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Testing of

Electromagnetic Emissions

per

USA: CFR Title 47, Part 15.249
Canada: RSS-210 and RSS-Gen

are herein reported for

Lionel L.L.C.
CAB-IL LEGACY

Test Report No.: 417124-665

Applicant/Provider:
Lionel L.L.C.
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Report by: Valdis V. Liepa, Ph.D. Report Date of Issue: August 20, 2013

Results of testing completed on (or before) August 20, 2013 are as follows.

Emissions: The transmitter fundamental emission meets the regulatory limit(s) by no less than 22.5 dB. Transmit chain spurious harmonic emissions comply by no less than 11.1 dB. Radiated spurious emissions associated with the receive chain of this device meet the regulatory limit(s) by no less than 3.0 dB. Unintentional spurious emissions from digital circuitry comply with the radiated emission limit(s) by more than 3.0 dB.

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1 Test Specifications, General Procedures, and Location

1.1 Test Specification and General Procedures

The ultimate goal of Lionel L.L.C. is to demonstrate that the Equipment Under Test (EUT) complies with the Rules and/or Directives below. Detailed in this report are the results of testing the Lionel L.L.C. CAB-IL LEGACY for compliance to:

Country/Region	Rules or Directive	Referenced Section(s)
United States	Code of Federal Regulations	CFR Title 47, Part 15.249
Canada	Industry Canada	RSS-210 and RSS-Gen

In association with the rules and directives outlined above, the following specifications and procedures are followed herein.

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"
ICES-003; Issue 5 (2012)	"Information Technology Equipment (ITE) Limits and methods of measurement"
Industry Canada	"The Measurement of Occupied Bandwidth"

1.2 Test Location and Equipment Used

Test Location The EUT was fully tested by **The University of Michigan Radiation Laboratory**, 3228 EECS Building, Ann Arbor, Michigan 48109-2122 USA. The Test Facility description and attenuation characteristics are on file with the FCC Laboratory, Columbia, Maryland (FCC Reg. No: 91050) and with Industry Canada, Ottawa, ON (File Ref. No: IC 2057A-1).

Test Equipment Pertinent test equipment used for measurements at this facility is listed in Table 1. The quality system employed at The University of Michigan Radiation Laboratory has been established to ensure all equipment has a clearly identifiable classification, calibration expiry date, and that all calibrations are traceable to the SI through NIST, other recognized national laboratories, accepted fundamental or natural physical constants, ratio type of calibration, or by comparison to consensus standards.

Table 1: The University of Michigan Radiation Laboratory Equipment List.

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

2 Configuration and Identification of the Equipment Under Test

2.1 Description and Declarations

The equipment under test is a 2.4 GHz lower power remote control. The EUT is approximately 8 x 3 x 1 in (approx.) in dimension, and is depicted in Figure 1. It is powered by a 6 VDC four AA size 1.5 VDC batteries. The EUT is a handheld remote used to control model trains. Table 2 outlines provider declared EUT specifications.

Figure 1: Photos of EUT.

Table 2: EUT Declarations.

General Declarations			
Equipment Type:	Transceiver	**Country of Origin:**	USA
Nominal Supply:	6 VDC	**Oper. Temp Range:**	−0C to +35C
Frequency Range:	2404 – 2480 MHz	**Antenna Dimension:**	1 cm (approx)
Antenna Type:	Chip	**Antenna Gain:**	0 dBi (declared)
Number of Channels:	150	**Channel Spacing:**	500 kHz
Alignment Range:	Not Applicable	**Type of Modulation:**	125 kbps MSK
United States			
FCC ID Number:	LIV-CABIL	**Classification:**	DXT
Canada			
IC Number:	7032A-CABIL	**Classification:**	LPD (2400 – 2483.5 MHz)

2.1.1 EUT Configuration

The EUT is configured for testing as depicted in Figure 2.

2.1.2 Modes of Operation

The EUT is capable of only a single mode of operation, as a low power transceiver.

2.1.3 Variants

There is only a single electrical variant of the EUT, as tested.

