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Test Report for the FCC and ISED Testing of an Raspberry Pi RMC2GW4B52 to FCC Rule 47CFR 15.247 and ISED RSS-247 for Raspberry Pi Ltd

Report number: C15421TR4
Project number: C7894

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Issue	Description						Issue by	Date
4	Copy 1		Copy 2		PDF	√	JB	2nd April 2024

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Test Report Change History

Issue	Date	Modification Details
1	2nd February 2024	First Issue
2	14th February 2024	Customer address updated
3	26th March 2024	Channel List added
4	2nd April 2024	Clarification of output power result added
5		
6		
7		
8		
9		
10		

Section 1 Test Location

All testing was performed at;

Eurofins E&E UK	Unit 5
	Speedwell Road
	Castleford
	WF10 5PY
Tel:	01977 731173
Website	http://www.yorkemc.co.uk
UKAS Testing No.	1574

UKAS Accreditation

Opinions and interpretations expressed herein are outside the scope of UKAS Accreditation.

Eurofins E&E UK latest accreditation schedule can be found at:
http://www.ukas.org/testing/lab_detail.asp?lab_id=989&location_id=&vMenuOption=3

Eurofins E&E UK Castleford Laboratory, is an Accredited facility recognised by the Federal Communications Commission (FCC) for certification testing. The appropriate FCC Designation Number is UK2013, dated 1st March 2021.

Eurofins E&E UK Castleford Laboratory is recognised by ISED for certification testing.
ISED Assigned Code: 22959
CAB Identifier: UK0004

Section 2 Customer Information

Company name	Raspberry Pi Ltd
Address	194 Cambridge Science Park
	Milton Road
	Cambridge
	CB4 0AB
	United Kingdom
Contact	Tom Westcott
Email	tom.westcott@raspberrypi.com

Section 3 Equipment Details

Equipment Under Test (EUT)

Date received:	15th November 2023
EUT name:	Raspberry Pi RMC2GW4B52
PMN:	Raspberry Pi RMC2GW4B52
HVIN:	Raspberry Pi RMC2GW4B52
FCC ID:	2ABCB-RMC2GW4B52
IC:	20953-RMC2GW4B52
EUT description:	The RMC2GW4B52 is a radio module with an on board antenna. The module has 2.4GHz Wi-Fi, Bluetooth classic and Bluetooth Low Energy functionality, which allows the user to connect to a 2.4GHz Wi-Fi network, BT Classic 5 compliant devices and BLE devices.
Antenna	Integral Antenna
Transmission	Frequency Hopping Spread Spectrum (FHSS) Bluetooth Classic
Modulation scheme	0xF0 8-bit Pattern
Operating frequency band	2400MHz to 2483.5MHz
No of units tested:	Unit 1: Radiated tests Unit 2: Conducted tests
EUT power:	3.3V via USB port
Highest internal frequency:	2.480GHz
Mode/s of operation:	Continuous transmit of packetised data at top, middle and bottom channels. Channels used: 2402MHz, 2440MHz and 2480MHz. Normal hopping operation.
Test software:	bt_mfg_test.uf2 Test Firmware installed. The radio module was mounted on a representative PCB and the test modes were controlled via USB connection to a Raspberry Pi 400 device. The output power was set to the default value in the test software.
Modifications incorporated during testing:	N/A

Ports and Cables	Cable Length	Screened/ unscreened	Connected to
USB cable	1m	unscreened	Raspberry Pi 400

EUT Monitoring/Auxiliary Equipment

Equipment name	Type no.	Serial no
Raspberry Pi 400	RPI-400	80000290905

EUT Photographs

Photographs are supplied separately.

Configuration of EUT

The apparatus was supplied in one single possible configuration.

BT Channel Number	Frequency	BT Channel Number	Frequency	BT Channel Number	Frequency
0	2402 MHz	27	2429 MHz	53	2455 MHz
1	2403 MHz	28	2430 MHz	54	2456 MHz
2	2404 MHz	29	2431 MHz	55	2457 MHz
3	2405 MHz	30	2432 MHz	56	2458 MHz
4	2406 MHz	31	2433 MHz	57	2459 MHz
5	2407 MHz	32	2434 MHz	58	2460 MHz
6	2408 MHz	33	2435 MHz	59	2461 MHz
7	2409 MHz	34	2436 MHz	60	2462 MHz
8	2410 MHz	35	2437 MHz	61	2463 MHz
9	2411 MHz	36	2438 MHz	62	2464 MHz
10	2412 MHz	37	2439 MHz	63	2465 MHz
11	2413 MHz	38	2440 MHz	64	2466 MHz
12	2414 MHz	39	2441 MHz	65	2467 MHz
13	2415 MHz	40	2442 MHz	66	2468 MHz
14	2416 MHz	41	2443 MHz	67	2469 MHz
15	2417 MHz	42	2444 MHz	68	2470 MHz
16	2418 MHz	43	2445 MHz	69	2471 MHz
17	2419 MHz	44	2446 MHz	70	2472 MHz
18	2420 MHz	45	2447 MHz	71	2473 MHz
19	2421 MHz	46	2448 MHz	72	2474 MHz
20	2422 MHz	47	2449 MHz	73	2475 MHz
21	2423 MHz	48	2450 MHz	74	2476 MHz
22	2424 MHz	49	2451 MHz	75	2477 MHz
23	2425 MHz	50	2452 MHz	76	2478 MHz
24	2426 MHz	51	2453 MHz	77	2479 MHz
25	2427 MHz	52	2454 MHz	78	2480 MHz
26	2428 MHz	-	-	-	-

BT Channelization

Lowest channel	Default
Middle channel	Default
Highest channel	Default

Power settings table

Note: Modulation type 0xF0 8-bit Pattern. Packet type 3-DH1. Packet length 65535 used for all tests.

EUT Monitoring/Auxiliary Equipment

None.

Monitoring Software

None. The channel required was selected via software prior to the testing.

Section 4Test Specifications

For USA:

Regulation / Test Standard	Regulation: Title 47 of the Code of Federal Regulations (CFR) Part 15 (47CFR15) Subpart C – Intentional Radiators Measurement standard: ANSI C63.10-2013 American National Standard of Procedures for Compliance Testing of Unlicensed Wireless Devices

Test description	Rule Part	Result Summary
Intentional emission, band occupancy, 20dB bandwidth	47 CFR 15.215(C) 47 CFR 15.247 (a)(1)	Pass
FHSS Requirements	Number of hopping channels 47CFR15.247(a)(1)(iii)	Pass
	Channel separation 47CFR15.247(a)(1)(iii)	Pass
	Hopping channel occupancy time 47CFR15.247(a)(1)(iii)	Pass
Peak power output (conducted)	47 CFR 15.247 b (1)	Pass
Radiated spurious emissions 30MHz to 25GHz	15.247(d)	Pass
Restricted band compliance	47CFR15.247(d) and 45CFR15.205 and 47CFR15.209	Pass
Conducted spurious emissions	FCC § 15.247(d)	Pass
Mains conducted emissions 150kHz to 30MHz Applicable if the apparatus connects to the AC supply directly or via other apparatus.	47 CFR Part 15C Section 15.207 Test standard: ANSI C63.10-2013 Not applicable – not mains powered	Not applicable

For Canada:

Regulation / Test Standard	RSS-247 Digital Transmission Systems (DTSs), Frequency Hopping Systems (FHSs) and Licence-Exempt Local Area Network (LE-LAN) Devices Issue 3 August 2023 And, RSS-Gen — General Requirements for Compliance of Radio Apparatus Issue 5 April 2018 +A1 March 2019 +A2 February 2021

Test description	RSS Reference	Result Summary
Intentional emission, band occupancy	-	Pass
99% Occupied Bandwidth	RSS-GEN Issue 5 April 2018 Section 6.7	Pass
FHSS Requirements	RSS-247 Issue 3 Section 5.1 Channel separation Hopping sequence System receiver bandwidth Number of hopping channels Hopping channel occupancy time	Pass
Peak power output (conducted)	RSS-247 Issue 3 Section 5.4 (b)	Pass
Radiated spurious emissions	RSS-247 Issue 3 Section 5.5	Pass
Restricted band compliance	RSS-247 Issue 3 Sections 3.3 and 5.5 RSS-Gen Issue 5 Section 8.10	Pass
Conducted spurious emissions	RSS-247 Issue 3 section 5.5	Pass
AC power line conducted emissions	RSS-247 Issue 3 Section 3.1 RSS Gen Section 8.8	Not applicable

Knowledge Database References

The following KDBs were referenced during the testing.
The latest knowledge database references are available via the FCC KDB website at:

https://apps.fcc.gov/kdb

4.1.1 Radiated Emissions (30MHz to 1000MHz)

Publication Number	Keyword	Publication Date
913591	Measurement of radiated emissions at the band-edge for a Part 15 RF Device	04/05/2017

4.1.2 Radiated Emissions (1GHz to 40GHz)

Publication Number	Keyword	Publication Date
414788	Test Site Validation Requirements above 1 GHz.	07/12/2018
414788	Comparison Noise Emitter (CNE), reference noise source, .pdf	07/12/2018
913591	Measurement of radiated emissions at the band-edge for a Part 15 RF Device	04/05/2017
414788	Comparison Noise Emitters (CNE), test equipment, Broadband.pdf	07/12/2018

Compliance Statement

The Raspberry Pi RMC2GW4B52, as tested, was shown to meet requirements of the standards listed in Section 4 of this report.

Note: Only the Bluetooth Classic functionality has been testing in this report.

Section 5 Spurious Emission Results – Radiated and Conducted

Test Specification

FCC Rule Part	47CFR 15.247 (d)
Standard	ANSI C63.10:2013
Measurement Uncertainty Radiated tests	The reported uncertainty of measurement y ± U, where expended uncertainty U is based on a standard uncertainty multiplied by a coverage factor of k=2, providing a level of confidence of approximately 95% is +/- 5.01dB for the frequency range from 9kHz to 30MHz +/- 6.26dB for the frequency range 30MHz to 1GHz +/- 5.14dB for the frequency range from 1GHz to 6GHz +/- 5.45dB for the frequency range from 6GHz to 18GHz
Measurement Uncertainty Conducted Power tests	±1.4dB

Procedure and Test Software Version

Radiated tests:- 47CFR15.205 and 47CFR15.209

Eurofins E&E UK test procedure (30MHz to 1GHz)	CEP23 Issue 9
Eurofins E&E UK test procedure (1GHz to 40GHz)	CEP64 Issue 10
Test software	RadiMation Version 2016.2.8

Conducted Tests 47CFR 15.247(d)

ANSi C63.10-2013 Clause reference:	11.11.2 and 11.11.3
Test software	N/A

Radiated Emissions (30MHz to 1GHz)

Radiated electric field emission measurements are applied as defined in 47CFR15.205 and 47CFR15.209.

5.1.1 Limits at 3m

Frequency (MHz)	Electric Field strength Limit (dBµV/m) at 3m measurement distance
	Quasi Peak
30 - 88	40.0
88 -216	43.5
216 - 960	46.0
960- 1000	54.0

Note: FCC 47 CFR Part 15 Section 15.209 and 15.205 specifies test limits at 3m

Receiver Settings

Receiver Parameters	Setting
Detector Function	Quasi Peak
Start Frequency	30MHz
Stop Frequency	1000MHz
Resolution Bandwidth	120kHz
Video Bandwidth	Auto

5.1.2 Emissions measurements

5.1.3 Date of Test

20th November 2023

5.1.4 Test Area

LAB 1 (SAC)

5.1.5 Tested by

L Trickett

5.1.6 Test Setup

The EUT was configured in the SAC on an 80cm high polystyrene table.

The measurement was performed with an antenna to EUT separation distance of 3m. The results were maximised in orientation 0-360 degrees and height 1-4m.

