ONE WORLD ○ OUR APPROVAL

Wireless test report – 342227-1TRFWL

Applicant:

GE Lighting Solutions LLC

Product name:

Wireless Integrated Thread Sensor

Model:

WIT100

FCC ID:

PUU-WIT100

IC Registration number:

10798A-PUU-WIT100

Specifications:

- **FCC 47 CFR Part 15 Subpart C, §15.247**

  Operation in the 902–928 MHz, 2400–2483.5 MHz, and 5725–5850 MHz

- **RSS-247, Issue 2, Feb 2017, Section 5**

  Digital Transmission Systems (DTSs), Frequency Hopping Systems (FHSs) and Licence-Exempt Local Area Network (LE-LAN) Devices

  5) Standard specifications for frequency hopping systems and digital transmission systems operating in the bands 902–928 MHz, 2400–2483.5 MHz and 5725–5850 MHz

Date of issue: March 29, 2018

Test engineer(s):	Yong Huang, Wireless/EMC Specialist	Signature:	
Reviewed by:	Andrey Adelberg, Senior Wireless/EMC Specialist	Signature:	

Test location(s)

Company name	Nemko Canada Inc.	
Address	303 River Road	292 Labrosse Avenue
City	Ottawa	Pointe-Claire
Province	Ontario	Quebec
Postal code	K1V 1H2	H9R 5L8
Country	Canada	Canada
Telephone	+1 613 737 9680	+1 514 694 2684
Facsimile	+1 613 737 9691	+1 514 694 3528
Toll free	+1 800 563 6336	
Website	www.nemko.com	www.nemko.com
Site number	FCC: CA2040; IC: 2040A-4 (3 m SAC)	FCC: CA2041; IC: 2040G-5 (3 m SAC)

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 Canada's ISO/IEC 17025 accreditation.

Copyright notification

Table of contents

Section 1. Report summary

1.1 Applicant and manufacturer

Company name	GE Lighting Solutions LLC
Address	1975 Noble Road
City	East Cleveland
Province/State	Ohio
Postal/Zip code	44112-6300
Country	USA

1.2 Test specifications

FCC 47 CFR Part 15, Subpart C, Clause 15.247	Operation in the 902–928 MHz, 2400–2483.5 MHz, and 5725–585 MHz
RSS-247, Issue 2, Feb 2017, Section 5	Digital Transmission Systems (DTSs), Frequency Hopping Systems (FHSs) and Licence-Exempt Local Area Network (LE-LAN) Devices

1.3 Test methods

558074 D01 DTS Meas Guidance v04 (April 5, 2017)	Guidance for Performing Compliance Measurements on Digital Transmission Systems (DTS) Operating Under §15.247
ANSI C63.10 v2013	American National Standard of Procedures for Compliance Testing of Unlicensed Wireless Devices

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 1.5 below. 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

Revision #	Date of issue	Details of changes made to test report
TRF	March 29, 2018	Original report issued

Section 2. Summary of test results

2.1 FCC Part 15 Subpart C, general requirements test results

Part	Test description	Verdict
§15.207(a)	Conducted limits	Pass[3]
§15.31(e)	Variation of power source	Pass[1]
§15.203	Antenna requirement	Pass[2]

Notes: [1] Measurements of the variation of the input power or the radiated signal level of the fundamental frequency component of the emission, as appropriate, was performed with the supply voltage varied between 85 % and 115 % of the nominal rated supply voltage. No noticeable output power variation was observed

[2] The Antennas are located within the enclosure of EUT and not user accessible.

[3].EUT is DC powered, power line conducted measurement were perform with AC adapter provided by customer.

2.2 FCC Part 15 Subpart C, intentional radiators test results for digital transmission systems (DTS)

Part	Test description	Verdict
§15.247(a)(2)	Minimum 6 dB bandwidth	Pass
§15.247(b)(3)	Maximum peak output power in the 902–928 MHz, 2400–2483.5 MHz, and 5725–5850 MHz bands	Pass
§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	Pass
§15.247(f)	Time of occupancy for hybrid systems	Not applicable

2.3 ISED RSS-GEN, Issue 4, test results

Part	Test description	Verdict
7.1.2	Receiver radiated emission limits	Not applicable
7.1.3	Receiver conducted emission limits	Not applicable
8.8	Power Line Conducted Emissions Limits for Licence-Exempt Radio Apparatus	Pass[2]

Notes: [1] According to sections 5.2 and 5.3 of RSS-Gen, Issue 4 the EUT does not have a stand-alone receiver neither scanner receiver, therefore exempt from receiver requirements.

[2] EUT is DC powered, power line conducted measurement were perform with AC adapter provided by customer.

2.4 ISED RSS-247, Issue 2, test results for digital transmission systems (DTS)

Part	Test description	Verdict
5.2 (a)	Minimum 6 dB bandwidth	Pass
5.2 (b)	Maximum power spectral density	Pass
5.3	Hybrid Systems	
5.3 (a)	Digital modulation turned off	Not applicable
5.3 (b)	Frequency hopping turned off	Not applicable
5.4	Transmitter output power and e.i.r.p. requirements	
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	Unwanted emissions	Pass

Notes: None

Section 3. Equipment under test (EUT) details

3.1 Sample information

Receipt date	November 17, 2017
Nemko sample ID number	Item #3,#4,#5,#6,#7,#8

3.2 EUT information

Product name	Wireless Integrated Thread Sensor
Model	WIT100
Serial number	001 & 002

3.3 Technical information

Applicant IC company number	10798A
IC UPN number	PUU-WIT100
All used IC test site(s) Reg. number	2040G-5
RSS number and Issue number	RSS-247 Issue 2, Feb 2017
Frequency band	2400–2483.5 MHz
Frequency Min (MHz)	2402 for GFSK, 2405 for OQPSK
Frequency Max (MHz)	2480
RF power Min (W), Conducted	N/A
RF power Max (W), Conducted	0.002 (3.11 dBm)
Field strength, Units @ distance	N/A
Measured BW (kHz) (6 dB)	659 for GFSK, 1619.4 for OQPSK
Calculated BW (kHz), as per TRC-43	N/A
Type of modulation	GFSK (BLE) and OQPSK (Thread)
Emission classification (F1D, G1D, D1D)	F1D
Transmitter spurious, Units @ distance	53.82 dBµV/m at 2483.5 MHz, @ 3 m
Power requirements	18 $V_{DC,}$ via 120 V_{AC} adapter
Antenna information	The EUT uses a unique antenna coupling/ non-detachable antenna to the intentional radiator. Antenna max peak gain is 2.15 dBi.

3.4 Product description and theory of operation

The WIT100 is a DALI-powered fixture-integrated sensor node that measures light and occupancy parameters, controls DALI-capable LED drivers realizing a distributed wireless control system.
The device is capable of a dual-radio operation by implementing the 802.15.4 (ZigBee, or Thread) and 802.15.1 (BLE) protocols. The radios are time-multiplexed, using one antenna – keeping the BOM-cost low, and the flexibility high.
Multiple external ZigBee Green Power wall-switches can be interfaced with the system – that makes manual overriding possible.
The control algorithm is highly flexible – including user profiles, occupancy-based control, distributed daylight harvesting – making the system fit for most use cases.
By using the easy commissioning mobile application, the system can be easily commissioned, and updated over the air (OTA).

3.5 EUT exercise details

EUT was set up as per client's test firmware, continuous transmit mode was configured during transmitter tests.

3.6 EUT setup diagram

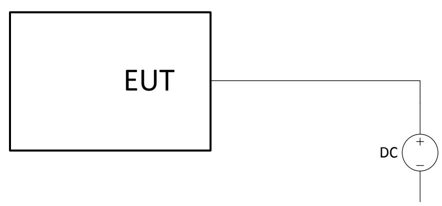


Figure 3.6-1: *Setup diagram*

3.7 EUT sub assemblies

Table 3.7-1: *EUT sub assemblies*

Description	Brand name	Model/Part number	Serial number
Integrated Wireless sensor node	GE	WIT100	001,002

Table 3.7-2: *Support equipment*

Description	Brand name	Model, Part number, Serial number, Revision level
Power supply DALI-BM RS-232	Tridonic	DALI-BM RS-232/PN:00ASY032G1
AC adapter	TRIAD	None

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	860–1060 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.

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

UKAS Lab 34 and TIA-603-B have been used as guidance for measurement uncertainty reasonable estimations with regards to previous experience and validation of data. 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.

Test name	Measurement uncertainty, dB
All antenna port measurements	0.55
Conducted spurious emissions	1.13
Radiated spurious emissions	3.78
AC power line conducted emissions	3.55

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	FA002532	2 year	June 5/19
Flush mount turntable	Sunol	FM2022	FA002550	—	NCR
Controller	Sunol	SC104V	FA002551	—	NCR
Antenna mast	Sunol	TLT2	FA002552	—	NCR
Power source	California Instruments	5001ix	FA001770	1 year	Feb. 1/18
Receiver/spectrum analyzer	Rohde & Schwarz	ESU 40	FA002071	1 year	Sept. 18/18
Bilog antenna (20–2000 MHz)	Sunol	JB1	FA002517	1 year	Oct. 5/18
Horn antenna (1–18 GHz)	EMCO	3115	FA001451	1 year	April 5/18
Horn antenna (18–40 GHz)	EMCO	3116	FA002487	2 year	Aug. 16/18
Pre-amplifier (0.5–18 GHz)	COM-POWER	PAM-118A	FA002561	1 year	Sept. 21/18
Pre-amplifier (18–40 GHz)	COM-POWER	PAM-840	FA002508	1 year	May 8/18
Spectrum analyzer	Rohde & Schwarz	FSV 40	FA002731	1 year	July 10/18
Four Line V-Network	TESEQ	NNB52	FA002339	1 year	May 10/18
50 Ω coax cable	C.C.A.	None	FA002603	—	VOU
50 Ω coax cable	C.C.A.	None	FA002605	—	VOU
50 Ω coax cable	C.C.A.	None	FA002831	—	VOU
2300-2583.5 MHz Notch Filter	Microwave Circuits	N0324413	FA002693	—	VOU

Note: NCR - no calibration required, VOU - verify on use

Section 8. Testing data

8.1 FCC 15.207(a) and RSS-Gen 8.8 AC power line conducted emissions limits

8.1.1 Definitions and limits

FCC:
Except as shown in paragraphs (b) and (c) of this section, for an intentional radiator 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). Compliance with the provisions of this paragraph shall be based on the measurement of the radio frequency voltage between each power line and ground at the power terminal. The lower limit applies at the boundary between the frequency ranges.

IC:
A radio apparatus that is designed to be connected to the public utility (AC) power line shall ensure that the radio frequency voltage, which 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 table below.

Unless the requirements applicable to a given device state otherwise, for any radio apparatus equipped to operate from the public utility AC power supply either directly or indirectly (such as with a battery charger), the radio frequency voltage of emissions conducted back onto the AC power lines in the frequency range of 0.15 MHz to 30 MHz shall not exceed the limits shown in table below. The more stringent limit applies at the frequency range boundaries.

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: * - The level decreases linearly with the logarithm of the frequency.
** - A linear average detector is required.

8.1.2 Test date

Start date	December 11, 2017

8.1.3 Observations, settings and special notes

The EUT was set up as tabletop configuration.

The spectral scan has been corrected with transducer factors (i.e. cable loss, LISN factors, and attenuators) for determination of compliance.

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.

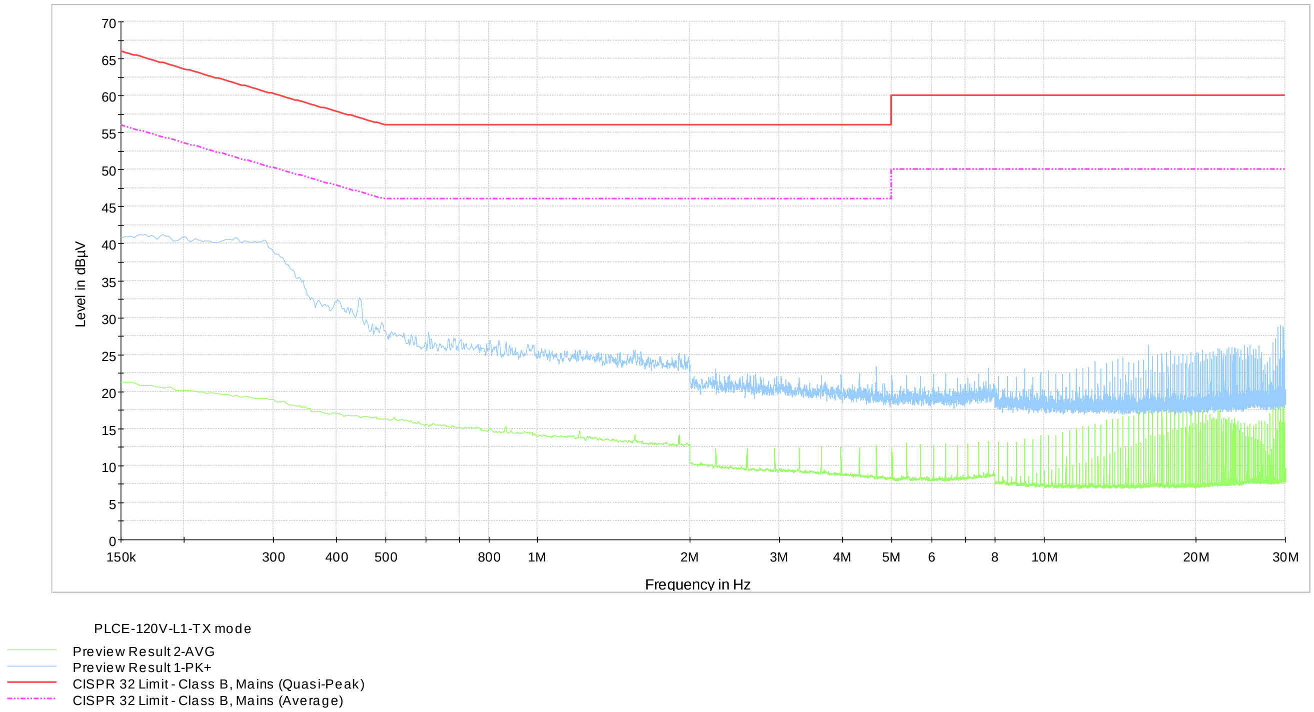
Receiver settings for preview measurements:

