125 Technology Parkway
Norcross, Georgia, US 30092

EMS Model CAL-Node

915 MHz Direct Sequence Spread Spectrum Transmitter

Testing Performed for: EMS
Testing Performed by: LXE Inc.

FCC ID: DNY160995

Issue Date: July 3, 2001

Table of Contents

1.0 General **3**
1.1 Introduction 3
1.2 Product Description 3
1.3 Theory of Operation 4

2.0 Location of Test Facility **7**

3.0 Description of Radiated Test Facility **7**
3.1 Radiated Test Site Illustration 7

4.0 Applicable Standards and References **8**

5.0 List of Test Equipment **8**

6.0 Test Methodology **9**

7.0 Support Equipment **11**

8.0 Test Setup Block Diagram **11**

9.0 Test Setup Photos **12**

10.0 Summary of Tests **14**
10.1 Section 15.203 - Antenna Requirement 14
10.2 Section 15.207 - Power Line Conducted Emissions 14
10.3 Section 15.247(a)(2) - 6dB Bandwidth Requirement 14
10.4 Section 15.247(b) - Peak Output Power 14
10.5 Section 15.247(c) - Spurious Emissions 14
10.5.1 RF Conducted Spurious Emissions 15
10.5.2 Radiated Spurious Emissions(Restricted Bands) 15
10.7 Section 15.247(d) - Power Spectral Density 16
10.8 Section 15.247(e) - Processing Gain 16

11.0 MPE Calculations **16**

12.0 Sample Label **17**

12.0 Conclusion **18**

Appendix A - Antenna Photos
Appendix B - Data Plots
Appendix C - Schematics/Parts List

1.0 GENERAL

1.1 Introduction
The purpose of this report is to demonstrate compliance with Part 15, Subpart C of the FCC's Code of Federal Regulations. Testing was performed for Electromagnetic Sciences Inc. by LXE Inc., a division of Electromagnetic Sciences Inc.

1.2 Product Description
The equipment under test(EUT) is a single channel, direct sequence spread spectrum transmitter, referred to as the CAL Node or generically as a PDU (Personnel Detection Unit). The CAL Node is a single component of the larger Prison Inmate and Safety Management(PRISM) system. PRISM is a system that uses a series of transmitters and receivers, connected to a main computer for purpose of, among others, the monitoring/tracking of prison inmates and guards inside of a correctional facility. The CAL Node is mounted on a wall or pole and is used transmit known messages for synchronization and system state of health testing. See Appendix A for detailed photographs of the EUT.

<u>Performance</u>
Output Power
RF Power output into a 50 ohm load shall be 14 dBm +/- 1 dBm.

RF Center Frequency
The PDU transmits at a carrier frequency of 915 MHz +/- I0 KHz.

Modulation Characteristics
Digital information is modulated onto the carrier via a Binary Phase Shift Keyed (BPSK) Direct Sequence encoding at 1 0 MHz +/-2 kHz. The PN code shall be programmable up to 127 bits.

<u>Physical Characteristics</u>
Dimensions of the PDU are 4.5 x 7 x 7 inches and does not exceed 50 oz with battery.

<u>Intended Application</u>
The CAL Node shall be designed for mounting on stationary structures.

<u>Environmental Conditions</u>
Temperature

Storage:	-20C to +65C.
Normal Operating:	15C to +35C
Short term operating extremes:	0C to 55C Temperature cycles: 2 per day

Humidity
The PDU shall withstand exposure to non-condensing relative humidity up to 100% over the normal operating temperatures.

Corrosion
The unit shall be designed to prevent corrosion or moisture accumulation effects which could lead to performance degradation.

Weather
The CAL Node PDU shall be designed to meet NEMA 4 enclosure ratings (General Purpose Indoor/Outdoor).

1.3 Theory Of Operation

The following paragraphs detail the operation of a single channel 915 MHz direct-sequence spread spectrum transmitter. A functional block diagram of is shown in Figure 1.3.1 for reference purposes.

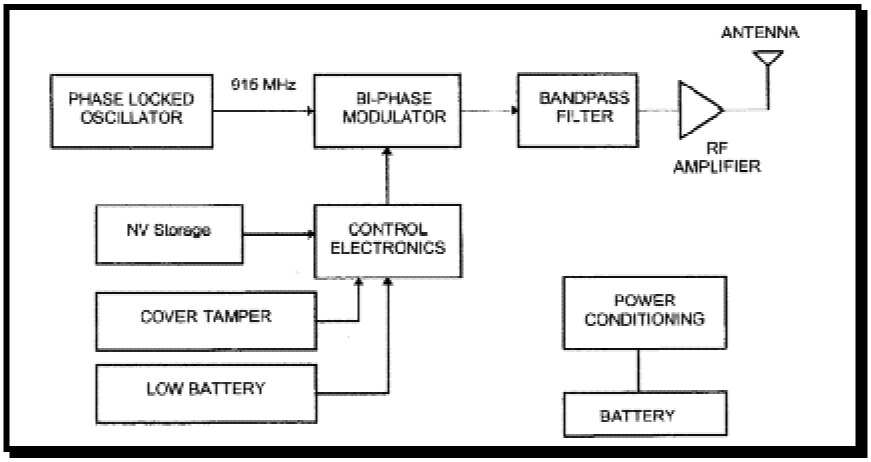


Figure 1.3.1: PRISM CAL Node Block Diagram.

