



The University of Michigan
Radiation Laboratory
3228 EECS Building
Ann Arbor, MI 48109-2122
Tel: (734) 764-0500

Measured Radio Frequency Emissions
From

Raven Industries Inc. Transmitter
Model(s): 20543-45T

Report No. 415031-321
July 27, 2006

Copyright © 2006

For:
Raven
Electronic Systems Division, 4372 Green Ash Drive
Earth City, MO 63045

Contact:
Tim Diehl
tim.diehl@ravenind.com
Tel: 314-291-2712 ext 3102
Fax: 314-291-0773
PO: Verbal

Measurements made by: Valdis V. Liepa

Tests supervised by:
Report approved by:

A handwritten signature in black ink, appearing to read "Valdis V. Liepa".

Valdis V. Liepa
Research Scientist

Test Report Prepared by: Joseph D. Brunett

Summary

Tests for compliance with FCC Regulations Part 15, Subpart C, and Industry Canada RSS-210/GEN, were performed on Raven Industries Inc. model(s) 20543-45T. This device is subject to the Rules and Regulations as a Transmitter.

In testing completed on July 24, 2006, the device tested in the worst case met the allowed FCC specifications for radiated emissions by 1.1 dB (see p. 6). Besides harmonics, there were no other significant spurious emissions found; emissions from digital circuitry were negligible. The conducted emission tests do not apply, since the device is powered from a 9 VDC battery.

University of Michigan Radiation Laboratory
FCC Part 15, IC RSS-210/Gen - Test Report No. 415031-321

1. Introduction

Raven Industries Inc. model 20543-45T 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 6, September 2005. The 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 Area Test Site are on file with FCC Laboratory, Columbia, Maryland (FCC Reg. No: 91050) and with Industry Canada, Ottawa, ON (File Ref. No: IC 2057).

2. Test Procedure and 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.

Table 2.1 Test Equipment.

| Test Instrument | Eqpt. Used | Manufacturer/Model |
|------------------------------------|-------------------|--|
| Spectrum Analyzer (0.1-1500 MHz) | | Hewlett-Packard, 182T/8558B |
| Spectrum Analyzer (9kHz-22GHz) | X | Hewlett-Packard 8593A SN: 3107A01358 |
| Spectrum Analyzer (9kHz-26GHz) | X | Hewlett-Packard 8593E, SN: 3412A01131 |
| Spectrum Analyzer (9kHz-26GHz) | | Hewlett-Packard 8563E, SN: 3310A01174 |
| Spectrum Analyzer (9kHz-40GHz) | | Hewlett-Packard 8564E, SN: 3745A01031 |
| Power Meter | | Hewlett-Packard, 432A |
| Power Meter | | Anritsu, ML4803A/MP |
| Harmonic Mixer (26-40 GHz) | | Hewlett-Packard 11970A, SN: 3003A08327 |
| Harmonic Mixer (40-60 GHz) | | Hewlett-Packard 11970U, SN: 2332A00500 |
| Harmonic Mixer (75-110 GHz) | | Hewlett-Packard 11970W, SN: 2521A00179 |
| Harmonic Mixer (140-220 GHz) | | Pacific Millimeter Prod., GMA, SN: 26 |
| S-Band Std. Gain Horn | | S/A, Model SGH-2.6 |
| C-Band Std. Gain Horn | | University of Michigan, NRL design |
| XN-Band Std. Gain Horn | | University of Michigan, NRL design |
| X-Band Std. Gain Horn | | S/A, Model 12-8.2 |
| X-band horn (8.2- 12.4 GHz) | | Narda 640 |
| X-band horn (8.2- 12.4 GHz) | | Scientific Atlanta , 12-8.2, SN: 730 |
| K-band horn (18-26.5 GHz) | | FXR, Inc., K638KF |
| Ka-band horn (26.5-40 GHz) | | FXR, Inc., U638A |
| U-band horn (40-60 GHz) | | Custom Microwave, HO19 |
| W-band horn(75-110 GHz) | | Custom Microwave, HO10 |
| G-band horn (140-220 GHz) | | Custom Microwave, HO5R |
| Bicone Antenna (30-250 MHz) | X | University of Michigan, RLBC-1 |
| Bicone Antenna (200-1000 MHz) | X | University of Michigan, RLBC-2 |
| Dipole Antenna Set (30-1000 MHz) | X | University of Michigan, RLDP-1,-2,-3 |
| Dipole Antenna Set (30-1000 MHz) | | EMCO 2131C, SN: 992 |
| Active Rod Antenna (30 Hz-50 MHz) | | EMCO 3301B, SN: 3223 |
| Active Loop Antenna (30 Hz-50 MHz) | | EMCO 6502, SN:2855 |
| Ridge-horn Antenna (300-5000 MHz) | X | University of Michigan |
| Amplifier (5-1000 MHz) | X | Avantak, A11-1, A25-1S |
| Amplifier (5-4500 MHz) | X | Avantak |
| Amplifier (4.5-13 GHz) | | Avantek, AFT-12665 |
| Amplifier (6-16 GHz) | | Trek |
| Amplifier (16-26 GHz) | | Avantek |
| LISN Box | | University of Michigan |
| Signal Generator | | Hewlett-Packard 8657B |

