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Measured Radio Frequency Emissions
From

Siemens LF Transmitter
Model(s): 5WY7977, 5WY8090

Report No. 415031-345
January 23, 2007

For:
Siemens VDO Automotive
4685 Investment Drive
Troy, MI 48098

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Summary

Tests for compliance with FCC Regulations, Part 15, Subpart C, and for compliance with Industry Canada RSS-210/Gen, were performed on Siemens VDO Automotive transmitter, models 5WY7977 and 5WY8090. This device is subject to Rules and Regulations as a transmitter.

In testing completed January 10, 2007, the device tested in the worst case met the allowed specifications for transmitter radiated emissions by 35.8 dB (see p. 7). Power line conducted emissions tests do not apply, since the device is powered from a 12 VDC vehicular system.

1. Introduction

Siemens model 5WY7977, 5WY8090 was tested for compliance with FCC Regulations, Part 15, adopted under Docket 87-389, April 18, 1989, and with Industry Canada RSS-210/Gen, Issue 6, September 2005. The tests were performed at the University of Michigan Radiation Laboratory Willow Run Test Range following the procedures described in ANSI C63.4-2003 "Methods of Measurement of Radio-Noise Emissions from Low-Voltage Electrical and Electronic Equipment in the Range of 9 kHz to 40 GHz". The Site description and attenuation characteristics of the Open 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 Procedures 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)	X	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		Hewlett-Packard 8657B

3. Device Under Test

3.1 Identification

The DUT is an automotive Passive Start and Entry (PASE) LF transmitter designed to communicate ID information to a customer identification device (CID) and is powered from an automotive 12 VDC source. The 125 kHz carrier is ASK modulated, the frequency generating circuitry is contained in the electronic control unit (ECU) module, and five ferrite loaded coils act as the antennas for the LF signal. The DUT was designed and manufactured by Siemens VDO Automotive, 4685 Investment Drive, Troy, MI 48098. It is identified as:

Siemens VDO Automotive LF Transmitter
Model: 5WY7977, 5WY8090
FCC ID: M3N5WY7977
IC: 267F-5WY7977

3.2 Models

There is only a single model of the device.

3.3 Modes of Operation

The device operates only in a single mode. However, the highest LF emissions occur when the in-dash LF coils are fired simultaneously as the key is placed in the vehicle ignition. All other coils are fired only individually, when a vehicle handle is lifted.

3.4 EMI Relevant Modifications

No EMI Relevant Modifications were performed by this test laboratory.

4. Emission Limits

4.1 Radiated Emission Limits

The DUT tested falls under the category of an Intentional Radiators and the Digital Devices, subject to Subpart C, Section 15.209; and Subpart B, Section 15.109 (transmitter generated signals excluded); and Subpart A, Section 15.33. The applicable testing frequencies with corresponding emission limits are given in Tables 4.1 and 4.2 below. As a digital device, it is exempt.

Table 4.1. Radiated Emission Limits (FCC: 15.205, 15.35; IC: RSS-210, 2.6 Tab. 1 & 3) (Transmitter)

Frequency (MHz)		Fundamental and Spurious* (µV/m)
0.009-0.490		2400/F(kHz), 300m
0.490-1.705		24,000/F(kHz), 30m
0.090-0.110	8.291-8.294	Restricted Bands
0.49-0.51	8.37625 - 8.38675	
2.1735-2.190	8.41425 - 8.41475	
3.020-3.026 (IC)	12.29 - 12.293	
4.125-4.128	12.51975 - 12.52025	
4.17725-4.17775	12.57675 - 12.57725	
4.20725-4.20775	13.36 - 13.41	
5.677-5.683 (IC)	16.42 - 16.423	
6.215-6.218	16.69475 - 16.69525	
6.26775-6.26825	16.80425 - 16.80475	
6.31175-6.31225	25.5 - 25.67	

* Harmonics must be below the fundamental.

For extrapolation to other distances, see Section 6.6.