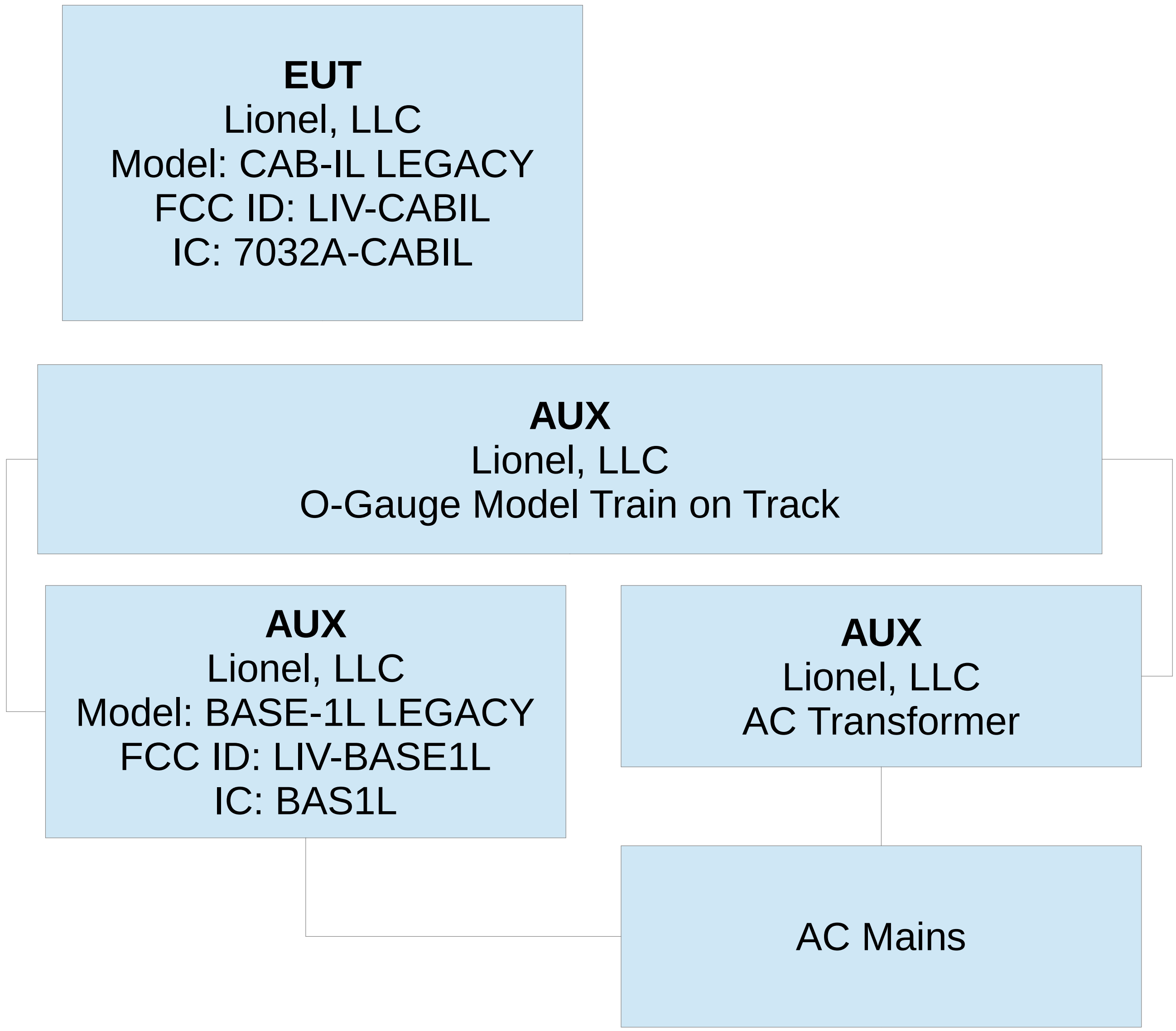


Figure 2: EUT Test Configuration Diagram.

2.1.4 Test Samples

Two samples were provided for testing, one normal operating and one sample that could be programmed for Low, Middle, High channel and receive only operation.

2.1.5 Functional Exerciser

Normal operating EUT functionality was verified by observation of train attached BASE-1L paired transceiver.

2.1.6 Modifications Made

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

2.1.7 Production Intent

The EUT appears to be a production ready sample.

2.1.8 Declared Exemptions and Additional Product Notes

None.

