ONE WORLD ○ OUR APPROVAL

# Test report

## 309502-1TRFWL

Date of issue: June 28, 2016

Applicant:

On Ramp Wireless

Product:

nanoNode, RPMA Wireless Module

Model:

NODE103

FCC ID: XTE-NODE103

IC Registration number: 8655A-NODE103

Specifications:

- FCC 47 CFR Part 15 Subpart C, §15.247
  Operation in the 902–928 MHz, 2400–2483.5 MHz, 5725–5850 MHz
- RSS-247, Issue 1, May 2015, Section 5
  Digital Transmission Systems (DTSs), Frequency Hopping Systems (FHSs) and Licence-Exempt Local Area Network (LE-LAN) Devices

Test location

| | |
|---|---|
| Company name | Nemko Canada Inc. |
| Address | 303 River Road |
| City | Ottawa |
| Province | Ontario |
| Postal code | K1V 1H2 |
| Country | Canada |
| Telephone | +1 613 737 9680 |
| Facsimile | +1 613 737 9691 |
| Toll free | +1 800 563 6336 |
| Website | www.nemko.com |
| Site number | FCC: 176392; IC: 2040A-4 (3 m semi anechoic chamber) |

| | |
|---|---|
| Tested by | Andrey Adelberg, Senior Wireless/EMC Specialist |
| Reviewed by | David Duchesne, Senior EMC/Wireless Specialist |
| Review date | June 28, 2016 |
| Reviewer signature |  |

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 | On-Ramp Wireless |
| Address | 10301 Meanley Drive |
| City | San Diego |
| Province/State | CA |
| Postal/Zip code | 92131 |
| Country | USA |

## 1.2 Test specifications

| | |
|---|---|
| FCC 47 CFR Part 15, Subpart C, Clause 15.247 | Operation in the 902–928 MHz, 2400–2483.5 MHz |
| RSS-247, Issue 1, May 2015, 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 DTS Meas Guidance v03r05 | Guidance for Performing Compliance Measurements on Digital Transmission Systems (DTS) Operating Under §15.247 |
| ANSI C63.10 v2013 | American National Standard of Procedures for Compliance Testing of Unlicensed Wireless Devices |

## 1.4 Statement of compliance

In the configuration tested, the EUT was found compliant.

Testing was completed against all relevant requirements of the test standard. 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 # | Details of changes made to test report |
|---|---|
| TRF | Original report issued |

# **Section 2.** Summary of test results

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

| Part | Test description | Verdict |
|---|---|---|
| §15.207(a) | Conducted limits | Pass |
| §15.31(e) | Variation of power source | Pass[1] |
| §15.203 | Antenna requirement | Pass[2] |

Notes: [1] Measurements of the variation of the input power or the radiated signal level of the fundamental frequency component of the emission, as appropriate, was performed with the supply voltage varied between 85 % and 115 % of the nominal rated supply voltage. No noticeable output power variation was observed

[2] The antennas are located within the enclosure of EUT and not user accessible.

## 2.2 FCC Part 15 Subpart C, intentional radiators test results

| Part | Test description | Verdict |
|---|---|---|
| §15.247(a)(1)(i) | Frequency hopping systems operating in the 902–928 MHz band | Not applicable |
| §15.247(a)(1)(ii) | Frequency hopping systems operating in the 5725–5850 MHz band | Not applicable |
| §15.247(a)(1)(iii) | Frequency hopping systems operating in the 2400–2483.5 MHz band | Not applicable |
| §15.247(a)(2) | Minimum 6 dB bandwidth for systems using digital modulation techniques | Pass |
| §15.247(b)(1) | Maximum peak output power of frequency hopping systems operating in the 2400–2483.5 MHz band and 5725–5850 MHz band | Not applicable |
| §15.247(b)(2) | Maximum peak output power of Frequency hopping systems operating in the 902–928 MHz band | Not applicable |
| §15.247(b)(3) | Maximum peak output power of systems using digital modulation 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 for digitally modulated devices | Pass |
| §15.247(f) | Time of occupancy for hybrid systems | Not applicable |

## 2.3 IC RSS-GEN, Issue 4, test results

| Part | Test description | Verdict |
|---|---|---|
| 7.1.2 | Receiver radiated emission limits | Not applicable |
| 7.1.3 | Receiver conducted emission limits | Not applicable |
| 8.8 | Power Line Conducted Emissions Limits for Licence-Exempt Radio Apparatus | Pass |

Notes: [1] According to sections 5.2 and 5.3 of RSS-Gen, Issue 4 the EUT does not have a stand-alone receiver neither scanner receiver, therefore exempt from receiver requirements.

## 2.4 IC RSS-247, Issue 1, test results

| Part | Test description | Verdict |
|---|---|---|
| 5.1 | Frequency Hopping Systems (FHSs) | |
| 5.1 (1) | Bandwidth of a frequency hopping channel | Not applicable |
| 5.1 (2) | Minimum channel spacing for frequency hopping systems | Not applicable |
| 5.1 (3) | Frequency hopping systems operating in the 902–928 MHz band | Not applicable |
| 5.1 (4) | Frequency hopping systems operating in the 2400–2483.5 MHz band | Not applicable |
| 5.1 (5) | Frequency hopping systems operating in the 5725–5850 MHz band | Not applicable |
| 5.2 | Digital Transmission Systems (DTSs) | |
| 5.2 (1) | Minimum 6 dB bandwidth | Pass |
| 5.2 (2) | Maximum power spectral density | Pass |
| 5.3 | Hybrid Systems | |
| 5.3 (1) | Digital modulation turned off | Not applicable |
| 5.3 (2) | Frequency hopping turned off | Not applicable |
| 5.4 | Transmitter output power and e.i.r.p. requirements | |
| 5.4 (1) | Frequency hopping systems operating in the 902–928 MHz band | Not applicable |
| 5.4 (2) | Frequency hopping systems operating in the 2400–2483.5 MHz band | Not applicable |
| 5.4 (3) | Frequency hopping systems operating in the 5725–5850 MHz | Not applicable |
| 5.4 (4) | Systems employing digital modulation techniques | Pass |
| 5.4 (5) | Point-to-point systems in 2400–2483.5 MHz and 5725–5850 MHz band | Not applicable |
| 5.4 (6) | Transmitters which operate in the 2400–2483.5 MHz band with multiple directional beams | Not applicable |
| 5.5 | Out-of-band emissions | Pass |

# **Section 3.** Equipment under test (EUT) details

## 3.1 Sample information

| | |
|---|---|
| Receipt date | May 16, 2016 |
| Nemko sample ID number | 133-002400 |

## 3.2 EUT information

| | |
|---|---|
| Product name | nanoNode, RPMA Wireless Module |
| Model | NODE103 |
| Model variant | N/A |
| Serial number | 740F00B5 |

## 3.3 Technical information

| | |
|---|---|
| Applicant IC company number | 8655A |
| IC UPN number | NODE103 |
| All used IC test site(s) Reg. number | 2040A-4 |
| RSS number and Issue number | RSS-247 Issue 1, May 2015 |
| Frequency band | 2400–2483.5 MHz |
| Frequency Min (MHz) | 2402 |
| Frequency Max (MHz) | 2475.63 |
| RF power Min (W), Conducted | N/A |
| RF power Max (W), Conducted | 0.1968 (22.94 dBm) |
| Field strength, Units @ distance | N/A |
| Measured BW (kHz) (6 dB) | 1017 (1.362 MHz 99% OBW) |
| Calculated BW (kHz), as per TRC-43 | N/A |
| Type of modulation | DSSS-BPSK |
| Emission classification (F1D, G1D, D1D) | 1M36G1D |
| Transmitter spurious, Units @ distance | 51.62 dBµV/m (average) at 2483.5 MHz @ 3 m |
| Power requirements | 3.6 $V_{DC}$ via 120 $V_{AC}$ 60 Hz adapter |
| Antenna information | Maximum antenna gain of 9 dBi.<br>The EUT uses a unique antenna coupling/ non-detachable antenna to the intentional radiator. |

## 3.4 Product description and theory of operation

Ingenu has developed RPMA, a wireless technology providing the world's best coverage, capacity, long life, and interoperability for IOT devices. The RPMA Network is comprised of Nodes (end points with RF Modems) and Access Points (APs). The nanoNode is one variant of the Nodes offered by Ingenu. The nanoNode is a small form factor wireless network module that easily integrates with a microcontroller or applications processor using a Serial Peripheral Interface (SPI).

## 3.5 EUT exercise details

EUT was connected to a laptop via USB connector. Special tool was running on the computer that controlled the transmitter parameters.

