Excellence in Compliance Testing

Certification Test Report

Frequency Hopping Spread Spectrum Transceiver

Test Report

FCC ID: VPU-4970726505

FCC Rule Part: 15.247

ACS Report Number: 07-0439 - 15C

Manufacturer: Georgia Institute of Technology
Model: Fluke-5

Test Begin Date: December 18, 2007
Test End Date: December 19, 2007

Report Issue Date: January 14, 2008

FOR THE SCOPE OF ACCREDITATION UNDER LAB Code 200612-0

This report is not be used to claim certification, approval, or endorsement by NVLAP, NIST or any government agency.

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This report contains 20 pages

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1.0 GENERAL

1.1 Purpose

The purpose of this report is to demonstrate compliance with Part 15 Subpart C of the FCC's Code of Federal Regulations.

1.2 Product Description

1.2.1 General

The Fluke-5 robot upgrade module is a device by which low cost robots are reprogrammed to support Microsoft Robotics Studio (MSRS) and expanded to provide the capability that instructional lessons depend upon. The specific areas of the robot which are upgraded include computation, wireless communication and sensors. The sensors which are included on the robot upgrade module include a camera, IR sensors and battery voltage detection.

Manufacturer Information:
Georgia Institute of Technology
85 5th Street
Atlanta, GA 30332-0760

Test Sample Condition:
The sample was provided with no visible defects and in working condition.

Detailed photographs of the EUT are filed separately with this filing.

1.2.2 Intended Use

The Fluke-5 robot upgrade module is a device by which low cost robots are reprogrammed to support Microsoft Robotics Studio (MSRS) and expanded to provide the capability that instructional lessons depend upon.

1.3 Test Methodology and Considerations

The Fluke-5 robot module was tested in multiple orientations for radiated emissions and the worst case data provided in this report.

After completion of the radiated emissions measurements, the Fluke-5 was modified with a temporary 50 ohm RF output SMA connector for conducted RF measurements.

2.0 TEST FACILITIES

2.1 Location

The radiated and conducted emissions test sites are located at the following address:

Advanced Compliance Solutions
5015 B.U. Bowman Drive
Buford, GA 30518
Phone: (770) 831-8048
Fax: (770) 831-8598

2.2 Laboratory Accreditations/Recognitions/Certifications

The Semi-Anechoic Chamber Test Site, Open Area Test Site (OATS) and Conducted Emissions Site have been fully described, submitted to, and accepted by the FCC, Industry Canada and the Japanese Voluntary Control Council for Interference by information technology equipment. In addition, ACS is compliant to ISO 17025 as certified by the National Institute of Standards and Technology under their National Voluntary Laboratory Accreditation Program. The following certification numbers have been issued in recognition of these accreditations and certifications:

FCC Registration Number: 894540
Industry Canada Lab Code: IC 4175
VCCI Member Number: 1831

- VCCI OATS Registration Number R-1526
- VCCI Conducted Emissions Site Registration Number: C-1608

NVLAP Lab Code: 200612-0

2.3 Radiated Emissions Test Site Description

2.3.1 Semi-Anechoic Chamber Test Site

The Semi-Anechoic Chamber Test Site consists of a 20' x 30' x 18' shielded enclosure. The chamber is lined with Toyo Ferrite Grid Absorber, model number FFG-1000. The ferrite tile grid is 101 x 101 x 19mm thick and weighs approximately 550 grams. These tiles are mounted on steel panels and installed directly on the inner walls of the chamber.

The turntable is 150cm in diameter and is located 160cm from the back wall of the chamber. The chamber is grounded via 1 - 8' copper ground rod, installed at the center of the back wall, it is bound to the ground plane using 3/4" stainless steel braided cable.

The turntable is all steel, flush mounted table installed in an all steel frame. The table is remotely operated from inside the control room located 25' from the range. The turntable is electrically bonded to the surrounding ground plane via steel fingers installed on the edge of the turn table. The steel fingers make constant contact with the ground plane during operation.

Behind the turntable is a 3' x 6' x 4' deep shielded pit used for support equipment if necessary. The pit is equipped with 1 - 4" PVC chases from the turntable to the pit that allow for cabling to the EUT if necessary. The underside of the turntable can be accessed from the pit so cables can be supplied to the EUT from the pit.

A diagram of the Semi-Anechoic Chamber Test Site is shown in Figure 2.3-1 below:

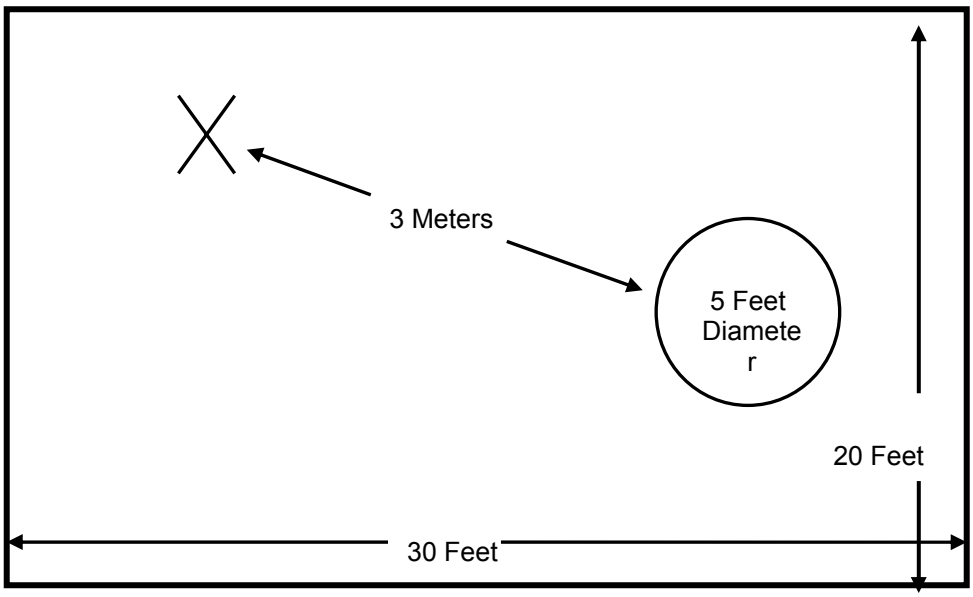

Figure 2.3-1: Semi-Anechoic Chamber Test Site

2.3.2 Open Area Tests Site (OATS)

The open area test site consists of a 40' x 66' concrete pad covered with a perforated electro-plated galvanized sheet metal. The perforations in the sheet metal are 1/8" holes that are staggered every 3/16". The individual sheets are placed to overlap each other by 1/4" and are riveted together to provide a continuous seam. Rivets are spaced every 3" in a 3 x 20 meter perimeter around the antenna mast and EUT area. Rivets in the remaining area are spaced as necessary to properly secure the ground plane and maintain the electrical continuity.

