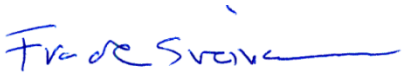
REP021445

Test Report

Product	Toy with Bluetooth Low Energy transceiver
Name and address of the applicant	LEGO System A/S Aastvej 1 7190 Billund, Denmark
Name and address of the manufacturer	LEGO System A/S Aastvej 1 7190 Billund, Denmark
Model	HUB NO.19
Rating	2402-2480MHz BLE transceiver
Trademark	LEGO
Additional information	Bluetooth Low Energy
Tested according to	**FCC Part 15.247** Frequency Hopping Transmitters / Digital Transmission Systems **Industry Canada RSS-247, Issue 2** Digital Transmission Systems (DTSs), Frequency Hopping Systems (FHSs) and Licence-Exempt Local Area Network (LE-LAN) Devices
Order number	PRJ0045981
Tested in period	2023-11-24 to 2023-12-15
Issue date	2023-12-21
Name and address of the testing laboratory	Nemko Scandinavia AS Instituttveien 6 2007 Kjeller, Norway www.nemko.com CAB Number: FCC: NO0001 ISED: NO470 ISED No: 2040D-1 **An accredited technical test executed under the Norwegian accreditation scheme**

Prepared by [Jan G Eriksen]



Approved by [Frode Sveinsen]

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Template version: C

Revision history

Revision	Date	Comment	Sign
A	2023-12-21	First edition	JGER

GENERAL REMARKS

This report applies only to the sample(s) tested. It is the manufacturer's responsibility to ensure the additional production units of this product are manufactured with identical electrical and mechanical components. The manufacturer is solely responsible for any modifications to the product that could result in non-compliance with the relevant regulations.

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Opinions expressed within this report regarding general assessments and qualifications for PASS or FAIL to the standards limits and requirements, are not part of the current accreditation. Neither are opinions expressed regarding model variants covered by the testing of this report.

CALIBRATION

All instruments used in the tests given in this test report are calibrated and traceable to national or international standards. Between calibrations all test set-ups are controlled and verified on a regular basis by periodic checks to ensure, with 95% confidence, that the instruments remain within the calibrated levels.

MEASUREMENT UNCERTAINTY

Measurement uncertainties are calculated or considered for all instruments and instrument set-ups used during these tests. Uncertainty figures are found in a separate clause in this report.

CONTENTS

1 INFORMATION

1.1 Test Item

Name	**HUB NO.19**
Model/version	**HUB NO.19**
FCC ID	**NPI103479**
ISED ID	**3072A-103479**
Serial number	**Radiated measurements: MAC-Adress 30:AF:7E:10:46:2D** **Conducted measurements: MAC-Adress 30:AF:7E:0A:28:77**
Hardware identity and/or version	**D**
Software identity and/or version	**1.2.02**
Frequency Range	**2402 – 2480 MHz**
Number of Channels	**40**
Operating Modes	**Bluetooth Low Energy ☒ 1Mb ☒ 2Mb**
Type of Modulation	**GFSK**
Conducted Output Power	**Less than 0 dBm**
Antenna Connector	**None**
Number of Antennas	**1**
Diversity or Smart Antennas	**No**
Power Supply	**Battery module 3.6 V, 2100 mAh**
Desktop Charger	**Charged from USB-C connector**

Description of Test Item

The tested device is a toy train.

The device contains Low Energy Bluetooth with 2 and 1 Mbps data rate.

The device is powered by a 3.6 V, 2100 mAh battery module.

1.2 Normal test condition

Temperature:	**20 - 24 °C**
Relative humidity:	**20 - 50 %**
Normal test voltage:	**3.6 V DC**

The values are the limit registered during the test period.

1.3 Test Engineer(s)

Jan G Eriksen

1.4 Antenna Requirement

Does the EUT have detachable antenna(s)?	☐ **YES**	☒ **NO**
If detachable, is the antenna connector(s) non-standard?	☐ **YES**	☐ **NO**
The tested equipment has only integral antennas. Conducted tests were performed with a temporary antenna connector.		

Requirement: FCC 15.203, 15.204

1.5 EUT Operating Modes

Description of operating modes	EUT in test mode transmitting modulated signals at 2402, 2440, and 2480 MHz respectively. At 1MB the signal is a pulsed wave and 2Mb the signal is non-pulsed.
Additional information	-

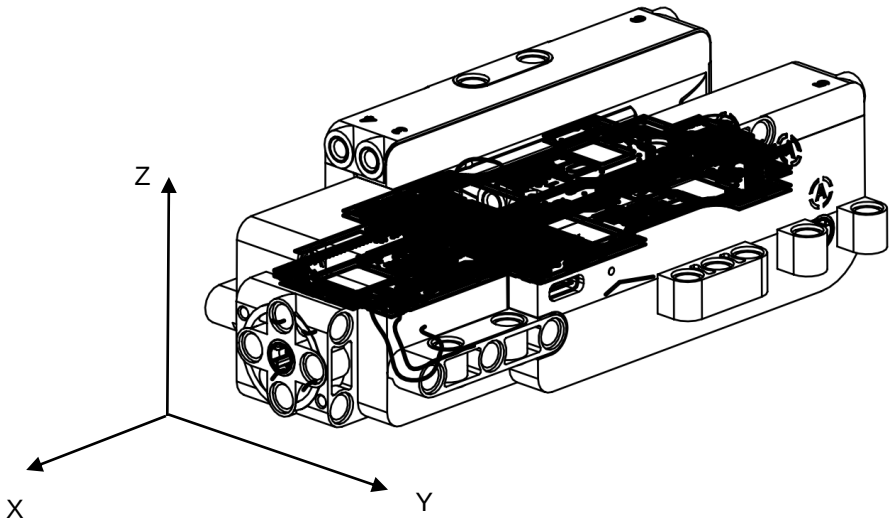
1.6 Comments

The radiated measurements were done with the EUT powered by a rechargeable battery 3.6V, 2100 mAh.

Conducted measurements were done with the device powered from external power supply. It was checked that power variations between 85% and 115% did not have any influence on the measurement results.

The EUT was positioned in three orientations and rotated (0-360 deg) in the XY, XZ, and YZ planes as shown in figure to find the maximum direction of transmitted signal and possible spurious emissions:

The receiving antenna has also been scanned in height from one to four meters and in horizontal and vertical polarization.



TEST REPORT SUMMARY

1.7 General

The tests were conducted for demonstrating compliance with FCC CFR 47 Part 15, paragraph 15.247 and ISED RSS-247 Issue 2 and RSS-GEN Issue 5.

Tests were performed in accordance with ANSI C63.4-2014 and ANSI C63.10-2013.

Radiated tests were performed in a semi-anechoic chamber at measuring distances of 3m.

A description of the test facility is on file with the FCC and ISED.

☒ **New Submission**	☒ **Production Unit**
☐ **Class II Permissive Change**	☐ **Pre-production Unit**
DTS Equipment Code	☐ **Family Listing**

1.8 Test Summary

Name of test	FCC Part 15 reference	RSS-247 Issue 2, RSS-GEN Issue 5 reference	ANSI C63.10-2013 Reference	Result
Supply Voltage Variations	15.31(e)	6.11 (RSS-GEN)	5.13	Pass
Antenna Requirement	15.203	6.8 (RSS-GEN)	5.8	Pass
Power Line Conducted Emission	15.107(a) 15.207(a)	7.2 / 8.8 (RSS-GEN)	6.2	Pass
Occupied Bandwidth (99% BW)	N/A	6.7 (RSS-GEN)	6.9.3	
DTS Bandwidth	15.247(a)(2)	5.2 (1) (RSS-247)	11.8 Option 2	Pass
Peak Power Output	15.247(b)	5.4 (RSS-247)	11.9.1.1	Pass
Power Spectral Density	15.247(d)	5.2 (2) (RSS-247)	11.10.2 PKPSD (DTS)	Pass
Spurious Emissions (Antenna Conducted)	15.247(c)	5.5 (RSS-247)	6.7 11.11 (DTS)	Pass
Spurious Emissions (Radiated)	15.247(c) 15.109(a) 15.209(a)	5.5 (RSS-247) 7.3 (RSS-GEN) 8.9 (RSS-GEN)	6.3, 6.5, 6.6, 6.10 11.12, 11.13 (DTS)	Pass

2 TEST RESULTS

2.1 Power Line Conducted Emissions

FCC Part 15.207

ISED RSS-GEN Issue 5, Clause 7.2 / 8.8

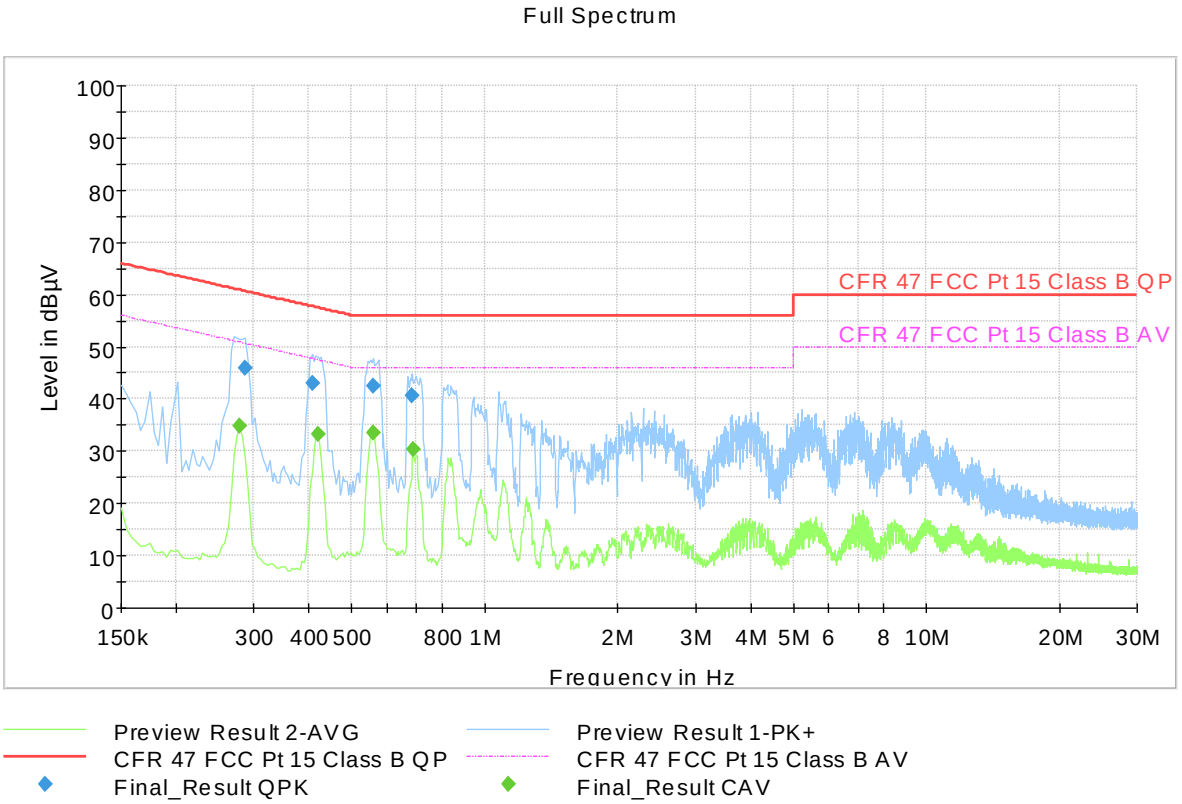
Measurement procedure: **ANSI C63.4-2014 using 50 µH/50 ohms LISN**

Test Results: **Complies**

Measurement Data: **120V 60Hz, See attached plots**

Highest measured value (L1 and N)

Frequency (MHz)	QuasiPeak (dBµV)	CAverage (dBµV)	Limit (dBµV)	Margin (dB)	Meas. Time (ms)	Bandwidth (kHz)	Line	Filter	Corr. (dB)
0.278000	---	35.0	50.9	15.9	15000.0	9.000	L1	OFF	9.7
0.286000	45.9	---	60.6	14.7	15000.0	9.000	N	OFF	9.7
0.406000	42.9	---	57.7	14.8	15000.0	9.000	N	OFF	9.6
0.418000	---	33.2	47.5	14.3	15000.0	9.000	L1	OFF	9.6
0.558000	42.4	---	56.0	13.6	15000.0	9.000	L1	OFF	9.6
0.558000	---	33.5	46.0	12.5	15000.0	9.000	L1	OFF	9.6
0.686000	40.6	---	56.0	15.4	15000.0	9.000	N	OFF	9.6
0.690000	---	30.5	46.0	15.5	15000.0	9.000	L1	OFF	9.6



2.2 Occupied Bandwidth (99% BW)

ISED Canada RSS-GEN Issue 5, Clause 6.7

Measurement procedure: ANSI C63.10-2013 Clause 6.9.2

EUT in test mode transmitting modulated signals at 2402, 2440, and 2480 MHz respectively.

At 1MB the signal is a pulsed wave and 2Mb the signal is non-pulsed.

Test Results: Complies

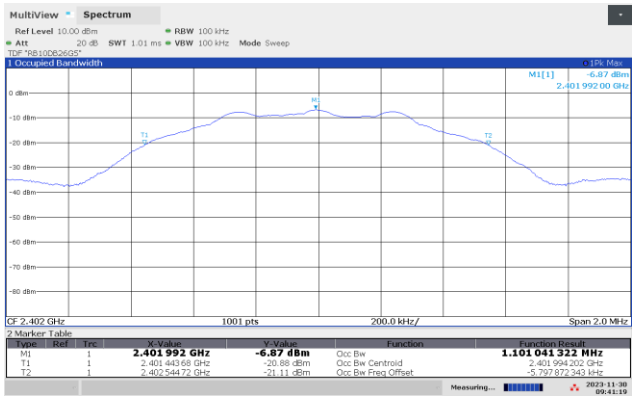
Measurement Data:

Carrier Frequency, Data Rate	Occupied Bandwidth (99% BW) (kHz)	
	1 Mb	2 Mb
2402 MHz	1101	2076
2440 MHz	1087	2059
2480 MHz	1096	2058

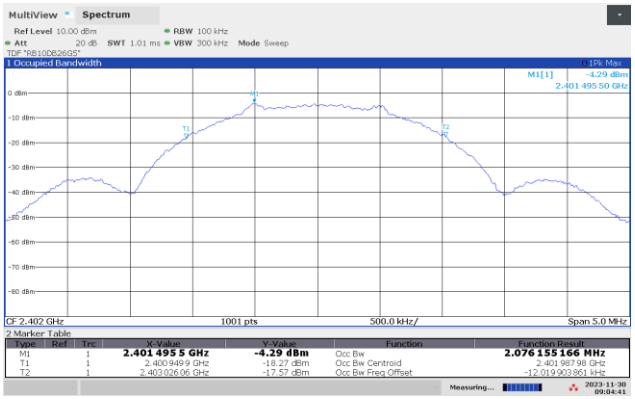
See attached plots

Requirements:

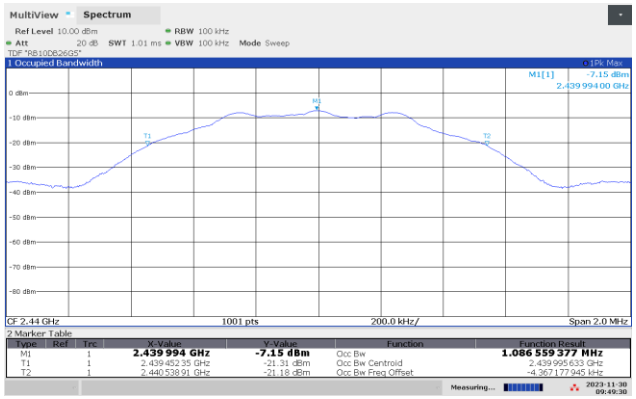
No requirement for 99% BW, reported for information only.



