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 6, 2006

Dear Alex Gizis,

Enclosed is the EMC test report for compliance testing of the Nomadio Digital Telemetry, GC-300 SRM (Secure Radio Module) Model AM05, 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.

Nicole E. Hellen
Documentation Department

Reference: (\Nomadio Digital Telemetry\ GC-300 SRM (Secure Radio Module) Model AM05\ EMC18325B-FCC247)

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Electromagnetic Compatibility
Test Report

For the

Nomadio Digital Telemetry
GC-300 SRM (Secure Radio Module) Model AM05

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

MET Report: 18325B-FCC247

January 6, 2006

Prepared For:

Nomadio Digital Telemetry
2400 Chestnut Street
Philadelphia, PA 19103

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

Electromagnetic Compatibility
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For the

Nomadio Digital Telemetry
GC-300 SRM (Secure Radio Module) Model AM05

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

Dusmantha Tennakoon
Electromagnetic Compatibility Lab

Nicole E. Hellen
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

Report Status Sheet

Revision	Report Date	Reason for Revision
Ø	January 6, 2006	Initial Issue.

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
dBμV	**D**eci-**B**els above one **micro V**olt
dBμV/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
μH	**micro H**enry
μF	**micro F**arad
μs	**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 the GC-300 SRM (Secure Radio Module) Model AM05, under Nomadio Digital Telemetry purchase order number 05-199.

This document describes the test setups, test methods, required test equipment, and the test limits used to perform compliance testing of the GC-300 SRM (Secure Radio Module) Model AM05. 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:	GC-300 SRM (Secure Radio Module) Model AM05	
Model(s) Covered:	GC-300 SRM (Secure Radio Module) Model AM05	
	Primary Power:	BATTERY (6VDC, 4xAA)
EUT Specifications:	**FCC ID:**	TSDNMD-AM05
	Equipment Code:	DSS
	Maximum RF Power Output:	17.99 dBm (0.0631 Watts)
	Equipment Frequency Range:	2.402-2.479 GHz
Analysis:	The results obtained relate only to the item(s) tested.	
Evaluated by:	Dusmantha Tennakoon	
Date(s):	January 6, 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).

1.3 Testing Summary

Paragraph	Name of Test	Compliance
Part 15, Subpart C, §15.203	Antenna Requirement	Compliant
Part 15, Subpart C, §15.205, §15.209	Spurious Radiated Emissions	Compliant
Part 15, Subpart B, §15.109	Unintentional 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

2.0 Equipment Configuration

2.1 Description of EUT

The GC-300 SRM (Secure Radio Module) Model AM05, Equipment Under Test (EUT) is a 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

All equipment incorporated as part of the EUT is included in the following list.

Name / Description	Model Number
GC-300 SRM (Secure Radio Module)	AM05

Table 2. Equipment Configuration

2.3 Support Equipment

Ref. ID	Name / Description	Manufacturer	Model Number	*Customer Supplied Calibration Data
1	CN20 cable	Nomadio	N/A	N/A
2	CN1 cable	Nomadio	N/A	N/A
3	CN2 cable	Nomadio	N/A	N/A

2.4 Ports and Cabling Information

Ref. ID	Port name on EUT	Cable Description or reason for no cable	Qty.	Length (m)	Shielded?	Termination Box ID & Port ID
1	CN20	CN20 cable terminator	1	0.3	N	N/A
2	CN1	CN1 cable terminator w/status LED & test select button	1	0.3	N	N/A
3	CN2	CN2 cable terminator with battery connector	1	0.1	N	N/A

2.5 Mode Of Operation

The EUT was transmitting continuously at max power and max data rate.

2.6 Modifications to EUT

No modifications were made to the EUT.

2.7 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.

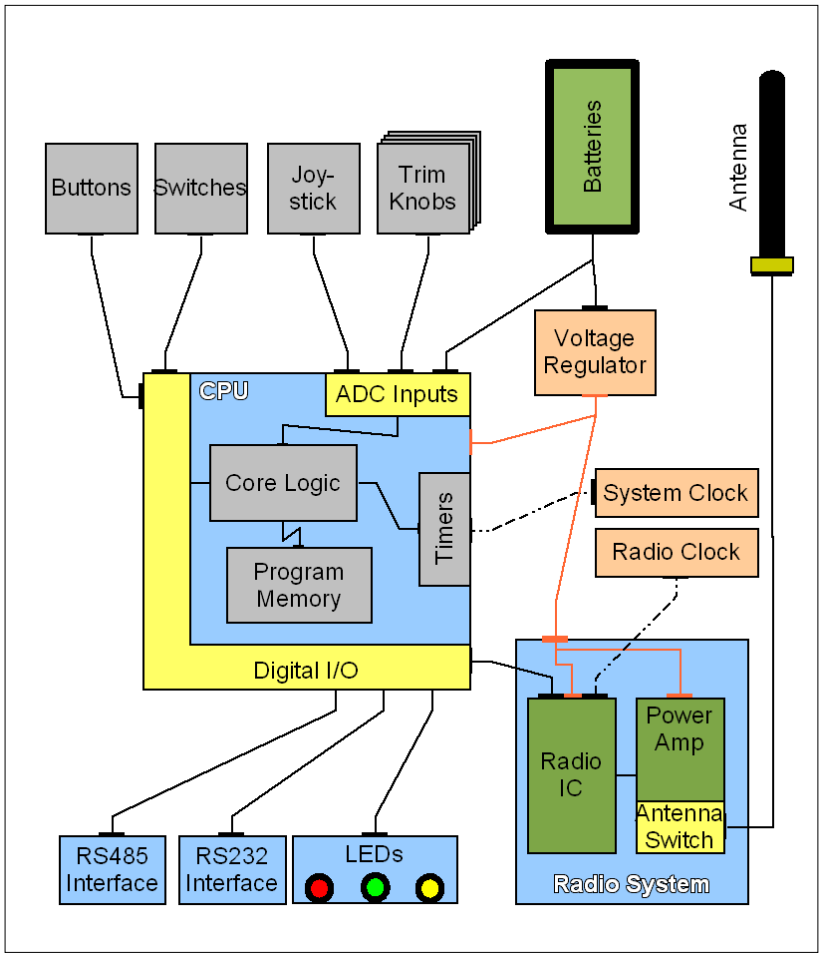


Figure 1. Block Diagram of Test Configuration

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 must 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.

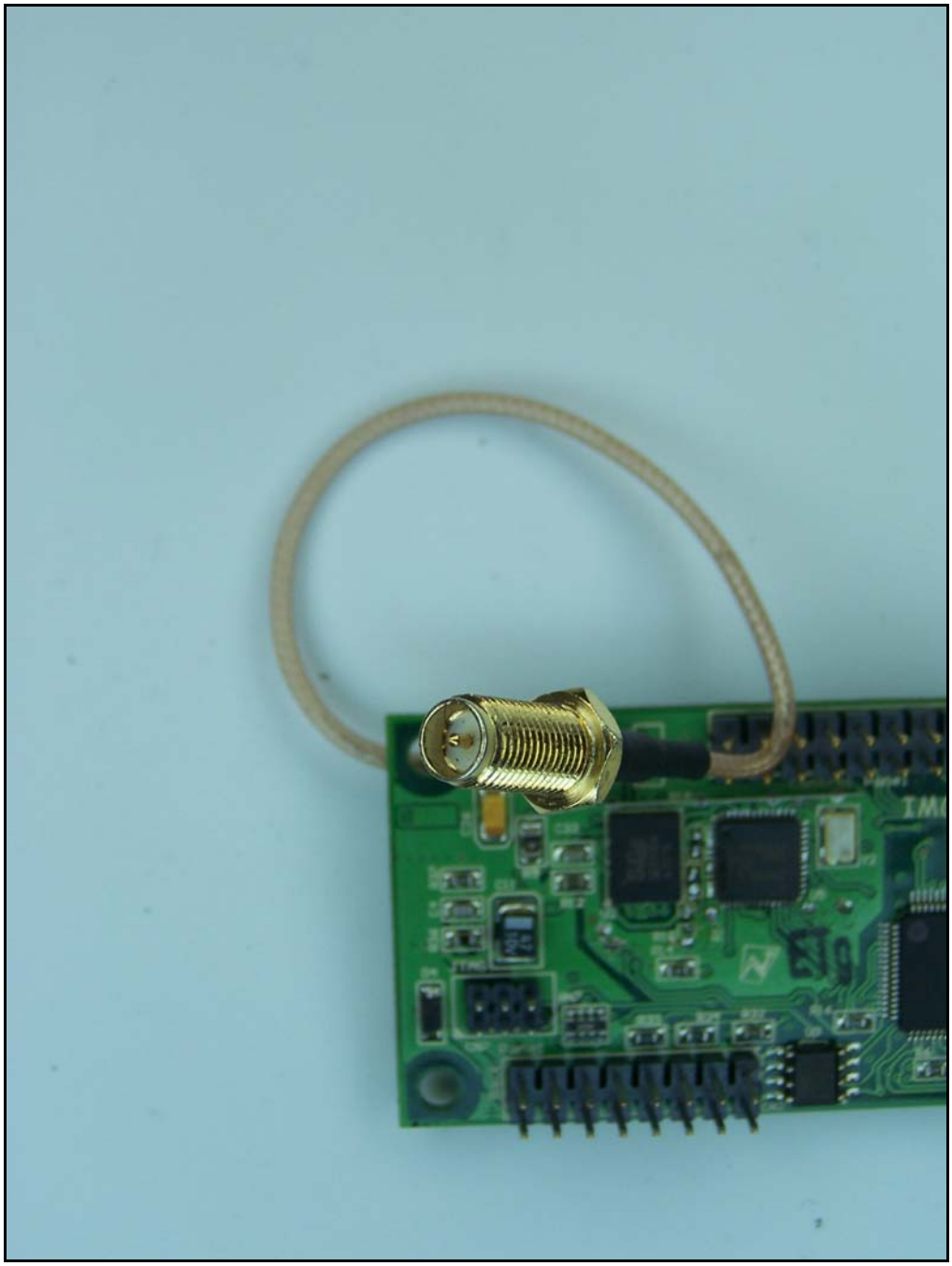
Results: The EUT complies with the requirements of this section. The antenna connector has a unique reverse SMA per 15.203 requirements.

Type of Antenna: Dipole

Gain of Antenna: 2 dBi

Test Engineer(s): Dusmantha Tennakoon

Test Date(s): December 12, 2005



Photograph 1. Antenna Connector

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 3:

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. Note 2: Above 38.6			

Table 3. 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 4. 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 complies with the requirements of this section.

Test Engineer(s): Dusmantha Tennakoon

Test Date(s): December 16, 2005

Spurious Radiated Emissions – (Average)

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)
1.034	0	V	1	21.13	24.19	0.00	9.54	35.78	54	-18.22
1.084	0	H	1	21.23	24.34	0.00	9.54	36.03	54	-17.97
1.092	0	V	1	26.39	24.36	0.00	9.54	41.21	54	-12.79
1.114	0	V	1	27.85	24.40	0.00	9.54	42.71	54	-11.29
1.114	0	H	1	22.93	24.40	0.00	9.54	37.79	54	-16.21
1.127	0	V	1	25.61	24.46	0.00	9.54	40.53	54	-13.47
1.129	0	H	1	23.14	24.44	0.00	9.54	38.04	54	-15.96
1.179	0	H	1	19.85	24.60	0.00	9.54	34.91	54	-19.09
1.196	0	V	1	28.83	24.61	0.00	9.54	43.90	54	-10.10
1.213	0	V	1	29.18	24.70	0.00	9.54	44.34	54	-9.66
1.223	0	H	1	22.67	24.72	0.00	9.54	37.85	54	-16.15
1.231	0	V	1	31.24	24.70	0.00	9.54	46.40	54	-7.60
1.236	0	V	1	29.29	24.76	0.00	9.54	44.51	54	-9.49
1.238	0	H	1	23.69	24.72	0.00	9.54	38.87	54	-15.13
2.2828	0	H	1	25.19	28.48	0.00	9.54	44.13	54	-9.87
2.348	0	V	1	25.42	28.60	0.00	9.54	44.48	54	-9.52
2.3637	0	H	1	18.39	28.67	0.00	9.54	37.52	54	-16.48
2.366	0	V	1	27.26	28.63	0.00	9.54	46.35	54	-7.65
2.3764	0	H	1	24.45	28.65	0.00	9.54	43.56	54	-10.44
2.381	0	V	1	26.93	28.71	0.00	9.54	46.10	54	-7.90
4.893	0	V	1	12.69	33.90	0.00	9.54	37.05	54	-16.95
4.913	0	H	1	12.52	33.84	0.00	9.54	36.82	54	-17.18

Table 5. Spurious Radiated Emissions – (Average) Test Results

Note: 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.

Spurious Radiated Emissions – (Peak)

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)
1.236	0	V	1	47.1	24.76	0.00	9.54	62.32	74	-11.68
1.231	0	V	1	47.04	24.70	0.00	9.54	62.20	74	-11.80
1.213	0	V	1	46.59	24.70	0.00	9.54	61.75	74	-12.25
1.196	0	V	1	44.4	24.61	0.00	9.54	59.47	74	-14.53
1.092	0	V	1	43.59	24.36	0.00	9.54	58.41	74	-15.59
1.114	0	V	1	42.6	24.40	0.00	9.54	57.46	74	-16.54
1.127	0	V	1	40.45	24.46	0.00	9.54	55.37	74	-18.63
1.034	0	V	1	37.48	24.19	0.00	9.54	52.13	74	-21.87
2.366	0	V	1	45.74	28.63	0.00	9.54	64.83	74	-9.17
2.381	0	V	1	44.17	28.71	0.00	9.54	63.34	74	-10.66
2.348	0	V	1	42.71	28.60	0.00	9.54	61.77	74	-12.23
4.893	0	V	1	37.05	33.90	0.00	9.54	61.41	74	-12.59
4.913	0	H	1	36.95	33.84	0.00	9.54	61.25	74	-12.75
1.238	0	H	1	44.65	24.72	0.00	9.54	59.83	74	-14.17
1.223	0	H	1	42.3	24.72	0.00	9.54	57.48	74	-16.52
1.114	0	H	1	40.89	24.40	0.00	9.54	55.75	74	-18.25
1.179	0	H	1	39.88	24.60	0.00	9.54	54.94	74	-19.06
1.129	0	H	1	39.43	24.44	0.00	9.54	54.33	74	-19.67
1.084	0	H	1	39.27	24.34	0.00	9.54	54.07	74	-19.93
2.2828	0	H	1	39.98	28.48	0.00	9.54	58.92	74	-15.08
2.3764	0	H	1	39.17	28.65	0.00	9.54	58.28	74	-15.72
2.3637	0	H	1	38.27	28.67	0.00	9.54	57.40	74	-16.60

Table 6. Spurious Radiated Emissions – (Peak) Test Results

Note: 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.

