

Test report

388354 – 1TRFWL

Date of issue: January 7, 2020

Applicant:

Carol Cole Company dba NuFace

Product:

Mini 2.0 (Facial Toning Device)

Model:

20400

Variants:

N/A

FCC ID: 2AGNA-20400

IC ID: 25861-20400

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 2, February 2017**

Digital Transmission Systems (DTSs), Frequency Hopping Systems (FHSs)
and License-Exempt Local Area Network (LE-LAN) Devices

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Tested by	Andres Martinez, Wireless Engineer
Reviewed by	Chip Fleury, Wireless and Certification Supervisor.
Review date	January 7, 2020
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 USA's ISO/IEC 17025 accreditation.

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Section 1. Report summary

1.1 Applicant and manufacturer

Company name	Carol Cole Company dba NuFace
Address	1325 Sycamore Ave. Suite A
City	Vista
Province/State	CA
Postal/Zip code	92081
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, 5725–5850 MHz
RSS-247, Issue 2, February 2017	Digital Transmission Systems (DTSS), Frequency Hopping Systems (FHSs) and License-Exempt Local Area Network (LE-LAN) Devices

1.3 Test methods

ANSI C63.10 v2013	American National Standard of Procedures for Compliance Testing of Unlicensed Wireless Devices
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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
§15.203	Antenna requirement	Pass ¹

Notes: EUT is battery powered but charged via AC adaptor.

¹The Antennas are located within the protective cover of EUT on PCB.

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

2.4 IC RSS-GEN, Issue 5, test results

Part	Test description	Verdict
7.3	Receiver radiated emission limits	Pass
7.4	Receiver conducted emission limits	Not applicable
8.8	Power Line Conducted Emissions Limits for License-Exempt Radio Apparatus	Pass

Notes: None.

2.5 IC RSS-247, Issue 2, 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

Notes: None

Section 3. Equipment under test (EUT) details

3.1 Sample information

Receipt date	November 20, 2019
Nemko sample ID number	388354

3.2 EUT information

Product name	Treatment Device
Model	20400
Model variant	N/A
Serial number	N/A

3.3 Technical information

All used IC test site(s) Reg. number	2040A
RSS number and Issue number	RSS-247 Issue 2, February 2017
Frequency band	2400–2483.5 MHz
Frequency Min (MHz)	2402
Frequency Max (MHz)	2480
RF power Min (dBm), Conducted/ERP/EIRP	3.99 dBm
RF power Max (dBm), Conducted/ERP/EIRP	4.87 dBm
Field strength, Units @ distance	N/A
Measured BW (kHz) (6 dB)	2402MHz: 703.23 kHz 2440MHz: 705.35 kHz 2480MHz: 705.98 kHz
Measured BW (MHz) (99%)	2402MHz: 1.0729 MHz 2441MHz: 1.0795 MHz 2480MHz: 1.0762 MHz
Power requirements	3V DC Battery
Antenna information	A worst-case scenario was used for the antenna gain 6 dBi. Antenna type is a micro strip PCB trace antenna.

3.4 Product description and theory of operation

The device consists of a handheld unit with two hemispherical electrodes intended to be applied to the user's skin, an enclosure, power button, several LEDs actuated simultaneously, and a charging connector. The device provides a speaker, and a vibration motor as an indicator in addition to the LEDs.

3.5 EUT exercise details

A EUT was set to transmit at 100% duty cycle. Customer provided batch files which set the transmitter to a specific frequency (2402MHz, 2441MHz, 2480MHz).

Using a J-link Module (customer provided equipment), USB to EUT connection, was able to program the EUT with a specific frequency. Software version at time of testing was Mini 2 v0.0.1



3.6 EUT sub assemblies

Table 3.6-1: EUT sub assemblies

Description	Brand name	Model/Part number	Serial Number
J-Link Module	Carol Cole	N/A	N/A

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

5.4 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.

5.5 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

6.4 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	1.38

Section 7. Test equipment

7.4 Test equipment list

Table 7.4-1: Equipment list

Equipment	Manufacturer	Model no.	Asset no.	Cal cycle	Next cal.
EMI Test Receiver	Rohde & Schwarz	ESU 40	E1121	2 years	05-25-2020
System controller	Sunol Sciences	SC104V	E1191	NCR	NCR
Antenna, Bilog	Schaffner	CBL 6111D	1763	1 year	01-17-2020
DRG Horn (medium)	ETS-Lindgren	3117-PA	E1139	1 tr	03-21-2020
System Controller 10m Chamber	Sunol Sciences	SC104V	E1129	NCR	NCR
Signal and Spectrum Analyzer	Rohde & Schwarz	FSV40	E1120	1 year	11-24-2020
Power Sensor	ETS-Lindgren	7002-006	E1062	1 year	02-27-2020
EMI Test Receiver	Rohde & Schwarz	ESCI 7	E1026	2 years	05-29-2021
Two Line V-Network	Rohde & Schwarz	ENV216	E1019	1 year	12 Jul 2020
Transient Limiter (10 dB pad)	Hewlett Packard	11947A	E1159	NCR	NCR

Section 8. Test Data

8.1 §15.207(a) and IC RSS-GEN, Issue 5 8.8 AC power line conducted emissions

8.1.1 Definitions and limits

For Low-power radio-frequency devices 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 μ H/50 Ω line impedance stabilization network (LISN). The lower limit applies at the boundary between the frequency ranges.

Table 8.1-1: Conducted emissions limit

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

Note: * - Decreases with the logarithm of the frequency.

8.1.2 Test summary

Test date:	January 8, 2020	Temperature:	20 °C
Test engineer:	Andres Martinez	Air pressure:	1005 mbar
Verdict:	Pass	Relative humidity:	45 %

8.1.3 Observations, settings and special notes

This is tested with both BLE on, BLE on low CH 2402MHz.

The spectral scan has been corrected with transducer factors (i.e. cable loss, LISN factors, and attenuators) for determination of compliance.

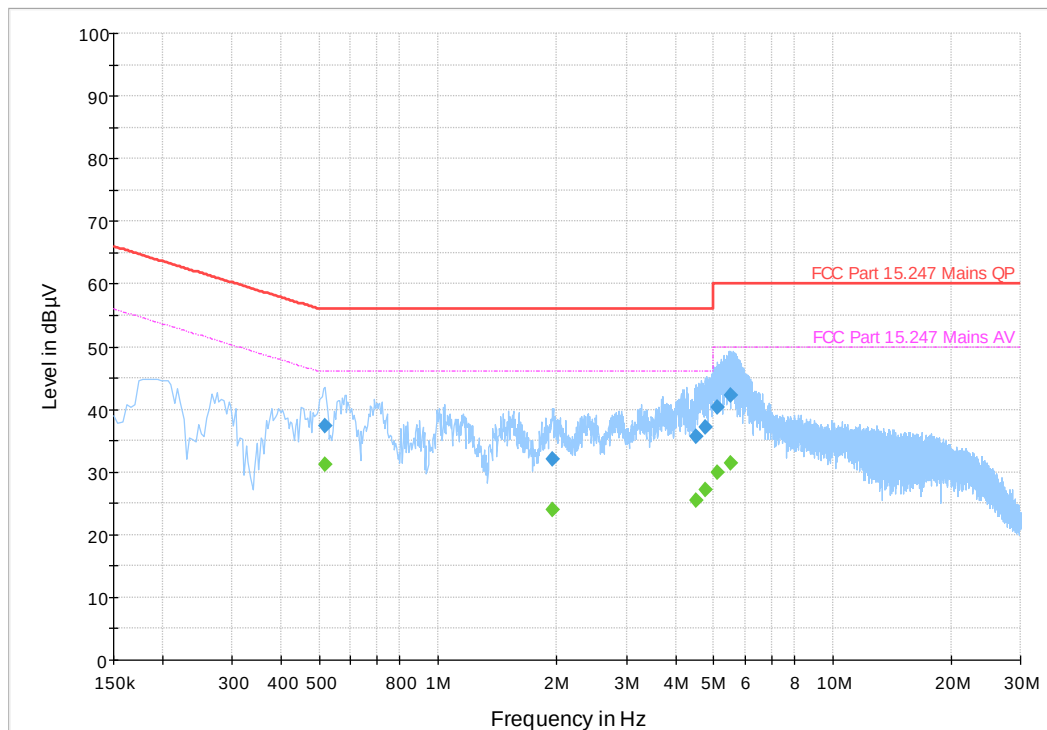
A preview measurement was generated with the receiver in continuous scan mode. Emissions detected within 6 dB or above limit were re-measured with the appropriate detector against the correlating limit and recorded as the final measurement.

