TEST REPORT

Test Report No. : UL-RPT-RP13551588-1616A

Applicant	:	Raspberry Pi Ltd
Manufacturer	:	Raspberry Pi Ltd
Model No.	:	Raspberry Pi Compute Module 4
Technology	:	*Bluetooth* – Low Energy
Test Standard(s)	:	Japan Radio Law Radio Equipment Regulations, Article 2, Paragraph 1, Item 19 MIC notice 88 Appendix 43

1. This test report shall not be reproduced except in full, without the written approval of UL International (UK) Ltd.
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: 21 March 2022

Checked by:

Ben Mercer
Lead Project Engineer, Radio Laboratory

Company Signatory:

Sarah Williams
RF Operations Leader, Radio Laboratory

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1 Customer Information

Company Name:	Raspberry Pi Ltd
Address:	Maurice Wilkes Building Cowley Road Cambridge CB4 0DS United Kingdom

2 Summary of Testing

2.1 General Information

Specification Reference:	Japan Radio Law Radio Equipment Regulations Article 2, Paragraph 1, Item 19
Specification Title:	N/A
Specification Reference:	Ordinance Regulating Radio Equipment
Specification Title:	Radio Equipment Rules
Location of Testing:	Unit 3 Horizon, Wade Road, Kingsland Business Park, Basingstoke, Hampshire, RG24 8AH, United Kingdom
Test Dates:	20 September 2021 to 04 February 2022

2.2 Summary of Test Results

Measurement	**Result**
Frequency Tolerance	✓
Occupied Bandwidth and Spreading Bandwidth	✓
Unwanted Emission Strength	✓
Output Power, Power Tolerance and EIRP	✓
Secondary Radiated Emission Strength	✓
Interference Prevention function	✓
Key to Results ✓ = Complied ✗ = Did not comply	

2.3 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.

2.4 Test and Measurement Equipment

Calibration Method

A: Calibration conducted by the National Institute of Information and Communications Technology (NICT) or a designated calibration agency under Article 102-18 paragraph (1) of the Radio Law.

B: Calibration conducted pursuant to the provisions of Article 135 or Article 144 of the Measurement Law (Law No. 51 of 1992) Japan Calibration Service System.

C: Calibration conducted in foreign countries, which shall be equivalent to the calibration conducted by the NICT or a designated calibration agency under Article 102-18 paragraph (1).

D: Calibration conducted by using other equipment that listed above from a) to c).

Test Equipment Used for Frequency Tolerance, Occupied Bandwidth, Unwanted Emission Strength and Secondary Radiated Emissions Strength

Asset No.	Instrument	Manufacturer	Type No.	Serial No.	Calibration Authority	Cal Method	Calibration Date	Cal. Interval
M2072	Thermohygrometer	Testo	608-H1	45257961	UL	D	08 Sep 2021	12
M2033	Signal Analyser	Rohde & Schwarz	FSV13	101667	Rohde & Schwarz	C	05 Aug 2021	12
M2036	Signal Analyser	Rohde & Schwarz	FSV30	101791	Rohde & Schwarz	C	21 May 2021	12
A3120	Attenuator	AtlanTecRF	AN18-10	237378#4	UL	D	Calibrated before use	-
G0614	Signal Generator	Rohde & Schwarz	SMB100A	177687	Rohde & Schwarz	C	19 May 2021	12

Test Equipment Used for Output Power, Power Tolerance and EIRP

Asset No.	Instrument	Manufacturer	Type No.	Serial No.	Calibration Authority	Cal Method	Calibration Date	Cal. Interval
M2072	Thermohygrometer	Testo	608-H1	45257961	UL	D	08 Sep 2021	12
M2036	Signal Analyser	Rohde & Schwarz	FSV30	101791	Rohde & Schwarz	C	21 May 2021	12
A3120	Attenuator	AtlanTecRF	AN18-10	237378#4	UL	D	Calibrated before use	-
G0614	Signal Generator	Rohde & Schwarz	SMB100A	177687	Rohde & Schwarz	C	19 May 2021	12
M1999	RF Power Sensor	Dare Instruments	RPR3006W	15I00041S NO79	Dare Calibrations	C	10 Jun 2021	12

Test Equipment Used for Interference Prevention Function

Asset No.	Instrument	Manufacturer	Type No.	Serial No.	Calibration Authority	Cal Method	Calibration Date	Cal. Interval
M2072	Thermohygrometer	Testo	608-H1	45257961	UL	D	08 Sep 2021	12
A3120	Attenuator	AtlanTecRF	AN18-10	237378#4	UL	D	Calibrated before use	-
M1758	Wideband Radio Communication Tester	Rohde & Schwarz	CMW 500	1201.0002 K50-117255-XP	Rohde & Schwarz	C	09 Apr 2021	12

3 Equipment Under Test (EUT)

3.1 Identification of Equipment Under Test (EUT)

Brand Name:	Raspberry Pi Ltd
Model Name or Number:	Raspberry Pi Compute Module 4
Test Sample Serial Number:	0000011031015231 *(Conducted sample #1)*
Hardware Version:	1.0
Software Version:	1.0

Brand Name:	Raspberry Pi Ltd
Model Name or Number:	Raspberry Pi Compute Module 4
Test Sample Serial Number:	0000011033775150 (Conducted sample #2)
Hardware Version:	1.0
Software Version:	1.0

3.2 Description of EUT

The equipment under test was a single board computer, containing a Bluetooth and WiFi radio module.

3.3 Modifications Incorporated in the EUT

No modifications were applied to the EUT during testing.