Table 4.2. Radiated Emission Limits (FCC: 15.33, 15.35, 15.109; 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 Limits

Table 4.3 Conducted Emission Limits (FCC:15.107 (CISPR); IC: RSS-Gen, 7.2.2 Table 2).

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. Radiated Emission Tests and Results

5.1 Semi-Anechoic Chamber Measurements
To become familiar with the radiated emission behavior of the DUT, the DUT was first studied and measured in a shielded semi-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 this case, the receiving antenna was an active loop, placed on a tripod, approximately 1.5 meters above ground.

The DUT was laid on the test table as seen in the included photos. Using the loop antenna we studied emissions up to 30 MHz. The spectrum analyzer resolution and video bandwidths were so as to measure the DUT emission without decreasing the EBW (emission bandwidth) of the device. Emissions were studied for all orientations of the DUT and loop antenna. In the chamber we also recorded the spectrum and modulation characteristics of the carrier. These data are presented in subsequent sections.

5.2 Outdoor Measurements
After the chamber measurements, the emissions on our outdoor 3-meter site were measured. For transmitter emissions a loop antenna was used; the resolution bandwidth maintained at such a level that the EBW (emission bandwidth) of the DUT was not reduced. See the attachment Test Setup Photos for measurement set-up. For digital emissions, bicone and dipole antennas were used. See Section 6.6 for low frequency field extrapolation of transmitter data from 3 m to 300 m.

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

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

where P_R = power recorded on spectrum analyzer, dB, measured at 3 m
K_A = antenna factor, dB/m
K_G = pre-amplifier gain, including cable loss, dB
K_E = pulse operation correction factor, dB (see 6.1)
C_F = 3/300 m or 3/30 m conversion factor, dB

When presenting the data, at each frequency the highest measured emission under all of the possible orientations is given. Computations and results are given in Table 5.1. There we see that as a transmitter, the DUT meets the limit by 35.8 dB.

6. Other Measurements and Computations

6.1 Correction For Pulse Operation
Under normal operation the transmitter will transmit a single dataset, lead by 8 wake-up pulses, each 0.1725 ms in duration, terminated by one 0.450 ms pulse. Next, 54 Manchester encoded pulses are sent, each exhibiting a 0.1725 ms pulse width with 0.2475 ms period. See Figure 6.1. This results in a duty cycle of

$$K_E = (8 \times 0.1725 \text{ ms} + 1 \times 0.450 \text{ ms} + 54 \times 0.1725 \text{ ms}) / 100 \text{ ms} = 0.020 < -20 \text{ dB}$$

6.2 Emission Spectrum
Using the loop antenna, the 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. From the plot we see that the -20 dB bandwidth is 23.2 kHz, and the emission in the 109 kHz restricted band is 28.5 dBc.

6.4 Effect of Supply Voltage Variation
For this test, the relative power radiated was measured at the fundamental as the voltage was varied from 6.0 to 16.0 volts. The DUT stopped operating below 10 VDC. The emission variation is shown in Figure 6.4.

6.5 Input Voltage and Current

V = 12.0 V

I = 320 mA (CW emission)

6.6 Field Behavior of Low Frequency Loop Transmitters

Because at the specified 300/30 m measurement distance the signal-to-noise (SNR) ratio of the test receiver is insufficient, measurements were made at 3 m (or 10 m). To translate the measurement to the 300/30 m distance, we refer to the journal paper: *Extrapolating Near-Field Emissions of Low-Frequency Loop Transmitters,* J.D.Brunett, V.V. Liepa, D.L.Sengupta, IEEE Trans. EMC, Vol. 47, No. 3, August 2005. The applicable worst-case field conversion tables are included here for reference.

