Choose Scandinavian trust

# Wireless test report 383829 – 2R1TRFWL

Applicant:

Interaxon Inc.

Product type:

Brain Activity Sensing Device

Model:

MS-01

FCC ID:

2ABZI-MS01

IC Registration number:

11834A-MS01

Specifications:

- FCC 47 CFR Part 15 Subpart C, §15.247

  Operation in the 902–928 MHz, 2400–2483.5 MHz, and 5725–5850 MHz

- RSS-247, Issue 2, Feb 2017, Section 5

  Digital Transmission Systems (DTSs), Frequency Hopping Systems (FHSs)
  and Licence-Exempt Local Area Network (LE-LAN) Devices
  5) Standard specifications for frequency hopping systems and digital transmission systems operating in the bands 902–928 MHz, 2400–2483.5 MHz and 5725–5850 MHz

Date of issue: February 26, 2020

Mark Libbrecht, EMC Specialist
Tested by

Signature

Andrey Adelberg, Senior Wireless/EMC Specialist
Reviewed by

Signature

Test location(s)

| | |
|---|---|
| Company name | Nemko Canada Inc. |
| Site name | Cambridge |
| Address | 130 Saltsman Drive, Unit #1 |
| City | Cambridge |
| Province | Ontario |
| Postal code | N3E 0B2 |
| Country | Canada |
| Telephone | Tel: +1 519 680 4811 |
| Website | www.nemko.com |
| Site number (3 m SAC) | FCC/IC: CA0101 |

Limits of responsibility

Note that the results contained in this report relate only to the items tested and were obtained in the period between the date of initial receipt of samples and the date of issue of the report.
This test report has been completed in accordance with the requirements of ISO/IEC 17025. All results contain in this report are within Nemko Canada's ISO/IEC 17025 accreditation.

Copyright notification

# Table of contents

# **Section 1.** Report summary

## 1.1 Applicant and manufacturer

| | |
|---|---|
| Company name | Interaxon Inc. |
| Address | 555 Richmond St. W #900 |
| City | Toronto |
| Province/State | Ontario |
| Postal/Zip code | M5V 3B1 |
| Country | Canada |

## 1.2 Test specifications

| | |
|---|---|
| FCC 47 CFR Part 15, Subpart C, Clause 15.247 | Operation in the 902–928 MHz, 2400–2483.5 MHz, and 5725–5850 MHz |
| RSS-247, Issue 2, Feb 2017, Section 5 | Digital Transmission Systems (DTSs), Frequency Hopping Systems (FHSs) and Licence-Exempt Local Area Network (LE-LAN) Devices |

## 1.3 Test methods

| | |
|---|---|
| 558074 D01 15.247 Meas Guidance v05r02 (April 2, 2019) | Guidance for compliance measurements on digital transmission system, frequency hopping spread spectrum system, and hybrid system devices operating under section 15.247 of the FCC rules. |
| ANSI C63.10 v2013 | American National Standard of Procedures for Compliance Testing of Unlicensed Wireless Devices |
| RSS-Gen, Issue 5 Amendment 1, March 2019 | General Requirements for Compliance of Radio Apparatus |

## 1.4 Statement of compliance

In the configuration tested, the EUT was found compliant.

Testing was performed against all relevant requirements of the test standard except as noted in section 1.5 below. Results obtained indicate that the product under test complies in full with the requirements tested. The test results relate only to the items tested.

*See "Summary of test results" for full details.*

## 1.5 Exclusions

None

## 1.6 Test report revision history

| Revision # | Date of issue | Details of changes made to test report |
|---|---|---|
| TRF | November 7, 2019 | Original report issued |
| 1RTRF | February 10, 2020 | Update model page 1, emission data page 7, theory page 8, channel page 16 |
| 2RTRF | February 26, 2020 | Section 3.5 updated with EUT exercise details |

# Section 2. Summary of test results

## 2.1 FCC Part 15 Subpart C, general requirements test results

***Table 2.1-1:*** *FCC general requirements results*

| Part | Test description | Verdict |
|---|---|---|
| §15.207(a) | Conducted limits | Not applicable |
| §15.31(e) | Variation of power source | Not applicable |
| §15.31(m) | Number of tested frequencies | Pass |
| §15.203 | Antenna requirement | Pass |

Notes: EUT is a battery operated device, the testing was performed using fresh batteries.

## 2.2 FCC Part 15 Subpart C, intentional radiators test results for digital transmission systems (DTS)

***Table 2.2-1:*** *FCC 15.247 results for DTS*

| Part | Test description | Verdict |
|---|---|---|
| §15.247(a)(2) | Minimum 6 dB bandwidth | Pass |
| §15.247(b)(3) | Maximum peak output power in the 902–928 MHz, 2400–2483.5 MHz, and 5725–5850 MHz bands | Pass |
| §15.247(c)(1) | Fixed point-to-point operation with directional antenna gains greater than 6 dBi | Not applicable |
| §15.247(c)(2) | Transmitters operating in the 2400–2483.5 MHz band that emit multiple directional beams | Not applicable |
| §15.247(d) | Spurious emissions | Pass |
| §15.247(e) | Power spectral density | Pass |
| §15.247(f) | Time of occupancy for hybrid systems | Not applicable |

## 2.3 ISED RSS-Gen, Issue 5, test results

***Table 2.3-1:*** *RSS-Gen results*

| Part | Test description | Verdict |
|---|---|---|
| 7.3 | Receiver radiated emission limits | Not applicable |
| 7.4 | Receiver conducted emission limits | Not applicable |
| 6.9 | Operating bands and selection of test frequencies | Pass |
| 8.8 | AC power-line conducted emissions limits | Not applicable |

Notes: [1] According to sections 5.2 and 5.3 of RSS-Gen, Issue 5 the EUT does not have a stand-alone receiver neither scanner receiver, therefore exempt from receiver requirements.
EUT is a battery operated device, the testing was performed using fresh batteries.

## 2.4 ISED RSS-247, Issue 2, test results for digital transmission systems (DTS)

***Table 2.4-1:*** *RSS-247 results for DTS*

| Part | Test description | Verdict |
|---|---|---|
| 5.2 (a) | Minimum 6 dB bandwidth | Pass |
| 5.2 (b) | Maximum power spectral density | Pass |
| 5.3 | Hybrid Systems | |
| 5.3 (a) | Digital modulation turned off | Not applicable |
| 5.3 (b) | Frequency hopping turned off | Not applicable |
| 5.4 | Transmitter output power and e.i.r.p. requirements | |
| 5.4 (d) | Systems employing digital modulation techniques | Pass |
| 5.4 (e) | Point-to-point systems in 2400–2483.5 MHz and 5725–5850 MHz band | Not applicable |
| 5.4 (f) | Transmitters which operate in the 2400–2483.5 MHz band with multiple directional beams | Not applicable |
| 5.5 | Unwanted emissions | Pass |

Notes: None

# Section 3. Equipment under test (EUT) details

## 3.1 Sample information

| | |
|---|---|
| Receipt date | October 17, 2019 |
| Nemko sample ID number | #1 (radiated), #2 (conducted) |

## 3.2 EUT information

| | |
|---|---|
| Product type | Brain Activity Sensing Device |
| Model | MS-01 |
| Serial number | 5000-0JPB-A062 (radiated), 5000-WKYA-A061 (conducted) |

## 3.3 Technical information

| | |
|---|---|
| Applicant IC company number | 11834A |
| IC UPN number | MS01 |
| All used IC test site(s) Reg. number | 2040A-4 |
| RSS number and Issue number | RSS-247 Issue 2, Feb 2017 |
| Frequency band | 2400–2483.5 MHz |
| Frequency Min (MHz) | 2402 |
| Frequency Max (MHz) | 2480 |
| RF power Max (W), Conducted | 0.000468 (−3.3 dBm) |
| Field strength, dBµV/m @ 3 m | N/A |
| Measured BW (kHz), 99% OBW | 1035 |
| Type of modulation | GFSK |
| Emission classification (F1D, G1D, D1D) | F1D |
| Transmitter spurious, dBµV/m @ 3 m | 41.1 @ 2484 MHz |
| Power requirements | 3.7 $V_{DC}$, 130 mAh battery |
| Antenna information | 0.5 dBi (peak gain)<br>Manufacturer: Johansson<br>Model: 2450AT18B100<br>Type: SMD ceramic antenna. |

## 3.4 Product description and theory of operation

EUT uses a BLE module operating 2402 – 2480 MHz. For further information please refer to operational description.

## 3.5 EUT exercise details

EUT was connected to a laptop via a USB to MicroUSB cable. The laptop was used to program the EUT using BlueNRG GUI V2.60 firmware provided by the customer. Power level = 5 (+2 dBm) used for all channels during testing.

