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Measured Radio Frequency Emissions
From

Hafele Electronic Door Locks
Models: DT2000 (US) and DT2000 (EU)

Report No. 415031-130
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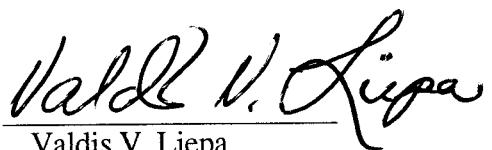
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Summary

Tests for compliance with FCC Regulations, Part 15, Subpart C, and for compliance with Industry Canada RSS-210, were performed on Hafele Electronic Door Locks. This device is subject to Rules and Regulations as a transmitter, and as a digital device.

In testing performed June 17 through July 29, 2002, the devices tested in the worst case met the allowed specifications for transmitter radiated emissions by 26.4 dB (see p. 6); the digital emissions, Class B, were met by at least 20 dB.

The conductive emission tests do not apply, since the device is powered by two 3-volt lithium batteries.

1. Introduction

Hafele Electronic Locks were tested for compliance with FCC Regulations, Part 15, adopted under Docket 87-389, April 18, 1989, and with Industry Canada RSS-210, Issue 5, 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 Reg. No: 91050) and with Industry Canada, Ottawa, ON (File Ref. No: IC 2057).

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	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 Millimiter 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)		University of Michigan, RLBC-2
Dipole Antenna Set (30-1000 MHz)		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)		University of Michigan
Amplifier (5-1000 MHz)		Avantak, A11-1, A25-1S
Amplifier (5-4500 MHz)		Avantak
Amplifier (4.5-13 GHz)		Avantek, AFT-12665
Amplifier (6-16 GHz)		Trek
Amplifier (16-26 GHz)		Avantek
LISN (50 μ H)		University of Michigan
Signal Generator (0.1-2060 MHz)		Hewlett-Packard, 8657B
Signal Generator (0.01-20 GHz)		Hewlett-Packard

3. Configuration and Identification of Device Under Test

The DUT is an electronic door lock that electronically identifies the "real" key and locks/unlocks the door. There are two models, one US style and the other Euro style. The main difference is in the mechanical layout of the handles, locks, bolts, etc. Electrically they are similar, except for the board that supports the transmit coil. The system tested consisted of a 135 kHz T/R module with coil antenna and a "passive" transponder imbedded in a plastic stick (key). The transponder in the key is considered passive and thus not subject to the Regulations. It uses the energy supplied by the transmitter coil to operate its micro and to transmit an ID/command code at extremely low level.

The DUT was designed and manufactured by Hafele. It is identified as:

Hafele Electronic Door Locks
Models: DT2000 (US), DT2000 (EU)
S/N: FCCTESTUS, FCCTESTEU; respectively
FCC ID: PW3108
IC:

One sample of each model was provided. We completely tested the US version, and for the EU version tested only at the fundamental, since other emissions were too low to be measured.

3.1 EMI Relevant Modifications

None.

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* (μ V/m)
0.009-0.490	2400/F(kHz), 300m
0.490-1.705	24,000/F(kHz), 30m
0.090-0.110	Restricted
0.49-0.51	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) μ V/m	E_{lim} dB(μ V/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 from an automobile 12VDC system.

5. Radiated Emission Tests and Results

5.1 Anechoic 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 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. Larger emissions were observed when the loop was perpendicular. In the chamber we also recorded the spectrum and modulation characteristics of the carrier. These data are presented in subsequent sections. In scanning from 0.0-2.0 MHz there were no spurious emissions observed other than harmonics. In some instances, it was difficult to separate the DUT emissions from AM band signals.

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/or 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(μ V/m), we use expression

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

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)

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 26.4 dB.

6. Other Measurements and Computations

6.1 Correction For Pulse Operation

When activated, the lock mechanism transmits 11 pulses 69.6 ms wide with period of about 250 ms. See Figure 6.1. Note on the trailing side a small extension. That is the response from the transponder or the key. The averaging factor for such operation is

$$K_E = 69.6 \text{ ms} / 100 \text{ ms} = 0.696 \text{ or } -3.1 \text{ dB}$$

6.2 Emission Spectrum

Using the loop antenna, the emission spectrum was recorded and is shown in Figure 6.2. Unfortunately, the measurement is contaminated by AM stations.

