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

Measured Radio Frequency Emissions From

Johnson Controls Interiors L.L.C. Home Link Transmitter Model CSPSIHL3

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For:
Johnson Controls, Inc.
Automotive Systems Group
915 E. 32nd Street
Holland, MI 49423

Contact:
Craig Harder
Craig.Harder@jci.com
Tel: (616) 394-6101 Fax: (616) 394-3877
P.O. verbal

Measurements made by:
Valdis V. Liepa
Craig Harder (JCI)

Tests supervised by:
Report approved by:
Valdis V. Liepa
Research Scientist

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, Model CSPSIHL3. 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 24 and December 14 and 17, 2001, in the worst case of the all combinations tested, the transmitter tested in the worst case met the allowed limits for radiated emissions by 0.7 dB at the fundamental (p.7) and by 2.4 dB at the harmonics (p.8). 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 transmitter, Model CSPSIHL3, 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 C63.4-1992 "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 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)		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)	X	Hewlett-Packard, 8657B
Signal Generator (0.01-20 GHz)		Hewlett-Packard

3. Configuration and Identification of Device Under Test

The DUT is a two-module device, consisting of a push-button control module and a transmitter with other electronics. It is powered by 12 VDC. The DUT is a learning garage door opener transmitter, a receiver for a tire-pressure monitoring system, and a trip computer. The display section is separate and is part of the car's instrument cluster. This document reports on the measurements of the transmitter emissions.

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 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 transmitter is activated only when a button is depressed, and ceases operation upon release of the button.

The DUT was designed by Johnson Controls, Inc., Automotive Systems Group, 915 E. 32nd Street, Holland, MI 49423, and will be manufactured by Jabil Circuits, Inc., 1700 Atlantic Blvd., Auburn Hills, MI, 48236. It is identified as:

Johnson Controls Homelink Transmitter
Model: CSPSIHL3
FCC ID: CB2CSPSIHL3
CANADA: to be provided by IC

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	
322-335.4 399.9-410 608-614	Restricted Bands		200	46.0
960-1240 1300-1427 1435-1626.5 1660-1710 1718.9-1722.2 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 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

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

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 0.7 dB (p. 7).

6. Other Measurements and Computations

6.1 Correction For Pulse Operation

As agreed previously between 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:

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

$K_E = 0.575/1.950 = 0.295$ or -10.60 dB.

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

$K_E = 1.0125/1.950 = 0.519$ or -5.69 dB.

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

$K_E = 1.6125/2.00 = 0.806$ or -1.87 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 300 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 135.0 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 6.8 to 18 volts. The emission variation is shown in Figure 6.4.

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

Supply Voltage	=	13.8 VDC
Current	=	320.0 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 286.1 to 303.7 MHz , from 307.7 to 321.1 MHz, from 336.6 to 398.95 MHz, and from 411.45 to 420.25 MHz . In any case, no frequency was repeated in the Restricted Bands. (Also, there were no spurious emissions in the Restricted Bands.)

Table 5.1. Highest Emissions Measured

Radiated Emissions											JCI, CS w/ PSI; 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	-21.8	Pk	18.1	20.4	72.3	73.9	1.6	side 30% duty factor
2	288	Dip	V	-26.2	Pk	18.1	20.4	67.9	73.9	6.0	flat
3	576	Dip	H	-54.8	Pk	24.4	17.2	48.8	53.9	5.1	side
4	576	Dip	V	-61.2	Pk	24.4	17.2	42.4	53.9	11.5	flat
5	864	Dip	H	-64.2	Pk	28.1	15.0	45.3	53.9	8.7	flat
6	864	Dip	V	-61.3	Pk	28.1	15.0	48.2	53.9	5.8	flat
7	1152	Horn	H	-69.2	Pk	20.2	28.1	19.3	53.9	34.6	flat
8	1440	Horn	H	-52.8	Pk	21.2	28.3	36.6	53.9	17.4	flat
9	1728	Horn	H	-57.7	Pk	21.9	27.8	32.8	53.9	21.2	flat
10	2016	Horn	H	-62.0	Pk	22.5	26.6	30.3	53.9	23.6	side
11	2304	Horn	H	-70.5	Pk	23.2	26.9	22.3	53.9	31.7	side, noise
12	2592	Horn	H	-70.0	Pk	24.0	26.6	23.8	53.9	30.1	end, noise
13	2880	Horn	H	-70.8	Pk	24.8	25.5	24.9	53.9	29.1	end, noise
14											
15											
16	288	Dip	H	-25.8	Pk	18.1	20.4	73.2	73.9	0.7	side 50% duty factor
17	288	Dip	V	-32.3	Pk	18.1	20.4	66.7	73.9	7.2	flat
18	576	Dip	H	-66.3	Pk	24.4	17.2	42.2	53.9	11.7	side
19	576	Dip	V	-63.8	Pk	24.4	17.2	44.7	53.9	9.2	flat
20	864	Dip	H	-66.8	Pk	28.1	15.0	47.6	53.9	6.3	side
21	864	Dip	V	-63.9	Pk	28.1	15.0	50.5	53.9	3.4	flat
22	1152	Horn	H	-66.9	Pk	20.2	28.1	26.5	53.9	27.4	side
23	1440	Horn	H	-56.2	Pk	21.2	28.3	38.1	53.9	15.9	flat
24	1728	Horn	H	-61.4	Pk	21.9	27.8	34.0	53.9	19.9	flat
25	2016	Horn	H	-65.0	Pk	22.5	26.6	32.3	53.9	21.7	flat
26	2304	Horn	H	-70.0	Pk	23.2	26.9	27.7	53.9	26.2	flat, noise
27	2592	Horn	H	-71.5	Pk	24.0	26.6	27.2	53.9	26.7	flat, noise
28	2880	Horn	H	-71.1	Pk	24.8	25.5	29.5	53.9	24.4	flat, noise
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39											

Meas. 7/24/01, 12/17/01; U of Mich.

