

WIRELESS TEST REPORT – 370465-1R1TRFWL

Applicant:

LEGO System A/S

Product:

Bluetooth and BLE Transceiver

Model:

HUB NO.6

Specifications:

Low Power 0002 (LP0002) January 10, 2018

Low-power Radio-frequency Devices Technical Regulations

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

Date of issue: **November 11, 2019**

David Duchesne, Senior EMC/Wireless Specialist

Tested by



Signature

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Reviewed by



Signature

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The tests included in this report are within the scope of this accreditation

Lab locations

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Test site registration	Organization	Recognition numbers and location		
	FCC/ISED	CA2040 (Ottawa/Almonte); CA2041 (Montreal); CA0101 (Cambridge)		
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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Section 1 Report summary

1.1 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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1.2 Test methods

558074 D01 15.247 Meas Guidance v05r02 (April 2, 2019)	Guidance for compliance measurements on digital transmission system, frequency hopping spread spectrum system, and hybrid system devices operating under section 15.247 of the FCC rules.
DA 00-705, Released March 30, 2000	Filing and Measurement Guidelines for Frequency Hopping Spread Spectrum Systems
ANSI C63.10 v2013	American National Standard of Procedures for Compliance Testing of Unlicensed Wireless Devices

1.3 Exclusions

None

1.4 Statement of compliance

In the configuration tested, the EUT was found compliant.

Testing was performed against all relevant requirements of the test standard except as noted in section 1.2 above. 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 Test report revision history

Table 1.5-1: Test report revision history

Revision #	Date of issue	Details of changes made to test report
TRF	November 5, 2019	Original report issued
R1	November 11, 2019	Correction to antenna gain.

Section 2 Engineering considerations

2.1 Modifications incorporated in the EUT for compliance

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

2.2 Technical judgment

None

2.3 Deviations from laboratory tests procedures

No deviations were made from laboratory procedures.

Section 3 Test conditions

3.1 Atmospheric conditions

Temperature	15 °C – 35 °C
Relative humidity	30 % – 60 %
Air pressure	86 kPa (860 mbar) – 106 kPa (1060 mbar)

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.

3.2 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 4 Measurement uncertainty

4.1 Uncertainty of measurement

The following referenced documents are used as guidance for measurement uncertainty reasonable estimations with regards to previous experience and validation of data:

1. TIA-603-B Land Mobile FM or PM Communications Equipment, Measurement and Performance Standards. Nov. 7, 2002
2. UKAS LAB 34: 2003: The Expression of Uncertainty in EMC Testing: United Kingdom Accreditation Service.
3. ETSI TR 100 028-1 v1.4.1 (2001-12): Electromagnetic Compatibility and Radio Spectrum Matters (ERM); Uncertainties in the measurement of mobile radio equipment characteristics; Part1".
4. ETSI TR 100 028-2 v 1.4.1(2001-12): Electromagnetic Compatibility and Radio Spectrum Matters (ERM); Uncertainties in the measurement of mobile radio equipment characteristics; Part2".

Nemko Canada, Inc. follows these test methods in order to satisfy ISO/IEC 17025 requirements for estimation of uncertainty of measurement for wireless products.

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

Table 4.1-1: Measurement uncertainty calculations

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

Section 5 Summary of test results

5.1 Testing location

Test location (s)	Ottawa
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5.2 Testing period

Test start date	October 25, 2019	Test end date	October 28, 2019
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5.3 Sample information

Receipt date	October 17, 2019	Nemko sample ID number	1 and 2
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5.4 Technical information

Operating band	2400–2483.5 MHz
Operating frequency range	2402–2480 MHz
Bandwidth 20 dB	Bluetooth: 1.4 MHz
Bandwidth 6 dB	BLE: 680 kHz
Types of modulation	GFSK, 8DPSK and 4 π DPSK
Data rate	3Mbit/s
EUT power requirements	7.3V _{DC} Internal battery
Antenna type	integral antenna, 2.1 dBi

5.5 Summary of test results

Table 5.5-1: Results

Part	Test description	Verdict
2.3	AC conducted limits	Not applicable ¹
3.10.1.2 (1)(A)	Maximum peak output power, operation within 2400–2483.5 MHz: For frequency hopping systems employing at least 75 hopping channels; below 1 watt	Pass
3.10.1.2 (1)(B)	Maximum peak output power, operation within 2400–2483.5 MHz: For frequency hopping systems according to section 3.10.1.6 (1) (A) (a) excluded by (A): below 0.125 watt	Not applicable
3.10.1.2 (1)(C)	Maximum peak output power, operation within 2400–2483.5 MHz: For systems using digital modulation: below 1 watt	Pass
3.10.1.2 (2)	Maximum peak output power, operation within 5725–5850 MHz: For frequency hopping systems below 1 watt	Not applicable
3.10.1.3 (1)(A)	Limits of antenna gains, operation within 2400–2483.5 MHz: Fixed point-to-point operation directional antenna gains greater than 6 dBi	Not applicable
3.10.1.3 (1)(B)	Limits of antenna gains, operation within 2400–2483.5 MHz: Transmitters that emit multiple directional beams	Not applicable
3.10.1.3 (2)	Limits of antenna gains, operation within 5725–5850 MHz: Fixed point-to-point operation within 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	Pass
3.10.1.6 (1)(A)(a)	Frequency hopping systems operating in the 2400–2483.5 MHz band, other requirements	Pass
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 was tested for both BLE and BT technologies.

¹The EUT is a battery-operated equipment, the testing was performed using fresh batteries.

Section 6 Information provided by the applicant

6.1 Disclaimer

This section contains information provided by the applicant and has been utilized to support the test plan. Inaccurate information provided by the applicant can affect the validity of the results contained within this test report. Nemko accepts no responsibility for the information contained within this section and the impact it may have on the test plan and resulting measurements.

6.2 Applicant/Manufacturer

Company name	LEGO System A/S
Address	Aastvej 1, 7190 Billund, Denmark

6.3 EUT information

Product name	Bluetooth and BLE Transceiver
Model	HUB NO.6
Serial number	Radiated sample: Marked as "FEP-1_135", Conducted sample: Marked as "FEP-EP5 019"
Hardware identity and/or version	10035801-E
Software identity and/or version	1.0.00.0000
Power requirements	7.3 V _{DC}
Description/theory of operation	The device is a toy which controls dedicated motors, sensors and remotely control via BLE or Bluetooth classic with remote device such as iOS, Android or similar.

6.4 EUT setup details

6.4.1 EUT Exercise

The EUT was setup for continuous transmission.

6.4.2 EUT test configuration



Figure 6.4-1: Block diagrams

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	January 24, 2020
Receiver/spectrum analyzer	Rohde & Schwarz	ESU 26	FA002043	1 year	May 8, 2020
Spectrum analyzer	Rohde & Schwarz	FSU	FA001877	1 year	October 26, 2019
Bilog antenna (20–3000 MHz)	Sunol	JB3	FA002108	1 year	January 3, 2020
Horn (1–18 GHz)	ETS Lindgren	3117	FA002840	1 year	January 16, 2020
Horn (1–18 GHz)	ETS Lindgren	3117	FA002840	1 year	January 16, 2020
Pre-amplifier (18–26 GHz)	Narda	BBS-1826N612	FA001550	—	VOU
Preamp (1–18 GHz)	ETS Lindgren	124334	FA002877	1 year	November 4, 2019
50 Ω coax cable	Huber + Suhner	None	FA003099	1 year	May 10, 2020
50 Ω coax cable	C.C.A.	None	FA002556	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 3.10.1.2 (1) Maximum FHHS peak output power (2400-2483.5 MHz band)

8.1.1 Definitions and limits

(A) For frequency hopping systems employing at least 75 hopping channels; below 1 watt (30 dBm)

Clause 3.10.1.3 (1) Limits of antenna gains

(A) For fixed, point-to-point operations, the peak conducted output power of the intentional radiator shall be reduced by 1dB for every 3dBi when the directional gain of the antenna exceeds 6dBi.

8.1.2 Test date

Start date October 25, 2019

8.1.3 Observations, settings and special notes

- The hopping was disabled for this test.
- The EUT was tested for BT.

Spectrum analyser settings:

Resolution bandwidth	> 20 dB bandwidth of the emission being measured
Video bandwidth	≥ RBW
Frequency span	approximately 5 times the 20 dB bandwidth, centered on a hopping channel
Detector mode	Peak
Trace mode	Max Hold

8.1.4 Test data

Table 8.1-1: Output power and EIRP results

Modulation type	Frequency, MHz	Output power, dBm	Output power limit, dBm	Margin, dB	Antenna gain, dBi	EIRP, dBm	EIRP limit, dBm	EIRP margin, dB
GFSK	2402	0.1	30.0	29.9	2.1	2.2	36.0	33.8
GFSK	2441	1.0	30.0	29.0	2.1	3.1	36.0	32.9
GFSK	2480	1.4	30.0	28.6	2.1	3.5	36.0	32.5
4πDQPSK	2402	0.6	30.0	29.4	2.1	2.7	36.0	33.3
4πDQPSK	2441	1.6	30.0	28.4	2.1	3.7	36.0	32.3
4πDQPSK	2480	1.7	30.0	28.3	2.1	3.8	36.0	32.2
8DPSK	2402	1.2	30.0	28.8	2.1	3.3	36.0	32.7
8DPSK	2441	2.1	30.0	27.9	2.1	4.2	36.0	31.8
8DPSK	2480	2.1	30.0	27.9	2.1	4.2	36.0	31.8

