Certification Test Report

FCC ID: 2AIGCWFB003

FCC Rule Part: 15.247
ISED Canada's Radio Standards Specification: RSS-247

TÜV SÜD Report Number: RD72137771.100

Manufacturer: Murata Electronics
Model: PAC-USWHS002-WF-2

Test Begin Date: March 27, 2018
Test End Date: April 05, 2018

Report Issue Date: May 29, 2018

FOR THE SCOPE OF ACCREDITATION UNDER LAB Code AT-1921

This report must not be used by the client to claim product certification, approval, or endorsement by ANAB, ANSI, or any agency of the Federal Government.

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This report contains 33 pages

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1 GENERAL

1.1 Purpose

The purpose of this report is to demonstrate compliance with Part 15 Subpart C of the FCC's Code of Federal Regulations and Innovation, Science and Economic Development Canada Radio Standards Specification: RSS-247 Certification.

1.2 Product Description

The PAC-USWHS002-WF-2 WIFI-BLE adapter is the second generation in its series. It wirelessly monitors and controls a MEUS HVAC unit via WIFI link. This device communicates wirelessly using either 802.11b/g/n WIFI mode or Bluetooth Smart (i.e. BLE) mode.

The current report addresses the evaluation of both BLE and WIFI modes.

Technical Information:

Detail	Description
Frequency Range	802.11b/g/n (HT20)/n (HT40): 2412 - 2462 MHz BLE: 2402 – 2480 MHz
Number of Channels	802.11b/g/n (HT20)/n (HT40): 11 BLE: 40 Channels
Modulation Format	802.11b: DSSS (DBPSK / DQPSK / CCK) 802.11g/n (HT20): OFDM (BPSK / QPSK / 16QAM / 64QAM) BLE: GFSK
Data Rates	802.11b: 1-11Mbps 802.11g: 6-54 Mbps 802.11n (HT 20): 6.5 – 72 Mbps BLE: 1 Mbps
Number of Inputs/Outputs	1T1R
Operating Voltage	12Vdc
Antenna Type / Gain	Inverted-F Antenna/ 3.3 dBi

Manufacturer Information:
Murata Electronics,
3079 Premiere Parkway, Suite 140
Duluth, GA, 30097
USA

EUT Serial Numbers:
RF CE BLE: 8134P008X100119F, RF CE WIFI: 8134P008X100117F, RE BLE: 8134P008X100123F, RE WIFI: 8134P008X100152F.

Test Sample Condition: The test samples were provided in good working order with no visible defects.

1.3 Test Methodology and Considerations

To program the unit for WIFI evaluation, the manufacturer provided commands scripts that are passed to the EUT through a terminal application, such as Putty or Tera term. Specific set of commands lines were created for each configuration indicating the WLAN channel, bandwidth, data rates, and power levels. During this evaluation, the power setting (-1), that was used, represented the highest level according to the manufacturer. The data presented in this report represents the worse case where applicable. The worse case data rates are also indicated in the table below for each mode.

Mode	Data Rate	Software Power Settings
802.11b	11 Mbps	-1
802.11g	6 Mbps	-1
802.11n HT20	MCS5	-1

For the Bluetooth Low Energy (BLE) evaluation, an interface was provided by the manufacturer which allows to specify the channel frequency, the BLE feature, and the power level. The power setting used during all testing was at 0dBm, which corresponds to the highest power level.

For radiated emissions measurements, the EUT was programmed to generate a continuously modulated signal on each channel investigated. The EUT was evaluated in three orthogonal orientations. The worst-case orientations were the Y-plane for WIFI and X-plane for BLE. See test setup photos for more information.

For RF conducted emissions measurements, the EUT was evaluated using a temporary SMA antenna connector which was tapped into the EUT board to facilitate connection to the test equipment.

2 TEST FACILITIES

2.1 Location

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

TÜV SÜD America Inc.
2320 Presidential Drive, Suite 101
Durham, NC 27703
Phone: (919) 381-4235

2.2 Laboratory Accreditations/Recognitions/Certifications

TÜV SÜD America Inc. is accredited to ISO/IEC 17025 by ANSI-ASQ National Accreditation Board under their ANAB program and has been issued certificate number AT-1921 in recognition of this accreditation. Unless otherwise specified, all test methods described within this report are covered under the ISO/IEC 17025 scope of accreditation.

FCC Registered Test Site Number: 637011
ISED Canada Test Site Registration Number: 20446

2.3 Radiated Emissions Test Site Description

2.3.1 Semi-Anechoic Chamber Test Site

The Semi-Anechoic Chamber Test Site consists of a 18' x 28' x 18' shielded enclosure. The chamber is lined with Samwha Electronics Co. LTD Ferrite Absorber, model number SFA300 (HSN-1). The ferrite tile is 10cm x 10 cm and weighs approximately 1.4lbs. These tiles are mounted on steel panels and installed directly on the inner walls of the chamber. On top of the ferrite tiles is DMAS HT-45 (Dutch Microwave Absorber Solutions) hybrid absorber on all walls except the wall behind the antenna mast which has a shorter DMAS HT-25 absorber.

The turntable is 1.50m in diameter and is located 150cm from the back wall of the chamber. The chamber is grounded via 1 - 8' copper ground rod, installed at the center of the back wall, it is bound to the ground plane using short #6 copper wire. The turntable is all steel, flush mounted table installed in an all steel frame. The table is remotely operated from inside the control room located 25' from the turntable. The turntable is electrically bonded to the surrounding ground plane via steel fingers installed on the edge of the turn table. The steel fingers make constant contact with the ground plane.

Behind the turntable is a 2' x 6' x 1.5' deep shielded pit used for support equipment if necessary. The pit is equipped with 2 - 4" PVC chase from the turntable to the pit that allow for cabling to the EUT if necessary. The underside of the turntable can be accessed from the pit so cables can be supplied to the EUT from the pit.

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

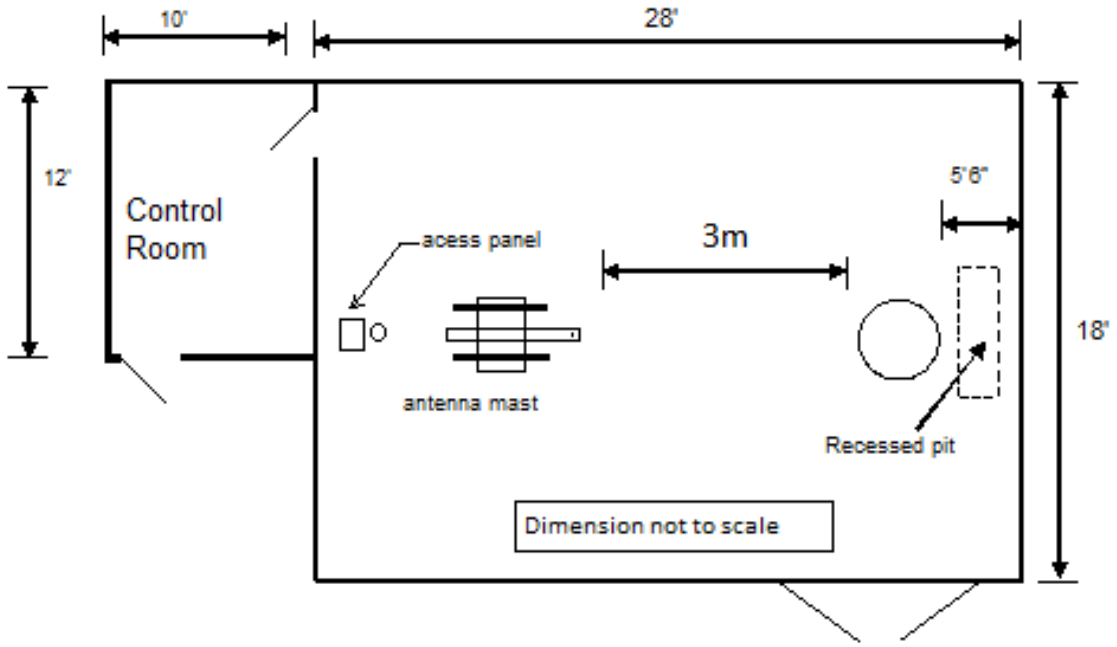


Figure 2.3.1-1: Semi-Anechoic Chamber Test Site

2.4 Conducted Emissions Test Site Description

The AC mains conducted EMI site is located in the main EMC lab. It consists of an 8' x 10' sheet galvanized steel horizontal ground reference plane (GRP) bonded every 6" to an 8' X 8' aluminum vertical ground plane.

A diagram of the room is shown below in figure 2.4-1:

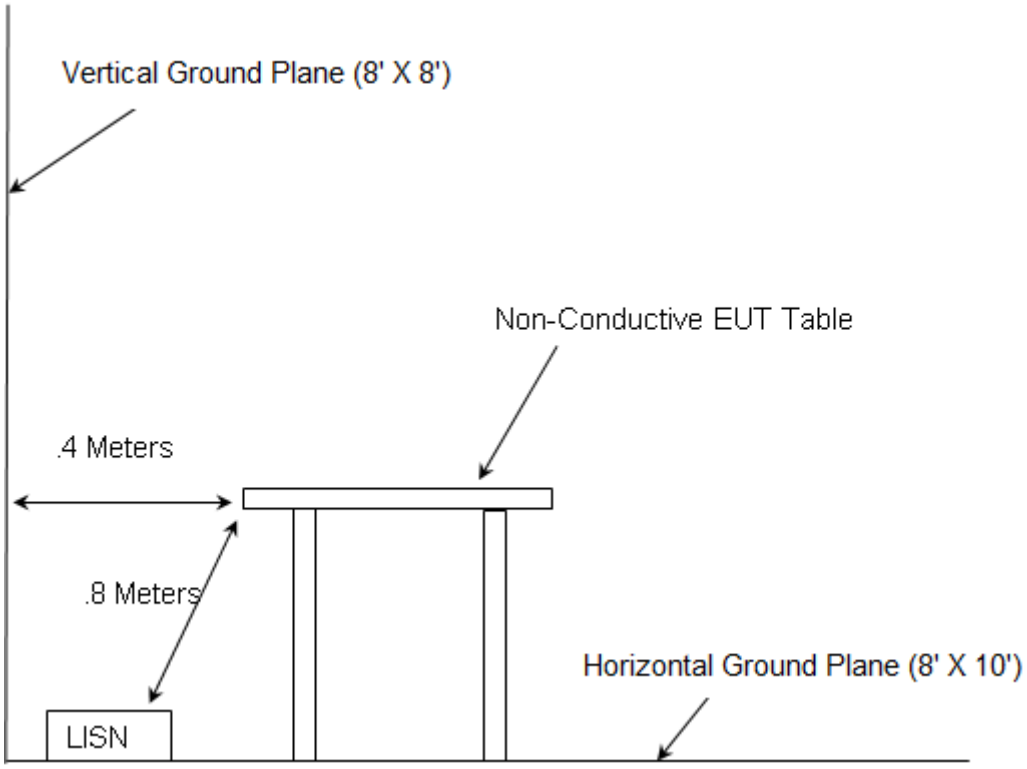


Figure 2.4-1: AC Mains Conducted EMI Site

3 APPLICABLE STANDARD REFERENCES

The following standards were used:

- ANSI C63.10-2013: American National Standard of Procedures for Compliance Testing of Unlicensed Wireless Devices
- US Code of Federal Regulations (CFR): Title 47, Part 2, Subpart J: Equipment Authorization Procedures, 2017
- US Code of Federal Regulations (CFR): Title 47, Part 15, Subpart C: Radio Frequency Devices, Intentional Radiators, 2017
- FCC KDB 558074 D01 DTS Meas Guidance v04 - Guidance for Performing Compliance Measurements on Digital Transmission Systems (DTS) Operating Under §15.247, April 5, 2017
- ISED Canada Radio Standards Specification: RSS-247, Digital Transmission Systems (DTSs), Frequency Hopping Systems (FHSs) and License-Exempt Local Area Network (LE-LAN) Devices, Issue 2, Feb 2017
- ISED Canada Radio Standards Specification: RSS-GEN – General Requirements for Compliance of Radio Apparatus, Issue 4, Nov 2014

4 LIST OF TEST EQUIPMENT

The calibration interval of test equipment is annually or the manufacturer's recommendations. Where the calibration interval deviates from the annual cycle based on the instrument manufacturer's recommendations, it shall be stated below.

