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# Measured Radio Frequency Emissions From

# **Johnson Controls Interiors Homelink Transmitter Model: SAHL3**

Report No. 415031-251
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For:
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**Summary**
Tests for compliance with FCC Regulations, Part 15, Subpart C, and for compliance with Industry Canada RSS-210, were performed on JCI Transmitter, Model SAHL3. In the tests the transmitters were trained to three duty factors (30%, 50%, and 80%) and to three frequencies (288 MHz, 310 MHz, and 418 MHz).

In testing completed on June 8, 2005, in the worst case of all combinations tested, the transmitter tested in the worst case met the allowed limits for radiated emissions by 4.0 dB at the fundamental (p.7-E) and by 7.4 dB at the harmonics (p.7-A). Besides harmonics there were no other significant spurious emissions found. It was also verified that the device will not transmit in Restricted Bands. The conductive emission tests do not apply, since the device is powered from a 12VDC automobile source.

## 1. Introduction

JCI Transmitter, Model SAHL3, was tested for compliance with FCC Regulations, Part 15, adopted under Docket 87-389, April 18, 1989, and with Industry Canada RSS-210, Issue 2, dated February 14, 1998. 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 Site facility 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 | Equip. 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 | Avantek, A11-1, A25-1S |
| Amplifier (5-4500 MHz) | X | Avantek |
| 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 | X | Hewlett-Packard 8657B |

## 3. Configuration and Identification of Device Under Test

The DUT is a learning garage door opener transmitter. The transmitter differs from a standard Garage Door Opener (GDO) in that it does not have a fixed frequency or code, but rather learns and repeats the frequency and code from another GDO, with capability to repeat up to three GDOs. The DUT uses a 20.0 MHz microprocessor crystal, and a 10.7 MHz frequency reference. The DUT transmits from 288 to 418 MHz. The forbidden bands are "blocked out" in firmware. Depending on the frequency and the duty factor of the GDO that is being learned, the DUT attenuates the emissions in firmware using predetermined attenuation settings. The transmitter is activated only when a button is depressed, and ceases operation upon release of the button.

The DUT was designed by Johnson Controls Interiors L.L.C., One Prince Center, Holland, MI 49423, and will be manufactured by Jabil Circuits, Inc., 1700 Atlantic Blvd., Auburn Hills, MI, 48236. It is identified as:

Johnson Controls Interiors L.L.C. Transmitter
Model: SAHL3
FCC ID: CB2SAHL3
IC: 2791021849 A5 2

Note, upon activation and deactivation, the DUT demonstrates emission overshoot and/or minor frequency drift and takes a few milliseconds to settle to the appropriate level. Best efforts were made to capture and report this peak value for the worst case orientations of the DUT on the OATS. These worst case emissions are as reported in the data table(s) provided.

### 3.1 EMI Relevant Modifications

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

## 4. Emission Limits

### 4.1 Radiated 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), Subpart B, (Section 15.109), and Subpart A, (Section 15.33). For Industry Canada it is subject to RSS-210, (Sections 6.1 and 6.3). The applicable testing frequencies with corresponding emission limits are given in Tables 4.1 and 4.2 below. As a digital device, the DUT is exempt; the learning receiver and the tire pressure monitoring receiver (if present) are subject to Class B limits.

Table 4.1. Radiated Emission Limits (FCC: 15.33, 15.35, 15.109; IC: RSS-210, 6.2.2(r)).
(Digital Class B)

| 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 BW)

Table 4.2. Radiated Emission Limits (FCC: 15.231(b), 15.205(a); IC: RSS-210; 6.1, 6.3) (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 | |
| 322-335.4<br>399.9-410<br>608-614 | Restricted Bands | | 200 | 46.0 |
| 960-1240<br>1300-1427<br>1435-1626.5<br>1660-1710<br>1718.9-1722.2<br>2200-2300 | Restricted Bands | | 500 | 54.0 |

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

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

**4.2 Conductive Emission Limits**

The conductive emission limits and tests do not apply here, since the DUT is powered from automotive 12 VDC source.

## 5. Radiated Emission Tests and Results

### 5.1 Semi-Anechoic Chamber Measurements

To familiarize with the radiated emission behavior of the DUT, the DUT was first studied and measured in a shielded 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. In testing for radiated emissions, the transmitter modified for continuous emissions was used. It was placed in a Styrofoam block to facilitate its orientation on any of its three major axis, i. e., flat down, on its side, or 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 the final compliance assessment. We note that for the horn antenna, the antenna pattern is more directive and hence 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. We also note, that in scanning from 30 MHz to 4.2 GHz using bicone and the ridge horn antennas, there were no other significant spurious emissions observed.

## 5.2 Outdoor Measurements
After the chamber measurements, the emissions were re-measured on the outdoor 3-meter site at fundamental and harmonics up to 1 GHz using tuned dipoles and/or the high frequency bicone. Photographs in Appendix show the DUT on the open in site table (OATS).

## 5.3 Computations and Results
To convert the dBm measured on the spectrum analyzer to dB(μV/m), we use expression

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

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
$K_E$ = pulse operation correction factor, dB (see Sec. 6.1)

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 Tables 5.1 through 5.3. There we see that the DUT meets the limit by 4.0 dB (p.7).

# 6. Other Measurements and Computations

## 6.1 Correction For Pulse Operation
As agreed previously between the FCC and Prince (now JCI), the DUT was taught signals of 30, 50, and 80% duty factors at 310 MHz. The repeated wave shapes were measured and from those the duty factors obtained. Figures 6.1(a) through 6.1(c) show the measured wave shapes from which the duty factors were computed. These are:

Antenna Tuning duty factor The DUT uses a preamble set of tuning and wakeup pulses before transmission begins. During this preamble, the worst case on time consists of one 13 ms pulse and one 27 ms pulse in a 100 ms window. Thus,

$K_E$ = (13.0 + 27.0) / 100 = 0.400 or -7.96 dB.

30% duty factor The worst case modulation consists of 675 μs wide pulses of period 2.000 ms. Thus,

$K_E$ = 0.675 / 2.000 = 0.338 or -9.43 dB. However, since the Antenna Tuning duty factor is dominant, we utilize a duty factor of -7.96 dB.

50% duty factor The modulation consists of 1.025 ms wide pulses of period 2.000 ms. Thus,

$K_E$ = 1.025 / 2.000 = 0.513 or -5.81dB.

80% duty factor The modulation consists of 1.6250 ms wide pulses of period 2.0000 ms. Thus,

$K_E$ = 1.6125/2.0000 = 0.806 or -1.9 dB.

## 6.2 Emission Spectrum
Using the ridge-horn antenna and the DUT placed in its aperture, emission spectrum was recorded and is shown in Figure 6.2. The antenna is near the cut off at 280 MHz, hence the signal received from the fundamental emission is reduced relative to its harmonics.

### 6.3 Bandwidth of the Emission Spectrum

The measured spectrum of the signals are shown in Figure 6.3. The measurements were made at 310 MHz for 30, 50, and 80% duty factor modulations. At 310 MHz the allowed (-20 dB, 0.25%) bandwidth is 775 kHz. From the plots we see that, in the worst case, the -20 dB bandwidth is 288.0 kHz for the 80% duty factor (Fig. 6.3(c)).

### 6.4 Effect of Supply Voltage Variation

The DUT has been designed to be powered from an automotive 12 VDC battery. For this test, a laboratory variable power supply was used and relative radiated field was measured at the fundamental, as the voltage was varied from 6 to 16 volts. The emission variation is shown in Figure 6.4.

### 6.5 Input Voltage and Current (310 MHz, 50% Duty, pulsed operation)

| | | |
|---|---|---|
| Supply Voltage | = | 12.0 VDC |
| Current | = | 45.0 mADC |

### 6.6 Verification of Non-operation in Restricted Bands

The DUT has been designed to learn and operate over 288 to 418 MHz frequency range. It also has been programmed to stay out of the Restricted Bands. In the operating range of the DUT, these bands are 240.0 - 285.0 MHz, 322.0 - 335.4 MHz, and 399.9 - 410.0 MHz. In addition, since the second harmonic of 304 - 307 MHz range falls in the restricted band, as a precaution, these frequencies were also excluded.

Using a 500 Hz 80% duty factor modulated carrier from a signal generator, the DUT was "taught" frequencies from 240.0 to 440.0 MHz. It repeated frequencies from 287.90 to 303.30 MHz, from 307.41 to 320.90 MHz, from 336.52 to 398.11 MHz, and from 411.10 to 419.91 MHz. In any case, no frequencies were repeated in the Restricted Bands. (Also, there were no spurious emissions in the Restricted Bands.)