Notes: EIRP = Conducted output power, dBm + Antenna gain, dBi

8.1.4 Test data, continued

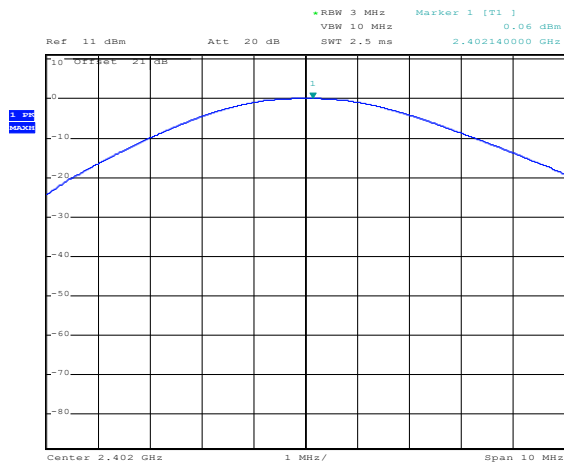


Figure 8.1-1: Output power sample plot – low channel

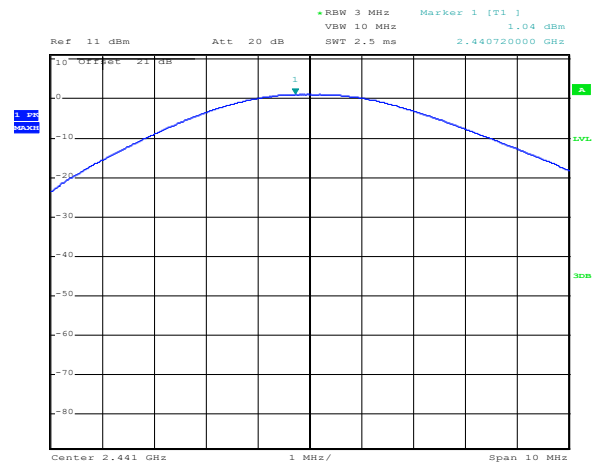


Figure 8.1-2: Output power sample plot – mid channel

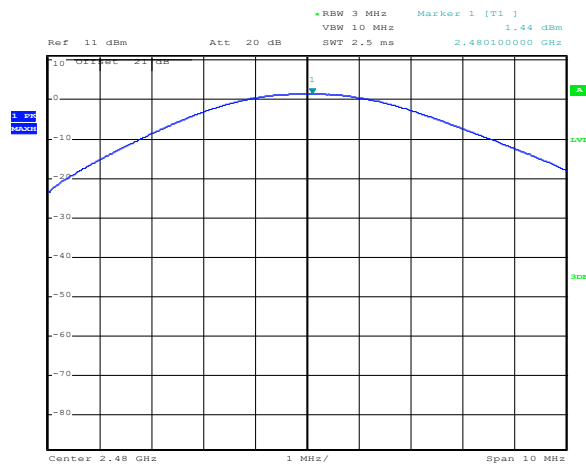


Figure 8.1-3: Output power sample plot – high channel

8.2 Clause 3.10.1.2 (1) Maximum DTS peak output power (2400-2483.5 MHz band)

8.2.1 Definitions and limits

(C) For systems using digital modulation: below 1 Watt (30 dBm)

Clause 3.10.1.3 (1) Limits of antenna gains

(A) For fixed, point-to-point operations, the peak conducted output power of the intentional radiator shall be reduced by 1dB for every 3dBi when the directional gain of the antenna exceeds 6dBi.

8.2.2 Test date

Start date	October 25, 2019
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8.2.3 Observations, settings and special notes

- The EUT was tested for BLE.
- The test was performed using method PKPM1 (Peak power meter method)

The spectrum analyser settings:

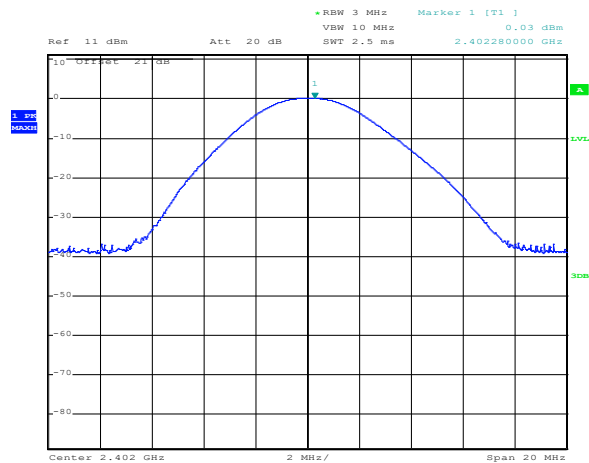
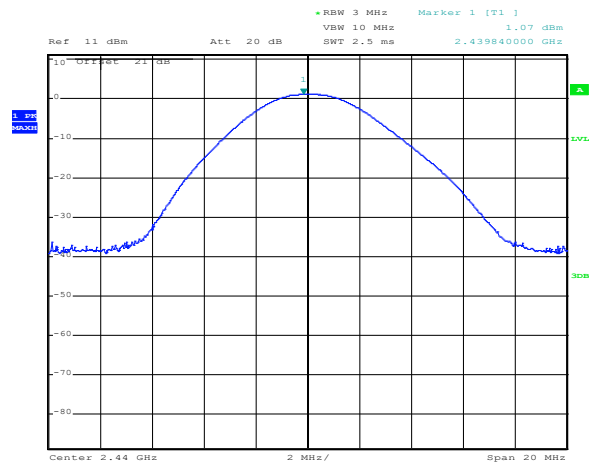
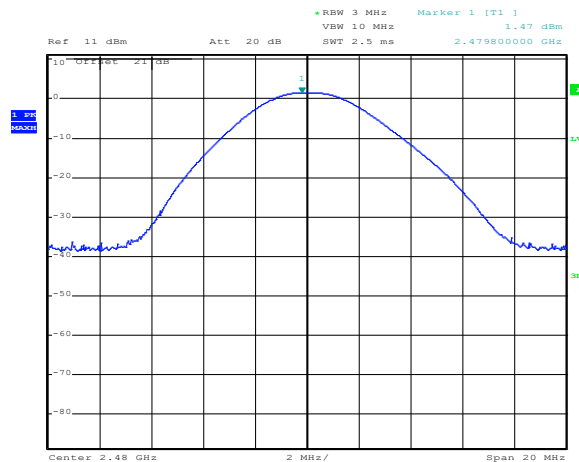
Resolution bandwidth	2 MHz
Video bandwidth	$\geq 3 \times \text{RBW}$
Detector mode	Peak
Trace mode	Max Hold

8.2.4 Test data

Table 8.2-1: Output power and EIRP measurements results

Frequency, MHz	Conducted output power, dBm		Margin, dB	Antenna gain, dBi	EIRP, dBm	EIRP limit, dBm	EIRP margin, dB
	Measured	Limit					
2402	0.0	30.0	30.0	2.1	2.1	36.0	33.9
2440	1.1	30.0	28.9	2.1	3.2	36.0	32.8
2480	1.5	30.0	28.5	2.1	3.6	36.0	32.4

Notes: EIRP = Conducted output power, dBm + Antenna gain, dBi


Figure 8.2-1: Output Power – low channel

Figure 8.2-2: Output Power – mid channel

Figure 8.2-3: Output Power – high channel

8.3 Clause 3.10.1.5 Limits on emissions outside the frequency band (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:

- (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.
- (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 date

Start date	October 28, 2019
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8.3.3 Observations, settings and special notes

- The EUT was tested for both BLE and BT.
- 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).

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
Trace mode:	Average

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

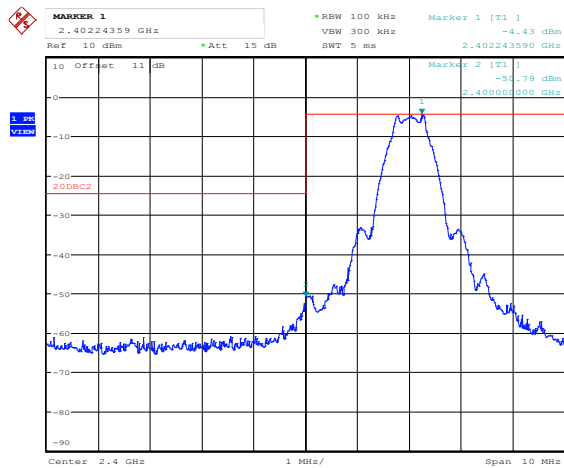


Figure 8.3-1: Conducted spurious emissions outside restricted bands at the lower band edge (2400 MHz), on BLE – low channel

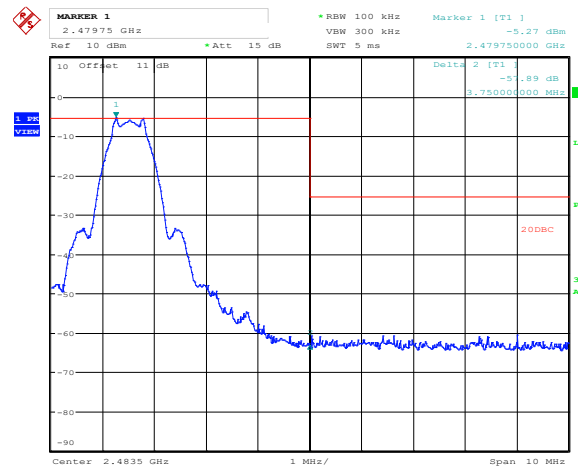


Figure 8.3-2: Conducted spurious emissions outside restricted bands at the upper band edge (2483.5 MHz), on BLE – high channel

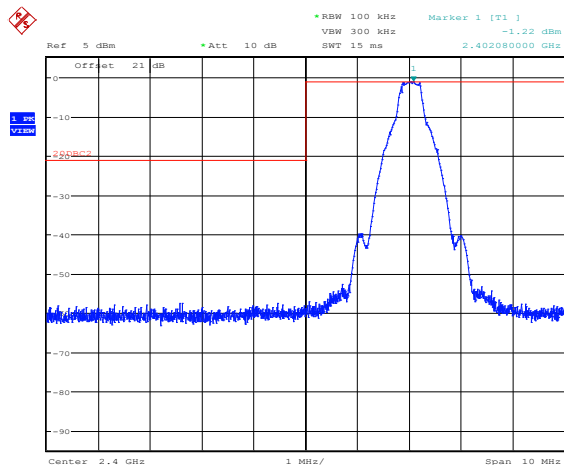


Figure 8.3-3: Conducted spurious emissions outside restricted bands at the lower band edge (2400 MHz), on BT, GFSK – low channel

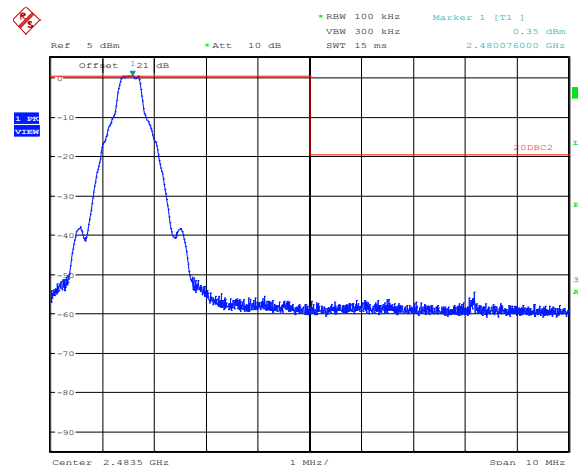


Figure 8.3-4: Conducted spurious emissions outside restricted bands at the upper band edge (2483.5 MHz), on BT, GFSK – high channel

