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

Measured Radio Frequency Emissions From

Delphi-Delco Audi A4 Immobilizer Model: VW A4 KOMBI

Report No. 415031-077
March 12, 2001

Copywrite © 2001

For:
Delphi-Delco Electronics Systems
One Corporate Center
Kokomo, IN 46904-9005

PO: verbal/Bill Lusa, Defiance

Contact:
Steve Miller
Tel: 810-257-8129
Fax: 810-257-6673

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 Delphi-Delco Immobilizer. This device is subject to Rules and Regulations as a transmitter, but such measurements were made to access the device's overall emissions.

In testing performed February 6 and 18, 2001, the device tested in the worst case met the allowed specifications for transmitter radiated emissions by 45.0 dB (see p. 6); the digital emission, Class B, were met by at least 20 dB.

The conductive emission tests do not apply, since the device is powered from an automotive 12 VDC battery.

1. Introduction

Delphi-Delco Immobilizer was 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 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	Equipment Used	Manufacturer/Model	Cal. Date/By
Spectrum Analyzer (9kHz-22GHz)	X	Hewlett-Packard 8593A SN: 3107A01358	December 2000/UM
Spectrum Analyzer (9kHz-26GHz)	X	Hewlett-Packard 8593E SN: 3107A01131	December 2000/HP
Spectrum Analyzer (0.1-1500 MHz)		Hewlett-Packard 182T/8558B SN: 1529A01114/543592	December 2000/UM
Preamplifier (5-1000MHz)	X	Watkins-Johnson A11 -1 plus A25-1S	December 2000/UM
Preamplifier (5-4000 MHz)		Avantek	Oct. 1999/ U of M Rad Lab
Broadband Bicone (20-200 MHz)	X	University of Michigan	June 1999/U of M Rad Lab
Broadband Bicone (200-1000 MHz)	X	University of Michigan	June 1999/U of M Rad Lab
Dipole Antenna Set (25-1000 MHz)		University of Michigan	June 2000/UM
Dipole Antenna Set (30-1000 MHz)		EMCO 3121C SN: 992	June 2000/UM
Active Loop Antenna (0.090-30MHz)	X	EMCO 6502 SN: 2855	December 1999/UM
Active Rod (30Hz-50 MHz)		EMCO 3301B SN: 3223	December 1999/UM
Ridge-horn Antenna (0.5-5 GHz)		University of Michigan	March 1999/U of M Rad Lab
LISN Box		University of Michigan	Dec. 2000/U of M Rad Lab
Signal Generator (0.1-2060 MHz)		Hewlett-Packard 8657B	January 2000/Uof M Rad Lab

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 tested consisted of a T/R module located in an instrument panel, a coil T/R antenna , and a "passive" transponder imbedded in a key. The transponder in the key is considered passive because it uses only energy supplied by the transmitter coil to operate its micro and, hence, is not subject to the regulations. A two-meter cable was used to supply power to the instrument panel. The T/R coil with the key was on an 80 cm twisted pair line comming from the panel the panel. The power was supplied from 13.8 VDC laboratory power supply.

The DUT was designed and manufactured by Delphi-Delco. It is identified as:

Delphi-Delco Immobilizer
Model: VW A4 KOMBI
SN: 03210003
FCC ID: L2C0012TR
CANADA: to be provided by IC

One module was provided und used in the tests.

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 from an automobile 12VDC system.

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

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

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 45.0 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 when a key is placed into the ignition. When the ignition key is turned on, an interrogation pulse is sent out and if the key is responds with proper code, the immobilizer goes in sleep mode. The interrogation pulse is 210.0 ms long. See Figure 6.1. The averaging factor for such operation is

$$K_E = 100 \text{ ms} / 100 \text{ ms} = 1.00 \text{ or } 0.0 \text{ dB}$$

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 180 Hz and the center requency is about 125.08 kHz.

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 6.0 to 18.0 volts. The emission variation is shown in Figure 6.4.

