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Measured Radio Frequency Emissions
From

Wanco, Inc.
K-band Modular Doppler Radar
FCC ID: UQXWRDR192
Model(s): WRDR-E

Report No. 415031-402
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For:
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Summary
Tests for compliance with FCC Regulations, according to Part 15.245 were performed on Wanco WRDR-E Doppler radar. In testing completed January 4, 2008, the device tested met the emission limits at the fundamental by 8.6 dB, at the harmonics by 1.6 dB, and spurious emissions FCC/IC by more than 1.6 dB. For RF Health Hazard, the maximum RF field at a 20 cm distance was calculated to be 0.052 mW/cm^2. The DUT is designed for operation on a 12 VDC system, but ac mains conducted emissions were measured with a laboratory power supply and meet the FCC/IC limit by more than 15.3 dB.

1. Introduction

The Wanco WRDR-E Doppler radar was tested for compliance with FCC Regulations, Part 15, adopted under Docket 87-389, April 18, 1989 as amended. The tests were performed at the University of Michigan Radiation Laboratory Willow Run Test Range following the procedures described in ANSI C63.4-2005 "Methods of Measurement of Radio-Noise Emissions from Low-Voltage Electrical and Electronic Equipment in the Range of 9 kHz to 40 GHz." The Site description and attenuation characteristics of the Open Site facility are on file with FCC Laboratory, Columbia, Maryland (FCC Reg. No: 91050) and with Industry Canada, Ottawa, ON (File Ref. No: IC 2057A-1).

2. Test 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)		Hewlett-Packard 8592L, SN: 3710A00856
Spectrum Analyzer (9kHz-26GHz)	X	Hewlett-Packard 8593E, SN: 3412A01131
Spectrum Analyzer (9kHz-26GHz)	X	Hewlett-Packard 8563E, SN: 3310A01174
Spectrum Analyzer (9kHz-40GHz)	X	Hewlett-Packard 8564E, SN: 3745A01031
Power Meter		Hewlett-Packard, 432A
Power Meter		Anritsu, ML4803A/MP
Harmonic Mixer (26.5-40 GHz)	X	Hewlett-Packard 11970A, SN: 3003A08327
Harmonic Mixer (40-60 GHz)	X	Hewlett-Packard 11970U, SN: 2332A00500
Harmonic Mixer (60-90 GHz)	X	Pacific Millimeter Prod., VN, SN: 47
Harmonic Mixer (75-110 GHz)	X	Hewlett-Packard 11970W, SN: 2521A00179
Harmonic Mixer (140-220 GHz)		Pacific Millimeter Prod., GMA, SN: 26
X-band horn (8.2- 12.4 GHz)		Narda 640
X-band horn (8.2- 12.4 GHz)	X	Scientific Atlanta , 12-8.2, SN: 730
K-band horn (18-26.5 GHz)	X	FXR, Inc., K638KF
Ka-band horn (26.5-40 GHz)	X	FXR, Inc., U638A
U-band horn (40-60 GHz)	X	Custom Microwave, HO19
V-band horn (60-90 GHz)	X	Custom Microwave, HO12
W-band horn (75-110 GHz)	X	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)		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)		Avantek, A11-1, A25-1S
Amplifier (5-4500 MHz)	X	Avantek
Amplifier (4.5-13 GHz)	X	Avantek, AFT-12665
Amplifier (6-16 GHz)	X	Trek
LISN (50 μH)		University of Michigan
Signal Generator (0.1-2060 MHz)		Hewlett-Packard, 8657B
Signal Generator (0.01-20 GHz)	X	Hewlett-Packard, 8550B / 83592A

3. Configuration and Identification of Device Under Test

The Device Under Test (DUT) is a 24.125 GHz Doppler Radar. The radar transceiver uses an advanced PHEMT oscillator to generate a continuous wave (CW) signal centered at 24.125 GHz, which is transmitted via a planar patch antenna array. It is used to measure very small changes in the speed of a vehicle approaching the radar. The size of the DUT is 12 (W) x 12(H) x 5.5(D) cm with a single cable on the bottom side. Nominal operating voltage is 12.6 VDC; for testing this was supplied by a laboratory style power supply.

