Test report

412895-2TRFWL

Date of issue: May 12, 2021

Applicant:

GE Current, a Daintree Company

Product:

Radio receiver

Model:

A1028250

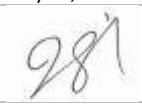
FCC ID: 2AS3F-A1028250 IC: 25008-A1028250

Specifications:

- FCC 47 CFR Part 15, Subpart C – §15.247
  Operation within the bands 902 – 928 MHz, 2400 – 2483.5 MHz, 5727 – 5850 MHz
- Industry Canada RSS-247, Issue 2
  Digital Transmission Systems (DTSs), Frequency Hopping Systems (FHSs) and Licence-Exempt Local Area Network (LE-LAN) Devices

Lab and test locations

Company name	Nemko USA Inc.
Address	2210 Faraday Ave, Suite 150
City	Carlsbad
State	California
Postal code	92008
Country	USA
Telephone	+1 760 444 3500
Website	www.nemko.com
FCC Site Number	Test Firm Registration Number: 392943 Designation Number: US5058
ISED Test Site	2040B-3

Tested by	David Hewitt, EMC Specialist
Reviewed by	James Cunningham, EMC/MIL/WL Supervisor
Review date	May 12, 2021
Reviewer signature	

Limits of responsibility

Note that the results contained in this report relate only to the items tested and were obtained in the period between the date of initial receipt of samples and the date of issue of the report.
This test report has been completed in accordance with the requirements of ISO/IEC 17025. All results contain in this report are within Nemko USA's ISO/IEC 17025 accreditation.
This report must not be used by the client to claim product certification, approval, or endorsement by NVLAP, NIST, or any agency of the U.S. Government.

Copyright notification

Table of Contents

Section 1 Report summary

1.1 Applicant

Company name	GE Current, a Daintree Company
Address	1975 Noble Road Bldg 335
City	East Cleveland
Province/State	OH
Postal/Zip code	44112
Country	USA

1.2 Manufacturer

Company name	GE Current, a Daintree Company
Address	1975 Noble Road Bldg 335
City	East Cleveland
Province/State	OH
Postal/Zip code	44112
Country	USA

1.3 Test specifications

FCC 47 CFR Part 15, Subpart C – §15.247	Operation within the bands 902-928 MHz, 2400-2483.5 MHz, and 5725-5850 MHz
IC RSS-247 Issue 2	Digital Transmission Systems (DTSs), Frequency Hopping Systems (FHSs) and Licence-Exempt Local Area Network (LE-LAN) Devices

1.4 Test methods

ANSI C63.10-2013	American National Standard of Procedures for Compliance Testing of Unlicensed Wireless Devices
558074 D01 DTS Measurement Guidance v03r02 (June 5, 2014)	Guidance for Performing Compliance Measurements on Digital Transmission Systems (DTS) Operating Under §15.247

1.5 Exclusions

None

1.6 Statement of compliance

In the configuration tested, the EUT was found compliant.

Testing was performed against all relevant requirements of the test standard. Results obtained indicate that the product under test complies in full with the requirements tested. The test results relate only to the items tested.

See "Summary of test results" for full details.

1.7 Test report revision history

Table 1.7-1: *Test report revision history*

Revision #	Details of changes made to test report
412895-2TRFWL	Original report issued
Notes:	None

Section 2 Summary of test results

2.1 FCC Part 15 Subpart C, general requirements

Part	Test description	Verdict
§15.207(a)	Conducted limits	Pass
§15.31(e)	Variation of power source	Pass
§15.203	Antenna requirement	Pass

Notes: EUT is powered via USB from host support laptop.
The antenna is located within the protective cover of EUT on PCB

2.2 FCC Part 15.247

Part	Test description	Verdict
§15.247(a)(1)(i)	Frequency hopping systems operating in the 902–928 MHz band	Not applicable
§15.247(a)(1)(ii)	Frequency hopping systems operating in the 5725–5850 MHz band	Not applicable
§15.247(a)(1)(iii)	Frequency hopping systems operating in the 2400–2483.5 MHz band	Not applicable
§15.247(a)(2)	Minimum 6 dB bandwidth for systems using digital modulation techniques	Pass
§15.247(b)(1)	Maximum peak output power of frequency hopping systems operating in the 2400–2483.5 MHz band and 5725–5850 MHz band	Not applicable
§15.247(b)(2)	Maximum peak output power of Frequency hopping systems operating in the 902–928 MHz band	Not applicable
§15.247(b)(3)	Maximum peak output power of systems using digital modulation in the 902–928 MHz, 2400–2483.5 MHz, and 5725–5850 MHz bands	Pass
§15.247(b)(4)	Transmitting antennas of directional gain greater than 6 dBi	Not applicable
§15.247(c)(1)	Fixed point-to-point operation with directional antenna gains greater than 6 dBi	Not applicable
§15.247(c)(2)	Transmitters operating in the 2400–2483.5 MHz band that emit multiple directional beams	Not applicable
§15.247(d)	Spurious emissions	Pass
§15.247(e)	Power spectral density for digitally modulated devices	Pass
§15.247(f)	Time of occupancy for hybrid systems	Not applicable

2.3 IC RSS-247, Issue 2

Part	Test description	Verdict
5.1 (a)	Bandwidth of a frequency hopping channel	Not applicable
5.1 (b)	Minimum channel spacing for frequency hopping systems	Not applicable
5.1 (c)	Frequency hopping systems operating in the 902–928 MHz band	Not applicable
5.1 (d)	Frequency hopping systems operating in the 2400–2483.5 MHz band	Not applicable
5.1 (e)	Frequency hopping systems operating in the 5725–5850 MHz band	Not applicable
5.2 (a)	Minimum 6 dB bandwidth	Pass
5.2 (b)	Maximum power spectral density	Pass
5.3 (a)	Digital modulation turned off	Not applicable
5.3 (b)	Frequency hopping turned off	Not applicable
5.4 (a)	Frequency hopping systems operating in the 902–928 MHz band	Not applicable
5.4 (b)	Frequency hopping systems operating in the 2400–2483.5 MHz band	Not applicable
5.4 (c)	Frequency hopping systems operating in the 5725–5850 MHz	Not applicable
5.4 (d)	Systems employing digital modulation techniques	Pass
5.4 (e)	Point-to-point systems in 2400–2483.5 MHz and 5725–5850 MHz band	Not applicable
5.4 (f)	Transmitters which operate in the 2400–2483.5 MHz band with multiple directional beams	Not applicable
5.5	Out-of-band emissions	Pass

2.4 IC RSS-GEN, Issue 5

Part	Test description	Verdict
7.3	Receiver radiated emission limits	Not applicable
7.4	Receiver conducted emission limits	Not applicable
8.8	Power Line Conducted Emissions Limits for License-Exempt Radio Apparatus	Pass

Section 3 Equipment under test (EUT) details

3.1 Sample information

Receipt date	March 18, 2021
Nemko sample ID number	NEx: 412895

3.2 EUT information

Product name	Radio receiver
Model	A1028250
Serial number	Sample 1 (U.FL antenna port): 5C0272FFFE09BBB9 Sample 2 (U.FL antenna port): 5C0272FFFE09BC48 Sample 3 (Chip Antenna): 5C0272FFFE09BC18
Part number	A-1025577-01-Rev2

3.3 Technical information

Used IC test site(s) reg. number	2040A
RSS number and issue	RSS-247 issue 2 (February 2017)
Frequency band	2400 – 2483.5 MHz
Minimum frequency (MHz)	2405
Maximum frequency (MHz)	2480
Minimum output power (dBm)	6.46 (e.i.r.p.)
Maximum output power (dBm)	8.61 (e.i.r.p.)
Measured 6 dB bandwidth	2405 MHz: 1840 kHz 2440 MHz: 1700 kHz 2480 MHz: 1710 kHz
Type of modulation	802.15.4
Emission classification	F1D
Power requirements	3.3 V_{DC}; 0.2 A
Antenna information	2.5 dBi gain antenna on PCB

3.4 EUT exercise and monitoring details

EUT was exercised using RAILTEST Firmware and debug board and monitored by U.FL connector and pigtail to the spectrum analyzer. Sample was tested in both Zigbee and Zigbee transmit formats.

Table 3.4-1: *EUT sub assemblies*

Description	Brand name	Model/Part number	Serial number	Rev.
Radio receiver	Silicon Labs	A-1017508	Sample 1 (U.FL antenna port): 5C0272FFFE09BBB9 Sample 2 (U.FL antenna port): 5C0272FFFE09BC48 Sample 3 (Chip Antenna): 5C0272FFFE09BC18	--

Table 3.4-2: *EUT interface ports*

Description	Qty.
U.FL	1

Table 3.4-3: *Support equipment*

Description	Brand name	Model/Part number	Serial number	Rev.
Support Laptop	Dell	Latitude E7470	18326692370	--
STK/WSTK Debug Board	Silicon Labs	PCB4001	164623105	A03
STK/WSTK Debug Adapter	Silicon Labs	PCB8010	180409668	A02

Table 3.4-4: *Inter-connection cables*

Cable description	From	To	Length (m)
10-pin ribbon cable	EUT	STK/WSTK Debug Adapter	0.2

3.5 EUT setup diagram

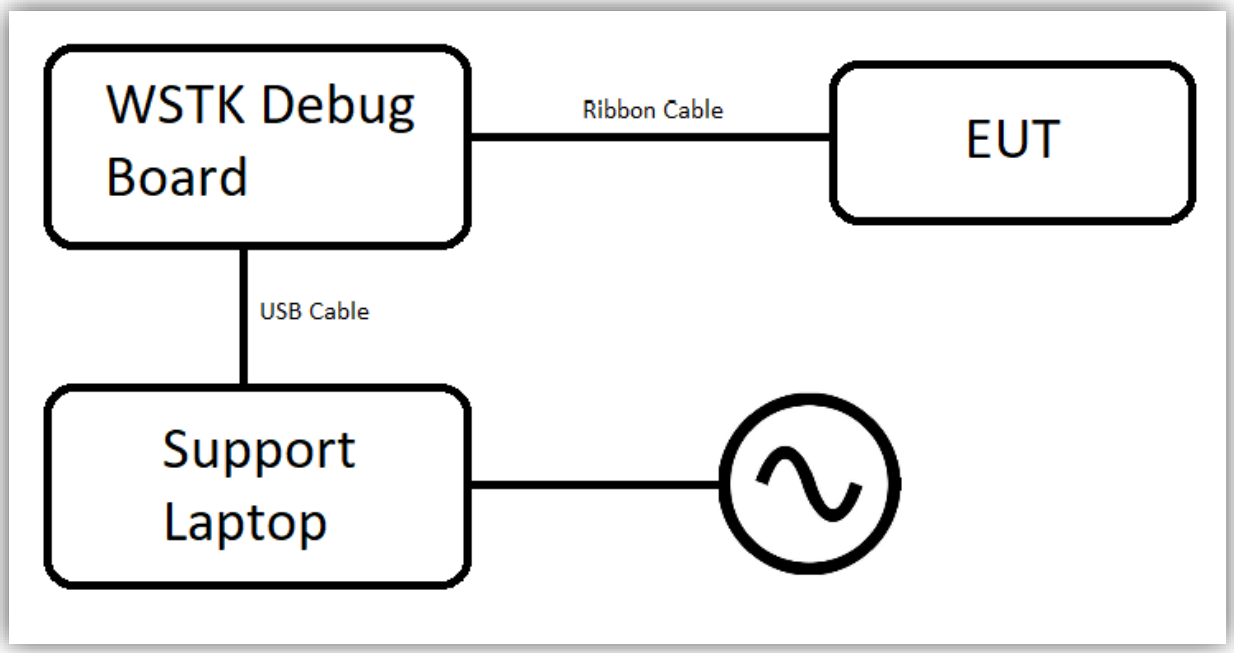


Figure 3.5-1: *Setup diagram*

Section 4 Engineering considerations

4.1 Modifications incorporated in the EUT

There were no modifications performed to the EUT during this assessment.

4.2 Technical judgment

None

4.3 Deviations from laboratory tests procedures

No deviations were made from laboratory procedures.

Section 5 Test conditions

5.1 Atmospheric conditions

Temperature	15-30 °C
Relative humidity	20-75 %
Air pressure	86–106 kPa

When it is impracticable to carry out tests under these conditions, a note to this effect stating the ambient temperature and relative humidity during the tests shall be recorded and stated.

5.2 Power supply range

The normal test voltage for equipment to be connected to the mains shall be the nominal mains voltage. For the purpose of the present document, the nominal voltage shall be the declared voltage, or any of the declared voltages ±5 %, for which the equipment was designed.

Section 6 Measurement uncertainty

6.1 Uncertainty of measurement

Measurement uncertainty budgets for the tests are detailed below. Measurement uncertainty calculations assume a coverage factor of K = 2 with 95% certainty.

Test name	Measurement uncertainty, dB
Radiated spurious emissions	3.78
Powerline conducted emissions	1.38
All antenna port measurements	0.55
Conducted spurious emissions	1.13

Section 7 Test Equipment

Table 6.1-1: *Test Equipment List*

Equipment	Manufacturer	Model no.	Asset no.	Cal cycle	Next cal.
EMI Test Receiver	Rohde & Schwarz	ESCI 7	E1026	1 yr	24 Feb 2022
Transient Limiter	Hewlett-Packard	11947A	684	1 yr	20 Apr 2021
Two Line V-Network	Rohde & Schwarz	ENV216	E1019	1 yr	4 Aug 2021
Signal and spectrum analyzer	Rohde & Schwarz	FSW43	E1302	1 yr	18 Sep 2021
Power sensor	ETS Lindgren	7002-006	E1062	1 yr	14 Oct 2021
EMI Test Receiver	Rohde & Schwarz	ESU40	E1121	1 yr	1 Dec 2021
System Controller	Sunol Sciences	SC104V	E1129	NCR	NCR
Bilog Antenna (30-1000MHz)	Schaffner	CBL6111D	1763	2 yr	18 Feb 2022
DRG Horn Antenna (1-18GHz)	ETS-Lindgren	3117-PA	E1160	1 yr	2 Dec 2021
Rectangular Horn Antenna (18-26GHz)	Sage Millimeter, Inc.	SAR-2309-42-S2	E1143	2 yr	13 Nov 2022
Low Noise Amplifier	Sage Millimeter, Inc.	SBL-1834034030-KFKF	E1228	1 yr	8 Apr 2022

Notes: NCR - no calibration required

Table 6.1-2: *Test Software*

Manufacturer of Software	Details
Rohde & Schwarz	EMC 32 V10.60.10 (AC conducted emissions)
Rohde & Schwarz	EMC 32 V10.60.15 (radiated emissions)

Notes: None

Section 8 Testing data

8.1 FCC 15.207(a) and IC RSS-GEN, Issue 5 8.8 AC power line conducted emissions

8.1.1 Definition and limits

Title 47 → Chapter I → Subchapter A → Part 15 → Subpart C → §15.207(a)
RSS-Gen → §8.8

For Low-power radio-frequency devices that is designed to be connected to the public utility (AC) power line, the radio frequency voltage that is conducted back onto the AC power line on any frequency or frequencies, within the band 150 kHz to 30 MHz, shall not exceed the limits in the following table, as measured using a 50 µH/50 Ω line impedance stabilization network (LISN). The lower limit applies at the boundary between the frequency ranges.

Table 8.1-1: *Conducted emissions limit*

Frequency of emission, MHz	Conducted limit, dBµV	
	Quasi-peak	Average
0.15–0.5	66 to 56*	56 to 46*
0.5–5	56	46
5–30	60	50

Note: * - Decreases with the logarithm of the frequency.

8.1.2 Test summary

Verdict	Pass		
Test date	April 5, 2021	Temperature	23 °C
Test engineer	David Hewitt, EMC Specialist	Air pressure	1006 mbar
Test location	Ground Plane	Relative humidity	51 %

8.1.3 Notes

Testing was performed with the Zigbee transmitter operating on a fixed channel at client-specified full power. Low, middle, and high channels were tested.

Testing was performed according to ANSI C63.10 §6.2.

8.1.4 Setup details

Port under test	AC mains of host support equipment
EUT setup configuration	Table top
Measurement details	A preview measurement was generated with the receiver in continuous scan mode. Emissions detected within 6 dB or above limit were re-measured with the appropriate detector against the correlating limit and recorded as the final measurement.

Receiver settings:

Resolution bandwidth	9 kHz
Video bandwidth	30 kHz
Detector mode	– Peak and Average (Preview measurement) – Quasi-peak and CAverage (Final measurement)
Trace mode	Max Hold
Measurement time	– 100 ms (Peak and Average preview measurement) – 5000 ms (Quasi-peak final measurement) – 5000 ms (CAverage final measurement)

8.1.5 Test data

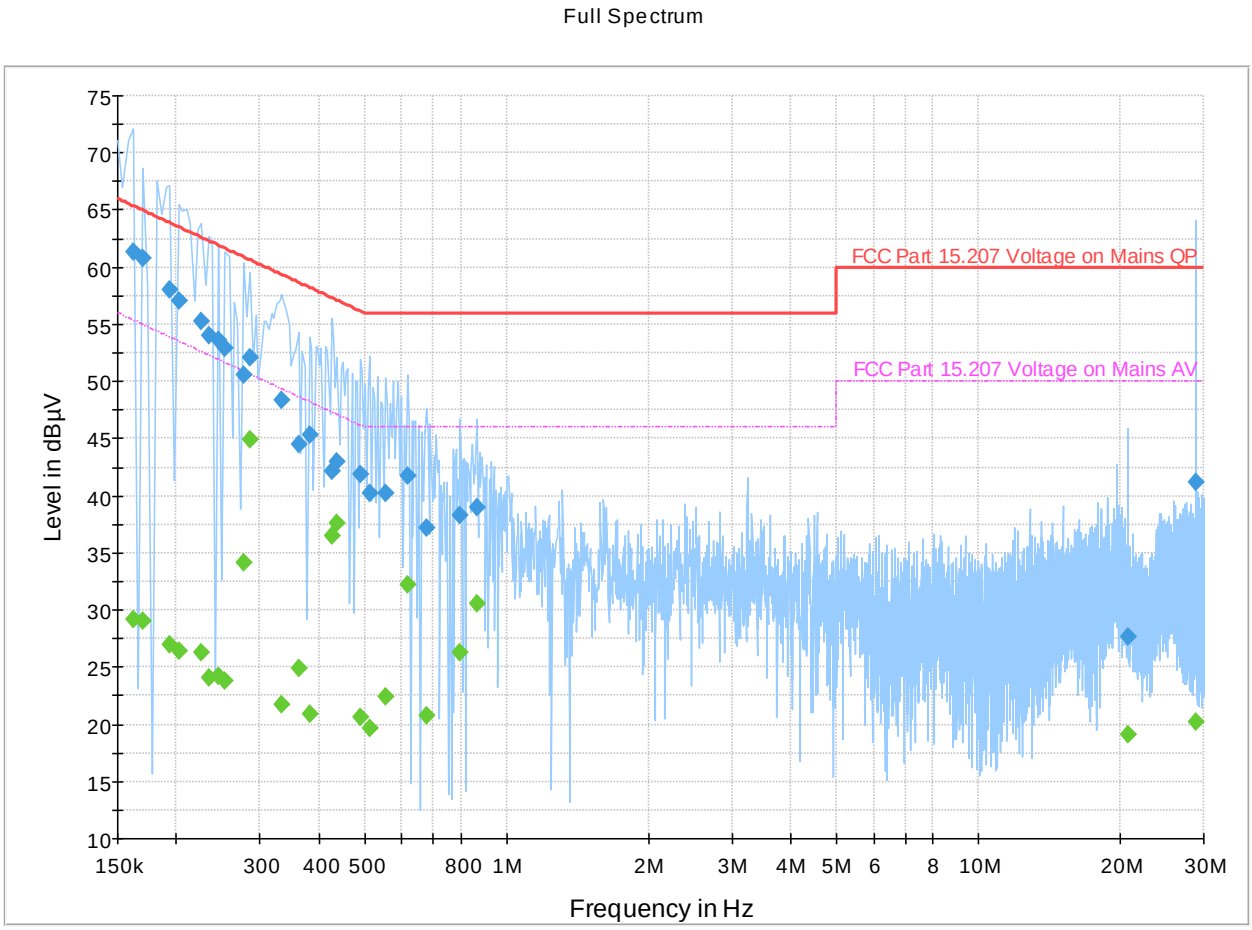


Figure 8.1-1: *AC conducted emissions spectral plot, Zigbee 2405 MHz*

Table 8.1-2: *AC conducted emissions results, Zigbee 2405 MHz*

Frequency (MHz)	QuasiPeak (dBµV)	CAverage (dBµV)	Limit (dBµV)	Margin (dB)	Meas. Time (ms)	Bandwidth (kHz)	Line	Filter	Corr. (dB)
0.162000	---	29.14	55.36	26.22	5000.0	9.000	N	ON	19.5
0.162000	61.33	---	65.36	4.03	5000.0	9.000	N	ON	19.5
0.170000	60.84	---	64.96	4.12	5000.0	9.000	L1	ON	19.6
0.170000	---	29.00	54.96	25.96	5000.0	9.000	L1	ON	19.6
0.194000	58.09	---	63.86	5.77	5000.0	9.000	L1	ON	19.6
0.194000	---	27.01	53.86	26.85	5000.0	9.000	L1	ON	19.6
0.202000	57.12	---	63.53	6.41	5000.0	9.000	L1	ON	19.5
0.202000	---	26.47	53.53	27.06	5000.0	9.000	L1	ON	19.5
0.226000	55.27	---	62.60	7.33	5000.0	9.000	L1	ON	19.5
0.226000	---	26.27	52.60	26.32	5000.0	9.000	L1	ON	19.5
0.234000	---	24.10	52.31	28.21	5000.0	9.000	N	ON	19.5
0.234000	54.03	---	62.31	8.28	5000.0	9.000	N	ON	19.5
0.246000	---	24.15	51.89	27.74	5000.0	9.000	L1	ON	19.5
0.246000	53.66	---	61.89	8.23	5000.0	9.000	L1	ON	19.5
0.254000	52.94	---	61.63	8.68	5000.0	9.000	L1	ON	19.5
0.254000	---	23.76	51.63	27.87	5000.0	9.000	L1	ON	19.5
0.278000	50.52	---	60.88	10.36	5000.0	9.000	N	ON	19.4
0.278000	---	34.09	50.88	16.78	5000.0	9.000	N	ON	19.4
0.286000	---	44.97	50.64	5.67	5000.0	9.000	L1	ON	19.5
0.286000	52.12	---	60.64	8.52	5000.0	9.000	L1	ON	19.5
0.334000	---	21.70	49.35	27.65	5000.0	9.000	L1	ON	19.5
0.334000	48.32	---	59.35	11.03	5000.0	9.000	L1	ON	19.5
0.362000	---	24.86	48.68	23.82	5000.0	9.000	N	ON	19.4
0.362000	44.46	---	58.68	14.22	5000.0	9.000	N	ON	19.4
0.382000	45.29	---	58.24	12.94	5000.0	9.000	L1	ON	19.5
0.382000	---	20.87	48.24	27.37	5000.0	9.000	L1	ON	19.5
0.426000	42.14	---	57.33	15.19	5000.0	9.000	N	ON	19.4
0.426000	---	36.54	47.33	10.79	5000.0	9.000	N	ON	19.4
0.438000	---	37.54	47.10	9.56	5000.0	9.000	L1	ON	19.4
0.438000	43.05	---	57.10	14.05	5000.0	9.000	L1	ON	19.4
0.490000	41.85	---	56.17	14.32	5000.0	9.000	L1	ON	19.4
0.490000	---	20.67	46.17	25.49	5000.0	9.000	L1	ON	19.4
0.514000	---	19.72	46.00	26.28	5000.0	9.000	L1	ON	19.4
0.514000	40.17	---	56.00	15.83	5000.0	9.000	L1	ON	19.4
0.554000	---	22.46	46.00	23.54	5000.0	9.000	L1	ON	19.4
0.554000	40.28	---	56.00	15.72	5000.0	9.000	L1	ON	19.4
0.618000	---	32.18	46.00	13.82	5000.0	9.000	L1	ON	19.4
0.618000	41.68	---	56.00	14.32	5000.0	9.000	L1	ON	19.4
0.678000	37.21	---	56.00	18.79	5000.0	9.000	L1	ON	19.4
0.678000	---	20.80	46.00	25.20	5000.0	9.000	L1	ON	19.4
0.798000	---	26.26	46.00	19.74	5000.0	9.000	L1	ON	19.4
0.798000	38.25	---	56.00	17.75	5000.0	9.000	L1	ON	19.4
0.866000	---	30.61	46.00	15.39	5000.0	9.000	L1	ON	19.4
0.866000	38.94	---	56.00	17.06	5000.0	9.000	L1	ON	19.4
20.746000	---	19.10	50.00	30.90	5000.0	9.000	L1	ON	20.2
20.746000	27.68	---	60.00	32.32	5000.0	9.000	L1	ON	20.2
28.810000	---	20.22	50.00	29.78	5000.0	9.000	N	ON	20.1
28.810000	41.19	---	60.00	18.81	5000.0	9.000	N	ON	20.1

Notes: Result (dBµV) = receiver/spectrum analyzer value (dBµV) + correction factor (dB)
Correction factor (dB) = LISN factor IL (dB) + cable loss (dB) + transient limiter (dB)
The maximum measured value observed over a period of 5 seconds was recorded.

