



The University of Michigan
Radiation Laboratory
3228 EECS Building
Ann Arbor, MI 48109-2122
Tel: (734) 764-0500
Fax: (734) 647-2106

Measured Radio Frequency Emissions
From

Lear Corporation Transmitter
FCC ID: KOBT510A
IC: 3521A-T510A

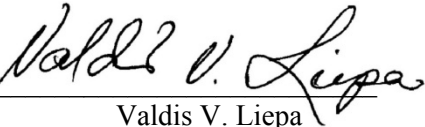
Test Report No. 417124-499
April 24, 2009

Copyright © 2009

For:
Lear Corporation
21557 Telegraph Rd
Southfield, MI 48033
Contact: John Nantz
jnantz@lear.com
Phone: 248-447-1354
Fax: 248.447.1689

Measurements made by: Joseph D. Brunett

Testing supervised by:
Report Approved by:


Valdis V. Liepa

Research Scientist

Test report written by: Joseph D. Brunett

Summary

Tests for compliance with FCC Regulations, CFR 47, Part 15 and with Industry Canada RSS-210/Gen, were performed on a Lear, FCC ID: KOBT510A, IC: 3521A-T510A. This device under test (DUT) is subject to the rules and regulations as a Transmitter.

In testing completed on March 10, 2009, the DUT tested met the allowed specifications for radiated emissions by 43.6 dB. Conducted emissions are not subject to regulation as the DUT is powered by a 12 VDC battery.

Table of Contents

| | | |
|----|--|---|
| 1. | Introduction..... | 3 |
| 2. | Equipment Used..... | 3 |
| 3. | Device Under Test | 4 |
| | 3.1 Description & Block Diagram | 4 |
| | 3.2 Variants | 4 |
| | 3.3 Modes of Operation | 4 |
| | 3.4 Exemptions | 4 |
| | 3.5 EMC Relevant Modifications | 4 |
| 4. | Emissions Limits..... | 5 |
| | 4.1 Radiated Emissions Limits..... | 5 |
| 5. | Measurement Procedures | 6 |
| | 5.1 Semi-Anechoic Chamber Radiated Emissions..... | 6 |
| | 5.2 Outdoor Radiated Emissions..... | 6 |
| | 5.3 Radiated Field Computations..... | 6 |
| | 5.4 Indoor Power Line Conducted Emissions..... | 6 |
| | 5.5 Supply Voltage Variation..... | 7 |
| 6. | Test Results..... | 7 |
| | 6.1 Radiated Emissions..... | 7 |
| | 6.1.1 Correction for Pulse Operation | 7 |
| | 6.1.2 Emission Spectrum | 7 |
| | 6.1.3 Emission Bandwidth | 7 |
| | 6.1.4 Supply Voltage and Supply Voltage Variation..... | 7 |
| | 6.2 Conducted Emissions..... | 7 |

1. Introduction

This Lear Transmitter was tested for compliance with FCC Regulations, Part 15, adopted under Docket 87-389, April 18, 1989 as subsequently amended, and with Industry Canada RSS-210/Gen, Issue 7, June 2007. Tests were performed at the University of Michigan Radiation Laboratory Willow Run Test Range following the procedures described in ANSI C63.4-2003 "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 2057A-1).

2. Equipment Used

The test equipment commonly used in our facility is listed in Table 2.1. Except where indicated as a pre-test, monitoring, or support device; all equipment listed below is a part of the University of Michigan Radiation Laboratory (UMRL) quality system. This quality system has been established to ensure all equipment has a clearly identifiable classification, calibration expiry date, and that all calibrations are traceable to national standards.

