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# Measured Radio Frequency Emissions From

# **Johnson Controls Interiors L.L.C. Home Link Transmitter Series FN145**

Report No. 415031-106
December 11, 2001



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 Johnson Controls (Universal Garage Door Opener) Transmitter, Series FN145. 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 performed on July 10 and 11 and December 10 and 11, 2001, in the worst case of the all combinations tested, the transmitters tested in the worst case met the allowed limits for radiated emissions by 1.1 dB at the fundamental (p.8) and by 2.5 dB at the harmonics (p.10). Besides harmonics and presence of short "blips" when locking the VCO to the required frequency, there were no other significant spurious emissions found.

The conductive emission tests do not apply, since the device is powered from a 12V automobile source.

## 1. Introduction

Johnson Controls transmitters, Series FN145, were 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 C63.4-1992 "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 file 31040/SIT) and with Industry Canada, Ottawa, ON (File Ref. No: IC2057).

## 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 Millimiter 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) | | 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 (50 µH) | | University of Michigan |
| Signal Generator (0.1-2060 MHz) | | Hewlett-Packard, 8657B |
| Signal Generator (0.01-20 GHz ) | | Hewlett-Packard |

## 3. Configuration and Identification of Device Under Test

The DUT is a 7 x 6 x 2 inch OEM device that goes in automobile console and is powered by 12 VDC. The DUT contains a learning garage door opener transmitter, and convenience devices, such as, a compass, a trip computer, and temperature display. It 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 an another GDO, with capability to repeat up to three GDOs. The DUT uses a 20.0 MHz crystal frequency reference and operates over 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 DUT was designed and manufactured by Johnson Controls, Inc., Automotive Systems Group, 915 E. 32nd Street, Holland, MI 49423. It is identified as:

Johnson Controls Homelink Transmitter
Series: FN145
Models: FN145-AB, -BB, -DB**, -EB, -FB*, -JB*
FCC ID: CB2FN145HL3
CANADA: to be provided by IC

-DB** --- fully tested
-FB*, -JB* --- partially tested

The six models listed above are based on the same PCB and the same RF section. The differences are in the plastic cases used and the functionality of the electronics in the non-RF section. The fully loaded one is FN145-DB** and on this one full tests were made. The -FB* and -JB* were depopulated and these were spot measured to verify compliance. The -AB, -BB, and -EB just uses slightly different plastics from the ones tested.

### 3.1 EMI Relevant Modifications

There were no modifications made to the DUT by this laboratory after submission for final testing. However, during the development of the product, JCI used the University of Michigan facilities to optimize the firmware of the device.

## 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 considered as a Class B device.

Table 4.1. 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) (μV/m) | Fundamental Ave. $E_{lim}$ (3m) dB (μV/m) | Spurious** Ave. $E_{lim}$ (3m) (μV/m) | Spurious** Ave. $E_{lim}$ (3m) 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

Table 4.2. 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)

### 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 Anechonic Chamber Measurements

To familiarize with the radiated emission behavior of the DUT, the DUT was first studied and measured in a shielded anechonic 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 shows 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 1.1 dB (p. 8).

## 6. Other Measurements and Computations

### 6.1 Correction For Pulse Operation

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

30% duty factor The modulation consists of 0.6125 ms wide pulses of period 1.950 ms. Thus,

$K_E = 0.6125/1.950 = 0.3141$ or -10.1 dB.

50% duty factor The modulation consists of 1.0125 ms wide pulses of period 2.00 ms. Thus,

$K_E = 1.0125/2.00 = 0.506$ or -5.9 dB.

80% duty factor The modulation consists of 1.6625 ms wide pulses of period 2.00 ms. Thus,

$K_E = 1.6625/2.00 = 0.831$ or -1.6 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.

**6.3 Bandwidth of the Emission Spectrum**
The measured spectrum of the signal is 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 85.0 kHz for 30% duty factor (Fig. 6.3(a)).

**6.4 Effect of Supply Voltage Variation**
The DUT has been designed to be powered from automotive 12 V 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 9 to 18 volts. The emission variation is shown in Figure 6.4.

**6.5 Input Voltage and Current (310 MHz, pulsed operation)**

| | | |
|---|---|---|
| Supply Voltage | = | 12.6 VDC |
| Current | = | 420.0 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 50% duty factor modulated carrier from a signal generator, the DUT was "taught" frequencies from 240.0 to 440.0 MHz. It repeated frequencies from 286.05 to 303.6 MHz , from 307.58 to 321.03 MHz, from 336.65 to 398.5 MHz, and from 411.13 to 419.5 MHz . In any case, no frequency was repeated in the Restricted Bands. (Also, there were no spurious emissions in the Restricted Bands.)

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## Table 5.1. Highest Emissions Measured

