



W66 N220 Commerce Court

Cedarburg, WI 53012

USA Phone: 262.375.4400 • Fax: 262.375.4248 www.lsr.com

TEST REPORT # 311362 BT LSR Job #: C-1371

Compliance Testing of: TiWi5

Test Date(s): January 18th to April 25th 2012

Prepared For: LS Research, LLC W66 N220 Commerce Ct. Cedarburg, WI 53012

This Test Report is issued under the Authority of: Khairul Aidi Zainal, Senior EMC Engineer

Signature: -

Date:5-16-12

Test Report Reviewed by: Peter Feilen, EMC Engineer

Signature: Leta File

Date: 5/15/12

Signature

Khairul Aidi Zainal, Senior EMC Engineer.

Project Engineer:

Date:5-16-12

This Test Report may not be reproduced, except in full, without written approval of LS Research, LLC.

TABLE OF CONTENTS

EXHIBIT 1. INTRODUCTION		4
1.1 - Scope		4
1.2 – Normative References		4
1.3 - LS Research, LLC Test F	acility	5
1.4 – Location of Testing		5
1.5 – Test Equipment Utilized		5
EXHIBIT 2. PERFORMANCE ASS	ESSMENT	6
2.1 – Client Information		6
2.2 - Equipment Under Test (E	EUT) Information	6
2.3 - Associated Antenna Des	cription	6
2.4 - EUT'S Technical Specific	cations	7
2.5 - Product Description		8
EXHIBIT 3. EUT OPERATING COI	NDITIONS & CONFIGURATION	S DURING TESTS9
3.1 - Climate Test Conditions.		9
3.2 - Applicability & Summary	Of EMC Emission Test Results	9
3.3 - Modifications Inocorpora	ted In The EUT For Compliance	Purposes9
3.4 - Deviations & Exclusions	From Test Specifications	9
EXHIBIT 4. DECLARATION OF CO	ONFORMITY	
EXHIBIT 5. RADIATED EMISSION	S TEST	
5.1 - Test Setup		
5.2 - Test Procedure		
5.3 - Test Equipment Utilized.		
5.4 - Test Results		
5.5 - Calculation of Radiated E	Emissions Limits	
5.6 - Radiated Emissions Test	Data Chart	14
5.7 - Screen Captures - Radia	ated Emissions Test	
EXHIBIT 6. CONDUCTED EMISSI	ONS TEST, AC POWER LINE	23
6.1 - Test Setup		23
6.2 - Test Procedure		
6.3 - Test Equipment Utilized		
6.4 - Test Results		23
6.5 - FCC Limits of Conducted	I Emissions at the AC Mains Por	ts24
6.6 - CONDUCTED EMISSIO	NS TEST DATA CHART	
Prepared For: LS Research LLC	EUT: TiWi5	LS Research, LLC
Report # 311362 B	NIODEL #: TIWI5	Template: 15.247 FHSS Page 2 of 48
	Conducted Measurements: SN051201 Radiated Measurements: SN011201,SN081201	

6.7 Screen Captures – Conducted Emissions Test	25
EXHIBIT 7. OCCUPIED BANDWIDTH	26
7.1 - Limits	26
7.2 - Method of Measurements	26
7.3 - Test Data	26
7.4 - Screen Captures - Occupied Bandwidth	27
EXHIBIT 8. BAND EDGE MEASUREMENTS	30
8.1 - Method of Measurements	30
8.2. Band edge captures	31
8.2.2.2 EDR2	34
EXHIBIT 9. POWER OUTPUT (CONDUCTED)	36
9.1 - Method of Measurements	36
9.2 - Test Data	36
9.3 - Screen Captures – Power Output (Conducted)	37
EXHIBIT 10. CONDUCTED SPURIOUS EMISSIONS: 15.247(d)	38
10.1 - Limits	38
10.2 – Conducted Harmonic And Spurious RF Measurements	38
10.3- Screen Captures – Spurious Radiated Emissions	38
EXHIBIT 11. FREQUENCY & POWER STABILITY OVER VOLTAGE VARIATIONS	40
EXHIBIT 12. CHANNEL PLAN AND SEPARATION	41
EXHIBIT 13. CHANNEL OCCUPANCY	43
EXHIBIT 14. EQUAL CHANNEL USAGE AND PSEUDORANDOM HOPPING SEQUENCE	44
EXHIBIT 15. RECEIVER SYNCHRONIZATION AND RECEIVER INPUT BANDWIDTH	45
APPENDIX A – Test Equipment List	46
APPENDIX B – Test Standards: CURRENT PUBLICATION DATES RADIO	47
APPENDIX C - Uncertainty Statement	48

Prepared For: LS Research LLC	EUT: TiWi5	LS Research, LLC
Report # 311362 B	Model #: TiWi5	Template: 15.247 FHSS
LSR Job #: C-1371	Serial#: Conducted Measurements: SN051201 Radiated Measurements: SN011201,SN081201	Page 3 of 48

EXHIBIT 1. INTRODUCTION

<u> 1.1 - Scope</u>

References:	FCC Part 15, Subpart C, Section 15.247 and 15.209 FCC Part 2, Section 2.1043 paragraph (b)1. RSS GEN and RSS 210 Annex 8
Title:	 FCC : Telecommunication – Code of Federal Regulations, CFR 47, Part 15. IC : Low-power License-exempt Radio-communication Devices (All Frequency Bands): Category I Equipment
Purpose of Test:	To gain FCC and IC Certification Authorization for Low- Power License-Exempt Transmitters.
Test Procedures:	Both conducted and radiated emissions measurements were conducted in accordance with American National Standards Institute ANSI C63.4 – American National Standard for Methods of Measurement of Radio-Noise Emissions from Low-Voltage Electrical and Electronic Equipment in the Range of 9 kHz to 40 GHz.
Environmental Classification:	Commercial, Industrial or Business Residential

<u>1.2 – Normative References</u>

Publication	Year	Title
FCC CFR Parts 0-15	2012	Code of Federal Regulations – Telecommunications
ANSI C63.4	2003	American National Standard for Methods of Measurement of Radio-Noise Emissions from Low-Voltage Electrical and Electronic Equipment in the Range of 9 kHz to 40 GHz.
RSS-210 Annex 8	2010	Low-power License-exempt Radio communication Devices (All Frequency Bands): Category I Equipment
RSS-GEN Issue 3	2010	General Requirements and Information for the Certification of Radio Apparatus
ANSI C63.10	2009	American National Standard for Testing Unlicensed Wireless Devices
FCC KDB DA 00-705 FHSS Measurement Guidance	2000	Guidance for Performing Compliance Measurements on Frequency Hopping Spread Spectrum Transmission Systems (FHSS) Operating Under §15.247

Prepared For: LS Research LLC	EUT: TiWi5	LS Research, LLC
Report # 311362 B	Model #: TiWi5	Template: 15.247 FHSS
LSR Job #: C-1371	Serial#: Conducted Measurements: SN051201 Radiated Measurements: SN011201,SN081201	Page 4 of 48

<u>1.3 - LS Research, LLC Test Facility</u>

LS Research, LLC is accredited by A2LA (American Association for Laboratory Accreditation) to conform to ISO/IEC 17025, 2005 "General Requirements for the Competence of Calibration and Testing Laboratories".

LS Research, LLC's scope of accreditation includes all test methods listed herein, unless otherwise noted. Accreditation status can be verified at A2LA's web site: <u>www.a2la2.net</u>.

<u>1.4 – Location of Testing</u>

All testing was performed at the following location utilizing the facilities listed below, unless otherwise noted.

LS Research, LLC W66 N220 Commerce Court Cedarburg, Wisconsin, 53012 USA,

List of Facilities Located at LS Research, LLC:

Compact Chamber Semi-Anechoic Chamber Open Area Test Site (OATS)

<u> 1.5 – Test Equipment Utilized</u>

A complete list of equipment utilized in testing is provided in Appendix A of this test report. Calibration dates are indicated in Appendix A. All test equipment is calibrated by a calibration laboratory accredited to the requirements of ISO/IEC 17025, and traceable to the SI standard.

Prepared For: LS Research LLC	EUT: TiWi5	LS Research, LLC
Report # 311362 B	Model #: TiWi5	Template: 15.247 FHSS
LSR Job #: C-1371	Serial#: Conducted Measurements: SN051201 Radiated Measurements: SN011201,SN081201	Page 5 of 48

EXHIBIT 2. PERFORMANCE ASSESSMENT

2.1 - Client Information

Manufacturer Name:	LS Research, LLC
Address:	W66N220 Commerce Ct, Cedarburg, WI 53012
Contact Name:	Matt Meiller

2.2 - Equipment Under Test (EUT) Information

The following information has been supplied by the applicant.

