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Measured Radio Frequency Emissions
From

Thomas & Betts Corporation Transmitter
FCC ID: DE4-4130T
IC: 2998A-4130T

Test Report No. 417124-544
December 8, 2009

For:
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Summary

Tests for compliance with FCC Regulations, CFR 47, Part 15 and with Industry Canada RSS-210/Gen, were performed on a Thomas & Betts, FCC ID: DE4-4130T, IC: 2998A-4130T. This device under test (DUT) is subject to the rules and regulations as a Transmitter.

In testing completed on December 4, 2009, the DUT tested met the allowed specifications for radiated emissions by 2.9 dB. Conducted emissions are not subject to regulation as the DUT is powered by two 3 VDC batteries.

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1. Introduction

This Thomas & Betts transmitter was tested for compliance with FCC Regulations, Part 15, adopted under Docket 87-389, April 18, 1989 as subsequently amended, and with Industry Canada RSS-210/Gen, Issue 7, June 2007. 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 2057A-1).

2. Equipment Used

The test equipment commonly used in our facility is listed in Table 2.1. Except where indicated as a pre-test, monitoring, or support device; all equipment listed below is a part of the University of Michigan Radiation Laboratory (UMRL) quality system. This quality system has been established to ensure all equipment has a clearly identifiable classification, calibration expiry date, and that all calibrations are traceable to national standards.

Table 2.1 Test Equipment.

Test Instrument	Used	Manufacturer/Model	Q Number
Spectrum Analyzer (9kHz-26GHz)	☒	Hewlett-Packard 8593E, SN: 3412A01131	HP8593E1
Spectrum Analyzer (9kHz-6.5GHz)	☒	Hewlett-Packard 8595E, SN: 3543A01546	JDB8595E
Power Meter	☐	Hewlett-Packard, 432A	HP432A1
Harmonic Mixer (26-40 GHz)	☐	Hewlett-Packard 11970A, SN: 3003A08327	HP11970A1
Harmonic Mixer (40-60 GHz)	☐	Hewlett-Packard 11970U, SN: 2332A00500	HP11970U1
Harmonic Mixer (75-110 GHz)	☐	Hewlett-Packard 11970W, SN: 2521A00179	HP11970W1
Harmonic Mixer (140-220 GHz)	☐	Pacific Millimeter Prod., GMA, SN: 26	PMPGMA1
S-Band Std. Gain Horn	☐	S/A, Model SGH-2.6	SBAND1
C-Band Std. Gain Horn	☐	University of Michigan, NRL design	CBAND1
XN-Band Std. Gain Horn	☐	University of Michigan, NRL design	XNBAND1
X-Band Std. Gain Horn	☐	S/A, Model 12-8.2	XBAND1
X-band horn (8.2- 12.4 GHz)	☐	Narda 640	XBAND2
X-band horn (8.2- 12.4 GHz)	☐	Scientific Atlanta , 12-8.2, SN: 730	XBAND3
K-band horn (18-26.5 GHz)	☐	FXR, Inc., K638KF	KBAND1
Ka-band horn (26.5-40 GHz)	☐	FXR, Inc., U638A	KABAND1
U-band horn (40-60 GHz)	☐	Custom Microwave, HO19	UBAND1
W-band horn(75-110 GHz)	☐	Custom Microwave, HO10	WBAND1
G-band horn (140-220 GHz)	☐	Custom Microwave, HO5R	GBAND1
Bicone Antenna (30-250 MHz)	☒	University of Michigan, RLBC-1	LBBIC1
Bicone Antenna (200-1000 MHz)	☒	University of Michigan, RLBC-2	HBBIC1
Dipole Antenna Set (30-1000 MHz)	☒	University of Michigan, RLDP-1,-2,-3	UMDIP1
Dipole Antenna Set (30-1000 MHz)	☐	EMCO 3121C, SN: 992 (Ref. Antennas)	EMDIP1
Active Rod Antenna (30 Hz-50 MHz)	☐	EMCO 3301B, SN: 3223	EMROD1
Active Loop Antenna (30 Hz-50 MHz)	☐	EMCO 6502, SN:2855	EMLOOP1
Ridge-horn Antenna (300-5000 MHz)	☒	University of Michigan	UMRH1
Amplifier (5-1000 MHz)	☒	Avantek, A11-1, A25-1S	AVAMP1
Amplifier (5-4500 MHz)	☒	Avantek	AVAMP2
Amplifier (4.5-13 GHz)	☐	Avantek, AFT-12665	AVAMP3
Amplifier (6-16 GHz)	☐	Trek	TRAMP1
Amplifier (16-26 GHz)	☐	Avantek	AVAMP4
LISN Box	☐	University of Michigan	UMLISN1
Signal Generator	☐	Hewlett-Packard 8657B	HPSG1

