Franklin Robotics, Inc.

Report of FCC and ISED Canada Intentional Radiator Testing

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Applicable Models	***Tertill***
Test Laboratory	***Core Compliance Testing Services, LLC*** ***79 River Road*** ***Hudson, NH 03051***
Test Dates	**July 10 – July 19, 2018**
Tested & Reviewed By	***Ken MacGrath, Manager*** ***George Correia, Test Engineer***
Signature, Manager	
Signature, Test Engineer	

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1.0 GENERAL INFORMATION

1.1 Product Description

Equipment Under Test (EUT): Tertill

Manufacturer: Franklin Robotics, Inc.
Applicable Models: Tertill
Serial Number: T1S-001C
Power Supply: (1) 18650 Lithium Ion battery, 3.7V, 2600mAh

EUT Technical Specifications:

A) Channels, Operating Frequency and Modulation

Tested Channel	Operating Frequency (MHz)	Modulation Type
1	2402	FSK
2	2440	FSK
3	2480	FSK

B) Rated output power: 1.44 milliwatts (1.57 dBm). Refer to section 4.0 of this report.

C) Antenna Designation: PCB trace, non-user replaceable (fixed), -2.4dBi (max).

D) This report documents the results for the Franklin Robotics Tertill which is a solar powered weeding robot for home gardens.

E) FCC ID: 2APTN-TERTILL001
IC ID: 23895-TERTILL001

F) Maximum Permissible Exposure (MPE): The EUT meets the MPE requirements by exclusion with reference to FCC Part 2.1091 for mobile devices and FCC KDB 447498 D01 General RF Exposure Guidance v06, and FCC KDB 865664 D02 RF Exposure Reporting v01r02.

1.2 Applicable Documents and Standards

This test report is based on the following standards.

- FCC CFR47, Part 15, Subpart C, Section 15.247
- FCC CFR47, Part 15, Subpart C, Section 15.209
- Industry Canada RSS-247, Issue 2, February 2017, Spectrum Management and Telecommunications, Radio Standards Specification, Digital Transmission Systems (DTSs), Frequency Hopping Systems (FHSs) and License-Exempt Local Area Network (LE-LAN) Devices
- RSS-GEN, Issue 5, April 2018, Spectrum Management and Telecommunications, Radio Standards Specification, General Requirements for Compliance of Radio Apparatus
- ANSI C63.10: 2013, American National Standard of Procedures for Compliance Testing of Unlicensed Wireless Devices
- ANSI C63.4: 2014

Maximum Permissible Exposure

- FCC Part 2.1091, Radiofrequency radiation exposure evaluation: mobile devices
- FCC KDB 447498 D01 General RF Exposure Guidance v06
- FCC KDB 865664 D02 RF Exposure Reporting v01r02

1.3 Test Dates

July 10 – July 19, 2018

1.4 Test Methodology

Testing was done according to the standards listed in section 1.2. Radiated testing was performed at an antenna-to-EUT distance of 3-meters.

1.5 Test Facility

The Alternative Open Area Test Site (OATS) and ferrite lined shielded chamber used to collect the radiated emissions data is located at Core Compliance Testing Services, 79 River Road, Hudson, NH. Radiated prescans are done in the ferrite lined shielded chamber and all final radiated emissions testing is done in the OATS which conforms to the site attenuation characteristics defined by ANSI C63.4-2014, MP5 and OST-55. The test facility is A2LA accredited to ISO 17025 (certificate # 2778.01) and is an ISED Canada registered wireless test site (site # 11794A-1).

1.6 Test Equipment List

All equipment used in the testing process has up to date calibrations traceable to the National Institute of Standards and Technology (NIST). Refer to the Table 1 below for a complete list of equipment used during the test.

Table 1: Test Equipment

Asset #	Description	Manufacturer	Model	Serial Number	Calibration Date	Calibration Due Date
3	Preamplifier 8447F OPT H64	Agilent/HP	8447F-H64	3113A07400	1/02/18	1/02/20
6	EMI Receiver/RF Filter Sytem	HP	8546A	3942A00506/3704A00463	12/20/17	12/20/18
15	Horn Antenna	EMCO	3115	9906-5841	N/A	N/A
17	Antenna, Bilog (Green)	Schaffner-Chase	CBL6112B	2602	12/28/16	12/28/18
17a	Attenuator, 4db Pad	Huber-Suhner	6804.17. A	1001701788		
18	Antenna, Bilog (Yellow)	Chase	CBL6140	1041	N/A	N/A
19	Pre-amplifier	HP/Agilent	08449B	3008A01322	12/13/17	12/13/19
20	Cable, 8 Meters	Andrew	ETS1-50T-S01	00a1108339	12/13/17	12/13/19
21	Cable, 25 meters with 2 Wurth Ferrites @ each end of the cable	A.H. Systems	SC-18G-25	1306	1/02/18	1/02/20
30	Semi-Anechoic chamber	Keene Ray Proof	N/A	8298	9/08/17	9/08/18
51	Analyzer RF Unit	Rohde & Schwarz	ESMI	845364/009	2/16/18	2/16/19
52	Analyzer Display Unit	Rohde & Schwarz		845442/014		
84	Spectrum Analyzer	Agilent	E4407B	US41192608	1/2/18	1/2/20
103	Loop Antenna	Com-Power	AL-130	121056	5/1/18	5/1/20
109	Alternative Open Area Test Site	Strongwell	10 Meter	None	12/15/16	12/15/18
114	Humidity Alert	Control Company	4040	122171578	10/17/17	10/17/18
126	DRG Horn Antenna 700M-18GHz	A.H. Systems	SAS-571	782	4/27/18	4/27/20
133	Horn Antenna 15-26.5 GHz	Schwarzbeck	BBHA9170	9170	7/13/16	7/13/19
138	Preamplifier	Miteq	NSP1001200-NF-S	701275	1/02/18	1/02/20
144	EMI Test Receiver	Rohde & Schwarz	ESMI	848926/003 - 849182/001	4/23/18	4/23/19
148	SMA Cable	Thermax	DCA5573-12	None	7/31/18	7/31/19

All equipment used for testing has been calibrated according to methods and procedures defined by the National Institute of Standards and Technology (NIST).

1.7 Measurement Uncertainty

Radiated Emissions up to 1GHz, Expanded Uncertainty	4.19
Radiated Emissions 1-18GHz, Expanded Uncertainty	4.84
Conducted Emissions up to 30MHz, Expanded Uncertainty	2.65
Telco Conducted Emissions up to 30MHz, Expanded Uncertainty	2.83

The measurement uncertainty of radiated emissions data is based on the test equipment used and the OATS site attenuation data. The measurement uncertainty of conducted emissions and Telco conducted emissions data is based on the test equipment used.

1.8 Equipment Modifications

The firmware was modified to provide continuous transmit at maximum power (+4 dBm) with modulation applied at the low (2402MHz), middle (2440MHz), and high (2480MHz) channels.

2.0 SYSTEM TEST CONFIGURATION

2.1 EUT Configuration

The EUT configuration for testing was based on the requirements as given in the applicable standards and was operated in a manner which intends to maximize its emissions characteristics in a continuous transmit application as detailed in section 2.2.

2.2 EUT Exercise

The EUT has been tested under operating conditions and was programmed to allow it to remain in continuous transmitting mode.

Voltage variation testing was initially done to determine the worst case voltage in the 3.7 – 4.2 VDC battery range. The voltage was varied using an external power supply. The test was done at the low, mid, and high channels. The following data was recorded and the worst case of 4.2VDC was used for all subsequent testing given in this report.

Power Supply Voltage (VDC)	Channel Frequency (MHz)	Measured Output (dBµV)
3.7	2402	95.66
4.0	2402	95.04
4.2	**2402**	**95.80**
3.7	2440	91.63
4.0	2440	91.72
4.2	**2440**	**92.11**
3.7	2480	90.13
4.0	2480	90.14
4.2	**2480**	**90.14**

External Power Supply: Thurlby Thandar Instruments (TTi) Model TSX3510P

The EUT was operated as follows:

Transmit Channel	Transmit Freq. (MHz)	Transmit Power Level	Test Mode	Modulation
1	2402	+4dBm (max)	BLE mode @ 1Mbps data rate	FSK
	2402	+4dBm (max)	BLE mode @ 2Mbps data rate	FSK
	2402	+4dBm (max)	Nordic mode @ 1Mbps data rate	FSK
	2402	+4dBm (max)	Nordic mode @ 2Mbps data rate	FSK
2	2440	+4dBm (max)	BLE mode @ 1Mbps data rate	FSK
	2440	+4dBm (max)	BLE mode @ 2Mbps data rate	FSK
	2440	+4dBm (max)	Nordic mode @ 1Mbps data rate	FSK
	2440	+4dBm (max)	Nordic mode @ 2Mbps data rate	FSK
3	2480	+4dBm (max)	BLE mode @ 1Mbps data rate	FSK
	2480	+4dBm (max)	BLE mode @ 2Mbps data rate	FSK
	2480	+4dBm (max)	Nordic mode @ 1Mbps data rate	FSK
	2480	+4dBm (max)	Nordic mode @ 2Mbps data rate	FSK

3.0 SUMMARY OF TEST RESULTS

Table 2: Test Summary

Rules	Description Of Test	Test Report Section	Result
FCC 15.247 (b) (3) RSS-247, 5.4 (d)	Peak Output Power (1 W)	4.0	*Pass*
FCC 15.247 (a) (2) RSS-247, 5.2 (a)	6dB Bandwidth (≥500kHz)	5.0	*Pass*
FCC 15.247 (d) RSS-247, 5.5	100 kHz Band Edge Measurements	6.0	*Pass*
FCC 15.247 (e) RSS-247, 5.2 (b)	Peak Power Spectral Density (8dBm/3kHz)	7.0	*Pass*
FCC 15.209 (a) - (f) RSS-GEN, 8.9	Unintentional/Spurious Emissions	8.0	*Pass*
FCC 15.203 FCC 15.247 (4) (i) RSS-GEN, 6.8 RSS-247, 5.4 (f) (ii)	Antenna Requirement	9.0	*Pass*
FCC Part 2.1091 FCC KDB 447498 D01	Maximum Permissible Exposure (MPE)	10.0	*Pass*
FCC 15.207 (a) RSS-GEN, 8.8	Conducted Emissions	N/A	**N/A*

*No connection to AC power.

4.0 PEAK OUTPUT POWER MEASUREMENT

4.1 Applicable Standards

FCC 15.247 (b) (3), RSS-247, 5.4 (d). For systems using digital modulation techniques in the 2400 – 2483.5 MHz band, the maximum peak conducted output power is 1.0 Watt.

4.2 Measurement Procedure

Place the EUT on a 1.5m high polystyrene stand and set it into transmitting mode. Measurements were made with typical modulation applied.

Utilizing the radiated emissions method, the EUT was set up on a three meter OATS. The field strength was maximized by rotating the turntable and adjusting the antenna height. Measurements were further optimized for vertical and horizontal polarization of the receive antenna.

The peak field strength for each transmit frequency was recorded.

To convert field strength at 3 meters to power in Watts, the following formula was

Used: $P = (E \times d)^2 / (30 \times G)$

Where:
P = Power in Watts
E = Field strength in V/m
d = Measurement distance in meters
G = Numerical Gain of Antenna

Repeat the above procedures for each of the low, mid, and high frequency channels.

4.3 Measurement Results Summary

Channel	Frequency (MHz)	Reading (dBµV)	Cable Loss (dB)	Preamp Gain (dB)	A.F. (dB)	Field Strength (dBµV/m)	Field Strength (µV/m)	Antenna Numerical Gain	Power Calculation (mW)	*EIRP (dBm)
Low	2402.000	97.2	8.5	37.6	28.7	96.8	69183	1.0	1.435890	1.57
Mid	2440.000	93.9	8.7	37.6	28.8	93.8	48978	1.0	0.719650	-1.43
High	2480.000	91.7	8.7	37.6	29.0	91.8	38905	1.0	0.454068	-3.43

*Field strength includes cable loss, preamplifier gain, and antenna factor as shown below each of the following plots. The antenna numerical gain was set to 1.0 in the tables in this section because the antenna is an integral part of the EUT and EIRP data was used in the power calculations.

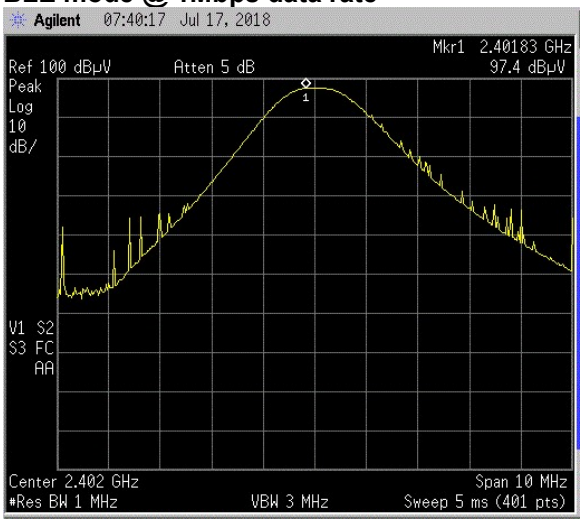
4.4 Peak Output Power Test Results

The peak output power plots are shown on the following pages.

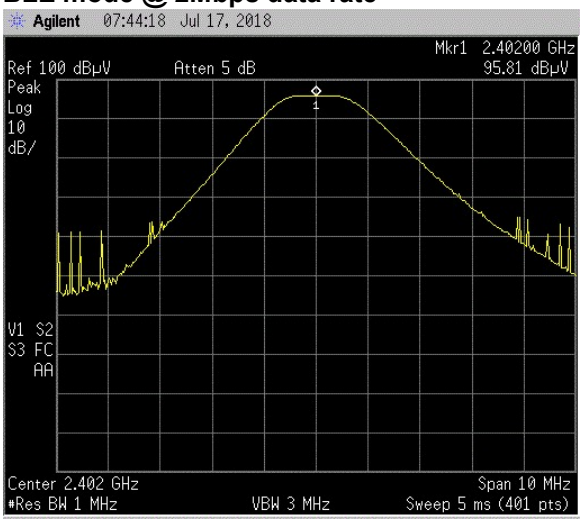
4.4 Peak Output Power Test Results (continued)

Peak Power Output Data Plot (Low – 2402MHz)

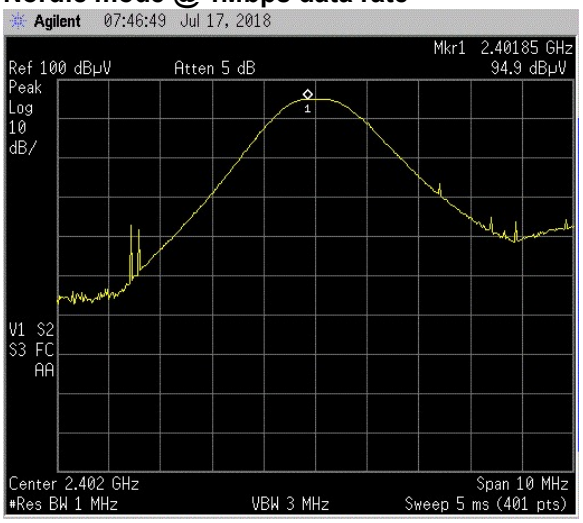
BLE mode @ 1Mbps data rate



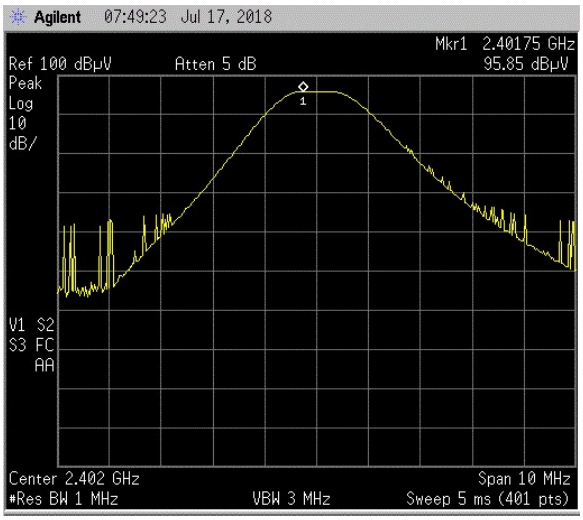
BLE mode @ 2Mbps data rate



Nordic mode @ 1Mbps data rate



Nordic mode @ 2Mbps data rate



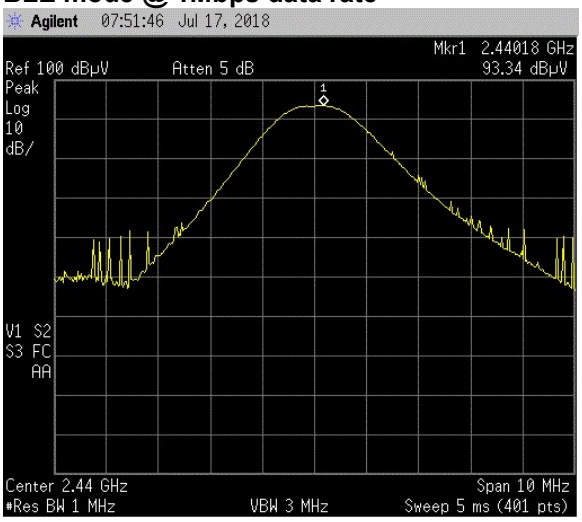
Operating Mode	Frequency (MHz)	Reading (dBµV)	Cable Loss (dB)	Preamp Gain (dB)	A.F. (dB)	Field Strength (dBµV/m)	Field Strength (µV/m)	Antenna Numerical Gain	Power Calculation (mW)	*EIRP (dBm)
BLE, 1Mbps	2402.000	97.2	8.5	37.6	28.7	96.8	69183	1.0	1.435890	1.57
BLE, 2Mbps	2402.000	95.7	8.5	37.6	28.7	95.3	58210	1.0	1.016532	0.07
Nordic, 1Mbps	2402.000	95.1	8.5	37.6	28.7	94.7	54325	1.0	0.885363	-0.53
Nordic, 2Mbps	2402.000	96.3	8.5	37.6	28.7	95.9	62373	1.0	1.167135	0.67

*EIRP calculation Ref: 4.2

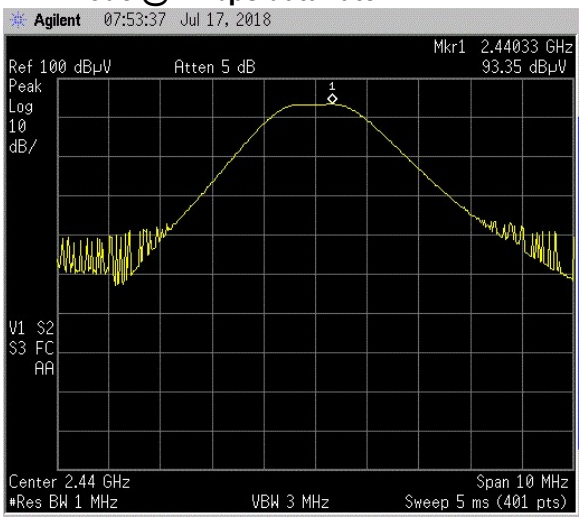
4.4 Peak Output Power Test Results (continued)