3.4 Additional Information Related to Testing

Category of Equipment:	*Bluetooth* Low Energy (Digital Transmission System)		
Type of Radio Wave:	F1D		
Power Supply Requirement(s):	Nominal	5.0 VDC*	
Max Antenna Gain:	3.5 dBi		
Channel Spacing:	2 MHz		
Modulation:	GFSK		
Data Rate:	1 Mbps		
Declared Output Power:	1.0 mW		
Transmit Frequency Range:	2402 MHz to 2480 MHz		
Transmit Channels Tested:	**Channel ID**	**Channel Number**	**Channel Frequency (MHz)**
	Bottom	0	2402
	Middle	19	2440
	Top	39	2480
Receive Frequency Range:	2400 MHz to 2483.5 MHz		
Receive Channels Tested:	**Channel ID**	**Channel Number**	**Channel Frequency (MHz)**
	Bottom	0	2402
	Middle	19	2440
	Top	39	2480

**Note: The input voltage to the RF circuit varies by less than 1% when the input voltage from the external power supply to the receiver varies ± 10%. Tests were therefore performed at the rated input voltage only.*

3.5 Support Equipment

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

Description:	Development board
Brand Name:	Raspberry Pi Ltd
Model Name or Number:	Compute Module 4 IO Board
Serial Number:	0000011032152810

Description:	Development board
Brand Name:	Raspberry Pi Ltd
Model Name or Number:	Compute Module 4 IO Board
Serial Number:	000001103152784

Description:	LCD Monitor
Brand Name:	Asus
Model Name or Number:	ProArt PA238
Serial Number:	D9LMTF114809

Description:	Keyboard
Brand Name:	Dell
Model Name or Number:	KB212-B
Serial Number:	0C643N

Description:	Mouse
Brand Name:	Microsoft
Model Name or Number:	1113
Serial Number:	X821908-002

Description:	HDMI Cable
Brand Name:	Raspberry Pi Ltd
Model Name or Number:	Not marked or stated
Serial Number:	Not marked or stated

Description:	Switching Adaptor
Brand Name:	PRO-ELEC
Model Name or Number:	PEL00848
Serial Number:	Not marked or stated

4 Operation and Monitoring of the EUT during Testing

4.1 Operating Modes

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

- Transmitting in *Bluetooth* LE test mode at maximum power on bottom, middle or top channel as required.
- Receive Mode on bottom, middle and top channel as required.
- For Interference Prevention Function testing, the EUT was configured for normal operation.

4.2 Configuration and Peripherals

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

- The EUT was controlled using *Bluetooth* LE test commands run from within the terminal application on the EUT. The *Bluetooth* LE test commands were used to enable continuous transmission and to select the test channels and packet types as required.
- Receive tests: *Bluetooth* LE test mode was active but not transmitting.
- The EUT was powered from an AC/DC switch mode power supply.
- The customer supplied an RF cable to the EUT in order to perform conducted measurements. The respective path loss was measured and accounted for as an RF level offset.
- For Interference Prevention Function testing the EUT was connected with a companion device.

5 Measurements, Examinations and Derived Results

5.1 General Comments

Measurement uncertainties are evaluated in accordance with current best practice. Our reported expanded uncertainties are based on standard uncertainties, which are multiplied by an appropriate coverage factor to provide a statistical confidence level of approximately 95%. Please refer to Section 6 *Measurement Uncertainty* for details.

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.

5.2 Test Results

5.2.1 Frequency Tolerance

Test Summary:

Test Engineer:	Raghavendra Katti	**Test Date:**	20 September 2021
Test Sample Serial Number:	0000011031015231		

Reference:	Ordinance Regulating Radio Equipment – Article 5 & Annex 1
Test Method:	Clause Notice 88 Annex 43 – Test Methods for Radio Equipment listed in Article 2, paragraph 1, Item (19), Section 3

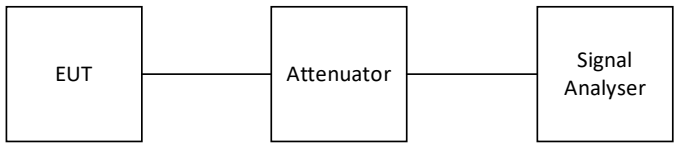
Environmental Conditions:

Temperature (°C):	23
Relative Humidity (%):	49

Note(s):

1. The signal analyser was connected to the RF port on the EUT using suitable attenuation and RF cable.
2. The signal analyser resolution bandwidth was set to 100 kHz and video bandwidth 100 kHz. A peak detector was used, sweep time was set to auto and the trace mode was Max Hold.
3. The frequency deviation was calculated by averaging f_L and f_H.
4. Lowest frequency of the power envelope (f_L) ; the furthest frequency below the maximum power frequency at which the output power falls below the level of -10 dBc.
5. Highest frequency of the power envelope (f_H); the furthest frequency above the maximum power frequency at which the output power falls below the level of -10 dBc.

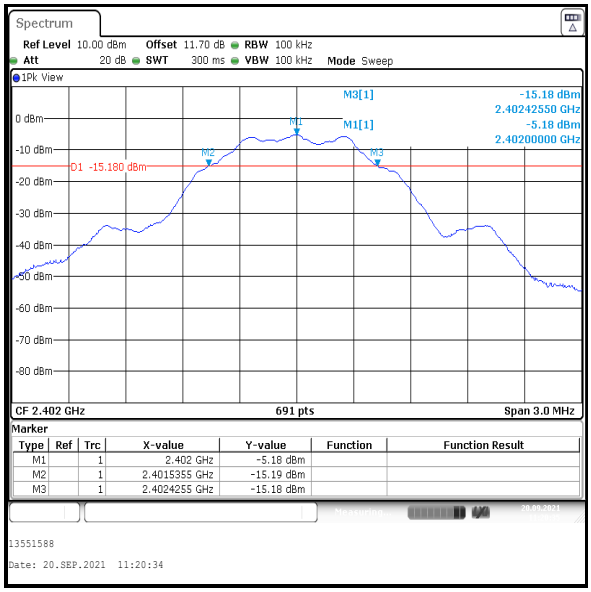
Test Setup Diagram:



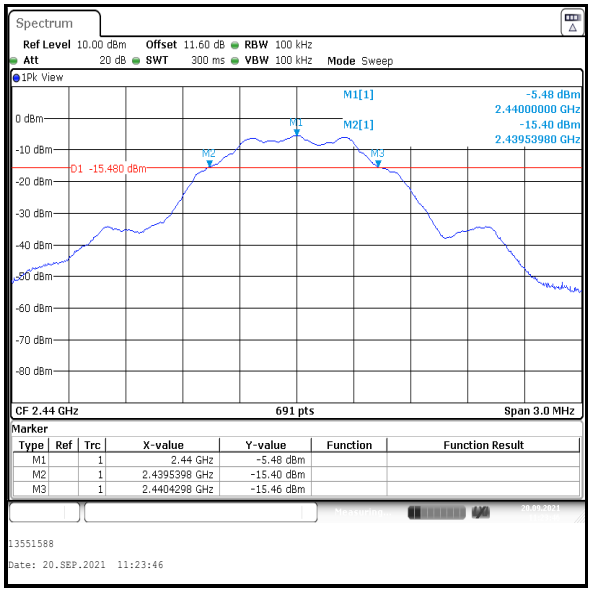
Results:

Channel	Channel Frequency (MHz)	Measured Frequency (MHz)	Tolerance (kHz)	Tolerance (ppm)	Limit (ppm)	Result
Bottom	2402	2401.980500	-19.50	-8.1	±50.0	Complied
Middle	2440	2439.984800	-15.20	-6.2	±50.0	Complied
Top	2480	2479.989150	-10.85	-4.4	±50.0	Complied

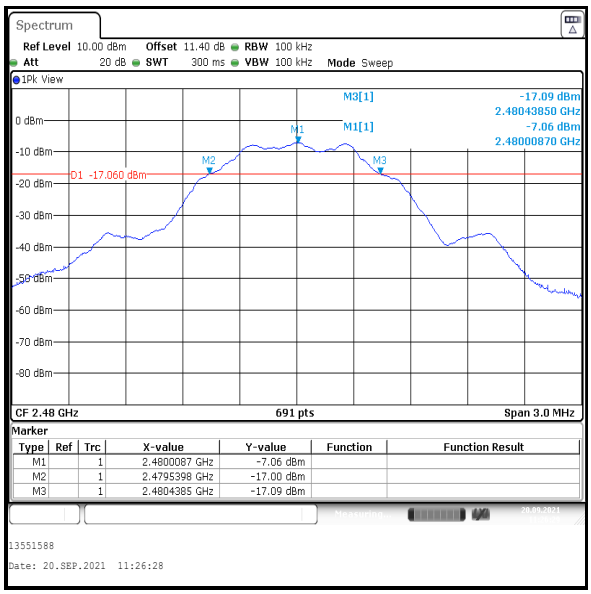
Frequency Tolerance (continued)



Bottom Channel



Middle Channel



Top Channel

5.2.2 Occupied Bandwidth and Spreading Bandwidth

Test Summary:

Test Engineer:	Jose Bayona	**Test Date:**	31 January 2022
Test Sample Serial Number:	0000011033775150		

Reference:	Ordinance Regulating Radio Equipment – Article 6 & Article 49-20
Test Method:	Clause Notice 88 Annex 43 – Test Methods for Radio Equipment listed in Article 2, paragraph 1, Item (19), Section 4

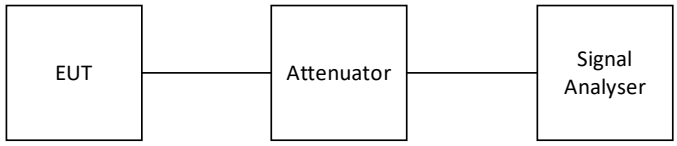
Environmental Conditions:

Temperature (°C):	23
Relative Humidity (%):	48

Note(s):

1. Occupied Bandwidth was performed using the 99% Occupied Bandwidth function of a signal analyser.
2. Spreading Bandwidth was performed using the 90% Occupied Bandwidth function of a signal analyser.
3. The signal analyser was connected to the RF port on the EUT using suitable attenuation and RF cable.
4. The signal analyser resolution bandwidth was set to 30 kHz and video bandwidth 30 kHz. A peak detector was used, sweep time was set to auto and the trace mode was Max Hold.

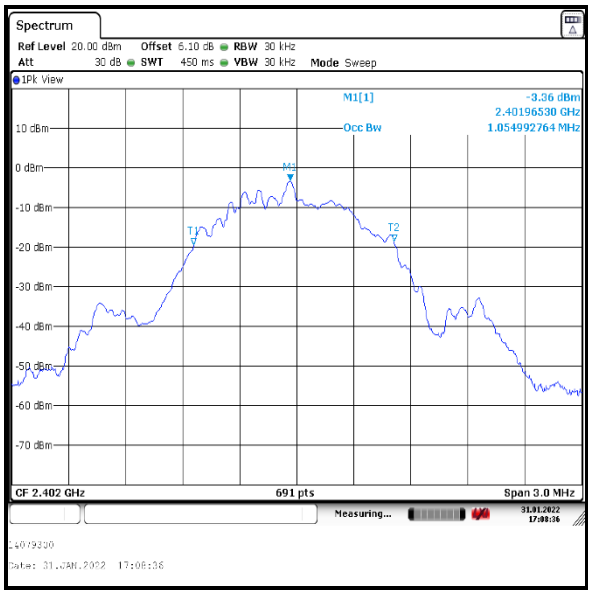
Test Setup Diagram:



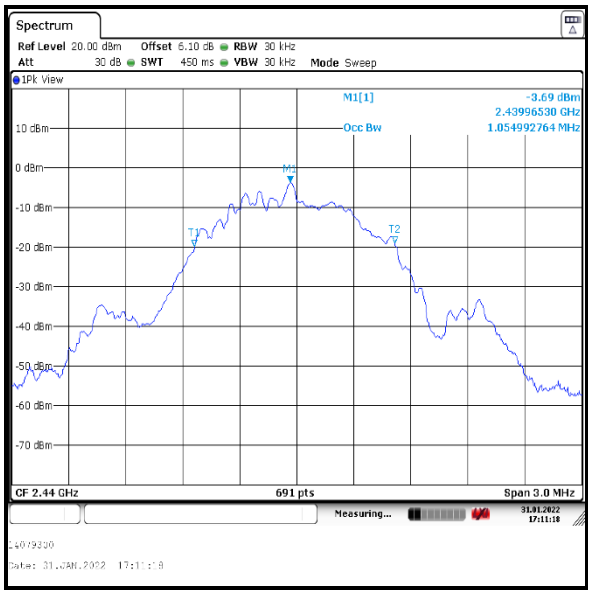
Occupied Bandwidth and Spreading Bandwidth (continued)

Results: Occupied Bandwidth

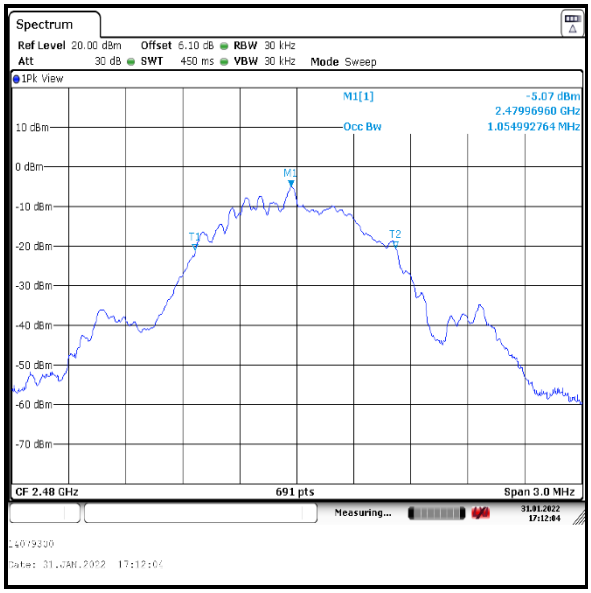
Channel	Occupied Bandwidth (MHz)	Limit (MHz)	Margin (MHz)	Result
Bottom	1.055	26.0	24.945	Complied
Middle	1.055	26.0	24.945	Complied
Top	1.055	26.0	24.945	Complied



Bottom Channel



Middle Channel

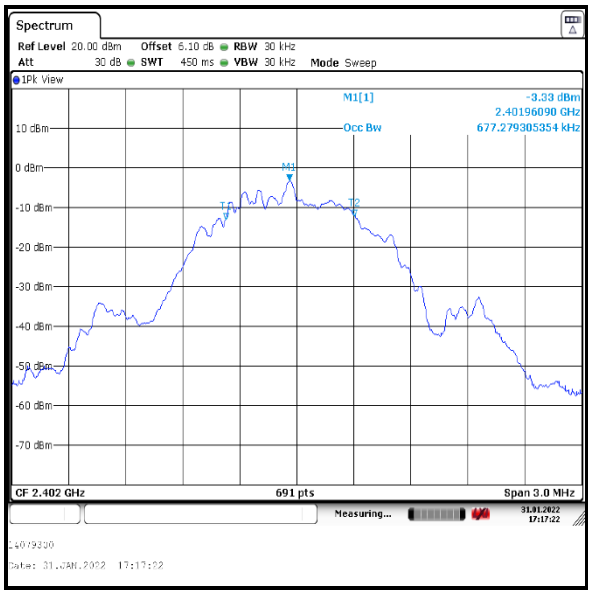


Top Channel

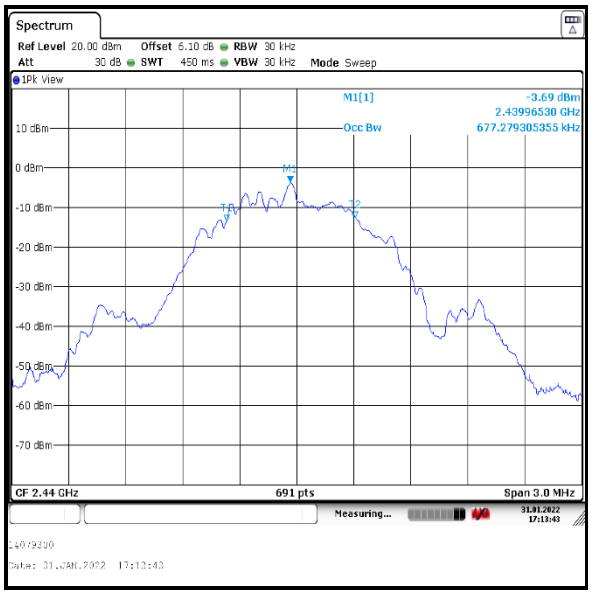
Occupied Bandwidth and Spreading Bandwidth (continued)

Results: Spreading Bandwidth

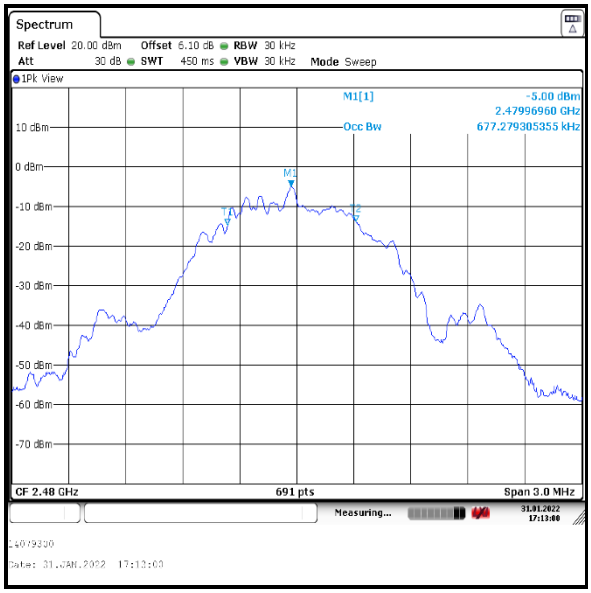
Channel	Spreading Bandwidth (kHz)	Limit (kHz)	Margin (kHz)	Result
Bottom	677.3	≥500.0	177.3	Complied
Middle	677.3	≥500.0	177.3	Complied
Top	677.3	≥500.0	177.3	Complied