3. Configuration and Identification of Device Under Test

The DUT is a 310 MHz thirteen button low power transmitter designed to send identification and control signals for adjustable bed control. The SAW stabilized carrier is a pulse position modulated, and coding is performed by an IC timed by a 4 MHz internal oscillator.

The DUT was designed and manufactured by Raven, Electronic Systems Division, 4372 Green Ash Drive , Earth City, MO 63045. It is identified as:

Raven Transmitter
Model: 20543-45T
FCC ID: KSMBR20543-45T
IC: 2004 104 237

3.2 Models

Only one model was provided for testing.

3.3 Modes of Operation

The DUT is manually activated and ceases to transmit within 5 seconds of deactivation. See Figure 6.1. The device continues to transmit while the button is depressed up to 35 seconds.

3.4 EMI/EMC Relevant Modifications

There were no modifications made to the DUT by this laboratory.

4. Emission Limits

The DUT tested falls under the category of an Intentional Radiators and the Digital Devices. For FCC, it is subject to Part 15, Subpart C, (Section 15.231(a-c), 15.209), and Subpart A, (Section 15.33). For Industry Canada it is subject to RSS-210 (Section 2.6 and 2.7). The applicable testing frequencies with corresponding emission limits are given in Tables 4.1 and 4.2 below.

4.1 Radiated Emission Limits

Table 4.1. Radiated Emission Limits (FCC: 15.33, 15.35, 15.209; IC: RSS-210, 2.7 Table 2).
(Digital Class B)

| Freq. (MHz) | E _{lim} (3m) μ V/m | E _{lim} dB(μ V/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 BW)

Table 4.2. Radiated Emission Limits (FCC: 15.231(b), 15.205(a); IC: RSS-210; 2.7 Table 4).
(Transmitter)

| Frequency (MHz) | Fundamental Ave. E _{lim} (3m) | | Spurious** Ave. E _{lim} (3m) | |
|--|---|-----------|--|-----------|
| | (μV/m) | dB (μV/m) | (μV/m) | dB (μV/m) |
| 260.0-470.0 | 3750-12500* | | 375-1250 | |
| 315 | 6042 | 75.6 | 604.2 | 55.6 |
| 433.9 | 10966 | 80.8 | 1096.6 | 60.8 |
| 322-335.4 399.9-410 608-614 | Restricted Bands | | 200 | 46.0 |
| 960-1240/1427(IC) 1300-1427 1435-1626.5 1645.5-1646.5 (IC) 1660-1710 1718.9-1722.2 2200-2300 | Restricted Bands | | 500 | 54.0 |

* Linear interpolation, formula: $E = -7083 + 41.67 \cdot f$ (MHz)

** Measure up to tenth harmonic; 120 kHz BW up to 1 GHz, 1 MHz BW above 1 GHz

4.3 Exemptions

None.

4.4 Power Line Conducted Emission Limits

The power line conducted emission limits and tests do not apply here, as the DUT is powered by a 6 VDC battery.

4.5 Supply Voltage Variation

Measurements of the variation in the fundamental radiated emission shall be performed with the supply voltage varied between 85% and 115% of the nominal rated value. For battery operated equipment, the equipment tests shall be performed using a new battery.