## 3.6 EUT setup diagram

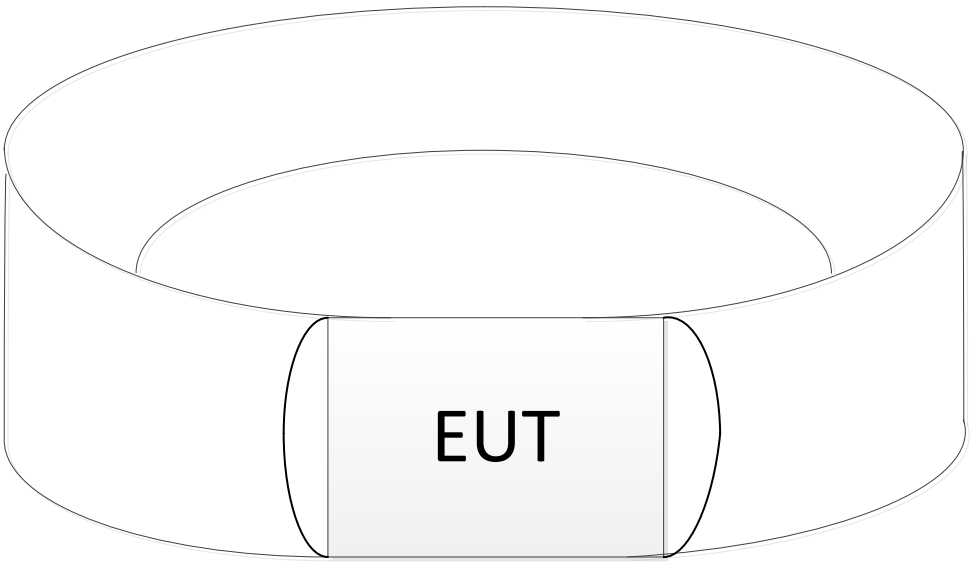



***Figure 3.6-1:*** *Setup diagram*

## 3.7 EUT sub assemblies

***Table 3.7-1:*** *EUT sub assemblies*

| Description | Brand name | Model/Part number | Serial number |
|---|---|---|---|
| Brain sensing headband | None | None | 037 |

# **Section 4.** Engineering considerations

## 4.1 Modifications incorporated in the EUT

There were no modifications performed to the EUT during this assessment.

## 4.2 Technical judgment

None

## 4.3 Deviations from laboratory tests procedures

No deviations were made from laboratory procedures.

# Section 5. Test conditions

## 5.1 Atmospheric conditions

| | |
|---|---|
| Temperature | 15–30 °C |
| Relative humidity | 20–75 % |
| Air pressure | 860–1060 mbar |

When it is impracticable to carry out tests under these conditions, a note to this effect stating the ambient temperature and relative humidity during the tests shall be recorded and stated.

## 5.2 Power supply range

The normal test voltage for equipment to be connected to the mains shall be the nominal mains voltage. For the purpose of the present document, the nominal voltage shall be the declared voltage, or any of the declared voltages ±5 %, for which the equipment was designed.

# Section 6. Measurement uncertainty

## 6.1 Uncertainty of measurement

UKAS Lab 34 and TIA-603-B have been used as guidance for measurement uncertainty reasonable estimations with regards to previous experience and validation of data. Nemko Canada, Inc. follows these test methods in order to satisfy ISO/IEC 17025 requirements for estimation of uncertainty of measurement for wireless products.

Measurement uncertainty budgets for the tests are detailed below. Measurement uncertainty calculations assume a coverage factor of K = 2 with 95% certainty.

***Table 6.1-1:*** *Measurement uncertainty*

| Test name | Measurement uncertainty, dB |
|---|---|
| All antenna port measurements | 0.55 |
| Conducted spurious emissions | 1.13 |
| Radiated spurious emissions | 3.78 |
| AC power line conducted emissions | 3.55 |

# Section 7. Test equipment

## 7.1 Test equipment list

***Table 7.1-1:*** *Equipment list*

| Equipment | Manufacturer | Model no. | Serial no. | Asset no. | Cal./Ver. cycle | Next cal./ver. |
|---|---|---|---|---|---|---|
| 3 m EMI test chamber | TDK | SAC-3 | | FA003012 | 1 year | Nov. 19/19 |
| Flush mount turntable | SUNAR | FM2022 | | FA003006 | — | NCR |
| Controller | SUNAR | SC110V | 050118-1 | FA002976 | — | NCR |
| Antenna mast | SUNAR | TLT2 | 042418-5 | FA003007 | — | NCR |
| Receiver/spectrum analyzer | Rohde & Schwarz | ESR26 | 101367 | FA002969 | 1 year | June 4/20 |
| Spectrum analyzer | Rohde & Schwarz | FSW43 | 104437 | FA002971 | 1 year | June 21/20 |
| Horn antenna (1–18 GHz) | ETS-Lindgren | 3117 | 00052793 | FA002911 | 1 year | Sept 11/20 |
| Preamp (1–18 GHz) | ETS-Lindgren | 124334 | 00224880 | FA002956 | 1 year | Sept 26/20 |
| Bilog antenna (30–2000 MHz) | SUNAR | JB1 | A053018-2 | FA003009 | 1 year | Dec. 6/19 |
| 50 Ω coax cable | Huber + Suhner | None | 457630 | FA003047 | 1 year | Nov 12/19 |
| 50 Ω coax cable | Huber + Suhner | None | 457624 | FA003044 | 1 year | Nov 12/19 |
| AC Power source | Chroma | 61605 | 616050002253 | FA003034 | — | VOU |
| Filter 2.4 – 2.4835 GHz | Microwave Circuits | N0324413 | 499781 | FA003027 | 1 year | Oct. 1/20 |
| Horn antenna (18-25 GHz) | ETS-Lindgren | 3116B | 00122305 | FA001847 | 1 year | July 7/20 |

Note: NCR - no calibration required, VOU - verify on use

# Section 8. Testing data

## 8.1 FCC 15.31(e) Variation of power source

### 8.1.1 Definitions and limits

For intentional radiators, measurements of the variation of the input power or the radiated signal level of the fundamental frequency component of the emission, as appropriate, shall be performed with the supply voltage varied between 85% and 115% of the nominal rated supply voltage. For battery operated equipment, the equipment tests shall be performed using a new battery.

### 8.1.2 Test date

| | |
|---|---|
| Start date | October 17, 2019 |

### 8.1.3 Observations, settings and special notes

The testing was performed as per ANSI C63.10 Section 5.13.

a) Where the device is intended to be powered from an external power adapter, the voltage variations shall be applied to the input of the adapter provided with the device at the time of sale. If the device is not marketed or sold with a specific adapter, then a typical power adapter shall be used.
b) For devices where operating at a supply voltage deviating ±15% from the nominal rated value may cause damages or loss of intended function, test to minimum and maximum allowable voltage per manufacturer's specification and document in the report.
c) For devices with wide range of rated supply voltage, test at 15% below the lowest and 15% above the highest declared nominal rated supply voltage.
d) For devices obtaining power from an input/output (I/O) port (USB, firewire, etc.), a test jig is necessary to apply voltage variation to the device from a support power supply, while maintaining the functionalities of the device.

For battery-operated equipment, the equipment tests shall be performed using a variable power supply.

### 8.1.4 Test data

| | | | |
|---|---|---|---|
| EUT Power requirements: | ☐ AC | ☐ DC | ☒ Battery |
| If EUT is an AC or a DC powered, was the noticeable output power variation observed? | ☐ YES | ☐ NO | ☒ N/A |
| If EUT is battery operated, was the testing performed using fresh batteries? | ☐ YES | ☐ NO | ☒ N/A |
| If EUT is rechargeable battery operated, was the testing performed using fully charged batteries? | ☒ YES | ☐ NO | ☐ N/A |

## 8.2 FCC 15.31(m) and RSS-Gen 6.9 Number of frequencies

### 8.2.1 Definitions and limits

**FCC:**
Measurements on intentional radiators or receivers shall be performed and, if required, reported for each band in which the device can be operated with the device operating at the number of frequencies in each band specified in the following table.

**ISED:**
Except where otherwise specified, measurements shall be performed for each frequency band of operation for which the radio apparatus is to be certified, with the device operating at the frequencies in each band of operation shown in table below. The frequencies selected for measurements shall be reported in the test report.

***Table 8.2-1:*** *Frequency Range of Operation*

| Frequency range over which the device operates (in each band) | Number of test frequencies required | Location of measurement frequency inside the operating frequency range |
|---|---|---|
| 1 MHz or less | 1 | Center (middle of the band) |
| 1–10 MHz | 2 | 1 near high end, 1 near low end |
| Greater than 10 MHz | 3 | 1 near high end, 1 near center and 1 near low end |

Note: “near” means as close as possible to or at the centre / low end / high end of the frequency range over which the device operates.

### 8.2.2 Test date

| | |
|---|---|
| Start date | October 17, 2019 |

### 8.2.3 Observations, settings and special notes

Per ANSI C63.10 Subclause 5.6.2.1:
The number of channels tested can be reduced by measuring the center channel bandwidth first and then applying the following relaxations as appropriate:

a) For each operating mode, if the measured channel bandwidth on the middle channel is at least 150% of the minimum permitted bandwidth, then it is not necessary to measure the bandwidth on the high and low channels.
b) For multiple-input multiple-output (MIMO) systems, if the measured channel bandwidth on testing the middle channel exceeds the minimum permitted bandwidth by more than 50% on one transmit chain, then it is not necessary to repeat testing on the other chains.
c) If the measured channel bandwidth on the middle channel is less than 50% of the maximum permitted bandwidth, then it is not necessary to measure the bandwidth on the high and low channels.