Table 4-1: Test Equipment

Asset ID	Manufacturer	Model #	Equipment Type	Serial #	Last Calibration Date	Calibration Due Date
DEMC0277	EMCO	93146	Antennas	9904-5199	9/12/2016	9/12/2018
DEMC0626	EMCO	3110B	Antennas	9411-1945	3/21/2017	3/21/2019
DEMC3002	Rohde & Schwarz	ESU40	Receiver	100346	7/24/2017	7/24/2018
DEMC3006	Rohde & Schwarz	TS-PR18	Amplifiers	122006	1/10/2018	1/10/2019
DEMC3007	Rohde & Schwarz	TS-PR26	Amplifiers	100051	1/10/2018	1/10/2019
DEMC3008	Rohde & Schwarz	NRP2	Meter	103131	2/15/2018	2/15/2019
DEMC3009	Rohde & Schwarz	NRP-Z81	Meter	102397	2/15/2018	2/15/2019
DEMC3011	Rohde & Schwarz	ENV216	LISN	3011	1/10/2018	1/10/2019
DEMC3012	Rohde & Schwarz	EMC32-EB	Software	100731	NCR	NCR
DEMC3016	Fei Teng Wireless Technology	HA-07M18G-NF	Antennas	2013120203	2/7/2018	2/7/2020
DEMC3027	Micro-Tronics	BRM50702	Filter	175	1/7/2018	1/7/2019
DEMC3032	Hasco, Inc.	HLL142-S1-S1-192/WA	Cables	3075	1/9/2018	1/9/2019
DEMC3037	Hasco, Inc.	HLL142-S1-S1-18	Cables	6367	1/9/2018	1/9/2019
DEMC3038	Florida RF Labs	NMSE-290AW-60.0-NMSE	Cable Set	1448	1/5/2018	1/5/2019
DEMC3039	Florida RF Labs	NMSE-290AW-396.0-NMSE	Cable Set	1447	1/5/2018	1/5/2019
DEMC3048	Aeroflex Inmet	26AH-06	Attenuator	1447	1/9/2018	1/9/2019
DEMC3049	Aeroflex Inmet	26AH-20	Attenuator	1443	1/9/2018	1/9/2019
DEMC3051	Mountain View Cable	BMS-RG400-264.0-BMS	Cables	3051	1/8/2018	1/8/2019
DEMC3055	Rohde & Schwarz	3005	Cables	3055	1/8/2018	1/8/2019
DEMC3057	Advanced Technical Materials	42-441-6/BR	Antennas	R110602	NCR	NCR
DEMC3059	Mountain View Cable	A	Cables	3059	1/9/2018	1/9/2019
DEMC3085	Rohde & Schwarz	FSW43	Spectrum Analyzer	103997	3/15/2018	3/15/2019

NCR = No Calibration Required
DMAS MT-25 RF absorber material was used on the floor for all final measurements above 1 GHz.
Asset DEMC3002: Firmware Version: ESU40 is 4.73 SP4
Asset DEMC3012: Software Version: EMC32-B is 9.15
Asset DEMC3085: Instrument Firmware 2.90 SP1

5 SUPPORT EQUIPMENT

Table 5-1: Support Equipment

Item	Equipment Type	Manufacturer	Model Number	Serial Number
1	EUT	Murata ElectronicsMurata Electronics	PAC-USWHS002-WF-2	(See sect 1.2: EUT serial numbers)
2	Bench Power Supply	Sorensen	QRD20-4	2716
3	EUT Power supply	Volgen	SPU10-105	TUV #6
4	Computer	Dell	Latitude D630	G03F3F1

Table 5-2: Cable Description

Cable #	Cable Type	Length	Shield	Termination
A	Power cable	1.87 m	No	1 to 3
B	Power supply	1 m	No	1 to 2
C	USB cable	1.8 m	No	1 to 4

6 EQUIPMENT UNDER TEST SETUP BLOCK DIAGRAM

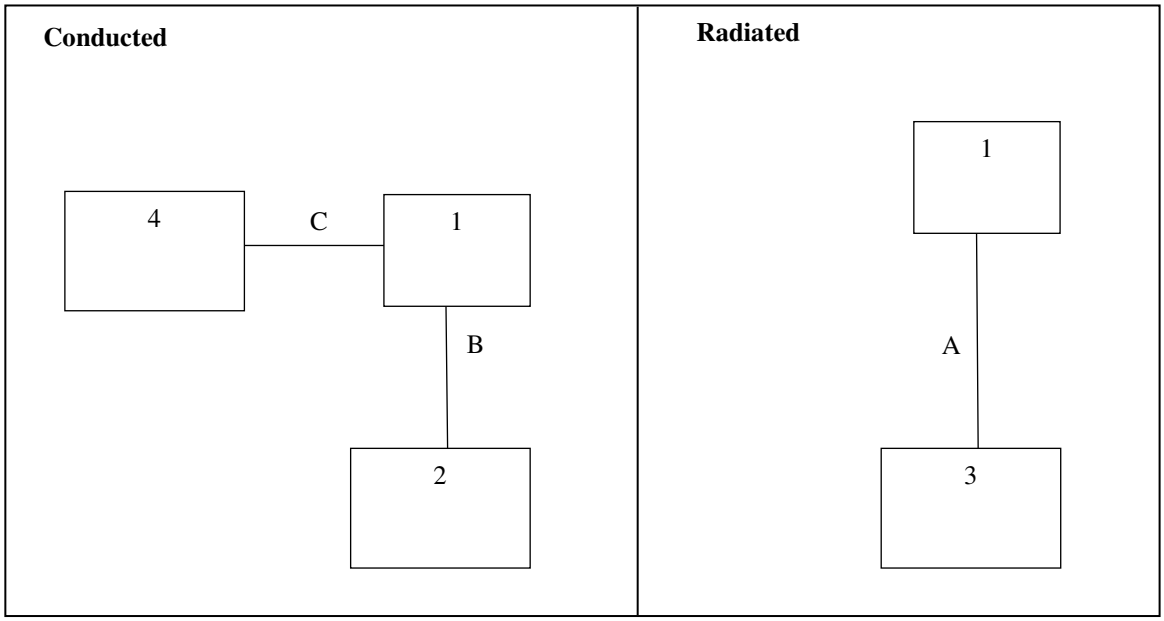


Figure 6-1: Test Setup Block Diagram

7 SUMMARY OF TESTS

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

7.1 Antenna Requirement – FCC: 15.203

The inverted-F antenna is an integral part of the PCB board of the device. Therefore, the antenna meets the requirement of Section 15.203.

7.2 Power Line Conducted Emissions – FCC: 15.207; ISED Canada: RSS-Gen 8.8

7.2.1 Measurement Procedure

ANSI C63.10-2013 section 6 was the guiding document for this evaluation. Conducted emissions were evaluated from 150kHz to 30MHz with the spectrum analyzer's resolution bandwidth set to 9kHz and the video bandwidth set to 30kHz. The calculation for the conducted emissions is as follows:

Corrected Reading = Analyzer Reading + LISN Loss + Cable Loss
Margin = Applicable Limit - Corrected Reading

7.2.2 Measurement Results

Performed by: Charles Callis

Table 7.2.2-1: Conducted EMI Results – Line 1

Frequency (MHz)	QuasiPeak (dBµV)	Average (dBµV)	Limit (dBµV)	Margin (dB)	Meas. Time (ms)	Bandwidth (kHz)	Line	Filter	Corr. (dB)
0.206000	---	42.83	53.17	10.34	5000.0	9.000	L1	OFF	9.6
0.206000	55.08	---	63.20	8.12	5000.0	9.000	L1	OFF	9.6
0.312000	---	36.03	49.68	13.65	5000.0	9.000	L1	OFF	9.6
0.312000	44.85	---	59.72	14.87	5000.0	9.000	L1	OFF	9.6
0.412000	---	31.30	47.48	16.18	5000.0	9.000	L1	OFF	9.7
0.412000	38.76	---	57.50	18.74	5000.0	9.000	L1	OFF	9.7
0.520000	---	29.10	46.00	16.90	5000.0	9.000	L1	OFF	9.7
0.520000	35.79	---	56.00	20.21	5000.0	9.000	L1	OFF	9.7
0.624000	---	24.11	46.00	21.89	5000.0	9.000	L1	OFF	9.7
0.624000	28.92	---	56.00	27.08	5000.0	9.000	L1	OFF	9.7
0.828000	---	18.61	46.00	27.39	5000.0	9.000	L1	OFF	9.7
0.828000	24.26	---	56.00	31.74	5000.0	9.000	L1	OFF	9.7
3.428000	---	17.56	46.00	28.44	5000.0	9.000	L1	OFF	9.8
3.428000	25.77	---	56.00	30.23	5000.0	9.000	L1	OFF	9.8
4.256000	---	20.92	46.00	25.08	5000.0	9.000	L1	OFF	9.9
4.256000	26.57	---	56.00	29.43	5000.0	9.000	L1	OFF	9.9
7.782000	---	22.87	50.00	27.13	5000.0	9.000	L1	OFF	10.0
7.782000	26.98	---	60.00	33.02	5000.0	9.000	L1	OFF	10.0
29.570000	---	18.36	50.00	31.64	5000.0	9.000	L1	OFF	10.2
29.570000	25.49	---	60.00	34.51	5000.0	9.000	L1	OFF	10.2

Table 7.2.2-2: Conducted EMI Results – Line 2

Frequency (MHz)	QuasiPeak (dBµV)	Average (dBµV)	Limit (dBµV)	Margin (dB)	Meas. Time (ms)	Bandwidth (kHz)	Line	Filter	Corr. (dB)
0.210000	---	37.60	53.00	15.40	5000.0	9.000	N	OFF	9.6
0.210000	46.56	---	63.04	16.48	5000.0	9.000	N	OFF	9.6
0.408000	---	22.98	47.55	24.57	5000.0	9.000	N	OFF	9.6
0.408000	34.40	---	57.58	23.18	5000.0	9.000	N	OFF	9.6
0.516000	---	25.69	46.00	20.31	5000.0	9.000	N	OFF	9.6
0.516000	32.97	---	56.00	23.03	5000.0	9.000	N	OFF	9.6
0.616000	---	22.74	46.00	23.26	5000.0	9.000	N	OFF	9.6
0.616000	28.97	---	56.00	27.03	5000.0	9.000	N	OFF	9.6
0.928000	---	22.37	46.00	23.63	5000.0	9.000	N	OFF	9.7
0.928000	28.39	---	56.00	27.61	5000.0	9.000	N	OFF	9.7
1.440000	---	11.67	46.00	34.33	5000.0	9.000	N	OFF	9.7
1.440000	21.89	---	56.00	34.11	5000.0	9.000	N	OFF	9.7
3.304000	---	23.27	46.00	22.73	5000.0	9.000	N	OFF	9.8
3.304000	31.11	---	56.00	24.89	5000.0	9.000	N	OFF	9.8
4.956000	---	24.73	46.00	21.27	5000.0	9.000	N	OFF	9.8
4.956000	27.82	---	56.00	28.18	5000.0	9.000	N	OFF	9.8
6.818000	---	27.40	50.00	22.60	5000.0	9.000	N	OFF	9.9
6.818000	30.64	---	60.00	29.36	5000.0	9.000	N	OFF	9.9
28.826000	---	24.22	50.00	25.78	5000.0	9.000	N	OFF	10.2
28.826000	30.64	---	60.00	29.36	5000.0	9.000	N	OFF	10.2

7.3 6dB / 99% Bandwidth – FCC: 15.247(a)(2); ISED Canada: RSS-247 5.2(1)

7.3.1 Measurement Procedure

The 6dB bandwidth was measured in accordance with the FCC KDB 558074 D01 DTS Meas Guidance. The Resolution Bandwidth (RBW) of the spectrum analyzer was set to 100 kHz. The Video Bandwidth (VBW) was set to ≥ 3 times the RBW. The trace was set to max hold with a peak detector active. The marker-delta function of the spectrum analyzer was utilized to determine the 6dB bandwidth of the emission.