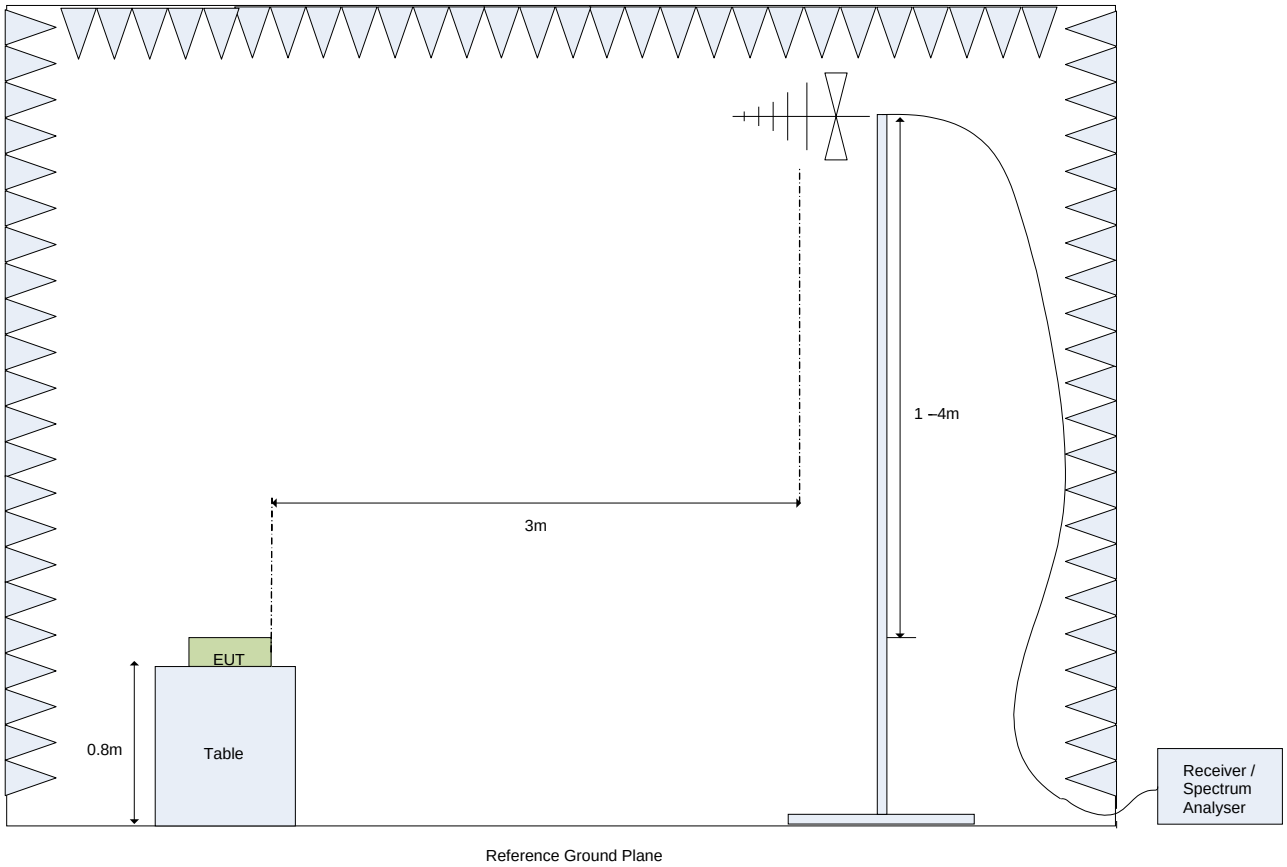


Figure 1 Test Setup for E-Field Measurements from 30MHz to 1GHz

Note 1 : With the EUT de-energized the ambient radio noise and signals met the 6dB peak detection requirement of ANSI C63.10-2013.

Note 2 : There were no significant environmental temperature changes during the test duration and hence it was not considered necessary to consider any variation in cable loss.

Operating Mode During testing

During spurious emission testing the equipment under test was set to transmit at the same frequency on the following channels: 2402MHz, 2440MHz and 2480MHz.

The equipment under test was pre-scanned using peak detection when operating on all three channels. Final measurements were performed with the equipment under test operating on 2402MHz.

5.1.7 Electric field emissions, 30MHz to 1GHz

Figure 2 Electric field emissions Plot, 30MHz to 1GHz, 2402MHz Operation

Frequency	Quasi-Peak	Quasi Peak Limit	Quasi-Peak Difference	Quasi-Peak Status	Angle	Height	Polarization
MHz	dBµV/m	dBµV/m	dB		degrees	m	
173.82	10.3	43.5	-33.2	Pass	185	1.0	Vertical
91.50	40.0	43.5	-3.5	Pass	95	1.1	Vertical
93.72	37.9	43.5	-5.6	Pass	165	1.2	Vertical
98.88	33.3	43.5	-10.2	Pass	230	1.0	Vertical
101.10	34.2	43.5	-9.3	Pass	130	1.0	Vertical
120.06	26.1	43.5	-17.4	Pass	215	1.0	Vertical
148.50	36.4	43.5	-7.1	Pass	185	1.0	Vertical
74.40	32.5	40.0	-7.5	Pass	225	1.4	Vertical
77.04	31.5	40.0	-8.5	Pass	160	1.2	Vertical
214.38	30.0	43.5	-13.5	Pass	135	1.1	Vertical
317.58	25.6	46.0	-20.4	Pass	155	1.5	Vertical
384.84	25.2	46.0	-20.8	Pass	170	1.1	Vertical
480.83	16.7	46.0	-29.3	Pass	175	2.1	Horizontal
56.52	26.7	40.0	-13.3	Pass	120	1.0	Vertical
33.12	27.4	40.0	-12.6	Pass	135	1.0	Vertical

Table 1 Electric Field Emissions Peaks, 30MHz to 1GHz. 2402MHz Operation

Figure 3 Electric field emissions Plot, 30MHz to 1GHz, Operation on 2440MHz - Peak detector scan

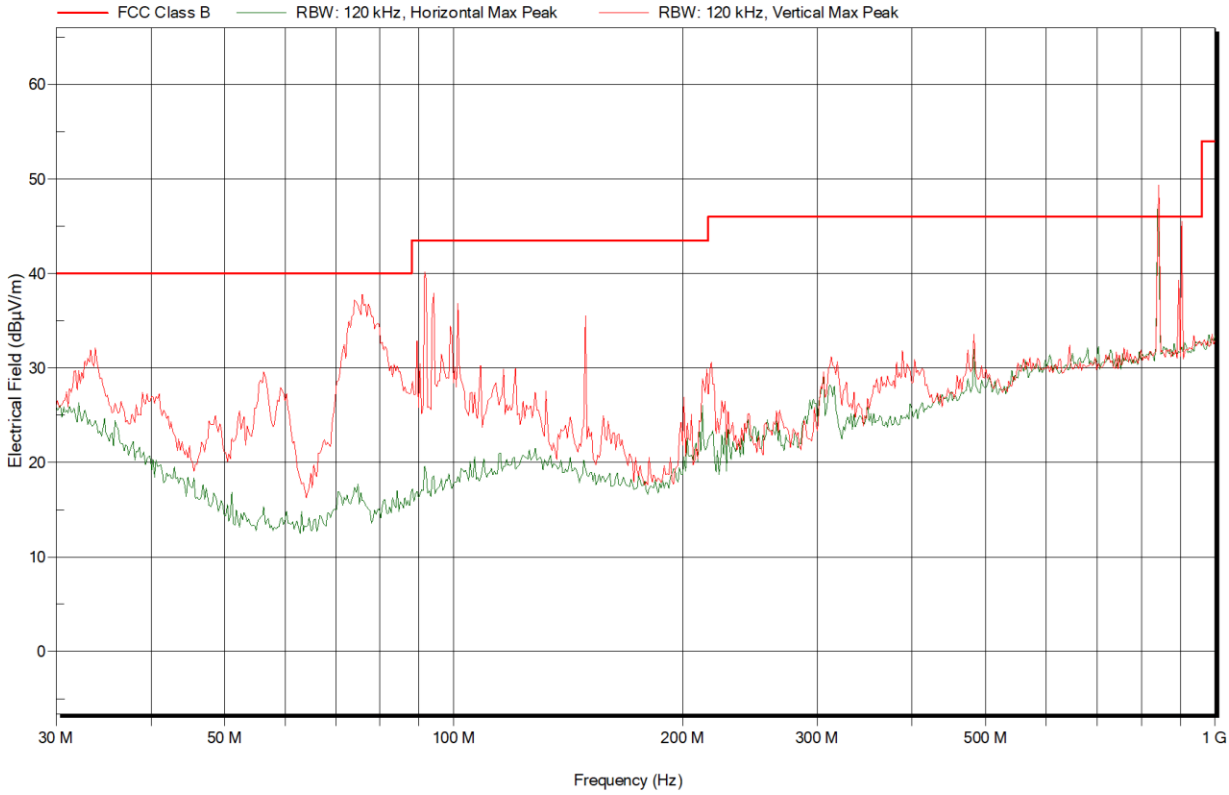


Figure 4 Electric field emissions Plot, 30MHz to 1GHz, Operation on 2480MHz - Peak detector scan

Radiated Emissions (1GHz to 18GHz)

5.1.8 Limits

Frequency (GHz)	Limit (dBµV/m)	Limit (dBµV/m)
	Peak	Average
1-18	74.0	54.0

5.1.9 Receiver Settings

Receiver Parameters	Setting
Detector Function	Average and Peak
Start Frequency	1GHz
Stop Frequency	18GHz
Resolution Bandwidth	1MHz
Video Bandwidth	Auto

5.1.10 Emissions measurements

5.1.11 Date of Test

21st November 2023

5.1.12 Test Area

LAB 1 (SAC)

5.1.13 Tested by

L Trickett

5.1.14 Test Setup

The EUT was configured in the SAC on an 1.5m high table Exploratory measurements on the EUT were carried out to identify suspect frequencies and worst case orientations, see Section 5.1.15.

The measurement was then performed with an antenna to EUT separation distance of 3m.

The antenna was kept in the “cone of radiation” from the EUT and pointed at the area both in azimuth and elevation using the tilt mechanism on the antenna mast.

The results were maximised in orientation 0-360 degrees and height 1-4m.

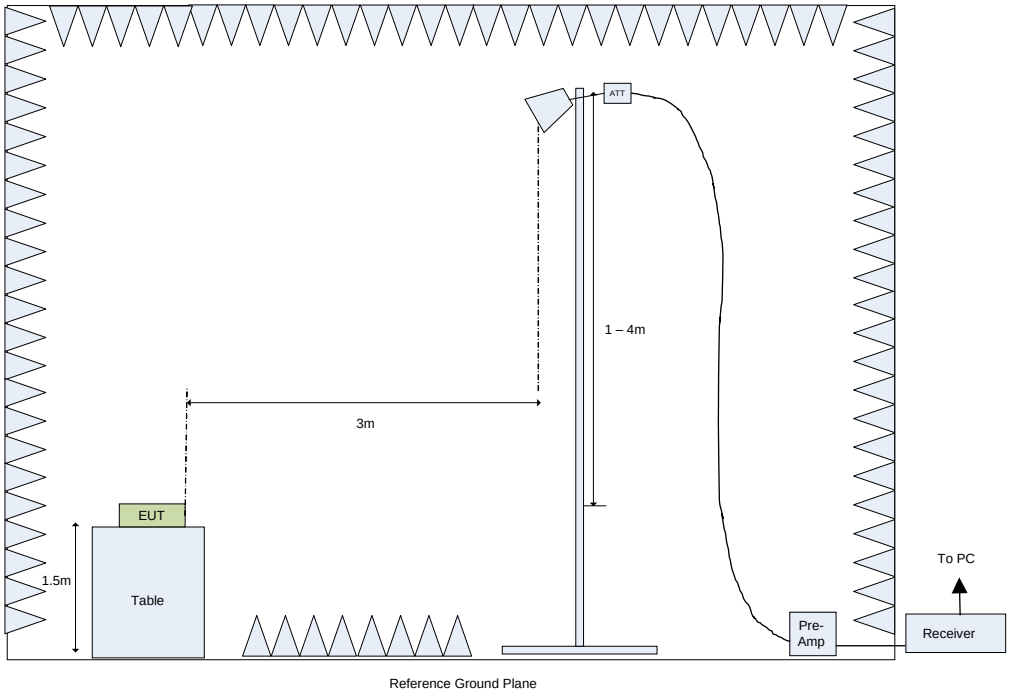


Figure 5 Test Setup for Final E-Field Measurements from 1GHz to 18GHz

Note 1: With the EUT de-energized the ambient radio noise and signals met the 6dB peak detection requirement of ANSI C63.4-2010.

Note 2: There were no significant environmental temperature changes during the test duration and hence it was not considered necessary to consider any variation in cable loss.

Note 3: On all swept and final measurements made between 1GHz and 18GHz a 2.4GHz Microtronics BRM50702 notch filter was placed in the measurement chain between the antenna and pre-amplifier in order to prevent the artificial generation of harmonics within the pre-amplifier.

5.1.15 Exploratory Radiated Emission Maximization

During exploratory testing, suspect emissions from the EUT were identified both in terms of the frequency and directionality. This was achieved by manually positioning the antenna close to the EUT and also by scanning it over all sides of the EUT whilst observing a spectral display. The typical distance between the surface of the EUT and the scanning antenna was circa 30cm.

Frequency (GHz)	Mode of operation	EUT face *	Emissions Angle (w.r.t. turntable)	Height	Polarization
1.128	Transmitting on channel 2402MHz	front face	0	1.5	H
1.136	Transmitting on channel 2480MHz	front face	0	1.5	H
1.144	Transmitting on channel 2440MHz	front face	0	1.5	H
1.224	Transmitting on channel 2480MHz	front face	0	1.5	H
1.441	Transmitting on channel 2440MHz	front face	0	1.5	H
1.743	Transmitting on channel 2402MHz & 2480MHz	front face	0	1.5	H
1.761	Transmitting on channel 2402MHz & 2480MHz	front face	0	1.5	H
1.806	Transmitting on channel 2402MHz & 2480MHz	front face	0	1.5	H
1.897	Transmitting on channel 2480MHz	front face	0	1.5	H
1.898	Transmitting on channel 2440MHz	front face	0	1.5	H
1.952	Transmitting on channel 2440MHz	front face	0	1.5	H
4.794	Transmitting on channel 2480MHz	front face	0	1.5	H
4.795	Transmitting on channel 2440MHz	front face	0	1.5	H
4.804	Transmitting on channel 2402MHz	front face	0	1.5	H
4.880	Transmitting on channel 2440MHz	front face	0	1.5	H
4.960	Transmitting on channel 2480MHz	front face	0	1.5	H

Table 2 Frequencies identified during Exploratory Radiated Emission maximization

Note 1: The front face of the EUT is deemed to be 0°, which is then turned in a clockwise direction through 360°.

