Report on the Radio Testing

For

Renishaw Plc

on

RTSQE

Report no. TRA-046258-47-00B

3 April 2020

Report Number: TRA-046258-47-00B
Issue: B

# REPORT ON THE RADIO TESTING OF A
# Renishaw Plc
# RTSQE
# WITH RESPECT TO SPECIFICATION
# FCC 47CFR 15.247

TEST DATE: 20th November - 20th December 2019

Written by: D Winstanley
Radio Senior Test Engineer

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Reason: I am approving this document
Date: 2020.04.06 09:16:06 +01'00'

Date: 3 April 2020

# 1 Revision Record

| *Issue Number* | *Issue Date* | *Revision History* |
|---|---|---|
| A | 20th January 2020 | Original |
| B | 3 April 2020 | Typographical Corrections |

## 2 Summary

| | |
|---|---|
| TEST REPORT NUMBER: | TRA-046258-47-00B |
| WORKS ORDER NUMBER: | TRA-046258-00 |
| PURPOSE OF TEST: | USA: Testing of radio frequency equipment per the relevant authorization procedure of chapter 47 of CFR (code of federal regulations) Part 2, subpart J.. |
| TEST SPECIFICATION(S): | 47CFR15.247 |
| EQUIPMENT UNDER TEST (EUT): | RTSQE |
| FCC IDENTIFIER: | KQGRTSQE |
| EUT SERIAL NUMBER: | Conducted - 2C3K88, Radiated - 2C3K87 |
| MANUFACTURER/AGENT: | Renishaw Plc |
| ADDRESS: | New Mills<br>Wotton Under Edge<br>Gloucestershire<br>GL12 8JR<br>United Kingdom |
| CLIENT CONTACT: | Rich Warren<br>☎ 01453 523240<br>✉ richard.warren@renishaw.com |
| TEST DATE: | 20th November - 20th December 2019 |
| TESTED BY: | D Winstanley<br>Element |

## *2.1 Test Summary*

| *Test Method and Description* | | *Requirement Clause47CFR15* | *Applicable to this equipment* | *Result / Note* |
|---|---|---|---|---|
| Radiated spurious emissions (restricted bands of operation and cabinet radiation) | | 15.205 | ☒ | *Pass Note 4* |
| AC power line conducted emissions | | 15.207 | ☐ | *Note 1* |
| Carrier frequency separation | | 15.247(a)(1) | ☒ | *Pass Note 2* |
| Number of hopping channels | | 15.247(a)(1) (i), (ii) and (iii) | ☒ | *Pass Note 2* |
| Average time of occupancy | | 15.247(a)(1) (i), (ii) and (iii) | ☒ | *Pass Note 2* |
| Maximum peak conducted output power | | 15.247 (a)(1), (b)(1) and (b)(2) | ☒ | *Pass Note 2* |
| Conducted carrier power | Peak | 15.247(b)(3) | ☐ | *Pass Note 3* |
| | Max. | | ☒ | |
| Power spectral density, conducted | | 15.247(e) | ☒ | *Pass Note 3* |
| 20dB emission bandwidth | | 15.247(a)(1) (i) and (ii) | ☒ | *Pass Note 2* |
| Occupied bandwidth | | 15.247(a)(2) | ☒ | *Pass Note 3* |
| Out-of-band emissions | | 15.247(d) | ☒ | *Pass Note 4* |

**Notes:**

1 Note applicable EUT is battery powered
2 Applicable for Mode 1 and Mode 2 – FHSS Operation
3 Applicable for Mode 2 – DTS operation
4 Applicable for Mode 1 and Mode 2 (both FHSS and DTS Operation) EUT uses same modulation techniques for both FHSS and DTS operation

The results contained in this report relate only to the items tested, in the condition at time of test, and were obtained in the period between the date of initial receipt of samples and the date of issue of the report.

The apparatus was set up and exercised using the configurations, modes of operation and arrangements defined in this report only. Any modifications made are identified in Section 8 of this report.

Particular operating modes, apparatus monitoring methods and performance criteria required by the standards tested to have been performed except where identified in Section 5.2 of this test report (Deviations from Test Standards).

# 3 Contents

# 4 Introduction

This report TRA-046258-47-00B presents the results of the Radio testing on a Renishaw Plc, RTSQE to specification 47CFR15 Radio Frequency Devices.

The testing was carried out for Renishaw Plc by Element, at the address detailed below.

☐ Element Hull
Unit E
South Orbital Trading Park
Hedon Road
Hull
HU9 1NJ
UK

☒ Element Skelmersdale
Unit 1
Pendle Place
Skemersdale
West Lancashire
WN8 9PN
UK

This report details the configuration of the equipment, the test methods used and any relevant modifications where appropriate.

All test and measurement equipment under the control of the laboratory and requiring calibration is subject to an established programme and procedures to control and maintain measurement standards. The quality management system meets the principles of ISO 9001, and has quality control procedures for monitoring the validity of tests undertaken. Records and sufficient detail are retained to establish an audit trail of calibration records relating to its test results for a defined period. Under control of the established calibration programme, key quantities or values of the test & measurement instrumentation are within specification and comply with the relevant traceable internationally recognised and appropriate standard specifications, which are UKAS calibrated as such where these properties have a significant effect on results. Participation in inter-laboratory comparisons and proficiency testing ensures satisfactory correlation of results conform to Elements own procedures, as well as statistical techniques for analysis of test data providing the appropriate confidence in measurements.

Throughout this report EUT denotes equipment under test.

FCC Site Listing:
Element is accredited for the above sites under the US-EU MRA, Designation number UK0009.

IC Registration Number(s):

| | |
|---|---|
| Element Hull | 3483A |
| Element North West | 3930B |

The test site requirements of ANSI C63.4-2014 are met up to 1GHz.

The test site SVSWR requirements of CISPR 16-1-4:2010 are met over the frequency range 1 GHz to 18 GHz.

# 5 Test Specifications

## *5.1 Normative References*

- FCC 47 CFR Ch. I – Part 15 – Radio Frequency Devices.
- ANSI C63.10-2013 – American National Standard of Procedures for Compliance Testing of Unlicensed Wireless Devices.
- ANSI C63.4-2014 – American National Standard for Methods of Measurement of Radio-Noise Emissions from Low-Voltage Electrical and Electronic Equipment in the Range of 9 kHz to 40 GHz.

## *5.2 Deviations from Test Standards*

There were no deviations from the test standard.

# 6 Glossary of Terms

| | |
|---|---|
| **§** | denotes a section reference from the standard, not this document |
| **AC** | Alternating Current |
| **ANSI** | American National Standards Institute |
| **BW** | bandwidth |
| **C** | Celsius |
| **CFR** | Code of Federal Regulations |
| **CW** | Continuous Wave |
| **dB** | decibel |
| **dBm** | dB relative to 1 milliwatt |
| **DC** | Direct Current |
| **DSSS** | Direct Sequence Spread Spectrum |
| **EIRP** | Equivalent Isotropically Radiated Power |
| **ERP** | Effective Radiated Power |
| **EUT** | Equipment Under Test |
| **FCC** | Federal Communications Commission |
| **FHSS** | Frequency Hopping Spread Spectrum |
| **Hz** | hertz |
| **IC** | Industry Canada |
| **ITU** | International Telecommunication Union |
| **LBT** | Listen Before Talk |
| **m** | metre |
| **max** | maximum |
| **MIMO** | Multiple Input and Multiple Output |
| **min** | minimum |
| **MRA** | Mutual Recognition Agreement |
| **N/A** | Not Applicable |
| **PCB** | Printed Circuit Board |
| **PDF** | Portable Document Format |
| **Pt-mpt** | Point-to-multipoint |
| **Pt-pt** | Point-to-point |
| **RF** | Radio Frequency |
| **RH** | Relative Humidity |
| **RMS** | Root Mean Square |
| **Rx** | receiver |
| **s** | second |
| **SVSWR** | Site Voltage Standing Wave Ratio |
| **Tx** | transmitter |
| **UKAS** | United Kingdom Accreditation Service |
| **V** | volt |
| **W** | watt |
| **Ω** | ohm |

# 7 Equipment Under Test

## *7.1 EUT Identification*

- Name: RTSQE
- Serial Number: Conducted - 2C3K88, Radiated - 2C3K87
- Model Number: RTSQE
- Software Revision: Not Applicable
- Build Level / Revision Number: Not Applicable

## *7.2 System Equipment*

Equipment listed below forms part of the overall test setup and is required for equipment functionality and/or monitoring during testing. The compliance levels achieved in this report relate only to the EUT and not items given in the following list.

*Not Applicable – No support/monitoring equipment required.*

## *7.3 EUT Mode of Operation*

### *7.3.1 Transmission*

The mode of operation for Tx tests was as follows.

The EUT contains selections for test menus for Mode 1 or Mode 2 and selection of normal operation.

These test menus allow the unit to be set to top, middle or bottom frequencies or hopping across all frequencies in either Mode 1 or Mode 2.

## *7.4 EUT Radio Parameters*

### *7.4.1 General*

| | |
|---|---|
| ***Frequency of operation:*** | 2400 MHz - 2483.5 MHz |
| ***Modulation type(s):*** | Mode 1: 1 MBps Binary GFSK Frequency Hopping<br>Mode 2: 2 MBps Binary GFSK Frequency Hopping<br>Mode 2: 2 MBps Binary GFSK DSSS |
| ***Occupied channel bandwidth(s):*** | Mode 1: 1 MHz<br>Mode 2: 2 MHz |
| ***Channel spacing:*** | Mode 1: 1 MHz<br>Mode 2: 2 MHz |
| ***Declared output power(s):*** | Mode 1: 0dBm<br>Mode 2: +4dBm |
| ***Nominal Supply Voltage:*** | 3.0 Vdc |
| ***Antenna Gain:*** | -1.65 dBi |

## *7.5 EUT Description*

The EUT is a measuring probe, using the 2400 MHz - 2483.5 MHz frequency band, and uses frequency hopping and DTS.

Mode 1 uses FHSS operating over 79 channels.
Mode 2 uses DTS and FHSS over 39 channels. DTS mode is used during setup and FHSS mode in probe operation.

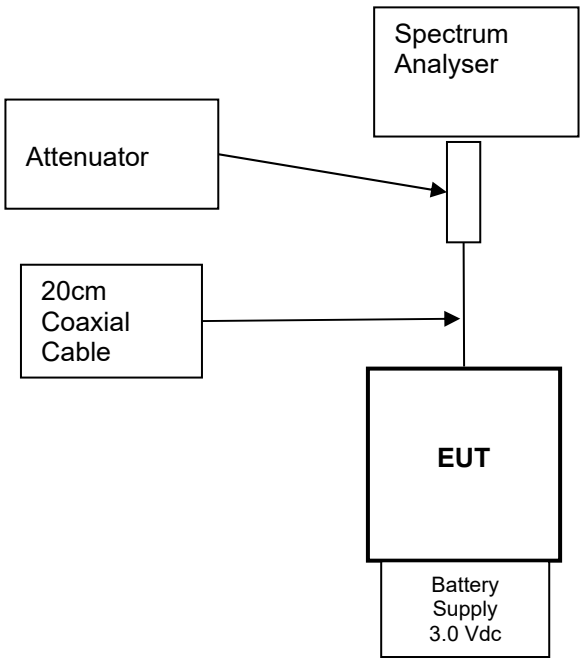
# 8 Modifications

No modifications were performed during this assessment.

# 9 EUT Test Setup

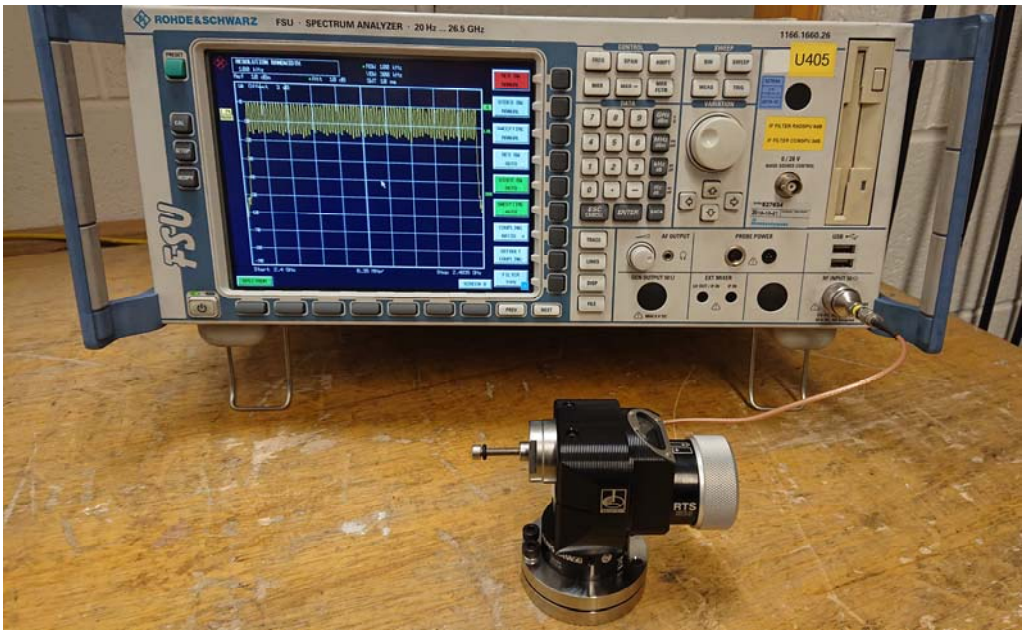
## *9.1 Block Diagram*

The following diagram shows basic EUT interconnections with cable type and cable lengths identified:



### *9.2 General Set-up Photograph*

The following photograph shows basic EUT set-up:




### *9.3 Measurement software*

Where applicable, the following software was used to perform measurements contained within this report.

Element Emissions R5 (See Note)
Element Transmitter Bench Test (See Note)
ETS Lindgren EMPower V1.0.4.2

Note:

The version of the Element software used is recorded in the results sheets contained within this report.

# 10 General Technical Parameters

## *10.1 Normal Conditions*

The E U T was tested under the normal environmental conditions of the test laboratory, except where otherwise stated. The normal power source applied was approx. 3 Vdc from alkaline batteries

## *10.2 Varying Test Conditions*

There are no specific frequency stability requirements for the type of device. The results contained in this report demonstrate that the occupied bandwidth is contained within the authorised band and the manufacturer has declared sufficient frequency stability (refer to section 7.4).

Variation of supply voltage is required to ensure stability of the declared output power. During carrier power testing the following variations were made:

| | ***Category*** | ***Nominal*** | ***Variation*** |
|---|---|---|---|
| ☐ | Mains | 110 V ac +/-2 % | 85 % and 115 % |
| ☒ | Battery | New battery | N/A |

# 11 Radiated emissions

## *11.1 Definitions*

*Spurious emissions*
Emissions on a frequency or frequencies, which are outside the necessary bandwidth and the level of which may be reduced without affecting the corresponding transmission of information. Spurious emissions include harmonic emissions, parasitic emissions, intermodulation products and frequency conversion products, but exclude out-of-band emissions.

*Restricted bands*
A frequency band in which intentional radiators are permitted to radiate only spurious emissions but not fundamental signals.

## *11.2 Test Parameters*

| | |
|---|---|
| Test Location: | Element Skelmersdale |
| Test Chamber: | Chamber 3 |
| Test Standard and Clause: | ANSI C63.10-2013, Clause 6.5 and 6.6 |
| EUT Channels Measured: | Low / Mid / High |
| EUT Channel Bandwidths: | 1 MHz / 2 MHz |
| Deviations From Standard: | None |
| Measurement BW: | 30 MHz to 1 GHz: 120 kHz; Above 1 GHz: 1 MHz |
| Measurement Detector: | Up to 1 GHz: quasi-peak; Above 1 GHz: RMS average and Peak |

**Environmental Conditions (Normal Environment)**

| | |
|---|---|
| Temperature: 23 °C | +15 ºC to +35 ºC (as declared) |
| Humidity: 39 % RH | 20 % RH to 75 % RH (as declared) |
| Supply: 3 V dc | |

## *11.3 Test Limit*

Unwanted emissions that fall within the restricted frequency bands shall comply with the limits specified:

**General Field Strength Limits for License-Exempt Transmitters at Frequencies above 30 MHz**

| *Frequency (MHz)* | *Field Strength (µV/m at 3 m)* |
|---|---|
| 30 to 88 | 100 |
| 88 to 216 | 150 |
| 216 to 960 | 200 |
| Above 960 | 500 |

### *11.4 Test Method*

With the EUT setup as per section 9 of this report and connected as per Figure i, the emissions from the EUT were measured on a spectrum analyzer / EMI receiver.

Radiated electromagnetic emissions from the EUT are checked first by preview scans. Preview scans for all spectrum and modulation characteristics are checked, using a peak detector and where applicable worst-case determined for function, operation, orientation, etc. for both vertical and horizontal polarisations. Pre-scan plots are shown with a peak detector and 100 kHz RBW.

If the EUT connects to auxiliary equipment and is table or floor standing, the configurations prescribed in ANSI C63.10 are followed. Alternatively, a layout closest to normal use (as declared by the provider) is employed, (see EUT setup photographs for more detail).

Emissions between 30 MHz and 1 GHz are measured using calibrated broadband antennas. Emissions above 1 GHz are characterized using standard gain horn antennas. Pre-amplifiers and filters are used where required. Care is taken to ensure that test receiver resolution bandwidth, video bandwidth and detector type(s) meet the regulatory requirements.

For both horizontal and vertical polarizations, the EUT is then rotated through 360 degrees in azimuth until the highest emission is detected. At the previously determined azimuth the test antenna is raised and lowered from 1 to 4 m in height until a maximum emission level is detected, this maximum value is recorded.

Power values measured on the test receiver / analyzer are converted to field strength, FS, in dBµV/m at the regulatory distance, using:

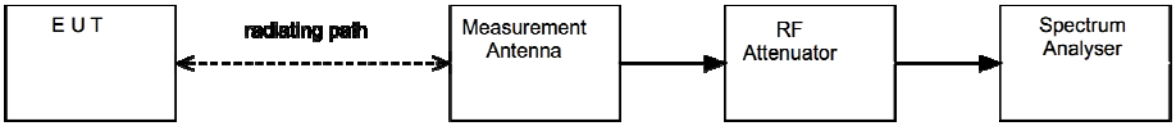
$$FS = PR + CL + AF – PA + DC – CF$$

Where,

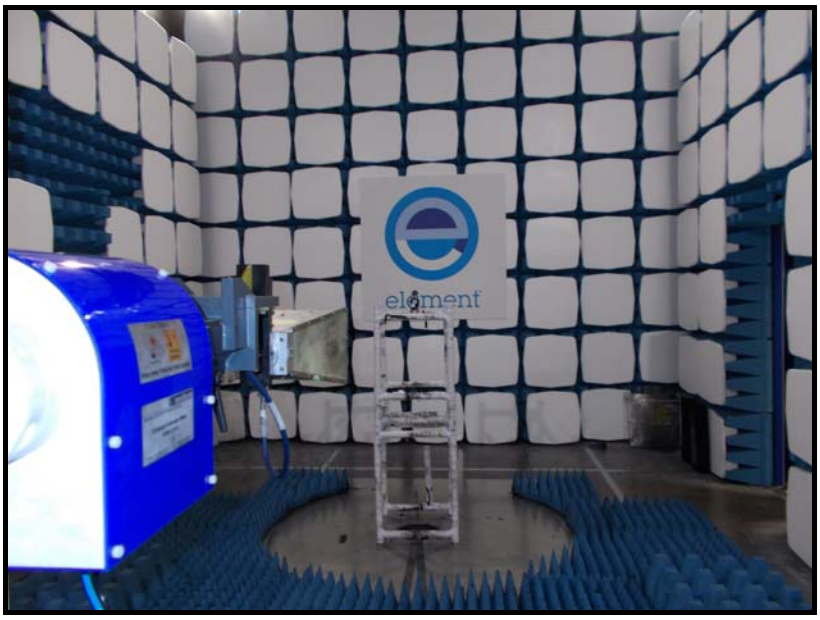
PR is the power recorded on the receiver / spectrum analyzer in dBµV;
CL is the cable loss in dB;
AF is the test antenna factor in dB/m;
PA is the pre-amplifier gain in dB (where used);
DC is the duty correction factor in dB (where used, e.g. harmonics of pulsed fundamental);
CF is the distance factor in dB (where measurement distance different to limit distance);

This field strength value is then compared with the regulatory limit.