Per ANSI C63.10 Subclause 5.6.2.2:
For devices with multiple operating modes, measurements on the middle channel can be used to determine the worst-case mode(s). The worst-case modes are as follows:

a) Band edge requirements—Measurements on the mode with the widest bandwidth can be used to cover the same channel (center frequency) on modes with narrower bandwidth that have the same or lower output power for each modulation family (e.g., OFDM and direct sequence spread spectrum).
b) Spurious emissions—Measure the mode with the highest output power and the mode with the highest output power spectral density for each modulation family (e.g., OFDM and direct sequence spread spectrum).
c) In-band PSD—Measurements on the mode with the narrowest bandwidth can be used to cover all modes within the same modulation family of an equal or lower output power provided the result is less than 50% of the limit.

### 8.2.4 Test data

***Table 8.2-2:*** *Test channels selection*

| Start of Frequency range, MHz | End of Frequency range, MHz | Frequency range bandwidth, MHz | Low channel, MHz | Mid channel, MHz | High channel, MHz |
|---|---|---|---|---|---|
| 2400 | 2483.5 | 83.5 | 2402 | 2440 | 2480 |

## 8.3 FCC 15.203 and RSS-Gen, section 6.8 Antenna requirement

### 8.3.1 Definitions and limits

**FCC:**
An intentional radiator shall be designed to ensure that no antenna other than that furnished by the responsible party shall be used with the device. The use of a permanently attached antenna or of an antenna that uses a unique coupling to the intentional radiator shall be considered sufficient to comply with the provisions of this section. The manufacturer may design the unit so that a broken antenna can be replaced by the user, but the use of a standard antenna jack or electrical connector is prohibited. This requirement does not apply to intentional radiators that must be professionally installed, such as perimeter protection systems and some field disturbance sensors, or to other intentional radiators which, in accordance with §15.31(d), must be measured at the installation site. However, the installer shall be responsible for ensuring that the proper antenna is employed so that the limits in this part are not exceeded.

**ISED:**
The applicant for equipment certification shall provide a list of all antenna types that may be used with the transmitter, where applicable (i.e. for transmitters with detachable antenna), indicating the maximum permissible antenna gain (in dBi) and the required impedance for each antenna. The test report shall demonstrate the compliance of the transmitter with the limit for maximum equivalent isotropically radiated power (e.i.r.p.) specified in the applicable RSS, when the transmitter is equipped with any antenna type, selected from this list.

For expediting the testing, measurements may be performed using only the antenna with highest gain of each combination of transmitter and antenna type, with the transmitter output power set at the maximum level. However, the transmitter shall comply with the applicable requirements under all operational conditions and when in combination with any type of antenna from the list provided in the test report.

### 8.3.2 Test date

| | |
|---|---|
| Start date | October 17, 2019 |

### 8.3.3 Observations, settings and special notes

None

### 8.3.4 Test data

| | | | |
|---|---|---|---|
| Must the EUT be professionally installed? | ☐ YES | ☒ NO | |
| Does the EUT have detachable antenna(s)? | ☐ YES | ☒ NO | |
| If detachable, is the antenna connector(s) non-standard? | ☐ YES | ☐ NO | ☒ N/A |

## 8.4 FCC 15.247(a)(2) and RSS-247 5.2(a) Minimum 6 dB bandwidth for DTS systems

### 8.4.1 Definitions and limits

**FCC:**
Systems using digital modulation techniques may operate in the 902–928 MHz, 2400–2483.5 MHz, and 5725–5850 MHz bands. The minimum 6 dB bandwidth shall be at least 500 kHz.

**ISED:**
The minimum 6 dB bandwidth shall be 500 kHz.

### 8.4.1 Test date

| | |
|---|---|
| Start date | October 19, 2019 |

### 8.4.2 Observations, settings and special notes

The test was performed as per KDB 558074, section 8.2 with reference to ANSI C63.10 subclause 11.8.
Spectrum analyser settings:

| | |
|---|---|
| Resolution bandwidth | 100 kHz |
| Video bandwidth | ≥3 × RBW |
| Frequency span | 3 MHz |
| Detector mode | Peak |
| Trace mode | Max Hold |

### 8.4.3 Test data

***Table 8.4-1:*** *6 dB bandwidth results*

| Frequency, MHz | 6 dB bandwidth, kHz | Minimum limit, kHz | Margin, MHz |
|---|---|---|---|
| 2402 | 755 | 500 | 255 |
| 2440 | 779 | 500 | 279 |
| 2480 | 764 | 500 | 264 |

***Table 8.4-2:*** *99% occupied bandwidth results*

| Frequency, MHz | 99% occupied bandwidth, kHz |
|---|---|
| 2402 | 1035 |
| 2440 | 1035 |
| 2480 | 1034 |

Note: there is no 99% occupied bandwidth limit in the standard's requirements, the measurement results provided for information purposes only.