## 3.6 EUT setup diagram

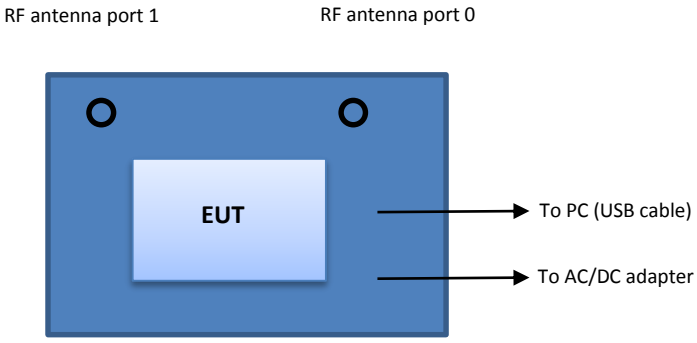



***Figure 3.6-1:*** *Setup diagram*

## 3.7 EUT sub assemblies

***Table 3.7-1:*** *EUT auxiliary equipment*

| Description | Brand name | Model/Part number | Serial number |
|---|---|---|---|
| Laptop | Acer | Aspire 3610 | LXA7405212 538022F6KS00 |
| Power adapter | CUI | 3A-211DN05 | – |

# **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

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

| 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. | Asset no. | Cal cycle | Next cal. |
|---|---|---|---|---|---|
| 3 m EMI test chamber | TDK | SAC-3 | FA002047 | 1 year | Dec. 01/16 |
| Flush mount turntable | Sunol | FM2022 | FA002082 | — | NCR |
| Controller | Sunol | SC104V | FA002060 | — | NCR |
| Antenna mast | Sunol | TLT2 | FA002061 | — | NCR |
| AC Power source | California Instruments | 3001i | FA001021 | 1 year | Aug. 27/16 |
| Receiver/spectrum analyzer | Rohde & Schwarz | ESU 26 | FA002043 | 1 year | Jan. 07/17 |
| Bilog antenna (20–3000 MHz) | Sunol | JB3 | FA002108 | 1 year | Apr. 28/17 |
| Horn antenna (1–18 GHz) | EMCO | 3115 | FA000825 | 1 year | Apr. 26/17 |
| Pre-amplifier (1–18 GHz) | JCA | JCA118-503 | FA002091 | 1 year | April 26/17 |
| LISN | Rohde & Schwarz | ENV216 | FA002023 | 1 year | Mar. 08/17 |

Note: NCR - no calibration required

# Section 8. Testing data

## 8.1 FCC 15.207(a) and RSS-Gen 8.8 AC power line conducted emissions limits

### 8.1.1 Definitions and limits

**FCC:**
Except as shown in paragraphs (b) and (c) of this section, for an intentional radiator that is designed to be connected to the public utility (AC) power line, the radio frequency voltage that is conducted back onto the AC power line on any frequency or frequencies, within the band 150 kHz to 30 MHz, shall not exceed the limits in the following table, as measured using a 50 µH/50 Ω line impedance stabilization network (LISN). Compliance with the provisions of this paragraph shall be based on the measurement of the radio frequency voltage between each power line and ground at the power terminal. The lower limit applies at the boundary between the frequency ranges.

**IC:**
A radio apparatus that is designed to be connected to the public utility (AC) power line shall ensure that the radio frequency voltage, which is conducted back onto the AC power line on any frequency or frequencies within the band 150 kHz to 30 MHz, shall not exceed the limits in table below.

Unless the requirements applicable to a given device state otherwise, for any radio apparatus equipped to operate from the public utility AC power supply either directly or indirectly (such as with a battery charger), the radio frequency voltage of emissions conducted back onto the AC power lines in the frequency range of 0.15 MHz to 30 MHz shall not exceed the limits shown in table below. The more stringent limit applies at the frequency range boundaries.

***Table 8.1-1:*** *Conducted emissions limit*

| Frequency of emission, MHz | Conducted limit, dBµV | |
|---|---|---|
| | Quasi-peak | Average** |
| 0.15–0.5 | 66 to 56* | 56 to 46* |
| 0.5–5 | 56 | 46 |
| 5–30 | 60 | 50 |

Note: * - The level decreases linearly with the logarithm of the frequency.
** - A linear average detector is required.

### 8.1.2 Test summary

| | | | |
|---|---|---|---|
| Test date | May 20, 2016 | Temperature | 22 °C |
| Test engineer | Andrey Adelberg | Air pressure | 1009 mbar |
| Verdict | Pass | Relative humidity | 30 % |

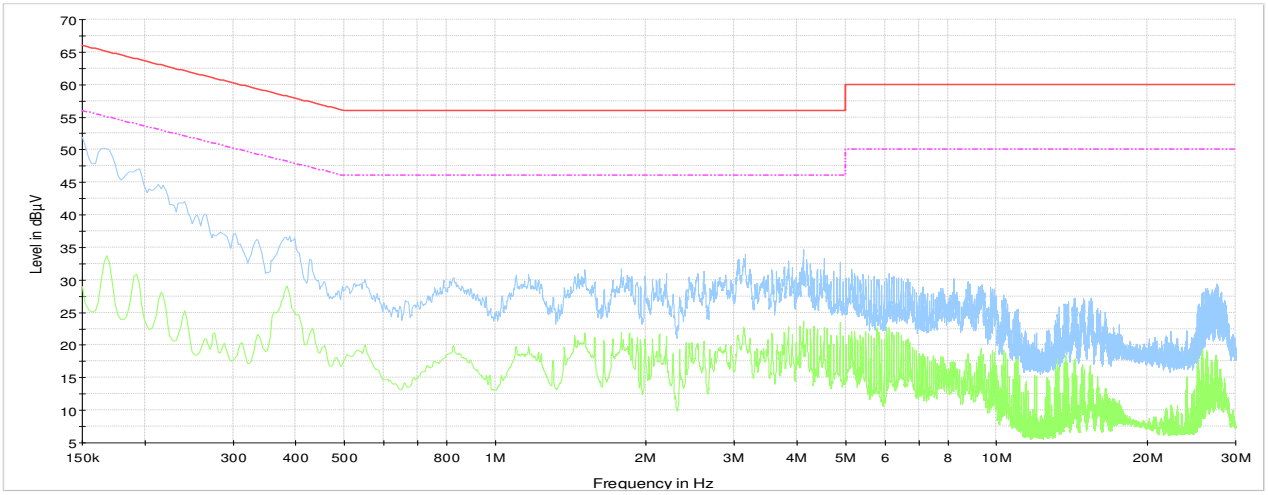
### 8.1.3 Observations, settings and special notes

| | |
|---|---|
| Port under test | AC input external adapter |
| EUT setup configuration | Table top |
| Measurement details | A preview measurement was generated with the receiver in continuous scan mode. Emissions detected within 6 dB or above limit were re-measured with the appropriate detector against the correlating limit and recorded as the final measurement. |

Receiver settings:

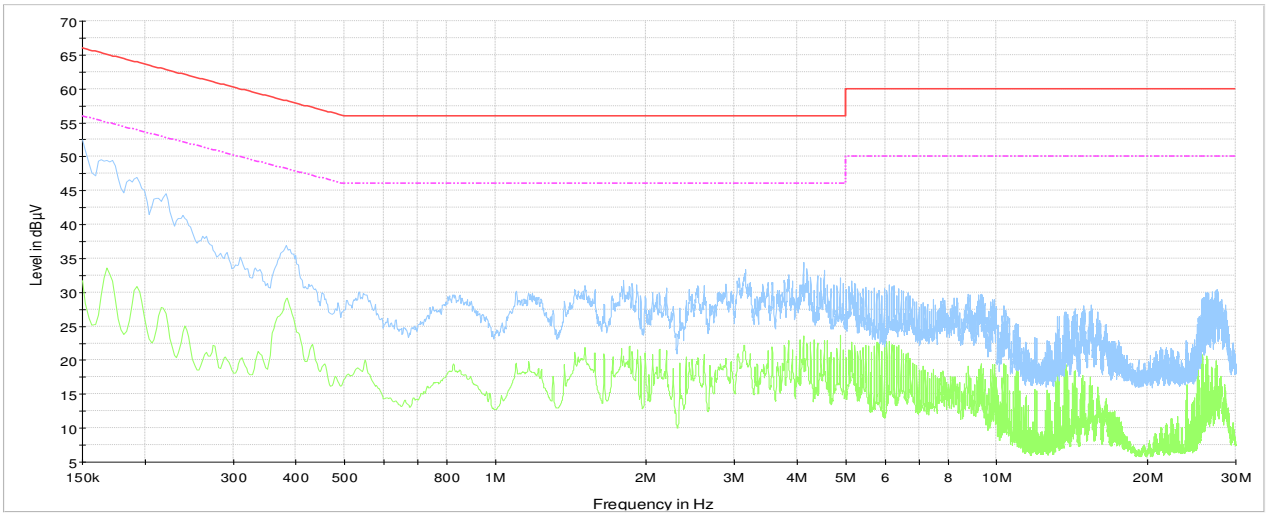
| | |
|---|---|
| Resolution bandwidth | 9 kHz |
| Video bandwidth | 30 kHz |
| Detector mode | – Peak and Average (Preview measurement)<br>– Quasi-peak and CAverage (Final measurement) |
| Trace mode | Max Hold |
| Measurement time | – 100 ms (Peak and Average preview measurement)<br>– 1000 ms (Quasi-peak final measurement)<br>– 160 ms (CAverage final measurement) |

### 8.1.4 Test data




*The spectral plot has been corrected with transducer factors. (i.e. cable loss, LISN factors, and attenuators)*

***Plot 8.1-1:*** *Conducted emissions on phase line*




*The spectral plot has been corrected with transducer factors. (i.e. cable loss, LISN factors, and attenuators)*

***Plot 8.1-2:*** *Conducted emissions on neutral line*

# 8.2 FCC 15.247(a)(2) and RSS-247 5.2(1) Minimum 6 dB bandwidth for systems using digital modulation techniques

## 8.2.1 Definitions and limits

**FCC §15.247 (a)(2):**

(a) Operation under the provisions of this Section is limited to frequency hopping and digitally modulated intentional radiators that comply with the following provisions:

(2) 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.

**RSS-247, Clause 5.2 (1):**

The minimum 6 dB bandwidth shall be 500 kHz.