The occupied bandwidth measurement function of the spectrum analyzer was used to measure the 99% bandwidth. The span of the analyzer was set to capture all products of the modulation process, including the emission sidebands. The resolution bandwidth was set to 1% to 5% of the occupied bandwidth. The video bandwidth was set to 3 times the resolution bandwidth.

7.3.2 Measurement Results

Performed by Jean Tezil

Table 7.2.2-1: 6dB / 99% Bandwidth – 802.11b

Frequency (MHz)	6dB Bandwidth (MHz)	99% Bandwidth (MHz)
2412	9.032	14.016
2437	9.046	14.008
2462	8.094	14.001

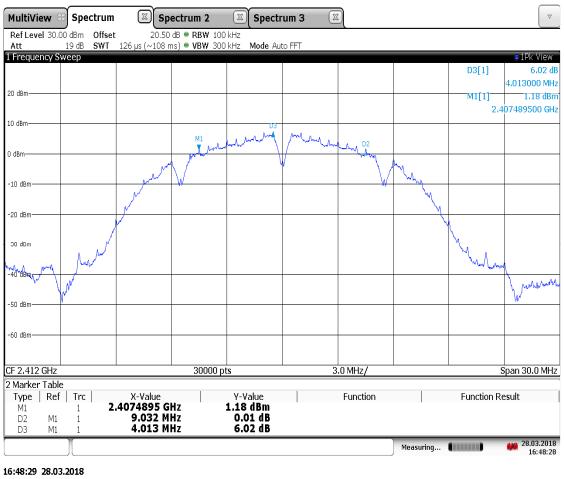


Figure 7.2.2-1: 6dB Bandwidth – 802.11b – 2412 MHz

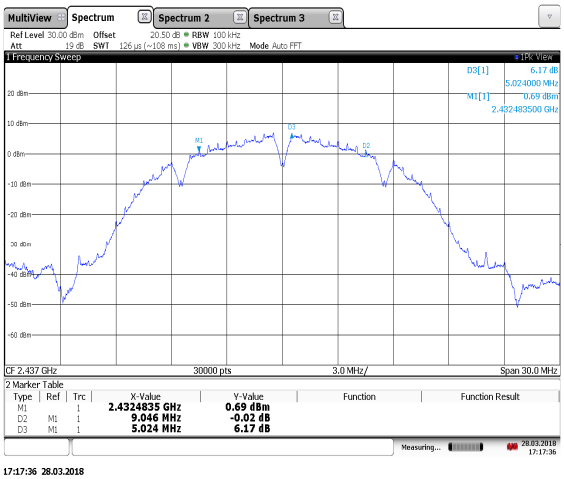
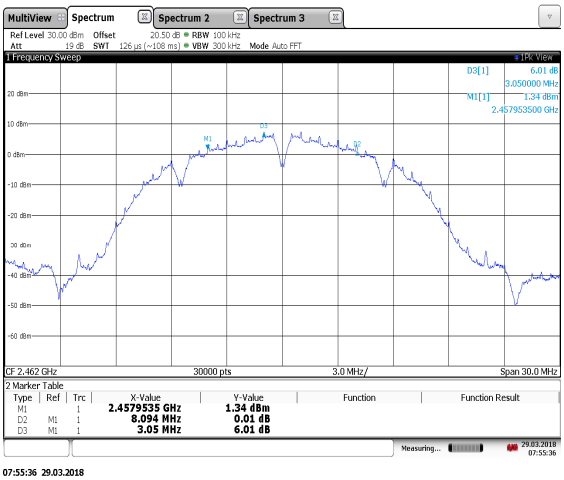
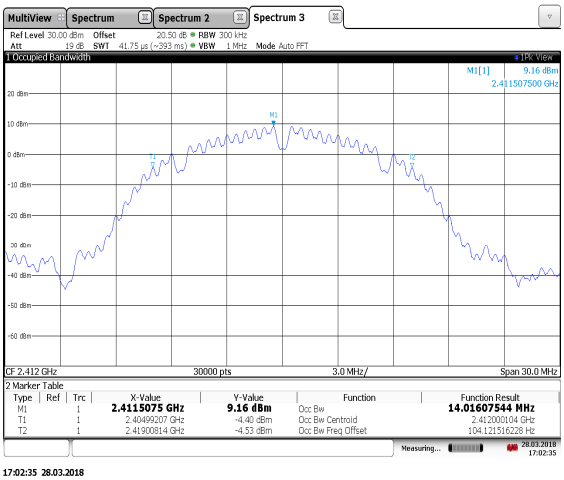


Figure 7.2.2-2: 6dB Bandwidth – 802.11b – 2437 MHz



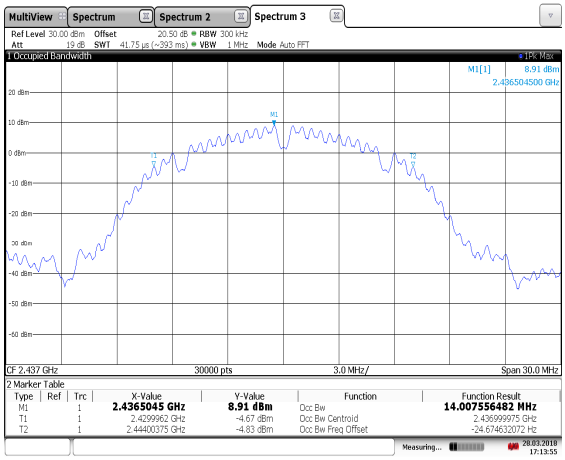
07:55:36 29.03.2018

Figure 7.2.2-3: 6dB Bandwidth – 802.11b – 2462 MHz



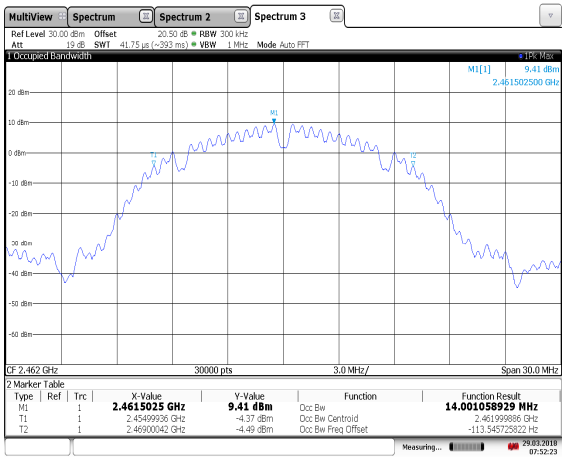
17:02:35 28.03.2018

Figure 7.2.2-4: 99% Bandwidth – 802.11b – 2412 MHz



17:13:56 28.03.2018

Figure 7.2.2-5: 99% Bandwidth – 802.11b – 2437 MHz



07:52:24 29.03.2018

Figure 7.2.2-6: 99% Bandwidth – 802.11b – 2462 MHz

Table 7.2.2-2: 6dB / 99% Bandwidth – 802.11g

Frequency (MHz)	6dB Bandwidth (MHz)	99% Bandwidth (MHz)
2412	16.320	16.409
2437	16.333	16.398
2462	16.299	16.422

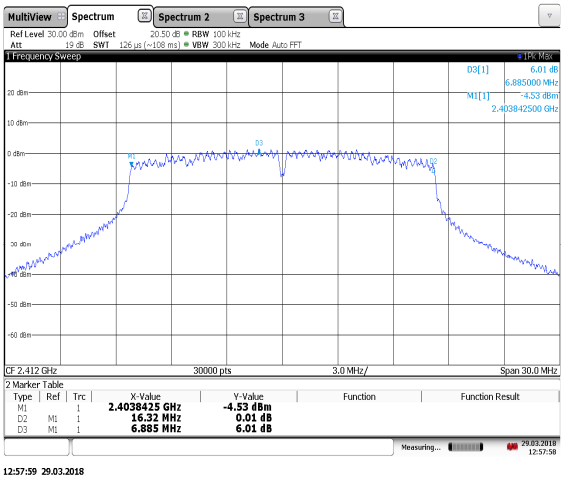


Figure 7.2.2-7: 6dB Bandwidth – 802.11g – 2412 MHz

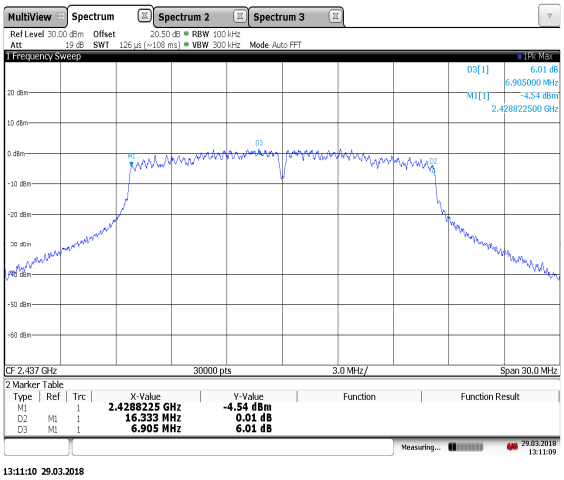


Figure 7.2.2-8: 6dB Bandwidth – 802.11g – 2437 MHz

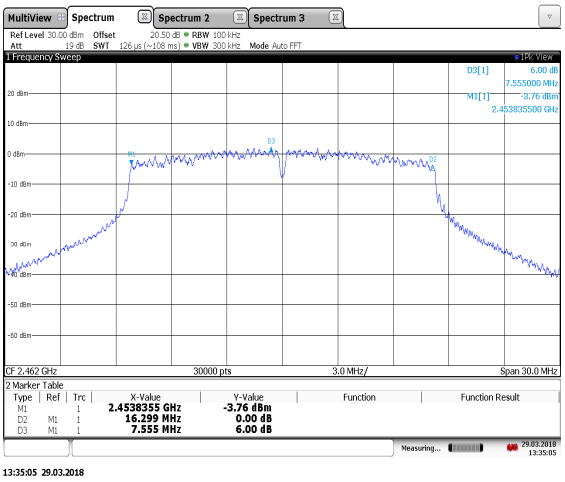


Figure 7.2.2-9: 6dB Bandwidth – 802.11g – 2462 MHz

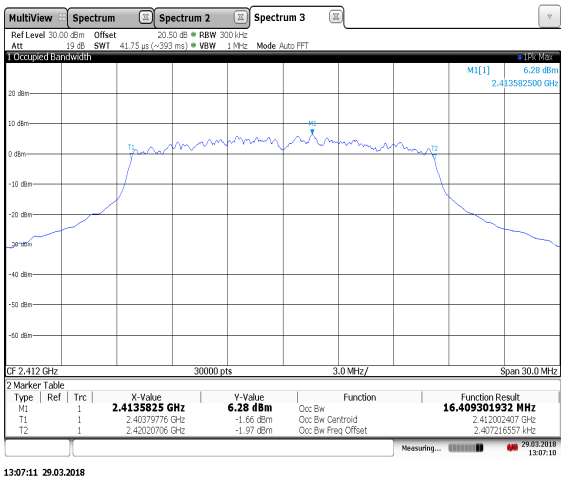
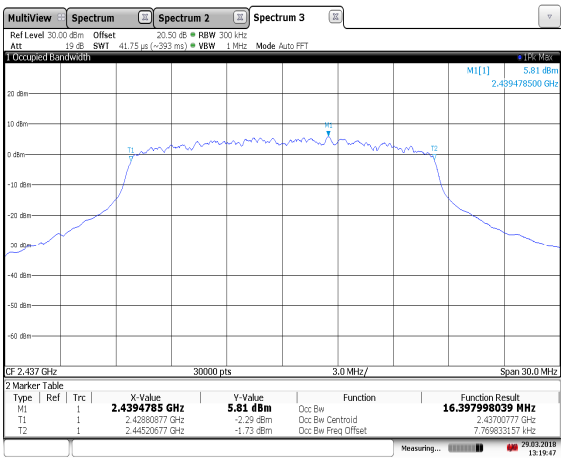
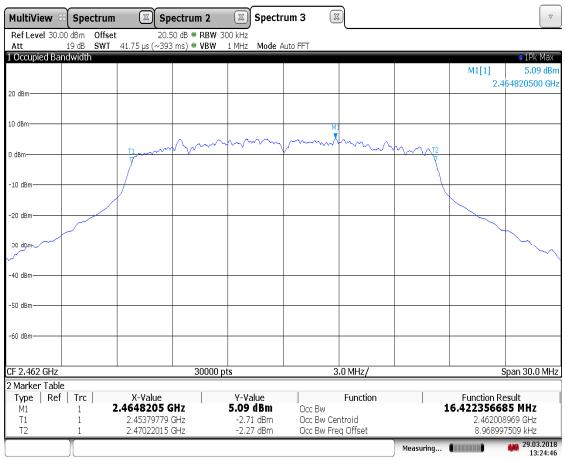


