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Wireless test report – 404987-2R1TRFWL

Applicant:

Eleven-X Inc.

Product type:

Parking Stall Sensor

Model:

PRK001001

FCC ID:

2A0X5PRK001001

IC Registration number:

22369-PRK001001

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: November 24, 2020

Mark Libbrecht, EMC Specialist	Mark Libbrecht
Tested by	Signature
Fahar A Sukkoor, EMC/Wireless Specialist	
Reviewed by	Signature

Nemko Canada Inc., a testing laboratory, is accredited by the Standards Council of Canada. The tests included in this report are within the scope of this accreditation

Test location(s)

Company name	Nemko Canada Inc.
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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.

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Section 1. Report summary

1.1 Applicant and manufacturer

Company name	Eleven-X Inc.
Address	375 Hagey Blvd., Suite 311
City	Waterloo
Province/State	Ontario
Postal/Zip code	N2L 6R5
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 5725–585 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 12, 2020	Original report issued
R1TRF	November 24, 2020	Update HVIN

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	Pass
§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 9, 2020
Nemko sample ID number	1

3.2 EUT information

Product type	Parking Stall Sensor
Model	PRK001001
Software Version	0.11.2
Model variant	1.0
Serial number	70B3B514900E0152

3.3 Technical information

Applicant IC company number	22369
IC UPN number	22369-PRK001001
All used IC test site(s) Reg. number	24676
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	0.0031 (4.9 dBm) 1 MHz BW @ 2480 MHz 0.0032 (5.0 dBm) 2 MHz BW @ 2436 MHz
Field strength, dBµV/m @ 3 m	N/A
Measured BW (kHz), 99% OBW	1042.8 (1 MHz BW) @ 2402 MHz 2067.3 (2 MHz BW) @ 2480 MHz
Type of modulation	BLE
Emission classification (F1D, G1D, D1D)	F1D
Transmitter spurious, dBµV/m @ 3 m	62.8 (peak) 41.6 (average) 1 MHz BW @ 2390 MHz 65.7 (peak) 45.1 (average) 2 MHz BW @ 2483.5 MHz
Power requirements	Battery: 3.6V non-rechargeable Lithium Thionyl Chloride D-Cell
Antenna information	Peak gain = -1 dBi

3.4 Product description and theory of operation

The eleven smart parking sensor is an innovative patent-pending LoRaWAN®-based device that utilizes multiple technologies including magnetic sensing, Radar, and Bluetooth: The sensor sends parking events over LoRaWAN to the eleven-x SPS analytics platform where the data provides key analytics and insight to help parking manager understand the usage of the parking assets.

3.5 EUT exercise details

EUT was set to transmit continuously at 100% duty cycle.

3.6 EUT setup diagram

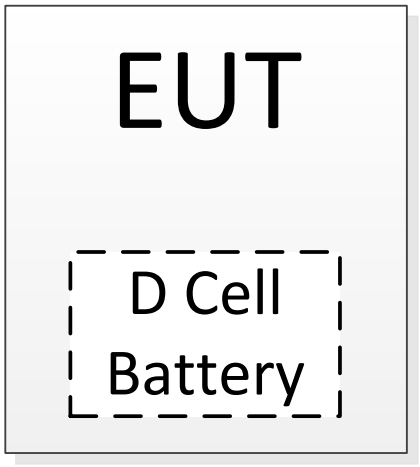

Figure 3.6-1: *Setup diagram*

3.7 EUT sub assemblies

Table 3.7-1: *EUT sub assemblies*

Description	Brand name	Model/Part number	Serial number
3.6 V_{DC} D Cell Battery	Tadiran	TL-4930	None

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.	Asset no.	Cal cycle	Next cal.
3 m EMI test chamber	TDK	SAC-3	FA003012	1 year	Oct. 10/21
Flush mount turntable	SUNAR	FM2022	FA003006	—	NCR
Controller	SUNAR	SC110V	FA002976	—	NCR
Antenna mast	SUNAR	TLT2	FA003007	—	NCR
Receiver/spectrum analyzer	Rohde & Schwarz	ESR26	FA002969	1 year	Dec. 4/20
Spectrum analyzer	Rohde & Schwarz	FSW43	FA002971	1 year	June 21/21
Horn antenna (1–18 GHz)	ETS Lindgren	3117	FA002911	1 year	Sept. 11/21
Preamp (1–18 GHz)	ETS Lindgren	124334	FA002956	1 year	Mar. 18/21
Bilog antenna (30–2000 MHz)	SUNAR	JB1	FA003010	1 year	Sept. 17/21
Horn antenna (18–40 GHz)	EMCO	3116B	FA002948	1 year	Jan. 9/21
50 Ω coax cable	Huber + Suhner	None	FA003047	1 year	Sept. 30/21
50 Ω coax cable	Huber + Suhner	None	FA003044	1 year	Oct. 7/21
Notch filter 2.4 – 2.4835 GHz	Microwave circuits	N0324413	FA003027	1 year	Oct. 8/21

Note: NCR - no calibration required

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 9, 2020

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 9, 2020

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, 1 MHz BW*

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	2436	2480

Table 8.2-3: *Test channels selection, 2 MHz BW*

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	2436	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 9, 2020

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 13, 2020

8.4.2 Observations, settings and special notes

The test was performed as per with reference to ANSI C63.10 subclause 6.9.
Spectrum analyser settings:

Analyzer settings used for 6 dB bandwidth measurements

Resolution bandwidth	100 kHz
Video bandwidth	≥3 × RBW
Frequency span	2 – 5 × OBW
Detector mode	Peak
Trace mode	Max Hold

Analyzer settings used for 99% Occupied bandwidth measurements

Resolution bandwidth	1 – 5 % OBW
Video bandwidth	≥3 × RBW
Frequency span	2 – 5 × OBW
Detector mode	Peak
Trace mode	Max Hold

8.4.3 Test data

Table 8.4-1: *6 dB bandwidth results, 1 MHz BW*

Frequency, MHz	6 dB bandwidth, kHz	Minimum limit, kHz	Margin, kHz
2402	786	500	286
2436	788	500	288
2480	782	500	282

Table 8.4-2: *6 dB bandwidth results, 2 MHz BW*

Frequency, MHz	6 dB bandwidth, kHz	Minimum limit, kHz	Margin, kHz
2402	1310	500	810
2436	1330	500	830
2480	1640	500	1140