Product Name:	TiWi5
Model Number:	TiWi5
Serial Number:	Conducted Measurements:SN051201
	Radiated Measurements:
	SN081201, SN011201

2.3 - Associated Antenna Description

There are two types antenna associated with the EUT:

- 1. A dual-band sleeve dipole antenna with a peak gain of 2.0 dBi in the 2.4GHz and 5.0GHz band.
- 2. A Johanson Technology dual-band ceramic chip antenna with a peak gain of 1.0dBi in the 2.4GHz and -1.5 dBi in the 5GHz band.

Prepared For: LS Research LLC	EUT: TiWi5	LS Research, LLC
Report # 311362 B	Model #: TiWi5	Template: 15.247 FHSS
LSR Job #: C-1371	Serial#: Conducted Measurements: SN051201 Radiated Measurements: SN011201,SN081201	Page 6 of 48

2.4 - EUT'S Technical Specifications

EUT Frequency Range (in MHz)	2402 MHz to 2480 MHz	
Maximum Conducted output power in Watts	0.0121 Watts	
Minimum Conducted output power in Watts	0.0097 Watts	
Field Strength at 3 meters	Not Applicable	
Maximum Conducted output power in dBm	10.8 dBm	
Occupied Bandwidth (99% BW)	GFSK = 870 kHz	
	EDR2 = 1200 kHz	
	EDR3 = 1198 kHz	
Type of Modulation	FHSS	
EIRP (in mW)	N/A	
Transmitter Spurious (worst case) at 3 meters	48.56 dBµV/m at 4804 MHz	
Stepped (Y/N)	N/A	
Step Value:	N/A	
Frequency Tolerance %, Hz, ppm	Better than 100 PPM	
Transceiver Model # (if applicable)	WL1273L	
Antenna Information		
Detachable/non-detachable	Both Detachable and non-detachable	
Туре	Dual band Sleeve Dipole and Ceramic	
	Chip antenna	
Gain (in dBi)	Dipole: 2.4GHz and 5.8GHz = 2.0dBi	
	Chip antenna: 2.4GHz = 1.0dBi	
	5.8GHz = -1.5dBi	
EUT will be operated under FCC Rule Part(s)	15.247	
EUT will be operated under RSS Rule Part(s)	RSS 210	
Modular Filing	Yes No	
Portable or Mobile?	Mobile	

Prepared For: LS Research LLC	EUT: TiWi5	LS Research, LLC
Report # 311362 B	Model #: TiWi5	Template: 15.247 FHSS
LSR Job #: C-1371	Serial#: Conducted Measurements: SN051201 Radiated Measurements: SN011201,SN081201	Page 7 of 48

RF Technical Information:

Type of		SAR Evaluation: Device Used in the Vicinity of the Human Head
Evaluation		SAR Evaluation: Body-worn Device
(check one)	Х	RF Evaluation

If <u>RF Evaluation</u> checked above, test engineer to complete the following:

Evaluated against exposure limits: 🔲 General Public Use	Controlled Use
Duty Cycle used in evaluation: 100 %	
Standard used for evaluation: OET 65	
Measurement Distance: 20 cm	
RF Value: 0.0379 V/m A/m X W/m ²	
Measured Computed 🛛 C	Calculated

2.5 - Product Description

The TIWI5 module is a multi-standard module with support for WLAN (802.11 a/b/g/n), Bluetooth 2.1+EDR and Bluetooth 4.0 (LE).

Prepared For: LS Research LLC	EUT: TiWi5	LS Research, LLC
Report # 311362 B	Model #: TiWi5	Template: 15.247 FHSS
LSR Job #: C-1371	Serial#: Conducted Measurements: SN051201 Radiated Measurements: SN011201,SN081201	Page 8 of 48

EXHIBIT 3. EUT OPERATING CONDITIONS & CONFIGURATIONS DURING TESTS

3.1 - Climate Test Conditions

Temperature:	70 -71° F
Humidity:	32-42%
Pressure:	728-741mmHg

3.2 - Applicability & Summary Of EMC Emission Test Results

FCC and IC Paragraph	Test Requirements	Compliance (Yes/No)
FCC : 15.207 IC : RSS GEN sect. 7.2.2	Power Line Conducted Emissions Measurements	Yes
FCC : 15.247 (a)(1)(i) IC : RSS 210 A8.1 (a)	20 dB Bandwidth	Yes
FCC : 15.247(b) & 1.1310 IC : RSS 210 A8.4	Maximum Output Power	Yes
FCC : 15.247(i), 1.1307, 1.1310, 2.1091 & 2.1093 IC : RSS 102	RF Exposure Limit	Yes
FCC :15.247(c) IC : RSS 210 A8.5	RF Conducted Spurious Emissions at the Transmitter Antenna Terminal	Yes
FCC:15.247 (a)(1)(i) IC: RSS 210 (b)	Carrier Frequency Separation	Yes
FCC:15.247 (a)(1)(i),(ii),(iii) IC: RSS 210 (c),(d),(e)	Number of hopping channels	Yes
FCC:15.247 (a)(1)(i),(ii),(iii) IC: RSS 210 (c),(d),(e)	Time of occupancy (Dwell Time)	Yes
FCC : 15.247(c), 15.209 & 15.205 IC : RSS 210 A8.2(b), section 2.2, 2.6 and 2.7	Transmitter Radiated Emissions	Yes

3.3 - Modifications Inocorporated In The EUT For Compliance Purposes

🖂 None

Ýes (explain below)

<u>3.4 - Deviations & Exclusions From Test Specifications</u>

None Yes (explain below)

Prepared For: LS Research LLC	EUT: TiWi5	LS Research, LLC
Report # 311362 B	Model #: TiWi5	Template: 15.247 FHSS
LSR Job #: C-1371	Serial#: Conducted Measurements: SN051201 Radiated Measurements: SN011201,SN081201	Page 9 of 48

EXHIBIT 4. DECLARATION OF CONFORMITY

The EUT was found to MEET the requirements as described within the specification of FCC Title 47, CFR Part 15.247, and Industry Canada RSS-210, Issue 8 (2010), Section Annex 8 (section A8.1) for a Frequency Hopping Spread Spectrum (FHSS) Transmitter.

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

LS Research, LLC certifies that the data contained herein was taken under conditions that meet or exceed the requirements of the test specifications. The results in this Test Report apply only to the item(s) tested on the above-specified dates. Any modifications made to the EUT subsequent to the indicated test date(s) will invalidate the data herein, and void this certification.

Prepared For: LS Research LLC	EUT: TiWi5	LS Research, LLC
Report # 311362 B	Model #: TiWi5	Template: 15.247 FHSS
LSR Job #: C-1371	Serial#: Conducted Measurements: SN051201 Radiated Measurements: SN011201,SN081201	Page 10 of 48

EXHIBIT 5. RADIATED EMISSIONS TEST

<u>5.1 - Test Setup</u>

The test setup was assembled in accordance with Title 47, CFR FCC Part 15, RSS GEN and ANSI C63.4-2003. The EUT was placed on an 80cm high non-conductive pedestal, centered on a flush mounted 2-meter diameter turntable inside a 3 meter Semi-Anechoic, FCC listed Chamber. The EUT was operated in continuous modulated transmit mode for final testing using power as provided by a bench DC supply. 3 separate units were provided for testing on 3 different channels.

The applicable limits apply at a 3 meter distance. Measurements above 4 GHz were performed at a 1.0 meter separation distance. The calculations to determine these limits are detailed in the following pages. Please refer to Appendix A for a complete list of test equipment. The test sample was operated on one of three (3) standard channels: low (2402MHz), middle (2440MHz) and high (2480MHz) to comply with FCC Part 15.31(m). The channels and operating modes were controlled via laptop PC.

5.2 - Test Procedure

Radiated RF measurements were performed on the EUT in a 3 meter Semi-Anechoic, FCC listed Chamber. The frequency range from 30 MHz to 10000 MHz was scanned and investigated. The radiated RF emission levels were manually noted at the various fixed degree settings of azimuth on the turntable and antenna height. The EUT was placed on a non-conductive pedestal in the 3 meter Semi-Anechoic Chamber, with the antenna mast placed such that the antenna was 3 meters from the EUT. A Bi-conical Antenna was used to measure emissions from 30 MHz to 300 MHz, and a Log Periodic Antenna was used to measure emissions from 300 MHz to 1000 MHz A Double-Ridged Waveguide Horn Antenna was used from 1 GHz to 18 GHz. The maximum radiated RF emissions were found by raising and lowering the antenna between 1 and 4 meters in height, using both horizontal and vertical antenna polarities. From 18-25 GHz, a standard gain horn antenna with preamp was used.