The DUT was manufactured by Wanco, Inc., 5870 Tennyson St., Arvada, CO 80003. It is identified as:

Wanco Doppler radar
Model(s): WRDR-E
S/N: prototype
FCC ID: UQXWRDR192
IC: 6809A-WRDR192

Please note this device does not require features to prevent continuous operation, as emissions in the restricted bands, other than the second and third, fully comply with the limits given in 15.209 (15.245(b)(1)(iii)).

3.1 Changes made to the DUT

No changes were made to the DUT by this test laboratory.

4. Emission Limits

4.1 Radiated Emission Limits

The DUT tested falls under the category of an Intentional Radiator, subject to Section 15.245 and all other sections referred to therein. The applicable critical testing frequencies with corresponding emission limits are given in Tables 4.1 and 4.2.

Table 4.1. Radiated Emission Limits (Ref. FCC 15.209, 15.245, RSS-210 Annex 7) --Transmitter.

Fundamental Frequency	Fundamental Ave. E_{lim}(3m)		Harmonics Ave. E_{lim}(3m)		Spurious** Ave. E_{lim}(3m)	
(MHz)	(mV/m)	dB(μV/m)	(mV/m)	dB(μV/m)	(mV/m)	dB(μV/m)
24075-24175	2500	128	25.0*	88.0*	50 dBc or 15.209	

* 2nd and 3rd harmonics only
** Other than fundamental and harmonics, 50 dB down from fundamental or 15.209 limits.

Table 4.3. Radiated Emission Limits (FCC: 15.33, 15.35, 15.209; IC: RSS-210, 2.7 Table 2).
(Digital Class B)

Freq. (MHz)	E_{lim} (3m) 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 Limit

Table 4.4 Conducted Emission Limits (FCC/CISPR:15.107; IC: RSS-210, 6.6).

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

Notes:
1. The lower limit shall apply at the transition frequency
2. The limit decreases linearly with the logarithm of the frequency in the range 0.15-0.50 MHz:

*Class B Quasi-peak: dBμV = 50.25 - 19.12*log(f)
*Class B Average: dBμV = 40.25 - 19.12*log(f)

3. 9 kHz RBW

5. Test Procedure and Computations

5.1 Test Procedure: General

Prior to any measurements, all active components of the test setup were allowed a warm-up for a period of approximately one hour, or as recommended by their manufacturers.

5.2 Radiated Emissions

5.2.1 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 DUT was placed on the test table flat, 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 ridged horn and standard gain horn antennas above 300 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. Photographs included in this filing show the indoor testing of the DUT.

Note 1: For the horn antennas used, the antenna pattern is 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 characteristics of the carrier. This data is presented in subsequent sections. As a general procedure, emissions are first tested using a peak detector. If the DUT does not meet the quasi-peak (or average) limits via these measurements, quasi-peak (or average) measurements are then made to demonstrate compliance.

5.2.2 Open Area Test Site (OATS) Radiated Emission Tests

After chamber measurements, emissions up to 1000 MHz were re-measured on the outdoor 3-meter site using tuned dipoles and/or Bicone antennas. Photographs included in this filing show the DUT on the Open Area Test Site (OATS).

5.2.3 Field Computations

When the measurement is made at a distance other than 3 meters, the reading is extrapolated to 3 meters. This is done using the 20 dB/decade field behavior relation when translating in the far field, and 40 dB/decade relation when translating in the near field per the FCC's mm-wave measurement procedures. The near-field/far-field criterion, N/F, is based on

$$N/F = 2\,D^2/\text{wavelength}$$

where D is the maximum dimension of the transmitter or receiver antenna , and the wavelength is that of the measurement frequency. Suppose N/F = 2 m and the measurement is made at 1 m. Here the 40 dB/decade relation is applied from 1 to 2 m, and 20 dB/decade relation is applied from 2 to 3 m. In dB, this gives a 15.6 dB adjustment.