| Radiated Emissions | | | | | | | | | | | JCI, FN145; 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 |
| 1 | 288 | Dip | H | -21.5 | Pk | 18.1 | 21.2 | 72.4 | 73.9 | 1.5 | side 30% duty factor FN145-DB |
| 2 | 288 | Dip | V | -23.2 | Pk | 18.1 | 21.2 | 70.7 | 73.9 | 3.2 | flat |
| 3 | 576 | Dip | H | -52.4 | Pk | 24.4 | 18.0 | 51.0 | 53.9 | 2.9 | flat |
| 4 | 576 | Dip | V | -54.3 | Pk | 24.4 | 18.0 | 49.1 | 53.9 | 4.8 | side |
| 5 | 864 | Dip | H | -69.7 | Pk | 28.1 | 15.8 | 39.5 | 53.9 | 14.4 | flat |
| 6 | 864 | Dip | V | -65.7 | Pk | 28.1 | 15.8 | 43.5 | 53.9 | 10.4 | flat |
| 7 | 1152 | Horn | H | -58.1 | Pk | 20.2 | 28.1 | 31.0 | 53.9 | 23.0 | flat |
| 8 | 1440 | Horn | H | -59.3 | Pk | 21.2 | 28.3 | 30.6 | 53.9 | 23.3 | flat |
| 9 | 1728 | Horn | H | -64.6 | Pk | 21.9 | 27.8 | 26.4 | 53.9 | 27.5 | end |
| 10 | 2016 | Horn | H | -61.8 | Pk | 22.5 | 26.6 | 31.1 | 53.9 | 22.8 | flat |
| 11 | 2304 | Horn | H | -69.8 | Pk | 23.2 | 26.9 | 23.5 | 53.9 | 30.4 | flat |
| 12 | 2592 | Horn | H | -69.9 | Pk | 24.0 | 26.6 | 24.5 | 53.9 | 29.5 | flat |
| 13 | 2880 | Horn | H | -70.5 | Pk | 24.8 | 25.5 | 25.7 | 53.9 | 28.2 | flat, noise |
| 14 | | | | | | | | | | | |
| 15 | 288 | Dip | H | -21.2 | Pk | 18.1 | 21.2 | 72.7 | 73.9 | 1.2 | side 30% duty factor FN145-FB |
| 16 | 288 | Dip | H | -21.4 | Pk | 18.1 | 21.2 | 72.5 | 73.9 | 1.4 | side 30% duty factor FN145-JB |
| 17 | | | | | | | | | | | |
| 18 | 288 | Dip | H | -25.7 | Pk | 18.1 | 21.2 | 72.3 | 73.9 | 1.6 | side 50% duty factor |
| 19 | 288 | Dip | V | -28.9 | Pk | 18.1 | 21.2 | 69.1 | 73.9 | 4.8 | end |
| 20 | 576 | Dip | H | -58.2 | Pk | 24.4 | 18.0 | 49.3 | 53.9 | 4.6 | flat |
| 21 | 576 | Dip | V | -63.7 | Pk | 24.4 | 18.0 | 43.8 | 53.9 | 10.1 | end |
| 22 | 864 | Dip | H | -70.8 | Pk | 28.1 | 15.8 | 42.6 | 53.9 | 11.3 | flat |
| 23 | 864 | Dip | V | -67.5 | Pk | 28.1 | 15.8 | 45.9 | 53.9 | 8.0 | flat |
| 24 | 1152 | Horn | H | -64.8 | Pk | 20.2 | 28.1 | 28.4 | 53.9 | 25.5 | side |
| 25 | 1440 | Horn | H | -56.9 | Pk | 21.2 | 28.3 | 37.1 | 53.9 | 16.8 | flat |
| 26 | 1728 | Horn | H | -65.1 | Pk | 21.9 | 27.8 | 30.0 | 53.9 | 23.9 | flat |
| 27 | 2016 | Horn | H | -66.1 | Pk | 22.5 | 26.6 | 30.9 | 53.9 | 23.0 | flat |
| 28 | 2304 | Horn | H | -70.3 | Pk | 23.2 | 26.9 | 27.1 | 53.9 | 26.8 | flat, noise |
| 29 | 2592 | Horn | H | -70.3 | Pk | 24.0 | 26.6 | 28.2 | 53.9 | 25.7 | side, noise |
| 30 | 2880 | Horn | H | -70.7 | Pk | 24.8 | 25.5 | 29.6 | 53.9 | 24.3 | end, noise |
| 31 | | | | | | | | | | | |
| 32 | 288 | Dip | H | -26.1 | Pk | 18.1 | 21.2 | 71.9 | 73.9 | 2.0 | side 50% duty factor FN145-FB |
| 33 | 288 | Dip | H | -25.6 | Pk | 18.1 | 21.2 | 72.4 | 73.9 | 1.5 | side 50% duty factor FN145-JB |
| 34 | | | | | | | | | | | |
| 35 | | | | | | | | | | | |
| 36 | | | | | | | | | | | |
| 37 | | | | | | | | | | | |
| 38 | | | | | | | | | | | |
| 39 | | | | | | | | | | | |

Meas. 7/10,11/01; 12/10,11/01; U of Mich.

## Table 5.1(Cont.). Highest Emissions Measured

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Radiated Emissions | | | | | | | | | | | JCI, FN145; 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 |
| 1 | 288 | Dip | H | -29.9 | Pk | 18.1 | 21.2 | 72.4 | 73.9 | 1.5 | side 80% duty factor FN145-DB |
| 2 | 288 | Dip | V | -33.2 | Pk | 18.1 | 21.2 | 69.1 | 73.9 | 4.8 | end |
| 3 | 576 | Dip | H | -63.1 | Pk | 24.4 | 18.0 | 48.7 | 53.9 | 5.2 | flat |
| 4 | 576 | Dip | V | -65.8 | Pk | 24.4 | 18.0 | 46.0 | 53.9 | 7.9 | end |
| 5 | 864 | Dip | H | -71.3 | Pk | 28.1 | 15.8 | 46.4 | 53.9 | 7.5 | flat |
| 6 | 864 | Dip | V | -67.5 | Pk | 28.1 | 15.8 | 50.2 | 53.9 | 3.7 | flat |
| 7 | 1152 | Horn | H | -67.9 | Pk | 20.2 | 28.1 | 29.6 | 53.9 | 24.3 | side |
| 8 | 1440 | Horn | H | -64.6 | Pk | 21.2 | 28.3 | 33.7 | 53.9 | 20.2 | side |
| 9 | 1728 | Horn | H | -68.1 | Pk | 21.9 | 27.8 | 31.3 | 53.9 | 22.6 | flat |
| 10 | 2016 | Horn | H | -69.5 | Pk | 22.5 | 26.6 | 31.8 | 53.9 | 22.1 | side |
| 11 | 2304 | Horn | H | -70.4 | Pk | 23.2 | 26.9 | 31.3 | 53.9 | 22.6 | end, noise |
| 12 | 2592 | Horn | H | -70.4 | Pk | 24.0 | 26.6 | 32.4 | 53.9 | 21.5 | side, noise |
| 13 | 2880 | Horn | H | -69.6 | Pk | 24.8 | 25.5 | 35.0 | 53.9 | 18.9 | end, noise |
| 14 | | | | | | | | | | | |
| 15 | 288 | Dip | H | -30.5 | Pk | 18.1 | 21.2 | 71.8 | 73.9 | 2.1 | side 80% duty factor FN145-FB |
| 16 | 288 | Dip | H | -29.5 | Pk | 18.1 | 21.2 | 72.8 | 73.9 | 1.1 | side 80% duty factor FN145-JB |
| 17 | | | | | | | | | | | |
| 18 | | | | | | | | | | | |
| 19 | | | | | | | | | | | |
| 20 | | | | | | | | | | | |
| 21 | | | | | | | | | | | |
| 22 | | | | | | | | | | | |
| 23 | | | | | | | | | | | |
| 24 | | | | | | | | | | | |
| 25 | | | | | | | | | | | |
| 26 | | | | | | | | | | | |
| 27 | | | | | | | | | | | |
| 28 | | | | | | | | | | | |
| 29 | | Digital emissions are more than 20 dB below FCC Class B limit. | | | | | | | | | |
| 30 | | | | | | | | | | | |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Conducted Emissions | | | | | | | |
| # | Freq. MHz | Line Side | Det. Used | Vtest dBµV | Vlim dBµV | Pass dB | Comments |
| 1 | | | | | | | |
| 2 | | | | | | | |
| 3 | | | | Not Applicable | | | |
| 4 | | | | | | | |
| 5 | | | | | | | |

Meas. 7/10,11/01; 12/10,11/01; U of Mich.

