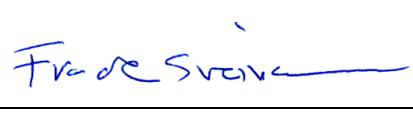


Test Report

Product	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	LEAF No.2
Rating	3Vdc (Primary Batteries)
Trademark	LEGO
Serial number	See page 3
Additional information	This tested device can be operated with BLE.
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	407586
Tested in period	2020.11.20 – 2020.11.21
Issue date	2021.01.04
Name and address of the testing laboratory	 Institutveien 6 Kjeller, Norway
	CAB Number: FCC: NO0001 ISED: NO0470  TEL: +47 22 96 03 30 FAX: +47 22 96 05 50
	 TEST 033
	An accredited technical test executed under the Norwegian accreditation scheme
	 
	Prepared by [G.Suhanthakumar] Approved by [Frode Sveinsen]
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Template version: C

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1 INFORMATION

1.1 Test Item

Name	LEGO
FCC ID	NPI77127
ISED ID	3072A-77127
Model/version	LEAF No.2
Serial number	CummaTec crystal: - Radiated sample : Marked as " 140" - Conducted sample: Marked as "136" Epson crystal: - Radiated sample : Marked as "FEP0036" - Conducted sample: Marked as "38"
Hardware identity and/or version	49282L
Software identity and/or version	1.00.00.0
Frequency Band	2400 – 2483.5 MHz
Frequency Range	2402 – 2480 MHz
Tunable Bands	None
Number of Channels	40
Operating Modes	TX and RX
Measured BW (99%)	2.1 MHz
Emission clasification	F1D
Transmitter spurious, dBμV/m@3m	PK, 55.90dB μ V/m @2.4835GHz; AV 49.33 dB μ V/m@2.4835GHz
Type of Modulation	GFSK
User Frequency Adjustment	None
Conducted Output Power, Max	CummaTec crystal:0.00055 W (-2.6dBm) Epson crystal:0.00057 W (-2.4dBm)
Type of Power Supply	3.0Vdc (2x 1.5Vdc AAA batteries)
Antenna Connector	Only integral antenna
Number of Antennas	1
Diversity or Smart Antennas	None
Desktop Charger	N/A

Description of Test Item

The device tested is a construction toy which communicate via BLE with remote device such as iOS, Android or similar.

1.2 Normal test condition

Temperature: 20 - 24 °C
Relative humidity: 20 - 50 %
Normal test voltage: 3.0Vdc

Channel nr	Frequency (MHz)	Modulation	Power setting dBm
37	2402	GFSK	0
17	2440	GFSK	0
39	2480	GFSK	0

The values are the limit registered during the test period.

1.3 Test Engineer(s)

G.Suhanthakumar

1.4 Description of modification for Modification Filing

Not applicable.

1.5 Family List Rational

Not Applicable.

1.6 Antenna Requirement

Is the antenna detachable?

Yes No

If detachable, is the antenna connector non-standard?

Yes No

Type of antenna connector: N/A

Ref. FCC §15.203

1.7 Worst-Case Configuration and Mode

Radiated Emissions were performed with the EUT set to transmit at the channel with the highest output power as worst-case scenario.

1.8 Comments

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

No ports to be populated for spurious emission measurements.

2 TEST REPORT SUMMARY

2.1 General

All measurements are traceable to national standards.

The tests were conducted for demonstrating compliance with FCC CFR 47 Part 15, paragraph 15.247 and ISED Canada 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 distances of 1m, 3m and 10m.

A description of the test facility is on file with 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



THIS TEST REPORT APPLIES ONLY TO THE ITEM(S) AND CONFIGURATIONS TESTED.

Deviations from, additions to, or exclusions from the test specifications are described in "Summary of Test Data".

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2.2 Test Summary

Name of test	FCC Part 15 reference	RSS-247 Issue 2, RSS-GEN Issue 5 reference	Result
Supply Voltage Variations	15.31(e)	6.11 (RSS-GEN)	N/A ¹
Number of frequencies	15.31(m)	6.8 (RSS-GEN)	Complies
Antenna Requirement	15.203	6.8 (RSS-GEN)	Complies ²
Power Line Conducted Emission	15.107(a) 15.207(a)	7.2 / 8.8 (RSS-GEN)	Complies ¹
99% Occupied Bandwidth	N/A	6.7 (RSS-GEN)	-
Minimum 6 dB Bandwidth	15.247(a)(2)	5.2 (1) (RSS-247)	Complies
Peak Power Output	15.247(b)	5.4 (RSS-247)	Complies
Power Spectral Density	15.247(e)	5.2 (2) (RSS-247)	Complies
Spurious Emissions (Antenna Conducted)	15.247(c)(d)	5.5 (RSS-247)	Complies
Spurious Emissions (Radiated)	15.247(c)(d) 15.109(a) 15.209(a)	5.5 (RSS-247) 7.3 (RSS-GEN) 8.9 (RSS-GEN)	Complies

¹ The tested equipment only operates with battery.

² Integral antenna.

-Only for information

3 TEST RESULTS

3.1 Number of Frequencies

FCC Part 15.31 (m)

ISED RSS-GEN Issue 5, Clause 6.8

Authorized Band:	2400 - 2483.5 MHz
Frequency band width:	83.5MHz
Low Channel:	2402MHz
Mid channel:	2440MHz
High Channel:	2480MHz

3.2 99% Occupied Bandwidth

RSS-Gen, 6.7

ISED Canada RSS-247 Issue 2, Clause 5.1

ISED Canada RSS-GEN Issue 5, Clause 6.7

Measurement procedure: ANSI C63.10-2013 Clause 6.9.2 / 7.8.3

Test Results: Complies

Measurement Data:

Channel Frequency (MHz)	With CummaTec crystal Measured 99% BW (MHz)	With Epson crystal Measured 99% BW (MHz)
2402	2.1	2.1
2440	2.1	2.1
2480	2.1	2.1

See attached plots.

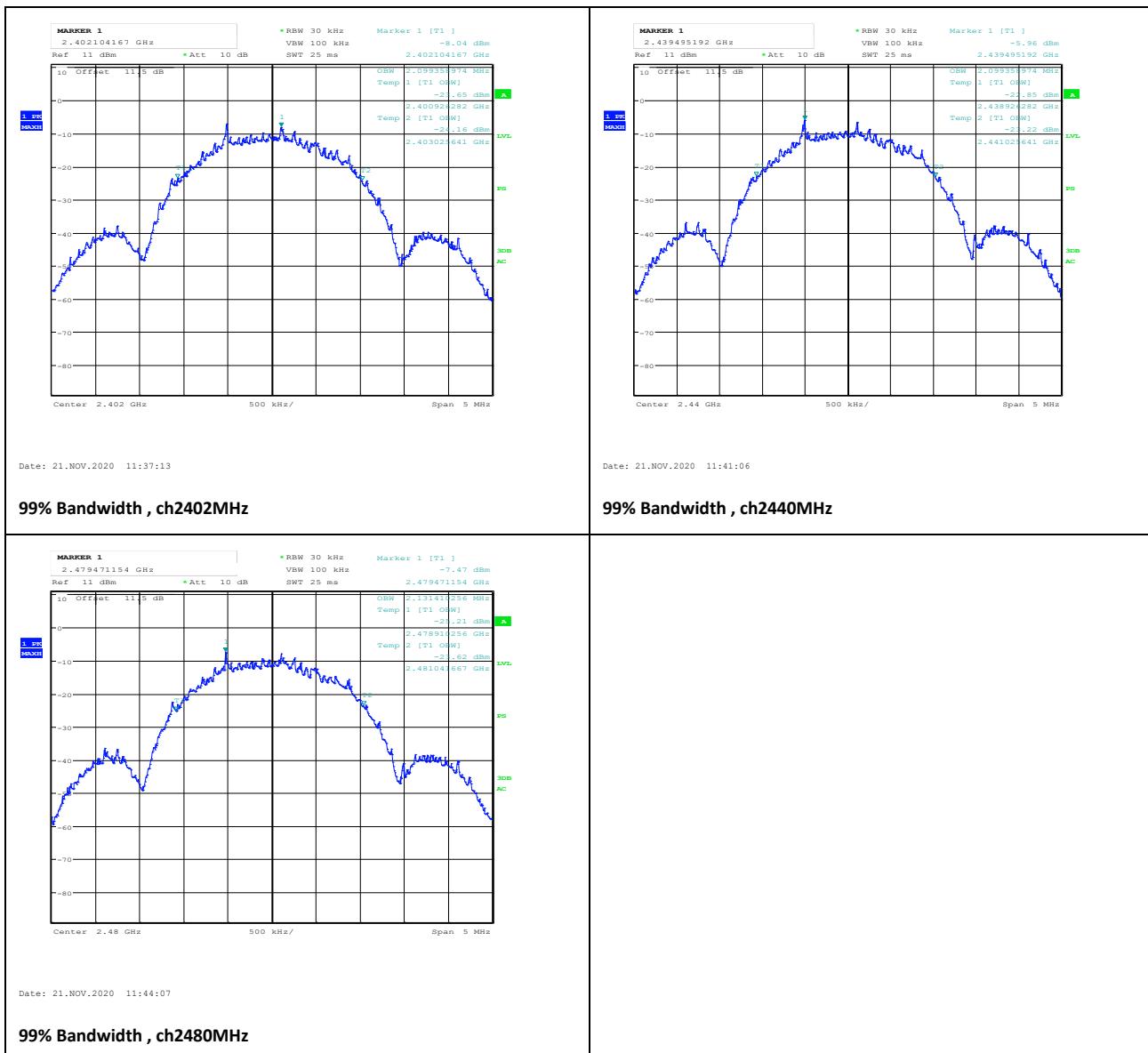
Requirements:

Frequency hopping systems in the 2400 - 2483.5 MHz band shall use at least 15 non-overlapping channels. No requirements for bandwidth for this frequency band.

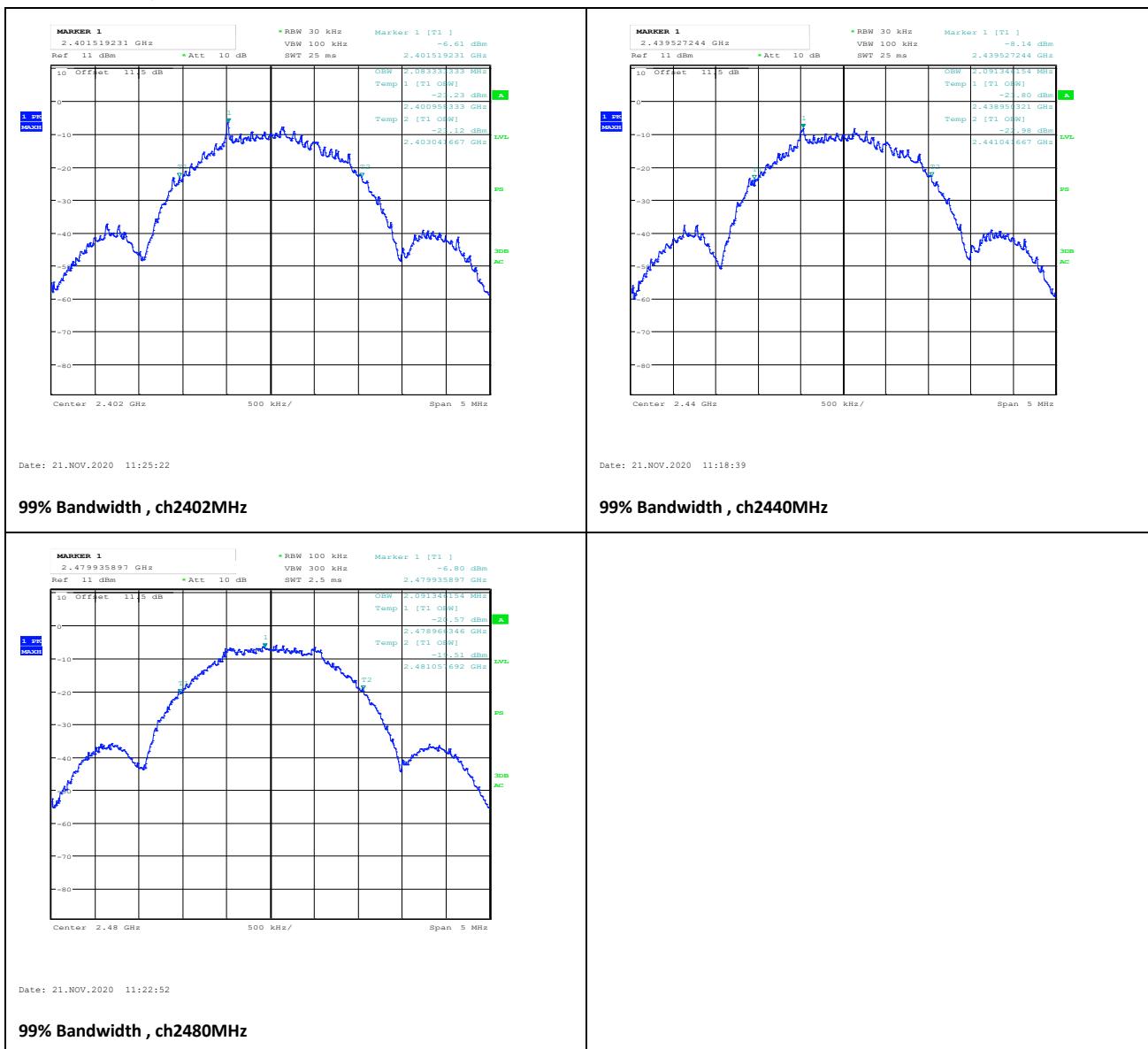
No requirements for Digital Transmission Systems.

