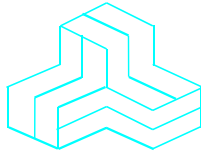


ENGINEERING TEST REPORT



Border router/Bridge
Model(s): BRD10
FCC ID: XFF-BRD10

Applicant:

MMB Research Inc.
25 Adelaide Street East, Suite 400
Toronto, ON M5C 3A1
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.: 19MMBN014_FCC15C247B

This Test report is Issued under the Authority of
Tri M. Luu
Vice President of Engineering
UltraTech Group of Labs

Date: July 11, 2019

Report Prepared by: Dan Huynh

Tested by: Hung Trinh

Issued Date: July 11, 2019

Test Dates:
April 17, 18, 2019
June 19, 2019

- *The results in this Test Report apply only to the sample(s) tested, and the sample tested is randomly selected.*
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- *This test report shall not be reproduced, except in full, without a written approval from UltraTech*

UltraTech

3000 Bristol Circle, Oakville, Ontario, Canada L6H 6G4
Tel.: (905) 829-1570 Fax.: (905) 829-8050
Website: www.ultratech-labs.com, Email: vic@ultratech-labs.com, Email: tri@ultratech-labs.com



1309



CA 0001/2049



AT-1945



SL2-IN-E-1119R



CA2049

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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: | <ul style="list-style-type: none">▪ ANSI C63.4▪ ANSI C63.10▪ FCC KDB Publication No. 558074 D01 15.247 Meas Guidance v05r01 |
| Environmental Classification: | <ul style="list-style-type: none">[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 v05r01 | 2019 | 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: | 25 Adelaide Street East, Suite 400 Toronto, ON M5C 3A1 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: | 25 Adelaide Street East, Suite 400 Toronto, ON M5C 3A1 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: | Border router/Bridge |
| Model(s): | BRD10 |
| Serial Number: | Test Sample |
| Type of Equipment: | Digital Transmission System (DTS) |
| Input Power Supply Type: | 5V, 1A via USB Hub |
| Primary User Functions of EUT: | Home automation/ IoT device |

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, 1A |
| RF Output Power Rating: | 2.67 dBm |
| Operating Frequency Range: | 2402 - 2480 MHz (for 1 Mbps); 2404 - 2478 MHz (for 2 Mbps) |
| RF Output Impedance: | 50 Ω |
| Duty Cycle: | Continuous |
| Modulation Type: | GFSK |
| Antenna Connector Type(s): | Integral |

2.4. ASSOCIATED ANTENNA DESCRIPTIONS

| Antenna Type | Manufacturer | Model | Maximum Gain (dBi) |
|---|--------------|-------------------|--------------------|
| ¹ PCB trace antenna | MMB Networks | PCB trace antenna | -0.68 |
| ² Dual band (2.4&5G) PCB trace antenna | MMB Networks | PCB trace antenna | 0.86 |

¹ For BLE and Zigbee modes

² For WiFi Mode

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 | Micro USB | 1 | Micro USB | Shielded |
| 2 | 802.15.4/BLE RF port for Mfg. test & calibration | 1 | SWG connector | Shielded |
| 3 | 2.4GHz/5GHz RF port for Mfg. test & calibration | 1 | SWG connector | Shielded |
| 4 | GPIO ports | 3 | 24 position connector plug, SMT | N/A |

ULTRATECH GROUP OF LABS

3000 Bristol Circle, Oakville, Ontario, Canada L6H 6G4
Tel. #: 905-829-1570, Fax. #: 905-829-8050, Email: vic@ultratech-labs.com, Website: <http://www.ultratech-labs.com>

File #: 19MMBN014_FCC15C247B

July 11, 2019

All test results contained in this engineering test report are traceable to National Institute of Standards and Technology (NIST)

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 USB Hub |

| Ancillary Equipment # 2 | |
|--------------------------|--------------|
| Description: | USB Hub |
| Brand name: | Insignia |
| Model Name or Number: | NS-PCH5421-C |
| Serial Number: | -- |
| Connected to EUT's Port: | Micro USB |

| Ancillary Equipment # 3 | |
|--------------------------|----------------------------------|
| Description: | AC/DC Adapter |
| Brand name: | Shenzhen Luda Electrical Co. Ltd |
| Model Name or Number: | HL-050/2000-FBOS-EE |
| Serial Number: | -- |
| Connected to EUT's Port: | Connected to USB Hub 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 USB Hub |

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): | 1 Mbps: 2402 - 2480 MHz 2 Mbps: 2404 - 2478 MHz |
| Frequency(ies) Tested: | 1 Mbps: 2402 MHz, 2440 MHz, 2480 MHz 2 Mbps: 2404 MHz, 2440 MHz, 2478 MHz |
| RF Power Output: (measured maximum output power at antenna terminals) | 2.67 dBm Peak |
| Normal Test Modulation: | GFSK |
| 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:

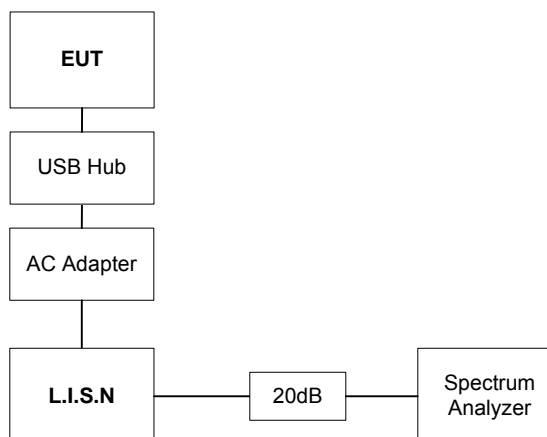
| Frequency of emission (MHz) | Conducted Limits (dB μ V) | |
|--------------------------------|-------------------------------|-----------|
| | Quasi-peak | Average |
| 0.15–0.5 | 66 to 56* | 56 to 46* |
| 0.5–5 | 56 | 46 |
| 5–30 | 60 | 50 |

*Decreases linearly with the logarithm of the frequency

5.1.2. Method of Measurements

ANSI C63.4

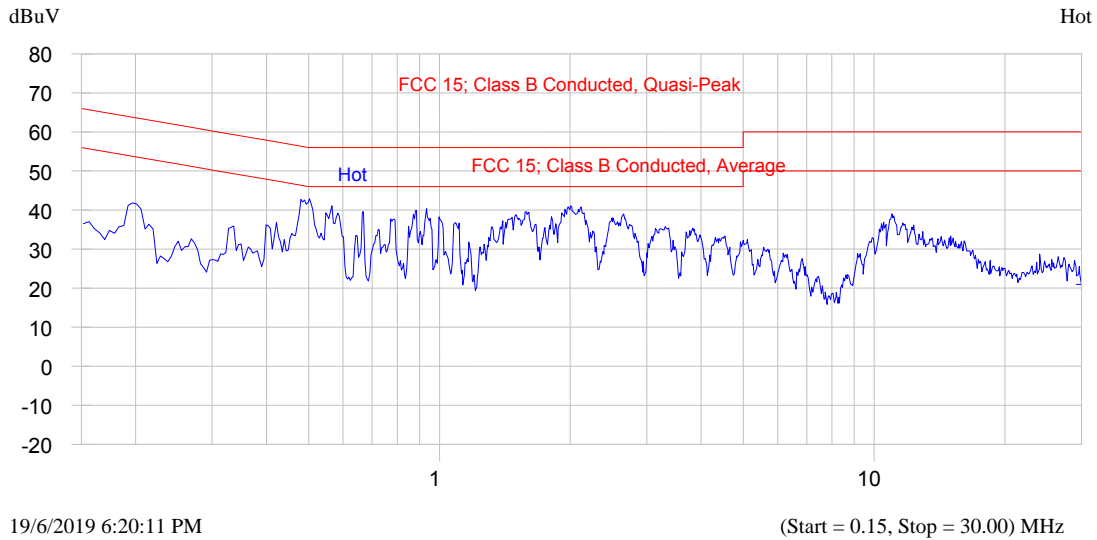
5.1.3. Test Arrangement



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

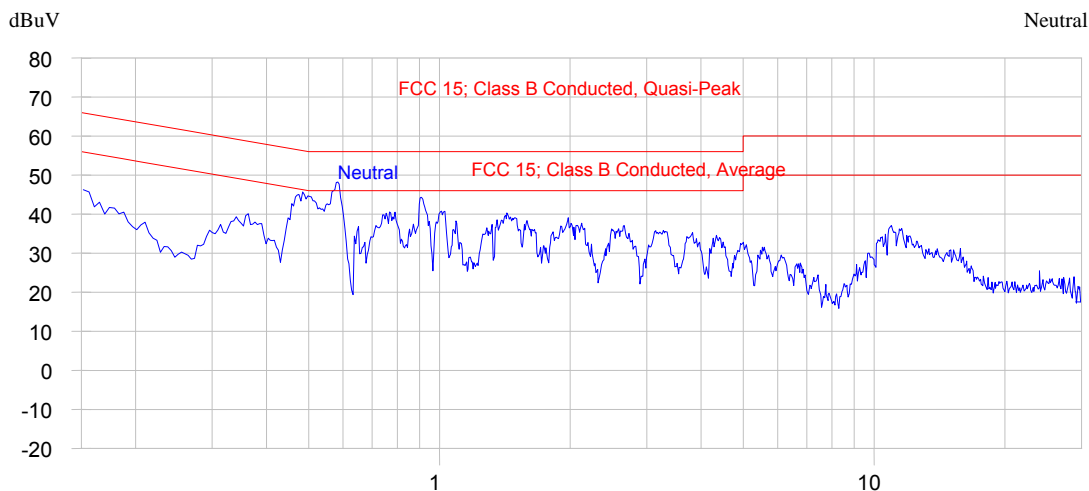


Current List

| Frequency MHz | Peak dBuV | QP dBuV | QP-QP Limit dB | Avg dBuV | Avg-Avg Limit dB | Trace Name |
|------------------|--------------|------------|-------------------|-------------|---------------------|------------|
| 0.174 | 45.0 | 40.5 | -24.2 | 26.8 | -27.9 | Hot |
| 0.506 | 44.2 | 40.6 | -15.4 | 28.8 | -17.2 | Hot |
| 0.583 | 47.0 | 44.3 | -11.7 | 32.3 | -13.7 | Hot |
| 0.908 | 43.4 | 39.4 | -16.6 | 27.0 | -19.0 | Hot |
| 2.016 | 42.4 | 39.5 | -16.5 | 32.9 | -13.1 | Hot |

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

Current Graph



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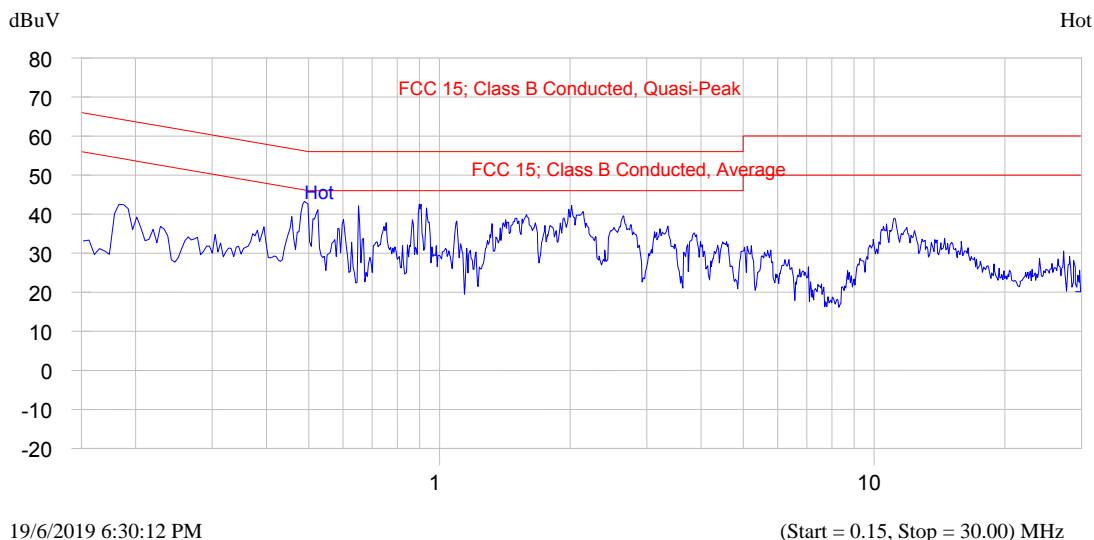
(Start = 0.15, Stop = 30.00) MHz

Current List

| Frequency MHz | Peak dBuV | QP dBuV | QP-QP Limit dB | Avg dBuV | Avg-Avg Limit dB | Trace Name |
|------------------|--------------|------------|-------------------|-------------|---------------------|------------|
| 0.154 | 46.8 | 44.4 | -21.3 | 37.7 | -18.1 | Neutral |
| 0.362 | 40.2 | 38.0 | -20.6 | 30.7 | -17.9 | Neutral |
| 0.487 | 46.7 | 44.3 | -11.9 | 37.2 | -9.0 | Neutral |
| 0.582 | 48.8 | 47.2 | -8.8 | 40.2 | -5.8 | Neutral |
| 0.900 | 45.2 | 42.7 | -13.3 | 35.2 | -10.8 | Neutral |

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

Current Graph

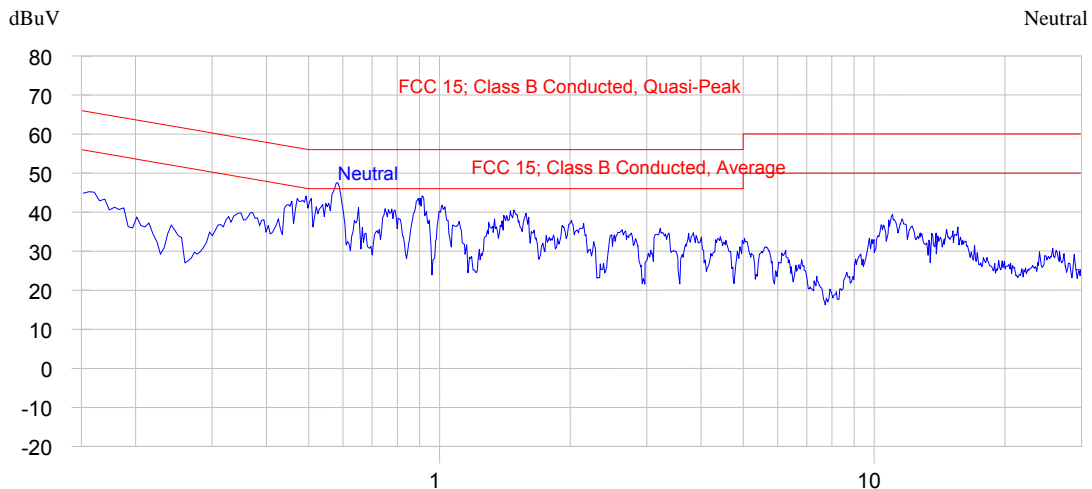


Current List

| Frequency MHz | Peak dBuV | QP dBuV | QP-QP Limit dB | Avg dBuV | Avg-Avg Limit dB | Trace Name |
|------------------|--------------|------------|-------------------|-------------|---------------------|------------|
| 0.183 | 43.4 | 39.1 | -25.3 | 25.9 | -28.4 | Hot |
| 0.490 | 44.3 | 40.9 | -15.3 | 29.1 | -17.0 | Hot |
| 0.508 | 43.6 | 39.0 | -17.0 | 27.3 | -18.7 | Hot |
| 0.642 | 41.8 | 34.3 | -21.7 | 16.7 | -29.3 | Hot |
| 0.899 | 43.6 | 40.4 | -15.6 | 28.9 | -17.1 | Hot |
| 2.015 | 42.4 | 39.4 | -16.6 | 32.2 | -13.8 | Hot |