Resolution bandwidth	9 kHz
Video bandwidth	30 kHz
Detector mode	Peak and Average
Trace mode	Max Hold
Measurement time	1000 ms

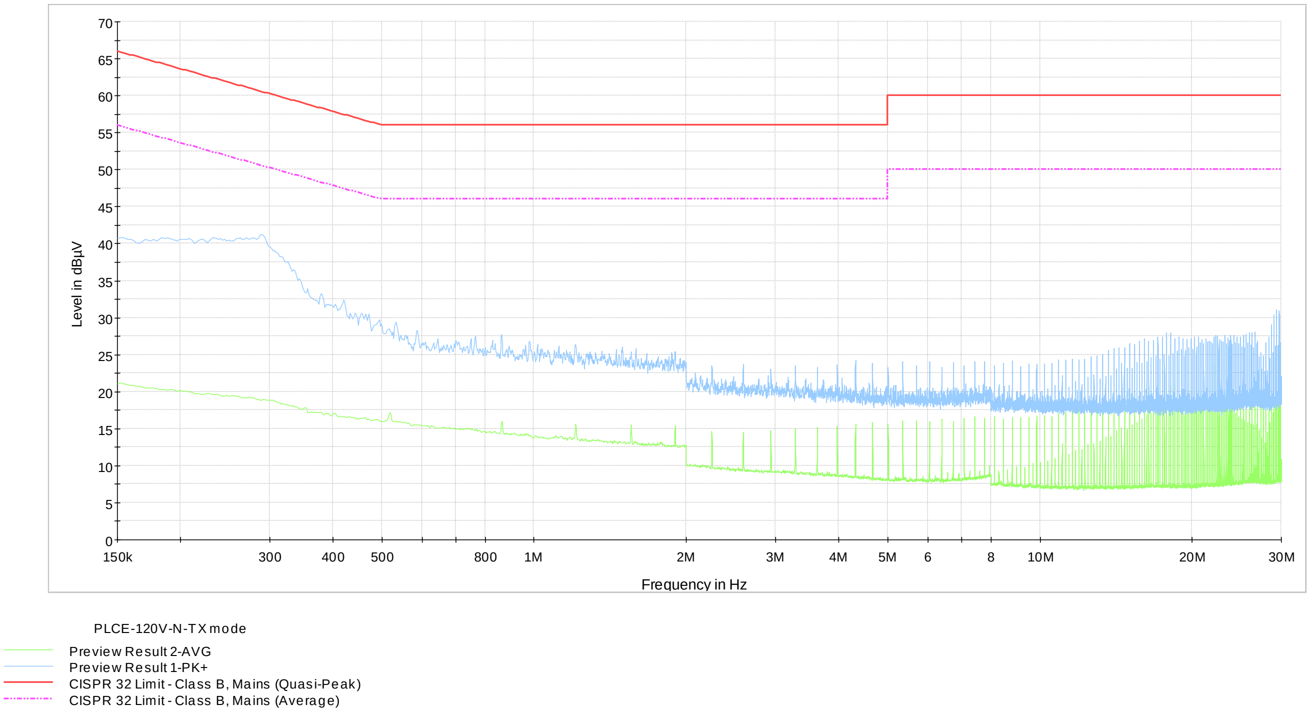
Receiver settings for final measurements:

Resolution bandwidth	9 kHz
Video bandwidth	30 kHz
Detector mode	Quasi-Peak and Average
Trace mode	Max Hold
Measurement time	1000 ms

8.1.4 Test data



Plot 8.1-1: *Conducted emissions on phase line*



Plot 8.1-2: *Conducted emissions on neutral line*

8.2 FCC 15.247(a)(2) and RSS-247 5.2(a) Minimum 6 dB bandwidth for DTS systems

8.2.1 Definitions and limits

FCC:
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.

ISED:
The minimum 6 dB bandwidth shall be 500 kHz.

8.2.2 Test date

Start date	November 27, 2017

8.2.3 Observations, settings and special notes

Spectrum analyser settings:

Resolution bandwidth	100 kHz
Video bandwidth	≥3 × RBW
Frequency span	1 MHz for GFSK; 3 MHz for OQPSK
Detector mode	Peak
Trace mode	Max Hold

8.2.4 Test data

Table 8.2-1: *6 dB bandwidth results*

Modulation	Frequency, MHz	6 dB bandwidth, kHz	Limit, kHz	Margin, kHz
GFSK	2402	655.0	500	155.0
	2440	659.0	500	159.0
	2480	658.5	500	158.5
OQPSK	2405	1619.4	500	1119.4
	2445	1610.7	500	1110.7
	2480	1619.4	500	1119.4

Table 8.2-2: *99 % bandwidth results*

Modulation	Frequency, MHz	99% bandwidth, kHz
GFSK	2402	758.0
	2440	802.0
	2480	727.0
OQPSK	2405	2430.0
	2445	2417.5
	2480	2572.5

