The University of Michigan
Radiation Laboratory
3228 EECS Building
Ann Arbor, MI 48109-2122
Tel: (734) 747-1792

Measured Radio Frequency Emissions
From

Delco 2000 Passkey-III Reader/Exciter P/N: 16266469 P/N: 9353715

Report No. 415031-938
June 30, 1998

For:
Delco Electronics Corporation
One Corporate Center
Mail Stop S119
P.O. Box 9005
Kokomo, IN 46904-9005

Contact:
Kevin D. Davis
Tel: (765) 451-7551
Fax: (765) 451-7499
PO: EKS70940

Measurements made by: Glenn Thibodeau

Tests supervised by:
Report approved by: Valdis V. Liepa
Research Scientist

Summary

Tests for compliance with FCC Regulations subject to Part 15, Subpart C, were performed on Delco 2000 Passkey-III Immobilizer. This device is subject to rules and regulations as a transmitter. As a digital device it is exempt, but measurements were made nevertheless to assess the device's overall emissions.

In testing performed on June 16, 1998, the device tested in the worst case met the allowed specifications for transmitter radiated emissions by 41.3 dB (see p. 6).

The conductive emission tests do not apply, since the device is powered from an automobile 12V system.

1. Introduction

Delco 2000 Immobilizer was tested for compliance with FCC Regulations, Part 15, adopted under Docket 87-389, April 18, 1989. 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 attenuation characteristics of the Open Site facility are on file with FCC Laboratory, Columbia, Maryland. (FCC file 31040/SIT)

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 (9 kHz-22 GHz)	X	Hewlett-Packard 8593A SN: 3107A01358	July 1997/HP
Spectrum Analyzer (9 kHz-26 GHz)		Hewlett-Packard 8593E SN: 3107A01131	June1997/HP
Spectrum Analyzer (0.1-1500 MHz)	X	Hewlett-Packard 182T/8558B SN: 1529A01114/543592	August 1996/U of M Rad Lab
Preamplifier (5-1000 MHz)	X	Watkins-Johnson A11 -1 plus A25-1S	May 1997/U of M Rad Lab
Preamplifier (5-4000 MHz)		Avantek	Nov. 1992/ U of M Rad Lab
Power Meter		Hewlett-Packard 432A	August 1989/U of M Rad Lab
w/ Thermistor		Hewlett-Packard 478A	August 1989/U of M Rad Lab
Broadband Bicone (20-200 MHz)	X	University of Michigan	July 1988/U of M Rad Lab
Broadband Bicone (200-1000 MHz)	X	University of Michigan	June 1996/U of M Rad Lab
Dipole Antenna Set (25-1000 MHz)		University of Michigan	June 1996/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 (0.090-30 MHz)	X	EMCO 6502 SN: 2855	December 1993/EMCO
Active Rod (30 Hz-50 MHz)		EMCO 3301B SN: 3223	December 1993/EMCO
Ridge-horn Antenna (0.5-5 GHz)		University of Michigan	February 1991/U of M Rad Lab
LISN Box		University of Michigan	May 1997/U of M Rad Lab
Signal Cables	X	Assorted	March 1997/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
EMI/Fld Int. Meter (30-1000 MHz)		Stoddard NM-37/57A SN: 0606-80119	August 1989/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 car security system that electronically identifies the "real" ignition key for the car. The system consists of a T/R module, a coupling coil (antenna), a metal lock housing, and a passive transponder in the key. The operating frequency is 131.0 kHz. The clock for digital circuitry is 4.19 MHz, to which RF is also referenced. The transponder in the key is considered passive because it uses the energy supplied by the transmitter coil to operate its micro and, hence, is not subject to the rules. A three meter, three wire (B+, data, gnd), generic harness was used in testing; power was supplied from 13.8 VDC power supply and the digital line was left open.

The DUT was designed and manufactured by Delco Electronics Kokomo. It is identified as:

Delco 2000 Passkey-III Reader/Exciter
PN: 16255451
SN: 46981590003
FCC ID: L2C0003TR
CANADA:

The P/N: 16266469 was the device tested. The P/N: 9353715 is an identical device but with a harness length of 700-710 mm instead of 520-530 mm. Because the DUT harness is a part of the length of the test harness, the longer harness will have no effect on the results obtained. Hence, both devices are covered by these tests.

3.1 EMI Relevant Modifications

None.

4. Emission Limits

4.1 Radiated Emission Limits

The DUT tested falls under the category of a transmitter, subject to 6.2.1. 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 (Ref: RSS-210; 6.2.1, 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 extrapolating to other distances, see Section 6.6.

Table 4.2. Radiated Emission Limits (Ref: 15.33, 15.35, 15.109) -- Digital.

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 from an automobile 12V 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 Figure 5.1. Using the loop antenna we studied emissions up to 2 MHz. The resolution and video bandwidths were 1 kHz. The 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. We also note that in scanning from 0.0 to 2.0 MHz there were no spurious emissions observed other than harmonics. It was sometimes difficult to separate the DUT emissions from the AM band.

