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Test report no.:

220480-AU01+W05

for:

AiSight GmbH
Vibration sensor node for industrial
machineries
V4PRO

according to:

47 CFR Part 15, §15.247
RSS-247

Accreditation:

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Table of contents

1	Summary of test results	7
2	Referenced publications	9
3	Equipment under test (EUT)	10
3.1	General information	10
3.2	Radio specifications	11
3.3	Photo documentation	12
4	Test configuration and mode of operation	13
4.1	Test configuration	13
4.2	Mode of operation	13
5	Test procedures	14
5.1	General specifications	14
5.2	Antenna-port conducted measurements	15
5.3	AC powerline conducted emissions	15
5.4	Radiated emissions below 30 MHz	17
5.5	Radiated emissions from 30 MHz to 1 GHz	20
5.6	Radiated emissions above 1 GHz	23
5.7	Bandwidth measurements	26
5.8	Maximum peak conducted output power	27
5.9	Power spectral density	27
6	Test results	28
6.1	AC powerline conducted emissions	29
6.2	6 dB bandwidth	33
6.3	Occupied bandwidth	42
6.4	Conducted output power	51
6.5	Power spectral density	61
6.6	Band-edge measurements	70
6.7	Antenna-port conducted measurements	84
6.8	Radiated emissions below 30 MHz	98
6.9	Radiated emissions from 30 MHz to 1 GHz	101
6.10	Radiated emissions from 1 GHz to 25 GHz (10 th harmonic)	105
7	Equipment calibration status	110
8	Measurement uncertainties	111
9	Revision history	112

List of figures

Figure 1:	Setup for antenna-port conducted measurements	15
Figure 2:	Setup for AC power-line conducted emissions test from 150 kHz to 30 MHz	16
Figure 3:	Setup for radiated emissions test below 30 MHz	19
Figure 4:	Setup for radiated emissions test from 30 MHz to 1 GHz	22
Figure 5:	Setup for radiated emissions test above 1 GHz	25
Figure 6:	Chart of AC powerline conducted emissions on L1	31
Figure 7:	Chart of AC powerline conducted emissions on N	32
Figure 8:	Chart of 6 dB bandwidth test on lowest channel, 125 kbps	34
Figure 9:	Chart of 6 dB bandwidth test on middle channel, 125 kbps	34

Figure 10: Chart of 6 dB bandwidth test on highest channel, 125 kbps.....	35
Figure 11: Chart of 6 dB bandwidth test on lowest channel, 500 kbps	36
Figure 12: Chart of 6 dB bandwidth test on middle channel, 500 kbps.....	36
Figure 13: Chart of 6 dB bandwidth test on highest channel, 500 kbps.....	37
Figure 14: Chart of 6 dB bandwidth test on lowest channel, 1 Mbps	38
Figure 15: Chart of 6 dB bandwidth test on middle channel, 1 Mbps	38
Figure 16: Chart of 6 dB bandwidth test on highest channel, 1 Mbps	39
Figure 17: Chart of 6 dB bandwidth test on lowest channel, 2 Mbps	40
Figure 18: Chart of 6 dB bandwidth test on middle channel, 2 Mbps	40
Figure 19: Chart of 6 dB bandwidth test on highest channel, 2 Mbps	41
Figure 20: Chart of occupied bandwidth test on lowest channel, 125 kbps	43
Figure 21: Chart of occupied bandwidth test on middle channel, 125 kbps.....	43
Figure 22: Chart of occupied bandwidth test on highest channel, 125 kbps.....	44
Figure 23: Chart of occupied bandwidth test on lowest channel, 500 kbps	45
Figure 24: Chart of occupied bandwidth test on middle channel, 500 kbps.....	45
Figure 25: Chart of occupied bandwidth test on highest channel, 500 kbps.....	46
Figure 26: Chart of occupied bandwidth test on lowest channel, 1 Mbps	47
Figure 27: Chart of occupied bandwidth test on middle channel, 1 Mbps	47
Figure 28: Chart of occupied bandwidth test on highest channel, 1 Mbps	48
Figure 29: Chart of occupied bandwidth test on lowest channel, 2 Mbps	49
Figure 30: Chart of occupied bandwidth test on middle channel, 2 Mbps	49
Figure 31: Chart of occupied bandwidth test on highest channel, 2 Mbps	50
Figure 32: Chart of conducted output power on lowest channel, 125 kbps	53
Figure 33: Chart of conducted output power on middle channel, 125 kbps.....	53
Figure 34: Chart of conducted output power on highest channel, 125 kbps.....	54
Figure 35: Chart of conducted output power on lowest channel, 500 kbps	55
Figure 36: Chart of conducted output power on middle channel, 500 kbps	55
Figure 37: Chart of conducted output power on highest channel, 500 kbps	56
Figure 38: Chart of conducted output power on lowest channel, 1 Mbps	57
Figure 39: Chart of conducted output power on middle channel, 1 Mbps.....	57
Figure 40: Chart of conducted output power on highest channel, 1 Mbps.....	58
Figure 41: Chart of conducted output power on lowest channel, 2 Mbps	59
Figure 42: Chart of conducted output power on middle channel, 2 Mbps.....	59
Figure 43: Chart of conducted output power on highest channel, 2 Mbps.....	60
Figure 44: Chart of power spectral density on lowest channel, 125 kbps	62
Figure 45: Chart of power spectral density on middle channel, 125 kbps	62
Figure 46: Chart of power spectral density on highest channel, 125 kbps	63
Figure 47: Chart of power spectral density on lowest channel, 500 kbps	64
Figure 48: Chart of power spectral density on middle channel, 500 kbps	64
Figure 49: Chart of power spectral density on highest channel, 500 kbps	65
Figure 50: Chart of power spectral density on lowest channel, 1 Mbps.....	66
Figure 51: Chart of power spectral density on middle channel, 1 Mbps	66
Figure 52: Chart of power spectral density on highest channel, 1 Mbps	67
Figure 53: Chart of power spectral density on lowest channel, 2 Mbps.....	68
Figure 54: Chart of power spectral density on middle channel, 2 Mbps	68
Figure 55: Chart of power spectral density on highest channel, 2 Mbps	69
Figure 56: Chart of band-edge measurement on lowest channel, 125 kbps	72
Figure 57: Chart of band-edge measurement on highest channel (PK), 125 kbps.....	73
Figure 58: Chart of band-edge measurement on highest channel (AV), 125 kbps.....	74
Figure 59: Chart of band-edge measurement on lowest channel, 500 kbps	75
Figure 60: Chart of band-edge measurement on highest channel (PK), 500 kbps.....	76
Figure 61: Chart of band-edge measurement on highest channel (AV), 500 kbps.....	77
Figure 62: Chart of band-edge measurement on lowest channel, 1 Mbps	78
Figure 63: Chart of band-edge measurement on highest channel (PK), 1 Mbps.....	79
Figure 64: Chart of band-edge measurement on highest channel (AV), 1 Mbps.....	80
Figure 65: Chart of band-edge measurement on lowest channel, 2 Mbps	81
Figure 66: Chart of band-edge measurement on highest channel (PK), 2 Mbps.....	82
Figure 67: Chart of band-edge measurement on highest channel (AV), 2 Mbps.....	83
Figure 68: Chart of emissions test from 9 kHz to 25 GHz on lowest channel, 125 kbps, PK-detector	86
Figure 69: Chart of emissions test from 9 kHz to 25 GHz on middle channel, 125 kbps, PK-detector.....	87
Figure 70: Chart of emissions test from 9 kHz to 25 GHz on highest channel, 125 kbps, PK-detector.....	88
Figure 71: Chart of emissions test from 9 kHz to 25 GHz on lowest channel, 500 kbps, PK-detector	89

Figure 72: Chart of emissions test from 9 kHz to 25 GHz on middle channel, 500 kbps, PK-detector.....	90
Figure 73: Chart of emissions test from 9 kHz to 25 GHz on highest channel, 500 kbps, PK-detector.....	91
Figure 74: Chart of emissions test from 9 kHz to 25 GHz on lowest channel, 1 Mbps, PK-detector	92
Figure 75: Chart of emissions test from 9 kHz to 25 GHz on middle channel, 1 Mbps, PK-detector	93
Figure 76: Chart of emissions test from 9 kHz to 25 GHz on highest channel, 1 Mbps, PK-detector	94
Figure 77: Chart of emissions test from 9 kHz to 25 GHz on lowest channel, 2 Mbps, PK-detector	95
Figure 78: Chart of emissions test from 9 kHz to 25 GHz on middle channel, 2 Mbps, PK-detector	96
Figure 79: Chart of emissions test from 9 kHz to 25 GHz on highest channel, 2 Mbps, PK-detector	97
Figure 80: Chart of emissions test below 30 MHz on lowest channel, 1 Mbps, EUT position Y, antenna in line to the EUT.....	100
Figure 81: Chart of emissions test from 30 MHz to 1 GHz on lowest channel, 1 Mbps, EUT position X, antenna polarization vertical	103
Figure 82: Chart of radiated emissions pre-measurement from 1 GHz to 17 GHz on lowest channel, 1 Mbps, EUT position Y, antenna polarization horizontal	107
Figure 83: Chart of exploratory emissions measurement from 17 GHz to 25 GHz on lowest channel, 1 Mbps	107
Figure 84: Chart of radiated emissions pre-measurement from 1 GHz to 17 GHz on middle channel, 1 Mbps, EUT position Y, antenna polarization horizontal	108
Figure 85: Chart of exploratory emissions measurement from 17 GHz to 25 GHz on middle channel, 1 Mbps	108
Figure 86: Chart of emissions test from 1 GHz to 17 GHz on highest channel, 1 Mbps, EUT position Y, antenna polarization horizontal	109
Figure 87: Chart of exploratory emission test from 17 GHz to 25 GHz on highest channel, 1 Mbps, at 0.5 m	109

List of tables

Table 1: Radio specifications of EUT	12
Table 2: Tested channel(s).....	12
Table 3: EUT used for testing.....	13
Table 4: Support equipment used for testing	13
Table 5: Ports of EUT and appropriate cables	13
Table 6: Bandwidth and detector type for AC power-line conducted emissions test	15
Table 7: Sample calculation	16
Table 8: Recalculation factors for extrapolation	17
Table 9: Bandwidth and detector type for radiated emissions test below 30 MHz.....	17
Table 10: Sample calculation	18
Table 11: Bandwidth and detector type for radiated emissions test from 30 MHz to 1 GHz	20
Table 12: Sample calculation	20
Table 13: Sample calculation	23
Table 14: Bandwidth and trace settings for exploratory radiated emissions test above 1 GHz.....	23
Table 15: Bandwidth and detector type for final radiated emissions test above 1 GHz.....	24
Table 16: Limits for AC powerline conducted emissions according to 15.207(a) and RSS-Gen, section 8.8	30
Table 17: Results of AC powerline conducted emissions on L1	31
Table 18: Results of AC powerline conducted emissions on N.....	32
Table 19: Results of 6 dB bandwidth test, 125 kbps	35
Table 20: Results of 6 dB bandwidth test, 500 kbps	37
Table 21: Results of 6 dB bandwidth test, 1 Mbps.....	39
Table 22: Results of 6 dB bandwidth test, 2 Mbps.....	41
Table 23: Results of occupied bandwidth test, 125 kbps	44
Table 24: Results of occupied bandwidth test, 500 kbps	46
Table 25: Results of occupied bandwidth test, 1 Mbps	48
Table 26: Results of occupied bandwidth test, 2 Mbps.....	50
Table 27: Results of conducted output power, 125 kbps	54
Table 28: Results of conducted output power, 500 kbps	56
Table 29: Results of conducted output power, 1 Mbps	58
Table 30: Results of conducted output power, 2 Mbps	60
Table 31: Results of conducted power spectral density, 125 kbps	63
Table 32: Results of conducted power spectral density, 500 kbps	65
Table 33: Results of conducted power spectral density, 1 Mbps	67

Table 34: Results of conducted power spectral density, 2 Mbps	69
Table 35: Restricted bands of operation according to §15.205 and RSS-Gen section 8.10	71
Table 36: Result of band-edge measurement on lowest channel, 125 kbps	72
Table 37: Test results of band-edge measurements on highest channel, 125 kbps.....	74
Table 38: Result of band-edge measurement on lowest channel, 500 kbps	75
Table 39: Test results of band-edge measurements on highest channel, 500 kbps.....	77
Table 40: Result of band-edge measurement on lowest channel, 1 Mbps	78
Table 41: Test results of band-edge measurements on highest channel, 1 Mbps	80
Table 42: Result of band-edge measurement on lowest channel, 2 Mbps	81
Table 43: Test results of band-edge measurements on highest channel, 2 Mbps	83
Table 44: General radiated emission limits from 9 kHz to 25 GHz according to §15.209	84
Table 45: General radiated emission limits from 9 kHz to 30 MHz according to RSS-Gen section 8.9	85
Table 46: General radiated emission limits from 30 MHz to 25 GHz according to RSS-Gen section 8.9	85
Table 47: Results of emissions test from 9 kHz to 25 GHz on lowest channel, 125 kbps	86
Table 48: Results of emissions test from 9 kHz to 25 GHz on middle channel, 125 kbps.....	87
Table 49: Results of emissions test from 9 kHz to 25 GHz on highest channel, 125 kbps.....	88
Table 50: Results of emissions test from 9 kHz to 25 GHz on lowest channel, 500 kbps	89
Table 51: Results of emissions test from 9 kHz to 25 GHz on middle channel, 500 kbps.....	90
Table 52: Results of emissions test from 9 kHz to 25 GHz on highest channel, 500 kbps.....	91
Table 53: Results of emissions test from 9 kHz to 25 GHz on lowest channel, 1 Mbps	92
Table 54: Results of emissions test from 9 kHz to 25 GHz on middle channel, 1 Mbps.....	93
Table 55: Results of emissions test from 9 kHz to 25 GHz on highest channel, 1 Mbps.....	94
Table 56: Results of emissions test from 9 kHz to 25 GHz on lowest channel, 2 Mbps	95
Table 57: Results of emissions test from 9 kHz to 25 GHz on middle channel, 2 Mbps.....	96
Table 58: Results of emissions test from 9 kHz to 25 GHz on highest channel, 2 Mbps.....	97
Table 59: General radiated emission limits up to 30 MHz according to §15.209.....	99
Table 60: General radiated emission limits from 9 kHz to 30 MHz according to section 8.9 of RSS-Gen	99
Table 61: General radiated emission limits $\geq$ 30 MHz according to §15.209 and RSS-Gen section 8.9...	102
Table 62: Results of emissions test from 30 MHz to 1 GHz on lowest channel, 1 Mbps.....	103
Table 63: General radiated emission limits above 960 MHz according to §15.209 and RSS-Gen	106
Table 64: Results of radiated emissions test from 1 GHz to 25 GHz on lowest channel, 1 Mbps	107
Table 65: Results of radiated emissions test from 1 GHz to 25 GHz on middle channel, 1 Mbps	108
Table 66: Results of emissions test from 1 GHz to 25 GHz on highest channel, 1 Mbps	109

1 Summary of test results

System type: Digital transmission system (DTS)

47 CFR part and section	Test	Equivalent to IC radio standard(s)	Page	Result	Note(s)
15.207	AC power line conducted emissions 150 kHz to 30 MHz	RSS-Gen, section 8.8	29	Passed	2
15.247(a)(2)	6 dB bandwidth	RSS-247, section 5.2(a)	33	Passed	---
---	Occupied bandwidth	RSS-Gen, section 6.7	42	For reference only	---
15.247(b)	Conducted output power	RSS-247, section 5.4	51	Passed	---
15.247(e)	Power spectral density	RSS-247, section 5.2(b)	61	Passed	---
15.247(d)	Band-edge measurements	RSS-247, section 5.5	70	Passed	---
15.247(d)	Antenna-port conducted measurements	RSS-247, section 5.5	84	Passed	3
15.247(d)	Radiated emissions below 30 MHz	RSS-247, section 5.5	98	Passed	---
15.247(d)	Radiated emissions from 30 MHz to 1 GHz	RSS-247, section 5.5	101	Passed	---
15.247(d)	Radiated emissions from 1 GHz to 25 GHz (10th harmonic)	RSS-247, section 5.5	105	Passed	---
15.247(i)	Radio frequency radiation exposure	RSS-Gen, Section 3.4	---	Not performed	4

Note(s):

- 1 For information about EUT see clause 3.
- 2 Measurements to demonstrate compliance with the conducted limits are not required for devices which only employ battery power for operation and which do not operate from the AC power lines or contain provisions for operation while connected to the AC power lines. Devices that include, or make provisions for, the use of battery chargers which permit operating while charging, AC adapters or battery eliminators or that connect to the AC power lines indirectly, obtaining their power through another device which is connected to the AC power lines, shall be tested to demonstrate compliance with the conducted limits.
- 3 If antenna port conducted tests cannot be performed (e.g. for portable or handheld devices with integral antenna), then radiated tests are performed for demonstrating compliance to the conducted emission requirements (see "Spurious radiated emissions 9 kHz to 10th harmonic").
- 4 Radio frequency radiation exposure is in consideration in another test report.

Straubing, July 18, 2023



Tested by
Konrad Graßl
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Approved by
Christian Kiermeier
Reviewer

2 Referenced publications

<i>Publication</i>	<i>Title</i>
CFR 47 Part 2 October 2022	Code of Federal Regulations, Title 47 (Telecommunication), Part 2 (Frequency allocation and radio treaty matters; General rules and regulations) of the Federal Communication Commission (FCC)
CFR 47 Part 15 October 2022	Code of Federal Regulations, Title 47 (Telecommunication), Part 15 (Radio Frequency Devices) of the Federal Communication Commission (FCC)
KDB Publication no. 412172 August 7, 2015	Guidelines for determining the Effective Radiated Power (ERP) and Equivalent Isotropically Radiated Power (EIRP) of an RF transmitting system
KDB Publication no. 558074 April 02, 2019	Guidance for Performing Compliance Measurements on Digital Transmission Systems (DTS), Frequency Hopping Spread Spectrum Sytem, and Hybrid System Devices Operating Under §15.247 of the FCC Rules
KDB Publication no. 662911 October 31, 2013	Emissions Testing of Transmitters with Multiple Outputs in the Same Band (e.g., MIMO, Smart Antenna, etc)
ANSI C63.10 June 2013	American National Standard of Procedures for Compliance Testing of Unlicensed Wireless Devices
RSS-Gen Issue 5 April 2018 Amendment 1 (March 2019) Amendment 2 (February 2021)	Spectrum Management and Telecommunications - Radio Standards Specification - General Requirements for Compliance of Radio Apparatus
RSS-247, Issue 2 February 2017	Spectrum Management and Telecommunications - Radio Standards Specification - Digital Transmission Systems (DTSS), Frequency Hopping Systems (FHSS) and Licence-Exempt Local Area Network (LE-LAN) Devices

3 Equipment under test (EUT)

All Information in this clause is declared by customer.

3.1 General information

Product type:	Vibration sensor node for industrial machineries		
Model name:	V4PRO		
Serial number(s):	DC4A9ECERT01		
Manufacturer:	AiSight GmbH		
Version:	Hardware:	V4ProR4.2	
	Software:	v4pro-ab-1.0	
Short description:	EUT is a vibration sensor node for industrial machineries with a BLE module operating in the 2.4 GHz band. The EUT also employs WLAN 2.4 GHz which is in consideration in another test report.		
Additional modifications:	None		
FCC ID:	2A34W-V4PRO		
IC registration number:	28248-V4PRO		
Designation of emissions:	1M02F7D--		
	1M04F7D--		
	1M04F7D--		
	2M03F7D--		
Power supply:	DC supply		
	Nominal voltage:	24 V	
Device type:	☐ Portable	☒ Mobile	☐ Fixed

3.2 Radio specifications

System type (Note 1):	Digital transmission system (DTS)		
Application frequency band:	2400.0 MHz - 2483.5 MHz		
Number of RF channels:	40		
Nominal bandwidth:	2 MHz		
Modulation(s):	GFSK		
Data rate(s):	125 kbps, 500 kbps, 1 Mbps, 2 Mbps		
Antenna:	Type:	PCB antenna	
	Gain:	1.1 dBi (maximum)	
	Model:	2.4 GHz Freedom Flexible PCB Antenna	
	Manufacturer:	Taoglas	
	Connector:	☐ external	☒ internal
		☐ temporary	☐ none (integral antenna)

Note(s):

1. "DTS" is the equipment class for digital transmission systems, "DSS" for all other Part 15 spread spectrum transmitters as used for equipment authorization system form 731.

<i>Channel no.</i>	<i>Operating frequency</i>	<i>Channel no.</i>	<i>Operating frequency</i>
37	2402 MHz	18	2442 MHz
0	2404 MHz	19	2444 MHz
1	2406 MHz	20	2446 MHz
2	2408 MHz	21	2448 MHz
3	2410 MHz	22	2450 MHz
4	2412 MHz	23	2452 MHz
5	2414 MHz	24	2454 MHz
6	2416 MHz	25	2456 MHz
7	2418 MHz	26	2458 MHz
8	2420 MHz	27	2460 MHz
9	2422 MHz	28	2462 MHz
10	2424 MHz	29	2464 MHz
38	2426 MHz	30	2466 MHz
11	2428 MHz	31	2468 MHz
12	2430 MHz	32	2470 MHz
13	2432 MHz	33	2472 MHz
14	2434 MHz	34	2474 MHz
15	2436 MHz	35	2476 MHz
16	2438 MHz	36	2478 MHz
17	2440 MHz	39	2480 MHz

Table 1: Radio specifications of EUT

<i>Channel</i>	<i>Frequency (MHz)</i>
Low	2402
Middle	2440
High	2480

Table 2: Tested channel(s)

3.3 Photo documentation

For external photos of the EUT see annex B, for internal ones see annex C. Photos taken during testing including EUT positions can be found in annex A.

4 Test configuration and mode of operation

4.1 Test configuration

<i>Device</i>	<i>Type designation</i>	<i>Serial or inventory no.</i>	<i>Manufacturer</i>
Vibration sensor node for industrial machineries	V4PRO	DC4A9ECERT01	AiSight GmbH

Table 3: EUT used for testing

<i>Device</i>	<i>Type designation</i>	<i>Serial or inventory no.</i>	<i>Manufacturer</i>
Multi-protocol USB GPIO Chip adapter	FT232H	---	Adafruit industries
Laptop	P137G	---	Dell
Power supply for laptop	LA90PM170	---	Dell
Power supply for EUT	TRE25R240	---	Cincon Electronics Co., Ltd.

Table 4: Support equipment used for testing

<i>Port</i>	<i>Classification</i>
DC power port	DC power

Table 5: Ports of EUT and appropriate cables

4.2 Mode of operation

The EUT was connected to the laptop via the multi-protocol USB GPIO adapter. The test software called “EspRFTTestTool_v2.8” was used for setting the appropriate parameters like channel, TX packets, duty cycle, modulation type and power attenuation.

Note(s):

1. For all tests the power level of “10” was used in the test software.
2. All tests were performed with duty cycle $\geq 98\%$.

5 Test procedures

5.1 General specifications

5.1.1 Test setups

Tabletop devices are placed on a non-conductive table with a height of 0.8 m. In case of AC power-line conducted emissions test, the rear of the EUT is located 40 cm to the vertical wall of the RF-shielded (screened) room which is used as vertical conducting plane. For radiated emission measurements above 1 GHz, tabletop devices are placed at a height of 1.5 m above the floor using a support made of styrene placed on top of the non-conductive table.

All other surfaces of tabletop or floor-standing EUTs are at least 80 cm from any other grounded conducting surface. This includes the case or cases of one or more LISNs when performing an AC power-line conducted emissions test.

Radiated emission measurements of equipment that can be used in multiple orientations (e.g. portable or handheld devices) are performed with the EUT in each of three orthogonal axis positions.

5.1.2 Conversion to conducted test results

If test procedures described herein are based on the use of an antenna-port conducted test configuration, but the EUT cannot provide such a configuration (e.g., portable or handheld devices with integral antenna), radiated tests are performed for demonstrating compliance to the conducted requirements.

If a radiated test configuration has to be used, then the measured power or field strength levels are converted to equivalent conducted power levels for comparison to the applicable limit. For this purpose, at first the radiated field strength or power levels are converted to EIRP as described in annex G of ANSI C63.10 and KDB Publication 412172, document D01. The equivalent conducted power is then determined by subtracting the EUT transmit antenna gain from the EIRP (assuming logarithmic representation).

For devices utilizing multiple antenna technologies, KDB Publication 662911 applies.

