**MET Laboratories, Inc.** *Safety Certification - EMI - Telecom Environmental Simulation*
914 WEST PATAPSCO AVENUE ● BALTIMORE, MARYLAND 21230-3432 ● PHONE (410) 354-3300 ● FAX (410) 354-3313

.
Nomadio Digital Telemetry
2400 Chestnut Street
Philadelphia, PA 19103

January 12, 2006

Dear Alex Gizis,

Enclosed is the EMC test report for compliance testing of the Nomadio Digital Telemetry,GC-205, RCU (ROBOT CONTROL UNIT), as tested to the requirements of Title 47 of the CFR, Ch. 1 (10-1-03 ed.), Part 15 Subpart C, §15.247 for Intentional Radiators and FCC Declaration of Conformity under CFR, Part 15, Subpart B For a Class B Unintentional Radiator.

Thank you for using the services of MET Laboratories, Inc. If you have any questions regarding these results or if MET can be of further service to you, please feel free to contact me.

Sincerely yours,
MET LABORATORIES, INC.

Molly Sunderland
Documentation Department

Reference: (\Nomadio Digital Telemetry\EMC18325A-FCC247)

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# Electromagnetic Compatibility
# Test Report

For the

## Nomadio Digital Telemetry
## GC-205, RCU (ROBOT CONTROL UNIT)

**Tested in Accordance with**
**Title 47 of the CFR**
**FCC Part 15, Subpart B and Subpart C**

**MET Report: 18325A-FCC247**

January 12, 2006

**Prepared For:**

**Nomadio Digital Telemetry**
**2400 Chestnut Street**
**Philadelphia, PA 19103**

**Prepared By:**
**MET Laboratories, Inc.**
914 West Patapsco Avenue
Baltimore, MD 21230



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# Electromagnetic Compatibility
# Test Report

For the

## Nomadio Digital Telemetry
## GC-205, RCU (ROBOT CONTROL UNIT)

**Tested in Accordance with**
**Title 47 of the CFR**
**FCC Part 15, Subpart B and Subpart C**

Dusmantha Tennakoon
Electromagnetic Compatibility Lab

Molly Sunderland
Documentation Department

**Engineering Statement:** The measurements shown in this report were made in accordance with the procedures indicated, and the emissions from this equipment were found to be within the limits applicable. I assume full responsibility for the accuracy and completeness of these measurements, and for the qualifications of all persons taking them. It is further stated that upon the basis of the measurements made, the equipment tested is capable of operation in accordance with the requirements of Part 15, §15.247 of the FCC Rules under normal use and maintenance.

Kevin Mehaffey
Manager, Electromagnetic Compatibility Lab



DOC-EMC702 2/26/2004

# Report Status Sheet

| Revision | Report Date | Reason for Revision |
|---|---|---|
| Ø | January 12, 2006 | Initial Issue. |


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# List of Terms and Abbreviations

| | |
|---|---|
| **AC** | **A**lternating **C**urrent |
| **ACF** | **A**ntenna **C**orrection **F**actor |
| **Cal** | **Cal**ibration |
| **d** | **M**easurement **D**istance |
| **dB** | **D**eci **B**els |
| **dB$\mu$V** | **D**eci-**B**els above one **micro V**olt |
| **dB$\mu$V/m** | **D**eci-**B**els above one **micro V**olt **per m**eter |
| **DC** | **D**irect **C**urrent |
| **DCF** | **D**istance **C**orrection **F**actor |
| **E** | **E**lectric Field |
| **EUT** | **E**quipment **U**nder **T**est |
| **f** | **F**requency |
| **FCC** | **F**ederal **C**ommunications **C**ommission |
| **H** | Magnetic Field |
| **GHz** | **G**iga **H**ertz |
| **Hz** | **H**ertz |
| **ICES** | **I**nterference-**C**ausing **E**quipment **S**tandard |
| **kHz** | **k**ilo**h**ertz |
| **kPa** | **k**ilo**pa**scal |
| **kV** | **k**ilo **V**olt |
| **LISN** | **L**ine **I**mpedance **S**tabilization **N**etwork |
| **MHz** | **M**ega**H**ertz |
| **$\mu$H** | **micro H**enry |
| **$\mu$F** | **micro F**arad |
| **$\mu$s** | **micro s**econds |
| **RF** | **R**adio **F**requency |
| **RMS** | **R**oot-**M**ean-**S**quare |

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# 1.0 Introduction

## 1.1 Overview

MET Laboratories, Inc. was contracted by Nomadio Digital Telemetry to perform testing on theGC-205, RCU (ROBOT CONTROL UNIT), under Nomadio Digital Telemetry purchase order number 05-216.

This document describes the test setups, test methods, required test equipment, and the test limits used to perform compliance testing of the GC-205, RCU (ROBOT CONTROL UNIT). All applicable tests were performed in accordance with Title 47 of the CFR, FCC Part 15, Subpart B and Subpart C.

| | | |
|---|---|---|
| **Type of Submission/Rule:** | Part 15.247 Original Filing | |
| **Model(s) Tested:** | NMD-AM06 | |
| **Model(s) Covered:** | NMD-AM06 | |
| | **Primary Power:** | 6 VDC (4 x "AA" Batteries) |
| **EUT Specifications:** | **FCC ID:** | TSDNMD-AM06 |
| | **Equipment Code:** | DSS |
| | **Maximum RF Power Output:** | 16.80 dBm (0.04798 Watts) |
| | **Equipment Frequency Range:** | 2.447 – 2.479 GHz |
| **Analysis:** | The results obtained relate only to the item(s) tested. | |
| **Evaluated by:** | Dusmantha Tennakoon | |
| **Date(s):** | January 12, 2006 | |

## 1.2 Test Site

All testing was performed at MET Laboratories, Inc., 914 West Patapsco Avenue, Baltimore, MD 21230. All equipment used in making physical determinations is accurate and bears recent traceability to the National Institute of Standards and Technology.

Radiated Emissions measurements were performed in a semi-anechoic chamber. In accordance with §2.948(a)(3), a complete site description is contained at MET Laboratories. In accordance with §2.948(d), MET Laboratories has been accredited by the National Voluntary Laboratory Accreditation Program (Lab Code: 100273-0).

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## 1.3 Testing Summary

| Paragraph | Name of Test | Compliance |
|---|---|---|
| Part 15, Subpart C, §15.203 | Antenna Requirement | Compliant |
| Part 15, Subpart C, §15.205 | Restricted Bands of Operation | Compliant |
| Part 15, Subpart B, §15.109 | Radiated Emissions | Compliant |
| Part 15, Subpart C, §15.247(a) (1) | Bandwidth and Separation Requirements | Compliant |
| Part 15, Subpart C, §15.247(a) (1)(iii) | Number of Channels and Time of Occupancy | Compliant |
| Part 15, Subpart C, §15.247(b) | Peak Power Output | Compliant |
| Part 15, Subpart C, §15.247(i) | RF Exposure | Compliant |
| Part 15, Subpart C, §15.247(d) | Spurious Conducted Emissions | Compliant |
| Part 15, Subpart C, §15.247 | Band Edge Measurements | Compliant |
| Part 15, Subpart C, §15.247(g) | Hopping Capability Requirements | Compliant |
| Part 15, Subpart C, §15.247(h) | Non-Coordination Requirements | Compliant |

**Table 1. Testing Summary**

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# 2.0 Equipment Configuration

## 2.1 Description of EUT

Wireless USB 2.4GHz FHSS remote telemetry and control system, intended for use for control with remotely-controlled military scale-model unmanned ground vehicles.

## 2.2 Equipment Configuration

The EUT was set up as outlined in Figure 1. All equipment incorporated as part of the EUT is included in the following list.

| Name / Description | Model Number |
|---|---|
| GC-205 Robot Control Unit | AM06 |

**Table 2. Equipment Configuration**

## 2.3 Support Equipment

No support equipment is necessary for the normal operation and testing of the EUT.

## 2.4 Ports and Cabling Information

| Ref. ID | Port name on EUT | Cable Description or reason for no cable | Qty. | Length (m) | Shielded? |
|---|---|---|---|---|---|
| 1 | Serial | Serial cable connection | 1 | 1 | Y |
| 2 | Servo connections | Servo termination cable | 4 | 0.3 | N |

**Table 3. Ports and Cabling**

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## 2.5 Mode Of Operation

The EUT was set to transmit at max power and max data rate.

## 2.6 Method of Monitoring

RS232 interface and/or external "bind" button used to set mode of operation. All output levels were verified prior to test.

## 2.7 Modifications to EUT

No modifications were made to the EUT.

## 2.8 Disposition of EUT

The test sample including all support equipment submitted to the Electro-Magnetic Compatibility Lab for testing was returned to Nomadio Digital Telemetry upon completion of testing.

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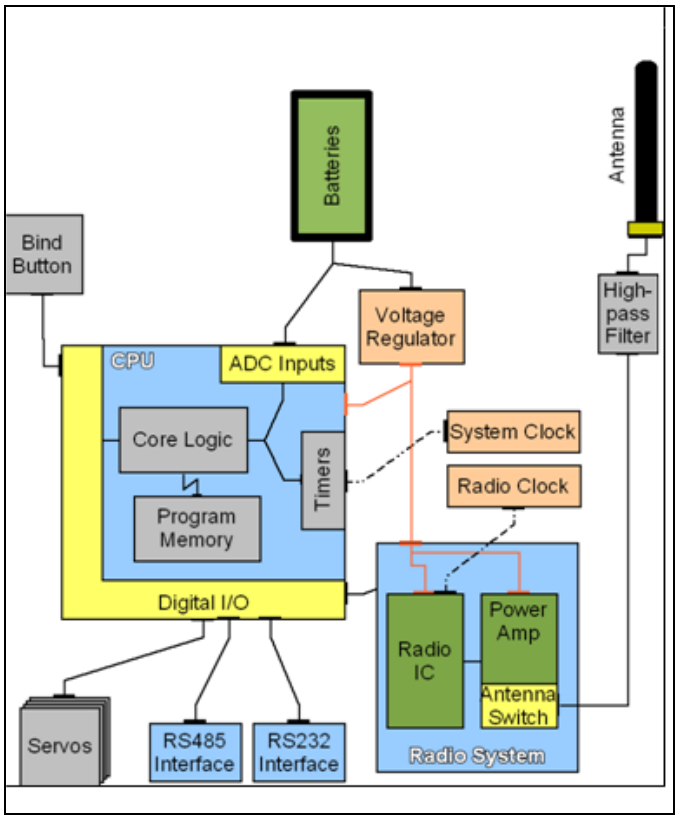


**Figure 1. Block Diagram of Test Configuration**

# 3.0 Electromagnetic Compatibility Test Data

## 3.1 Antenna Requirements

**Test Requirement:**

**§ 15.203:** An intentional radiator shall be designed to ensure that no antenna other than that furnished by the responsible party shall be used with the device. The use of a permanently attached antenna or of an antenna that uses a unique coupling to the intentional radiator shall be considered sufficient to comply with the provisions of this section. The manufacturer may design the unit so that a broken antenna can be replaced by the user, but the use of a standard antenna jack or electrical connector is prohibited.

The structure and application of the EUT were analyzed to determine compliance with Section 15.203 of the Rules. Section 15.203 states that the subject device must meet at least one of the following criteria:

a.) Antenna be permanently attached to the unit.

b.) Antenna must use a unique type of connector to attach to the EUT.

c.) Unit must be professionally installed. Installer shall be responsible for verifying that the correct antenna is employed with the unit.

**Results:**

The EUT was found **compliant** with the requirements of this section. The antenna has an unique connector (reverse SMA). The gain of the antenna is 2 dBi.

Type of Antenna: dipole

Gain of Antenna: 2.0 dBi

**Test Engineer(s):** Dusmantha Tennakoon

**Test Date(s):** December 12, 2005

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**Photograph 1. EUT Antenna Requirements**

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## 3.2 Spurious Radiated Emissions

**Test Requirement(s):** **§ 15.205 (a):** Except as shown in paragraph (d) of **15.205 Restricted bands of operation**, only spurious emissions are permitted in any of the frequency bands specified in Table 4:

| MHz | MHz | MHz | GHz |
|---|---|---|---|
| 0.090–0.110 | 16.42–16.423 | 399.9–410 | 4.5–5.15 |
| 0.495–0.505 (Note 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 | (Note 2) |
| 13.36–13.41. | | | |
| Note 1: Until February 1, 1999, this restricted band shall be 0.490–0.510 MHz.<br>Note 2: Above 38.6 | | | |

**Table 4. Restricted Bands of Operation from FCC Part 15, § 15.205**

**§ 15.205 (b):** (b) Except as provided in paragraphs (d) and (e), the field strength of emissions appearing within these frequency bands shall not exceed the limits shown in Section 15.209. At frequencies equal to or less than 1000 MHz, compliance with the limits in Section 15.209 shall be demonstrated using measurement instrumentation employing a CISPR quasi-peak detector. Above 1000 MHz, compliance with the emission limits in Section 15.209 shall be demonstrated based on the average value of the measured emissions. The provisions in Section 15.35 apply to these measurements.

**§ 15.35 (b):** …When average radiated emission measurements are specified in this part, including emission measurements below 1000 MHz, there also is a limit on the radio frequency emissions, as measured using instrumentation with a peak detector function, corresponding to 20 dB above the maximum permitted average limit for the frequency being investigated unless a different peak emission limit is otherwise specified in the rules…

| Frequency (MHz) | Field Strength (Microvolts/meter) | Measurement Distance (meters) |
|---|---|---|
| 0.009 – 0.490 | 2400/F (kHz) | 300 |
| 0.490 – 1.705 | 24000/F (kHz) | 30 |
| 1.705 – 30.0 | 30 | 30 |
| 30 - 88 | 100 ** | 3 |
| 88 - 216 | 150 ** | 3 |
| 216 - 960 | 200 ** | 3 |
| Above 960 | 500 | 3 |
| ** Except as provided in paragraph (g), fundamental emissions from intentional radiators operating under this Section shall not be located in the frequency bands 54-72 MHz, 76-88 MHz, 174-216 MHz or 470-806 MHz. However, operation within these frequency bands is permitted under other sections of this Part, e.g., Sections 15.231 and 15.241. | | |

**Table 5. Radiated Emissions Limits from § 15.209 (a)**

**Test Procedure:** The EUT was configured with the control software to transmit at maximum power. Measurements above 1 GHz were made with a ridge guide horn antenna at a distance of 1m. Cable loss has been accounted for in the raw measurement. The frequency range of interest was that indicative to spurious emissions associated with the intentional radiator section of the EUT.

**Test Results:** The EUT was found **compliant** with the requirements of this section.

**Test Engineer(s):** Dusmantha Tennakoon

**Test Date(s):** December 13, 2005

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| Frequency (GHz) | EUT Azimuth (Degrees) | Antenna Polarity (H/V) | Antenna HEIGHT (m) | Uncorrected Amplitude (dBuv) | Antenna Correction Factor (dB) (+) | System Gain (dB) (-) | Distance Correction Factor (dB) (-) | Corrected Amplitude (dBuv) | Limit (dBuv) | Margin (dB) |
|---|---|---|---|---|---|---|---|---|---|---|
| 1.721 | 180 | H | 1.00 | 17.33 | 26.56 | 0.00 | 9.54 | 34.35 | 74.00 | -39.65 |
| 1.725 | 180 | V | 1.00 | 26.28 | 26.58 | 0.00 | 9.54 | 43.32 | 74.00 | -30.68 |
| 1.726 | 180 | V | 1.00 | 27.07 | 26.48 | 0.00 | 9.54 | 44.01 | 74.00 | -29.99 |
| 1.747 | 180 | V | 1.00 | 29.46 | 26.69 | 0.00 | 9.54 | 46.61 | 74.00 | -27.39 |
| 1.916 | 180 | H | 1.00 | 22.41 | 27.40 | 0.00 | 9.54 | 40.27 | 74.00 | -33.73 |
| 1.949 | 180 | V | 1.00 | 24.78 | 27.55 | 0.00 | 9.54 | 42.79 | 74.00 | -31.21 |
| 1.974 | 180 | V | 1.00 | 23.49 | 27.78 | 0.00 | 9.54 | 41.73 | 74.00 | -32.27 |
| 1.981 | 180 | H | 1.00 | 21.86 | 27.81 | 0.00 | 9.54 | 40.13 | 74.00 | -33.87 |
| 2.166 | 180 | H | 1.00 | 28.49 | 28.23 | 0.00 | 9.54 | 47.18 | 74.00 | -26.82 |
| 2.341 | 180 | H | 1.00 | 24.32 | 28.62 | 0.00 | 9.54 | 43.40 | 74.00 | -30.60 |
| 2.356 | 180 | V | 1.00 | 26.98 | 28.61 | 0.00 | 9.54 | 46.05 | 74.00 | -27.95 |
| 2.395 | 180 | V | 1.00 | 27.45 | 28.75 | 0.00 | 9.54 | 46.66 | 74.00 | -27.34 |
| 4.938 | 180 | H | 1.00 | 39.37 | 34.03 | 0.00 | 9.54 | 63.86 | 74.00 | -10.14 |
| 4.947 | 180 | V | 1.00 | 40.17 | 34.05 | 0.00 | 9.54 | 64.68 | 74.00 | -9.32 |

**Table 6. Spurious Radiated Emissions 15.209, Test Results – Peak**

Note 1 : The EUT was tested at 1 m. The data has been corrected for comparison with the 3 m limit using the formula: 20log (1 m/3 m) as expressed in the 'Distance Correction' column.