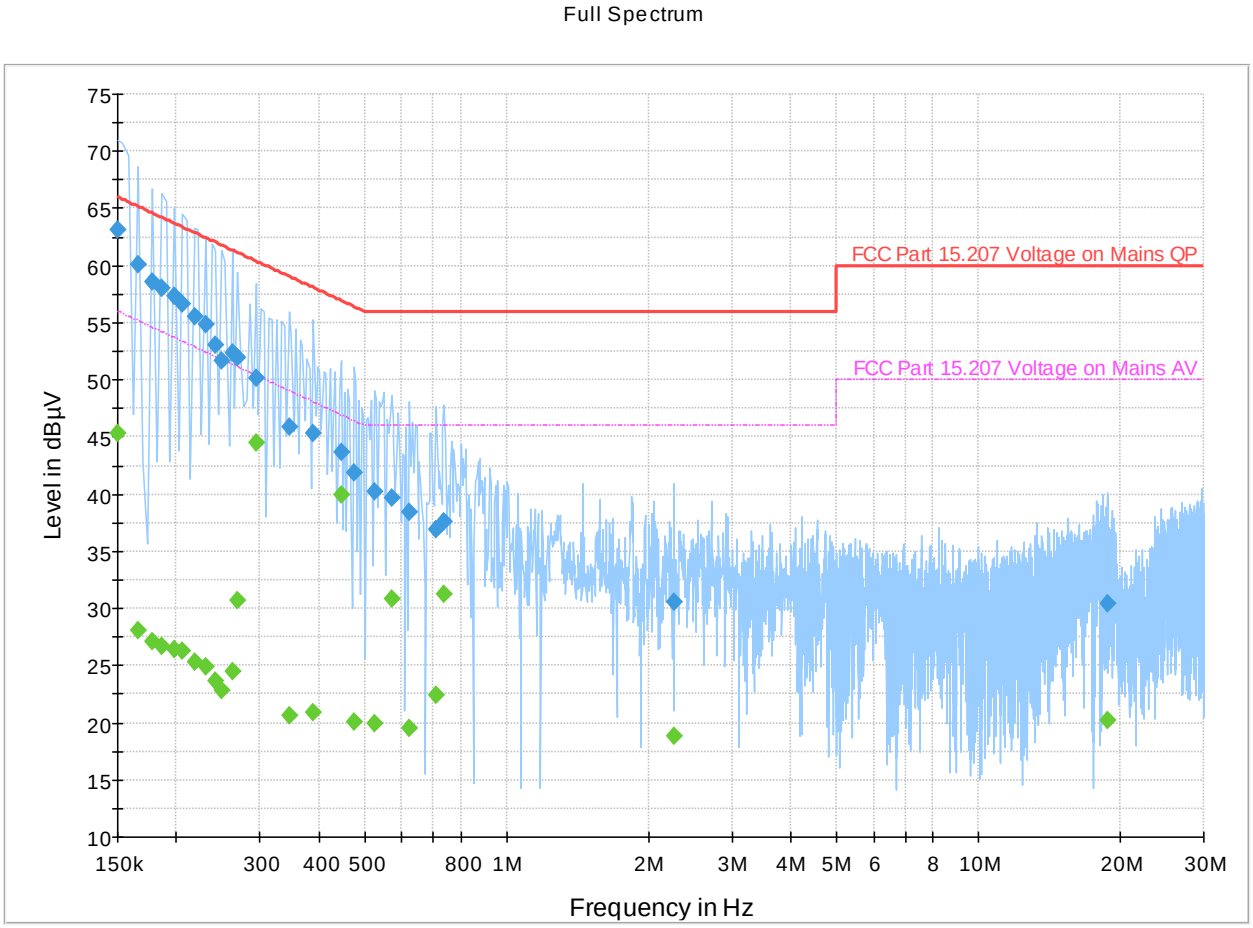


Figure 8.1-2: *AC conducted emissions spectral plot, Zigbee 2440 MHz*

Table 8.1-3: *AC conducted emissions results, Zigbee 2440 MHz*

Frequency (MHz)	QuasiPeak (dBµV)	CAverage (dBµV)	Limit (dBµV)	Margin (dB)	Meas. Time (ms)	Bandwidth (kHz)	Line	Filter	Corr. (dB)
0.150000	---	45.31	56.00	10.69	5000.0	9.000	L1	ON	19.6
0.150000	63.18	---	66.00	2.82	5000.0	9.000	L1	ON	19.6
0.166000	---	28.12	55.16	27.04	5000.0	9.000	N	ON	19.5
0.166000	60.14	---	65.16	5.02	5000.0	9.000	N	ON	19.5
0.178000	58.58	---	64.58	6.00	5000.0	9.000	N	ON	19.5
0.178000	---	27.17	54.58	27.40	5000.0	9.000	N	ON	19.5
0.186000	58.06	---	64.21	6.16	5000.0	9.000	N	ON	19.5
0.186000	---	26.67	54.21	27.54	5000.0	9.000	N	ON	19.5
0.198000	57.32	---	63.69	6.37	5000.0	9.000	L1	ON	19.5
0.198000	---	26.41	53.69	27.29	5000.0	9.000	L1	ON	19.5
0.206000	56.65	---	63.37	6.72	5000.0	9.000	L1	ON	19.5
0.206000	---	26.28	53.37	27.09	5000.0	9.000	L1	ON	19.5
0.218000	55.55	---	62.90	7.34	5000.0	9.000	L1	ON	19.5
0.218000	---	25.29	52.90	27.61	5000.0	9.000	L1	ON	19.5
0.230000	---	24.91	52.45	27.54	5000.0	9.000	L1	ON	19.5
0.230000	54.85	---	62.45	7.60	5000.0	9.000	L1	ON	19.5
0.242000	53.08	---	62.03	8.95	5000.0	9.000	N	ON	19.5
0.242000	---	23.66	52.03	28.37	5000.0	9.000	N	ON	19.5
0.250000	51.71	---	61.76	10.05	5000.0	9.000	N	ON	19.5
0.250000	---	22.89	51.76	28.86	5000.0	9.000	N	ON	19.5
0.262000	52.32	---	61.37	9.05	5000.0	9.000	L1	ON	19.5
0.262000	---	24.50	51.37	26.87	5000.0	9.000	L1	ON	19.5
0.270000	---	30.72	51.12	20.40	5000.0	9.000	L1	ON	19.5
0.270000	51.94	---	61.12	9.18	5000.0	9.000	L1	ON	19.5
0.294000	50.14	---	60.41	10.28	5000.0	9.000	L1	ON	19.5
0.294000	---	44.55	50.41	5.86	5000.0	9.000	L1	ON	19.5
0.346000	---	20.63	49.06	28.43	5000.0	9.000	N	ON	19.4
0.346000	45.88	---	59.06	13.17	5000.0	9.000	N	ON	19.4
0.390000	---	20.88	48.06	27.19	5000.0	9.000	L1	ON	19.5
0.390000	45.31	---	58.06	12.75	5000.0	9.000	L1	ON	19.5
0.446000	43.68	---	56.95	13.27	5000.0	9.000	L1	ON	19.4
0.446000	---	39.89	46.95	7.06	5000.0	9.000	L1	ON	19.4
0.474000	---	20.05	46.44	26.39	5000.0	9.000	L1	ON	19.4
0.474000	41.83	---	56.44	14.61	5000.0	9.000	L1	ON	19.4
0.526000	---	19.95	46.00	26.05	5000.0	9.000	L1	ON	19.4
0.526000	40.28	---	56.00	15.72	5000.0	9.000	L1	ON	19.4
0.570000	---	30.78	46.00	15.22	5000.0	9.000	L1	ON	19.4
0.570000	39.72	---	56.00	16.28	5000.0	9.000	L1	ON	19.4
0.622000	---	19.50	46.00	26.50	5000.0	9.000	L1	ON	19.4
0.622000	38.50	---	56.00	17.50	5000.0	9.000	L1	ON	19.4
0.710000	---	22.39	46.00	23.61	5000.0	9.000	L1	ON	19.4
0.710000	36.96	---	56.00	19.04	5000.0	9.000	L1	ON	19.4
0.738000	---	31.20	46.00	14.80	5000.0	9.000	L1	ON	19.4
0.738000	37.64	---	56.00	18.36	5000.0	9.000	L1	ON	19.4
2.266000	---	18.79	46.00	27.21	5000.0	9.000	L1	ON	19.4
2.266000	30.51	---	56.00	25.49	5000.0	9.000	L1	ON	19.4
18.726000	---	20.24	50.00	29.76	5000.0	9.000	N	ON	20.3
18.726000	30.39	---	60.00	29.61	5000.0	9.000	N	ON	20.3

Notes: Result (dBµV) = receiver/spectrum analyzer value (dBµV) + correction factor (dB)
Correction factor (dB) = LISN factor IL (dB) + cable loss (dB) + transient limiter (dB)
The maximum measured value observed over a period of 5 seconds was recorded.

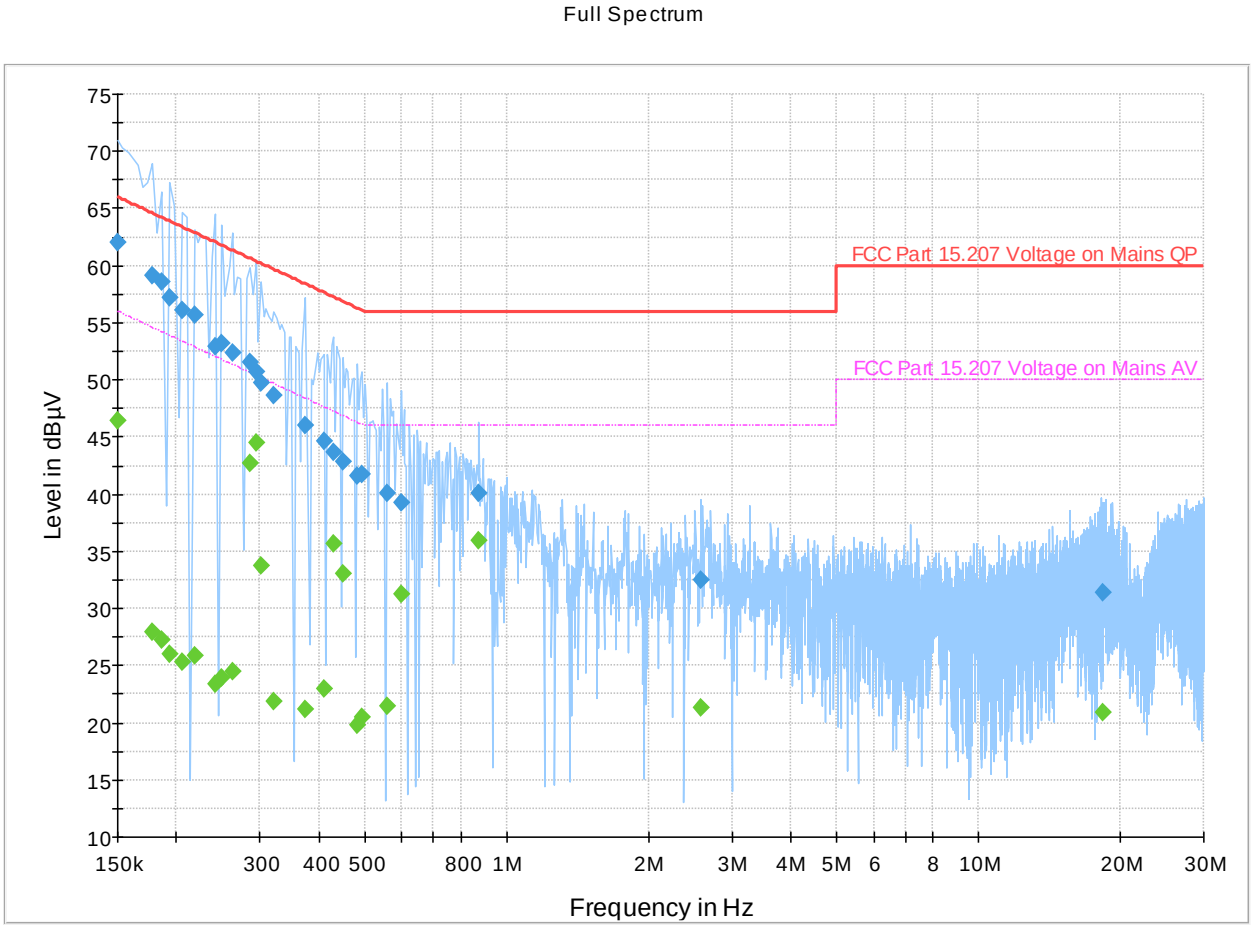


Figure 8.1-3: *AC conducted emissions spectral plot, Zigbee 2480 MHz*

Table 8.1-4: *AC conducted emissions results, Zigbee 2480 MHz*

Frequency (MHz)	QuasiPeak (dBµV)	CAverage (dBµV)	Limit (dBµV)	Margin (dB)	Meas. Time (ms)	Bandwidth (kHz)	Line	Filter	Corr. (dB)
0.150000	---	46.40	56.00	9.60	5000.0	9.000	L1	ON	19.6
0.150000	61.96	---	66.00	4.04	5000.0	9.000	L1	ON	19.6
0.178000	---	27.90	54.58	26.68	5000.0	9.000	L1	ON	19.6
0.178000	59.16	---	64.58	5.42	5000.0	9.000	L1	ON	19.6
0.186000	---	27.20	54.21	27.01	5000.0	9.000	L1	ON	19.6
0.186000	58.63	---	64.21	5.58	5000.0	9.000	L1	ON	19.6
0.194000	57.13	---	63.86	6.73	5000.0	9.000	N	ON	19.5
0.194000	---	26.06	53.86	27.80	5000.0	9.000	N	ON	19.5
0.206000	---	25.38	53.37	27.99	5000.0	9.000	N	ON	19.5
0.206000	56.16	---	63.37	7.21	5000.0	9.000	N	ON	19.5
0.218000	---	25.84	52.90	27.05	5000.0	9.000	L1	ON	19.5
0.218000	55.68	---	62.90	7.21	5000.0	9.000	L1	ON	19.5
0.242000	52.88	---	62.03	9.15	5000.0	9.000	N	ON	19.5
0.242000	---	23.39	52.03	28.63	5000.0	9.000	N	ON	19.5
0.250000	---	23.95	51.76	27.81	5000.0	9.000	L1	ON	19.5
0.250000	53.18	---	61.76	8.57	5000.0	9.000	L1	ON	19.5
0.262000	---	24.51	51.37	26.86	5000.0	9.000	L1	ON	19.5
0.262000	52.31	---	61.37	9.06	5000.0	9.000	L1	ON	19.5
0.286000	---	42.67	50.64	7.97	5000.0	9.000	L1	ON	19.5
0.286000	51.48	---	60.64	9.16	5000.0	9.000	L1	ON	19.5
0.294000	---	44.51	50.41	5.90	5000.0	9.000	L1	ON	19.5
0.294000	50.72	---	60.41	9.69	5000.0	9.000	L1	ON	19.5
0.302000	49.71	---	60.19	10.48	5000.0	9.000	L1	ON	19.5
0.302000	---	33.74	50.19	16.45	5000.0	9.000	L1	ON	19.5
0.322000	---	21.83	49.66	27.83	5000.0	9.000	L1	ON	19.5
0.322000	48.65	---	59.66	11.00	5000.0	9.000	L1	ON	19.5
0.374000	---	21.19	48.41	27.22	5000.0	9.000	L1	ON	19.5
0.374000	45.98	---	58.41	12.43	5000.0	9.000	L1	ON	19.5
0.410000	44.59	---	57.65	13.06	5000.0	9.000	L1	ON	19.5
0.410000	---	22.93	47.65	24.72	5000.0	9.000	L1	ON	19.5
0.430000	---	35.70	47.25	11.56	5000.0	9.000	L1	ON	19.4
0.430000	43.66	---	57.25	13.60	5000.0	9.000	L1	ON	19.4
0.450000	42.82	---	56.88	14.05	5000.0	9.000	L1	ON	19.4
0.450000	---	33.03	46.88	13.85	5000.0	9.000	L1	ON	19.4
0.482000	---	19.86	46.31	26.45	5000.0	9.000	L1	ON	19.4
0.482000	41.65	---	56.31	14.66	5000.0	9.000	L1	ON	19.4
0.494000	41.68	---	56.10	14.42	5000.0	9.000	L1	ON	19.4
0.494000	---	20.55	46.10	25.55	5000.0	9.000	L1	ON	19.4
0.558000	40.03	---	56.00	15.97	5000.0	9.000	L1	ON	19.4
0.558000	---	21.40	46.00	24.60	5000.0	9.000	L1	ON	19.4
0.598000	39.23	---	56.00	16.77	5000.0	9.000	L1	ON	19.4
0.598000	---	31.29	46.00	14.71	5000.0	9.000	L1	ON	19.4
0.874000	---	35.89	46.00	10.11	5000.0	9.000	L1	ON	19.4
0.874000	40.13	---	56.00	15.87	5000.0	9.000	L1	ON	19.4
2.590000	---	21.34	46.00	24.66	5000.0	9.000	L1	ON	19.4
2.590000	32.47	---	56.00	23.53	5000.0	9.000	L1	ON	19.4
18.294000	---	20.89	50.00	29.11	5000.0	9.000	N	ON	20.3
18.294000	31.41	---	60.00	28.59	5000.0	9.000	N	ON	20.3

Notes: Result (dBµV) = receiver/spectrum analyzer value (dBµV) + correction factor (dB)
Correction factor (dB) = LISN factor IL (dB) + cable loss (dB) + transient limiter (dB)
The maximum measured value observed over a period of 5 seconds was recorded.

8.2 FCC 15.247(a)(2) and RSS-247 5.2(1) Minimum 6 dB bandwidth for systems using digital modulation techniques References

8.2.1 Definition and limits

Title 47 → Chapter I → Subchapter A → Part 15 → Subpart C → §15.247(a)(2)
RSS-247 → §5.2(a)

(a) Operation under the provisions of this Section is limited to frequency hopping and digitally modulated intentional radiators that comply with the following provisions:

(2) Systems using digital modulation techniques may operate in the 902–928 MHz, 2400–2483.5 MHz and 5725–5850 MHz bands. The minimum 6 dB bandwidth shall be at least 500 kHz.

8.2.2 Test summary

Verdict	Pass		
Test date	April 6, 2021	Temperature	22 °C
Test engineer	David Hewitt, EMC Specialist	Air pressure	1005 mbar
Test location	Ground Plane	Relative humidity	48 %

8.2.1 Notes

Testing was performed with the Zigbee transmitter operating on a fixed channel at client-specified full power. Low, middle, and high channels were tested.

The EUT antenna port was connected to the spectrum analyzer via low loss cable and a suitable attenuator. The loss of this assembly was corrected for via a transducer factor in the spectrum analyzer.