8.3.4 Test data, continued

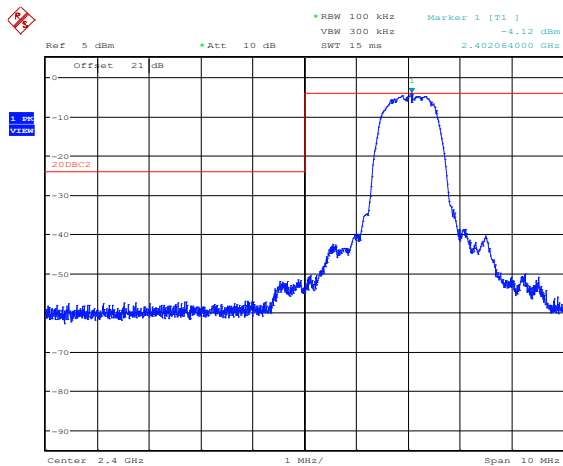


Figure 8.3-5: Conducted spurious emissions outside restricted bands at the lower band edge (2400 MHz), on BT, 4 π DPSK – low channel

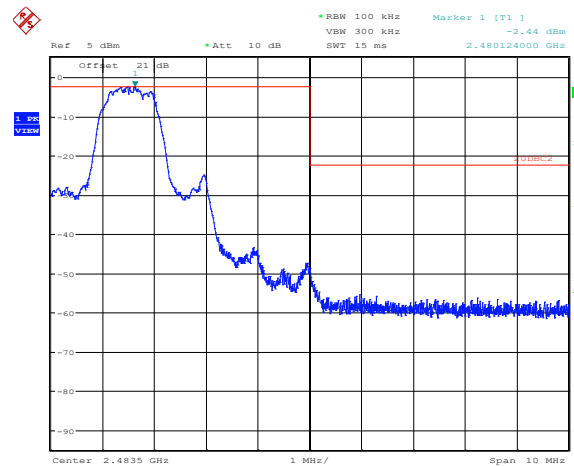


Figure 8.3-6: Conducted spurious emissions outside restricted bands at the upper band edge (2483.5 MHz), on BT, 4 π DPSK – high channel

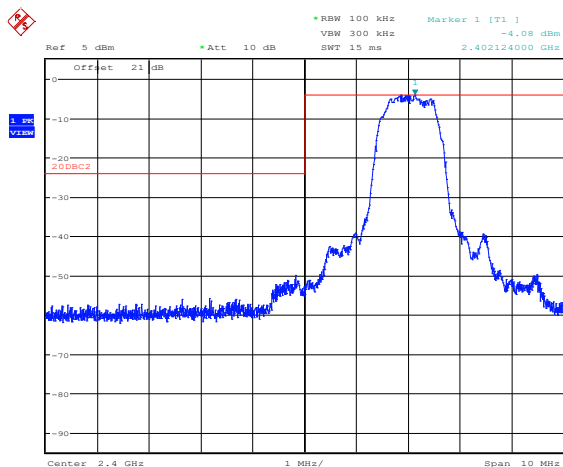


Figure 8.3-7: Conducted spurious emissions outside restricted bands at the lower band edge (2400 MHz), on BT, 8 π DPSK – low channel

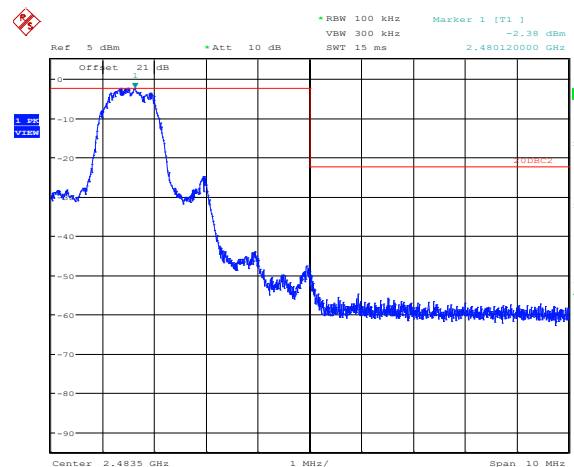


Figure 8.3-8: Conducted spurious emissions outside restricted bands at the upper band edge (2483.5 MHz), on BT, 8 π DPSK – high channel

8.3.4 Test data, continued

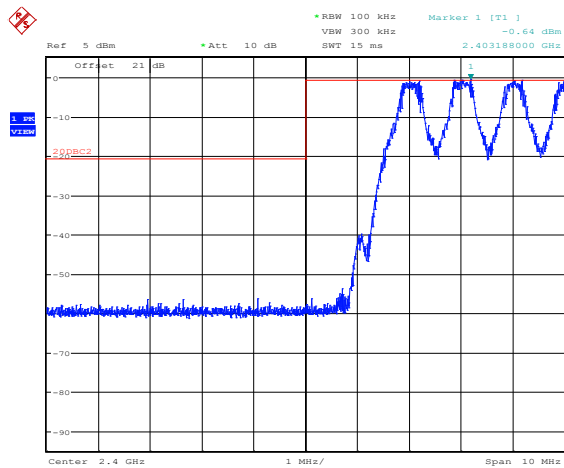


Figure 8.3-9: Conducted spurious emissions outside restricted bands at the lower band edge (2400 MHz), on BT – hopping

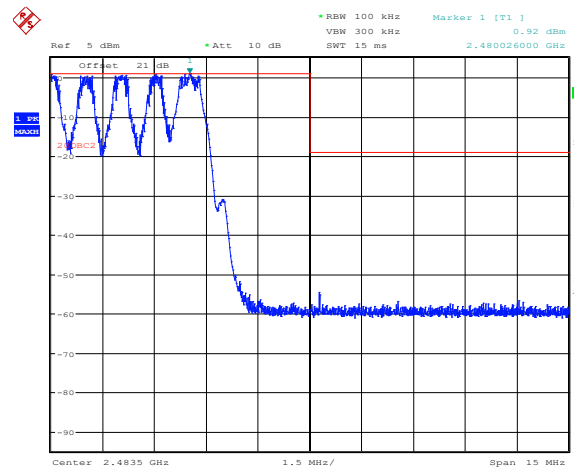


Figure 8.3-10: Conducted spurious emissions outside restricted bands at the upper band edge (2483.5 MHz), on BT – hopping

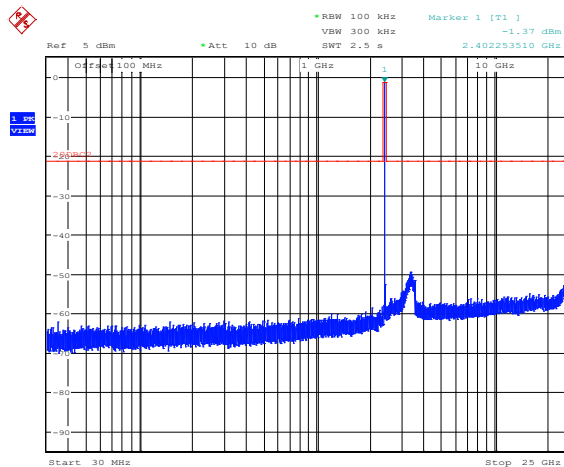


Figure 8.3-11: Conducted spurious emissions outside restricted bands, on BLE – low channel

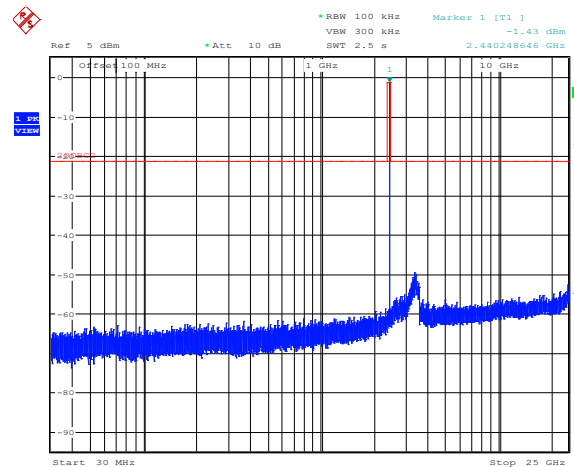


Figure 8.3-12: Conducted spurious emissions outside restricted bands, on BLE – mid channel

8.3.4 Test data, continued

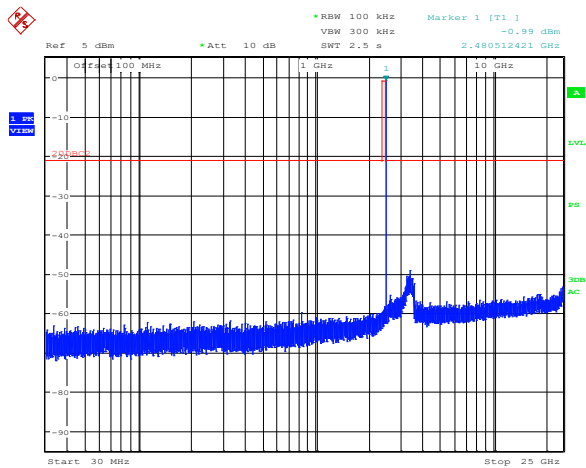


Figure 8.3-13: Conducted spurious emissions outside restricted bands, on BLE – high channel

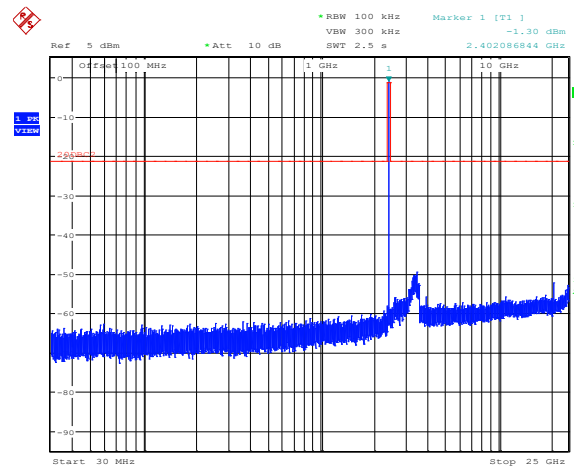


Figure 8.3-14: Conducted spurious emissions outside restricted bands, on BT, GFSK – low channel