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

Prepared For: LS Research LLC	EUT: TiWi5	LS Research, LLC
Report # 311362 B	Model #: TiWi5	Template: 15.247 FHSS
LSR Job #: C-1371	Serial#: Conducted Measurements: SN051201 Radiated Measurements: SN011201,SN081201	Page 11 of 48

5.3 - Test Equipment Utilized

A list of the test equipment and antennas utilized for the Radiated Emissions test can be found in Appendix A. This list includes calibration information and equipment descriptions. All equipment is calibrated and used according to the operation manuals supplied by the manufacturers. All calibrations of the antennas used were performed at an IEC/ISO 17025 accredited calibration laboratory, traceable to the SI standard. In addition, the Connecting Cables were measured for losses using a calibrated Signal Generator and an EMI Receiver. The resulting correction factors and the cable loss factors from these calibrations were entered into the EMI Receiver database. As a result, the data taken from the EMI Receiver accounts for the antenna correction factor as well as cable loss or other corrections, and can therefore be entered into the database as a corrected meter reading. The EMI Receiver was operated with resolution bandwidths as prescribed in ANSI C63.4.

5.4 - Test Results

The EUT was found to **MEET** the Radiated Emissions requirements of Title 47 CFR, FCC Part 15.247 and Canada RSS-210, Issue 8 (2010), Annex 8 for a FHSS transmitter. The frequencies with significant RF signal strength were recorded and plotted as shown in the Data Charts and Graphs.

Prepared For: LS Research LLC	EUT: TiWi5	LS Research, LLC
Report # 311362 B	Model #: TiWi5	Template: 15.247 FHSS
LSR Job #: C-1371	Serial#: Conducted Measurements: SN051201 Radiated Measurements: SN011201,SN081201	Page 12 of 48

5.5 - Calculation of Radiated Emissions Limits

Reported data:

For both fundamental and spurious emissions measurement, the data reported includes all necessary correction factors. These correction factors are loaded onto the EMI receiver when measurements are performed.

Reported Measurement data = Raw receiver measurement $(dB\mu V/m)$ + Antenna correction Factor + Cable factor (dB) + Miscellaneous factors when applicable (dB) – amplification factor when applicable (dB).

Generic example of reported data at 200 MHz:

Reported Measurement data = 18.2 (raw receiver measurement) + 15.8 (antenna factor) + 1.45 (cable factor) = 35.45 (dBµV/m).

As specified in 15.247 (d) and RSS 210 A8.5, radiated emissions that fall within the restricted band described in 15.205(c) for FCC and section 2.2 of RSS 210 for IC, must comply with the general emissions limit.

The following table depicts the general radiated emission limits above 30 MHz. These limits are obtained from Title 47 CFR, Part 15.209, for radiated emissions measurements. These limits were applied to any signals found in the 15.205 restricted bands. The mentioned limits correspond to those limits listed in RSS GEN.

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

Sample conversion of field strength (μ V/m to dB μ V/m): dB μ V/m = 20 log ₁₀ (100)= 40 dB μ V/m (from 30-88 MHz)

Prepared For: LS Research LLC	EUT: TiWi5	LS Research, LLC
Report # 311362 B	Model #: TiWi5	Template: 15.247 FHSS
LSR Job #: C-1371	Serial#: Conducted Measurements: SN051201 Radiated Measurements: SN011201,SN081201	Page 13 of 48

5.6 - Radiated Emissions Test Data Chart

Manufacturer:	LS Research LLC						
Date(s) of Test:	January 18 th to April 25 th 2012						
Project Engineer:	Khair	ul Aidi Zainal					
Test Engineer(s):	Khair	ul Aidi Zainal, Peter Feilen	i, Mi	ke F	lintzke, Adam	Alge	er and Shane
	Rism	eyer.					
Voltage:	3.6 V	DC					
Operation Mode:	Conti	nuous transmit, modulated	l mo	bde			
Environmental	Temperature: 71°F						
Conditions in the	Relat	ive Humidity: 32 %					
Lab:		-					
		Single PhaseVAC			3 Phase	_VA	С
EUT POwer.		Battery		Х	Other: Bend	h D	C Supply
EUT Placement:	X 80cm non-conductive table 10cm Spacers						
FUT Test Location:	Y	3 Meter Semi-Anechoic	2/10m OATS				
	^	FCC Listed Chamber					
Measurements:		Pre-Compliance Preliminary X Final				Final	
Detectors Used:	X	Peak	Х		Quasi-Peak	X	Average

Frequency Range Inspected: 30 MHz to 10000 MHz

The following table depicts the level of significant spurious radiated RF emissions found (other than the fundamentals and its harmonics):

With Dipole Antenna

FREQ	ANT	EUT	HEIGHT	AZIMUTH	PEAK	Q.PEAK	AVERAGE	LIMIT	MARGIN
(MHz)			(cm)	(°)	(dBµv/m)	(dBµv/m)	(dBµv/m)	(dBµv/m)	(dB)
298.20	Н	FS	1.00	0	32.2	24.9	18.5	46.0	21.1
84.04	V	FS	1.00	335	36.4	32.7	22.9	40.0	7.3
33.20	V	FS	1.00	0	31.4	26.3	17.2	40.0	13.7
800.68	V	FS	1.28	3	41.0	38.8	33.4	46.0	7.2
800.68	V	VS	1.00	343	40.2	38.2	32.9	46.0	7.8
800.67	V	SS	1.41	0	39.1	36.5	31.1	46.0	9.5
800.67	Н	SS	1.07	12	40.1	37.7	32.4	46.0	8.3
800.67	Н	VS	1.07	167	41.4	39.2	33.9	46.0	6.8
800.67	Н	FS	1.09	110	43.6	41.7	36.6	46.0	4.4
1601.00	Н	FS	1.00	67	43.5	42.2	37.1	54.0	16.9
1601.00	V	FS	1.36	44	40.3	38.2	32.6	54.0	21.4
2386.00	Н	VS	1.10	0	50.1		22.3	54.0	31.7
2386.00	V	VS	1.00	0	55.1	49.3	23.8	54.0	30.2
2345.00	V	VS	1.00	82	55.4	49.2	23.6	54.0	30.4

Note:

1. H: Horizontal, VS: Vertical dipole straight, SS: Side dipole straight, FS: Flat dipole straight.

Prepared For: LS Research LLC	EUT: TiWi5	LS Research, LLC
Report # 311362 B	Model #: TiWi5	Template: 15.247 FHSS
LSR Job #: C-1371	Serial#: Conducted Measurements: SN051201 Radiated Measurements: SN011201,SN081201	Page 14 of 48

With Chip Antenna

FREQ	ANT	EUT	HEIGHT	AZIMUTH	PEAK	Q.PEAK	AVERAGE	LIMIT	MARGIN
			_						
(MHz)			(cm)	(°)	(dBµv/m)	(dBµv/m)	(dBµv/m)	(dBµv/m)	(dB)
875.00	V	V	1.00	0	39.1	36.6	34.2	46.0	11.8
375.00	V	V	1.00	263	31.2	28.6	26.5	46.0	19.5
625.00	V	S	1.00	0	36.6	34.4	31.7	46.0	14.3
875.00	V	F	1.42	226	39.0	36.1	33.7	46.0	12.3
625.00	V	F	1.00	101	37.3	35.1	33.0	46.0	13.0
99.00	V	F	1.00	129	26.5	24.7	23.2	43.0	19.8
165.00	V	S	2.23	297	28.9	26.8	25.0	43.0	18.0

Note:

1. H: Horizontal, V: Vertical, F: Flat.

Prepared For: LS Research LLC	EUT: TiWi5	LS Research, LLC
Report # 311362 B	Model #: TiWi5	Template: 15.247 FHSS
LSR Job #: C-1371	Serial#: Conducted Measurements: SN051201 Radiated Measurements: SN011201,SN081201	Page 15 of 48

RADIATED EMISSIONS DATA CHART (continued)

With Dipole Antenna

The following table depicts the level of radiated emissions of channel 2402 MHz in the restricted band:

Dipole Bent:

Frequency (MHz)	Height (m)	Azimuth (degree)	Peak Reading (dBµV/m)	Avg Reading (dBμV/m)	Avg Limit (dBµV/m)	Margin (dB)	Antenna Polarity	EUT orientation
4804	1.03	242	60.0	43.7	63.5	19.8	Vertical	Flat
12010	1.18	0	57.0	48.8	63.5	14.7	Vertical	Vertical