### 6.6 Verification for Deactivation Within 5 Seconds

When a button is depressed, the DUT transmits up to 20 seconds. When the button is released, the transmission ceases at that time. Figure 6.5 shows emission when the DUT button is depressed for about two seconds.

### 6.6 Learning receiver emissions

When the DUT is put in learn mode, a detector sweeps typically from 285 to 420 MHz looking for a signal. Once found, it locks onto the signal and learns its frequency and modulation. The detector is based on a superheterodyne design, with 10.7 MHz IF. The emissions are anticipated from the LO circuit.

The emissions were measured for low (288 MHz), mid (310 MHz), and high (418 MHz) ends of the band for fundamental and harmonics up to 2.0 GHz. Measurements were made on OATS (up to 1 GHz) and in the chamber above 1 GHz. The emissions are presented in Table 6.1. There it shows that the detector emissions meet Class B limits by 11.2 dB.


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# Table 5.1  Highest Emissions Measured

| Radiated Emission - RF | | | | | | | | | | | JCI, PM/MK; FCC/IC; 288 MHz |
|---|---|---|---|---|---|---|---|---|---|---|---|
| # | Freq. MHz | Ant. Used | Ant. Pol. | Pr dBm | Det. Used | Ka dB/m | Kg dB | E3* dBµV/m | E3lim dBµV/m | Pass dB | Comments |
| 30 % Duty Factor (meas. XX dB) | | | | | | | | | | | |
| 1 | 288.0 | Dip | H | -30.4 | Pk | 18.1 | 19.2 | 67.6 | 73.9 | **6.3** | flat |
| 2 | 288.0 | Dip | V | -31.2 | Pk | 18.1 | 19.2 | 66.8 | 73.9 | 7.1 | end |
| 3 | 576.0 | Dip | H | -59.4 | Pk | 24.4 | 17.6 | 46.5 | 53.9 | 7.4 | flat |
| 4 | 576.0 | Dip | V | -62.9 | Pk | 24.4 | 17.6 | 43.0 | 53.9 | 10.9 | end |
| 5 | 864.0 | Dip | H | -78.2 | Pk | 28.1 | 15.4 | 33.5 | 53.9 | 20.4 | flat, 30 kHz RBW, background |
| 6 | 864.0 | Dip | V | -78.7 | Pk | 28.1 | 15.4 | 33.0 | 53.9 | 20.9 | end, 30 kHz RBW, background |
| 7 | 1152.0 | Horn | H | -61.4 | Pk | 20.2 | 28.1 | 29.8 | 53.9 | 24.1 | flat |
| 8 | 1440.0 | Horn | H | -54.3 | Pk | 21.1 | 28.3 | 37.6 | 53.9 | 16.3 | flat |
| 9 | 1728.0 | Horn | H | -66.8 | Pk | 21.8 | 27.8 | 26.3 | 53.9 | 27.6 | flat |
| 10 | 2016.0 | Horn | H | -64.1 | Pk | 22.5 | 26.6 | 30.9 | 53.9 | 23.0 | flat |
| 11 | 2304.0 | Horn | H | -71.0 | Pk | 23.3 | 26.9 | 24.4 | 53.9 | 29.5 | max all, noise |
| 12 | 2592.0 | Horn | H | -71.6 | Pk | 24.1 | 26.6 | 24.9 | 53.9 | 29.0 | max all, noise |
| 13 | 2880.0 | Horn | H | -71.0 | Pk | 25.0 | 25.5 | 27.5 | 53.9 | 26.4 | max all, noise |
| 14 | | | | | | | | | | | |
| 50 % Duty Factor (meas. XX dB) | | | | | | | | | | | |
| 15 | 288.0 | Dip | H | -33.1 | Pk | 18.1 | 19.2 | 67.0 | 73.9 | **6.9** | flat |
| 16 | 288.0 | Dip | V | -35.2 | Pk | 18.1 | 19.2 | 64.9 | 73.9 | 9.0 | end |
| 17 | 576.0 | Dip | H | -65.9 | Pk | 24.4 | 17.6 | 42.1 | 53.9 | 11.8 | flat |
| 18 | 576.0 | Dip | V | -70.0 | Pk | 24.4 | 17.6 | 38.0 | 53.9 | 15.9 | side |
| 19 | 864.0 | Dip | H | -81.9 | Pk | 28.1 | 15.4 | 32.0 | 53.9 | 21.9 | flat, 30 kHz RBW, background |
| 20 | 864.0 | Dip | V | -79.0 | Pk | 28.1 | 15.4 | 34.9 | 53.9 | 19.0 | end, 30 kHz RBW, background |
| 21 | 1152.0 | Horn | H | -67.1 | Pk | 20.2 | 28.1 | 24.1 | 53.9 | 29.8 | flat |
| 22 | 1440.0 | Horn | H | -56.2 | Pk | 21.1 | 28.3 | 35.7 | 53.9 | 18.2 | flat |
| 23 | 1728.0 | Horn | H | -67.2 | Pk | 21.8 | 27.8 | 25.9 | 53.9 | 28.0 | end |
| 24 | 2016.0 | Horn | H | -67.3 | Pk | 22.5 | 26.6 | 27.7 | 53.9 | 26.2 | flat |
| 25 | 2304.0 | Horn | H | -72.4 | Pk | 23.3 | 26.9 | 23.0 | 53.9 | 30.9 | max all, noise |
| 26 | 2592.0 | Horn | H | -71.8 | Pk | 24.1 | 26.6 | 24.7 | 53.9 | 29.2 | max all, noise |
| 27 | 2880.0 | Horn | H | -71.9 | Pk | 25.0 | 25.5 | 26.6 | 53.9 | 27.3 | max all, noise |
| 28 | | | | | | | | | | | |
| 29 | | | | | | | | | | | |
| 30 | | | | | | | | | | | |
| 31 | | | | | | | | | | | |
| 32 | | | | | | | | | | | |
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| 35 | | | | | | | | | | | |
| 36 | | | | | | | | | | | |
| 37 | | | | | | | | | | | |

Meas. 5/31/2005 - 06/02/2005; U of Mich.

# Table 5.1 Highest Emissions Measured

| Radiated Emission - RF | | | | | | | | | | | JCI, PM/MK; FCC/IC; 288 MHz |
|---|---|---|---|---|---|---|---|---|---|---|---|
| # | Freq. MHz | Ant. Used | Ant. Pol. | Pr dBm | Det. Used | Ka dB/m | Kg dB | E3* dBμV/m | E3lim dBμV/m | Pass dB | Comments |
| 80 % Duty Factor (meas. XX dB) | | | | | | | | | | | |
| 1 | 288.0 | Dip | H | -36.4 | Pk | 18.1 | 19.2 | 67.8 | 73.9 | **6.1** | flat |
| 2 | 288.0 | Dip | V | -38.6 | Pk | 18.1 | 19.2 | 65.6 | 73.9 | 8.3 | end |
| 3 | 576.0 | Dip | H | -69.7 | Pk | 24.4 | 17.6 | 42.5 | 53.9 | 11.4 | flat |
| 4 | 576.0 | Dip | V | -74.4 | Pk | 24.4 | 17.6 | 37.8 | 53.9 | 16.1 | end |
| 5 | 864.0 | Dip | H | -79.6 | Pk | 28.1 | 15.4 | 38.4 | 53.9 | 15.5 | flat, 30 kHz RBW, background |
| 6 | 864.0 | Dip | V | -80.0 | Pk | 28.1 | 15.4 | 38.0 | 53.9 | 15.9 | side, 30 kHz RBW, background |
| 7 | 1152.0 | Horn | H | -68.5 | Pk | 20.2 | 28.1 | 29.0 | 53.9 | 24.9 | flat |
| 8 | 1440.0 | Horn | H | -59.2 | Pk | 21.1 | 28.3 | 39.0 | 53.9 | 14.9 | end |
| 9 | 1728.0 | Horn | H | -68.3 | Pk | 21.8 | 27.8 | 31.1 | 53.9 | 22.8 | flat |
| 10 | 2016.0 | Horn | H | -69.0 | Pk | 22.5 | 26.6 | 32.3 | 53.9 | 21.6 | flat |
| 11 | 2304.0 | Horn | H | -68.4 | Pk | 23.3 | 26.9 | 33.3 | 53.9 | 20.6 | flat |
| 12 | 2592.0 | Horn | H | -72.6 | Pk | 24.1 | 26.6 | 30.2 | 53.9 | 23.7 | max all, noise |
| 13 | 2880.0 | Horn | H | -72.0 | Pk | 25.0 | 25.5 | 32.8 | 53.9 | 21.1 | max all, noise |
| 14 | | | | | | | | | | | |
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| 37 | | | | | | | | | | | |

Meas. 5/31/2005 - 06/02/2005; U of Mich.