Note 2: With no emissions observed above 5GHz during the exploratory investigation, final measurements were performed up to 7GHz only.

5.1.16 Electric field emissions, 1GHz to 18GHz

The equipment under test was pre-scanned using peak detection when operating on all three channels. Final measurements were performed with the equipment under test operating on 2440MHz

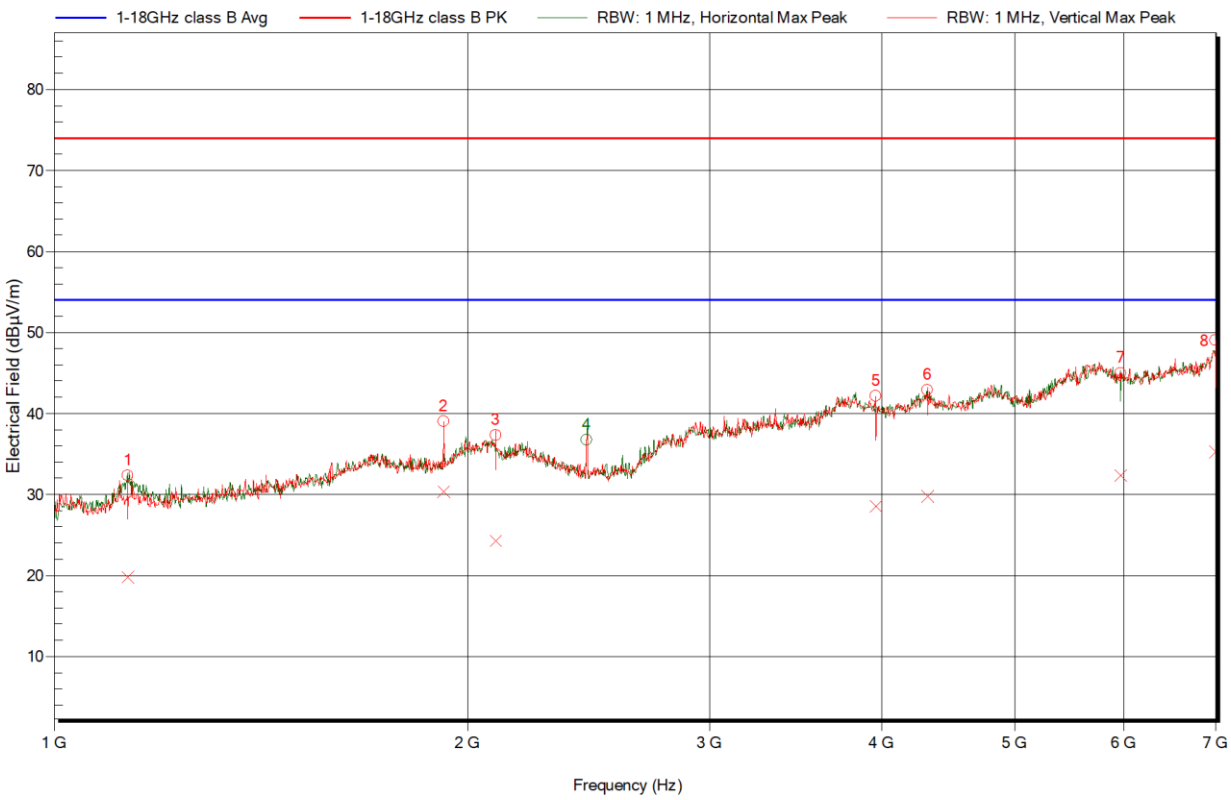


Figure 6 Electric field emissions Plot, 1GHz to 7GHz. Operation on 2440MHz

Frequency	Average	Average Limit	Average Difference	Average Status	Angle	Height	Polarization
GHz	dBµV/m	dBµV/m	dB		degrees	m	
1.132	19.78	54	-34.22	Pass	150	1.4	Vertical
1.920	30.35	54	-23.65	Pass	330	2.7	Vertical
2.096	24.26	54	-29.74	Pass	345	3.9	Vertical
3.959	28.56	54	-25.44	Pass	40	4.0	Vertical
4.318	29.78	54	-24.22	Pass	355	2.3	Vertical
5.968	32.35	54	-21.65	Pass	10	2.7	Horizontal
6.995	35.25	54	-18.75	Pass	150	2.6	Vertical

Table 3 Electric Field Emissions Peaks, 1GHz to 7GHz – Operation on 2440MHz

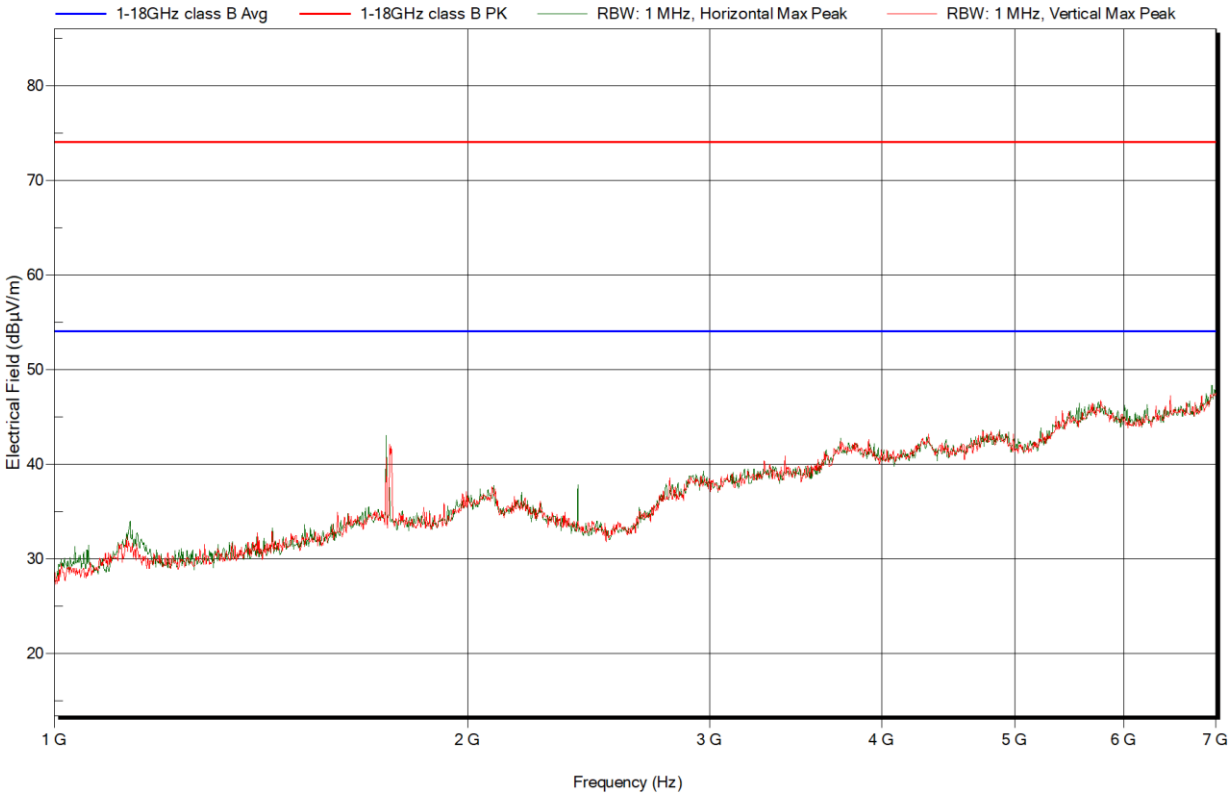


Figure 7 Electric field emissions Plot, 1GHz to 7GHz, Operation on 2402MHz - Peak detector scan

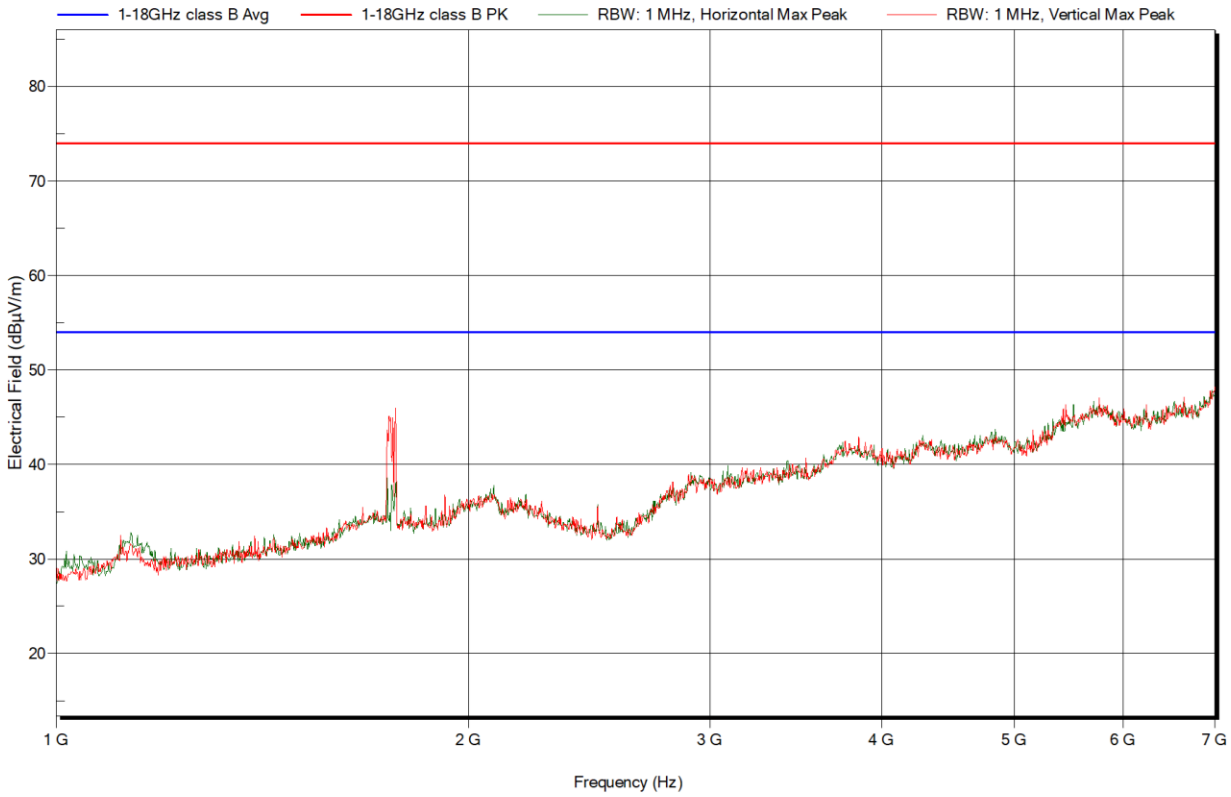


Figure 8 Electric field emissions Plot, 1GHz to 7GHz, Operation on 2480MHz – Peak detector scan

5.1.17 Example field strength calculation

The total average corrections are shown in the above table. This correction figure consists of Preamplifier gain (PG), Antenna factor (AF); and Cable loss (CL), and where necessary distance extrapolation factor (dB).

Field strength (FS) is calculated as follows:

FS (dBµV/m) = Indicated Signal Level (dBµV) - PG (dB) + AF (dB) + CL (dB)

5.1.18 Sample Data

From Figure 6 and table 3, The Average level at 6.995GHz is calculated as follows:

FS (dBµV/m) = 42.73(dBµV) – 54.93(dB) + 39.65(dB/m) + 7.80(dB) = 35.25dBµV/m

Radiated Emissions (18GHz to 25GHz)

5.1.19 Limits

Frequency (GHz)	Limit (dBµV/m)	Limit (dBµV/m)
	Peak	Average
18-25	74.0	54.0

5.1.20 Receiver Settings

Receiver Parameters	Setting
Detector Function	Average and Peak
Start Frequency	18GHz
Stop Frequency	25GHz
Resolution Bandwidth	1MHz
Video Bandwidth	Auto

5.1.21 Emissions measurements

5.1.22 Date of Test

21st November 2023

5.1.23 Test Area

LAB 1 (SAC)

5.1.24 Tested by

L Trickett

5.1.25 Test Setup

This is the same as for the 1-18GHz range for final measurements, except with a measurement distance of 1m.

5.1.26 Exploratory Radiated Emission Maximization

During exploratory testing, suspect emissions from the EUT were identified both in terms of the frequency and directionality. This was achieved by manually positioning the antenna close to the EUT and also by scanning it over all sides of the EUT whilst observing a spectral display. The typical distance between the surface of the EUT and the scanning antenna was circa 30cm.

Frequency (GHz)	Mode of operation	EUT face *	Emissions Angle (w.r.t. turntable)	Height	Polarization
-	Tx on channels 2402MHz, 2440MHz and 2480MHz.	-	-	-	-

Table 4 Frequencies identified during Exploratory Radiated Emission maximization

Note 1: The front face of the EUT is deemed to be 0°, which is then turned in a clockwise direction through 360°.