The entire ground plane extends 12' beyond the turntable edge and 16' beyond the antenna mast when set to a 10 meter measurement distance. The ground plane is grounded via 4 - 8' copper ground rods, each installed at a corner of the ground plane and bound to the ground plane using 3/4" stainless steel braided cable.

The turntable is an all aluminum 10' flush mounted table installed in an all aluminum frame. The table is remotely operated from inside the control room located 40' from the range. The turntable is electrically bonded to the surrounding ground plane via steel fingers installed on the edge of the turn table. The steel fingers make constant contact with the ground plane during operation.

Adjacent to the turntable is a 7' x 7' square and 4' deep concrete pit used for support equipment if necessary. The pit is equipped with 5 - 4" PVC chases from the pit to the control room that allow for cabling to the EUT if necessary. The underside of the turntable can be accessed from the pit so cables can be supplied to the EUT from the pit. The pit is covered with 2 sheets of 1/4" diamond style re-enforced steel sheets. The sheets are painted to match the perforated steel ground plane; however the underside edges have been masked off to maintain the electrical continuity of the ground plane. All reflecting objects are located outside of the ellipse defined in ANSI C63.4.

A diagram of the Open Area Test Site is shown in Figure 2.3-2 below:

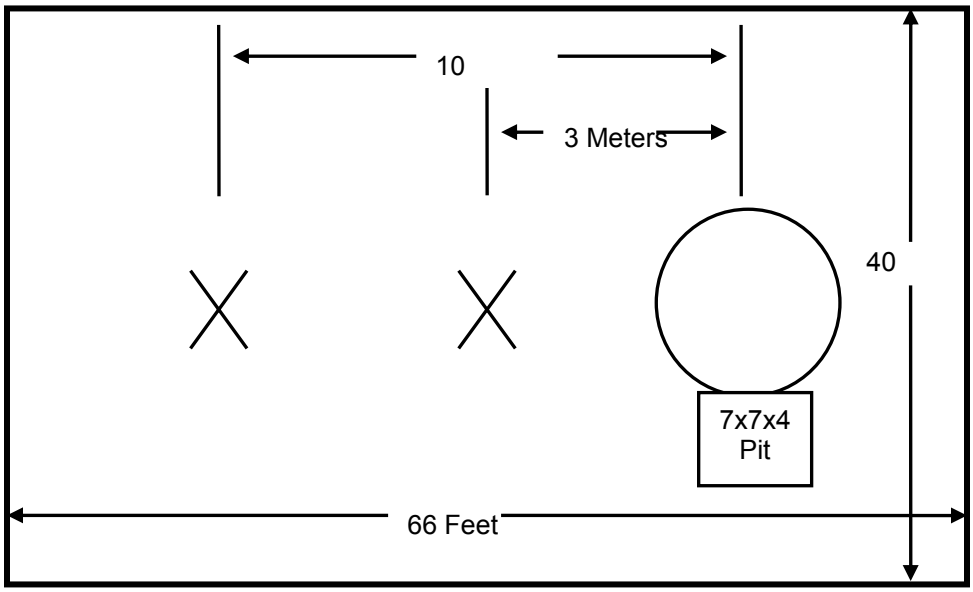

Figure 2.3-2: Open Area Test Site

2.4 Conducted Emissions Test Site Description

The AC mains conducted EMI site is located in the main EMC lab. It consists of an 8' x 8' solid aluminum horizontal group reference plane (GRP) bonded every 3" to an 8' X 8' vertical ground plane.

The site is of sufficient size to test table top and floor standing equipment in accordance with section 6.1.4 of ANSI C63.4.

A diagram of the room is shown below in figure 4.1.3-1:

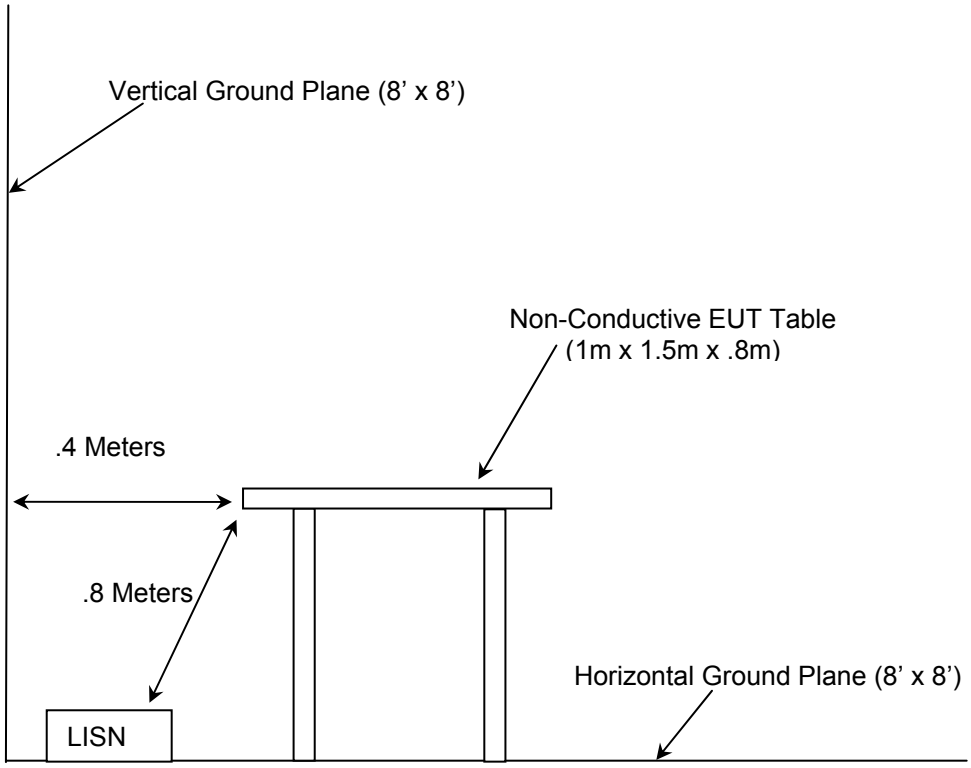

Figure 2.4-1: AC Mains Conducted EMI Site

3.0 APPLICABLE STANDARD REFERENCES

The following standards were used:

- ANSI C63.4-2003: Method of Measurements of Radio-Noise Emissions from Low-Voltage Electrical and Electronic Equipment in the 9KHz to 40GHz
- US Code of Federal Regulations (CFR): Title 47, Part 2, Subpart J: Equipment Authorization Procedures, 2006
- US Code of Federal Regulations (CFR): Title 47, Part 15, Subpart C: Radio Frequency Devices, Intentional Radiators, 2006
- FCC OET Bulletin 65 Appendix C - Evaluating Compliance with FCC Guidelines for Human Exposure to Radiofrequency Electromagnetic Fields, 2001
- FCC Public Notice DA 00-705 - Filing and Measurement Guidelines for Frequency Hopping Spread Spectrum Systems, March 30, 2000

4.0 LIST OF TEST EQUIPMENT

All test equipment used for regulatory testing is calibrated yearly or according to manufacturer's specifications.

Equipment Calibration Information					
ACS#	**Mfg.**	**Eq. type**	**Model**	**S/N**	**Cal. Due**
1	Rohde & Schwarz	Spectrum Analyzers	ESMI - Display	833771/007	10-26-2008
2	Rohde & Schwarz	Spectrum Analyzers	ESMI-Receiver	839587/003	10-26-2008
22	Agilent	Amplifiers	8449B	3008A00526	04-10-2008
30	Spectrum Technologies	Antennas	DRH-0118	970102	05-10-2008
282	Microwave Circuits	Filters	H2G020G4	74541	03-09-2008
283	Rohde & Schwarz	Spectrum Analyzers	FSP40	1000033	11-09-2008
290	Florida RF Cables	Cables	SMSE-200-72.0-SMRE	None	11-21-2008
291	Florida RF Cables	Cables	SMRE-200W-12.0-SMRE	None	11-21-2008
292	Florida RF Cables	Cables	SMR-290AW-480.0-SMR	None	11-21-2008
321	Hewlett Packard	Amplifiers	HPC 8447D	1937A02809	07-17-2008
332	Rohde & Schwarz	Amplifiers	TS-PR40	100021	10-26-2008
333	Rohde&Schwarz	Antennas	Sep-60	49404	09-11-2007
334	Rohde&Schwarz	Antennas	Oct-60	45576	09-11-2007
335	Suhner	Cables	SF-102A	882/2A	10-25-2008
343	Florida RF Cables	Cables	SMRE-200W-12.0-SMRE	N/A	11-21-2008
345	Suhner Sucoflex	Cables	102A	1077/2A	10-25-2008
346	Aeroflex/Weinschel	Attenuators	54A-10	T1362	10-25-2008

Table 4-1: Test Equipment

5.0 SUPPORT EQUIPMENT

Table 5-1: Support Equipment

Manufacturer	Equipment Type	Model Number	Serial Number
OK Industries	DC Power Supply	PS732	36095

6.0 EQUIPMENT UNDER TEST SETUP BLOCK DIAGRAM

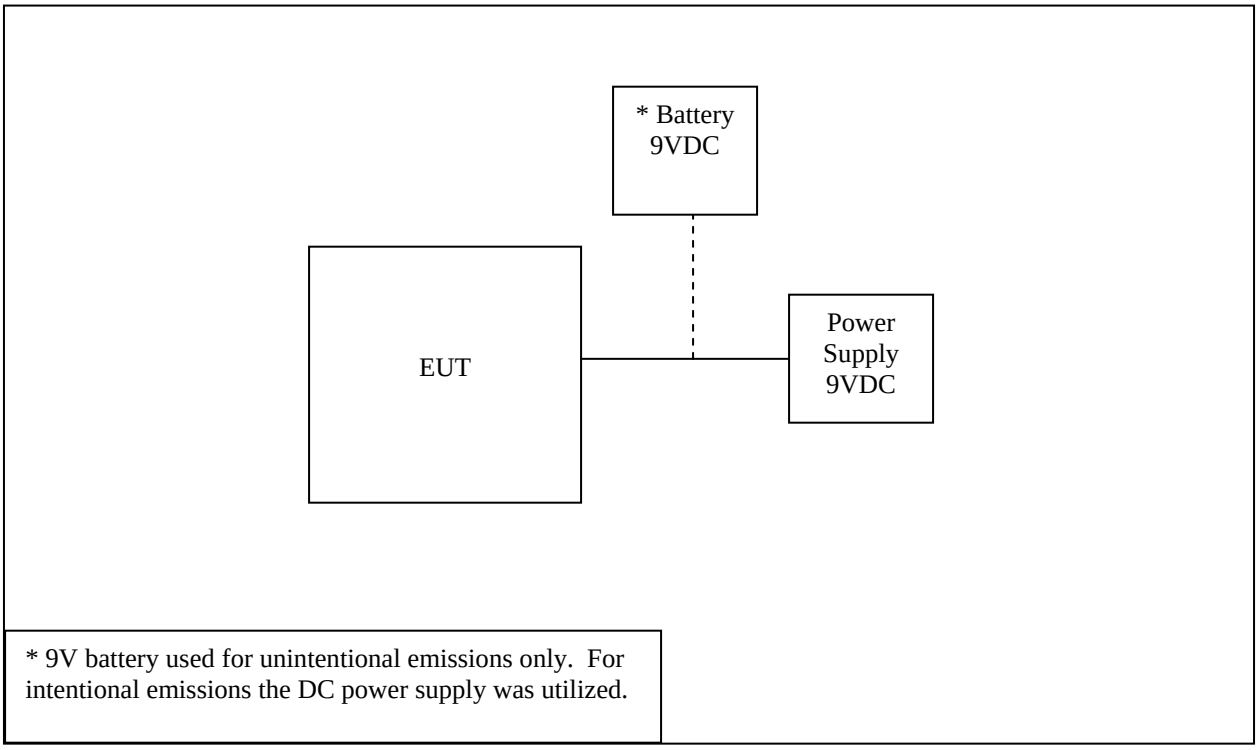

Figure 6-1: EUT Test Setup

*See Test Setup photographs for additional detail.

7.0 SUMMARY OF TESTS

Along with the tabular data shown below, plots were taken of all signals deemed important enough to document.