## Table 5.2. Highest Emissions Measured

| Radiated Emissions | | | | | | | | | | | JCI, FN145; 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 |
| 1 | 310 | Dip | H | -21.4 | Pk | 18.8 | 20.9 | 73.4 | 75.3 | 1.9 | side 30% duty factor FN145-DB |
| 2 | 310 | Dip | V | -22.7 | Pk | 18.8 | 20.9 | 72.1 | 75.3 | 3.2 | end |
| 3 | 620 | Dip | H | -51.8 | Pk | 25.1 | 17.6 | 52.7 | 55.3 | 2.6 | flat |
| 4 | 620 | Dip | V | -54.8 | Pk | 25.1 | 17.6 | 49.7 | 55.3 | 5.6 | side |
| 5 | 927 | Dip | H | -69.1 | Pk | 26.1 | 15.3 | 38.7 | 55.3 | 16.6 | flat |
| 6 | 927 | Dip | V | -75.2 | Pk | 26.1 | 15.3 | 32.6 | 55.3 | 22.7 | end |
| 7 | 1240 | Horn | H | -59.7 | Pk | 20.4 | 28.0 | 29.6 | 54.0 | 24.4 | flat |
| 8 | 1550 | Horn | H | -56.1 | Pk | 21.5 | 28.2 | 34.1 | 54.0 | 19.9 | flat |
| 9 | 1860 | Horn | H | -65.5 | Pk | 22.1 | 28.3 | 25.2 | 55.3 | 30.1 | end |
| 10 | 2170 | Horn | H | -65.8 | Pk | 22.8 | 27.1 | 26.9 | 55.3 | 28.5 | flat |
| 11 | 2480 | Horn | H | -70.6 | Pk | 23.8 | 26.5 | 23.7 | 55.3 | 31.7 | flat |
| 12 | 2790 | Horn | H | -70.0 | Pk | 24.5 | 25.6 | 25.9 | 54.0 | 28.2 | flat, noise |
| 13 | 3100 | Horn | H | -68.7 | Pk | 25.8 | 25.1 | 29.0 | 55.3 | 26.3 | end, noise |
| 14 | | | | | | | | | | | |
| 15 | 310 | Dip | H | -21.2 | Pk | 18.8 | 20.9 | 73.6 | 75.3 | 1.7 | side 30% duty factor FN145-FB |
| 16 | 310 | Dip | H | -21.4 | Pk | 19.8 | 20.9 | 74.4 | 76.3 | 1.9 | side 30% duty factor FN145-JB |
| 17 | | | | | | | | | | | |
| 18 | 310 | Dip | H | -25.9 | Pk | 18.8 | 20.9 | 73.1 | 75.3 | 2.2 | side 50% duty factor |
| 19 | 310 | Dip | V | -27.3 | Pk | 18.8 | 20.9 | 71.7 | 75.3 | 3.6 | end |
| 20 | 620 | Dip | H | -58.9 | Pk | 25.1 | 17.6 | 49.7 | 55.3 | 5.6 | flat |
| 21 | 620 | Dip | V | -64.9 | Pk | 25.1 | 17.6 | 43.7 | 55.3 | 11.6 | end |
| 22 | 930 | Dip | H | -71.1 | Pk | 26.1 | 15.2 | 40.9 | 55.3 | 14.5 | flat |
| 23 | 930 | Dip | V | -75.1 | Pk | 26.1 | 15.2 | 36.9 | 55.3 | 18.5 | end |
| 24 | 1240 | Horn | H | -61.1 | Pk | 20.4 | 28.0 | 32.4 | 54.0 | 21.6 | flat |
| 25 | 1550 | Horn | H | -59.8 | Pk | 21.5 | 28.2 | 34.5 | 54.0 | 19.5 | flat |
| 26 | 1860 | Horn | H | -67.8 | Pk | 22.1 | 28.3 | 27.0 | 55.3 | 28.3 | flat |
| 27 | 2170 | Horn | H | -68.4 | Pk | 22.8 | 27.1 | 28.4 | 55.3 | 26.9 | flat |
| 28 | 2480 | Horn | H | -70.3 | Pk | 23.8 | 26.5 | 28.1 | 55.3 | 27.2 | end, noise |
| 29 | 2790 | Horn | H | -70.4 | Pk | 24.5 | 25.6 | 29.6 | 54.0 | 24.4 | end, noise |
| 30 | 3100 | Horn | H | -69.1 | Pk | 25.8 | 25.1 | 32.7 | 55.3 | 22.6 | side, noise |
| 31 | | | | | | | | | | | |
| 32 | 310 | Dip | H | -25.3 | Pk | 18.8 | 20.9 | 73.7 | 75.3 | 1.6 | side 50% duty factor FN145-FB |
| 33 | 310 | Dip | H | -25.3 | Pk | 19.8 | 20.9 | 74.7 | 76.3 | 1.6 | side 50% duty factor FN145-JB |
| 34 | | | | | | | | | | | |
| 35 | | | | | | | | | | | |
| 36 | | | | | | | | | | | |
| 37 | | | | | | | | | | | |
| 38 | | | | | | | | | | | |
| 39 | | | | | | | | | | | |

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## Table 5.2(Cont.). Highest Emissions Measured

