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Measured Radio Frequency Emissions
From

Digi-Code
Garage Door Opener Transmitter
Models CR-5010 and CR-5020

Report No. 415031-027
March 1, 2000

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For:
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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 Digi-Code transmitter. This device is subject to the Rules and Regulations as a transmitter and as a digital device.

In testing performed on February 28, 29, and March 1, 2000, the device tested in the worst case met the allowed specifications for radiated emissions by 1.8 dB at fundamental and by 10.4 dB at harmonics (see p. 7). Besides harmonics, there were no other significant spurious emissions found; emissions from digital circuitry were negligible. Since the device is powered by a 9-volt battery, the conductive emission tests do not apply.

1. Introduction

Digi-Code transmitter, Models CR-5010 and CR-5020, were tested for compliance with FCC Regulations, Part 15, adopted under Docket 87-389, April 18, 1989, and with Industry Canada RSS-210, Issue 2, dated February 14, 1998. 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 file 31040/SIT) and with Industry Canada, Ottawa, ON (File Ref. No: IC2057).

2. Test Procedure and Equipment Used

The test equipment commonly used in our facility is listed in Table 2.1 below. The second column identifies the specific equipment used in these tests. The HP 8593E spectrum analyzer is used for primary amplitude and frequency reference.

Table 2.1. Test Equipment.

Test Instrument	Equipment Used	Manufacturer/Model	Cal. Date/By
Spectrum Analyzer (9kHz-22GHz)	X	Hewlett-Packard 8593A SN: 3107A01358	October 1999/UM
Spectrum Analyzer (9kHz-26GHz)	X	Hewlett-Packard 8593E SN: 3107A01131	September 1999/HP
Spectrum Analyzer (0.1-1500 MHz)		Hewlett-Packard 182T/8558B SN: 1529A01114/543592	October 1999/U of M Rad Lab
Preamplifier (5-1000MHz)	X	Watkins-Johnson A11 -1 plus A25-1S	October 1999/U of M Rad Lab
Preamplifier (5-4000 MHz)	X	Avantek	Oct. 1999/ U of M Rad Lab
Broadband Bicone (20-200 MHz)	X	University of Michigan	June 1996/U of M Rad Lab
Broadband Bicone (200-1000 MHz)		University of Michigan	June 1996/U of M Rad Lab
Dipole Antenna Set (25-1000 MHz)	X	University of Michigan	Dec. 1997/U of M Rad Lab
Dipole Antenna Set (30-1000 MHz)		EMCO 3121C SN: 992	June 1996/U of M Rad Lab
Active Loop Antenna (0.090-30MHz)		EMCO 6502 SN: 2855	December 1993/ EMCO
Active Rod (30Hz-50 MHz)		EMCO 3301B SN: 3223	December 1993/EMCO
Ridge-horn Antenna (0.5-5 GHz)	X	University of Michigan	March 1999/U of M Rad Lab
LISN Box		University of Michigan	Dec. 1997/U of M Rad Lab
Signal Cables	X	Assorted	January 1993/U of M Rad Lab
X-Y Plotter		Hewlett-Packard 7046A	During Use/U of M Rad Lab
Signal Generator (0.1-990 MHz)		Hewlett-Packard 8656A	January 1990/U of M Rad Lab
Printer	X	Hewlett-Packard 2225A	August 1989/HP

3. Configuration and Identification of Device Under Test

The DUT is a cigarette-pack size 1- and 2-button low power transmitter designed to send identification and control for opening and closing garage doors. It is activated by depressing a button and keeps transmitting repeated words as long as a button is depressed. Emission is a pulse-width modulated code on a 300 MHz carrier generated by an LC stabilized oscillator. Coding is performed by a microchip, timed by an RC circuit.

