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Measured Radio Frequency Emissions
From

Siemens Transmitter
Models: 5WY7385, 5WY7389

Report No. 415031-202
April 6, 2004

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, were performed on Siemens VDO Automotive transmitter, model 5WY7385, 5WY7389. This device is subject to Rules and Regulations as a transmitter.

In testing completed November 14, 2003, the device tested in the worst case met the allowed specifications for transmitter radiated emissions by 21.1 dB (see p. 7); digital emissions, Class B, were met by at least 20 dB. The conducted emissions tests do not apply, since the device is powered from a 12 VDC system.

1. Introduction

Siemens model 5WY7385, 5WY7389 was tested for compliance with FCC Regulations, Part 15, adopted under Docket 87-389, April 18, 1989, and with Industry Canada RSS-210, Issue 5, November, 2001. 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 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. Configurations and Identification of Device Under Test

The DUT is a 1.125 MHz LF transmitter designed for an onboard automobile Tire Pressure Monitoring System (TPMS), and as such, it is powered from an automotive 12 VDC source. It is housed in a plastic case approximately 4 by 2 by 1 inches. Coil is internal. For testing, a generic harness was provided by the manufacturer. The DUT is designed to operate at 125 kHz.

The DUT was designed and manufactured by Siemens VDO Automotive,4685 Investment Drive,Troy, MI 48098. It is identified as:

Siemens VDO Automotive Transmitter
Model: 5WY7385, 5WY7389
FCC ID: M3N65982701
CANADA: 267F-65982701

Two models of the device were provided. The 5WY7385 (Auto Locate) model contains additional digital i/o for communicating actuator control signals to other devices. Both models included in this filing are identical with regards to their RF/LF sections. The RKE 315 MHz receiver portion of this device has a separate DoC.

3.1 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 (6.2.2(r), 6.3)).
(Transmitter)

Frequency (MHz)	Fundamental and Spurious* (µV/m)
0.009-0.490 0.490-1.705	2400/F(kHz), 300m 24,000/F(kHz), 30m
0.090-0.110 0.49-0.51	Restricted Bands

* 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, 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

Table 4.3 Conducted Emission Limits (FCC:15.107 (CISPR); 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. Radiated Emission Tests and Results

5.1 Anechoic Chamber Measurements

To become familiar 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 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 Attachment-Test Setup Photos. Using the loop antenna we studied emissions up to 2 MHz. The spectrum analyzer resolution and video bandwidths were usually set to 1 kHz, and sometimes to 300 Hz. Emissions were studied with the plane of the loop perpendicular and parallel to the direction of propagation from the DUT. 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 was usually 1 kHz. See Appendix for measurement set-up. For digital emissions bicone and dipole antennas were used. See Section 6.6 for 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 21.1 dB. Digital emissions, Class B, were met by 20 dB.

6. Other Measurements and Computations

6.1 Correction For Pulse Operation

Under normal operation, this transmitter transmits a 53.5 ms pulse every 63.25 ms. Thus, in a 100 ms window there is a minimum transmission gap of 9.75 ms. See Figure 6.1. Thus the averaging factor is

$$K_E = (100 \text{ ms} – 9.75 \text{ ms}) / 100 \text{ ms} = 0.902 \text{ or } -0.9 \text{ dB}$$

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 1.393 kHz, at 110 kHz, the emission is down 41.2 dB from the carrier.

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 5.9 to 18 volts. The emission variation is shown in Figure 6.4.