**Figure i Test Setup**



### *11.5 Test Set-up Photographs*

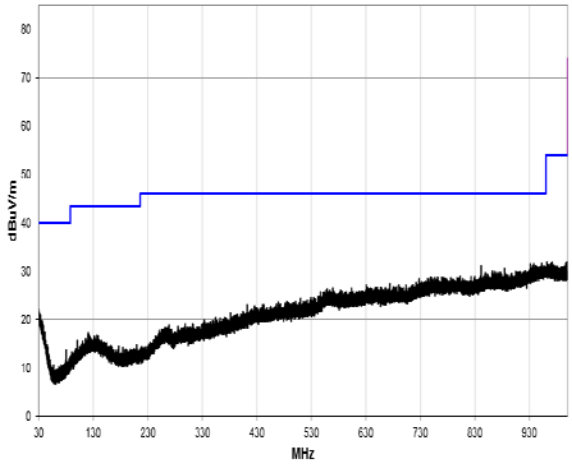




### *11.6 Test Equipment*

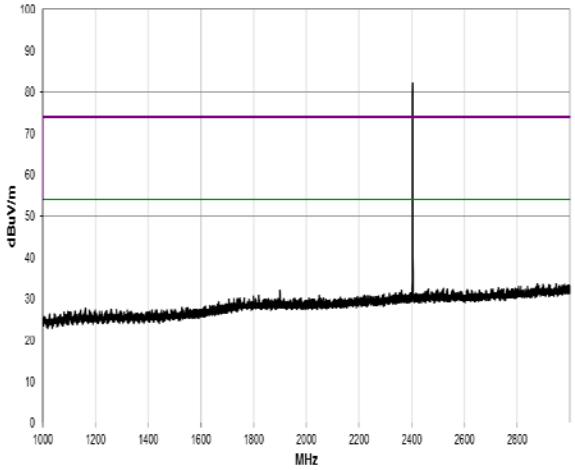
| *Equipment Description* | *Manufacturer* | *Equipment Type* | *Element No* | *Due For Calibration* |
|---|---|---|---|---|
| Spectrum Analyser | R&S | FSU46 | REF910 | 2020-10-17 |
| Bilog | Chase | CBL611/A | U573 | 2021-09-19 |
| Log Periodic Ant | Chase | UPA6108 | L203 | 2020-06-11 |
| PreAmp | Watkins Johnson | 6201-69 | U372 | 2020-02-25 |
| 8449B | Agilent | Pre Amp | L572 | 2020-10-15 |
| 1-18GHz Horn | EMCO | 3115 | L139 | 2021-07-16 |

### *11.7 Test Results*

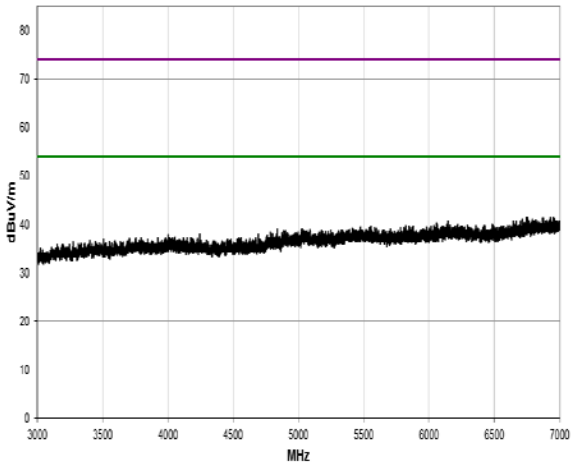
2403 MHz – 1 Mbps



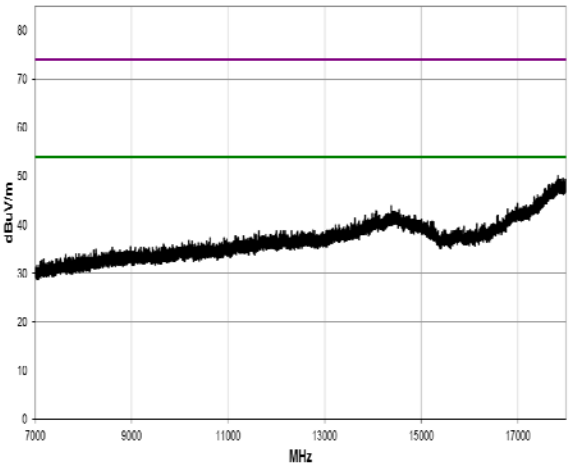

30 MHz to 1 GHz



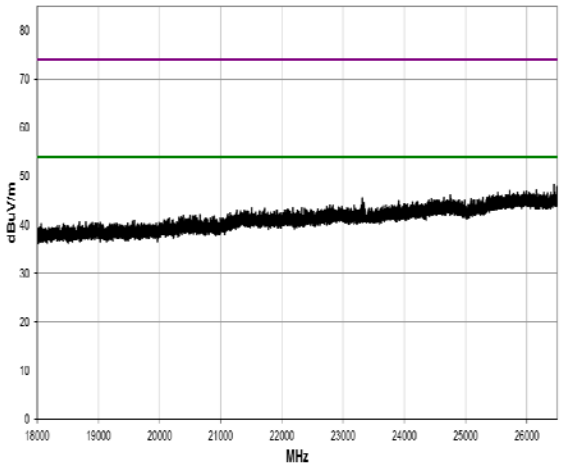

1 GHz to 3 GHz




3 GHz to 7 GHz



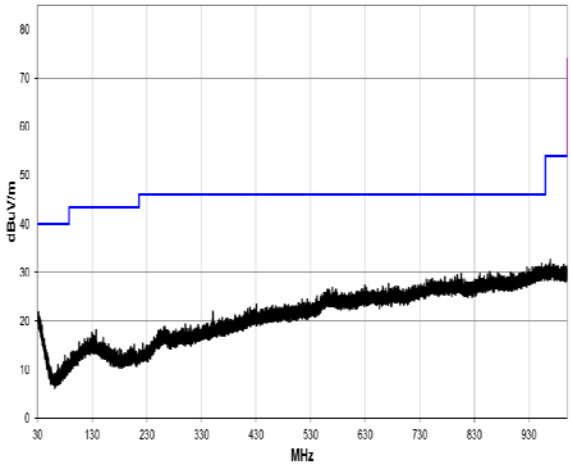

7 GHz to 18 GHz



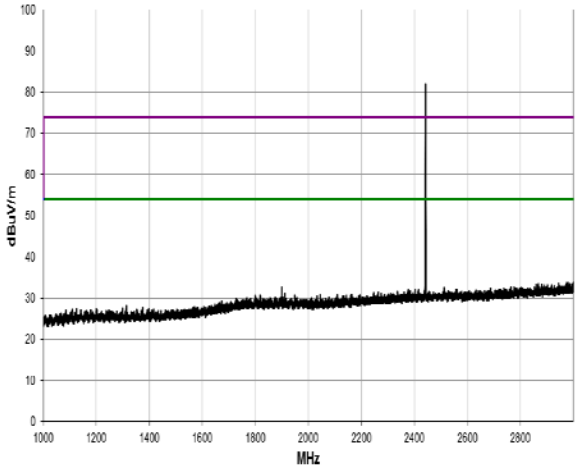

18 GHz to 26.5 GHz

| ***Frequency 2403 MHz; Data rate 1 Mbps:*** | | | | | |
|---|---|---|---|---|---|
| ***Emission*** | ***Frequency (MHz)*** | ***Level (dBm)*** | ***Limit (dBm)*** | ***Margin (dB)*** | ***Result*** |
| No significant emissions above the system measurement noise floor | | | | | PASS |

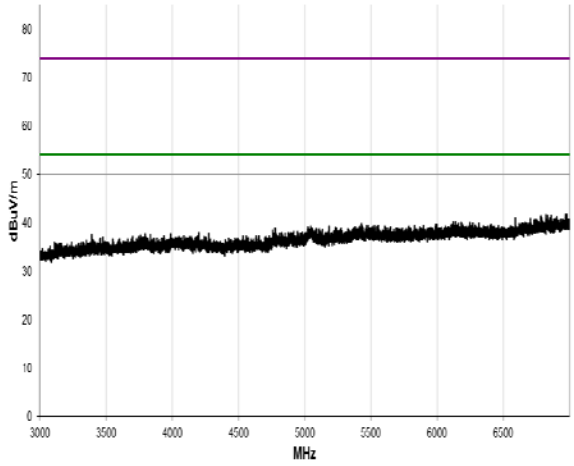
2442 MHz – 1 Mbps



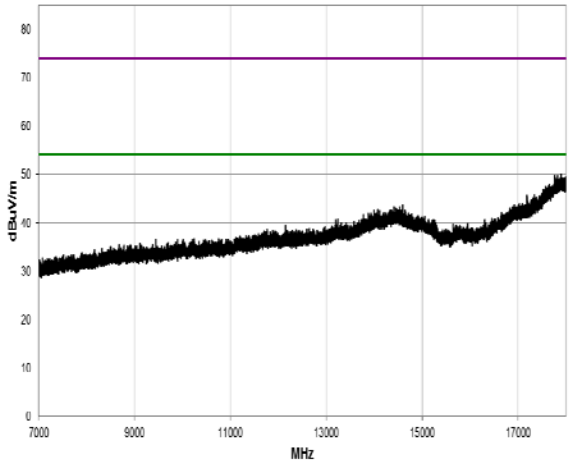

30 MHz to 1 GHz



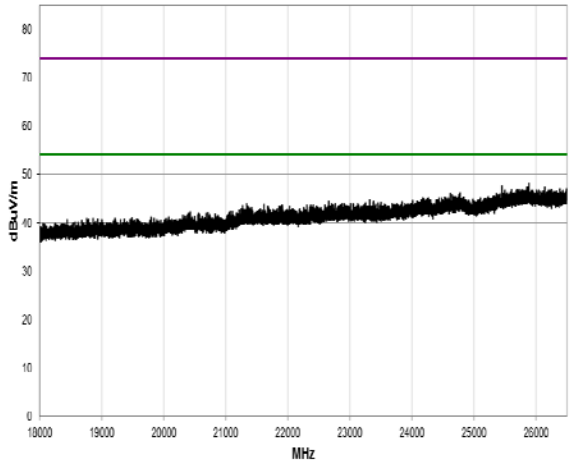

1 GHz to 3 GHz




3 GHz to 7 GHz



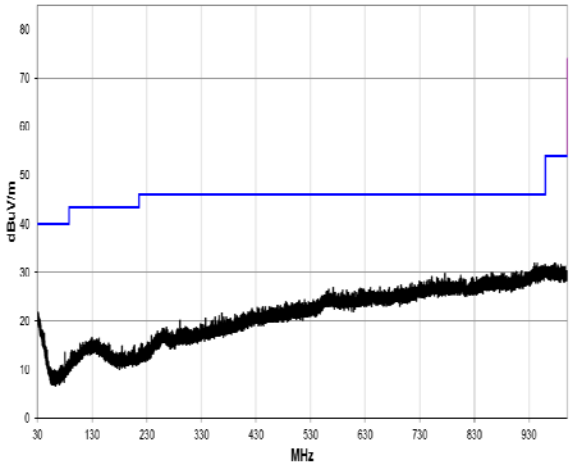

7 GHz to 18 GHz



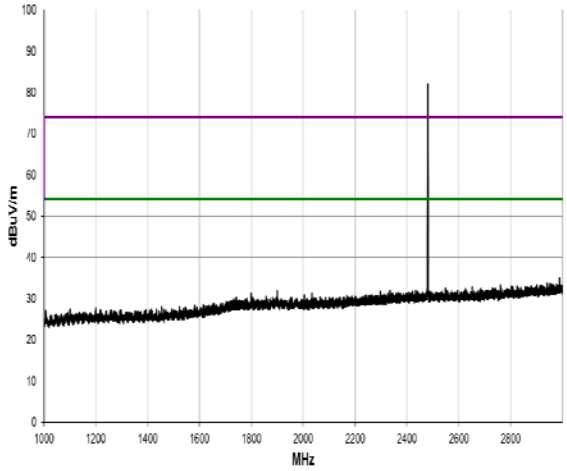

18 GHz to 26.5 GHz

| *Frequency 2442 MHz; Data rate 1 Mbps:* | | | | | |
|---|---|---|---|---|---|
| ***Emission*** | ***Frequency (MHz)*** | ***Level (dBm)*** | ***Limit (dBm)*** | ***Margin (dB)*** | ***Result*** |
| No significant emissions above the system measurement noise floor | | | | | PASS |

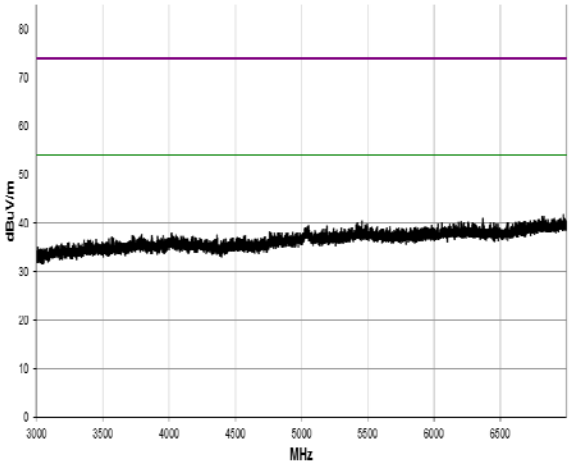
2481 MHz – 1 Mbps



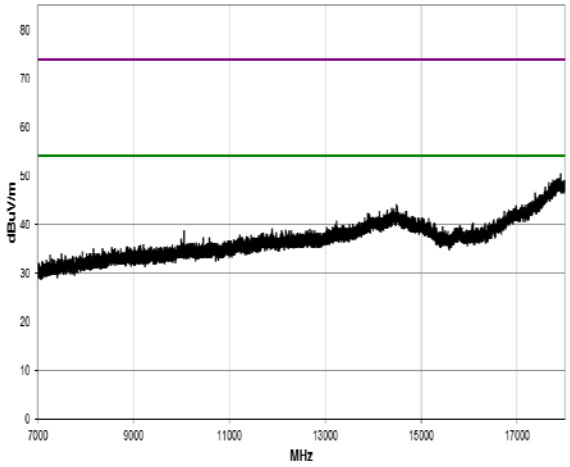

30 MHz to 1 GHz



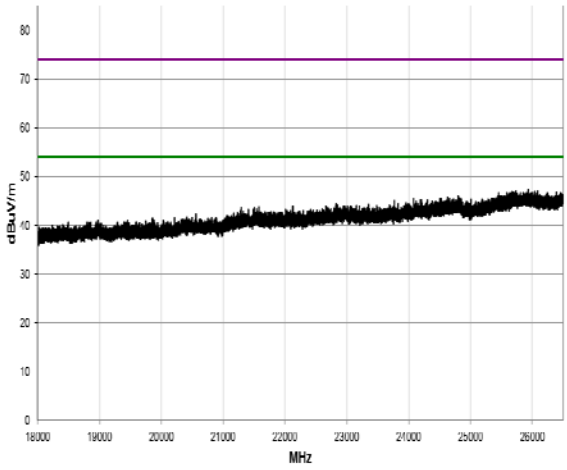

1 GHz to 3 GHz




3 GHz to 7 GHz



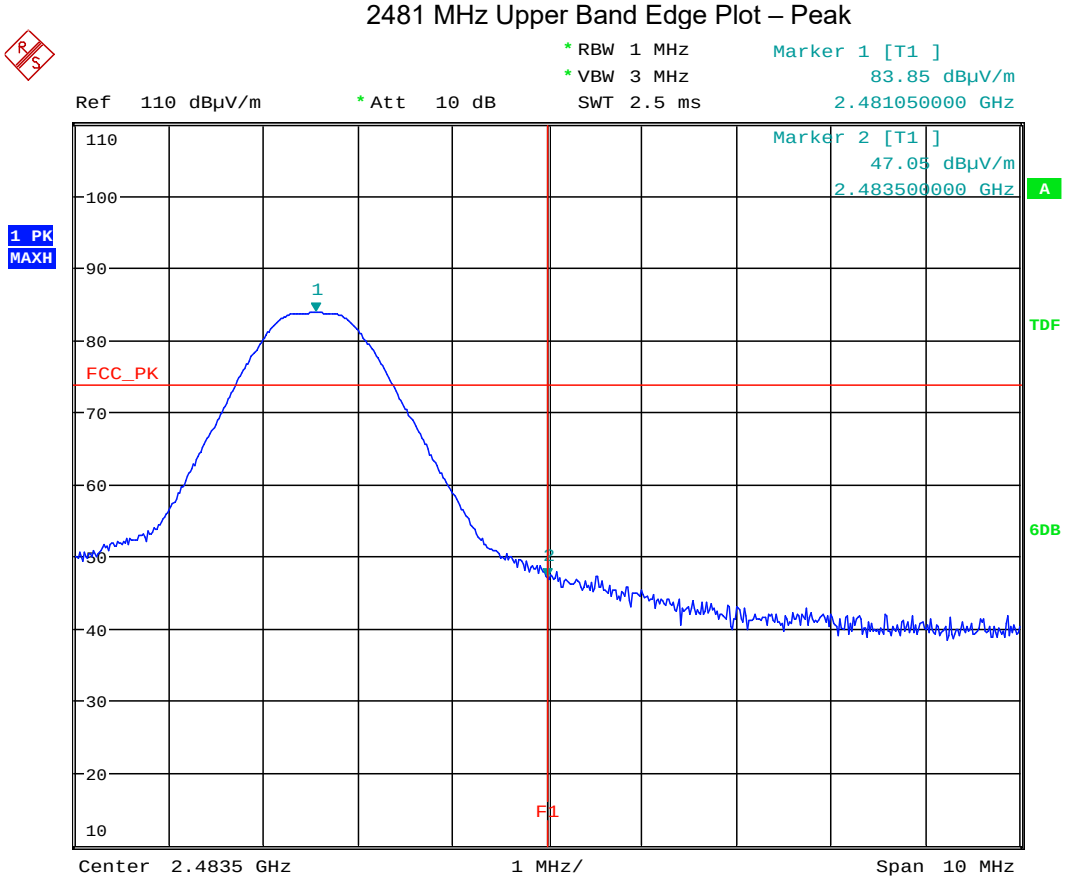

7 GHz to 18 GHz




18 GHz to 26.5 GHz

| ***Frequency 2481 MHz; Data rate 1 Mbps:*** | | | | | |
|---|---|---|---|---|---|
| ***Emission*** | ***Frequency (MHz)*** | ***Level (dBm)*** | ***Limit (dBm)*** | ***Margin (dB)*** | ***Result*** |
| No significant emissions above the system measurement noise floor | | | | | PASS |