Figure 7.2.2-10: 99% Bandwidth – 802.11g – 2412 MHz



13:19:48 29.03.2018

Figure 7.2.2-11: 99% Bandwidth – 802.11g – 2437 MHz



13:24:46 29.03.2018

Figure 7.2.2-12: 99% Bandwidth – 802.11g – 2462 MHz

Table 7.2.2-3: 6dB / 99% Bandwidth – 802.11n (HT20)

Frequency (MHz)	6dB Bandwidth (MHz)	99% Bandwidth (MHz)
2412	17.211	17.503
2437	17.228	17.560
2462	16.933	17.523

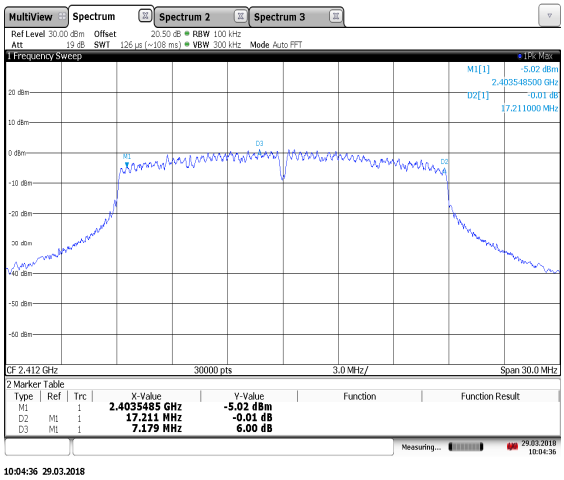


Figure 7.2.2-13: 6dB Bandwidth – 802.11n (HT20) – 2412 MHz

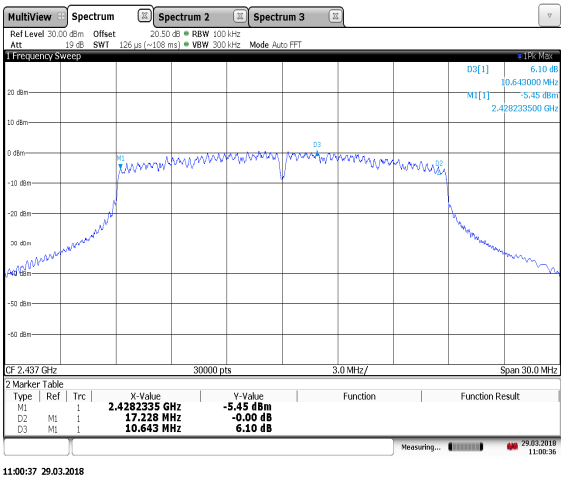


Figure 7.2.2-14: 6dB Bandwidth – 802.11n (HT20) – 2437 MHz

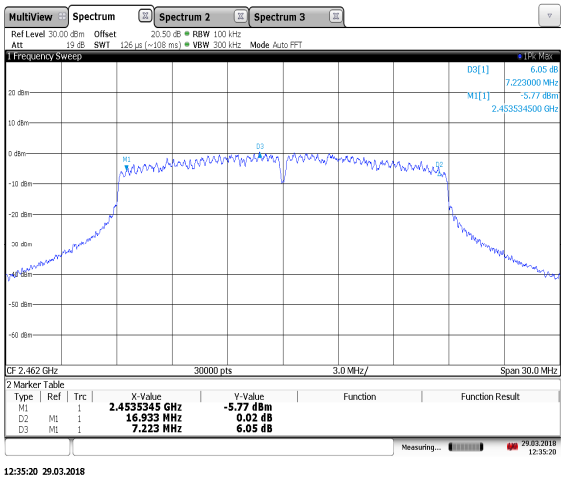


Figure 7.2.2-15: 6dB Bandwidth – 802.11n (HT20) – 2462 MHz

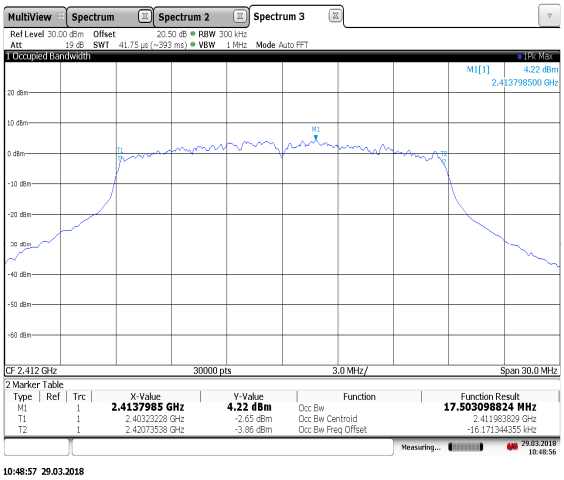


Figure 7.2.2-16: 99% Bandwidth – 802.11n (HT20) – 2412 MHz

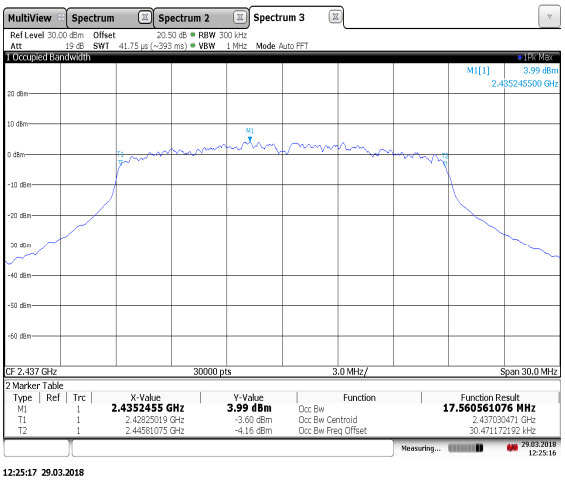


Figure 7.2.2-17: 99% Bandwidth – 802.11n (HT20) – 2437 MHz

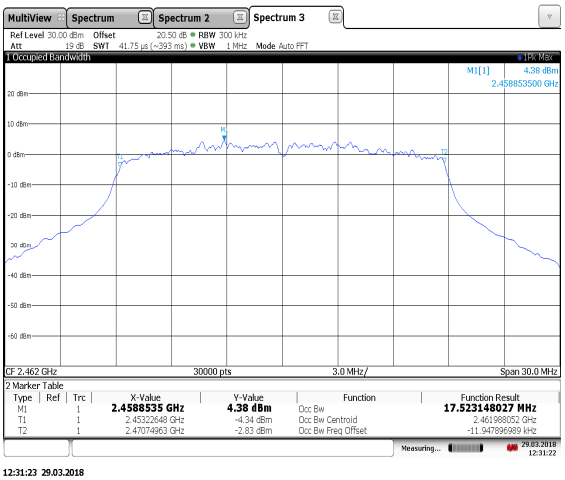
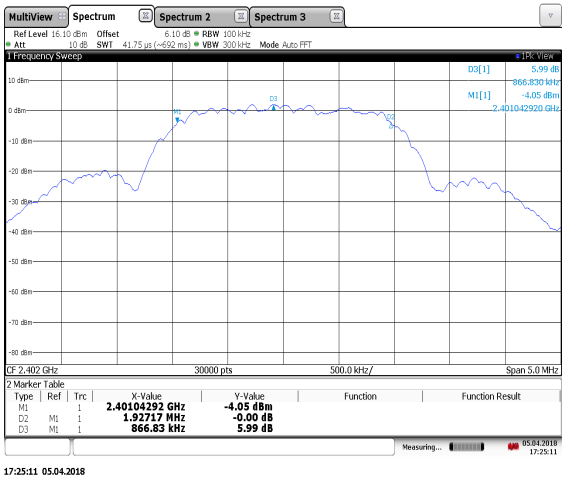


Figure 7.2.2-18: 99% Bandwidth – 802.11n (HT20) – 2462 MHz

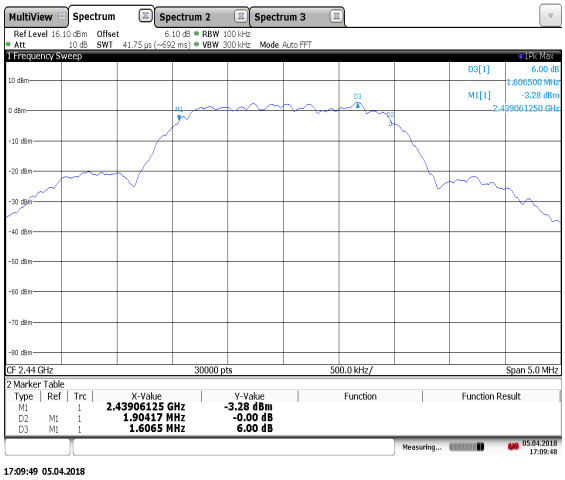
Table 7.2.2-4: 6dB / 99% Bandwidth – BLE

Frequency (MHz)	6dB Bandwidth (MHz)	99% Bandwidth (MHz)
2402	1.927	2.266
2440	1.904	2.284
2480	1.913	2.280