Photograph 2. Spurious Radiated Emissions Test Setup

Unintentional Radiated Emission Limits

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 7.

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 7.

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 7. 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

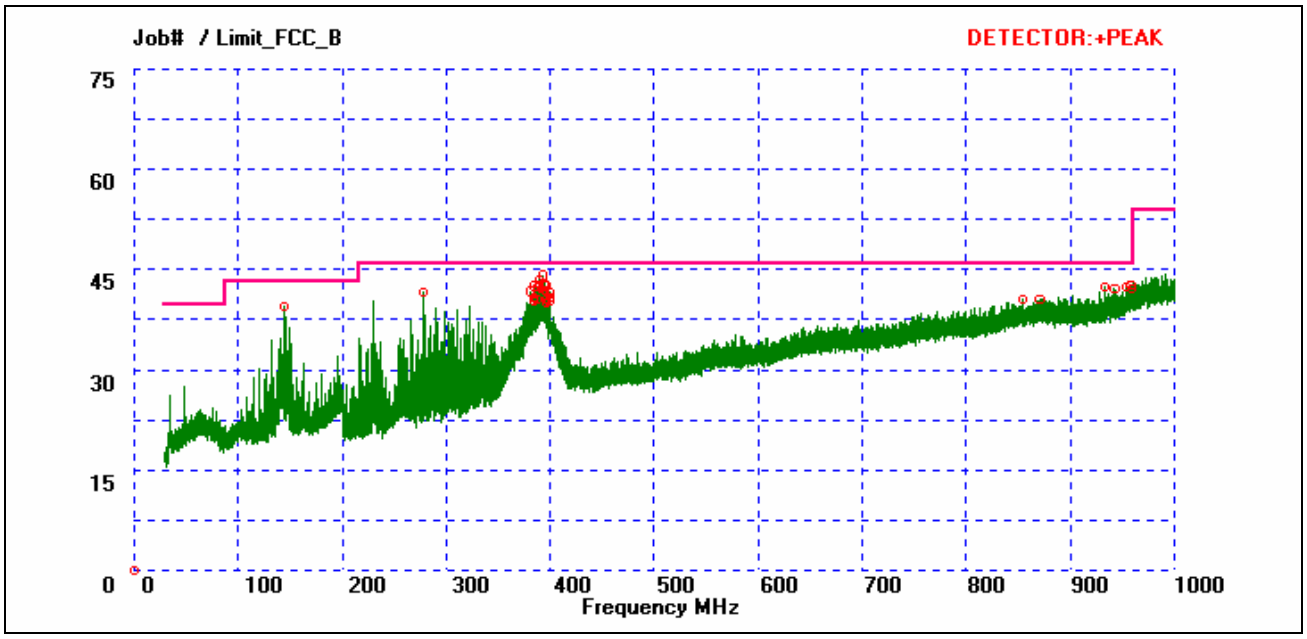
Unintentional Radiated Emissions – 30 MHz to 1 GHz

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)
144.756	344	H	2.12	29.15	8.00	1.13	0.00	38.28	43.50	-5.22
144.756	79	V	2.64	21.92	7.80	1.13	0.00	30.86	43.50	-12.64
146.767	346	H	2.05	27.96	8.04	1.15	0.00	37.14	43.50	-6.36
146.767	76	V	2.60	21.00	7.76	1.15	0.00	29.91	43.50	-13.59
278.452	75	H	1.00	23.09	12.44	1.50	0.00	37.03	46.00	-8.97
278.452	360	V	1.78	16.02	11.90	1.50	0.00	29.42	46.00	-16.58
280.464	83	H	1.00	22.74	12.52	1.50	0.00	36.76	46.00	-9.24
280.464	360	V	1.57	15.61	11.93	1.50	0.00	29.04	46.00	-16.96
298.558	110	H	1.00	21.19	13.14	1.50	0.00	35.83	46.00	-10.17
298.558	28	V	1.44	14.17	12.40	1.50	0.00	28.07	46.00	-17.93
389.898	65	H	2.29	21.36	15.10	1.67	0.00	38.13	46.00	-7.87
389.898	161	V	1.17	13.62	15.20	1.67	0.00	30.49	46.00	-15.51

Table 8. Radiated Emissions – 30 MHz to 1 GHz Test Results

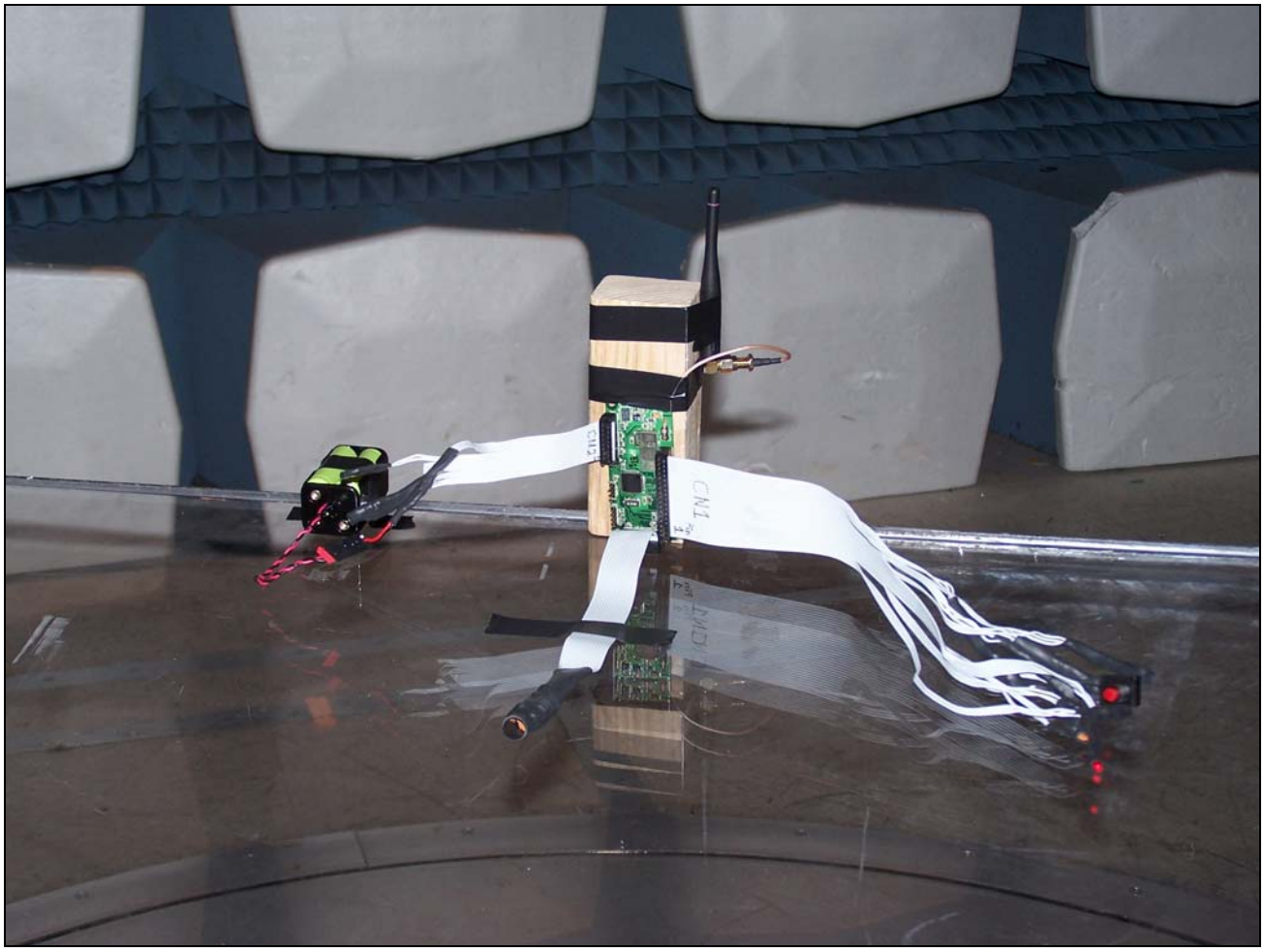
Note: The EUT was tested at 3 m.

Radiated Emissions Limits Test Results



Plot 1. Radiated Emissions Test Results, Pre-Scan

Radiated Emission Limits Test Setup



Photograph 3. Radiated Emission Limits Test Setup

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. See Photograph 4 for a picture of the test setup.

Test Results

The EUT complies with the requirements of this section.

Bandwidth and Separation Requirements

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

Channel Number	20 db Bandwidth
Channel 1	1.290 MHz
Channel 38	1.300 MHz
Channel 78	1.305 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)

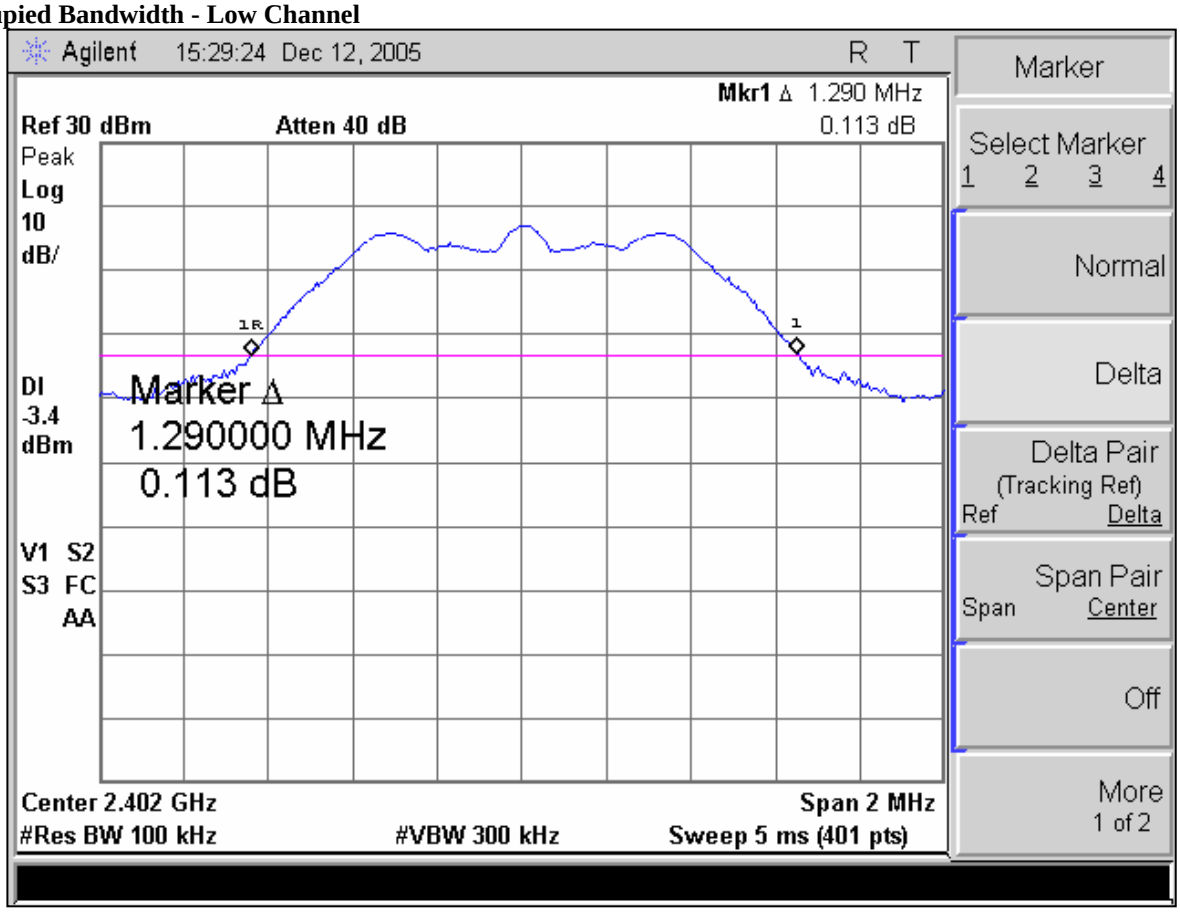
Channel Number(s)	Channel Separation
Channel 1 and 2	1.005 MHz
Channel 38 and 39	.998 MHz
Channel 77 and 78	1.013 MHz