8.2.2 Setup details

EUT setup configuration	Table top
Test facility	Nemko San Diego
Measurement method	558074 D01 DTS Measurement Guidance §8.2 ANSI C63.10 §11.8.1 using built-in marker function of the spectrum analyzer

Receiver/spectrum analyzer settings:

Resolution bandwidth	100 kHz
Video bandwidth	300 kHz
Detector mode	Peak
Trace mode	Max Hold
Measurement time	Long enough for trace to stabilize

8.2.3 Test data

Table 8.2-1: *6 dB occupied bandwidth test data*

Test Frequency (MHz)	Bandwidth (kHz)	Limit (kHz)	Margin (kHz)
2405	1840	> 500	1340
2440	1700	> 500	1200
2480	1710	> 500	1210

8.2.5 Test data, continued

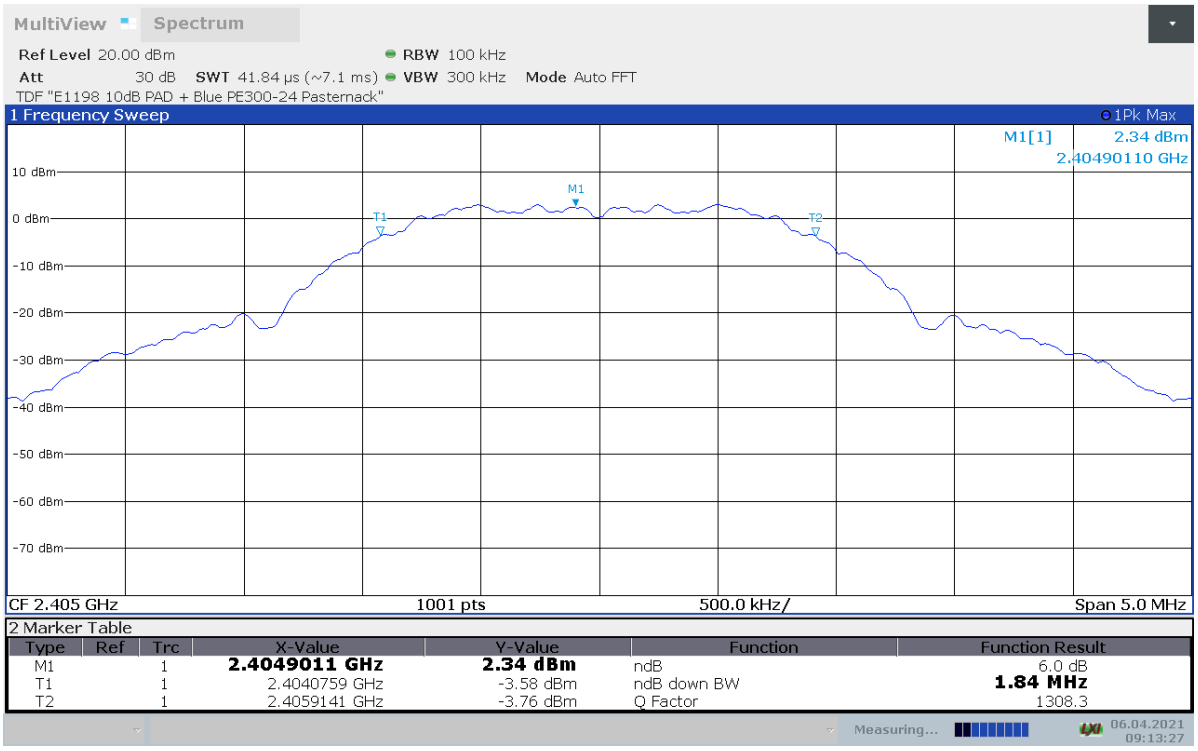


Figure 8.2-1: *6 dB occupied bandwidth, 2405 MHz*

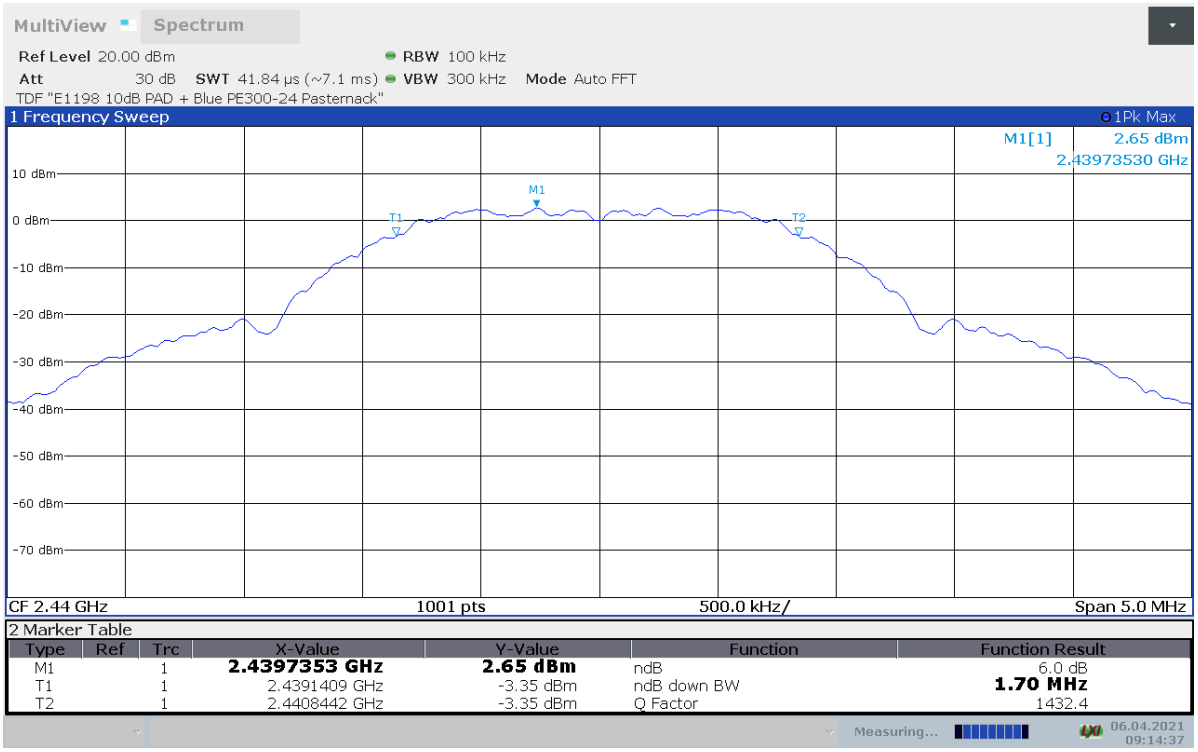


Figure 8.2-2: *6 dB occupied bandwidth, 2440 MHz*

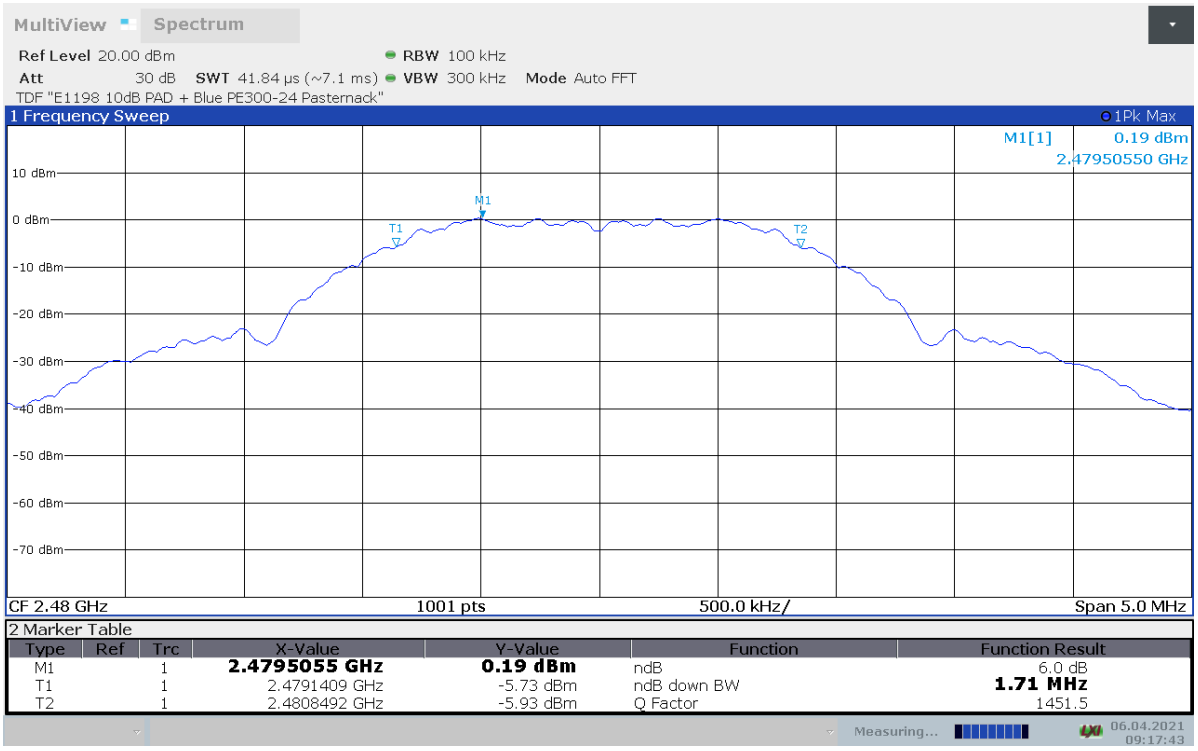


Figure 8.2-3: *6 dB occupied bandwidth, 2480 MHz*

8.3 FCC 15.247(b) and RSS-247 5.4 (4) Transmitter output power and e.i.r.p. requirements

8.3.1 Definition and limits

Title 47 → Chapter I → Subchapter A → Part 15 → Subpart C → §15.247(b)(2) / (3)

(b) The maximum peak conducted output power of the intentional radiator shall not exceed the following:

(3) For systems using digital modulation in the 902–928 MHz, 2400–2483.5 MHz, and 5725–5850 MHz bands: 1 W (30 dBm). As an alternative to a peak power measurement, compliance with the one-Watt limit can be based on a measurement of the maximum conducted output power. Maximum Conducted Output Power is defined as the total transmit power delivered to all antennas and antenna elements averaged across all symbols in the signaling alphabet when the transmitter is operating at its maximum power control level. Power must be summed across all antennas and antenna elements. The average must not include any time intervals during which the transmitter is off or is transmitting at a reduced power level. If multiple modes of operation are possible (e.g., alternative modulation methods), the maximum conducted output power is the highest total transmit power occurring in any mode.

(4) The conducted output power limit specified in paragraph (b) of this Section is based on the use of antennas with directional gains that do not exceed 6 dBi. Except as shown in paragraph (c) of this Section, if transmitting antennas of directional gain greater than 6 dBi are used, the conducted output power from the intentional radiator shall be reduced below the stated values in paragraphs (b)(1), (b)(2), and (b)(3) of this Section, as appropriate, by the amount in dB that the directional gain of the antenna exceeds 6 dBi.

(i) Systems operating in the 2400–2483.5 MHz band that are used exclusively for fixed, point-to-point operations may employ transmitting antennas with directional gain greater than 6 dBi provided the maximum peak output power of the intentional radiator is reduced by 1 dB for every 3 dB that the directional gain of the antenna exceeds 6 dBi.

RSS-247 → §5.4(d)

(d) For DTSs employing digital modulation techniques operating in the bands 902-928 MHz and 2400-2483.5 MHz, the maximum peak conducted output power shall not exceed 1 W. The e.i.r.p. shall not exceed 4 W, except as provided in section 5.4(e).

As an alternative to a peak power measurement, compliance can be based on a measurement of the maximum conducted output power. The maximum conducted output power is the total transmit power delivered to all antennas and antenna elements, averaged across all symbols in the signalling alphabet when the transmitter is operating at its maximum power control level. Power must be summed across all antennas and antenna elements. The average must not include any time intervals during which the transmitter is off or transmitting at a reduced power level. If multiple modes of operation are implemented, the maximum conducted output power is the highest total transmit power occurring in any mode.

8.3.2 Test summary

Verdict	Pass		
Test date	April 6, 2021	Temperature	22 °C
Test engineer	David Hewitt, EMC Specialist	Air pressure	1005 mbar
Test location	Wireless bench	Relative humidity	50 %

8.3.3 Notes

Testing was performed with the Zigbee transmitter operating on a fixed channel at client-specified full power. Low, middle, and high channels were tested.

The attenuation of the interconnecting cable was included in the power meter software as a correction factor.

The antenna gain is 1.5 dBi per client declaration.

The duty cycle of transmitter output signal is 100%, so no duty cycle correction factor was necessary.

EIRP = Conducted Power + Declared Antenna Gain

8.3.4 Setup details

EUT setup configuration	Table top
Test facility	Nemko San Diego
Measurement method	ANSI C63.10 §11.9.2.3 AVGPM Power Meter

8.3.5 Test data

Table 8.3-1: *Output power*

Test Frequency (MHz)	Measured Conducted Power (dBm)	Conducted Limit (dBm)	Antenna Gain (dBi)	EIRP (dBm)	EIRP Limit (dBm)
2405	7.11	30.0	2.5	9.61	36.0
2440	7.04	30.0	2.5	9.54	36.0
2480	4.96	30.0	2.5	9.46	36.0

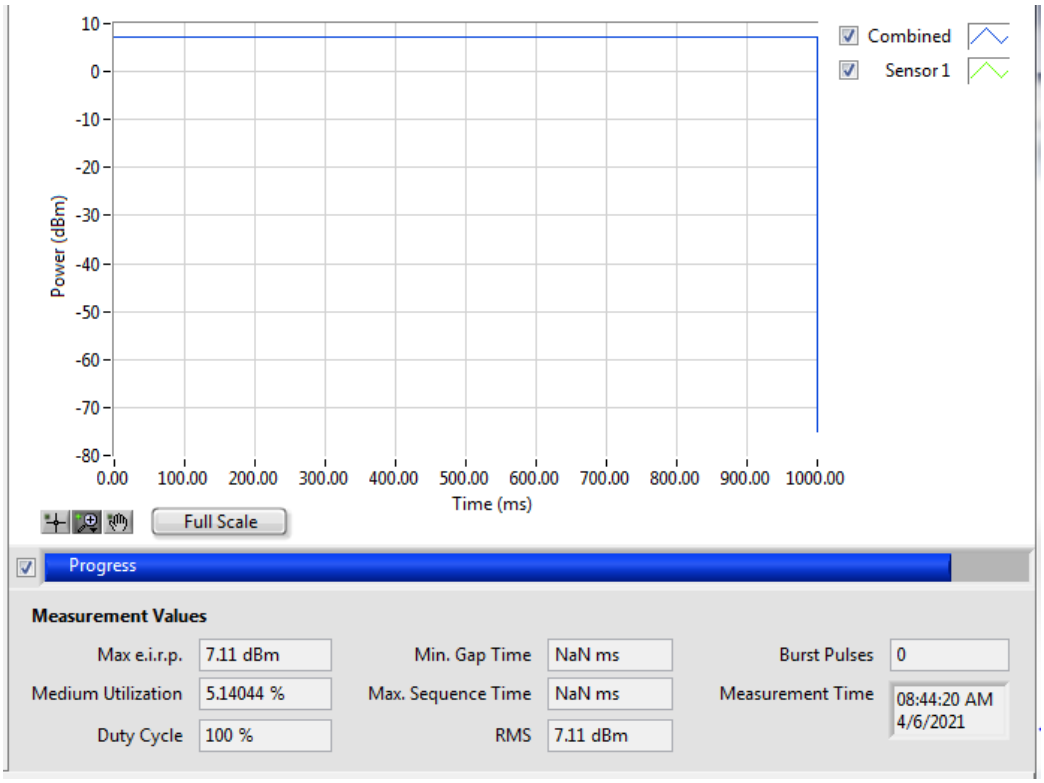


Figure 8.3-1: *Output power, 2405 MHz*

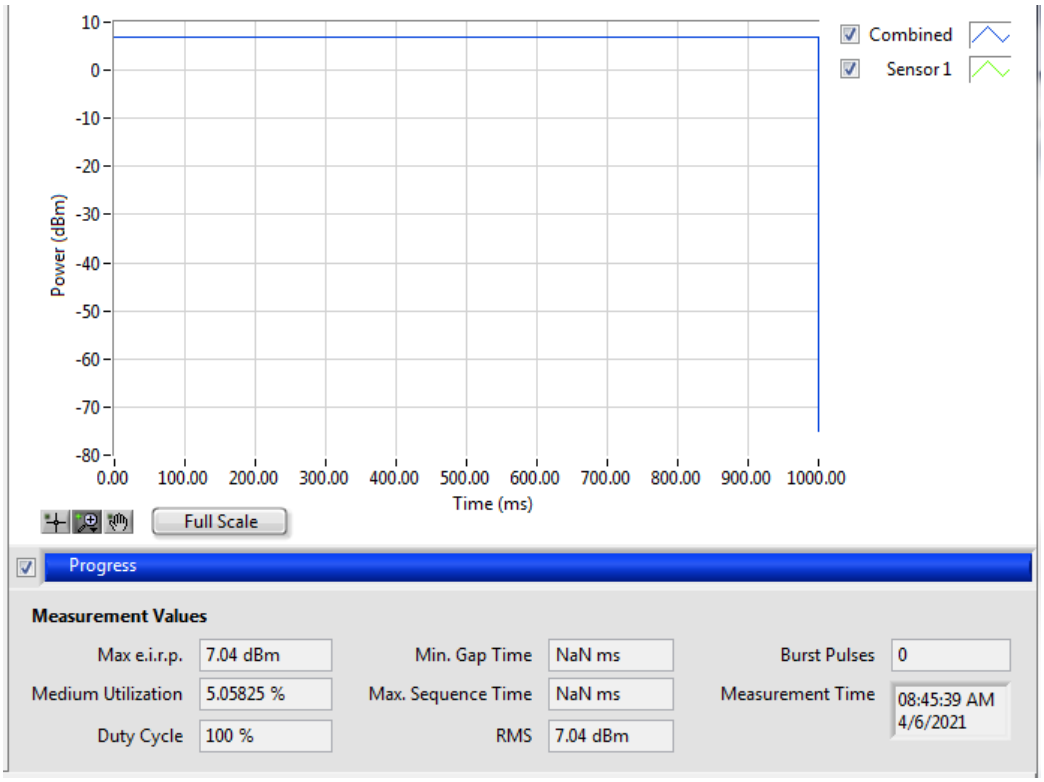


Figure 8.3-2: *Output power, 2440 MHz*

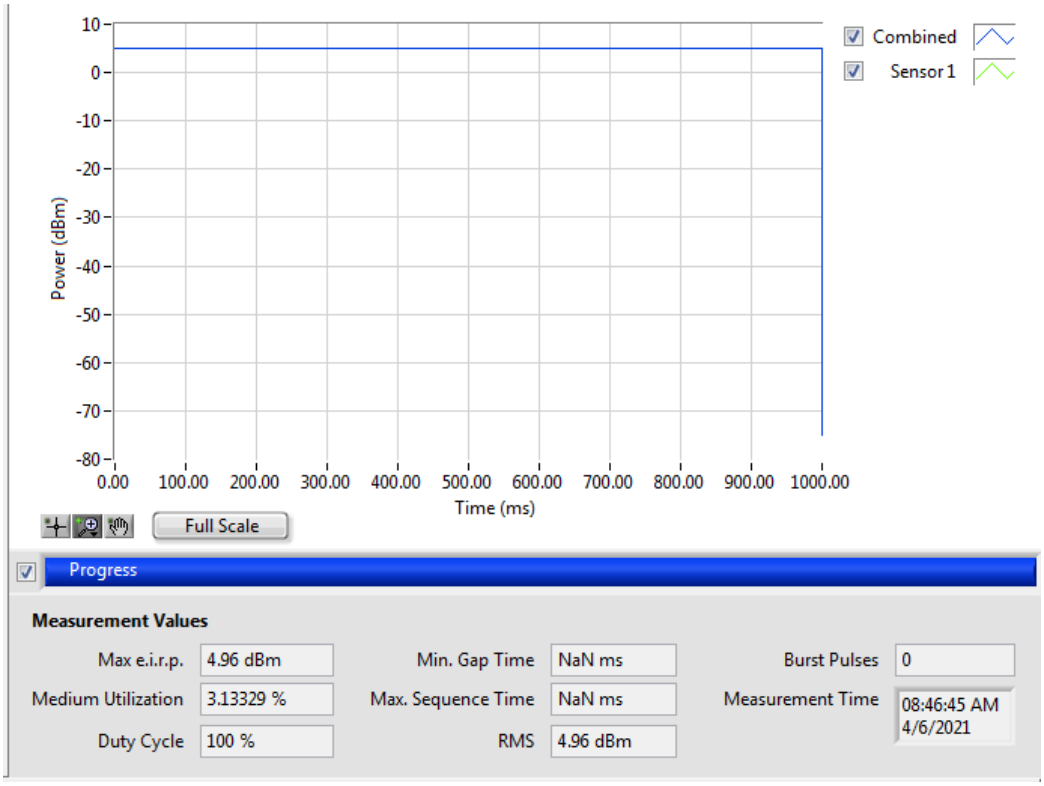


Figure 8.3-3: *Output power, 2480 MHz*

8.4 FCC Part 15.247(d) and RSS-247 5.5 Conducted band-edge spurious emissions

8.4.1 Definition and limits

Title 47 → Chapter I → Subchapter A → Part 15 → Subpart C → §15.247(d)

(d) In any 100 kHz bandwidth outside the frequency band in which the spread spectrum or digitally modulated intentional radiator is operating, the radio frequency power that is produced by the intentional radiator shall be at least 20 dB below that in the 100 kHz bandwidth within the band that contains the highest level of the desired power, based on either an RF conducted or a radiated measurement, provided the transmitter demonstrates compliance with the peak conducted power limits. If the transmitter complies with the conducted power limits based on the use of RMS averaging over a time interval, as permitted under paragraph (b)(3) of this section, the attenuation required under this paragraph shall be 30 dB instead of 20 dB. Attenuation below the general limits specified in §15.209(a) is not required. In addition, radiated emissions which fall in the restricted bands, as defined in §15.205(a), must also comply with the radiated emission limits specified in §15.209(a) (see §15.205(c)).

RSS-247 → §5.5

In any 100 kHz bandwidth outside the frequency band in which the spread spectrum or digitally modulated device is operating, the RF power that is produced shall be at least 20 dB below that in the 100 kHz bandwidth within the band that contains the highest level of the desired power, based on either an RF conducted or a radiated measurement, provided that the transmitter demonstrates compliance with the peak conducted power limits. If the transmitter complies with the conducted power limits based on the use of root-mean-square averaging over a time interval, as permitted under section 5.4(d), the attenuation required shall be 30 dB instead of 20 dB. Attenuation below the general field strength limits specified in RSS-Gen is not required.

8.4.2 Test summary

Verdict	Pass		
Test date	April 6, 2021	Temperature	23 °C
Test engineer	David Hewitt, EMC Specialist	Air pressure	1007 mbar
Test location	Wireless bench (Conducted)	Relative humidity	48 %

8.4.3 Notes

Testing was performed with the Zigbee transmitter operating on a fixed channel at client-specified full power. Low, middle, and high channels were tested.

The EUT antenna port was connected to the spectrum analyzer via low loss cable and a suitable attenuator. The loss of this assembly was corrected for via a transducer factor in the spectrum analyzer.