3. Device Under Test

3.1 Description & Block Diagram

The DUT is a 315.0 MHz Transmitter designed to communicate with a wireless doorbell inside a home. It is powered by two 3 VDC batteries and is housed in a plastic case approximately 0.75 x 0.75 x 3.0 inches in dimension. For testing, a generic harness was provided by the manufacturer. The DUT is designed and manufactured by Thomas & Betts Corporation, 8155 T&B Boulevard, Memphis, TN 38125.

Device	[Make], Model	[S/N],P/N	EMC Consideration
EUT (fully tested)	[Thomas & Betts], 4128T	-	plastic face plate
Variant	[Thomas & Betts], 4130T	-	brass face plate
Variant	[Thomas & Betts], 4133T	-	nickel face plate
EUT (fully tested)	[Thomas & Betts], 4137T	-	bronze face plate

3.2 Variants and Samples

There are four variants of the EUT. All four variants employ the same PCB, components, and plastic shell, but have different face plates that are attached during manufacturing. Three models (4130T, 4133T, 4137T) employ metal face plates and exhibit identical RF emissions. Model 4128T employs a plastic faceplate resulting is higher RF emissions. Models 4128T and 4137T are fully tested to demonstrate compliance. Four face plates, plastics, one normal operating PCB, and one PCB modified for continuously repeated pulses were supplied as test samples.

3.3 Modes of Operation

The EUT is capable of only a single mode of operation as reported herein. After button press, the EUT ceases transmission within 5 seconds are required by regulations and as shown in Figure 6.1.

3.4 Exemptions

None.

3.5 EMC Relevant Modifications

No EMI Relevant Modifications were performed by this test laboratory.

4. Emissions Limits

4.1 Radiated Emissions Limits

The DUT tested falls under the category of an Intentional Radiator. The applicable testing frequencies and corresponding emission limits set by both the FCC and IC are given in Tables 4.1 and 4.2 below.

Table 4.1. TX Emission Limits (FCC: 15.231(b), .205(a); IC: RSS-210 2.7 T4).

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	
315	6042	75.6	604.2	55.6
433.9	10966	80.8	1096.6	60.8
322-335.4 399.9-410 608-614	Restricted Bands		200	46.0
960-1240/1427(IC) 1300-1427 1435-1626.5 1645.5-1646.5 (IC) 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. Spurious Emission Limits (FCC: 15.33, .35, .109/209; IC: RSS-210 2.7, T2)

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 RBW), PRF of intentional emissions > 20 Hz for QPK to apply.

4.2 Power Line Conducted Emissions Limits

Table 4.3 Emission Limits (FCC:15.107 (CISPR); IC: RSS-Gen, 7.2.2 T2).

Frequency (MHz)	Class A (dBμV) Quasi-peak	Class A (dBμV) Average	Class B (dBμV) Quasi-peak	Class B (dBμV) 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. Measurement Procedures

5.1 Semi-Anechoic Chamber Radiated Emissions

To become familiar with the radiated emission behavior of the DUT, the device is first studied and measured in our 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.

The DUT is laid on the test table as shown in the included block diagram and/or photographs. A shielded loop antenna is employed when studying emissions from 9 kHz to 30 MHz. Above 30 MHz and below 250 MHz a biconical antenna is employed. Above 250 MHz a ridge or and standard gain horn antennas are used. The spectrum analyzer resolution and video bandwidths are set so as to measure the DUT emission without decreasing the emission bandwidth (EBW) of the device. Emissions are studied for all orientations (3-axes) of the DUT and all test antenna polarizations. In the chamber, spectrum and modulation characteristics of intentional carriers are recorded. Receiver spurious emissions are measured with an appropriate carrier signal applied. Associated test data is presented in subsequent sections.