5. Test Procedures

5.1 Semi-Anechoic Chamber Radiated Emission Testing

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

In testing for radiated emissions, a transmitter was provided by the manufacturer that is capable of repeated emissions. It was placed on the test table flat, on its side, and on its end. In the chamber we studied and recorded all the emissions using a Bicone antenna up to 300 MHz and a ridged horn antenna above 200 MHz. The measurements made in the chamber below 1 GHz are used for pre-test evaluation only. The measurements made above 1 GHz are used in pre-test evaluation and in final compliance assessment. We note that for the horn antenna, the antenna pattern is directive and the measurement is essentially that of free space (no ground reflection). Consequently, it is not essential to measure the DUT for both antenna polarizations, as long as the DUT is measured on all three of its major axis. In the chamber we also recorded the spectrum and modulation characteristics of the carrier. These data are presented in subsequent sections.

5.2 Open Area Test Site (OATS) Radiated Emission Testing

After the chamber measurements are complete, emissions are re-measured on the outdoor 3-meter open area test site at the fundamental and harmonics up to 1 GHz using tuned dipoles and/or a high frequency biconical antenna. The DUT is placed on the test table flat, on its side, and on its end, and worst case emissions are recorded. Photographs included in this filing show the DUT on the OATS.

5.3 Field Calculation for Radiated Emission Measurements

To convert the dBm's measured on the spectrum analyzer to dB(μ V/m), we use expression

$$E_3(\text{dB}\mu\text{V/m}) = 107 + P_R + K_A - K_G$$

where P_R = power recorded on spectrum analyzer, dB, measured at 3m
 K_A = antenna factor, dB/m
 K_G = pre-amplifier gain, including cable loss, dB

When presenting the data, at each frequency the highest measured emission under all of the possible orientations is given. Computations and results are given in Table 5.1. There we see that the DUT meets the limit by 1.1 dB.

5.4 Power Line Conducted Emission Testing

These tests do not apply, since the DUT is powered from a 9 VDC battery.

6. Test Results

6.1 Correction For Pulse Operation

When the transmitter is activated (by button press), it transmits repeated 75 ms PPM words, with 132.5 ms period until the button is released (up to 35 seconds). In the worst case, one PPM word consists of one 1ms leading pulse followed by 13 narrow (0.525 ms) PPM pulses. See Figure 6.1. Computing the duty factor results in:

$$K_E = (1 \times 1.0 \text{ ms} + 13 \times 0.525 \text{ ms}) / 100 \text{ ms} = 0.078 < -20.0 \text{ dB}.$$

6.2 Emission Spectrum

Using the ridge-horn antenna and DUT placed in its aperture, emission spectrum was recorded and is shown in Figure 6.2. We note that in scanning from 30 MHz to 4.5 GHz using Bicone and the ridge horn antennas, there were no other significant spurious emissions observed.

6.3 Bandwidth of the Emission Spectrum

The measured spectrum of the signal is shown in Figure 6.3. The allowed (-20 dB, 99%) bandwidth is 0.25% of 310 MHz, or 775.0 kHz. From the plot we see that the -20 dB bandwidth is 55.0 kHz, and the center frequency is 309.94 MHz.

6.4 Effect of Supply Voltage Variation and Test Battery Voltages

The DUT has been designed to be powered by a 9 VDC battery. For this test, the battery was replaced by a laboratory variable power supply. Relative power radiated was measured at the fundamental as the voltage was varied from 4 to 12 volts. The emission variation is shown in Figure 6.4.

| | | | |
|-----------------------------|----------------|------------|-----------------|
| Batteries: | before testing | $V_{oc} =$ | 9.41 V |
| | after testing | $V_{oc} =$ | 9.15 V |
| Ave. current from batteries | | $I =$ | 7.1 mA (pulsed) |