A 915MHz RF signal is generated by the phased locked loop. This signal is modulated at 10 MHz by the BPSK modulator, amplified/filtered and then transmitted via a small antenna inside the CAL NODE. The RF circuitry is enabled and controlled by the control electronics (CE). The CE imposes a direct sequence code on top of the information bits and uses this digital stream of data to drive the BPSK modulator. An RF ID and status bits are included in the information. The RF ID and other programmable features are stored in Non-Volatile memory.

Information bits are transmitted serially in the order shown in Table 1 below (bit #0 is transmitted first):

Table 1: Information Sequence

Bit No	Function	Bit Value	Time(usec)
0	Preamble	1	0.0
1	Preamble	1	6.3
2	Preamble	1	12.6
3	ID14	16384	18.9
4	ID13	8192	25.2
5	ID12	4096	31.5
6	ID1 1	2048	37.8
7	ID10	1024	44.1
8	ID9	512	50.4
9	ID8	256	56.7
10	ID7	128	63.0
11	ID6	64	69.3
12	ID5	32	75.6
13	ID4	16	81.9
14	ID3	8	88.2
15	ID2	4	94.5
16	ID1	2	100.8
17	IDO	1	107.1
18	Battery OK	16	113.4
19	Cover Tamper	8	119.7
20	spare	4	126.0
21	spare	2	132.3
22	spare	1	138.6
23	CRC	N/A	144.9
24	CRC	N/A	151.2
25	CRC	N/A	157.5
26	CRC	N/A	163.8
27	CRC	N/A	170.1

Preamble
Each information sequence begins with three digital 1's. These are used by other portions of the system to synchronize the data stream.

ID Bits
Fifteen ID bits are provided to allow for setting of unique RF codes. This ID will be stored in the non-volatile memory and will not be alterable by the wearer of the unit.

Note: ID codes shall contain at least three l's (cannot have an ID of zero, for example).

Battery Ok
A digital "1" indicates the battery is OK, a digital "O" indicates the end of life is near

Cover Tamper
When set to a digital "1", indicates that the Cal Node cover has been opened.

Spare, Bit 20
This field is not used by the Cal Node and shall be a zero.

Spare, Bit 21
This field is not used by the Cal Node and shall be a zero

Spare, Bit 22
This field is not used by the Cal Node and shall be a zero

The nominal transmit interval is be programmable to 1, 2, 4, 8, 16, 32, 64, 128, 256, or 512 seconds. The interval is varied pseudo randomly on each occurrence by 5 to 100ms to prevent recurrent collisions between two PDU'S.

When a high priority event occurs, the PDU transmits 20 messages for that event, one every 500 ms +/-5 to 100ms. The alarm indication remains active for the duration of the 20 messages (even if the actual alarm ceases). New alarms of this type are not initiated during this 20 message period. New alarms of a different type may be initiated during this period and will extend the Priority Alarm Transmission to allow for 20 messages with the new alarm bit set.

A high priority alarm occurs when any of the following events starts or ends:

- Cover Tamper
- Low Battery.

A cyclic redundancy checksum code is used to validate the data stream. The circuit used is shown below in Figure 2:

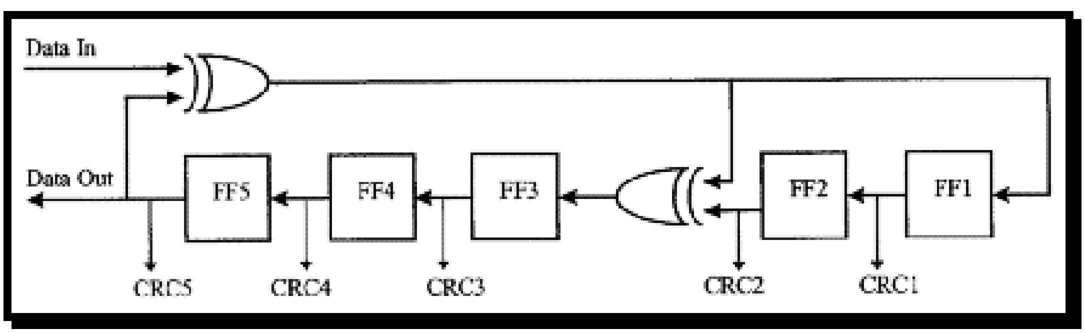


Figure 1.3.2: Cyclic Redundancy Checksum Diagram

2.0 LOCATION OF TEST FACILITY

The LXE test facility is located at the following address:

LXE, Inc.
An Electromagnetic Sciences Company
125 Technology Parkway
Norcross, GA US 30092-2993
Tel: (770) 447-4224
Fax: (770) 447-6928

Radiated emission tests were conducted at the manufacture's test facility at a location specifically prepared for this testing. The radiated emissions test site meets the characteristics of ANSI C63.4:1992, CISPR 16 and EN 55022:1994. This site has been fully described and submitted to the FCC, and accepted in their letter marked 31040/SIT, 1300F2.