## 8.2.2 Test summary

| | | | |
|---|---|---|---|
| Test date | May 16, 2016 | Temperature | 22 °C |
| Test engineer | Andrey Adelberg | Air pressure | 1006 mbar |
| Verdict | Pass | Relative humidity | 31 % |

## 8.2.3 Observations, settings and special notes

Measurements were performed as per 558074 D01 DTS Meas Guidance v03r05 (The test was performed using method described in Section 8.1)

Spectrum analyser settings:

| | |
|---|---|
| Resolution bandwidth | 100 kHz |
| Video bandwidth | ≥3 × RBW |
| Frequency span | 5 MHz |
| Detector mode | Peak |
| Trace mode | Max Hold |

## 8.2.4 Test data

***Table 8.2-1:*** *6 dB bandwidth results for Ant0*

| Frequency, MHz | 6 dB bandwidth, MHz | Limit, MHz | Margin, MHz |
|---|---|---|---|
| 2402.00 | 1.001 | 0.500 | 0.501 |
| 2439.81 | 1.001 | 0.500 | 0.501 |
| 2475.63 | 1.001 | 0.500 | 0.501 |

***Table 8.2-2:*** *6 dB bandwidth results for Ant1*

| Frequency, MHz | 6 dB bandwidth, MHz | Limit, MHz | Margin, MHz |
|---|---|---|---|
| 2402.00 | 1.017 | 0.500 | 0.517 |
| 2439.81 | 1.010 | 0.500 | 0.510 |
| 2475.63 | 1.008 | 0.500 | 0.508 |

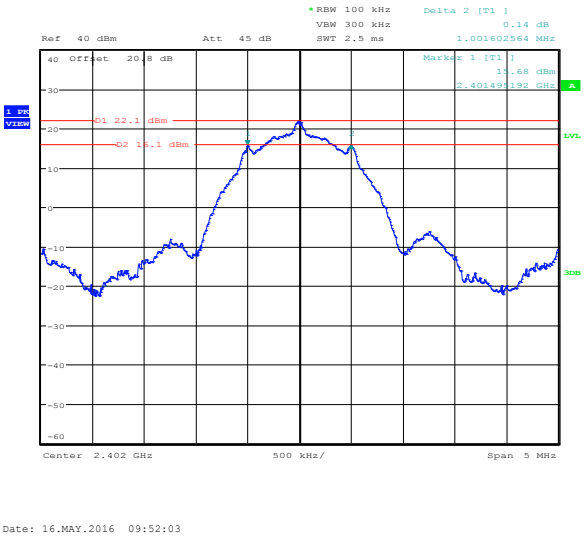



***Figure 8.2-1:*** *6 dB bandwidth on Ant0, sample plot*

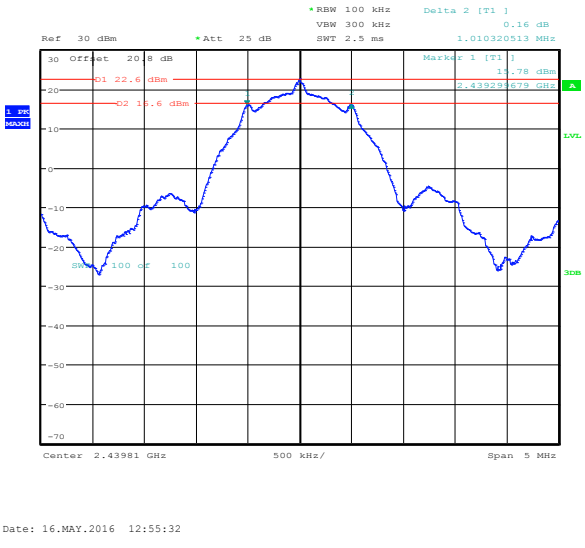



***Figure 8.2-2:*** *6 dB bandwidth on Ant1, sample plot*

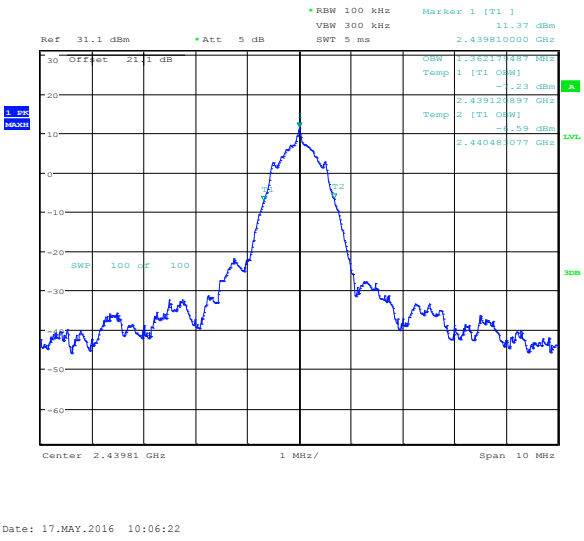



***Figure 8.2-3:*** *99% occupied bandwidth, sample plot*

## 8.3 FCC 15.247(b) and RSS-247 5.4 (4) Transmitter output power and e.i.r.p. requirements

### 8.3.1 Definitions and limits

**FCC §15.247 (b)(3,4):**

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

(3) For systems using digital modulation in the 902–928 MHz, 2400–2483.5 MHz, and 5725–5850 MHz bands: 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.

**RSS-247, Clause 5.4 (4):**

For DTSs employing digital modulation techniques operating in the bands 902–928 MHz and 2400–2483.5 MHz, the maximum peak conducted output power shall not exceed 1W. Except as provided in Section 5.4(5), the e.i.r.p. shall not exceed 4 W.
Fixed point-to-point systems in the bands 2400-2483.5 MHz and 5725-5850 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. 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.

### 8.3.2 Test summary

| | | | |
|---|---|---|---|
| Test date | May 16, 2016 | Temperature | 22 °C |
| Test engineer | Andrey Adelberg | Air pressure | 1005 mbar |
| Verdict | Pass | Relative humidity | 31 % |

### 8.3.3 Observations, settings and special notes

The test was performed according to DTS guidelines section 9.2.3.1: Method AVGPM (Measurement using an RF average power meter).

### 8.3.4 Test data

***Table 8.3-1:*** *Output power measurements results for Ant0*

| Frequency, MHz | Conducted output power, dBm | | Margin, dB | Antenna gain, dBi | EIRP, dBm | EIRP limit, dBm | EIRP margin, dB |
|---|---|---|---|---|---|---|---|
| | on Ant0 | Limit | | | | | |
| 2402.00 | 22.94 | 30.00 | 7.06 | 9.00 | 31.94 | 36.00 | 4.06 |
| 2439.81 | 22.78 | 30.00 | 7.22 | 9.00 | 31.78 | 36.00 | 4.22 |
| 2475.63 | 22.61 | 30.00 | 7.39 | 9.00 | 31.61 | 36.00 | 4.39 |

***Table 8.3-2:*** *Output power measurements results for Ant1*

| Frequency, MHz | Conducted output power, dBm | | Margin, dB | Antenna gain, dBi | EIRP, dBm | EIRP limit, dBm | EIRP margin, dB |
|---|---|---|---|---|---|---|---|
| | on Ant1 | Limit | | | | | |
| 2402.00 | 22.89 | 30.00 | 7.11 | 9.00 | 31.89 | 36.00 | 4.11 |
| 2439.81 | 22.84 | 30.00 | 7.16 | 9.00 | 31.84 | 36.00 | 4.16 |
| 2475.63 | 22.67 | 30.00 | 7.33 | 9.00 | 31.67 | 36.00 | 4.33 |

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

### 8.4.1 Definitions and limits

**FCC §15.247 (d):**

In any 100 kHz bandwidth outside the frequency band in which the spread spectrum or digitally modulated intentional radiator is operating, the radio frequency power that is produced by the intentional radiator shall be at least 20 dB below that in the 100 kHz bandwidth within the band that contains the highest level of the desired power, based on either an RF conducted or a radiated measurement, provided the transmitter demonstrates compliance with the peak conducted power limits. If the transmitter complies with the conducted power limits based on the use of RMS averaging over a time interval, as permitted under paragraph (b)(3) of this section, the attenuation required under this paragraph shall be 30 dB instead of 20 dB. Attenuation below the general limits specified in §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)).