To convert the dBm measured and extrapolated to 3 m, the E_3(dBμV/m) is computed from

$$E_3(\text{dB}\mu\text{V/m}) = 107 + Pr + K_a - Kg + K_e$$

Where P_r = power recorded on spectrum analyzer, dBm (or extrapolated to 3 m distance)
K_a = antenna factor, dB/m
K_g = pre-amp gain, dB
K_e = pulse operation correction factor, dB (see 6.1)

For microwave measurements, either the receive antenna is connected directly to the spectrum analyzer, or it is connected to an external mixer followed by an insignificant length of cable. Hence, no cable loss term is used. The mixer conversion losses are programmed in the spectrum analyzer and are included in the dB values. The results are given in Tables 6.1 and 6.2.

6. Measurement Results

6.1 Digital Radiated Emissions (FCC 15.209)

Table 6.1. Digital Radiated Emissions 30 MHz to 1000 MHz. RBW = 120 kHz, VBW>RBW. DUT meets FCC/IC Class B Digital emissions limits by more than 1.6 dB.

6.2 Radiated Emissions – Peak to Average Ratio (FCC 15.245, 15.35)

Figure 6.1. The DUT is designed to operate as a CW source. Thus, Peak-to (Power) Average Ratio is 0.0 dB.

6.3 Radiated Emissions – Fundamental & Harmonics (FCC 15.245)

Figures 6.1 - 6.2., Table 6.1. Fundamental and Harmonic Radiated Emissions. RBW = 1 MHz, VBW ≥ 3xRBW; Pk, (RBW = 100 kHz, VBW > RBW for bandwidth meas.) (Pk > QPk > Avg. where applicable. Limits are average limits.) The emission bandwidth for the DUT is measured to be 430.0 kHz. No emissions were detected at the band edges.

6.4 Radiated Emissions - Spurious (FCC 15.245, 15.209)
Figure 6.3, Table 6.2. Spurious Radiated Emissions. (no emissions observed) RBW=120 kHz (f < 1 GHz), RBW=1 MHz (f > 1 GHz), VBW>RBW; (Pk > QPk > Avg, where applicable. Limits are Average Limits.) Spurious must be 50 dB down from fundamental or at the 15.209 limit (15.245(b)(1)(iii)).

6.5 Conducted Emissions (FCC 15.107)
Table 6.1. To demonstrate modular compliance, a laboratory power supply was used to power the device under test. Conducted emissions were measured using a LISN in the standard set-up.

6.6 Effect of Supply Voltage Variation (FCC 15.31(e))
Figure 6.4. The DUT is designed to operate on 12.6 VDC, originating from a 12 V battery. The relative radiated emissions and frequency were recorded at the fundamental (24.125 GHz) as the supply voltage was varied from 5 to 32 VDC. Current at 12.6 VDC was 150 mA.

6.7 Potential Health Hazard EM Radiation Level
The minimum separation distance calculated following FCC OET Bulletin 65 is calculated as follows, where S is power density,

$$EIRP(dBm) = E_3(dB\mu V/m) - 95.2 \ \ dB(\ mW/(\mu V/m)\ )$$

$$EIRP = 119.4\ (dB\mu V/m) - 95.2 \ \ dB(\ mW/(\mu V/m)\ ) = 24.2\ dBm = 263.0\ mW$$

$$ERP = EIRP - 2.15 = 24.2 - 2.15 = 22.05\ dBm$$
$$= 160.3\ mW = 0.160\ W$$

Thus, the power density at 20 cm becomes $S(mW/cm^2) = EIRP(mW)/(4\pi\ R(cm)^2) = 0.052\ mW/cm^2$

NOTE:
(1) Under no circumstances is the ERP of this device greater than 3W, as required by 2.1091 and the FCC mm-wave accepted test procedures.

6.8 Sample Field Computations
<u>FUNDAMENTAL</u>

Refer to:
(a) Table 6.1 ; p. 7.
(b) Section 6.2; Figure 6.1, peak power measurement; p. 9.
(c) Table 4.1; limit; p. 3; limit 128 dB(μV/m)
(d) Section 6.2; peak-to-(power)average ratio, p. 5; (0.0 dB)

The approach is to follow standard equations for computing field strength, see equations and conversion factors in Section 5.2.3, p. 4 of the report.