3.0 DESCRIPTION OF OPEN AREA TEST SITE

The open area test site(OATS) is located in the center of the rooftop of the building. The roof is located at a height of approximately 8 meters above the ground. The 3 meters radiated emissions test site is an open, flat area (open area) test site approximately 6.2m x 9.2m in dimension. All reflecting objects including test personnel lie outside the perimeter of the ellipse. The 3 meters test site ground plane is made of a 1/4" metal screen mesh which extends 2 meters past the mast and equipment under test(EUT). Material of the ground plane, comprised of individual 1/4" metal screen mesh rolls, were soldered at the seams with gaps smaller than 1/10 of the wavelength at 1000MHz. The ground plane is connected to the earth ground by ground rods. All wiring is done at floor level around the test site periphery. The radiated emissions test setup is shown in figure 1.

3.1 Radiated Emissions Testing Facility Drawing

All dimensions are in meters(m)

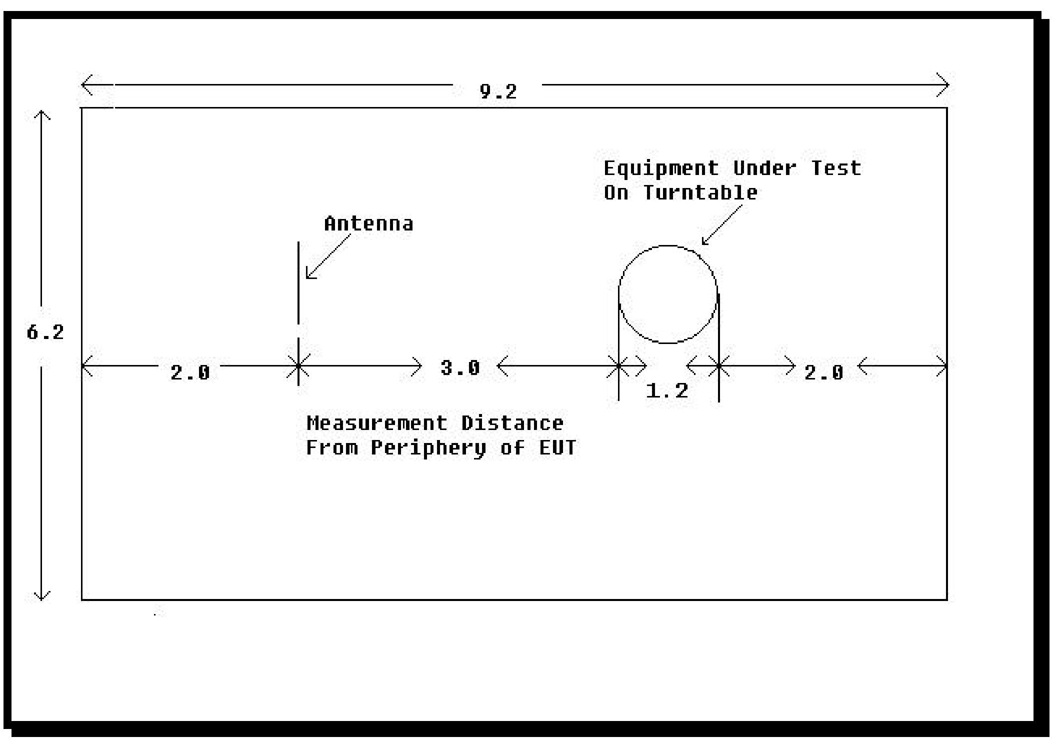


Figure 3.1.1: Open Area Test Site(OATS)

4.0 Applicable Standard References

The following standards were used for this test:

1 - ANSI C63.4-1992: Method of Measurements of Radio-Noise Emissions from Low-Voltage Electrical and Electronic Equipment in the 9KHz to 40GHz

2 - US Code of Federal Regulations (CRF): Title 47, Part 15, Radio Frequency Devices, Subpart C, Intentional Radiators (October 1997)

5.0 List of Test Equipment

Radiated field strength measurements are taken with a spectrum analyzer. For peak measurements the spectrum analyzer was set with both the VBW and the RBW at 1MHz. Average measurements were taken with the RBW at 1MHz and the VBW at 10Hz. The sweep rate was set to auto to optimize the measurement. Adequate attenuation was used to protect the analyzer from damage.