7.1 Antenna Requirement

The ANT-2.45-CHP-x is a ¼ wave omni-directional a 0.5dBi gain antenna chip.

7.2 Power Line Conducted Emissions

The Fluke-5 Bluetooth FHSS module receives its power from the robot host battery. No Power Line Conducted Tests were performed.

7.3 Radiated Emissions - Unintentional Radiation

7.3.1 Test Methodology

Radiated emissions tests were performed over the frequency range of 30MHz to 12.5GHz. Measurements of the radiated field strength were made at a distance of 3m from the boundary of the equipment under test (EUT) and the receiving antenna. The antenna height was varied from 1m to 4m so that the maximum radiated emissions level would be detected. Radiated measurements were made with the Spectrum Analyzer's resolution bandwidth set to 120 KHz for measurements from 30 - 1000MHz. For measurement above 1000MHz both peak and average measurements were taken. Peak measurements were taken with the RBW and VBW set 1MHz. Average measurements are taken with the RBW and VBW set to 1MHz and 10 Hz respectively.

7.3.2 Test Results

Results of the test are given in Table 7.3-1 below:

Table 7.3-1: Radiated Emissions Tabulated Data

Frequency (MHz)	Level (dBuV)	Antenna Polarity	Correction Factors	Corrected Level (dBuV/m)	Limit (dBuV/m)	Margin (dB)
	Qpk/Avg	(H/V)	(dB)	Qpk/Avg	Qpk/Avg	Qpk/Avg
30	20.00	H	-6.70	13.30	40.0	26.70
50	10.00	H	-16.70	-6.70	40.0	46.70
70	8.00	H	-19.90	-11.90	40.0	51.90
90	10.00	H	-16.60	-6.60	43.5	50.10
100	12.00	H	-15.20	-3.20	43.5	46.70
300	13.00	H	-10.90	2.10	46.0	43.90
500	22.00	H	-6.00	16.00	46.0	30.00
800	28.00	H	-0.10	27.90	46.0	18.10
1000	30.00	H	2.90	32.90	54.0	21.10

* Note: All emissions above 1000 MHz were attenuated below the permissible limit.

7.4 Peak Output Power

7.4.1 Test Methodology (Conducted Method)

The 20dB bandwidth of the EUT was within the resolution bandwidth of spectrum analyzer, therefore the power measurement was made using the spectrum analyzer method. The RF output port of the EUT was directly connected to the input of the spectrum analyzer. The resolution and video bandwidth were set to > 20 dB bandwidth of the emission measured. The device employs >50 channels therefore the power is limited to 1 Watt.

7.4.2 Test Results

Results are shown below in table 7.4-1 and the worst case was plotted and shown in figure 7.4-1 to 7.4-3 below:

Table 7.4-1: RF Output Power

Frequency [MHz]	Level [dBm]
2402	8.58
2441	7.04
2480	2.45

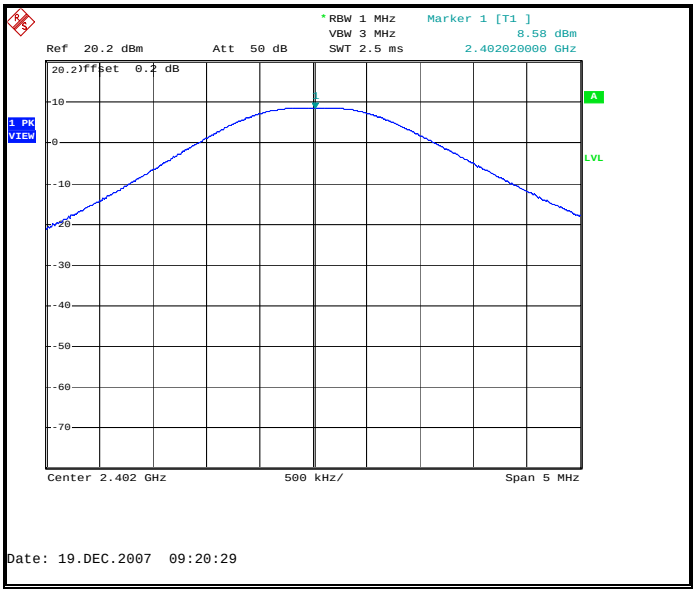

Figure 7.4-1: Output power – Low Channel

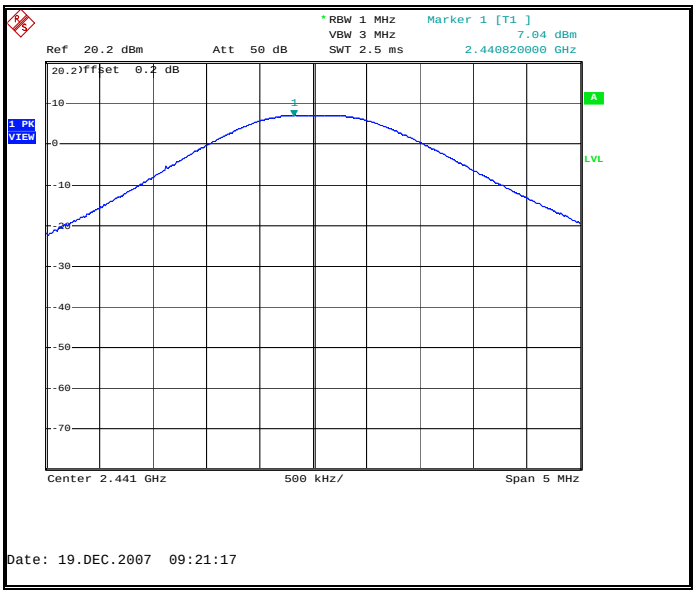

Figure 7.4-2: Output power – Mid Channel

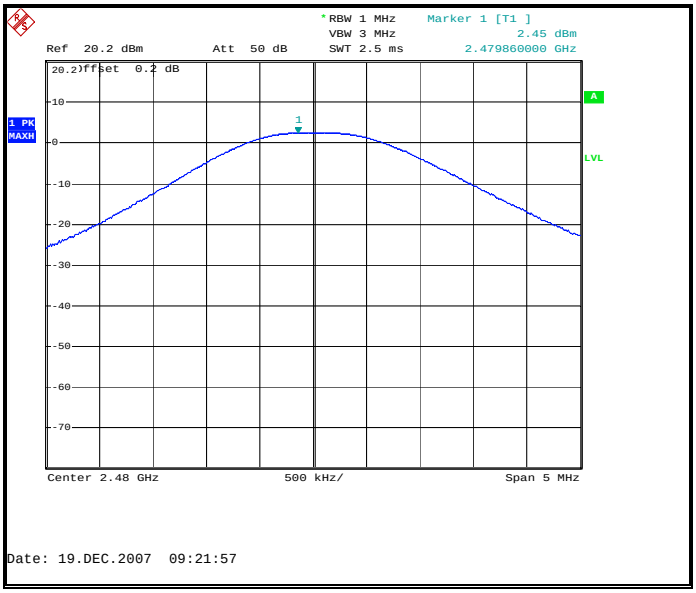

Figure 7.4-3: Output power – High Channel

7.5 Channel Usage Requirements

7.5.1 Carrier Frequency Separation

7.5.1.1 Test Methodology

The span of the spectrum analyzer was set wide enough to capture two adjacent peaks and the RBW and VBW were set to ≥ 1% of the span.

7.5.1.2 Test Results

The maximum 20dB bandwidth of the hopping channel was measured to be 884kHz (See figure 7.5.4-1 to 7.5.4-3 below). The adjacent channel separation was measured to be 1002kHz. Results are shown in figure 7.5.1-1 below:

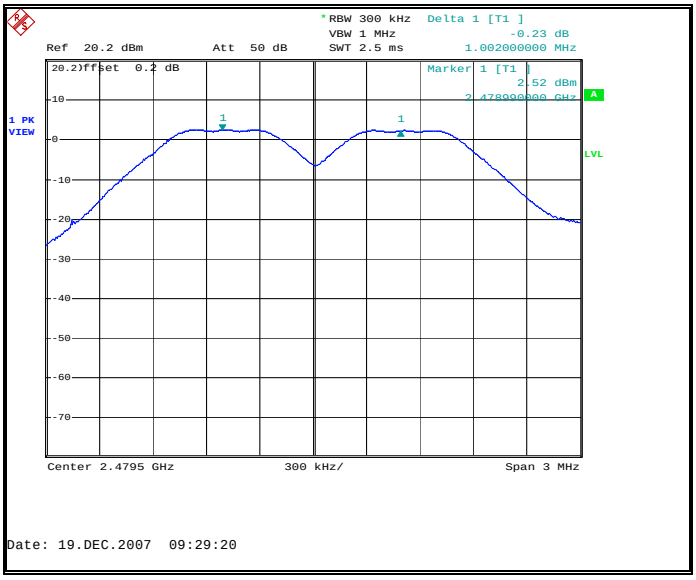

Figure 7.5.1-1: Carrier Frequency Separation

7.5.2 Number of Hopping Channels

The 20dB bandwidth of the device is greater than 250 kHz. The device employs 79 hopping channels as required. Results are shown in Figure 7.5.2-1 below:

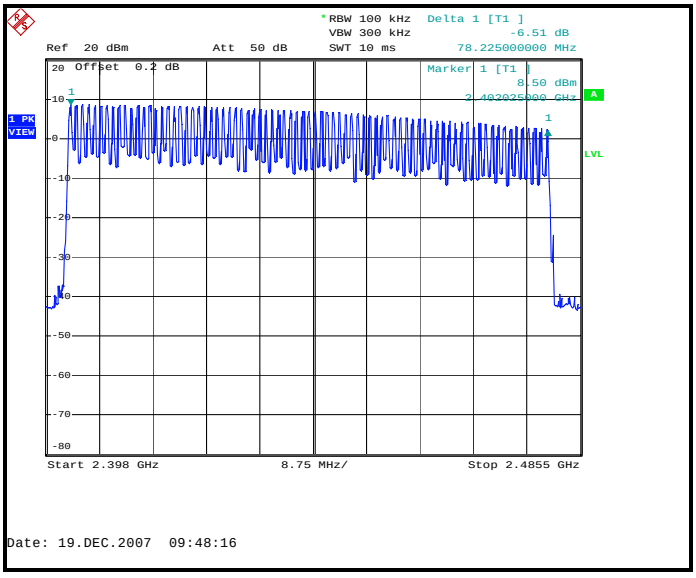

Figure 7.5.2-1: Number of Hopping Channels

7.5.3 Channel Dwell Time

7.5.3.1 Test Methodology

The emission measured centered on the analyzer and the span set to 0 Hz. The RBW was set to 1 MHz and the VBW to 3 MHz. Sweep time was set to 10 ms to capture the burst duration of the emission. The marker –delta function of the analyzer was employed to measure the burst duration.

7.5.3.2 Test Results

The duration of the RF transmission is 2.9 ms. Bluetooth uses 3 different packet types for data transmission. The worst case dwell time will occur with the longest packet type, DH5. A DH5 packet occupies 5 time slots (each 625 usecs) to transmit and then 1 time slot in receive mode. Bluetooth uses 79 different channels, thus it hops approximately 267 times a second. Thus, the same channel is visited 3.38 times a second, and over 31.6 seconds (0.4ms * 79 channels) it is visited 107 times. The TX time on one channel for the largest packet, the DH5 packet, was measured to be 2.9 milliseconds.

Therefore the dwell time for a 31.6 second window is 107 * 2.9 = 310.3 milliseconds

A single transmission is shown in figure 7.5.3-1 below:

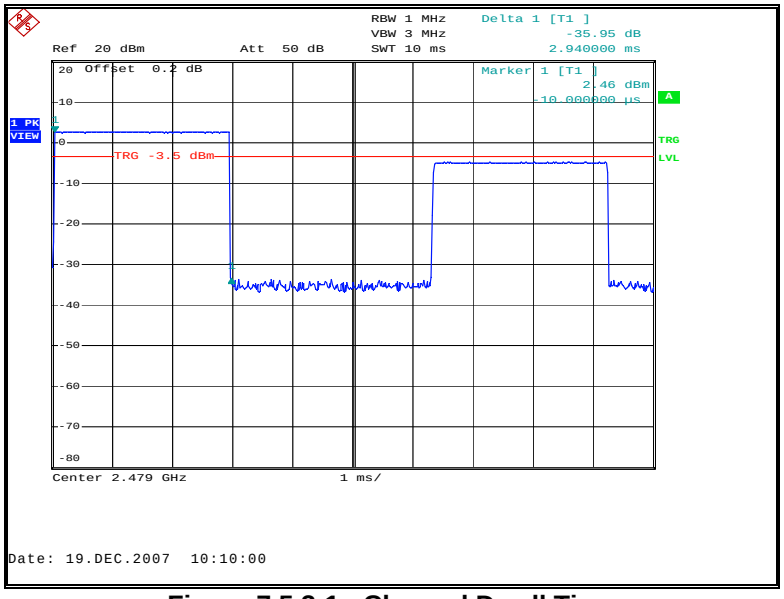

Figure 7.5.3-1: Channel Dwell Time

7.5.4 20dB Bandwidth

7.5.4.1 Test Methodology

The spectrum analyzer span was set to 2 to 3 times the estimated 20 dB bandwidth of the emission. The RBW was to ≥ 1% of the estimated 20 dB bandwidth. The trace was set to max hold with a peak detector active. The Delta function of the analyzer was utilized to determine the 20 dB bandwidth of the emission. The span and RBW were examined and re-adjusted if necessary to meet the requirements of 2 to 3 times the 20 bandwidth for the span and ≥ 1% of the 20 dB bandwidth for the RBW.

7.5.4.2 Test Results

The maximum 20dB bandwidth was found to be approximately 884kHz. Results are shown below in Table 7.5.4-1 and Figures 7.5.4-1 through 7.5.4-3.

Table 7.5.4-1

Channel	Frequency (MHz)	20dB Bandwidth (kHz)
Low	2402	856.0
Mid.	2441	864.0
High	2480	884.0

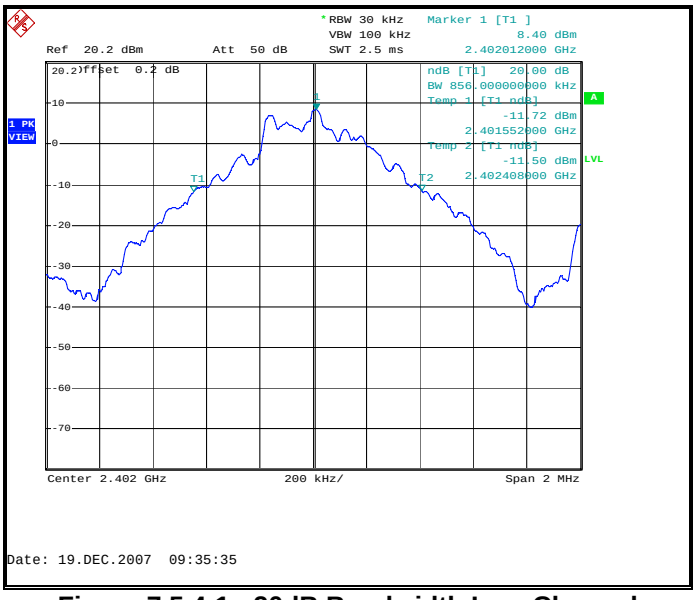

Figure 7.5.4-1: 20dB Bandwidth Low Channel

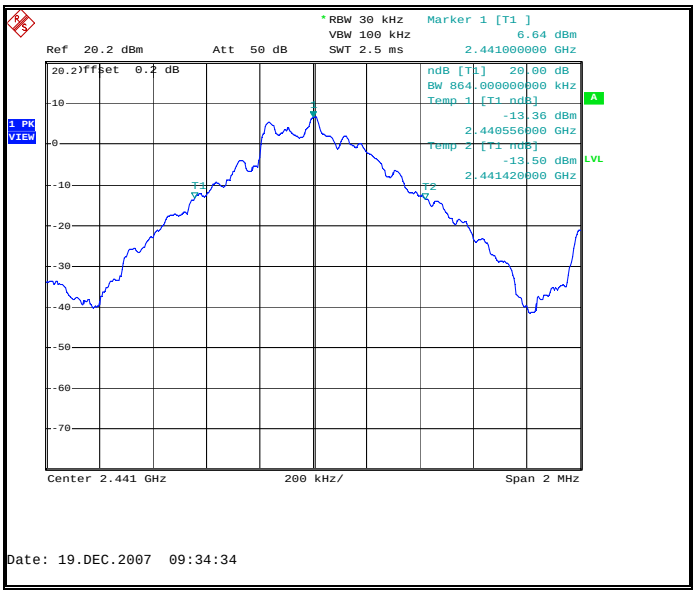

Figure 7.5.4-2: 20dB Bandwidth Mid Channel

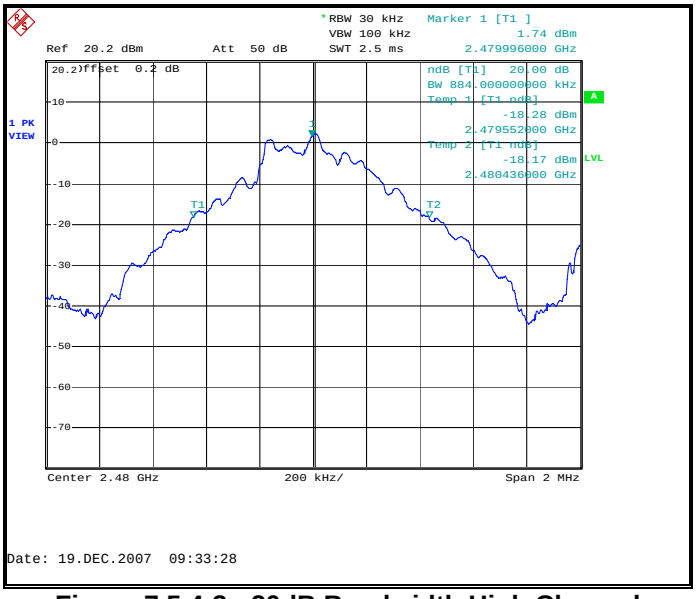

Figure 7.5.4-3: 20dB Bandwidth High Channel

7.6 Band-Edge Compliance and Spurious Emissions

7.6.1 Band-Edge Compliance of RF Emissions

7.6.1.1 Test Methodology

The EUT was investigated at the low and high channels of operation to determine band-edge compliance. All antenna types were evaluated. Because the upper band-edge coincides with a restricted band, band-edge compliance for the upper band-edge was determined using the radiated mark-delta method as outlined in FCC DA 00-705. The radiated field strength of the fundamental emission was first determined and then the mark-delta method was used to determine the field strength of the band-edge emissions.