## 8.4.1 Test data, continued

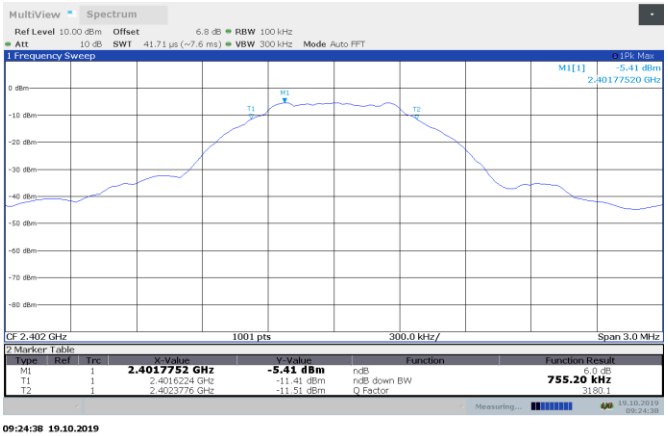



***Figure 8.4-1:*** *6 dB bandwidth on low channel*

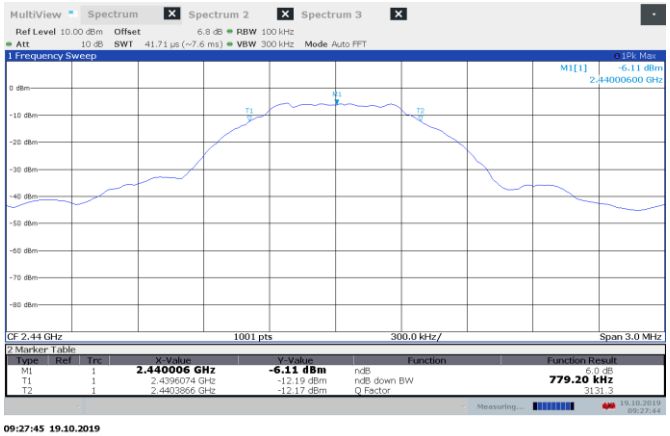



***Figure 8.4-2:*** *6 dB bandwidth on mid channel*

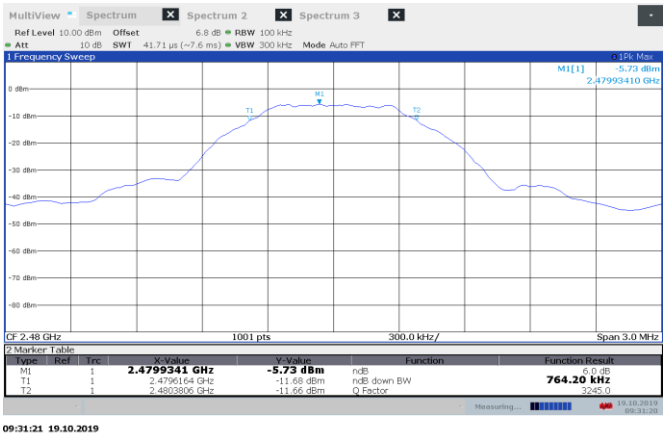



***Figure 8.4-3:*** *6 dB bandwidth on high channel*

## 8.4.1 Test data, continued

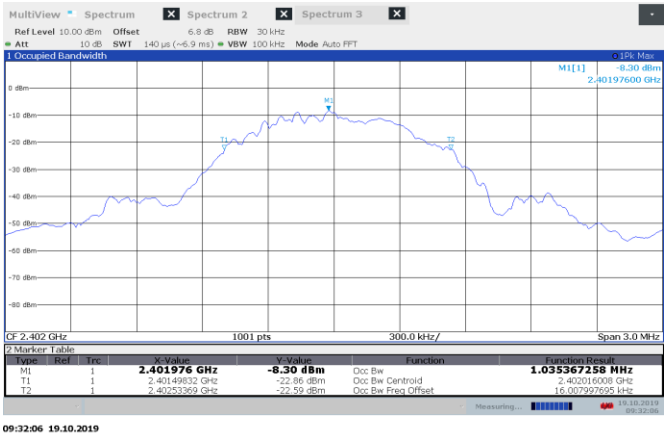



***Figure 8.4-4:*** *99% occupied bandwidth on low channel*

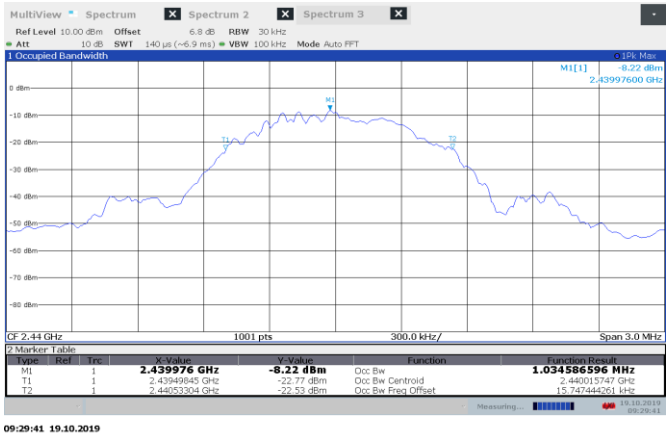



***Figure 8.4-5:*** *99% occupied bandwidth on mid channel*

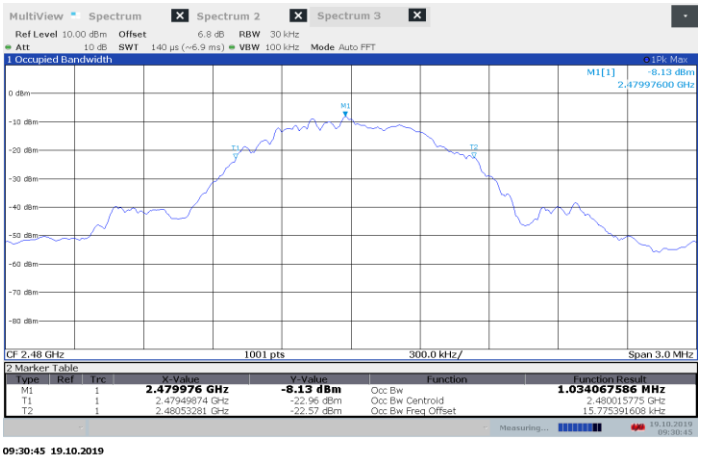



***Figure 8.4-6:*** *99% occupied bandwidth on high channel*

## 8.5 FCC 15.247(b) and RSS-247 5.4(d) Transmitter output power and e.i.r.p. requirements for DTS in 2 GHz

### 8.5.1 Definitions and limits

**FCC:**

(b) The maximum peak conducted output power of the intentional radiator shall not exceed the following:

(3) For systems using digital modulation in the 2400–2483.5 MHz band: 1 W (30 dBm). 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)(1), (b)(2), and (b)(3) of this section, as appropriate, by the amount in dB that the directional gain of the antenna exceeds 6 dBi.

(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)(1), (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.

**ISED:**
d. For DTSs employing digital modulation techniques operating in the 2400–2483.5 MHz band, the maximum peak conducted output power shall not exceed 1 W. The e.i.r.p. shall not exceed 4 W, except as provided in section 5.4(e).

As an alternative to a peak power measurement, compliance can be based on a measurement of the maximum conducted output power. The maximum conducted output power is the total transmit power delivered to all antennas and antenna elements, averaged across all symbols in the signalling 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 transmitting at a reduced power level. If multiple modes of operation are implemented, the maximum conducted output power is the highest total transmit power occurring in any mode.
e. Fixed point-to-point systems in the 2400–2483.5 MHz band 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. Point-to-multipoint systems, omnidirectional applications and multiple co-located transmitters transmitting the same information are prohibited from exceeding an e.i.r.p. of 4 W.
f. Transmitters operating in the band 2400–2483.5 MHz, may employ antenna systems that emit multiple directional beams simultaneously or sequentially, for the purpose of directing signals to individual receivers or to groups of receivers, provided that 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 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 applicable output power limit specified in sections 5.4(b) and 5.4(d). 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 the sum of 10 log (number of array elements or staves) plus the directional gain of the element or stave having the highest gain.
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 applicable power limit specified in sections 5.4(b) and 5.4(d). If transmitted beams overlap, the power shall be reduced to ensure that their aggregate power does not exceed the applicable limit specified in sections 5.4(b) and 5.4(d). In addition, the aggregate power transmitted simultaneously on all beams shall not exceed the applicable limit specified in sections 5.4(b) and 5.4(d) by more than 8 dB.
iv Transmitters that transmit a single directional beam shall operate under the provisions of sections 5.4(b), 5.4(d) and 5.4(e).

### 8.5.1 Test date

| | |
|---|---|
| Start date | October 19, 2019 |

### 8.5.2 Observations, settings and special notes

The test was performed as per KDB 558074, section 8.3 with reference to ANSI C63.10 subclause 11.9.1 (peak power)
The test was performed using method RBW≥DTS bandwidth (Maximum peak conducted output power)
Spectrum analyser settings:

| | |
|---|---|
| Resolution bandwidth | 1 MHz |
| Video bandwidth | ≥3 × RBW |
| Frequency span | 3 MHz |
| Detector mode | Peak |
| Trace mode | Max Hold |

### 8.5.3 Test data

***Table 8.5-1:*** *Output power measurements results*

| Frequency, MHz | Conducted output power, dBm | | Margin, dB | Antenna gain, dBi | EIRP, dBm | EIRP limit, dBm | EIRP margin, dB |
|---|---|---|---|---|---|---|---|
| | Measured | Limit | | | | | |
| 2402 | -3.3 | 30.0 | 33.3 | 0.5 | -2.8 | 36.0 | 38.8 |
| 2440 | -3.3 | 30.0 | 33.3 | 0.5 | -2.8 | 36.0 | 38.8 |
| 2480 | -3.3 | 30.0 | 33.3 | 0.5 | -2.8 | 36.0 | 38.8 |

Note: WFL connector offset (0.6 dB) added to conducted output power measured values

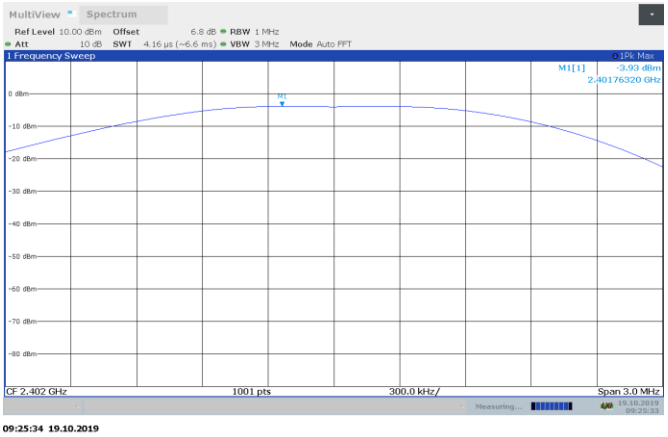



***Figure 8.5-1:*** *Output power on low channel*

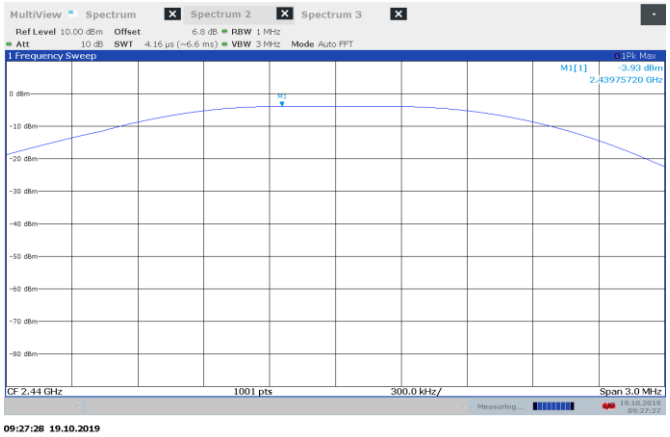



***Figure 8.5-2:*** *Output power on mid channel*

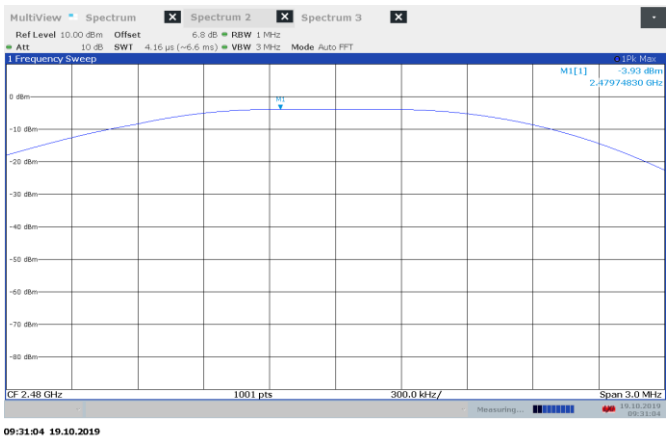



***Figure 8.5-3:*** *Output power on high channel*

## 8.6 FCC 15.247(d) and RSS-247 5.5 Spurious (out-of-band) unwanted emissions

### 8.6.1 Definitions and limits

**FCC:**
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)).

**ISED:**
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, as permitted under section 5.4(d), the attenuation required shall be 30 dB instead of 20 dB. Attenuation below the general field strength limits specified in RSS-Gen is not required.

