REGULATORY TEST REPORT

TITLE: ERT Repeater FH FCC Test Report
AUTHOR: Drew Rosenberg

REV	CCO	DESCRIPTION OF CHANGE	DATE	*APPROVALS*	
A		INITIAL RELEASE		(Function)	
				(Function)	

REVISION HISTORY

				(Function)	
				(Function)	
				(Function)	

Summary

Test Data Summary

FCC 15.247 Frequency Hopper

FCC ID: EO9-SPIRIT
Device Model: ERT Repeater

Model Numbers:
Sleeve: SPI-0001-002
Pole: SPI-0005-002

Serial Numbers:
Sleeve: 50024, 00129
Pole: 60003

Rule	Description	Max. Reading	Pass/Fail
15.207	Powerline Conducted Emissions	> 10dB Margin	Pass
15.247(a)(1)	Carrier Frequency Separation	> 20dB Bandwidth	Pass
15.247(a)(1)(i)	Number of hopping Channels	50	Pass
15.247(a)(1),(g), and (h)	Hopping System Requirements	N/A	Pass
15.247(a)(1)(i)	20dB Bandwidth	125 kHz	Pass
15.247(b)	Power Output	29.5 dBm	Pass
15.247(c)	Spurious Emissions	-52dBc	Pass
15.205	Restricted Bands - sleeve	10.7 dB margin	Pass
15.205	Restricted Bands – pole mount	9.7 dB margin	Pass
15.247(b)(5)	MPE Minimum safe distance	9.98 cm	Pass

Cognizant Personnel

Name	Title
Drew Rosenberg	Regulatory Engineer
Mark Kvamme	Senior Technician
Scott Cumeralto	Principal Engineer

FCC Part 15.207

Powerline Conducted Emissions

Measure the AC powerline conducted emissions from 150kHz to 30 MHz using a 50µH/50Ω line impedance stabilization network (LISN). Verify that no emissions exceed the following limits:

Frequency (MHz)	Quasi-Peak (dBuV)	Average (dBuV)
0.15-0.5	66 to 56*	56 to 46*
0.5-5	56	46
5-30	60	50

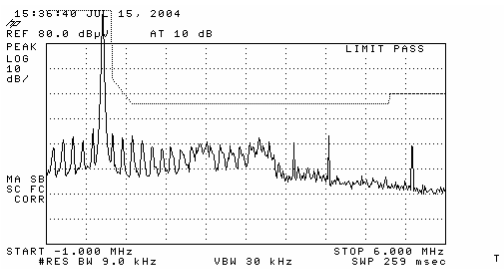
*Decreases with the logarithm of frequency

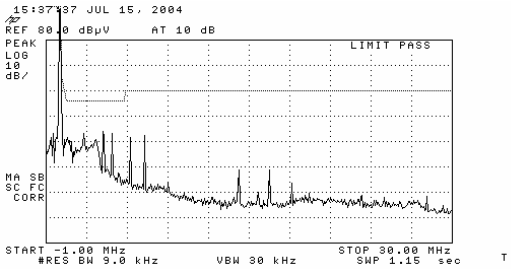
Equipment Used	Asset Number
LISN	8925
Spectrum Analyzer	6964

Date	Temp/Humidity ºF / %	Tested by
7/15/2004	78 / 71	Mark Kvamme

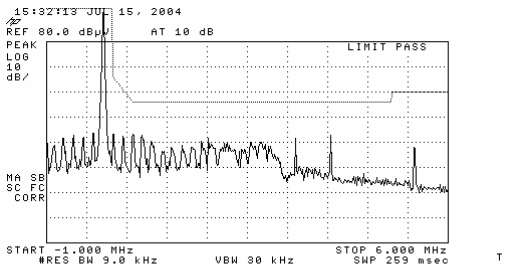
Unit tested: 50024

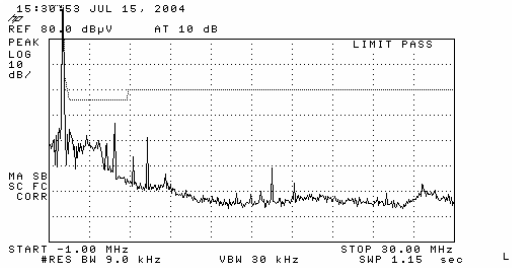
L1





L2





FCC Part 15.247(a)(1)

Carrier Frequency Separation

Verify that the channel separation is > the 20dB bandwidth of a single transmission.

