ENGINEERING TEST REPORT

Multiprotocol Gateway
Model(s): GWY20
FCC ID: XFF-GWY20

Applicant:

MMB Research Inc.
243 College St, Suite 500
Toronto, ON M5T 1R5
Canada

In Accordance With

Federal Communications Commission (FCC)
Part 15, Subpart C, Section 15.247
Digital Modulation Systems (DTS) Operating in 2400 – 2483.5 MHz Band

UltraTech's File No.: 18MMBN004_FCC15C247Z

This Test report is Issued under the Authority of Tri M. Luu Vice President of Engineering UltraTech Group of Labs Date: November 29, 2018	
Report Prepared by: Dan Huynh Issued Date: November 29, 2018	Tested by: Hung Trinh Test Dates: September 19, 21, 22, 24, 2018

- *The results in this Test Report apply only to the sample(s) tested, and the sample tested is randomly selected.*
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EXHIBIT 1. INTRODUCTION

1.1. SCOPE

Reference:	FCC Part 15, Subpart C, Section 15.247
Title:	Code of Federal Regulations (CFR), Title 47 – Telecommunication, Part 15 – Radio Frequency Devices
Purpose of Test:	Equipment Certification for Digital Modulation Systems (DTS) Operating Under §15.247
Test Procedures:	▪ ANSI C63.4 ▪ ANSI C63.10 ▪ FCC KDB Publication No. 558074 D01 15.247 Meas Guidance v05
Environmental Classification:	[x] Commercial, industrial or business environment [x] Residential environment

1.2. RELATED SUBMITTAL(S)/GRANT(S)

None.

1.3. NORMATIVE REFERENCES

Publication	Year	Title
47 CFR Parts 0-19	2018	Code of Federal Regulations (CFR), Title 47 – Telecommunication
ANSI C63.4	2014	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
ANSI C63.10	2013	American National Standard of Procedures for Compliance Testing of Unlicensed Wireless Devices
FCC, KDB Publication No. 558074 D01 15.247 Meas Guidance v05	2018	GUIDANCE FOR COMPLIANCE MEASUREMENTS ON DIGITAL TRANSMISSION SYSTEM, FREQUENCY HOPPING SPREAD SPECTRUM SYSTEM, AND HYBRID SYSTEM DEVICES OPERATING UNDER SECTION 15.247 OF THE FCC RULES

EXHIBIT 2. PERFORMANCE ASSESSMENT

2.1. CLIENT INFORMATION

Applicant	
Name:	MMB Research Inc.
Address:	243 College St, Suite 500 Toronto, ON M5T 1R5 Canada
Contact Person:	Hussein Nagji Phone #: 416-636-3145 x237 Fax #: n/a Email Address: hussein.nagji@mmbnetworks.com

Manufacturer	
Name:	MMB Research Inc.
Address:	243 College St, Suite 500 Toronto, ON M5T 1R5 Canada
Contact Person:	Hussein Nagji Phone #: 416-636-3145 x237 Fax #: n/a Email Address: hussein.nagji@mmbnetworks.com

2.2. EQUIPMENT UNDER TEST (EUT) INFORMATION

The following information (with the exception of the Date of Receipt) has been supplied by the applicant.

Brand Name:	MMB Research Inc.
Product Name:	Multiprotocol Gateway
Model(s):	GWY20
Serial Number:	Test Sample
Type of Equipment:	Digital Transmission System (DTS)
Input Power Supply Type:	5V, 2.4A via AC/DC adapter
Primary User Functions of EUT:	Home automation/ IoT gateway

2.3. EUT'S TECHNICAL SPECIFICATIONS

Transmitter	
Equipment Type:	Mobile Base station (fixed use)
Intended Operating Environment:	Residential environment Commercial, industrial or business environment
Power Supply Requirement:	5V, 2.4A
RF Output Power Rating:	20.27 dBm Peak
Operating Frequency Range:	2405 - 2480 MHz
RF Output Impedance:	50 Ω
Duty Cycle:	Continuous
Modulation Type:	O-QPSK
Antenna Connector Types:	Integral

2.4. ASSOCIATED ANTENNA DESCRIPTIONS

Antenna Type	Manufacturer	Model	Maximum Gain (dBi)
Inverted F PCB trace antenna	MMB Networks	Inverted F PCB trace antenna	5.2

2.5. LIST OF EUT'S PORTS

Port Number	EUT's Port Description	Number of Identical Ports	Connector Type	Cable Type (Shielded/Non-shielded)
1	Ethernet	1	RJ-45	Non-shielded
2	USB	1	USB	Shielded
3	DC Power Jack	1	DC Barrel Power Jack	Non-shielded

2.6. ANCILLARY EQUIPMENT

The EUT was tested while connected to the following representative configuration of ancillary equipment necessary to exercise the ports during tests:

Ancillary Equipment # 1	
Description:	Laptop
Brand name:	Lenovo
Model Name or Number:	ThinkPad Edge 0578
Serial Number:	IS057882 ULRBXKBG
Connected to EUT's Port:	Connected to Router

Ancillary Equipment # 2	
Description:	Router
Brand name:	D-Link
Model Name or Number:	DIR-615
Serial Number:	F3HR181012581
Connected to EUT's Port:	Ethernet

Ancillary Equipment # 3	
Description:	AC/DC Adapter
Brand name:	I.T.E Power Supply
Model Name or Number:	RH-050240US
Serial Number:	--
Connected to EUT's Port:	DC Jack

EXHIBIT 3. EUT OPERATING CONDITIONS AND CONFIGURATIONS DURING TESTS

3.1. CLIMATE TEST CONDITIONS

The climate conditions of the test environment are as follows:

Temperature:	21 to 23 °C
Humidity:	45 to 58%
Pressure:	102 kPa
Power Input Source:	5V via AC/DC adapter

3.2. OPERATIONAL TEST CONDITIONS & ARRANGEMENT FOR TESTS

Operating Modes:	The transmitter was operated in a continuous transmission mode with the carrier modulated as specified in the Test Data.
Special Test Software:	Test software provided by the Applicant to operate the EUT at each channel frequency continuously and in the range of typical modes of operation.
Special Hardware Used:	N/A
Transmitter Test Antenna:	The EUT is tested with the antenna fitted in a manner typical of normal intended use as integral antenna equipment as described with the test results.

Transmitter Test Signals	
Frequency Band(s):	2405 - 2480 MHz
Frequency(ies) Tested:	2405 MHz, 2440 MHz, 2475 MHz, 2480 MHz
RF Power Output: (measured maximum output power at antenna terminals)	20.27 dBm Peak
Normal Test Modulation:	O-QPSK
Modulating Signal Source:	Internal

EXHIBIT 4. SUMMARY OF TEST RESULTS

4.1. LOCATION OF TESTS

All of the measurements described in this report were performed at Ultratech Group of Labs located in the city of Oakville, Province of Ontario, Canada.

- AC Power Line Conducted Emissions were performed in UltraTech's shielded room, 24'(L) by 16'(W) by 8'(H).

- Radiated Emissions were performed at the Ultratech's 3-10 TDK Semi-Anechoic Chamber situated in the Town of Oakville, province of Ontario. This test site been calibrated in accordance with ANSI C63.4, and found to be in compliance with the requirements of Sec. 2.948 of the FCC Rules. The descriptions and site measurement data of the Oakville 3-10 TDK Semi-Anechoic Chamber has been filed with ANAB File No.: AT-1945.

4.2. APPLICABILITY & SUMMARY OF EMC EMISSION TEST RESULTS

FCC Section(s)	Test Requirements	Compliance (Yes/No)
15.203	Antenna requirements	Yes*
15.207(a)	AC Power Line Conducted Emissions	Yes
15.247(a)(2)	6 dB Bandwidth	Yes
15.247(b)(3)	Peak Conducted Output Power	Yes
15.247(d)	Band-Edge and RF Conducted Spurious Emissions at the Transmitter Antenna Terminal	Yes
15.247(d), 15.209 & 15.205	Transmitter Spurious Radiated Emissions	Yes
15.247(e)	Power Spectral Density	Yes
15.247(i), 1.1307, 1.1310, 2.1091	RF Exposure	Yes

* The EUT complies with the requirement; it employs a unique (non-standard) antenna connector or integral antenna.

4.3. MODIFICATIONS INCORPORATED IN THE EUT FOR COMPLIANCE PURPOSES

None.

EXHIBIT 5. TEST DATA

5.1. POWER LINE CONDUCTED EMISSIONS [§15.207(a)]

5.1.1. Limit(s)

The equipment shall meet the limits of the following table:

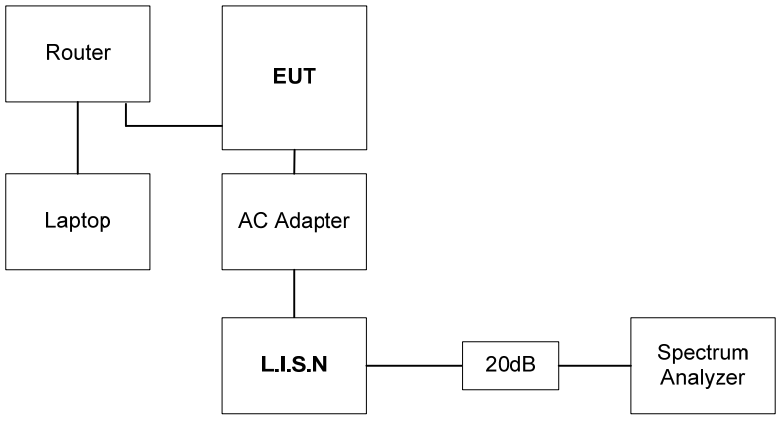
Frequency of emission (MHz)	Conducted Limits (dBμV)	
	Quasi-peak	Average
0.15–0.5 .....……..	66 to 56*	56 to 46*
0.5–5 .....……..	56	46
5-30 ……..	60 ..……..	50