Table 5.1(Cont.). Highest Emissions Measured

Radiated Emissions										JCI, CS w/ PSI; 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	-30.9	Pk	18.1	20.4	71.9	73.9	**2.0**	side 80% duty factor
2	288	Dip	V	-35.5	Pk	18.1	20.4	67.3	73.9	6.6	flat
3	576	Dip	H	-70.8	Pk	24.4	17.2	41.5	53.9	12.4	side
4	576	Dip	V	-67.1	Pk	24.4	17.2	45.2	53.9	8.7	flat
5	864	Dip	H	-70.1	Pk	28.1	15.0	48.1	53.9	5.8	side
6	864	Dip	V	-66.7	Pk	28.1	15.0	51.5	53.9	2.4	flat
7	1152	Horn	H	-60.6	Pk	20.2	28.1	36.6	53.9	17.3	side
8	1440	Horn	H	-57.5	Pk	21.2	28.3	40.6	53.9	13.3	flat
9	1728	Horn	H	-62.8	Pk	21.9	27.8	36.4	53.9	17.5	flat
10	2016	Horn	H	-67.6	Pk	22.5	26.6	33.5	53.9	20.4	flat
11	2304	Horn	H	-71.1	Pk	23.2	26.9	30.4	53.9	23.5	end, noise
12	2592	Horn	H	-71.1	Pk	24.0	26.6	31.4	53.9	22.5	side, noise
13	2880	Horn	H	-70.7	Pk	24.8	25.5	33.7	53.9	20.2	end, noise
14											
15											
16											
17											
18											
19											
20											
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22											
23											
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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. 7/24/01, 12/17/01; U of Mich.

Table 5.2. Highest Emissions Measured

Radiated Emissions											JCI, CS w/ PSI; 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	20.1	73.7	75.3	1.6	side 30% duty factor
2	310	Dip	V	-24.5	Pk	18.8	20.1	70.6	75.3	4.7	flat
3	620	Dip	H	-52.8	Pk	25.1	16.7	52.0	55.3	3.3	side
4	620	Dip	V	-55.2	Pk	25.1	16.7	49.6	55.3	5.7	end
5	927	Dip	H	-69.4	Pk	26.1	14.4	38.7	55.3	16.6	end
6	927	Dip	V	-73.4	Pk	26.1	14.4	34.7	55.3	20.6	end
7	1240	Horn	H	-59.9	Pk	20.4	28.0	28.9	54.0	25.1	flat
8	1550	Horn	H	-58.4	Pk	21.5	28.2	31.3	54.0	22.8	flat
9	1860	Horn	H	-62.9	Pk	22.1	28.3	27.3	55.3	28.0	flat
10	2170	Horn	H	-64.3	Pk	22.8	27.1	27.8	55.3	27.5	flat
11	2480	Horn	H	-70.5	Pk	23.8	26.5	23.2	55.3	32.1	side, noise
12	2790	Horn	H	-70.7	Pk	24.5	25.6	24.6	54.0	29.4	side, noise
13	3100	Horn	H	-69.4	Pk	25.8	25.1	27.8	55.3	27.6	side, noise
14											
15											
16	310	Dip	H	-25.7	Pk	18.8	20.1	74.3	75.3	1.0	side 50% duty factor
17	310	Dip	V	-28.9	Pk	18.8	20.1	71.1	75.3	4.2	flat
18	620	Dip	H	-60.1	Pk	25.1	16.7	49.6	55.3	5.7	flat
19	620	Dip	V	-63.6	Pk	25.1	16.7	46.1	55.3	9.2	end
20	930	Dip	H	-70.4	Pk	26.1	14.4	42.6	55.3	12.7	end
21	930	Dip	V	-74.5	Pk	26.1	14.4	38.5	55.3	16.8	end
22	1240	Horn	H	-63.7	Pk	20.4	28.0	30.0	54.0	24.0	flat
23	1550	Horn	H	-59.9	Pk	21.5	28.2	34.7	54.0	19.3	side
24	1860	Horn	H	-63.8	Pk	22.1	28.3	31.3	55.3	24.0	flat
25	2170	Horn	H	-66.1	Pk	22.8	27.1	30.9	55.3	24.4	flat
26	2480	Horn	H	-70.3	Pk	23.8	26.5	28.3	55.3	27.0	end, noise
27	2790	Horn	H	-71.2	Pk	24.5	25.6	29.0	54.0	25.0	end, noise
28	3100	Horn	H	-69.2	Pk	25.8	25.1	32.9	55.3	22.4	side, noise
29											
30											
31											
32											
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36											
37											
38											
39											

Meas. 7/24/01, 12/17/01; U of Mich.