5.2 Antenna-port conducted measurements

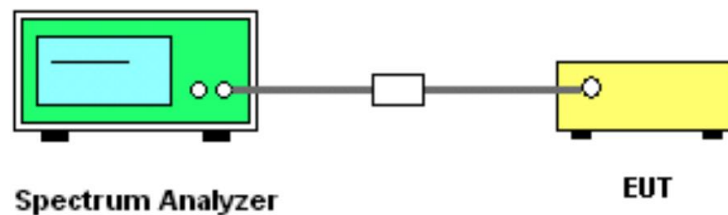


Figure 1: Setup for antenna-port conducted measurements

The RF signal of the EUT is measured conducted at the antenna port. In case of no permanent antenna connector available, a temporary antenna connector should be supplied by the manufacturer. The specific insertion loss of the signal path, which is matched to 50 Ohm, is determined. The test receiver is set to analyzer mode with pre-selector activated. The measurement readings on the test receiver are corrected by the signal path loss.

For frequency hopping systems (FHSS) and digital transmission systems (DTS) the settings as specified by KDB Publication 558074, document D01, are used.

If a radiated test configuration has to be used, conversion to conducted test results is performed according to clause 5.1.2.

5.3 AC powerline conducted emissions

AC power-line conducted emissions are measured according to clause 6.2 of ANSI C63.10 over the frequency range from 150 kHz to 30 MHz to determine the line-to-ground radio-noise voltage that is conducted from all of the EUT current-carrying power input terminals that are directly (or indirectly via separate transformers or power supplies) connected to a public power network. The tests are performed in a shielded room.

If the EUT normally receives power from another device that in turn connects to the public utility ac power lines, measurements are made on that device with the EUT in operation to demonstrate that the device continues to comply with the appropriate limits while providing the EUT with power. If the EUT is operated only from internal or dedicated batteries, with no provisions for connection to the public utility ac power lines (600 VAC or less) to operate the EUT (such as an adapter), then ac power-line conducted measurements are not required.

For direct current (dc) powered devices where the ac power adapter is not supplied with the device, an “off-the-shelf” unmodified ac power adapter is used. If the device is supposed to be installed in a host (e.g., the device is a module or PC card), then it is tested in a typical compliant host.

Frequency (f)	Measurement receiver bandwidth	Step size	Detector type		
			Prescan	Prescan with FFT	Final scan
150 kHz ≤ f < 30 MHz	9 kHz	≤ 4.5 kHz	Peak, Average	Quasi-peak, Average	Quasi-peak, Average

Table 6: Bandwidth and detector type for AC power-line conducted emissions test

The AC power-line conducted emissions test is performed in the following steps:

- The EUT is arranged as tabletop or floor-standing equipment, as applicable, and connected to a line impedance stabilization network (LISN) with 50 μH / 50 Ω. If required, a second LISN of the same type and terminated by 50 Ω is used for peripheral devices. The EUT is switched on.
- The measurement equipment is connected to the LISN for the EUT and set-up according to the specifications of the test (see table 6). At the LISN, the neutral line is selected to be tested.

- c) The prescan is performed with both detectors activated at the same time. If the test receiver is capable of FFT analysis, it is used for prescan, but not for final scan.
- d) When the prescan is completed, maximum levels with less margin than 10 dB or exceeding the limit are determined and collected in a list.
- e) With the first frequency of the list selected, a frequency zoom over a range of ten times of the measurement receiver bandwidth around this frequency is performed. If the EUT has no significant drift in frequency, the frequency zoom can be skipped.
- f) For final scan, the emission level is measured and the maximum is recorded.
- g) Steps e) to f) are repeated for all other frequencies in the list. At least the six highest EUT emissions relative to the limit have to be recorded.
- h) Steps c) to g) are repeated for all current-carrying conductors of all of the power cords of EUT, i.e. all phase and (if used) neutral line(s).

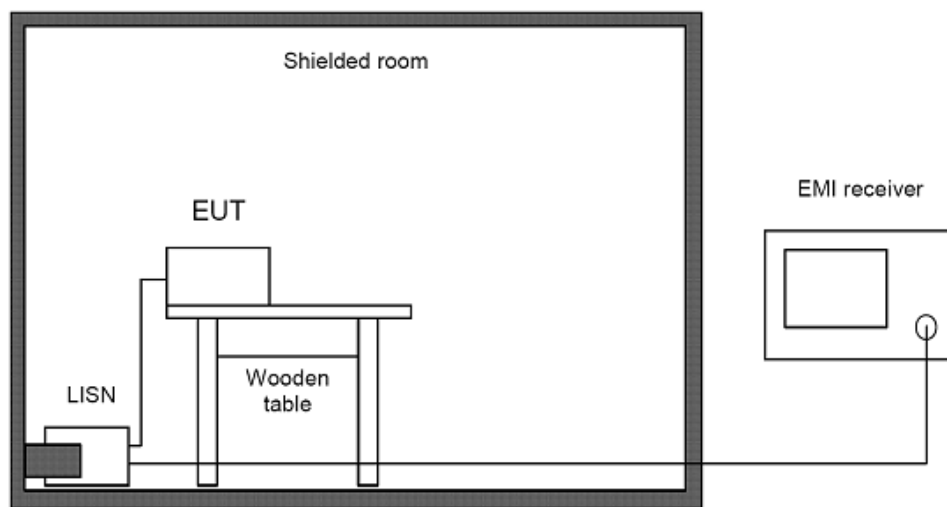


Figure 2: Setup for AC power-line conducted emissions test from 150 kHz to 30 MHz

Phase	Frequency (MHz)	Reading value (dBμV)	AMN correction (dB)	Cable attenuation + 10 dB attenuator (dB)	Correction factor (Corr.) (dB)	Level (dBμV)
L 1	10	10	0.6	10.9	11.5	21.5
N	10	10	1.0	10.9	11.9	21.9

Table 7: Sample calculation

Correction factor = Artificial mains network correction + Cable attenuation + 10 dB

Level = Reading value + Correction factor = 10 dBμV + 11.5 dB = 21.5 dBμV

Prescans are performed with all detectors activated at the same time. If the test receiver is capable of FFT analysis, it is used for prescans, but not for final scans. If no limit is specified for certain detectors, final scan measurement with these detectors may be omitted.

5.4 Radiated emissions below 30 MHz

Radiated emissions below 30 MHz are measured according to clause 6.4 of ANSI C63.10 using an inductive shielded loop antenna. As this antenna measures the magnetic field only, its antenna factors are converted to electric field strength values assuming a free space impedance of 377Ω as described in clause 4.3.1 of ANSI C63.10. This results in an additional correction of 51.53 dB.

According to clause 6.4.3 of ANSI C63.10, at frequencies below 30 MHz, measurements may be performed at a distance closer than that specified in the requirements. In this case, the results are extrapolated to the specified distance by using a recalculation factor determined according to one of the methods described in clause 6.4.4 of ANSI C63.10, provided that the maximum dimension of the device is equal to or less than 0.625 times the wavelength at the frequency being measured. As the minimum wavelength is 10 meters corresponding to the maximum frequency of 30 MHz, this requirement is fulfilled if the maximum dimension of the device is equal to or less than 6.25 meters.

Unless otherwise stated, the recalculation factor is determined according to clause 6.4.4.2 “Extrapolation from the measurement of a single point” of ANSI C63.10:

$$\begin{aligned} d_{\text{near field}} &= 47.77 / f_{\text{MHz}}, \text{ or} \\ f_{\text{MHz}} &= 47.77 / d_{\text{near field}} \end{aligned}$$

The frequency f_{MHz} at which the near field distance is equal to the limit and/or test distance is important for selection of the right formula to determine the recalculation factor:

$$\begin{aligned} f_{\text{MHz}}(300 \text{ m}) &\approx 0.159 \text{ MHz} \\ f_{\text{MHz}}(30 \text{ m}) &\approx 1.592 \text{ MHz} \\ f_{\text{MHz}}(3 \text{ m}) &\approx 15.923 \text{ MHz} \end{aligned}$$

Based on the test distances for the general radiated emission limits as specified in §15.209 of 47 CFR Part 15 or RSS-Gen, the following formulas are used to determine the recalculation factor:

Frequency (f)	d_{limit}	d_{measure}	Formula for recalculation factor
9 kHz $\leq f \leq$ 159 kHz 490 kHz $< f \leq$ 1.592 MHz	300 m 30 m	3 m	$-40 \log(d_{\text{limit}} / d_{\text{measure}})$
159 kHz $< f \leq$ 490 kHz 1.592 MHz $< f \leq$ 15.923 MHz	300 m 30 m	3 m	$-40 \log(d_{\text{near field}} / d_{\text{measure}}) - 20 \log(d_{\text{limit}} / d_{\text{near field}})$
$f > 15.923 \text{ MHz}$	30 m	3 m	$-20 \log(d_{\text{limit}} / d_{\text{measure}})$

Table 8: Recalculation factors for extrapolation

The radiated measurements below 30 MHz are performed in a fully anechoic room (called “CDC”). The measurement distance is 3 meters. The emissions of the EUT are recorded with an EMI test receiver configured as described in table 9.

Frequency (f)	Measurement receiver bandwidth	Step size	Detector type
9 kHz $\leq f <$ 150 kHz	200 Hz	$\leq 100 \text{ Hz}$	Peak Quasi-peak Aerage
150 kHz $\leq f <$ 30 MHz	9 kHz	$\leq 4.5 \text{ kHz}$	Peak Quasi-peak Aerage

Table 9: Bandwidth and detector type for radiated emissions test below 30 MHz

<i>Frequency</i> (MHz)	<i>Reading value</i> (dBμV)	<i>Antenna correction</i> (dB/m)	<i>Cable attenuation</i> (dB)	<i>Correction factor (Corr.)</i> (dB)	<i>Level</i> (dBμV/m)
10	20.00	19.59	0.33	19.92	39.92

Table 10: Sample calculation

Correction factor = Antenna correction + Cable attenuation

Level = Reading value + Correction factor = 20 dBμV + 19.92 dB = 39.92 dBμV/m

Prescans are performed with all detectors activated at the same time. If the test receiver is capable of FFT analysis, it is used for prescans, but not for final scans. If no limit is specified for certain detectors, final scan measurement with these detectors may be omitted.

The radiated emissions test below 30 MHz is performed in the following steps:

5.4.1 Automatic test method

- The loop antenna is positioned with its plane perpendicular to the ground with the lowest height of the antenna 1 m above the ground.
- The EUT is placed in its standard position on a turntable capable of rotation through 360° in the horizontal plane and arranged as tabletop or floor-standing equipment, as applicable. The EUT is switched on.
- The measurement equipment is connected to the loop antenna and set-up according to the specifications of the test (see table 9).
- The EUT is turned to a position likely to get the maximum and the test antenna is rotated to detect the maximum of the fundamental in this EUT position.
- Then the EUT is rotated in a horizontal plane through 360° in steps of 20°. Starting at 0°, at each table position the spectrum for the full frequency range is recorded. If the emission at a certain frequency is higher than the levels already recorded, the current table position is noted as the maximum position.
- After the last prescan, the significant maximum emissions and their table positions are determined and collected in a list.
- With the test receiver set to the first frequency of the list, the EUT is rotated by ±180° around the table position found during prescans while measuring the emission level continuously. For final scan, the worst-case table position is set and the maximum emission level is recorded.
- Step g) is repeated for all other frequencies in the list.

If the EUT may be used in various positions, steps a) to h) are repeated in two other orthogonal positions.

5.4.2 Manual test method

- a) The loop antenna is positioned with its plane perpendicular to the ground with the lowest height of the antenna 1 m above the ground.
- b) The EUT is placed in its standard position on a turntable capable of rotation through 360° in the horizontal plane and arranged as tabletop or floor-standing equipment, as applicable. The EUT is switched on.
- c) The measurement equipment is connected to the loop antenna and set-up according to the specifications of the test (see table 9).
- d) The EUT is turned to a position likely to get the maximum and the test antenna is rotated to detect the maximum of the fundamental in this EUT position.
- e) Then the EUT is rotated in a horizontal plane through 360° continuously. The scan table method in receiver mode of the measurement instrument is used for pre-measurements. The max hold function is used.
- f) After the last prescan, the significant maximum emissions are determined and collected in a list.
- g) Final scan: the test receiver is set in the bargraph max hold function and is set to the first frequency of the list, the EUT is rotated by 360° while measuring the emission level continuously. The worst-case table position and the maximum emission level is recorded.
- h) Step g) is repeated for all other frequencies in the list.

If the EUT may be used in various positions, steps a) to h) are repeated in two other orthogonal positions.

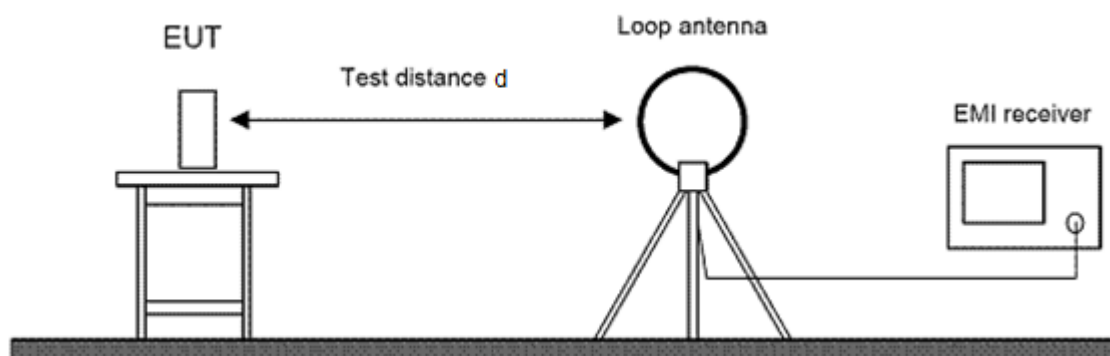


Figure 3: Setup for radiated emissions test below 30 MHz

5.5 Radiated emissions from 30 MHz to 1 GHz

Radiated emissions in the frequency range 30 MHz to 1 GHz are measured according to clause 6.5 of ANSI C63.10 using a semi-anechoic chamber (SAC) with a ground plane on the floor. The measurement distance is 3 meters. The emissions of the EUT are recorded with an EMI test receiver configured as described in table 11.

<i>Frequency (f)</i>	<i>Measurement receiver bandwidth</i>	<i>Step size</i>	<i>Detector type</i>		
			<i>Prescan</i>	<i>Prescan with FFT</i>	<i>Final scan</i>
30 MHz $\leq f \leq$ 1 GHz	120 kHz	$\leq$ 60 kHz	Peak	Quasi-peak	Quasi-peak

Table 11: Bandwidth and detector type for radiated emissions test from 30 MHz to 1 GHz

<i>Frequency (MHz)</i>	<i>Reading value (dBμV)</i>	<i>Antenna correction (dB/m)</i>	<i>Cable attenuation (dB)</i>	<i>Correction factor (Corr.) (dB)</i>	<i>Level (dBμV/m)</i>
100	30.00	11.71	1.06	12.77	42.77

Table 12: Sample calculation

Correction factor = Antenna correction + Cable attenuation

Level = Reading value + Correction factor = 30 dB μ V + 12.77 dB = 42.77 dB μ V/m

The measurement antenna is a combination of a biconical antenna and a logarithmic-periodic dipole array antenna. It is mounted on a support capable of allowing the antenna to be used in either horizontal or vertical polarization and in a height between 1 m and 4 m above the ground plane.

If the test receiver is capable of FFT analysis, it is used for prescans, but not for final scans.

The radiated emissions test from 30 MHz to 1 GHz is performed in the following steps:

5.5.1 Automatic test method

- a) The measurement antenna is oriented initially for vertical polarization.
- b) The EUT is placed in its standard position on a turntable capable of rotation through 360° in the horizontal plane and arranged as tabletop or floor-standing equipment, as applicable. The EUT is switched on.
- c) The measurement equipment is connected to the measurement antenna and set-up according to the specifications of the test (see table 11).
- d) The table position is set to 0°.
- e) The antenna height is set to 1 m.
- f) The spectrum for the full frequency range is recorded. If the emission at a certain frequency is higher than the levels already recorded, the polarization and height of the measurement antenna as well as the current table position are noted as the maximum position.
- g) The antenna height is increased to 4 m in steps of 50 cm. At each height, step f) is repeated.
- h) The polarization of the measurement antenna is changed to horizontal.
- i) The antenna height is decreased from 4 m to 1 m in steps of 50 cm. At each height, step f) is repeated.
- j) The EUT is rotated in a horizontal plane through 360° in steps of 20°. At each table position, steps e) to i) are repeated.
- k) After the last prescan, the significant maximum emissions with their polarizations and heights of the measurement antenna as well as their table positions are determined and collected in a list.
- l) With the test receiver set to the first frequency of the list, the measurement antenna is set to the polarization and height and the table is moved to the position as determined during prescans.
- m) The antenna is moved at a height from 1 m to 4 m and the EUT is rotated through 360° while measuring the emission level continuously.
- n) For final scan, the worst-case positions of antenna and table are set and the maximum emission level is recorded. At least, frequency and level of the six highest emissions relative to the limit have to be recorded. However, emissions more than 20 dB below the limit do not need to be reported.
- o) Steps l) to n) are repeated for all other frequencies in the list.

If the EUT may be used in various positions, steps a) to o) are repeated in two other orthogonal positions.

5.5.2 Manual test method

- a) The measurement antenna is oriented initially for vertical polarization.
- b) The EUT is placed in its standard position on a turntable capable of rotation through 360° in the horizontal plane and arranged as tabletop or floor-standing equipment, as applicable. The EUT is switched on.
- c) The measurement equipment is connected to the measurement antenna and set-up according to the specifications of the test (see table 11).
- d) The table position is set to 0°.
- e) The antenna height is set to 1 m.
- f) The spectrum for the full frequency range is recorded. The measurement is performed with peak detector and max hold.
- g) The antenna height is increased to 4 m in steps of 50 cm. At each height, step f) is repeated or the measurement is stopped after all heights were measured.
- h) The polarization of the measurement antenna is changed to horizontal.
- i) The antenna height is decreased from 4 m to 1 m in steps of 50 cm. At each height, step f) is repeated.
- j) The EUT is rotated in a horizontal plane through 360° continuously. At each table position, steps e) to i) are repeated.
- k) After the last prescan, the significant maximum emissions with their polarizations and heights of the measurement antenna are determined and collected in a list.
- l) Final scan: the test receiver is set in the bargraph max hold function and is set to the first frequency of the list, the EUT is rotated by 360° and the antenna is moved from 1 m to 4 m while measuring the emission level continuously. The worst-case table position and the maximum emission level is recorded.
- m) Step l) is repeated for all other frequencies in the list. At least, frequency and level of the six highest emissions relative to the limit have to be recorded. However, emissions more than 20 dB below the limit do not need to be reported.

If the EUT may be used in various positions, steps a) to o) are repeated in two other orthogonal positions.

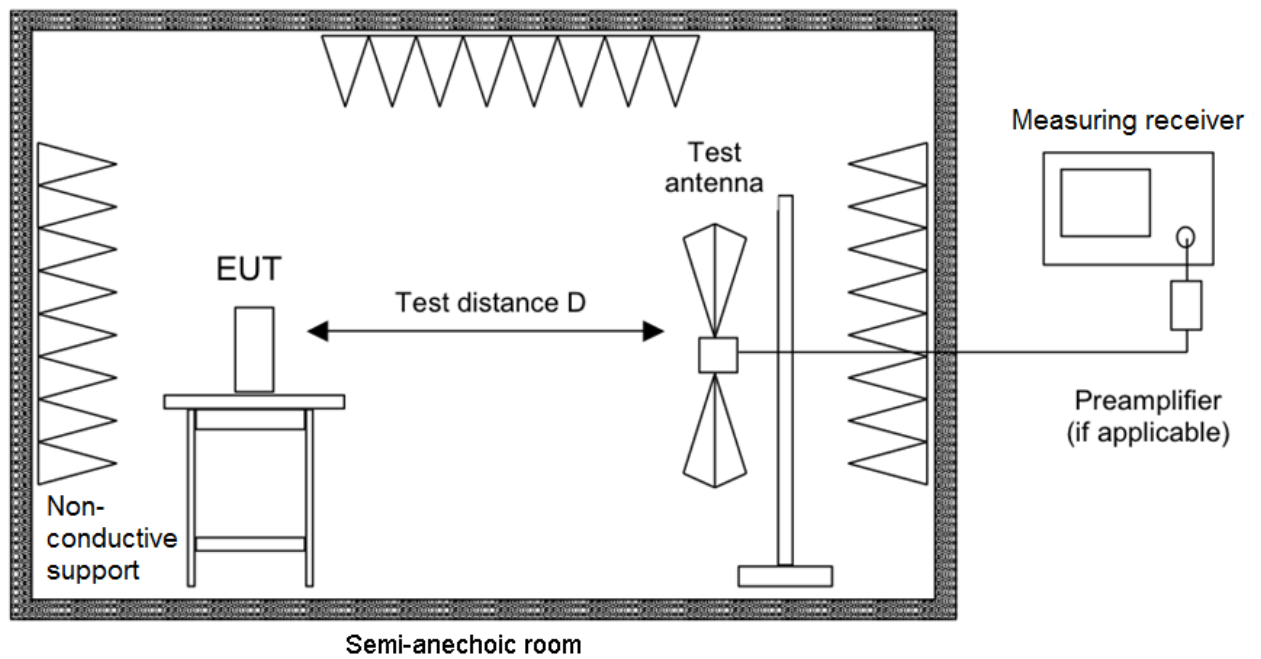


Figure 4: Setup for radiated emissions test from 30 MHz to 1 GHz

5.6 Radiated emissions above 1 GHz

Radiated emissions above 1 GHz are measured according to clause 6.6 of ANSI C63.10 by conducting exploratory and final radiated emission tests. According to clause 6.6.4.1 of ANSI C63.10, measurements may be performed at a distance closer than that specified in the requirements. However, an attempt shall be made to avoid making final measurements in the near field of both the measurement antenna and the EUT.

For measurement of radiated emissions above 1 GHz, horn antennas are used.

Test chamber	Frequency (MHz)	Reading value (dBμV)	Antenna correction (dB/m)	Correction pre-amplifier (dB)	Cable attenuation (dB)	Correction factor (Corr.) (dB)	Level (dBμV/m)
SAC3	2400	50.00	27.76	-47.91	5.24	-14.92	35.08
FS-SAC	2400	50.00	27.76	-34.57	3.51	-3.30	46.70

Table 13: Sample calculation

Correction factor = Antenna correction + Correction pre-amplifier + Cable attenuation

SAC3:

Level = Reading value + Correction factor = 50.00 dBμV - 14.92 dB/m = 35.08 dBμV/m

FS-SAC:

Level = Reading value + Correction factor = 50.00 dBμV - 3.30 dB/m = 46.70 dBμV/m

5.6.1 Exploratory radiated emissions measurements

Exploratory radiated emissions above 1 GHz are measured in a semi-anechoic chamber with RF absorbing material on the floor or a fully anechoic room. They are performed by moving the receiving antenna over all sides of the EUT at a closer distance (e.g. 0.5 or 1 m) while observing the display of the test receiver to find the emissions to be re-tested during final radiated emission measurements.

According to clause 5.3.3 of ANSI C63.10, when performing measurements at a distance other than that specified, the results shall be extrapolated to the specified distance using an extrapolation factor of 20 dB/decade of distance (inverse of linear distance for field-strength measurements). To simplify testing and documentation, the limits are increased accordingly instead of decreasing the results.

The emissions of the EUT are displayed and recorded with an EMI test receiver operating in the spectrum analyzer mode using the settings as described in table 14.

Frequency (f)	Resolution bandwidth	Video bandwidth	Sweep time	Trace detector(s)
$f \geq 1 \text{ GHz}$	1 MHz	3 MHz	AUTO	Max Peak, Average

Table 14: Bandwidth and trace settings for exploratory radiated emissions test above 1 GHz

If during exploratory radiated emissions measurements no levels to be re-tested are found, the final radiated emissions measurement may be omitted. In this case, the chart of the exploratory radiated emissions measurements has to be reported.

5.6.2 Final radiated emissions measurements

Final radiated emissions above 1 GHz are measured in the semi-anechoic chamber (SAC3) or Free space semi-anechoic chamber (FS-SAC) with RF absorbing material on the floor between measurement antenna and EUT. The measurement distance is 3 meters in the semi-anechoic chamber (SAC3) or 1.5 m in the Free space semi-anechoic chamber (FS-SAC). The emissions of the EUT are recorded with an EMI test receiver configured as described in table 15.

Frequency (f)	Measurement receiver bandwidth	Step size	Detector type	
			Prescan	Final scan
$f \geq 1 \text{ GHz}$	1 MHz	$\leq 500 \text{ kHz}$	Peak, Average	Peak, Average

Table 15: Bandwidth and detector type for final radiated emissions test above 1 GHz

Prescans are performed with both detectors activated at the same time. If the test receiver is capable of FFT analysis, it is used for prescans, but not for final scans.

The horn antenna is mounted on a support capable of allowing the antenna to be used in either horizontal or vertical polarization and to be moved in a scan height range between 1 m and the scan height upper range defined in clause 6.6.3.3 of ANSI C63.10. When the EUT is manipulated through three different orientations, the scan height upper range for the measurement antenna is limited to 2.5 m above the ground plane or 0.5 m above the top of the EUT, whichever is higher. Otherwise, the scan height upper range is 4 m above the ground plane.