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 1.91 kHz and the center frequency is about 136.5 kHz.

6.4 Effect of Supply Voltage Variation

The DUT has been designed to be operated by two 3-volt batteries. For this test, the relative power radiated was measured at the fundamental as the voltage was varied from 4.0 to 8.0 volts. The emission variation is shown in Figure 6.4.

6.5 Battery Voltage and Current

$$V = 5.94 \text{ V (start)} \quad V = 5.88 \text{ V (end)}$$

$$I = 23.0 \text{ mA (during transmission)}$$

6.6 Field Behavior from 125 kHz to 1.25 MHz

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 limits from the 300/30 m distance to the 3 m, we computed the field behavior for a Hertzian (small loop) dipole using equations found in most antenna books, for example 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	Extrap positions	Correction (dB)	Notes
125	Radial	3m/300m	117.9 dB	Axial coupling
125	Transverse	3m/300m	121.2 dB	Planar coupling
250	Radial	3m/300m	114.6 dB	Axial coupling
250	Transverse	3m/300m	113.4 dB	Planar coupling
375	Radial	3m/300m	111.9 dB	Axial coupling
375	Transverse	3m/300m	105.6 dB	Planar coupling
500	Radial	3m/30m	59.6 dB	Axial coupling
500	Transverse	3m/30m	60.6 dB	Planar coupling
625	Radial	3m/30m	59.4 dB	Axial coupling
625	Transverse	3m/30m	60.6 dB	Planar coupling
750	Radial	3m/30m	59.1 dB	Axial coupling
750	Transverse	3m/30m	60.8 dB	Planar coupling
875	Radial	3m/30m	58.9 dB	Axial coupling
875	Transverse	3m/30m	61.0 dB	Planar coupling
1000	Radial	3m/30m	58.6 dB	Axial coupling
1000	Transverse	3m/30m	61.2 dB	Planar coupling
1125	Radial	3m/30m	58.3 dB	Axial coupling
1125	Transverse	3m/30m	61.2 dB	Planar coupling
1250	Radial	3m/30m	57.9 dB	Axial coupling
1250	Transverse	3m/30m	61.2 dB	Planar coupling

In the data table, Table 5.1, at 125kHz (and harmonics) the measurement is decreased by the dB values given above.

Table 5.1 Highest Emissions Measured

Transmitter Radiated Emissions										Hafele DT2000 Tiris (US); FCC/IC	
#	Freq. MHz	Ant. Used	Ant. Orien.	Pr, 3m dBm	Det. Used	Ka dB/m	Kg dB	E* dB μ V/m	Elim* dB μ V/m	Pass dB	Comments
1	0.1364	Loop	V/perp	-51.4	Pk	9.9	0.0	-55.5	24.9	80.4	loop perp. (axis in dir. of prop.)
2	0.1364	Loop	V/par	-47.4	Pk	9.9	0.0	-54.8	24.9	79.7	loop paral (loop in dir. of prop.)
3	0.2728	Loop	V/perp	-80.6	Pk	9.8	0.0	-81.5	18.9	100.4	noise
4	0.2728	Loop	V/par	-74.8	Pk	9.8	0.0	-74.5	18.9	93.4	noise
5	0.4092	Loop	V/perp	-73.2	Pk	9.8	0.0	-71.4	15.4	86.8	noise
6	0.4092	Loop	V/par	-73.2	Pk	9.8	0.0	-65.1	15.4	80.5	noise
7	0.5456	Loop	V/perp	-73.6	Pk	9.8	0.0	-16.4	32.9	49.3	noise
8	0.5456	Loop	V/par	-78.2	Pk	9.8	0.0	-22.0	32.9	54.9	noise
9	0.6820	Loop	V/perp	-77.9	Pk	9.8	0.0	-20.5	30.9	51.4	noise
10	0.6820	Loop	V/par	-64.7	Pk	9.8	0.0	-8.5	30.9	39.4	noise, background rf
11	0.8184	Loop	V/perp	-75.2	Pk	9.8	0.0	-17.5	29.3	46.8	noise
12	0.8184	Loop	V/par	-79.8	Pk	9.8	0.0	-23.8	29.3	53.1	noise
13	0.9548	Loop	V/perp	-56.4	Pk	9.8	0.0	1.5	28.0	26.5	noise, background rf
14	0.9548	Loop	V/par	-54.2	Pk	9.8	0.0	1.6	28.0	26.4	noise, background rf
15	1.0912	Loop	V/perp	-70.9	Pk	9.8	0.0	-12.7	26.8	39.5	noise
16	1.0912	Loop	V/par	-76.3	Pk	9.8	0.0	-20.7	26.8	47.5	noise
17	1.2276	Loop	V/perp	-75.4	Pk	9.8	0.0	-16.9	25.8	42.7	noise
18	1.2276	Loop	V/par	-83.8	Pk	9.8	0.0	-28.2	25.8	54.0	noise
19	1.3640	Loop	V/perp	-79.6	Pk	9.8	0.0	-20.7	24.9	45.6	noise
20	1.3640	Loop	V/par	-69.9	Pk	9.8	0.0	-14.3	24.9	39.2	noise, background rf
Hafele DT2000 Tiris (EU)											
1	0.1359	Loop	V/perp	-51.7	Pk	9.9	0.0	-55.8	24.9	80.7	loop perp. (axis in dir. of prop.)
2	0.1359	Loop	V/par	-48.2	Pk	9.9	0.0	-55.6	24.9	80.5	loop paral (loop in dir. of prop.)
* Averaging applies to 0.490 MHz, 3.1 dB in this case											
Limit at 300m for f<0.490MHz; 30m for f>0.490MHz											
Measurements made at 3m, see Sec.6.6 for extrapolation values											
Usually 9kHz RBW used, sometimes lower to reduce instrument and ambient noise											
Digital Radiated Emissions, Class B											
#	Freq. MHz	Ant. Used	Ant. Pol.	Pr dBm	Det. Used	Ka dB/m	Kg dB	E3 dB μ V/m	E3lim dB μ V/m	Pass dB	Comments
			Meets class B limit by more than 20dB								