Table 8.4-3: *99% Occupied bandwidth results, 1 MHz BW*

Frequency, MHz	99% Occupied bandwidth, kHz
2402	1042.8
2436	1039.3
2480	1039.3

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

Table 8.4-4: *99% Occupied bandwidth results, 2 MHz BW*

Frequency, MHz	99% Occupied bandwidth, kHz
2402	2066.1
2436	2065.5
2480	2067.3

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

8.4.4 Test data, continued

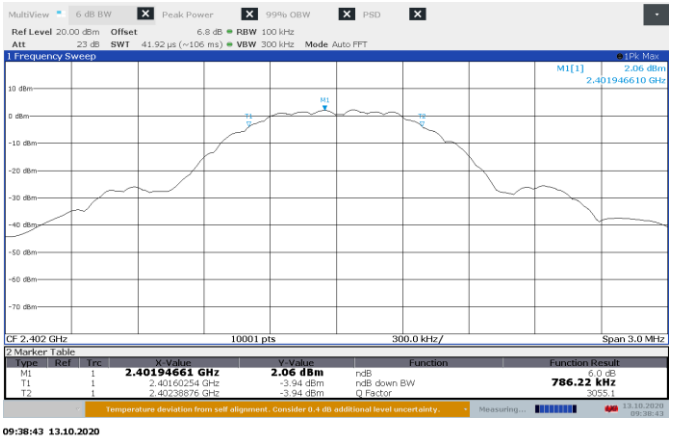

Figure 8.4-1: *6 dB bandwidth, low channel 1 MHz BW*

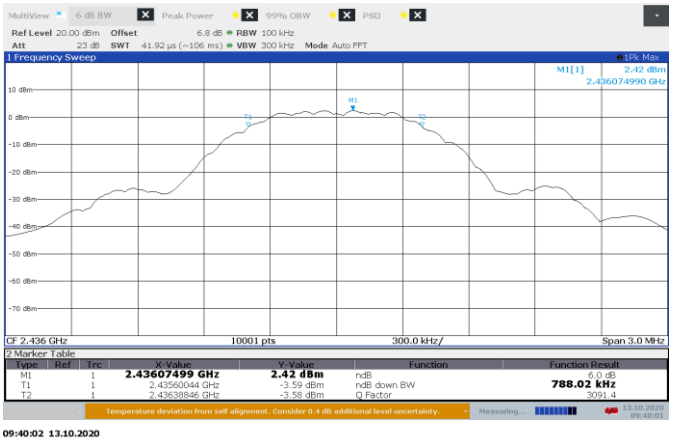

Figure 8.4-2: *6 dB bandwidth, mid channel 1 MHz BW*

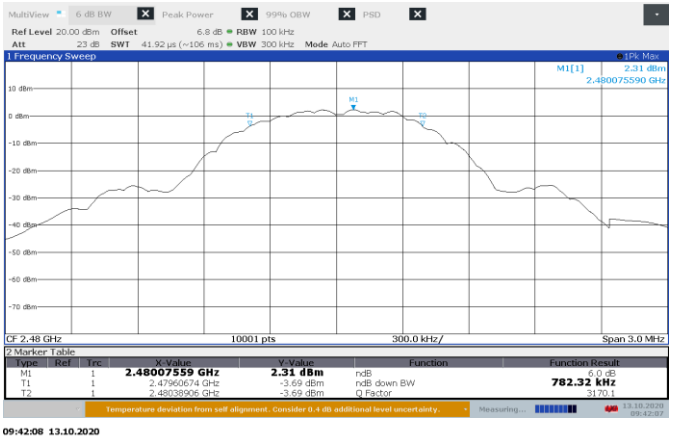

Figure 8.4-3: *6 dB bandwidth, high channel 1 MHz BW*

8.4.5 Test data, continued

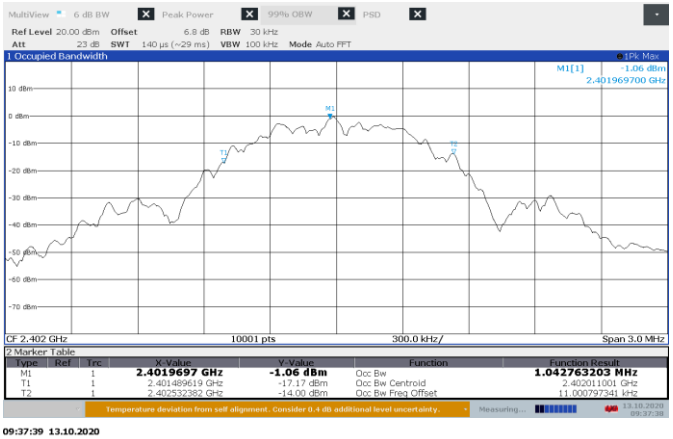

Figure 8.4-4: *99% Occupied bandwidth, low channel 1 MHz BW*

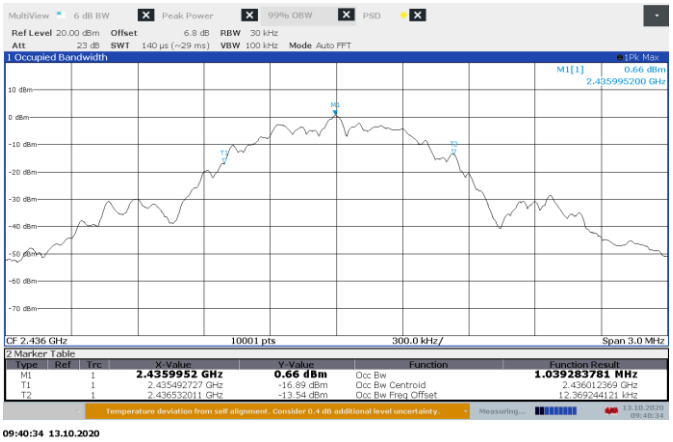

Figure 8.4-5: *99% Occupied bandwidth, mid channel 1 MHz BW*

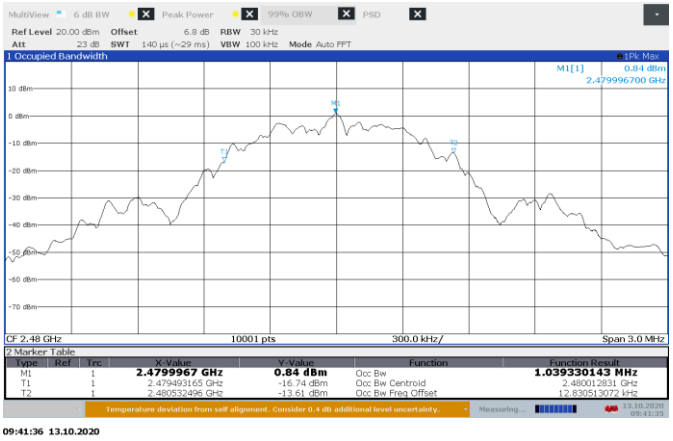

Figure 8.4-6: *99% Occupied bandwidth, high channel 1 MHz BW*

8.4.1 Test data, continued

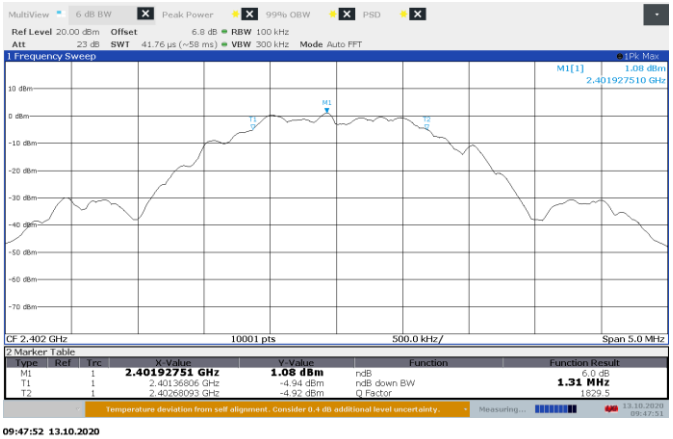

Figure 8.4-7: *6 dB bandwidth, low channel 2 MHz BW*

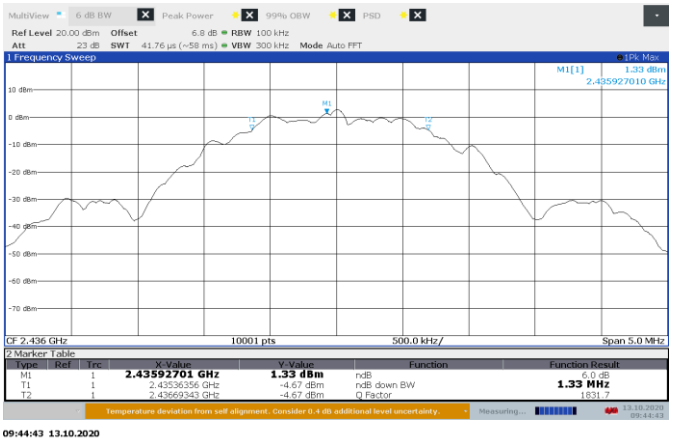

Figure 8.4-8: *6 dB bandwidth, mid channel 2 MHz BW*

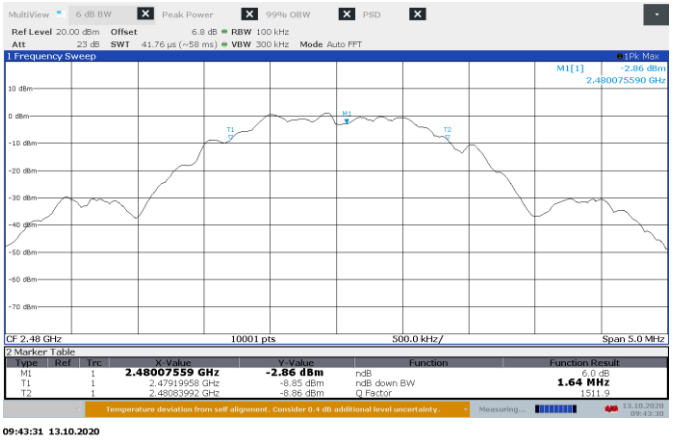

Figure 8.4-9: *6 dB bandwidth, high channel 2 MHz BW*

8.4.2 Test data, continued

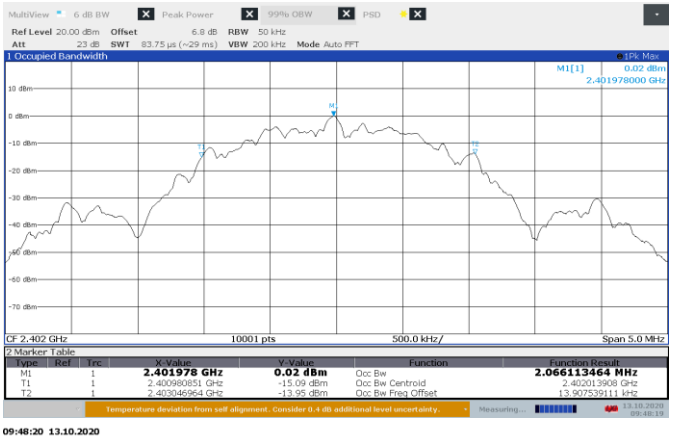

Figure 8.4-10: *99% Occupied bandwidth, low channel 2 MHz BW*

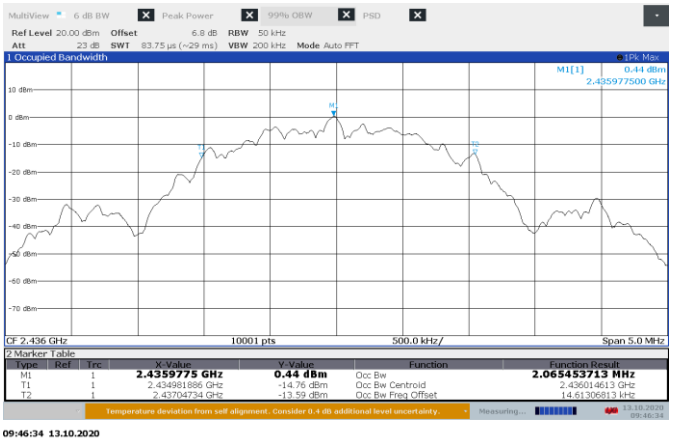

Figure 8.4-11: *99% Occupied bandwidth, mid channel 2 MHz BW*

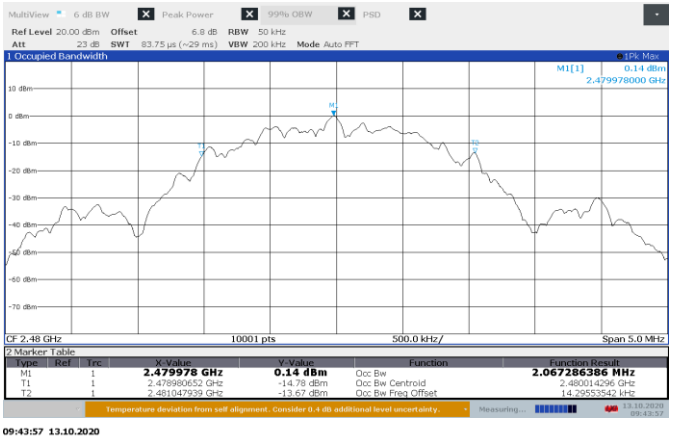

Figure 8.4-12: *99% Occupied bandwidth, high channel 2 MHz BW*

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).

8.5.2 Test date

Start date	October 13, 2020

8.5.3 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)
Reported EUT antenna peak gain = -1 dBi. Per ANSI 63.10 (2013) clause 11.12.2.6 , 2 dBi gain used for all power calculations
The test was performed using method RBW≥DTS bandwidth (Maximum peak conducted output power)
Spectrum analyser settings:

Resolution bandwidth	≥ OBW
Video bandwidth	≥3 × RBW
Frequency span	2 – 5 × OBW
Detector mode	Peak
Trace mode	Max Hold

8.5.4 Test data

Table 8.5-1: *Output power measurements results, 1 MHz BW*

Frequency, MHz	Conducted output power, dBm		Margin, dB	Antenna gain, dBi	EIRP, dBm	EIRP limit, dBm	EIRP margin, dB
	Measured	Limit					
2402	4.7	30.0	25.3	2.0	6.7	36.0	29.3
2436	4.9	30.0	25.1	2.0	6.9	36.0	29.1
2480	4.9	30.0	25.1	2.0	6.9	36.0	29.1

Note: Additional 0.5 dB added to conducted output power measurements to account for UFL connector

Table 8.5-2: *Output power measurements results, 2 MHz BW*

Frequency, MHz	Conducted output power, dBm		Margin, dB	Antenna gain, dBi	EIRP, dBm	EIRP limit, dBm	EIRP margin, dB
	Measured	Limit					
2402	4.8	30.0	25.2	2.0	6.8	36.0	29.2
2436	5.0	30.0	25.0	2.0	7.0	36.0	29.0
2480	4.9	30.0	25.1	2.0	6.9	36.0	29.1

Note: Additional 0.5 dB added to conducted output power measurements to account for UFL connector