5.2 Outdoor Radiated Emissions

After measurements are performed indoors, emissions on our outdoor 3-meter Open Area Test Site (OATS) are made, when applicable. If the DUT connects to auxiliary equipment and is table or floor standing, the configurations prescribed in ANSI C63.4 are employed. Alternatively, an on-table layout more representative of actual use may be employed if the resulting emissions appear to be worst-case in such a configuration. Any intentionally radiating elements are placed on the test table flat, on their side, and on their end (3-axes) and worst case emissions are recorded. For each configuration the DUT is rotated 360 degrees about its azimuth and the receive antenna is raised and lowered between 1 and 4 meters to maximize radiated emissions from the device. Receiver spurious emissions are measured with an appropriate carrier signal applied. For devices with intentional emissions below 30 MHz, our shielded loop antenna at a 1 meter receive height is used. Low frequency field extrapolation to the regulatory limit distance is employed as needed. Emissions between 30 MHz and 1 GHz are measured using tuned dipoles and/or biconical antennas. Care is taken to ensure that the RBW and VBW used meet the regulatory requirements, and that the EBW of the DUT is not reduced. The Photographs included in this report show the Test Setup.

5.3 Radiated Field Computations

To convert the dBm values measured on the spectrum analyzer to dB(μV/m), we use expression

$$E3(dB\mu V/m) = 107 + PR + KA - KG + KE - CF$$

where

PR	=	power recorded on spectrum analyzer, dBm, measured at 3 m
KA	=	antenna factor, dB/m
KG	=	pre-amplifier gain, including cable loss, dB
KE	=	duty correction factor, dB
CF	=	distance conversion (employed only if limits are specified at alternate distance), dB

When presenting the data at each frequency, the highest measured emission under all of the possible DUT orientations (3-axes) is given.

5.4 Indoor Power Line Conducted Emissions

When applicable, power line conducted emissions are measured in our semi-anechoic chamber. If the DUT connects to auxiliary equipment and is table or floor standing, the configurations prescribed in ANSI C63.4 are employed. Alternatively, an on-table layout more representative of actual use may be employed if the resulting emissions appear to be worst-case in such a configuration.

The conducted emissions measured with the spectrum analyzer and recorded (in dBμV) from 0-2 MHz and 2-30 MHz for both the ungrounded (Hi) and grounded (Lo) conductors. The spectrum analyzer is set to peak-hold mode in order to record the highest peak throughout the course of functional operation. Only when the emission exceeds or is near the limit are quasi-peak and average detection used.

5.5 Supply Voltage Variation

Measurements of the variation in the fundamental radiated emission were performed with the supply voltage varied by no less than 85% and 115% of the nominal rated value. For battery operated equipment, tests were performed using a new battery, and worst case emissions are re-checked employing a new battery.

6. Test Results

6.1 Radiated Emissions

6.1.1 Correction for Pulse Operation

See Figure 6.1. When the transmitter is activated (by single button press), it will, in the worst case, repeat four identical transmissions. Each transmission consists of one constant wake-tone followed by two pulse-position modulated (PPM) data words. The wake-tone exhibits a constant pulse width of 0.145 ms in a period of 1.130 ms for 165 m. Computing the duty factor results in:

$$K_{wake} = (0.145 \text{ ms} / 1.130 \text{ ms}) = 0.128 \text{ or } -17.8 \text{ dB.}$$

Each of the following PPM data words consists of one wide pulse (1.531 ms) followed by thirteen (0.543 ms) PPM pulses. Within a given 100 ms window, the worst PPM duty cycle arises from two wide and 14 narrow pulses. Computing the duty factor results in:

$$K_{PPM} = (2 \times 1.531 \text{ ms} + 14 \times 0.543 \text{ ms}) / 100 \text{ ms} = 0.107 \text{ or } -19.4 \text{ dB.}$$

Thus, the wake-tone duty cycle of -17.8 dB is employed in this report.

6.1.2 Emission Spectrum

The relative DUT emission spectrum is recorded and is shown in Figure 6.2.