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

With CummaTec crystal



With Epson crystal



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:

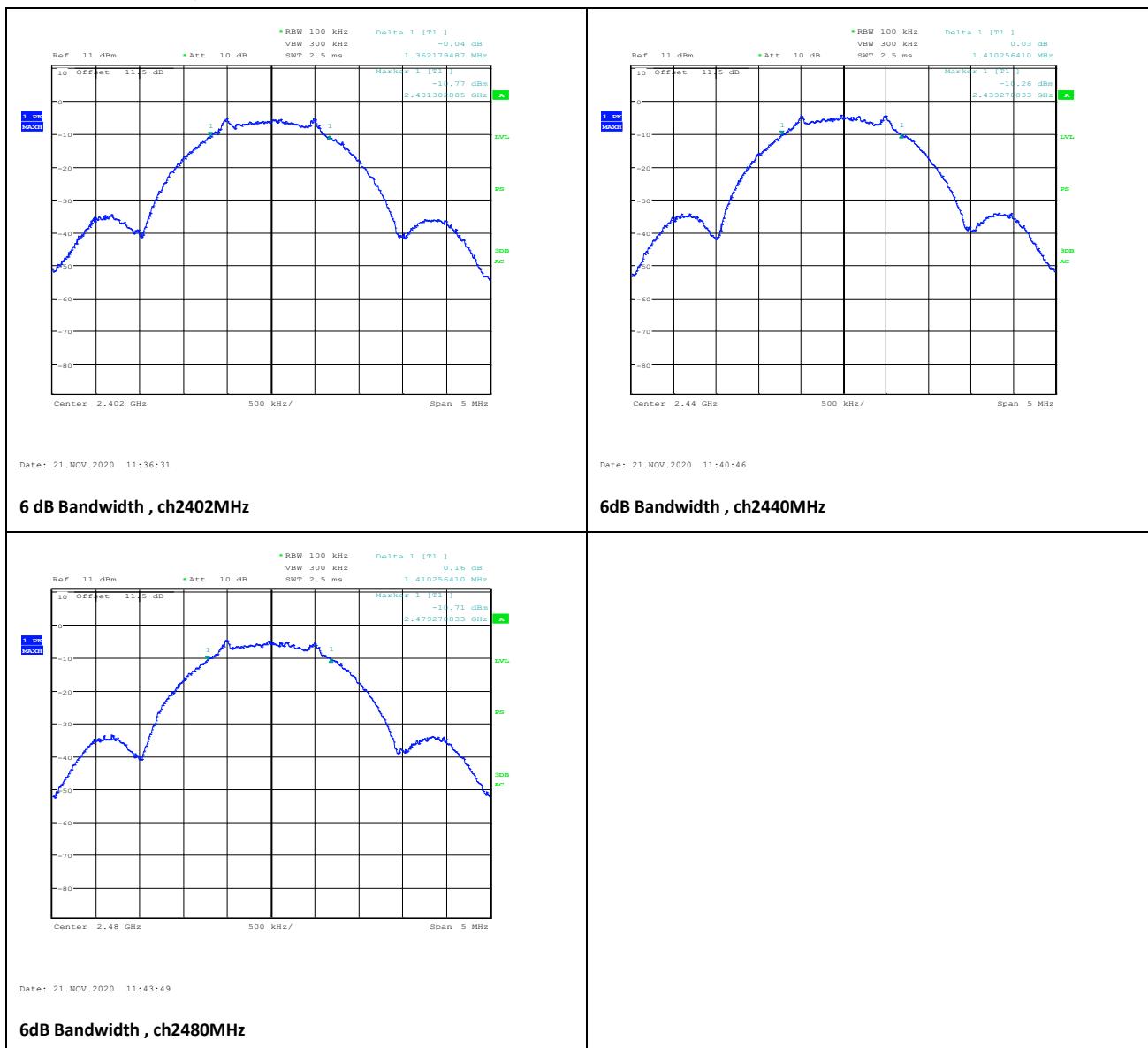
Channel Frequency (MHz)	With CummaTec crystal Measured DTS BW (MHz)	With Epson crystal Measured DTS BW (MHz)
2402	1.4	1.4
2440	1.4	1.4
2480	1.4	1.3

Requirements:

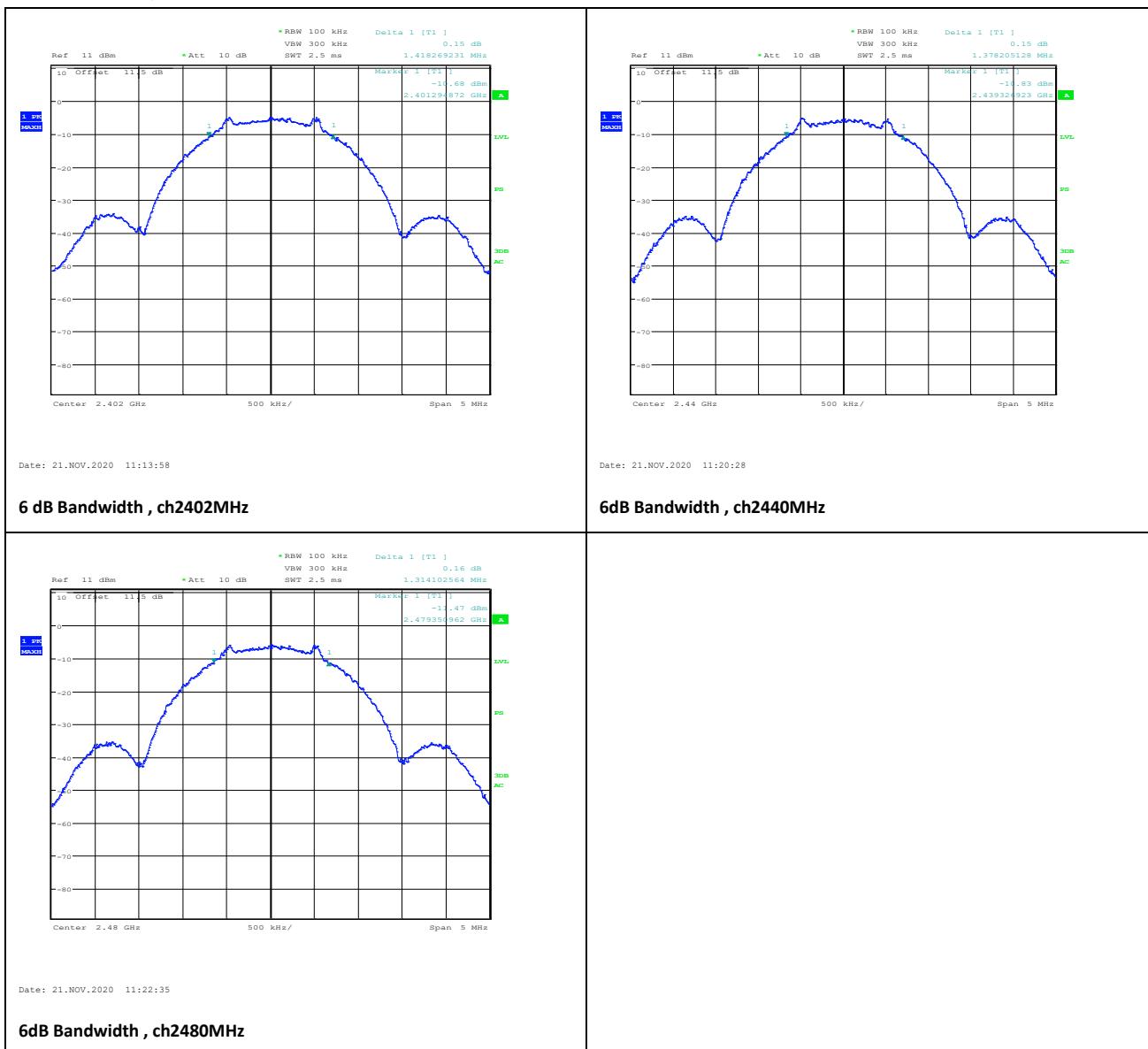
For Digital Transmission Systems in the 2400-2483.5 MHz band the minimum 6 dB bandwidth shall be at least 500 KHz.

No requirements for Frequency Hopping Systems.

With Cummatec crystal



With Epson crystal



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:

With CummaTec crystal

	2402 MHz	2440 MHz	2480 MHz
Measured Conducted Power (dBm)	-3.48	-2.60	-3.02
Conducted Power (mWatts)	0.45	0.55	0.50
Field Strength (dB μ V/m), HP	91.08	90.52	89.84
EIRP, Calculated (mWatts)	0.38	0.34	0.29
Antenna gain (dBi)	-0.7	-2.1	-2.4

With Epson crystal

	2402 MHz	2440 MHz	2480 MHz
Measured Conducted Power (dBm)	-3.06	-2.44	-3.97
Conducted Power (mWatts)	0.49	0.57	0.49
Field Strength (dB μ V/m), HP	91.14	89.07	90.30
EIRP, Calculated (mWatts)	0.39	0.24	0.32
Antenna gain (dBi)	-1.0	-3.7	-1.9

Maximum is obtained in XY plane and in HP.

Antenna gain = $10 \times \log (\text{EIRP}/\text{Conducted power})$ dBi

EIRP is calculated from measured field strength by the formulas in KDB 412172 D01 Determining ERP and EIRP v01.

See attached plots.

Requirements:

The maximum peak output power shall not exceed the following limits:

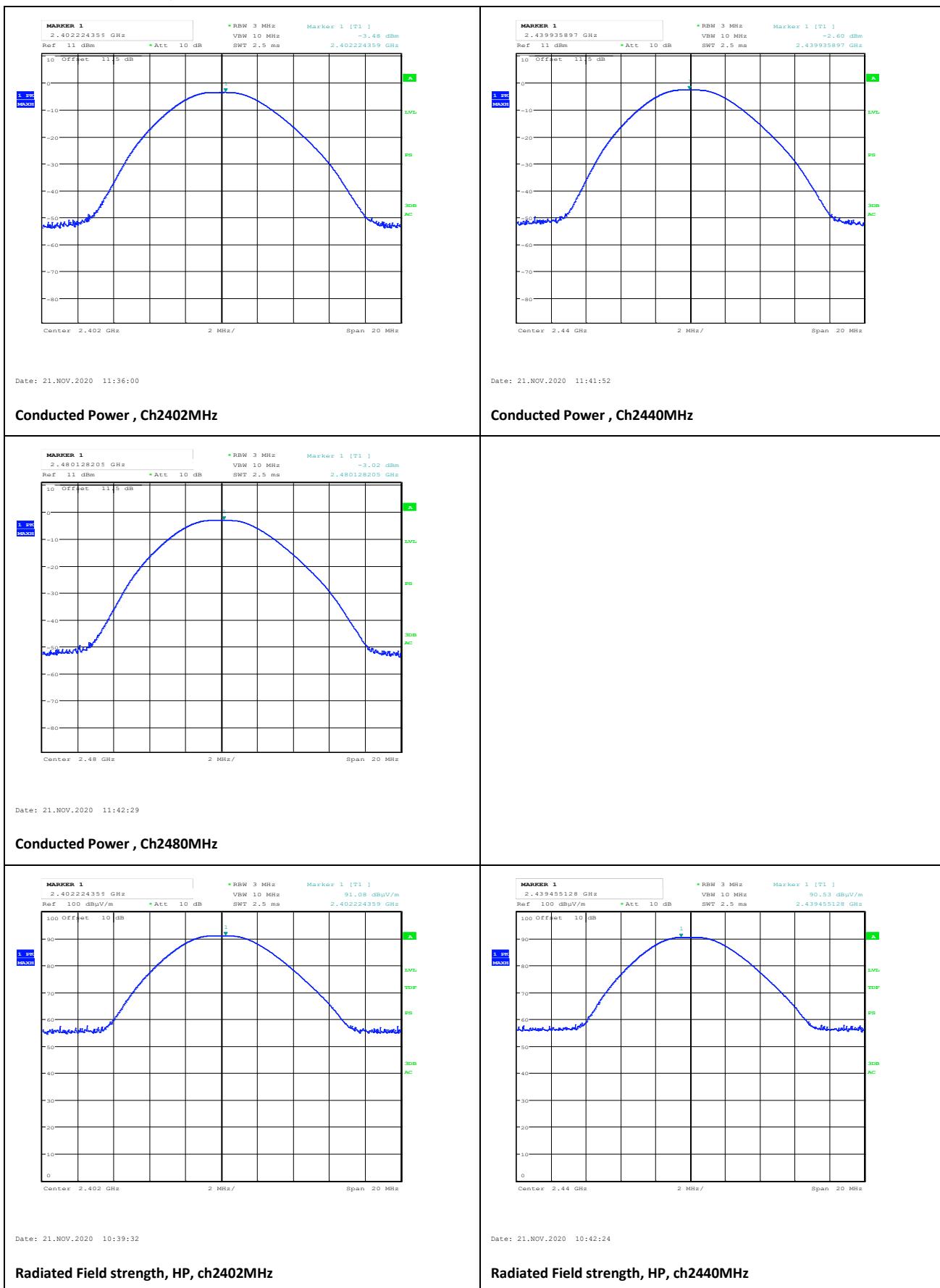
For frequency hopping systems employing at least 75 hopping channels: 1 Watt