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| Frequency (GHz) | EUT Azimuth (Degrees) | Antenna Polarity (H/V) | Antenna HEIGHT (m) | Uncorrected Amplitude (dBuv) | Antenna Correction Factor (dB) (+) | System Gain (dB) (-) | Distance Correction Factor (dB) (-) | Corrected Amplitude (dBuv) | Limit (dBuv) | Margin (dB) |
|---|---|---|---|---|---|---|---|---|---|---|
| 1.721 | 180 | H | 1.00 | 9.34 | 26.56 | 0.00 | 9.54 | 26.36 | 54.00 | -27.64 |
| 1.725 | 180 | V | 1.00 | 7.85 | 26.58 | 0.00 | 9.54 | 24.89 | 54.00 | -29.11 |
| 1.726 | 180 | V | 1.00 | 7.97 | 26.48 | 0.00 | 9.54 | 24.91 | 54.00 | -29.09 |
| 1.747 | 180 | V | 1.00 | 7.73 | 26.69 | 0.00 | 9.54 | 24.88 | 54.00 | -29.12 |
| 1.916 | 180 | H | 1.00 | 21.43 | 27.40 | 0.00 | 9.54 | 39.29 | 54.00 | -14.71 |
| 1.949 | 180 | V | 1.00 | 18.39 | 27.55 | 0.00 | 9.54 | 36.40 | 54.00 | -17.60 |
| 1.974 | 180 | V | 1.00 | 17.66 | 27.78 | 0.00 | 9.54 | 35.90 | 54.00 | -18.10 |
| 1.981 | 180 | H | 1.00 | 19.44 | 27.81 | 0.00 | 9.54 | 37.71 | 54.00 | -16.29 |
| 2.166 | 180 | H | 1.00 | 16.45 | 28.23 | 0.00 | 9.54 | 35.14 | 54.00 | -18.86 |
| 2.341 | 180 | H | 1.00 | 19.22 | 28.62 | 0.00 | 9.54 | 38.30 | 54.00 | -15.70 |
| 2.356 | 180 | V | 1.00 | 19.42 | 28.61 | 0.00 | 9.54 | 38.49 | 54.00 | -15.51 |
| 2.395 | 180 | V | 1.00 | 15.28 | 28.75 | 0.00 | 9.54 | 34.49 | 54.00 | -19.51 |
| 4.938 | 180 | H | 1.00 | 20.72 | 34.03 | 0.00 | 9.54 | 45.21 | 54.00 | -8.79 |
| 4.947 | 180 | V | 1.00 | 21.66 | 34.05 | 0.00 | 9.54 | 46.17 | 54.00 | -7.83 |

**Table 7. Spurious Radiated Emissions 15.209 – Average**

Note 1 : The EUT was tested at 1 m. The data has been corrected for comparison with the 3 m limit using the formula: 20log (1 m/3 m) as expressed in the 'Distance Correction' column.

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**Photograph 2. Spurious Radiated Emissions 15.209, Test Setup**

## 3.3 Unintentional Radiated Emissions

**Test Requirement(s):** **15.109 (a)** Except for Class A digital devices, the field strength of radiated emissions from unintentional radiators at a distance of 3 meters shall not exceed the Class B limits expressed in Table 8.

**15.109 (b)** The field strength of radiated emissions from a Class A digital device, as determined at a distance of 10 meters, shall not exceed the Class A limits expressed in Table 8.

| Frequency (MHz) | Field Strength (dBµV/m) | |
|---|---|---|
| | §15.109 (b), Class A Limit (dBµV) @ 10m | §15.109 (a),Class B Limit (dBµV) @ 3m |
| 30 - 88 | 39.00 | 40.00 |
| 88 - 216 | 43.50 | 43.50 |
| 216 - 960 | 46.40 | 46.00 |
| Above 960 | 49.50 | 54.00 |

**Table 8. Radiated Emissions Limits calculated from FCC Part 15, §15.109 (a) (b)**

**Test Procedures:** The EUT was placed on a non-metallic table, 80 cm above the ground plane inside a semi-anechoic chamber. The method of testing and test conditions of ANSI C63.4 were used. An antenna was located 3 m from the EUT on an adjustable mast. A pre-scan was first performed in order to find prominent radiated emissions. For final emissions measurements at each frequency of interest, the EUT was rotated and the antenna height was varied between 1 m and 4 m in order to maximize the emission. Measurements in both horizontal and vertical polarities were made and the data was recorded. Unless otherwise specified, measurements were made using a quasi-peak detector with a 120 kHz bandwidth.

**Test Results:** The EUT was found **compliant** with the Class B requirements of this section.

**Test Engineer(s):** Dusmantha Tennakoon

**Test Date(s):** December 16, 2005

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| Frequency (MHz) | EUT Azimuth (Degrees) | Antenna Polarity (H/V) | Antenna HEIGHT (m) | Uncorrected Amplitude (dBuv) | Antenna Correction Factor (dB) (+) | Cable Loss (dB) (+) | Distance Correction Factor (dB) (-) | Corrected Amplitude (dBuv) | Limit (dBuv) | Margin (dB) |
|---|---|---|---|---|---|---|---|---|---|---|
| 102.662 | 107 | H | 1.00 | 25.73 | 7.53 | 1.00 | 0.00 | 34.26 | 43.50 | -9.24 |
| 102.662* | 47 | V | 1.00 | 32.05 | 7.89 | 1.00 | 0.00 | 40.94 | 43.50 | -2.56 |
| 103.701 | 114 | H | 1.85 | 21.74 | 7.38 | 1.00 | 0.00 | 30.12 | 43.50 | -13.38 |
| 103.701 | 0 | V | 1.00 | 25.19 | 7.85 | 1.00 | 0.00 | 34.04 | 43.50 | -9.46 |
| 104.643 | 121 | H | 1.94 | 18.98 | 7.25 | 1.00 | 0.00 | 27.23 | 43.50 | -16.27 |
| 104.643 | 0 | V | 1.00 | 22.39 | 7.81 | 1.00 | 0.00 | 31.20 | 43.50 | -12.30 |
| 108.702 | 117 | H | 2.08 | 24.09 | 6.83 | 1.00 | 0.00 | 31.92 | 43.50 | -11.58 |
| 108.702 | 0 | V | 1.00 | 29.26 | 7.43 | 1.00 | 0.00 | 37.69 | 43.50 | -5.81 |
| 114.739 | 115 | H | 2.52 | 19.04 | 6.70 | 1.00 | 0.00 | 26.74 | 43.50 | -16.76 |
| 114.739 | 0 | V | 1.00 | 24.80 | 7.11 | 1.00 | 0.00 | 32.91 | 43.50 | -10.59 |
| 847.040 | 0 | H | 1.00 | 5.80 | 21.96 | 2.48 | 0.00 | 30.24 | 46.00 | -15.76 |
| 847.040 | 0 | V | 1.00 | 5.80 | 21.60 | 2.48 | 0.00 | 29.88 | 46.00 | -16.12 |

**Table 9. Radiated Emissions 15.109, Test Results**

Note 1: * - At this frequency, the measured electric-field strength exhibits a margin of compliance that is less than 3 dB below the specification limit. We recommend that every emission measured, have at least a 3 dB margin to allow for deviations in the emission characteristics that may occur during the production process.

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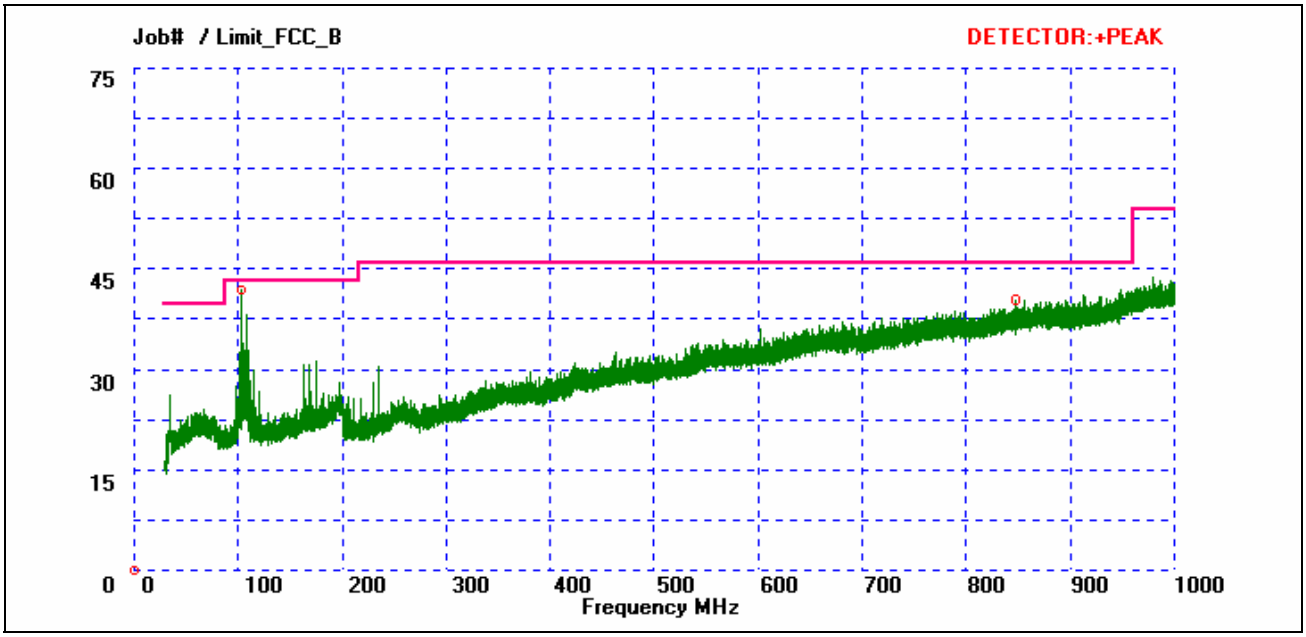
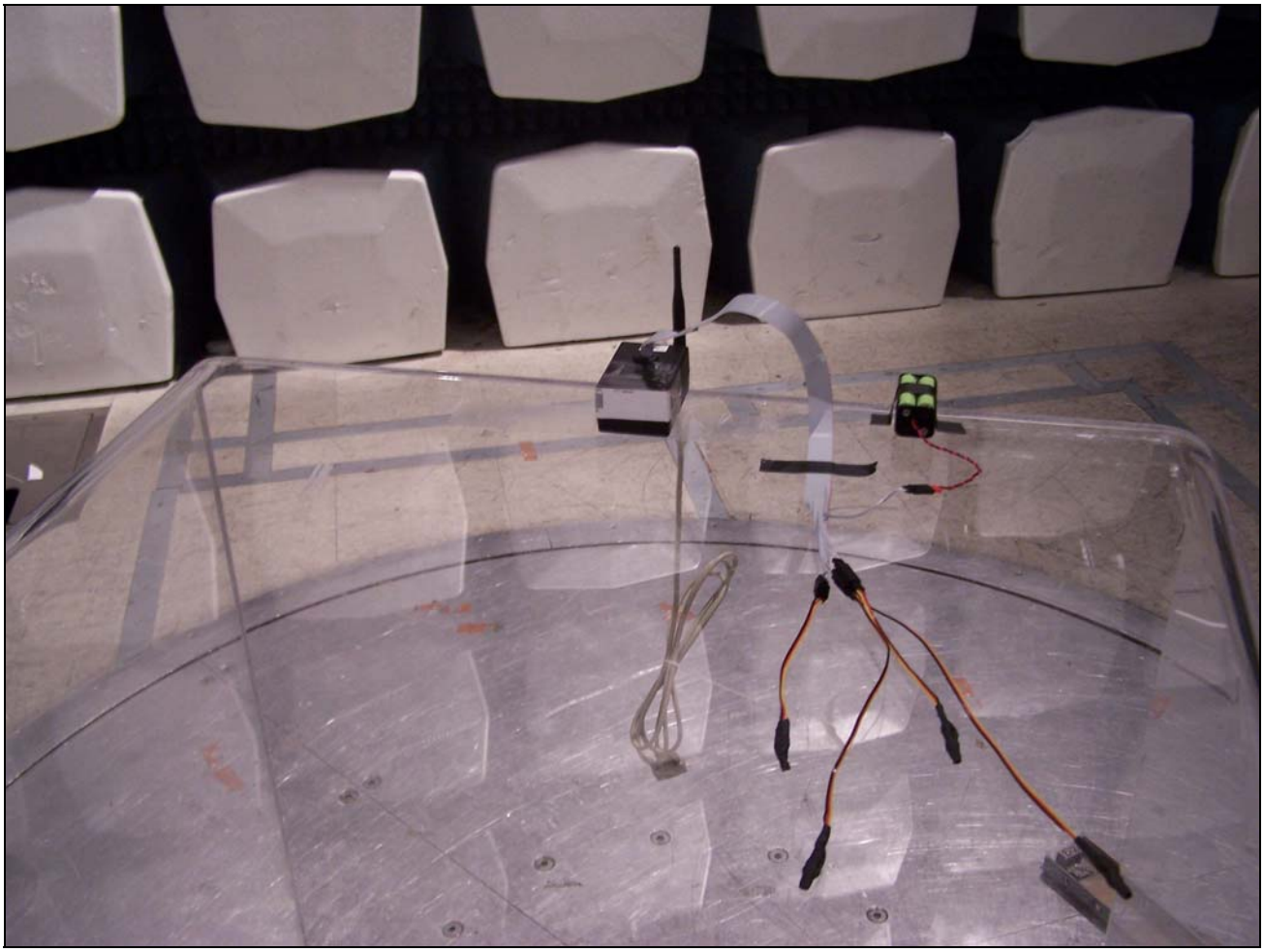



**Plot 1. Radiated Emissions 15.109, PreScan**



**Photograph 3. Radiated Emissions 15.109, Test Setup**

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## 3.4 Bandwidth and Separation Requirements

**Test Requirements:** **§ 15.247(a):** Operation under the provisions of this section is limited to frequency hopping and digitally modulated intentional radiators that comply with the following provisions:

**§ 15.247(a) (1):** Frequency hopping systems shall have hopping channel carrier frequencies separated by a minimum of 25 kHz or the 20 dB bandwidth of the hopping channel, whichever is greater. Alternatively, frequency hopping systems operating in the 2400 – 2483.5 MHz band may have hopping channel carrier frequencies that are separated by 25 kHz or two-thirds of the 20 dB bandwidth of the hopping channel, whichever is greater, provided the systems operate with an output power no greater than 125 mW. The system shall hop to channel frequencies that are selected at the system hopping rate from a pseudorandomly ordered list of hopping frequencies. Each frequency must be used equally on the average by each transmitter. The system shall have input bandwidths that match the hopping channel bandwidths of their corresponding transmitters and shall shift frequencies in synchronization with the transmitted signals.

**Test Procedure:** The EUT's transmitter output was connected directly to the spectrum analyzer. The bandwidth of the low, mid, and high channels was measured. Adjacent channel separation was measured as well.