To compute the field strength we use:

$$\begin{aligned} E_3\ dB(\mu V/m) &= 107 + Pr + Ka - Kg + Ke \\ &= 107 + -20.8 + 33.2 + 0.0 + 0.0 \\ &= 119.4\ dB(\mu V/m) \end{aligned}$$

The limit is 128 dB(μV/m) .

Table 6.1 Highest Radiated Emissions Measured

Fund. & Harmonics Radiated Emissions — Wanco WRDR-E

#	Freq. GHz	Ant. Used	Ant. D,cm	Meas. dist, m	Pr dBm	N/F m	Pr(3m) dBm	Ka dB/m	Kg dB	E3 dBμV/m	E3lim dBμV/m	Pass* dB	Comments (Notes)
1	24.125	K-horn	10.2	3.00	-20.8	1.67	-20.8	33.2	0.0	119.4	128.0	8.6	(3,4)
2	48.250	U-horn	9.2	0.30	-55.2	2.72	-94.4	39.1	0.0	51.7	88.0	36.2	(2,3,4,5)
3	72.375	W-horn	9.2	0.30	-59.9	4.08	-99.9	41.0	0.0	48.1	88.0	39.9	(1,2,3,4,5)
4	96.500	W-horn	9.2	0.30	-61.0	5.45	-101.0	46.4	0.0	52.4	54.0	**1.6**	(1,2,3,4,5)
5													

NOTES:

(1) When measured at 0.3 m from the DUT, no signal was detected anywhere, even at horn surface
(2) Mixer conversion loss is programmed in the spectrum analyzer and automatically adjusts the readings
(3) When extrapolating to 3 m, use Near (40 dB/dec) and Far Fld (20 dB/dec) behavior
(4) For Ave. measurement a 1 Hz VBW was used, sometimes higher; RBW was always 1 MHz
(5) DUT max. antenna size, D= 9.2 cm
(6) At 24.125 GHz, Peak to Average ratio was measured to be 0.0 dB
* All emissions, except for fundamental meet FCC 15.209 Class B emissions limits (see Table 6.2)

Power Line Conducted Emissions

#	Freq. MHz	Line Side	Peak Det., dBμV Vtest	Vlim*	Pass dB	Comments
1	0.15	Hi	37.8	56.0	18.2	
2	0.82	Hi	27.2	46.0	18.8	
3	1.17	Hi	26.8	46.0	19.2	
4	1.51	Hi	27.8	46.0	18.2	
5	3.68	Hi	30.7	46.0	**15.3**	
6	7.28	Hi	29.8	50.0	20.2	
7	15.00	Hi	25.0	50.0	25.0	
8	29.03	Hi	30.0	50.0	20.0	
9						
10						
11	0.18	Lo	31.3	54.7	23.4	
12	1.03	Lo	27.4	46.0	18.6	
13	1.51	Lo	27.7	46.0	18.3	
14	7.70	Lo	28.0	50.0	22.0	
15	15.23	Lo	26.0	50.0	24.0	
16	21.00	Lo	27.0	50.0	23.0	
17	29.03	Lo	31.9	50.0	18.1	
18	29.40	Lo	31.3	50.0	18.7	
19	29.93	Lo	30.5	50.0	19.5	
20						
21						
22	*Average Limit. Since Vpk ≥ Vqp ≥ Vave and if Vtestpeak < Vavelim, then Vqplim and Vavelim are met.					

Meas. 11/07/2007-1/04/2008; U of Mich.

