



TEST REPORT

Test Report No. : UL-RPT-RP13337971-1216A V2.0

Customer : Raspberry Pi (Trading) Ltd

Model No. / PMN : RPI-RM0

HVIN : RPI-RM0

FCC ID : 2ABCB-RPIRM0

ISED Certification No. : IC: 20953-RPIRM0

Technology : *Bluetooth* – Low Energy

Test Standard(s) : FCC Parts 15.247(a)(2), 15.247(e), 15.247(b)(3) & 15.247(d)
Innovation, Science and Economic Development Canada
RSS-247 Issue 2 Sections 5.2(a), 5.2(b) & 5.4(d) & 5.5
RSS-Gen Issue 5 Sections 6.7, 6.12 & 8.2

Test Laboratory : UL International (UK) Ltd, Basingstoke, Hampshire, RG24 8AH,
United Kingdom

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2. The results in this report apply only to the sample(s) tested.
3. The sample tested is in compliance with the above standard(s).
4. The test results in this report are traceable to the national or international standards.
5. Version 2.0 supersedes all previous versions.

Date of Issue: 30 October 2020

Checked by:

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Customer Information

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Report Revision History

Version Number	Issue Date	Revision Details	Revised By
1.0	20/10/2020	Initial Version	Sarah Williams
2.0	30/10/2020	Lower Band Edge results added	Ben Mercer

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1. Attestation of Test Results

1.1. Description of EUT

The equipment under test was a *Bluetooth* and WiFi radio module.

1.2. General Information

Specification Reference:	47CFR15.247
Specification Title:	Code of Federal Regulations Volume 47 (Telecommunications): Part 15 Subpart C (Intentional Radiators) - Section 15.247
Specification Reference:	47CFR15.209
Specification Title:	Code of Federal Regulations Volume 47 (Telecommunications): Part 15 Subpart C (Intentional Radiators) - Section 15.209
Specification Reference:	RSS-Gen Issue 5 March 2019
Specification Title:	General Requirements for Compliance of Radio Apparatus
Specification Reference:	RSS-247 Issue 2 February 2017
Specification Title:	Digital Transmission Systems (DTSs), Frequency Hopping Systems (FHSs) and Licence-Exempt Local Area Network (LE-LAN) Devices
Site Registration:	FCC: 621311, ISEDC: 20903
Location of Testing:	Unit 3 Horizon, Wade Road, Kingsland Business Park, Basingstoke, Hampshire, RG24 8AH, United Kingdom
Test Dates:	28 July 2020 to 28 October 2020

1.3. Summary of Test Results

FCC Reference (47CFR)	ISED Canada Reference	Measurement	Result
Part 15.35(c)	RSS-Gen 8.2	Transmitter Duty Cycle	Note 1
N/A	RSS-Gen 6.7	Transmitter 99% Occupied Bandwidth	
Part 15.247(a)(2)	RSS-Gen 6.7 / RSS-247 5.2(a)	Transmitter Minimum 6 dB Bandwidth	
Part 15.247(b)(3)	RSS-Gen 6.12 / RSS-247 5.4(d)	Transmitter Maximum Peak Output Power	
Part 15.247(e)	RSS-247 5.2(b)	Transmitter Power Spectral Density	Note 2
Part 15.247(d) & 15.209(a)	RSS-Gen 6.13 / RSS-247 5.5	Transmitter Band Edge conducted Emissions	

Key to Results

 = Complied  = Did not comply

Note(s):

1. The measurement was performed to assist in the calculation of the level of the emissions. The EUT cannot transmit continuously and sweep triggering/signal gating cannot be implemented.
2. In accordance with ANSI C63.10 Section 11.10.1, PSD measurements are not required if the maximum conducted output power is less than the PSD limit of 8 dBm / 3 kHz. The PSD level is therefore deemed to be equal to the measured output power.

1.4. Deviations from the Test Specification

For the measurements contained within this test report, there were no deviations from, additions to, or exclusions from the test specification identified above.

2. Summary of Testing

2.1. Facilities and Accreditation

The test site and measurement facilities used to collect data are located at Unit 3 Horizon, Wade Road, Kingsland Business Park, Basingstoke, Hampshire, RG24 8AH, United Kingdom.