8.5.5 Test data, continued

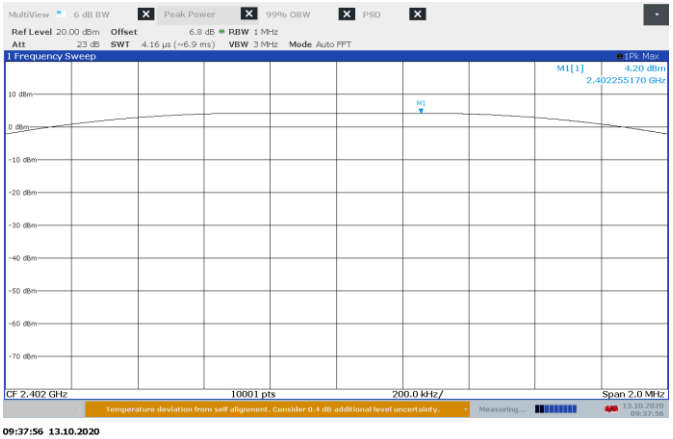

Figure 8.5-1: *Output power on low channel, 1 MHz BW*

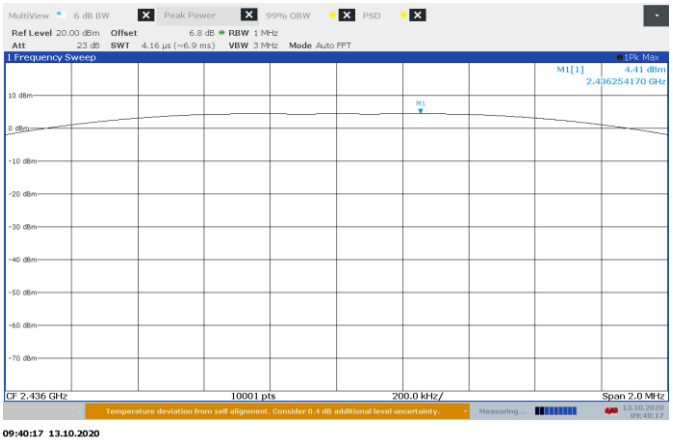

Figure 8.5-2: *Output power on mid channel, 1 MHz BW*

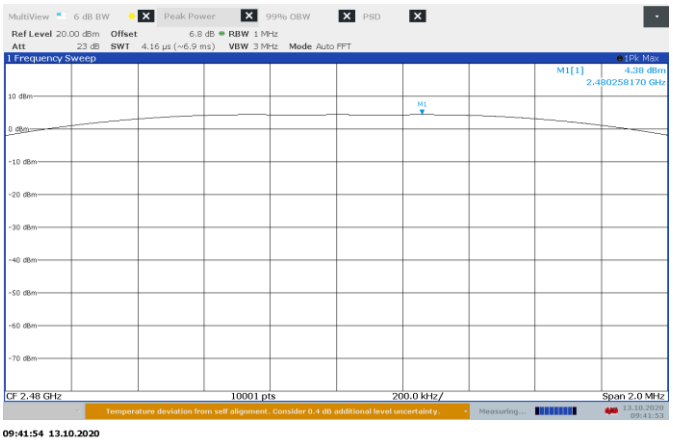

Figure 8.5-3: *Output power on high channel, 1 MHz BW*

8.5.1 Test data, continued

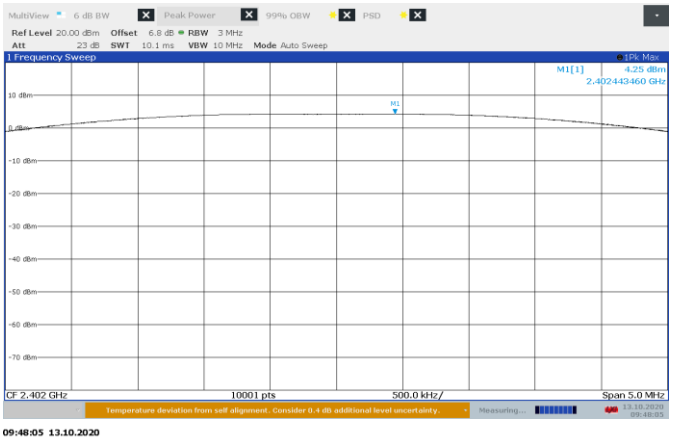

Figure 8.5-4: *Output power on low channel, 2 MHz BW*

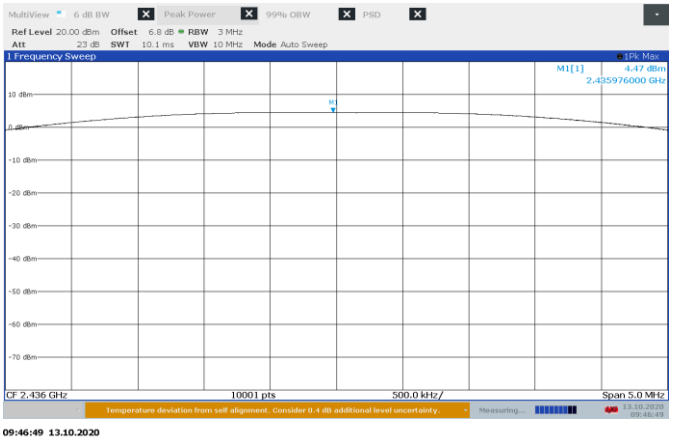

Figure 8.5-5: *Output power on mid channel, 2 MHz BW*

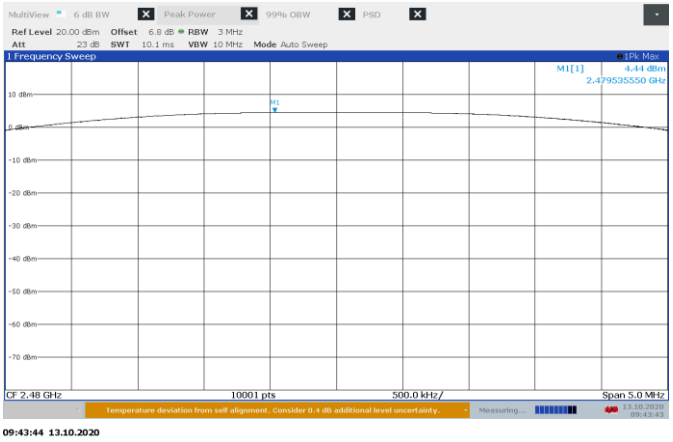

Figure 8.5-6: *Output power on high channel, 2 MHz BW*

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 µV/m	dBµV/m	Measurement distance, 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			

8.6.2 Test date

Start date	October 13, 2020

8.6.3 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 30 MHz – 18 GHz were performed at a distance of 3 m
Radiated measurements 18 - 25 GHz were performed at a distance of 1 m
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:	3 MHz
Detector mode:	RMS
Trace mode:	Average
Trace counts:	1000

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 restricted band edge field strength measurement, 1 MHz BW*

Channel	Frequency, MHz	Peak Field strength, dBµV/m		Margin, dB	Average Field strength, dBµV/m		Margin, dB
		Measured	Limit		Measured	Limit	
Low	2390.0	62.8	74.0	11.2	41.6	54.0	12.4
High	2483.5	62.6	74.0	11.4	41.9	54.0	21.1

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

Table 8.6-5: *Radiated restricted band edge field strength measurement, 2 MHz BW*

Channel	Frequency, MHz	Peak Field strength, dBµV/m		Margin, dB	Average Field strength, dBµV/m		Margin, dB
		Measured	Limit		Measured	Limit	
Low	2390.0	55.6	74.0	18.4	44.7	54.0	9.3
High	2483.5	65.7	74.0	8.3	45.1	54.0	8.9