Note 2: No emissions were identified for further investigation above 18GHz.

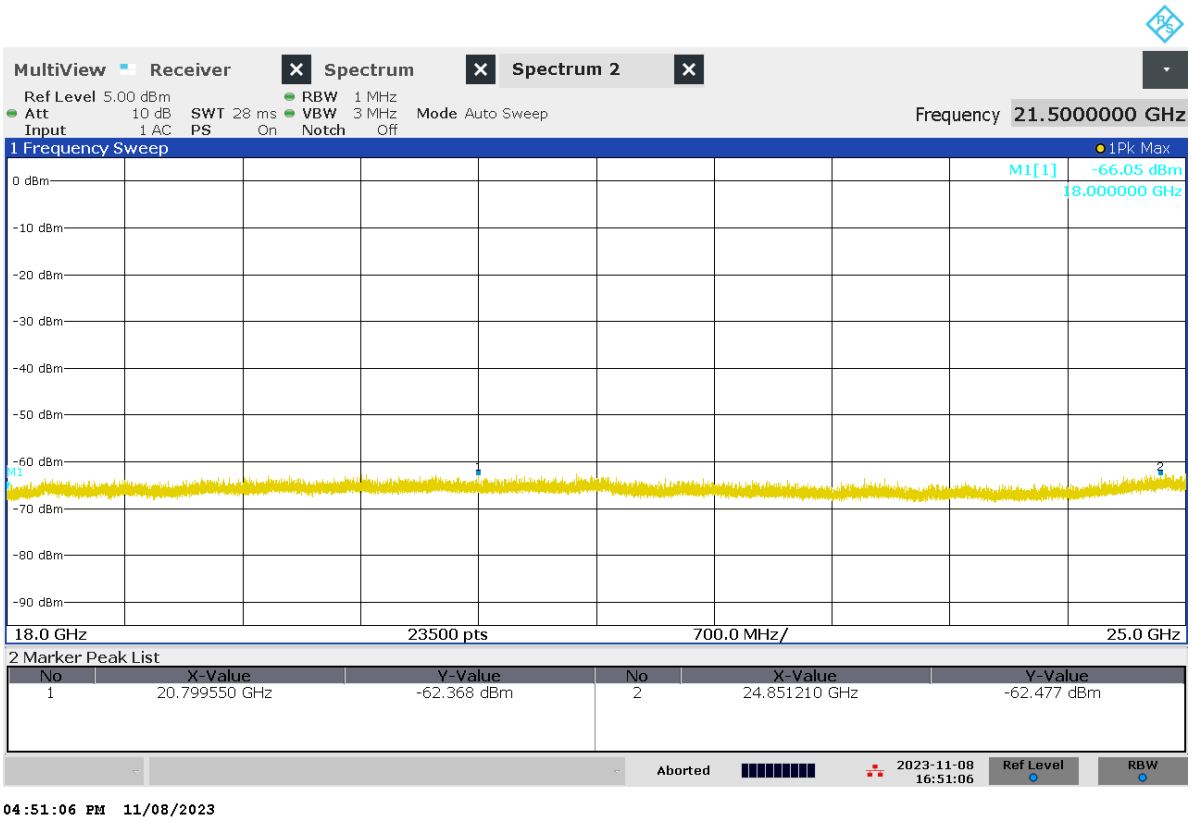


Figure 9 – Manual investigation – Operating on BT channel 2402MHz

Figure 10 – Manual investigation – Operating on BT channel 2440MHz

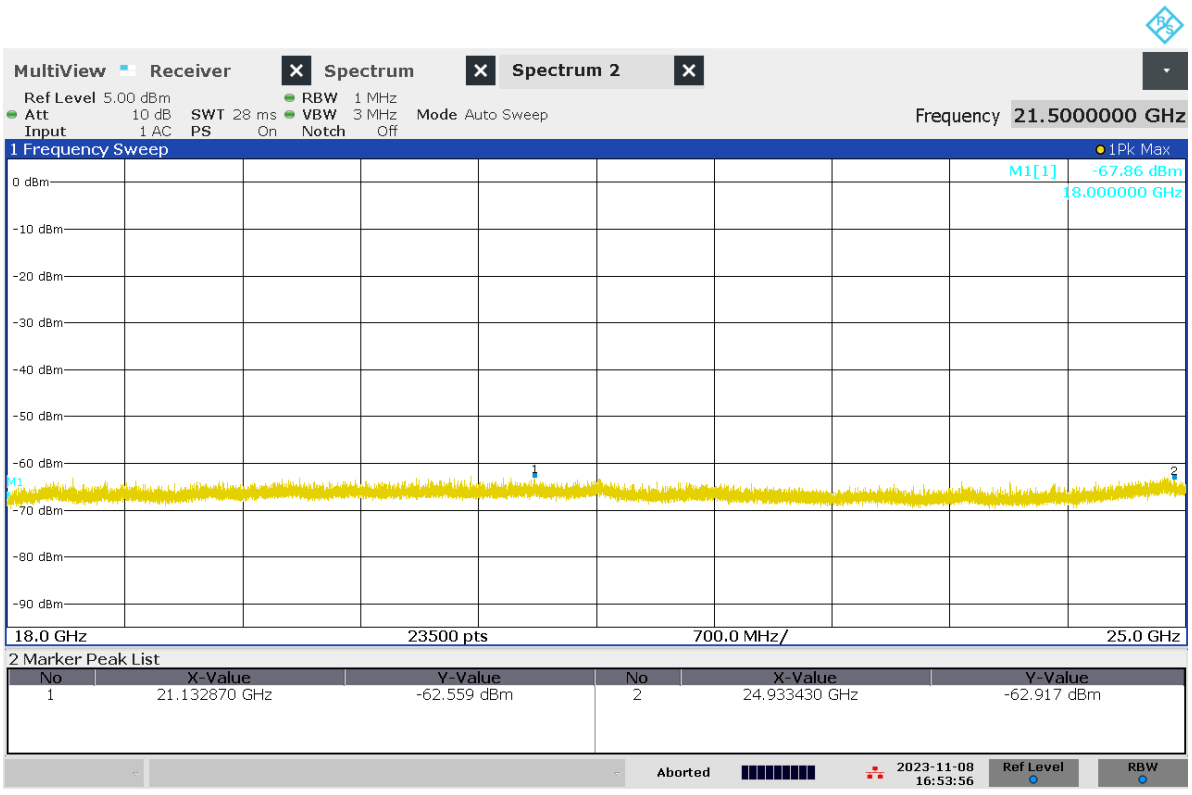


Figure 11 – Manual investigation – Operating on BT channel 2480MHz

Conducted Spurious Emissions 30MHz to 25GHz

5.1.27 Limits

Frequency (MHz)	Limit, 47CFR 15.247(d)
	Peak
30 – 25000	-20dBc

Spectrum analyser settings as specified by ANSI C63.10-2013 Clause 11.11.2

Receiver Parameters	Setting
Detector Function	Peak
Start Frequency	30MHz
Stop Frequency	25000MHz
Resolution Bandwidth	100kHz
Video Bandwidth	300kHz
Sweep rate	Auto couple
Trace mode	Max hold

5.1.28 Emissions measurements

5.1.29 Date of Test

16th November 2023

5.1.30 Test Area

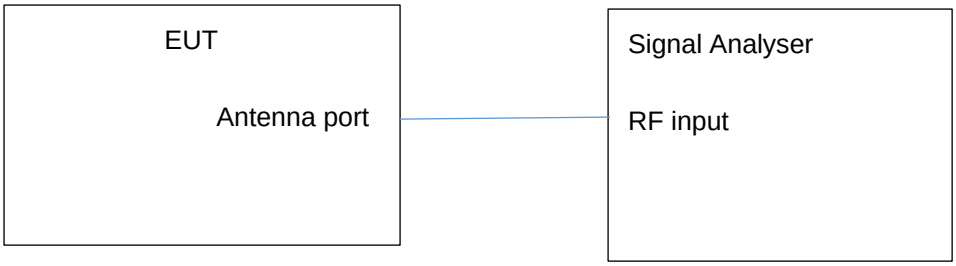
LAB 5

5.1.31 Tested by

L Trickett

5.1.32 Test Setup

The antenna port was connected directly to the signal analyser.



5.1.33 Test Results

The results of the conducted spurious emissions are stated below and by the signal analyser images.

All disturbances detected were > 20dB below the carrier.

5.1.34 Antenna port conducted emissions, 30MHz to 25GHz

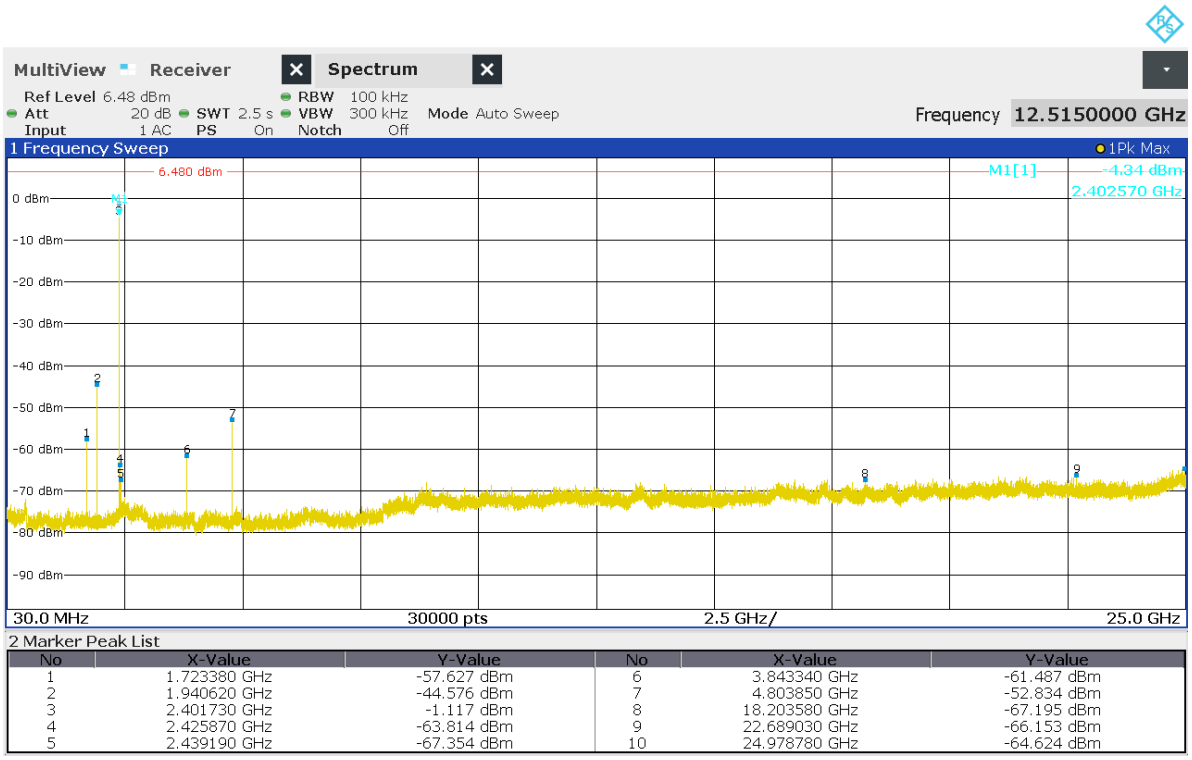


Figure 12 Conducted emissions 30MHz to 25GHz. Operation on channel 2402MHz.

