



## **REGULATORY COMPLIANCE TEST REPORT**

**FCC CFR47 Part 15 SubPart C 15.247**

**ISED RSS-247 Issue 2, February 2017**

**Report No.: TUV R116-U2 Rev C (BLE)**

**Company: SONOS Inc.**

**Model Name: S23**

## REGULATORY COMPLIANCE TEST REPORT

**Company:** Sonos Inc.

**Model Name:** S23

**To:** FCC CFR47 Part 15 Subpart C 15.247 (DTS)  
ISED RSS-247 Issue 2, February 2017

Test Report Serial No.: TUVR116-U2 Rev C (BLE)

This report supersedes: NONE

**Applicant:** Sonos Inc  
614 Chapala St.  
Santa Barbara, California 93101  
USA

Issue Date: 25<sup>th</sup> July 2019

**This Test Report is Issued Under the Authority of:**

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**MiCOM Labs is an ISO 17025 Accredited Testing Laboratory**

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## 1. ACCREDITATION, LISTINGS & RECOGNITION

### 1.1. TESTING ACCREDITATION

MiCOM Labs, Inc. is an accredited Electrical testing laboratory per the international standard ISO/IEC 17025:2005. The company is accredited by the American Association for Laboratory Accreditation (A2LA) [www.a2la.org](http://www.a2la.org) test laboratory number 2381.01. MiCOM Labs test schedule is available at the following URL; <http://www.a2la.org/scopepdf/2381-01.pdf>



## 1.2. RECOGNITION

MiCOM Labs, Inc has widely recognized wireless testing capabilities. Our international recognition includes Conformity Assessment Body designation by APEC MRA countries. MiCOM Labs test reports are accepted globally.

| Country   | Recognition Body                                                                                 | Status | Phase      | Identification No.                      |
|-----------|--------------------------------------------------------------------------------------------------|--------|------------|-----------------------------------------|
| USA       | Federal Communications Commission (FCC)                                                          | TCB    | -          | US0159<br>Listing #: 102167             |
| Canada    | Industry Canada (IC)                                                                             | FCB    | APEC MRA 2 | US0159<br>Listing #: 4143A-2<br>4143A-3 |
| Japan     | MIC (Ministry of Internal Affairs and Communication)                                             | CAB    | APEC MRA 2 | RCB 210                                 |
|           | VCCI                                                                                             | --     | --         | A-0012                                  |
| Europe    | European Commission                                                                              | NB     | EU MRA     | NB 2280                                 |
| Australia | Australian Communications and Media Authority (ACMA)                                             | CAB    | APEC MRA 1 | US0159                                  |
| Hong Kong | Office of the Telecommunication Authority (OFTA)                                                 | CAB    | APEC MRA 1 |                                         |
| Korea     | Ministry of Information and Communication Radio Research Laboratory (RRL)                        | CAB    | APEC MRA 1 |                                         |
| Singapore | Infocomm Development Authority (IDA)                                                             | CAB    | APEC MRA 1 |                                         |
| Taiwan    | National Communications Commission (NCC)<br>Bureau of Standards, Metrology and Inspection (BSMI) | CAB    | APEC MRA 1 |                                         |
| Vietnam   | Ministry of Communication (MIC)                                                                  | CAB    | APEC MRA 1 |                                         |

EU MRA – European Union Mutual Recognition Agreement.

NB – Notified Body

APEC MRA – Asia Pacific Economic Community Mutual Recognition Agreement. Recognition agreement under which test lab is accredited to regulatory standards of the APEC member countries.

Phase I - recognition for product testing

Phase II – recognition for both product testing and certification

### 1.3. PRODUCT CERTIFICATION

MiCOM Labs, Inc. is an accredited Product Certification Body per the international standard ISO/IEC 17065:2012. The company is accredited by the American Association for Laboratory Accreditation (A2LA) [www.a2la.org](http://www.a2la.org) test laboratory number 2381.02. MiCOM Labs test schedule is available at the following URL; <http://www.a2la.org/scopepdf/2381-02.pdf>



United States of America – Telecommunication Certification Body (TCB)  
Industry Canada – Certification Body, CAB Identifier – US0159  
Europe – Notified Body (NB), NB Identifier - 2280  
Japan – Recognized Certification Body (RCB), RCB Identifier - 210

## 2. DOCUMENT HISTORY

| Document History |                            |                                                               |
|------------------|----------------------------|---------------------------------------------------------------|
| Revision         | Date                       | Comments                                                      |
| Draft            | 3 <sup>rd</sup> May 2019   | Initial Draft                                                 |
| Rev A            | 20 <sup>th</sup> May 2019  | Initial Release                                               |
| Rev B            | 16 <sup>th</sup> July 2019 | Client required modification to Section 5.1 Technical Details |
| Rev C            | 25 <sup>th</sup> July 2019 | Client requested change to Section 5.6 Cabling and I/O Ports  |
| .                |                            |                                                               |
| .                |                            |                                                               |
| .                |                            |                                                               |

In the above table the latest report revision will replace all earlier versions.

### 3. TEST RESULT CERTIFICATE

|                                                                                            |                                                                                               |
|--------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------|
| <b>Manufacturer:</b> Sonos Inc<br>614 Chapala St.<br>Santa Barbara California 93101<br>USA | <b>Tested By:</b> MiCOM Labs, Inc.<br>575 Boulder Court<br>Pleasanton California 94566<br>USA |
| <b>Model:</b> S23                                                                          | <b>Telephone:</b> +1 925 462 0304                                                             |
| <b>Type Of Equipment:</b> Home Audio Equipment                                             | <b>Fax:</b> +1 925 462 0306                                                                   |
| <b>S/N's:</b> 48A6B820046C5, 48A6B820046E7                                                 |                                                                                               |
| <b>Test Date(s):</b> 29 <sup>th</sup> April – 2 <sup>nd</sup> May 2019                     | <b>Website:</b> www.micomlabs.com                                                             |

| STANDARD(S)                                                                | TEST RESULTS       |
|----------------------------------------------------------------------------|--------------------|
| FCC CFR 47 Part 15 Subpart C 15.247 (DTS)<br>ISED RSS-247 Issue 2<br>(BLE) | EQUIPMENT COMPLIES |

MiCOM Labs, Inc. tested the equipment mentioned in accordance with the requirements set forth in the above standards. Test results indicate that the equipment tested is capable of demonstrating compliance with the requirements as documented within this report.

#### Notes:

1. This document reports conditions under which testing was conducted and the results of testing performed.
2. Details of test methods used have been recorded and kept on file by the laboratory.
3. Test results apply only to the item(s) tested.

Approved & Released for MiCOM Labs, Inc. by:



Graeme Grieve  
Quality Manager MiCOM Labs, Inc.

Gordon Hurst  
President & CEO MiCOM Labs, Inc.



## 4. REFERENCES AND MEASUREMENT UNCERTAINTY

### 4.1. Normative References

| REF. | PUBLICATION            | YEAR                       | TITLE                                                                                                                                                                                                 |
|------|------------------------|----------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| I    | KDB 662911 D01 & D02   | Oct 31 2013                | Guidance for measurement of output emission of devices that employ single transmitter with multiple outputs or systems with multiple transmitters operating simultaneously in the same frequency band |
| II   | KDB 558074 D01 v05     | 24th August 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.             |
| III  | A2LA                   | August 2018                | R105 - Requirement's When Making Reference to A2LA Accreditation Status                                                                                                                               |
| IV   | ANSI C63.10            | 2013                       | American National Standard for Testing Unlicensed Wireless Devices                                                                                                                                    |
| V    | ANSI C63.4             | 2014                       | American National Standards for Methods of Measurement of Radio-Noise Emissions from Low-Voltage Electrical and Electronic Equipment in the Range of 9 kHz to 40 GHz                                  |
| VI   | CISPR 32               | 2015                       | Electromagnetic compatibility of multimedia equipment - Emission requirements                                                                                                                         |
| VII  | ETSI TR 100 028        | 2001-12                    | Parts 1 and 2 Electromagnetic compatibility and Radio Spectrum Matters (ERM); Uncertainties in the measurement of mobile radio equipment characteristics                                              |
| VIII | FCC 47 CFR Part 15.247 | 2016                       | Radio Frequency Devices; Subpart C – Intentional Radiators                                                                                                                                            |
| IX   | ICES-003               | Issue 5 March 2019         | Information Technology Equipment (Including Digital Apparatus) – Limits and methods of measurement.                                                                                                   |
| X    | M 3003                 | Edition 3 Nov.2012         | Expression of Uncertainty and Confidence in Measurements                                                                                                                                              |
| XI   | RSS-247 Issue 2        | Feb 2017                   | Digital Transmission Systems (DTSs), Frequency Hopping System (FHSs) and Licence-Exempt Local Area Network (LE-LEN) Devices                                                                           |
| XII  | RSS-Gen Issue 5        | April 2018                 | General Requirements for Compliance of Radio Apparatus                                                                                                                                                |
| XIII | FCC 47 CFR Part 2.1033 | 2016                       | FCC requirements and rules regarding photographs and test setup diagrams.                                                                                                                             |
| XIV  | KDB 789033 D02 V02r01  | 14th December, 2017        | Guidelines For Compliance Testing Of Unlicensed National Information Infrastructure (U-NII) Devices Part 15, Subpart E                                                                                |
| XV   | 15.207                 | 28 <sup>th</sup> June 2019 | Conducted limits                                                                                                                                                                                      |

## **4.2. Test and Uncertainty Procedure**

Conducted and radiated emission measurements were conducted in accordance with American National Standards Institute ANSI C63.4, listed in the Normative References section of this report.

Measurement uncertainty figures are calculated in accordance with ETSI TR 100 028 Parts 1 and 2.

Measurement uncertainties stated are based on a standard uncertainty multiplied by a coverage factor  $k = 2$ , providing a level of confidence of approximately 95 % in accordance with UKAS document M 3003 listed in the Normative References section of this report.

## 5. PRODUCT DETAILS AND TEST CONFIGURATIONS

### 5.1. Technical Details

| Details                              | Description                                                                                                                                                                                                                                                                                     |
|--------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Purpose:                             | Test of the Sonos Inc S23 to:<br>FCC CFR 47 Part 15 Subpart C 15.247 (DTS).<br>Radio Frequency Devices; Subpart C – Intentional Radiators<br>ISED RSS-247<br>Digital Transmission Systems (DTSS), Frequency Hopping<br>System (FHSS) and Licence-Exempt Local Area Network (LE-<br>LEN) Devices |
| Applicant:                           | Sonos Inc<br>614 Chapala St.<br>Santa Barbara California 93101 USA                                                                                                                                                                                                                              |
| Manufacturer:                        | Sonos Inc                                                                                                                                                                                                                                                                                       |
| Laboratory performing the tests:     | MiCOM Labs, Inc.<br>575 Boulder Court<br>Pleasanton California 94566 USA                                                                                                                                                                                                                        |
| Test report reference number:        | TUV116-U2                                                                                                                                                                                                                                                                                       |
| Date EUT received:                   | 22 <sup>nd</sup> April 2019                                                                                                                                                                                                                                                                     |
| Standard(s) applied:                 | FCC CFR 47 Part 15 Subpart C 15.247 (DTS)                                                                                                                                                                                                                                                       |
| Dates of test (from - to):           | 29 <sup>th</sup> April – 2 <sup>nd</sup> May 2019                                                                                                                                                                                                                                               |
| No of Units Tested:                  | 2                                                                                                                                                                                                                                                                                               |
| Product Family Name:                 | N/A                                                                                                                                                                                                                                                                                             |
| Model(s):                            | S23                                                                                                                                                                                                                                                                                             |
| Location for use:                    | Indoors                                                                                                                                                                                                                                                                                         |
| Declared Frequency Range(s):         | 2400 - 2483.5 MHz;                                                                                                                                                                                                                                                                              |
| Type of Modulation:                  | GFSK                                                                                                                                                                                                                                                                                            |
| EUT Modes of Operation:              | BLE                                                                                                                                                                                                                                                                                             |
| Declared Nominal Output Power (dBm): | 0 dBm                                                                                                                                                                                                                                                                                           |
| Transmit/Receive Operation:          | Transceiver                                                                                                                                                                                                                                                                                     |
| Rated Input Voltage and Current:     | 12Vdc 1A                                                                                                                                                                                                                                                                                        |
| Operating Temperature Range:         | 0°C - 40°C                                                                                                                                                                                                                                                                                      |
| ITU Emission Designator:             | 1M2G1D                                                                                                                                                                                                                                                                                          |
| Hardware Rev:                        | A100                                                                                                                                                                                                                                                                                            |
| Firmware Ver:                        | See Software Rev.                                                                                                                                                                                                                                                                               |
| Software Rev:                        | 52.10-64150-1-29                                                                                                                                                                                                                                                                                |

## 5.2. Scope Of Test Program

### Sonos Inc S23

The scope of the test program was to test the Sonos Inc S23 configurations in the frequency ranges 2400 - 2483.5 MHz; for compliance against the following specifications:

### FCC CFR 47 Part 15 Subpart C 15.247 (DTS)

Radio Frequency Devices; Subpart C – Intentional Radiators

### ISSED RSS-247 Issue 2

Digital Transmission Systems (DTSs), Frequency Hopping System (FHSs) and Licence-Exempt Local Area Network (LE-LEN) Devices

## 5.3. Equipment Model(s) and Serial Number(s)

| Type (EUT/Support) | Equipment Description | Mfr        | Model No.  | Serial No.    |
|--------------------|-----------------------|------------|------------|---------------|
| EUT                | Home Audio Equipment  | SONOS Inc. | S23        | 48A6B820046C5 |
| EUT                | Home Audio Equipment  | SONOS Inc. | S23        | 48A6B820046E7 |
| EUT                | Power Supply          | SONOS Inc  | CPS012027U |               |
| Support            | Laptop                | Lenovo     | X230       |               |

## 5.4. External A.C/D.C. Power Adaptor

| AC/DC Adaptor                                                                                                        |
|----------------------------------------------------------------------------------------------------------------------|
| Manufacturer: SONOS<br>Model: CPS012027U<br>I: 100 – 240 V <sub>AC</sub> , 50/60 Hz<br>O: +12 V <sub>DC</sub> 1.00 A |

## 5.5. Antenna Details

| Type                                                                                       | Manufacturer | Model | Family | Gain (dBi) | BF Gain | Dir BW | X-Pol | Frequency Band (MHz) |
|--------------------------------------------------------------------------------------------|--------------|-------|--------|------------|---------|--------|-------|----------------------|
| integral                                                                                   | Welshin      | --    | PIFA   | 3.3        | N/A     | 360°   | N/A   | 2400 - 2483.5        |
| BF Gain - Beamforming Gain<br>Dir BW - Directional BeamWidth<br>X-Pol - Cross Polarization |              |       |        |            |         |        |       |                      |

## 5.6. Cabling and I/O Ports

| Port Type        | Max Cable Length | # of Ports | Conn Type | Data Type | Bit Rate    | Environment |
|------------------|------------------|------------|-----------|-----------|-------------|-------------|
| ENET             | >10m             | 2          | No        | Conn Type | 10,100,1000 |             |
| DC               | 1m               | 1          |           |           |             |             |
| Other Port Type* |                  | *          | *         | *         |             |             |

\*This port(s) is fully described in the technical documentation included in the related FCC and ISSED filings.

## 5.7. Test Configurations

Results for the following configurations are provided in this report:

| Results for the following configurations are provided in this report: |                                        |                         |         |          |
|-----------------------------------------------------------------------|----------------------------------------|-------------------------|---------|----------|
| Operational Mode(s)<br>(802.11a/b/g/n/ac)                             | Data Rate with Highest Power<br>MBit/s | Channel Frequency (MHz) |         |          |
|                                                                       |                                        | Low                     | Mid     | High     |
| 2400 - 2483.5 MHz                                                     |                                        |                         |         |          |
| BLE                                                                   | 1                                      | 2,402.00                | 2426.00 | 2,480.00 |

## 5.8. Equipment Modifications

The following modifications were required to bring the equipment into compliance:

1. NONE

## 5.9. Deviations from the Test Standard

The following deviations from the test standard were required in order to complete the test program:

1. NONE

## 6. TEST SUMMARY

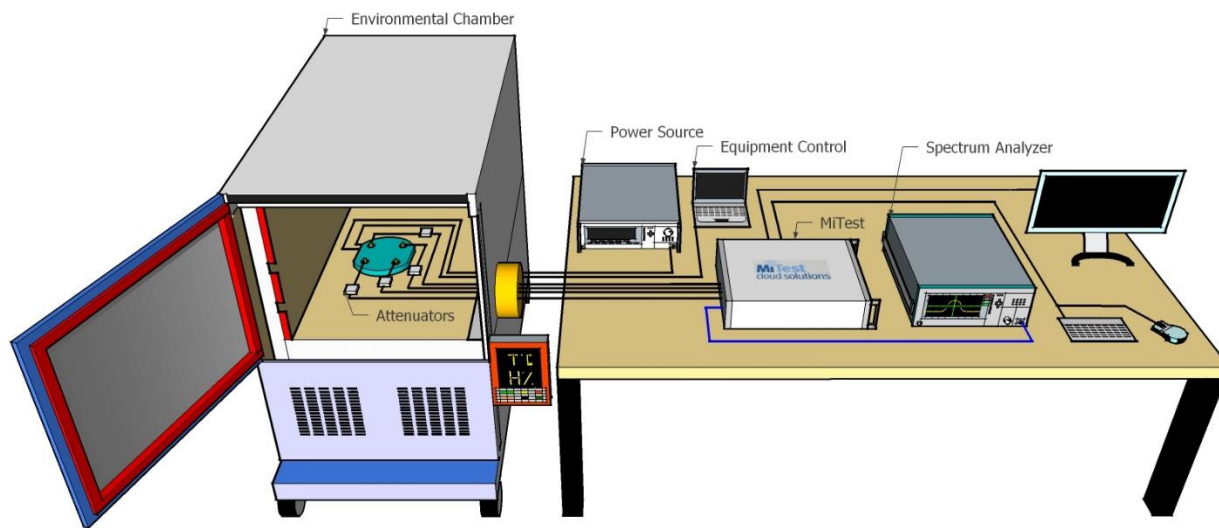
### List of Measurements

| Test Header                                 | Result                       | Data Link                 |
|---------------------------------------------|------------------------------|---------------------------|
| 6 dB & 99% Bandwidth                        | Complies                     | <a href="#">View Data</a> |
| Conducted Output Power                      | Complies                     | <a href="#">View Data</a> |
| Power Spectral Density                      | Complies                     | <a href="#">View Data</a> |
| Emissions                                   | Complies                     | -                         |
| (1) Conducted Emissions                     | Complies                     | -                         |
| (i) Conducted Spurious Emissions            | Complies                     | <a href="#">View Data</a> |
| (ii) Conducted Band-Edge Emissions          | Complies                     | <a href="#">View Data</a> |
| (2) Radiated Emissions                      | Complies                     | -                         |
| (i) TX Spurious & Restricted Band Emissions | Complies                     | <a href="#">View Data</a> |
| (ii) Restricted Edge & Band-Edge Emissions  | Complies                     | <a href="#">View Data</a> |
| (3) Digital Emissions (0.03 - 1 GHz)        | Complies                     | <a href="#">View Data</a> |
| (4) AC Wireline Emissions                   | Complies                     | <a href="#">View Data</a> |
| RF Unique Connector                         | Complies (Integral Antennas) | -                         |

## 7. TEST EQUIPMENT CONFIGURATION(S)

### 7.1. Conducted Test Setup

MiTest Automated Test System



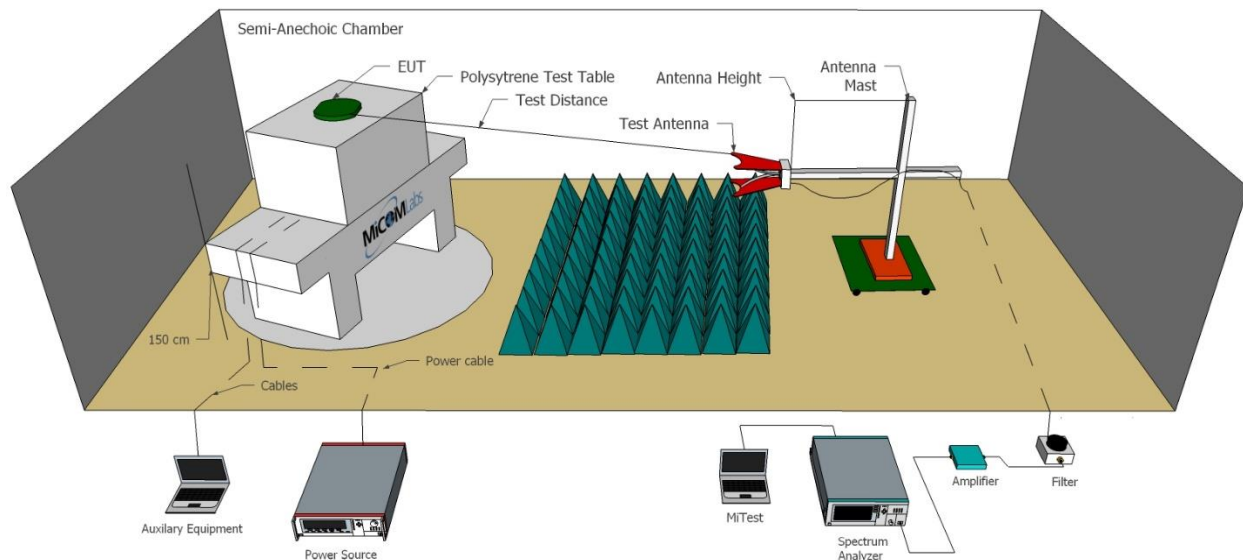
A full system calibration was performed on the test station and any resulting system losses (or gains) were considered in the production of all final measurement data.

| Asset# | Description                                    | Manufacturer         | Model#      | Serial#       | Calibration Due Date |
|--------|------------------------------------------------|----------------------|-------------|---------------|----------------------|
| 249    | Resistance Thermometer                         | Thermotronics        | GR2105-02   | 9340 #2       | 30 Oct 2019          |
| 361    | Desktop for RF#1, Labview Software installed   | Dell                 | Vostro 220  | WS RF#1       | Not Required         |
| 378    | Rohde & Schwarz 40 GHz Receiver with Generator | Rhode & Schwarz      | ESIB40      | 100107/040    | 12 Oct 2019          |
| 405    | DC Power Supply 0-60V                          | Agilent              | 6654A       | MY4001826     | Cal when used        |
| 408    | USB to GPIB interface                          | National Instruments | GPIB-USB HS | 14C0DE9       | Not Required         |
| 445    | PoE Injector                                   | D-Link               | DPE-101GL   | QTAH1E2000625 | Not Required         |
| 461    | Spectrum Analyzer                              | Agilent              | E4440A      | MY46185537    | 20 Sep 2019          |
| 510    | Barometer/Thermometer                          | Control Company      | 68000-49    | 170871375     | 11 Dec 2019          |
| 75     | Environmental Chamber                          | Thermatron           | SE-300-2-2  | 27946         | 24 Feb 2020          |

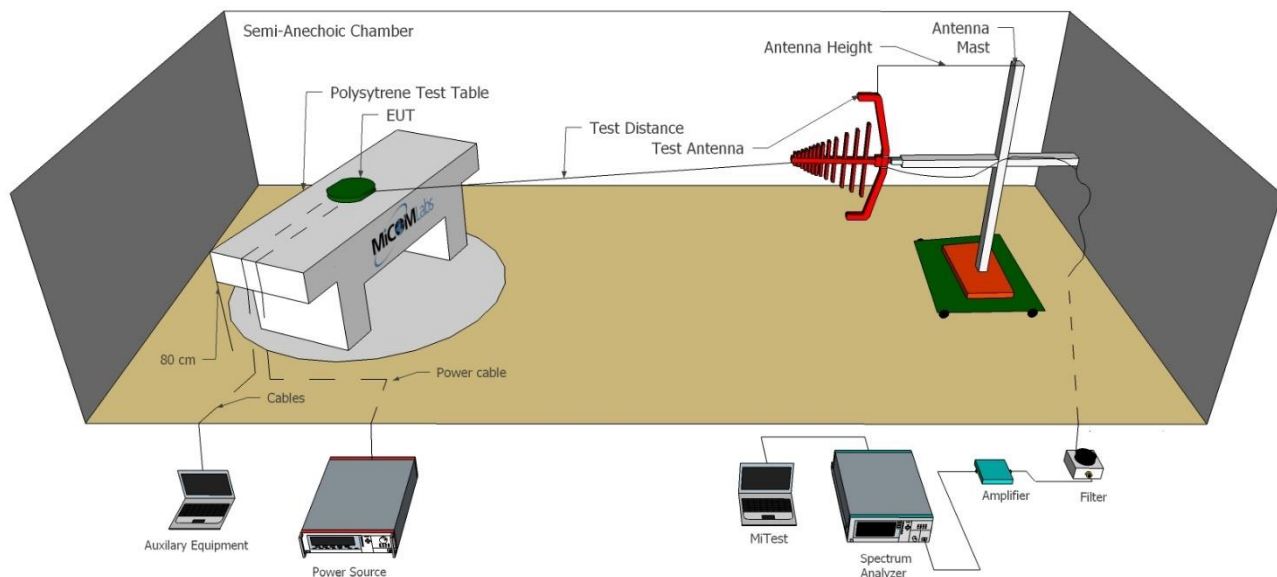
## 7.2. Radiated Emissions - 3m Chamber

The following tests were performed using the radiated test set-up shown in the diagram below.  
Radiated emissions above and below 1GHz.