Bottom Channel



Middle Channel



Top Channel

5.2.3 Unwanted Emission Strength

Test Summary:

Test Engineer:	Jose Bayona	**Test Date:**	01 February 2022
Test Sample Serial Number:	0000011033775150		

Reference:	Ordinance Regulating Radio Equipment – Article 7 & Annex 3-26
Test Method:	Clause Notice 88 Annex 43 – Test Methods for Radio Equipment listed in Article 2, paragraph 1, Item (19), Section 5

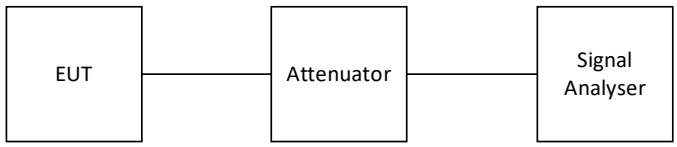
Environmental Conditions:

Temperature (°C):	22
Relative Humidity (%):	53

Note(s):

1. The signal analyser was connected to the EUT antenna port via suitable RF cables and attenuators. The RF path loss was calibrated and included as reference level offset.
2. No spurious emissions were detected above the noise floor of the measuring receiver, therefore the highest peak noise floor reading of the measuring receiver was recorded in the table below.
3. The signal analyser resolution bandwidth was set to 1 MHz and video bandwidth 1 MHz. An RMS detector was used, sweep time was set to auto and the trace mode was Max Hold.

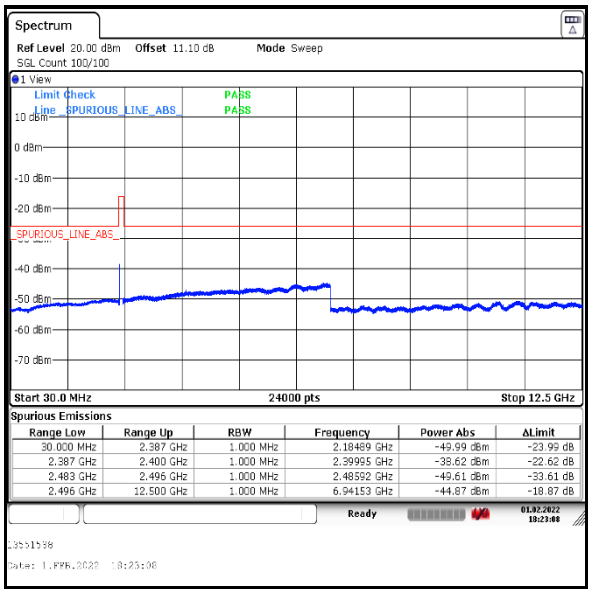
Test Setup Diagram:



Unwanted Emission Strength (continued)

Results: Bottom Channel

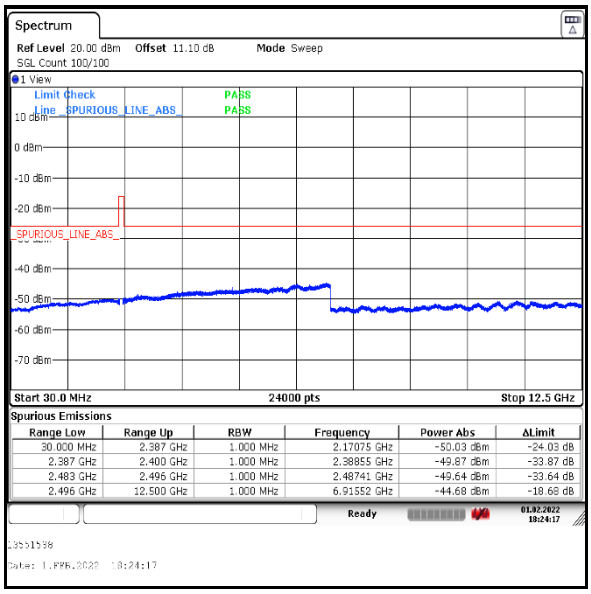
Frequency Range (MHz)	Frequency (MHz)	Peak Level (dBm)	Peak Level (µW)	Limit (µW)	Margin (µW)	Result
≥30 , ≤2387	2184.890	-50.0	0.010	2.5	2.490	Complied
≥2387 , ≤2400	2399.950	-38.6	0.137	25.0	24.863	Complied
≥2483.5 , ≤2496.5	2485.920	-49.6	0.011	25.0	24.989	Complied
≥2496.5 , ≤12500	6941.530	-44.9	0.033	2.5	2.467	Complied



Unwanted Emission Strength (continued)

Results: Middle Channel

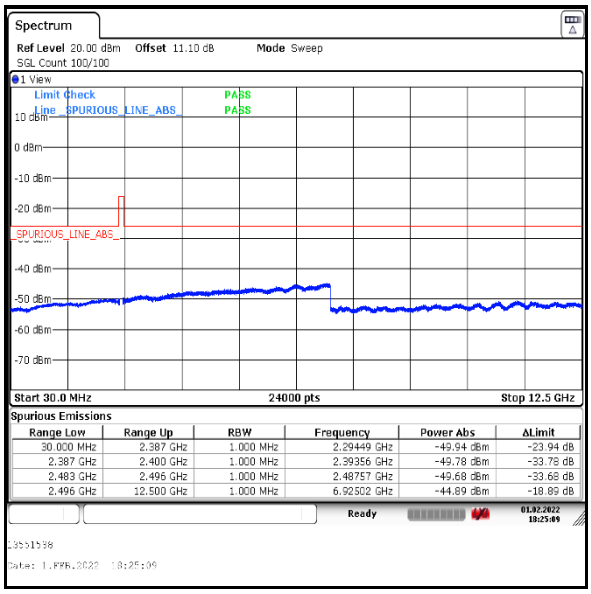
Frequency Range (MHz)	Frequency (MHz)	Peak Level (dBm)	Peak Level (µW)	Limit (µW)	Margin (µW)	Result
≥30 , ≤2387	2170.750	-50.03	0.009931	2.5	2.490	Complied
≥2387 , ≤2400	2388.55	-49.87	0.010304	25.0	24.990	Complied
≥2483.5 , ≤2496.5	2487.410	-49.64	0.010864	25.0	24.989	Complied
≥2496.5 , ≤12500	6915.520	-44.68	0.034041	2.5	2.466	Complied



