

Test Report

Product	Hearing Protection with Bluetooth
Name and address of the applicant	Husqvarna AB Drottninggatan 2 SE-561 82 Huskvarna, Sweden
Name and address of the manufacturer	Husqvarna AB Drottninggatan 2 SE-561 82 Huskvarna, Sweden
Model	HP500C-1, HP500C-2
Rating	3.7Vdc max. 200mA
Trademark	 Husqvarna®
Additional information	Bluetooth, DECT 6.0
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	PRJ0014324
Tested in period	2022-10-18 to 2022-10-25
Issue date	2023-06-30
Name and address of the testing laboratory	 Nemko Scandinavia AS Instituttveien 6 2007 Kjeller, Norway www.nemko.com
	CAB Number: FCC: NO0001 ISED: NO0470 ISED No: 2040D-1
	  An accredited technical test executed under the Norwegian accreditation scheme
	Prepared by [Frode Sveinsen] 
	Approved by [G.Suhanthakumar] 
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Template version: C

Revision history

Revision	Date	Comment	Sign
A	2023-06-27	First edition	FS
B	2023-06-30	Added Model Overview	FS

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.

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1 INFORMATION

1.1 Test Item

Name	Husqvarna
Model	HP500C-1, HP500C-2
FCC ID	ZASHP500
ISED ID	23307-HP500
Serial number	Conducted Sample: R317 Radiated Sample: R313
Hardware identity and/or version	853505
Software identity and/or version	0.1.0-EP1_Cert
Frequency Range	2402 – 2480 MHz
Number of Channels	40
Operating Modes	Bluetooth Low Energy <input checked="" type="checkbox"/> 1Mb <input checked="" type="checkbox"/> 2Mb
Type of Modulation	GFSK
Conducted Output Power	0.76 mW
Antenna Connector	None
Number of Antennas	1
Diversity or Smart Antennas	No
Power Supply	Secondary Battery (3.7V Li-Ion)
Interfaces	UCB-C port for charging

Description of Test Item

The EUT is a Hearing Protection with Bluetooth and DECT.

This Bluetooth Low Energy part has been tested as a DTS device and fulfills all requirements DTS devices.

All tests were performed on a HP500C-1.

1.2 Model Overview

Name	Model No	Style	BT/BLE	DECT	FCC ID	IC ID
X-COM Active	HP500C-1	Headband	YES	YES	ZASHP500	23307-HP500
	HP500C-2	Helmet Mount	YES	YES	ZASHP500	23307-HP500
X-SYNC	HP500BT-1	Headband	YES	NO	TBD	TBD
	HP500BT-2	Helmet Mount	YES	NO	TBD	TBD

The Headband and Helmet Mount models are electrically identical.

TBD = To Be Decided

1.3 Normal test condition

Temperature:	20 - 24 °C
Relative humidity:	20 - 50 %
Normal test voltage:	3.7 V DC (Nominal Battery Voltage)

The values are the limit registered during the test period.

1.4 Test Engineer(s)

Frode Sveinsen

1.5 Antenna Requirement

Does the EUT have detachable antenna(s)?	<input type="checkbox"/> YES	<input checked="" type="checkbox"/> NO
If detachable, is the antenna connector(s) non-standard?	<input type="checkbox"/> YES	<input type="checkbox"/> NO
The tested equipment has only integral antennas. Conducted tests were performed with a temporary antenna connector.		

Requirement: FCC 15.203, 15.204

1.6 EUT Operating Modes

Operating modes	Radiated Emissions and Power Line Conducted Emissions were performed with the EUT set to transmit at the channel with the highest output power as worst-case scenario.
Additional information	Power Level: PL3

1.7 Comments

All measurements were done with the EUT powered by a fully charged battery.

All ports were populated during spurious emission measurements.

2 TEST REPORT SUMMARY

2.1 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 made in a semi-anechoic chamber at measuring distance of 3m.

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

<input checked="" type="checkbox"/> New Submission	<input checked="" type="checkbox"/> Production Unit
<input type="checkbox"/> Class II Permissive Change	<input type="checkbox"/> Pre-production Unit
DTS Equipment Code	<input type="checkbox"/> Family Listing

2.2 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	Complies
Antenna Requirement	15.203	6.8 (RSS-GEN)	5.8	Complies
Power Line Conducted Emission	15.107(a) 15.207(a)	7.2 / 8.8 (RSS-GEN)	6.2	Complies
Occupied Bandwidth (99% BW)	N/A	6.7 (RSS-GEN)	6.9.3	Complies
DTS Bandwidth	15.247(a)(2)	5.2 (1) (RSS-247)	11.8 Option 2	Complies
Peak Power Output	15.247(b)	5.4 (RSS-247)	11.9.1.1	Complies
Power Spectral Density	15.247(d)	5.2 (2) (RSS-247)	11.10.2 PKPSD (DTS)	Complies
Spurious Emissions (Antenna Conducted)	15.247(c)	5.5 (RSS-247)	6.7 11.11 (DTS)	Complies
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)	Complies

3 TEST RESULTS

3.1 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 μ H/50 ohms LISN

Test Results: Complies

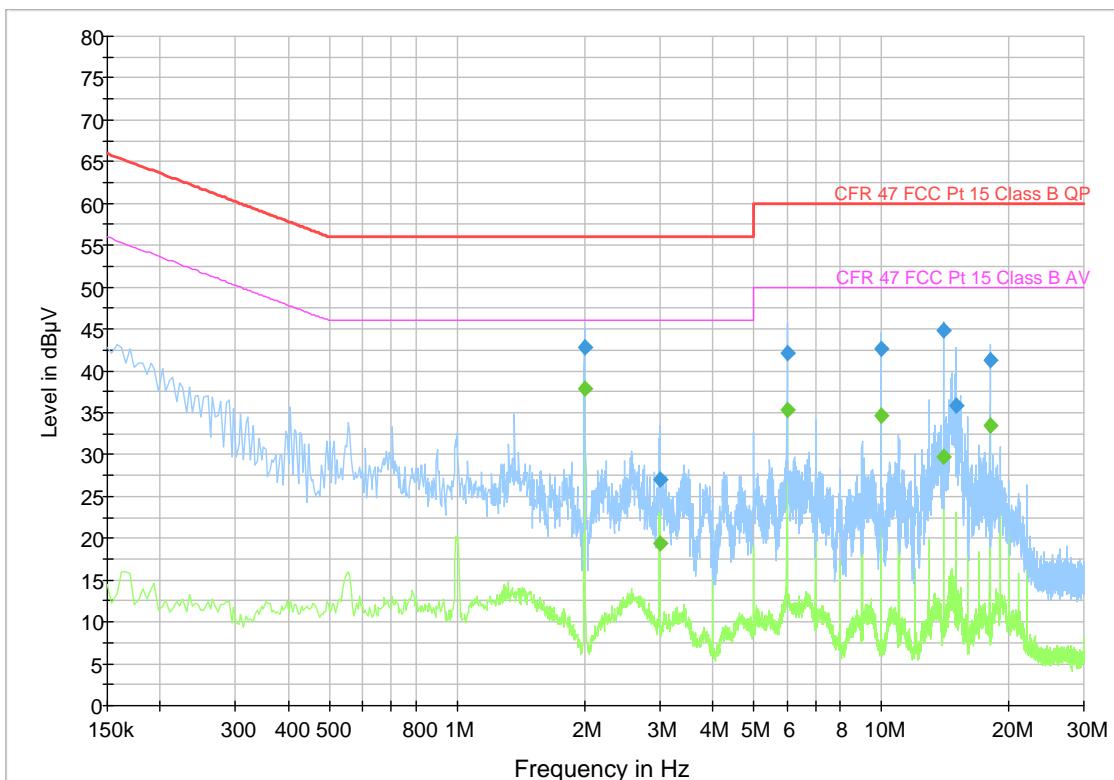
Measurement Data: EUT Charging from USB Charger, 120V 60Hz.

See attached plots.