6.5 Input Voltage and Current

V = 12.3 V

I = 100 mA (with test box)

6.6 Field Behavior at 125 kHz

Because at the specified 300/30 m measurement distance the signal is too small to measure, measurements were made at 3 m. To translate the measurement from 3 m to the 300/30 m distance, we computed the field behavior for a Hertzian (small loop) dipole using equations found in most antenna books, such as, Balanis Antenna Theory Analysis and Design, 1997 John Wiley & Sons, 2nd Edition, pg. 207-208. The applicable results that we need are:

Freq (kHz)	H-component	Extrapolated Position	Correction (dB)	Notes
125	Vertical – Radial	3m/300m	117.9 dB	Axial coupling
125	Vertical –Transverse	3m/300m	121.2 dB	Planar coupling
125	Horizontal –Transverse	3m/300m	121.2 dB	Planar coupling
250	Vertical – Radial	3m/300m	114.6 dB	Axial coupling
250	Vertical –Transverse	3m/300m	113.4 dB	Planar coupling
250	Horizontal –Transverse	3m/300m	113.4 dB	Planar coupling
375	Vertical – Radial	3m/300m	111.8 dB	Axial coupling
375	Vertical –Transverse	3m/300m	105.8 dB	Planar coupling
375	Horizontal –Transverse	3m/300m	105.8 dB	Planar coupling
500	Vertical – Radial	3m/30m	59.6 dB	Axial coupling
500	Vertical –Transverse	3m/30m	60.4 dB	Planar coupling
500	Horizontal –Transverse	3m/30m	60.4 dB	Planar coupling
625	Vertical – Radial	3m/30m	59.4 dB	Axial coupling
625	Vertical –Transverse	3m/30m	60.6 dB	Planar coupling
625	Horizontal –Transverse	3m/30m	60.6 dB	Planar coupling
750	Vertical – Radial	3m/30m	59.1 dB	Axial coupling
750	Vertical –Transverse	3m/30m	60.8 dB	Planar coupling
750	Horizontal –Transverse	3m/30m	60.8 dB	Planar coupling
875	Vertical – Radial	3m/30m	58.9 dB	Axial coupling
875	Vertical –Transverse	3m/30m	61.0 dB	Planar coupling
875	Horizontal –Transverse	3m/30m	61.0 dB	Planar coupling
1000	Vertical – Radial	3m/30m	58.6 dB	Axial coupling
1000	Vertical –Transverse	3m/30m	61.2 dB	Planar coupling
1000	Horizontal –Transverse	3m/30m	61.2 dB	Planar coupling
1125	Vertical – Radial	3m/30m	58.3 dB	Axial coupling
1125	Vertical –Transverse	3m/30m	61.2 dB	Planar coupling
1125	Horizontal –Transverse	3m/30m	61.2 dB	Planar coupling
1250	Vertical – Radial	3m/30m	57.9 dB	Axial coupling
1250	Vertical –Transverse	3m/30m	61.1 dB	Planar coupling
1250	Horizontal –Transverse	3m/30m	61.1 dB	Planar coupling

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, which ever is applicable.

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Table 5.1 Highest Emissions Measured