Table 2.1 Test Equipment.

| Test Instrument | Used | Manufacturer/Model | Q Number |
|------------------------------------|-------------------------------------|--|-----------|
| Spectrum Analyzer (9kHz-26GHz) | <input checked="" type="checkbox"/> | Hewlett-Packard 8593E, SN: 3412A01131 | HP8593E1 |
| Spectrum Analyzer (9kHz-6.5GHz) | <input checked="" type="checkbox"/> | Hewlett-Packard 8595E, SN: 3543A01546 | JDB8595E |
| Power Meter | <input type="checkbox"/> | Hewlett-Packard, 432A | HP432A1 |
| Harmonic Mixer (26-40 GHz) | <input type="checkbox"/> | Hewlett-Packard 11970A, SN: 3003A08327 | HP11970A1 |
| Harmonic Mixer (40-60 GHz) | <input type="checkbox"/> | Hewlett-Packard 11970U, SN: 2332A00500 | HP11970U1 |
| Harmonic Mixer (75-110 GHz) | <input type="checkbox"/> | Hewlett-Packard 11970W, SN: 2521A00179 | HP11970W1 |
| Harmonic Mixer (140-220 GHz) | <input type="checkbox"/> | Pacific Millimeter Prod., GMA, SN: 26 | PMPGMA1 |
| S-Band Std. Gain Horn | <input type="checkbox"/> | S/A, Model SGH-2.6 | SBAND1 |
| C-Band Std. Gain Horn | <input type="checkbox"/> | University of Michigan, NRL design | CBAND1 |
| XN-Band Std. Gain Horn | <input type="checkbox"/> | University of Michigan, NRL design | XNBAND1 |
| X-Band Std. Gain Horn | <input type="checkbox"/> | S/A, Model 12-8.2 | XBAND1 |
| X-band horn (8.2- 12.4 GHz) | <input type="checkbox"/> | Narda 640 | XBAND2 |
| X-band horn (8.2- 12.4 GHz) | <input type="checkbox"/> | Scientific Atlanta , 12-8.2, SN: 730 | XBAND3 |
| K-band horn (18-26.5 GHz) | <input type="checkbox"/> | FXR, Inc., K638KF | KBAND1 |
| Ka-band horn (26.5-40 GHz) | <input type="checkbox"/> | FXR, Inc., U638A | KABAND1 |
| U-band horn (40-60 GHz) | <input type="checkbox"/> | Custom Microwave, HO19 | UBAND1 |
| W-band horn(75-110 GHz) | <input type="checkbox"/> | Custom Microwave, HO10 | WBAND1 |
| G-band horn (140-220 GHz) | <input type="checkbox"/> | Custom Microwave, HO5R | GBAND1 |
| Bicone Antenna (30-250 MHz) | <input checked="" type="checkbox"/> | University of Michigan, RLBC-1 | LBBIC1 |
| Bicone Antenna (200-1000 MHz) | <input checked="" type="checkbox"/> | University of Michigan, RLBC-2 | HBBIC1 |
| Dipole Antenna Set (30-1000 MHz) | <input type="checkbox"/> | University of Michigan, RLDP-1,-2,-3 | UMDIP1 |
| Dipole Antenna Set (30-1000 MHz) | <input type="checkbox"/> | EMCO 3121C, SN: 992 (Ref. Antennas) | EMDIP1 |
| Active Rod Antenna (30 Hz-50 MHz) | <input type="checkbox"/> | EMCO 3301B, SN: 3223 | EMROD1 |
| Active Loop Antenna (30 Hz-50 MHz) | <input checked="" type="checkbox"/> | EMCO 6502, SN:2855 | EMLOOP1 |
| Ridge-horn Antenna (300-5000 MHz) | <input checked="" type="checkbox"/> | University of Michigan | UMRH1 |
| Amplifier (5-1000 MHz) | <input checked="" type="checkbox"/> | Avantek, A11-1, A25-1S | AVAMP1 |
| Amplifier (5-4500 MHz) | <input checked="" type="checkbox"/> | Avantek | AVAMP2 |
| Amplifier (4.5-13 GHz) | <input type="checkbox"/> | Avantek, AFT-12665 | AVAMP3 |
| Amplifier (6-16 GHz) | <input type="checkbox"/> | Trek | TRAMP1 |
| Amplifier (16-26 GHz) | <input type="checkbox"/> | Avantek | AVAMP4 |
| LISN Box | <input type="checkbox"/> | University of Michigan | UMLISN1 |
| Signal Generator | <input type="checkbox"/> | Hewlett-Packard 8657B | HPSG1 |

3. Device Under Test

3.1 Description & Block Diagram

The DUT is a 125 kHz transmitter (initiator) designed for automotive/vehicular applications, and as such it is powered by a 12 VDC source. The device is housed in a plastic case approximately 30 x 14 x 8 cm in dimension. For testing, a generic harness was provided by the manufacturer. Four LF antennas are external to the case. The DUT is designed and manufactured by Lear Corporation – ESD, C/Fusters 54 43800, VALLS (Tarragona) Spain.