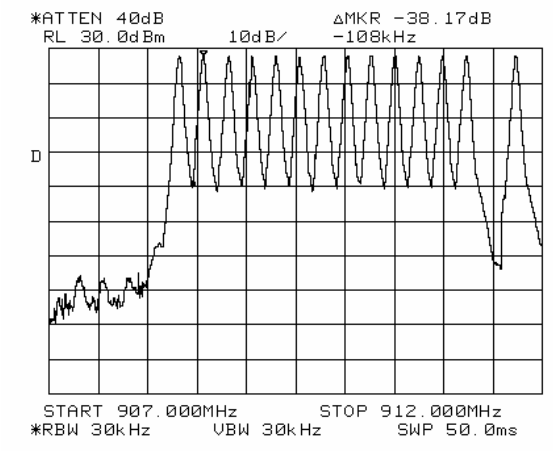
Use the following analyzer settings:
RBW >= 1% of the span
VBW >= RBW
Sweep = auto, Detector function = peak
Trace = max hold

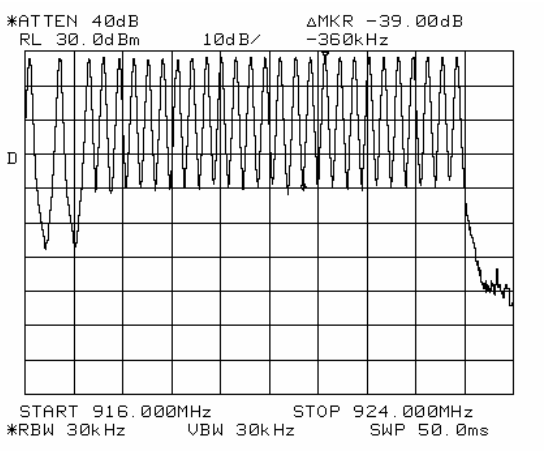
Equipment Used	Serial Number
Spectrum Analyzer	3720A00372

Date	Tested by
9/13/2004	Scott Cumeralto

Unit tested: 00129

The plots below show that each hopping channel is outside of the 20dB bandwidth of its adjacent channels.





FCC Part 15.247(a)(1)(i)

Number of Hopping Channels

The EUT must have its hopping function enabled. Use the following spectrum analyzer settings:

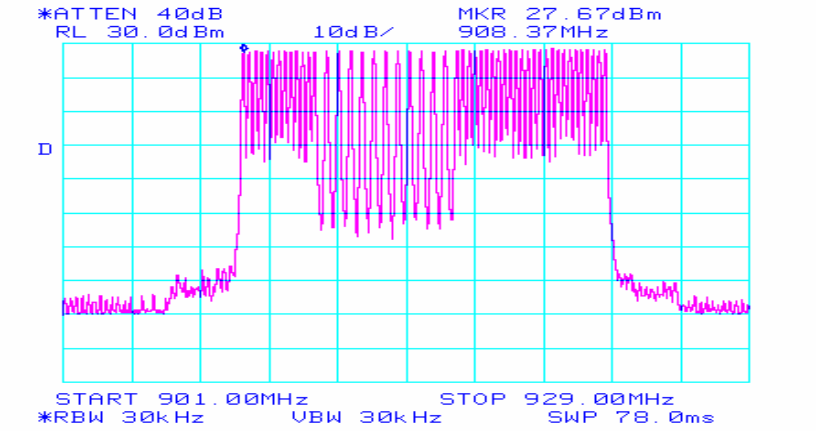
Span = the frequency band of operation
RBW >= 1% of the span, VBW >= RBW
Sweep = auto, Detector function = peak
Trace = max hold
Allow the trace to stabilize.

Equipment Used	Serial Number
Spectrum Analyzer	3720A00372

Date	Tested by
9/13/2004	Scott Cumeralto

Unit tested: 00129

The following depicts the full 50 RF channels on the UUT under normal hopping operation. The unit was exercised utilizing a Simulated ERT packet generator operated on a single receiver channel and allowing the repeater to operate in the hopping mode. The channels are pseudo randomly selected base on the table supplied/programmed at the time of manufacturing. A list of the channels and the pseudo random hop table is supplied is supplied below:



1	908.34763	17	913.18091	33	918.98084	49	922.84747
2	908.58929	18	913.66424	34	919.22251	50	923.08913
3	908.83096	19	914.14756	35	919.46417		
4	909.07262	20	914.63089	36	919.70584		
5	909.31428	21	915.11422	37	919.9475		
6	909.55595	22	915.59755	38	920.18916		
7	909.79761	23	916.08088	39	920.43083		
8	910.03928	24	916.5642	40	920.67249		
9	910.28094	25	917.04753	41	920.91416		
10	910.52260	26	917.28920	42	921.15582		
11	910.76427	27	917.53086	43	921.39748		
12	911.00593	28	917.77252	44	921.63915		
13	911.24760	29	918.01419	45	921.88081		
14	911.73092	30	918.25585	46	922.12248		
15	912.21425	31	918.49752	47	922.36414		
16	912.69758	32	918.73918	48	922.60580		

FCC 15.247(a)(1),(g), & (h)