Dipole Straight:

Frequency (MHz)	Height (m)	Azimuth (degree)	Peak Reading (dBµV/m)	Avg Reading (dBμV/m)	Avg Limit (dBµV/m)	Margin (dB)	Antenna Polarity	EUT orientation
4804	1.03	226	58.5	41.2	63.5	22.3	Vertical	Vertical
12010	1	320	55.5	39.0	63.5	24.6	Horizontal	Side

The following table depicts the level of significant radiated emissions of channel 2440 MHz in the restricted band:

Dipole Bent:

Frequency (MHz)	Height (m)	Azimuth (degree)	Peak Reading (dBµV/m)	Avg Reading (dBμV/m)	Avg Limit (dBµV/m)	Margin (dB)	Antenna Polarity	EUT orientation
4880	1	271	59.1	41.3	63.5	22.2	Vertical	Side
7320	1.05	140	56.9	43.9	63.5	19.6	Vertical	Flat
12200	1.19	4	61.3	47.3	63.5	16.2	Vertical	Vertical

Dipole Straight:

Frequency (MHz)	Height (m)	Azimuth (degree)	Peak Reading (dBµV/m)	Avg Reading (dBμV/m)	Avg Limit (dBµV/m)	Margin (dB)	Antenna Polarity	EUT orientation
4880	1	188	62.7	42.3	63.5	21.2	Horizontal	Side
7320	1	121	56.3	46.7	63.5	16.8	Horizontal	Side
12200	1	351	64.1	48.3	63.5	15.2	Horizontal	Flat

Notes:

1. Measurements above 4 GHz were made at 1 meters of separation from the EUT. The limits were adjusted to reflect this measurement distance.

2. H: Horizontal, V: Vertical, S: Side, F: Flat.

3. Refer to exhibit 5.5 on explanation of how data is reported.

Prepared For: LS Research LLC	EUT: TiWi5	LS Research, LLC
Report # 311362 B	Model #: TiWi5	Template: 15.247 FHSS
LSR Job #: C-1371	Serial#: Conducted Measurements: SN051201 Radiated Measurements: SN011201,SN081201	Page 16 of 48

The following table depicts the level of significant radiated emissions of channel 2480 MHz in the restricted band: Dipole Bent:

Frequency (MHz)	Height (m)	Azimuth (degree)	Peak Reading (dBµV/m)	Avg Reading (dBμV/m)	Avg Limit (dBµV/m)	Margin (dB)	Antenna Polarity	EUT orientation
4960	1.23	264	55.0	38.8	63.5	24.7	Vertical	Side
7440	1	245	53.1	38.2	63.5	25.4	Horizontal	Flat
12400	1.1	22	58.2	40.4	63.5	23.1	Horizontal	Side

Dipole Straight:

Frequency (MHz)	Height (m)	Azimuth (degree)	Peak Reading (dBµV/m)	Avg Reading (dBμV/m)	Avg Limit (dBµV/m)	Margin (dB)	Antenna Polarity	EUT orientation
4960	1	223	60.8	40.5	63.5	23.1	Vertical	Vertical
7440	1	140	54.4	38.4	63.5	25.1	Horizontal	Flat
12400	1.17	23	56.4	40.1	63.5	23.4	Vertical	Vertical

Notes:

1. Measurements above 4 GHz were made at 1 meters of separation from the EUT. The limits were adjusted to reflect this measurement distance.

2. H: Horizontal, V: Vertical, S: Side, F: Flat.

3. Refer to exhibit 5.5 on explanation of how data is reported.

Prepared For: LS Research LLC	EUT: TiWi5	LS Research, LLC
Report # 311362 B	Model #: TiWi5	Template: 15.247 FHSS
LSR Job #: C-1371	Serial#: Conducted Measurements: SN051201 Radiated Measurements: SN011201,SN081201	Page 17 of 48

With Chip Antenna

The following table depicts the level of significant radiated harmonic emissions seen on Channel Low:

Frequency (MHz)	Height (m)	Azimuth (degree)	Peak Reading (dBµV/m)	Avg Reading (dBμV/m)	Avg Limit (dBµV/m)	Margin (dB)	Antenna Polarity	EUT orientation
4804	1.00	44	60.5	58.1	63.5	5.4	Vertical	Vertical
12010	1.00	314	58.5	45.3	63.5	18.2	Horizontal	Vertical
19216	1.00	304	57.2	44.9	63.5	18.6	Vertical	Vertical

The following table depicts the level of significant radiated harmonic emissions seen on Channel Middle:

Frequency (MHz)	Height (m)	Azimuth (degree)	Peak Reading (dBµV/m)	Avg Reading (dBμV/m)	Avg Limit (dBµV/m)	Margin (dB)	Antenna Polarity	EUT orientation
4880	1.08	162	67.5	54.0	63.5	9.5	Horizontal	Vertical
7320	1.00	32	58.0	51.8	63.5	11.7	Horizontal	Vertical
12200	1.00	312	66.2	52.1	63.5	11.4	Horizontal	Vertical
19520	1.00	28	56.9	43.0	63.5	20.6	Horizontal	Side

The following table depicts the level of significant radiated harmonic emissions seen on Channel High:

Frequency (MHz)	Height (m)	Azimuth (degree)	Peak Reading (dBµV/m)	Avg Reading (dBμV/m)	Avg Limit (dBµV/m)	Margin (dB)	Antenna Polarity	EUT orientation
4960	1.00	37	70.9	56.6	63.5	6.9	Vertical	Flat
7440	1.04	35	58.7	47.3	63.5	16.2	Horizontal	Vertical
12400	1.07	326	67.7	52.7	63.5	10.8	Vertical	Flat
19840	1.00	36	54.0	41.1	63.5	22.4	Horizontal	Side
22320	1.00	327	50.6	37.9	63.5	25.6	Vertical	Vertical

Notes:

1. A Quasi-Peak Detector was used in measurements below 1 GHz. To ensure the peak emissions did not exceed 20 dB above the limits a peak detector was used. A peak detector with video averaging was used for measurements above 1 GHz.

2. Measurements above 4 GHz were made at 1 meters of separation from the EUT. Limits have been corrected to reflect the change in measurement distance.

3. Refer to exhibit 5.5 on explanation of how data is reported.

Prepared For: LS Research LLC	EUT: TiWi5	LS Research, LLC
Report # 311362 B	Model #: TiWi5	Template: 15.247 FHSS
LSR Job #: C-1371	Serial#: Conducted Measurements: SN051201 Radiated Measurements: SN011201,SN081201	Page 18 of 48

5.7 - Screen Captures - Radiated Emissions Test

These screen captures represent Peak Emissions. For radiated emission measurements, a Quasi-Peak detector function is utilized when measuring frequencies below 1 GHz, and a video averaged Peak detector function is utilized when measuring frequencies above 1 GHz.

The signature scans shown here are from worst-case emissions, as measured on channels 2402 MHz, 2440 MHz, or 2480 MHz, with the sense antenna both in vertical and horizontal polarity for worst case presentations.



300-1000 MHz, at 3m	
🔆 Agilent 22:15:59 Mar 21, 2012 🛛 🛛 R T	Peak Search
Preselicontifiin Meas At Mkr EMI Peak:31.43 dBuV Presel: 52.30 MHz 0P: 26.33 dBuV Inout: RF Path: Filter Fmissions 32.30 MHz 0P: 19 dBuV Prese, 4 dB Sain 0N	Next Peak
	Next Pk Right
Ref 60 dB µ V ●Atten 10 dB 35.62 dBµV ●EmiPk Log	Next Pk Left
5	Min Search
ار المحمد الم	Pk-Pk Search
	Mkr → CF
M1 S2 Start 300.0 MHz Res BW (CISPR) 120 kHz ===================================	More 1 of 2
DE Preselector alignment required, 9 kHz to 20 MHz	P

Prepared For: LS Research LLC	EUT: TiWi5	LS Research, LLC
Report # 311362 B	Model #: TiWi5	Template: 15.247 FHSS
LSR Job #: C-1371	Serial#: Conducted Measurements: SN051201 Radiated Measurements: SN011201,SN081201	Page 19 of 48



1000-2310 MHz, at 3m

2310-2390 MHz, at 3m



Prepared For: LS Research LLC	EUT: TiWi5	LS Research, LLC
Report # 311362 B	Model #: TiWi5	Template: 15.247 FHSS
LSR Job #: C-1371	Serial#: Conducted Measurements: SN051201 Radiated Measurements: SN011201,SN081201	Page 20 of 48



Note: The frequency range 2483.5-2500 MHz is in the Band-edge section (Exhibit 8).