Test receiver settings:

Frequency span	150 kHz to 30 MHz
Detector mode	Peak (preview mode); Quasi-Peak and Average (final measurements)
Resolution bandwidth	9 kHz
Video bandwidth	30 kHz
Trace mode	Max Hold
Measurement time	1000 ms

8.1.4 Test data

Full Spectrum



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

Figure 8.1-1: Conducted disturbance at mains port spectral plot on phase and neutral line

Table 8.1-2: Conducted disturbance at mains port (Quasi-Peak and CAverage) results on phase and neutral line.

Frequency (MHz)	QuasiPeak (dBμV)	CAverage (dBμV)	Limit (dBμV)	Margin (dB)	Meas. Time (ms)	Bandwidth (kHz)	Line	Filter	Corr . (dB)
0.514000	---	31.22	46.00	14.78	5000.0	9.000	L1	ON	19.5
0.514000	37.39	---	56.00	18.61	5000.0	9.000	L1	ON	19.5
1.946000	---	24.04	46.00	21.96	5000.0	9.000	L1	ON	19.5
1.946000	32.15	---	56.00	23.85	5000.0	9.000	L1	ON	19.5
4.490000	---	25.39	46.00	20.61	5000.0	9.000	L1	ON	19.5
4.490000	35.62	---	56.00	20.38	5000.0	9.000	L1	ON	19.5
4.774000	---	27.16	46.00	18.84	5000.0	9.000	L1	ON	19.5
4.774000	37.25	---	56.00	18.75	5000.0	9.000	L1	ON	19.5
5.122000	---	29.96	50.00	20.04	5000.0	9.000	L1	ON	19.5
5.122000	40.42	---	60.00	19.58	5000.0	9.000	L1	ON	19.5
5.522000	---	31.33	50.00	18.67	5000.0	9.000	L1	ON	19.5
5.522000	42.25	---	60.00	17.75	5000.0	9.000	L1	ON	19.5

Notes:

¹ Result (dBμV) = receiver/spectrum analyzer value (dBμV) + correction factor (dB)

² Correction factor (dB) = LISN factor IL (dB) + cable loss (dB) + transient limiter (dB)

³ The maximum measured value observed over a period of 5 seconds was recorded.

8.2 FCC 15.247(a)(2) and RSS-247 5.2(1) Minimum 6 dB bandwidth for systems using digital modulation techniques and RSS, 6.7 Occupied bandwidth 99%

8.2.1 Definitions and limits

FCC and IC:

- (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:

The occupied bandwidth or the “99% emission bandwidth” is defined as the frequency range between two points, one above and the other below the carrier frequency, within which 99% of the total transmitted power of the fundamental transmitted emission is contained. The occupied bandwidth shall be reported for all equipment in addition to the specified bandwidth required in the applicable RSSs.

8.2.2 Test summary

Test date	December 17, 2019	Temperature	20 °C
Test engineer	Andres Martinez	Air pressure	1005 mbar
Verdict	Pass	Relative humidity	45 %

8.2.3 Observations, settings and special notes

Spectrum analyzer settings:

Resolution bandwidth	100 kHz
Video bandwidth	$\geq 3 \times \text{RBW}$
Frequency span	4 MHz and 5 MHz
Detector mode	Peak
Trace mode	Max Hold

8.2.4 Test data

Table 8.2-1: 6 dB bandwidth results

Modulation	Frequency, MHz	6dB bandwidth, kHz	Limit, kHz	Result
GFSK	2402	703.23	500	Pass
	2441	705.35	500	Pass
	2480	705.98	500	Pass

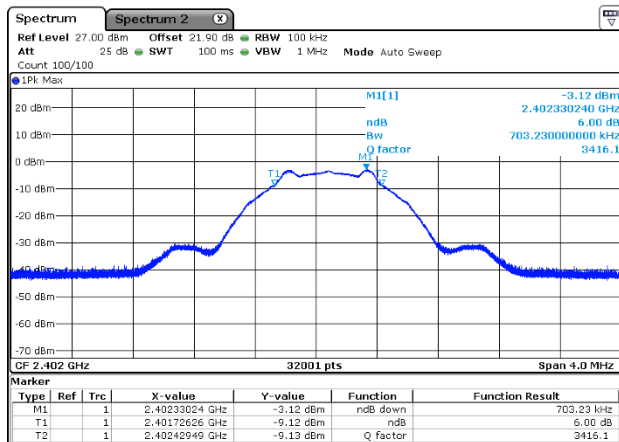


Figure 8.2-1: 6 dB bandwidth @ 2402MHz

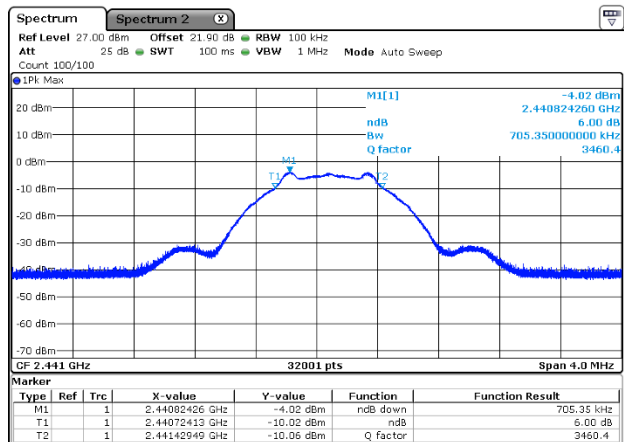


Figure 8.2-2: 6 dB bandwidth @ 2441MHz

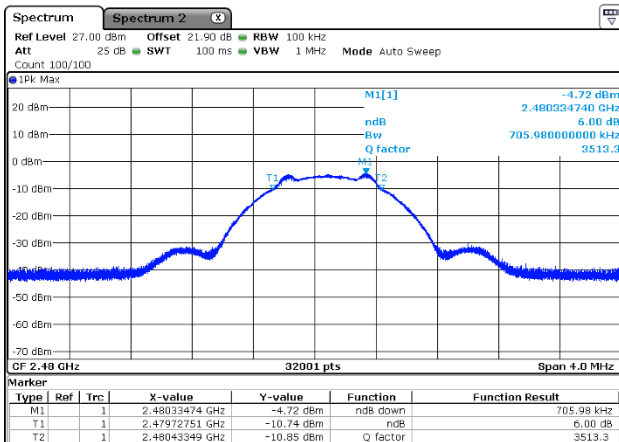


Figure 8.2-3: 6 dB bandwidth @ 2480MHz

Table 8.2-2: 99% bandwidth results

Modulation	Frequency, MHz	99% bandwidth, MHz	Verdict
GFSK	2402	1.0729	Pass
	2441	1.0795	Pass
	2480	1.0762	Pass