5.2 Outdoor Measurements

After the chamber measurements, the emissions were measured on our outdoor 3-meter site. The DUT was laid on the turntable and the loop antenna was set at a 3 meter distance. Only the first (fundamental) harmonic could be seen. The resolution bandwidth used outdoors was 1 kHz.

See Section 6.6 for field extrapolation measurements 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

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

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 the DUT meets the limit by 41.3 dB.

6. Other Measurements and Computations

6.1 Correction For Pulse Operation
In normal application the transmitter is activated when a key is placed into the ignition. It then transmits continuous at 128.5 kHz. For such, the averaging factor or pulse operation correction factor is

$$K_E = 100 \text{ ms} / 100 \text{ ms} = 1.0 \text{ or } 0.0 \text{ dB}$$

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 950 Hz. We note that it is the spectrum analyzer IF bandwidth response, rather than the signal bandwidth.

6.4 Effect of Supply Voltage Variation
The DUT has been designed to be operated from an automobile 12VDC system. For this test, the relative power radiated was measured at the fundamental as the voltage was varied from 5.0 to 16.0 volts. The emission variation is shown in Figure 6.4.

6.5 Input Voltage and Current

V = 13.8 V

I = 167.3 mA

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:

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

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

Even though these measurements were made at 134 kHz and the current DUT operates at 128 kHz, the frequencies are sufficiently close to use the same field behavior profiles for extrapolating fields to other distances.

The University of Michigan
Radiation Laboratory
3228 EECS Building
Ann Arbor, MI 48109-2122
(734) 647-1792

Table 5.1 Highest Emissions Measured

Radiated Emissions											Delco 2000 Passkey III; 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	127.6	Loop	V	-42.5	Pk	9.9	0.0	-15.7	25.6	**41.3**	loop normal (axis in dir. of prop.)
2	127.6	Loop	V	-47.3	Pk	9.9	0.0	-42.8	25.6	68.4	loop planar (loop in dir. of prop.)
3	255.2	Loop	V	-71.1	Pk	9.8	0.0	-44.4	25.6	70.0	loop normal, noise floor
4	255.2	Loop	V	-71.8	Pk	9.8	0.0	-67.4	25.6	93.0	loop planar, noise floor
5	382.8	Loop	V	-75.5	Pk	9.8	0.0	-48.8	25.6	74.4	loop normal, noise floor
6	382.8	Loop	V	-76.9	Pk	9.8	0.0	-72.5	25.6	98.1	loop planar, noise floor
7	510.4	Loop	V	-76.5	Pk	9.8	0.0	-49.8	25.6	75.4	loop normal, noise floor
8	510.4	Loop	V	-77.2	Pk	9.8	0.0	-72.8	25.6	98.4	loop planar, noise floor
9	638.0	Loop	V	-63.0	Pk	9.8	0.0	-36.3	25.6	61.9	loop normal, noise floor
10	638.0	Loop	V	-72.5	Pk	9.8	0.0	-68.1	25.6	93.7	loop planar, noise floor
		All other harmonics are in the noise (Pr < -63 dBm)									
		* The averaging factor is 0 dB; data is extrapolated to 300m									
		1 kHz RBW used in measurements									

Digital Emissions									Class B Limits		
#	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	87.0	Bic	H	-72.0	Pk	11.4	24.4	22.0	40.0	18.0	
2	87.0	Bic	V	-68.0	Pk	11.4	24.4	26.0	40.0	14.0	
3	166.3	Bic	H	-78.0	Pk	15.3	23.3	21.0	43.5	22.5	
4	174.2	Bic	H	-77.0	Pk	15.5	23.2	22.3	43.5	21.2	
5											
6											
7											
8											
9											
10											
11											

Conducted Emissions							
#	Freq. MHz	Line Side	Det. Used	Vtest dBμV	Vlim dBμV	Pass dB	Comments
		Not Applicable					

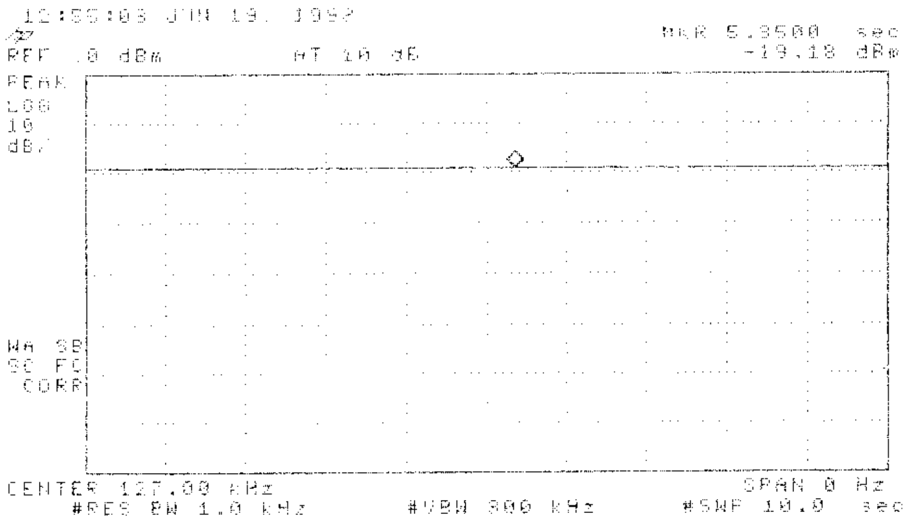

Figure 6.1. Transmissions modulation characteristics. Transmission is continuous.