2500-4000 MHz, at 3m					
🔆 Agilent 11:03:	21 Jan 18, 2012		RT	Freq/Channel	
Meas At Emissions	: Mkr EMIPeak: N/A OP: N/A EMIAvg: N/A	Presel: Input: RF	Path: Bypass	Center Freq 3.25000000 GHz	
		м	kr1 3.850 8 GHz	Start Freq 2.50000000 GHz	
Ref 70 dBµV •EmiPk Log	#Atten 0 dB		50.49 dBµV	Stop Frec 4.00000000 GHz	
5 dB/				CF Step 150.000000 MHz Puto Mar	
DI				Freq Offset	
LgAv				Signal Track ^{On <u>Of</u>}	
Start 2.500 GHz •Res BW (CISPR)	1 MHz +VBW 3	0 Hz Sweep 57.	Stop 4.000 GHz 33 s (2002 pts)		
File Operation S	tatus, C:\AHORN39.A	NT file loaded			

Prepared For: LS Research LLC	EUT: TiWi5	LS Research, LLC
Report # 311362 B	Model #: TiWi5	Template: 15.247 FHSS
LSR Job #: C-1371	Serial#: Conducted Measurements: SN051201 Radiated Measurements: SN011201,SN081201	Page 21 of 48





Prepared For: LS Research LLC	EUT: TiWi5	LS Research, LLC
Report # 311362 B	Model #: TiWi5	Template: 15.247 FHSS
LSR Job #: C-1371	Serial#: Conducted Measurements: SN051201 Radiated Measurements: SN011201,SN081201	Page 22 of 48

EXHIBIT 6. CONDUCTED EMISSIONS TEST, AC POWER LINE

<u>6.1 - Test Setup</u>

The test area and setup are in accordance with ANSI C63.4-2003 and with Title 47 CFR, FCC Part 15, Industry Canada RSS-210 and RSS GEN. The EUT was placed on a non-conductive wooden table, with a height of 80 cm above the reference ground plane. The EUT's power cable was plugged into a 50Ω (ohm), $50/250 \mu$ H Line Impedance Stabilization Network (LISN). The AC power supply of 120V was provided via an appropriate broadband EMI Filter, and then to the LISN line input. Final readings were then taken and recorded. After the EUT was setup and connected to the LISN, the RF Sampling Port of the LISN was connected to a 10 dB Attenuator-Limiter, and then to the EMI Receiver. The EMCO LISN used has the ability to terminate the unused port with a 50Ω (ohm) load when switched to either L1 (line) or L2 (neutral).

<u>6.2 - Test Procedure</u>

The EUT was investigated in continuous modulated transmit mode and continuous receive mode for this portion of the testing. The appropriate frequency range and bandwidths were selected on the EMI Receiver, and measurements were made. The bandwidth used for these measurements is 9 kHz, as specified in CISPR 16-1, Section 1, Table 1, for Quasi-Peak and Average detectors in the frequency range of 150 kHz to 30 MHz. Final readings were then taken and recorded.

An off-the-shelf DC power supply was used during the test to supply the EUT with the appropriate DC voltage.

6.3 - Test Equipment Utilized

A list of the test equipment and accessories utilized for the Conducted Emissions test is provided in Appendix A. This list includes calibration information and equipment descriptions. All equipment is calibrated and used according to the operation manuals supplied by the manufacturers. Calibrations of the LISN and Limiter are traceable to N.I.S.T. All cables are calibrated and checked periodically for conformance. The emissions are measured on the EMI Receiver, which has automatic correction for all factors stored in memory and allows direct readings to be taken.

6.4 - Test Results

The EUT was found to **MEET** the Conducted Emission requirements of FCC CFR 47 Part **15.207** and **15.107**, Conducted Emissions. See the Data Charts and Graphs for more details of the test results. By virtue of meeting the requirements of FCC, the EUT also meets the requirements of IC **RSS 210** and **RSS GEN**.

Prepared For: LS Research LLC	EUT: TiWi5	LS Research, LLC
Report # 311362 B	Model #: TiWi5	Template: 15.247 FHSS
LSR Job #: C-1371	Serial#: Conducted Measurements: SN051201 Radiated Measurements: SN011201,SN081201	Page 23 of 48

6.5 - FCC Limits of Conducted Emissions at the AC Mains Ports

Frequency Range	Class B Limit	s (dBµV)	Measuring	
(MHz)	Quasi-Peak	Average	Bandwidth	
0.150 -0.50 *	66-56	56-46	RBW = 9 kHz	
0.5 – 5.0	56	46	VBW \geq 9 kHz for QP	
5.0 – 30	60	50	VBW = 1 Hz for Average	
* The limit decreases linearly with				
this range.				

6.6 - CONDUCTED EMISSIONS TEST DATA CHART Frequency Range inspected: 150 KHz to 30 MHz

Manufacturer:	LS Research					
Date(s) of Test:	Apr	April 25 th 2012				
Project Engineer:	Kha	airul Aidi Zainal				
Test Engineer:	Mik	e Hintzke				
Voltage:	120	VAC				
Operation Mode:	Cor	Continuous transmit, modulated				
Environmental	Ten	Temperature: 71° F				
Conditions in the Lab:	Rel	Relative Humidity: 40%				
Test Location:	Х	AC Mains Test are	ea			Chamber
	Х	X 40cm from Vertical Ground Plane 10			10cm Spacers	
	Х	X 80cm above Ground Plane Other:			Other:	
Measurements:		Pre-Compliance		Preliminary	Х	Final
Detectors Used:		Peak	Х	Quasi-Peak	X	Average

		<u>Quasi-Peak</u>				<u>Average</u>	
Frequency (MHz)	Line	Q-Peak Reading (dBµV)	Q-Peak Limit (dBµV)	Quasi-Peak Margin (dB)	Average Reading (dBµV)	Average Limit (dBµV)	Average Margin (dB)
0.150	L1	35.2	66.0	30.8	5.2	56.0	50.8
0.302	L1	32.2	60.2	28.0	10.7	50.2	39.5
1.106	L1	27.2	56.0	28.8	-2.7	46.0	48.7
0.150	L2	34.6	66.0	31.4	4.9	56.0	51.1
0.416	L2	20.0	57.5	37.5	-7.0	47.5	54.5
0.295	L2	30.0	60.4	30.4	0.6	50.4	49.8
1.025	L2	27.6	56.0	28.4	-2.4	46.0	48.4
0.618	L2	22.1	56.0	33.9	17.7	46.0	28.3

Notes:

1) The emissions listed are characteristic of the power supply used, and did not change by the EUT.

Prepared For: LS Research LLC	EUT: TiWi5	LS Research, LLC
Report # 311362 B	Model #: TiWi5	Template: 15.247 FHSS
LSR Job #: C-1371	Serial#: Conducted Measurements: SN051201 Radiated Measurements: SN011201,SN081201	Page 24 of 48

6.7 Screen Captures - Conducted Emissions Test

These screen captures represent Peak Emissions. For conducted emission measurements, both a Quasi-Peak detector function and an Average detector function are utilized. The emissions must meet both the Quasi-peak limit and the Average limit as described in 47 CFR 15.207 and RSS GEN 7.2.2 (Table 2).



Prepared For: LS Research LLC	EUT: TiWi5	LS Research, LLC
Report # 311362 B	Model #: TiWi5	Template: 15.247 FHSS
LSR Job #: C-1371	Serial#: Conducted Measurements: SN051201 Radiated Measurements: SN011201,SN081201	Page 25 of 48

EXHIBIT 7. OCCUPIED BANDWIDTH

<u>7.1 - Limits</u>

Per FCC CFR 47 15.247 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, as is the case with this device, 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.

7.2 - Method of Measurements

The transmitter output was connected to the Spectrum Analyzer. The bandwidth of the fundamental frequency was measured with the Spectrum Analyzer using 30 kHz RBW and 100 kHz VBW.

For this portion of the tests, a direct measurement of the transmitted signal was performed at the antenna port of the EUT, via a cable connection to a spectrum analyzer. An attenuator was placed in series with the cable to protect the spectrum analyzer. The loss from the cable and the attenuator were added on the analyzer as gain offset settings, allowing direct measurements, without the need for any further corrections. The EUT was configured to run in a continuous transmit mode, while being supplied with typical data as a modulation source. The spectrum analyzer was used in peak-hold mode while measurements were made, as presented in the chart below.