Unwanted Emission Strength (continued)

Results: Top Channel

Frequency Range (MHz)	Frequency (MHz)	Peak Level (dBm)	Peak Level (µW)	Limit (µW)	Margin (µW)	Result
≥30 , ≤2387	2294.490	-49.94	0.010139	2.5	2.490	Complied
≥2387 , ≤2400	2393.56	-49.78	0.010520	25.0	24.989	Complied
≥2483.5 , ≤2496.5	2487.57	-49.68	0.010765	25.0	24.989	Complied
≥2496.5 , ≤12500	6925.020	-44.89	0.032434	2.5	2.468	Complied



5.2.4 Output Power, Power Tolerance and EIRP

Test Summary:

Test Engineer:	Jose Bayona	**Test Date:**	04 February 2022
Test Sample Serial Number:	0000011033775150		

Reference:	Ordinance Regulating Radio Equipment – Article 49-20 & Article 14
Test Method:	Clause Notice 88 Annex 43 – Test Methods for Radio Equipment listed in Article 2, paragraph 1, Item (19), Section 6
Peak Antenna Gain "G" (dBi):	3.5

Environmental Conditions:

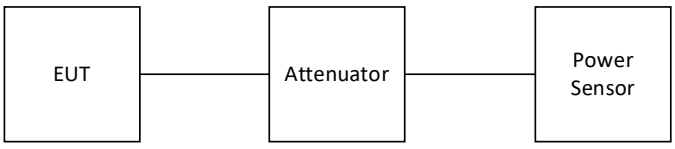
Temperature (°C):	24
Relative Humidity (%):	51

Note(s):

1. The power meter was connected to the RF port on the EUT using suitable attenuation and RF cable. An RF level offset has been included in the power meter to compensate for the loss of the attenuator and RF cable.
2. Measurements were performed with a fast power sensor which automatically averaged across the bursts. Therefore no duty cycle correction calculations were required.
3. The peak antenna gain was added to the conducted output power measured to obtain the EIRP.
4. Tolerance was calculated by using the following calculation:

*Tolerance = Output Power / Declared Power*100 – 100*

Test Setup Diagram:



Output Power, Power Tolerance and EIRP(continued)

Results: RF Output Power

Channel	Measured Output Power (dBm)	Output Power (mW)	Limit (mW)	Margin (mW)	Result
Bottom	0.5	1.1	10.0	8.9	Complied
Middle	0.1	1.0	10.0	9.0	Complied
Top	0.1	1.0	10.0	9.0	Complied

Results: EIRP

Channel	Output Power (dBm)	Antenna Gain (dBi)	EIRP (dBm)	Limit (dBm)	Margin (dB)	Result
Bottom	0.5	3.5	4.0	12.14	8.1	Complied
Middle	0.1	3.5	3.6	12.14	8.5	Complied
Top	0.1	3.5	3.6	12.14	8.5	Complied

Results: RF Output Power Tolerance

Channel	Output Power (mW)	Declared Output Power (mW)	Tolerance (%)	Limit (%)	Margin (%)	Result
Bottom	1.1	1.0	+10.0	+20 to -80	10.0	Complied
Middle	1.0	1.0	0.0	+20 to -80	20.0	Complied
Top	1.0	1.0	0.0	+20 to -80	20.0	Complied

5.2.5 Secondary Radiated Emissions Strength

Test Summary:

Test Engineer:	Jose Bayona	**Test Date:**	01 February 2022
Test Sample Serial Number:	0000011033775150		

Reference:	Ordinance Regulating Radio Equipment – Article 24
Test Method:	Clause Notice 88 Annex 43 – Test Methods for Radio Equipment listed in Article 2, paragraph 1, Item (19), Section 7

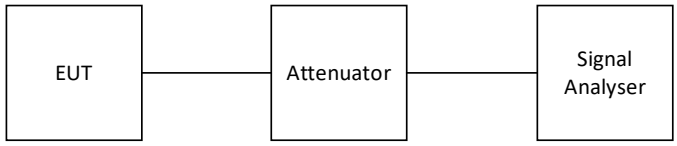
Environmental Conditions:

Temperature (°C):	22
Relative Humidity (%):	53

Note(s):

1. No spurious emissions were detected above the noise floor of the measuring receiver, therefore the highest peak noise floor reading of the measuring receiver was recorded in the table below.
2. The signal analyser was connected to the EUT antenna port via suitable RF cables and attenuators. The RF path loss was calibrated and included as a reference level offset.
3. The resolution bandwidth of the signal analyser was set to 100 kHz for frequencies below 1 GHz and 1 MHz for frequencies above 1 GHz. The video bandwidth was set to the same value as the resolution bandwidth. A peak detector was used, sweep time was set to auto and the trace mode was Max Hold.