Meas. 06/17/02; U of Mich.

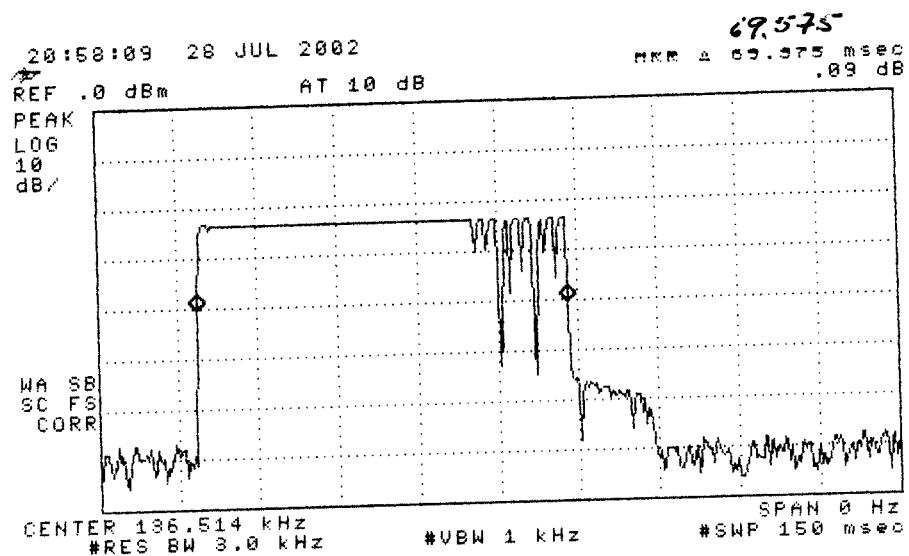


Figure 6.1. Transmission modulation characteristics.