*Decreases linearly with the logarithm of the frequency

5.1.2. Method of Measurements

ANSI C63.4

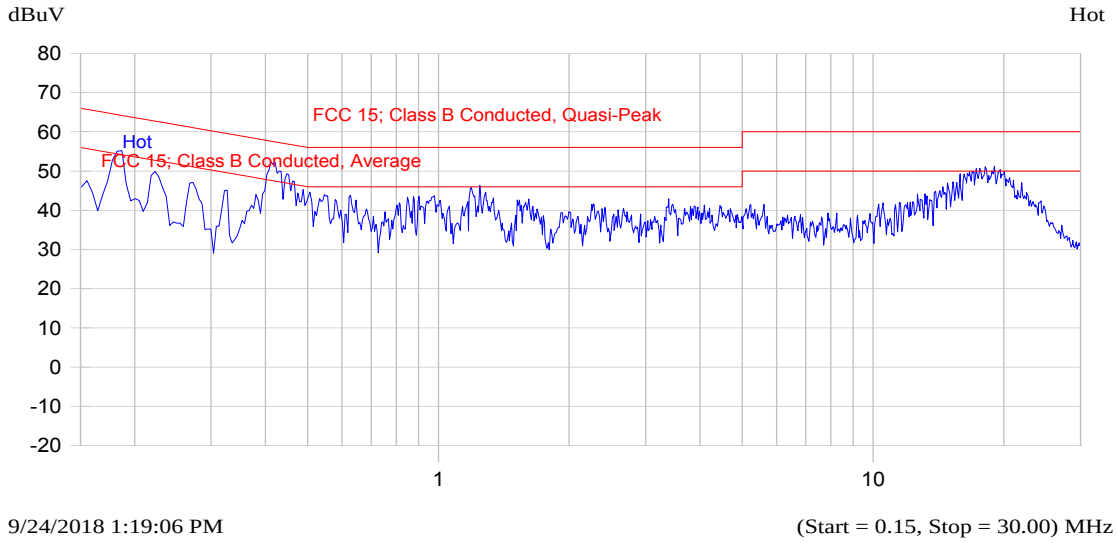
5.1.3. Test Arrangement



5.1.4. Test Data

Plot 5.1.4.1. Power Line Conducted Emissions (Tx Mode)
Line Voltage: 120 VAC; Line Tested: Hot

Current Graph

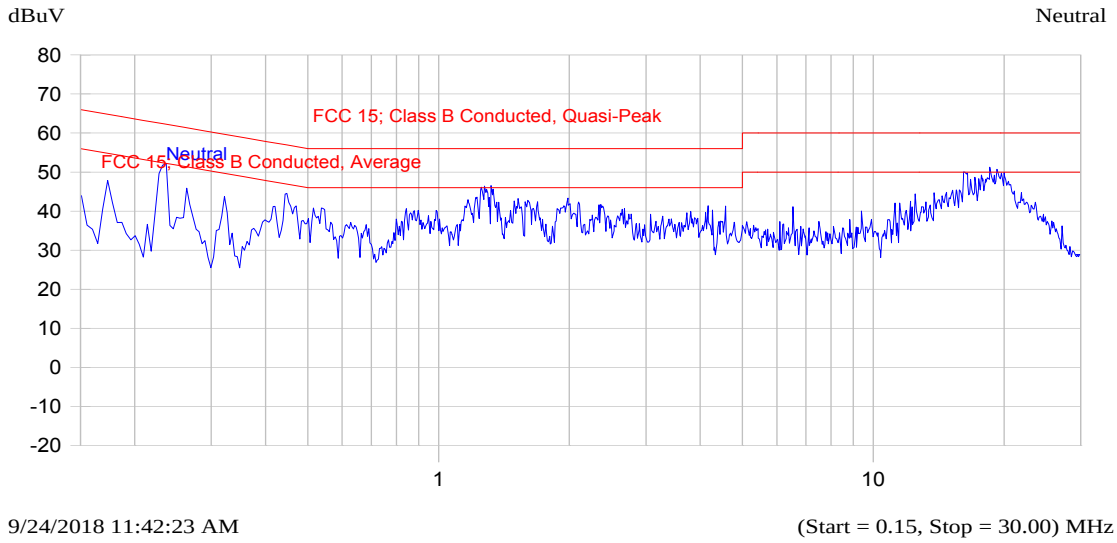


Current List

Frequency MHz	Peak dBuV	QP dBuV	QP-QP Limit dB	Avg dBuV	Avg-Avg Limit dB	Trace Name
0.183	57.0	54.3	-10.1	46.2	-8.2	Hot
0.412	53.3	50.3	-7.3	41.5	-6.1	Hot
0.451	49.9	46.7	-10.2	37.5	-9.3	Hot
1.242	46.1	41.6	-14.4	31.5	-14.5	Hot
18.117	51.1	46.4	-13.6	36.5	-13.5	Hot

Plot 5.1.4.2. Power Line Conducted Emissions (Tx Mode)
Line Voltage: 120 VAC Line Tested: Neutral

Current Graph

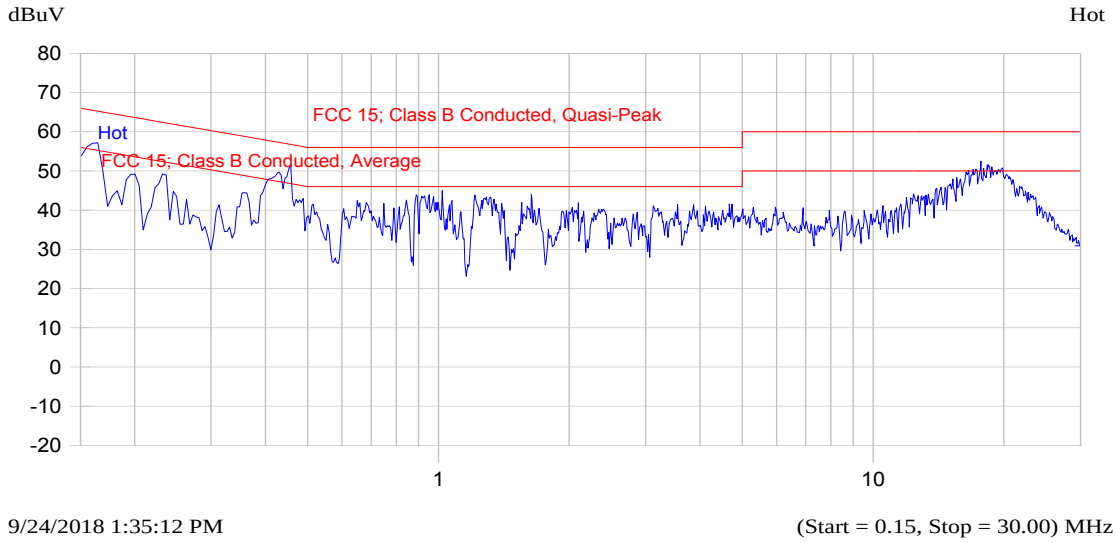


Current List

Frequency MHz	Peak dBuV	QP dBuV	QP-QP Limit dB	Avg dBuV	Avg-Avg Limit dB	Trace Name
0.228	52.5	49.0	-13.6	34.0	-18.6	Neutral
0.445	45.7	41.7	-15.2	31.2	-15.8	Neutral
1.282	47.9	42.8	-13.2	32.0	-14.0	Neutral
18.532	49.3	44.6	-15.4	35.8	-14.2	Neutral

Plot 5.1.4.3. Power Line Conducted Emissions (Rx Mode)
Line Voltage: 120 VAC; Line Tested: Hot

Current Graph

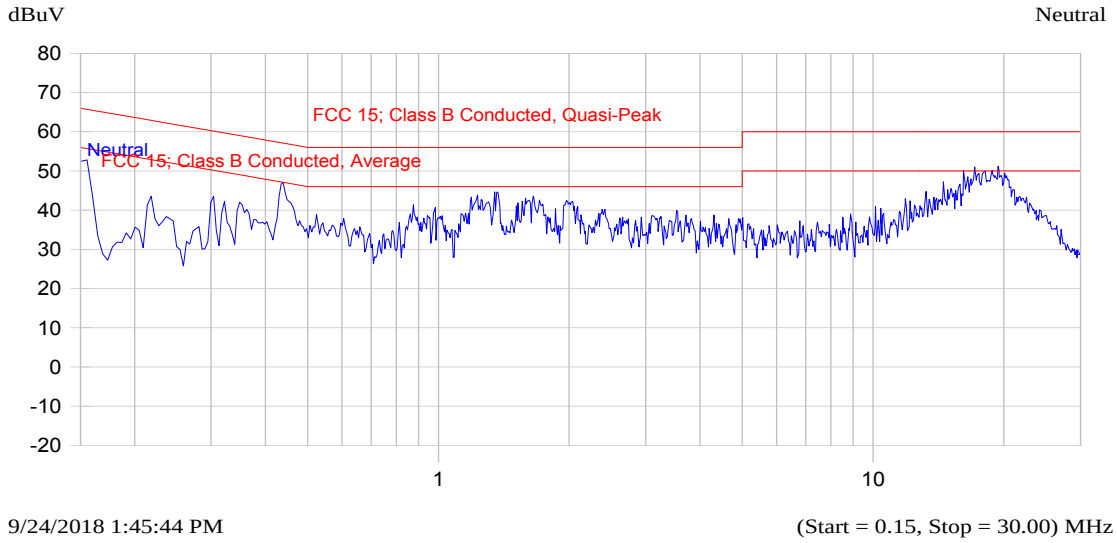


Current List

Frequency MHz	Peak dBuV	QP dBuV	QP-QP Limit dB	Avg dBuV	Avg-Avg Limit dB	Trace Name
0.156	58.5	55.4	-10.2	47.0	-8.7	Hot
0.454	51.1	45.7	-11.1	34.4	-12.4	Hot
1.022	43.6	38.9	-17.1	28.9	-17.1	Hot
1.638	40.4	36.7	-19.3	27.5	-18.5	Hot
17.704	50.1	45.8	-14.2	35.1	-14.9	Hot

Plot 5.1.4.4. Power Line Conducted Emissions (Rx Mode)
Line Voltage: 120 VAC; Line Tested: Neutral

