

Wireless test report – 368147-1TRFWL

Applicant:

LEGO System A/S

Product name:

Bluetooth Low Energy Transceiver

Model:

Hub No. 2

Specifications:

Low Power 0002 (LP0002) January 10, 2018

Low-power Radio-frequency Devices

Clause 3.10.1 Intentional radiators employing frequency hopping spread spectrum and digital modulation techniques

Date of issue: July 22, 2019

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Test site registration	Organization	Recognition numbers and location		
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Website	www.nemko.com			

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 contained in this report are within Nemko Canada's ISO/IEC 17025 accreditation.

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Table of contents

Table of contents	3
Section 1. Report summary	4
1.1 Applicant and manufacturer	4
1.2 Test specifications	4
1.3 Test methods	4
1.4 Statement of compliance EUT was compliant.	4
1.5 Exclusions	4
1.6 Test report revision history	4
Section 2. Summary of test results	5
2.1 Testing location	5
2.2 Testing period	5
2.3 Sample information	5
2.4 LP0002, intentional radiators test results	5
Section 3. Equipment under test (EUT) details	6
3.1 EUT information	6
3.2 Technical information	6
3.3 EUT exercise details	6
3.4 EUT setup diagram	7
Section 4. Engineering considerations	8
4.1 Modifications incorporated in the EUT for compliance	8
4.2 Technical judgment	8
4.3 Deviations from laboratory tests procedures	8
Section 5. Test conditions	9
5.1 Atmospheric conditions	9
5.2 Power supply range	9
Section 6. Measurement uncertainty	10
6.1 Uncertainty of measurement	10
Section 7. Test equipment	11
7.1 Test equipment list	11
Section 8. Testing data	12
8.1 Clause 3.10.1.6 (2)(A) Minimum 6 dB bandwidth for systems using digital modulation tech	12
8.2 Clause 3.10.1.2 (1)(C) Transmitter maximum peak output power for systems using digital modulation	15
8.3 Clause 3.10.1.5 Spurious emissions	17
8.4 Clause 3.10.1.6 (2)(B) Peak power spectral density for digitally modulated devices	26
Section 9. Block diagrams of test set-ups	28
9.1 Radiated emissions set-up for frequencies below 1 GHz	28
9.2 Radiated emissions set-up for frequencies above 1 GHz	28
9.3 Antenna port set-up	29
Section 10. EUT photos	30
10.1 External photos	30

Section 1. Report summary

1.1 Applicant and manufacturer

Name and address of the applicant	LEGO System A/S
Name and address of the manufacturer	Aastvej 1, 7190 Billund, Denmark

1.2 Test specifications

LP0002 January 10, 2018, Clause 3.10.1	Intentional radiators employing frequency hopping spread spectrum and digital modulation techniques
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1.3 Test methods

558074 D01 DTS Meas Guidance v05 (August, 2018)	Guidance for Performing Compliance Measurements on Digital Transmission Systems (DTS) Operating Under §15.247
ANSI C64.3 v 2003	American National Standard for Methods of Measurement of Radio- Noise Emissions from Low-Voltage Electrical and Electronic Equipment in the Range of 9 kHz to 40 GHz

1.4 Statement of compliance EUT was compliant.

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.

1.5 Exclusions

None

1.6 Test report revision history

Table 1.6-1: Test report revision history

Revision #	Date of issue	Details of changes made to test report
TRF	July 22, 2019	Original report issued

Section 2. Summary of test results

2.1 Testing location

Test location (s)	Ottawa
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2.2 Testing period

Test start date	July 17, 2019
Test end date	July 18, 2019

2.3 Sample information

Receipt date	July 10, 2019
Nemko sample ID number	Item # 4 and 3

2.4 LP0002, intentional radiators test results

Table 2.4-1: Result summary

Part	Test description	Verdict
2.3	Conducted limits	Not applicable
3.10.1.2 (1)(A) or (B)	Maximum peak output power for frequency hopping systems operating in the 2400–2483.5 MHz band	Not applicable
3.10.1.2 (1)(C)	Maximum peak output power of systems using digital modulation in the 2400–2483.5 MHz band	Pass
3.10.1.2 (2)	Maximum peak output power for frequency hopping systems operating in the 5725–5850 MHz band	Not applicable
3.10.1.3 (1)(A)	Fixed point-to-point operation within 2.4 GHz band with directional antenna gains greater than 6 dBi	Not applicable
3.10.1.3 (1)(B)	Transmitters that emit multiple directional beams	Not applicable
3.10.1.3 (2)	Fixed point-to-point operation within 5.8 GHz band with directional antenna gains greater than 6 dBi	Not applicable
3.10.1.5	Limits on emissions outside the frequency band (Spurious emissions)	Pass
3.10.1.6 (1)(A)	Hopping channel carrier frequencies separation requirements	Not applicable
3.10.1.6 (1)(A)(a)	Frequency hopping systems operating in the 2400–2483.5 MHz band, other requirements	Not applicable
3.10.1.6 (1)(A)(b)	Frequency hopping systems operating in the 5725–5850 MHz band, other requirements	Not applicable
3.10.1.6 (2)(A)	Minimum 6 dB bandwidth for systems using digital modulation techniques	Pass
3.10.1.6 (2)(B)	Power spectral density for digitally modulated devices	Pass
3.10.1.6 (3)	Hybrid systems requirements	Not applicable

Notes: The EUT is a battery-operated equipment, the testing was performed using fresh batteries.

Section 3. Equipment under test (EUT) details

3.1 EUT information

Product name	Bluetooth Low Energy Transceiver
Model	Hub No. 2
Serial number	None
Hardware identity and/or version	EP2i
Software identity and/or version	1.0.00.000
Power requirements	9 V _{DC} from 6 x type AA batteries
Product description and theory of operation	The EUT is a toy which controls dedicated motors and is controlled via BLE with a remote device (iOS, Android or similar)

3.2 Technical information

Frequency band	2400–2483.5 MHz
Frequency Min (MHz)	2402 (Low Channel)
Frequency Max (MHz)	2480 (High Channel)
RF power Max (W), Conducted	0.0004 (-3.8 dBm)
Field strength, Units @ distance	N/A
Measured BW (MHz) (99 %)	1.1
Calculated BW (kHz), as per TRC-43	N/A
Type of modulation	Digital (GFSK)
Emission classification (F1D, G1D, D1D)	F1D
Transmitter spurious, dB μ V/m @ 3 m	53.0 (average) at 2483.5 MHz
Antenna information	Integral

3.3 EUT exercise details

The EUT was setup to continuously transmit at specific channels.