To keep the emission signal within the illumination area of the 3 dB beamwidth of the measurement antenna, the automatic tilt function of the antenna support device is used to point the antenna at an angle toward the source of the emission.

The final radiated emissions test above 1 GHz is performed in the following steps:

5.6.2.1 Automatic measurement method

- The measurement antenna is oriented initially for vertical polarization.
- The EUT is placed in its standard position on a turntable capable of rotation through 360° in the horizontal plane and arranged as tabletop or floor-standing equipment, as applicable. The EUT is switched on.
- The measurement equipment is connected to the measurement antenna and set-up according to the specifications of the test (see table 15).
- The table position is set to 0°.
- The antenna height is set to 1 m.
- The spectrum for the full frequency range is recorded. If the emission at a certain frequency is higher than the levels already recorded, the polarization and height of the measurement antenna as well as the current table position are noted as the maximum position.
- The antenna height is increased to the scan height upper range in steps of 50 cm. At each height, step f) is repeated.
- The polarization of the measurement antenna is changed to horizontal.
- The antenna height is decreased from the scan height upper range to 1 m in steps of 50 cm. At each height, step f) is repeated.
- The EUT is rotated in a horizontal plane through 360° in steps of 20°. At each table position, steps e) to i) are repeated.
- After the last prescan, the significant maximum emissions with their polarizations and heights of the measurement antenna as well as their table positions are determined and collected in a list.
- With the test receiver set to the first frequency of the list, the measurement antenna is set to the polarization and height and the table is moved to the position as determined during prescans.
- The antenna is moved from 1 m to 4 m around this height and the EUT is rotated through 360° around while measuring the emission level continuously.
- The worst-case positions of antenna and table and the maximum emission level are recorded.

- o) Steps l) to n) are repeated for all other frequencies in the list. At least, frequency and level of the six highest emissions relative to the limit have to be recorded. However, emissions more than 20 dB below the limit do not need to be reported.

If the EUT may be used in various positions, steps a) to o) are repeated in two other orthogonal positions.

5.6.2.2 Manual measurement method

- a) The measurement antenna is oriented initially for vertical polarization.
- b) The EUT is placed in its standard position on a turntable capable of rotation through 360° in the horizontal plane and arranged as tabletop or floor-standing equipment, as applicable. The EUT is switched on.
- c) The measurement equipment is connected to the measurement antenna and set-up according to the specifications of the test (see table 15).
- d) The table position is set to 0°.
- e) The antenna height is set to 1 m.
- f) The EUT is rotated in a horizontal plane through 360° The spectrum for the full frequency range is recorded using the peak detector.
- g) The antenna height is increased to the scan height upper range in steps of 50 cm. At each height, step f) is repeated.
- h) The polarization of the measurement antenna is changed to horizontal.
- i) The antenna height is decreased from the scan height upper range to 1 m in steps of 50 cm. At each height, step f) is repeated.
- j) After the last prescan, the significant maximum emissions with their polarizations are determined and collected in a list.
- k) For the final scan the test receiver is set to the first frequency of the list. By using the bargraph max hold function of the measurement receiver the emission in consideration is maximised by rotating the EUT in the horizontal plane through 360° and moving the antenna from 1 m to 4 m (2.5 m).
- l) The worst-case positions of antenna and table and the maximum emission level are recorded.
- m) Steps l) to n) are repeated for all other frequencies in the list. At least, frequency and level of the six highest emissions relative to the limit have to be recorded. However, emissions more than 20 dB below the limit do not need to be reported.

If the EUT may be used in various positions, steps a) to o) are repeated in two other orthogonal positions.

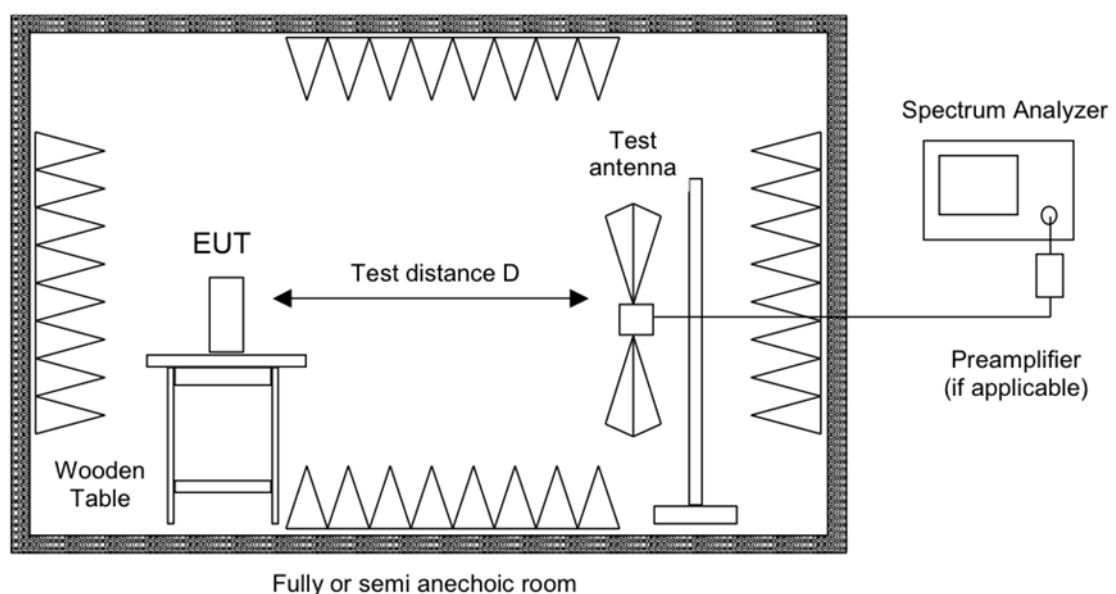


Figure 5: Setup for radiated emissions test above 1 GHz

5.7 Bandwidth measurements

In case of antenna-port conducted tests as described in clause 5.2 cannot be performed, according to section 3.0 of KDB 558074 D01, results of radiated tests are used for demonstrating compliance to the conducted emission requirements. For details about conversion see clause 5.1.2

5.7.1 6 dB bandwidth (DTS bandwidth)

The 6 dB bandwidth or DTS bandwidth is measured according to clause 8.0 of KDB Publication 558074, document D01, using the following settings:

- a) Resolution bandwidth RBW = 100 kHz
- b) Video bandwidth (VBW) $\geq 3 \times$ RBW
- c) Detector = Peak
- d) Trace mode = max hold
- e) Sweep = auto couple

After the trace is stabilized, the maximum width of the emission that is constrained by the frequencies associated with the two outermost amplitude points (upper and lower frequencies) that are attenuated by 6 dB relative to the maximum level measured in the fundamental emission.

If using the automatic bandwidth measurement capability of the test instrument (6 dB down function), care shall be taken so that the bandwidth measurement is not influenced by any intermediate power nulls in the fundamental emission that might be ≥ 6 dB. In addition, it has to be checked that this function delivers the two outermost amplitude points.

5.7.2 99 % occupied bandwidth

According to section 6.7 of RSS-Gen, the occupied bandwidth (OBW) is defined as the 99 % emission bandwidth.

The span of the spectrum analyzer is set large enough to capture all products of the modulation process, including the emission skirts, around the carrier frequency, but small enough to avoid having other emissions (e.g. on adjacent channels) within the span.

The resolution bandwidth is in the range of 1 % to 5 % of the occupied bandwidth and the video bandwidth is not smaller than three times the resolution bandwidth. Video averaging is not permitted.

If possible, the detector of the spectrum analyzer is set to "Sample". However, if the device is not transmitting continuously, a peak, or peak hold is used in place of the sampling detector since this usually produces a wider bandwidth than the actual bandwidth (worst-case measurement).

To measure the 99 % emission bandwidth, the OBW function of the test receiver is used with the power bandwidth set to 99 %. This function indicates the lowest frequency (starting from the left side of the span) and the highest frequency (starting from the right side of the span) where 0.5% of the total sum is reached. The difference between the two frequencies is the 99 % occupied bandwidth.

5.8 Maximum peak conducted output power

In case of antenna-port conducted tests as described in clause 5.2 cannot be performed, according to section 3.0 of KDB 558074 D01, results of radiated tests are used for demonstrating compliance to the conducted emission requirements. For details about conversion see clause 5.1.2

The maximum conducted output power test method for digital transmission systems (DTS) refers to section 8.3.1.1 of KDB Publication 558074, document D01.

The spectrum analyzer settings are as follows:

- a) Span $\geq 3 \times \text{RBW}$, centered on a channel
- b) RBW $\geq$ DTS bandwidth
- c) VBW $\geq 3 \times \text{RBW}$
- d) Sweep time = auto coupled
- e) Detector function = peak
- f) Trace mode = max hold
- g) Reference level = more than $10 \cdot \log(\text{OBW}/\text{RBW})$ dB above peak of spectral envelope

After the trace is stabilized, the marker-to-peak function is used to set the marker to the peak of the emission. The indicated level is the maximum peak conducted output power.

5.9 Power spectral density

The power spectral density test method for DTS systems refers to section 8.4 of KDB Publication 558074, document D01.

The spectrum analyzer settings are as follows:

- a) Span = 1.5 times the DTS bandwidth, centered on a channel
- b) RBW: $3 \text{ kHz} \leq \text{RBW} \leq 100 \text{ kHz}$
- c) VBW $\geq 3 \times \text{RBW}$
- d) Sweep time = auto coupled or $\geq \text{span}/\text{RBW}$ in seconds, whichever is greater
- e) Detector function = peak
- f) Trace mode = max hold
- g) Reference level = more than $10 \cdot \log(\text{OBW}/\text{RBW})$ dB above peak of spectral envelope

After the trace is stabilized, the marker-to-peak function is used to set the marker to the peak of the emission. The indicated level is the power spectral density.

In case of antenna-port conducted tests as described in clause 5.2 cannot be performed, according to section 3.0 of KDB 558074 D01, results of radiated tests are used for demonstrating compliance to the conducted emission requirements. For details about conversion see clause 5.1.2

6 Test results

This clause gives details about the test results as collected in the summary of test results on page 7.

For information about measurement uncertainties see page 111.

The climatic conditions are recorded during the tests. It is ensured that the climatic conditions are within the following ranges:

<i>Ambient temperature</i>	<i>Ambient humidity</i>	<i>Ambient pressure</i>
15°C to 35°C	30 % to 75 %	86 kPa to 106 kPa

Note(s):

1. All tests were performed at 120 V and 60 Hz.

6.1 AC powerline conducted emissions

Section(s) in 47 CFR Part 15:	Requirement(s):	15.207(a)
	Reference(s)	ANSI C63.10, clause 6.2
Section(s) in RSS:	Requirement(s):	RSS-Gen, section 8.8
	Reference(s):	ANSI C63.10, clause 6.2

Performed by:	Jennifer Riedel B. Eng.	Date(s) of test:	February 13, 2023
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Result:	☒ Test passed	☐ Test not passed
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6.1.1 Test equipment

Type	Designation	Manufacturer	Inventory no.
Shielded room	P92007	Siemens Matsushita	E00107
EMI test receiver	ESR 7	Rohde & Schwarz	E01549
Artificial mains network	ESH2-Z5	Rohde & Schwarz	E00004
Attenuator (10 dB)	50FHB-010-10	JFW Industries	E00471
Cable set shielded room	RG 223/U RG 223/U	AME HF-Technik AME HF-Technik	E00741 E00804
Test software	EMC32-(M)EB, V10.60.20	Rohde & Schwarz	E00777, E00778 or E01073

6.1.2 Limits

According to §15.207(a):

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 μ H / 50 ohms 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.

According to §15.207(c):

Measurements to demonstrate compliance with the conducted limits are not required for devices which only employ battery power for operation and which do not operate from the AC power lines or contain provisions for operation while connected to the AC power lines. Devices that include, or make provisions for, the use of battery chargers which permit operating while charging, AC adapters or battery eliminators or that connect to the AC power lines indirectly, obtaining their power through another device which is connected to the AC power lines, shall be tested to demonstrate compliance with the conducted limits.

According to RSS-Gen, section 8.8:

Unless stated otherwise in the applicable RSS, for radio apparatus that are designed to be connected to the public utility AC power network, the radio frequency voltage that is conducted back onto the AC power line on any frequency or frequencies within the range 150 kHz to 30 MHz shall not exceed the limits in of the following table, as measured using a 50 μ H / 50 Ω line impedance stabilization network. This requirement applies for the radio frequency voltage measured between each power line and the ground terminal of each AC power-line mains cable of the EUT.

For an EUT that connects to the AC power lines indirectly, through another device, the requirement for compliance with the limits in the following table shall apply at the terminals of the AC power-line mains cable of a representative support device, while it provides power to the EUT. The lower limit applies at the boundary between the frequency ranges. The device used to power the EUT shall be representative of typical applications.

Frequency of emission (MHz)	Conducted limit (dB μ V)	
	Quasi-peak	Average
0.15-0.5	66 to 56*	56 to 46*
0.5-5	56	46
5-30	60	50

Table 16: Limits for AC powerline conducted emissions according to 15.207(a) and RSS-Gen, section 8.8

*Decreases with the logarithm of the frequency

6.1.3 Test procedure

The AC powerline conducted emissions are measured using the test procedure as described in clause 5.3.

6.1.4 Test results

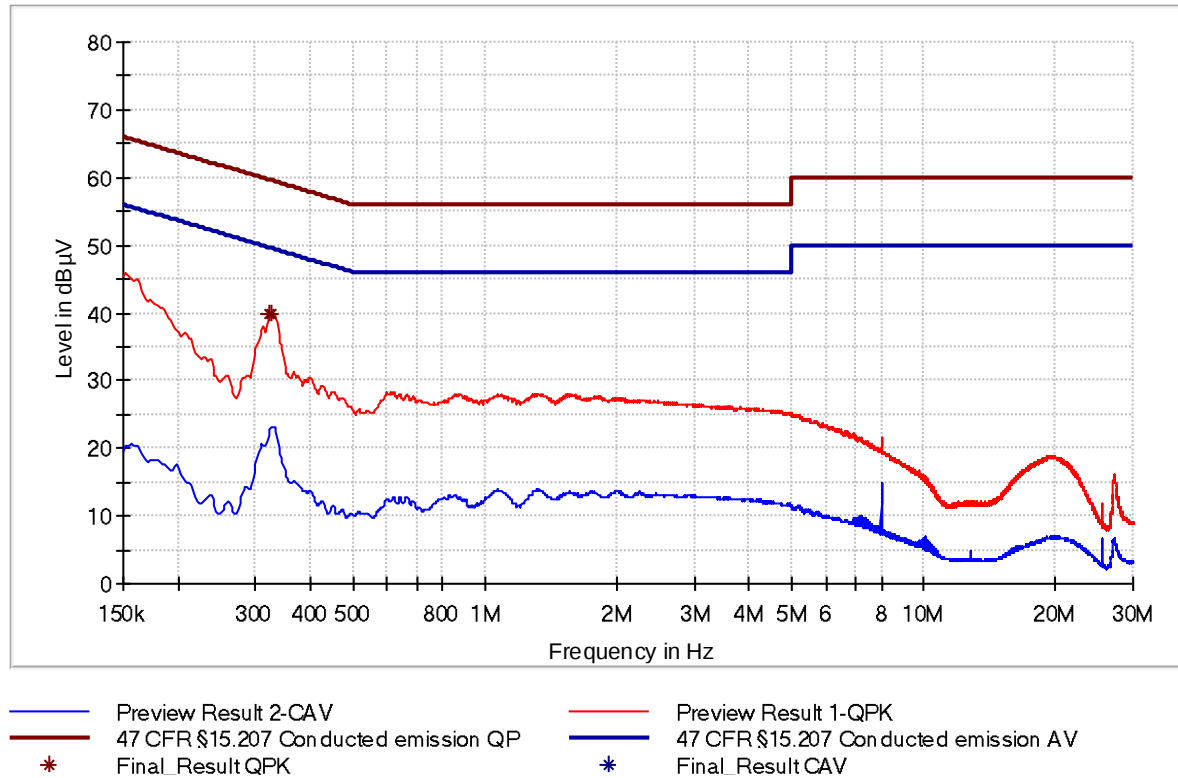


Figure 6: Chart of AC powerline conducted emissions on L1

Frequency (MHz)	QuasiPeak (dBμV)	Average (dBμV)	Limit (dBμV)	Margin (dB)	Meas. Time (ms)	Bandwidth (kHz)	Line	PE	Corr. (dB)
0.323250	39.87	---	59.62	19.75	1000.0	9.000	L1	GND	10.1
0.325500	39.93	---	59.57	19.64	1000.0	9.000	L1	GND	10.1

Table 17: Results of AC powerline conducted emissions on L1

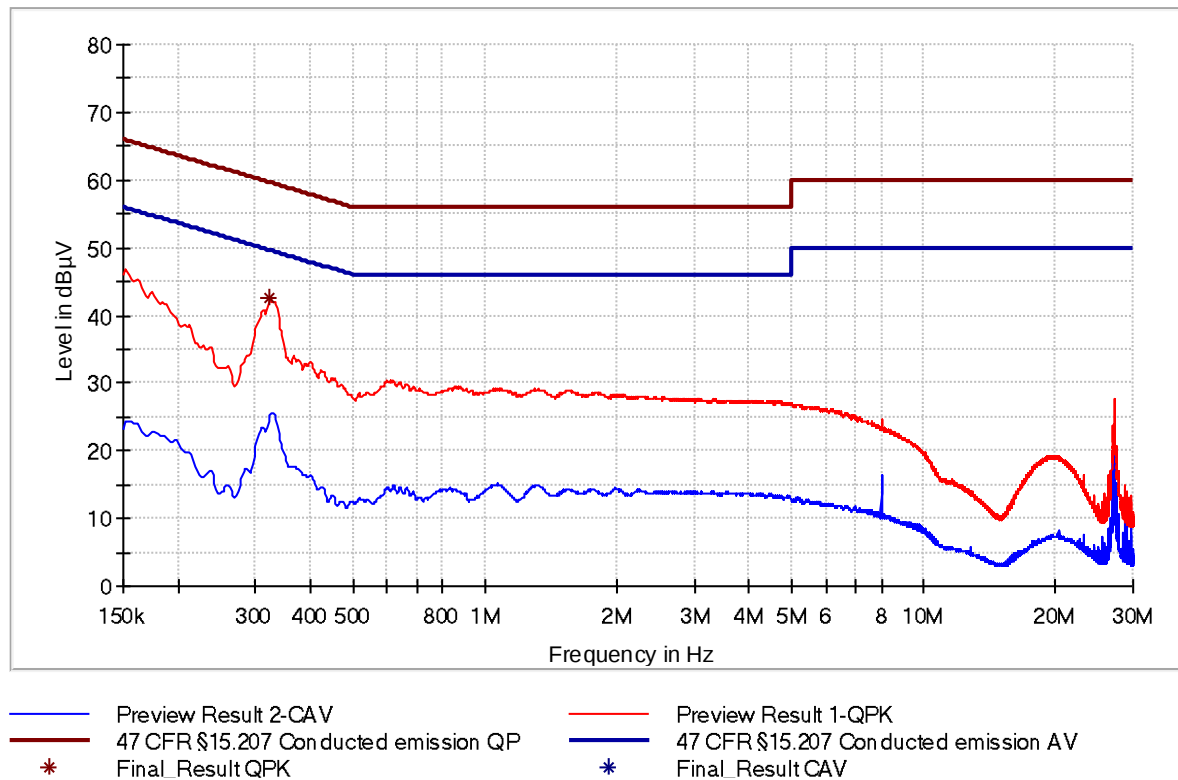


Figure 7: Chart of AC powerline conducted emissions on N

Frequency (MHz)	QuasiPeak (dBμV)	Average (dBμV)	Limit (dBμV)	Margin (dB)	Meas. Time (ms)	Bandwidth (kHz)	Line	PE	Corr. (dB)
0.323250	42.50	---	59.62	17.12	1000.0	9.000	N	GND	10.1

Table 18: Results of AC powerline conducted emissions on N

6.2 6 dB bandwidth

Section(s) in 47 CFR Part 15:	Requirement(s): Reference(s):	15.247(a)(2) KDB558074 D01, clause 8.2 ANSI C63.10, clause 11.8
Section(s) in RSS:	Requirement(s): Reference(s):	RSS-247, section 5.2(a) KDB558074 D01, clause 8.2 ANSI C63.10, clause 11.8

Performed by:	Jennifer Riedel B. Eng.	Date(s) of test:	January 9, 2023
Result:	☒ Test passed	☐ Test not passed	

6.2.1 Test equipment

Type	Designation	Manufacturer	Inventory no.
EMI test receiver	ESU 26	Rohde & Schwarz	W00002

6.2.2 Limits

According to §15.247(a)(2) and RSS-247 section 5.2(a):
Systems using digital modulation techniques (DTS) may operate in the 2400-2483.5 MHz band. The minimum 6 dB bandwidth shall be at least 500 kHz.

6.2.3 Test procedure

The 6 dB bandwidth is measured using the test procedure as described in clause 5.7.1 and referring to the

- ☒ test method for conducted measurements as described in clause 5.2.
- ☐ test method for radiated measurements as described in clause 5.6.