Test Engineer: Dusmantha Tennakoon

Test Date: December 12, 2005

Occupied Bandwidth Test Data

Occupied Bandwidth - Low Channel

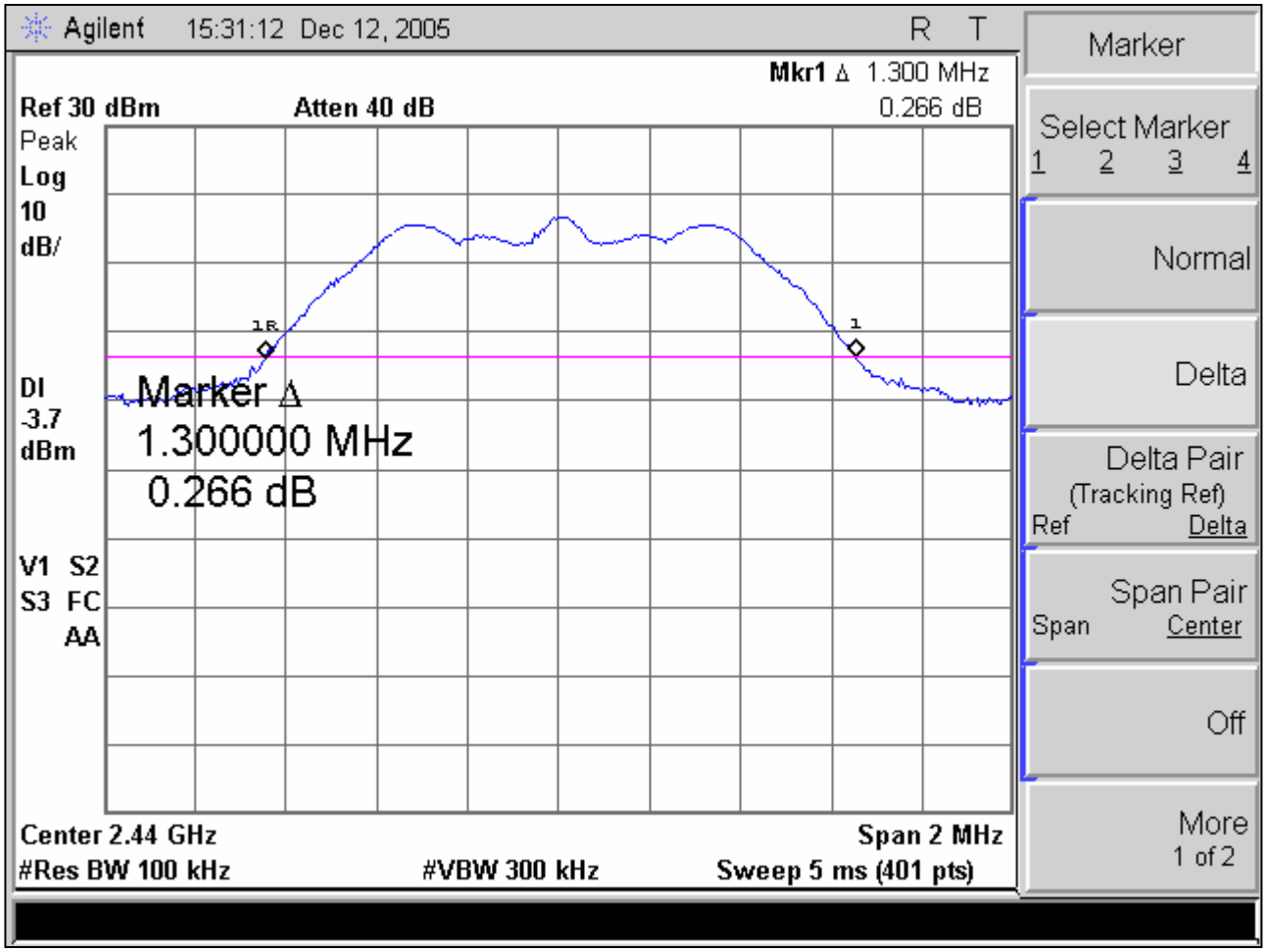


Plot 2. Occupied Bandwidth; Test Results, Channel 1

BW = 1.29 MHz

Occupied Bandwidth Test Data

Occupied Bandwidth – Mid Channel

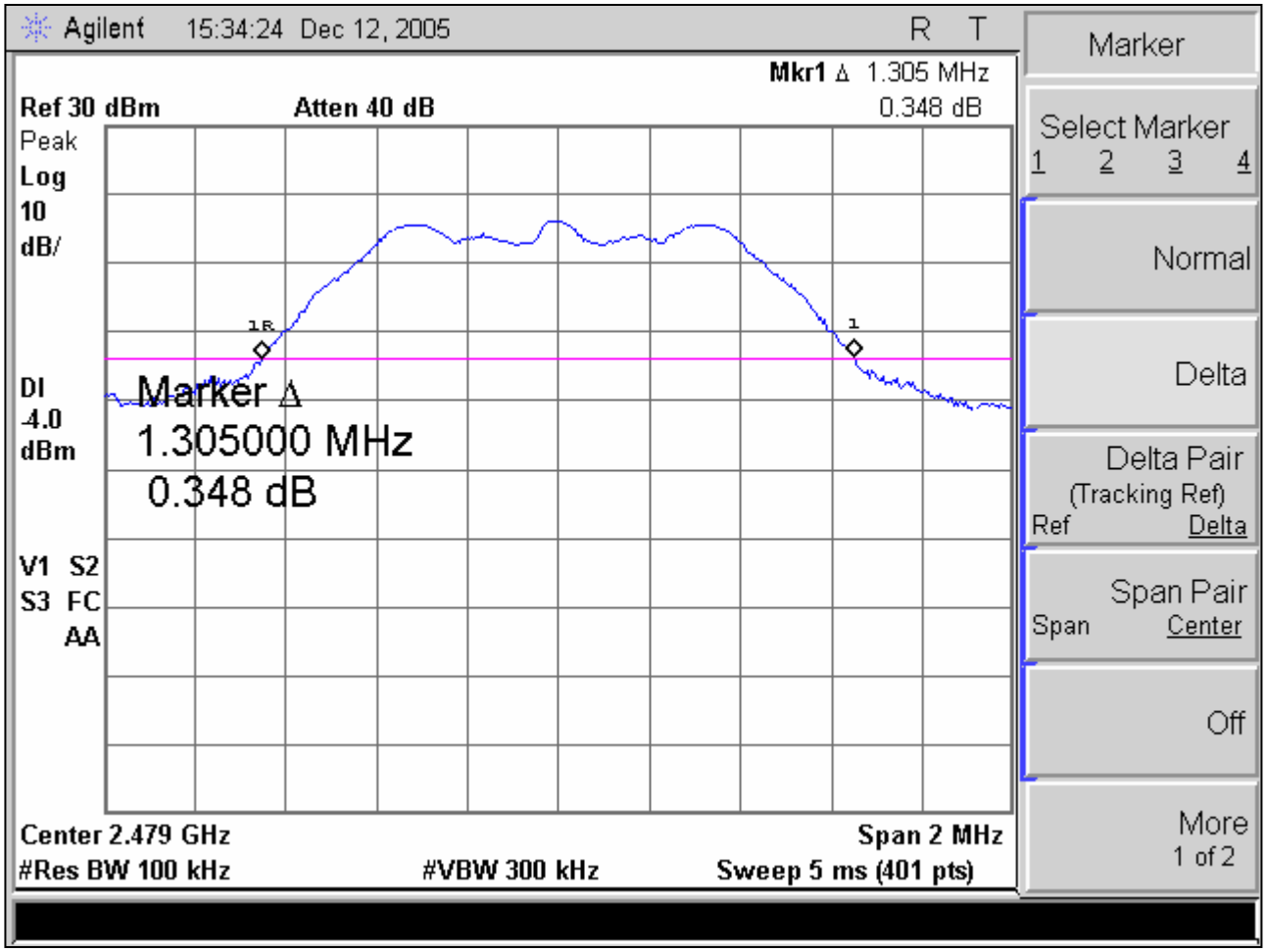


Plot 3. Occupied Bandwidth; Test Results, Channel 38

BW = 1.3 MHz

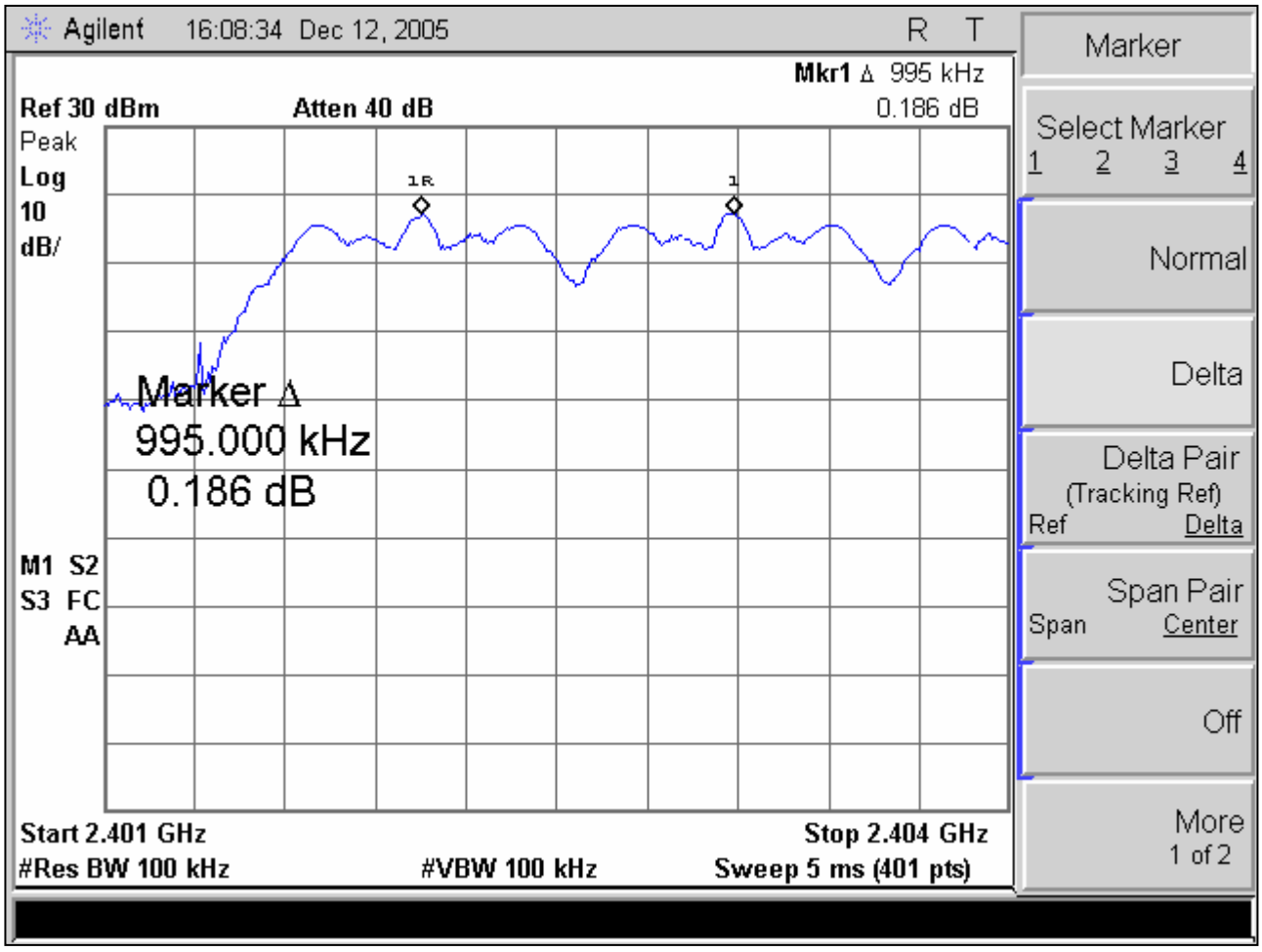
Occupied Bandwidth Test Data

Occupied Bandwidth – High Channel



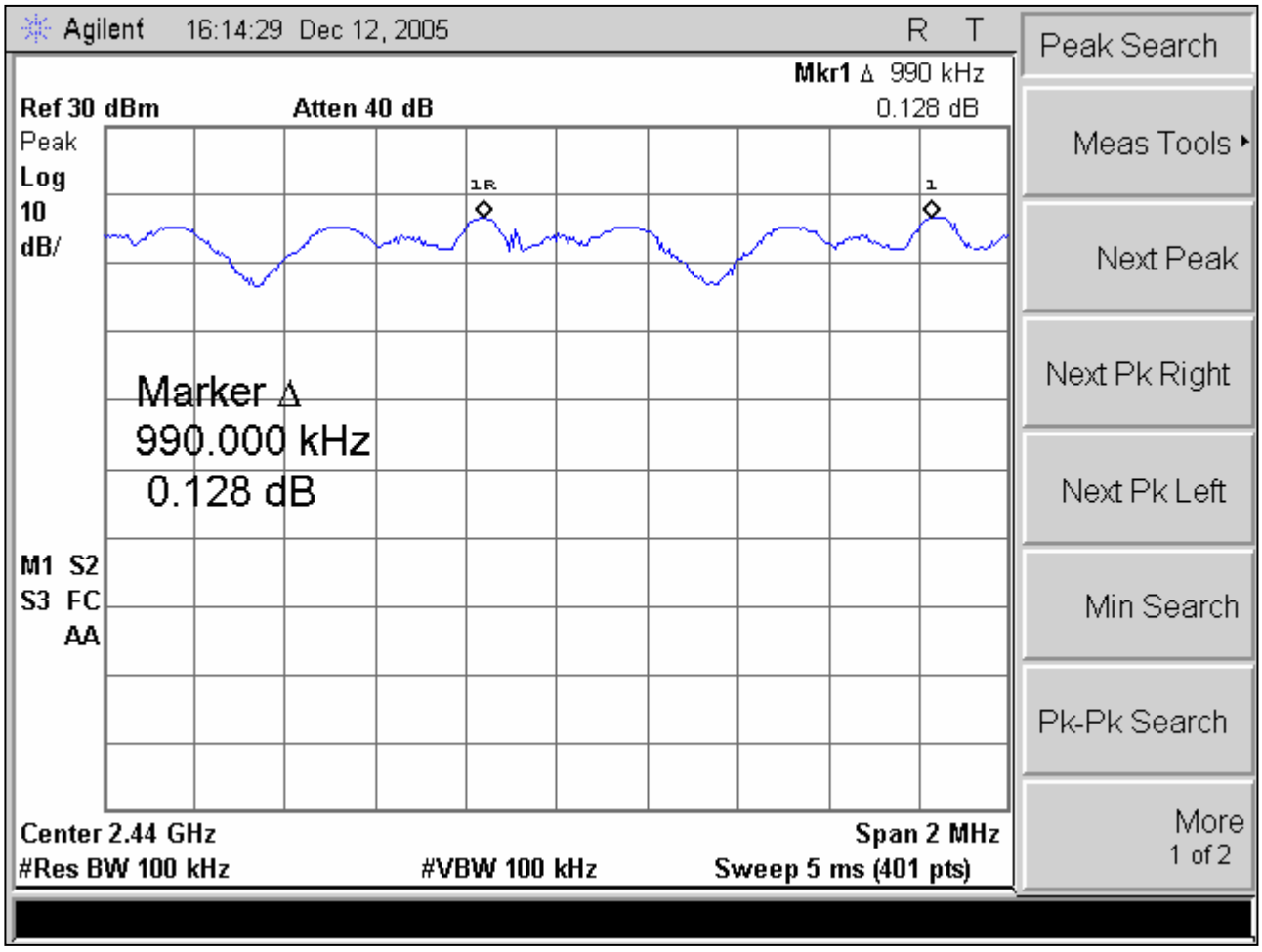
Plot 4. Occupied Bandwidth; Test Results, Channel 78

