# L.S. Compliance, Inc.

W66 N220 Commerce Court
Cedarburg, WI 53012
262-375-4400 Fax: 262-375-4248


COMPLIANCE TESTING OF:

## MX Encoder

Prepared For:

Simbex, LLC
Attention: Mr. Jeffrey Chu
10 Water Street, Suite 410
Lebanon, NH 03766

Test Report Number:

304554-Tx-v3

Test Dates:

February 28TH through March 29TH, 2005


*All results of this report relate only to the items that were tested. This report is not to be reproduced, except in full, without written approval of L. S. Compliance, Inc.*

## Table of Contents

## 1. L. S. Compliance In Review

**L.S. Compliance - Accreditations and Listing's**

**As an EMC Testing Laboratory, our Accreditation and Assessments are recognized through the following:**

**A2LA – American Association for Laboratory Accreditation**

Accreditation based on ISO/IEC 17025 : 1999
with Electrical (EMC) Scope of Accreditation
A2LA Certificate Number: 1255.01

**Federal Communications Commission (FCC) – USA**

Listing of 3 Meter Semi-Anechoic Chamber based on Title 47 CFR – Part 2.948
FCC Registration Number: 90756

Listing of 3 and 10 meter OATS based on Title 47CFR – Part 2.948
FCC Registration Number: 90757

**Industry Canada**

On file, 3 Meter Semi-Anechoic Chamber based on RSS-212 – Issue 1
File Number: IC 3088-A

On file, 3 and 10 Meter OATS based on RSS-212 – Issue 1
File Number: IC 3088

**U. S. Conformity Assessment Body (CAB) Validation**

Validated by the European Commission as a U. S. Competent Body operating under the U. S. /EU, Mutual Recognition Agreement (MRA) operating under the European Union Electromagnetic Compatibility –Council Directive 89/336/EEC, Article 10.2.
Date of Validation: January 16, 2001

Validated by the European Commission as a U.S. Notified Body operating under the U.S./EU, Mutual Recognition Agreement (MRA) operating under the European Union Telecommunication Equipment – Council Directive 99/5/EC, Annex V.

Date of Validation: November 20, 2002
Notified Body Identification Number: 1243

## 2. A2LA Certificate of Accreditation

THE AMERICAN
ASSOCIATION
FOR LABORATORY
ACCREDITATION

**ACCREDITED LABORATORY**

A2LA has accredited

**L.S. COMPLIANCE, INC.**
**Cedarburg, WI**

for technical competence in the field of

**Electrical Testing**

The accreditation covers the specific tests and types of tests listed on the agreed scope of accreditation. This laboratory meets the requirements of ISO/IEC 17025 - 1999 "General Requirements for the Competence of Testing and Calibration Laboratories" and any additional program requirements in the identified field of testing. Testing and calibration laboratories that comply with this International Standard also operate in accordance with ISO 9001 or ISO 9002 (1994).

Presented this 26th day of March 2003.

President
For the Accreditation Council
Certificate Number 1255.01
Valid to January 31, 2005

For tests or types of tests to which this accreditation applies, please refer to the laboratory's Electrical Scope of Accreditation.

## 3. A2LA Scope of Accreditation

**American Association for Laboratory Accreditation**

SCOPE OF ACCREDITATION TO ISO/IEC 17025-1999

L.S. COMPLIANCE, INC.
W66 N220 Commerce Court
Cedarburg, WI 53012
James Blaha Phone: 262 375 4400

ELECTRICAL (EMC)

Valid to: January 31, 2005 Certificate Number: 1255-01

In recognition of the successful completion of the A2LA evaluation process, accreditation is granted to this laboratory to perform the following tests:

| Test | Test Method(s) |
|---|---|
| Emissions | |
| Conducted | |
| Continuous/Discontinuous | Code of Federal Regulations (CFR) 47, FCC Method Parts 15, 18 using ANSI C63.4; EN: 55011, 55022, 50081-1, 50081-2; CISPR: 11, 12, 14-1, 22; CNS 13438 |
| Radiated | Code of Federal Regulations (CFR) 47, FCC Method Parts 15, 18 using ANSI C63.4; EN: 55011, 55022, 50081-1, 50081-2; CISPR: 11, 12, 14-1, 22; CNS 13438 |
| Current Harmonics | IEC 61000-3-2; EN 61000-3-2 |
| Voltage Fluctuations & Flicker | IEC 61000-3-3; EN 61000-3-3 |
| Immunity | EN: 50082-1, 50082-2<br>EN 61000-6-2<br>CISPR: 14-2, 24 |
| Conducted Immunity | |
| Fast Transients/Burst | IEC 61000-4-4;<br>EN 61000-4-4 |
| Surge | IEC: 61000-4-5; ENV 50142;<br>EN 61000-4-5 |
| RF Fields | IEC: 61000-4-6; ENV 50141;<br>EN 61000-4-6 |
| Voltage Dips/Interruptions | IEC 61000-4-11;<br>EN 61000-4-11 |

Roxanne M. Robinson

(A2LA Cert. No. 1255-01) 05/13/03 Page 1 of 2

**5301 Buckeystown Pike, Suite 350 • Frederick, MD 21704-8373 • Phone: 301-644 3248 • Fax: 301-662 2974**

## 4. Validation Letter – U.S. Competent Body for EMC Directive 89/336/EEC

NIST CENTENNIAL 1901-2001

UNITED STATES DEPARTMENT OF COMMERCE
National Institute of Standards and Technology
Gaithersburg, Maryland 20899-

January 16, 2001

Mr. James J. Blaha
L.S. Compliance Inc.
W66 N220 Commerce Court
Cedarburg, WI 53012-2636

Dear Mr. Blaha:

I am pleased to inform you that the European Commission has validated your organization's nomination as a U.S. Conformity Assessment Body (CAB) for the following checked (✓) sectoral annex(es) of the U.S.-EU Mutual Recognition Agreement (MRA).

(✓) Electromagnetic Compatibility-Council Directive 89/336/EEC, Article 10(2)
( ) Telecommunication Equipment-Council Directive 98/13/EC, Annex III
( ) Telecommunication Equipment-Council Directive 98/13/EC, Annex III and IV
Identification Number:
( ) Telecommunication Equipment-Council Directive 98/13/EC, Annex V
Identification Number:

This validation is only for the location noted in the address block, unless otherwise indicated below.

(✓) Only the facility noted in the address block above has been approved.
( ) Additional EMC facilities:
( ) Additional R&TTE facilities:

Please note that an organization's validations for various sectors of the MRA are listed on our web site at http://ts.nist.gov/mra. You may now participate in the conformity assessment activities for the operational period of the MRA as described in the relevant sectoral annex or annexes of the U.S.-EU MRA document.

NIST will continue to work with you throughout the operational period. All CABs validated for the operational phase of the Agreement must sign and return the enclosed CAB declaration form, which states that each CAB is responsible for notifying NIST of any relevant changes such as accreditation status, liability insurance, and key staff involved with projects under the MRA. Please be sure that you fully understand the terms under which you are obligated to operate as a condition of designation as a CAB. As a designating authority, NIST is responsible for monitoring CAB performance to ensure continued competence under the terms of the MRA.

NIST

## 5. Signature Page

Prepared By: June 27, 2005

Teresa A. White, Document Coordinator Date

Tested By: June 27, 2005

Abtin Spantman, EMC Engineer Date

Approved By: June 27, 2005

Kenneth L. Boston, EMC Lab Manager Date
PE #31926 Licensed Professional Engineer
Registered in the State of Wisconsin, United States

## 6. Product and General Information

| | | | | | | |
|---|---|---|---|---|---|---|
| Manufacturer: | Simbex, LLC | | | | | |
| Date(s) of Test: | February 28th through March 29th, 2005 | | | | | |
| Test Engineer(s): | | Tom Smith | √ | Abtin Spantman | | Ken Boston |
| Model #: | MX Encoder | | | | | |
| Serial #: | 121704-0067 | | | | | |
| Voltage: | 3.6 VDC | | | | | |
| Operation Mode: | Normal, continuous transmit, and 'Hopping' mode | | | | | |

## 7. Introduction

Between February 28th and March 29th, 2005, a series of Conducted and Radiated RF Emission tests were performed on one sample of the Simbex, LLC, Model Number MX Encoder, Serial Number 121704-0067, here forth referred to as the "*Equipment Under Test*" or "*EUT*". These tests were performed using the procedures outlined in ANSI C63.4-2003 for intentional radiators, and in accordance with the limits set forth in FCC Part 15.247 (Industry Canada RSS-210) for a low power transmitter. These tests were performed by Abtin Spantman, EMC Engineer at L.S. Compliance, Incorporated.

All Radiated and Conducted RF Emission tests were performed upon the EUT to measure the emissions in the frequency bands described in Title 47 CFR, FCC Part 15, including 15.35, 15.205, 15.247 and Industry Canada RSS-210 to determine whether these emissions are below the limits expressed within the standards. These tests were performed in accordance with the procedures described in the American National Standard for methods of measurement of Radio-Noise Emissions from Low-Voltage Electrical and Electronic Equipment in the Range of 9 kHz to 40 GHz (ANSI C63.4-2003). Another document used as a reference for the EMI Receiver specification was the Comite International Special Des Perturbations Radioelelectriques (CISPR) Number 16-1, 2003.

All tests were performed at L.S. Compliance, Inc., in Cedarburg, Wisconsin, unless otherwise noted.

## 8. Product Description

The system is called the Head Impact Telemetry System™ (HIT System™) and is the first device to continuously monitor, analyze and record a player's on-field head impact experience, and which is practical enough to be used in all game and practice situations. The HIT System not only monitors and records the impact history for all players simultaneously, but also can signal the sidelines staff to the occurrence of an impact that conforms to a Suspect Impact Profile™. The system monitors standard impact measures, such as maximum g's, Head Impact Criteria (HIC), and Gadd Severity Index (GSI), or customized metrics based on any of the components of impact location, impact magnitude, impact duration, linear and angular acceleration components and the exact times. The portion of the system tested and covered by this report is the transmitter characteristics of the transceiver used inside the helmet, named the MX encoder.

The HIT System™ is comprised of four main systems: the MX Encoders, the Sideline Receiver, the Alert Pager, and the Computer. The Sideline Receiver, Alert Pager, and Computer are all stored within a protective Field Case. The MX Encoders are installed inside Riddell VSR-4 and Revolution football helmets, measure impacts as they occur on the field, and transmit impact data to the Sideline Receiver. The Sideline Receiver manages impact information recorded by the MXEncoders and relays it to the Computer, where the data is processed, analyzed, and stored. When impacts matching user selectable Suspect Impact Profiles (SIP's) are received, the Alert Pager System sends a signal to the Alert Beeper, signaling sideline staff that a SIP has occurred.

The Mx Encoder system is comprised of three major elements: a single board radio transceiver, a sensor wiring harness and a three cell 3.6 VDC Nickel Metal Hydride (NiMH) rechargeable battery pack. When fully integrated, the three elements are connected to one another with mating cables and connectors and are encapsulated in a sealed plastic package. The sealed unit is then inserted into a football helmet and firmly attached in place with Velcro strips. Spring loaded pressure tabs press the 7 sensors against the user's skull.

The radio is a frequency hopping spread spectrum transceiver operating in the 902 MHz to 928 MHz ISM band. It transmits with a nominal power of 0.2 watts (+23 dBm) into an integrated PCB trace antenna with a nominal gain of 0 dBi. The transmitter uses direct FSK modulation, with a crystal controlled Phase Locked Loop oscillator. Transmissions occur within a group of 50 channels which are chosen from a pool of 53 available channels. Each radio is programmed with a seed value which determines the table based on a defined pseudorandom generator. Each channel carries a single packet of information for a duration no longer than 52 mS.

The sensor wiring harness is comprised of six solid state single axis accelerometers and a thermistor. Each accelerometer measures impacts received to the helmet and the thermistor measures the wearer's head temperature. Analog signals from these sensors are digitized by the radio's microcontroller and the resulting data is transmitted to a master radio station for further processing.

The battery pack is comprised of three AA size NiMH batteries with a nominal 750 mAHr capacity. The batteries are recharged by an external charger, and must be removed from the helmet for charging.

A deployed HITS System is comprised of a grouping of as many as one hundred individual helmet systems described above and a single Sideline Controller. Each helmet system operates independently and wireless data transfers are made from helmets to their mated Sideline Controller as each helmet is polled by that Sideline Controller. There are no peer to peer communications between helmet units. Because of the unique addressing scheme used, the helmets will not respond to another group's (team's) sideline controller.