6.2.4 Test results

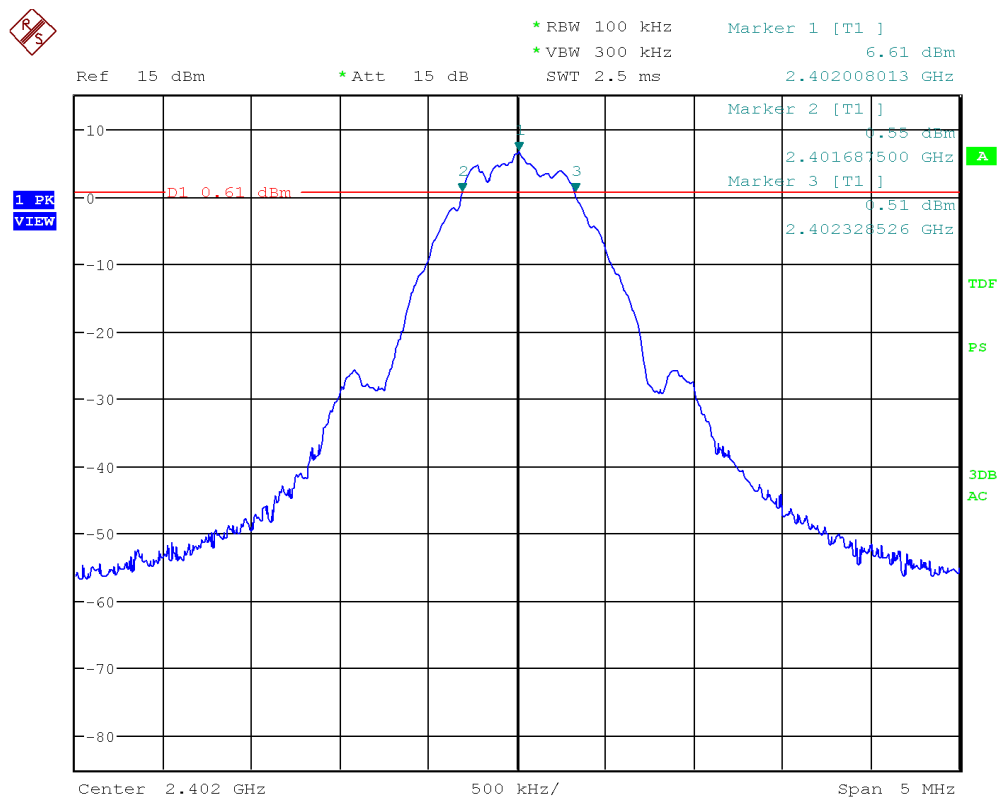


Figure 8: Chart of 6 dB bandwidth test on lowest channel, 125 kbps

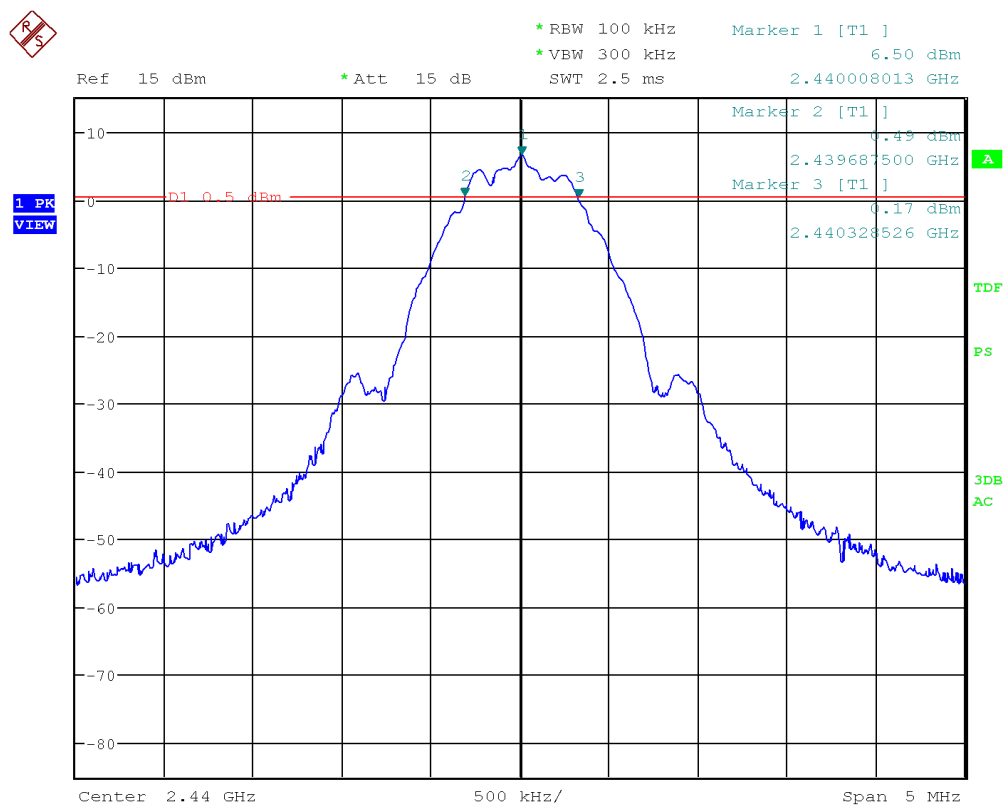


Figure 9: Chart of 6 dB bandwidth test on middle channel, 125 kbps

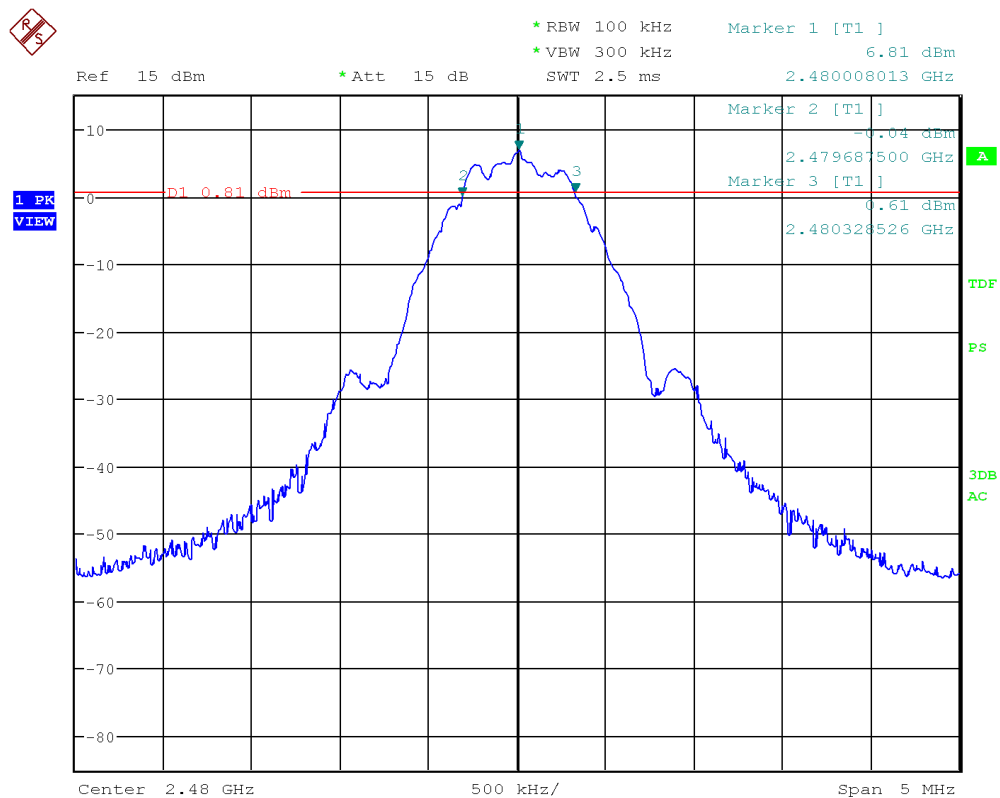


Figure 10: Chart of 6 dB bandwidth test on highest channel, 125 kbps

Channel	6 dB bandwidth (kHz)	Bandwidth limit (kHz)	Lower frequency of bandwidth (MHz)	Lower frequency of designated band (MHz)	Upper frequency of bandwidth (MHz)	Upper frequency of designated band (MHz)	Result
low	641.026	≥ 500	2401.688	2400.000	2402.329	2483.500	Passed
middle	641.026	≥ 500	2439.688	2400.000	2440.329	2483.500	Passed
high	641.026	≥ 500	2479.688	2400.000	2480.329	2483.500	Passed

Table 19: Results of 6 dB bandwidth test, 125 kbps

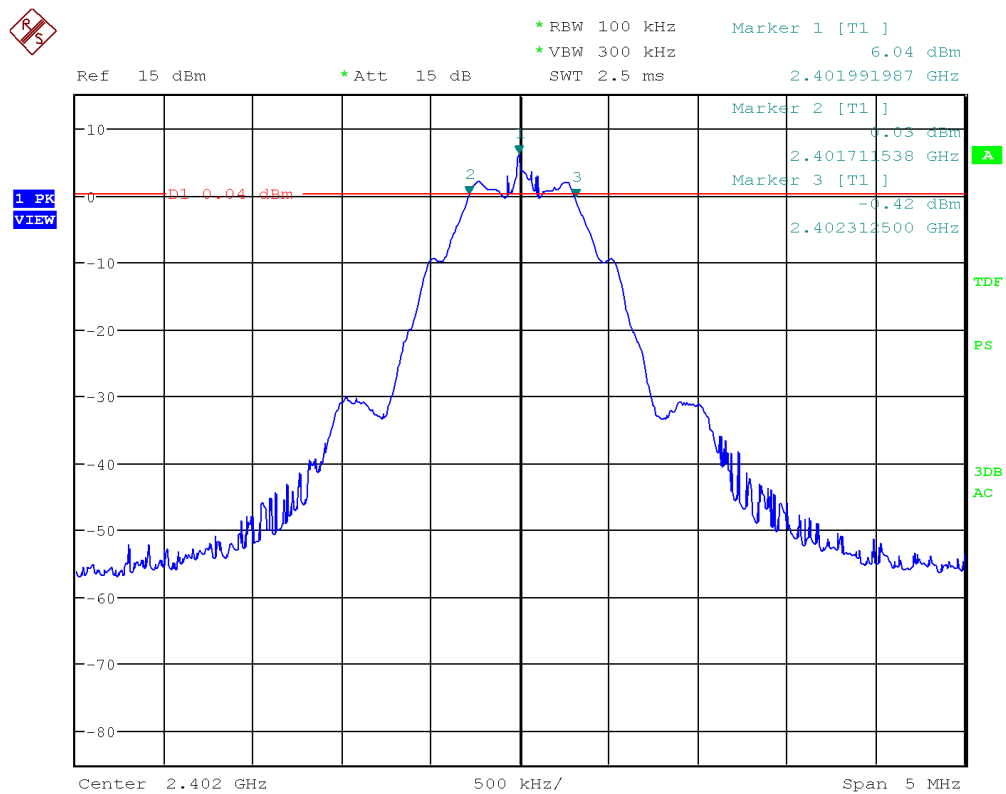


Figure 11: Chart of 6 dB bandwidth test on lowest channel, 500 kbps

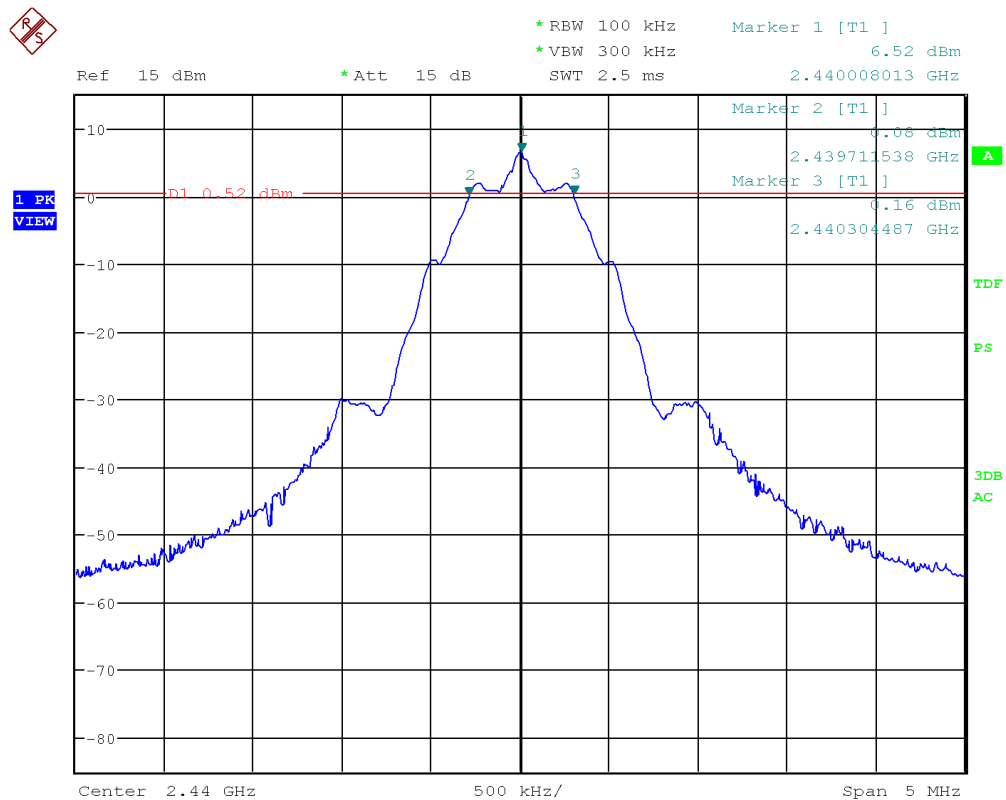


Figure 12: Chart of 6 dB bandwidth test on middle channel, 500 kbps

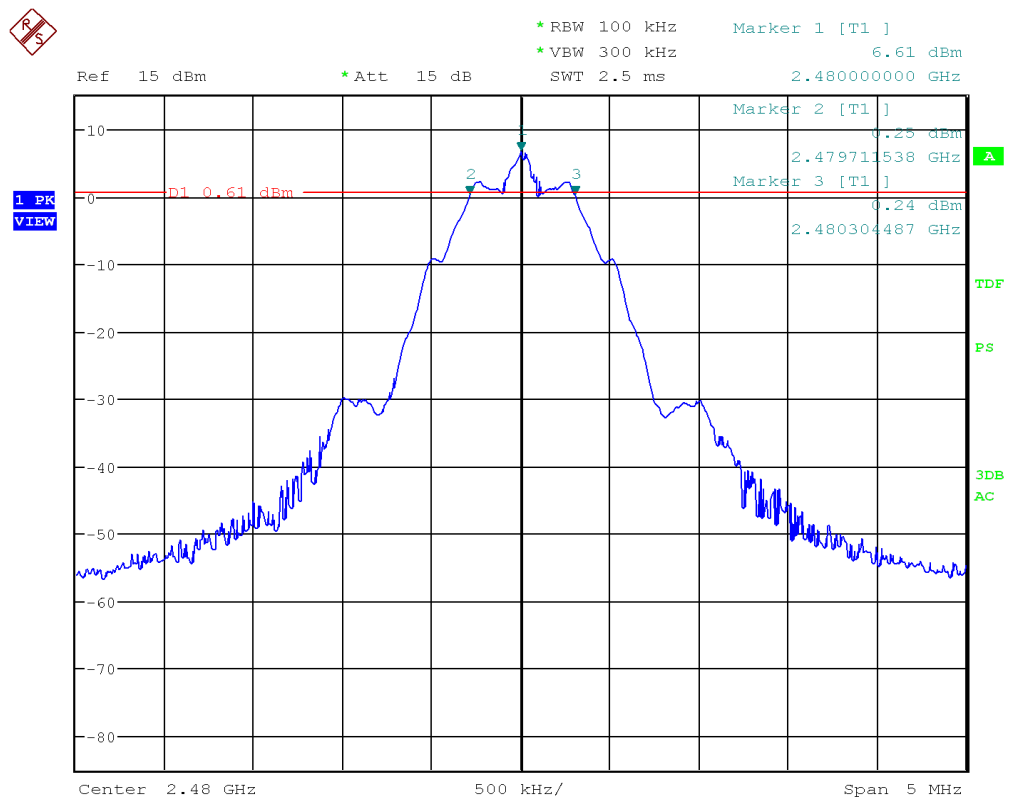


Figure 13: Chart of 6 dB bandwidth test on highest channel, 500 kbps

Channel	6 dB bandwidth (kHz)	Bandwidth limit (kHz)	Lower frequency of bandwidth (MHz)	Lower frequency of designated band (MHz)	Upper frequency of bandwidth (MHz)	Upper frequency of designated band (MHz)	Result
low	601.962	≥ 500	2401.712	2400.000	2402.313	2483.500	Passed
middle	592.949	≥ 500	2439.712	2400.000	2440.304	2483.500	Passed
high	592.949	≥ 500	2479.712	2400.000	2480.304	2483.500	Passed

Table 20: Results of 6 dB bandwidth test, 500 kbps

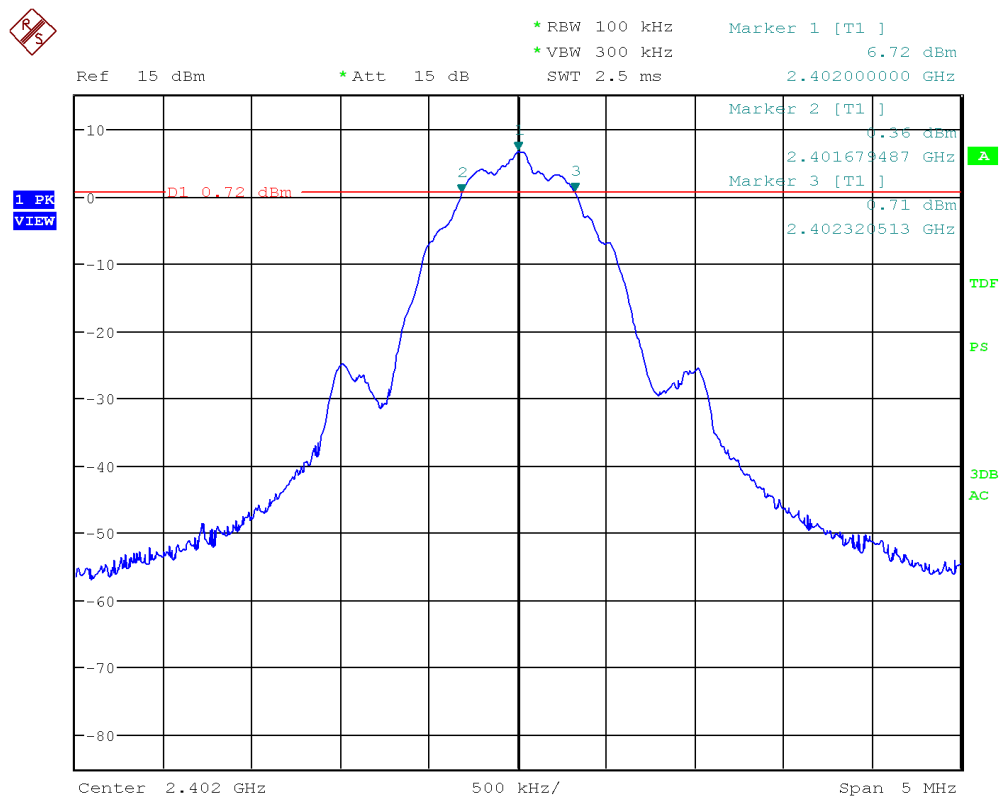


Figure 14: Chart of 6 dB bandwidth test on lowest channel, 1 Mbps

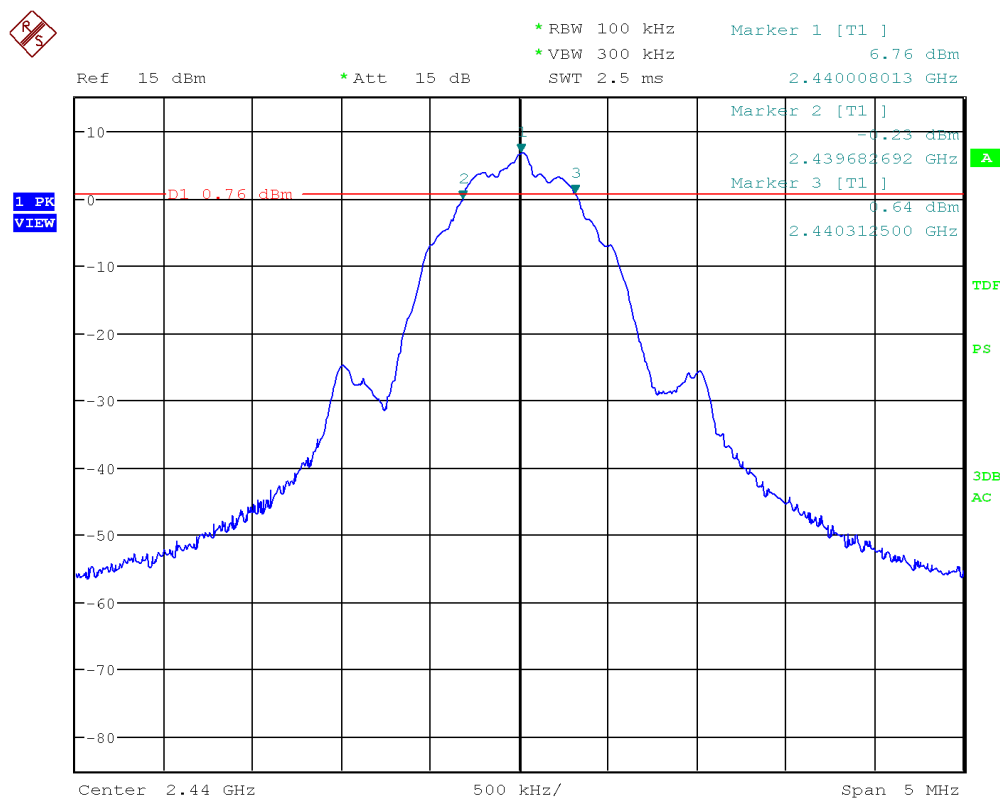


Figure 15: Chart of 6 dB bandwidth test on middle channel, 1 Mbps

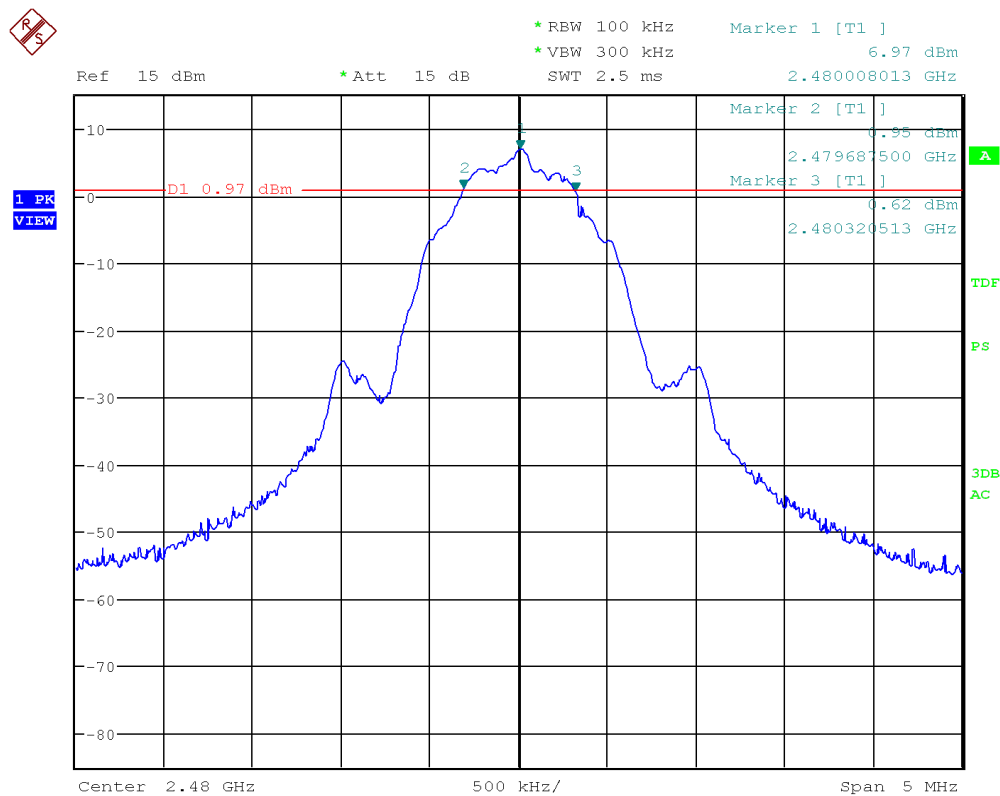


Figure 16: Chart of 6 dB bandwidth test on highest channel, 1 Mbps

Channel	6 dB bandwidth (kHz)	Bandwidth limit (kHz)	Lower frequency of bandwidth (MHz)	Lower frequency of designated band (MHz)	Upper frequency of bandwidth (MHz)	Upper frequency of designated band (MHz)	Result
low	641.026	≥ 500	2401.679	2400.000	2402.321	2483.500	Passed
middle	629.808	≥ 500	2439.683	2400.000	2440.313	2483.500	Passed
high	633.013	≥ 500	2479.688	2400.000	2480.321	2483.500	Passed