UL International (UK) Ltd is accredited by UKAS. The tests reported herein have been performed in accordance with its terms of accreditation.

2.2. Methods and Procedures

Reference:	ANSI C63.10-2013
Title:	American National Standard of Procedures for Compliance Testing of Unlicensed Wireless Devices
Reference:	KDB 558074 D01 15.247 Meas Guidance v05r02, April 2, 2019
Title:	Guidance for Compliance Measurements on Digital Transmission System, Frequency Hopping Spread Spectrum System, and Hybrid System Devices Operating Under Section 15.247 of the FCC Rules

2.3. Calibration and Uncertainty

Measuring Instrument Calibration

In accordance with UKAS requirements all the measurement equipment is on a calibration schedule. All equipment was within the calibration period on the date of testing.

Measurement Uncertainty

No measurement or test can ever be perfect and the imperfections give rise to error of measurement in the results. Consequently the result of a measurement is only an approximation to the value measured (the specific quantity subject to measurement) and is only complete when accompanied by a statement of the uncertainty of the approximation.

The expression of uncertainty of a measurement result allows realistic comparison of results with reference values and limits given in specifications and standards.

The uncertainty of the result may need to be taken into account when interpreting the measurement results.

The reported expanded uncertainties below are based on a standard uncertainty multiplied by an appropriate coverage factor such that a confidence level of approximately 95% is maintained. For the purposes of this document “approximately” is interpreted as meaning “effectively” or “for most practical purposes”.

Measurement Type	Range	Confidence Level (%)	Calculated Uncertainty
Duty Cycle	2.4 GHz to 2.4835 GHz	95%	±1.14 %
99% Occupied Bandwidth	2.4 GHz to 2.4835 GHz	95%	±3.92 %
Minimum 6 dB Bandwidth	2.4 GHz to 2.4835 GHz	95%	±4.59 %
Conducted Maximum Peak Output Power	2.4 GHz to 2.4835 GHz	95%	±1.13 dB
Conducted Band Edge Emissions	2.4 GHz to 2.4835 GHz	95%	±2.62 dB

The methods used to calculate the above uncertainties are in line with those recommended within the various measurement specifications. Where measurement specifications do not include guidelines for the evaluation of measurement uncertainty the published guidance of the appropriate accreditation body is followed.

2.4. Test and Measurement Equipment**Test Equipment Used for Transmitter Conducted Tests**

Asset No.	Instrument	Manufacturer	Type No.	Serial No.	Date Calibration Due	Cal. Interval (Months)
M2001	Thermohygrometer	Testo	608-H1	45041824	05 Jan 2021	12
M1999	RF Power Sensor	Dare Instruments	RPR3006W	15I00041SN 079	28 May 2021	12
A2525	Attenuator	AtlanTecRF	AN18W5-10	832827	Calibrated before use	-
M1835	Signal Analyser	Rohde & Schwarz	FSV30	103050	14 Apr 2021	12
G0614	Signal Generator	Rohde & Schwarz	SMB100A	177687	19 May 2023	36
M1886	Test Receiver	Rohde & Schwarz	ESU26	1000554	15 May 2021	12
G0628	Vector Signal generator	Rohde & Schwarz	SMBV100A	261847	08 October 2023	36
A2527	Attenuator	AltanTechRF	AN18W5-20	832828#2	Calibrated before use	-

3. Equipment Under Test (EUT)

3.1. Identification of Equipment Under Test (EUT)

Brand Name:	Raspberry Pi
Model Name or Number / PMN:	RPI-RM0
Test Sample Serial Number:	3185953 (<i>Conducted sample</i>)
Hardware Version:	V1.0
Software Version:	V1.0
FCC ID:	2ABCB-RPIRM0
ISED Canada Certification Number:	IC: 20953-RPIRM0

3.2. Modifications Incorporated in the EUT

No modifications were applied to the EUT during testing.

3.3. Additional Information Related to Testing

Technology Tested:	Bluetooth Low Energy (Digital Transmission System)		
Type of Unit:	Transceiver		
Channel Spacing:	2 MHz		
Modulation:	GFSK		
Data Rate:	1 Mbps		
Power Supply Requirement(s):	Nominal	5.0 VDC	
Maximum Conducted Output Power:	4.7 dBm		
Transmit Frequency Range:	2402 MHz to 2480 MHz		
Transmit Channels Tested:	Channel ID	Channel Number	Channel Frequency (MHz)
	Bottom	37	2402
	Middle	17	2440
	Top	39	2480

3.4. Description of Available Antennas

The table below lists the internal niche antenna and the external antenna available.