**RSS-247, Clause 5.5:**

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(4), 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 8.4-1:*** *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 8.4-2:*** *IC restricted frequency bands*

| MHz | MHz | MHz | GHz |
|---|---|---|---|
| 0.090–0.110 | 12.51975–12.52025 | 399.9–410 | 5.35–5.46 |
| 2.1735–2.1905 | 12.57675–12.57725 | 608–614 | 7.25–7.75 |
| 3.020–3.026 | 13.36–13.41 | 960–1427 | 8.025–8.5 |
| 4.125–4.128 | 16.42–16.423 | 1435–1626.5 | 9.0–9.2 |
| 4.17725–4.17775 | 16.69475–16.69525 | 1645.5–1646.5 | 9.3–9.5 |
| 4.20725–4.20775 | 16.80425–16.80475 | 1660–1710 | 10.6–12.7 |
| 5.677-5.683 | 25.5–25.67 | 1718.8–1722.2 | 13.25–13.4 |
| 6.215–6.218 | 37.5–38.25 | 2200–2300 | 14.47–14.5 |
| 6.26775–6.26825 | 73–74.6 | 2310–2390 | 15.35–16.2 |
| 6.31175–6.31225 | 74.8–75.2 | 2655–2900 | 17.7–21.4 |
| 8.291–8.294 | 108–138 | 3260–3267 | 22.01–23.12 |
| 8.362–8.366 | 156.52475–156.52525 | 3332–3339 | 23.6–24.0 |
| 8.37625–8.38675 | 156.7–156.9 | 3345.8–3358 | 31.2–31.8 |
| 8.41425–8.41475 | 240–285 | 3500–4400 | 36.43–36.5 |
| 12.29–12.293 | 322–335.4 | 4500–5150 | Above 38.6 |

Note: Certain frequency bands listed in Table 8.4-2 and above 38.6 GHz are designated for low-power licence-exempt applications. These frequency bands and the requirements that apply to the devices are set out in this Standard

***Table 8.4-3:*** *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 | | | |

## 8.4.2 Test summary

| | | | |
|---|---|---|---|
| Test date | May 16, 2016 | Temperature | 23 °C |
| Test engineer | Andrey Adelberg | Air pressure | 1004 mbar |
| Verdict | Pass | Relative humidity | 33 % |

## 8.4.3 Observations, settings and special notes

The spectrum was searched from 30 MHz to the 10th harmonic.
EUT was set to transmit with 100 % duty cycle.
Radiated measurements were performed at a distance of 3 m.
Since fundamental power was tested using average method, the spurious emissions limit is −30 dBc/100 kHz.
All plots were adjusted to reflect appropriate correction factors.

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 conducted spurious emissions measurements:

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

### 8.4.4 Test data


***Figure 8.4-1:*** *Duty cycle measurement*

Duty cycle correction factor was calculated as follows:

$$20 \times \text{Log}_{10}(0.5) = -6 \text{ dB}$$

2483.5 MHz restricted band edge delta marker measurement results:

Antenna 0: Field strength measurement result of the fundamental with 1 MHz RBW is 120.55 dBµV/m. Delta marker at 2483.5 MHz with 100 kHz RBW is 63.93 dB, therefore peak field strength at 2483.5 MHz is 120.55 – 63.93 = 56.62 dBµV/m.

Antenna 1: Field strength measurement result of the fundamental with 1 MHz RBW is 121.21 dBµV/m. Delta marker at 2483.5 MHz with 100 kHz RBW is 63.59 dB, therefore peak field strength at 2483.5 MHz is 121.21 – 63.59 = 57.62 dBµV/m.

***Table 8.4-4:*** *Radiated field strength measurement results for Anto*

| Channel | Frequency, MHz | Peak Field strength, dBµV/m | | Margin, dB | Average Field strength, dBµV/m | | Margin, dB |
|---|---|---|---|---|---|---|---|
| | | Measured | Limit | | Calculated | Limit | |
| Low | 2390.0 | 56.62 | 74.00 | 17.07 | 50.93 | 54.00 | 3.07 |
| Low | 4804.0 | 53.42 | 74.00 | 20.58 | 47.42 | 54.00 | 6.58 |
| Low* | 19211.5 | 50.88 | 74.00 | 23.12 | 44.88 | 54.00 | 9.12 |
| Mid | 4879.5 | 51.71 | 74.00 | 22.29 | 45.71 | 54.00 | 8.29 |
| Mid | 7319.6 | 50.47 | 74.00 | 23.53 | 44.47 | 54.00 | 9.53 |
| Mid* | 19514.4 | 54.34 | 74.00 | 19.66 | 48.34 | 54.00 | 5.66 |
| High | 2483.5 | 56.62 | 74.00 | 17.38 | 50.62 | 54.00 | 3.38 |
| High | 4951.5 | 50.42 | 74.00 | 23.58 | 44.42 | 54.00 | 9.58 |
| High* | 19211.5 | 50.47 | 74.00 | 23.53 | 44.47 | 54.00 | 9.53 |

Notes: Field strength includes correction factor of antenna, cable loss, amplifier, and attenuators where applicable.
Average calculation example. 2390 MHz Peak measurement was 56.62 dBµV/m. Average = 56.62 – 6 = 50.62 dBµV/m
* - measurements were performed at 1 m distance to increase the receiver signal-to-noise ratio. Correction factor of 9.54 dB was deducted from the measurement result in order to compare the result with 3 m limit.

***Table 8.4-5:*** *Radiated field strength measurement results for Ant1*

| Channel | Frequency, MHz | Peak Field strength, dBµV/m | | Margin, dB | Average Field strength, dBµV/m | | Margin, dB |
|---|---|---|---|---|---|---|---|
| | | Measured | Limit | | Calculated | Limit | |
| Low | 2390.0 | 56.07 | 74.00 | 17.93 | 50.07 | 54.00 | 3.93 |
| Low | 7206.0 | 47.51 | 74.00 | 26.49 | 41.51 | 54.00 | 12.49 |
| Low* | 19211.5 | 50.47 | 74.00 | 23.53 | 44.47 | 54.00 | 9.53 |
| Mid* | 19514.4 | 52.47 | 74.00 | 21.53 | 46.47 | 54.00 | 7.53 |
| High | 4951.3 | 47.93 | 74.00 | 26.07 | 41.93 | 54.00 | 12.07 |
| High | 2483.5 | 57.62 | 74.00 | 16.38 | 51.62 | 54.00 | 2.38 |

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

Average calculation example. 2390 MHz Peak measurement was 56.07 dBµV/m. Average = 56.62 – 6 = 50.07 dBµV/m

* - measurements were performed at 1 m distance to increase the receiver signal-to-noise ratio. Correction factor of 9.54 dB was deducted from the measurement result in order to compare the result with 3 m limit.