3.4 EUT setup diagram

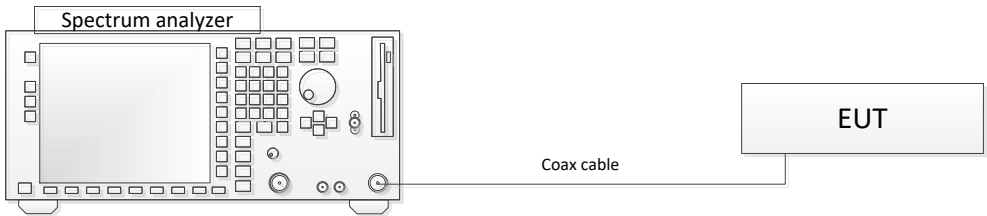


Figure 3.4-1: Setup diagram for antenna port measurements

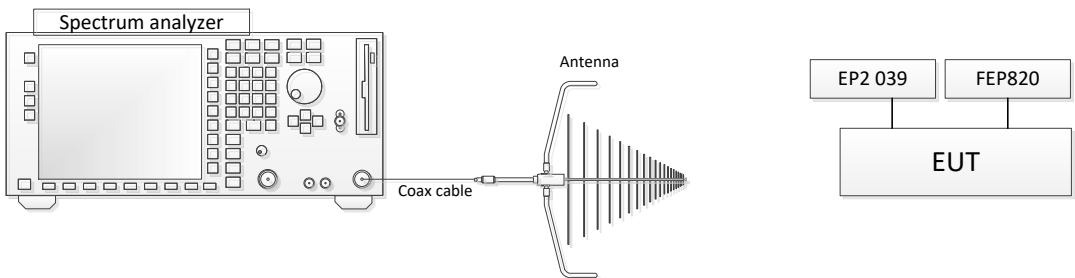


Figure 3.4-2: Setup diagram for radiated measurements



Section 4. Engineering considerations

4.1 Modifications incorporated in the EUT for compliance

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 $\pm 5\%$, for which the equipment was designed.

Section 6. Measurement uncertainty

6.1 Uncertainty of measurement

Nemko Canada Inc. has calculated measurement uncertainty and is documented in EMC/MUC/001 “Uncertainty in EMC measurements.” Measurement uncertainty was calculated using the methods described in CISPR 16-4 Specification for radio disturbance and immunity measuring apparatus and methods – Part 4: Uncertainty in EMC measurements; as well as described in UKAS LAB34: The expression of Uncertainty in EMC Testing. Measurement uncertainty calculations assume a coverage factor of K=2 with 95% certainty.

Table 6.1-1: Measurement uncertainty

Test name	Measurement uncertainty, dB
All antenna port measurements	0.55
Radiated spurious emissions	3.78

Section 7. Test equipment

7.1 Test equipment list

Table 7.1-1: Equipment list

Equipment	Manufacturer	Model no.	Asset no.	Cal cycle	Next cal.
3 m EMI test chamber	TDK	SAC-3	FA002047	1 year	Jan.24, 2020
Receiver/spectrum analyzer	Rohde & Schwarz	ESU 26	FA002043	1 year	May 8, 2020
Horn antenna (1–18 GHz)	EMCO	3115	FA000825	1 year	Oct. 8, 2019
Horn antenna (18–40 GHz)	EMCO	3116	FA001847	1 year	Oct. 9, 2019
Bilog antenna (20–3000 MHz)	Sunol	JB3	FA002108	1 year	Jan. 3, 2020
Preamplifier (1–18 GHz)	ETS Lindgren	124334	FA002873	1 year	Nov. 4, 2019
Pre-amplifier (18–26 GHz)	Narda	BBS-1826N612	FA001550	—	VOU
50 Ω coax cable	C.C.A.	None	FA002555	1 year	April 18, 2020
50 Ω coax cable	Huber + Suhner	None	FA002830	1 year	April 18, 2020
Notch filter 2400–2483 MHz	Microwave Circuits	2400–2483 MHz	FA001940	—	VOU

Notes: VOU - verify on use

Section 8. Testing data

8.1 Clause 3.10.1.6 (2)(A) Minimum 6 dB bandwidth for systems using digital modulation tech

8.1.1 Definitions and limits

For digitally modulated systems, the minimum 6 dB bandwidth shall be at least 500 kHz.

8.1.2 Test summary

Verdict **Pass**

8.1.3 Observations, settings and special notes

None

8.1.4 Test data

Table 8.1-1: 6 dB bandwidth results

Frequency, MHz	6 dB bandwidth, kHz	Minimum limit, kHz	Margin, kHz
2402	721.2	500.0	221.2
2440	729.2	500.0	229.2
2480	737.2	500.0	237.2

Table 8.1-2: 99 % bandwidth results

Frequency, MHz	99 % bandwidth, MHz
2402	1.1
2440	1.1
2480	1.1

Notes: There is no 99% occupied bandwidth requirement, this value is reported for information only.