Peak Power Output Data Plot (Mid – 2440MHz)

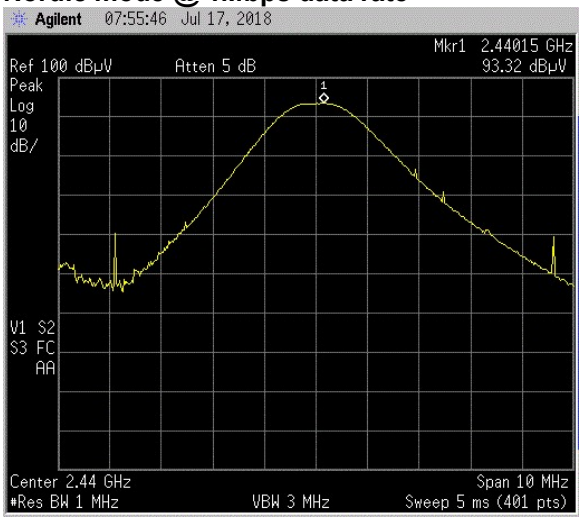
BLE mode @ 1Mbps data rate



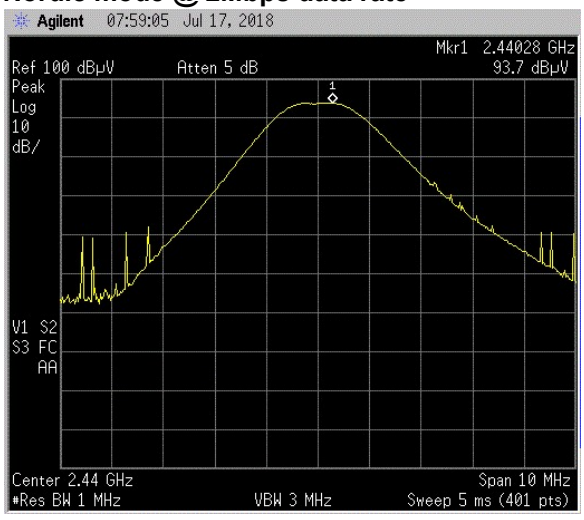
BLE mode @ 2Mbps data rate



Nordic mode @ 1Mbps data rate



Nordic mode @ 2Mbps data rate



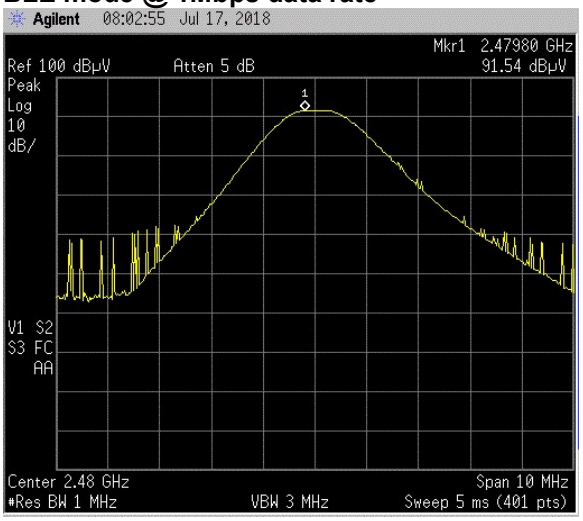
Operating Mode	Frequency (MHz)	Reading (dBµV)	Cable Loss (dB)	Preamp Gain (dB)	A.F. (dB)	Field Strength (dBµV/m)	Field Strength (µV/m)	Antenna Numerical Gain	Power Calculation (mW)	*EIRP (dBm)
BLE, 1Mbps	2440.000	93.7	8.7	37.6	28.8	93.6	47863	1.0	0.687260	-1.63
BLE, 2Mbps	2440.000	93.9	8.7	37.6	28.8	93.8	48978	1.0	0.719650	-1.43
Nordic, 1Mbps	2440.000	93.6	8.7	37.6	28.8	93.5	47315	1.0	0.671616	-1.73
Nordic, 2Mbps	2440.000	93.9	8.7	37.6	28.8	93.8	48978	1.0	0.719650	-1.43

*EIRP calculation Ref: 4.2

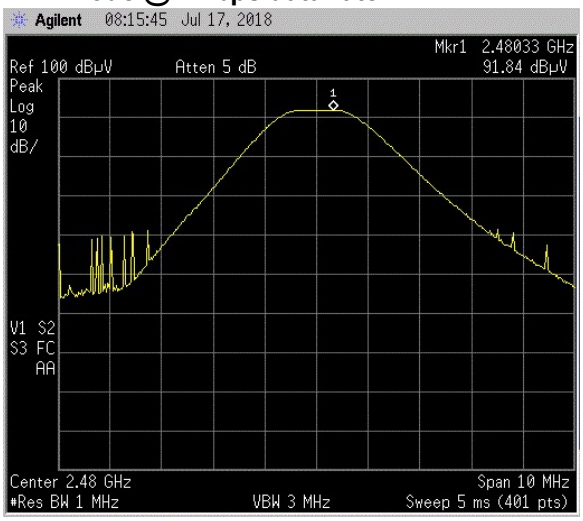
4.4 Peak Output Power Test Results (continued)

Peak Power Output Data Plot (High – 2480MHz)

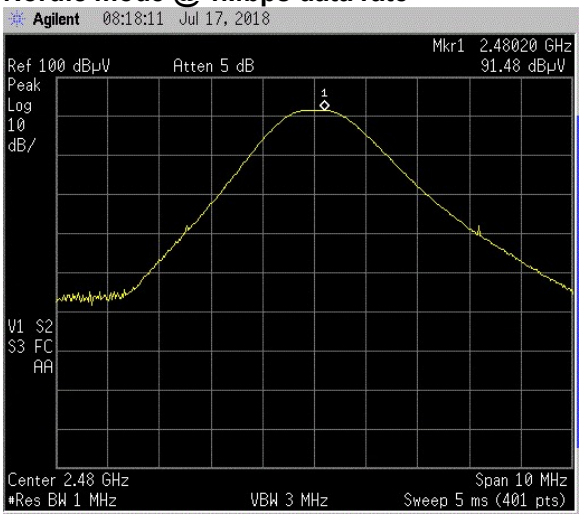
BLE mode @ 1Mbps data rate



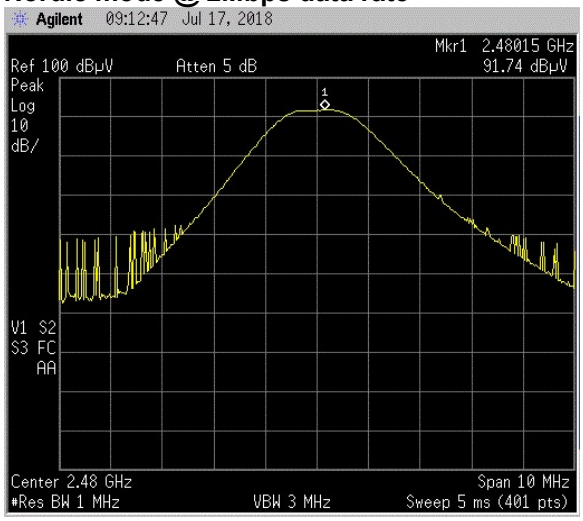
BLE mode @ 2Mbps data rate



Nordic mode @ 1Mbps data rate



Nordic mode @ 2Mbps data rate



Operating Mode	Frequency (MHz)	Reading (dBµV)	Cable Loss (dB)	Preamp Gain (dB)	A.F. (dB)	Field Strength (dBµV/m)	Field Strength (µV/m)	Antenna Numerical Gain	Power Calculation (mW)	*EIRP (dBm)
BLE, 1Mbps	2480.000	91.6	8.7	37.6	29.0	91.7	38459	1.0	0.443733	-3.53
BLE, 2Mbps	2480.000	91.7	8.7	37.6	29.0	91.8	38905	1.0	0.454068	-3.43
Nordic, 1Mbps	2480.000	91.3	8.7	37.6	29.0	91.4	37154	1.0	0.414115	-3.83
Nordic, 2Mbps	2480.000	91.7	8.7	37.6	29.0	91.8	38905	1.0	0.454068	-3.43

*EIRP calculation Ref: 4.2

4.5 Peak Output Power Measurement Conclusion

The EUT meets the peak output power requirement of FCC 15.247 (b) (3) and RSS-247, 5.4 (d). The maximum peak power output power was 1.436 mW which is under the 1.0 Watt limit (+30 dBm).

5.0 6dB BANDWIDTH

5.1 Applicable Standards

FCC 15.247 (a) (2), RSS-247, 5.2 (a). For systems using digital modulation techniques in the 2400 – 2483.5 MHz band, the minimum 6 dB bandwidth shall be at least 500 kHz.

5.2 Measurement Procedure

Measure the maximum width of the emission that is constrained by the frequencies associated with the two outermost amplitude points that are attenuated by 6 dB, relative to the peak of the fundamental frequency.

These measurements were performed at the low, mid, and high channel frequencies.

5.3 Measurement Results Summary

Channel	Bandwidth (kHz)
1 - Low – 2402MHz	500
2 - Mid – 2440MHz	505
3 - High – 2480MHz	505

Note that the worst case 6dB bandwidth results are given above and these occurred when using Nordic mode at 1Mbps data rate.

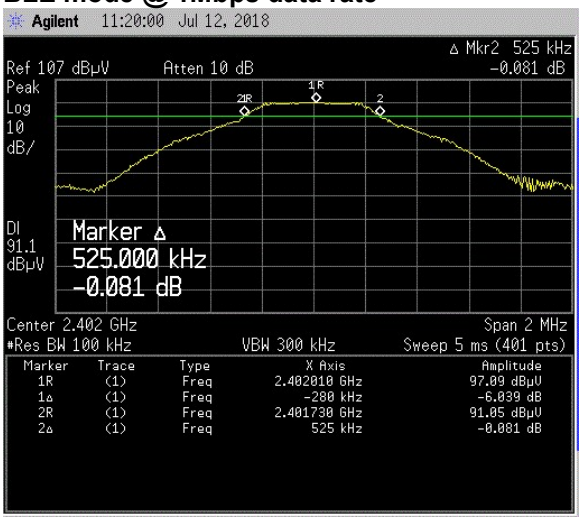
5.4 6dB Bandwidth Test Results

The 6dB bandwidth plots are shown on the following pages.

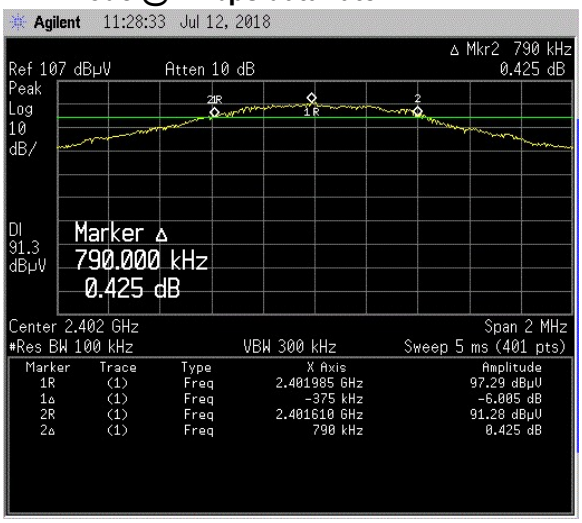
5.4 6dB Bandwidth Test Results (continued)

6dB Bandwidth Data Plot (Low – 2402MHz)

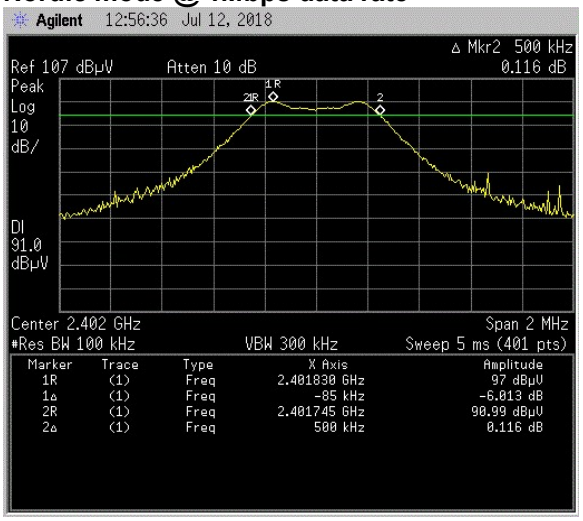
BLE mode @ 1Mbps data rate



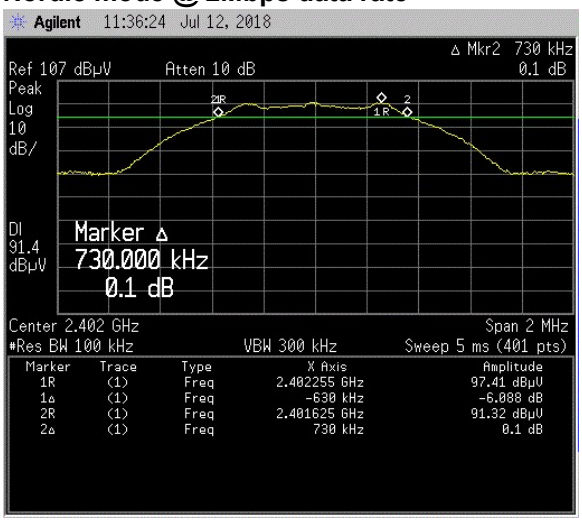
BLE mode @ 2Mbps data rate



Nordic mode @ 1Mbps data rate



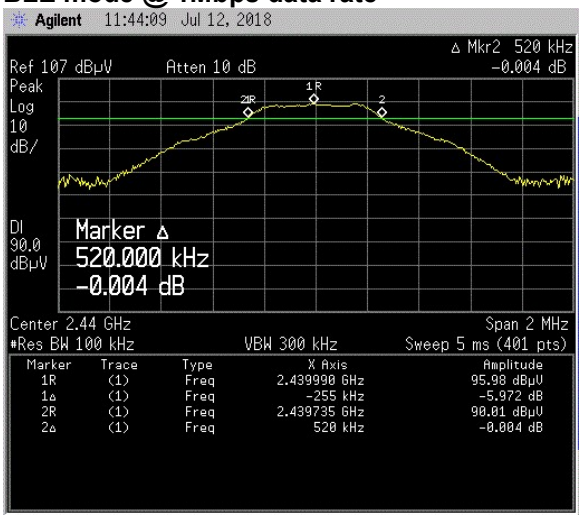
Nordic mode @ 2Mbps data rate



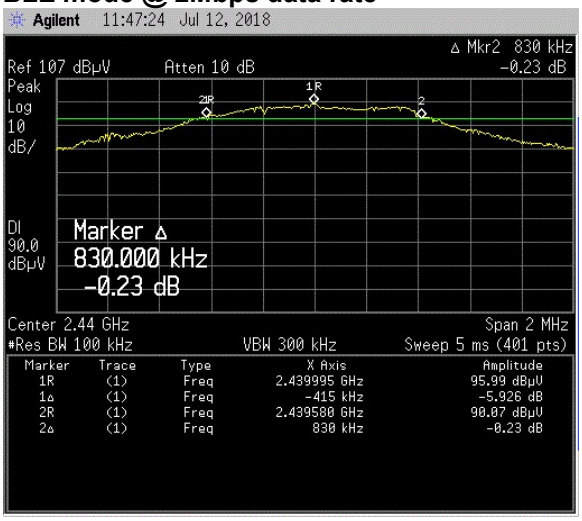
5.4 6dB Bandwidth Test Results (continued)

6dB Bandwidth Data Plot (Mid – 2440MHz)

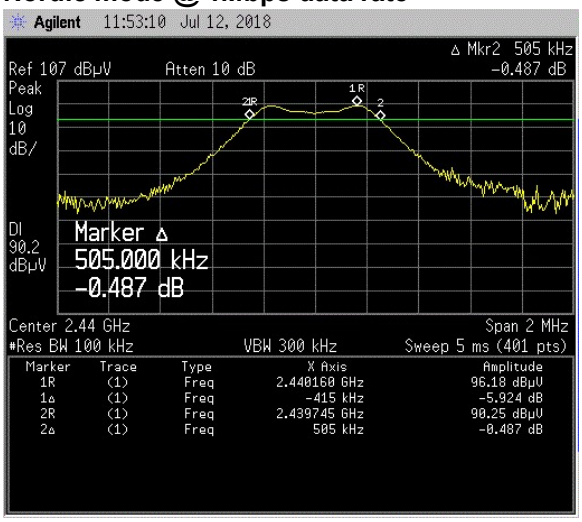
BLE mode @ 1Mbps data rate



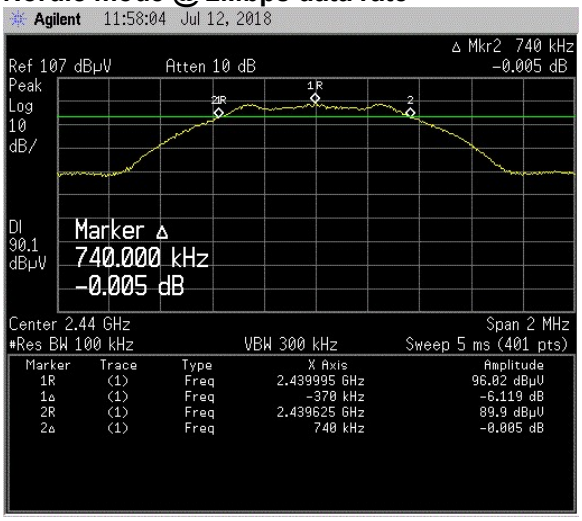
BLE mode @ 2Mbps data rate



Nordic mode @ 1Mbps data rate



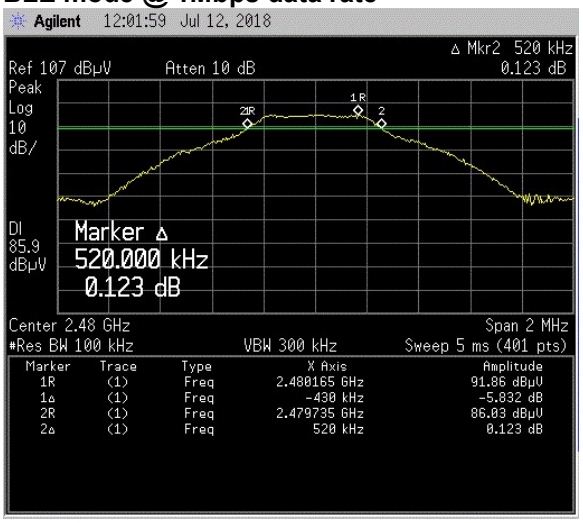
Nordic mode @ 2Mbps data rate



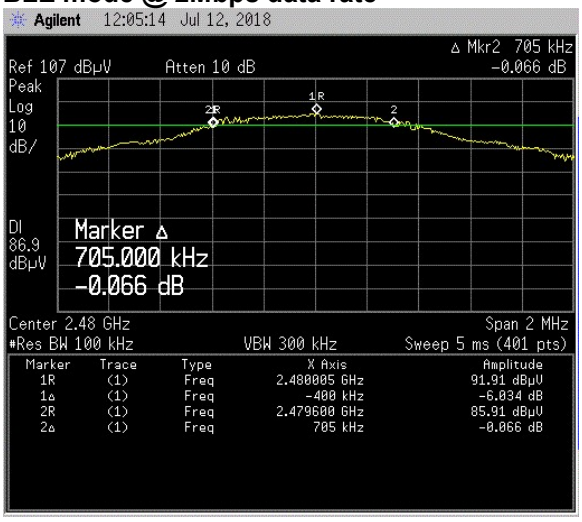
5.4 6dB Bandwidth Test Results (continued)