Radiated Emissions Above 1GHz Test Setup



Radiated Emissions Below 1GHz Test Setup



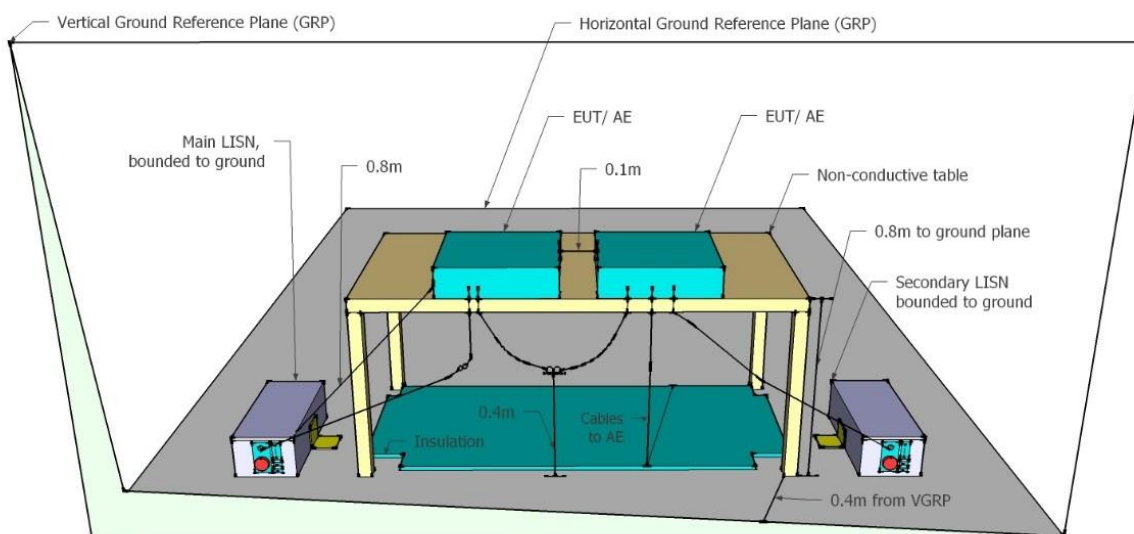


A full system calibration was performed on the test station and any resulting system losses (or gains) were considered in the production of all final measurement data.

| Asset# | Description                                       | Manufacturer         | Model#                                  | Serial#     | Calibration Due Date |
|--------|---------------------------------------------------|----------------------|-----------------------------------------|-------------|----------------------|
| 170    | Video System Controller for Semi Anechoic Chamber | Panasonic            | WV-CU101                                | 04R08507    | Not Required         |
| 298    | 3M Radiated Emissions Chamber Maintenance Check   | MiCOM                | 3M Chamber                              | 298         | 21 Apr 2020          |
| 336    | Active Loop Antenna                               | Emco                 | 6502                                    | 00060498    | 29 Nov 2019          |
| 338    | Sunol 30 to 3000 MHz Antenna                      | Sunol                | JB3                                     | A052907     | 4 Apr 2020           |
| 378    | Rohde & Schwarz 40 GHz Receiver with Generator    | Rhode & Schwarz      | ESIB40                                  | 100107/040  | 12 Oct 2019          |
| 397    | Amp 10 - 2500MHz                                  | MiCOM Labs           | Amp 10 - 2500 MHz                       | NA          | 12 Apr 2020          |
| 399    | ETS 1-18 GHz Horn Antenna                         | ETS                  | 3117                                    | 00154575    | 12 Oct 2019          |
| 406    | Amplifier for Radiated Emissions                  | MiCOM Labs           | 40dB 1 to 18GHz Amp                     | 0406        | 12 Apr 2020          |
| 410    | Desktop Computer                                  | Dell                 | Inspiron 620                            | WS38        | Not Required         |
| 411    | Mast/Turntable Controller                         | Sunol Sciences       | SC98V                                   | 060199-1D   | Not Required         |
| 412    | USB to GPIB Interface                             | National Instruments | GPIB-USB HS                             | 11B8DC2     | Not Required         |
| 413    | Mast Controller                                   | Sunol Science        | TWR95-4                                 | 030801-3    | Not Required         |
| 415    | Turntable Controller                              | Sunol Sciences       | Turntable Controller                    | None        | Not Required         |
| 416    | Gigabit ethernet filter                           | ETS-Lingren          | Gigafoil 260366                         | None        | Not Required         |
| 447    | MiTest Rad Emissions Test Software                | MiCOM                | Rad Emissions Test Software Version 1.0 | 447         | Not Required         |
| 462    | Schwarzbeck cable from Antenna to Amplifier.      | Schwarzbeck          | AK 9513                                 | 462         | 9 Oct 2019           |
| 463    | Schwarzbeck cable from Amplifier to Bulkhead.     | Schwarzbeck          | AK 9513                                 | 463         | 9 Oct 2019           |
| 464    | Schwarzbeck cable from Bulkhead to Receiver       | Schwarzbeck          | AK 9513                                 | 464         | 9 Oct 2019           |
| 465    | Low Pass Filter DC-1000 MHz                       | Mini-Circuits        | NLP-1200+                               | VUU01901402 | 9 Oct 2019           |
| 480    | Cable - Bulkhead to Amp                           | SRC Haverhill        | 157-3050360                             | 480         | 24 Aug 2019          |
| 481    | Cable - Bulkhead to Receiver                      | SRC Haverhill        | 151-3050787                             | 481         | 24 Aug 2019          |
| 510    | Barometer/Thermometer                             | Control Company      | 68000-49                                | 170871375   | 11 Dec 2019          |
| 518    | Cable - Amp to Antenna                            | SRC Haverhill        | 157-3051574                             | 518         | 24 Aug 2019          |

### 7.3. ac Wireline Emissions

#### Test Setup – Power Input / Output Port



A full system calibration was performed on the test station and any resulting system losses (or gains) were taken into account in the production of all final measurement data.

| Asset# | Description                                   | Manufacturer           | Model#                      | Serial#     | Calibration Due Date |
|--------|-----------------------------------------------|------------------------|-----------------------------|-------------|----------------------|
| 184    | Pulse Limiter                                 | Rhode & Schwarz        | ESH3Z2                      | 357.8810.52 | 6 Oct 2019           |
| 190    | LISN (two-line V-network)                     | Rhode & Schwarz        | ESH3Z5                      | 836679/006  | 18 Oct 2019          |
| 287    | Rohde & Schwarz 40 GHz Receiver               | Rhode & Schwarz        | ESIB40                      | 100201      | 2 Jul 2019           |
| 295    | Conducted Emissions Chamber Maintenance Check | MiCOM                  | Conducted Emissions Chamber | 295         | 19 Jun 2019          |
| 307    | BNC-CABLE                                     | Megaphase              | 1689 1GVT4                  | 15F50B002   | 11 Jun 2019          |
| 316    | Dell desktop computer workstation             | Dell                   | Desktop                     | WS04        | Not Required         |
| 372    | AC Variable PS                                | California Instruments | 1251P                       | L06951      | Cal when used        |
| 388    | LISN (3 Phase) 9kHz - 30MHz                   | Rohde & Schwarz        | ESH2-Z5                     | 892107/022  | 20 Oct 2019          |
| 496    | MiTest Conducted Emissions test software.     | MiCOM                  | Test Software Version 1.0   | 496         | Not Required         |
| 510    | Barometer/Thermometer                         | Control Company        | 68000-49                    | 170871375   | 11 Dec 2019          |

## 8. MEASUREMENT AND PRESENTATION OF TEST DATA

The measurement and graphical data presented in this test report was generated automatically using state-of-the-art technology creating an easy to read report structure. Numerical measurement data is separated from supporting graphical data (plots) through hyperlinks. Numerical measurement data can be reviewed without scrolling through numerous graphical pages to arrive at the next data matrix.

Plots have been relegated into the Appendix 'Graphical Data'.

Test and report automation was performed by [MiTest](#). [MiTest](#) is an automated test system developed by MiCOM Labs. [MiTest](#) is the first cloud based modular test system enabling end-to-end automation of regulatory compliance testing for conducted RF testing.



The Patented MiCOM Labs “[MiTest](#)” Automated Test System“

## 9. TEST RESULTS

### 9.1. 6 dB & 99% Bandwidth

| Conducted Test Conditions for 6 dB and 99% Bandwidth                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                                |                     |             |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------|---------------------|-------------|
| Standard:                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | FCC CFR 47:15.247<br>RSS-247   | Ambient Temp. (°C): | 24.0 - 27.5 |
| Test Heading:                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | 6 dB and 99 % Bandwidth        | Rel. Humidity (%):  | 32 - 45     |
| Standard Section(s):                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | 15.247 (a)(2)<br>RSS-247 5.2 a | Pressure (mBars):   | 999 - 1001  |
| Reference Document(s):                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | See Normative References       |                     |             |
| <p>Test Procedure for 6 dB and 99% Bandwidth Measurement</p> <p>The bandwidth at 6 dB and 99 % was measured with a spectrum analyzer connected to the antenna terminal, while EUT is operating in transmission mode at the appropriate center frequency.</p> <p>Testing was performed under ambient conditions at nominal voltage. Where the device operated with multiple antenna ports i.e. MIMO device, each port was measured and reported.</p> <p>Test configuration and setup used for the measurement was per the Conducted Test Set-up specified in this document.</p> <p><b>Limits for 6 dB and 99% Bandwidth</b></p> <p>(a) Operation under the provisions of this Section is limited to frequency hopping and digitally modulated intentional radiators that comply with the following provisions:</p> <p>(2) Systems using digital modulation techniques may operate in the 902-928 MHz and 2400-2483.5 MHz bands. The minimum 6 dB bandwidth shall be at least 500 kHz.</p> |                                |                     |             |

#### Equipment Configuration for 6 dB & 99% Bandwidth

|                                |                |                                   |                |
|--------------------------------|----------------|-----------------------------------|----------------|
| <b>Variant:</b>                | BLE            | <b>Duty Cycle (%):</b>            | 66             |
| <b>Data Rate:</b>              | 125 kBit/s     | <b>Antenna Gain (dBi):</b>        | Not Applicable |
| <b>Modulation:</b>             | GFSK           | <b>Beam Forming Gain (Y)(dB):</b> | Not Applicable |
| <b>TPC:</b>                    | Not Applicable | <b>Tested By:</b>                 | SB             |
| <b>Engineering Test Notes:</b> |                |                                   |                |

#### Test Measurement Results

| Test Frequency | Measured 6 dB Bandwidth (MHz) |    |    |    | 6 dB Bandwidth (MHz) |        | Limit  | Lowest Margin |
|----------------|-------------------------------|----|----|----|----------------------|--------|--------|---------------|
|                | Port(s)                       |    |    |    | Highest              | Lowest |        |               |
| MHz            | a                             | b  | c  | d  |                      |        | KHz    | MHz           |
| 2402.0         | <a href="#">0.689</a>         | -- | -- | -- | 0.689                | 0.689  | ≥500.0 | -0.19         |
| 2426.0         | <a href="#">0.689</a>         | -- | -- | -- | 0.689                | 0.689  | ≥500.0 | -0.19         |
| 2480.0         | <a href="#">0.689</a>         | -- | -- | -- | 0.689                | 0.689  | ≥500.0 | -0.19         |

| Test Frequency | Measured 99% Bandwidth (MHz) |    |    |    | Maximum 99% Bandwidth (MHz) |
|----------------|------------------------------|----|----|----|-----------------------------|
|                | Port(s)                      |    |    |    |                             |
| MHz            | a                            | b  | c  | d  |                             |
| 2402.0         | <a href="#">1.194</a>        | -- | -- | -- | 1.194                       |
| 2426.0         | <a href="#">1.194</a>        | -- | -- | -- | 1.194                       |
| 2480.0         | <a href="#">1.194</a>        | -- | -- | -- | 1.194                       |

#### Traceability to Industry Recognized Test Methodologies

|                          |                                  |
|--------------------------|----------------------------------|
| Work Instruction:        | WI-03 MEASURING RF SPECTRUM MASK |
| Measurement Uncertainty: | ±2.81 dB                         |

Note: click the links in the above matrix to view the graphical image (plot).

## 9.2. Conducted Output Power

| Conducted Test Conditions for Fundamental Emission Output Power |                                     |                     |             |
|-----------------------------------------------------------------|-------------------------------------|---------------------|-------------|
| Standard:                                                       | FCC CFR 47:15.247<br>RSS-247        | Ambient Temp. (°C): | 24.0 - 27.5 |
| Test Heading:                                                   | Output Power                        | Rel. Humidity (%):  | 32 - 45     |
| Standard Section(s):                                            | 15.247 (b) & (c)<br>RSS-247 5.4 (d) | Pressure (mBars):   | 999 - 1001  |
| Reference Document(s):                                          | See Normative References            |                     |             |

Test Procedure for Fundamental Emission Output Power Measurement

In the case of average power measurements an average power sensor was utilized.

For peak power measurements the spectrum analyzer built-in power function was used to integrate peak power over the 20 dB bandwidth.

Testing was performed under ambient conditions at nominal voltage only. Where the device operated with multiple antenna ports i.e. MIMO device, each port was measured, summed (Σ) and reported.

Test configuration and setup used for the measurement was per the Conducted Test Set-up specified in this document.

Supporting Information

Calculated Power = A + G + Y+ 10 log (1/x) dBm

A = Total Power [10\*Log10 (10<sup>a/10</sup> + 10<sup>b/10</sup> + 10<sup>c/10</sup> + 10<sup>d/10</sup>)]

G = Antenna Gain

Y = Beamforming Gain

x = Duty Cycle (average power measurements only)

**Limits for Fundamental Emission Output Power**

(b) The maximum peak conducted output power of the intentional radiator shall not exceed the following for non-frequency hopping systems:

(3) For systems using digital modulation in the 902-928 MHz and 2400-2483.5 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.

(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)(3) of this section, as appropriate, by the amount in dB that the directional gain of the antenna exceeds 6 dBi.

(c) Operation with directional antenna gains greater than 6 dBi.

(1) Fixed point-to-point operation:

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

(iii) Fixed, point-to-point operation, as used in paragraphs (c)(1)(i) and (c)(1)(ii) of this section, excludes the use of point-to-multipoint systems, omnidirectional applications, and multiple co-located intentional radiators transmitting the same information. The operator of the spread spectrum or digitally modulated intentional radiator or, if the equipment is professionally installed, the installer is responsible for ensuring that the system is used exclusively for fixed, point-to-point operations. The instruction manual furnished with the intentional radiator shall contain language in the installation

instructions informing the operator and the installer of this responsibility.

(2) In addition to the provisions in paragraphs (b)(3), (b)(4) and (c)(1)(i) of this section, transmitters operating in the 2400-2483.5 MHz band that emit multiple directional beams, simultaneously or sequentially, for the purpose of directing signals to individual receivers or to groups of receivers provided the emissions comply with the following:

(i) Different information must be transmitted to each receiver.

(ii) If the transmitter employs an antenna system that emits multiple directional beams but does not do emit multiple directional beams simultaneously, the total output power conducted to the array or arrays that comprise the device, i.e., the sum of the power supplied to all antennas, antenna elements, staves, etc. and summed across all carriers or frequency channels, shall not exceed the limit specified in paragraph (b)(1) or (b)(3) of this section, as applicable. However, the total conducted output power shall be reduced by 1 dB below the specified limits for each 3 dB that the directional gain of the antenna/antenna array exceeds 6 dBi. The directional antenna gain shall be computed as follows:

(A) The directional gain shall be calculated as the sum of  $10 \log$  (number of array elements or staves) plus the directional gain of the element or stave having the highest gain.

(B) A lower value for the directional gain than that calculated in paragraph (c)(2)(ii)(A) of this section will be accepted if sufficient evidence is presented, e.g., due to shading of the array or coherence loss in the beamforming.

(iii) If a transmitter employs an antenna that operates simultaneously on multiple directional beams using the same or different frequency channels, the power supplied to each emission beam is subject to the power limit specified in paragraph (c)(2)(ii) of this section. If transmitted beams overlap, the power shall be reduced to ensure that their aggregate power does not exceed the limit specified in paragraph (c)(2)(ii) of this section. In addition, the aggregate power transmitted simultaneously on all beams shall not exceed the limit specified in paragraph (c)(2)(ii) of this section by more than 8 dB.

(iv) Transmitters that emit a single directional beam shall operate under the provisions of paragraph (c)(1) of this section.



#### Equipment Configuration for Peak Output Power

|                                |                |                                   |                |
|--------------------------------|----------------|-----------------------------------|----------------|
| <b>Variant:</b>                | BLE            | <b>Duty Cycle (%):</b>            | 66.0           |
| <b>Data Rate:</b>              | 125 kBit/s     | <b>Antenna Gain (dBi):</b>        | 3.30           |
| <b>Modulation:</b>             | GFSK           | <b>Beam Forming Gain (Y)(dB):</b> | Not Applicable |
| <b>TPC:</b>                    | Not Applicable | <b>Tested By:</b>                 | SB             |
| <b>Engineering Test Notes:</b> |                |                                   |                |

#### Test Measurement Results

| Test Frequency | Measured Output Power (dBm) |    |    |    | Calculated Total Power<br>Σ Port(s) | Limit | Margin | EUT Power Setting |
|----------------|-----------------------------|----|----|----|-------------------------------------|-------|--------|-------------------|
|                | Port(s)                     |    |    |    |                                     |       |        |                   |
| MHz            | a                           | b  | c  | d  | dBm                                 | dBm   | dB     |                   |
| 2402.0         | -7.02                       | -- | -- | -- | -7.02                               | 30.00 | -37.02 | Max               |
| 2426.0         | -6.97                       | -- | -- | -- | -6.97                               | 30.00 | -36.97 | Max               |
| 2480.0         | -6.62                       | -- | -- | -- | -6.62                               | 30.00 | -36.62 | Max               |

#### Traceability to Industry Recognized Test Methodologies

|                          |                                 |
|--------------------------|---------------------------------|
| Work Instruction:        | WI-01 MEASURING RF OUTPUT POWER |
| Measurement Uncertainty: | $\pm 1.33$ dB                   |

The above measurements are true pulse readings and therefore a Duty Cycling correction factor is not required.

2402 MHz EIRP = -3.72dBm

2426 MHz EIRP = -3.67dBm

2480 MHz EIRP = -3.32dBm



### 9.3. Power Spectral Density

| Conducted Test Conditions for Power Spectral Density |                              |                            |             |
|------------------------------------------------------|------------------------------|----------------------------|-------------|
| <b>Standard:</b>                                     | FCC CFR 47:15.247<br>RSS-247 | <b>Ambient Temp. (°C):</b> | 24.0 - 27.5 |
| <b>Test Heading:</b>                                 | Power Spectral Density       | <b>Rel. Humidity (%):</b>  | 32 - 45     |
| <b>Standard Section(s):</b>                          | 15.247 (e)<br>RSS-247 5.2 b  | <b>Pressure (mBars):</b>   | 999 - 1001  |
| <b>Reference Document(s):</b>                        | See Normative References     |                            |             |

#### Test Procedure for Power Spectral Density

The transmitter output was connected to a spectrum analyzer and the measured made in a 3 kHz resolution bandwidth using the analyzer auto-coupled sweep-time. A peak value was found over the full emission bandwidth and the spectrum downloaded for post processing purposes.

Where the device operated with multiple antenna ports i.e. MIMO device, each port was measured separately. The Peak Power Spectral Density is the highest level found across the emission bandwidth. With multiple antenna port measurements the numerical analyzer data from each port is summed (â) and a link to this additional graphic is provided.

Testing was performed under ambient conditions at nominal voltage only.

Test configuration and setup used for the measurement was per the Conducted Test Set-up specified in this document.

Measure and sum the spectra across the outputs. With this technique, spectra are measured at each output of the device at the required resolution bandwidth. The individual spectra are then summed mathematically in linear power units. Unlike in-band power measurements, in which the sum involves a single measured value (output power) from each output, measurements for compliance with PSD limits involve summing entire spectra across corresponding frequency bins on the various outputs. Consistency is maintained for any device with multiple transmitter outputs to be certain the individual outputs are all aligned with the same span and same number of points. In this instance, the linear power spectrum value within the first spectral bin of output 0 is summed with that in the first spectral bin of output 1, and the first spectral bin of output 2, and so on up to the Nth output to obtain the true value for the first frequency bin of the summed spectrum. The summed spectrum value for each frequency bin is computed in this fashion. These summed spectral values were post processed and the resulting numerical and graphical data presented.

#### NOTE:

It may be observed that the spectrum in some antenna port plots break the limit line however this in itself does NOT constitute a failure. In all cases a spectrum summation plot is provided in order to prove compliance. A failure occurs only after the summation of all spectrum plots have been summed and are found to be greater than the limit line.

#### Supporting Information

Calculated Power =  $A + 10 \log (1/x)$  dBm

$A = \text{Total Power Spectral Density } [10 \log_{10} (10^{a/10} + 10^{b/10} + 10^{c/10} + 10^{d/10})]$

$x = \text{Duty Cycle}$

#### Limits Power Spectral Density

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. This power spectral density shall be determined in accordance with the provisions of paragraph (b) of this section. The same method of determining the conducted output power shall be used to determine the power spectral density.

#### Equipment Configuration for Power Spectral Density - Peak

|                                |                |                                   |                |
|--------------------------------|----------------|-----------------------------------|----------------|
| <b>Variant:</b>                | BLE            | <b>Duty Cycle (%):</b>            | 66.0           |
| <b>Data Rate:</b>              | 125 kBit/s     | <b>Antenna Gain (dBi):</b>        | 3.30           |
| <b>Modulation:</b>             | GFSK           | <b>Beam Forming Gain (Y)(dB):</b> | Not Applicable |
| <b>TPC:</b>                    | Not Applicable | <b>Tested By:</b>                 | SB             |
| <b>Engineering Test Notes:</b> |                |                                   |                |

#### Test Measurement Results

| Test Frequency | Measured Power Spectral Density |    |    |    | Amplitude Summation    | Limit    | Margin |
|----------------|---------------------------------|----|----|----|------------------------|----------|--------|
|                | Port(s) (dBm/3KHz)              |    |    |    |                        |          |        |
| MHz            | a                               | b  | c  | d  | dBm/3KHz               | dBm/3KHz | dB     |
| 2402.0         | <a href="#">-8.531</a>          | -- | -- | -- | <a href="#">-8.531</a> | 2.0      | -10.5  |
| 2426.0         | <a href="#">-7.271</a>          | -- | -- | -- | <a href="#">-7.271</a> | 2.0      | -9.3   |
| 2480.0         | <a href="#">-6.003</a>          | -- | -- | -- | <a href="#">-6.003</a> | 2.0      | -8.0   |

#### Traceability to Industry Recognized Test Methodologies

|                          |                                  |
|--------------------------|----------------------------------|
| Work Instruction:        | WI-03 MEASURING RF SPECTRUM MASK |
| Measurement Uncertainty: | ±2.81 dB                         |

Note: click the links in the above matrix to view the graphical image (plot).

## 9.4. Emissions

### 9.4.1. Conducted Emissions

#### 9.4.1.1. Conducted Spurious Emissions

| Conducted Test Conditions for Transmitter Conducted Spurious and Band-Edge Emissions |                                      |                     |             |
|--------------------------------------------------------------------------------------|--------------------------------------|---------------------|-------------|
| Standard:                                                                            | FCC CFR 47:15.247<br>RSS-247 Issue 2 | Ambient Temp. (°C): | 24.0 - 27.5 |
| Test Heading:                                                                        | Max Unwanted Emission Levels         | Rel. Humidity (%):  | 32 - 45     |
| Standard Section(s):                                                                 | 15.247 (d)<br>RSS-247 5.5            | Pressure (mBars):   | 999 - 1001  |
| Reference Document(s):                                                               | See Normative References             |                     |             |

**Test Procedure for Transmitter Conducted Spurious and Band-Edge Emissions Measurement**  
Transmitter Conducted Spurious and Band-Edge emissions were measured at a limit of 30 dBc (average detector) or 20 dBc (peak detector) below the highest in-band spectral density measured with a spectrum analyzer connected to the antenna terminal. Measurements were made while EUT was operating in transmit mode of operation at the appropriate centre frequency closest to the band-edge. Emissions were maximized during the measurement and limits derived from the peak spectral power and drawn on each plot.

Where the device operated with multiple antenna ports i.e. MIMO device, each port was measured separately. Testing was performed under ambient conditions at nominal voltage only.

Test configuration and setup used for the measurement was per the Conducted Test Set-up specified in this document.

**Limits Transmitter Conducted Spurious and Band-Edge Emissions**  
(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 §15.209(a) is not required. In addition, radiated emissions which fall in the restricted bands, as defined in §15.205(a), must also comply with the radiated emission limits specified in §15.209(a) (see §15.205(c)).

#### Measured Frequency Range

Conducted spurious emissions were measured from 9 kHz to 26 GHz covering the entire range specified under FCC Section 15.33. No spurious emissions were found within 6 dB of the limit.

#### Equipment Configuration for Conducted Spurious Emissions - Peak

|                                |                |                               |                |
|--------------------------------|----------------|-------------------------------|----------------|
| <b>Variant:</b>                | BLE            | <b>Duty Cycle (%):</b>        | 66             |
| <b>Data Rate:</b>              | 125 kBit/s     | <b>Antenna Gain (dBi):</b>    | Not Applicable |
| <b>Modulation:</b>             | GFSK           | <b>Beam Forming Gain (Y):</b> | Not Applicable |
| <b>TPC:</b>                    | Not Applicable | <b>Tested By:</b>             | SB             |
| <b>Engineering Test Notes:</b> |                |                               |                |

#### Test Measurement Results

| Test Frequency | Frequency Range | Conducted Spurious Emissions - Peak (dBm) |        |        |       |        |       |        |       |
|----------------|-----------------|-------------------------------------------|--------|--------|-------|--------|-------|--------|-------|
|                |                 | Port a                                    |        | Port b |       | Port c |       | Port d |       |
| MHz            | MHz             | SE                                        | Limit  | SE     | Limit | SE     | Limit | SE     | Limit |
| 2402.0         | 30.0 - 26000.0  | <a href="#">-40.778</a>                   | -25.62 | --     | --    | --     | --    | --     | --    |
| 2426.0         | 30.0 - 26000.0  | <a href="#">-39.551</a>                   | -28.91 | --     | --    | --     | --    | --     | --    |
| 2480.0         | 30.0 - 26000.0  | <a href="#">-39.698</a>                   | -25.64 | --     | --    | --     | --    | --     | --    |

#### Traceability to Industry Recognized Test Methodologies

|                          |                                               |
|--------------------------|-----------------------------------------------|
| Work Instruction:        | WI-05 MEASUREMENT OF SPURIOUS EMISSIONS       |
| Measurement Uncertainty: | <=40 GHz $\pm 2.37$ dB, > 40 GHz $\pm 4.6$ dB |

Note: click the links in the above matrix to view the graphical image (plot).

#### 9.4.1.2. Conducted Band-Edge Emissions

Low Channel

##### Equipment Configuration for Conducted Low Band-Edge Emissions - Peak

|                                |                |                                   |                |
|--------------------------------|----------------|-----------------------------------|----------------|
| <b>Variant:</b>                | BLE            | <b>Duty Cycle (%):</b>            | 66.0           |
| <b>Data Rate:</b>              | 125 kBit/s     | <b>Antenna Gain (dBi):</b>        | Not Applicable |
| <b>Modulation:</b>             | GFSK           | <b>Beam Forming Gain (Y)(dB):</b> | Not Applicable |
| <b>TPC:</b>                    | Not Applicable | <b>Tested By:</b>                 | SB             |
| <b>Engineering Test Notes:</b> |                |                                   |                |

##### Test Measurement Results

| <b>Channel Frequency:</b>    | 2402.0 MHz                  |                  |                    |                 |                     |         |
|------------------------------|-----------------------------|------------------|--------------------|-----------------|---------------------|---------|
| <b>Band-Edge Frequency:</b>  | 2400.0 MHz                  |                  |                    |                 |                     |         |
| <b>Test Frequency Range:</b> | 2200.0 - 2405.0 MHz         |                  |                    |                 |                     |         |
| Port(s)                      | Band-Edge Markers and Limit |                  |                    | Revised Limit   |                     | Margin  |
|                              | M1 Amplitude (dBm)          | Plot Limit (dBm) | M2 Frequency (MHz) | Amplitude (dBm) | M2A Frequency (MHz) | (MHz)   |
| a                            | <a href="#">-39.76</a>      | -25.95           | 2401.30            | --              | --                  | -13.810 |

##### Traceability to Industry Recognized Test Methodologies

|                                 |                                               |
|---------------------------------|-----------------------------------------------|
| <b>Work Instruction:</b>        | WI-05 MEASUREMENT OF SPURIOUS EMISSIONS       |
| <b>Measurement Uncertainty:</b> | <=40 GHz $\pm 2.37$ dB, > 40 GHz $\pm 4.6$ dB |

Note: click the links in the above matrix to view the graphical image (plot).

## High Channel

### Equipment Configuration for Conducted High Band-Edge Emissions - Peak

|                                |                |                                   |                |
|--------------------------------|----------------|-----------------------------------|----------------|
| <b>Variant:</b>                | BLE            | <b>Duty Cycle (%):</b>            | 66.0           |
| <b>Data Rate:</b>              | 125 kBit/s     | <b>Antenna Gain (dBi):</b>        | Not Applicable |
| <b>Modulation:</b>             | GFSK           | <b>Beam Forming Gain (Y)(dB):</b> | Not Applicable |
| <b>TPC:</b>                    | Not Applicable | <b>Tested By:</b>                 | SB             |
| <b>Engineering Test Notes:</b> |                |                                   |                |

### Test Measurement Results

| <b>Channel Frequency:</b>    | 2480.0 MHz                  |                  |                    |                 |                     |          |
|------------------------------|-----------------------------|------------------|--------------------|-----------------|---------------------|----------|
| <b>Band-Edge Frequency:</b>  | 2483.5 MHz                  |                  |                    |                 |                     |          |
| <b>Test Frequency Range:</b> | 2479.0 - 2500.0 MHz         |                  |                    |                 |                     |          |
| Port(s)                      | Band-Edge Markers and Limit |                  |                    | Revised Limit   |                     | Margin   |
|                              | M3 Amplitude (dBm)          | Plot Limit (dBm) | M2 Frequency (MHz) | Amplitude (dBm) | M2A Frequency (MHz) | (MHz)    |
| a                            | <a href="#">-42.724</a>     | -25.08           | 2483.50            | --              | --                  | -17.6443 |

### Traceability to Industry Recognized Test Methodologies

|                                 |                                               |
|---------------------------------|-----------------------------------------------|
| <b>Work Instruction:</b>        | WI-05 MEASUREMENT OF SPURIOUS EMISSIONS       |
| <b>Measurement Uncertainty:</b> | <=40 GHz $\pm 2.37$ dB, > 40 GHz $\pm 4.6$ dB |

Note: click the links in the above matrix to view the graphical image (plot).