Measurement method used was FCC OET Public Notice DA 00-705.

Modulation	Channel	Frequency (MHz)	20dB EBW (kHz)	99% EBW (kHz)
	0	2402	989	865
GFSK	19	2440	992	870
	39	2480	949	866
	0	2402	1322	1195
EDR2	19	2440	1319	1200
	39	2480	1309	1200
	0	2402	1336	1191
EDR3	19	2440	1334	1198
	39	2480	1316	1197

<u> 7.3 - Test Data</u>

Prepared For: LS Research LLC	EUT: TiWi5	LS Research, LLC
Report # 311362 B	Model #: TiWi5	Template: 15.247 FHSS
LSR Job #: C-1371	Serial#: Conducted Measurements: SN051201 Radiated Measurements: SN011201,SN081201	Page 26 of 48

7.4 - Screen Captures - Occupied Bandwidth

7.4.1 GFSK





Q







Prepared For: LS Research LLC	EUT: TiWi5	LS Research, LLC
Report # 311362 B	Model #: TiWi5	Template: 15.247 FHSS
LSR Job #: C-1371	Serial#: Conducted Measurements: SN051201 Radiated Measurements: SN011201,SN081201	Page 27 of 48

7.4.2 EDR2

Low Channel





High channel

* Agilent 17:26:50 Mar 20, 2012 R T	Meas Setup
Ch Freq 2.48 GHz Trig Free Occupied Bandwidth	Avg Number 10 On <u>Qt</u>
Ref 15 dBm Atten 10 dB Ext PG -10 dB	Avg Mode Exp Repeat
#Peak Log 10 → ←	Max Hold On Off
	Occ BW % Pw 99.00 %
Center 2.48 GHz Span 3 MHz #Res BW 30 kHz #VBW 100 kHz Sweep 9.99 ms (1000 pts)	OBW Spar 3.0000000 MHz
Occupied Bandwidth Occ BW % Pwr 99.00 % 1.1996 MHz × dB -20.00 dB	x dB -20.00 dB
Transmit Freq Error -3.064 kHz x dB Bandwidth 1.309 MHz	Optimize Ref Level

Prepared For: LS Research LLC	EUT: TiWi5	LS Research, LLC
Report # 311362 B	Model #: TiWi5	Template: 15.247 FHSS
LSR Job #: C-1371	Serial#: Conducted Measurements: SN051201 Radiated Measurements: SN011201,SN081201	Page 28 of 48

7.4.3 EDR3

Low Channel





High channel

* Agilent 17:43:23 Mar 20, 2012 R T	Meas Setup
Ch Freq 2.48 GHz Trig Free Occupied Bandwidth	Avg Number 10 On <u>Qt</u> f
Ref 15 dBm Atten 10 dB Ext PG -10 dB	Avg Mode Exp Repeat
PPeak Log 10 → ↓ ←	Max Hold On Off
	Occ BW % Pw 99.00 %
Center 2.48 GHz Span 3 MHz #Res BW 30 KHz #VBW 100 kHz Sweep 9.99 ms (1000 pts)	OBW Spar 3.0000000 MHz
Occupied Bandwidth Occ BW % Pwr 99.00 % 1.1968 MHz x dB -20.00 dB	x dB -20.00 dB
Transmit Freq Error 1.534 kHz x dB Bandwidth 1.316 MHz	Optimize Ref Level

Prepared For: LS Research LLC	EUT: TiWi5	LS Research, LLC
Report # 311362 B	Model #: TiWi5	Template: 15.247 FHSS
LSR Job #: C-1371	Serial#: Conducted Measurements: SN051201 Radiated Measurements: SN011201,SN081201	Page 29 of 48

EXHIBIT 8. BAND EDGE MEASUREMENTS

8.1 - Method of Measurements

FCC 15.247(d) require a measurement of spurious emission levels to be at least 20 dB lower than the fundamental emission level, in particular at the Band-Edges where the intentional radiator operates. Also, RSS 210 Section 2.2 requires that unwanted emissions meet limits listed in RSS GEN and also to the limits in the applicable annex. The EUT was operated in continuous transmit mode with continuous modulation, with internally generated data as the modulating source. The EUT was operated at the lowest channel for the investigation of the lower Band-Edge, and at the highest channel for the investigation of the higher Band-Edge.

The Band-edge measurements were performed conducted and radiated. The measurement of band-edge was performed to satisfy FCC 15.247(d).

Conducted measurements of the spurious emission were performed with a measurement bandwidth of 100kHz.

Measurement method used was FCC OET Public Notice DA 00-705.

Prepared For: LS Research LLC	EUT: TiWi5	LS Research, LLC
Report # 311362 B	Model #: TiWi5	Template: 15.247 FHSS
LSR Job #: C-1371	Serial#: Conducted Measurements: SN051201 Radiated Measurements: SN011201,SN081201	Page 30 of 48

8.2. Band edge captures.

8.2.1 Radiated Band-edge in Restricted Band:

8.2.1.1 Bluetooth GFSK





B. Chip antenna



Prepared For: LS Research LLC	EUT: TiWi5	LS Research, LLC
Report # 311362 B	Model #: TiWi5	Template: 15.247 FHSS
LSR Job #: C-1371	Serial#: Conducted Measurements: SN051201 Radiated Measurements: SN011201,SN081201	Page 31 of 48

8.2.1.2 Bluetooth EDR2





Prepared For: LS Research LLC	EUT: TiWi5	LS Research, LLC
Report # 311362 B	Model #: TiWi5	Template: 15.247 FHSS
LSR Job #: C-1371	Serial#: Conducted Measurements: SN051201 Radiated Measurements: SN011201,SN081201	Page 32 of 48

8.2.1.3 Bluetooth EDR3





Prepared For: LS Research LLC	EUT: TiWi5	LS Research, LLC
Report # 311362 B	Model #: TiWi5	Template: 15.247 FHSS
LSR Job #: C-1371	Serial#: Conducted Measurements: SN051201 Radiated Measurements: SN011201,SN081201	Page 33 of 48

8.2.2 Conducted Band-edge:

8.2.2.1 GFSK



8.2.2.2 EDR2

🔆 Agi	lent	16:01:37	7 Mar 20	D, 2012					R	T	Trace/View	莱	Agile	ent	17:29:0	6 Mar 20), 2012					R	T	Peak Search
								Mkr1 :	2.400000	GHz											Mkr1 ∆	-9.357	MHz	
Ref 15	dBm		Atten	10 dB	Ext PG	5 -10 dB			-41.48	dBm	Trace	Re	et15d ⊳ak [1Bm		Atten	10 dB	Ext PG	5 -10 dB			53.2	3 dB	Meas Tools +
Log											<u>1 2 3</u>	Lo	g i	¢										Micus roois
10										1		10		1										
dB/										+	Clear Write	dB	s/ -	\rightarrow										Next Peak
										1														
											Max Hold			1										Next Pk Right
-9.8	<u> </u>									[—			ŀ	- \										
dBm									\mathcal{N}															
								, M	\$ <u>/</u>		Min Hold				\sim			18						Next Pk Left
M1 S2	<u> </u>							where .				V1	S2		1444	and the manufactures	minthe gere.	manth	للدائد والمستحد	المعاطية	dire from the			
S3 FC	terrand	University		en aller	hit with the f	-what when					View	\$3	FC											Min Search
A AA												A	AA											
											Disale													Die Die Generale
		-									Diallik		ŀ											PK-PK Search
Center	2.397	GHz							Span 1	0 MHz	More 1 of 2	Sta	art 2.4	48 GH:	z							Stop 2.	5 GHz	More 1 of 2
#Res B	vv 100	kHz		#V	RAA 300	kHz	Swee	p 9.99 m	ns (1000	pts)		#R	tes BV	V 300	kHz		#\	/BW 1 N	IHZ	Sweep	o 9.99 m	s (1000	pts)	J
				Lc	wei	r ba	nd e	edge	е								U	opei	r bai	nd e	edge	Э		
								-													-			

Prepared For: LS Research LLC	EUT: TiWi5	LS Research, LLC
Report # 311362 B	Model #: TiWi5	Template: 15.247 FHSS
LSR Job #: C-1371	Serial#: Conducted Measurements: SN051201 Radiated Measurements: SN011201,SN081201	Page 34 of 48

8.2.2.3 EDR3



8.2.2.3 Hopping mode



Prepared For: LS Research LLC	EUT: TiWi5	LS Research, LLC
Report # 311362 B	Model #: TiWi5	Template: 15.247 FHSS
LSR Job #: C-1371	Serial#: Conducted Measurements: SN051201 Radiated Measurements: SN011201,SN081201	Page 35 of 48

EXHIBIT 9. POWER OUTPUT (CONDUCTED)

9.1 - Method of Measurements

The conducted RF output power of the EUT was measured at the antenna port using a short RF cable along with an attenuator as protection for the spectrum analyzer. The loss from the cable and the attenuator were added on the analyzer as gain offset settings, allowing direct measurements without the need for any further corrections. The unit was configured to run in a continuous transmit mode, while being supplied with typical data as a modulation source. The spectrum analyzer was used with resolution bandwidths set to 1 MHz and a span of 5 MHz, Bluetooth, and 3 MHz and a span of 10 MHz, wireless, with measurements from a peak detector presented in the chart below.