| Radiated Emissions | | | | | | | | | | | JCI, FN145; 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 |
| 1 | 310 | Dip | H | -30.5 | Pk | 18.8 | 20.9 | 72.8 | 75.3 | 2.5 | side 80% duty factor FN145-DB |
| 2 | 310 | Dip | V | -31.9 | Pk | 18.8 | 20.9 | 71.4 | 75.3 | 3.9 | end |
| 3 | 620 | Dip | H | -60.1 | Pk | 25.1 | 17.6 | 52.8 | 55.3 | 2.5 | side |
| 4 | 620 | Dip | V | -64.7 | Pk | 25.1 | 17.6 | 48.2 | 55.3 | 7.1 | end |
| 5 | 927 | Dip | H | -72.6 | Pk | 26.1 | 15.3 | 43.6 | 55.3 | 11.7 | flat |
| 6 | 927 | Dip | V | -75.1 | Pk | 26.1 | 15.3 | 41.1 | 55.3 | 14.2 | flat |
| 7 | 1240 | Horn | H | -67.2 | Pk | 20.4 | 28.0 | 30.6 | 54.0 | 23.4 | flat |
| 8 | 1550 | Horn | H | -62.1 | Pk | 21.5 | 28.2 | 36.5 | 54.0 | 17.5 | flat |
| 9 | 1860 | Horn | H | -70.3 | Pk | 22.1 | 28.3 | 28.8 | 55.3 | 26.5 | flat |
| 10 | 2170 | Horn | H | -69.9 | Pk | 22.8 | 27.1 | 31.2 | 55.3 | 24.1 | flat, noise |
| 11 | 2480 | Horn | H | -70.1 | Pk | 23.8 | 26.5 | 32.6 | 55.3 | 22.7 | side, noise |
| 12 | 2790 | Horn | H | -69.9 | Pk | 24.5 | 25.6 | 34.4 | 54.0 | 19.6 | side, noise |
| 13 | 3100 | Horn | H | -69.2 | Pk | 25.8 | 25.1 | 36.9 | 55.3 | 18.4 | side, noise |
| 14 | | | | | | | | | | | |
| 15 | 310 | Dip | H | -30.3 | Pk | 18.8 | 20.9 | 73.0 | 75.3 | 2.3 | side 80% duty factor FN145-FB |
| 16 | 310 | Dip | H | -29.9 | Pk | 18.8 | 20.9 | 73.4 | 75.3 | 1.9 | side 80% duty factor FN145-JB |
| 17 | | | | | | | | | | | |
| 18 | | | | | | | | | | | |
| 19 | | | | | | | | | | | |
| 20 | | | | | | | | | | | |
| 21 | | | | | | | | | | | |
| 22 | | | | | | | | | | | |
| 23 | | | | | | | | | | | |
| 24 | | | | | | | | | | | |
| 25 | | | | | | | | | | | |
| 26 | | | | | | | | | | | |
| 27 | | | | | | | | | | | |
| 28 | | | | | | | | | | | |
| 29 | | Digital emissions are more than 20 dB below FCC Class B limit. | | | | | | | | | |
| 30 | | | | | | | | | | | |

| Conducted Emissions | | | | | | | |
|---|---|---|---|---|---|---|---|
| # | Freq. MHz | Line Side | Det. Used | Vtest dBµV | Vlim dBµV | Pass dB | Comments |
| 1 | | | | | | | |
| 2 | | | | | | | |
| 3 | | | | | | | |
| 4 | | | | Not Applicable | | | |
| 5 | | | | | | | |

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## Table 5.3. Highest Emissions Measured

| Radiated Emissions | | | | | | | | | | | JCI, FN145; 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 |
| 1 | 418 | Dip | H | -24.9 | Pk | 21.1 | 19.6 | 73.5 | 80.3 | 6.8 | side 30% duty factor FN145-DB |
| 2 | 418 | Dip | V | -23.0 | Pk | 21.1 | 19.6 | 75.4 | 80.3 | 4.9 | flat |
| 3 | 836 | Dip | H | -54.6 | Pk | 27.7 | 16.0 | 54.1 | 60.3 | 6.2 | side |
| 4 | 836 | Dip | V | -57.2 | Pk | 27.7 | 16.0 | 51.5 | 60.3 | 8.8 | flat |
| 5 | 1254 | Horn | H | -49.5 | Pk | 20.5 | 28.1 | 39.8 | 60.3 | 20.5 | flat |
| 6 | 1672 | Horn | H | -56.0 | Pk | 21.5 | 28.1 | 34.3 | 54.0 | 19.7 | flat |
| 7 | 2090 | Horn | H | -62.0 | Pk | 22.7 | 26.8 | 30.8 | 60.3 | 29.5 | side |
| 8 | 2508 | Horn | H | -71.1 | Pk | 24.0 | 26.5 | 23.3 | 60.3 | 37.0 | side, noise |
| 9 | 2926 | Horn | H | -68.9 | Pk | 25.1 | 25.2 | 27.9 | 60.3 | 32.4 | side, noise |
| 10 | 3344 | Horn | H | -69.3 | Pk | 26.5 | 24.7 | 29.4 | 54.0 | 24.6 | side, noise |
| 11 | 3762 | Horn | H | -70.3 | Pk | 27.7 | 24.3 | 30.0 | 54.0 | 24.0 | end, noise |
| 12 | 4180 | Horn | H | -71.3 | Pk | 28.9 | 20.7 | 33.8 | 54.0 | 20.2 | end, noise |
| 13 | | | | | | | | | | | |
| 14 | 418 | Dip | H | -20.9 | Pk | 21.1 | 19.6 | 77.5 | 80.3 | 2.8 | end 30% duty factor FN145-FB |
| 15 | 418 | Dip | V | -20.7 | Pk | 21.1 | 19.6 | 77.7 | 80.3 | 2.6 | end 30% duty factor FN145-JB |
| 16 | | | | | | | | | | | |
| 17 | 418 | Dip | H | -28.8 | Pk | 21.1 | 19.6 | 73.8 | 80.3 | 6.5 | side 50% duty factor FN145-DB |
| 18 | 418 | Dip | V | -25.4 | Pk | 21.1 | 19.6 | 77.2 | 80.3 | 3.1 | end |
| 19 | 836 | Dip | H | -61.9 | Pk | 27.7 | 16.0 | 50.9 | 60.3 | 9.4 | side |
| 20 | 836 | Dip | V | -64.3 | Pk | 27.7 | 16.0 | 48.5 | 60.3 | 11.8 | flat |
| 21 | 1254 | Horn | H | -55.0 | Pk | 20.5 | 28.1 | 38.5 | 60.3 | 21.8 | flat |
| 22 | 1672 | Horn | H | -63.2 | Pk | 21.5 | 28.1 | 31.3 | 54.0 | 22.7 | flat |
| 23 | 2090 | Horn | H | -63.4 | Pk | 22.7 | 26.8 | 33.6 | 60.3 | 26.7 | flat |
| 24 | 2508 | Horn | H | -71.2 | Pk | 24.0 | 26.5 | 27.4 | 60.3 | 32.9 | side, noise |
| 25 | 2926 | Horn | H | -68.2 | Pk | 25.1 | 25.2 | 32.8 | 60.3 | 27.5 | side, noise |
| 26 | 3344 | Horn | H | -70.6 | Pk | 26.5 | 24.7 | 32.3 | 54.0 | 21.7 | flat, noise |
| 27 | 3762 | Horn | H | -69.5 | Pk | 27.7 | 24.3 | 35.0 | 54.0 | 19.0 | end, noise |
| 28 | 4180 | Horn | H | -70.6 | Pk | 28.9 | 20.7 | 38.7 | 54.0 | 15.3 | end, noise |
| 29 | | | | | | | | | | | |
| 30 | 418 | Dip | H | -25.7 | Pk | 21.1 | 19.6 | 76.9 | 80.3 | 3.4 | end 50% duty factor FN145-FB |
| 31 | 418 | Dip | H | -25.4 | Pk | 21.1 | 19.6 | 77.2 | 80.3 | 3.1 | end 50% duty factor FN145-JB |
| 32 | | | | | | | | | | | |
| 33 | | | | | | | | | | | |
| 34 | | | | | | | | | | | |
| 35 | | | | | | | | | | | |
| 36 | | | | | | | | | | | |
| 37 | | | | | | | | | | | |
| 38 | | | | | | | | | | | |
| 39 | | | | | | | | | | | |