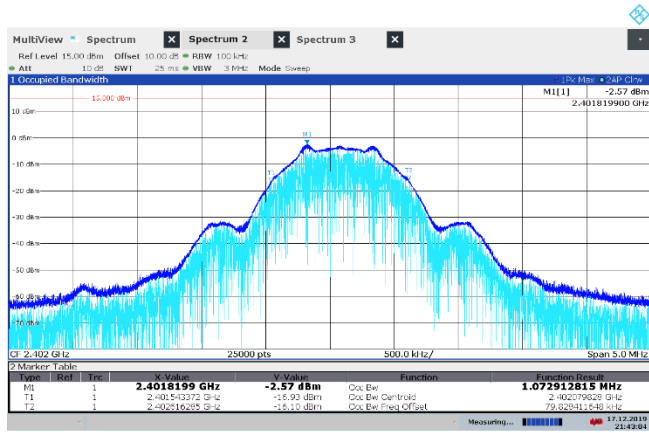


Figure 8.2-4: 99% bandwidth, 2402MHz

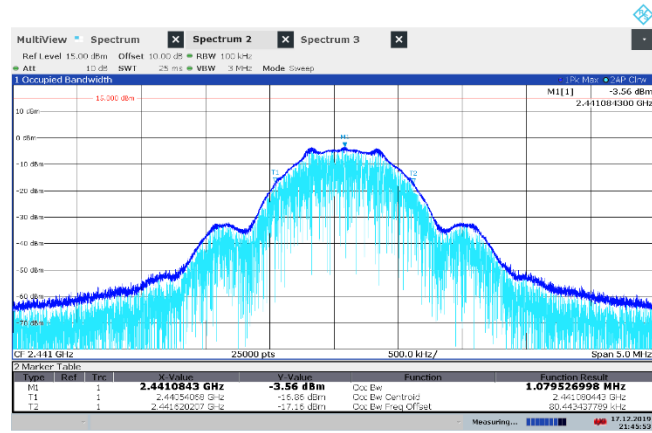


Figure 8.2-5: 99% bandwidth, 2441 MHz

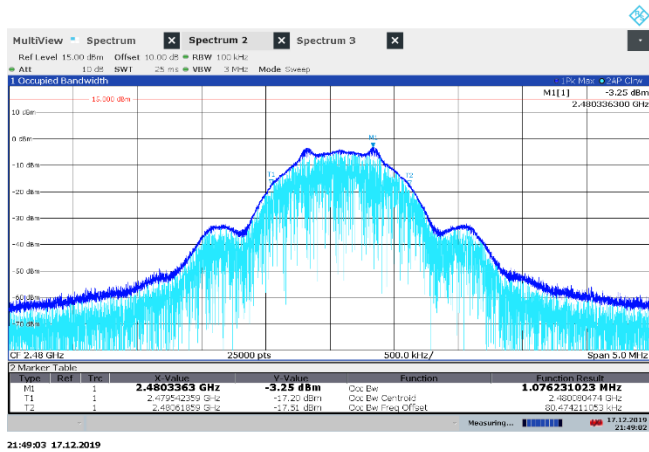


Figure 8.2-6: 99% bandwidth, 2480MHz

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:

- (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.
 - (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 peak 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.

Fixed, point-to-point operation, as used in paragraphs (b)(3)(i) and (b)(3)(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 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.

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

IC:

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	December 17, 2019	Temperature	20 °C
Test engineer	Andres Martinez	Air pressure	1005 mbar
Verdict	Pass	Relative humidity	45 %

8.3.3 Observations, settings and special notes

Measurement using a Power meter on peak setting with EUT transmitting at full power throughout each sweep.

Attenuation = Antenna gain 6 dbi (worst case).

Output power = Power meter reading + cable loss + Antenna gain

8.3.4 Test data

Table 8.3-1: Output power measurements results.

Modulation	Frequency, MHz	Conducted output power, dBm	Antenna Gain (dBi)	EIRP (dBm)	Margin, dB		Verdict
		EUT			Limit		
GSFK	2402	-1.13	6	4.87	30	25.13	Pass
	2441	-1.59	6	4.41	30	25.59	Pass
	2480	-2.01	6	3.99	30	26.01	Pass

Note: Attenuation includes cable loss and antenna gain.

8.4 FCC 15.247(d) and RSS-247 5. Spurious (out-of-band) emissions

8.4.1 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)).

IC:

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– 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: 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			

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	December 19, 2019	Temperature	21 °C
Test engineer	Andres Martinez	Air pressure	1005 mbar
Verdict	Pass	Relative humidity	45 %

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 3m measurement distance.
 A notch filter of 2.4 GHz was used.

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

Resolution bandwidth:	120 kHz
Video bandwidth:	300 kHz
Detector mode:	Peak (Preview measurement) Quasi-peak (Final measurement)
Trace mode:	Max Hold

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

Resolution bandwidth:	1 MHz
Video bandwidth:	3 MHz
Detector mode:	Average
Trace mode:	Max Hold