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

8.6.5 Test data, continued

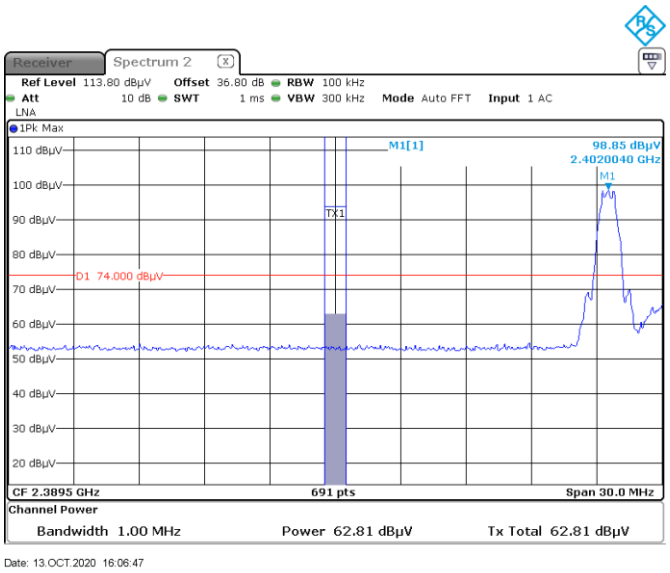

Figure 8.6-1: *Restricted Band Edge Emissions, low channel 1 MHz BW, Peak*

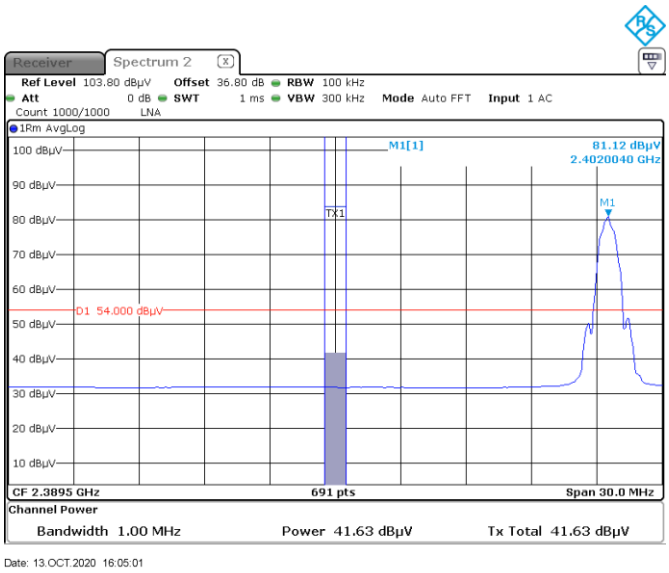

Figure 8.6-2: *Restricted Band Edge Emissions, low channel 1 MHz BW, Average*

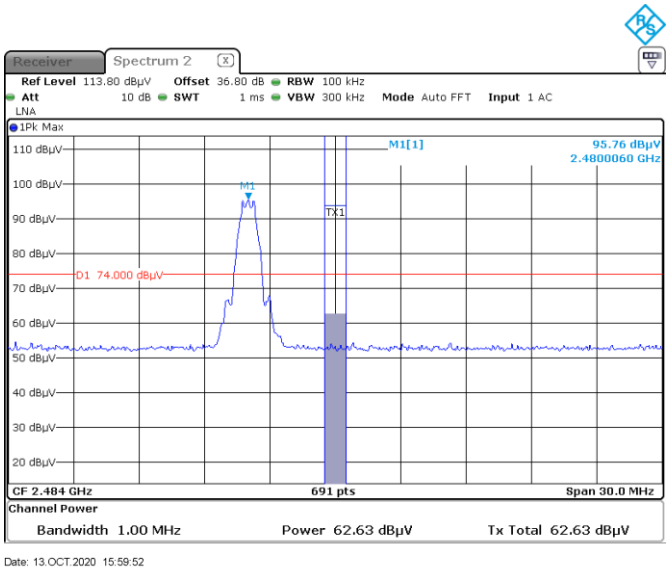

Figure 8.6-3: *Restricted Band Edge Emissions, high channel 1 MHz BW, Peak*

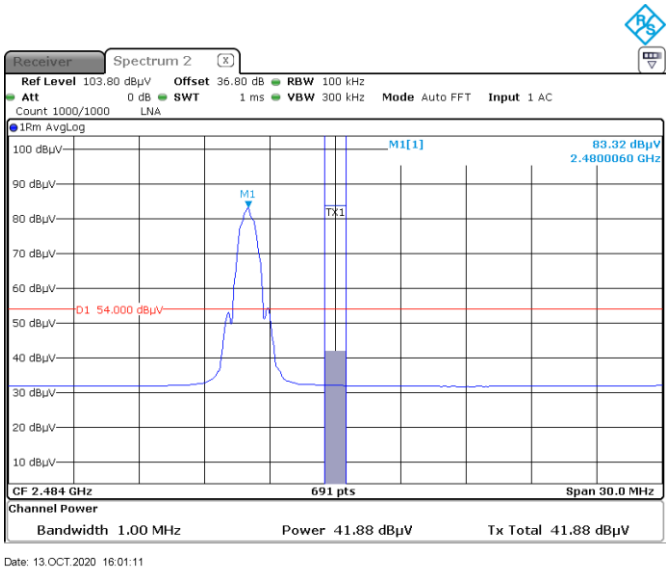

Figure 8.6-4: *Restricted Band Edge Emissions, high channel 1 MHz BW, Average*

8.6.1 Test data, continued

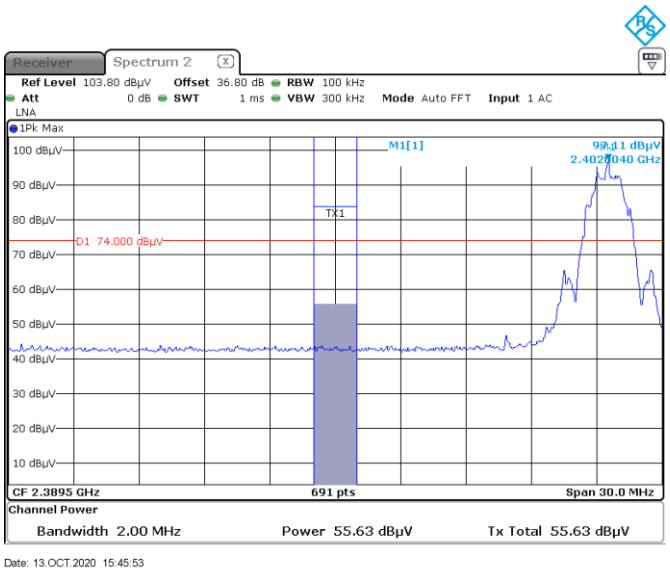

Figure 8.6-5: *Restricted Band Edge Emissions, low channel 2 MHz BW, Peak*

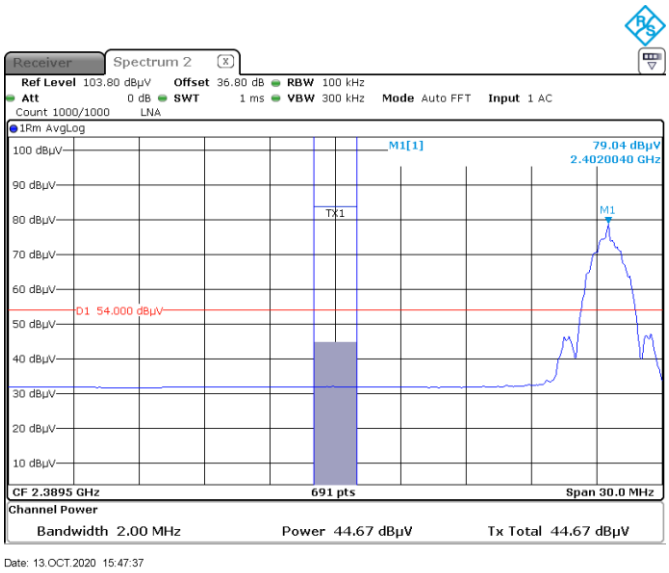

Figure 8.6-6: *Restricted Band Edge Emissions, low channel 2 MHz BW, Average*

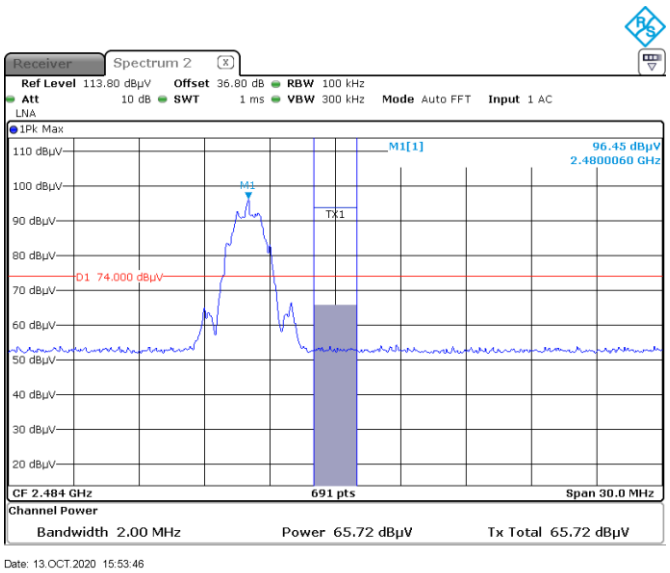

Figure 8.6-7: *Restricted Band Edge Emissions, high channel 2 MHz BW, Peak*

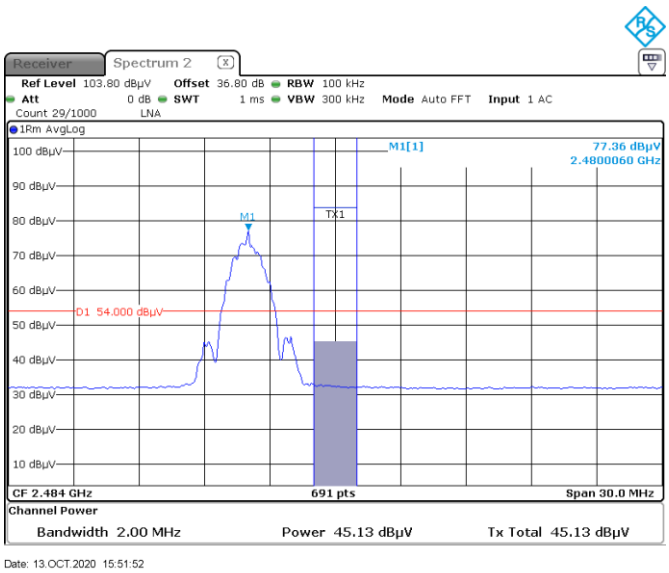

Figure 8.6-8: *Restricted Band Edge Emissions, high channel 2 MHz BW, Average*

8.6.2 Test data, continued

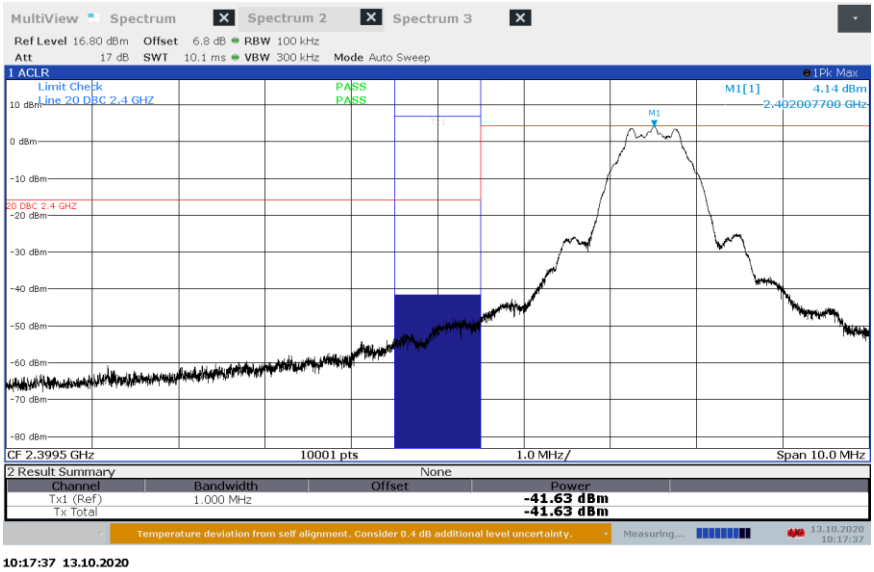

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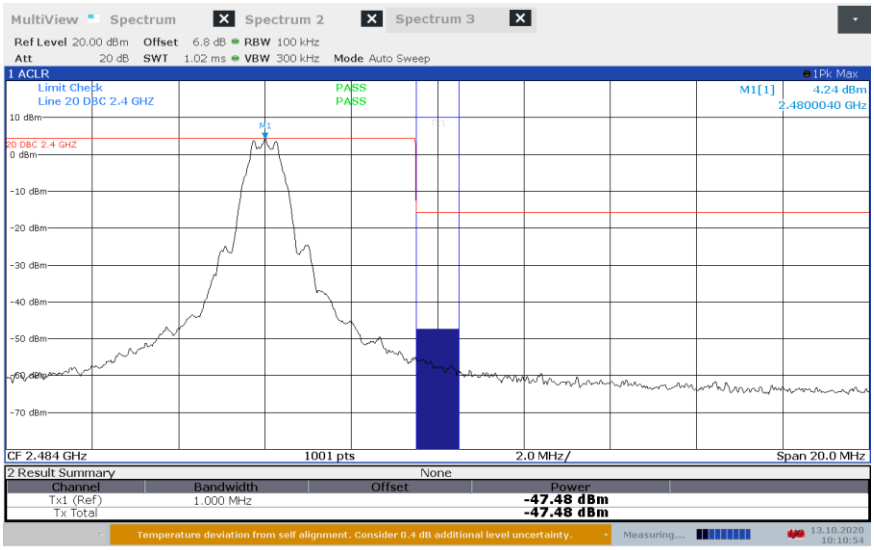
Figure 8.6-9: *Conducted Band Edge Emissions, low channel 1 MHz BW*