BW = 1.305 MHz



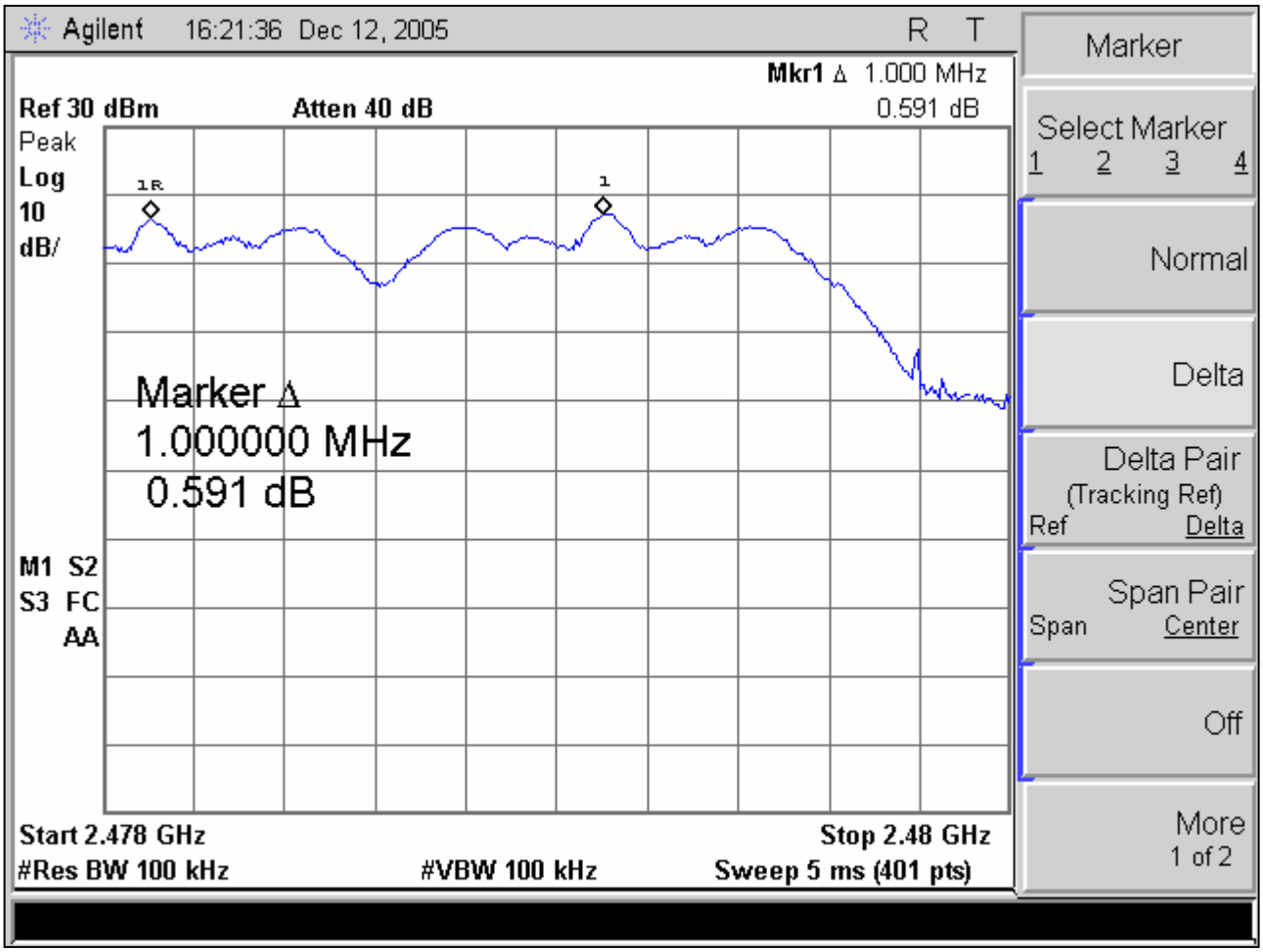
Plot 5. Channel Separation, Test Results, Channel 1 and 2

1.005 MHz



Plot 6. Channel Separation, Test Results, Channel 38 and 39

0.998 MHz



Plot 7. Channel Separation, Test Results, Channel 77 and 78

1.013 MHz

Bandwidth and Channel Separation Test Setup

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.

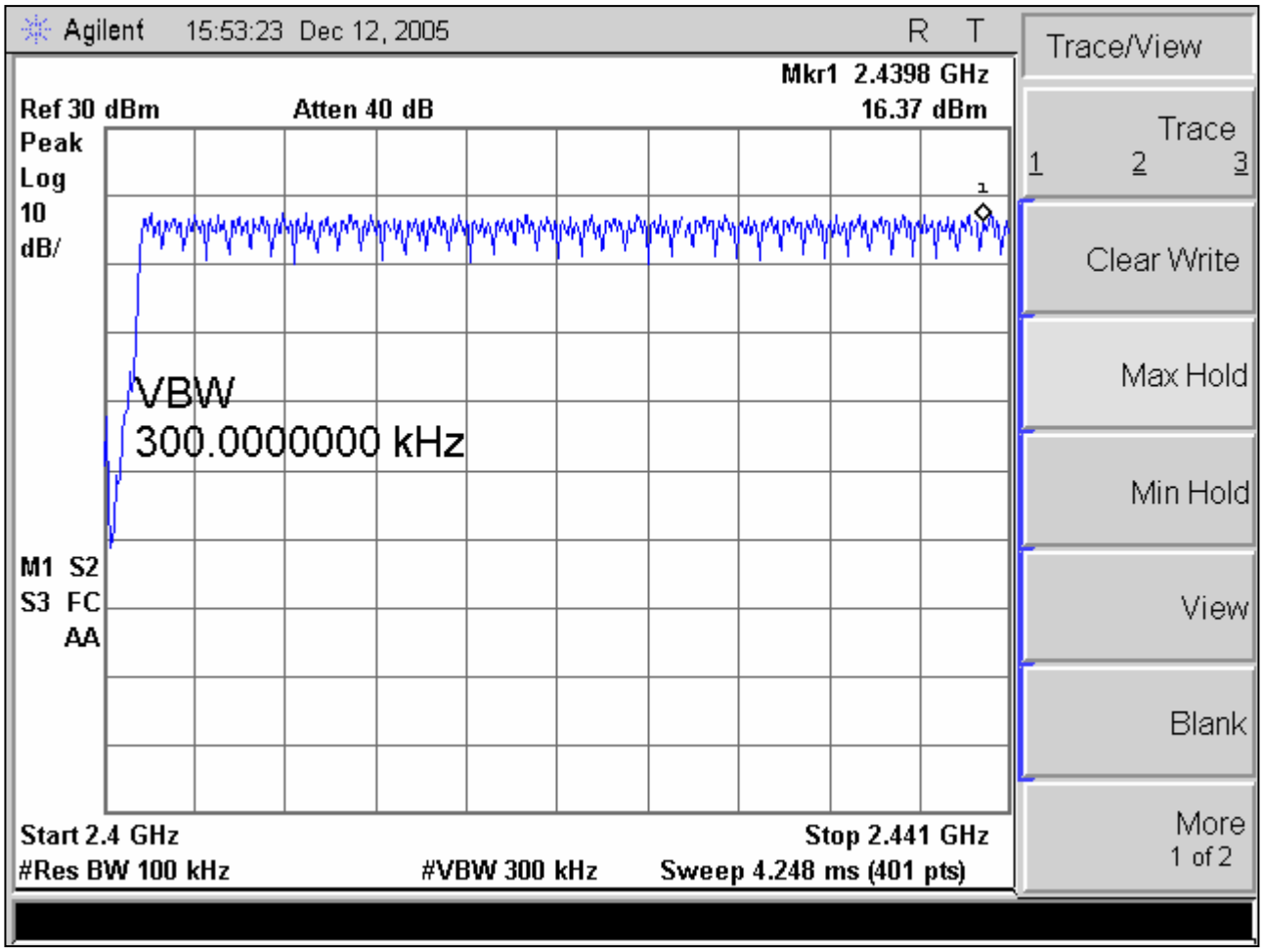
Test Results: The EUT complies with the requirements of this section.

1) Number of Channels (See Plot 8 and Plot 9)
This device has 78 channels.

2) Dwell Time

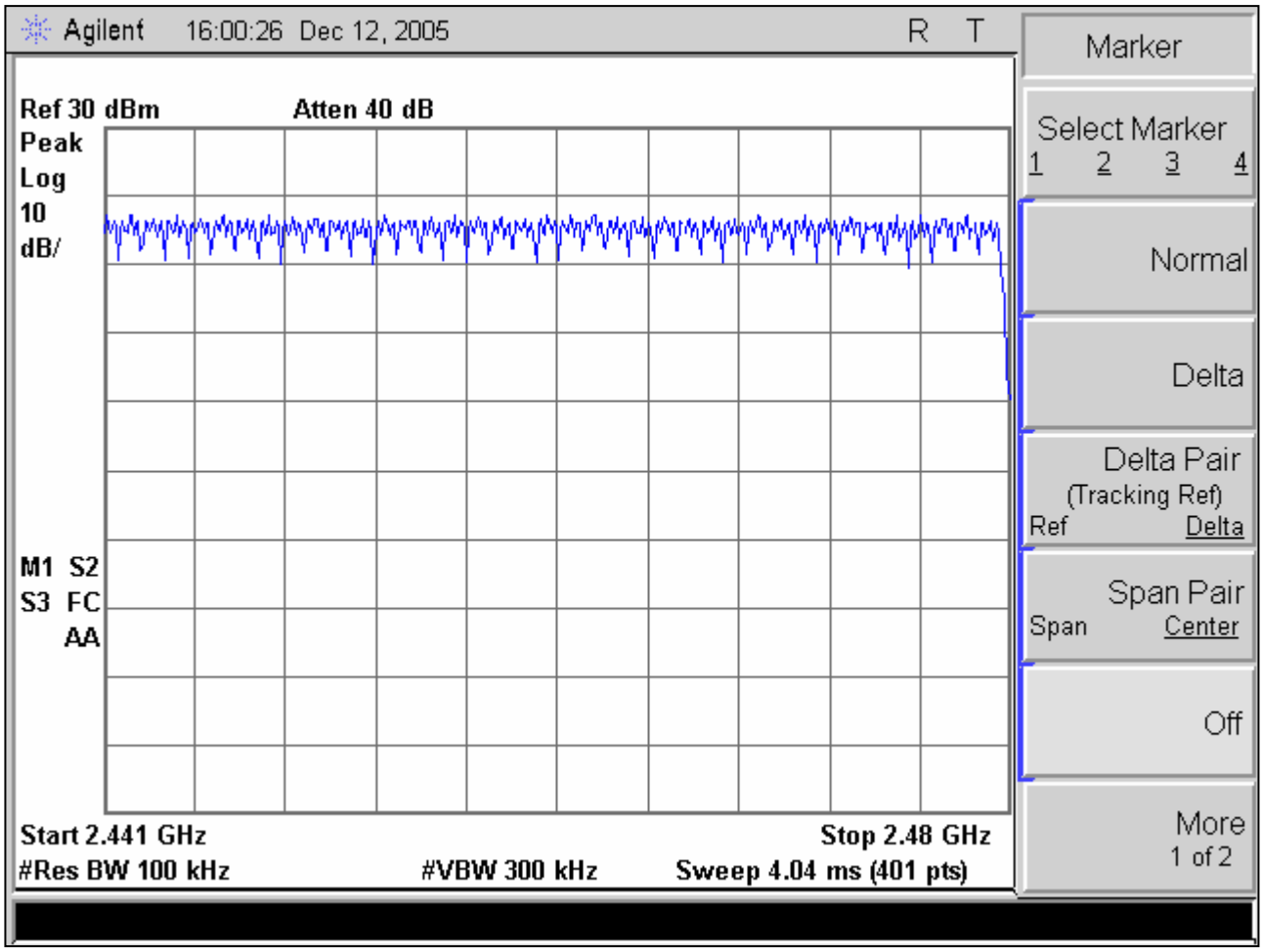
The Dwell Time for a single channel is 8.25 ms (See Plot 10). The device has 78 channels. Each channel was repeated on average forty times in a 31.2 second (78 x 0.4) period (See Plot 11). Therefore, the average Dwell Time in a 31.2 second period equals 330 ms (40 x 8.25 ms).