Highest measured value (L1 and N):

Frequency (MHz)	QuasiPeak (dB μ V)	Average (dB μ V)	Limit (dB μ V)	Margin (dB)	Meas. Time (ms)	Bandwidth (kHz)	Line	Filter	Corr. (dB)
1.998000	42.87	---	56.00	13.13	15000.0	9.000	L1	OFF	9.7
2.002000	---	37.82	46.00	8.18	15000.0	9.000	L1	OFF	9.7
6.002000	---	35.29	50.00	14.71	15000.0	9.000	L1	OFF	9.8
6.002000	42.07	---	60.00	17.93	15000.0	9.000	N	OFF	9.6
10.002000	---	34.67	50.00	15.33	15000.0	9.000	N	OFF	9.6
10.002000	42.65	---	60.00	17.35	15000.0	9.000	N	OFF	9.6
14.002000	44.86	---	60.00	15.14	15000.0	9.000	N	OFF	9.7
18.002000	---	33.53	50.00	16.47	15000.0	9.000	N	OFF	9.7
18.002000	41.19	---	60.00	18.81	15000.0	9.000	L1	OFF	9.9

Full Spectrum



3.2 Occupied Bandwidth (99% BW)

ISED Canada RSS-GEN Issue 5, Clause 6.7

Measurement procedure: ANSI C63.10-2013 Clause 6.9.2

Test Results: Complies

Measurement Data:

Carrier Frequency, Data Rate	Occupied Bandwidth (99% BW)
2440 MHz, 1Mb	1.05 MHz
2440 MHz, 2Mb	2.09 MHz

Occupied Bandwidth is the same for all channels.

See attached plots.

Requirements:

No requirements for Digital Transmission Systems.



3.3 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

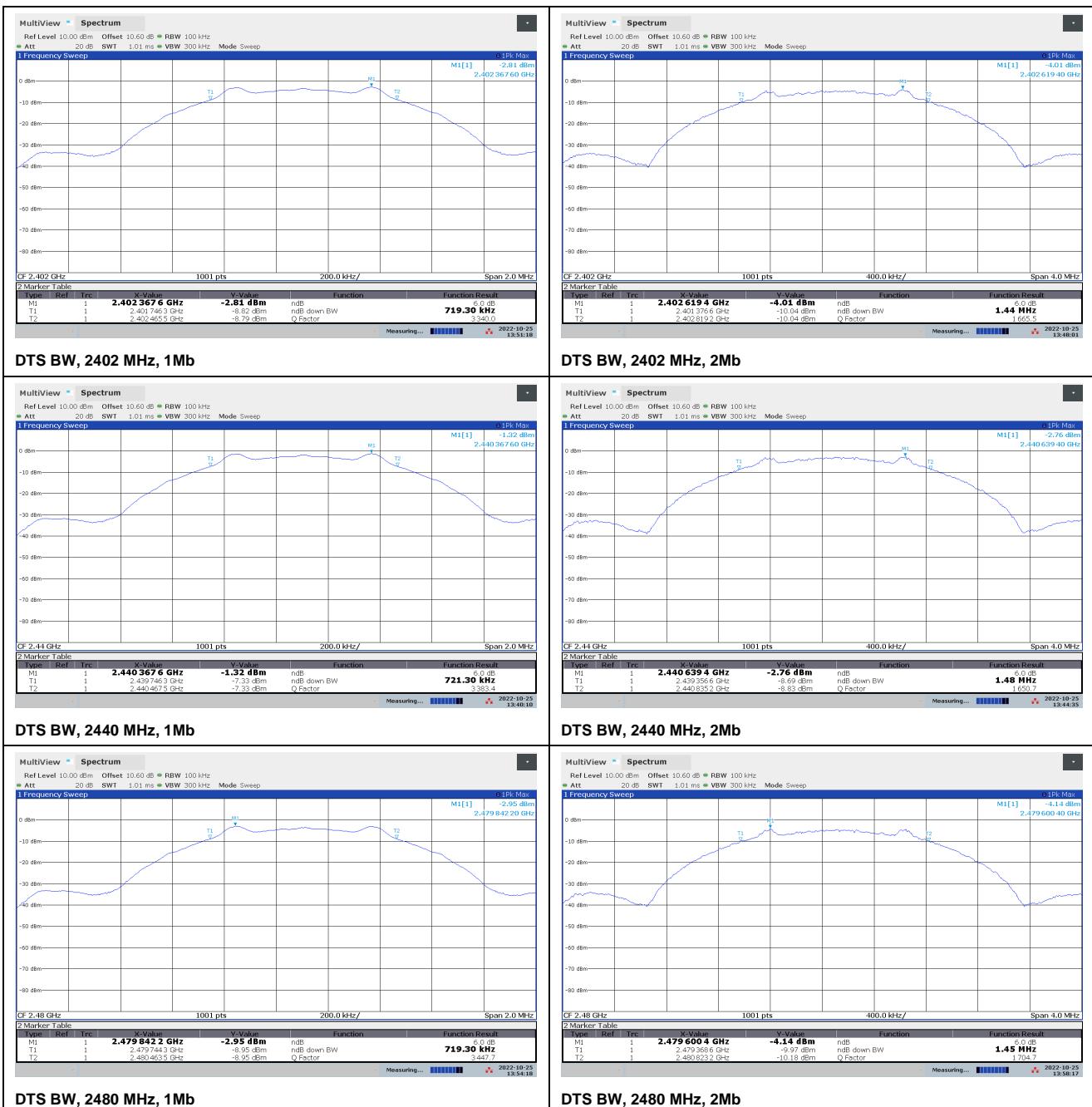
Test Results: Complies

Measurement Data:

Bitrate	Measured DTS Bandwidth		
	2402 MHz	2440 MHz	2480 MHz
1 Mb	719 kHz	721 kHz	719 kHz
2 Mb	1.44 MHz	1.48 MHz	1.45 MHz

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	
2400-2483.5 MHz	The minimum 6 dB bandwidth shall be at least 500 kHz.
5725-5850 MHz	



3.4 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

Measurement Data:

Carrier Frequency	Peak Conducted Power, dBm		Field Strength, dB μ V/m @3m	Peak EIRP, dBm	Antenna Gain, dBi
	1Mb	2Mb			
2402 MHz	-2.7	-2.6	99.9	4.7	7.4
2440 MHz	-1.3	-1.2	100.4	5.2	6.4
2480 MHz	-2.8	-2.8	99.2	4.0	6.8

Carrier Frequency	Peak Conducted Power, mW	
	1Mb	2Mb
2402 MHz	0.54	0.55
2440 MHz	0.75	0.76
2480 MHz	0.52	0.53