Hopping System Requirements

Unit tested: 00129

Equipment Used	Serial Number
Spectrum Analyzer	3720A00372

Date	Tested by
9/17/2004	Scott Cumeralto

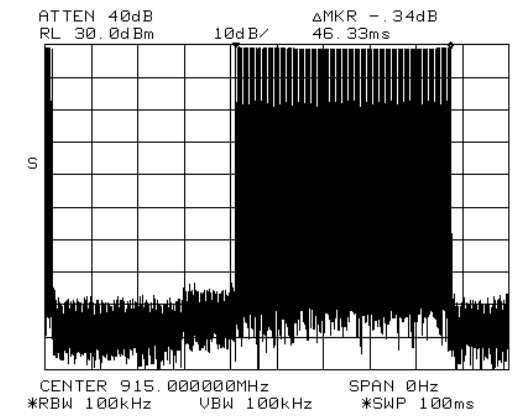
The repeater uses the 50 channels equally on average and does not exceed the 400ms channel occupancy time during retransmission of longest length message. In normal operation, the repeater simply retransmits all messages heard within a population of ERTs.

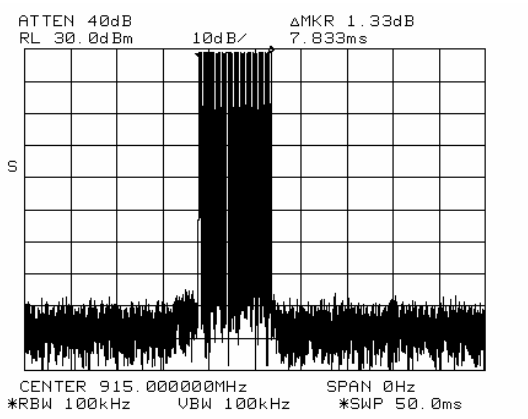
Messages are divided into two categories. The first is an IDM, which requires 46.3 ms of transmission time. The second is an SCM, which requires 7.8 ms transmission time. Upon reception of any random ERT within the population, the repeater selects the next transmit channels in the pseudo-random hop table and retransmits the information obtained from the originating ERT. ***The transmit channels are in no way synchronized with the receiver channels.*** The receiver channels are sequentionally selected on a consistant timing schedule. The randomization of ERT reception is based on a number of variable such as frequency hopping of the ERT as well as randomized timing of the ERT transmissions. Additional randomization comes from RF collisions, random hopping frequency of the receiver and normal RF propagation variations.

However, upon successful reception of an ERT message and validation of proper CRC, the repeater transmitter utilizes the next hop channel from the list of 50 for re-transmission. The transmission only occurs once on each channel per message reception thus will never exceed the 400 ms maximum transmission time per transmission or per channel. Additionally, the unit is half duplex and requires a valid reception before retransmission, thus the unit is incapable of exceeding the 400 ms per channel in any 20 second period.

As an example, the fastest reception a retransmission feasible is 50 messages per second
With each message requiring 7.8 ms. The total is 390 ms in any 1 second period or at a maximum of 156 ms in a 400 ms period.

Another feature which is required for proper operation is the randomization of the initial channel during power up. This randomization allows for multiple repeaters to regain power and not get in lock step with one another. This feature also further randomizes the channels per the FCC hopping and equal occupancy requirements.





FCC Part 15.247(a)(1)

20 dB Bandwidth

Use the following spectrum analyzer settings:

Span = approximately 2 to 3 times the 20 dB bandwidth, centered on a hopping channel