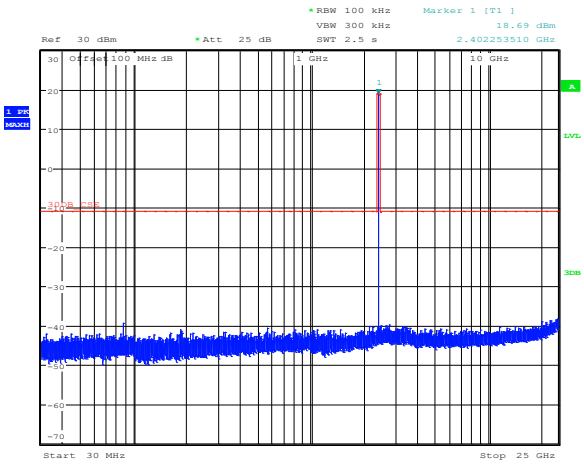



***Figure 8.4-2:*** *Conducted spurious emissions for Ant0, low channel*

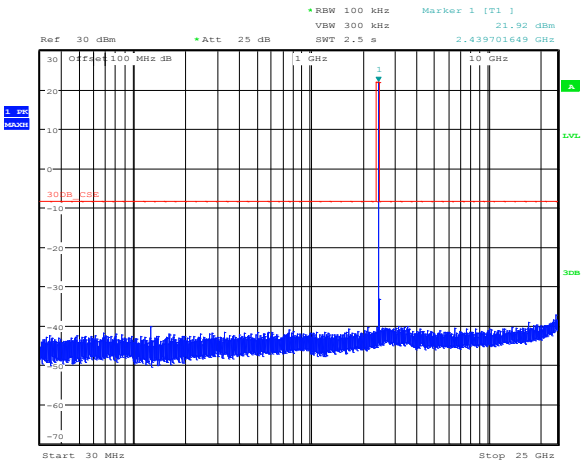



***Figure 8.4-3:*** *Conducted spurious emissions for Ant0, mid channel*

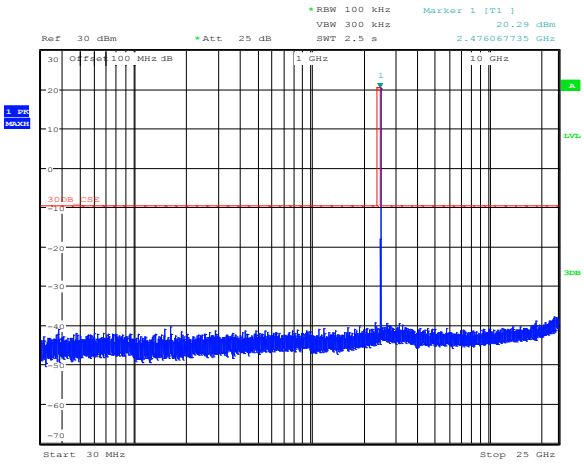



***Figure 8.4-4:*** *Conducted spurious emissions for Ant0, high channel*

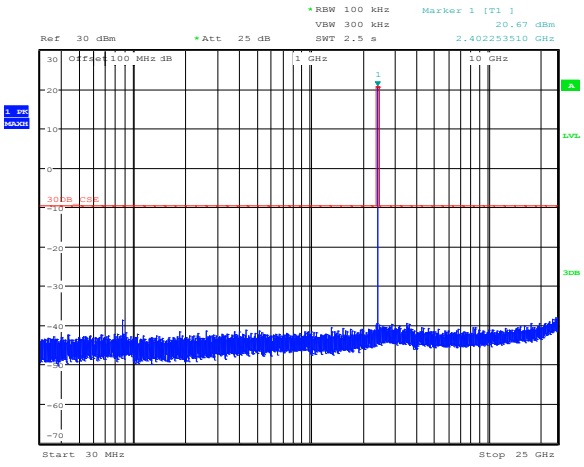



***Figure 8.4-5:*** *Conducted spurious emissions for Ant1, low channel*

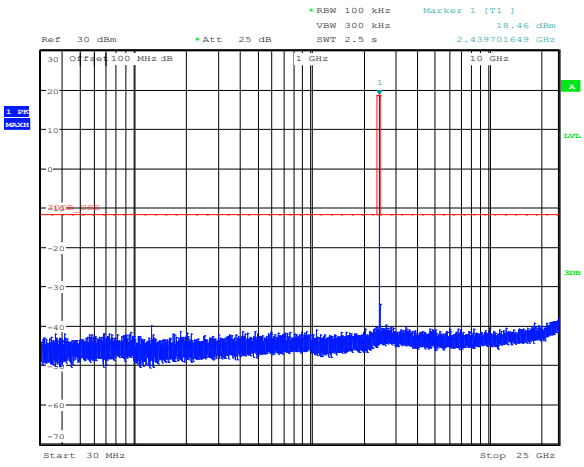



***Figure 8.4-6:*** *Conducted spurious emissions for Ant1, mid channel*

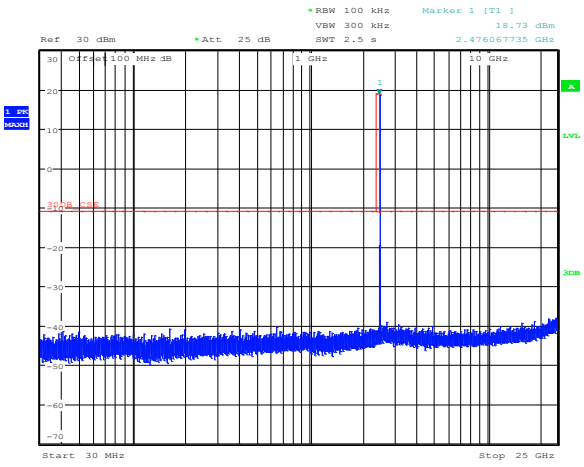



***Figure 8.4-7:*** *Conducted spurious emissions for Ant1, high channel*

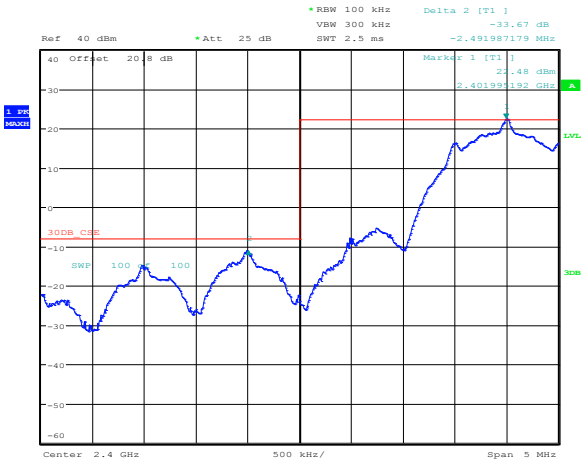



***Figure 8.4-8:*** *Conducted spurious emissions at the lower band edge for Ant0, low channel*

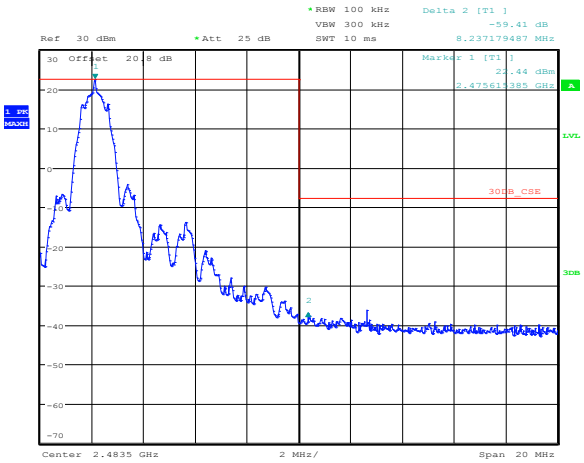



***Figure 8.4-9:*** *Conducted spurious emissions at the upper band edge for Ant0, high channel*

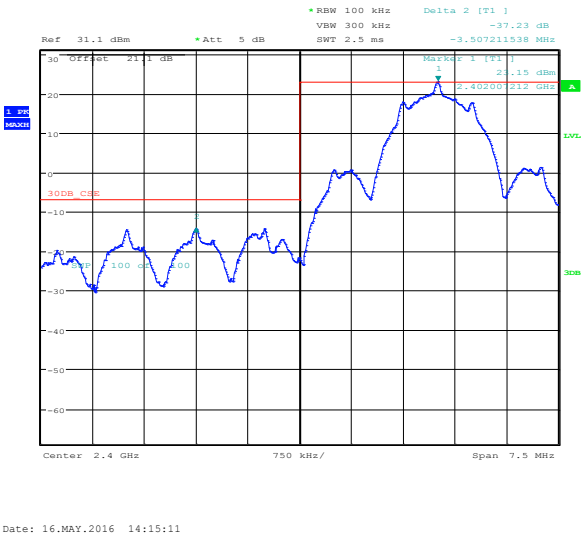



***Figure 8.4-10:*** *Conducted spurious emissions at the lower band edge for Ant1, low channel*

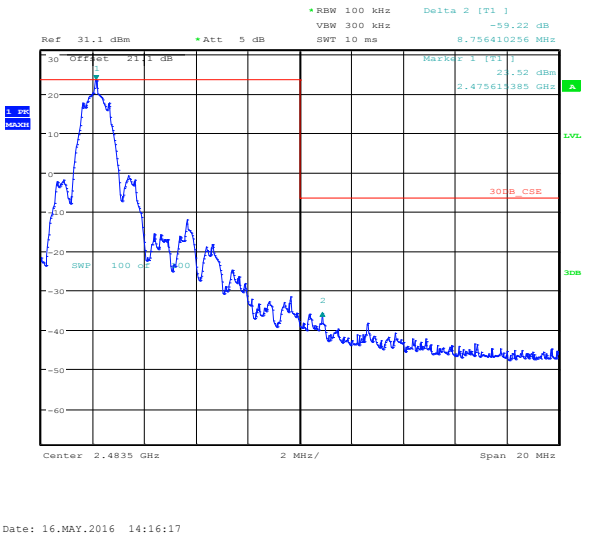



***Figure 8.4-11:*** *Conducted spurious emissions at the upper band edge for Ant1, high channel*

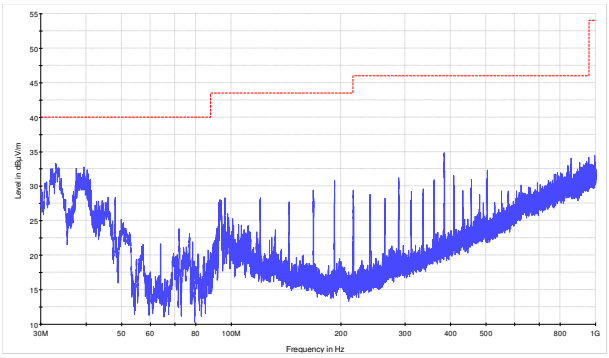



***Figure 8.4-12:*** *Radiated spurious emissions below 1 GHz for Ant0, low channel*

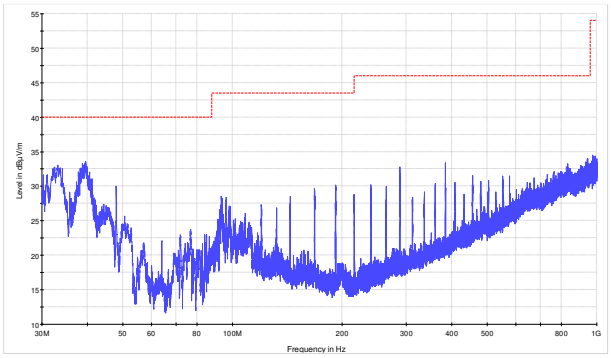



***Figure 8.4-13:*** *Radiated spurious emissions below 1 GHz for Ant0, mid channel*

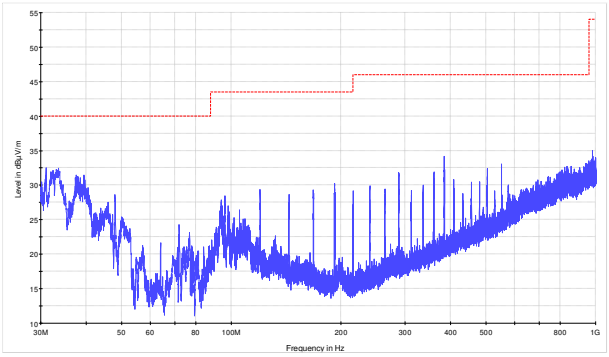



***Figure 8.4-14:*** *Radiated spurious emissions below 1 GHz for Ant0, high channel*

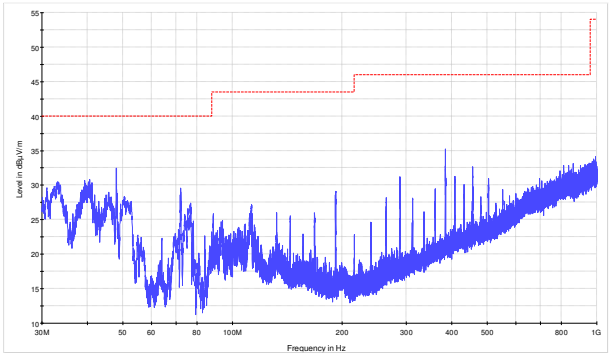



***Figure 8.4-15:*** *Radiated spurious emissions below 1 GHz for Ant1, low channel*

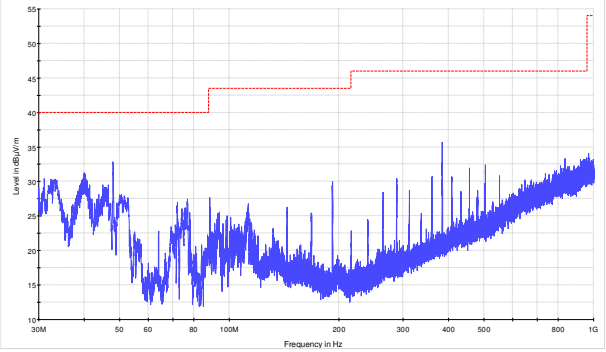



***Figure 8.4-16:*** *Radiated spurious emissions below 1 GHz for Ant1, mid channel*

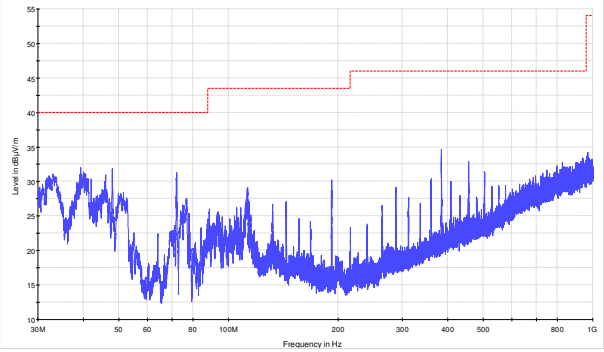



***Figure 8.4-17:*** *Radiated spurious emissions below 1 GHz for Ant1, high channel*

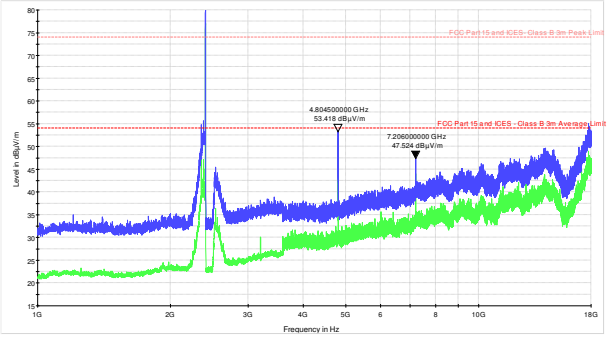



***Figure 8.4-18:*** *Radiated spurious emissions below 18 GHz for Ant0, low channel*

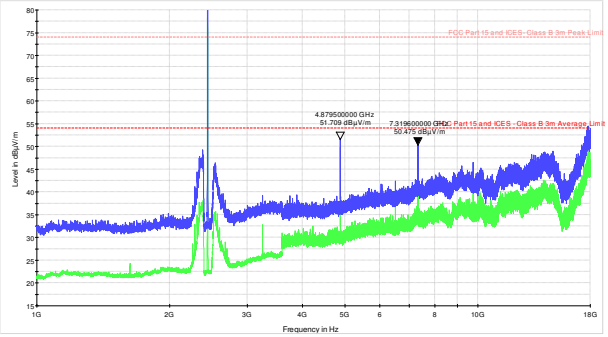



