



# 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) |  |

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## 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

|                        |                            |
|------------------------|----------------------------|
| <u>Drew Rosenberg</u>  | <u>Regulatory Engineer</u> |
| Name                   | Title                      |
| <u>Mark Kvamme</u>     | <u>Senior Technician</u>   |
| Name                   | Title                      |
| <u>Scott Cumeralto</u> | <u>Principal Engineer</u>  |
| Name                   | Title                      |

## FCC Part 15.207

### Powerline Conducted Emissions

Measure the AC powerline conducted emissions from 150kHz to 30 MHz using a 50 $\mu$ H/50 $\Omega$  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             |

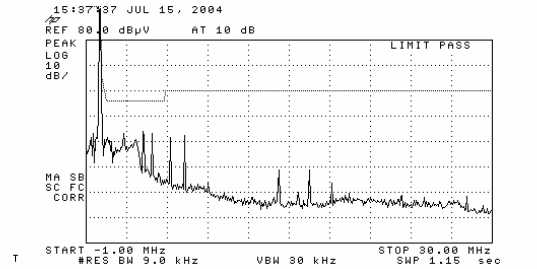
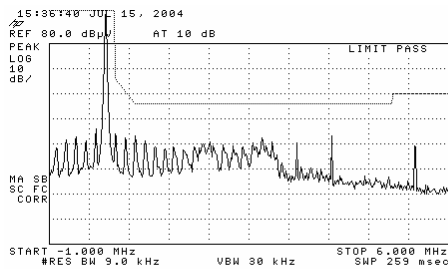
\*Decreases with the logarithm of frequency

| Equipment Used    | Asset Number |
|-------------------|--------------|
| LISN              | 8925         |
| Spectrum Analyzer | 6964         |

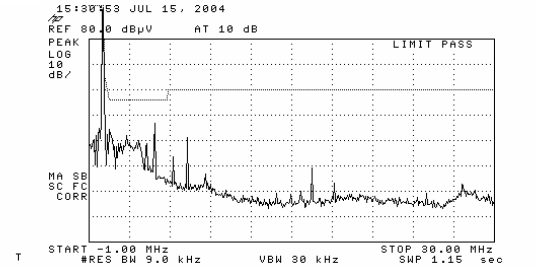
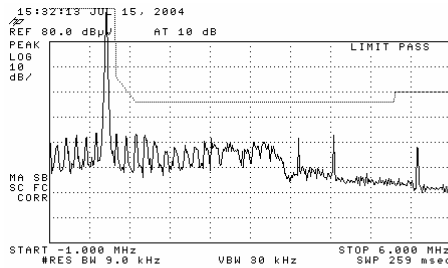
| Date      | Temp/Humidity °F / % | Tested by   |
|-----------|----------------------|-------------|
| 7/15/2004 | 78 / 71              | Mark Kvamme |

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

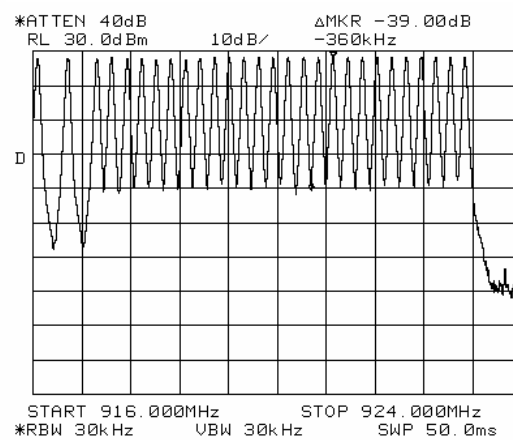
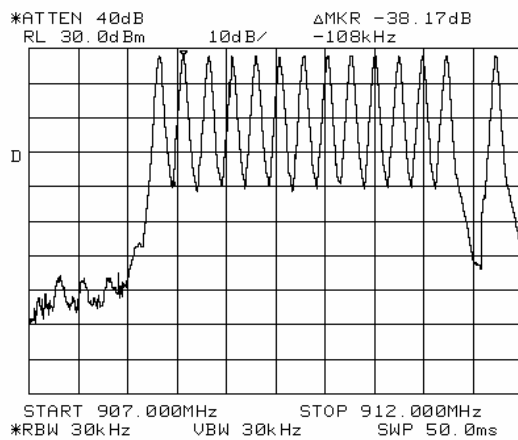
Trace = max hold

| 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:

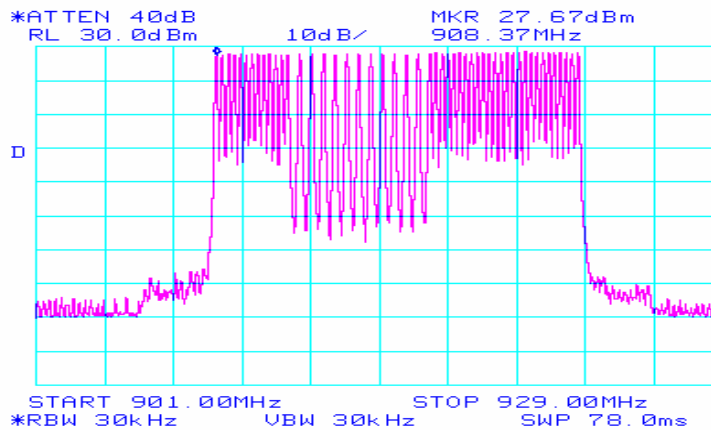
Span = the frequency band of operation  
RBW  $\geq$  1% of the span, VBW  $\geq$  RBW  
Sweep = auto, Detector function = peak  
Trace = max hold  
Allow the trace to stabilize.

| 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 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 |

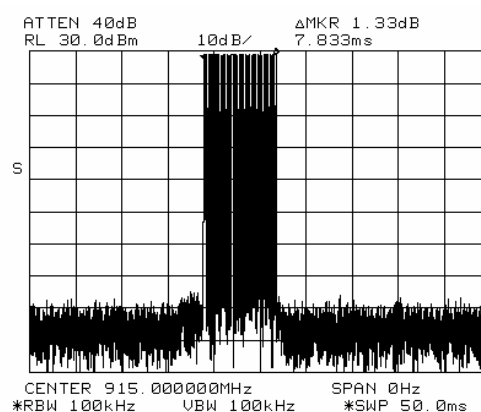
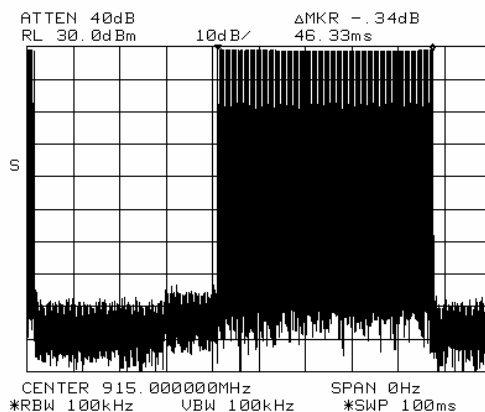
The repeater uses the 50 channels equally on average and does not exceed the 400ms channel occupancy time during retransmission of longest length message. In normal operation, the repeater simply retransmits all messages heard within a population of ERTs.

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 sequentially selected on a consistent 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 <sup>3</sup> 1% of the 20 dB bandwidth

VBW <sup>3</sup> RBW

Sweep = auto

Detector function = peak

Trace = max hold

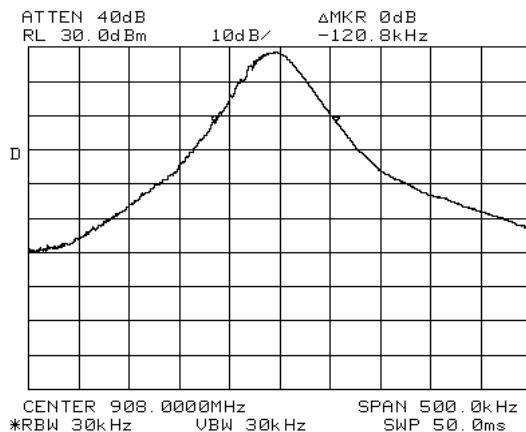
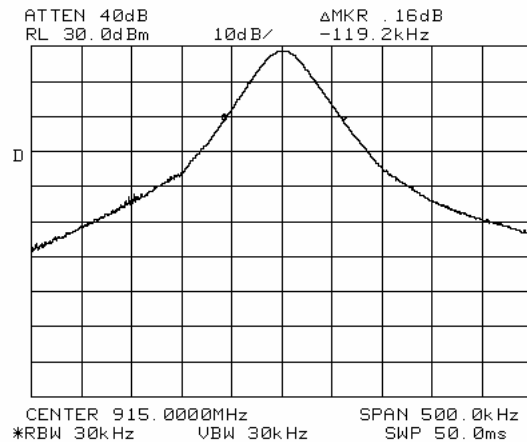
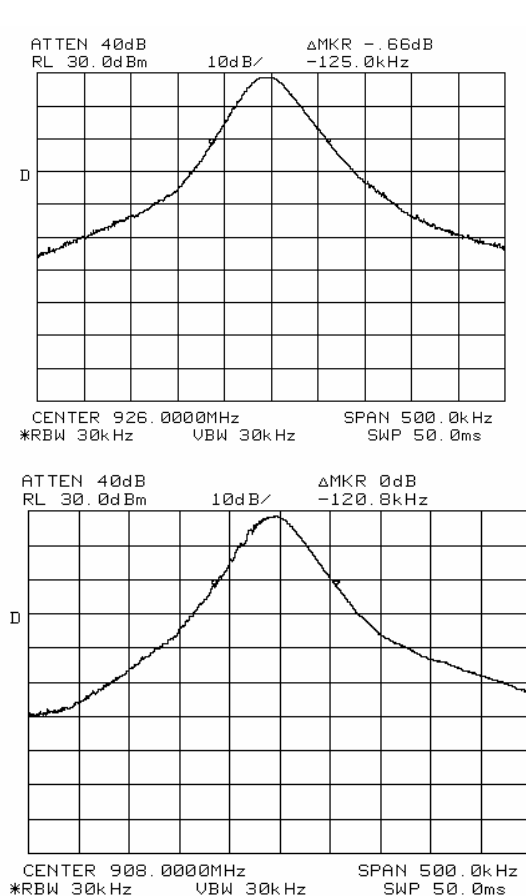
The EUT should be transmitting at its maximum data rate. Allow the trace to stabilize. Use the marker-to-peak function to set the marker to the peak of the emission. Use the marker-delta function to measure 20 dB down one side of the emission. Reset the marker-delta function, and move the marker to the 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