## 2481 MHz Upper Band Edge Plot – Peak

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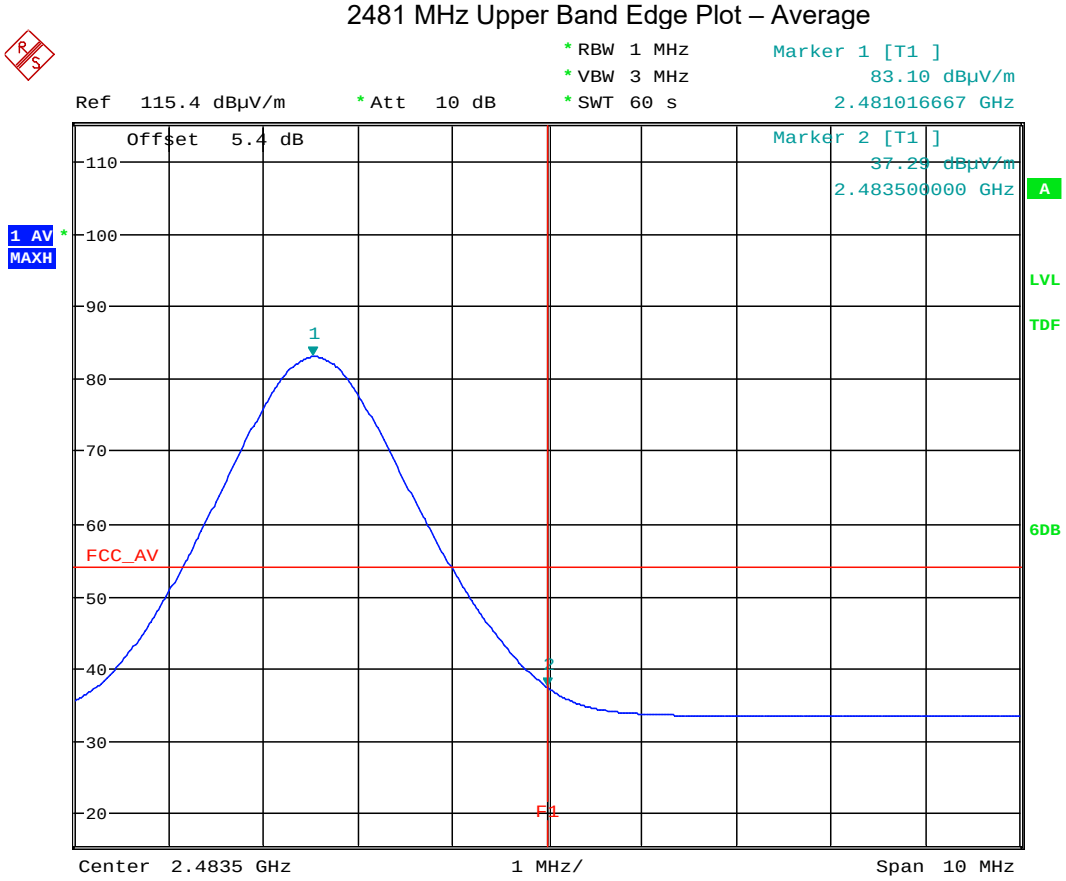
## 2481 MHz Upper Band Edge Plot – Average

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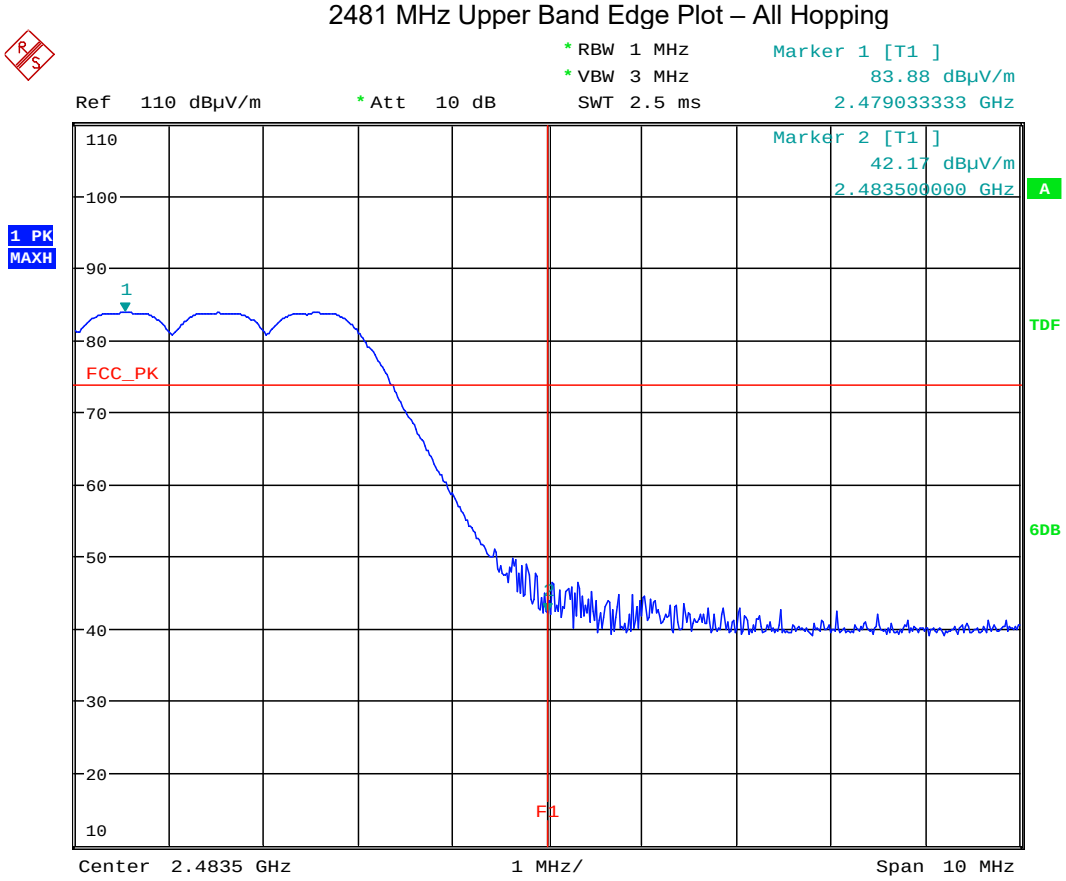
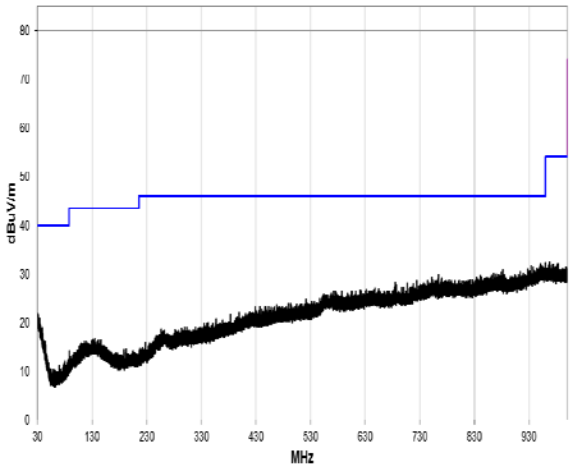
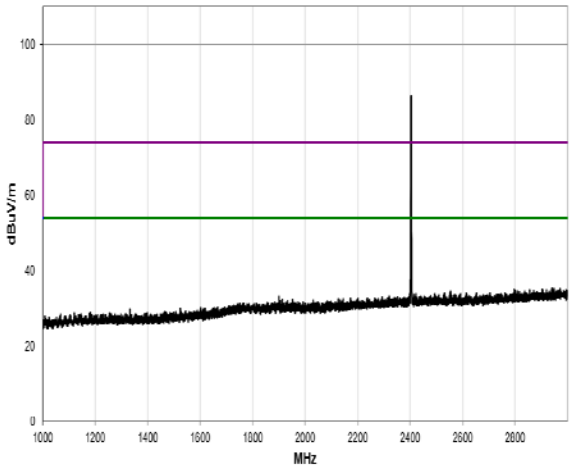
## 2481 MHz Upper Band Edge Plot – All Hopping



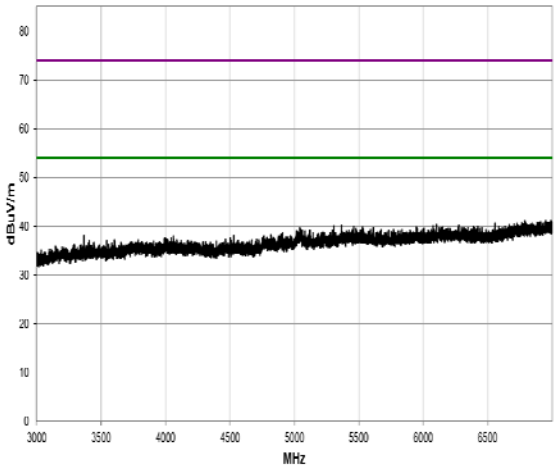
2404 MHz – 2 Mbps



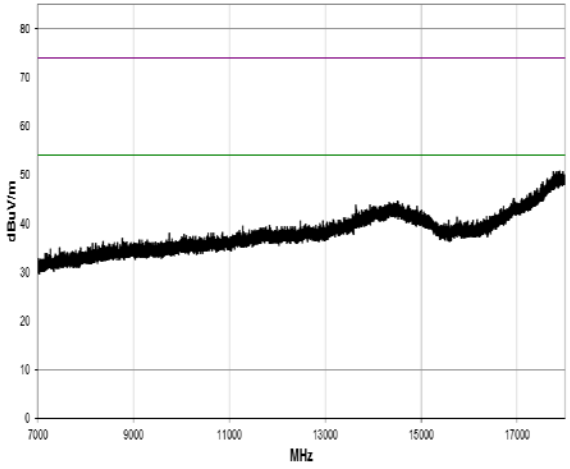

30 MHz to 1 GHz



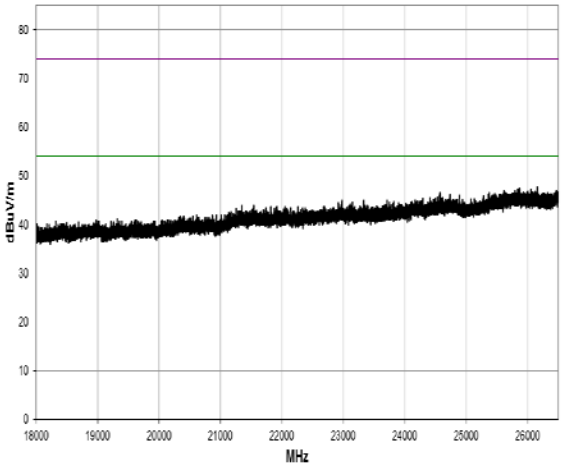

1 GHz to 3 GHz




3 GHz to 7 GHz



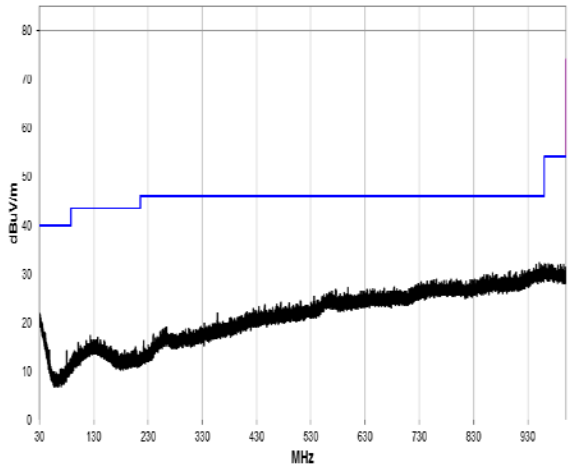

7 GHz to 18 GHz



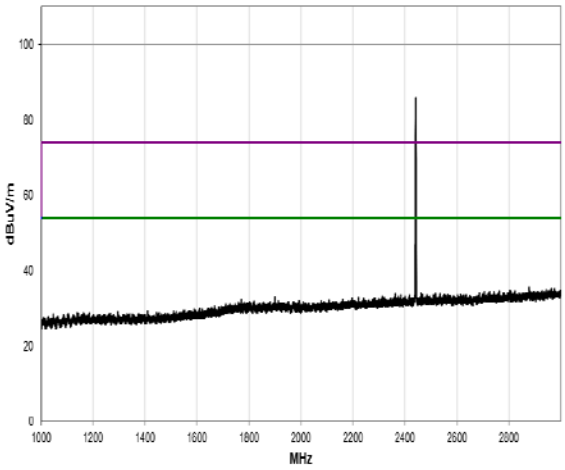

18 GHz to 26.5 GHz

| ***Frequency 2404 MHz; Data rate 2 Mbps:*** | | | | | |
|---|---|---|---|---|---|
| ***Emission*** | ***Frequency (MHz)*** | ***Level (dBm)*** | ***Limit (dBm)*** | ***Margin (dB)*** | ***Result*** |
| No significant emissions above the system measurement noise floor | | | | | PASS |

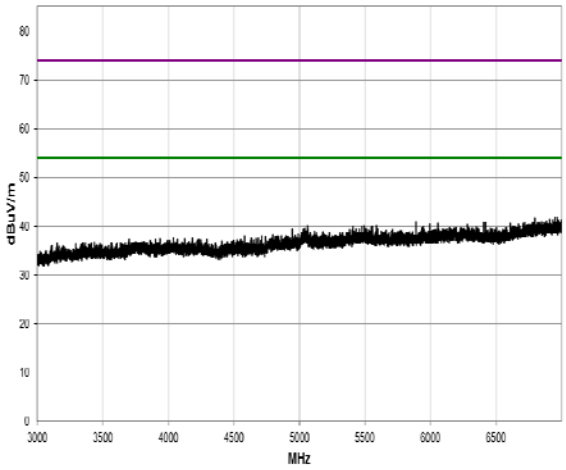
2442 MHz – 2 Mbps



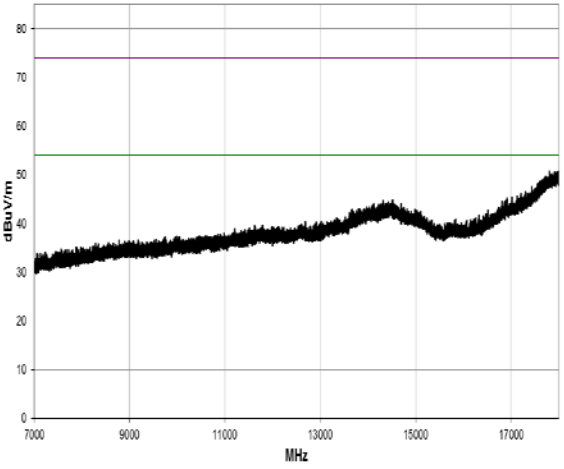

30 MHz to 1 GHz



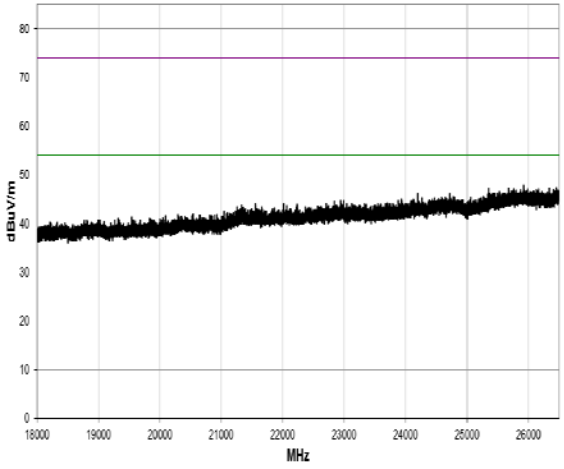

1 GHz to 3 GHz




3 GHz to 7 GHz



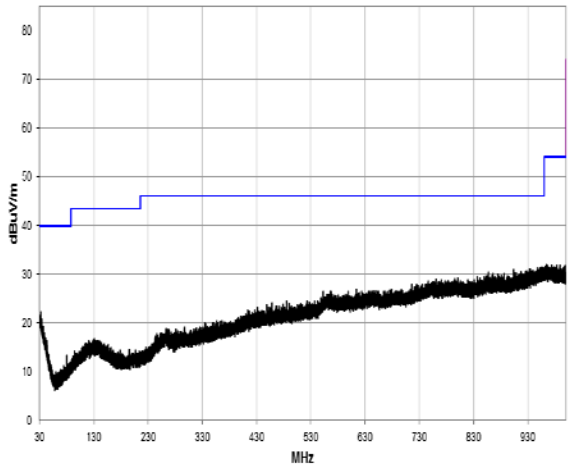

7 GHz to 18 GHz



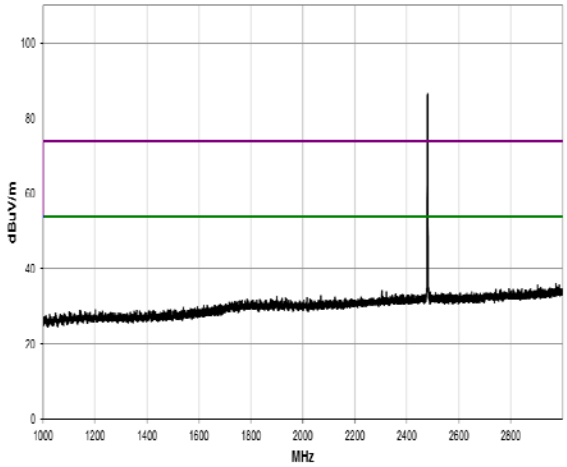

18 GHz to 26.5 GHz

| ***Frequency 2442 MHz; Data rate 2 Mbps:*** | | | | | |
|---|---|---|---|---|---|
| ***Emission*** | ***Frequency (MHz)*** | ***Level (dBm)*** | ***Limit (dBm)*** | ***Margin (dB)*** | ***Result*** |
| No significant emissions above the system measurement noise floor | | | | | PASS |

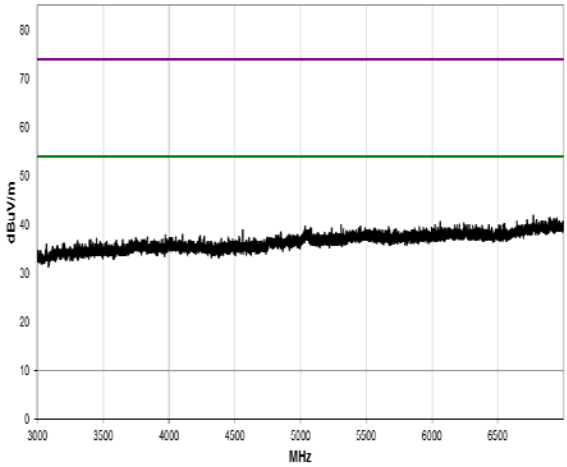
2480 MHz – 2 Mbps



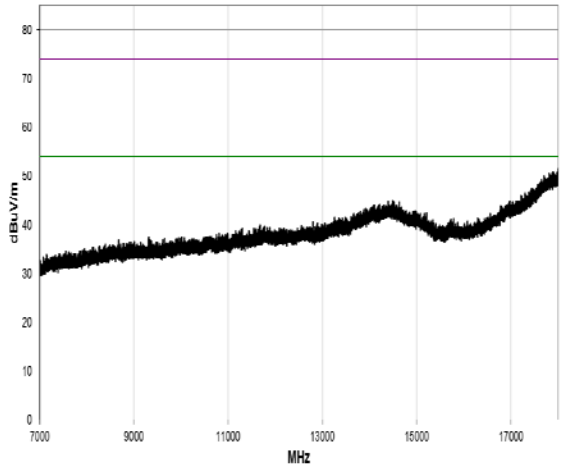

30 MHz to 1 GHz



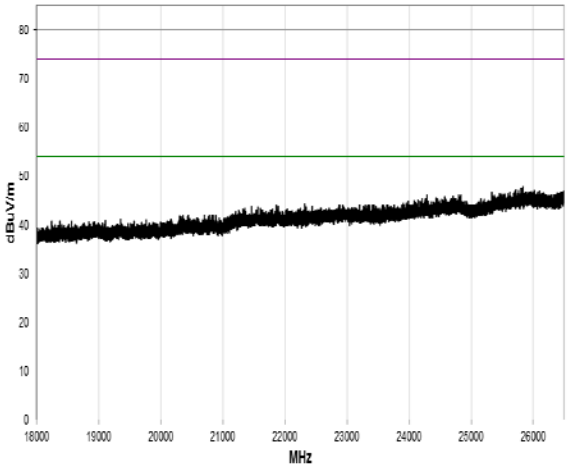

1 GHz to 3 GHz




3 GHz to 7 GHz



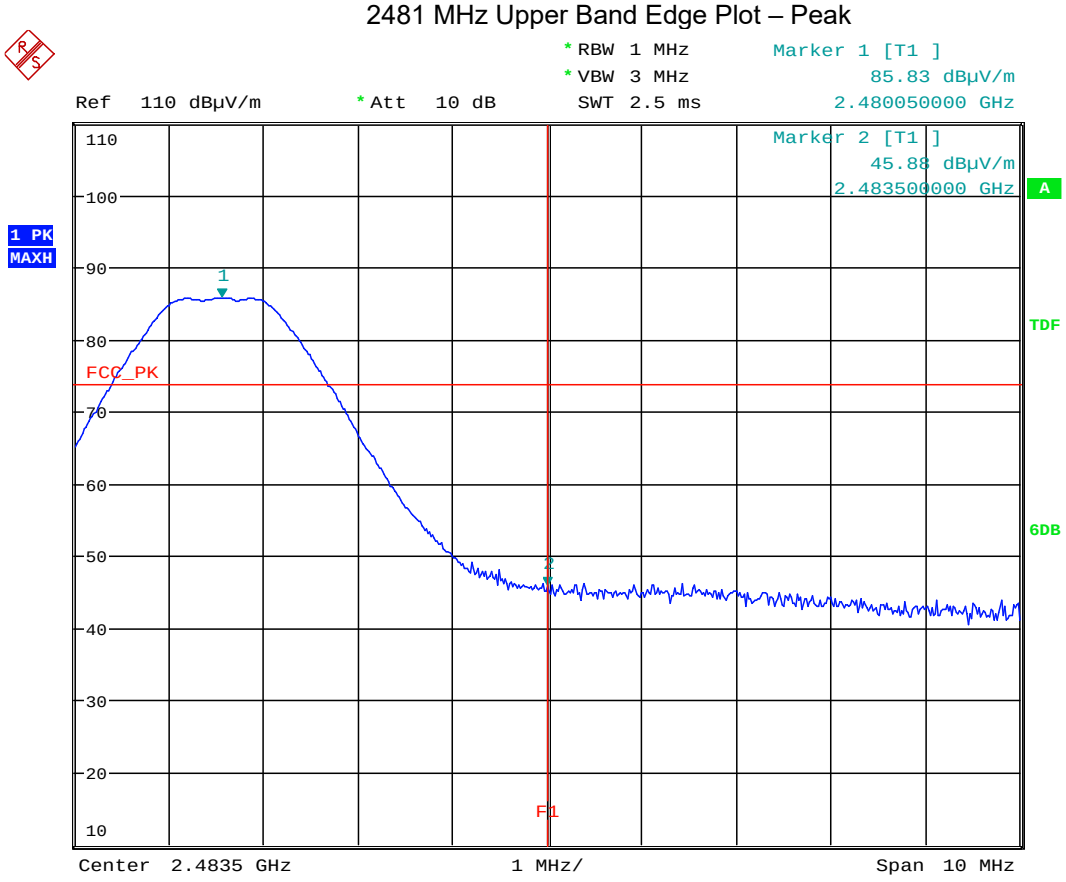

7 GHz to 18 GHz




18 GHz to 26.5 GHz

| ***Frequency 2480 MHz; Data rate 2 Mbps:*** | | | | | |
|---|---|---|---|---|---|
| ***Emission*** | ***Frequency (MHz)*** | ***Level (dBm)*** | ***Limit (dBm)*** | ***Margin (dB)*** | ***Result*** |
| No significant emissions above the system measurement noise floor | | | | | PASS |