6dB Bandwidth Data Plot (High – 2480MHz)

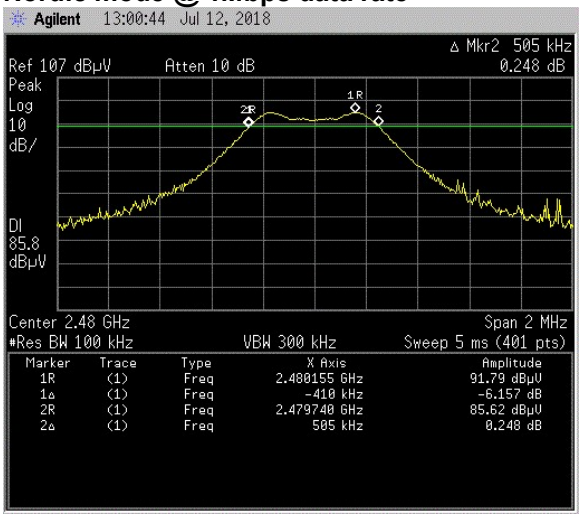
BLE mode @ 1Mbps data rate



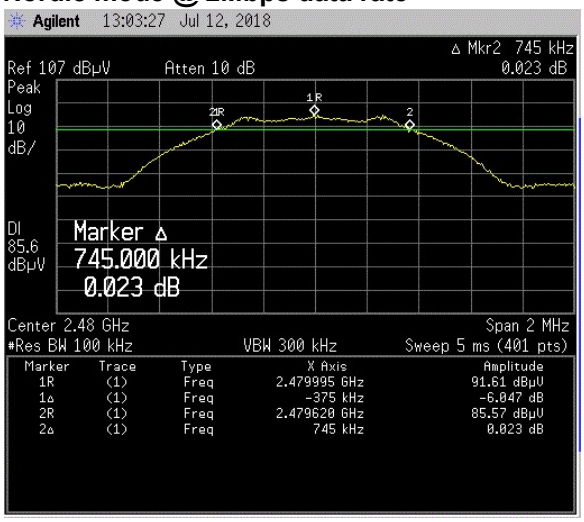
BLE mode @ 2Mbps data rate



Nordic mode @ 1Mbps data rate



Nordic mode @ 2Mbps data rate



5.5 6dB Bandwidth Measurement Conclusion

The EUT meets the 6dB bandwidth requirements of FCC 15.247 (a) (2) and RSS-247, 5.2 (a). The worst case 6dB bandwidth of the EUT occurred when using Nordic mode at a 1Mbps data rate and was 500kHz which meets the 500kHz minimum bandwidth requirement.

6.0 100kHz BAND EDGE MEASUREMENTS

6.1 Applicable Standards

FCC 15.247 (d), RSS-247, 5.5. In any 100kHz bandwidth outside the frequency bands in which the digitally modulated intentional radiator is operating, the radio frequency power that is produced by the intentional radiator shall be at least 20dB below that in the 100KHz bandwidth within the band that contains the highest level of the desired power. In addition, radiated emissions, which fall in the restricted bands, as defined in FCC 15.205 (a) and RSS-GEN, 8.10, must also comply with the radiated emission limits specified in FCC 15.209 (a) and RSS-GEN, 8.9.

6.2 Measurement Procedure

- Place the EUT on a 1.5m high polystyrene stand and set it in transmitting mode with modulation.
- Set the center frequency of the spectrum analyzer to the operating frequency.
- Set the spectrum analyzer RBW= 100kHz, VBW=300KHz, Span=10MHz, Sweep Auto
- Mark the peak, 2.402 GHz, Low channel and record the maximum level. The lower band edge is 2.400GHz. The upper band edge is 2.4835 GHz.
- Set the delta marker to the next lower frequency of spurious emission outside of the band and record the peak.
- Repeat the above procedures at 2.480 GHz, High channel and measure the next highest spurious emission and record the level.

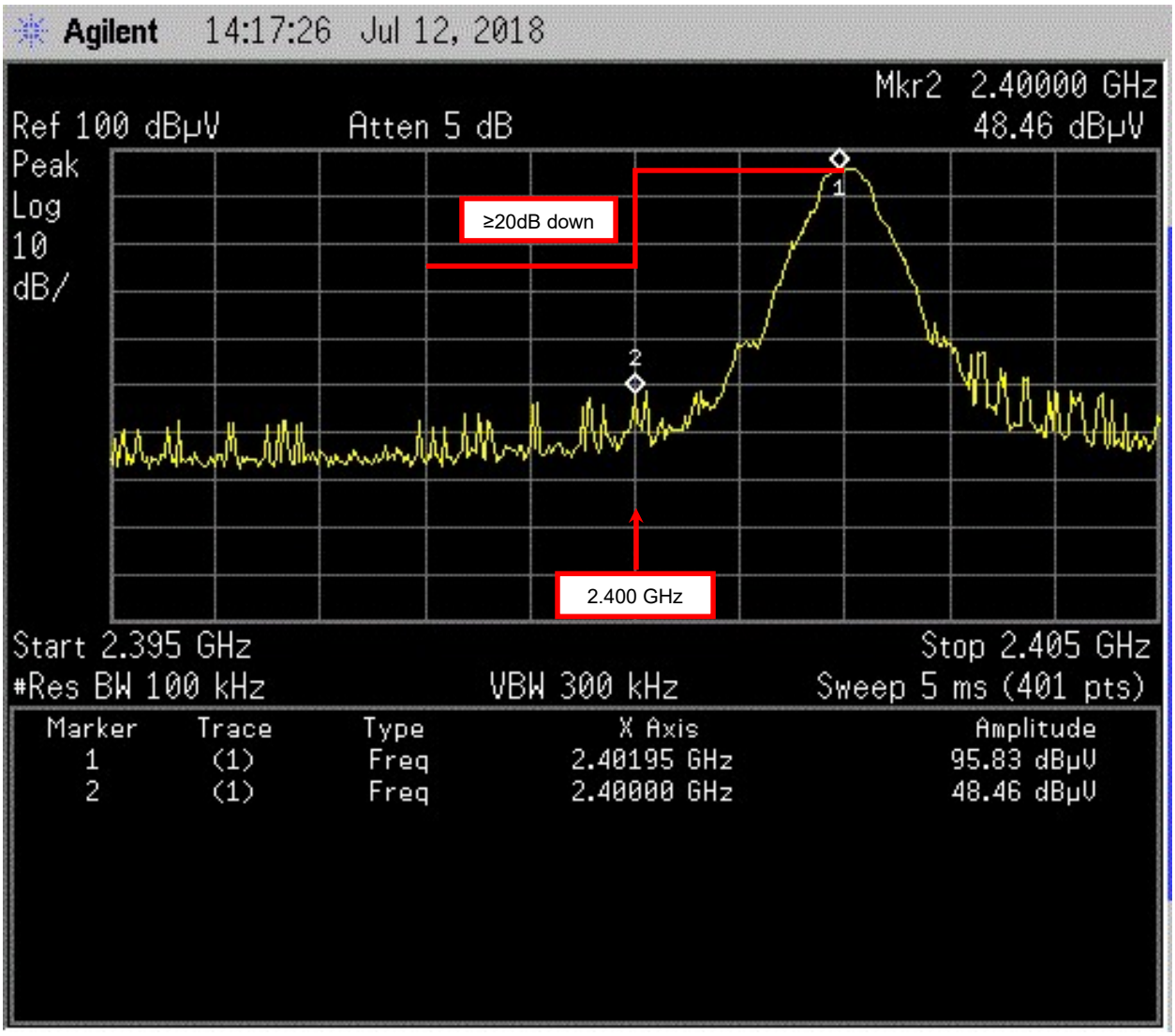
6.3 100kHz Band Edge Measurement Test Results

The 100kHz band edge measurement plots are shown on the following pages.

6.3 100kHz Band Edge Measurement Test Results (continued)

100kHz Band Edge Measurement Data (Low – 2402MHz)

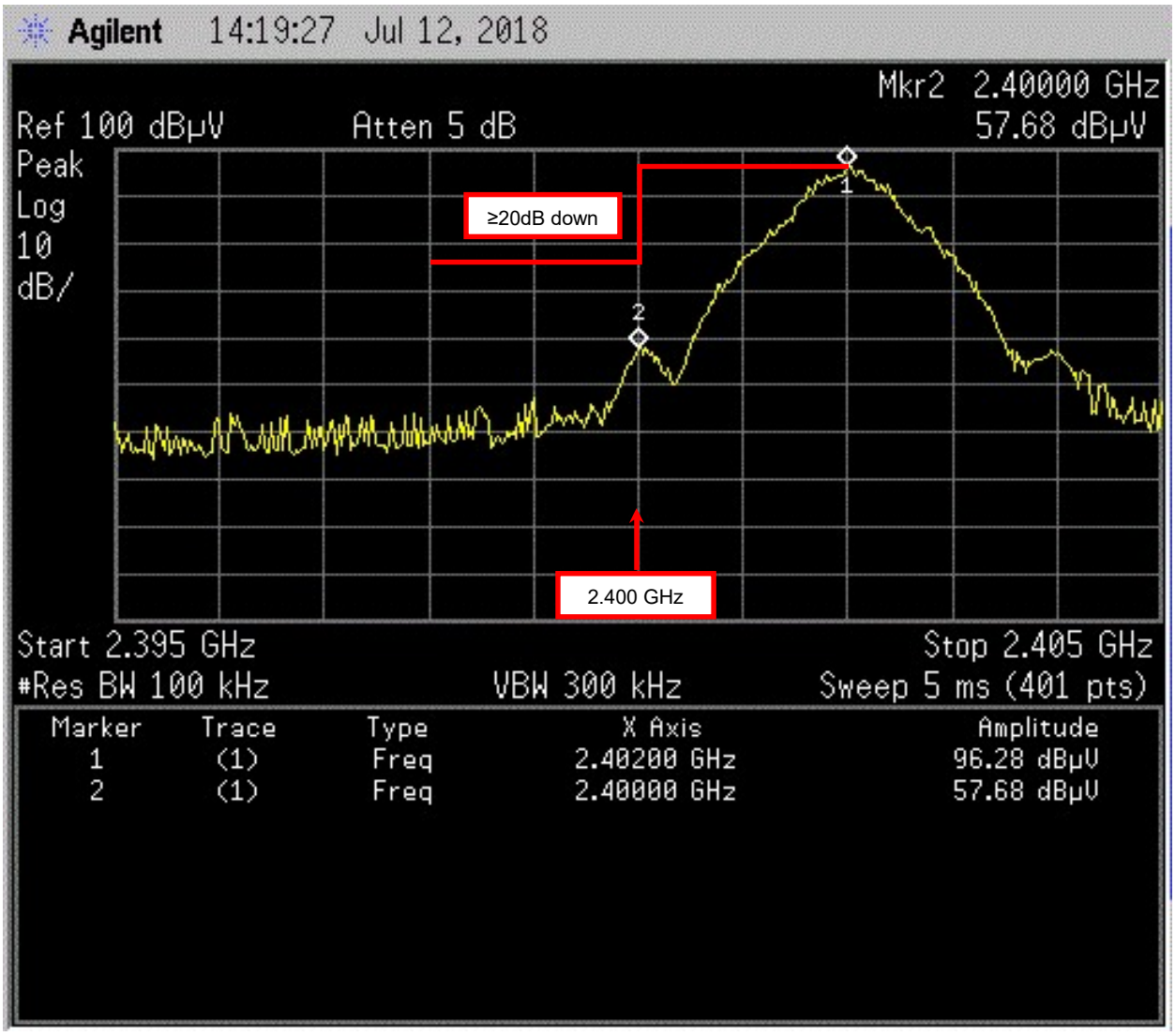
BLE mode @ 1Mbps data rate



6.3 100kHz Band Edge Measurement Test Results (continued)

100kHz Band Edge Measurement Data (Low – 2402MHz)

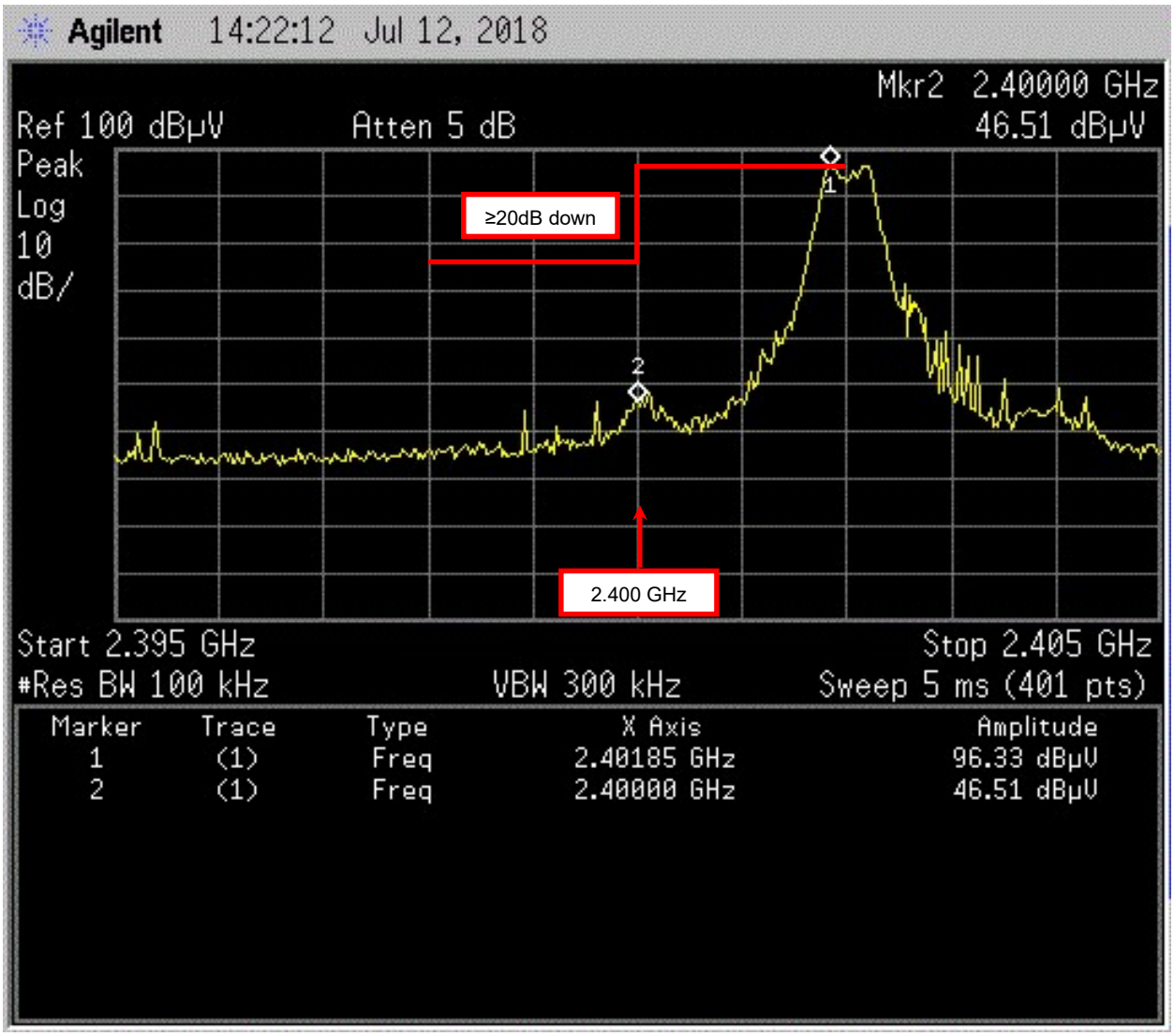
BLE mode @ 2Mbps data rate



6.3 100kHz Band Edge Measurement Test Results (continued)

100kHz Band Edge Measurement Data (Low – 2402MHz)

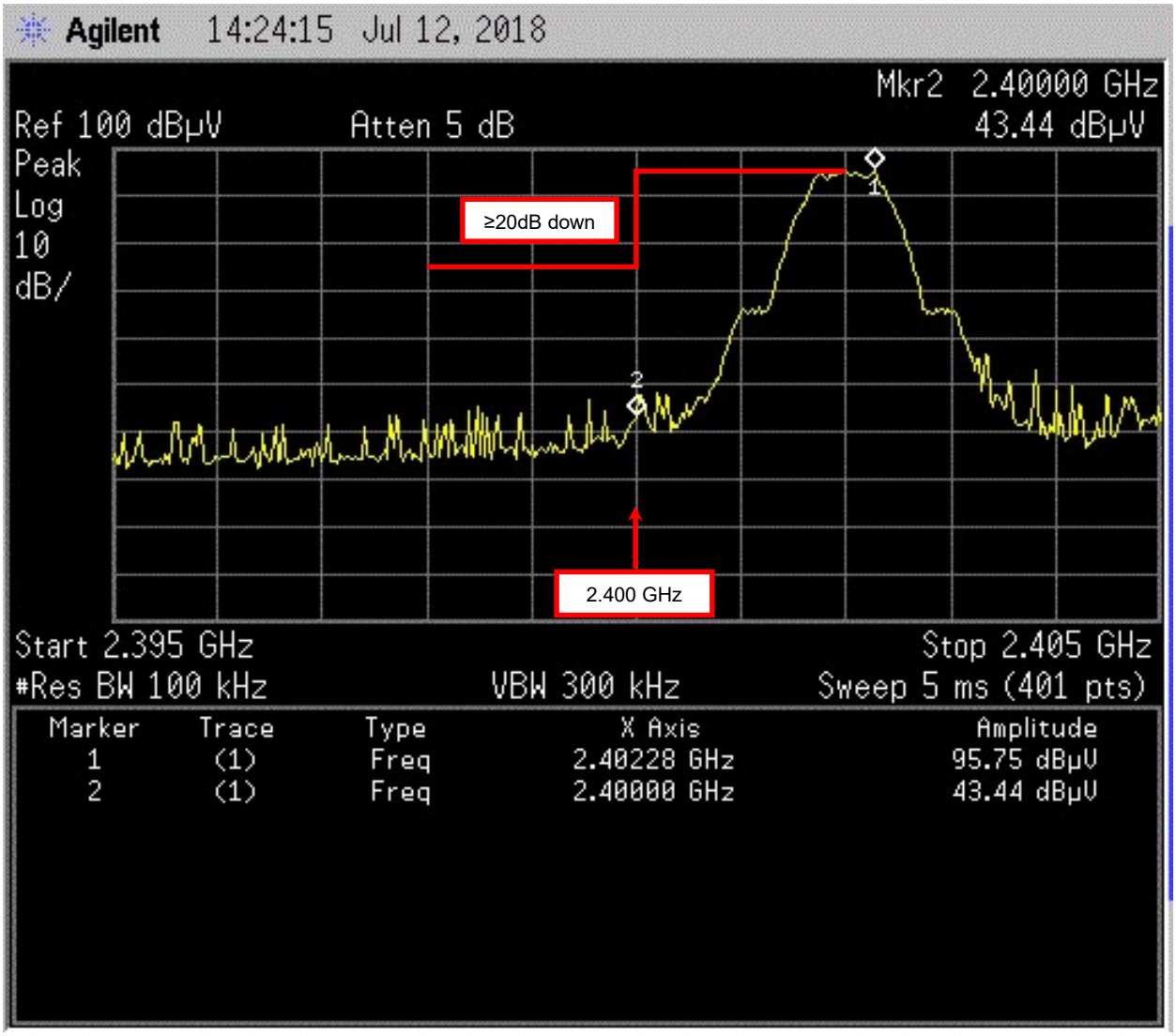
Nordic mode @ 1Mbps data rate



6.3 100kHz Band Edge Measurement Test Results (continued)