3 Emissions

3.1 General Test Procedures

3.1.1 Radiated Test Setup and Procedures

Radiated electromagnetic emissions from the EUT are first evaluated in our shielded fully anechoic chamber. Spectrum and modulation characteristics of all emissions are recorded, and emissions above 1 GHz are fully characterized. The anechoic chamber contains a set-up similar to that of our outdoor 3-meter site, with a turntable and antenna mast. Instrumentation, including spectrum analyzers and other test equipment as detailed in Section 1.2 are employed. After indoor pre-scans, emission measurements are made on our outdoor 3-meter Open Area Test Site (OATS). If the EUT connects to auxiliary equipment and is table or floor standing, the configurations prescribed in ANSI C63.4 / CISPR-22 are followed. Alternatively, a layout closest to normal use (as declared by the provider) is employed if the resulting emissions appear to be worst-case in such a configuration. See Figure 3. All

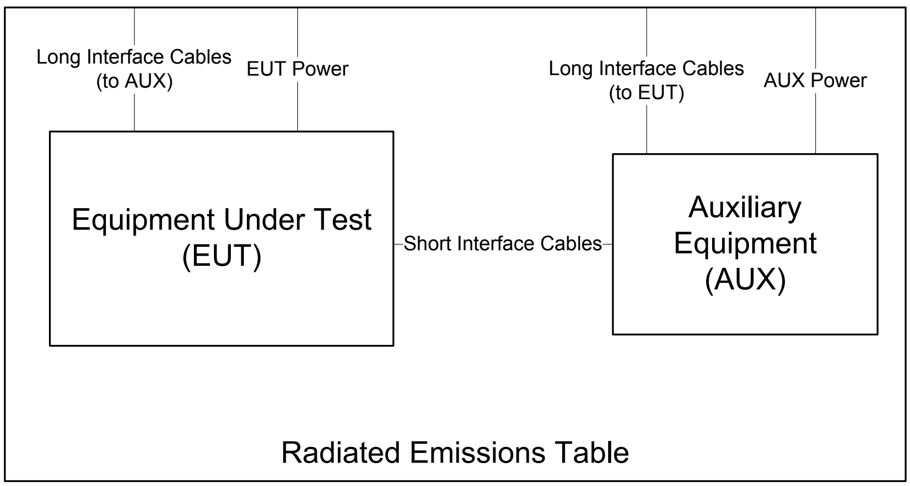


Figure 3: Radiated Emissions Diagram of the EUT.

intentionally radiating elements are placed on the test table lying flat, on their side, and on their end (3-axes) and the resulting worst case emissions are recorded. For both horizontal and vertical polarizations, the test antenna is raised and lowered from 1 to 4 m in height until a maximum emission level is detected. The EUT is then rotated through 360^o in azimuth until the highest emission is detected. The test antenna is then raised and lowered one last time from 1 to 4 m and the worst case value is recorded. Photographs of the test setup employed are depicted in Figure 4.

If the EUT exhibits spurious emissions due to internal receiver circuitry, such emissions are measured with an appropriate carrier signal applied. For devices with intentional emissions below 30 MHz, a shielded loop antenna is used as the test antenna. It is placed at a 1 meter receive height and appropriate low frequency magnetic field extrapolation to the regulatory limit distance is employed. Emissions between 30 MHz and 1 GHz are measured using tuned dipoles and/or calibrated broadband antennas. Emissions above 1 GHz are characterized using standard gain horn antennas or calibrated broadband ridge-horn antennas. Care is taken to ensure that test receiver resolution and video bandwidths meet the regulatory requirements, and that the emission bandwidth of the EUT is not reduced.

Where regulations allow for direct measurement of field strength, power values (dBm) measured on the test receiver / analyzer are converted to dBμV/m at the regulatory distance, using

$$E_{dist} = 107 + P_R + K_A - K_G + K_E - C_F$$

where P_R is the power recorded on spectrum analyzer, in dBm, K_A is the test antenna factor in dB/m, K_G is the combined pre-amplifier gain and cable loss in dB, K_E is duty correction factor (when applicable) in dB, and C_F is a distance conversion (employed only if limits are specified at alternate distance) in dB. This field strength value is then compared with the regulatory limit. If effective isotropic radiated power (EIRP) is compute, it is computed as