Manufacturer	Type	Frequency Range (MHz)	Antenna Gain (dBi)
ProAnt	Internal	2400 to 2480	3.5
Raspberry Pi	External	2400 to 2480	2.0

3.5. Description of Test Setup

Support Equipment

The following support equipment was used to exercise the EUT during testing:

Description:	Pi4 board used as test jig
Brand Name:	Raspberry Pi4
Model Name or Number:	Pi4
Serial Number:	10000000ae5754eo

Description:	Micro SD Card with OS image
Brand Name:	SanDisk
Model Name or Number:	16 GB card
Serial Number:	Not marked or stated

Description:	USB Mouse
Brand Name:	Microsoft
Model Name or Number:	1113
Serial Number:	Not marked or stated

Description:	USB Keyboard
Brand Name:	Dell
Model Name or Number:	KB212-B
Serial Number:	Not marked or stated

Description:	Power Supply. 100-230 VAC Input / 5 VDC Output
Brand Name:	Raspberry Pi4
Model Name or Number:	KSA-15E-051300HK
Serial Number:	Not marked or stated

Description:	USB Mouse
Brand Name:	Raspberry Pi
Model Name or Number:	RPI-MOUSE
Serial Number:	Not marked or stated

Description:	USB Keyboard
Brand Name:	HP
Model Name or Number:	KU-0316
Serial Number:	Not marked or stated

Support Equipment (continued)

Description:	Monitor
Brand Name:	ASUS
Model Name or Number:	PA238
Serial Number:	D9LMTF114809

Operating Modes

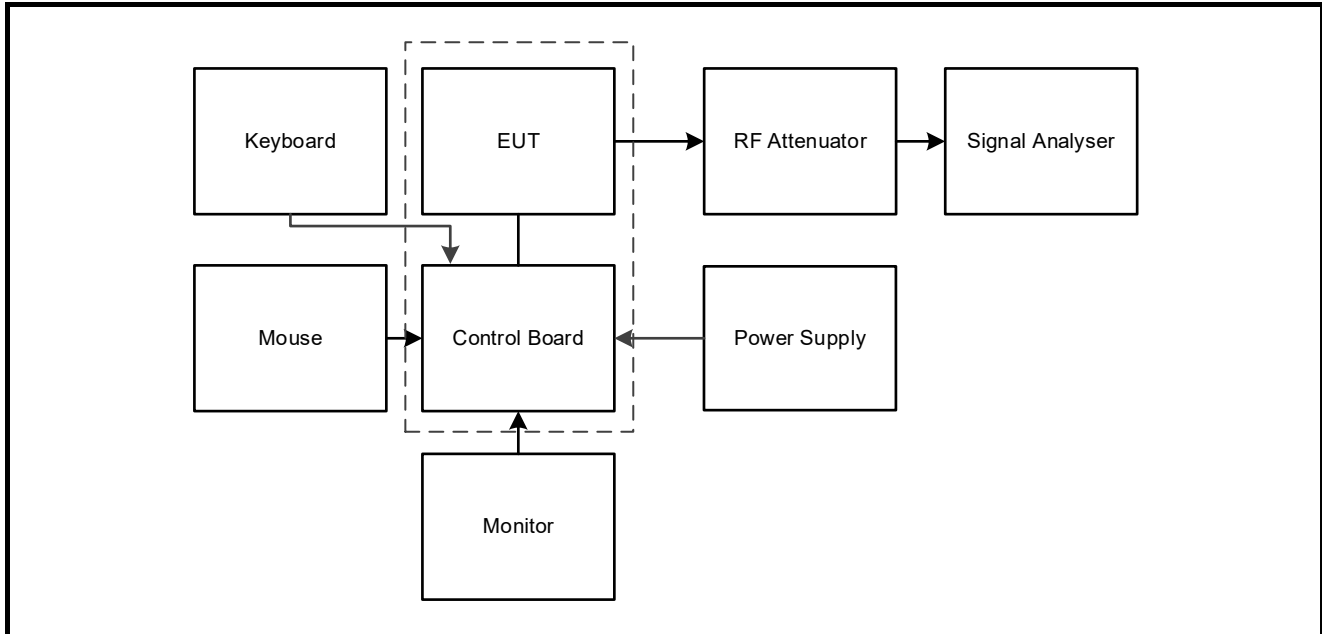
The EUT was tested in the following operating mode(s):

- Transmitting at maximum power in *Bluetooth* LE mode with modulation, maximum possible data length available and Pseudorandom Bit Sequence 9.