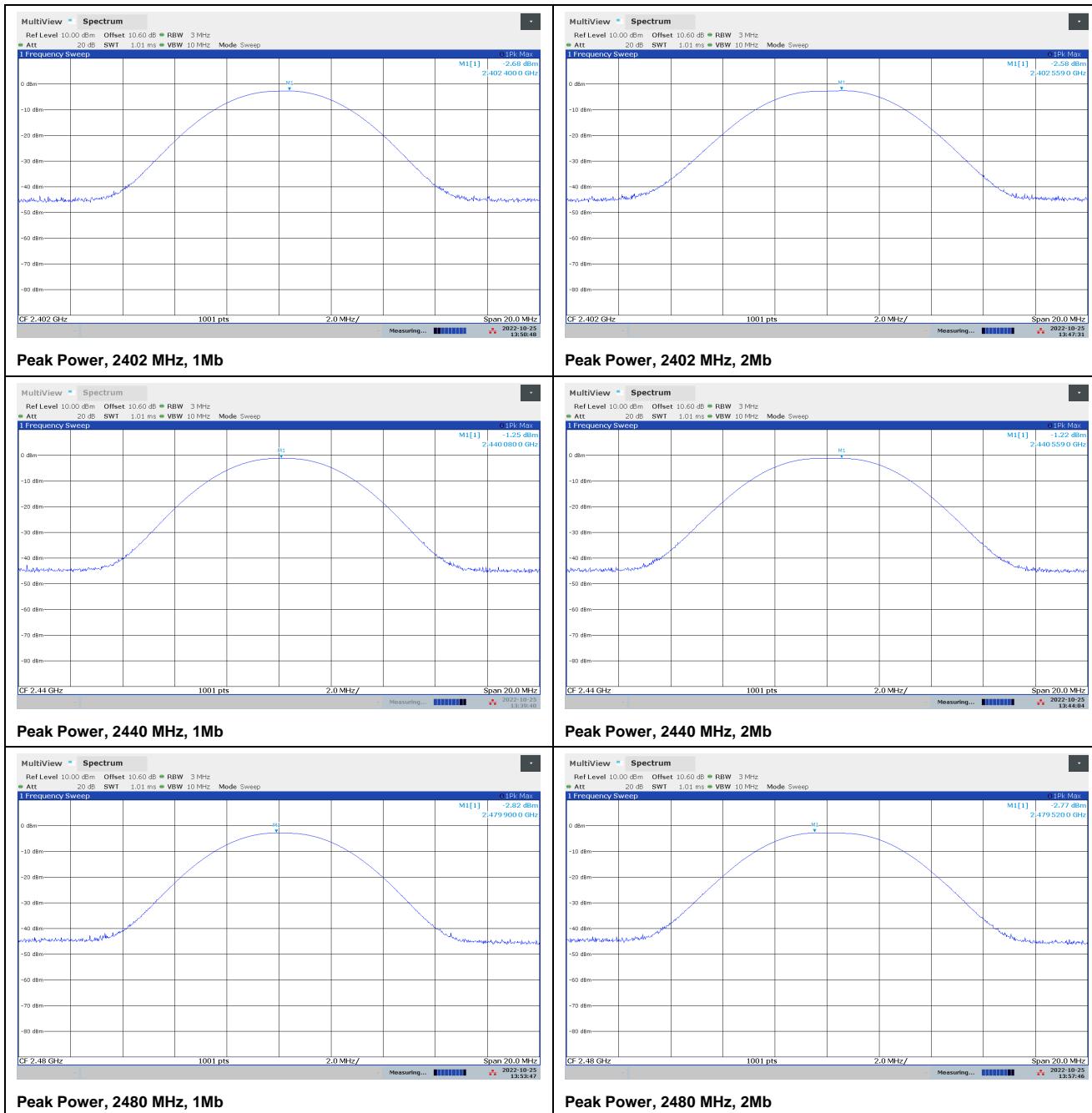
Output Power reported is Maximum Peak Power.

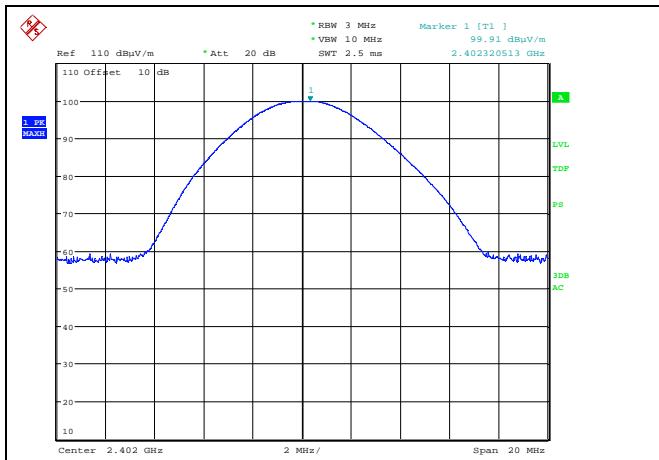
Radiated Power was calculated from measured Field Strength using the method described in FCC KDB 412172 D01.

See attached plots.

Antenna Gain is above 6 dBi, maximum allowed output power is reduced by the amount in dB that exceeds 6 dBi.

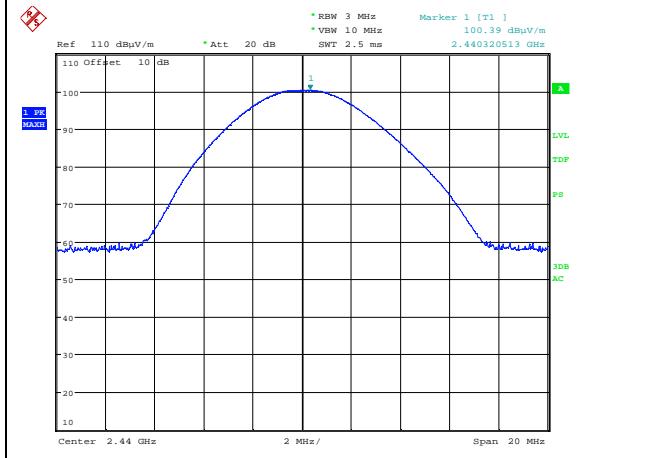
Requirements for Digital Modulation systems
For systems using digital modulation in the 902-928 MHz, 2400-2483.5 MHz, and 5725-5850 MHz bands: 1 Watt.
As an alternative to a peak power measurement, compliance with the 1 Watt limit can be based on a measurement of the maximum conducted output power. Maximum 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 <i>maximum conducted output power</i> 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.





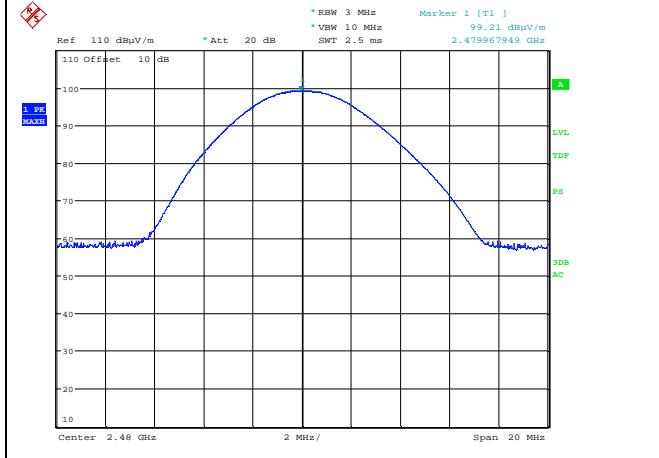
Date: 18.OCT.2022 12:48:47

Maximum Peak EIRP, 2402 MHz, 1Mb



Date: 18.OCT.2022 12:25:17

Maximum Peak EIRP, 2440 MHz, 1Mb



Date: 18.OCT.2022 12:19:24

Maximum Peak EIRP, 2480 MHz, 1Mb

3.5 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

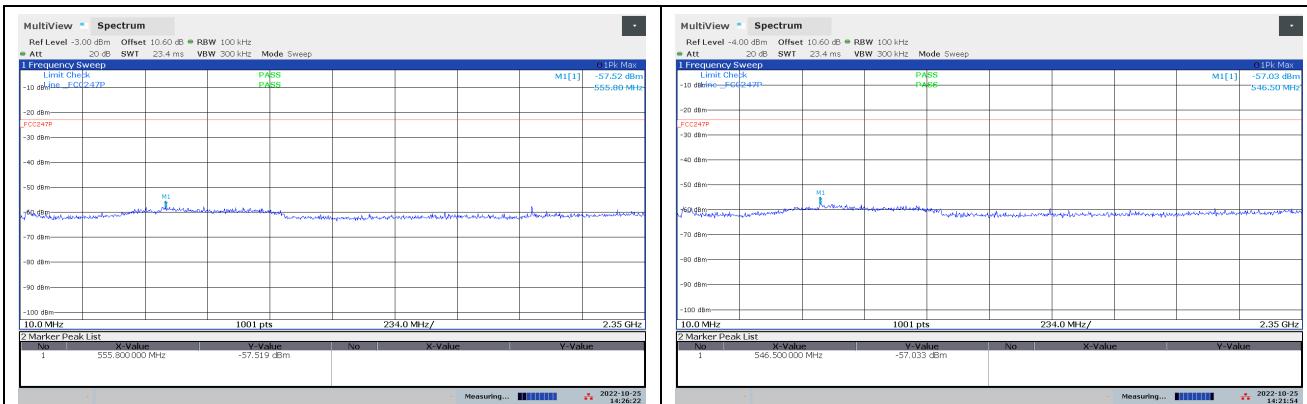
Measurement Data:

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

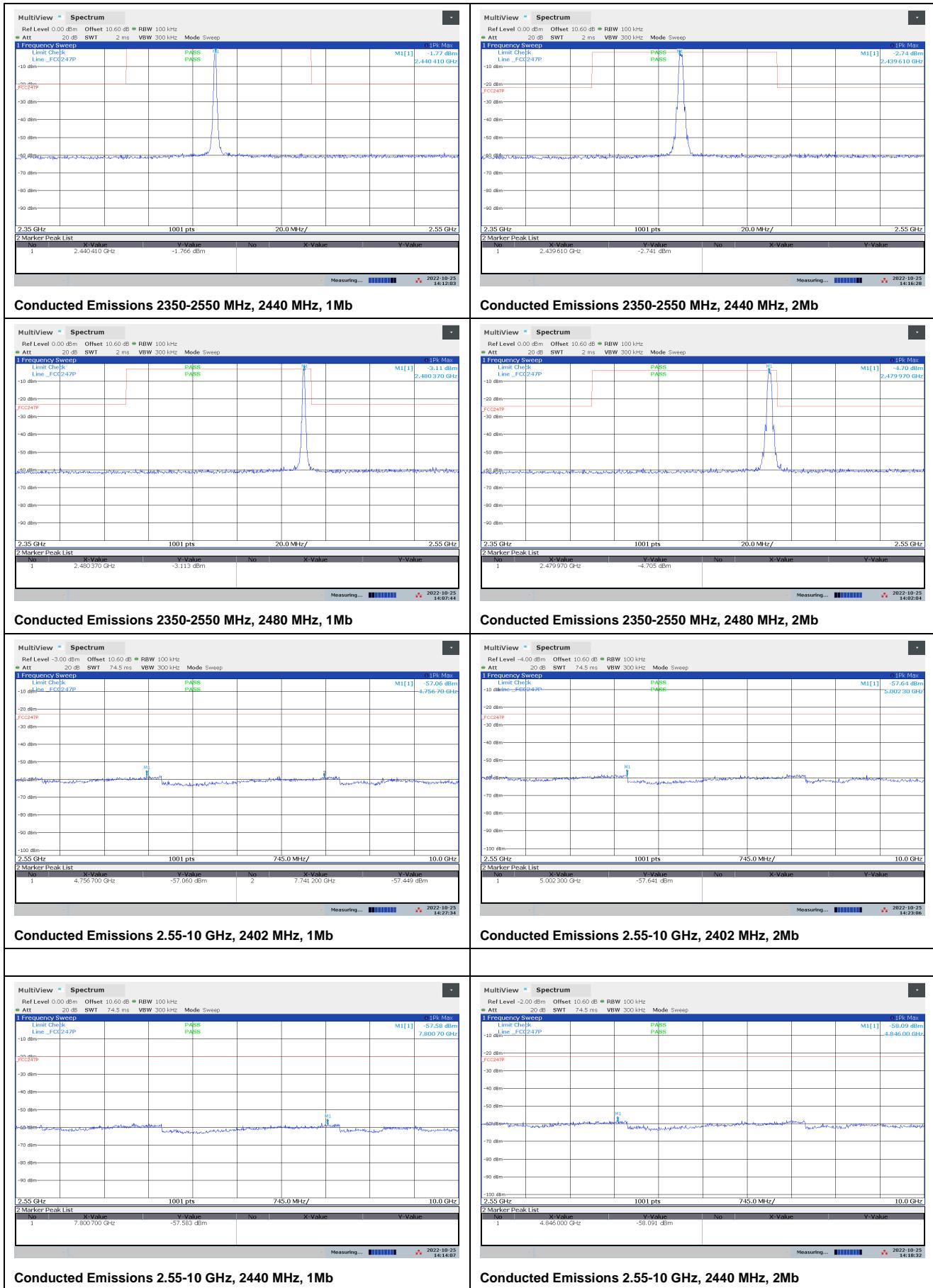
Measured with Peak Detector

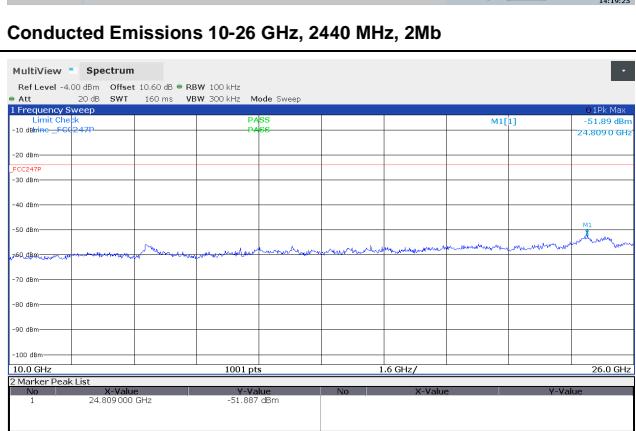
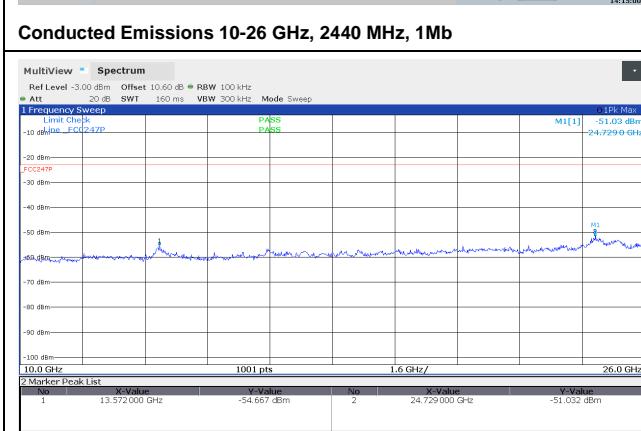
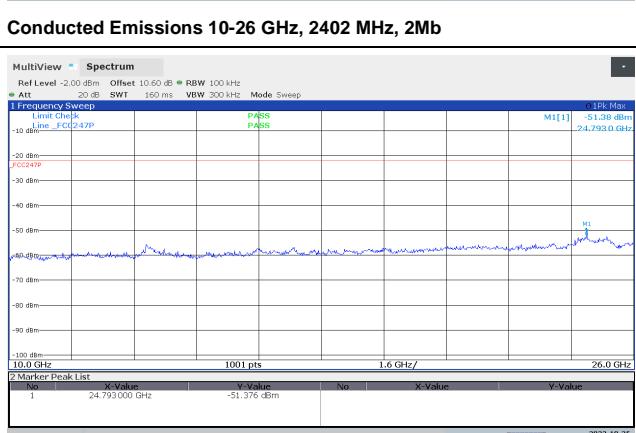
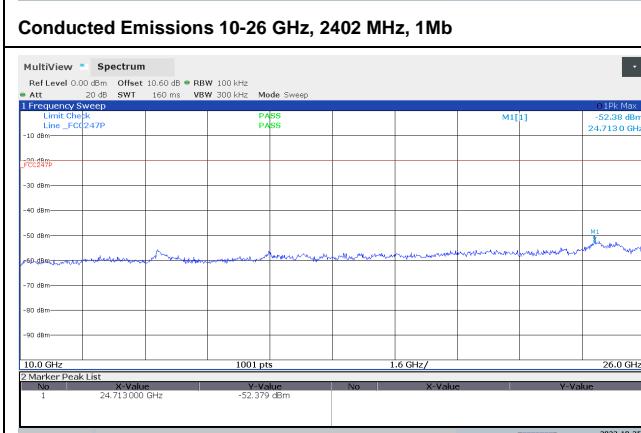
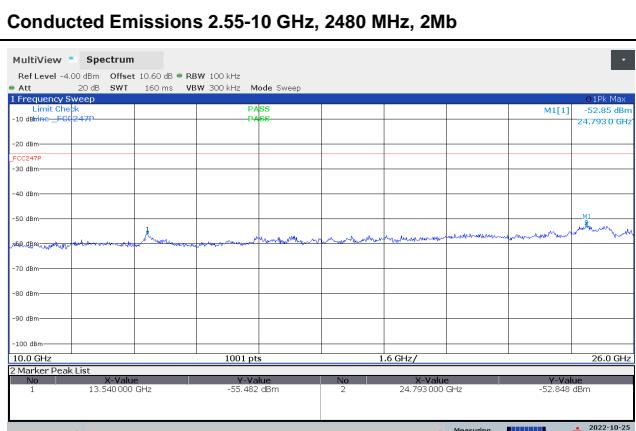
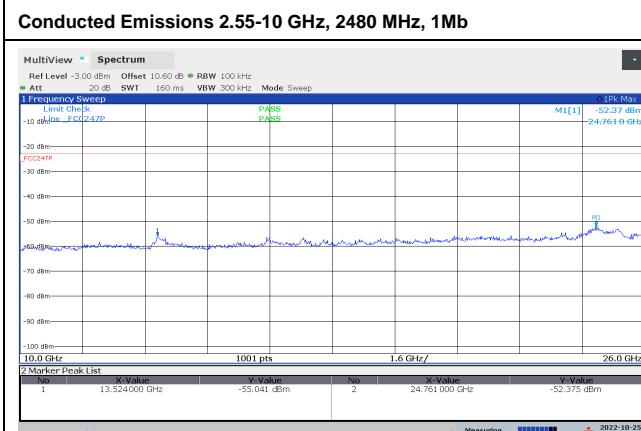
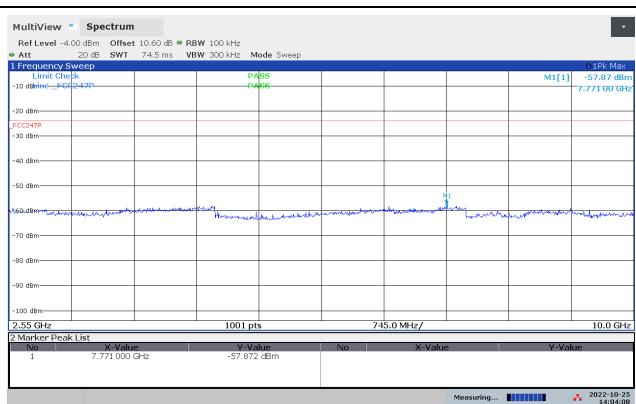
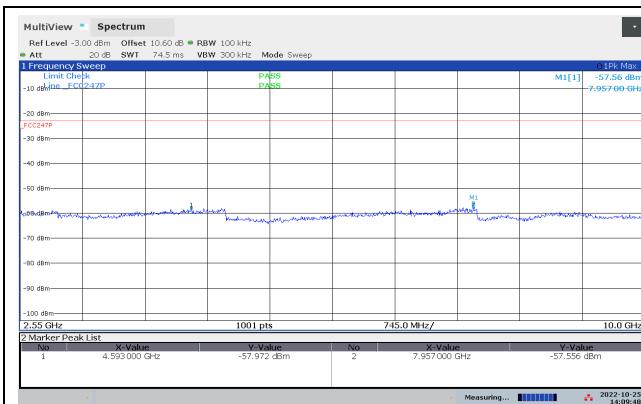
RF conducted power to 25 GHz: see attached plots.