## 2481 MHz Upper Band Edge Plot – Peak

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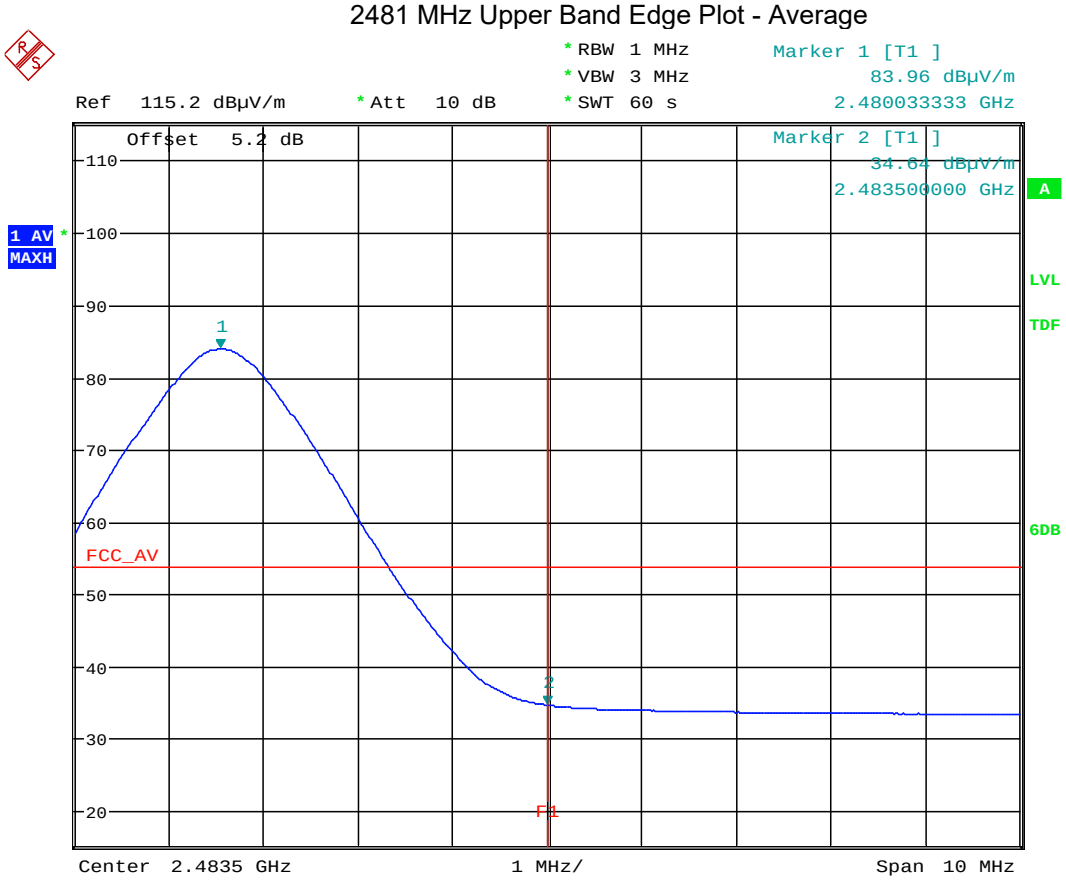
## 2481 MHz Upper Band Edge Plot - Average

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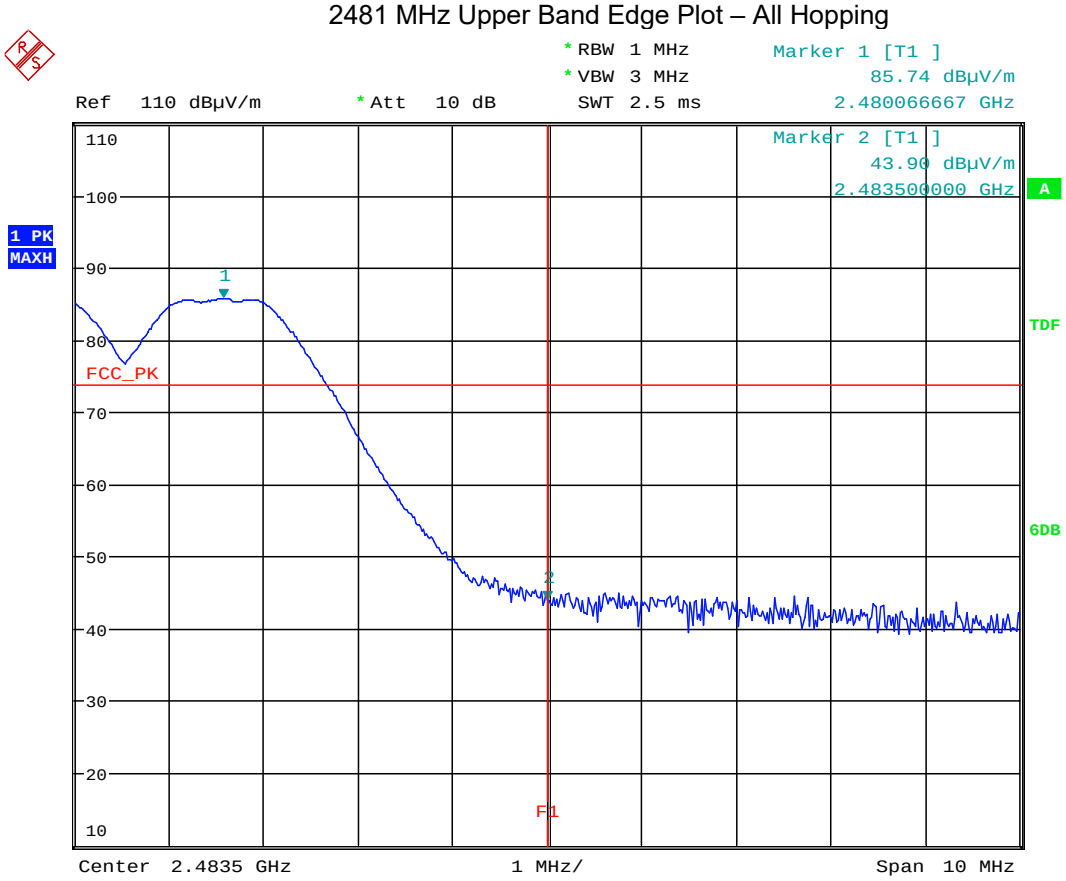
## 2481 MHz Upper Band Edge Plot – All Hopping

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# 12 Carrier frequency separation

## *12.1 Definition*

The carrier frequency separation is the frequency separation between two adjacent hopping frequencies.

## *12.2 Test Parameters*

| | |
|---|---|
| Test Location: | Element Skelmersdale |
| Test Chamber: | Radio Laboratory |
| Test Standard and Clause: | ANSI C63.10-2013, Clause 7.8.2 |
| EUT Channels / Frequencies Measured: | Mode 1: 2403 to 2481 MHz<br>Mode 2: 2404 to 2480 |
| EUT 20dB Bandwidth: | Mode 1: 940.4 kHz<br>Mode 2: 1839.7 kHz |
| EUT Test Modulations: | Internal pattern generation – hopping enabled |
| Deviations From Standard: | None |
| Measurement BW: | 100 kHz |
| Measurement Detector: | Peak |

**Environmental Conditions (Normal Environment)**

| | |
|---|---|
| Temperature: 23 °C | +15 ºC to +35 ºC (as declared) |
| Humidity: 29 % RH | 20 % RH to 75 % RH (as declared) |
| Supply: 3.0 Vdc | |

## *12.3 Test Limit*

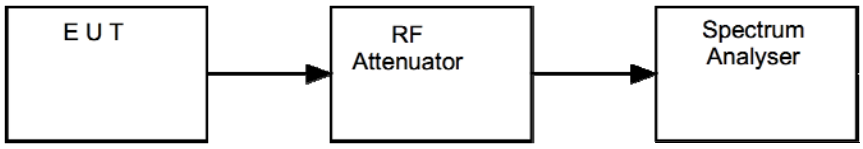
Frequency hopping systems shall have hopping channel carrier frequencies separated by a minimum of 25 kHz or the -20 dB bandwidth of the hopping channel, whichever is greater. Alternatively, frequency hopping systems operating in the band 2400 to 2483.5 MHz may have hopping channel carrier frequencies that are separated by 25 kHz or two-thirds of the -20 dB bandwidth of the hopping channel, whichever is greater, provided that the systems operate with an output power no greater than 0.125 W.

### *12.4 Test Method*

With the EUT setup as per section 9 of this report and connected as per Figure iii, the emissions of the EUT were measured on a spectrum analyser.

The measurements were performed with EUT set at its maximum duty. All modulation schemes, data rates and power settings were used to observe the worst-case configuration in each nominal bandwidth.

**Figure iii Test Setup**

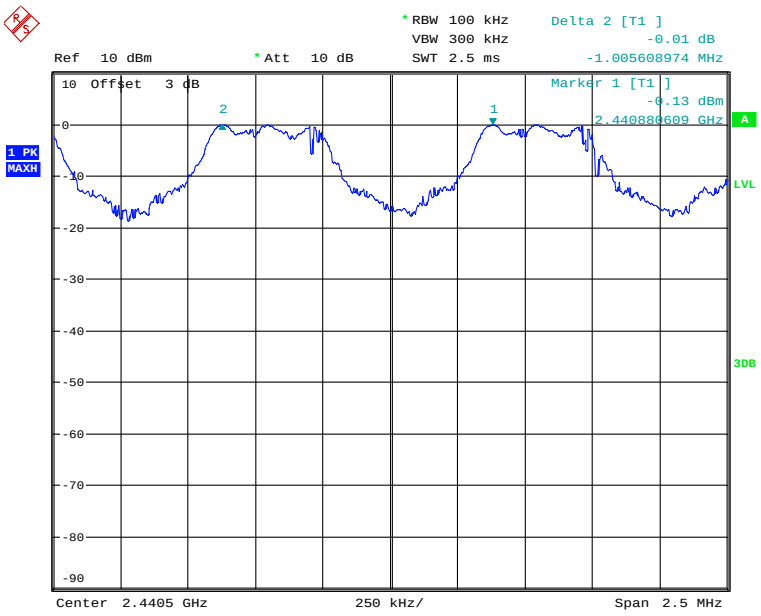



### *12.5 Test Equipment*

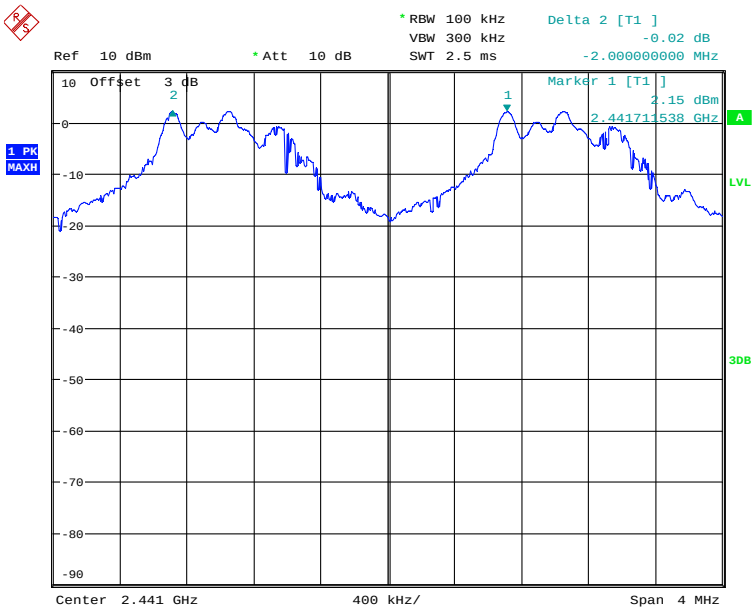
| Equipment Type | Manufacturer | Equipment Description | Element No | Due For Calibration |
|---|---|---|---|---|
| FSU26 | R&S | Spectrum Analyser | U405 | 2020-10-21 |
| AA18-03H | Atlantec | 3dB SMA Attenuator | U637 | Cal in Use |

## 12.6 Test Results

| Mode 1: 1Mbps | | | | |
|---|---|---|---|---|
| **Data Rate** | **$F1_c$ (MHz)** | **$F2_c$ (MHz)** | **Channel Separation, $F2_c - F1_c$ (kHz)** | **Result** |
| 1 MBps | 2439.875000 | 2440.880609 | 1005.608974 | PASS |




| Mode 2: 2Mbps | | | | |
|---|---|---|---|---|
| **Data Rate** | **$F1_c$ (MHz)** | **$F2_c$ (MHz)** | **Channel Separation, $F2_c - F1_c$ (MHz)** | **Result** |
| 2 MBps | 2439.711538 | 2441.711538 | 2 MHz | PASS |



# 13 Number of hopping frequencies

## *13.1 Definition*

The total number of hopping frequencies (the centre frequencies defined within the hopping sequence of a FHSS equipment) which are randomly sequenced in order to spread the transmission.

## *13.2 Test Parameters*

| | |
|---|---|
| Test Location: | Element Skelmersdale |
| Test Chamber: | Radio Laboratory |
| Test Standard and Clause: | ANSI C63.10-2013, Clause 7.8.3 |
| EUT Channels / Frequencies Measured: | All; 2405 – 2480 MHz |
| EUT 20dB Bandwidth: | Mode 1: 940.4 kHz<br>Mode 2: 1839.7 kHz |
| EUT Test Modulations: | Internal pattern generation – hopping enabled |
| Deviations From Standard: | None |
| Measurement Detector: | Peak |

**Environmental Conditions (Normal Environment)**

| | |
|---|---|
| Temperature: 24 °C | +15 ºC to +35 ºC (as declared) |
| Humidity: 37 % RH | 20 % RH to 75 % RH (as declared) |
| Supply: 3.0 V dc | |

## *13.3 Test Limit*

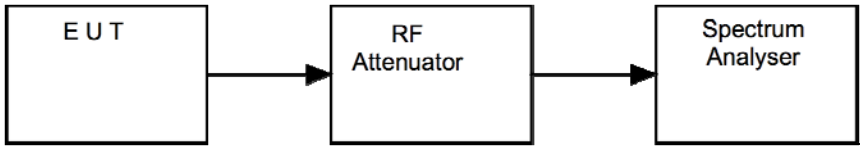
- For frequency hopping systems in the band 902 to 928 MHz: if the -20 dB bandwidth of the hopping channel is less than 250 kHz, the system shall use at least 50 hopping channels; If the -20 dB bandwidth of the hopping channel is 250 kHz or greater, the system shall use at least 25 hopping channels;
- Frequency hopping systems operating in the band 2400 to 2483.5 MHz shall use at least 15 hopping channels;
- Frequency hopping systems operating in the band 5725 to 5850 MHz shall use at least 75 hopping channels.

### *13.4 Test Method*

With the EUT setup as per section 9 of this report and connected as per Figure iv, the emissions of the EUT were measured on a spectrum analyser.

The measurements were performed with EUT set at its maximum duty. All modulation schemes, data rates and power settings were used to observe the worst-case configuration in each nominal bandwidth.

**Figure iv Test Setup**

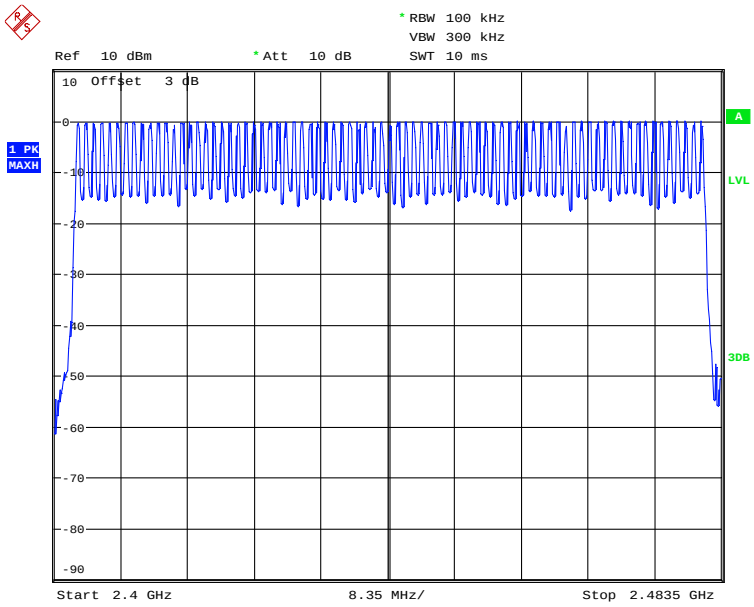



### *13.5 Test Equipment*

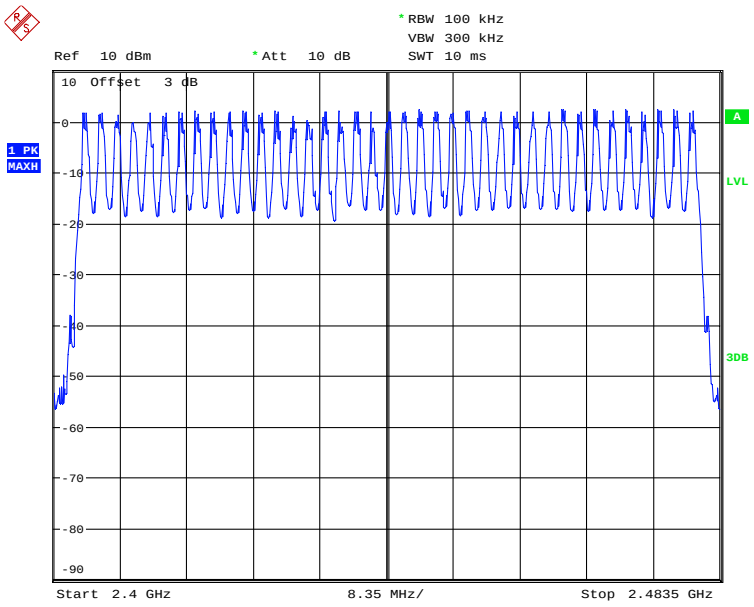
| Equipment Type | Manufacturer | Equipment Description | Element No | Due For Calibration |
|---|---|---|---|---|
| FSU26 | R&S | Spectrum Analyser | U405 | 2020-10-21 |
| AA18-03H | Atlantec | 3dB SMA Attenuator | U637 | Cal in Use |

### *13.6 Test Results*

| | | | | |
|---|---|---|---|---|
| ***Data Rate*** | ***Lowest channel, $F_{CL}$ (MHz)*** | ***Highest channel, $F_{CH}$ (MHz)*** | ***Number of channels observed*** | ***Result*** |
| 1 MBps | 2403.0 MHz | 2481.0 MHz | 79 | PASS |




| | | | | |
|---|---|---|---|---|
| ***Data Rate*** | ***Lowest channel, $F_{CL}$ (MHz)*** | ***Highest channel, $F_{CH}$ (MHz)*** | ***Number of channels observed*** | ***Result*** |
| 2 MBps | 2404.0 MHz | 2480.0 MHz | 39 | PASS |



# 14 Average channel occupancy

## *14.1 Definition*

The channel occupancy is the total of the transmitter 'on' times, during an observation period, on a particular hopping frequency.