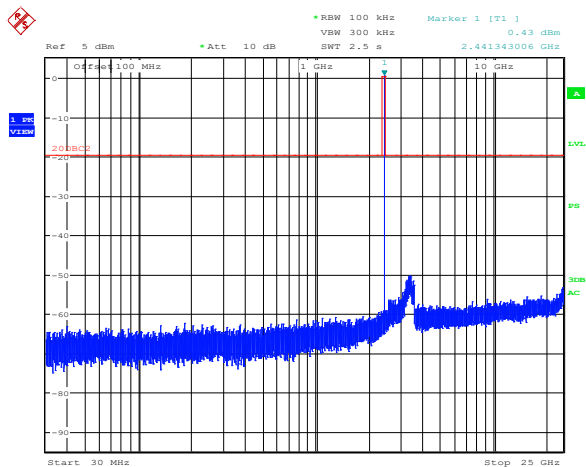


Figure 8.3-15: Conducted spurious emissions outside restricted bands, on BT, GFSK – mid channel

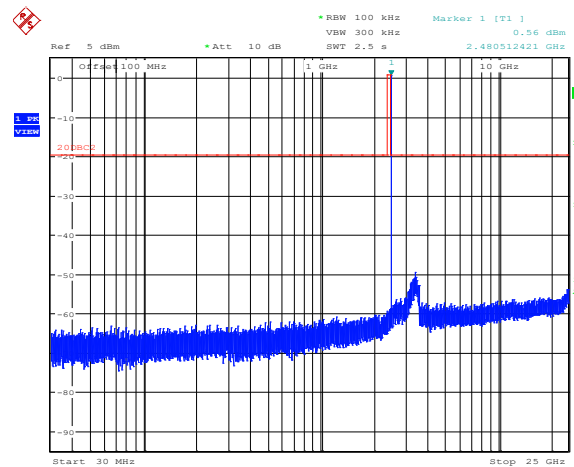


Figure 8.3-16: Conducted spurious emissions outside restricted bands, on BT, GFSK – high channel

8.3.4 Test data, continued

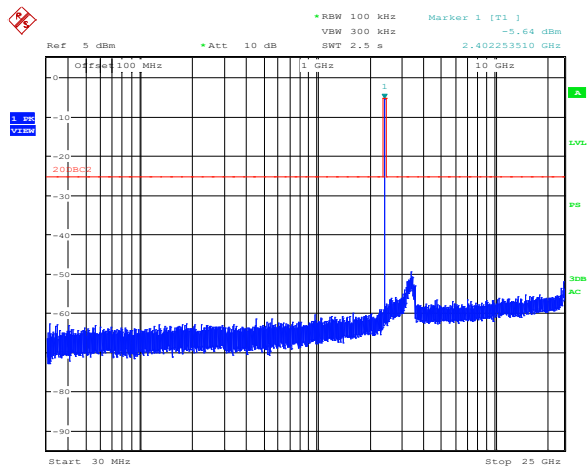


Figure 8.3-17: Conducted spurious emissions outside restricted bands, on BT, 4πDPSK – low channel

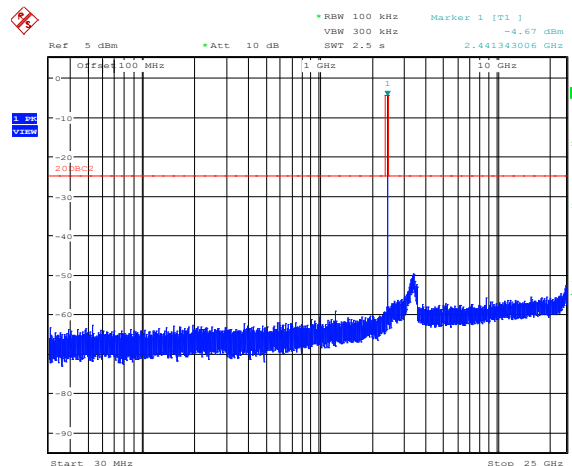


Figure 8.3-18: Conducted spurious emissions outside restricted bands, on BT, 4πDPSK – mid channel

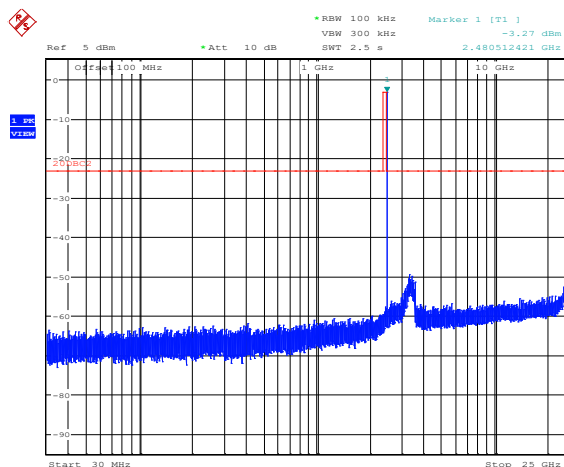


Figure 8.3-19: Conducted spurious emissions outside restricted bands, on BT, 4πDPSK – high channel

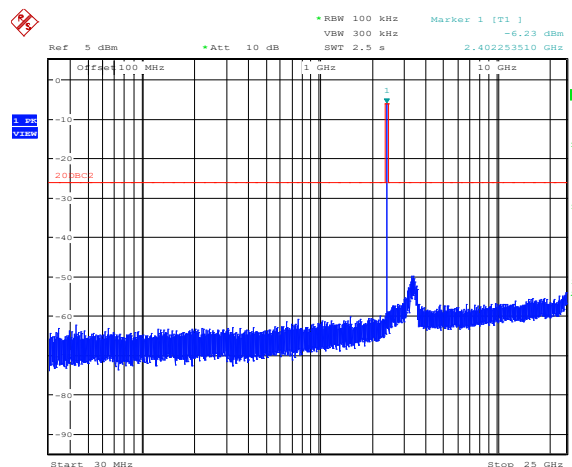


Figure 8.3-20: Conducted spurious emissions outside restricted bands, on BT, 8DPSK – low channel

8.3.4 Test data, continued

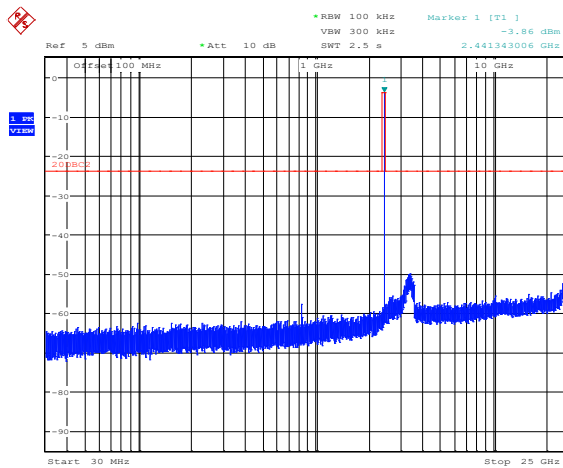


Figure 8.3-21: Conducted spurious emissions outside restricted bands, on BT, 8DPSK – mid channel

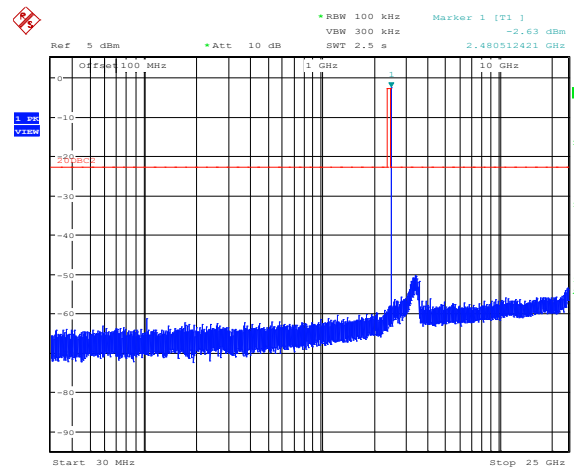


Figure 8.3-22: Conducted spurious emissions outside restricted bands, on BT, 4πDQPSK – high channel

8.3.4 Test data, continued

§15.35(c) When the radiated emission limits are expressed in terms of the average value of the emission, and pulsed operation is employed; the measurement field strength shall be determined by averaging over one complete pulse train, including blanking intervals, as long as the pulse train does not exceed 0.1 seconds.

$$\text{Duty cycle or average factor} = 20 \times \log_{10} \left(\frac{T_{x_{on}}}{T_{x_{period}}} \right)$$

Duty cycle/average factor calculations for BT.

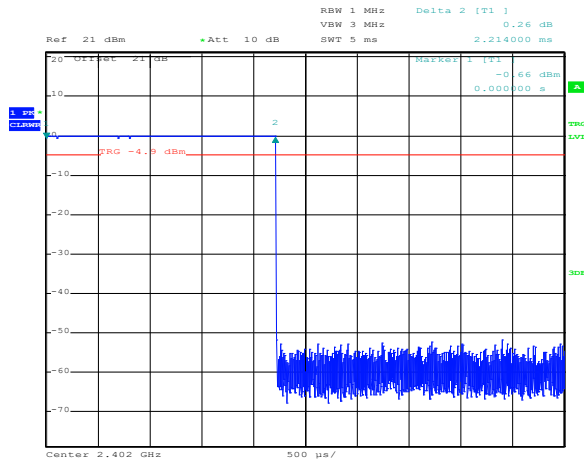


Figure 8.3-23: Burst Pulse with = 2.2 ms (DH5)

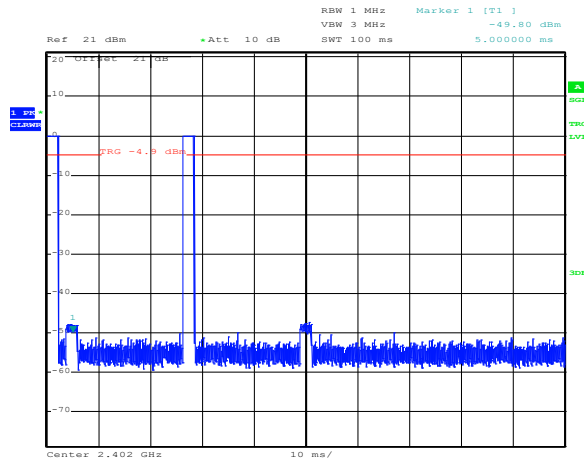


Figure 8.3-24: Tx on time over 100 ms (2 pulses)

$$\text{Duty cycle or average factor} = 20 \times \log_{10} \left(\frac{4.4}{100} \right) = -27 \text{ dB}$$

Note: A maximum DCCF of -20 dB was used for calculations to demonstrate compliance with radiated spurious (out-of-band) unwanted emissions.