## 9.4.2. Radiated Emissions

### 9.4.2.3. TX Spurious & Restricted Band Emissions

| Radiated Test Conditions for Radiated Spurious and Band-Edge Emissions (Restricted Bands) |                                                 |                            |             |
|-------------------------------------------------------------------------------------------|-------------------------------------------------|----------------------------|-------------|
| <b>Standard:</b>                                                                          | FCC CFR 47 Part 15 Subpart C<br>RSS-GEN Issue 5 | <b>Ambient Temp. (°C):</b> | 20.0 - 24.5 |
| <b>Test Heading:</b>                                                                      | Radiated Spurious and Band-Edge Emissions       | <b>Rel. Humidity (%):</b>  | 32 - 45     |
| <b>Standard Section(s):</b>                                                               | 15.205, 15.209<br>RSS-Gen 8.9                   | <b>Pressure (mBars):</b>   | 999 - 1001  |
| <b>Reference Document(s):</b>                                                             | See Normative References                        |                            |             |

#### Test Procedure for Radiated Spurious and Band-Edge Emissions (Restricted Bands)

Radiated emissions for restricted bands above 1 GHz are measured in the anechoic chamber at a 3-meter distance on every azimuth in both horizontal and vertical polarities. The emissions are recorded and maximized as a function of azimuth by rotation through 360° with a spectrum analyzer in peak hold mode. Depending on the frequency band spanned a notch filter and waveguide filter was used to remove the fundamental frequency. The highest emissions relative to the limit are listed for each frequency spanned. Measurements on any restricted band frequency or frequencies above 1 GHz are based on the use of measurement instrumentation employing peak and average detectors. All measurements were performed using a resolution bandwidth of 1 MHz.

Test configuration and setup for Radiated Spurious and Band-Edge Measurement were per the Radiated Test Set-up specified in this document.

#### Limits for Restricted Bands

Peak emission: 74 dBuV/m

Average emission: 54 dBuV/m

#### Field Strength Calculation

The field strength is calculated by adding the Antenna Factor and Cable Loss, and subtracting Amplifier Gain from the measured reading. All factors are included in the reported data.

$$FS = R + AF + CORR - FO$$

where:

FS = Field Strength

R = Measured Spectrum analyzer Input Amplitude

AF = Antenna Factor

CORR = Correction Factor = CL – AG + NFL

CL = Cable Loss

AG = Amplifier Gain

FO = Distance Falloff Factor

NFL = Notch Filter Loss or Waveguide Loss

Example:

Given receiver input reading of 51.5 dBmV; Antenna Factor of 8.5 dB; Cable Loss of 1.3 dB; Falloff Factor of 0 dB, an Amplifier Gain of 26 dB and Notch Filter Loss of 1 dB. The Field Strength (FS) of the measured emission is:

$$FS = 51.5 + 8.5 + 1.3 - 26.0 + 1 = 36.3 \text{ dBmV/m}$$

Conversion between dBmV/m (or dBmV) and mV/m (or mV) are as follows:

$$\text{Level (dBmV/m)} = 20 * \text{Log (level (mV/m))}$$

$$40 \text{ dBmV/m} = 100 \text{ mV/m}$$

$$48 \text{ dBmV/m} = 250 \text{ mV/m}$$

#### Restricted Bands of Operation (15.205)

(a) Except as shown in paragraph (d) of this section, only spurious emissions are permitted in any of the frequency bands listed below:

| Frequency Band    |                     |               |             |
|-------------------|---------------------|---------------|-------------|
| MHz               | MHz                 | MHz           | GHz         |
| 0.090-0.110       | 16.42-16.423        | 399.9-410     | 4.5-5.15    |
| 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         | 2690-2900     | 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     | Above 38.6  |
| 13.36-13.41       |                     |               |             |

(b) Except as provided in paragraphs (d) and (e) of this section, the field strength of emissions appearing within these frequency bands shall not exceed the limits shown in §15.209. At frequencies equal to or less than 1000 MHz, compliance with the limits in §15.209 shall be demonstrated using measurement instrumentation employing a CISPR quasi-peak detector. Above 1000 MHz, compliance with the emission limits in §15.209 shall be demonstrated based on the average value of the measured emissions. The provisions in §15.35 apply to these measurements.

(c) Except as provided in paragraphs (d) and (e) of this section, regardless of the field strength limits specified elsewhere in this subpart, the provisions of this section apply to emissions from any intentional radiator.

(d) The following devices are exempt from the requirements of this section:

- (1) Swept frequency field disturbance sensors operating between 1.705 and 37 MHz provided their emissions only sweep through the bands listed in paragraph (a) of this section, the sweep is never stopped with the fundamental emission within the bands listed in paragraph (a) of this section, and the fundamental emission is outside of the bands listed in paragraph (a) of this section more than 99% of the time the device is actively transmitting, without compensation for duty cycle.
- (2) Transmitters used to detect buried electronic markers at 101.4 kHz which are employed by telephone companies.
- (3) Cable locating equipment operated pursuant to §15.213.
- (4) Any equipment operated under the provisions of §15.253, 15.255, and 15.256 in the frequency band 75-85 GHz, or §15.257 of this part.
- (5) Biomedical telemetry devices operating under the provisions of §15.242 of this part are not subject to the restricted band 608-614 MHz but are subject to compliance within the other restricted bands.
- (6) Transmitters operating under the provisions of subparts D or F of this part.
- (7) Devices operated pursuant to §15.225 are exempt from complying with this section for the 13.36-13.41 MHz band only.
- (8) Devices operated in the 24.075-24.175 GHz band under §15.245 are exempt from complying with the requirements of this section for the 48.15-48.35 GHz and 72.225-72.525 GHz bands only, and shall not exceed the limits specified in §15.245(b).
- (9) Devices operated in the 24.0-24.25 GHz band under §15.249 are exempt from complying with the requirements of this section for the 48.0-48.5 GHz and 72.0-72.75 GHz bands only, and shall not exceed the limits specified in §15.249(a).

(e) Harmonic emissions appearing in the restricted bands above 17.7 GHz from field disturbance sensors operating under the provisions of §15.245 shall not exceed the limits specified in §15.245(b).



**§15.209 Radiated emission limits; general requirements.**

(a) Except as provided elsewhere in this subpart, the emissions from an intentional radiator shall not exceed the field strength levels specified in the following table:

| Frequency (MHz) | Field strength (microvolts/meter) | Measurement distance (meters) |
|-----------------|-----------------------------------|-------------------------------|
| 0.009-0.490     | 2400/F(kHz)                       | 300                           |
| 0.490-1.705     | 24000/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                             |

\*\*Except as provided in paragraph (g), fundamental emissions from intentional radiators operating under this section shall not be located in the frequency bands 54-72 MHz, 76-88 MHz, 174-216 MHz or 470-806 MHz. However, operation within these frequency bands is permitted under other sections of this part, e.g., §§15.231 and 15.241.

(b) In the emission table above, the tighter limit applies at the band edges.

(c) The level of any unwanted emissions from an intentional radiator operating under these general provisions shall not exceed the level of the fundamental emission. For intentional radiators which operate under the provisions of other sections within this part and which are required to reduce their unwanted emissions to the limits specified in this table, the limits in this table are based on the frequency of the unwanted emission and not the fundamental frequency. However, the level of any unwanted emissions shall not exceed the level of the fundamental frequency.

(d) The emission limits shown in the above table are based on measurements employing a CISPR quasi-peak detector except for the frequency bands 9-90 kHz, 110-490 kHz and above 1000 MHz. Radiated emission limits in these three bands are based on measurements employing an average detector.

(e) The provisions in §§15.31, 15.33, and 15.35 for measuring emissions at distances other than the distances specified in the above table, determining the frequency range over which radiated emissions are to be measured, and limiting peak emissions apply to all devices operated under this part.

(f) In accordance with §15.33(a), in some cases the emissions from an intentional radiator must be measured to beyond the tenth harmonic of the highest fundamental frequency designed to be emitted by the intentional radiator because of the incorporation of a digital device. If measurements above the tenth harmonic are so required, the radiated emissions above the tenth harmonic shall comply with the general radiated emission limits applicable to the incorporated digital device, as shown in §15.109 and as based on the frequency of the emission being measured, or, except for emissions contained in the restricted frequency bands shown in §15.205, the limit on spurious emissions specified for the intentional radiator, whichever is the higher limit. Emissions which must be measured above the tenth harmonic of the highest fundamental frequency designed to be emitted by the intentional radiator and which fall within the restricted bands shall comply with the general radiated emission limits in §15.109 that are applicable to the incorporated digital device.

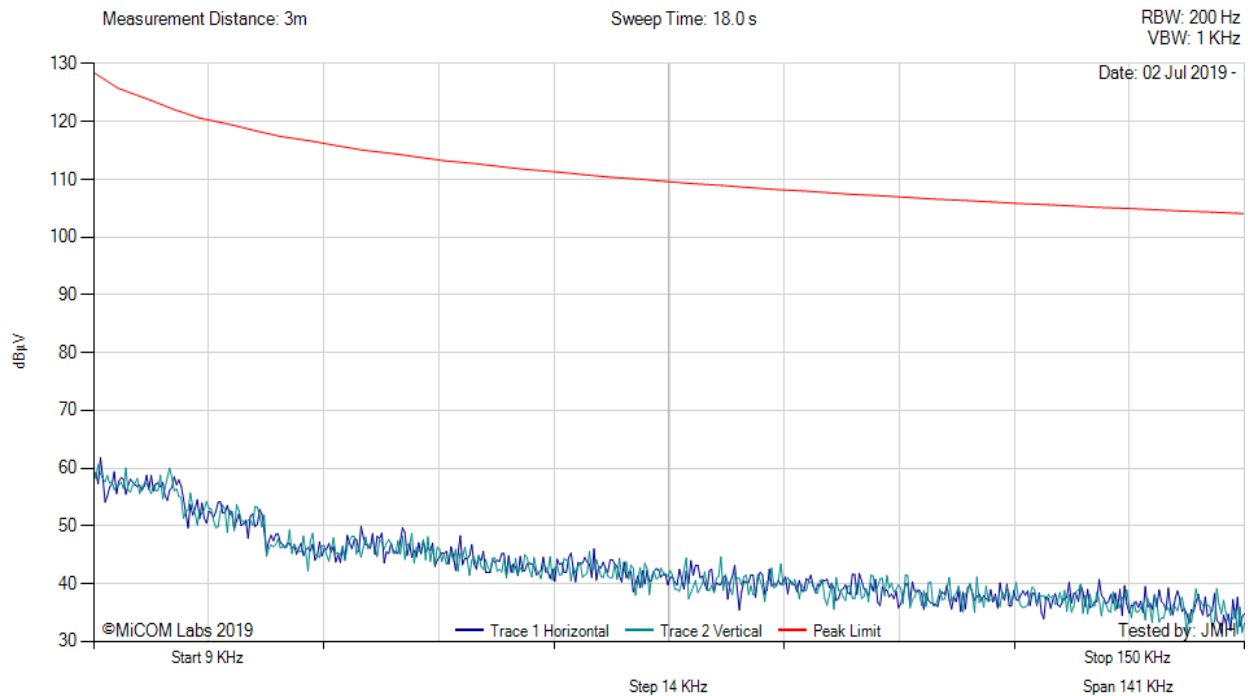
(g) Perimeter protection systems may operate in the 54-72 MHz and 76-88 MHz bands under the provisions of this section. The use of such perimeter protection systems is limited to industrial, business and commercial applications.

### TX Spurious Emissions 9 KHz – 30 MHz

No Emissions found within 20 dB of Limit. Per 15.31 (o) The amplitude of spurious emissions from intentional radiators and emissions from unintentional radiators which are attenuated more than 20 dB below the permissible value need not be reported unless specifically required elsewhere in this part.



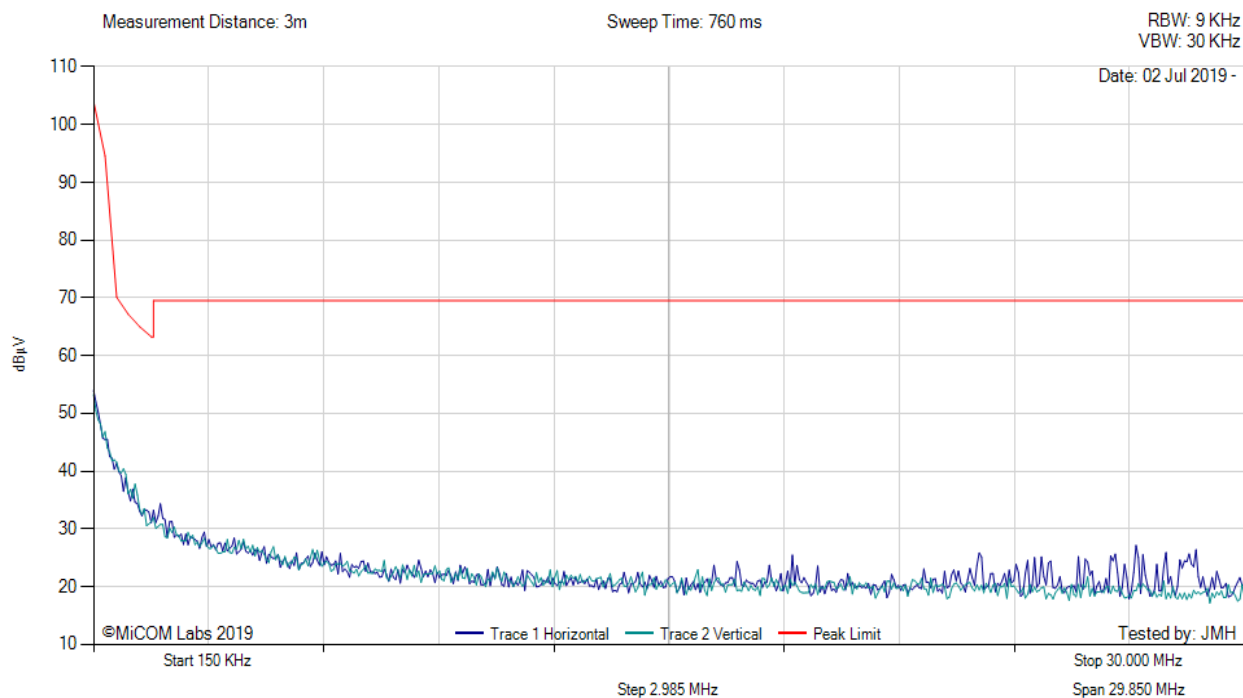
Variant: S23 , Test Freq: 2402.00 MHz, Power Setting: max



There are no emissions found within 20dB of the limit line.

**Test Notes:** Eut powered by AC/DC PS. BLE. Connected to laptop outside chamber via ENET. 2nd ENET connected to Hub with data transferring. Audio ports looped back. EUT transmitting maximum power.

Variant: S23, Test Freq: 2402.00 MHz, Power Setting: max

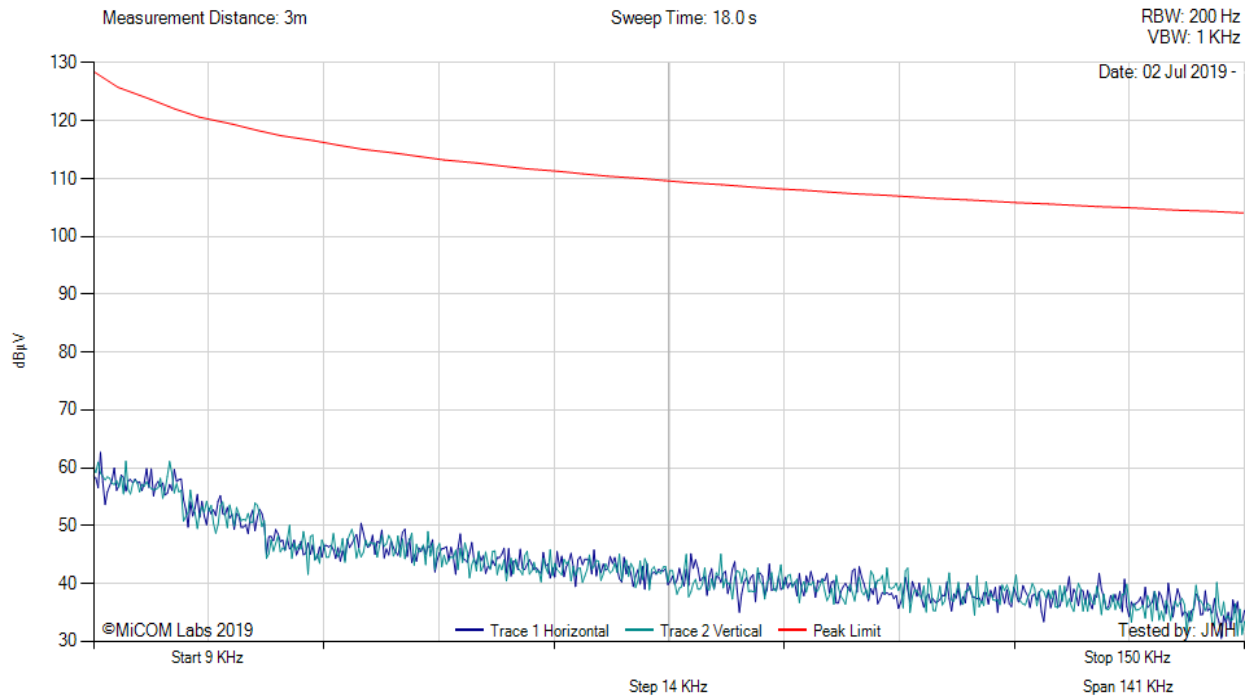


There are no emissions found within 20dB of the limit line.

**Test Notes:** Eut powered by AC/DC PS. BLE. Connected to laptop outside chamber via ENET. 2nd ENET connected to Hub with data transferring. Audio ports looped back. EUT transmitting maximum power.



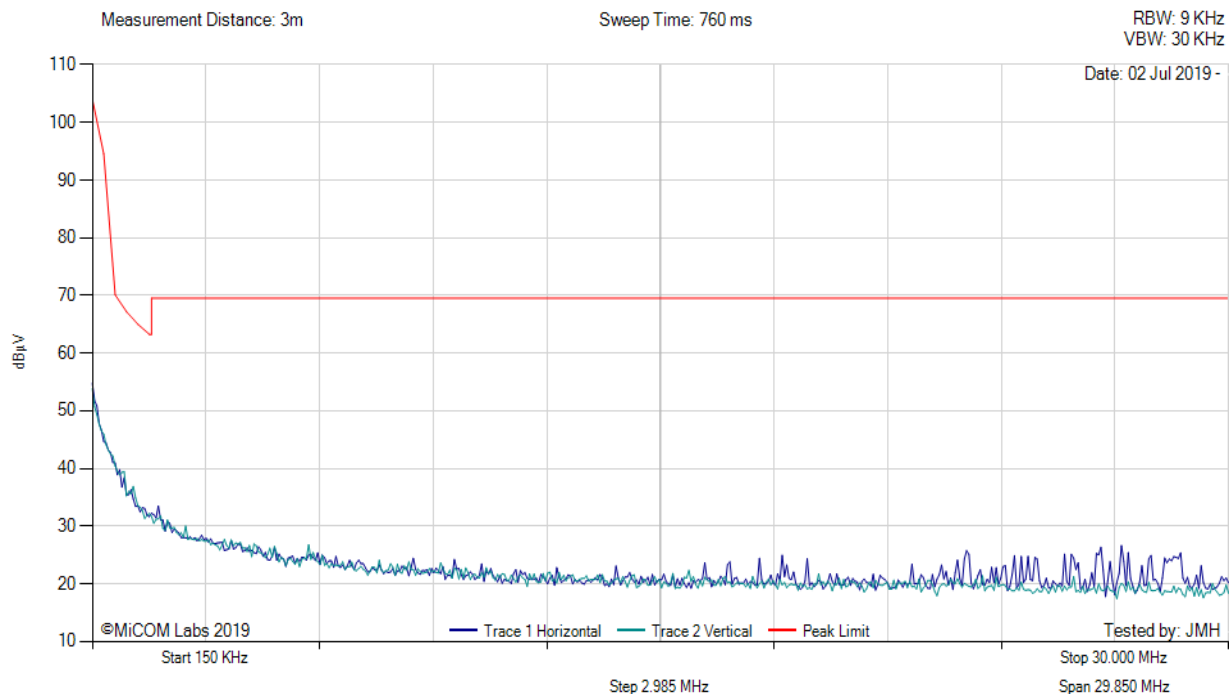
Variant S23, Test Freq: 2426.00 MHz, Power Setting: max



There are no emissions found within 20dB of the limit line.

**Test Notes:** Eut powered by AC/DC PS. BLE. Connected to laptop outside chamber via ENET. 2nd ENET connected to Hub with data transferring. Audio ports looped back. EUT transmitting maximum power.

Variant: S23, Test Freq: 2426 MHz, Power Setting: max

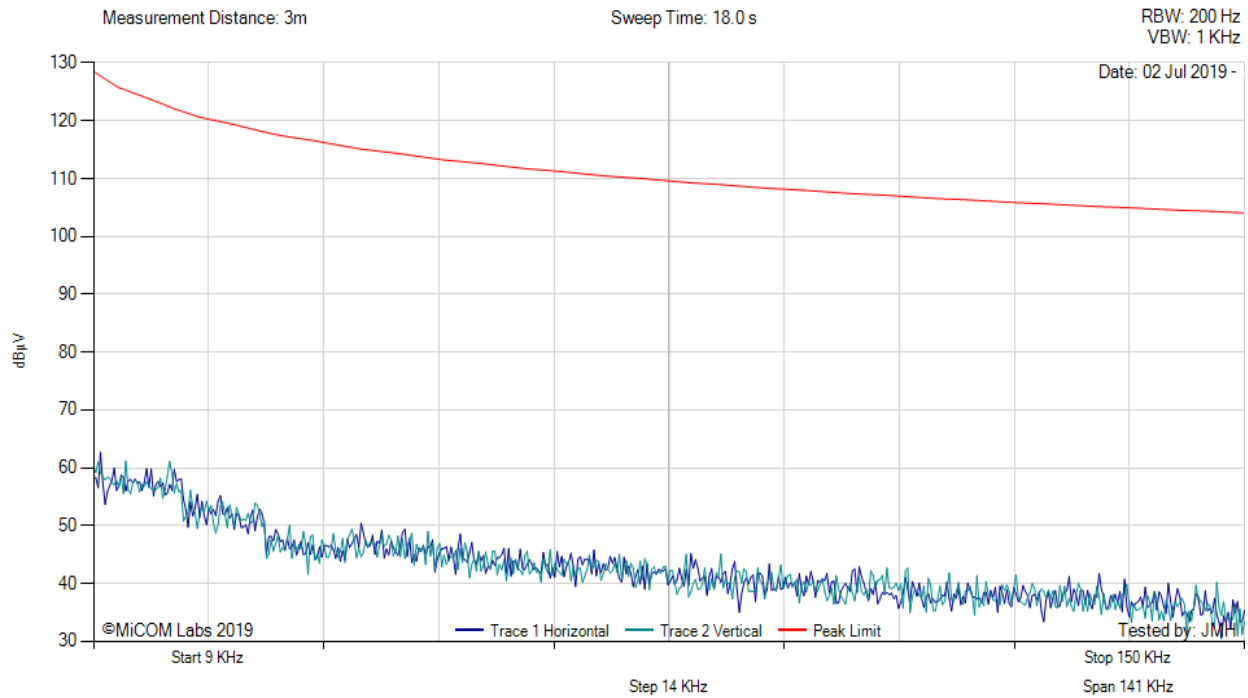


There are no emissions found within 20dB of the limit line.

**Test Notes:** Eut powered by AC/DC PS. BLE. Connected to laptop outside chamber via ENET. 2nd ENET connected to Hub with data transferring. Audio ports looped back. EUT transmitting maximum power.



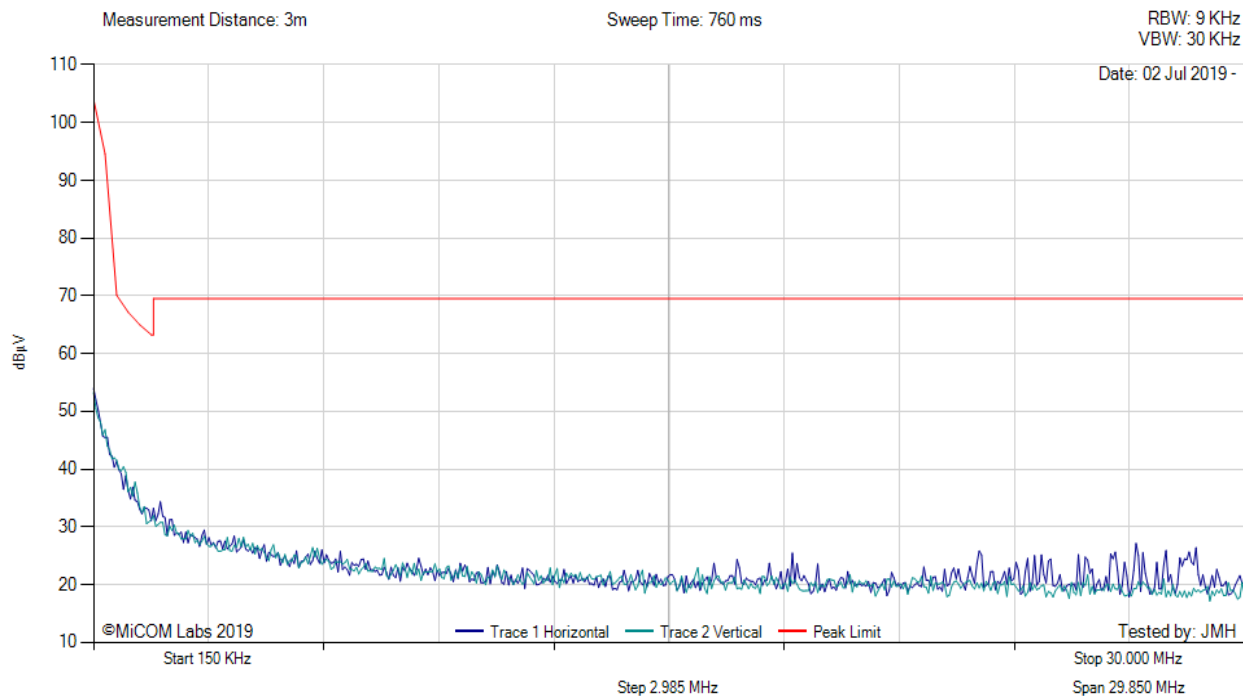
Variant: S23 , Test Freq: 2480.00 MHz, Power Setting: max



There are no emissions found within 20dB of the limit line.

**Test Notes:** Eut powered by AC/DC PS. BLE. Connected to laptop outside chamber via ENET. 2nd ENET connected to Hub with data transferring. Audio ports looped back. EUT transmitting maximum power.

Variant: S23, Test Freq: 2480.00 MHz, Power Setting: max



There are no emissions found within 20dB of the limit line.

**Test Notes:** Eut powered by AC/DC PS. BLE. Connected to laptop outside chamber via ENET. 2nd ENET connected to Hub with data transferring. Audio ports looped back. EUT transmitting maximum power.

#### Equipment Configuration for TX Spurious & Restricted Band Emissions 1 – 18 GHz

|                                 |                |                        |            |
|---------------------------------|----------------|------------------------|------------|
| <b>Antenna:</b>                 | WD PCB         | <b>Variant:</b>        | BLE        |
| <b>Antenna Gain (dBi):</b>      | 3.30           | <b>Modulation:</b>     | GFSK       |
| <b>Beam Forming Gain (Y):</b>   | Not Applicable | <b>Duty Cycle (%):</b> | 66         |
| <b>Channel Frequency (MHz):</b> | 2402.00        | <b>Data Rate:</b>      | 125 kBit/s |
| <b>Power Setting:</b>           | Max            | <b>Tested By:</b>      | JMH        |

#### Test Measurement Results

[Click here to view measurement data...](#)

Test Notes: EUT powered by AC/DC PS. Connected to laptop outside chamber via ENET. 2.4 G Notch in front of amp to prevent overload. No Tx Spurious Emissions were found. EUT transmitting maximum power.



### Equipment Configuration for TX Spurious & Restricted Band Emissions 1 – 18 GHz

|                                 |                |                        |            |
|---------------------------------|----------------|------------------------|------------|
| <b>Antenna:</b>                 | WD PCB         | <b>Variant:</b>        | BLE        |
| <b>Antenna Gain (dBi):</b>      | 3.30           | <b>Modulation:</b>     | GFSK       |
| <b>Beam Forming Gain (Y):</b>   | Not Applicable | <b>Duty Cycle (%):</b> | 66         |
| <b>Channel Frequency (MHz):</b> | 2426.00        | <b>Data Rate:</b>      | 125 kBit/s |
| <b>Power Setting:</b>           | Max            | <b>Tested By:</b>      | JMH        |

### Test Measurement Results

| 1000.00 - 18000.00 MHz |               |          |               |         |              |                  |            |        |         |              |           |            |
|------------------------|---------------|----------|---------------|---------|--------------|------------------|------------|--------|---------|--------------|-----------|------------|
| Num                    | Frequency MHz | Raw dBμV | Cable Loss dB | AF dB/m | Level dBμV/m | Measurement Type | Pol        | Hgt cm | Azt Deg | Limit dBμV/m | Margin dB | Pass /Fail |
| #1                     | 4852.03       | 65.52    | -2.53         | -12.40  | 50.59        | Max Peak         | Horizontal | 102    | 4       | 74.0         | -23.4     | Pass       |
| #2                     | 4852.03       | 46.05    | -2.53         | -12.40  | 31.12        | Max Avg          | Horizontal | 102    | 4       | 54.0         | -22.9     | Pass       |

Test Notes: EUT powered by AC/DC PS. Connected to laptop outside chamber via ENET. 2.4 G Notch in front of amp to prevent overload.