# Table 5.1 Highest Emissions Measured

| Radiated Emission - RF | | | | | | | | | | | JCI, PM/MK; FCC/IC; 310 MHz |
|---|---|---|---|---|---|---|---|---|---|---|---|
| # | Freq. MHz | Ant. Used | Ant. Pol. | Pr dBm | Det. Used | Ka dB/m | Kg dB | E3* dBμV/m | E3lim dBμV/m | Pass dB | Comments |
| 30 % Duty Factor (meas. XX dB) | | | | | | | | | | | |
| 1 | 310.0 | Dip | H | -29.1 | Pk | 18.8 | 18.9 | 69.8 | 75.3 | **5.5** | flat |
| 2 | 310.0 | Dip | V | -29.6 | Pk | 18.8 | 18.9 | 69.3 | 75.3 | 6.0 | end |
| 3 | 620.0 | Dip | H | -66.3 | Pk | 25.1 | 17.2 | 40.6 | 55.3 | 14.7 | flat |
| 4 | 620.0 | Dip | V | -68.4 | Pk | 25.1 | 17.2 | 38.5 | 55.3 | 16.8 | side |
| 5 | 930.0 | Dip | H | -85.3 | Pk | 28.7 | 15.0 | 27.5 | 55.3 | 27.8 | flat, 30 kHz RBW, noise |
| 6 | 930.0 | Dip | V | -88.6 | Pk | 28.7 | 15.0 | 24.2 | 55.3 | 31.1 | side, 30 kHz RBW, noise |
| 7 | 1240.0 | Horn | H | -65.8 | Pk | 20.5 | 28.0 | 25.8 | 54.0 | 28.2 | sid |
| 8 | 1550.0 | Horn | H | -59.4 | Pk | 21.4 | 28.2 | 32.9 | 54.0 | 21.1 | flat |
| 9 | 1860.0 | Horn | H | -67.4 | Pk | 22.2 | 28.3 | 25.5 | 55.3 | 29.8 | flat |
| 10 | 2170.0 | Horn | H | -69.1 | Pk | 22.9 | 27.1 | 25.8 | 55.3 | 29.5 | max all, noise |
| 11 | 2480.0 | Horn | H | -71.4 | Pk | 23.8 | 26.5 | 24.9 | 55.3 | 30.4 | max all, noise |
| 12 | 2790.0 | Horn | H | -71.7 | Pk | 24.7 | 25.6 | 26.4 | 54.0 | 27.6 | max all, noise |
| 13 | 3100.0 | Horn | H | -71.2 | Pk | 25.7 | 25.1 | 28.4 | 55.3 | 26.9 | max all, noise |
| 14 | | | | | | | | | | | |
| 50 % Duty Factor (meas. XX dB) | | | | | | | | | | | |
| 15 | 310.0 | Dip | H | -31.8 | Pk | 18.8 | 18.9 | 69.2 | 75.3 | **6.1** | flat |
| 16 | 310.0 | Dip | V | -33.3 | Pk | 18.8 | 18.9 | 67.7 | 75.3 | 7.6 | end |
| 17 | 620.0 | Dip | H | -76.7 | Pk | 25.1 | 17.2 | 32.4 | 55.3 | 22.9 | flat |
| 18 | 620.0 | Dip | V | -77.9 | Pk | 25.1 | 17.2 | 31.2 | 55.3 | 24.1 | side |
| 19 | 930.0 | Dip | H | -87.2 | Pk | 28.7 | 15.0 | 27.7 | 55.3 | 27.6 | flat, 30 kHz RBW, noise |
| 20 | 930.0 | Dip | V | -88.1 | Pk | 28.7 | 15.0 | 26.8 | 55.3 | 28.5 | end, 30 kHz RBW, noise |
| 21 | 1240.0 | Horn | H | -68.7 | Pk | 20.5 | 28.0 | 22.9 | 54.0 | 31.1 | flat |
| 22 | 1550.0 | Horn | H | -60.6 | Pk | 21.4 | 28.2 | 31.7 | 54.0 | 22.3 | flat |
| 23 | 1860.0 | Horn | H | -69.3 | Pk | 22.2 | 28.3 | 23.6 | 55.3 | 31.7 | flat |
| 24 | 2170.0 | Horn | H | -71.0 | Pk | 22.9 | 27.1 | 23.9 | 55.3 | 31.4 | max all, noise |
| 25 | 2480.0 | Horn | H | -72.7 | Pk | 23.8 | 26.5 | 23.6 | 55.3 | 31.7 | max all, noise |
| 26 | 2790.0 | Horn | H | -72.0 | Pk | 24.7 | 25.6 | 26.1 | 54.0 | 27.9 | max all, noise |
| 27 | 3100.0 | Horn | H | -71.7 | Pk | 25.7 | 25.1 | 27.9 | 55.3 | 27.4 | max all, noise |
| 28 | | | | | | | | | | | |
| 29 | | | | | | | | | | | |
| 30 | | | | | | | | | | | |
| 31 | | | | | | | | | | | |
| 32 | | | | | | | | | | | |
| 33 | | | | | | | | | | | |
| 34 | | | | | | | | | | | |
| 35 | | | | | | | | | | | |
| 36 | | | | | | | | | | | |
| 37 | | | | | | | | | | | |

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# Table 5.1 Highest Emissions Measured

| Radiated Emission - RF | | | | | | | | | | | JCI, PM/MK; FCC/IC; 310 MHz |
|---|---|---|---|---|---|---|---|---|---|---|---|
| # | Freq. MHz | Ant. Used | Ant. Pol. | Pr dBm | Det. Used | Ka dB/m | Kg dB | E3* dBμV/m | E3lim dBμV/m | Pass dB | Comments |
| 80 % Duty Factor (meas. XX dB) | | | | | | | | | | | |
| 1 | 310.0 | Dip | H | -35.9 | Pk | 18.8 | 18.9 | 69.3 | 75.3 | **6.0** | flat |
| 2 | 310.0 | Dip | V | -36.5 | Pk | 18.8 | 18.9 | 68.7 | 75.3 | 6.6 | end |
| 3 | 620.0 | Dip | H | -79.1 | Pk | 25.1 | 17.2 | 34.1 | 55.3 | 21.2 | flat |
| 4 | 620.0 | Dip | V | -83.2 | Pk | 25.1 | 17.2 | 30.0 | 55.3 | 25.3 | side, noise |
| 5 | 930.0 | Dip | H | -88.2 | Pk | 28.7 | 15.0 | 30.9 | 55.3 | 24.4 | flat, 30 kHz RBW, noise |
| 6 | 930.0 | Dip | V | -87.9 | Pk | 28.7 | 15.0 | 31.2 | 55.3 | 24.1 | side, 30 kHz RBW, noise |
| 7 | 1240.0 | Horn | H | -72.9 | Pk | 20.5 | 28.0 | 25.0 | 54.0 | 29.0 | max all, noise |
| 8 | 1550.0 | Horn | H | -71.6 | Pk | 21.4 | 28.2 | 27.0 | 54.0 | 27.0 | max all, noise |
| 9 | 1860.0 | Horn | H | -72.0 | Pk | 22.2 | 28.3 | 27.2 | 55.3 | 28.1 | max all, noise |
| 10 | 2170.0 | Horn | H | -70.8 | Pk | 22.9 | 27.1 | 30.3 | 55.3 | 25.0 | max all, noise |
| 11 | 2480.0 | Horn | H | -72.7 | Pk | 23.8 | 26.5 | 29.9 | 55.3 | 25.4 | max all, noise |
| 12 | 2790.0 | Horn | H | -72.1 | Pk | 24.7 | 25.6 | 32.3 | 54.0 | 21.7 | max all, noise |
| 13 | 3100.0 | Horn | H | -73.5 | Pk | 25.7 | 25.1 | 32.4 | 55.3 | 22.9 | max all, noise |
| 14 | | | | | | | | | | | |
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| 15 | | | | | | | | | | | |
| 16 | | | | | | | | | | | |
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| 27 | | | | | | | | | | | |
| 28 | | | | | | | | | | | |
| 29 | | | | | | | | | | | |
| 30 | | | | | | | | | | | |
| 31 | | | | | | | | | | | |
| 32 | | | | | | | | | | | |
| 33 | | | | | | | | | | | |
| 34 | | | | | | | | | | | |
| 35 | | | | | | | | | | | |
| 36 | | | | | | | | | | | |
| 37 | | | | | | | | | | | |