8.4.4 Setup details

EUT setup configuration	Tabletop
Test facility	Wireless bench
Measurement details	Conducted band edge measurement performed as per C63.10 §6.10.4 Conducted spurious emissions measurement performed as per C63.10 §11.11

Spectrum analyzer settings for conducted spurious emissions:

Resolution bandwidth	100 kHz
Video bandwidth	300 kHz
Detector mode	Peak
Trace mode	Max Hold
Measurement time	Long enough for trace to stabilize

8.4.5 Test data

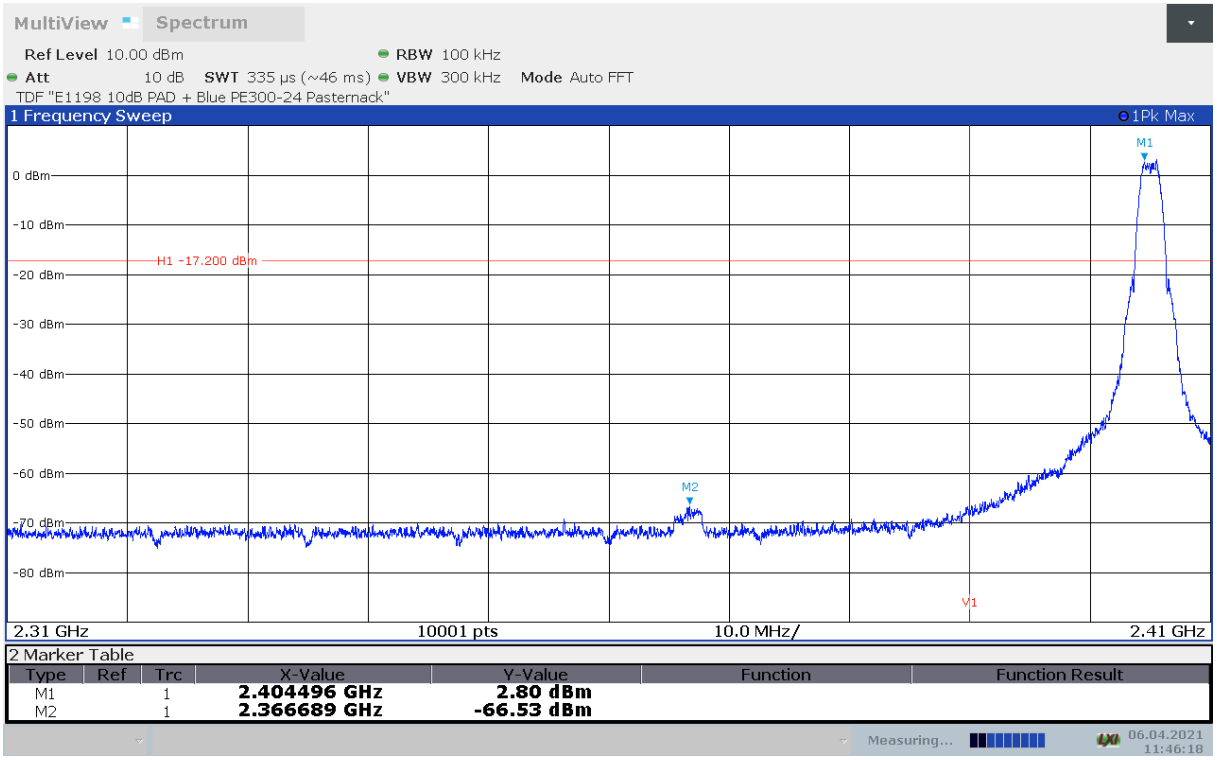


Figure 8.4-1: *Conducted Band edge measurement, 2405 MHz*

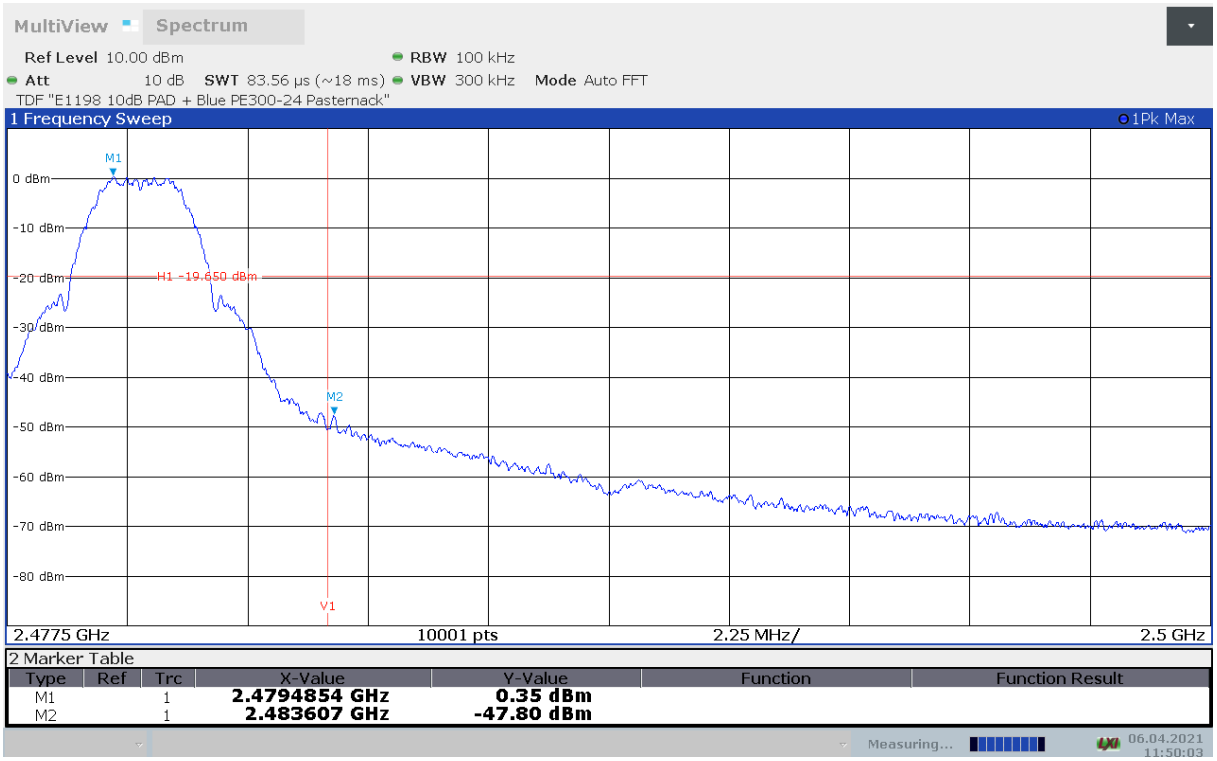


Figure 8.4-2: *Conducted Band edge measurement, 2480 MHz*

8.5 FCC 15.247(d) and RSS-247 5.5 Conducted spurious emissions

8.5.1 Definition and limits

Title 47 → Chapter I → Subchapter A → Part 15 → Subpart C → §15.247(d)

(d) In any 100 kHz bandwidth outside the frequency band in which the spread spectrum or digitally modulated intentional radiator is operating, the radio frequency power that is produced by the intentional radiator shall be at least 20 dB below that in the 100 kHz bandwidth within the band that contains the highest level of the desired power, based on either an RF conducted or a radiated measurement, provided the transmitter demonstrates compliance with the peak conducted power limits. If the transmitter complies with the conducted power limits based on the use of RMS averaging over a time interval, as permitted under paragraph (b)(3) of this section, the attenuation required under this paragraph shall be 30 dB instead of 20 dB. Attenuation below the general limits specified in §15.209(a) is not required. In addition, radiated emissions which fall in the restricted bands, as defined in §15.205(a), must also comply with the radiated emission limits specified in §15.209(a) (see §15.205(c)).

RSS-247 → §5.5

In any 100 kHz bandwidth outside the frequency band in which the spread spectrum or digitally modulated device is operating, the RF power that is produced shall be at least 20 dB below that in the 100 kHz bandwidth within the band that contains the highest level of the desired power, based on either an RF conducted or a radiated measurement, provided that the transmitter demonstrates compliance with the peak conducted power limits. If the transmitter complies with the conducted power limits based on the use of root-mean-square averaging over a time interval, as permitted under section 5.4(d), the attenuation required shall be 30 dB instead of 20 dB. Attenuation below the general field strength limits specified in RSS-Gen is not required.

8.5.1 Test summary

Verdict	Pass		
Test date	April 6, 2021	Temperature	23 °C
Test engineer	David Hewitt, EMC Specialist	Air pressure	1007 mbar
Test location	Wireless bench (Conducted)	Relative humidity	48 %

8.5.2 Notes

Testing was performed with the Zigbee transmitter operating on a fixed channel at client-specified full power. Low, middle, and high channels were tested.

The EUT antenna port was connected to the spectrum analyzer via low loss cable and a suitable attenuator. The loss of this assembly was corrected for via a transducer factor in the spectrum analyzer.

The spectrum was searched from 30 MHz to 26 GHz (above the 10th harmonic of the highest transmit frequency of 2480 MHz).

8.5.3 Setup details

EUT setup configuration	Tabletop
Test facility	Wireless bench
Measurement details	Conducted spurious emissions measurement performed as per C63.10 §11.11.3

Spectrum analyzer settings for conducted spurious emissions:

Resolution bandwidth	100 kHz
Video bandwidth	300 kHz
Detector mode	Peak
Trace mode	Max Hold
Measurement time	Long enough for trace to stabilize

8.5.4 Test data

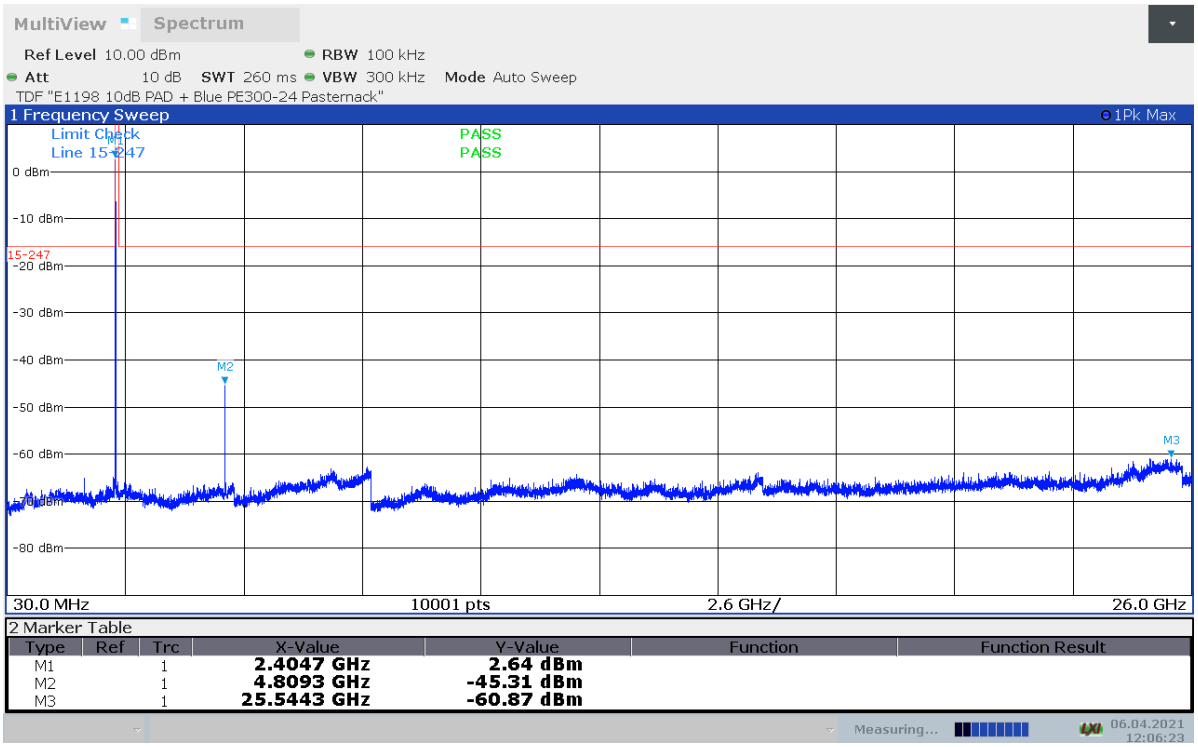


Figure 8.5-1: *Conducted spurious emissions, 2405 MHz*

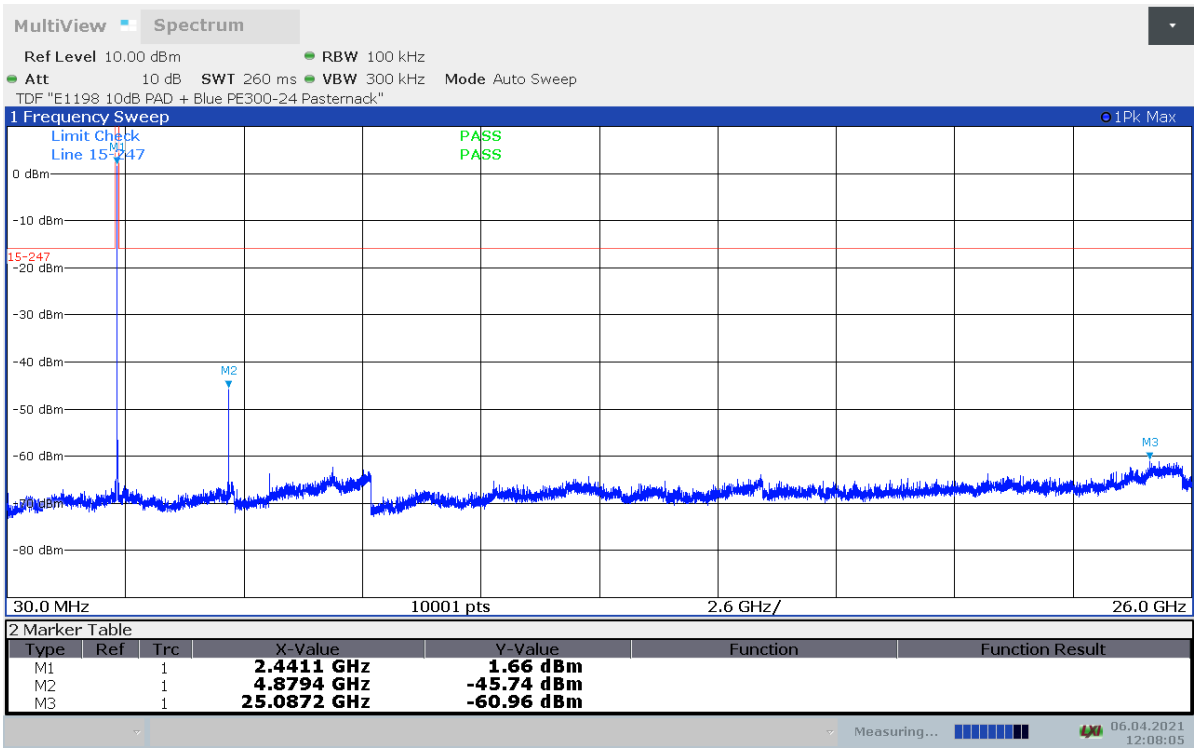


Figure 8.5-2: *Conducted spurious emissions, 2440 MHz*

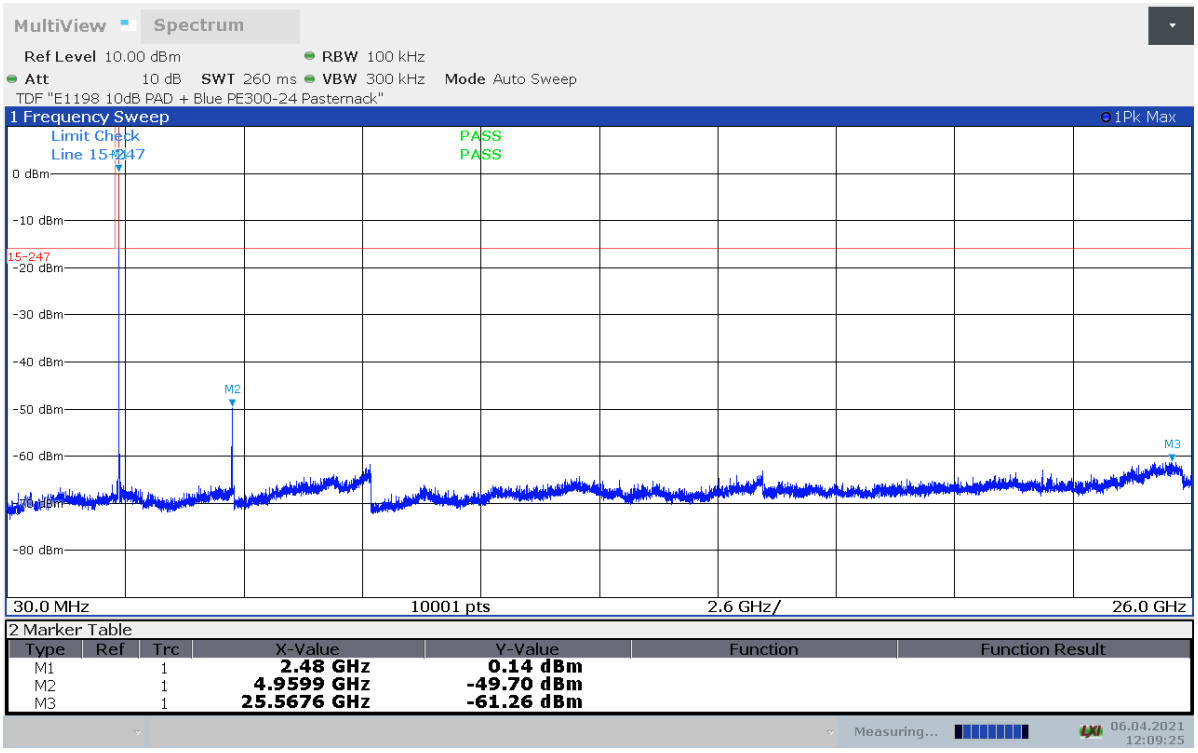


Figure 8.5-3: *Conducted spurious emissions, 2480 MHz*

Note: For the conducted emissions plots above, peaks within 2400-2483.5MHz are transmitter fundamentals signals and are not evaluated against the relevant limits.

8.6 FCC 15.247(d) and RSS-247 5.5 Radiated restricted band-edges and spurious emission

8.6.1 Definition and limits

Title 47 → Chapter I → Subchapter A → Part 15 → Subpart C → §15.247(d)

(d) In any 100 kHz bandwidth outside the frequency band in which the spread spectrum or digitally modulated intentional radiator is operating, the radio frequency power that is produced by the intentional radiator shall be at least 20 dB below that in the 100 kHz bandwidth within the band that contains the highest level of the desired power, based on either an RF conducted or a radiated measurement, provided the transmitter demonstrates compliance with the peak conducted power limits. If the transmitter complies with the conducted power limits based on the use of RMS averaging over a time interval, as permitted under paragraph (b)(3) of this section, the attenuation required under this paragraph shall be 30 dB instead of 20 dB. Attenuation below the general limits specified in §15.209(a) is not required. In addition, radiated emissions which fall in the restricted bands, as defined in §15.205(a), must also comply with the radiated emission limits specified in §15.209(a) (see §15.205(c)).

RSS-247 → §5.5

In any 100 kHz bandwidth outside the frequency band in which the spread spectrum or digitally modulated device is operating, the RF power that is produced shall be at least 20 dB below that in the 100 kHz bandwidth within the band that contains the highest level of the desired power, based on either an RF conducted or a radiated measurement, provided that the transmitter demonstrates compliance with the peak conducted power limits. If the transmitter complies with the conducted power limits based on the use of root-mean-square averaging over a time interval, as permitted under section 5.4(d), the attenuation required shall be 30 dB instead of 20 dB. Attenuation below the general field strength limits specified in RSS-Gen is not required.

Table 8.6-1: *FCC §15.209– Radiated emission limits*

Frequency, MHz	Field strength of emissions		Measurement distance, m
	µV/m	dBµV/m	
0.009–0.490	2400/F	$67.6 - 20 \times \log_{10}(F)$	300
0.490–1.705	24000/F	$87.6 - 20 \times \log_{10}(F)$	30
1.705–30.0	30	29.5	30
30–88	100	40.0	3
88–216	150	43.5	3
216–960	200	46.0	3
above 960	500	54.0	3

Notes: In the emission table above, the tighter limit applies at the band edges.
For frequencies above 1 GHz the limit on peak RF emissions is 20 dB above the maximum permitted average emission limit applicable to the equipment under test.

Table 8.6-2: *FCC restricted frequency bands*

MHz	MHz	MHz	GHz
0.090–0.110	16.42–16.423	399.9–410	4.5–5.15
0.495–0.505	16.69475–16.69525	608–614	5.35–5.46
2.1735–2.1905	16.80425–16.80475	960–1240	7.25–7.75
4.125–4.128	25.5–25.67	1300–1427	8.025–8.5
4.17725–4.17775	37.5–38.25	1435–1626.5	9.0–9.2
4.20725–4.20775	73–74.6	1645.5–1646.5	9.3–9.5
6.215–6.218	74.8–75.2	1660–1710	10.6–12.7
6.26775–6.26825	108–121.94	1718.8–1722.2	13.25–13.4
6.31175–6.31225	123–138	2200–2300	14.47–14.5
8.291–8.294	149.9–150.05	2310–2390	15.35–16.2
8.362–8.366	156.52475–156.52525	2483.5–2500	17.7–21.4
8.37625–8.38675	156.7–156.9	2690–2900	22.01–23.12
8.41425–8.41475	162.0125–167.17	3260–3267	23.6–24.0
12.29–12.293	167.72–173.2	3332–3339	31.2–31.8
12.51975–12.52025	240–285	3345.8–3358	36.43–36.5
12.57675–12.57725	322–335.4	3600–4400	Above 38.6
13.36–13.41			

8.6.2 Test summary

Verdict	Pass		
Test date	April 7, 2021	Temperature	20 °C
Test engineer	David Hewitt, EMC Specialist	Air pressure	1009 mbar
Test location	3m semi-anechoic chamber (Radiated)	Relative humidity	60 %
Test date	April 8, 2021	Temperature	20 °C
Test engineer	David Hewitt, EMC Specialist	Air pressure	1008 mbar
Test location	3m semi-anechoic chamber (Radiated)	Relative humidity	60 %
Test date	April 9, 2021	Temperature	20 °C
Test engineer	David Hewitt, EMC Specialist	Air pressure	1007 mbar
Test location	3m semi-anechoic chamber (Radiated)	Relative humidity	58 %

8.6.3 Notes

Testing was performed with the Zigbee transmitter operating on a fixed channel at client-specified full power. Low, middle, and high channels were tested.

The spectrum was searched from 30 MHz to 26 GHz (above the 10th harmonic of the highest transmit frequency of 2480 MHz).

Radiated measurements were performed at a 3 m measurement distance.