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

Current Graph



19/6/2019 6:39:00 PM

(Start = 0.15, Stop = 30.00) MHz

Current List

| Frequency MHz | Peak dBuV | QP dBuV | QP-QP Limit dB | Avg dBuV | Avg-Avg Limit dB | Trace Name |
|------------------|--------------|------------|-------------------|-------------|---------------------|------------|
| 0.162 | 45.9 | 42.2 | -23.2 | 34.0 | -21.3 | Neutral |
| 0.488 | 46.4 | 44.5 | -11.7 | 37.6 | -8.6 | Neutral |
| 0.583 | 49.2 | 47.4 | -8.6 | 40.3 | -5.7 | Neutral |
| 0.909 | 45.0 | 42.2 | -13.8 | 34.1 | -11.9 | Neutral |
| 1.482 | 40.9 | 38.0 | -18.0 | 30.4 | -15.6 | Neutral |
| 11.040 | 39.4 | 36.3 | -23.7 | 30.0 | -20.0 | Neutral |

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

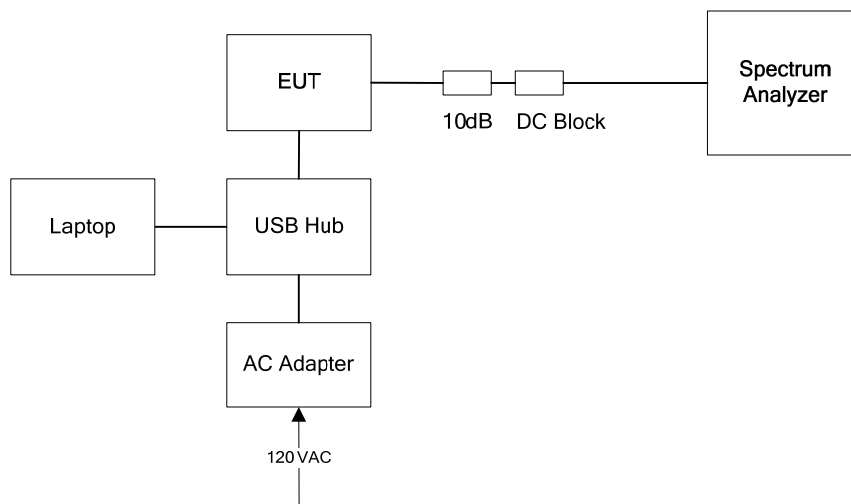
5.2.1. Limit(s)

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

5.2.2. Method of Measurements

KDB 558074 D01 15.247 Meas Guidance v05r01, Section 8.2 DTS Bandwidth (11.8.1 Option 2 ANSI C63.10-2013)

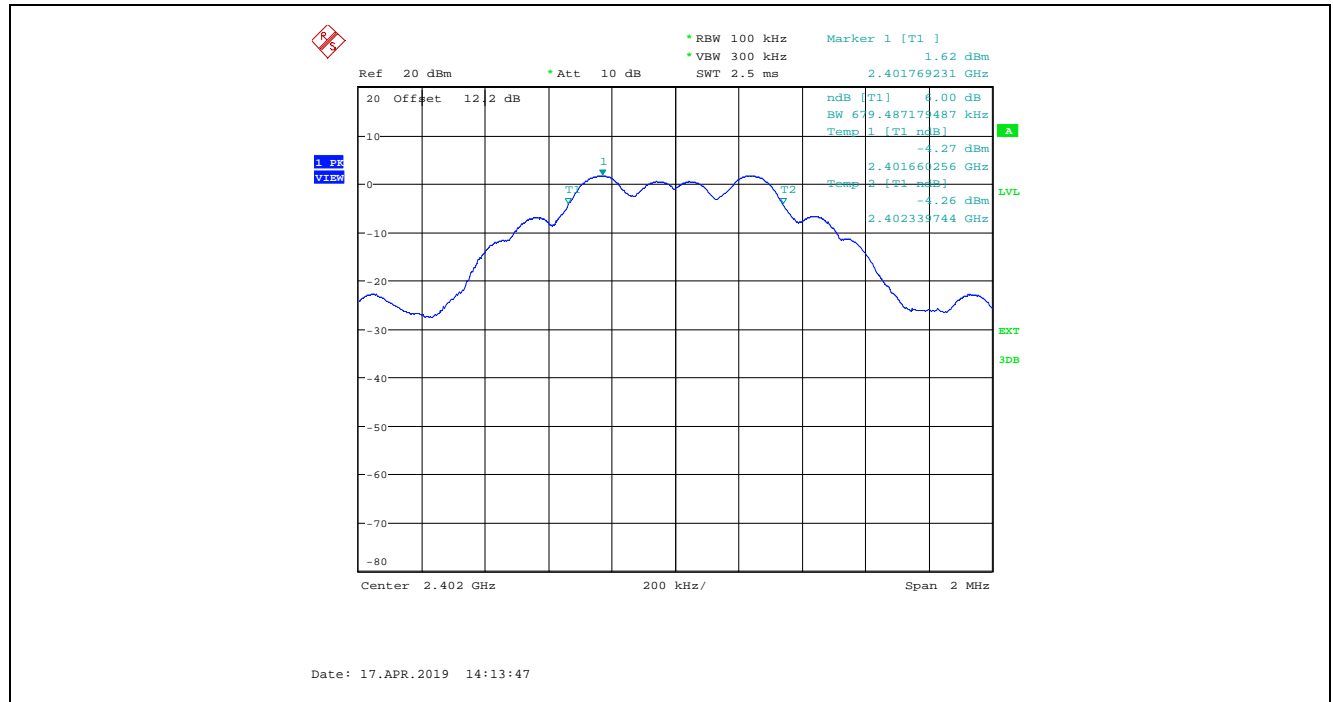
5.2.3. Test Arrangement



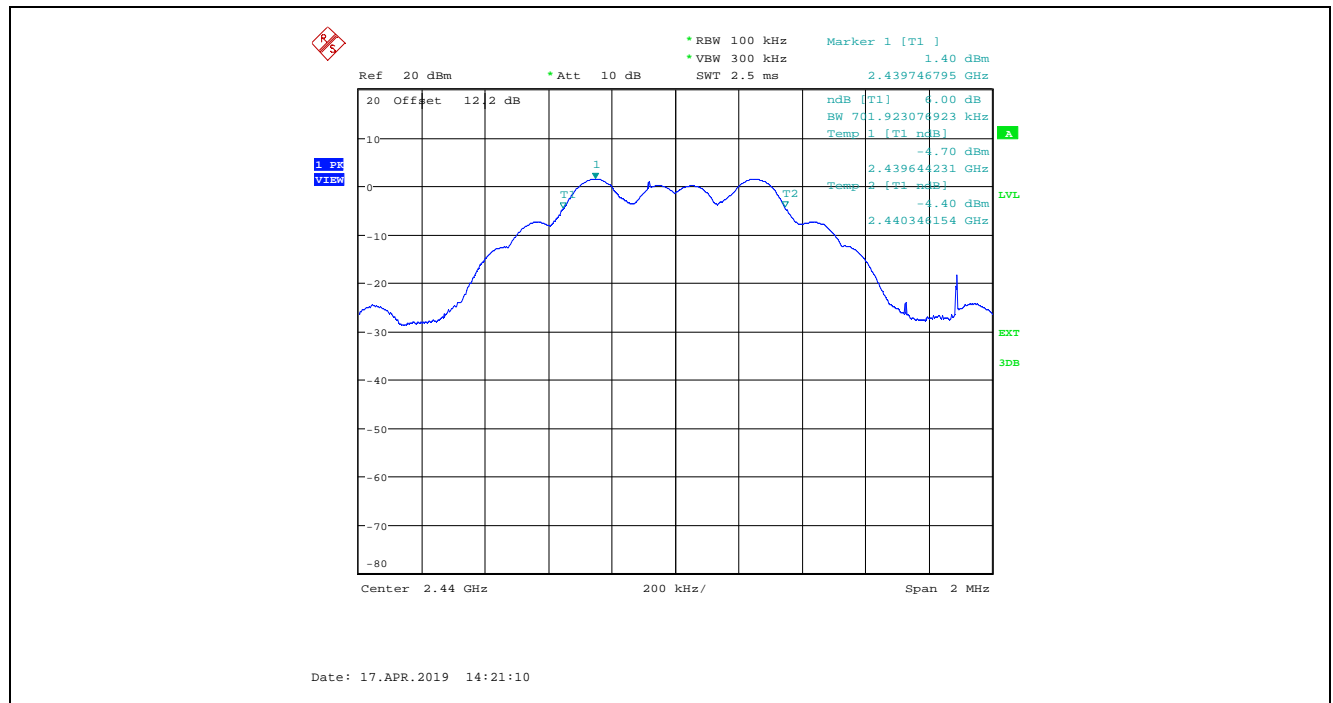
5.2.4. Test Data

| Modulation | Data Rate (Mbps) | Power Setting | Channel | Frequency (MHz) | 6dB BW (kHz) | Min. Limit (kHz) |
|------------|------------------|---------------|---------|-----------------|--------------|------------------|
| GFSK | 1 | 15 | 37 | 2402 | 679.49 | 500 |
| | | 15 | 17 | 2440 | 701.92 | 500 |
| | | 15 | 39 | 2480 | 698.72 | 500 |
| | 2 | 15 | 00 | 2404 | 1346.15 | 500 |
| | | 15 | 17 | 2440 | 1379.81 | 500 |
| | | 15 | 36 | 2478 | 1394.23 | 500 |

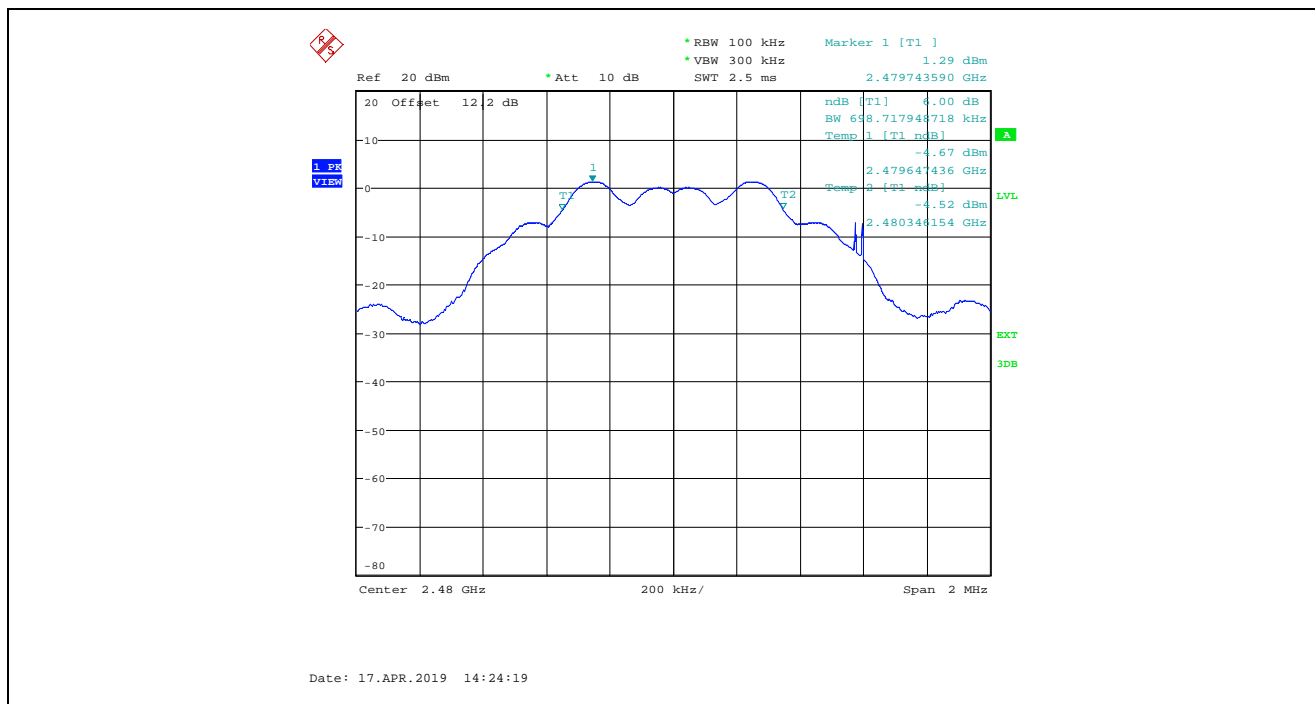
Plot 5.2.4.1. 6 dB Bandwidth, GFSK Modulation, Power Setting at 15, Channel 37, 2402 MHz, 1 Mbps