The DUT was designed and manufactured by Digi-Code, 307 Robins Drive, Troy, MI 48083. It is identified as:

Digi-Code Garage Door Opener Transmitter
Model: CR-5010 (1-button)
Model: CR-5020 (2-button)
SN: FCC1BTEST
SN: FCC2BTEST
FCC ID:
CANADA:

Two units were provided, a 1-button and 2-button version. Both are built on the same PCB, but with different population in the btton area . The 2-button version was fully tested, and the 1-button only for the worst case emission.

3.1 EMI Relevant Modifications

The 2.2K emmiter resistor in the oscillator circuit was changed to 2.7K to reduce the fundamental emission that exceeded the allowed limits from the unit originally submitted.

4. Emission Limits

4.1 Radiated Emission Limits

The DUT tested falls under the category of an Intentional Radiators and the Digital Devices. For FCC, it is subject to Part 15, Subpart C, (Section 15.231), Subpart B, (Section 15.109), and Subpart A, (Section 15.33). For Industry Canada it is subject to RSS-210, (Sections 6.1 and 6.3). The applicable testing frequencies with corresponding emission limits are given in Tables 4.1 and 4.2 below. As a digital device, the DUT is considered as a Class B device.

Table 4.1. Radiated Emission Limits (FCC: 15.231(b), 15.205(a); IC: RSS-210; 6.1, 6.3) Transmitter.

Frequency	Fundamental Ave. E_{lim} (3m)		Spurious** Ave. E_{lim} (3m)	
(MHz)	(μV/m)	dB (μV/m)	(μV/m)	dB (μV/m)
260.0-470.0	3750-12500*		375-1250	
322-335.4 399.9-410 608-614	Restricted Bands		200	46.0
960-1240 1300-1427 1435-1626.5 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. 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

The conductive emission limits and tests do not apply here, since the DUT is powered by one 9-volt battery.

5. Radiated Emission Tests and Results

5.1 Anechonic 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 transmitter was activated using the lock/unlock button with a special wooden clamp for repeated pulse emissions. It 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 a ridged horn antenna above 200 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. We note that for the horn antenna, the antenna pattern is more 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 spectrum and modulation characteristics of the carrier. These data are presented in subsequent sections. We also note that in scanning from 30 MHz to 3.15 GHz using bicone and the ridge horn antennas, there were no other significant spurious emissions observed.

5.2 Outdoor Measurements

After the chamber measurements, the emissions were re-measured on the outdoor 3-meter site at fundamental and harmonics up to 1 GHz using tuned dipoles and/or the high frequency bicone.

Photographs in Appendix show the DUT on the open in site table (OATS).

5.3 Computations and Results

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

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

where
P_R = power recorded on spectrum analyzer, dB, measured at 3m
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)

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 the DUT meets the limit by 1.8 dB.

6. Other Measurements and Computations

6.1 Correction For Pulse Operation

When the transmitter is activated by momentary push on the button, it transmits repeated PWM coded words as long as the button is depressed. The words repeat every 40 ms. In each word there are 10 bits. The "worst case" occurs when all the bits in the word are wide (as set by a dip switch). The width of these pulses is 1.5125 ms. See Figure 6.1. Thus, the duty factor

$$K_E = (10 * 1.5125)\ \mathrm{ms}/\ 40.0\ \mathrm{ms} = 0.378 \text{ or } -8.5\mathrm{dB}.$$

6.2 Emission Spectrum

Using the ridge-horn antenna and DUT placed in its aperture, 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. The allowed (-20 dB) bandwidth is 0.25% of 300 MHz, or 750.0 KHz. From the plot we see that the -20 dB bandwidth is 92.0 kHz, and the center frequency is 299.97 MHz.

6.4 Effect of Supply Voltage Variation

The DUT has been designed to be powered by a 9-volt battery. For this test, the battery was replaced by a laboratory variable power supply. Relative power radiated was measured at the fundamental as the voltage was varied from 7 to 12 volts. The emission variation is shown in Figure 6.4.

