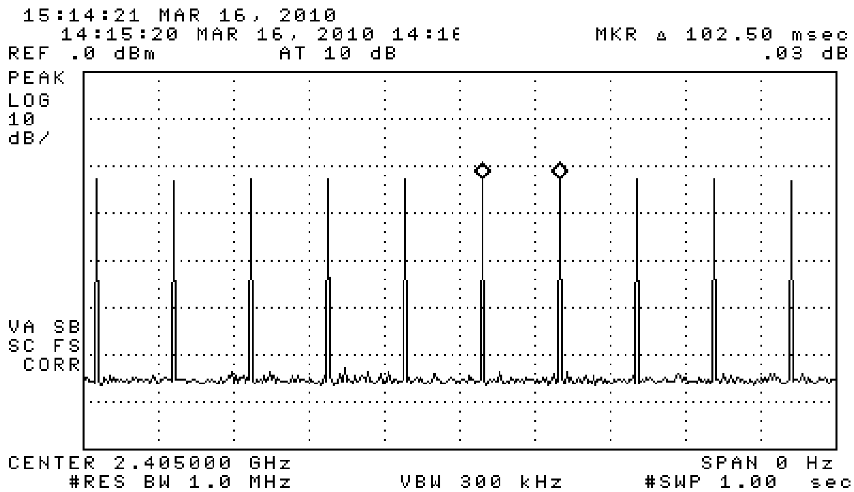
**Average and Quasi-Peak* Meas. 01/29/10; U of Mich.
Since Vpeak >= Vqp >= Vave and if Vtestpeak < Vavelim, then Vqplim and Vavelim are met.



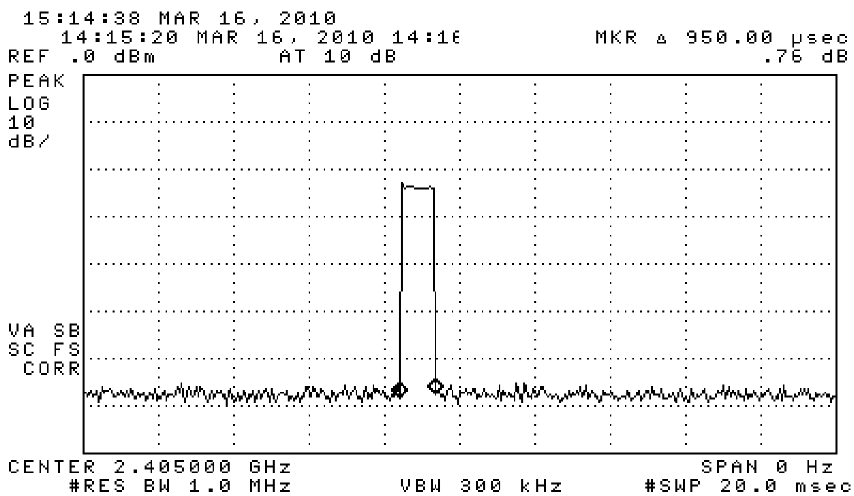


Figure 6.1. Transmission modulation characteristics. (top) complete transmission, (center) expanded transmission, (bottom) expanded word.