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## Table 5.3(Cont.). Highest Emissions Measured

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Radiated Emissions** | | | | | | | | | | | JCI, RS EVIC; 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 |
| 1 | 418 | Dip | H | -33.7 | Pk | 21.1 | 19.6 | 73.2 | 80.3 | 7.1 | side 80% duty factor FN145-DB |
| 2 | 418 | Dip | V | -29.2 | Pk | 21.1 | 19.6 | 77.7 | 80.3 | 2.6 | end |
| 3 | 836 | Dip | H | -66.5 | Pk | 27.7 | 16.0 | 50.6 | 60.3 | 9.7 | side |
| 4 | 836 | Dip | V | -68.1 | Pk | 27.7 | 16.0 | 49.0 | 60.3 | 11.3 | flat |
| 5 | 1254 | Horn | H | -60.7 | Pk | 20.5 | 28.1 | 37.1 | 60.3 | 23.2 | side |
| 6 | 1672 | Horn | H | -67.0 | Pk | 21.5 | 28.1 | 31.8 | 54.0 | 22.2 | end |
| 7 | 2090 | Horn | H | -64.3 | Pk | 22.7 | 26.8 | 37.0 | 60.3 | 23.3 | flat |
| 8 | 2508 | Horn | H | -70.8 | Pk | 24.0 | 26.5 | 32.1 | 60.3 | 28.2 | end, noise |
| 9 | 2926 | Horn | H | -68.9 | Pk | 25.1 | 25.2 | 36.4 | 60.3 | 23.9 | end, noise |
| 10 | 3344 | Horn | H | -70.3 | Pk | 26.5 | 24.7 | 36.9 | 54.0 | 17.1 | end, noise |
| 11 | 3762 | Horn | H | -70.2 | Pk | 27.7 | 24.3 | 38.6 | 54.0 | 15.4 | end, noise |
| 12 | 4180 | Horn | H | -71.3 | Pk | 28.9 | 20.7 | 42.3 | 54.0 | 11.7 | end, noise |
| 13 | | | | | | | | | | | |
| 14 | 418 | Dip | V | -29.6 | Pk | 21.1 | 19.6 | 77.3 | 80.3 | 3.0 | end 80% duty factor FN145-FB |
| 15 | 418 | Dip | V | -29.7 | Pk | 21.1 | 19.6 | 77.2 | 80.3 | 3.1 | end 80% duty factor FN145-JB |
| 16 | | | | | | | | | | | |
| 17 | | | | | | | | | | | |
| 18 | | | | | | | | | | | |
| 19 | | | | | | | | | | | |
| 20 | | | | | | | | | | | |
| 21 | | | | | | | | | | | |
| 22 | | | | | | | | | | | |
| 23 | | | | | | | | | | | |
| 24 | | | | | | | | | | | |
| 25 | | | | | | | | | | | |
| 26 | | | | | | | | | | | |
| 27 | | | | | | | | | | | |
| 28 | | | | | | | | | | | |
| 29 | | Digital emissions are more than 20 dB below FCC Class B limit. | | | | | | | | | |
| 30 | | | | | | | | | | | |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Conducted Emissions** | | | | | | | |
| # | Line Side | Line Side | Det. Used | Vtest dBμV | Vlim dBμV | Pass dB | Comments |
| 1 | | | | | | | |
| 2 | | | | | | | |
| 3 | | | | Not Applicable | | | |
| 4 | | | | | | | |
| 5 | | | | | | | |

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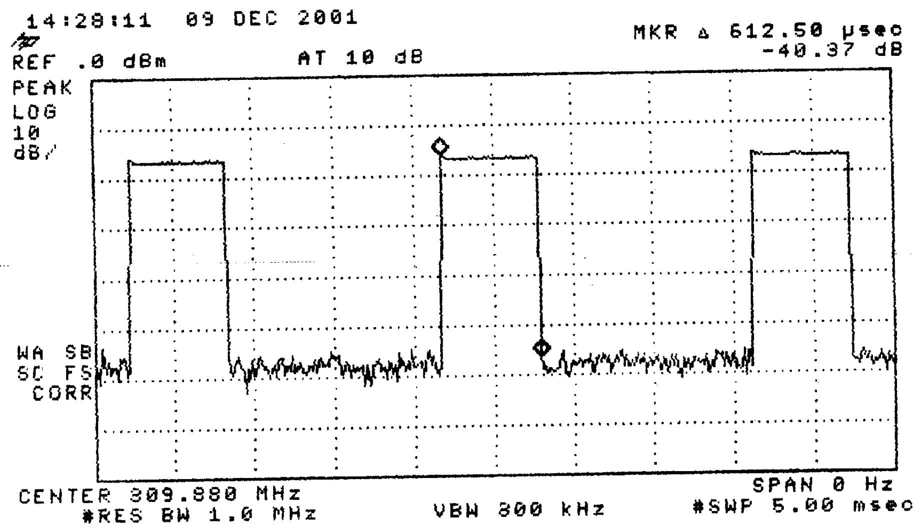