Table 5.1 Highest Emissions Measured

| Radiated Emission - RF | | | | | | | | | | | Raven Ultramatic; 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 | 310.0 | Dip | H | - 8.6 | Pk | 18.4 | 22.6 | 74.2 | 75.3 | 1.1 | flat |
| 2 | 310.0 | Dip | V | -12.6 | Pk | 18.4 | 22.6 | 70.2 | 75.3 | 5.1 | side |
| 3 | 620.0 | Dip | H | -43.0 | Pk | 24.2 | 19.6 | 48.7 | 55.3 | 6.7 | flat |
| 4 | 620.0 | Dip | V | -43.2 | Pk | 24.2 | 19.6 | 48.5 | 55.3 | 6.9 | end |
| 5 | 930.0 | Dip | H | -57.9 | Pk | 28.7 | 17.7 | 40.1 | 55.3 | 15.2 | flat |
| 6 | 930.0 | Dip | V | -55.0 | Pk | 28.7 | 17.7 | 43.0 | 55.3 | 12.3 | end |
| 7 | 1240.0 | Horn | H | -30.0 | Pk | 20.5 | 28.0 | 49.5 | 54.0 | 4.5 | flat |
| 8 | 1550.0 | Horn | H | -40.2 | Pk | 21.4 | 28.0 | 40.2 | 54.0 | 13.8 | flat |
| 9 | 1860.0 | Horn | H | -43.9 | Pk | 22.2 | 28.0 | 37.3 | 55.3 | 18.1 | side |
| 10 | 2170.0 | Horn | H | -43.4 | Pk | 22.9 | 28.1 | 38.4 | 55.3 | 16.9 | side |
| 11 | 2480.0 | Horn | H | -50.4 | Pk | 23.8 | 28.3 | 32.1 | 55.3 | 23.3 | flat |
| 12 | 2790.0 | Horn | H | -44.4 | Pk | 24.7 | 28.2 | 39.1 | 54.0 | 14.9 | side |
| 13 | 3100.0 | Horn | H | -54.2 | Pk | 25.7 | 27.9 | 30.6 | 55.3 | 24.8 | side |
| 14 | | | | | | | | | | | |
| 15 | | | | | | | | | | | |
| 16 | | | | | | | | | | | |
| 17 | | | | | | | | | | | |
| 18 | * Includes 20 dB duty factor | | | | | | | | | | |
| 19 | | | | | | | | | | | |
| 20 | | | | | | | | | | | |
| 21 | | | | | | | | | | | |
| 22 | | | | | | | | | | | |
| 23 | | | | | | | | | | | |
| 24 | | | | | | | | | | | |
| 25 | | | | | | | | | | | |
| 26 | | | | | | | | | | | |
| 27 | | | | | | | | | | | |
| Digital Radiated Emissions* | | | | | | | | | | | |
| # | Freq. kHz | Ant. Used | Ant. Pol. | Pr dBm | Det. Used | Ka dB/m | Kg dB | E3 dBμV/m | E3lim dBμV/m | Pass dB | Comments |
| 1 | | | | | | | | | | | |
| 2 | | | | | | | | | | | |
| 3 | | | | | | | | | | | |
| 4 | Digital emissions more than 20 dB below FCC/IC Class B Limit. | | | | | | | | | | |
| 5 | | | | | | | | | | | |
| 6 | | | | | | | | | | | |
| 7 | | | | | | | | | | | |
| 8 | | | | | | | | | | | |
| 9 | | | | | | | | | | | |

Meas. 06/14/2006; U of Mich.

University of Michigan Radiation Laboratory
FCC Part 15, IC RSS-210/Gen - Test Report No. 415031-321

