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

Measured Radio Frequency Emissions
From

Bartec USA
125 kHz Transmitter Report
Model(s): TECH 300

Report No. 415031-333a
September 16, 2006

For:
Bartec USA LLC
44231 Phoenix Drive
Sterling Heights, MI 48314

Contact:
Scot Holloway
Tel: 586-685-1300
Fax: 586-323-3801

Measurements made by: Joseph D. Brunett

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/Gen, were performed on Bartec transmitter, model TECH 300. This device is subject to Rules and Regulations as both an LF transmitter and a 315/433.92 MHz receiver. This test report detailsonly the worst transmitter radiated emissions, see the Receiver Test Report for digital emissions compliance.

In testing completed September 16, 2006, the DUT met the FCC/IC radiated emissions limits by 35.5 dB (see p. 7). Conducted emissions tests do not apply, since the device is powered from a 9 VDC system.

1. Introduction

Bartec USA LLC model TECH 300 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 a device containing a 315 MHz receiver, a 433 MHz receiver, and a 125 kHz transmitter. This report details the emissions relating to the 125 kHz transmitter portion of the device. The DUT is designed for actuating automobile Tire Pressure Monitoring (TPM) Sensors and is powered from a 9 VDC source. It is housed in a plastic case approximately 2.5 by 6 by 1.25 inches. Coils are internal. The device contains a microprocessor timed by a 4 MHz crystal oscillator. The DUT was designed and manufactured by Bartec, 44231 Phoenix Drive, Sterling Heights, MI 48314. It is identified as:

Bartec LF Transmitter
Model: TECH300
FCC ID: SX8- DBL3
IC: 5736A- DBL3

3.2 Models

There is only one model of the device.

3.3 Modes of Operation

Six LF modulations can be selected by the user on this device. All six modes were tested, and the worst case emissions are reported herein. The CW mode was determined to have the highest fundamental and harmonic emissions, and is fully reported. The fundamental emissions for the other 5 modes are also provided.

3.4 EMI Relevant Modifications

During testing for spurious emissions, it was determined that a ferrite bead (FerriShield SS2034 from kit no. EK28B0032) had to be applied to the end of the USB cable near the DUT in order to meet the FCC Class A digital emissions requirements (see Receiver Test Report).

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.

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 0.490-1.705	2400/F(kHz), 300m 24,000/F(kHz), 30m

0.090-0.110 0.49-0.51 2.1735-2.190 3.020-3.026 (IC) 4.125-4.128 4.17725-4.17775 4.20725-4.20775 5.677-5.683 (IC) 6.215-6.218 6.26775-6.26825 6.31175-6.31225	8.291-8.294 8.37625 - 8.38675 8.41425 - 8.41475 12.29 - 12.293 12.51975 - 12.52025 12.57675 - 12.57725 13.36 - 13.41 16.42 - 16.423 16.69475 - 16.69525 16.80425 - 16.80475 25.5 - 25.67	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, 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 35.5 dB. Digital Emissions are reported in the associated Receiver Test Report.

6. Other Measurements and Computations

6.1 Correction For Pulse Operation

For the fundamental and spurious emissions data reported in this report, a 0.0 dB correction has been applied. While pulse correction is applicable (up to 490 kHz), it was determined that the emissions under CW were the worst case. A full list of modes of operation has been provided as part of the Description of Operation Exhibit. Figure 6.1 illustrates the CW mode and one other mode.

6.2 Emission Spectrum

Using the loop antenna, the emission spectrum was recorded and is shown in Figure 6.2. This plot includes data from all 6 modes of operation.

6.3 Bandwidth of the Emission Spectrum

All six modes of operation were tested, and the worst case bandwidth is reported here. The measured spectrum of the worst case signal (Mode 6) is shown in Figure 6.3. From the plot we see that the -20 dB bandwidth is 27.1 kHz. The first null of the frequency domain sinc function generated by the maximum LF modulation rate appears at 120 kHz, indicating that the emissions in the 110 kHz restricted band are unintentional emissions (not subject to the 26 dBc requirement).

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 6.9 to 11.0 volts. The emission variation is shown in Figure 6.4.

6.5 Input Voltage and Current

Vstart = 9.6 V

Vstop = 8.9 V

I = 141 mA (Mode 1 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.