Limit Location:	300 (m)		Limit Location:	30 (m)	
Meas. Distance:	3 (m)	10 (m)	Meas. Distance:	3 (m)	10 (m)
Frequency (kHz)	CF (dB)	CF (dB)	Frequency (MHz)	CF (dB)	CF (dB)
9.0	116.7	81.8	0.490	56.4	9.6
10.6	116.7	81.8	0.582	56.2	11.1
12.6	116.7	81.8	0.690	56.0	12.9
14.8	116.7	81.8	0.820	55.7	15.0
17.5	116.6	81.9	0.973	55.4	17.3
20.7	116.6	81.9	1.155	54.9	19.5
24.4	116.6	81.9	1.371	54.4	20.8
28.9	116.6	82.0	1.627	53.7	21.0
34.1	116.5	82.0	1.931	52.9	20.5
40.3	116.4	82.1	2.292	52.0	19.8
47.6	116.3	82.2	2.721	49.8	19.1
56.2	116.2	82.4	3.230	46.6	15.8
66.4	116.0	82.6	3.834	43.3	12.7
78.4	115.8	82.9	4.551	40.1	10.3
92.7	115.4	83.1	5.402	36.8	9.0
109.4	115.0	83.4	6.412	33.5	8.5
129.3	114.5	83.3	7.612	30.3	8.5
152.7	113.9	82.6	9.035	27.0	8.6
180.4	113.1	81.0	10.725	23.9	8.8
213.1	112.2	78.7	12.730	21.2	9.0
251.7	111.3	76.0	15.111	19.3	9.1
297.3	108.3	73.3	17.937	18.4	9.2
351.2	105.2	70.8	21.292	18.2	9.3
414.8	102.1	68.4	25.274	18.3	9.3
490.0	99.1	66.3	30.000	18.4	9.4

In the data table, Table 5.1, the measured field is decreased by the dB values given above to represent the field at 300m or 30m, whichever is applicable.

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Table 5.1 Highest Emissions Measured

Radiated Emission - LF												Siemens PASE; FCC/IC
#	Freq. kHz	Ant. Used	Ant. Orien.	Pr, 3m dBm	Det. Used	Ka dB/m	Kg dB	Conv.** 3/30/300 m	E* dBµV/m	Elim dBµV/m	Pass dB	Comments
1	125.0	Loop	V/perp	-26.1	Pk	9.9	0.0	114.8	-24.0	25.7	49.7	loop perp. (axis in dir. of prop.)
2	125.0	Loop	V/par	-27.2	Pk	9.9	0.0	114.8	-25.1	25.7	50.8	loop paral. (loop in dir. of prop.)
3	125.0	Loop	H	-28.4	Pk	9.9	0.0	114.8	-26.3	25.7	52.0	loop horiz. (loop in horiz. plane)
4	250.0	Loop	V/perp	-62.4	Pk	9.8	0.0	110.4	-56.0	19.6	75.6	noise
5	250.0	Loop	V/par	-59.9	Pk	9.8	0.0	110.4	-53.5	19.6	73.1	noise
6	250.0	Loop	H	-62.4	Pk	9.8	0.0	110.4	-56.0	19.6	75.6	noise
7	375.0	Loop	V/perp	-65.8	Pk	9.8	0.0	104.5	-53.5	16.1	69.6	noise
8	375.0	Loop	V/par	-64.2	Pk	9.8	0.0	104.5	-51.9	16.1	68.0	noise
9	375.0	Loop	H	-65.6	Pk	9.8	0.0	104.5	-53.3	16.1	69.4	noise
10	500.0	Loop	V/perp	-67.8	Pk	9.8	0.0	56.3	- 7.3	33.6	40.9	noise
11	500.0	Loop	V/par	-66.2	Pk	9.8	0.0	56.3	- 5.7	33.6	39.3	noise
12	500.0	Loop	H	-68.2	Pk	9.8	0.0	56.3	- 7.7	33.6	41.3	noise
13	625.0	Loop	V/perp	-71.3	Pk	9.8	0.0	56.1	-10.6	31.7	42.3	noise
14	625.0	Loop	V/par	-69.7	Pk	9.8	0.0	56.1	- 9.0	31.7	40.7	noise
15	625.0	Loop	H	-70.1	Pk	9.8	0.0	56.1	- 9.4	31.7	41.1	noise
16	750.0	Loop	All	-66.6	Pk	9.8	0.0	55.9	- 5.7	30.1	35.8	background
17	875.0	Loop	All	-73.4	Pk	9.8	0.0	55.6	-12.2	28.8	41.0	noise
18	1000.0	Loop	All	-75.6	Pk	9.8	0.0	55.4	-14.2	27.6	**41.8**	noise
19	1125.0	Loop	All	-73.4	Pk	9.8	0.0	55.1	-11.7	26.6	38.3	noise
20	1250.0	Loop	All	-77.3	Pk	9.8	0.0	54.8	-15.3	25.7	40.9	noise
21												
22	* Averaging applies up to 490 kHz, 0.0 dB in this case											
23	Limit at 300m for f<0.490MHz; 30m for f>0.490MHz											
24	Measurements made at 3 m, see Test Report Sec. 6.6 for extrapolation information											
25	9 kHz RBW for f > 150 kHz.											
26	** Represents the worst case conversion factor for all possible orientations and ground mate											
27												
28												