8.1.4 Test data, continued

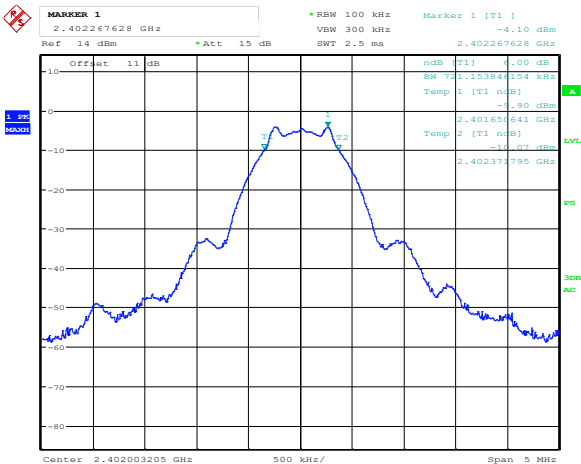


Figure 8.1-1: 6 dB bandwidth on low channel

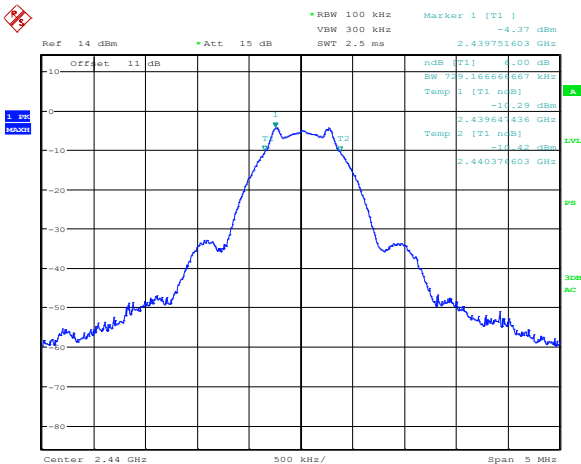


Figure 8.1-2: 6 dB bandwidth on mid channel

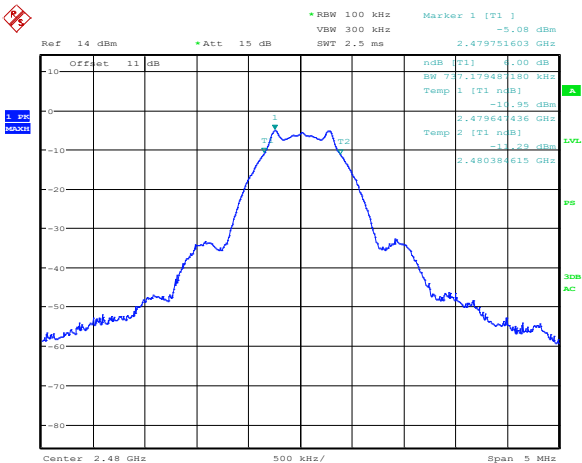


Figure 8.1-3: 6 dB bandwidth on high channel

8.1.4 Test data, continued

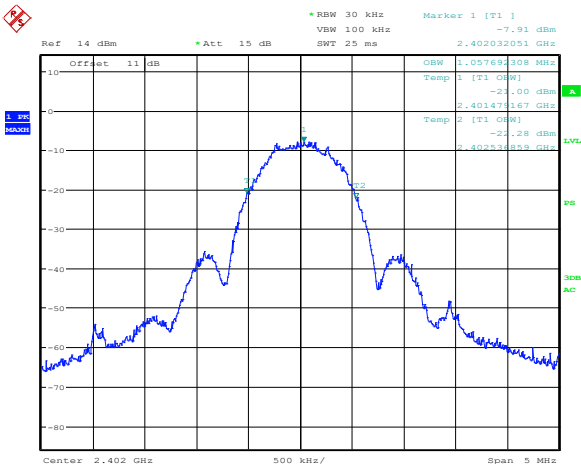


Figure 8.1-4: 99 % bandwidth on low channel

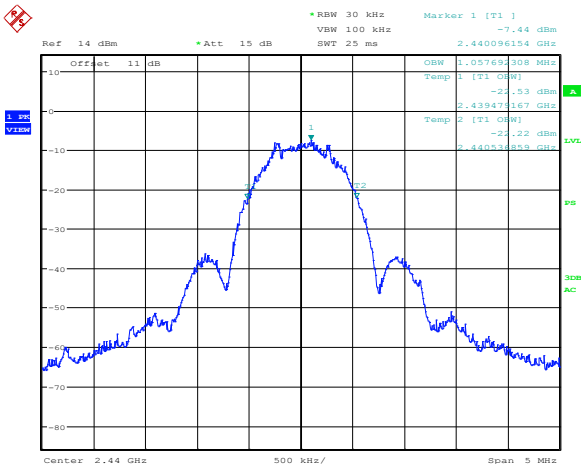


Figure 8.1-5: 99 % bandwidth on mid channel

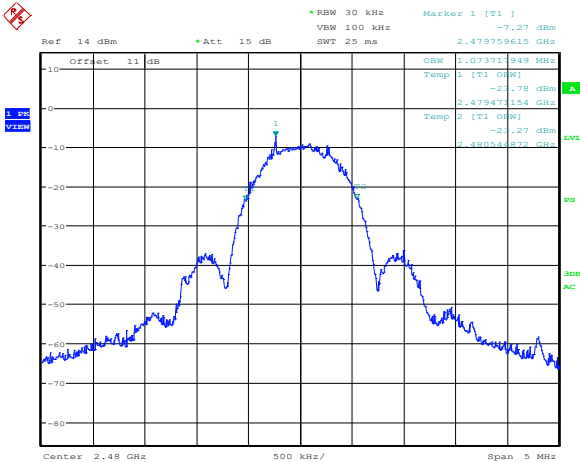


Figure 8.1-6: 99 % bandwidth on high channel

8.2 Clause 3.10.1.2 (1)(C) Transmitter maximum peak output power for systems using digital modulation

8.2.1 Definitions and limits

The maximum peak output power for systems using digital modulation in the 2400–2483.5 MHz band: 1 Watt (30 dBm).

3.10.1.2 (3) When using the transmitting antennas with the directional gain over 6 dBi except for (1) and (2), the maximum conducted output power shall be reduced in equal quantity according to the total dBi of the antenna directional gain over 6 dBi.

3.10.1.2 (1)(A) Systems operating in the 2400–2483.5 MHz band, for fixed, point-to-point operations, the peak conducted output power of the intentional radiator shall be reduced by 1 dB for every 3 dBi when the directional gain of the antenna exceeds 6 dBi.

3.10.1.2 (2) When operating in 5725–5850 MHz and by fixed point-to-point operation, the directional gain of the transmitting antenna shall exceed 6 dBi without reducing the maximum conducted output power.

8.2.2 Test summary

Verdict **Pass**

8.2.3 Observations, settings and special notes

The test was performed according to DTS guidelines using peak method.

8.2.4 Test data

Table 8.2-1: Output power measurements results

Frequency, MHz	Conducted output power, dBm		Margin, dB	Antenna gain, dBi	EIRP, dBm	EIRP limit, dBm	EIRP margin, dB
	Measured	Limit					
2402	-3.8	30.0	33.8	4.0	0.2	36.0	35.8
2440	-4.2	30.0	34.2	4.0	-0.2	36.0	36.2
2480	-4.8	30.0	34.8	4.0	-0.8	36.0	36.8