RBW ³ 1% of the 20 dB bandwidth

VBW ³ RBW

Sweep = auto

Detector function = peak

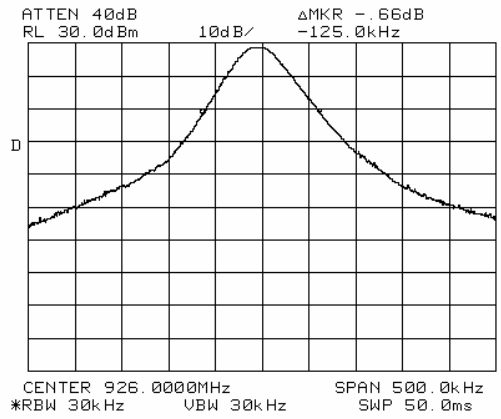
Trace = max hold

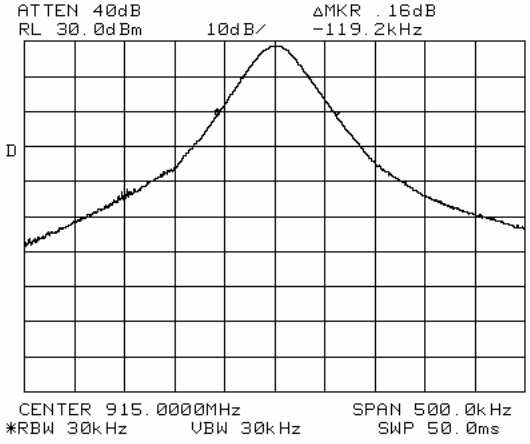
The EUT should be transmitting at its maximum data rate. Allow the trace to stabilize. Use the marker-to-peak function to set the marker to the peak of the emission. Use the marker-delta function to measure 20 dB down one side of the emission. Reset the marker-delta function, and move the marker to the other side of the emission, until it is (as close as possible to) even with the reference marker level. The marker-delta reading at this point is the 20 dB bandwidth of the emission. If this value varies with different modes of operation (e.g., data rate, modulation format, etc.), repeat this test for each variation. The limit is specified in one of the subparagraphs of this Section. Submit this plot(s).

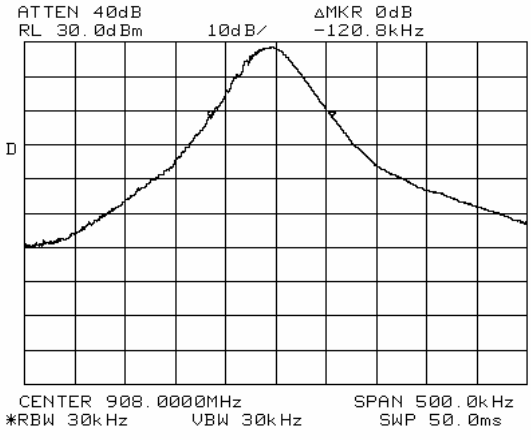
Equipment Used	Serial Number
Spectrum Analyzer	3720A00372

Date	Tested by
9/13/2004	Scott Cumeralto

Unit tested: 00129







FCC Part 15.247(b)

Power Output

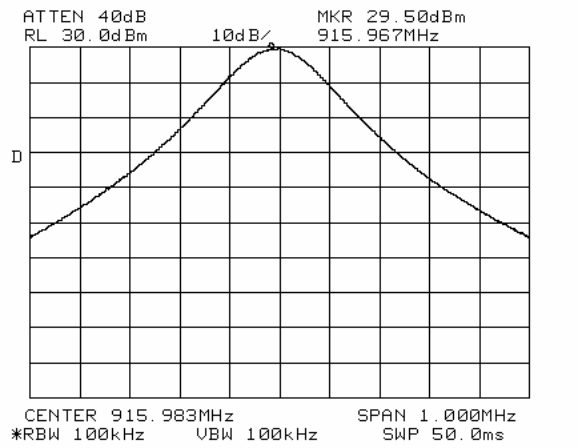
This is an RF conducted test. Use a direct connection between the antenna port of the transmitter and the spectrum analyzer, through suitable attenuation. Set the RBW > 6dB bandwidth of the emission or use a peak power meter.

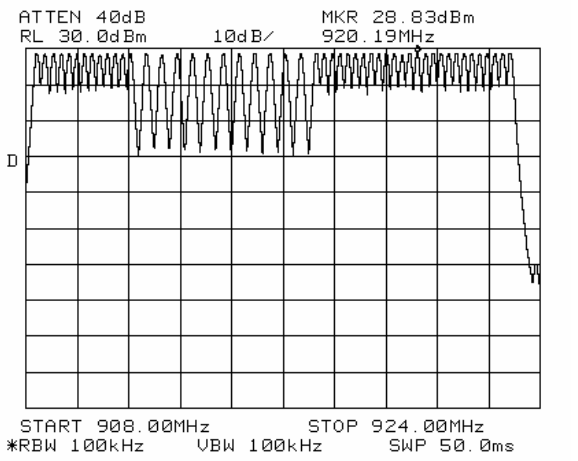
If the device has an integrated antenna, either measure the EIRP and divide by the antenna gain or solder a connector to the board and document how impedance matching is made to the test equipment.

Equipment Used	Serial Number
Spectrum Analyzer	3720A00372

Date	Tested by
9/13/2004	Scott Cumeralto

Unit tested: 00129





FCC Part 15.247(c)