Number of Channels



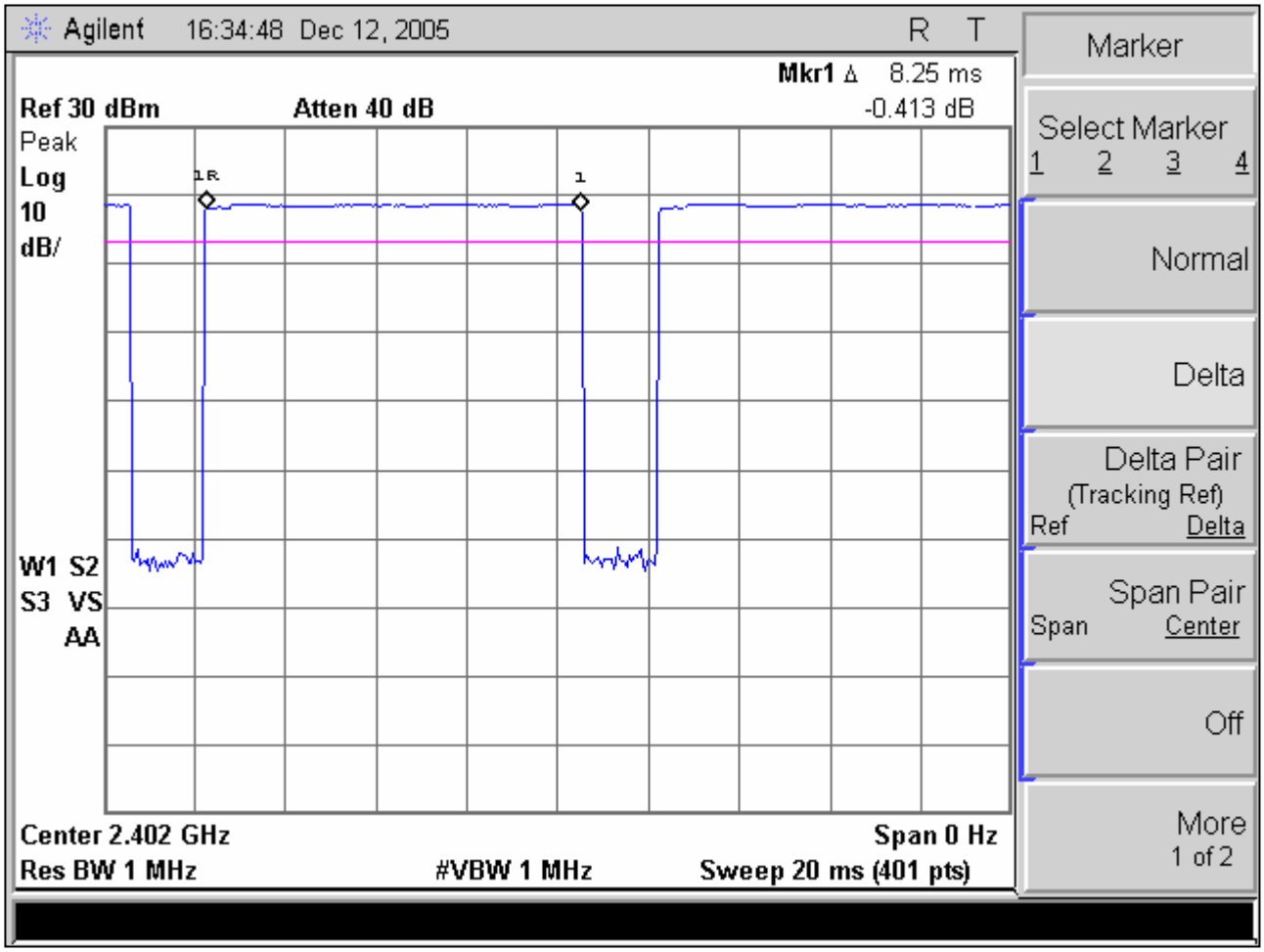
Plot 8. Number of Channels – Part 1

Number of Channels



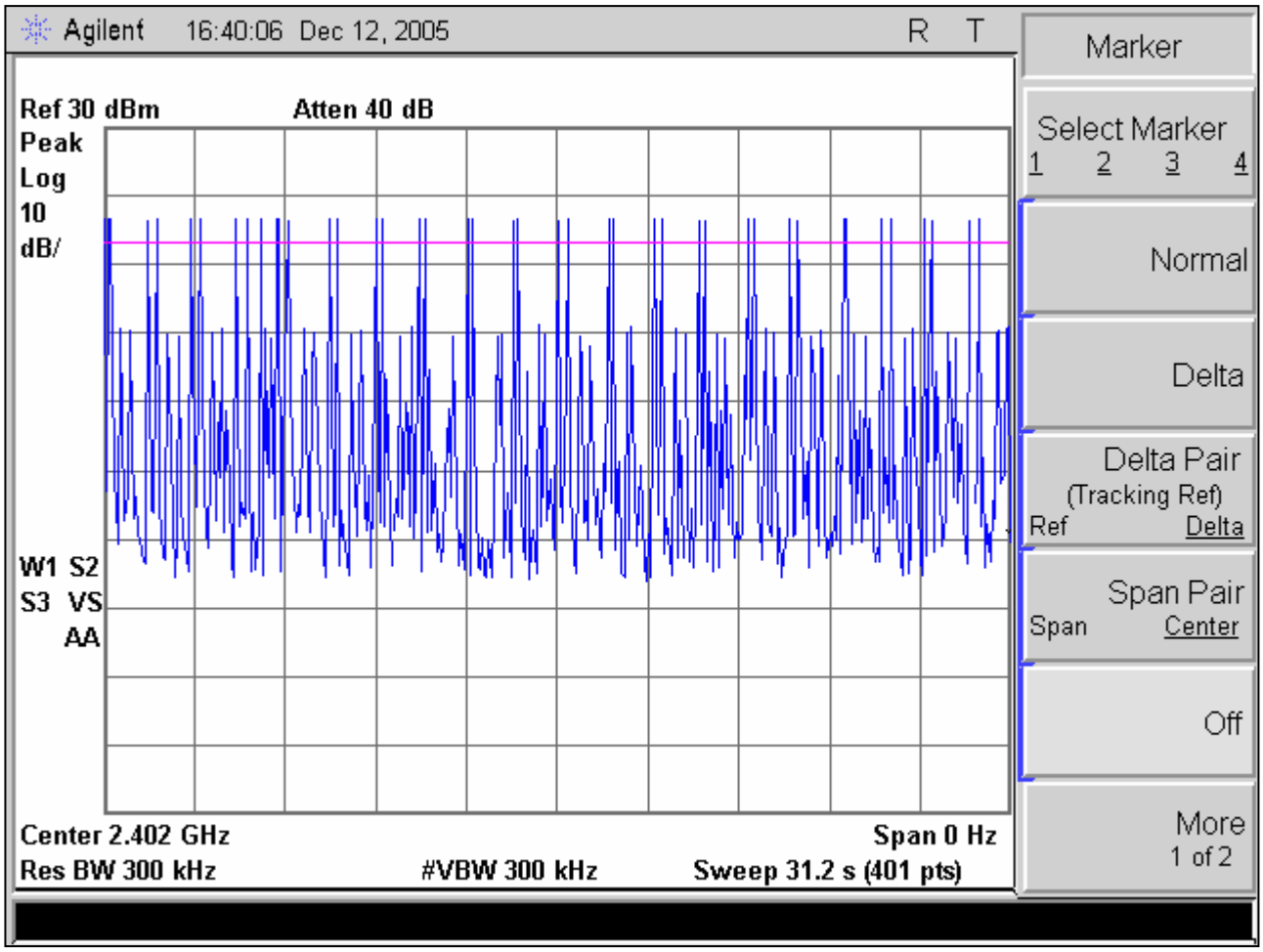
Plot 9. Number of Channels – Part 2

Dwell Time Test Results



Plot 10. Dwell Time of an Individual Channel

Dwell Time Test Results



Plot 11. Number of Times a Channel is Repeated in a 31.2 second Period

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 complies with the requirements of this section.

Peak Output Power = 17.99 dBm (0.0631 Watts)

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

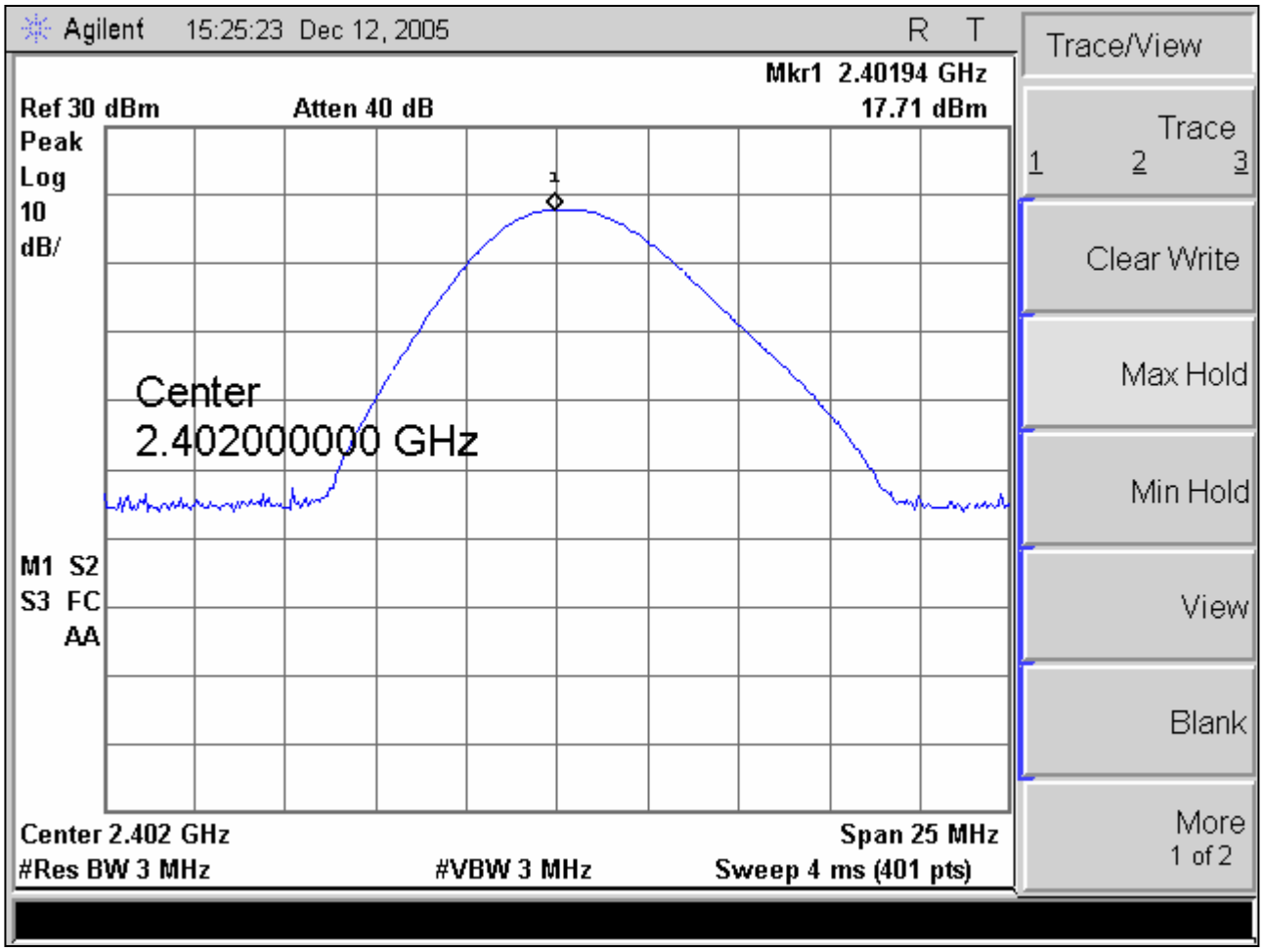
Channel	Peak Output Power (dBm)
Low	17.99 dBm
Mid	17.92 dBm
High	17.76 dBm

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

Test Engineer: Dusmantha Tennakoon

Test Date: December 12, 2005

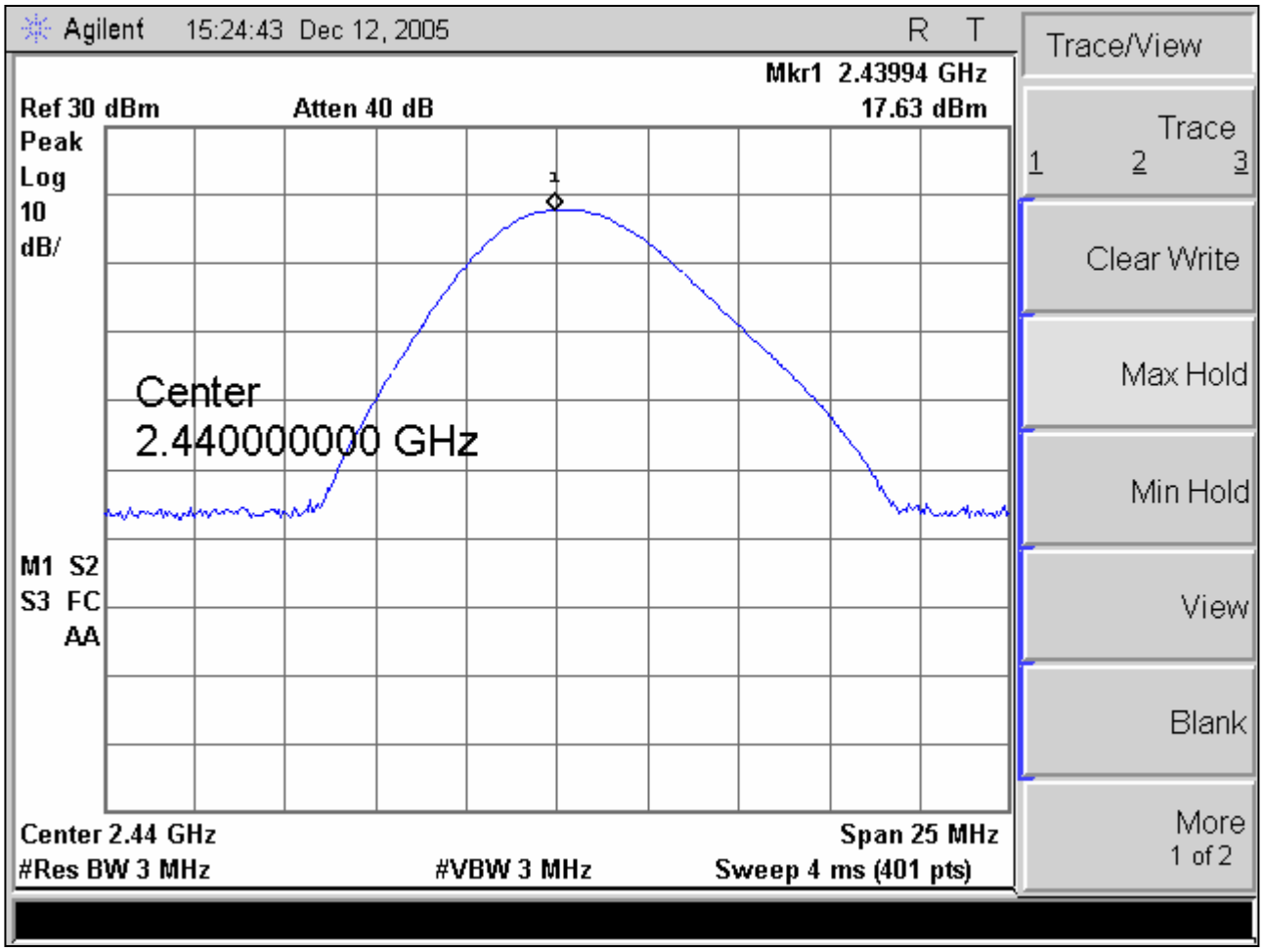
Peak Power Output Test Results



Plot 12. Peak Power Output Test Results – Channel 1

Output Power = Measured + Cable Loss
Cable Loss = .28 dB
Output Power = 17.99 dBm

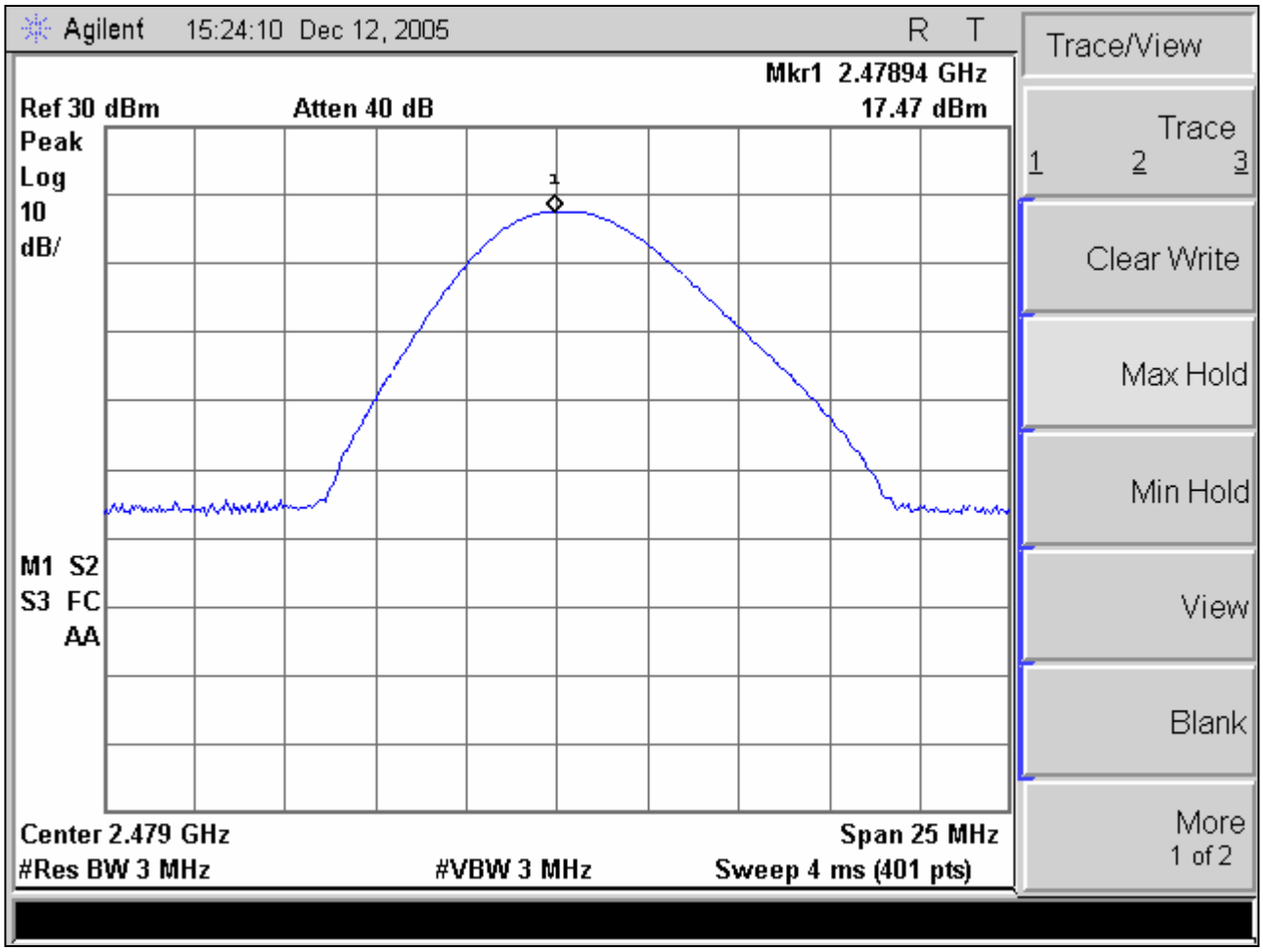
Peak Power Output



Plot 13. Peak Power Output Test Results – Channel 38

Output Power = Measured + Cable Loss
Cable Loss =.29 dB
Output Power = 17.92 dBm

Peak Power Output



Plot 14. Peak Power Output Test Results – Channel 78

Output Power = Measured + Cable Loss
Cable Loss = 0.29 dB
Output Power = 17.76 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 9. 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 = 17.99 dBm (peak) with maximum antenna gain of 2 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

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

Where, S = Power Density (10 W/m²)
P = Power Input to antenna (0.0631 Watts)
G = Antenna Gain (1.6 numeric)
R = distance to the center of radiation of antenna (in meter)
$R = \sqrt{((0.0631 \times 1.6) / 4 \pi 10)} = 0.0284$ m

The distance between the human and the RF antenna should not be less than 0.0284 m.