8.2.4 Test data, continued

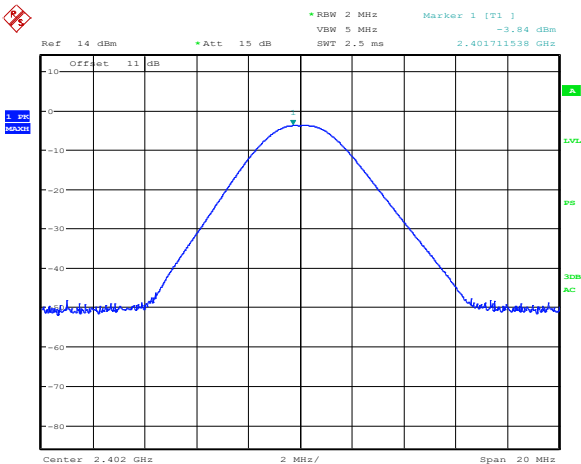


Figure 8.2-1: Output power on low channel

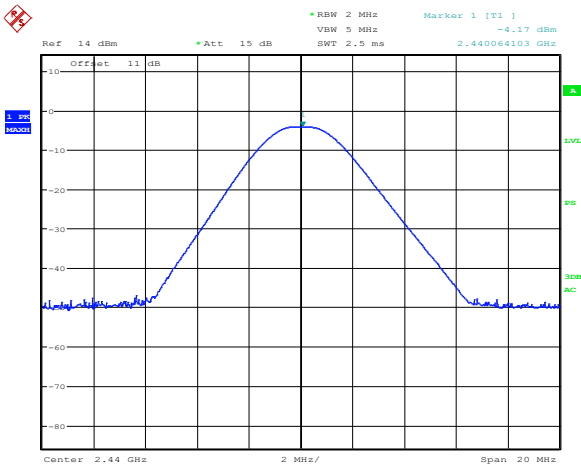


Figure 8.2-2: Output power on mid channel

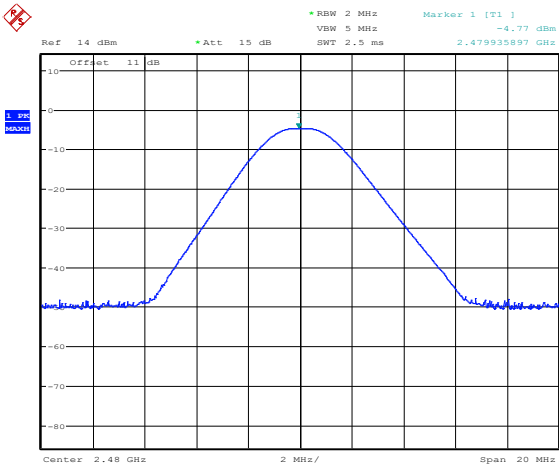


Figure 8.2-3: Output power on high channel

8.3 Clause 3.10.1.5 Spurious emissions

8.3.1 Definitions and limits

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 below that in the 100 kHz bandwidth within the band that contains the highest level of the desired power, the attenuation shall be as below:

3.10.1.5 (1) The attenuation shall be at least 20 dB when the conducted power is measured according to Appendix II of this section, based on either an RF conducted or a radiated measurement.

3.10.1.5 (2) The attenuation shall be at least 30 dB when the conducted power is measured according to the paragraph (1) (C) of this section 3.10.1.2.

In addition, radiated emissions that fall under Section 2.7 the restricted bands must also comply with the radiated emission limit specified in Section 2.8.

Table 8.3-1: Section 2.8 Radiated emission limits

Frequency, MHz	Field strength of emissions		Measurement distance, m
	$\mu\text{V/m}$	$\text{dB}\mu\text{V/m}$	
0.009–0.490	2400/F	$67.6 - 20 \times \log_{10}(\text{F})$	300
0.490–1.705	24000/F	$87.6 - 20 \times \log_{10}(\text{F})$	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. F is in kHz units
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 8.3-2: Section 2.7 Restricted frequency bands

MHz	MHz	MHz
0.090–0.110	240.00–285.00	3332.0–3339.0
0.490–0.510	322.00–335.40	3345.8–3358.0
2.172–2.198	399.90–410.00	3500.0–4400.0
3.013–3.033	485.00–510.00	4500.0–5250.0
4.115–4.198	608.00–614.00	5350.0–5460.0
5.670–5.690	703.00–748.00	7250.0–7750.0
6.200–6.300	758.00–803.00	8025.0–8500.0
8.230–8.400	825.00–915.00	9000.0–9200.0
12.265–12.600	930.00–1240.0	9300.0–9500.0
13.340–13.430	1300.0–1427.0	10600–12700
14.965–15.020	1435.0–1626.5	13250–13400
16.700–16.755	1660.0–1785.0	14470–14500
19.965–20.020	1805.0–1880.0	15350–16200
25.500–25.700	1885.0–1900.0	17700–21400
37.475–38.275	1905.0–1985.0	22010–23120
73.500–75.400	2010.0–2025.0	23600–24000
108.00–138.00	2110.0–2170.0	31200–31800
149.90–150.05	2200.0–2300.0	36430–36500
156.70–156.90	2310.0–2390.0	Above 38600
162.01–167.17	2483.5–2900.0	
167.72–173.20	3260.0–3267.0	

Notes: None

8.3.2 Test summary

Verdict	Pass
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8.3.3 Observations, settings and special notes

- The EUT was operating at 100% duty cycle.
- The spectrum was searched from 30 MHz to the 10th harmonic.
- Cabinet radiation measurements were performed at a distance of 3 m.
- EUT was rotated in 3 planes to find the maximum value for radiated emissions.
- Since fundamental power was tested using peak power method, the spurious emissions outside restricted bands limit is –20 dBc/100 kHz
- Conducted plots have been corrected with associated transducer factors (i.e. cable loss attenuators).
- Radiated plots are a summation of a vertical and horizontal scan. The spectral plots have been corrected with the associated transducer factors (i.e. antenna factors, cable loss, amplifier gains, and attenuators).

Spectrum analyser settings for radiated below 1 GHz:

Resolution bandwidth:	100 kHz
Video bandwidth:	300 kHz
Detector mode:	Peak
Trace mode:	Max Hold

Spectrum analyser settings for peak radiated measurements above 1 GHz:

Resolution bandwidth:	1 MHz
Video bandwidth:	3 MHz
Detector mode:	Peak
Trace mode:	Max Hold

Spectrum analyser settings for average radiated measurements above 1 GHz:

Resolution bandwidth:	1 MHz
Video bandwidth:	10 Hz
Detector mode:	Peak
Trace mode:	Max Hold

Spectrum analyser settings for conducted spurious emissions outside restricted bands measurements:

Resolution bandwidth:	100 kHz
Video bandwidth:	300 kHz
Detector mode:	Peak
Trace mode:	Max Hold

8.3.4 Test data

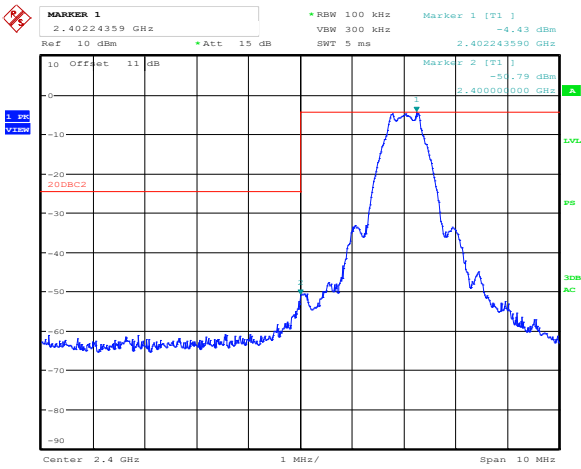


Figure 8.3-1: Conducted spurious emissions outside restricted bands at the lower band edge (2400 MHz), on low channel

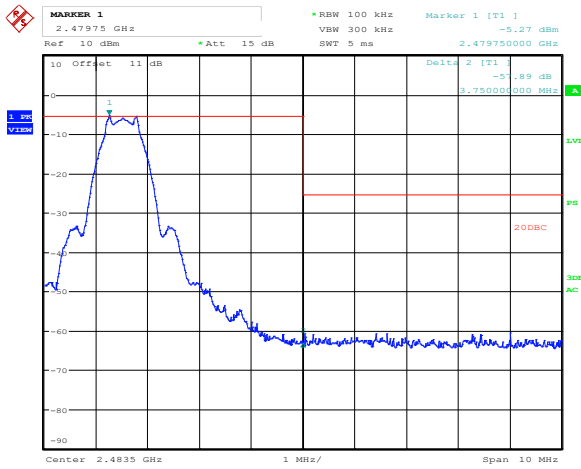


Figure 8.3-2: Conducted spurious emissions outside restricted bands at the upper band edge (2483.5 MHz), on high channel