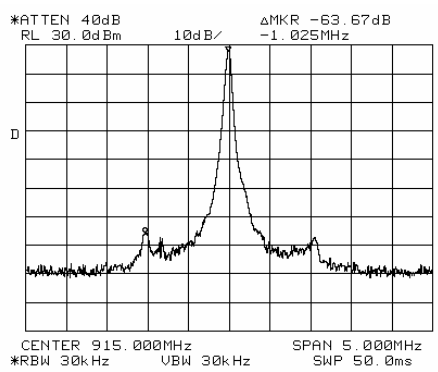
Spurious Emissions

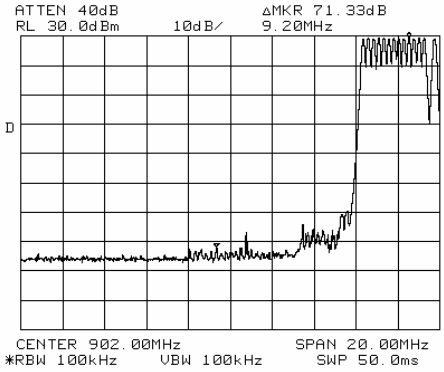
This is an RF conducted test: Set RBW = 100 kHz, Video bandwidth (VBW) > RBW, scan up through 10th harmonic. All harmonics/spurs must be at least 20 dB down from the highest emission level within the authorized band *as measured with a 100 kHz RBW.*

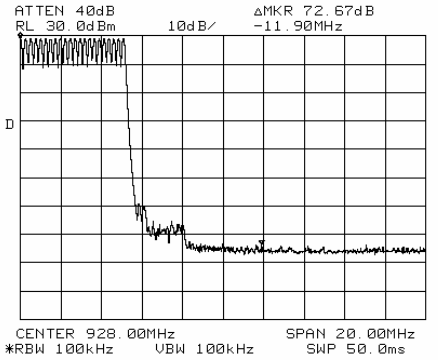
Equipment Used	Serial Number
Spectrum Analyzer	3720A00372

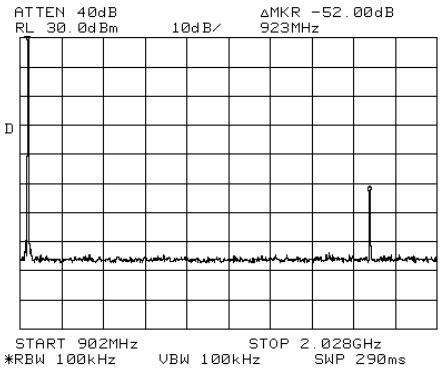
Date	Tested by
9/13/2004	Scott Cumeralto