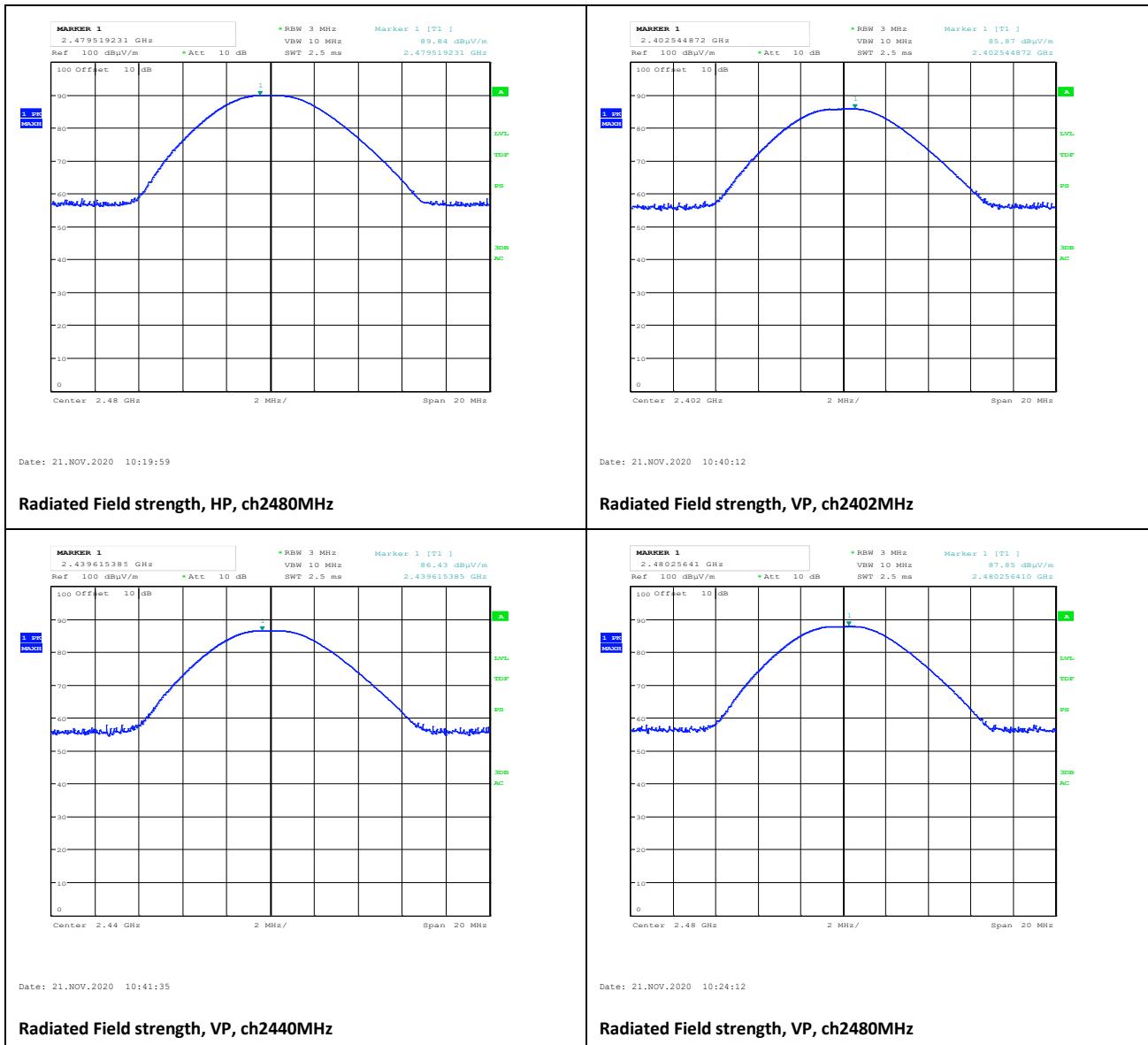
For all other frequency hopping systems in the 2400 - 2483.5 MHz band: 0.125 Watts

For Digital Transmission Systems in the 2400 - 2483.5 MHz band: 1 Watt

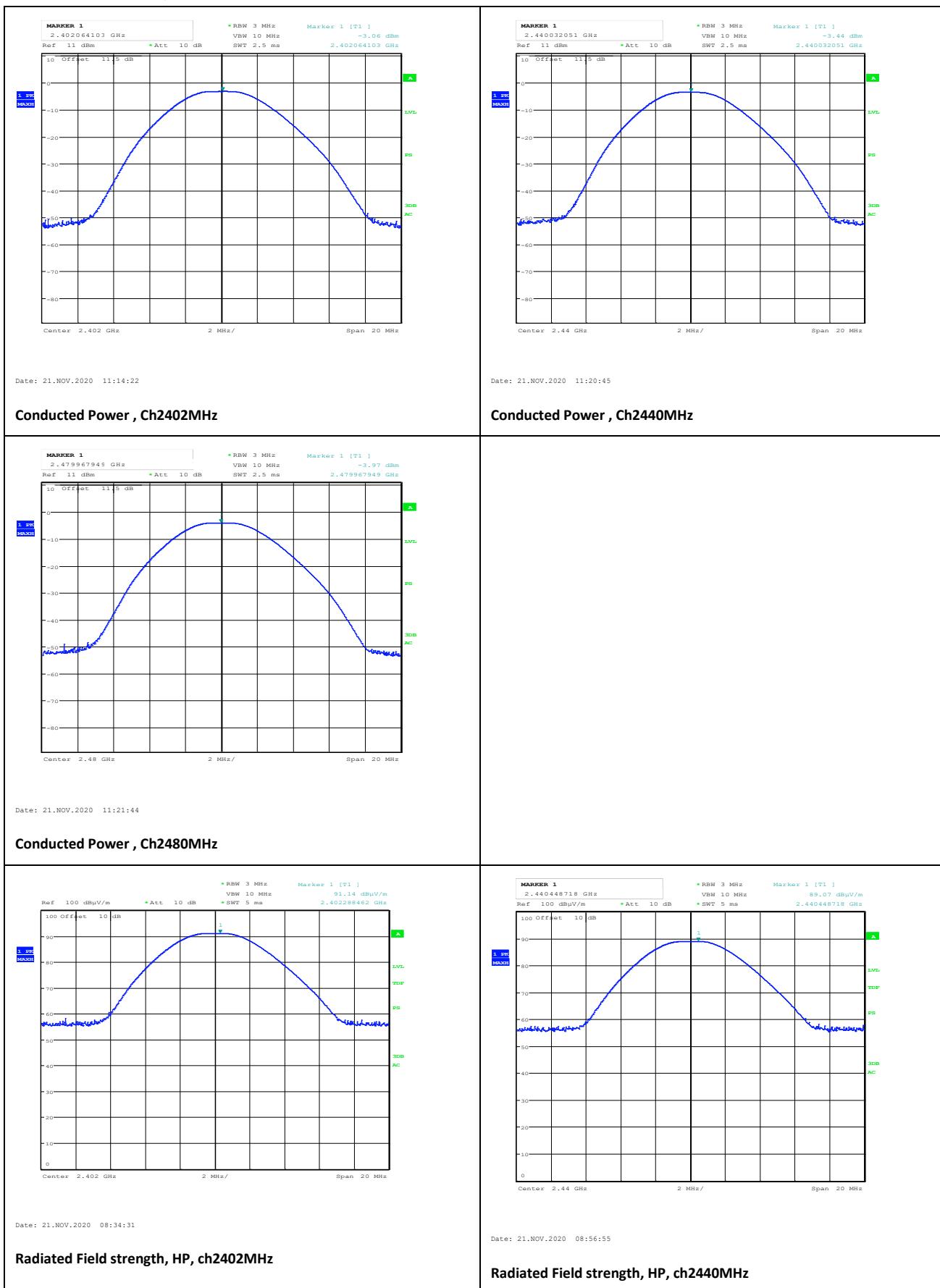
If transmitting antennas of directional gain greater than 6 dBi are used, the peak output power from the intentional radiator shall be reduced below the stated value above by the amount in dB that the directional gain of the antenna exceeds 6 dBi.

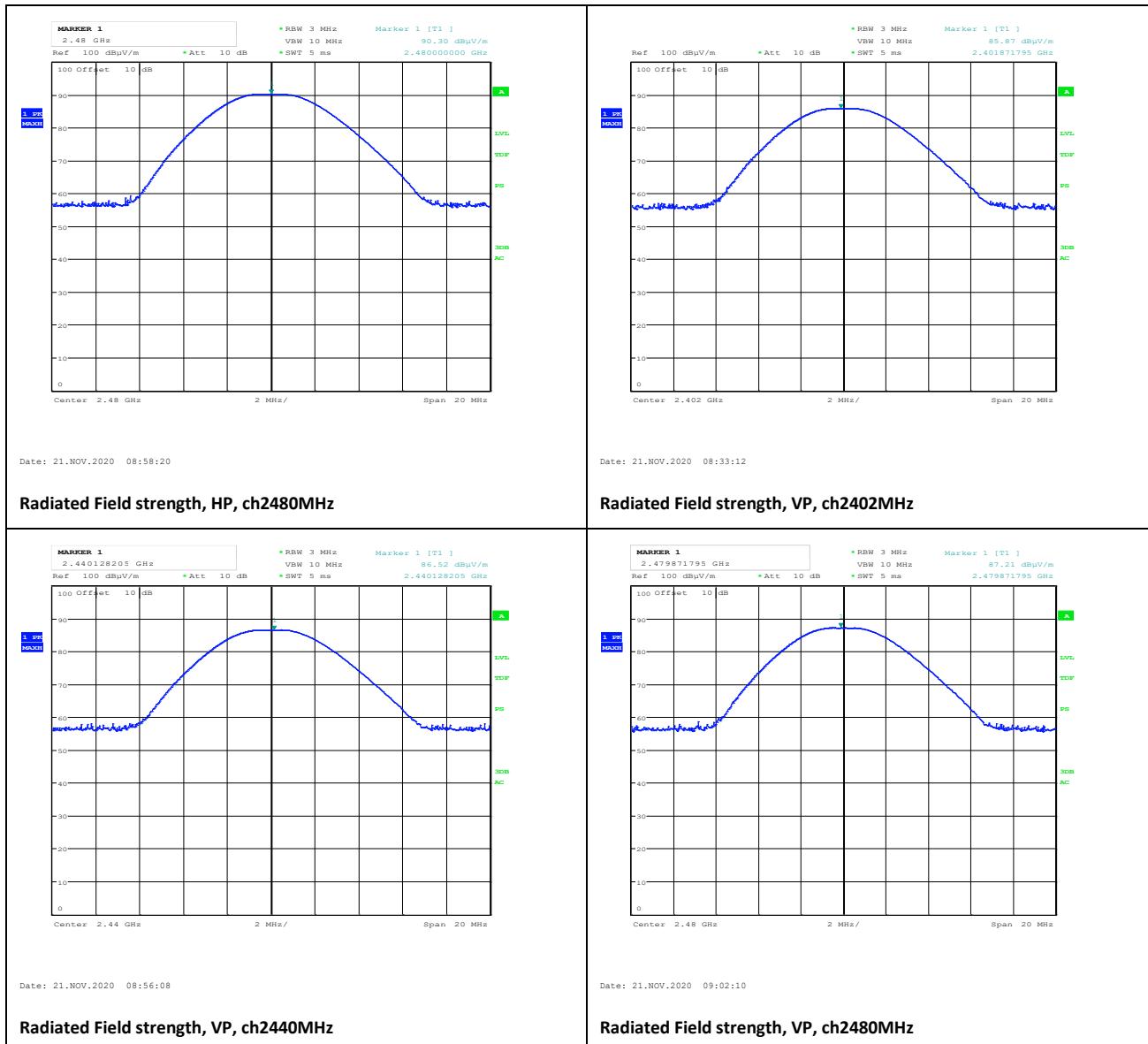
With CrommaTec crystal





With CummaTec crystal





3.5 Conducted Emissions at Antenna Connector

Para. No.: 15.247 (d)

ISED Canada RSS-247 Issue 2, Clause 5.5

Measurement procedure: ANSI C63.10-2013 Clause 11.11

Test Results: Complies

With CummaTec crystal

Carrier Frequency	Highest Value (dBc)	Margin (dB)	Verdict
2402 MHz	45.9	>30	Pass
2440 MHz	45.9	>30	Pass
2480 MHz	51.4	>30	Pass

With Epson crystal

Carrier Frequency	Highest Value (dBc)	Margin (dB)	Verdict
2402 MHz	52.2	>30	Pass
2440 MHz	48.9	>30	Pass
2480 MHz	50.3	>30	Pass

Measured with Peak Detector

RF conducted power to 25 GHz: see attached plots.