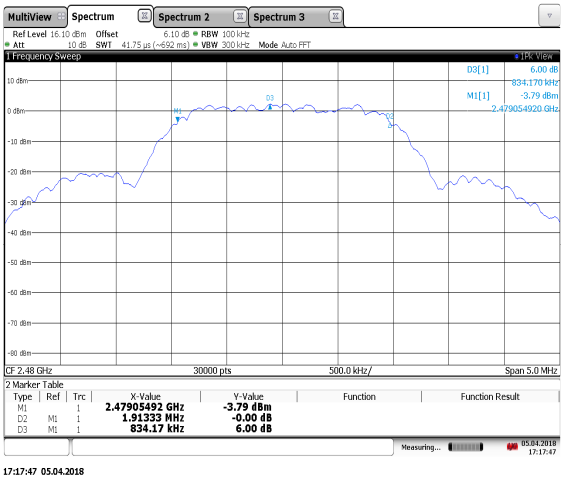
17:25:11 05.04.2018

Figure 7.2.2-19: 6dB Bandwidth – BLE – 2402 MHz



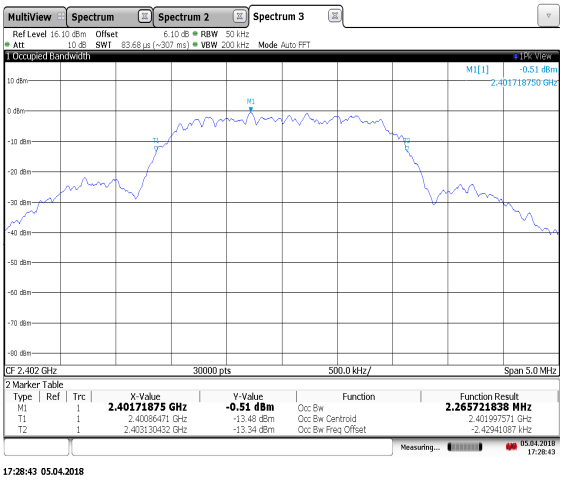
17:09:49 05.04.2018

Figure 7.2.2-20: 6dB Bandwidth – BLE – 2440 MHz



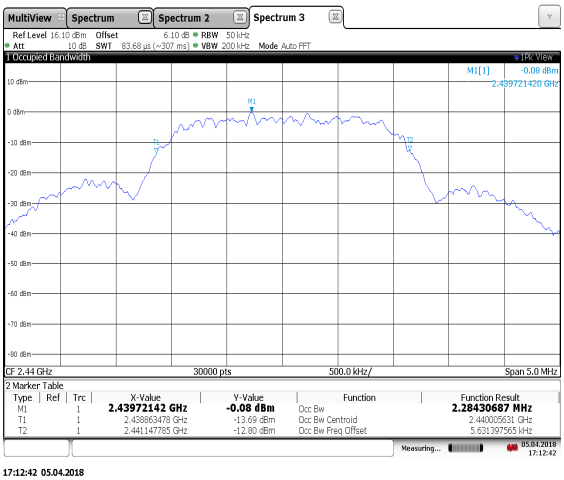
17:17:47 05.04.2018

Figure 7.2.2-21: 6dB Bandwidth – BLE – 2480 MHz



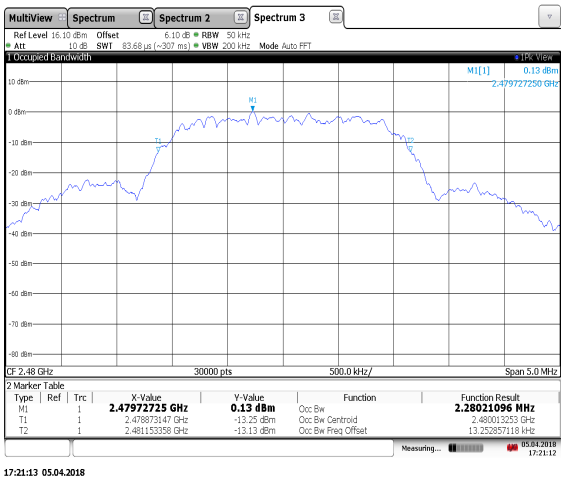
17:28:43 05.04.2018

Figure 7.2.2-22: 99% Bandwidth – BLE – 2402 MHz



17:12:42 05.04.2018

Figure 7.2.2-23: 99% Bandwidth – BLE – 2440 MHz



17:21:13 05.04.2018

Figure 7.2.2-24: 99% Bandwidth – BLE – 2480 MHz

7.4 Fundamental Emission Output Power – FCC: 15.247(b)(3); ISED Canada: RSS-247 5.4(4)

7.4.1 Maximum peak conducted output power - Measurement Procedure

The maximum peak conducted output power was measured in accordance with FCC KDB 558074 D01 DTS Measurement Guidance utilizing the PKPM1 Peak power meter method. The RF output of the equipment under test was directly connected to the input of the peak power meter applying suitable attenuation.

7.4.2 Measurement Results

Performed by Jean Tezil

Table 7.3.2-1: Maximum Peak Conducted Output Power - 802.11b

Frequency (MHz)	Output Power (dBm)
2412	20.49
2437	20.19
2462	22.64

Table 7.3.2-2: Maximum Peak Conducted Output Power – 802.11g

Frequency (MHz)	Output Power (dBm)
2412	24.71
2437	24.41
2462	24.20

Table 7.3.2-3: Maximum Peak Conducted Output Power – 802.11n (HT20)

Frequency (MHz)	Output Power (dBm)
2412	24.06
2437	24.50
2462	24.47

Table 7.3.2-4: Maximum Peak Conducted Output Power – BLE

Frequency (MHz)	Output Power (dBm)
2402	8.05
2440	7.47
2480	7.28

7.5 Emission Levels – FCC: 15.247(d), 15.205, 15.209; ISED Canada RSS-247 5.5, RSS-Gen 8.9/8.10

7.5.1 Emissions into Non-restricted Frequency Bands

7.5.1.1 Measurement Procedure

The unwanted emissions into non-restricted bands were measured conducted in accordance with FCC KDB 558074 D01 DTS Measurement Guidance. The RF output of the equipment under test was directly connected to the input of the spectrum analyzer applying suitable attenuation. The Resolution Bandwidth (RBW) of the spectrum analyzer was set to 100 kHz. The Video Bandwidth (VBW) was set to ≥ 300 kHz. The trace was set to max hold with a peak detector active. The resulting spectrum analyzer peak level was used to determine the reference level with respect to the 20 dBc limit. The spectrum span was then adjusted for the measurement of spurious emissions from 30 MHz to 25GHz, 10 times the highest fundamental frequency. Additionally, a pre-scan was performed from 9 kHz or the lowest frequency generated to 30 MHz.

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

7.5.1.2 Measurement Results

Performed by Jean Tezil

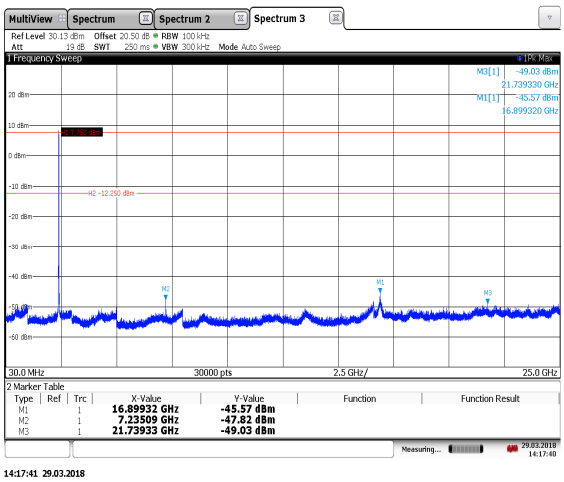


Figure 7.5.1.2-1: 30 MHz – 25 GHz – 802.11b – 2412 MHz

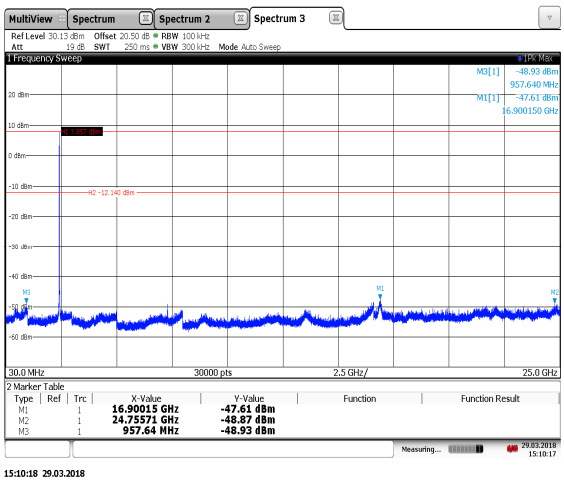
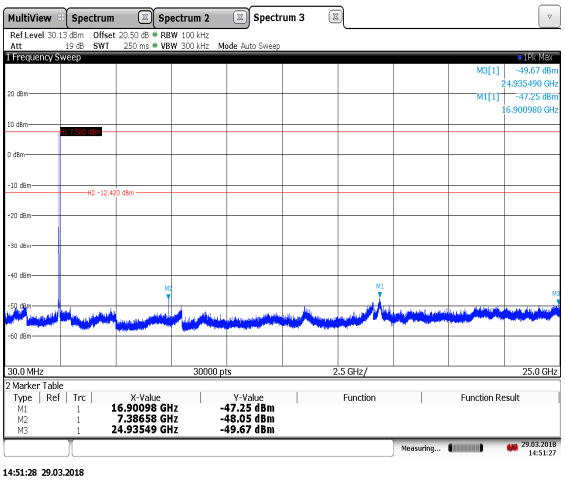
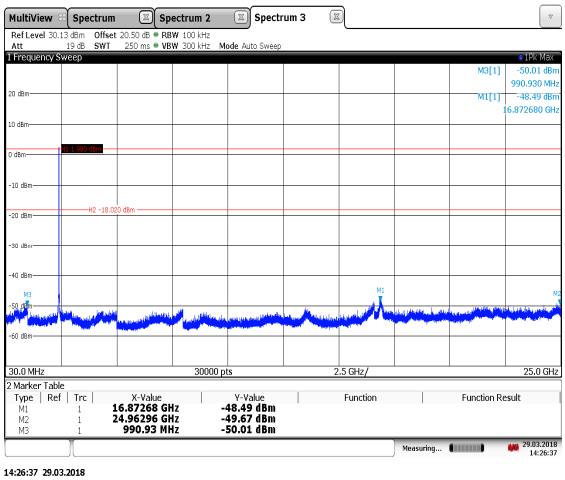