Table 6.2 Highest Radiated Emissions Measured

RF Spurious Radiated Emissions — Wanco WRDR-E

#	Freq. GHz	Ant. Used	Ant. D,cm	Meas. dist, m	Pr dBm	N/F m	Pr(3m) dBm	Ka dB/m	Kg dB	E3 dBμV/m	E3lim* dBμV/m	Pass dB	Comments (Notes)
1	.03 - 1	Bic	N/A	3.00	-69.9	-	-69.9	10.1	26.2	39.6	46.0	6.4	max all, see below
2	1 to 2	R-Horn	9.2	3.00	-68.2	-	-68.2	21.5	28.1	32.2	54.0	21.8	noise
3	2 to 4.5	R-Horn	9.2	3.00	-78.8	-	-78.8	26.0	25.0	29.2	54.0	24.8	noise
4	4.5 to 8	C-horn	9.2	3.00	-60.0	1.40	-60.0	24.7	37.5	34.2	54.0	19.8	noise
5	6 to 8.6	XN-horn	28.9	3.00	-69.1	3.34	-69.1	25.3	37.0	26.2	54.0	27.8	noise
6	8.6to13	X-horn	19.4	3.00	-68.9	2.16	-68.9	28.5	37.0	29.6	54.0	24.4	noise
7	13to18	Ku-horn	15.2	1.00	-73.9	2.00	-89.5	29.3	17.0	29.9	54.0	24.1	noise
8	18to26	K-horn	10.2	0.30	-62.6	1.25	-95.0	33.2	0.0	45.2	54.0	8.8	noise
9	26to40	Ka-horn	9.2	0.30	-57.9	1.47	-91.7	36.0	0.0	51.3	54.0	2.7	noise
10	40-76	U-horn	9.2	0.30	-59.9	2.26	-99.9	41.0	0.0	48.1	54.0	5.9	noise
11	76-110	W-horn	9.2	0.30	-61.0	4.34	-101.0	46.4	0.0	52.4	54.0	**1.6**	noise
12													
13													
14													

NOTES:
(1) When measured at 0.3 m from the DUT, no signal was detected anywhere, even at the radome
(2) Mixer conversion loss is programmed in the spectrum analyzer and automatically adjusts the readings
(3) When extrapolating to 3 m, use Near (40 dB/dec) and Far Fld (20 dB/dec) behavior
(4) For Ave. measurement a 1 Hz VBW was used, sometimes higher; RBW was always 1 MHz
(5) DUT max. antenna size, D= 9.2 cm
(6) At 24.125 GHz, Peak to Average ratio was measured to be 0.0 dB
* 50 dB down from the Fundamental

Digital Radiated Emissions (Class B)

#	Freq. MHz	Ant. Used	Ant. Pol.	Meas. dist, m	Pr dBm	Det. Used	Pr(3m) dBm	Ka dB/m	Kg dB	E3 dBμV/m	E3lim dBμV/m	Pass dB	Comments
1	119.6	Bic	V	3.00	-80.7	Pk	-80.7	9.9	25.0	11.2	43.5	32.3	
2	200.1	Bic	H	3.00	-65.8	Pk	-65.8	14.7	23.8	32.1	43.5	11.4	
3	200.1	Bic	V	3.00	-70.4	Pk	-70.4	14.7	23.8	27.5	43.5	16.0	
4	220.1	Bic	H	3.00	-74.8	Pk	-74.8	14.8	23.6	23.4	46.0	22.6	
7	220.1	Bic	H	3.00	-77.3	Pk	-77.3	14.8	23.6	20.9	46.0	25.1	
8	240.5	Bic	V	3.00	-73.1	Pk	-73.1	14.6	23.4	25.1	46.0	20.9	
9	240.5	Bic	H	3.00	-74.0	Pk	-74.0	14.6	23.4	24.2	46.0	21.8	
10	300.1	Sbic	V	3.00	-71.5	Pk	-71.5	17.9	22.8	30.6	46.0	15.4	
11	300.1	Sbic	H	3.00	-74.6	Pk	-74.6	17.9	22.8	27.5	46.0	18.5	
12	400.1	Sbic	V	3.00	-75.1	Pk	-75.1	21.1	21.7	31.4	46.0	14.6	
13	500.1	Sbic	H	3.00	-69.9	Pk	-69.9	23.2	20.7	39.6	46.0	**6.4**	
14	900.1	Sbic	H	3.00	-79.3	Pk	-79.3	29.2	17.9	39.1	46.0	6.9	
4													

Meas. 11/07/2007-12/02/2007; U of Mich.