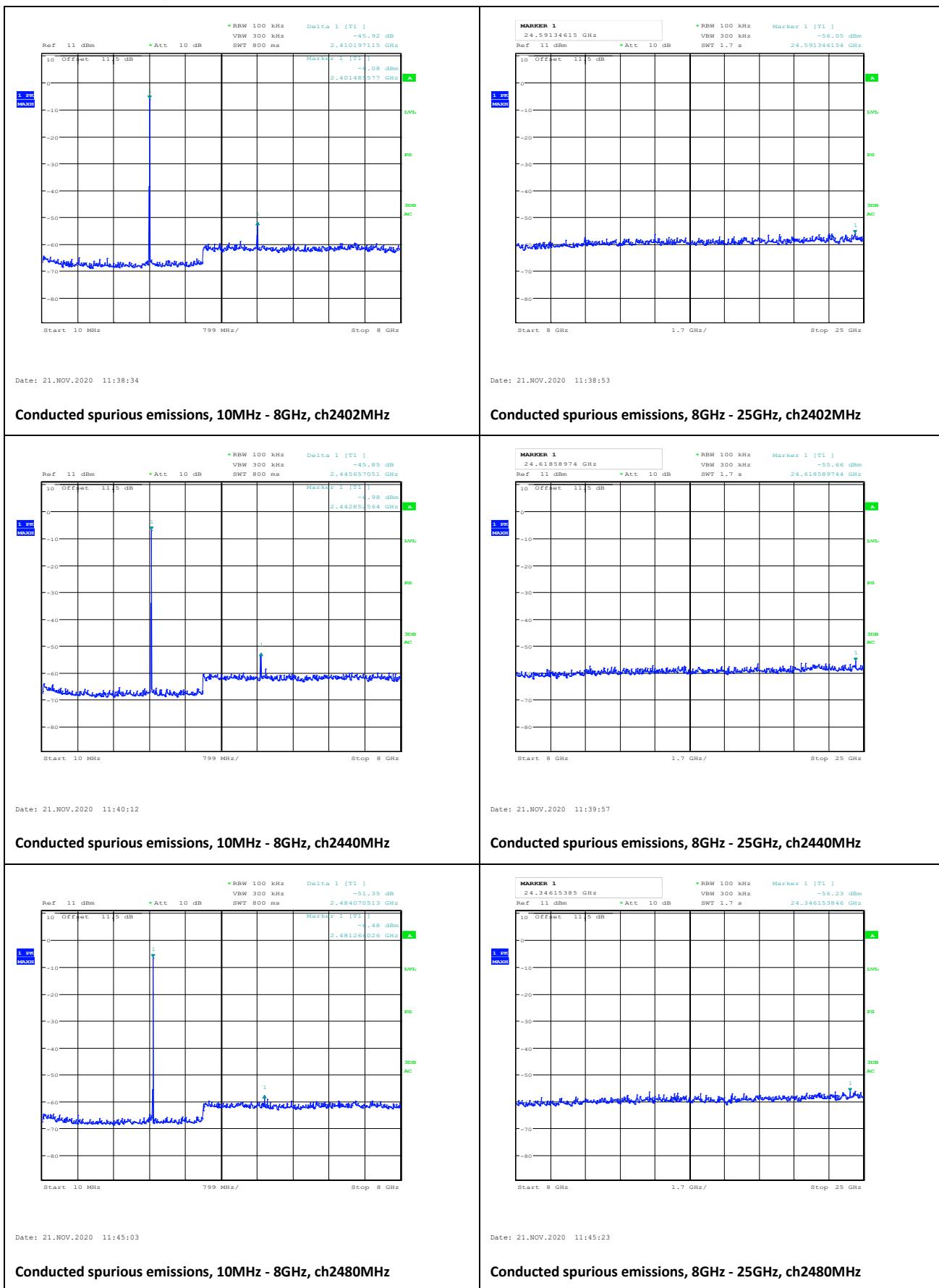
Limit

Peak measurement	RMS averaging
20 dBc or more in 100 kHz bandwidth	30 dBc or more in 100 kHz bandwidth

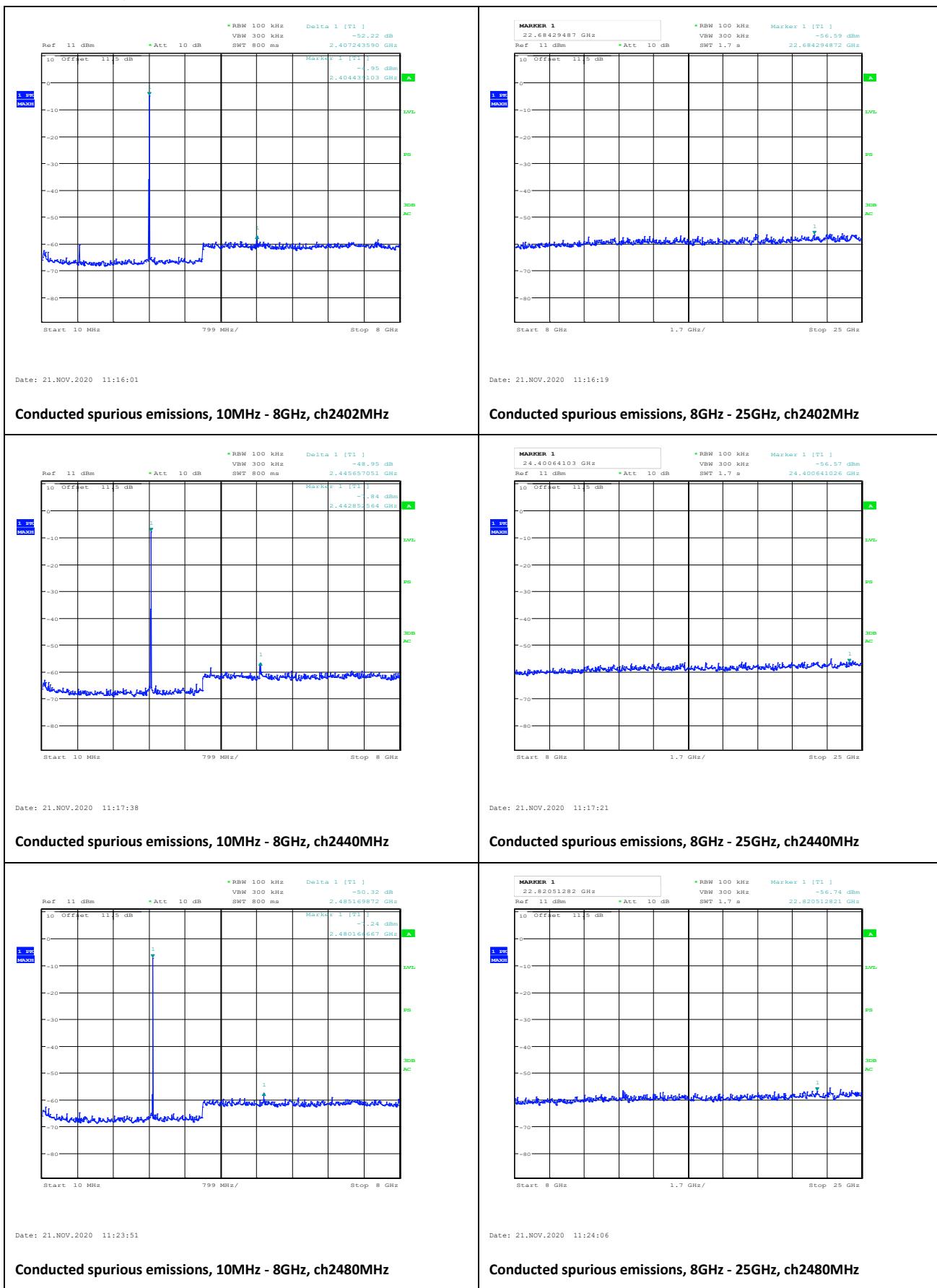
Detector type shall be the same as used for measuring Output Power.

Attenuation below the general limits specified in part 15.209(a) is not required.

With CummaTec crystal



With Epson crystal



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 4 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 Spurious Emissions (Radiated)

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:

With CummaTec Crystal

Band-Edge

	Measured field strength (dB μ V/m)		Limit	Margin	
	2390 MHz	2483.5 MHz		dB μ V/m	dB
Peak Detector	50.82	53.36	74	23.18	20.64
Average Detector	/	/	54	/	/
Average with DC correction	/	/	54	/	/

With Epson Crystal

Band-Edge

	Measured field strength (dB μ V/m)		Limit	Margin	
	2390 MHz	2483.5 MHz		dB μ V/m	dB
Peak Detector	51.55	55.90	74	22.45	18.1
Average Detector	/	49.33	54	/	4.67
Average with DC correction	/	/	54	/	/

See attached plots.

Duty Cycle Correction Factor Calculation:

37 Byte payload

Duty Cycle = On Time / (ON+OFF time) = 391 μ s / (623.1 μ s) = 0.63

Duty Cycle Correction factor = -20 x log (Duty Cycle) = -4 dB

0 Byte payload

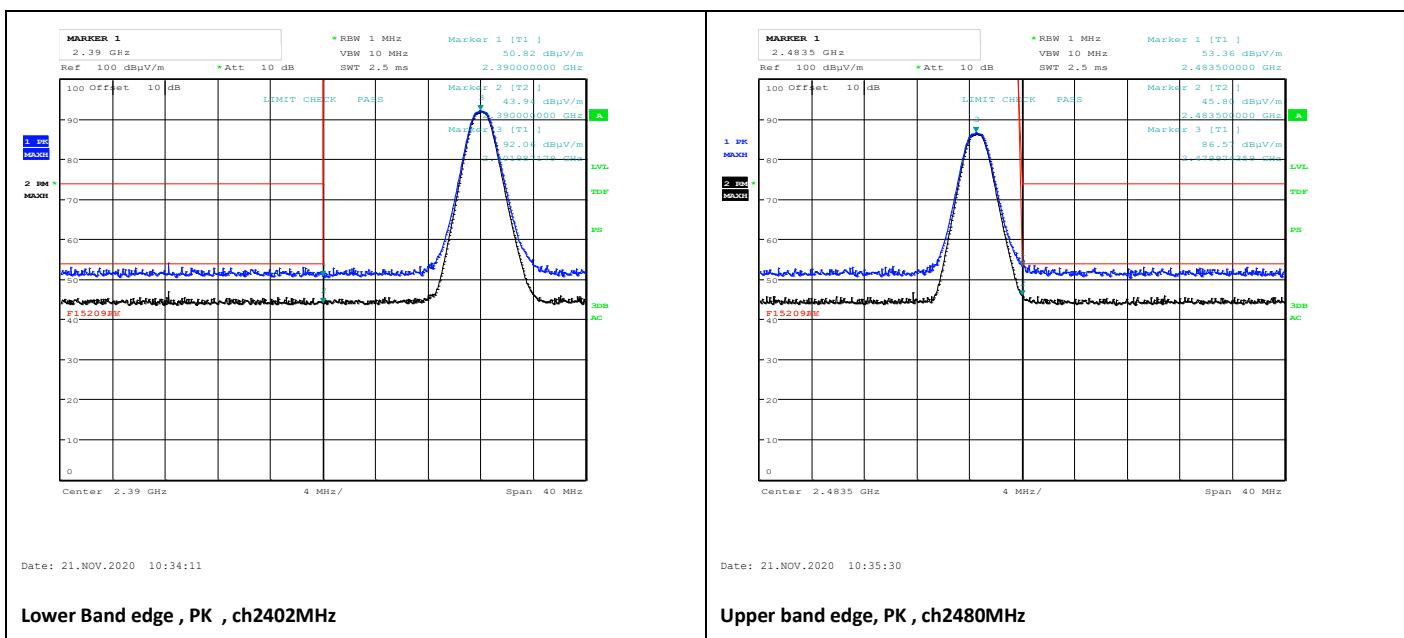
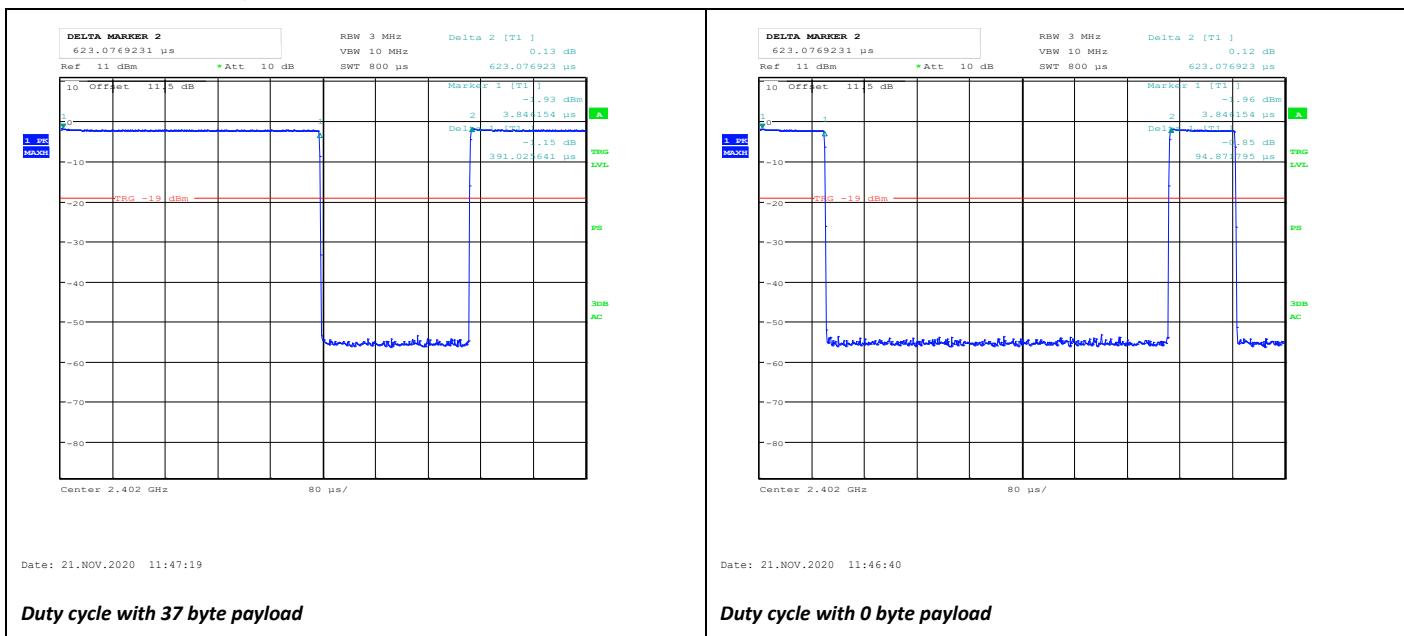
Duty Cycle = On Time / (ON+OFF time) = 94.9 μ s / (623.1 μ s) = 0.15