8.6.4 Setup details

EUT setup configuration	Tabletop
Test facility	Nemko San Diego
Measurement details	Radiated spurious emissions measurement performed as per C63.10 §11.12

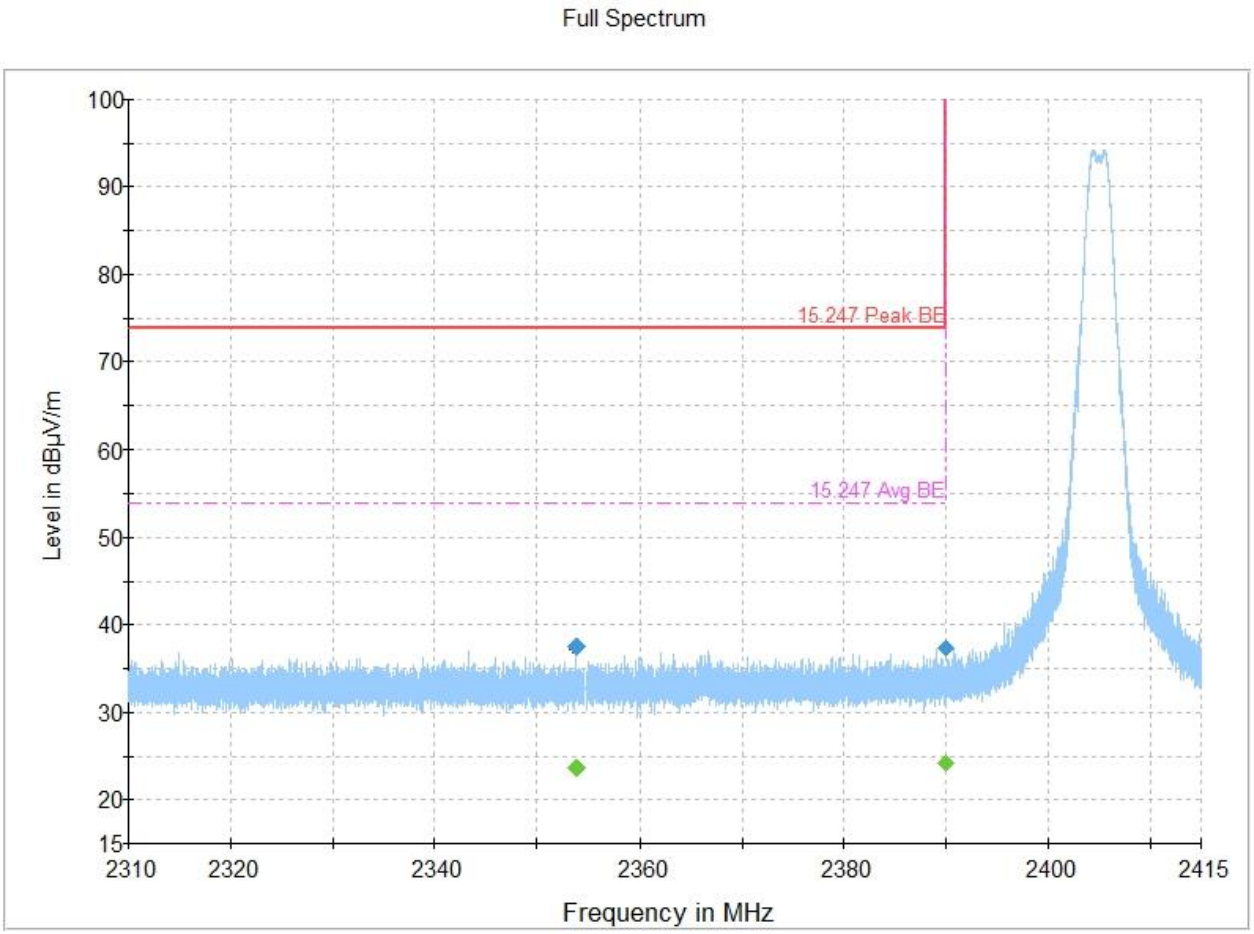
Receiver settings for radiated measurements within restricted bands below 1 GHz:

Resolution bandwidth	120 kHz
Video bandwidth	300 kHz
Detector mode	Peak (preview measurements) Quasi-Peak (final measurements)
Trace mode	Max Hold
Measurement time	5 s (final measurements)

Receiver settings for radiated measurements within restricted bands above 1 GHz:

Resolution bandwidth	1 MHz
Video bandwidth	3 MHz
Detector mode	Average and peak (final measurements)
Trace mode	Max Hold
Measurement time	5 s (final measurements)

8.6.5 Test data



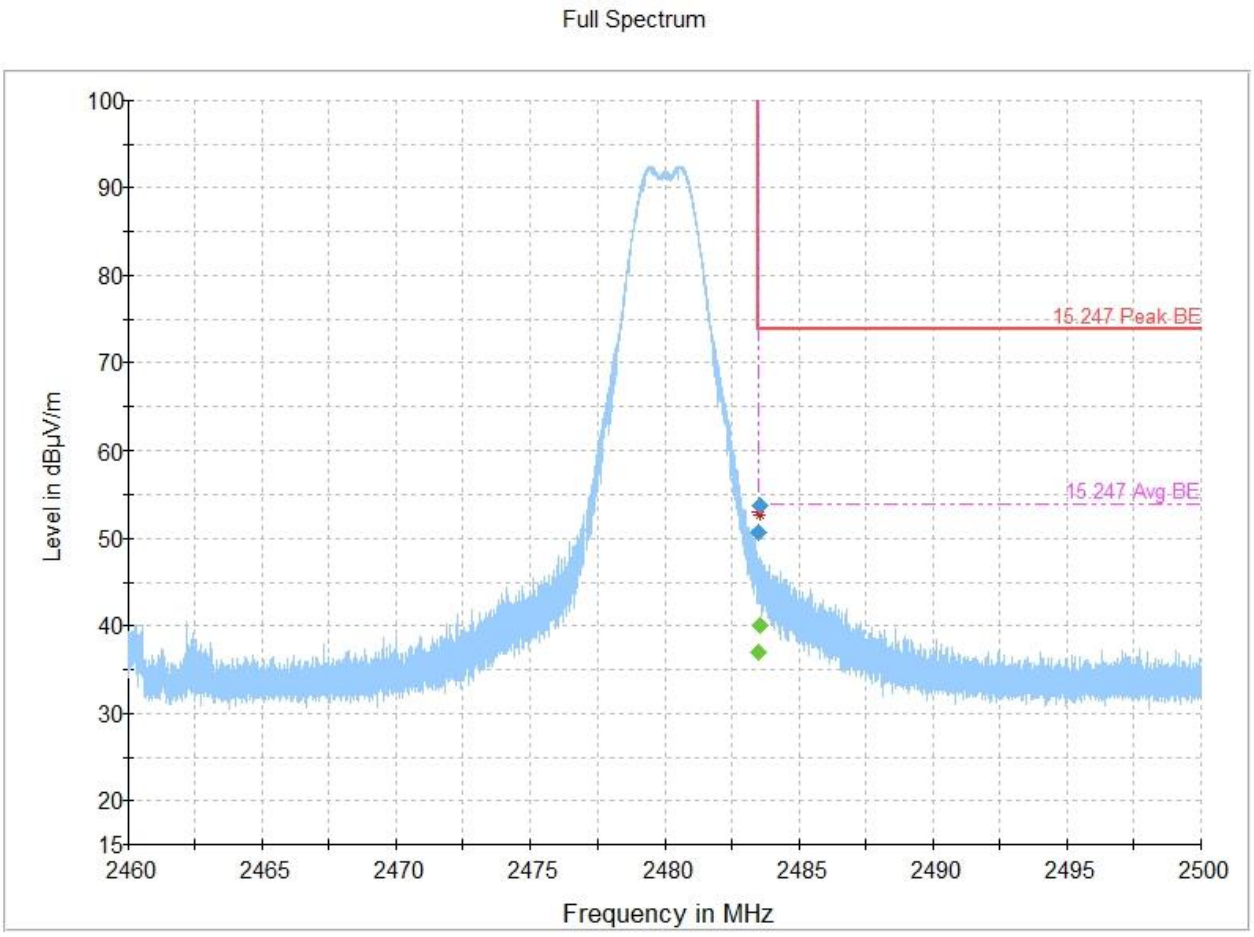
The spectral plot is a summation of a vertical and horizontal scan. The spectral scan has been corrected with the associated transducer factors (i.e. antenna factors, cable loss, amplifier gains, and attenuators).

Figure 8.6-1: *Radiated emissions, restricted band edge, low channel spectral plot*

Table 8.6-2: *Radiated emissions, restricted band edge, low channel results*

Frequency (MHz)	MaxPeak (dBµV/m)	CAverage (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Meas. Time (ms)	Bandwidth (kHz)	Height (cm)	Pol	Azimuth (deg)	Corr. (dB/m)
2353.830500	---	23.72	53.90	30.18	5000.0	1000.000	139.0	V	25.0	-10.3
2353.830500	37.64	---	73.90	36.26	5000.0	1000.000	139.0	V	25.0	-10.3
2390.000000	---	24.15	53.90	29.75	5000.0	1000.000	310.0	V	60.0	-10.1
2390.000000	37.44	---	73.90	36.46	5000.0	1000.000	310.0	V	60.0	-10.1

Notes: [1] Field strength (dBµV/m) = receiver/spectrum analyzer value (dBµV) + correction factor (dB)
[2] Correction factor = antenna factor ACF (dB) + cable loss (dB)
[3] The maximum measured value observed over a period of 5 seconds was recorded.



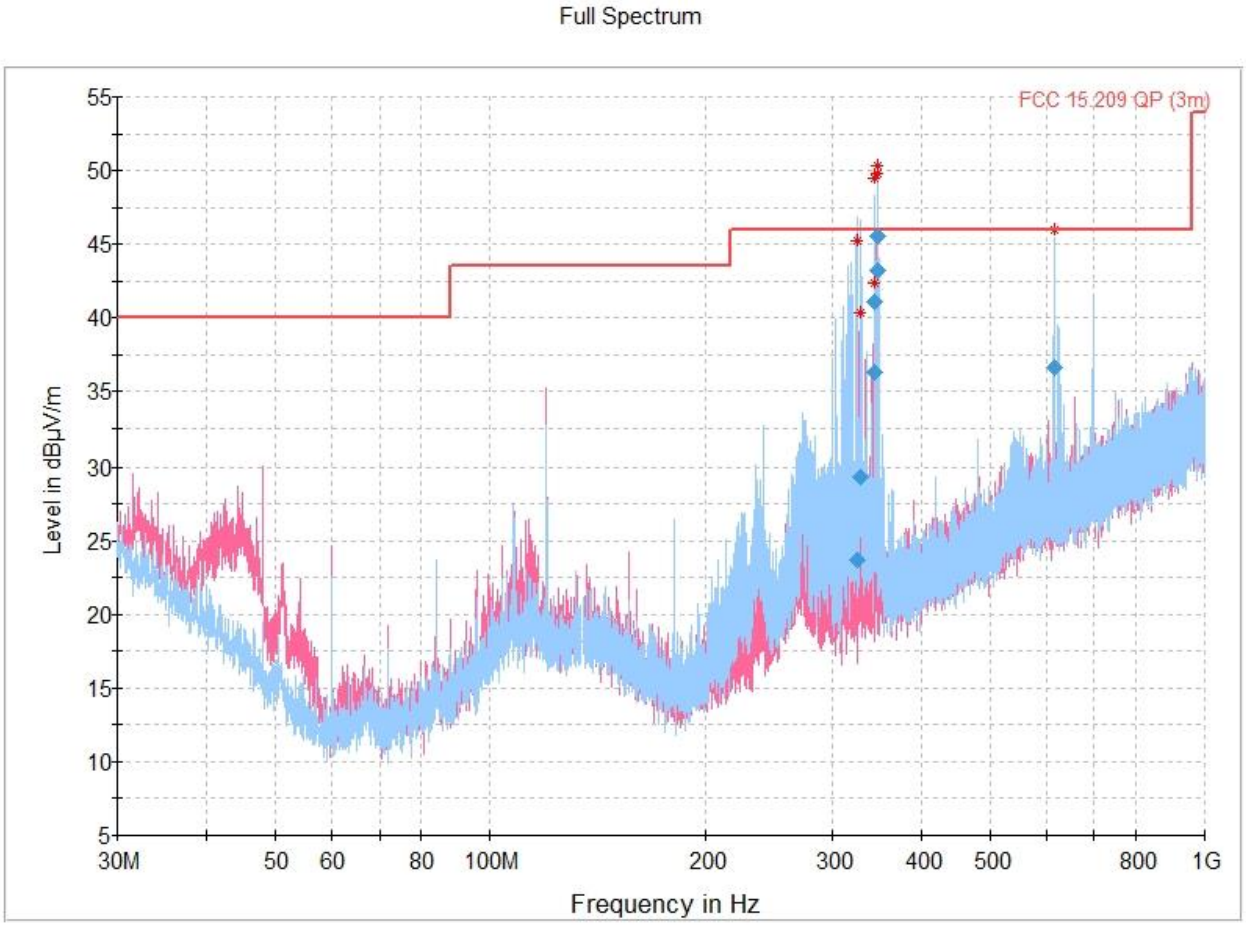
The spectral plot is a summation of a vertical and horizontal scan. The spectral scan has been corrected with the associated transducer factors (i.e. antenna factors, cable loss, amplifier gains, and attenuators).

Figure 8.6-2: *Radiated emissions, restricted band edge, high channel spectral plot*

Table 8.6-3: *Radiated emissions, restricted band edge, high channel results*

Frequency (MHz)	MaxPeak (dBµV/m)	CAverage (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Meas. Time (ms)	Bandwidth (kHz)	Height (cm)	Pol	Azimuth (deg)	Corr. (dB/m)
2483.500000	---	36.96	53.90	16.94	5000.0	1000.000	144.0	H	297.0	-9.5
2483.500000	50.72	---	73.90	23.18	5000.0	1000.000	144.0	H	297.0	-9.5
2483.525333	---	40.14	53.90	13.76	5000.0	1000.000	117.0	H	308.0	-9.5
2483.525333	53.78	---	73.90	20.12	5000.0	1000.000	117.0	H	308.0	-9.5

Notes: [1] Field strength (dBµV/m) = receiver/spectrum analyzer value (dBµV) + correction factor (dB)
[2] Correction factor = antenna factor ACF (dB) + cable loss (dB)
[3] The maximum measured value observed over a period of 5 seconds was recorded.



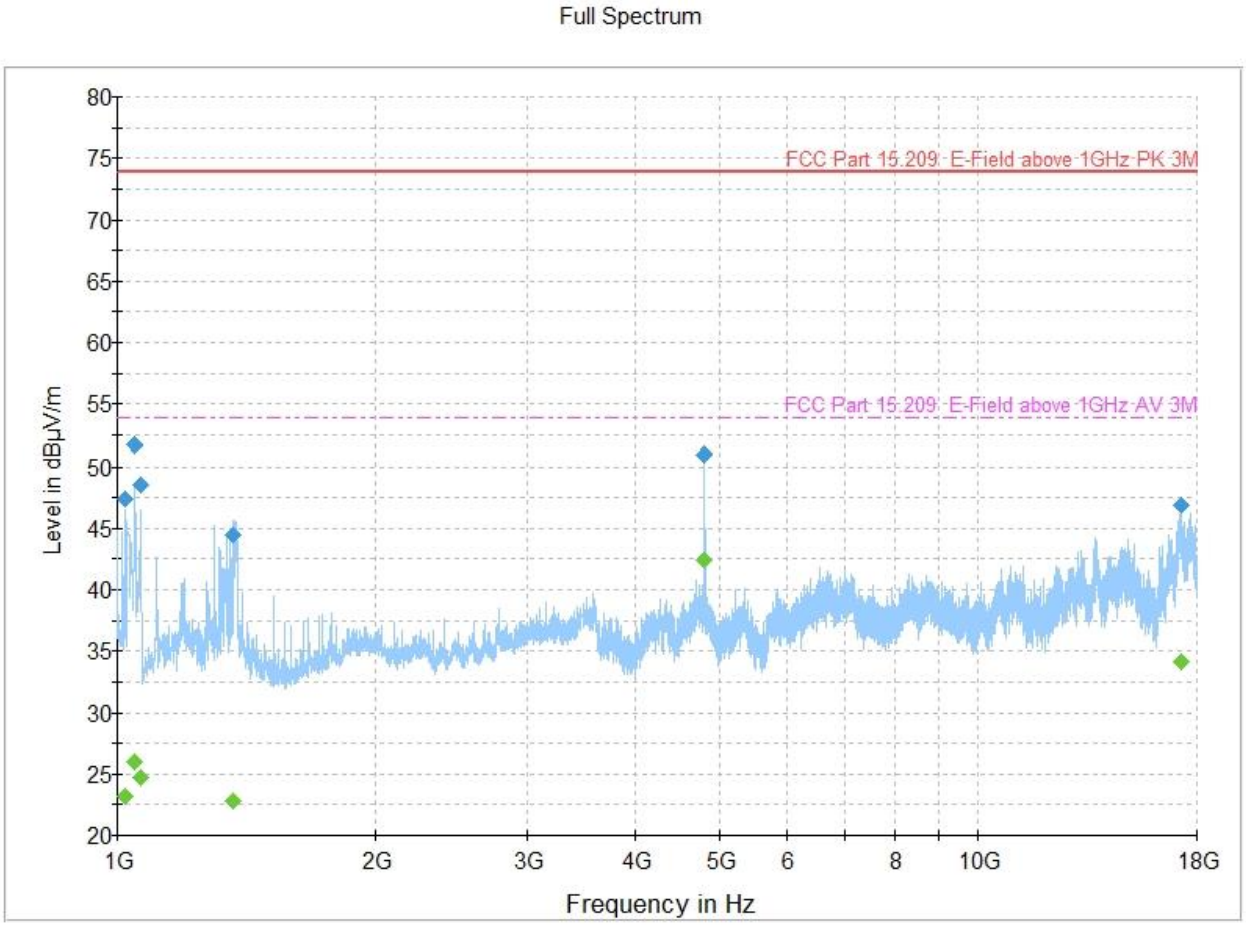
The spectral plot is a summation of a vertical and horizontal scan. The spectral scan has been corrected with the associated transducer factors (i.e. antenna factors, cable loss, amplifier gains, and attenuators).

Figure 8.6-3: *Radiated emissions, low channel, 30 – 1000 MHz spectral plot*

Table 8.6-4: *Radiated emissions, low channel, 30 – 1000 MHz (Quasi-Peak) results*

Frequency (MHz)	QuasiPeak (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Meas. Time (ms)	Bandwidth (kHz)	Height (cm)	Pol	Azimuth (deg)	Corr. (dB/m)
326.076000	23.72	46.00	22.28	5000.0	120.000	331.0	H	10.0	22.9
328.951000	29.28	46.00	16.72	5000.0	120.000	165.0	H	112.0	23.0
343.849000	41.14	46.00	4.86	5000.0	120.000	118.0	H	60.0	23.5
344.758667	36.28	46.00	9.72	5000.0	120.000	215.0	H	326.0	23.5
348.363000	45.58	46.00	0.42	5000.0	120.000	110.0	H	308.0	23.6
348.632667	43.24	46.00	2.76	5000.0	120.000	100.0	H	54.0	23.6
614.936000	36.65	46.00	9.35	5000.0	120.000	127.0	H	341.0	29.2

Notes:
[1] Field strength (dBµV/m) = receiver/spectrum analyzer value (dBµV) + correction factor (dB)
[2] Correction factor = antenna factor ACF (dB) + cable loss (dB)
[3] The maximum measured value observed over a period of 5 seconds was recorded.
[4] Limits converted to dBµV/m and an inverse proportionality factor of 20 dB per decade has been used to normalize the specification limit to a measurement distance of 3 meters to determine compliance.



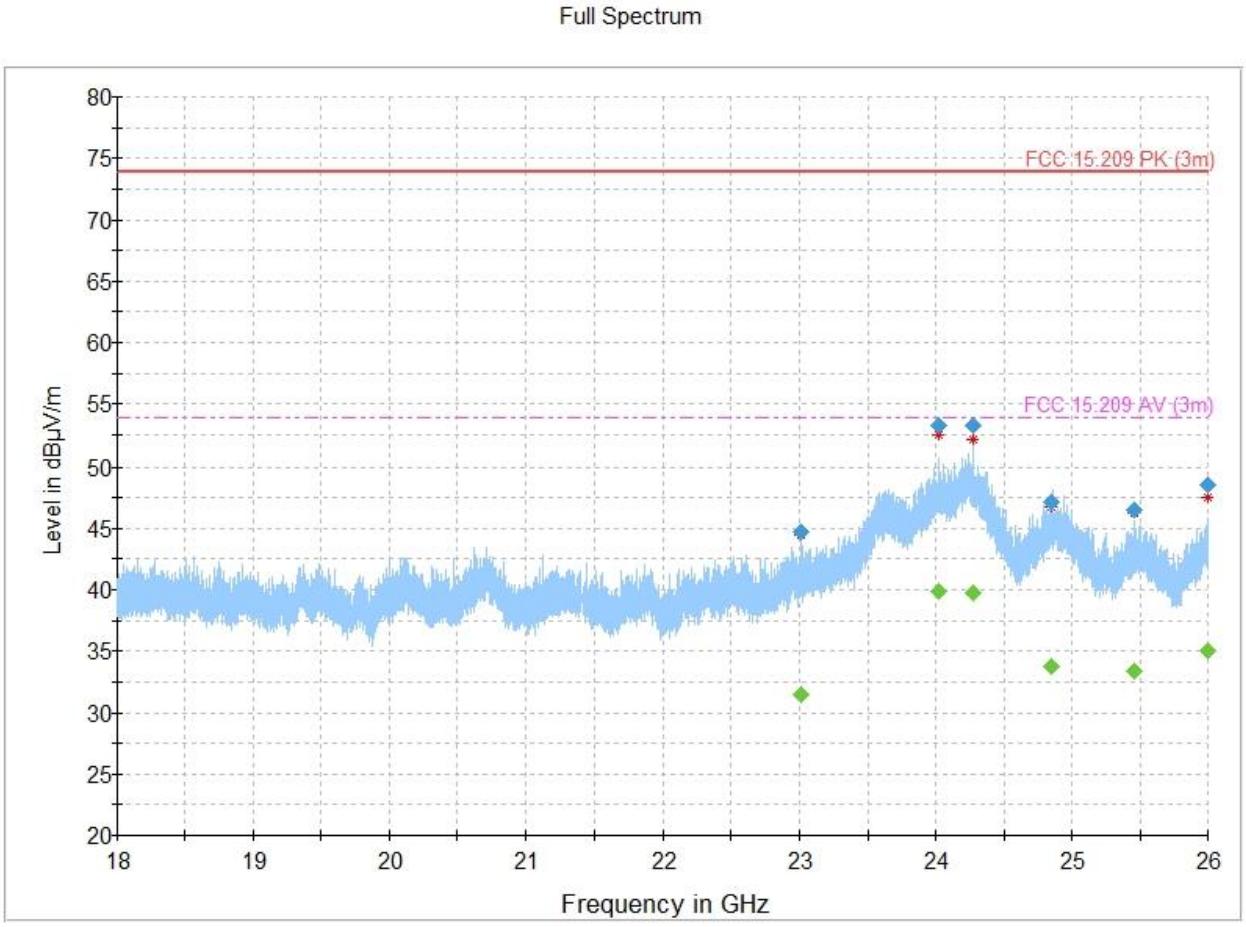
The spectral plot is a summation of a vertical and horizontal scan. The spectral scan has been corrected with the associated transducer factors (i.e. antenna factors, cable loss, amplifier gains, and attenuators).