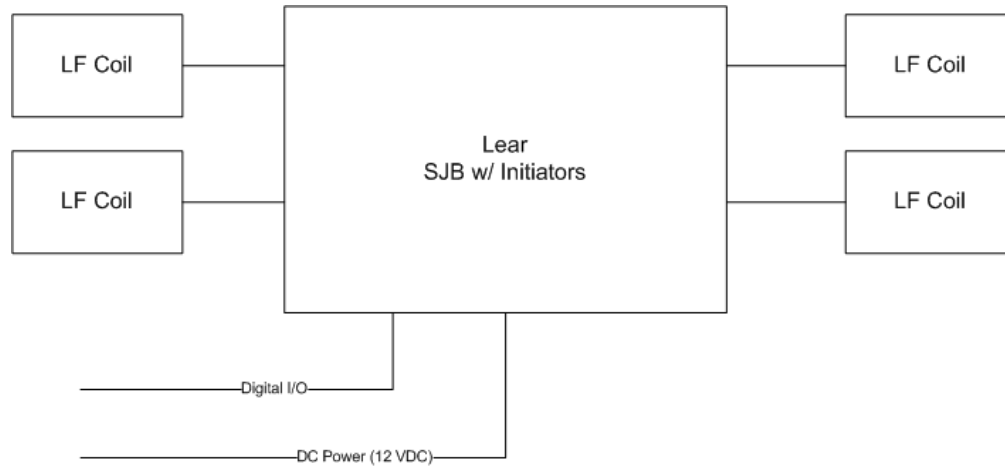


Figure 3.1 Block Diagram

| Device | [Make], Model | [S/N],P/N | EMC Consideration |
|--------------------|------------------|--------------|-------------------|
| DUT | [Lear], KOBT510A | [89J9105401] | FCC+IC |
| 4 LF antenna coils | FoMoCo | 5WK4 7595 | - |

| Cables | [Make], Model | Length | EMC Consideration |
|------------------|---------------|--------|-------------------|
| DC power | [Lear] | 2 m | Twisted pair |
| Digital Comm | [Lear] | 2 m | Twisted pair |
| LF antenna feeds | [Lear] | 2 m | Twisted pair |

3.2 Variants

There is only a single variant of this device.

3.3 Modes of Operation

The device is capable of only a single mode of operation (cw transmission) as reported.

3.4 Exemptions

- The DUT is permanently installed in a transportation vehicle. As such, digital emissions are exempt (per FCC 15.103(a) and IC correspondence on ICES-003) from regulation.

3.5 EMC Relevant Modifications

No EMI Relevant Modifications were performed by this test laboratory.

4. Emissions Limits

4.1 Radiated Emissions Limits

The DUT tested falls under the category of an Intentional Radiator. The applicable testing frequencies and corresponding emission limits set by both the FCC and IC are given in Tables 4.1 and 4.2 below.

Table 4.1. Transmitter Radiated Emission Limits (FCC: 15.205, 15.35; IC: RSS-210, 2.6 Tab. 1,3)

| Frequency (MHz) | | Fundamental and Spurious* ($\mu\text{V/m}$) |
|------------------|---------------------|---|
| 0.009-0.490 | | 2400/F(kHz), 300m |
| 0.490-1.705 | | 24,000/F(kHz), 30m |
| 0.090-0.110 | 8.291-8.294 | Restricted Bands |
| 0.49-0.51 | 8.37625 - 8.38675 | |
| 2.1735-2.190 | 8.41425 - 8.41475 | |
| 3.020-3.026 (IC) | 12.29 - 12.293 | |
| 4.125-4.128 | 12.51975 - 12.52025 | |
| 4.17725-4.17775 | 12.57675 - 12.57725 | |
| 4.20725-4.20775 | 13.36 - 13.41 | |
| 5.677-5.683 (IC) | 16.42 - 16.423 | |
| 6.215-6.218 | 16.69475 - 16.69525 | |
| 6.26775-6.26825 | 16.80425 - 16.80475 | |
| 6.31175-6.31225 | 25.5 - 25.67 | |

* Harmonics must be below the fundamental. To translate measurements to the 300/30 m distance, we refer to the journal paper: "Extrapolating Near-Field Emissions of Low-Frequency Loop Transmitters," J. D. Brunett, V. V. Liepa, D. L. Sengupta, IEEE Trans. EMC, Vol. 47, No. 3, August 2005.