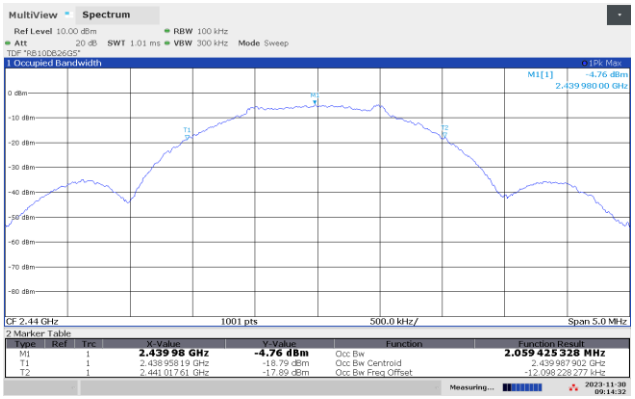
2402 MHz, 99% Occupied BW, 1Mb



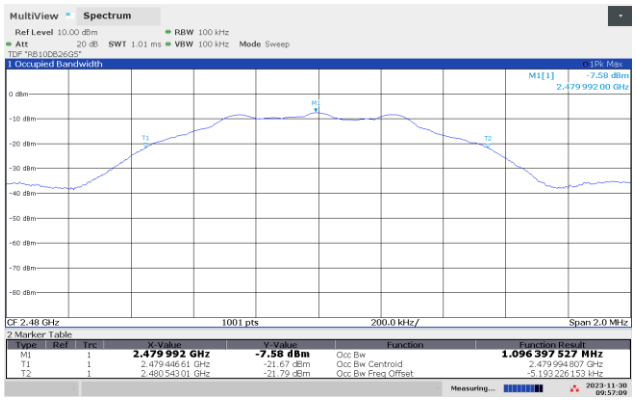
2402 MHz, 99% Occupied BW, 2Mb



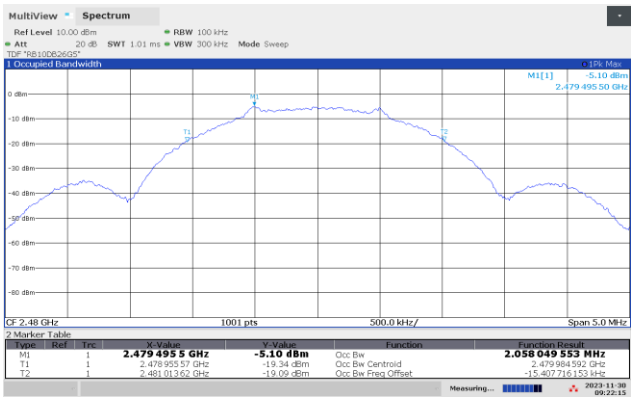
2440 MHz, 99% Occupied BW, 1Mb



2440 MHz, 99% Occupied BW, 2Mb



2480 MHz, 99% Occupied BW, 1Mb



2480 MHz, 99% Occupied BW, 2Mb

2.3 DTS Bandwidth

FCC Part 15.247 (a)(2)

ISED Canada RSS-247 Issue 2, Clause 5.2 (a)

Measurement procedure: **ANSI C63.10-2013 Clause 11.8**

Test Results: **Complies**

EUT in test mode transmitting modulated signals at 2402, 2480, and 2480 MHz respectively. At 1MB the signal is a pulsed wave and 2Mb the signal is non-pulsed.

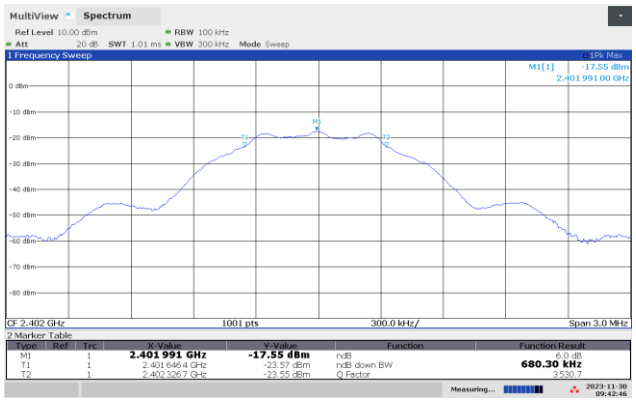
Measurement Data:

Modulation type and bitrate	Measured DTS Bandwidth (kHz)		
	2402 MHz	2440 MHz	2480 MHz
GFSK 1 Mbps	680.3	683.3	680.3
GFSK 2 Mbps	1400	1350	1350

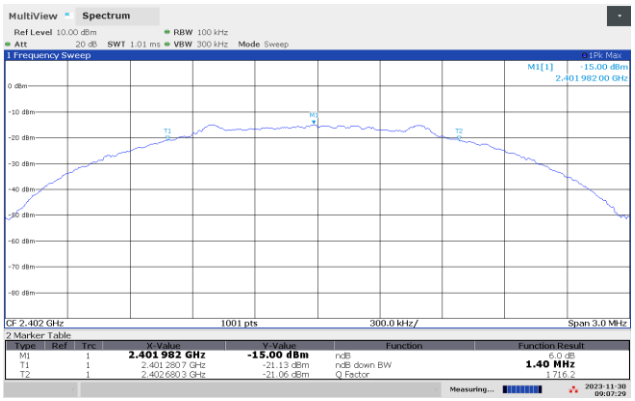
Power supply variation within 85 % to 115% of nominal value has no influence on measured value.

Frequency Band	Requirement for systems using Digital Modulation
902-928 MHz	The minimum 6 dB bandwidth shall be at least 500 kHz.
2400-2483.5 MHz	
5725-5850 MHz	

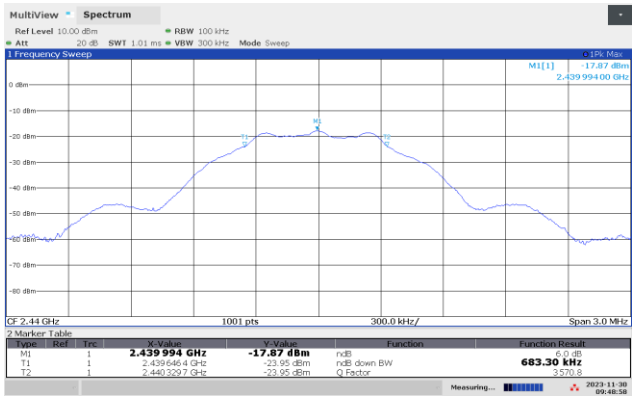
No requirements for Frequency Hopping Systems.



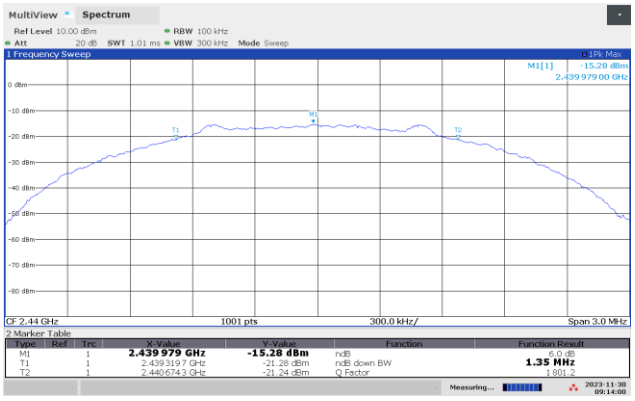
DTS BW, 2402 MHz, 1M



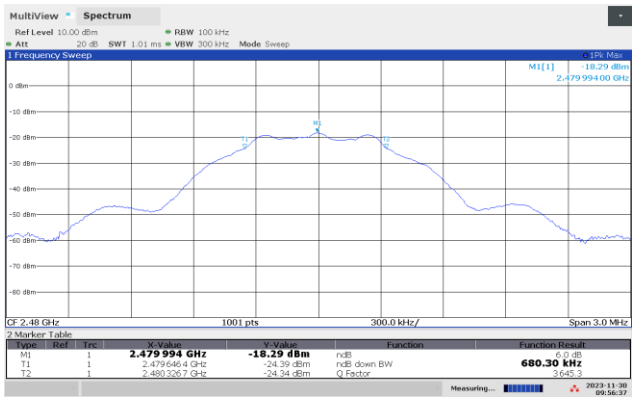
DTS BW, 2402 MHz, 2M



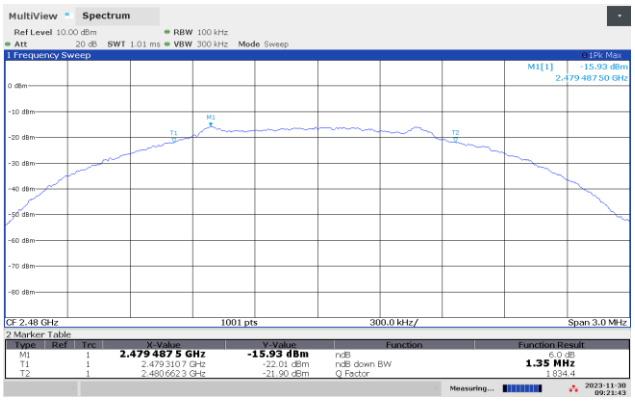
DTS BW, 2440 MHz, 1M



DTS BW, 2440 MHz, 2M



DTS BW, 2480 MHz, 1M



DTS BW, 2480 MHz, 2M

2.4 Peak Power Output

FCC Part 15.247 (b)

ISED Canada RSS-247 Issue 2, Clause 5.4

Measurement procedure: ANSI C63.10-2013 Clause 11.9.1.2

Test Results: Complies

EUT in test mode transmitting modulated signals at 2402, 2480, and 2480 MHz respectively. At 1MB the signal is a pulsed wave and 2Mb the signal is non-pulsed.

Maximization of the signal was performed at 2Mb and then the value at 1Mb was measured at the found maximum position (angle, height, polarization).

Measurement Data:

Carrier Frequency	Peak Conducted Power dBm		Peak EIRP dBµV/m @3m		Antenna gain dBi	
	GFSK 1Mb	GFSK 2Mb	GFSK 1Mb	GFSK 2Mb	GFSK 1M	GFSK 2M
2402 MHz	-6.59	-2.64	91.96	95.82	3.32	3.23
2440 MHz	-6.90	-3.00	90.84	94.74	2.51	2.51
2480 MHz	-7.29	-3.48	90.44	94.53	2.50	2.78

Output Power reported is Maximum Peak Power.

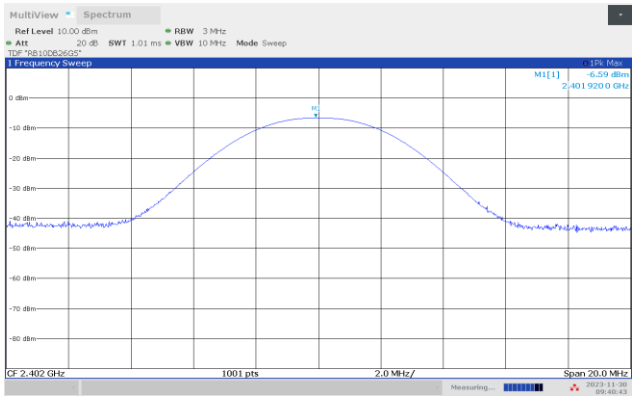
The Integrated Band Power Method was used to measure Output Power

Radiated Power was calculated from measured Field Strength using the method described in FCC KDB 412172 D01.

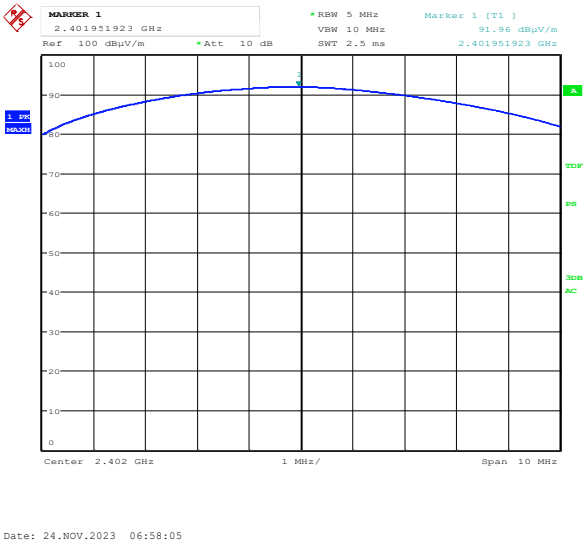
Antenna Gain is less than 6 dBi.

See attached plots.

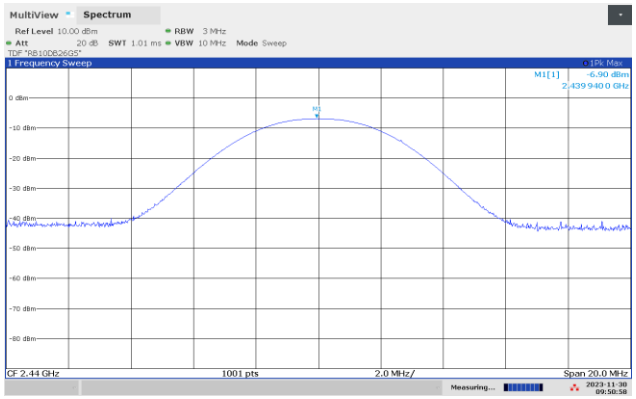
Requirements for Digital Modulation systems
For systems using digital modulation in the 902-928 MHz, 2400-2483.5 MHz, and 5725-5850 MHz bands: 1 Watt. As an alternative to a peak power measurement, compliance with the 1 Watt limit can be based on a measurement of the maximum conducted output power. Maximum 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.
Maximum allowed Antenna Gain
If transmitting antennas of directional gain greater than 6 dBi are used, the peak output power from the intentional radiator shall be reduced below the stated value above by the amount in dB that the directional gain of the antenna exceeds 6 dBi.