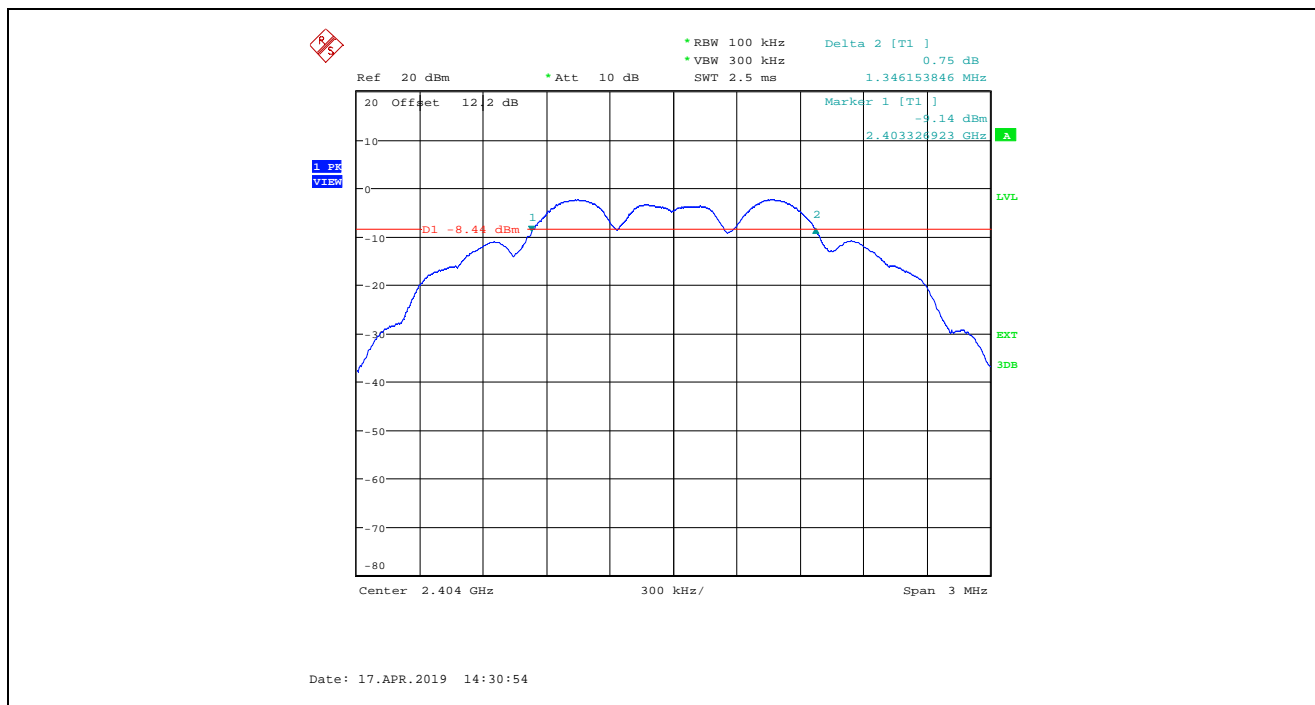
Plot 5.2.4.2. 6 dB Bandwidth, GFSK Modulation, Power Setting at 15, Channel 17, 2440 MHz, 1 Mbps



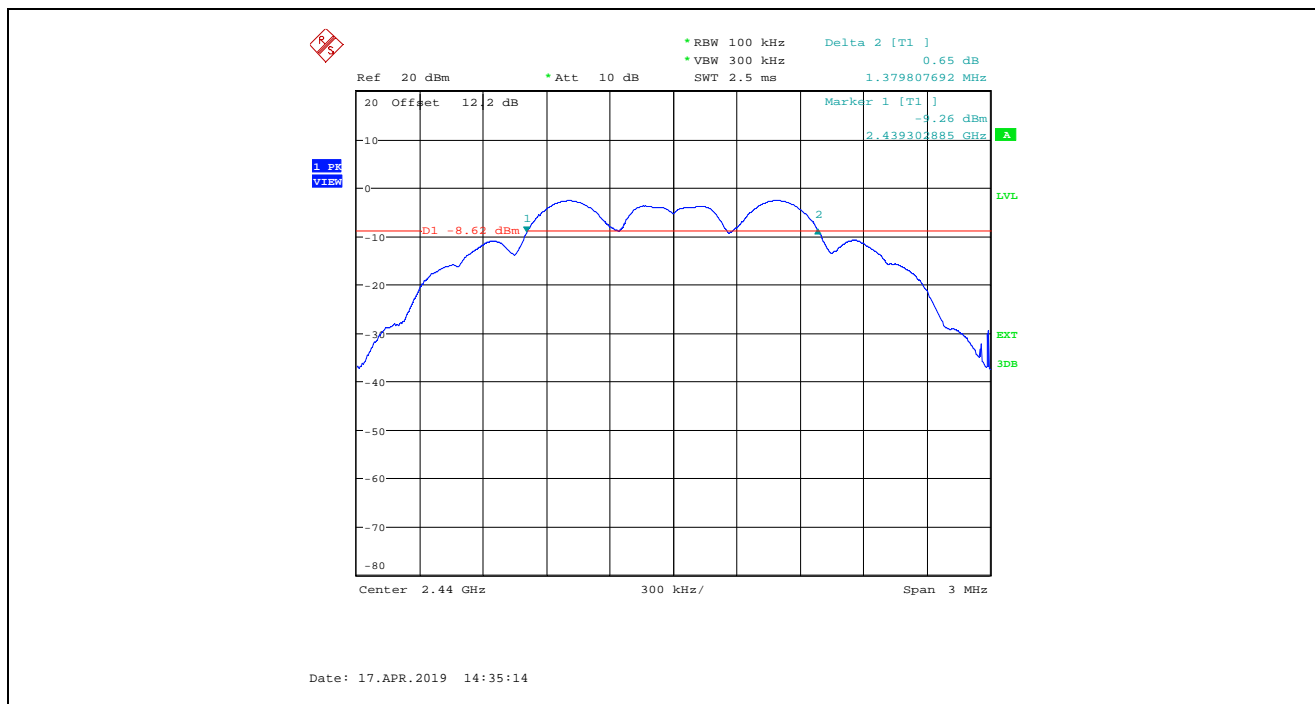
Plot 5.2.4.3. 6 dB Bandwidth, GFSK Modulation, Power Setting at 15, Channel 39, 2480 MHz, 1 Mbps



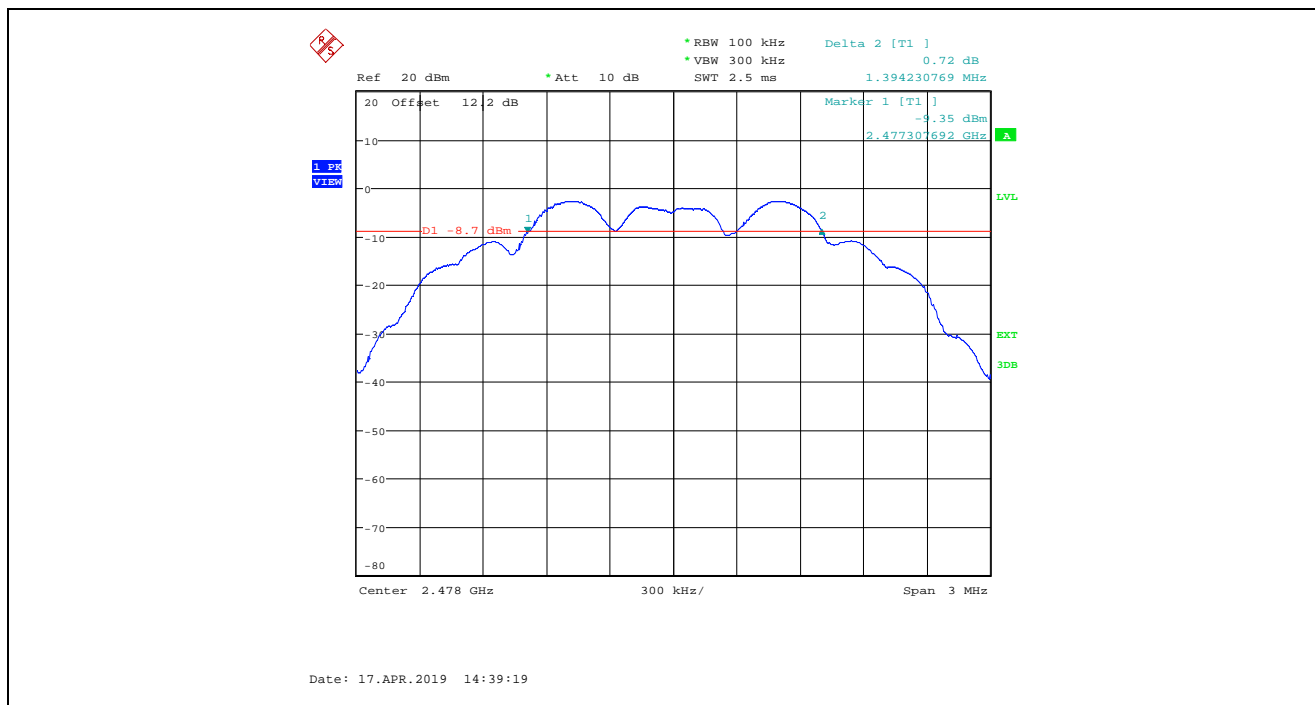
Plot 5.2.4.4. 6 dB Bandwidth, GFSK Modulation, Power Setting at 15, Channel 00, 2404 MHz, 2 Mbps



Plot 5.2.4.5. 6 dB Bandwidth, GFSK Modulation, Power Setting at 15, Channel 17, 2440 MHz, 2 Mbps



Plot 5.2.4.6. 6 dB Bandwidth, GFSK Modulation, Power Setting at 15, Channel 36, 2478 MHz, 2 Mbps



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

5.3.1. Limit(s)

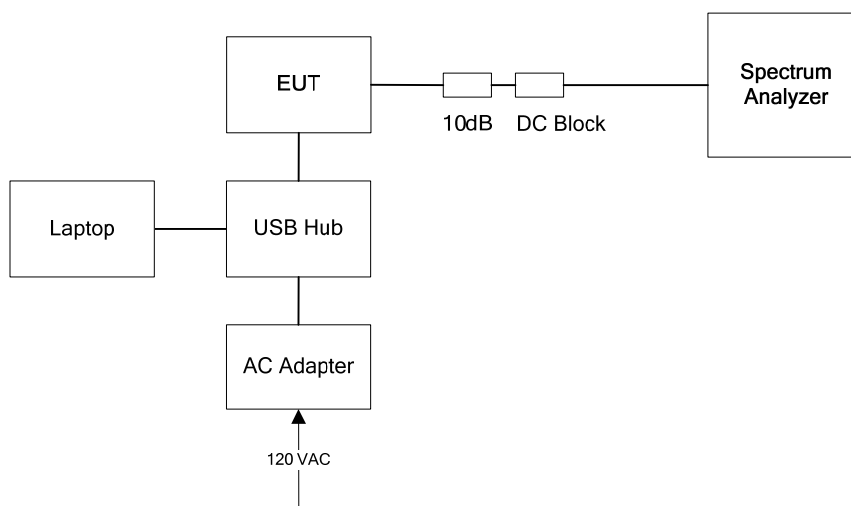
§ 15.247(b)(3): For systems using digital modulation in the 902-928 MHz, 2400-2483.5 MHz, and 5725-5850 MHz bands: 1 Watt. As an alternative to a peak power measurement, compliance with the one Watt limit can be based on a measurement of the maximum conducted output power. Maximum Conducted Output Power 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 v05r01, Section 8.3.1.1 RBW \geq DTS bandwidth / Subclause 11.9.1.1 of ANSI C63.10