10:10:55 13.10.2020

Figure 8.6-10: *Conducted Band Edge Emissions, high channel 1 MHz BW*

8.6.1 Test data, continued

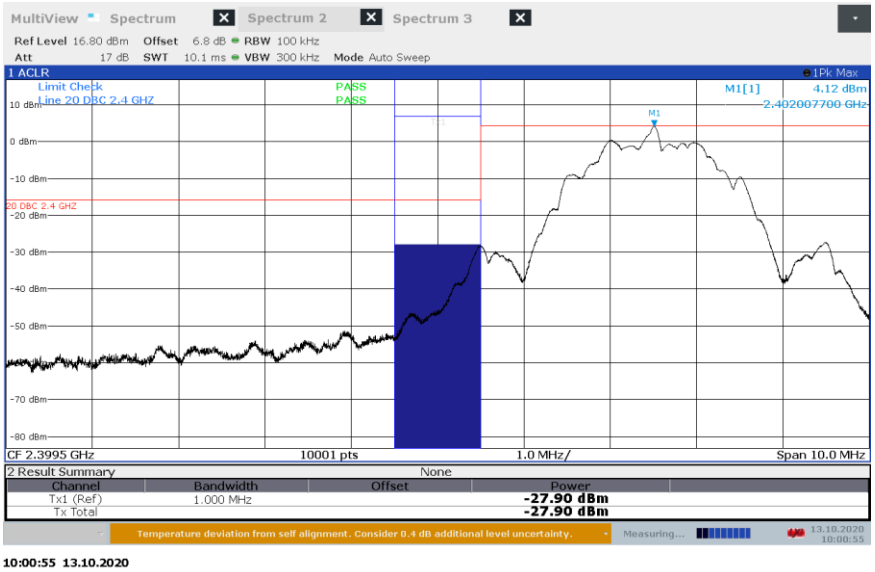


Figure 8.6-11: *Conducted Band Edge Emissions, low channel 2 MHz BW*

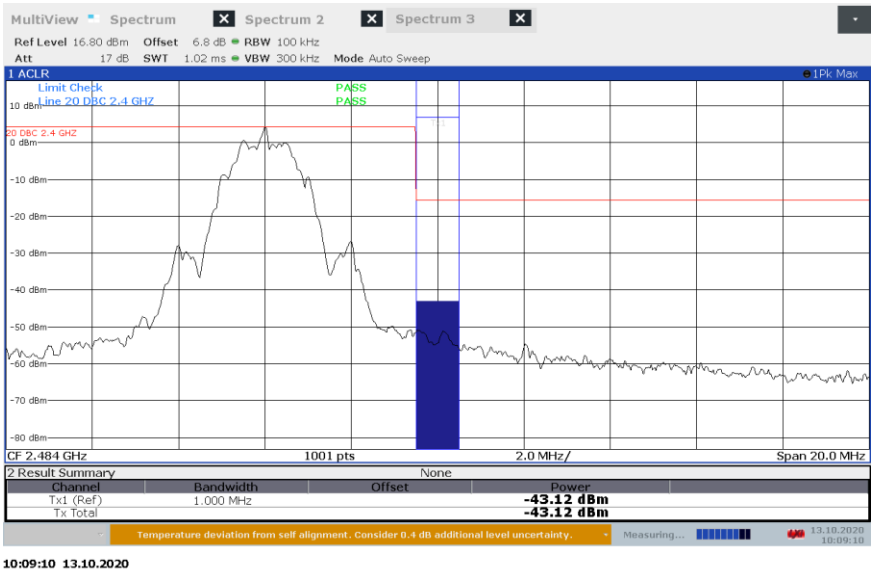


Figure 8.6-12: *Conducted Band Edge Emissions, high channel 2 MHz BW*

8.6.2 Test data, continued

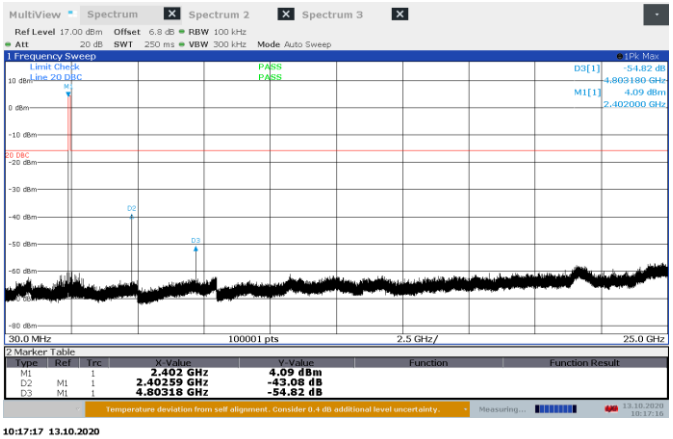


Figure 8.6-13: *Conducted Spurious Emissions, low channel 1 MHz BW*

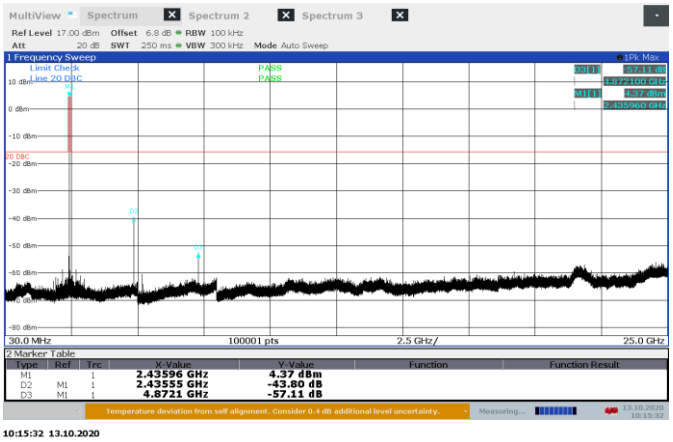


Figure 8.6-14: *Conducted Spurious Emissions, mid channel 1 MHz BW*

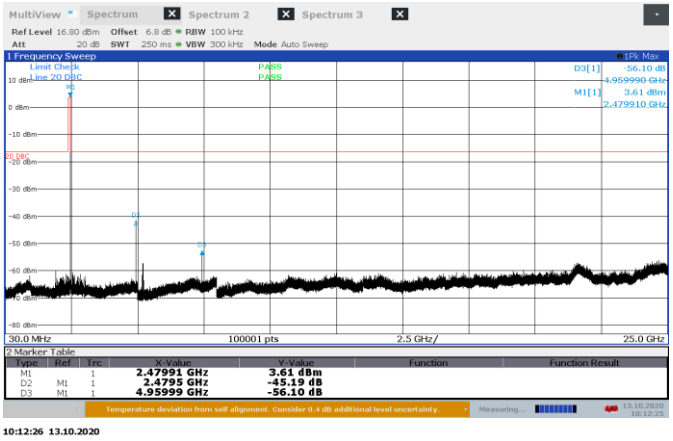


Figure 8.6-15: *Conducted Spurious Emissions, high channel 1 MHz BW*

8.6.1 Test data, continued

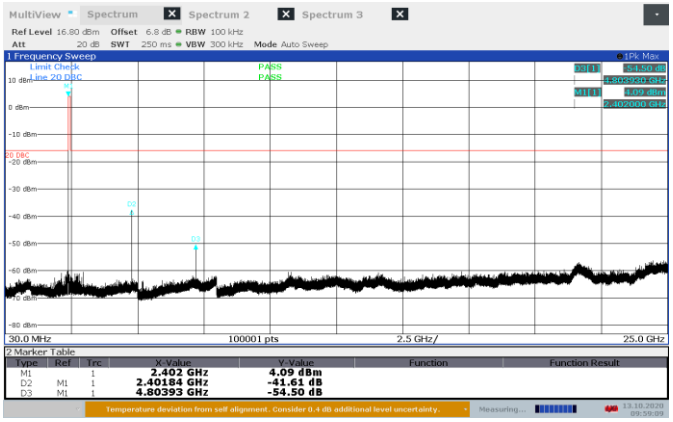


Figure 8.6-16: *Conducted Spurious Emissions, low channel 2 MHz BW*

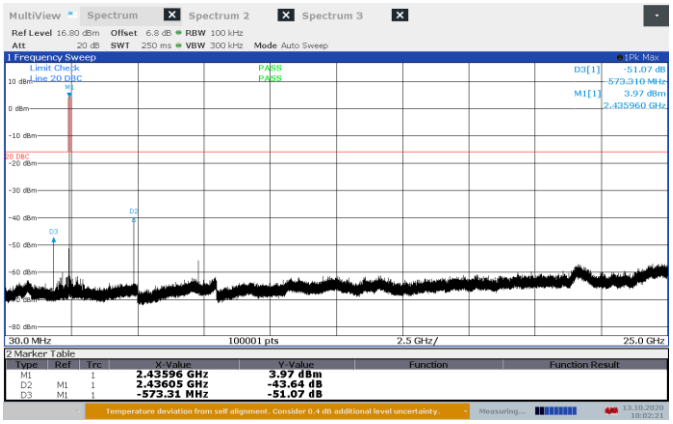


Figure 8.6-17: *Conducted Spurious Emissions, mid channel 2 MHz BW*

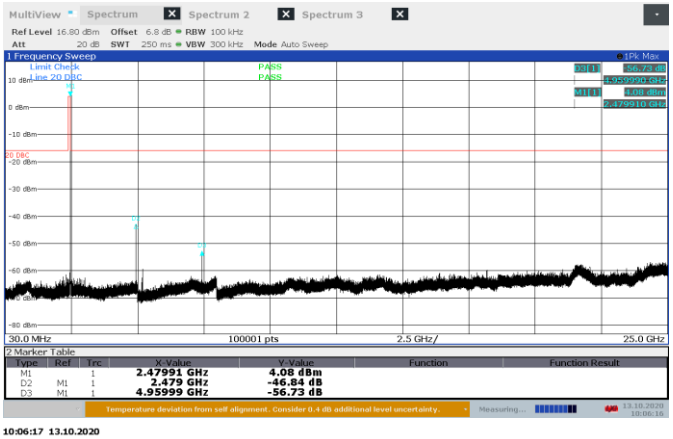


Figure 8.6-18: *Conducted Spurious Emissions, high channel 2 MHz BW*

8.6.2 Test data, continued

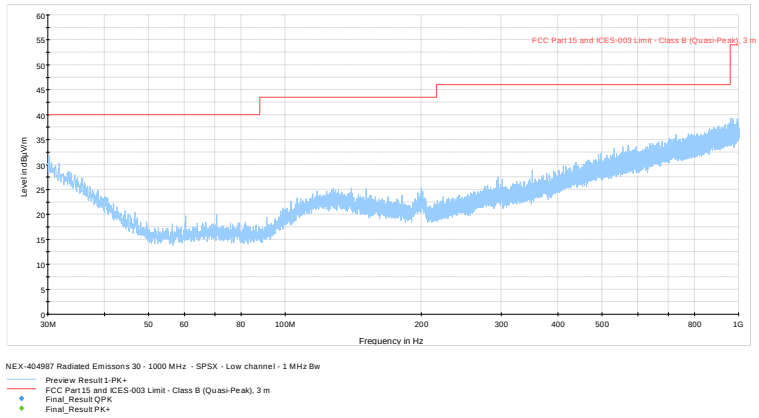


Figure 8.6-19: *Radiated Spurious Emissions 30 MHz – 1 GHz, low channel 1 MHz BW*

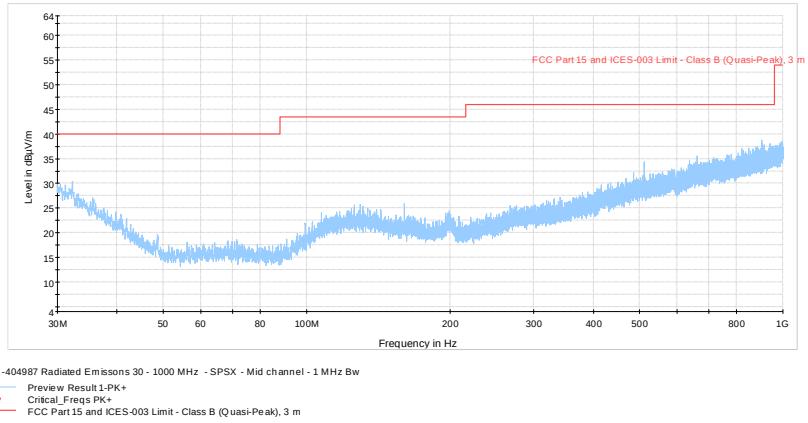


Figure 8.6-20: *Radiated Spurious Emissions 30 MHz – 1 GHz, mid channel 1 MHz BW*