Table 5.2(Cont.). Highest Emissions Measured

Radiated Emissions — JCI, CS w/ PSI; 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	-29.9	Pk	18.8	20.1	74.0	75.3	1.4	side 80% duty factor
2	310	Dip	V	-33.0	Pk	18.8	20.1	70.9	75.3	4.5	flat
3	620	Dip	H	-66.9	Pk	25.1	16.7	46.6	55.3	8.7	flat
4	620	Dip	V	-68.3	Pk	25.1	16.7	45.2	55.3	10.1	end
5	927	Dip	H	-73.4	Pk	26.1	14.4	43.4	55.3	11.9	end
6	927	Dip	V	-75.9	Pk	26.1	14.4	40.9	55.3	14.4	end
7	1240	Horn	H	-66.6	Pk	20.4	28.0	30.9	54.0	23.1	side
8	1550	Horn	H	-59.1	Pk	21.5	28.2	39.3	54.0	14.7	flat
9	1860	Horn	H	-66.4	Pk	22.1	28.3	32.5	55.3	22.8	flat
10	2170	Horn	H	-68.6	Pk	22.8	27.1	32.2	55.3	23.1	flat
11	2480	Horn	H	-70.1	Pk	23.8	26.5	32.3	55.3	23.0	end, noise
12	2790	Horn	H	-69.1	Pk	24.5	25.6	34.9	54.0	19.1	side, noise
13	3100	Horn	H	-69.4	Pk	25.8	25.1	36.5	55.3	18.8	flat, noise
14											
15											
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

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

Meas. 7/24/01, 12/17/01; U of Mich.

Table 5.3. Highest Emissions Measured

Radiated Emissions											JCI, CS w/ PSI; 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	-22.1	Pk	21.1	18.7	76.7	80.3	3.6	side 30% duty factor
2	418	Dip	V	-21.0	Pk	21.1	18.7	77.8	80.3	2.5	end
3	836	Dip	H	-53.7	Pk	27.7	15.1	55.3	60.3	5.0	flat
4	836	Dip	V	-57.4	Pk	27.7	15.1	51.6	60.3	8.7	end
5	1254	Horn	H	-45.6	Pk	20.5	28.1	43.2	60.3	17.1	flat
6	1672	Horn	H	-44.6	Pk	21.5	28.1	45.2	54.0	8.8	flat
7	2090	Horn	H	-55.5	Pk	22.7	26.8	36.8	60.3	23.5	end
8	2508	Horn	H	-66.4	Pk	24.0	26.5	27.5	60.3	32.8	end
9	2926	Horn	H	-69.0	Pk	25.1	25.2	27.3	60.3	33.0	flat, noise
10	3344	Horn	H	-70.5	Pk	26.5	24.7	27.7	54.0	26.3	side, noise
11	3762	Horn	H	-70.3	Pk	27.7	24.3	29.5	54.0	24.5	side, noise
12	4180	Horn	H	-71.9	Pk	28.9	20.7	32.7	54.0	21.3	side, noise
13											
14											
15	418	Dip	H	-26.7	Pk	21.1	18.7	77.0	80.3	3.3	side 50% duty factor
16	418	Dip	V	-25.8	Pk	21.1	18.7	77.9	80.3	2.4	end
17	836	Dip	H	-61.9	Pk	27.7	15.1	52.0	60.3	8.3	flat
18	836	Dip	V	-64.2	Pk	27.7	15.1	49.7	60.3	10.6	side
19	1254	Horn	H	-54.9	Pk	20.5	28.1	38.8	60.3	21.5	flat
20	1672	Horn	H	-53.3	Pk	21.5	28.1	41.4	54.0	12.6	flat
21	2090	Horn	H	-61.4	Pk	22.7	26.8	35.8	60.3	24.5	flat
22	2508	Horn	H	-69.3	Pk	24.0	26.5	29.5	60.3	30.8	flat
23	2926	Horn	H	-68.3	Pk	25.1	25.2	32.9	60.3	27.4	side. noise
24	3344	Horn	H	-70.7	Pk	26.5	24.7	32.4	54.0	21.6	end, noise
25	3762	Horn	H	-70.7	Pk	27.7	24.3	34.0	54.0	20.0	side, noise
26	4180	Horn	H	-71.9	Pk	28.9	20.7	37.6	54.0	16.4	end, noise
27											
28											
29											
30											
31											
32											
33											
34											
35											
36											
37											
38											
39											

Meas. 7/24/01, 12/14/01; U of Mich.

Table 5.3(Cont.). Highest Emissions Measured

Radiated Emissions											JCI, CS w/ PSI; 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	-30.5	Pk	21.1	18.7	77.0	80.3	3.3	side 80% duty factor
2	418	Dip	V	-29.7	Pk	21.1	18.7	77.8	80.3	2.5	end
3	836	Dip	H	-66.1	Pk	27.7	15.1	51.6	60.3	8.7	flat
4	836	Dip	V	-69.3	Pk	27.7	15.1	48.4	60.3	11.9	side
5	1254	Horn	H	-63.8	Pk	20.5	28.1	33.7	60.3	26.6	end
6	1672	Horn	H	-61.7	Pk	21.5	28.1	36.8	54.0	17.2	side
7	2090	Horn	H	-61.7	Pk	22.7	26.8	39.3	60.3	21.0	flat
8	2508	Horn	H	-71.1	Pk	24.0	26.5	31.5	60.3	28.8	side, noise
9	2926	Horn	H	-69.4	Pk	25.1	25.2	35.6	60.3	24.7	flat, noise
10	3344	Horn	H	-70.1	Pk	26.5	24.7	36.8	54.0	17.2	end, noise
11	3762	Horn	H	-70.2	Pk	27.7	24.3	38.3	54.0	15.7	end, noise
12	4180	Horn	H	-71.9	Pk	28.9	20.7	41.4	54.0	12.6	end, noise
13											
14											
15											
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							

Meas. 7/24/01, 12/14/01; U of Mich.