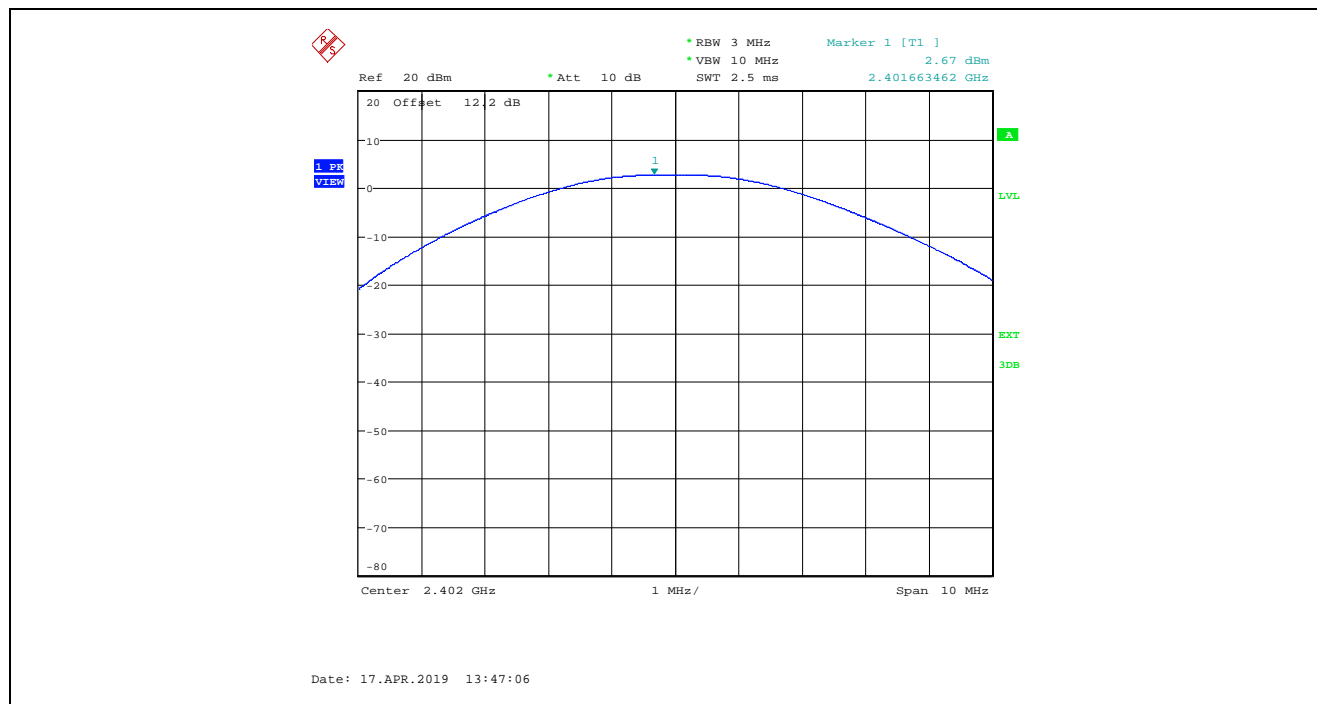
5.3.3. Test Arrangement



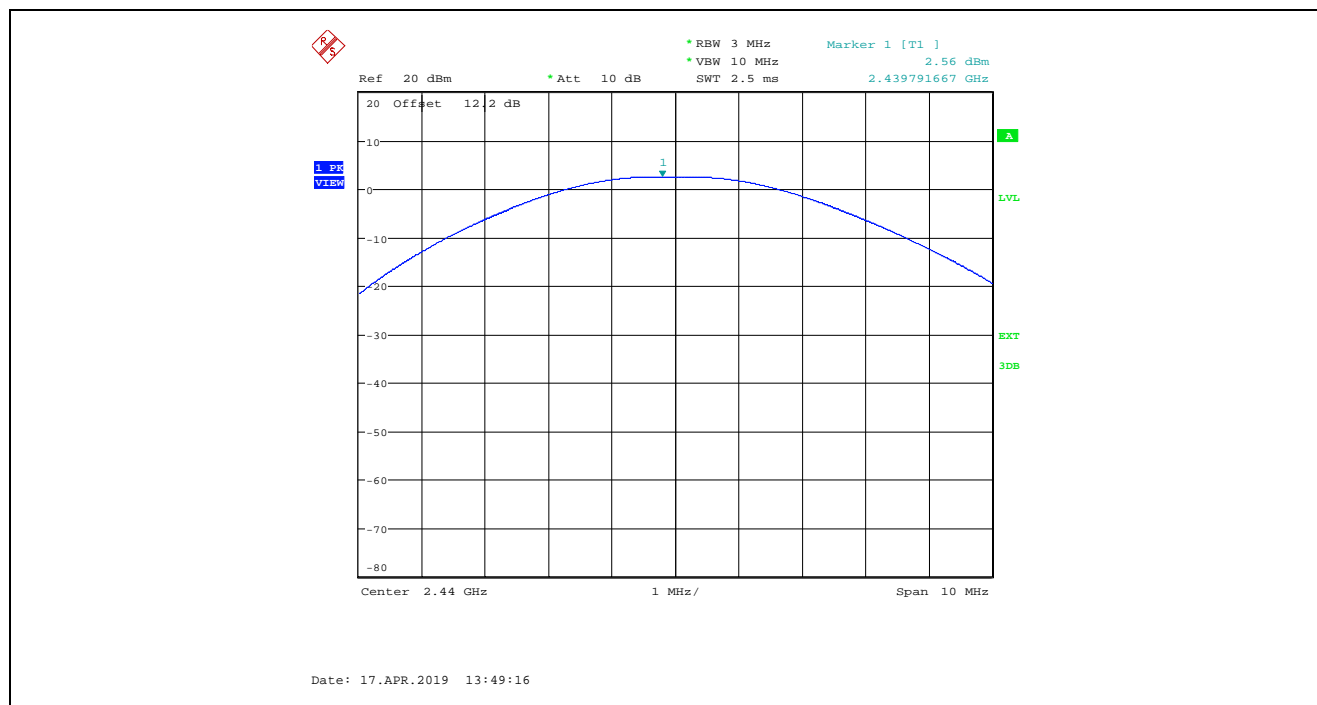
5.3.4. Test Data

| Peak Conducted Power and Power Settings for EUT with -0.68 dBi PCB Trace Antenna | | | | | | | |
|--|------------------|---------------|---------|-----------------|------------------|--------------------|------------|
| Modulation | Data Rate (Mbps) | Power Setting | Channel | Frequency (MHz) | Peak Power (dBm) | Assembly Gain (dB) | EIRP (dBm) |
| GFSK | 1 | 15 | 37 | 2402 | 2.67 | -0.68 | 1.99 |
| | | 15 | 17 | 2440 | 2.56 | -0.68 | 1.88 |
| | | 15 | 39 | 2480 | 2.47 | -0.68 | 1.79 |
| | 2 | 15 | 0 | 2404 | 2.67 | -0.68 | 1.99 |
| | | 15 | 17 | 2440 | 2.57 | -0.68 | 1.89 |
| | | 15 | 36 | 2478 | 2.49 | -0.68 | 1.81 |

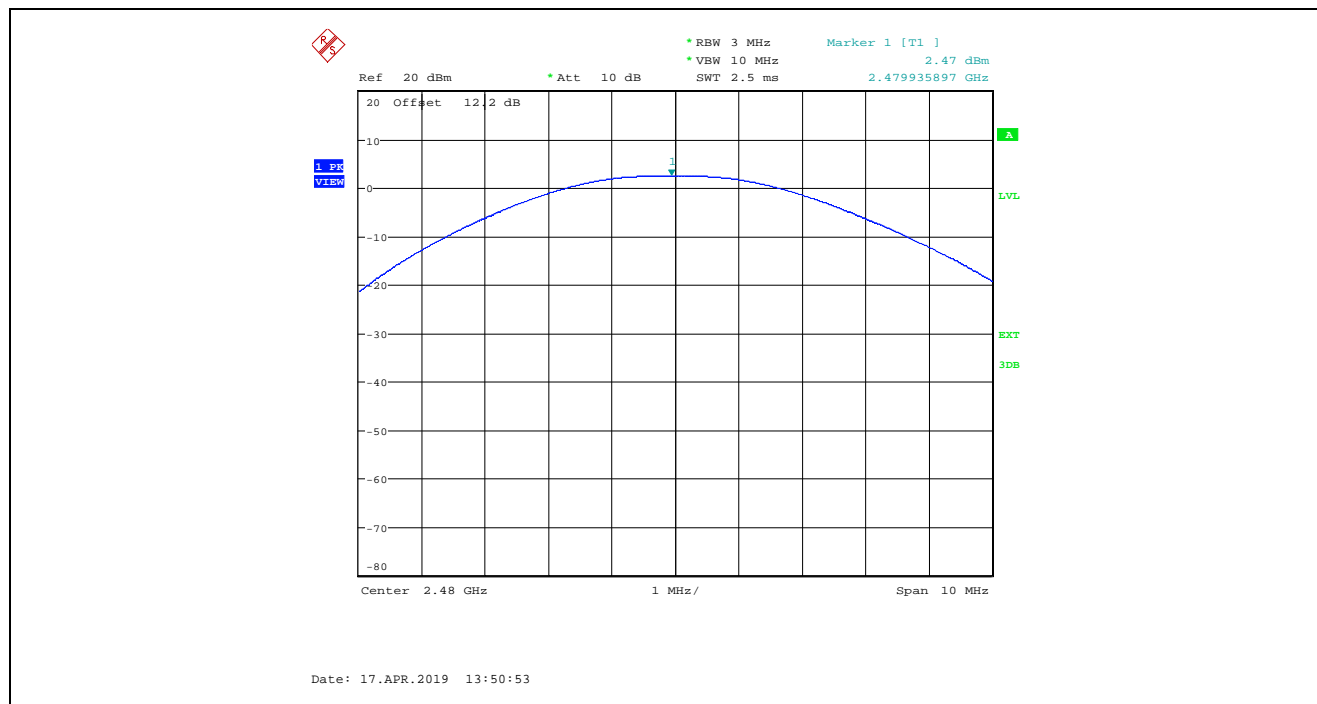
Plot 5.3.4.1. Maximum Peak Conducted Output Power, GFSK Modulation, 1 Mbps, Power Setting 15, Ch 37, 2402 MHz



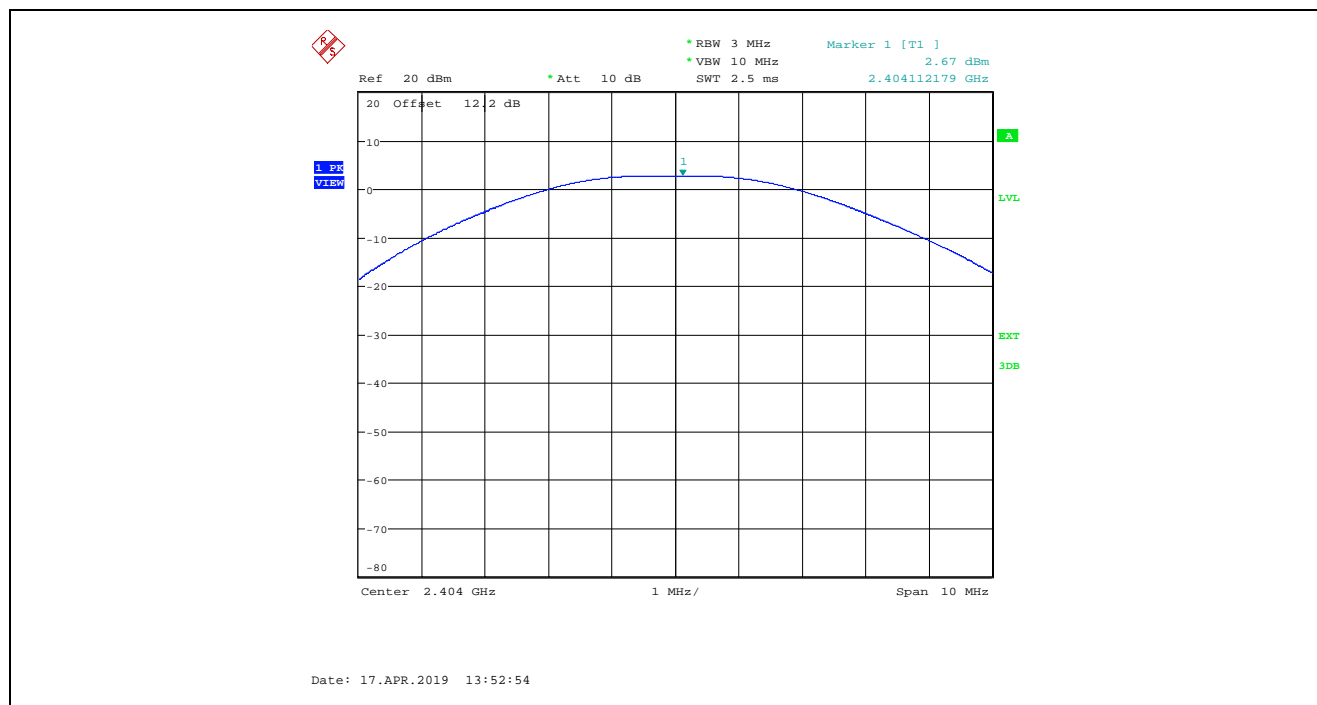
Plot 5.3.4.2. Maximum Peak Conducted Output Power, GFSK Modulation, 1 Mbps, Power Setting 15, Ch 17, 2440 MHz



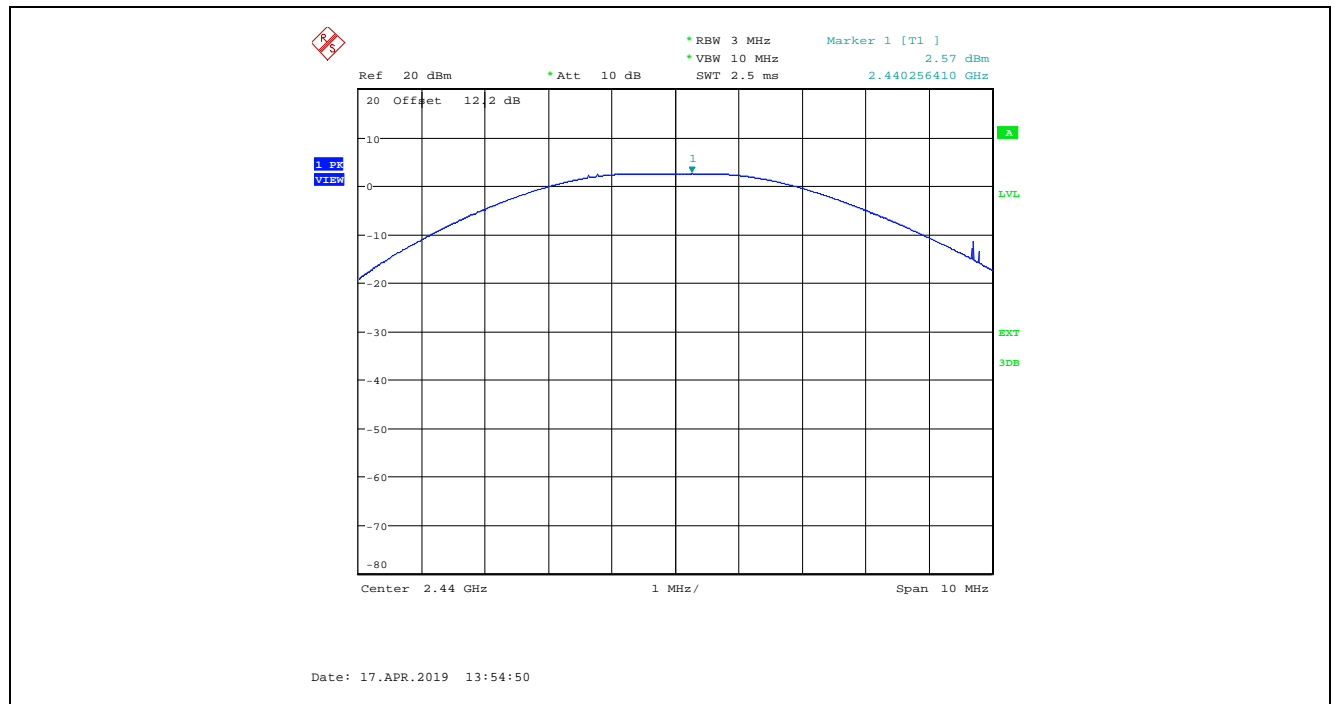
Plot 5.3.4.3. Maximum Peak Conducted Output Power, GFSK Modulation, 1 Mbps, Power Setting 15, Ch 39, 2480 MHz



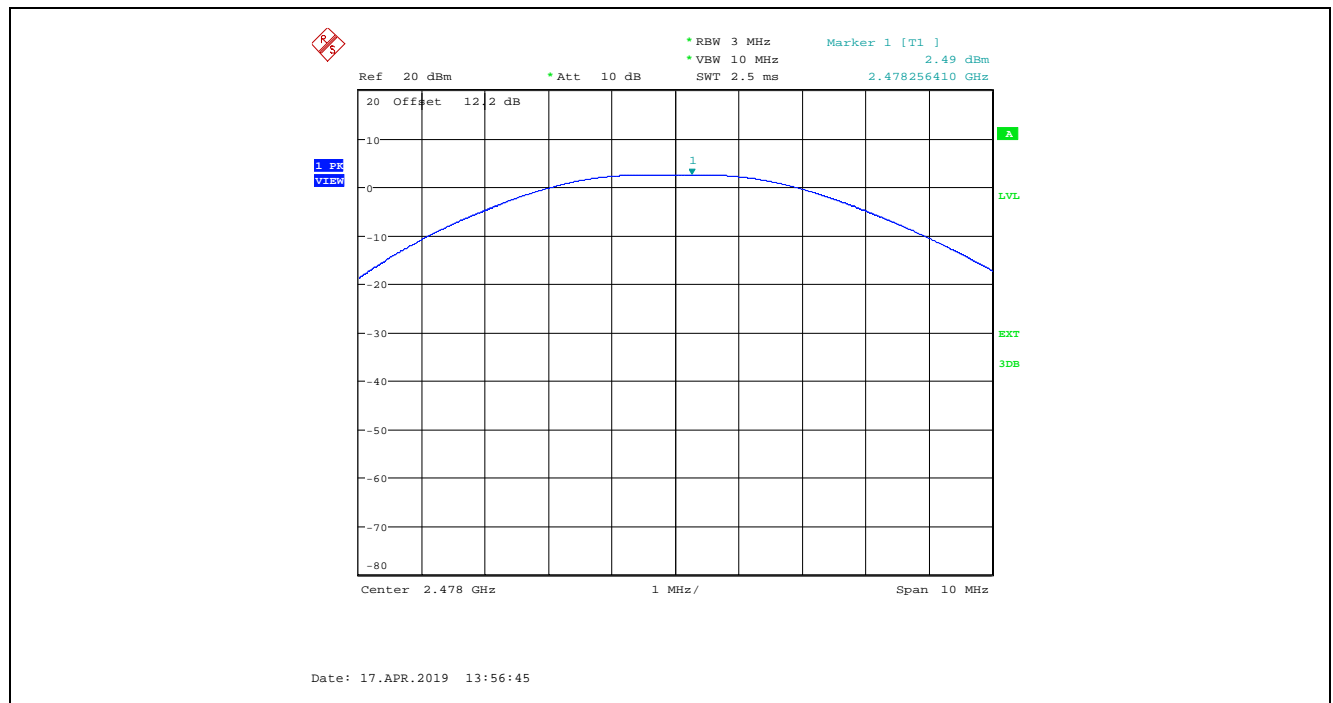
Plot 5.3.4.4. Maximum Peak Conducted Output Power, GFSK Modulation, 2 Mbps, Power Setting 15, Ch 00, 2404 MHz