### Equipment Configuration for TX Spurious & Restricted Band Emissions 1 – 18 GHz

|                                 |                |                        |            |
|---------------------------------|----------------|------------------------|------------|
| <b>Antenna:</b>                 | WD PCB         | <b>Variant:</b>        | BLE        |
| <b>Antenna Gain (dBi):</b>      | 3.30           | <b>Modulation:</b>     | GFSK       |
| <b>Beam Forming Gain (Y):</b>   | Not Applicable | <b>Duty Cycle (%):</b> | 66         |
| <b>Channel Frequency (MHz):</b> | 2480.00        | <b>Data Rate:</b>      | 125 kBit/s |
| <b>Power Setting:</b>           | Max            | <b>Tested By:</b>      | JMH        |

### Test Measurement Results

| 1000.00 - 18000.00 MHz |               |          |               |         |              |                  |            |        |         |              |           |            |
|------------------------|---------------|----------|---------------|---------|--------------|------------------|------------|--------|---------|--------------|-----------|------------|
| Num                    | Frequency MHz | Raw dBμV | Cable Loss dB | AF dB/m | Level dBμV/m | Measurement Type | Pol        | Hgt cm | Azt Deg | Limit dBμV/m | Margin dB | Pass /Fail |
| #1                     | 4960.06       | 64.93    | -2.55         | -12.13  | 50.25        | Max Peak         | Horizontal | 147    | 46      | 74.0         | -23.8     | Pass       |
| #2                     | 4960.06       | 49.15    | -2.55         | -12.13  | 36.27        | Max Avg          | Horizontal | 147    | 46      | 54.0         | -17.7     | Pass       |

Test Notes: EUT powered by AC/DC PS. Connected to laptop outside chamber via ENET. 2.4 G Notch in front of amp to prevent overload. DC Correction 1.8 dB.

### Equipment Configuration for TX Spurious & Restricted Band Emissions 18 – 26.5 GHz

|                                 |                |                        |            |
|---------------------------------|----------------|------------------------|------------|
| <b>Antenna:</b>                 | WD PCB         | <b>Variant:</b>        | BLE        |
| <b>Antenna Gain (dBi):</b>      | 3.30           | <b>Modulation:</b>     | GFSK       |
| <b>Beam Forming Gain (Y):</b>   | Not Applicable | <b>Duty Cycle (%):</b> | 66         |
| <b>Channel Frequency (MHz):</b> | 2402.00        | <b>Data Rate:</b>      | 125 kBit/s |
| <b>Power Setting:</b>           | Max            | <b>Tested By:</b>      | JMH        |

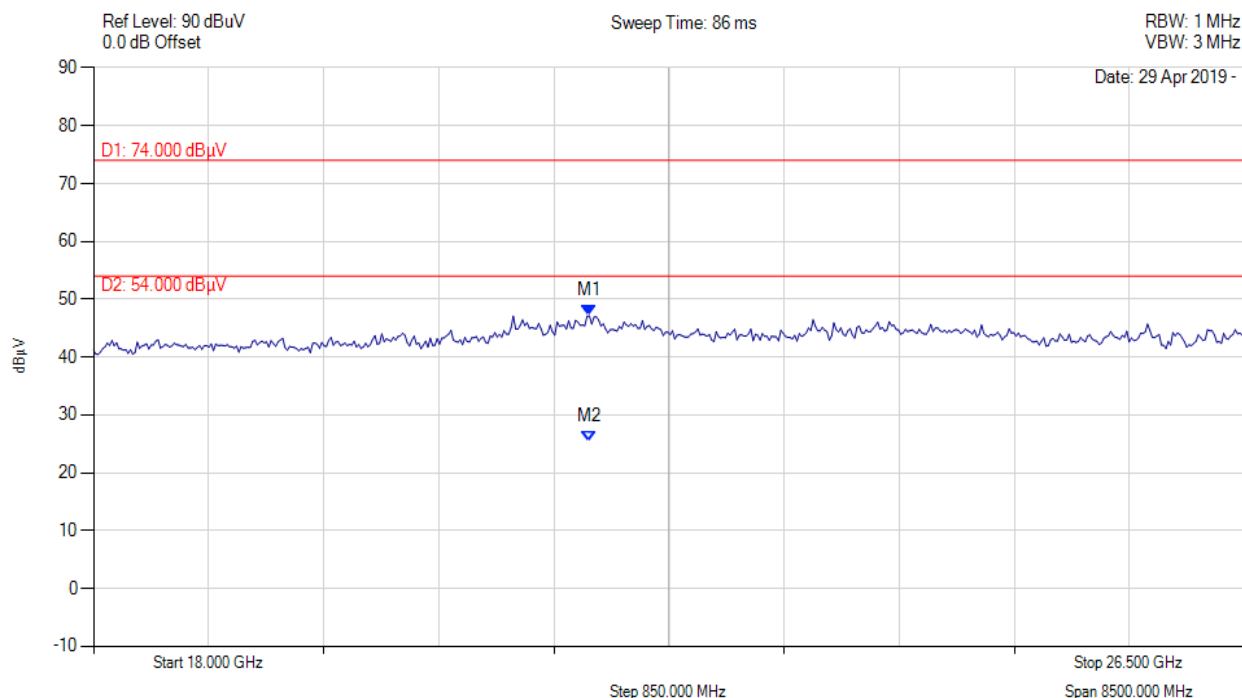
### Test Measurement Results

Test Notes: EUT powered by AC/DC PS. Connected to laptop outside chamber via ENET. 2.4 G Notch in front of amp to prevent overload EUT transmitting maximum power.



### TX SPURIOUS & RESTRICTED BAND EMISSIONS 18.0 -26.5 GHz

Variant: BLE, Test Freq: 2402.00 MHz, Antenna: WD PCB, Power Setting: Max, Duty Cycle (%): 66



| Analyzer Setup                                                                    | Marker:Frequency:Amplitude                                     | Test Results                   |
|-----------------------------------------------------------------------------------|----------------------------------------------------------------|--------------------------------|
| Detector = MAX PEAK<br>Sweep Count = 0<br>RF Atten (dB) = 10<br>Trace Mode = VIEW | M1 : 21.662 GHz : 47.126 dBuV<br>M2 : 21.662 GHz : 25.426 dBuV | Channel Frequency: 2402.00 MHz |

\*Trace is max hold composite of vertical and horizontal orientations

### Equipment Configuration for TX Spurious & Restricted Band Emissions 18 – 26.5 GHz

|                                 |                |                        |            |
|---------------------------------|----------------|------------------------|------------|
| <b>Antenna:</b>                 | WD PCB         | <b>Variant:</b>        | BLE        |
| <b>Antenna Gain (dBi):</b>      | 3.30           | <b>Modulation:</b>     | GFSK       |
| <b>Beam Forming Gain (Y):</b>   | Not Applicable | <b>Duty Cycle (%):</b> | 66         |
| <b>Channel Frequency (MHz):</b> | 2426.00        | <b>Data Rate:</b>      | 125 kBit/s |
| <b>Power Setting:</b>           | Max            | <b>Tested By:</b>      | JMH        |

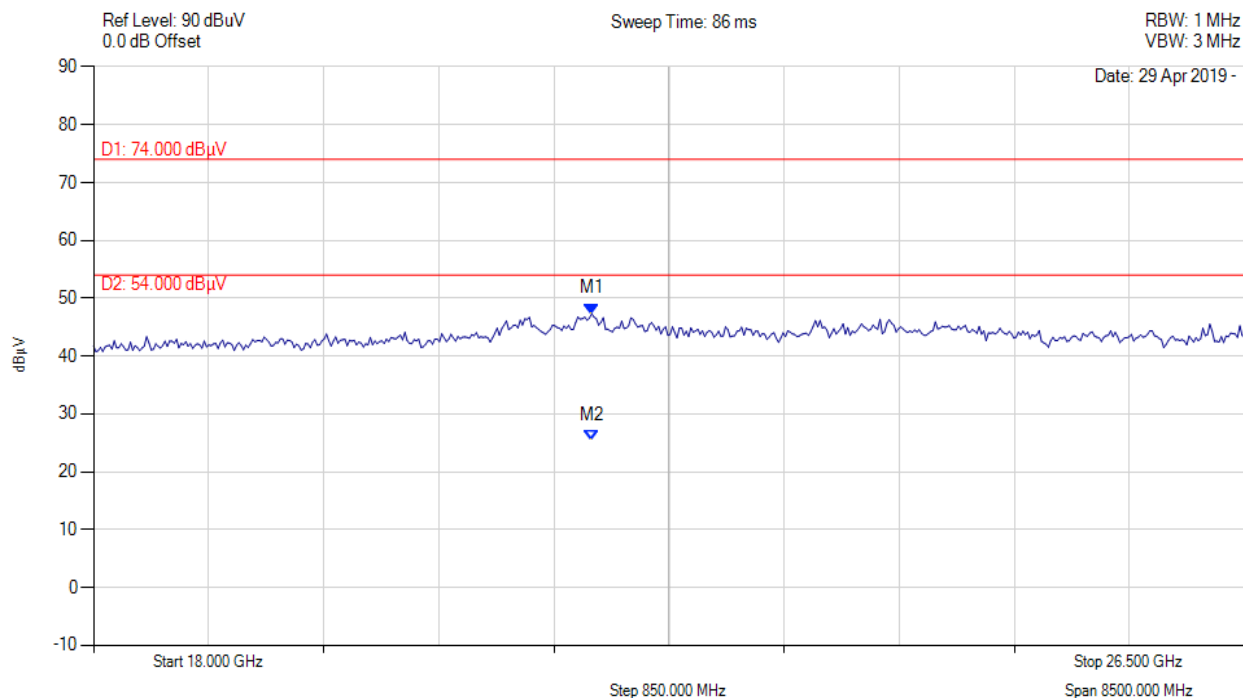
### Test Measurement Results

Test Notes: EUT powered by AC/DC PS. Connected to laptop outside chamber via ENET. 2.4 G Notch in front of amp to prevent overload EUT transmitting maximum power.



### TX SPURIOUS & RESTRICTED BAND EMISSIONS 18.0 -26.5 GHz

Variant: BLE, Test Freq: 2426.00 MHz, Antenna: WD PCB, Power Setting: Max, Duty Cycle (%): 66



| Analyzer Setup                                                                    | Marker:Frequency:Amplitude                                     | Test Results                   |
|-----------------------------------------------------------------------------------|----------------------------------------------------------------|--------------------------------|
| Detector = MAX PEAK<br>Sweep Count = 0<br>RF Atten (dB) = 10<br>Trace Mode = VIEW | M1 : 21.679 GHz : 47.311 dBuV<br>M2 : 21.679 GHz : 25.308 dBuV | Channel Frequency: 2426.00 MHz |

### Equipment Configuration for TX Spurious & Restricted Band Emissions 18 – 26.5 GHz

|                                 |                |                        |            |
|---------------------------------|----------------|------------------------|------------|
| <b>Antenna:</b>                 | WD PCB         | <b>Variant:</b>        | BLE        |
| <b>Antenna Gain (dBi):</b>      | 3.30           | <b>Modulation:</b>     | GFSK       |
| <b>Beam Forming Gain (Y):</b>   | Not Applicable | <b>Duty Cycle (%):</b> | 66         |
| <b>Channel Frequency (MHz):</b> | 2480.00        | <b>Data Rate:</b>      | 125 kBit/s |
| <b>Power Setting:</b>           | Max            | <b>Tested By:</b>      | JMH        |

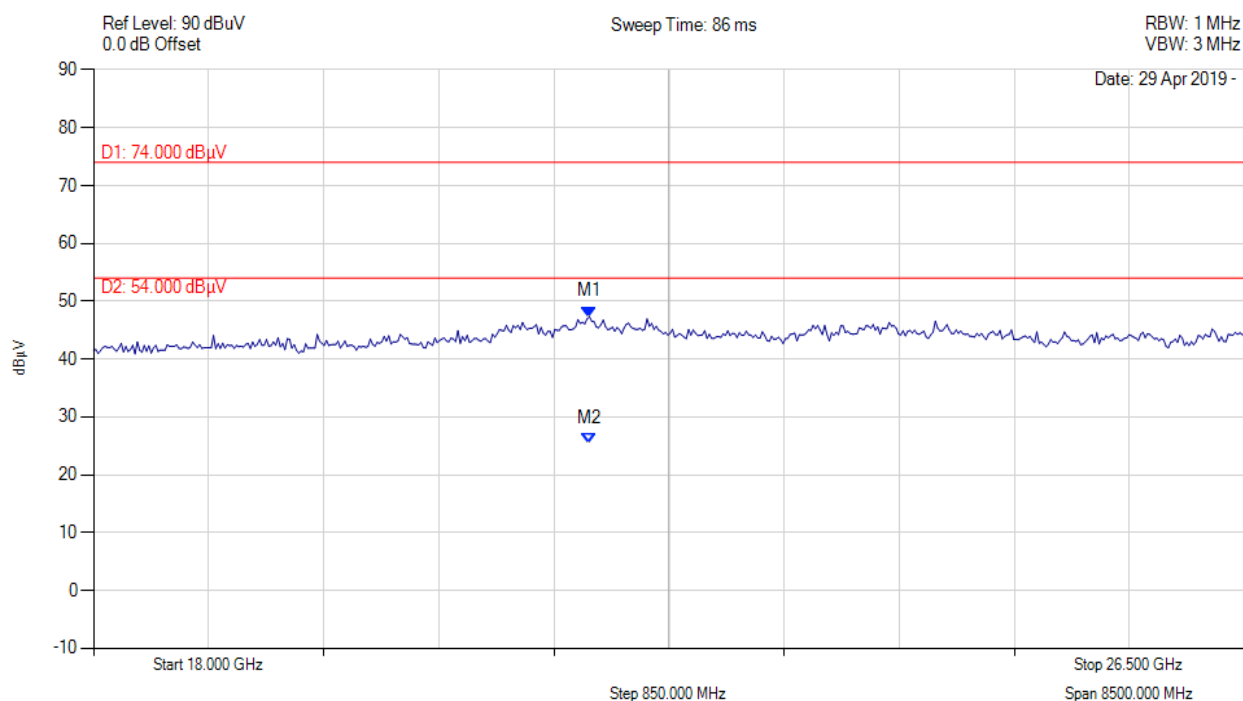
### Test Measurement Results

Test Notes: EUT powered by AC/DC PS. Connected to laptop outside chamber via ENET. 2.4 G Notch in front of amp to prevent overload EUT transmitting maximum power.



### TX SPURIOUS & RESTRICTED BAND EMISSIONS 18.0 -26.5 GHz

Variant: BLE, Test Freq: 2480.00 MHz, Antenna: WD PCB, Power Setting: Max, Duty Cycle (%): 66



| Analyzer Setup                                                                    | Marker:Frequency:Amplitude                                     | Test Results                   |
|-----------------------------------------------------------------------------------|----------------------------------------------------------------|--------------------------------|
| Detector = MAX PEAK<br>Sweep Count = 0<br>RF Atten (dB) = 10<br>Trace Mode = VIEW | M1 : 21.662 GHz : 47.330 dBuV<br>M2 : 21.662 GHz : 25.488 dBuV | Channel Frequency: 2480.00 MHz |

#### 9.4.2.4. Restricted Edge & Band-Edge Emissions

| WD PCB           |                           | Band-Edge Freq | Limit 74.0dBµV/m | Limit 54.0dBµV/m | Power Setting |
|------------------|---------------------------|----------------|------------------|------------------|---------------|
| Operational Mode | Operating Frequency (MHz) | MHz            | dBµV/m           | dBµV/m           |               |
| BLE              | 2402.00                   | 2390.00        | 57.05            | 37.57            | Max           |
| BLE              | 2480.00                   | 2483.50        | 67.85            | 38.44            | Max           |

### Equipment Configuration for Radiated - Lower Restricted Band-Edge Emissions

|                                 |                |                        |            |
|---------------------------------|----------------|------------------------|------------|
| <b>Antenna:</b>                 | WD PCB         | <b>Variant:</b>        | BLE        |
| <b>Antenna Gain (dBi):</b>      | 3.30           | <b>Modulation:</b>     | GFSK       |
| <b>Beam Forming Gain (Y):</b>   | Not Applicable | <b>Duty Cycle (%):</b> | 66         |
| <b>Channel Frequency (MHz):</b> | 2402.00        | <b>Data Rate:</b>      | 125 kBit/s |
| <b>Power Setting:</b>           | Max            | <b>Tested By:</b>      | JMH        |

### Test Measurement Results

| 2310.00 - 2422.00 MHz |               |          |               |         |              |                  |            |        |         |              |           |            |
|-----------------------|---------------|----------|---------------|---------|--------------|------------------|------------|--------|---------|--------------|-----------|------------|
| Num                   | Frequency MHz | Raw dBμV | Cable Loss dB | AF dB/m | Level dBμV/m | Measurement Type | Pol        | Hgt cm | Azt Deg | Limit dBμV/m | Margin dB | Pass /Fail |
| #1                    | 2390.00       | 5.58     | -1.77         | 31.96   | 37.57        | Max Avg          | Horizontal | 148    | 36      | 54.0         | -16.4     | Pass       |
| #2                    | 2390.00       | 26.86    | -1.77         | 31.96   | 57.05        | Max Peak         | Horizontal | 148    | 36      | 74.0         | -17.0     | Pass       |
| #3                    | 2390.00       | --       | --            | --      | --           | Restricted-Band  | --         | --     | --      | --           | --        | --         |

Test Notes: EUT powered by AC/DC PS. Connected to laptop outside chamber via ENET. DC Correction 1.8 dB.

### Equipment Configuration for Radiated - Upper Restricted Band-Edge Emissions

|                                 |                |                        |            |
|---------------------------------|----------------|------------------------|------------|
| <b>Antenna:</b>                 | WD PCB         | <b>Variant:</b>        | BLE        |
| <b>Antenna Gain (dBi):</b>      | Not Applicable | <b>Modulation:</b>     | GFSK       |
| <b>Beam Forming Gain (Y):</b>   | Not Applicable | <b>Duty Cycle (%):</b> | 66         |
| <b>Channel Frequency (MHz):</b> | 2480.00        | <b>Data Rate:</b>      | 125 kBit/s |
| <b>Power Setting:</b>           | Max            | <b>Tested By:</b>      | JMH        |

### Test Measurement Results

| 2452.00 - 2520.00 MHz |               |          |               |         |              |                  |            |        |         |              |           |            |
|-----------------------|---------------|----------|---------------|---------|--------------|------------------|------------|--------|---------|--------------|-----------|------------|
| Num                   | Frequency MHz | Raw dBμV | Cable Loss dB | AF dB/m | Level dBμV/m | Measurement Type | Pol        | Hgt cm | Azt Deg | Limit dBμV/m | Margin dB | Pass /Fail |
| #1                    | 2483.50       | 6.09     | -1.78         | 32.33   | 38.44        | Max Avg          | Horizontal | 148    | 48      | 54.0         | -15.6     | Pass       |
| #2                    | 2483.50       | 37.30    | -1.78         | 32.33   | 67.85        | Max Peak         | Horizontal | 148    | 48      | 74.0         | -6.2      | Pass       |
| #3                    | 2483.50       | --       | --            | --      | --           | Restricted-Band  | --         | --     | --      | --           | --        | --         |

Test Notes: EUT powered by AC/DC PS. Connected to laptop outside chamber via ENET. DC Correction 1.8 dB.



#### 9.4.3. Digital Emissions / Radiated Spurious Emissions (0.03 - 1 GHz)

| Test Conditions for Digital Emissions |                                       |                            |             |
|---------------------------------------|---------------------------------------|----------------------------|-------------|
| <b>Standard:</b>                      | FCC CFR 47:15.109<br>ICES-003 Issue 6 | <b>Ambient Temp. (°C):</b> | 24.0 - 27.5 |
| <b>Test Heading:</b>                  | Radiated Emissions Limits             | <b>Rel. Humidity (%):</b>  | 32 - 45     |
| <b>Standard Section(s):</b>           | 15.109 (a)<br>ICES-003 6.2.1          | <b>Pressure (mBars):</b>   | 999 - 1001  |
| <b>Reference Document(s):</b>         | See Normative References              |                            |             |

#### Test Procedure for Radiated Emissions Measurement

##### Test Procedure

Testing 30 – 1,000 MHz was performed in an anechoic chamber using a CISPR compliant receiver. Preliminary radiated emissions were measured on every azimuth and with the receiving antenna in both horizontal and vertical polarizations. To further maximize emissions the receive antenna was varied between 1 and 4 meters. The emissions are recorded with receiver in peak hold mode.

Emissions nearest the limits were chosen for maximization and formal measurement using a CISPR Compliant receiver. Emissions from 30 MHz – 1000 MHz are measured utilizing a CISPR compliant quasi-peak detector with a tuned receiver, using a bandwidth of 120 kHz.. Only the highest emissions relative to the limit are listed.

##### 15.109 Radiated limits.

((a) Except for Class A digital devices, the field strength of radiated emissions from unintentional radiators at a distance of 3 meters shall not exceed the following values:

| Frequency (MHz) | Quasi-peak Limit (dBμV/m) | Measurement Distance (meters) |
|-----------------|---------------------------|-------------------------------|
| 30 to 88        | 40                        | 3                             |
| 88-216          | 43.5                      | 3                             |
| 216-960         | 46                        | 3                             |
| 960-1000        | 54                        | 3                             |

(b) The field strength of radiated emissions from a Class A digital device, as determined at a distance of 10 meters, shall not exceed the following:

| Frequency(MHz) | Quasi-peak Limit (dBμV/m) | Measurement Distance (meters) |
|----------------|---------------------------|-------------------------------|
| 30 to 88       | 49.5                      | 3                             |
| 88-216         | 54                        | 3                             |
| 216-960        | 56.5                      | 3                             |
| 960-1000       | 60                        | 3                             |

##### Traceability

| Laboratory Measurement Uncertainty |               |
|------------------------------------|---------------|
| Measurement uncertainty            | +5.6/ -4.5 dB |

#### Equipment Configuration for Digital Emissions

|                                 |                |                        |                |
|---------------------------------|----------------|------------------------|----------------|
| <b>Antenna:</b>                 | WD PCB         | <b>Variant:</b>        | BLE            |
| <b>Antenna Gain (dBi):</b>      | 3.3            | <b>Modulation:</b>     | GFSK           |
| <b>Beam Forming Gain (Y):</b>   | Not Applicable | <b>Duty Cycle (%):</b> | Not Applicable |
| <b>Channel Frequency (MHz):</b> | 2402.00        | <b>Data Rate:</b>      | Not Applicable |
| <b>Power Setting:</b>           | Max            | <b>Tested By:</b>      | JMH            |

#### Test Measurement Results

| 30.00 - 1000.00 MHz                                                                                                                                           |               |          |               |         |              |                  |            |        |         |              |           |            |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------|----------|---------------|---------|--------------|------------------|------------|--------|---------|--------------|-----------|------------|
| Num                                                                                                                                                           | Frequency MHz | Raw dBμV | Cable Loss dB | AF dB/m | Level dBμV/m | Measurement Type | Pol        | Hgt cm | Azt Deg | Limit dBμV/m | Margin dB | Pass /Fail |
| <a href="#">#1</a>                                                                                                                                            | 31.96         | 29.79    | 3.53          | -8.70   | 24.62        | MaxQP            | Vertical   | 109    | 339     | 40.0         | -15.4     | Pass       |
| <a href="#">#2</a>                                                                                                                                            | 98.17         | 45.63    | 4.00          | -18.60  | 31.03        | MaxQP            | Vertical   | 106    | 8       | 43.0         | -12.0     | Pass       |
| <a href="#">#3</a>                                                                                                                                            | 124.18        | 39.12    | 4.12          | -14.60  | 28.64        | MaxQP            | Vertical   | 102    | 76      | 43.0         | -14.4     | Pass       |
| <a href="#">#4</a>                                                                                                                                            | 146.84        | 47.08    | 4.23          | -15.90  | 35.41        | MaxQP            | Vertical   | 102    | 174     | 43.0         | -7.6      | Pass       |
| <a href="#">#5</a>                                                                                                                                            | 338.68        | 42.47    | 4.98          | -13.70  | 33.75        | MaxQP            | Horizontal | 101    | 257     | 46.0         | -12.3     | Pass       |
| <a href="#">#6</a>                                                                                                                                            | 361.26        | 40.96    | 5.06          | -12.70  | 33.52        | MaxQP            | Horizontal | 102    | 276     | 46.0         | -12.5     | Pass       |
| Test Notes: EUT powered by AC/DC PS. Connected to laptop outside chamber via ENET. 2nd ENET connected to Hub with data transferring. Audio ports looped back. |               |          |               |         |              |                  |            |        |         |              |           |            |

Note: click the links in the above matrix to view the graphical image (plot).

#### Equipment Configuration for Digital Emissions

|                                 |                |                        |                |
|---------------------------------|----------------|------------------------|----------------|
| <b>Antenna:</b>                 | WD PCB         | <b>Variant:</b>        | BLE            |
| <b>Antenna Gain (dBi):</b>      | 3.3            | <b>Modulation:</b>     | Not Applicable |
| <b>Beam Forming Gain (Y):</b>   | Not Applicable | <b>Duty Cycle (%):</b> | Not Applicable |
| <b>Channel Frequency (MHz):</b> | 2426           | <b>Data Rate:</b>      | Not Applicable |
| <b>Power Setting:</b>           | Max            | <b>Tested By:</b>      | JMH            |

#### Test Measurement Results

| 30.00 - 1000.00 MHz                                                                                                                                           |               |          |               |         |              |                  |            |        |         |              |           |            |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------|----------|---------------|---------|--------------|------------------|------------|--------|---------|--------------|-----------|------------|
| Num                                                                                                                                                           | Frequency MHz | Raw dBμV | Cable Loss dB | AF dB/m | Level dBμV/m | Measurement Type | Pol        | Hgt cm | Azt Deg | Limit dBμV/m | Margin dB | Pass /Fail |
| <a href="#">#1</a>                                                                                                                                            | 31.78         | 28.69    | 3.53          | -8.70   | 23.52        | MaxQP            | Vertical   | 122    | 352     | 40.0         | -16.5     | Pass       |
| <a href="#">#2</a>                                                                                                                                            | 98.06         | 46.15    | 4.00          | -18.60  | 31.55        | MaxQP            | Vertical   | 101    | 1       | 43.0         | -11.5     | Pass       |
| <a href="#">#3</a>                                                                                                                                            | 124.18        | 39.62    | 4.12          | -14.60  | 29.14        | MaxQP            | Vertical   | 100    | 73      | 43.0         | -13.9     | Pass       |
| <a href="#">#4</a>                                                                                                                                            | 146.74        | 46.88    | 4.23          | -15.90  | 35.21        | MaxQP            | Vertical   | 99     | 171     | 43.0         | -7.8      | Pass       |
| <a href="#">#5</a>                                                                                                                                            | 338.68        | 41.57    | 4.98          | -13.70  | 32.85        | MaxQP            | Horizontal | 101    | 257     | 46.0         | -13.2     | Pass       |
| <a href="#">#6</a>                                                                                                                                            | 361.26        | 40.26    | 5.06          | -12.70  | 32.62        | MaxQP            | Horizontal | 100    | 270     | 46.0         | -13.4     | Pass       |
| Test Notes: EUT powered by AC/DC PS. Connected to laptop outside chamber via ENET. 2nd ENET connected to Hub with data transferring. Audio ports looped back. |               |          |               |         |              |                  |            |        |         |              |           |            |

Note: click the links in the above matrix to view the graphical image (plot).