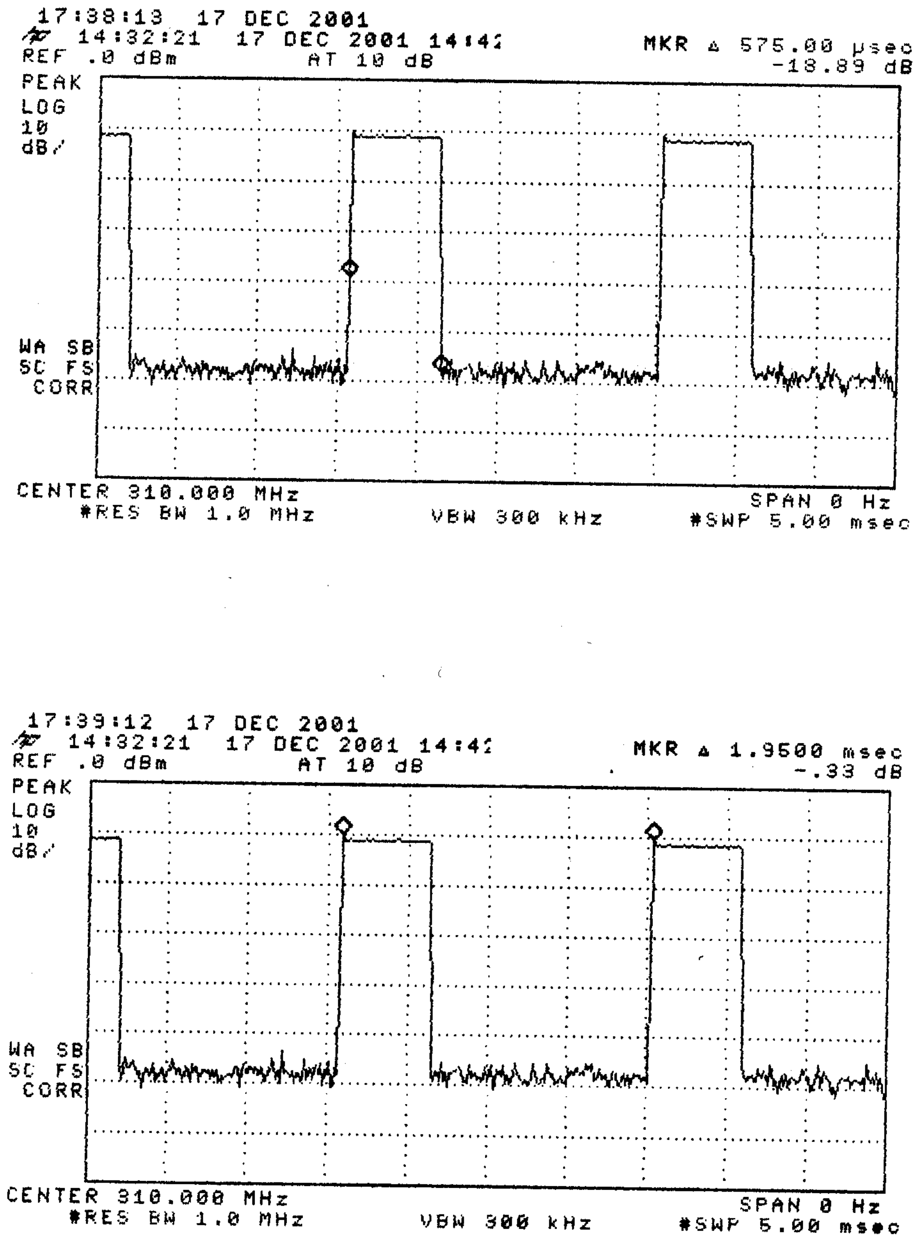
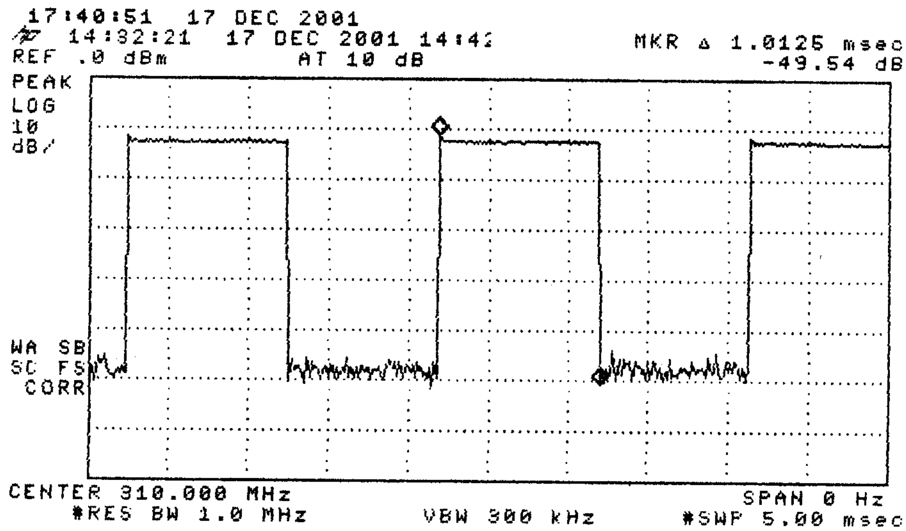


Figure 6.1(a). Transmissions modulation characteristics: (top) pulse width, (bottom) pulse period. (310 MHz, 30% duty factor).