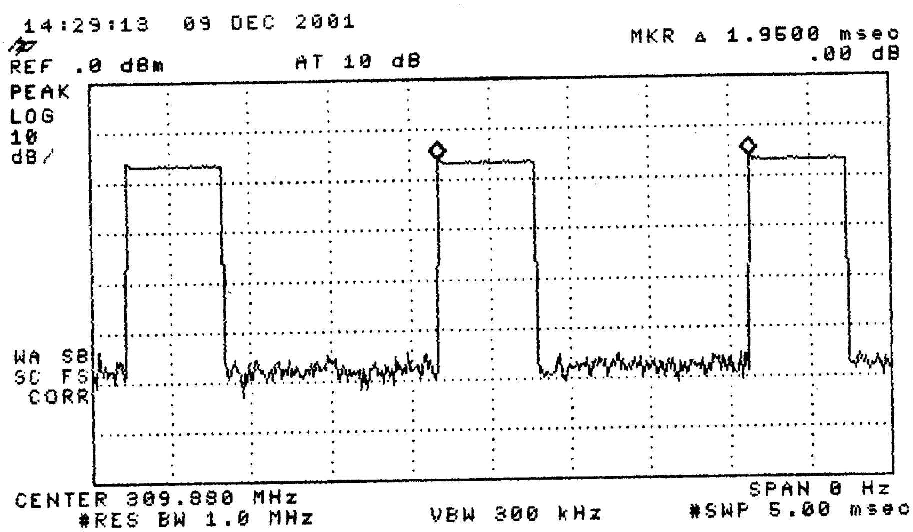
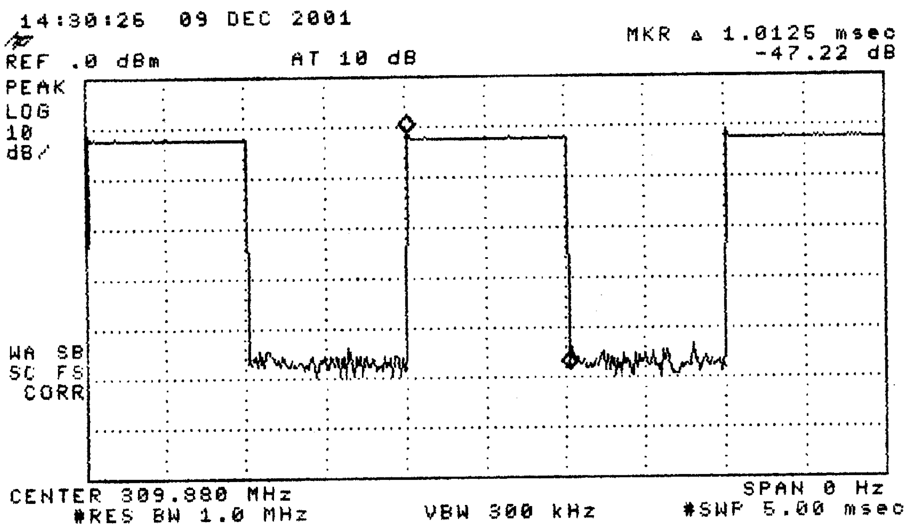




Figure 6.1(a). Transmissions modulation characteristics: (top) pulse width, (bottom) pulse period. (310 MHz, 30% duty factor).



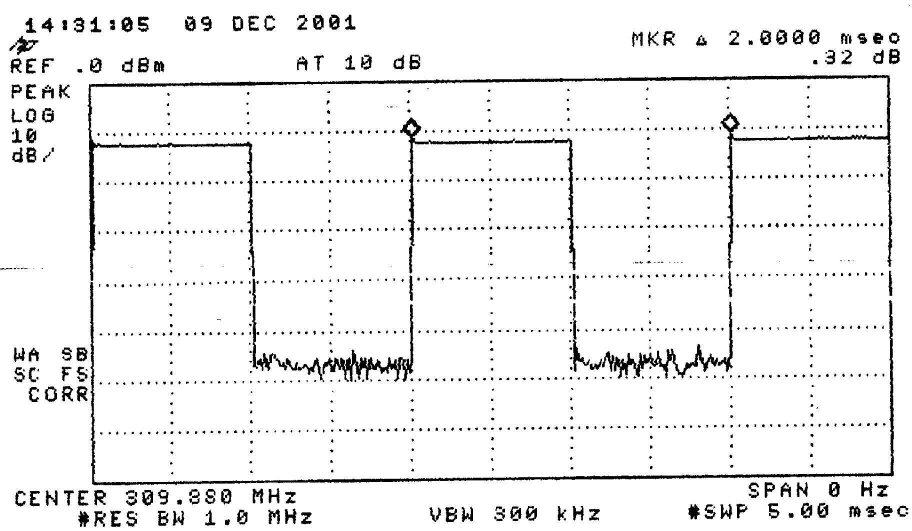
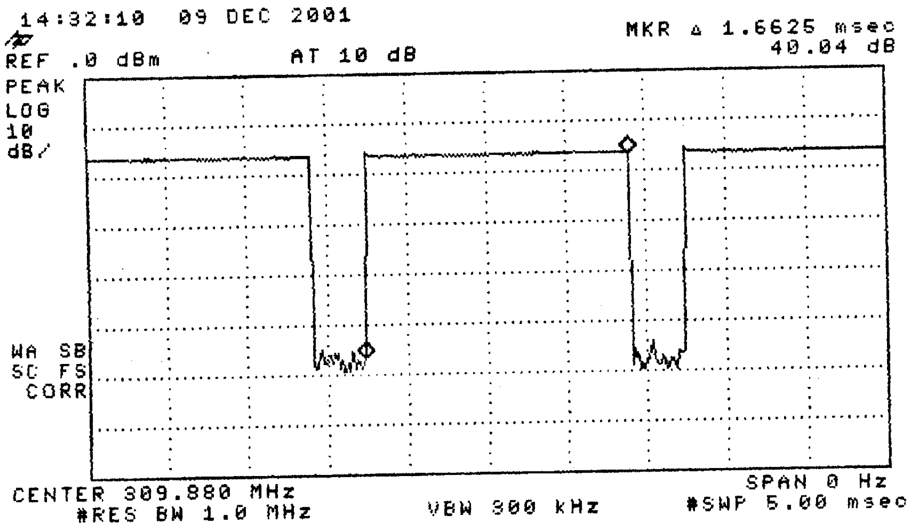




Figure 6.1(b). Transmissions modulation characteristics: (top) pulse width, (bottom) pulse period. (310 MHz, 50% duty factor).