6.1.3 Emission Bandwidth

The emission bandwidth of the signal is shown in Figure 6.3. The allowed 99% bandwidth is 0.25% of 315.0 MHz, or 787.25 kHz. From the plot we see that the EBW is 65.0 kHz, and the center frequency is 315 MHz.

6.1.4 Supply Voltage and Supply Voltage Variation

The DUT has been designed to be powered by a 6 VDC battery. For this test, relative radiated power was measured at the fundamental as the voltage was varied from 2.0 to 8.0 volts. The emission variation is shown in Figure 6.4.

Batteries:	before testing	V_{oc} =	6.46 V
	after testing	V_{oc} =	6.24 V
Ave. current from batteries		I =	1.2 mA (pulsed)

6.2 Conducted Emissions

These tests do not apply, since the DUT is powered from a 6 VDC battery.

Table 6.1 Highest Emissions Measured

Radiated Emission - RF RKE											TnB Doorbell Txs; FCC/IC
#	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	**Plastic front (model: 4128T)**										
2	315.0	Dip	H	-16.7	Pk	18.6	21.3	69.7	75.6	5.9	flat
3	315.0	Dip	V	-21.1	Pk	18.6	21.3	65.3	75.6	10.3	end
4	630.0	Dip	H	-42.5	Pk	24.4	18.3	52.8	55.6	**2.9**	flat
5	630.0	Dip	V	-55.7	Pk	24.4	18.3	39.6	55.6	16.1	end
6	945.0	Dip	H	-49.3	Pk	28.8	16.4	52.3	55.6	3.3	side
7	945.0	Dip	V	-50.0	Pk	28.8	16.4	51.6	55.6	4.0	end
8	1260.0	Horn	H	-38.9	Pk	20.6	28.0	42.9	54.0	11.1	flat
9	1575.0	Horn	H	-47.7	Pk	21.5	28.0	35.0	54.0	19.0	side
10	1890.0	Horn	H	-55.9	Pk	22.2	28.0	27.5	55.6	28.1	flat
11	2205.0	Horn	H	-50.7	Pk	23.0	28.1	33.4	54.0	20.6	flat
12	2520.0	Horn	H	-53.4	Pk	23.9	28.3	31.4	55.6	24.3	flat
13	2835.0	Horn	H	-56.7	Pk	24.8	28.2	29.1	54.0	24.9	end
14	3150.0	Horn	H	-55.8	Pk	25.8	27.9	31.3	55.6	24.3	flat
15	**Brushed metal front (model: 4137T)**										
16	315.0	Dip	H	-22.9	Pk	18.6	21.3	63.5	75.6	12.1	side
17	315.0	Dip	V	-26.4	Pk	18.6	21.3	60.0	75.6	15.6	end
18	630.0	Dip	H	-44.9	Pk	24.4	18.3	50.4	55.6	5.3	flat
19	630.0	Dip	V	-46.8	Pk	24.4	18.3	48.5	55.6	7.2	end
20	945.0	Dip	H	-50.3	Pk	28.8	16.4	51.3	55.6	**4.3**	flat
21	945.0	Dip	V	-51.4	Pk	28.8	16.4	50.2	55.6	5.4	end
22	1260.0	Horn	H	-44.3	Pk	20.6	28.0	37.5	54.0	16.5	flat
23	1575.0	Horn	H	-49.7	Pk	21.5	28.0	33.0	54.0	21.0	side
24	1890.0	Horn	H	-57.1	Pk	22.2	28.0	26.3	55.6	29.3	side
25	2205.0	Horn	H	-51.2	Pk	23.0	28.1	32.9	54.0	21.1	end
26	2520.0	Horn	H	-58.9	Pk	23.9	28.3	25.9	55.6	29.8	end
27	2835.0	Horn	H	-58.7	Pk	24.8	28.2	27.1	54.0	26.9	end
28	3150.0	Horn	H	-52.3	Pk	25.8	27.9	34.8	55.6	20.8	end
29											
30											
31											

Digital Emissions							
#	Freq. MHz	Line Side	Det. Used	Vtest dBμV	Vlim dBμV	Pass dB	Comments
32							
33	Digital emissions more than 20 dB below FCC/IC Class B Limit.						
34							
35							
36							

Meas.11/16/09; U of Mich.