Test Engineer: Dusmantha Tennakoon,

Test Date: December 12, 2005

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).

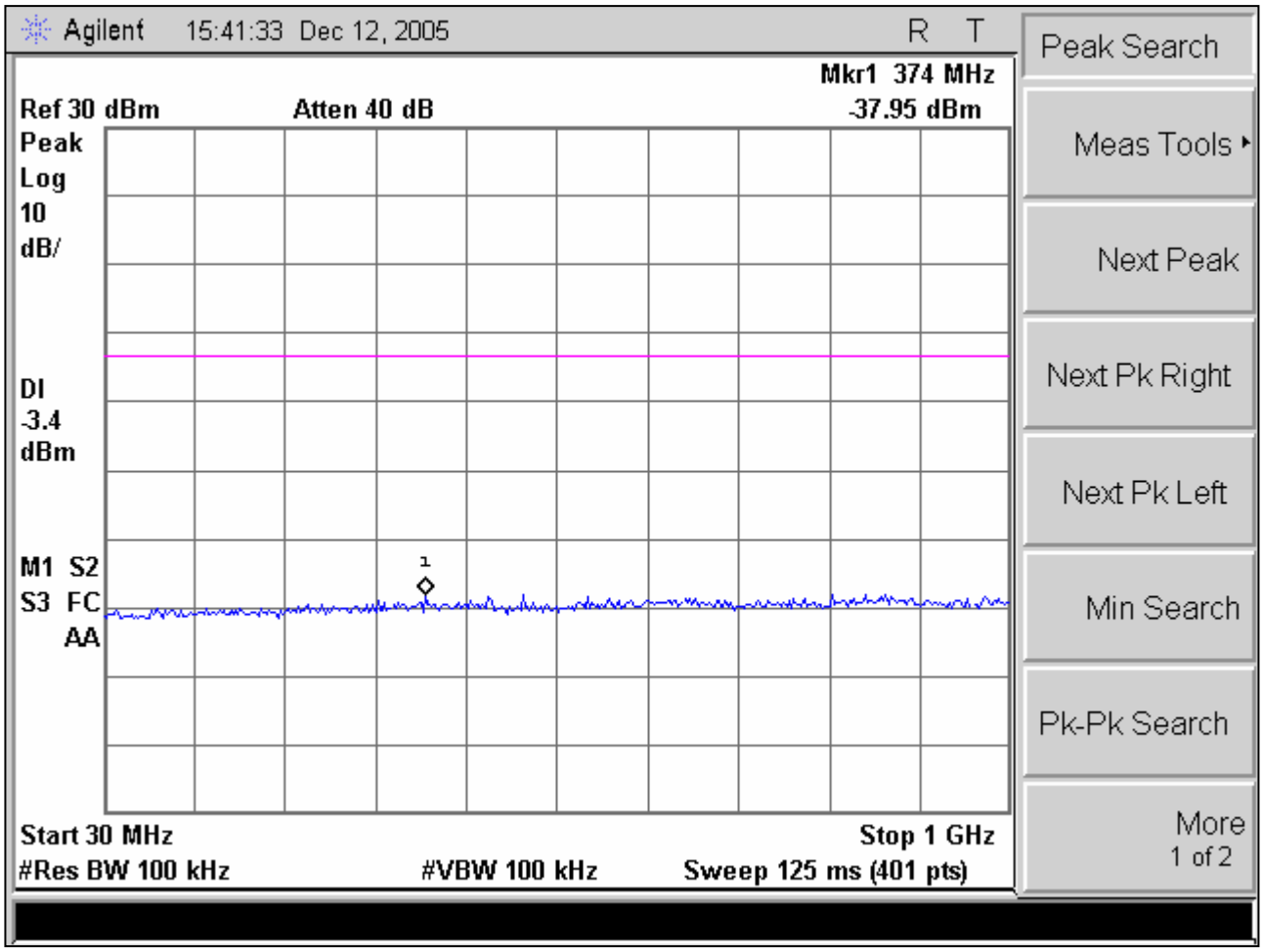
Test Procedure: The EUT was configured with the control software to transmit at maximum power. The transmit output was connected to the analyzer through an attenuator. RBW = 100 kHz, VBW $\geq$ RBW.

Test Results: The EUT complies 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. See Photograph 5 for a picture of the test setup.

Test Engineer: Dusmantha Tenakoon

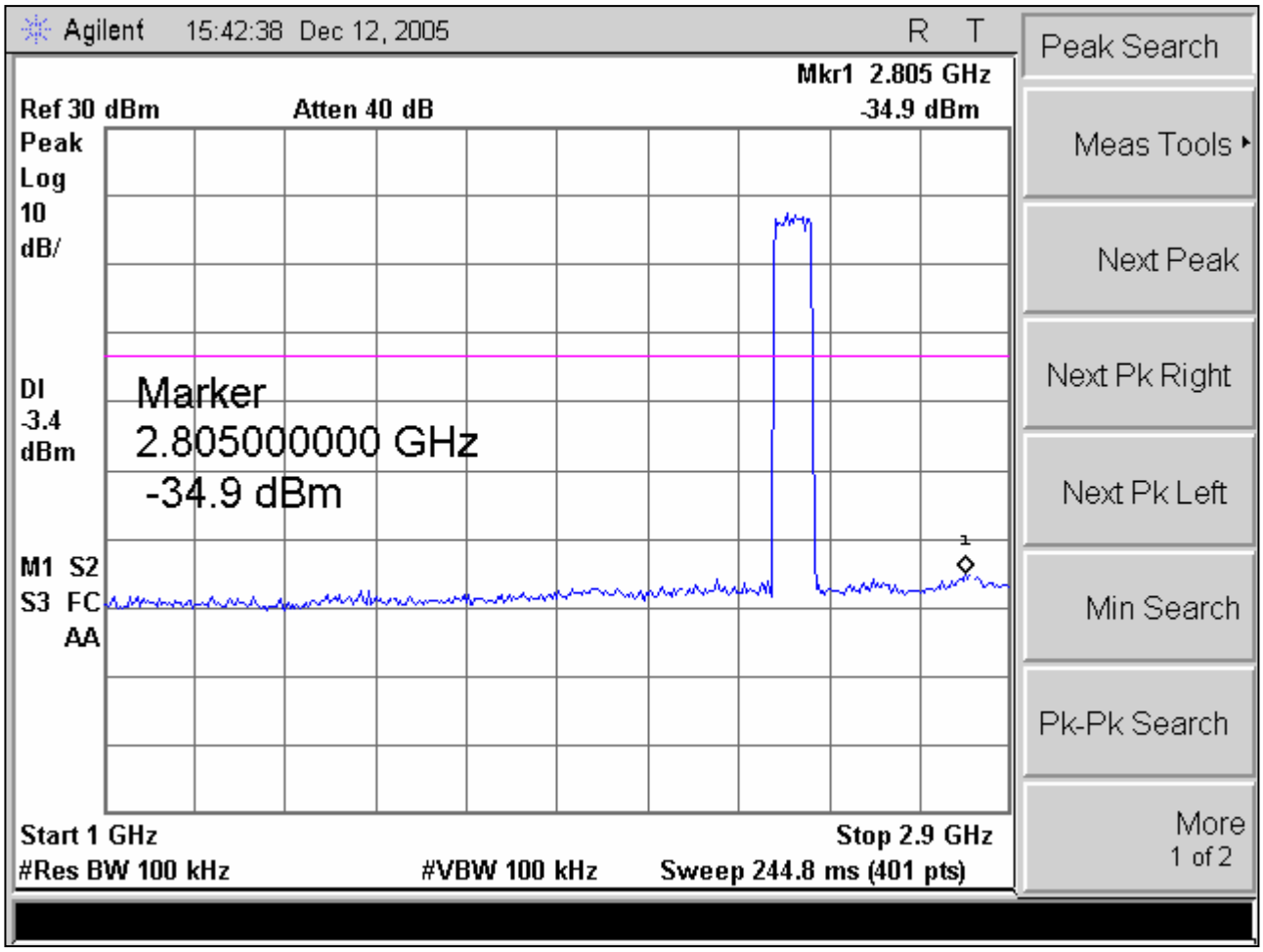
Test Date: December 12, 2005

Spurious Conducted Emissions



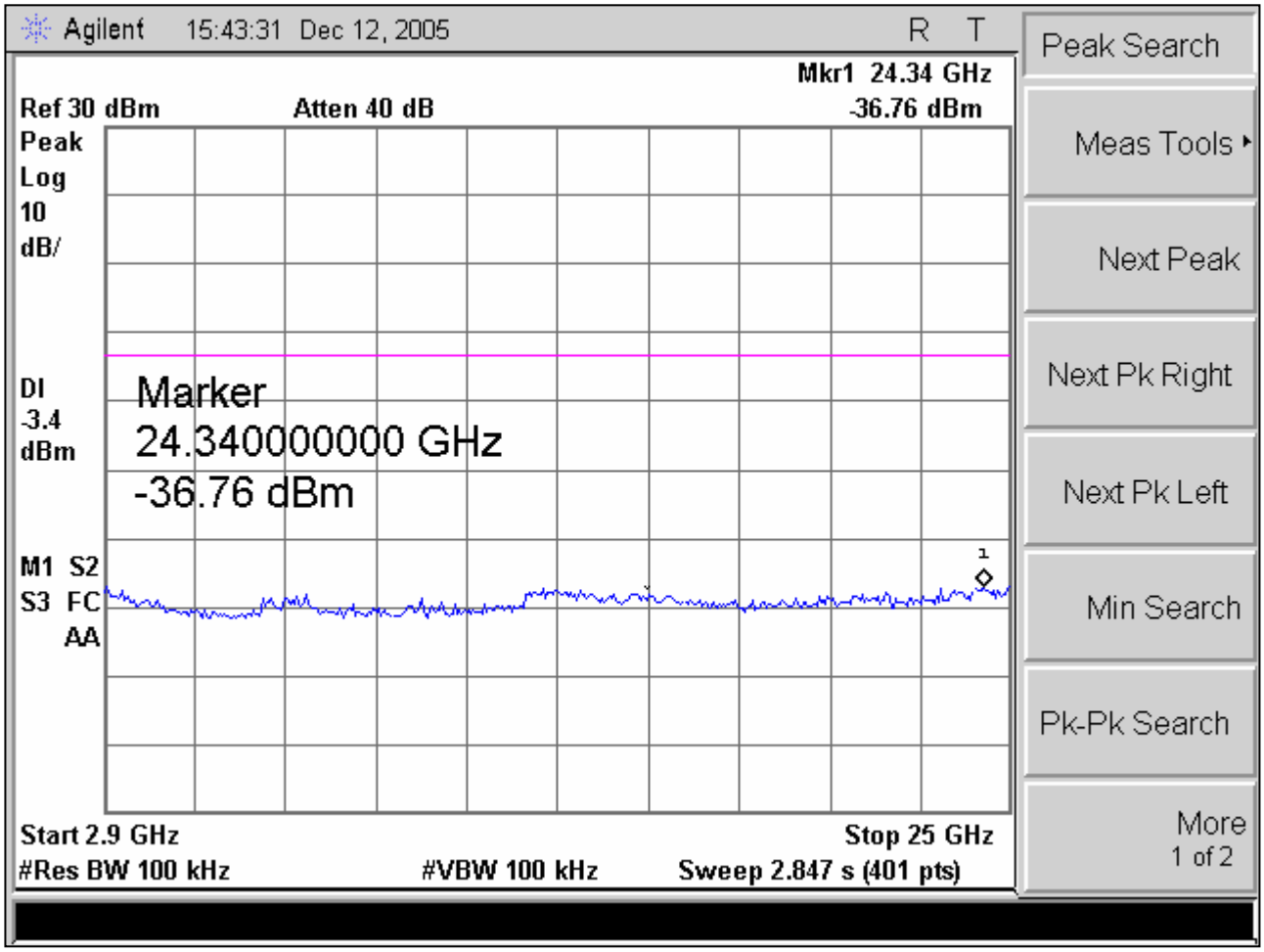
Plot 15. Spurious Conducted Emission Test Plot – 30 MHz to 1 GHz

Spurious Conducted Emissions



Plot 16. Spurious Conducted Emission Test Plot – 1 GHz to 2.9 GHz

Spurious Conducted Emissions



Plot 17. Spurious Conducted Emission Test Plot – 2.9 GHz to 25 GHz

Spurious Conducted Emissions

Photograph 5. Spurious Conducted Emissions Test setup

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 3:

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. Note 2: Above 38.6			

Table 10. Restricted Bands of Operation from FCC Part 15, § 15.205

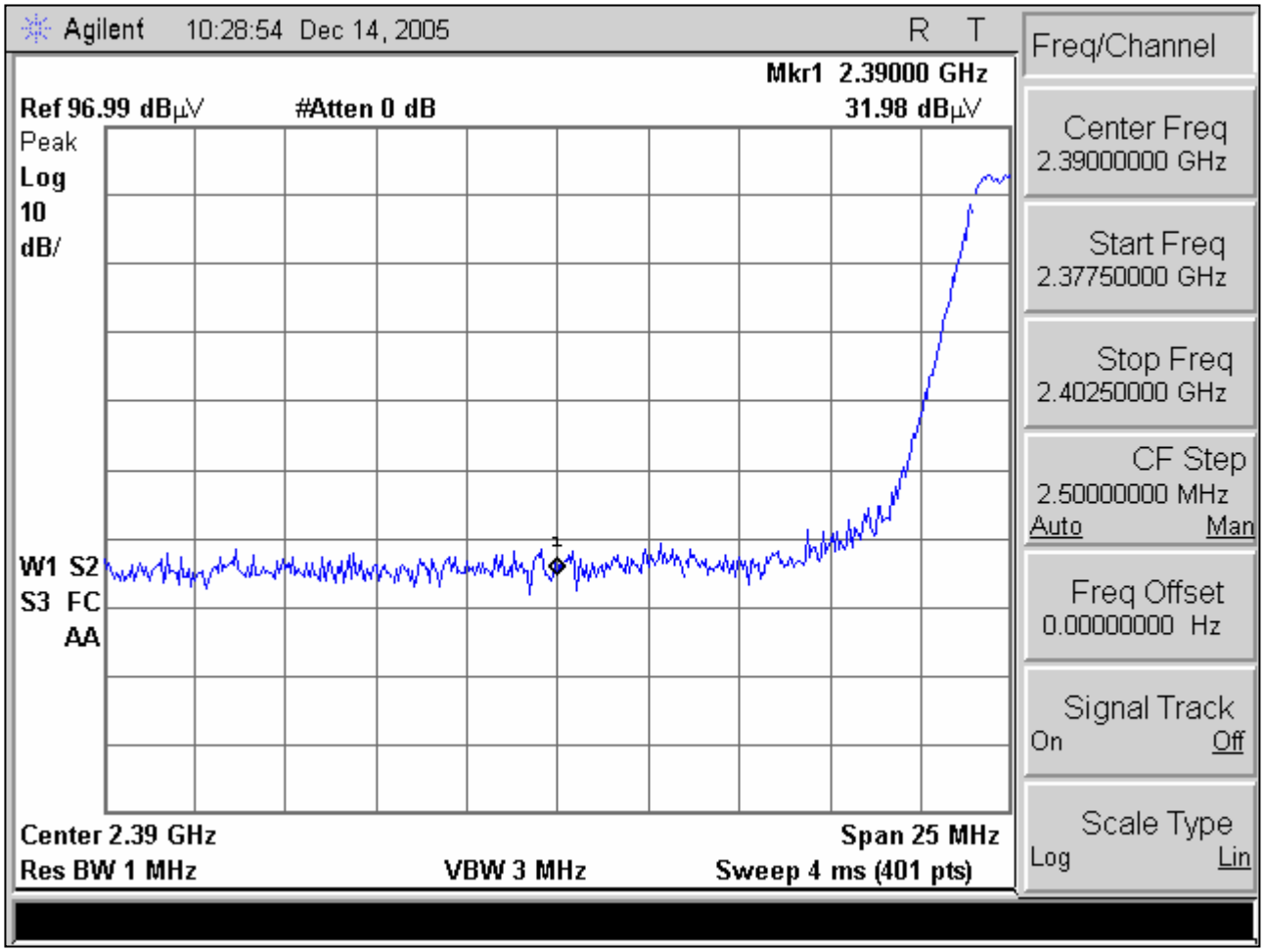
Test Procedure: The EUT was set up on Channel 33. A plot of each channel was taken with a marker showing the nearest bordering Restricted Band.

Test Results: The EUT complies with Band Edge Measurement requirements.

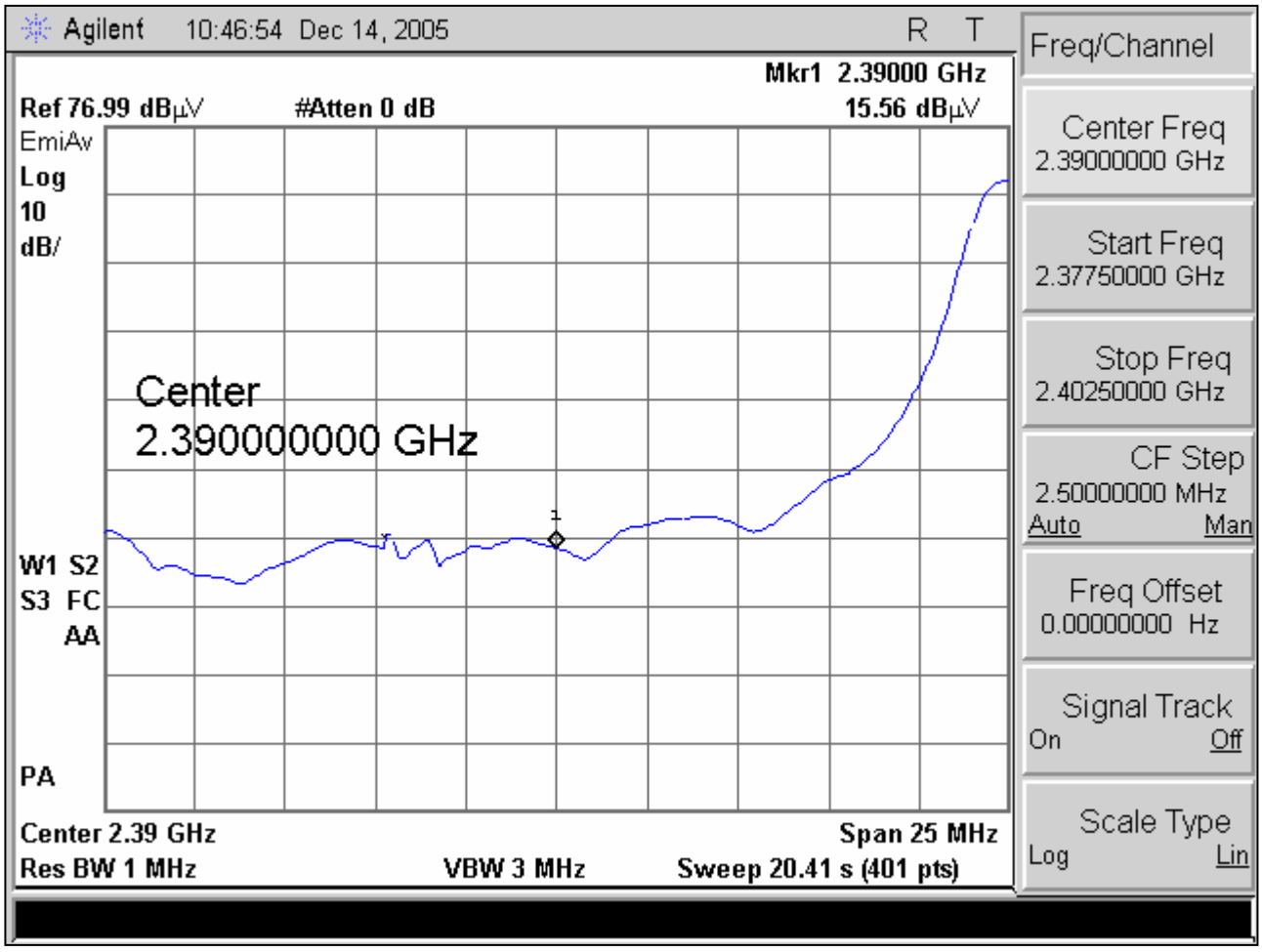
Test Engineer: Dusmantha Tennakoon

Test Date: December 13, 2005 to December 14, 2005

Band Edge Measurements Test Results

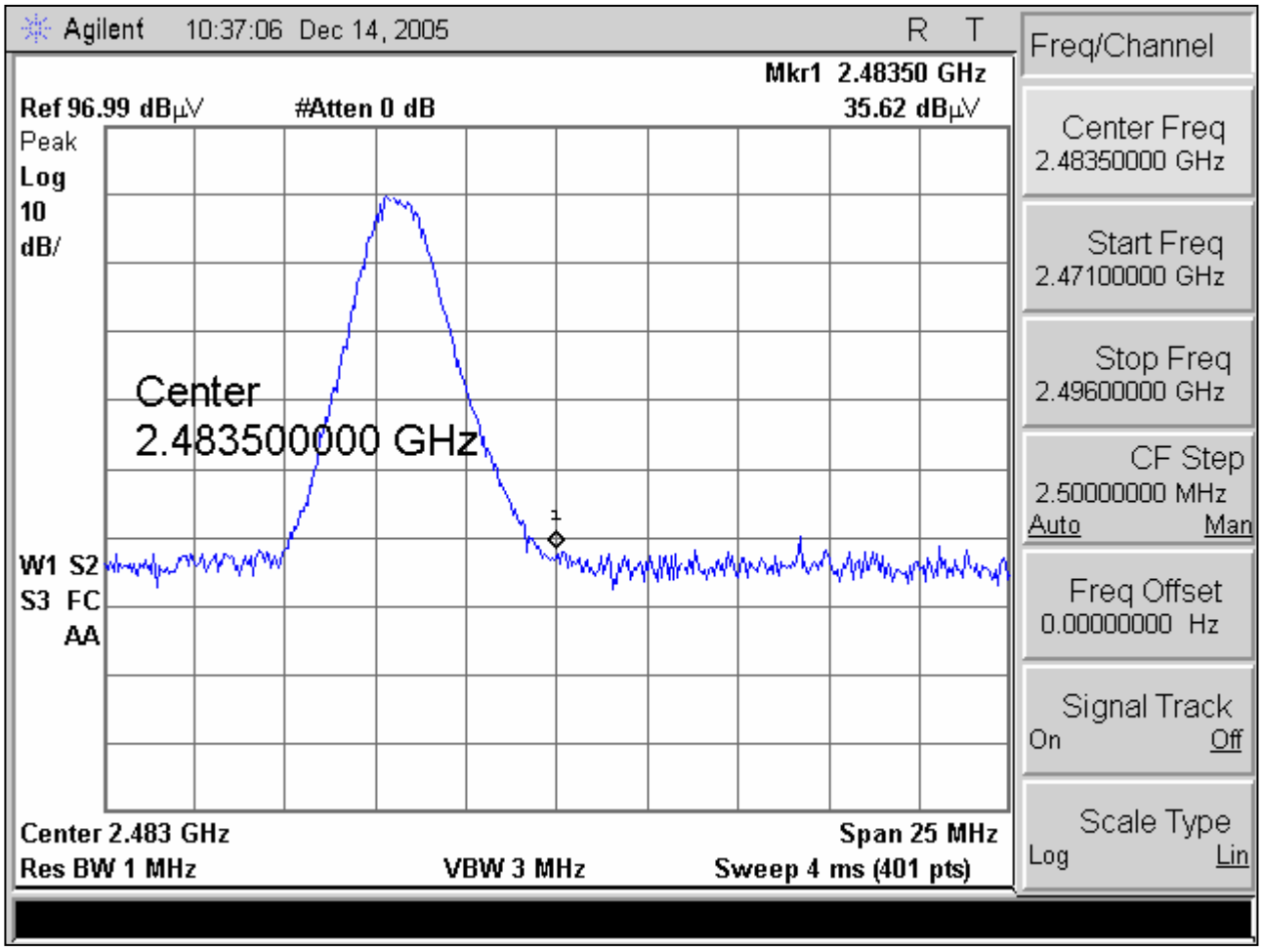


Plot 18. Band Edge Test Results, Channel 1, Peak



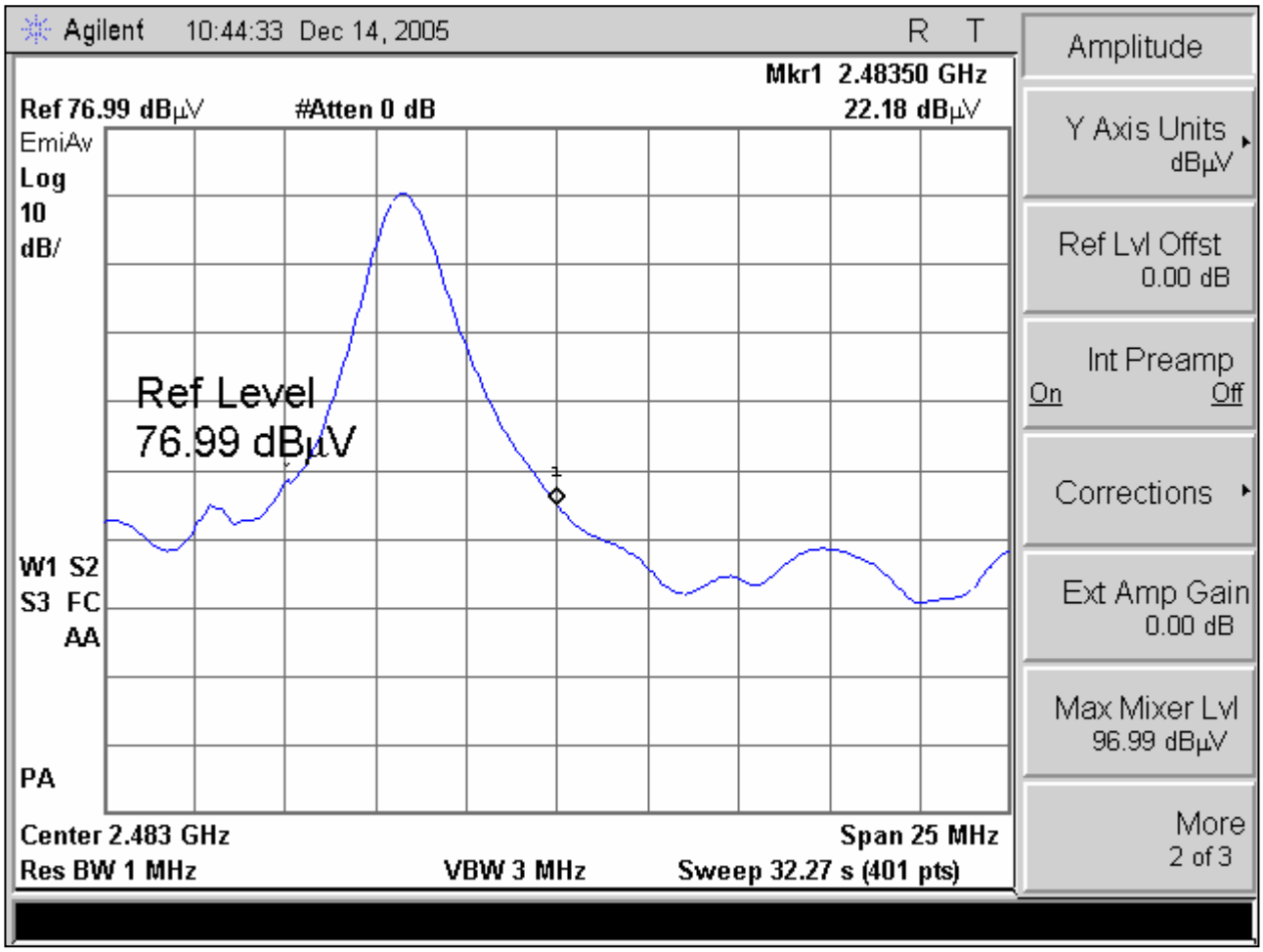
Plot 19. Band Edge Test Results, Channel 1, Average

Average Power level @ 2.39GHz = Measured + Antenna Correction Factor + Cable Loss
= 15.56 + 28.89 + 2.40
= 46.85 dBµV



Plot 20. Band Edge Test Results, Channel 78 - Peak

Band Edge Measurements Test Results



Plot 21. Band Edge Test Results, Channel 78 - Average

Average Power level @ 2.4835GHz = Measured + Antenna Correction Factor + Cable Loss
= 22.18 + 28.89 + 2.60
= 53.67 dBµV

Photograph 6. Band Edge Test Setup

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:

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 (32 × 32 = 1024 hops for an established connection to a GC-205 RCU, 32 × 32 = 2496 hops for a connection to a Sensor Car Transceiver, 15 × 32 = 480 hops for link establishment).