8.2.5 Test data, continued

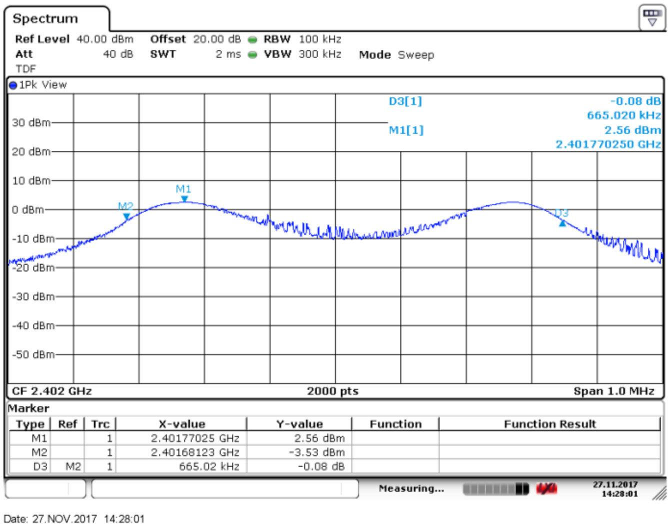


Figure 8.2-1: 6 dB bandwidth on low channel, GFSK

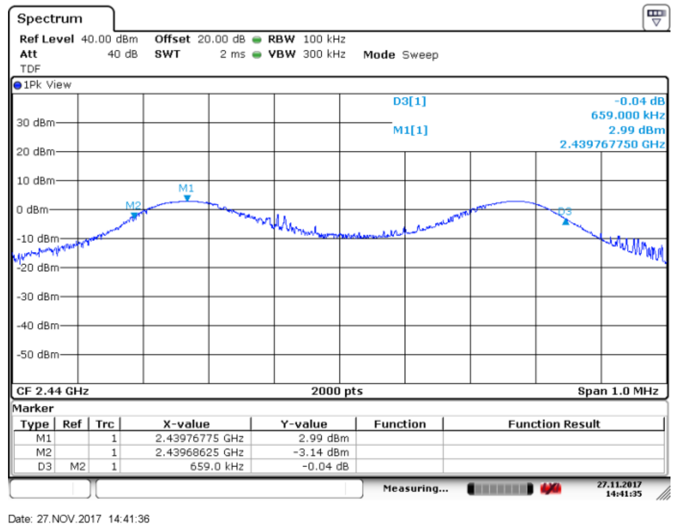


Figure 8.2-2: 6 dB bandwidth on mid channel, GFSK

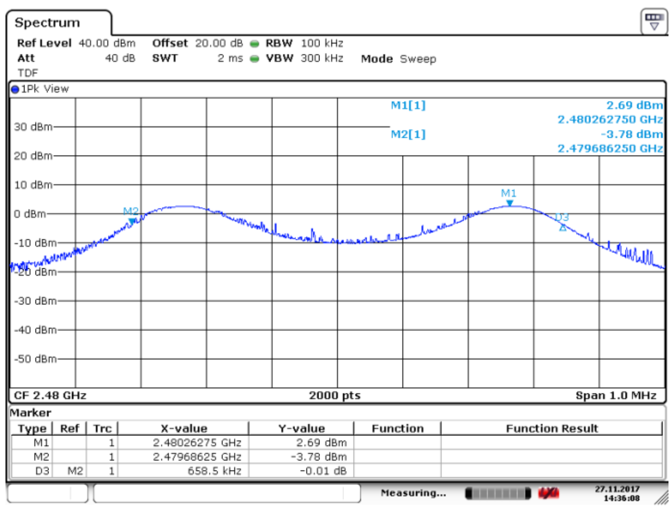


Figure 8.2-3: 6 dB bandwidth on high channel, GFSK

8.2.6 Test data, continued

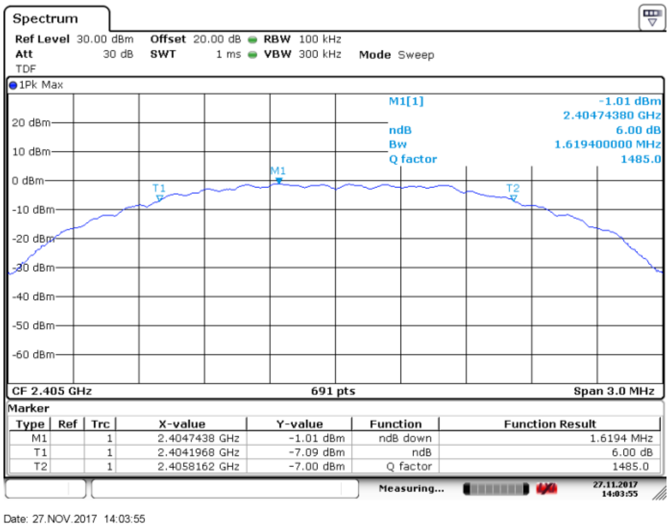


Figure 8.2-4: 6 dB bandwidth on low channel, OQPSK

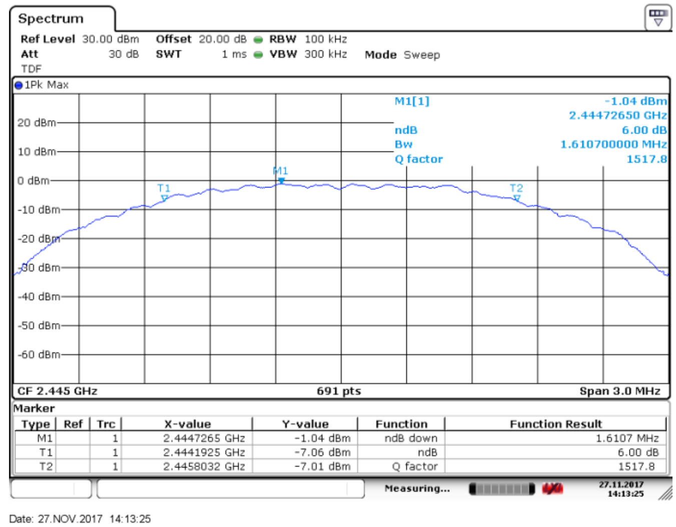


Figure 8.2-5: 6 dB bandwidth on mid channel, OQPSK

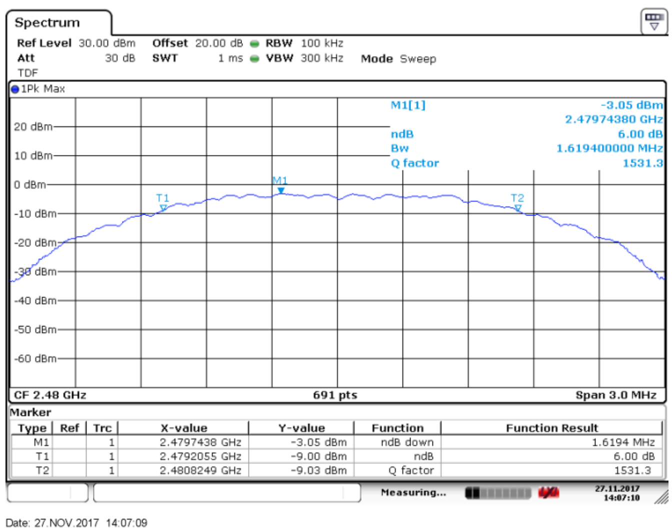


Figure 8.2-6: 6 dB bandwidth on high channel, OQPSK

8.2.4 Test data, continued

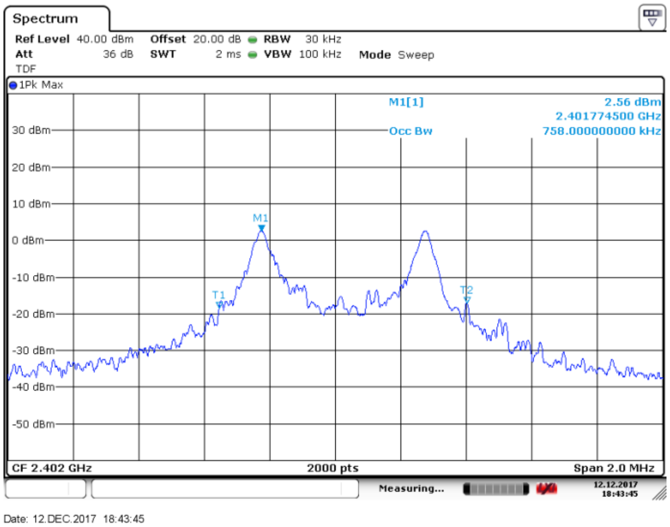


Figure 8.2-7: 99% bandwidth on low channel, GFSK

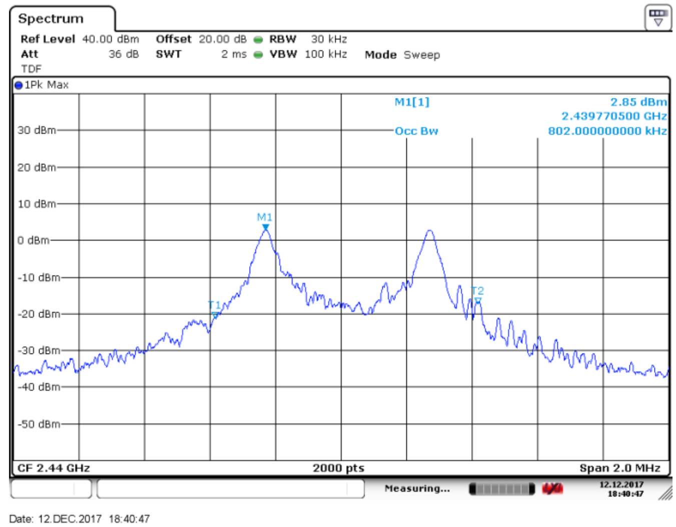


Figure 8.2-8: 99% bandwidth on mid channel, GFSK

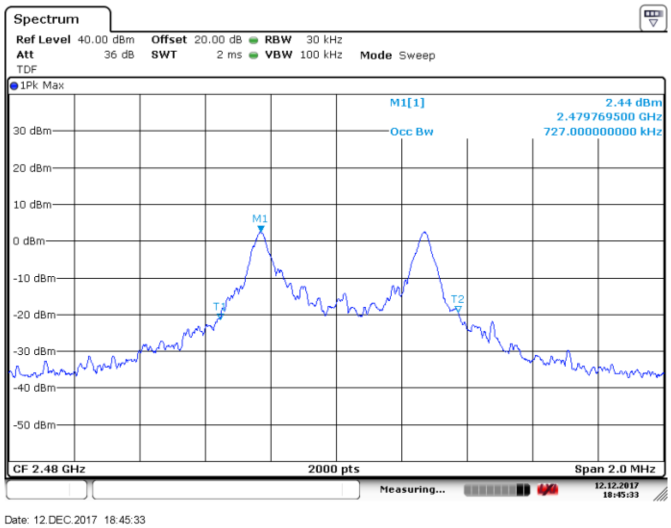


Figure 8.2-9: 99% bandwidth on high channel, GFSK

8.2.4 Test data, continued

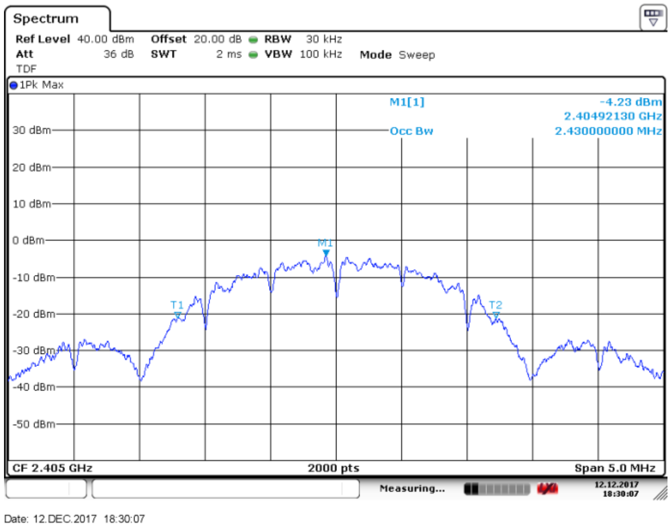


Figure 8.2-10: 99% bandwidth on low channel, OQPSK

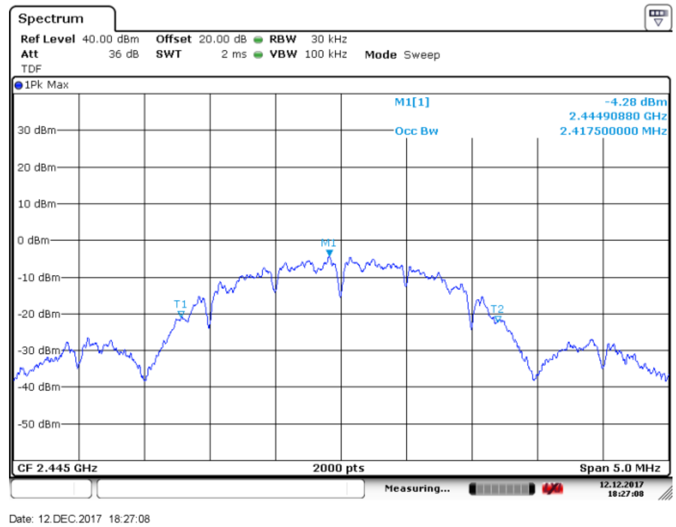


Figure 8.2-11: 99% bandwidth on mid channel, OQPSK

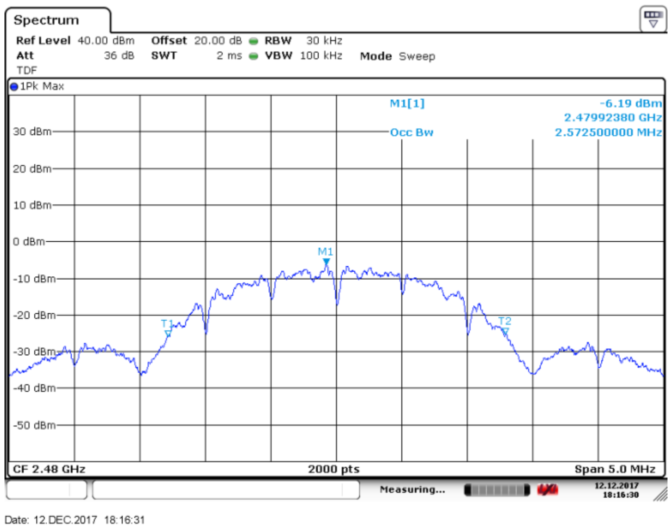


Figure 8.2-12: 99% bandwidth on high channel, OQPSK

8.3 FCC 15.247(b) and RSS-247 5.4 (d) Transmitter output power and e.i.r.p. requirements for DTS in 2 GHz

8.3.1 Definitions and limits

FCC:

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

(3) For systems using digital modulation in the 2400–2483.5 MHz band: 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.

(c) Operation with directional antenna gains greater than 6 dBi.
(1) Fixed point-to-point operation:
(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 conducted 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.
(iii) Fixed, point-to-point operation, as used in paragraphs (c)(1)(i) and (c)(1)(ii) of this section, excludes the use of point-to-multipoint systems, omnidirectional applications, and multiple co-located intentional radiators transmitting the same information. The operator of the spread spectrum or digitally modulated intentional radiator or, if the equipment is professionally installed, the installer is responsible for ensuring that the system is used exclusively for fixed, point-to-point operations. The instruction manual furnished with the intentional radiator shall contain language in the installation instructions informing the operator and the installer of this responsibility.
(2) In addition to the provisions in paragraphs (b)(1), (b)(3), (b)(4) and (c)(1)(i) of this section, transmitters operating in the 2400–2483.5 MHz band that emit multiple directional beams, simultaneously or sequentially, for the purpose of directing signals to individual receivers or to groups of receivers provided the emissions comply with the following:
(i) Different information must be transmitted to each receiver.
(ii) If the transmitter employs an antenna system that emits multiple directional beams but does not do emit multiple directional beams simultaneously, the total output power conducted to the array or arrays that comprise the device, i.e., the sum of the power supplied to all antennas, antenna elements, staves, etc. and summed across all carriers or frequency channels, shall not exceed the limit specified in paragraph (b)(1) or (b)(3) of this section, as applicable. However, the total conducted output power shall be reduced by 1 dB below the specified limits for each 3 dB that the directional gain of the antenna/antenna array exceeds 6 dBi. The directional antenna gain shall be computed as follows:
(A) The directional gain shall be calculated as the sum of 10 log (number of array elements or staves) plus the directional gain of the element or stave having the highest gain.
(B) A lower value for the directional gain than that calculated in paragraph (c)(2)(ii)(A) of this section will be accepted if sufficient evidence is presented, e.g., due to shading of the array or coherence loss in the beamforming.
(iii) If a transmitter employs an antenna that operates simultaneously on multiple directional beams using the same or different frequency channels, the power supplied to each emission beam is subject to the power limit specified in paragraph (c)(2)(ii) of this section. If transmitted beams overlap, the power shall be reduced to ensure that their aggregate power does not exceed the limit specified in paragraph (c)(2)(ii) of this section. In addition, the aggregate power transmitted simultaneously on all beams shall not exceed the limit specified in paragraph (c)(2)(ii) of this section by more than 8 dB.
(iv) Transmitters that emit a single directional beam shall operate under the provisions of paragraph (c)(1) of this section.

ISED:
d. For DTSs employing digital modulation techniques operating in the 2400–2483.5 MHz band, 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.
e. Fixed point-to-point systems in the 2400–2483.5 MHz band are permitted to have an e.i.r.p. higher than 4 W provided that the higher e.i.r.p. is achieved by employing higher gain directional antennas and not higher transmitter output powers. Point-to-multipoint systems, omnidirectional applications and multiple co-located transmitters transmitting the same information are prohibited from exceeding an e.i.r.p. of 4 W.
f. Transmitters operating in the band 2400–2483.5 MHz, may employ antenna systems that emit multiple directional beams simultaneously or sequentially, for the purpose of directing signals to individual receivers or to groups of receivers, provided that the emissions comply with the following:

i Different information must be transmitted to each receiver.
ii If the transmitter employs an antenna system that emits multiple directional beams, but does not emit multiple directional beams simultaneously, the total output power conducted to the array or arrays that comprise the device (i.e. the sum of the power supplied to all antennas, antenna elements, staves, etc., and summed across all carriers or frequency channels) shall not exceed the applicable output power limit specified in sections 5.4(b) and 5.4(d). However, the total conducted output power shall be reduced by 1 dB below the specified limits for each 3 dB that the directional gain of the antenna/antenna array exceeds 6 dBi. The directional antenna gain shall be computed as the sum of 10 log (number of array elements or staves) plus the directional gain of the element or stave having the highest gain.
iii If a transmitter employs an antenna that operates simultaneously on multiple directional beams using the same or different frequency channels, the power supplied to each emission beam is subject to the applicable power limit specified in sections 5.4(b) and 5.4(d). If transmitted beams overlap, the power shall be reduced to ensure that their aggregate power does not exceed the applicable limit specified in sections 5.4(b) and 5.4(d). In addition, the aggregate power transmitted simultaneously on all beams shall not exceed the applicable limit specified in sections 5.4(b) and 5.4(d) by more than 8 dB.
iv Transmitters that transmit a single directional beam shall operate under the provisions of sections 5.4(b), 5.4(d) and 5.4(e).

8.3.2 Test date

Start date	December 12, 2017

8.3.3 Observations, settings and special notes

The test was performed according to DTS guidelines section 9.1 Maximum peak conducted output power.

8.3.4 Test data

Table 8.3-1: *Output power measurements results for GFSK*

Frequency, MHz	Conducted output power, dBm		Margin, dB	Antenna gain, dBi	EIRP, dBm	EIRP limit, dBm	EIRP margin, dB
	Measured	Limit					
2402	2.97	30	27.03	2.15	5.12	36	30.88
2440	3.11	30	26.89	2.15	5.26	36	30.74
2480	2.89	30	27.11	2.15	5.04	36	30.96

Table 8.3-2: *Output power measurements results for OQPSK*

Frequency, MHz	Conducted output power, dBm		Margin, dB	Antenna gain, dBi	EIRP, dBm	EIRP limit, dBm	EIRP margin, dB
	Measured	Limit					
2405	3.35	30	26.65	2.15	5.50	36	30.50
2445	3.28	30	26.72	2.15	5.43	36	30.57
2480	1.50	30	28.50	2.15	3.65	36	32.35