1) 20 dB bandwidth: The low, mid, and high channels measured. (See Plot 2, Plot 3, and Plot 4)

| Channel Number | 20 db Bandwidth |
|---|---|
| Channel 1 | 1.350 MHz |
| Channel 17 | 1.355 MHz |
| Channel 33 | 1.290 MHz |

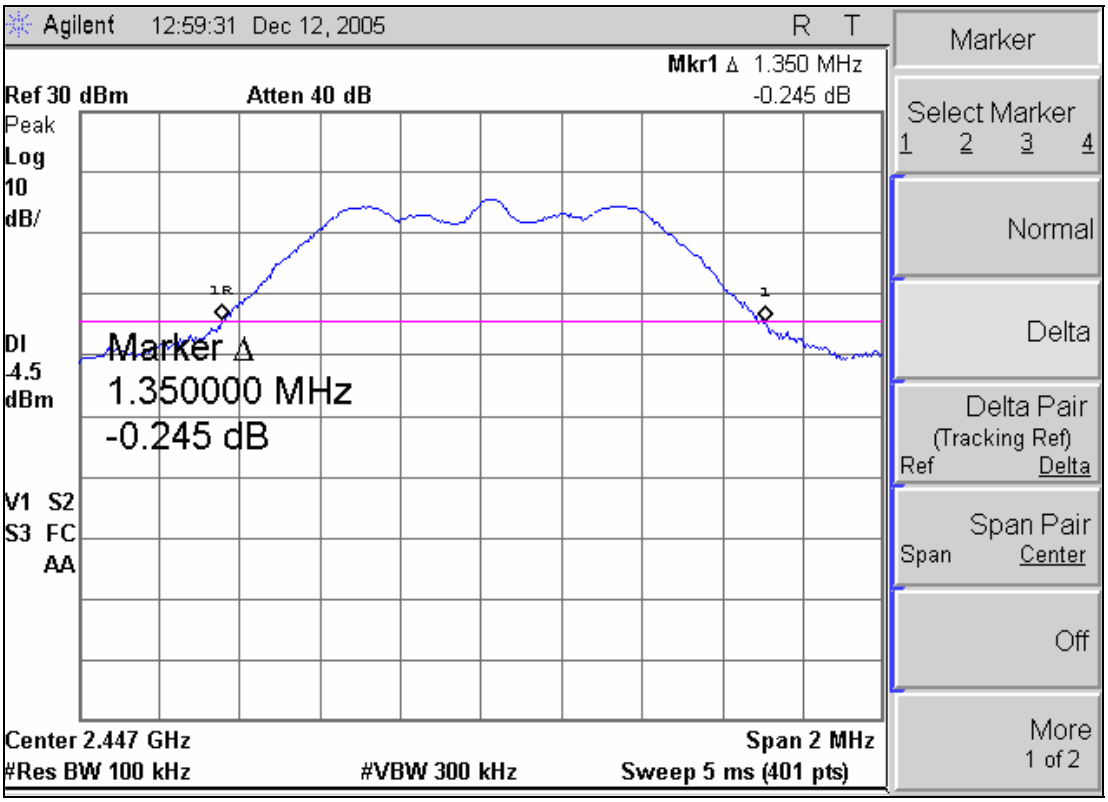
2) Channel Separation: The maximum power is less than 125 mW. Therefore, the channel separation may be 25 kHz, or 2/3 that of the 20 dB bandwidth of a channel, whichever is greater. (See Plot 5, Plot 6, and Plot 7

| Channel Number(s) | Channel Separation |
|---|---|
| Channels 1 and 2 | 0.998 MHz |
| Channels 17 and 18 | 0.998 MHz |
| Channels 32 and 33 | 0.998 MHz |

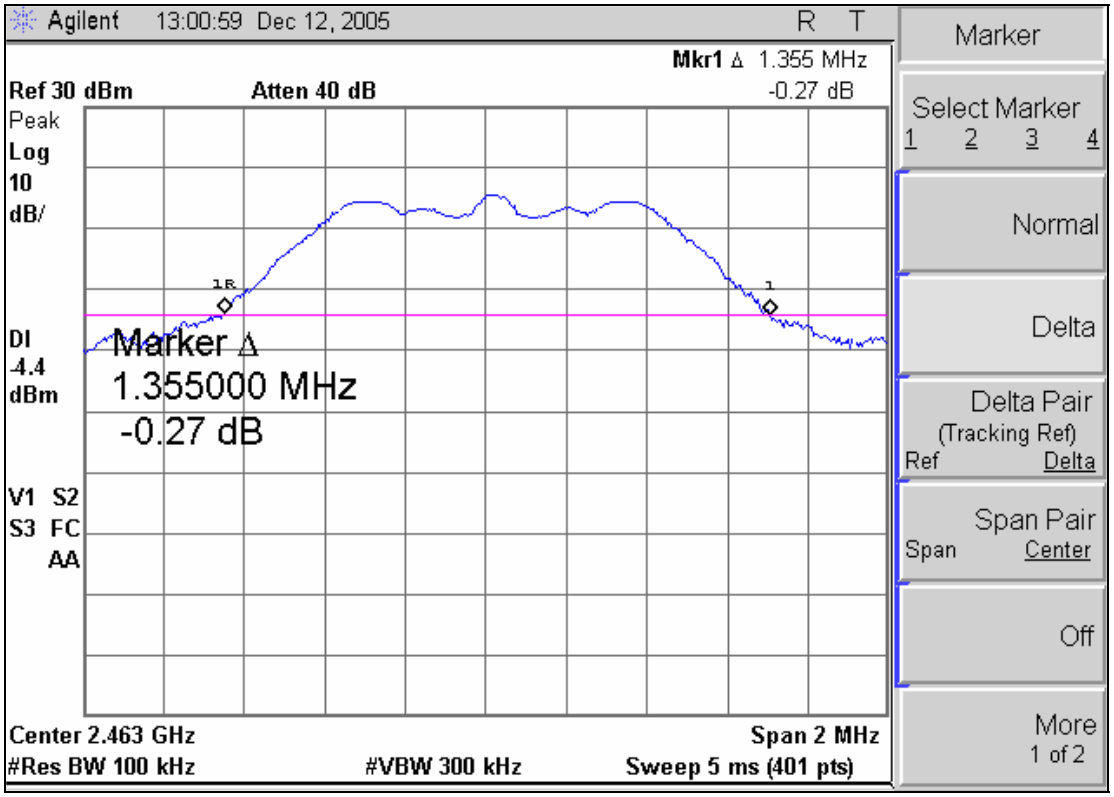
**Test Results** The EUT was found **compliant** with the requirements of this section.

**Test Engineer:** Dusmantha Tennakoon

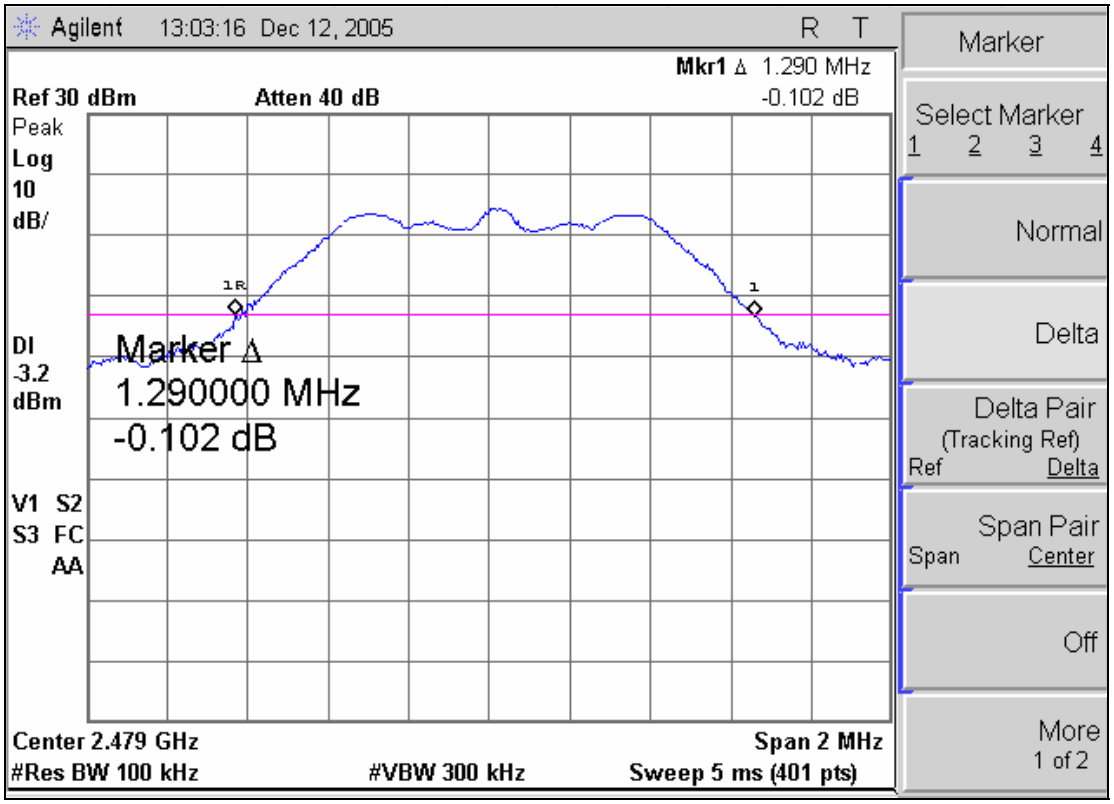
**Test Date:** December 12, 2005



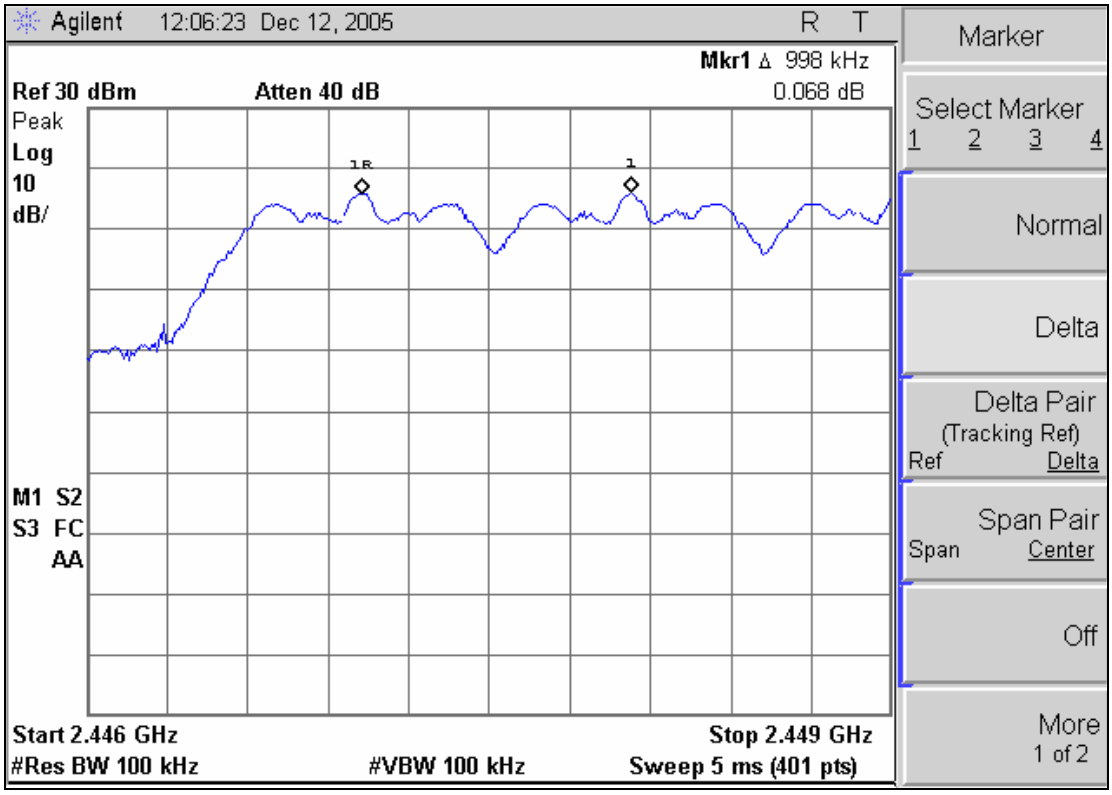

**Plot 2. Occupied Bandwidth – Channel 1**



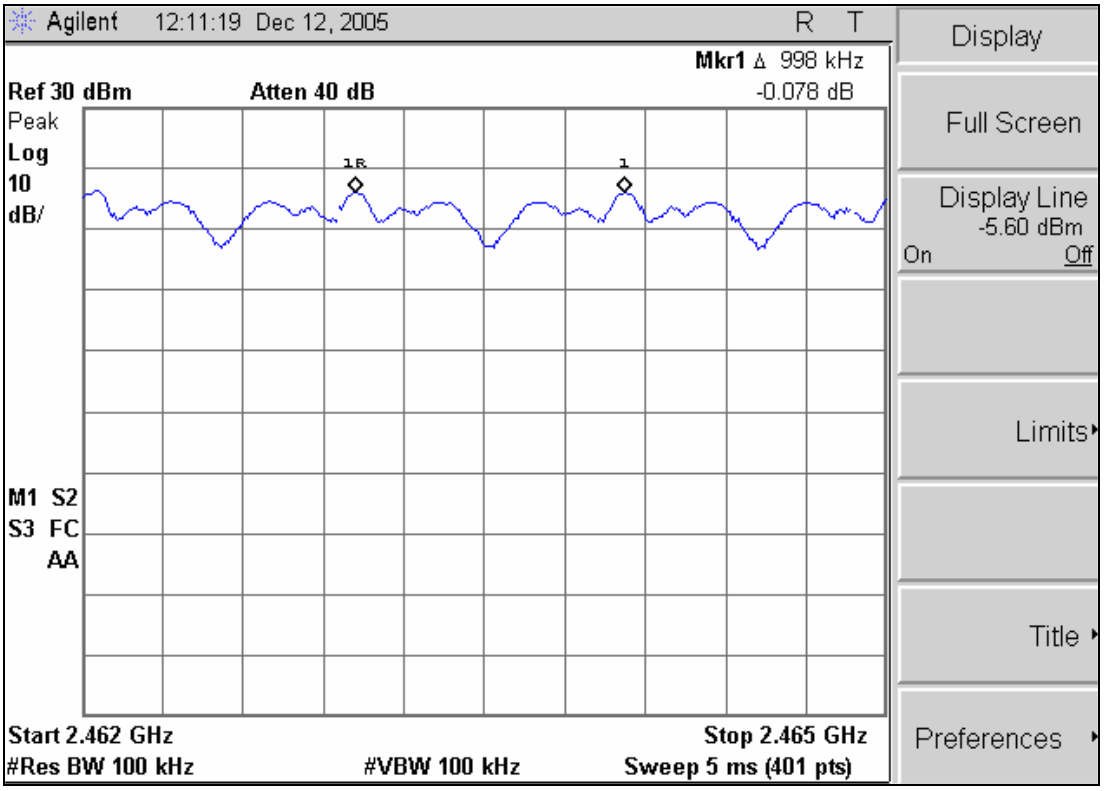

**Plot 3. Occupied Bandwidth – Channel 17**



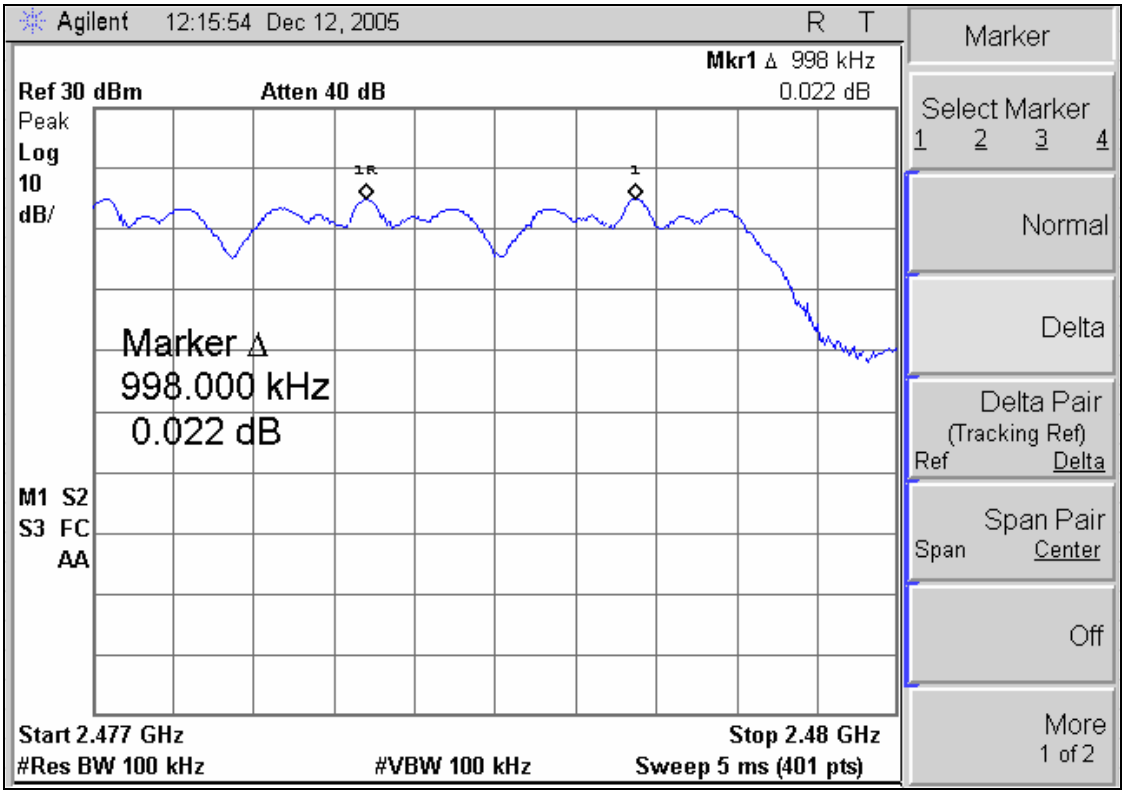

**Plot 4. Occupied Bandwidth – Channel 33**




**Plot 5. Channel Separation – Channels 1 and 2**




**Plot 6. Channel Separation – Channels 17 and 18**




**Plot 7. Channel Separation – Channels 32 and 33**

**Photograph 4. Bandwidth and Channel Separation Test Setup**

## 3.5 Number of Channels and Time of Occupancy

**Test Requirements:** **§ 15.247(a) (1) (iii):** Frequency hopping systems in the 2400 – 2483.5 MHz band shall use at least 15 channels. The average time of occupancy on any channel shall not be greater than 0.4 seconds within a period of 0.4 seconds multiplied by the number of hopping channels employed. Frequency hopping systems may avoid or suppress transmissions on a particular frequency provided that a minimum of 15 channels are used.