Duty Cycle Correction factor = -20 x log (Duty Cycle) = -16.5 dB

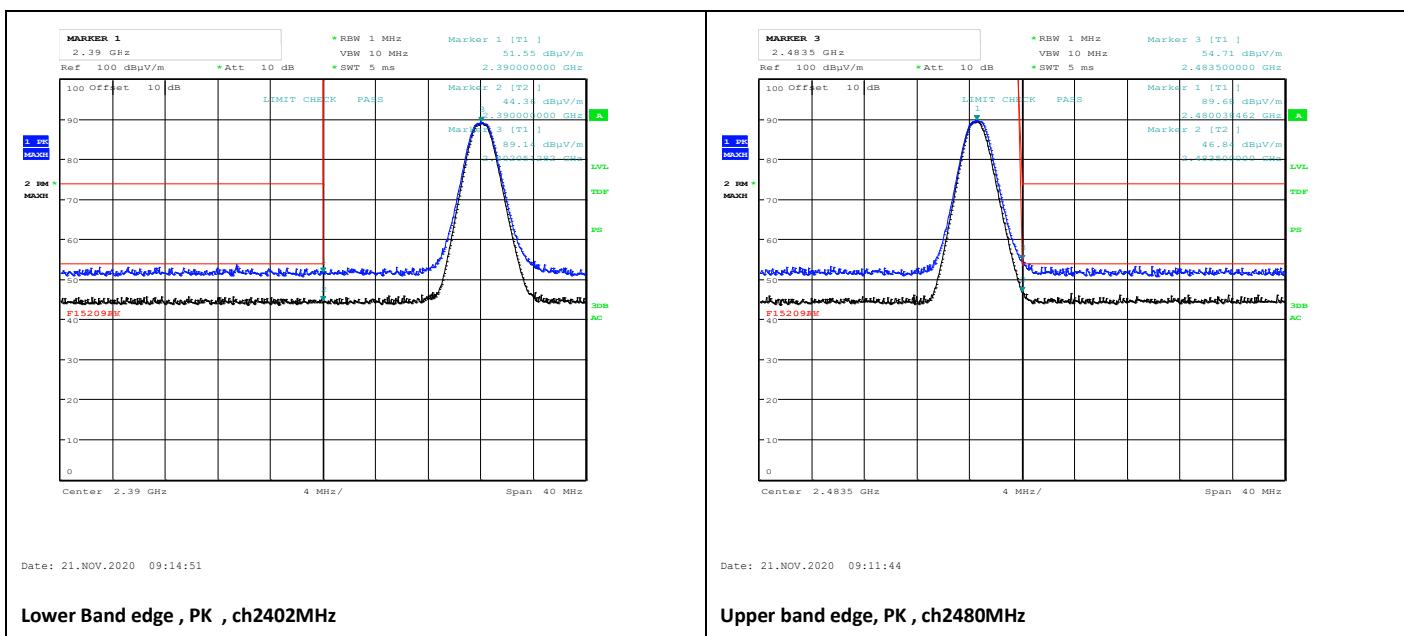
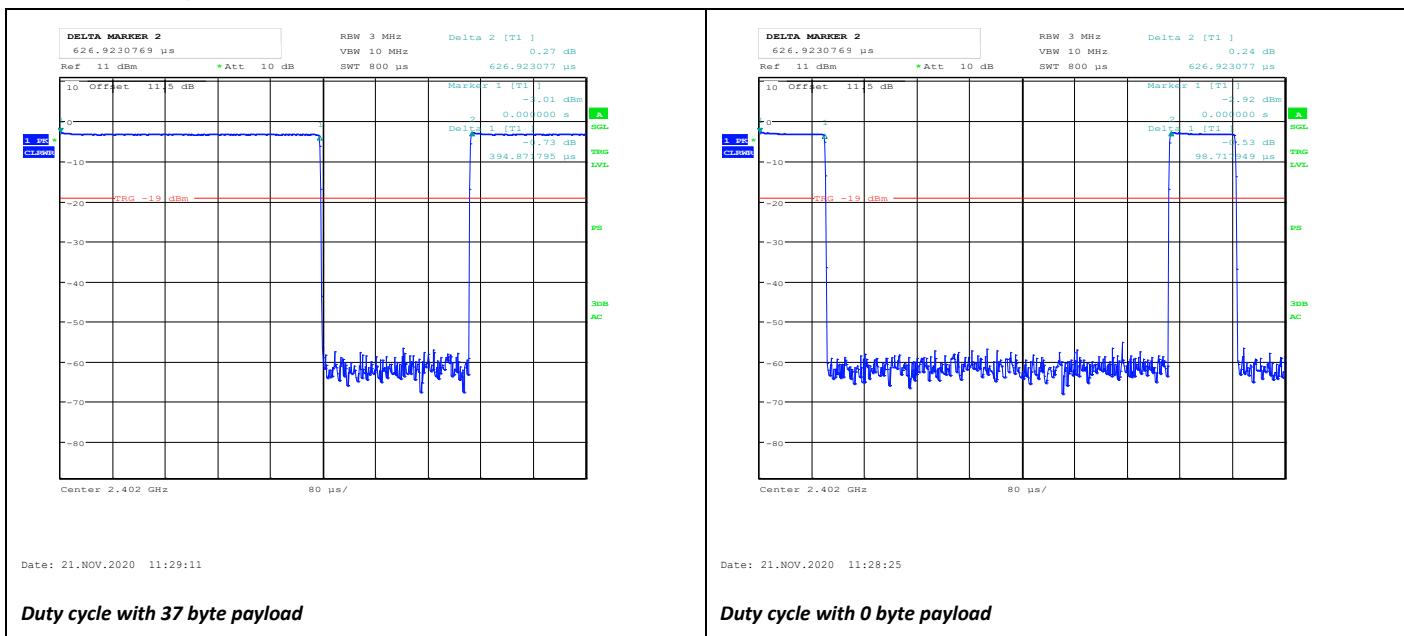
Maximum allowed Duty Cycle Correction: 20 dB

Maximum Duty Cycle Correction Factor according to Para 15.35 (b): 20 dB

With CummaTec Crystal



With Epson Crystal



Radiated emission 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

Detector: Quasi-Peak

Measuring distance 3 m

Tested in TX mode

With CummaTec Crystal

Frequency (MHz)	QuasiPeak (dB μ V/m)	Limit (dB μ V/m)	Margin (dB)	Meas. Time (ms)	Bandwidth (kHz)	Height (cm)	Pol	Azimuth (deg)
/	/		/		/	/	/	/

With Epson Crystal

Frequency (MHz)	QuasiPeak (dB μ V/m)	Limit (dB μ V/m)	Margin (dB)	Meas. Time (ms)	Bandwidth (kHz)	Height (cm)	Pol	Azimuth (deg)
/	/		/		/	/	/	/

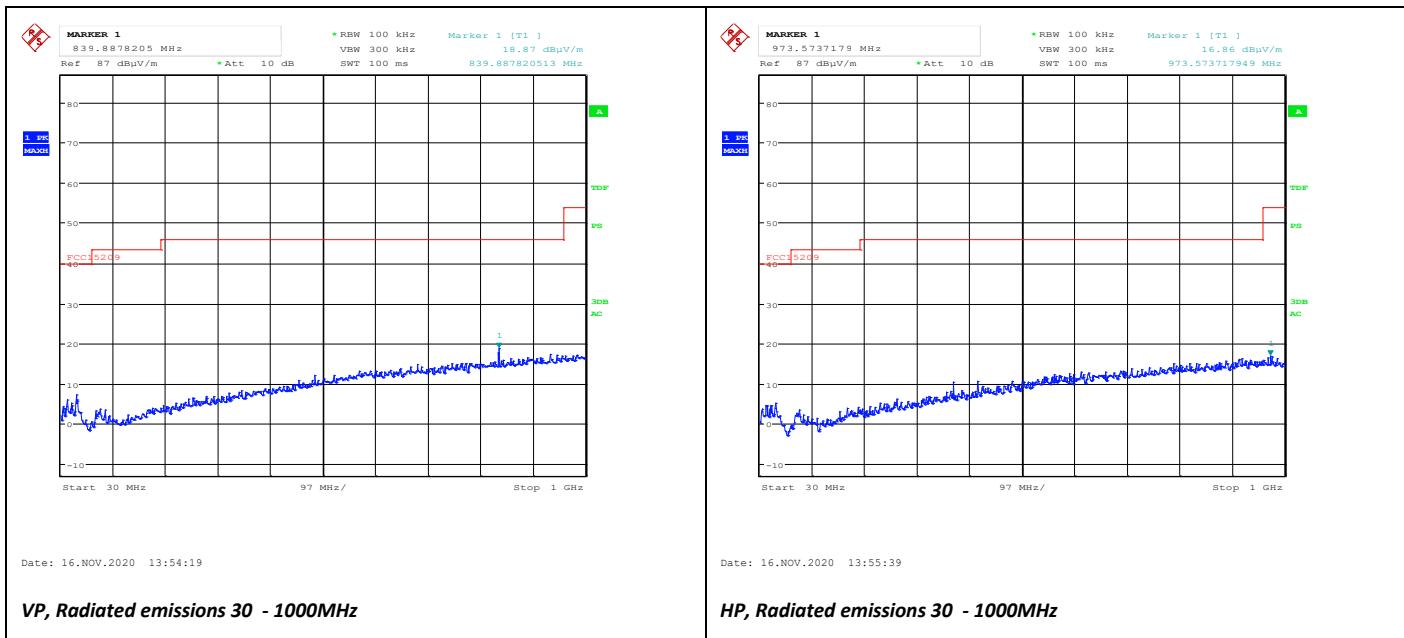
See attached plots

Requirements/Limit

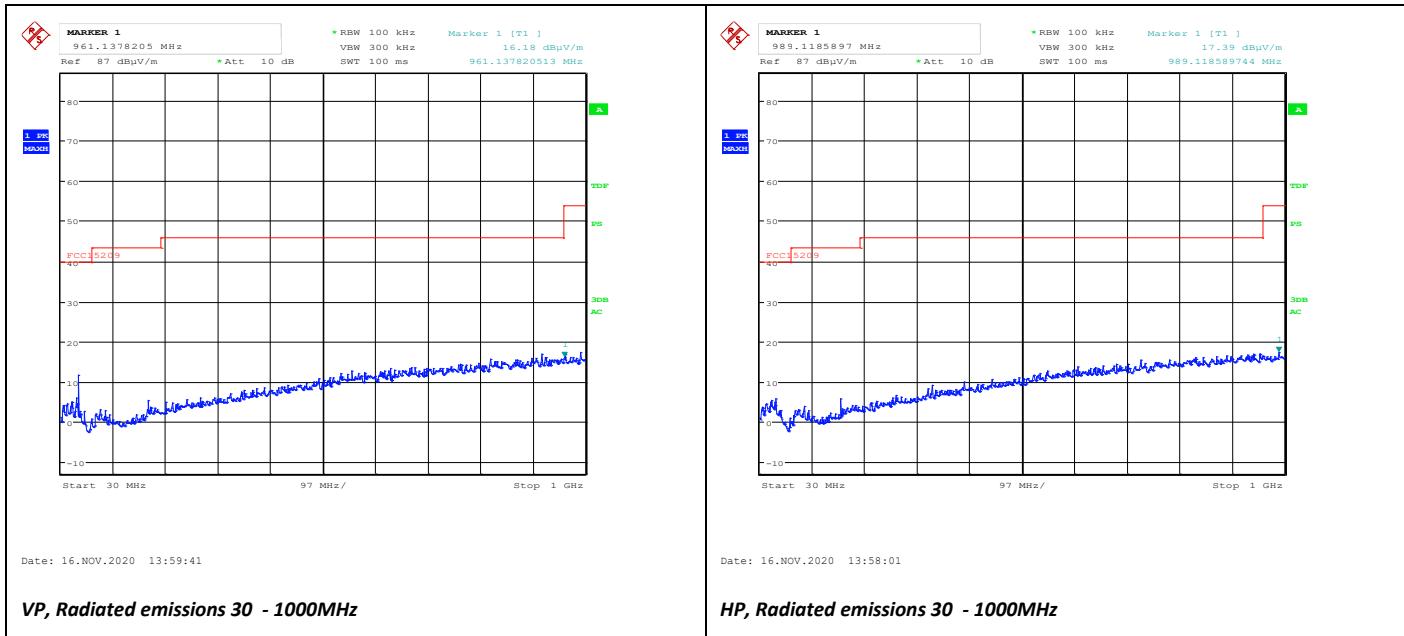
FCC	Part 15.209 @ frequencies defined in §15.205		
ISED	RSS-GEN Issue 5, Clause 8.9 @ frequencies defined in clause 8.10		
Radiated emission limit @3 meters			
Frequency (MHz)		Quasi Peak (μV/m)	Quasi Peak (dBμV/m)
30 – 88		100	40.0
88 – 216		150	43.5
216 – 960		200	46.0
Above 960		500	54.0

The limit above 1000 MHz is specified for Average Detector, when the measurement is performed with a Peak Detector a Duty-Cycle Correction Factor has to be calculated to find the corresponding Average Detector value.