#### Equipment Configuration for Digital Emissions

|                                 |                |                        |                |
|---------------------------------|----------------|------------------------|----------------|
| <b>Antenna:</b>                 | WD PCB         | <b>Variant:</b>        | BLE            |
| <b>Antenna Gain (dBi):</b>      | 3.3            | <b>Modulation:</b>     | GFSK           |
| <b>Beam Forming Gain (Y):</b>   | Not Applicable | <b>Duty Cycle (%):</b> | Not Applicable |
| <b>Channel Frequency (MHz):</b> | 2480.00        | <b>Data Rate:</b>      | Not Applicable |
| <b>Power Setting:</b>           | Max            | <b>Tested By:</b>      | JMH            |

#### Test Measurement Results

| 30.00 - 1000.00 MHz |               |          |               |         |              |                  |            |        |         |              |           |            |
|---------------------|---------------|----------|---------------|---------|--------------|------------------|------------|--------|---------|--------------|-----------|------------|
| Num                 | Frequency MHz | Raw dBμV | Cable Loss dB | AF dB/m | Level dBμV/m | Measurement Type | Pol        | Hgt cm | Azt Deg | Limit dBμV/m | Margin dB | Pass /Fail |
| <a href="#">#1</a>  | 31.84         | 28.39    | 3.53          | -8.70   | 23.24        | MaxQP            | Vertical   | 119    | 345     | 40.0         | -16.8     | Pass       |
| <a href="#">#2</a>  | 98.35         | 45.26    | 4.00          | -18.60  | 30.67        | MaxQP            | Vertical   | 106    | 7       | 43.0         | -12.3     | Pass       |
| <a href="#">#3</a>  | 124.58        | 38.91    | 4.12          | -14.60  | 28.43        | MaxQP            | Vertical   | 101    | 76      | 43.0         | -14.6     | Pass       |
| <a href="#">#4</a>  | 146.79        | 47.99    | 4.23          | -15.90  | 36.33        | MaxQP            | Vertical   | 100    | 178     | 43.0         | -6.7      | Pass       |
| <a href="#">#5</a>  | 338.76        | 41.47    | 4.98          | -13.70  | 32.74        | MaxQP            | Horizontal | 106    | 253     | 46.0         | -13.3     | Pass       |
| <a href="#">#6</a>  | 361.00        | 40.95    | 5.06          | -12.70  | 33.31        | MaxQP            | Horizontal | 100    | 275     | 46.0         | -12.7     | Pass       |

Test Notes: EUT powered by AC/DC PS. Connected to laptop outside chamber via ENET. 2nd ENET connected to Hub with data transferring. Audio ports looped back.

No spurious emissions found.

Note: click the links in the above matrix to view the graphical image (plot).

#### 9.4.4. AC Wireline Emissions

| Test Conditions for AC Mains Conducted Emissions |                               |                            |             |
|--------------------------------------------------|-------------------------------|----------------------------|-------------|
| <b>Standard:</b>                                 | FCC CFR 47:15.107<br>ICES-003 | <b>Ambient Temp. (°C):</b> | 24.0 - 27.5 |
| <b>Test Heading:</b>                             | AC Mains Conducted Limits     | <b>Rel. Humidity (%):</b>  | 32 - 45     |
| <b>Standard Section(s):</b>                      | 15.207<br>RSS-GEN Section 8.8 | <b>Pressure (mBars):</b>   | 999 - 1001  |
| <b>Reference Document(s):</b>                    | See Normative References      |                            |             |

##### Test Method

The test method shall be in accordance with ANSI C63.4 and the Artificial Mains Networks (AMNs) shall be connected to the AC mains power source. The measurement frequency range extends from 150 kHz to 30 MHz. When the EUT is a transmitter operating at frequencies below 30 MHz, then the exclusion band for transmitters applies for measurements in the transmit mode of operation.

##### Test Procedure for AC Mains Conducted Emissions Measurement

The conducted emissions are measured in a shielded room with a spectrum analyzer in peak hold in the first instance. Emissions closest to the limit are measured in the quasi-peak mode (QP) with the tuned receiver using a bandwidth of 9 kHz. The emissions are maximized further by cable manipulation. The highest emissions relative to the limit are listed.

##### 15.107 Conducted limits.

(a) Except for Class A digital devices, for equipment that is designed to be connected to the public utility (AC) power line, the radio frequency voltage that is conducted back onto the AC power line on any frequency or frequencies within the band 150 kHz to 30 MHz shall not exceed the limits in the following table, as measured using a 50  $\mu$ H/50 ohms line impedance stabilization network (LISN). Compliance with the provisions of this paragraph shall be based on the measurement of the radio frequency voltage between each power line and ground at the power terminal. The lower limit applies at the band edges.

| Frequency of emission (MHz) | Conducted limit (dB $\mu$ V) |           |
|-----------------------------|------------------------------|-----------|
|                             | Quasi-peak                   | Average   |
| 0.15-0.5                    | 66 to 56*                    | 56 to 46* |
| 0.5-5                       | 56                           | 46        |
| 5-30                        | 60                           | 50        |

\*Decreases with the logarithm of the frequency.

(b) For a Class A digital device that is designed to be connected to the public utility (AC) power line, the radio frequency voltage that is conducted back onto the AC power line on any frequency or frequencies within the band 150 kHz to 30 MHz shall not exceed the limits in the following table, as measured using a 50  $\mu$ H/50 ohms LISN. Compliance with the provisions of this paragraph shall be based on the measurement of the radio frequency voltage between each power line and ground at the power terminal. The lower limit applies at the boundary between the frequency ranges.

| Frequency of emission (MHz) | Conducted limit (dB $\mu$ V) |         |
|-----------------------------|------------------------------|---------|
|                             | Quasi-peak                   | Average |
| 0.15-0.5                    | 79                           | 66      |
| 0.5-30                      | 73                           | 60      |

##### Traceability

All conducted emission measurements are traceable to national standards. The uncertainty of measurement at a confidence level of not less than 95 %, with a coverage factor of k=2, in the range 9 kHz – 30 MHz (Average & Quasi-peak) is  $\pm 2.64$  dB.

| Laboratory Measurement Uncertainty |               |
|------------------------------------|---------------|
| Measurement uncertainty            | $\pm 2.64$ dB |

|              |                          |                       |          |
|--------------|--------------------------|-----------------------|----------|
| Model:       | S23                      | Configuration tested: | AC/DC PS |
| Input power: | 120V <sub>AC</sub> /60Hz | Standard:             | FCC      |

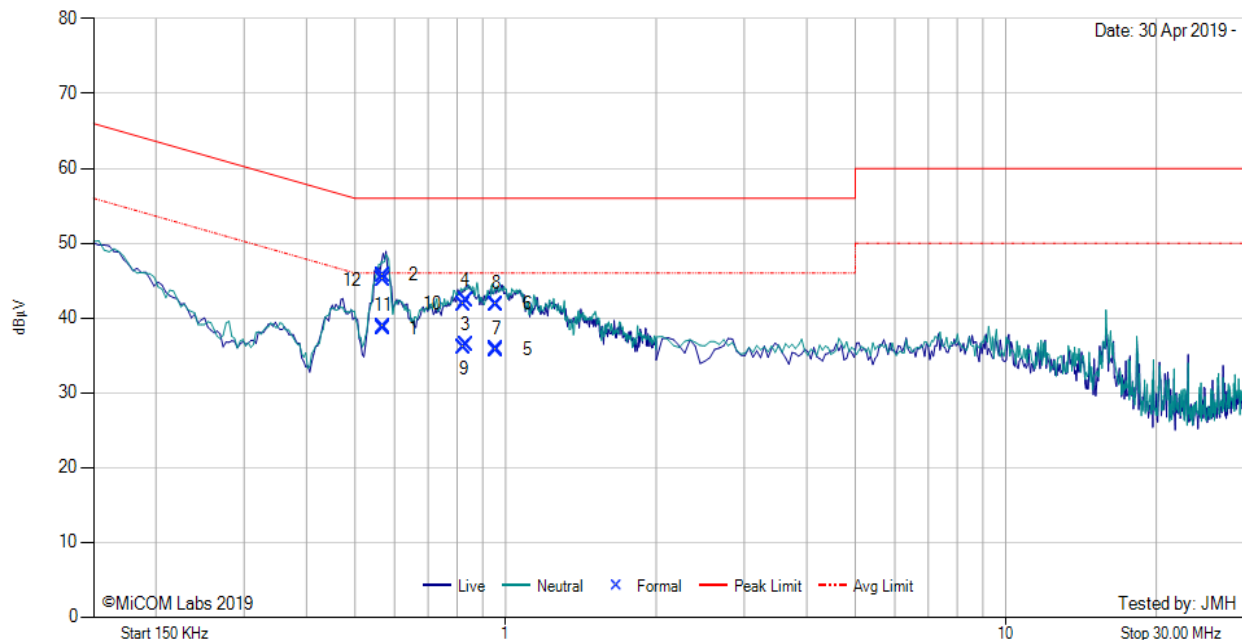


Variant: , Test Freq: 0.00 MHz

Measurement Distance: N/A

Sweep Time: 940 ms

RBW: 9 KHz  
VBW: 10 KHz

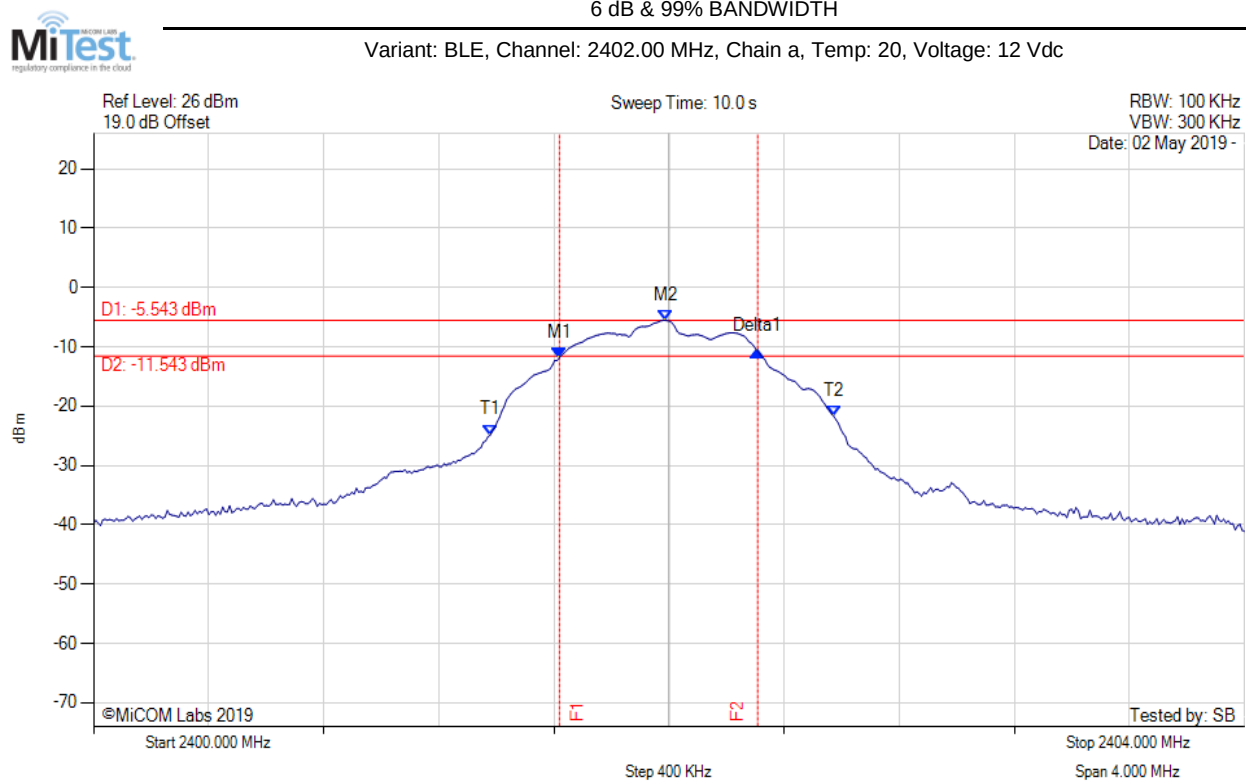


| Num | Frequency MHz | Raw dBμV | Cable Loss dB | Factor dB | Total Correction dBμV | Corrected Value dBμV | Measurement Type | Line    | Limit dBμV/m | Margin dB | Pass /Fail |
|-----|---------------|----------|---------------|-----------|-----------------------|----------------------|------------------|---------|--------------|-----------|------------|
| 1   | 0.570         | 28.56    | 0.10          | 9.92      | 10.02                 | 38.58                | Max Avg          | Live    | 46.0         | -7.4      | Pass       |
| 2   | 0.570         | 35.69    | 0.10          | 9.92      | 10.02                 | 45.71                | Max Qp           | Live    | 56.0         | -10.3     | Pass       |
| 3   | 0.833         | 26.28    | 0.10          | 9.94      | 10.04                 | 36.32                | Max Avg          | Neutral | 46.0         | -9.7      | Pass       |
| 4   | 0.833         | 32.28    | 0.10          | 9.94      | 10.04                 | 42.32                | Max Qp           | Neutral | 56.0         | -13.7     | Pass       |
| 5   | 0.960         | 25.79    | 0.08          | 9.93      | 10.01                 | 35.80                | Max Avg          | Neutral | 46.0         | -10.2     | Pass       |
| 6   | 0.960         | 31.85    | 0.08          | 9.93      | 10.01                 | 41.86                | Max Qp           | Neutral | 56.0         | -14.1     | Pass       |
| 7   | 0.959         | 25.73    | 0.08          | 9.93      | 10.01                 | 35.74                | Max Avg          | Live    | 46.0         | -10.3     | Pass       |
| 8   | 0.959         | 31.83    | 0.08          | 9.93      | 10.01                 | 41.84                | Max Qp           | Live    | 56.0         | -14.2     | Pass       |
| 9   | 0.825         | 25.96    | 0.10          | 9.94      | 10.04                 | 36.00                | Max Avg          | Live    | 46.0         | -10.0     | Pass       |
| 10  | 0.825         | 31.77    | 0.10          | 9.94      | 10.04                 | 41.81                | Max Qp           | Live    | 56.0         | -14.2     | Pass       |
| 11  | 0.569         | 28.86    | 0.10          | 9.92      | 10.02                 | 38.88                | Max Avg          | Live    | 46.0         | -7.1      | Pass       |
| 12  | 0.569         | 35.05    | 0.10          | 9.92      | 10.02                 | 45.07                | Max Qp           | Live    | 56.0         | -10.9     | Pass       |

**Test Notes:** EUT powered by AC/DC PS 120V 60 Hz, connected to laptop via ethernet. 2nd ethernet cable connected to hub with traffic. Transmitting 2412b WiFi and BLE for maximum load. Audio ports looped back. For test purposes EUT was set to transmit maximum power

## **A. APPENDIX - GRAPHICAL IMAGES**

## A.1. 6 dB & 99% Bandwidth



| Analyzer Setup                                                                        | Marker:Frequency:Amplitude                                                                                                                                                                | Test Results                                                                       |
|---------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------|
| Detector = MAX PEAK<br>Sweep Count = 0<br>RF Atten (dB) = 20<br>Trace Mode = MAX HOLD | M1 : 2401.619 MHz : -11.791 dBm<br>M2 : 2401.988 MHz : -5.543 dBm<br>Delta1 : 689 KHz : 1.078 dB<br>T1 : 2401.379 MHz : -24.862 dBm<br>T2 : 2402.573 MHz : -21.748 dBm<br>OBW : 1.194 MHz | Measured 6 dB Bandwidth: 0.689 MHz<br>Limit: $\geq 500.0$ kHz<br>Margin: -0.19 MHz |

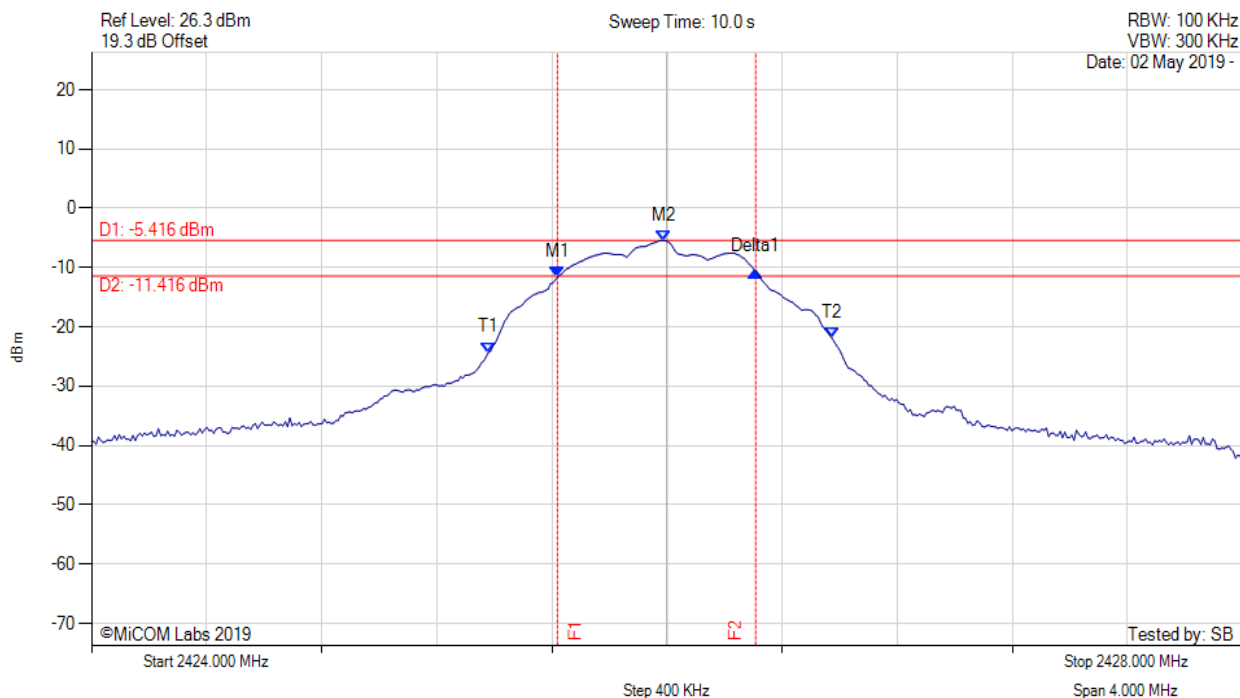
[back to matrix](#)



6 dB & 99% BANDWIDTH



Variant: BLE, Channel: 2426.00 MHz, Chain a, Temp: 20, Voltage: 12 Vdc



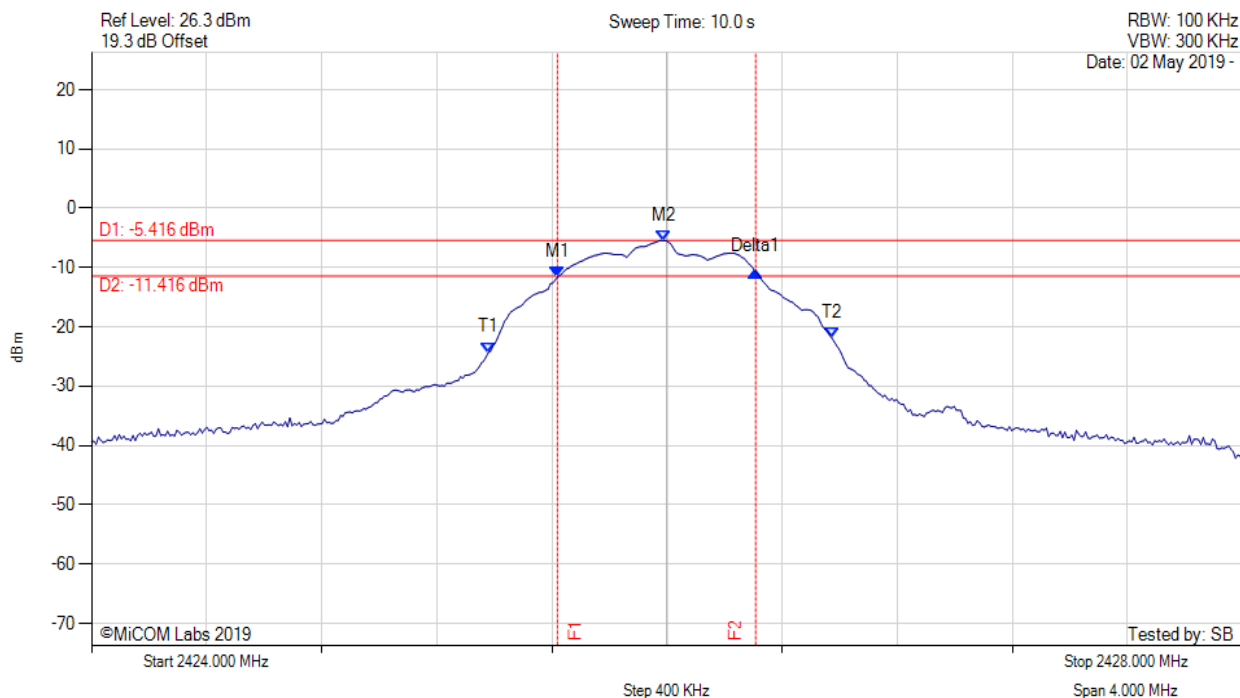
| Analyzer Setup                                                                        | Marker:Frequency:Amplitude                                                                                                                                                                | Test Results                                                                       |
|---------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------|
| Detector = MAX PEAK<br>Sweep Count = 0<br>RF Atten (dB) = 20<br>Trace Mode = MAX HOLD | M1 : 2425.619 MHz : -11.605 dBm<br>M2 : 2425.988 MHz : -5.416 dBm<br>Delta1 : 689 KHz : 0.927 dB<br>T1 : 2425.379 MHz : -24.326 dBm<br>T2 : 2426.573 MHz : -21.875 dBm<br>OBW : 1.194 MHz | Measured 6 dB Bandwidth: 0.689 MHz<br>Limit: $\geq 500.0$ kHz<br>Margin: -0.19 MHz |

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6 dB & 99% BANDWIDTH



Variant: BLE, Channel: 2426.00 MHz, Chain a, Temp: 20, Voltage: 12 Vdc



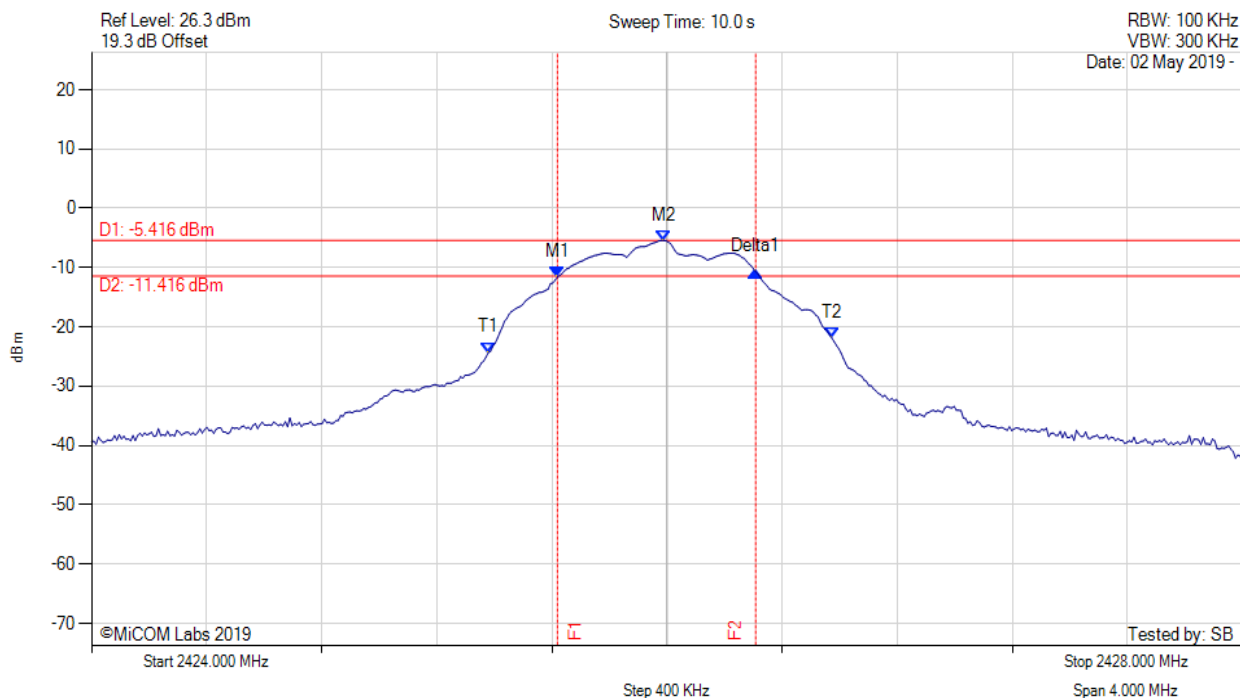
| Analyzer Setup                                                                        | Marker:Frequency:Amplitude                                                                                                                                                                | Test Results                   |
|---------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------|
| Detector = MAX PEAK<br>Sweep Count = 0<br>RF Atten (dB) = 20<br>Trace Mode = MAX HOLD | M1 : 2425.619 MHz : -11.605 dBm<br>M2 : 2425.988 MHz : -5.416 dBm<br>Delta1 : 689 KHz : 0.927 dB<br>T1 : 2425.379 MHz : -24.326 dBm<br>T2 : 2426.573 MHz : -21.875 dBm<br>OBW : 1.194 MHz | Channel Frequency: 2426.00 MHz |

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# 6 dB & 99% BANDWIDTH



Variant: BLE, Channel: 2426.00 MHz, Chain a, Temp: 20, Voltage: 12 Vdc



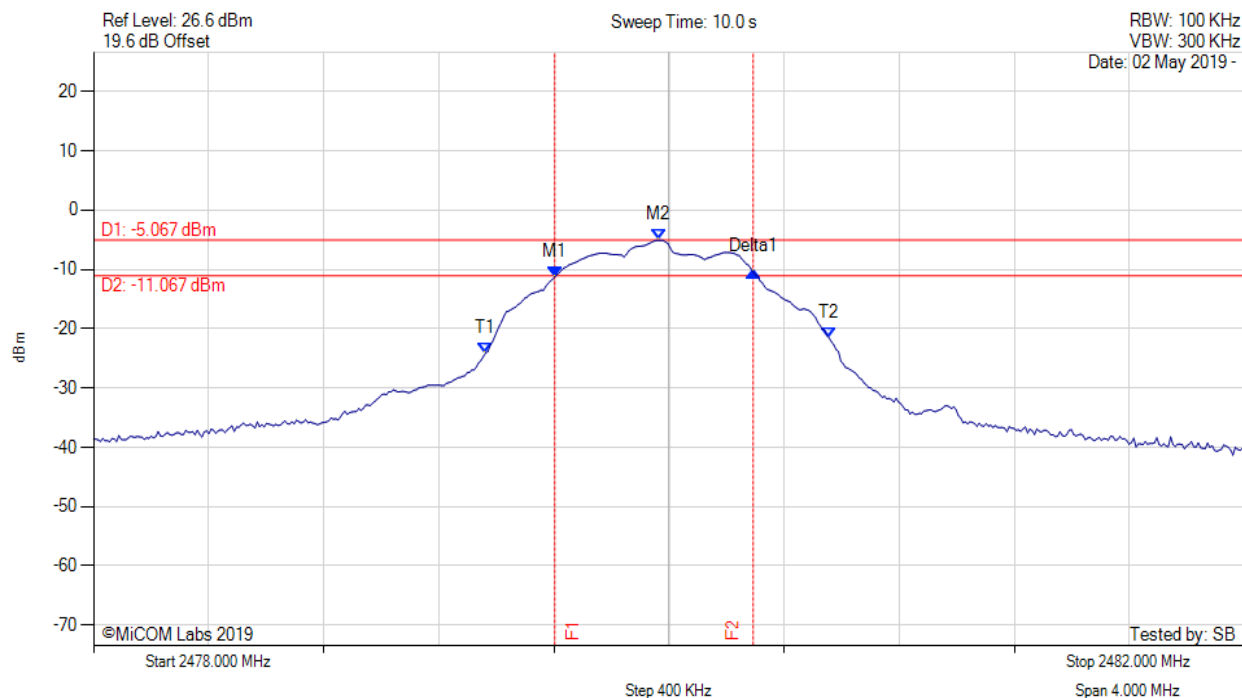
| Analyzer Setup                                                                        | Marker:Frequency:Amplitude                                                                                                                                                                | Test Results                                                                       |
|---------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------|
| Detector = MAX PEAK<br>Sweep Count = 0<br>RF Atten (dB) = 20<br>Trace Mode = MAX HOLD | M1 : 2425.619 MHz : -11.605 dBm<br>M2 : 2425.988 MHz : -5.416 dBm<br>Delta1 : 689 KHz : 0.927 dB<br>T1 : 2425.379 MHz : -24.326 dBm<br>T2 : 2426.573 MHz : -21.875 dBm<br>OBW : 1.194 MHz | Measured 6 dB Bandwidth: 0.689 MHz<br>Limit: $\geq 500.0$ kHz<br>Margin: -0.19 MHz |