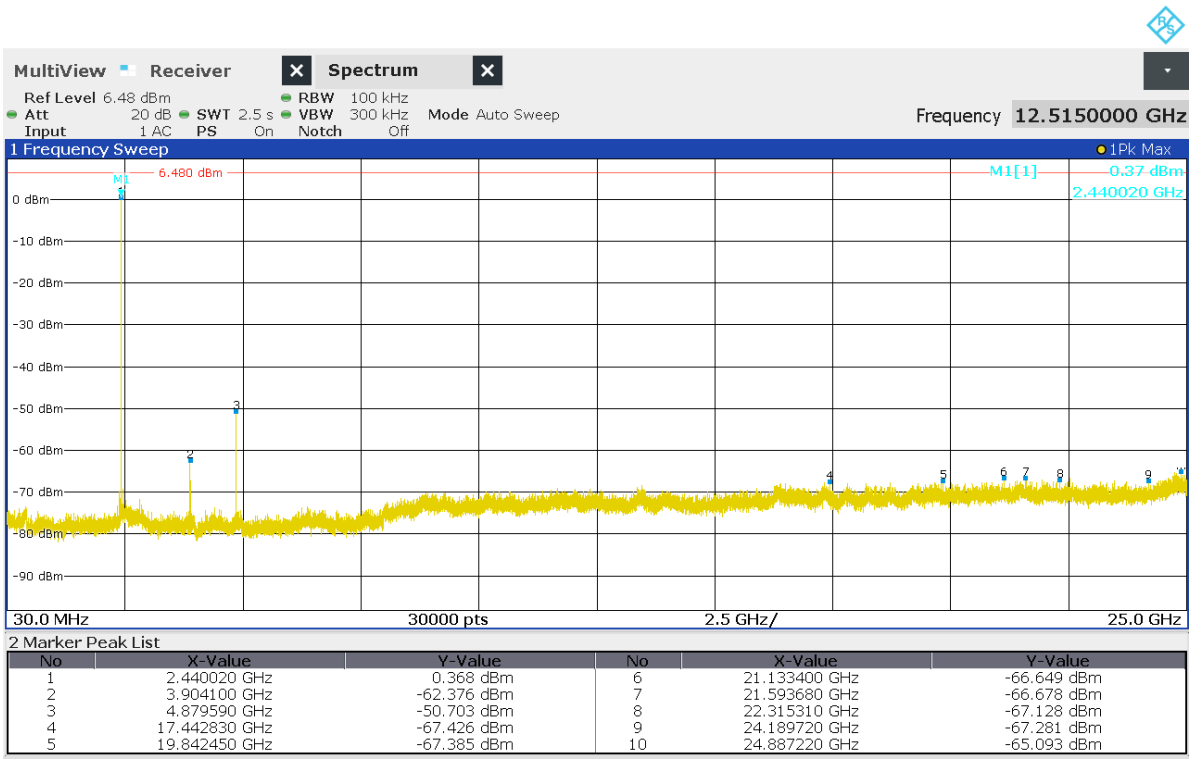
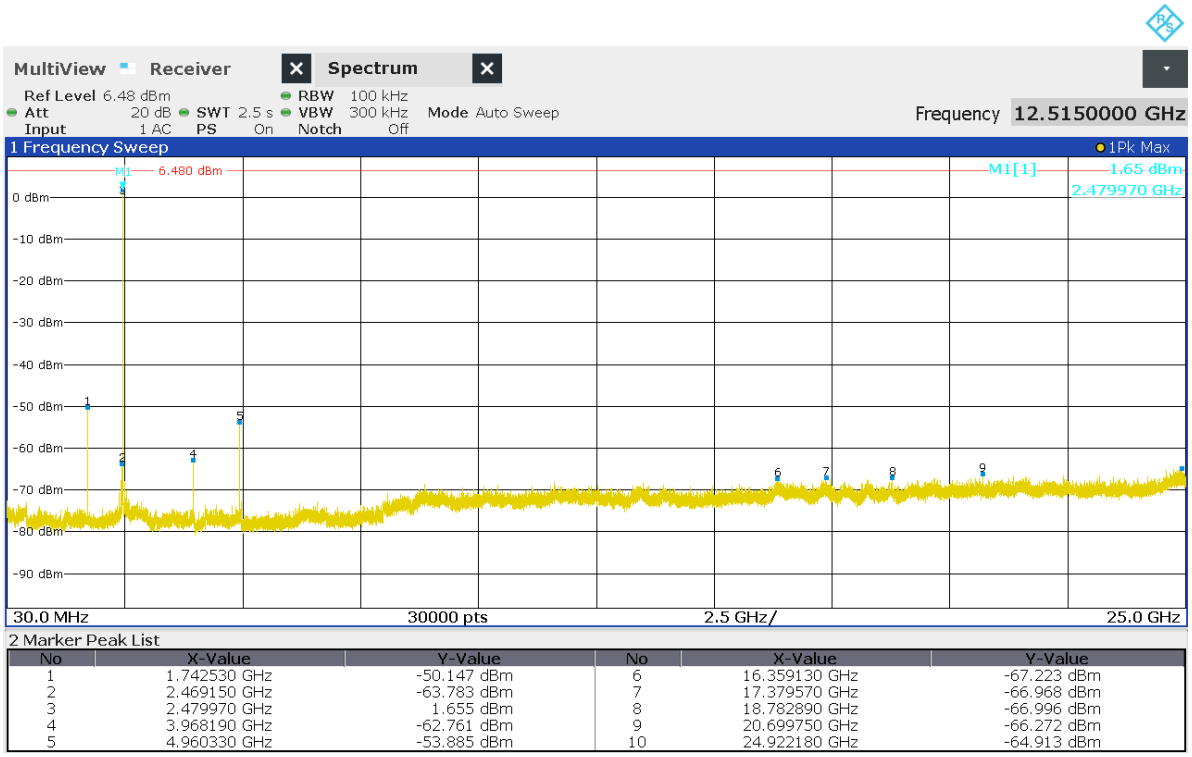


Figure 13 Conducted emissions 30MHz to 25GHz. Operation on channel 2440MHz.



No	X-Value	Y-Value	No	X-Value	Y-Value
1	1.742530 GHz	-50.147 dBm	6	16.359130 GHz	-67.223 dBm
2	2.469150 GHz	-63.783 dBm	7	17.379570 GHz	-66.968 dBm
3	2.479970 GHz	1.655 dBm	8	18.782890 GHz	-66.996 dBm
4	3.968190 GHz	-62.761 dBm	9	20.699750 GHz	-66.272 dBm
5	4.960330 GHz	-53.885 dBm	10	24.922180 GHz	-64.913 dBm

Figure 14 Conducted emissions 30MHz to 25GHz. Operation on channel 2480MHz.

Section 6 20dB Bandwidth and 99% Occupied Bandwidth

Test Specification

FCC Rule Part	46CFR 15.247 (a)(1)
Standard	ANSI C63.10:2013
Measurement Uncertainty Frequency tests	$\pm 9x10^{-8}$

Procedure and Test Software Version

Conducted Tests

ANSi C63.10-2013 Clause reference:	7.8.7
Test software	N/A

Frequency (MHz)	Limit, 47CFR 15.247(a)(1) 20dB bandwidth
	Peak
2400MHz to 2483.5MHz	Less than or equal to 1.5 times the channel separation, provided the systems operate with an output power no greater than 125 mW.

Spectrum analyser settings as specified by ANSI C63.10-2013 Clause 6.9.2

Receiver Parameters	Setting
Detector Function	Peak
Span	3MHz
Resolution Bandwidth	20kHz
Video Bandwidth	100kHz
Sweep rate	Auto couple
Trace mode	Max hold

6.1.1 Emissions measurements

6.1.2 Date of Test

16th November 2023

6.1.3 Test Area

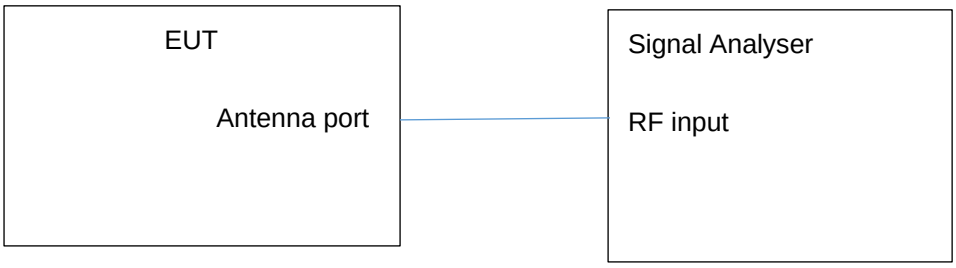
LAB 5

6.1.4 Tested by

L Trickett

6.1.5 Test Setup

The antenna port was connected directly to the signal analyser.



6.1.6 Test Results

The results of the 20dB bandwidth measurements are stated in the table below and by the signal analyser images.

Channel (MHz)	99% Occupied Bandwidth (MHz)	Measured 20dB bandwidth (MHz)	limit (MHz)	Figure	Result
2402.0	1.1748	1.27	1.5	15 & 18	Pass
2440.0	1.1713	1.23	1.5	16 & 19	Pass
2480.0	1.1732	1.27	1.5	17 & 20	Pass

Table 5 Bandwidth Measurements

Figure 15 Bandwidth at 20dB Point. Operation on channel 2402MHz

Figure 16 Bandwidth at 20dB Point. Operation on channel 2440MHz

Figure 17 Bandwidth at 20dB Point. Operation on channel 2480MHz

Figure 18 99% Occupied Bandwidth. Operation on channel 2402MHz

Figure 19 99% Occupied Bandwidth. Operation on channel 2440MHz

Figure 20 99% Occupied Bandwidth. Operation on channel 2480MHz

Section 7 Peak Output Power

Test Specification

FCC Rule Part	46CFR 15.247 (b)(1)
Standard	ANSI C63.10:2013
Measurement Uncertainty Conducted Power tests	±1.4dB

Procedure and Test Software Version

Conducted Tests

ANSi C63.10-2013 Clause reference:	7.8.5
Test software	N/A

Frequency (MHz)	Limit, 47CFR 15.247(b)(1)
	Peak
2400MHz to 2483.5MHz	0.125 watt

Spectrum analyser settings as specified by ANSI C63.10-2013 Clause 7.8.5

Receiver Parameters	Setting
Detector Function	Peak
Span	7MHz
Resolution Bandwidth	2MHz
Video Bandwidth	5MHz
Sweep rate	Auto couple
Trace mode	Max hold

7.1.1 Emissions measurements

7.1.2 Date of Test

16th November 2023

7.1.3 Test Area

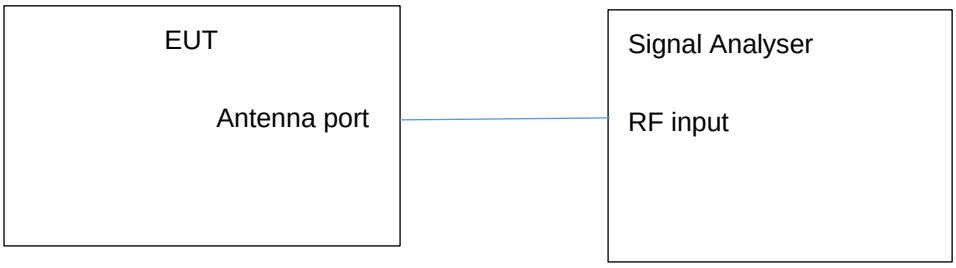
LAB 5

7.1.4 Tested by

L Trickett

7.1.5 Test Setup

The antenna port was connected directly to the signal analyser.



7.1.6 Test Result

The results of the peak output power measurements are stated in the table below and by the signal analyser images.

Channel (MHz)	Peak Power (dBm)	Peak Power (Watts)	Limit (Watts)	Figure
2402	2.67	0.00185	0.125	21
2440	4.44	0.00278	0.125	22
2480	5.26	0.00336	0.125	23

Table 6 Peak Output Power Measurements

Note: Values in the table above adjusted for a cable loss of 0.6dB

The MAX antenna gain is 4.2 dBi, MAX EIRP=MAX peak power *MAX antenna gain=5.26+4.2=9.46 dBm, The Max EIRP is 9.46 dBm (0.0088W) and does not exceed 4W, which meets the EIRP requirement of RSS-247 section 5.4.