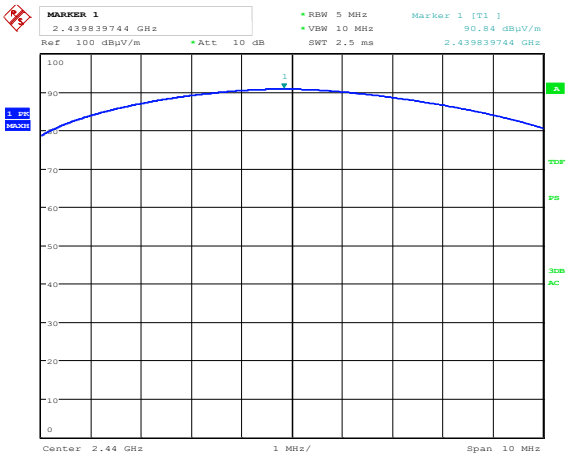
Peak Power, 2402 MHz, 1Mb



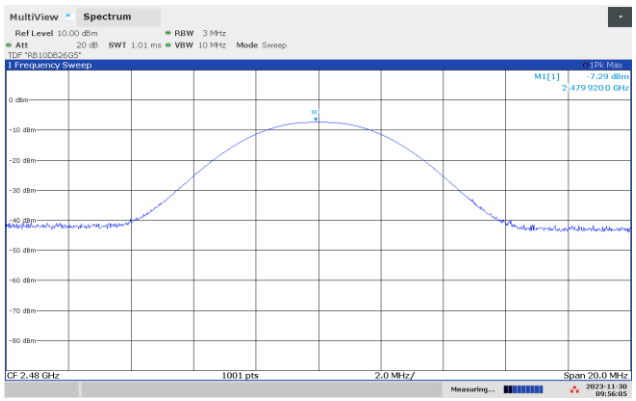
Peak EIRP, 2402 MHz, 1Mb



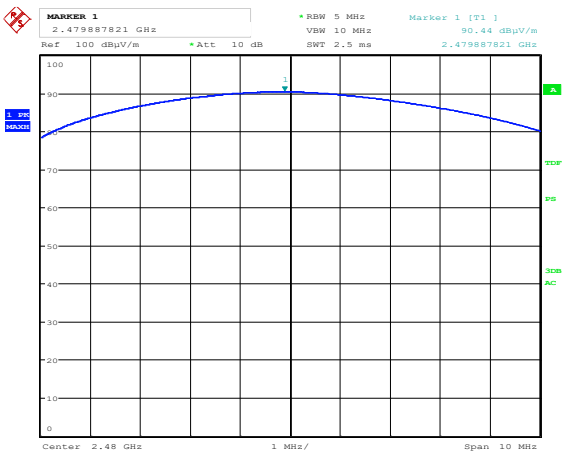
Peak Power, 2440 MHz, 1Mb



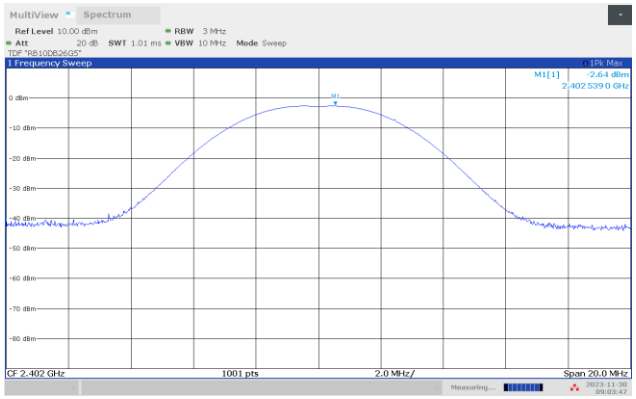
Peak EIRP, 2440 MHz, 1Mb



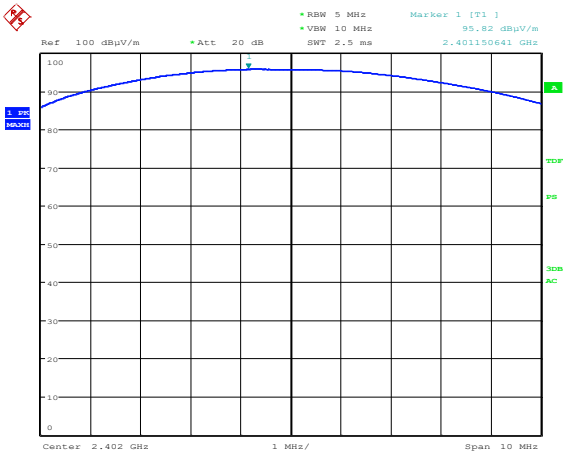
Peak Power, 2480 MHz, 1Mb



Peak EIRP, 2480 MHz, 1Mb



Peak Power, 2402 MHz, 2Mb



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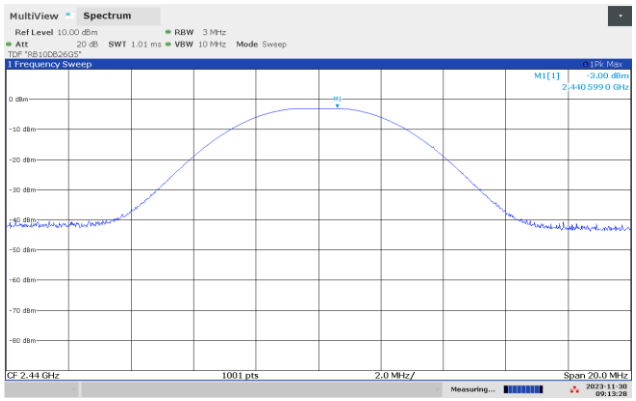
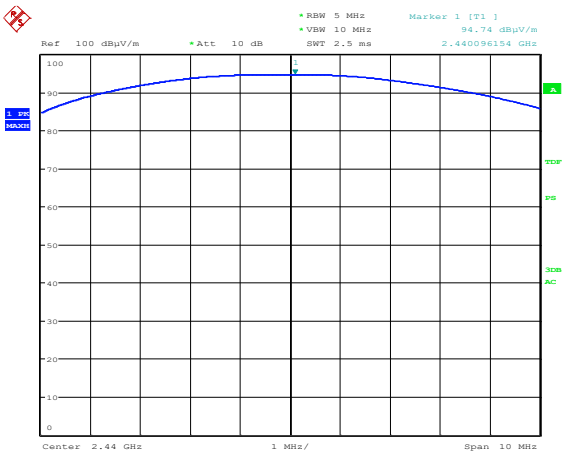
Peak EIRP, 2402 MHz, 2Mb



Peak Power, 2440 MHz, 2Mb



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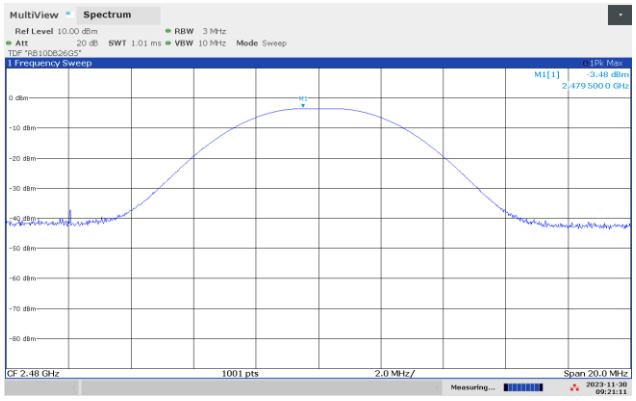
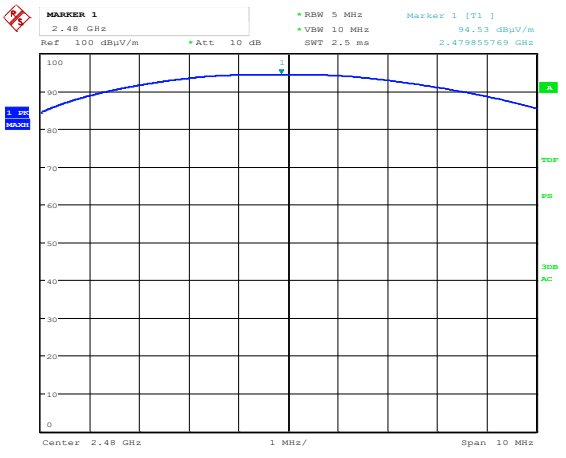
Peak EIRP, 2440 MHz, 2Mb



Peak Power, 2480 MHz, 2Mb



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Peak EIRP, 2480 MHz, 2Mb

2.5 Conducted Emissions at Antenna Connector

FCC Part 15.247 (d)

ISED Canada RSS-247 Issue 2, Clause 5.5

Measurement procedure: ANSI C63.10-2013 Clause 11.11

Test Results: Complies

EUT in test mode transmitting modulated signals at 2402, 2440, and 2480 MHz respectively. At 1Mb the signal is a pulsed wave and 2Mb the signal is non-pulsed.

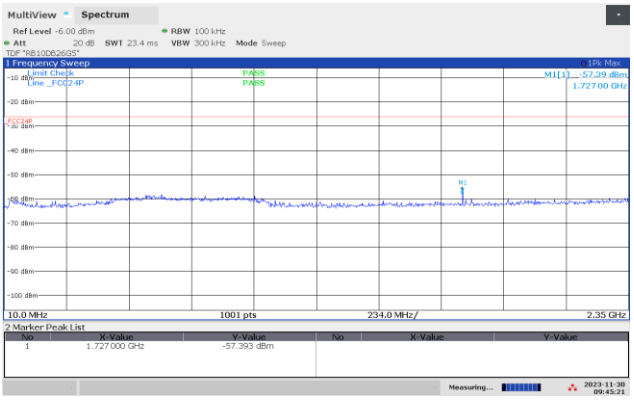
Measurement Data:

Carrier Frequency	Highest Value (dBc)	Margin (dB)	Verdict
2402 MHz, 1Mb	> 40	> 20	Pass
2402 MHz, 2Mb	> 40	> 20	Pass
2440 MHz, 1Mb	> 40	> 20	Pass
2440 MHz, 2Mb	> 40	> 20	Pass
2480 MHz, 1Mb	> 40	> 20	Pass
2480 MHz, 2Mb	> 40	> 20	Pass

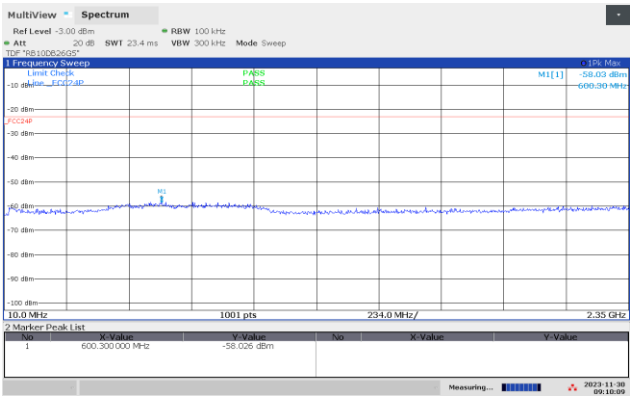
Measured with Peak Detector

RF conducted power to 25 GHz: see attached plots.

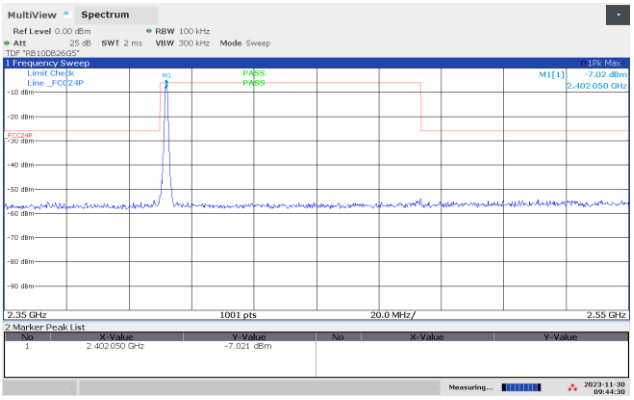
Requirements for all systems	
Peak measurement	**RMS averaging (alternative measurement)**
20 dB or more below carrier measured in 100 kHz bandwidth	30 dB or more below carrier measured in 100 kHz bandwidth
In any 100 kHz bandwidth outside the frequency band in which the spread spectrum or digitally 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.	



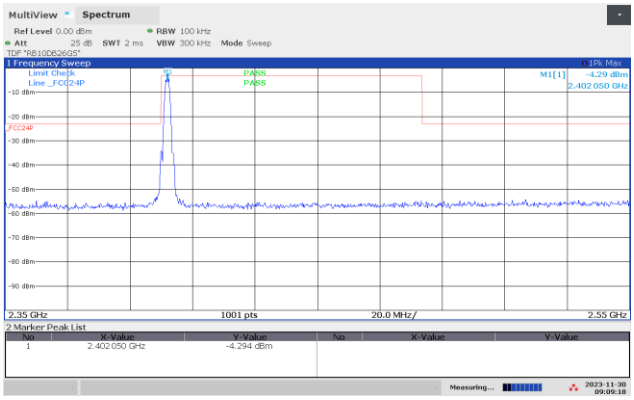
Conducted Emissions 10-2350 MHz, 2402 MHz, 1Mb



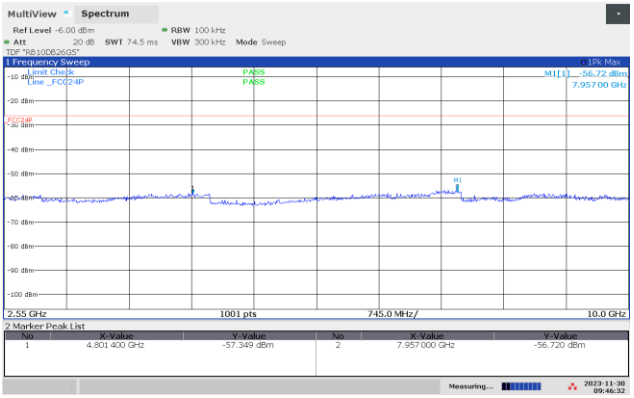
Conducted Emissions 10-2350 MHz, 2402 MHz, 2Mb



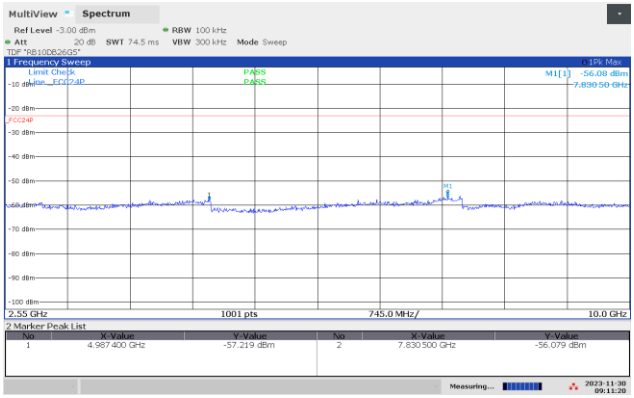
Conducted Emissions 2350-2550 MHz, 2402 MHz, 1Mb