Figure 7.5.1.2-2: 30 MHz – 25 GHz – 802.11b – 2437 MHz



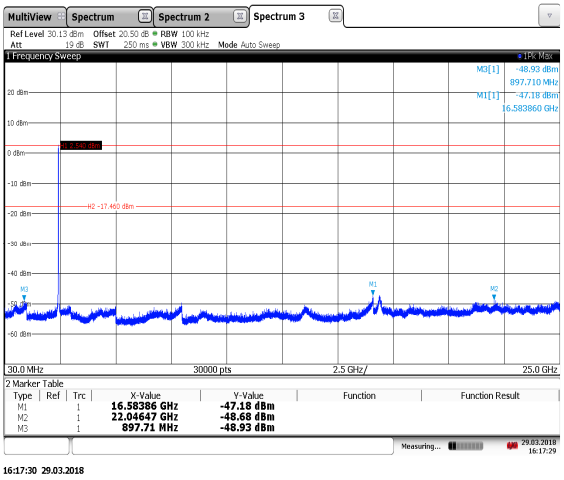
14:51:28 29.03.2018

Figure 7.5.1.2-3: 30 MHz – 25 GHz – 802.11b – 2462 MHz



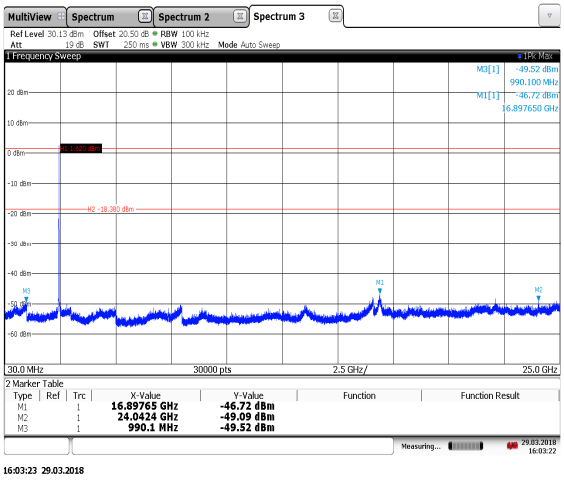
14:26:37 29.03.2018

Figure 7.5.1.2-4: 30 MHz – 25 GHz – 802.11g – 2412 MHz



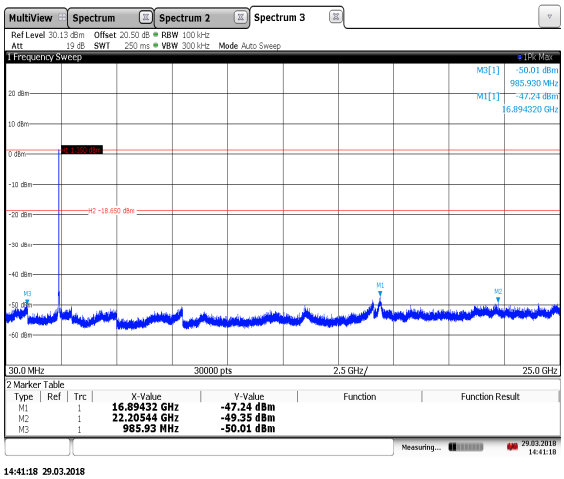
16:17:30 29.03.2018

Figure 7.5.1.2-5: 30 MHz – 25 GHz – 802.11g – 2437 MHz



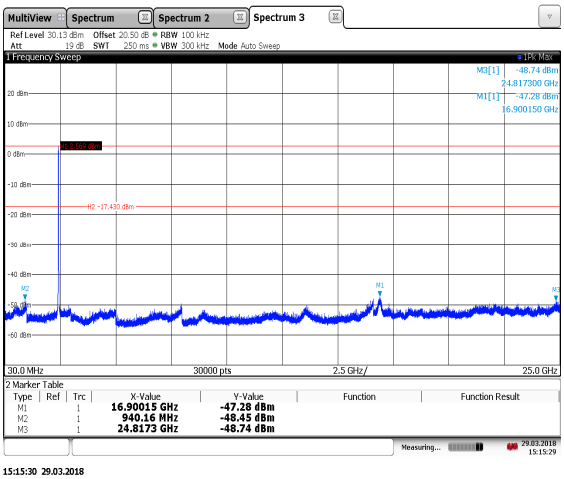
16:03:23 29.03.2018

Figure 7.5.1.2-6: 30 MHz – 25 GHz – 802.11g – 2462 MHz



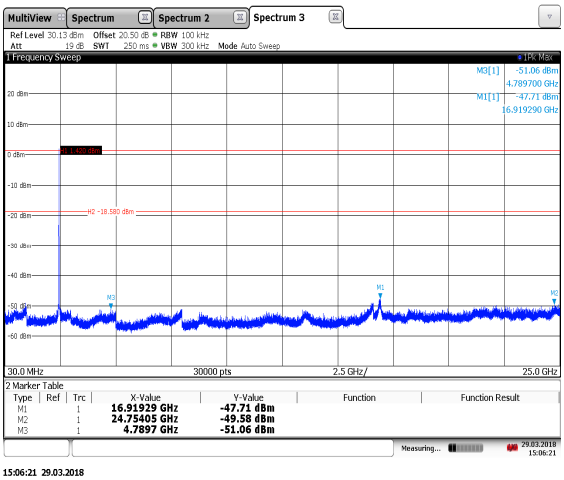
14:41:18 29.03.2018

Figure 7.5.1.2-7: 30 MHz – 25 GHz – 802.11n (HT20) – 2412 MHz



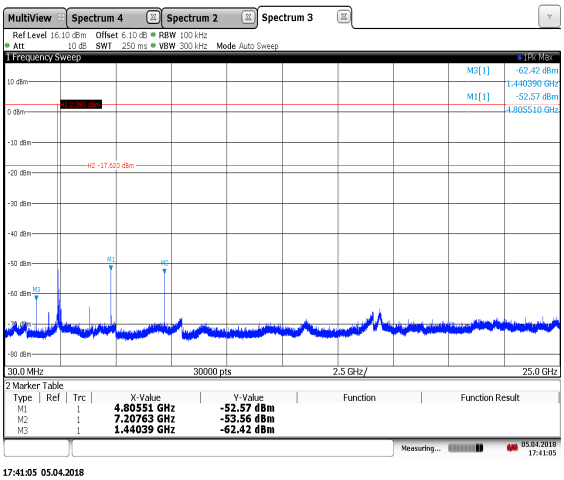
15:15:30 29.03.2018

Figure 7.5.1.2-8:30 MHz – 25 GHz – 802.11n (HT20) – 2437 MHz



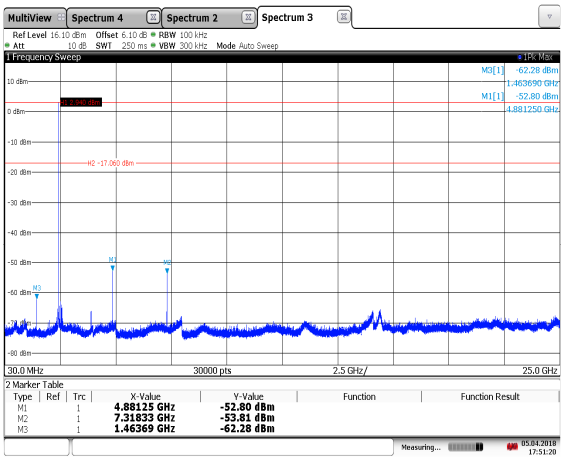
15:06:21 29.03.2018

Figure 7.5.1.2-9: 30 MHz – 25 GHz – 802.11n (HT20) – 2462 MHz



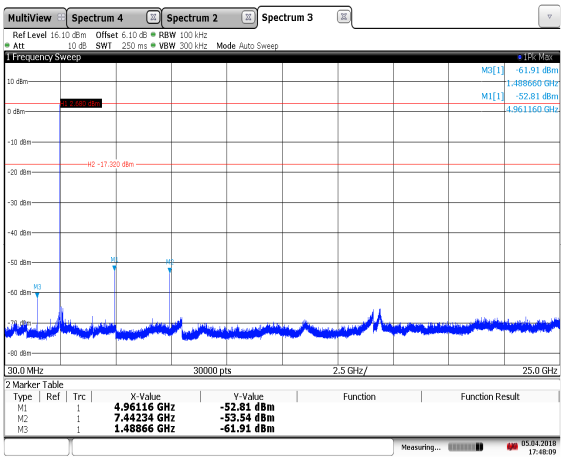
17:41:05 05.04.2018

Figure 7.5.1.2-10: 30 MHz – 25 GHz – BLE – 2402 MHz



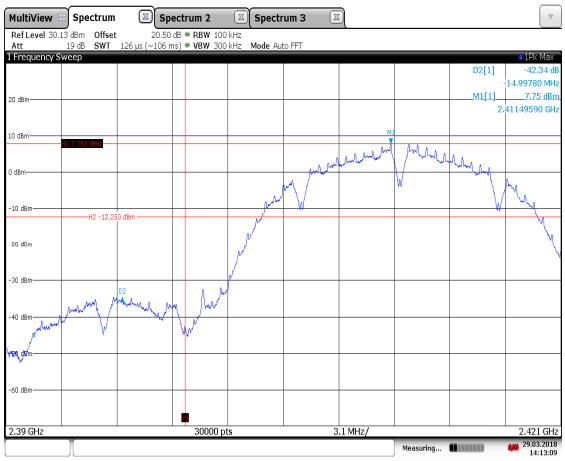
17:51:21 05.04.2018

Figure 7.5.1.2-11: 30 MHz – 25 GHz – BLE – 2440 MHz



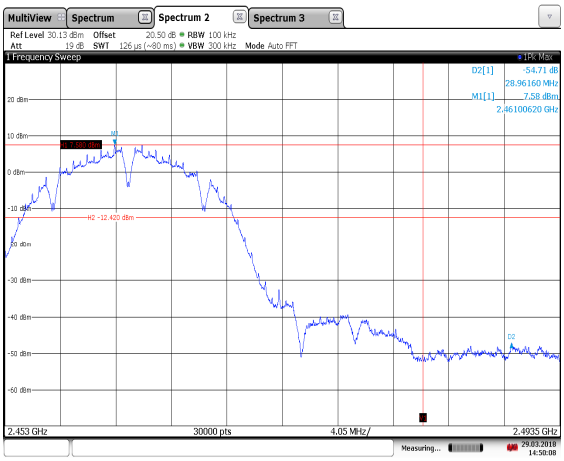
17:48:10 05.04.2018

Figure 7.5.1.2-12: 30 MHz – 25 GHz – BLE – 2480 MHz



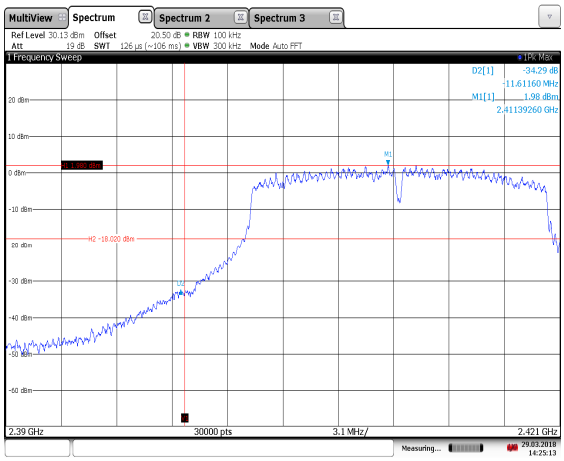
14:13:09 29.03.2018

Figure 7.5.1.2-13: Lower Band-edge – 802.11b – 2412 MHz



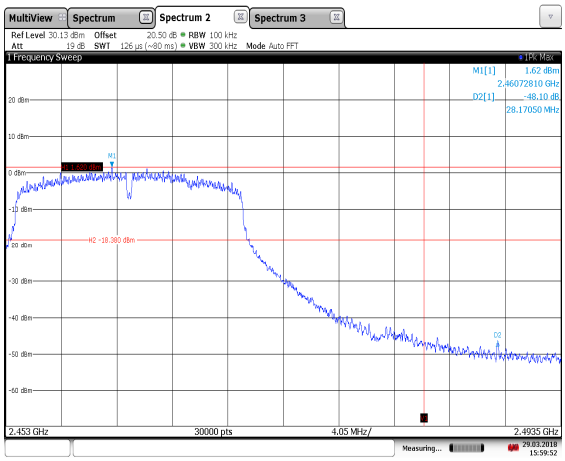
14:50:08 29.03.2018

Figure 7.5.1.2-14: Upper Band-edge – 802.11b – 2462 MHz



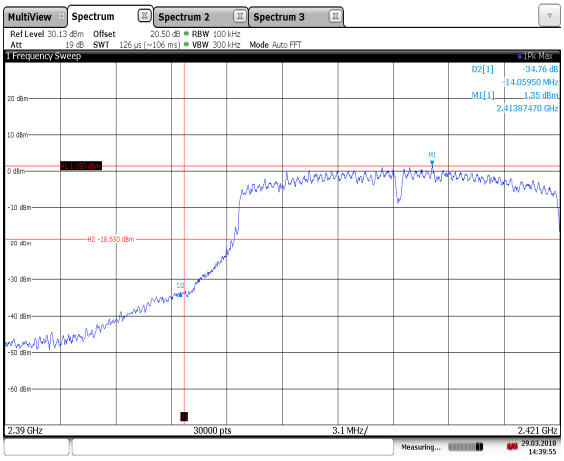
14:25:14 29.03.2018

Figure 7.5.1.2-15: Lower Band-edge – 802.11g – 2412 MHz



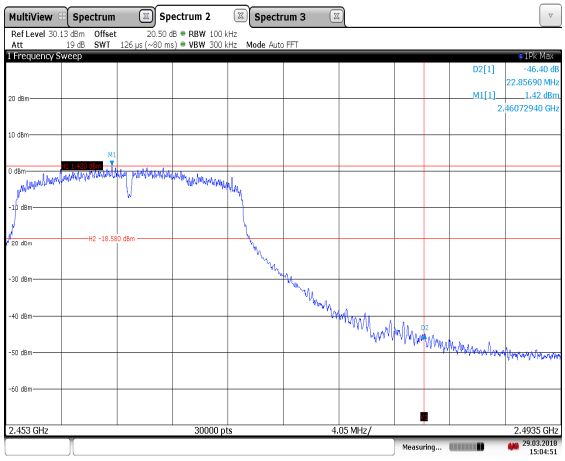
15:59:53 29.03.2018

Figure 7.5.1.2-16: Upper Band-edge – 802.11g – 2462 MHz



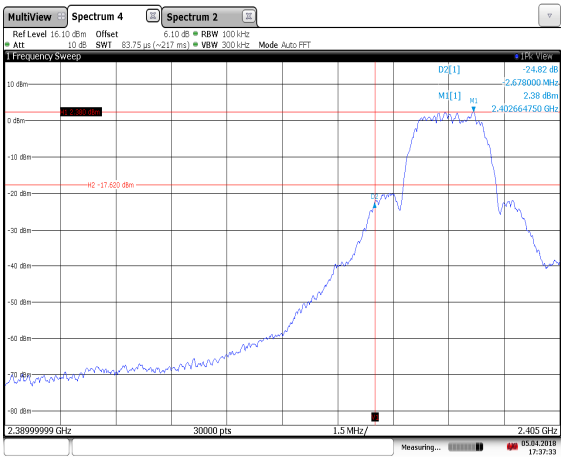
14:39:55 29.03.2018

Figure 7.5.1.2-17: Lower Band-edge – 802.11n (HT20) – 2412 MHz



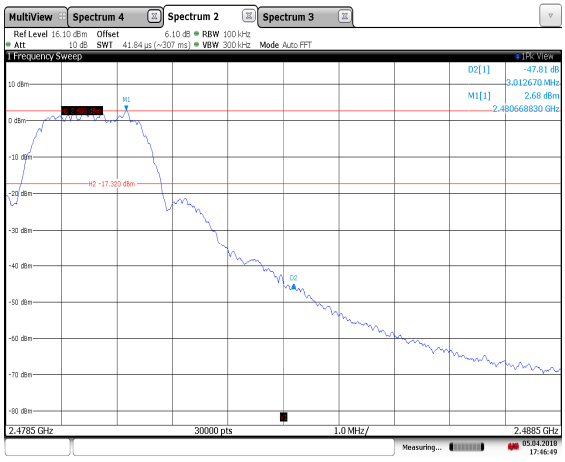
15:04:51 29.03.2018

Figure 7.5.1.2-18: Upper Band-edge – 802.11n (HT20) – 2462 MHz



17:37:33 05.04.2018

Figure 7.5.1.2-19: Lower Band-edge – BLE – 2402 MHz



17:46:49 05.04.2018

Figure 7.5.1.2-20: Upper Band-edge – – BLE – 2480 MHz

7.6 Emissions into Restricted Frequency Bands

7.6.1 Measurement Procedure

The unwanted emissions into restricted bands were measured radiated over the frequency range of 30MHz to 25GHz, 10 times the highest fundamental frequency.

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

Each emission found to be in a restricted band as defined by section 15.205, including any emission at the operational band-edge, was compared to the radiated emission limits as defined in section 15.209.

7.6.1.1 Duty Cycle Correction

The Duty Cycle Correction was not required for Wi-Fi.

A duty cycle correction factor -26.576dB was applied for the BLE radio and was based on the calculations below using data from the manufacturer provided theory of operation.

Maximum duty cycle is calculated as (176us / 3.75ms) = 0.0469.
Duty cycle derating factor in dB = 20 * log (0.0469) = -26.576 dB.

7.6.1.2 Measurement Results

Performed by Charles Callis

Table 7.6.1.3-1: Radiated Spurious Emissions Tabulated Data – 802.11b

Frequency (MHz)	Level (dBuV)		Antenna Polarity	Correction Factors	Corrected Level (dBuV/m)		Limit (dBuV/m)		Margin (dB)	
	pk	Qpk/Avg	(H/V)	(dB)	pk	Qpk/Avg	pk	Qpk/Avg	pk	Qpk/Avg
Low Channel = 2412 MHz										
2390	69.2	55.3	H	-3.88	65.32	51.42	74.0	54.0	8.7	2.6
Middle Channel = 2437 MHz										
4874	41.50	26.90	V	2.61	44.11	29.51	74.0	54.0	29.9	24.5
7311	51.10	34.90	H	7.22	58.32	42.12	74.0	54.0	15.7	11.9
7311	51.00	35.20	V	7.22	58.22	42.42	74.0	54.0	15.8	11.6
High Channel = 2462 MHz										
2483.5	69.1	55.1	H	-3.66	65.44	51.44	74.0	54.0	8.6	2.6
4924	42.9	27.6	H	2.59	45.49	30.19	74.0	54.0	28.5	23.8
4924	44.60	28.90	V	2.59	47.19	31.49	74.0	54.0	26.8	22.5