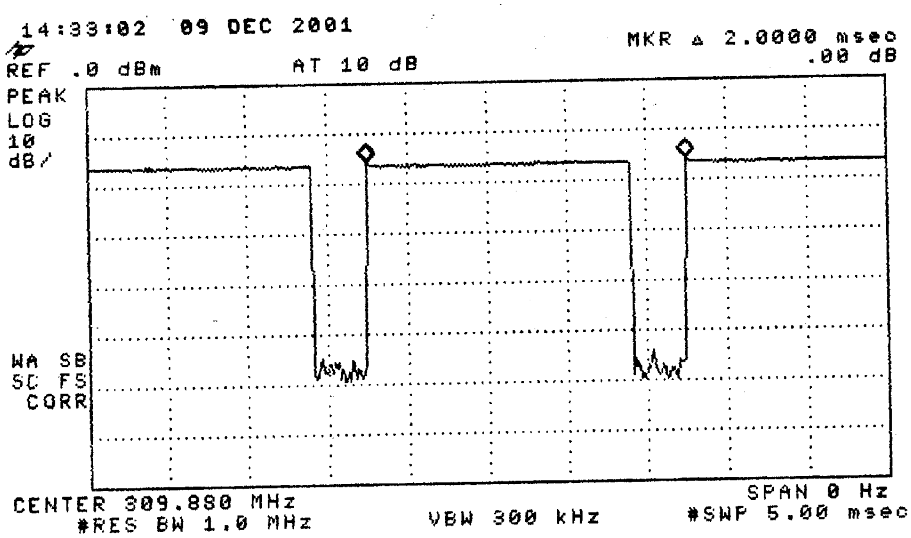




Figure 6.1(c). Transmissions modulation characteristics: (top) pulse width, (bottom) pulse period. (310 MHz, 80% duty factor).

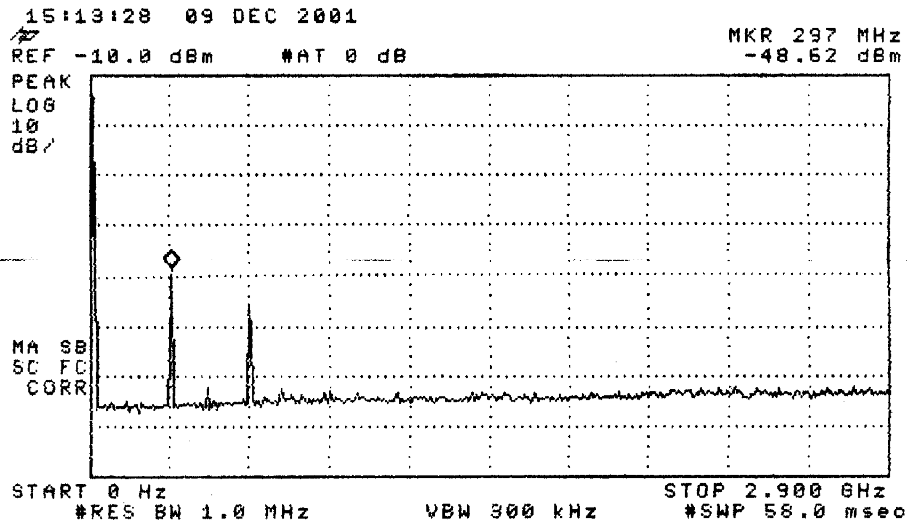



Figure 6.2(a). Emission spectrum of the DUT (288 MHz, 50% duty factor). The amplitudes are only indicative (not calibrated).

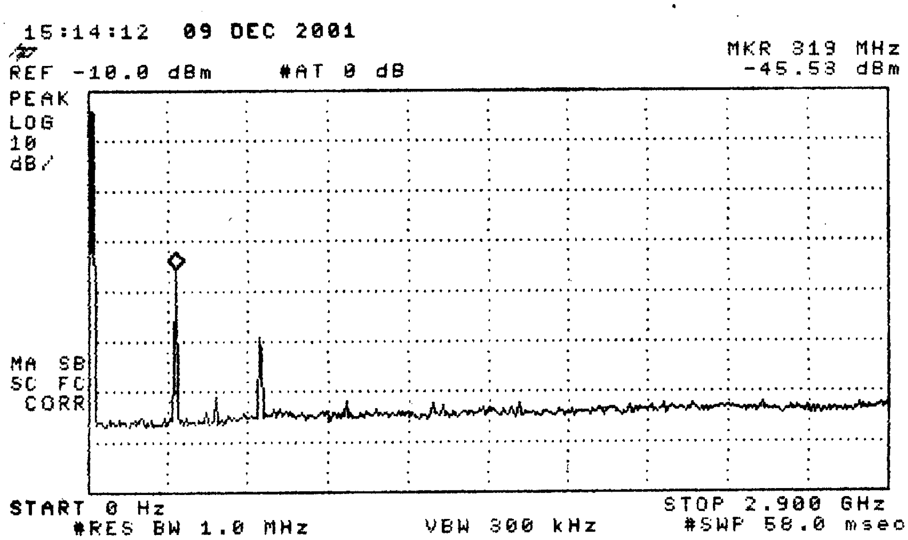



Figure 6.2(b). Emission spectrum of the DUT (310 MHz, 50% duty factor). The amplitudes are only indicative (not calibrated).

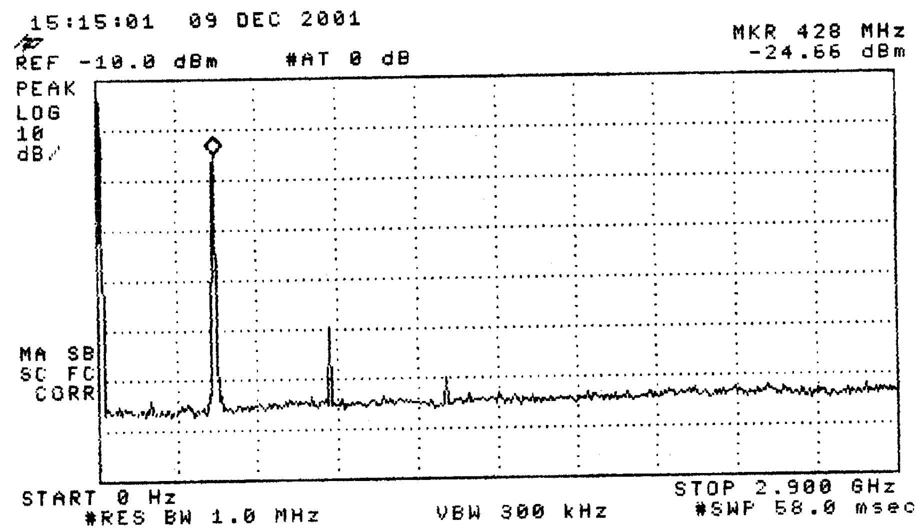



Figure 6.2(c). Emission spectrum of the DUT (418 MHz, 50% duty factor). The amplitudes are only indicative (not calibrated).