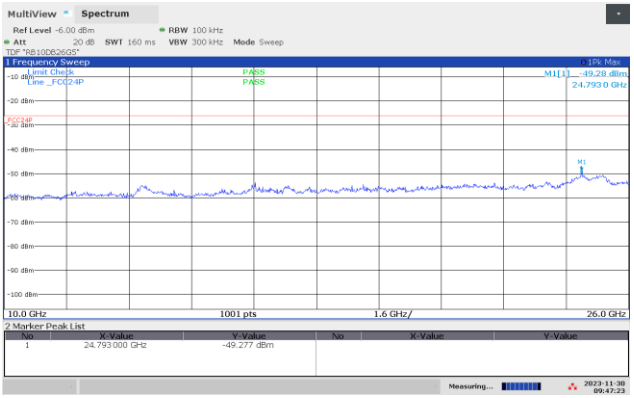
Conducted Emissions 2350-2550 MHz, 2402 MHz, 2Mb



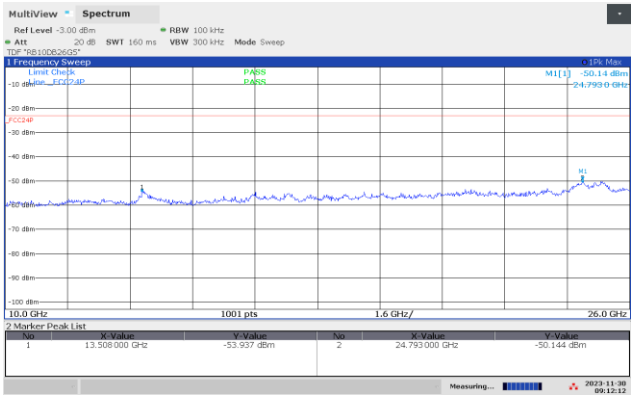
Conducted Emissions 2550-10000 MHz, 2402 MHz, 1Mb



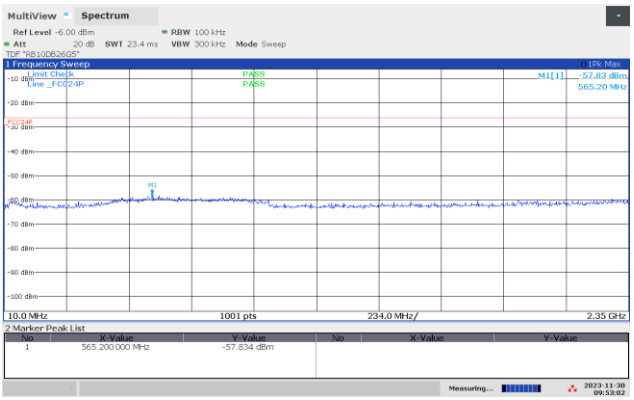
Conducted Emissions 2550-10000 MHz, 2402 MHz, 2Mb



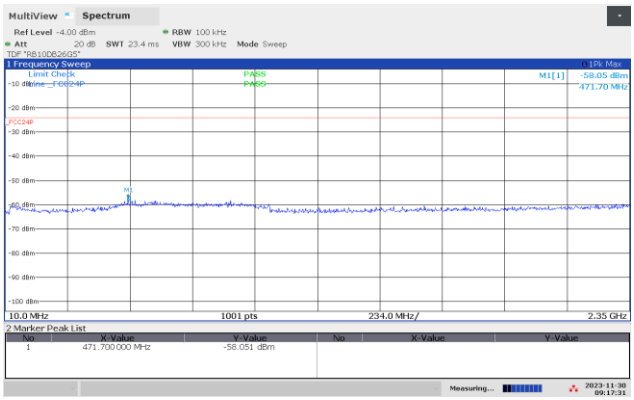
Conducted Emissions 10-26 GHz, 2402 MHz, 1Mb



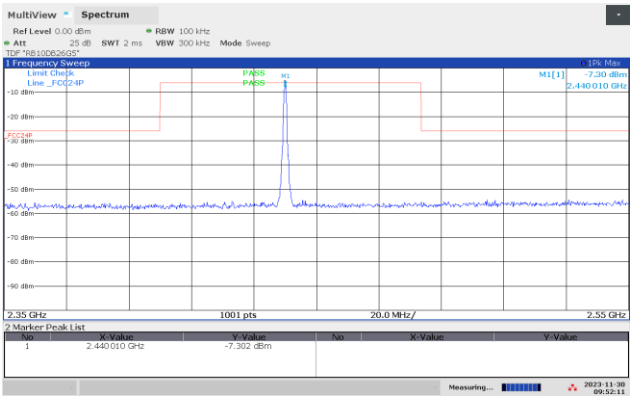
Conducted Emissions 10-26 GHz, 2402 MHz, 2Mb



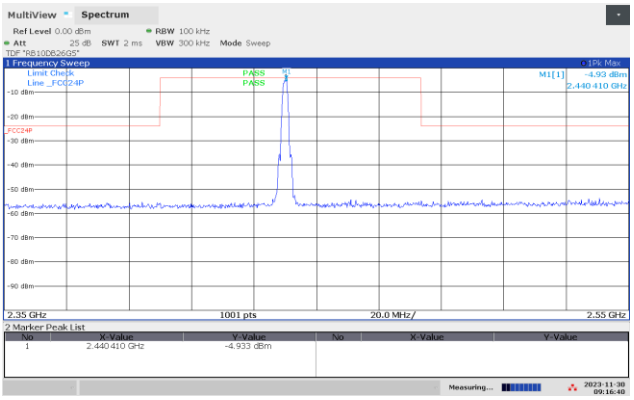
Conducted Emissions 10-2350 MHz, 2440 MHz, 1Mb



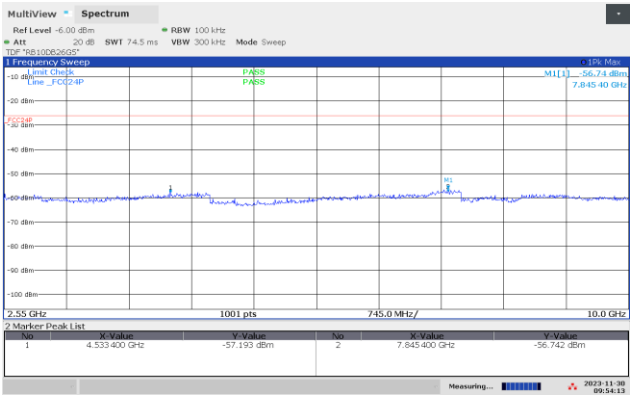
Conducted Emissions 10-2350 MHz, 2440 MHz, 2Mb



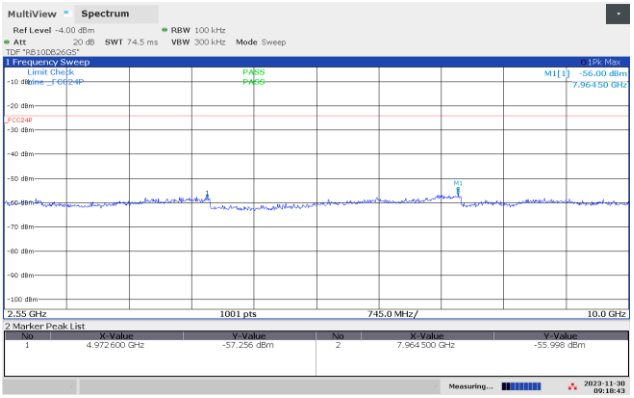
Conducted Emissions 2350-2550 MHz, 2440 MHz, 1Mb



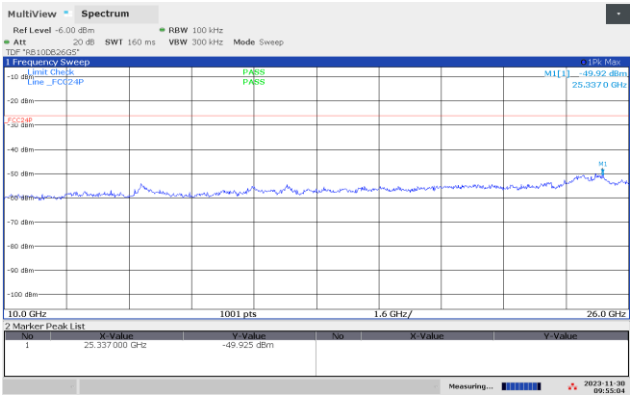
Conducted Emissions 2350-2550 MHz, 2440 MHz, 2Mb



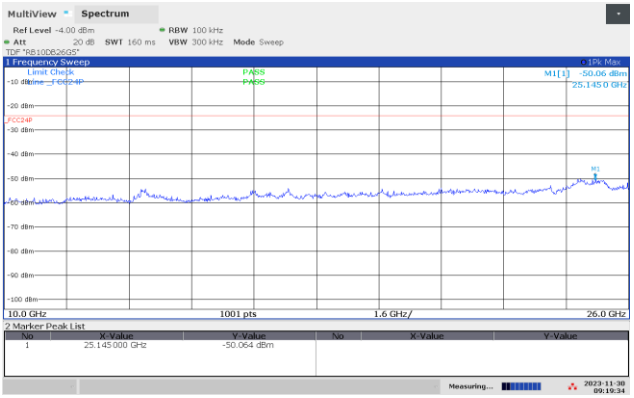
Conducted Emissions 2550-10000 MHz, 2440 MHz, 1Mb



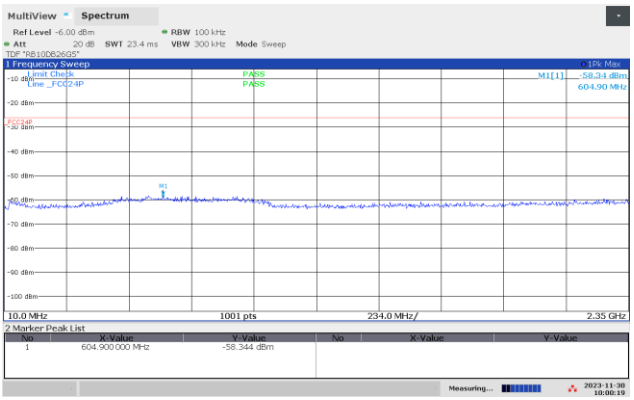
Conducted Emissions 2550-10000 MHz, 2440 MHz, 2Mb



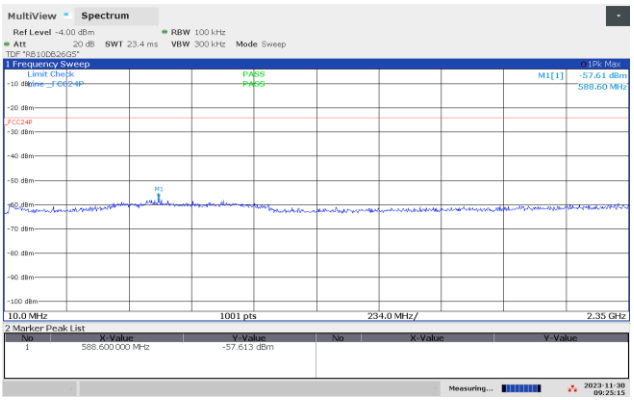
Conducted Emissions 10-26 GHz, 2440 MHz, 1Mb



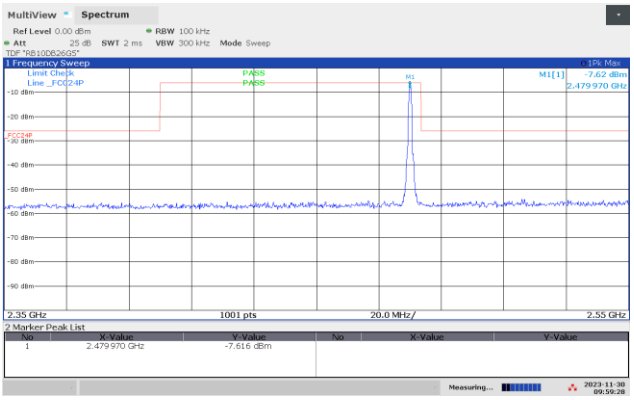
Conducted Emissions 10-26 GHz, 2440 MHz, 2Mb



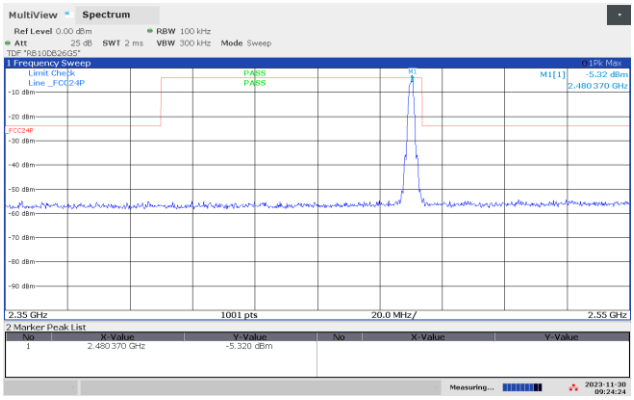
Conducted Emissions 10-2350 MHz, 2480 MHz, 1Mb



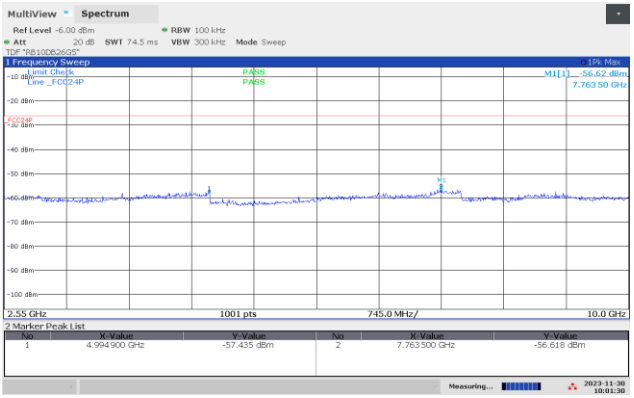
Conducted Emissions 10-2350 MHz, 2480 MHz, 2Mb



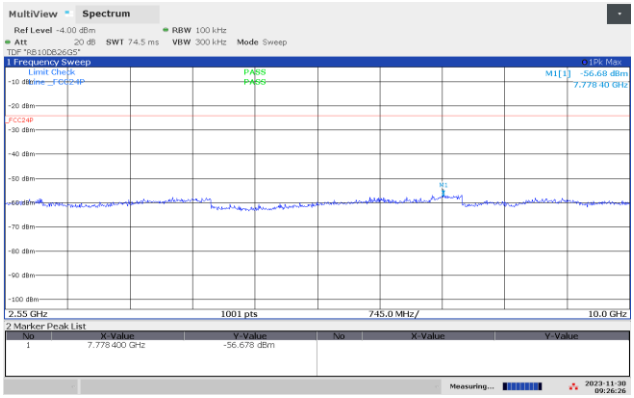
Conducted Emissions 2350-2550 MHz, 2480 MHz, 1Mb