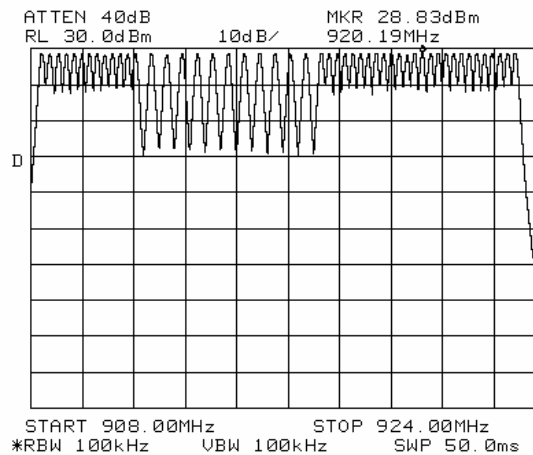
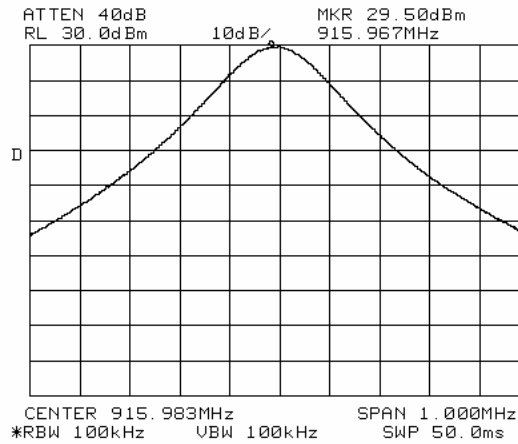
This is an RF conducted test. Use a direct connection between the antenna port of the transmitter and the spectrum analyzer, through suitable attenuation. Set the RBW > 6dB bandwidth of the emission or use a peak power meter.

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)