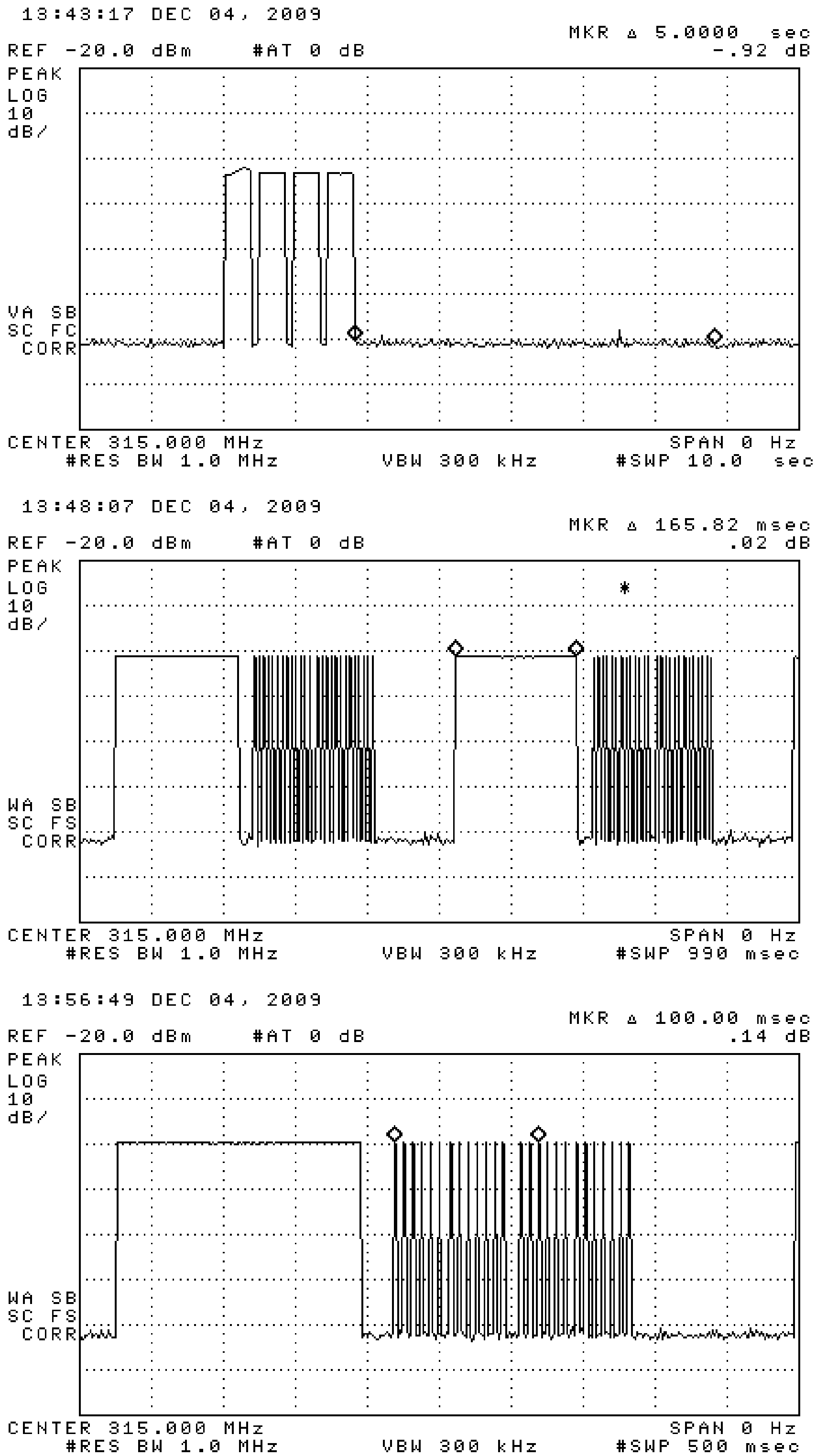
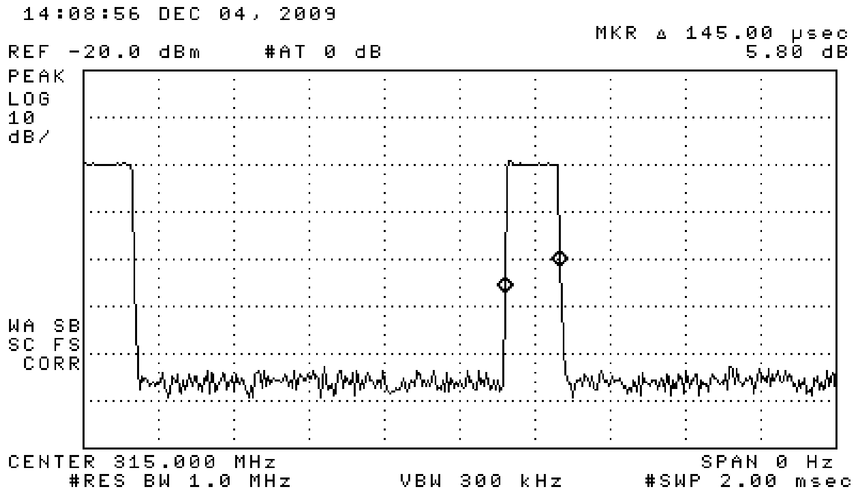