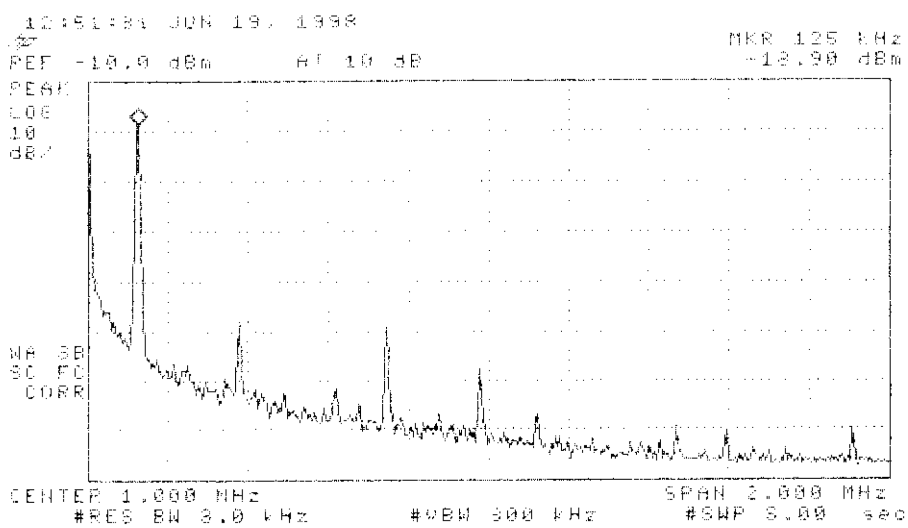

Figure 6.2. Emission spectrum of the DUT.
The amplitudes are only indicative (not calibrated).

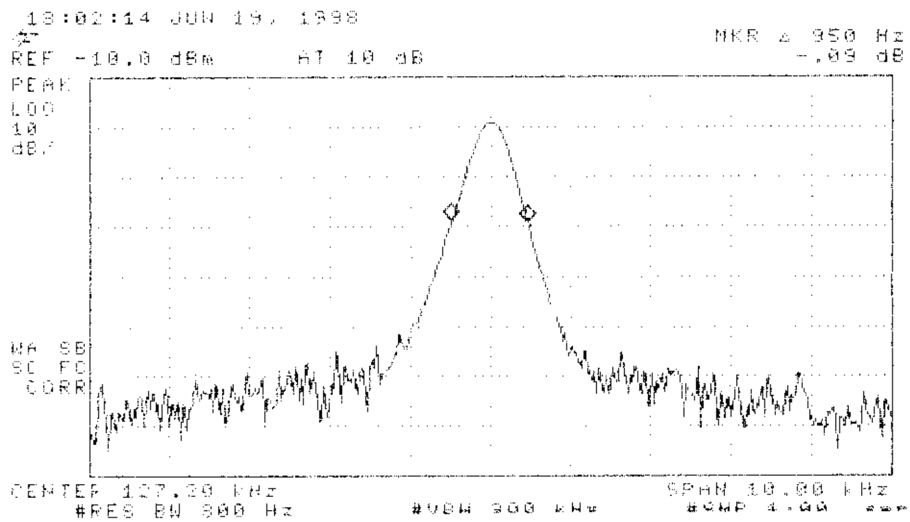

Figure 6.3. Measured bandwidth of the DUT.