Table 4.2. Spurious Emission Limits (FCC: 15.33, .35, .109/209; IC: RSS-210 2.7, T2)

| Freq. (MHz) | E_{lim} (3m) $\mu\text{V/m}$ | E_{lim} dB($\mu\text{V/m}$) |
|-------------|--------------------------------|---------------------------------|
| 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 RBW), PRF of intentional emissions > 20 Hz for QPK to apply.

Power Line Conducted Emissions Limits

Table 4.3 Emission Limits (FCC:15.107 (CISPR); IC: RSS-Gen, 7.2.2 T2).

| Frequency (MHz) | Class A (dB μV) | | Class B (dB μV) | |
|-----------------|-----------------------------|---------|-----------------------------|----------|
| | Quasi-peak | Average | Quasi-peak | Average |
| .150 - 0.50 | 79 | 66 | 66 - 56* | 56 - 46* |
| 0.50 - 5 | 73 | 60 | 56 | 46 |
| 5 - 30 | 73 | 60 | 60 | 50 |

Notes:

- The lower limit shall apply at the transition frequency
- The limit decreases linearly with the logarithm of the frequency in the range 0.15-0.50 MHz:
 *Class B Quasi-peak: $\text{dB}\mu\text{V} = 50.25 - 19.12 \cdot \log(f)$
 *Class B Average: $\text{dB}\mu\text{V} = 40.25 - 19.12 \cdot \log(f)$
- 9 kHz RBW

5. Measurement Procedures

5.1 Semi-Anechoic Chamber Radiated Emissions

To become familiar with the radiated emission behavior of the DUT, the device is first studied and measured in our shielded semi-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.

The DUT is laid on the test table as shown in the included block diagram. A shielded loop antenna is employed when studying emissions from 9 kHz to 30 MHz. Above 30 MHz and below 250 MHz a biconical antenna is employed. Above 250 MHz a ridge or standard gain horn antennas are used. The spectrum analyzer resolution and video bandwidths are set so as to measure the DUT emission without decreasing the emission bandwidth (EBW) of the device. Emissions are studied for all orientations (3-axes) of the DUT and all test antenna polarizations. In the chamber spectrum and modulation characteristics of the carrier are recorded. This data is presented in subsequent sections.

5.2 Outdoor Radiated Emissions

After measurements are performed indoors, emissions on our outdoor 3-meter Open Area Test Site (OATS) are made. If the DUT connects to auxiliary equipment and is table or floor standing, the configurations prescribed in ANSI C63.4 are employed. Alternatively, an on-table layout more representative of actual use may be employed if the resulting emissions appear to be worst-case in such a configuration. Any intentionally radiating elements are placed on the test table flat, on their side, and on their end (3-axes) and worst case emissions are recorded. For each configuration the DUT is rotated 360 degrees about its azimuth and the receive antenna is raised and lowered between 1 and 4 meters to maximize radiated emissions from the device. For devices with intentional emissions below 30 MHz, our shielded loop antenna at a 1 meter received height is used and low frequency field extrapolation to the regulatory limit distance is employed as needed. Emissions between 30 MHz and 1 GHz are measured using tuned dipoles and/or biconical antennas. Care is taken to ensure that the RBW and VBW used meet the regulatory requirements, and that the EBW of the DUT is not reduced. The Photographs included in this report show the DUT on the OATS.

5.3 Radiated Field Computations

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

$$E3(\text{dB}\mu\text{V/m}) = 107 + \text{PR} + \text{KA} - \text{KG} + \text{KE} - \text{CF}$$

where

- PR = power recorded on spectrum analyzer, dB, measured at 3 m
- KA = antenna factor, dB/m
- KG = pre-amplifier gain, including cable loss, dB
- KE = duty correction factor, dB
- CF = distance conversion (employed only if limits are specified at alternate distance), dB

When presenting the data at each frequency, the highest measured emission under all of the possible DUT orientations (3-axes) is given.