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# Table 5.1 Highest Emissions Measured

| Radiated Emission - RF | | | | | | | | | | | JCI, PM/MK; FCC/IC; 418 MHz |
|---|---|---|---|---|---|---|---|---|---|---|---|
| # | Freq. MHz | Ant. Used | Ant. Pol. | Pr dBm | Det. Used | Ka dB/m | Kg dB | E3* dBμV/m | E3lim dBμV/m | Pass dB | Comments |
| 30 % Duty Factor (meas. XX dB) | | | | | | | | | | | |
| 1 | 418.0 | Dip | H | -29.8 | Pk | 21.5 | 17.8 | 73.0 | 80.3 | 7.3 | flat |
| 2 | 418.0 | Dip | V | -26.5 | Pk | 21.5 | 17.8 | 76.3 | 80.3 | **4.0** | end |
| 3 | 836.0 | Dip | H | -62.6 | Pk | 27.8 | 15.6 | 48.7 | 60.3 | 11.6 | flat, 30 kHz RBW |
| 4 | 836.0 | Dip | V | -67.3 | Pk | 27.8 | 15.6 | 44.0 | 60.3 | 16.3 | side, 30 kHz RBW |
| 5 | 1254.0 | Horn | H | -55.1 | Pk | 31.5 | 28.1 | 47.3 | 60.3 | 13.0 | flat |
| 6 | 1672.0 | Horn | H | -54.6 | Pk | 21.7 | 28.1 | 38.1 | 54.0 | 15.9 | flat |
| 7 | 2090.0 | Horn | H | -62.7 | Pk | 22.7 | 26.8 | 32.2 | 60.3 | 28.1 | flat |
| 8 | 2508.0 | Horn | H | -72.0 | Pk | 23.8 | 26.5 | 24.4 | 60.3 | 35.9 | max all, noise |
| 9 | 2926.0 | Horn | H | -72.2 | Pk | 25.1 | 25.2 | 26.8 | 60.3 | 33.5 | max all, noise |
| 10 | 3344.0 | Horn | H | -73.6 | Pk | 26.4 | 24.7 | 27.2 | 54.0 | 26.8 | max all, noise |
| 11 | 3762.0 | Horn | H | -72.9 | Pk | 27.7 | 24.3 | 29.6 | 54.0 | 24.4 | max all, noise |
| 12 | 4180.0 | Horn | H | -73.9 | Pk | 29.0 | 20.7 | 33.4 | 54.0 | 20.6 | max all, noise |
| 13 | | | | | | | | | | | |
| 14 | | | | | | | | | | | |
| 50 % Duty Factor (meas. XX dB) | | | | | | | | | | | |
| 15 | 418.0 | Dip | H | -34.6 | Pk | 21.5 | 17.8 | 70.3 | 80.3 | 10.0 | flat |
| 16 | 418.0 | Dip | V | -30.9 | Pk | 21.5 | 17.8 | 74.0 | 80.3 | **6.3** | end |
| 17 | 836.0 | Dip | H | -68.9 | Pk | 27.8 | 15.6 | 44.5 | 60.3 | 15.8 | flat, 30 kHz RBW |
| 18 | 836.0 | Dip | V | -73.8 | Pk | 27.8 | 15.6 | 39.6 | 60.3 | 20.7 | end, 30 kHz RBW |
| 19 | 1254.0 | Horn | H | -61.5 | Pk | 31.5 | 28.1 | 40.9 | 60.3 | 19.4 | flat |
| 20 | 1672.0 | Horn | H | -60.3 | Pk | 21.7 | 28.1 | 32.4 | 54.0 | 21.6 | flat |
| 21 | 2090.0 | Horn | H | -65.7 | Pk | 22.7 | 26.8 | 29.2 | 60.3 | 31.1 | flat |
| 22 | 2508.0 | Horn | H | -71.3 | Pk | 23.8 | 26.5 | 25.1 | 60.3 | 35.2 | max all, noise |
| 23 | 2926.0 | Horn | H | -72.9 | Pk | 25.1 | 25.2 | 26.1 | 60.3 | 34.2 | max all, noise |
| 24 | 3344.0 | Horn | H | -73.0 | Pk | 26.4 | 24.7 | 27.8 | 54.0 | 26.2 | max all, noise |
| 25 | 3762.0 | Horn | H | -73.4 | Pk | 27.7 | 24.3 | 29.1 | 54.0 | 24.9 | max all, noise |
| 26 | 4180.0 | Horn | H | -74.9 | Pk | 29.0 | 20.7 | 32.4 | 54.0 | 21.6 | max all, noise |
| 27 | | | | | | | | | | | |
| 28 | | | | | | | | | | | |
| 29 | | | | | | | | | | | |
| 30 | | | | | | | | | | | |
| 31 | | | | | | | | | | | |
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| 33 | | | | | | | | | | | |
| 34 | | | | | | | | | | | |
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| 36 | | | | | | | | | | | |
| 37 | | | | | | | | | | | |

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# Table 5.1 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 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Radiated Emission - RF** | | | | | | | | | | | JCI, PM/MK; FCC/IC; 418 MHz |
| 80 % Duty Factor (meas. XX dB) | | | | | | | | | | | |
| 1 | 418.0 | Dip | H | -39.1 | Pk | 21.5 | 17.8 | 70.0 | 80.3 | 10.3 | flat |
| 2 | 418.0 | Dip | V | -35.6 | Pk | 21.5 | 17.8 | 73.5 | 80.3 | **6.8** | end, noise |
| 3 | 836.0 | Dip | H | -74.1 | Pk | 27.8 | 15.6 | 43.4 | 60.3 | 16.9 | flat, 30 kHz RBW |
| 4 | 836.0 | Dip | V | -78.0 | Pk | 27.8 | 15.6 | 39.5 | 60.3 | 20.8 | end, 30 kHz RBW |
| 5 | 1254.0 | Horn | H | -59.8 | Pk | 31.5 | 28.1 | 48.9 | 60.3 | 11.4 | flat |
| 6 | 1672.0 | Horn | H | -61.0 | Pk | 21.7 | 28.1 | 37.9 | 54.0 | 16.1 | flat |
| 7 | 2090.0 | Horn | H | -65.9 | Pk | 22.7 | 26.8 | 35.3 | 60.3 | 25.0 | flat |
| 8 | 2508.0 | Horn | H | -72.2 | Pk | 23.8 | 26.5 | 30.5 | 60.3 | 29.8 | max all, noise |
| 9 | 2926.0 | Horn | H | -72.9 | Pk | 25.1 | 25.2 | 32.3 | 60.3 | 28.0 | max all, noise |
| 10 | 3344.0 | Horn | H | -73.0 | Pk | 26.4 | 24.7 | 34.1 | 54.0 | 19.9 | max all, noise |
| 11 | 3762.0 | Horn | H | -73.5 | Pk | 27.7 | 24.3 | 35.3 | 54.0 | 18.7 | max all, noise |
| 12 | 4180.0 | Horn | H | -74.7 | Pk | 29.0 | 20.7 | 38.9 | 54.0 | 15.1 | max all, noise |
| 13 | | | | | | | | | | | |
| 14 | | | | | | | | | | | |
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| 16 | | | | | | | | | | | |
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| 34 | | | | | | | | | | | |
| 35 | | | | | | | | | | | |
| 36 | | | | | | | | | | | |
| 37 | | | | | | | | | | | |