Current Graph



Current List

Frequency MHz	Peak dBuV	QP dBuV	QP-QP Limit dB	Avg dBuV	Avg-Avg Limit dB	Trace Name
0.425	57.0	45.8	-11.5	34.7	-12.7	Neutral
1.354	45.0	41.2	-14.8	30.8	-15.2	Neutral
19.364	50.8	45.4	-14.6	35.2	-14.8	Neutral

5.2. OCCUPIED BANDWIDTH [§ 15.247(a)(2)]

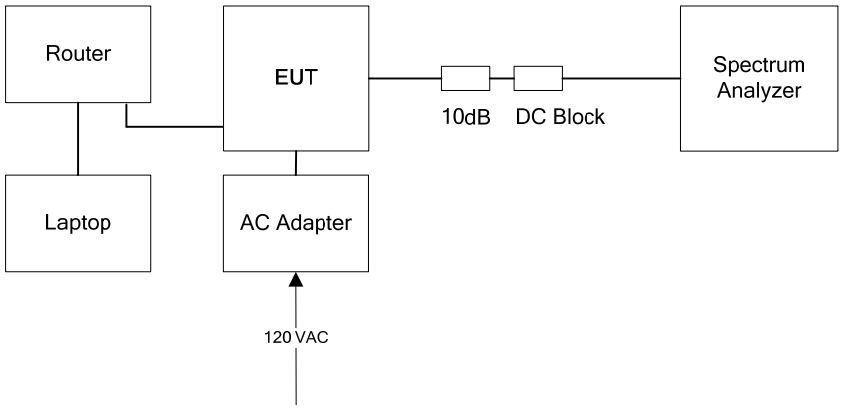
5.2.1. Limit(s)

The minimum 6 dB bandwidth shall be at least 500 kHz.

5.2.2. Method of Measurements

FCC KDB 558074 D01 15.247 Meas Guidance v05, Section 8.2 DTS Bandwidth / ANSI C63.10 Subclause 11.8.1 Option 2 PKPSD.

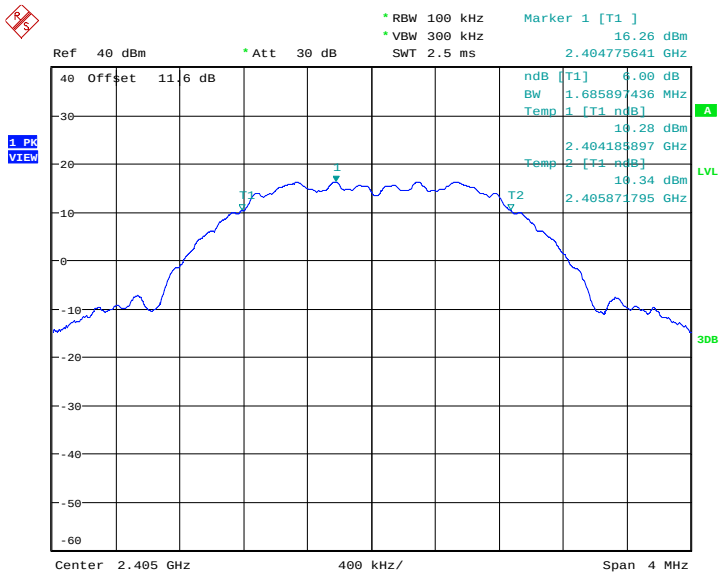
5.2.3. Test Arrangement



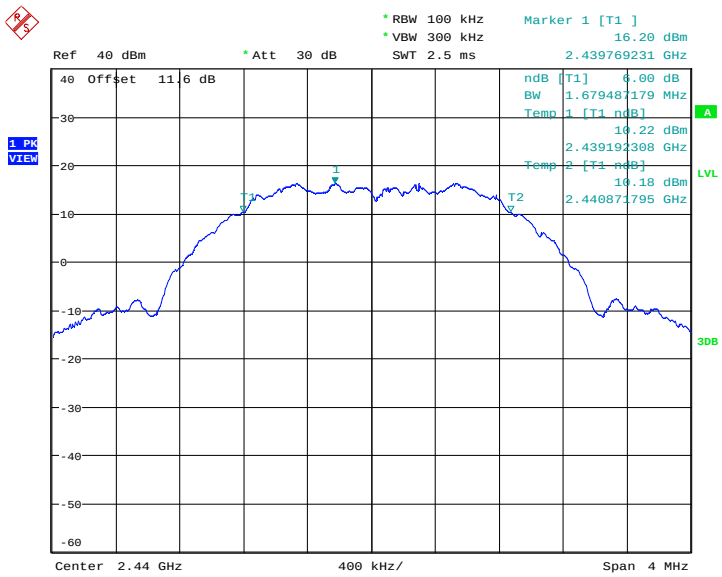
5.2.4. Test Data

Modulation	Power Setting	Channel	Frequency (MHz)	6dB BW (MHz)	Min. Limit (kHz)
O-QPSK	200	11	2405	1.69	500
	200	18	2440	1.68	500
	200	25	2475	1.68	500
	100	26	2480	1.66	500

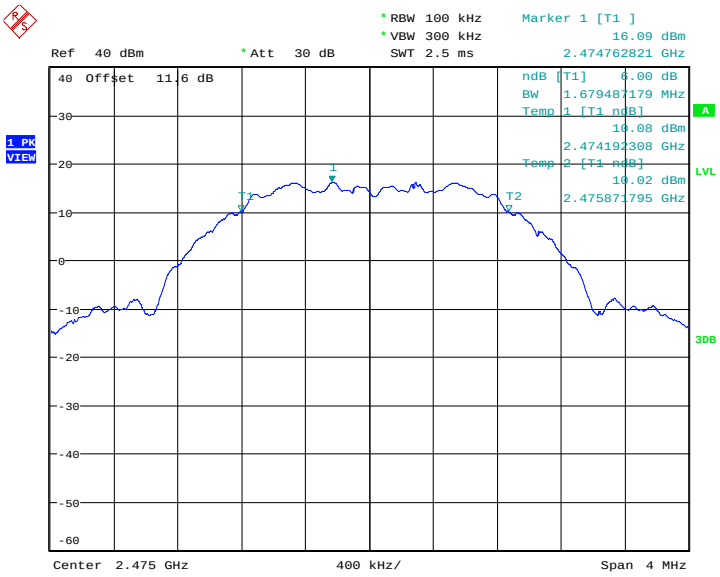
Plot 5.2.4.1. 6 dB Bandwidth, O-QPSK Modulation, Power Setting at 200, Channel 11, 2405 MHz



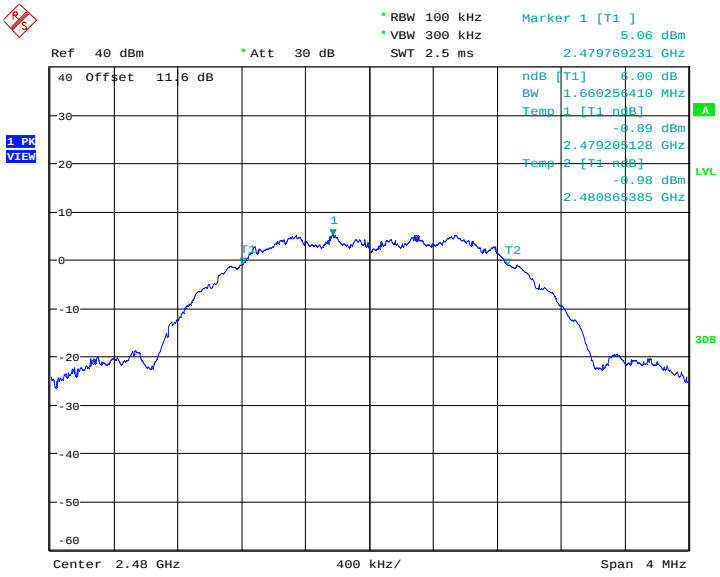
Plot 5.2.4.2. 6 dB Bandwidth, O-QPSK Modulation, Power Setting at 200, Channel 18, 2440 MHz



Plot 5.2.4.3. 6 dB Bandwidth, O-QPSK Modulation, Power Setting at 200, Channel 25, 2475 MHz



Plot 5.2.4.4. 6 dB Bandwidth, O-QPSK Modulation, Power Setting at 100, Channel 26, 2480 MHz



5.3. PEAK CONDUCTED OUTPUT POWER - DTS [§ 15.247(b)(3)]

5.3.1. Limit(s)

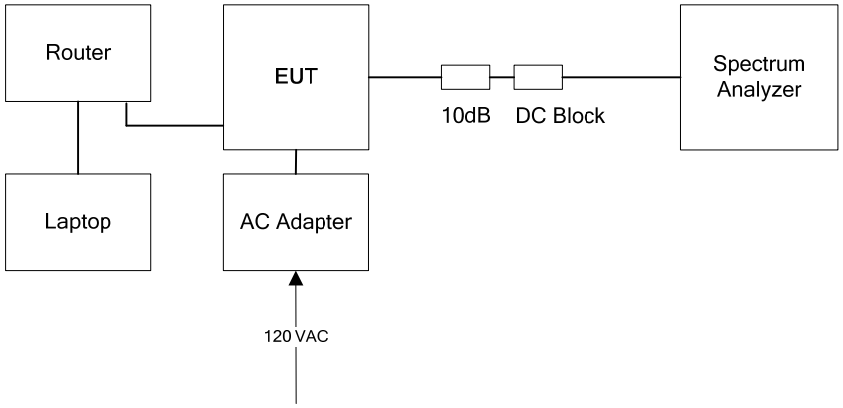
§ 15.247(b)(3): For systems using digital modulation in the 902-928 MHz, 2400-2483.5 MHz, and 5725-5850 MHz bands: 1 Watt. As an alternative to a peak power measurement, compliance with the one Watt limit can be based on a measurement of the maximum conducted output power. Maximum Conducted Output Power is defined as the total transmit power delivered to all antennas and antenna elements averaged across all symbols in the signaling alphabet when the transmitter is operating at its maximum power control level. Power must be summed across all antennas and antenna elements. The average must not include any time intervals during which the transmitter is off or is transmitting at a reduced power level. If multiple modes of operation are possible (e.g., alternative modulation methods), the *maximum conducted output power* is the highest total transmit power occurring in any mode.