The lower band-edge compliance was determined using the marker-delta method in which the radio frequency power that is produced by the EUT is at least 20 dB below that in the 100 kHz bandwidth within the band that contains the highest level of desired power.

For average measurements the duty cycle correction detailed in section 7.6.3.2 was applied.

7.6.1.2 Test Results

Band-edge compliance is displayed in Table 7.6.1.2-1 and Figures 7.6.1.2-1 – 7.6.1.2-2.

Table 7.6.1.2-1: Upper Band-edge Marker Delta Method

Frequency (MHz)	Level (dBuV)		Antenna Polarity	Correction Factors	Fundamental Field Strength (dBuV/m)		Delta-Marker (dB)	Band-edge Field Strength (dBuV/m)		Margin to Limit (dBuV/m) 74	54
	pk	avg	(H/V)	(dB)	pk	avg		pk	avg	pk	avg
2480	102.54	102.54	V	-2.04	100.50	69.75	44.47	56.03	25.28	17.97	28.72

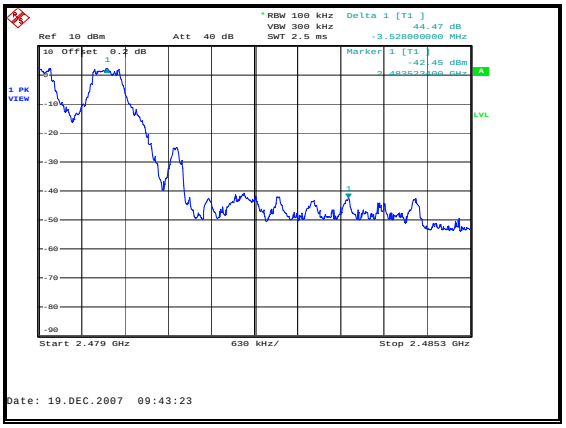

Figure 7.6.1.2-1: Upper Band-edge (Radiated)

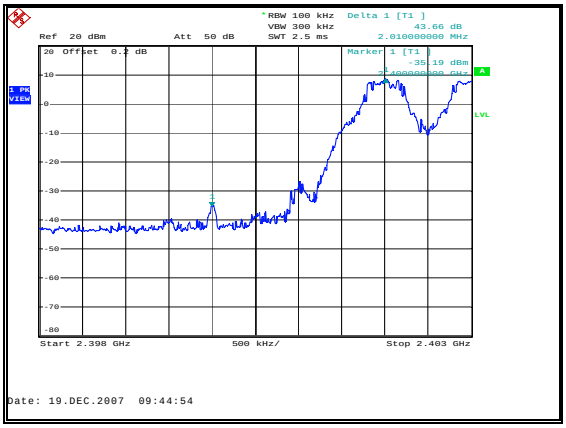

Figure 7.6.1.2-2: Lower Band-edge (Conducted)

7.6.2 RF Conducted Spurious Emissions

The RF Conducted Spurious Emissions were measured in accordance with the FCC KDB Publication No. 558074 “Guidance on Measurements for Digital Transmission Systems (47 CFR 15.247)”. The RF output of the equipment under test was directly connected to the input of the Spectrum Analyzer. The EUT was investigated for conducted spurious emissions from 30MHz to 26GHz, 10 times the highest fundamental frequency. For each measurement, the spectrum analyzer’s RBW was set to 100 kHz and the VBW was set to 300 kHz. The peak detector and Max Hold function of the analyzer were utilized.

7.6.2.2 Test Results

In a 100 kHz bandwidth, the radio frequency power that was produced by the EUT emissions is at least 20 dB below that in the 100 kHz bandwidth within the band that contains the highest level of desired power. RF Conducted Emissions are displayed in Figures 7.6.2.2-1 through 7.6.2.2-6.