Transmitter Radiated Emissions												Siemens KJ WCM Imm.; 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	-30.0	Pk	9.9	0.0	117.9	-31.9	25.7	57.6	loop perp. (axis in dir. of prop.)
2	125.0	Loop	V/par	-35.8	Pk	9.9	0.0	121.2	-41.0	25.7	66.7	loop paral. (loop in dir. of prop.)
3	125.0	Loop	H	-36.7	Pk	9.9	0.0	121.2	-41.9	25.7	67.6	loop horiz. (loop in horiz. plane)
4	250.0	Loop	V/perp	-66.1	Pk	9.8	0.0	114.6	-64.8	19.6	84.4	loop perp. (axis in dir. of prop.)
5	250.0	Loop	V/par	-65.9	Pk	9.8	0.0	113.4	-63.4	19.6	83.0	loop paral. (loop in dir. of prop.)
6	250.0	Loop	H	-66.4	Pk	9.8	0.0	113.4	-63.9	19.6	83.5	loop horiz. (loop in horiz. plane)
7	375.0	Loop	V/perp	-61.5	Pk	9.8	0.0	111.8	-57.4	16.1	73.5	loop perp. (axis in dir. of prop.)
8	375.0	Loop	V/par	-65.5	Pk	9.8	0.0	105.8	-55.4	16.1	71.5	loop paral. (loop in dir. of prop.)
9	375.0	Loop	H	-65.9	Pk	9.8	0.0	105.8	-55.8	16.1	71.9	loop horiz. (loop in horiz. plane)
10	500.0	Loop	V/perp	-70.8	Pk	9.8	0.0	59.6	-13.6	33.6	47.2	noise, background rf
11	500.0	Loop	V/par	-72.5	Pk	9.8	0.0	60.4	-16.1	33.6	49.7	noise, background rf
12	500.0	Loop	H	-70.9	Pk	9.8	0.0	60.4	-14.5	33.6	48.1	noise, background rf
13	625.0	Loop	V/perp	-64.7	Pk	9.8	0.0	59.4	- 7.3	31.7	39.0	noise, background rf
14	625.0	Loop	V/par	-62.0	Pk	9.8	0.0	60.6	- 5.8	31.7	37.5	noise, background rf
15	625.0	Loop	H	-64.9	Pk	9.8	0.0	60.6	- 8.7	31.7	40.4	noise, background rf
16	750.0	Loop	All	-57.5	Pk	9.8	0.0	59.1	0.2	30.1	29.9	noise, background rf
17	875.0	Loop	All	-68.2	Pk	9.8	0.0	58.9	-10.3	28.8	39.1	noise, background rf
18	1000.0	Loop	All	-57.9	Pk	9.8	0.0	58.6	0.3	27.6	27.3	noise, background rf
19	1125.0	Loop	All	-53.0	Pk	9.8	0.0	58.3	5.5	26.6	**21.1**	noise, background rf
20	1250.0	Loop	All	-68.2	Pk	9.8	0.0	57.9	- 9.3	25.7	35.0	noise, background rf
21												
22	* Averaging applies up to 490 kHz, -10.15 dB in this case											
23	Limit at 300m for f<0.490MHz; 30m for f>0.490MHz											
24	Measurements made at 3 m, see Sec. 6.6 for extrapolation information											
25	Usually, 9 kHz RBW is used, sometimes lower to reduce ambient and instrument											
26												

Digital Radiated Emissions, Class B												
#	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												
2	Digital emission were > 20 dB below the Class B limit											
3												
4												
5												
6												
7												
8												
9												
10												
11												

Meas. 11/10/2003; U of Mich.