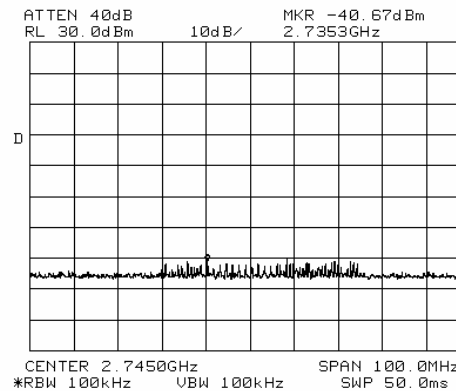
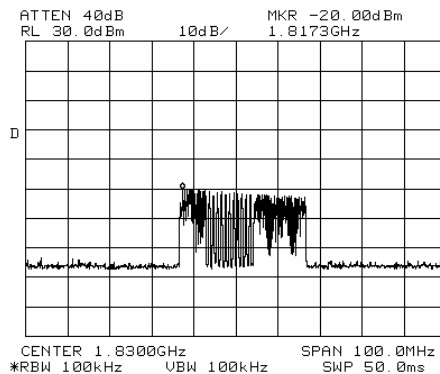
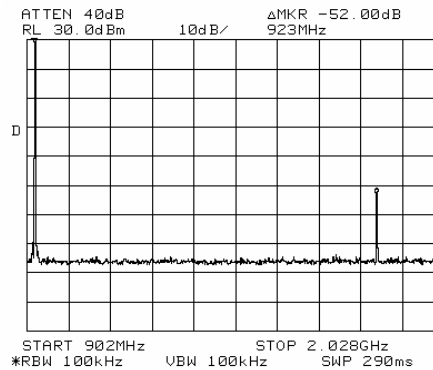
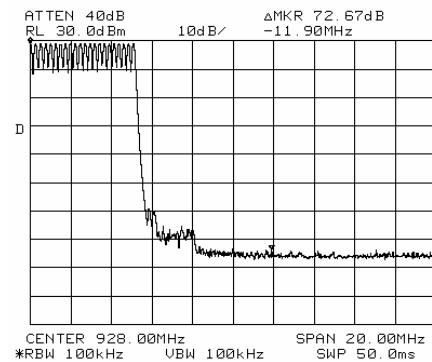
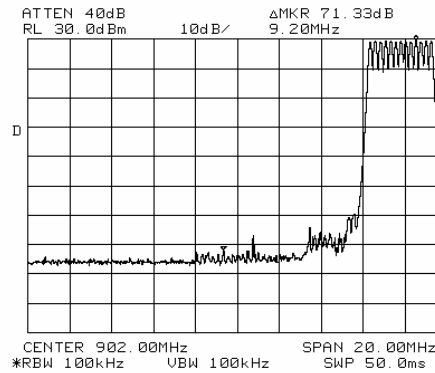
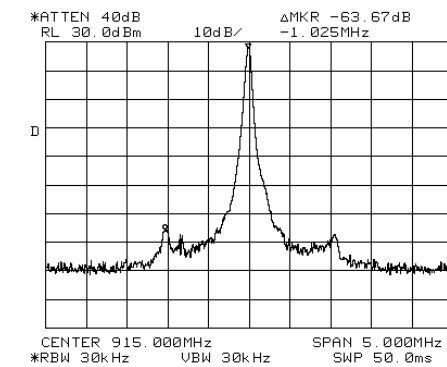
### Spurious Emissions