Each helmet and sideline controller is uniquely addressed in such a manner that communications may only take place between helmets and their mated sideline controller. The coordination of hop sequences, addresses, etc. is conducted during factory assembly as systems are built to order for a particular customer. The system does not automatically re-configure channel hopping sequences in the field.

The receiver uses direct conversion meaning that there is no offset local oscillator. Individual channel selection occurs within the receiver without the need for external filtering. An overall band-pass filter restricts the receiver to the stated ISM band.

## 9. Test Requirements

The above mentioned tests were performed in order to determine the compliance of the Simbex, LLC, Model Number MX Encoder with limits contained in various provisions of Title 47 CFR, FCC Part 15, including:

| | | |
|---|---|---|
| 15.205 | 15.247a | 15.247d |
| 15.207 | 15.247b | 15.247g |
| 15.209 | 15.247c | |

## 10. Summary of Test Report

### DECLARATION OF CONFORMITY

The Simbex, LLC, Model Number MX Encoder, Serial Number 121704-0067, was found to **MEET** the requirements as described within the specification of Title 47 CFR FCC, Part 15.247, and Industry Canada RSS-210, Section 6.2.2(o) for a Frequency Hopping Spread Spectrum Transmitter.

The enclosed test results pertain to the sample(s) of the test item listed, and only for the tests performed on the data sheets. Any subsequent modification or changes to the test items could invalidate the data contained herein, and could therefore invalidate the findings of this report.

Some emissions are seen to be within 3dB of their respective limits. As these levels are within the tolerances of the test equipment and site employed, there is a possibility that this unit, or a similar unit selected out of production may not meet the required limit specification if tested by another agency.

## 11. Radiated Emissions Test

### Test Setup

The test setup was assembled in accordance with Title 47, CFR FCC Part 15 and ANSI C63.4-2003. The EUT was placed on an 80cm high non-conductive pedestal, centered on a flush mounted 2-meter diameter turntable inside a 3 meter Semi-Anechoic, FCC listed Chamber. The EUT was operated in continuous modulated transmit mode, using power as provided by internal rechargeable batteries at 3.6 VDC. The unit has the capability to operate on 53 channels, controllable via special test programming and jumpers.

The applicable limits apply at a 3 meter distance. Measurements above 5 GHz were performed at a 1.0 meter separation distance. The calculations to determine these limits are detailed in the following pages. Please refer to Appendix A for a complete list of test equipment. The test sample was operated on one of three (3) standard channels: low (Ch:00, 902.77 MHz), middle (Ch:27, 915.28 MHz) and high (Ch:52, 927.21 MHz) to comply with FCC Part 15.35. The channels and operating modes were changed using jumper selections along with special test mode programming.

### Test Procedure

Radiated RF measurements were performed on the EUT in a 3 meter Semi-Anechoic, FCC listed Chamber. The frequency range from 30 MHz to 10000 MHz was scanned and investigated. The radiated RF emission levels were manually noted at the various fixed degree settings of azimuth on the turntable and antenna height. The EUT was placed on a non-conductive pedestal in the 3 meter Semi-Anechoic Chamber, with the antenna mast placed such that the antenna was 3 meters from the EUT. A Biconical Antenna was used to measure emissions from 30 MHz to 300 MHz, and a Log Periodic Antenna was used to measure emissions from 300 MHz to 1000 MHz. A Double-Ridged Waveguide Horn Antenna was used from 1 GHz to 18 GHz. The maximum radiated RF emissions were found by raising and lowering the antenna between 1 and 4 meters in height, using both horizontal and vertical antenna polarities.

The battery voltage was checked frequently, and the batteries were charged as necessary.

The EUT was rotated along three orthogonal axis during the investigations to find the highest emission levels.

## Test Equipment Utilized

A list of the test equipment and antennas utilized for the Radiated Emissions test can be found in Appendix A. This list includes calibration information and equipment descriptions. All equipment is calibrated and used according to the operation manuals supplied by the manufacturers. All calibrations of the antennas used were performed at an N.I.S.T. traceable site. In addition, the Connecting Cables were measured for losses using a calibrated Signal Generator and a HP 8546A EMI Receiver. The resulting correction factors and the cable loss factors from these calibrations were entered into the HP 8546A EMI Receiver database. As a result, the data taken from the HP 8546A EMI Receiver accounts for the antenna correction factor as well as cable loss or other corrections, and can therefore be entered into the database as a corrected meter reading. The HP 8546A EMI Receiver was operated with a resolution bandwidth of 120 kHz for measurements below 1 GHz (video bandwidth of 300 kHz), and a bandwidth of 1 MHz for measurements above 1 GHz (video bandwidth of 1 MHz). From 5 GHz to 10 GHz, an HP E4407 Spectrum Analyzer and an EMCO Horn Antenna were used.

## Test Results

The EUT was found to **MEET** the Radiated Emissions requirements of Title 47 CFR, FCC Part 15.247 for a FHSS transmitter [Canada RSS-210, Clause 6.2.2(o)]. The frequencies with significant RF signal strength were recorded and plotted as shown in the Data Charts and Graphs.

# CALCULATION OF RADIATED EMISSIONS LIMITS

The maximum peak output power of an intentional radiator in the 902-928 MHz band, as specified in 47 CFR 15.247 (b)(2), is 1 Watt for systems employing at least 50 hopping channels. The harmonic and spurious RF emissions, as measured in any 100kHz bandwidth, as specified in 15.247 (d), shall be at least 20 dB below the measured power of the desired signal, and must also meet the requirements described in 15.205(c).

The following table depicts the Class B limits for an unintentional radiator. These limits are obtained from Title 47 CFR, Part 15.209, for radiated emissions measurements. These limits were applied to any signals found in the 15.205 restricted bands.

| Frequency (MHz) | 3 m Limit μV/m | 3 m Limit (dBμV/m) | 1 m Limit (dBμV/m) |
|---|---|---|---|
| 30-88 | 100 | 40.0 | - |
| 88-216 | 150 | 43.5 | - |
| 216-960 | 200 | 46.0 | - |
| 960-24,000 | 500 | 54.0 | 63.5 |

Sample conversion from field strength μV/m to dBμV/m:
dBμV/m = 20 log $_{10}$ (100)
= 40 dBμV/m (from 30-88 MHz)

For measurements made at 1.0 meter, a 9.5 dB correction has been invoked.

960 MHz to 10,000 MHz
500μV/m or 54.0 dB/μV/m at 3 meters
54.0 + 9.5 = 63.5 dB/μV/m at 1 meter

For measurements made at 0.3 meter, a 20 dB correction has been invoked.

960 MHz to 10,000 MHz
500μV/m or 54.0 dB/μV/m at 3 meters
54.0 + 20 = 74 dB/μV/m at 0.3 meters

# Radiated Emissions Data Chart

**3 Meter Measurements of Electromagnetic Radiated Emissions**
**Test Standard: 47CFR, Part 15.205 and 15.247(FHSS)**
**Frequency Range Inspected: 30 MHz to 10000 MHz**

<table>
<tr><td>Manufacturer:</td><td colspan="6">Simbex, LLC</td></tr>
<tr><td>Date(s) of Test:</td><td colspan="6">February 28th through March 29th, 2005</td></tr>
<tr><td>Test Engineer(s):</td><td></td><td>Tom Smith</td><td>√</td><td>Abtin Spantman</td><td></td><td>Ken Boston</td></tr>
<tr><td>Model #:</td><td colspan="6">MX Encoder</td></tr>
<tr><td>Serial #:</td><td colspan="6">121704-0067</td></tr>
<tr><td>Voltage:</td><td colspan="6">3.6 VDC</td></tr>
<tr><td>Operation Mode:</td><td colspan="6">Normal, continuous transmit, and ‘Hopping’ mode</td></tr>
<tr><td rowspan="2">EUT Power:</td><td></td><td colspan="2">Single Phase ___VAC</td><td></td><td colspan="2">3 Phase ___VAC</td></tr>
<tr><td>√</td><td colspan="2">Battery</td><td></td><td colspan="2">Other:</td></tr>
<tr><td>EUT Placement:</td><td>√</td><td colspan="2">80cm non-conductive table</td><td></td><td colspan="2">10cm Spacers</td></tr>
<tr><td>EUT Test Location:</td><td>√</td><td colspan="2">3 Meter Semi-Anechoic FCC Listed Chamber</td><td></td><td colspan="2">3/10m OATS</td></tr>
<tr><td>Measurements:</td><td></td><td>Pre-Compliance</td><td></td><td>Preliminary</td><td>√</td><td>Final</td></tr>
<tr><td>Detectors Used:</td><td>√</td><td>Peak</td><td>√</td><td>Quasi-Peak</td><td>√</td><td>Average</td></tr>
</table>

**Environmental Conditions in the Lab:**
Temperature: 20 – 25°C
Relative Humidity: 30 – 60 %

**Test Equipment Used:**
EMI Measurement Instrument: HP8546A and Agilent E4407B
Log Periodic Antenna: EMCO #93146
Horn Antenna: EMCO #3115
Biconical Antenna: EMCO 93110

The following table depicts the level of significant spurious radiated RF emissions found:

| Frequency (MHz) | Antenna Polarity | Channel | Height (meters) | Azimuth (0° - 360°) | Measured ERP (dBμV/m) | 15.205 Limit (dBμV/m) | Margin (dB) |
|---|---|---|---|---|---|---|---|
| 966.2 | V | 52 | 1.00 | 60 | 51.2 | 54.0 | 2.8 |
| 975.9 | V | 52 | 1.00 | 60 | 50.7 | 54.0 | 3.3 |
| 985.6 | V | 52 | 1.00 | 60 | 49.9 | 54.0 | 4.1 |

*Notes:*

1) *A Quasi-Peak Detector was used in measurements below 1 GHz, and an Average Detector was used in measurements above 1 GHz. The Peak detector was also use to ensure that the emission levels do not exceed 20 dB beyond the Average limits.*
2) *No significant spurious emissions observed. All spurious emissions were better than 20 dB below the limits..*

The following table depicts the level of significant radiated RF fundamental and harmonic emissions seen on Channel 00:

| Frequency (MHz) | Antenna Polarity | Height (meters) | Azimuth (0° - 360°) | Measured ERP (dBμV/m) | 15.205/ 15.247 Limit (dBμV/m) | Margin (dB) |
|---|---|---|---|---|---|---|
| 902.8 * | H | 1.50 | 30 | 111.3 | 125.2 | 13.9 |
| 1805.5 | H | 1.00 | 160 | 69.5 | 91.3 | 21.8 |
| 2708.3 | H | 1.30 | 170 | 45.3 | 54.0 | 8.7 |
| 3611.1 | H | 1.45 | 145 | 47.4 | 54.0 | 6.6 |
| 4513.9 | H | 1.30 | 310 | 46.7 | 54.0 | 7.3 |
| 5416.6 | H | 1.00 | 5 | 62.4 | 63.2 | 0.8 |
| 6319.4 | H | 1.00 | 275 | 51.4 | 100.8 | 49.4 |
| 7222.2 | H | 1.05 | 280 | 54.4 | 100.8 | 46.4 |
| 8124.9 | H | 1.00 | 0 | 42.2 | 63.2 | 21.0 |
| 9027.7 | H | 1.00 | 120 | 54.4 | 63.2 | 8.8 |

The following table depicts the level of significant radiated RF fundamental and harmonic emissions seen on Channel 27:

| Frequency (MHz) | Antenna Polarity | Height (meters) | Azimuth (0° - 360°) | Measured ERP (dBμV/m) | 15.205/ 15.247 Limit (dBμV/m) | Margin (dB) |
|---|---|---|---|---|---|---|
| 915.3 * | H | 1.50 | 30 | 110.1 | 125.2 | 15.1 |
| 1830.6 | H | 1.05 | 160 | 69.0 | 90.1 | 21.1 |
| 2745.8 | H | 1.35 | 120 | 51.1 | 54.0 | 2.9 |
| 3661.1 | V | 1.00 | 0 | 46.7 | 54.0 | 7.3 |
| 4576.4 | H | 1.30 | 100 | 46.8 | 54.0 | 7.2 |
| 5491.7 | H | 1.00 | 0 | 66.4 | 99.6 | 33.2 |
| 6407.0 | H | 1.00 | 310 | 47.1 | 99.6 | 52.5 |
| 7322.2 | H | 1.15 | 285 | 55.2 | 63.2 | 8.0 |
| 8237.5 | H | 1.00 | 260 | 43.7 | 63.2 | 19.5 |
| 9152.8 | H | 1.00 | 0 | 55.7 | 63.2 | 7.5 |