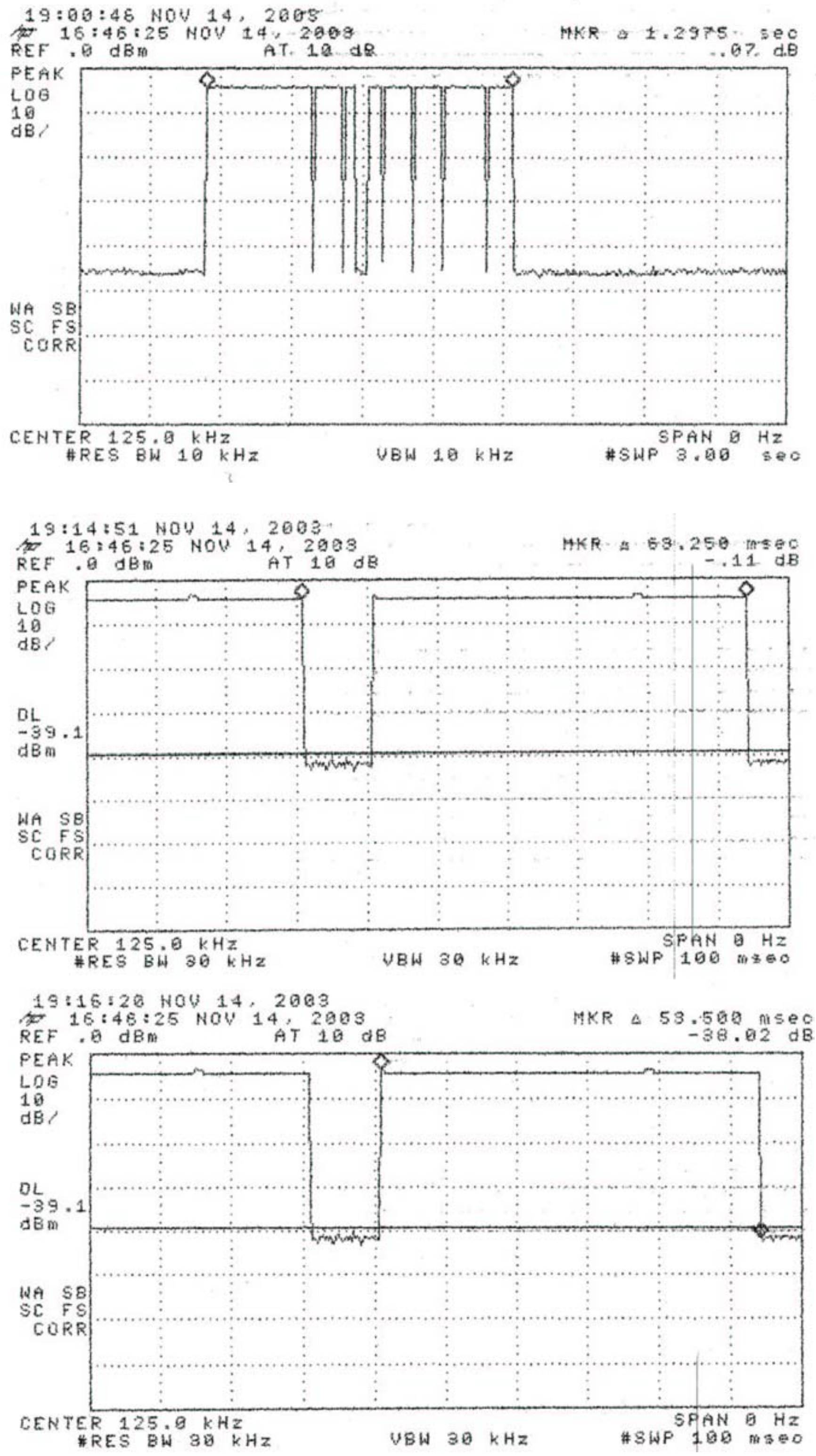

Figure 6.1. Transmission modulation characteristics.

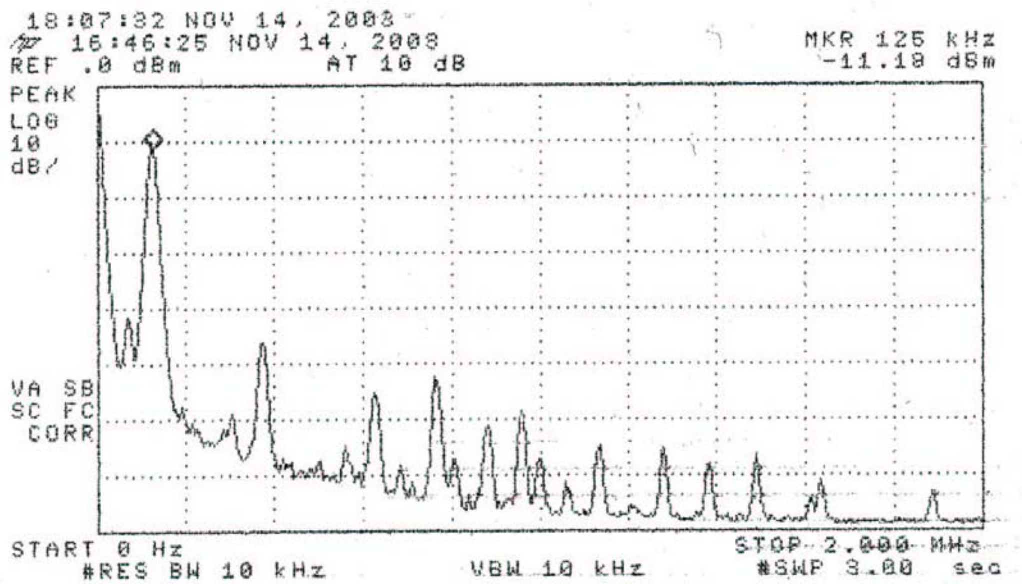

Figure 6.2. Emission spectrum of the DUT. The amplitudes are only indicative (not calibrated).