Table 21: Results of 6 dB bandwidth test, 1 Mbps

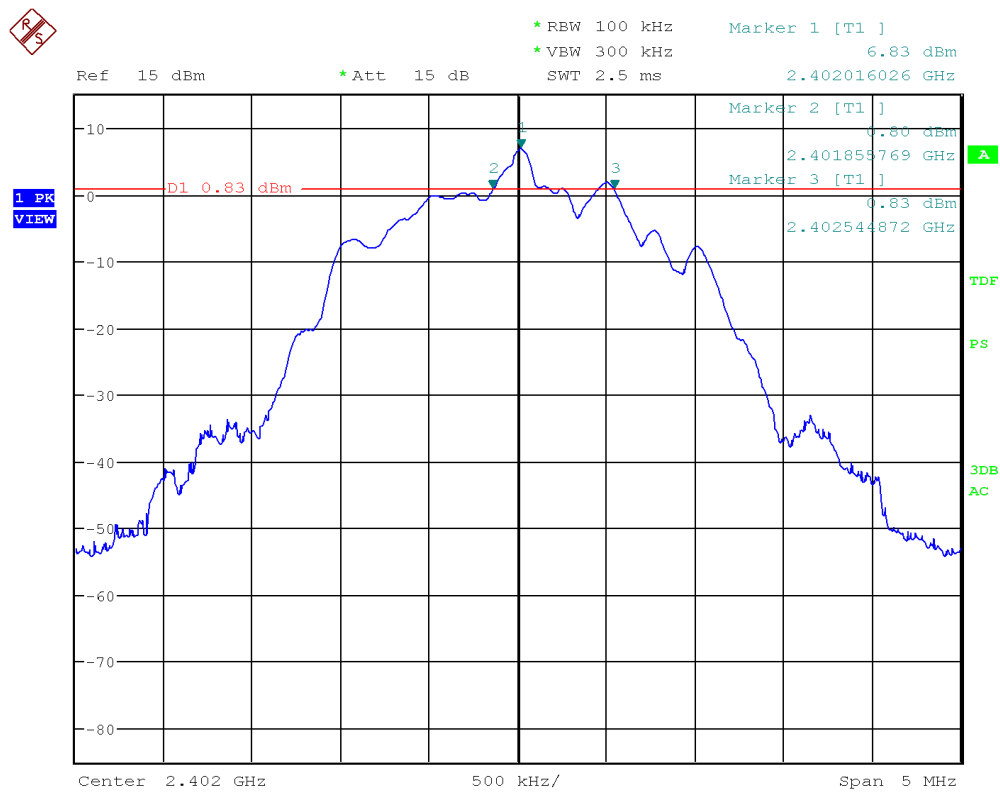


Figure 17: Chart of 6 dB bandwidth test on lowest channel, 2 Mbps

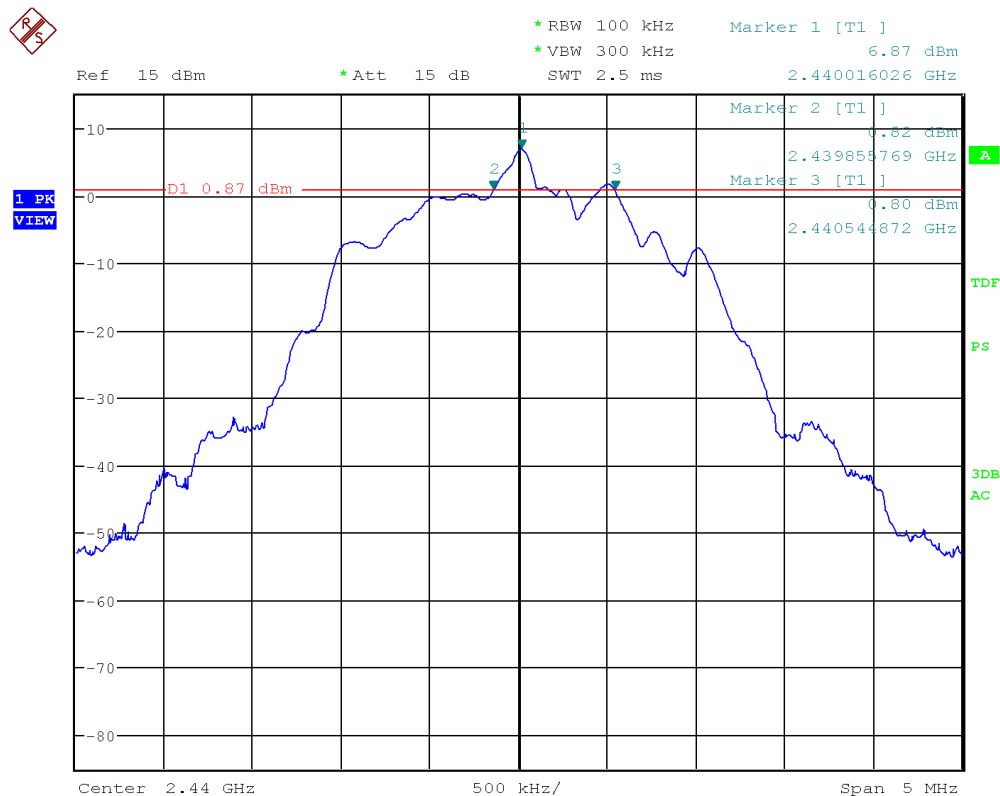


Figure 18: Chart of 6 dB bandwidth test on middle channel, 2 Mbps

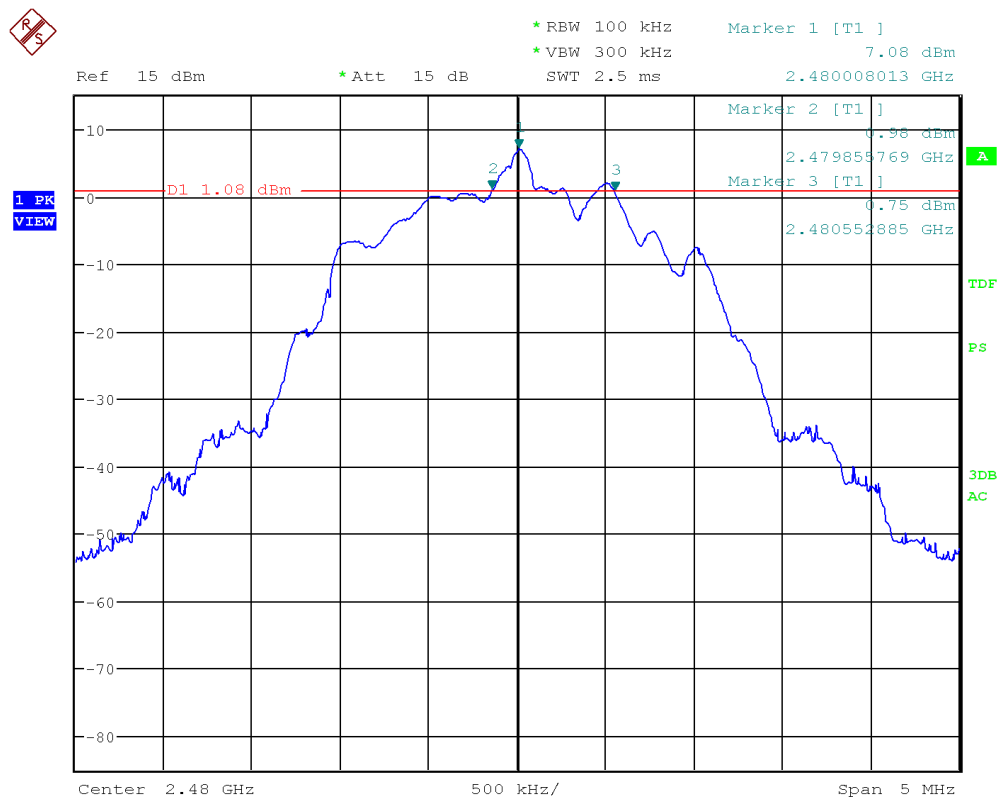


Figure 19: Chart of 6 dB bandwidth test on highest channel, 2 Mbps

Channel	6 dB bandwidth (kHz)	Bandwidth limit (kHz)	Lower frequency of bandwidth (MHz)	Lower frequency of designated band (MHz)	Upper frequency of bandwidth (MHz)	Upper frequency of designated band (MHz)	Result
low	689.103	≥ 500	2401.856	2400.000	2402.545	2483.500	Passed
middle	689.103	≥ 500	2439.856	2400.000	2440.545	2483.500	Passed
high	697.116	≥ 500	2479.856	2400.000	2480.553	2483.500	Passed

Table 22: Results of 6 dB bandwidth test, 2 Mbps

6.3 Occupied bandwidth

Section(s) in 47 CFR Part 15: Requirement(s): ---
Reference(s): KDB 558074 D01, section 5.2

Section(s) in RSS: Requirement(s): RSS-Gen, section 6.7
Reference(s): KDB 558074 D01, section 5.2
ANSI C63.10, clause 6.9

Performed by:	Jennifer Riedel B. Eng.	Date(s) of test:	January 9, 2023
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Result:	☒ Test passed	☐ Test not passed
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6.3.1 Test equipment

Type	Designation	Manufacturer	Inventory no.
EMI test receiver	ESU 26	Rohde & Schwarz	W00002

6.3.2 Limits

According to section 5.2 of KDB Publication 558074, document D01:
The 99 % occupied bandwidth is necessary for setting the proper reference level and input attenuation.

According to RSS-Gen, section 6.7:
The occupied bandwidth or the “99% emission bandwidth” has to be reported for all equipment in addition to the specified bandwidth required in RSS-247.

6.3.3 Test procedure

The occupied bandwidth is measured using the test procedure as described in clause 5.7.2 and referring to the

- ☒ test method for conducted measurements as described in clause 5.2.
- ☐ test method for radiated measurements as described in clause 5.6.

6.3.4 Test results

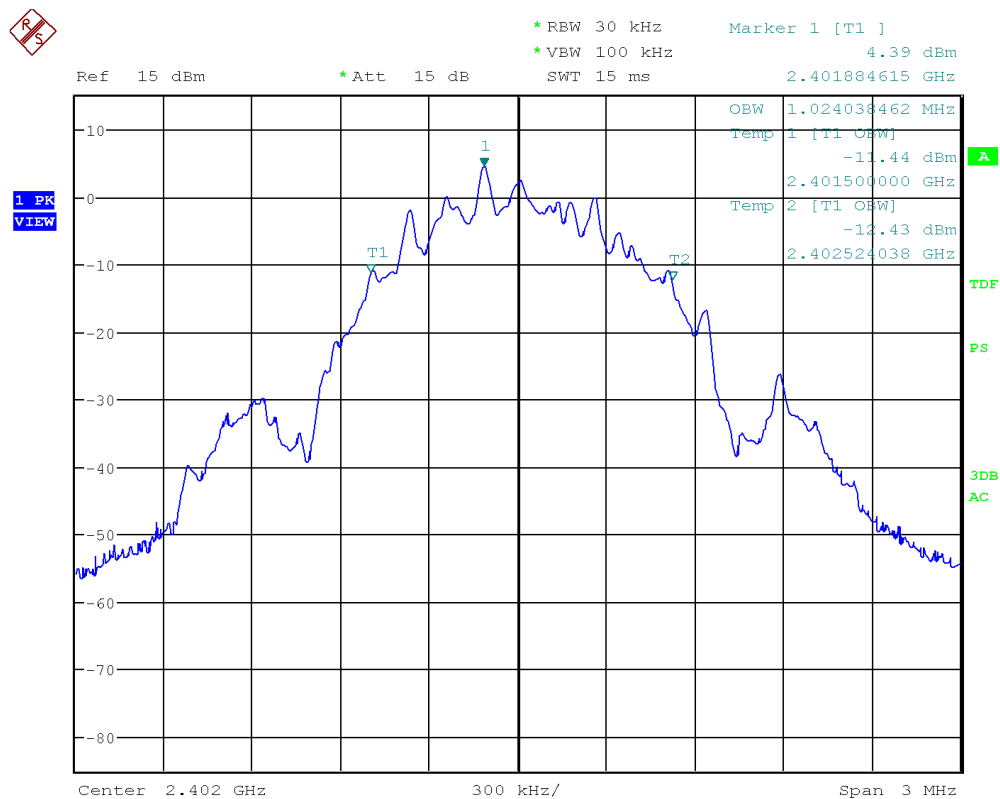


Figure 20: Chart of occupied bandwidth test on lowest channel, 125 kbps

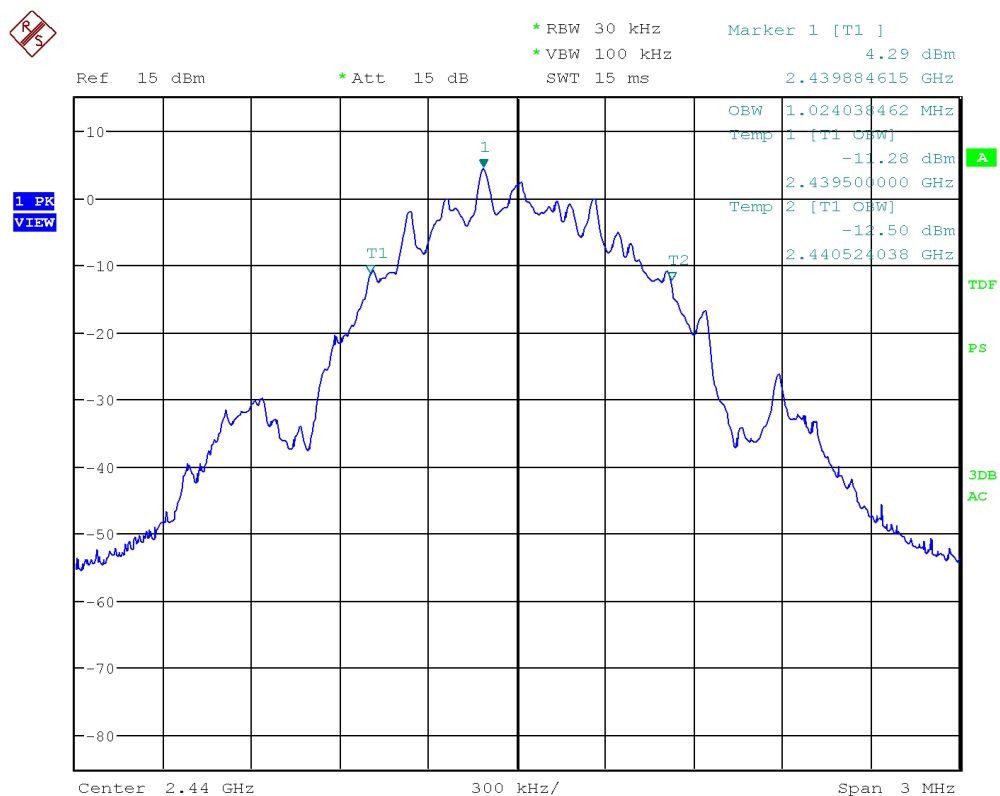


Figure 21: Chart of occupied bandwidth test on middle channel, 125 kbps

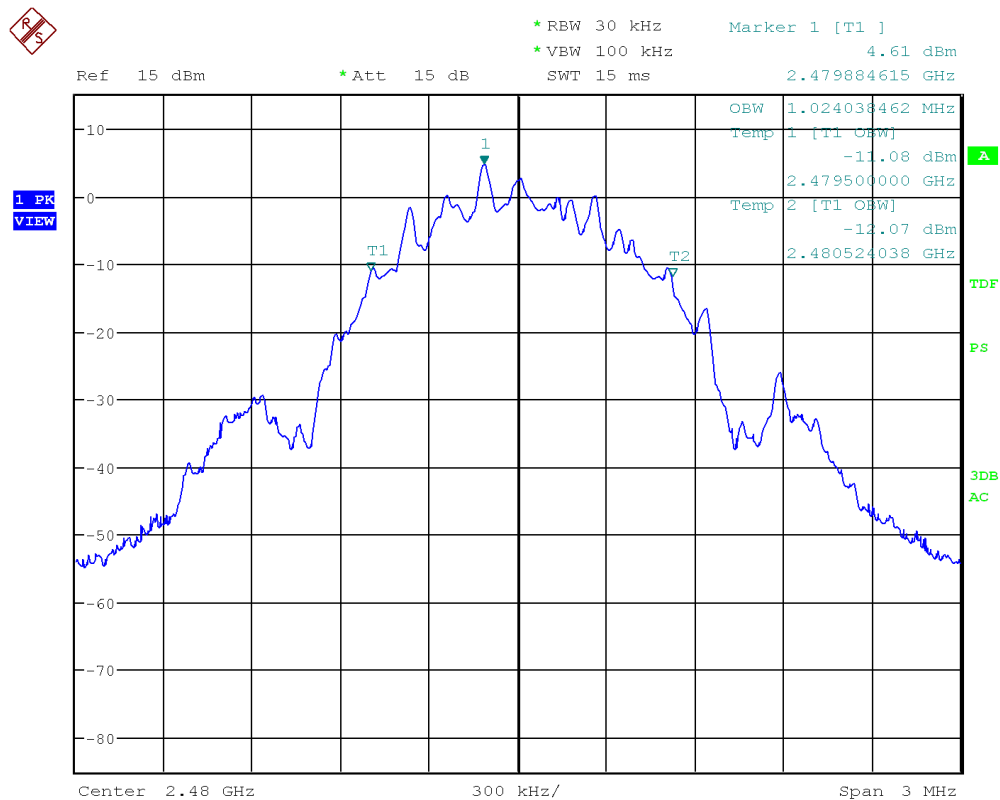


Figure 22: Chart of occupied bandwidth test on highest channel, 125 kbps

Channel	99 % occupied bandwidth (kHz)	Result
low	1024.038	Recorded
middle	1024.038	Recorded
high	1024.038	Recorded

Table 23: Results of occupied bandwidth test, 125 kbps

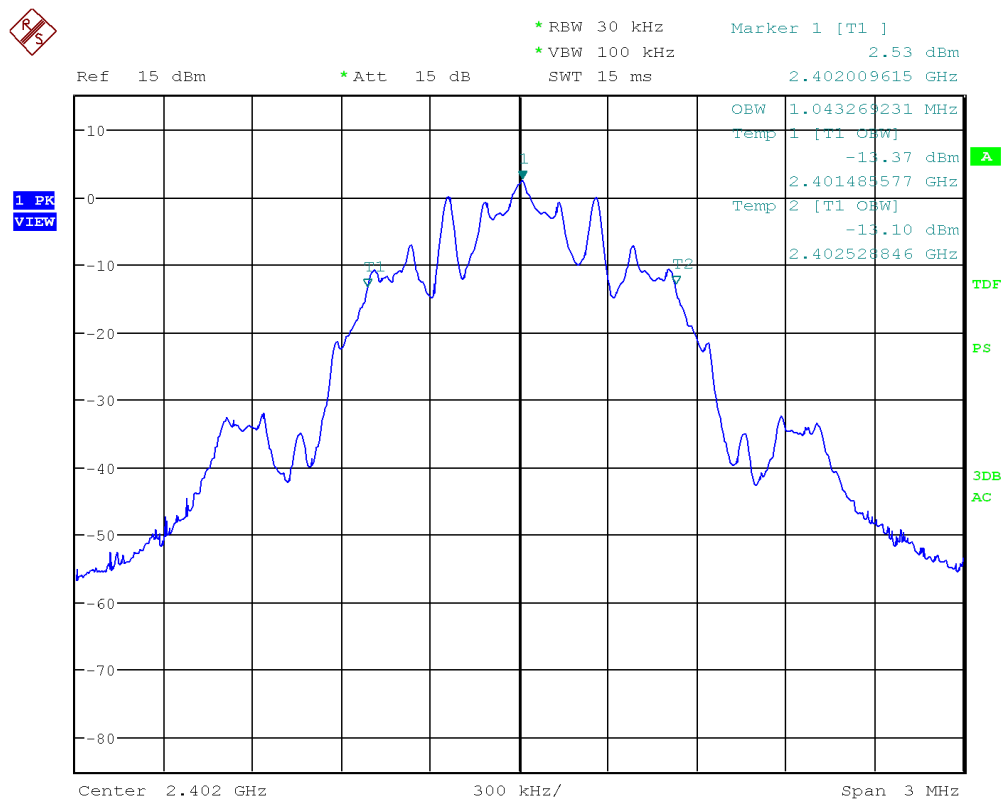


Figure 23: Chart of occupied bandwidth test on lowest channel, 500 kbps

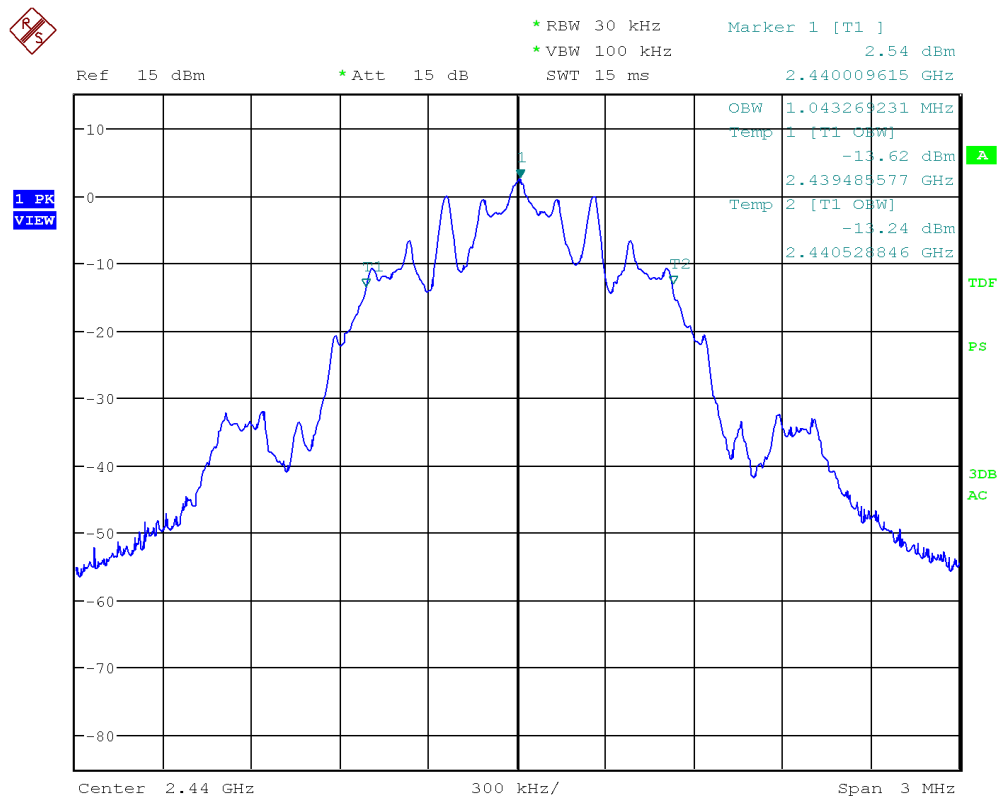


Figure 24: Chart of occupied bandwidth test on middle channel, 500 kbps

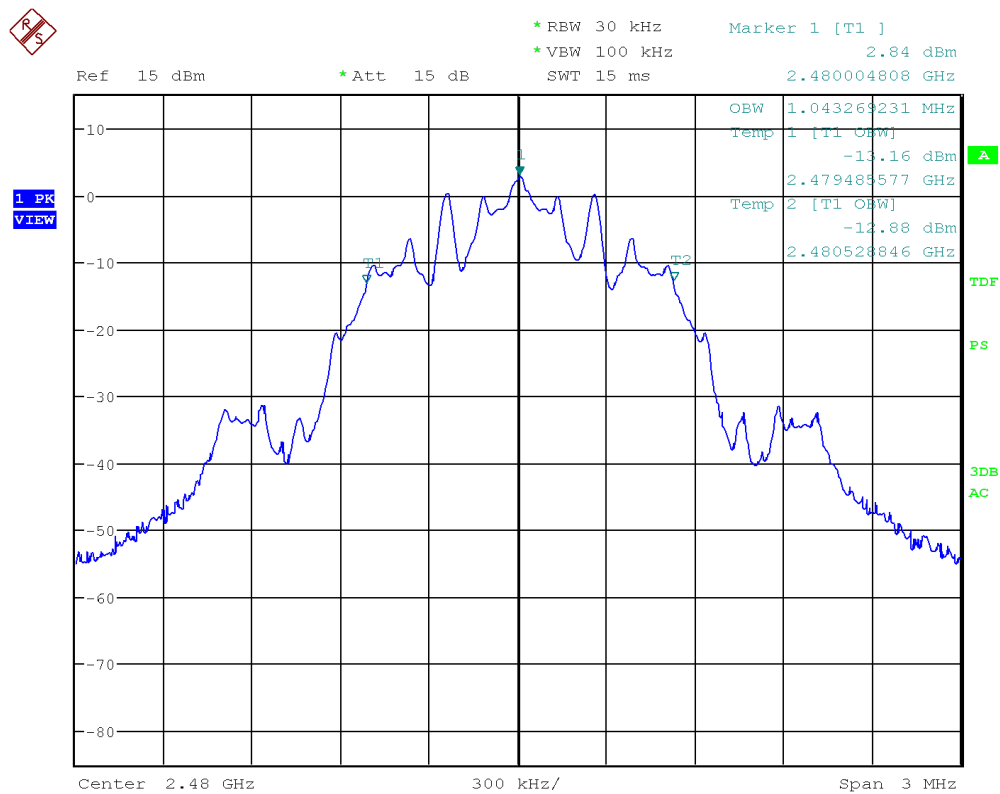


Figure 25: Chart of occupied bandwidth test on highest channel, 500 kbps

Channel	99 % occupied bandwidth (kHz)	Result
low	1043.269	Recorded
middle	1043.269	Recorded
high	1043.269	Recorded