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## Table 6.1 Highest Emissions Measured

| Radiated Emission - RF | | | | | | | | | | | JCI, PM/MK RX; 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 | 288.0 | SBic | H,V | -82.7 | Pk | 18.1 | 19.2 | 23.2 | 46.0 | 22.8 | max. of all, noise floor |
| 2 | 299.6 | SBic | H,V | -82.6 | Pk | 18.5 | 19.0 | 23.8 | 46.0 | 22.2 | max. of all, noise floor |
| 3 | 346.3 | SBic | H,V | -79.6 | Pk | 19.8 | 18.5 | 28.7 | 46.0 | 17.3 | max. of all, noise floor |
| 4 | 384.8 | SBic | H,V | -80.7 | Pk | 20.7 | 18.1 | 29.0 | 46.0 | 17.0 | max. of all, noise floor |
| 5 | 387.7 | SBic | H,V | -81.6 | Pk | 20.8 | 18.0 | 28.2 | 46.0 | 17.8 | max. of all, noise floor |
| 6 | 422.5 | SBic | H,V | -80.5 | Pk | 21.6 | 17.7 | 30.4 | 46.0 | 15.6 | max. of all, noise floor |
| 7 | 1073.0 | Horn | H,V | -60.0 | Pk | 19.9 | 28.0 | 38.9 | 54.0 | 15.1 | max. of all |
| 8 | 1090.0 | Horn | H,V | -56.2 | Pk | 20.0 | 28.0 | 42.8 | 54.0 | **11.2** | max. of all |
| 9 | 1288.0 | Horn | H,V | -62.7 | Pk | 20.5 | 28.0 | 36.8 | 54.0 | 17.2 | max. of all |
| 10 | 1313.0 | Horn | H,V | -60.4 | Pk | 20.6 | 28.0 | 39.2 | 54.0 | 14.8 | max. of all |
| 11 | 1398.0 | Horn | H,V | -62.1 | Pk | 20.9 | 28.0 | 37.8 | 54.0 | 16.2 | max. of all |
| 12 | 1628.0 | Horn | H,V | -62.3 | Pk | 21.5 | 28.2 | 38.0 | 54.0 | 16.0 | max. of all |
| 13 | 1660.0 | Horn | H,V | -62.6 | Pk | 21.6 | 28.2 | 37.8 | 54.0 | 16.2 | max. of all |
| 14 | 1680.0 | Horn | H,V | -62.5 | Pk | 21.7 | 28.2 | 38.0 | 54.0 | 16.0 | max. of all |
| 15 | 1888.0 | Horn | H,V | -62.3 | Pk | 22.3 | 28.2 | 38.8 | 54.0 | 15.2 | max. of all |
| 16 | 1923.0 | Horn | H,V | -62.7 | Pk | 22.4 | 28.2 | 38.5 | 54.0 | 15.5 | max. of all |
| 17 | | | | | | | | | | | |
| 18 | | | | | | | | | | | |

| Radiated Emission - Digital (Class B) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | | | | | | | | | | | |
| 2 | | | | | | | | | | | |
| 3 | Digital Emissions more than 20 dB below FCC Class B limits | | | | | | | | | | |
| 4 | | | | | | | | | | | |
| 5 | | | | | | | | | | | |
| 6 | | | | | | | | | | | |
| 7 | | | | | | | | | | | |
| 8 | | | | | | | | | | | |
| 9 | | | | | | | | | | | |
| 10 | | | | | | | | | | | |
| 11 | | | | | | | | | | | |
| 12 | | | | | | | | | | | |
| 13 | | | | | | | | | | | |

| Conducted Emissions | | | | | | | |
|---|---|---|---|---|---|---|---|
| # | Freq. MHz | Line Side | Det. Used | Vtest dBμV | Vlim dBμV | Pass dB | Comments |
| 1 | | | | | | | |
| 2 | Not applicable | | | | | | |
| 3 | | | | | | | |

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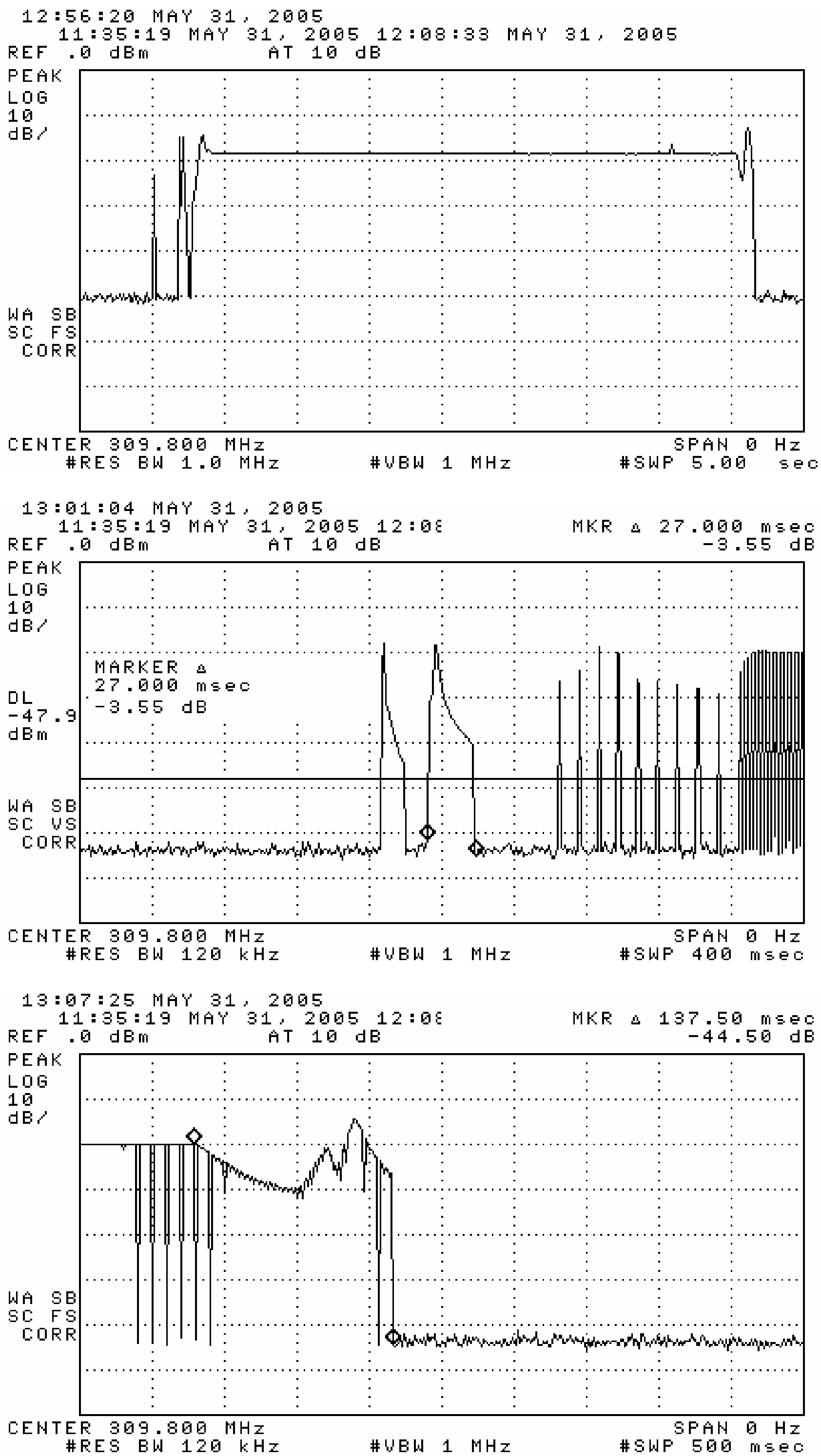



Figure 6.1(a). Transmissions modulation characteristics: (top) full transmission, (middle) Tuning & Wake-up, (bottom) Turn-off. (310 MHz, 30% duty factor).