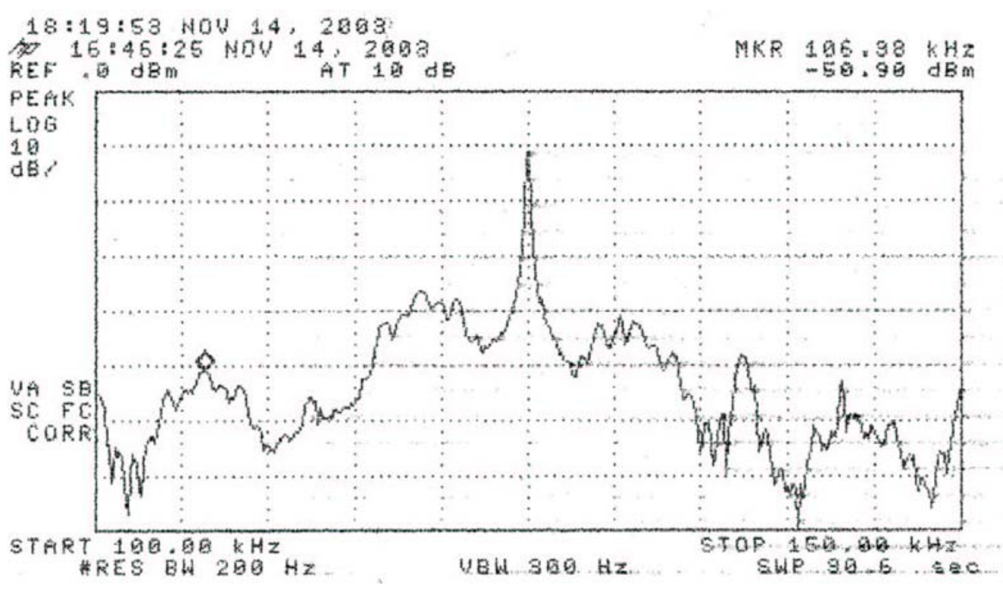

Figure 6.3.Measured bandwidth of the DUT. (pulsed)

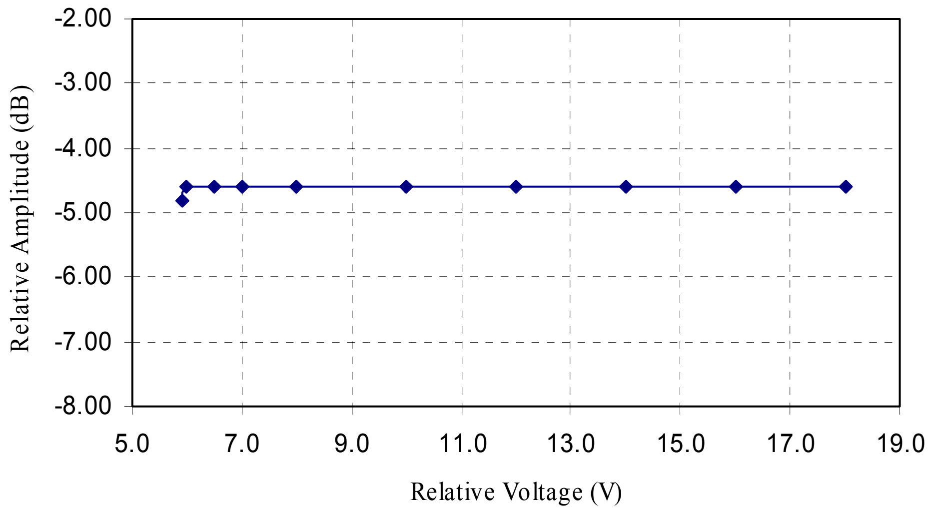

Figure 6.4. Relative emission at 135 kHz vs. supply voltage.