6.5 Input Voltage at Battery Terminals

Batteries:	before testing	V_{oc}	=	9.3 V
	after testing	V_{oc}	=	8.9 V
Ave. current from batteries		I	=	22.6 mA (continuous pulsed)

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Table 5.1 Highest Emissions Measured

Radiated Emission - RF											Digi-Code, 300 MHz; 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	299.5	Dip	H	-22.4	Pk	18.5	21.7	72.9	74.7	1.8	flat; 2-button
2	299.5	Dip	V	-25.6	Pk	18.5	21.7	69.7	74.7	5.0	end
3	600.0	Dip	H	-73.0	Pk	24.8	18.3	31.9	74.7	42.8	flat, noise
4	600.0	Dip	V	-78.0	Pk	24.8	18.3	26.9	74.7	47.8	end, noise
5	900.0	Dip	H	-74.0	Pk	28.9	16.1	37.3	55.6	18.3	side, noise
6	900.0	Dip	V	-75.0	Pk	28.9	16.1	36.3	55.6	19.3	end, noise
7	1200.0	Horn	H	-47.2	Pk	20.4	28.1	43.6	54.0	10.4	flat
8	1500.0	Horn	H	-49.2	Pk	21.4	28.2	42.5	54.0	11.5	flat
9	1800.0	Horn	H	-58.2	Pk	22.1	28.1	34.3	55.6	21.3	end
10	2100.0	Horn	H	-68.6	Pk	22.9	27.0	25.8	55.6	29.8	max all, noise
11	2400.0	Horn	H	-68.9	Pk	24.0	26.6	27.0	55.6	28.6	max all, noise
12	2700.0	Horn	H	-68.7	Pk	24.9	25.4	29.3	54.0	24.7	max all
13	3000.0	Horn	H	-68.1	Pk	25.2	24.8	30.8	55.6	24.8	max all
14											
15	1-button at worst case										
16	299.5	Dip	H	-22.4	Pk	18.5	21.7	72.9	74.7	1.8	flat; 1-button
17											
18			All transmitter orientations were measured; above are the major emissions.								
17			*includes -8.5 dB duty factor								

Digital Emissions											
#	Freq. MHz	Ant. Used	Ant. Pol.	Pr dBm	Det. Used	Ka dB/m	Kg dB	E3* dBμV/m	E3lim dBμV/m	Pass dB	Comments
22											
23											
24			Digital emissions are more than 20 dB below FCC Class B limit								
25											

Conducted Emissions							
#	Freq. MHz	Line Side	Det. Used	Vtest dBμV	Vlim dBμV	Pass dB	Comments
1							
2		Not applicable					
3							
4							
5							
6							
7							

Meas. 2/28,3/1/2000; U of Mich.