***Table 8.6-1:*** *FCC §15.209 and RSS-Gen – Radiated emission limits*

| Frequency, MHz | Field strength of emissions | | Measurement distance, m |
|---|---|---|---|
| | µV/m | dBµV/m | |
| 0.009–0.490 | 2400/F | $67.6 - 20 \times \log_{10}(F)$ | 300 |
| 0.490–1.705 | 24000/F | $87.6 - 20 \times \log_{10}(F)$ | 30 |
| 1.705–30.0 | 30 | 29.5 | 30 |
| 30–88 | 100 | 40.0 | 3 |
| 88–216 | 150 | 43.5 | 3 |
| 216–960 | 200 | 46.0 | 3 |
| above 960 | 500 | 54.0 | 3 |

Notes: In the emission table above, the tighter limit applies at the band edges.
For frequencies above 1 GHz the limit on peak RF emissions is 20 dB above the maximum permitted average emission limit applicable to the equipment under test

***Table 8.6-2:*** *ISED restricted frequency bands*

| MHz | MHz | MHz | GHz |
|---|---|---|---|
| 0.090–0.110 | 12.57675–12.57725 | 399.9–410 | 7.25–7.75 |
| 0.495–0.505 | 13.36–13.41 | 608–614 | 8.025–8.5 |
| 2.1735–2.1905 | 16.42–16.423 | 960–1427 | 9.0–9.2 |
| 3.020–3.026 | 16.69475–16.69525 | 1435–1626.5 | 9.3–9.5 |
| 4.125–4.128 | 16.80425–16.80475 | 1645.5–1646.5 | 10.6–12.7 |
| 4.17725–4.17775 | 25.5–25.67 | 1660–1710 | 13.25–13.4 |
| 4.20725–4.20775 | 37.5–38.25 | 1718.8–1722.2 | 14.47–14.5 |
| 5.677–5.683 | 73–74.6 | 2200–2300 | 15.35–16.2 |
| 6.215–6.218 | 74.8–75.2 | 2310–2390 | 17.7–21.4 |
| 6.26775–6.26825 | 108–138 | 2483.5–2500 | 22.01–23.12 |
| 6.31175–6.31225 | 149.9–150.05 | 2655–2900 | 23.6–24.0 |
| 8.291–8.294 | 156.52475–156.52525 | 3260–3267 | 31.2–31.8 |
| 8.362–8.366 | 156.7–156.9 | 3332–3339 | 36.43–36.5 |
| 8.37625–8.38675 | 162.0125–167.17 | 3345.8–3358 | Above 38.6 |
| 8.41425–8.41475 | 167.72–173.2 | 3500–4400 | |
| 12.29–12.293 | 240–285 | 4500–5150 | |
| 12.51975–12.52025 | 322–335.4 | 5350–5460 | |

Note: Certain frequency bands listed in Table 8.6-2 and above 38.6 GHz are designated for licence-exempt applications. These frequency bands and the requirements that apply to related devices are set out in the 200 and 300 series of RSSs.

***Table 8.6-3:*** *FCC restricted frequency bands*

| 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 | | | |

### 8.6.1 Test date

| | |
|---|---|
| Start date | October 17, 2019 |

### 8.6.2 Observations, settings and special notes

The spectrum was searched from 30 MHz to the 10th harmonic.
Radiated measurements were performed at a distance of 3 m from 30 MHz – 18 GHz.
Radiated measurements were performed at a distance of 1 m from 18 - 25 GHz.
DTS emissions in non-restricted frequency bands test was performed as per KDB 558074, section 8.5 with reference to ANSI C63.10 subclause 11.11.
Since fundamental power was tested using the maximum peak conducted output power procedure to demonstrate compliance, the spurious emissions limit is −20 dBc/100 kHz.
DTS emissions in restricted frequency bands test was performed as per KDB 558074, section 8.6 with reference to ANSI C63.10 subclause 11.12.
DTS band-edge emission measurements test was performed as per KDB 558074, section 8.7 with reference to ANSI C63.10 subclause 11.13.

Spectrum analyser settings for radiated measurements within restricted bands below 1 GHz:

| | |
|---|---|
| Resolution bandwidth: | 100 kHz |
| Video bandwidth: | 300 kHz |
| Detector mode: | Peak |
| Trace mode: | Max Hold |

Spectrum analyser settings for peak radiated measurements within restricted bands above 1 GHz:

| | |
|---|---|
| Resolution bandwidth: | 1 MHz |
| Video bandwidth: | 3 MHz |
| Detector mode: | Peak |
| Trace mode: | Max Hold |

Spectrum analyser settings for average radiated measurements within restricted bands above 1 GHz:

| | |
|---|---|
| Resolution bandwidth: | 1 MHz |
| Video bandwidth: | 10 Hz |
| Detector mode: | Peak |
| Trace mode: | Max Hold |

Spectrum analyser settings for conducted spurious emissions measurements:

| | |
|---|---|
| Resolution bandwidth: | 100 kHz |
| Video bandwidth: | 300 kHz |
| Detector mode: | Peak |
| Trace mode: | Max Hold |

## 8.6.4 Test data

***Table 8.6-4:*** *Radiated field strength measurement results – Restricted Bands*

| Channel | Frequency, MHz | Peak Field strength, dBµV/m | | Margin, dB | Average Field strength, dBµV/m | | Margin, dB |
|---|---|---|---|---|---|---|---|
| | | Measured | Limit | | Measured | Limit | |
| Low | 2390.0 | 53.58 | 74.00 | 20.42 | 40.79 | 54.00 | 13.21 |
| High | 2483.5 | 66.63 | 74.00 | 7.37 | 41.09 | 54.00 | 12.91 |

Notes: Field strength includes correction factor of antenna, cable loss, amplifier, and attenuators where applicable.