Test Engineer: Dusmantha Tennakoon

Test Date: December 20, 2005

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.

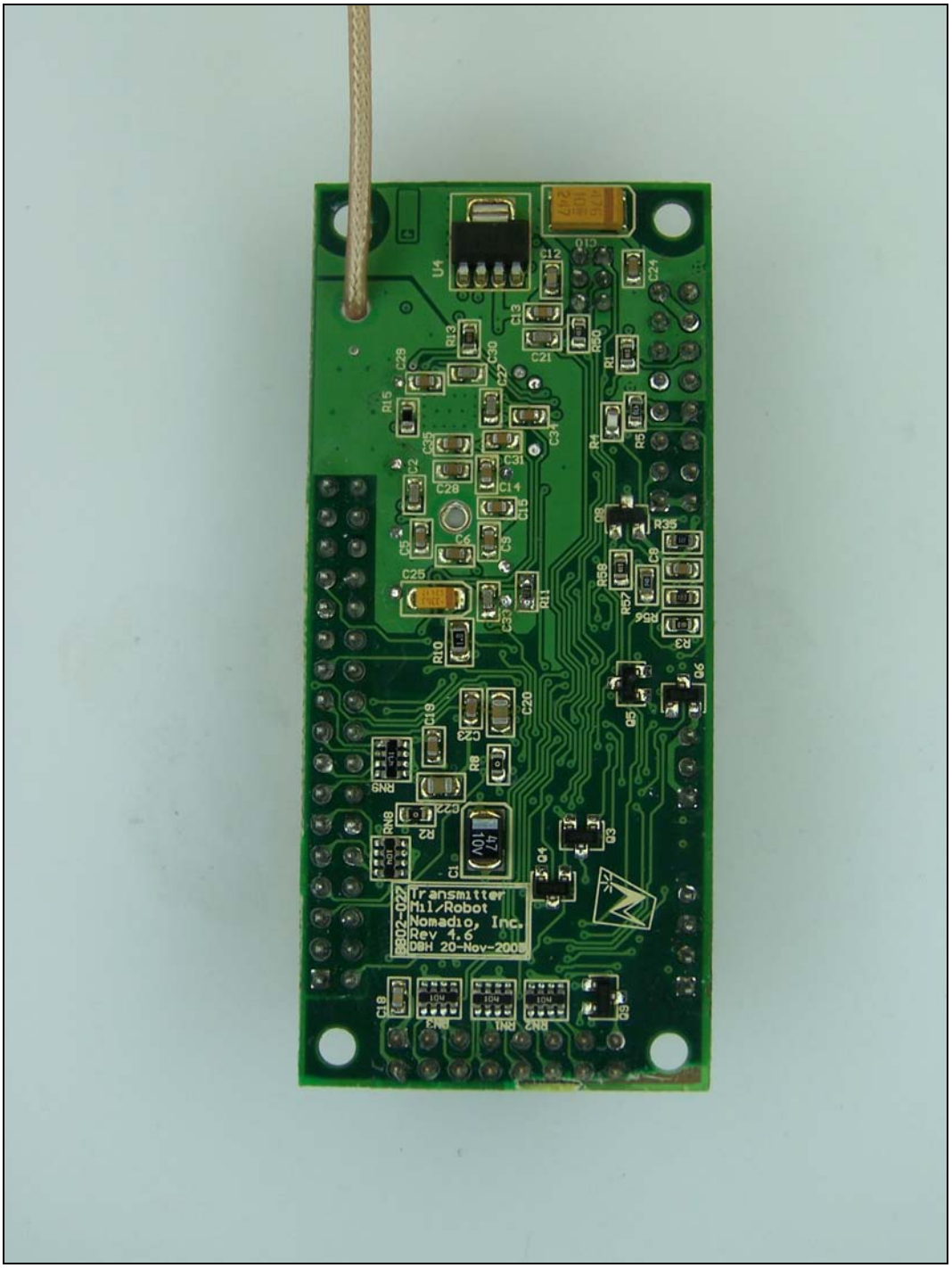
System Receiver Hopping Capability – Customer Declaration:

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.

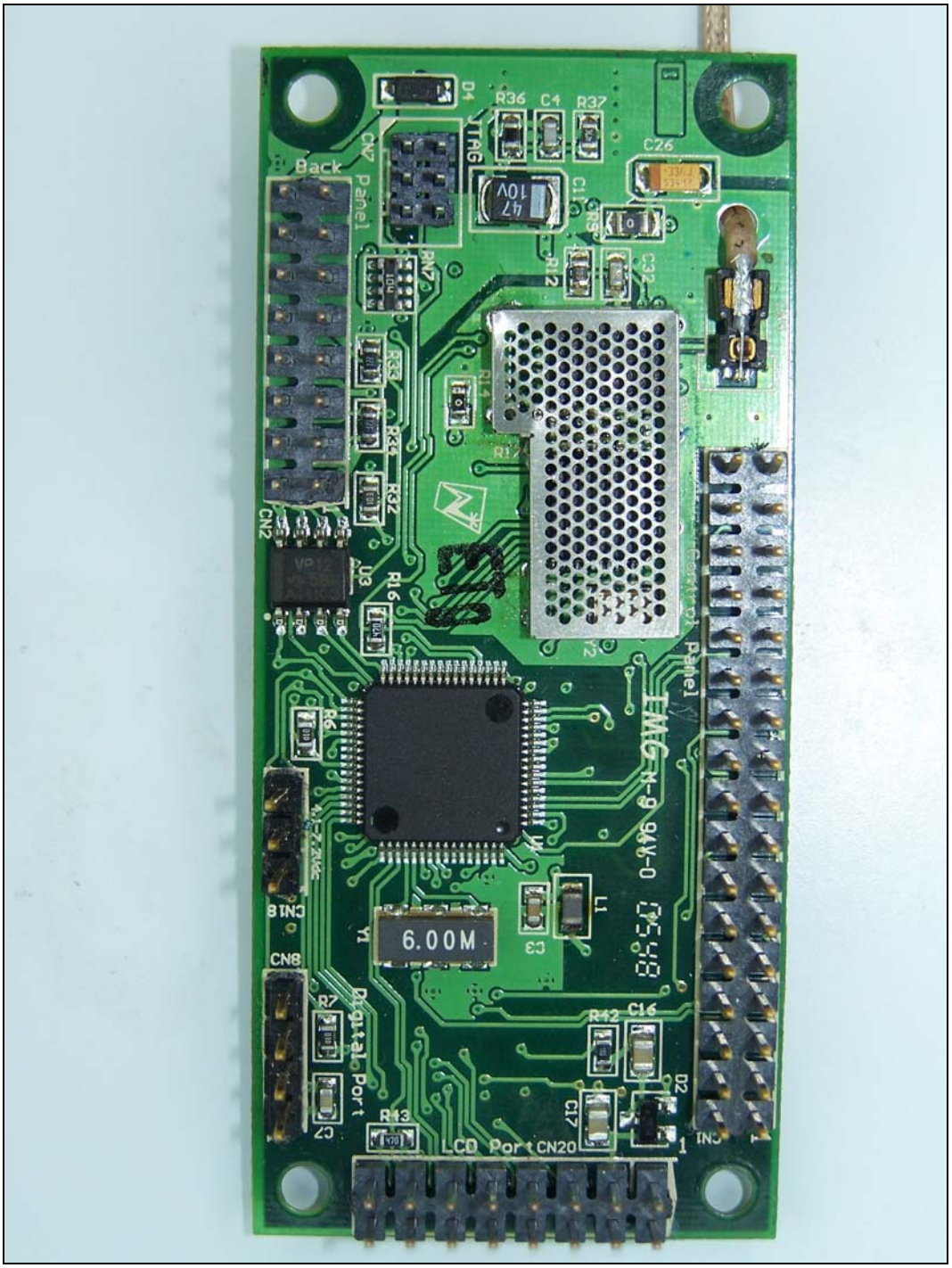
Test Engineer: Dusmantha Tennakoon

Test Date: December 20, 2005

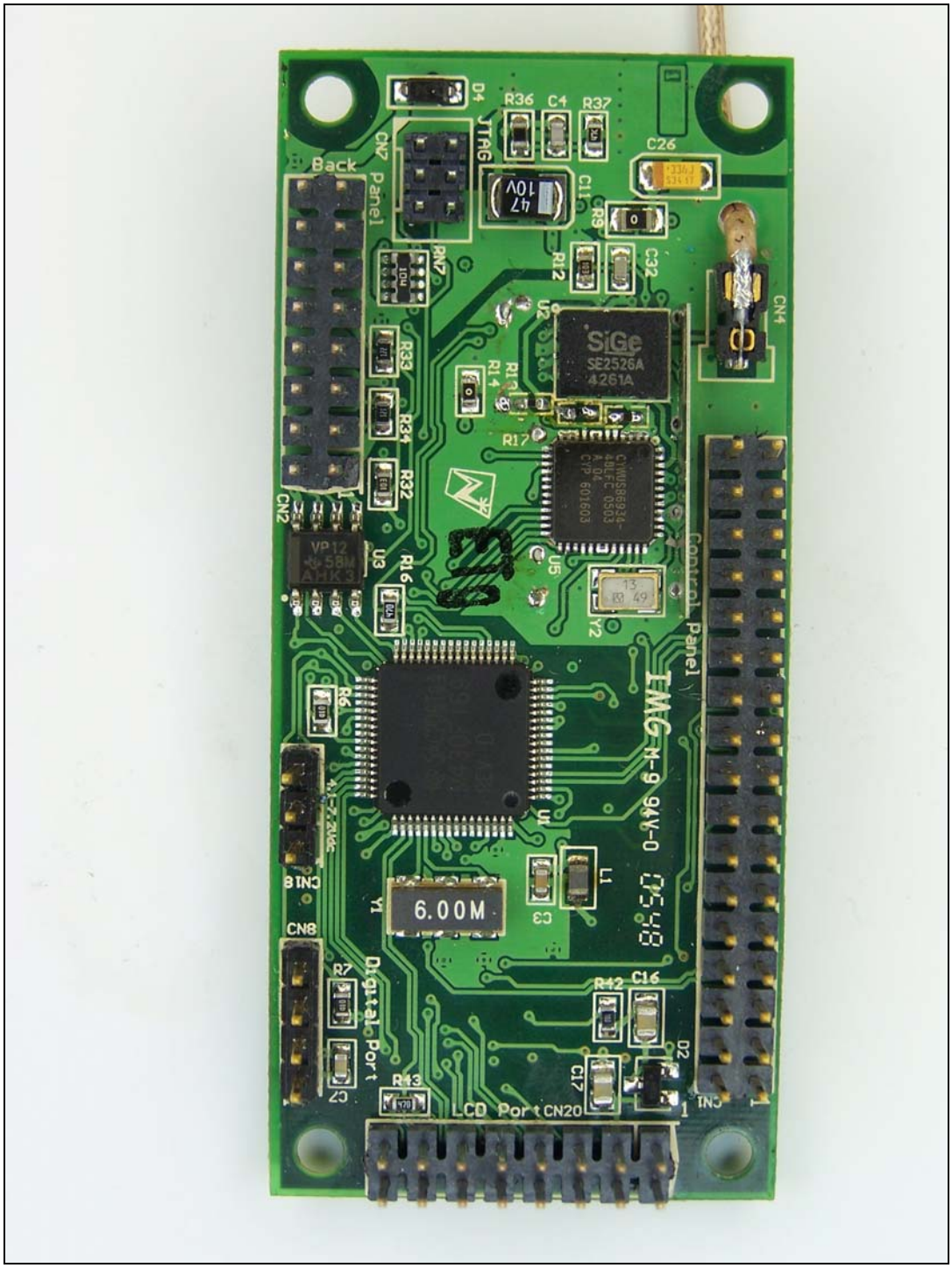
3.12 Internal Photographs



Photograph 7. Internal Photograph 1



Photograph 8. Internal Photograph 2 (With Shield)



Photograph 9. Internal Photograph 3 (Without Shield)

4.0 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	05/13/2005	05/13/2006
1T4300	SEMI-ANECHOIC CHAMBER # 1	EMC TEST SYSTEMS	NONE	05/03/2003	04/03/2006
1T4459	Thermo-Hygrometer	Fisher Scientific	11-661-71D	11/08/2004	11/08/2006
1T4409	EMI Receiver	Rhode & Schwarz	ESIB7	04/14/2005	04/14/2006
IT2665	Antenna; horn	EMCO	3115	3/28/05	3/28/06
IT4351	Spectrum Analyzer	Agilent	E7405A	10/4/05	10/4/06
IT4503	Shielded Room	Universal Shielding	N/A	4/30/05	4/30/06

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

5.0 Compliance Information

5.1 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.

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.

§ 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.

5.2 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.

6.0 Annex 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-300 SRM 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 2402 MHz to 2479 MHz, for a total of 78 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. Some remote devices, such as the GC-205 RCU, use a reduced frequency set. The SRU adapts its hop sequence to match the capabilities of the linked device.

This is accomplished by adapting the basic Nomadio hop sequence to use only those frequencies available on the linked device. 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 79×2^{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-300 can use four different hop sets, depending on device configuration and the nature of the linked device. These hop sets include a full-band 78 channel hop set, a full-band 15-channel hop set for rendezvous, a 32-channel hop limited to the upper portion of the band, and a 15-channel rendezvous hop set limited to the upper portion of the band.

The rendezvous hop set is set at system configuration time, depending on the nature of the intended remote device. Six channels are shared between the two rendezvous sets, allowing connections between GC-series devices and Sensor devices. When a connection is established, the remote device selects the hop set used for the connection.

Channel Sets

Full Band	Rendezvous	3, 8, 13, 18, 23, 28, 33, 38, 43, 48, 53, 58, 63, 68, 73
	Connected	0, 1, 2, ... 75, 76, 77
Reduced Band	Rendezvous	48, 53, 58, 63, 68, 73, 50, 54, 57, 61, 64, 67, 71, 74, 77
	Connected	45, 46, 47, ... 75, 76, 77

Frequency = channel + 2402 MHz

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 ($32 \times 32 = 1024$ hops for an established connection to a GC-205 RCU, $32 \times 32 = 2496$ hops for a connection to a Sensor Car Transceiver, $15 \times 32 = 480$ 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.