8.4.4 Test data

Full Spectrum

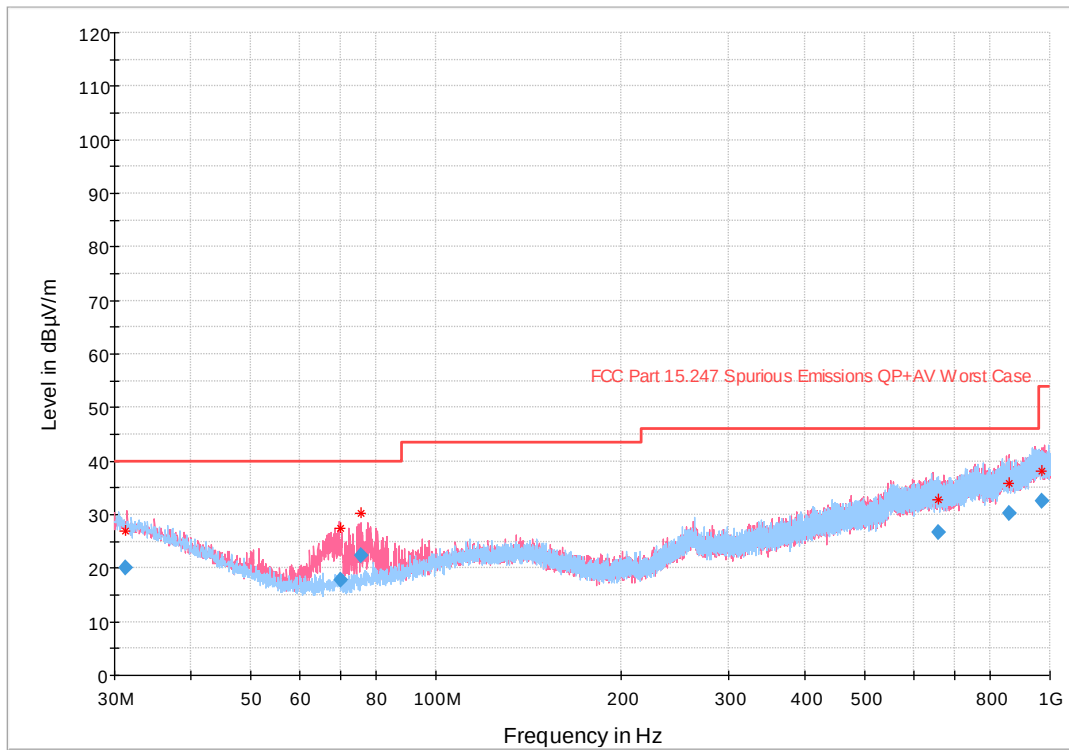
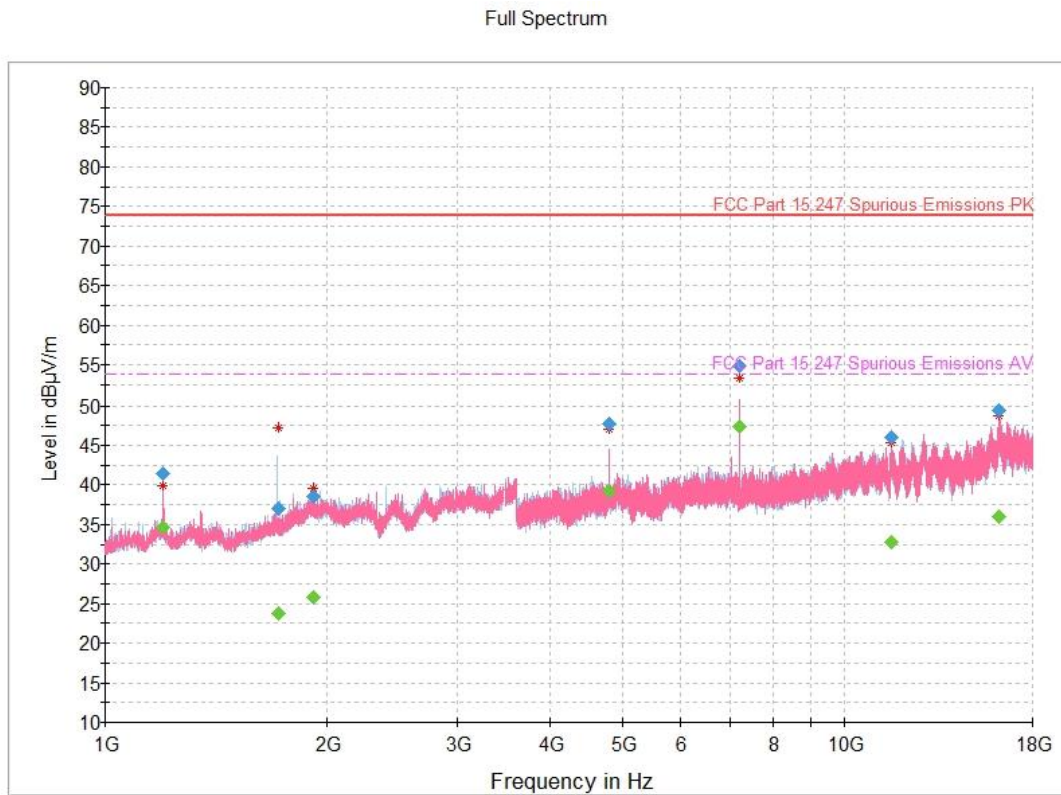


Figure 8.4-1: Radiated spurious emissions, 30MHz to 1GHz at worst case.

Frequency (MHz)	QuasiPeak (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Meas. Time (ms)	Bandwidth (kHz)	Height (cm)	Pol	Azimuth (deg)	Corr. (dB)
31.315000	19.97	40.00	20.03	5000.0	120.000	369.3	V	184.	24.6
69.873000	17.76	40.00	22.24	5000.0	120.000	240.0	V	353.	13.2
75.450500	22.40	40.00	17.60	5000.0	120.000	124.8	V	0.0	13.9
657.217000	26.67	46.00	19.33	5000.0	120.000	205.2	H	118.	30.1
859.307500	30.25	46.00	15.75	5000.0	120.000	385.3	V	49.0	33.5
971.659500	32.59	53.90	21.31	5000.0	120.000	269.7	V	96.0	35.8
Notes: Field strength (dBµV/m) = receiver/spectrum analyzer value (dBµV) + correction factor (dB) Correction factors = antenna factor ACF (dB) + cable loss (dB) Limits converted to dBµV/m and an inverse proportionality factor of 20 dB per decade has been used to normalize the specification limit to a measurement distance of 3 meters to determine compliance.									

Table 8.4-2: Radiated field strength measurement results, 30MHz to 1GHz.



x

Figure 8.4-2: Radiated spurious emissions, 1GHz to 18GHz, 2402MHz

Frequency (MHz)	MaxPeak (dBµV/m)	CAverage (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Meas. Time (ms)	Bandwidth (kHz)	Height (cm)	Pol	Azimuth (deg)	Corr. (dB/m)
1200.033333	---	34.67	53.90	19.23	5000.0	1000.000	196.0	V	73.0	-14.5
1200.033333	41.49	---	73.90	32.41	5000.0	1000.000	196.0	V	73.0	-14.5
1720.866667	---	23.69	53.90	30.21	5000.0	1000.000	191.0	H	71.0	-13.5
1720.866667	37.00	---	73.90	36.90	5000.0	1000.000	191.0	H	71.0	-13.5
1912.100000	38.51	---	73.90	35.39	5000.0	1000.000	165.0	V	110.0	-11.7
1912.100000	---	25.75	53.90	28.15	5000.0	1000.000	165.0	V	110.0	-11.7
4803.866667	47.65	---	73.90	26.25	5000.0	1000.000	139.0	V	183.0	-3.1
4803.866667	---	39.19	53.90	14.71	5000.0	1000.000	139.0	V	183.0	-3.1
7205.566667	---	47.41	53.90	6.49	5000.0	1000.000	151.0	V	253.0	-1.1
7205.566667	54.92	---	73.90	18.98	5000.0	1000.000	151.0	V	253.0	-1.1
11604.033333	---	32.68	53.90	21.22	5000.0	1000.000	111.0	H	10.0	2.7
11604.033333	45.93	---	73.90	27.97	5000.0	1000.000	111.0	H	10.0	2.7
Notes: Field strength (dBµV/m) = receiver/spectrum analyzer value (dBµV) + correction factor (dB) Correction factors = antenna factor ACF (dB) + cable loss (dB) Limits converted to dBµV/m and an inverse proportionality factor of 20 dB per decade has been used to normalize the specification limit to a measurement distance of 3 meters to determine compliance.										

Table 8.4-3: Radiated field strength measurement results, 1GHz to 18GHz, 2402MHz.