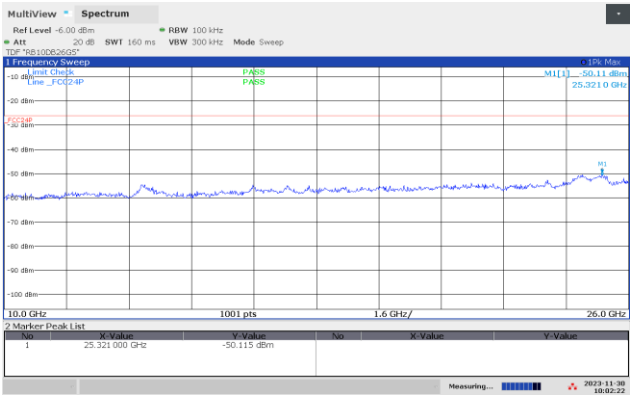
Conducted Emissions 2350-2550 MHz, 2480 MHz, 2Mb



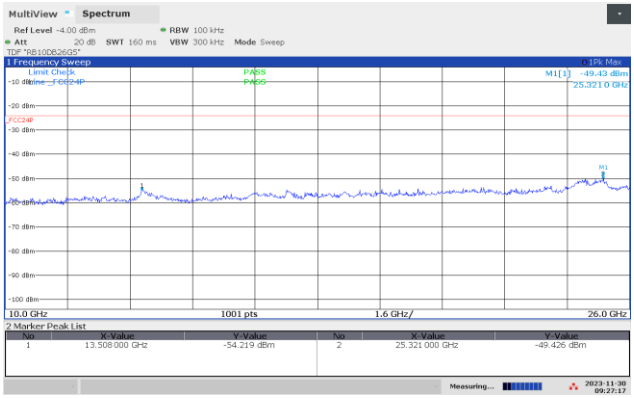
Conducted Emissions 2550-10000 MHz, 2480 MHz, 1Mb



Conducted Emissions 2550-10000 MHz, 2480 MHz, 2Mb



Conducted Emissions 10-26 GHz, 2480 MHz, 1Mb



Conducted Emissions 10-26 GHz, 2480 MHz, 2Mb

2.6 Restricted Bands of operation

Restricted Bands of operation for FCC and ISED are defined in FCC Part 15.205 and ISED RSS-GEN, Issue 5 clause 8.10.

Generally, no fundamentals are allowed in the restricted bands and all emissions must comply with the limits in FCC 15.209 or RSS-GEN, Issue 5, clause 8.9.

FCC (MHz)	ISED (MHz)	FCC (GHz)	ISED (GHz)
0.090-0.110		**0.96-1.24** **1.3-1.427**	**0.96-1.427**
0.495-0.505		1.435-1.6265	
2.1735-2.1905		1.6455-1.6465	
	3.020-3.026	1.660-1.710	
4.125-4.128		1.7188-1.7222	
4.17725-4.17775		2.2-2.3	
4.20725-4.20775		2.31-2.39	
	5.677-5.683	2.4835-2.5	
6.215-6.218		**2.69-2.9**	**2.655-2.9**
6.26775-6.26825		3.26-3.267	
6.31175-6.31225		3.332-3.339	
8.291-8.294		3.3458-3.358	
8.362-8.366		**3.6-4.4**	**3.5-4.4**
8.37625-8.38675		4.5-5.15	
8.41425-8.41475		5.35-5.46	
12.29-12.293		7.25-7.75	
12.51975-12.52025		8.025-8.5	
12.57675-12.57725		9.0-9.2	
13.36-13.41		9.3-9.5	
16.42-16.423		10.6-12.7	
16.69475-16.69525		13.25-13.4	
16.80425-16.80475		14.47-14.5	
25.5-25.67		15.35-16.2	
37.5-38.25		17.7-21.4	
73-74.6		22.01-23.12	
74.8-75.2		23.6-24.0	
108-121.94 **123-138**	**108-138**	31.2-31.8	
149.9-150.05		36.43-36.5	
156.52475-156.52525		Above 38.6	
156.7-156.9			
162.0125-167.17			
167.72-173.2			
240-285			
322-335.4			
399.9-410			
608-614			

Frequencies in **Bold** text are specific for FCC or ISED, all other frequencies are common.

2.7 Radiated Emissions, Band Edge

FCC Part 15.209 (a)

ISED Canada RSS-GEN Issue 5, Clause 7.3 / 8.9

Measurement procedure: **ANSI C63.10-2013 Clause 11.12**

Test Results: Complies

EUT in test mode transmitting modulated signals at 2402, 2480, and 2480 MHz respectively. At 1Mb the signal is a pulsed wave and 2Mb the signal is non-pulsed.

For 2Mb both the peak and average levels are measured and compared with the respective limits. For 1Mb only the peak level is measured and used in the table below as it complies with both peak and average limits.

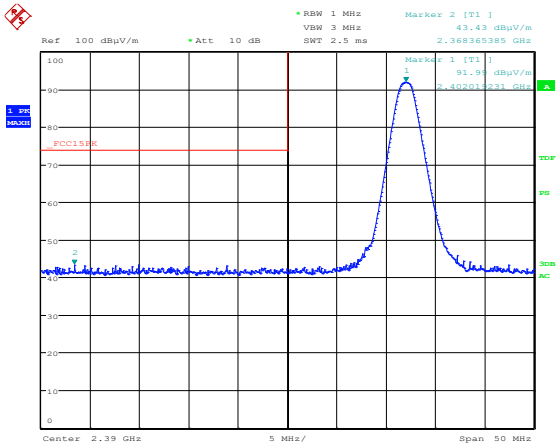
Measurement Data:

Peak Detector					
Modulation and Bitrate	Measured field strength (dBµV/m)		Limit	Margin	
	2390 MHz	2483.5 MHz	dB	dB	
GFSK, 1Mb	43.4	48.1	74	30.6	25.9
GFSK, 2Mb	44.0	57.7	74	30.0	17.3

Average Detector					
Modulation and Bitrate	Measured field strength (dBµV/m)		Limit	Margin	
	2390 MHz	2483.5 MHz	dB	dB	
GFSK, 1Mb	*	*	54	*	*
GFSK, 2Mb	*	51.8	54	*	2.2

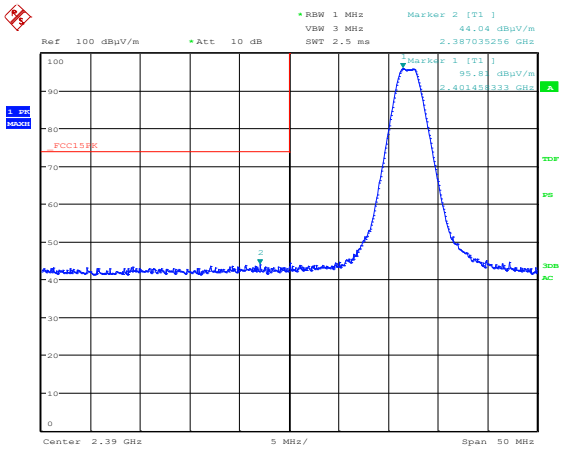
* Measured Peak Value is below the Average Limit

See attached plots.



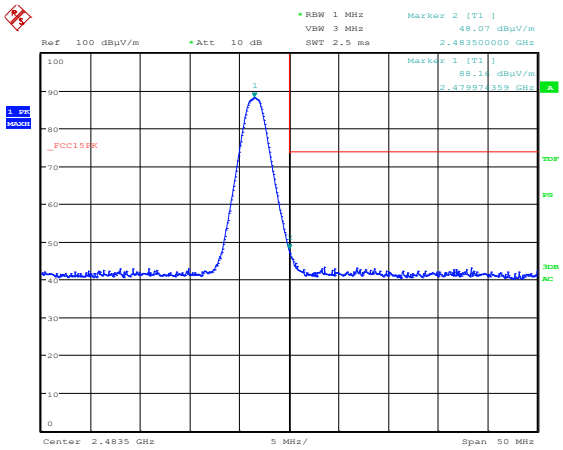
Date: 24.NOV.2023 06:56:49

XZ-plane, VP, Lower Band Edge, 2402 MHz, 1Mb, Peak



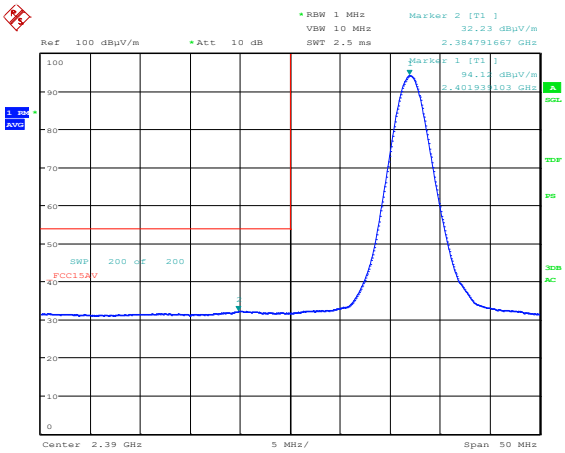
Date: 24.NOV.2023 06:54:22

XZ-plane, VP, Lower Band Edge, 2402 MHz, 2Mb, Peak



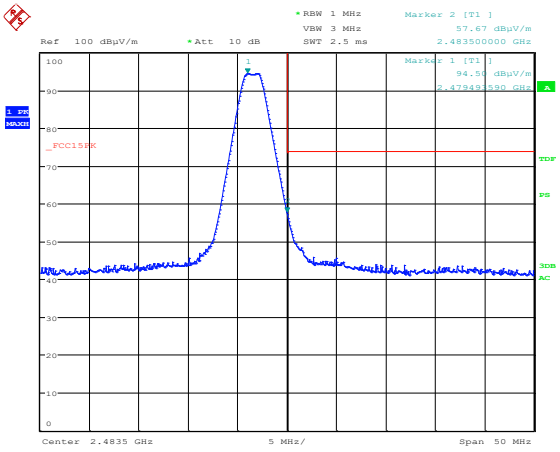
Date: 23.NOV.2023 14:26:22

XZ-plane, HP, Upper Band Edge, 2480 MHz, 1Mb, Peak



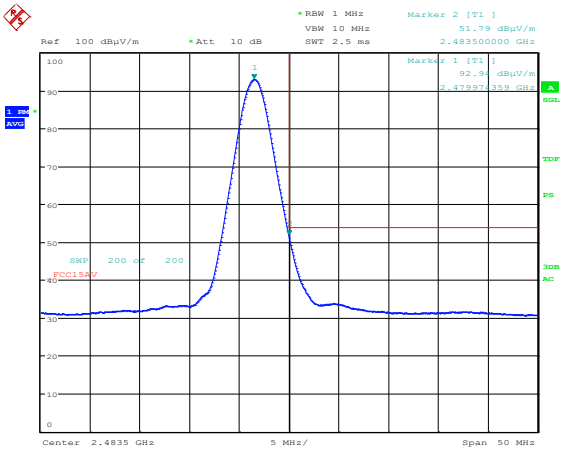
Date: 24.NOV.2023 06:54:49

XZ-plane, VP, Lower Band Edge, 2402 MHz, 2Mb, Average



Date: 24.NOV.2023 07:11:31

XZ-plane, HP, Upper Band Edge, 2480 MHz, 2Mb, Peak



Date: 24.NOV.2023 07:12:03

XZ-plane, HP, Upper Band Edge, 2480 MHz, 2Mb, Average

2.8 Radiated Emissions, 30 – 1000 MHz.

FCC Part 15.209 (a)

ISED Canada RSS-GEN Issue 5, Clause 7.3/8.9

Measurement procedure: ANSI C63.10-2013 Clause 11.12

Test Results: Complies

EUT in test mode transmitting modulated signals at 2402, 2480, and 2480 MHz respectively. At 1MB the signal is a pulsed wave and 2Mb the signal is non-pulsed.

Measurement Data:

Detector: Peak or Quasi-Peak as applicable.

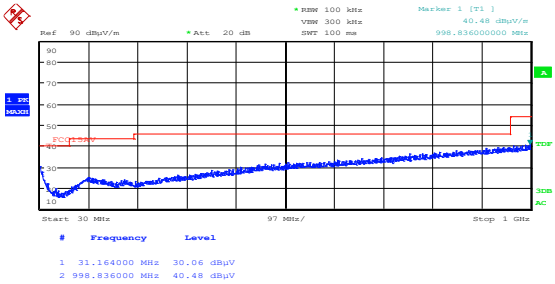
Measuring distance 3 m

Measured Frequency (MHz)	Carrier Frequency (MHz)	Modulation	Measured Emission (dBµV/m)	Limit (dBµV/m)	Margin (dB)
30 – 88	2402/2440/2480	1Mb/2Mb	< 33	40.0	> 7.0
88 – 216	2402/2440/2480	1Mb/2Mb	< 30	43.5	> 13.5
216 – 960	2402/2440/2480	1Mb/2Mb	< 40	46.0	> 6.0
960 – 1000	2402/2440/2480	1Mb/2Mb	< 44	54.0	> 10

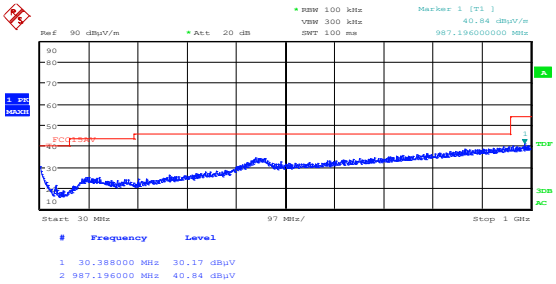
See attached plots

Requirements/Limit

FCC	Part 15.209 @ frequencies defined in §15.205	
ISED	RSS-GEN Issue 5, Clause 8.9 @ frequencies defined in clause 8.10	
Frequency	Radiated emission limit @3 meters	
30 – 88 MHz	100 µV/m	40.0 dBµV/m
88 – 216 MHz	150 µV/m	43.5 dBµV/m
216 – 960 MHz	200 µV/m	46.0 dBµV/m
960 – 1000 MHz	500 µV/m	54.0 dBµV/m
	Limits above are with Quasi Peak Detector	