8.3.4 Test data, continued

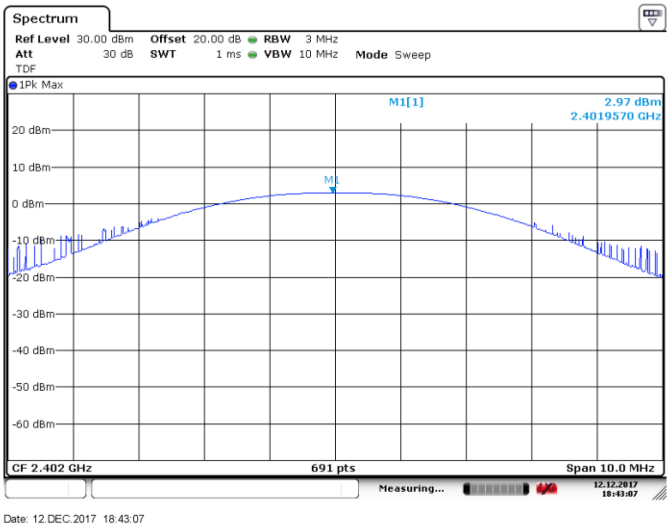


Figure 8.3-1: *Output power on low channel, GFSK*

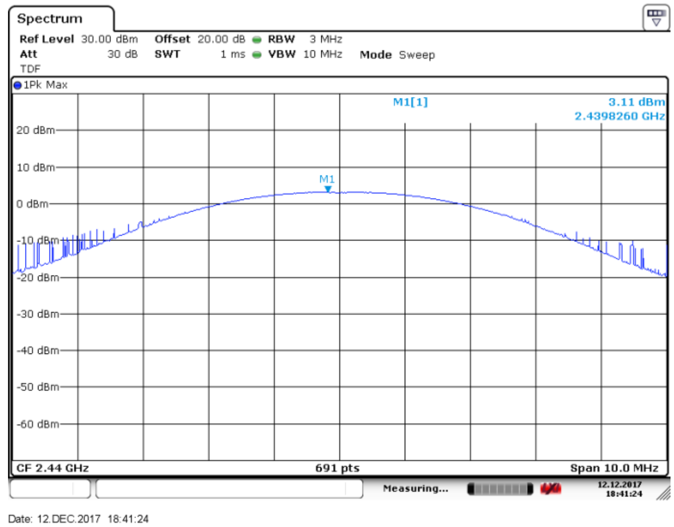


Figure 8.3-2: *Output power on mid channel, GFSK*

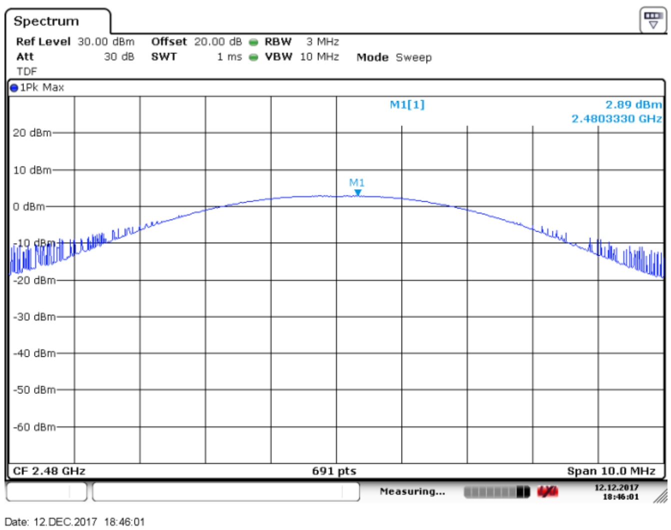


Figure 8.3-3: *Output power on high channel, GFSK*

8.3.4 Test data, continued

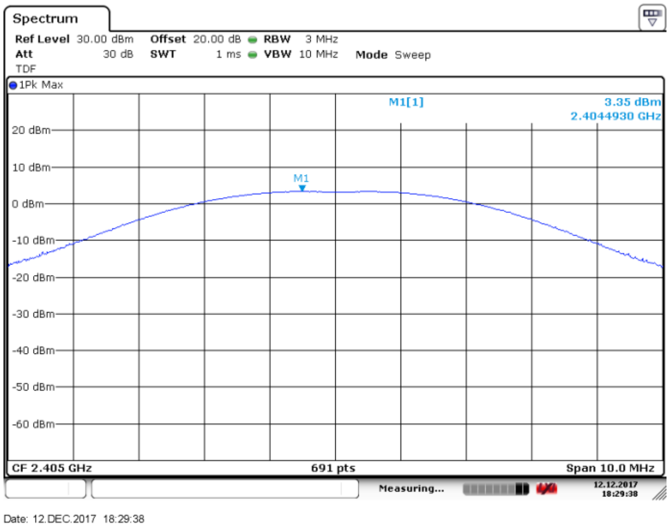


Figure 8.3-4: *Output power on low channel, OQPSK*

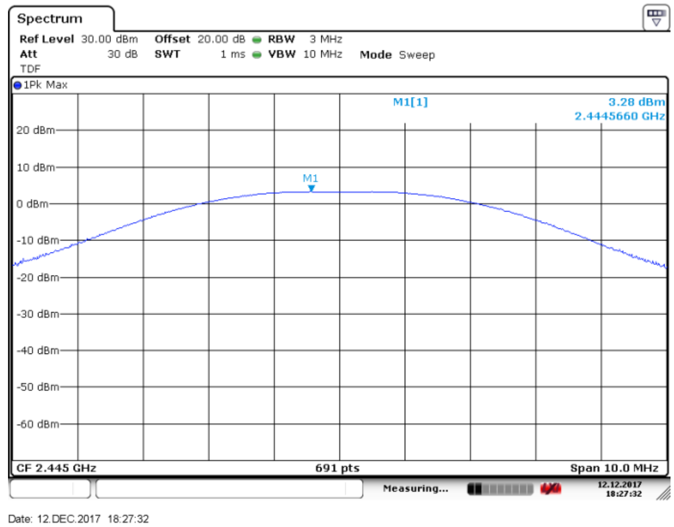


Figure 8.3-5: *Output power on mid channel, OQPSK*

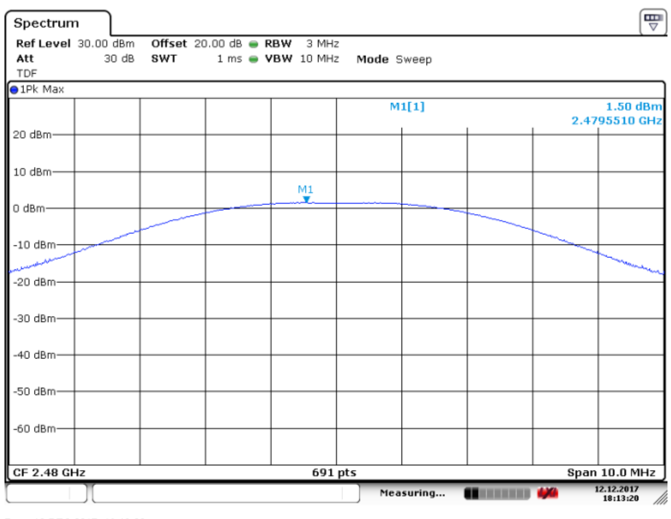


Figure 8.3-6: *Output power on high channel, OQPSK*

8.4 FCC 15.247(d) and RSS-247 5.5 Spurious (out-of-band) unwanted emissions

8.4.1 Definitions and limits

FCC:
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)).

ISED:
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 8.4-1: *FCC §15.209 and RSS-Gen – 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 8.4-2: *ISED restricted frequency bands*

MHz	MHz	MHz	GHz
0.090–0.110	12.51975–12.52025	399.9–410	5.35–5.46
2.1735–2.1905	12.57675–12.57725	608–614	7.25–7.75
3.020–3.026	13.36–13.41	960–1427	8.025–8.5
4.125–4.128	16.42–16.423	1435–1626.5	9.0–9.2
4.17725–4.17775	16.69475–16.69525	1645.5–1646.5	9.3–9.5
4.20725–4.20775	16.80425–16.80475	1660–1710	10.6–12.7
5.677-5.683	25.5–25.67	1718.8–1722.2	13.25–13.4
6.215–6.218	37.5–38.25	2200–2300	14.47–14.5
6.26775–6.26825	73–74.6	2310–2390	15.35–16.2
6.31175–6.31225	74.8–75.2	2655–2900	17.7–21.4
8.291–8.294	108–138	3260–3267	22.01–23.12
8.362–8.366	156.52475–156.52525	3332–3339	23.6–24.0
8.37625–8.38675	156.7–156.9	3345.8–3358	31.2–31.8
8.41425–8.41475	240–285	3500–4400	36.43–36.5
12.29–12.293	322–335.4	4500–5150	Above 38.6

Note: Certain frequency bands listed in Table 8.4-2 and above 38.6 GHz are designated for low-power licence-exempt applications. These frequency bands and the requirements that apply to the devices are set out in this Standard

Table 8.4-3: *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			

8.4.1 Test date

Start date	November 27, 2017

8.4.2 Observations, settings and special notes

The spectrum was searched from 30 MHz to the 10th harmonic.
EUT was set to transmit with 100 % duty cycle. Cabinet radiation emissions tests were performed while the antenna port was terminated with a 50 Ω load in place of the antenna.
Radiated measurements were performed at distance of 3 m.
Since fundamental power was tested using peak method, the spurious emissions limit is −20 dBc/100 kHz

Spectrum analyzer settings for conducted spurious emissions measurements:

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

Spectrum analyzer settings for radiated measurements within restricted bands below 1 GHz:

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

Spectrum analyzer settings for peak radiated measurements within restricted bands above 1 GHz:

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

Spectrum analyzer settings for average conducted measurements within restricted bands above 1 GHz:

Resolution bandwidth:	1 MHz
Video bandwidth:	3 MHz
Detector mode:	power averaging (RMS)
Trace mode:	averaging (RMS)

Spectrum analyzer settings for average radiated measurements within restricted bands above 1 GHz:

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

8.4.4 Test data

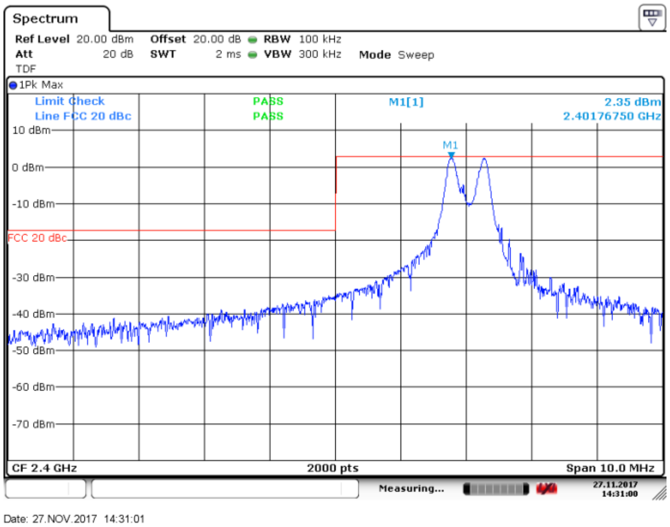


Figure 8.4-1: Conducted spurious emission at band edge outside restricted band, low channel, GFSK

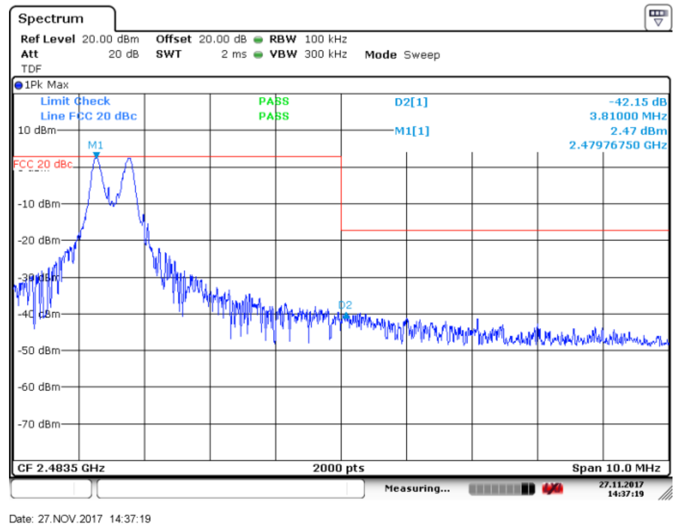


Figure 8.4-2: Conducted spurious emissions at band edge outside restricted band, High channel, GFSK

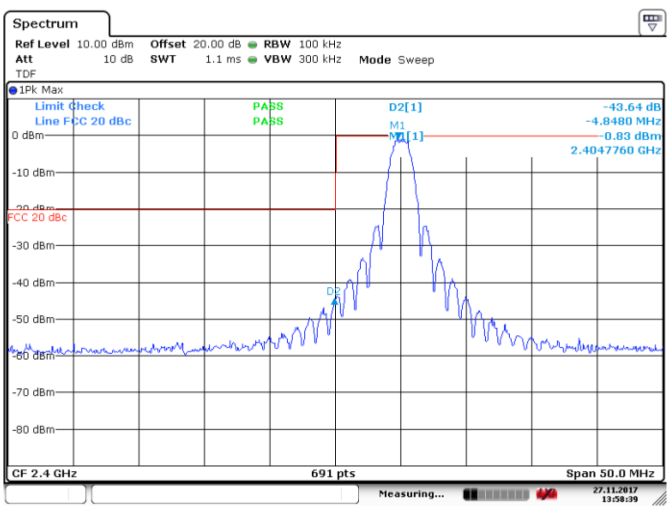


Figure 8.4-3: Conducted spurious emission at band edge outside restricted band, low channel, OQPSK

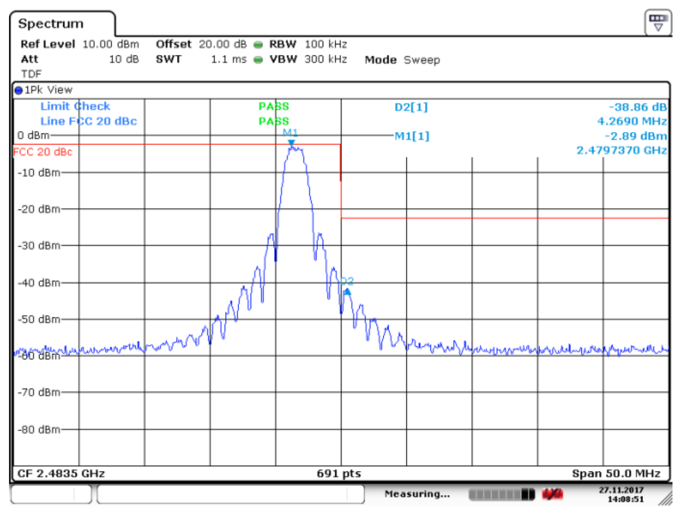


Figure 8.4-4: Conducted spurious emissions at band edge outside restricted band, High channel, OQPSK

