

The University of Michigan
Radiation Laboratory
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Measured Radio Frequency Emissions
From

**Lear Receiver
Model RFA-C+**

Report No. 415031-023
December 28, 1999

For:
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Dearborn, Michigan 48126-9982

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Summary

Tests for compliance with FCC Regulations subject to Part 15, Subpart B, and with Industry Canada Regulations subject to RSS-210, were performed on Lear RKE Receiver, Model RFA-C+. This device is subject to FCC Rules and Regulations as a Receiver. As a Digital Device it is exempt, but such measurements were made to assess the receiver's overall emissions.

In testing performed on August 28 and December 28, 1999, the devices tested in the worst case met the allowed FCC (Class B) specifications for radiated emissions by 12.4 dB (see p. 6). The conductive emission tests do not apply, since the device is powered from an automotive 12 VDC system.

1. Introduction

Lear RKE receiver, Model RFA-C+, 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 file 31040/SIT) 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 | October 1999/UM |
| Spectrum Analyzer (9kHz-26GHz) | X | Hewlett-Packard 8593E SN: 3107A01131 | September 1999/HP |
| Spectrum Analyzer (0.1-1500 MHz) | | Hewlett-Packard 182T/8558B SN: 1529A01114/543592 | October 1999/U of M Rad Lab |
| Preamplifier (5-1000MHz) | X | Watkins-Johnson A11 -1 plus A25-1S | Oct. 1999/U of M Rad Lab |
| Preamplifier (5-4000 MHz) | X | Avantek | Nov. 1996/ U of M Rad Lab |
| Broadband Bicone (20-200 MHz) | X | University of Michigan | June 1996/U of M Rad Lab |
| Broadband Bicone (200-1000 MHz) | | University of Michigan | June 1996/U of M Rad Lab |
| Dipole Antenna Set (25-1000 MHz) | X | University of Michigan | June 1997/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 (0.090-30MHz) | | EMCO 6502 SN: 2855 | December 1993/ EMCO |
| Active Rod (30Hz-50 MHz) | | EMCO 3301B SN: 3223 | December 1993/EMCO |
| Ridge-horn Antenna (0.5-5 GHz) | X | University of Michigan | March 1999/U of M Rad Lab |
| LISN Box | | University of Michigan | Dec 1997/U of M Rad Lab |
| Signal Cables | X | Assorted | January 1993/U of M Rad Lab |
| X-Y Plotter | | Hewlett-Packard 7046A | During Use/U of M Rad Lab |
| Signal Generator (0.1-990 MHz) | X | Hewlett-Packard 8656A | January 1990/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 315.0 MHz superegenerative receiver, designed for onboard automobile security/convenience applications and, as such, it is powered from an automobile 12 VDC source. The receiver is housed in a small plastic case approximately 3 x 2 x 0.75 inches, having one multi-pin connector for power input and digital signal output. The antenna is internal. For testing, a "generic" harness was made up, one bundle containing a pair of power-up wires and another wire for digital (serial) output. The length of the harness was about 2.0 m and the ends of signal wires were left open. In the receiver, decoding, signal processing, etc., are performed by a micro, timed by a 4.19 MHz oscillator.

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

Lear RKE Receiver
Model: RFA-C+
SN: FCCRFA-C+
FCC ID: KOBLEAR1CR
CANADA:

3.1 Modifications Made

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

4. Emission Limits

For FCC the DUT falls under Part 15, Subpart B, "Unintentional Radiators". For Industry Canada the DUT falls under Receiver category and is subject to technical requirement of sections 7.1 to 7.4 in RSS-210. The pertinent test frequencies, with corresponding emission limits, are given in Tables 4.1 and 4.2 below.

4.1 Radiated Emission Limits

Table 4.1. Radiated Emission Limits (FCC: 15.33, 15.35, 15.109; IC: RSS-210, 7.3).

| 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: Quasi-Peak readings apply to 1000 MHz (120 kHz BW)
Average readings apply above 1000 MHz (1 MHz BW)

4.2 Conducted Emission Limits

Table 4.2. Conducted Emission Limits (FCC: 15.107; IC: RSS-210, 6.6).

| Freq. (MHz) | μ V | dB(μ V) |
|---------------|---------|--------------|
| 0.450 - 1.705 | 250 | 48.0 |
| 1.705 - 30.0 | 250 | 48.0 |

Note: Quasi-Peak readings apply here

4.3 Antenna Power Conduction Limits

(FCC: 15.111(a); IC: RSS-210, 7.2). $P_{max} = 2 \text{ nW}$; for frequency range see Table 4.1.