Figure 8.6-4: *Radiated emissions, low channel, 1 – 18 GHz spectral plot*

Table 8.6-5: *Radiated emissions, low channel, 1 – 18 GHz (Quasi-Peak) results*

Frequency (MHz)	MaxPeak (dBµV/m)	CAverage (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Meas. Time (ms)	Bandwidth (kHz)	Height (cm)	Pol	Azimuth (deg)	Corr. (dB/m)
1022.122222	47.33	---	73.90	26.57	1000.0	1000.000	233.0	H	42.0	-15.0
1022.122222	---	23.13	53.90	30.77	1000.0	1000.000	233.0	H	42.0	-15.0
1049.222222	51.76	---	73.90	22.14	1000.0	1000.000	410.0	H	258.0	-15.3
1049.222222	---	26.02	53.90	27.88	1000.0	1000.000	410.0	H	258.0	-15.3
1064.222222	48.56	---	73.90	25.34	1000.0	1000.000	108.0	V	156.0	-15.1
1064.222222	---	24.69	53.90	29.21	1000.0	1000.000	108.0	V	156.0	-15.1
1364.955556	---	22.74	53.90	31.16	1000.0	1000.000	196.0	H	31.0	-14.4
1364.955556	44.41	---	73.90	29.49	1000.0	1000.000	196.0	H	31.0	-14.4
4808.800000	50.92	---	73.90	22.98	1000.0	1000.000	171.0	H	41.0	-1.7
4808.800000	---	42.48	53.90	11.42	1000.0	1000.000	171.0	H	41.0	-1.7
17264.500000	---	34.20	53.90	19.70	1000.0	1000.000	278.0	H	98.0	14.6
17264.500000	46.88	---	73.90	27.02	1000.0	1000.000	278.0	H	98.0	14.6

Notes: [1] Field strength (dBµV/m) = receiver/spectrum analyzer value (dBµV) + correction factor (dB)
[2] Correction factor = antenna factor ACF (dB) + cable loss (dB) - pre amp (dB)
[3] The maximum measured value observed over a period of 5 seconds was recorded.



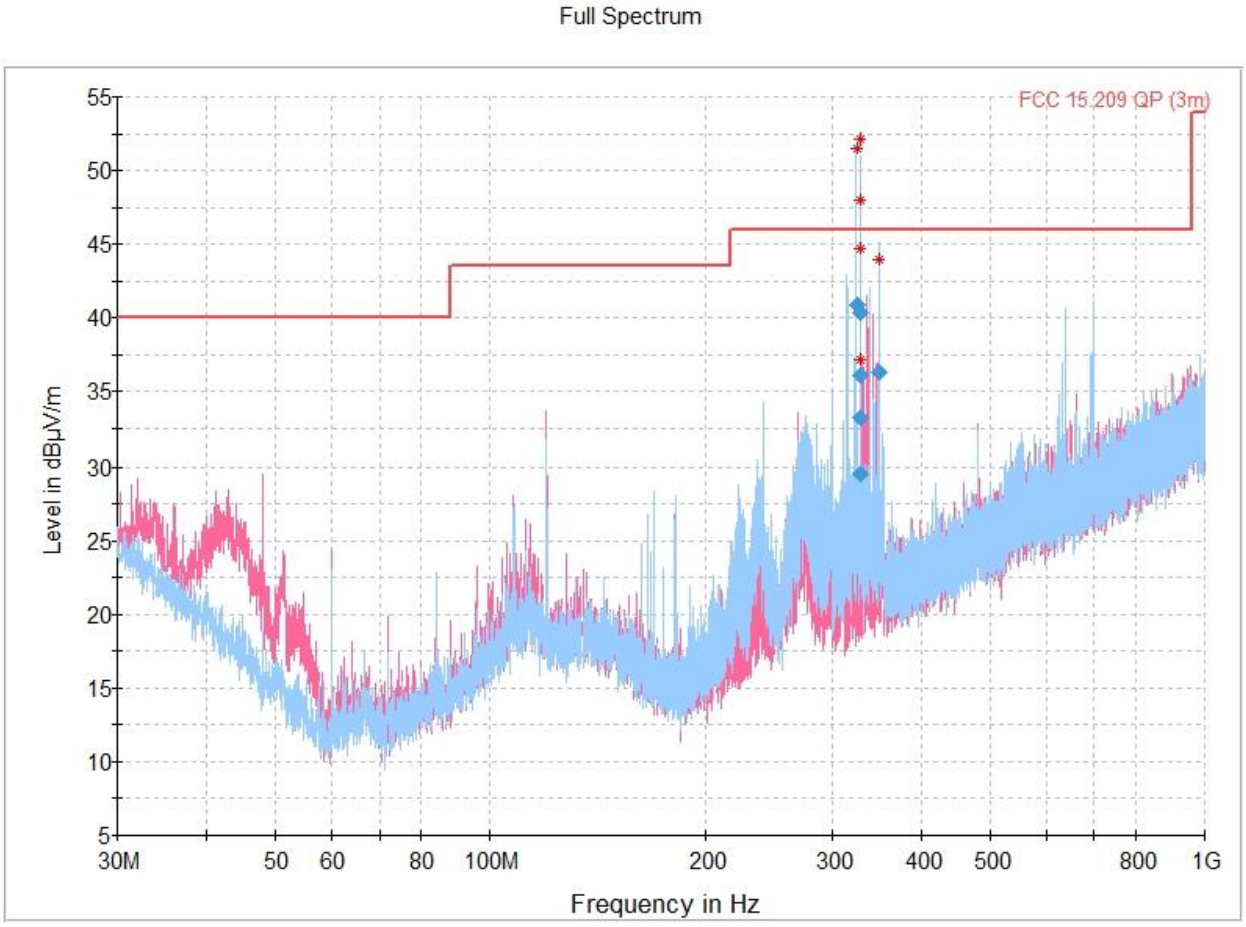
The spectral plot is a summation of a vertical and horizontal scan. The spectral scan has been corrected with the associated transducer factors (i.e. antenna factors, cable loss, amplifier gains, and attenuators).

Figure 8.6-5: *Radiated emissions, low channel, 18 – 26 GHz spectral plot*

Table 8.6-6: *Radiated emissions, low channel, 18 – 26 GHz (Peak and Average) results*

Frequency (MHz)	MaxPeak (dBµV/m)	CAverage (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Meas. Time (ms)	Bandwidth (kHz)	Height (cm)	Pol	Azimuth (deg)	Corr. (dB/m)
23014.700000	44.68	---	73.90	29.22	5000.0	1000.000	326.0	H	156.0	20.9
23014.700000	---	31.50	53.90	22.40	5000.0	1000.000	326.0	H	156.0	20.9
24026.966667	---	39.81	53.90	14.09	5000.0	1000.000	191.0	H	220.0	29.7
24026.966667	53.28	---	73.90	20.62	5000.0	1000.000	191.0	H	220.0	29.7
24272.366667	---	39.70	53.90	14.20	5000.0	1000.000	271.0	V	164.0	28.7
24272.366667	53.29	---	73.90	20.61	5000.0	1000.000	271.0	V	164.0	28.7
24855.700000	---	33.80	53.90	20.10	5000.0	1000.000	301.0	H	339.0	24.7
24855.700000	47.11	---	73.90	26.79	5000.0	1000.000	301.0	H	339.0	24.7
25464.500000	46.48	---	73.90	27.42	5000.0	1000.000	187.0	H	332.0	24.0
25464.500000	---	33.31	53.90	20.59	5000.0	1000.000	187.0	H	332.0	24.0
25996.366667	---	35.04	53.90	18.86	5000.0	1000.000	125.0	V	302.0	25.4
25996.366667	48.56	---	73.90	25.34	5000.0	1000.000	125.0	V	302.0	25.4

Notes: [1] Field strength (dBµV/m) = receiver/spectrum analyzer value (dBµV) + correction factor (dB)
[2] Correction factor = antenna factor ACF (dB) + cable loss (dB) - pre amp (dB)
[3] The maximum measured value observed over a period of 5 seconds was recorded.



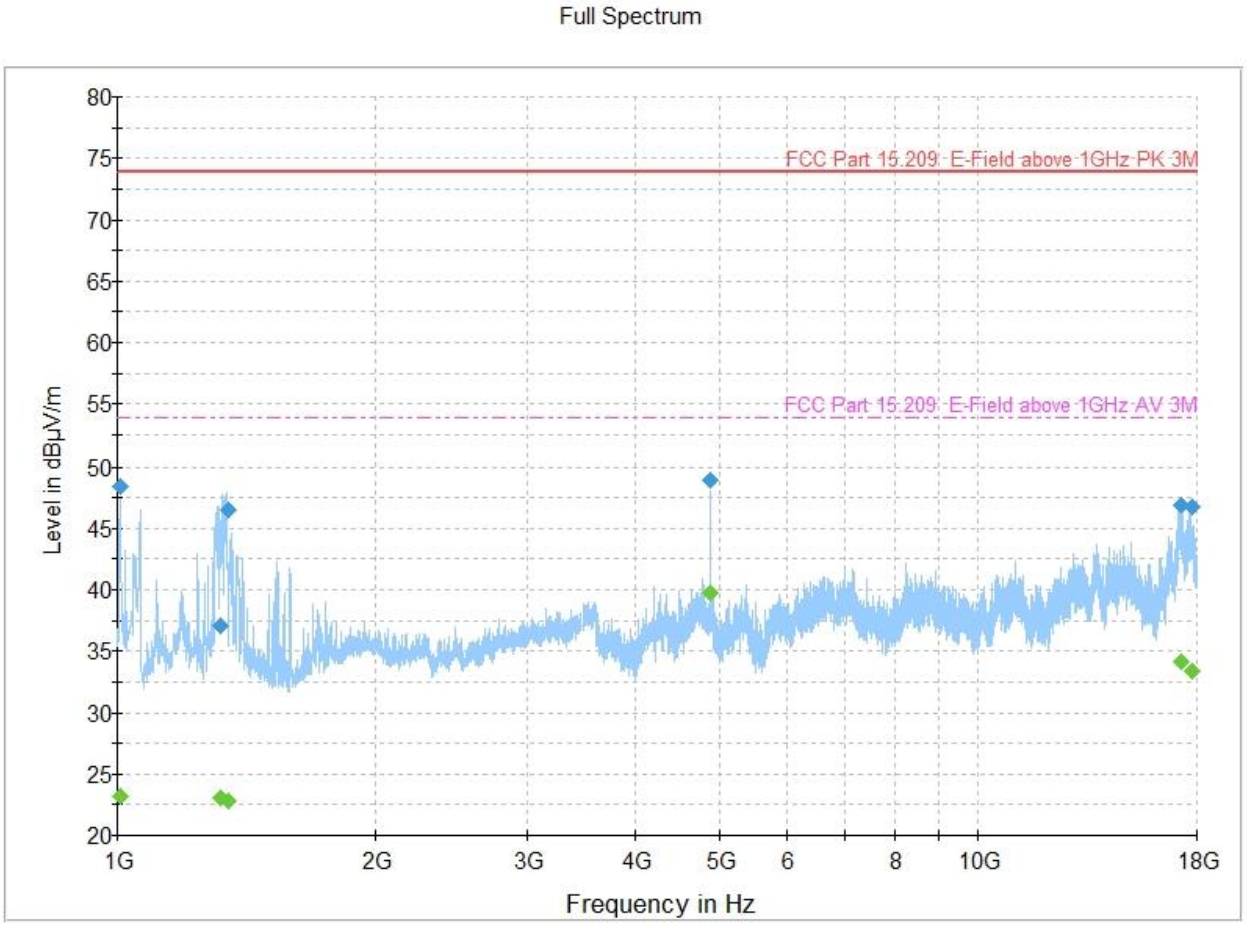
The spectral plot is a summation of a vertical and horizontal scan. The spectral scan has been corrected with the associated transducer factors (i.e. antenna factors, cable loss, amplifier gains, and attenuators).

Figure 8.6-6: *Radiated emissions, middle channel, 30 – 1000 MHz spectral plot*

Table 8.6-7: *Radiated emissions, middle channel, 30 – 1000 MHz (Quasi-Peak) results*

Frequency (MHz)	QuasiPeak (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Meas. Time (ms)	Bandwidth (kHz)	Height (cm)	Pol	Azimuth (deg)	Corr. (dB/m)
324.999667	40.83	46.00	5.17	5000.0	120.000	138.0	H	313.0	22.7
328.501667	40.35	46.00	5.65	5000.0	120.000	100.0	H	198.0	22.9
329.001333	29.49	46.00	16.51	5000.0	120.000	410.0	H	249.0	23.0
329.183333	33.29	46.00	12.71	5000.0	120.000	148.0	H	21.0	23.0
329.292333	36.06	46.00	9.94	5000.0	120.000	138.0	H	272.0	23.0
349.139667	36.33	46.00	9.67	5000.0	120.000	370.0	H	0.0	23.6

Notes:
[1] Field strength (dBµV/m) = receiver/spectrum analyzer value (dBµV) + correction factor (dB)
[2] Correction factor = antenna factor ACF (dB) + cable loss (dB)
[3] The maximum measured value observed over a period of 5 seconds was recorded.
[4] Limits converted to dBµV/m and an inverse proportionality factor of 20 dB per decade has been used to normalize the specification limit to a measurement distance of 3 meters to determine compliance.



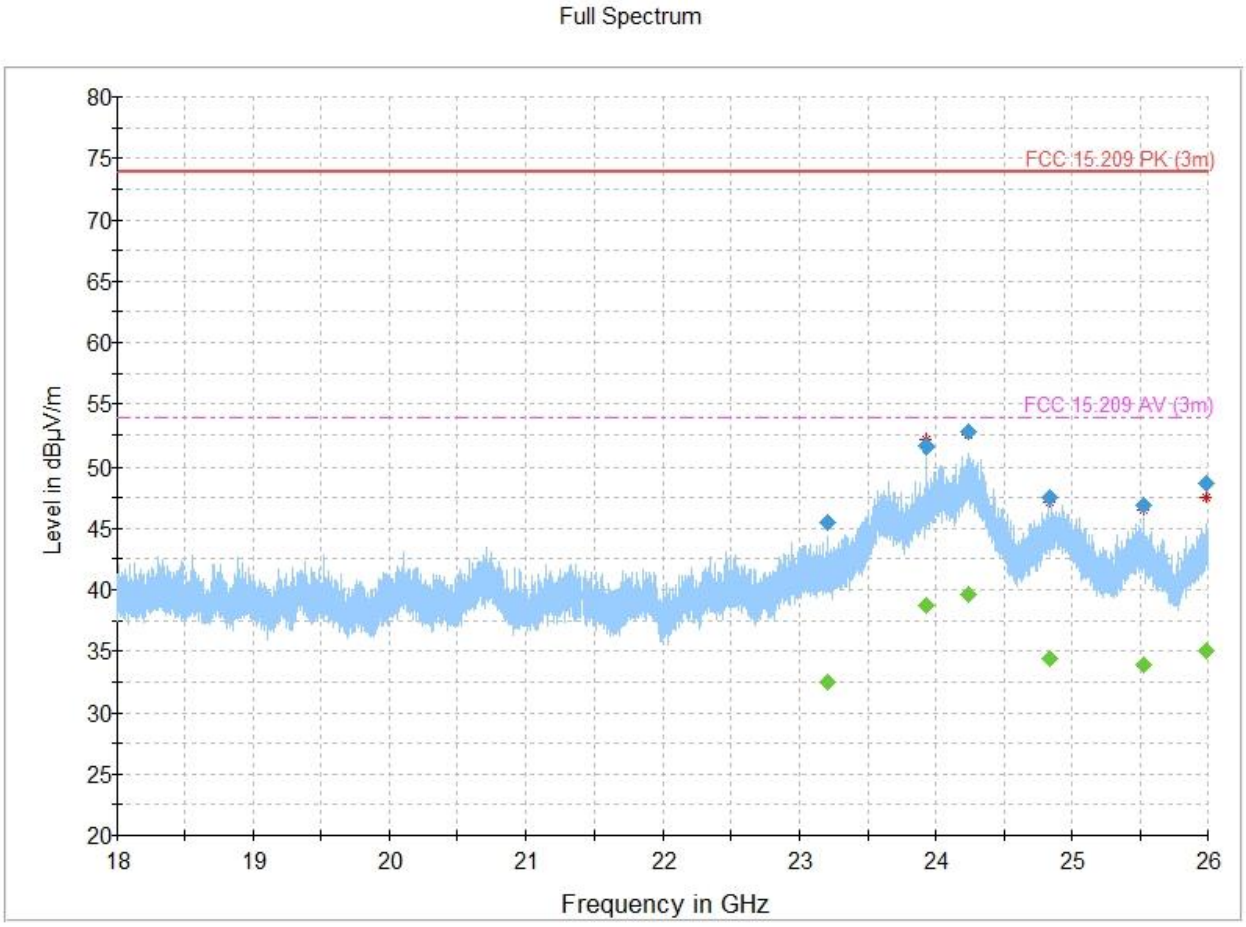
The spectral plot is a summation of a vertical and horizontal scan. The spectral scan has been corrected with the associated transducer factors (i.e. antenna factors, cable loss, amplifier gains, and attenuators).

Figure 8.6-7: *Radiated emissions, middle channel, 1 – 18 GHz spectral plot*

Table 8.6-8: *Radiated emissions, middle channel, 1 – 18 GHz (Quasi-Peak) results*

Frequency (MHz)	MaxPeak (dBµV/m)	CAverage (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Meas. Time (ms)	Bandwidth (kHz)	Height (cm)	Pol	Azimuth (deg)	Corr. (dB/m)
1008.900000	48.36	---	73.90	25.54	1000.0	1000.000	369.0	H	278.0	-14.8
1008.900000	---	23.15	53.90	30.75	1000.0	1000.000	369.0	H	278.0	-14.8
1316.888889	---	23.10	53.90	30.80	1000.0	1000.000	131.0	H	202.0	-14.3
1316.888889	37.02	---	73.90	36.88	1000.0	1000.000	131.0	H	202.0	-14.3
1346.655556	---	22.80	53.90	31.10	1000.0	1000.000	158.0	H	66.0	-14.4
1346.655556	46.53	---	73.90	27.37	1000.0	1000.000	158.0	H	66.0	-14.4
4881.088889	---	39.69	53.90	14.21	1000.0	1000.000	127.0	V	310.0	-2.0
4881.088889	48.92	---	73.90	24.98	1000.0	1000.000	127.0	V	310.0	-2.0
17278.988889	46.92	---	73.90	26.98	1000.0	1000.000	365.0	H	345.0	14.5
17278.988889	---	34.16	53.90	19.74	1000.0	1000.000	365.0	H	345.0	14.5
17742.866667	---	33.40	53.90	20.50	1000.0	1000.000	366.0	H	222.0	14.3
17742.866667	46.77	---	73.90	27.13	1000.0	1000.000	366.0	H	222.0	14.3

Notes: [1] Field strength (dBµV/m) = receiver/spectrum analyzer value (dBµV) + correction factor (dB)
[2] Correction factor = antenna factor ACF (dB) + cable loss (dB) - pre amp (dB)
[3] The maximum measured value observed over a period of 5 seconds was recorded.



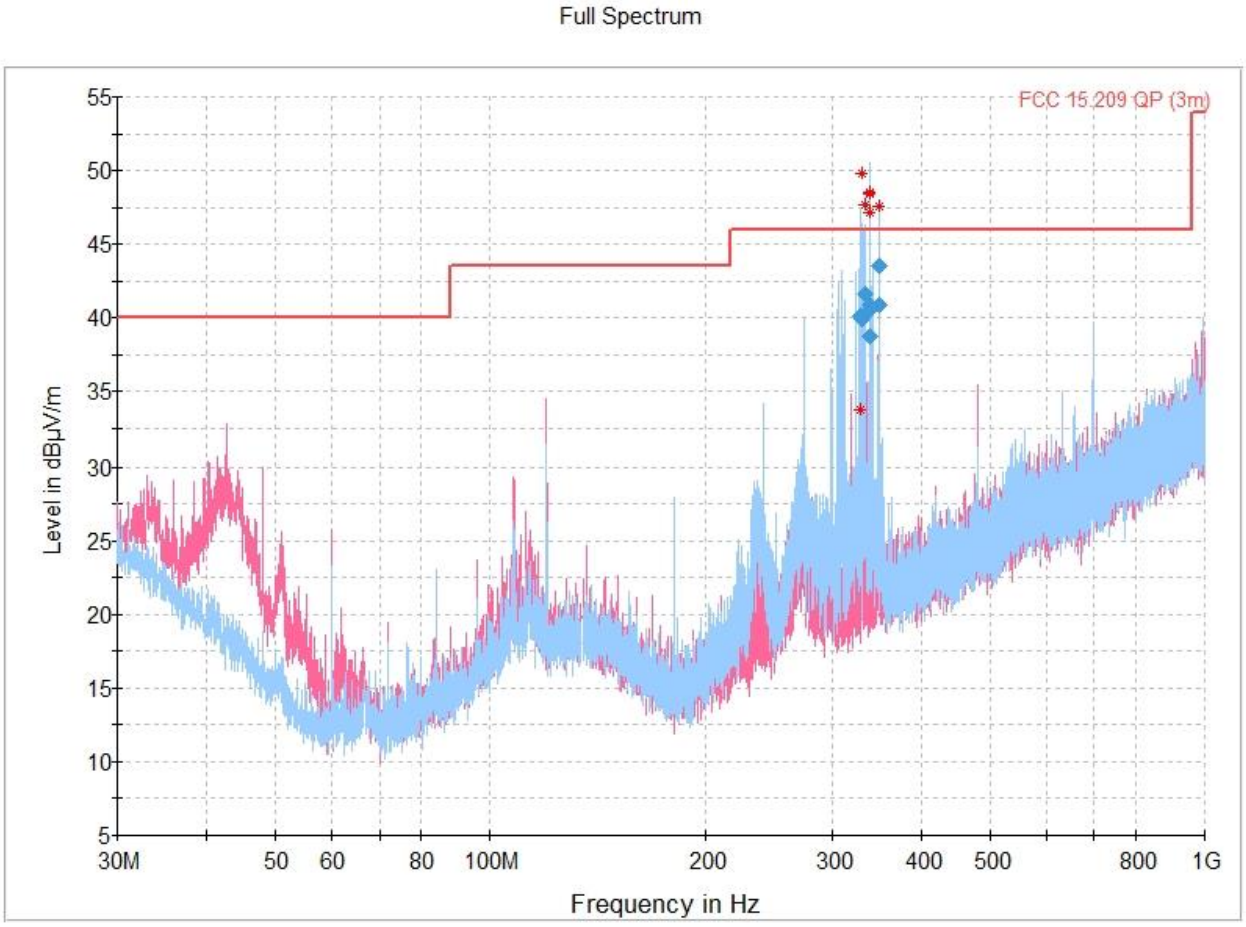
The spectral plot is a summation of a vertical and horizontal scan. The spectral scan has been corrected with the associated transducer factors (i.e. antenna factors, cable loss, amplifier gains, and attenuators).

