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

Measured Radio Frequency Emissions
From

Hafele Elecctronic Lock Safe
Model: DMT 32 (TIRIS)

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For:
Hafele America Co.
3901 Cheyenne Drive
Archdale, NC 27263
PO: 40607

Contact:
Rudor Teich
dteich@RMTAI.com
10 Ridge Road
West Orange, NJ 07052
Tel: 973-669-8214
Fax: 973-669-5161

Measurements made by: Valdis Liepa

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, were performed on Hafele Electronic Lock Safe. This device is subject to Rules and Regulations as a transmitter, and as a digital device.

In testing performed March 12 through April 8, 2002, the device tested in the worst case met the allowed specifications for transmitter radiated emissions by 43.8 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 four AA batteries.

1. Introduction

Hafele Electronic Lock Safe 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, dated 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 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)	X	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)	X	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 μH)		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 lock that electronically identifies the "real" key and locks/unlocks the safe. The system tested consisted of a 134 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 extemely low level.

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

Hafele Electronic Lock Safe
Model: DTM 32 (TIRIS)
SN: 031202
FCC ID: PW3106
CANADA: not applied for

One DUT was supplied with a standard and a special key programmed to activate the DUT to transmit continuous pulsed signal for 40 seconds for emission measurements.

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* (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
The conductive emission limits and tests do not apply here, since the DUT is powered by four AA batteries.

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 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 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

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

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 43.8 dB. The digital emissions, Class B, were met by at least 20 dB.

6. Other Measurements and Computations

6.1 Correction For Pulse Operation

In normal a operation the transmitter is activated by pushing on the toutch pad. Pulsed transmission lasts for 3 seconds of pulses 67.5 ms wide and period of 97.5 ms. When the transponder key is is brought within inches of the transmit antenna, the safe either locks/unlocks depending on the previous state. The frequency is about 134 kHz. See Figure 6.1. The averaging factor for such operation is

$$K_E = 67.5 \text{ ms} / 97.5 \text{ ms} = 0.692 \text{ or } -3.2 \text{ dB}$$

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 6.25 kHz and the center fequency is 134.35 kHz.

6.4 Effect of Supply Voltage Variation

The DUT has been designed to be operated from four AA batteries. For this test, the relative power radiated was measured at the fundamental as the voltage was varied from 5.5 to 8.0 volts. The emission variation is shown in Figure 6.4.

6.5 Input Voltage and Current

Vstart = 6.05 V

Vstop = 6.02 V

I = 68 mA (continuous pulsed emission)

6.6 Field Behavior at 134 kHz

Because at the specified 300 m measurement distance the signal is too small to measure, measurements were made at 3 m. To relate the 300 m distance to the 3 m, field attenuation experiments were performed (August 17, 1994) using two loops, one transmitting, the other receiving. Even then we could only go up to 50 m before noise became a factor. Measurements were made with the loops coplanar (planes of the loops in the same plane) and with loops axial (same axis for both loops). Figures 6.5 and 6.6 show results. From these we then deduce the difference in dB between the 300 m and 3 m distances is:

Coplanar case: 0.0 - (-112.4) = 112.4 dB (56 dB/decade)

Axial case: - 6.0 - (- 96.1) = 90.1 dB (45 dB/decade)