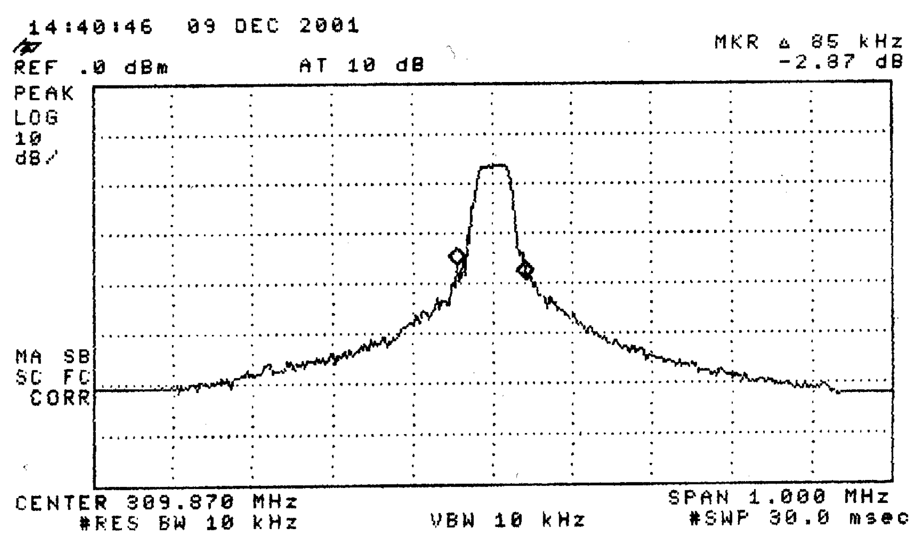



Figure 6.3(a). Measured bandwidth of the DUT. (Pulsed mode, 310 MHz, 30% duty factor).

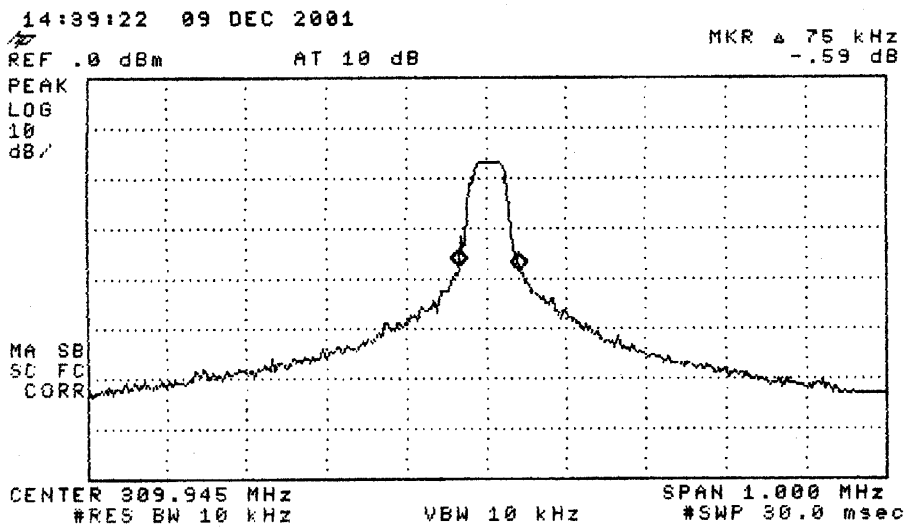



Figure 6.3(b). Measured bandwidth of the DUT.
(Pulsed mode, 310 MHz, 50% duty factor).

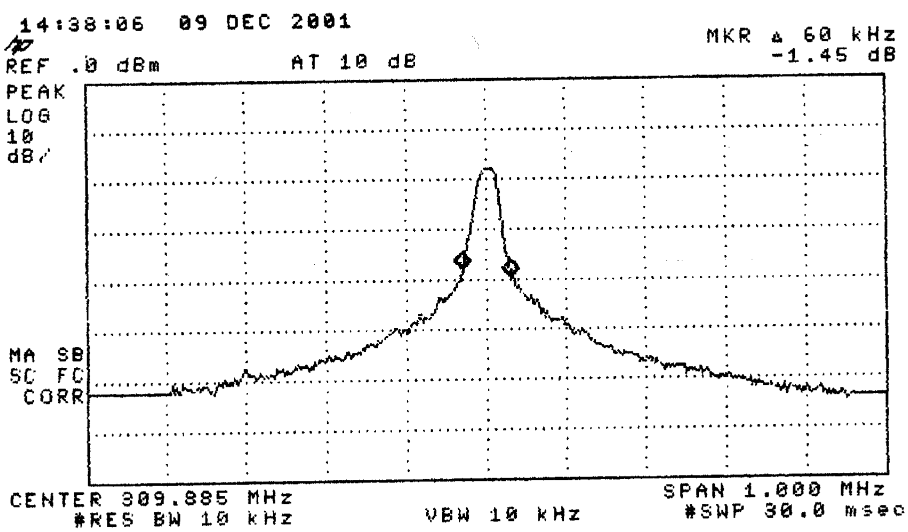



Figure 6.3(c). Measured bandwidth of the DUT.
(Pulsed mode, 310 MHz, 80% duty factor).

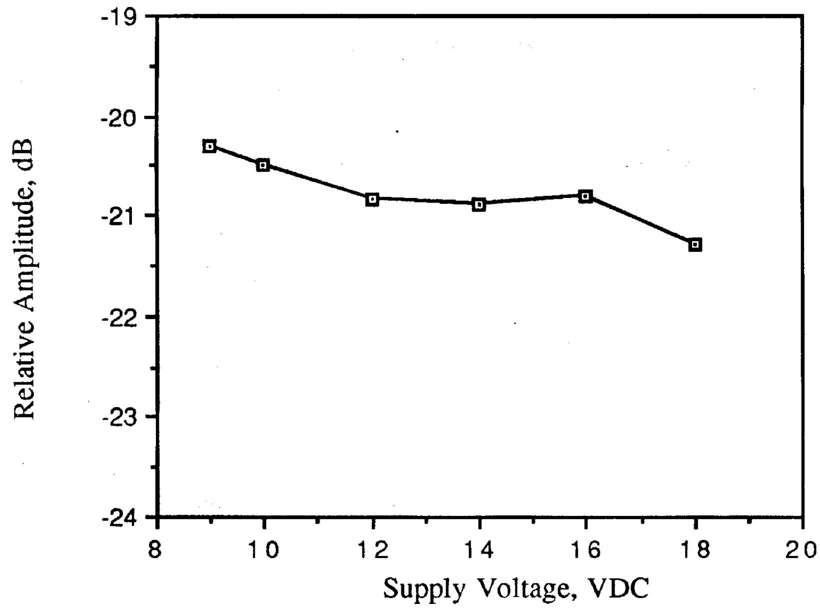



Figure 6.4. Relative emission vs. supply voltage. (310 MHz, continuous pulsed)