Full Spectrum

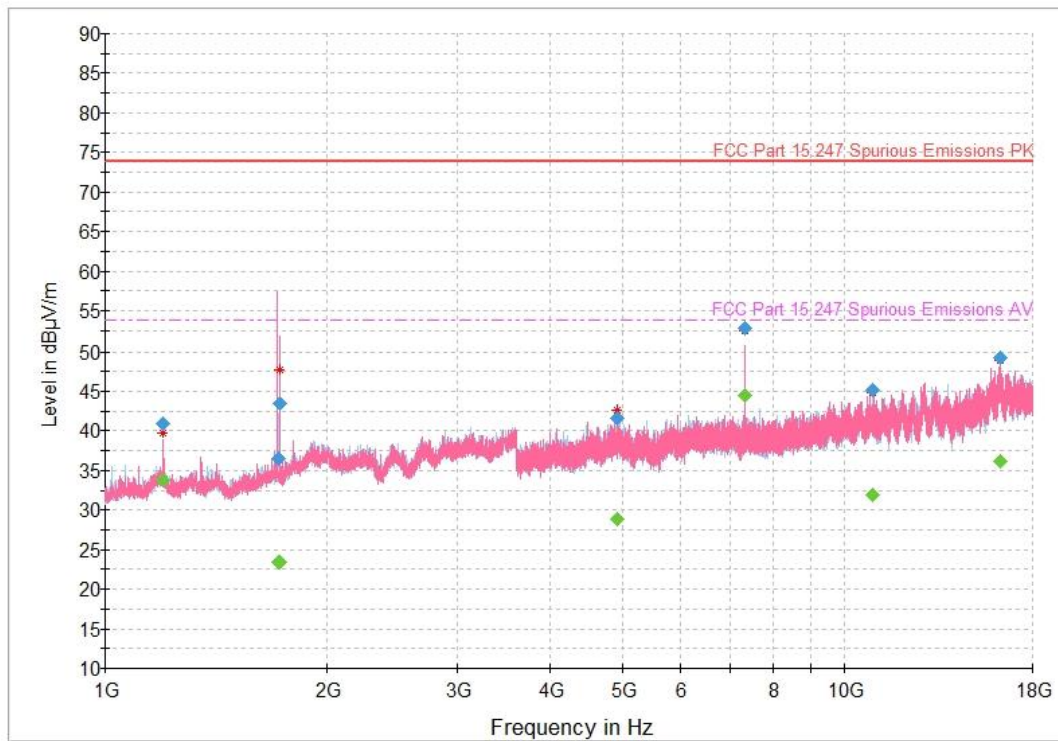


Figure 8.4-3: Radiated spurious emissions, 1GHz to 18GHz, 2440MHz

Frequency (MHz)	MaxPeak (dBμV/m)	RMS (dBμV/m)	Limit (dBμV/m)	Margin (dB)	Meas. Time (ms)	Bandwidth (kHz)	Height (cm)	Pol	Azimuth (deg)	Corr. (dB/m)
1199.866667	40.97	---	73.90	32.93	5000.0	1000.000	251.0	V	11.0	-14.5
1199.866667	---	33.83	53.90	20.07	5000.0	1000.000	251.0	V	11.0	-14.5
1716.700000	---	23.35	53.90	30.55	5000.0	1000.000	200.0	V	172.0	-13.5
1716.700000	36.51	---	73.90	37.39	5000.0	1000.000	200.0	V	172.0	-13.5
1722.766667	43.44	---	73.90	30.46	5000.0	1000.000	160.0	V	255.0	-13.5
1722.766667	---	23.40	53.90	30.50	5000.0	1000.000	160.0	V	255.0	-13.5
4919.900000	41.64	---	73.90	32.26	5000.0	1000.000	227.0	H	8.0	-3.4
4919.900000	---	28.80	53.90	25.10	5000.0	1000.000	227.0	H	8.0	-3.4
7323.900000	52.74	---	73.90	21.16	5000.0	1000.000	150.0	V	0.0	-1.0
7323.900000	---	44.49	53.90	9.41	5000.0	1000.000	150.0	V	0.0	-1.0
10932.266667	---	31.92	53.90	21.98	5000.0	1000.000	223.0	H	10.0	2.2
10932.266667	45.16	---	73.90	28.74	5000.0	1000.000	223.0	H	10.0	2.2
Notes: Field strength (dBμV/m) = receiver/spectrum analyzer value (dBμV) + correction factor (dB) Correction factors = antenna factor ACF (dB) + cable loss (dB) Limits converted to dBμV/m and an inverse proportionality factor of 20 dB per decade has been used to normalize the specification limit to a measurement distance of 3 meters to determine compliance.										

Table 8.4-4: Radiated field strength measurement results, 1GHz to 18GHz, 2441MHz.