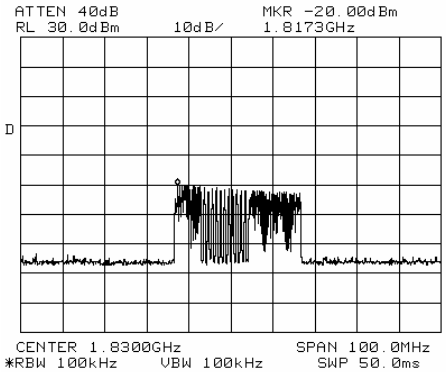
Unit tested: 00129

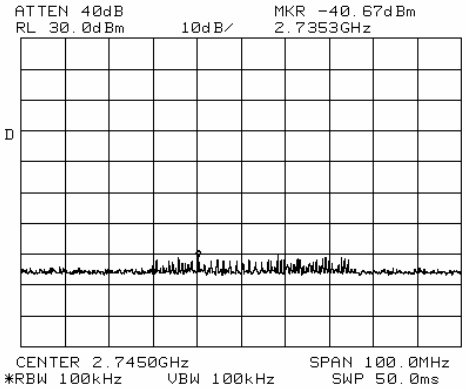


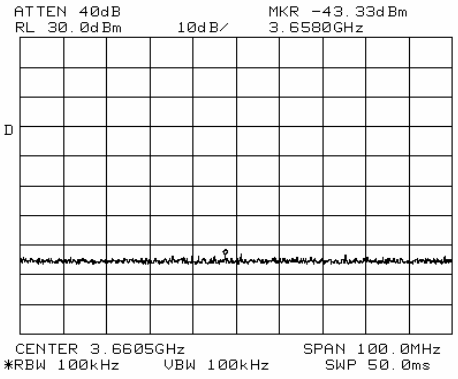


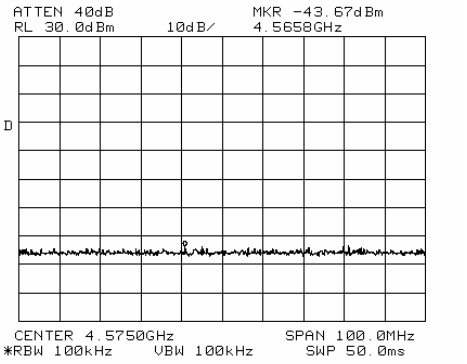


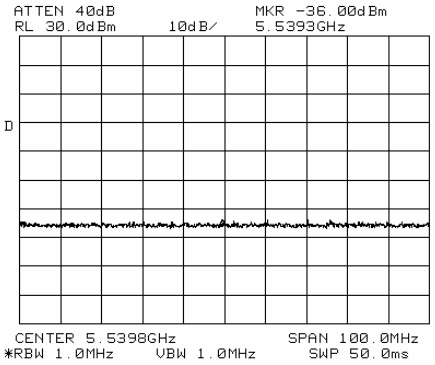


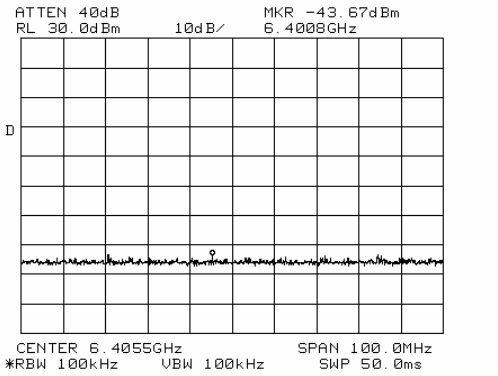


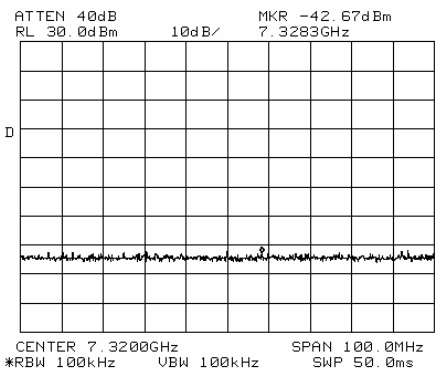


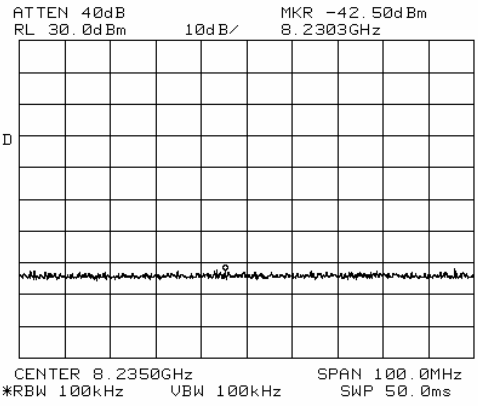

ATTEN 40dB
RL 30.0dBm
10dB/
MKR -43.33dBm
3.6580GHz
D
CENTER 3.6605GHz
SPAN 100.0MHz
*RBW 100kHz
VBW 100kHz
SWP 50.0ms

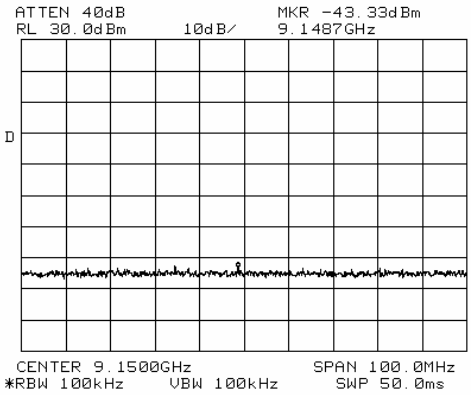

ATTEN 40dB
RL 30.0dBm
10dB/
MKR -43.67dBm
4.5658GHz
D
CENTER 4.5750GHz
SPAN 100.0MHz
*RBW 100kHz
VBW 100kHz
SWP 50.0ms

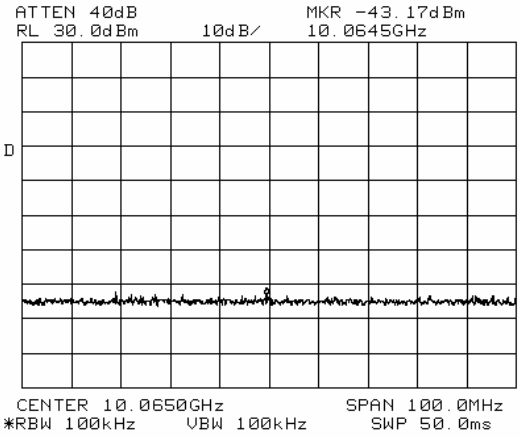

ATTEN 40dB
RL 30.0dBm
10dB/
MKR -36.00dBm
5.5393GHz
D
CENTER 5.5398GHz
SPAN 100.0MHz
*RBW 1.0MHz
VBW 1.0MHz
SWP 50.0ms


ATTEN 40dB
RL 30.0dBm
10dB/
MKR -43.67dBm
6.4008GHz
D
CENTER 6.4055GHz
SPAN 100.0MHz
*RBW 100kHz
VBW 100kHz
SWP 50.0ms


ATTEN 40dB
RL 30.0dBm
10dB/
MKR -42.67dBm
7.3283GHz
D
CENTER 7.3200GHz
SPAN 100.0MHz
*RBW 100kHz
VBW 100kHz
SWP 50.0ms