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# 6 dB & 99% BANDWIDTH



Variant: BLE, Channel: 2480.00 MHz, Chain a, Temp: 20, Voltage: 12 Vdc



| Analyzer Setup                                                                        | Marker:Frequency:Amplitude                                                                                                                                                                | Test Results                                                                       |
|---------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------|
| Detector = MAX PEAK<br>Sweep Count = 0<br>RF Atten (dB) = 20<br>Trace Mode = MAX HOLD | M1 : 2479.603 MHz : -11.232 dBm<br>M2 : 2479.964 MHz : -5.067 dBm<br>Delta1 : 689 KHz : 0.836 dB<br>T1 : 2479.363 MHz : -24.101 dBm<br>T2 : 2480.557 MHz : -21.620 dBm<br>OBW : 1.194 MHz | Measured 6 dB Bandwidth: 0.689 MHz<br>Limit: $\geq 500.0$ kHz<br>Margin: -0.19 MHz |

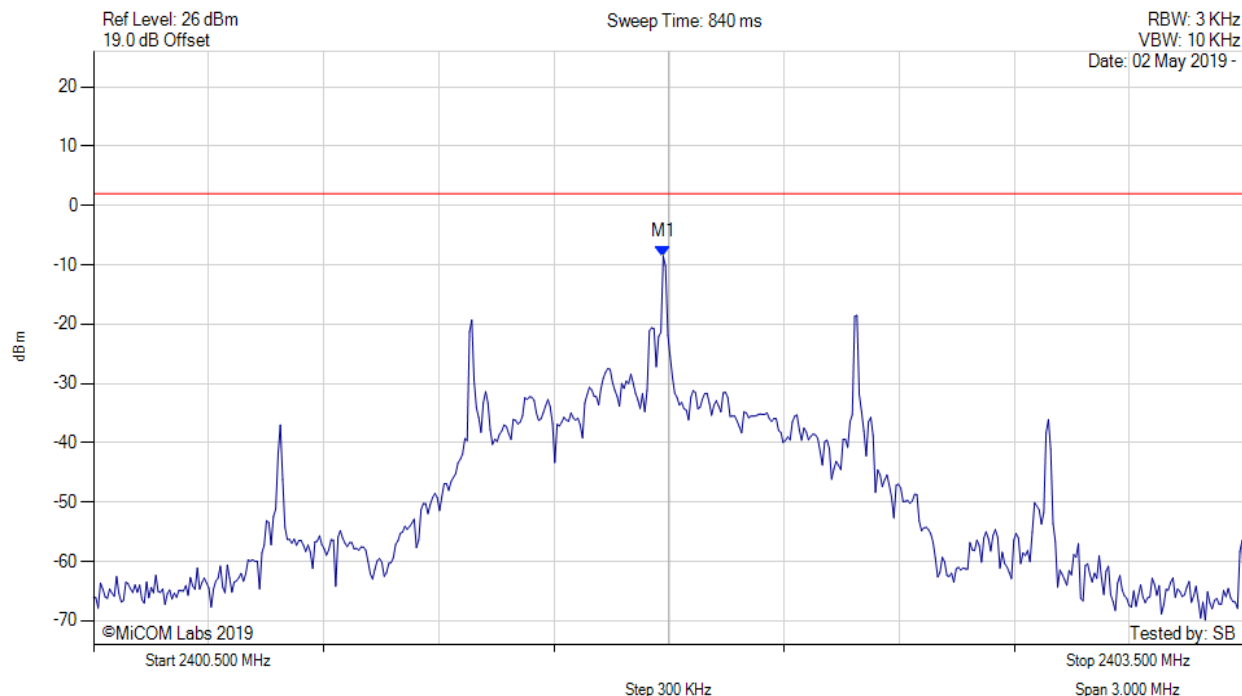
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## A.2. Power Spectral Density



### POWER SPECTRAL DENSITY - PEAK

Variant: BLE, Channel: 2402.00 MHz, Chain a, Temp: 20, Voltage: 12 Vdc



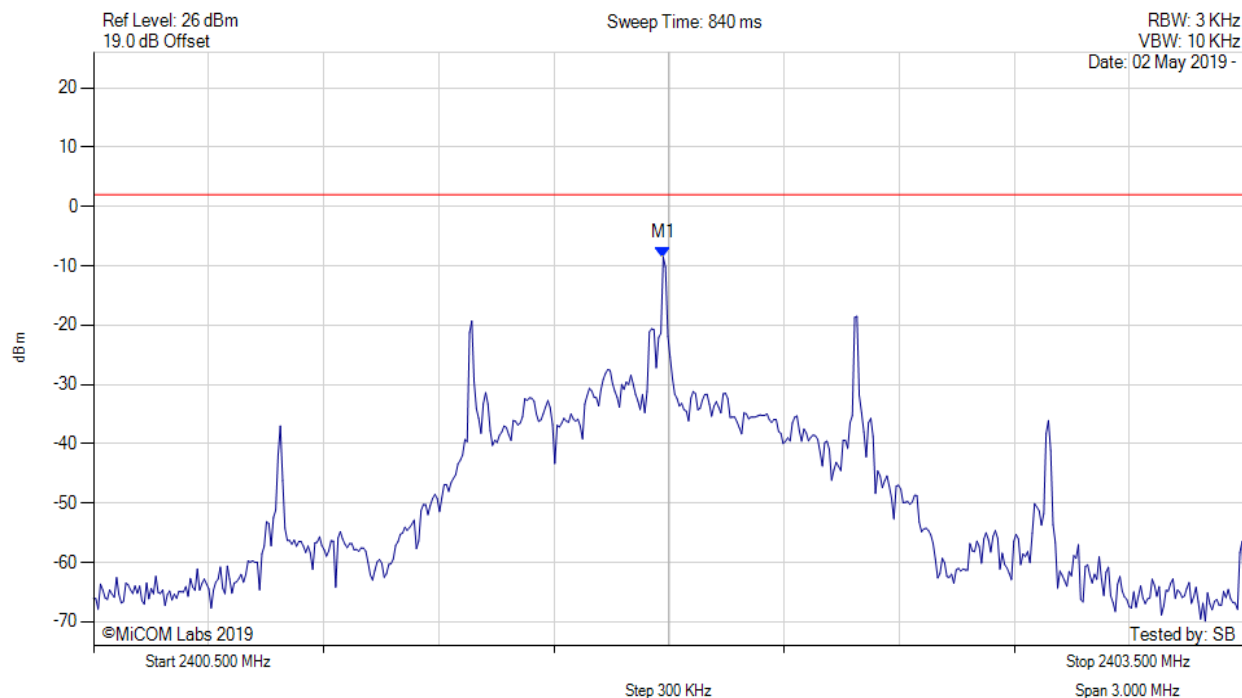
| Analyzer Setup                                                                    | Marker:Frequency:Amplitude     | Test Results                                |
|-----------------------------------------------------------------------------------|--------------------------------|---------------------------------------------|
| Detector = MAX PEAK<br>Sweep Count = 0<br>RF Atten (dB) = 20<br>Trace Mode = VIEW | M1 : 2401.985 MHz : -8.531 dBm | Limit: $\leq 1.980$ dBm<br>Margin: 10.51 dB |

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POWER SPECTRAL DENSITY - PEAK



Variant: BLE, Channel: 2402.00 MHz, SUM, Temp: 20, Voltage: 12 Vdc



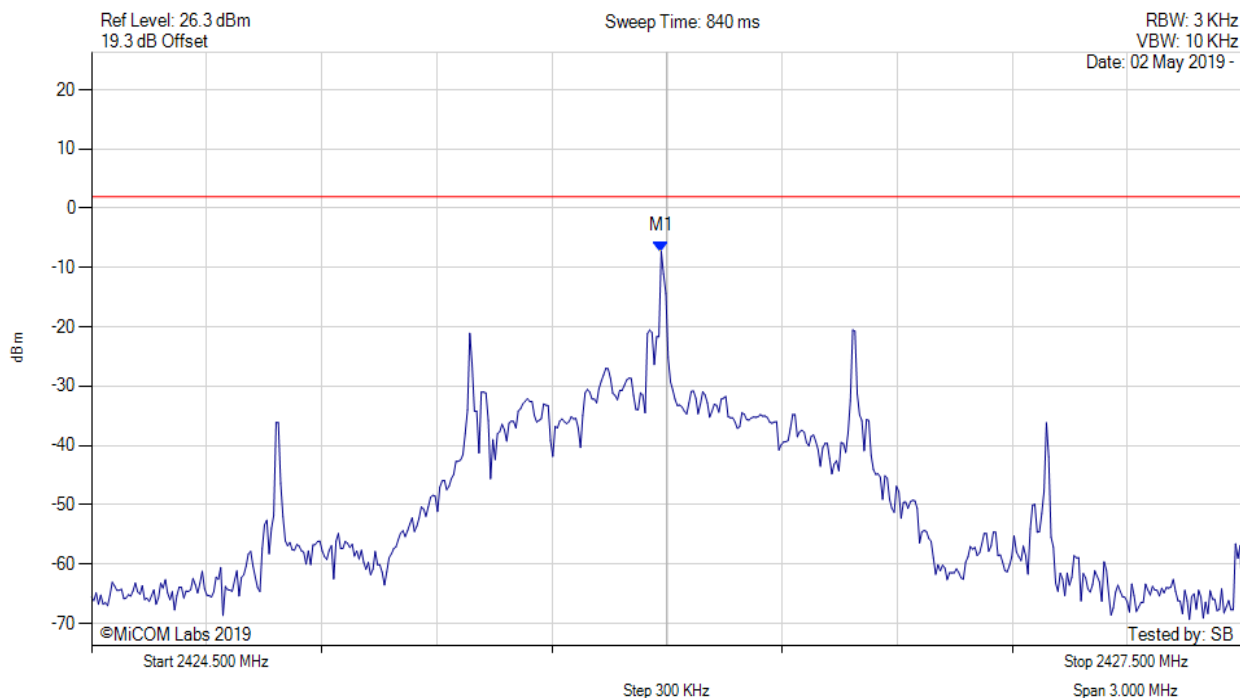
| Analyzer Setup                                                                    | Marker:Frequency:Amplitude     | Test Results                              |
|-----------------------------------------------------------------------------------|--------------------------------|-------------------------------------------|
| Detector = MAX PEAK<br>Sweep Count = 0<br>RF Atten (dB) = 20<br>Trace Mode = VIEW | M1 : 2401.985 MHz : -8.531 dBm | Limit: $\leq 2.0$ dBm<br>Margin: -10.5 dB |

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# POWER SPECTRAL DENSITY - PEAK



Variant: BLE, Channel: 2426.00 MHz, Chain a, Temp: 20, Voltage: 12 Vdc



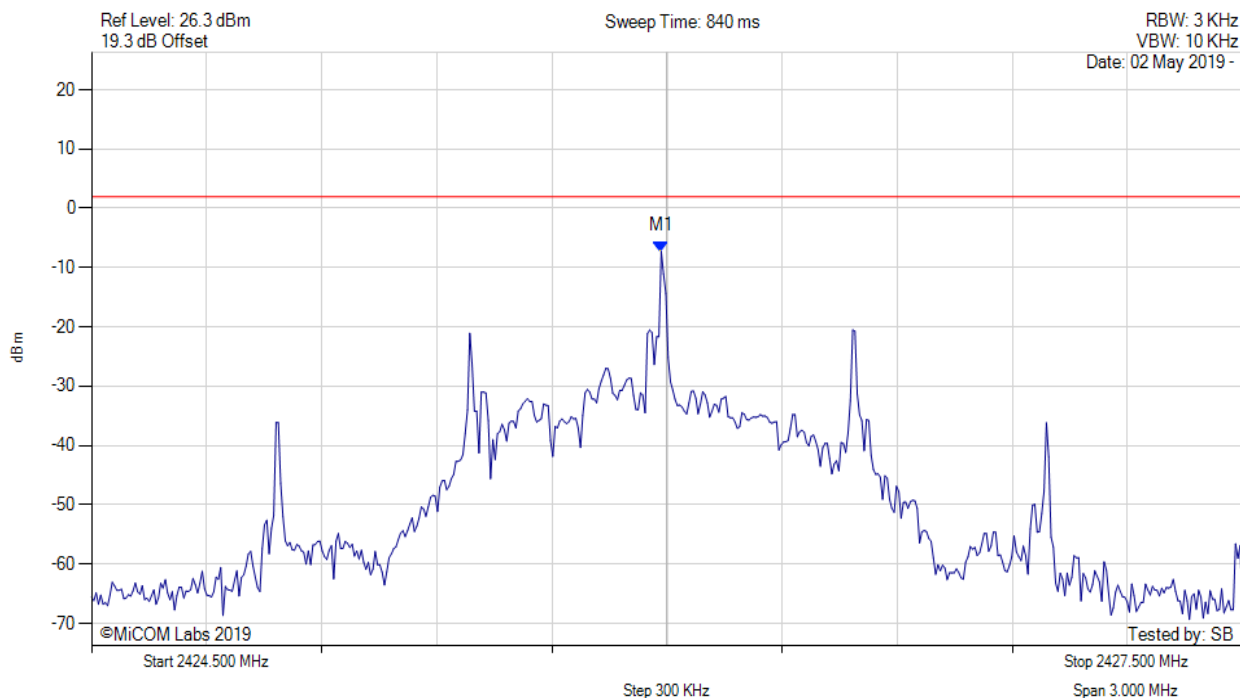
| Analyzer Setup                                                                    | Marker:Frequency:Amplitude     | Test Results                   |
|-----------------------------------------------------------------------------------|--------------------------------|--------------------------------|
| Detector = MAX PEAK<br>Sweep Count = 0<br>RF Atten (dB) = 20<br>Trace Mode = VIEW | M1 : 2425.985 MHz : -7.271 dBm | Channel Frequency: 2426.00 MHz |

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# POWER SPECTRAL DENSITY - PEAK



Variant: BLE, Channel: 2426.00 MHz, Chain a, Temp: 20, Voltage: 12 Vdc



| Analyzer Setup                                                                    | Marker:Frequency:Amplitude     | Test Results                               |
|-----------------------------------------------------------------------------------|--------------------------------|--------------------------------------------|
| Detector = MAX PEAK<br>Sweep Count = 0<br>RF Atten (dB) = 20<br>Trace Mode = VIEW | M1 : 2425.985 MHz : -7.271 dBm | Limit: $\leq 1.980$ dBm<br>Margin: 9.25 dB |

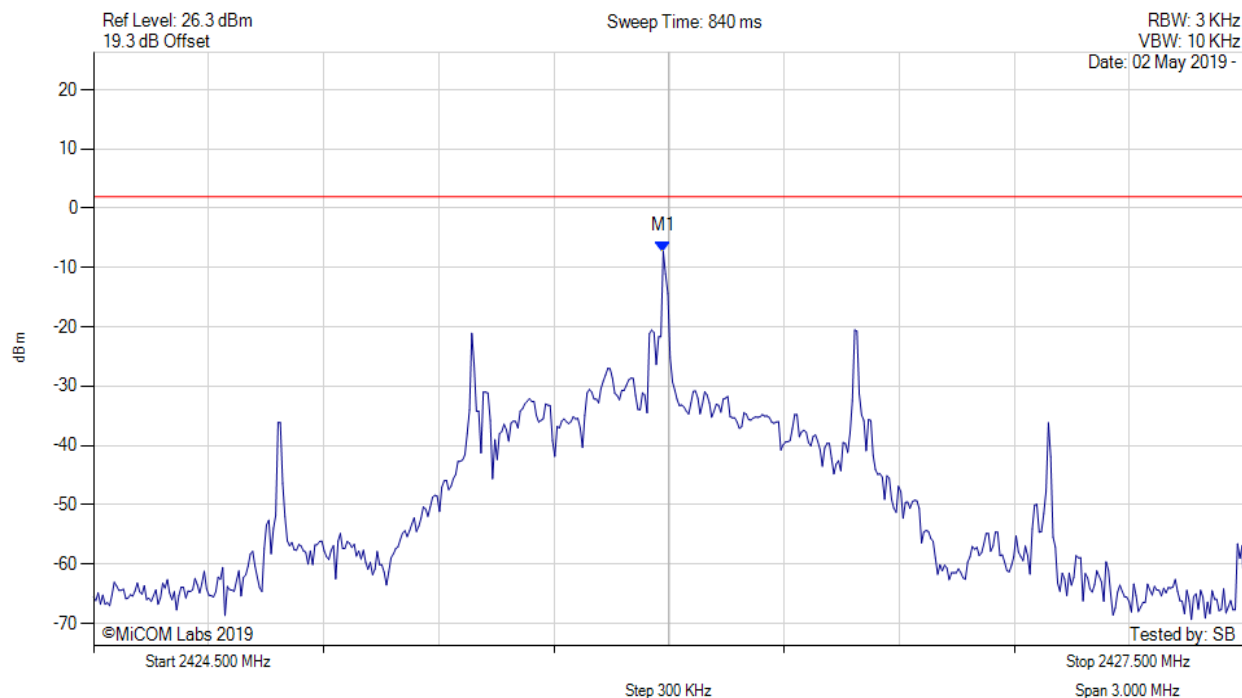
[back to matrix](#)



# POWER SPECTRAL DENSITY - PEAK



Variant: BLE, Channel: 2426.00 MHz, Chain a, Temp: 20, Voltage: 12 Vdc



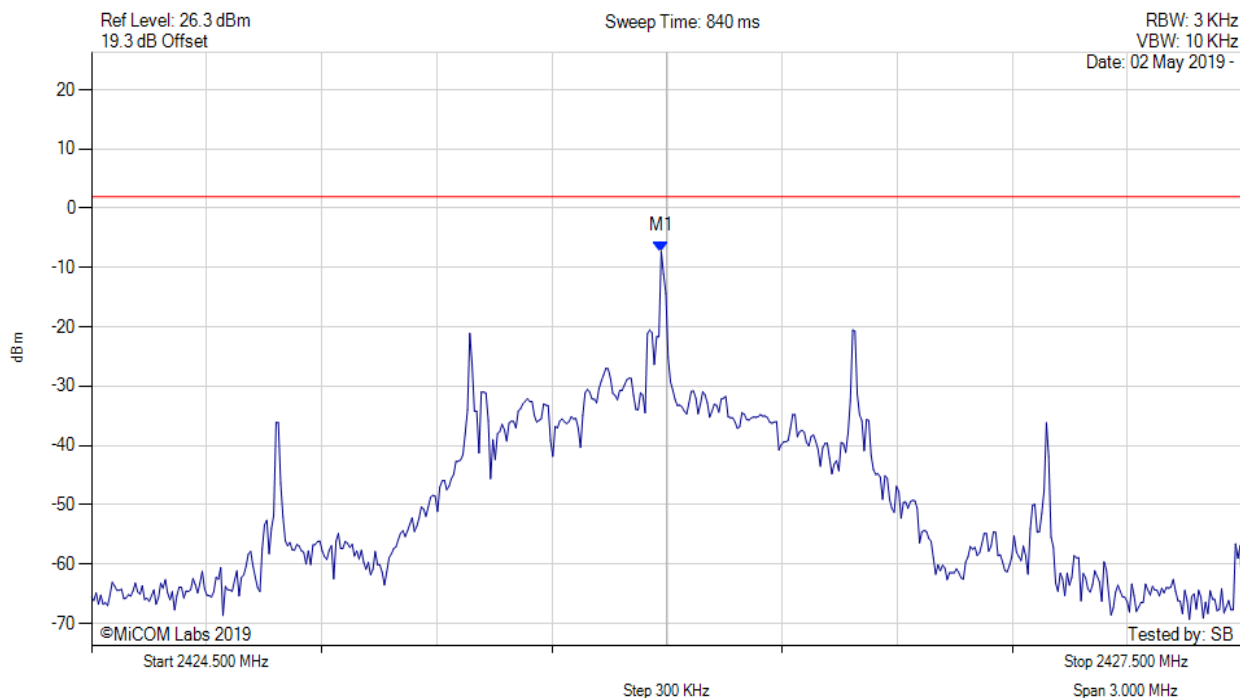
| Analyzer Setup                                                                    | Marker:Frequency:Amplitude     | Test Results                               |
|-----------------------------------------------------------------------------------|--------------------------------|--------------------------------------------|
| Detector = MAX PEAK<br>Sweep Count = 0<br>RF Atten (dB) = 20<br>Trace Mode = VIEW | M1 : 2425.985 MHz : -7.271 dBm | Limit: $\leq 1.980$ dBm<br>Margin: 9.25 dB |

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POWER SPECTRAL DENSITY - PEAK



Variant: BLE, Channel: 2426.00 MHz, SUM, Temp: 20, Voltage: 12 Vdc



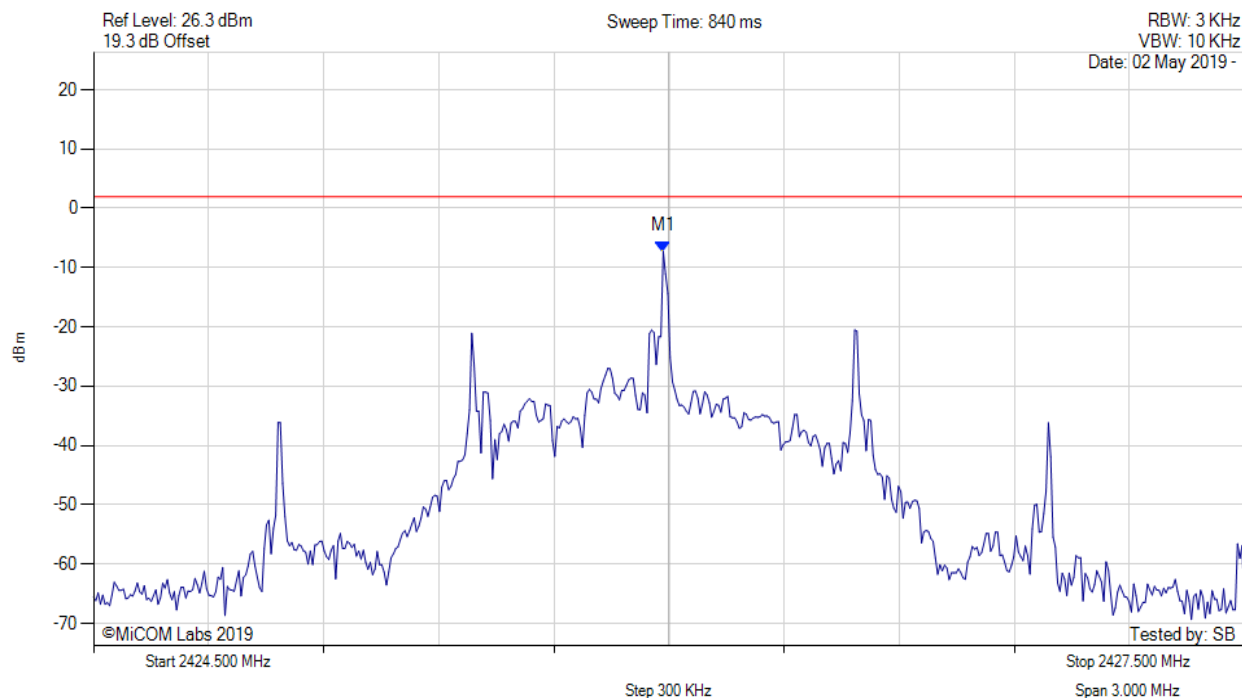
| Analyzer Setup                                                                    | Marker:Frequency:Amplitude     | Test Results                             |
|-----------------------------------------------------------------------------------|--------------------------------|------------------------------------------|
| Detector = MAX PEAK<br>Sweep Count = 0<br>RF Atten (dB) = 20<br>Trace Mode = VIEW | M1 : 2425.985 MHz : -7.271 dBm | Limit: $\leq 2.0$ dBm<br>Margin: -9.3 dB |

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POWER SPECTRAL DENSITY - PEAK



Variant: BLE, Channel: 2426.00 MHz, SUM, Temp: 20, Voltage: 12 Vdc



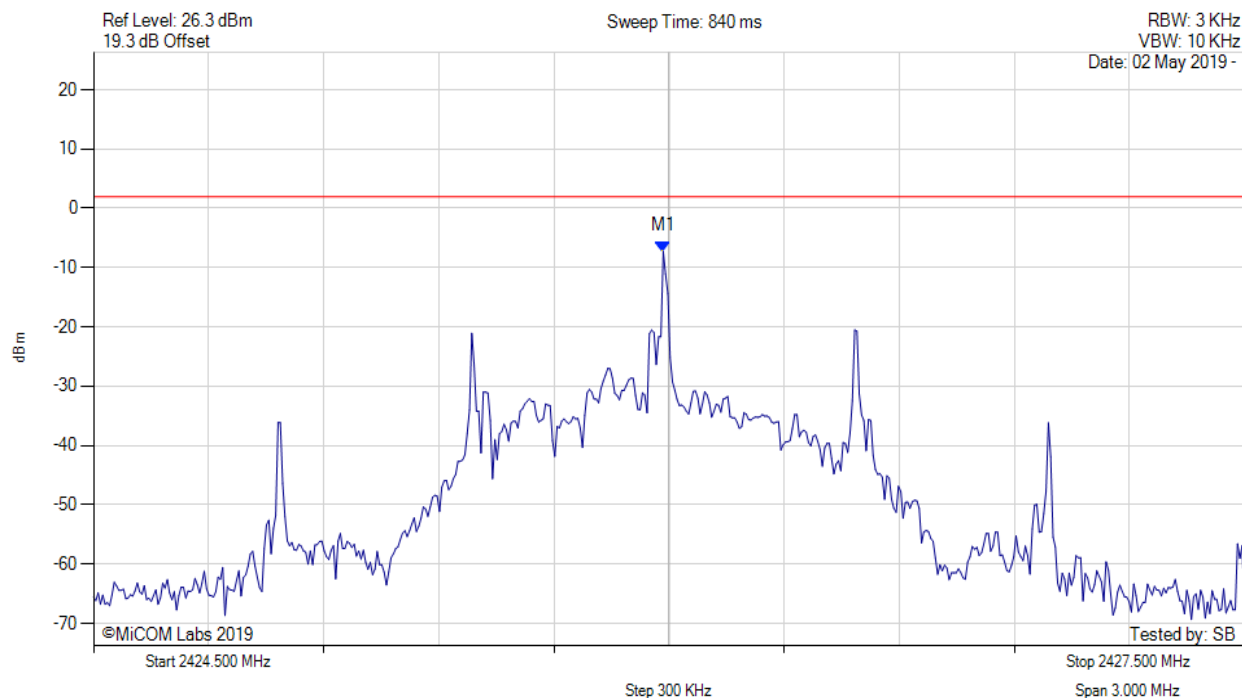
| Analyzer Setup                                                                    | Marker:Frequency:Amplitude     | Test Results                   |
|-----------------------------------------------------------------------------------|--------------------------------|--------------------------------|
| Detector = MAX PEAK<br>Sweep Count = 0<br>RF Atten (dB) = 20<br>Trace Mode = VIEW | M1 : 2425.985 MHz : -7.271 dBm | Channel Frequency: 2426.00 MHz |

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POWER SPECTRAL DENSITY - PEAK