$$EIRP(dBm) = E_{3m}(dB\mu V/m) - 95.2.$$

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

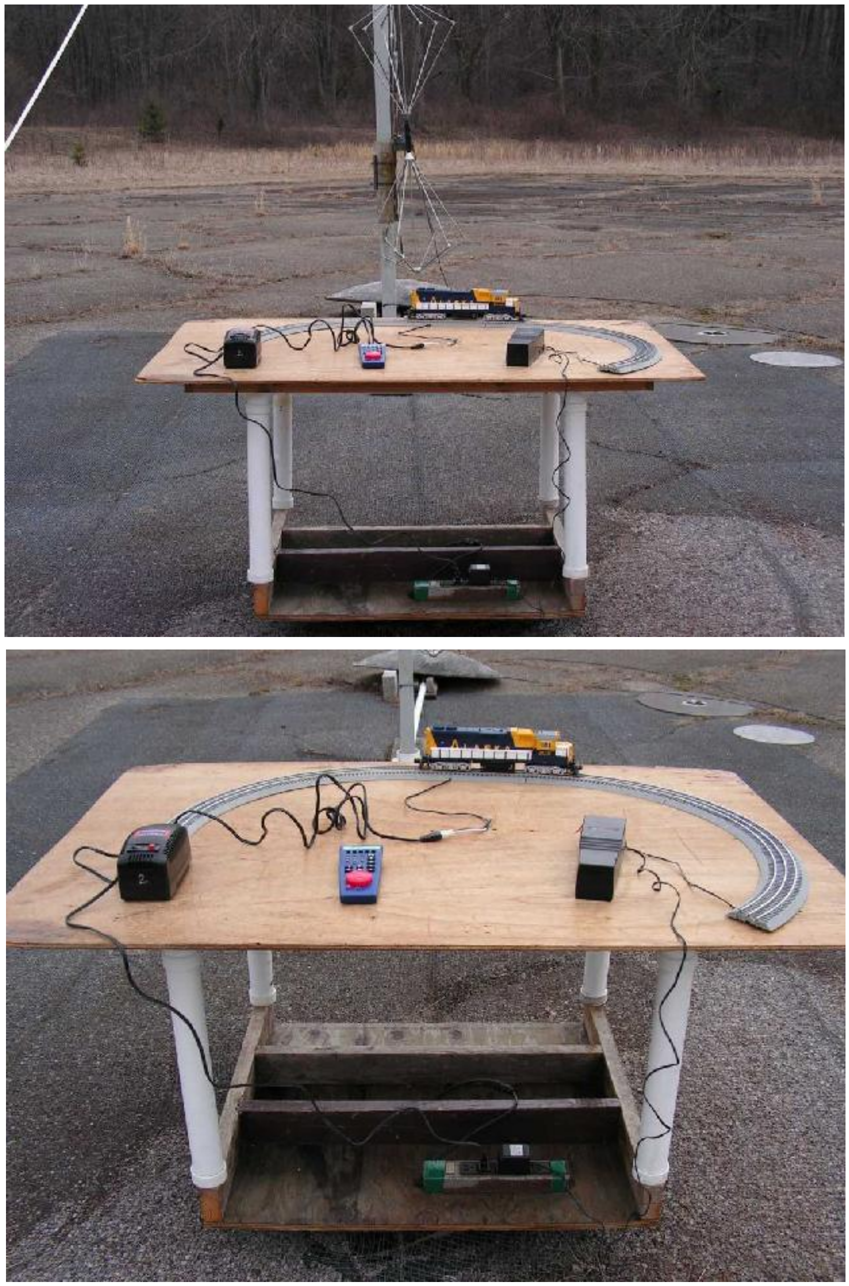


Figure 4: Radiated Emissions Test Setup Photograph(s).

3.1.2 Conducted Emissions Test Setup and Procedures

Battery Power Conducted Spurious The EUT is not subject to measurement of power line conducted emissions as it is powered solely by its internal battery.

3.1.3 Power Supply Variation

Tests at extreme supply voltages are made if required by the the procedures specified in the test standard, and results of this testing are detailed in this report.

In the case the EUT is designed for operation from a lead-acid battery power source, the extreme test voltages are evaluated between 90% and 130% of the nominal battery voltage declared by the manufacturer. For float charge applications using gel-cell type batteries, extreme test voltages are evaluated between 85% and 115% of the nominal battery voltage declared. For all battery operated equipment, worst case intentional and spurious emissions are re-checked employing a new (fully charged) battery.

3.2 Intentional Emissions

3.2.1 Fundamental Emission Pulsed Operation

The details and results of testing the EUT for pulsed operation are summarized in Table 3. Plots showing the measurements made to obtain these values are provided in Figure 5.