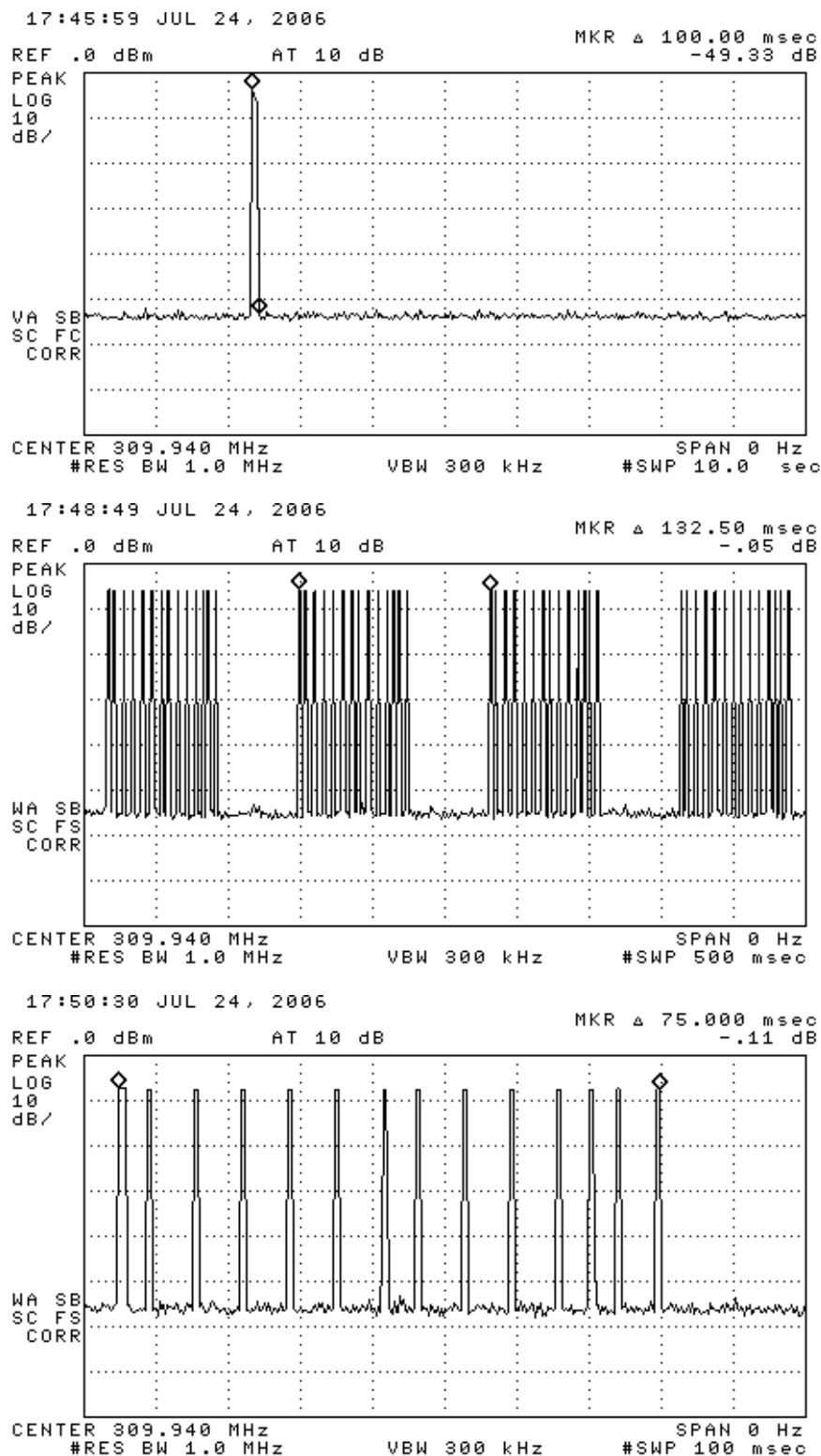


Figure 6.1(a). Transmissions modulation characteristics: (top) single transmission, (center) repetition period, (bottom) expanded word.