100kHz Band Edge Measurement Data (Low – 2402MHz)

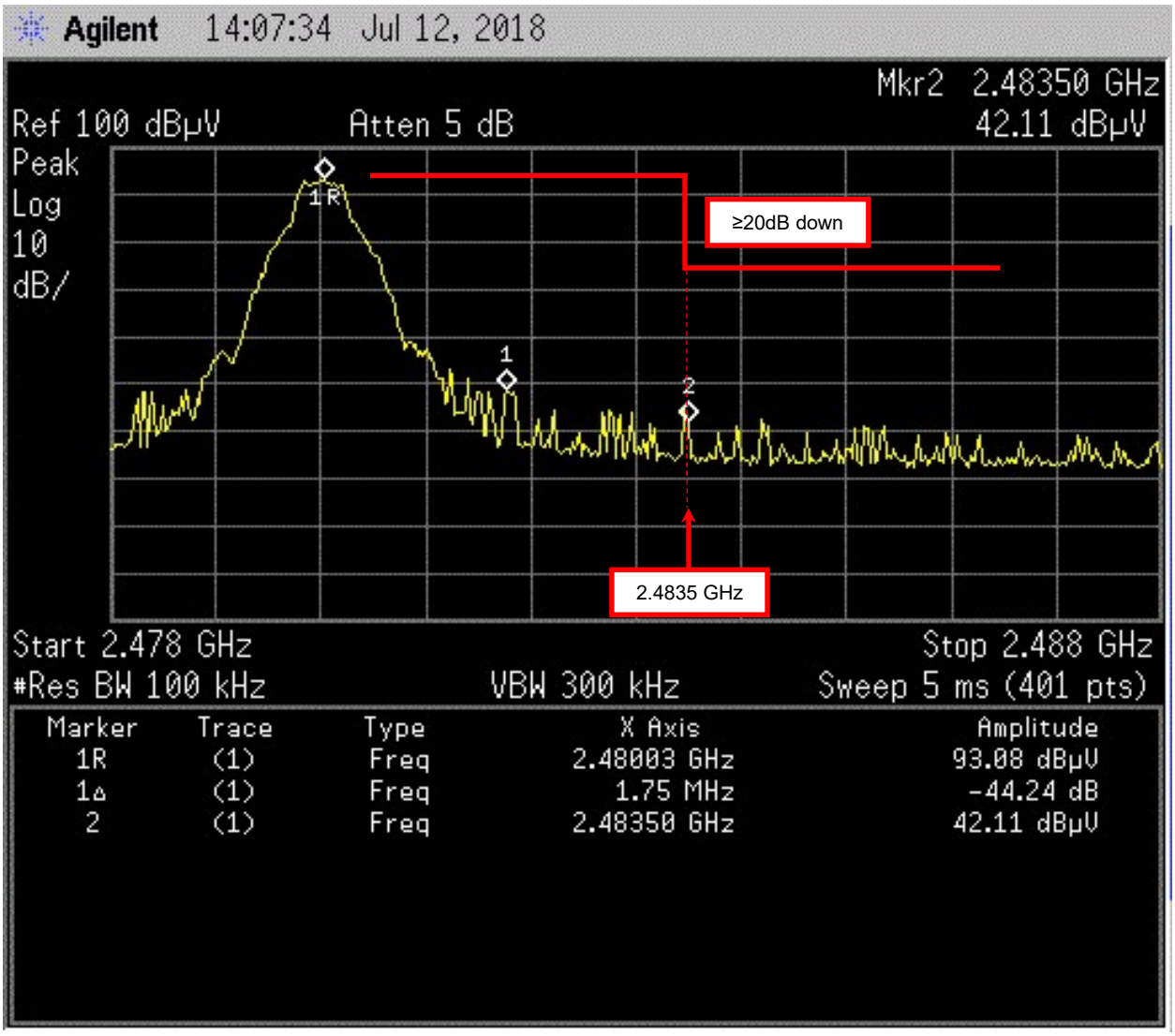
Nordic mode @ 2Mbps data rate



6.3 100kHz Band Edge Measurement Test Results (continued)

100kHz Band Edge Measurement Data (High – 2480MHz)

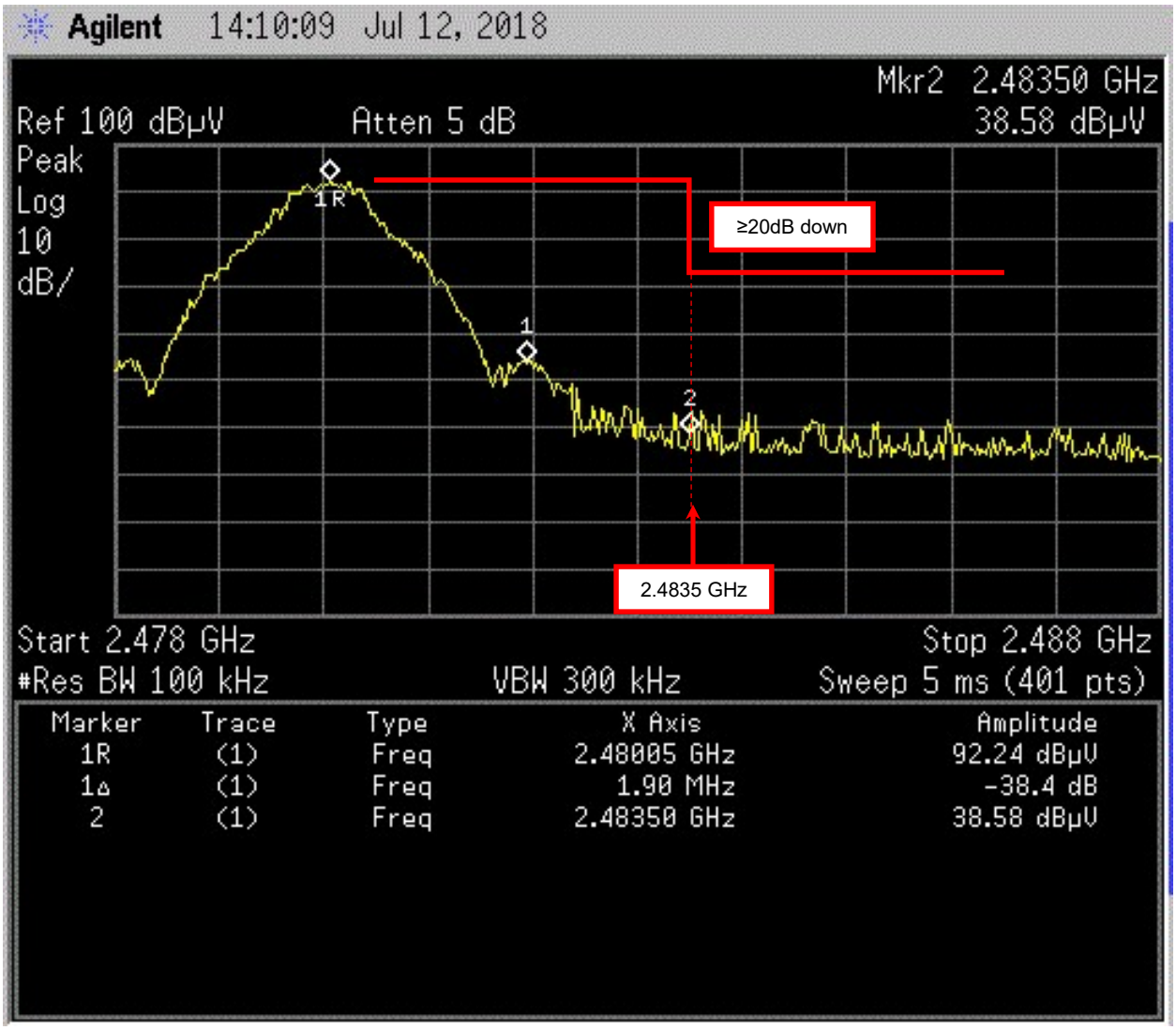
BLE mode @ 1Mbps data rate



6.3 100kHz Band Edge Measurement Test Results (continued)

100kHz Band Edge Measurement Data (High – 2480MHz)

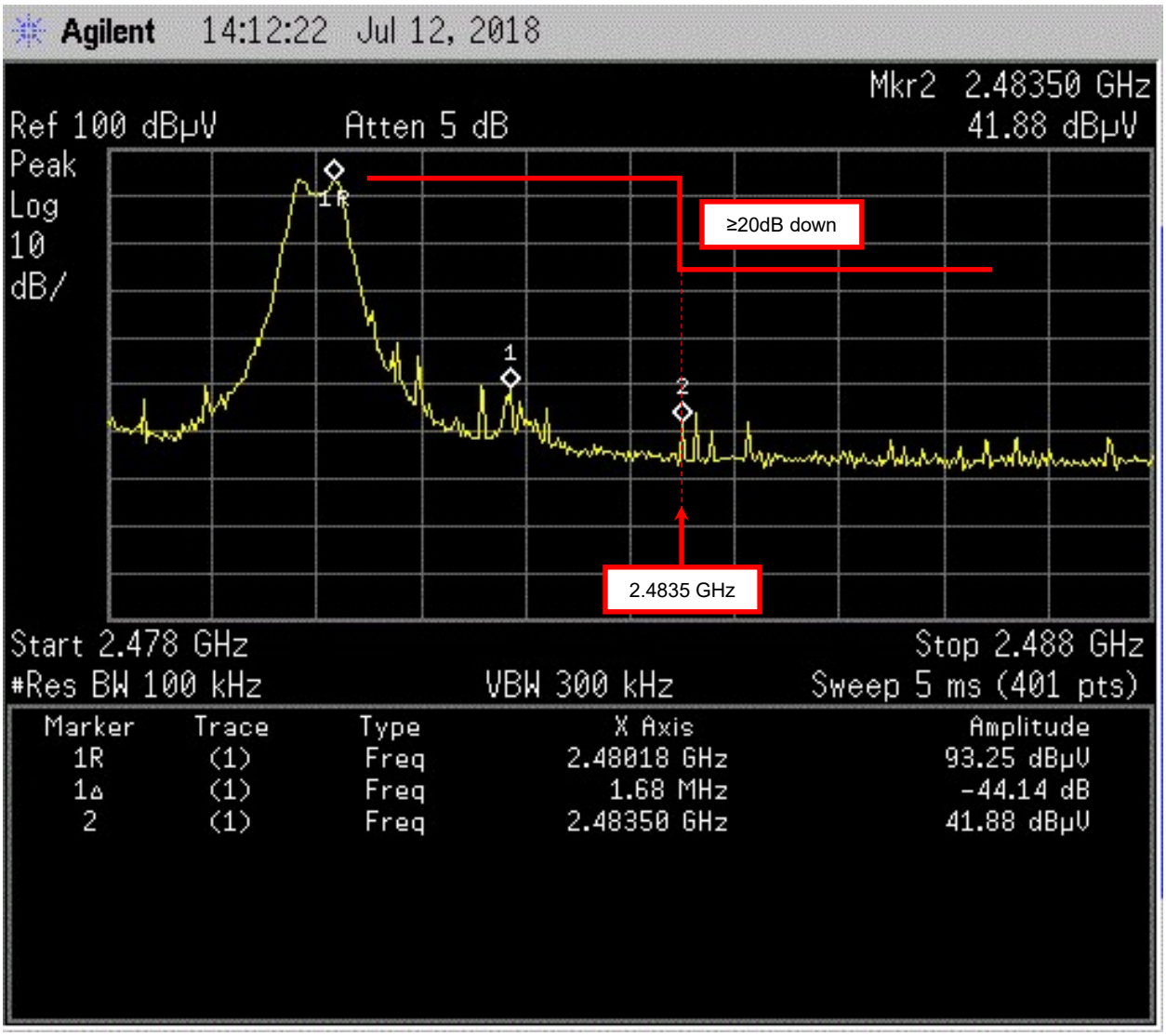
BLE mode @ 2Mbps data rate



6.3 100kHz Band Edge Measurement Test Results (continued)

100kHz Band Edge Measurement Data (High – 2480MHz)

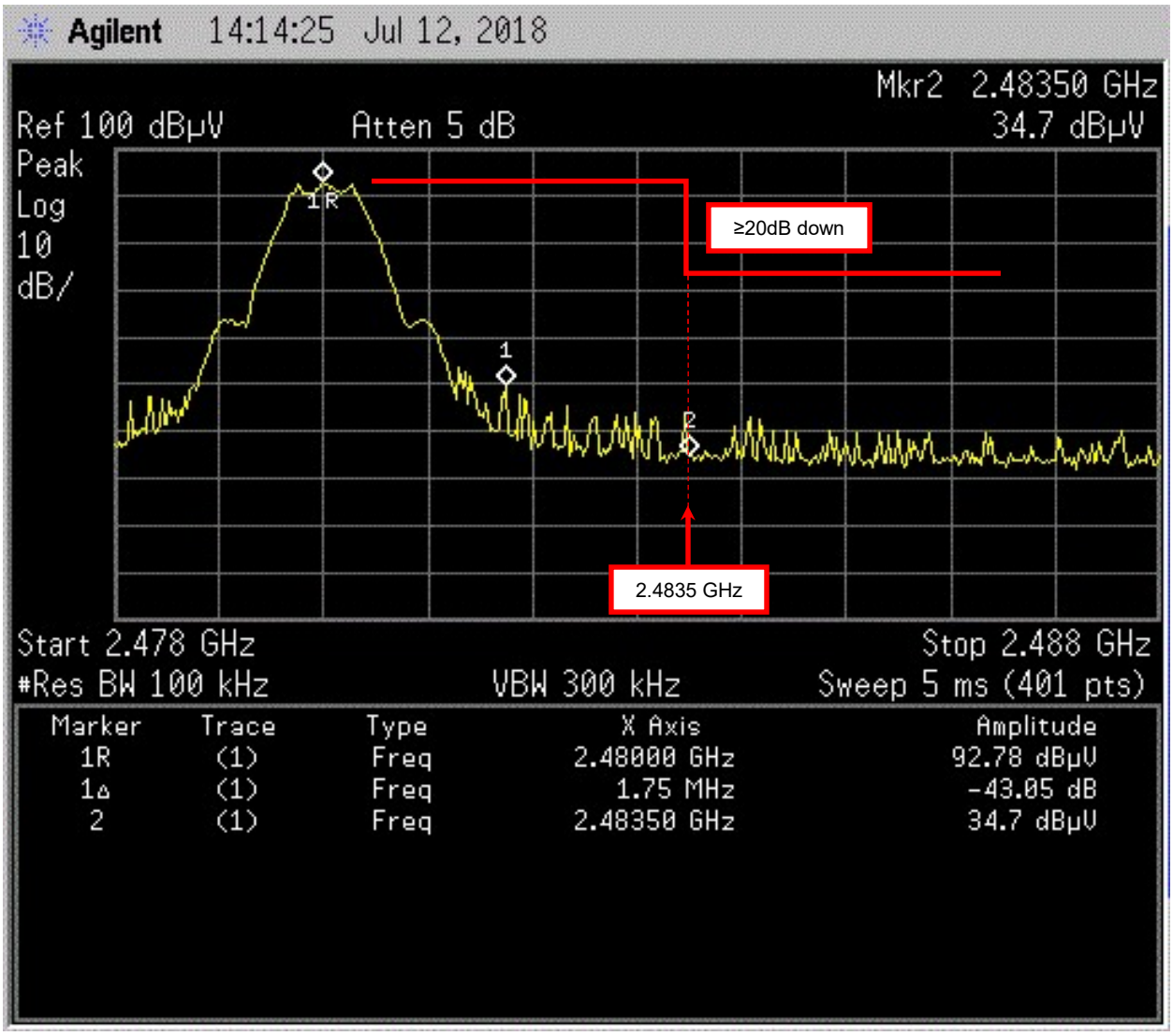
Nordic mode @ 1Mbps data rate



6.3 100kHz Band Edge Measurement Test Results (continued)

100kHz Band Edge Measurement Data (High – 2480MHz)

Nordic mode @ 2Mbps data rate



6.4 100kHz Band Edge Measurement Conclusion

The EUT meets the 100kHz band edge measurement requirements of FCC 15.247 (d) and RSS-247, 5.5.

7.0 PEAK POWER SPECTRAL DENSITY

7.1 Applicable Standards

FCC 15.247 (e), RSS-247, 5.2 (b). For digitally modulated systems, the peak power spectral density conducted from the intentional radiator to the antenna shall not be greater than 8 dBm in any 3kHz band during any time of continuous transmission.

7.2 Measurement Procedure

- Place the EUT on a 1.5m high polystyrene stand and set it in continuous transmit mode with modulation.
- Set the spectrum analyzer RBW = 3kHz, VBW = 10kHz, Span = 1MHz, Sweep = Auto.
- Record the maximum reading.
- Repeat above procedures for low, mid, and high frequency channels.

7.3 Peak Power Spectral Density Measurement Results

This data table and the plots on the following pages show the Peak Power Spectral Density test results.