Variant: BLE, Channel: 2426.00 MHz, SUM, Temp: 20, Voltage: 12 Vdc



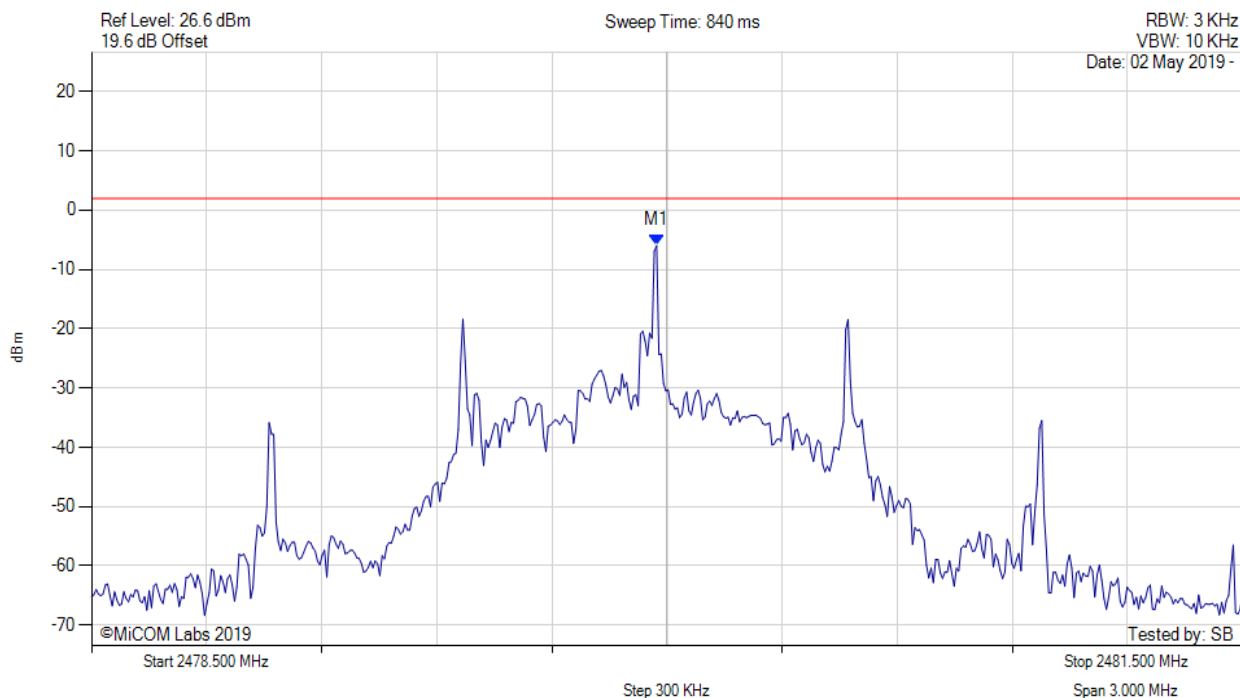
| Analyzer Setup                                                                    | Marker:Frequency:Amplitude     | Test Results                             |
|-----------------------------------------------------------------------------------|--------------------------------|------------------------------------------|
| Detector = MAX PEAK<br>Sweep Count = 0<br>RF Atten (dB) = 20<br>Trace Mode = VIEW | M1 : 2425.985 MHz : -7.271 dBm | Limit: $\leq 2.0$ dBm<br>Margin: -9.3 dB |

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POWER SPECTRAL DENSITY - PEAK



Variant: BLE, Channel: 2480.00 MHz, Chain a, Temp: 20, Voltage: 12 Vdc



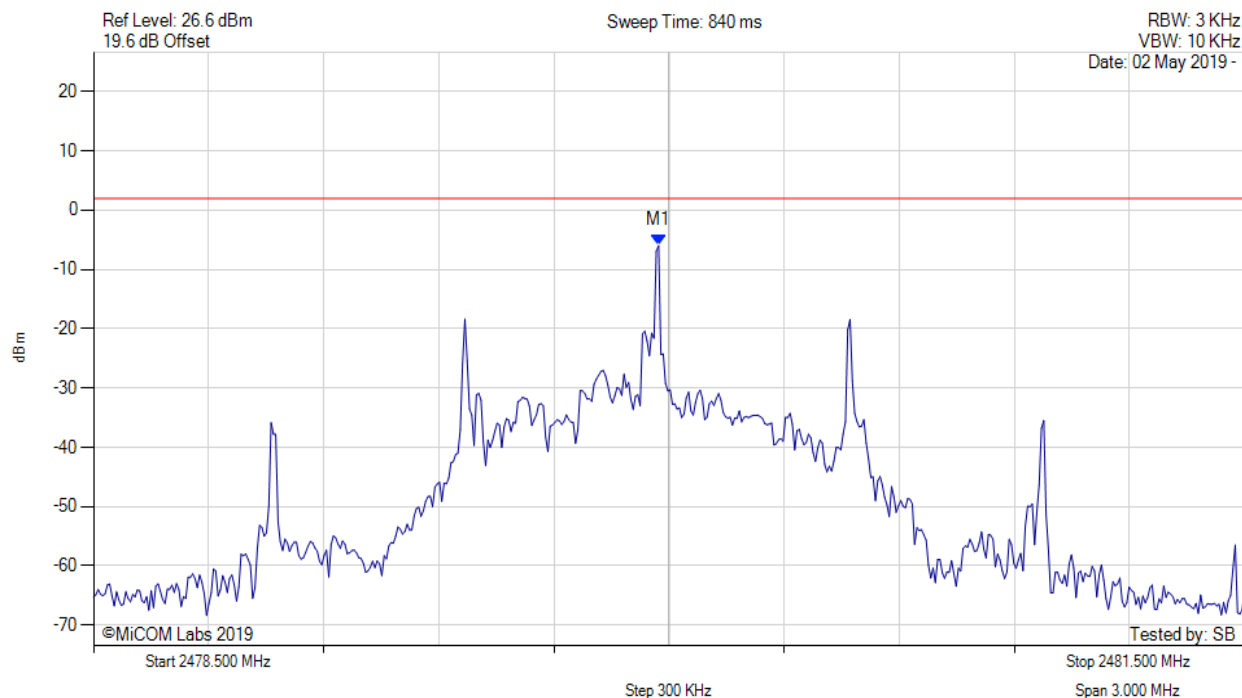
| Analyzer Setup                                                                    | Marker:Frequency:Amplitude     | Test Results                               |
|-----------------------------------------------------------------------------------|--------------------------------|--------------------------------------------|
| Detector = MAX PEAK<br>Sweep Count = 0<br>RF Atten (dB) = 20<br>Trace Mode = VIEW | M1 : 2479.973 MHz : -6.003 dBm | Limit: $\leq 1.980$ dBm<br>Margin: 7.98 dB |

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POWER SPECTRAL DENSITY - PEAK



Variant: BLE, Channel: 2480.00 MHz, SUM, Temp: 20, Voltage: 12 Vdc



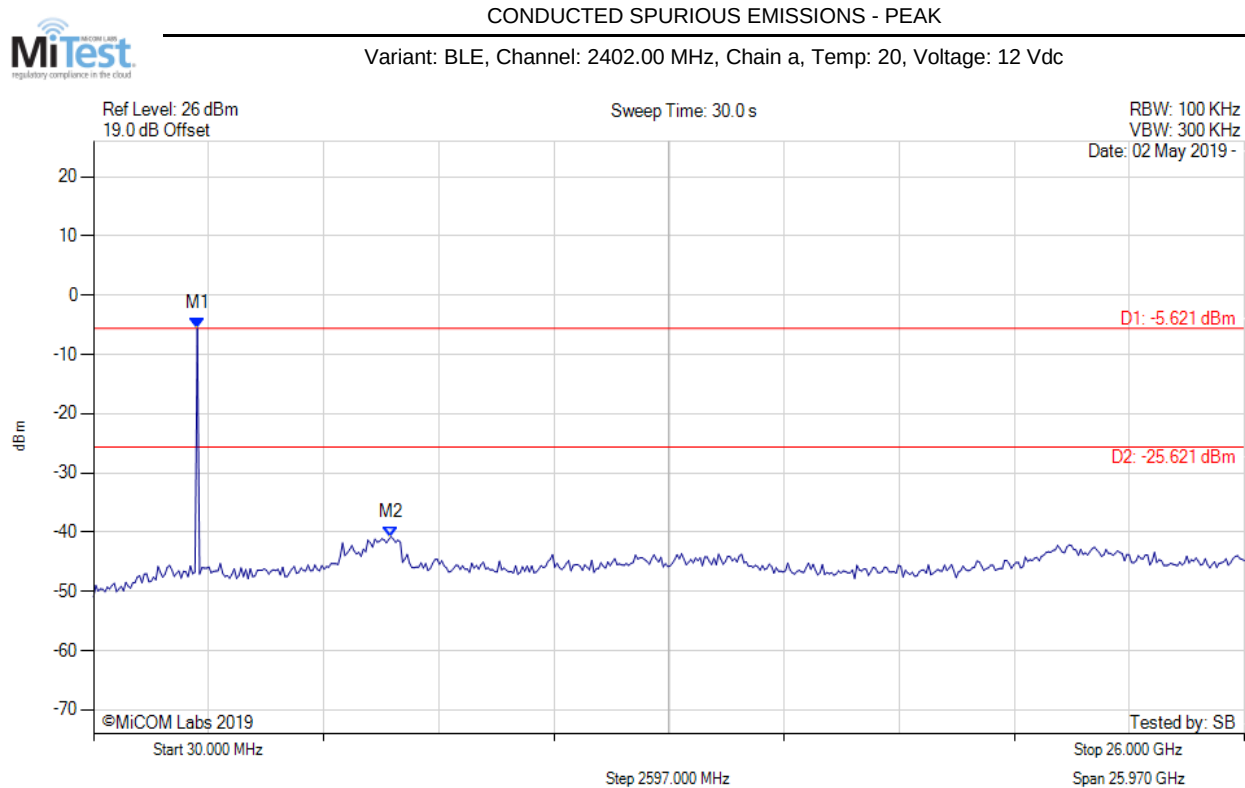
| Analyzer Setup                                                                    | Marker:Frequency:Amplitude     | Test Results                             |
|-----------------------------------------------------------------------------------|--------------------------------|------------------------------------------|
| Detector = MAX PEAK<br>Sweep Count = 0<br>RF Atten (dB) = 20<br>Trace Mode = VIEW | M1 : 2479.973 MHz : -6.003 dBm | Limit: $\leq 2.0$ dBm<br>Margin: -8.0 dB |

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### A.3. Emissions

#### A.3.1. Conducted Emissions

##### A.3.1.1. Conducted Spurious Emissions



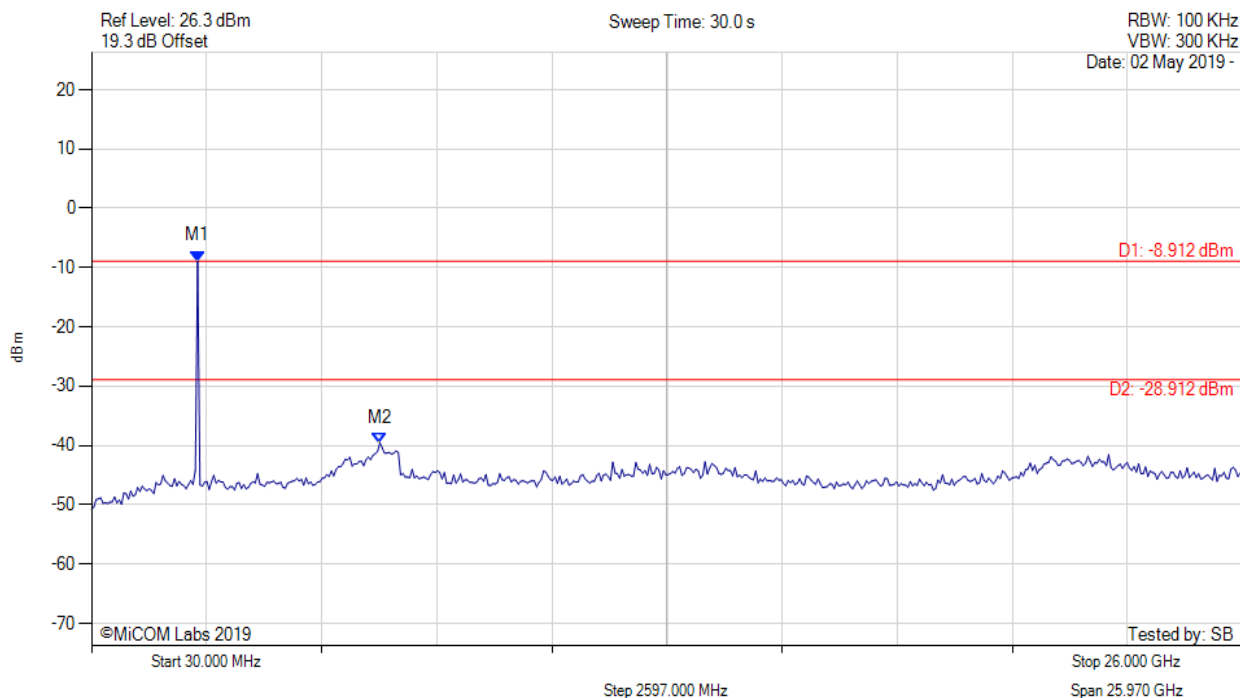
| Analyzer Setup                                                                    | Marker:Frequency:Amplitude                                        | Test Results                           |
|-----------------------------------------------------------------------------------|-------------------------------------------------------------------|----------------------------------------|
| Detector = MAX PEAK<br>Sweep Count = 0<br>RF Atten (dB) = 20<br>Trace Mode = VIEW | M1 : 2371.984 MHz : -5.621 dBm<br>M2 : 6743.687 MHz : -40.778 dBm | Limit: -25.62 dBm<br>Margin: -15.16 dB |

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# CONDUCTED SPURIOUS EMISSIONS - PEAK



Variant: BLE, Channel: 2426.00 MHz, Chain a, Temp: 20, Voltage: 12 Vdc



| Analyzer Setup                                                                    | Marker:Frequency:Amplitude                                        | Test Results                           |
|-----------------------------------------------------------------------------------|-------------------------------------------------------------------|----------------------------------------|
| Detector = MAX PEAK<br>Sweep Count = 0<br>RF Atten (dB) = 20<br>Trace Mode = VIEW | M1 : 2424.028 MHz : -8.912 dBm<br>M2 : 6535.511 MHz : -39.551 dBm | Limit: -28.91 dBm<br>Margin: -10.64 dB |

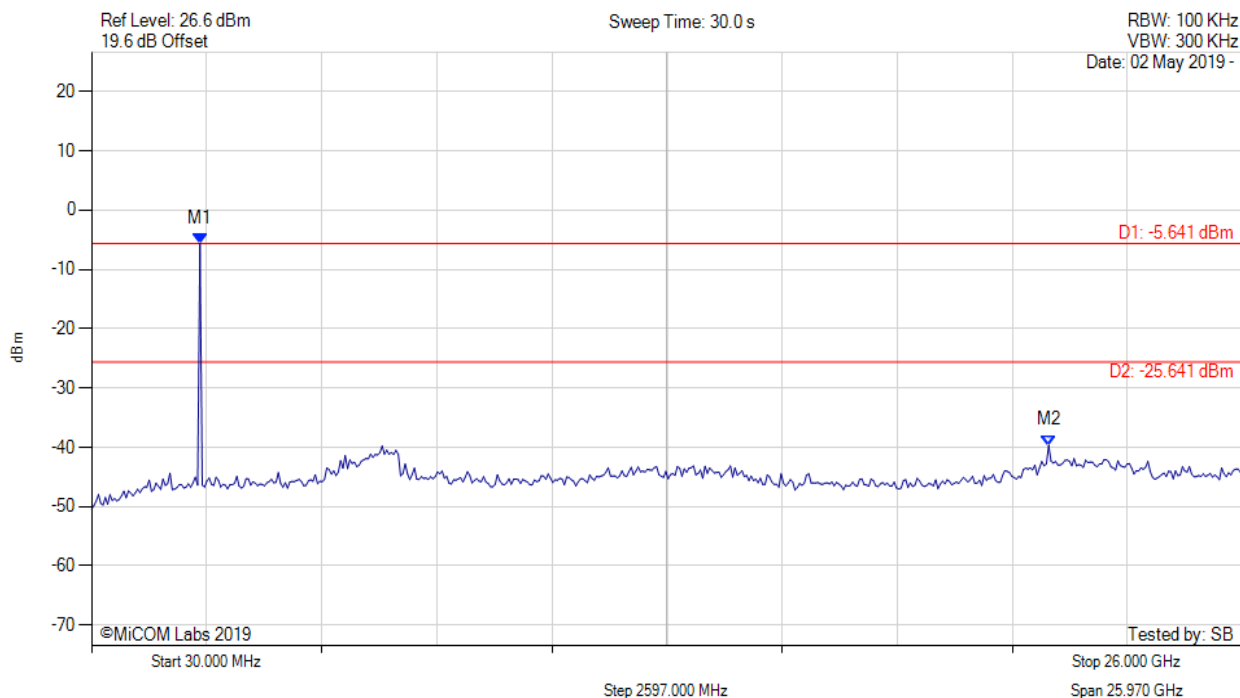
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# CONDUCTED SPURIOUS EMISSIONS - PEAK



Variant: BLE, Channel: 2480.00 MHz, Chain a, Temp: 20, Voltage: 12 Vdc



| Analyzer Setup                                                                    | Marker:Frequency:Amplitude                                      | Test Results                           |
|-----------------------------------------------------------------------------------|-----------------------------------------------------------------|----------------------------------------|
| Detector = MAX PEAK<br>Sweep Count = 0<br>RF Atten (dB) = 20<br>Trace Mode = VIEW | M1 : 2476.072 MHz : -5.641 dBm<br>M2 : 21.628 GHz : -39.698 dBm | Limit: -25.64 dBm<br>Margin: -14.06 dB |

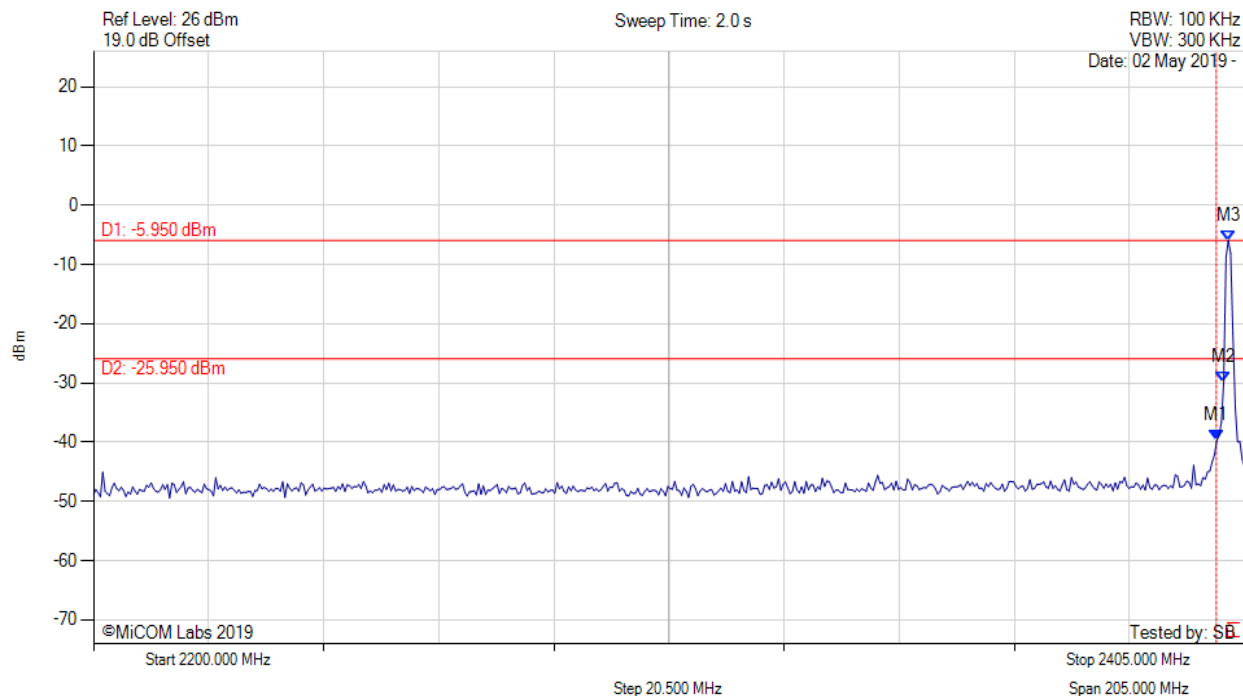
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### A.3.1.2. Conducted Band-Edge Emissions



#### CONDUCTED LOW BAND-EDGE EMISSION - PEAK

Variant: BLE, Channel: 2402.00 MHz, Chain a, Temp: 20, Voltage: 12 Vdc



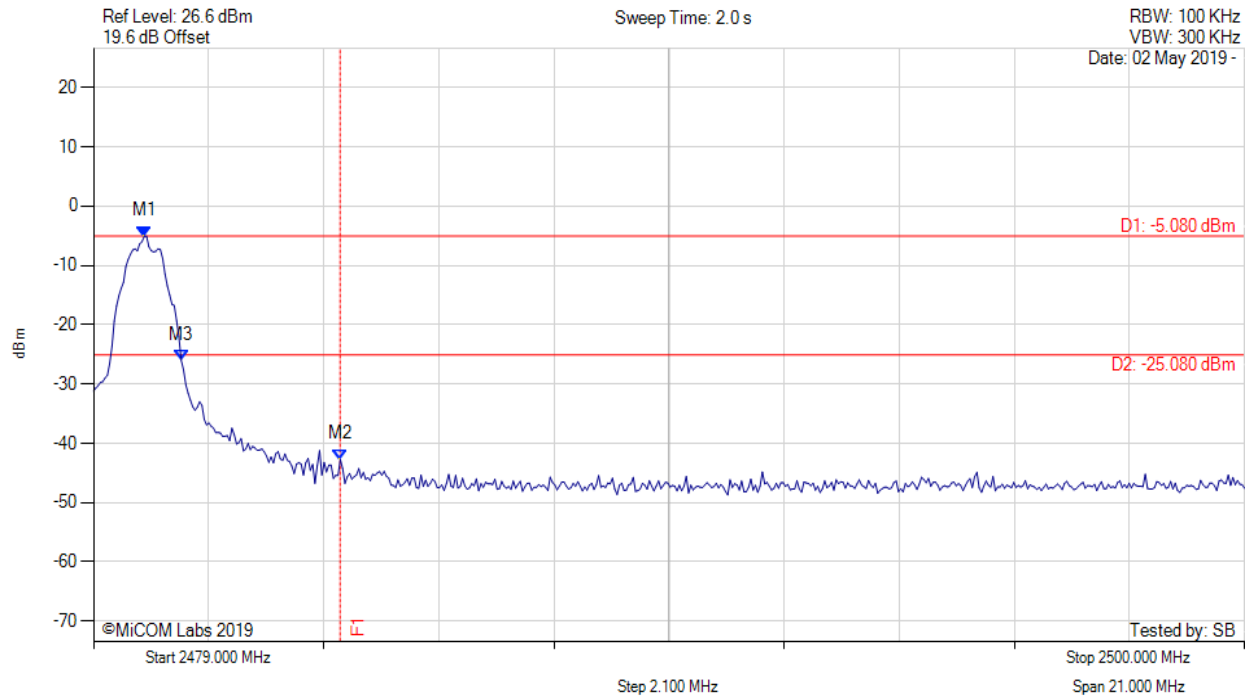
| Analyzer Setup                                                                         | Marker:Frequency:Amplitude                                                                           | Test Results                   |
|----------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------|--------------------------------|
| Detector = MAX PEAK<br>Sweep Count = 0<br>RF Atten (dB) = 20<br>Trace Mode = CLR/WRITE | M1 : 2400.000 MHz : -39.759 dBm<br>M2 : 2401.303 MHz : -29.956 dBm<br>M3 : 2402.124 MHz : -5.950 dBm | Channel Frequency: 2402.00 MHz |

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# CONDUCTED HIGH BAND-EDGE EMISSION - PEAK

Variant: BLE, Channel: 2480.00 MHz, Chain a, Temp: 20, Voltage: 12 Vdc



| Analyzer Setup                                                                         | Marker:Frequency:Amplitude                                                                           | Test Results                   |
|----------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------|--------------------------------|
| Detector = MAX PEAK<br>Sweep Count = 0<br>RF Atten (dB) = 20<br>Trace Mode = CLR/WRITE | M1 : 2479.926 MHz : -5.084 dBm<br>M2 : 2483.500 MHz : -42.724 dBm<br>M3 : 2480.599 MHz : -25.999 dBm | Channel Frequency: 2480.00 MHz |

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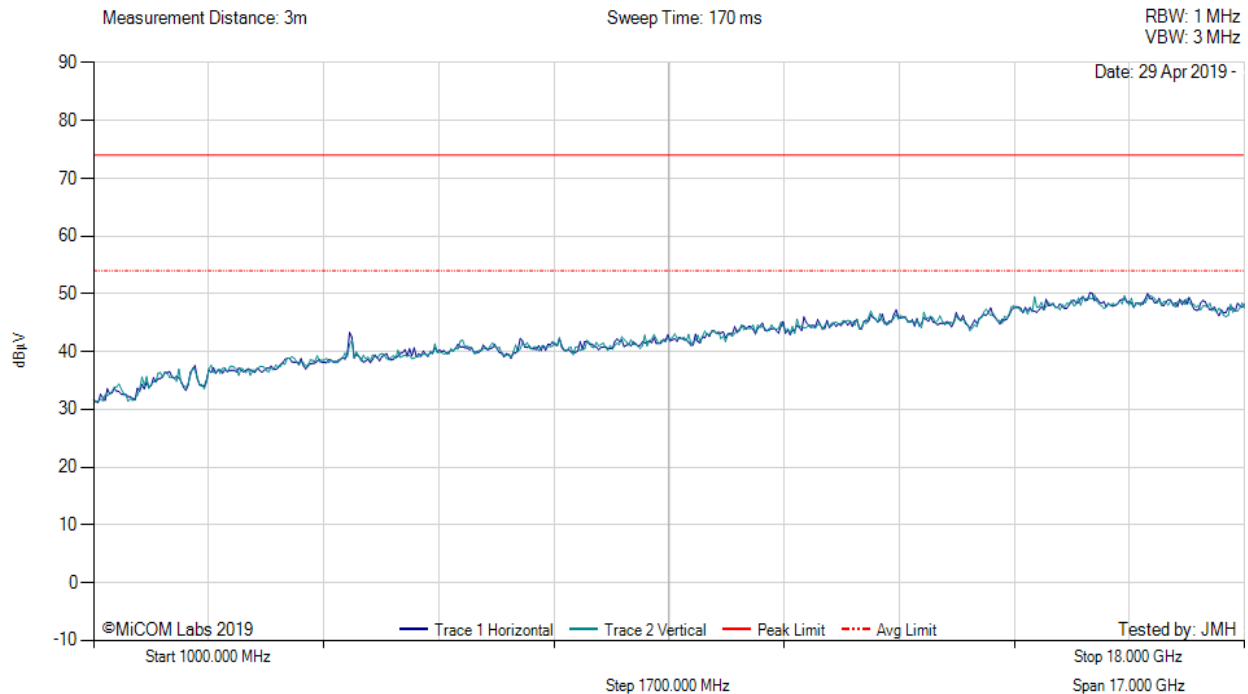
### A.3.2. Radiated Emissions

#### A.3.2.3. TX Spurious & Restricted Band Emissions



#### TX SPURIOUS & RESTRICTED BAND EMISSIONS 1 – 18 GHz

Variant: BLE, Test Freq: 2402.00 MHz, Antenna: WD PCB, Power Setting: Max, Duty Cycle (%): 66



There are no emissions found within 6dB of the limit line.

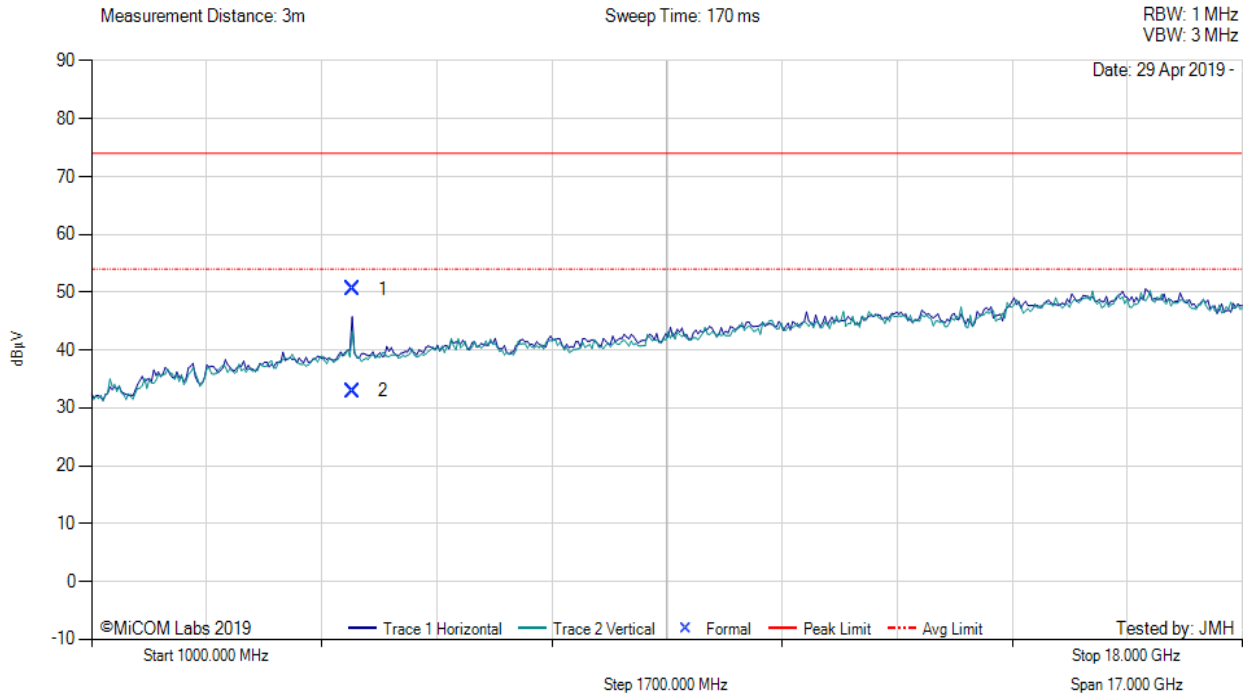
**Test Notes:** EUT powered by AC/DC PS. Connected to laptop outside chamber via ENET. 2.4 G Notch in front of amp to prevent overload.