5. Emission Tests and Results

NOTE: Even though the FCC and/or Industry Canada specify that both the radiated and conductive emissions be measured using the Quasi-Peak and/or average detection schemes, we normally use peak detection since especially the Quasi-Peak is cumbersome to use with our instrumentation. In case the measurement fails to meet the limits, or the measurement is near the limit, it is remeasured using appropriate detection. We note, that since the peak detected signal is always higher or equal to the Quasi-Peak or average detected signal, the margin of compliance may be better, but not worse, than indicated in this report. The type of detection used is indicated in the data table, Table 5.1.

5.1 Anechoic Chamber Radiated Emission Tests

To familiarize with the radiated emission behavior of the DUT, it was studied and measured in the shielded anechoic chamber. In the chamber there is a set-up similar to that of an outdoor 3-meter site, with turntable, antenna mast, and a ground plane. Instrumentation includes spectrum analyzers and other equipment as needed.

To study and test for radiated emissions, the DUT was powered by a laboratory power supply at 13.5 VDC. A 315 MHz CW signal was injected (radiated) from a nearby signal generator using a short wire antenna. The DUT was taped to a syrofoam block and placed on the test table on each of the three axis. At each orientation, the table was rotated to obtain maximum signal for vertical and horizontal emission polarizations. This sequence was repeated throughout the required frequency range.

In the chamber we studied and recorded all the emissions using a ridge-horn antenna, which covers 200 MHz to 5000 MHz, up to 2 GHz. In scanning from 30 MHz to 2.0 GHz, there were no spurious emissions observed other than the LO and injection signal (315 MHz), and the LO harmonics. Figures 5.1 and 5.2 show emissions measured 0-1000 MHz and 1000-2000 MHz, respectively. These measurements are made with a ridge-horn antenna at 3m, with spectrum analyzer in peak hold mode and the receiver rotated in all orientations. The measurements up to 1000 MHz (Fig. 5.1) are used for initial evaluation only, but those above 1000 MHz (Fig. 5.2) are used in final assessment for compliance.

5.2 Open Site Radiated Emission Tests

The DUT was then moved to the 3 meter Open Field Test Site where measurements were repeated up to 1000 MHz using a small bicone, or dipoles when the measurement is near the limit. The DUT was exercised as described in Sec. 5.1 above. The measurements were made with a spectrum analyzer using 120 kHz IF bandwidth and peak detection mode, and, when appropriate, using Quasi-Peak or average detection (see 5.0). The test set-up photographs are in the Appendix (i.e., end of this report).

The emissions from digital circuitry were measured using a standard bicone. These results are also presented in Table 5.1.

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 12.4 dB.

5.4 Conducted Emission Tests

These tests do not apply, since the DUT is powered from an automotive 12 VDC system.

6. Other Measurements

6.1 Emission Spectrum Near Fundamental

Near operating frequency the emission spectrum is measured typically over 50 MHz span with and without injection signal. These data are taken with the DUT close to antenna and hence amplitudes are relative. The plots are shown in Figure 6.1.

6.2 Effect of Supply Voltage Variation

The DUT has been designed to operate from 12 VDC power. Using a spectrum analyzer, relative radiated emissions were recorded at the "fundamental" (316 MHz) as voltage was varied from 6.5 to 18.0 VDC. Figure 6.2 shows the emission variation.

6.3 Operating Voltage and Current

$$\begin{array}{ll} V & = 12.0 \text{ VDC} \\ I & = 2.0 \text{ mA DC} \end{array}$$

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Table 5.1 Highest Emissions Measured