8.3.4 Test data, continued

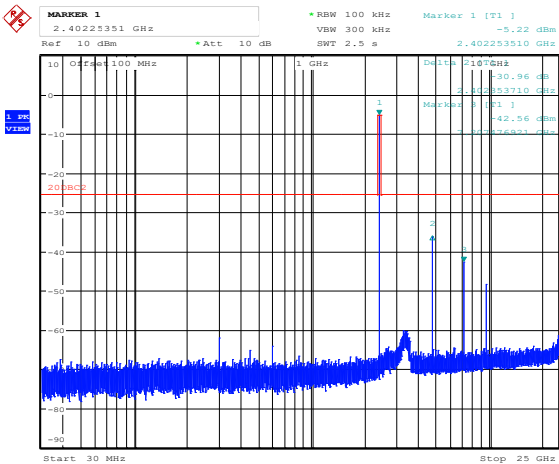


Figure 8.3-3: Conducted spurious emissions outside restricted bands on low channel

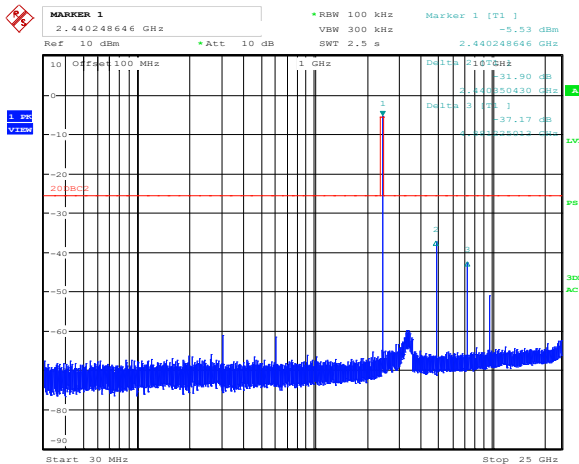


Figure 8.3-4: Conducted spurious emissions outside restricted bands on mid channel

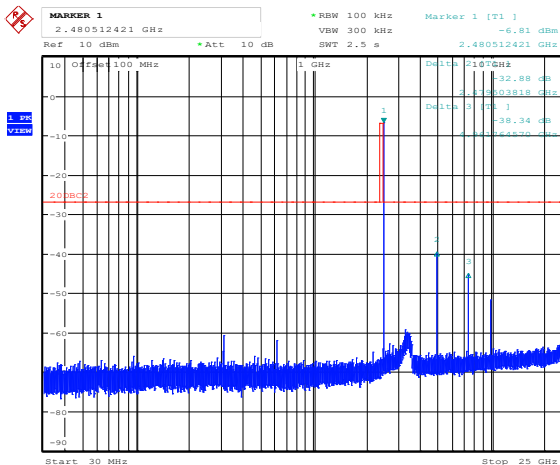


Figure 8.3-5: Conducted spurious emissions outside restricted bands on high channel

Table 8.3-3: Radiated field strength measurement results

Channel	Frequency, MHz	Peak Field strength, dBμV/m		Peak Margin, dB	Average Field strength, dBμV/m		Average Margin, dB
		Measured	Limit		Measured	Limit	
Low	2390	55.0	74.0	19.0	42.0	54.0	12.0
High	2483.5	60.0	74.0	14.0	53.0	54.0	1.0

Notes: Field strength includes correction factor of antenna, cable loss, amplifier, and attenuators where applicable.