Plot 5.3.4.5. Maximum Peak Conducted Output Power, GFSK Modulation, 2 Mbps, Power Setting 15, Ch 17, 2440 MHz



Plot 5.3.4.6. Maximum Peak Conducted Output Power, GFSK Modulation, 2 Mbps, Power Setting 15, Ch 36, 2478 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

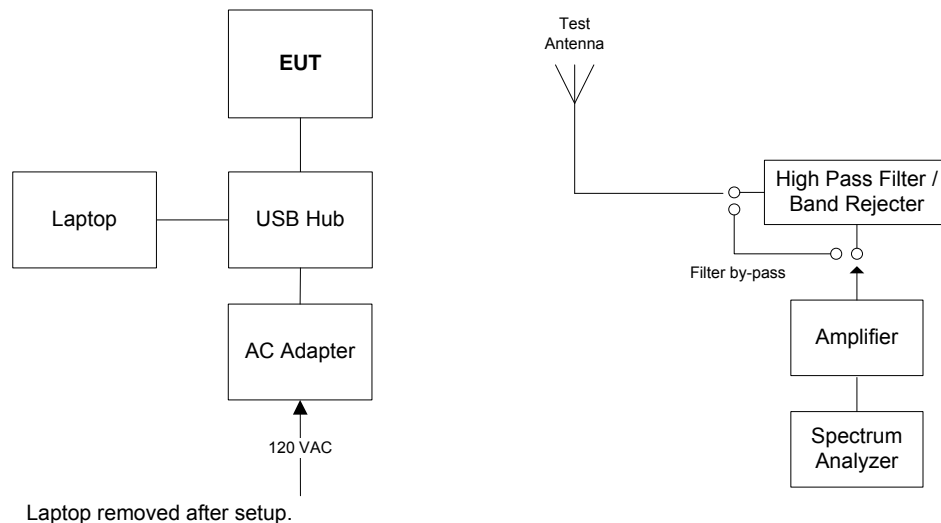
| Frequency (MHz) | Field Strength (microvolts/meter) | Measurement Distance (meters) |
|-----------------|-----------------------------------|-------------------------------|
| 0.009 - 0.490 | 2,400 / F (kHz) | 300 |
| 0.490 - 1.705 | 24,000 / F (kHz) | 30 |
| 1.705 - 30.0 | 30 | 30 |
| 30 - 88 | 100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

5.4.2. Method of Measurements

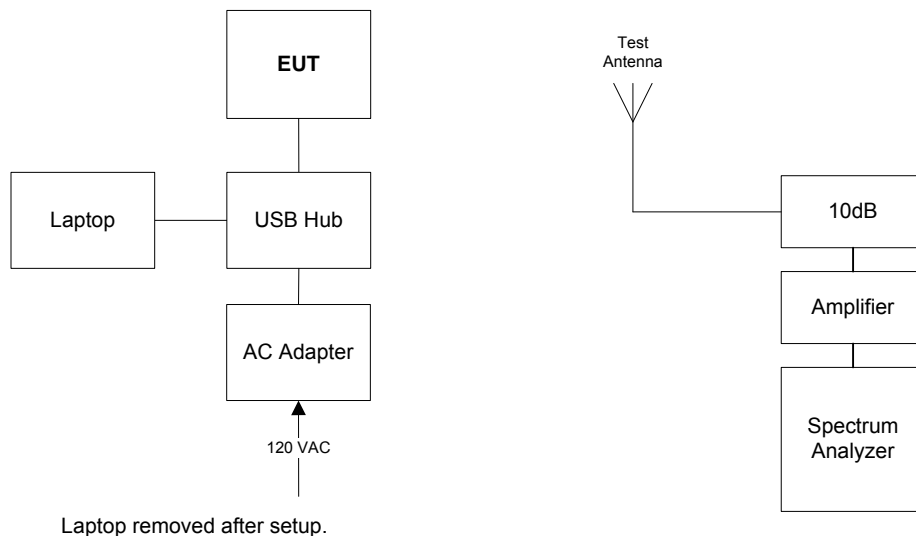
KDB 558074 D01 15.247 Meas Guidance v05r01, Sections 8.5, 8.6 and 8.7 / Subclauses 11.11, 11.12 and 11.13 of ANSI C63.10.

5.4.3. Test Arrangement

Radiated Emissions



Band-Edge Radiated Emissions



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.

| Operating Mode: | | GFSK Modulation, 1 Mbps, Power Setting 15 | | | | | |
|------------------------|------------------------|---|---------------------|-----------------------|-----------------------|-------------|-----------|
| Fundamental Frequency: | | 2402 MHz | | | | | |
| Frequency Test Range: | | 30 MHz – 25 GHz | | | | | |
| 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 |
| 2402 | 99.38 | -- | V | -- | -- | -- | -- |
| 2402 | 99.53 | -- | H | -- | -- | -- | -- |
| 30 - 25000 | * | * | V/H | * | * | * | Pass |

* No spurious component detected.

| Operating Mode: | | GFSK Modulation, 1 Mbps, Power Setting 15 | | | | | |
|------------------------|------------------------|---|---------------------|-----------------------|-----------------------|-------------|-----------|
| Fundamental Frequency: | | 2440 MHz | | | | | |
| Frequency Test Range: | | 30 MHz – 25 GHz | | | | | |
| 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 | 99.87 | -- | V | -- | -- | -- | -- |
| 2440 | 98.73 | -- | H | -- | -- | -- | -- |
| 30 - 25000 | * | * | V/H | * | * | * | Pass |

* No spurious component detected.

| Operating Mode: | | GFSK Modulation, 1 Mbps, Power Setting 15 | | | | | |
|------------------------|------------------------|---|---------------------|-----------------------|-----------------------|-------------|-----------|
| Fundamental Frequency: | | 2480 MHz | | | | | |
| Frequency Test Range: | | 30 MHz – 25 GHz | | | | | |
| 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 | 98.18 | -- | V | -- | -- | -- | -- |
| 2480 | 97.38 | -- | H | -- | -- | -- | -- |
| 30 - 25000 | * | * | V/H | * | * | * | Pass |

* No spurious component detected.

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3000 Bristol Circle, Oakville, Ontario, Canada L6H 6G4
Tel. #: 905-829-1570, Fax. #: 905-829-8050, Email: vic@ultratech-labs.com, Website: <http://www.ultratech-labs.com>

File #: 19MMBN014_FCC15C247B
July 11, 2019

All test results contained in this engineering test report are traceable to National Institute of Standards and Technology (NIST)

| Operating Mode: GFSK Modulation, 2 Mbps, Power Setting 15 Fundamental Frequency: 2404 MHz Frequency Test Range: 30 MHz – 25 GHz | | | | | | | |
|---|------------------------|-----------------------|---------------------|-----------------------|-----------------------|-------------|-----------|
| 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 |
| 2404 | 99.69 | -- | V | -- | -- | -- | -- |
| 2404 | 99.81 | -- | H | -- | -- | -- | -- |
| 30 - 25000 | * | * | V/H | * | * | * | Pass |

* No spurious component detected.

| Operating Mode: GFSK Modulation, 2 Mbps, Power Setting 15 Fundamental Frequency: 2440 MHz Frequency Test Range: 30 MHz – 25 GHz | | | | | | | |
|---|------------------------|-----------------------|---------------------|-----------------------|-----------------------|-------------|-----------|
| 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 | 99.82 | -- | V | -- | -- | -- | -- |
| 2440 | 99.73 | -- | H | -- | -- | -- | -- |
| 30 - 25000 | * | * | V/H | * | * | * | Pass |

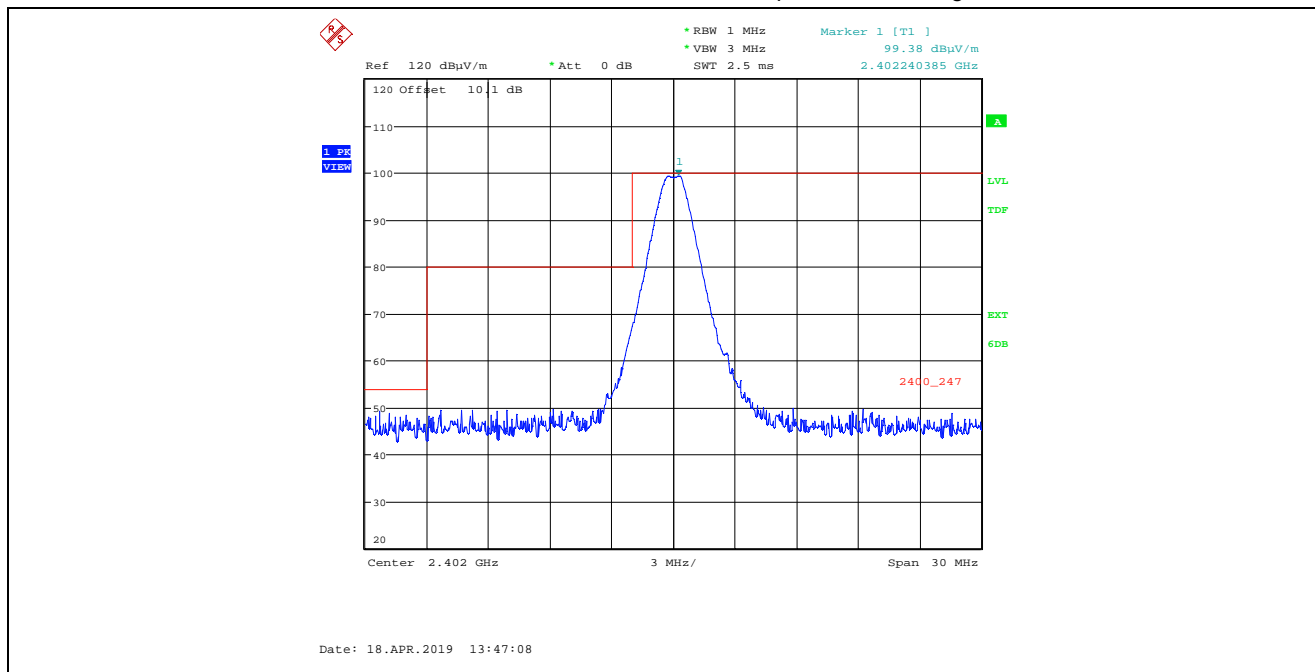
* No spurious component detected.

| Operating Mode: GFSK Modulation, 2 Mbps, Power Setting 15 Fundamental Frequency: 2478 MHz Frequency Test Range: 30 MHz – 25 GHz | | | | | | | |
|---|------------------------|-----------------------|---------------------|-----------------------|-----------------------|-------------|-----------|
| 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 |
| 2478 | 97.06 | -- | V | -- | -- | -- | -- |
| 2478 | 97.87 | -- | H | -- | -- | -- | -- |
| 30 - 25000 | * | * | V/H | * | * | * | Pass |

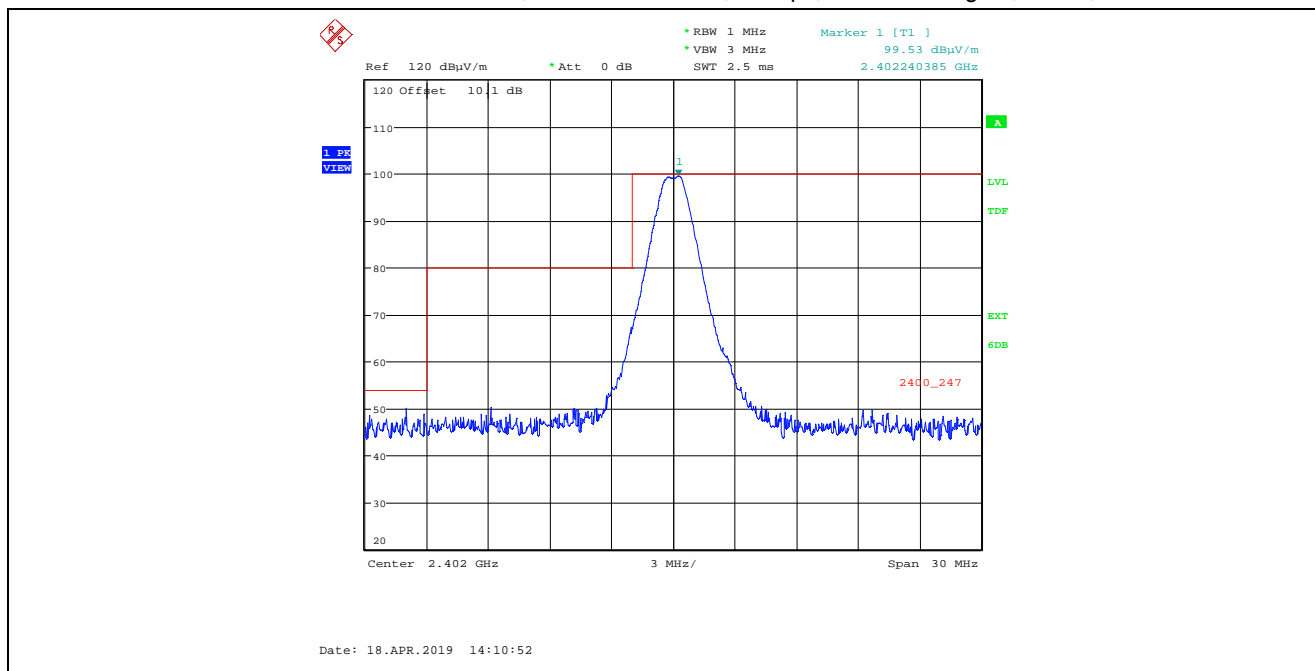
* No spurious component detected.