6.5 Input Voltage and Current

V = 12.6 V

I = 1.1 A (CW 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

Delphi/Audi Immob; 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	125.3	Loop	V	-46.2	Pk	9.9	0.0	-19.4	25.6	45.0	loop normal (axis in dir. of prop.)
2	125.3	Loop	V	-50.0	Pk	9.9	0.0	-23.2	25.6	48.8	loop planar (loop in dir. of prop.)
3	250.6	Loop	V	-75.2	Pk	9.8	0.0	-48.5	25.6	74.1	loop normal, noise
4	250.6	Loop	V	-76.3	Pk	9.8	0.0	-49.6	25.6	75.2	loop planar, noise
5	379.9	Loop	V	-75.5	Pk	9.8	0.0	-48.8	25.6	74.4	loop normal, noise
6	379.9	Loop	V	-76.8	Pk	9.8	0.0	-50.1	25.6	75.7	loop planar, noise
7	501.2	Loop	V	-83.3	Pk	9.8	0.0	-56.6	25.6	82.2	loop normal, noise
8	501.2	Loop	V	-80.9	Pk	9.8	0.0	-54.2	25.6	79.8	loop planar, noise
9	626.5	Loop	V	-60.5	Pk	9.8	0.0	-33.8	25.6	59.4	loop normal, noise
10	626.5	Loop	V	-62.8	Pk	9.8	0.0	-36.1	25.6	61.7	loop planar, noise
		All other harmonics/orientations are in the noise (Pr < -70 dBm)									
		* The averaging factor is 0.0 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. 02/06/01, 02/18/01; U of Mich.

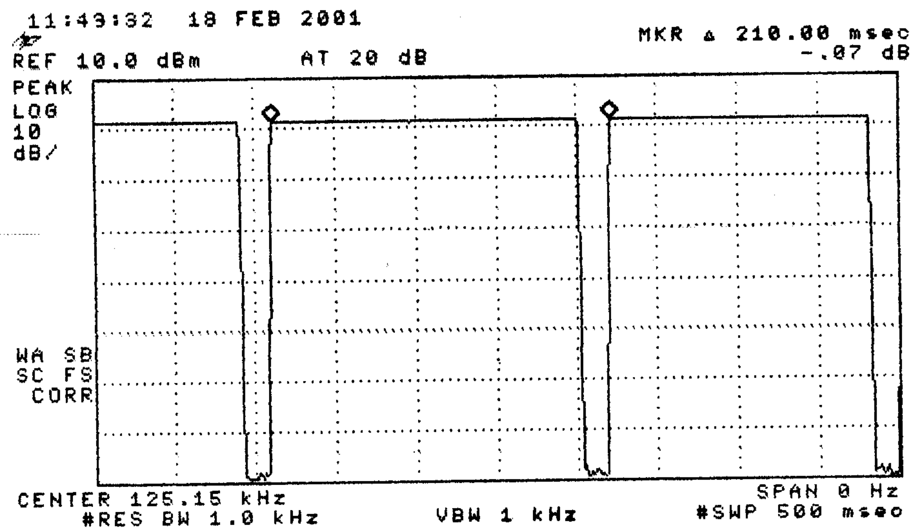

Figure 6.1. Transmission modulation characteristics.