7386	48.00	36.00	H	7.39	55.39	43.39	74.0	54.0	18.6	10.6
7386	48.70	33.70	V	7.39	56.09	41.09	74.0	54.0	17.9	12.9

Table 7.6.1.3-2: Radiated Spurious Emissions Tabulated Data – 802.11g

Frequency (MHz)	Level (dBuV)		Antenna Polarity	Correction Factors	Corrected Level (dBuV/m)		Limit (dBuV/m)		Margin (dB)	
	pk	Qpk/Avg	(H/V)	(dB)	pk	Qpk/Avg	pk	Qpk/Avg	pk	Qpk/Avg
Low Channel = 2412 MHz										
2390	70.10	55.80	H	-3.88	66.22	51.92	74.0	54.0	7.8	2.1
Middle Channel = 2437 MHz										
7311	45.30	29.40	H	7.22	52.52	36.62	74.0	54.0	21.5	17.4
7311	45.20	29.80	V	7.22	52.42	37.02	74.0	54.0	21.6	17.0
High Channel = 2462 MHz										
2483.5	69.4	55.3	H	-3.66	65.74	51.64	74.0	54.0	8.3	2.4
7386	43.60	28.80	H	7.39	50.99	36.19	74.0	54.0	23.0	17.8
7386	44.00	29.00	V	7.39	51.39	36.39	74.0	54.0	22.6	17.6

Table 7.6.1.3-3: Radiated Spurious Emissions Tabulated Data – 802.11n (HT20)

Frequency (MHz)	Level (dBuV)		Antenna Polarity	Correction Factors	Corrected Level (dBuV/m)		Limit (dBuV/m)		Margin (dB)	
	pk	Qpk/Avg	(H/V)	(dB)	pk	Qpk/Avg	pk	Qpk/Avg	pk	Qpk/Avg
Low Channel = 2412 MHz										
2390	72.9	55.4	H	-3.88	69.02	51.52	74.0	54.0	5.0	2.5
12060	37.30	23.50	H	11.73	49.03	35.23	74.0	54.0	25.0	18.8
14472	37.90	26.90	V	12.97	50.87	39.87	74.0	54.0	23.1	14.1
Middle Channel = 2437 MHz										
7311	42.10	30.40	H	7.22	49.32	37.62	74.0	54.0	24.7	16.4
7311	43.40	29.70	V	7.22	50.62	36.92	74.0	54.0	23.4	17.1
High Channel = 2462 MHz										
2483.5	69.3	55	H	-3.66	65.64	51.34	74.0	54.0	8.4	2.7
7386	43.20	35.70	H	7.39	50.59	43.09	74.0	54.0	23.4	10.9
7386	42.80	31.40	V	7.39	50.19	38.79	74.0	54.0	23.8	15.2

Table 7.6.1.3-4: Radiated Spurious Emissions Tabulated Data – BLE

Frequency (MHz)	Level (dBuV)		Antenna Polarity	Correction Factors	Corrected Level (dBuV/m)		Limit (dBuV/m)		Margin (dB)	
	pk	Qpk/Avg	(H/V)	(dB)	pk	Qpk/Avg	pk	Qpk/Avg	pk	Qpk/Avg
Low Channel = 2402 MHz										
2390	68.60	54.80	H	-3.88	64.72	24.35	74.0	54.0	9.3	29.7
4804	56.30	49.30	H	2.64	58.94	25.36	74.0	54.0	15.1	28.6
4804	48.60	40.60	V	2.64	51.24	16.66	74.0	54.0	22.8	37.3
Middle Channel = 2440 MHz										
4880	56.80	49.50	H	2.61	59.41	25.53	74.0	54.0	14.6	28.5
4880	49.70	41.60	V	2.61	52.31	17.63	74.0	54.0	21.7	36.4
7320	44.40	33.00	H	7.24	51.64	13.66	74.0	54.0	22.4	40.3
High Channel = 2480 MHz										
2483.5	74.00	59.40	H	-3.66	70.34	29.16	74.0	54.0	3.7	24.8
2483.5	68.90	55.10	V	-3.66	65.24	24.86	74.0	54.0	8.8	29.1
4960	57.60	50.20	H	2.58	60.18	26.20	74.0	54.0	13.8	27.8
4960	50.20	41.80	V	2.58	52.78	17.80	74.0	54.0	21.2	36.2
7440	49.50	40.10	H	7.51	57.01	21.03	74.0	54.0	17.0	33.0

Duty cycle: 4.69%

7.6.1.3 Sample Calculation:

$R_C = R_U + CF_T$

Where:

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

Example Calculation: Peak – WIFI (Table 7.6.1.3-1)

Corrected Level: 69.2dBuV/m – 3.88dB = 65.32 dBuV/m
Margin: 74dBuV/m – 65.32dBuV/m = 8.68dB

Example Calculation: Average – WIFI (Table 7.6.1.3-1)

Corrected Level: 55.3dBuV/m – 3.88dB = 51.42dBuV
Margin: 54dBuV – 45.56 dBuV = 2.58dB

Example Calculation: Peak – BLE (Table 7.6.1.3-4)

Corrected Level: 68.6dBuV/m – 3.88dB = 64.72dBuV/m
Margin: 74dBuV/m – 64.72dBuV/m = 9.28dB

Example Calculation: Average – BLE (Table 7.6.1.3-4)

Corrected Level: 54.8dBuV/m – 3.88dB – 26.576dB = 24.344dBuV
Margin: 54dBuV – 24.344dBuV - = 29.656dB

7.7 Power Spectral Density – FCC: 15.247(e); ISED Canada: RSS-247 5.2(2)

7.7.1 Measurement Procedure

The power spectral density was measured in accordance with the FCC KDB 558074 D01 DTS Meas Guidance utilizing the PKPSD (peak PSD) method. The RF output of the equipment under test was directly connected to the input of the spectrum analyzer applying suitable attenuation. The Resolution Bandwidth (RBW) of the spectrum analyzer was set to 10 kHz. The Video Bandwidth (VBW) was set to 30 kHz. Span was set to 1.5 times the DTS bandwidth. The trace was set to max hold with a peak detector active.