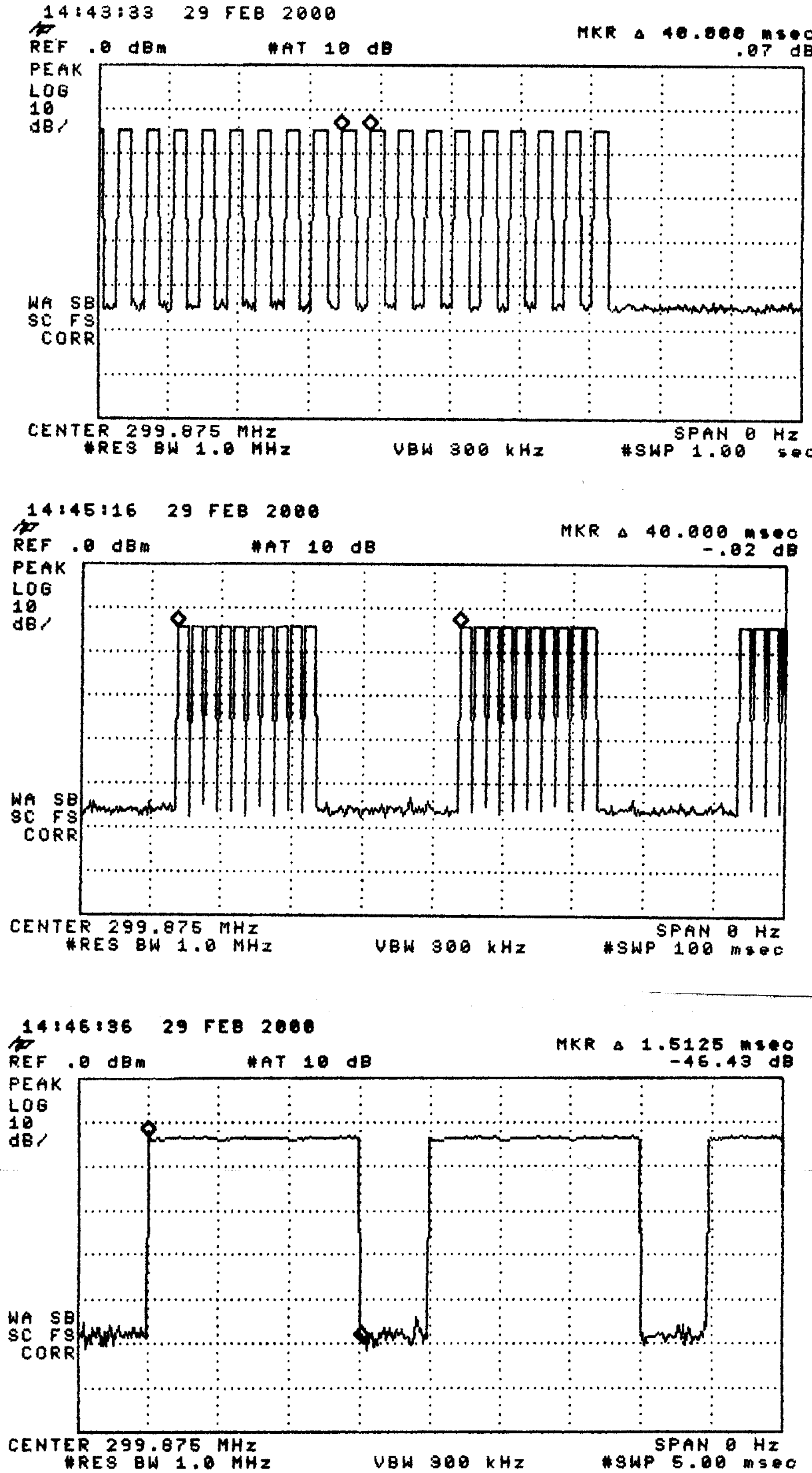

Figure 6.1. Transmissions modulation characteristics: (top) transmission repetition, (center) transmission pulses, (bottom) pulse width.