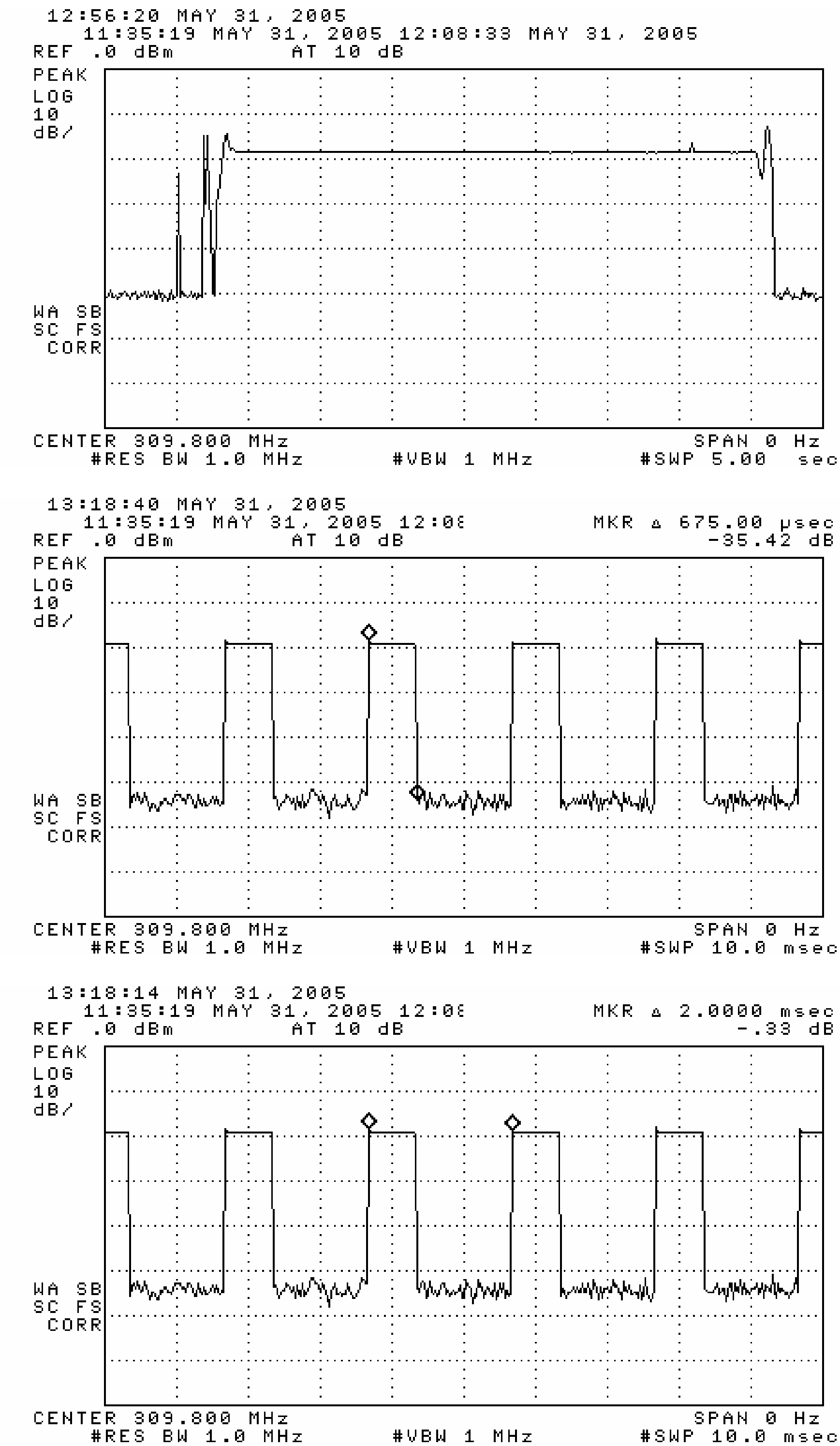



Figure 6.1(a). Transmissions modulation characteristics: (top) full transmission, (middle) pulse width, (bottom) pulse period. (310 MHz, 30% duty factor).

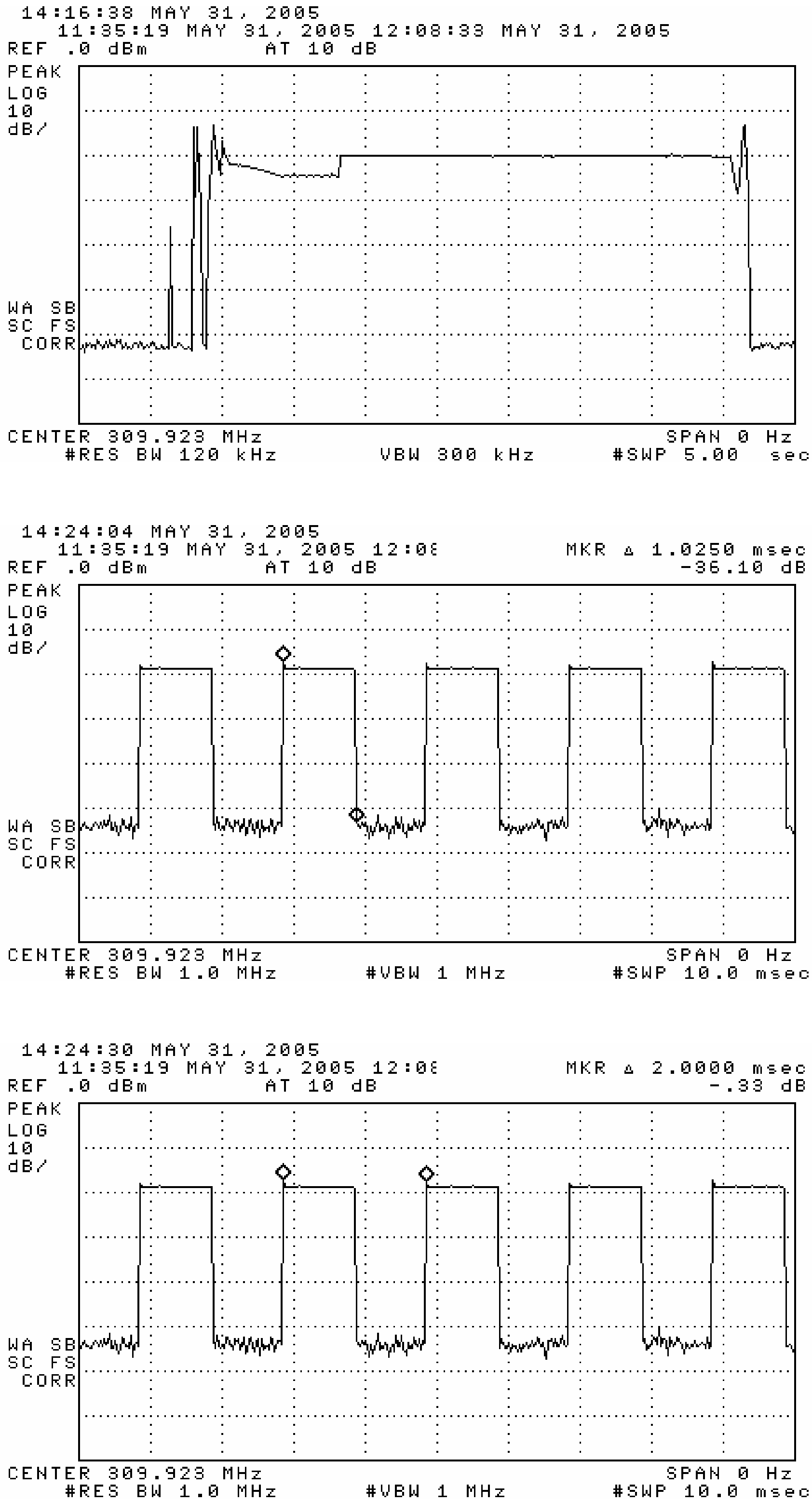



Figure 6.1(b). Transmissions modulation characteristics: (top) full transmission, (middle) pulse width, (bottom) pulse period. (310 MHz, 50% duty factor).