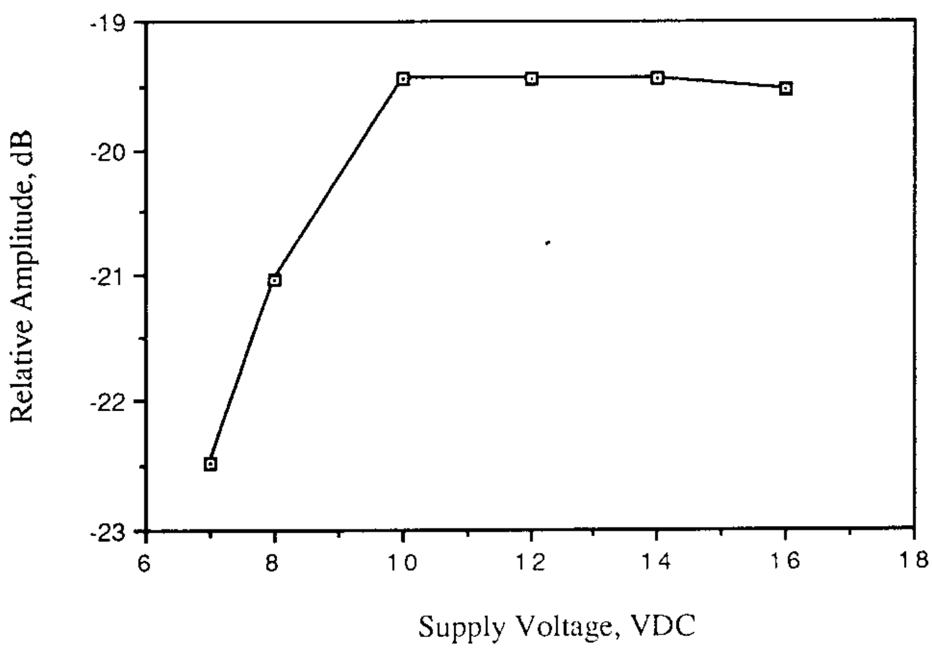

Figure 6.4. Relative emission at 131 kHz vs. supply voltage.

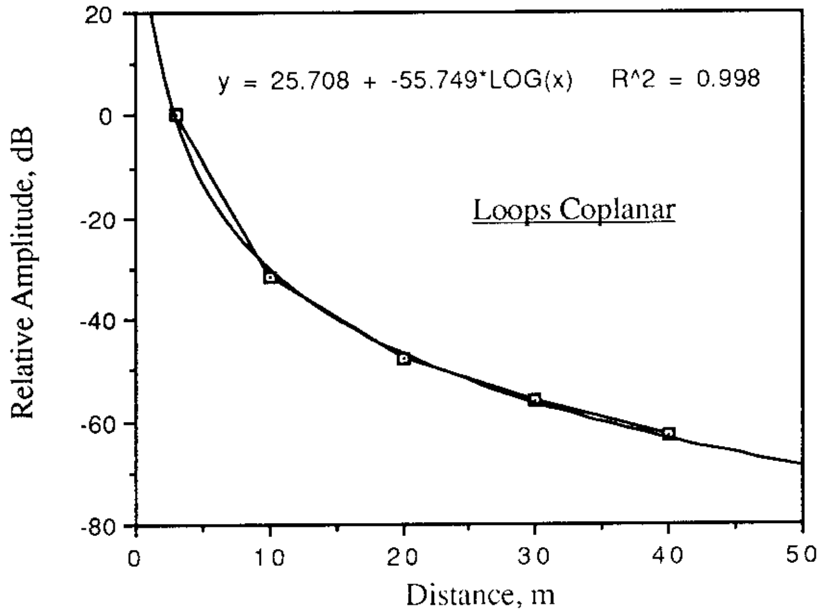

Figure 6.5. Field attenuation for case of coplanar loops.

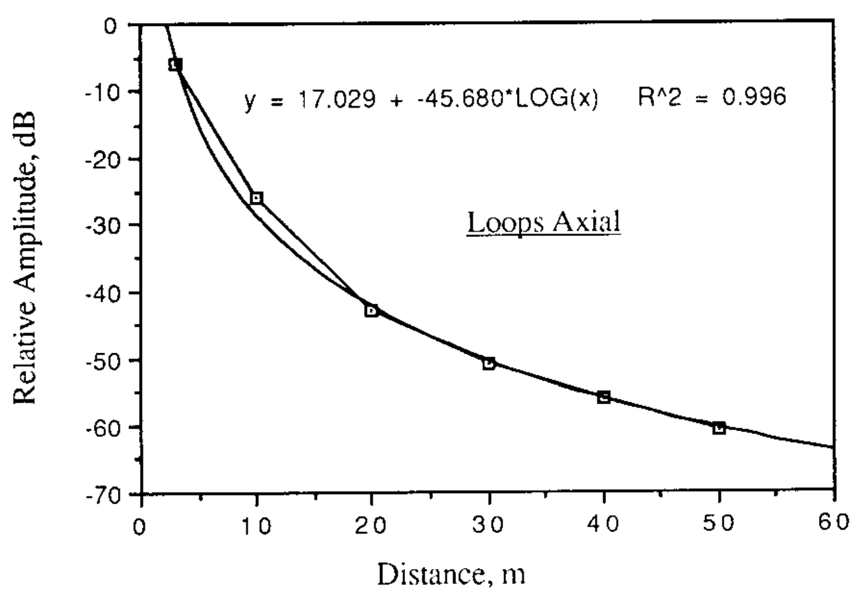

Figure 6.6. Field attenuation for case of axial loops.