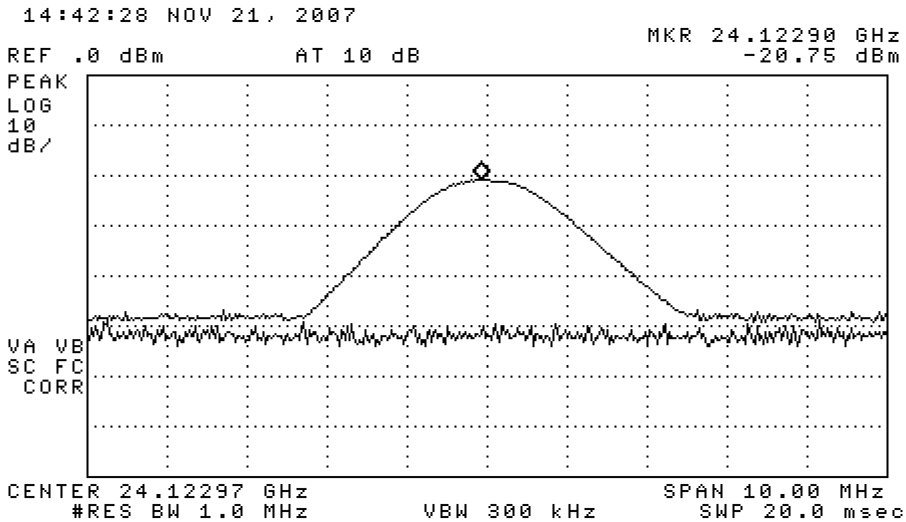


Figure 6.1. Fundamental spectrum. (3 meters, peak hold)

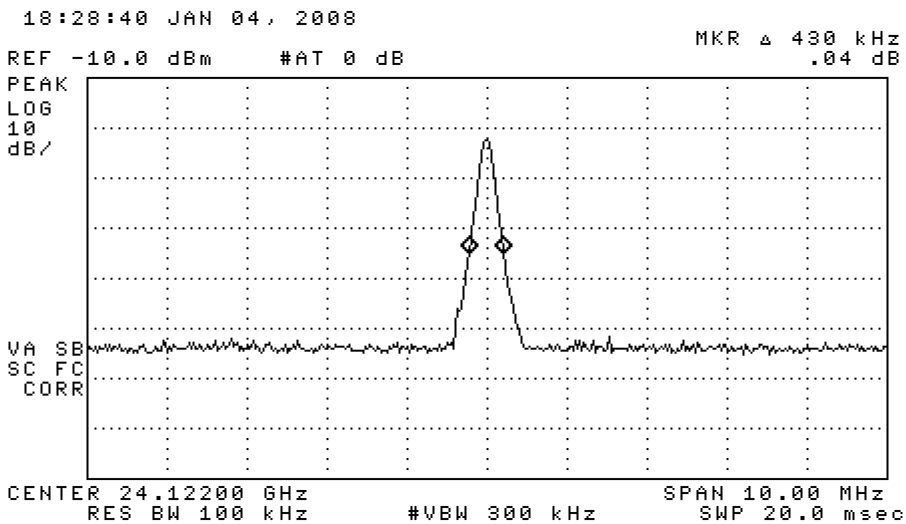
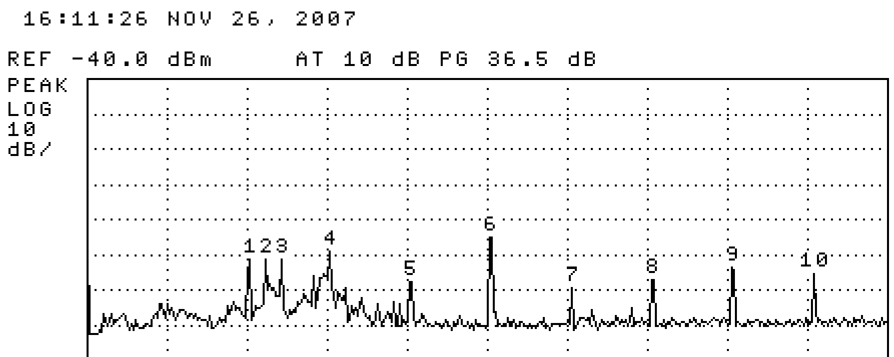
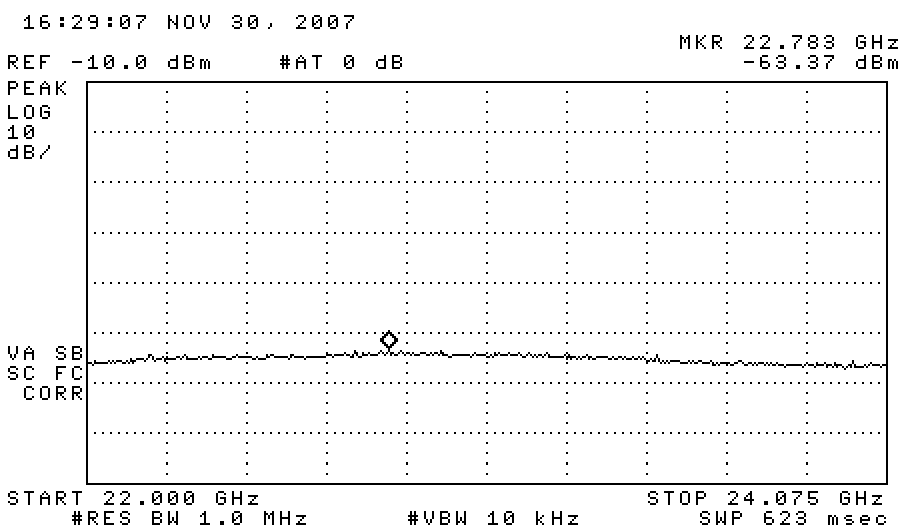