| # | Radiated Emission - RF | | | | | | | | | | Comments |
|----|---|--------------|--------------|-----------|--------------|------------|----------|--------------------|--------|------------|-------------------------------|
| | Freq. MHz | Ant. Used | Ant. Pol. | Pr dBm | Det. Used | Ka dB/m | Kg dB | E3 dB μ V/m | E3lim* | Pass dB | |
| 1 | 316.0 | Dip | H | -79.3 | Pk | 18.9 | 22.2 | 24.4 | 46.0 | 21.6 | flat |
| 2 | 316.0 | Dip | H | -79.0 | Pk | 18.9 | 22.2 | 24.7 | 46.0 | 21.3 | side |
| 3 | 316.0 | Dip | H | -82.0 | Pk | 18.9 | 22.2 | 21.7 | 46.0 | 24.3 | end |
| 4 | 316.0 | Dip | V | -81.5 | Pk | 18.9 | 22.2 | 22.2 | 46.0 | 23.8 | flat |
| 5 | 316.0 | Dip | V | -81.7 | Pk | 18.9 | 22.2 | 22.0 | 46.0 | 24.0 | side |
| 6 | 316.0 | Dip | V | -82.2 | Pk | 18.9 | 22.2 | 21.5 | 46.0 | 24.5 | end |
| 7 | 630.0 | Dip | H/V | -86.5 | Pk | 26.1 | 18.9 | 27.7 | 46.0 | 18.3 | max. of all, noise; 10 kHz BW |
| 8 | 945.0 | Dip | H/V | -86.5 | Pk | 29.5 | 16.5 | 33.6 | 46.0 | 12.4 | max. of all, noise; 10 kHz BW |
| 9 | 1280.0 | Horn | H | -63.0 | Pk | 20.6 | 28.0 | 36.6 | 54.0 | 17.4 | max. of all, noise |
| 10 | 1320.0 | Horn | H | -62.5 | Pk | 21.0 | 28.1 | 37.4 | 54.0 | 16.6 | max. of all, noise |
| 11 | 1520.0 | Horn | H | -63.0 | Pk | 21.3 | 28.3 | 37.0 | 54.0 | 17.0 | max. of all, noise |
| 12 | 1610.0 | Horn | H | -63.0 | Pk | 21.4 | 28.2 | 37.2 | 54.0 | 16.8 | max. of all, noise |
| 13 | 1780.0 | Horn | H | -62.0 | Pk | 21.8 | 27.9 | 38.9 | 54.0 | 15.1 | max. of all, noise |
| 14 | 1850.0 | Horn | H | -62.0 | Pk | 22.2 | 28.2 | 39.0 | 54.0 | 15.0 | max. of all, noise |
| 15 | 1950.0 | Horn | H | -63.0 | Pk | 22.4 | 28.3 | 38.1 | 54.0 | 15.9 | max. of all, noise |
| 16 | | | | | | | | | | | |
| 17 | | | | | | | | | | | |
| 18 | | | | | | | | | | | |
| 19 | | | | | | | | | | | |
| 20 | | | | | | | | | | | |
| 21 | | | | | | | | | | | |
| 22 | Digital emissions more than 20 dB below FCC/IC Class B Limit. | | | | | | | | | | |
| 23 | | | | | | | | | | | |
| 24 | | | | | | | | | | | |
| 25 | | | | | | | | | | | |
| 26 | | | | | | | | | | | |
| 27 | | | | | | | | | | | |

| Conducted Emissions | | | | | | | |
|---------------------|----------------|--------------|--------------|---------------------|--------------------|------------|----------|
| # | Freq. MHz | Line Side | Det. Used | Vtest dB μ V | Vlim dB μ V | Pass dB | Comments |
| | | | | | | | |
| | Not applicable | | | | | | |
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Meas. 8/24, 12/28/99; U of Mich.