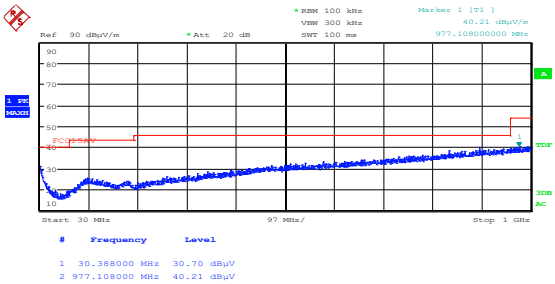


Date: 4.DEC.2023 10:19:40



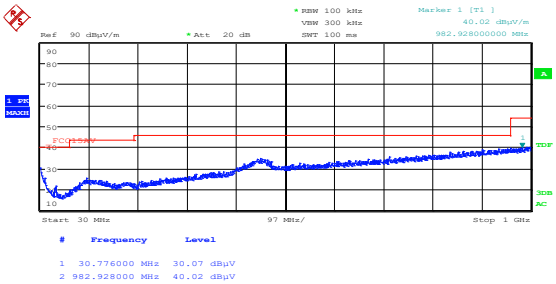
Date: 4.DEC.2023 10:17:44

Radiated Emissions 30 - 1000 MHz, 2402, 1Mb, HP



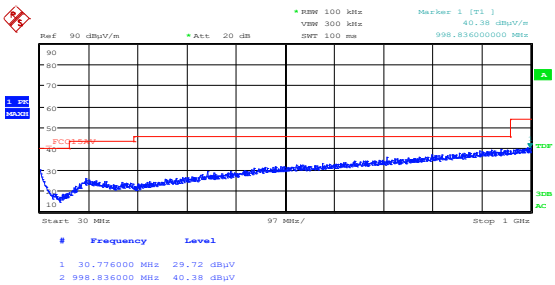
Date: 4.DEC.2023 09:24:05

Radiated Emissions 30 - 1000 MHz, 2402, 1Mb, VP



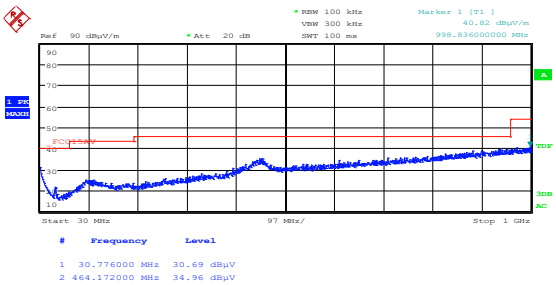
Date: 4.DEC.2023 09:22:09

Radiated Emissions 30 - 1000 MHz, 2402, 2Mb, HP



Date: 4.DEC.2023 10:24:56

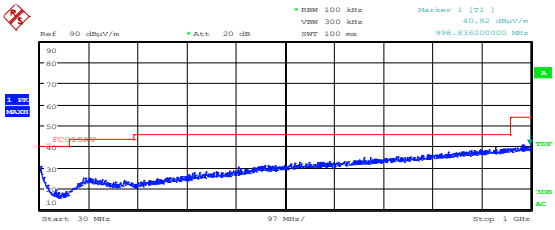
Radiated Emissions 30 - 1000 MHz, 2402, 2Mb, VP



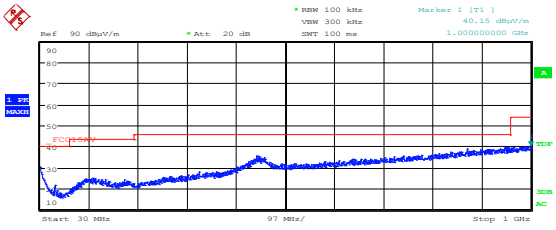
Date: 4.DEC.2023 10:23:00

Radiated Emissions 30 - 1000 MHz, 2440, 1Mb, HP

Radiated Emissions 30 - 1000 MHz, 2440, 1Mb, VP

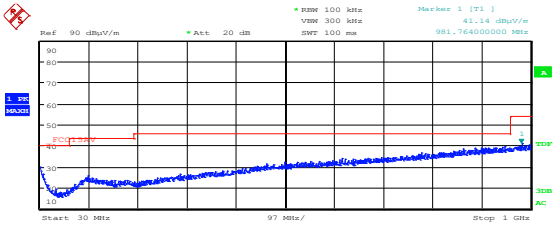


Date: 4.DEC.2023 09:40:39



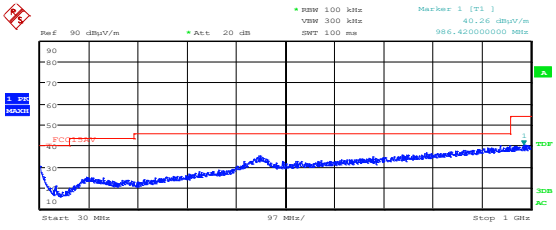
Date: 4.DEC.2023 09:38:43

Radiated Emissions 30 - 1000 MHz, 2440, 2Mb, HP



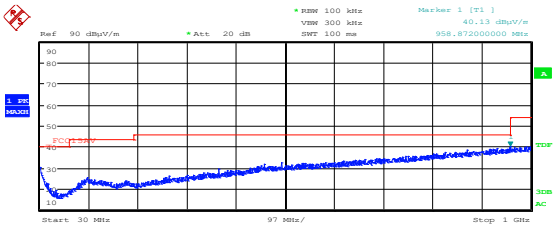
Date: 4.DEC.2023 10:30:04

Radiated Emissions 30 - 1000 MHz, 2440, 2Mb, VP



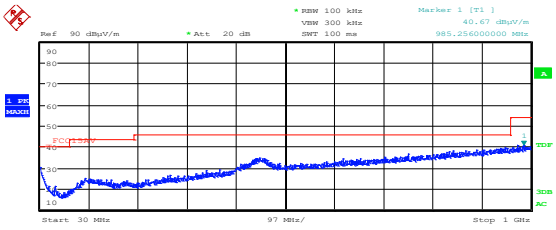
Date: 4.DEC.2023 10:28:08

Radiated Emissions 30 - 1000 MHz, 2480, 1Mb, HP



Date: 4.DEC.2023 09:52:21

Radiated Emissions 30 - 1000 MHz, 2480, 1Mb, VP



Date: 4.DEC.2023 09:50:25

Radiated Emissions 30 - 1000 MHz, 2480, 2Mb, HP

Radiated Emissions 30 - 1000 MHz, 2480, 2Mb, VP

2.9 Radiated Emissions, 1 – 26 GHz

FCC Part 15.209 (a)

ISED Canada RSS-GEN Issue 5, Clause 7.3/8.9

Measurement procedure: ANSI C63.10-2013 Clause 11.12

Test Results: Complies

EUT in test mode transmitting modulated signals at 2402, 2480, and 2480 MHz respectively. At 1MB the signal is a pulsed wave and 2Mb the signal is non-pulsed.

Measurement Data:

Measuring distance: 3m (1 – 18 GHz)

A pre-scan was performed above 18 GHz and no spurious emissions were detected.

RBW=1 MHz

Measured Frequency (GHz)	Carrier Frequency (MHz)	Modulation	Measured Emissions (dBµV/m)		Limit (dBµV/m)		Margin (dB)	
		1Mb / 2Mb	Peak	Average	Pk	Av	Pk	Av
2nd Harm *)	2402 / 2440 / 2480	1Mb / 2Mb	< 50	< 40	74	54	> 24	> 14
3rd Harm *)	2440 / 2480	1Mb / 2Mb	< 50	< 40	74	54	> 24	> 14
5th Harm *)	2402 / 2440 / 2480	1Mb / 2Mb	< 54	< 44	74	54	> 20	> 10
8th Harm *)	2402 / 2440 / 2480	1Mb / 2Mb	< 60	< 50	74	54	> 34 **)	> 24 **)
9th Harm *)	2480	1Mb / 2Mb	< 60	< 50	74	54	> 34 **)	> 24 **)

Note: *) Listed harmonic values giving spurious within restricted frequency bands (shown in table in Clause 2.6).

) Prescan measured at 20-25 cm distance – see plot below. Transducer Factor in analyzer is not corrected for this – thus **the margin in the table above at these frequencies has been adjusted by 20 dB [~ 20 * log (3 / 0.25) = 21.6 dB].

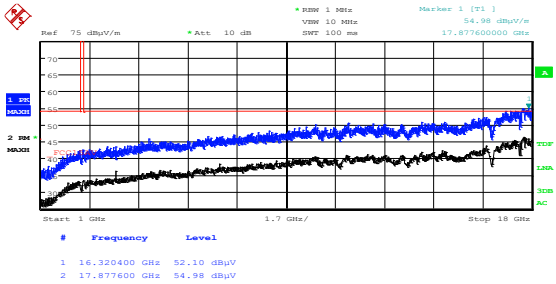
A Band Reject Filter was used for measurements from 1 GHz to 18 GHz

Antenna factor, amplifier gain, and cable loss are included in spectrum analyzer “Transducer factor”.

See plots.

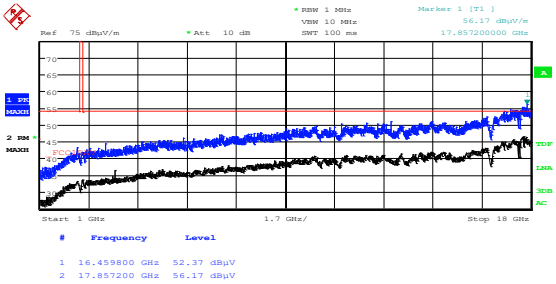
Requirements/Limit

FCC	Part 15.209 @ frequencies defined in §15.205	
ISED	RSS-GEN Issue 5, clause 8.9 @ frequencies defined in clause 8.10	
	Radiated emission limit @3 meters	
Frequency	Average Detector	Peak Detector
1 – 26 GHz	54.0 dBµV/m	74.0 dBµV/m