## *14.2 Test Parameters*

| | |
|---|---|
| Test Location: | Element Skelmersdale |
| Test Chamber: | Radio Laboratory |
| Test Standard and Clause: | ANSI C63.10-2013, Clause 7.8.4 |
| Frequencies Measured: | 2442.0 MHz |
| EUT 20dB bandwidth: | Mode 1: 940.4 kHz<br>Mode 2: 1839.7 kHz |
| EUT Number of hopping channels: | Mode 1: 79<br>Mode 2: 39 |
| EUT Test Modulations: | Internal pattern generation – hopping enabled |
| Deviations From Standard: | None |
| Measurement BW: | 100 kHz |
| Measurement Detector: | Peak |

**Environmental Conditions (Normal Environment)**

| | |
|---|---|
| Temperature: 22 °C | +15 ºC to +35 ºC (as declared) |
| Humidity: 30 % RH | 20 % RH to 75 % RH (as declared) |
| Supply: 3.0 Vdc | |

## *14.3 Test Limit*

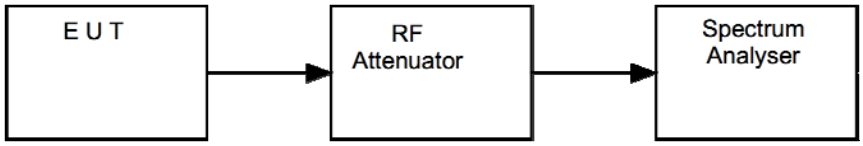
- For frequency hopping systems in the band 902 to 928 MHz: if the -20 dB bandwidth of the hopping channel is less than 250 kHz, the average time of occupancy on any channel shall not be greater than 0.4 seconds within a 20 second period;
  If the -20 dB bandwidth of the hopping channel is 250 kHz or greater, the average time of occupancy on any channel shall not be greater than 0.4 seconds within a 10 second period;
- Frequency hopping systems operating in the band 2400 to 2483.5 MHz: The average time of occupancy on any channel shall not be greater than 0.4 seconds within a period of 0.4 seconds, multiplied by the number of hopping channels employed;
- Frequency hopping systems operating in the band 5725 to 5850 MHz: The average time of occupancy on any frequency shall not be greater than 0.4 seconds within a 30 second period.

### *14.4 Test Method*

With the EUT setup as per section 9 of this report and connected as per Figure v, the emissions of the EUT were measured on a spectrum analyser.

The measurements were performed with EUT set at its maximum duty. A number of hops were observed to confirm consistency of the dwell time / observe the worst case. All modulation schemes, data rates and power settings were used to observe the worst-case configuration.

**Figure v Test Setup**

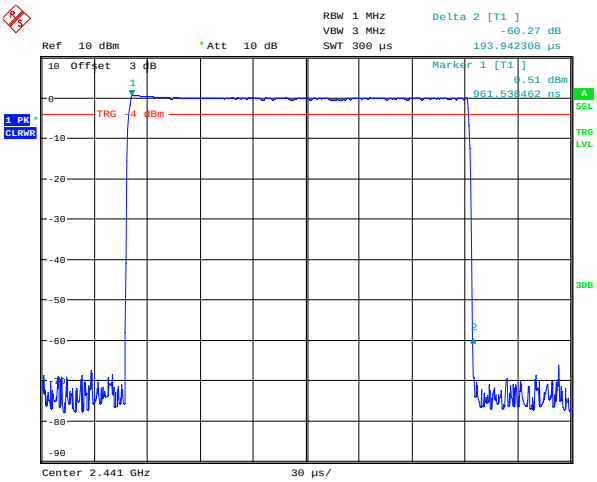



### *14.5 Test Equipment*

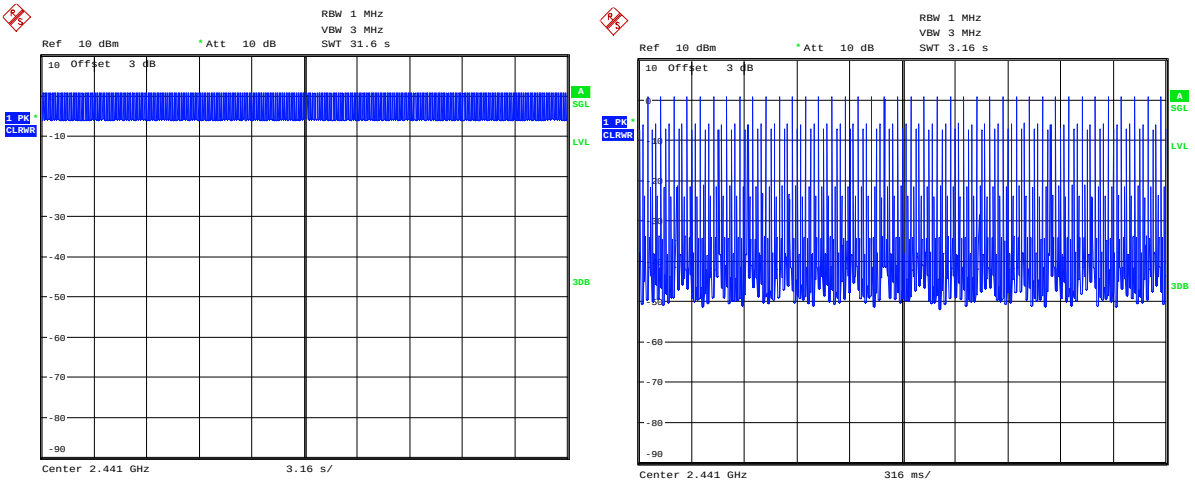
| Equipment Type | Manufacturer | Equipment Description | Element No | Due For Calibration |
|---|---|---|---|---|
| FSU26 | R&S | Spectrum Analyser | U405 | 2020-10-21 |
| AA18-03H | Atlantec | 3dB SMA Attenuator | U637 | Cal in Use |

## 14.6 Test Results

| Mode 1: 1Mbps | | | | | |
|---|---|---|---|---|---|
| **Data Rate** | **Individual occupancy time (ms)** | **Observation period (s)** | **Number of hops observed** | **Average time of occupancy (s)** | **Result** |
| 1Mbps | 0.193942 | 31.6 | 400 | 0.0775768 | PASS |



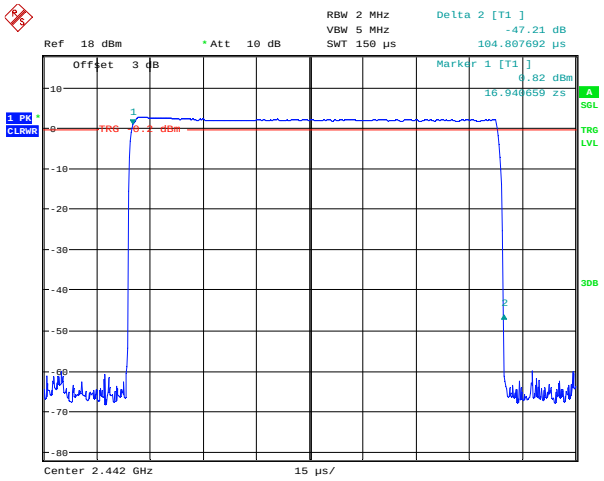

TX On



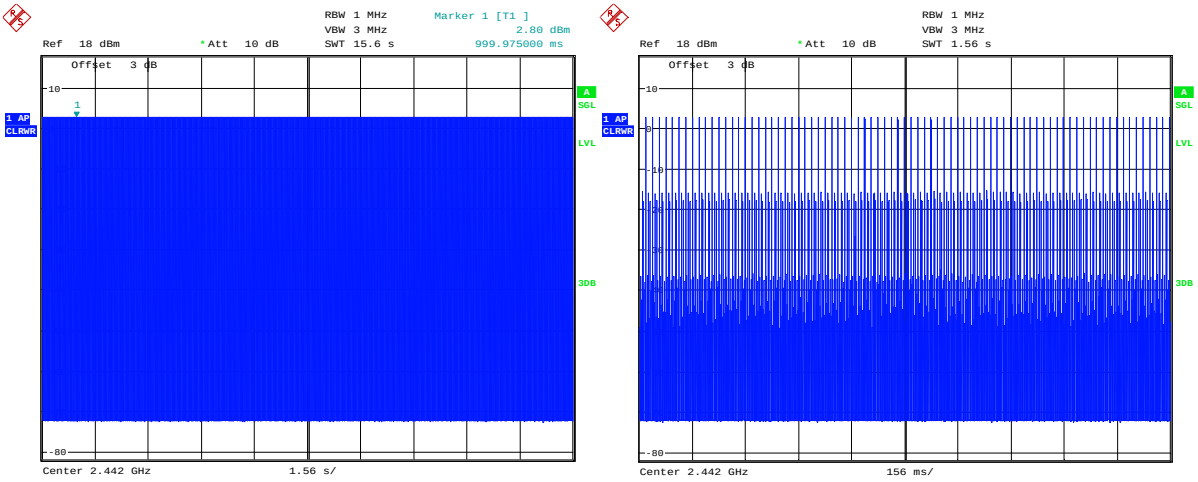

Number of Transmissions in measurement period

Number of transmissions in a 3.16 second period = 40
Number of transmissions in a 31.6 second period = 40 * 10 = 400

| Mode 2: 2Mbps | | | | | |
|---|---|---|---|---|---|
| ***Data Rate*** | ***Individual occupancy time (ms)*** | ***Observation period (s)*** | ***Number of hops observed*** | ***Average time of occupancy (s)*** | ***Result*** |
| 2Mbps | 0.104807 | 15.6 | 810 | 0.08489367 | PASS |




TX On




Number of Transmissions in measurement period

Number of transmissions in a 1.56 second period = 81
Number of transmissions in a 15.6 second period = 81 * 10 = 810

# 15 Maximum peak conducted output power

## *15.1 Definition*

The maximum peak conducted output power is defined as the maximum power level measured with a peak detector using a filter with width and shape of which is sufficient to accept the signal bandwidth.

The 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.

## *15.2 Test Parameters*

| | |
|---|---|
| Test Location: | Element Skelmersdale |
| Test Chamber: | Radio Laboratory |
| Test Standard and Clause: | ANSI C63.10-2013, Clause 7.8.5 |
| Frequencies Measured: | Mode 1: 2403 MHz / 2442 MHz / 2481 MHz – hopping disabled.<br>Mode 2: 2404 MHz / 2442 MHz / 2480 MHz – hopping disabled / DTS |
| EUT Channel Bandwidths: | Mode 1: 1 MHz<br>Mode 2: 2 MHz |
| Deviations From Standard: | None |
| Measurement BW: | Mode 1: 1 MHz<br>Mode 2: 2 MHz |
| Spectrum Analyzer Video BW: | Mode 1: 3 MHz<br>Mode 2: 5 MHz |
| Measurement Detector: | Peak |
| Voltage Extreme Environment Test Range: | Battery Power = new battery. |

**Environmental Conditions (Normal Environment)**

| | |
|---|---|
| Temperature: 24 °C | +15 ºC to +35 ºC (as declared) |
| Humidity: 37 % RH | 20 % RH to 75 % RH (as declared) |

### *15.3 Test Limit*

- For frequency hopping systems operating in the band 902 to 928 MHz, the maximum peak conducted output power shall not exceed 1 W, and the e.i.r.p. shall not exceed 4 W, if the hopset uses 50 or more hopping channels;
  the maximum peak conducted output power shall not exceed 0.25 W, and the e.i.r.p. shall not exceed 1 W, if the hopset uses less than 50 hopping channels.
- For frequency hopping systems operating in the band 2400 to 2483.5 MHz and employing at least 75 hopping channels, the maximum peak conducted output power shall not exceed 1 W; for all other frequency hopping systems in the band, the maximum peak conducted output power shall not exceed 0.125 W. The e.i.r.p. shall not exceed 4 W.
- For frequency hopping systems operating in the band 5725 to 5850 MHz, the maximum peak conducted output power shall not exceed 1 W. The e.i.r.p. shall not exceed 4 W.
- Point-to-point systems in the bands 2400-2483.5 MHz and 5725 to 5850 MHz are permitted to have an e.i.r.p. higher than 4 W provided that the higher e.i.r.p. is achieved by employing higher gain directional antennas and not higher transmitter output powers.

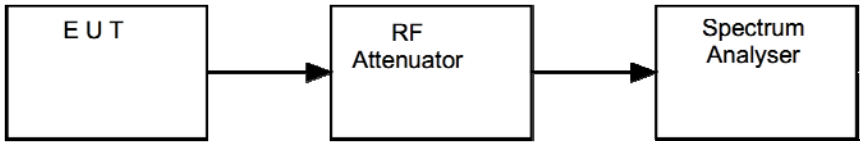
- For systems employing digital modulation techniques operating in the bands 902 to 928 MHz, 2400 to 2483.5 MHz and 5725 to 5850 MHz, the maximum peak conducted output power shall not exceed 1 W.

### *15.4 Test Method*

With the EUT setup as per section 9 of this report and connected as per Figure vi, the resolution bandwidth of the spectrum analyser was increased above the EUT occupied bandwidth and the peak emission data noted.

The measurements were performed with EUT set at its maximum duty. All modulation schemes, data rates and power settings were used to observe the worst-case configuration in each bandwidth.

**Figure vi Test Setup**

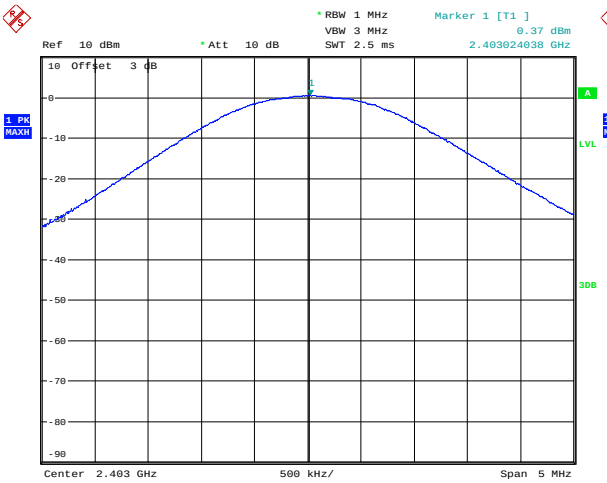



### *15.5 Test Equipment*

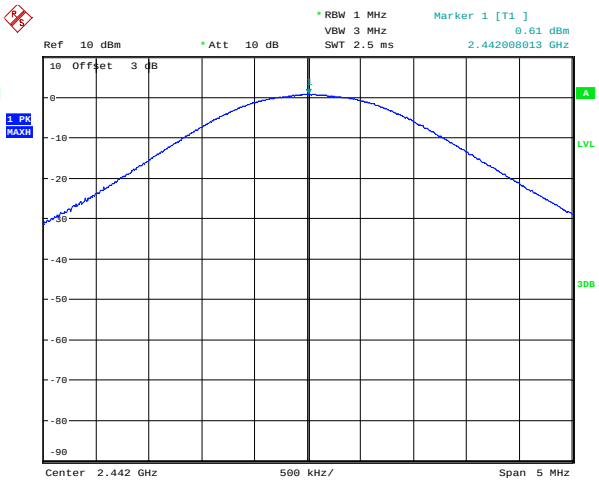
| Equipment Type | Manufacturer | Equipment Description | Element No | Due For Calibration |
|---|---|---|---|---|
| FSU26 | R&S | Spectrum Analyser | U405 | 2020-10-21 |
| SMBV100A | R&S | Signal Generator | U677 | 2020-05-07 |
| AA18-10H | Atlantic Microwave | Attenuator | U634 | Cal using U405 and U677 |

## 15.6 Test Results

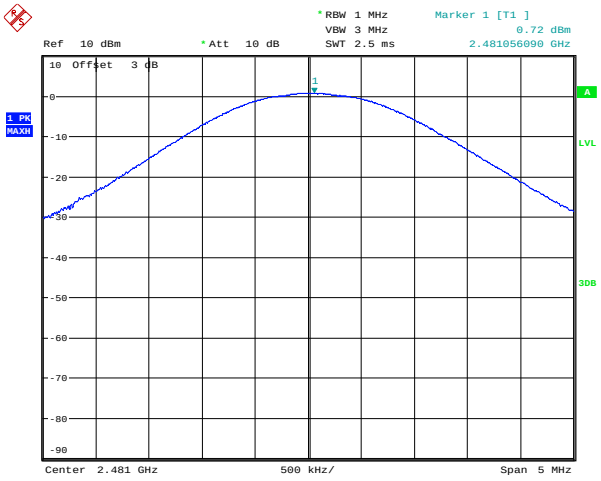
| Mode 1: 1 Mbps | | | | | | | |
|---|---|---|---|---|---|---|---|
| Channel Frequency (MHz) | Analyzer Level (dBm) | Cable loss (dB) | Maximum Peak Conducted Output power (dBm) | Maximum peak conducted output power (W) | Antenna gain (dBi) | E.I.R.P. (W) | Result |
| 2403 | -2.63 | 3.00 | 0.37 | 0.0011 | -1.65 | 0.0007 | PASS |
| 2442 | -2.39 | 3.00 | 0.61 | 0.0012 | -1.65 | 0.0008 | PASS |
| 2481 | -2.28 | 3.00 | 0.72 | 0.0012 | -1.65 | 0.0008 | PASS |