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

Table 5.1 Highest Emissions Measured

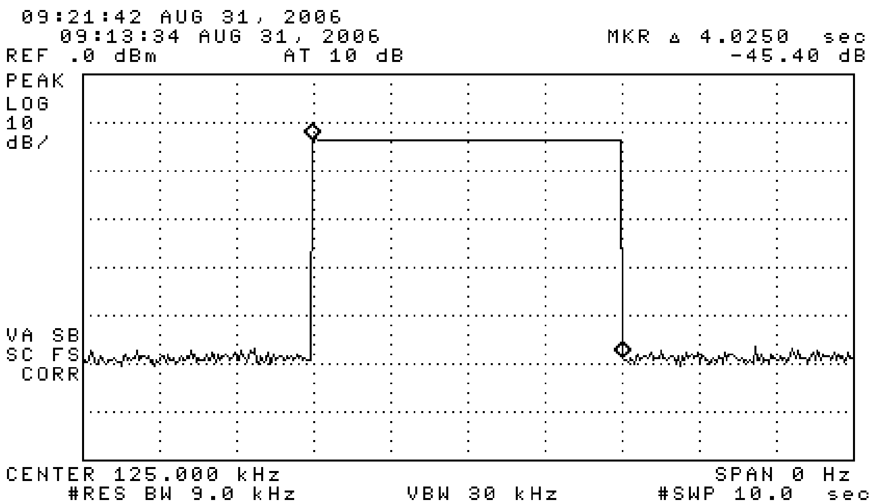
Radiated Emission - LF Bartec W300; FCC/IC

#	Tx. Mod	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	1	125.0	Loop	V/perp	-32.9	Pk	9.9	0.0	114.8	-30.8	25.7	56.5	loop perp. (axis in dir. of prop.)
2		125.0	Loop	V/par	-40.8	Pk	9.9	0.0	114.8	-38.7	25.7	64.4	loop paral. (loop in dir. of prop.)
3		125.0	Loop	H	-38.7	Pk	9.9	0.0	114.8	-36.6	25.7	62.3	loop horiz. (loop in horiz. plane)
4		250.0	Loop	V/perp	-61.2	Pk	9.8	0.0	110.4	-54.8	19.6	74.4	loop perp. (axis in dir. of prop.)
5		250.0	Loop	V/par	-67.7	Pk	9.8	0.0	110.4	-61.3	19.6	80.9	loop paral. (loop in dir. of prop.)
6		250.0	Loop	H	-64.0	Pk	9.8	0.0	110.4	-57.6	19.6	77.2	loop horiz. (loop in horiz. plane)
7		375.0	Loop	V/perp	-62.8	Pk	9.8	0.0	104.5	-50.5	16.1	66.6	max all
8		500.0	Loop	V/perp	-79.9	Pk	9.8	0.0	56.3	-19.4	33.6	53.0	noise
9		625.0	Loop	V/perp	-78.0	Pk	9.8	0.0	56.1	-17.3	31.7	49.0	background
10		750.0	Loop	All	-69.4	Pk	9.8	0.0	55.9	- 8.5	30.1	38.6	background
11		875.0	Loop	All	-76.9	Pk	9.8	0.0	55.6	-15.7	28.8	44.5	max all
12		1000.0	Loop	All	-83.1	Pk	9.8	0.0	55.4	-21.7	27.6	49.3	background
13		1125.0	Loop	All	-70.6	Pk	9.8	0.0	55.1	- 8.9	26.6	**35.5**	background
14		1250.0	Loop	All	-80.0	Pk	9.8	0.0	54.8	-18.0	25.7	43.6	background
15													
16	2	125.0	Loop	V/perp	-34.2	Pk	9.9	0.0	114.8	-32.1	25.7	57.8	max all
17	3	125.0	Loop	V/perp	-44.7	Pk	9.9	0.0	114.8	-42.6	25.7	68.3	max all
18	4	125.0	Loop	V/perp	-47.0	Pk	9.9	0.0	114.8	-44.9	25.7	70.6	max all
19	5	125.0	Loop	V/perp	-46.9	Pk	9.9	0.0	114.8	-44.8	25.7	70.5	max all
20	6	125.0	Loop	V/perp	-46.8	Pk	9.9	0.0	114.8	-44.7	25.7	70.4	max all
20													
20													
20													
16	* Averaging applies up to 490 kHz, 0.0 dB in this case, no duty applied in other modes for simplic												
17	Limit at 300m for f<0.490MHz; 30m for f>0.490MHz												
18	Measurements made at 3 m, see Test Report Sec. 6.6 for extrapolation information												
19	9 kHz RBW for f > 150 kHz.												
20	** Represents the worst case conversion factor for all possible orientations and ground materials.												
6													

Spurious 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
10													
11													
12													
13	See Reciever Test Report												
14													
15													
16													
17													

Meas. 09/13/2006; U of Mich.