Configuration and Peripherals

The EUT was tested in the following configuration(s):

- The Pi4 test jig was used to run *Bluetooth* LE test commands on the EUT. The Pi4 test jig was used to enable continuous transmission and to select the test channels and packet types as required.
- The EUT was powered via the Pi4 test jig which was powered from an AC/DC switch mode power supply.

Test Setup Diagrams**Conducted Tests:****Test Setup for Transmitter Conducted Tests**

4. Antenna Port Test Results

4.1. Transmitter Duty Cycle

Test Summary:

Test Engineers:	Matthew Botfield & Jose Bayona	Test Date:	28 July 2020
Test Sample Serial Number:	3185953		

FCC Reference:	Part 15.35(c)
ISED Canada Reference:	RSS-Gen 8.2
Test Method Used:	FCC KDB 558074 Section 6 referencing ANSI C63.10 Section 11.6

Environmental Conditions:

Temperature (°C):	23
Relative Humidity (%):	52

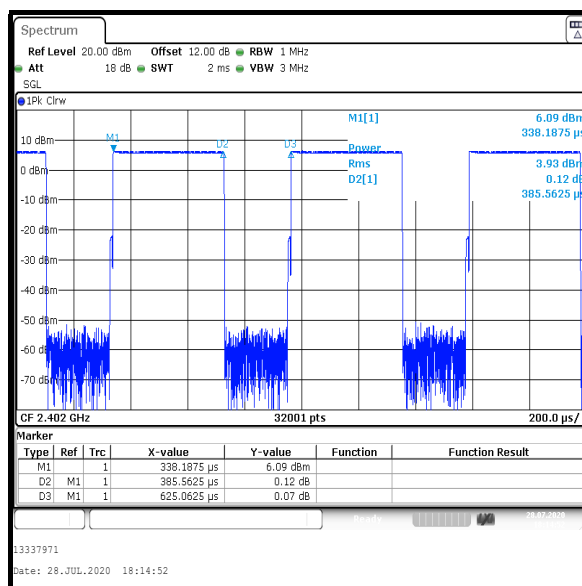
Note(s):

- In order to assist with the determination of the average level of spurious emissions field strength in LE mode, measurements were made of duty cycle to determine the transmission duration and the silent period time of the transmitter. The transmitter duty cycle was measured using a spectrum/signal analyser in the time domain and calculated by using the following calculation:

$$10 \log (1 / (\text{On Time} / [\text{Period or } 100 \text{ ms whichever is the lesser}])).$$

Results:

Pulse Duration (µs)	Period (µs)	Duty Cycle (dB)
385.563	625.063	2.1



4.2. Transmitter 99% Occupied Bandwidth

Test Summary:

Test Engineers:	Matthew Botfield & Jose Bayona	Test Date:	28 July 2020
Test Sample Serial Number:	3185953		

FCC Reference:	N/A
ISED Canada Reference:	RSS-Gen 6.7
Test Method Used:	RSS-Gen 6.7 and Notes below

Environmental Conditions:

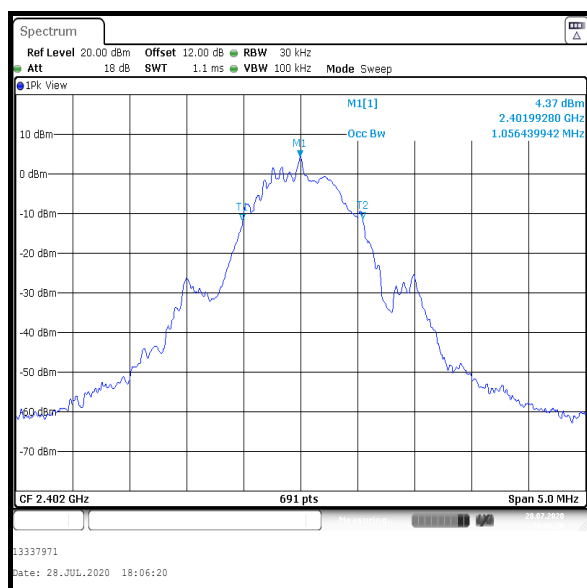
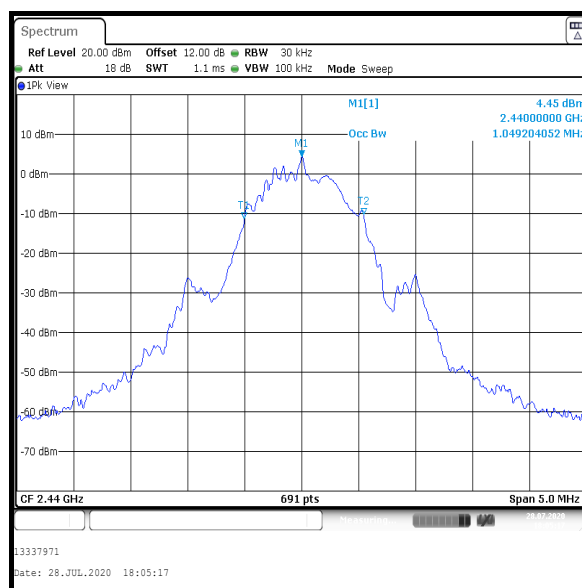
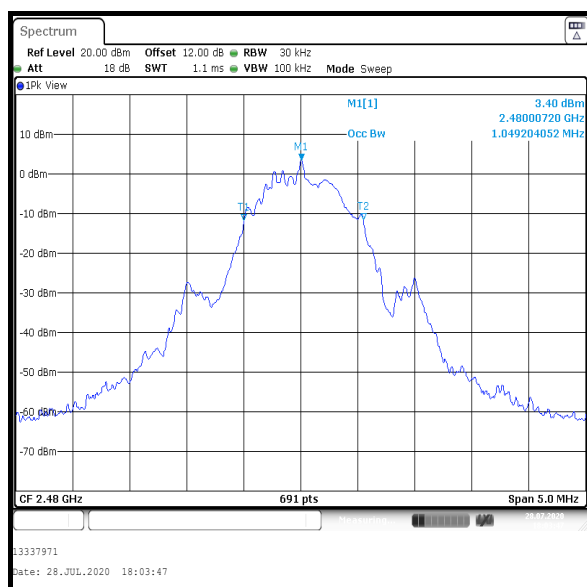
Temperature (°C):	23
Relative Humidity (%):	52

Note(s):

1. The 99% emission bandwidth was measured using the signal analyser occupied bandwidth function. The resolution bandwidth was set in the range of 1% to 5% of the occupied bandwidth and the video bandwidth set to 3 times the resolution bandwidth. The span was set to capture all products of the modulation process including emission skirts.
2. The signal analyser resolution bandwidth was set to 30 kHz and video bandwidth 100 kHz. A peak detector was used, sweep time was set to auto and the trace mode was Max Hold. The span was set to 5 MHz. The signal analyser function set the measurements to be made at 99% of the emission bandwidth. The results are given in the tables below.
3. The signal analyser was connected to the RF port on the EUT using suitable attenuation and RF cable.

Transmitter 99% Occupied Bandwidth (continued)**Results:**

Channel	99% Occupied Bandwidth (kHz)
Bottom	1056.440
Middle	1049.204
Top	1049.204

**Bottom Channel****Middle Channel****Top Channel**

4.3. Transmitter Minimum 6 dB Bandwidth

Test Summary:

Test Engineers:	Matthew Botfield & Jose Bayona	Test Date:	28 July 2020
Test Sample Serial Number:	3185953		

FCC Reference:	Part 15.247(a)(2)
ISED Canada Reference:	RSS-Gen 6.7 / RSS-247 5.2(a)
Test Method Used:	FCC KDB 558074 Section 8.2 referencing ANSI C63.10 Section 11.8.1

Environmental Conditions:

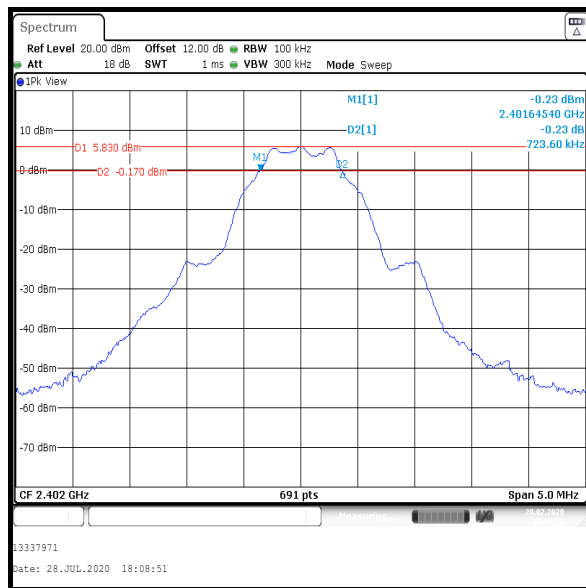
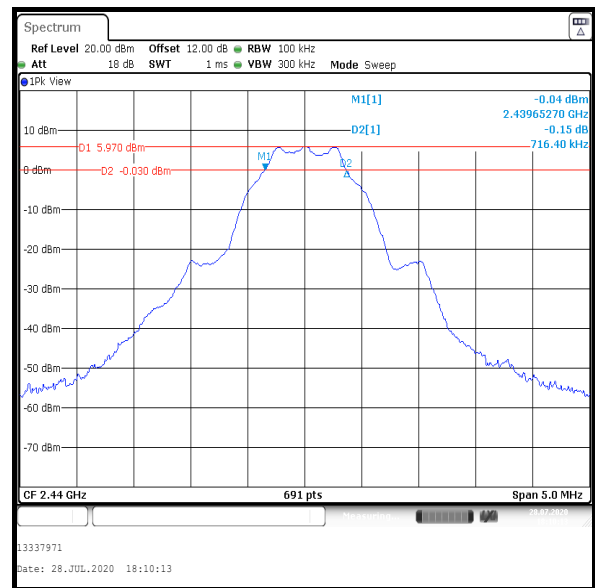
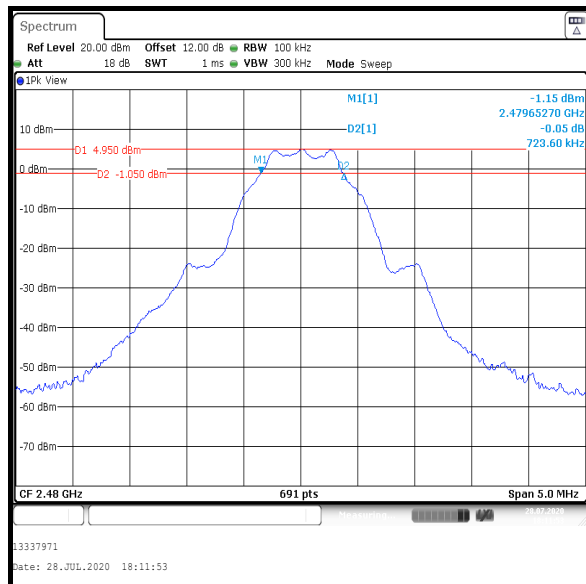
Temperature (°C):	23
Relative Humidity (%):	52

Note(s):

1. 6 dB DTS bandwidth tests were performed using a signal analyser in accordance with ANSI C63.10 Section 11.8.1 Option 1 measurement procedure. The signal analyser resolution bandwidth was set to 100 kHz and video bandwidth 300 kHz. A peak detector was used, sweep time was set to auto and the trace mode was Max Hold. The DTS bandwidth was measured at 6 dB down from the peak of the signal.
2. The signal analyser was connected to the RF port on the EUT using suitable attenuation and RF cable.