The following table depicts the level of significant radiated RF fundamental and harmonic emissions seen on Channel 52:

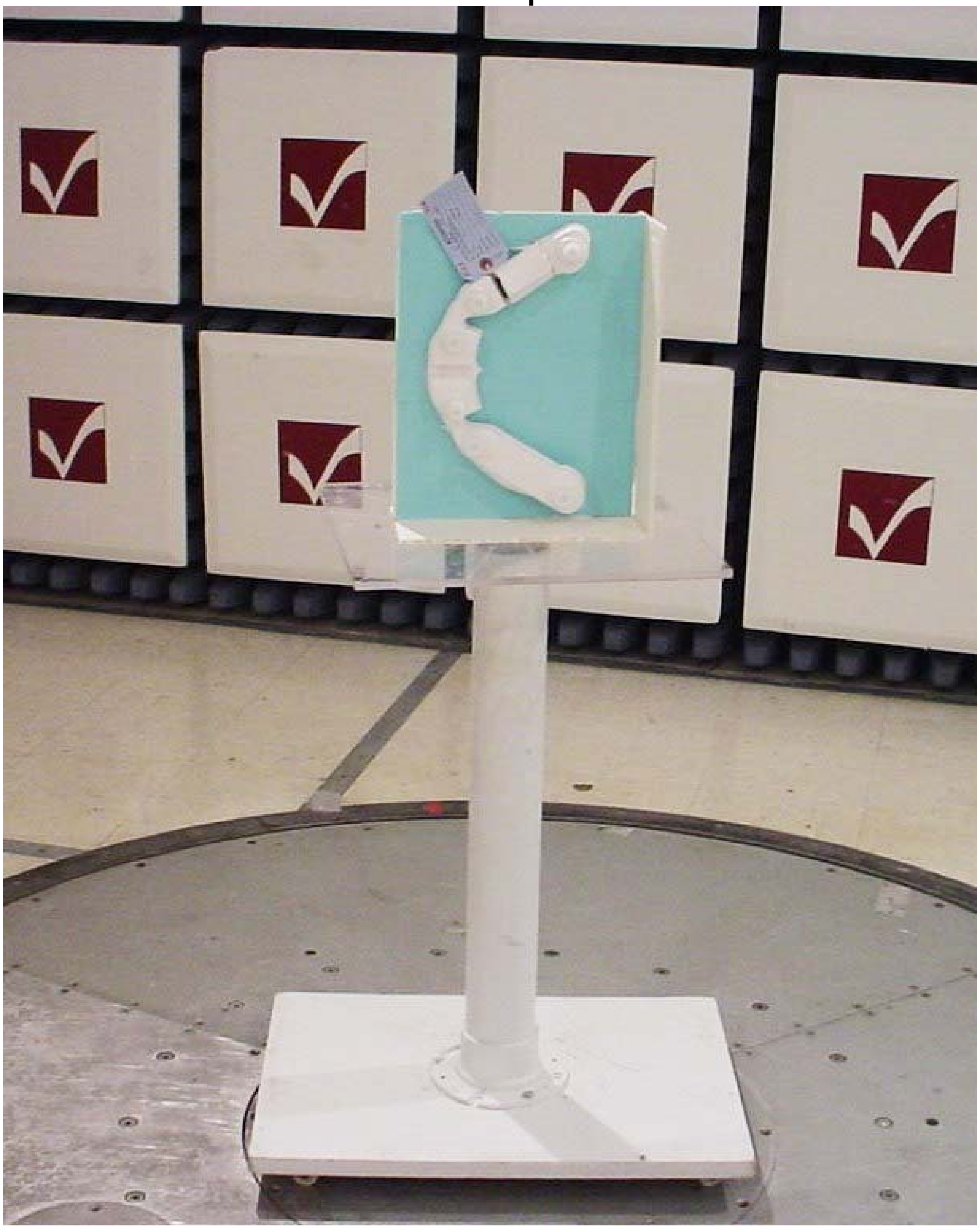
| Frequency (MHz) | Antenna Polarity | Height (meters) | Azimuth (0° - 360°) | Measured ERP (dBμV/m) | 15.205/ 15.247 Limit (dBμV/m) | Margin (dB) |
|---|---|---|---|---|---|---|
| 927.2 * | H | 1.45 | 40 | 112.0 | 125.2 | 13.2 |
| 1854.4 | H | 1.05 | 130 | 69.7 | 92.0 | 22.3 |
| 2781.6 | H | 1.50 | 80 | 43.5 | 54.0 | 10.5 |
| 3708.8 | V | 1.35 | 215 | 46.9 | 54.0 | 7.1 |
| 4636.1 | V | 1.00 | 225 | 47.1 | 54.0 | 6.9 |
| 5563.3 | H | 1.00 | 350 | 69.2 | 101.5 | 32.3 |
| 6490.5 | H | 1.05 | 280 | 45.1 | 101.5 | 56.4 |
| 7417.7 | H | 1.05 | 280 | 54.8 | 63.2 | 8.4 |
| 8344.9 | H | 1.00 | 120 | 46.6 | 63.2 | 16.6 |
| 9272.1 | H | 1.00 | 110 | 55.5 | 101.5 | 46.0 |

Notes: A Quasi-Peak Detector was used in measurements below 1 GHz, and a Peak as well as an Average Detector was used in measurements above 1 GHz. Only the results from the Average detector are published in the table above. The peak detector was used to ensure the peak emissions did not exceed 20 dB above the limits. Measurements above 5 GHz were made at 1 meters of separation from the EUT, and at 0.3 m separation at 18 – 26 GHz.

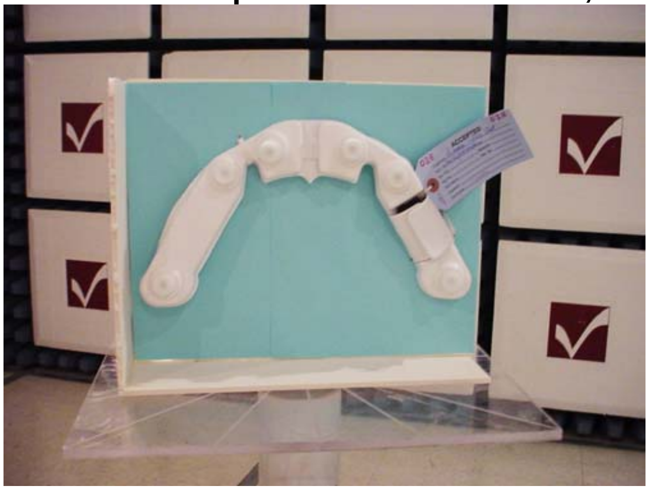
* Measurements taken to evaluate ERP of fundamental signal.

## Photos Taken During Radiated Emission Testing

**Overall View of the EUT setup in vertical orientation**



**View of the EUT setup in vertical orientation, close-up**



**View of the EUT setup in Horizontal orientation, close-up**

**View of the EUT setup in Side orientation, close-up**

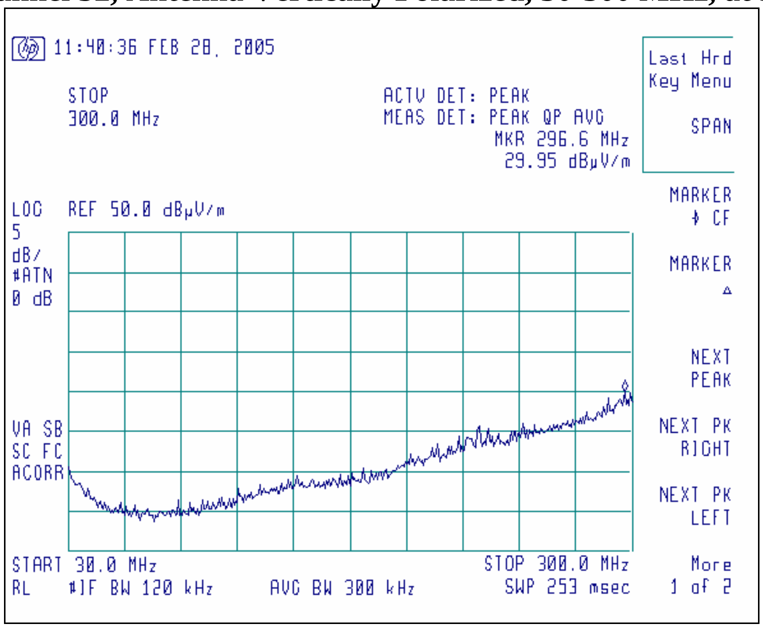
## Graphs made during Radiated Emission Testing

### *Screen Captures of Radiated RF Emissions:*

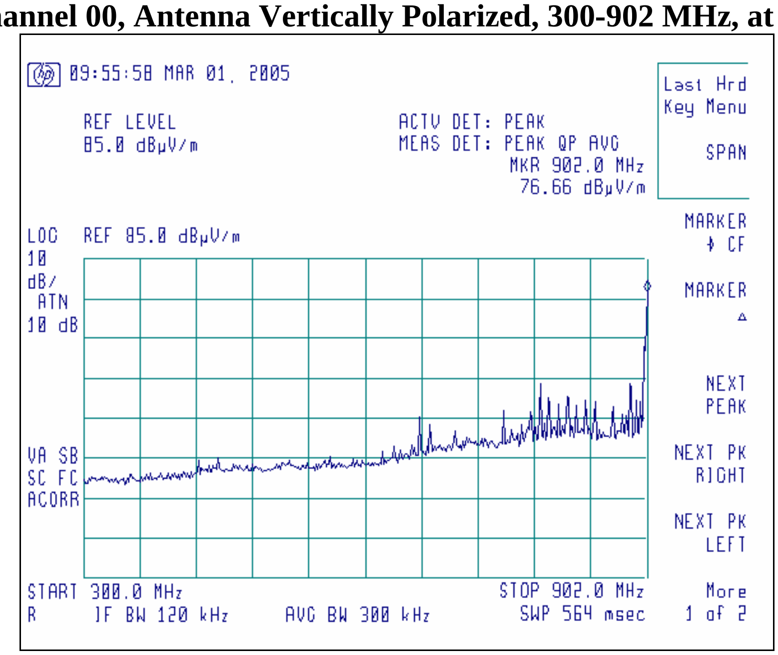
Please note these screen captures represent Peak Emissions. For radiated emission measurements, we utilize a Quasi-Peak detector function when measuring frequencies below 1 GHz, and an Average detector function when measuring frequencies above 1 GHz.

The signature scans shown here are from worst-case emissions, as measured on channels 00, 27, or 52, with the sense and EUT antennas both in vertical polarity for worst case presentations.