2403 MHz

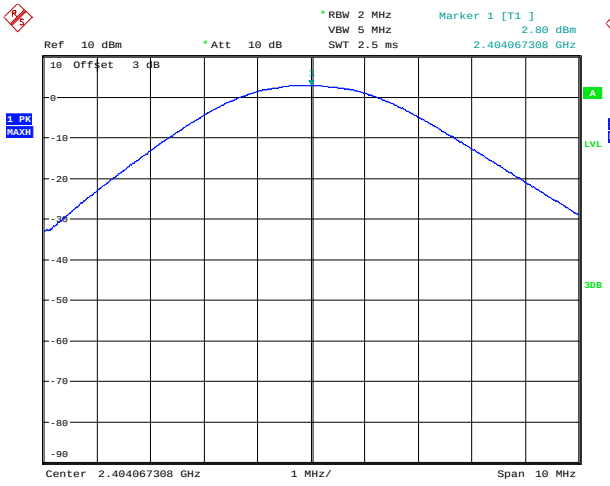



2442 MHz

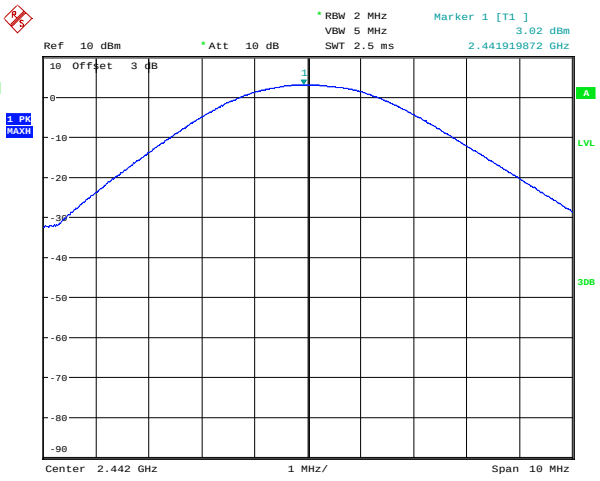



2481 MHz

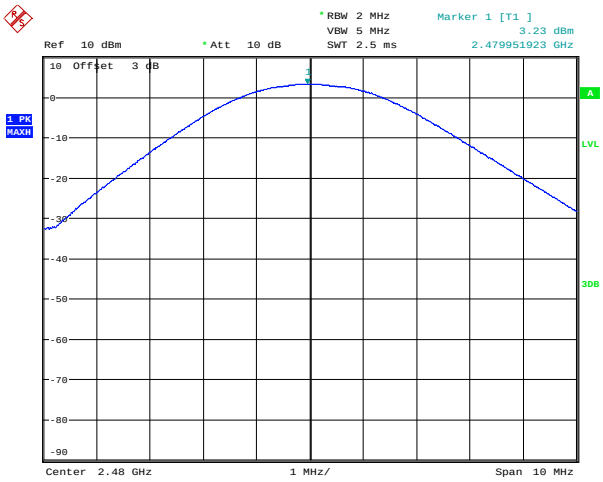
| Mode 2: 2 Mbps | | | | | | | |
|---|---|---|---|---|---|---|---|
| ***Channel Frequency (MHz)*** | ***Analyzer Level (dBm)*** | ***Cable loss (dB)*** | ***Maximum Peak Conducted Output power (dBm)*** | ***Maximum peak conducted output power (W)*** | ***Antenna gain (dBi)*** | ***E.I.R.P. (W)*** | ***Result*** |
| 2404 | -0.20 | 3.00 | 2.80 | 0.0019 | -1.65 | 0.0013 | PASS |
| 2442 | 0.02 | 3.00 | 3.02 | 0.0020 | -1.65 | 0.0014 | PASS |
| 2480 | 0.23 | 3.00 | 3.23 | 0.0021 | -1.65 | 0.0014 | PASS |




2404 MHz




2442 MHz




2480 MHz

# 16 Power spectral density

## *16.1 Definition*

The power per unit bandwidth.

## *16.2 Test Parameters*

| | |
|---|---|
| Test Location: | Element Skelmersdale |
| Test Chamber: | Radio Laboratory |
| Test Standard and Clause: | ANSI C63.10-2013, Clause 11.10 |
| EUT Channels / Frequencies Measured: | 2404 MHz / 2442 MHz / 2480 MHz |
| EUT Channel Bandwidths: | 2 MHz |
| Deviations From Standard: | None |
| Measurement BW: | 100 kHz |
| Spectrum Analyzer Video BW:<br>(requirement at least 3x RBW) | 300 kHz |
| Measurement Span:<br>(requirement 1.5 times Channel BW) | 1.3 MHz |
| Measurement Detector: | Peak |

**Environmental Conditions (Normal Environment)**

| | |
|---|---|
| Temperature: 24 °C | +15 ºC to +35 ºC (as declared) |
| Humidity: 37 % RH | 20 % RH to 75 % RH (as declared) |

## *16.3 Test Limit*

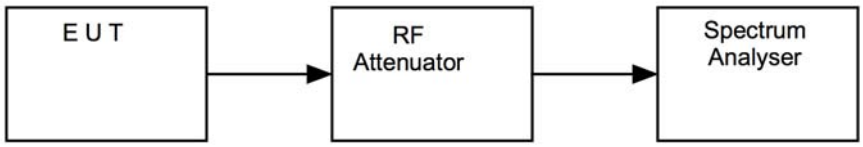
The transmitter power spectral density conducted from the transmitter to the antenna shall not be greater than 8 dBm in any 3 kHz band during any time interval of continuous transmission.

### *16.4 Test Method*

With the EUT setup as per section 9 of this report and connected as per Figure vi, the peak emission of the EUT was measured on a spectrum analyser, with path losses taken into account.

The measurements were performed with EUT set at its maximum duty. All modulation schemes, data rates and power settings were used to observe the worst case configuration in each bandwidth.

**Figure vi Test Setup**




### *16.5 Test Equipment*

| Equipment Type | Manufacturer | Equipment Description | Element No | Due For Calibration |
|---|---|---|---|---|
| FSU26 | R&S | Spectrum Analyser | U405 | 2020-10-21 |
| AA18-03H | Atlantec | 3dB SMA Attenuator | U637 | Cal in Use |

### *16.6 Test Results*

| ***Mode 2: 2 Mbps*** | | | | |
|---|---|---|---|---|
| ***Channel Frequency (MHz)*** | ***Analyzer Level (dBm)*** | ***Cable loss (dB)*** | ***Power (dBm)*** | ***Result*** |
| 2404 | -1.05 | 3.00 | 1.95 | PASS |
| 2442 | -0.83 | 3.00 | 2.17 | PASS |
| 2480 | -0.58 | 3.00 | 2.42 | PASS |

# 17 Occupied Bandwidth

## *17.1 Definition*

The emission bandwidth (x dB) is defined as the frequency range between two points, one above and one below the carrier frequency, at which the spectral density of the emission is attenuated x dB below the maximum in-band spectral density of the modulated signal.

## *17.2 Test Parameters*

| | |
|---|---|
| Test Location: | Element Skelmersdale |
| Test Chamber: | Radio Laboratory |
| Test Standard and Clause: | IC: ANSI C63.10-2013, Clause 6.9<br>FCC: ANSI C63.10-2013, Clause 11.8 |
| Frequencies Measured: | Mode 1: 2403 MHz / 2442 MHz / 2481 MHz – hopping stopped.<br>Mode 2: 2404 MHz / 2442 MHz / 2480 MHz – hopping stopped / DTS |
| EUT Channel Bandwidths: | Mode 1: 1 MHz<br>Mode 2: 2 MHz |
| EUT Test Modulations: | Mode 1: 1MBps Binary GFSK<br>Mode 2: 1MBps Binary GFSK |
| Deviations From Standard: | None |
| Measurement BW: | 30 kHz / 100 kHz |
| Spectrum Analyzer Video BW: | 100 kHz / 300 kHz |
| Measurement Span: | 1.3 MHz / 3MHz / 5 MHz |
| Measurement Detector: | Peak |

**Environmental Conditions (Normal Environment)**

| | |
|---|---|
| Temperature: 24 °C | +15 ºC to +35 ºC (as declared) |
| Humidity: 37 % RH | 20 % RH to 75 % RH (as declared) |
| Supply: 3.0 Vdc | |

## *17.3 Test Limit*

- For frequency hopping systems in the band 902 to 928 MHz: The maximum allowed -20 dB bandwidth of the hopping channel is 500 kHz.
- Frequency hopping systems operating in the band 5725 to 5850 MHz: The maximum -20 dB bandwidth of the hopping channel shall be 1 MHz

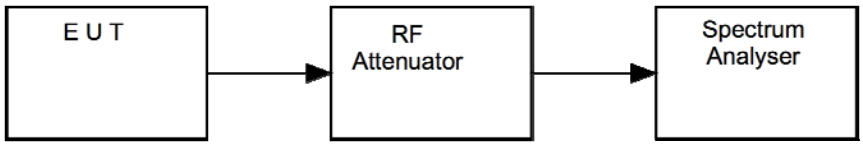
- For DTS The minimum -6 dB bandwidth shall be at least 500 kHz.

### *17.4 Test Method*

With the EUT setup as per section 9 of this report and connected as per Figure vii, the bandwidth of the EUT was measured on a spectrum analyser.

The measurements were performed with EUT set at its maximum duty. All modulation schemes, data rates and power settings were used to observe the worst-case configuration in each bandwidth.

**Figure vii Test Setup**



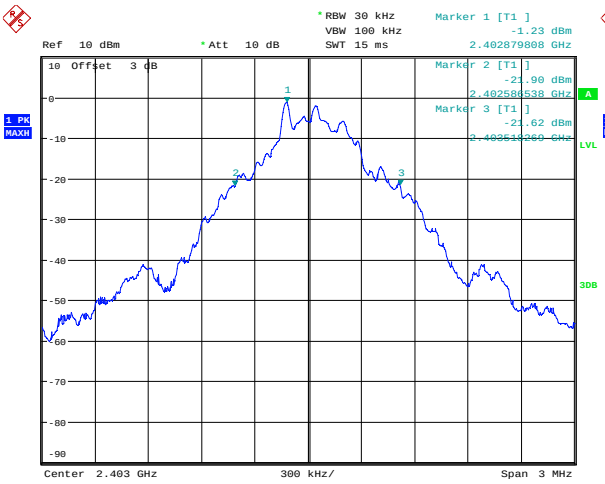

### *17.5 Test Equipment*

### *17.6 Test Equipment*

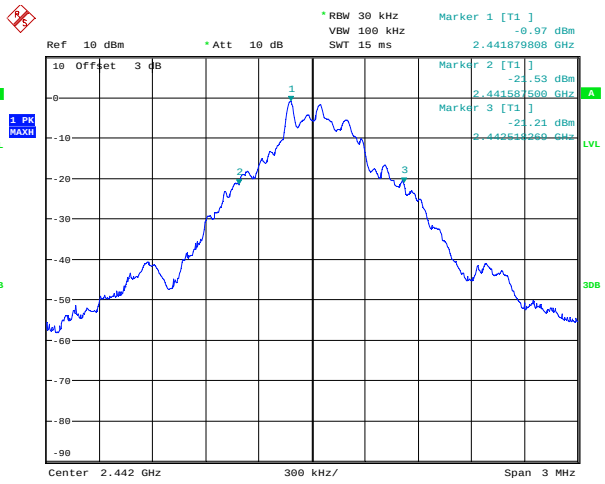
| Equipment Type | Manufacturer | Equipment Description | Element No | Due For Calibration |
|---|---|---|---|---|
| FSU26 | R&S | Spectrum Analyser | U405 | 2020-10-21 |
| AA18-03H | Atlantec | 3dB SMA Attenuator | U637 | Cal in Use |

## 17.7 Test Results

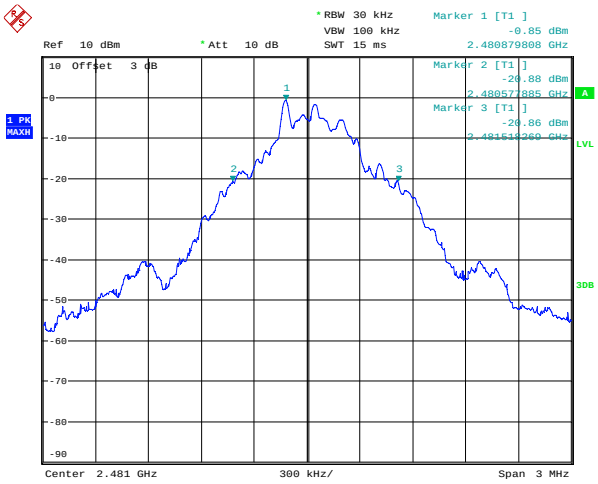
| Mode 1: 1 Mbps 20 dB Bandwidth | | | | |
|---|---|---|---|---|
| **Channel Frequency (MHz)** | **$F_L$ (MHz)** | **$F_H$ (MHz)** | **20dB Bandwidth (kHz)** | **Result** |
| 2403.0 | 2402.586538 | 2403.518269 | 931.7 | PASS |
| 2442.0 | 2441.587500 | 2442.518269 | 930.8 | PASS |
| 2481.0 | 2480.577885 | 2481.518269 | 940.4 | PASS |




2403 MHz

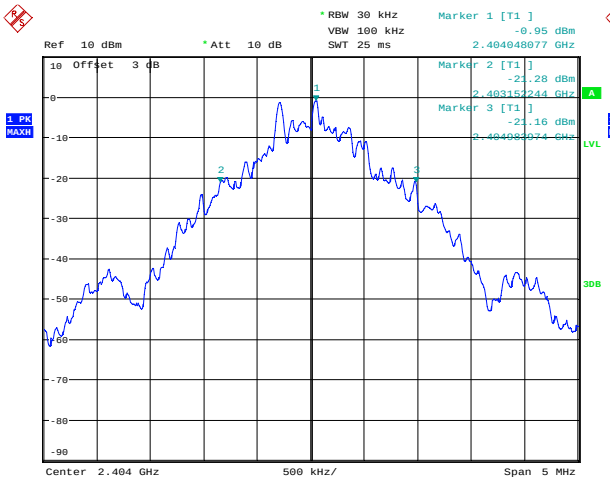



2442.0 MHz

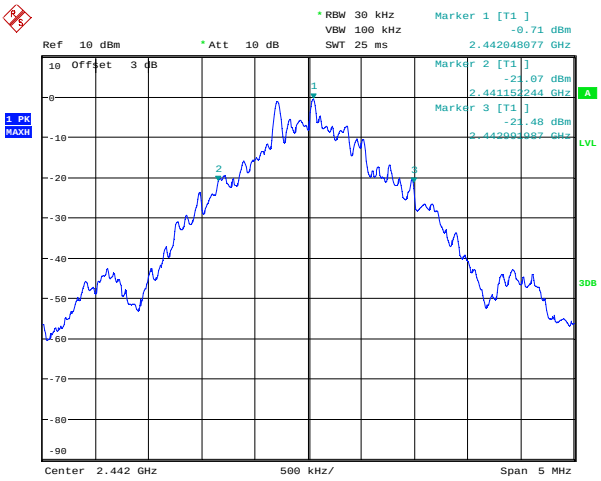



2481 MHz

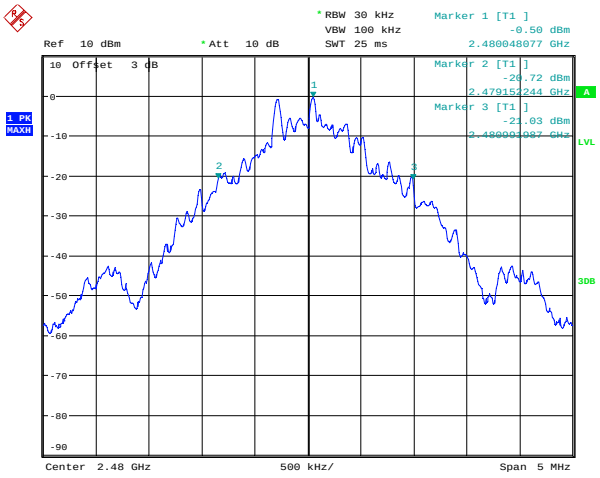
| Mode 2: 2Mbps 20 dB Bandwidth | | | | |
|---|---|---|---|---|
| **Channel Frequency (MHz)** | **$F_L$ (MHz)** | **$F_H$ (MHz)** | **20dB Bandwidth (kHz)** | **Result** |
| 2404.0 | 2403.152244 | 2404.983974 | 1831.7 | PASS |
| 2442.0 | 2441.152244 | 2442.991987 | 1839.7 | PASS |
| 2480.0 | 2479.152244 | 2480.991987 | 1839.7 | PASS |




2404 MHz

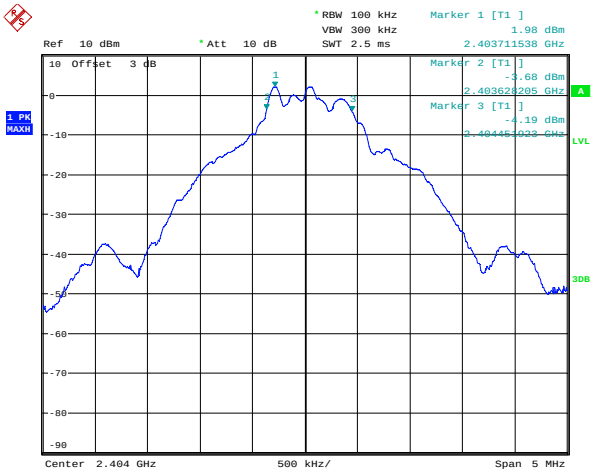



2442.0 MHz

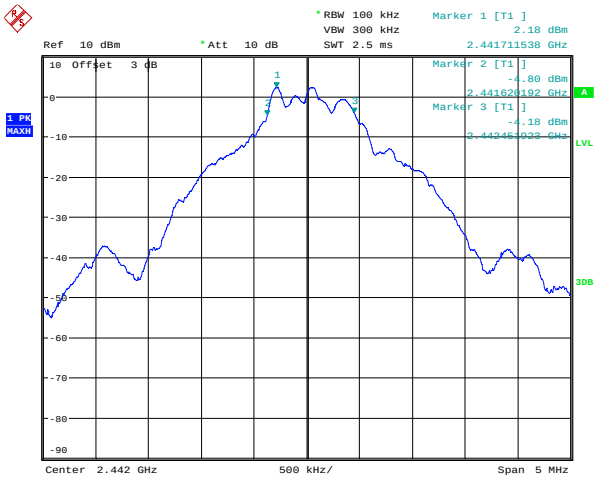



2480 MHz

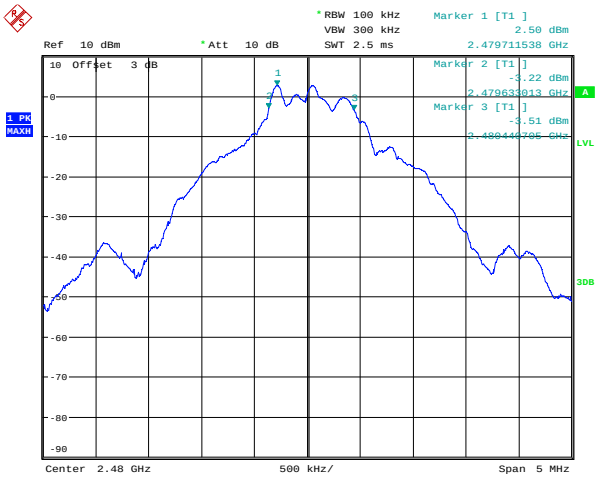
| Mode 2: 2 Mbps 6 dB DTS bandwidth | | | | |
|---|---|---|---|---|
| **Channel Frequency (MHz)** | **$F_L$ (MHz)** | **$F_H$ (MHz)** | **6dB Bandwidth (kHz)** | **Result** |
| 2404.0 | 2403.628205 | 2404.451923 | 823.7 | PASS |
| 2442.0 | 2441.620192 | 2442.451923 | 831.7 | PASS |
| 2480.0 | 2479.633013 | 2480.440705 | 807.7 | PASS |




2404 MHz




2442 MHz




2480 MHz

# 18 Out-of-band and conducted spurious emissions

## *18.1 Definition*

*Out-of-band emission.*
Emission on a frequency or frequencies immediately outside the necessary bandwidth that results from the modulation process but excluding spurious emissions.

*Spurious emission.*
Emission on a frequency or frequencies that are outside the necessary bandwidth and the level of which may be reduced without affecting the corresponding transmission of information. Spurious emissions include harmonic emissions, parasitic emissions, intermodulation products, and frequency conversion products, but exclude out-of-band emissions.