Digital Radiated Emissions*												
#	Freq. kHz	Ant. Used	Ant. Pol.	Pr dBm	Det. Used	Ka dB/m	Kg dB		E3 dBµV/m	E3lim dBµV/m	Pass dB	Comments
1												
2												
3												
4												
5												
6												
7												
8												
9	* For devices used in transportation vehicles, digital emissions are exempt from FCC regulations per FCC 15.103(a)											

Meas. 01/10/2007; U of Mich.

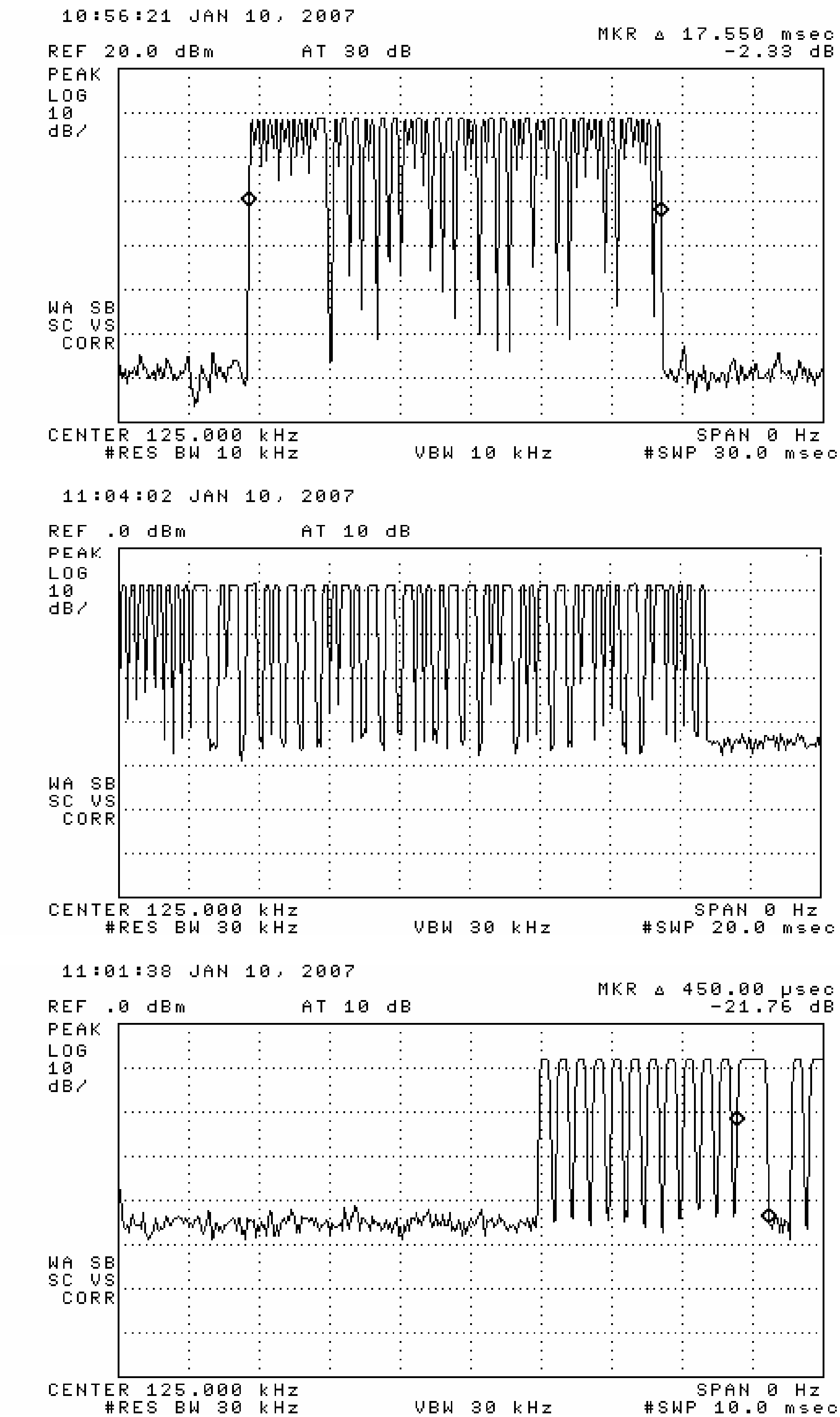
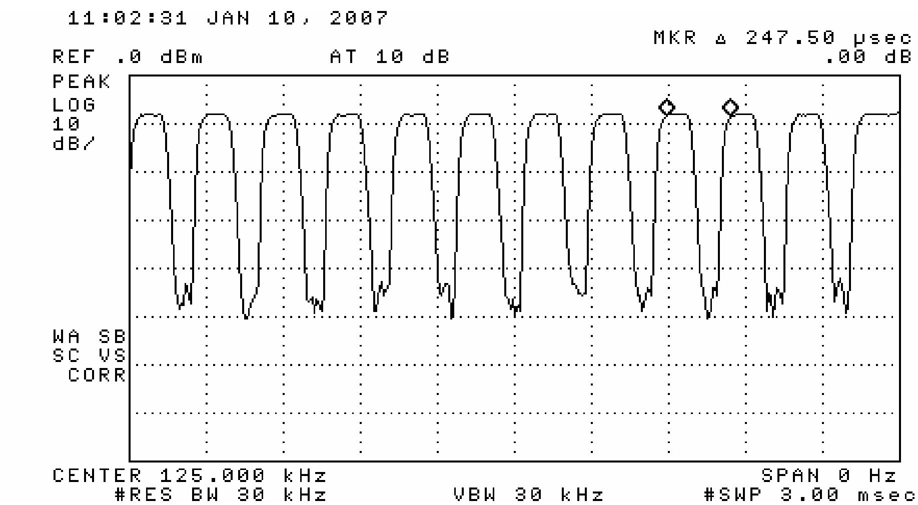


Figure 6.1(a). Transmission modulation characteristics. (top) Complete transmission, (middle) Complete transmission, (bottom) Wake-up pulses