TABLE 2.4-1 TEST AND SUPPORT EQUIPMENT

Description	Manufacturer	Model/Part #	Serial #	Last Calibration
Spectrum Analyzer	Hewlett Packard	HP 8591A	3131A02254	04/05/98
Spectrum Analyzer	Hewlett Packard	HP 8563E	3304A00657	
Preamplifier	LXE	20-1000 MHz	001	03/22/98
Preamplifier	Hewlett Packard	83006A	3116A01317	10/05/98
HI-Pass Filter	MiniCircuits	SHP-1000		
HI-Pass Filter	MicroWave Circuits	H3G020G2	0001	01/05/99
Signal Generator	Hewlett Packard	8657B	2915U00198	02/05/98
LISN	EMCO	3810/2NM	9505-1024	04/29/98
Biconical Antenna	EMCO	3104C	9012-4360	05/12/98
Biconical Antenna	Electro-Metric	BIA-25	1165	05/06/98
Log Periodic	EMCO	3146	3011-2946	03/30/98
Horn Antenna	ElectroMetric	RGA-60	6166	
Horn Antenna	ElectroMetric	RGA-60	6165	
Dipole Antenna Set	CDI	Roberts Dipole	265	03/19/98
RF Cable	Belden	RF1	001	03/22/98
RF Cable	Belden	RF2	002	03/22/98
RF Cable			NSN	10/05/98
RF Cable			7015	10/05/98
RF Cable			6986	10/05/98
Antenna Mast	CDI	CDI	N/A	N/A
Turntable	CDI	CDI	N/A	N/A
RF Enclosure	Lindgren Enclosure	14-2/2-0	8147	N/A

6.0 Test Methodology

For the radiated emissions tests, measurements were made over the frequency range of 30MHz to 10 times the highest fundamental frequency. Measurements of the radiated field strength were made at a distance of 3m from the boundary of the equipment under test(EUT)and the receiving antenna. The antenna height was varied from 1m to 4m so that the maximum radiated emissions level would be detected. A nonconductive remotely controlled turntable approximately 0.91m x 1.2m x 0.8m was used to measure radiated emissions from all sides of the EUT. The turntable has a center opening that allows cabling to be routed directly down to the conducting ground plane.

Due to high ambient noise levels and small EUT size, radiated emission measurements may be made at a distance of 1 meter. An inverse proportionality factor of 20 dB per decade is used to normalize the measured data to the specified distance to determine compliance. The formula used to calculate an inverse proportionality factor is 20 log (D1/D2), where D1 is the distance used and D2 is the specified distance.

Radiated measurements were made with the Spectrum Analyzer's resolution bandwidth set to 120KHz for measurements above 30MHz and below 1000MHz, and 1MHz for measurements above 1000 MHz. The calculation for the radiated emissions strength is as follows:

Due to the low duty cycle of the transmitter, average readings were extrapolated from the peak readings correcting for the duty cycle of the transmitter using the formula 20log(Duty Cycle). Where the duty cycle is defined as a percentage of any 100mS span that the pulse encompasses. The duty cycle is found by dividing the pulse width by 100mS and multiplying the quotient by 100%.

Figure 1 below shows the 176.4µS pulsewidth of a typical transmission. Figure 2 below shows the period of the transmitter to be 520mS. Figure 2 also shows that the pulse only occurs once in any 100mS span.