## *18.2 Test Parameters*

| | |
|---|---|
| Test Location: | Element Skelmersdale |
| Test Chamber: | Radio Laboratory |
| Test Standard and Clause: | ANSI C63.10-2013, Clause 7.8.8<br>ANSI C63.10-2013, Clause 11.11 |
| Frequencies Measured: | Mode 1: 2403 MHz / 2442 MHz / 2481 MHz<br>Mode 2: 2404 MHz / 2442 MHz / 2480 MHz |
| EUT Channel Bandwidths: | Mode 1: 1 MHz<br>Mode 2: 2 MHz |
| Deviations From Standard: | None |
| Measurement BW: | 100 kHz |
| Spectrum Analyzer Video BW:<br>(requirement at least 3x RBW) | 300 kHz |
| Measurement Detector: | Peak |
| Measurement Range: | 30 MHz to 25 GHz |

**Environmental Conditions (Normal Environment)**

| | |
|---|---|
| Temperature: 24°C | +15 ºC to +35 ºC (as declared) |
| Humidity: 37 % RH | 20 % RH to 75 % RH (as declared) |
| Supply: 3.0 Vdc | |

## *18.3 Test Limits*

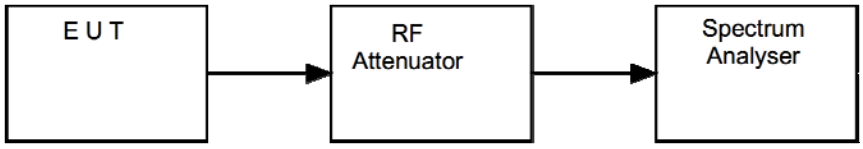
In any 100 kHz bandwidth outside the frequency band in which the spread spectrum or digitally modulated device is operating, the RF power that is produced shall be at least 20 dB below that in the 100 kHz bandwidth within the band that contains the highest level of the desired power, based on either an RF conducted or a radiated measurement, provided that the transmitter demonstrates compliance with the peak conducted power limits. If the transmitter complies with the conducted power limits based on the use of root-mean-square averaging over a time interval, the attenuation required shall be 30 dB instead of 20 dB. Attenuation below the general field strength limits specified in FCC 47CFR15.209(a) / RSS-Gen is not required.

### *18.4 Test Method*

With the EUT setup as per section 9 of this report and connected as per Figure viii, the emissions from the EUT were measured on a spectrum analyser.

The measurements were performed with EUT set at its maximum duty. All modulation schemes, data rates and power settings were used to observe the worst case configuration in each bandwidth.

**Figure viii Test Setup**



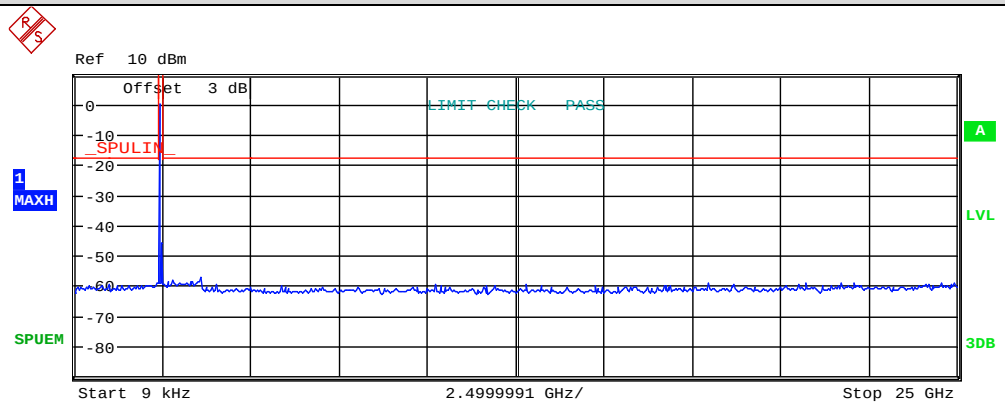

### *18.5 Test Equipment*

| Equipment Type | Manufacturer | Equipment Description | Element No | Due For Calibration |
|---|---|---|---|---|
| FSU26 | R&S | Spectrum Analyser | U405 | 2020-10-21 |
| AA18-03H | Atlantec | 3dB SMA Attenuator | U637 | Cal in Use |

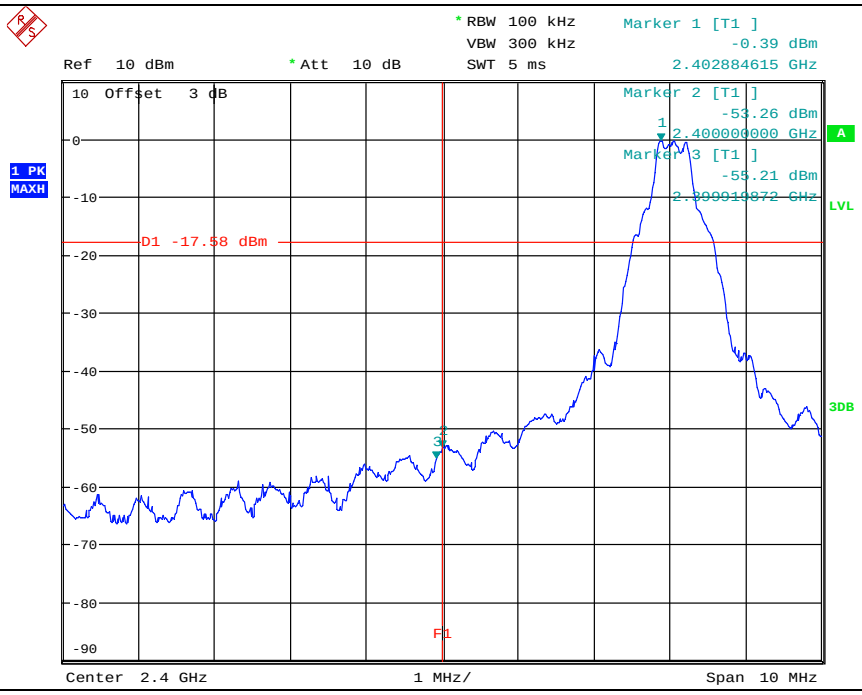
## 18.6 Test Results

| Mode 1: 1Mbps GFSK | | | | | | |
|---|---|---|---|---|---|---|
| Channel Frequency (MHz) | Emission Frequency (MHz) | Analyzer Level (dBm) | Emission Level (dBm) | Limit (dBm) | Margin (dB) | Result |
| 2403 | No Significant emissions within 20 dB of the limit | | | | | PASS |
| 2442 | No Significant emissions within 20 dB of the limit | | | | | PASS |
| 2481 | No Significant emissions within 20 dB of the limit | | | | | PASS |

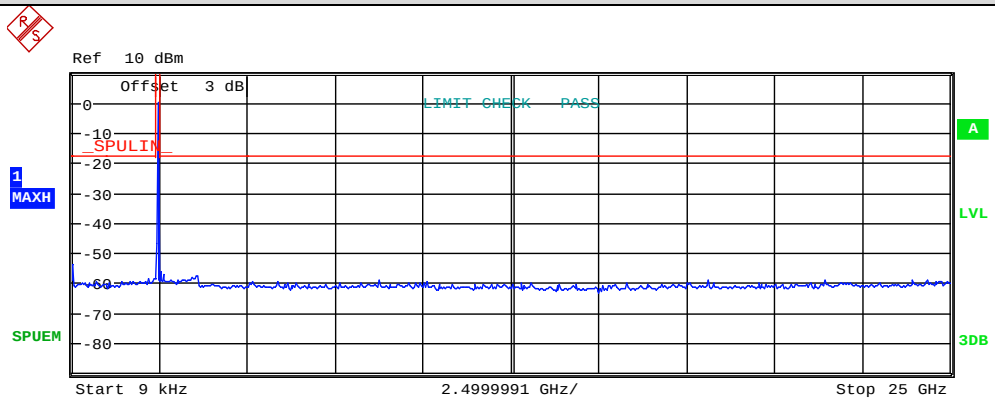
**Mode 1; Frequency: 2403 MHz**




| Start [Hz] | Stop [Hz] | RBW [Hz] | Freq [Hz] | PwrAbs [dBm] | Δ Limit [dB] |
|---|---|---|---|---|---|
| 9.000 k | 150.000 k | 1.00 k | 11.937500 k | -62.55 | -44.97 |
| 150.000 k | 30.000 M | 10.00 k | 176.865000 k | -62.45 | -44.87 |
| 30.000 M | 1.000 G | 100.00 k | 959.066000 M | -59.50 | -41.92 |
| 1.000 G | 2.400 G | 100.00 k | 2.339100 G | -59.38 | -41.80 |
| 2.400 G | 2.483 G | 2.00 M | 2.402998 G | -0.18 | -20.18 |
| 2.483 G | 5.000 G | 100.00 k | 3.579436 G | -57.42 | -39.84 |
| 5.000 G | 10.000 G | 100.00 k | 5.836000 G | -60.25 | -42.67 |
| 10.000 G | 15.000 G | 100.00 k | 10.226500 G | -59.54 | -41.96 |
| 15.000 G | 20.000 G | 100.00 k | 17.931500 G | -59.36 | -41.78 |
| 20.000 G | 25.000 G | 100.00 k | 24.541500 G | -59.05 | -41.47 |

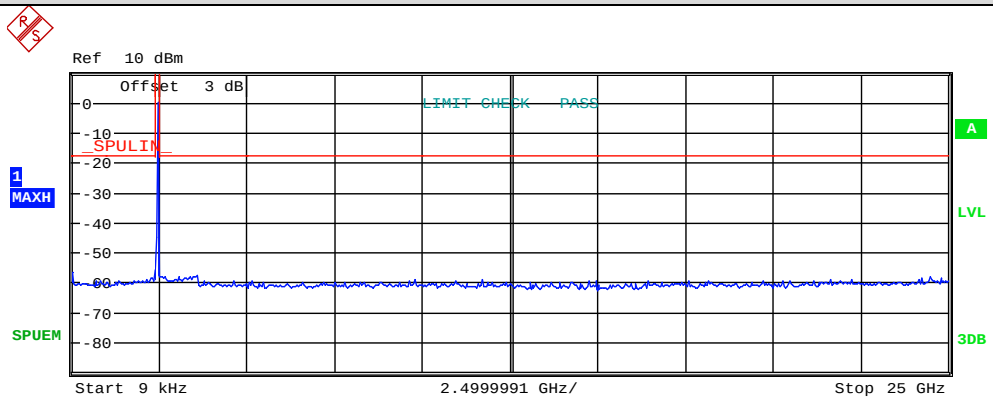


## *Mode 1; Frequency: 2440 MHz*

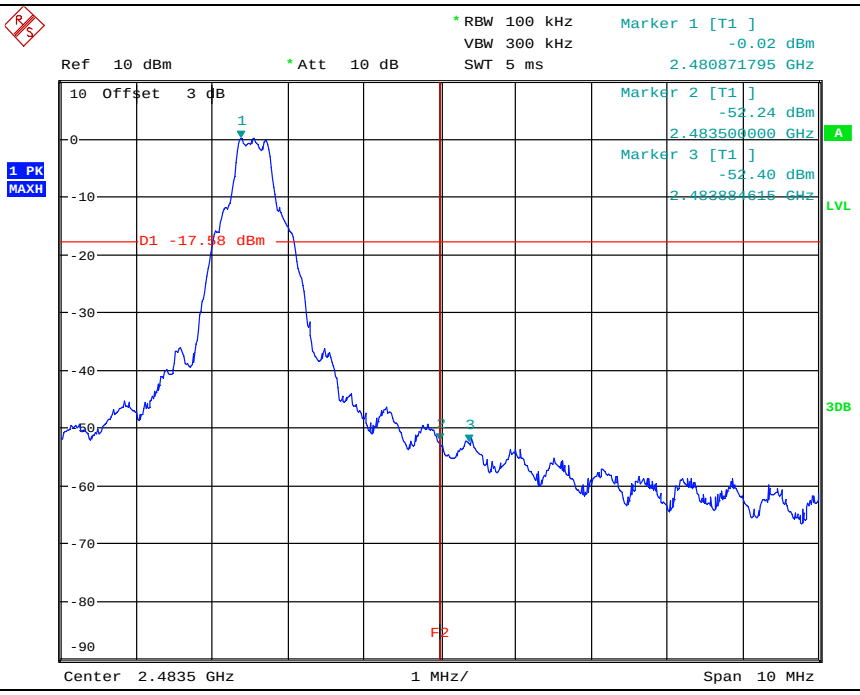



| Start [Hz] | Stop [Hz] | RBW [Hz] | Freq [Hz] | PwrAbs [dBm] | Δ Limit [dB] |
|---|---|---|---|---|---|
| 9.000 k | 150.000 k | 1.00 k | 9.000000 k | -53.96 | -36.38 |
| 150.000 k | 30.000 M | 10.00 k | 182.835000 k | -63.13 | -45.55 |
| 30.000 M | 1.000 G | 100.00 k | 33.298000 M | -59.82 | -42.24 |
| 1.000 G | 2.400 G | 100.00 k | 2.378160 G | -58.86 | -41.28 |
| 2.400 G | 2.483 G | 2.00 M | 2.442009 G | -0.03 | -20.03 |
| 2.483 G | 5.000 G | 100.00 k | 2.505897 G | -56.44 | -38.86 |
| 5.000 G | 10.000 G | 100.00 k | 8.730500 G | -59.45 | -41.87 |
| 10.000 G | 15.000 G | 100.00 k | 10.106000 G | -59.84 | -42.26 |
| 15.000 G | 20.000 G | 100.00 k | 18.111000 G | -59.36 | -41.78 |
| 20.000 G | 25.000 G | 100.00 k | 21.425500 G | -59.25 | -41.67 |

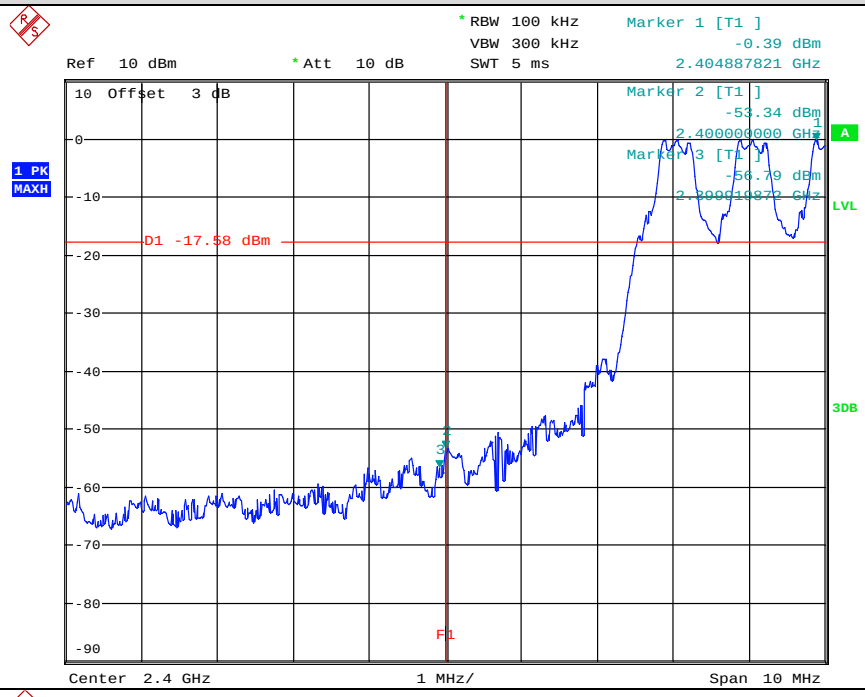
## *Mode 1; Frequency: 2481 MHz*

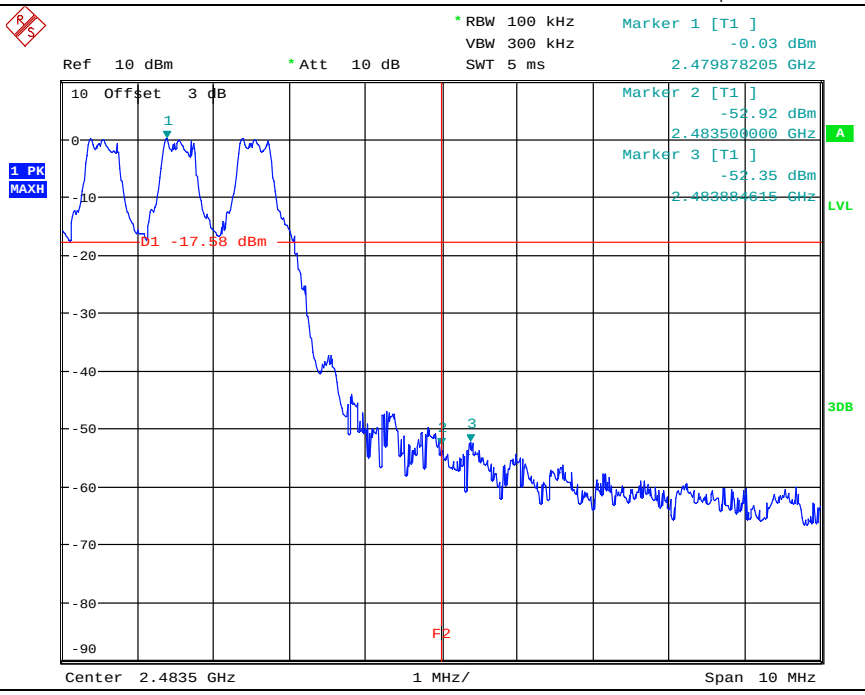



| Start [Hz] | Stop [Hz] | RBW [Hz] | Freq [Hz] | PwrAbs [dBm] | Δ Limit [dB] |
|---|---|---|---|---|---|
| 9.000 k | 150.000 k | 1.00 k | 9.000000 k | -56.91 | -39.33 |
| 150.000 k | 30.000 M | 10.00 k | 182.835000 k | -63.51 | -45.93 |
| 30.000 M | 1.000 G | 100.00 k | 691.831000 M | -59.63 | -42.05 |
| 1.000 G | 2.400 G | 100.00 k | 2.385160 G | -56.19 | -38.61 |
| 2.400 G | 2.483 G | 2.00 M | 2.481045 G | 0.03 | -19.97 |
| 2.483 G | 5.000 G | 100.00 k | 2.544903 G | -57.73 | -40.15 |
| 5.000 G | 10.000 G | 100.00 k | 9.769500 G | -59.43 | -41.85 |
| 10.000 G | 15.000 G | 100.00 k | 11.691000 G | -59.41 | -41.83 |
| 15.000 G | 20.000 G | 100.00 k | 17.569000 G | -59.67 | -42.09 |
| 20.000 G | 25.000 G | 100.00 k | 24.498000 G | -58.40 | -40.82 |