Full Spectrum

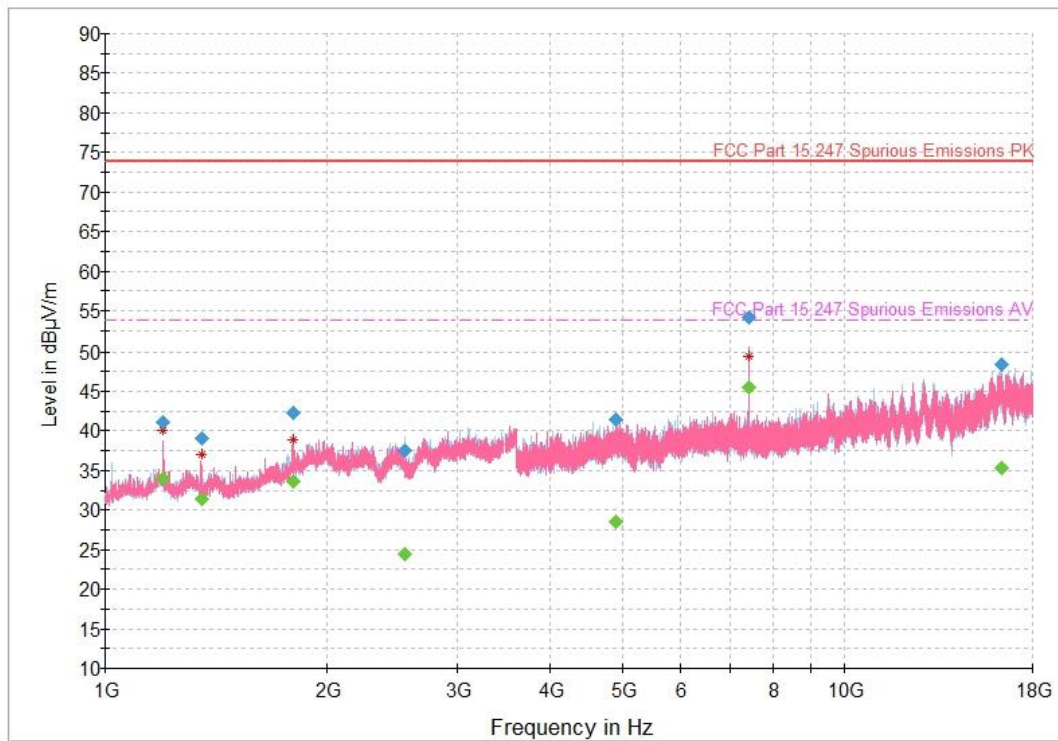


Figure 8.4-4: Radiated spurious emissions, 1GHz to 18GHz, 2480MHz

Frequency (MHz)	MaxPeak (dBμV/m)	RMS (dBμV/m)	Limit (dBμV/m)	Margin (dB)	Meas. Time (ms)	Bandwidth (kHz)	Height (cm)	Pol	Azimuth (deg)	Corr. (dB/m)
1199.866667	---	33.92	53.90	19.98	5000.0	1000.000	199.0	V	236.0	-14.5
1199.866667	41.02	---	73.90	32.88	5000.0	1000.000	199.0	V	236.0	-14.5
1350.033333	---	31.36	53.90	22.54	5000.0	1000.000	225.0	V	58.0	-15.1
1350.033333	38.98	---	73.90	34.92	5000.0	1000.000	225.0	V	58.0	-15.1
1799.966667	---	33.67	53.90	20.23	5000.0	1000.000	237.0	H	10.0	-12.9
1799.966667	42.32	---	73.90	31.58	5000.0	1000.000	237.0	H	10.0	-12.9
2549.766667	---	24.50	53.90	29.40	5000.0	1000.000	135.0	H	65.0	-10.4
2549.766667	37.59	---	73.90	36.31	5000.0	1000.000	135.0	H	65.0	-10.4
4908.166667	41.38	---	73.90	32.52	5000.0	1000.000	200.0	V	-2.0	-3.4
4908.166667	---	28.58	53.90	25.32	5000.0	1000.000	200.0	V	-2.0	-3.4
7441.133333	---	45.45	53.90	8.45	5000.0	1000.000	168.0	V	224.0	-0.5
7441.133333	54.13	---	73.90	19.77	5000.0	1000.000	168.0	V	224.0	-0.5
Notes: Field strength (dBμV/m) = receiver/spectrum analyzer value (dBμV) + correction factor (dB) Correction factors = antenna factor ACF (dB) + cable loss (dB) Limits converted to dBμV/m and an inverse proportionality factor of 20 dB per decade has been used to normalize the specification limit to a measurement distance of 3 meters to determine compliance.										

Table 8.4-5: Radiated field strength measurement results, 1GHz to 18GHz, 2480MHz.

Full Spectrum

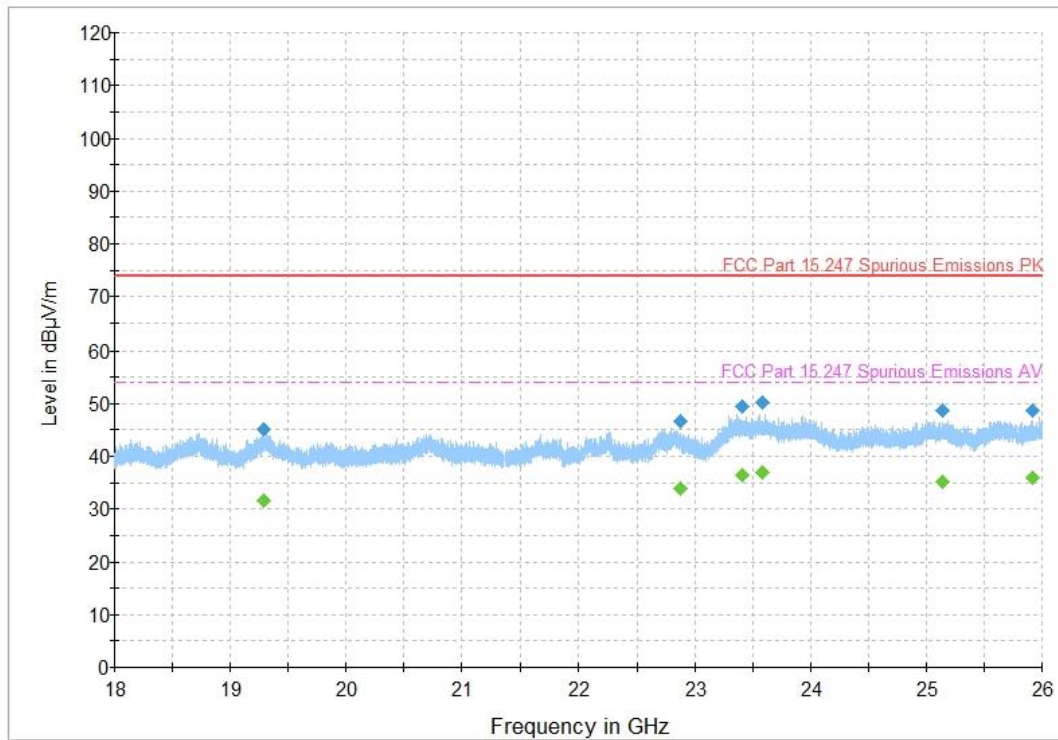


Figure 8.4-5: Radiated spurious emissions, 18GHz to 26GHz - Worst case

Frequency (MHz)	MaxPeak (dBµV/m)	CAverage (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Meas. Time (ms)	Bandwidth (kHz)	Height (cm)	Pol	Azimuth (deg)	Corr. (dB/m)
19284.272000	45.04	---	73.90	28.86	5000.0	1000.000	203.0	H	54.0	14.8
19284.272000	---	31.50	53.90	22.40	5000.0	1000.000	203.0	H	54.0	14.8
22872.279667	---	33.77	53.90	20.13	5000.0	1000.000	125.0	H	114.0	17.4
22872.279667	46.72	---	73.90	27.18	5000.0	1000.000	125.0	H	114.0	17.4
23410.899667	---	36.33	53.90	17.57	5000.0	1000.000	108.0	V	118.0	19.9
23410.899667	49.30	---	73.90	24.60	5000.0	1000.000	108.0	V	118.0	19.9
23586.156500	---	36.96	53.90	16.94	5000.0	1000.000	186.0	V	188.0	20.6
23586.156500	50.24	---	73.90	23.66	5000.0	1000.000	186.0	V	188.0	20.6
25141.551667	---	35.28	53.90	18.62	5000.0	1000.000	144.0	H	230.0	18.9
25141.551667	48.60	---	73.90	25.30	5000.0	1000.000	144.0	H	230.0	18.9
25913.117333	48.64	---	73.90	25.26	5000.0	1000.000	108.0	V	310.0	19.9
25913.117333	---	35.82	53.90	18.08	5000.0	1000.000	108.0	V	310.0	19.9
Notes: Field strength (dBµV/m) = receiver/spectrum analyzer value (dBµV) + correction factor (dB) Correction factors = antenna factor ACF (dB) + cable loss (dB) Limits converted to dBµV/m and an inverse proportionality factor of 20 dB per decade has been used to normalize the specification limit to a measurement distance of 3 meters to determine compliance.										

Table 8.4-6: Radiated field strength measurement results, 18GHz to 26GHz – Worst case.

8.5 FCC 15.247(d) Band edges

8.5.4 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)).

Per ANSI 63.10 band edges and restricted bands near the 2.4 to 2.4835 GHz band were performed using Antenna Conducted port method.

8.5.5 Test summary

Test date	December 17, 2019	Temperature	21 °C
Test engineer	Andres Martinez	Air pressure	1005 mbar
Verdict	Pass	Relative humidity	45 %

8.5.6 Observations, settings and special notes

None.