Measurement method used was FCC OET Public Notice DA 00-705.

<u>9.2 - Test Data</u>

The data reported includes all necessary correction factors. These correction factors are loaded onto the EMI receiver when measurements are performed.

Reported Measurement data = Raw receiver measurement (dBm) + Cable factor (dB) + Miscellaneous factors when applicable (dB).

Generic example of reported data at 2440 MHz:

Reported Measurement data = 9.35 (raw receiver measurement in dBm) + 0.85 (cable factor in dB) = 10.2 (dBm).

Modulation	Channel	Frequency (MHz)	Output Power (dBm)			
	0	2402	10.2			
GFSK	19	2440	10.2			
	39	2480	9.9			
	0	2402	10.1			
EDR2	19	2440	10.2			
	39	2480	9.9			
	0	2402	10.8			
EDR3	19	2440	10.8			
	20	2400	10.0			

Prepared For: LS Research LLC	EUT: TiWi5	LS Research, LLC
Report # 311362 B	Model #: TiWi5	Template: 15.247 FHSS
LSR Job #: C-1371	Serial#: Conducted Measurements: SN051201 Radiated Measurements: SN011201,SN081201	Page 36 of 48

9.3 - Screen Captures - Power Output (Conducted)

9.3.1 GFSK



9.3.1 EDR2



9.3.1 EDR3



Prepared For: LS Research LLC	EUT: TiWi5	LS Research, LLC
Report # 311362 B	Model #: TiWi5	Template: 15.247 FHSS
LSR Job #: C-1371	Serial#: Conducted Measurements: SN051201 Radiated Measurements: SN011201,SN081201	Page 37 of 48

EXHIBIT 10. CONDUCTED SPURIOUS EMISSIONS: 15.247(d)

Test Engineer: Adam Alger

10.1 - Limits

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.

10.2 - Conducted Harmonic And Spurious RF Measurements

FCC Part 15.247(d) and IC RSS 210 A8.5 both require a measurement of conducted harmonic and spurious RF emission levels, as reference to the carrier level when measured in a 100 kHz bandwidth. For this test, the spurious and harmonic RF emissions from the EUT were measured at the EUT antenna port using a short RF cable along with an attenuator as protection for the spectrum analyzer. The loss from the cable and the attenuator were added on the analyzer as gain offset settings, thereby allowing direct readings of the measurements made without the need for any further corrections. A spectrum analyzer was used with the resolution bandwidth set to 100 kHz for this portion of the tests. The unit was configured to run in a continuous transmit mode, while being supplied with typical data as a modulation source. The spectrum analyzer was used with measurements from a peak detector presented in the chart below. Screen captures were acquired and any noticeable spurious and harmonic signals were identified and measured.

Measurement method used was FCC OET Public Notice DA 00-705.

10.3- Screen Captures – Spurious Radiated Emissions



Prepared For: LS Research LLC	EUT: TiWi5	LS Research, LLC
Report # 311362 B	Model #: TiWi5	Template: 15.247 FHSS
LSR Job #: C-1371	Serial#: Conducted Measurements: SN051201 Radiated Measurements: SN011201,SN081201	Page 38 of 48





Prepared For: LS Research LLC	EUT: TiWi5	LS Research, LLC
Report # 311362 B	Model #: TiWi5	Template: 15.247 FHSS
LSR Job #: C-1371	Serial#: Conducted Measurements: SN051201 Radiated Measurements: SN011201,SN081201	Page 39 of 48

EXHIBIT 11. FREQUENCY & POWER STABILITY OVER VOLTAGE VARIATIONS

Test Engineer(s): Khairul Aidi Zainal

The power and frequency stability of the device was examined as a function of the input voltage available to the EUT. A Spectrum Analyzer was used to measure the RF output power and frequency at the appropriate frequency markers. Power was supplied by an external bench-type DC power supply and was varied $\pm 15\%$ from the nominal.

		BLUETOOTH						
	3.06	VDC	3.60	VDC	4.14	VDC		
	POWER (dBm)	FREQUENCY (Hz)	POWER (dBm)	FREQUENCY (Hz)	POWER (dBm)	FREQUENCY (Hz)	FREQ DRIFT (Hz)	Pout DRIFT (dBm)
LOW CHANNEL	9.4	2402000459	9.4	2402000479	9.4	2402000479	20	0.0
MID CHANNEL	9.4	2440000560	9.4	2440000560	9.4	2440000539	21	0.0
HIGH CHANNEL	9.2	2480000580	9.2	2480000560	9.2	2480000539	41	0.1

	3.06	VDC	3.60 VDC		4.14 VDC			
	POWER (dBm)	FREQUENCY (Hz)	POWER (dBm)	FREQUENCY (Hz)	POWER (dBm)	FREQUENCY (Hz)	FREQ DRIFT (Hz)	Pout DRIFT (dBm)
LOW CHANNEL	6.1	2412000969	6.4	2412000990	6.2	2412000990	21	0.3
MID CHANNEL	6.6	2437000920	6.7	2437000940	6.6	2437000960	40	0.1
HIGH CHANNEL	6.5	2462000939	6.6	2462000960	6.7	2462000960	21	0.3

WLAN 5.7 GHZ

	3.06 VDC		3.60 VDC		4.14 VDC			
	POWER (dBm)	FREQUENCY (Hz)	POWER (dBm)	FREQUENCY (Hz)	POWER (dBm)	FREQUENCY (Hz)	FREQ DRIFT (Hz)	Pout DRIFT (dBm)
LOW CHANNEL	3.8	5745002200	4.0	5745002300	4.0	5745002340	140	0.3
MID CHANNEL	2.7	5785002280	3.0	5785002360	3.2	5785002280	80	0.5
HIGH CHANNEL	2.1	5825002160	2.4	5825002220	2.6	5825002320	160	0.4

The power was then cycled On/Off to observe system response. No unusual response was observed, the emission characteristics were well behaved, and the system returned to the same state of operation as before the power cycle.

Prepared For: LS Research LLC	EUT: TiWi5	LS Research, LLC
Report # 311362 B	Model #: TiWi5	Template: 15.247 FHSS
LSR Job #: C-1371	Serial#: Conducted Measurements: SN051201 Radiated Measurements: SN011201,SN081201	Page 40 of 48

EXHIBIT 12. CHANNEL PLAN AND SEPARATION

Test Engineer: Adam Alger

A spectrum analyzer was used with a resolution bandwidth of 30 kHz to measure the channel separation of the EUT.

The following plots describe this spacing, and also establish the channel separation and plan.



Channel Spacing

Channel separation = <u>1.030 MHz</u>

Prepared For: LS Research LLC	EUT: TiWi5	LS Research, LLC
Report # 311362 B	Model #: TiWi5	Template: 15.247 FHSS
LSR Job #: C-1371	Serial#: Conducted Measurements: SN051201 Radiated Measurements: SN011201,SN081201	Page 41 of 48



Number of channels = <u>79 Channels</u>

Prepared For: LS Research LLC	EUT: TiWi5	LS Research, LLC
Report # 311362 B	Model #: TiWi5	Template: 15.247 FHSS
LSR Job #: C-1371	Serial#: Conducted Measurements: SN051201 Radiated Measurements: SN011201,SN081201	Page 42 of 48

EXHIBIT 13. CHANNEL OCCUPANCY

Part 15.247(a)(1) requires a channel occupancy, for this device, of no more than 400 milliseconds in a 31.6 second window. The channel occupancy for this EUT was measured using a spectrum analyzer, set to zero-span at the frequency of interest. With the analyzer in peak-hold mode, the transmission lengths can be measured by adjusting the sweep rate of the analyzer. A suitable sweep rate was used to measure the channel occupancy at the low, mid and high channels.