With CummaTec Crystal



With Epson Crystal



Radiated Emissions, 1-25 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

Measuring distance: 3m (1 – 18 GHz), 1m (18 – 25 GHz)

CummaTec crystal:

Peak Detector: (Restricted band frequencies)

Frequency	RF channel	Dist. corr. factor	Field strength, Peak Detector, 3m	Limit	Margin
GHz	L,M,H	dB	dB μ V/m	dB μ V/m	dB
4.804	M	0	53.89	74	20.11
4.880	H	0	51.92	74	22.08
4.960	L	0	50.94	74	23.06
Other freqs	L,M,H	0	None detected	74	>20

Epson crystal:

Peak Detector: (Restricted band frequencies)

Frequency	RF channel	Dist. corr. factor	Field strength, Peak Detector, 3m	Limit	Margin
GHz	L,M,H	dB	dB μ V/m	dB μ V/m	dB
4.804	M	0	55.,22	74	18.78
4.880	H	0	52.59	74	21.41
4.960	L	0	51.36	74	22.64
Other freqs	L,M,H	0	None detected	74	>20

Epson crystal:

Average Detector: (Restricted band frequencies)

Frequency	RF channel	Dist. corr. factor	Field strength, Peak Detector, 3m	Limit	Margin
GHz	L,M,H	dB	dB μ V/m	dB μ V/m	dB
4.804	M	0	50.,27	54	3.73
4.880	H	0	/	54	/
4.960	L	0	/	54	/
Other freqs	L,M,H	0	None detected	74	>20

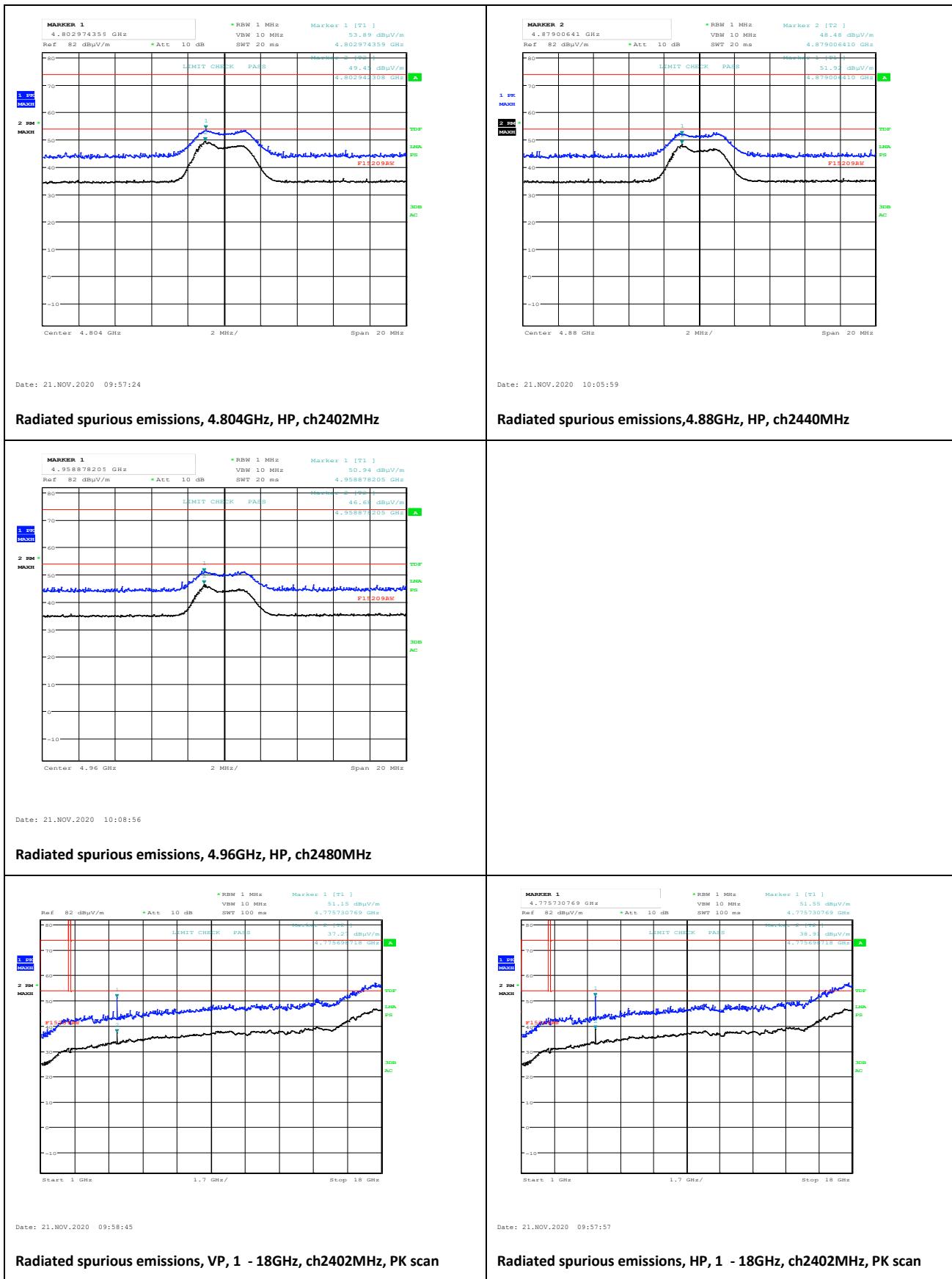
Maximum is obtained in HP

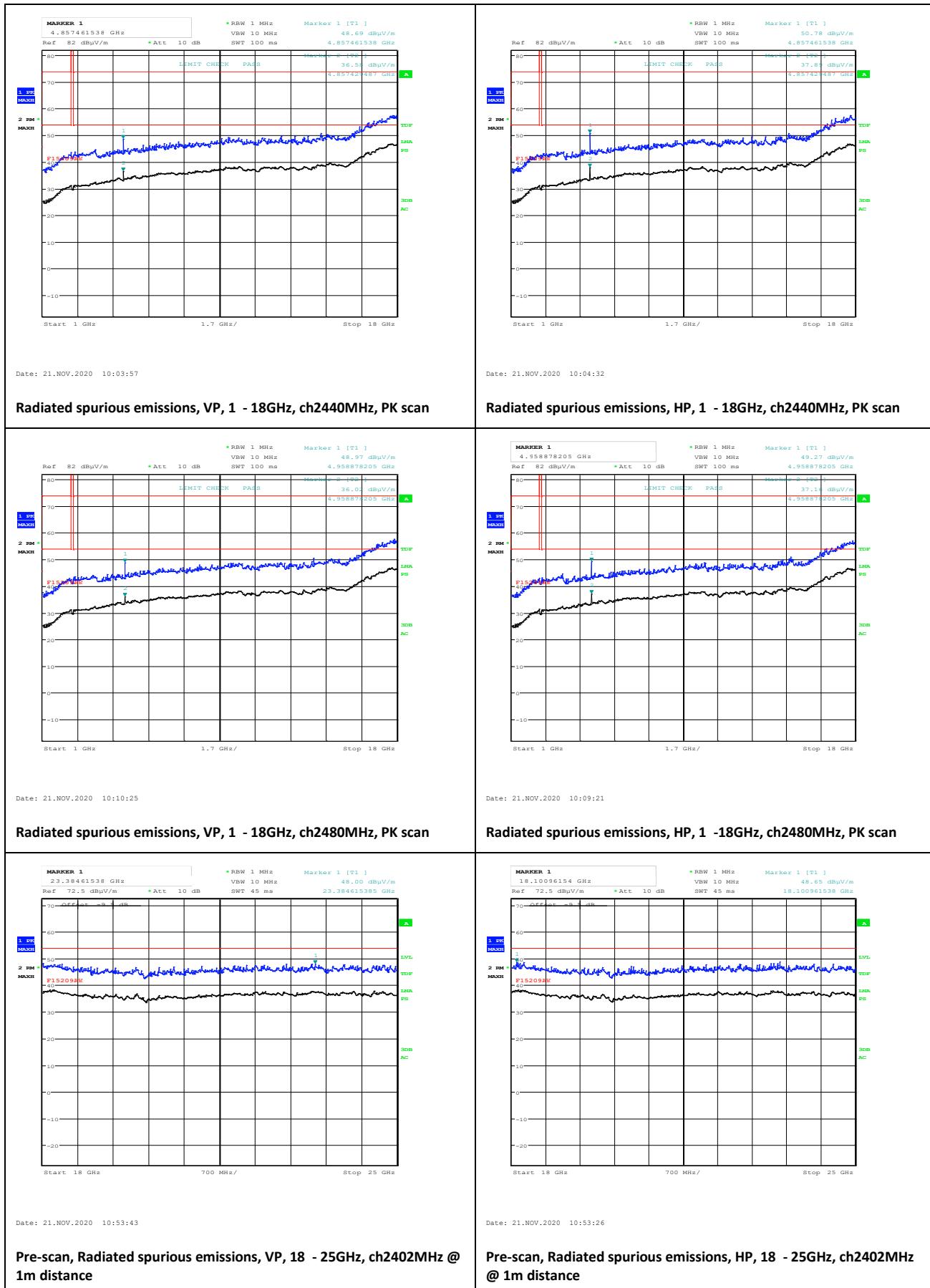
Antenna factor, amplifier gain and cable loss are included in spectrum analyzer “Transducer factor”,. See plots.

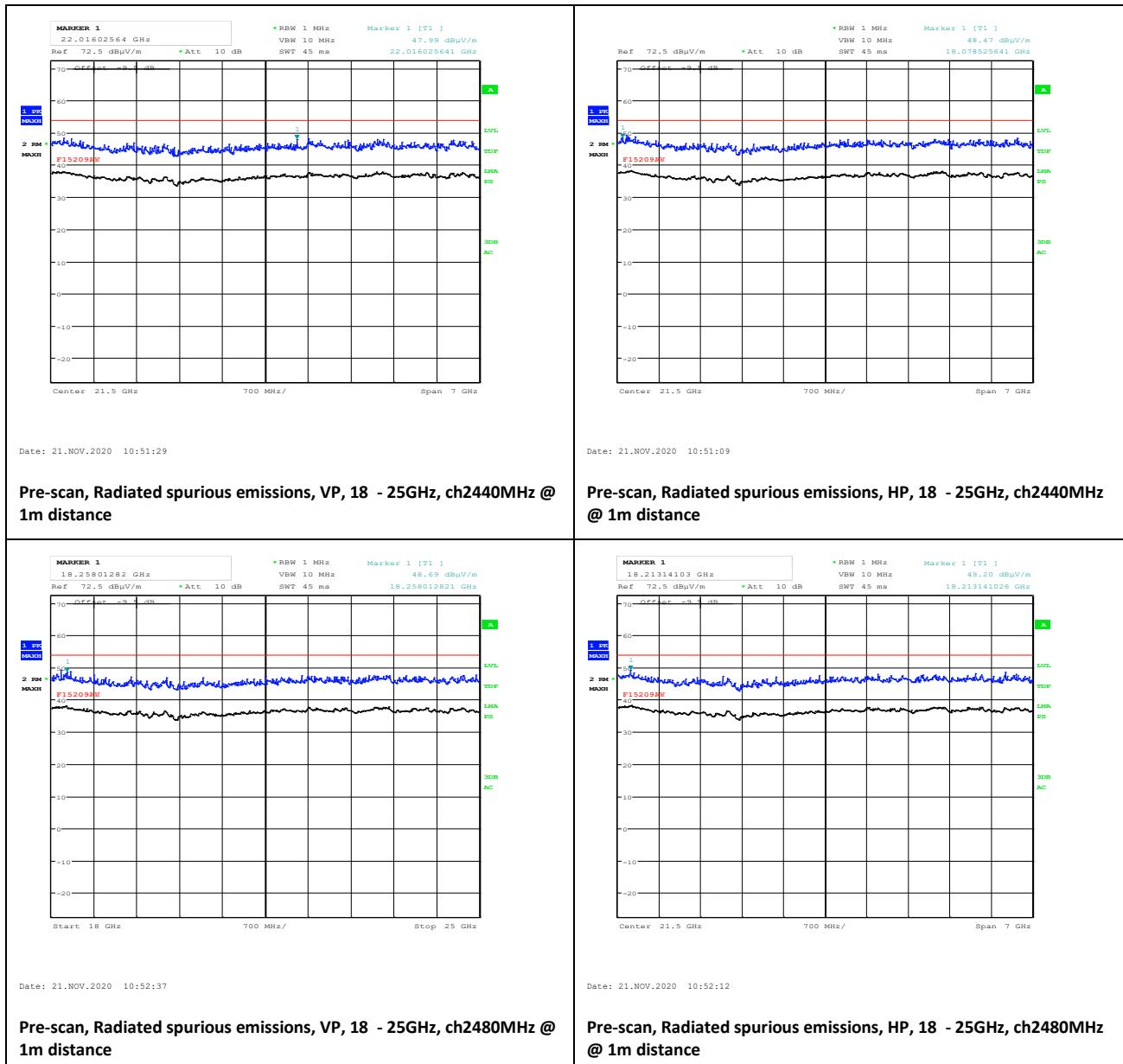
Requirements/Limit

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 (MHz)	AV (dB μ V/m)	Peak (dB μ V/m)
Above 1 GHz	54.0	74.0