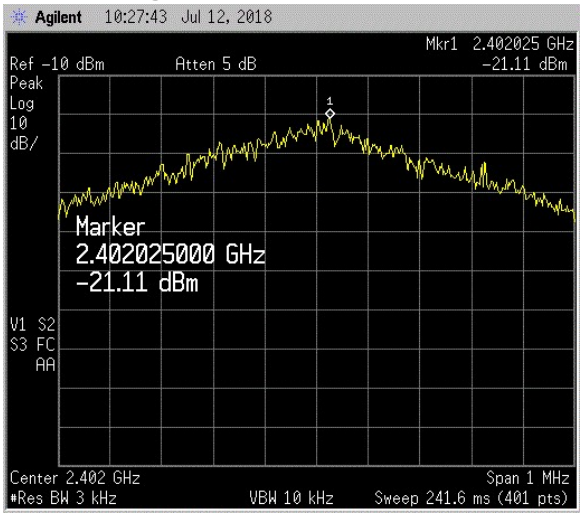
CH	Channel Frequency (GHz)	Maximum Limit (dBm)	Peak Power Spectral Density (dBm)
1 - Low	2.402	8.0	-9.5
2 - Mid	2.440	8.0	-8.4
3 - High	2.480	8.0	-9.8

Note that the worst case peak power spectral density results are given above and these occurred when using Nordic mode at 1Mbps data rate.

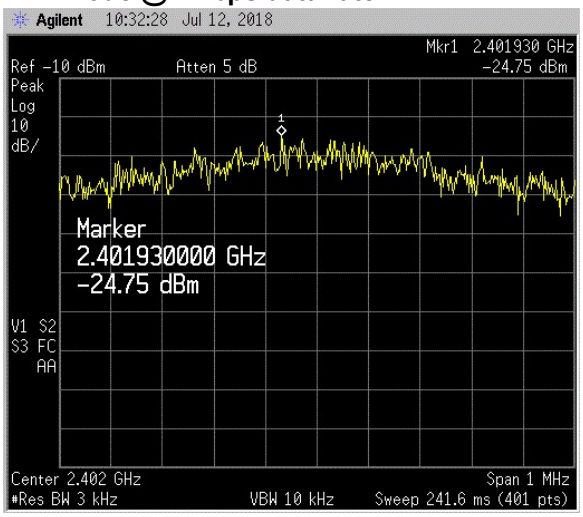
7.3 Peak Power Spectral Density Measurement Results (continued)

Power Spectral Density Test Plot (Low – 2402MHz)

BLE mode @ 1Mbps data rate

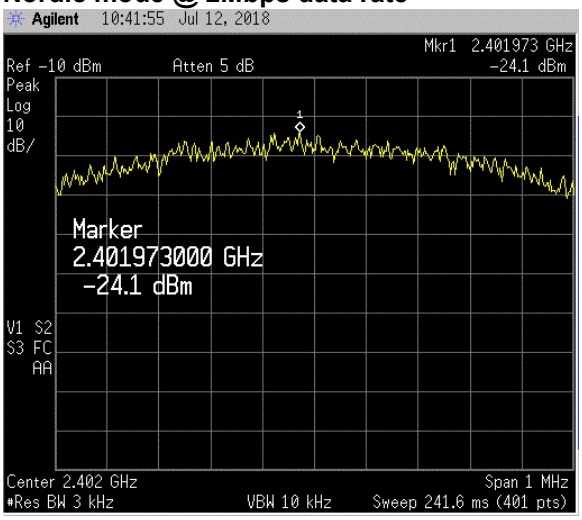


BLE mode @ 2Mbps data rate



Nordic mode @ 1Mbps data rate

Nordic mode @ 2Mbps data rate

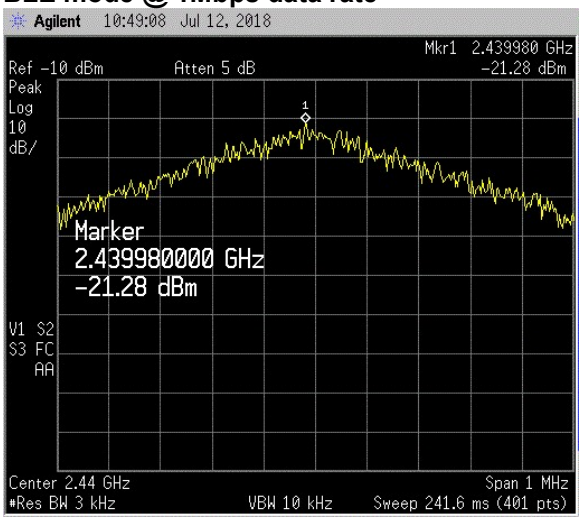


Operating Mode	Frequency (MHz)	Reading (dBm)	Loss (dB)	Preamp Gain (dB)	A.F. (dB)	Field Strength (dBm/m)	Field Strength (µV/m)	Calculation (mW)	*EIRP (dBm/MHz)	Limit (dBm/MHz)
BLE, 1Mbps	2402.0	-21.3	8.5	37.6	28.7	-21.7	18408	0.102	-9.9	8.0
BLE, 2Mbps	2402.0	-25.2	8.5	37.6	28.7	-25.6	11749	0.041	-13.8	8.0
Nordic, 1Mbps	2402.0	-20.9	8.5	37.6	28.7	-21.3	19275	0.111	-9.5	8.0
Nordic, 2Mbps	2402.0	-24.8	8.5	37.6	28.7	-25.2	12374	0.046	-13.4	8.0

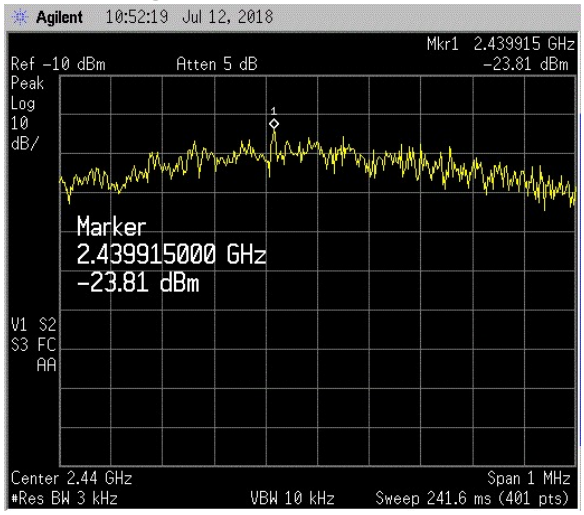
7.3 Peak Power Spectral Density Measurement Results (continued)

Power Spectral Density Test Plot (Mid – 2440MHz)

BLE mode @ 1Mbps data rate

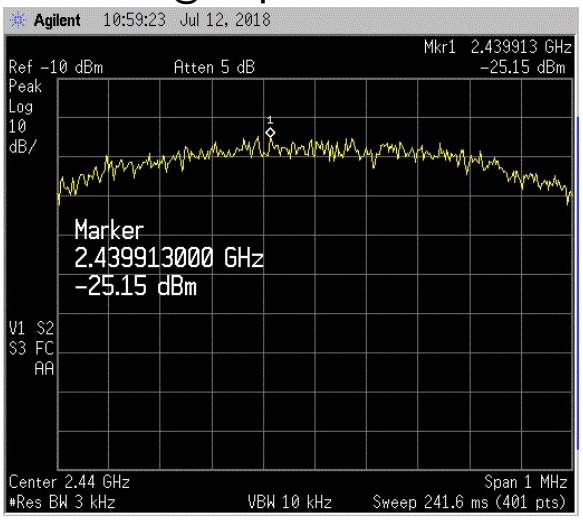


BLE mode @ 2Mbps data rate



Nordic mode @ 1Mbps data rate

Nordic mode @ 2Mbps data rate

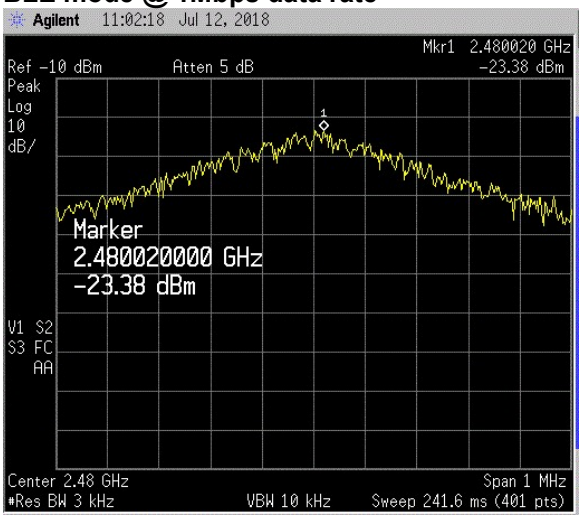


Operating Mode	Frequency (MHz)	Reading (dBm)	Loss (dB)	Preamp Gain (dB)	A.F. (dB)	Field Strength (dBm/m)	Field Strength (µV/m)	Calculation (mW)	*EIRP (dBm/MHz)	Limit (dBm/MHz)
BLE, 1Mbps	2440.0	-21.6	8.7	37.6	28.8	-21.7	18471	0.102	-9.9	8.0
BLE, 2Mbps	2440.0	-24.3	8.7	37.6	28.8	-24.4	13536	0.055	-12.6	8.0
Nordic, 1Mbps	2440.0	-20.1	8.7	37.6	28.8	-20.2	21878	0.144	-8.4	8.0
Nordic, 2Mbps	2440.0	-25.5	8.7	37.6	28.8	-25.6	11803	0.042	-13.8	8.0

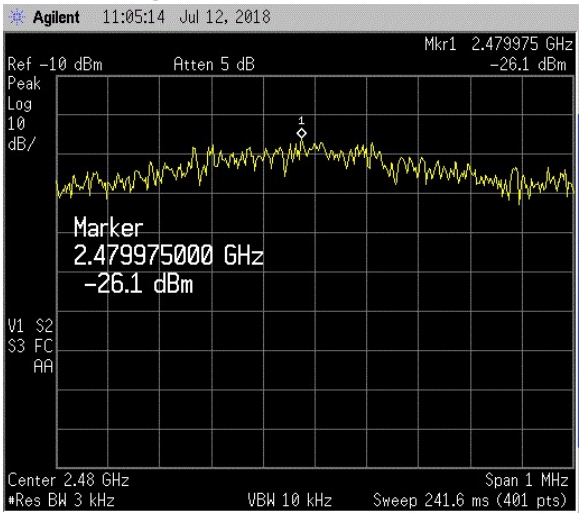
7.3 Peak Power Spectral Density Measurement Results (continued)

Power Spectral Density Test Plot (High – 2480MHz)

BLE mode @ 1Mbps data rate

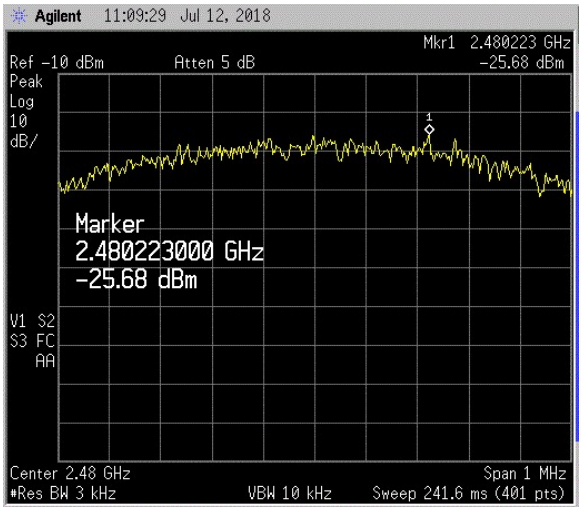


BLE mode @ 2Mbps data rate



Nordic mode @ 1Mbps data rate

Nordic mode @ 2Mbps data rate



Operating Mode	Frequency (MHz)	Reading (dBm)	Loss (dB)	Preamp Gain (dB)	A.F. (dB)	Field Strength (dBm/m)	Field Strength (µV/m)	Calculation (mW)	*EIRP (dBm/MHz)	Limit (dBm/MHz)
BLE, 1Mbps	2480.0	-23.6	8.7	37.6	29.0	-23.5	14945	0.067	-11.7	8.0
BLE, 2Mbps	2480.0	-26.7	8.7	37.6	29.0	-26.6	10495	0.033	-14.8	8.0
Nordic, 1Mbps	2480.0	-21.7	8.7	37.6	29.0	-21.6	18621	0.104	-9.8	8.0
Nordic, 2Mbps	2480.0	-25.8	8.7	37.6	29.0	-25.7	11668	0.041	-13.9	8.0

7.4 Peak Power Spectral Density Measurement Conclusion

The EUT meets the peak power spectral density requirements of FCC 15.247 (e) and RSS-247, 5.2 (b). The maximum power spectral density measured was -8.4 dBm which is under the 8 dBm limit.

8.0 UNINTENTIONAL/SPURIOUS RADIATED EMISSION TEST

8.1 Radiated Emissions

Preliminary testing was done in a ferrite lined shielded enclosure for frequency identification from the EUT. These scans are exploratory emission tests only that are voluntarily submitted. All final measurements were done on the OATS.

For the OATS testing, the EUT was placed on a turntable per ANSI C63.10, clause 6.3.1. The turntable was rotated 360 degrees to determine the position of maximum emission level. The EUT is set 3m away from the receiving antenna which was varied from 1m to 4m in height during the final OATS measurements, to find the highest emissions level. Each frequency of emission was maximized by changing the polarization of the receiving antenna both horizontal and vertical. In order to find out the maximum emissions, the relative positions of the transmitter (EUT) was rotated through three orthogonal axes according to the requirements in ANSI C63.10, clause 5.10.1.

8.2 Prescan Radiated Emissions

The radiated emissions prescan testing was performed in the 3 meter ferrite lined shielded chamber.

The EUT was placed on a 0.8m high polystyrene table for all measurements.

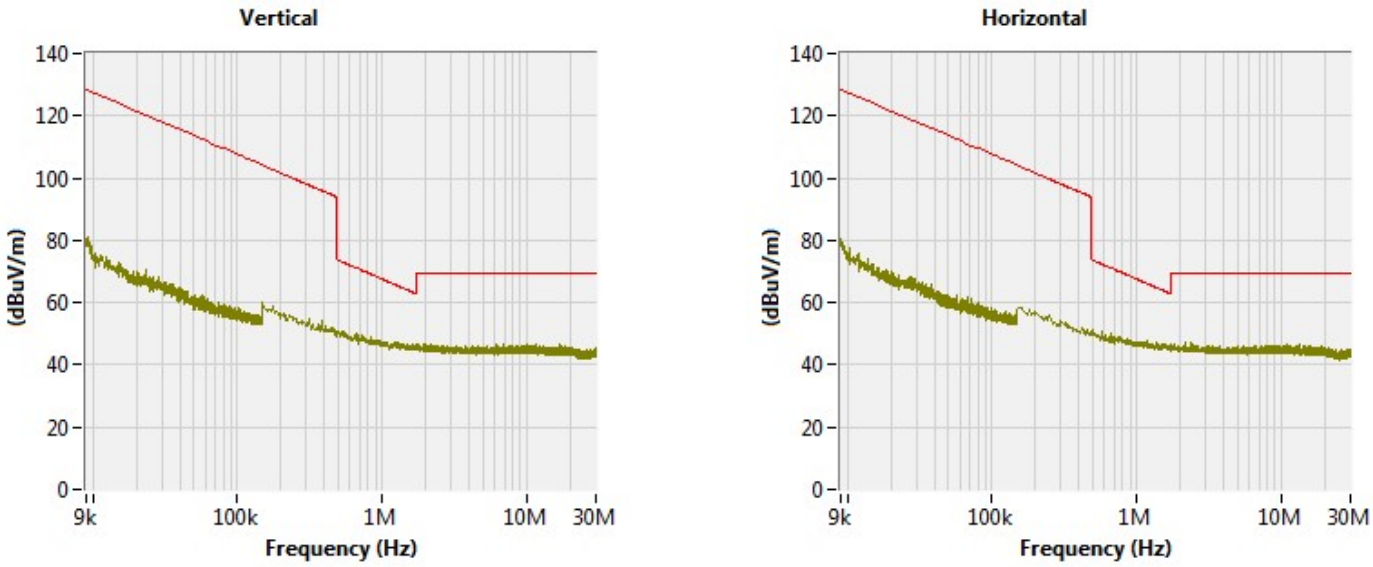
8.3 Prescan Measurement Procedure

- Prescans from 9kHz to 26GHz were done in the ferrite-lined shielded chamber for EUT frequency identification. These scans are exploratory emission tests only that are voluntarily submitted.

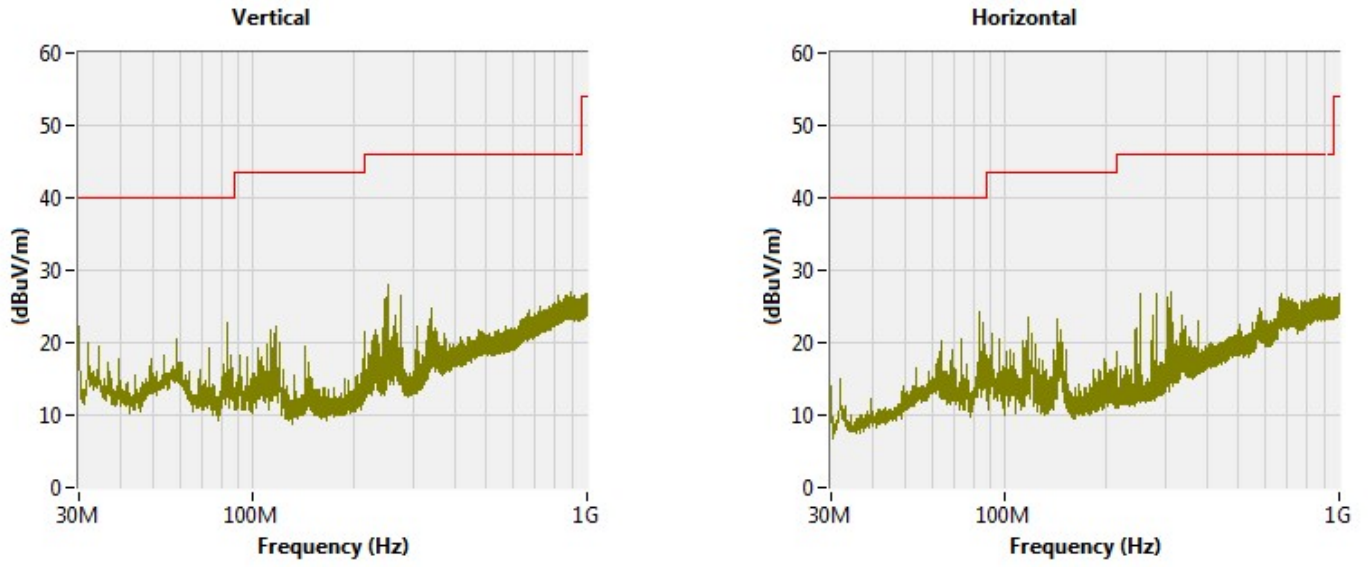
8.4 Prescan Measurement Results

The following plots show a summary of the prescan data that was collected.