Figure 8.6-8: *Radiated emissions, middle channel, 18 – 26 GHz spectral plot*

Table 8.6-9: *Radiated emissions, middle channel, 18 – 26 GHz (Peak and Average) results*

Frequency (MHz)	MaxPeak (dBµV/m)	CAverage (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Meas. Time (ms)	Bandwidth (kHz)	Height (cm)	Pol	Azimuth (deg)	Corr. (dB/m)
23208.633333	45.48	---	73.90	28.42	5000.0	1000.000	271.0	H	0.0	21.9
23208.633333	---	32.44	53.90	21.46	5000.0	1000.000	271.0	H	0.0	21.9
23932.766667	51.65	---	73.90	22.25	5000.0	1000.000	296.0	V	0.0	28.0
23932.766667	---	38.73	53.90	15.17	5000.0	1000.000	296.0	V	0.0	28.0
24240.233333	52.69	---	73.90	21.21	5000.0	1000.000	309.0	H	0.0	29.0
24240.233333	---	39.64	53.90	14.26	5000.0	1000.000	309.0	H	0.0	29.0
24835.833333	---	34.40	53.90	19.50	5000.0	1000.000	128.0	V	64.0	24.7
24835.833333	47.56	---	73.90	26.34	5000.0	1000.000	128.0	V	64.0	24.7
25529.966667	---	33.85	53.90	20.05	5000.0	1000.000	229.0	V	283.0	24.4
25529.966667	46.90	---	73.90	27.00	5000.0	1000.000	229.0	V	283.0	24.4
25993.900000	48.71	---	73.90	25.19	5000.0	1000.000	209.0	V	216.0	25.4
25993.900000	---	35.05	53.90	18.85	5000.0	1000.000	209.0	V	216.0	25.4

Notes: [1] Field strength (dBµV/m) = receiver/spectrum analyzer value (dBµV) + correction factor (dB)
[2] Correction factor = antenna factor ACF (dB) + cable loss (dB) - pre amp (dB)
[3] The maximum measured value observed over a period of 5 seconds was recorded.



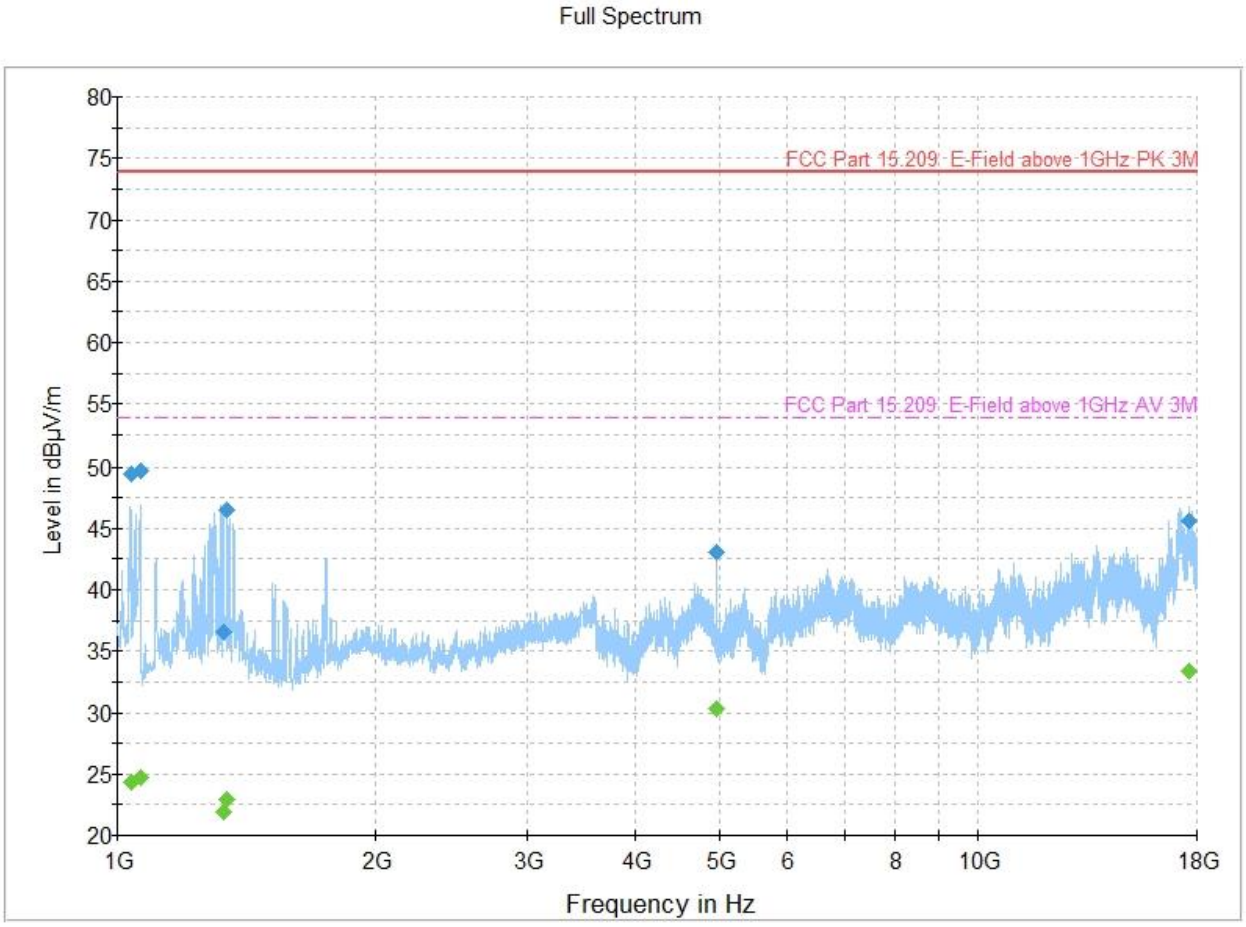
The spectral plot is a summation of a vertical and horizontal scan. The spectral scan has been corrected with the associated transducer factors (i.e. antenna factors, cable loss, amplifier gains, and attenuators).

Figure 8.6-9: *Radiated emissions, high channel, 30 – 1000 MHz spectral plot*

Table 8.6-10: *Radiated emissions, high channel, 30 – 1000 MHz (Quasi-Peak) results*

Frequency (MHz)	QuasiPeak (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Meas. Time (ms)	Bandwidth (kHz)	Height (cm)	Pol	Azimuth (deg)	Corr. (dB/m)
328.976667	40.13	46.00	5.87	5000.0	120.000	100.0	H	270.0	23.0
331.136000	39.89	46.00	6.11	5000.0	120.000	100.0	H	22.0	23.0
334.433333	41.57	46.00	4.43	5000.0	120.000	100.0	H	242.0	23.1
339.025333	40.55	46.00	5.46	5000.0	120.000	267.0	H	304.0	23.3
339.034667	40.91	46.00	5.09	5000.0	120.000	277.0	H	305.0	23.3
339.902667	38.80	46.00	7.20	5000.0	120.000	267.0	H	238.0	23.3
348.788333	40.90	46.00	5.10	5000.0	120.000	118.0	V	54.0	23.6
348.942333	43.56	46.00	2.44	5000.0	120.000	285.0	H	257.0	23.6

Notes:
[1] Field strength (dBµV/m) = receiver/spectrum analyzer value (dBµV) + correction factor (dB)
[2] Correction factor = antenna factor ACF (dB) + cable loss (dB)
[3] The maximum measured value observed over a period of 5 seconds was recorded.
[4] Limits converted to dBµV/m and an inverse proportionality factor of 20 dB per decade has been used to normalize the specification limit to a measurement distance of 3 meters to determine compliance.



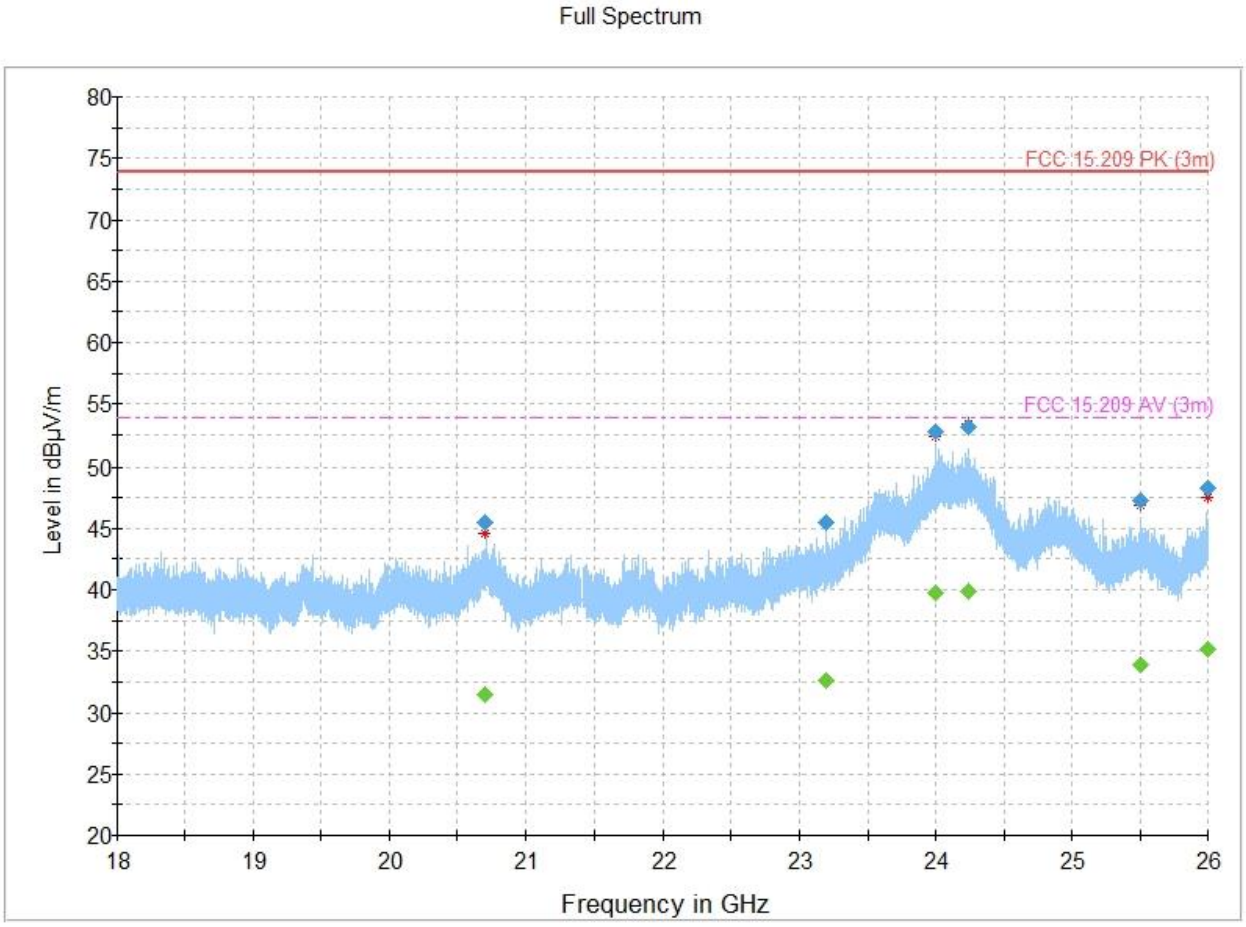
The spectral plot is a summation of a vertical and horizontal scan. The spectral scan has been corrected with the associated transducer factors (i.e. antenna factors, cable loss, amplifier gains, and attenuators).

Figure 8.6-10: *Radiated emissions, high channel, 1 – 18 GHz spectral plot*

Table 8.6-11: *Radiated emissions, high channel, 1 – 18 GHz (Quasi-Peak) results*

Frequency (MHz)	MaxPeak (dBµV/m)	CAverage (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Meas. Time (ms)	Bandwidth (kHz)	Height (cm)	Pol	Azimuth (deg)	Corr. (dB/m)
1037.488889	49.42	---	73.90	24.48	1000.0	1000.000	209.0	H	78.0	-15.1
1037.488889	---	24.32	53.90	29.58	1000.0	1000.000	209.0	H	78.0	-15.1
1064.366667	49.70	---	73.90	24.20	1000.0	1000.000	157.0	V	164.0	-15.1
1064.366667	---	24.65	53.90	29.25	1000.0	1000.000	157.0	V	164.0	-15.1
1328.277778	---	21.96	53.90	31.94	1000.0	1000.000	289.0	H	11.0	-14.4
1328.277778	36.57	---	73.90	37.33	1000.0	1000.000	289.0	H	11.0	-14.4
1342.433333	---	22.96	53.90	30.94	1000.0	1000.000	142.0	H	211.0	-14.4
1342.433333	46.50	---	73.90	27.40	1000.0	1000.000	142.0	H	211.0	-14.4
4958.600000	43.08	---	73.90	30.82	1000.0	1000.000	259.0	H	218.0	-2.1
4958.600000	---	30.26	53.90	23.64	1000.0	1000.000	259.0	H	218.0	-2.1
17614.700000	45.64	---	73.90	28.26	1000.0	1000.000	384.0	H	96.0	13.7
17614.700000	---	33.43	53.90	20.47	1000.0	1000.000	384.0	H	96.0	13.7

Notes: [1] Field strength (dBµV/m) = receiver/spectrum analyzer value (dBµV) + correction factor (dB)
[2] Correction factor = antenna factor ACF (dB) + cable loss (dB) - pre amp (dB)
[3] The maximum measured value observed over a period of 5 seconds was recorded.



The spectral plot is a summation of a vertical and horizontal scan. The spectral scan has been corrected with the associated transducer factors (i.e. antenna factors, cable loss, amplifier gains, and attenuators).

Figure 8.6-11: *Radiated emissions, high channel, 18 – 26 GHz spectral plot*

Table 8.6-12: *Radiated emissions, high channel, 18 – 26 GHz (Peak and Average) results*

Frequency (MHz)	MaxPeak (dBµV/m)	CAverage (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Meas. Time (ms)	Bandwidth (kHz)	Height (cm)	Pol	Azimuth (deg)	Corr. (dB/m)
20706.366667	---	31.52	53.90	22.38	5000.0	1000.000	319.0	H	0.0	20.1
20706.366667	45.42	---	73.90	28.48	5000.0	1000.000	319.0	H	0.0	20.1
23194.766667	45.44	---	73.90	28.46	5000.0	1000.000	194.0	V	180.0	21.7
23194.766667	---	32.63	53.90	21.27	5000.0	1000.000	194.0	V	180.0	21.7
23995.166667	---	39.71	53.90	14.19	5000.0	1000.000	189.0	V	147.0	29.2
23995.166667	52.73	---	73.90	21.17	5000.0	1000.000	189.0	V	147.0	29.2
24240.500000	53.18	---	73.90	20.72	5000.0	1000.000	183.0	H	238.0	29.0
24240.500000	---	39.86	53.90	14.04	5000.0	1000.000	183.0	H	238.0	29.0
25505.566667	---	33.88	53.90	20.02	5000.0	1000.000	352.0	V	170.0	24.2
25505.566667	47.24	---	73.90	26.66	5000.0	1000.000	352.0	V	170.0	24.2
25996.233333	---	35.14	53.90	18.76	5000.0	1000.000	296.0	V	156.0	25.4
25996.233333	48.29	---	73.90	25.61	5000.0	1000.000	296.0	V	156.0	25.4

Notes: [1] Field strength (dBµV/m) = receiver/spectrum analyzer value (dBµV) + correction factor (dB)
[2] Correction factor = antenna factor ACF (dB) + cable loss (dB) - pre amp (dB)
[3] The maximum measured value observed over a period of 5 seconds was recorded.

8.7 FCC 15.247(e) and RSS-247 5.2(b) Power spectral density of digital transmission system

8.7.1 References

Title 47 → Chapter I → Subchapter A → Part 15 → Subpart C → §15.247(e) / ANSI C63.10: 2013

(e) For digitally modulated systems, the power spectral density conducted from the intentional radiator to the antenna shall not be greater than 8 dBm in any 3 kHz band during any time interval of continuous transmission. This power spectral density shall be determined in accordance with the provisions of paragraph (b) of this Section. The same method of determining the conducted output power shall be used to determine the power spectral density.

RSS-247 → §5.2(b)

(a) The transmitter power spectral density conducted from the transmitter to the antenna shall not be greater than 8 dBm in any 3 kHz band during any time interval of continuous transmission. This power spectral density shall be determined in accordance with the provisions of Section 5.4(4), (i.e. the power spectral density shall be determined using the same method as is used to determine the conducted output power).

8.7.2 Test summary

Verdict	Pass		
Test date	April 6, 2021	Temperature	22 °C
Test engineer	David Hewitt, EMC Specialist	Air pressure	1006 mbar
Test location	Wireless bench	Relative humidity	48 %

8.7.3 Notes

Testing was performed with the Zigbee transmitter operating on a fixed channel at client-specified full power. Low, middle, and high channels were tested.

The EUT antenna port was connected to the spectrum analyzer via low loss cable and a suitable attenuator. The loss of this assembly was corrected for via a transducer factor in the spectrum analyzer.

8.7.4 Setup details

EUT setup configuration	Table top
Test facility	Nemko San Diego
Measurement details	Measurement performed as per C63.10 §11.10.3 (Method AVGPSD-1)

Receiver/spectrum analyzer settings:

Resolution bandwidth	3 kHz
Video bandwidth	10 kHz (≥ 3 x RBW)
Frequency span	≥ 1.5 x DTS bandwidth
Detector mode	RMS
Trace mode	Averaging
Averaging sweeps	100

8.7.5 Test data

Table 8.7-1: *Power spectral density of DTS*

Transmitter Frequency (MHz)	Measured Level (dBm/3 kHz)	Limit (dBm/3 kHz)
2405	-19.10	8.00
2440	-19.37	8.00
2480	-22.25	8.00