The University of Michigan
Radiation Laboratory
3228 EECS Building
Ann Arbor, MI 48109-2122
Tel: (734) 747-1792

Measured Radio Frequency Emissions
From

**Delco 2000 Passkey-III
Reader/Exciter
P/N: 9352359**

Report No. 415031-940
June 30, 1998

For:
Delco Electronics Corporation
One Corporate Center
Mail Stop S119
P.O. Box 9005
Kokomo, IN 46904-9005

Contact:
Kevin D. Davis
Tel: (765) 451-7551
Fax: (765) 451-7499
PO: EKS70753

Measurements made by: Glenn Thibodeau

Tests supervised by:
Report approved by:
Valdis V. Liepa
Research Scientist

Summary

Tests for compliance with FCC Regulations subject to Part 15, Subpart C, were performed on Delco 2000 Passkey-III Immobilizer. This device is subject to rules and regulations as a transmitter. As a digital device it is exempt, but measurements were made nevertheless to assess the device's overall emissions.

In testing performed on June 16, 1998, the device tested in the worst case met the allowed specifications for transmitter radiated emissions by 42.2 dB (see p. 6).

The conductive emission tests do not apply, since the device is powered from an automobile 12V system.

1. Introduction

Delco 2000 Immobilizer was tested for compliance with FCC Regulations, Part 15, adopted under Docket 87-389, April 18, 1989. 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 attenuation characteristics of the Open Site facility are on file with FCC Laboratory, Columbia, Maryland. (FCC file 31040/SIT)

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 (9 kHz-22 GHz)	X	Hewlett-Packard 8593A SN: 3107A01358	July 1997/HP
Spectrum Analyzer (9 kHz-26 GHz)		Hewlett-Packard 8593E SN: 3107A01131	June1997/HP
Spectrum Analyzer (0.1-1500 MHz)	X	Hewlett-Packard 182T/8558B SN: 1529A01114/543592	August 1996/U of M Rad Lab
Preamplifier (5-1000 MHz)	X	Watkins-Johnson A11 -1 plus A25-1S	May 1997/U of M Rad Lab
Preamplifier (5-4000 MHz)		Avantek	Nov. 1992/ U of M Rad Lab
Power Meter		Hewlett-Packard 432A	August 1989/U of M Rad Lab
w/ Thermistor		Hewlett-Packard 478A	August 1989/U of M Rad Lab
Broadband Bicone (20-200 MHz)	X	University of Michigan	July 1988/U of M Rad Lab
Broadband Bicone (200-1000 MHz)	X	University of Michigan	June 1996/U of M Rad Lab
Dipole Antenna Set (25-1000 MHz)		University of Michigan	June 1996/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 (0.090-30 MHz)	X	EMCO 6502 SN: 2855	December 1993/EMCO
Active Rod (30 Hz-50 MHz)		EMCO 3301B SN: 3223	December 1993/EMCO
Ridge-horn Antenna (0.5-5 GHz)		University of Michigan	February 1991/U of M Rad Lab
LISN Box		University of Michigan	May 1997/U of M Rad Lab
Signal Cables	X	Assorted	March 1997/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
EMI/Fld Int. Meter (30-1000 MHz)		Stoddard NM-37/57A SN: 0606-80119	August 1989/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 car security system that electronically identifies the "real" ignition key for the car. The system consists of a T/R module, a coupling coil (antenna), a plastic lock housing, and a passive transponder in the key. The operating frequency is 131.0 kHz. The clock for digital circuitry is 4.19 MHz, to which RF is also referenced. The transponder in the key is considered passive because it uses the energy supplied by the transmitter coil to operate its micro and, hence, is not subject to the rules. A three meter, three wire (B+, data, gnd), generic harness was used in testing; power was supplied from 13.8 VDC power supply and the digital line was left open.

The DUT was designed and manufactured by Delco Electronics Kokomo. It is identified as:

Delco 2000 Passkey-III Reader/Exciter
PN: 9352359
SN: 35981590001
FCC ID: L2C0003TR
CANADA:

3.1 EMI Relevant Modifications

None.

4. Emission Limits

4.1 Radiated Emission Limits

The DUT tested falls under the category of a transmitter, subject to 6.2.1. 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 (Ref: RSS-210; 6.2.1, 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 extrapolating to other distances, see Section 6.6.

Table 4.2. Radiated Emission Limits (Ref: 15.33, 15.35, 15.109) -- Digital.

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 from an automobile 12V 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 Figure 5.1. Using the loop antenna we studied emissions up to 2 MHz. The resolution and video bandwidths were 1 kHz. The 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. We also note that in scanning from 0.0 to 2.0 MHz there were no spurious emissions observed other than harmonics. It was sometimes difficult to separate the DUT emissions from the AM band.

5.2 Outdoor Measurements

After the chamber measurements, the emissions were measured on our outdoor 3-meter site. The DUT was laid on the turntable and the loop antenna was set at a 3 meter distance. Only the first (fundamental) harmonic could be seen. The resolution bandwidth used outdoors was 1 kHz.

See Section 6.6 for field extrapolation measurements 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

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

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 the DUT meets the limit by 42.2 dB.