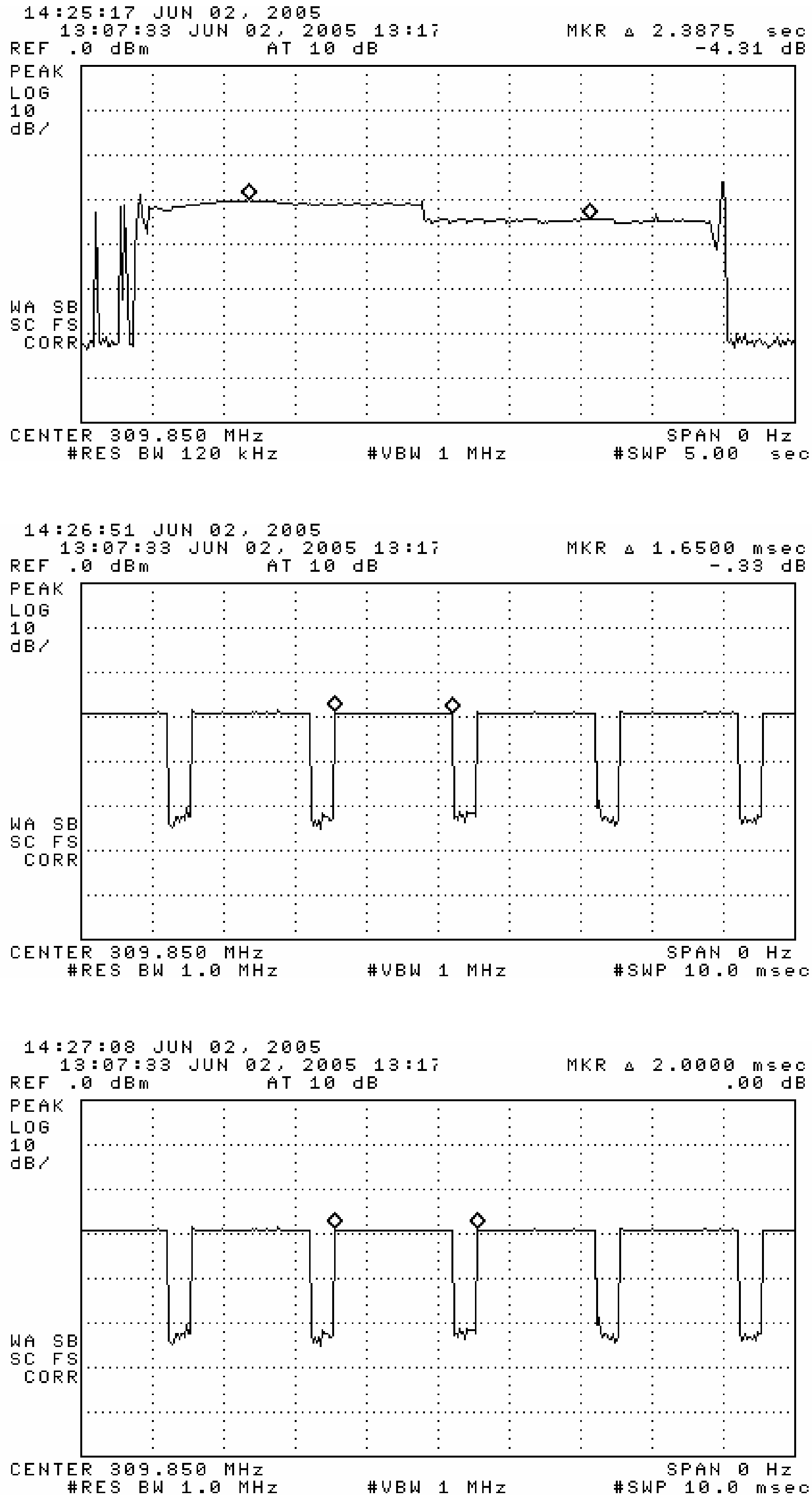



Figure 6.1(c). Transmissions modulation characteristics: (top) full transmission, (middle) pulse width, (bottom) pulse period. (310 MHz, 80% duty factor).

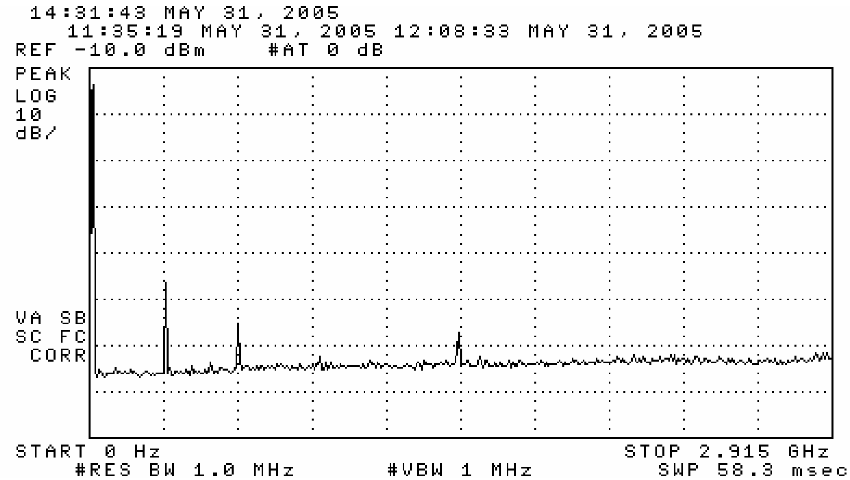



Figure 6.2(a). Emission spectrum of the DUT (288 MHz, 50% duty factor).
The amplitudes are only indicative (not calibrated).

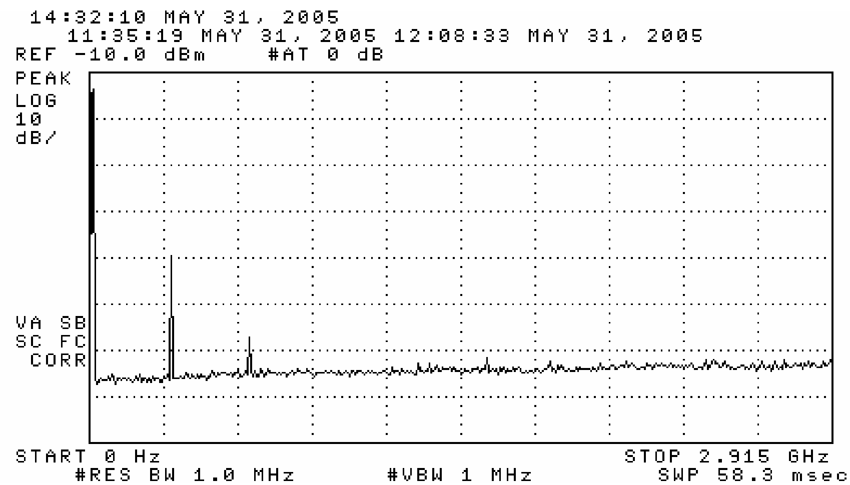



Figure 6.2(b). Emission spectrum of the DUT (310 MHz, 50% duty factor), (not calibrated).

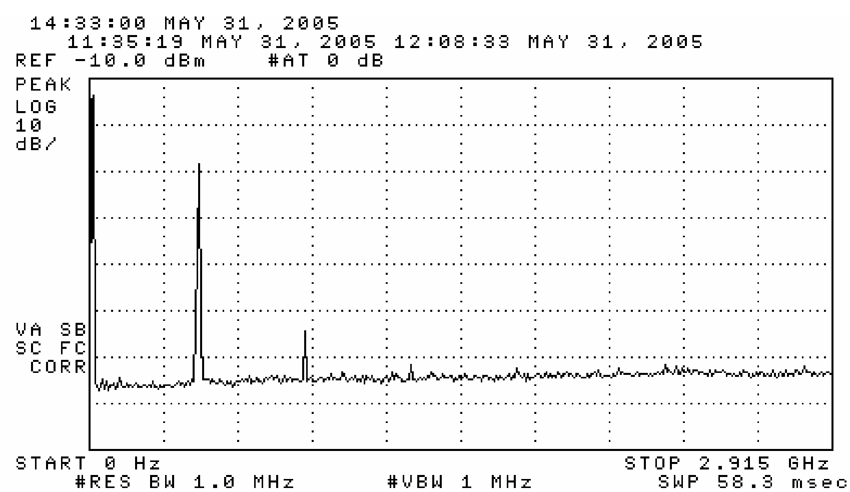



Figure 6.2(c). Emission spectrum of the DUT (418 MHz, 50% duty factor), (not calibrated).

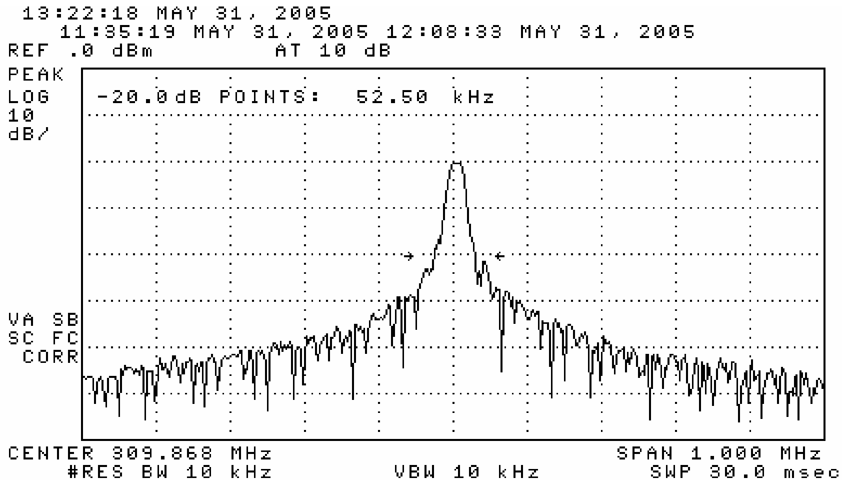



Figure 6.3(a). Measured bandwidth of the DUT. (Pulsed mode, 310 MHz, 30% duty factor).