***Figure 8.4-19:*** *Radiated spurious emissions below 18 GHz for Ant0, mid channel*

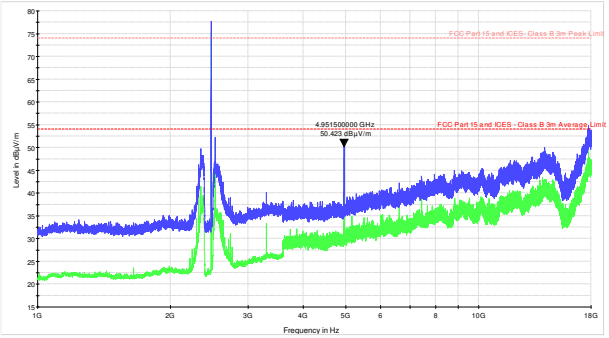



***Figure 8.4-20:*** *Radiated spurious emissions below 18 GHz for Ant0, high channel*

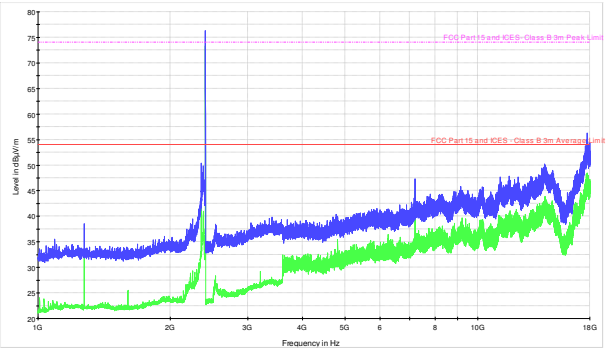



***Figure 8.4-21:*** *Radiated spurious emissions below 18 GHz for Ant1, low channel*

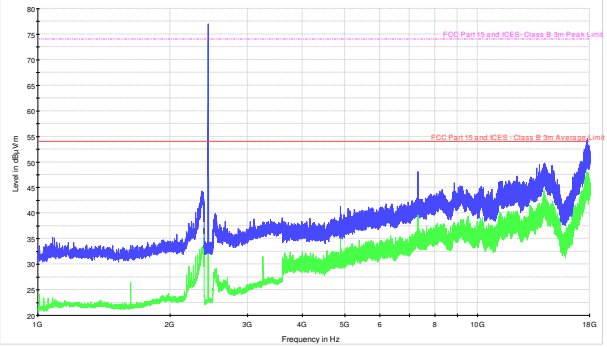



***Figure 8.4-22:*** *Radiated spurious emissions below 18 GHz for Ant1, mid channel*

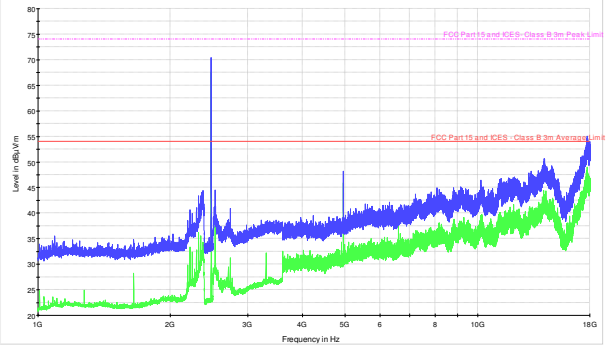



***Figure 8.4-23:*** *Radiated spurious emissions below 18 GHz for Ant1, high channel*

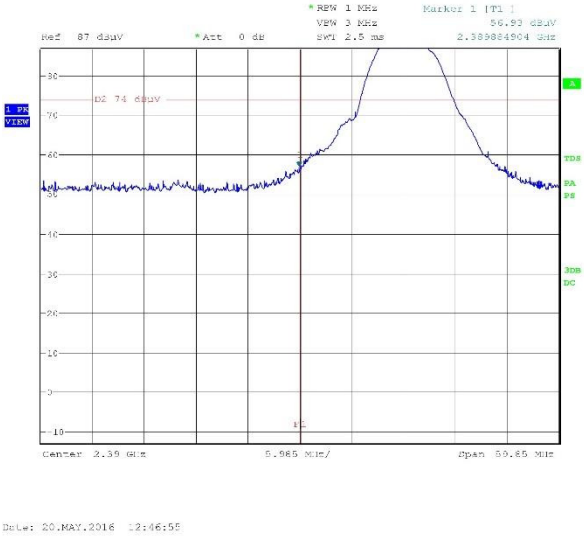



***Figure 8.4-24:*** *Radiated spurious emissions at the lower band edge for Ant0, low channel*

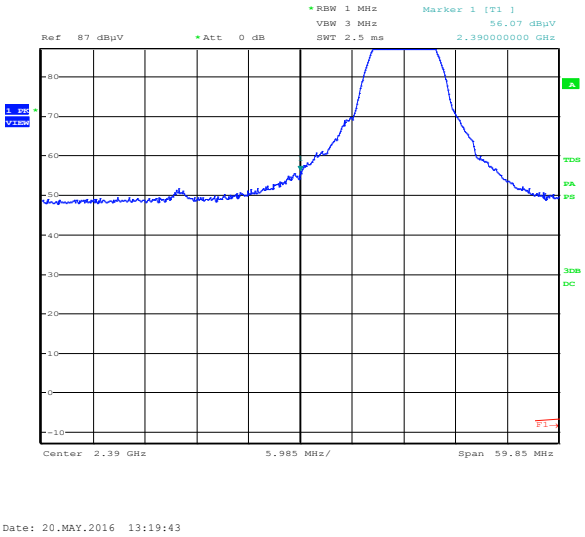



***Figure 8.4-25:*** *Radiated spurious emissions at the lower band edge for Ant1, low channel*

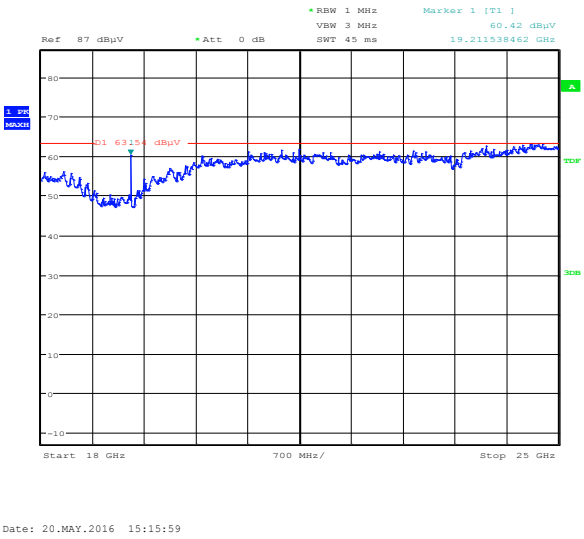



***Figure 8.4-26:*** *Radiated spurious emissions above 18 GHz for Ant0, low channel*

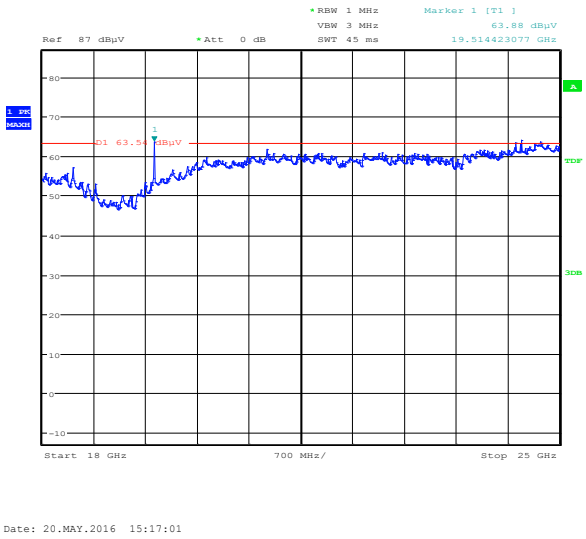



***Figure 8.4-27:*** *Radiated spurious emissions above 18 GHz for Ant0, mid channel*

Note: measurements above 18 GHz were performed at the distance of 1 m. 20 × Log (3 m/1 m) = 9.54 dB distance correction factor was applied to the average limit on the plots above. On the plots above, where peak trace (in blue) exceeded the average limit line (in red), both Peak and average were assessed and summarized in the Tables 8.4-4 and 8.4-5.

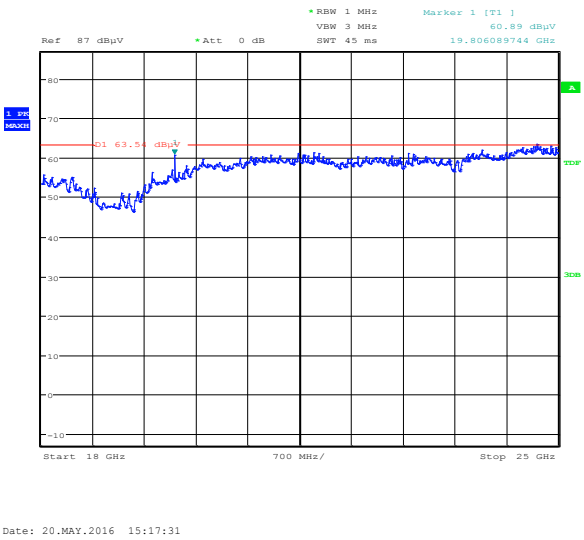



***Figure 8.4-28:*** *Radiated spurious emissions above 18 GHz for Ant0, high channel*

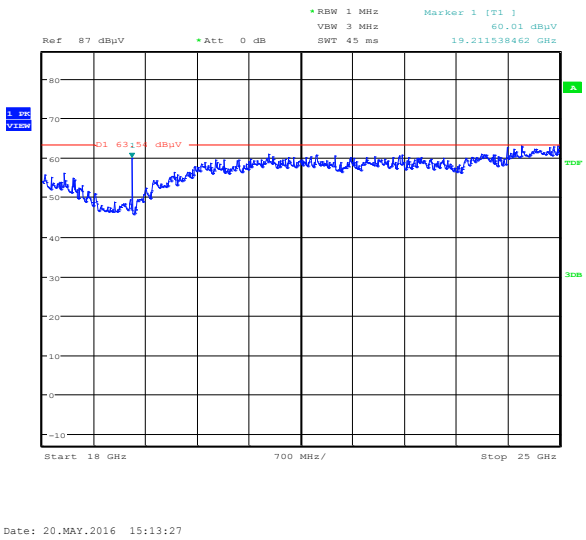



***Figure 8.4-29:*** *Radiated spurious emissions above 18 GHz for Ant1, low channel*

Note: measurements above 18 GHz were performed at the distance of 1 m. 20 × $Log_{10}$ (3 m/1 m) = 9.54 dB distance correction factor was applied to the average limit on the plots above. On the plots above, where peak trace (in blue) exceeded the average limit line (in red), both Peak and average were assessed and summarized in the Tables 8.4-4 and 8.4-5.

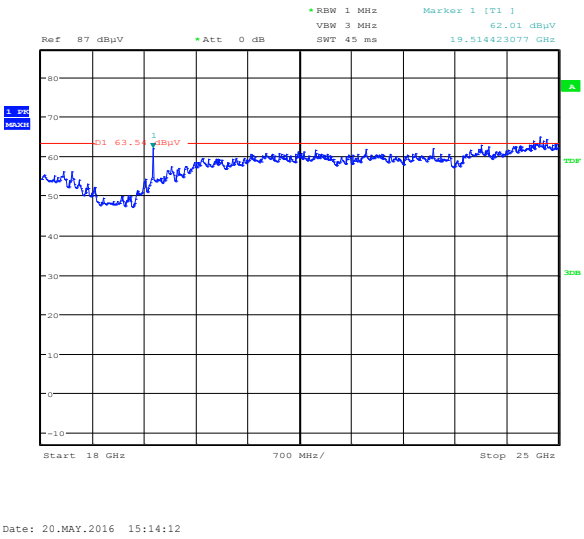