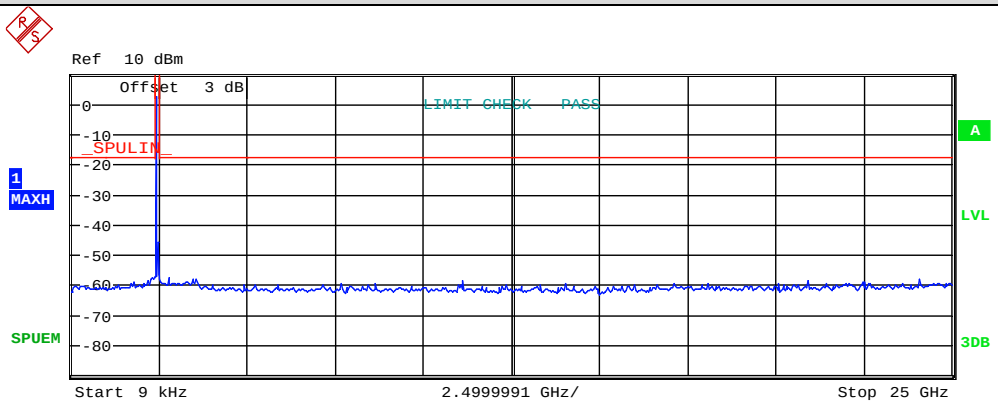
## *Mode 1; Bandedge Hopping*



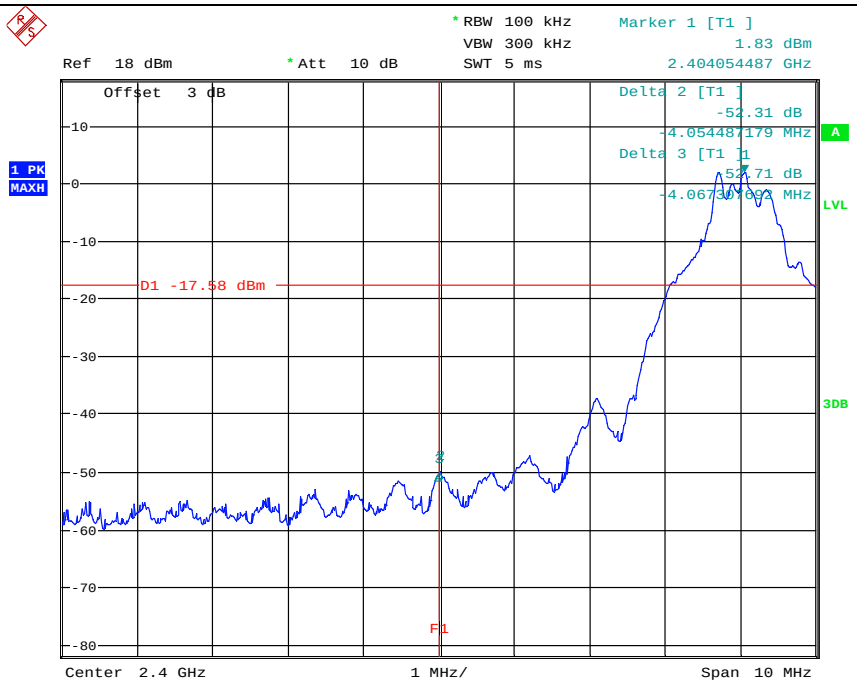



| Mode 2: 2Mbps GFSK | | | | | | |
|---|---|---|---|---|---|---|
| ***Channel Frequency (MHz)*** | ***Emission Frequency (MHz)*** | ***Analyzer Level (dBm)*** | ***Emission Level (dBm)*** | ***Limit (dBm)*** | ***Margin (dB)*** | ***Result*** |
| 2404 | No Significant emissions within 20 dB of the limit | | | | | PASS |
| 2442 | No Significant emissions within 20 dB of the limit | | | | | PASS |
| 2480 | No Significant emissions within 20 dB of the limit | | | | | PASS |

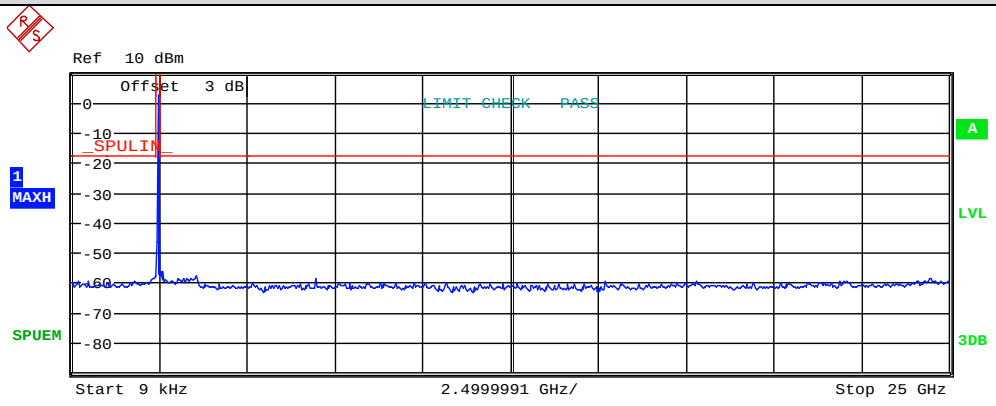
***Mode 2; Frequency: 2404 MHz***




| Start [Hz] | Stop [Hz] | RBW [Hz] | Freq [Hz] | PwrAbs [dBm] | Δ Limit [dB] |
|---|---|---|---|---|---|
| 9.000 k | 150.000 k | 1.00 k | 9.225962 k | -62.66 | -45.08 |
| 150.000 k | 30.000 M | 10.00 k | 167.910000 k | -63.32 | -45.74 |
| 30.000 M | 1.000 G | 100.00 k | 277.350000 M | -60.58 | -43.00 |
| 1.000 G | 2.400 G | 100.00 k | 2.399300 G | -57.53 | -39.95 |
| 2.400 G | 2.483 G | 2.00 M | 2.403983 G | 2.16 | -17.84 |
| 2.483 G | 5.000 G | 100.00 k | 2.492056 G | -57.60 | -40.02 |
| 5.000 G | 10.000 G | 100.00 k | 8.616500 G | -59.52 | -41.94 |
| 10.000 G | 15.000 G | 100.00 k | 11.111500 G | -58.83 | -41.25 |
| 15.000 G | 20.000 G | 100.00 k | 17.095500 G | -59.65 | -42.07 |
| 20.000 G | 25.000 G | 100.00 k | 24.087500 G | -58.26 | -40.68 |

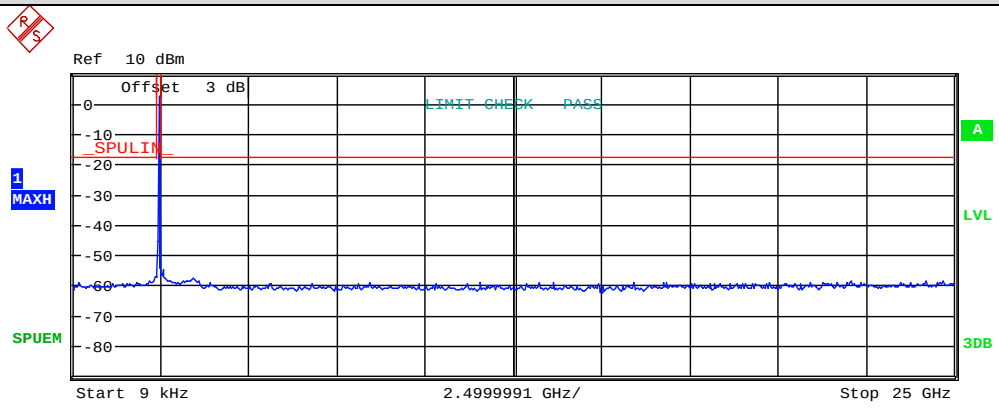


## *Mode 2; Frequency: 2442 MHz*

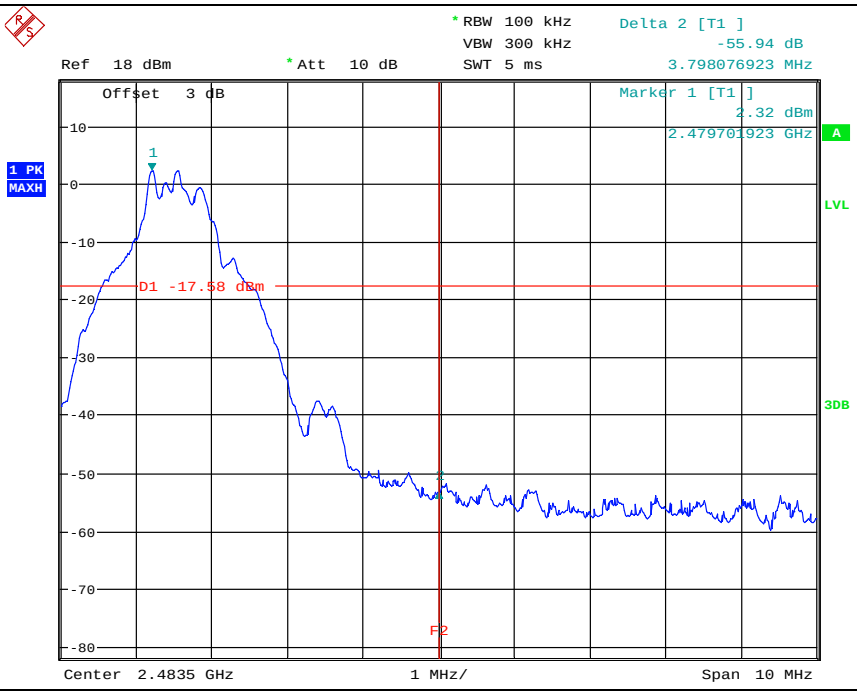



| Start [Hz] | Stop [Hz] | RBW [Hz] | Freq [Hz] | PwrAbs [dBm] | Δ Limit [dB] |
|---|---|---|---|---|---|
| 9.000 k | 150.000 k | 1.00 k | 9.000000 k | -60.32 | -42.74 |
| 150.000 k | 30.000 M | 10.00 k | 152.985000 k | -61.66 | -44.08 |
| 30.000 M | 1.000 G | 100.00 k | 169.874000 M | -59.79 | -42.21 |
| 1.000 G | 2.400 G | 100.00 k | 2.378160 G | -58.00 | -40.42 |
| 2.400 G | 2.483 G | 2.00 M | 2.441984 G | 2.26 | -17.74 |
| 2.483 G | 5.000 G | 100.00 k | 2.538108 G | -56.47 | -38.89 |
| 5.000 G | 10.000 G | 100.00 k | 6.944000 G | -58.95 | -41.37 |
| 10.000 G | 15.000 G | 100.00 k | 12.666500 G | -60.18 | -42.60 |
| 15.000 G | 20.000 G | 100.00 k | 17.779500 G | -59.69 | -42.11 |
| 20.000 G | 25.000 G | 100.00 k | 24.421000 G | -58.87 | -41.29 |

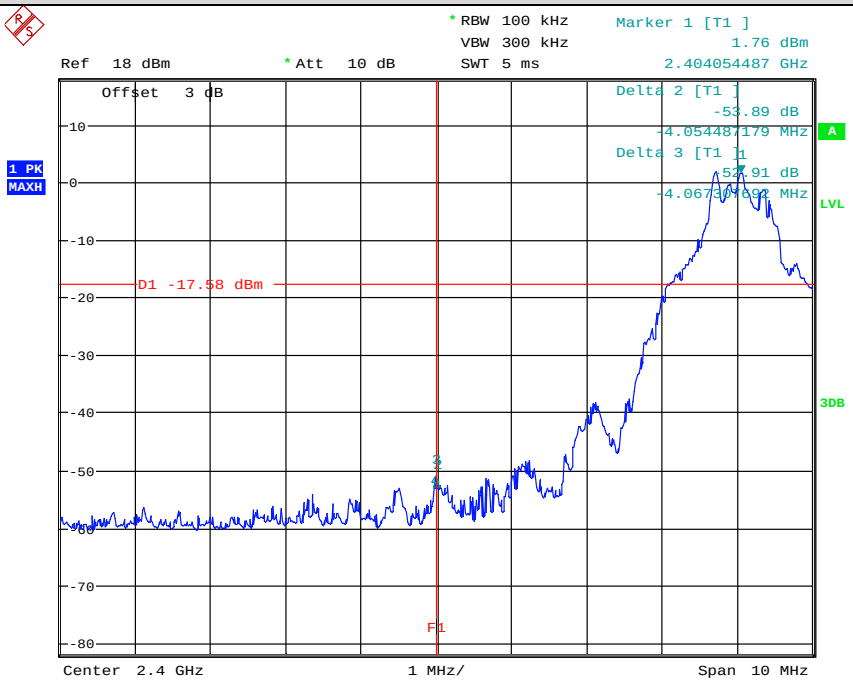
## *Mode 2; Frequency: 2480 MHz*

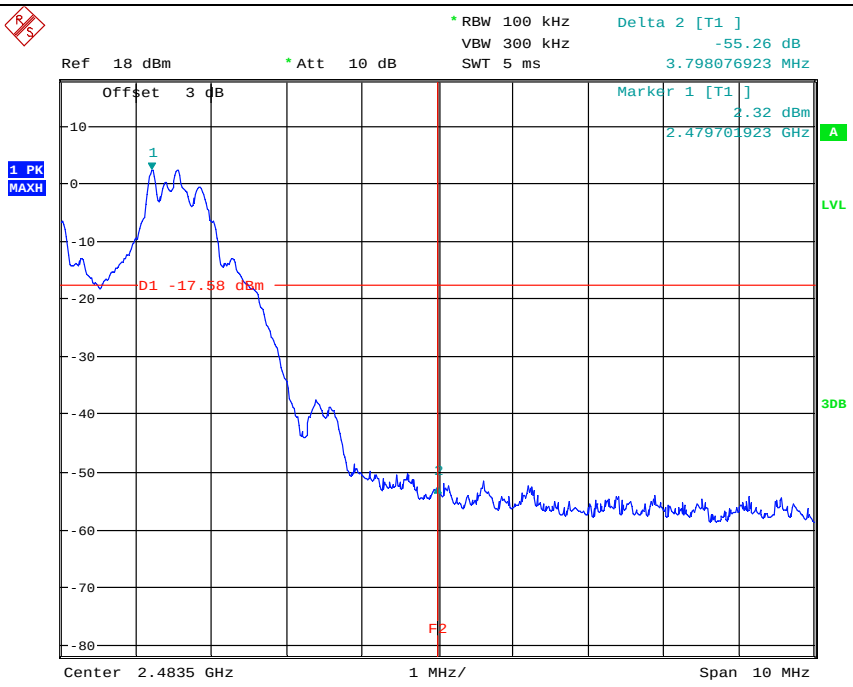



| Start [Hz] | Stop [Hz] | RBW [Hz] | Freq [Hz] | PwrAbs [dBm] | Δ Limit [dB] |
|---|---|---|---|---|---|
| 9.000 k | 150.000 k | 1.00 k | 9.000000 k | -63.79 | -46.21 |
| 150.000 k | 30.000 M | 10.00 k | 182.835000 k | -61.50 | -43.92 |
| 30.000 M | 1.000 G | 100.00 k | 165.800000 M | -59.20 | -41.62 |
| 1.000 G | 2.400 G | 100.00 k | 2.320060 G | -57.22 | -39.64 |
| 2.400 G | 2.483 G | 2.00 M | 2.479985 G | 2.37 | -17.63 |
| 2.483 G | 5.000 G | 100.00 k | 2.543896 G | -54.93 | -37.35 |
| 5.000 G | 10.000 G | 100.00 k | 8.395500 G | -59.34 | -41.76 |
| 10.000 G | 15.000 G | 100.00 k | 13.624000 G | -59.30 | -41.72 |
| 15.000 G | 20.000 G | 100.00 k | 16.731500 G | -59.15 | -41.57 |
| 20.000 G | 25.000 G | 100.00 k | 22.094000 G | -58.79 | -41.21 |



## *Mode 2; Bandedge Hopping*



# 19 Measurement Uncertainty

## Calculated Measurement Uncertainties

All statements of uncertainty are expanded standard uncertainty using a coverage factor of 1.96 to give a 95 % confidence:

**[1] Radiated spurious emissions**

Uncertainty in test result (30 MHz to 1 GHz) = **4.6 dB**
Uncertainty in test result (1 GHz to 18 GHz) = **4.7 dB**

**[2] AC power line conducted emissions**

Uncertainty in test result = **3.4 dB**

**[3] Occupied bandwidth**

Uncertainty in test result = **15.5 %**

**[4] Conducted carrier power**

Uncertainty in test result (Power Meter) = **1.08 dB**

**[5] Conducted / radiated RF power out-of-band**

Uncertainty in test result – up to 8.1 GHz = **3.31 dB**
Uncertainty in test result – 8.1 GHz to 15.3 GHz = **4.43 dB**
Uncertainty in test result (30 MHz to 1 GHz) = **4.75 dB**
Uncertainty in test result (1 GHz to 18 GHz) = **4.7 dB**

**[6] Frequency separation**

Uncertainty in test result (Spectrum Analyser) = **3.6 kHz**

**[7] Accumulated channel occupancy time**

Uncertainty in test result = **7.98 %**

**[8] Radiated RF power out-of-band**

Uncertainty in test result (30 MHz to 1 GHz) = **4.75 dB**
Uncertainty in test result (1 GHz to 18 GHz) = **4.46 dB**

**[9] Power spectral density**

Uncertainty in test result (Spectrum Analyser) = **3.11 dB**

**[10] ERP / EIRP**

Uncertainty in test result (Laboratory) = **4.71 dB**
Uncertainty in test result (Pershore OATS) = **4.26 dB**

# 20 RF Exposure

## KDB 447498

Section 4.3 General SAR test reduction and exclusion guidance

For Standalone SAR exclusion consideration, when SAR Exclusion Threshold requirement in KDB 447498 is satisfied, standalone SAR evaluation for general population exposure conditions by measurement or numerical simulation is not required.

In the frequency range below 100 MHz to 6 GHz and test separation distance of 50mm, the SAR Test Exclusion Threshold for operation in the 2400 – 2483.5 MHz band will be determined as follows

SAR Exclusion Threshold (SARET)

SAR Exclusion Threshold = Step 1 + Step 2

**Step 1**

$$NT = [ (MP/TSD^{A}) * \sqrt{f_{GHz}} ]$$

NT = Numeric Threshold (3.0 for 1-g SAR and 7.5 for 10-g SAR)
MP = Max Power of channel (mW) (inc tune up)
$TSD^{A}$ = Min Test separation Distance or 50mm (whichever is lower) = 50

We can transpose this formula to allow us to find the maximum power of a channel allowed and compare this to the measured maximum power.

$$= [(NT \times TSD^{A}) / \sqrt{f_{GHz}}]$$

For Distances Greater than 50 mm Step 2 applies

**Step 2**

$$(TSD^{B} – 50mm) * 10\}$$

Where:
$TSD^{B}$ = Min Test separation Distance (mm) = 50

**Operating Frequency 2.402 GHz**

SARET = [ (3.0 x 50) / √2.402 ] + { (50 – 50) * 10 }
SARET = [150 / 1.55 ] + (0 * 10 }
SARET = 96.77mW

**Operating Frequency 2.442 GHz**

SARET = [ (3.0 x 50) / √2.442 ] + { (50 – 50) * 10 }
SARET = [150 / 1.56 ] + (0 * 10 }
SARET = 96.15mW

**Operating Frequency 2.481 GHz**

SARET = [ (3.0 x 50) / √2.481 ] + { (50 – 50) * 10 }
SARET = [150 / 1.57 ] + (0 * 10 }
SARET = 95.54mW

| **Mode 1** | | | | |
|---|---|---|---|---|
| Evaluation Frequency | 2402 | 2442 | 2481 | MHz |
| SAR Exclusion Threshold | 96.77 | 96.15 | 95.54 | Watts |
| Conduced Power | 0.37 | 0.61 | 0.72 | dBm |
| Antenna Gain | -1.65 | -1.65 | -1.65 | dBi |
| EIRP | 0.74 | 0.79 | 0.81 | mW |
| **SAR Evaluation** | ***Exempt*** | | | |

Therefore standalone SAR evaluation for general population exposure conditions by measurement or numerical simulation is not required.

**Operating Frequency 2.404 GHz**

SARET = [ (3.0 x 50) / √2.404 ] + { (50 – 50) * 10 }
SARET = [150 / 1.55 ] + (0 * 10 }
SARET = 96.77mW

**Operating Frequency 2.440 GHz**

SARET = [ (3.0 x 50) / √2.44 ] + { (50 – 50) * 10 }
SARET = [150 / 1.56 ] + (0 * 10 }
SARET = 96.15mW

**Operating Frequency 2.480 GHz**

SARET = [ (3.0 x 50) / √2.48 ] + { (50 – 50) * 10 }
SARET = [150 / 1.57 ] + (0 * 10 }
SARET = 95.54mW

| **Mode 2** | | | | |
|---|---|---|---|---|
| Evaluation Frequency | 2404 | 2440 | 2480 | MHz |
| SAR Exclusion Threshold | 96.77 | 96.15 | 95.54 | Watts |
| Conduced Power | 2.80 | 3.02 | 3.23 | dBm |
| Antenna Gain | -1.65 | -1.65 | -1.65 | dBi |
| EIRP | 1.30 | 1.37 | 1.44 | mW |
| **SAR Evaluation** | ***Exempt*** | | | |

Therefore standalone SAR evaluation for general population exposure conditions by measurement or numerical simulation is not required.