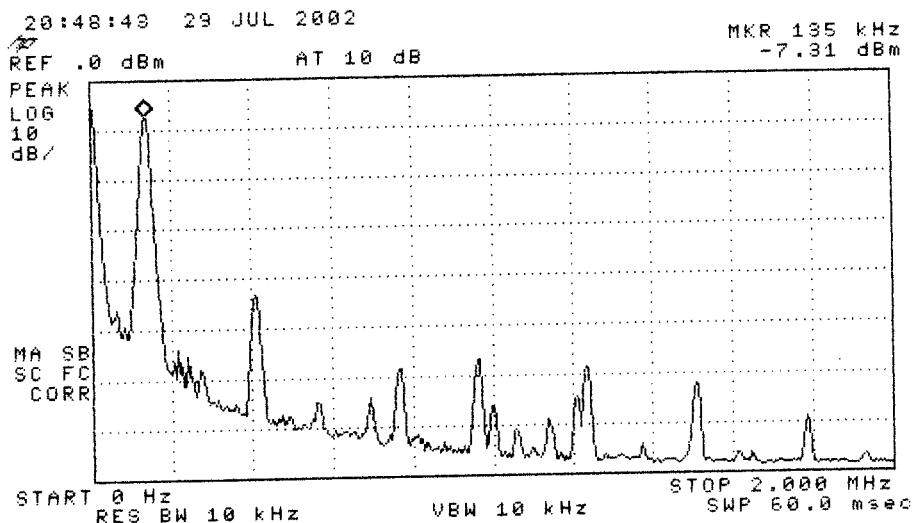


Figure 6.2. Emission spectrum of the DUT.
The amplitudes are only indicative (not calibrated).

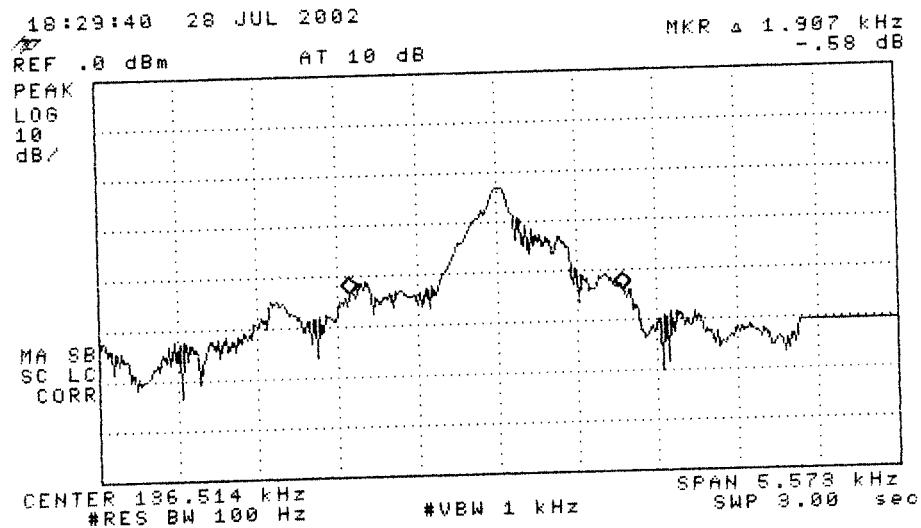


Figure 6.3. Measured bandwidth of the DUT. (pulsed)

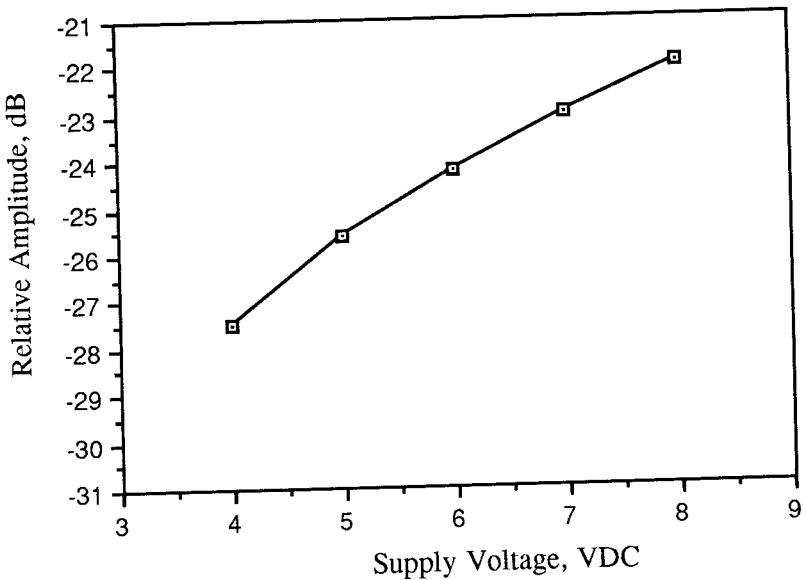


Figure 6.4. Relative emission at 136 kHz vs. supply voltage.