6. Other Measurements and Computations

6.1 Correction For Pulse Operation

In normal application the transmitter is activated when a key is placed into the ignition. It then transmits continuous at 128.5 kHz. For such, the averaging factor or pulse operation correction factor is

$$K_E = 100 \text{ ms} / 100 \text{ ms} = 1.0 \text{ or } 0.0 \text{ dB}$$

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 950 Hz. We note that it is the spectrum analyzer IF bandwidth response, rather than the signal bandwidth.

6.4 Effect of Supply Voltage Variation

The DUT has been designed to be operated from an automobile 12VDC system. For this test, the relative power radiated was measured at the fundamental as the voltage was varied from 5.0 to 16.0 volts. The emission variation is shown in Figure 6.4.

6.5 Input Voltage and Current

V = 13.8 V

I = 149.3 mA

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:

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

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

Even though these measurements were made at 134 kHz and the current DUT operates at 128 kHz, the frequencies are sufficiently close to use the same field behavior profiles for extrapolating fields to other distances.

The University of Michigan
Radiation Laboratory
3228 EECS Building
Ann Arbor, MI 48109-2122
(734) 647-1792

Table 5.1 Highest Emissions Measured

Radiated Emissions — Delco 2000 Passkey III; 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	135.6	Loop	V	-43.4	Pk	9.9	0.0	-16.6	25.6	**42.2**	loop normal (axis in dir. of prop.)
2	135.6	Loop	V	-48.2	Pk	9.9	0.0	-43.7	25.6	69.3	loop planar (loop in dir. of prop.)
3	271.2	Loop	V	-62.0	Pk	9.8	0.0	-35.3	25.6	60.9	loop normal, noise floor
4	271.2	Loop	V	-64.6	Pk	9.8	0.0	-60.2	25.6	85.8	loop planar, noise floor
5	406.8	Loop	V	-68.2	Pk	9.8	0.0	-41.5	25.6	67.1	loop normal, noise floor
6	406.8	Loop	V	-74.3	Pk	9.8	0.0	-69.9	25.6	95.5	loop planar, noise floor
7	542.4	Loop	V	-65.5	Pk	9.8	0.0	-38.8	25.6	64.4	loop normal, noise floor
8	542.4	Loop	V	-67.7	Pk	9.8	0.0	-63.3	25.6	88.9	loop planar, noise floor
9	678.0	Loop	V	-72.3	Pk	9.8	0.0	-45.6	25.6	71.2	loop normal, noise floor
10	678.0	Loop	V	-77.6	Pk	9.8	0.0	-73.2	25.6	98.8	loop planar, noise floor
		All other harmonics are in the noise (Pr < -62 dBm)									
		* The averaging factor is 0 dB; data is extrapolated to 300m									
		1 kHz RBW used in measurements									

Digital Emissions — Class B Limits

#	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	116.0	Bic	H	-71.0	Pk	13.4	24.0	25.4	43.5	18.1	
2	116.0	Bic	V	-73.0	Pk	13.4	24.0	23.4	43.5	20.1	
3											
4											
5											
6											
7											
8											
9											
10											
11											

Conducted Emissions

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

Meas.6/16/98; U of Mich.

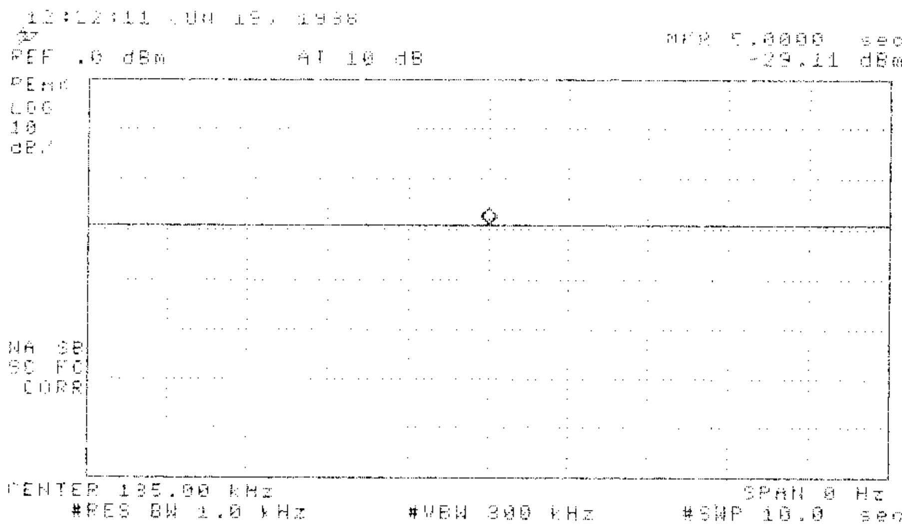

Figure 6.1. Transmissions modulation characteristics. Transmission is continuous.