8.4.4 Test data, continued

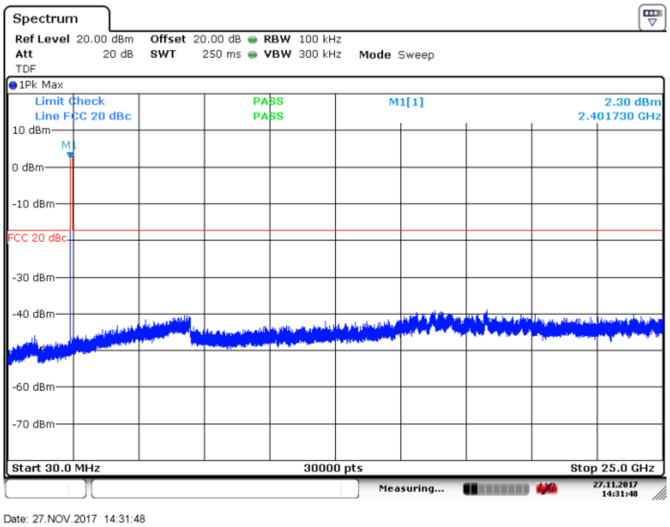


Figure 8.4-5: Conducted spurious emissions outside restricted band, Low channel, GFSK

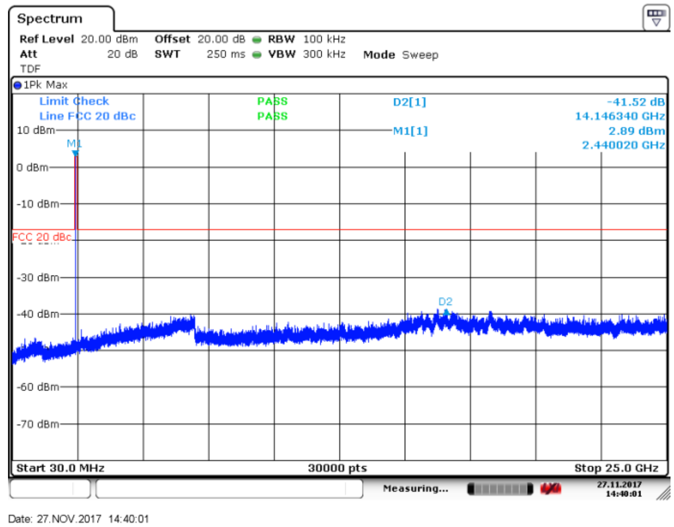


Figure 8.4-6: Conducted spurious emissions outside restricted band, Mid channel, GFSK

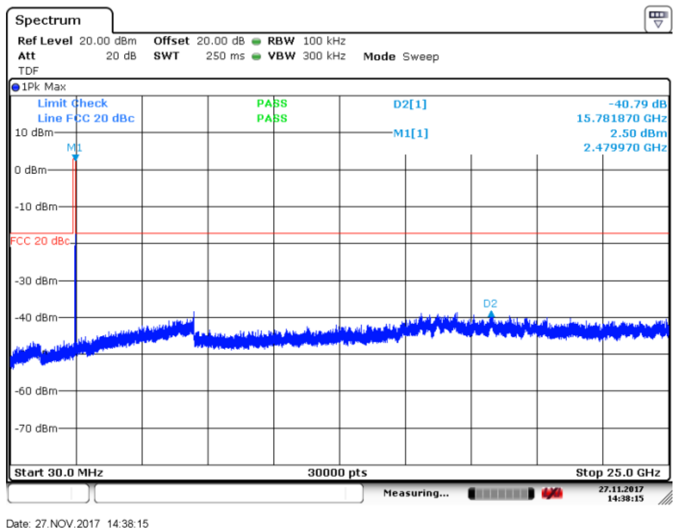


Figure 8.4-7: Conducted spurious emissions outside restricted band, High channel, GFSK

8.4.4 Test data, continued

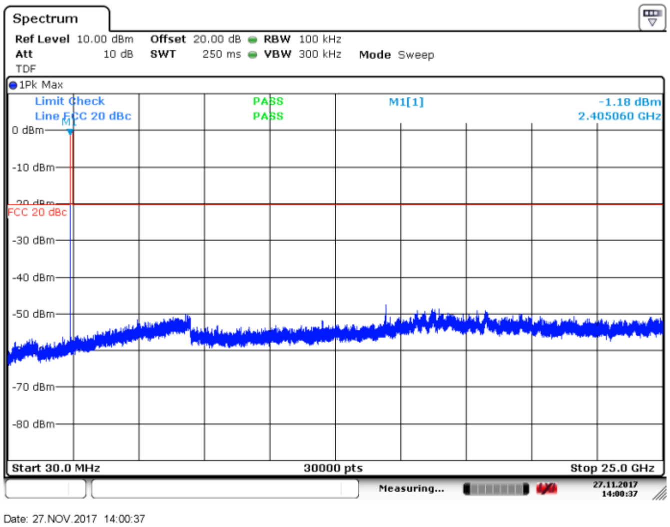


Figure 8.4-8: Conducted spurious emissions outside restricted band, Low channel, OQPSK

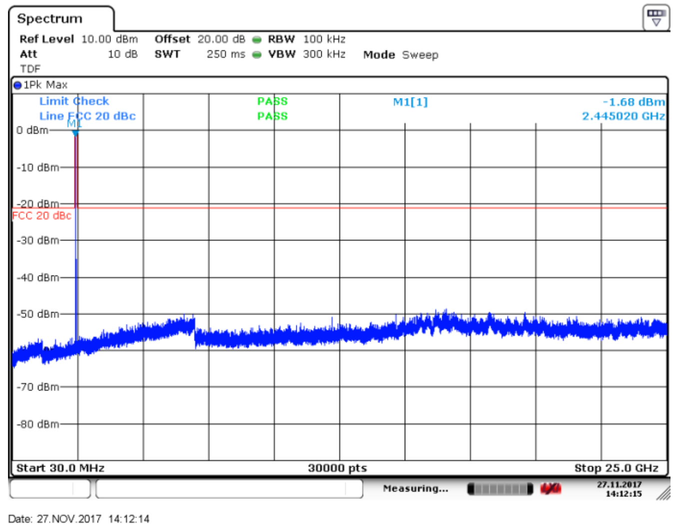


Figure 8.4-9: Conducted spurious emissions outside restricted band, Mid channel, OQPSK

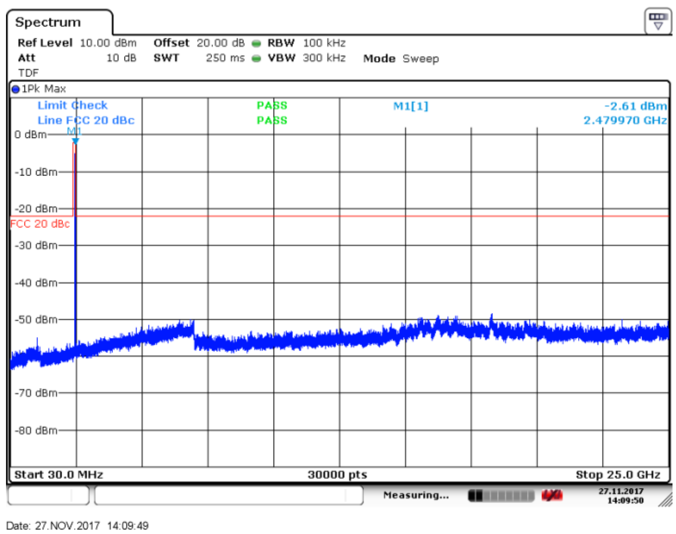
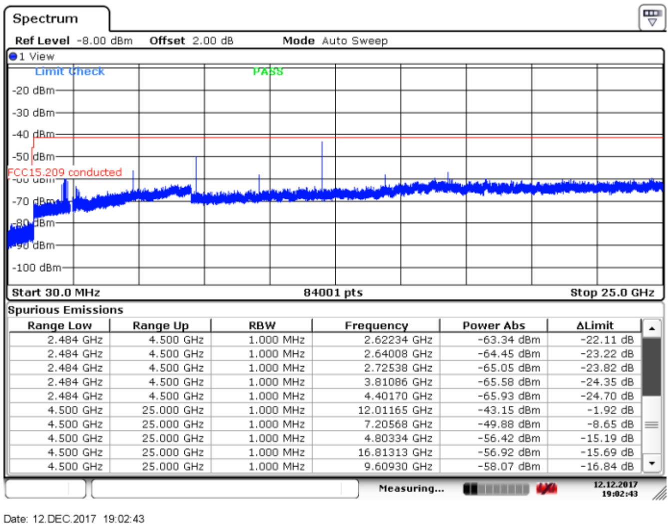


Figure 8.4-10: Conducted spurious emissions outside restricted band, High channel, OQPSK

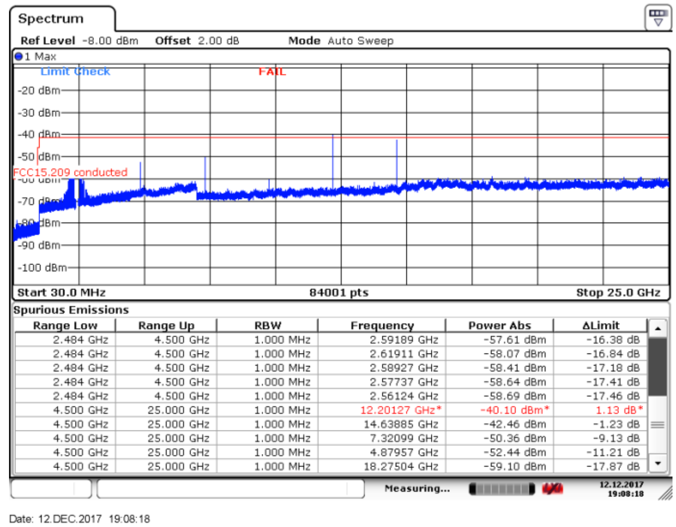
8.4.4 Test data, continued



Range Low	Range Up	RBW	Frequency	Power Abs	ΔLimit
2.484 GHz	4.500 GHz	1.000 MHz	2.62234 GHz	-63.34 dBm	-22.11 dB
2.484 GHz	4.500 GHz	1.000 MHz	2.64008 GHz	-64.45 dBm	-23.22 dB
2.484 GHz	4.500 GHz	1.000 MHz	2.72538 GHz	-65.05 dBm	-23.82 dB
2.484 GHz	4.500 GHz	1.000 MHz	3.81086 GHz	-65.58 dBm	-24.35 dB
2.484 GHz	4.500 GHz	1.000 MHz	4.40170 GHz	-65.93 dBm	-24.70 dB
4.500 GHz	25.000 GHz	1.000 MHz	12.01165 GHz	-43.15 dBm	-1.92 dB
4.500 GHz	25.000 GHz	1.000 MHz	7.20568 GHz	-49.88 dBm	-8.65 dB
4.500 GHz	25.000 GHz	1.000 MHz	4.80334 GHz	-56.42 dBm	-15.19 dB
4.500 GHz	25.000 GHz	1.000 MHz	16.81313 GHz	-56.92 dBm	-15.69 dB
4.500 GHz	25.000 GHz	1.000 MHz	9.60930 GHz	-58.07 dBm	-16.84 dB

Figure 8.4-11: Conducted spurious emissions within restricted band, Low channel, GFSK

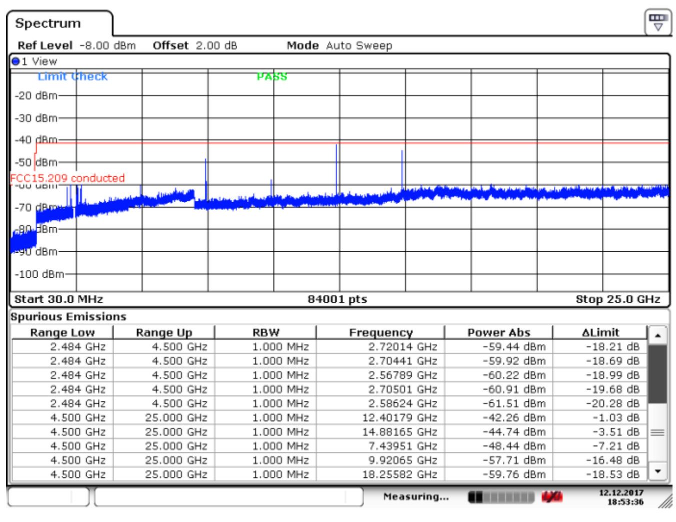
Note: Average reading at 12011 MHz is -50.3 dBm.



Range Low	Range Up	RBW	Frequency	Power Abs	ΔLimit
2.484 GHz	4.500 GHz	1.000 MHz	2.59189 GHz	-57.61 dBm	-16.38 dB
2.484 GHz	4.500 GHz	1.000 MHz	2.61911 GHz	-58.07 dBm	-16.84 dB
2.484 GHz	4.500 GHz	1.000 MHz	2.58927 GHz	-58.41 dBm	-17.18 dB
2.484 GHz	4.500 GHz	1.000 MHz	2.57737 GHz	-58.64 dBm	-17.41 dB
2.484 GHz	4.500 GHz	1.000 MHz	2.56124 GHz	-58.69 dBm	-17.46 dB
4.500 GHz	25.000 GHz	1.000 MHz	12.20127 GHz*	-40.10 dBm*	1.13 dB*
4.500 GHz	25.000 GHz	1.000 MHz	14.63885 GHz	-42.46 dBm	-1.23 dB
4.500 GHz	25.000 GHz	1.000 MHz	7.32099 GHz	-50.36 dBm	-9.13 dB
4.500 GHz	25.000 GHz	1.000 MHz	4.87957 GHz	-52.44 dBm	-11.21 dB
4.500 GHz	25.000 GHz	1.000 MHz	18.27504 GHz	-59.10 dBm	-17.87 dB

Figure 8.4-12: Conducted spurious emissions within restricted band, Mid channel, GFSK

Note: Average reading at 12201 MHz is -46.8 dBm; average reading at 14639 MHz is -46.9 dBm.