Transmitter Minimum 6 dB Bandwidth (continued)**Results:**

Channel	6 dB Bandwidth (kHz)	Limit (kHz)	Margin (kHz)	Result
Bottom	723.600	≥500	223.600	Complied
Middle	716.400	≥500	216.400	Complied
Top	723.600	≥500	223.600	Complied

**Bottom Channel****Middle Channel****Top Channel**

4.4. Transmitter Maximum Peak Output Power

Test Summary:

Test Engineer:	Matthew Botfield	Test Date:	07 September 2020
Test Sample Serial Number:	3185953		

FCC Reference:	Part 15.247(b)(3)
ISED Canada Reference:	RSS-Gen 6.12 / RSS-247 5.4(d)
Test Method Used:	FCC KDB 558074 Section 8.3.1.1 referencing ANSI C63.10 Section 11.9.1.1 and Notes below

Environmental Conditions:

Temperature (°C):	22
Relative Humidity (%):	56

Note(s):

1. Conducted power tests were performed using a signal analyser in accordance with ANSI C63.10 Section 11.9.1.1 with the RBW $\geq$ DTS bandwidth procedure.
2. The signal analyser resolution bandwidth was set to 1 MHz and video bandwidth of 3 MHz. A peak detector was used, sweep time was set to auto and trace mode was Max Hold. The span was set to 3 MHz. A marker was placed at the peak of the signal and the results recorded in the tables below.
3. The signal analyser was connected to the RF port on the EUT using suitable attenuation and RF cable. An RF level offset was entered on the signal analyser to compensate for the loss of the attenuator and RF cable.
4. The conducted power was added to the highest declared antenna gain to obtain the EIRP.

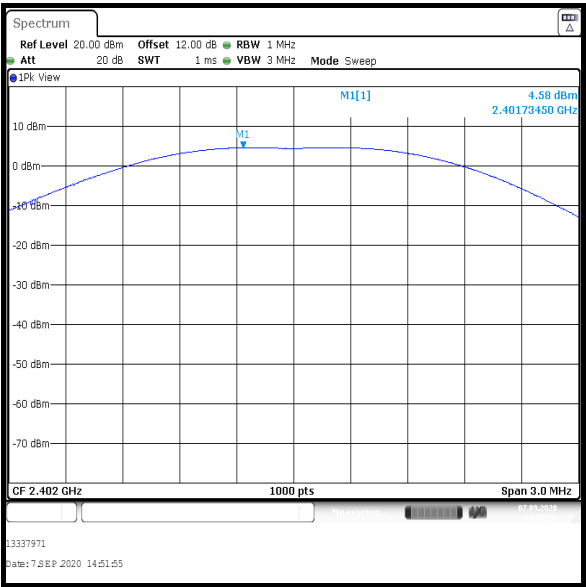
Results:

Channel	Conducted Peak Power (dBm)	Conducted Peak Power Limit (dBm)	Margin (dB)	Result
Bottom	4.6	30.0	25.4	Complied
Middle	4.7	30.0	25.3	Complied
Top	4.2	30.0	25.8	Complied

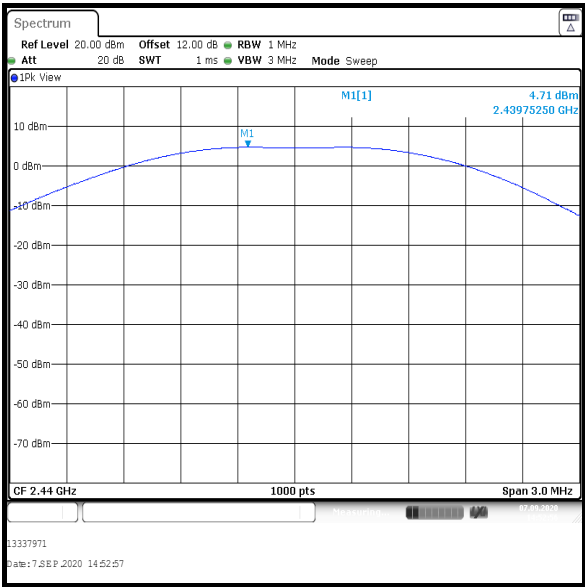
Channel	Conducted Peak Power (dBm)	Highest Declared Antenna Gain (dBi)	EIRP (dBm)	De Facto EIRP Limit (dBm)	Margin (dB)	Result
Bottom	4.6	3.5	8.1	36.0	27.9	Complied
Middle	4.7	3.5	8.2	36.0	27.8	Complied
Top	4.2	3.5	7.7	36.0	28.3	Complied

Transmitter Maximum Peak Output Power (continued)