**Test Procedures:** The EUT's transmitter output was connected directly to the spectrum analyzer. Plots were taken in order to measure the number of channels and Dwell Time.

**Test Results:** The EUT complies with the requirements of this section.

1) Number of Channels (See Plot 8)

   This device has 33 channels.

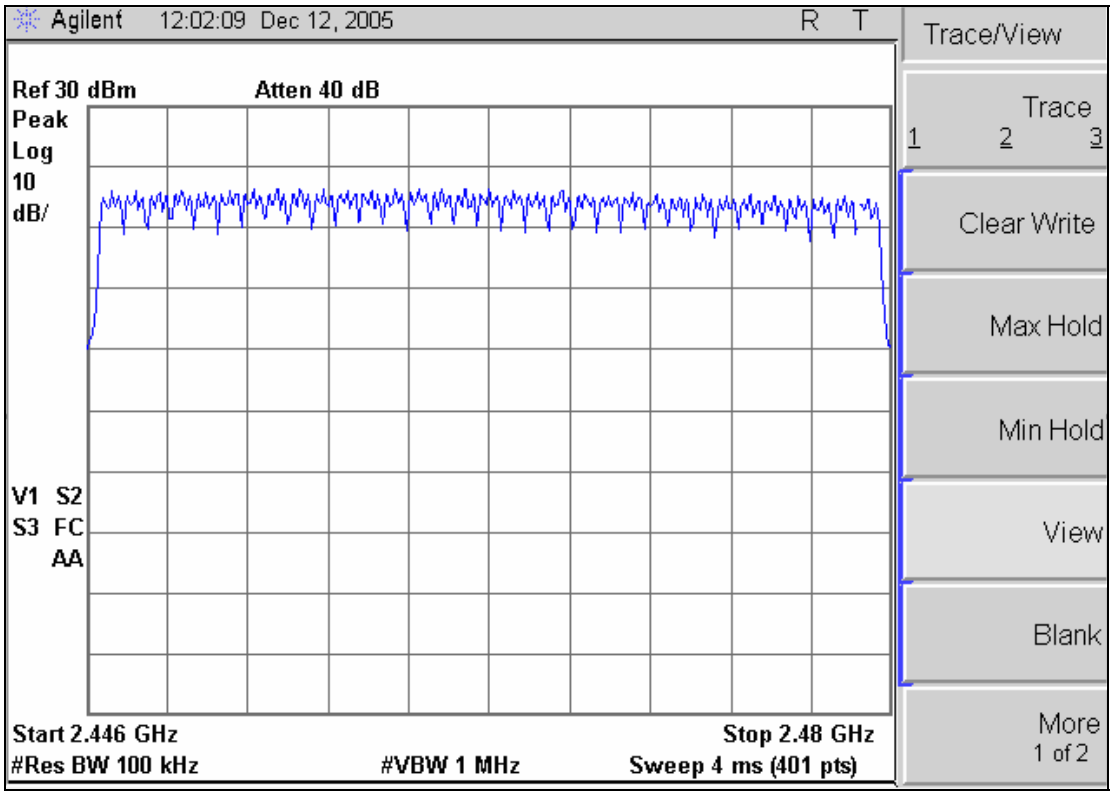
2) Dwell Time

   The Dwell Time for a single channel is 8.25 ms (See Plot 9). The device has 33 channels. Each channel was repeated on average forty times in a 13.2 second (33 x 0.4) period. Therefore, the average Dwell Time in a 13.2 second period equals 330 ms (40 x 8.25 ms).

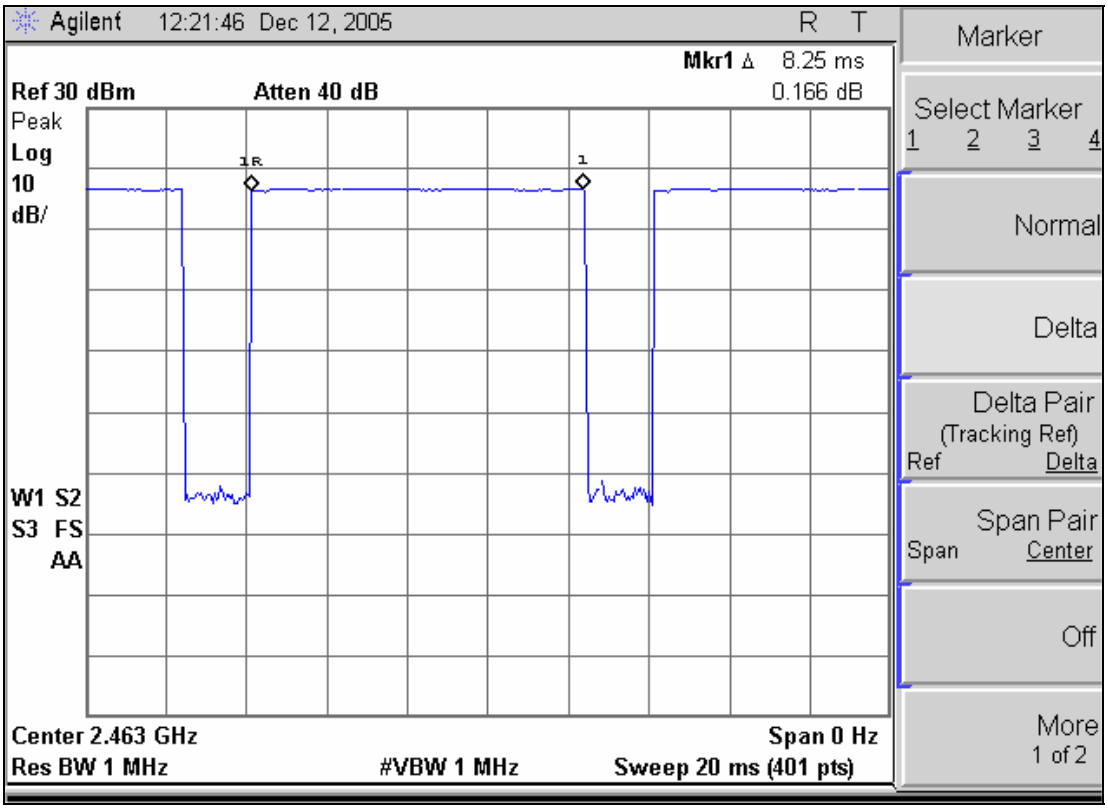
**Test Results:** The EUT was found **compliant** with the requirements of this section.

**Test Engineer(s):** Dusamantha Tennakoon

**Test Dates(s):** December 12, 2005




**Plot 8. Number of Channels**




**Plot 9. Dwell Time – 1**

## 3.6 Peak Power Output

**Test Requirements:** **§15.247(b):** The maximum peak output power of the intentional radiator shall not exceed the following:

**§15.247(b) (1):** For frequency hopping systems operating in the 2400 – 2483.5 MHz band employing at least 75 non-overlapping hopping channels, and all frequency hopping systems in the 5725 – 5850 MHz band: 1 Watt. For all other frequency hopping systems in the 2400 – 2483.5 MHz band: 0.125 Watts.

**Test Procedure:** The transmitter output of the EUT was connected to the spectrum analyzer through an attenuator. The power was set to the maximum output; low, mid and high channels were measured.

**Test Results:** The EUT was found **compliant** with the requirements of this section.

Peak Output Power = 16.80 dBm (0.04798 Watts)

The peak output power was determined from the plots on the following page(s).

| Channel | Peak Output Power (dBm) |
|---|---|
| Low | 16.43 dBm |
| Mid | 16.80 dBm |
| High | 15.76 dBm |

The cable used for Power Output measurements was a two-foot long ultra-flex coaxial cable.

**Test Engineer:** Dusmmantha Tennakoon

**Test Date:** December 12, 2005

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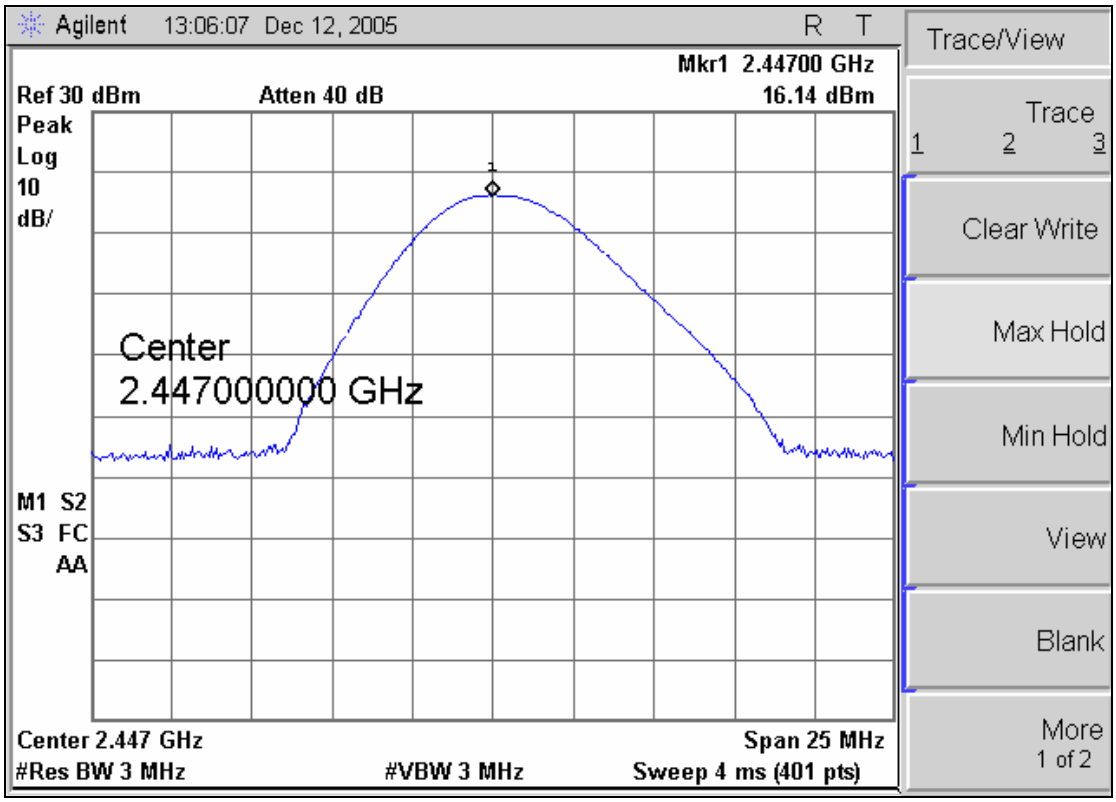
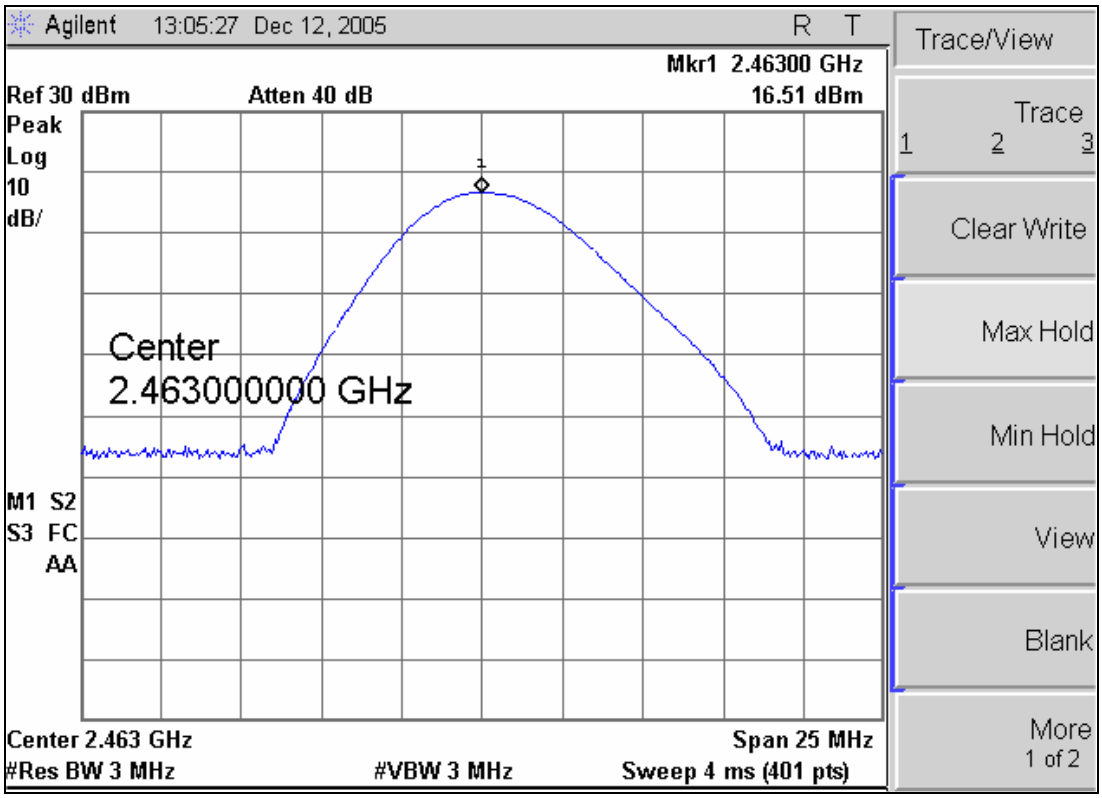


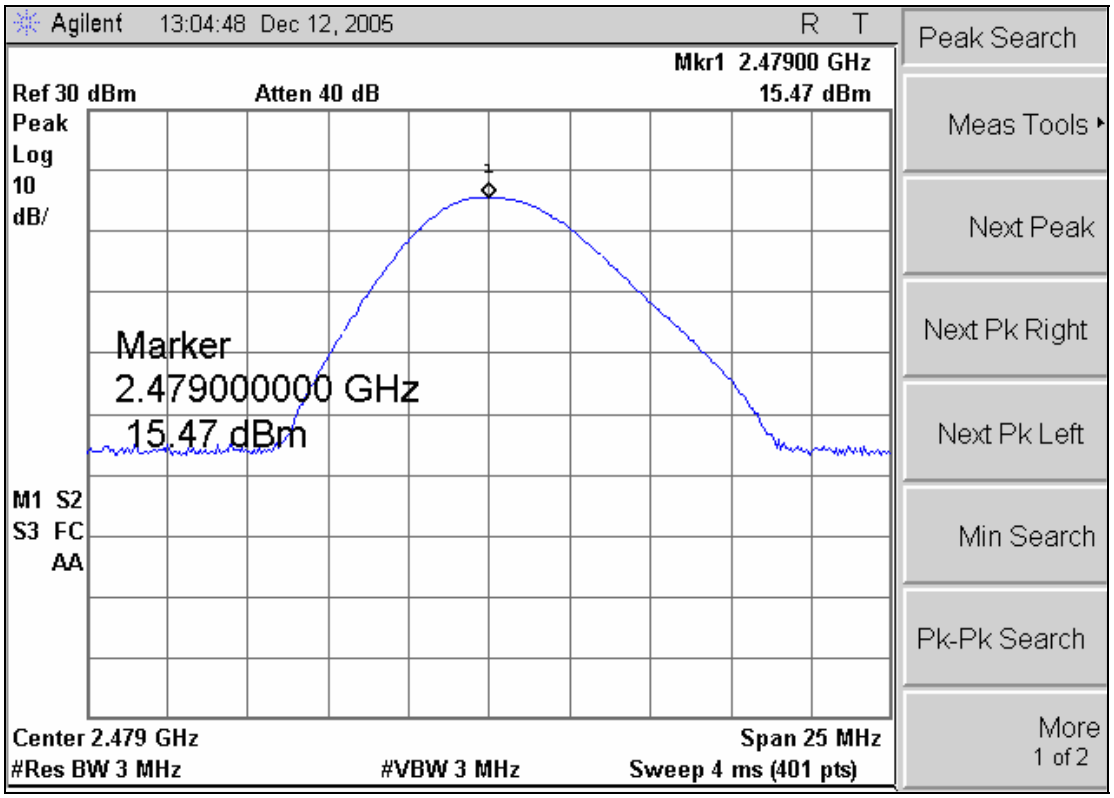

**Plot 10. Peak Output Power – Channel 1**

**Peak Output Power = Measured + Cable Loss**
**= 16.14 dBm + 0.29 dB**
**= 16.43 dBm**




**Plot 11. Peak Output Power – Channel 17**

**Peak Output Power = Measured + Cable Loss**
**= 16.51 dBm + 0.29 dB**
**= 16.80 dBm**




**Plot 12. Peak Output Power – Channel 33**

**Peak Output Power = Measured + Cable Loss**
**= 15.47 dBm + 0.29 dB**
**= 15.76 dBm**

## 3.7 RF Exposure

**RF Exposure Requirements -** **§15.247(i):** Systems operating under the provisions of this section shall be operated in a manner that ensures that the public is not exposed to radio frequency energy levels in excess of the Commission's guidelines.