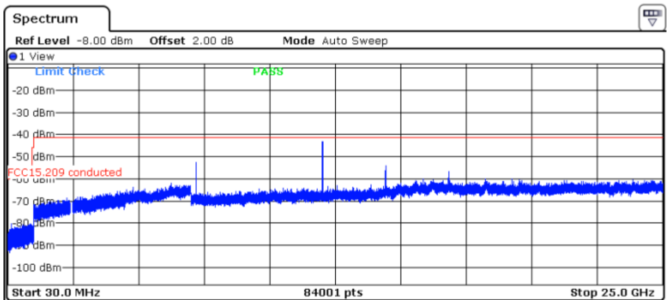


Range Low	Range Up	RBW	Frequency	Power Abs	ΔLimit
2.484 GHz	4.500 GHz	1.000 MHz	2.72014 GHz	-59.44 dBm	-18.21 dB
2.484 GHz	4.500 GHz	1.000 MHz	2.70441 GHz	-59.92 dBm	-18.69 dB
2.484 GHz	4.500 GHz	1.000 MHz	2.56789 GHz	-60.22 dBm	-18.99 dB
2.484 GHz	4.500 GHz	1.000 MHz	2.70501 GHz	-60.91 dBm	-19.68 dB
2.484 GHz	4.500 GHz	1.000 MHz	2.58624 GHz	-61.51 dBm	-20.28 dB
4.500 GHz	25.000 GHz	1.000 MHz	12.40179 GHz	-42.26 dBm	-1.03 dB
4.500 GHz	25.000 GHz	1.000 MHz	14.88165 GHz	-44.74 dBm	-3.51 dB
4.500 GHz	25.000 GHz	1.000 MHz	7.43951 GHz	-48.44 dBm	-7.21 dB
4.500 GHz	25.000 GHz	1.000 MHz	9.92065 GHz	-57.71 dBm	-16.48 dB
4.500 GHz	25.000 GHz	1.000 MHz	18.25582 GHz	-59.76 dBm	-18.53 dB

Figure 8.4-13: Conducted spurious emissions within restricted band, High channel, GFSK

Note: Average reading at 12401 MHz is -49.0 dBm; average reading at 14881 MHz is -52.6 dBm.

8.4.4 Test data, continued



Spurious Emissions

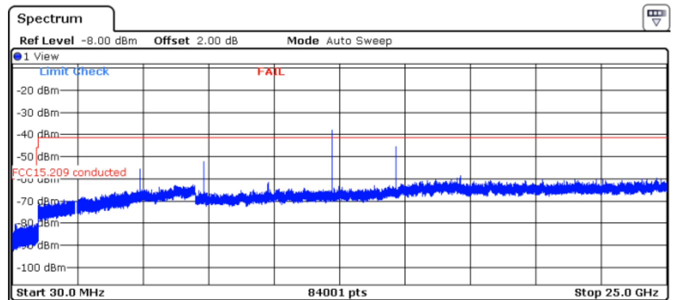
Range Low	Range Up	RBW	Frequency	Power Abs	ΔLimit
2.484 GHz	4.500 GHz	1.000 MHz	4.30974 GHz	-65.52 dBm	-24.29 dB
2.484 GHz	4.500 GHz	1.000 MHz	4.20690 GHz	-65.62 dBm	-24.39 dB
2.484 GHz	4.500 GHz	1.000 MHz	4.47832 GHz	-66.21 dBm	-24.98 dB
2.484 GHz	4.500 GHz	1.000 MHz	4.40149 GHz	-66.36 dBm	-25.13 dB
2.484 GHz	4.500 GHz	1.000 MHz	4.29341 GHz	-66.38 dBm	-25.15 dB
4.500 GHz	25.000 GHz	1.000 MHz	12.02766 GHz	-43.15 dBm	-1.92 dB
4.500 GHz	25.000 GHz	1.000 MHz	12.02254 GHz	-43.35 dBm	-2.12 dB
4.500 GHz	25.000 GHz	1.000 MHz	7.21401 GHz	-52.72 dBm	-11.49 dB
4.500 GHz	25.000 GHz	1.000 MHz	14.43257 GHz	-54.08 dBm	-12.85 dB
4.500 GHz	25.000 GHz	1.000 MHz	14.42745 GHz	-56.16 dBm	-14.93 dB

Measuring... 12.12.2017 19:13:47

Date: 12.DEC.2017 19:13:47

Figure 8.4-14: Conducted spurious emissions within restricted band, Low channel, OQPSK

Note: Average reading at 12028 MHz is -51.5 dBm; average reading at 12023 is -51.5 dBm.



Spurious Emissions

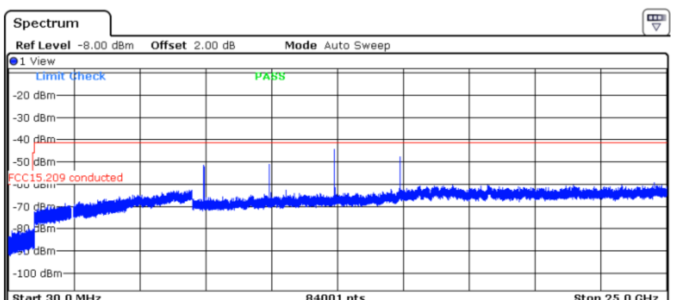
Range Low	Range Up	RBW	Frequency	Power Abs	ΔLimit
2.484 GHz	4.500 GHz	1.000 MHz	4.34745 GHz	-65.72 dBm	-24.49 dB
2.484 GHz	4.500 GHz	1.000 MHz	4.33757 GHz	-65.86 dBm	-24.63 dB
2.484 GHz	4.500 GHz	1.000 MHz	4.28151 GHz	-66.02 dBm	-24.79 dB
2.484 GHz	4.500 GHz	1.000 MHz	3.95766 GHz	-66.10 dBm	-24.87 dB
2.484 GHz	4.500 GHz	1.000 MHz	3.92157 GHz	-66.58 dBm	-25.35 dB
4.500 GHz	25.000 GHz	1.000 MHz	12.22754 GHz*	-38.09 dBm*	3.14 dB*
4.500 GHz	25.000 GHz	1.000 MHz	12.22241 GHz*	-38.49 dBm*	2.74 dB*
4.500 GHz	25.000 GHz	1.000 MHz	14.67345 GHz	-45.28 dBm	-4.05 dB
4.500 GHz	25.000 GHz	1.000 MHz	14.66704 GHz	-45.39 dBm	-4.16 dB
4.500 GHz	25.000 GHz	1.000 MHz	7.33380 GHz	-52.01 dBm	-10.78 dB

Measuring... 12.12.2017 19:33:41

Date: 12.DEC.2017 19:33:41

Figure 8.4-15: Conducted spurious emissions within restricted band, Mid channel, OQPSK

Note: Average reading at 12228 MHz is -46.4 dBm; average reading at 12222 MHz is -46.2 dBm; average reading at 14673 MHz is -53.2 dBm.



Spurious Emissions

Range Low	Range Up	RBW	Frequency	Power Abs	ΔLimit
4.500 GHz	25.000 GHz	1.000 MHz	12.40243 GHz	-44.25 dBm	-3.02 dB
4.500 GHz	25.000 GHz	1.000 MHz	12.39795 GHz	-44.53 dBm	-3.30 dB
4.500 GHz	25.000 GHz	1.000 MHz	14.88357 GHz	-47.75 dBm	-6.52 dB
4.500 GHz	25.000 GHz	1.000 MHz	14.87716 GHz	-48.28 dBm	-7.05 dB
4.500 GHz	25.000 GHz	1.000 MHz	9.91809 GHz	-50.92 dBm	-9.69 dB
4.500 GHz	25.000 GHz	1.000 MHz	9.92193 GHz	-51.42 dBm	-10.19 dB
4.500 GHz	25.000 GHz	1.000 MHz	7.43887 GHz	-51.47 dBm	-10.24 dB
4.500 GHz	25.000 GHz	1.000 MHz	24.54035 GHz	-59.37 dBm	-18.14 dB
4.500 GHz	25.000 GHz	1.000 MHz	18.21866 GHz	-60.32 dBm	-19.09 dB
4.500 GHz	25.000 GHz	1.000 MHz	16.88168 GHz	-60.33 dBm	-19.10 dB

Measuring... 12.12.2017 19:22:55

Date: 12.DEC.2017 19:22:55

Figure 8.4-16: Conducted spurious emissions within restricted band, High channel, OQPSK

Note: Average reading at 12402 MHz is -53.1 dBm; average reading at 12398 MHz is -53.2 dBm.

8.4.4 Test data, continued

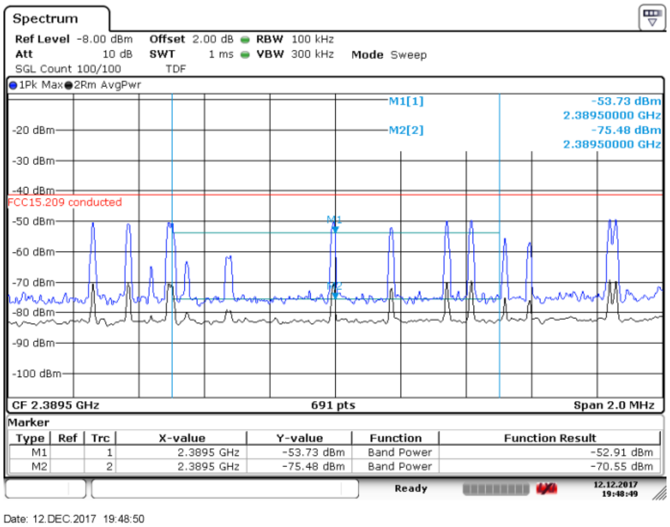


Figure 8.4-17: Conducted spurious emission at band edge of restricted band, low channel, GFSK

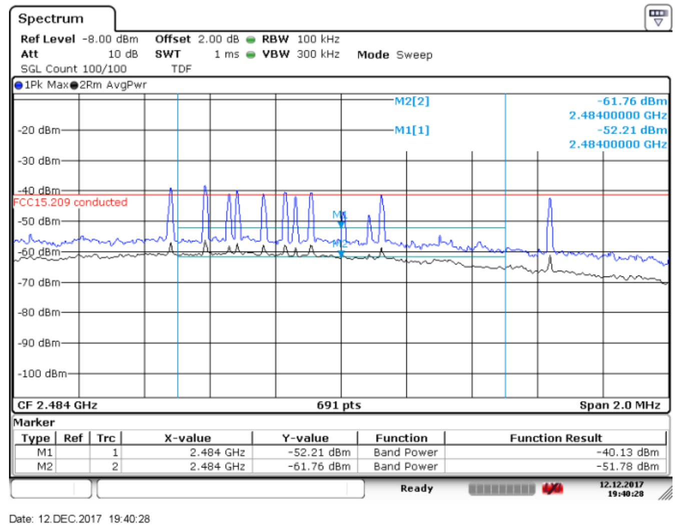


Figure 8.4-18: Conducted spurious emissions at band edge of restricted band, High channel, GFSK

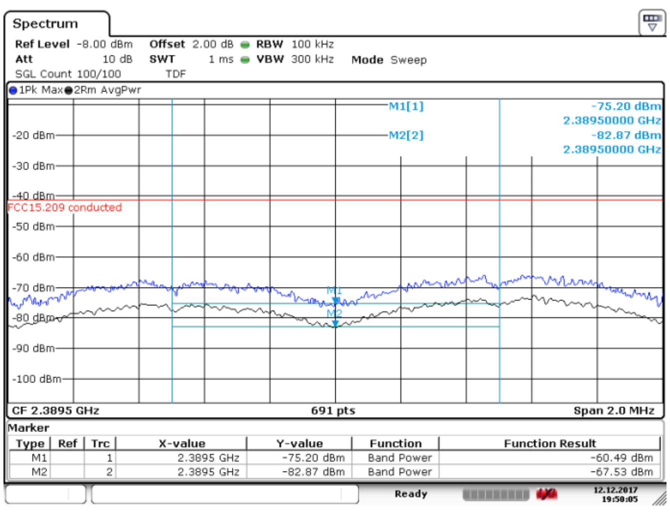


Figure 8.4-19: Conducted spurious emission at band edge of restricted band, low channel, OQPSK

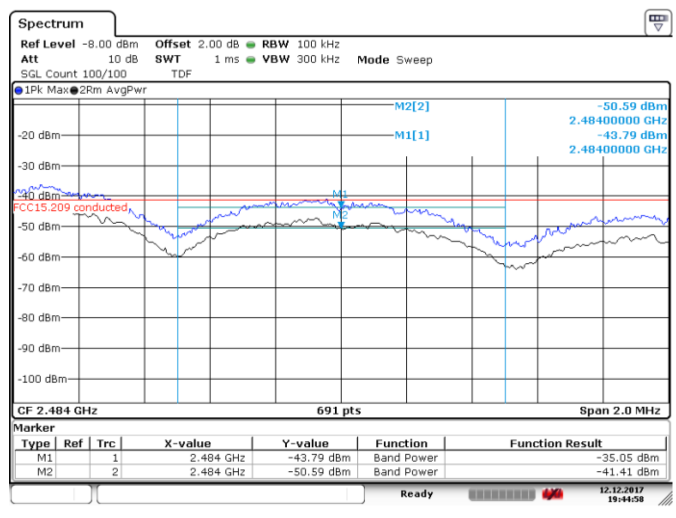


Figure 8.4-20: Conducted spurious emissions at band edge of restricted band, High channel, OQPSK