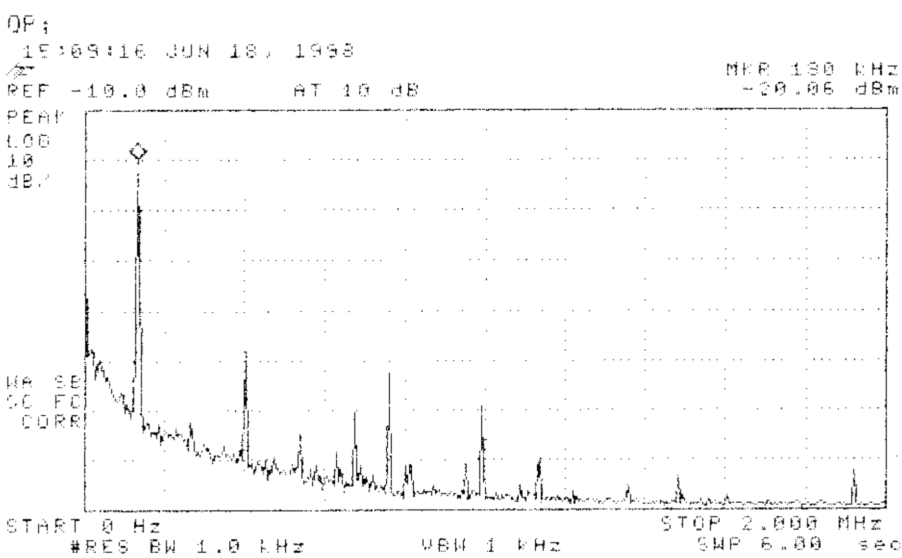

Figure 6.2. Emission spectrum of the DUT.
The amplitudes are only indicative (not calibrated).

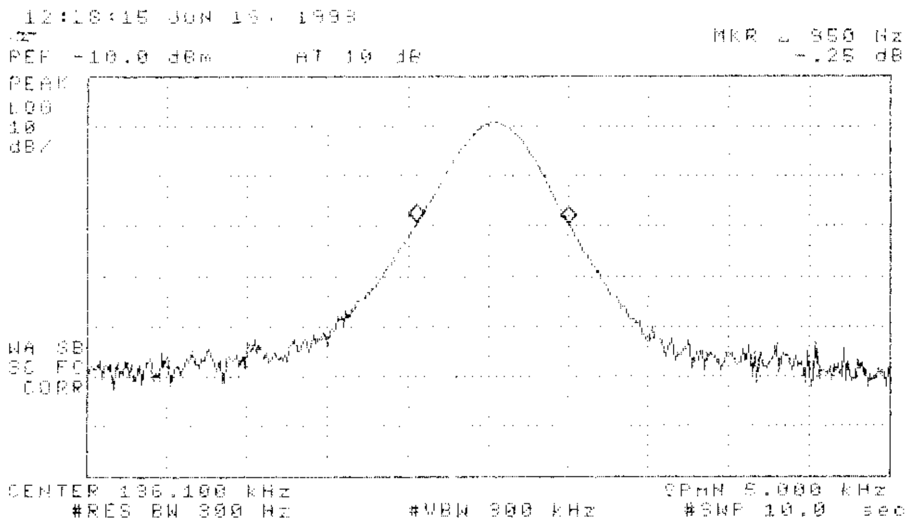

Figure 6.3. Measured bandwidth of the DUT.

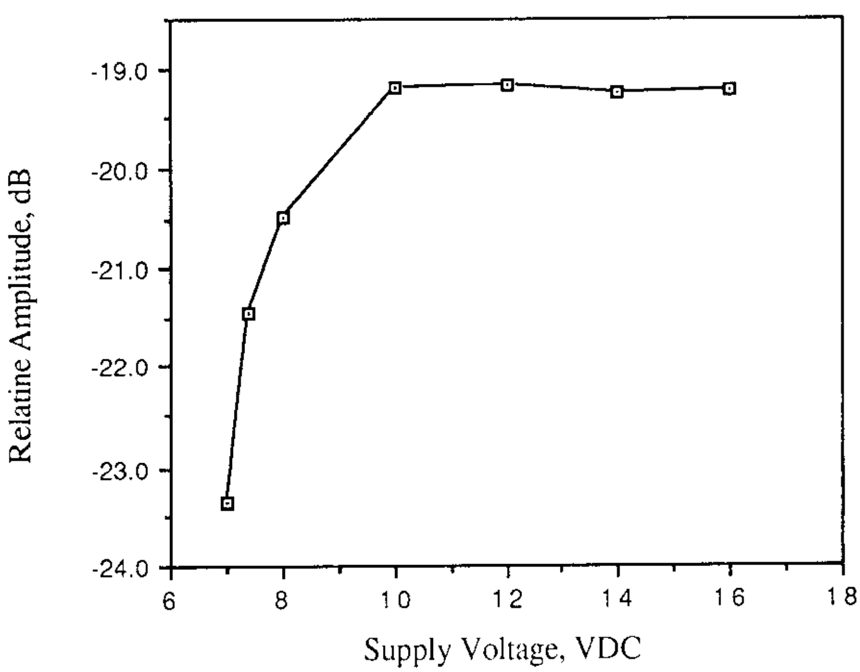

Figure 6.4. Relative emission at 131kHz vs. supply voltage.

