

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

Measured Radio Frequency Emissions
From

**Lear Corporation Transmitter
PN(s): 6L2A-1A176, 7C2A-1A176**

Report No. 415031-236
February 16, 2005

Copyright © 2005

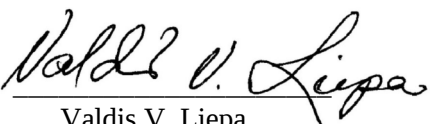
For:
Lear Corporation
5200 Auto Club Dr.
Dearborn, MI 48126-9982

Contact:
Tom Tang
Tel: (313) 593 - 9934
Fax: (313) 240 - 3062
PO: Verbal

Measurements made by:

Valdis V. Liepa

Tests supervised by:
Report approved by:


Valdis V. Liepa
Research Scientist

Summary

Tests for compliance with FCC Regulations Part 15, Subpart C, and Industry Canada RSS-210, were performed on Lear Corporation PN(s) 6L2A-1A176, 7C2A-1A176. This device is subject to the Rules and Regulations as a Transmitter.

In testing completed on February 15, 2005, the device tested in the worst case met the allowed FCC specifications for radiated emissions by 1.5 dB (see p. 6). Besides harmonics, there were no other significant spurious emissions found; emissions from digital circuitry were negligible. The conducted emission tests do not apply, since the device is powered from a 12 VDC battery.

1. Introduction

Lear Corporation PN(s) 6L2A-1A176, 7C2A-1A176 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, 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 pertinent test equipment commonly used in our facility for measurements is listed in Table 2.1 below. The middle column identifies the specific equipment used in these tests.

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 Millimeter 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)	X	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)		EMCO 6502, SN:2855
Ridge-horn Antenna (300-5000 MHz)	X	University of Michigan
Amplifier (5-1000 MHz)	X	Avantak, A11-1, A25-1S
Amplifier (5-4500 MHz)	X	Avantak
Amplifier (4.5-13 GHz)		Avantek, AFT-12665
Amplifier (6-16 GHz)		Trek
Amplifier (16-26 GHz)		Avantek
LISN Box		University of Michigan
Signal Generator		Hewlett-Packard 8657B

3. Configuration and Identification of Device Under Test

The DUT is a 315 MHz TPMS, Tire Pressure Monitor Sensor (transmitter), 1 x 0.25 x 3 inches in size. It operates at 315 MHz and the carrier can be both FSK and ASK modulated, depending on the mode of operation. The transmitter consists of an RF MMIC that is x-tal stabilized. The antenna is mounted on the PCB, internal to the case.

The DUT was designed and manufactured by Lear Corporation, 5200 Auto Club Dr., Dearborn, MI 48126-9982. It is identified as:

Lear Corporation Transmitter
PN(s): 6L2A-1A176, 7C2A-1A176
FCC ID: KOBFTD06A
IC: 3521A-FTD06A

There are two versions of the DUT, a high pressure (115 psi) version and low pressure (50 psi) version. The only difference between the two is the pressure sensors, having different calibration ranges. All other electronic components are identical. The transmitter section of the design is identical between the two different versions. The PCB, microprocessor and RF circuitry on both versions are identical. The two parts are differentiated by the following: housing color and part number, blue (6L2A-1A176) for 50 psi and green (7C2A-1A176) for 115 psi. The part numbers are laser etched onto the housing.

3.1 Modifications Made

There were no modifications made to the DUT by this laboratory.

4. 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.

4.1 Radiated Emission Limits

Table 4.1. 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)

Table 4.2. Radiated Emission Limits (FCC: 15.231(e), IC: RSS-210; 6.1, 6.3 Table 4).
(Data Transmission)

Frequency (MHz)	Fundamental Ave. E_{lim} (3m)		Spurious** Ave. E_{lim} (3m)	
	(μ V/m)	dB (μ V/m)	(μ V/m)	dB (μ V/m)
260.0-470.0	1500-5000*		150-500	
315.0	2418	67.7	241.8	47.7
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: $E = -2833.2 + 16.67 \cdot f$ (MHz)

** Measure up to tenth harmonic; 120 kHz RBW up to 1 GHz, 1 MHz RBW above 1 GHz

4.3 Conducted Emissions Limits

The conductive emission limits and tests do not apply here, since the DUT is powered by a 12 VDC battery.

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 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 Open Site Radiated Emission Tests

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 included in this filing show the DUT on the Open Area Test Site (OATS).