§ 15.247(b)(4): The conducted output power limit specified in paragraph (b) of this section is based on the use of antennas with directional gains that do not exceed 6 dBi. Except as shown in paragraph (c) of this section, if transmitting antennas of directional gain greater than 6 dBi are used, the conducted output power from the intentional radiator shall be reduced below the stated values in paragraphs (b)(1), (b)(2), and (b)(3) of this section, as appropriate, by the amount in dB that the directional gain of the antenna exceeds 6 dBi.

5.3.2. Method of Measurements & Test Arrangement

FCC KDB 558074 D01 15.247 Meas Guidance v05, Section 8.3.1.1 RBW ≥ DTS bandwidth / Subclause 11.9.1.1 of ANSI C63.10

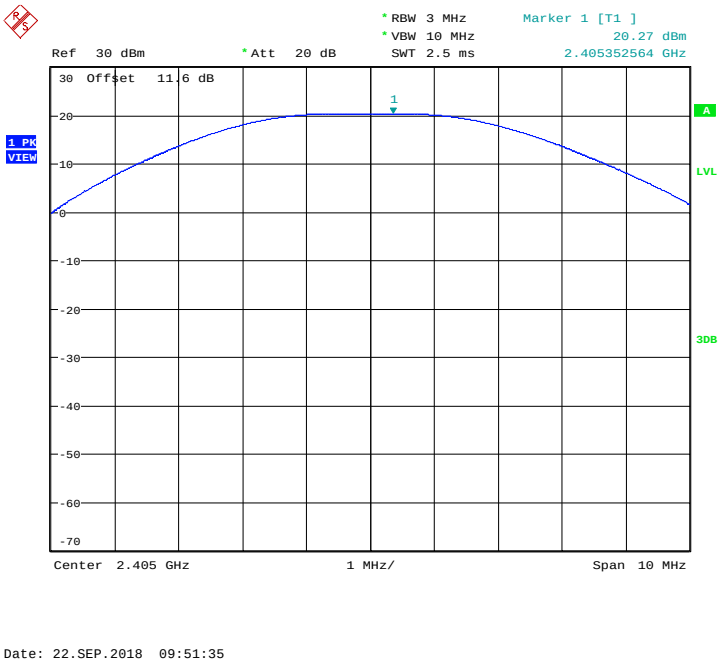
5.3.3. Test Arrangement



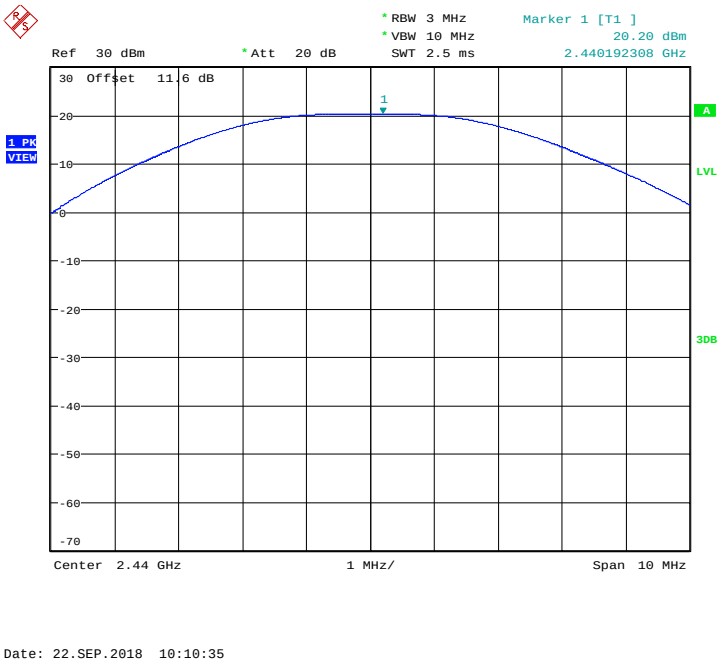
5.3.4. Test Data

Peak Conducted Power and Power Settings for EUT with 5.2 dBi Inverted F PCB Trace Antenna						
Modulation	**Power Setting**	**Channel**	**Frequency (MHz)**	**Peak Power (dBm)**	**Assembly Gain (dB)**	**EIRP (dBm)**
O-QPSK	200	11	2405	20.27	5.2	25.47
	200	18	2440	20.20	5.2	25.40
	200	25	2475	20.20	5.2	25.40
	100	26	2480	8.94	5.2	14.14

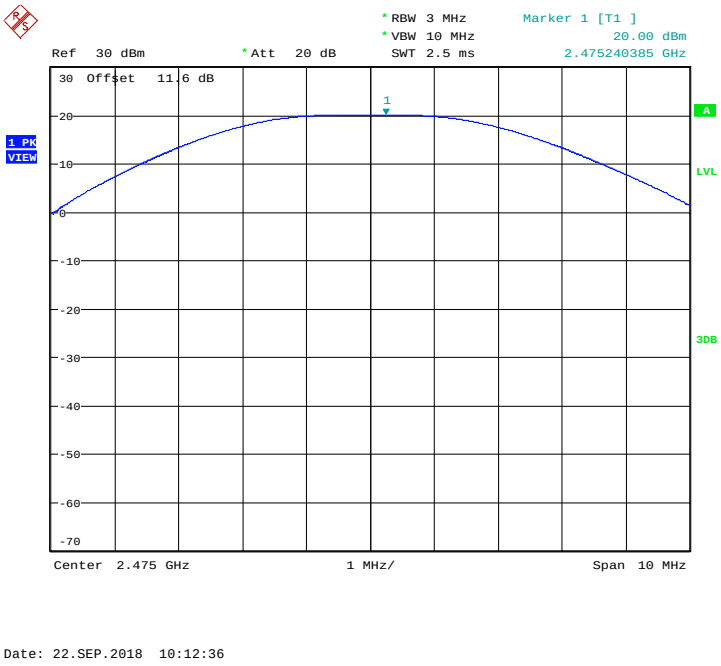
Plot 5.3.4.1. Maximum Peak Conducted Output Power, O-QPSK Modulation, Power Setting 200, Ch 11, 2405 MHz



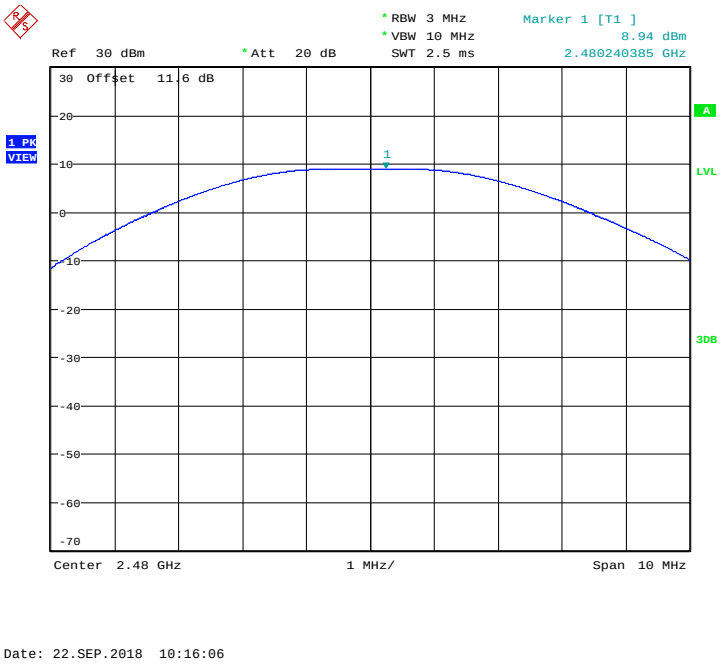
Plot 5.3.4.2. Maximum Peak Conducted Output Power, O-QPSK Modulation, Power Setting 200, Ch 18, 2440 MHz



Plot 5.3.4.3. Maximum Peak Conducted Output Power, O-QPSK Modulation, Power Setting 200, Ch 25, 2475 MHz



Plot 5.3.4.4. Maximum Peak Conducted Output Power, O-QPSK Modulation, Power Setting 100, Ch 26, 2480 MHz



5.4. TRANSMITTER SPURIOUS RADIATED EMISSIONS AT 3 METERS [§§ 15.247(d), 15.209 & 15.205]

5.4.1. Limit(s)

§ 15.247 (d): 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, provided the transmitter demonstrates compliance with the peak conducted power limits. If the transmitter complies with the conducted power limits based on the use of RMS averaging over a time interval, as permitted under paragraph (b)(3) of this section, the attenuation required under this paragraph shall be 30 dB instead of 20 dB. Attenuation below the general limits specified in Section 15.209(a) is not required. In addition, radiated emissions which fall in the restricted bands, as defined in Section 15.205(a), must also comply with the radiated emission limits specified in Section 15.209(a) (see Section 15.205(c)).

Section 15.205(a) - Restricted Bands of Operation

MHz	MHz	MHz	GHz
0.090–0.110	16.42–16.423	399.9–410	4.5–5.15
[1] 0.495–0.505	16.69475–16.69525	608–614	5.35–5.46
2.1735–2.1905	16.80425–16.80475	960–1240	7.25–7.75
4.125–4.128	25.5–25.67	1300–1427	8.025–8.5
4.17725–4.17775	37.5–38.25	1435–1626.5	9.0–9.2
4.20725–4.20775	73–74.6	1645.5–1646.5	9.3–9.5
6.215–6.218	74.8–75.2	1660–1710	10.6–12.7
6.26775–6.26825	108–121.94	1718.8–1722.2	13.25–13.4
6.31175–6.31225	123–138	2200–2300	14.47–14.5
8.291–8.294	149.9–150.05	2310–2390	15.35–16.2
8.362–8.366	156.52475–156.52525	2483.5–2500	17.7–21.4
8.37625–8.38675	156.7–156.9	2655–2900	22.01–23.12
8.41425–8.41475	162.0125–167.17	3260–3267	23.6–24.0
12.29–12.293	167.72–173.2	3332–3339	31.2–31.8
12.51975–12.52025	240–285	3345.8–3358	36.43–36.5
12.57675–12.57725	322–335.4	3600–4400	[2]
13.36–13.41.			