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.	



Measuring...  2022-10-25 14:26:22





3.6 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.

3.7 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

Measurement Data:

Peak Detector					
Modulation and Bitrate	Measured field strength (dB μ V/m)		Limit	Margin	
	2390 MHz	2483.5 MHz		dB	dB
GFSK, 1Mb	53.2	60.4	74	20.8	13.6
GFSK, 2Mb	55.3	64.7	74	18.7	9.3

Average Detector					
Modulation and Bitrate	Measured field strength (dB μ V/m)		Limit	Margin	
	2390 MHz	2483.5 MHz		dB	dB
GFSK, 1Mb	40.3	47.5	54	13.7	6.5
GFSK, 2Mb	36.9	46.3	54	17.1	7.1

Average values were measured using Peak Detector and corrected for Duty Cycle.

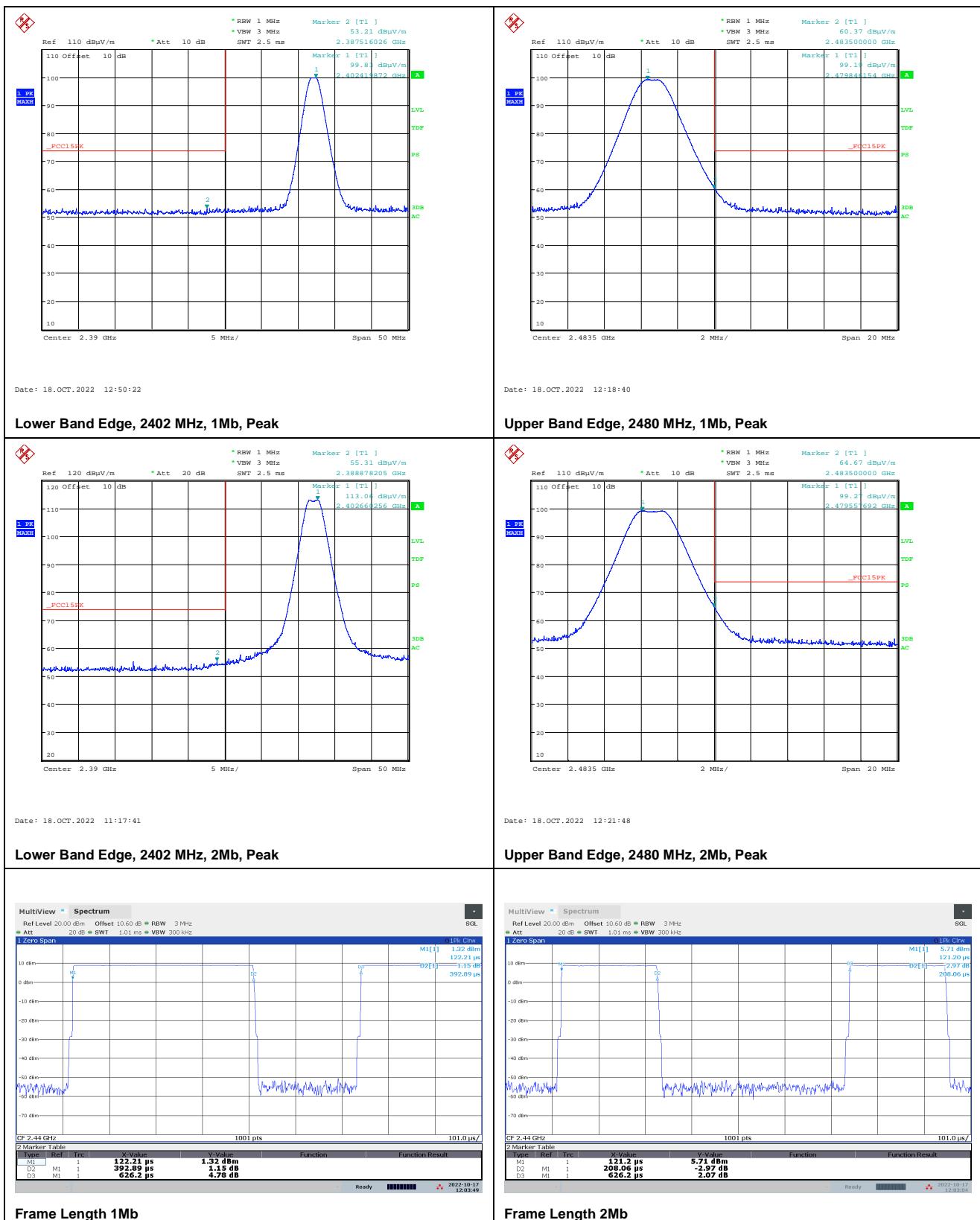
See attached plots.