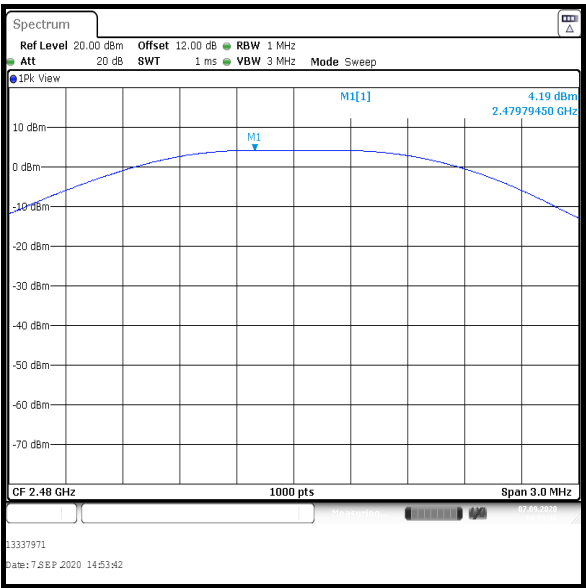
Results:



Bottom Channel



Middle Channel



Top Channel

4.5. Transmitter Band Edge Conducted Emissions

Test Summary:

Test Engineer:	Matthew Botfield	Test Date:	28 October 2020
Test Sample Serial Number:	3185953		

FCC Reference:	Part 15.247(d)
ISED Canada Reference:	RSS-Gen 6.13, 8.9 & 8.10 / RSS-247 5.5
Test Method Used:	KDB 558074 Section 8.7 referencing ANSI C63.10 Section 11.11, 11.12 & 11.13

Environmental Conditions:

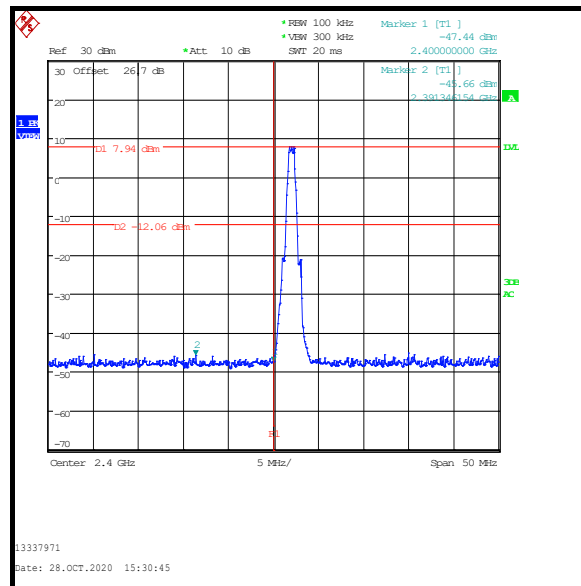
Temperature (°C):	21
Relative Humidity (%):	48

Note(s):

1. The EUT was set to transmit on the bottom channel when performing measurements at the lower band edge.
2. Upper band edge and lower restricted band results are contained within test report R13337971-E5 / E6.
3. As the band edges fall within non-restricted bands, only peak measurements are required. In accordance with FCC KDB 558074 Section 11.1, the test method in Section 11.3 was followed: the test receiver resolution bandwidth was set to 100 kHz and video bandwidth 300 kHz. A peak detector was used, sweep time was set to auto and trace mode was Max Hold. The test receiver was left to sweep for a sufficient length of time in order to maximise the carrier level and out-of-band emissions. A marker and corresponding reference level line were placed on the peak of the carrier. As the maximum peak conducted output power was measured using a peak detector in accordance with FCC KDB 558074 Section 9.1.1 an out-of-band limit line was placed 20 dB below the peak level (FCC KDB 558074 Section 11.1(a)). A marker was placed on the band edge spot frequencies and a second marker placed on the highest emission level in the adjacent non-restricted band of operation (where a higher level emission was present). Marker frequencies and levels were recorded.

Transmitter Band Edge Conducted Emissions (continued)**Results:**

Frequency (MHz)	Level (dBm)	-20 dBc Limit (dBm)	Margin (dB)	Result
2391.346	-45.7	-12.1	33.6	Complied
2400.000	-47.4	-12.1	35.3	Complied

**Lower Band Edge****--- END OF REPORT ---**