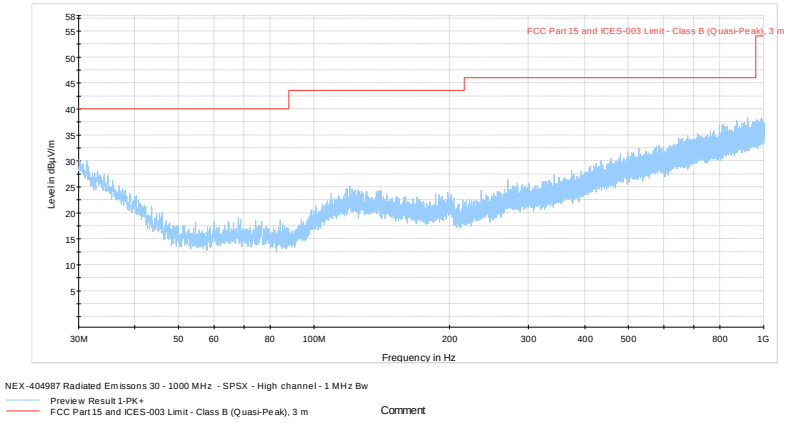


Figure 8.6-21: *Radiated Spurious Emissions 30 MHz – 1 GHz, high channel 1 MHz BW*

8.6.3 Test data, continued

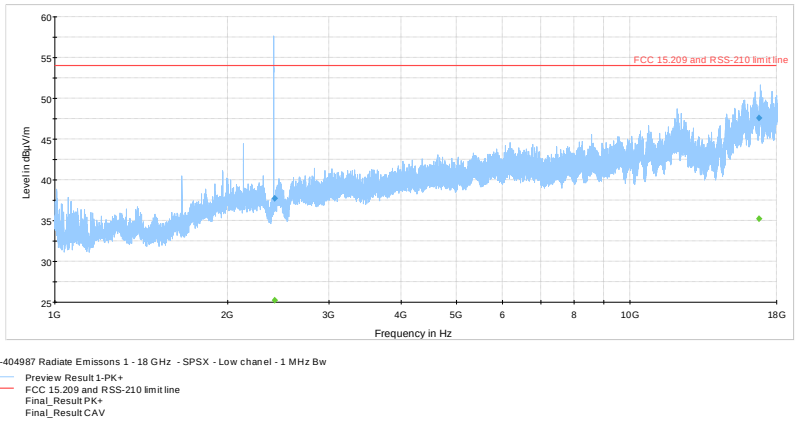


Figure 8.6-22: *Radiated Spurious Emissions 1 - 18 GHz, low channel 1 MHz BW*

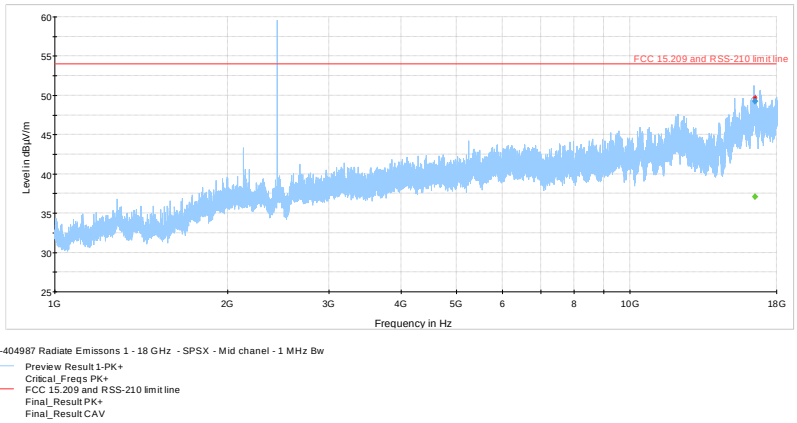


Figure 8.6-23: *Radiated Spurious Emissions 1 - 18 GHz, mid channel 1 MHz BW*

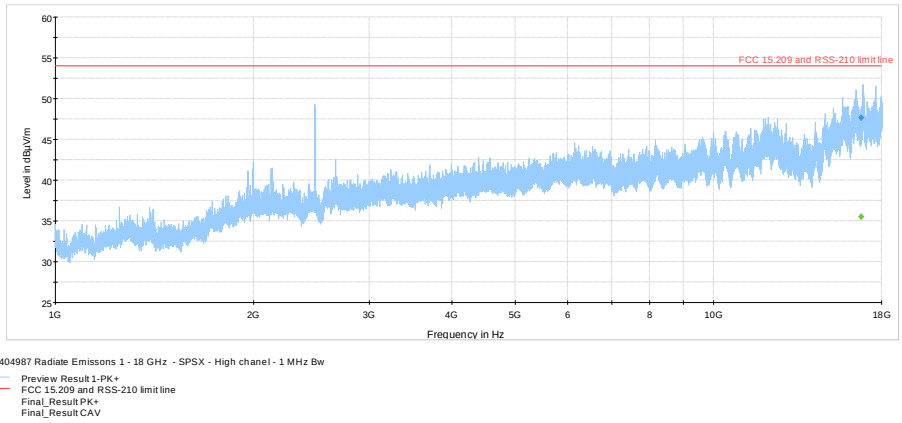


Figure 8.6-24: *Radiated Spurious Emissions 1 - 18 GHz, high channel 1 MHz BW*

8.6.4 Test data, continued

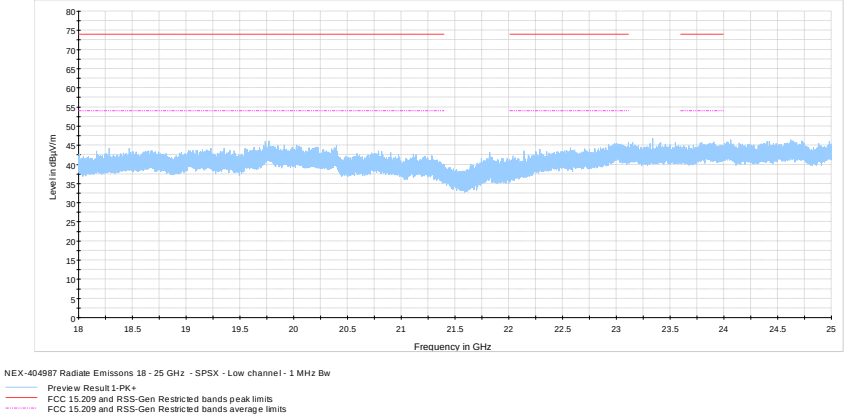


Figure 8.6-25: *Radiated Spurious Emissions 18 - 25 GHz, low channel 1 MHz BW*

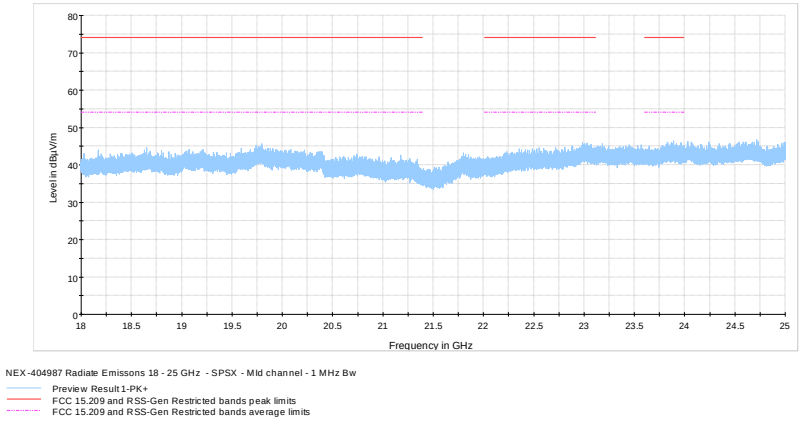


Figure 8.6-26: *Radiated Spurious Emissions 18 - 25 GHz, mid channel 1 MHz BW*

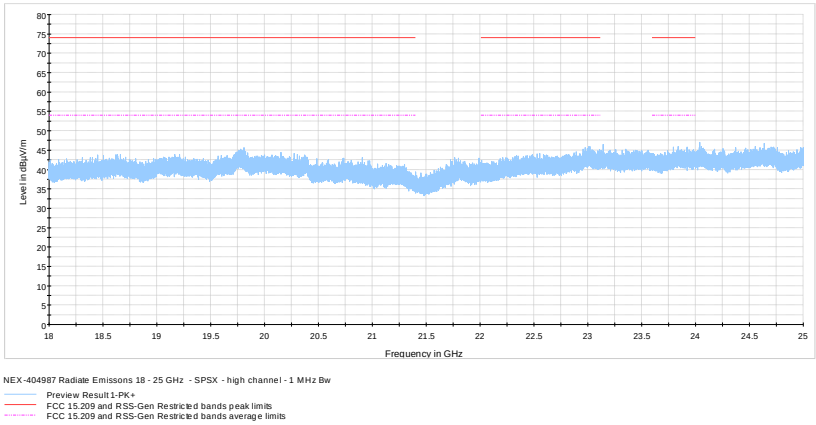
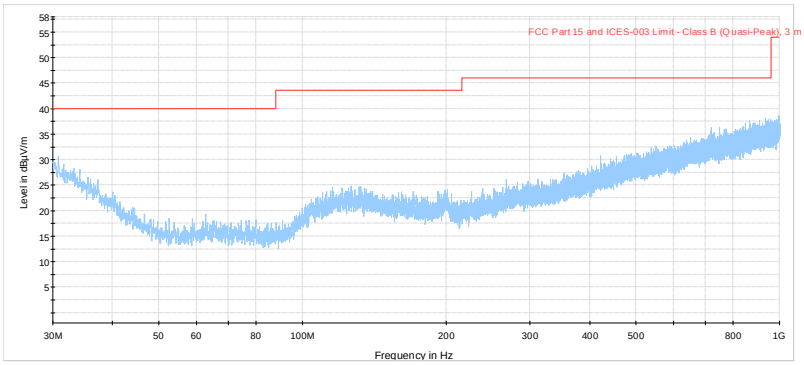


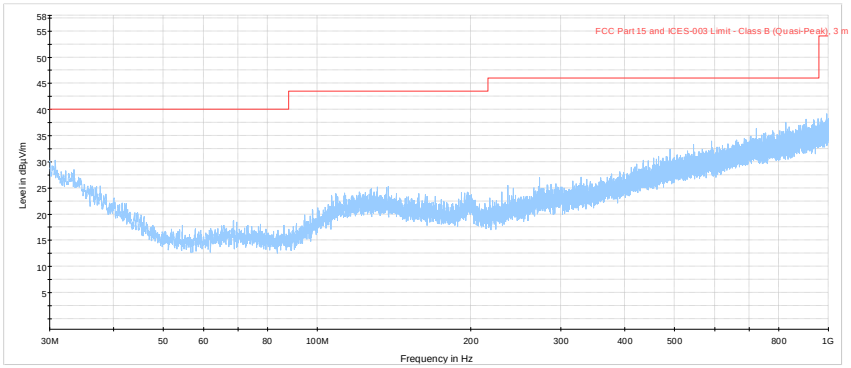
Figure 8.6-27: *Radiated Spurious Emissions 18 - 25 GHz, high channel 1 MHz BW*