5.4 Indoor Power Line Conducted Emissions

When applicable, power line conducted emissions are measured in our semi-anechoic chamber. If the DUT connects to auxiliary equipment and is table or floor standing, the configurations prescribed in

ANSI C63.4 are employed. Alternatively, an on-table layout more representative of actual use may be employed if the resulting emissions appear to be worst-case in such a configuration.

The conducted emissions measured with the spectrum analyzer and recorded (in dB μ V) from 0-2 MHz and 2-30 MHz for both the ungrounded (Hi) and grounded (Lo) conductors. The spectrum analyzer is set to peak-hold mode in order to record the highest peak throughout the course of functional operation. Only when the emission exceeds or is near the limit are quasi-peak and average detection used.

5.5 Supply Voltage Variation

Measurements of the variation in the fundamental radiated emission were performed with the supply voltage varied by no less than 85% and 115% of the nominal rated value. For battery operated equipment, tests were performed using a new battery, and worst case emissions are re-checked employing a new battery.

6. Test Results

6.1 Radiated Emissions

6.1.1 Correction for Pulse Operation

When the transmitter is automatically activated by the in-vehicle control module it can, in the worst case, transmit a CW signal for up to 18.1 seconds. Antennas are only activated one at a time. See Figure 6.1. Since this device transmits a CW signal for greater than 100 ms, no duty cycle is applied.

6.1.2 Emission Spectrum

The relative DUT emission spectrum is recorded and is shown in Figure 6.2.

6.1.3 Emission Bandwidth

The emission bandwidth of the signal is shown in Figure 6.3. From the plot we see that the 99% bandwidth 15.0 kHz. The emission is more than 60 dBc in the 110 kHz restricted band.

6.1.4 Supply Voltage and Supply Voltage Variation

The DUT has been designed to be powered by a 12 VDC battery. For this test, relative radiated power 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.

| | |
|----------------|-----------------|
| Supply Voltage | V = 12.0 V |
| Current | I = 328 mA (cw) |

6.2 Conducted Emissions

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

The University of Michigan
Radiation Laboratory
3228 EECS Building
Ann Arbor, MI 48109-2122
Tel: (734) 764-0500
Fax: (734) 647-2106