5.3 Computations and Results for Radiated Emissions

To convert the dBm's measured on the spectrum analyzer to dB(μ V/m), we use expression

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

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

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 1.5 dB.

5.4 Conducted Emission Tests

These tests do not apply, since the DUT is powered from a 12 VDC battery.

6. Other Measurements

6.1 Correction For Pulse Operation

When the transmitter is activated (either by LF pulse or motion), it can, in the worst case, transmit 9 pulses of Manchester encoded ASK data with a period of 61.0 ms, an on time of 8.3 ms, and a duty cycle of 51.2%, and/or transmit 4 FSK pulses with 107.5 ms period and an on time of 8.45 ms per period. See Figure 6.1. Computing the duty factor for both the ASK and FSK modulations results in

$$K_{E(\text{ASK})} = 0.512 * (2 * 8.3 \text{ ms}) / 100 \text{ ms} = 0.085 \text{ or } -21.4 \text{ dB.}$$
$$K_{E(\text{FSK})} = 8.45 \text{ ms} / 100 \text{ ms} = 0.085 \text{ or } -21.4 \text{ dB.}$$

Since no greater than 20 dB duty factor is allowed, $K_E = -20 \text{ dB}$ is used herein.

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 MHz, or 787.25 kHz. From the plot we see that the -20 dB bandwidth is 163.0 kHz, and the center frequency is 315 MHz.

6.4 Effect of Supply Voltage Variation

The DUT has been designed to be powered by 12 VDC 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 2 to 4 volts. The emission variation is shown in Figure 6.4.

6.5 Input Voltage at Battery Terminals

Batteries:	before testing	$V_{oc} =$	3.23 V
	after testing	$V_{oc} =$	3.03 V
Ave. current from batteries		$I =$	0.7 mA (pulsed)

Table 5.1 Highest Emissions Measured

Radiated Emission - RF										Lear/Ford TPM Tx; 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	315.0	Dip	H	-30.7	Pk	18.9	20.2	55.1	67.7	12.6	side
2	315.0	Dip	V	-32.9	Pk	18.9	20.2	52.9	67.7	14.8	flat
3	630.0	Dip	H	-63.2	Pk	25.2	16.8	32.2	47.7	15.5	side
4	630.0	Dip	V	-61.1	Pk	25.2	16.8	34.3	47.7	13.4	flat
5	945.0	Dip	H	-67.9	Pk	28.9	14.4	33.6	47.7	14.1	flat
6	945.0	Dip	V	-73.3	Pk	28.9	14.4	28.2	47.7	19.5	end
7	1260.0	Horn	H	-26.8	Pk	20.4	28.1	52.5	54.0	1.5	side
8	1575.0	Horn	H	-35.8	Pk	21.4	28.2	44.4	54.0	9.6	side
9	1890.0	Horn	H	-37.0	Pk	22.1	28.1	44.0	54.0	10.0	flat
10	2205.0	Horn	H	-48.9	Pk	22.9	27.0	34.0	54.0	20.0	flat
11	2520.0	Horn	H	-42.9	Pk	24.0	26.6	41.5	54.0	12.5	flat
12	2835.0	Horn	H	-41.0	Pk	24.9	25.4	45.5	54.0	8.5	flat
13	3150.0	Horn	H	-45.3	Pk	25.2	24.8	42.1	54.0	11.9	side
14											
15											
16	*includes -20.0 dB duty factor										
17											
18											
19											
20	Digital emissions > 20 dB below Class B limit										
21											
22											
23											
24											
25											
26											
27											
28											
29											
Conducted Emissions											
#	Freq. MHz	Line Side	Det. Used	Vtest dBµV	Vlim dBµV	Pass dB	Comments				
30											
31	Not applicable										
32											
33											
34											
35											
36											

Meas. 02/15/05; U of Mich.