8.4 Prescan Measurement Results (continued)

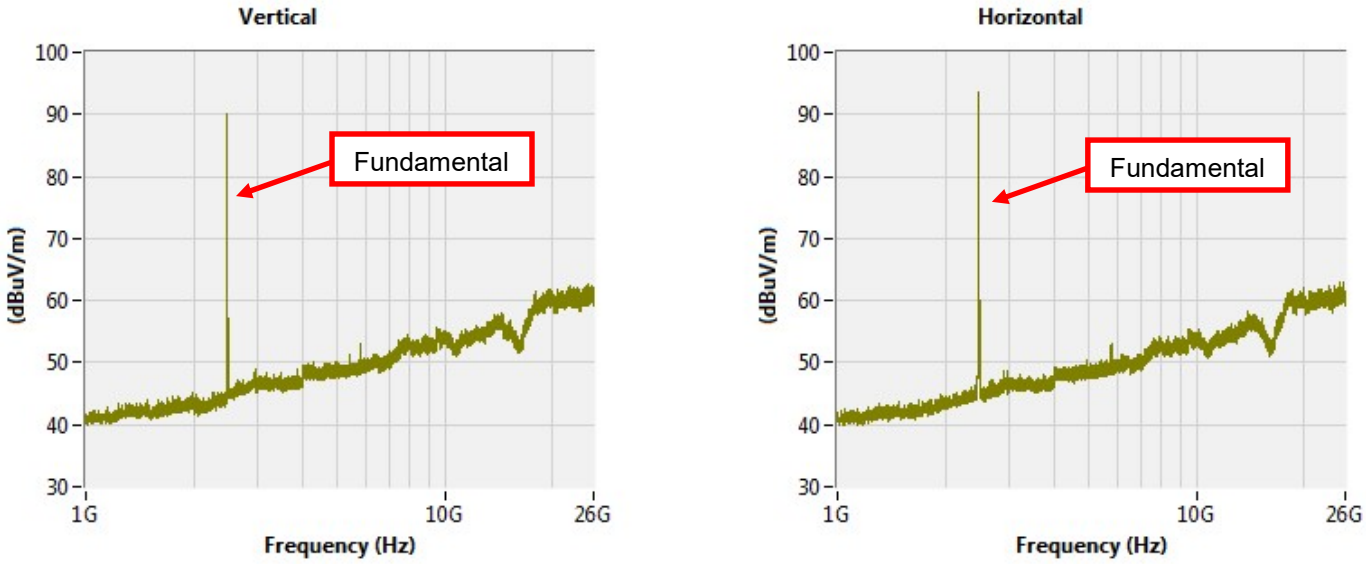


9kHz – 30MHz, Antenna: Magnetic Loop



30 - 1000MHz, Antenna: BiLog

8.4 Prescan Measurement Results (continued)



1-26GHz, Antenna: Horn

8.5 Radiated Emissions Applicable Standards

FCC 15.209 (a) – (f), RSS-GEN, 8.9. Emissions outside the authorized bands shall not exceed the radiated emission limits specified in FCC 15.209(a) – (f) and RSS-GEN, 8.9, and according to FCC 15.33(a)(1) and ANSI C63.10, section 5.5, for an intentional radiator operating below 10GHz, the frequency range of measurements shall encompass from the lowest frequency generated in the device or at least 30MHz to the tenth harmonic of the highest fundamental frequency or 40GHz, whichever is lower.

8.6 Radiated Emissions EUT Setup

The radiated emission tests were performed on the 3 meter open area test site.

The EUT was placed on an 80cm polystyrene table for measurements up to and including 1GHz and it was placed on a 1.5m high polystyrene stand for measurements above 1GHz.

8.7 Radiated Emissions Measurement Procedure

- The 80cm polystyrene table and 1.5m stand, when used, was placed on a turntable which is flush with the ground plane.
- The turntable was rotated 360 degrees to determine the position of maximum emission level.
- The EUT was 3m away from the receiving antenna which was varied from 1m to 4m to obtain the maximum emissions level.
- The data was recorded for at least the six highest emissions to ensure EUT compliance.
- Each emission was maximized by changing the polarization of the receiving antenna both horizontal and vertical.
- Emissions were measured with the EUT transmitting at the low, mid, and high frequencies with modulation applied.
- The worst case mode was tested for spurious and unintentional emissions. This was determined to be: BLE modulation at 1Mbps. Refer to Section 8.12 for determination of worst case emission mode and orientation.

8.8 Radiated Emissions Test Setup Photos

Refer to photos in the Tsup document.

8.9 Field Strength Calculation

The field strength is calculated by adding the Antenna Factor and Cable Factor and subtracting the Amplifier Gain and Duty Cycle Correction Factor (if any) from the measured reading. The basic equation is as follows:

$$FS = RA + AF + CL - AG$$

Where:
FS = Field Strength
RA = Reading Amplitude
AF = Antenna Factor
CL = Cable Attenuation Factor (Cable Loss)
AG = Amplifier Gain

8.10 Limit Extrapolation Method for Frequencies Below 30MHz

For radiated emissions results below 30MHz, the limit was adjusted based on a 40dB/decade extrapolation factor for distance (Reference: FCC Part 15.31 f 2). The field strength limit is calculated and converted to dBµV/m and then the 3m Limit Adjustment was added to this to get the 3 meter limit shown in the 9kHz - 30MHz results tables.

Frequency (MHz)	Field strength limit (microvolts/meter)	Measurement distance (meters)	3m Limit Adjustment (dB)	3m Limit (dBµV/m)
0.009-0.490	2400/F(kHz)	300	80	128.5 - 93.8
0.490-1.705	24000/F(kHz)	30	40	73.8 – 62.9
1.705-30.0	30	30	40	69.5 – 69.5
30.0	100	3	N/A	40.0

For example: At 32 kHz, the field strength limit is 2400/32 = 75 µV/m. This converts to 37.5 dBµV/m. To this is added the 3m Limit Adjustment of 80dB. Therefore the 3m limit at 32 kHz is 117.5 dBµV/m.

8.11 Duty Cycle Correction Factor

A duty cycle correction factor has been calculated and used to determine the average field strength from the peak field strength as given on the following pages.

The following duty cycle analysis was provided by Franklin Robotics.

Online Power Profile

Provided by Nordic Semi, manufacturer of nRF52832 processor and supplier of BLE software (SoftDevice)
Parameters chosen are worst-case allowed by BLE specification
Model retrieved on July 24, 2018

Model Parameters

BLE event type	Advertising	
Voltage	3.3	V
BLE interval	7.5	ms
TX payload	27	bytes
TX power	4	dB

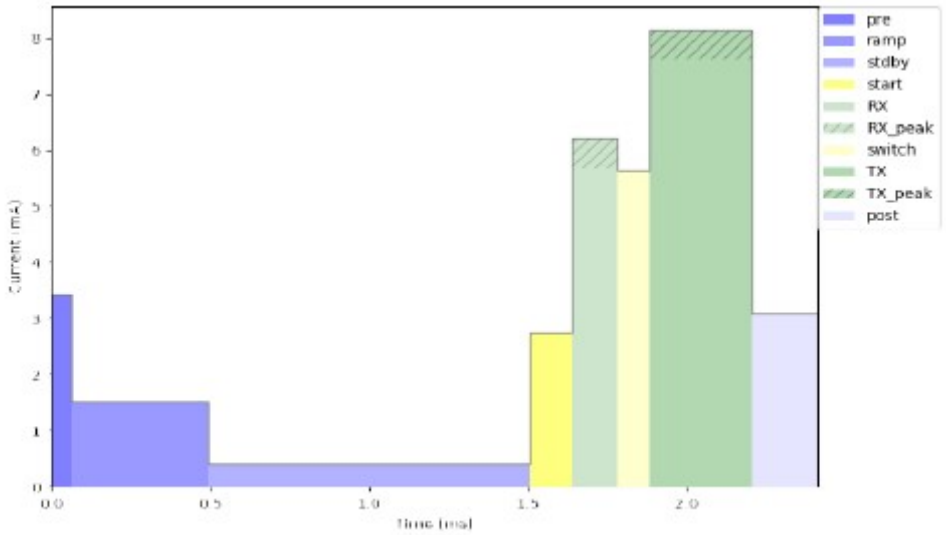
Test setup for model

Chip	nRF52832QFAAB0
Softdevice	s132 2.0.0
Model notes	32 MHz high frequency crystal
	32 kHz low frequency crystal
	Sleep clock accuracy master and slave: 20 ppm
	DCDC enabled
Franklin notes	Same crystal, accuracy, and DCDC setup
	We are using newer version of s132 SoftDevice

Estimated values

BLE event total charge:	6.2	uC
BLE event total length	2.4	ms
Average BLE event interval	7.5	ms
Total average current	824	uA

8.11 Duty Cycle Correction Factor (continued)



BLE Event Details

Stage	Description	Time (ms)	Length (us)	Avg. current (mA)	Peak current (mA)
pre	Pre-processing	0.0	61	3.4	
ramp	Standby + HFXO ramp	0.1	430	1.5	
stdby	Standby	0.5	1014	0.4	
start	Radio startup + CPU	1.5	133	2.8	
RX	Radio RX	1.6	143	5.7	6.2
switch	Radio switch	1.8	102	5.7	
TX	Radio TX	1.9	323	7.6	8.2
post	Post-processing	2.2	205	3.1	
	System On IDLE	2.4	5.1 ms	2.0 uA	
Total			7.5 ms	824 uA	

Total TX time (us)	323
Total cycle time (us)	7500
% of transmit time	4.307%
20 log (duty cycle)	-27.32

Test Description and notes

This tool estimates the current consumed by your BLE application to better understand how different parameters affect the current consumption. Choose parameters below to get the current consumption during different BLE scenarios. All numbers and calculations are based on actual current measurements conducted on the nRF52 chip, and they are correlated with the BLE power profiles found in the SoftDevice specification to build a model which estimates the current components involved.

Please read this blog post which explains the test setup and how the data has been analyzed to create the model.

Linked blog post: https://devzone.nordicsemi.com/b/blog/posts/nrf52-online-power-profiler

Accuracy Notes

The tool is based on a model of the measured values, and is not showing the actual measurement. The results are therefore estimates of the expected value. It is meant for evaluation purposes only, and will not give the exact numbers in every use case. Testing shows that the estimated average current is typically within 5% of the actual value for the reference parts. The device to device variations will add to this inaccuracy. Please refer to the nRF52 Product Specification for expected min/max values for the different current components.

8.11 Duty Cycle Correction Factor (continued)

Duty Cycle Correction Factor (ref: ANSI C63.10, 7.5)
δ(dB) = 20log(Δ) = 20 log (0.043) = -27.3 dB

8.12 Worst Case mode and orientation determination

3-Meter Radiated Emissions Results 1-18GHz

Date: 7/12/2018
Test Engineer: GC
Customer: Franklin Robotics
Product: Tertill, S/N T1S-001C, Board #A6A9
Configuration: As noted below.
EUT Voltage: 4.2VDC via External TTi Power Supply
Temperature (°C): 22.1
Relative Humidity (%): 51
Test Distance: **3 meters**
Frequency Range: **>1.0 GHz**
Antenna Asset #: **126**

Azimuth (deg)	Ant. Ht. (m)	Ant. Polarity	Frequency (MHz)	PK Reading (dBµV)	AV Reading (dBµV)	3m Antenna Factor (dB)	25m Cable Factor (dB)	8m Cable Factor (dB)	HP8449B Factor (dB)	PK Net (dBµV/m)	AV Net (dBµV/m)	
225.0	1.4	H	2402.0	97.2	94.9	28.7	6.0	2.5	37.6	96.8	94.5	2402MHz, BLE, 1Mbps
225.0	1.4	H	2402.0	95.7	92.9	28.7	6.0	2.5	37.6	95.3	92.5	2402MHz, BLE, 2Mbps
225.0	1.4	H	2402.0	95.1	94.0	28.7	6.0	2.5	37.6	94.7	93.6	2402MHz, Nordic, 1Mbps
225.0	1.4	H	2402.0	96.3	93.7	28.7	6.0	2.5	37.6	95.9	93.3	2402MHz, Nordic, 2Mbps
						#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	
225.0	1.4	H	2440.0	93.7	91.6	28.8	6.1	2.6	37.6	93.5	91.4	2440MHz, BLE, 1Mbps
225.0	1.4	H	2440.0	93.9	90.5	28.8	6.1	2.6	37.6	93.7	90.3	2440MHz, BLE, 2Mbps
225.0	1.4	H	2440.0	93.6	92.0	28.8	6.1	2.6	37.6	93.4	91.8	2440MHz, Nordic, 1Mbps
225.0	1.4	H	2440.0	93.9	91.1	28.8	6.1	2.6	37.6	93.7	90.9	2440MHz, Nordic, 2Mbps
						#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	
225.0	1.4	H	2480.0	91.6	89.8	29.0	6.1	2.6	37.6	91.7	89.9	2480MHz, BLE, 1Mbps
225.0	1.4	H	2480.0	91.7	88.6	29.0	6.1	2.6	37.6	91.8	88.7	2480MHz, BLE, 2Mbps
225.0	1.4	H	2480.0	91.3	90.1	29.0	6.1	2.6	37.6	91.4	90.2	2480MHz, Nordic, 1Mbps
225.0	1.4	H	2480.0	91.7	89.3	29.0	6.1	2.6	37.6	91.8	89.4	2480MHz, Nordic, 2Mbps
						#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	
225.0	1.7	V	2402.0	95.1	93.9	28.6	6.0	2.5	37.6	94.6	93.4	2402MHz, BLE, 1Mbps (worst case),
						#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	EUT standing on end (round surface); EUT bottom facing 225 deg.

The worst case operating mode was BLE at 1Mbps data rate. The worst case orientation is the normal orientation; i.e., unit standing on its wheels with the solar panel facing up.

8.13 Measurement Result – Radiated Emissions Data Tables

The data tables on the following page show the Radiated Emissions test results.

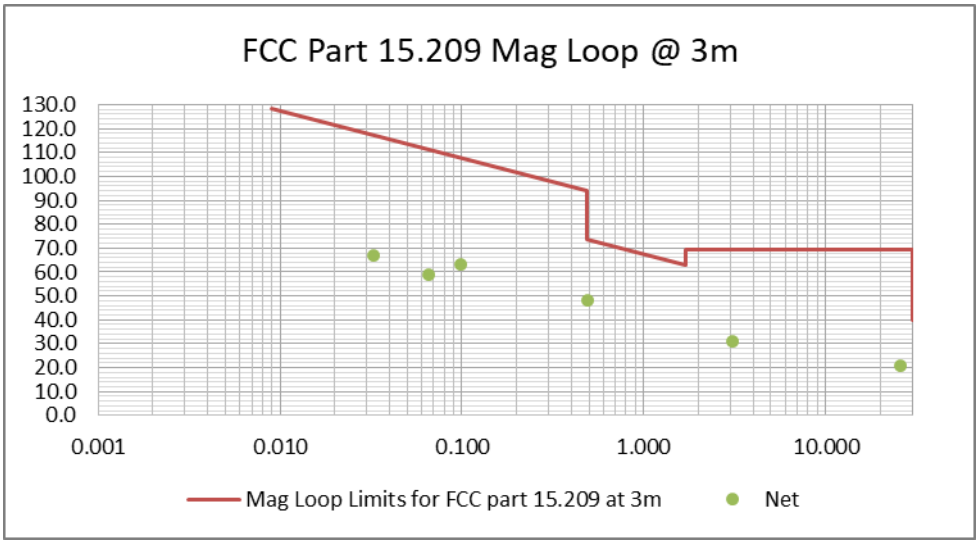
8.13 Measurement Result – Radiated Emissions Data Tables (continued)

3-Meter Magnetic Loop Radiated Emissions Results

Date: 7/18/2018
Test Engineer: GC
Customer: Franklin Robotics
Product: Tertill, S/N T1S-001C, Board #A6A9
Configuration: Worst cast: 2402MHz Transmit Channel, LED 2 lit, BLE Mode, 1Mbps
EUT Voltage: 4.2VDC via External TTi Power Supply
Temperature (°C): 25.1
Relative Humidity (%): 60
Test Distance: **3 meters**
Frequency Range: **9kHz-30MHz**
Antenna Asset #: **103**
Detector used: **Quasi-peak (QP) for all except as follows: Average (AVG) 9-90kHz and 110-490kHz**
Antenna Polarity: **V=plane of loop perpendicular to EUT face; H=plane of loop parallel to EUT face**

Azimuth (deg)	Ant. Ht. (m)	Ant. Polarity	Frequency (MHz)	Detector (QP or AV)	Reading (dBµV)	Mag Loop E Factor (dB)	25m Cable Factor (dB)	Net (dBµV/m)	FCC 15.209 Limit (dBµV/m)	FCC 15.209 Margin (dBµV/m)
315.0	1.0	V	0.033	AV	52.0	15.0	0.1	67.1	117.3	-50.2
90.0	1.0	V	0.066	AV	45.1	13.8	0.1	59.0	111.3	-52.3
90.0	1.0	V	0.098	QP	49.5	13.7	0.1	63.3	107.8	-44.5
180.0	1.0	V	0.492	QP	34.7	13.5	0.1	48.3	73.8	-25.5
180.0	1.0	V	3.060	QP	16.7	14.2	0.2	31.1	69.5	-38.4
0.0	1.0	V	25.911	QP	7.4	12.6	0.6	20.6	69.5	-48.9

NOTES:
Use the detector shown based on the frequency.
EN55032 has no limits below 30MHz.
RBW=9kHz



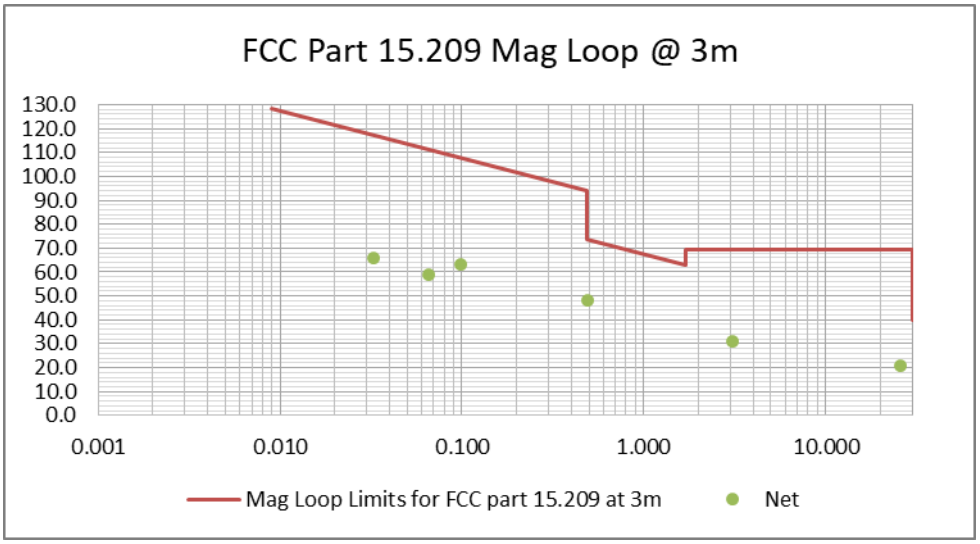
8.13 Measurement Result – Radiated Emissions Data Tables (continued)