Figure 6.1(a). Transmission modulation characteristics. (top) complete transmission, (center) expanded transmission, (bottom) expanded word.



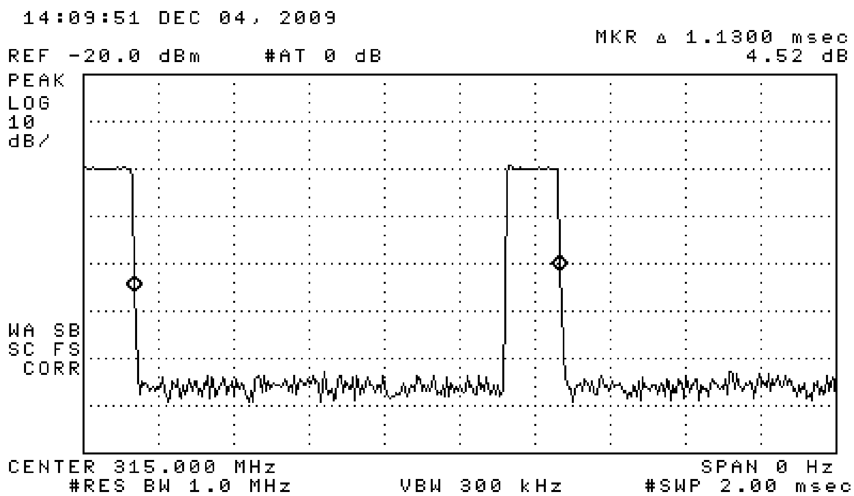
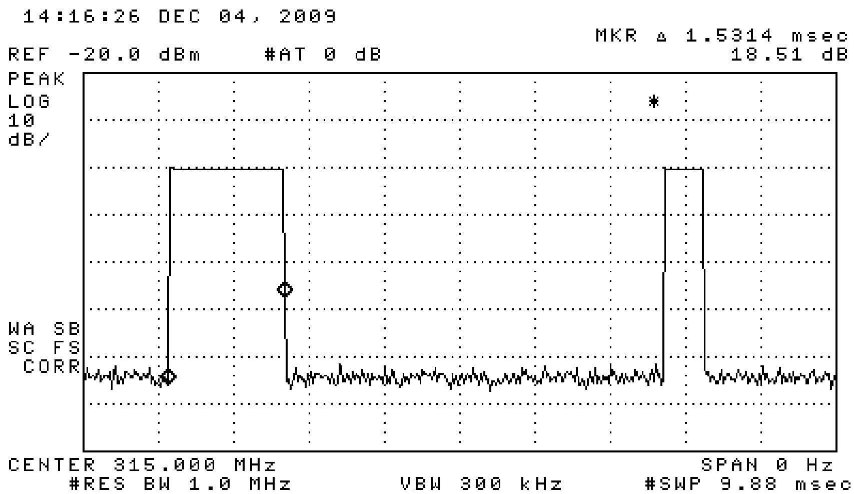


Figure 6.1(b). Transmission modulation characteristics.
(top) fast transmission pulse width, (bottom) fast transmission pulse period.