Table 3: Pulsed Emission Characteristics (Duty Cycle).

The DUT is designed to transmit no more than one 1.5 ms duration MSK frame every 11.0 ms. Thus, Peak-to (Power) Average Ratio is computed to be:

Duty Cycle Computation						Lionel; FCC/IC
#	Worst Case On-Time in 100 ms Window* (ms)	Duty Cycle (dB)				
1	13.64	-17.3				
2						

Meas. U. of Mich, 3/27/2013

* Example Computation: (1.5 ms / 11 ms) * 100 ms = 13.64 ms

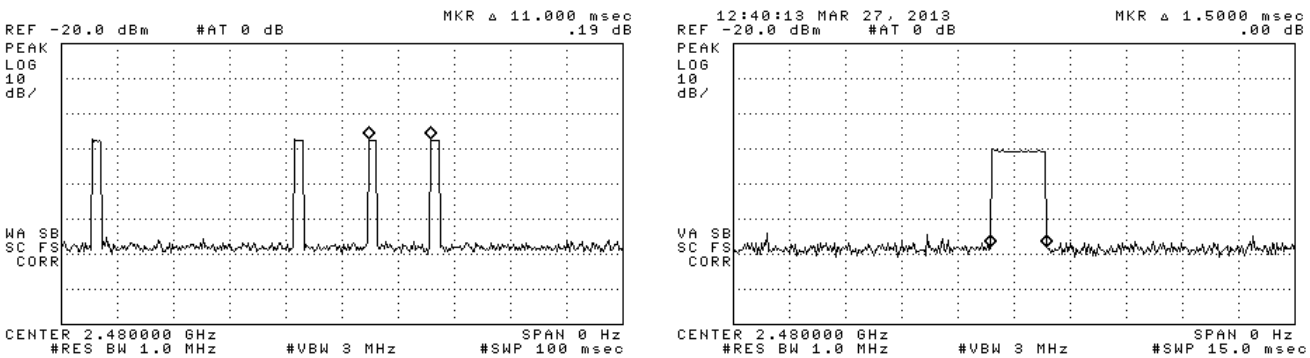


Figure 5: Pulsed Emission Characteristics (Duty Cycle).

3.2.2 Fundamental Emission Bandwidth

Emission bandwidth (EBW) of the EUT is measured with the device placed in the test mode(s) with the shortest available frame length and minimum frame spacing. Radiated emissions are recorded following the test procedures listed in Section 1.1. The 20 dB EBW is measured as the max-held peak-detected signal when the IF bandwidth is greater than or equal to 1% of the receiver span. For complex modulations other than ASK and FSK, the 99% emission bandwidth per IC test procedures has a different result, and is also separately reported.The results of EBW testing are summarized in Table 4. Plots showing measurements employed to obtain the emission bandwidth reported are provided in Figure 6.

Table 4: Intentional Emission Bandwidth.

The emission bandwidth of the signal is shown in the following Figure.

Measured Emission Bandwidth							Lionel; FCC/IC
#	Fund. Freq (MHz)	3 dB BW (kHz)	20 dB / 99% EBW (kHz)				
1	2404.0	205	795				
2	2439.5	190	770				
3	2480.0	165	785				