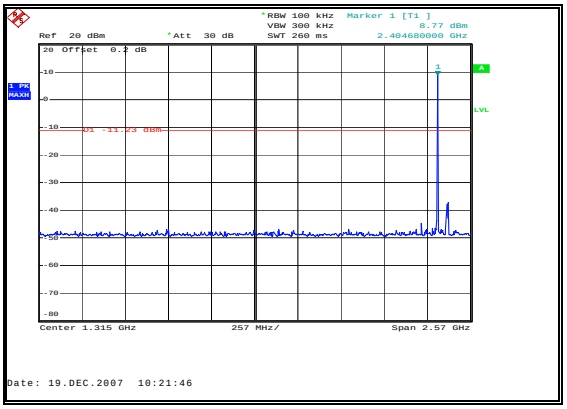

Figure 7.6.2.2-1: 30 MHz – 2.6 GHz – Low Channel

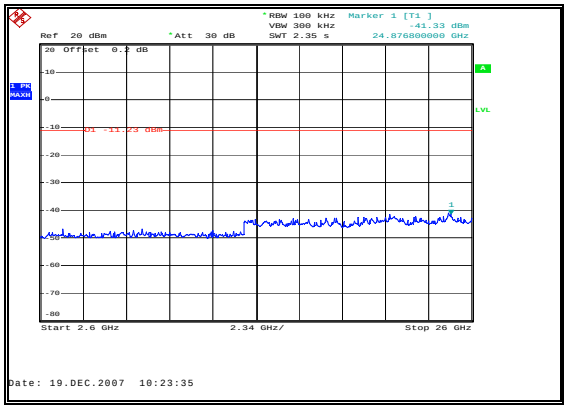

Figure 7.6.2.2-2: 2.6 GHz – 26 GHz – Low Channel

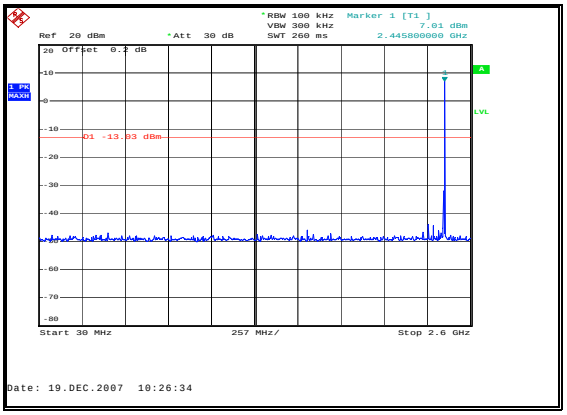

Figure 7.6.2.2-3: 30 MHz – 2.6 GHz –Mid Channel

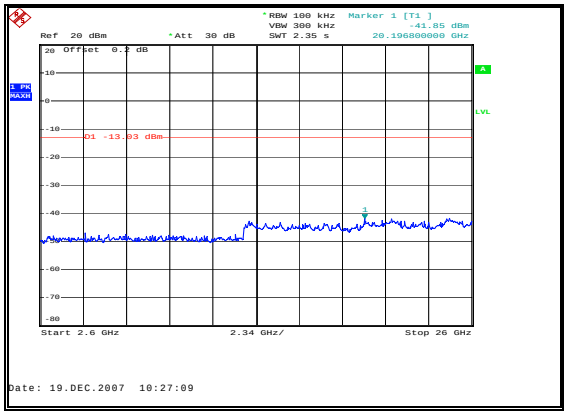

Figure 7.6.2.2-4: 2.6 GHz – 26 GHz – Mid Channel

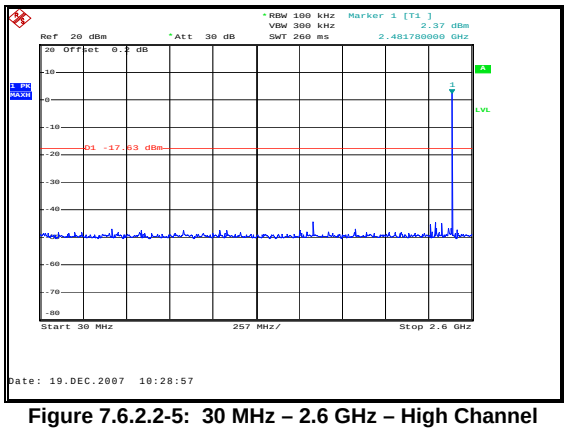

Figure 7.6.2.2-5: 30 MHz – 2.6 GHz – High Channel

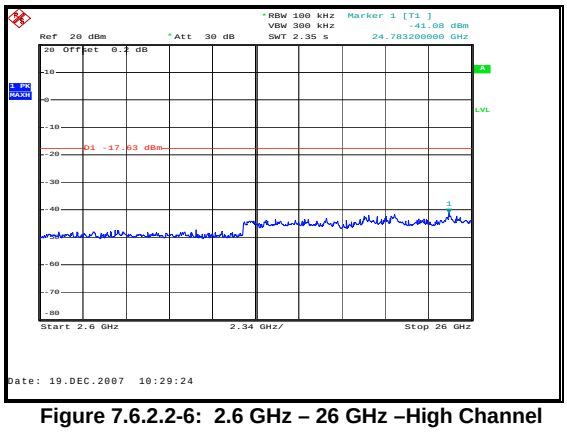

Figure 7.6.2.2-6: 2.6 GHz – 26 GHz –High Channel

7.6.3 Radiated Spurious Emissions – Intentional Radiation

7.6.3.1 Test Methodology

Radiated emissions tests were made over the frequency range of 30MHz to 25GHz, 10 times the highest fundamental frequency.

The EUT was rotated through 360° and the receive antenna height was varied from 1m to 4m so that the maximum radiated emissions level would be detected. For frequencies below 1000MHz, quasi-peak measurements were made using a resolution bandwidth (RBW) of 120 kHz and a video bandwidth (VBW) of 300 kHz. For frequencies above 1000MHz, measurements were made using an RBW of 1 MHz and a VBW of 3 MHz.

7.6.3.2 Duty Cycle Correction

For average radiated measurements in restricted bands, the measured peak level was reduced by a factor 30.75dB to account for the duty cycle of the EUT. The EUT transmits for 2.9ms on a channel and does not return to the same channel for over 229 ms. Therefore the duty cycle is 2.9%. The duty cycle correction factor is determined using the formula: 20log (0.029) = - 30.75dB.

7.6.3.3 Test Results

Radiated spurious emissions found in the band of 30MHz to 25GHz are reported in Table 7.6.3-1.

Frequency (MHz)	Level (dBuV)		Antenna Polarity	Correction Factors	Corrected Level (dBuV/m)		Limit (dBuV/m)		Margin (dB)	
	pk	Qpk/Avg	(H/V)	(dB)	pk	Qpk/Avg	pk	Qpk/Avg	pk	Qpk/Avg
Spurious Emissions - Low Channel										
4804	57.96	57.96	H	5.04	63.00	32.25	74.0	54.0	11.00	21.75
4804	62.37	62.37	V	5.07	67.44	36.68	74.0	54.0	6.56	17.32
Spurious Emissions - Mid Channel										
4882	51.75	51.75	H	5.21	56.96	26.21	74.0	54.0	17.04	27.79
4882	51.62	51.62	V	5.27	56.89	26.13	74.0	54.0	17.11	27.87
7323	50.85	50.85	H	9.75	60.60	29.84	74.0	54.0	13.40	24.16
7323	52.06	52.06	V	9.81	61.87	31.12	74.0	54.0	12.13	22.88
Spurious Emissions - High Channel										
4960	59.81	59.81	H	5.38	65.19	34.44	74.0	54.0	8.81	19.56
4960	58.40	58.40	V	5.47	63.87	33.12	74.0	54.0	10.13	20.88
7440	61.69	61.69	H	9.87	71.56	40.80	74.0	54.0	2.44	13.20
7440	63.78	63.78	V	9.95	73.73	42.98	74.0	54.0	0.27	11.02

Table 7.6.3-1: Radiated Spurious Emissions

***** *The magnitude of all emissions not reported were below the noise floor of the measurement system.*

7.6.3.4 Sample Calculation:

$R_C = R_U + CF_T$

Where:

CF_T	=	Total Correction Factor (AF+CA+AG)-DC (Average Measurements Only)
R_U	=	Uncorrected Reading
R_C	=	Corrected Level
AF	=	Antenna Factor
CA	=	Cable Attenuation
AG	=	Amplifier Gain
DC	=	Duty Cycle Correction Factor

Example Calculation

PEAK:
Corrected Level: 57.96 + 5.04 = 63.00dBuV
Margin: 74dBuV – 63.00dBuV = 11.00dB

AVERAGE:
Corrected Level: 57.96 + 5.04 - 30.75 = 32.25dBuV
Margin: 54dBuV – 32.25dBuV = 21.75dB

8.0 CONCLUSION
In the opinion of ACS, Inc. the Fluke-5, provided by the Georgia Institute of Technology meets the requirements of FCC Part 15 subpart C.

END REPORT