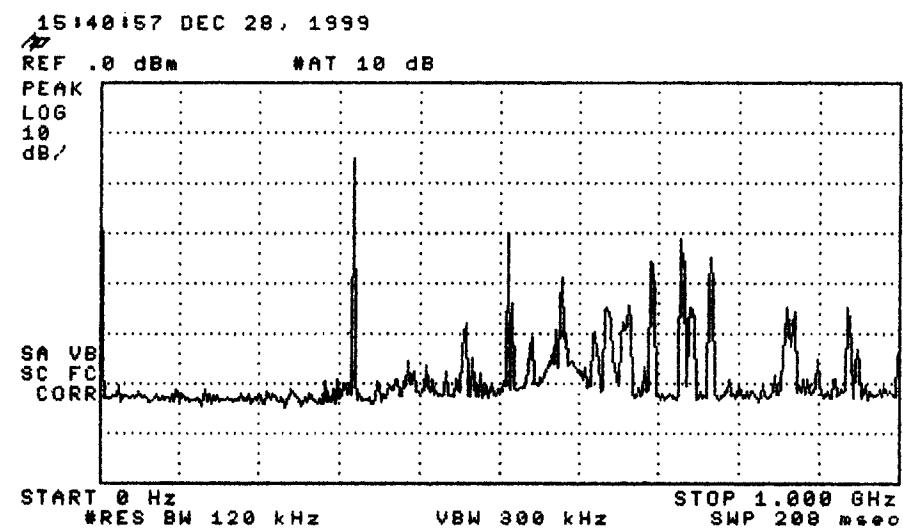
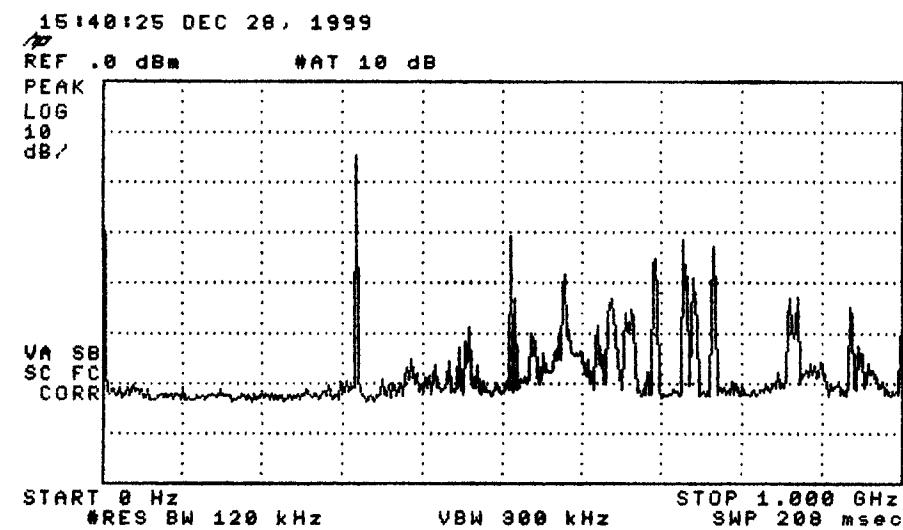


Figure 5.1. Emissions measured at 3 meters in anechoic chamber, 0-1000 MHz.
 (top) Receiver plus ambient
 (bottom) Ambient

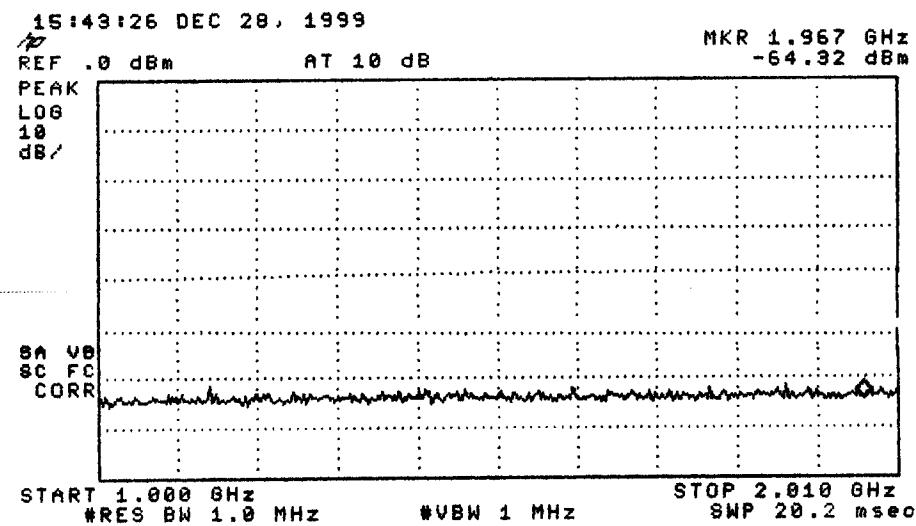
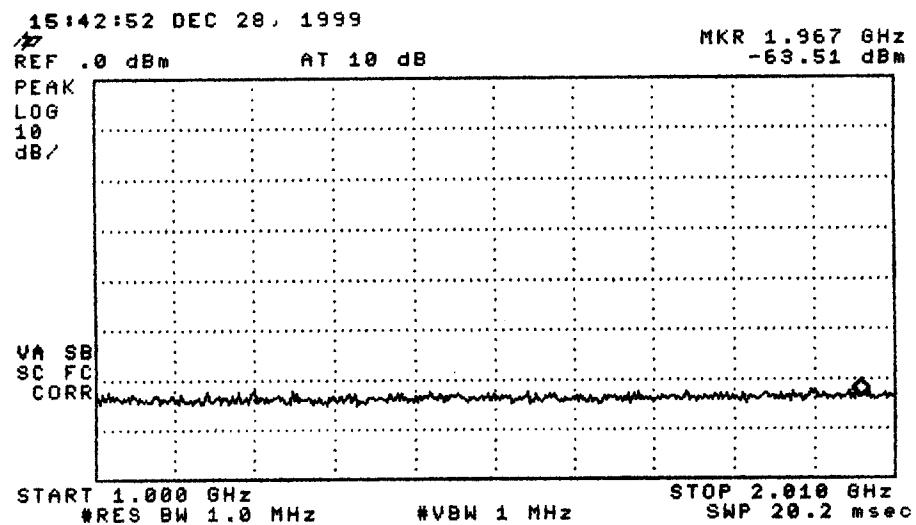