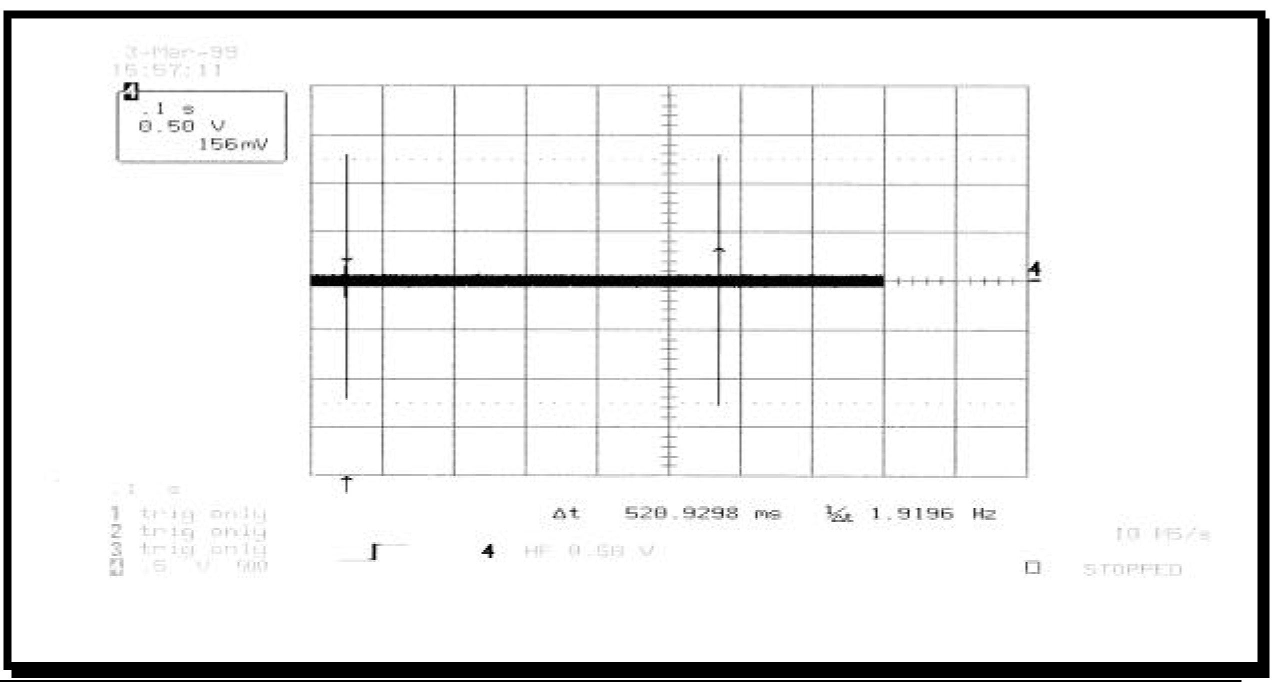


Figure 6.0: Transmission Period of EUT

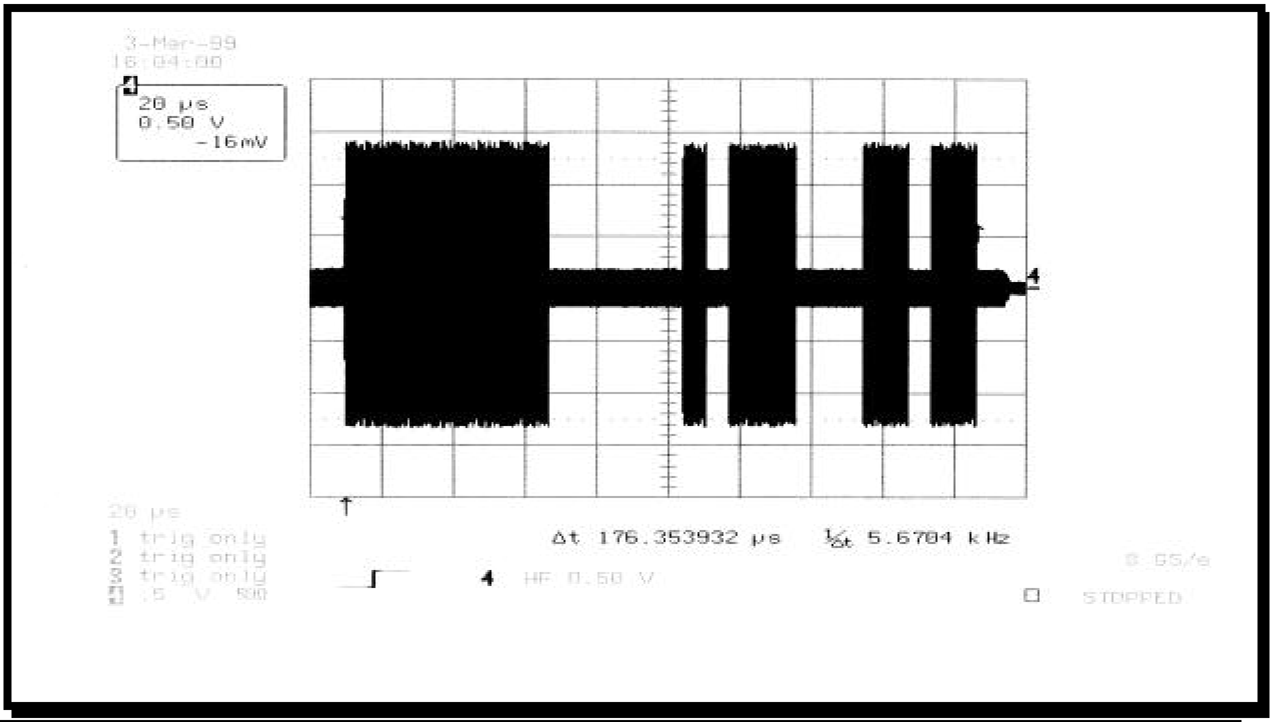


Figure 2: Pulse Width of the Transmitted Message

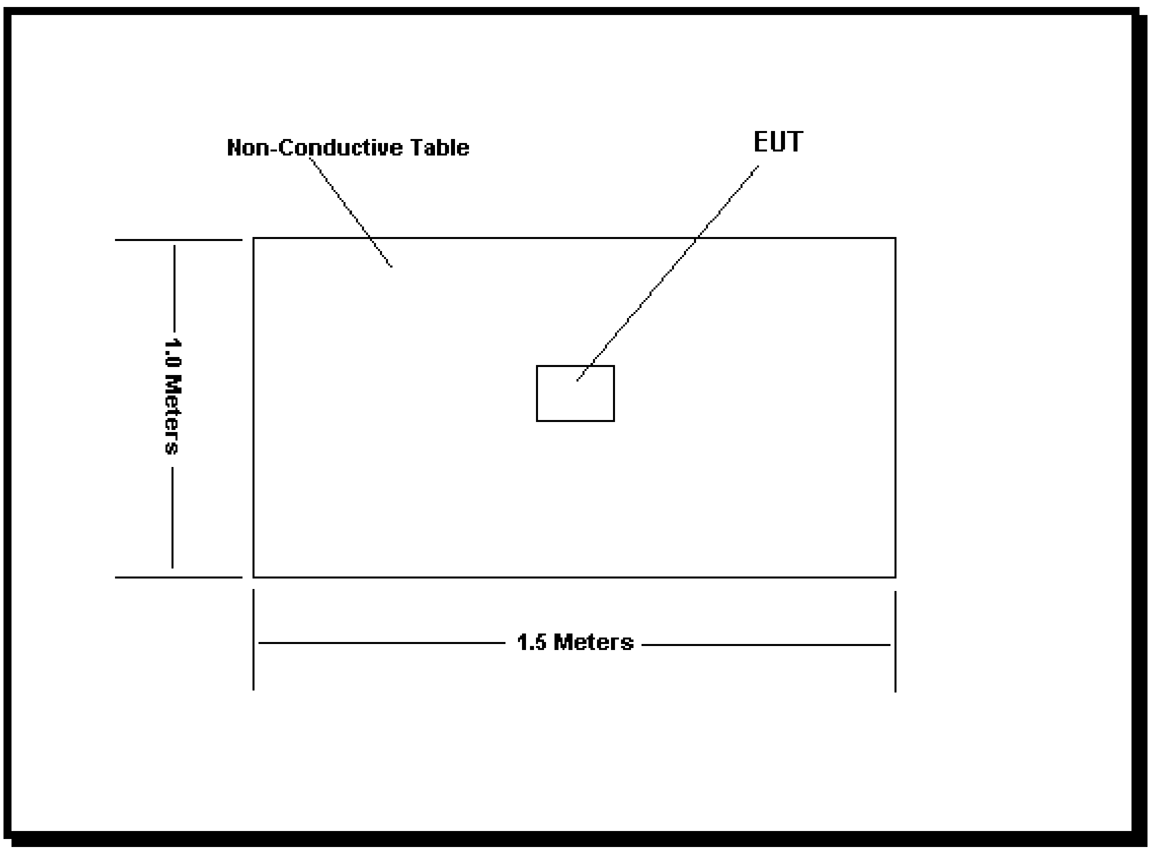
<u>Therefore, Using the above formula, we find the duty cycle to be:</u>
Duty Cycle = (176µS/100mS)x100% = .1764%
Duty Cycle Correction = 20log(Duty Cycle) or 20log(.1764%) = -15.1dB.

<u>So</u>
Average readings shown in table 10.6.2 in section 10.6, were obtained by reducing the peak values given in table 10.6.1 by 15.1dB.

7.0 Support Equipment

Manufacturer	Equipment Type	Model Number	Serial Number	FCC ID
The EUT is self supporting and required no support equipment				

8.0 Equipment Under Test Setup Block Diagram



9.0 Test Setup Photographs

Figure 9.1: Front View

Figure 9.2: Back View

10.0 Summary of Tests

Along with the tabular data shown below, plots were also taken of all signals deemed important enough to document. The tables below make reference to plot numbers that can be found in appendix A of this report.

10.1 Antenna Requirement - FCC Section 15.203

The antenna is a through hole mounted monopole whip and is permanently soldered to the PCB and can not be altered or substituted without causing damage to the unit. This antenna configuration satisfies section 15.203 of the rules. Photographs of the antenna are given in Appendix A of this report.

10.2 Power Line Conducted Emissions - FCC Section 15.207

The EUT is powered by a 3.5VDC battery and has no connection to the AC Mains. Conducted emissions are not required.

10.3 6dB Bandwidth Requirement - FCC Section 15.247(a)(2)

10.3.1 Band Utilization

Data Plots #1 and #2 in Appendix B show the upper and lower band edges respectively. The display line was set to 20dB down from the peak to show that all spurs outside of the band are greater than 20dB down from the peak.