Figure 6.2. Fundamental Bandwidth Measurement.



Pk	Freq (MHz)	Amplitude	Pk	Freq (MHz)	Amplitude
1	203	-91.63 dBm	6	503	-85.04 dBm
2	223	-91.56 dBm	7	605	-99.64 dBm
3	243	-91.25 dBm	8	705	-96.98 dBm
4	303	-89.18 dBm	9	805	-93.50 dBm
5	403	-97.73 dBm	10	908	-95.52 dBm

START 0 Hz STOP 1.000 GHz
#RES BW 120 kHz VBW 300 kHz SWP 208 msec



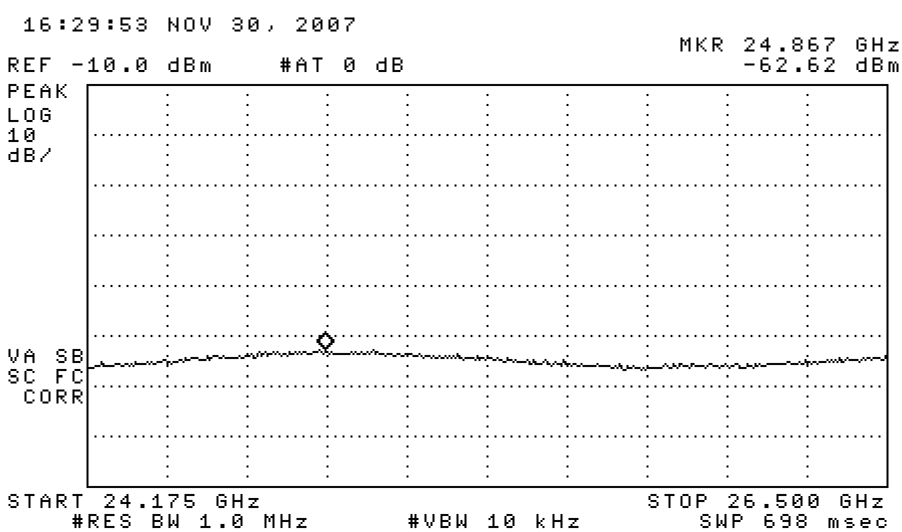


Figure 6.3. Relative Digital/Spurious Emissions. (top) 0-1000 MHz, (middle) 22-24.075 GHz - noise, (bottom) 24.175-26.5 GHz - noise