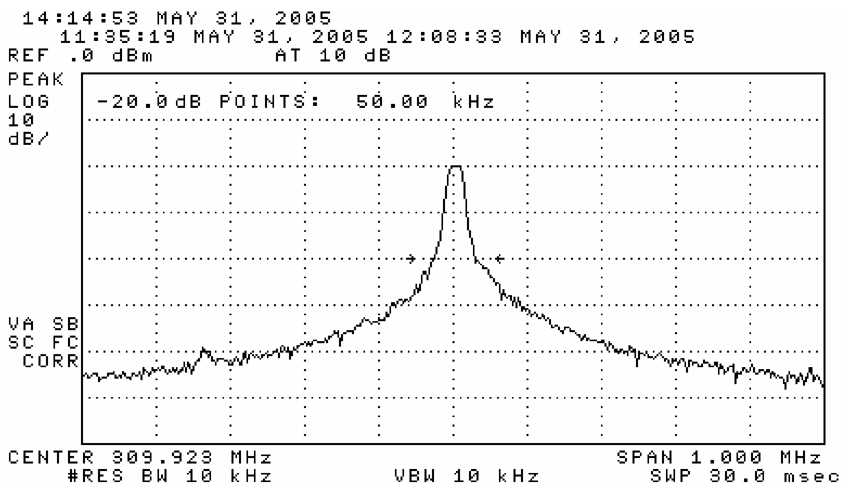



Figure 6.3(b). Measured bandwidth of the DUT. (Pulsed mode, 310 MHz, 50% duty factor).

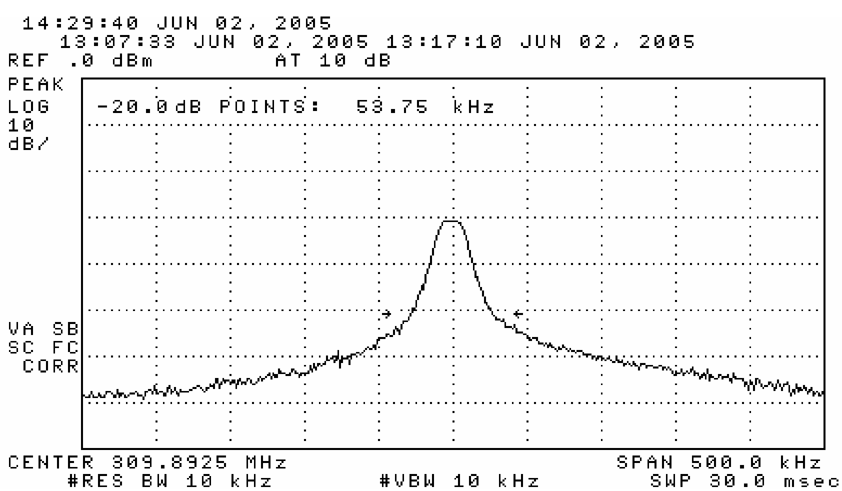



Figure 6.3(c). Measured bandwidth of the DUT. (Pulsed mode, 310 MHz, 80% duty factor).

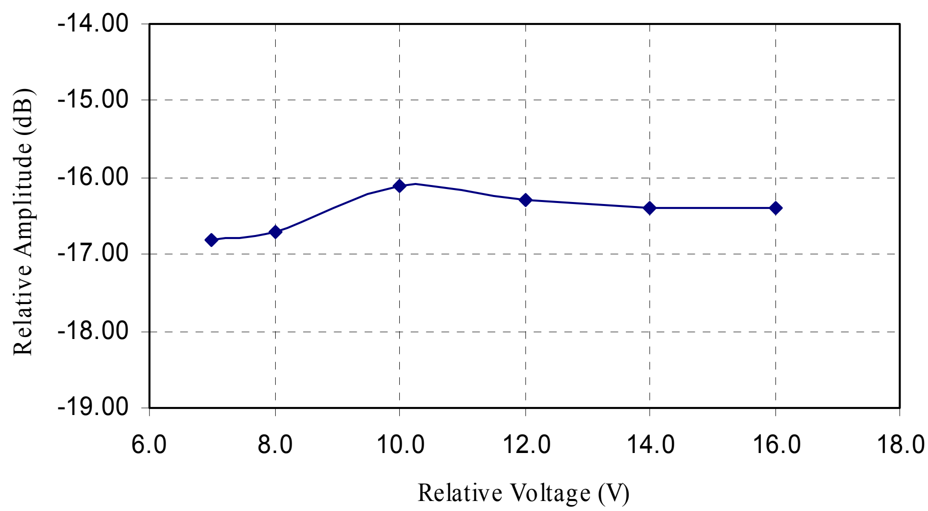



Figure 6.4. Relative emission vs. supply voltage. (310 MHz, continuous pulsed, 50% duty )

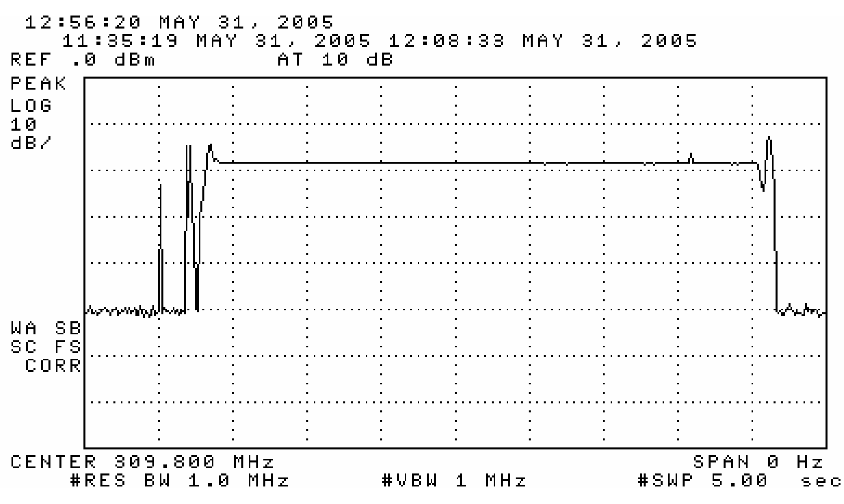
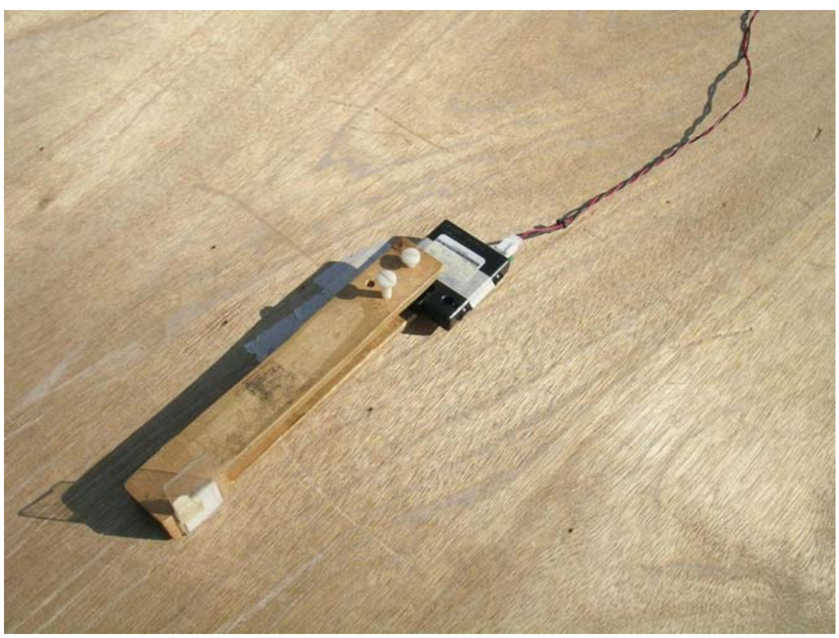



Figure 6.5. Emission when the DUT button is depressed for about 4 seconds.

Appendix: DUT on OATS



Appendix: Close-up of the DUT on OATS