10.3.2 6dB Bandwidth Requirement

The bandwidth of the spread spectrum signal 6dB down from the peak of fundamental frequency was found to be 8.08MHz, well above the required minimum of 500kHz.

See Data Plot #3 in Appendix B entitled: 6dB Bandwidth.

10.4 Peak Output Power Requirement - FCC Section 15.247(b)

The maximum peak modulated output power of the EUT was found to be -2.50dBm or 3.16mW, well below the 1 Watt requirement.

See Data Plot #4 in Appendix B entitled: Modulated Maximum Peak Output Power

10.5 Spurious Emissions - FCC Section 15.247(c)

10.5.1 RF Conducted Spurious Emissions

The EUT was investigated for conducted spurious emissions from 30MHz to 10GHz, which is just over 10 times the fundamental frequency. For each measurement, the spectrum analyzer's VBW was set to 100kHz and the RBW was set to 1MHz.

The RF conducted spurious emissions found in the band of 300MHz to 10GHz are reported below. The following plots were taken to show compliance and can be found in Appendix B:

Data Plot #5: Spurious Emissions from 30.0MHz - 1.0 GHz

No Spurious emissions were detected or were found to be >>20dB down from the fundamental frequency.

Data Plot #6: Spurious Emissions from 850 MHz - 2.0 GHz

One spur was detected in this band at 1.822GHz. It was found to be the first harmonic of the fundamental and was 34.67 dB down from the fundamental frequency.

Data Plot #7: Spurious Emissions from 1.90GHz - 4.0 GHz

The only detectable signal in this band was found to be 44.12 dB down from the fundamental frequency.

Data Plot #8: Spurious Emissions from 3.9 GHz - 7.0 GHz
No Spurious emissions were detected or were found to be >>20dB down from the fundamental frequency. The anomaly in this plot was determined to be a transition and a function of the spectrum analyzer.

Data Plot #9: Spurious Emissions from 6.9 GHz - 10.0 GHz
No Spurious emissions were detected or were found to be >>20dB down from the fundamental frequency. The anomaly in this plot was determined to be a transition and a function of the spectrum analyzer.

10.5.2 Radiated Spurious Emissions(Restricted Bands)

The peak radiated spurious emissions found in the restricted bands are reported below in table 10.5.1. Average measurements are shown in table 10.5.2. Plots have also been taken for each of the peak readings and are given in Appendix B. The average readings shown below were not measured due to the slow duty cycle. The peak readings were reduced by a factor of 15.1dB to reflect the 176.4µS duty cycle.

Table 10.5.1: Peak Radiated Spurious Emissions in Restricted Bands

Frequency (GHz)	Level (dBm)	Correction Factors	Range Correction	Corrected Level(dBm)	Corrected Level(uV/m)	Limit (uV/m)	Margin (uV/m)	Plot Number	Pass/Fail
2.745	-49.8	11.1	0	-38.7	2600.160	5000	2399.840	10	Pass
3.660	-66.3*	11.6	9.54	-45.16	1235.947	5000	3764.053	11	Pass
4.575	-69.3*	12.5	9.54	-47.26	970.510	5000	4029.490	12	Pass
7.320	-70.8*	19.71	9.54	-41.55	1872.837	5000	3127.163	Not Taken	Pass
8.235	-70.6*	20.55	9.54	-40.51	2111.057	5000	2888.943	Not Taken	Pass
9.150	-70.9*	21.1	9.54	-40.26	2172.701	5000	2827.299	Not Taken	Pass

* Signal could not be detected at a distance of 3 meters. Antenna was moved up to one meter and corrected as indicated in the range correction column.

Table 10.5.2: Average Radiated Spurious Emissions in Restricted Bands

Frequency (GHz)	Level (dBm)	Correction Factors	Range Correction	Corrected Level(dBm)	Corrected Level(uV/m)	Limit (uV/m)	Margin	Plot Number	Pass/Fail
2.745	-64.9	11.1	0	-53.8	457.088	500	42.9120	N/A	Pass
3.660	-81.4	11.6	9.54	-60.26	217.270	500	282.730	N/A	Pass
4.575	-84.4	12.5	9.54	-62.36	170.608	500	329.392	N/A	Pass
7.320	-85.9	19.71	9.54	-56.65	329.230	500	170.770	N/A	Pass
8.235	-85.7	20.55	9.54	-55.61	371.108	500	128.892	N/A	Pass
9.150	-86.0	21.1	9.54	-55.36	381.944	500	118.056	N/A	Pass

Sample Calculations
Corrected Level(dBm) = Receiver Level + Correction Factors - Range Correction
Conversion from dBm to uV/m = Antilog(dBm + 107)/20)

Duty Cycle Correction = 20Log(Duty Cycle) or 20Log(.1764mS) = -15.1dB
Range Correction = 20Log(D1/D2) Where D1 is the specified distance used and D2 is the distance used to

make measurements = [20Log(3/1)] = 9.54 dB

Example Calculation at 2.745 GHz: Antilog((-49.8 + 11.1 - 0 + 107)/20) = 2600.160uV/m

10.6 Power Spectral Density - FCC Section 15.247(d)
The power spectral density of the fundamental frequency was found to be -8.42dBm, well below the limit of 8dBm.