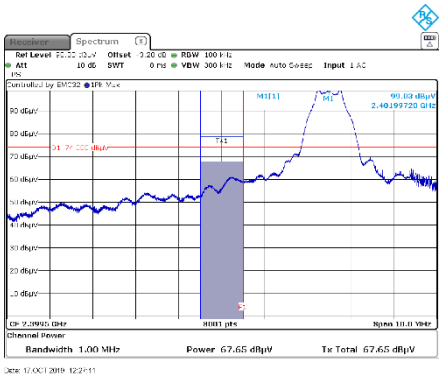



***Figure 8.6-1:*** *Radiated emissions in restricted Band 2390 MHz, Peak*

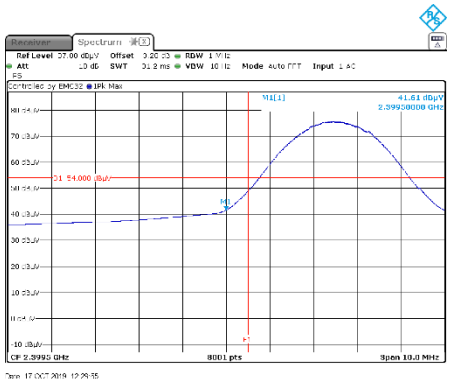



***Figure 8.6-2:*** *Radiated emissions in restricted Band 2390 MHz, Average*

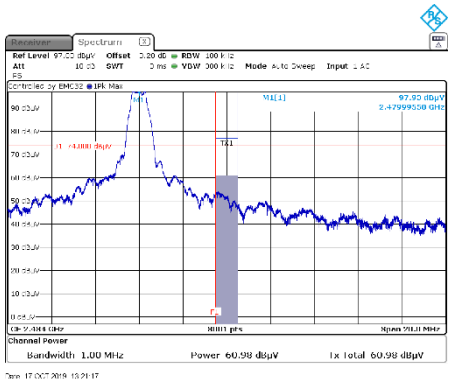



***Figure 8.6-3:*** *Radiated emissions in restricted Band 2483.5 MHz, Peak*

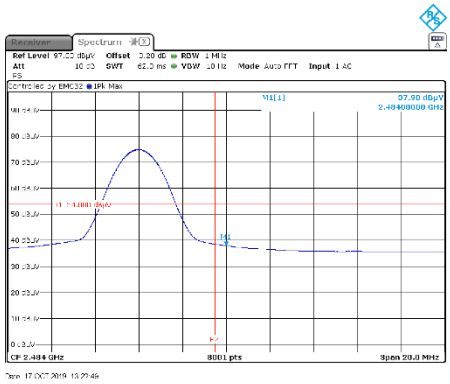



***Figure 8.6-4:*** *Radiated emissions in restricted Band 2483.5 MHz, Average*

## 8.6.4 Test data, continued

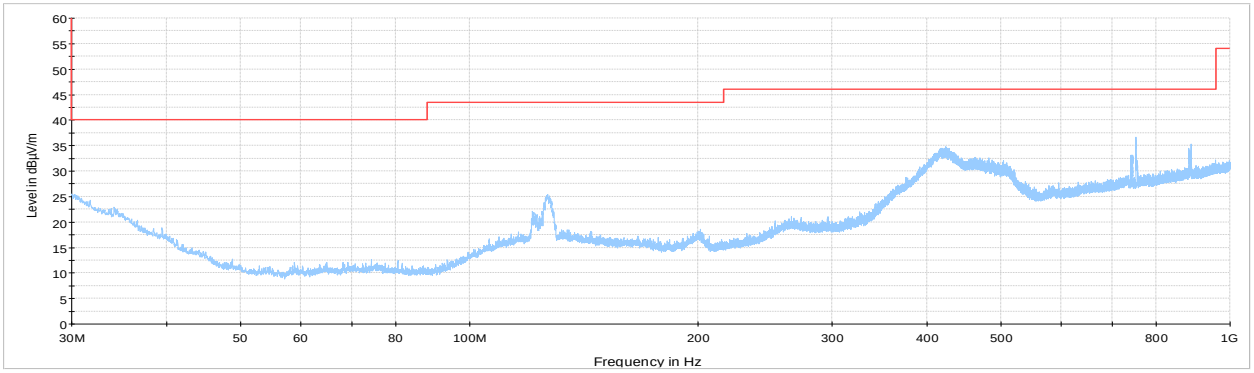



***Figure 8.6-5:*** *Radiated Spurious emissions 30 MHz – 1 GHz, low channel*

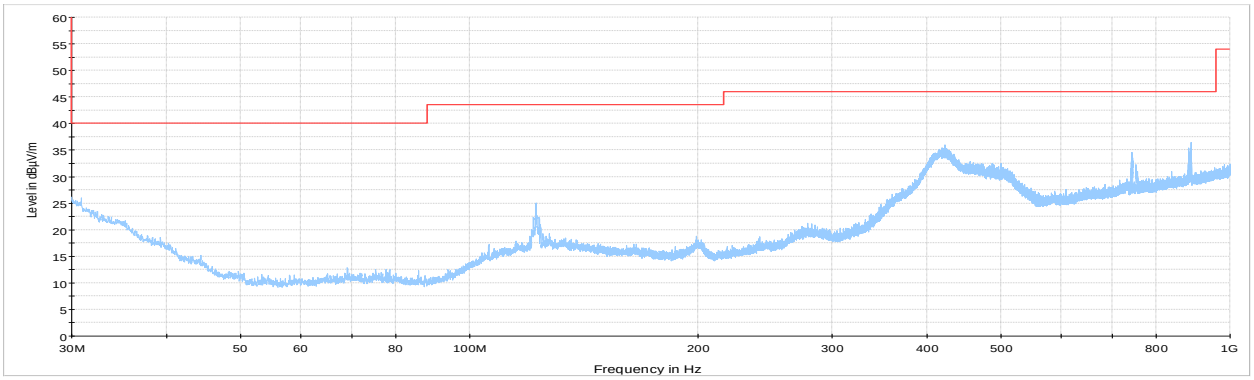



***Figure 8.6-6:*** *Radiated Spurious emissions 30 MHz – 1 GHz, mid channel*

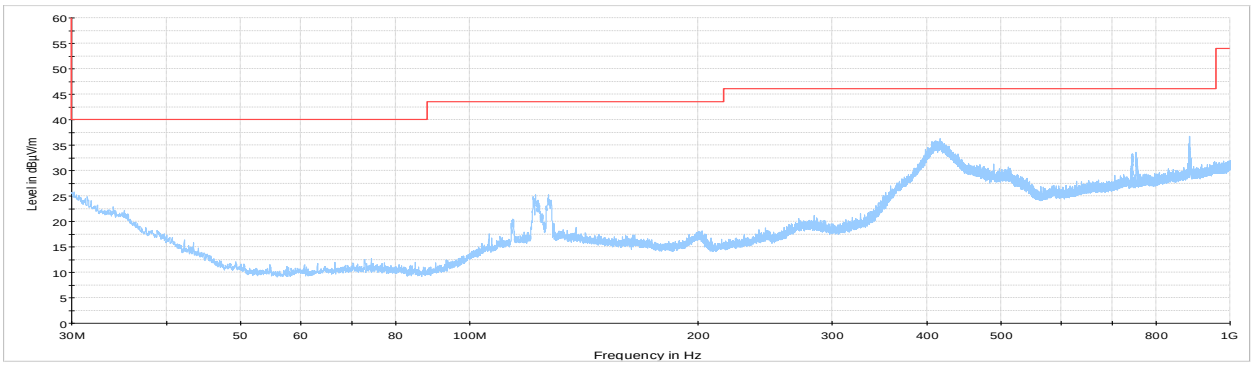



***Figure 8.6-7:*** *Radiated Spurious emissions 30 MHz – 1 GHz, high channel*

## 8.6.4 Test data, continued

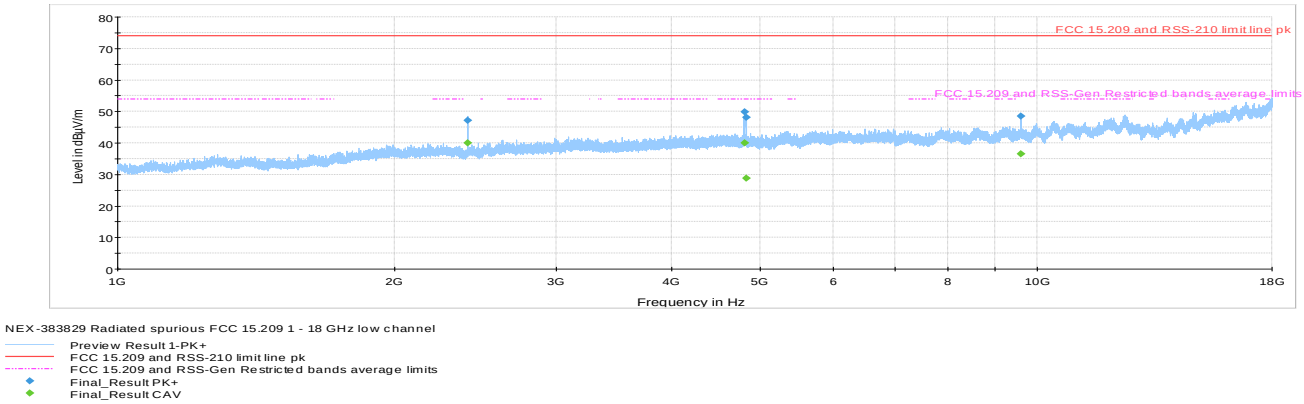



***Figure 8.6-8:*** *Radiated Spurious emissions 1-18 GHz, low channel*

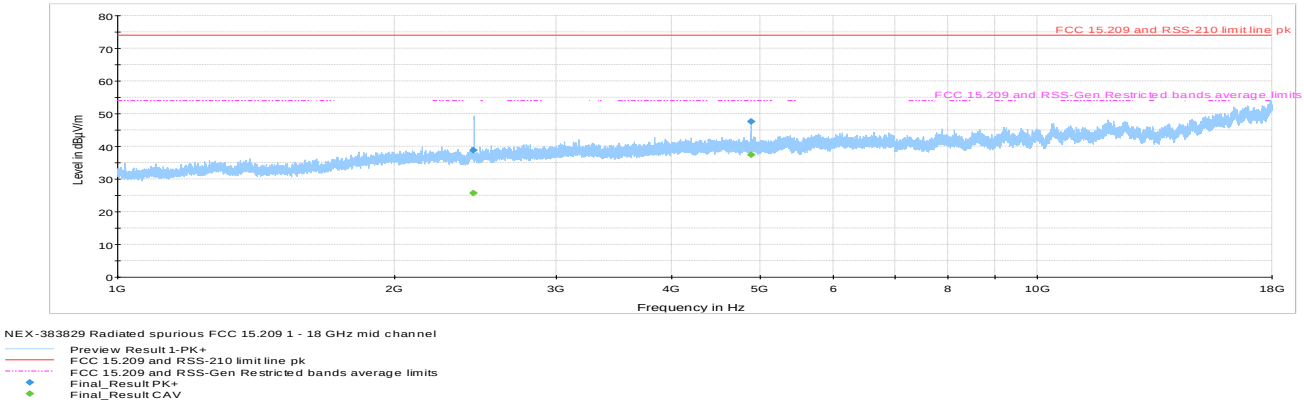



***Figure 8.6-9:*** *Radiated Spurious emissions 1 - 18GHz, mid channel*

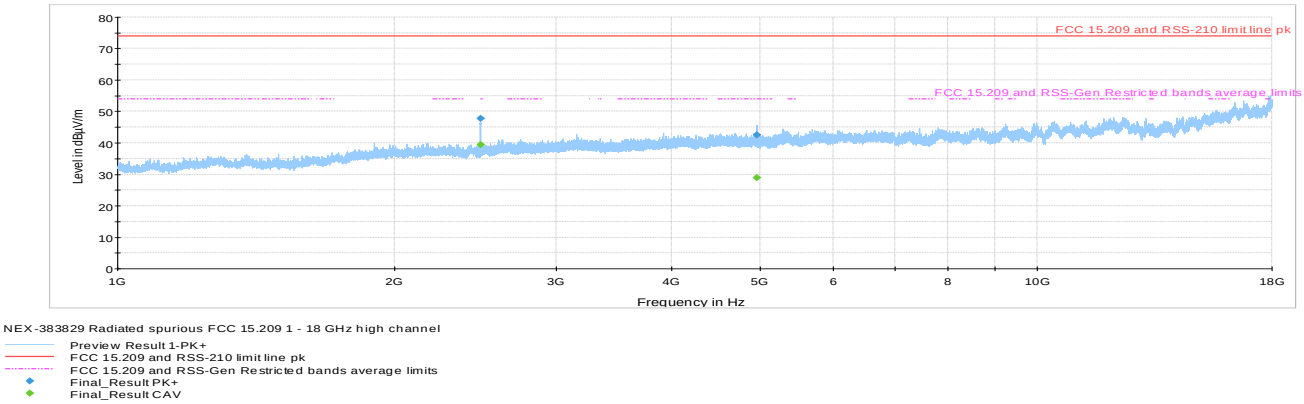



***Figure 8.6-10:*** *Radiated Spurious emissions 1 - 18 GHz, high channel*

## 8.6.4 Test data, continued

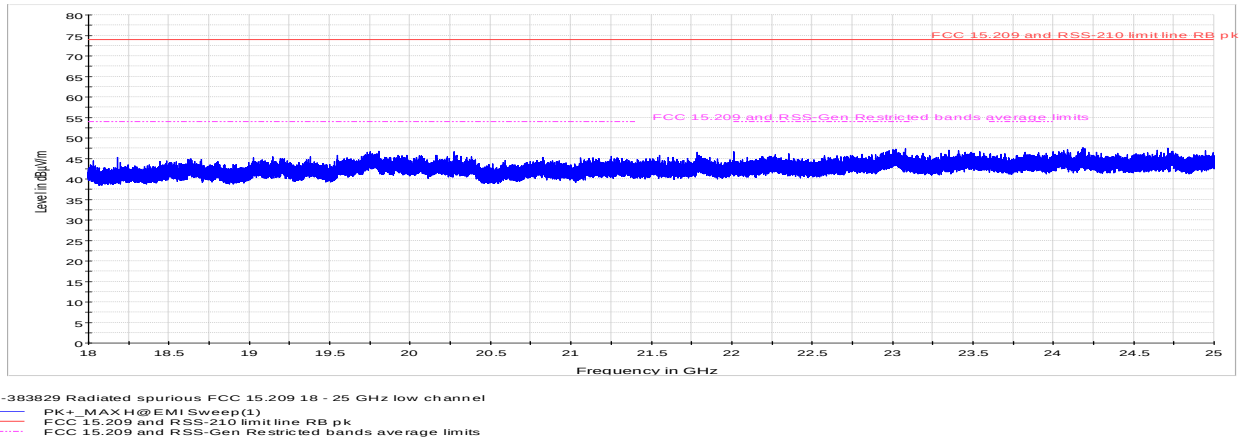



***Figure 8.6-11:*** *Radiated Spurious emissions 18 – 25 GHz low channel*

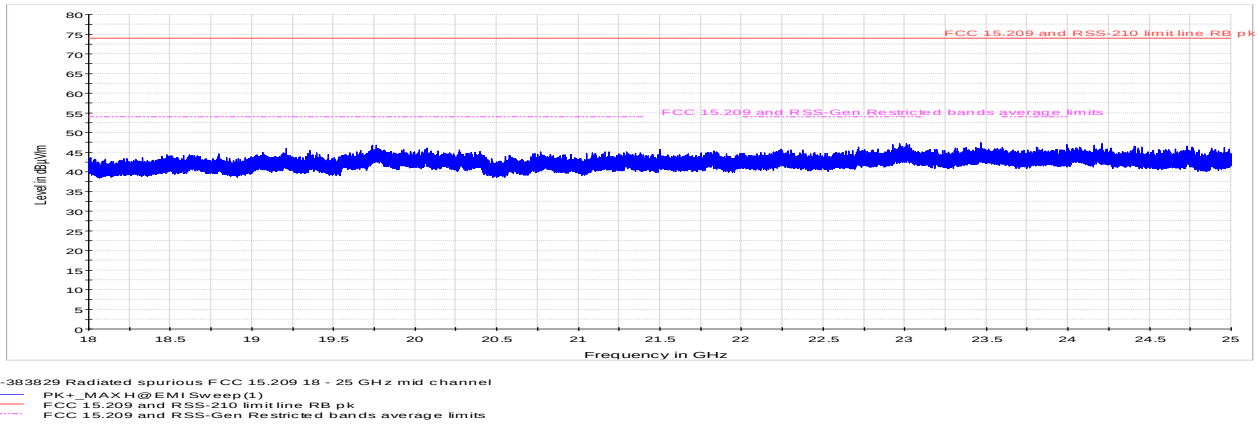



***Figure 8.6-12:*** *Radiated Spurious emissions 18 – 25 GHz mid channel*

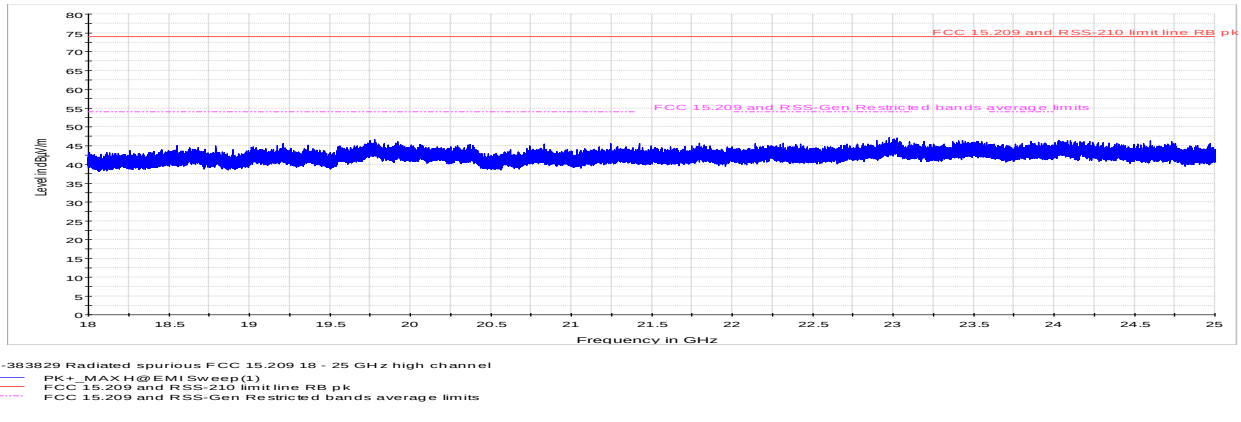