[1] Until February 1, 1999, this restricted band shall be 0.490–0.510 MHz.
[2] Above 38.6

Section 15.209(a) - Field Strength Limits within Restricted Frequency Bands

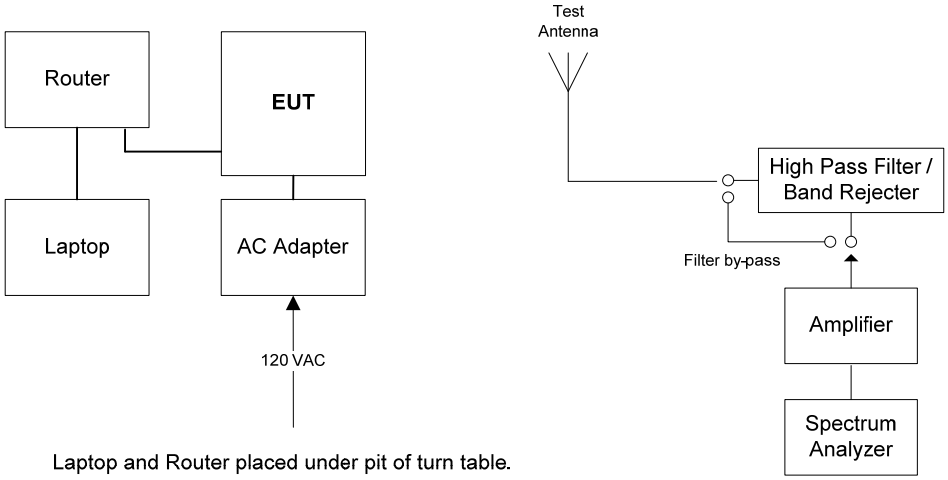
Frequency (MHz)	Field Strength (microvolts/meter)	Measurement Distance (meters)
0.009 - 0.490	2,400 / F (kHz)	300
0.490 - 1.705	24,000 / F (kHz)	30
1.705 - 30.0	30	30
30 – 88	100	3
88 – 216	150	3
216 – 960	200	3
Above 960	500	3

5.4.2. Method of Measurements

FCC KDB 558074 D01 15.247 Meas Guidance v05 Sections 8.5, 8.6 and 8.7 / Subclauses 11.11, 11.12 and 11.13.of ANSI C63.10.

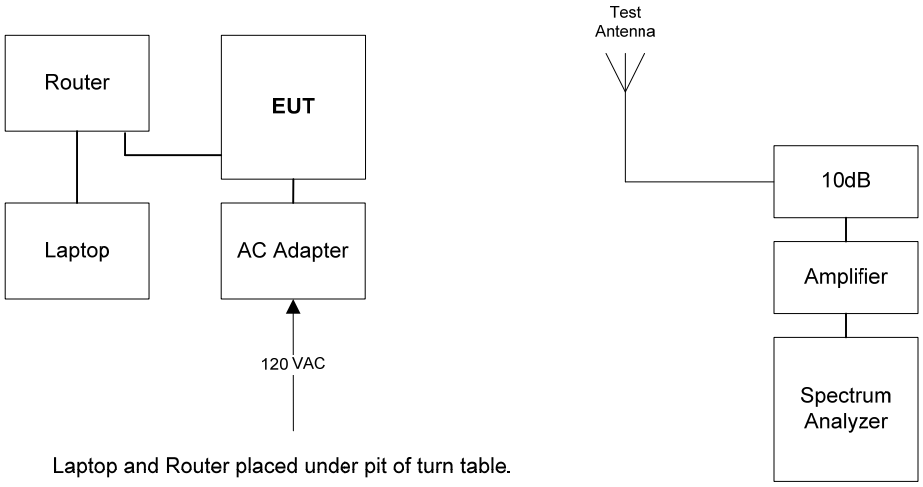
5.4.3. Test Arrangement

Radiated Emissions



Laptop and Router placed under pit of turn table.

Band-Edge Radiated Emissions



Laptop and Router placed under pit of turn table.

5.4.4. Test Data

5.4.4.1. Transmitter Spurious Radiated Emissions

Remark(s):

- All spurious emissions that are in excess of 20 dB below the specified limit shall be recorded.
- EUT shall be tested in three orthogonal positions.
- The simultaneous transmission was investigated and no new emissions were found.
- Exploratory tests performed to determined worst-case test configurations, the following test results at high power setting represent the worst-case.

Fundamental Frequency:	2405 MHz
Frequency Test Range:	30 MHz – 25 GHz
Power Setting:	200 (for fundamental and spurious emissions)

Frequency (MHz)	RF Peak Level (dBµV/m)	RF Avg Level (dBµV/m)	Antenna Plane (H/V)	Limit 15.209 (dBµV/m)	Limit 15.247 (dBµV/m)	Margin (dB)	Pass/ Fail
2405	113.58	--	V	--	--	--	--
2405	118.45	--	H	--	--	--	--
4810	57.37	46.24	V	54.0	98.5	-7.8	Pass*
4810	57.56	44.96	H	54.0	98.5	-9.0	Pass*

*Field strength of emissions appearing within restricted frequency bands shall not exceed the limits in § 15.209.

Fundamental Frequency:	2440 MHz
Frequency Test Range:	30 MHz – 25 GHz
Power Setting:	200 (for fundamental and spurious emissions)

Frequency (MHz)	RF Peak Level (dBµV/m)	RF Avg Level (dBµV/m)	Antenna Plane (H/V)	Limit 15.209 (dBµV/m)	Limit 15.247 (dBµV/m)	Margin (dB)	Pass/ Fail
2440	115.45	--	V	--	--	--	--
2440	118.94	--	H	--	--	--	--
4880	58.59	46.62	V	54.0	98.9	-7.4	Pass*
4880	59.08	47.14	H	54.0	98.9	-6.9	Pass*

*Field strength of emissions appearing within restricted frequency bands shall not exceed the limits in § 15.209.

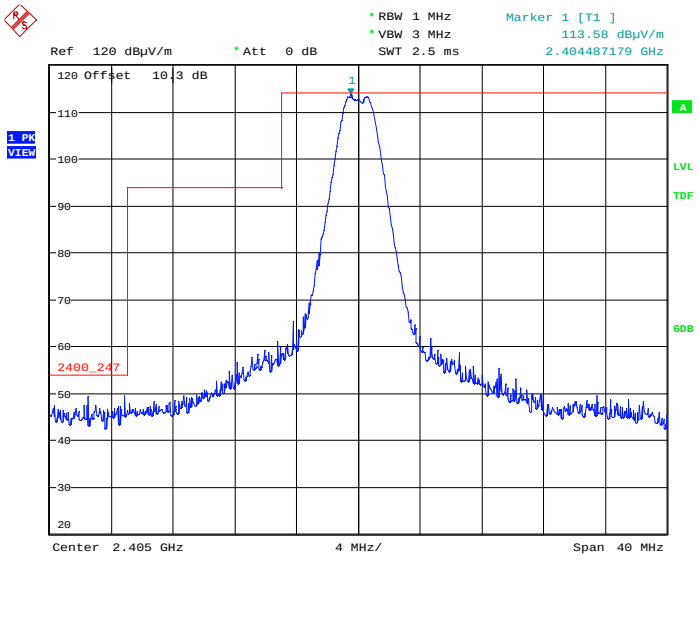
Fundamental Frequency:	2480 MHz
Frequency Test Range:	30 MHz – 25 GHz
Power Setting:	100 (for fundamental) 200 (for spurious emissions)

Frequency (MHz)	RF Peak Level (dBµV/m)	RF Avg Level (dBµV/m)	Antenna Plane (H/V)	Limit 15.209 (dBµV/m)	Limit 15.247 (dBµV/m)	Margin (dB)	Pass/ Fail
2480	104.01	--	V	--	--	--	--
2480	108.05	--	H	--	--	--	--
4960	58.24	46.45	V	54.0	88.1	-7.6	Pass*
4960	59.29	47.72	H	54.0	88.1	-6.3	Pass*

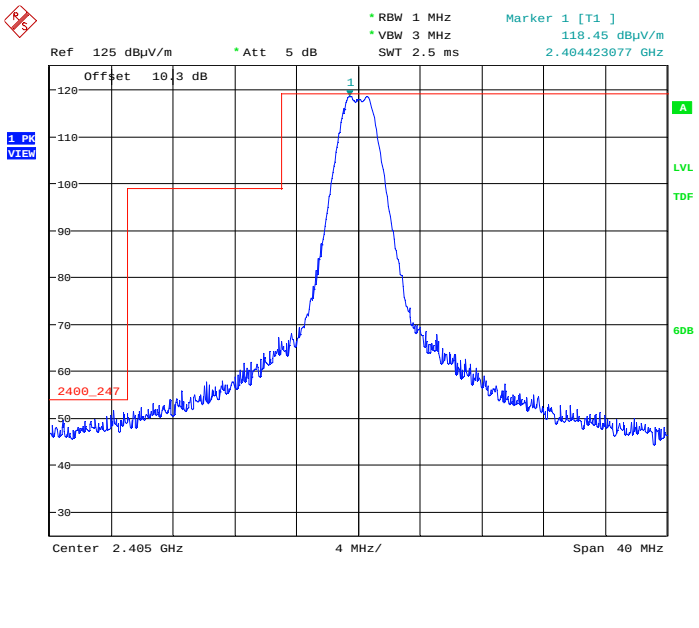
*Field strength of emissions appearing within restricted frequency bands shall not exceed the limits in § 15.209.