Table 6.1 Highest Emissions Measured

| Radiated Emission - LF | | | | | | | | | | | | Lear Spain SJB; FCC/IC |
|-----------------------------|--|-----------|-------------|------------|-----------|---------|-------|--------------------|-----------|--------------|-------------|-------------------------------------|
| # | Freq. kHz | Ant. Used | Ant. Orien. | Pr, 3m dBm | Det. Used | Ka dB/m | Kg dB | Conv.** 3/30/300 m | E* dBμV/m | Elim dBμV/m | Pass dB | Comments |
| 1 | 125.0 | Loop | V/perp | -31.9 | Pk | 9.9 | 0.0 | 114.8 | -29.8 | 25.7 | 55.5 | loop perp. (axis in dir. of prop.) |
| 2 | 125.0 | Loop | V/par | -32.0 | Pk | 9.9 | 0.0 | 114.8 | -29.9 | 25.7 | 55.6 | loop paral. (loop in dir. of prop.) |
| 3 | 125.0 | Loop | H | -33.0 | Pk | 9.9 | 0.0 | 114.8 | -30.9 | 25.7 | 56.6 | loop horiz. (loop in horiz. plane) |
| 4 | 250.0 | Loop | V/perp | -80.1 | Pk | 9.8 | 0.0 | 110.4 | -73.7 | 19.6 | 93.3 | loop perp. (noise) |
| 5 | 250.0 | Loop | V/par | -80.3 | Pk | 9.8 | 0.0 | 110.4 | -73.9 | 19.6 | 93.5 | loop paral. (noise) |
| 6 | 250.0 | Loop | H | -81.3 | Pk | 9.8 | 0.0 | 110.4 | -74.9 | 19.6 | 94.5 | loop horiz. (noise) |
| 7 | 375.0 | Loop | V/perp | -79.1 | Pk | 9.8 | 0.0 | 104.5 | -66.8 | 16.1 | 82.9 | loop perp. |
| 8 | 375.0 | Loop | V/par | -77.8 | Pk | 9.8 | 0.0 | 104.5 | -65.5 | 16.1 | 81.6 | loop paral. |
| 9 | 375.0 | Loop | H | -78.6 | Pk | 9.8 | 0.0 | 104.5 | -66.3 | 16.1 | 82.4 | loop horiz. |
| 10 | 500.0 | Loop | All | -77.8 | Pk | 9.8 | 0.0 | 56.3 | -17.3 | 33.6 | 50.9 | max all |
| 11 | 625.0 | Loop | All | -79.5 | Pk | 9.8 | 0.0 | 56.1 | -18.8 | 31.7 | 50.5 | max all |
| 12 | 750.0 | Loop | All | -75.6 | Pk | 9.8 | 0.0 | 55.9 | -14.7 | 30.1 | 44.8 | background |
| 13 | 875.0 | Loop | All | -78.0 | Pk | 9.8 | 0.0 | 55.6 | -16.8 | 28.8 | 45.6 | background |
| 14 | 1000.0 | Loop | All | -77.4 | Pk | 9.8 | 0.0 | 55.4 | -16.0 | 27.6 | 43.6 | max all |
| 15 | 1125.0 | Loop | All | -73.8 | Pk | 9.8 | 0.0 | 55.1 | -12.1 | 26.6 | 38.7 | background |
| 16 | 1250.0 | Loop | All | -80.9 | Pk | 9.8 | 0.0 | 54.8 | -18.9 | 25.7 | 44.5 | max all |
| 17 | | | | | | | | | | | | |
| 18 | | | | | | | | | | | | |
| 19 | | | | | | | | | | | | |
| 20 | | | | | | | | | | | | |
| 21 | | | | | | | | | | | | |
| 22 | * Averaging applies up to 490 kHz, 0.0 dB employed in this case | | | | | | | | | | | |
| 23 | Limit at 300m for f<0.490MHz; 30m for f>0.490MHz | | | | | | | | | | | |
| 24 | Measurements made at 3 m, see Test Report for extrapolation reference. | | | | | | | | | | | |
| 25 | 9 kHz RBW for f > 150 kHz. | | | | | | | | | | | |
| 26 | ** Represents the worst case conversion factor for all possible orientations and ground materials. | | | | | | | | | | | |
| 27 | | | | | | | | | | | | |
| 28 | | | | | | | | | | | | |
| Digital Radiated Emissions* | | | | | | | | | | | | |
| # | Freq. kHz | Ant. Used | Ant. Pol. | Pr dBm | Det. Used | Ka dB/m | Kg dB | | E3 dBμV/m | E3lim dBμV/m | Pass dB | Comments |
| 1 | | | | | | | | | | | | |
| 2 | | | | | | | | | | | | |
| 3 | | | | | | | | | | | | |
| 4 | | | | | | | | | | | | |
| 5 | | | | | | | | | | | | |
| 6 | | | | | | | | | | | | |
| 7 | | | | | | | | | | | | |
| 8 | | | | | | | | | | | | |
| 9 | * For devices used in transportation vehicles, digital emissions are exempt from FCC regulations per FCC 15.103(a) | | | | | | | | | | | |

Meas. 04/09/2009; U of Mich.