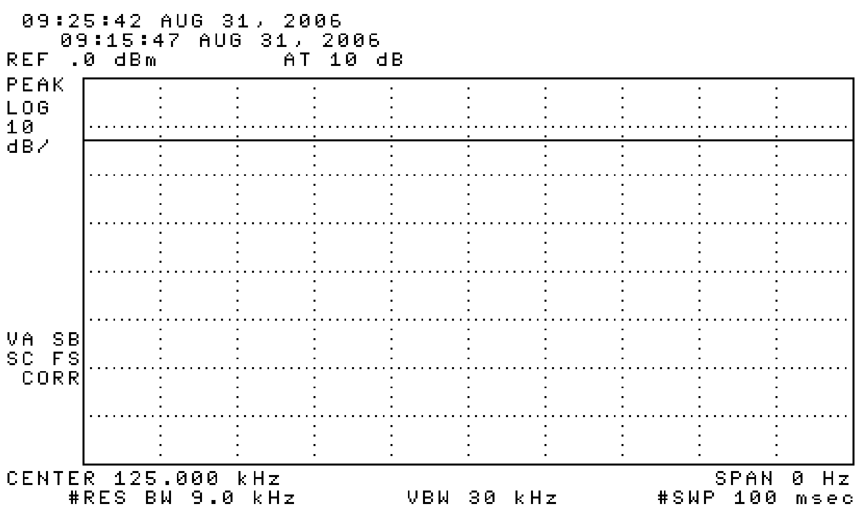


Figure 6.1(a). Transmission modulation characteristics; (top) CW emission, (bottom) CW duty