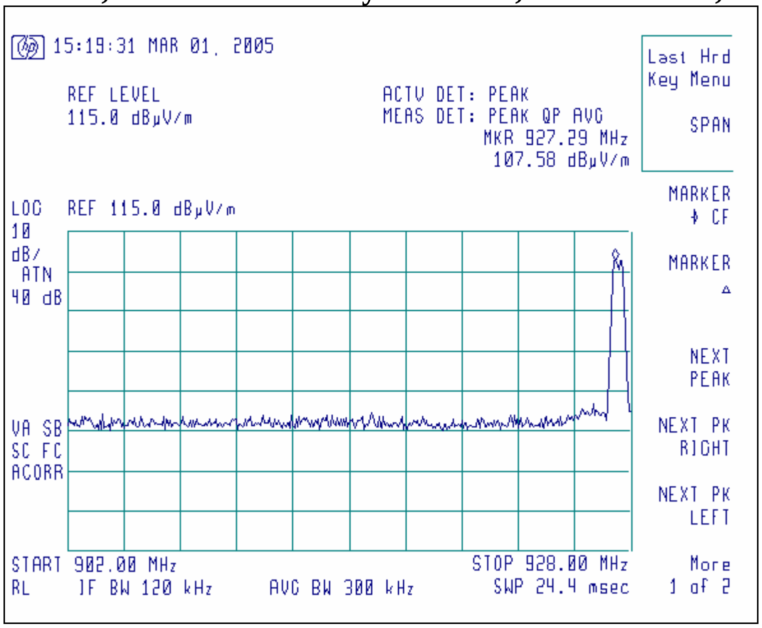
**Channel 52, Antenna Vertically Polarized, 30-300 MHz, at 3m.**



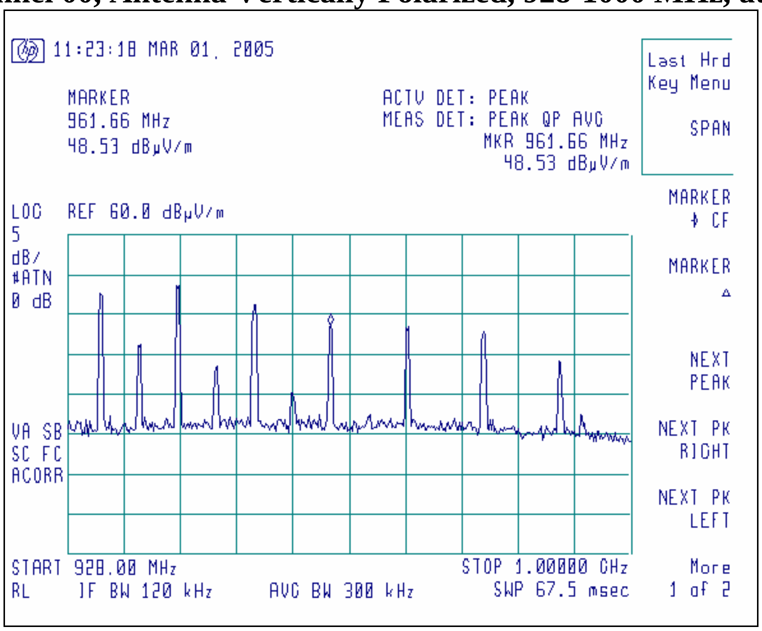

**Channel 00, Antenna Vertically Polarized, 300-902 MHz, at 3m.**



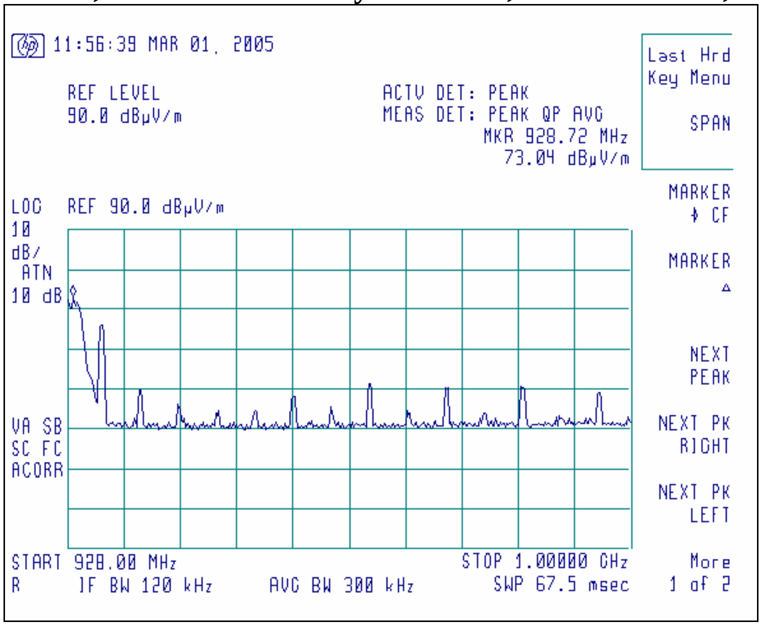
**Channel 52, Antenna Vertically Polarized, 902-928 MHz, at 3m.**



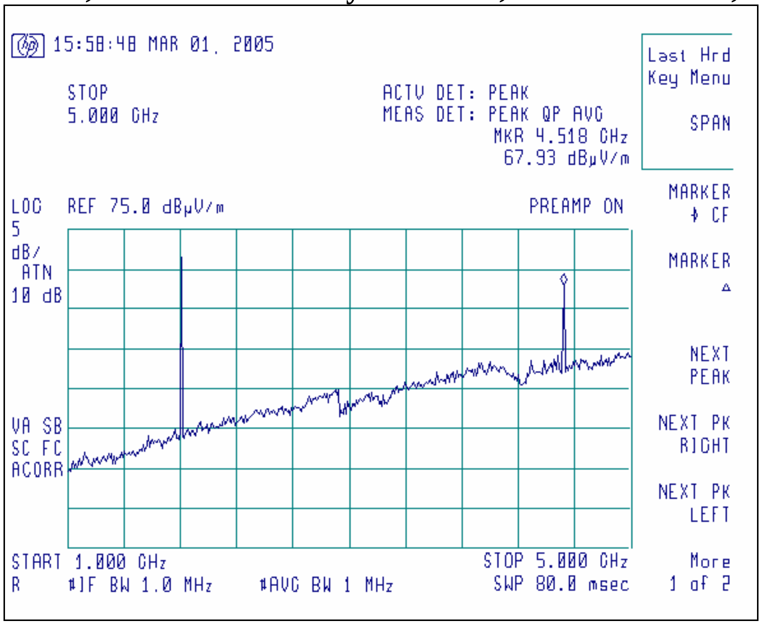

**Channel 00, Antenna Vertically Polarized, 928-1000 MHz, at 3m.**



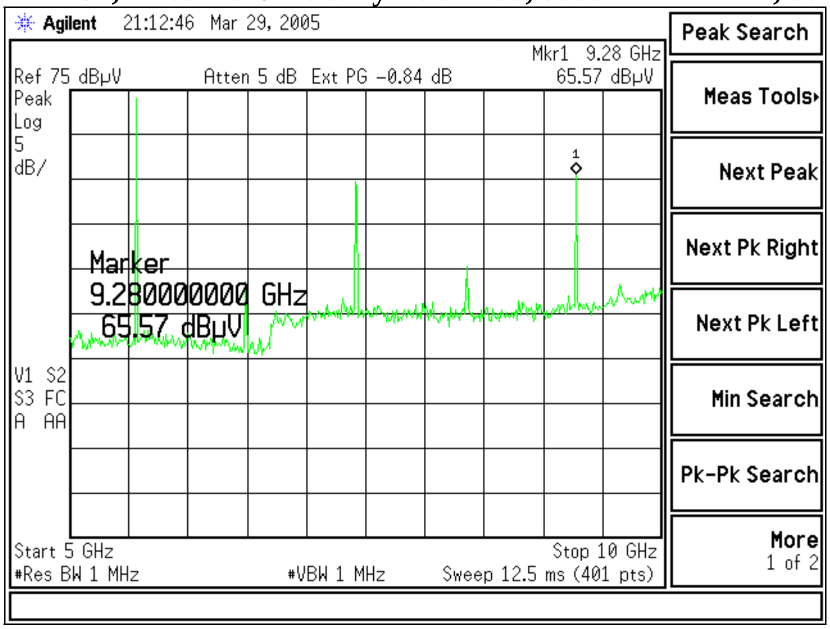
**Channel 52, Antenna Vertically Polarized, 928-1000 MHz, at 3m.**




**Channel 27, Antenna Vertically Polarized, 1000-5000 MHz, at 3m.**



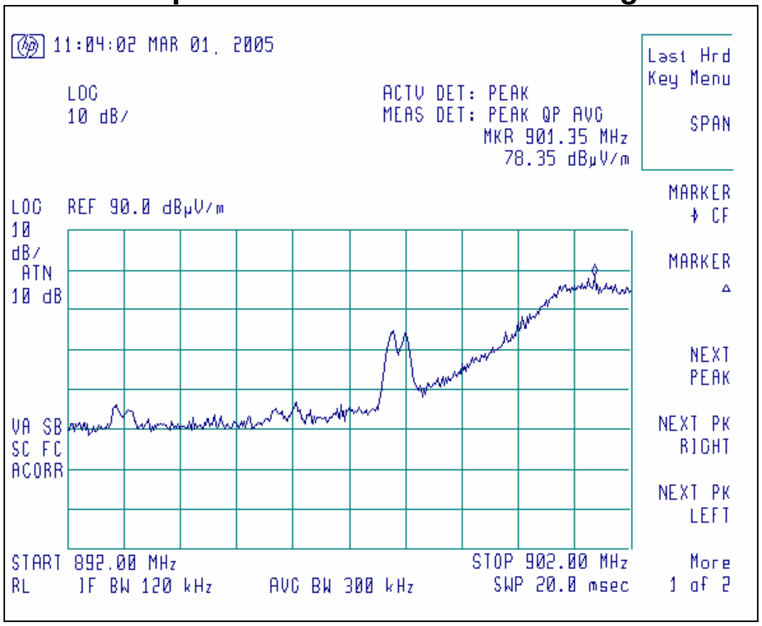
**Channel 52, Antenna Vertically Polarized, 5000-10000 MHz, at 1m.**



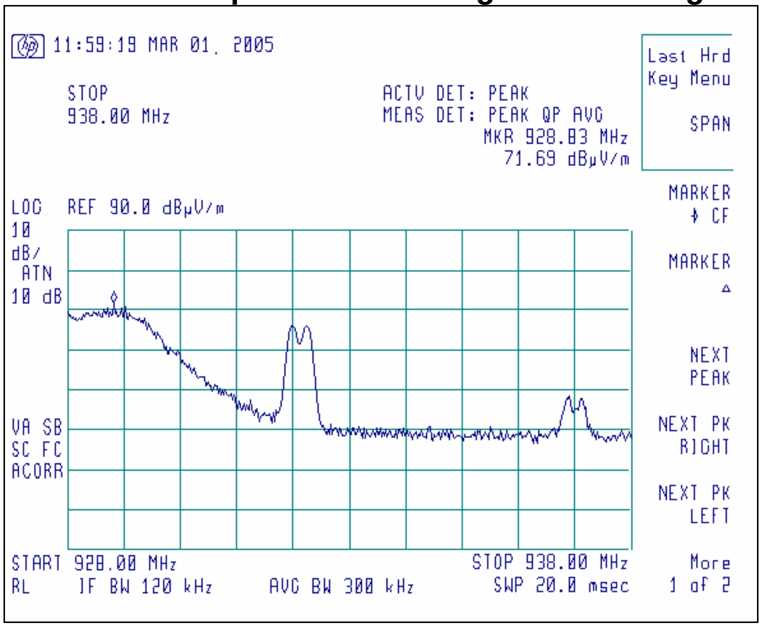
## 12. Band-Edge Measurements

FCC 15.209(b) and 15.247(d) require a measurement of spurious emission levels to be at least 20 dB lower than the fundamental emission level, in particular at the band-edges where the intentional radiator operates. The following screen captures demonstrate compliance of the intentional radiator at the 902-928 MHz band-edges, with emissions meeting the – 20 dBc limit. The EUT was operated in continuous transmit mode with continuous modulation, with internally generated data as the modulating source. The EUT was operated at the lowest channel for the investigation of the lower band-edge, and at the highest channel for the investigation of the higher band-edge.

**Screen Capture demonstrating -20 dBc compliance at the Lower Band-Edge**




**Screen Capture demonstrating -20 dBc compliance at the Higher Band-Edge**



## 13. Conducted RF Emissions onto AC Power Line

The EUT only operates on battery power and can not be connected to AC mains.
During the charging operation, the battery is removed from the transmitter.