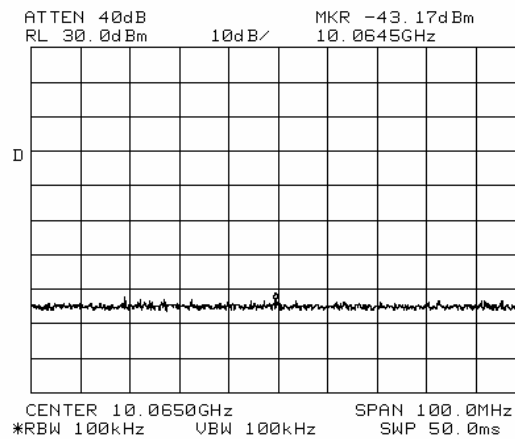
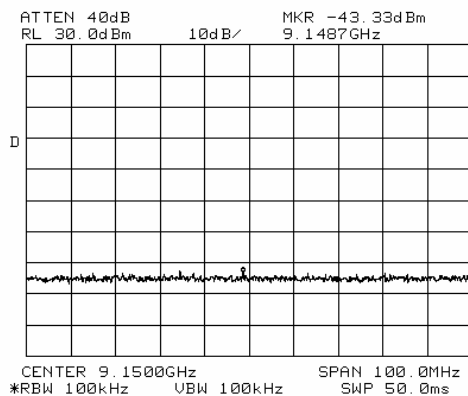
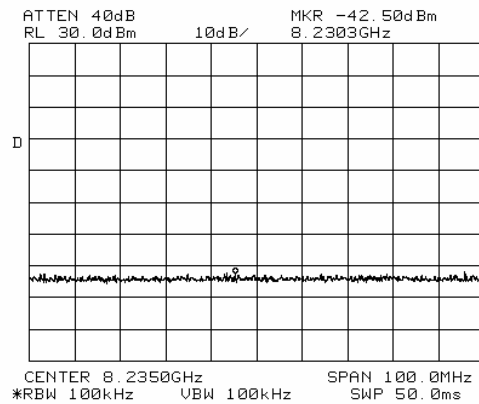
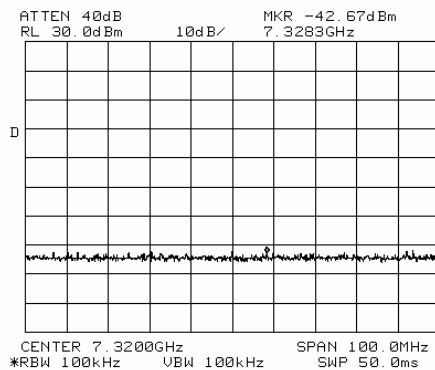
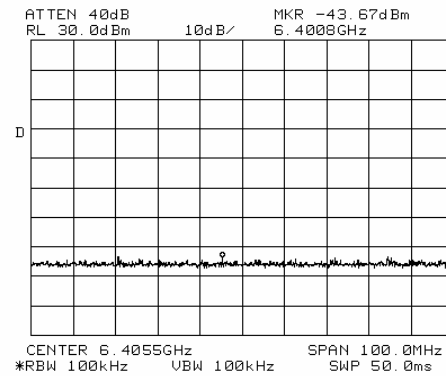
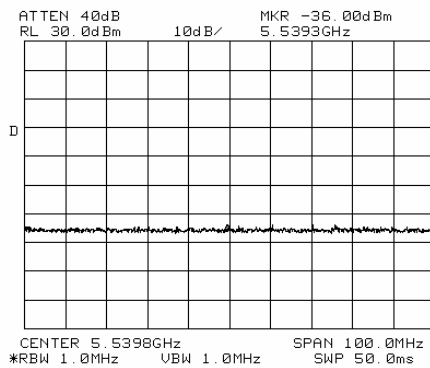
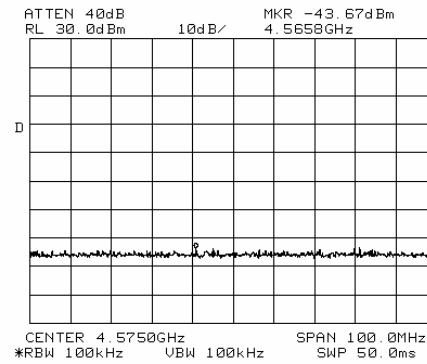
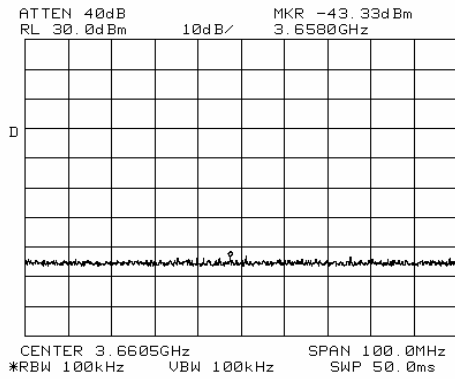
This is an RF conducted test: Set RBW = 100 kHz, Video bandwidth (VBW) > RBW, scan up through 10th harmonic. All harmonics/spurs must be at least 20 dB down from the highest emission level within the authorized band *as measured with a 100 kHz RBW*.

| Equipment Used    | Serial Number |
|-------------------|---------------|
| Spectrum Analyzer | 3720A00372    |

| Date      | Tested by       |
|-----------|-----------------|
| 9/13/2004 | Scott Cumeralto |

Unit tested: 00129





**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<br>°F / % | 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

$7.8+3+6+12 = 19.8\text{ms} < 100\text{ms}$

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

$46.33+3+44.5+3 = 96.83\text{ ms} < 100\text{ms}$

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:

$20*\log(0.239) = 12.4\text{dB of relaxation due to duty cycling.}$

## 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<br>°F / % | 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

**FCC Part 1.1310***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  $(f_{\text{MHz}}/1500) \text{ mW/cm}^2$  is not exceeded.

The power density is calculated as:

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

$P_d$  = power density in watts

$P_t$  = transmit power in watts

$G$  = numeric antenna gain

$r$  = distance between body and transmitter in centimeters.

$$P_{d\text{MAX}} = 928/1500 = .619 \text{ mW/cm}^2$$

$$P_t = 30 \text{ dBm} = 1000 \text{ mW}$$

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:

$$G_{\text{sleeve}} = 2.1 \text{ dBi}$$

$$G_{\text{pole}} = 5.1 \text{ dBi}$$

$$G = G_{\text{max}} = 5.1 \text{ dBi} = 3.24 \text{ numeric gain}$$

Solving for r:

$$0.619 \text{ mW/cm}^2 = 0.239 * 1000 \text{ mW} * 3.24 / 4\pi r^2$$

$$r = [0.239 * 1000 \text{ mW} * 3.24 / (4\pi * 0.619 \text{ mW/cm}^2)]^{1/2} = 9.98 \text{ cm}$$

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.