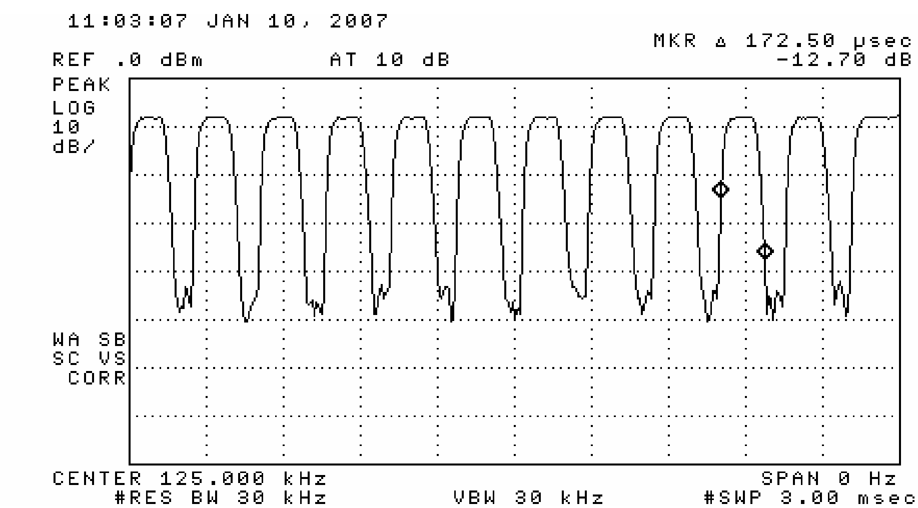


Figure 6.1(b). Transmission modulation characteristics. (top) pulse period, (bottom) pulse width.

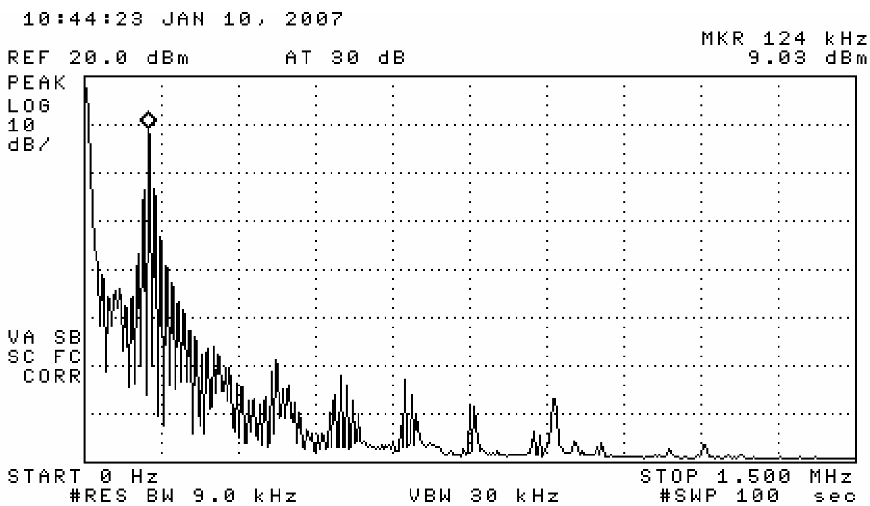


Figure 6.2. Emission spectrum of the DUT. The amplitudes are only indicative (not calibrated).

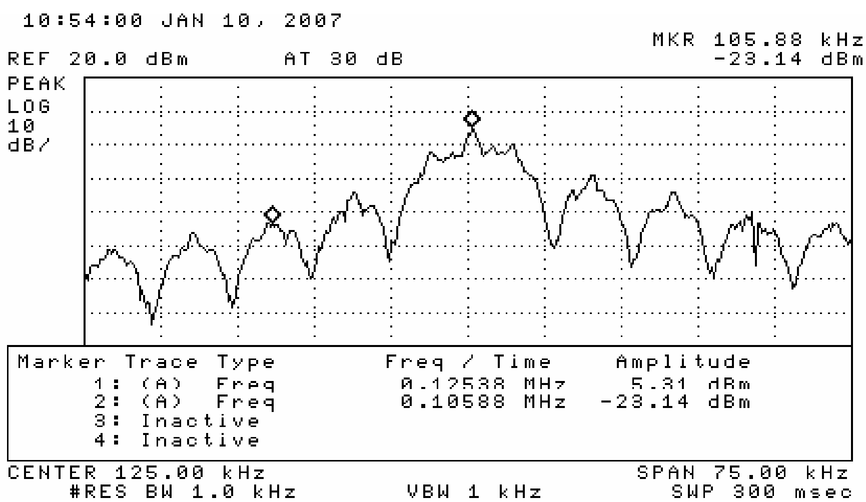


Figure 6.3.Measured bandwidth of the DUT. (pulsed)