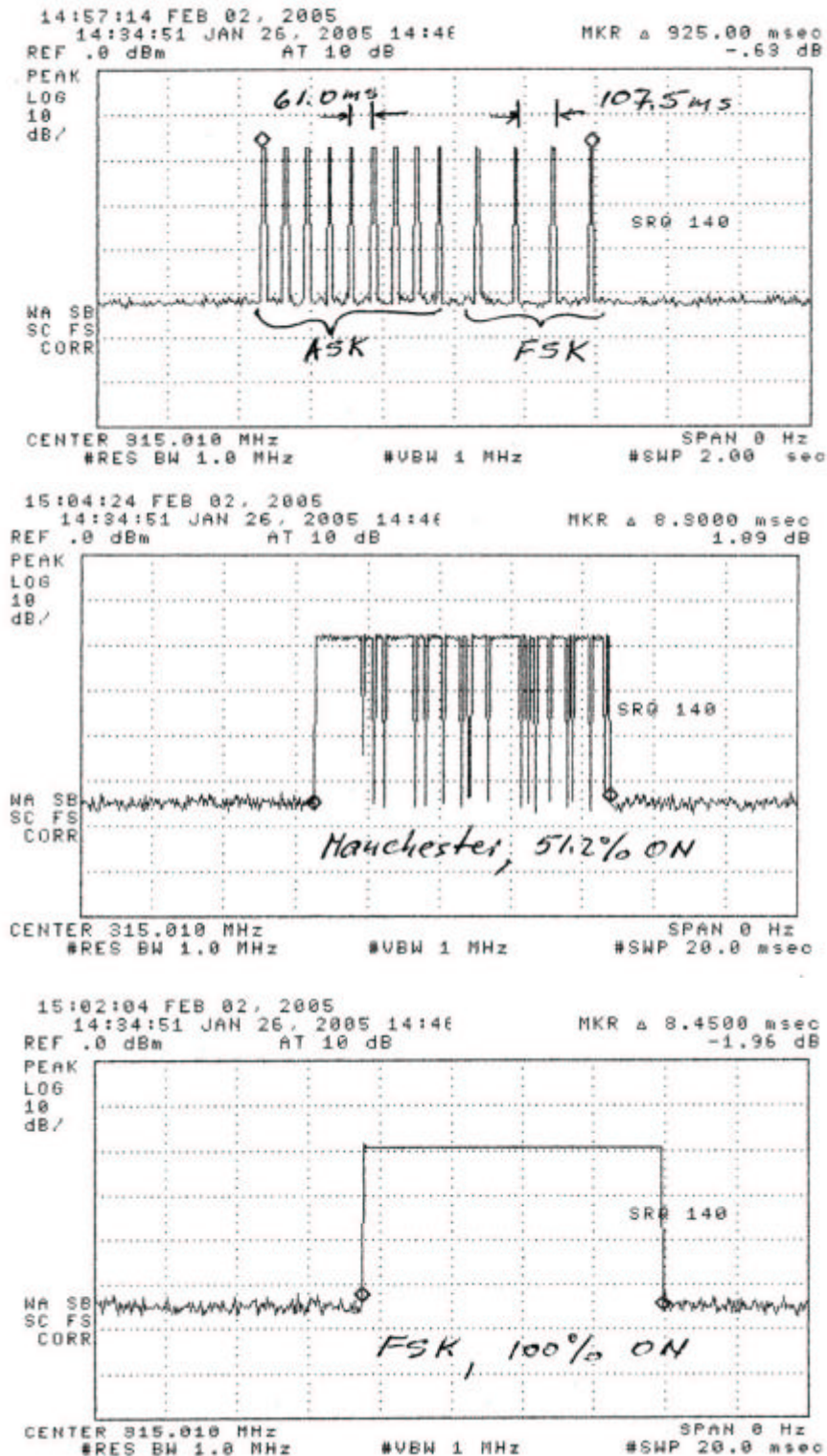


Figure 6.1. Transmissions modulation characteristics: (top) complete transmission, (center) expanded ASK, (bottom) expanded FSK.