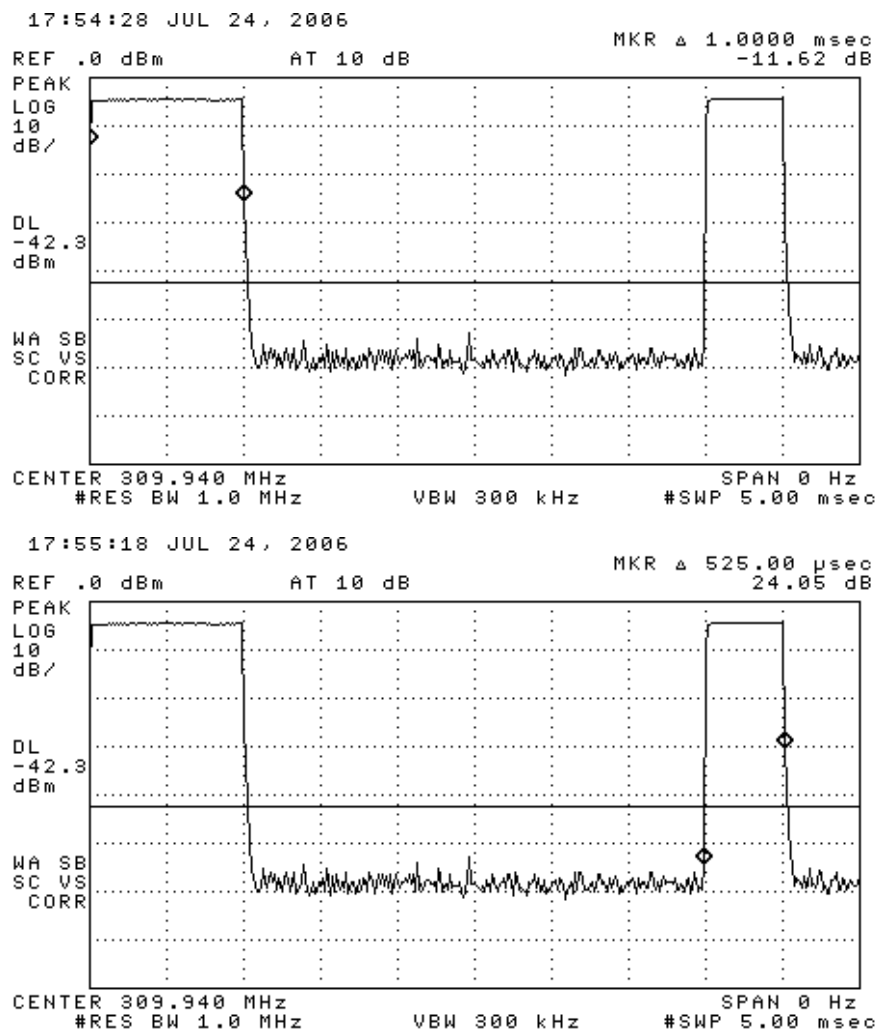


Figure 6.1(b). Transmissions modulation characteristics: (top) leading pulse, (bottom) narrow pulse.

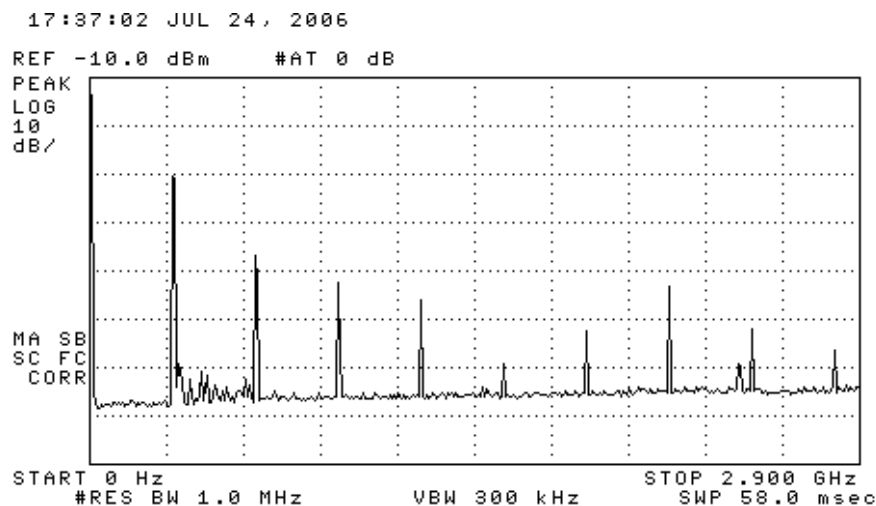


Figure 6.2. Emission spectrum of the DUT (pulsed emission). The amplitudes are only indicative (not calibrated).

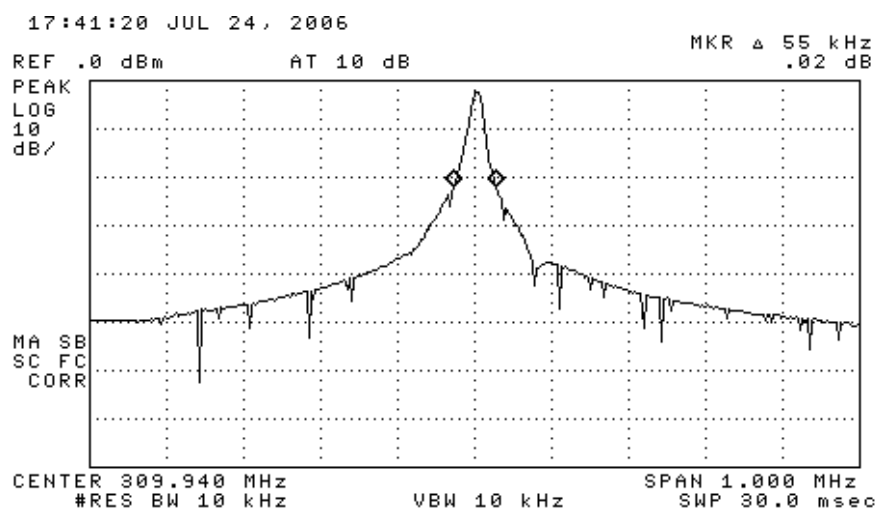


Figure 6.3. Measured bandwidth of the DUT (pulsed emission).