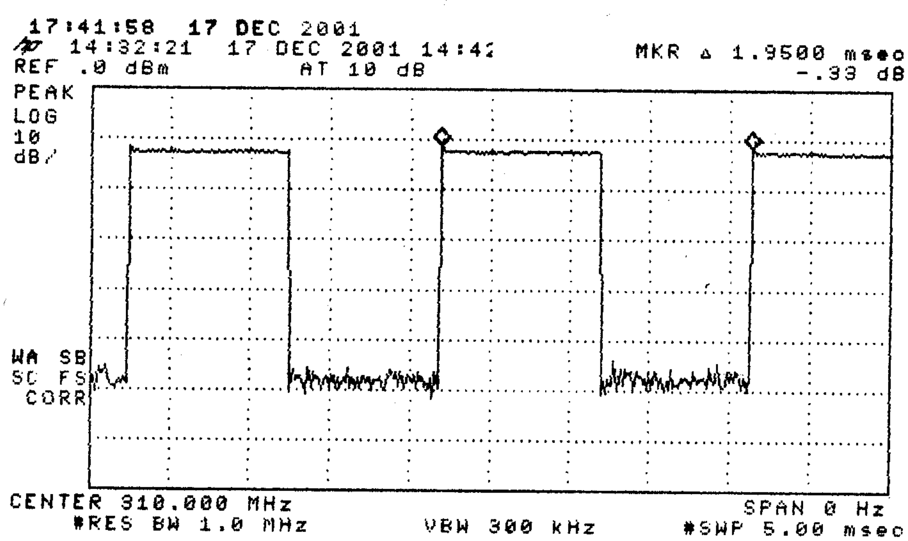
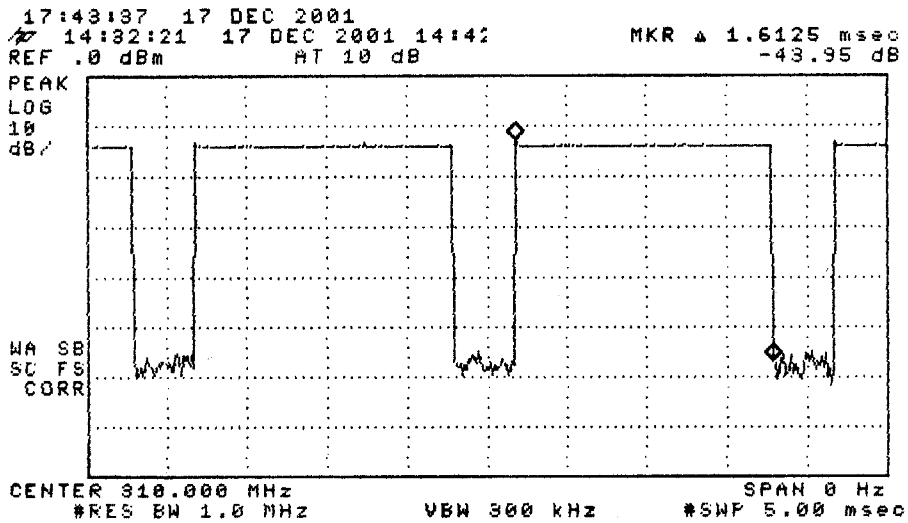


Figure 6.1(b). Transmissions modulation characteristics: (top) pulse width, (bottom) pulse period. (310 MHz, 50% duty factor).



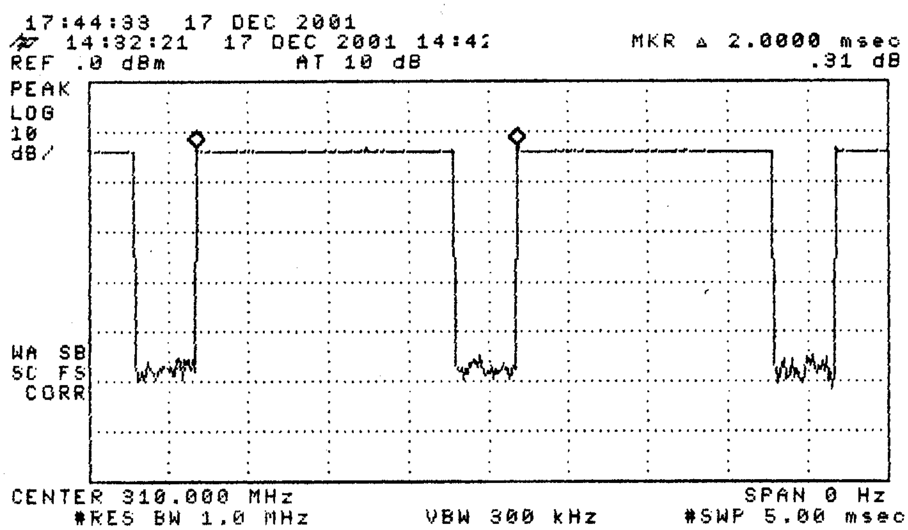


Figure 6.1(c). Transmissions modulation characteristics: (top) pulse width, (bottom) pulse period. (310 MHz, 80% duty factor).