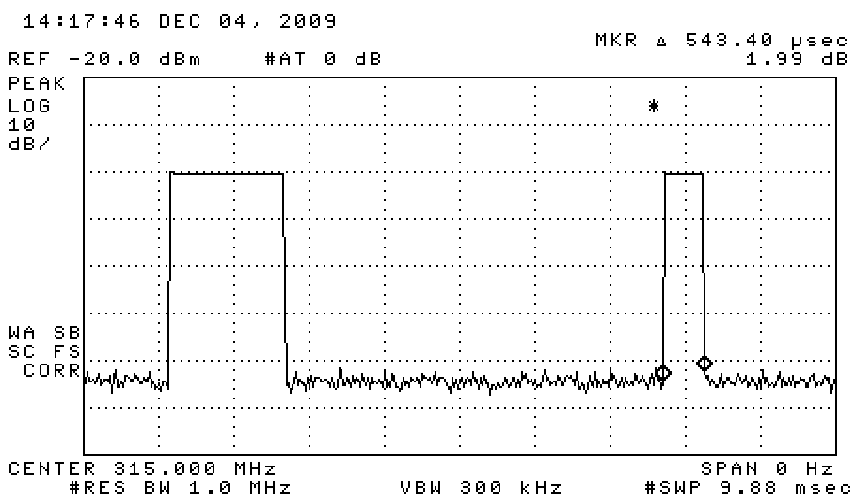


Figure 6.1(c). Transmission modulation characteristics.
(top) pulse-position wake pulse width, (bottom) pulse-position data pulse width.

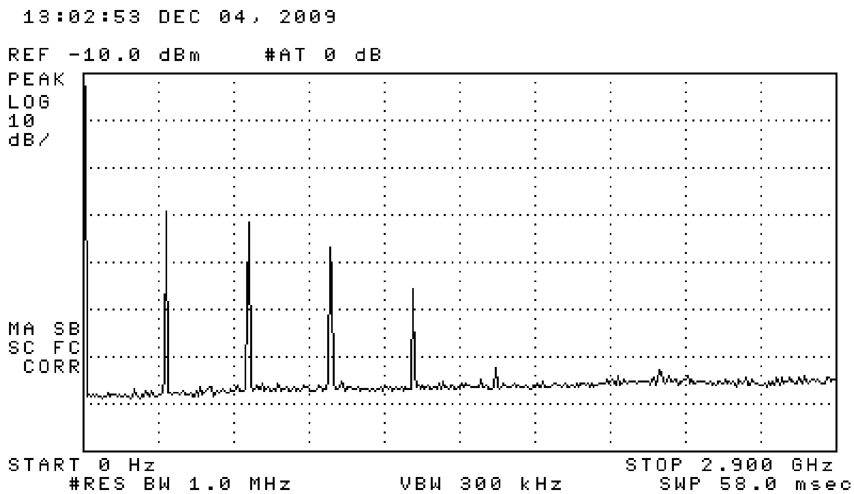


Figure 6.2. Emission spectrum of the DUT (pulsed emission). Amplitudes are only indicative (not calibrated).

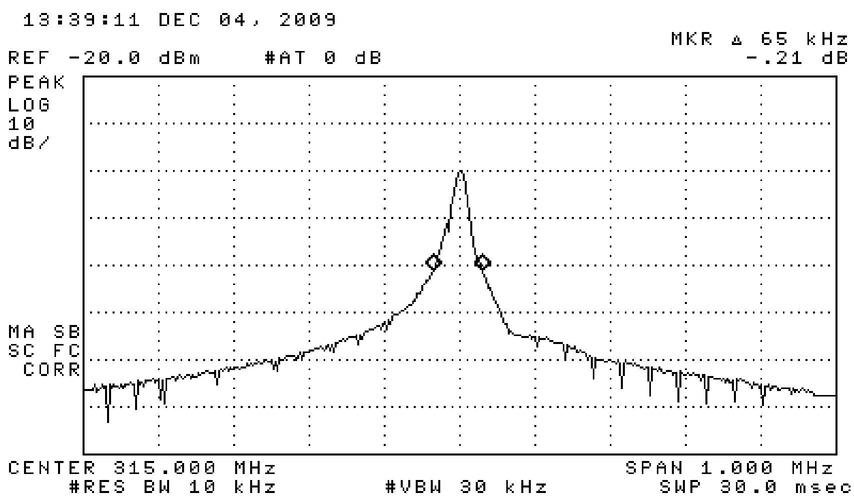


Figure 6.3. Measured emission bandwidth of the DUT (pulsed).