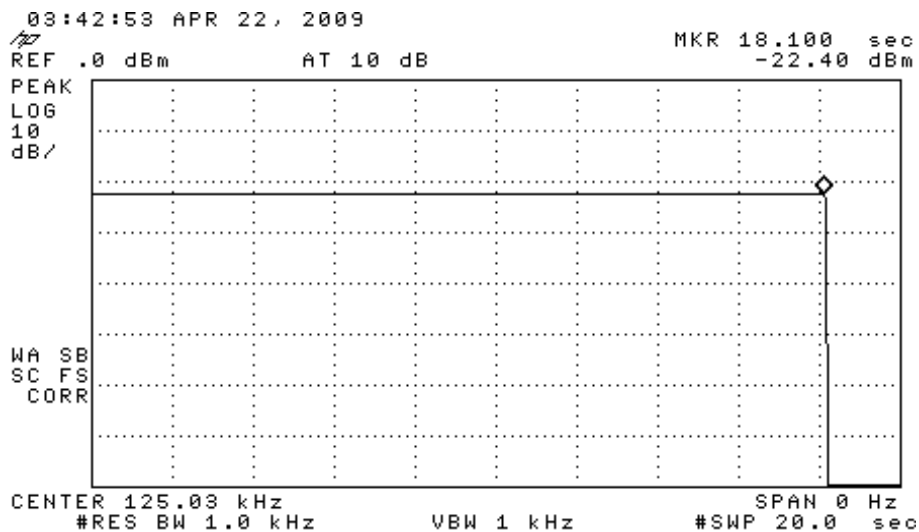


Figure 6.1. Transmission modulation characteristics. (top) complete cw transmission (18.1 sec)

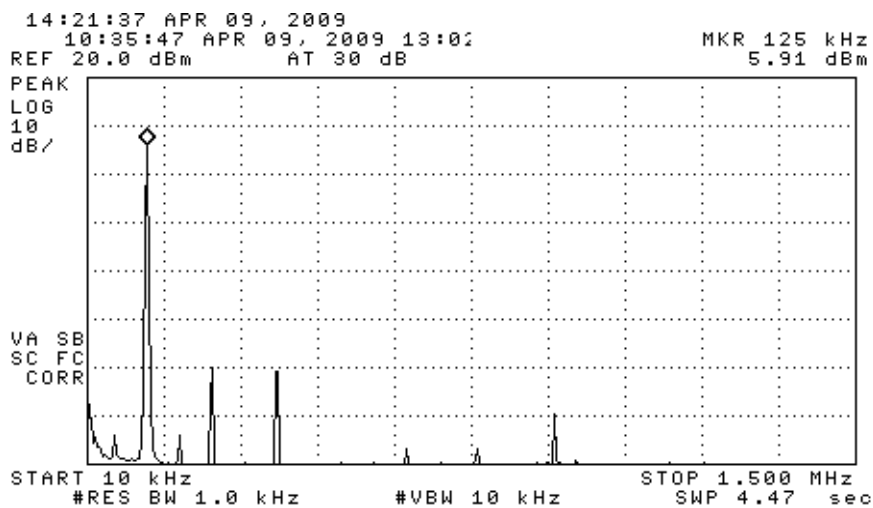


Figure 6.2. Emission spectrum of the DUT (pulsed emission). Amplitudes are only indicative (not calibrated).

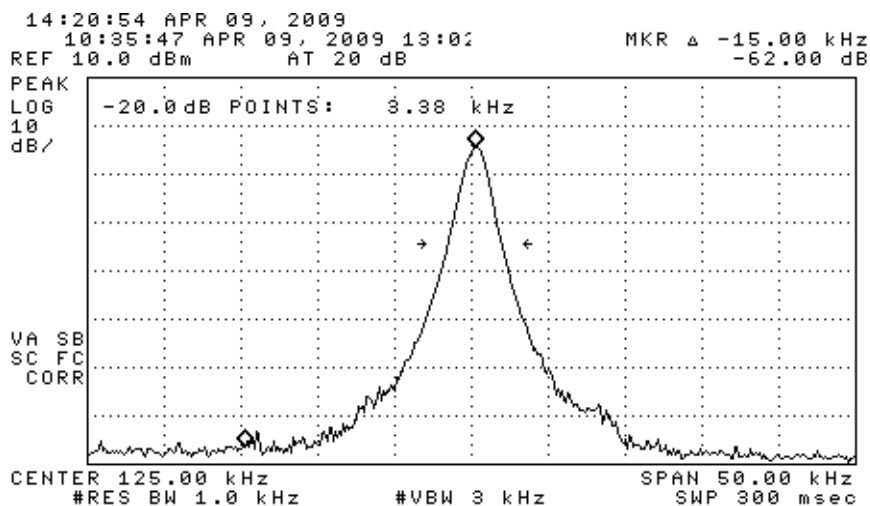


Figure 6.3. Measured emission bandwidth of the DUT (pulsed).