ATTEN 40dB
RL 30.0dBm
10dB/
MKR -42.50dBm
8.2303GHz
D
CENTER 8.2350GHz
SPAN 100.0MHz
*RBW 100kHz
VBW 100kHz
SWP 50.0ms


ATTEN 40dB
RL 30.0dBm
10dB/
MKR -43.33dBm
9.1487GHz
D
CENTER 9.1500GHz
SPAN 100.0MHz
*RBW 100kHz
VBW 100kHz
SWP 50.0ms


ATTEN 40dB
RL 30.0dBm
10dB/
MKR -43.17dBm
10.0645GHz
D
CENTER 10.0650GHz
SPAN 100.0MHz
*RBW 100kHz
VBW 100kHz
SWP 50.0ms

FCC Part 15.205

Restricted Bands - Sleeve

Measure the field strength of all transmitter spurious emissions in the restricted bands listed below according to the procedure in Appendix A

MHz	MHz	MHz	GHz
0.090-0.110	16.42-16.423	399.9-410	4.5-5.15
0.495-0.505 1	16.69475-16.69525	608-614	5.35-5.46
2.1735-2.1905	16.80425-16.80475	960-1240	7.25-7.75
4.125-4.128	25.5-25.67	1300-1427	8.025-8.5
4.17725-4.17775	37.5-38.25	1435-1626.5	9.0-9.2
4.20725-4.20775	73-74.6	1645.5-1646.5	9.3-9.5
6.215-6.218	74.8-75.2	1660-1710	10.6-12.7
6.26775-6.26825	108-121.94	1718.8-1722.2	13.25-13.4
6.31175-6.31225	123-138	2200-2300	14.47-14.5
8.291-8.294	149.9-150.05	2310-2390	15.35-16.2
8.362-8.366	156.52475-156.52525	2483.5-2500	17.7-21.4
8.37625-8.38675	156.7-156.9	2655-2900	22.01-23.12
8.41425-8.41475	162.0125-167.17	3260-3267	23.6-24.0
12.29-12.293	167.72-173.2	3332-3339	31.2-31.8
12.51975-12.52025	240-285	3345.8-3358	36.43-36.5
12.57675-12.57725	322-335.4	3600-4400	Above 38.6
13.36-13.41			

Equipment Used	Asset Number
Spectrum Analyzer	2064147
Double Ridged Waveguide Antenna (> 1GHz)	16256
Power Meter	6520
Power Sensor	6521
Signal Generator	12392

Date	Temp/Humidity ºF / %	Tested by
9/17/2004	73 / 55	Mark Kvamme

Unit tested: 50024

Prior to testing, the device emissions were checked with it oriented in three different orthogonal planes on the turntable. The worst case was found to be with the antenna pointing up.

Frequency (MHz)	Polarity	Level (dBµV)	ACF (dB)	Coax loss (dB)	Duty Cycle Relaxation	Final level (dBm)	Limit (dBm)	Margin (dBm)
2783.94	V	12.7	31.5	3.2	12.4	35.0	54.0	19.0
5460	V	14.7	36.2	4.8	12.4	43.3	54.0	10.7

Note: Only harmonics were found during the radiated emissions test.
The levels shown above are an absolute peak level. The transmitter duty cycle is shown below:

Duty Cycling:

SCM messages:

7.8ms transmit – Manchester encoded, 3ms delay, 6ms receive, 3ms delay, repeat
The Manchester encoding gives a transmit duty cycle of 50% during each transmission
7.8+3+6+12 = 19.8ms < 100ms
Therefore, the SCM duty cycle is: (7.8/2)/(7.8+3+6+3) = *19.6%*

IDM messages:

46.33ms transmit – Manchester encoding, 3ms delay, 44.5 ms receive. 3ms delay
The Manchester encoding gives a transmit duty cycle of 50% during each transmission
46.33+3+44.5+3 = 96.83 ms < 100ms
Therefore, the SCM duty cycle is: (46.33/2)/(46.33+3+44.5+3) = *23.9%*

Since IDM is the worst case, the maximum relaxation allowed due to duty cycling is:
20*log(0.239) = *12.4dB of relaxation due to duty cycling*.

FCC Part 15.205

Restricted Bands – Pole mount

Measure the field strength of all transmitter spurious emissions in the restricted bands listed below according to the procedure in Appendix A.