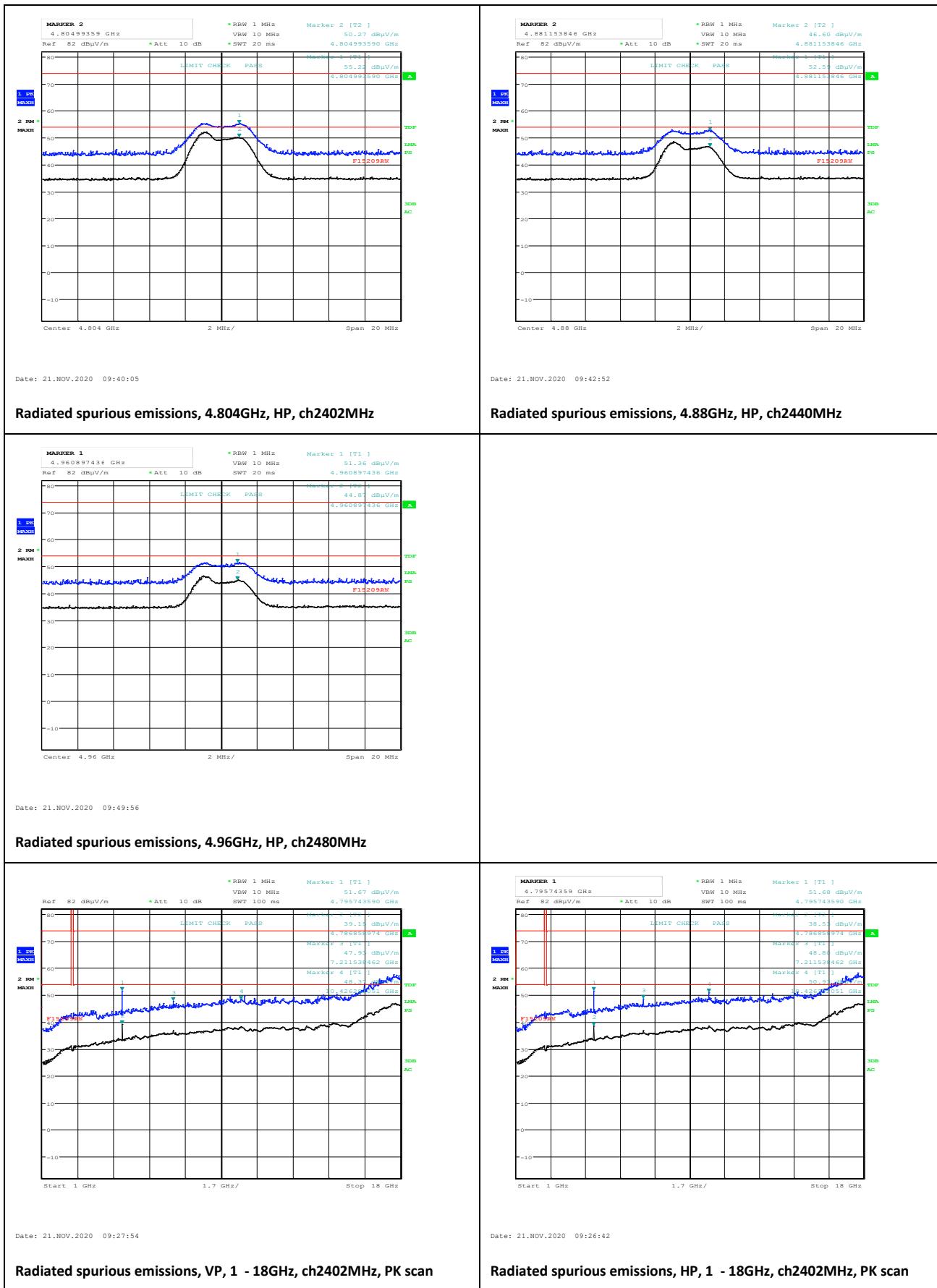
With CummaTec crystal

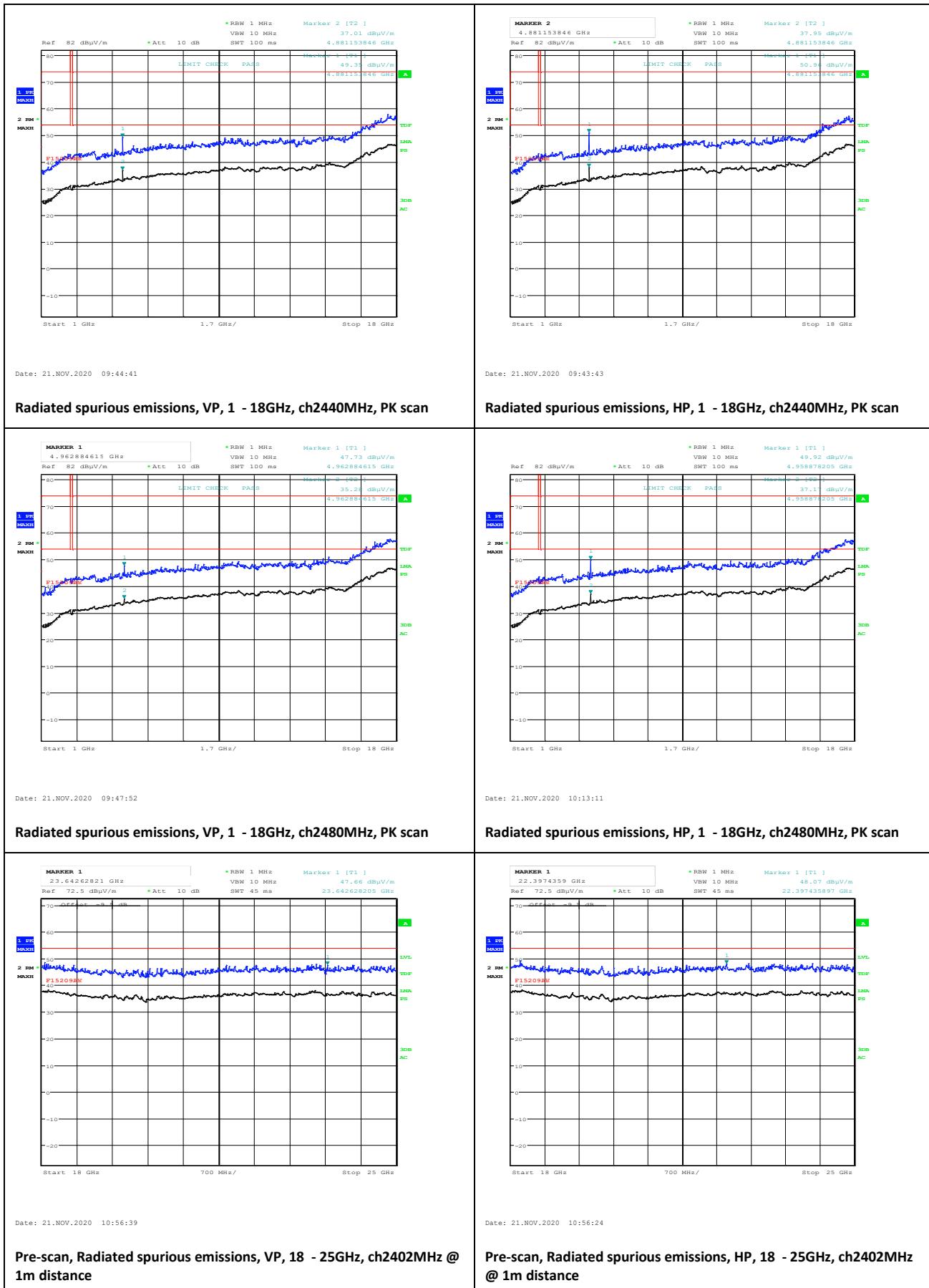


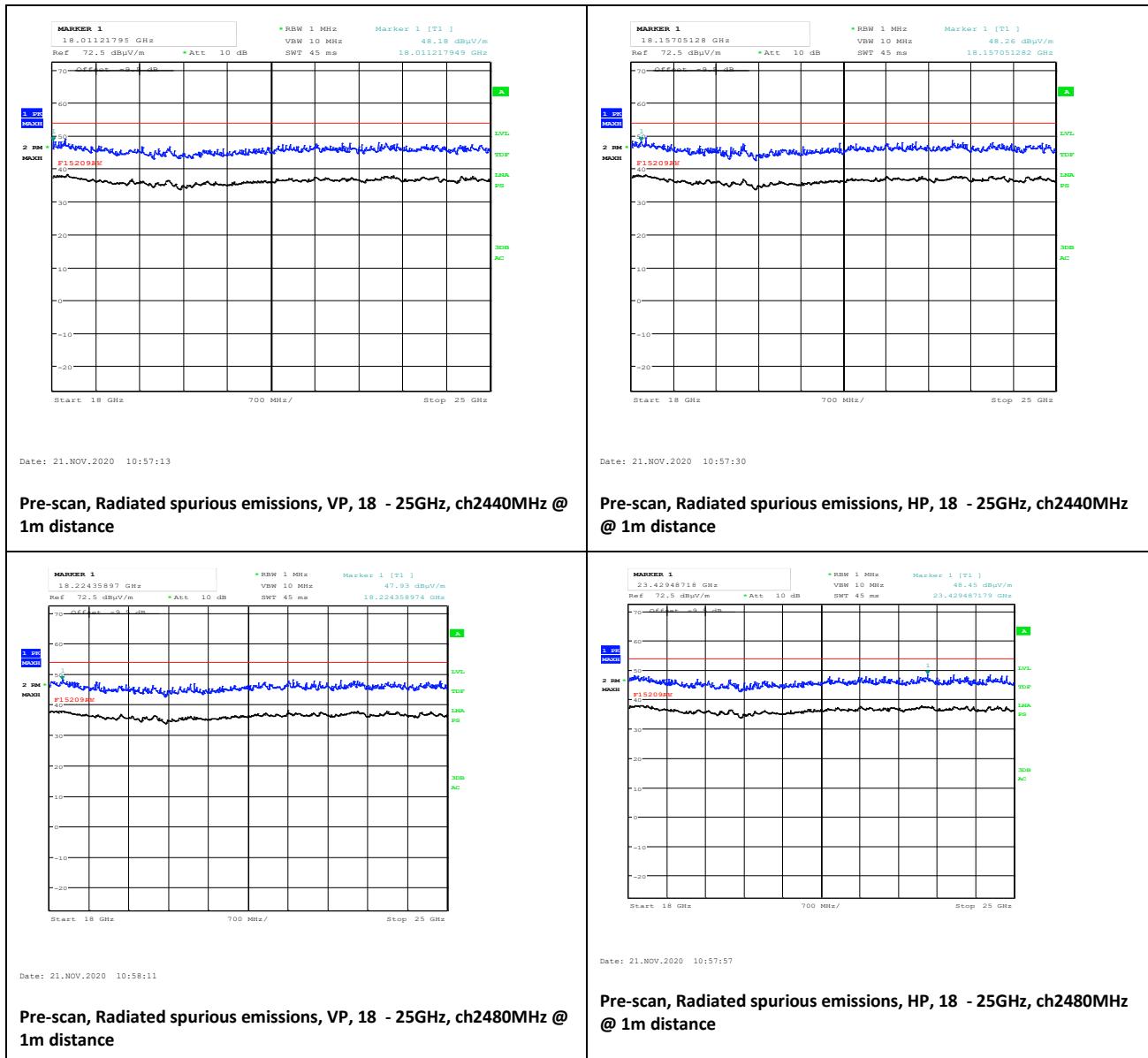




With Epson crystal







3.8 Power Spectral Density (PSD)

FCC part 15.247(e)

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

Measurement procedure: ANSI C63.10-2013 Clause 11.10

Test Results: Complies

Measured and Calculated Data:

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

With CummaTec crystal

	2402 MHz	2440 MHz	2480 MHz
Measured value (dBm)	-16.67	-17.64	-18.23
	2402 MHz	2440 MHz	2480 MHz

With Epson crystal

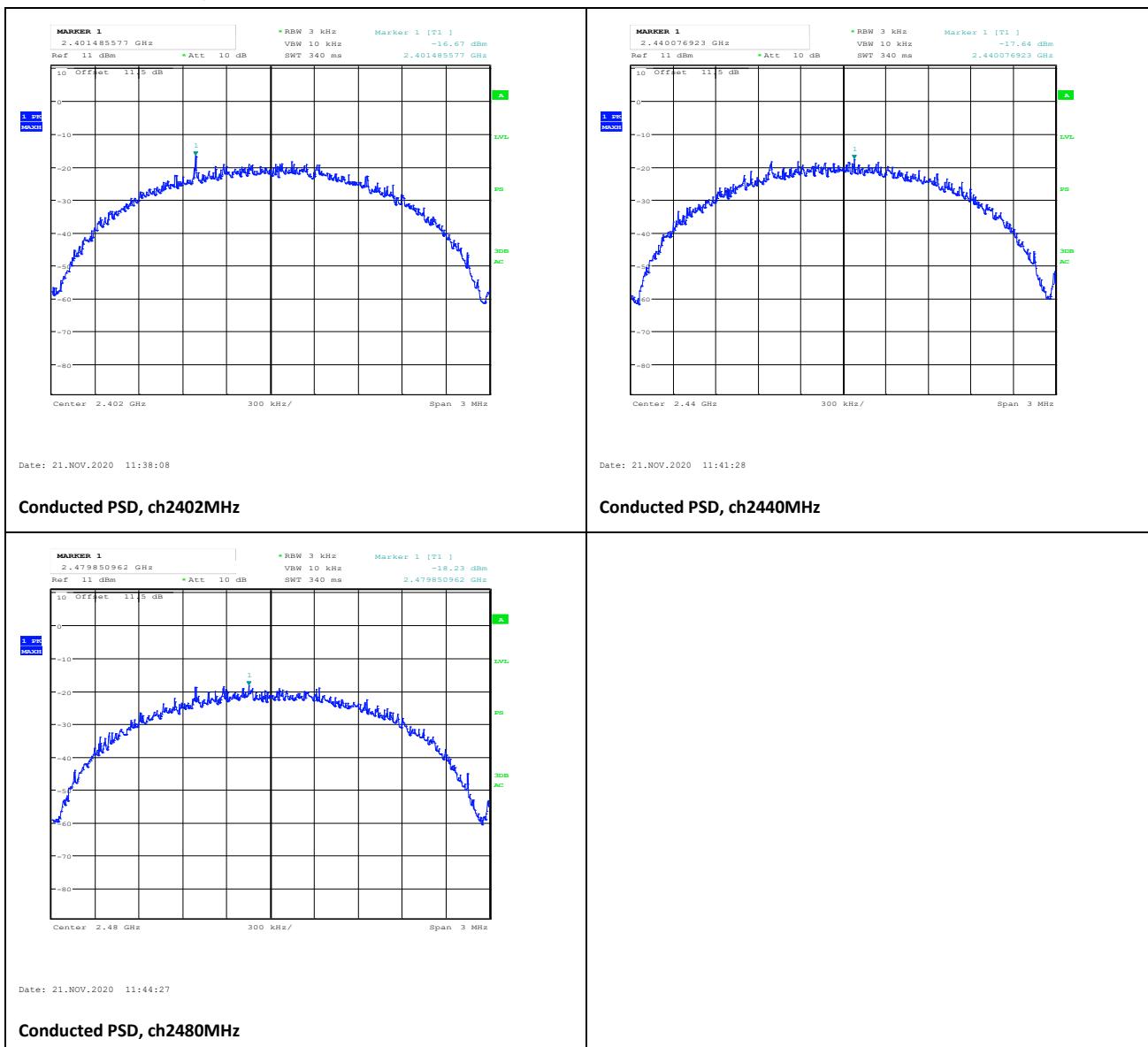
	2402 MHz	2440 MHz	2480 MHz
Measured value (dBm)	-17.74	-17.54	-18.43
	2402 MHz	2440 MHz	2480 MHz

Requirements:

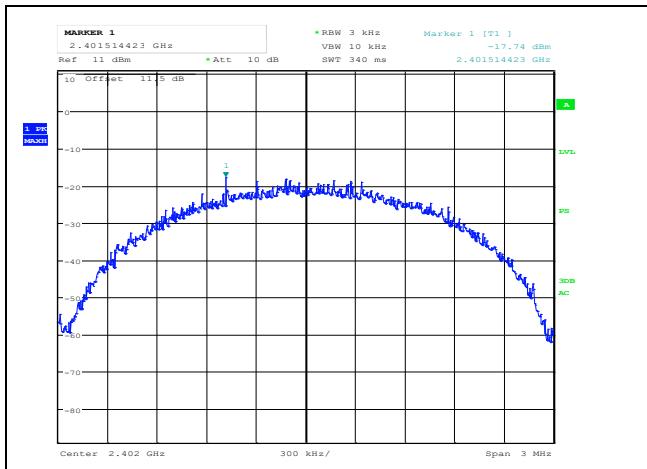
The Power Spectral Density of a Digital Transmission System shall be no greater than +8 dBm in any 3 kHz band

No requirements for Frequency Hopping Systems.

With crommaTec crystal

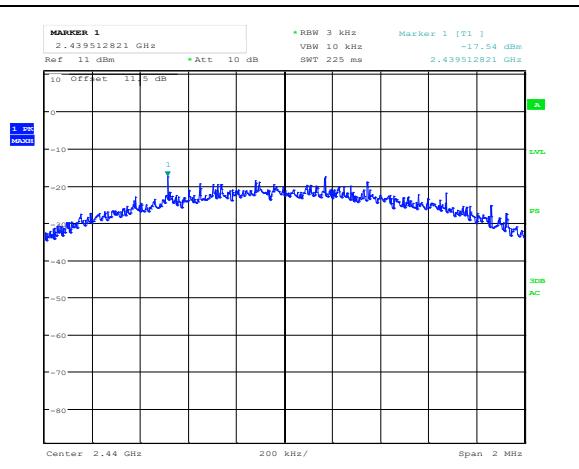


With Epson crystal



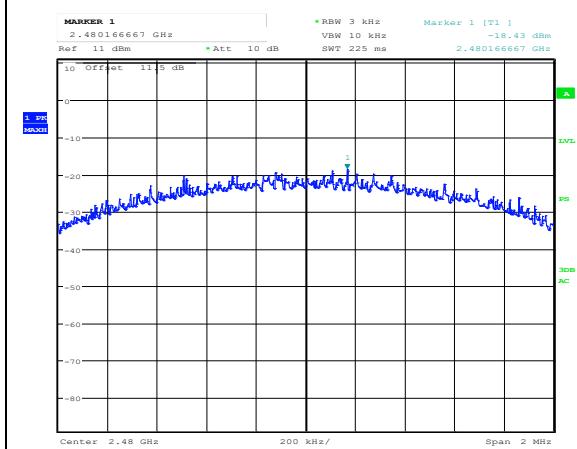
Date: 21.NOV.2020 11:13:08

Conducted PSD, ch2402MHz



Date: 21.NOV.2020 11:18:06

Conducted PSD, ch2440MHz



Date: 21.NOV.2020 11:23:14

Conducted PSD, ch2480MHz

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.

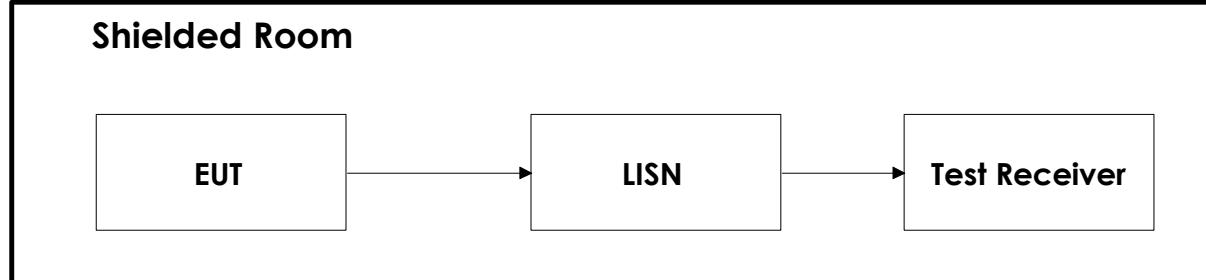
No.	Instrument/ ancillary	Type of instrument/ ancillary	Manufacturer	Ref. no.	Cal. Date	Cal. Due
1.	ESU40	EMI Receiver	Rohde & Schwarz	LR1639	2020.01	2021.01
2.	HFH2-Z2	Active Loop antenna	Rohde & Schwarz	LR1660	2019.11	2021.11
3.	3117-PA	Horn antenna with PreA	EMCO	LR 1717	2017.12	2020.12
4.	638	Antenna Horn	NARDA	LR 1480	N/A	
5.	637	Antenna Horn	NARDA	LR 099	N/A	
6.	VULB9163	Bi-log Hybrid Antenna	Schwarzbeck	LR 1616	2020.01	2022.01
7.	4768-10	Attenuator	Narda	LR 1356	Cal b4 use	
8.	NO324415	Notch Filter	Microwave	LR 1760	Cal b4 use	
9.	8449B	Pre-amplifier	Hewlett Packard	LR 1322	2020.08	2021.08
10.	310N	Pre-amplifier	Sonoma	LR 1686	2020.08	2021.08
11.	Model 45	Multimeter	Fluke	LT 5218	2020.11	2022.11
12.	6812B	AC power source	Agilent	LR 1515	2020.04	2021.04
13.	ESCI3	EMI Receiver	Rohde & Schwarz	N-4529	2019.10	2021.10
14.	ENV216	Two line network	Rohde & Schwarz	LR 1665	2019.11	2021.11

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

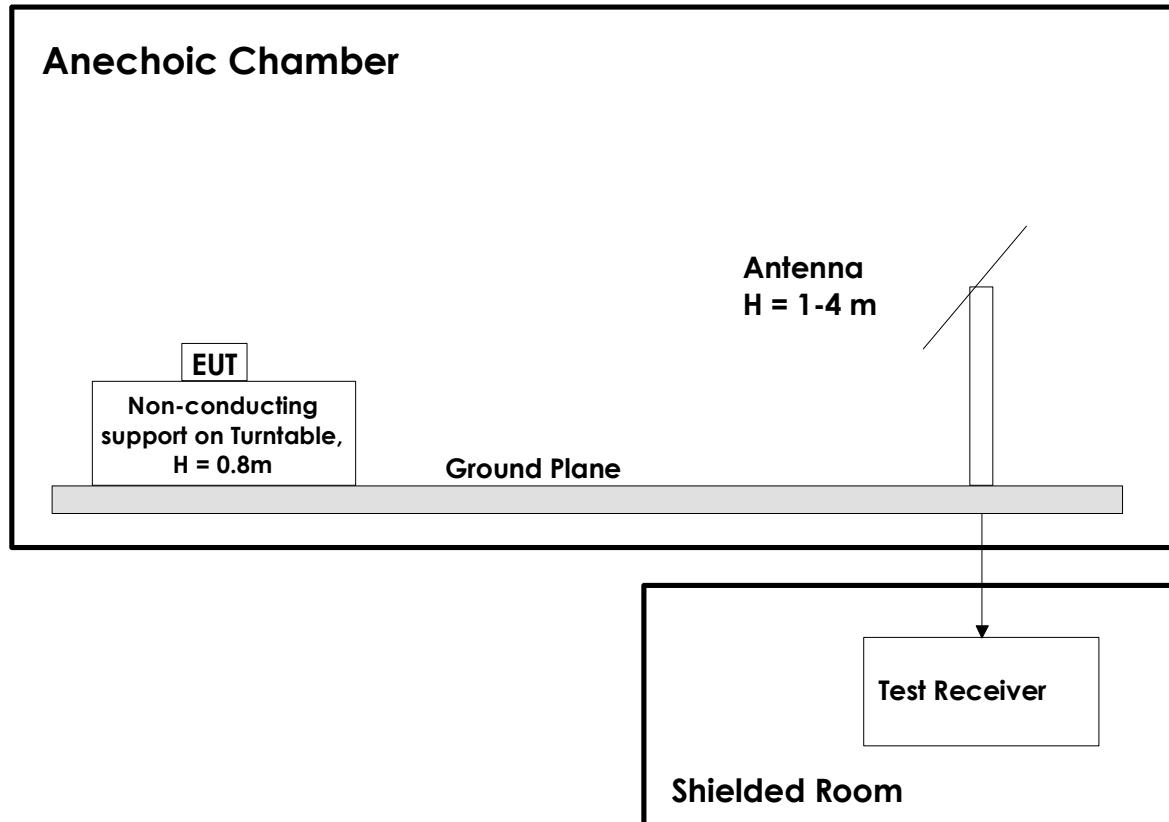
No.	Manufacturer	Name	Version	Comment
1	Rohde & Schwarz	GPIBShot	2.7	Screenshots from R&S Spectrum Analyzers
2	Rohde & Schwarz	RScommander	1.9.2 64bit	Software Tool for R&S Instruments
3	Rohde & Schwarz	EMC 32	10.50.40	Radiated Emission test software

6 BLOCK DIAGRAM

6.1 Power Line Conducted Emission



6.2 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.

Revision history

Version	Date	Comment	Sign
01	2021-01-04	First Version	gns