Duty cycle/average factor calculations for BLE

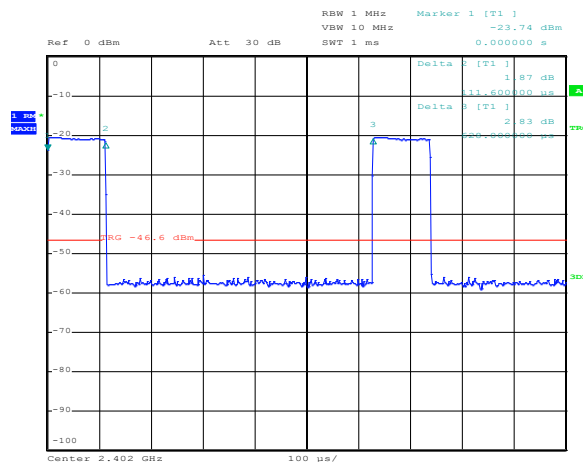


Figure 8.3-25: Duty cycle Tx Packet burst 37 bytes

Duty Cycle Correction Factor Calculation:

$$\text{Duty Cycle} = \text{On Time} / (\text{ON} + \text{OFF time}) = 11.6 \mu\text{s} / 628 \mu\text{s} = 0.18$$

$$\text{Duty Cycle Correction factor} = -20 \times \log_{10} (\text{Duty Cycle}) = -14.9 \text{ dB}$$

8.3.4 Test data, continued

Table 8.3-3: Radiated spurious emissions results BLE

Tx, Freq., MHz	Freq, MHz	Peak field strength, dBμV/m		Peak margin, dB	Average field strength, dBμV/m			Average margin, dB
		Measured	Limit		DCCF	Calculated	Limit	
2402	2390	56.6	74.0	17.4	-14.9	41.7	54.0	12.3
2402	7206	60.4	74.0	13.6	-14.9	45.5	54.0	8.5
2402	19216	47.9	74.0	26.1	-14.9	33.0	54.0	21.0
2440	7320	60.1	74.0	13.9	-14.9	45.2	54.0	8.8
2440	12200	53.5	74.0	20.5	-14.9	38.6	54.0	15.4
2440	19520	46.2	74.0	27.8	-14.9	31.3	54.0	22.7
2480	2483.5	59.2	74.0	14.8	-14.9	44.3	54.0	9.7
2480	7440	59.1	74.0	14.9	-14.9	44.2	54.0	9.8
2480	19840	44.2	74.0	29.8	-14.9	29.3	54.0	24.7

Notes: Field strength (dBμV/m) = Spectrum analyzer value (dBμV) + transducer factors (dB)
 Transducer factors (i.e. antenna factors, cable loss, amplifier gains, and attenuators).

- All other emissions within restricted bands were greater than 20 dB below the limit.
- All radiated emissions not within restricted bands were 40 dB below the fundamental transmitter power.

8.3.4 Test data, continued

Table 8.3-4: Radiated spurious emissions results BT

Tx, Freq., MHz	Freq, MHz	Peak field strength, dBμV/m		Peak margin, dB	Average field strength, dBμV/m			Average margin, dB
		Measured	Limit		DCCF	Calculated	Limit	
GFSK								
2402	2390	55.2	74.0	18.8	-20.0	35.2	54.0	18.8
2402	7206	60.1	74.0	13.9	-20.0	40.1	54.0	13.9
2402	19216	46.9	74.0	27.1	-20.0	26.9	54.0	27.1
2441	7323	59.3	74.0	14.7	-20.0	39.3	54.0	14.7
2441	12205	52.5	74.0	21.5	-20.0	32.5	54.0	21.5
2441	19528	46.3	74.0	27.7	-20.0	26.3	54.0	27.7
2480	2483.5	58.9	74.0	15.1	-20.0	38.9	54.0	15.1
2480	7440	58.1	74.0	15.9	-20.0	38.1	54.0	15.9
2480	19840	45	74.0	29.0	-20.0	25	54.0	29.0
4πDPSK								
2402	2390	55.7	74.0	18.3	-20.0	35.7	54.0	18.3
2402	7206	58.1	74.0	15.9	-20.0	38.1	54.0	15.9
2402	19216	47.3	74.0	26.7	-20.0	27.3	54.0	26.7
2441	7323	58.3	74.0	15.7	-20.0	38.3	54.0	15.7
2441	19528	44.9	74.0	29.1	-20.0	24.9	54.0	29.1
2480	2483.5	59.9	74.0	14.1	-20.0	39.9	54.0	14.1
2480	7440	56.8	74.0	17.2	-20.0	36.8	54.0	17.2
2480	19840	43.8	74.0	30.2	-20.0	23.8	54.0	30.2
8DPSK								
2402	2390	56.4	74.0	17.6	-20.0	36.4	54.0	17.6
2402	7206	58.4	74.0	15.6	-20.0	38.4	54.0	15.6
2402	19216	47.9	74.0	26.1	-20.0	27.9	54.0	26.1
2441	7323	58.7	74.0	15.3	-20.0	38.7	54.0	15.3
2441	19528	46.2	74.0	27.8	-20.0	26.2	54.0	27.8
2480	2483.5	59.6	74.0	14.4	-20.0	39.6	54.0	14.4
2480	7440	57.3	74.0	16.7	-20.0	37.3	54.0	16.7
2480	19840	43.2	74.0	30.8	-20.0	23.2	54.0	30.8
Hopping								
2402	2390	56.1	74.0	17.9	-20.0	36.1	54.0	17.9
2480	2483.5	63.4	74.0	10.6	-20.0	43.4	54.0	10.6

Notes: Field strength (dBμV/m) = Spectrum analyzer value (dBμV) + transducer factors (dB)
Transducer factors (i.e. antenna factors, cable loss, amplifier gains, and attenuators.

- All other emissions within restricted bands were greater than 20 dB below the limit.
- All radiated emissions not within restricted bands were 40 dB below the fundamental transmitter power.

8.4 Clause 3.10.1.6 (1)(A) Frequency hopping requirements in systems operating in the 2400–2483.5 MHz band

8.4.1 Definitions and limits

(1) Frequency hopping systems:

(A) Frequency hopping systems shall have hopping channel carrier frequencies separated by a minimum of 25 kHz or the 20 dB bandwidth of the hopping channel, whichever is greater. However, frequency hopping systems operated in 2400–2483.5 MHz with output power less than or equal to 125 mW, the intervals of hopping channel carrier frequencies shall not be less than 25 kHz or two thirds of the 20 dB bandwidth of the hopping channel, whichever is greater.

(a) Frequency hopping systems in the 2400–2483.5 MHz band shall use at least 15 non-overlapping channels. The average time of occupancy on any channel shall be less than or equal to 0.4 seconds within a period of 0.4 seconds multiplied by the number of hopping channels employed. The intelligent hopping techniques shall be used to avoid the occupancy on specific frequency hopping channel.

8.4.2 Test date

Start date	October 25, 2019
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8.4.3 Observations, settings and special notes

Measurements performed for BT.

Spectrum analyzer settings (Carrier frequency separation):

Resolution bandwidth	Start with the RBW set to approximately 30% of the channel spacing; adjust as necessary to best identify the center of each individual channel.
Video bandwidth	≥ RBW
Frequency span	Wide enough to capture the peaks of two adjacent channels
Detector mode	Peak
Trace mode	Max Hold

Spectrum analyzer settings (Number of hopping frequencies):

Resolution bandwidth	To identify clearly the individual channels, set the RBW to less than 30% of the channel spacing or the 20 dB bandwidth, whichever is smaller.
Video bandwidth	≥ RBW
Frequency span	The frequency band of operation. Depending on the number of channels the device supports, it may be necessary to divide the frequency range of operation across multiple spans, to allow the individual channels to be clearly seen.
Detector mode	Peak
Trace mode	Max Hold

Spectrum analyser settings (Time of occupancy):

Resolution bandwidth	1 MHz
Video bandwidth	≥ RBW
Frequency span	Zero span, centered on a hopping channel.
Detector mode	Peak
Trace mode	Max Hold

Spectrum analyser settings (20 dB bandwidth):

Resolution bandwidth	≥ 1–5% of the 20 dB bandwidth
Video bandwidth	≥ RBW
Frequency span	approximately 2 to 5 times the 20 dB bandwidth, centered on a hopping channel
Detector mode	Peak
Trace mode	Max Hold

8.4.4 Test data

Table 8.4-1: 20 dB bandwidth results

Modulation type	20 dB bandwidth, kHz
GFSK	959.0
4πDPSK	1400.0
8DPSK	1393.0

Notes: RF channel has no influence on 20 dB bandwidth. Measurement performed on one channel as representative.

Table 8.4-2: Carrier frequency separation results

Modulation type	Carrier frequency separation, kHz	Minimum limit ¹ , kHz	Margin, kHz
GFSK	1000	639.3	360.7
4πDPSK	1000	933.3	66.7
8DPSK	1000	928.7	71.3

Notes: ¹The output power was less than 125 mW. Minimum limit was calculated as two thirds of the 20 dB bandwidth of the hopping channel.

Table 8.4-3: Number of hopping frequencies results

Number of hopping frequencies	Minimum limit	Margin
79	15	64

Table 8.4-4: Average time of occupancy results

	Pulse width, ms	Number of pulses within period	Average time of occupancy, ms	Limit, ms	Margin, ms
DH1	0.292	320 ¹	93.4	400.0	306.6
DH3	1.190	180 ²	214.2	400.0	185.8
DH5	2.200	130 ³	286.0	400.0	114.0

Notes: — Measurement Period = 0.4 x channels = 31.6 s
— Average time of occupancy = Pulse width * Number of pulses within period