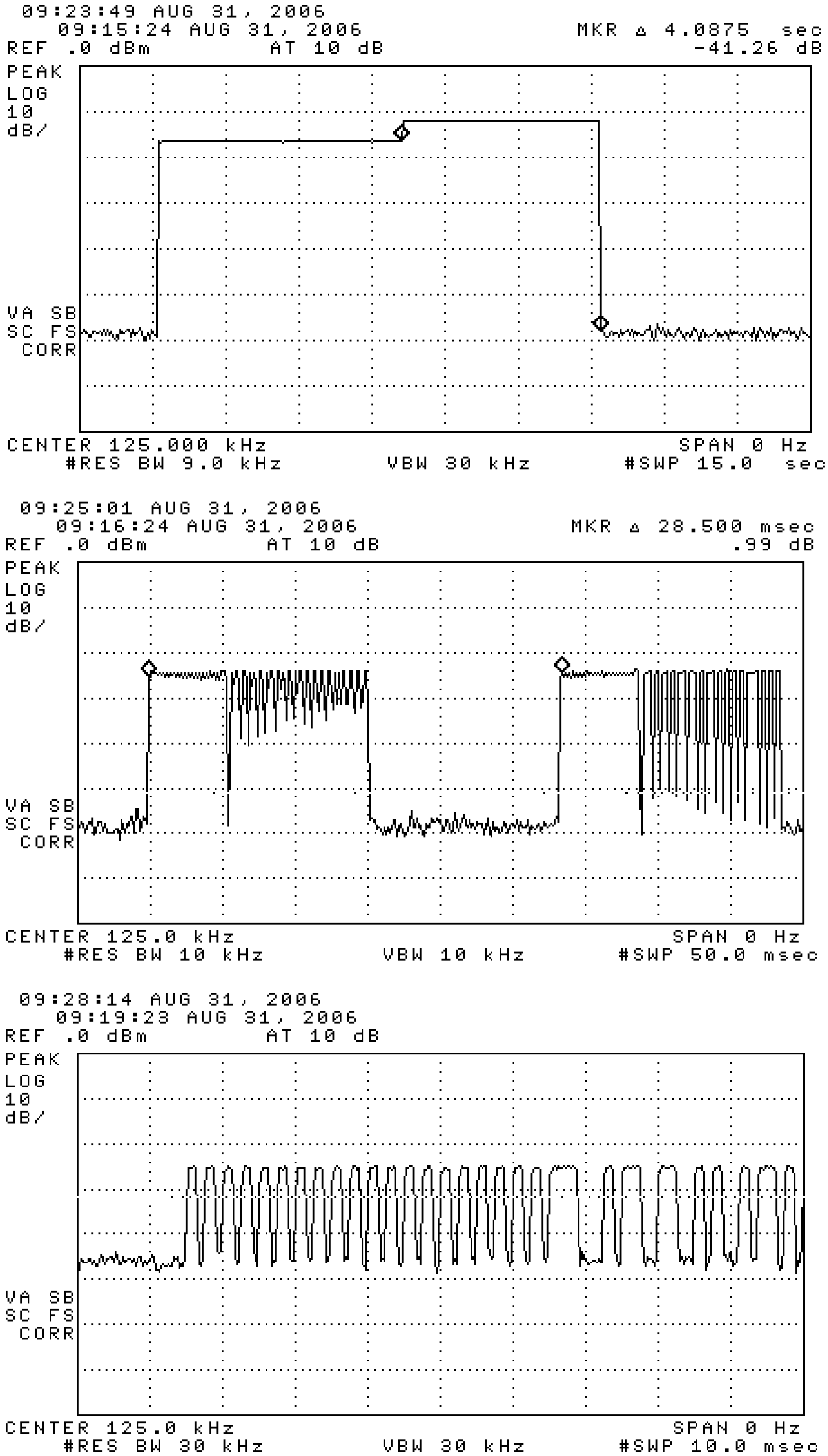


Figure 6.1(b). Transmission modulation characteristics. (top) Low power – pulsed High power – CW, (middle) Pulsed period, (bottom) pulse pattern.

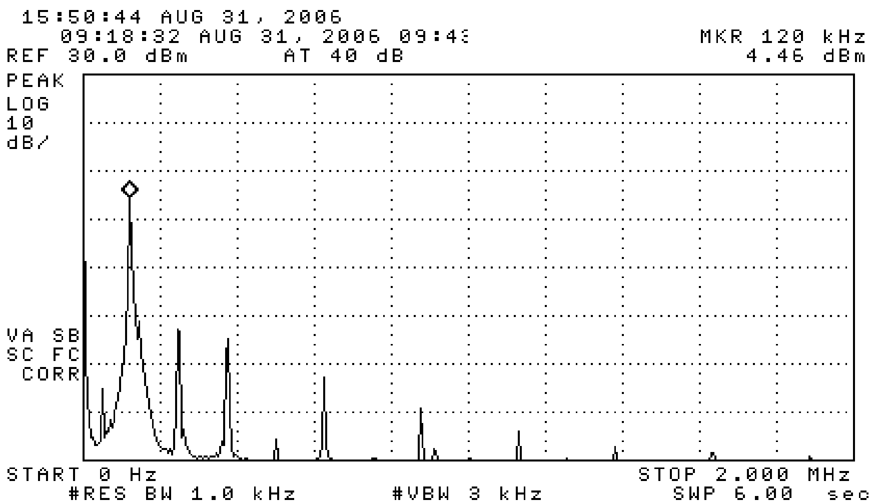


Figure 6.2. Emission spectrum of the DUT. The amplitudes are only indicative (not calibrated).