## 14. Occupied Bandwidth

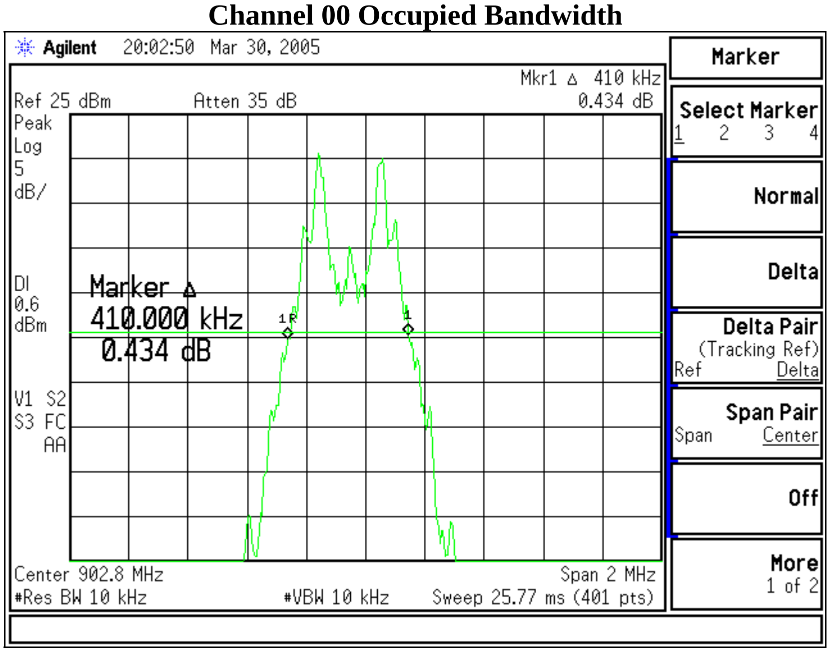
The 20 dB bandwidth requirement found in FCC Part 15.247(a)(1)(i) states a maximum allowed occupied bandwidth of 500 kHz. For this portion of the tests, a direct conducted measurement of the transmitted signal was performed at the antenna port of the EUT, via a cable connection to the HP E4407B spectrum analyzer. The loss from the cable was added on the analyzer as gain offset settings, there by allowing direct readings of the measurements without the need for any further corrections. A Hewlett Packard model E4407B spectrum analyzer was used with the resolution bandwidth set to 10 kHz for this portion of the tests. The EUT was configured to run in a continuous transmit mode, while being supplied with typical data as a modulation source. The spectrum analyzer was used in peak-hold mode while measurements were made, as presented in the chart below.

From this data, the closest measurement when compared to the specified limit, is 410 kHz, which is below the maximum limit of 500 kHz.

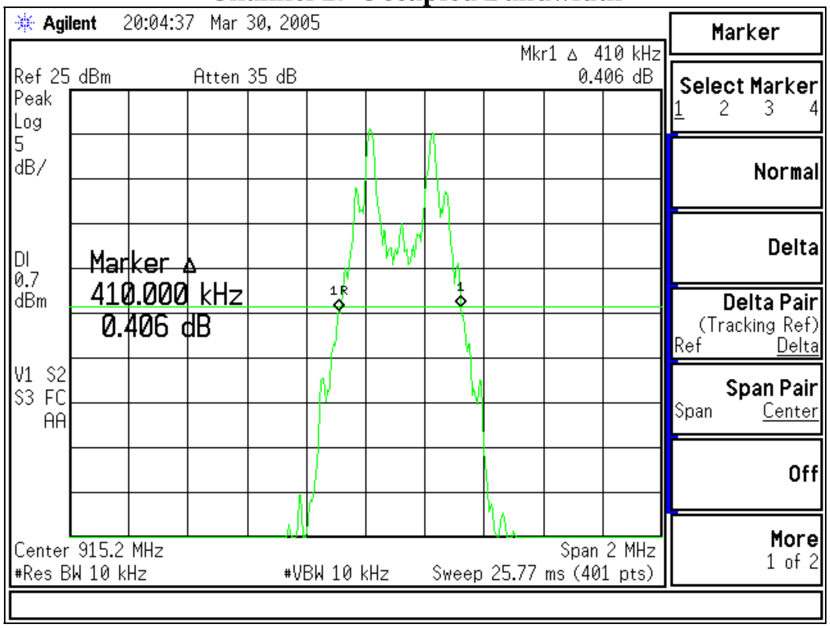
| Channel | Center Frequency (MHz) | Measured 20 dB BW (kHz) | Maximum Limit (kHz) |
|---|---|---|---|
| 00 | 902.8 | 410 | 500 |
| 27 | 915.3 | 410 | 500 |
| 52 | 927.2 | 365 | 500 |

### Plots of Occupied Bandwidth

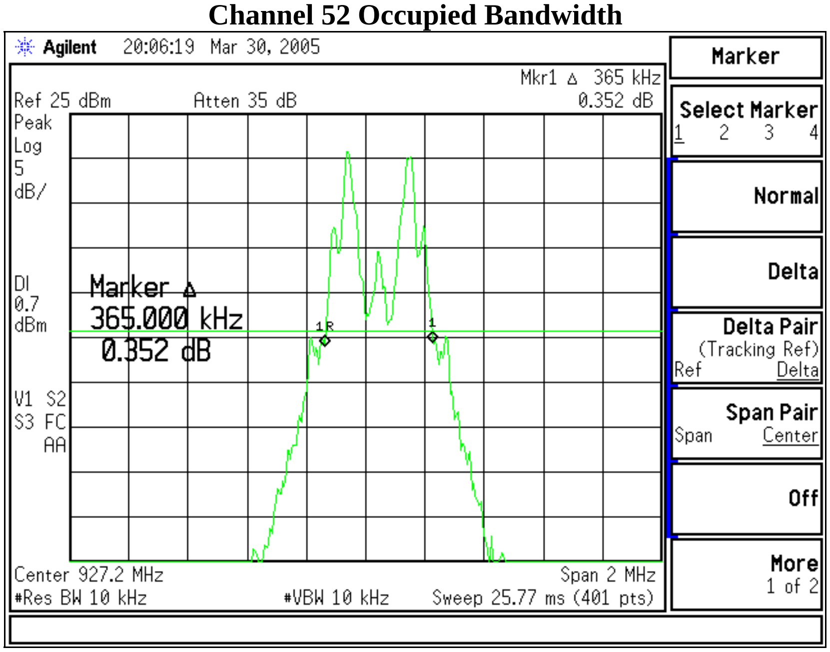
**Channel 00 Occupied Bandwidth**



**Channel 27 Occupied Bandwidth**



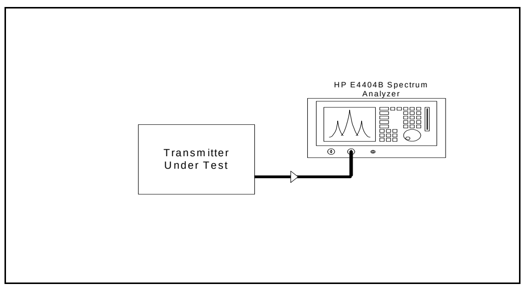

**Channel 52 Occupied Bandwidth**



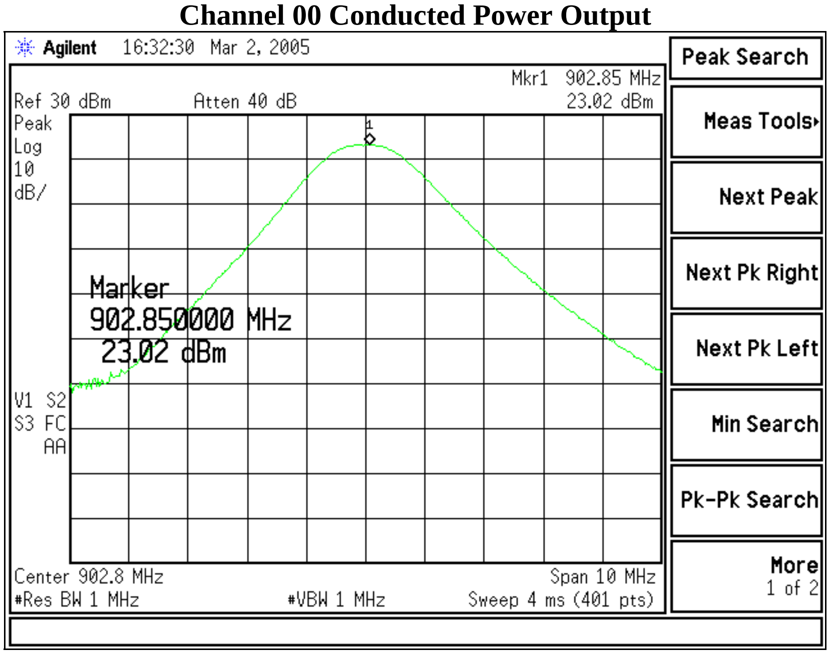
## 15. Power Output 15.247(b)

The conducted RF output power of the EUT was measured at the antenna port using a short RF cable for the spectrum analyzer. The loss from the cable was added on the analyzer as gain offset settings, there by allowing direct readings of the measurements without the need for any further corrections. The unit was configured to run in a continuous transmit mode, while being supplied with typical data as a modulation source. The spectrum analyzer was used with resolution and video bandwidths set to 1 MHz, and a span of 10 MHz, with measurements from a peak detector presented in the chart below. RF Power Output was also monitored while varying the DC voltage as sourced by a DC bench type power supply. No considerable variation in output power was seen while setting the DC voltage to 3.06 VDC (-15%) or to 4.14 VDC (+15%).

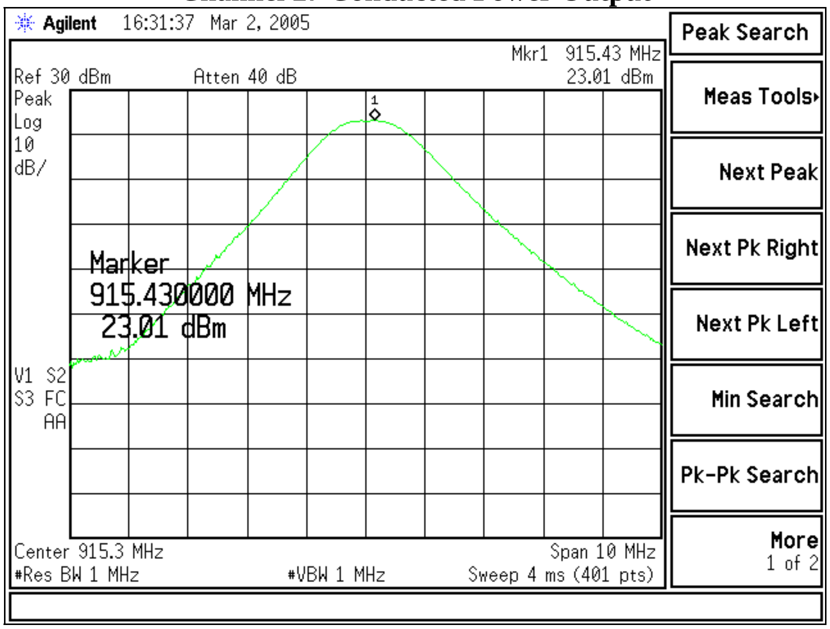
| CHANNEL | CENTER FREQ (MHz) | LIMIT (dBm) | MEASURED POWER (dBm) | MARGIN (dB) |
|---|---|---|---|---|
| 00 | 902.8 | + 30.0 | + 23.0 | 7.0 |
| 27 | 915.3 | + 30.0 | + 23.0 | 7.0 |
| 52 | 927.2 | + 30.0 | + 23.0 | 7.0 |



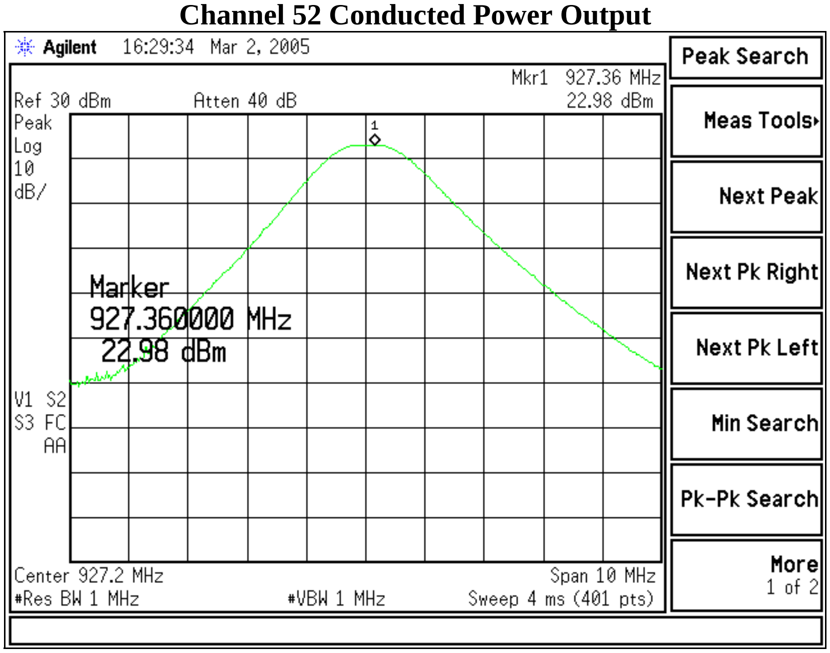

**Channel 00 Conducted Power Output**



**Channel 27 Conducted Power Output**




**Channel 52 Conducted Power Output**



## 16. Spurious Emissions 15.247(d)

FCC Part 15.247(d) requires a measurement of conducted harmonic and spurious RF emission levels, as reference to the carrier level when measured in a 100 kHz bandwidth. For this test, the spurious and harmonic RF emissions from the EUT were measured at the EUT antenna port using a short RF cable. The loss from the cable was added on the analyzer as gain offset settings, there by allowing direct readings of the measurements without the need for any further corrections. A Hewlett Packard model E4407B spectrum analyzer was used with the resolution bandwidth set to 100 kHz for this portion of the tests. The unit was configured to run in a continuous transmit mode, while being supplied with typical data as a modulation source. The spectrum analyzer was used with measurements from a peak detector presented in the chart below. Screen captures were acquired and any noticeable spurious and harmonic signals were identified and measured.