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

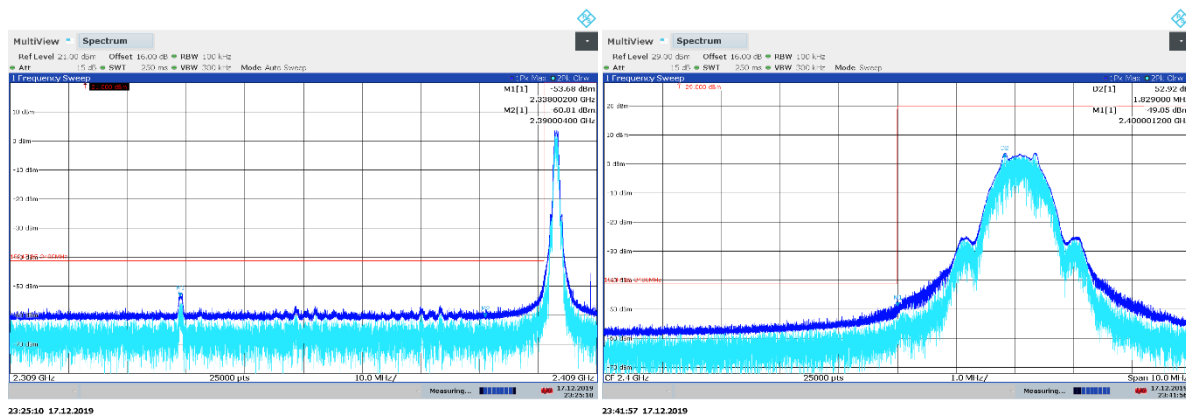


Figure 8.5-2: Low Band-edges emissions plots at 2.400 GHz edge

NOTE 1: 2390MHz is below the restricted band limit

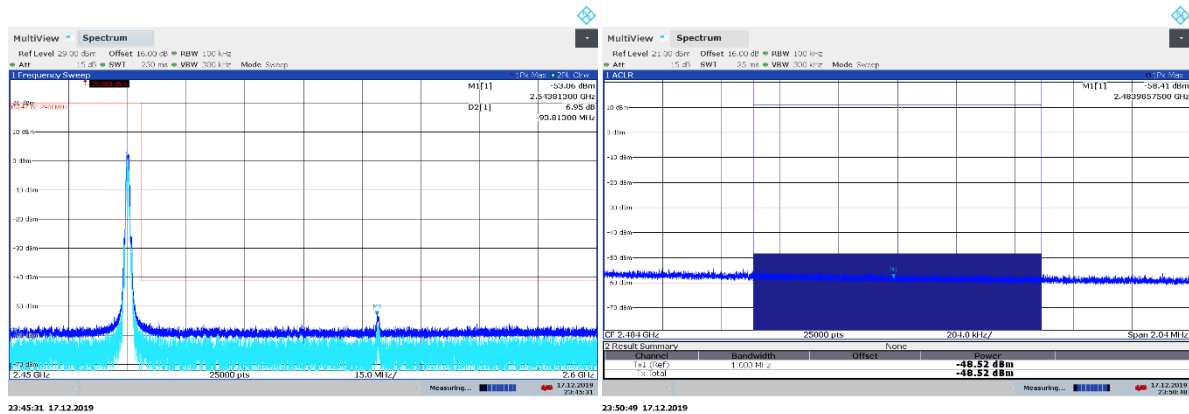


Figure 8.5-3: Band-edges emissions plots at 2.4835 GHz edge

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

8.6.1 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.

IC:

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).

8.6.2 Test summary

Test date	December 6, 2019	Temperature	25 °C
Test engineer	Andres Martinez	Air pressure	1005 mbar
Verdict	Pass	Relative humidity	45 %

8.6.3 Observations, settings and special notes

The test was performed using trace averaging with EUT transmitting at full power throughout each sweep.

Spectrum analyzer settings:

Resolution bandwidth:	100 kHz ($3 \text{ kHz} \leq \text{RBW} \leq 100 \text{ kHz}$)
Video bandwidth:	1 MHz ($\geq 3 \times \text{RBW}$)
Frequency span:	1.5 Times DTS bandwidth
Detector mode:	Peak
Trace mode:	Max hold
Averaging sweeps number:	100

8.6.4 Test data

Table 8.6-1: PSD measurements results.

Modulation	Frequency, MHz	PSD, dBm/100kHz	PSD limit, dBm/3kHz	Margin, dB
GFSK	2402	-3.12	8.00	11.12
	2441	-4.04	8.00	12.04
	2480	-4.76	8.00	12.76

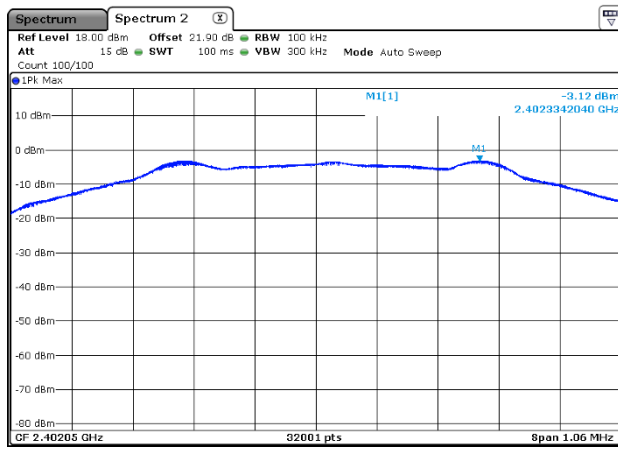


Figure 8.6-1: PSD plot on 2402MHz.

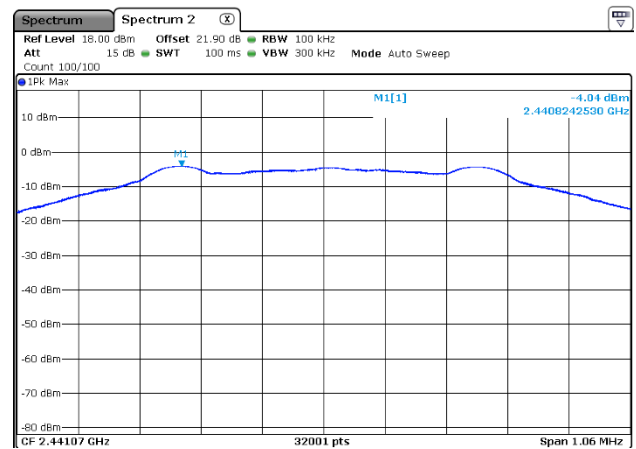


Figure 8.6-2: PSD plot on 2441MHz.