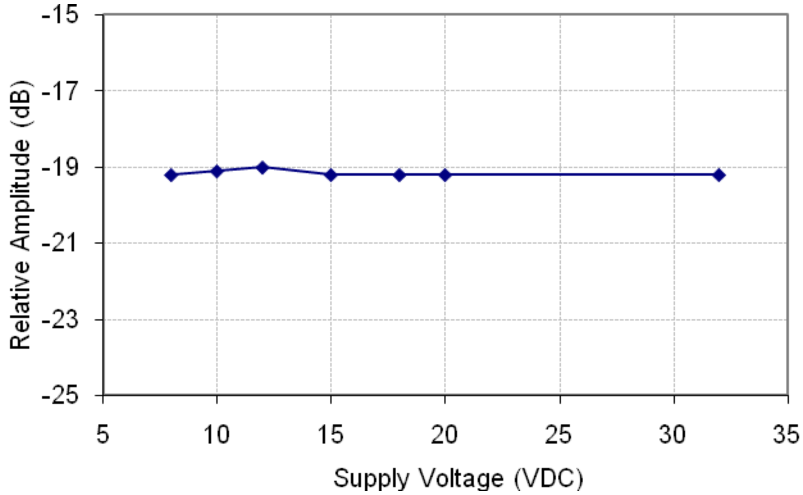
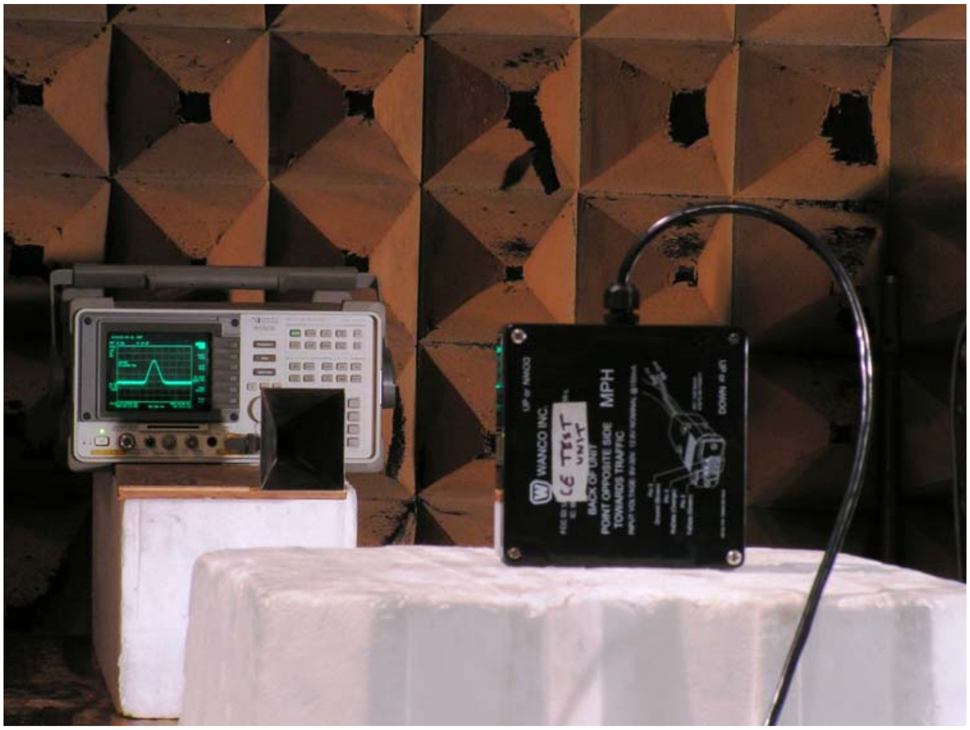


Figure 6.4. Relative emission at fundamental vs. supply voltage.

DUT on OATS



Indoor Measurements

Conducted Emissions Test Setup