Test Setup Diagram:



Secondary Radiated Emissions Strength (continued)

Results: Bottom Channel

Frequency Range (MHz)	Frequency (MHz)	Peak Level (dBm)	Peak Level (nW)	Limit (nW)	Margin (nW)	Result
30-1000	685.478	-79.3	0.012	4.0	3.988	Complied
1000-12500	6288.800	-64.7	0.339	20.0	19.661	Complied

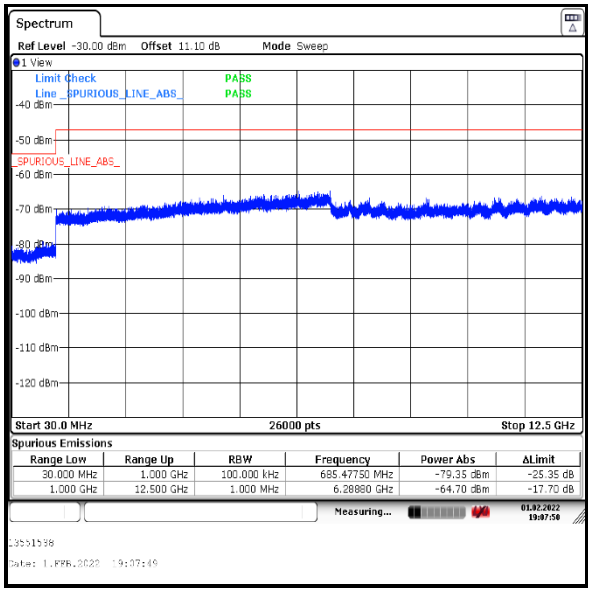
Results: Middle Channel

Frequency Range (MHz)	Frequency (MHz)	Peak Level (dBm)	Peak Level (nW)	Limit (nW)	Margin (nW)	Result
30-1000	799.453	-79.1	0.012	4.0	3.988	Complied
1000-12500	6787.140	-65.0	0.316	20.0	19.684	Complied

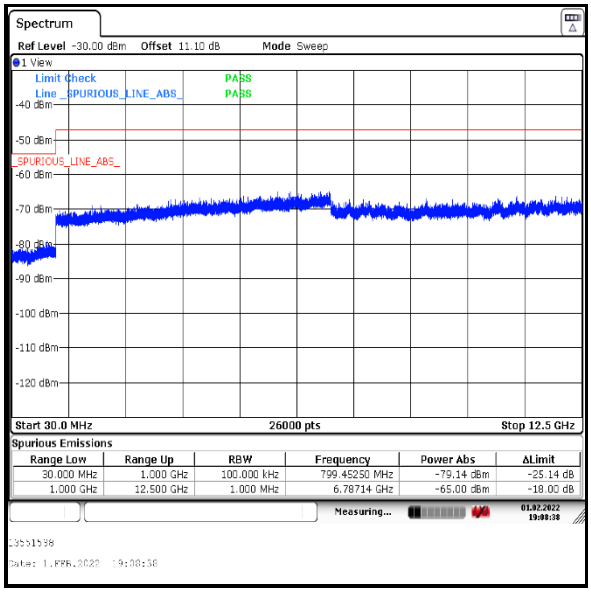
Results: Top Channel

Frequency Range (MHz)	Frequency (MHz)	Peak Level (dBm)	Peak Level (nW)	Limit (nW)	Margin (nW)	Result
30-1000	966.293	-79.6	0.011	4.0	3.989	Complied
1000-12500	5398.510	-64.5	0.355	20.0	19.645	Complied

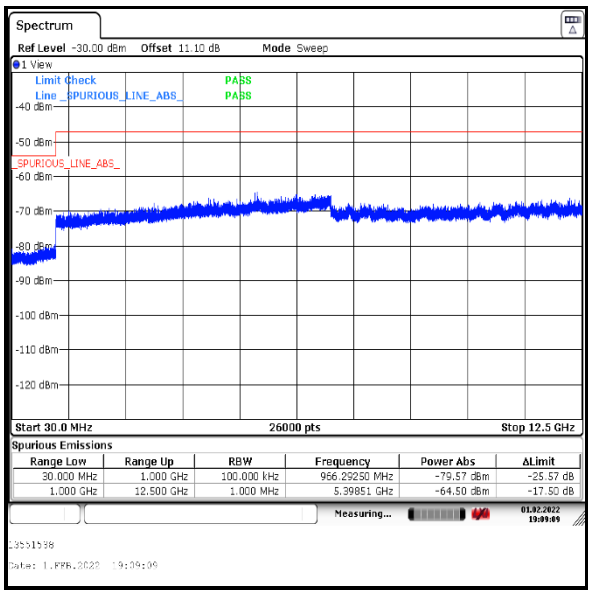
Secondary Radiated Emissions Strength (continued)



Bottom Channel



Middle Channel



Top Channel

5.2.6 Interference Prevention Function

Test Summary:

Test Engineer:	Raghavendra Katti	**Test Date:**	30 September 2021
Test Sample Serial Number:	0000011031015231		

Reference:	Ordinance Regulating Radio Equipment – Article 9-4
Test Method:	Clause Notice 88 Annex 43 – Test Methods for Radio Equipment listed in Article 2, paragraph 1, Item (19), Section 11

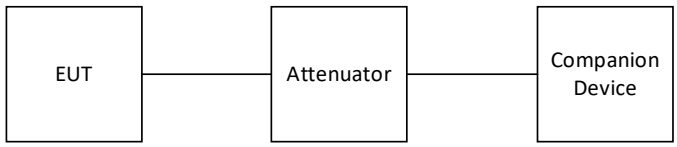
Environmental Conditions:

Temperature (°C):	22
Relative Humidity (%):	53

Note(s):

1. The EUT was configured for normal operation and connected to a companion device.
2. The EUT has the function to transmit the identification code automatically. The identification code was verified via the companion device.
3. The EUT possesses function to receive identification code automatically. The identification code transmitted by the companion device was identified. The EUT stopped transmitting when the ID code was different.

Test Setup Diagram:



Results:

Function	Result
Transmit Identification Code	Complied
Receive Identification Code	Complied

6 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 & Decision Rule

Overview

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.

Decision Rule

The decision rule applied is based upon the accuracy method criteria. The measurement uncertainty is met and the result is considered in conformance with the requirement criteria if the observed value is within the prescribed limit.