8.3.4 Test data, continued

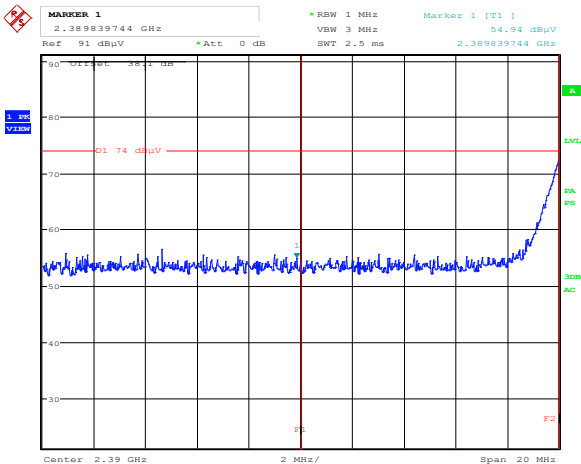


Figure 8.3-6: Lower band edge low channel, peak

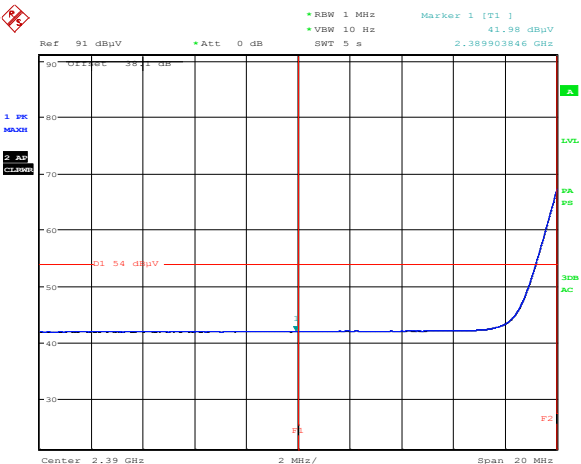


Figure 8.3-7: Lower band edge low channel, average

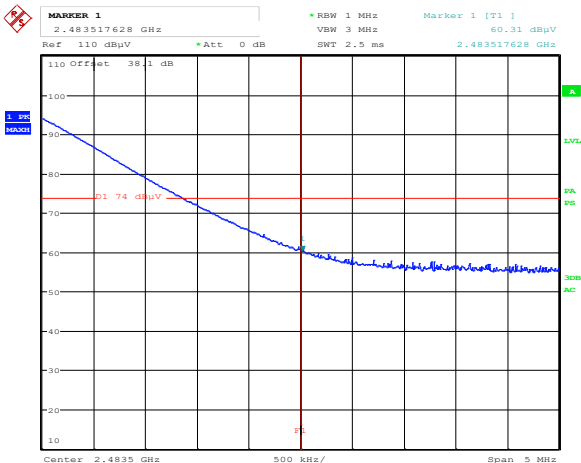


Figure 8.3-8: Upper band edge high channel, peak

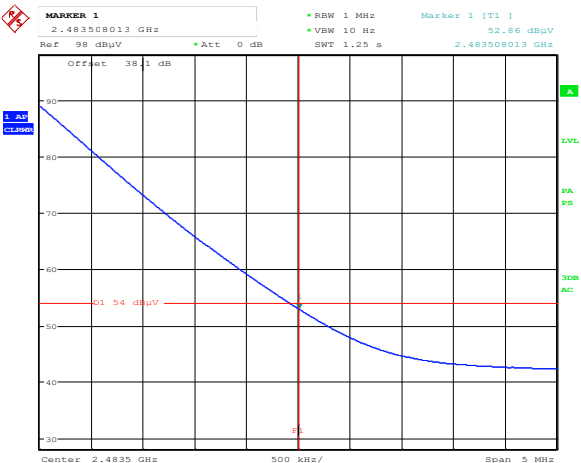


Figure 8.3-9: Upper band edge high channel, average

8.3.4 Test data, continued

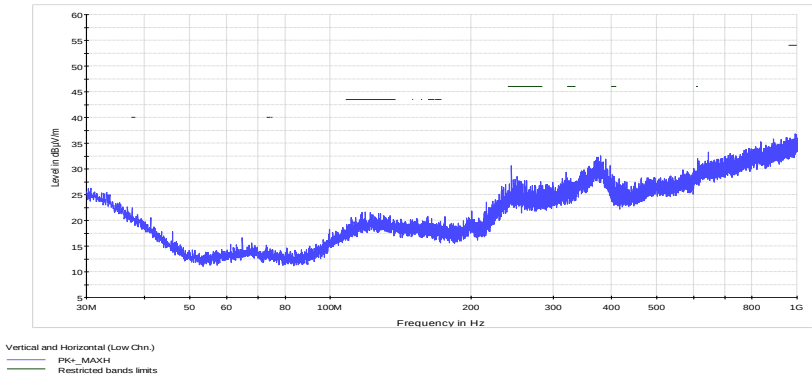


Figure 8.3-10: Radiated spurious emissions within restricted bands on low channel below 1 GHz

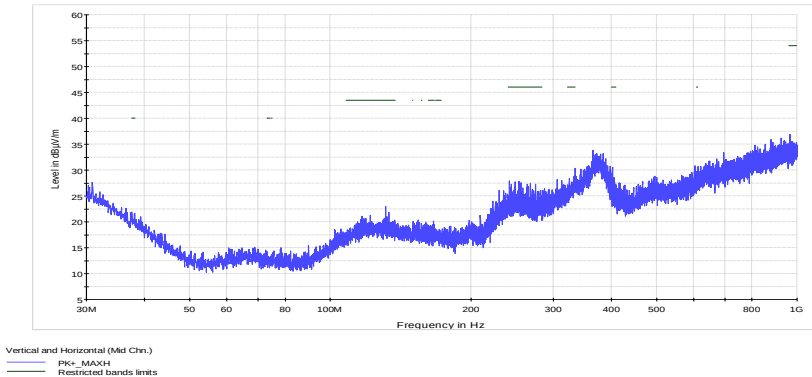


Figure 8.3-11: Radiated spurious emissions within restricted bands on mid channel below 1 GHz

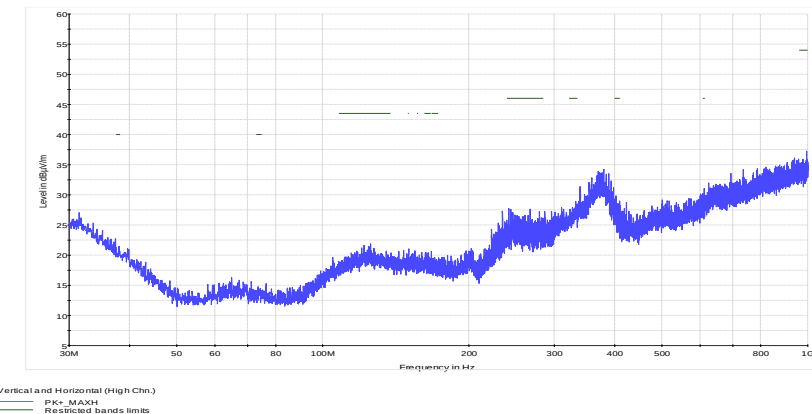


Figure 8.3-12: Radiated spurious emissions within restricted bands on high channel below 1 GHz

8.3.4 Test data, continued

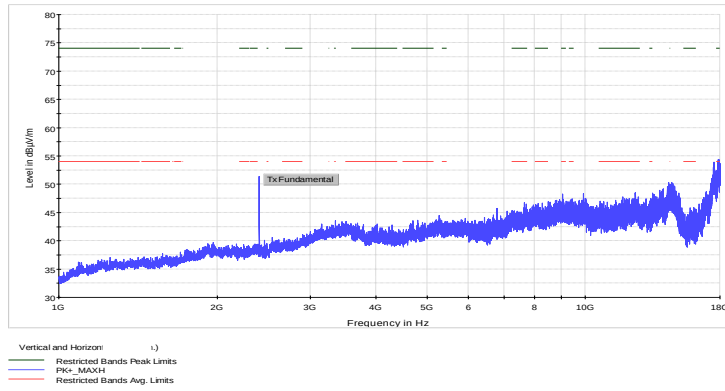


Figure 8.3-13: Radiated spurious emissions within restricted bands on low channel between 1 and 18 GHz

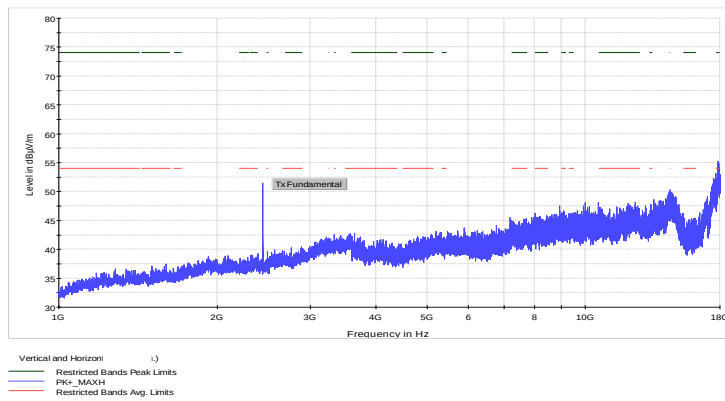


Figure 8.3-14: Radiated spurious emissions within restricted bands on mid channel between 1 and 18 GHz

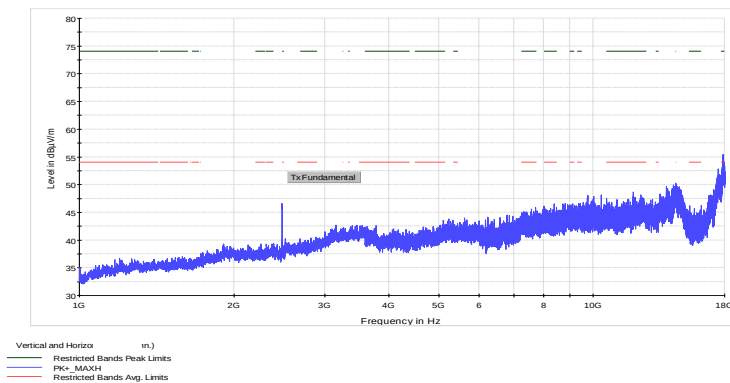


Figure 8.3-15: Radiated spurious emissions within restricted bands on high channel between 1 and 18 GHz

Special notes:

- Further investigation was verified from 17.7–18.0 GHz where the peak was above the average limit. No emissions were detected from the EUT.
- A 2400to 2483 MHz Notch filter was used to reduce the fundamental.