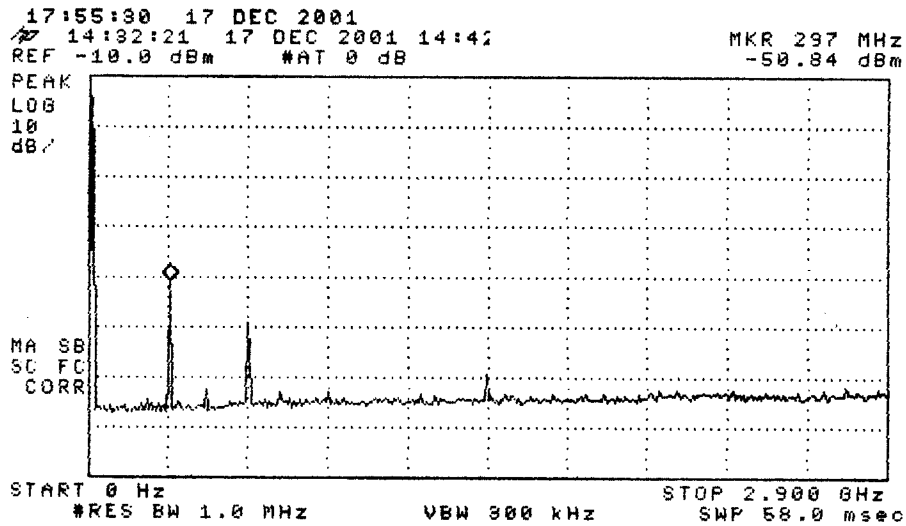


Figure 6.2(a). Emission spectrum of the DUT (288 MHz, 50% duty factor).
The amplitudes are only indicative (not calibrated).

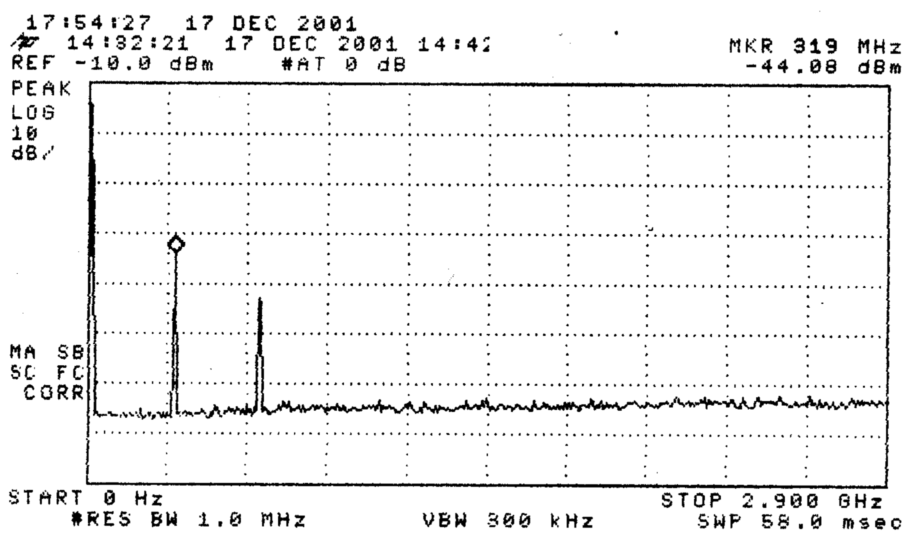


Figure 6.2(b). Emission spectrum of the DUT (310 MHz, 50% duty factor).
The amplitudes are only indicative (not calibrated).

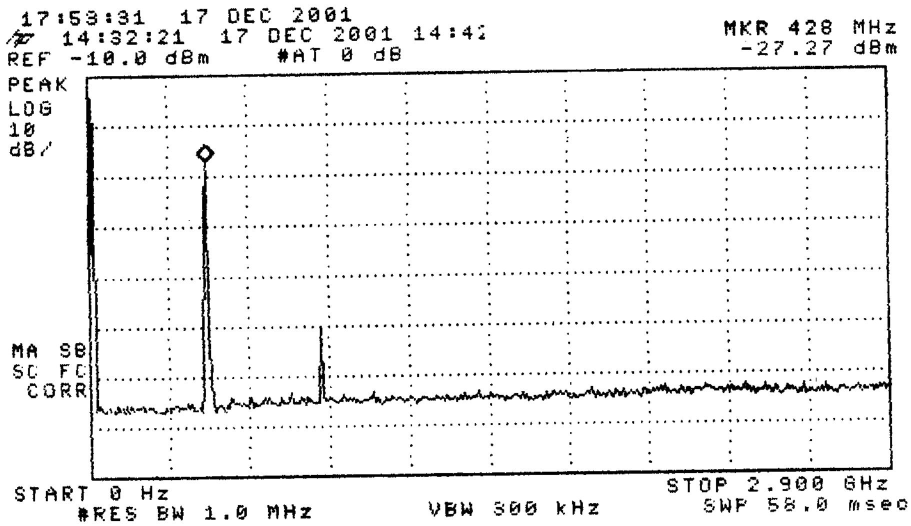


Figure 6.2(c). Emission spectrum of the DUT (418 MHz, 50% duty factor).
The amplitudes are only indicative (not calibrated).