5.4.4.2. Band-Edge Radiated Emissions

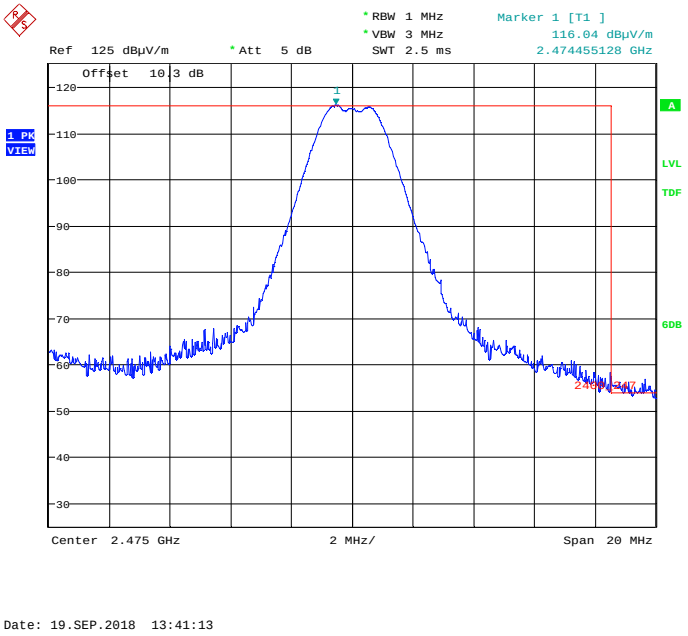
Plot 5.4.4.2.1. Band-Edge Radiated Emissions, Lower Band-edge
Rx Antenna in Vertical Polarization, O-QPSK Modulation, Power Setting 200, Ch 11, 2405 MHz



Plot 5.4.4.2.2. Band-Edge Radiated Emissions, Lower Band-edge
Rx Antenna in Horizontal Polarization, O-QPSK Modulation, Power Setting 200, Ch 11, 2405 MHz

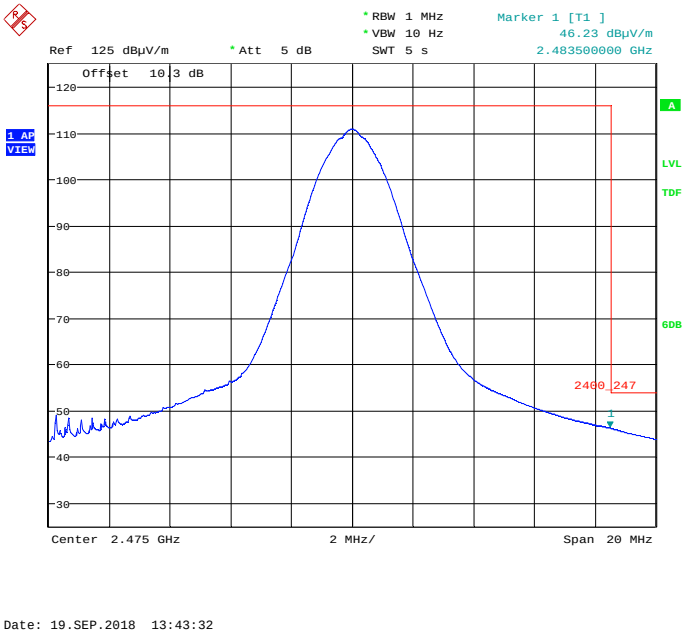


Plot 5.4.4.2.3. Band-Edge Radiated Emissions, Higher Band-edge
Rx Antenna in Vertical Polarization, O-QPSK Modulation, Power Setting 200, Ch 25, 2475 MHz



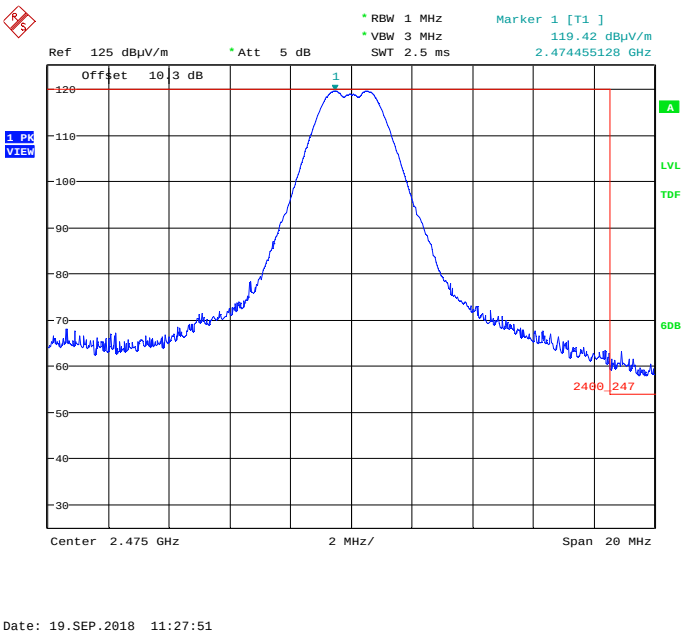
Peak: RBW = 1 MHz, VBW = 3 MHz

Plot 5.4.4.2.4. Band-Edge Radiated Emissions, Higher Band-edge
Rx Antenna in Vertical Polarization, O-QPSK Modulation, Power Setting 200, Ch 25, 2475 MHz



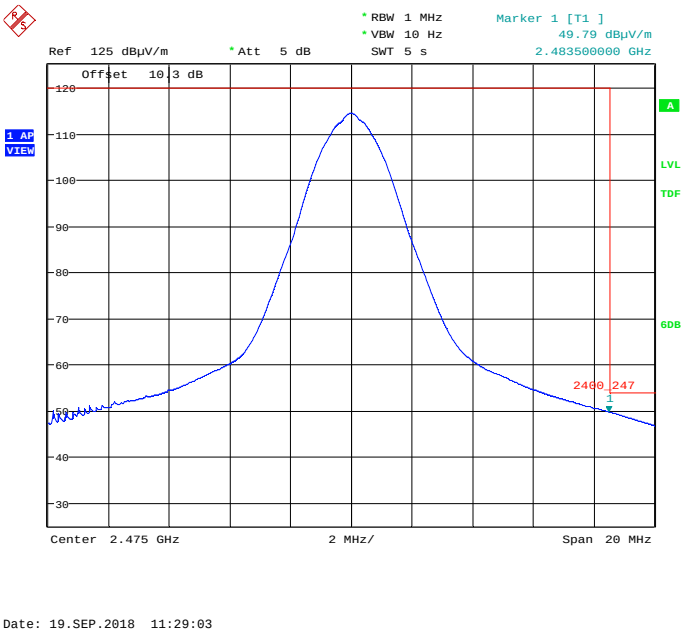
Average: RBW = 1 MHz, VBW = 10 Hz

Plot 5.4.4.2.5. Band-Edge Radiated Emissions, Higher Band-edge
Rx Antenna in Horizontal Polarization, O-QPSK Modulation, Power Setting 200, Ch 25, 2475 MHz



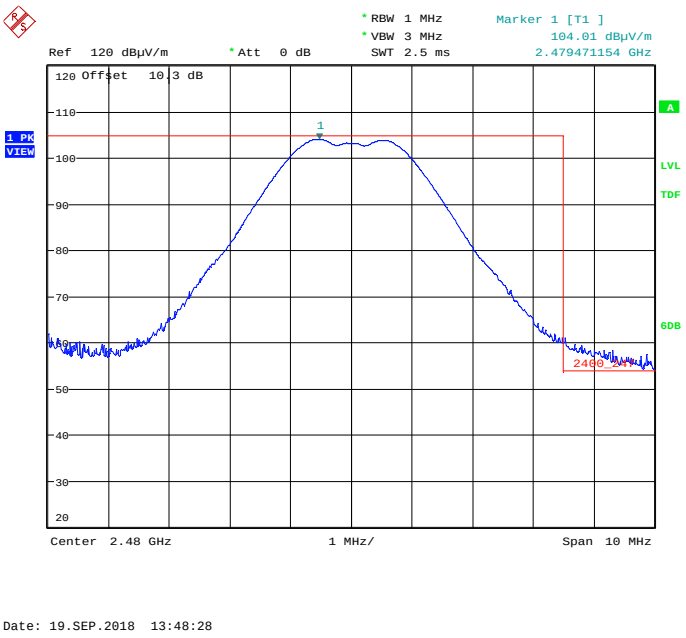
Peak: RBW = 1 MHz, VBW = 3 MHz

Plot 5.4.4.2.6. Band-Edge Radiated Emissions, Higher Band-edge
Rx Antenna in Horizontal Polarization, O-QPSK Modulation, Power Setting 200, Ch 25, 2475 MHz



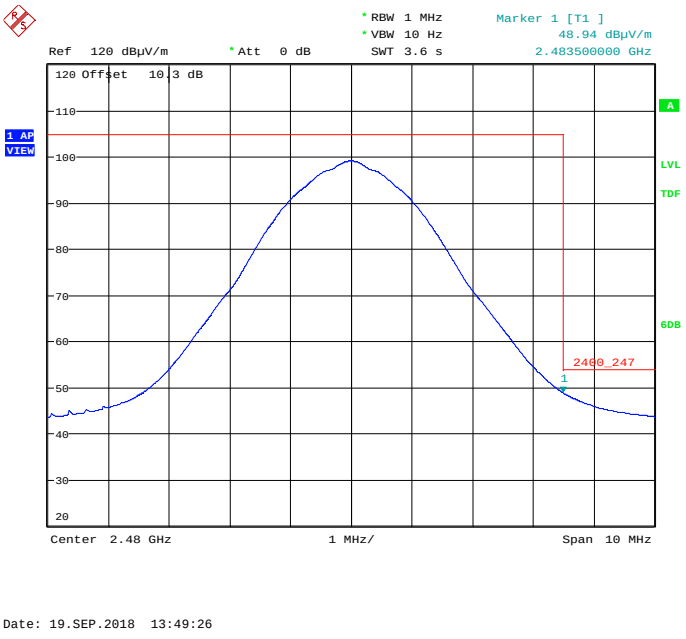
Average: RBW = 1 MHz, VBW = 10 Hz

Plot 5.4.4.2.7. Band-Edge Radiated Emissions, Higher Band-edge
Rx Antenna in Vertical Polarization, O-QPSK Modulation, Power Setting 100, Ch 26, 2480 MHz