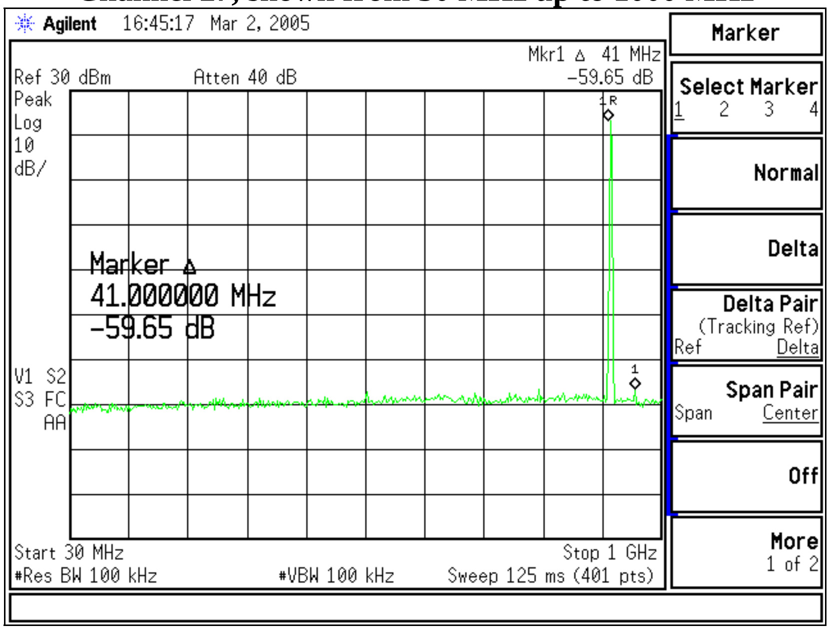
No significant emissions could be noted within -30 dBc of the fundamental level for this product.

| | Channel 00 | Channel 27 | Channel 52 |
|---|---|---|---|
| Fundamental | + 22.9 (dBm) | + 23.0 (dBm) | + 23.0 (dBm) |
| 2nd Harmonic | - 16.7 (dBm) | - 14.5 (dBm) | - 14.6 (dBm) |
| 3rd Harmonic | - 38.2 (dBm) | - 37.3 (dBm) | - 38.0 (dBm) |
| 4th Harmonic | - 38.5 (dBm) | - 38.3 (dBm) | - 38.4 (dBm) |
| 5th Harmonic | - 38.9 (dBm) | - 39.2 (dBm) | - 38.7 (dBm) |
| 6th Harmonic | Note (1) | Note (1) | Note (1) |
| 7th Harmonic | Note (1) | Note (1) | Note (1) |
| 8th Harmonic | Note (1) | Note (1) | Note (1) |
| 9th Harmonic | Note (1) | Note (1) | Note (1) |
| 10th Harmonic | Note (1) | Note (1) | Note (1) |

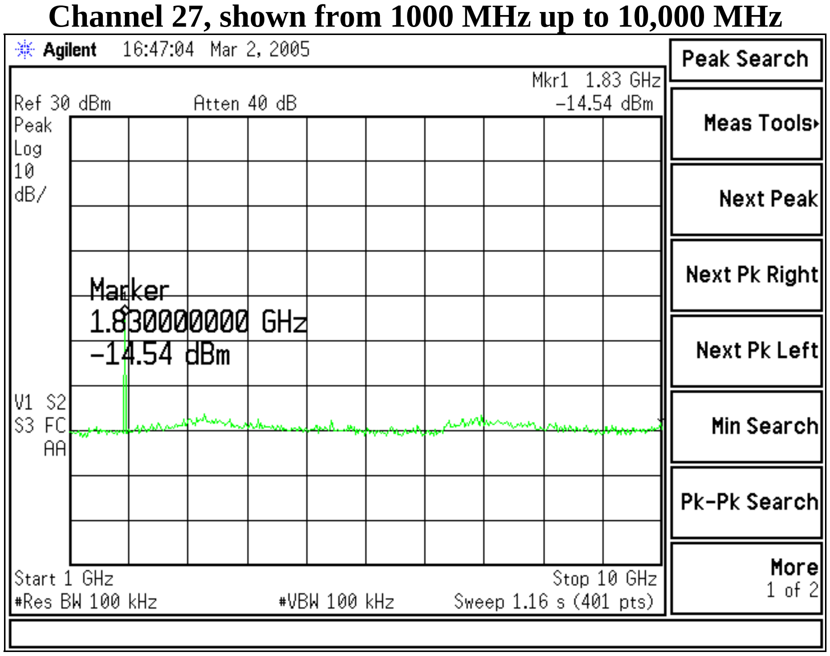
Notes:
(1) Measurement at system noise floor.

**Plots of Conducted Spurious and Fundamental Levels, Channel 27 shown as a representative sample**

**Channel 27, shown from 30 MHz up to 1000 MHz**




**Channel 27, shown from 1000 MHz up to 10,000 MHz**



## 17. Minimum Channel Separation

Part 15.247(a)(1) requires a minimum channel separation of 25 kHz or the equivalent of the 20 dB occupied bandwidth of the fundamental transmission, whichever is greater. An HP E4407B spectrum analyzer was used with a resolution bandwidth of 30 kHz to measure the channel separation of the EUT.

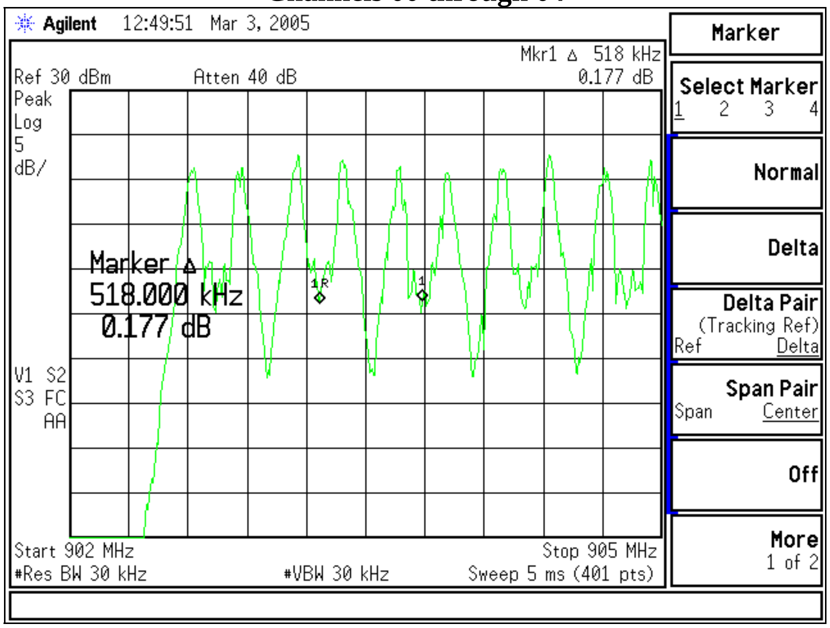
The minimum and maximum adjacent channel-separations measured for this device are 428 kHz and 535 kHz respectively. The maximum occupied bandwidth of the device, as reported in the previous section is 410 kHz. The minimum channel separation for the EUT exceeds the 25 kHz criteria, as well as the 20 dB occupied bandwidth criteria.

For this EUT, with a -20 dBc OCCBW of more than 250 kHz, there is a minimum of 25 hop channels required per 15.247 (a)(1)(i). The following plots describe the spacing, and establish the number of hop channels to be a total of 50.

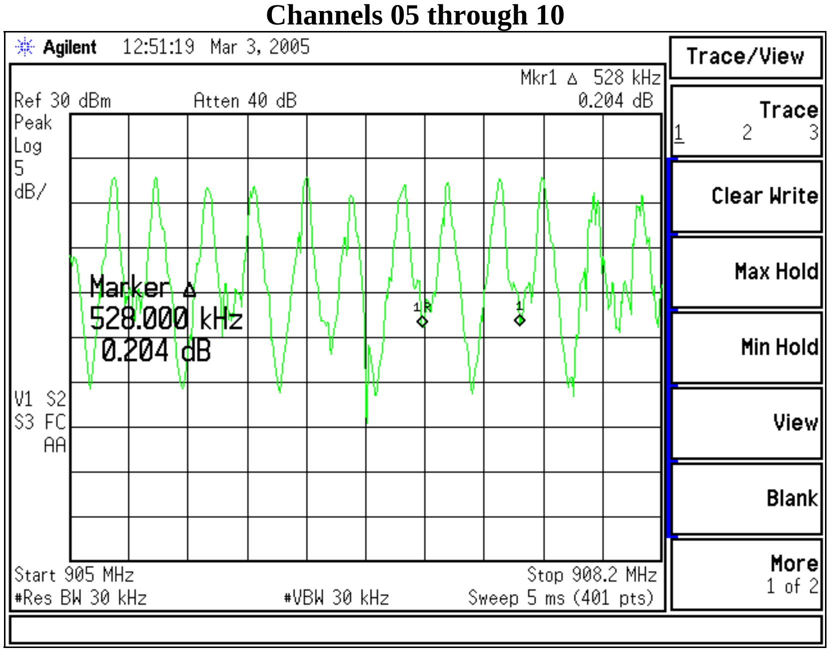
| Frequency Span | Number of Channels | Minimum Separation (kHz) |
|---|---|---|
| 902.0-905.0 | 5 | 518 |
| 905.0-908.2 | 6 | 528 |
| 908.2-911.2 | 7 | 435 |
| 911.2-914.2 | 5 | 428 |
| 914.2-917.2 | 7 | 435 |
| 917.2-919.8 | 6 | 436 |
| 919.8-922.8 | 5 | 443 |
| 922.8-925.9 | 6 | 535 |
| 925.9-928.0 | 3 | 509 |