Table 5.1 Highest Emissions Measured

Transmitter Radiated Emissions — RMT TIRIS Safe; FCC/IC

#	Freq. kHz	Ant. Used	Ant. Orien.	Pr, 3m dBm	Det. Used	Ka dB/m	Kg dB	E300* dBµV/m	E300lim dBµV/m	Pass dB	Comments
1	134.2	Loop	V	-41.8	Pk	9.9	0.0	-18.2	25.6	**43.8**	loop normal (axis in dir. of prop.)
2	134.2	Loop	V	-44.8	Pk	9.9	0.0	-21.2	25.6	46.8	loop planar (loop in dir. of prop.)
3	268.3	Loop	V	-75.6	Pk	9.8	0.0	-52.1	25.6	77.7	loop normal, noise
4	268.3	Loop	V	-74.8	Pk	9.8	0.0	-51.3	25.6	76.9	loop planar, noise
5	402.5	Loop	V	-69.6	Pk	9.8	0.0	-46.1	25.6	71.7	loop normal
6	402.5	Loop	V	-72.9	Pk	9.8	0.0	-49.4	25.6	75.0	loop planar
7	536.6	Loop	V	-73.6	Pk	9.8	0.0	-50.1	25.6	75.7	loop normal, noise
8	536.6	Loop	V	-73.7	Pk	9.8	0.0	-50.2	25.6	75.8	loop plana, noiser
9	670.8	Loop	V	-73.6	Pk	9.8	0.0	-50.1	25.6	75.7	loop normal, noise
10	670.8	Loop	V	-77.8	Pk	9.8	0.0	-54.3	25.6	79.9	loop planar, noise
11	804.9	Loop	V	-56.8	Pk	9.8	0.0	-33.3	25.6	58.9	loop normal, rf background
12	804.9	Loop	V	-61.4	Pk	9.8	0.0	-37.9	25.6	63.5	loop planar, rf background
13	939.1	Loop	V	-82.7	Pk	9.8	0.0	-59.2	25.6	84.8	loop normal
14	939.1	Loop	V	-82.9	Pk	9.8	0.0	-59.4	25.6	85.0	loop planar
15	1073.2	Loop	V	-83.2	Pk	9.8	0.0	-59.7	25.6	85.3	loop normal
16	1073.2	Loop	V	-77.9	Pk	9.8	0.0	-54.4	25.6	80.0	loop planar
17	1207.4	Loop	V	-50.1	Pk	9.8	0.0	-26.6	25.6	52.2	loop normal, rf background
18	1207.4	Loop	V	-49.9	Pk	9.8	0.0	-26.4	25.6	52.0	loop planar, rf background
19	1341.5	Loop	V	-68.2	Pk	9.8	0.0	-44.7	25.6	70.3	loop normal, noise
20	1341.5	Loop	V	-74.3	Pk	9.8	0.0	-50.8	25.6	76.4	loop plana, noise

* The averaging factor is -3.2 dB; data is extrapolated to 300m distance;
1 kHz RBW used in the measurements

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
		Meets class B limit by more than 20dB									

Conducted Emissions

#	Freq. MHz	Line Side	Det. Used	Vtest dBµV	Vlim dBµV	Pass dB	Comments
1							
2		Not applicable					
3							

Meas. 03/12/02; U of Mich.

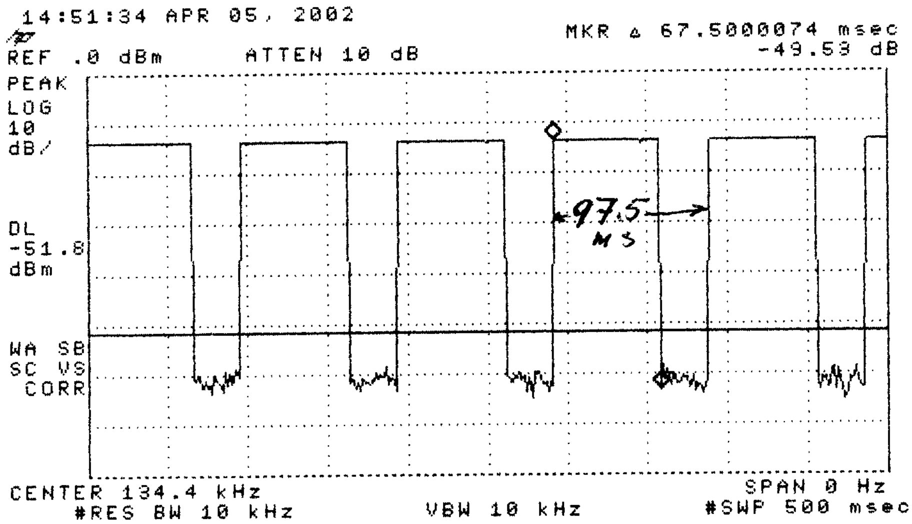

Figure 6.1. Transmission modulation characteristics.