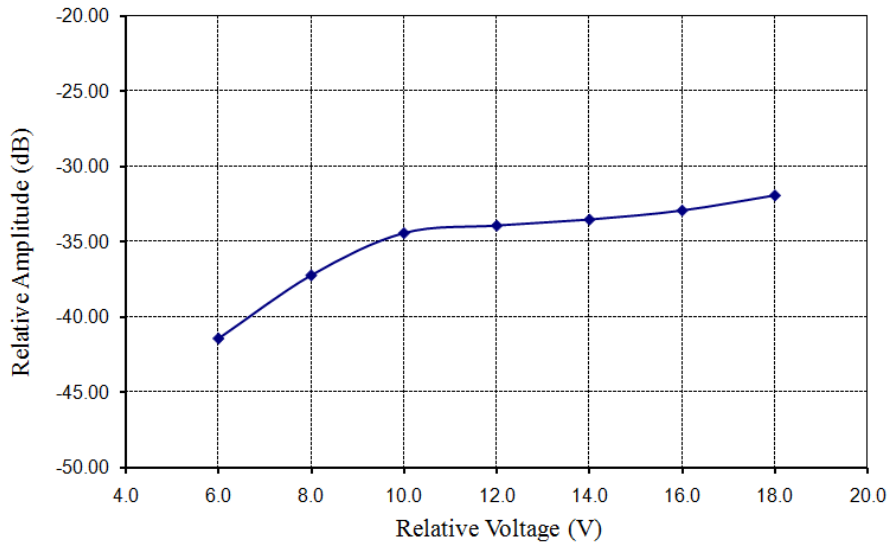
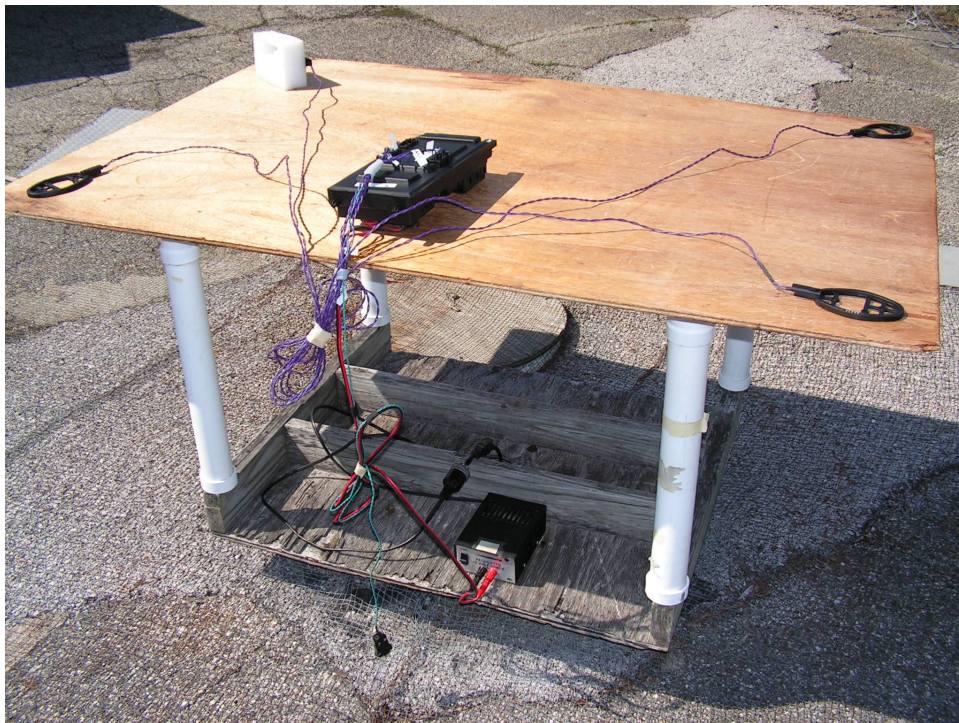


Figure 6.4. Relative emission at fundamental vs. supply voltage (pulsed).



Photograph 6.5. DUT on OATS (one of three axes tested)



Photograph 6.6. Close-up of DUT on OATS (one of three axes tested)