Meas. U. of Mich, 3/27/2013

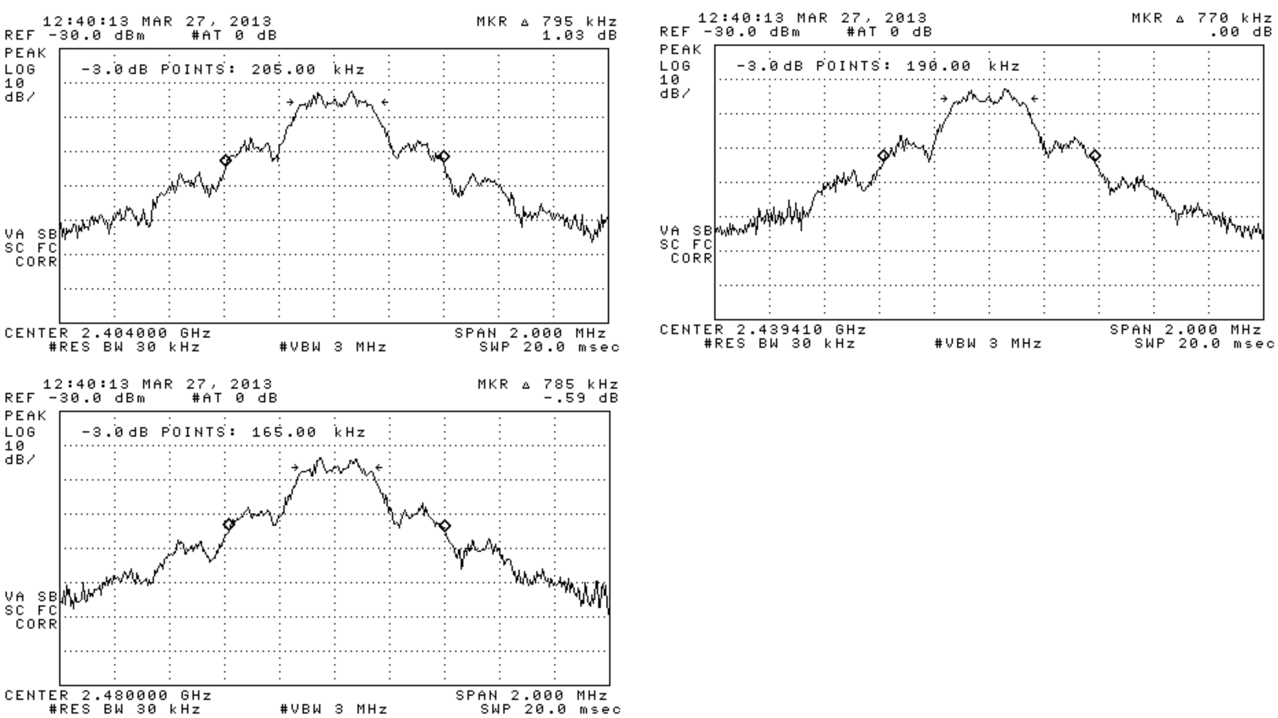


Figure 6: Intentional Emission Bandwidth.

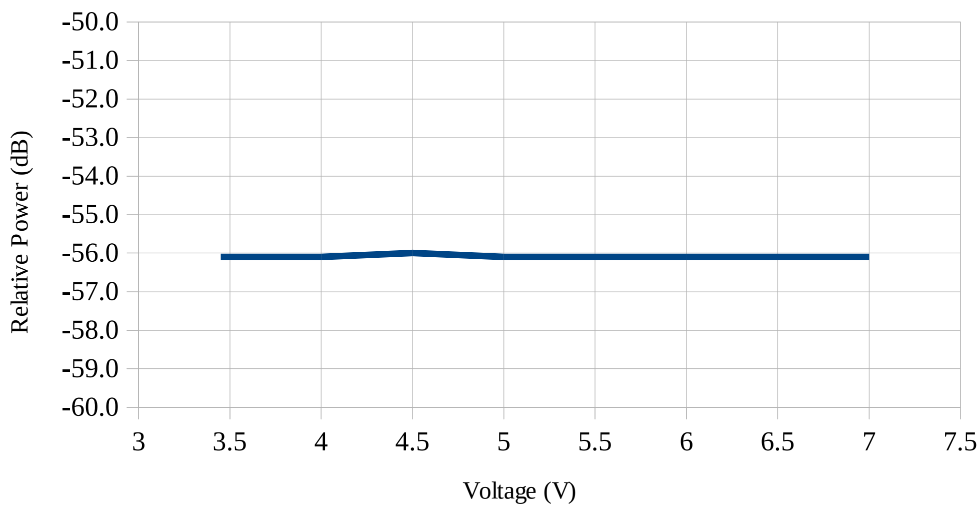
3.2.3 Fundamental Emission

Following the test procedures listed in Section 1.1, radiated emissions measurements are made on the EUT for both Horizontal and Vertical polarized fields. Table 5 details the results of these measurements.

Table 5: Fundamental Radiated Emissions.