8.6.1 Test data, continued



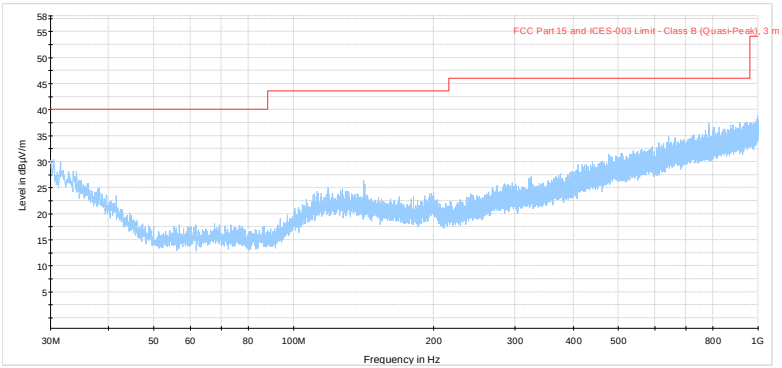
NEX-404987 Radiated Emissons 30 - 1000 MHz - SPSX - Low channel - 2 MHz Bw
Preview Result 1-PK+
FCC Part 15 and ICES-003 Limit - Class B (Quasi-Peak), 3 m

Figure 8.6-28: *Radiated Spurious Emissions 30 MHz – 1 GHz, low channel 2 MHz BW*



NEX-404987 Radiated Emissons 30 - 1000 MHz - SPSX - Mid channel - 2 MHz Bw
Preview Result 1-PK+
FCC Part 15 and ICES-003 Limit - Class B (Quasi-Peak), 3 m

Figure 8.6-29: *Radiated Spurious Emissions 30 MHz – 1 GHz, mid channel 2 MHz BW*



NEX-404987 Radiated Emissons 30 - 1000 MHz - SPSX - High channel - 2 MHz Bw
Preview Result 1-PK+
FCC Part 15 and ICES-003 Limit - Class B (Quasi-Peak), 3 m

Figure 8.6-30: *Radiated Spurious Emissions 30 MHz – 1 GHz, high channel 2 MHz BW*

8.6.2 Test data, continued

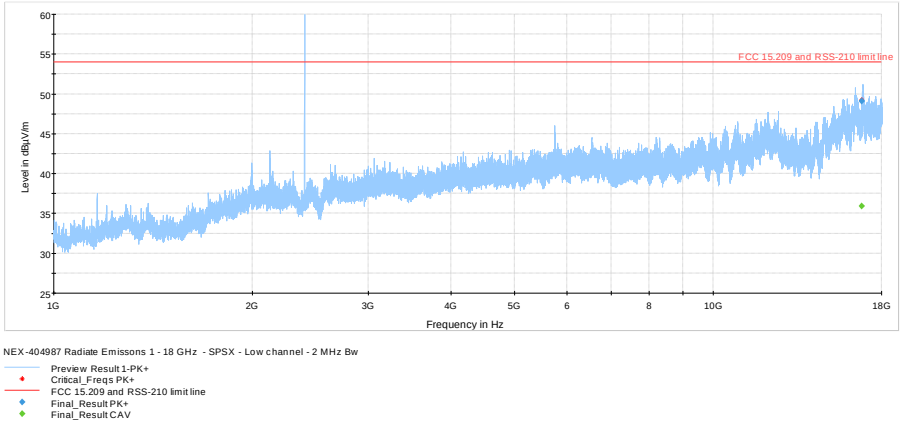


Figure 8.6-31: *Radiated Spurious Emissions 1 - 18 GHz, low channel 2 MHz BW*

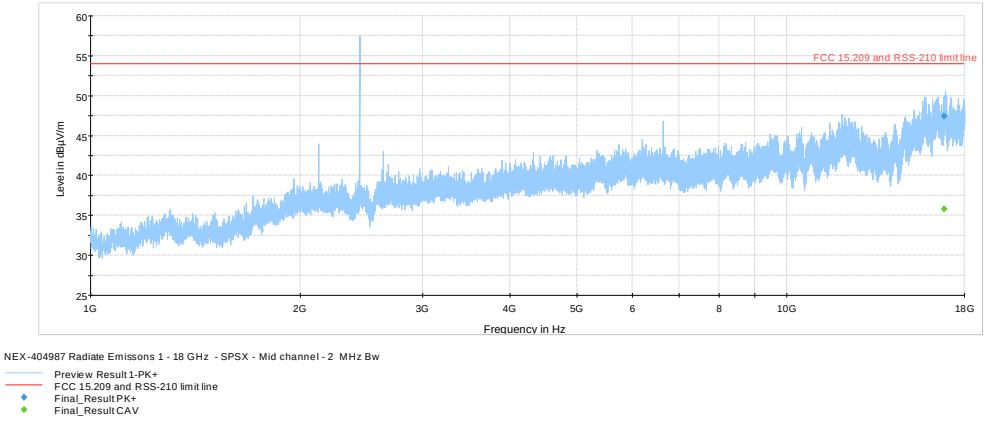


Figure 8.6-32: *Radiated Spurious Emissions 1 - 18 GHz, mid channel 2 MHz BW*

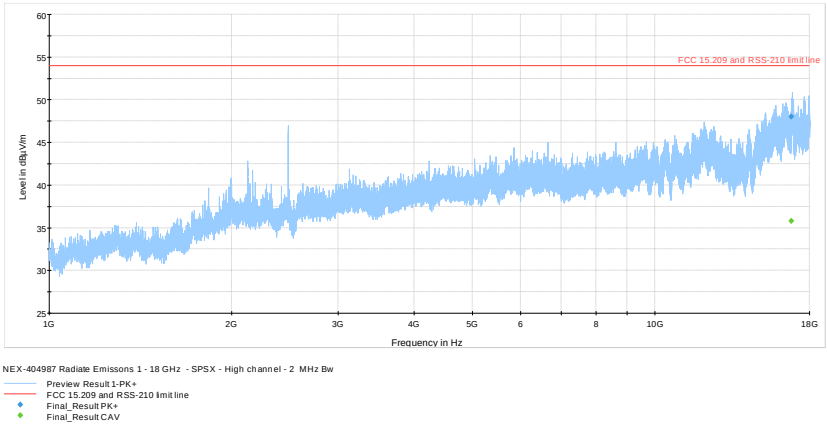


Figure 8.6-33: *Radiated Spurious Emissions 1 - 18 GHz, high channel 2 MHz BW*

8.6.3 Test data, continued

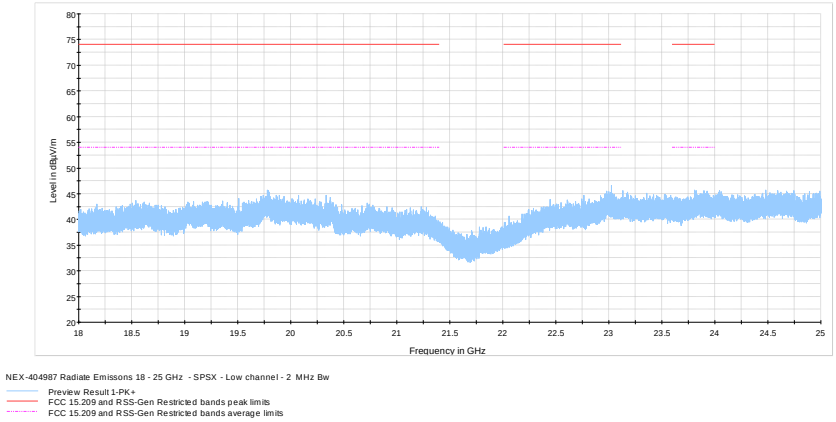


Figure 8.6-34: *Radiated Spurious Emissions 18 - 25 GHz, low channel 2 MHz BW*

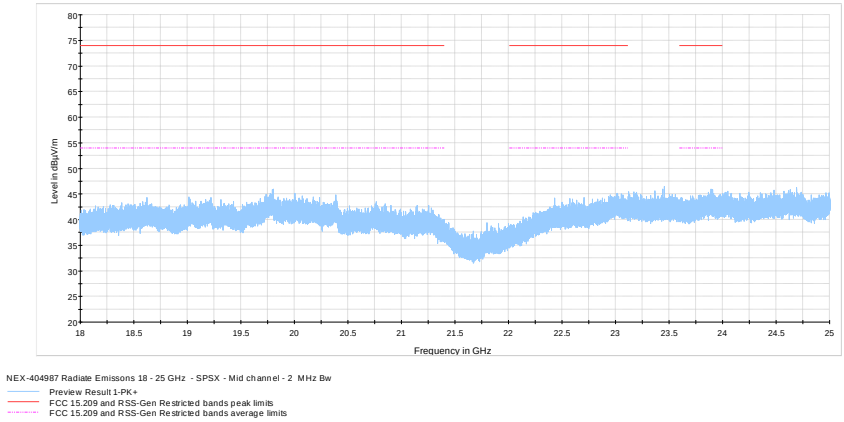


Figure 8.6-35: *Radiated Spurious Emissions 18 - 25 GHz, mid channel 2 MHz BW*

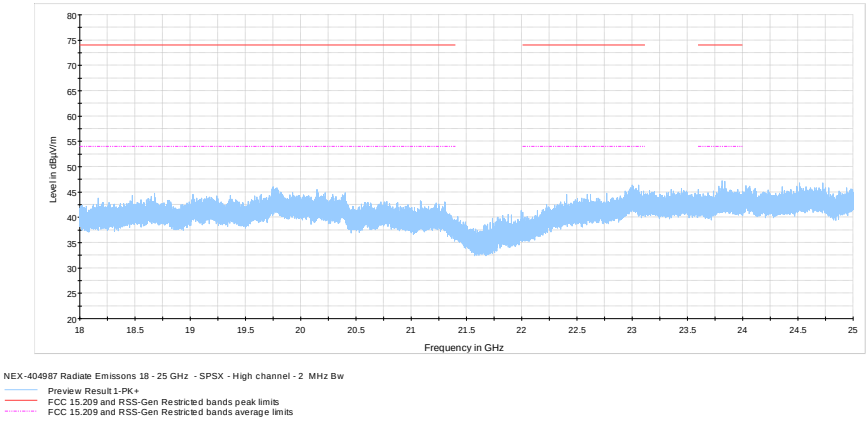


Figure 8.6-36: *Radiated Spurious Emissions 18 - 25 GHz, high channel 2 MHz BW*

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.