## Plots of Channel Separations

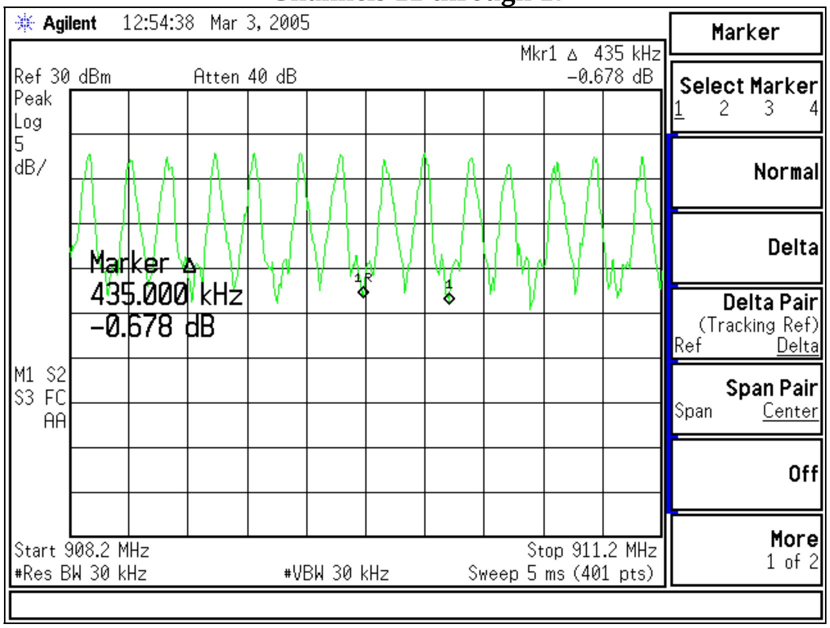
**Channels 00 through 04**



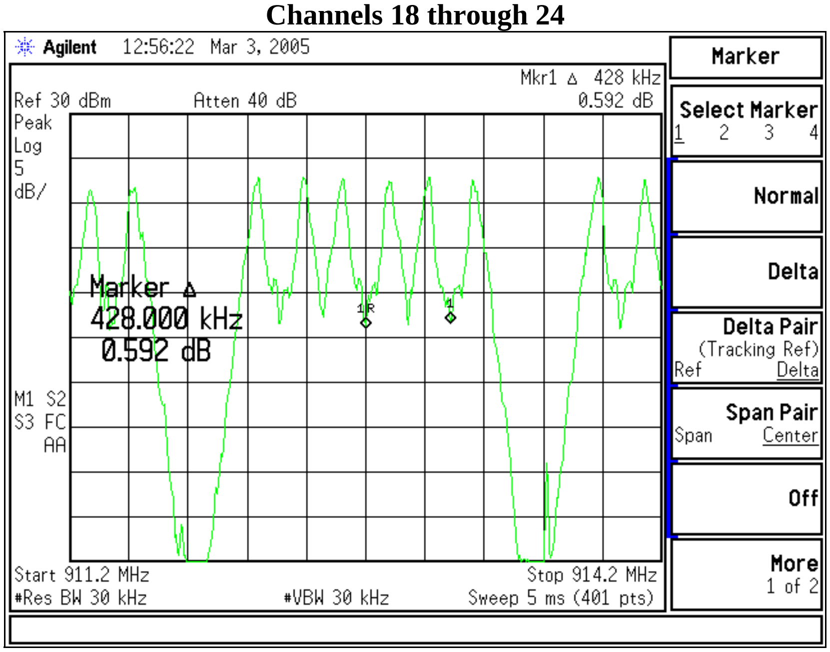

**Channels 05 through 10**



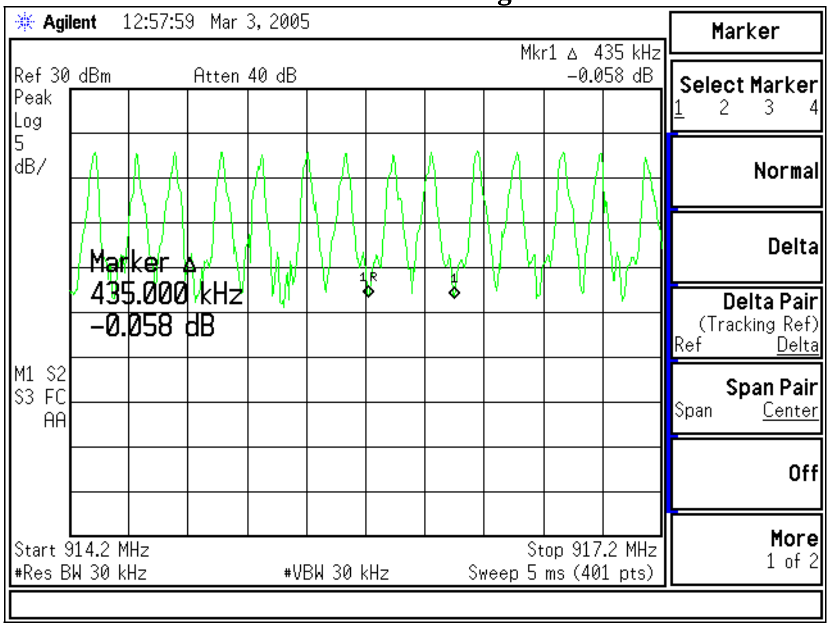
**Channels 11 through 17**



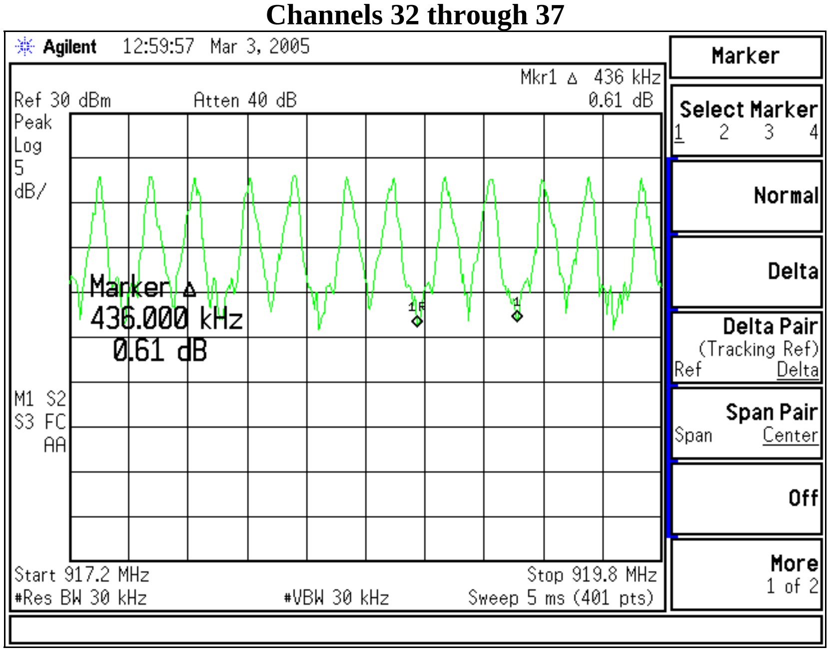

**Channels 18 through 24**



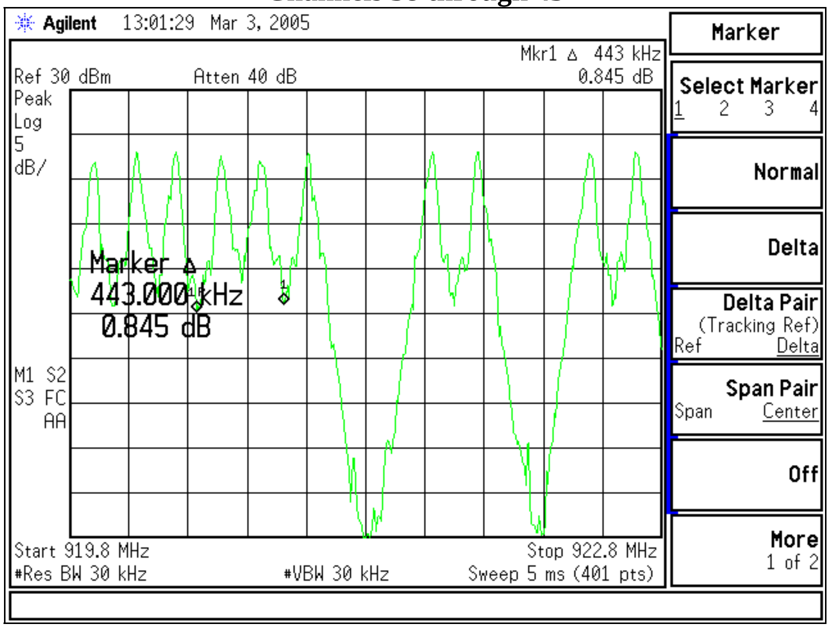
## Channels 25 through 31



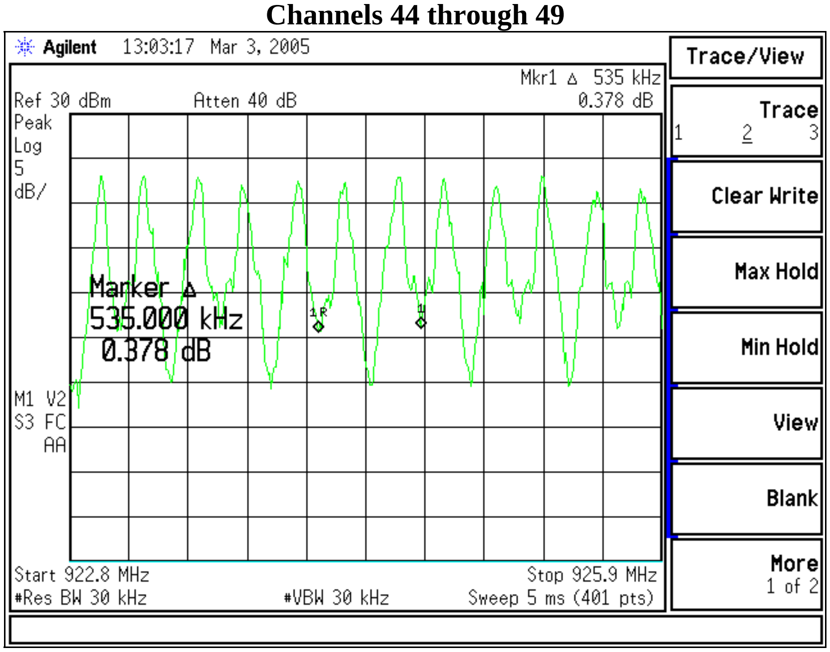

## Channels 32 through 37



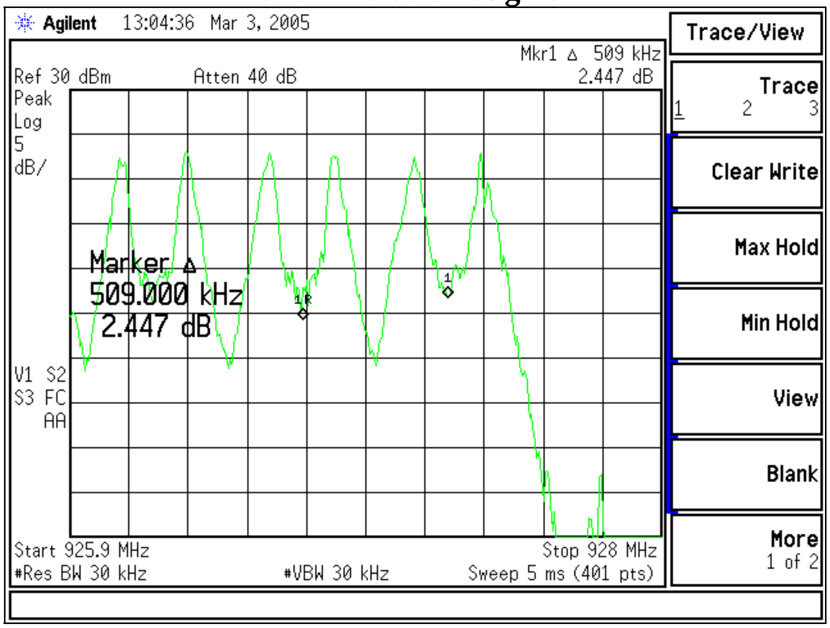
**Channels 38 through 43**




**Channels 44 through 49**



**Channels 50 through 52**



## 18. <u>Channel Occupancy</u>

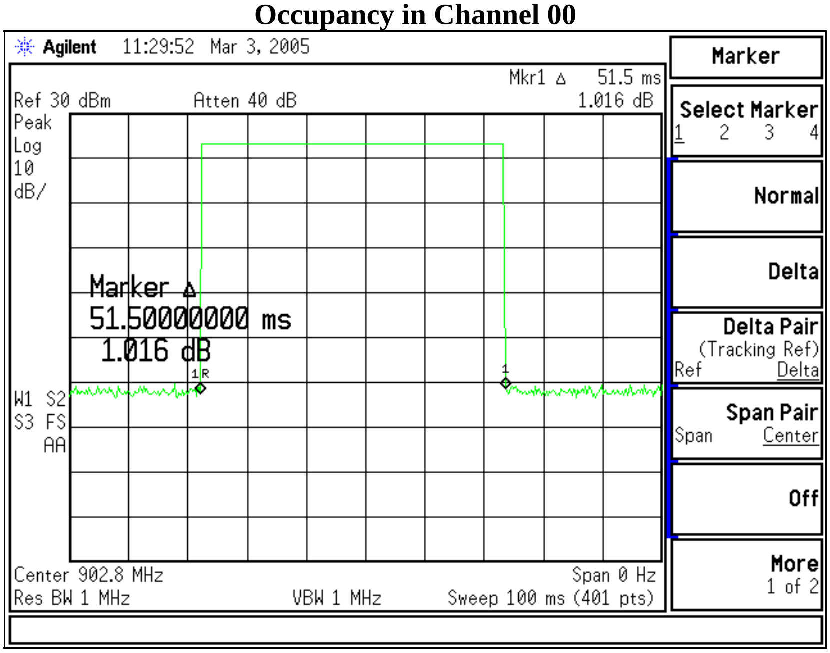
Part 15.247(a)(1) requires a channel occupancy, for this device, of no more than 400 milliseconds in a 10 second window. The channel occupancy for this EUT was measured using an HP E4407B spectrum analyzer, set to zero-span at the frequency of interest. With the analyzer in peak-hold mode, the transmission lengths can be measured by adjusting the sweep rate of the analyzer. A suitable sweep rate was used to measure the channel occupancy at the low, mid and high channels.