¹DH1 Number of pulses within 1 period = (Maximum 32 pulses per 3.16 s) * 10

²DH1 Number of pulses within 1 period = (Maximum 18 pulses per 3.16 s) * 10

³DH1 Number of pulses within 1 period = (Maximum 13 pulses per 3.16 s) * 10

8.4.4 Test data, continued

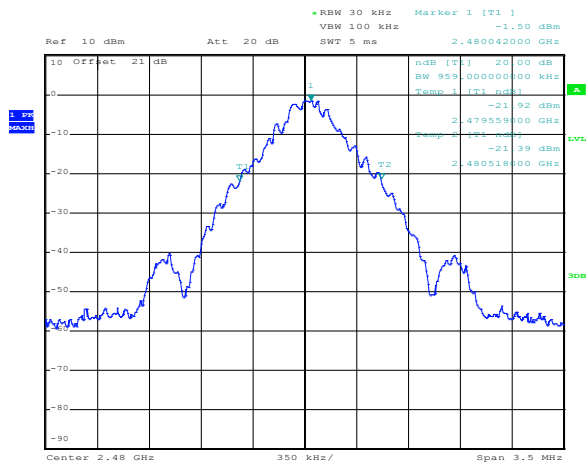


Figure 8.4-1: 20 dB bandwidth plot – GFSK

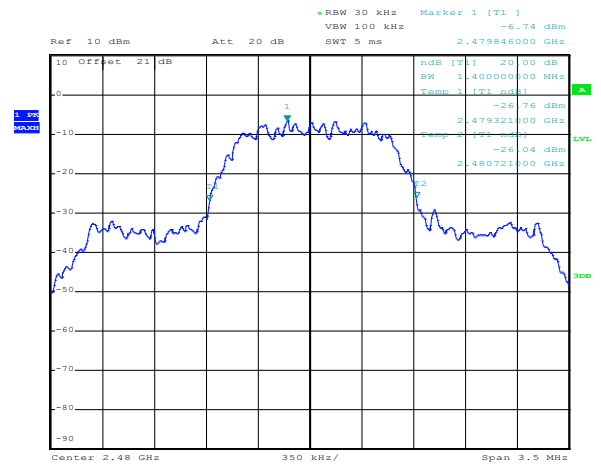


Figure 8.4-2: 20 dB bandwidth plot – 4 π DPSK

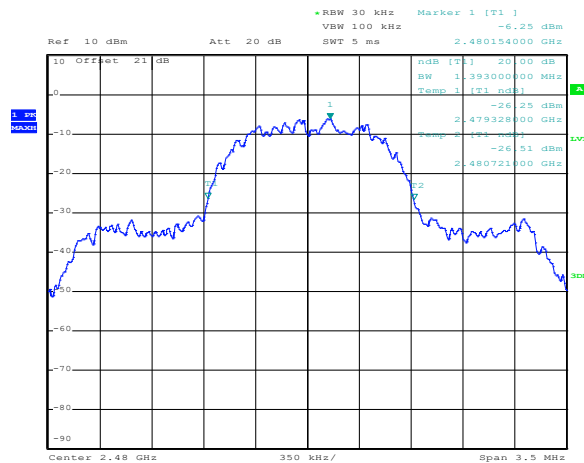


Figure 8.4-3: 20 dB bandwidth plot – 8DPSK

8.4.4 Test data, continued

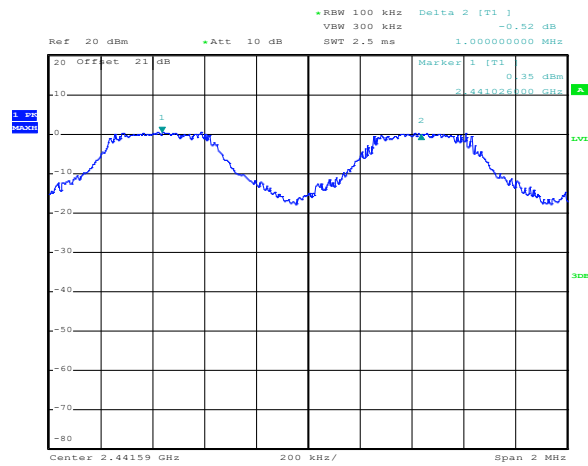


Figure 8.4-4: Carrier frequency separation – DH1/DH3/DH5

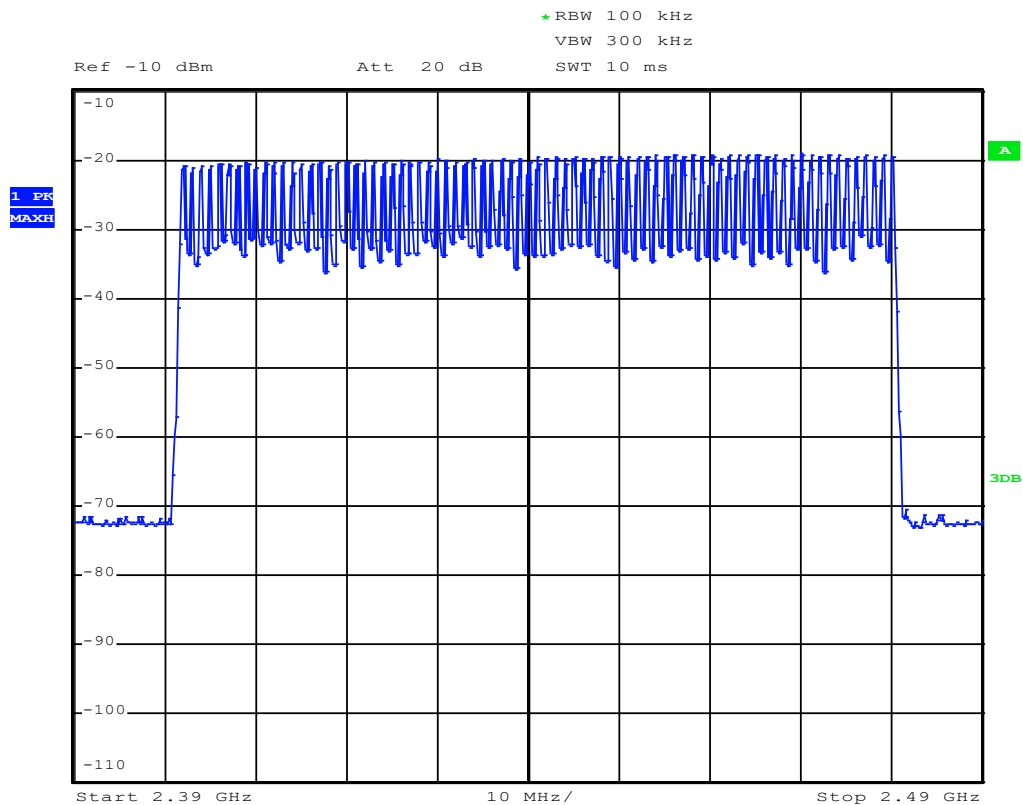


Figure 8.4-5: Number of hopping channels – GFSK, 4πDPSK, DH1/DH3/DH5

8.4.4 Test data, continued

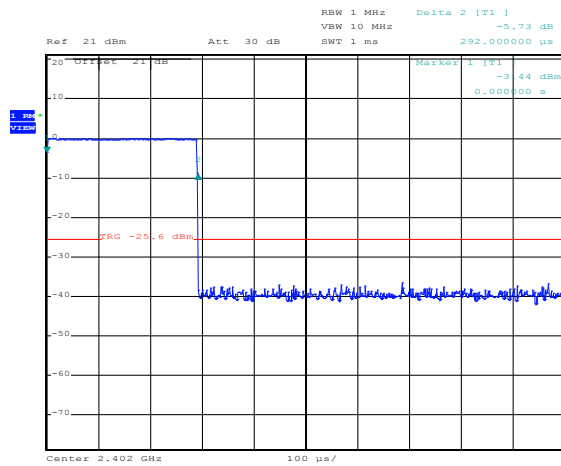


Figure 8.4-6: Burst length – DH1

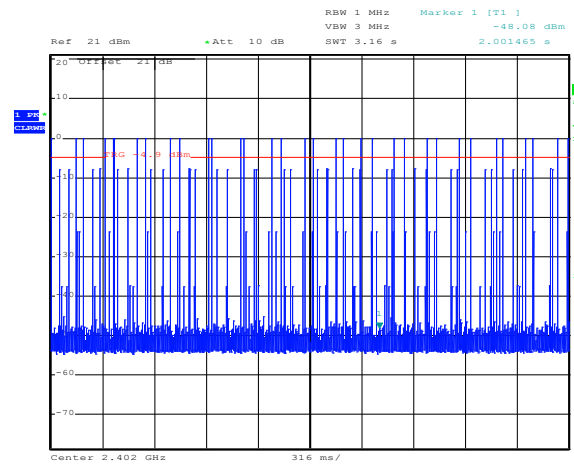


Figure 8.4-7: Dwell time – DH1

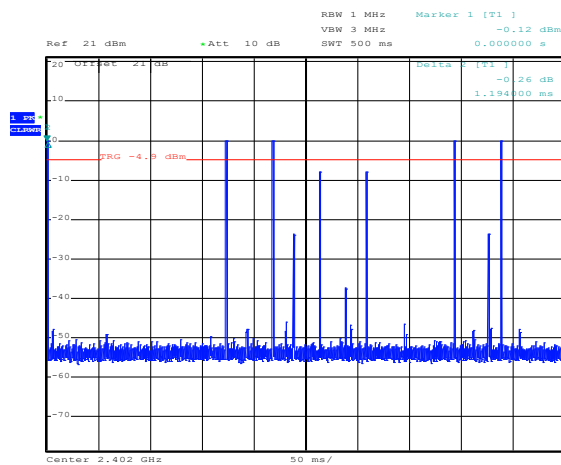


Figure 8.4-8: Burst length – DH3

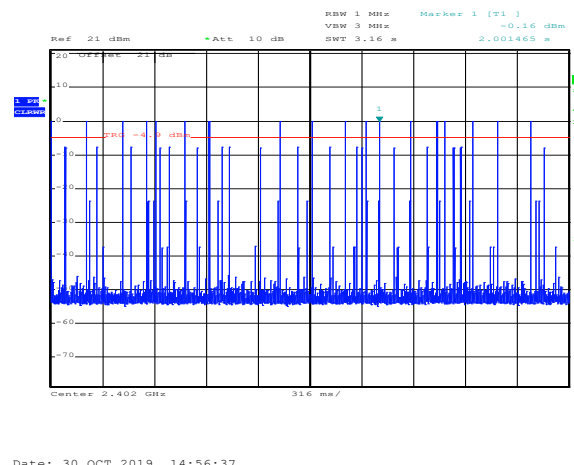


Figure 8.4-9: Dwell time – DH3

Date: 30.OCT.2019 14:56:37

8.4.4 Test data, continued

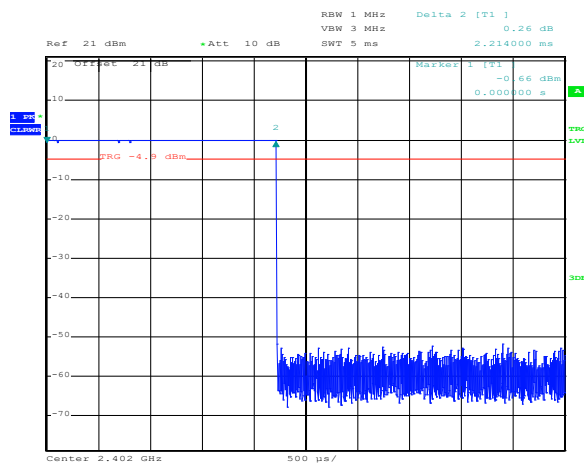


Figure 8.4-10: Burst length – DH5

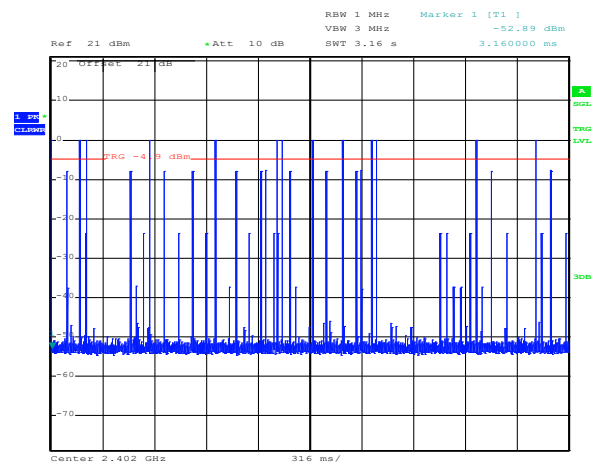


Figure 8.4-11: Dwell time – DH5

8.5 Clause 3.10.1.6 (2)(A) Minimum 6 dB bandwidth for systems using digital modulation techniques

8.5.1 Definitions and limits

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

8.5.2 Test date

Start date October 25, 2019

8.5.3 Observations, settings and special notes

Test performed for BLE.