Table 24: Results of occupied bandwidth test, 500 kbps

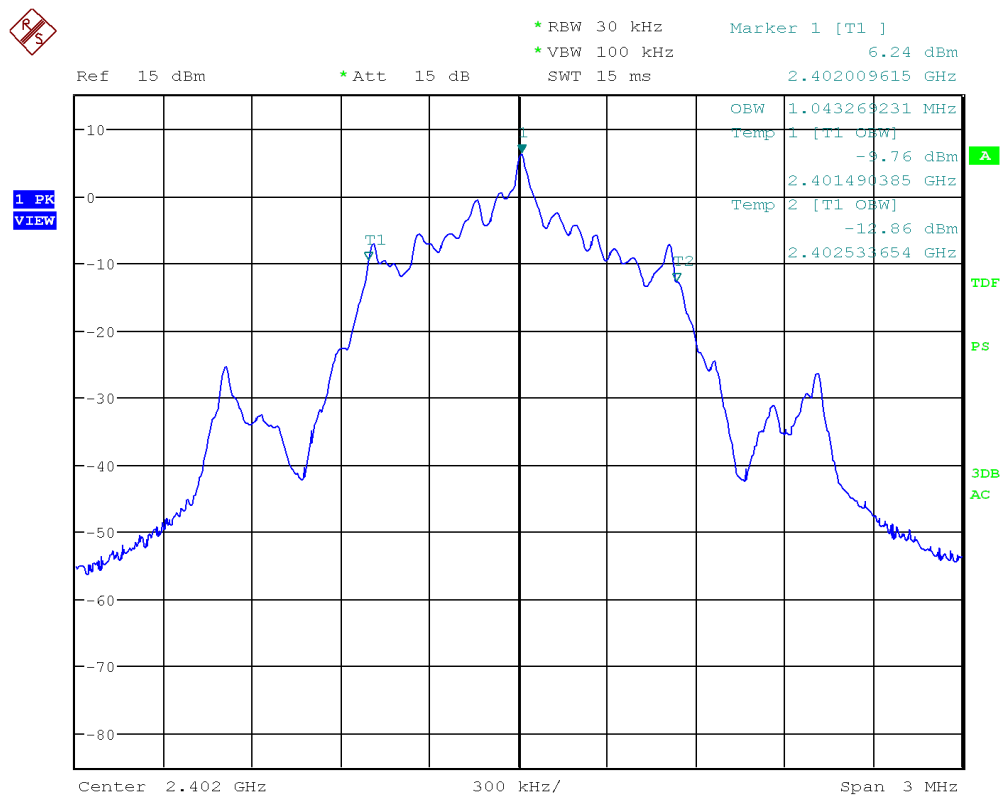


Figure 26: Chart of occupied bandwidth test on lowest channel, 1 Mbps

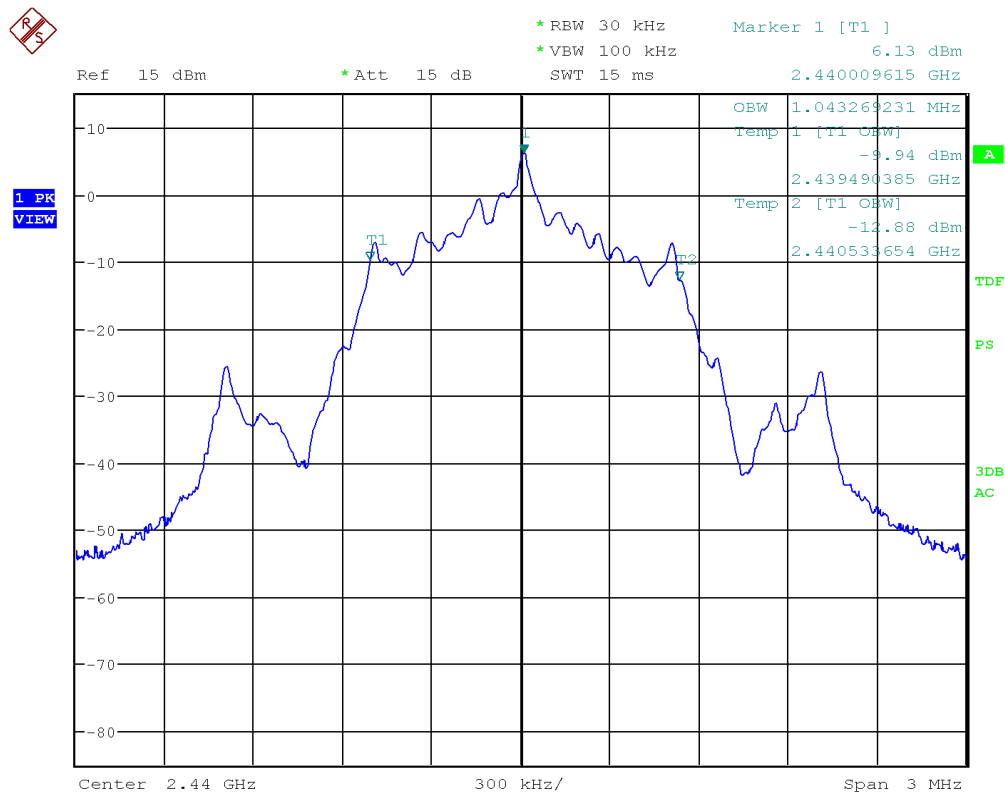


Figure 27: Chart of occupied bandwidth test on middle channel, 1 Mbps

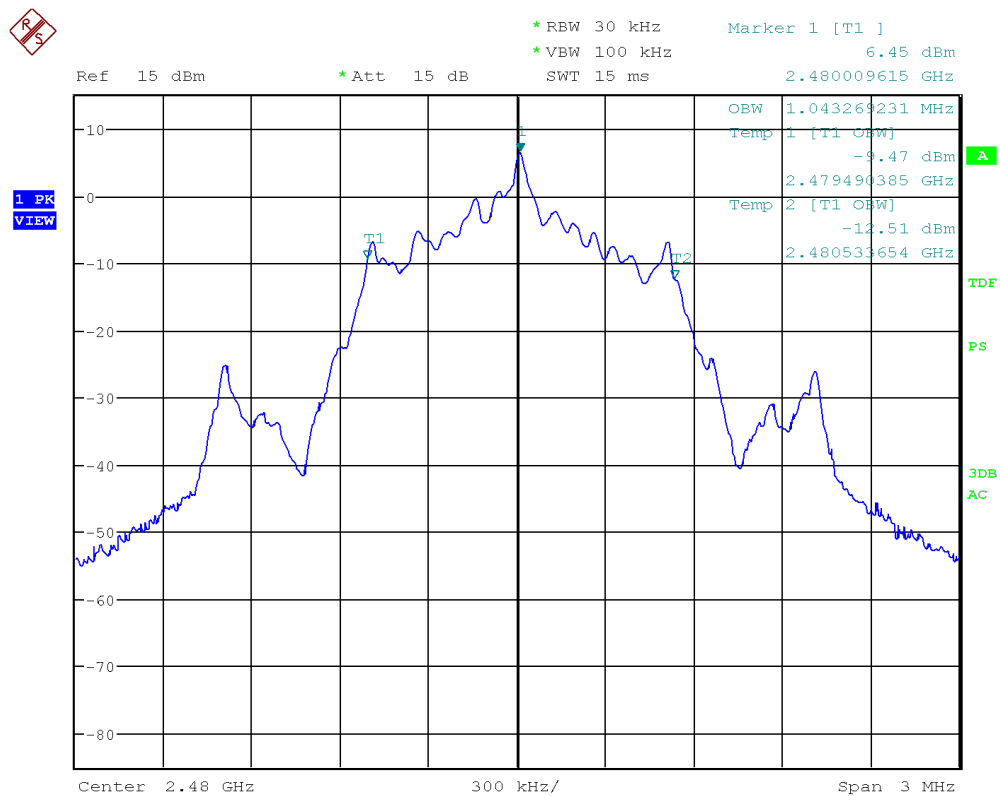


Figure 28: Chart of occupied bandwidth test on highest channel, 1 Mbps

Channel	99 % occupied bandwidth (kHz)	Result
low	1043.269	Recorded
middle	1043.269	Recorded
high	1043.269	Recorded

Table 25: Results of occupied bandwidth test, 1 Mbps



Figure 29: Chart of occupied bandwidth test on lowest channel, 2 Mbps



Figure 30: Chart of occupied bandwidth test on middle channel, 2 Mbps

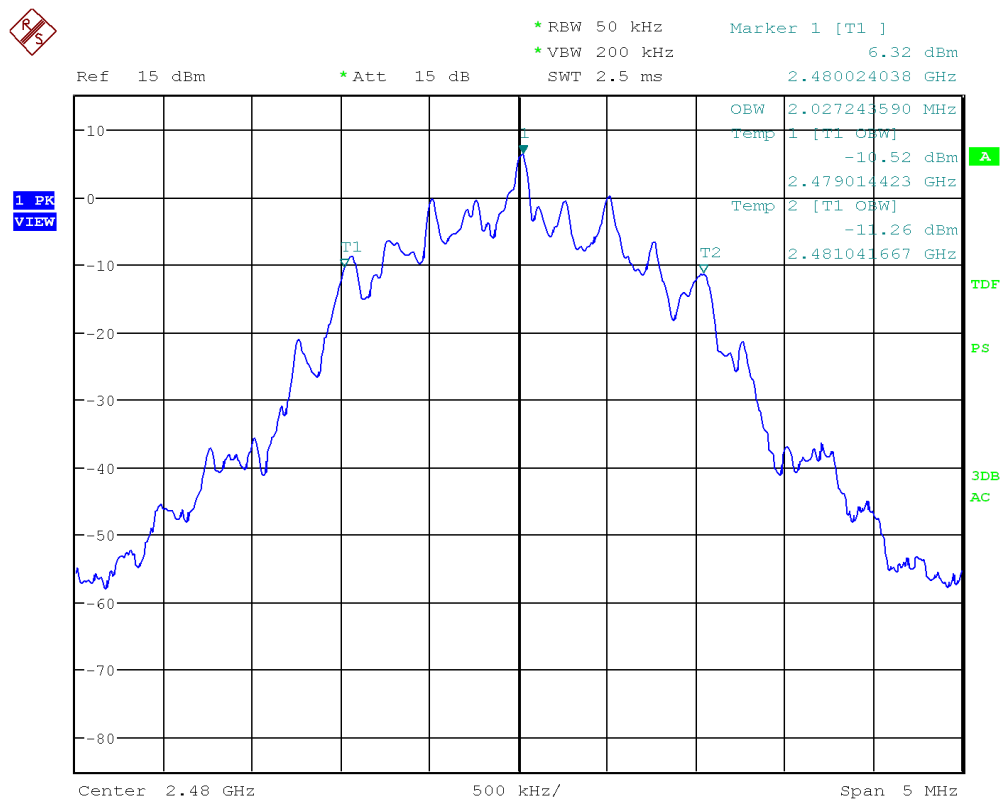


Figure 31: Chart of occupied bandwidth test on highest channel, 2 Mbps

Channel	99 % occupied bandwidth (kHz)	Result
low	2027.244	Recorded
middle	2027.244	Recorded
high	2027.244	Recorded

Table 26: Results of occupied bandwidth test, 2 Mbps

6.4 Conducted output power

Section(s) in 47 CFR Part 15:	Requirement(s):	15.247(b)
	Reference(s):	KDB 558074 D01, clause 8.3 ANSI C63.10, clause 11.9
Section(s) in RSS:	Requirement(s):	RSS-247, section 5.4(d)
	Reference(s):	KDB 558074 D01, clause 8.3 ANSI C63.10, clause 11.9

Performed by:	Konrad Graßl	Date(s) of test:	July 14, 2023
Result:	☒ Test passed	☐ Test not passed	

6.4.1 Test equipment

Type	Designation	Manufacturer	Inventory no.
EMI test receiver	ESU 26	Rohde & Schwarz	W00002

6.4.2 Limits

According to §15.247(b)(3):

For systems using digital modulation in the 2400-2483.5 MHz band: 1 Watt (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.

According to §15.247(b)(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.

According to RSS-247, section 5.4(d):

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

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

6.4.3 Test procedure

The maximum peak conducted output power is measured using the test procedure as described in clause 5.8 and referring to the

- ☒ test method for conducted measurements as described in clause 5.2.
- ☐ test method for radiated measurements as described in clause 5.6.

6.4.4 Test results

Note(s):

- The gain of the antenna is below 6 dBi, therefore a reduction of the conducted limit was not applied.

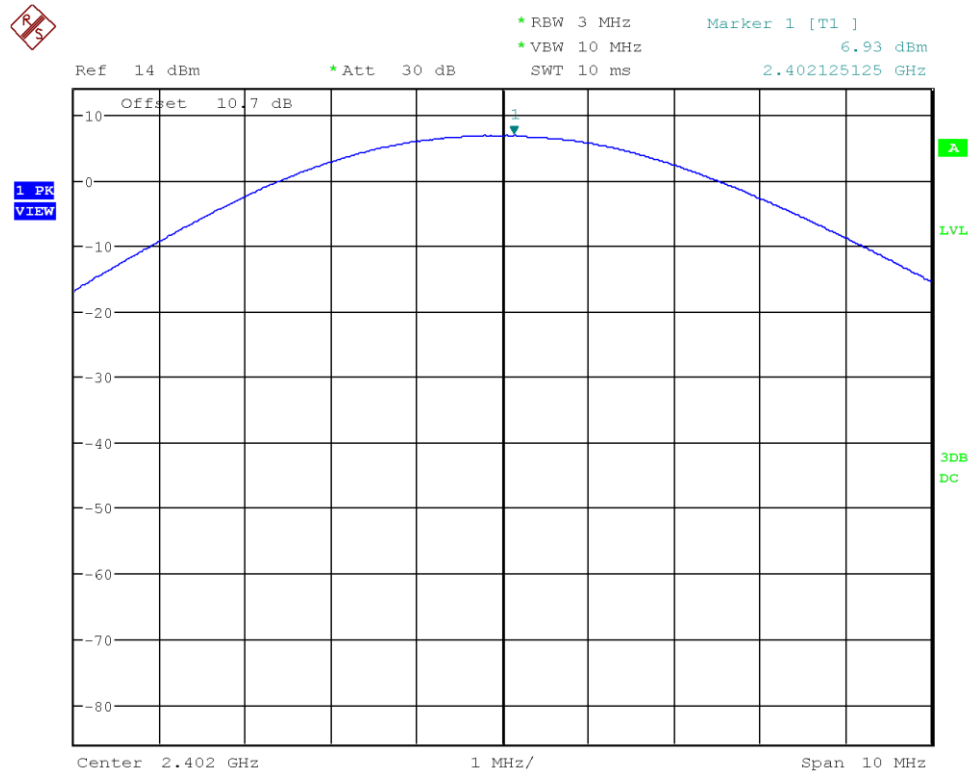


Figure 32: Chart of conducted output power on lowest channel, 125 kbps

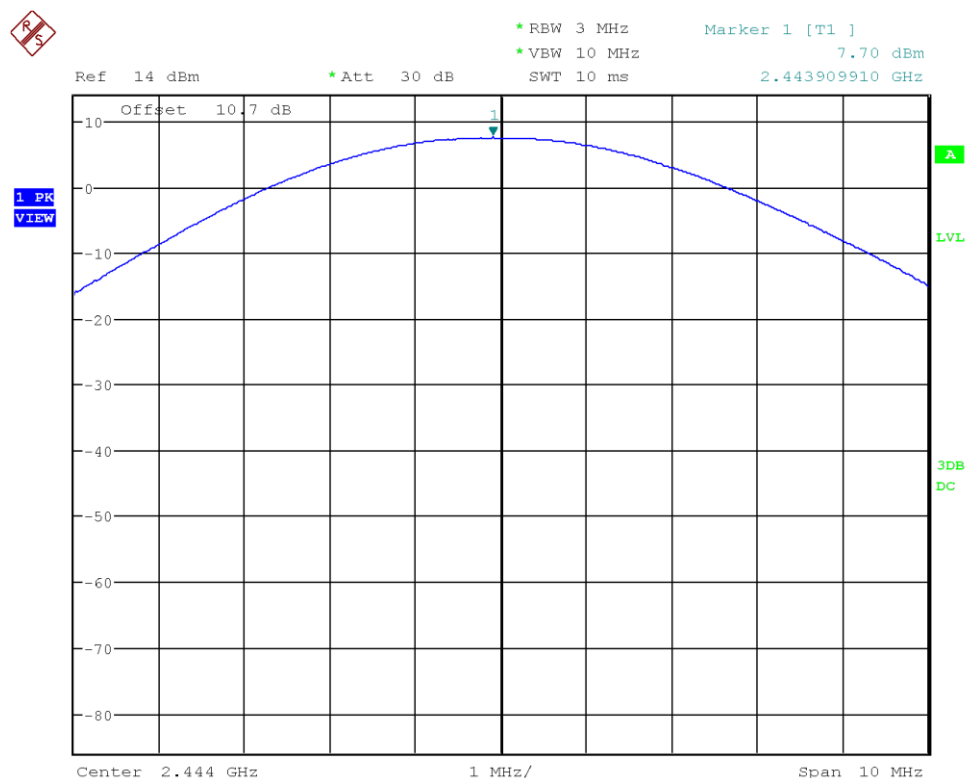


Figure 33: Chart of conducted output power on middle channel, 125 kbps

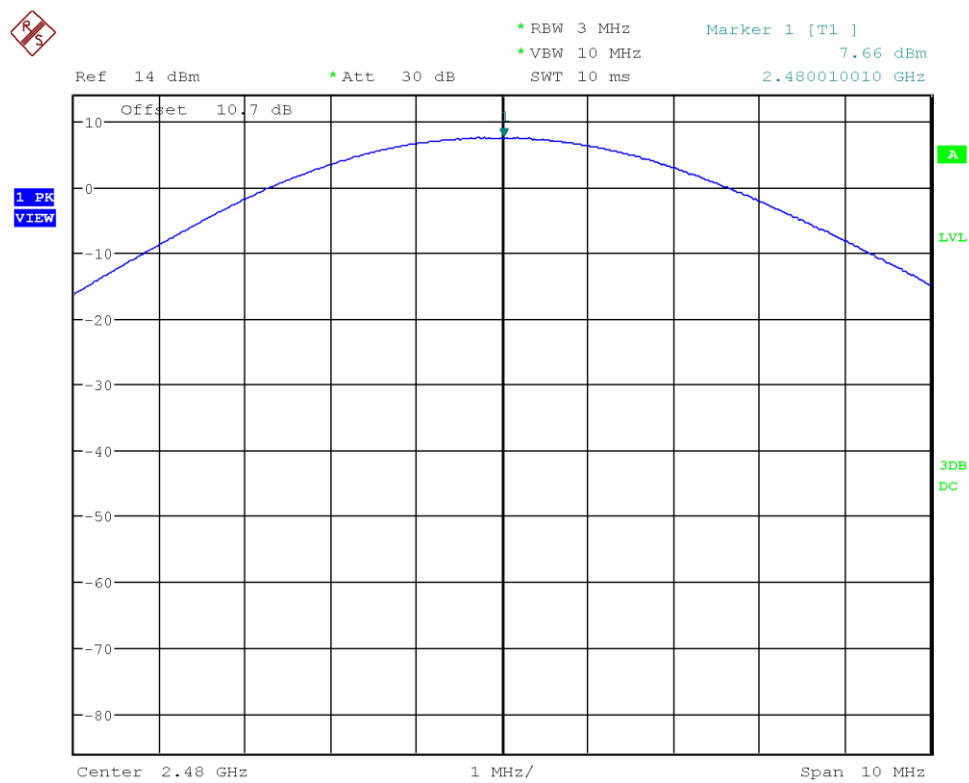


Figure 34: Chart of conducted output power on highest channel, 125 kbps

Channel	Conducted output power (dBm)	Limit (dBm)	Margin (dB)	Results
low	6.93	30.00	23.07	Passed
middle	7.70	30.00	22.30	Passed
high	7.66	30.00	22.34	Passed

Table 27: Results of conducted output power, 125 kbps

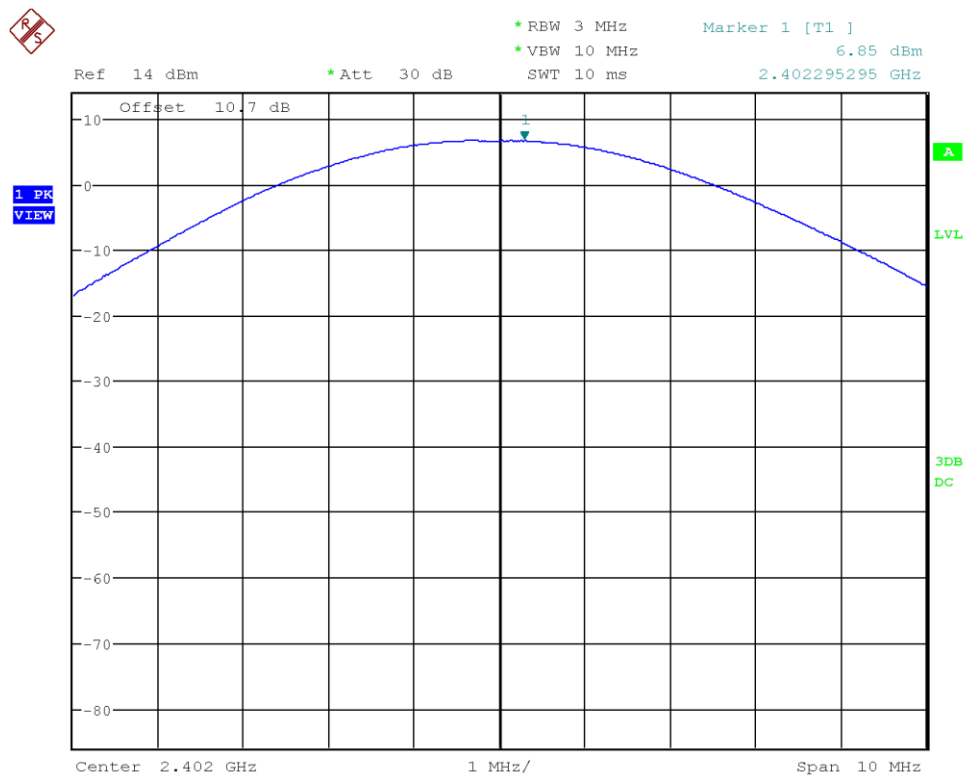


Figure 35: Chart of conducted output power on lowest channel, 500 kbps

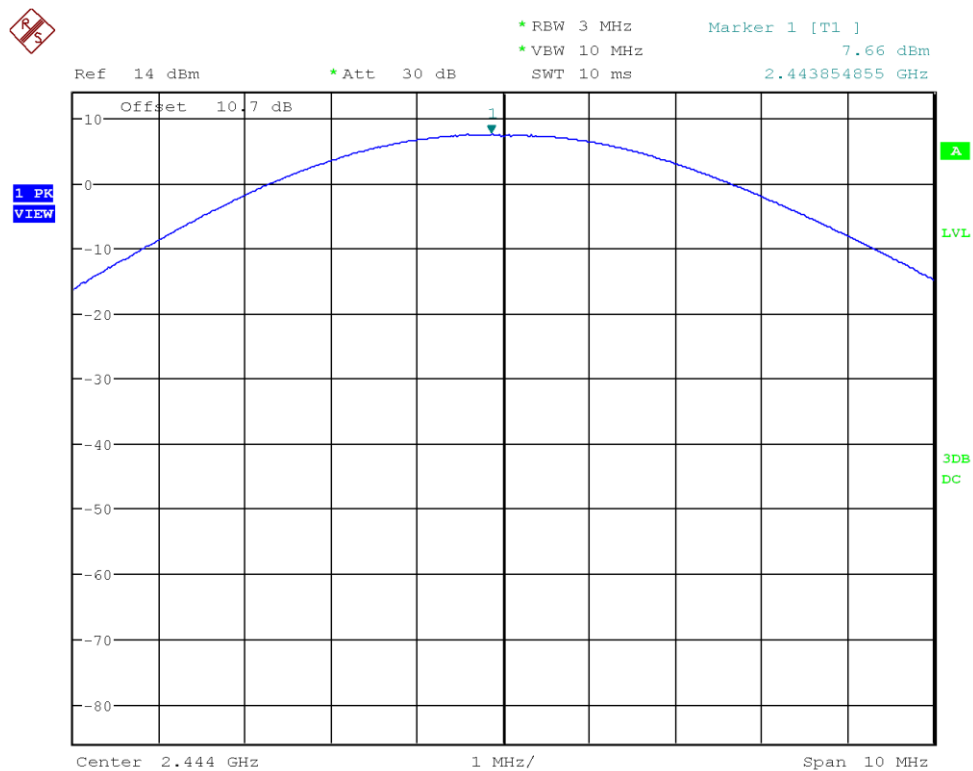


Figure 36: Chart of conducted output power on middle channel, 500 kbps

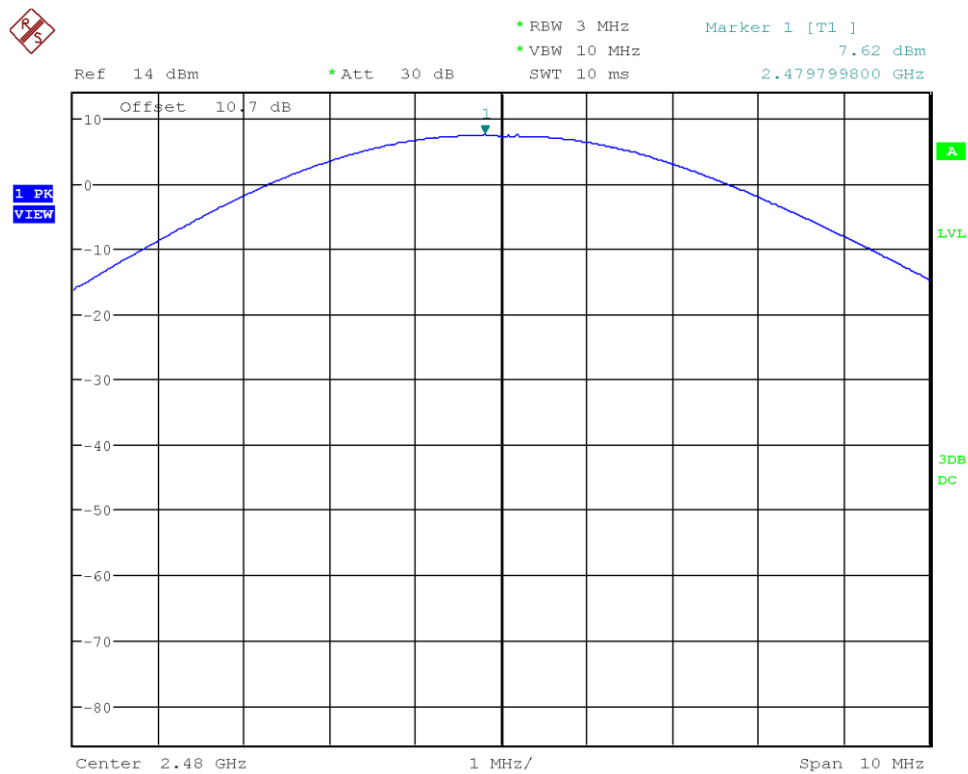


Figure 37: Chart of conducted output power on highest channel, 500 kbps

Channel	Conducted output power (dBm)	Limit (dBm)	Margin (dB)	Results
low	6.85	30.00	23.15	Passed
middle	7.66	30.00	22.34	Passed
high	7.62	30.00	22.38	Passed