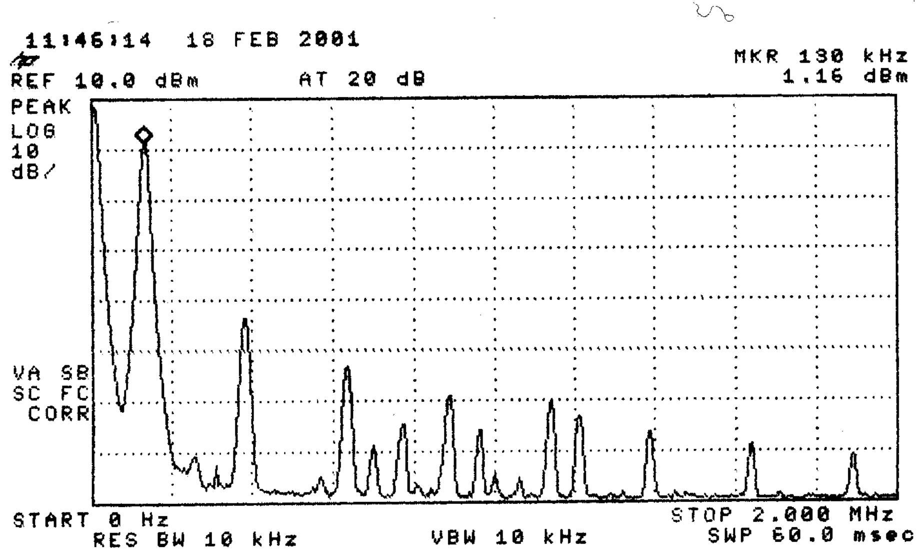

Figure 6.2. Emission spectrum of the DUT.
The amplitudes are only indicative (not calibrated).

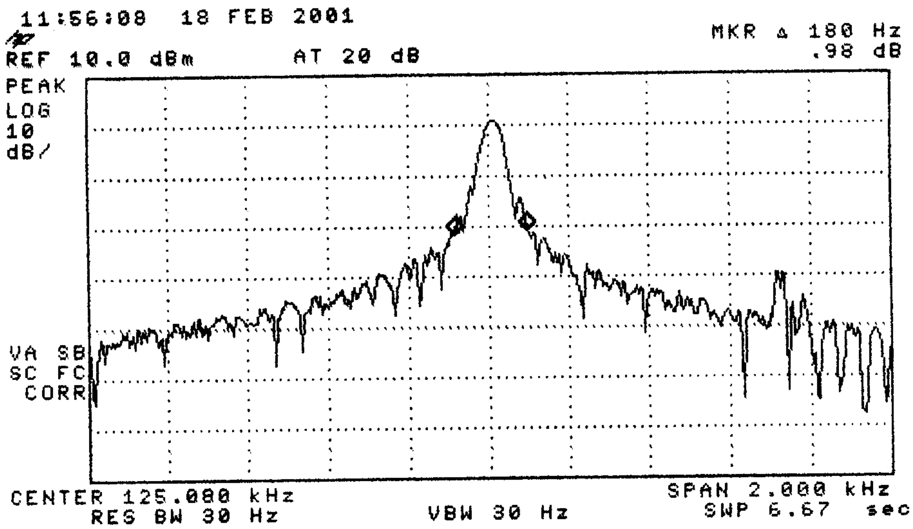

Figure 6.3. Measured bandwidth of the DUT. (pulsed)

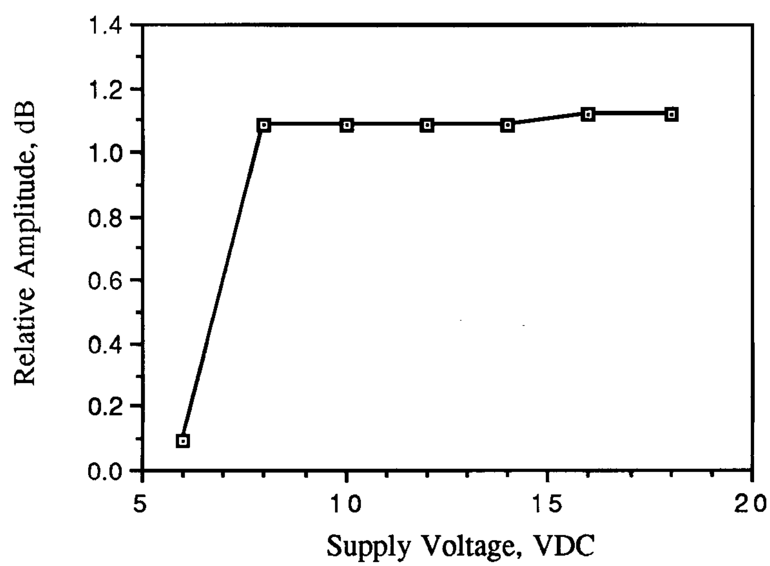

Figure 6.4. Relative emission at 125 kHz vs. supply voltage.