Figure 5.2. Emissions measured at 3 meters in anechoic chamber, 1000-2000 MHz.
(top) Receiver plus ambient
(bottom) Ambient

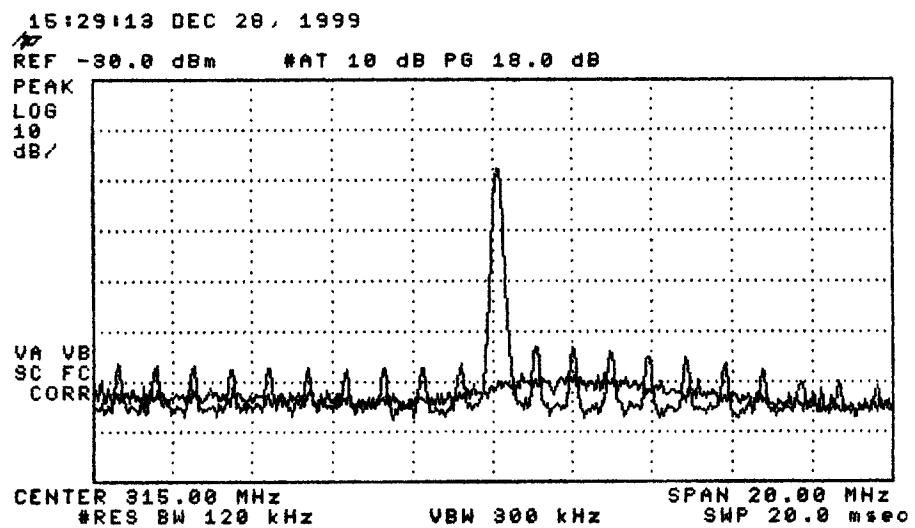


Figure 6.1. Relative receiver emissions in stand-by and "locked-in" modes. The final emission measurements were made with the receiver in "locked-in" mode.

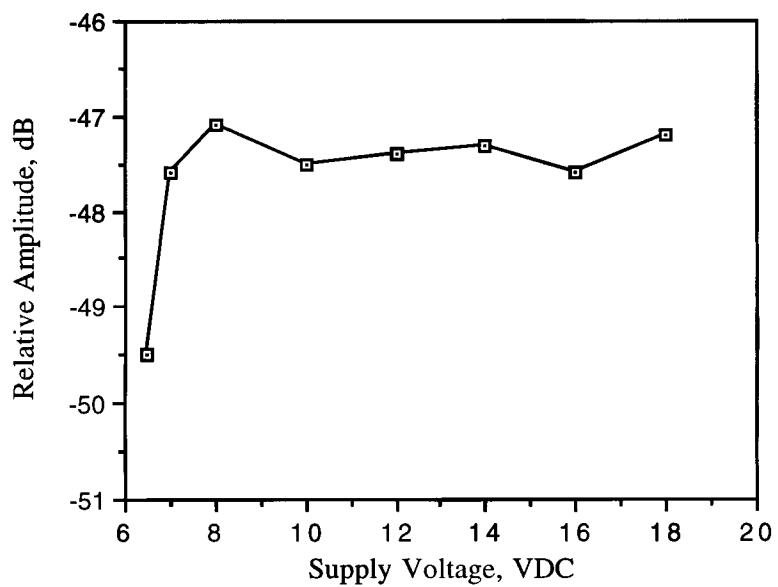


Figure 6.2. Relative emission at "fundamental" vs. supply voltage.