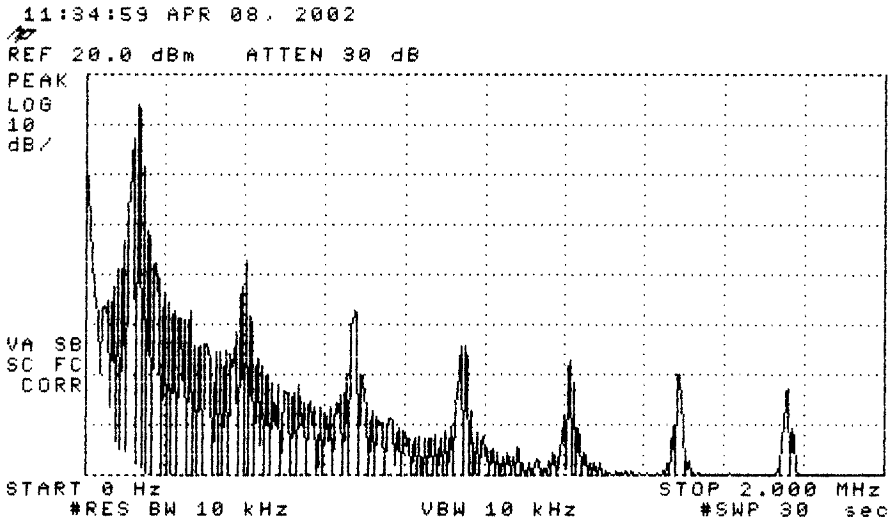

Figure 6.2. Emission spectrum of the DUT.
The amplitudes are only indicative (not calibrated).

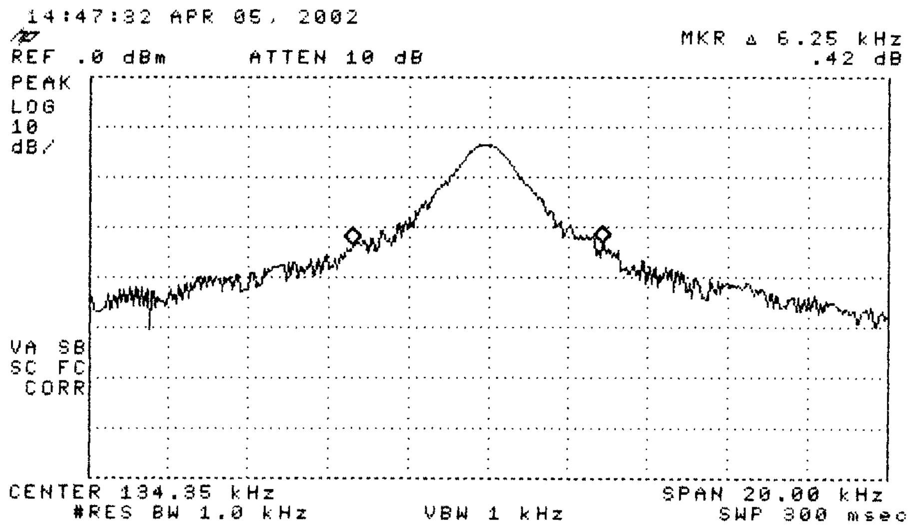

Figure 6.3. Measured bandwidth of the DUT (pulsed).

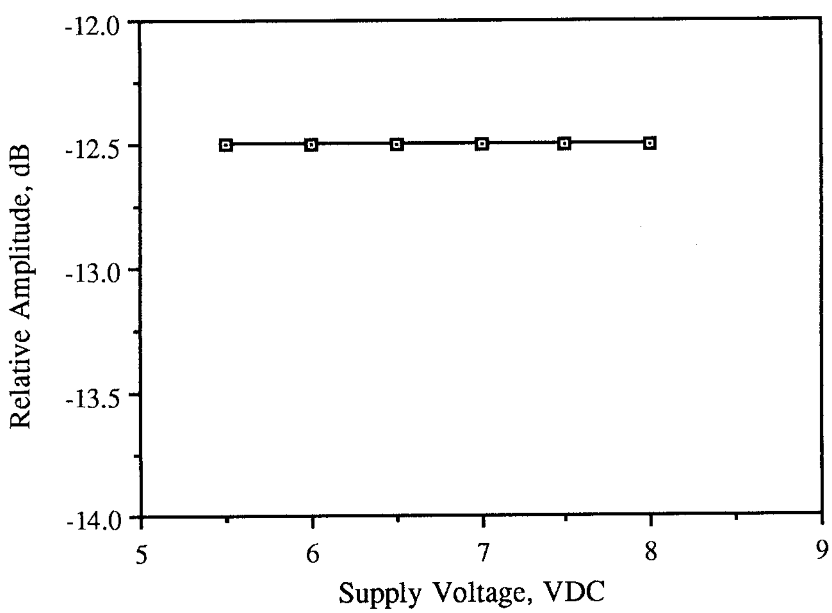

Figure 6.4. Relative emission at 134 kHz vs. supply voltage.