**RF Radiation Exposure Limits**: §1.1310: As specified in this section, the Maximum Permissible Exposure (MPE) Limit shall be used to evaluate the environmental impact of human exposure to radiofrequency (RF) radiation as specified in Sec. 1.1307 (b), except in the case of portable devices which shall be evaluated according to the provisions of Sec. 2.1903 of this chapter.

| Frequency Range (MHz) | Electric Field Strength (V/m) | Magnetic Field Strength (A/m) | Power Density (mW/cm²) | Average Time (minutes) |
|---|---|---|---|---|
| (A) Limits for Occupational / Control Exposures | | | | |
| 30 - 300 | 61.4 | 0.163 | 1.0 | 6 |
| 300 – 1500 | -- | -- | F/300 | 6 |
| 1500 – 100,000 | -- | -- | 5 | 6 |
| (B) Limits for General Population / Uncontrolled Exposure | | | | |
| 30 - 300 | 27.5 | 0.073 | 0.2 | 30 |
| 300 – 1500 | -- | -- | F/1500 | 30 |
| 1500 – 100,000 | -- | -- | 1.0 | 30 |

**Table 10. Limits for Maximum Permissible Exposure (MPE)**

Note: F = Frequency in MHz

**Test Results:** MPE Limit Calculation: the EUT's operating frequencies @ 2402 – 2479 MHz; conducted power = 16.80 dBm (peak) with maximum antenna gain of 2.0 dBi. Therefore, Limit for Uncontrolled exposure: 1 mW/ cm ² or 10 W/m ²

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

$$S = PG / 4\pi R^2 \quad \text{or} \quad R = \sqrt{PG / 4\pi S}$$

Where,
S = Power Density (10 W/m²)
P = Power Input to antenna (0.04798 Watts)
G = Antenna Gain (1.6 numeric)
R = distance to the center of radiation of antenna (in meter)
$R = \sqrt{(0.047987 \times 1.6) / 4 \pi 10} = 0.0247$ m

The distance between the human and the RF antenna should not be less than 0.0247 m.

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## 3.8 Spurious Conducted Emissions

**Test Requirements:** **§15.247(c):** In any 100 kHz bandwidth outside the frequency band in which the spread spectrum or digitally modulated intentional radiator is operating, the radio frequency power that is produced by the intentional radiator shall be at least 20 dB below that in the 100 kHz bandwidth within the band that contains the highest level of the desired power, based on either an RF conducted or a radiated measurement. Attenuation below the general limits specified in § 15.209(a) is not required. In addition, radiated emissions which fall in the restricted bands, as defined in § 15.205(a), must also comply with the radiated emission limits specified in § 15.209(a).

**Test Procedure:** The EUT was configured with the control software to transmit at maximum power. The transmit output was connected to the analyzer through an attenuator. RBW = 100 kHz, VBW $\geq$ RBW.

**Test Results:** The EUT was found **compliant** with the requirements of this section. Plots were taken between 30 MHz and 25 GHz to ensure that no conducted Spurious Emission was greater than -20 dBc.

**Test Engineer:** Dusmantha Tenakoon

**Test Date:** December 12, 2005

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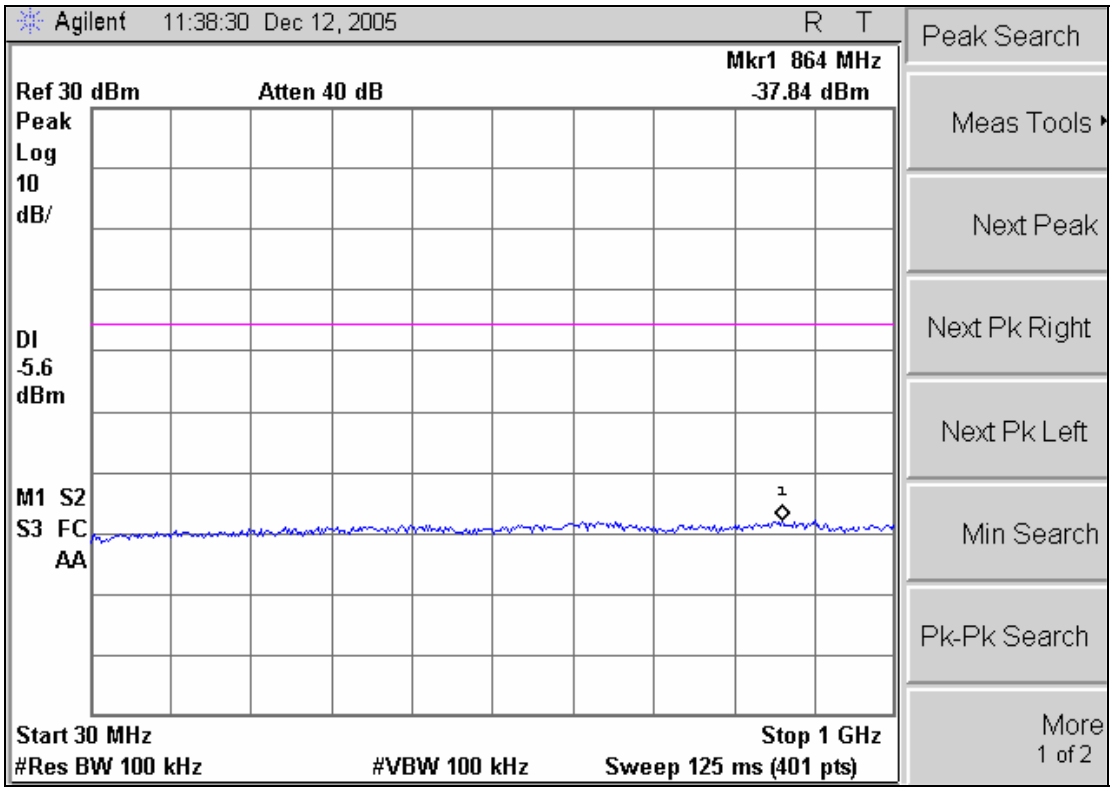
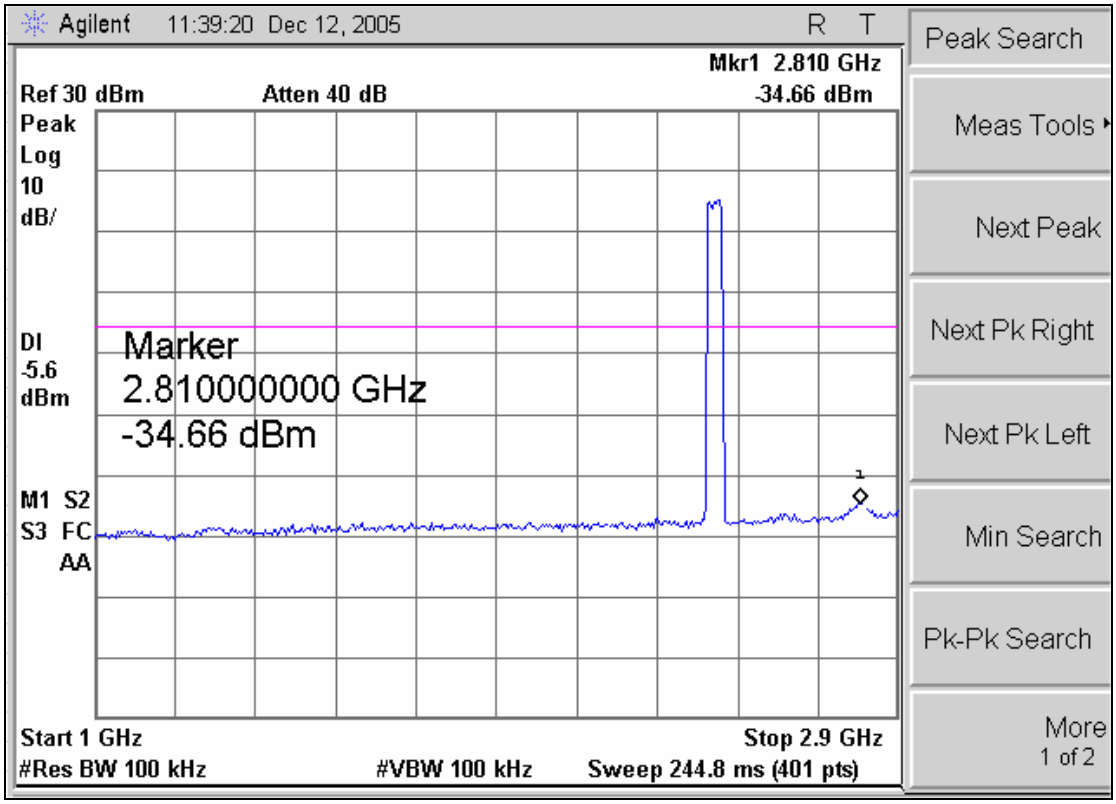
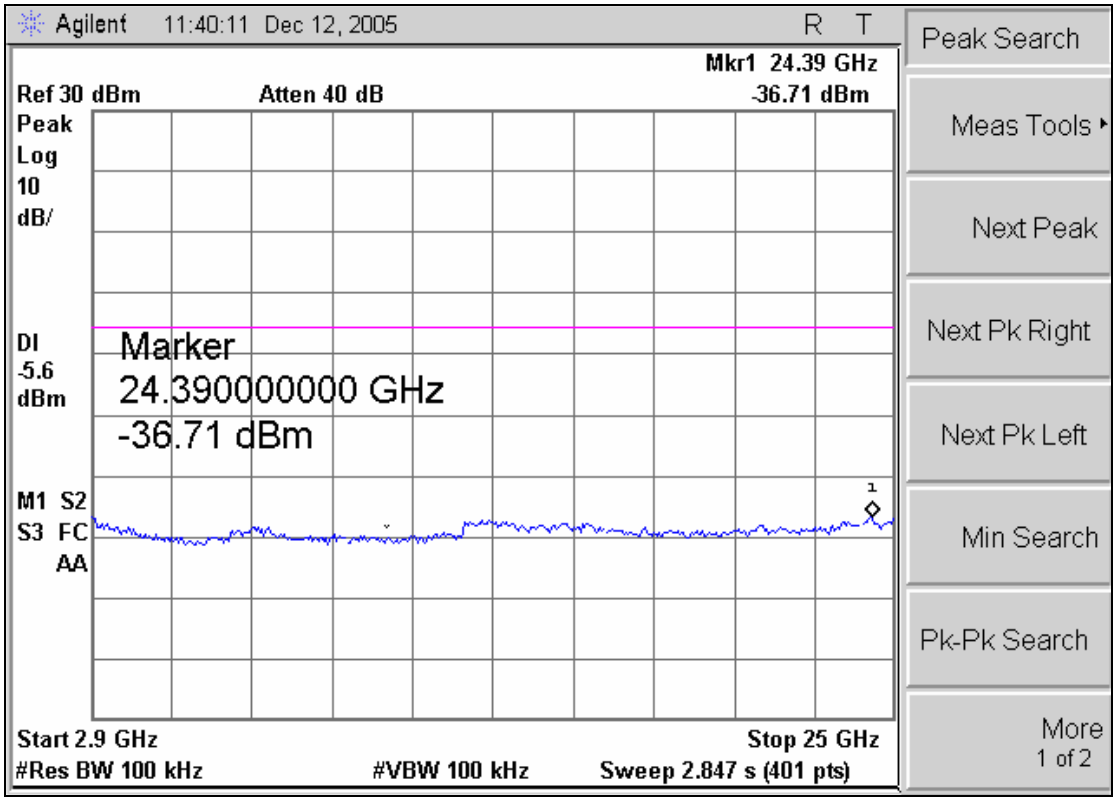



**Plot 13. Spurious Conducted Emissions – 1**




**Plot 14. Spurious Conducted Emissions – 2**




**Plot 15. Spurious Conducted Emissions – 3**

## 3.9 Band Edge Measurements

**Test Requirement(s):** **§ 15.205 (a):** Except as shown in paragraph (d) of **15.205 Restricted bands of operation**, only spurious emissions are permitted in any of the frequency bands specified in Table 4:

| MHz | MHz | MHz | GHz |
|---|---|---|---|
| 0.090–0.110 | 16.42–16.423 | 399.9–410 | 4.5–5.15 |
| 0.495–0.505 (Note 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 | (Note 2) |
| 13.36–13.41. | | | |
| Note 1: Until February 1, 1999, this restricted band shall be 0.490–0.510 MHz.<br>Note 2: Above 38.6 | | | |

**Table 11. Restricted Bands of Operation from FCC Part 15, § 15.205**

**Test Procedure:** The EUT was set up at maximum power on Channel 33. A plot of the channel was taken with a marker showing the nearest bordering Restricted Band. The lowest channel is at 2.447 GHz and is not near a restricted band.