DC Corrections Factor Actual Use

Bitrate	Packet Length	Frame Length	# Control Channels	# Hopping Channels	DC Correction Factor
1Mb	393 μ s	626 μ s	3	37	12.9 dB
2Mb	208 μ s	626 μ s	3	37	18.4 dB

DC During Measurement = $-20 \log(\text{Packet Length}/\text{Frame Length})$

DC During Actual Use = $20 \log((\text{packet length} / (\# \text{Control Channels} * \text{Frame Length})) + (\text{packet length} / (\# \text{Hopping channels} * \text{Frame Length})))$



3.8 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

Measurement Data:

Detector: Peak

Measuring distance 3 m

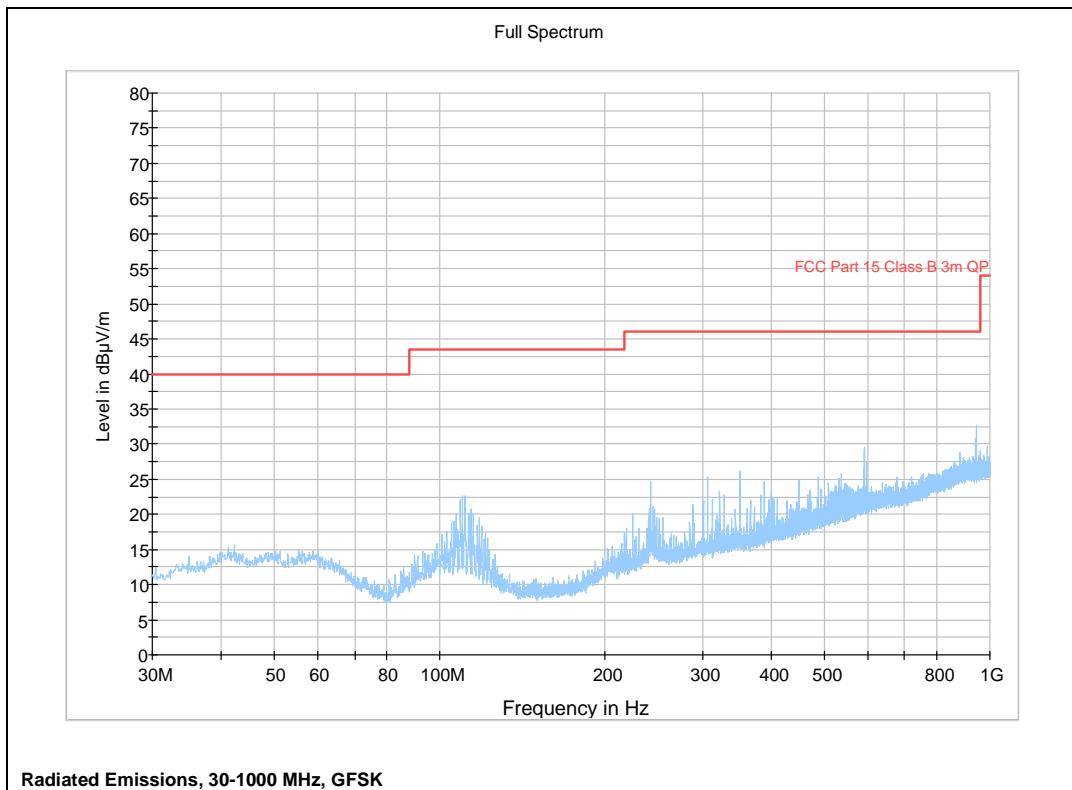
Tested in test mode with transmitter active

Measured Frequency (MHz)	Carrier Frequency (MHz)	Modulation	Measured Emission (dB μ V/m)	Limit (dB μ V/m)	Margin (dB)
30 – 88	2440	GFSK	< 20	40.0	> 20
88 – 216	2440	GFSK	< 23.5	43.5	> 20
216 – 960	2440	GFSK	< 36	46.0	> 10
960 – 1000	2440	GFSK	< 34	54.0	> 20

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 μ V/m	40.0 dB μ V/m	
88 – 216 MHz	150 μ V/m	43.5 dB μ V/m	
216 – 960 MHz	200 μ V/m	46.0 dB μ V/m	
960 – 1000 MHz	500 μ V/m	54.0 dB μ V/m	
Limits above are with Quasi Peak Detector			



3.9 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

Measurement Data:

Measuring distance: 3m (1 – 18 GHz)

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

Carrier freq. (MHz)	Measured Frequency (GHz)	Modulation	Measured Emission (dB μ V/m)		Limit (dB μ V/m)		Margin (dB)	
			Peak	Average	Pk	Av	Pk	Av
2480	9920	GFSK	55.8	42.9	74	54	18.2	11.1
	14880	GFSK	58.5	45.6	74	54	15.5	8.4

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

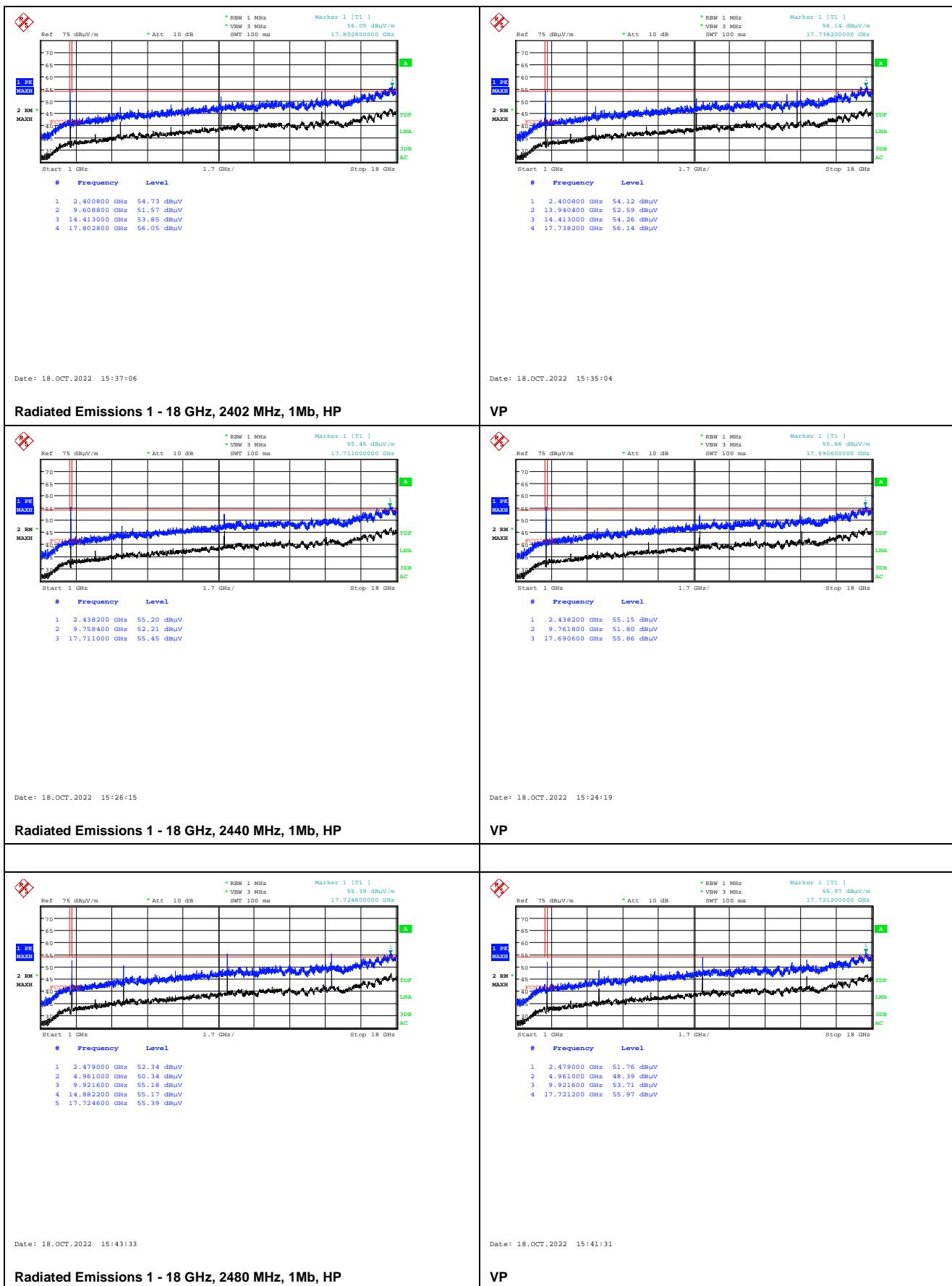
Antenna factor, amplifier gain and cable loss are included in spectrum analyzer “Transducer factor”.