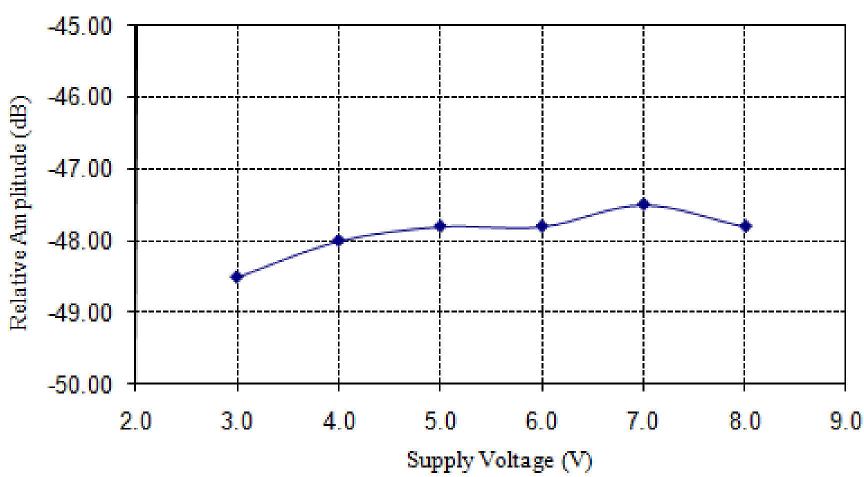
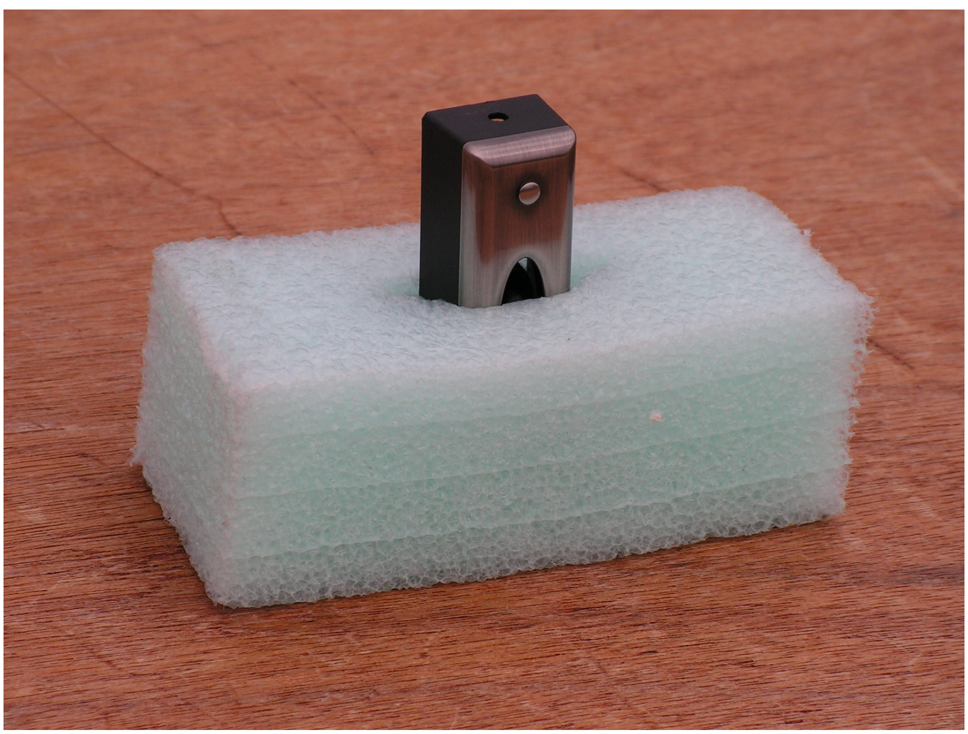


Figure 6.4. Relative emission at fundamental vs. supply voltage (pulsed).

Photograph 6.5. DUT on OATS (one of three axes tested)



Photograph 6.6. Close-up of DUT on OATS (one of three axes tested)