**Test Results:** The EUT was found **compliant** with Band Edge Measurement requirements.

**Test Engineer:** Dusmantha Tennakoon

**Test Date:** December 13, 2005

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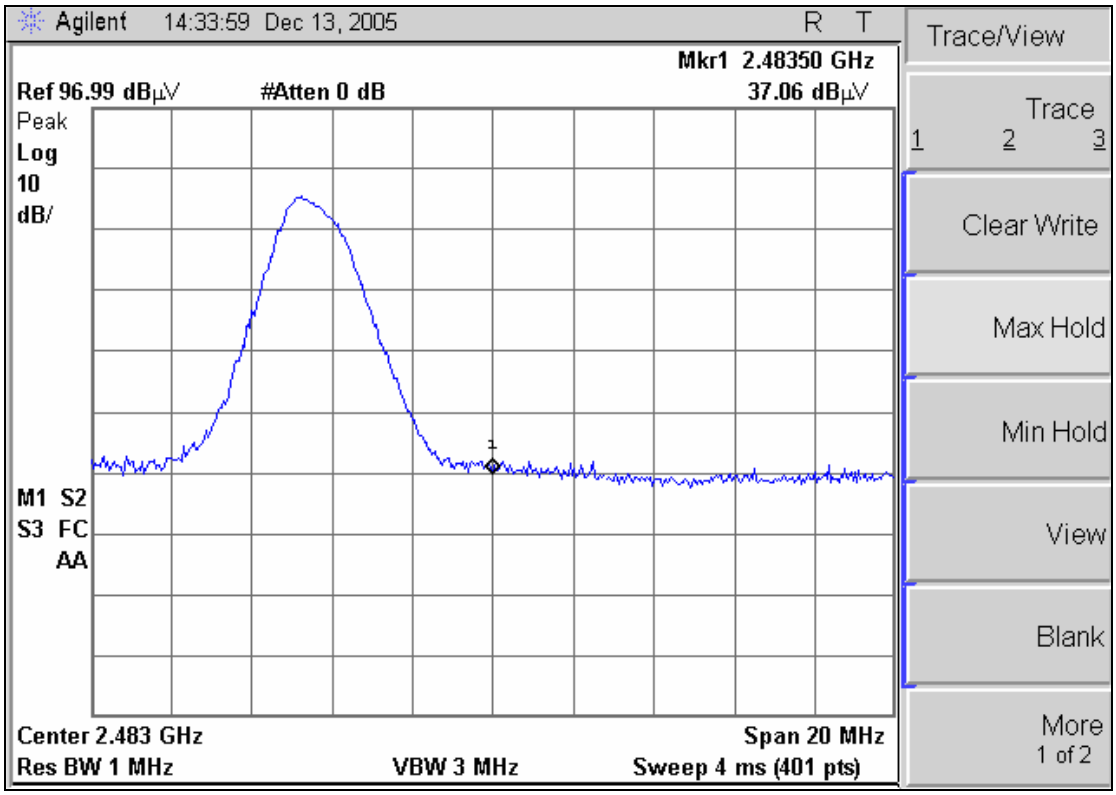
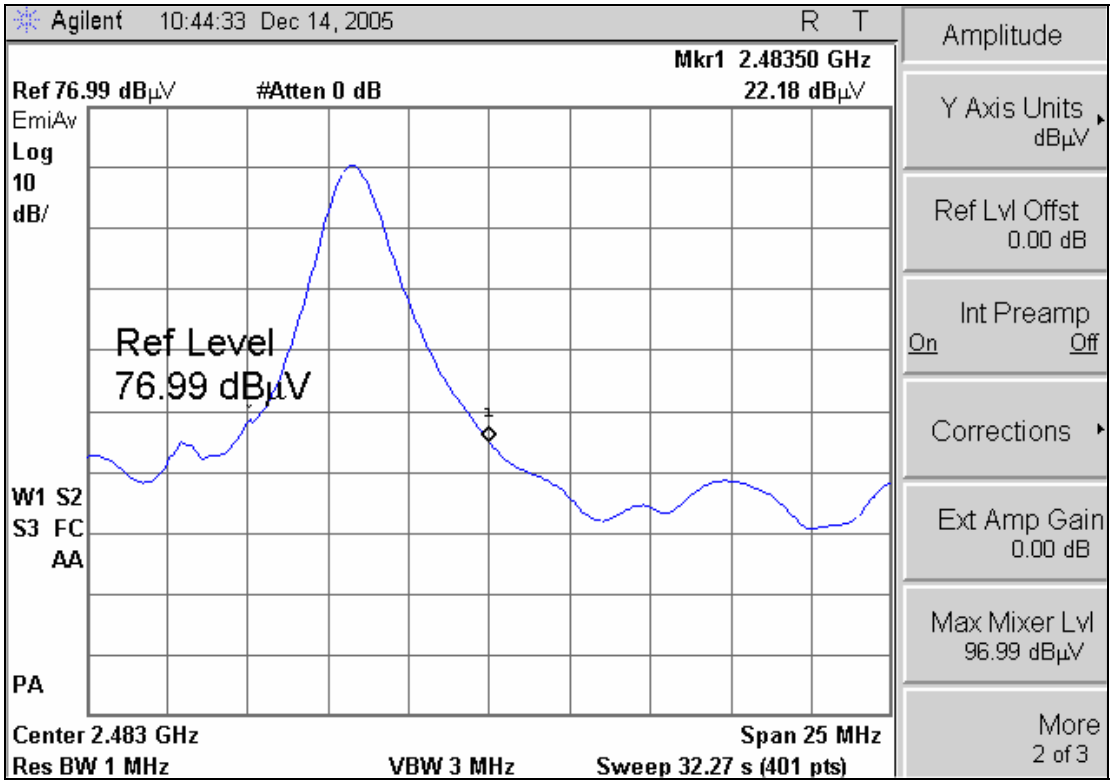



**Plot 16. Band Edge Emissions – Channel 33 (peak)**




**Plot 17. Band Edge Emissions – Channel 33 (average)**

Average Power Level @ 2.4835 GHz = Measured + Antenna Correction Factor + Cable Loss
= 22.18 + 28.98 + 2.60
+ 53.67 dBuv.

## 3.10 Hopping Capability Requirements

**Test Requirements:** **§15.247(g):** Frequency hopping spread spectrum systems are not required to employ all available hopping channels during each transmission. However, the system, consisting of both the transmitter and the receiver, must be designed to comply with all of the regulations in this section should the transmitter be presented with a continuous data (or information) stream. In addition, a system employing short transmission bursts must comply with the definition of a frequency hopping system and must distribute its transmissions over the minimum number of hopping channels specified in this section.

**Test Procedure:** As required by this section, a statement describing the hopping capability of this EUT is submitted as a separate exhibit. (See Annex 1 for complete listing of customer declaration)

**System Receiver Hopping Capability – Customer Declaration:**

**Test Results:** All messages fit within a single timeslot, and a new frequency is selected for each timeslot. The hopping algorithm is guaranteed to return each channel equally (see description above).

This ensures that all enabled channels are used equally over a period of 32 hops times the number of used channels (33 × 32 = 1056 hops for an established connection, 15 × 32 = 480 hops for link establishment).

**Test Engineer:** Dusmantha Tennakoon

**Test Date:** December 20, 2005

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## 3.11 Non-Coordinating Requirements

**Test Requirements:** **§15.247(h):** The incorporation of intelligence within a frequency hopping spread spectrum system that permits the system to recognize other users within the spectrum band so that it individually and independently chooses and adapts its hop sets to avoid hopping on occupied channels is permitted. The coordination of frequency hopping systems in any other manner for the express purpose of voiding the simultaneous occupancy of individual hopping frequencies by multiple transmitters is not permitted.

**Test Procedure:** As required by this section, a statement describing the non-coordinating capability of this EUT is submitted as a separate exhibit.

**Test Results:** **System Receiver Hopping Capability – Customer Declaration:**

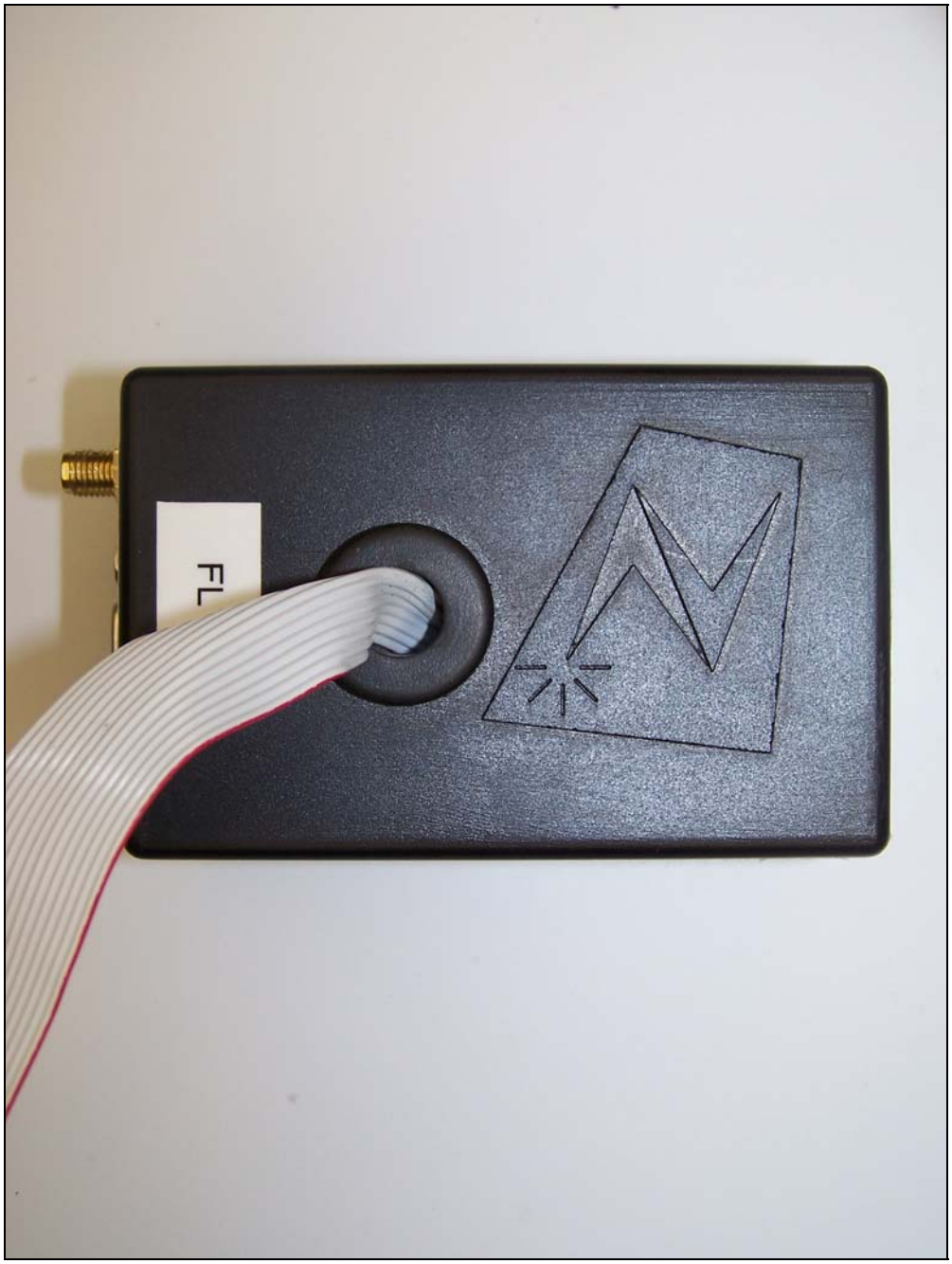
The link protocol only supports communication between a linked controller/remote transceiver pair. No mechanisms are provided for the inter-link communication necessary to synchronize hop sequences.

**Test Engineer:** Dusmantha Tennakoon

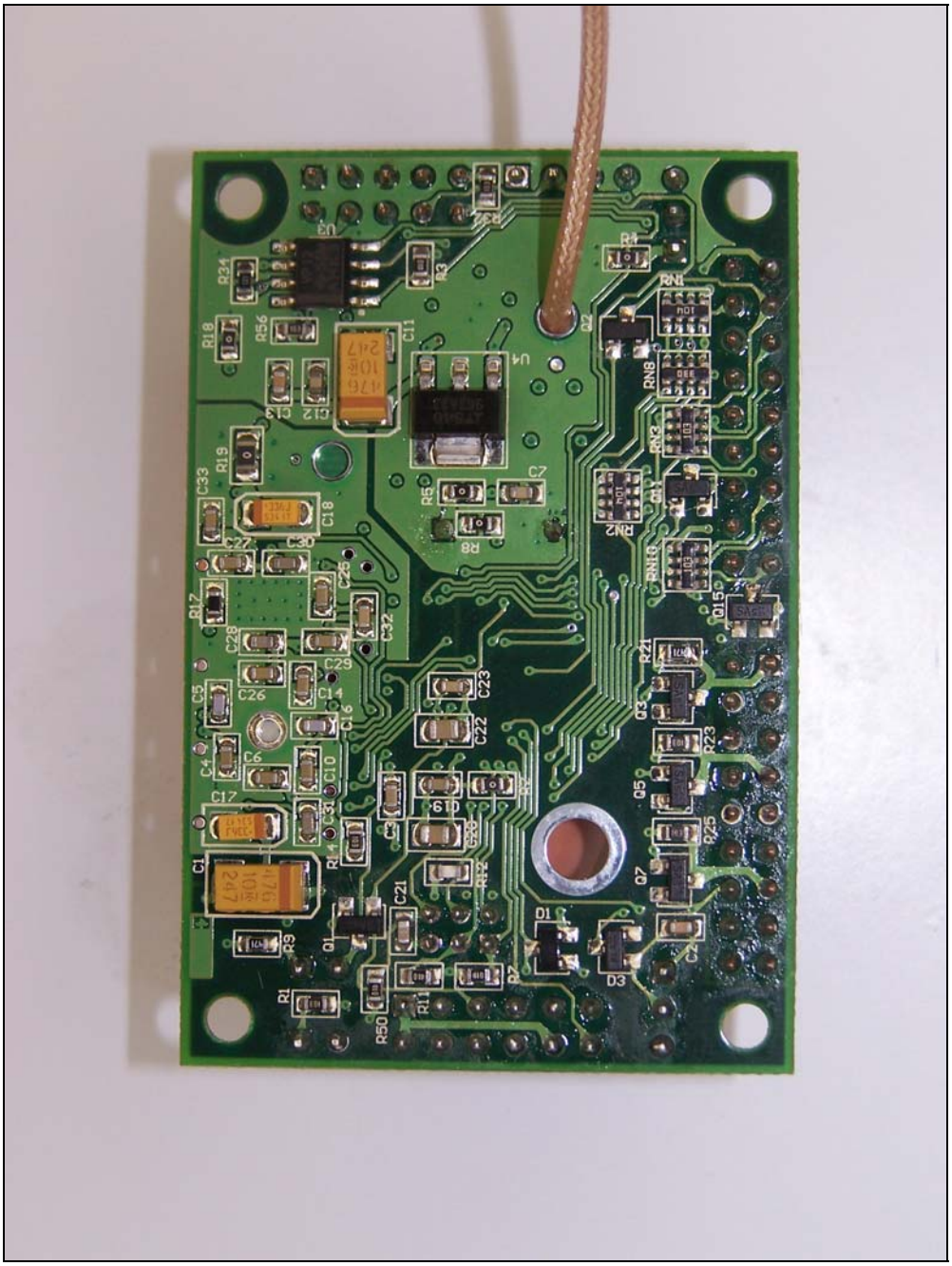
**Test Date:** December 20, 2005

# 4.0 Photographs

**Photograph 5. EUT Photograph – 1**




**Photograph 6, EUT Photograph – 2**



**Photograph 7, EUT Photograph – 3**

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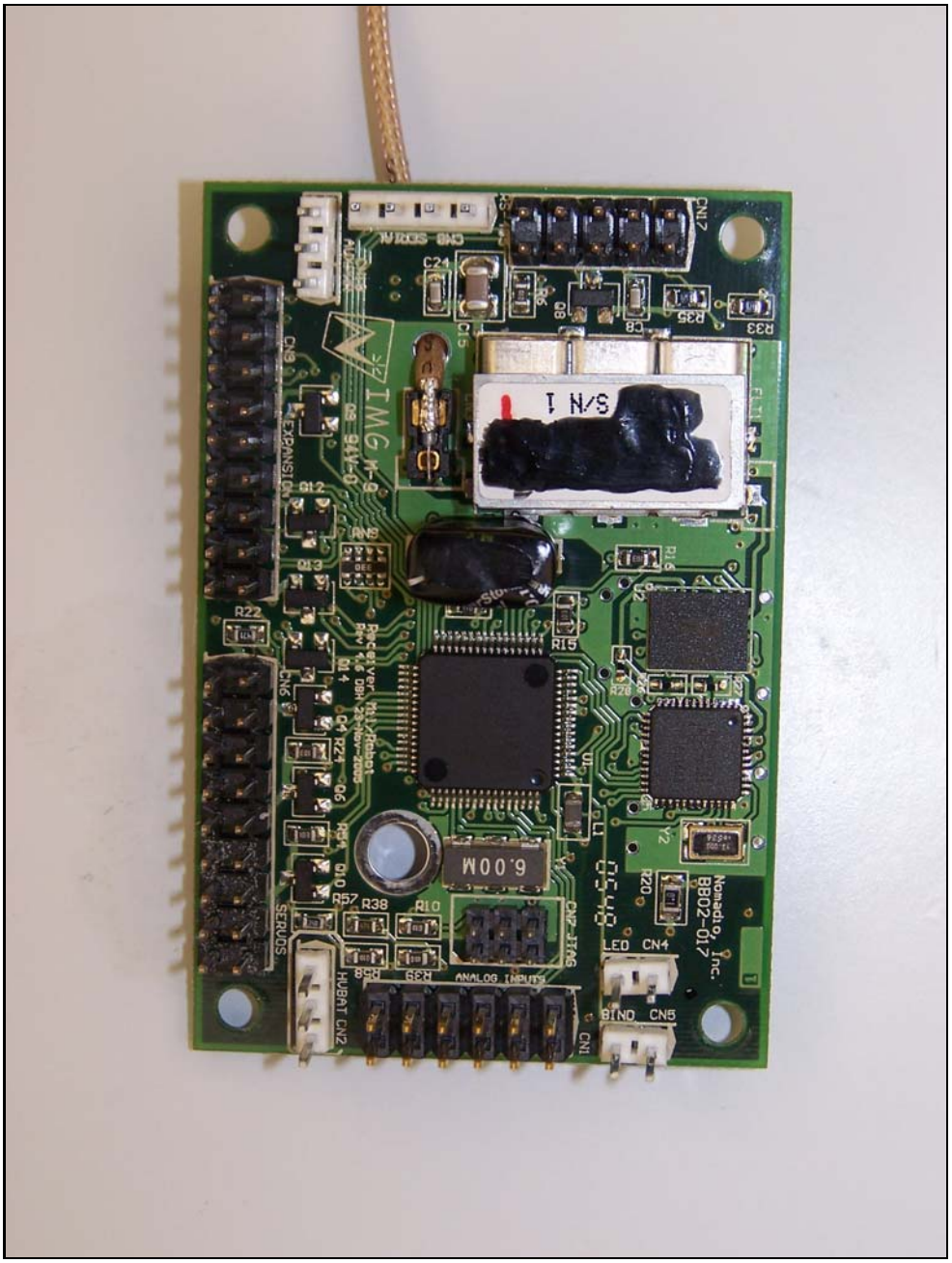