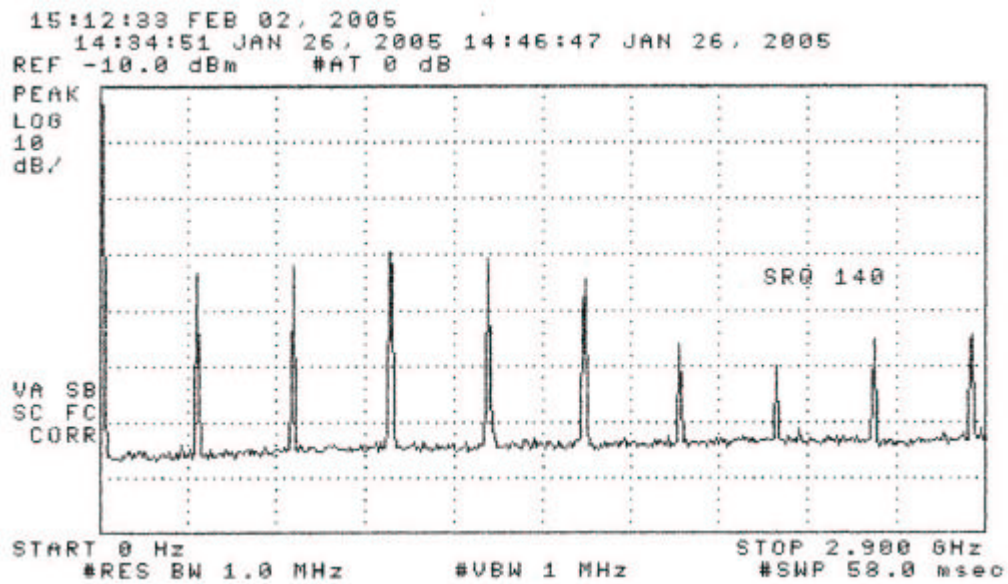


Figure 6.2. Emission spectrum of the DUT (pulsed emission).
 The amplitudes are only indicative (not calibrated).

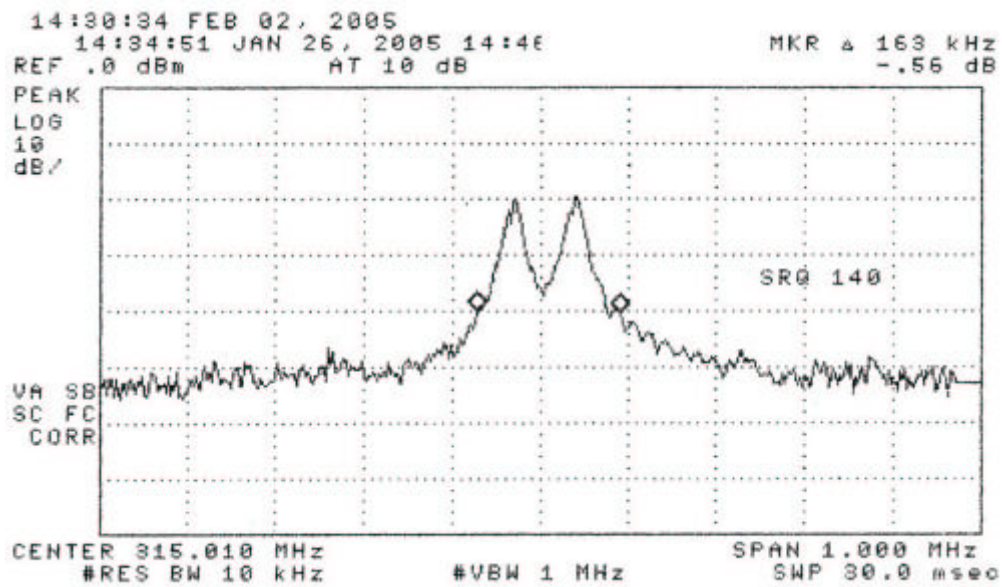


Figure 6.3. Measured bandwidth of the DUT (pulsed emission).

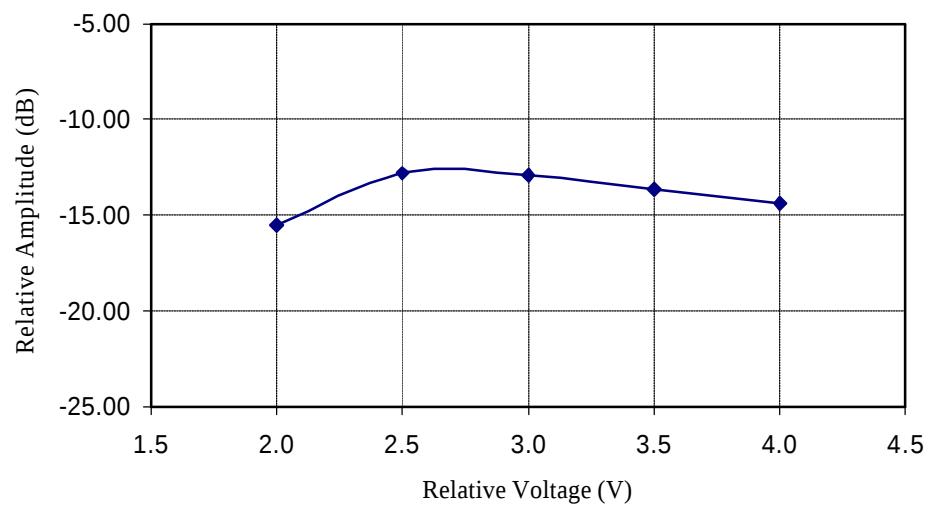


Figure 6.4. Relative emission at 315.0 MHz vs. supply voltage (pulsed emission).