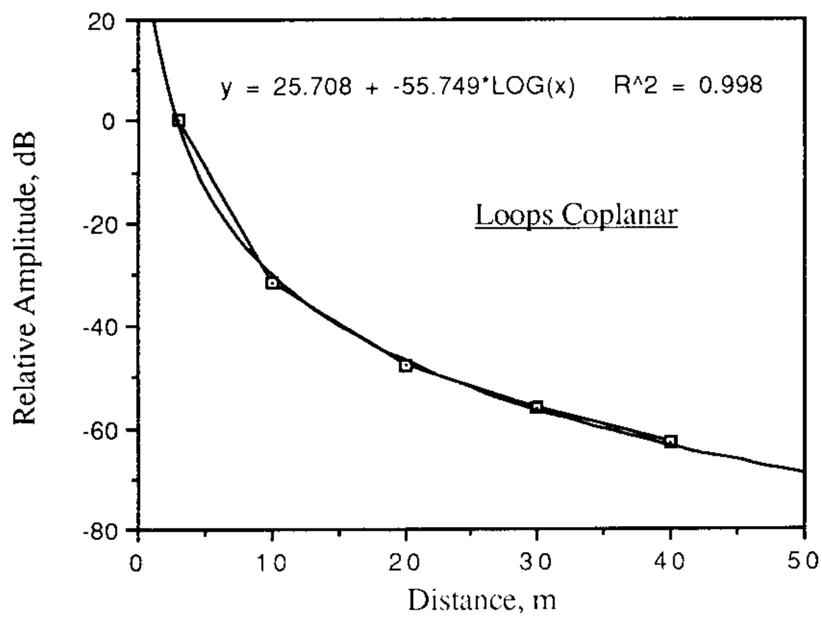

Figure 6.5. Field attenuation for case of coplanar loops.

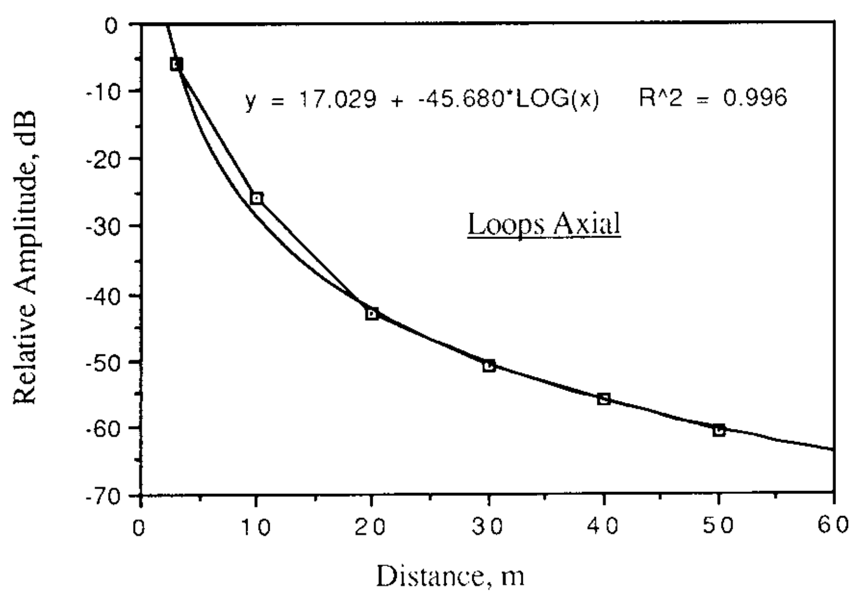

Figure 6.6. Field attenuation for case of axial loops.

Re: 2000 PassKey III Modules

The 2000 PassKey III system is a vehicle immobilization system. The system is intended to deter drive-away vehicle theft and also make the vehicle virtually impossible to "hot wire". The system consists of the PassKey controller, and a key mounted identification device (transponder/coded key) to determine if a valid driver is attempting to start the vehicle.

The system energizes and interrogates the unique security code from the transponder embedded in a key head. Key code received from the transponder is decoded and compared to key codes already learned by the system. If the coded key is valid, the PassKey III system sends a password to the powertrain controller via class II bus to indicate that fuel should be delivered to the engine. If a valid coded key is not detected, the PassKey III system will not send the password to the powertrain controller so that fuel will not be delivered to the engine.

The Reader/Exciter (R/E) circuit is a current-controlled oscillator activated with nominal frequency set to 131 kHz. The square wave signal generated by the oscillator is fed to a wave shaping stage and drives a series resonant RLC nominally tuned to 138.5kHz (with lock cylinder effect). The tuning caps differentiate between a zinc lock cylinder versus a plastic lock cylinder. The zinc tuned module (16266469) and the plastic tuned module (09352359) both utilize the same schematic.

- zinc lock cylinders have C20 installed and C18 & C19 deleted.
- plastic lock cylinders have C18 & C19 installed and C20 deleted.

EXHIBIT F
Page 1 of 1
U of Mich file 415031-238