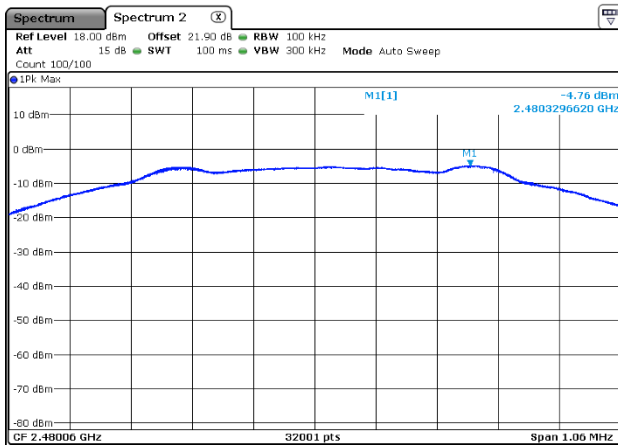
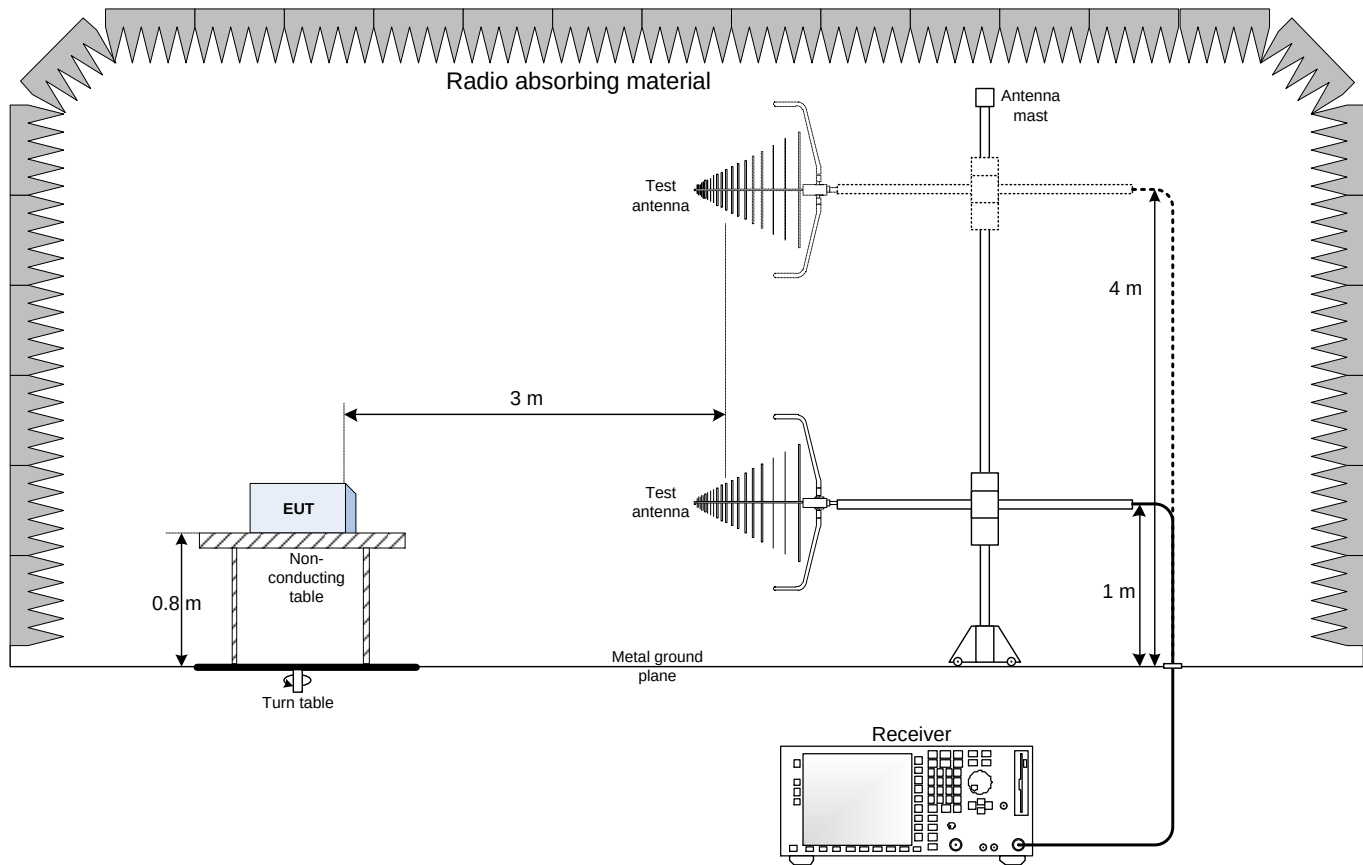


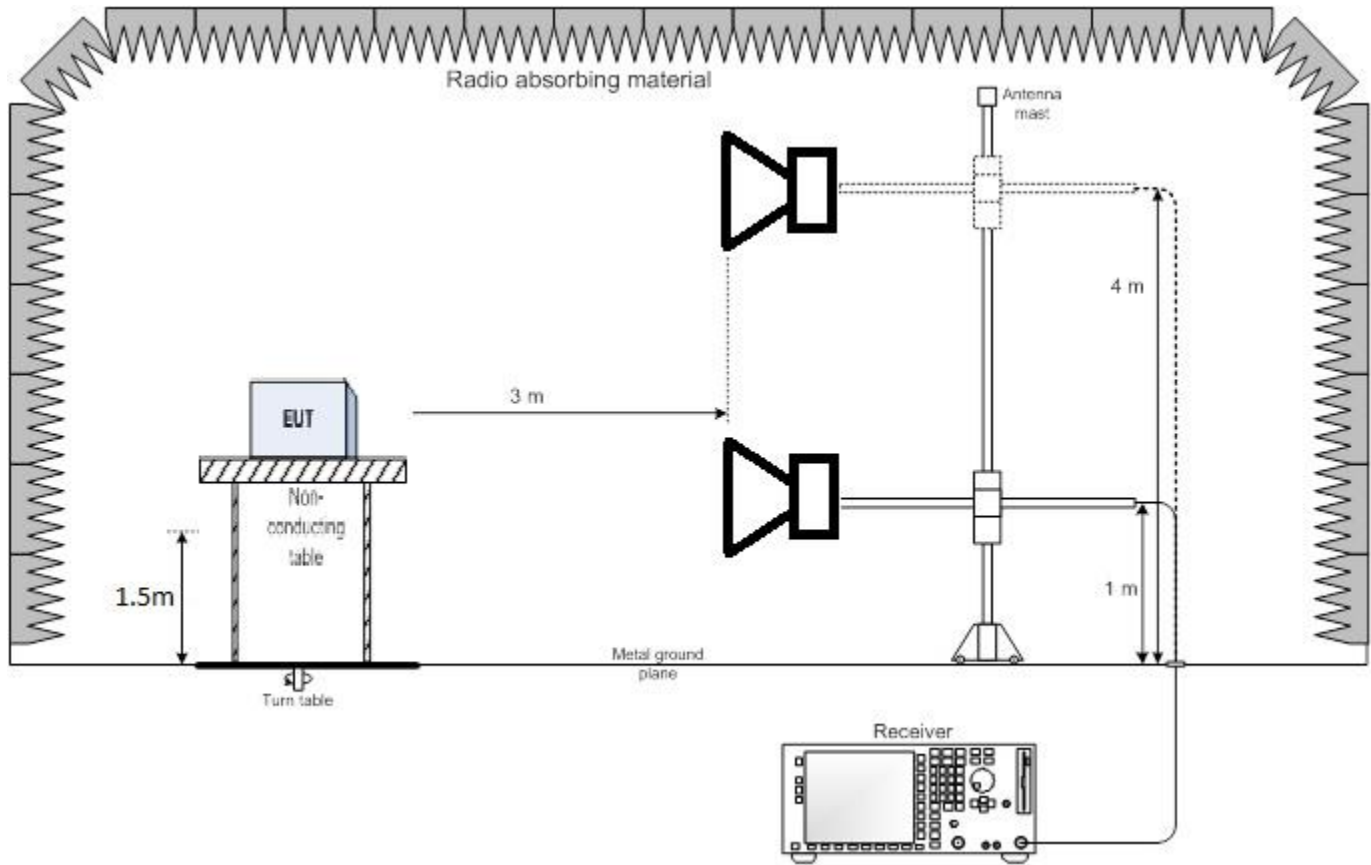
Figure 8.6-3: PSD plot on 2480MHz.

Section 9. Block diagrams of test set-ups

9.5 Radiated emissions set-up – Below 1GHz



9.6 Radiated emissions set-up – Above 1GHz



Thank you for choosing