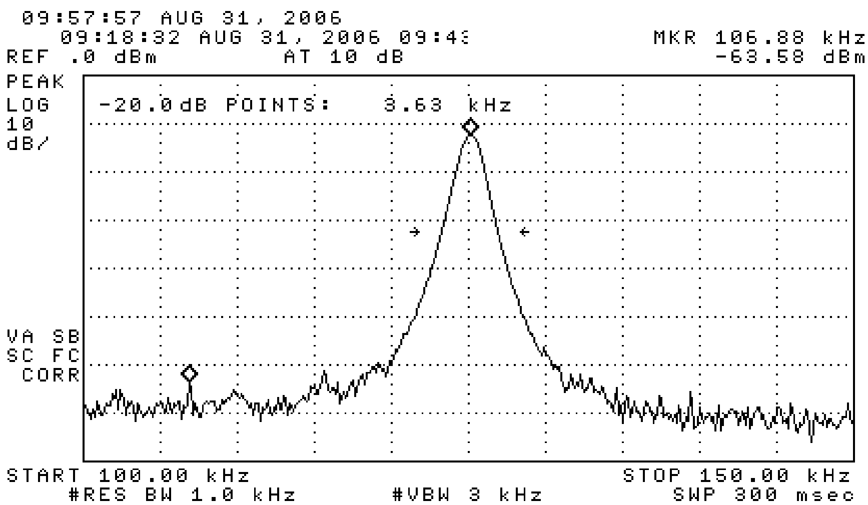


Figure 6.3a. Measured bandwidth of the DUT. CW modulation

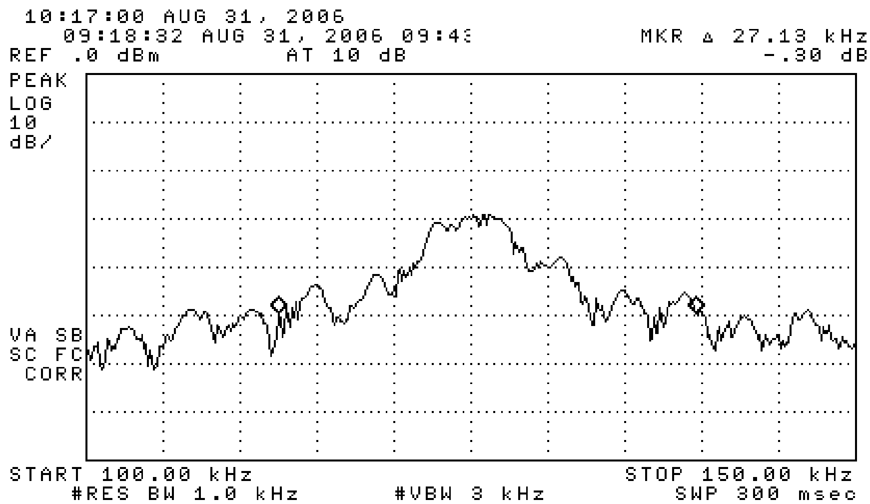


Figure 6.3b. Measured bandwidth of the DUT.
Highest data-rate pulsed modulation, mode 6.

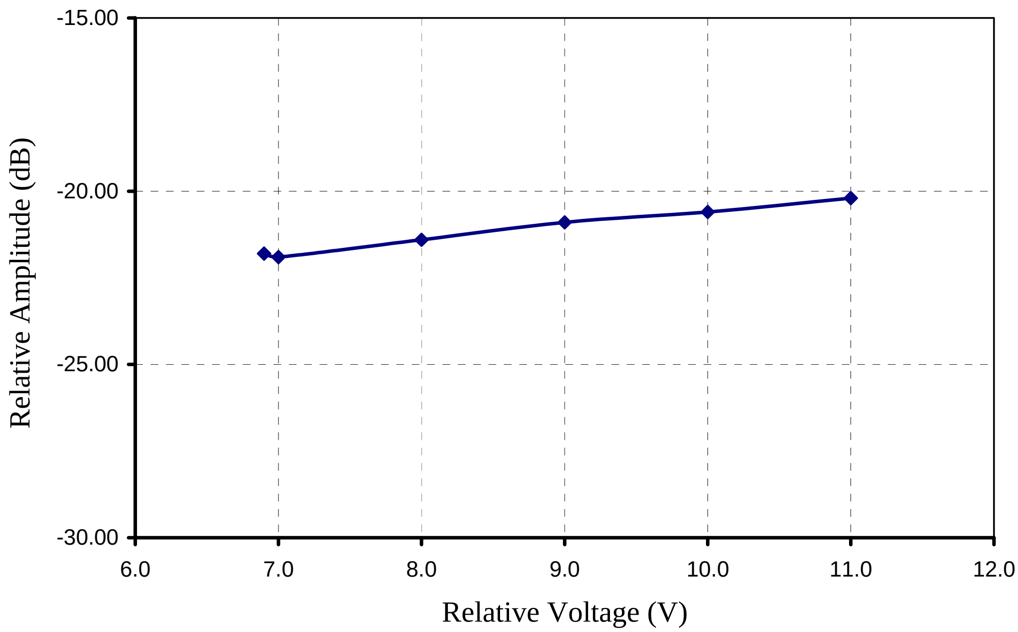


Figure 6.4. Relative emission at 125 kHz vs. supply voltage.

DUT on OATS

DUT on OATS (close-up)