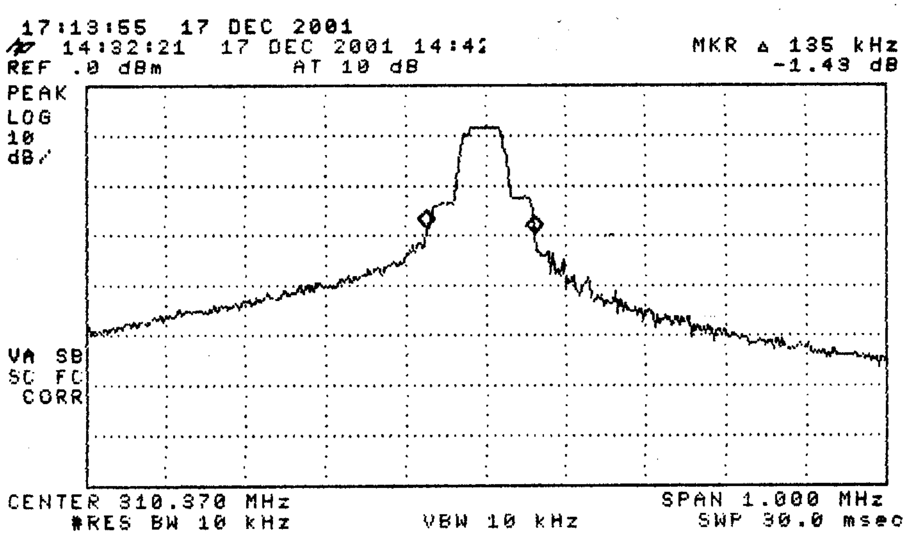


Figure 6.3(a). Measured bandwidth of the DUT.
(Pulsed mode, 310 MHz, 30% duty factor).

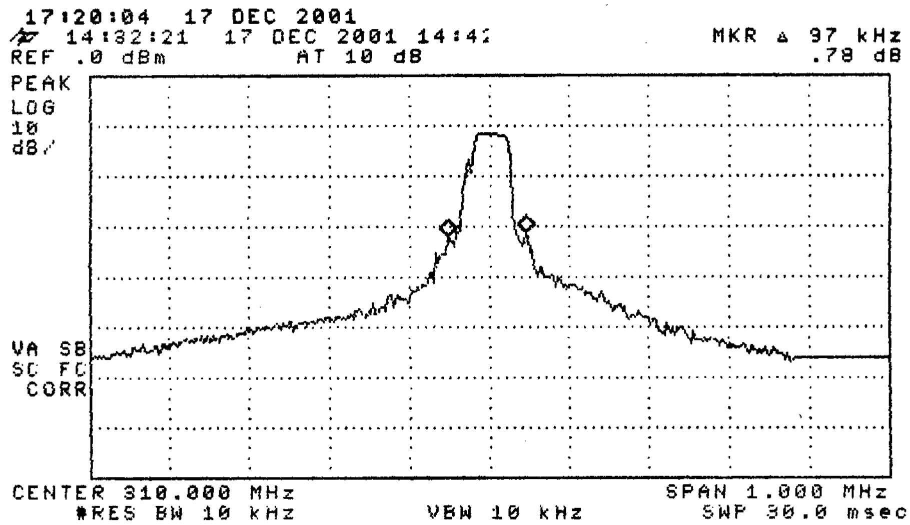


Figure 6.3(b). Measured bandwidth of the DUT.
(Pulsed mode, 310 MHz, 50% duty factor).

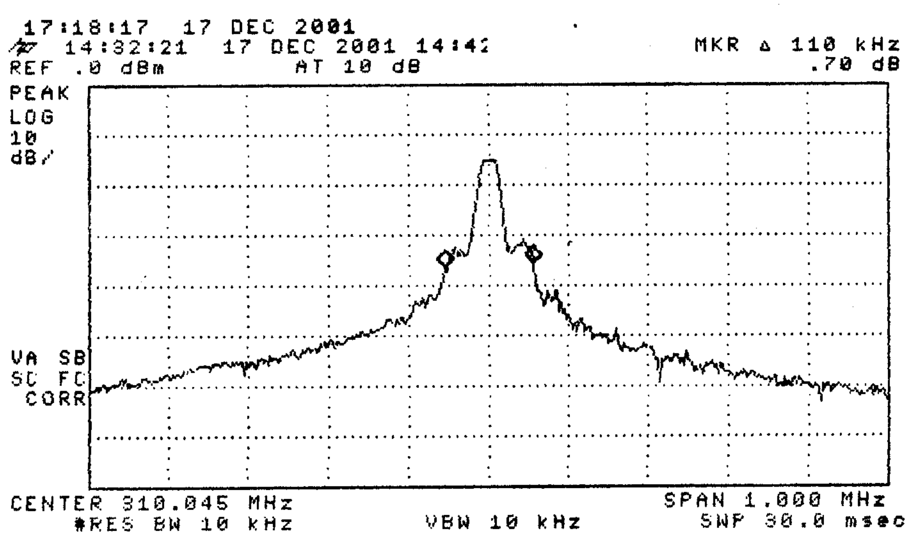


Figure 6.3(c). Measured bandwidth of the DUT.
(Pulsed mode, 310 MHz, 80% duty factor).