8.4.4 Test data, continued

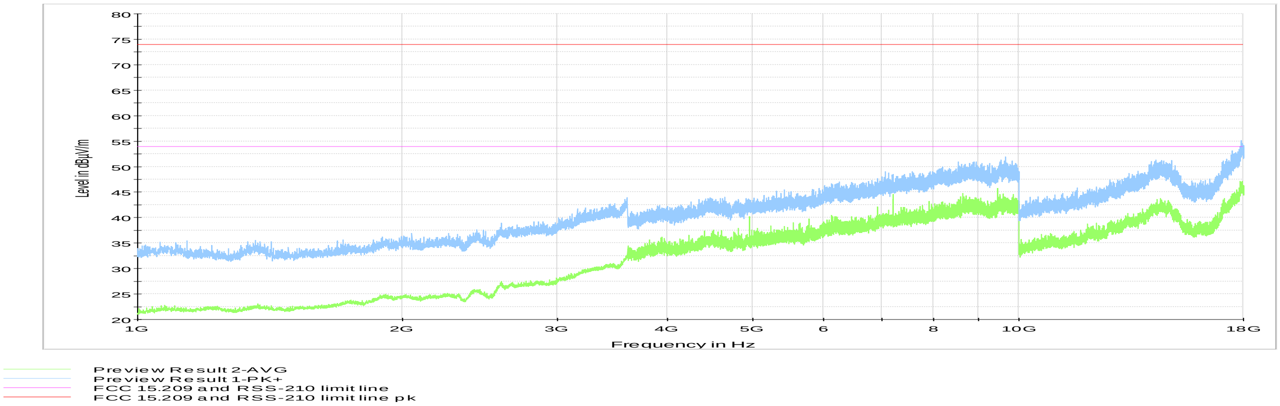


Figure 8.4-21: Cabinet Radiated spurious emissions 1 to18 GHz, Low channel, GFSK

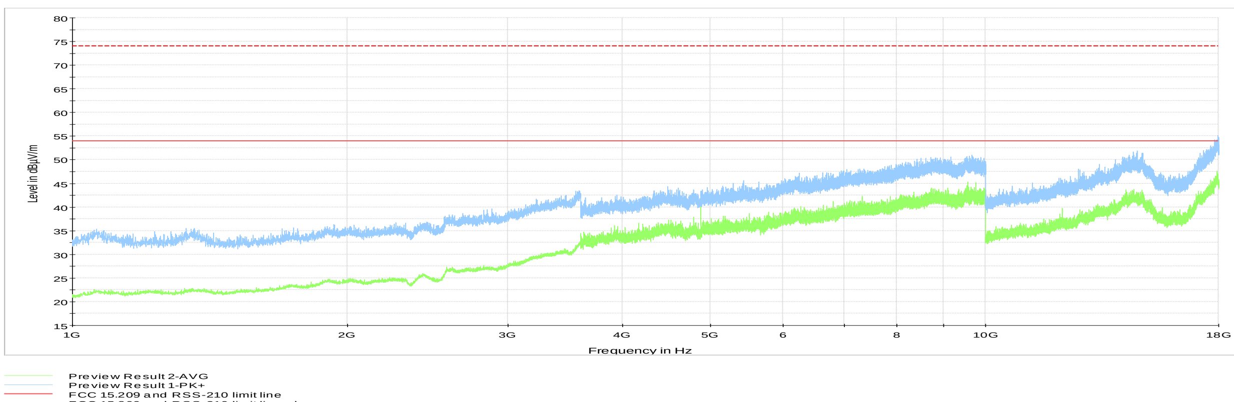


Figure 8.4-22: Cabinet Radiated spurious emissions 1 to18 GHz, mid channel, GFSK

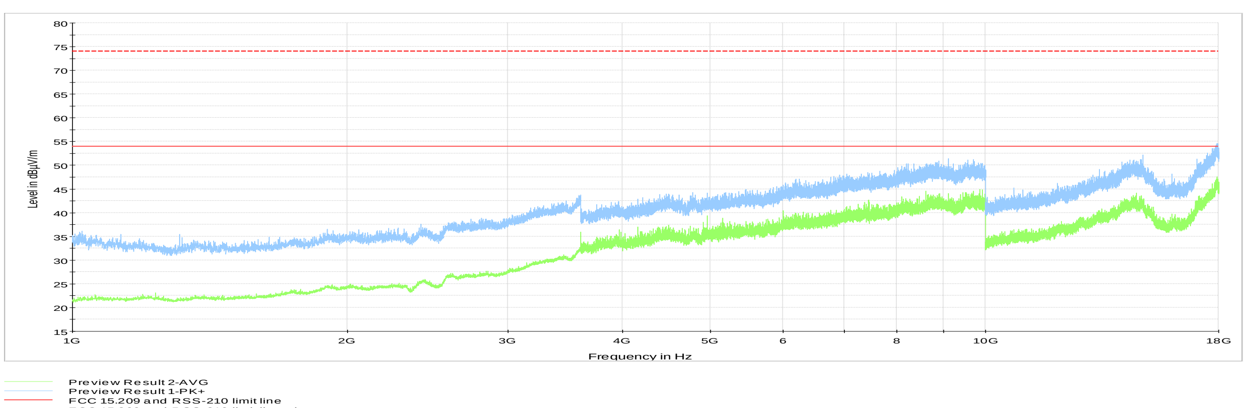


Figure 8.4-23: Cabinet Radiated spurious emissions 1 to18 GHz, High channel, GFSK

Note: Spectrum was investigated from 30 MHz to 25 GHz. Below 1 GHz and above 18 GHz, no emission related to RF portion were detected within 6 dB below the limit

8.4.4 Test data, continued

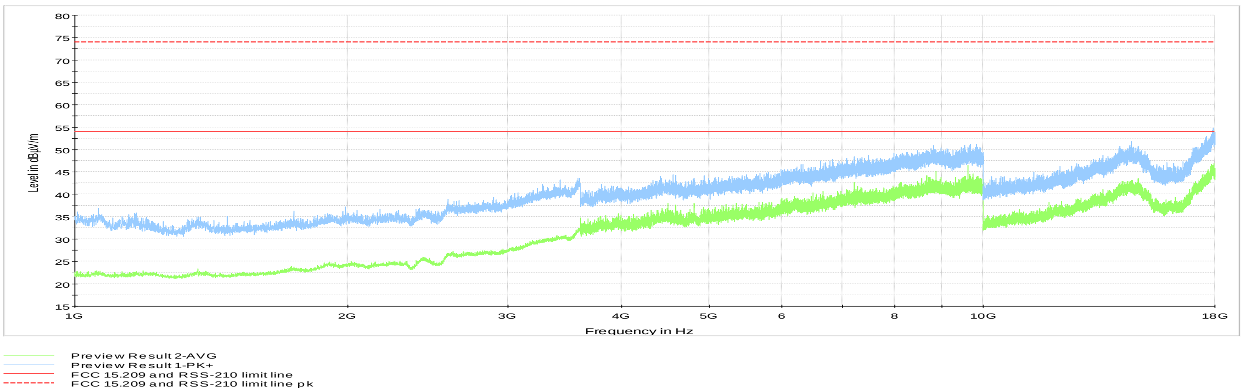


Figure 8.4-24: Cabinet Radiated spurious emissions 1 to18 GHz, Low channel, OQPSK

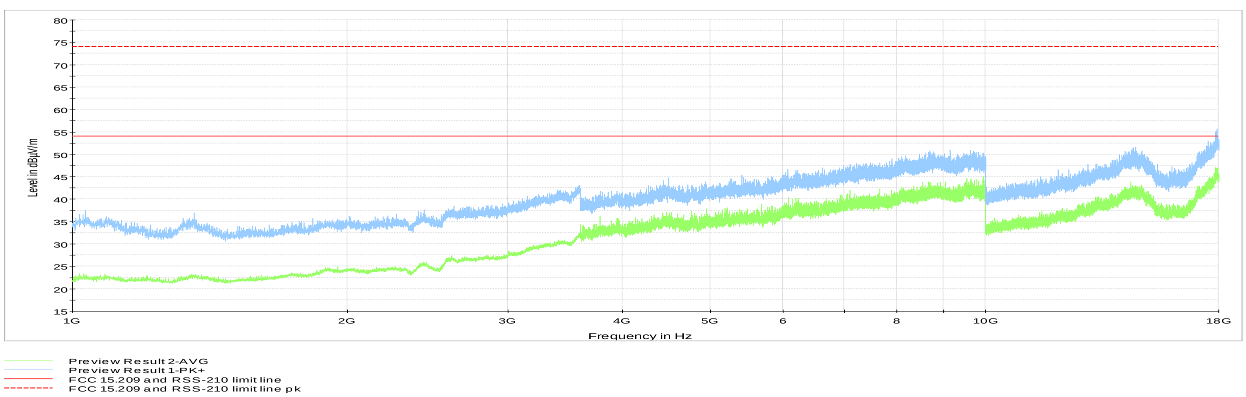


Figure 8.4-25: Cabinet Radiated spurious emissions 1 to18 GHz, mid channel, OQPSK

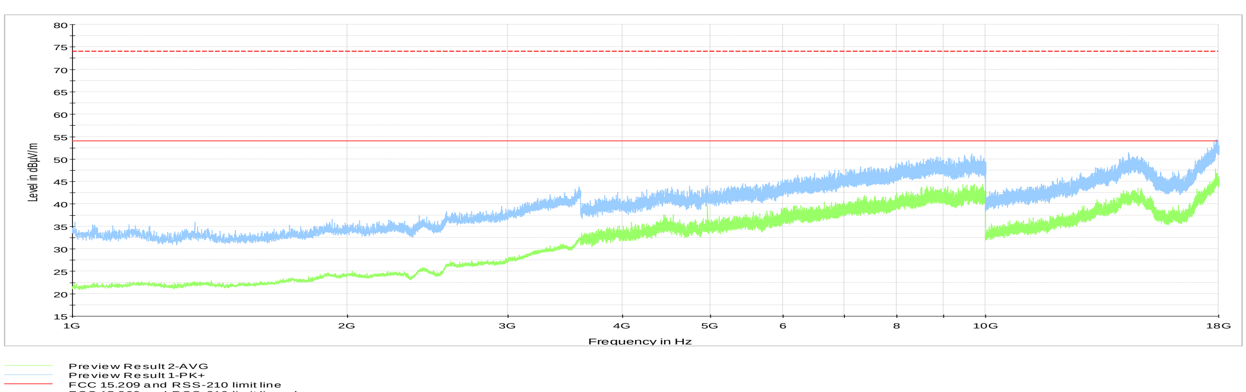


Figure 8.4-26: Cabinet Radiated spurious emissions 1 to18 GHz, High channel, OQPSK

Note: Spectrum was investigated from 30 MHz to 25 GHz. Below 1 GHz and above 18 GHz, no emission related to RF portion were detected within 6 dB below the limit

8.5 FCC 15.247(e) and RSS-247 5.2(b) Power spectral density for digitally modulated devices

8.5.1 Definitions and limits

FCC:
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.

ISED:
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(d), (i.e. the power spectral density shall be determined using the same method as is used to determine the conducted output power).

8.5.1 Test date

Start date	November 27, 2017

8.5.2 Observations, settings and special notes

The test was performed using method described in section 10.2 Method PKPSD (peak PSD).

Spectrum analyzer settings:

Resolution bandwidth:	3 kHz ≤ RBW ≤ 100 kHz
Video bandwidth:	≥3 × RBW
Frequency span:	1 MHz for GFSK, 3 MHz for OQPSK
Detector mode:	Peak
Trace mode:	Max hold

8.5.3 Test data

Table 8.5-1: PSD measurements results

Modulation	**Frequency, MHz**	**PSD, dBm/100 kHz**	**PSD limit, dBm/3 kHz**	**Margin, dB**
GFSK	2402	2.6	8	5.4
	2440	3.0	8	5.0
	2480	2.7	8	5.3
OQPSK	2405	-1.0	8	9.0
	2445	-1.0	8	9.0
	2480	-3.1	8	11.1