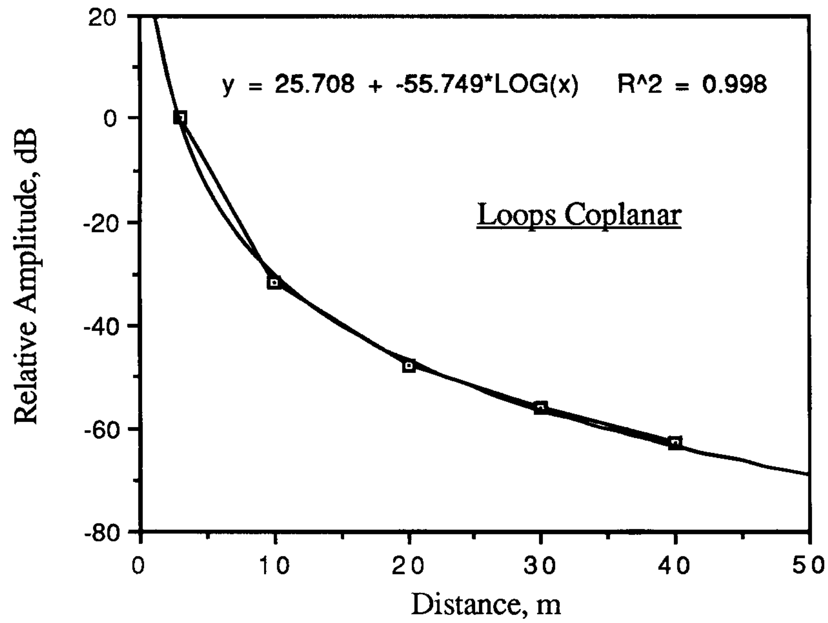

Figure 6.5. Field attenuation for case of coplanar loops.

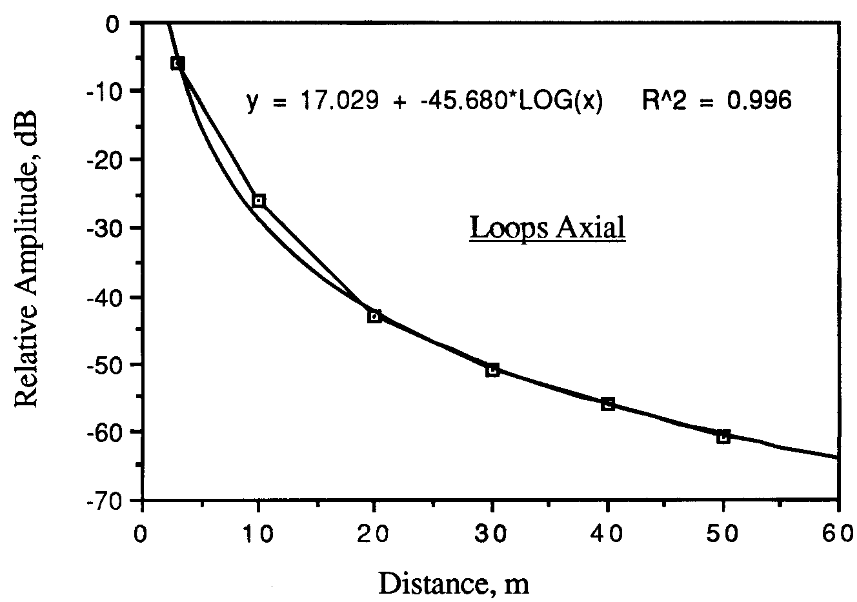

Figure 6.6. Field attenuation for case of axial loops.