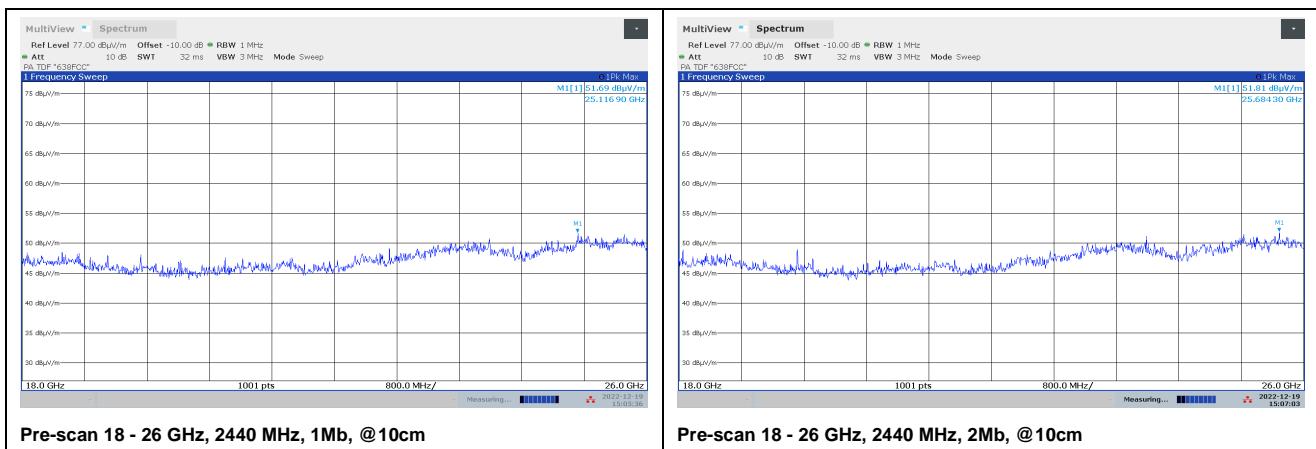
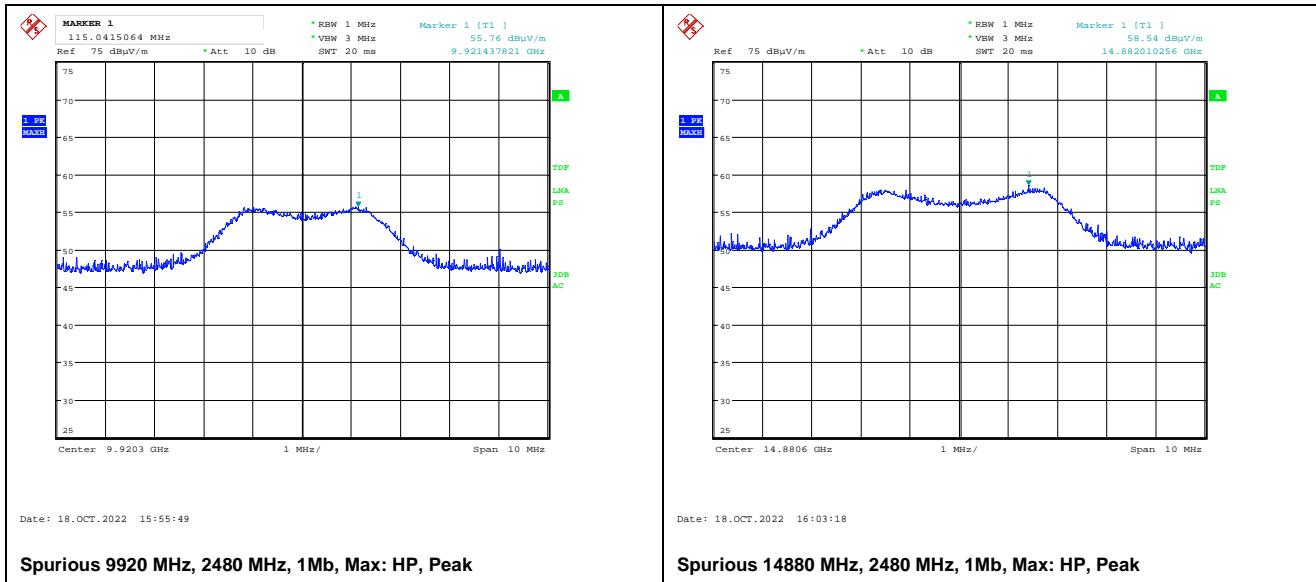
Average values are found by using peak values and correcting for duty cycle.

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 dB μ V/m	74.0 dB μ V/m





3.10 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

Measurement Data:

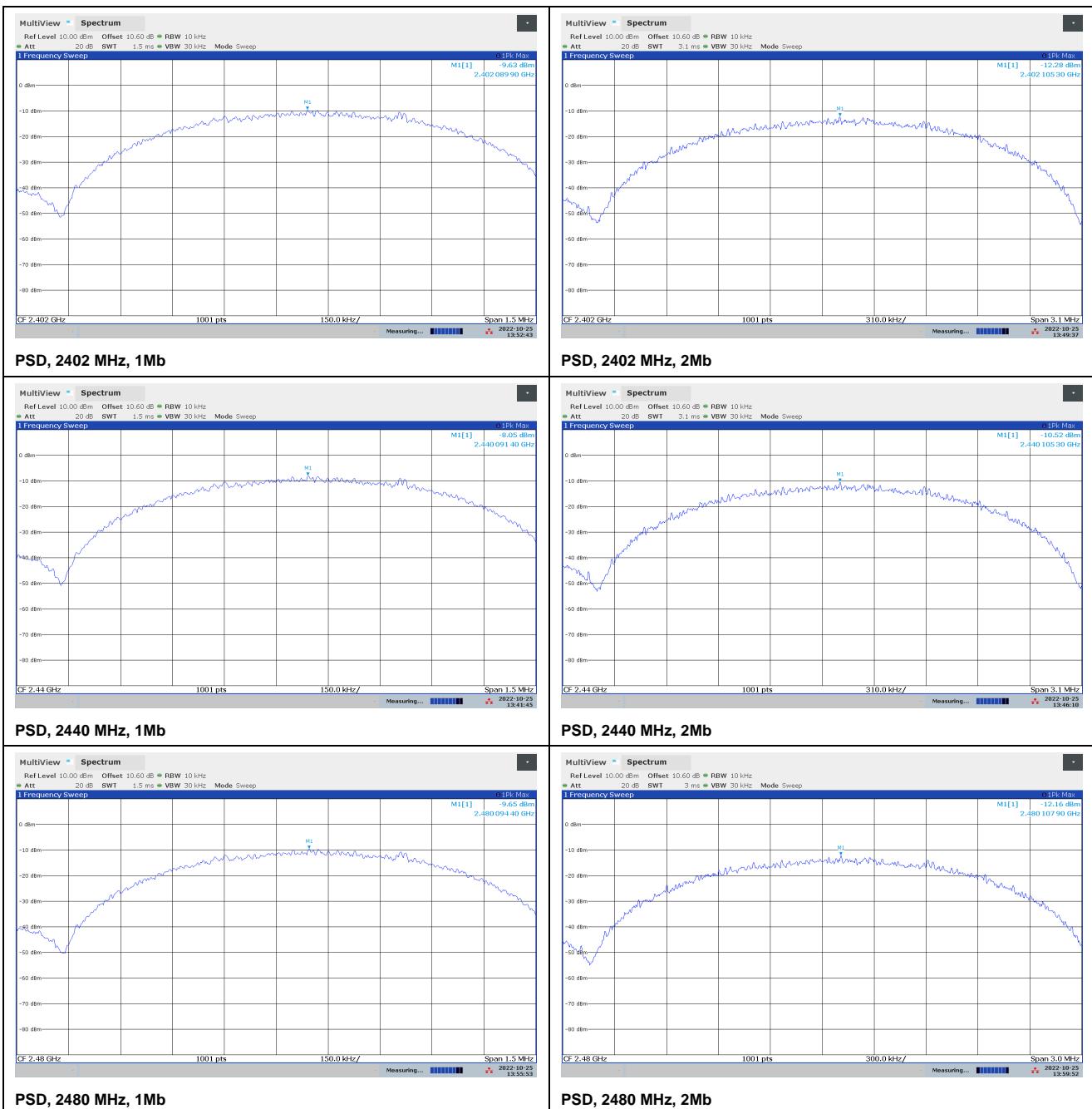
The measurement procedure PKPSD described in ANSI C63.10-2013 was used.