8.3.4 Test data, continued

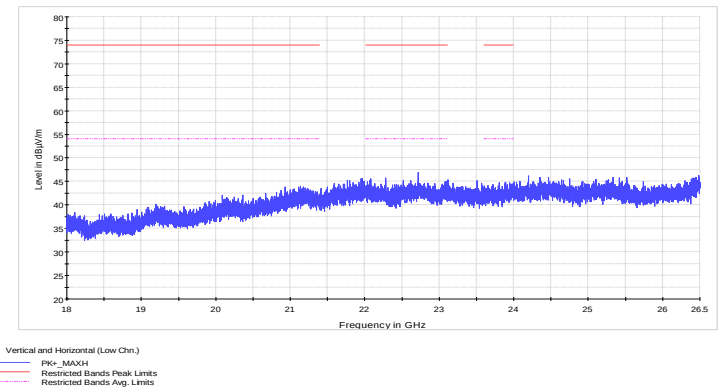


Figure 8.3-16: Radiated spurious emissions within restricted bands on low channel between 18 and 25 GHz

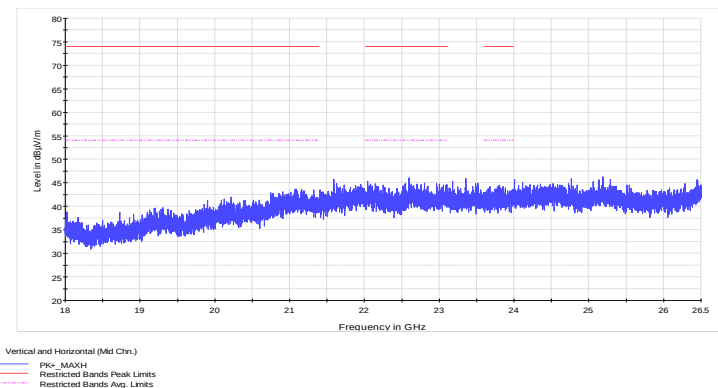


Figure 8.3-17: Radiated spurious emissions within restricted bands on mid channel between 18 and 25 GHz

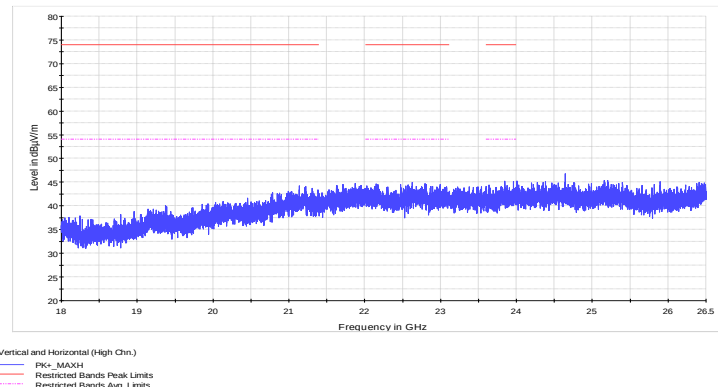


Figure 8.3-18: Radiated spurious emissions within restricted bands on high channel between 18 and 25 GHz

8.3.4 Setup photos



Figure 8.3-19: Radiated spurious emissions setup photo – below 1 GHz

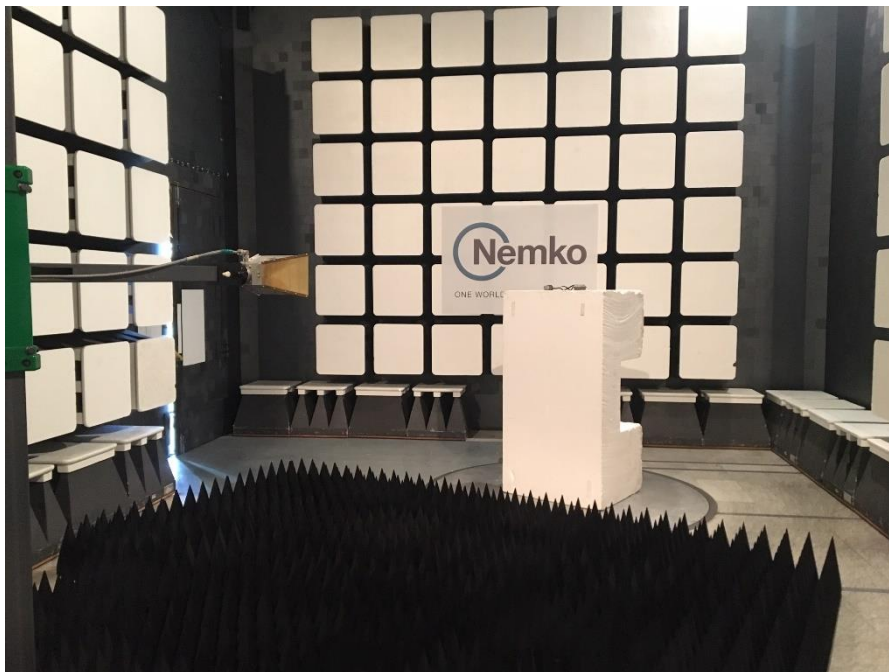


Figure 8.3-20: Radiated spurious emissions setup photo – above 1 GHz

8.4 Clause 3.10.1.6 (2)(B) Peak power spectral density for digitally modulated devices

8.4.1 Definitions and limits

For digitally modulated systems, the peak 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.

8.4.2 Test summary

Verdict Pass

8.4.3 Observations, settings and special notes

The output power was tested using peak detector, therefore PSD test was performed using peak method.