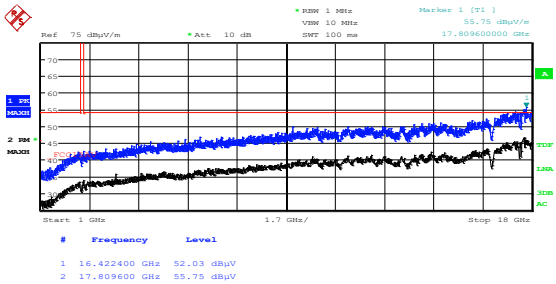
Date: 24.NOV.2023 12:22:23

Radiated Emissions 1 - 18 GHz, XY-plane, 2402, 1Mb, HP 200 cm



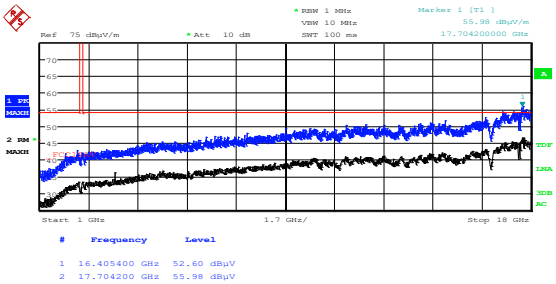
Date: 24.NOV.2023 12:20:27

Radiated Emissions 1 - 18 GHz, XY-plane, 2402, 1Mb, VP 150 cm



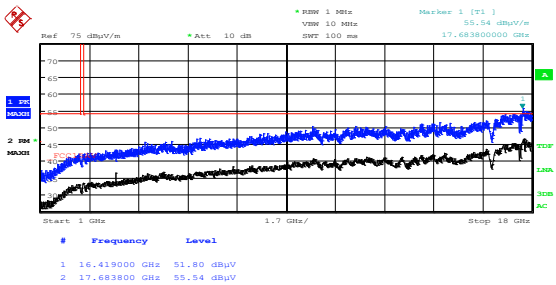
Date: 24.NOV.2023 12:13:56

Radiated Emissions 1 - 18 GHz, YZ-plane, 2402, 1Mb, HP 200 cm



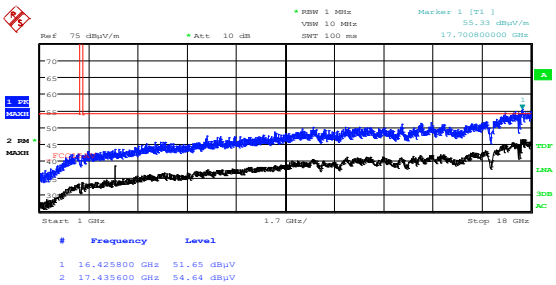
Date: 24.NOV.2023 12:12:00

Radiated Emissions 1 - 18 GHz, YZ-plane, 2402, 1Mb, VP 150 cm



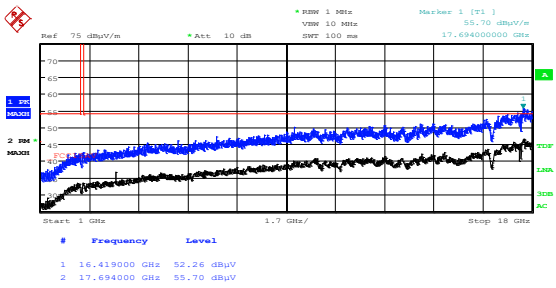
Date: 24.NOV.2023 13:05:04

Radiated Emissions 1 - 18 GHz, XY-plane, 2440, 1Mb, HP 200 cm



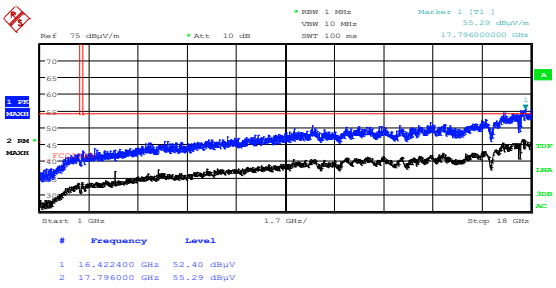
Date: 24.NOV.2023 13:03:08

Radiated Emissions 1 - 18 GHz, XY-plane, 2440, 1Mb, VP 150 cm



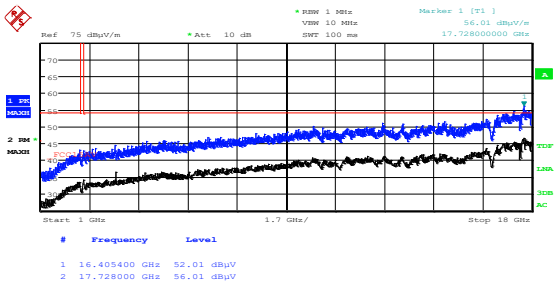
Date: 24.NOV.2023 12:49:12

Radiated Emissions 1 - 18 GHz, YZ-plane, 2440, 1Mb, HP 200 cm



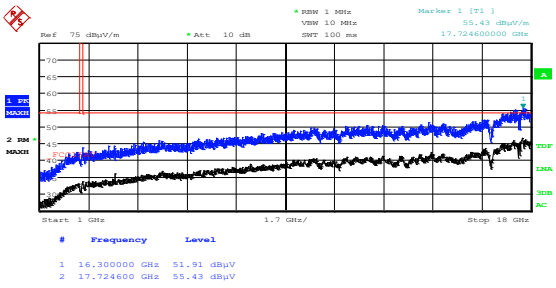
Date: 24.NOV.2023 12:47:16

Radiated Emissions 1 - 18 GHz, YZ-plane, 2440, 1Mb, VP 150 cm



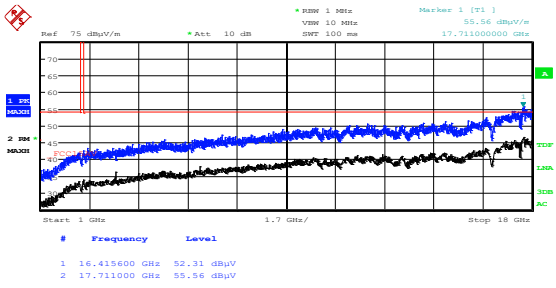
Date: 24.NOV.2023 13:30:47

Radiated Emissions 1 - 18 GHz, XY-plane, 2480, 1Mb, HP 200 cm



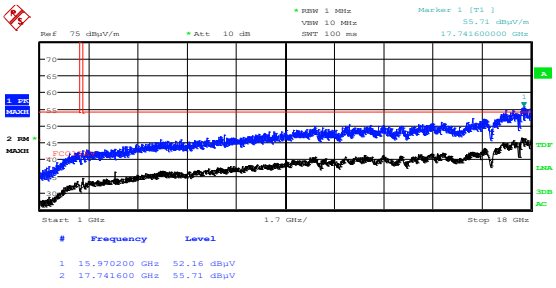
Date: 24.NOV.2023 13:28:51

Radiated Emissions 1 - 18 GHz, XY-plane, 2480, 1Mb, VP 150 cm



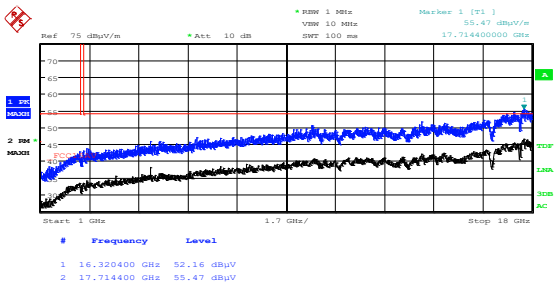
Date: 24.NOV.2023 13:45:06

Radiated Emissions 1 - 18 GHz, YZ-plane, 2480, 1Mb, HP 200 cm



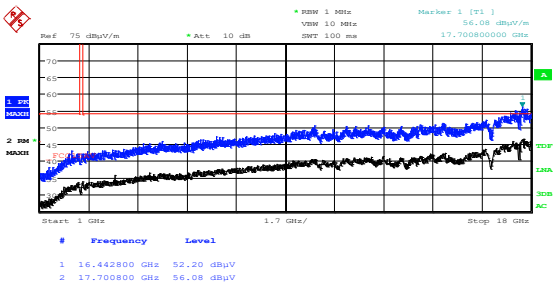
Date: 24.NOV.2023 13:43:10

Radiated Emissions 1 - 18 GHz, YZ-plane, 2480, 1Mb, VP 150 cm



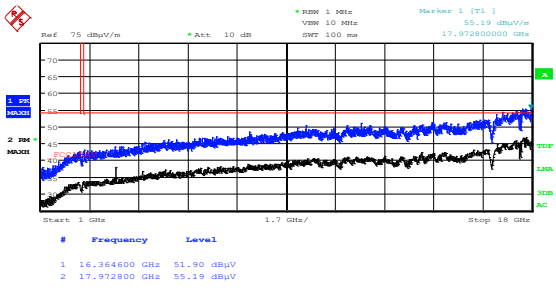
Date: 24.NOV.2023 09:17:27

Radiated Emissions 1 - 18 GHz, XY-plane, 2402, 2Mb, HP 200 cm



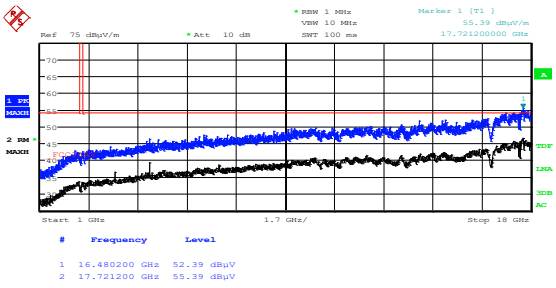
Date: 24.NOV.2023 09:15:30

Radiated Emissions 1 - 18 GHz, XY-plane, 2402, 2Mb, VP 150 cm



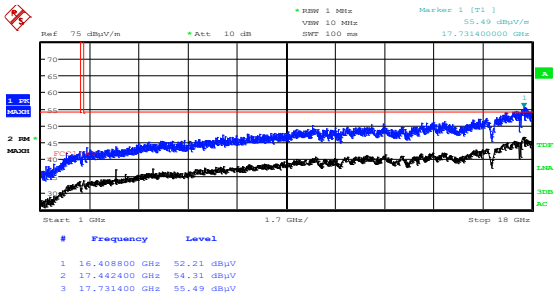
Date: 24.NOV.2023 08:57:41

Radiated Emissions 1 - 18 GHz, YZ-plane, 2402, 2Mb, HP 200 cm



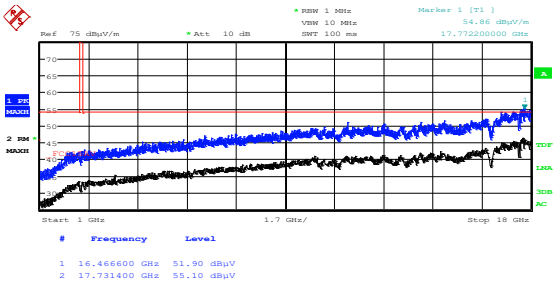
Date: 24.NOV.2023 08:55:44

Radiated Emissions 1 - 18 GHz, YZ-plane, 2402, 2Mb, VP 150 cm



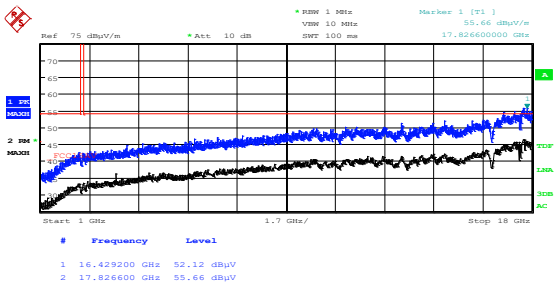
Date: 24.NOV.2023 09:45:13

Radiated Emissions 1 - 18 GHz, XY-plane, 2440, 2Mb, HP 200 cm



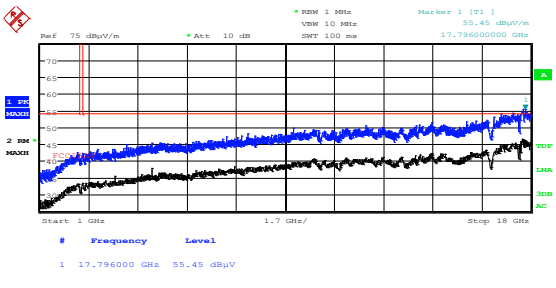
Date: 24.NOV.2023 09:43:16

Radiated Emissions 1 - 18 GHz, XY-plane, 2440, 2Mb, VP 150 cm



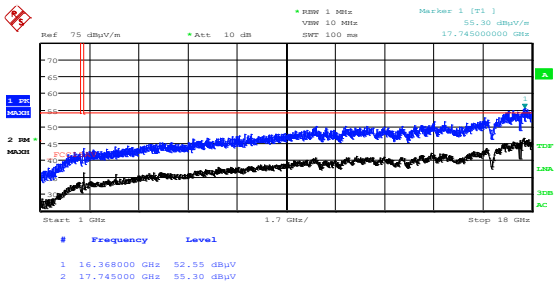
Date: 24.NOV.2023 10:05:39

Radiated Emissions 1 - 18 GHz, YZ-plane, 2440, 2Mb, HP 200 cm



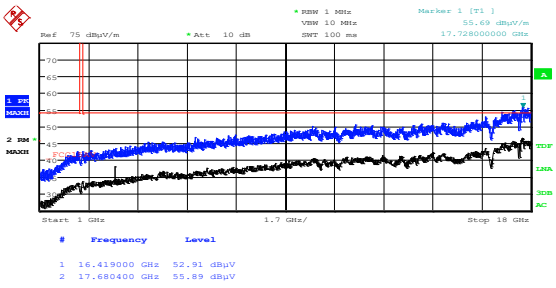
Date: 24.NOV.2023 10:03:43

Radiated Emissions 1 - 18 GHz, YZ-plane, 2440, 2Mb, VP 150 cm



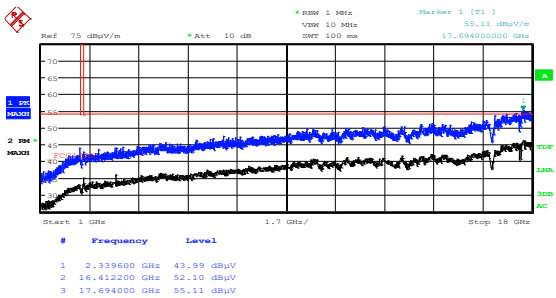
Date: 24.NOV.2023 10:25:11

Radiated Emissions 1 - 18 GHz, XY-plane, 2480, 2Mb, HP 200 cm



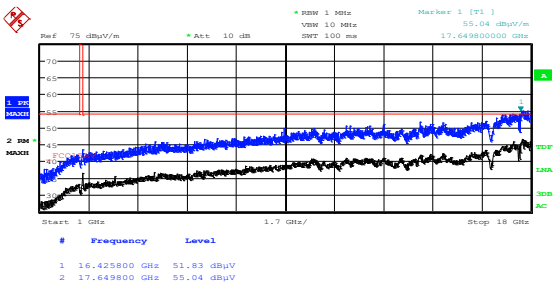
Date: 24.NOV.2023 10:23:14

Radiated Emissions 1 - 18 GHz, XY-plane, 2480, 2Mb, VP 150 cm



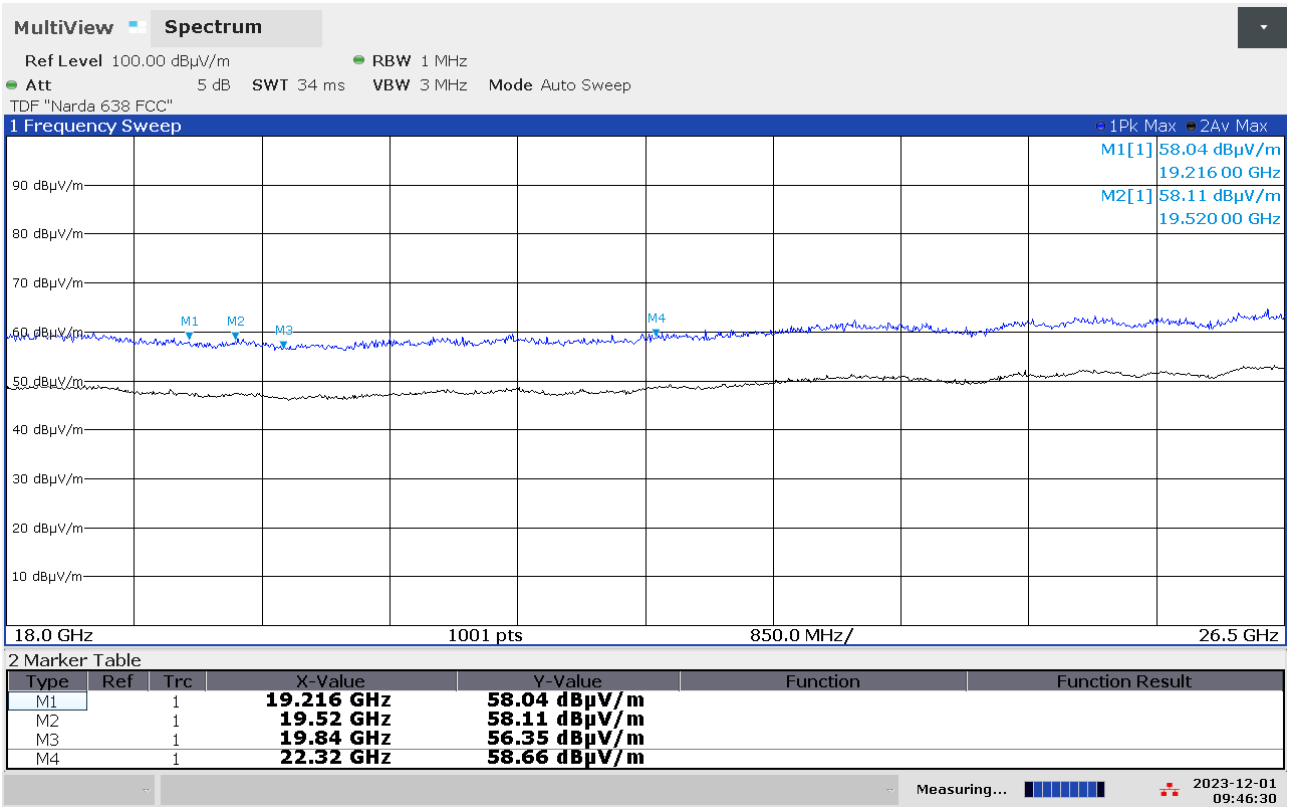
Date: 24.NOV.2023 10:11:18

Radiated Emissions 1 - 18 GHz, YZ-plane, 2480, 2Mb, HP 200 cm



Date: 24.NOV.2023 10:09:22

Radiated Emissions 1 - 18 GHz, YZ-plane, 2480, 2Mb, VP 150 cm



Prescan 20-25 cm distance, 2402, 2440, and 2480 MHz, 1&2 MBps, device rotatet in 3 axis and measurement antenna positioned in two orientations. The markers indicate frequencies for 4th harmonics at 19216, 19520, and 19840 MHz – and 5th harmonic at 22320 MHz.

2.10 Power Spectral Density (PSD)

FCC part 15.247(d)

ISED Canada RSS-247 Issue 2, Clause 5.2 (2)

Measurement procedure: ANSI C63.10-2013 Clause 11.10

Test Results: Complies

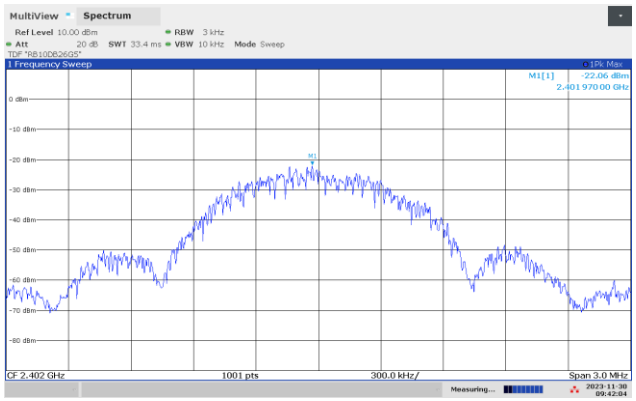
EUT in test mode transmitting modulated signals at 2402, 2480, and 2480 MHz respectively. At 1MB the signal is a pulsed wave and 2Mb the signal is non-pulsed.