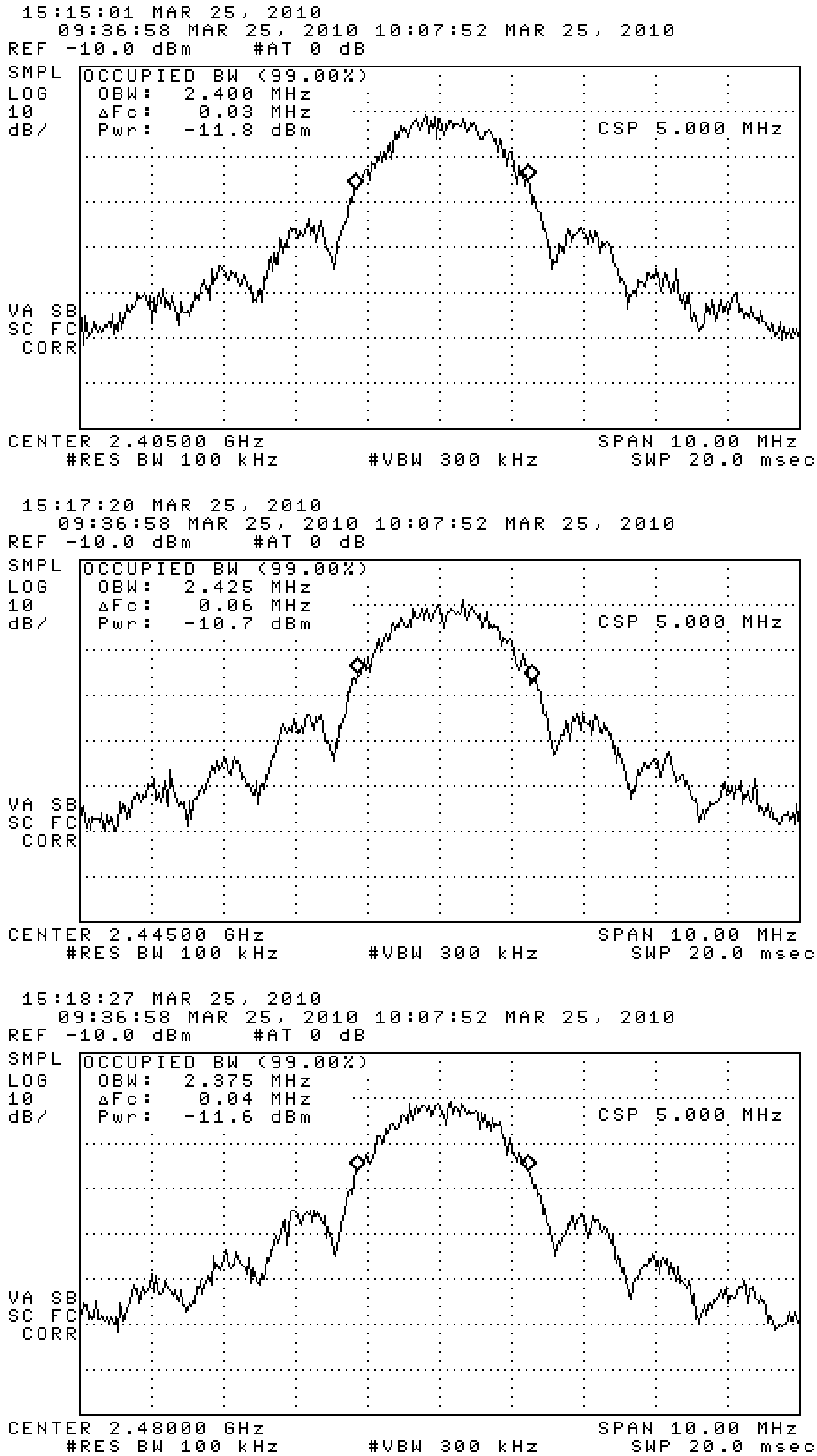


Figure 6.2. Measured emission bandwidth of the DUT (pulsed).

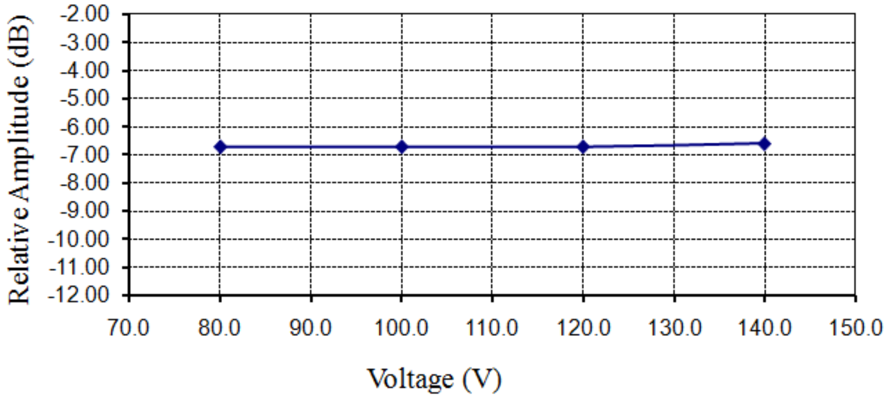


Figure 6.3. Relative emission at fundamental vs. supply voltage (pulsed).

Photograph 6.5. DUT on OATS + Indoor Setup (one of three axes tested)

Photograph 6.6. Close-up of DUT on OATS + Conducted Emissions Setup