8.4.4 Test data

Table 8.4-1: PSD measurements results

Frequency, MHz	PSD, dBm/3 kHz	PSD limit, dBm/3 kHz	Margin, dB
2402	-15.3	8.0	23.3
2440	-16.3	8.0	24.3
2480	-18.3	8.0	26.3

8.4.4 Test data, continued

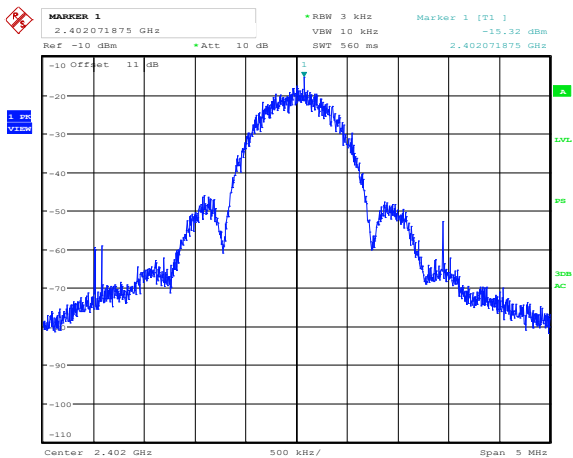


Figure 8.4-1: PSD sample plot on low channel

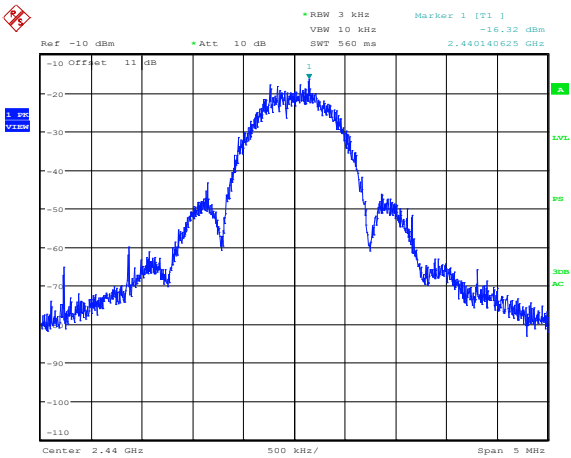


Figure 8.4-2: PSD sample plot on mid channel

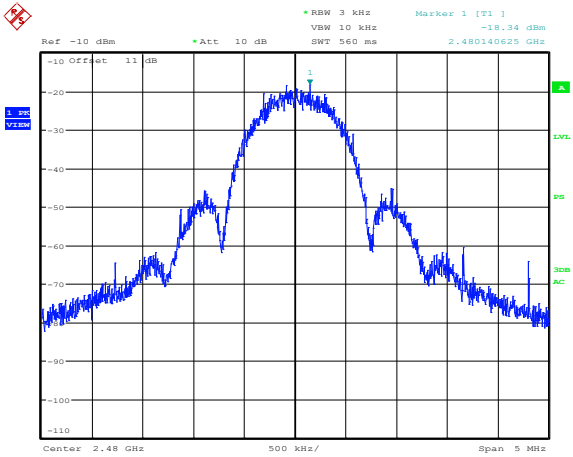
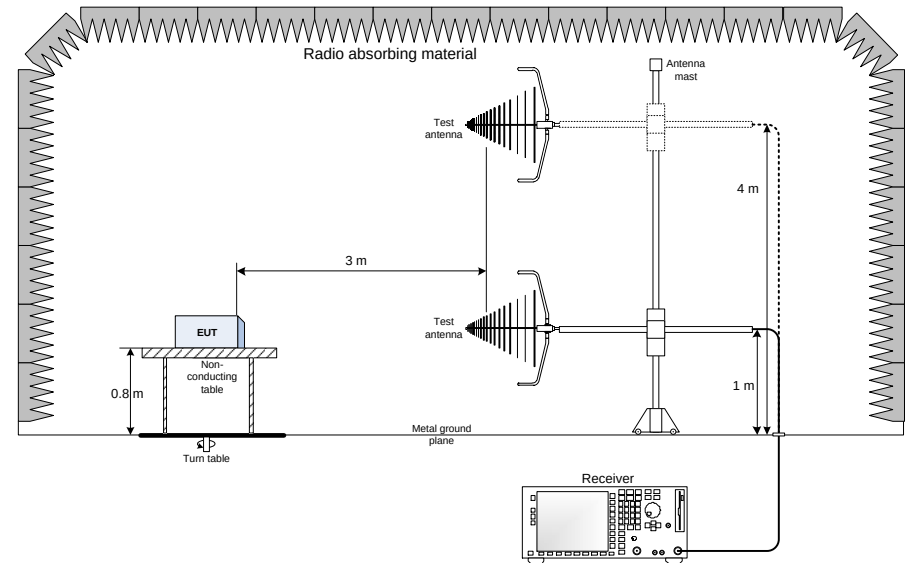


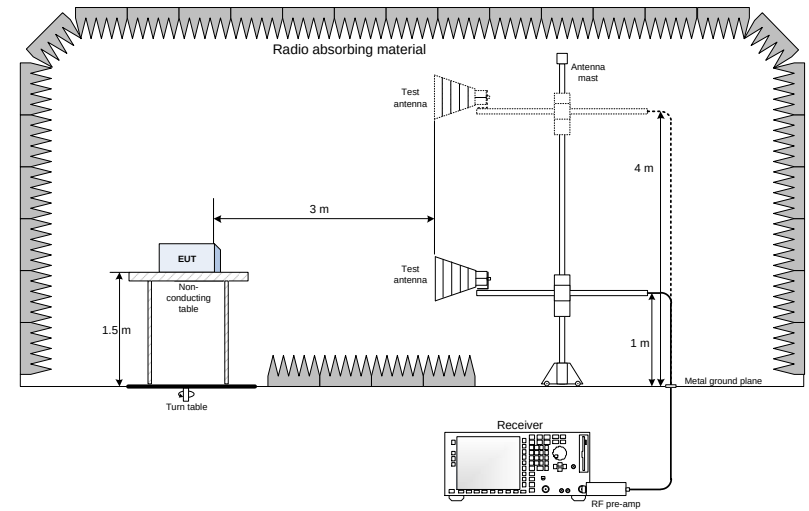
Figure 8.4-3: PSD sample plot on high channel

Section 9. Block diagrams of test set-ups

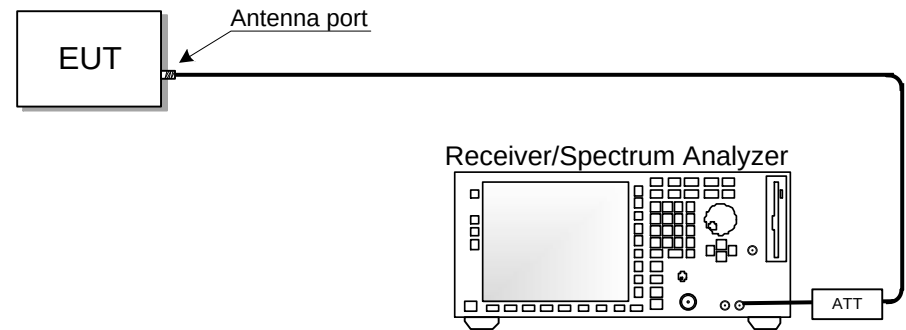
9.1 Radiated emissions set-up for frequencies below 1 GHz



9.2 Radiated emissions set-up for frequencies above 1 GHz



9.3 Antenna port set-up



Section 10. EUT photos

10.1 External photos



End of test report