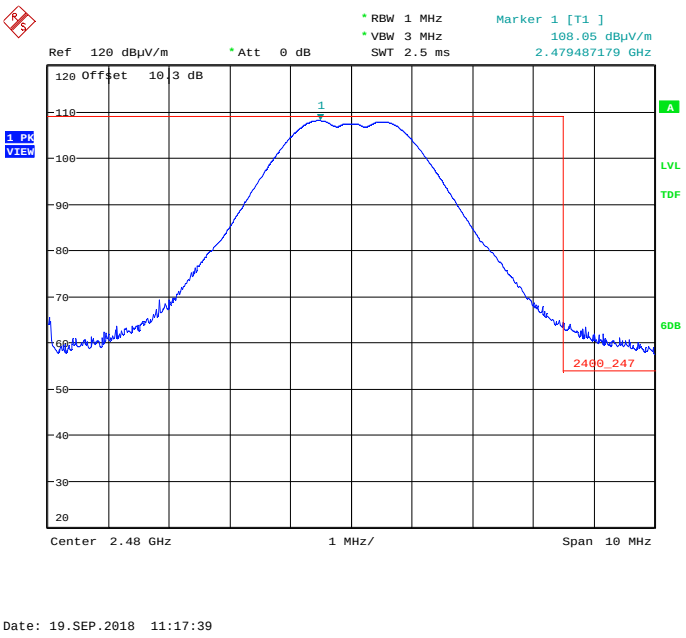
Peak: RBW = 1 MHz, VBW = 3 MHz

Plot 5.4.4.2.8. Band-Edge Radiated Emissions, Higher Band-edge
Rx Antenna in Vertical Polarization, O-QPSK Modulation, Power Setting 100, Ch 26, 2480 MHz



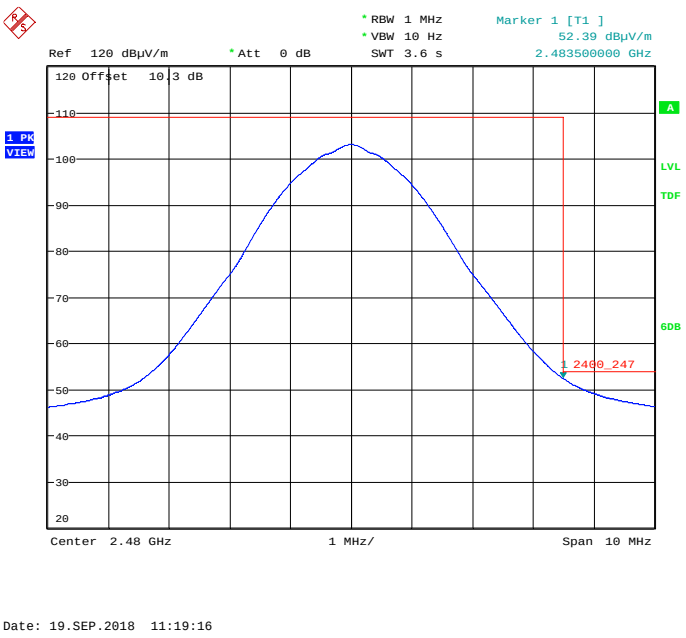
Average: RBW = 1 MHz, VBW = 10 Hz

Plot 5.4.4.2.9. Band-Edge Radiated Emissions, Higher Band-edge
Rx Antenna in Horizontal Polarization, O-QPSK Modulation, Power Setting 100, Ch 26, 2480 MHz



Peak: RBW = 1 MHz, VBW = 3 MHz

Plot 5.4.4.2.10. Band-Edge Radiated Emissions, Higher Band-edge
Rx Antenna in Horizontal Polarization, O-QPSK Modulation, Power Setting 100, Ch 26, 2480 MHz



Average: RBW = 1 MHz, VBW = 10 Hz

5.5. POWER SPECTRAL DENSITY [§ 15.247(e)]

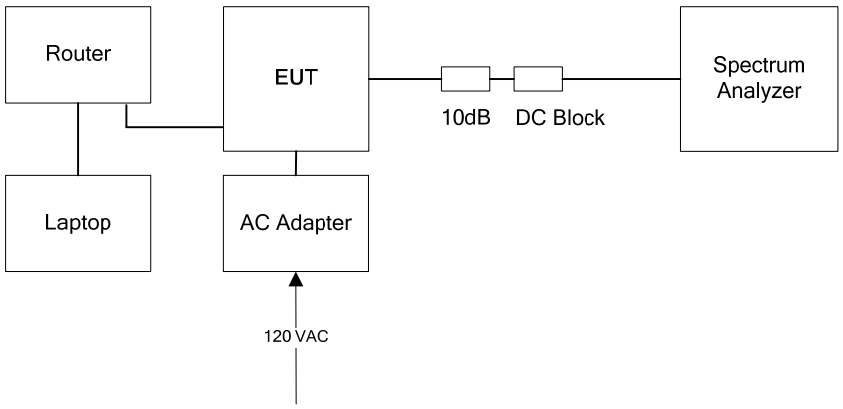
5.5.1. Limit(s)

For digitally modulated systems, the power spectral density conducted from the intentional radiator to the antenna shall not be greater than 8 dBm in any 3 kHz band during any time interval of continuous transmission.

5.5.2. Method of Measurements

FCC KDB 558074 D01 15.247 Meas Guidance v05, Section 8.4 / ANSI C63.10 Subclause 11.10.2 Method PKPSD (peak PSD).

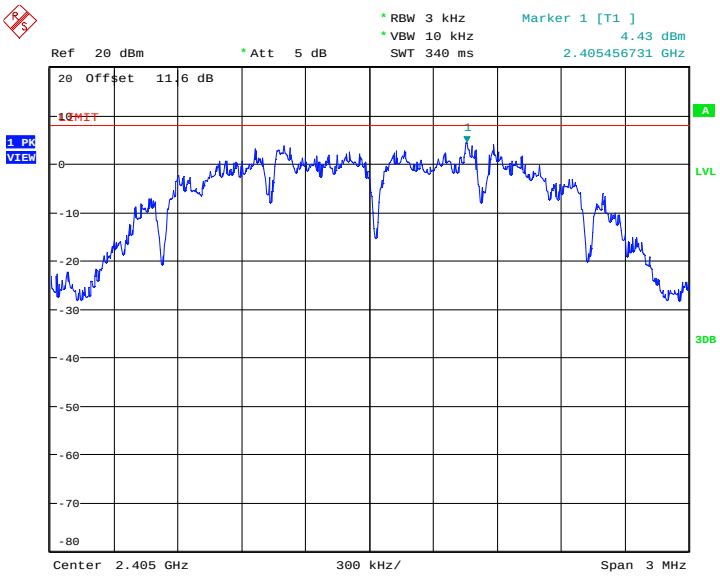
5.5.3. Test Arrangement



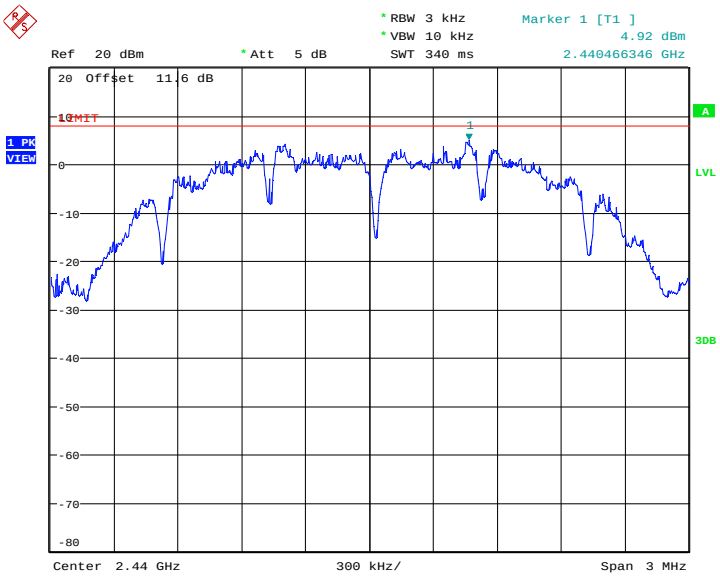
5.5.4. Test Data

Modulation	Power Setting	Channel	Frequency (MHz)	PSD (dBm)	Max. Limit (dBm)	Margin (dBm)
O-QPSK	200	11	2405	4.43	8	-3.57
		18	2440	4.92	8	-3.08
		25	2475	4.75	8	-3.25
	100	26	2480	-6.49	8	-14.49

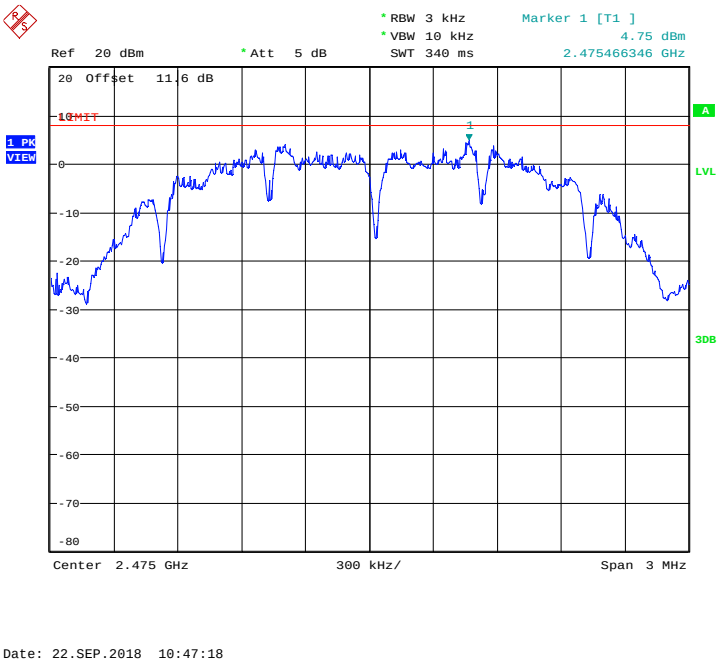
Plot 5.5.4.1. Power Spectral Density, O-QPSK Modulation, Power Setting 200, Channel 11, 2405 MHz