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# TX SPURIOUS & RESTRICTED BAND EMISSIONS 1 – 18 GHz

Variant: BLE, Test Freq: 2426.00 MHz, Antenna: WD PCB, Power Setting: Max, Duty Cycle (%): 66



| 1000.00 - 18000.00 MHz |               |          |               |         |              |                  |            |        |         |              |           |            |
|------------------------|---------------|----------|---------------|---------|--------------|------------------|------------|--------|---------|--------------|-----------|------------|
| Num                    | Frequency MHz | Raw dBμV | Cable Loss dB | AF dB/m | Level dBμV/m | Measurement Type | Pol        | Hgt cm | Azt Deg | Limit dBμV/m | Margin dB | Pass /Fail |
| 1                      | 4852.03       | 65.52    | -2.53         | -12.40  | 50.59        | Max Peak         | Horizontal | 102    | 4       | 74.0         | -23.4     | Pass       |
| 2                      | 4852.03       | 46.05    | -2.53         | -12.40  | 32.92        | Max Avg          | Horizontal | 102    | 4       | 54.0         | -21.1     | Pass       |

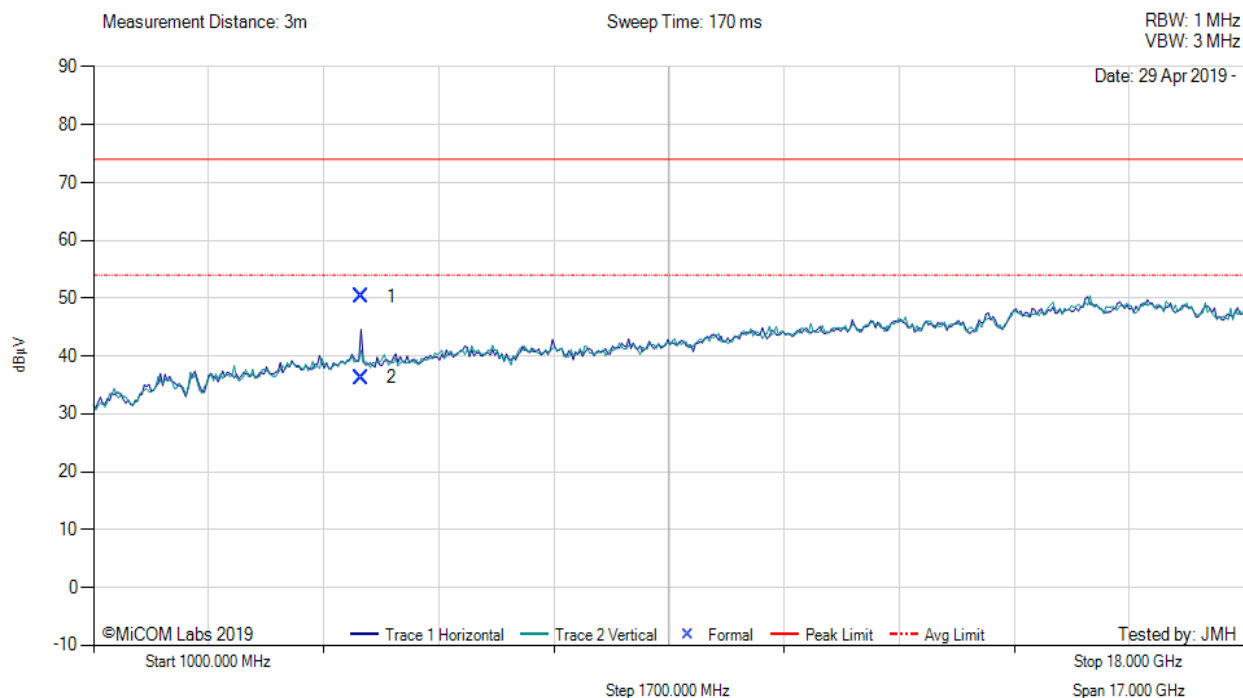
**Test Notes:** EUT powered by AC/DC PS. Connected to laptop outside chamber via ENET. 2.4 G Notch in front of amp to prevent overload. DC Correction 1.8 dB.

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# TX SPURIOUS & RESTRICTED BAND EMISSIONS 1 – 18 GHz

Variant: BLE, Test Freq: 2480.00 MHz, Antenna: WD PCB, Power Setting: Max, Duty Cycle (%): 66



| 1000.00 - 18000.00 MHz |               |          |               |         |              |                  |            |        |         |              |           |            |
|------------------------|---------------|----------|---------------|---------|--------------|------------------|------------|--------|---------|--------------|-----------|------------|
| Num                    | Frequency MHz | Raw dBμV | Cable Loss dB | AF dB/m | Level dBμV/m | Measurement Type | Pol        | Hgt cm | Azt Deg | Limit dBμV/m | Margin dB | Pass /Fail |
| 1                      | 4960.06       | 64.93    | -2.55         | -12.13  | 50.25        | Max Peak         | Horizontal | 147    | 46      | 74.0         | -23.8     | Pass       |
| 2                      | 4960.06       | 49.15    | -2.55         | -12.13  | 36.27        | Max Avg          | Horizontal | 147    | 46      | 54.0         | -17.7     | Pass       |

**Test Notes:** EUT powered by AC/DC PS. Connected to laptop outside chamber via ENET. 2.4 G Notch in front of amp to prevent overload. DC Correction 1.8 dB.

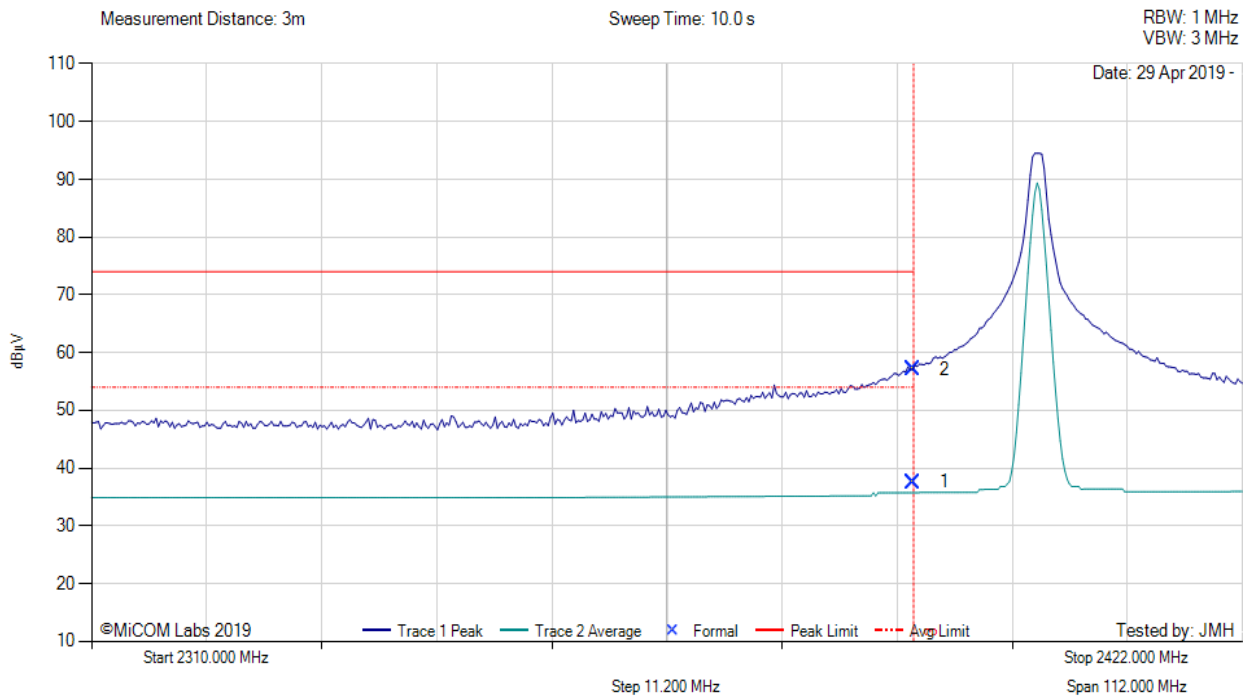
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### A.3.2.4. Restricted Edge & Band-Edge Emissions



#### RADIATED - LOWER RESTRICTED BAND-EDGE EMISSIONS

Variant: BLE, Test Freq: 2402.00 MHz, Antenna: WD PCB, Power Setting: Max, Duty Cycle (%): 66



| 2310.00 - 2422.00 MHz |               |          |               |         |              |                  |            |        |         |              |           |            |
|-----------------------|---------------|----------|---------------|---------|--------------|------------------|------------|--------|---------|--------------|-----------|------------|
| Num                   | Frequency MHz | Raw dBμV | Cable Loss dB | AF dB/m | Level dBμV/m | Measurement Type | Pol        | Hgt cm | Azt Deg | Limit dBμV/m | Margin dB | Pass /Fail |
| 1                     | 2390.00       | 5.58     | -1.77         | 31.96   | 37.57        | Max Avg          | Horizontal | 148    | 36      | 54.0         | -16.4     | Pass       |
| 2                     | 2390.00       | 26.86    | -1.77         | 31.96   | 57.05        | Max Peak         | Horizontal | 148    | 36      | 74.0         | -17.0     | Pass       |
| 3                     | 2390.00       | --       | --            | --      | --           | Restricted-Band  | --         | --     | --      | --           | --        | --         |

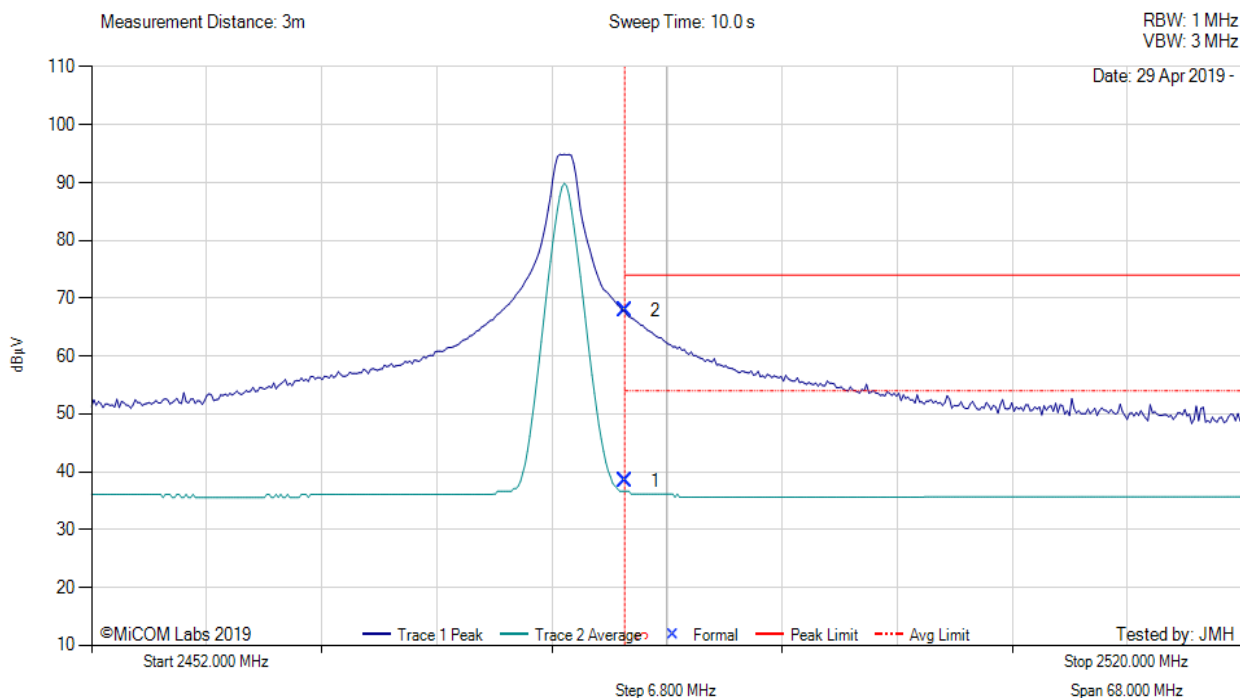
**Test Notes:** EUT powered by AC/DC PS. Connected to laptop outside chamber via ENET. DC Correction 1.8 dB.

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# RADIATED - UPPER RESTRICTED BAND-EDGE EMISSIONS

Variant: BLE, Test Freq: 2480.00 MHz, Antenna: WD PCB, Power Setting: Max, Duty Cycle (%): 66



| 2452.00 - 2520.00 MHz |               |          |               |         |              |                  |            |        |         |              |           |            |
|-----------------------|---------------|----------|---------------|---------|--------------|------------------|------------|--------|---------|--------------|-----------|------------|
| Num                   | Frequency MHz | Raw dBμV | Cable Loss dB | AF dB/m | Level dBμV/m | Measurement Type | Pol        | Hgt cm | Azt Deg | Limit dBμV/m | Margin dB | Pass /Fail |
| 1                     | 2483.50       | 6.09     | -1.78         | 32.33   | 38.44        | Max Avg          | Horizontal | 148    | 48      | 54.0         | -15.6     | Pass       |
| 2                     | 2483.50       | 37.30    | -1.78         | 32.33   | 67.85        | Max Peak         | Horizontal | 148    | 48      | 74.0         | -6.2      | Pass       |
| 3                     | 2483.50       | --       | --            | --      | --           | Restricted-Band  | --         | --     | --      | --           | --        | --         |

**Test Notes:** EUT powered by AC/DC PS. Connected to laptop outside chamber via ENET. DC Correction 1.8 dB.

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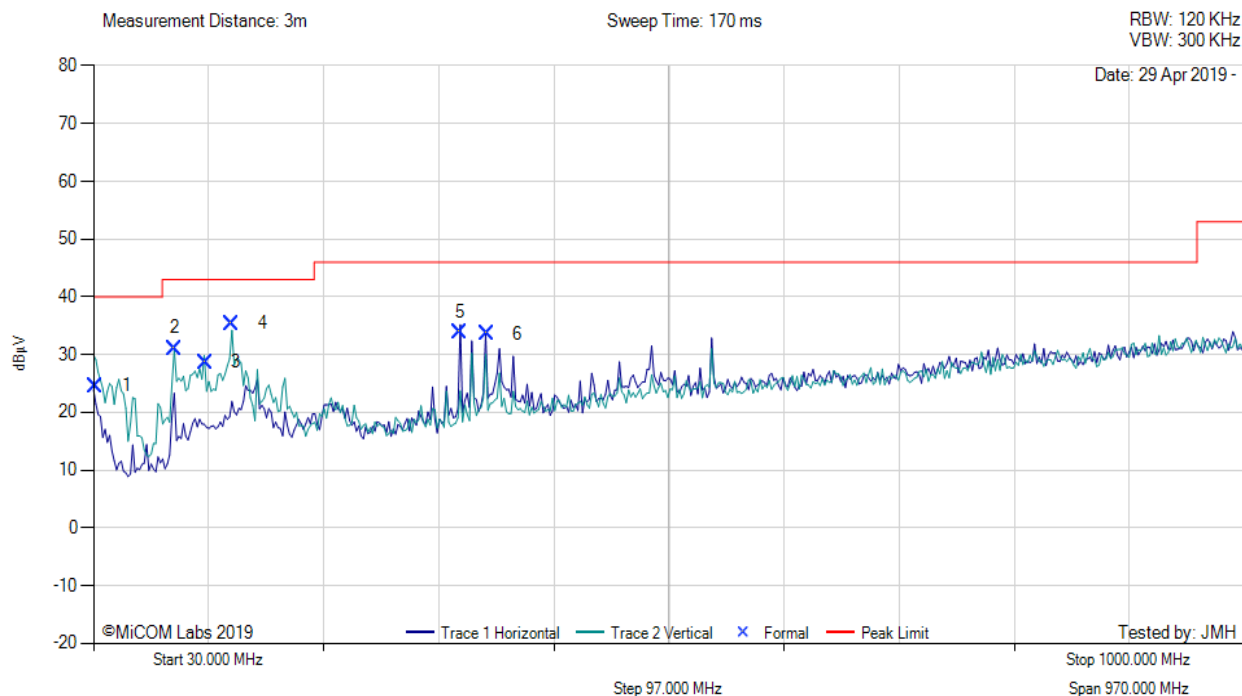


### A.3.3. Digital Emissions (0.03 - 1 GHz)



#### DIGITAL EMISSIONS

Variant: BLE, Test Freq: 2402.00 MHz, Antenna: WD PCB, Power Setting: Max



| 30.00 - 1000.00 MHz |               |          |               |         |              |                  |            |        |         |              |           |            |
|---------------------|---------------|----------|---------------|---------|--------------|------------------|------------|--------|---------|--------------|-----------|------------|
| Num                 | Frequency MHz | Raw dBμV | Cable Loss dB | AF dB/m | Level dBμV/m | Measurement Type | Pol        | Hgt cm | Azt Deg | Limit dBμV/m | Margin dB | Pass /Fail |
| 1                   | 31.96         | 29.79    | 3.53          | -8.70   | 24.62        | MaxQP            | Vertical   | 109    | 339     | 40.0         | -15.4     | Pass       |
| 2                   | 98.17         | 45.63    | 4.00          | -18.60  | 31.03        | MaxQP            | Vertical   | 106    | 8       | 43.0         | -12.0     | Pass       |
| 3                   | 124.18        | 39.12    | 4.12          | -14.60  | 28.64        | MaxQP            | Vertical   | 102    | 76      | 43.0         | -14.4     | Pass       |
| 4                   | 146.84        | 47.08    | 4.23          | -15.90  | 35.41        | MaxQP            | Vertical   | 102    | 174     | 43.0         | -7.6      | Pass       |
| 5                   | 338.68        | 42.47    | 4.98          | -13.70  | 33.75        | MaxQP            | Horizontal | 101    | 257     | 46.0         | -12.3     | Pass       |
| 6                   | 361.26        | 40.96    | 5.06          | -12.70  | 33.52        | MaxQP            | Horizontal | 102    | 276     | 46.0         | -12.5     | Pass       |

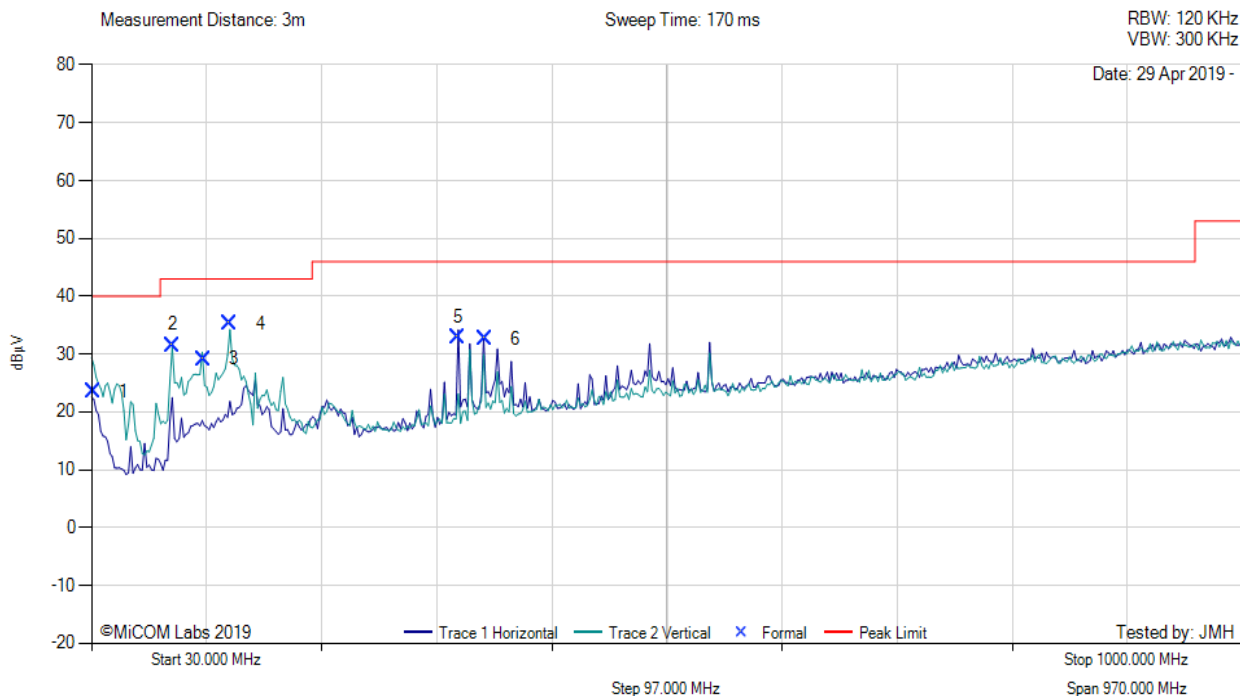
**Test Notes:** EUT powered by AC/DC PS. Connected to laptop outside chamber via ENET. 2nd ENET connected to Hub with data transferring. Audio ports looped back.

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# DIGITAL EMISSIONS

Variant: BLE, Test Freq: 2426.00 MHz, Antenna: AMPHENOL WD PCB, Power Setting: Max, Duty Cycle (%): 66



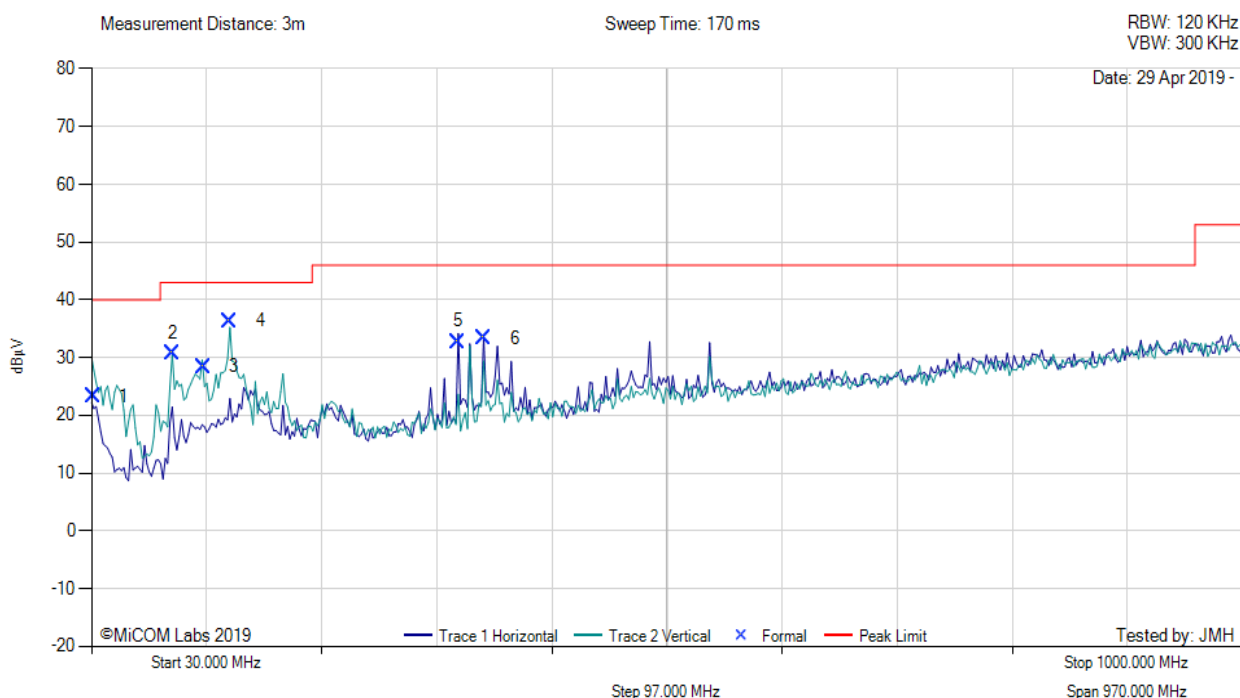
| 30.00 - 1000.00 MHz |               |          |               |         |              |                  |            |        |         |              |           |            |
|---------------------|---------------|----------|---------------|---------|--------------|------------------|------------|--------|---------|--------------|-----------|------------|
| Num                 | Frequency MHz | Raw dBµV | Cable Loss dB | AF dB/m | Level dBµV/m | Measurement Type | Pol        | Hgt cm | Azt Deg | Limit dBµV/m | Margin dB | Pass /Fail |
| 1                   | 31.78         | 28.69    | 3.53          | -8.70   | 23.52        | MaxQP            | Vertical   | 122    | 352     | 40.0         | -16.5     | Pass       |
| 2                   | 98.06         | 46.15    | 4.00          | -18.60  | 31.55        | MaxQP            | Vertical   | 101    | 1       | 43.0         | -11.5     | Pass       |
| 3                   | 124.18        | 39.62    | 4.12          | -14.60  | 29.14        | MaxQP            | Vertical   | 100    | 73      | 43.0         | -13.9     | Pass       |
| 4                   | 146.74        | 46.88    | 4.23          | -15.90  | 35.21        | MaxQP            | Vertical   | 99     | 171     | 43.0         | -7.8      | Pass       |
| 5                   | 338.68        | 41.57    | 4.98          | -13.70  | 32.85        | MaxQP            | Horizontal | 101    | 257     | 46.0         | -13.2     | Pass       |
| 6                   | 361.26        | 40.26    | 5.06          | -12.70  | 32.62        | MaxQP            | Horizontal | 100    | 270     | 46.0         | -13.4     | Pass       |

**Test Notes:** EUT powered by AC/DC PS. Connected to laptop outside chamber via ENET. 2nd ENET connected to Hub with data transferring. Audio ports looped back.

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# DIGITAL EMISSIONS

Variant: BLE, Test Freq: 2480.00 MHz, Antenna: WD PCB, Power Setting: Max



| 30.00 - 1000.00 MHz |               |          |               |         |              |                  |            |        |         |              |           |            |
|---------------------|---------------|----------|---------------|---------|--------------|------------------|------------|--------|---------|--------------|-----------|------------|
| Num                 | Frequency MHz | Raw dBμV | Cable Loss dB | AF dB/m | Level dBμV/m | Measurement Type | Pol        | Hgt cm | Azt Deg | Limit dBμV/m | Margin dB | Pass /Fail |
| 1                   | 31.84         | 28.39    | 3.53          | -8.70   | 23.24        | MaxQP            | Vertical   | 119    | 345     | 40.0         | -16.8     | Pass       |
| 2                   | 98.35         | 45.26    | 4.00          | -18.60  | 30.67        | MaxQP            | Vertical   | 106    | 7       | 43.0         | -12.3     | Pass       |
| 3                   | 124.58        | 38.91    | 4.12          | -14.60  | 28.43        | MaxQP            | Vertical   | 101    | 76      | 43.0         | -14.6     | Pass       |
| 4                   | 146.79        | 47.99    | 4.23          | -15.90  | 36.33        | MaxQP            | Vertical   | 100    | 178     | 43.0         | -6.7      | Pass       |
| 5                   | 338.76        | 41.47    | 4.98          | -13.70  | 32.74        | MaxQP            | Horizontal | 106    | 253     | 46.0         | -13.3     | Pass       |
| 6                   | 361.00        | 40.95    | 5.06          | -12.70  | 33.31        | MaxQP            | Horizontal | 100    | 275     | 46.0         | -12.7     | Pass       |

**Test Notes:** EUT powered by AC/DC PS. Connected to laptop outside chamber via ENET. 2nd ENET connected to Hub with data transferring. Audio ports looped back.

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