MHz	MHz	MHz	GHz
0.090-0.110	16.42-16.423	399.9-410	4.5-5.15
0.495-0.505 1	16.69475-16.69525	608-614	5.35-5.46
2.1735-2.1905	16.80425-16.80475	960-1240	7.25-7.75
4.125-4.128	25.5-25.67	1300-1427	8.025-8.5
4.17725-4.17775	37.5-38.25	1435-1626.5	9.0-9.2
4.20725-4.20775	73-74.6	1645.5-1646.5	9.3-9.5
6.215-6.218	74.8-75.2	1660-1710	10.6-12.7
6.26775-6.26825	108-121.94	1718.8-1722.2	13.25-13.4
6.31175-6.31225	123-138	2200-2300	14.47-14.5
8.291-8.294	149.9-150.05	2310-2390	15.35-16.2
8.362-8.366	156.52475-156.52525	2483.5-2500	17.7-21.4
8.37625-8.38675	156.7-156.9	2655-2900	22.01-23.12
8.41425-8.41475	162.0125-167.17	3260-3267	23.6-24.0
12.29-12.293	167.72-173.2	3332-3339	31.2-31.8
12.51975-12.52025	240-285	3345.8-3358	36.43-36.5
12.57675-12.57725	322-335.4	3600-4400	Above 38.6
13.36-13.41			

Equipment Used	Asset Number
Spectrum Analyzer	2064147
Double Ridged Waveguide Antenna (Harmonics)	16256
Biconical	11730
Power Meter	6520
Power Sensor	6521
Signal Generator	12392

Date	Temp/Humidity ºF / %	Tested by
10/01/2004	55 / 69	Mark Kvamme

Unit tested: 60003

Prior to testing, the device emissions were checked with it oriented in three different orthogonal planes on the turntable. The worst case was found to be with the antenna pointing up.

Frequency (MHz)	Polarity	Level (dBµV)	ACF (dB)	Coax loss (dB)	Final level (dBm)	Limit (dBm)	Margin (dBm)
72.0	V	20.3	8.8	0.4	29.5	40.0	10.5
74.3	V	15.4	8.8	0.4	24.6	40.0	15.4
156.9	V	19.6	13.4	0.8	33.8	43.5	9.7

Notes:

- No radiated harmonic emissions were found in the pole mount configuration.
- All measurements shown above are peak measurements

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Maximum Permissible Exposure (MPE)

Note: This evaluation is not needed if the device has been tested and found to meet the minimum SAR requirements in test 6b of this document.

Determine the minimum safe distance from the transmitter where a power density of (f_{MHz}/1500) mW/cm^2 is not exceeded.

The power density is calculated as:

$$P_d = (Duty\ Cycle)*P_t*G/4\pi r^2$$

P_d = power density in watts
P_t = transmit power in watts
G = numeric antenna gain
r = distance between body and transmitter in centimeters.

P_{dMAX} = 928/1500 = .619mW/cm^2

P_t = 30 dBm = 1000 mW
Worst case duty cycle =23.9% (from the restricted bands section)

As mentioned earlier, there are two types of antennas for this product. The sleeve repeater has a gain of 2.1dBi and the pole mount repeater has a gain of 5.1dBi:
G_{sleeve} = 2.1dBi
G_{pole} = 5.1dBi
G = G_{max} = 5.1dBi = 3.24 numeric gain

Solving for r:
0.619mW/cm^2 = 0.239*1000mW*3.24/4πr^2
r = [0.239*1000mW*3.24/(4π∗0.619mW/cm^2)]$^{1/2}$ = *9.98 cm*

The users manual will state that a maximum safe distance of 20cm must be maintained during transmit.

Appendix A

Field Strength Measurement Procedure

This test measures the field strength of radiated emissions using a spectrum analyzer and a receiving antenna in accordance with ANSI C63.4-2003. During the test, the EUT is to be placed on a non-conducting support at 80 cm above the horizontal ground plane of the OATS. The horizontal distance between the antenna and the DUT is to be exactly 3 meters. Levels below 1 GHz are to be measured with the spectrum analyzer resolution bandwidth at 120 kHz and levels at or above 1 GHz are to be measured with the spectrum analyzer resolution bandwidth at 1 MHz.

1) Monitor the frequency range of interest at a fixed antenna height and EUT azimuth.
2) If appropriate, manipulate the system cables to produce the highest amplitude signal relative to the limit. Note the amplitude and frequency of the suspect signal.
3) Rotate the EUT 360° to maximize the suspected highest amplitude signal. If the signal or another at a different frequency is observed to exceed the previously noted highest amplitude signal by 1 dB or more, go back to the azimuth and repeat step b). Otherwise, orient the EUT azimuth to repeat the highest amplitude observation and proceed.
4) Move the antenna over its fully allowed range of travel to maximize the suspected highest amplitude signal. If the signal or another at a different frequency is observed to exceed the previously noted highest amplitude signal by 1 dB or more, return to step b) with the antenna fixed at this height. Otherwise, move the antenna to the height that repeats the highest amplitude observation and proceed.
5) Change the polarity of the antenna and repeat step b), step c), and step d). Compare the resulting suspected highest amplitude signal with that found for the other polarity. Select and note the higher of the two signals. This signal is termed the highest observed signal with respect to the limit for this EUT operational mode.