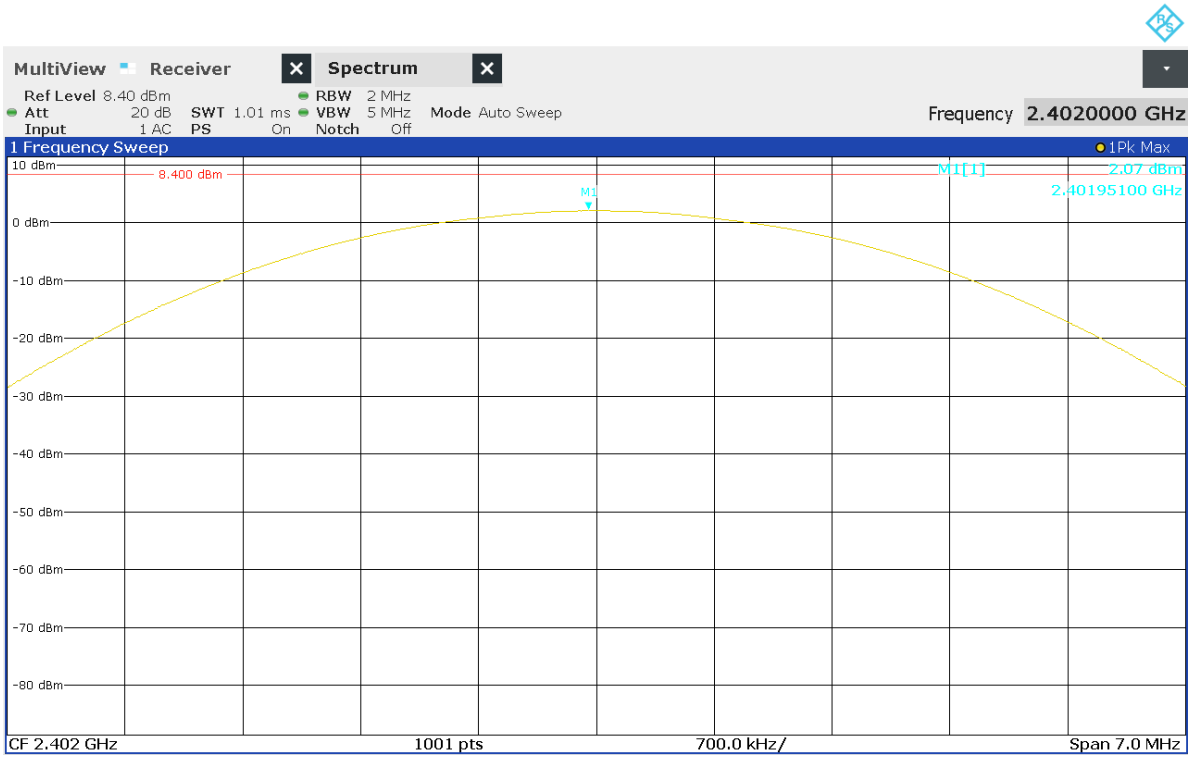


Figure 21 Peak output power, Operation on channel 2402MHz

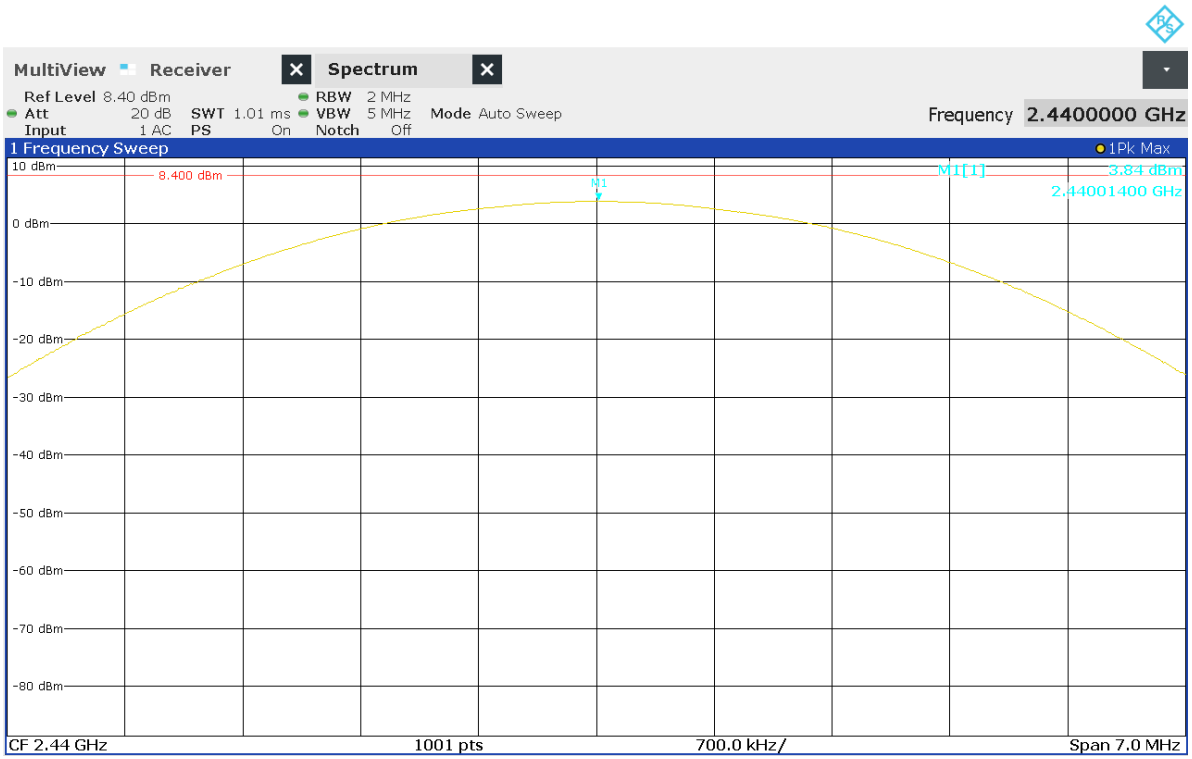


Figure 22 Peak output power, Operation on channel 2440MHz

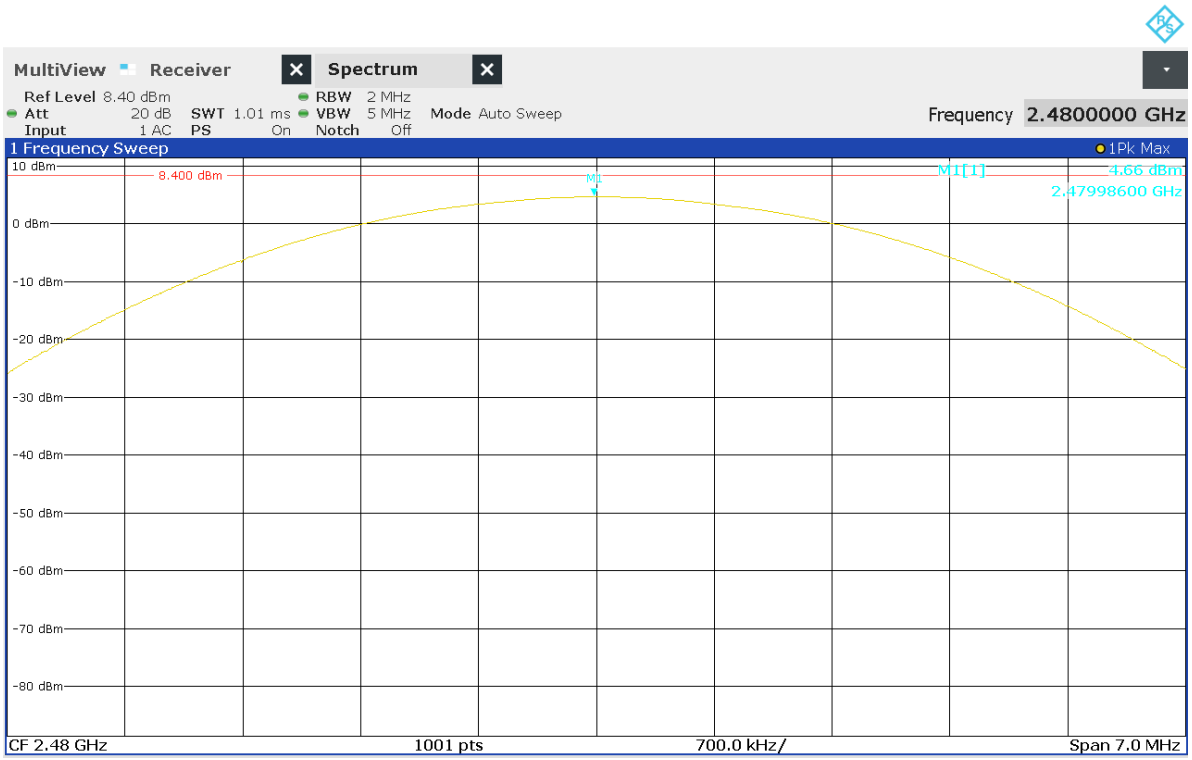


Figure 23 Peak output power, Operation on channel 2480MHz

Section 8 Frequency Hopping Spread Spectrum Requirements

Number of Hopping Frequencies

FCC Rule Part	47CFR15.247(a)(1)(iii)
Standard	ANSI C63.10:2013

Frequency hopping systems in the 2400-2483.5MHz band shall use at least 15 channels.

The procedure described in ANSI C63.10-2013 Clause 7.8.3 was followed.

8.1.1 Date of Test

16th November 2023

8.1.2 Test Area

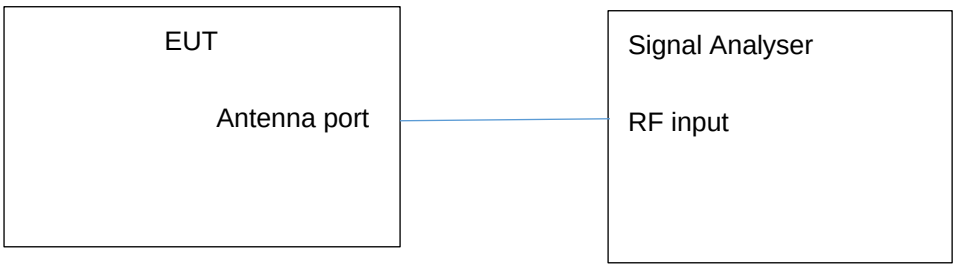
LAB 5

8.1.3 Tested by

L Trickett

8.1.4 Test Setup

The antenna port was connected directly to the signal analyser.



8.1.5 Test Results

The results show that 79 hopping channels were utilised. The analyser screen displays show the 79 hopping channels, split into two subranges:

Overall requirement of at least 15 channels was met.

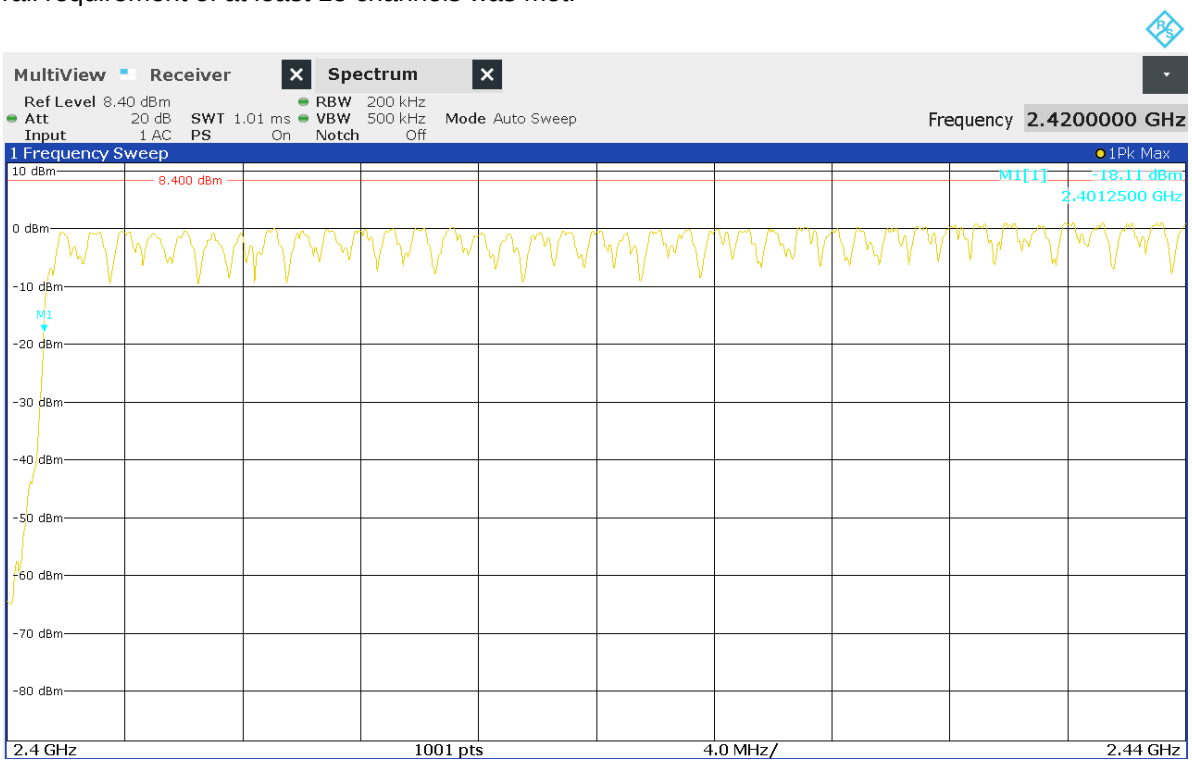


Figure 24 Number of hopping frequencies (1/2)

Figure 25 Number of hopping frequencies (2/2)

Frequency Hopping Channel Separation

FCC Rule Part	47CFR15.247(a)(1)
Standard	ANSI C63.10:2013
Measurement Uncertainty Frequency tests	$\pm 9 \times 10^{-8}$

8.1.6 Date of Test

16th November 2023

8.1.7 Test Area

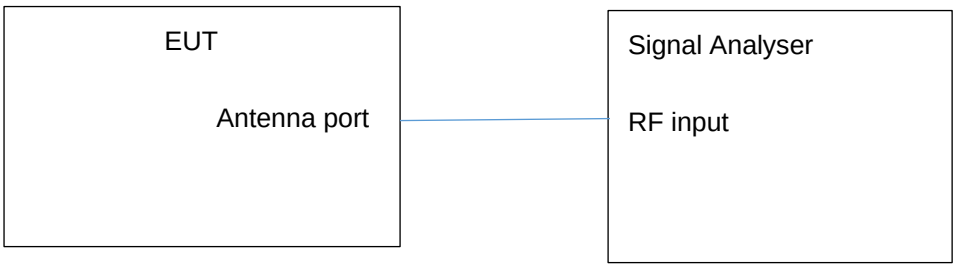
LAB 5

8.1.8 Tested by

L Trickett

8.1.9 Test Setup

The antenna port was connected directly to the signal analyser.



8.1.10 Requirement 47CFR15.247(a)(1)

Frequency hopping systems operating in the 2400-2483.5 MHz band may have hopping channel carrier frequencies that are separated by 25 kHz or two-thirds of the 20 dB bandwidth of the hopping channel, whichever is greater, provided the systems operate with an output power no greater than 125 mW.

As the output power was measured to be less than 125 mW and since two thirds of the measured 20dB bandwidth is greater than 25kHz, the carrier frequency separation shall be > two thirds of the measured 20dB bandwidth.

8.1.11 Procedure

The procedure described in ANSI C63.10-2013 Clause 7.8.2 was followed.