***Figure 8.4-30:*** *Radiated spurious emissions above 18 GHz for Ant1, mid channel*

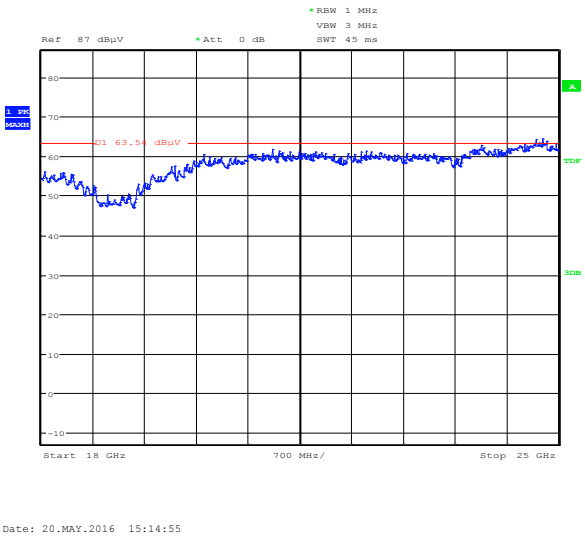



***Figure 8.4-31:*** *Radiated spurious emissions above 18 GHz for Ant1, high channel*

Note: measurements above 18 GHz were performed at the distance of 1 m. 20 × $Log_{10}$ (3 m/1 m) = 9.54 dB distance correction factor was applied to the average limit on the plots above. On the plots above, where peak trace (in blue) exceeded the average limit line (in red), both Peak and average were assessed and summarized in the Tables 8.4-4 and 8.4-5.

## 8.5 FCC 15.247(e) and RSS-247 5.2(2) Power spectral density for digitally modulated devices

### 8.5.1 Definitions and limits

**FCC §15.247 (e):**

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.

**RSS-247, Clause 5.2 (2):**

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(4), (i.e. the power spectral density shall be determined using the same method as is used to determine the conducted output power).

### 8.5.2 Test summary

| | | | |
|---|---|---|---|
| Test date | May 16, 2016 | Temperature | 23 °C |
| Test engineer | Andrey Adelberg | Air pressure | 1005 mbar |
| Verdict | Pass | Relative humidity | 32 % |

### 8.5.3 Observations, settings and special notes

The test was performed using method described in section 10.3 Method AVGPSD-1 (trace averaging with EUT transmitting at full power throughout each sweep). Spectrum analyser settings:

| | |
|---|---|
| Resolution bandwidth: | 3 kHz |
| Video bandwidth: | 10 kHz |
| Frequency span: | 5 MHz |
| Detector mode: | Sample |
| Trace mode: | Power averaging |
| Averaging sweeps number: | 100 |

### 8.5.4 Test data

***Table 8.5-1:*** *PSD measurements results for Ant0*

| Frequency, MHz | PSD, dBm/3 kHz | PSD limit, dBm/3 kHz | Margin, dB |
|---|---|---|---|
| 2402.00 | -0.99 | 8.00 | 8.99 |
| 2439.81 | -0.77 | 8.00 | 8.77 |
| 2475.63 | -1.26 | 8.00 | 9.26 |

***Table 8.5-2:*** *PSD measurements results for Ant1*

| Frequency, MHz | PSD, dBm/3 kHz | PSD limit, dBm/3 kHz | Margin, dB |
|---|---|---|---|
| 2402.00 | -1.48 | 8.00 | 9.48 |
| 2439.81 | -1.19 | 8.00 | 9.19 |
| 2475.63 | -1.27 | 8.00 | 9.27 |