8.7.2 Test date

Start date	October 13, 2020

8.7.3 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

8.7.4 Test data

Table 8.7-1: *PSD measurements results, 1 MHz BW*

Frequency, MHz	PSD, dBm/3 kHz	PSD limit, dBm/3 kHz	Margin, dB
2402	-12.6	8.0	20.6
2436	-12.3	8.0	20.3
2480	-12.5	8.0	20.5

Note: Additional 0.5 dB added to conducted PSD measurements to account for UFL connector

Table 8.7-2: *PSD measurements results, 2 MHz BW*

Frequency, MHz	PSD, dBm/3 kHz	PSD limit, dBm/3 kHz	Margin, dB
2402	-14.3	8.0	22.3
2436	-13.8	8.0	21.8
2480	-13.9	8.0	21.9

Note: Additional 0.5 dB added to conducted PSD measurements to account for UFL connector

8.7.5 Test data, continued

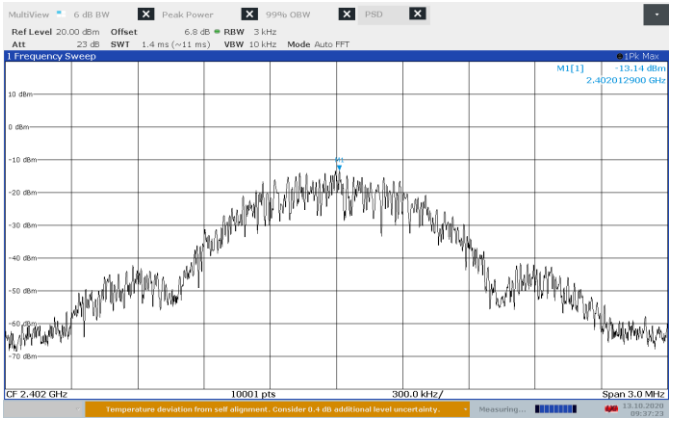


Figure 8.7-1: *PSD on low channel, 1 MHz BW*

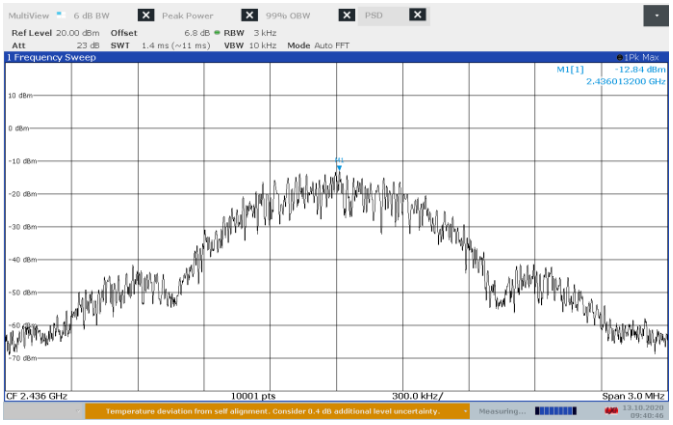


Figure 8.7-2: *PSD on mid channel, 1 MHz BW*

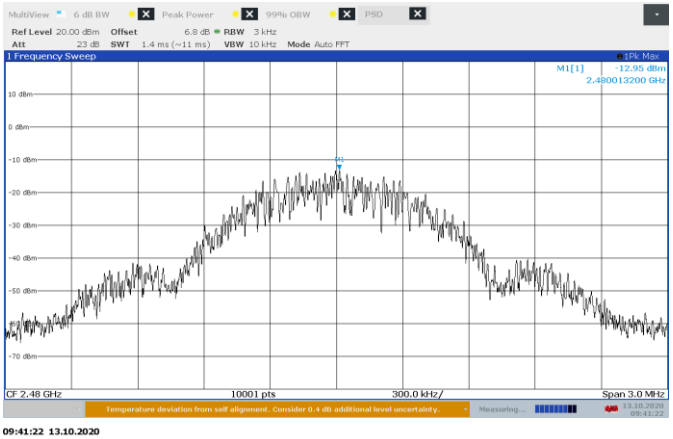


Figure 8.7-3: *PSD on high channel, 1 MHz BW*

8.7.1 Test data, continued

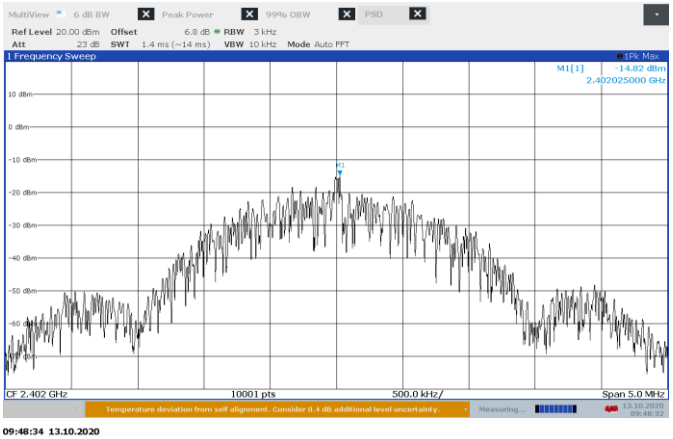


Figure 8.7-4: *PSD on low channel, 2 MHz BW*

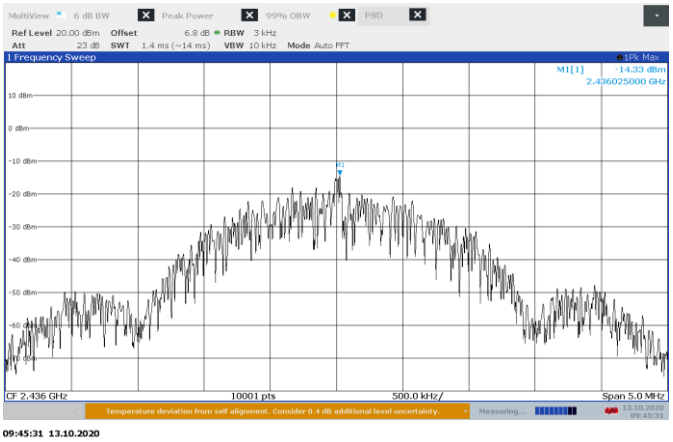


Figure 8.7-5: *PSD on mid channel, 2 MHz BW*

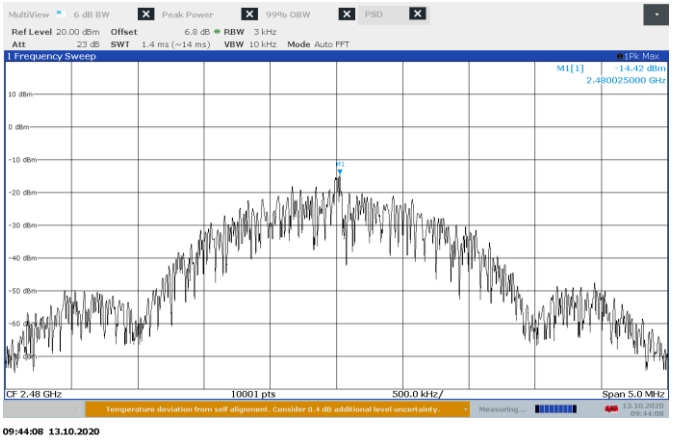
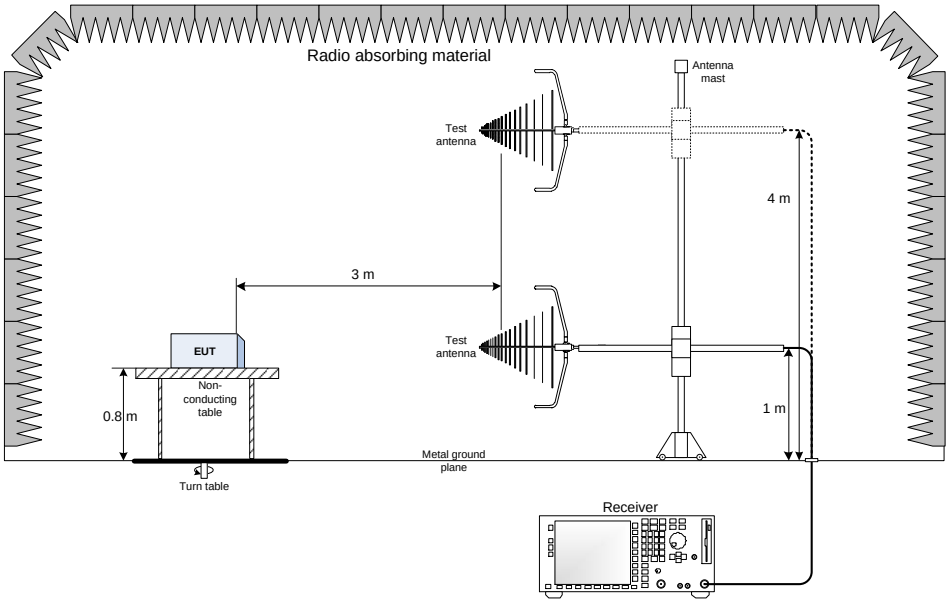


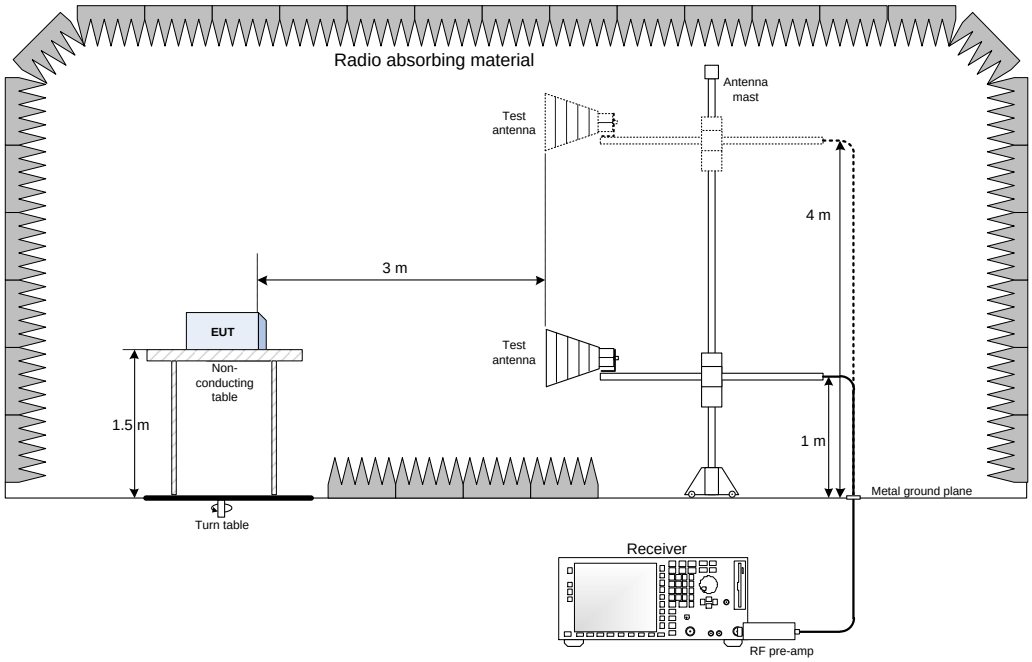
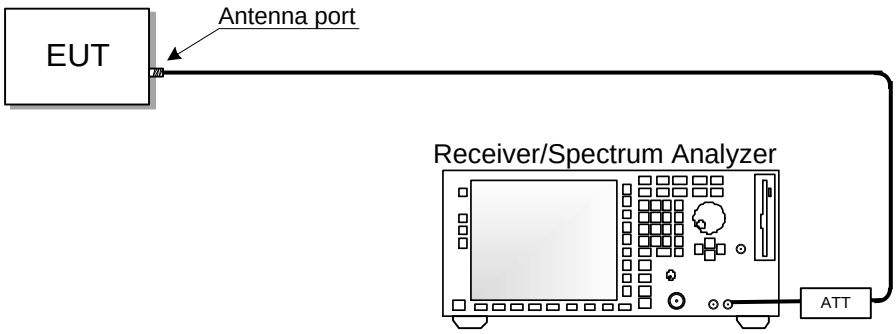
Figure 8.7-6: *PSD on high channel, 2 MHz BW*

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