8.5.4 Test data, continued

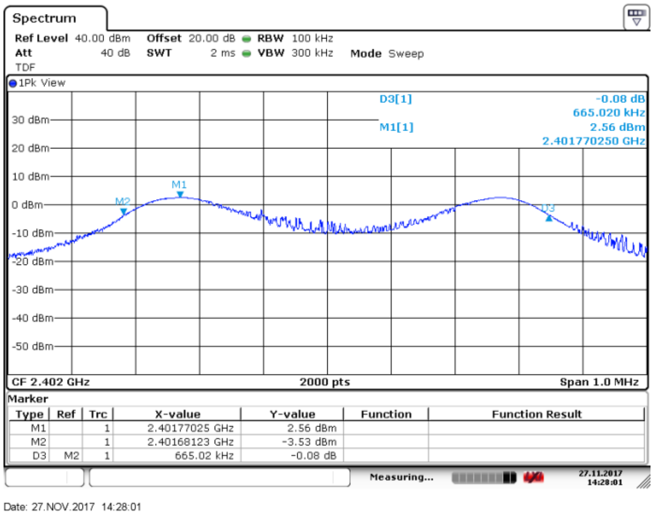


Figure 8.5-1: PSD plot on Low channel, GFSK

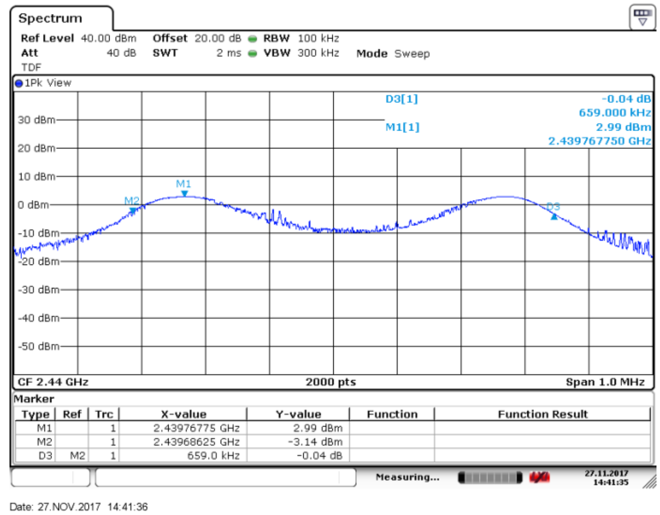


Figure 8.5-2: PSD plot on Mid channel, GFSK

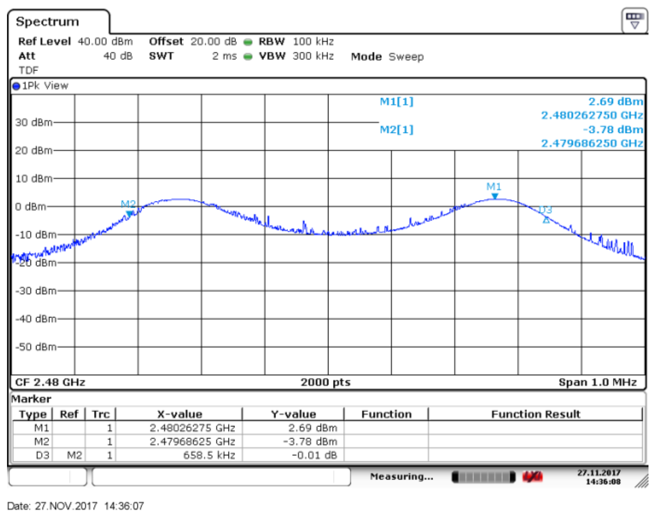


Figure 8.5-3: PSD plot on High channel, GFSK

8.5.4 Test data, continued

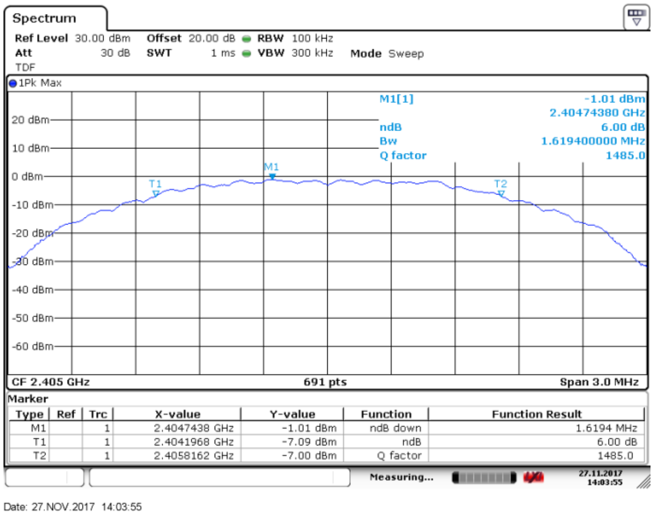


Figure 8.5-4: PSD plot on Low channel, OQPSK

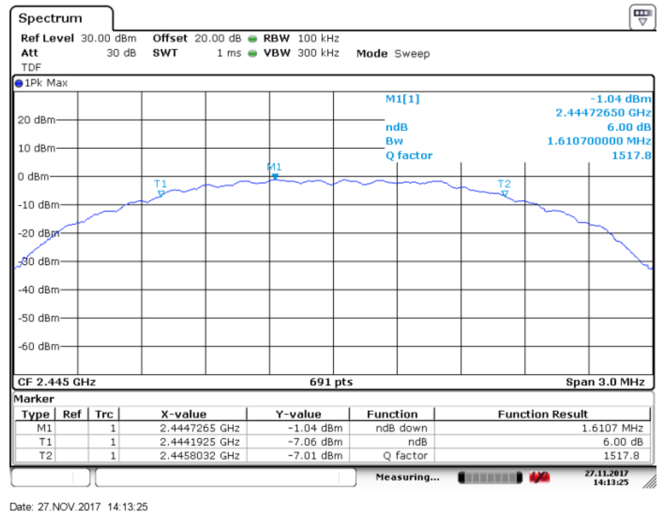


Figure 8.5-5: PSD plot on Mid channel, OQPSK

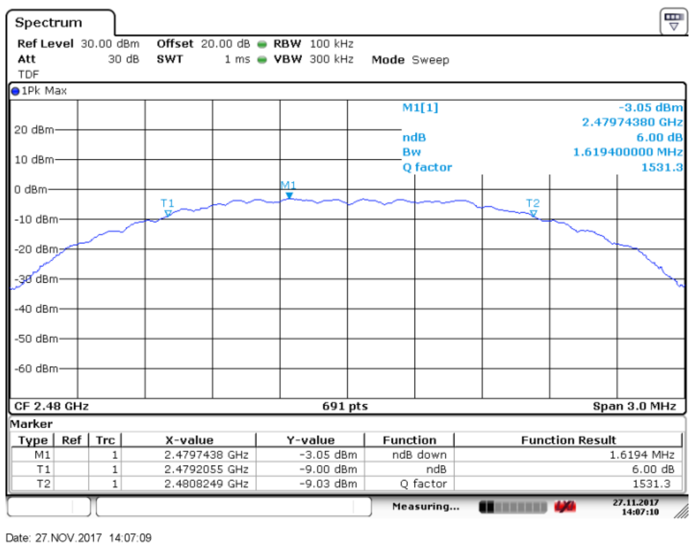
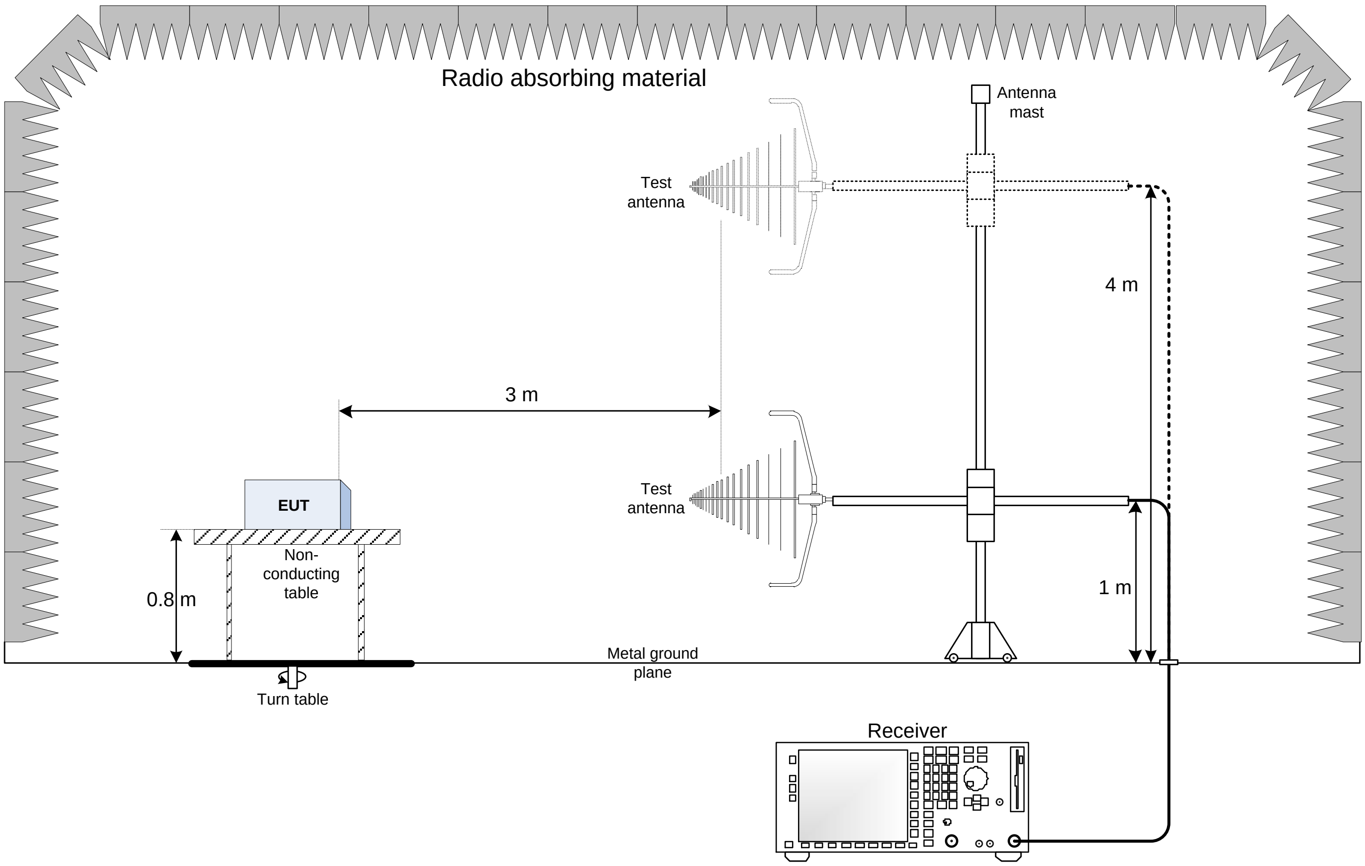


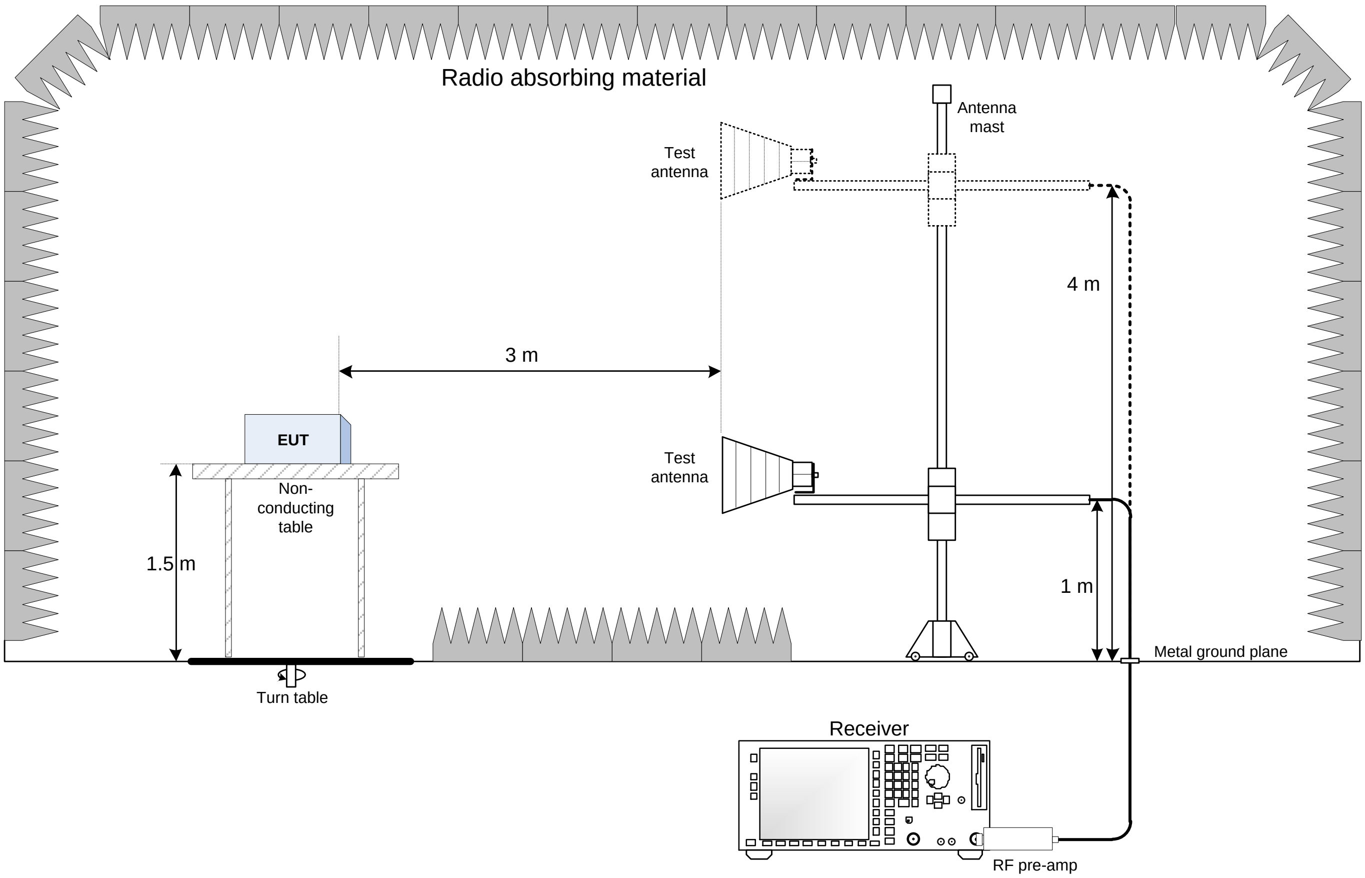
Figure 8.5-6: PSD plot on High channel, OQPSK

Section 9. Block diagrams of test set-ups

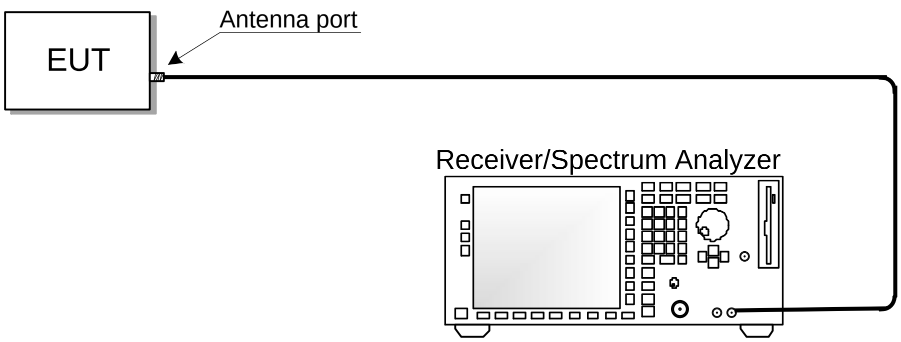
9.1 Radiated emissions set-up for frequencies below 1 GHz



9.2 Radiated emissions set-up for frequencies above 1 GHz



9.3 Conducted antenna port set-up



9.4 Conducted emissions set-up