3-Meter Magnetic Loop Radiated Emissions Results

Date:	7/18/2018
Test Engineer:	GC
Customer:	Franklin Robotics
Product:	Tertill, S/N T1S-001C, Board #A6A9
Configuration:	Worst cast: 2440MHz Transmit Channel, LED 2 lit, BLE Mode, 1Mbps
EUT Voltage:	4.2VDC via External TTi Power Supply
Temperature (°C):	25.4
Relative Humidity (%):	60
Test Distance:	**3 meters**
Frequency Range:	**9kHz-30MHz**
Antenna Asset #:	**103**
Detector used:	**Quasi-peak (QP) for all except as follows: Average (AVG) 9-90kHz and 110-490kHz**
Antenna Polarity:	**V=plane of loop perpendicular to EUT face; H=plane of loop parallel to EUT face**

Azimuth (deg)	Ant. Ht. (m)	Ant. Polarity	Frequency (MHz)	Detector (QP or AV)	Reading (dBµV)	Mag Loop E Factor (dB)	25m Cable Factor (dB)	Net (dBµV/m)	FCC 15.209 Limit (dBµV/m)	FCC 15.209 Margin (dBµV/m)
315.0	1.0	V	0.033	AV	50.6	15.0	0.1	65.7	117.3	-51.6
90.0	1.0	V	0.066	AV	45.1	13.8	0.1	59.0	111.3	-52.3
90.0	1.0	V	0.098	QP	49.6	13.7	0.1	63.4	107.8	-44.4
180.0	1.0	V	0.492	QP	34.7	13.5	0.1	48.3	73.8	-25.5
180.0	1.0	V	3.060	QP	16.8	14.2	0.2	31.2	69.5	-38.3
0.0	1.0	V	25.911	QP	7.7	12.6	0.6	20.9	69.5	-48.6

NOTES:
Use the detector shown based on the frequency.
EN55032 has no limits below 30MHz.
RBW=9kHz



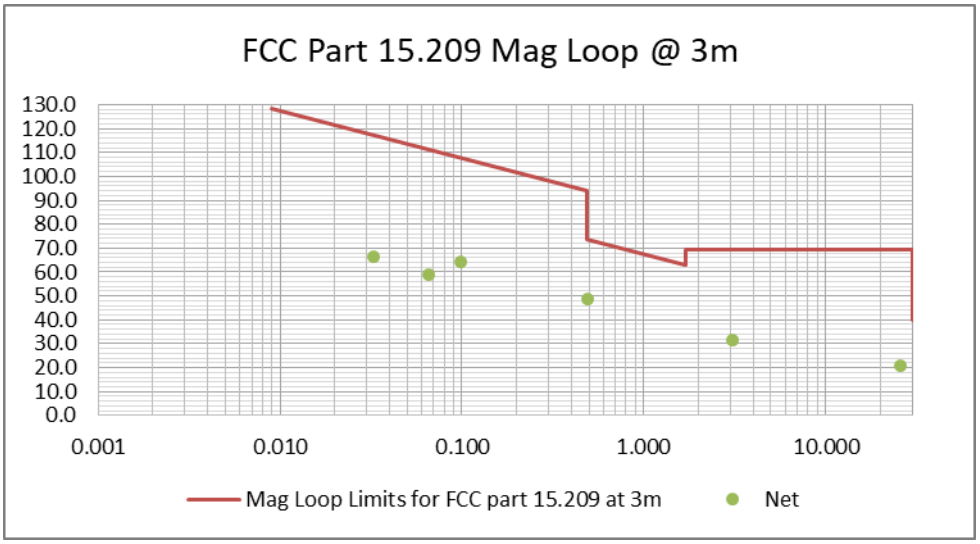
8.13 Measurement Result – Radiated Emissions Data Tables (continued)

3-Meter Magnetic Loop Radiated Emissions Results

Date: 7/18/2018
Test Engineer: GC
Customer: Franklin Robotics
Product: Tertill, S/N T1S-001C, Board #A6A9
Configuration: Worst cast: 2480MHz Transmit Channel, LED 2 lit, BLE Mode, 1Mbps
EUT Voltage: 4.2VDC via External TTi Power Supply
Temperature (°C): 25.4
Relative Humidity (%): 59
Test Distance: **3 meters**
Frequency Range: **9kHz-30MHz**
Antenna Asset #: **103**
Detector used: **Quasi-peak (QP) for all except as follows: Average (AVG) 9-90kHz and 110-490kHz**
Antenna Polarity: **V=plane of loop perpendicular to EUT face; H=plane of loop parallel to EUT face**

Azimuth (deg)	Ant. Ht. (m)	Ant. Polarity	Frequency (MHz)	Detector (QP or AV)	Reading (dBµV)	Mag Loop E Factor (dB)	25m Cable Factor (dB)	Net (dBµV/m)	FCC 15.209 Limit (dBµV/m)	FCC 15.209 Margin (dBµV/m)
315.0	1.0	V	0.033	AV	51.3	15.0	0.1	66.4	117.3	-50.9
90.0	1.0	V	0.066	AV	45.2	13.8	0.1	59.1	111.3	-52.2
90.0	1.0	V	0.098	QP	50.3	13.7	0.1	64.1	107.8	-43.7
180.0	1.0	V	0.492	QP	34.9	13.5	0.1	48.5	73.8	-25.3
180.0	1.0	V	3.060	QP	16.9	14.2	0.2	31.3	69.5	-38.2
0.0	1.0	V	25.911	QP	7.7	12.6	0.6	20.9	69.5	-48.6

NOTES:
Use the detector shown based on the frequency.
EN55032 has no limits below 30MHz.
RBW=9kHz



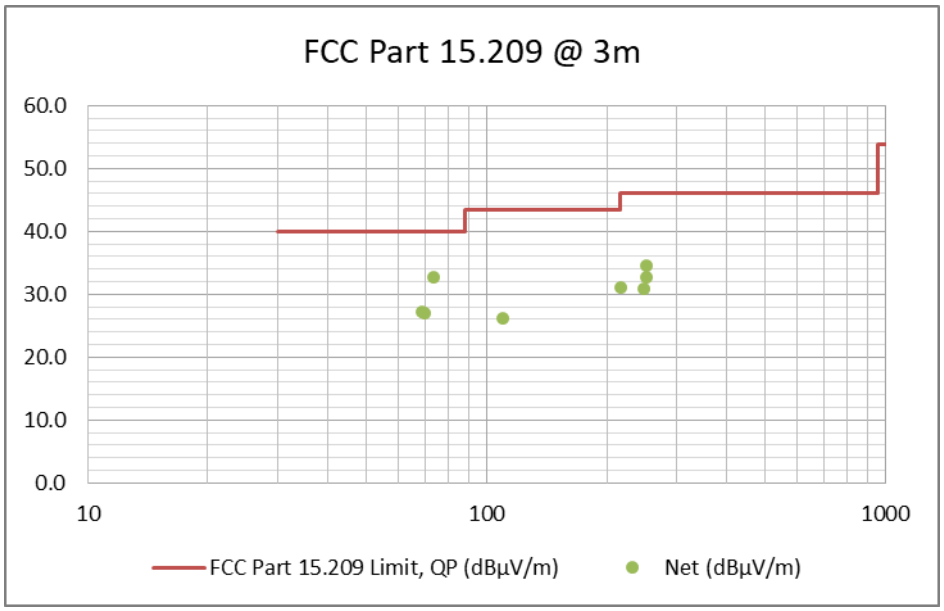
8.13 Measurement Result – Radiated Emissions Data Tables (continued)

3-Meter Radiated Emissions Results

Date: 7/18/2018
Test Engineer: GC
Customer: Franklin Robotics
Product: Tertill, S/N T1S-001C, Board #A6A9
Configuration: Worst cast: 2402MHz Transmit Channel, LED 2 lit, BLE Mode, 1Mbps
EUT Voltage: 4.2VDC via External TTi Power Supply
Temperature (°C): 23.1
Relative Humidity (%): 65
Test Distance: **3 meters**
Frequency Range: **30-1000MHz**
Antenna Asset #: **17**

Azimuth (deg)	Ant. Ht. (m)	Ant. Polarity	Frequency (MHz)	QP Reading (dBµV)	3m Antenna Factor (dB)	25m Cable Factor (dB)	Net (dBµV/m)	FCC Part 15.209 QP Limit (dBµV/m)	FCC Part 15.209 QP Margin (dBµV/m)
180.0	1.0	V	68.8	15.7	10.5	1.0	27.2	40.0	-12.8
180.0	1.0	V	70.1	15.4	10.5	1.0	27.0	40.0	-13.0
180.0	1.0	V	73.7	20.6	11.0	1.1	32.6	40.0	-7.4
67.5	1.5	H	110.0	8.5	16.4	1.3	26.2	43.5	-17.3
90.0	1.4	H	216.4	14.9	14.4	1.7	31.0	46.0	-15.0
180.0	1.2	H	247.4	12.4	16.7	1.9	31.0	46.0	-15.0
0.0	1.2	H	250.9	13.8	17.0	1.9	32.7	46.0	-13.3
180.0	1.4	H	252.0	15.6	17.1	1.9	34.6	46.0	-11.4

NOTES:
RBW=120kHz
Scanned 30-1000 MHz



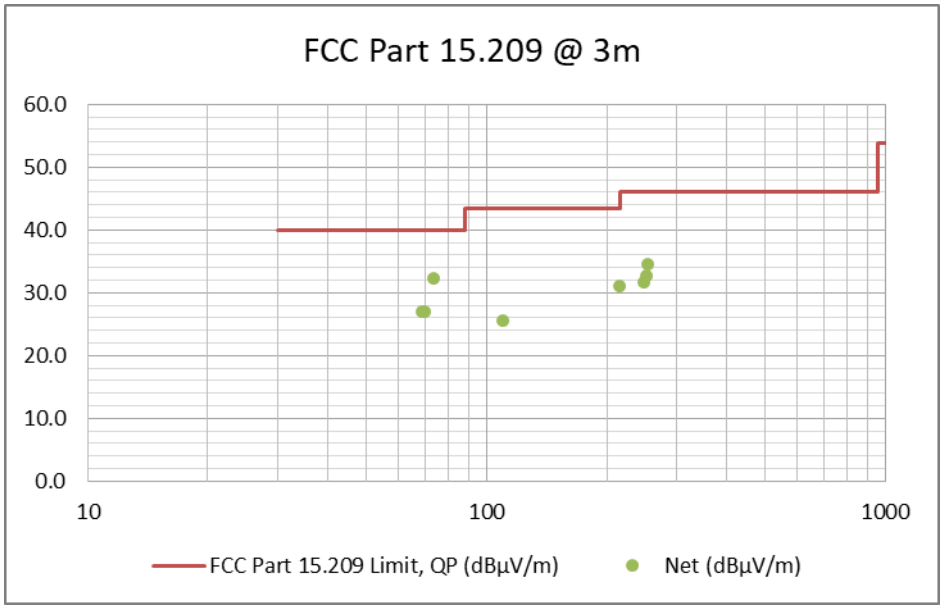
8.13 Measurement Result – Radiated Emissions Data Tables (continued)

3-Meter Radiated Emissions Results

Date: 7/18/2018
Test Engineer: GC
Customer: Franklin Robotics
Product: Tertill, S/N T1S-001C, Board #A6A9
Configuration: Worst cast: 2440MHz Transmit Channel, LED 2 lit, BLE Mode, 1Mbps
EUT Voltage: 4.2VDC via External TTi Power Supply
Temperature (°C): 23.6
Relative Humidity (%): 63
Test Distance: **3 meters**
Frequency Range: **30-1000MHz**
Antenna Asset #: **17**

Azimuth (deg)	Ant. Ht. (m)	Ant. Polarity	Frequency (MHz)	QP Reading (dBµV)	3m Antenna Factor (dB)	25m Cable Factor (dB)	Net (dBµV/m)	FCC Part 15.209 QP Limit (dBµV/m)	FCC Part 15.209 QP Margin (dBµV/m)
180.0	1.0	V	68.8	15.6	10.5	1.0	27.1	40.0	-12.9
180.0	1.0	V	70.1	15.4	10.5	1.0	26.9	40.0	-13.1
180.0	1.0	V	73.7	20.3	11.0	1.1	32.3	40.0	-7.7
45.0	1.5	H	110.0	7.9	16.4	1.3	25.6	43.5	-17.9
90.0	1.5	H	216.1	15.0	14.4	1.7	31.1	46.0	-14.9
180.0	1.2	H	247.4	13.1	16.7	1.9	31.6	46.0	-14.4
0.0	1.2	H	250.9	13.9	17.0	1.9	32.8	46.0	-13.2
180.0	1.5	H	252.8	15.5	17.2	1.9	34.6	46.0	-11.4

NOTES:
RBW=120kHz
Scanned 30-1000 MHz



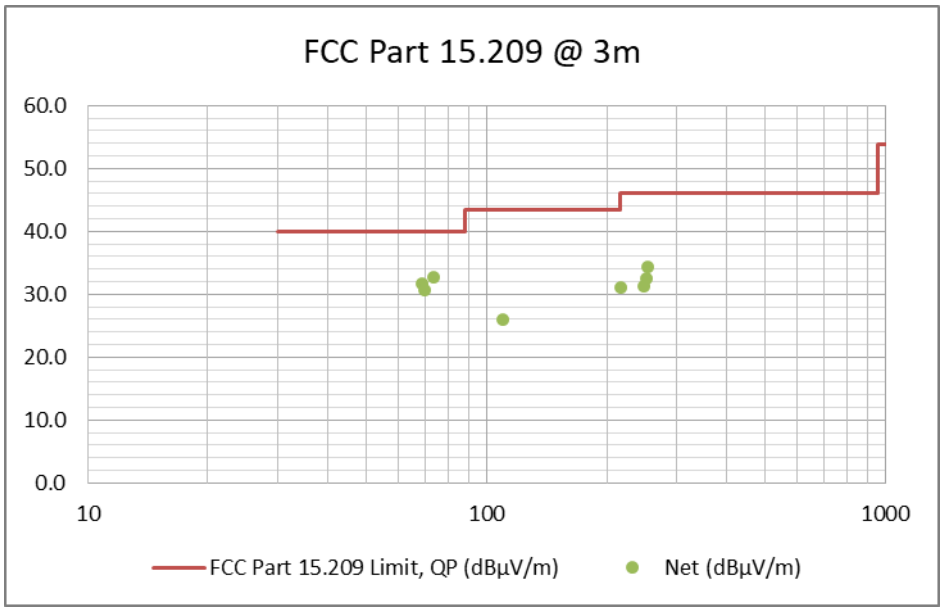
8.13 Measurement Result – Radiated Emissions Data Tables (continued)

3-Meter Radiated Emissions Results

Date: 7/18/2018
Test Engineer: GC
Customer: Franklin Robotics
Product: Tertill, S/N T1S-001C, Board #A6A9
Configuration: Worst cast: 2480MHz Transmit Channel, LED 2 lit, BLE Mode, 1Mbps
EUT Voltage: 4.2VDC via External TTi Power Supply
Temperature (°C): 25
Relative Humidity (%): 62
Test Distance: **3 meters**
Frequency Range: **30-1000MHz**
Antenna Asset #: **17**

Azimuth (deg)	Ant. Ht. (m)	Ant. Polarity	Frequency (MHz)	QP Reading (dBµV)	3m Antenna Factor (dB)	25m Cable Factor (dB)	Net (dBµV/m)	FCC Part 15.209 QP Limit (dBµV/m)	FCC Part 15.209 QP Margin (dBµV/m)
315.0	1.0	V	68.8	20.2	10.5	1.0	31.7	40.0	-8.3
315.0	1.2	V	70.1	19.2	10.5	1.0	30.7	40.0	-9.3
315.0	1.2	V	73.7	20.6	11.0	1.1	32.6	40.0	-7.4
67.5	1.3	H	110.0	8.2	16.4	1.3	25.9	43.5	-17.6
90.0	1.4	H	216.4	15.0	14.4	1.7	31.1	46.0	-14.9
180.0	1.2	H	247.3	12.7	16.7	1.9	31.2	46.0	-14.8
0.0	1.2	H	250.9	13.7	17.0	1.9	32.6	46.0	-13.4
180.0	1.3	H	252.8	15.3	17.2	1.9	34.4	46.0	-11.6

NOTES:
RBW=120kHz
Scanned 30-1000 MHz



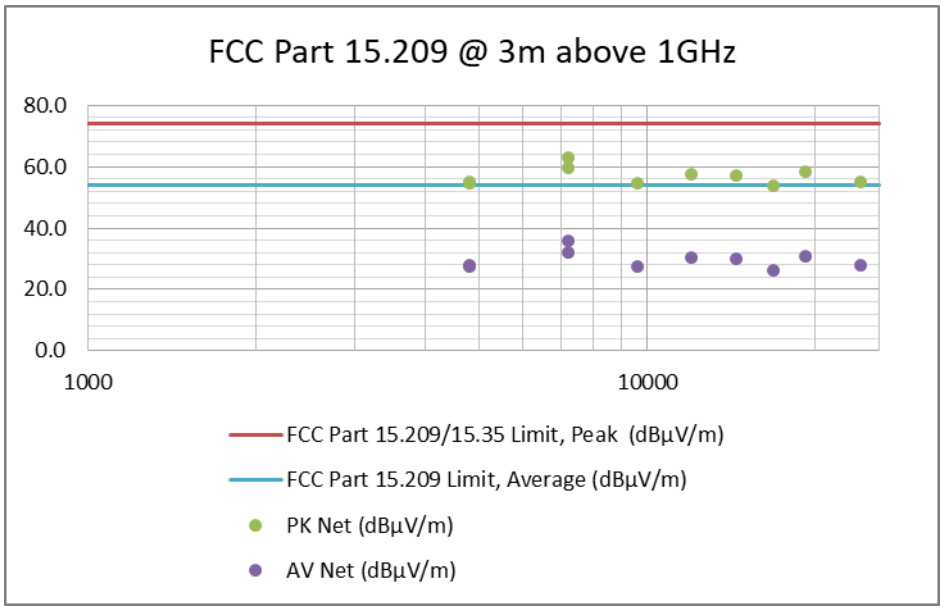
8.13 Measurement Result – Radiated Emissions Data Tables (continued)

3-Meter Radiated Emissions Results 1-25GHz

Date: 7/17/2018
Test Engineer: GC
Customer: Franklin Robotics
Product: Tertill, S/N T1S-001C, Board #A6A9
Configuration: Worst cast: 2402MHz Transmit Channel, LED 2 lit, BLE Mode, 1Mbps
EUT Voltage: 4.2VDC via External TTi Power Supply
Temperature (°C): 25
Relative Humidity (%): 59
Test Distance: **3 meters**
Frequency Range: **>1.0 GHz**
Antenna Asset #: **126 and 133**