Modulation Type and Bitrate	Measured Power Spectral Density (dBm/3kHz)		
	2402 MHz	2440 MHz	2480 MHz
GFSK 1Mb	-14.9	-13.3	-14.9
GFSK 2Mb	-17.5	-15.7	-17.4

The measured values with 10kHz RBW are corrected by a Bandwidth Correction Factor of -5.2 dB.

Requirements:

The Power Spectral Density of a Digital Transmission System shall be no greater than +8 dBm in any 3 kHz band



4 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

5 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.

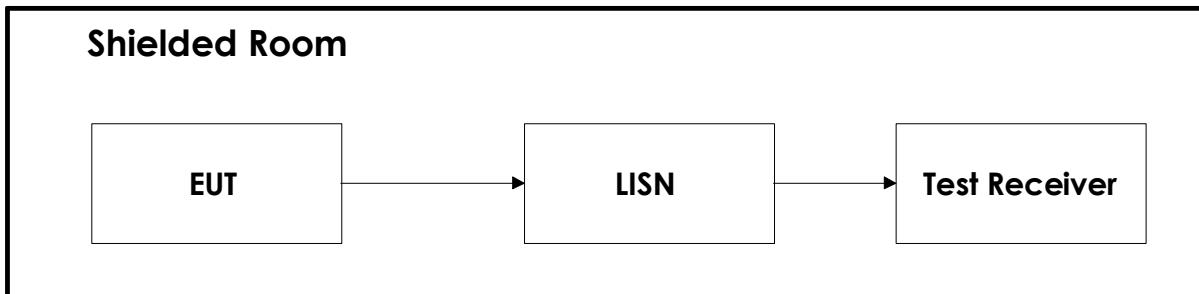
No.	Model number	Description	Manufacturer	Ref. no.	Cal. date	Cal. Due
1	FSW43	Spectrum Analyzer	Rohde & Schwarz	LR 1690	2022-01	2023-01
2	ESU40	Measuring Receiver	Rohde & Schwarz	LR 1639	2022-01	2023-01
3	6810.17B	Attenuator	Suhner	LR 1669	2019-07	2020-07
4	NO324415	Band Reject Filter (2.4 GHz)	Microwave Circuits	LR 1760	COU	
5	VULB 9163	BiLog Antenna	Schwarzbech	LR 1616	2021-05	2024-05
6	317	Pre-amplifier	Sonoma Inst.	LR 1687	2022-08	2023-08
7	3117-PA	Horn Antenna +PreAmp	EMCO	LR 1717	2022-08	2023-08
8	L01G18G1	LowPass Filter (1 GHz)	Microwave Circuits	LR 1768	COU	
9	8449B	Pre-amplifier	Hewlett Packard	LR 1322	2022-08	2023-08
10	638	Antenna Horn	Narda	LR 1480	N/A	
11	6812B	AC Power Source	Agilent	LR 1515	2022-11	2024-11
12	Model 87V	Multimeter	Fluke	LR 1600	2022-03	2024-03
13	ESCI3	Measuring Receiver	Rohde & Schwarz	N-4259	2021-10	2023-10
14	ENV216	Two Line V-Network	Rohde & Schwarz	LR 1665	2021-12	2023-12
15	ST18/SMA/N/36	RF Cable	Suhner	LR 1627	COU	

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

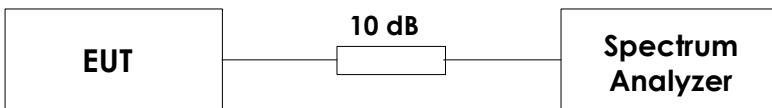
No.	Manufacturer	Name	Version	Comment
1	Rohde & Schwarz	EMC32	10.50.40	EMC test software
2	Nemko AS	RSPlot	1.0.8.0	Screen capture from R&S Spectrum Analyzers

6 BLOCK DIAGRAM

6.1 Power Line Conducted Emission

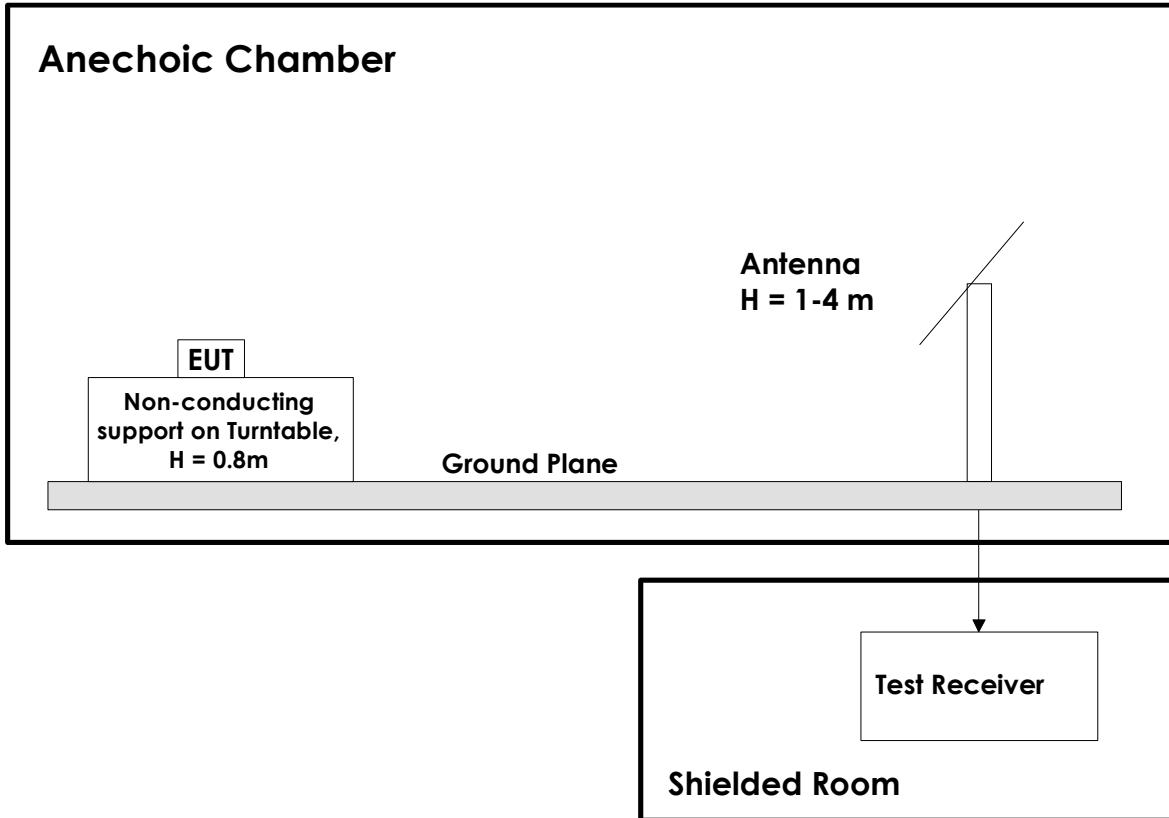


6.2 Conducted Tests



This test set-up is used for all Conducted tests.

6.3 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.