Table 28: Results of conducted output power, 500 kbps

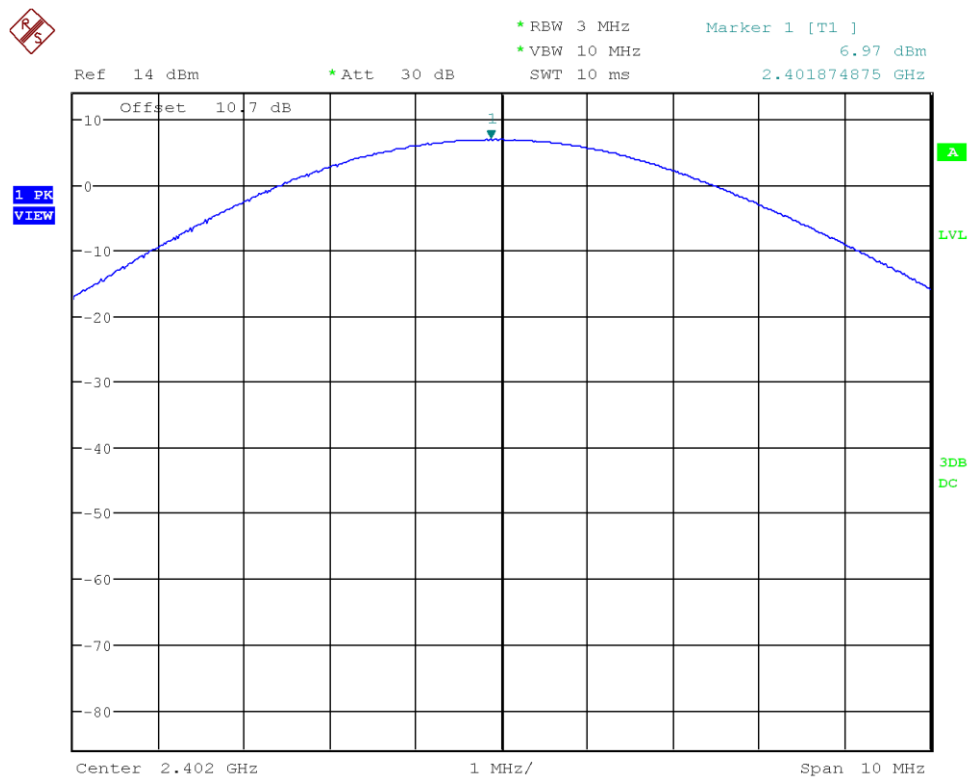


Figure 38: Chart of conducted output power on lowest channel, 1 Mbps

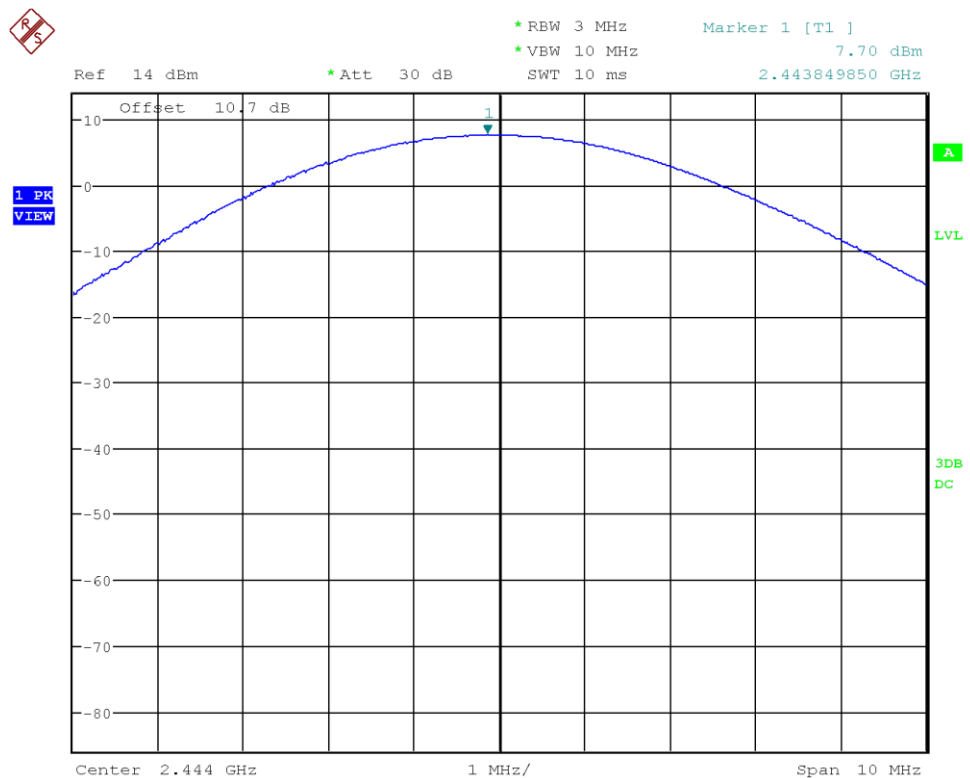


Figure 39: Chart of conducted output power on middle channel, 1 Mbps

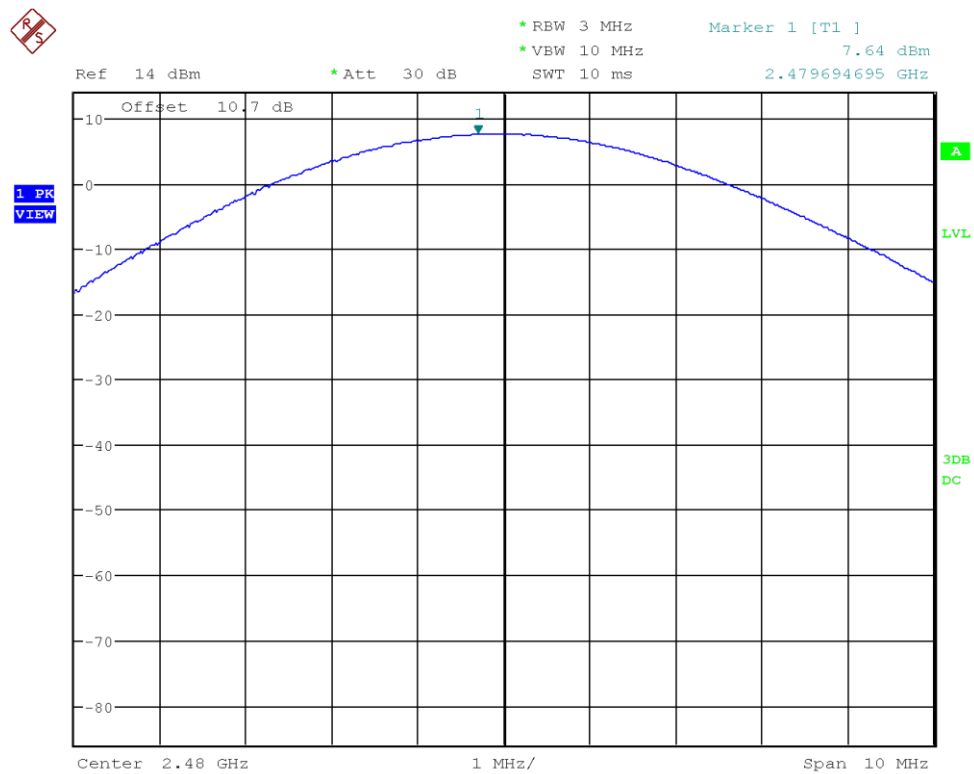


Figure 40: Chart of conducted output power on highest channel, 1 Mbps

Channel	Conducted output power (dBm)	Limit (dBm)	Margin (dB)	Results
low	6.97	30.00	23.03	Passed
middle	7.70	30.00	22.30	Passed
high	7.64	30.00	22.36	Passed

Table 29: Results of conducted output power, 1 Mbps

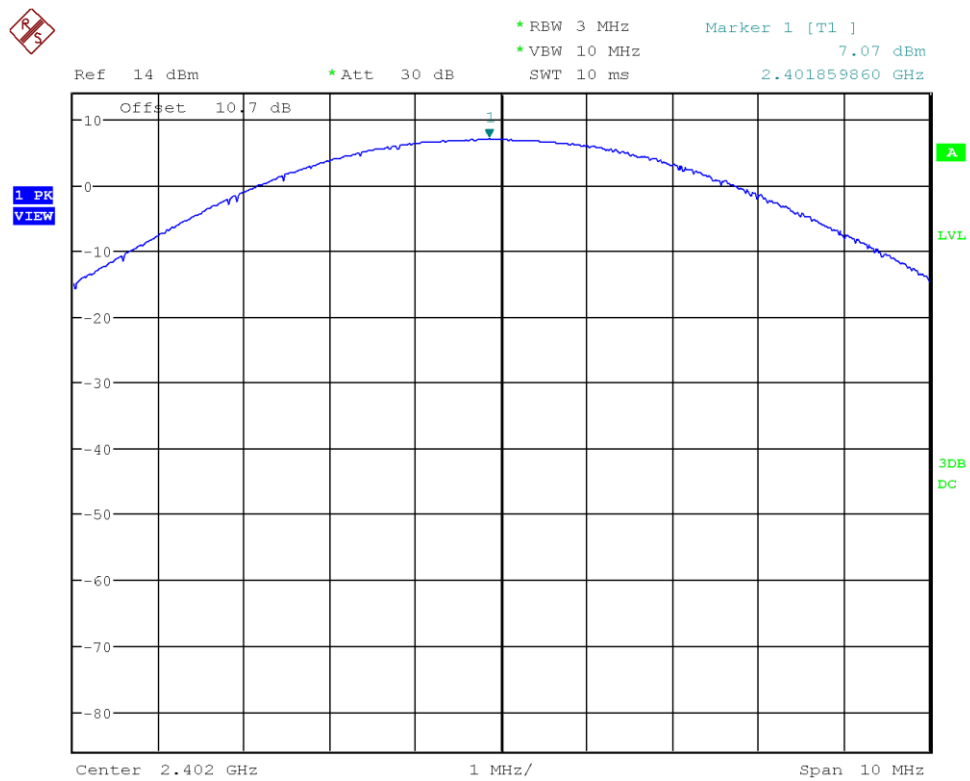


Figure 41: Chart of conducted output power on lowest channel, 2 Mbps

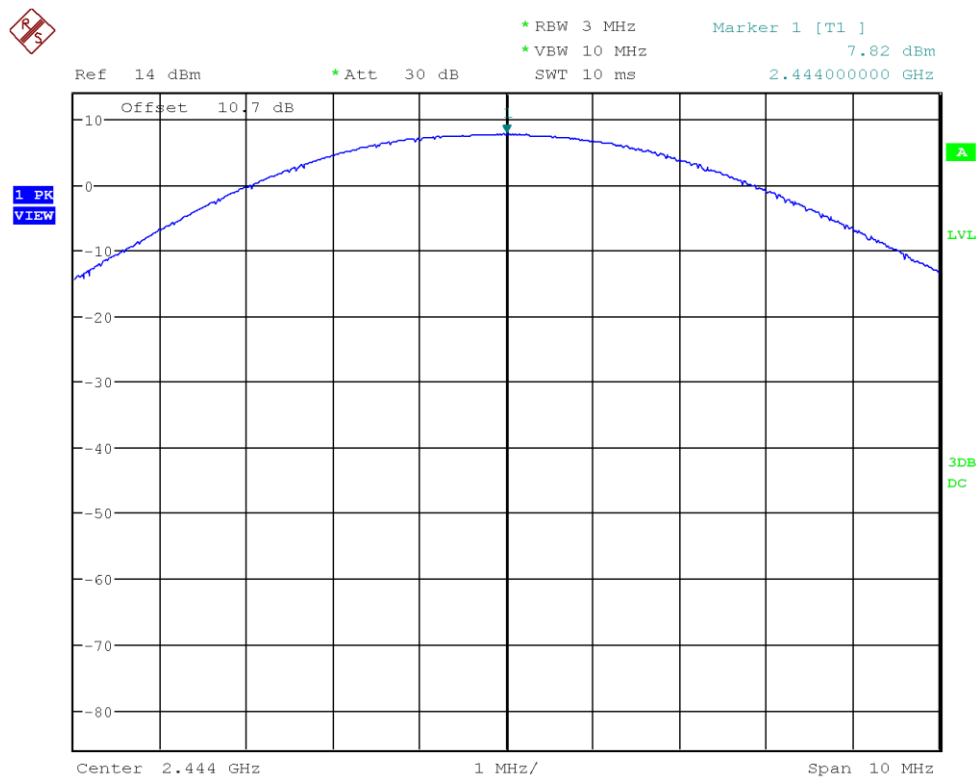


Figure 42: Chart of conducted output power on middle channel, 2 Mbps

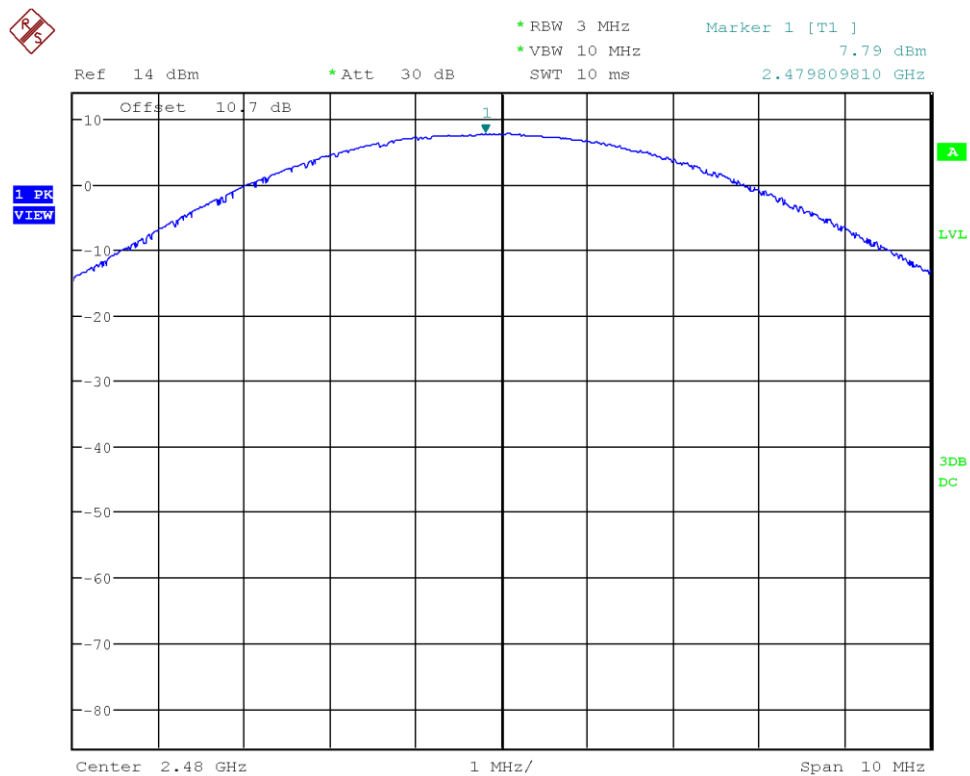


Figure 43: Chart of conducted output power on highest channel, 2 Mbps

Channel	Conducted output power (dBm)	Limit (dBm)	Margin (dB)	Results
low	7.07	30.00	22.93	Passed
middle	7.82	30.00	22.18	Passed
high	7.79	30.00	22.21	Passed

Table 30: Results of conducted output power, 2 Mbps

6.5 Power spectral density

Section(s) in 47 CFR Part 15:	Requirement(s):	15.247(e)
	Reference(s):	KDB 558074 D01, clause 8.4 ANSI C63.10, clause 11.10
Section(s) in RSS:	Requirement(s):	RSS-247, section 5.2(b)
	Reference(s):	KDB 558074 D01, clause 8.4 ANSI C63.10, clause 11.10

Performed by:	Jennifer Riedel B. Eng.	Date(s) of test:	January 9, 2023
Result:	☒ Test passed	☐ Test not passed	

6.5.1 Test equipment

Type	Designation	Manufacturer	Inventory no.
EMI test receiver	ESU 26	Rohde & Schwarz	W00002

6.5.2 Limits

According to §15.247(e) and RSS-247 section 5.2(b):

For digitally modulated systems (DTS), 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.

The same method of determining the conducted output power shall be used to determine the power spectral density.

6.5.3 Test procedure

The power spectral density is measured using the test procedure as described in clause 5.9 and referring to the

- ☒ test method for conducted measurements as described in clause 5.2.
- ☐ test method for radiated measurements as described in clause 5.6.

6.5.4 Test results

Note(s):

1. The gain of the antenna is below 6 dBi, therefore a reduction of the conducted limit was not applied.

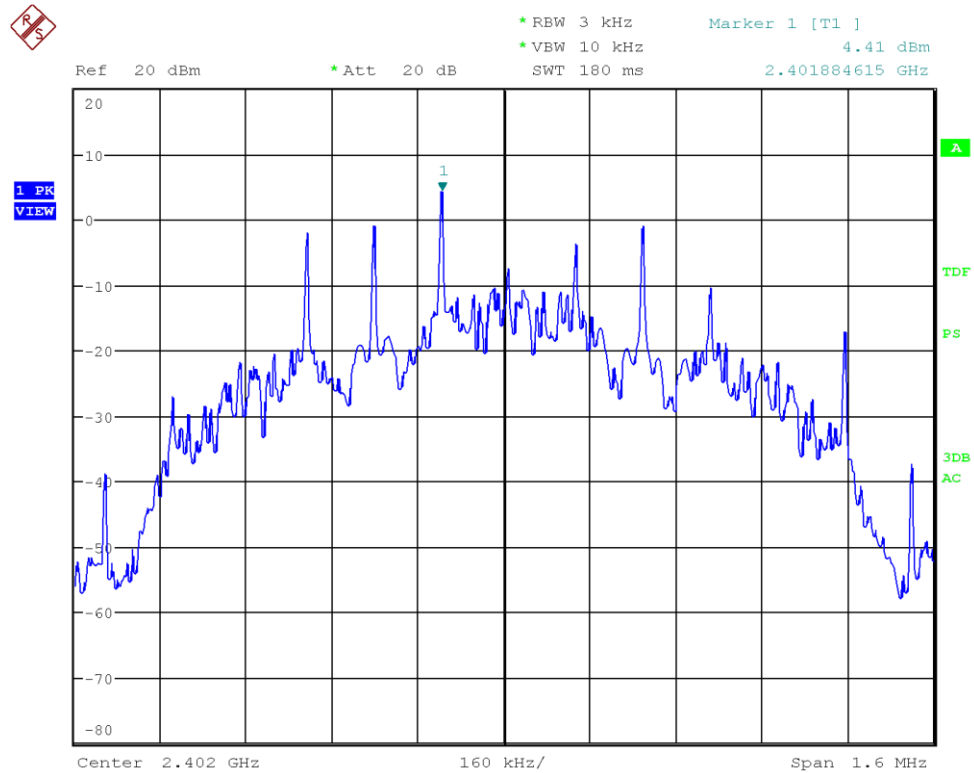


Figure 44: Chart of power spectral density on lowest channel, 125 kbps

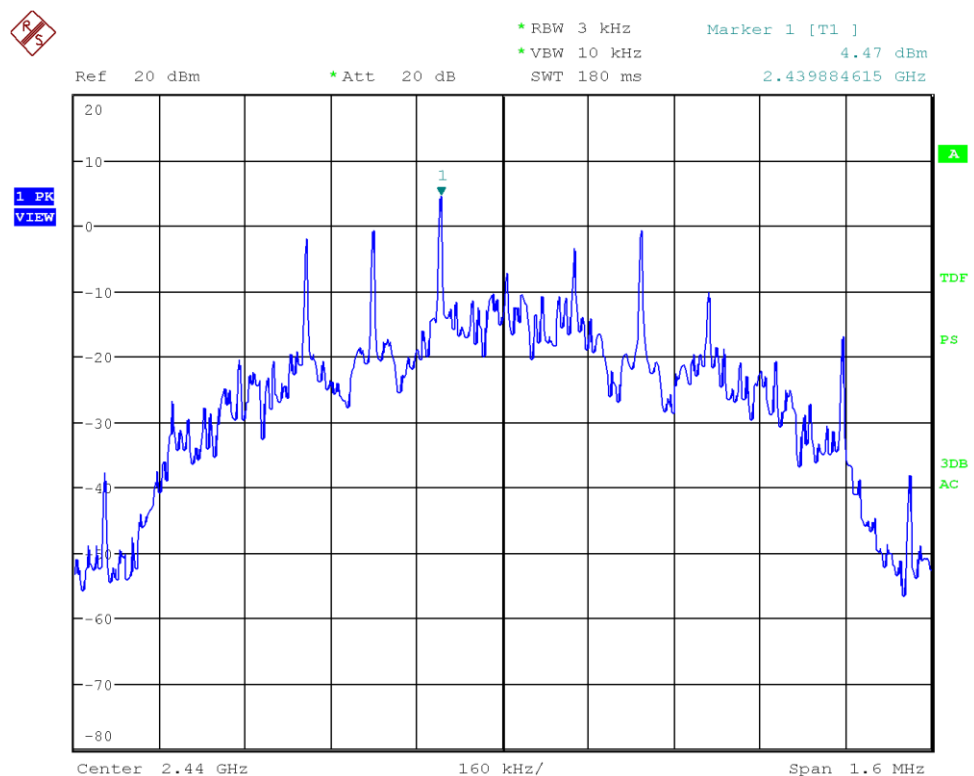


Figure 45: Chart of power spectral density on middle channel, 125 kbps

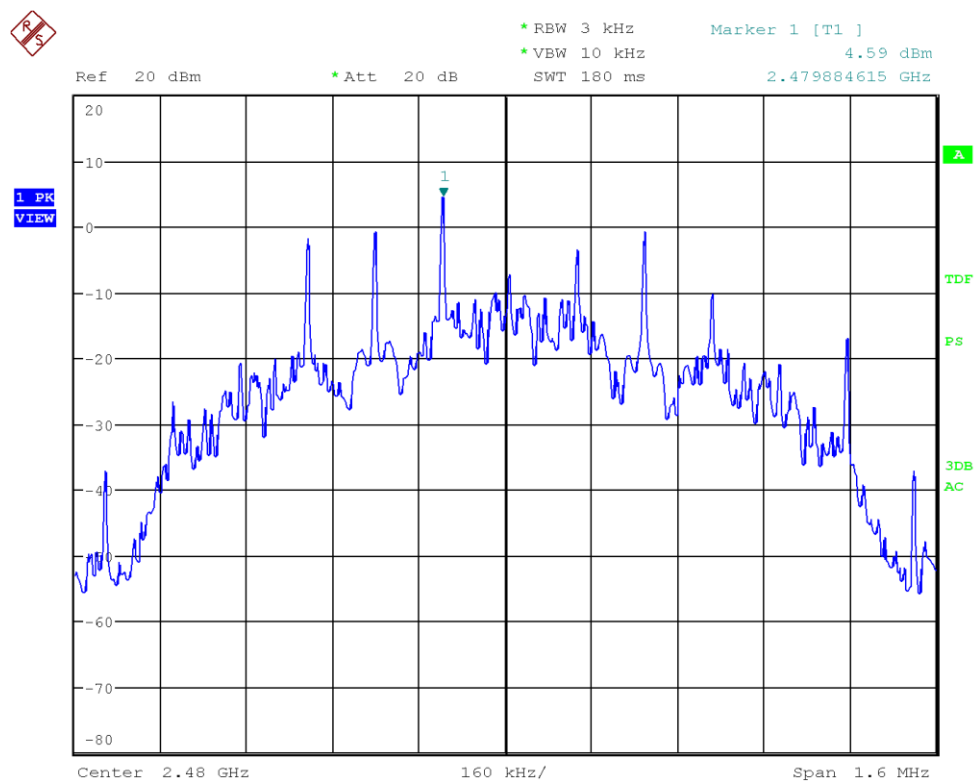


Figure 46: Chart of power spectral density on highest channel, 125 kbps

Channel	Power spectral density (dBm/3 kHz)	Limit (dBm/3 kHz)	Margin (dB)	Results
low	4.41	8.00	3.59	Passed
middle	4.47	8.00	3.53	Passed
high	4.59	8.00	3.41	Passed