**Photograph 8. EUT Photograph – 4**

**Photograph 9. EUT Photograph – 5**

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**Photograph 10. EUT Photograph – 6**

**Photograph 11. EUT Photograph – 7**

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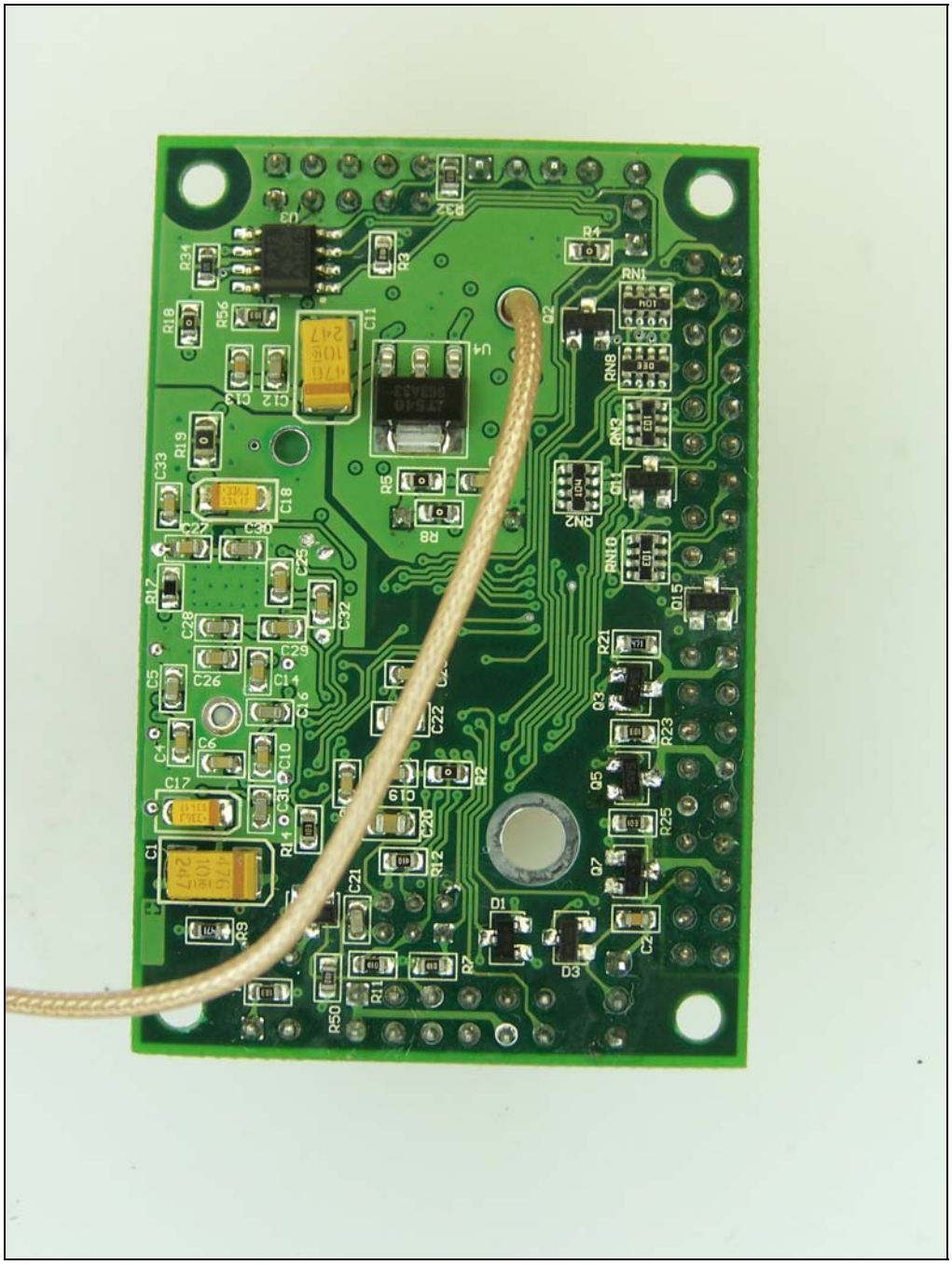

**Photograph 12. EUT Photograph – 8**

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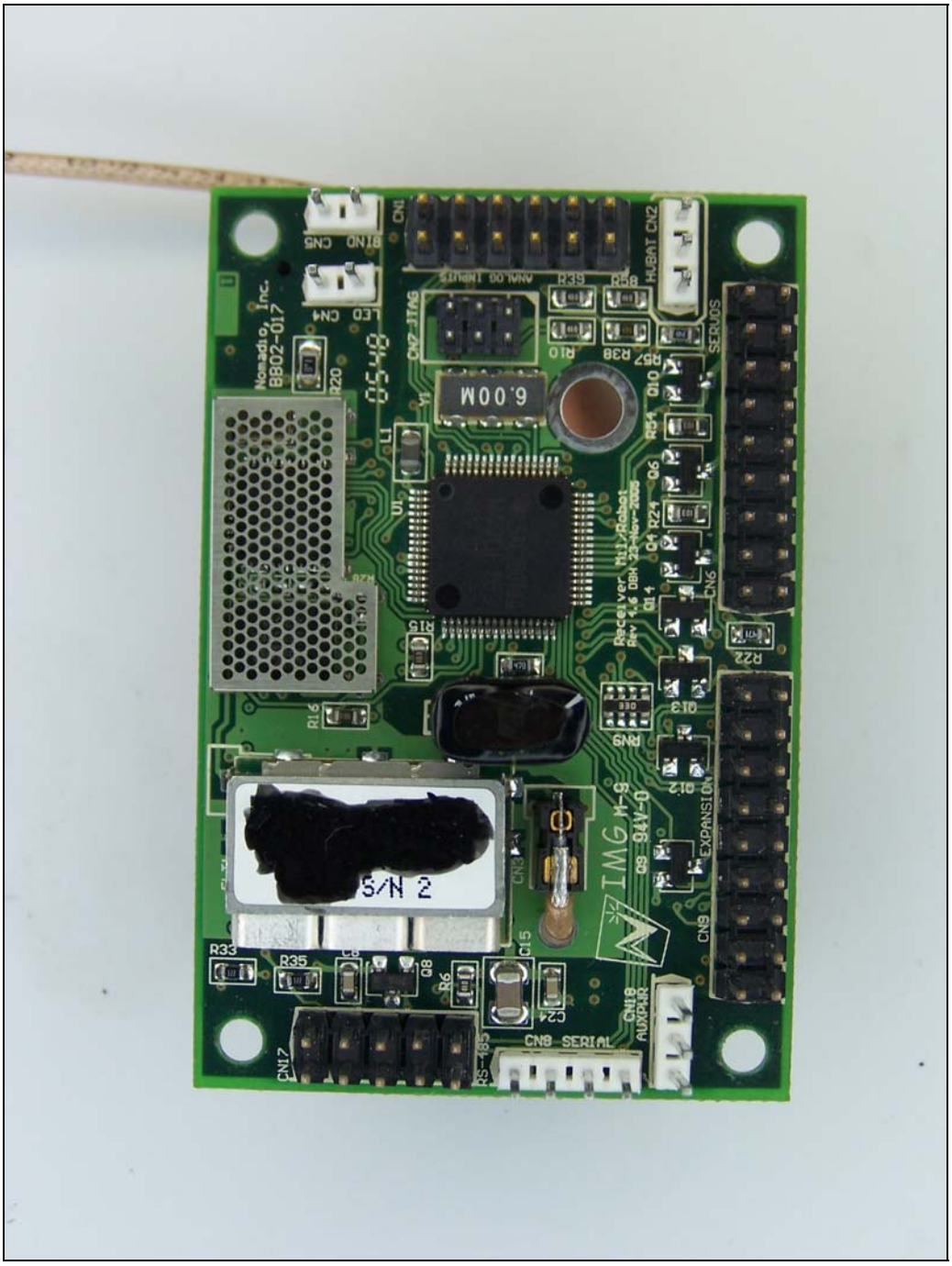
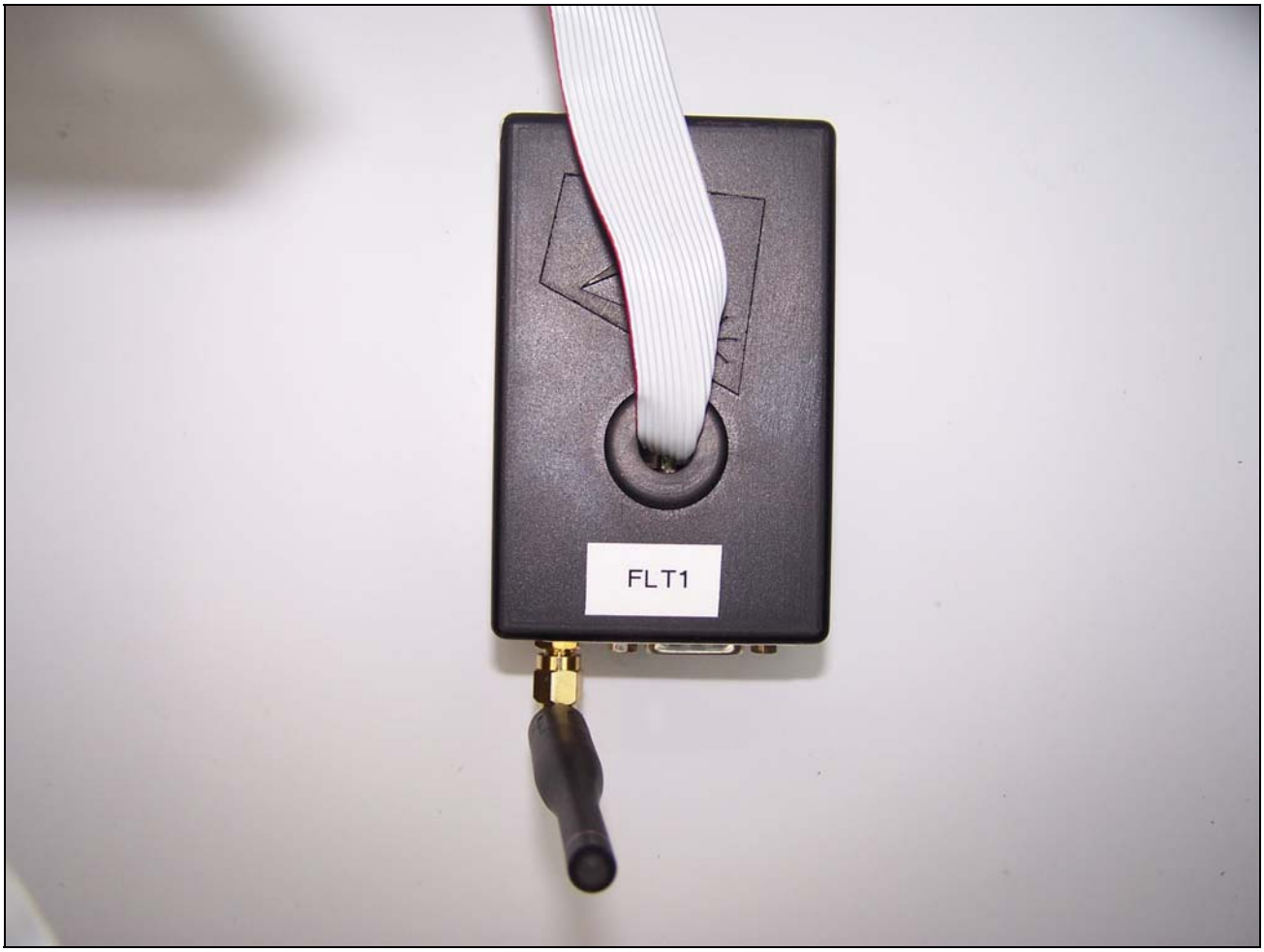



**Photograph 13. EUT Photograph – 9**




**Photograph 14. EUT Photograph – 10**

**Photograph 15. EUT Photograph - 11**

## 5.0 Test Equipment

Calibrated test equipment utilized during testing was maintained in a current state of calibration per the requirements of ANSI/NCSL Z540-1-1994 and ANSI/ISO/IEC 17025:2000.

| MET Asset # | Nomenclature | Manufacturer | Model | Last Cal Date | Cal Due Date |
|---|---|---|---|---|---|
| 1T4303 | Antenna BILOG | Schafner-Chase EMC | CBL6140A | 5/13/2005 | 5/13/2006 |
| 1T4300 | Semi-anechoic Chamber # 1 | EMC Test Systems | None Listed | 5/3/2003 | 4/3/2006 |
| 1T4409 | EMI Receiver | Rhode & Schwars | ESP17 | 4/14/2005 | 4/14/2006 |
| 1T4462 | Thermo-Hygrometer | Fisher Scientific | 11-661-7D | 11/8/2004 | 11/8/2006 |
| 1T4459 | Thermo-Hygrometer | Fisher Scientific | 11-661-710 | 11/8/2004 | 11/8/2006 |
| 1T4351 | Spectrum Analyzer | Agilent | F7405A | 10/4/2005 | 10/4/2006 |
| 1T2665 | Antenna; horn | EMCO | 3115 | 3/28/2005 | 3/28/2006 |
| 1T4288 | Spectrum Analyzer | HP | 8563A | 12/13/2004 | 12/13/2005 |
| 1T4351 | Spectrum Analyzer | Agilent | E7405A | 10/4/2005 | 10/4/2006 |
| 1T4354 | Signal Generator | HP | 83752A | 12/13/2004 | 12/13/2005 |
| 1T4351 | SPECTRUM ANALYZER | AGILENT | E7405A | 10/4/2005 | 10/4/2006 |
| 1T4503 | SHIELDED ROOM | UNIVERSAL SHIELDING CORP | N/A | 4/30/2005 | 4/30/2006 |

Note: Functionally verified test equipment is verified using calibrated instrumentation at the time of testing.

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# 6.0 Compliance Information

## 6.1 Certification Information

The following is extracted from Title 47 of the Code of Federal Regulations, Part 2, Subpart I — Marketing of Radio frequency devices:

**§ 2.801 Radio-frequency device defined.**

As used in this part, a radio-frequency device is any device which in its operation is capable of Emitting radio-frequency energy by radiation, conduction, or other means. Radio- frequency devices include, but are not limited to:

(a) The various types of radio communication transmitting devices described throughout this chapter.

*(b) The incidental, unintentional and intentional radiators defined in Part 15 of this chapter.*

(c) The industrial, scientific, and medical equipment described in Part 18 of this chapter.

(d) Any part or component thereof which in use emits radio-frequency energy by radiation, conduction, or other means.