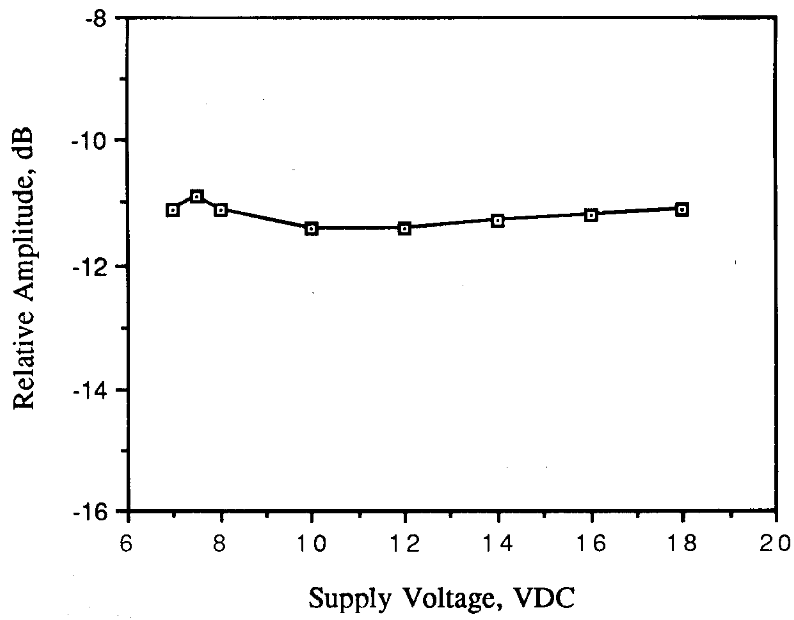
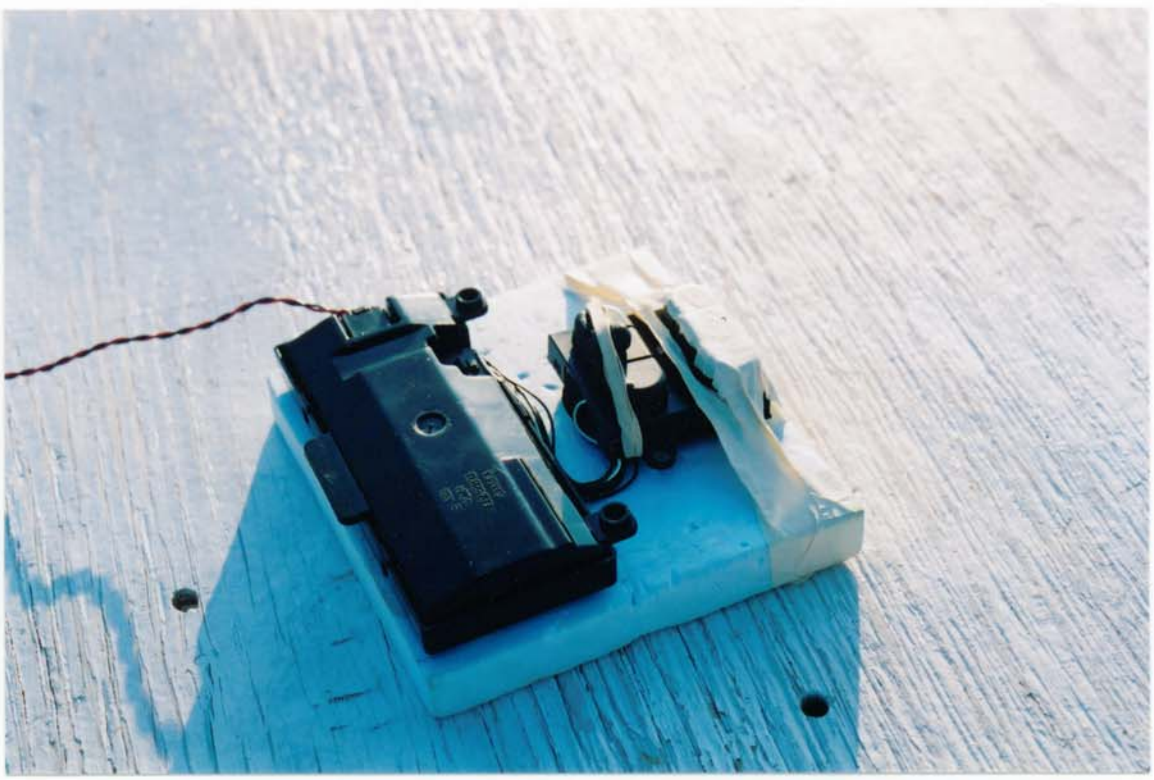


Figure 6.4. Relative emission vs. supply voltage. (310 MHz, continuous pulsed)

Appendix: DUT on OATS



Appendix: Close-up of the DUT on OATS