See Data Plot #13 in Appendix B entitled: Power Spectral Density

10.7 Processing Gain - FCC Section 15.247(e)
The processing gain is 17 dB for the transmitter and a minimum of 15 dB for the receiver.

11.0 MPE Calculations

Worst case calculations are offered to demonstrate compliance with the Limits of Maximum Permissible Exposure. Calculations were made with reference to OET bulletin 65, Edition 97-01, August 1997.

After evaluation of the document, Equation 5 in section 2 is determined to be relevant to LXE equipment. The equation is given as :

$S = EIRP/4\pi R^2 = (1.64)ERP/4\pi R^2 = (0.41)ERP/\pi R^2$

Where
S = Power Density(mW/cm^2)
EIRP = Equivalent(or effective) isotropically radiated power
ERP = Power referenced to a half-wave dipole radiator
R = Distance from center of radiation pattern to the point of interest

CAL Node
The CAL Node is intended to be mounted high on a wall. No less than 12 feet or 365.8cm.

Given:
- Radio ERP = -2.50 dBm or 562µW as measured.
- EIRP = 1.64xERP

Assuming:
Average person is 6ft. tall or 182.9cm

Therefore
R = 365.8cm - 182.9cm = 182.9cm
ERP_T = -2.50dBm(Radio ERP) + 0dBi(Antenna Gain) = -2.50dBm or 562µW

Result
$S = (0.41)ERP/\pi R^2 = (0.41)562\mu W/\pi(182.9cm)^2$
$S = 2.19nW/cm^2$

The results obtained by these calculations were compared to the limits given in Table 1 of Appendix A of said document and found to be well below the specified 5mW/cm^2 for Occupational/Controlled Exposure environments, and well below the 1mW/cm^2 for General Population/Controlled Exposure environments.

Additionally, the minimum MPE distance is .270cm. All radiating components will be enclosed inside of a NEMA Type 4 enclosure that provides a barrier of greater than 2cm from the antenna to the closest outside point of the enclosure. If installed properly, no person will be able to get closer than 2cm.

12.0 Sample Label

The label shown below will be placed on the top of the unit in plain view.

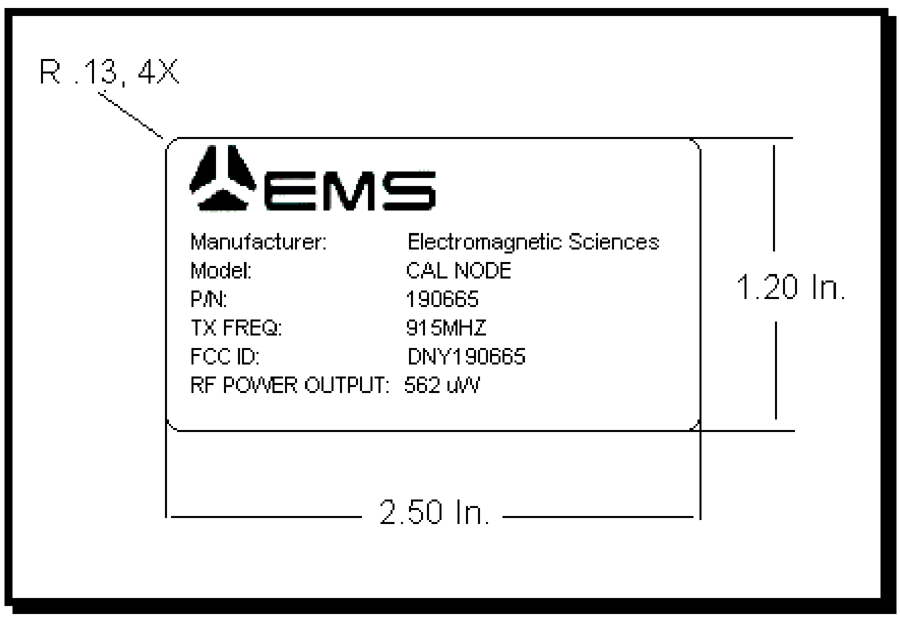


Figure 12.0: Sample Label

13.0 Conclusion

The product covered by this report has been tested and found to comply with the requirements as described in Part 15, Subpart C, Section 15.247 of the FCC Code of Federal Regulations.

Prepared by:	Reviewed by:
R. Sam Wismer	Erik Collins
RF Approvals Engineer	EMI/EMC Engineer
LXE, Inc.	LXE, Inc.
Date: March 4, 1999	Date: March 4, 1999