5.4.4.2. Band-Edge Radiated Emissions

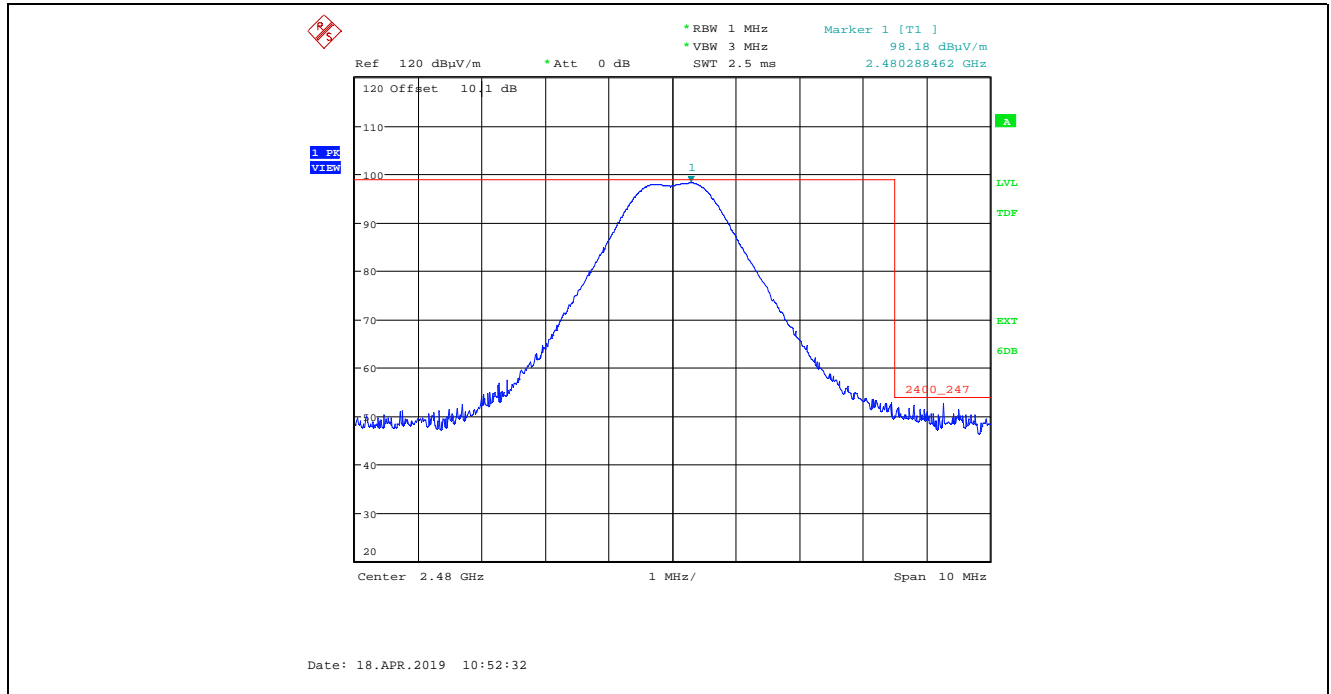
Plot 5.4.4.2.1. Band-Edge Radiated Emissions, Lower Band-edge
Rx Antenna in Vertical Polarization, GFSK Modulation, 1 Mbps, Power Setting 15, Ch 37, 2402 MHz



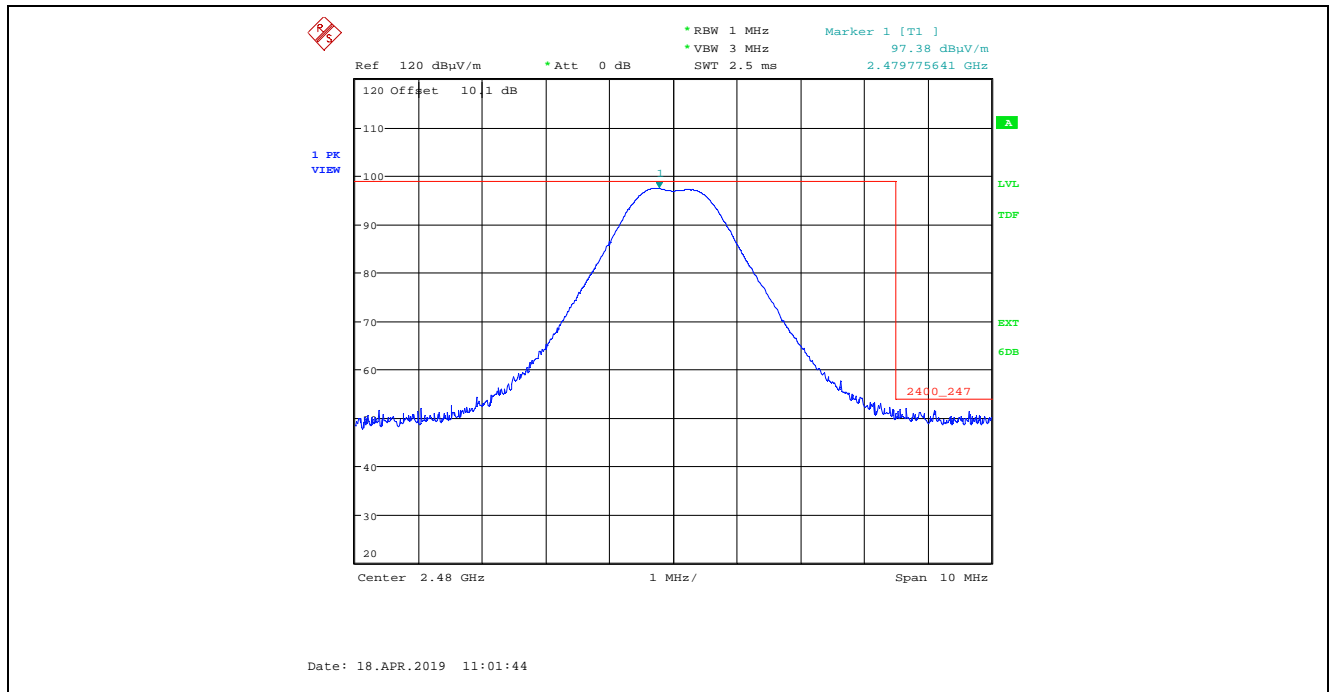
Plot 5.4.4.2.2. Band-Edge Radiated Emissions, Lower Band-edge
Rx Antenna in Horizontal Polarization, GFSK Modulation, 1 Mbps, Power Setting 15, Ch 37, 2402 MHz



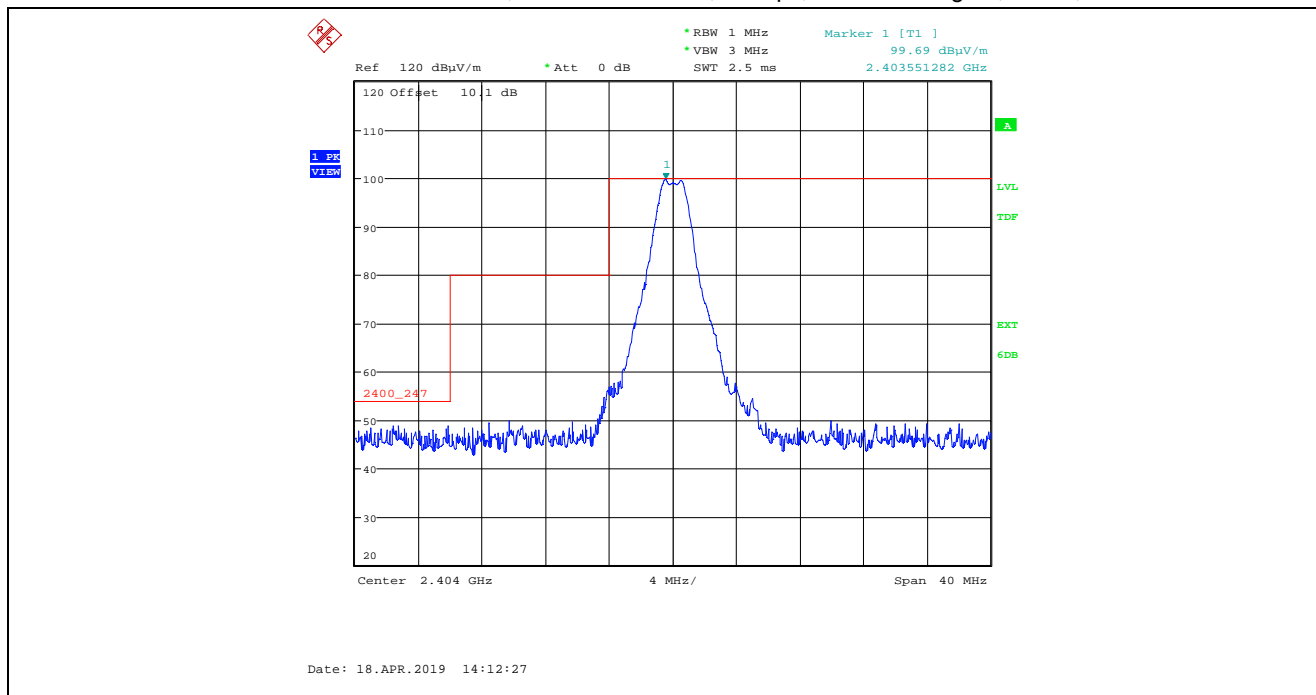
Plot 5.4.4.2.3. Band-Edge Radiated Emissions, Higher Band-edge
Rx Antenna in Vertical Polarization, GFSK Modulation, 1 Mbps, Power Setting 15, Ch 39, 2480 MHz



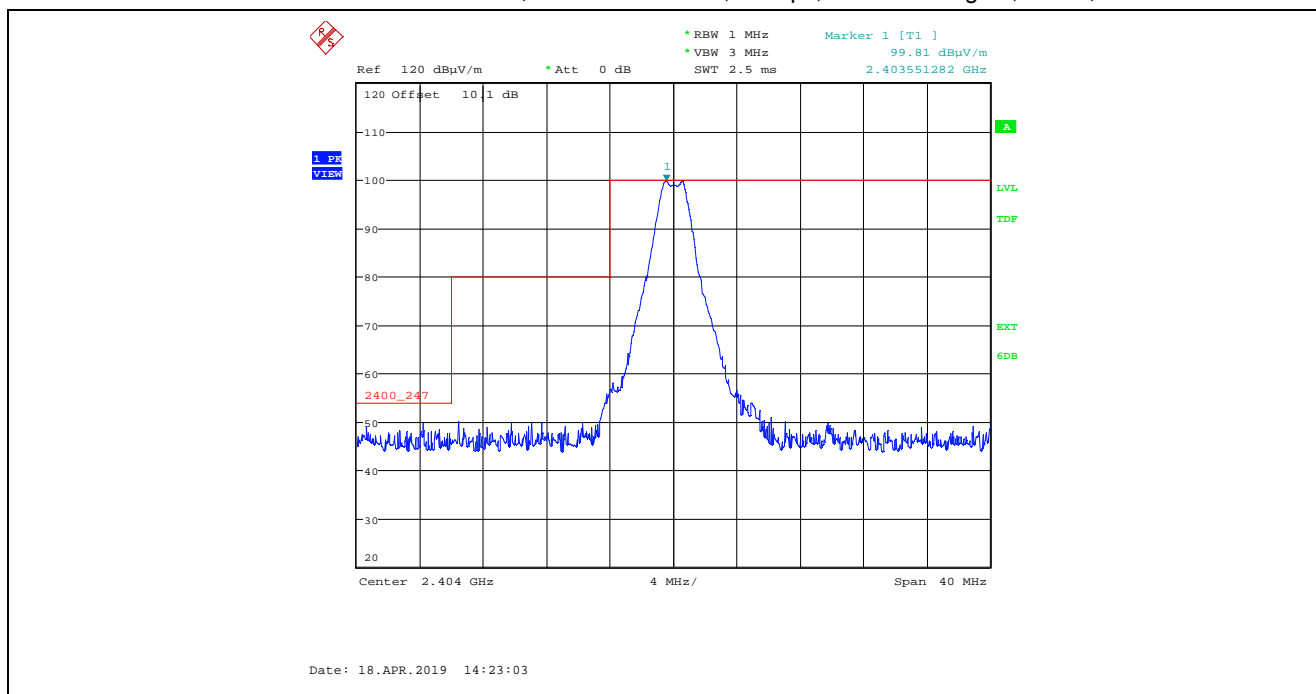
Plot 5.4.4.2.4. Band-Edge Radiated Emissions, Higher Band-edge
Rx Antenna in Horizontal Polarization, GFSK Modulation, 1 Mbps, Power Setting 15, Ch 39, 2480 MHz



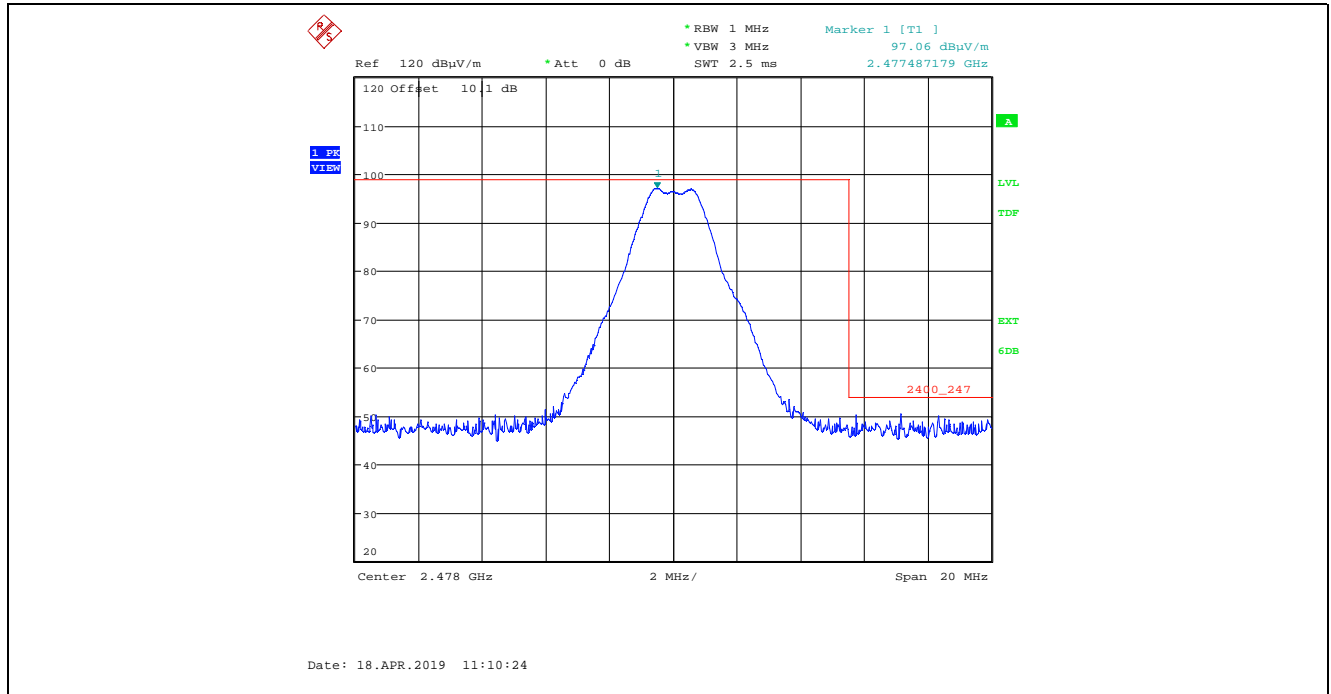
Plot 5.4.4.2.5. Band-Edge Radiated Emissions, Lower Band-edge
 Rx Antenna in Vertical Polarization, GFSK Modulation, 2 Mbps, Power Setting 15, Ch 00, 2404 MHz