The longest time any transmission will occur on a **single channel is 2.22 milliseconds**. In a 7.9 second window, each channel has 33 transmission cycles. The maximum occupancy in a 31.6 second window is calculated by multiplying 132 transmission cycles by 2.22 milliseconds transmission duration per cycle, to arrive **at 290 milliseconds total occupancy**.

Plots of Channel Occupancy



Channel Occupancy

Prepared For: LS Research LLC	EUT: TiWi5	LS Research, LLC
Report # 311362 B	Model #: TiWi5	Template: 15.247 FHSS
LSR Job #: C-1371	Serial#: Conducted Measurements: SN051201 Radiated Measurements: SN011201,SN081201	Page 43 of 48

EXHIBIT 14. EQUAL CHANNEL USAGE AND PSEUDORANDOM HOPPING SEQUENCE.

By virtue of being an IEEE 802.15 Bluetooth device, the EUT is inherently compliant to the requirements.

Prepared For: LS Research LLC	EUT: TiWi5	LS Research, LLC
Report # 311362 B	Model #: TiWi5	Template: 15.247 FHSS
LSR Job #: C-1371	Serial#: Conducted Measurements: SN051201 Radiated Measurements: SN011201,SN081201	Page 44 of 48

EXHIBIT 15. RECEIVER SYNCHRONIZATION AND RECEIVER INPUT BANDWIDTH.

By virtue of being an IEEE 802.15 Bluetooth device, the EUT is inherently compliant to the requirements.

Prepared For: LS Research LLC	EUT: TiWi5	LS Research, LLC
Report # 311362 B	Model #: TiWi5	Template: 15.247 FHSS
LSR Job #: C-1371	Serial#: Conducted Measurements: SN051201 Radiated Measurements: SN011201,SN081201	Page 45 of 48

<u> APPENDIX A – Test Equipment List</u>



	Dale:	20-Dec-2011		Type Test :	Radiated Measure	ements		Job#:	C-1371
Pre	pared By	Aiti		Qustomer :	LSR			Quale #	311362
Asset#		Description		Manufacturer	Model#	Serial#	Cal Date	Cal Due Dale	Equipment Status
EE 96007	3	SpectrumAnalyzer		Agilent	E4446A	US45300564	4/25/2011	4/25/2012	Active Calibration
EE 960 14	7	Pre-Amp		Adv. Micro	WLA612	123101	1/4/2011	1/4/2012	Active Calibration
EE 960 14	6	Std. Gain Hom Ant. w/pream	P	Adv. Micro	WLA622-4	123001	11/3/2011	11/3/2012	Active Calibration
EE 960 19	x	3Hz-13.2GHz SpectrumAna	zer	Agilent	E4445A	MY 48250225	6/6/2011	6/6/2012	Active Calibration
EE 96016	3B	NF Preselecter		Agilent	N9039A	MY 46520110	6/11/2011	6/11/2012	Active Calibration
	91 44	20.5-40GHZ LINA		Lucammun lecht	ALN-35144050	1103/17-01	10492011	1042/12	Active Calibration
AA 9600		Financial Antenna		BICO	931108	9601-2280	6/10/2011	6/10/2012	Active Calibration
AA 9600	78	Log Periodic Antenna		EMCO	93146	9701-4855	11/15/2011	11/15/2012	Active Calibration
AA 9600	61	Double Ridge Hom Anlenna		EMCO	3115	6907	1/4/2011	1/4/2012	Active Calibration
AA 9601	37	Standard Gain Horn Ant.		EMCO	3160-10	69259	10/4/2011	10/4/2014	Active Calibration
AA 9601	60	UTIFILEX Cable		Micro-Coak	UFC142A-0-0720-20	[218652-001	104/2011	1044/2012	Active Calibration
			Project Engineer.	ADI		_ 0)ualily Assurance	EPER	
×	Wireles Equi Date:	s Product Development pment Calibration : 20-Dec-2011		_ Type Test:	Conducted measu	rements		Job#:	<u>C-1371</u>
Pre	spared By	Aidi		Qustomer :	LSR			_ Quale #	311362
Asset#		Description		Manufacturer	Model#	Serial#	Cal Date	Cal Due Dale	Equipment Status
AA 9601	43	Phaseflex		Gore	EKD01D01048.0	5546519	6/1/2011	6/1/2012	Active Calibration
CC 0002	21C	SpectrumAnalyzer		HP	E4407B	US39160256	5442011	5/4/2012	Active Calibration
HE 96007	3	Spectrum Analyzer Discustor		Agilent	E4446A	US45300564	4/25/2011	4/25/2012	Active Calbration
AA 9601	44	masenex		Gore	EKLUTILUTIU?20	5800373	6472011	64142012	ACIVE CHETAION
			Project Engineer:	ADI		_ 0)ualiy Assuranci	<u>adamalger</u>	
	S RE	SEARCH LLC							
	Wireles Equi	s Product Development pment Calibration							
	Date	20-Dec-2011		Type Test	AC mains			_իրհ#-	C-1371
Prz	mared Pe			Oistoner -	LSR			 Curie #	311362
		1				1	1		
Asset#		Description		Manufacturer	Model#	Serial#	Cal Dale	Cal Due Dale	Equipment Status
HE 96001	6	Hill Neceiver Dif Descriver filter or -1		HP ID	8546A System	3617A00320,3448A	11/22/2011	11/22/2012	Active Calibration
AA 0604	14 172	can Necever-Met Section Transient Linder		п [.] нР	0:370UA 11947A	3448AUU296 3407A02545	11/2/2011	11/2/2012	Active Calibration
AA 9600	75	LISN		EMCO	3810/2NM	9612-1710	9/19/2011	9/19/2012	Active Calibration
			Project Engineer	Aiti		r	halik Asarana	r Mike Hintzke	
			· · · · · · · · · · · · · · · · · · ·	er mad					

Prepared For: LS Research LLC	EUT: TiWi5	LS Research, LLC
Report # 311362 B	Model #: TiWi5	Template: 15.247 FHSS
LSR Job #: C-1371	Serial#: Conducted Measurements: SN051201 Radiated Measurements: SN011201,SN081201	Page 46 of 48

APPENDIX B – Test Standards: CURRENT PUBLICATION DATES RADIO

STANDARD #	DATE	Am. 1	Am. 2
ANSI C63.4	2003		
ANSI C63.10	2009		
FCC 47 CFR, Parts 0-15, 18,			
90, 95	2012		
RSS GEN	2010		
RSS 210	2010		

Prepared For: LS Research LLC	EUT: TiWi5	LS Research, LLC
Report # 311362 B	Model #: TiWi5	Template: 15.247 FHSS
LSR Job #: C-1371	Serial#: Conducted Measurements: SN051201 Radiated Measurements: SN011201,SN081201	Page 47 of 48

APPENDIX C - Uncertainty Statement

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

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

	PARAMETER	LSR ± Uncertainty
1	Radio Frequency, from F0	±1.3x10 ⁻⁷
2	Total RF conducted Power	±1.38 dB
3	RF conducted power density	±1.38 dB
4	Conducted spurious emissions	±1.38 dB
5	Radiated emissions	±4.87 dB
6	Temperature	±0.64° C
7	Humidity	±2.9 %
8	DC voltage	±0.03 %
9	Low frequency voltage	±0.1 %

Measurement Type	Particular Configuration	Uncertainty Values
Radiated Emissions	3 – Meter chamber, Biconical Antenna	4.82 dB
Radiated Emissions	3-Meter Chamber, Log Periodic	4.88 dB
	Antenna	
Radiated Emissions	3-Meter Chamber, Horn Antenna	4.85 dB
Radiated Emissions	10-Meter OATS, Biconical Antenna	4.32 dB
Radiated Emissions	10-Meter OATS, Log Periodic Antenna	3.63 dB
Absolute Conducted Emissions	Agilent PSA/ESA Series	1.38 dB
AC Line Conducted Emissions	Shielded Room/EMCO LISN	3.20 dB
Radiated Immunity	3 Volts/Meter in 3-Meter Chamber	2.05 Volts/Meter
Conducted Immunity	3 Volts level	2.33 V
EFT Burst, Surge, VDI	230 VAC	54.4 V
ESD Immunity	Discharge at 15kV	3200 V
Temperature/Humidity	Thermo-hygrometer	0.64° / 2.88 %RH

Prepared For: LS Research LLC	EUT: TiWi5	LS Research, LLC
Report # 311362 B	Model #: TiWi5	Template: 15.247 FHSS
LSR Job #: C-1371	Serial#: Conducted Measurements: SN051201 Radiated Measurements: SN011201,SN081201	Page 48 of 48