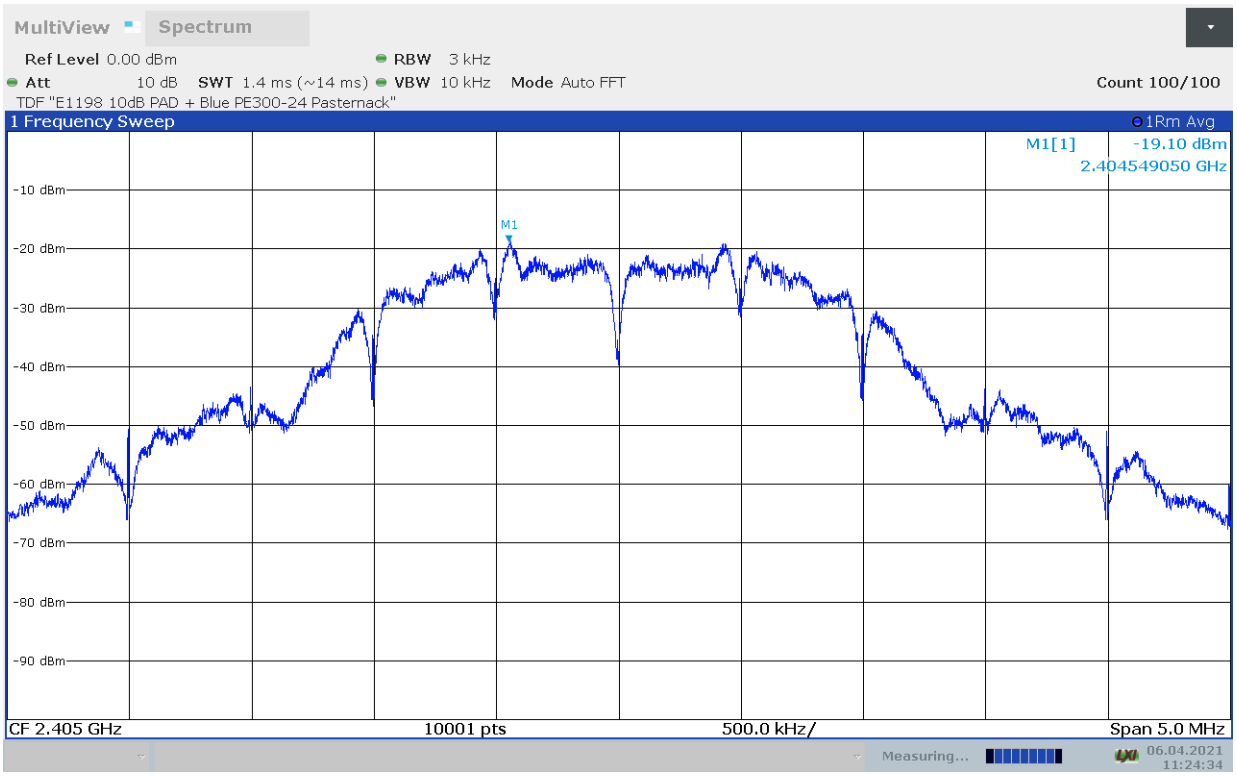


Figure 8.7-1: *Power spectral density of digital transmission system, 2405 MHz*

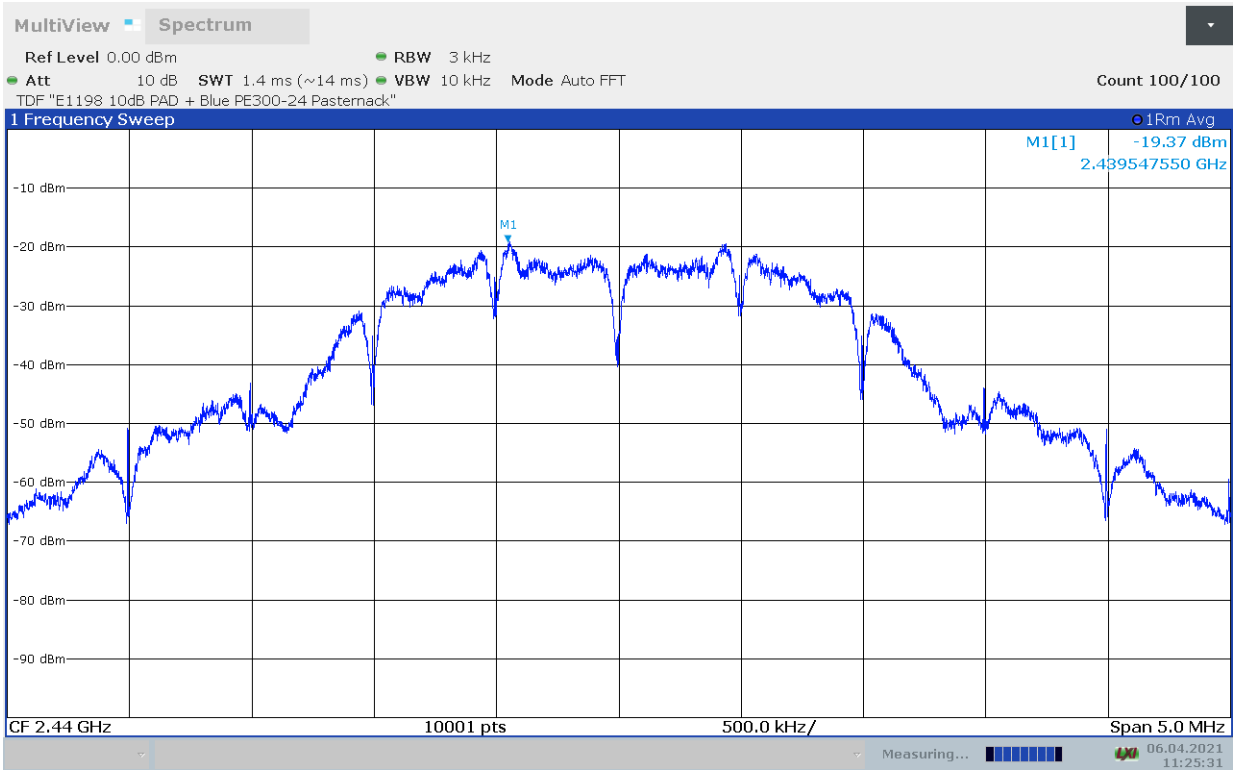


Figure 8.7-2: *Power spectral density of digital transmission system, 2440 MHz*

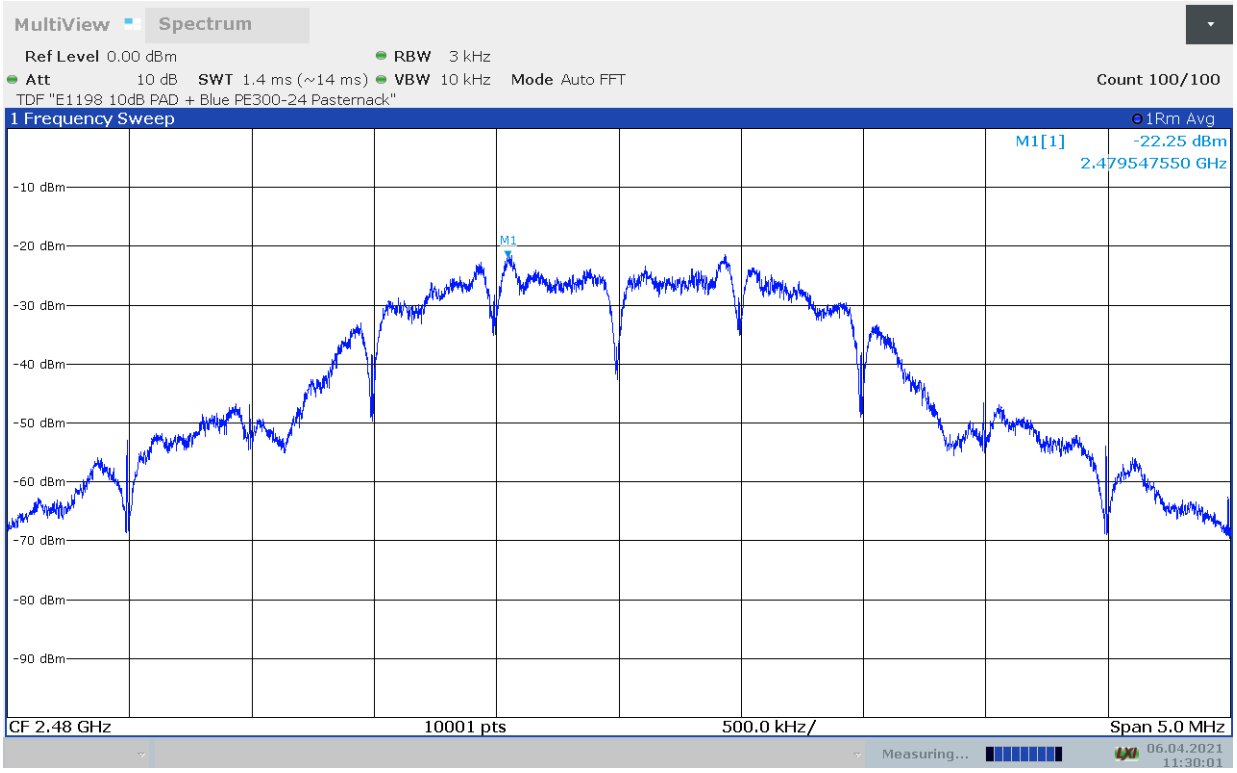


Figure 8.7-3: *Power spectral density of digital transmission system, 2480 MHz*

8.8 RSS-GEN 6.7 Occupied bandwidth (or 99% emission bandwidth)

8.8.1 References

RSS-Gen → §6.7

The occupied bandwidth or the "99% emission bandwidth" is defined as the frequency range between two points, one above and the other below the carrier frequency, within which 99% of the total transmitted power of the fundamental transmitted emission is contained. The occupied bandwidth shall be reported for all equipment in addition to the specified bandwidth required in the applicable RSSs.

8.8.2 Test summary

Test date	April 5, 2021	Temperature	23 °C
Test engineer	David Hewitt, EMC Specialist	Air pressure	1005 mbar
Test location	Wireless bench	Relative humidity	53 %

8.8.3 Notes

Testing was performed with the Zigbee transmitter operating on a fixed channel at client-specified full power. Low, middle, and high channels were tested.

The EUT antenna port was connected to the spectrum analyzer via low loss cable and a suitable attenuator. The loss of this assembly was corrected for via a transducer factor in the spectrum analyzer.

8.8.4 Setup details

EUT setup configuration	Tabletop
Test facility	Nemko San Diego
Measurement details	Measurement performed as per C63.10 §6.9.3 using the built-in function of the spectrum analyzer

Receiver/spectrum analyzer settings:

Resolution bandwidth	50 kHz
Video bandwidth	200 kHz
Detector mode	Peak
Trace mode	Max Hold
Measurement time	Long enough for trace to stabilize

8.8.5 Test data

Table 8.8-1: *99% Occupied bandwidth*

Test Frequency (MHz)	M1 (MHz)	T1 (MHz)	T2 (MHz)	99%Bandwidth (MHz)
2405 (Low channel)	2.405021	2.40386829	2.4061139	2.245618129
2440 (Mid channel)	2.439979	2.43886748	2.44111425	2.246773335
2480 (High channel)	2.479979	2.47886126	2.48111733	2.256063072

8.8.5 Test data, continued

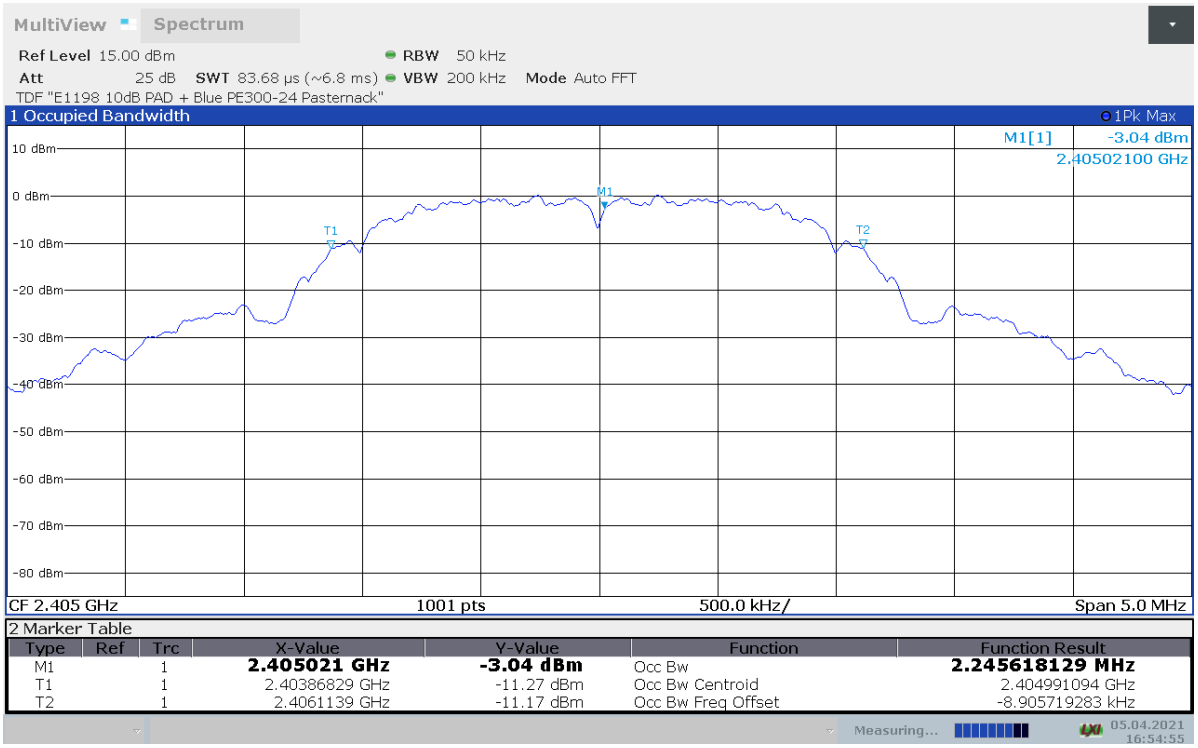


Figure 8.8-1: *99% bandwidth, 2405 MHz*

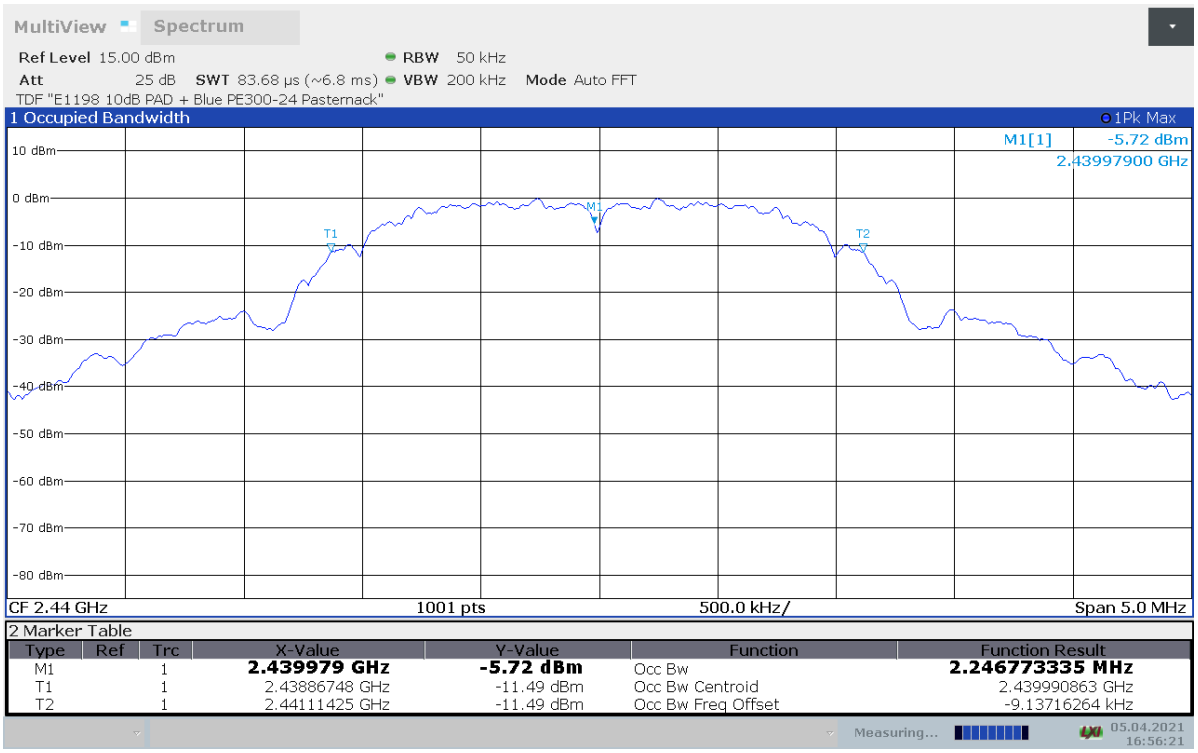


Figure 8.8-2: *99% bandwidth, 2440 MHz*

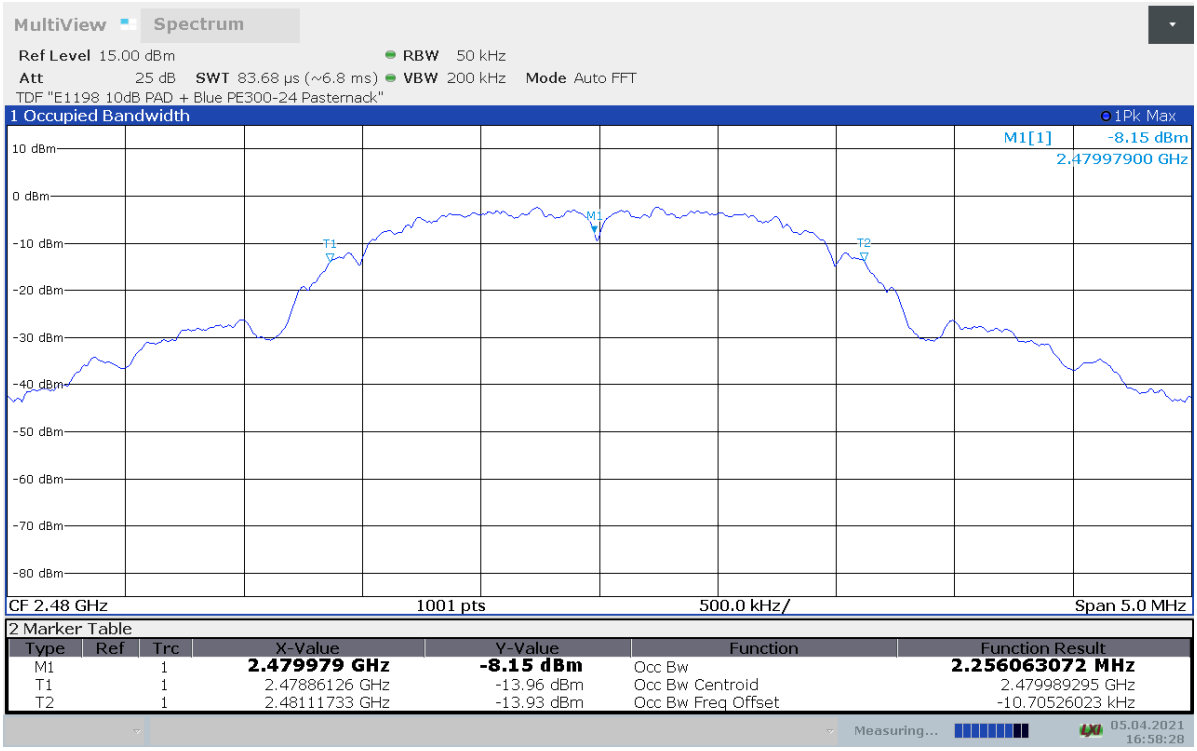


Figure 8.8-3: *99% bandwidth, 2480 MHz*

Section 9 Block diagrams of test set-ups

9.1 Radiated emissions set-up

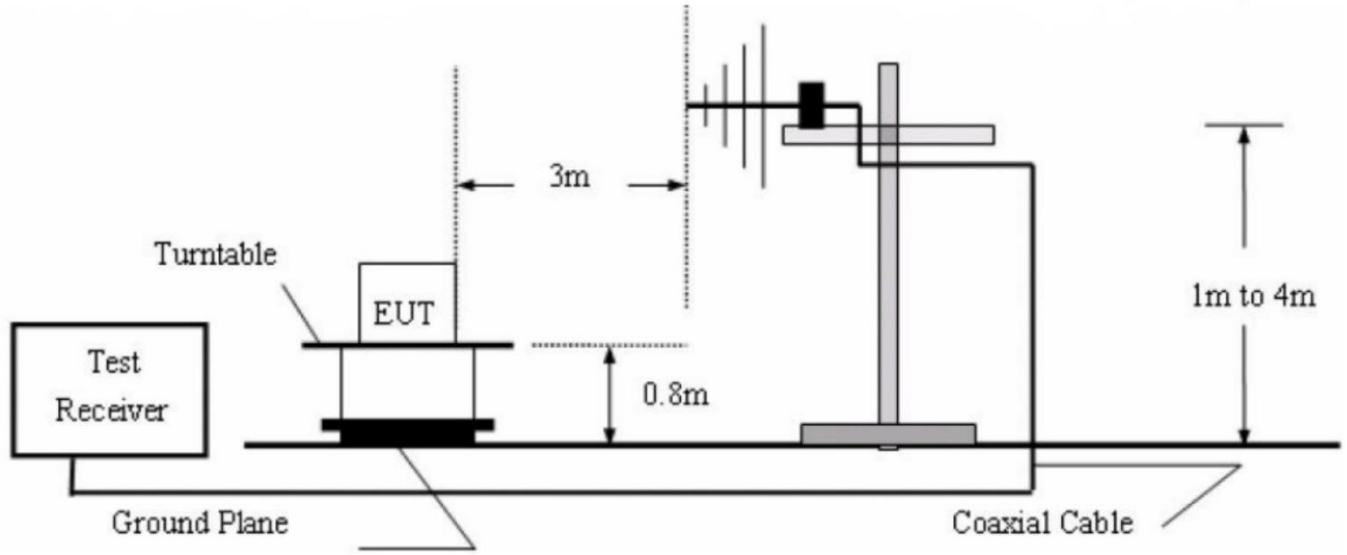


Figure 9.1-1: *30 MHz - 1000 MHz Setup*

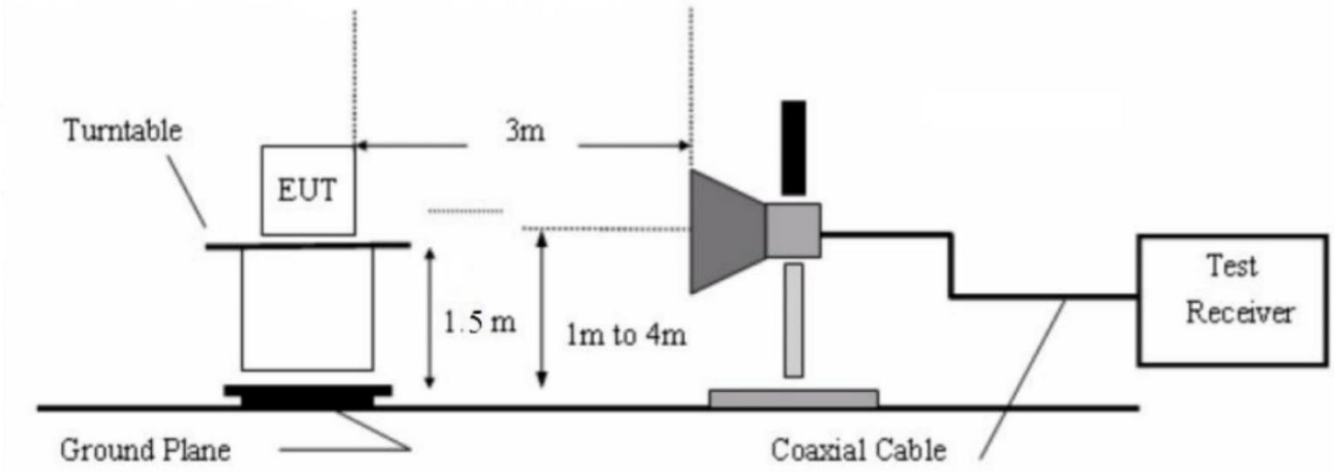


Figure 9.1-2: 1 GHz - 26 GHz Setup

9.2 Conducted emissions set-up

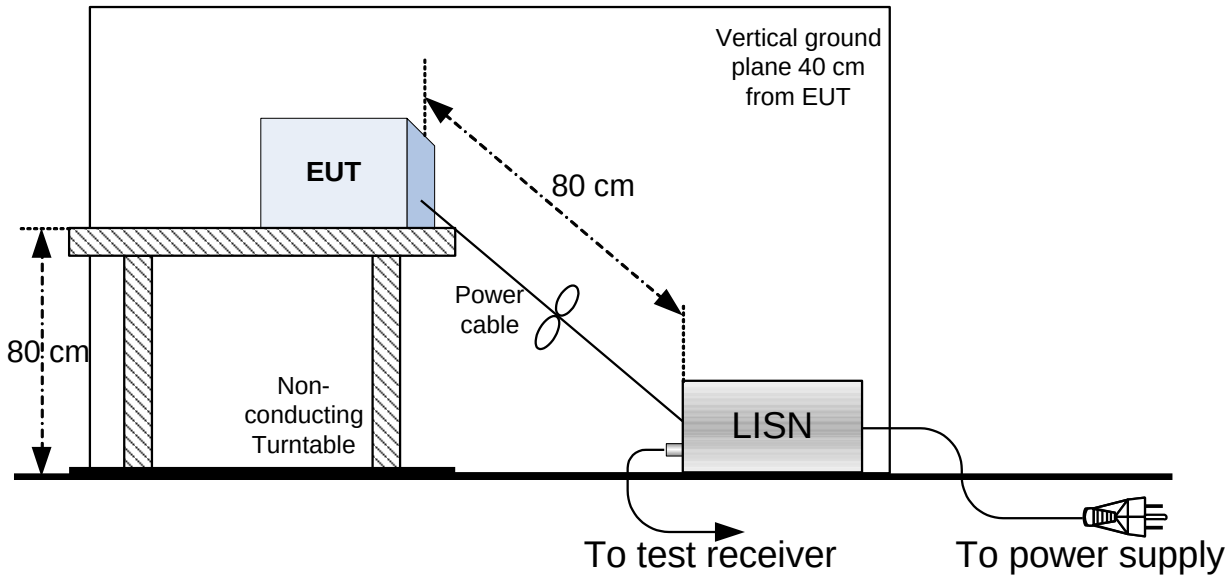


Figure 9.2-1: *150 kHz to 30 MHz Conducted Emissions Setup*