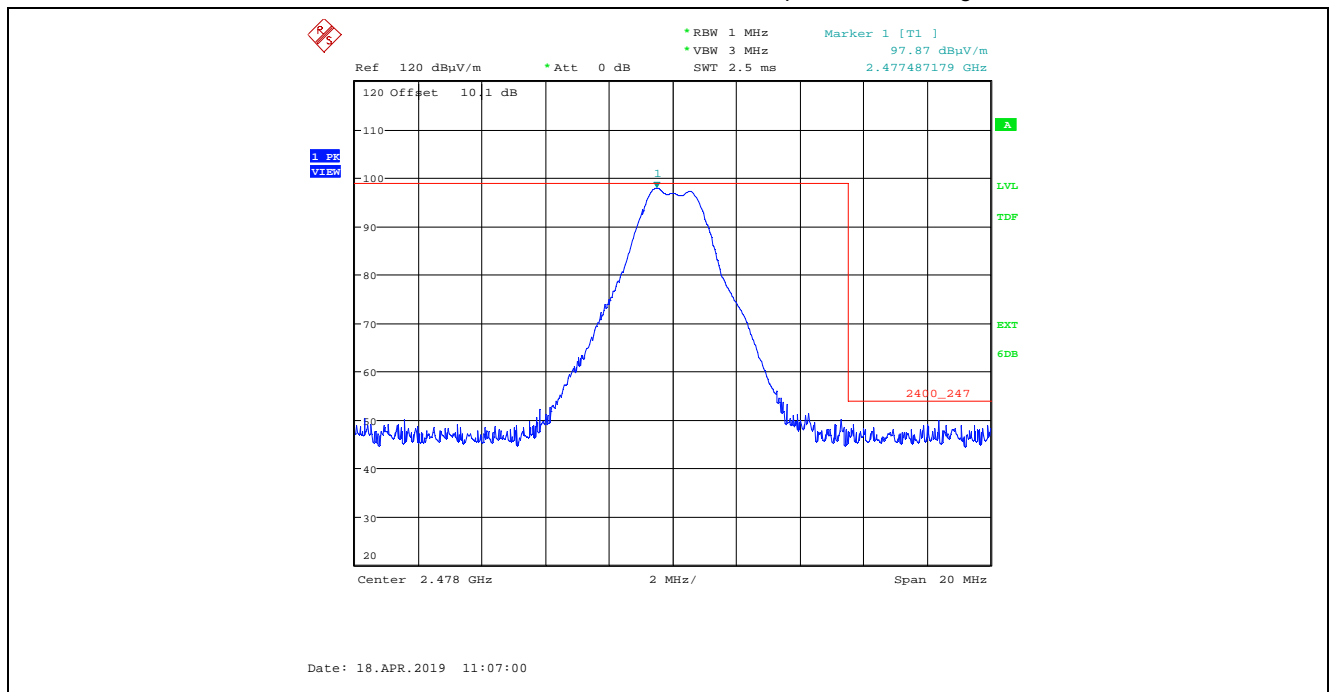
Plot 5.4.4.2.6. Band-Edge Radiated Emissions, Lower Band-edge
 Rx Antenna in Horizontal Polarization, GFSK Modulation, 2 Mbps, Power Setting 15, Ch 00, 2404 MHz



Plot 5.4.4.2.7. Band-Edge Radiated Emissions, Higher Band-edge
Rx Antenna in Vertical Polarization, GFSK Modulation, 2 Mbps, Power Setting 15, Ch 36, 2478 MHz



Plot 5.4.4.2.8. Band-Edge Radiated Emissions, Higher Band-edge
Rx Antenna in Horizontal Polarization, GFSK Modulation, 2 Mbps, Power Setting 15, Ch 36, 2478 MHz



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

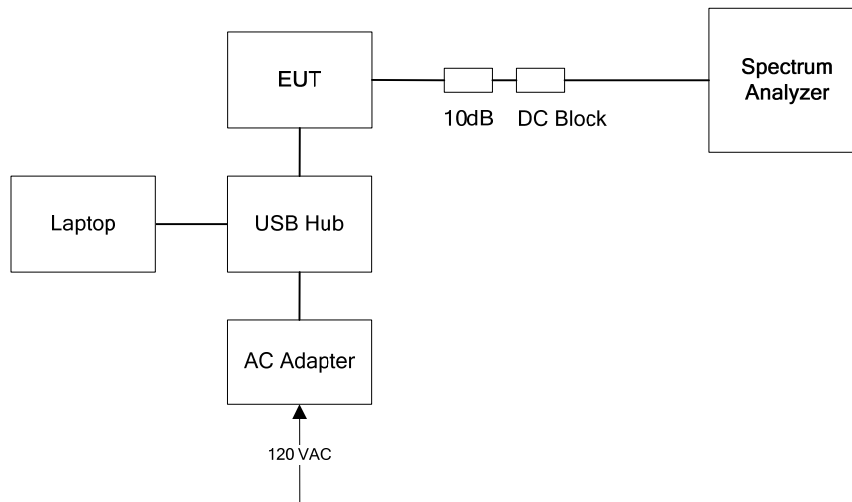
5.5.1. Limit(s)

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 v05r01, Section 8.4 / ANSI C63.10 Subclause 11.10.2 Method PKPSD (peak PSD).

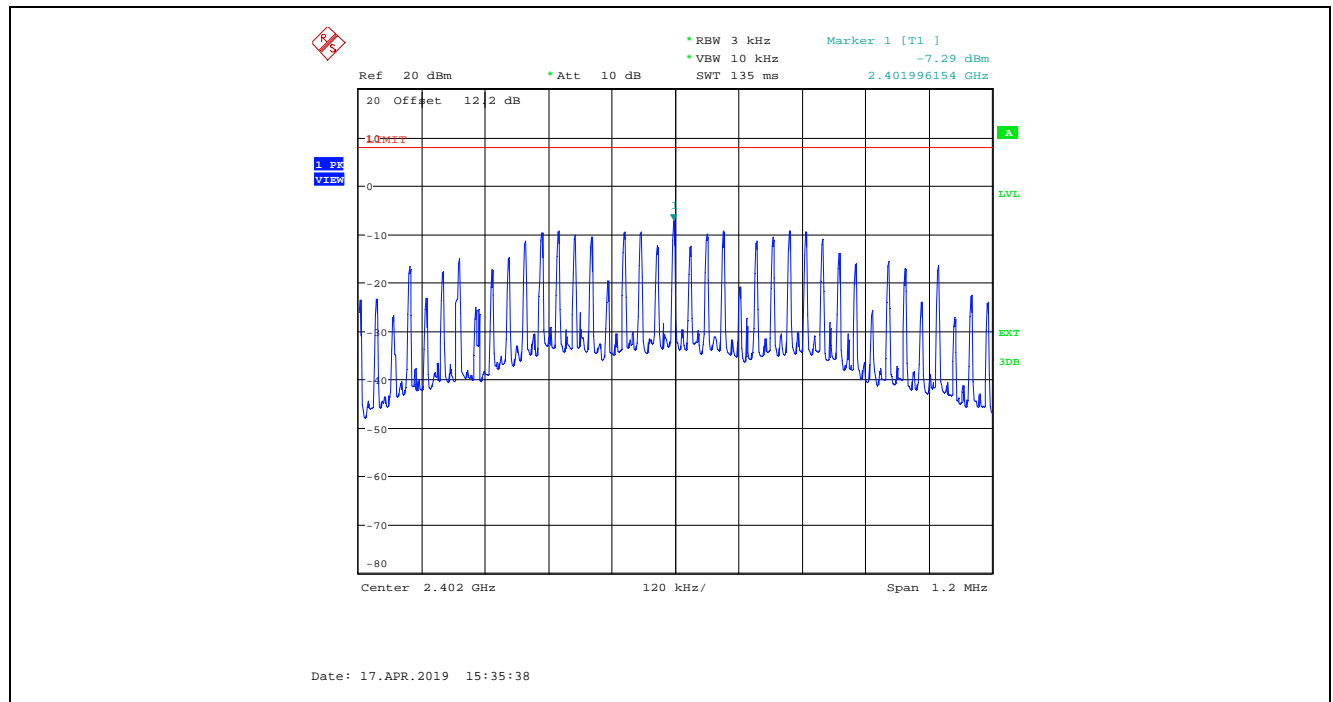
5.5.3. Test Arrangement



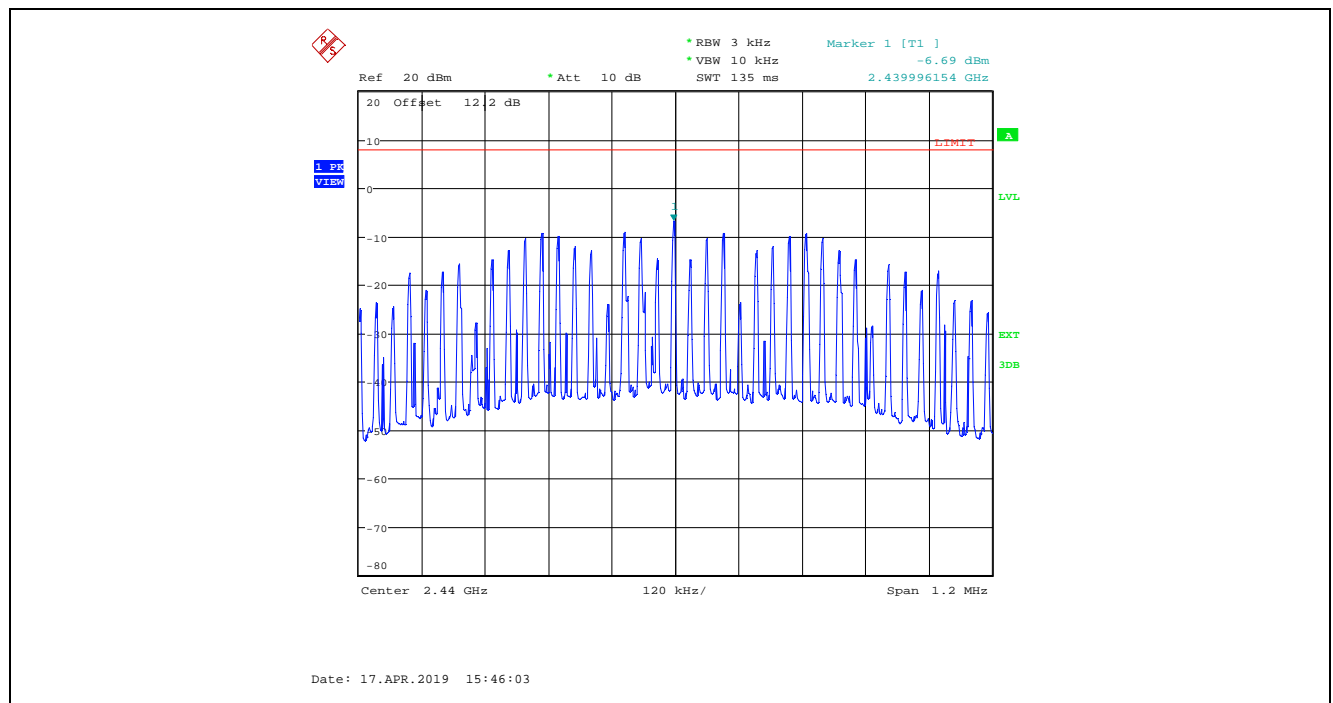
5.5.4. Test Data

| Modulation | Data Rate (Mbps) | Power Setting | Channel | Frequency (MHz) | PSD (dBm) | Max. Limit (dBm) | Margin (dBm) |
|------------|------------------|---------------|---------|-----------------|-----------|------------------|--------------|
| GFSK | 1 | 15 | 37 | 2402 | -7.29 | 8 | -15.29 |
| | | 15 | 17 | 2440 | -6.69 | 8 | -14.69 |
| | | 15 | 39 | 2480 | -5.73 | 8 | -13.73 |
| | 2 | 15 | 0 | 2404 | -6.76 | 8 | -14.76 |
| | | 15 | 17 | 2440 | -6.65 | 8 | -14.65 |
| | | 15 | 36 | 2478 | -6.69 | 8 | -14.69 |