Spectrum analyzer settings were:

Resolution bandwidth	100 kHz
Video bandwidth	$\geq 3 \times \text{RBW}$
Detector mode	Peak
Trace mode	Max Hold

8.5.4 Test data

Table 8.5-1: 6 dB bandwidth results

Frequency, MHz	6 dB bandwidth, kHz	Minimum limit, kHz	Margin, kHz
2402	680.0	500.0	180
2440	672.0	500.0	172
2480	672.0	500.0	172

Table 8.5-2: 99 % bandwidth results

Frequency, MHz	99 % bandwidth, MHz
2402	1.05
2440	1.05
2480	1.05

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

8.5.4 Test data, continued

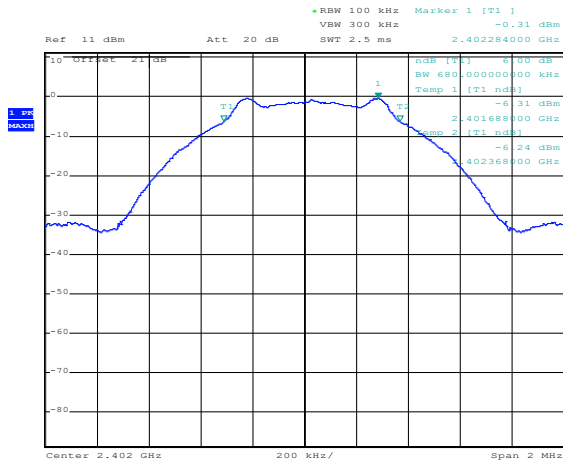


Figure 8.5-1: 6 dB bandwidth plot – low channel

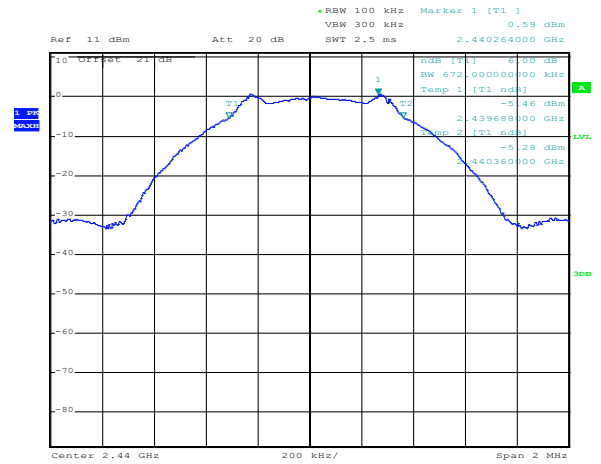


Figure 8.5-2: 6 dB bandwidth plot – mid channel

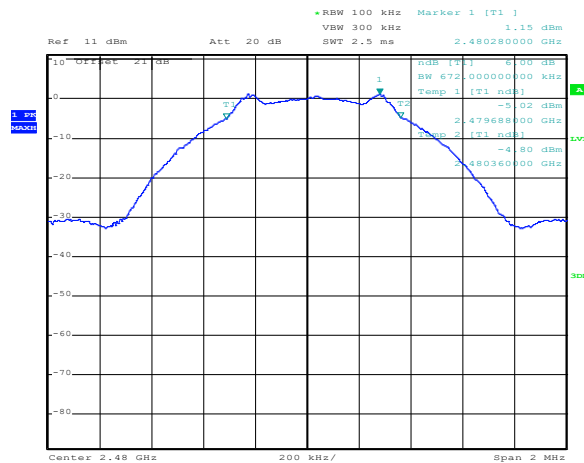


Figure 8.5-3: 6 dB bandwidth plot – high channel

8.5.4 Test data, continued

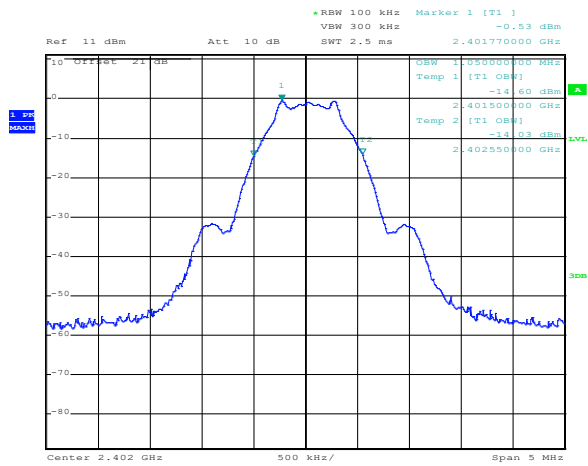


Figure 8.5-4: 99% bandwidth plot – low channel

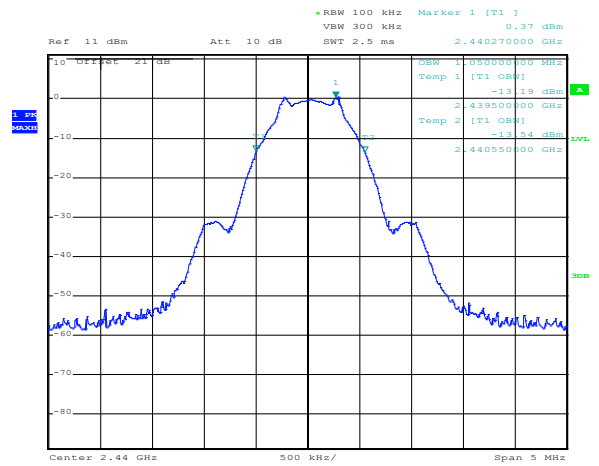


Figure 8.5-5: 99% bandwidth plot – mid channel

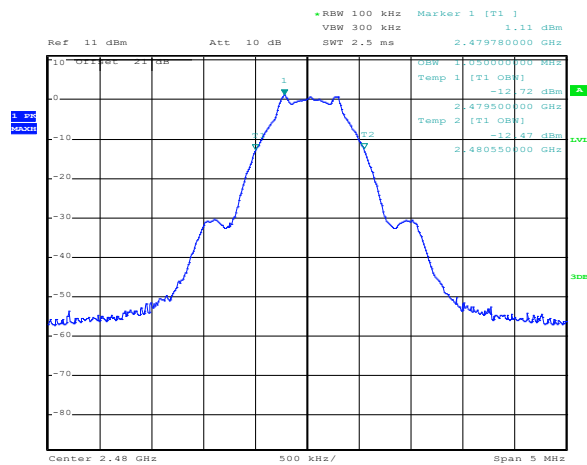


Figure 8.5-6: 99% bandwidth plot – high channel

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

8.6.1 Definitions and limits

For digitally modulated systems, the peak power spectral density conducted from the intentional radiator to the antenna shall be less than or equal to 8 dBm in any 3kHz band during any time interval of continuous transmission,

8.6.2 Test date

Start date	October 25, 2019
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8.6.3 Observations, settings and special notes

- The test was performed using method PKPSD (peak PSD).
- Test performed for BLE.

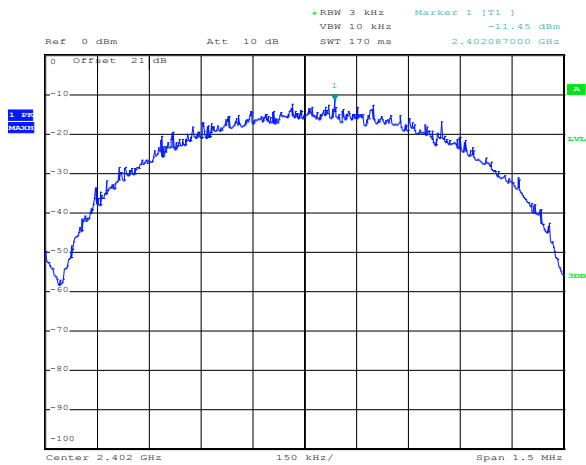
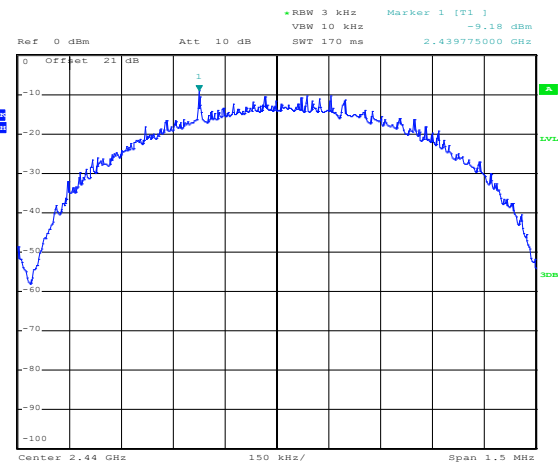
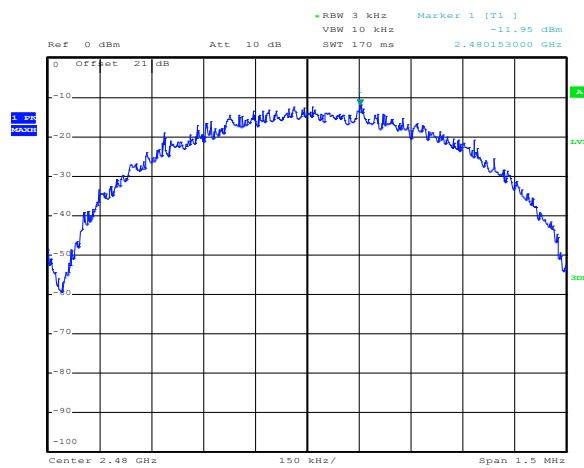
Spectrum analyzer settings were:

Resolution bandwidth:	3 kHz
Video bandwidth:	10 kHz
Span:	1.5 times the DTS bandwidth
Detector mode:	Peak
Trace mode:	Max hold

8.6.4 Test data

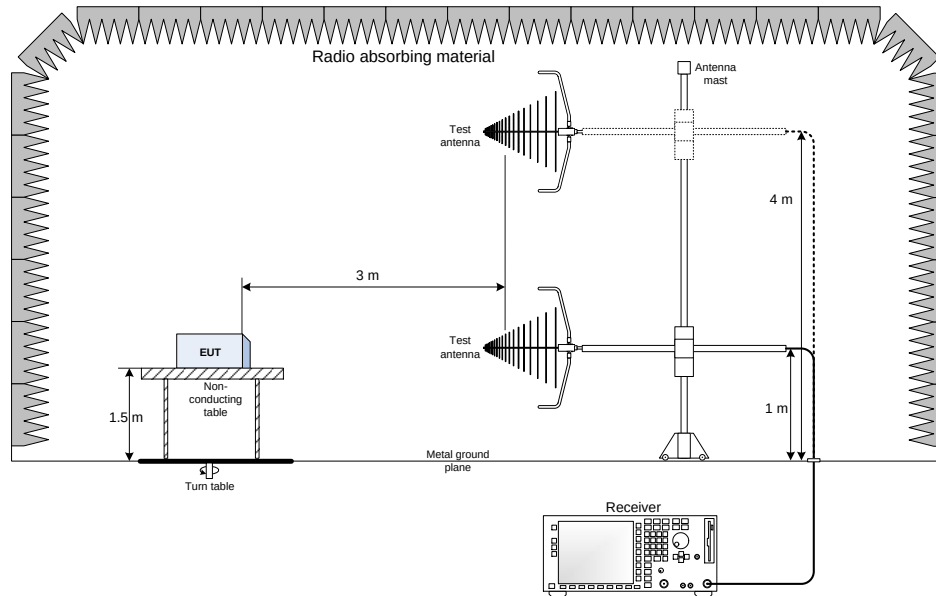
Table 8.6-1: PSD measurements results

Frequency, MHz	PSD, dBm/3 kHz	PSD limit, dBm/3 kHz	Margin, dB
2402	-11.5	8.0	19.5
2440	-9.2	8.0	17.2
2480	-12.0	8.0	20.0

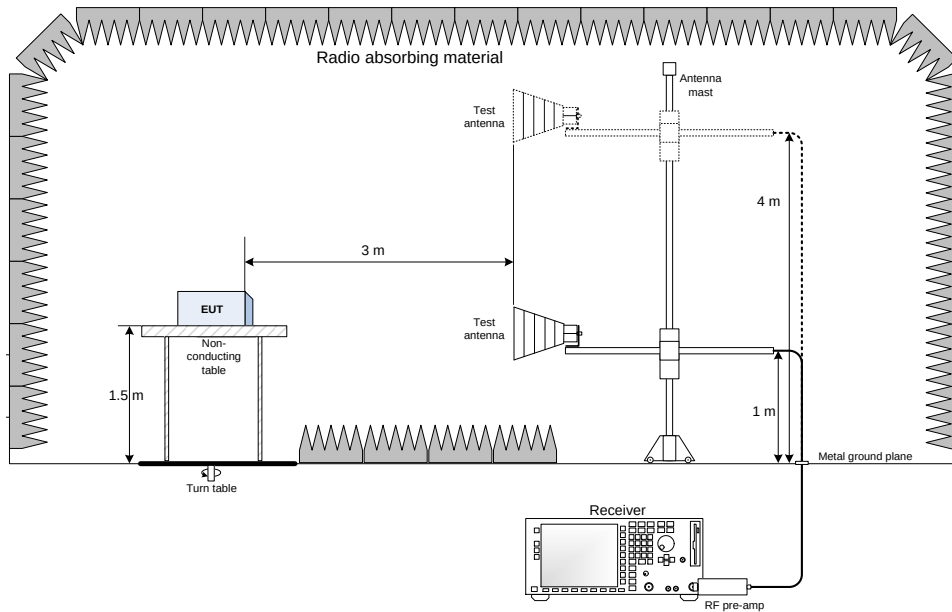

Figure 8.6-1: PSD – low channel

Figure 8.6-2: PSD plot – mid channel

Figure 8.6-3: PSD plot – high channel

Section 9 Block diagrams/Test set-ups photos/Detailed external photos

9.1 Block diagram of Radiated emissions set-up



9.2 Radiated emissions set-up above 1 GHz



9.3 Radiated emissions set-up photos



Figure 9.3-1: Radiated spurious emissions setup photo below 1 GHz



Figure 9.3-2: Radiated spurious emissions setup photo below 1 GHz

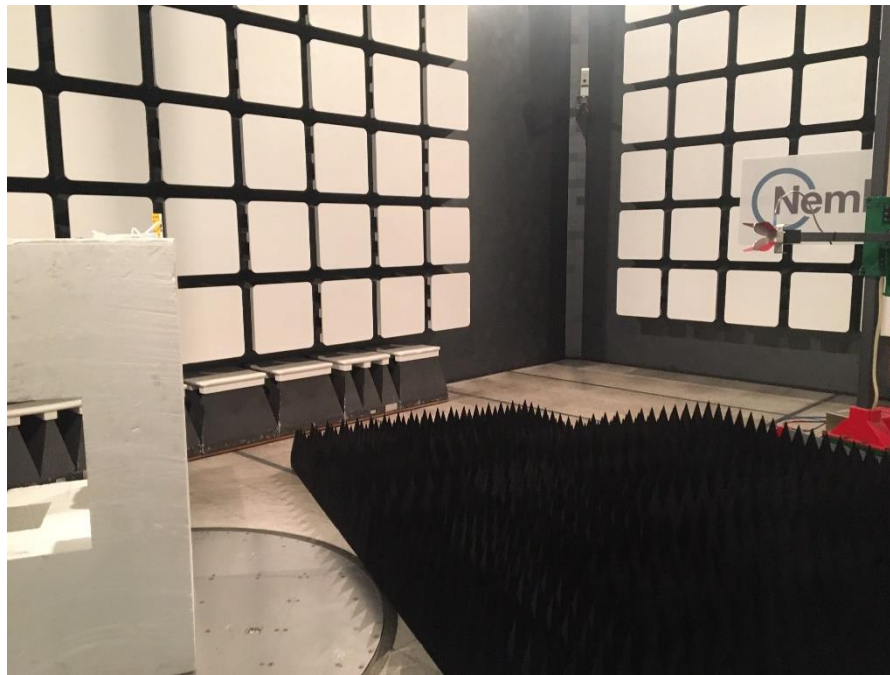


Figure 9.3-3: Radiated spurious emissions setup photo above 1 GHz

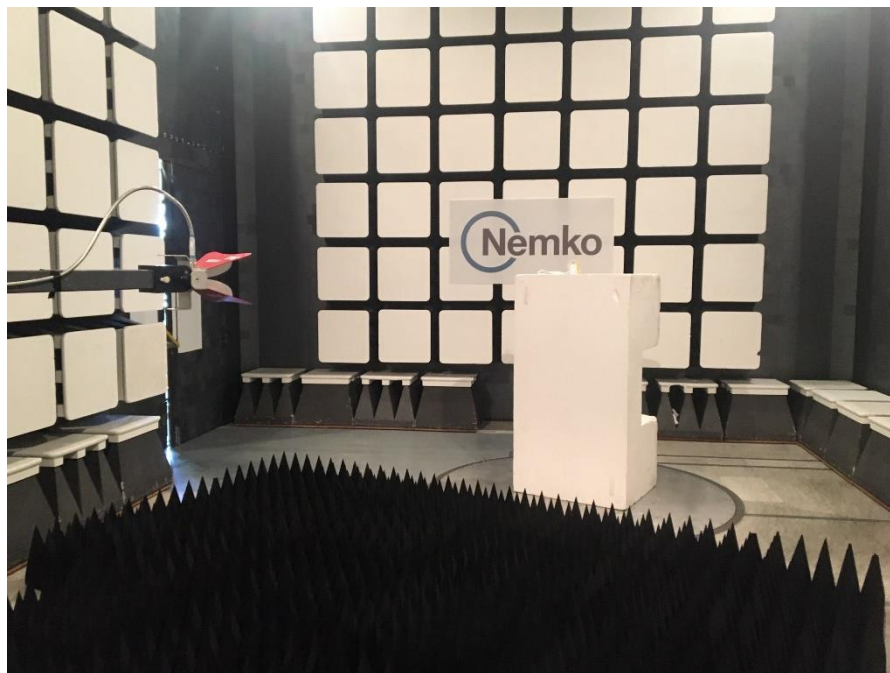
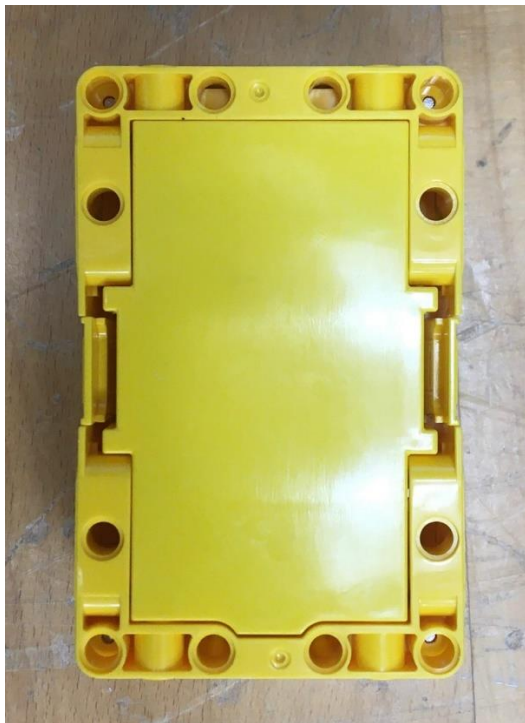


Figure 9.3-4: Radiated spurious emissions setup photo above 1 GHz

9.4 External photos



End of the test report