Measurement Data:

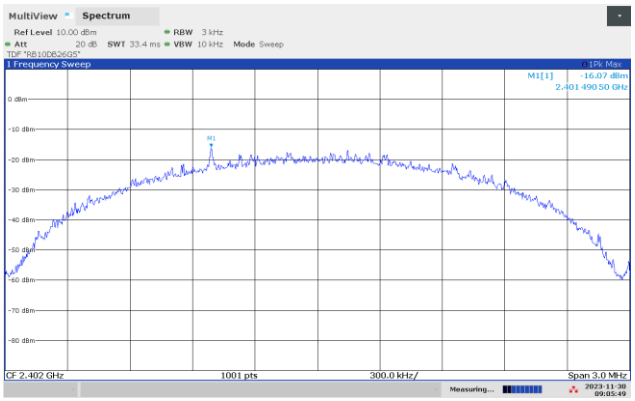
The measurement procedure PKPSD described in ANSI C63.10-2013 was used.

Modulation Type and Bitrate	Measured Power Spectral Density (dBm/3kHz)		
	2402 MHz	2440 MHz	2480 MHz
GFSK 1Mb	-22.06	-22.46	-23.11
GFSK 2Mb	-16.07	-16.67	-17.01

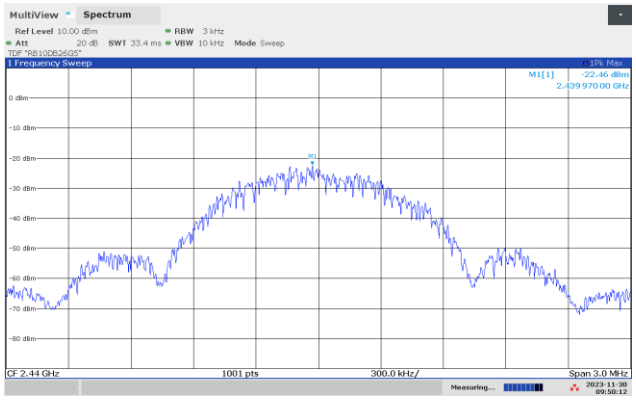
Requirement for systems using Digital Modulation
The power spectral density conducted from the intentional radiator to the antenna shall not be greater than 8 dBm in any 3 kHz band during any time interval of continuous transmission.



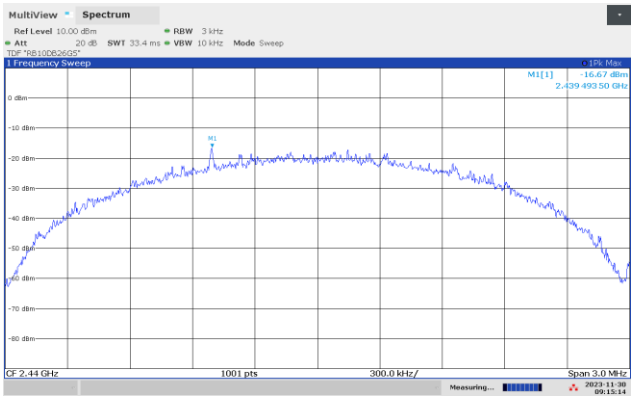
PSD, 2402 MHz, 1Mb



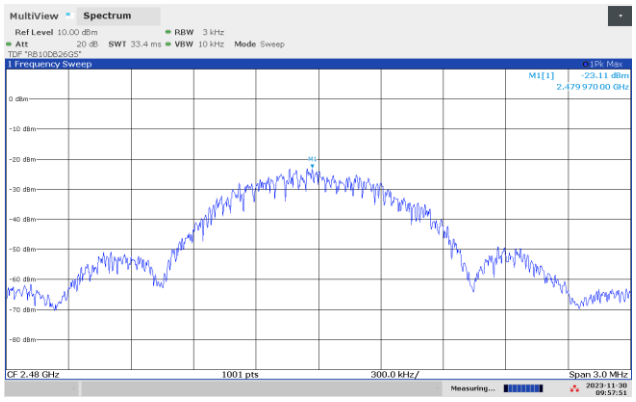
PSD, 2402 MHz, 2Mb



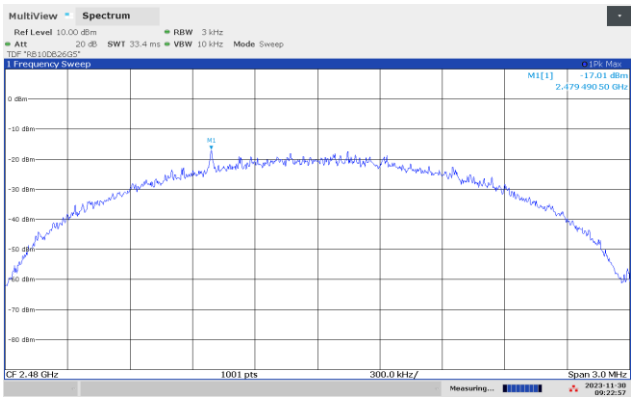
PSD, 2440 MHz, 1Mb



PSD, 2440 MHz, 2Mb



PSD, 2480 MHz, 1Mb



PSD, 2480 MHz, 2Mb

3 Measurement Uncertainty

Measurement Uncertainty Values		
Test Item		**Uncertainty**
Output Power		±0.5 dB
Power Spectral Density		±0.5 dB
Out of Band Emissions, Conducted	**< 3.6 GHz**	±0.6 dB
	> 3.6 GHz	±0.9 dB
Spurious Emissions, Radiated	**< 1 GHz**	±2.5 dB
	> 1 GHz	±2.2 dB
Emission Bandwidth		±4 %
Power Line Conducted Emissions		+2.9 / -4.1 dB
Spectrum Mask Measurements	**Frequency**	±5 %
	Amplitude	±1.0 dB
Frequency Error		±0.6 ppm
Temperature Uncertainty		±1 °C

All uncertainty values are expanded standard uncertainty to give a confidence level of 95%, based on coverage factor k=2

4 LIST OF TEST EQUIPMENT

To facilitate inclusion on each page of the test equipment used for related tests, each item of test equipment and ancillaries are identified (numbered) by the Test Laboratory.

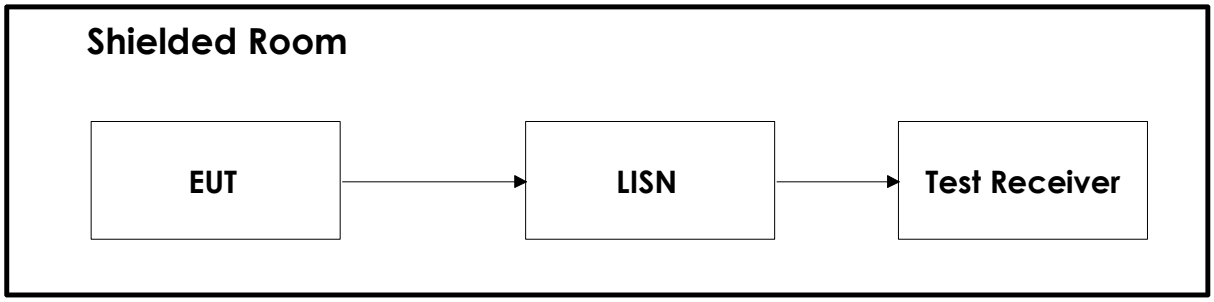
No.	Instrument	Type of instrument	Manufacturer	Ref. no.	Cal Date	Cal Due
1	FSW26	Spectrum Analyzer	Rohde & Schwarz	LR 1640	2023.02	2024.02
2	FSW43	Spectrum Analyzer	Rohde & Schwarz	LR 1690	2023.02	2024.02
3	ESU40	EMI receiver	Rohde & Schwarz	LR 1639	2023.02	2024.02
4	JB1	Bilog Antenna	SunAR	LR 1734	2023.01	2024.02
5	3115	Horn antenna	EMCO	LR 1330	2022.11	2024.11
6	DBF-520-20	Horn Antenna	SD	LR 101	2021.07	2024.07
7	LNA-40-00101800	Preamplifier	NardaMiteq	LR 1747	2023.08	2024.08
8	638	Horn Antenna	Narda	LR 098	2021.07	2024.07
9	8449B	Preamplifier 26GHz	HP	LR 1322	2023.08	2024.08
10	637	Horn Antenna	Narda	LR 097	2021.07	2024.07
11	JS4 Standalone	Preamplifier 40GHz	NardaMiteq	LR 1591	2023.02	2024.02
12	HFH2-Z2	Loop Antenna	Rohde & Schwarz	LR 1660	2022.01	2024.01
13	CMW500	Communications tester	Rohde & Schwarz	LR 1791	2022.03	2025.03
14	SMBV-100B	Signal generator	Rohde & Schwarz	LR 1743	2022.01	2024.01
15	6810.17A	Attenuator	Suhner	LR 1284	Cal-Before-Use	
16	Sucoflex 102	Cable Microwave	Suhner		2023.05	2025.05
17	TS8997	Test System	Rohde & Schwarz	/		
18	SMB100A	RF generator	Rohde & Schwarz	LR 1656	2023.02	2025.02
18.1	SMW200A	Vector generator	Rohde & Schwarz	LR 1807	2022.09	2024.09
18.2	FSVA3044	Spectrum analyzer	Rohde & Schwarz	LR 1808	2022.09	2024.09
18.3	OSP220	open switch and control platform	Rohde & Schwarz	LR 1806	2022.09	2024.09
18.4	OSP120	open switch and control platform	Rohde & Schwarz	LR 1793	2022.02	2024.08
18.5	Model 87 V	Multimeter	Fluke	N-4669	2023.04	2025.04
19	3115	Double Ridged Horn Antenna	EMCO	LR 1226	2022.12	2025.12
20	3115	Double Ridged Horn Antenna	EMCO	LR 1330	2022.11	2025.11
21	No324415	Notch Filter	Microwave Circuits	LR 1785	2021.07	2024.07
22	CPX400S	DC Source	AimTTi	LR 1711	LT 5218 for control	
23	45 DMM	Multimeter	Fluke	LT 5218	2023.04	2025.04
24	6812B	AC Power Source	Agilent	LR 1515	2022.12	2023.12
25	ACS TY80	Climatic Chamber	ACS	LR 1083	2023.03	2025.03
26	VC 4060	Climate Chamber	Votsch	LR 1435	2022.12	2025.12

The software listed below has been used for one or more tests.

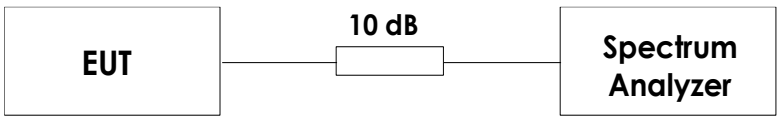
No.	Manufacturer	Name	Version	Comment
1	Rohde & Schwarz	EMC32	10.50.40	EMC test software
2	Rohde & Schwarz	GPIBShot	2.7	Screenshots from R&S Spectrum Analyzers

5 BLOCK DIAGRAM

5.1 Power Line Conducted Emission

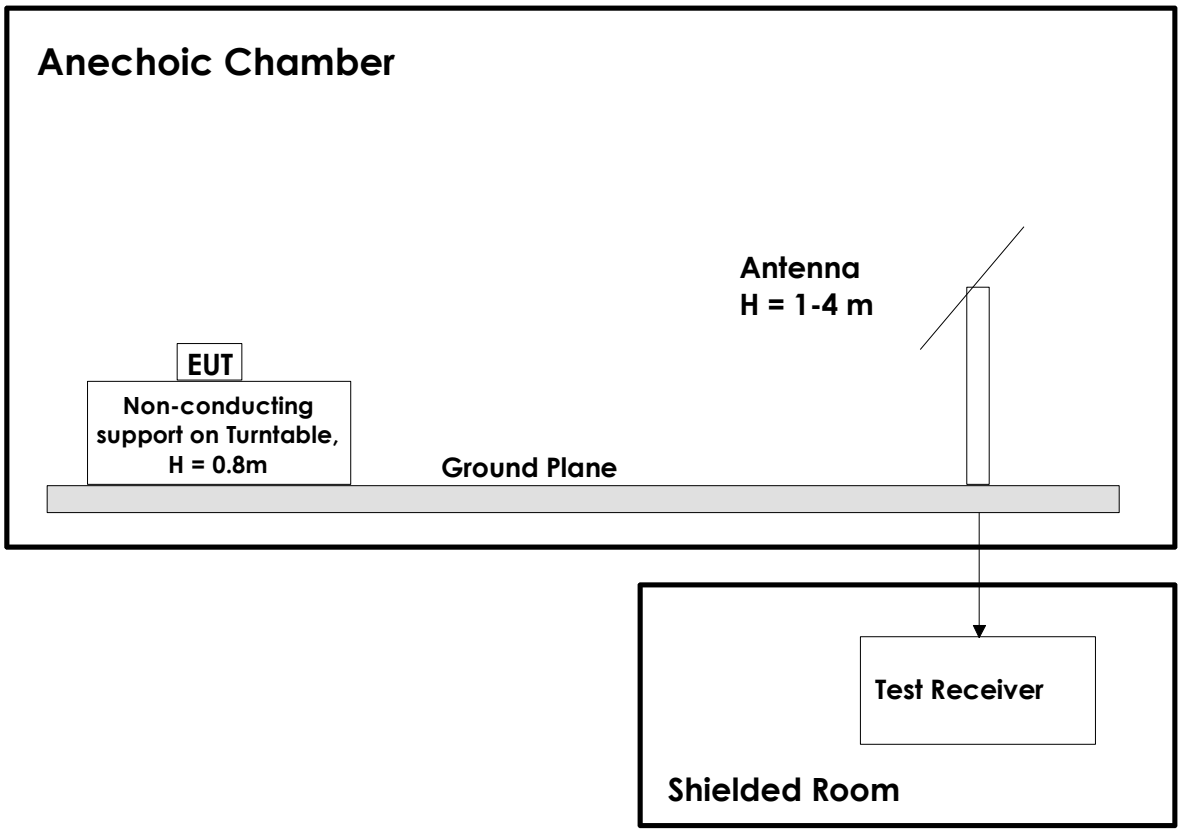


5.2 Conducted Tests



This test set-up is used for all Conducted tests.
For Frequency Stability test the EUT was placed in a climatic chamber.

5.3 Test Site Radiated Emission



This test setup is used for all radiated emissions tests. For frequencies below 30 MHz the measuring distance is 10m, for all other frequencies it is 3m or 1m. Emissions above 1 GHz are measured with a Spectrum Analyzer and Horn Antenna. For measurements above 18 GHz the test receiver is moved inside the anechoic chamber and located next to the antenna to minimize the cable loss. All measurements at 1GHz and above were performed with turntable height 1.5m and with the ground plane covered by absorbers. A pre-amplifier is used for all measurements above 30 MHz, and High-Pass or Band-Pass filter is used for all harmonics.