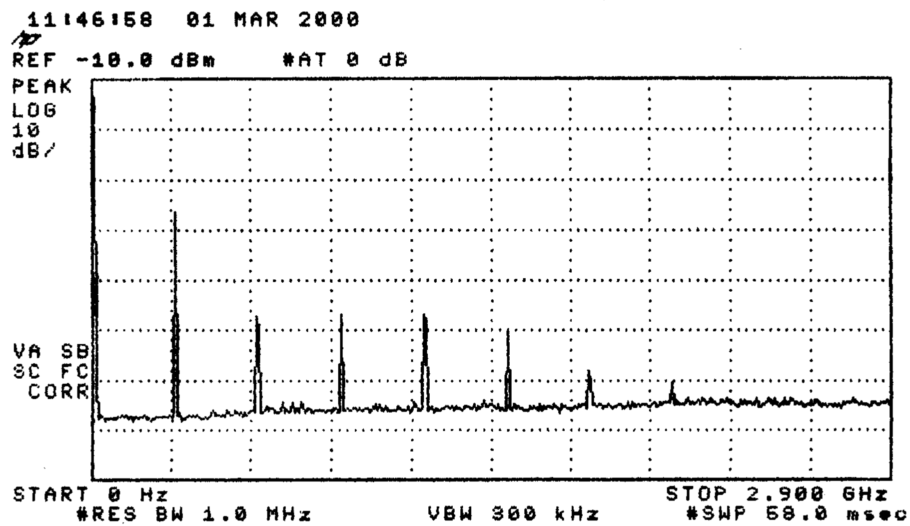

Figure 6.2. Emission spectrum of the DUT in free space (pulsed emission). The amplitudes are only indicative (not calibrated).

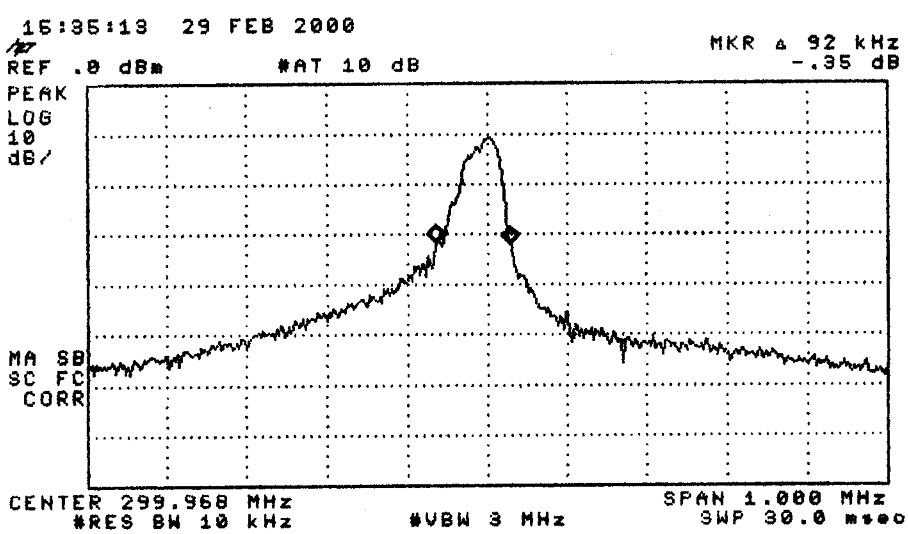

Figure 6.3. Measured bandwidth of the DUT (repated pulsed emission).

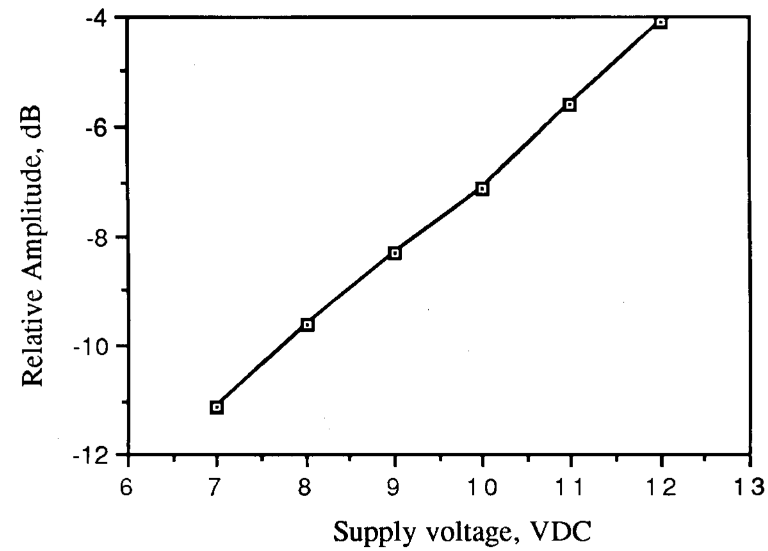

Figure 6.4. Relative emission at 300.0 MHz vs. supply voltage. (pulsed emission)