Measurement Uncertainty

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”.

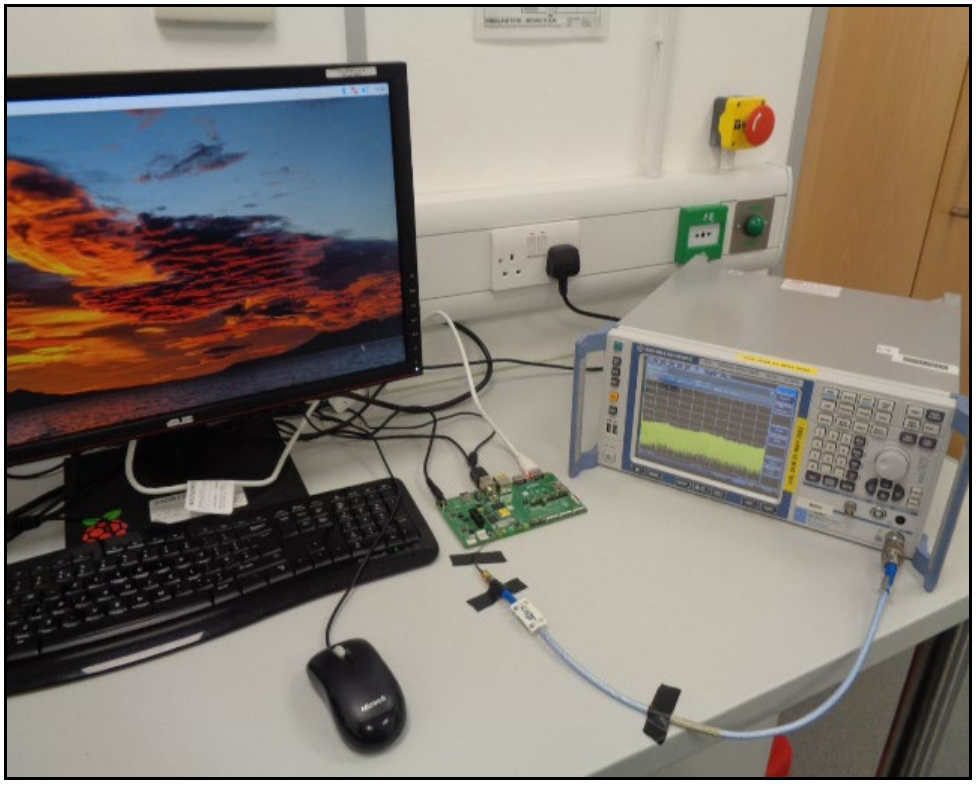
Measurement Type	Confidence Level (%)	Calculated Uncertainty
Frequency Tolerance	95%	±1.62 ppm
Occupied Bandwidth and Spreading Bandwidth	95%	±3.92 %
Unwanted Emission Strength	95%	±2.62 dB
Output Power, Power Tolerance and EIRP	95%	±1.13 dB
Secondary Radiated Emission Strength	95%	±2.62 dB

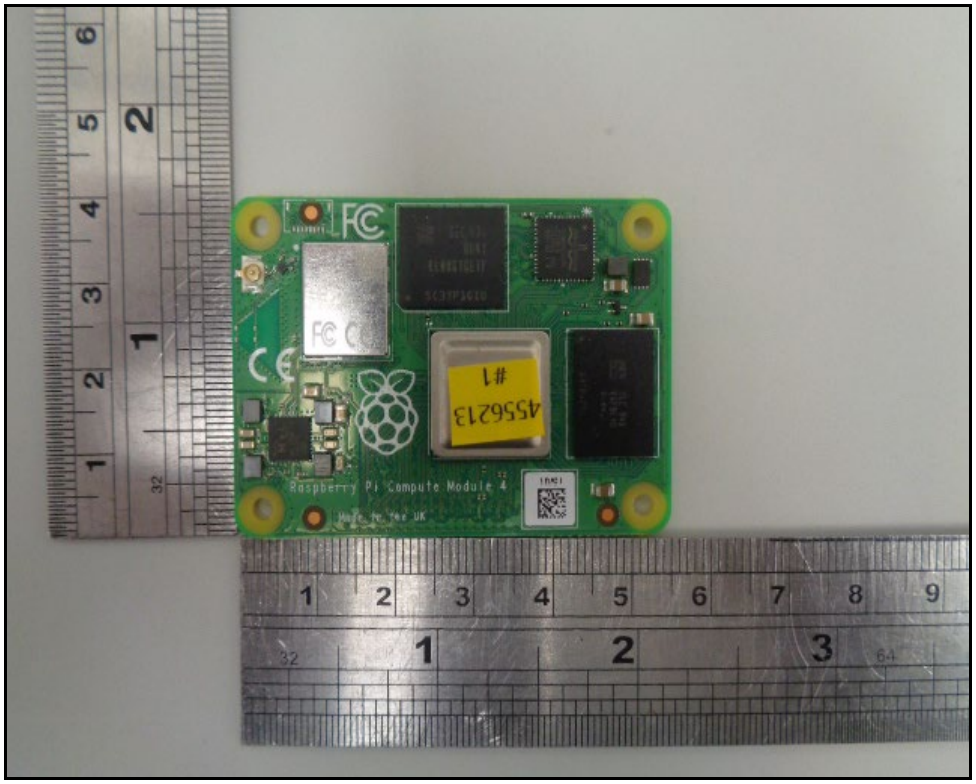
The methods used to calculate the above uncertainties are in line with those recommended within the various measurement specifications. Where measurement specifications do not include guidelines for the evaluation of measurement uncertainty the published guidance of the appropriate accreditation body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

7 Report Revision History

Version Number	Revision Details		
	Page No(s)	Clause	Details
1.0	-	-	Initial Version
2.0	-	-	Updates requested by CO

Appendix 1. Photographs of Test Setup





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