Azimuth (deg)	Ant. Ht. (m)	Ant. Polarity	Frequency (MHz)	PK Reading (dBµV)	Duty Cycle Correction (dB)	3m Antenna Factor (dB)	25m Cable Factor (dB)	8m Cable Factor (dB)	HP8449B Factor (dB)	PK Net (dBµV/m)	AV Net (dBµV/m)	FCC Part 15.209/15.35 PK Limit ($dB_{\mu}V/m$)	FCC Part 15.209/15.35 PK Margin (dBµV/m)	FCC Part 15.209 AV Limit ($dB_{\mu}V/m$)	FCC Part 15.209 AV Margin (dBµV/m)
90.0	1.4	H	4804.2	46.6	-27.3	33.0	8.8	4.2	37.4	55.2	27.9	73.9	-18.7	53.9	-26.0
180.0	1.5	V	4804.2	46.2	-27.3	32.9	8.8	4.2	37.4	54.8	27.5	73.9	-19.1	53.9	-26.4
90.0	1.2	H	7205.4	45.6	-27.3	38.5	10.7	5.9	37.6	63.1	35.8	73.9	-10.8	53.9	-18.1
180.0	1.5	V	7205.4	42.1	-27.3	38.5	10.7	5.9	37.6	59.6	32.3	73.9	-14.3	53.9	-21.6
180.0	1.5	H	9608.2	35.3	-27.3	37.9	12.8	6.8	38.1	54.7	27.4	73.9	-19.2	53.9	-26.5
180.0	1.5	H	12010.2	33.3	-27.3	39.5	14.4	7.7	37.4	57.5	30.2	73.9	-16.4	53.9	-23.7
180.0	1.5	H	14412.1	27.7	-27.3	41.6	15.9	8.2	36.1	57.3	30.0	73.9	-16.6	53.9	-23.9
180.0	1.5	H	16814.1	21.3	-27.3	41.5	17.6	9.2	36.0	53.7	26.4	73.9	-20.2	53.9	-27.5
180.0	1.6	H	19216.0	27.0	-27.3	38.0	18.7	10.0	35.4	58.3	31.0	73.9	-15.6	53.9	-22.9
180.0	1.6	H	24020.0	19.5	-27.3	39.6	19.7	11.5	35.3	55.1	27.8	73.9	-18.8	53.9	-26.1

NOTES:
RBW=1MHz
Scanned 1 to 25 GHz



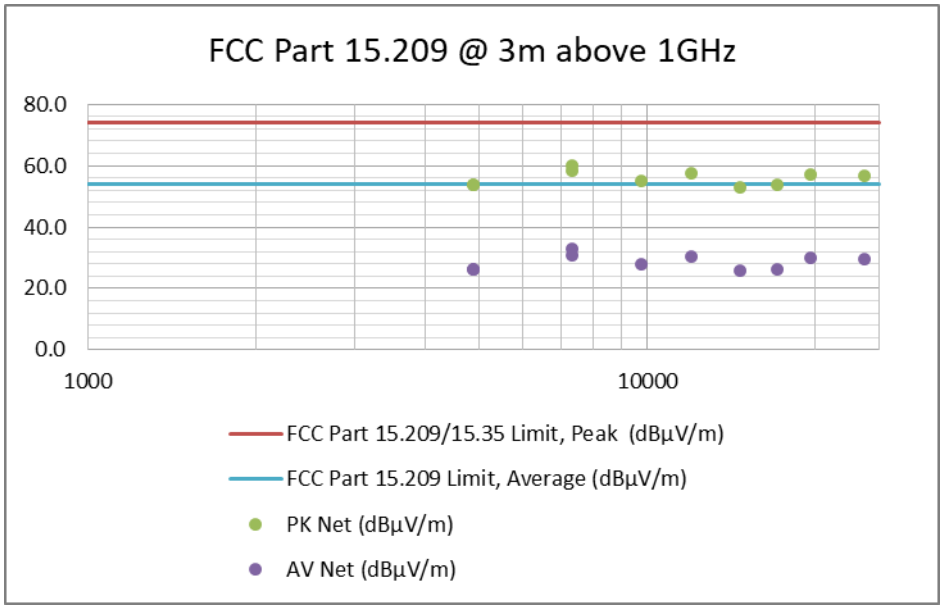
8.13 Measurement Result – Radiated Emissions Data Tables (continued)

3-Meter Radiated Emissions Results 1-25GHz

Date: 7/17/2018
Test Engineer: GC
Customer: Franklin Robotics
Product: Tertill, S/N T1S-001C, Board #A6A9
Configuration: Worst cast: 2440MHz Transmit Channel, LED 2 lit, BLE Mode, 1Mbps
EUT Voltage: 4.2VDC via External TTi Power Supply
Temperature (°C): 25
Relative Humidity (%): 59
Test Distance: **3 meters**
Frequency Range: **>1.0 GHz**
Antenna Asset #: **126 and 133**

Azimuth (deg)	Ant. Ht. (m)	Ant. Polarity	Frequency (MHz)	PK Reading (dBµV)	Duty Cycle Correction (dB)	3m Antenna Factor (dB)	25m Cable Factor (dB)	8m Cable Factor (dB)	HP8449B Factor (dB)	PK Net (dBµV/m)	AV Net (dBµV/m)	FCC Part 15.209/15.35 PK Limit ($dB_{\mu}V/m$)	FCC Part 15.209/15.35 PK Margin (dBµV/m)	FCC Part 15.209 AV Limit ($dB_{\mu}V/m$)	FCC Part 15.209 AV Margin (dBµV/m)
90.0	1.3	H	4880.2	44.7	-27.3	33.2	8.9	4.2	37.4	53.7	26.4	73.9	-20.2	53.9	-27.5
180.0	1.8	V	4880.2	44.7	-27.3	33.2	8.9	4.2	37.4	53.6	26.3	73.9	-20.3	53.9	-27.6
180.0	1.6	H	7320.2	40.2	-27.3	39.0	10.8	6.0	37.7	58.3	31.0	73.9	-15.6	53.9	-22.9
45.0	2.4	V	7320.2	42.1	-27.3	39.0	10.8	6.0	37.7	60.1	32.8	73.9	-13.8	53.9	-21.1
180.0	1.6	H	9760.2	35.5	-27.3	37.9	12.9	6.8	38.1	55.1	27.8	73.9	-18.8	53.9	-26.1
180.0	1.6	H	12010.2	33.3	-27.3	39.5	14.4	7.7	37.4	57.5	30.2	73.9	-16.4	53.9	-23.7
180.0	1.6	H	14640.2	23.0	-27.3	42.0	16.1	8.3	36.3	52.9	25.6	73.9	-21.0	53.9	-28.3
180.0	1.6	H	17080.2	19.6	-27.3	42.7	17.7	9.4	35.7	53.6	26.3	73.9	-20.3	53.9	-27.6
180.0	1.6	H	19560.0	26.0	-27.3	38.0	18.8	10.1	35.8	57.1	29.8	73.9	-16.8	53.9	-24.1
180.0	1.6	H	24440.0	21.1	-27.3	39.5	19.9	11.7	35.5	56.7	29.4	73.9	-17.2	53.9	-24.5

NOTES:
RBW=1MHz
Scanned 1 to 25 GHz



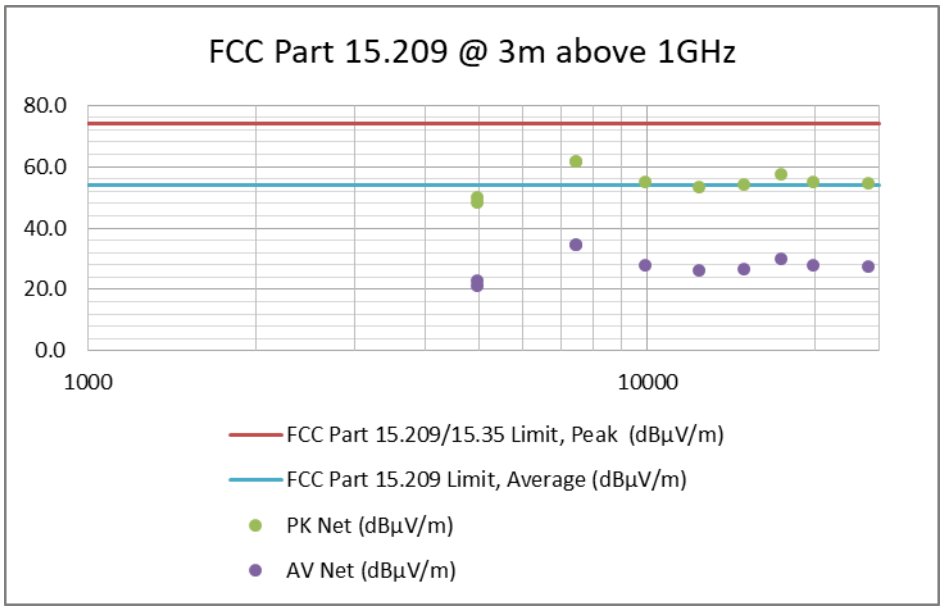
8.13 Measurement Result – Radiated Emissions Data Tables (continued)

3-Meter Radiated Emissions Results 1-25GHz

Date: 7/17/2018
Test Engineer: GC
Customer: Franklin Robotics
Product: Tertill, S/N T1S-001C, Board #A6A9
Configuration: Worst cast: 2480MHz Transmit Channel, LED 2 lit, BLE Mode, 1Mbps
EUT Voltage: 4.2VDC via External TTi Power Supply
Temperature (°C): 25
Relative Humidity (%): 59
Test Distance: 3 meters
Frequency Range: >1.0 GHz
Antenna Asset #: 126 and 133

Azimuth (deg)	Ant. Ht. (m)	Ant. Polarity	Frequency (MHz)	PK Reading (dBµV)	Duty Cycle Correction (dB)	3m Antenna Factor (dB)	25m Cable Factor (dB)	8m Cable Factor (dB)	HP8449B Factor (dB)	PK Net (dBµV/m)	AV Net (dBµV/m)	FCC Part 15.209/15.35 PK Limit ($dB_{\mu}V/m$)	FCC Part 15.209/15.35 PK Margin (dBµV/m)	FCC Part 15.209 AV Limit ($dB_{\mu}V/m$)	FCC Part 15.209 AV Margin (dBµV/m)
90.0	1.3	H	4960.0	39.1	-27.3	33.4	9.0	4.3	37.4	48.3	21.0	73.9	-25.6	53.9	-32.9
202.5	1.6	V	4960.0	41.0	-27.3	33.3	9.0	4.3	37.4	50.2	22.9	73.9	-23.7	53.9	-31.0
90.0	1.0	H	7439.5	43.4	-27.3	39.4	10.9	6.0	37.7	61.9	34.6	73.9	-12.0	53.9	-19.3
90.0	1.2	V	7439.5	43.5	-27.3	39.3	10.9	6.0	37.7	61.9	34.6	73.9	-12.0	53.9	-19.3
90.0	1.0	V	9919.5	35.3	-27.3	37.9	13.0	6.9	38.1	55.0	27.7	73.9	-18.9	53.9	-26.2
90.0	1.0	V	12399.5	27.3	-27.3	40.3	14.7	7.9	36.7	53.5	26.2	73.9	-20.4	53.9	-27.7
90.0	1.0	V	14879.5	24.3	-27.3	41.9	16.2	8.3	36.6	54.0	26.7	73.9	-19.9	53.9	-27.2
90.0	1.0	V	17359.5	21.7	-27.3	43.7	18.0	9.7	35.7	57.4	30.1	73.9	-16.5	53.9	-23.8
180.0	1.6	H	19840.0	24.2	-27.3	38.0	18.9	10.1	36.1	55.1	27.8	73.9	-18.8	53.9	-26.1
180.0	1.6	H	24800.0	19.0	-27.3	39.4	20.0	11.9	35.7	54.6	27.3	73.9	-19.3	53.9	-26.6

NOTES:
RBW=1MHz
Scanned 1 to 25 GHz



8.14 Unintentional/Spurious Radiated Emissions Measurement Conclusion

The EUT meets the unintentional/spurious radiated emissions requirements of FCC 15.209 (a) through (f) and RSS-GEN, 8.9. The worst case unintentional/spurious radiated emission measured was 32.6 dBµV/m (QP) at 73.7MHz. The FCC/RSS-GEN limit at that frequency is 40.0 dBµV/m (100.0 microvolts/meter).

9.0 ANTENNA REQUIREMENT

9.1 Applicable Standards

FCC 15.203, 15.247 (4) (i), RSS-GEN, 6.8, RSS-247, 5.4 (f) (ii). An intentional radiator shall be designed to ensure that no antenna other than furnished by the responsible party shall be used with the device.

Systems operating in the 2400-2483.5MHz bands that are used exclusively for fixed, point-to-point operations may employ transmitting antennas with directional gain greater than 6dBi provided the maximum peak output power of the intentional radiator is reduced by 1 dB for every 3 dB that the directional gain of the antenna exceeds 6 dBi.

9.2 Antenna Connected Construction

The directional gain of the antenna used for transmitting is -2.4dBi (max), and the antenna is permanently mounted to the EUT (PCB trace) with no consideration of replacement.

9.3 Antenna Requirement Conclusion

The EUT antenna meets the requirements of FCC 15.203, 15.247 (4) (i), RSS-GEN, 6.8, and RSS-247, 5.4 (f) (ii).

10.0 MAXIMUM PERMISSIBLE EXPOSURE

10.1 Applicable Standards

FCC Part 2.1091, KDB 447498 D01 General RF Exposure Guidance v06. An intentional radiator shall be evaluated for radiofrequency radiation exposure to persons. This EUT is considered a mobile device in that it is intended to be used in other than fixed locations and to generally be used in such a way that a separation distance of at least 20 centimeters is normally maintained between the transmitter's radiating structure and the body of the user or nearby persons.

10.2 MPE Calculations

General SAR test exclusion guidance is given in KDB 447498 D01 General RF Exposure Guidance v06. It states that for 100 MHz to 6 GHz and test separation distances ≤ 50 mm, the 1-g and 10-g SAR test exclusion thresholds are determined by the following:

[(max. power of channel, including tune-up tolerance, mW) / (min. test separation distance, mm)] X [√f(GHz)]

≤ 3.0 for 1-g SAR, and ≤ 7.5 for 10-g extremity SAR, where

- f(GHz) is the RF channel transmit frequency in GHz
- Power and distance are rounded to the nearest mW and mm before calculation
- The result is rounded to one decimal place for comparison
- The values 3.0 and 7.5 are referred to as numeric thresholds in step b) below

The test exclusions are applicable only when the minimum test separation distance is ≤ 50 mm, and for transmission frequencies between 100 MHz and 6 GHz. When the minimum test separation distance is < 5 mm, a distance of 5 mm according to 4.1 f) is applied to determine SAR test exclusion.

Using this equation for determining the 1-g and 10-g SAR and using the worst case peak power measurements at the three channels tested and the worst case separation distance of 5.0 mm, the following was determined:

Channel	Frequency (MHz)	EIRP (mW)	EIRP (dBm)	*Minimum Test Separation Distance (mm)	SAR Test Exclusion Calculation (mW)	1-g SAR Exclusion if ≤ 3.0	10-g SAR Exclusion if ≤ 7.5
Low	2402.000	1.435890	1.57	5.00	0.3	EXCLUDED	EXCLUDED
Mid	2440.000	0.719650	-1.43	5.00	0.3	EXCLUDED	EXCLUDED
High	2480.000	0.454068	-3.43	5.00	0.0	EXCLUDED	EXCLUDED
*Used worst case separation distance of 5mm.							

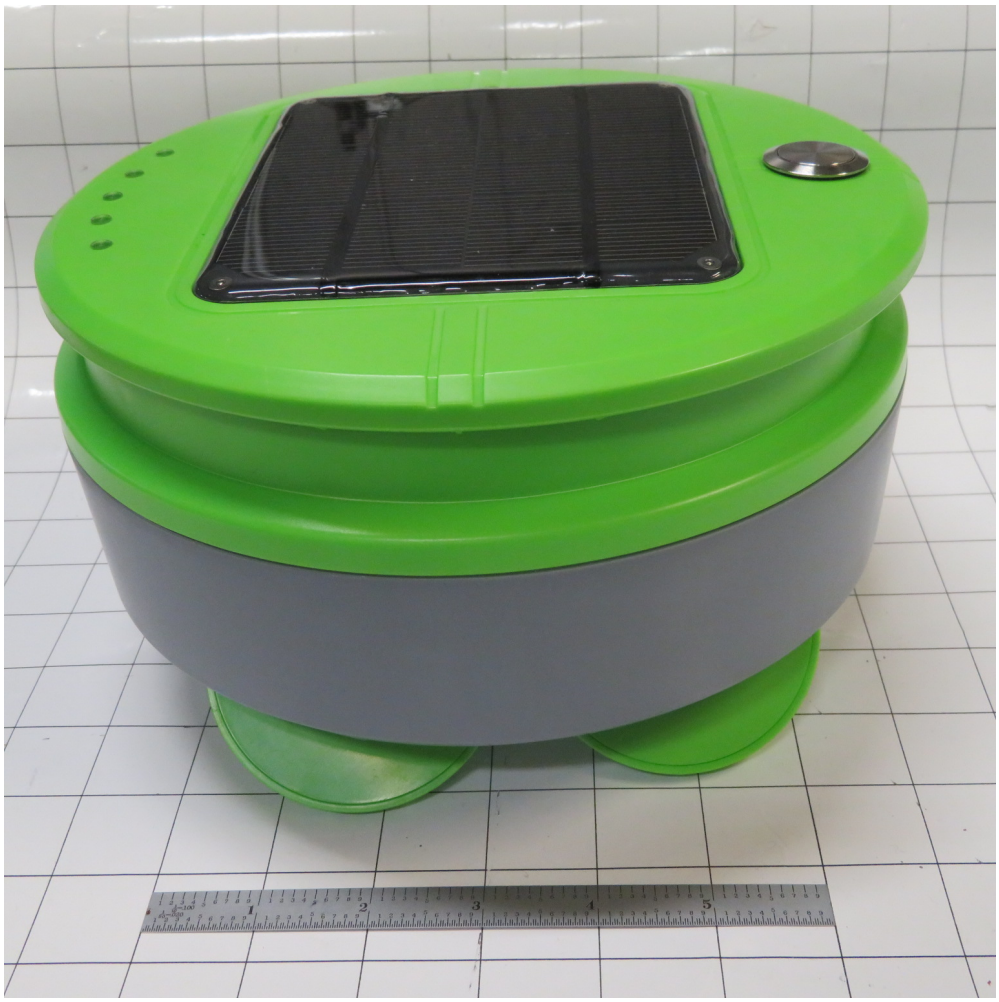
10.3 MPE Conclusion

Since the worst case peak power is below the SAR test exclusion power thresholds, the EUT is excluded from the SAR evaluation.

11.0 PHOTOGRAPHS

Franklin Robotics

Tertill



Additional Photographs can be found in separate documents:

Tertill Tsup.pdf
Tertill Intpho.pdf
Tertill Extpho.pdf.

END OF TEST REPORT