The longest time any transmission will occur on a single channel is 51.75 ms. With a total of 50 channels used, each occupying a 51.75 ms slot, it will take 2.59 seconds for the sequence to repeat. In a 10 second window, each channel would have 3.87 transmission cycles. The maximum occupancy in a 10 second window is calculated by multiplying the 3.87 transmission cycles by 51.75 ms transmission duration per cycle, to arrive at 200 ms total occupancy.

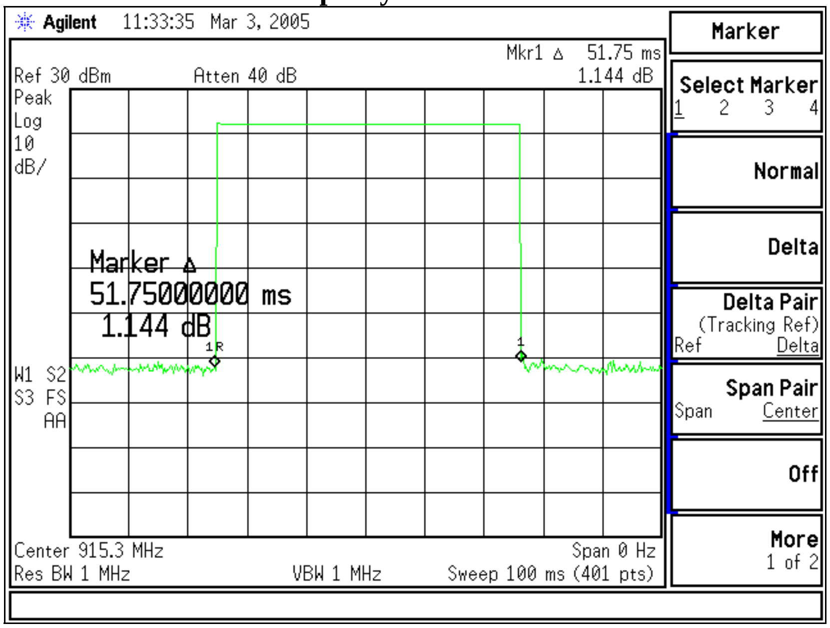
| Channel | Frequency (MHz) | Occupancy Per transmission (ms) | Occupancy in any 10 second window (ms) |
|---|---|---|---|
| 00 | 902.8 | 51.50 | 200 |
| 27 | 915.3 | 51.75 | 200 |
| 52 | 927.2 | 51.75 | 200 |

### Plots of Channel Occupancy

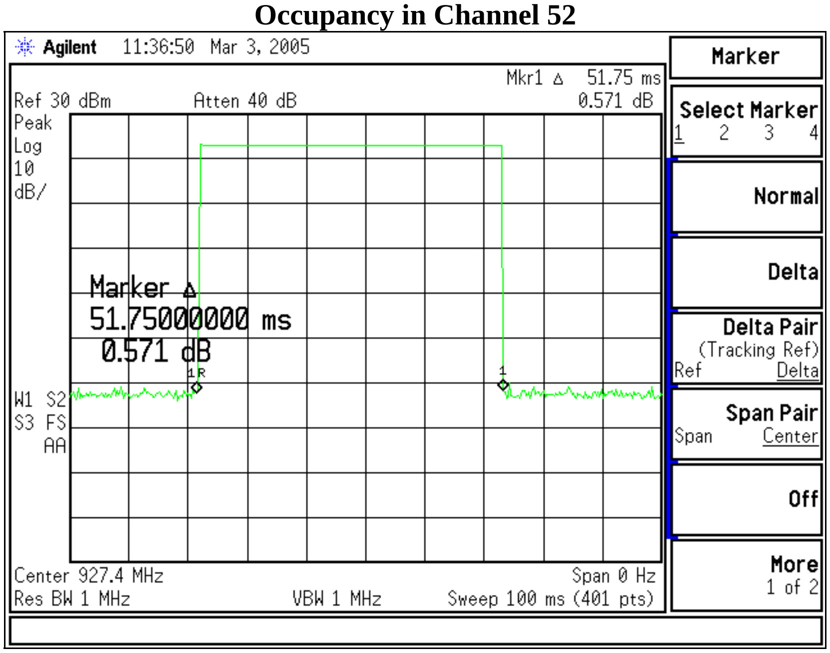
**Occupancy in Channel 00**



**Occupancy in Channel 26**




**Occupancy in Channel 52**



## 19. Frequency and Power Stability requirements

A Spectrum Analyzer was used to measure the frequency at the appropriate frequency markers. For this test, transmitter portion of the EUT placed in continuous transmit CW mode. Power was supplied by an external bench-type variable power supply, and the frequency of operation was monitored using the spectrum analyzer. The frequency was measured with a receiver resolution bandwidth of 300 Hz, and video bandwidth of 300 Hz. The data presented below is from channel 27 presenting sample frequency variation measurements.

| | DC Voltage Source | | |
|---|---|---|---|
| | 3.06 V | 3.60 V | 4.14 V |
| Channel 00 | +21.2 (dBm) | +23.0 (dBm) | +23.2 (dBm) |
| Channel 27 | +21.4 (dBm) | +23.0 (dBm) | +23.1 (dBm) |
| Channel 52 | +21.0 (dBm) | +23.0 (dBm) | +23.2 (dBm) |

| | DC Voltage Source | | |
|---|---|---|---|
| | 3.06 V | 3.60 V | 4.14 V |
| Channel 27 | 915.32100 (MHz) | 915.32128 (MHz) | 915.32162 (MHz) |

The power was then cycled On/Off to observe system response. No unusual response was observed, the emission characteristics were well behaved, and the system returned to the same state of operation as before the power cycle, in this case, the test mode. A wide frequency sweep was also investigated, with minimum and maximum input voltages, to ensure that no unexpected anomalies have occurred.

No anomalies were noted, in the measured transmit power, varying approximately 2 dB, during the voltage variation tests.

*The information on this page is provided by the manufacturer.*

## 20. Equal Channel Usage

50 channels are chosen from a pool of 53 available frequencies. These channels are arrayed in a table which the system uses to determine the next hopping channel. Each radio is programmed with a seed value which determines the table based on a defined pseudorandom generator. Each channel carries a single packet of information for a duration no longer than 52 mS. Each time a transmission is made the system uses the next frequency in the table. The table is started over once the end has been reached. Thus, any given frequency will not be reused until all other frequencies have been accessed.

## 21. Pseudorandom Hopping Pattern

Each helmet and sideline controller is uniquely addressed in such a manner that communications may only take place between helmets and their mated sideline controller. The coordination of hop sequences, addresses, etc. is conducted during factory assembly as systems are built to order for a particular customer. The system does not automatically re-configure channel hopping sequences in the field.

The hopping table is built using an 8 bit seed into an $X^{15}+1$ pseudorandom number generator giving the possibility of 256 unique pseudorandom hopping tables. Output from the generator is used to pick frequencies from a pool of 53 available channels.

## 22. Receiver Synchronization

The problem of addressing individual grouping of helmets extends to the selection of RF channels. As described, this system defines a set of 53 channels which covers the 902 – 928 MHz ISM band. Of those 53 channels, only 50 are used within a subset of grouped hop channels. The grouping of the select 50 channels and the order in which the channels are sequenced are determined by a set of pseudorandom number sets.

## 23. Receiver Input Bandwidth

The receiver uses direct conversion meaning that there is no offset local oscillator. In other words, the receiver local oscillator is tuned to be the same as the radio operating frequency. Individual channel selection occurs within the receiver without the need for external filtering. An overall bandpass filter restricts the receiver to the stated ISM band.

## 24. MPE Calculations

The following calculations are based on a printed circuit board trace antenna with declared antenna gain of approximately 0 dBi.

**Prediction of MPE limit at a given distance**

Equation from page 18 of OET Bulletin 65, Edition 97-01

$$S = \frac{PG}{4\pi R^2}$$

where: S = power density
P = power input to the antenna
G = power gain of the antenna in the direction of interest relative to an isotropic radiator
R = distance to the center of radiation of the antenna

| | | |
|---|---|---|
| Maximum peak output power at antenna input terminal: | 23.00 | (dBm) |
| Maximum peak output power at antenna input terminal: | 199.526 | (mW) |
| Antenna gain(typical): | 0 | (dBi) |
| Maximum antenna gain: | 1.000 | (numeric) |
| Prediction distance: | 20 | (cm) |
| Prediction frequency: | 915 | (MHz) |
| MPE limit for uncontrolled exposure at prediction frequency: | 0.62 | (mW/cm^2) |
| Power density at prediction frequency: | 0.039694 | (mW/cm^2) |
| Maximum allowable antenna gain: | 11.9 | (dBi) |
| Margin of Compliance at 20 cm = | 11.9 | dB |

# Appendix A

## Test Equipment List

| Asset # | Manufacturer | Model # | Serial # | Description | Date | Due |
|---|---|---|---|---|---|---|
| AA960008 | EMCO | 3816/2NM | 9701-1057 | Line Impedance Stabilization Network | 9/15/04 | 9/15/05 |
| AA960031 | HP | 119474A | 3107A01708 | Transient Limiter | Note 1 | Note 1 |
| AA960077 | EMCO | 93110B | 9702-2918 | Biconical Antenna | 9/16/04 | 9/16/05 |
| AA960078 | EMCO | 93146 | 9701-4855 | Log-Periodic Antenna | 9/16/04 | 9/16/05 |
| AA960081 | EMCO | 3115 | 6907 | Double Ridge Horn Antenna | 12/06/04 | 12/06/05 |
| CC00221C | Agilent | E4407B | US39160256 | Spectrum Analyzer | 12/06/04 | 12/06/05 |
| EE960004 | EMCO | 2090 | 9607-1164 | Device Controller | N/A | N/A |
| EE960013 | HP | 8546A | 3617A00320 | Receiver RF Section | 9/16/04 | 9/16/05 |
| EE960014 | HP | 85460A | 3448A00296 | Receiver Pre-Selector | 9/16/04 | 9/16/05 |
| N/A | LSC | Cable | 0011 | 3 Meter ½" Armored Cable | Note 1 | Note 1 |
| N/A | LSC | Cable | 0038 | 1 Meter RG 214 Cable | Note 1 | Note 1 |
| N/A | LSC | Cable | 0050 | 10 Meter RG 214 Cable | Note 1 | Note 1 |
| N/A | Pasternack | Attenuator | N/A | 10 dB Attenuator | Note 1 | Note 1 |

*Note 1 - Equipment calibrated within a traceable system.*

## Uncertainty Statement

This uncertainty represents an expanded uncertainty expressed
at approximately the 95% confidence level, using a coverage factor of k=2.

*Table of Expanded Uncertainty Values, (K=2) for Specified Measurements*

| Measurement Type | Particular Configuration | Uncertainty Values |
|---|---|---|
| Radiated Emissions | 3 – Meter chamber, Biconical Antenna | 4.24 dB |
| Radiated Emissions | 3-Meter Chamber, Log Periodic Antenna | 4.8 dB |
| Radiated Emissions | 10-Meter OATS, Biconical Antenna | 4.18 dB |
| Radiated Emissions | 10-Meter OATS, Log Periodic Antenna | 3.92 dB |
| Conducted Emissions | Shielded Room/EMCO LISN | 1.60 dB |
| Radiated Immunity | 3 Volts/Meter in 3-Meter Chamber | 1.128 Volts/Meter |
| Conducted Immunity | 3 Volts level | 1.0 V |

# Appendix B

## Antenna Specification

The antenna is a printed circuit board trace antenna, 5.5 cm in length, with a declared gain of approximately 0 dBi.   The antenna is permanent and not removable.

# Appendix C

## Firmware and Setup Instructions

The channel selection and mode of operation selection, on the test sample was accomplished by inserting specifically coded jumper header selections as provided by the manufacturer.