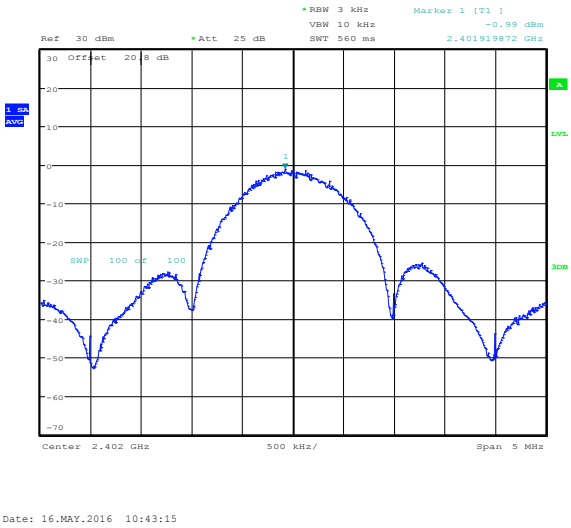



***Figure 8.5-1:*** *PSD sample plot on Ant0*

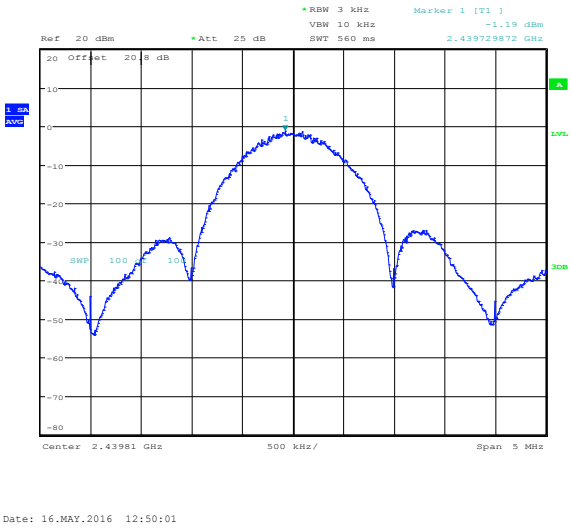
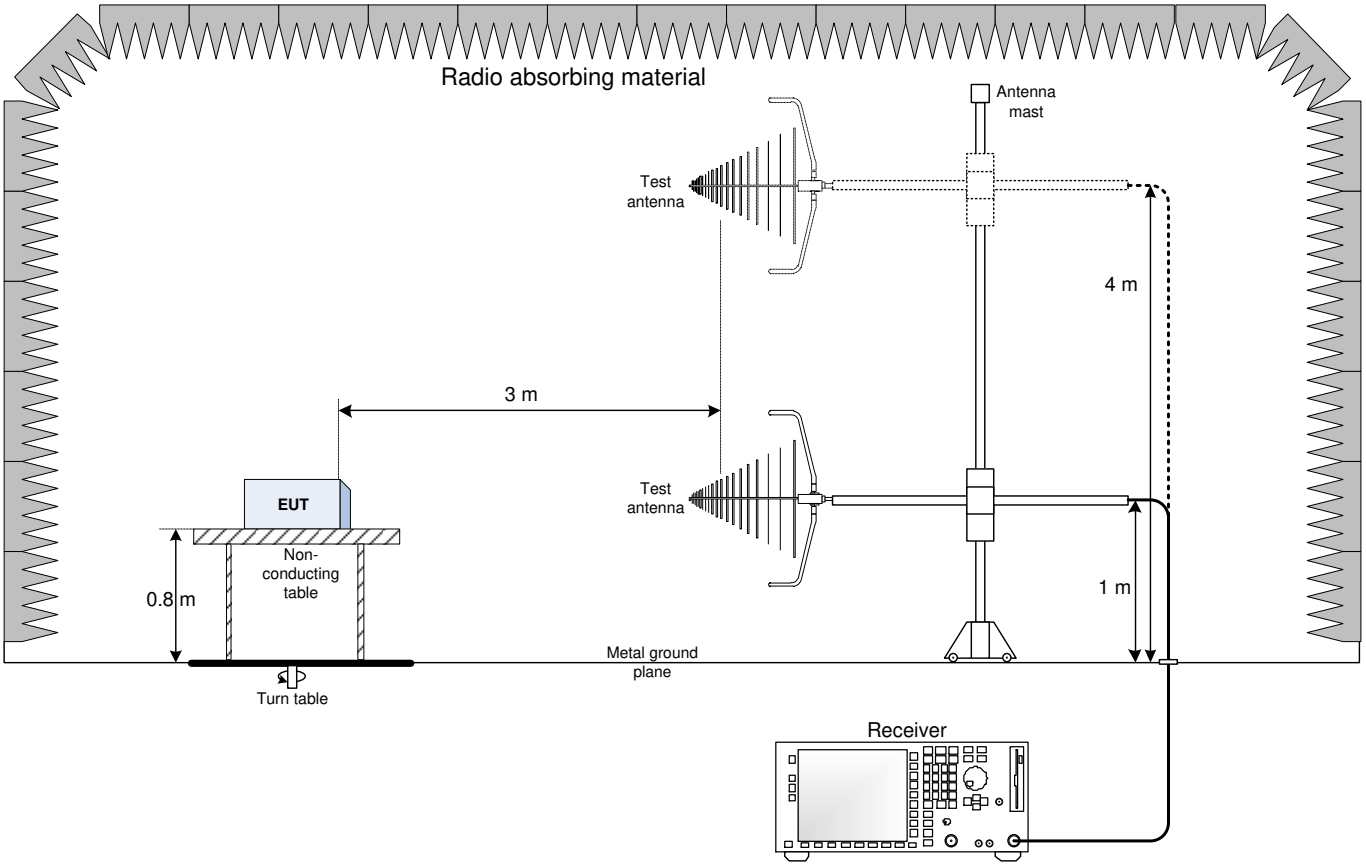


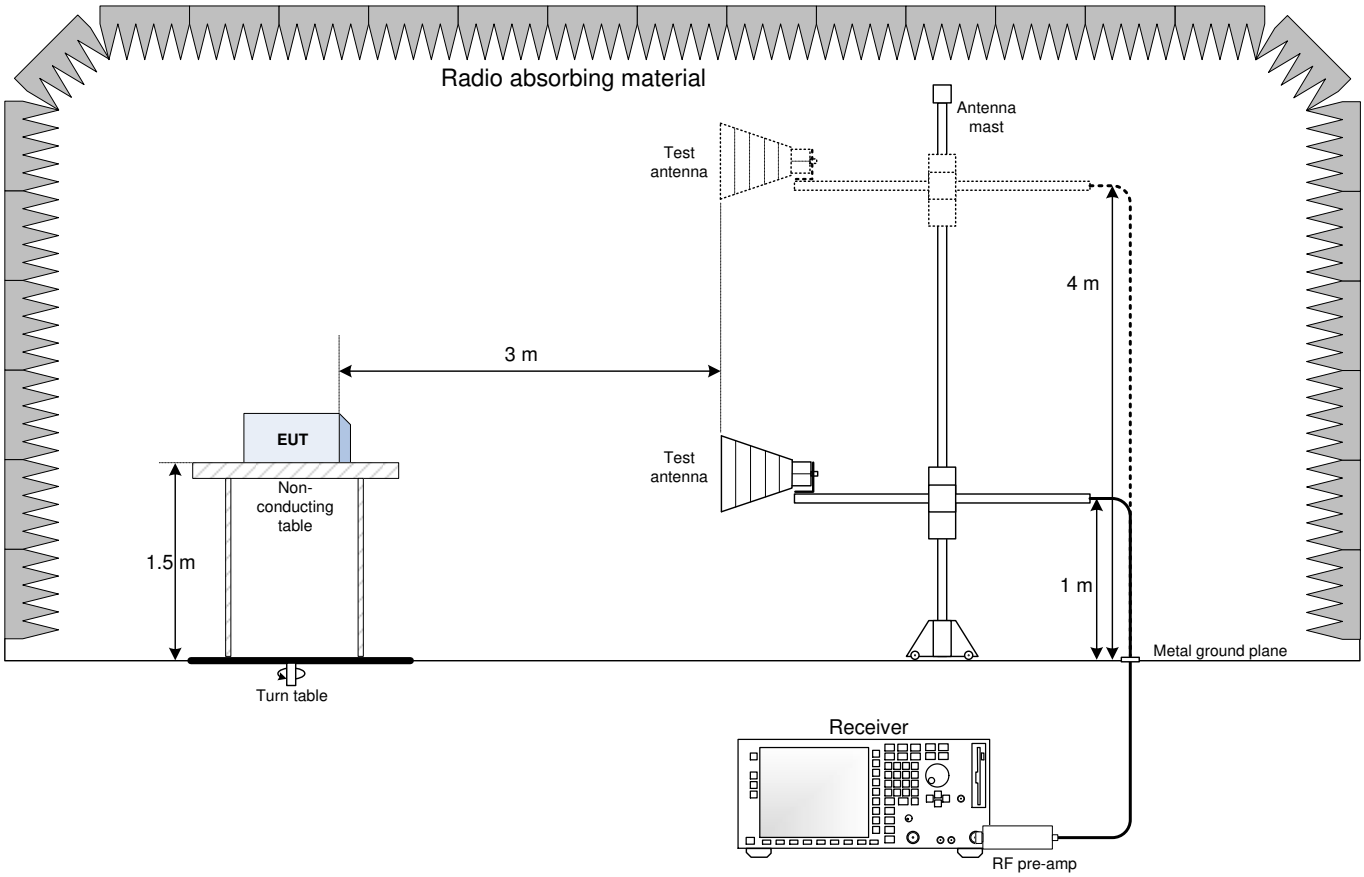

***Figure 8.5-2:*** *PSD sample plot on Ant1*

# **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 Conducted emissions set-up