***Figure 8.6-13:*** *Radiated Spurious emissions 18 – 25 GHz high channel*

8.6.4 Test data, continued


***Figure 8.6-14:*** *Conducted band edge emissions, low channel*


***Figure 8.6-15:*** *Conducted band edge emissions, high channel*

8.6.4 Test data, continued

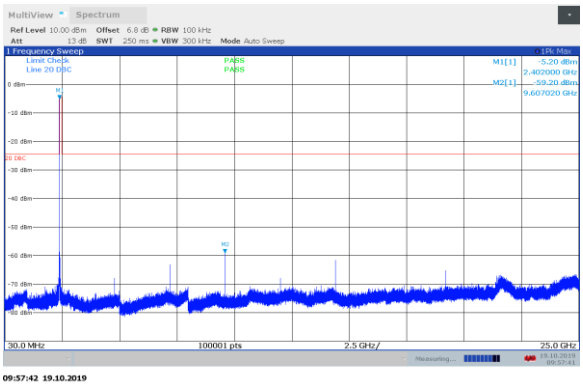



***Figure 8.6-16:*** *Conducted spurious emissions low channel*

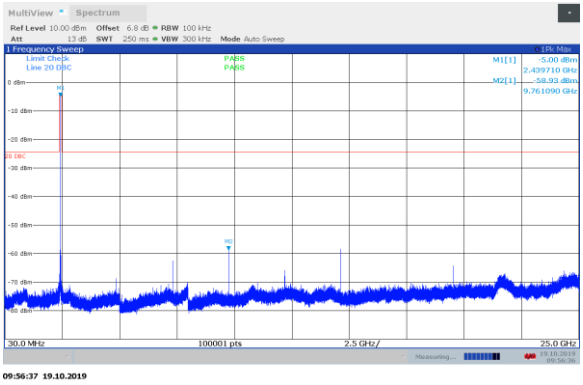



***Figure 8.6-17:*** *Conducted spurious emissions for mid channel*

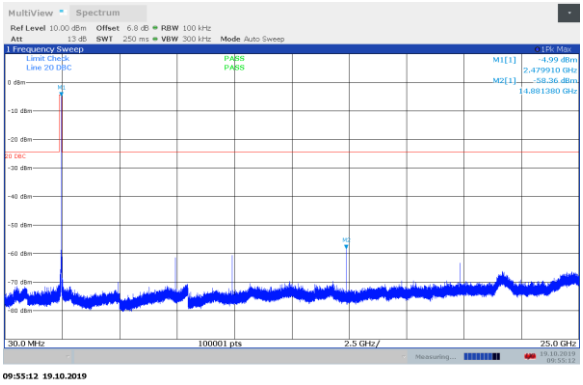



***Figure 8.6-18:*** *Conducted spurious emissions for high channel*

## 8.7 FCC 15.247(e) and RSS-247 5.2(b) Power spectral density for digitally modulated devices

### 8.7.1 Definitions and limits

**FCC:**
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.

(f) For the purposes of this section, hybrid systems are those that employ a combination of both frequency hopping and digital modulation techniques. The frequency hopping operation of the hybrid system, with the direct sequence or digital modulation operation turned-off, shall have an average time of occupancy on any frequency not to exceed 0.4 seconds within a time period in seconds equal to the number of hopping frequencies employed multiplied by 0.4. The power spectral density conducted from the intentional radiator to the antenna due to the digital modulation operation of the hybrid system, with the frequency hopping operation turned off, shall not be greater than 8 dBm in any 3 kHz band during any time interval of continuous transmission.