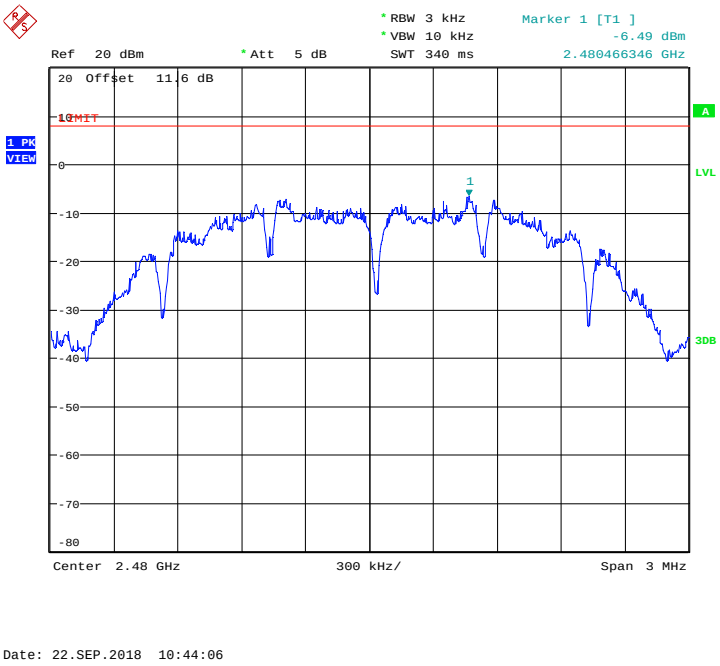
Plot 5.5.4.2. Power Spectral Density, O-QPSK Modulation, Power Setting 200, Channel 18, 2440 MHz



Plot 5.5.4.3. Power Spectral Density, O-QPSK Modulation, Power Setting 200, Channel 25, 2475 MHz



Plot 5.5.4.4. Power Spectral Density, O-QPSK Modulation, Power Setting 100, Channel 26, 2480 MHz



5.6. RF EXPOSURE REQUIRMENTS [§§ 15.247(i), 1.1310 & 2.1091]

5.6.1. Limits

§ **1.1310:** The criteria listed in the following table shall be used to evaluate the environmental impact of human exposure to radio-frequency (RF) radiation as specified in 1.1307(b).

Limits for Maximum Permissible Exposure (MPE)

Frequency range (MHz)	Electric field strength (V/m)	Magnetic field strength (A/m)	Power density (mW/cm^2)	Averaging time (minutes)
(A) Limits for Occupational/Controlled Exposures				
0.3-3.0	614	1.63	*(100)	6
3.0-30	1842/f	4.89/f	*($900/f^2$)	6
30-300	61.4	0.163	1.0	6
300-1500			f/300	6
1500-100,000			5	6
(B) Limits for General Population/Uncontrolled Exposure				
0.3-1.34	614	1.63	*(100)	30
1.34-30	824/f	2.19/f	*($180/f^2$)	30
30-300	27.5	0.073	0.2	30
300-1500			f/1500	30
1500-100,000			1.0	30

f = frequency in MHz
* = Plane-wave equivalent power density

Note 1: Occupational/controlled limits apply in situations in which persons are exposed as a consequence of their employment provided those persons are fully aware of the potential for exposure and can exercise control over their exposure. Limits for occupational/controlled exposure also apply in situations when an individual is transient through a location where occupational/controlled limits apply provided he or she is made aware of the potential for exposure.

Note 2: General population/uncontrolled exposures apply in situations in which the general public may be exposed, or in which persons that are exposed as a consequence of their employment may not be fully aware of the potential for exposure or can not exercise control over their exposure.

5.6.2. Method of Measurements

Calculation Method of Power Density/RF Safety Distance:

$$S = \frac{PG}{4\pi \cdot r^2} = \frac{EIRP}{4\pi \cdot r^2}$$

Where, P: power input to the antenna in mW
EIRP: Equivalent (effective) isotropic radiated power.
S: power density mW/cm^2
G: numeric gain of antenna relative to isotropic radiator
r: distance to centre of radiation in cm

5.6.3. RF Evaluation

Remark(s):

The EUT contained ZigBee/ BLE and WiFi radio modules with the following operating conditions:

- BLE and WiFi may transmit at the same time
- Zigbee and WiFi may transmit at the same time
- BLE and Zigbee will NOT transmit at the same time

Pursuant to KDB 447498 D01 General RF Exposure Guidance v06, Section 7.2:

Simultaneous transmission MPE test exclusion applies when the sum of the MPE ratios for all simultaneously transmitting antennas incorporated in a host device is ≤ 1.0, according to calculated/estimated, numerically modeled, or measured field strengths or power density.

The sum of the MPE ratios for all simultaneously transmitting antennas incorporated in the EUT is ≤ 1.0 as calculated in the following table.

EUT Co-located MPE for BLE/Zigbee with WiFi Radio								
Transmitter	**Frequency Band (MHz)**	**Frequency**	**Max. EIRP (dBm)**	**Max. EIRP (mW)**	**Evaluation Distance (cm)**	**Power Density (mW/cm^2)**	**Power Density Limit (mW/cm^2)**	**Power Density MPE Ratio**
BLE	2402-2480	2402	25.53	357.273	20	0.071	1.0	**0.071**
Zigbee	2405-2480	2405	25.47	352.371	20	0.070	1.0	0.070
802.11b	2412-2462	2412	28.36	685.488	20	0.136	1.0	0.136
802.11g	2412-2462	2412	28.83	763.836	20	0.152	1.0	**0.152**
802.11n	2412-2462	2412	28.65	732.825	20	0.146	1.0	0.146
Worst Case Combination (BLE with WiFi 802.11g mode) :								**0.223**

EXHIBIT 6. TEST EQUIPMENT LIST

Test Instruments	Manufacturer	Model No.	Serial No.	Frequency Range	Cal. Due Date
Spectrum Analyzer	Agilent	E7405A	US39440181	9 kHz–26.5 GHz	04 Feb 2019
Attenuator	Pasternack	PE7010-20	ATT13	DC–2 GHz	21 Mar 2019
LISN	EMCO	3825/2R	1165	10 kHz–30 MHz	03 Nov 2018
Spectrum Analyzer	Rohde & Schwarz	FSU26	200946	20Hz–26.5 GHz	25 Jul 2020
DC Block	Hewlett Packard	11742A	12460	0.045 – 26.5 GHz	See Note 1
Attenuator	Hewlett Packard	8493C	0465	DC - 26.5 GHz	See Note 1
EMI Receiver	Rohde & Schwarz	ESU40	100037	20Hz–40 GHz	04 May 2019
RF Amplifier	Com-Power	PAM-0118A	551052	0.5 – 18 GHz	26 Jun 2019
RF Amplifier	Hewlett Packard	84498	3008A00769	1 – 26.5 GHz	01 Oct 2019
Biconilog	EMCO	3142C	00026873	26-3000 MHz	27 Apr 2020
Horn Antenna	EMCO	3155	5061	1 – 18 GHz	30 Apr 2020
Horn Antenna	ETS-Lindgren	3160-09	001183858	18 – 26.5 GHz	11 Oct 2019
High Pass Filter	K & L	11SH10-4000/T12000	4	Cut off 2.4 GHz	See Note 1
Band Reject Filter	Micro-Tronics	BRM50701	105	Cut off 2.4-2.483 GHz	See Note 1
Attenuator	Pasternack	PE7024-10	4	DC–26.5 GHz	See Note 1
Note 1: Internal Verification/Calibration check					

EXHIBIT 7. MEASUREMENT UNCERTAINTY

The measurement uncertainties stated were calculated in accordance with the requirements of CISPR 16-4-2 @ IEC:2003 and JCGM 100:2008 (GUM 1995) – Guide to the Expression of Uncertainty in Measurement.

7.1. LINE CONDUCTED EMISSION MEASUREMENT UNCERTAINTY

	Line Conducted Emission Measurement Uncertainty (9 kHz – 30 MHz):	**Measured**	**Limit**
u_c	**Combined standard uncertainty:** $u_c(y) = \sqrt{\sum_{I=1}^{m} u_i^2(y)}$	**± 1.44**	**± 1.8**
U	**Expanded uncertainty U:** $U = 2u_c(y)$	**± 2.89**	**± 3.6**

7.2. RADIATED EMISSION MEASUREMENT UNCERTAINTY

	Radiated Emission Measurement Uncertainty @ 3m, Horizontal (30-1000 MHz):	**Measured (dB)**	**Limit (dB)**
u_c	**Combined standard uncertainty:** $u_c(y) = \sqrt{\sum_{I=1}^{m} u_i^2(y)}$	**± 2.39**	**± 2.6**
U	**Expanded uncertainty U:** $U = 2u_c(y)$	**± 4.79**	**± 5.2**

	Radiated Emission Measurement Uncertainty @ 3m, Vertical (30-1000 MHz):	**Measured (dB)**	**Limit (dB)**
u_c	**Combined standard uncertainty:** $u_c(y) = \sqrt{\sum_{I=1}^{m} u_i^2(y)}$	**± 2.39**	**± 2.6**
U	**Expanded uncertainty U:** $U = 2u_c(y)$	**± 4.78**	**± 5.2**

	Radiated Emission Measurement Uncertainty @ 3 m, Horizontal & Vertical (1 – 18 GHz):	**Measured (dB)**	**Limit (dB)**
u_c	**Combined standard uncertainty:** $u_c(y) = \sqrt{\sum_{I=1}^{m} u_i^2(y)}$	**± 1.87**	**Under consideration**
U	**Expanded uncertainty U:** $U = 2u_c(y)$	**± 3.75**	**Under consideration**