Radiated Emissions – Fundamental											Lionel, CAB-1L; 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	2404.0	Horn S	H	-41.2	Pk	21.5	- 1.5	71.5	94.0	22.5	low channel (L), Ch 1
2	2439.5	Horn S	H	-41.6	Pk	21.5	- 1.5	71.1	94.0	22.9	mid channel (M), Ch 5
3	2480.0	Horn S	H	-41.6	Pk	21.5	- 1.5	71.1	94.0	22.9	high channel (H), Ch 9
4											
5											
6											
7											
8											
9											
10											
11	* Includes 17.3 dB duty factor										
12	* Peak measured with 1 MHz RBW and 3 MHz VBW										

Meas. 05/24, 06/03/2013; U of Mich.



3.3 Unintentional Emissions

3.3.1 Transmit Chain Spurious Emissions

The results for the measurement of transmit chain spurious emissions at the nominal voltage and temperature are provided in Table 6. Measurements are performed to 10 times the highest fundamental operating frequency.

Table 6: Transmit Chain Spurious Emissions.

Radiated Emissions – Transmitter Spurious											Lionel, CAB-1L; 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	2404.0										low channel (L)
2	2439.5										mid channel (M)
3	2480.0										high channel (H)
4	**Band Edge Emissions**										
5	2400.0	Horn S	H	-72.6	Pk	21.5	- 1.5	40.1	54.0	13.9	band edge, LMH channels
6	2483.5	Horn S	H	-70.6	Pk	21.5	- 1.5	42.1	54.0	**11.9**	band edge, LMH channels
7	**Harmonic Emissions**										
8	4808.0	Horn C	H	-43.4	Pk	24.6	38.0	32.9	54.0	21.1	
9	4879.0	Horn C	H	-47.0	Pk	24.6	38.0	29.3	54.0	24.7	
10	4960.0	Horn C	H	-45.5	Pk	24.6	38.0	30.8	54.0	23.2	
11	7212.0	Horn XN	H	-56.7	Pk	25.1	36.8	21.3	54.0	32.7	
12	7318.5	Horn XN	H	-63.9	Pk	25.2	36.8	14.2	54.0	39.8	noise
13	7440.0	Horn XN	H	-61.8	Pk	25.3	36.8	16.4	54.0	37.6	
14	9616.0	Horn X	H	-60.7	Pk	27.8	36.8	20.0	54.0	34.0	noise
15	9758.0	Horn X	H	-61.1	Pk	27.9	36.8	19.7	54.0	34.3	noise
16	9920.0	Horn X	H	-60.7	Pk	28.0	36.8	20.2	54.0	33.8	noise
17	12020.0	Horn X	H	-63.3	Pk	31.7	35.7	22.4	54.0	31.6	noise, all channels
18	14424.0	Horn Ku	H	-62.7	Pk	33.2	17.3	42.9	54.0	11.1	noise, all channels
19	16828.0	Horn Ku	H	-61.9	Pk	34.6	34.0	28.4	54.0	25.6	noise, all channels
20	19232.0	Horn K	H	-57.9	Pk	32.2	32.0	32.0	54.0	22.0	noise, all channels
21	21636.0	Horn K	H	-55.2	Pk	32.7	32.0	35.2	54.0	18.8	noise, all channels
22	24040.0	Horn K	H	-53.0	Pk	33.2	32.0	37.9	54.0	16.1	noise, all channels
23											
24	* Includes 17.3 dB duty factor										
25	* Peak measured with 1 MHz RBW and 3 MHz VBW										

Meas. 05/24, 06/03/2013; U of Mich.

3.3.2 Radiated Receiver Spurious

The results for the measurement of radiated receiver spurious emissions (emissions from the receiver chain, e.g. LO or VCO) at the nominal voltage and temperature are reported in Table 7. Receive chain emissions are measured to 5 times the highest receive chain frequency employed or 4 GHz, whichever is higher. If no emissions are detected, only those noise floor emissions at the LO/VCO frequency are reported.

Table 7: Receiver Chain Spurious Emissions ≥ 30 MHz.