**ISED:**
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. This power spectral density shall be determined in accordance with the provisions of section 5.4(d), (i.e. the power spectral density shall be determined using the same method as is used to determine the conducted output power).

5.3 Hybrid systems
Hybrid systems employ a combination of both frequency hopping and digital transmission techniques and shall comply with the following:

a. With the frequency hopping turned off, the digital transmission operation shall comply with the power spectral density requirements for digital modulation systems set out in of section 5.2(b) or section 6.2.4 for hybrid devices operating in the band 5725–5850 MHz.

### 8.7.1 Test date

| | |
|---|---|
| Start date | October 19, 2019 |

### 8.7.2 Observations, settings and special notes

Power spectral density test was performed as per KDB 558074, section 8.4 with reference to ANSI C63.10 subclause 11.10.
The test was performed using method PKPSD (peak PSD).
Spectrum analyser settings:

| | |
|---|---|
| Resolution bandwidth: | 3 kHz |
| Video bandwidth: | ≥3 × RBW |
| Frequency span: | 1.5 times the DTS BW (Peak) |
| Detector mode: | Peak |
| Trace mode: | Max hold |

## 8.7.3 Test data

***Table 8.7-1:*** *PSD measurements results*

| Frequency, MHz | PSD, dBm/3 kHz | PSD limit, dBm/3 kHz | Margin, dB |
|---|---|---|---|
| 2402 | -19.5 | 8.00 | 27.5 |
| 2440 | -19.5 | 8.00 | 27.5 |
| 2480 | -19.5 | 8.00 | 27.5 |

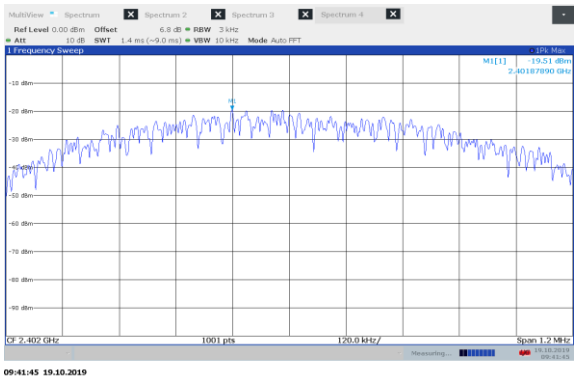



***Figure 8.7-1:*** *PSD low channel*

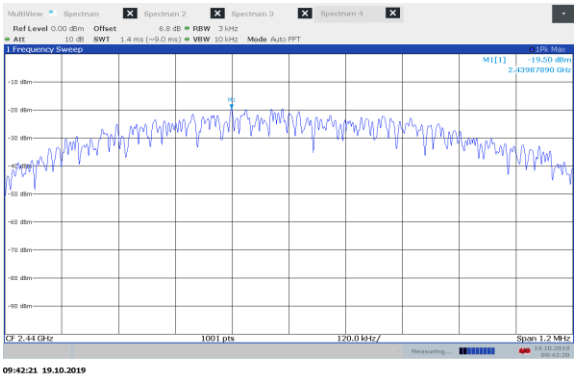



***Figure 8.7-2:*** *PSD mid channel*

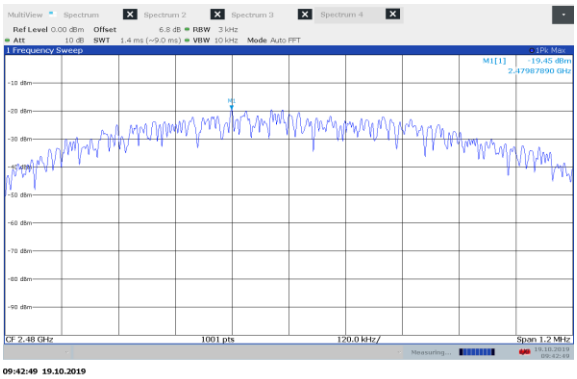
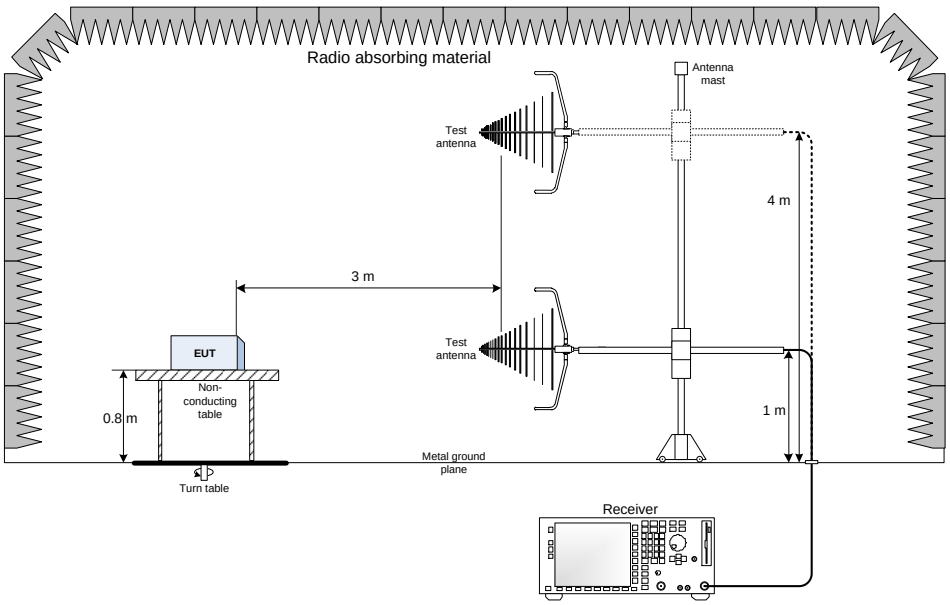


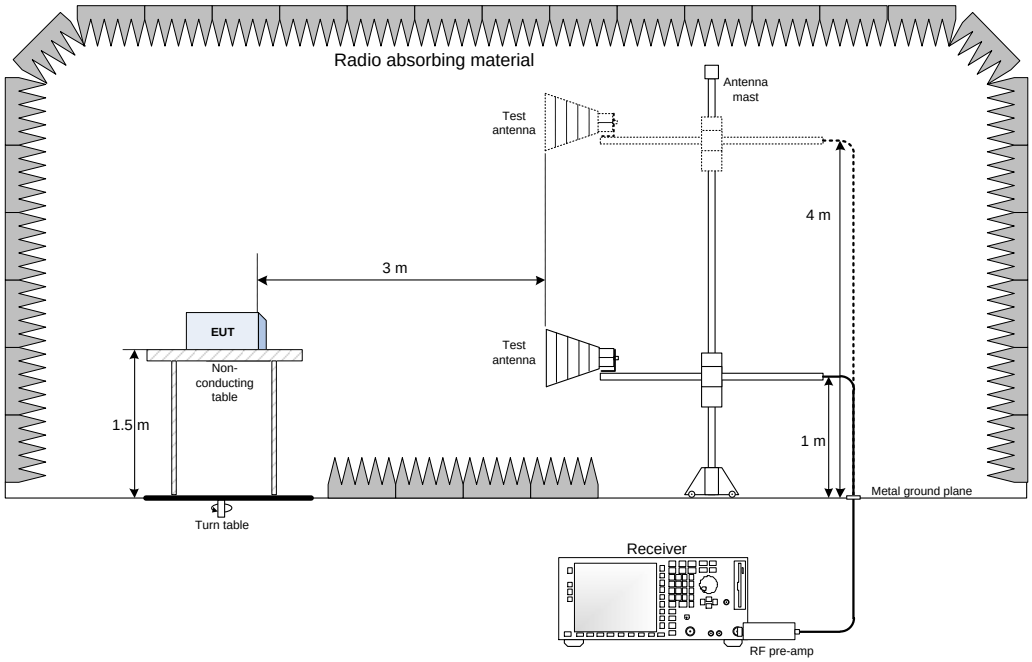

***Figure 8.7-3:*** *PSD high channel*

# Section 9. Block diagrams of test set-ups

## 9.1 Radiated emissions set-up for frequencies below 1 GHz




## 9.2 Radiated emissions set-up for frequencies above 1 GHz



## 9.3 Antenna port set-up