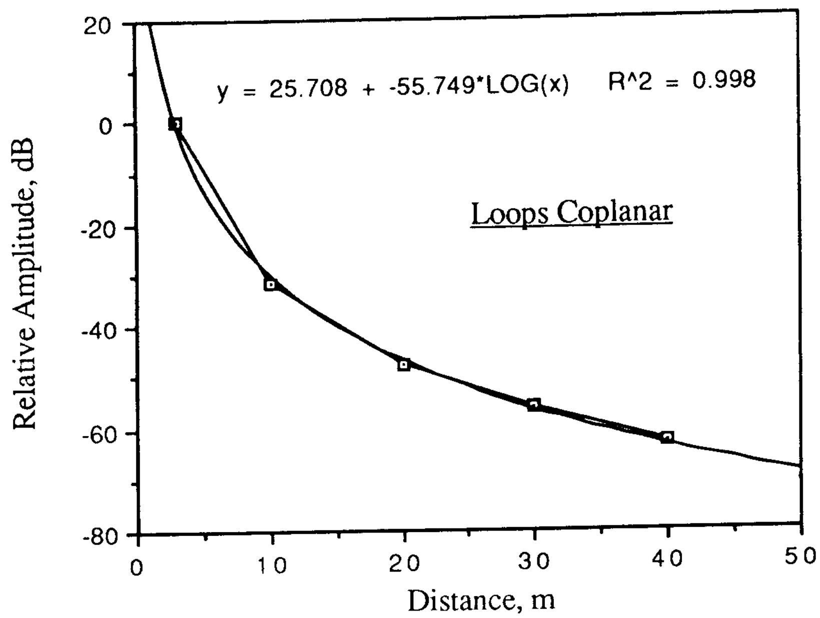

Figure 6.5. Field attenuation for case of coplanar loops.

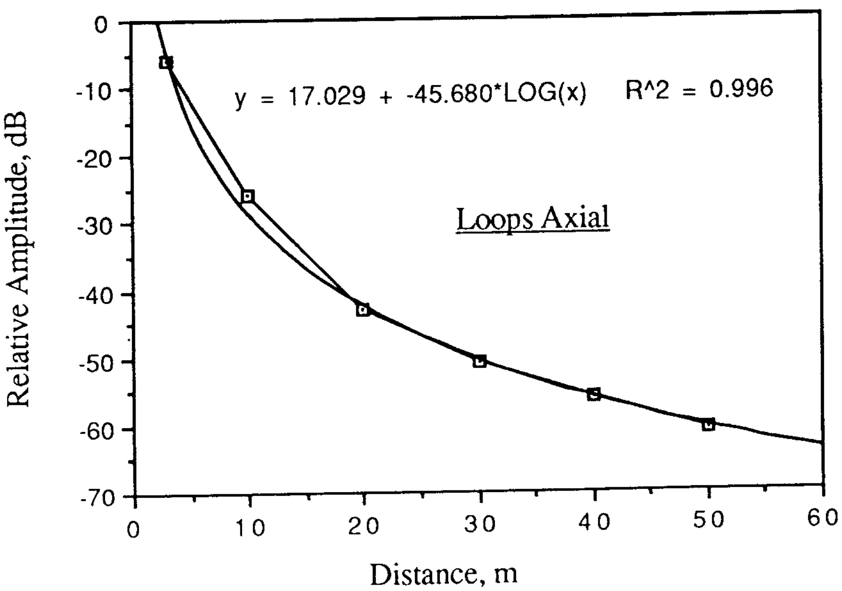

Figure 6.6. Field attenuation for case of axial loops.

DMT 32 (TIRIS) – DUT on OATS

DMT 32 (TIRIS) – DUT up close