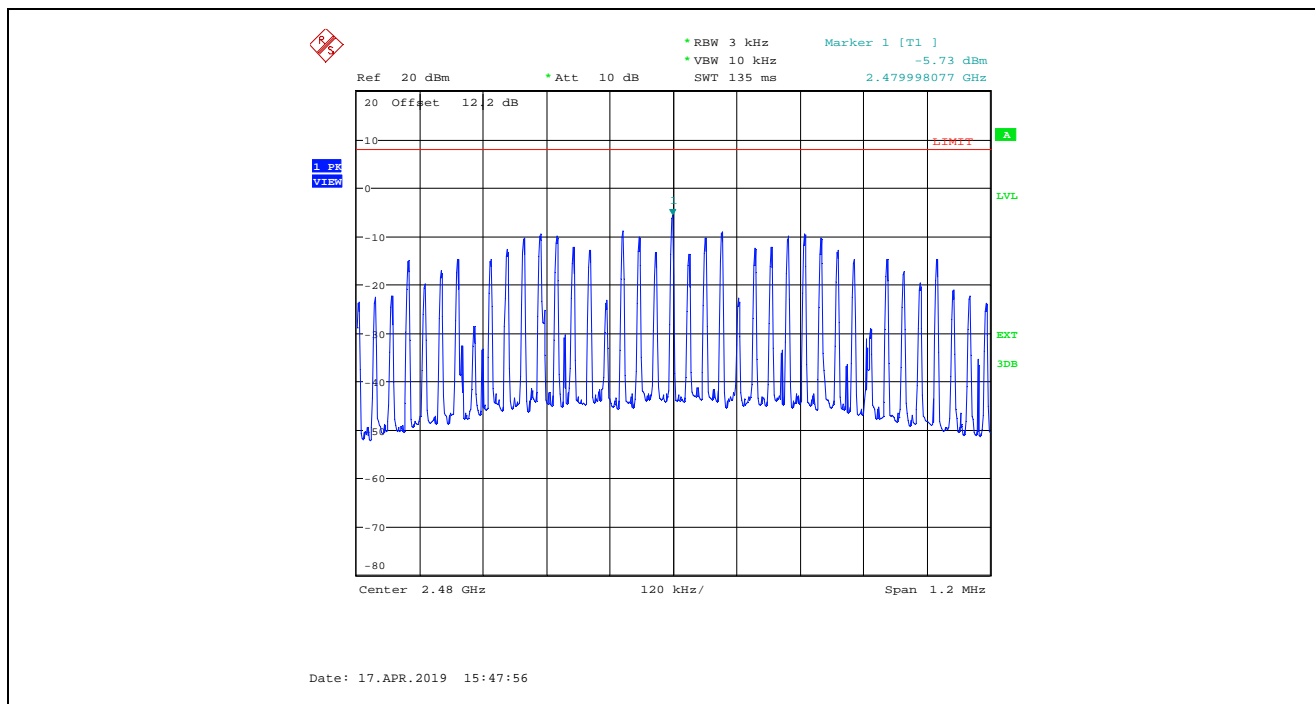
Plot 5.5.4.1. Power Spectral Density, GFSK Modulation, 1 Mbps, Power Setting 15, Channel 37, 2402 MHz



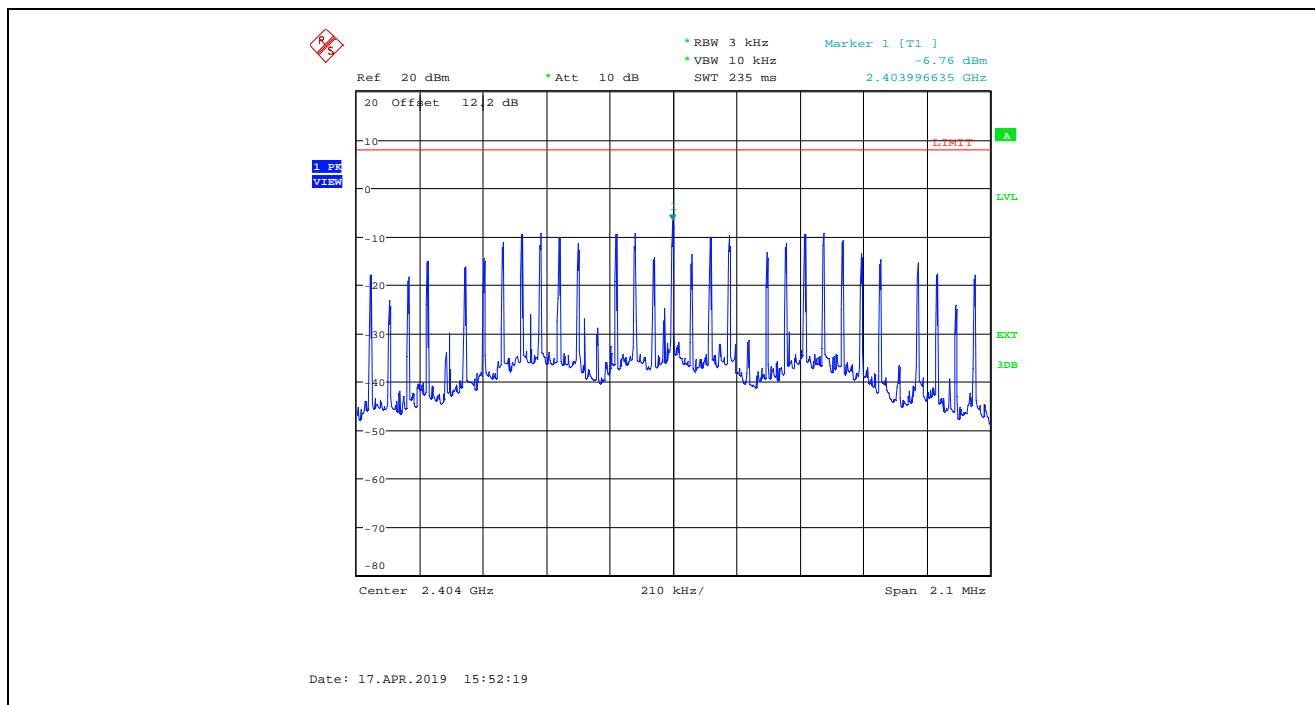
Plot 5.5.4.2. Power Spectral Density, GFSK Modulation, 1 Mbps, Power Setting 15, Channel 17, 2440 MHz



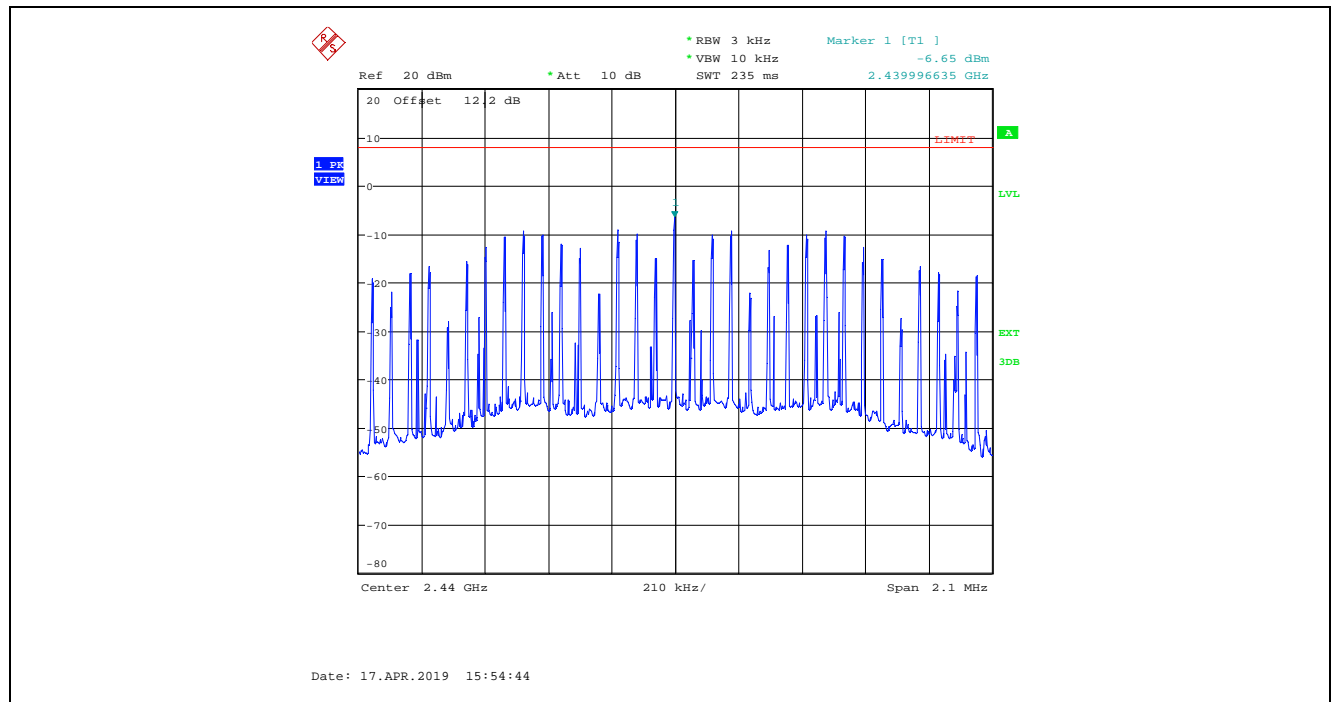
Plot 5.5.4.3. Power Spectral Density, GFSK Modulation, 1 Mbps, Power Setting 15, Channel 39, 2480 MHz



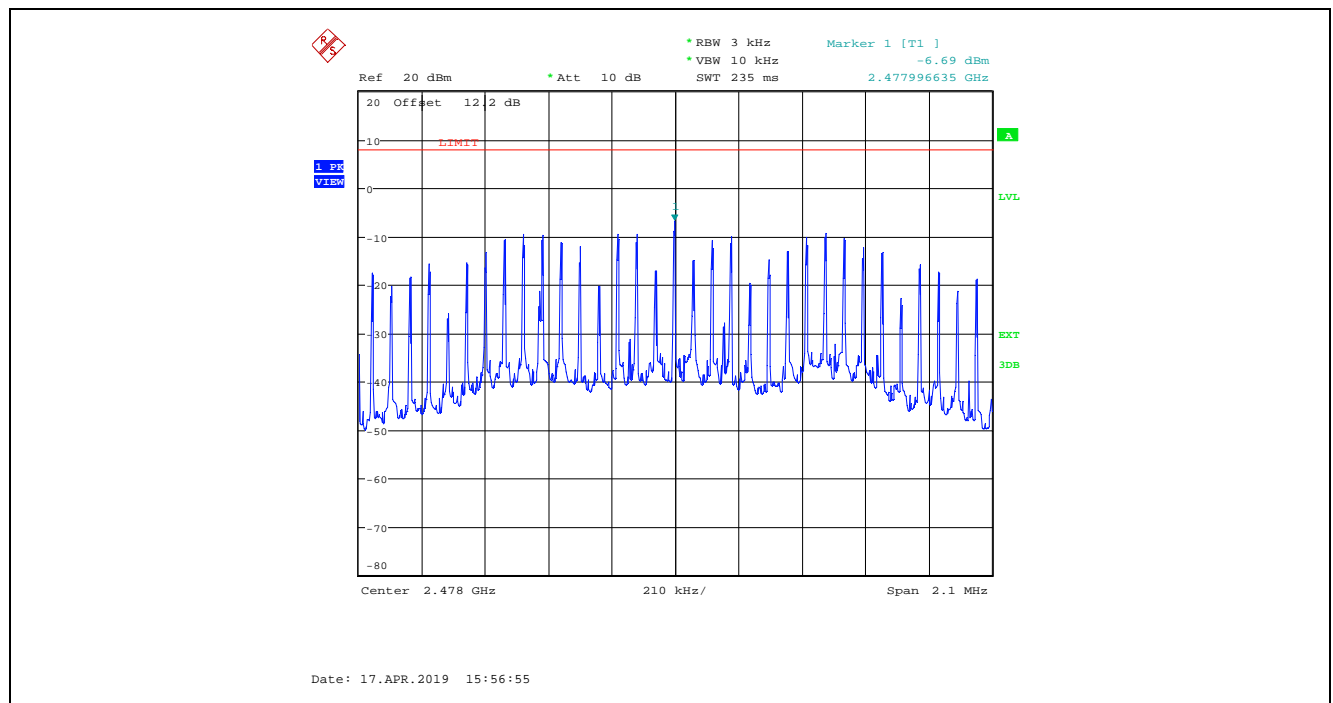
Plot 5.5.4.4. Power Spectral Density, GFSK Modulation, 2 Mbps, Power Setting 15, Channel 00, 2404 MHz



Plot 5.5.4.5. Power Spectral Density, GFSK Modulation, 2 Mbps, Power Setting 15, Channel 17, 2440 MHz



Plot 5.5.4.6. Power Spectral Density, GFSK Modulation, 2 Mbps, Power Setting 15, Channel 36, 2478 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/cm²
 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 | 1.99 | 1.581 | 20 | 0.0003 | 1.0 | 0.0003 |
| Zigbee | 2405-2480 | 2405 | 22.08 | 161.436 | 20 | 0.0321 | 1.0 | 0.0321 |
| 802.11b | 2412-2462 | 2412 | 19.92 | 98.175 | 20 | 0.0195 | 1.0 | 0.0195 |
| 802.11g | 2412-2462 | 2412 | 24.78 | 300.608 | 20 | 0.0598 | 1.0 | 0.0598 |
| 802.11n | 2412-2462 | 2412 | 24.84 | 304.789 | 20 | 0.0606 | 1.0 | 0.0606 |
| Worst Case Combination (Zigbee with WiFi 802.11n mode) : | | | | | | | | 0.0928 |

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3000 Bristol Circle, Oakville, Ontario, Canada L6H 6G4
 Tel. #: 905-829-1570, Fax. #: 905-829-8050, Email: vic@ultratech-labs.com, Website: <http://www.ultratech-labs.com>

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 July 11, 2019

All test results contained in this engineering test report are traceable to National Institute of Standards and Technology (NIST)

EXHIBIT 6. TEST EQUIPMENT LIST

| Test Instruments | Manufacturer | Model No. | Serial No. | Frequency Range | Cal. Due Date |
|---|-----------------|--------------------|--------------|-----------------------|---------------|
| Spectrum Analyzer | Hewlett Packard | HP8593EM | 3710A00223 | 9 kHz–22 GHz | 13 May 2020 |
| Attenuator | Rohde & Schwarz | EZ-25 | 1023.7796.03 | 150 kHz–30 MHz | 07 Jun 2020 |
| LISN Used | EMCO | 3825/2R | 1165 | 150 kHz–30 MHz | 18 Oct 2019 |
| 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 | 15 Mar 2020 |
| RF Amplifier | Com-Power | PAM-0118A | 551052 | 0.5 – 18 GHz | 26 Jul 2019 |
| RF Amplifier | Hewlett Packard | 84498 | 3008A00769 | 1 – 26.5 GHz | 15 May 2020 |
| Biconilog | EMCO | 3142B | 1575 | 26-2000 MHz | 10 May 2020 |
| Horn Antenna | EMCO | 3155 | 6570 | 1 – 18 GHz | 11 Oct 2020 |
| Horn Antenna | ETS-Lindgren | 3160-09 | 001183858 | 18 – 26.5 GHz | 27 Oct 2020 |
| 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 |
| Note 1: Internal Verification/Calibration check | | | | | |

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3000 Bristol Circle, Oakville, Ontario, Canada L6H 6G4
 Tel. #: 905-829-1570, Fax. #: 905-829-8050, Email: vic@ultratech-labs.com, Website: <http://www.ultratech-labs.com>

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 July 11, 2019

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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 |