Radiated Emissions - Receiver											Lionel, CAB-1L; 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	1065.0	R-Horn	H	-59.9	Pk	19.9	28.1	38.9	54.0	15.1	
2	1098.0	R-Horn	H	-61.1	Pk	20.0	28.1	37.9	54.0	16.1	
3	1133.0	R-Horn	H	-62.1	Pk	20.2	28.1	37.0	54.0	17.0	
4	2215.0	R-Horn	H	-71.0	Pk	23.0	26.5	32.6	54.0	21.4	noise
5	2930.0	R-Horn	H	-70.2	Pk	25.1	24.3	37.6	54.0	16.4	noise
6	3454.9	R-Horn	H	-70.0	Pk	26.8	23.2	40.6	54.0	13.4	noise
7	4103.0	R-Horn	H	-72.5	Pk	28.7	20.6	42.6	54.0	11.4	noise
8	4873.0	C-Horn	H	-55.6	Pk	24.6	38.0	38.0	54.0	16.0	
9	4881.0	C-Horn	H	-42.6	Pk	24.6	38.0	51.0	54.0	**3.0**	
10	6401.6	XN-Horn	H	-61.3	Pk	24.4	38.0	32.1	54.0	21.9	noise
11	7800.2	XN-Horn	H	-60.5	Pk	25.6	36.8	35.3	54.0	18.7	noise
12	10160.0	X-Horn	H	-60.3	Pk	28.1	36.8	38.0	54.0	16.0	noise
13	12095.0	X-Horn	H	-63.4	Pk	31.8	35.1	40.3	55.0	14.7	noise
14	* Peak measured with 1 MHz RBW and 3 MHz VBW										
15	Measured together with BASE-1L Unit										

Meas. 05/24, 06/03/2013; U of Mich.

3.3.3 Radiated Digital Spurious

The results for the measurement of digital spurious emissions (emissions arising from digital circuitry) at the nominal voltage and temperature are provided in Table 8. Radiation from digital components has been measured to 4 GHz, or to five times the maximum digital component operating frequency, whichever is greater.

Table 8: Radiated Digital Spurious Emissions.

Digital Spurious Emissions											Lionel, CAB-1L ; FCC/IC 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
1	32.1	Bic	H	-73.9	Pk	12.7	25.8	20.0	40.0	20.0	
2	40.2	Bic	V	-66.1	Pk	10.7	25.7	25.9	40.0	14.1	
3	48.2	Bic	H	-71.3	Pk	9.3	25.6	19.4	40.0	20.6	
4	55.1	Bic	H	-68.2	Pk	8.5	25.5	21.8	40.0	18.2	
5	50.2	Bic	H	-57.4	Pk	9.1	25.6	33.1	40.0	6.9	
6	50.2	Bic	V	-59.9	Pk	9.1	25.6	30.6	40.0	9.4	
7	66.2	Bic	H	-65.0	Pk	7.7	25.3	24.4	40.0	15.6	
8	75.7	Bic	H	-74.3	Pk	7.5	25.2	15.0	40.0	25.0	
9	80.2	Bic	H	-68.8	Pk	7.6	25.1	20.6	40.0	19.4	
10	115.7	Bic	H	-76.4	Pk	9.6	24.6	15.7	43.5	27.8	
11	144.1	Bic	H	-67.7	Pk	12.0	24.1	27.2	43.5	16.3	
12	144.1	Bic	V	-64.9	Pk	12.0	24.1	30.0	43.5	13.5	
13	148.7	Bic	H	-71.4	Pk	12.4	24.0	23.9	43.5	19.6	
14	165.1	Bic	H	-56.2	Pk	13.5	23.8	40.5	43.5	**3.0**	
15	165.1	Bic	V	-61.6	Pk	13.5	23.8	35.1	43.5	8.4	
16	198.0	Bic	H	-72.3	Pk	14.6	23.3	26.0	43.5	17.5	
17	208.1	Bic	H	-70.9	Pk	14.8	23.2	27.6	43.5	15.9	
18	208.1	Bic	V	-74.3	Pk	14.8	23.2	24.2	43.5	19.3	
19	224.0	Bic	H	-70.6	Pk	14.7	23.0	28.1	46.0	17.9	
20	240.0	Bic	H	-77.0	Pk	14.7	22.9	21.7	46.0	24.3	
21	274.8	Sbic	H	-74.9	Pk	16.8	22.6	26.3	46.0	19.7	
22	274.8	Sbic	V	-79.0	Pk	16.8	22.6	22.2	46.0	23.8	
23	309.3	Sbic	V	-73.6	Pk	18.3	22.1	29.5	46.0	16.5	
24	378.0	Sbic	V	-77.7	Pk	20.5	21.4	28.5	46.0	17.5	
25											
26	Measured together with BASE-1L Unit, 120 kHz RBW, 300 kHz VBW										
27											
43											

Meas. 03/27/13; U of Mich.