**§ 2.803 Marketing of radio frequency devices prior to equipment authorization.**

(a) Except as provided elsewhere in this chapter, no person shall sell or lease, or offer for sale or lease (including advertising for sale or lease), or import, ship or distribute for the purpose of selling or leasing or offering for sale or lease, any radio frequency device unless:

(1) In the case of a device subject to certification, such device has been authorized by the Commission in accordance with the rules in this chapter and is properly identified and labeled as required by §2.925 and other relevant sections in this chapter; or

(2) In the case of a device that is not required to have a grant of equipment authorization issued by the Commission, but which must comply with the specified technical standards prior to use, such device also complies with all applicable administrative (including verification of the equipment or authorization under a Declaration of Conformity, where required), technical, labeling and identification requirements specified in this chapter.

(d) Notwithstanding the provisions of paragraph (a) of this section, the offer for sale solely to business, commercial, industrial, scientific or medical users (but not an offer for sale to other parties or to end users located in a residential environment) of a radio frequency device that is in the conceptual, developmental, design or pre-production stage is permitted prior to equipment authorization or, for devices not subject to the equipment authorization requirements, prior to a determination of compliance with the applicable technical requirements *provided* that the prospective buyer is advised in writing at the time of the offer for sale that the equipment is subject to the FCC rules and that the equipment will comply with the appropriate rules before delivery to the buyer or to centers of distribution.

(e)(1) Notwithstanding the provisions of paragraph (a) of this section, prior to equipment authorization or determination of compliance with the applicable technical requirements any radio frequency device may be operated, but not marketed, for the following purposes and under the following conditions:

*(i) Compliance testing;*

(ii) Demonstrations at a trade show provided the notice contained in paragraph (c) of this section is displayed in a conspicuous location on, or immediately adjacent to, the device;

(iii) Demonstrations at an exhibition conducted at a business, commercial, industrial, scientific or medical location, but excluding locations in a residential environment, provided the notice contained in paragraphs (c) or (d) of this section, as appropriate, is displayed in a conspicuous location on, or immediately adjacent to, the device;

(iv) Evaluation of product performance and determination of customer acceptability, provided such operation takes place at the manufacturer's facilities during developmental, design or pre-production states; or

(v) Evaluation of product performance and determination of customer acceptability where customer acceptability of a radio frequency device cannot be determined at the manufacturer's facilities because of size or unique capability of the device, provided the device is operated at a business, commercial, industrial, scientific or medical user's site, but not at a residential site, during the development, design or pre-production stages.

(e)(2) For the purpose of paragraphs (e)(1)(iv) and (e)(1)(v) of this section, the term *manufacturer's facilities* includes the facilities of the party responsible for compliance with the regulations and the manufacturer's premises, as well as the facilities of other entities working under the authorization of the responsible party in connection with the development and manufacture, but not the marketing, of the equipment.

(f) For radio frequency devices subject to verification and sold solely to business, commercial, industrial, scientific and medical users (excluding products sold to other parties or for operation in a residential environment), parties responsible for verification of the devices shall have the option of ensuring compliance with the applicable technical specifications of this chapter at each end user's location after installation, provided that the purchase or lease agreement includes a proviso that such a determination of compliance be made and is the responsibility of the party responsible for verification of the equipment.

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**The following is extracted from Title 47 of the Code of Federal Regulations, Part 2, Subpart J — Equipment Authorization Procedures:**

**§ 2.901 Basis and Purpose**

(a) In order to carry out its responsibilities under the Communications Act and the various treaties and international regulations, and in order to promote efficient use of the radio spectrum, the Commission has developed technical standards for radio frequency equipment and parts or components thereof. The technical standards applicable to individual types of equipment are found in that part of the rules governing the service wherein the equipment is to be operated.[1] *In addition to the technical standards provided, the rules governing the service may require that such equipment be verified by the manufacturer or importer*, be authorized under a Declaration of Conformity, or receive an equipment authorization from the Commission by one of the following procedures: certification or registration.

(b) The following sections describe the verification procedure, the procedure for a Declaration of Conformity, and the procedures to be followed in obtaining certification from the Commission and the conditions attendant to such a grant.

**§ 2.907 Certification.**

(a) Certification is an equipment authorization issued by the Commission, based on representation and test data submitted by the applicant.

(b) Certification attaches to all units subsequently marketed by the grantee which are identical (see Section 2.908) to the sample tested except for permissive changes or other variations authorized by the Commission pursuant to Section 2.1043.

[1] In this case, the equipment is subject to the rules of Part 15. More specifically, the equipment falls under Subpart B (of Part 15), which deals with unintentional radiators.

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**§ 2.948 Description of measurement facilities.**

(a) Each party making measurements of equipment that is subject to an equipment authorization under Part 15 or Part 18 of this chapter, regardless of whether the measurements are filed with the Commission or kept on file by the party responsible for compliance of equipment marketed within the U.S. or its possessions, shall compile a description of the measurement facilities employed.

(1) If the measured equipment is subject to the verification procedure, the description of the measurement facilities shall be retained by the party responsible for verification of the equipment.

*(i) If the equipment is verified through measurements performed by an independent laboratory, it is acceptable for the party responsible for verification of the equipment to rely upon the description of the measurement facilities retained by or placed on file with the Commission by that laboratory. In this situation, the party responsible for the verification of the equipment is not required to retain a duplicate copy of the description of the measurement facilities.*

(ii) If the equipment is verified based on measurements performed at the installation site of the equipment, no specific site calibration data is required. It is acceptable to retain the description of the measurement facilities at the site at which the measurements were performed.

(2) If the equipment is to be authorized by the Commission under the certification procedure, the description of the measurement facilities shall be filed with the Commission's Laboratory in Columbia, Maryland. The data describing the measurement facilities need only be filed once but must be updated as changes are made to the measurement facilities or as otherwise described in this section. At least every three years, the organization responsible for filing the data with the Commission shall certify that the data on file is current.

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## 6.2 Label and User's Manual Information

The following is extracted from Title 47 of the Code of Federal Regulations, Part 15, Subpart A — General:

**§ 15.19 Labeling requirements.**

*(a) In addition to the requirements in Part 2 of this chapter, a device subject to certification or verification shall be labeled as follows:*

(1) Receivers associated with the operation of a licensed radio service, e.g., FM broadcast under Part 73 of this chapter, land mobile operation under Part 90, etc., shall bear the following statement in a conspicuous location on the device:

This device complies with Part 15 of the FCC Rules. Operation is subject to the condition that this device does not cause harmful interference.

(2) A stand-alone cable input selector switch, shall bear the following statement in a conspicuous location on the device:

This device is verified to comply with Part 15 of the FCC Rules for use with cable television service.

(3) All other devices shall bear the following statement in a conspicuous location on the device:

*This device complies with Part 15 of the FCC Rules. Operation is subject to the following two conditions: (1) This device may not cause harmful interference, and (2) this device must accept any interference received, including interference that may cause undesired operation.*

(4) Where a device is constructed in two or more sections connected by wires and marketed together, the statement specified under paragraph (a) of this section is required to be affixed only to the main control unit.

(5) When the device is so small or for such use that it is not practicable to place the statement specified under paragraph (a) of this section on it, the information required by this paragraph shall be placed in a prominent location in the instruction manual or pamphlet supplied to the user or, alternatively, shall be placed on the container in which the device is marketed. However, the FCC identifier or the unique identifier, as appropriate, must be displayed on the device.

**§ 15.21 Information to user.**

The users manual or instruction manual for an intentional or unintentional radiator shall caution the user that changes or modifications not expressly approved by the party responsible for compliance could void the user's authority to operate the equipment.

## § 15.27 Special Accessories.

(a) Equipment marketed to a consumer must be capable of complying with the necessary regulations in the configuration in which the cables and/or special connectors are required to enable an unintentional or intentional radiator to comply with the emission limits in this part, the equipment must be marketed with, i.e. shipped and sold with, those special accessories. However, in lieu of shipping or packaging the special accessories with the unintentional or intentional radiator, the responsible party may employ other methods of ensuring that the special accessories are provided to the consumer, without additional charge.

Information detailing any alternative method used to supply the special accessories for a grant of equipment authorization or retained in the verification records, as appropriate. The party responsible for the equipment, as detailed in §2.909 of this chapter, shall ensure that these special accessories are provided with the equipment. The instruction manual for such devices shall include appropriate instructions on the first page of text concerned with the installation of the device that these special accessories must be used with the device. It is the responsibility of the user to use the needed special accessories supplied with the equipment.

## § 15.105 Information to the user.

(a) For a Class B digital device or peripheral, the instructions furnished the user shall include the following or similar statement, placed in a prominent location in the text of the manual:

> Note: This equipment has been tested and found to comply with the limits for a Class B digital device, pursuant to Part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference when the equipment is operated in a residential environment. This equipment generates, uses, and can radiate radio frequency energy and, if not installed and used in accordance with the instruction manual, may cause harmful interference to radio communications. However, there is no guarantee that interference will not occur in a particular installation. If this equipment does cause harmful interference to radio or television reception, which can be determined by turning the equipment off and on, the user is encouraged to try to correct the interference by one or more of the following measures:
>
> – Reorient or relocate the receiving antenna.
>
> – Increase the separation between the equipment and receiver.
>
> – Connect the equipment into an outlet on a circuit different from that to which the receiver is connected.
>
> – Consult the dealer or an experienced radio/TV technician for help.

# 7.0 Appendix 1: Customer Declarations

**Section 15.247(a):**
*Describe how the EUT meets the definition of a frequency hopping spread spectrum system, found in Section 2.1, based on the technical description.*

The GC-205 RCU is designed with a commercially available frequency-agile digitally modulated radio ASIC. This ASIC is designed to be capable of changing frequencies between packets. The device's firmware takes advantage of this capability by selecting a new operating frequency 100 times per second.

The ASIC uses GFSK modulation and is operated with carrier frequencies on 1 MHz steps from 2447 MHz to 2479 MHz, for a total of 33 channels. Output power is below 125 mW, so the maximum permissible 20 dB bandwidth by Section 15.247(a)(1) is 1.5 MHz. The system hopping rate is 100 Hz.

Link initialization uses a reduced hop set of 15 frequencies. This reduces the time spent in an unsynchronized state, while complying with the requirements of Section 15.247(a)(1)(iii).

The ASIC's digital modulation capabilities are used to provide enhanced robustness through interference detection due to redundant data transmission. The radio is never operated on a static carrier frequency, so the hybrid rules of Section 15.247(f) do not apply.

**Pseudorandom Frequency Hopping Sequence**
*Describe how the hopping sequence is generated. Provide an example of the hopping sequence channels, in order to demonstrate that the sequence meets the requirement specified in the definition of a frequency hopping spread spectrum system, found in Section 2.1.*

The hopping sequence is generated in a manner compatible with other Nomadio devices. This is accomplished by adapting the basic Nomadio hop sequence to use only those frequencies available to the GC-205 RCU. The basic hop set includes 79 channels from 2402 MHz to 2480 MHz. If the generated channel is enabled that channel is used for the current slot. If the channel is not enabled a replacement is selected from the list of enabled channels.

*Basic Hop Sequence*
The basic hop sequence selects frequencies from a 79-entry list. The list is ordered so that any 32-channel span in the list covers at least 64 MHz of spectrum. This is accomplished by listing all even channels (2402 MHz to 2480 MHz) followed by all odd channels (2403 MHz to 2479 MHz).

A 32-channel wide window is initialized to point into the list. The 32-selected channels are shuffled for the next 32 hops, so that each channel is used exactly once.

When all 32 entries from the current window have been used once, the window is advanced 16 entries in the table, in a circular fashion (the first table entry, 2402 MHz, is considered to immediately follow the last entry, 2479 MHz) and the control inputs to the shuffle stage are changed. After the window has been advanced 79 times it returns to the starting position. This occurs after $79 \times 32 = 2528$ hops.

There are $2^{14}$ possible shuffle patterns, used over the course of $2^{19}$ hops. When all patterns have been used, the phase of the 5-bit shuffle data input is changed. This increases the period of the shuffle output to $2^{24}$ hops. When this period expires, however, the sliding window will not be in the starting position. The two periods will not align until $79 \times 2^{24}$ hops, at which point the pattern repeats. At 100 frames per second this is approximately 151 days of continuous operation, well in excess of the normal operational period of the system.

Because the base operation is a 32-channel shuffle, it is impossible for any single channel to be used on more than two consecutive slots, which only occurs if the channel is last in one shuffle and first in the next shuffle. Every channel is used 32 times in a 2528 hop cycle.

Each stage of calculation includes an exclusive-or with a portion of the link GUID. This ensures that two linked pairs will follow different hopping sequences, even if their positions in the hop sequence happen to be closely synchronized.

*Limiting Channel Use*
After a channel is generated by the basic sequence it is checked against the list of usable channels. If the channel is not usable a replacement is selected. The replacement is chosen using the shuffle output index (0-31) along with a sliding window into the list of used channels. The window is moved each time the base sequence window is moved. The used channel list is equivalent to the base channel list with unused channels removed. That is, all even used channels are listed followed by all used odd channels.

When the used channel set contains 32 or more channels, a given replacement channel can be used at most once for a given 32-channel shuffle. If fewer than 32 channels are in use (such as during rendezvous) a channel may be used as a substitute more than once in a 32-channel shuffle. Over time, as the selection window is moved through the hop set, each channel will be used the same number of times as any other.

*Channel Set Selection*
The GC-205 RCU is limited to using the 33 channels from 2447 to 2479 MHz. All 33 channels are used when a link is established. The RCU specifies the channels to be used, allowing link establishment with the OCU.

During link initialization, a reduced hop set of 15 channels are used. Six of these channels are shared with full-band devices. The remaining nine channels are unique to the GC-205 system. This provides for a fast connection between two GC-205 devices, while still allowing connections between GC-205 and other Nomadio devices.

**Equal Hopping Frequency Use**
*Describe how each individual EUT meets the requirement that each of its hopping channels is used equally on average (e.g., that each new transmission event begins on the next channel in the hopping sequence after the final channel used in the previous transmission event).*

All messages are sent on the basis of a shared 100 Hz clock. On each timeslot, both devices in a linked pair generate a new frequency using the algorithm described above. Normally, the slave device will activate its receiver and the master device will transmit a message. The slave will respond with a short ACK message on the same channel.

If the master expects a response to a message (such as telemetry data) the response is sent from the slave in the next timeslot, using the frequency the request was received on. Both devices still execute the channel selection algorithm but discard the result. This ensures the devices remain synchronized if the slave device missed the request message, in which case both devices spend a timeslot receiving, likely on different frequencies.

All messages fit within a single timeslot, and a new frequency is selected for each timeslot. The hopping algorithm is guaranteed to return each channel equally on average (see description above).

Simulations of the hop algorithm over various length hop sequences (10,000 to over 300 million hops) and hop sets show no sustained bias toward or away from any channel.

**System Receiver Input Bandwidth**
*Describe how the associated receiver(s) complies with the requirement that its input bandwidth (either RF or IF) matches the bandwidth of the transmitted signal.*

The EUT is designed with a commercially available frequency-agile digitally modulated radio ASIC. This ASIC is used on both ends of the link, and is designed with matching transmitter and receiver bandwidths.

**System Receiver Hopping Capability**

*Describe how the associated receiver(s) has the ability to shift frequencies in synchronization with the transmitted signals.*

Each link consists of a master device and a slave device. Timeslot synchronization is maintained by tracking packet transmission and reception times. The master device internally generates a 100 Hz clock signal and sends packets on the basis of this clock. The slave records packet reception times and uses this timing information to adjust its 100 Hz clock to match the master clock's period and phase.

The hop algorithm on the slave device is initialized to match the master's during link initialization. Both devices step through the hop sequence on every timeslot.

Link initialization uses an unsynchronized hop sequence with a 15 channel hop set. The listening device hops at a reduced rate (typically 50 ms dwell time) to increase the odds of matching channels with the advertising device.

**Section 15.247(g):**

*Describe how the EUT complies with the requirement that it be designed to be capable of operating as a true frequency hopping system.*

All messages fit within a single timeslot, and a new frequency is selected for each timeslot. The hopping algorithm is guaranteed to return each channel equally (see description above).

This ensures that all enabled channels are used equally over a period of 32 hops times the number of used channels ($33 \times 32 = 1056$ hops for an established connection, $15 \times 32 = 480$ hops for link establishment).

**Section 15.247(h):**

*Describe how the EUT complies with the requirement that it not have the ability to be coordinated with other FHSS systems in an effort to avoid the simultaneous occupancy of individual hopping frequencies by multiple transmitters.*

The link protocol only supports communication between a linked controller/remote transceiver pair. No mechanisms are provided for the inter-link communication necessary to synchronize hop sequences.

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