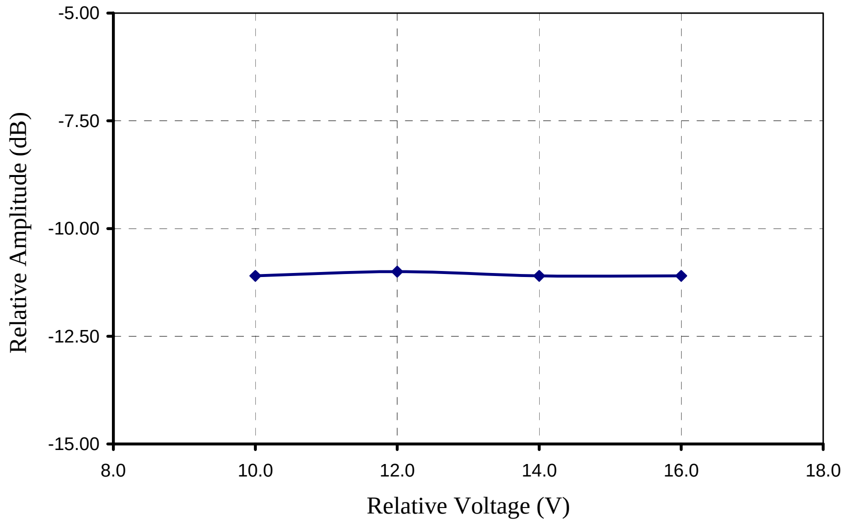
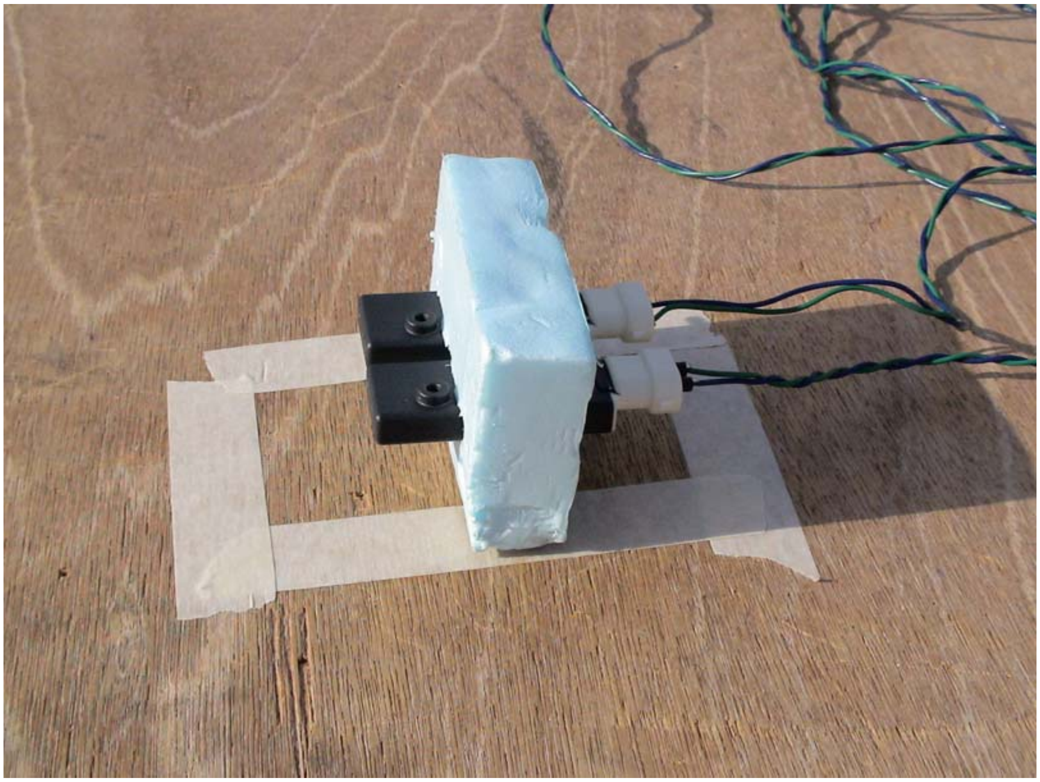


Figure 6.4. Relative emission at 135 kHz vs. supply voltage.

DUT on OATS



DUT on OATS (close-up)