7.7.2 Measurement Results

Performed by Jean Tezil

Table 7.6.2-1: Peak Power Spectral Density – 802.11b

Frequency (MHz)	PSD Level (dBm)
2412	-3.52
2437	-4.57
2462	-3.52

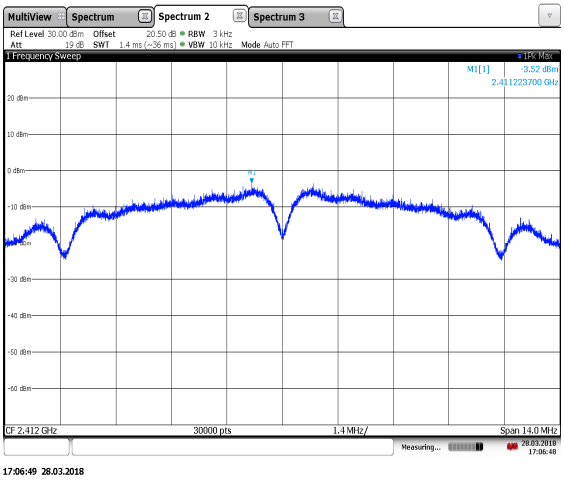


Figure 7.6.2-1: PSD Plot – 802.11b – 2412 MHz

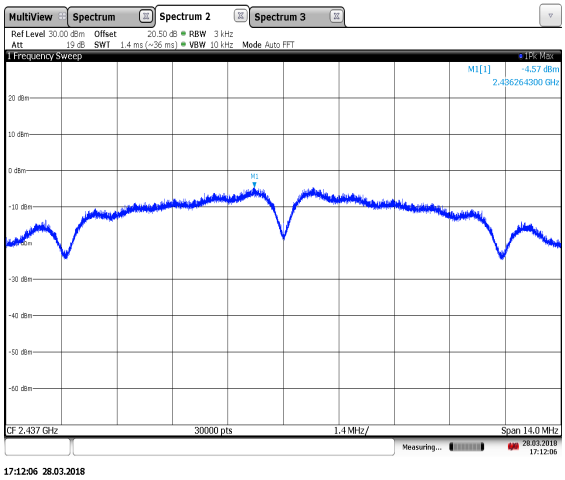


Figure 7.6.2-2: PSD Plot – 802.11b – 2437 MHz

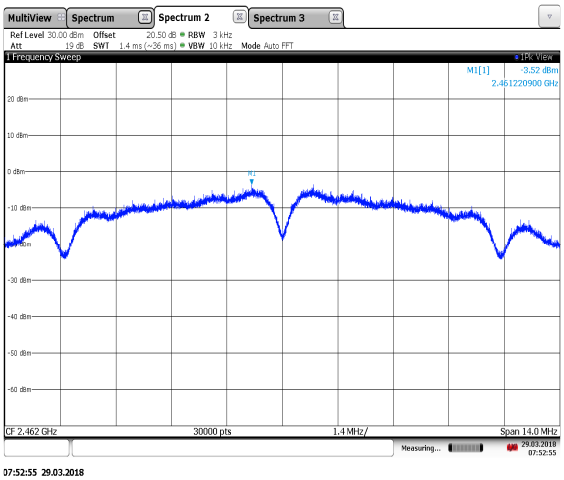


Figure 7.6.2-3: PSD Plot – 802.11b – 2462 MHz

Table 7.6.2-2: Peak Power Spectral Density – 802.11g

Frequency (MHz)	PSD Level (dBm)
2412	-10.66
2437	-11.10
2462	-10.86

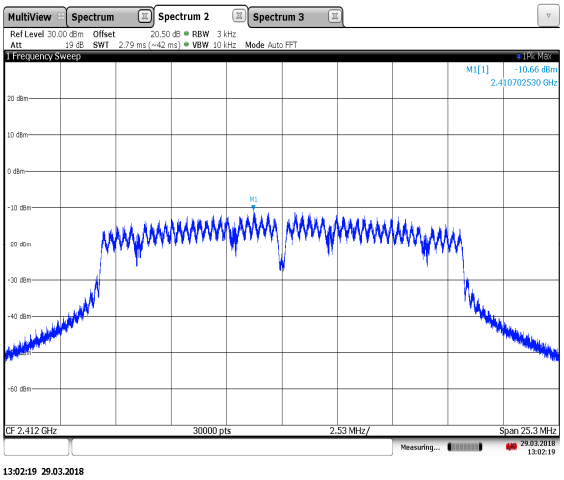


Figure 7.6.2-4: PSD Plot – 802.11g – 2412 MHz

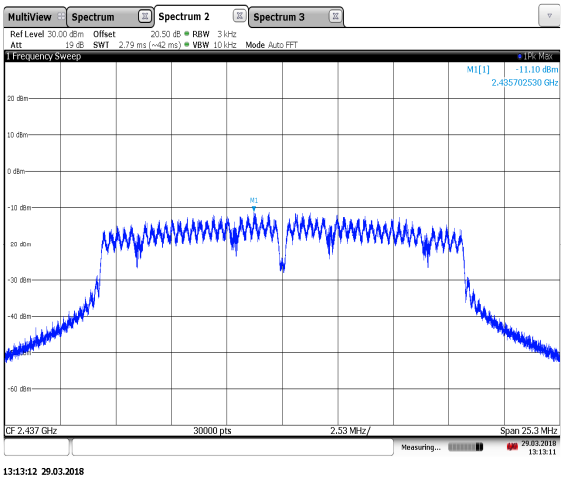


Figure 7.6.2-5: PSD Plot – 802.11g – 2437 MHz

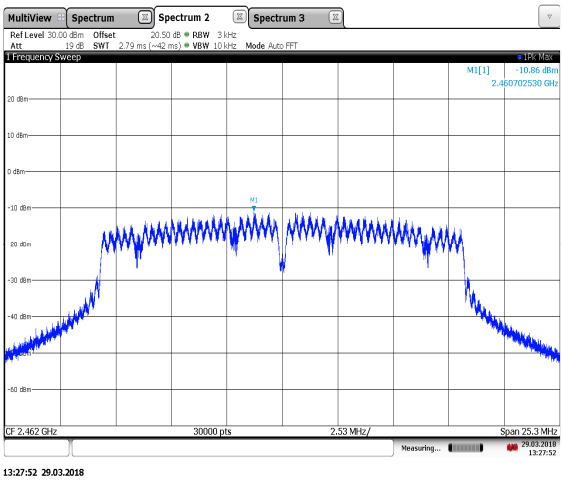


Figure 7.6.2-6: PSD Plot – 802.11g – 2462 MHz

Table 7.6.2-3: Peak Power Spectral Density – 802.11n (HT20)

Frequency (MHz)	PSD Level (dBm)
2412	-11.82
2437	-12.35
2462	-12.21

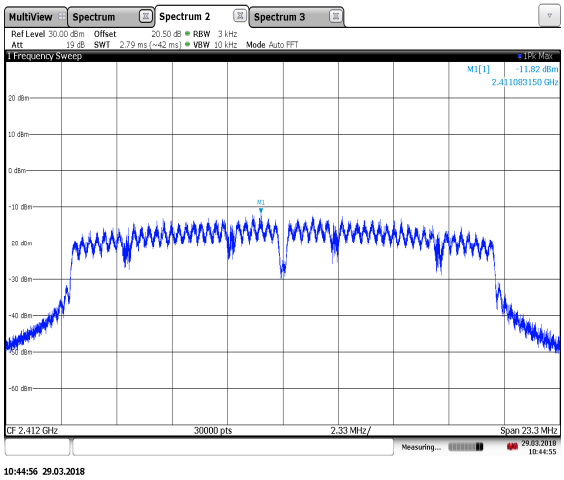


Figure 7.6.2-7: PSD Plot – 802.11n (HT20) – 2412 MHz

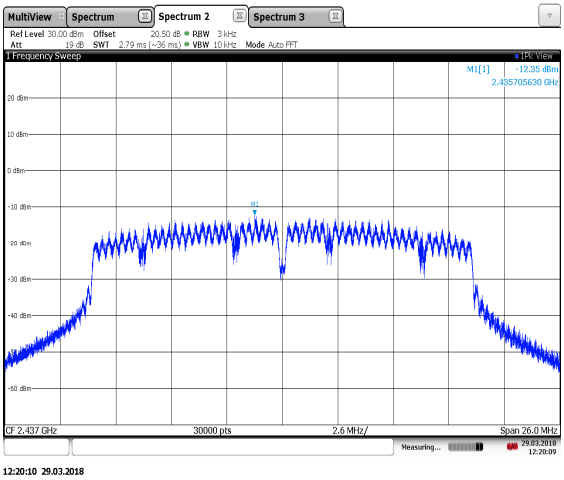


Figure 7.6.2-8: PSD Plot – 802.11n (HT20) – 2437 MHz

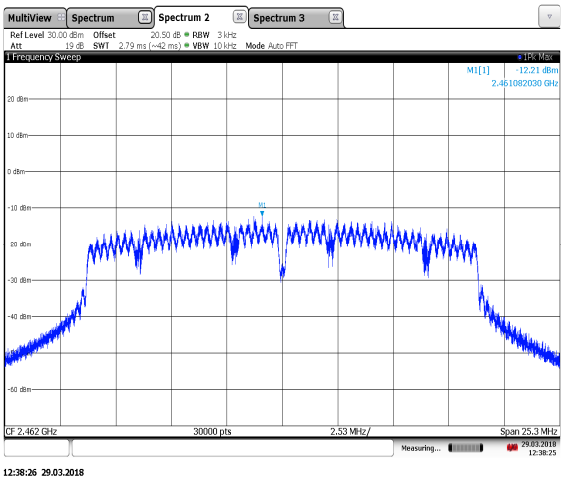


Figure 7.6.2-9: PSD Plot – 802.11n (HT20) – 2462 MHz

Table 7.6.2-4: Peak Power Spectral Density – BLE

Frequency (MHz)	PSD Level (dBm)
2402	-10.94
2440	-10.88
2480	-10.67

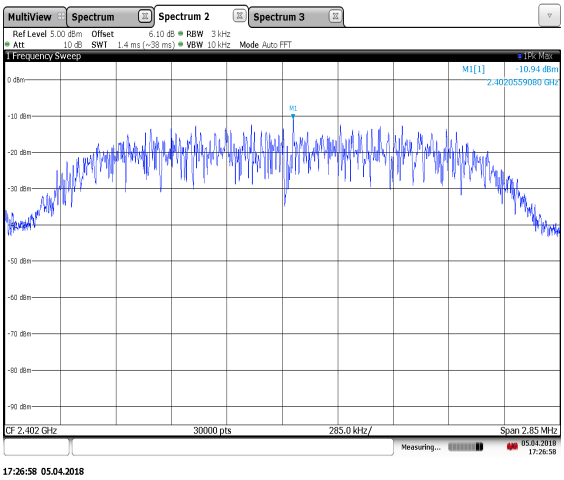


Figure 7.6.2-7: PSD Plot – BLE – 2402 MHz

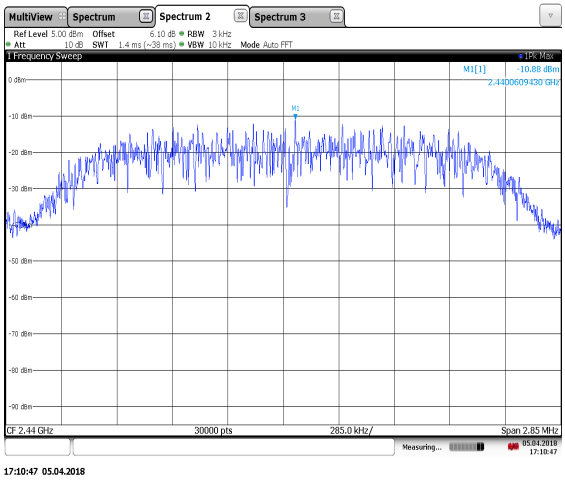


Figure 7.6.2-8: PSD Plot – BLE – 2440 MHz

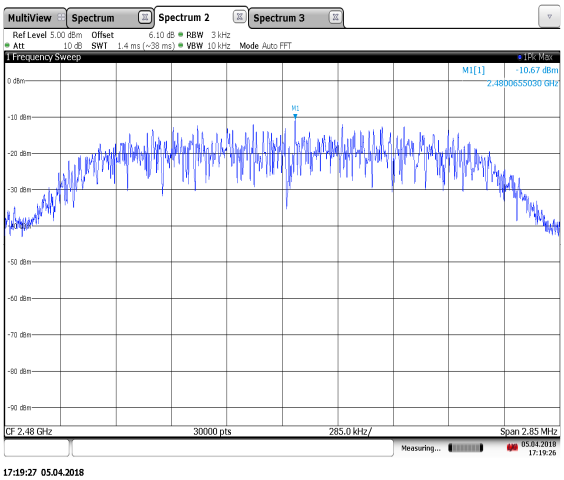


Figure 7.6.2-9: PSD Plot – BLE – 2480 MHz

8 MEASUREMENT UNCERTAINTY

The expanded laboratory measurement uncertainty figures (U_{Lab}) provided below correspond to an expansion factor (coverage factor) k = 1.96 which provide confidence levels of 95%.

Parameter	U_{lab}
Occupied Channel Bandwidth	± 0.004%
RF Conducted Output Power	± 0.689 dB
Power Spectral Density	±0.5 dB
Antenna Port Conducted Emissions	± 2.717 dB
Radiated Emissions	± 5.877 dB
Temperature	± 0.860 ℃
Radio Frequency	±2.832 x 10-8
AC Power Line Conducted Emissions	±2.85

9 CONCLUSION

In the opinion of TÜV SÜD America Inc. the PAC-USWHS002-WF-2, manufactured by Murata Electronics meets the requirements of FCC Part 15 subpart C and ISED Canada Radio Standards Specification: RSS-247 for the tests documented herein.

END REPORT