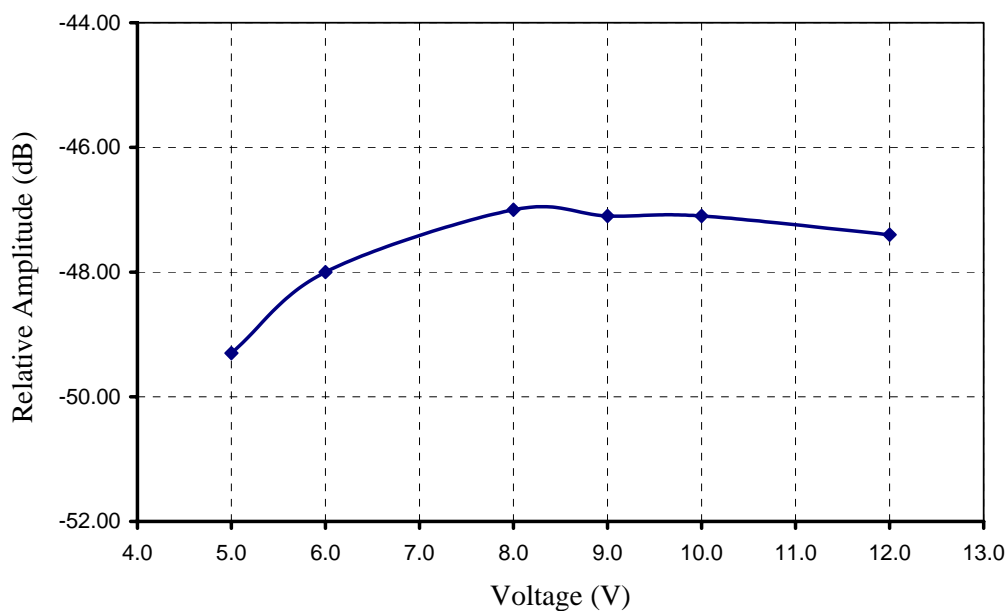
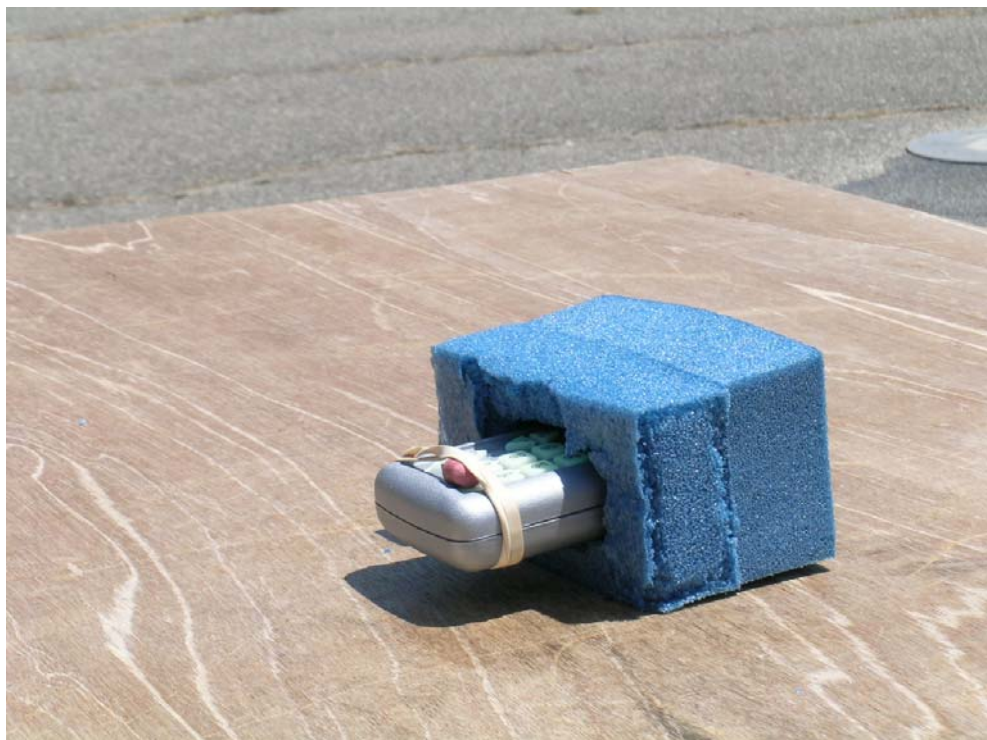


Figure 6.5. Relative emission at 315.0 MHz vs. supply voltage (pulsed emission).



DUT on OATS



DUT on OATS (close-up)