8.1.12 Test Results

Between any two adjacent channels the carrier separation was measured to be, compliant with the requirement.

Measured Separation (kHz)	Limit (kHz)	Result
981.5	>846.7	Pass

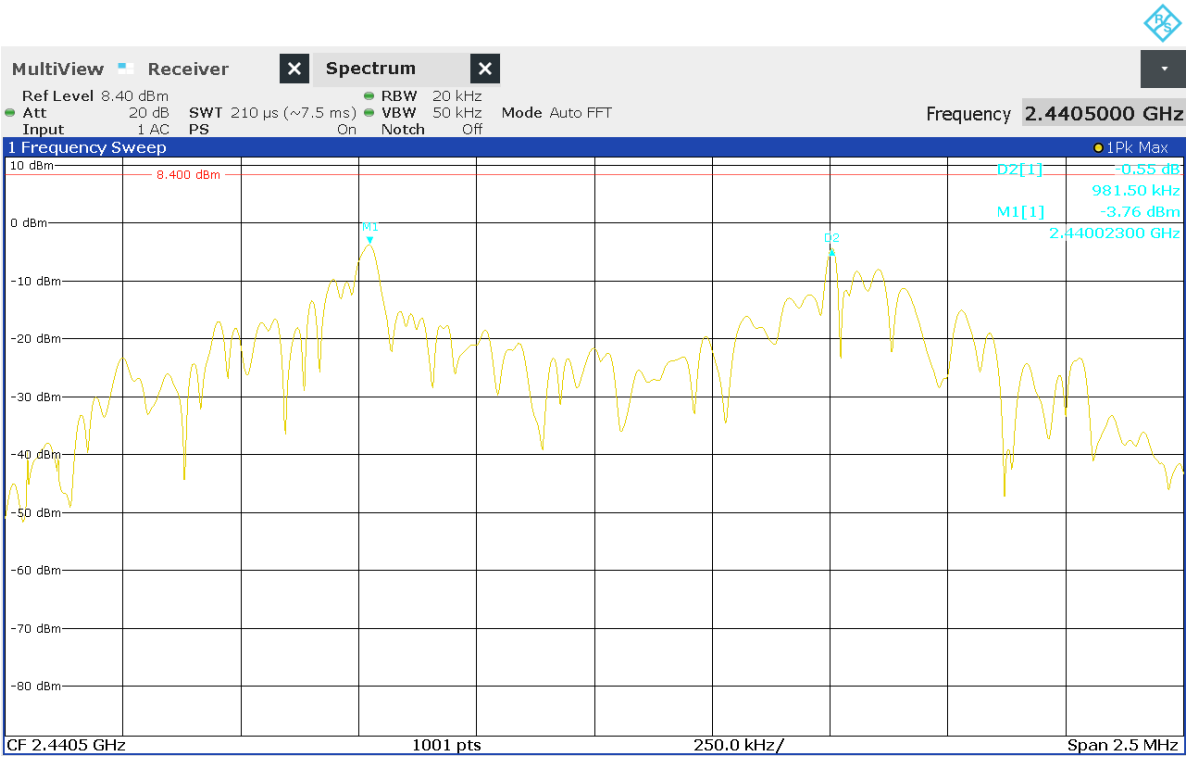


Figure 26 Carrier frequency separation

Hopping Channel Occupancy Time

FCC Rule Part	47CFR15.247(a)(1)(iii)
Standard	ANSI C63.10:2013

8.1.13 Date of Test

16th November 2023

8.1.14 Test Area

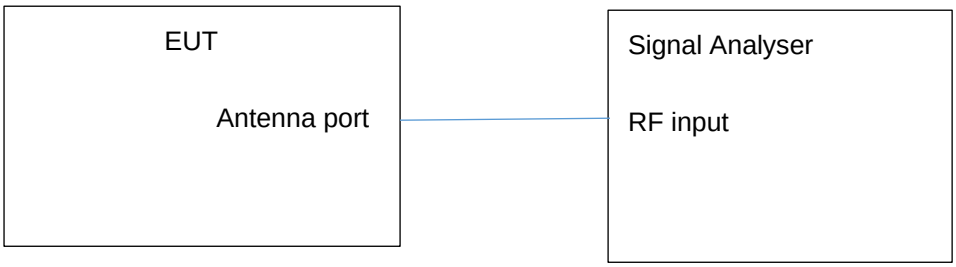
LAB 5

8.1.15 Tested by

L Trickett

8.1.16 Test Setup

The antenna port was connected directly to the signal analyser.



8.1.17 Requirement 47CFR15.247(a)(1)(iii)

The average time of occupancy on any channel shall not be greater than 0.4 seconds within a period of 0.4 seconds multiplied by the number of hopping channels employed.

8.1.18 Procedure

The procedure described in ANSI C63.10-2013 Clause 7.8.4 was followed.

8.1.19 Test Results

Sweep time (s)	No of hops measured in sweep time	No of hopping channels used	period specified by requirements	No of hops in period specified by requirements	Occupancy time (s)	Limit (s)	Average time of occupancy (s)
1	11	79	31.6	347.6	3.90×10^{-04}	0.4	0.1356

Figure 27 Transmit time per hop

Figure 28 Number of Hops in specified period

Section 9 Band Edge Compliance

Test Specification

FCC Rule Part	46CFR 15.205 and 47CFR15.209
Standard	ANSI C63.10:2013
Measurement Uncertainty Radiated tests	The reported uncertainty of measurement y ± U, where expended uncertainty U is based on a standard uncertainty multiplied by a coverage factor of k=2, providing a level of confidence of approximately 95% is +/- 5.14dB for the frequency range from 1GHz to 6GHz

Procedure and Test Software Version

Conducted Tests

ANSi C63.10-2013 Clause reference:	Clause 6.10.4 Authorised band-edge measurements
Test software	N/A

Frequency (MHz)	Limit, 47CFR 15.247(e)
	Peak
2400MHz to 2483.5MHz	Measured signal at the band edge must be below the radiated emission limits of 47CFR15.209

Spectrum analyser settings as specified by ANSI C63.10-2013 Clause 6.10.5 “Restricted band-edge measurements”

Receiver Parameters	Setting
Detector Function	Peak
Span	As necessary
Resolution Bandwidth	100kHz (Authorised band edge) 1MHz (Restricted band edge)
Video Bandwidth	3 x RBW
Sweep rate	Auto couple
Trace mode	Max hold

9.1.1 Emissions measurements

9.1.2 Date of Test

21st November 2023

9.1.3 Test Area

LAB 5

9.1.4 Tested by

L Trickett

9.1.5 Test Setup

The test setup was identical to radiated emissions testing 1-18GHz.

9.1.6 Test Results

Results are presented in two formats:

Tabular results of measurements at the band edges. Manual measurements were performed to measure the maximum value of signal at the band edge. The tabular data includes the following:

1. Polarity of the measurement antenna
2. Frequency at the band edge
3. Amplitude of signal at the input of the test receiver
4. Pre-amplifier gain
5. Cable loss
6. Antenna factor
7. Resultant Electric field strength = 3-4+5+6

Spectrum analyser screen displays are also included. Please note that the screen displays do not include losses or antenna factor.

Tabular Data

The following radiated measurements were made at the band edges:

Upper band edge

Polarity	frequency (MHz)	Amplitude (dBuV)	Preamp (dB)	Cable loss (dB)	AF(dB/m)	E (dBuV/m)	Limit (dBuV/m)	Margin (dB)
H	2483.5	66.70	54.03	3.19	29.89	45.75	74.00	28.25
V	2483.5	68.90	54.03	3.19	29.89	47.95	74.00	26.05

Table 7 Operation on 2480MHz Channel, Peak detector measurements

Polarity	frequency (MHz)	Amplitude (dBuV)	Preamp (dB)	Cable loss (dB)	AF(dB/m)	E (dBuV/m)	Limit (dBuV/m)	Margin (dB)
H	2483.5	48.70	54.03	3.19	29.89	27.75	54.00	26.25
V	2483.5	49.30	54.03	3.19	29.89	28.35	54.00	25.65

Table 8 Operation on Channel 2480MHz, average detector measurements

Lower band edge

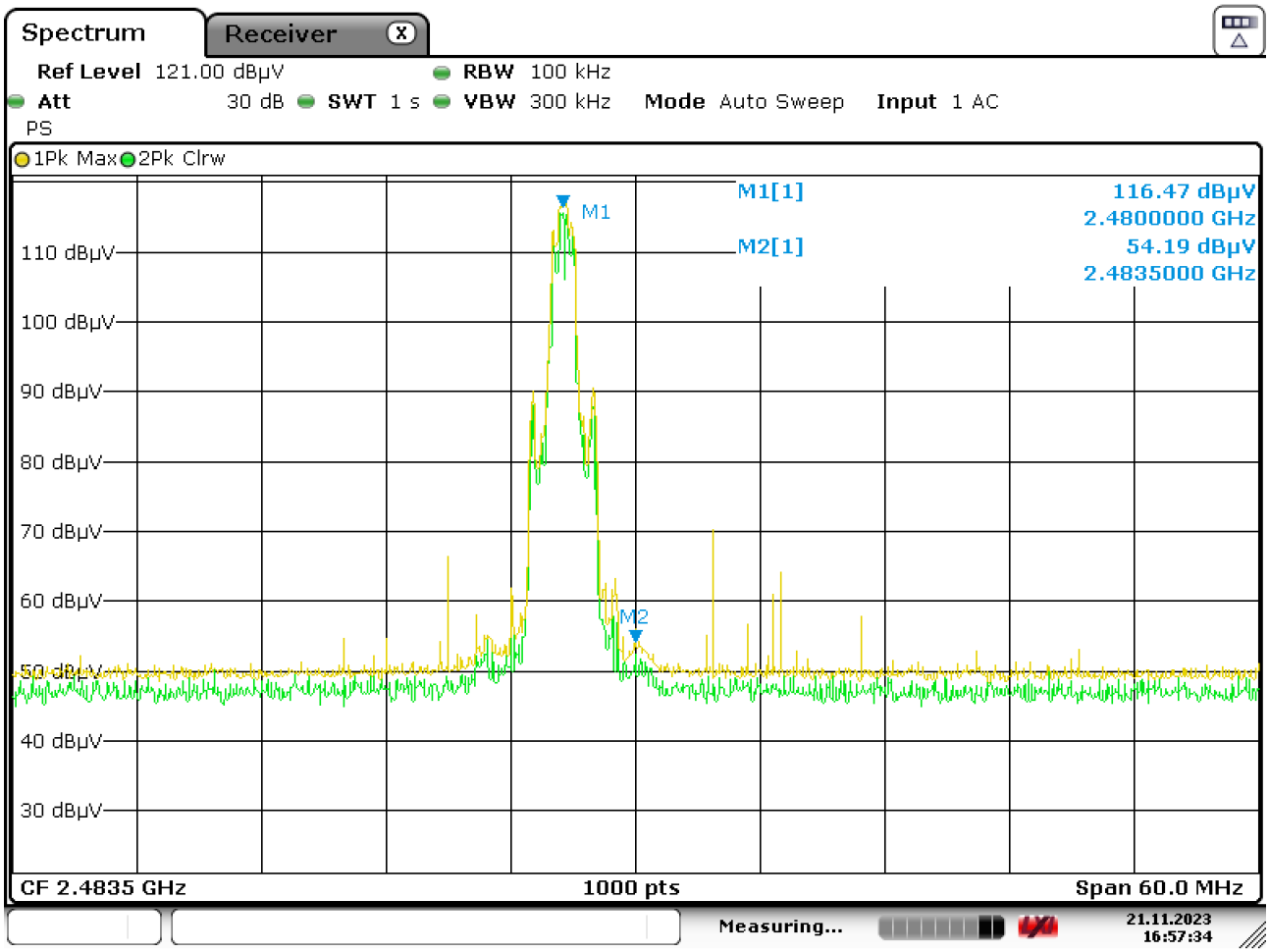
Polarity	frequency (MHz)	Amplitude (dBuV)	Preamp (dB)	Cable loss (dB)	AF(dB/m)	E (dBuV/m)	Limit (dBuV/m)	Margin (dB)
H	2400	89.30	54.02	3.14	29.67	68.09	74.00	5.91
V	2400	89.10	54.02	3.14	29.67	67.89	74.00	6.11

Table 9 Operation on channel 2402MHz Peak detector measurements

Polarity	frequency (MHz)	Amplitude (dBuV)	Preamp (dB)	Cable loss (dB)	AF(dB/m)	E (dBuV/m)	Limit (dBuV/m)	Margin (dB)
H	2400	59.80	54.02	3.14	29.67	38.59	54.00	15.41
V	2400	59.70	54.02	3.14	29.67	38.49	54.00	15.51

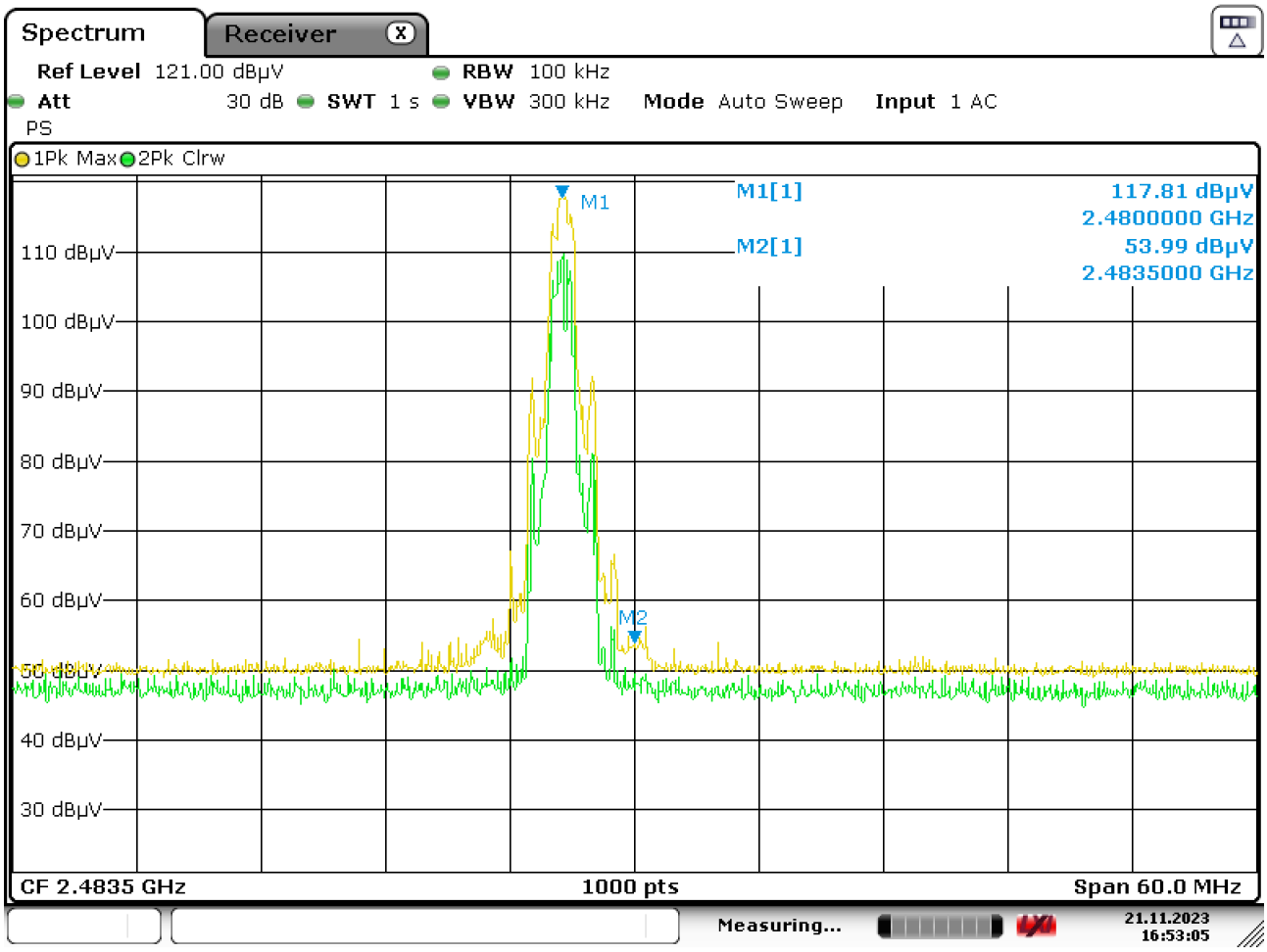
Table 10 Operation on channel 2402MHz average detector measurements

Spectrum analyser displays



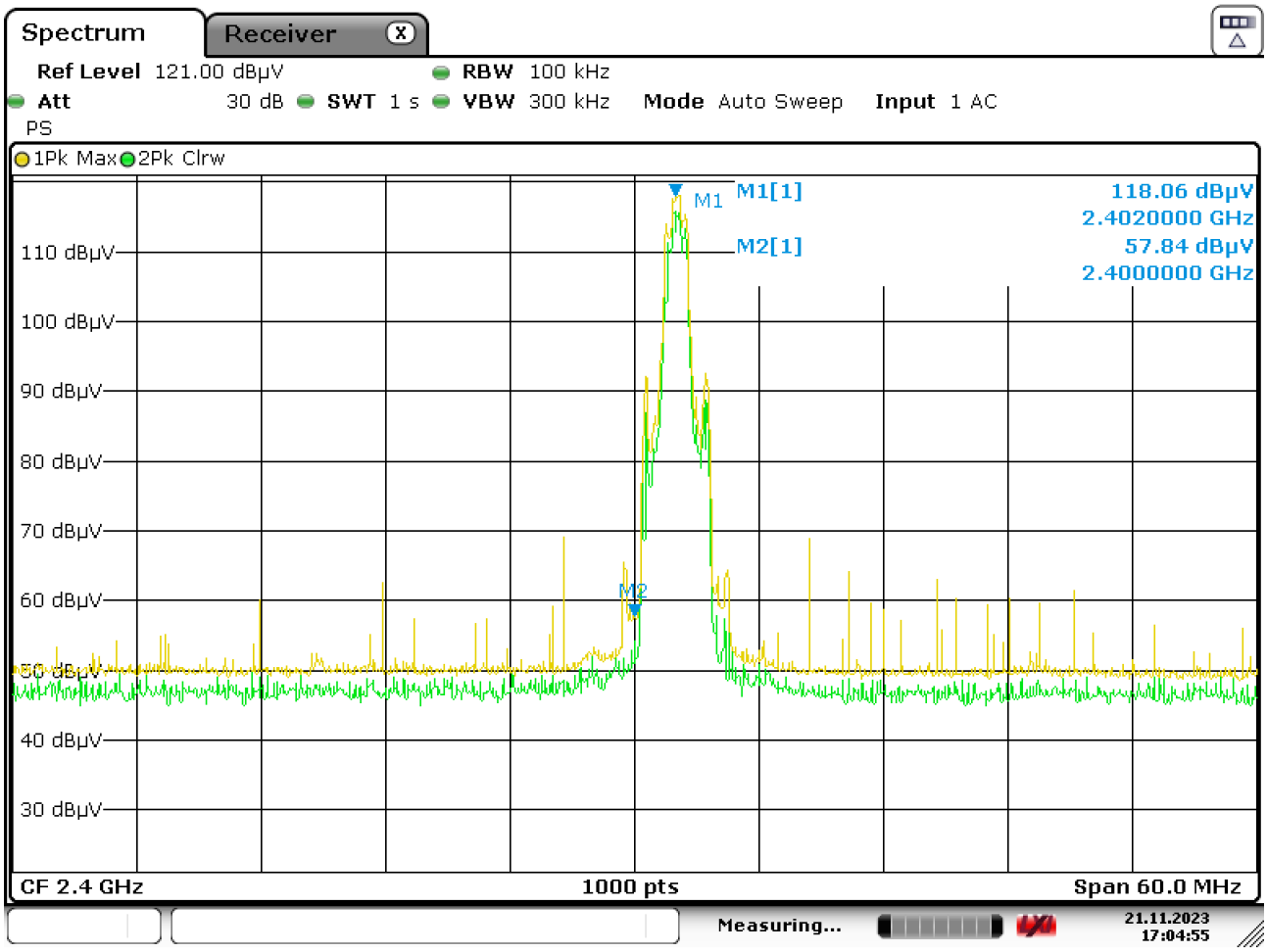
Date: 21.NOV.2023 16:57:34

Figure 29 Band Edge Measurement – upper band edge - horizontal polarity



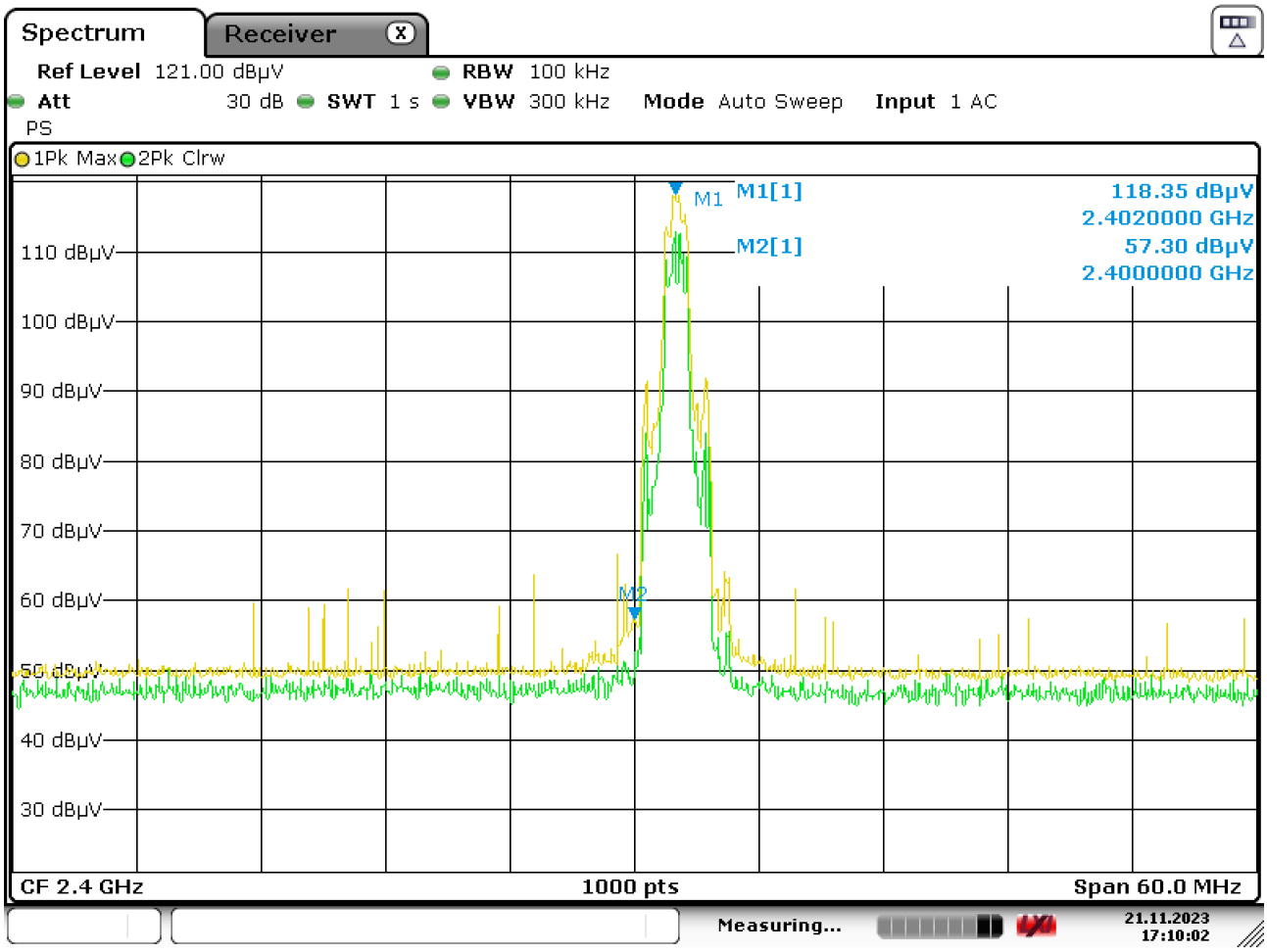
Date: 21.NOV.2023 16:53:05

Figure 30 Band Edge Measurement – upper band edge - vertical polarity



Date: 21.NOV.2023 17:04:55

Figure 31 Band Edge Measurement – lower band edge - horizontal polarity



Date: 21.NOV.2023 17:10:02

Figure 32 Band Edge Measurement – lower band edge - vertical polarity

Appendix A EUT Test Photos

Test set up photographs are supplied separately.

Appendix B Test Equipment List

Conducted Emissions from Antenna Port

Item	Serial No.	Last Calibration Date	Calibration Interval
RF Cable	Cable 23	30th November 2022	12 Months
R&S ESW44 EMI Receiver	C0751	10th July 2023	12 Months
Kikusui PCR200M	C0198	-	-

Radiated Emissions Equipment

Item	Serial No.	Last Calibration Date	Calibration Interval
Laboratory 1 Semi-Anechoic Chamber	C0471	6th December 2022	36 Months
ETS Lindgren 2017B Mast (1 – 4m) with tilting mechanism	--	N/A	N/A
R & S ESR26	C0502	8th August 2023	12 Months
Kikusui PCR200M	C0198	-	-
Teseq CBL6112D Bilog Antenna	C0506	12th January 2023	36 Months
HF29 Cable	20147.01.09.001	30th November 2022	12 Months
HF31 Cable	19148.06.13.002	30th November 2022	12 Months
HF35 Cable	19149.02.13.003	30th November 2022	12 Months
HF27 Cable	19149.03.13.004	30th November 2022	12 Months
Schwarzbeck STLP 9148 Antenna 1-18GHz	C0626	12th April 2022	24 Months
2.4GHz Microtronics BRM50702 notch filter	79178	1st December 2022	12 Months
BONN BLMA 0118-M Preamplifier	C0702	7th July 2023	12 Months
ETS Lingren 3116C-PA Horn Antenna 18-40GHz	C0433	28th September 2023	36 Months

----------END OF REPORT----------