Table 31: Results of conducted power spectral density, 125 kbps

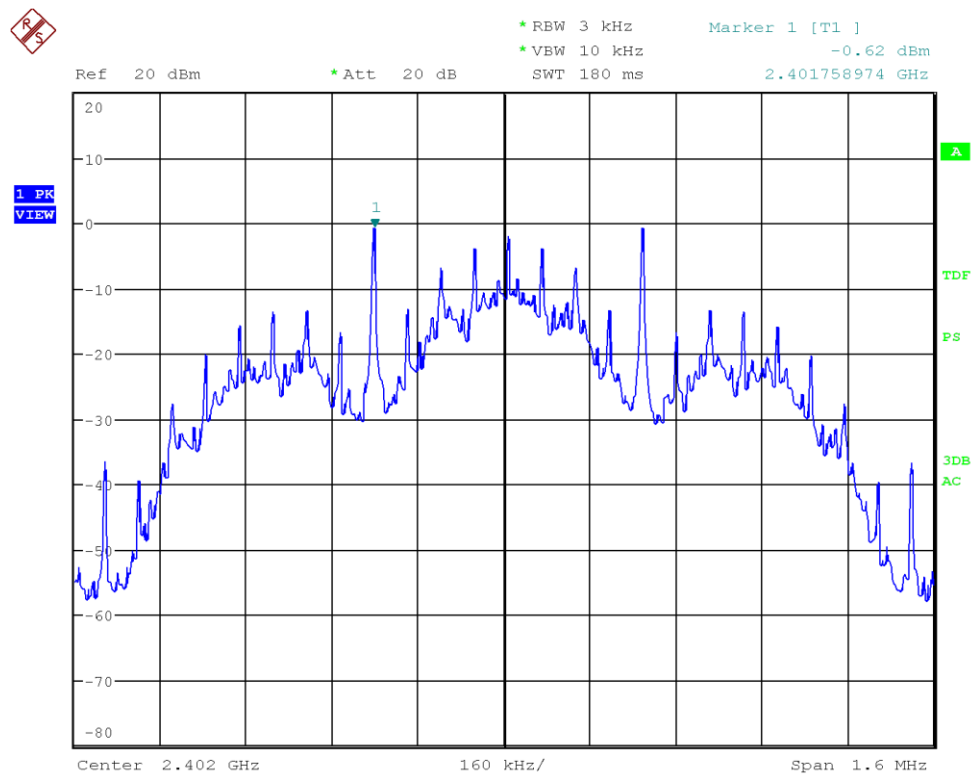


Figure 47: Chart of power spectral density on lowest channel, 500 kbps

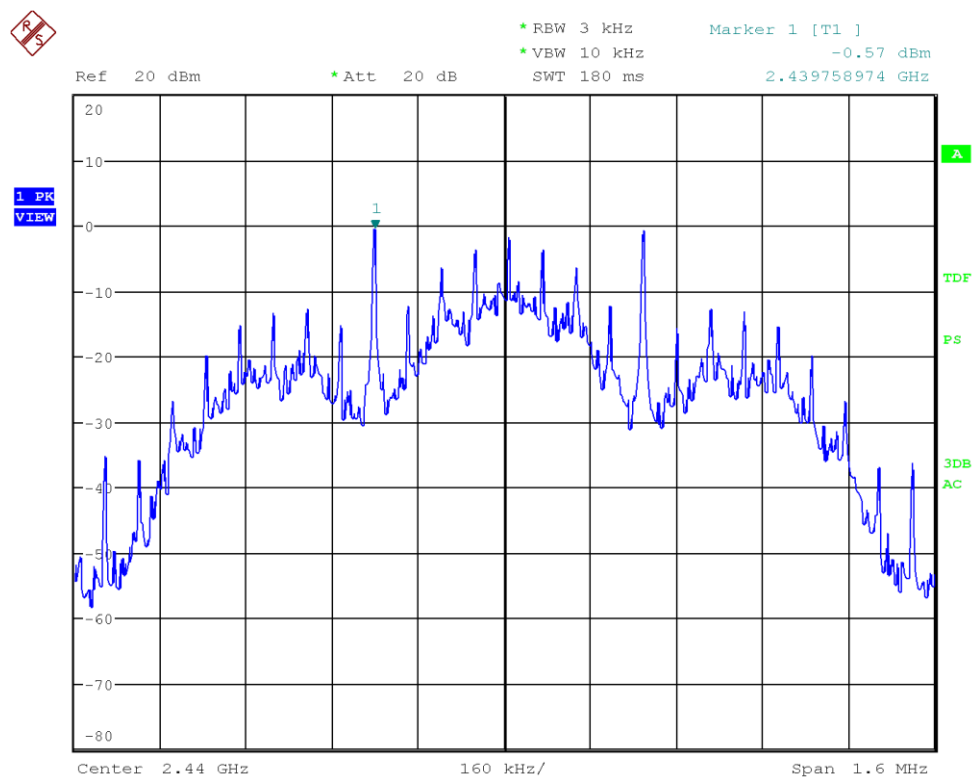


Figure 48: Chart of power spectral density on middle channel, 500 kbps

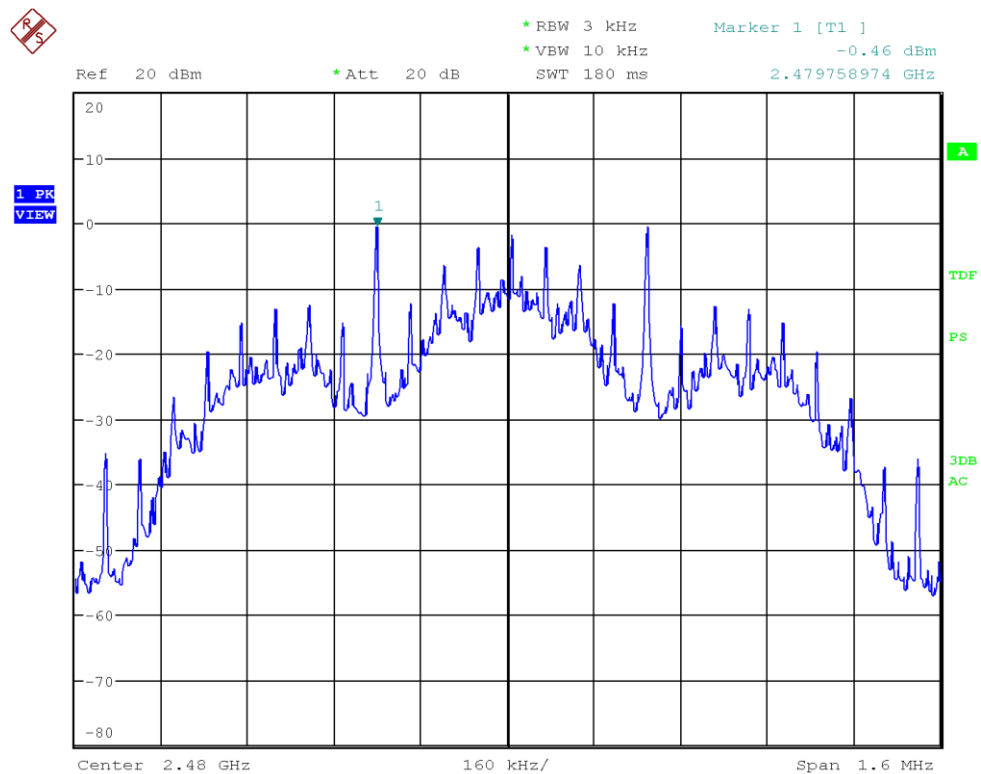


Figure 49: Chart of power spectral density on highest channel, 500 kbps

Channel	Power spectral density (dBm/3 kHz)	Limit (dBm/3 kHz)	Margin (dB)	Results
low	-0.62	8.00	8.62	Passed
middle	-0.57	8.00	8.57	Passed
high	-0.46	8.00	8.46	Passed

Table 32: Results of conducted power spectral density, 500 kbps

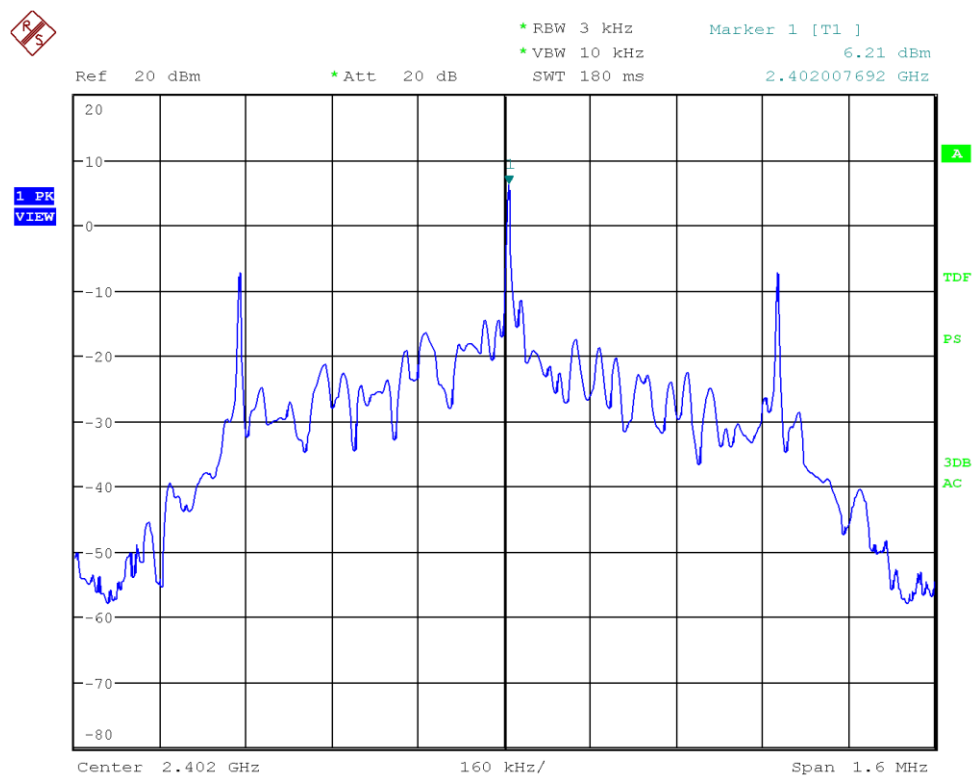


Figure 50: Chart of power spectral density on lowest channel, 1 Mbps

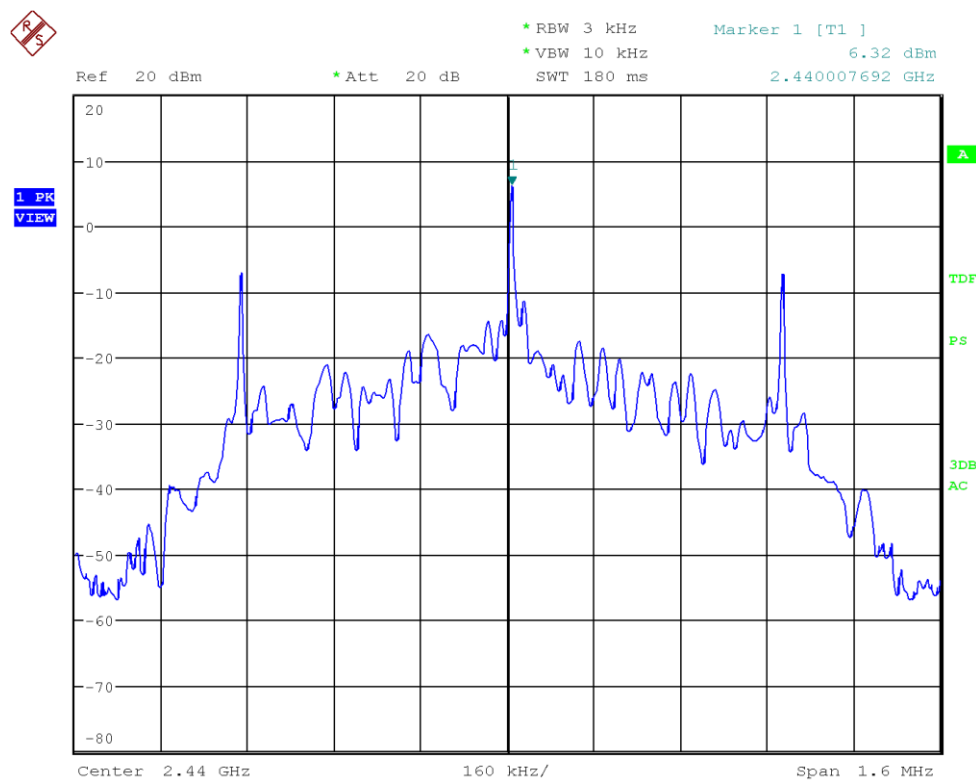


Figure 51: Chart of power spectral density on middle channel, 1 Mbps

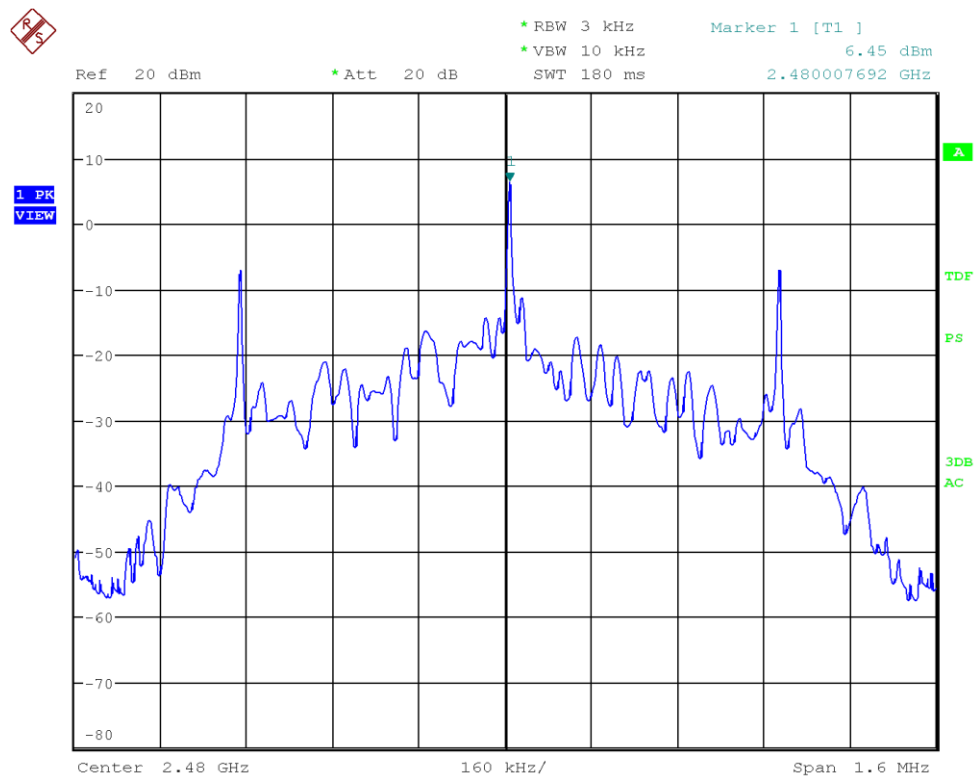


Figure 52: Chart of power spectral density on highest channel, 1 Mbps

Channel	Power spectral density (dBm/3 kHz)	Limit (dBm/3 kHz)	Margin (dB)	Results
low	6.21	8.00	1.79	Passed
middle	6.32	8.00	1.68	Passed
high	6.45	8.00	1.55	Passed

Table 33: Results of conducted power spectral density, 1 Mbps

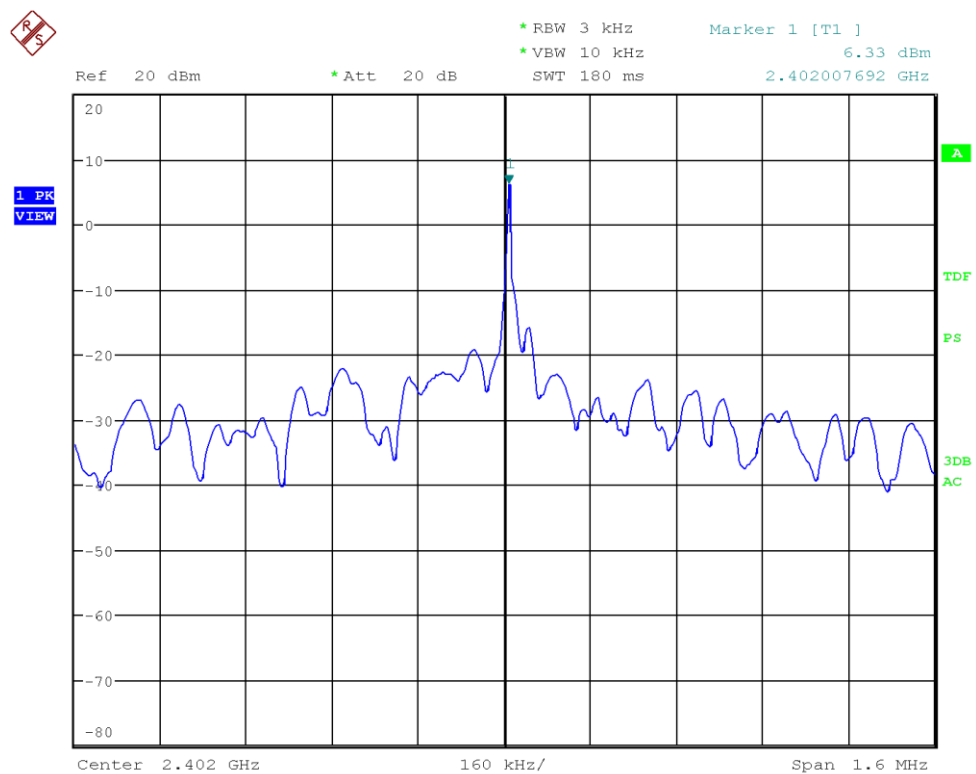


Figure 53: Chart of power spectral density on lowest channel, 2 Mbps

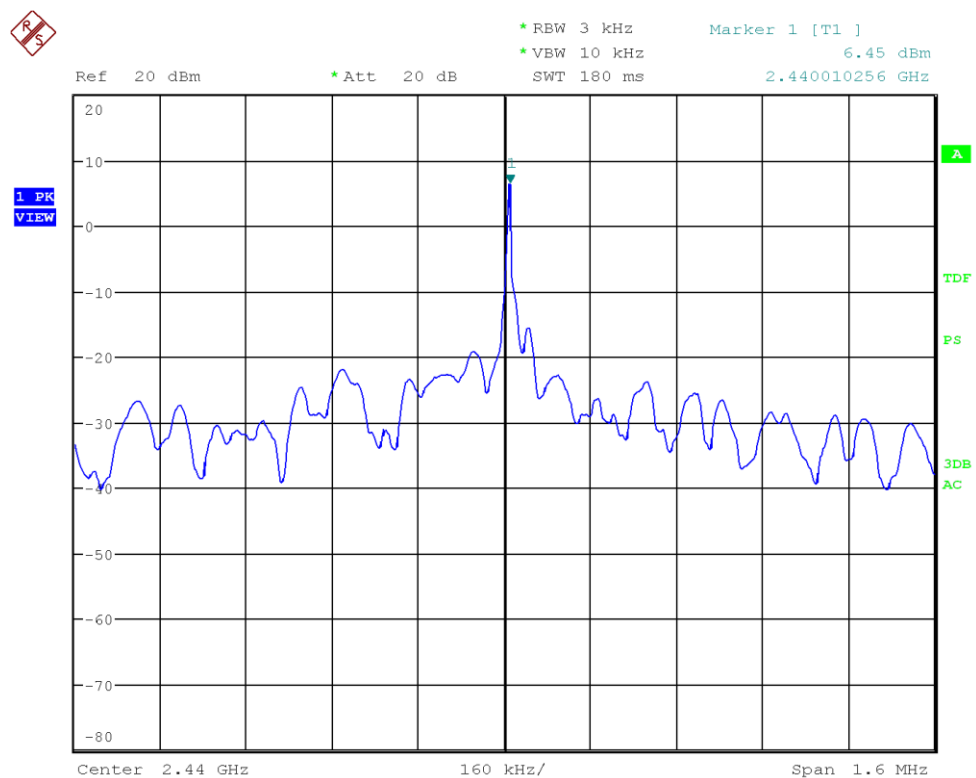


Figure 54: Chart of power spectral density on middle channel, 2 Mbps

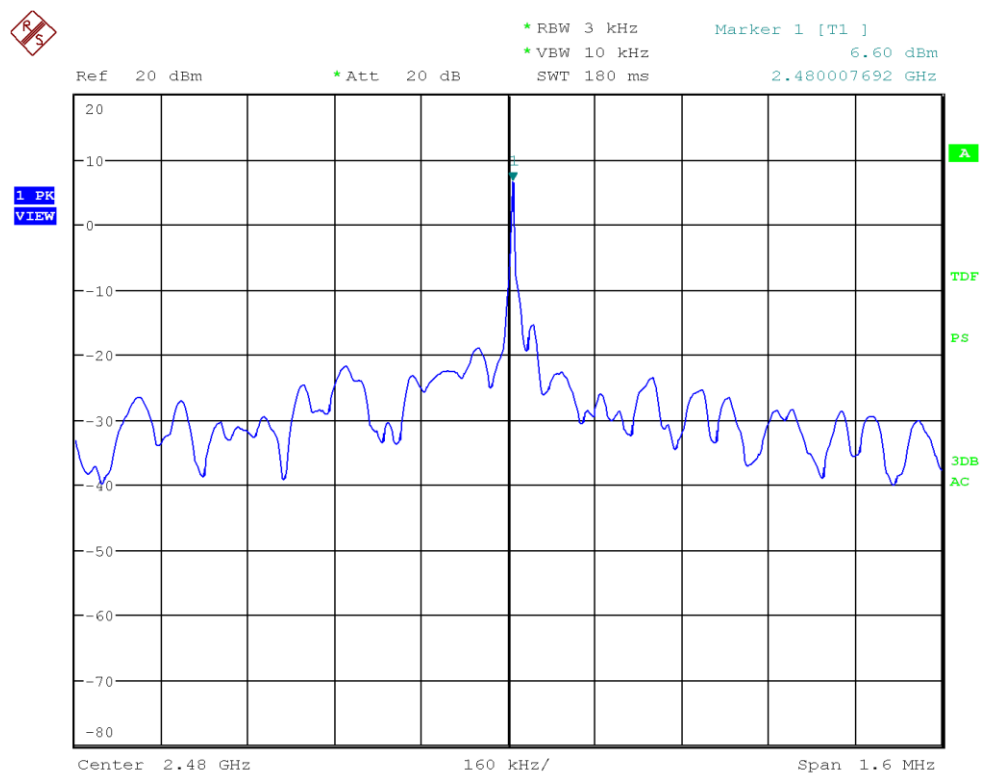


Figure 55: Chart of power spectral density on highest channel, 2 Mbps

Channel	Power spectral density (dBm/3 kHz)	Limit (dBm/3 kHz)	Margin (dB)	Results
low	6.33	8.00	1.67	Passed
middle	6.45	8.00	1.55	Passed
high	6.60	8.00	1.40	Passed

Table 34: Results of conducted power spectral density, 2 Mbps

6.6 Band-edge measurements

Section(s) in 47 CFR Part 15:	Requirement(s):	15.247(d)
	Reference(s):	KDB 558074 D01, clause 8.7 ANSI C63.10, clause 11.13
Section(s) in RSS:	Requirement(s):	RSS-247, section 5.5
	Reference(s):	KDB 558074 D01, clause 8.7 ANSI C63.10, clause 11.13

Performed by:	Jennifer Riedel B. Eng.	Date(s) of test:	January 10, 2023
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Result:	☒ Test passed	☐ Test not passed
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6.6.1 Test equipment

Type	Designation	Manufacturer	Inventory no.
EMI test receiver	ESU 26	Rohde & Schwarz	W00002

6.6.2 Limits

According to §15.247(d) and RSS-247 section 5.5:

In any 100 kHz bandwidth outside of 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. In addition, radiated emissions which fall in the restricted bands (see table 35) must also comply with the radiated emission limits specified in §15.209(a) and RSS-Gen section 8.10.

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			

Table 35: Restricted bands of operation according to §15.205 and RSS-Gen section 8.10

6.6.3 Test procedure

The band-edge measurements are performed using the

- ☒ test procedure for conducted measurements as described in clause 5.2.
- ☐ test procedure for radiated measurements as described in clause 5.6.

According to clause 11.12.2.1 of ANSI C63.10-2013:

Antenna-port conducted measurements may also be used as an alternative to radiated measurements for determining compliance in the restricted frequency bands requirements. If conducted measurements are performed, then proper impedance matching must be ensured and an additional radiated test for cabinet/case emissions is required.

6.6.4 Test results

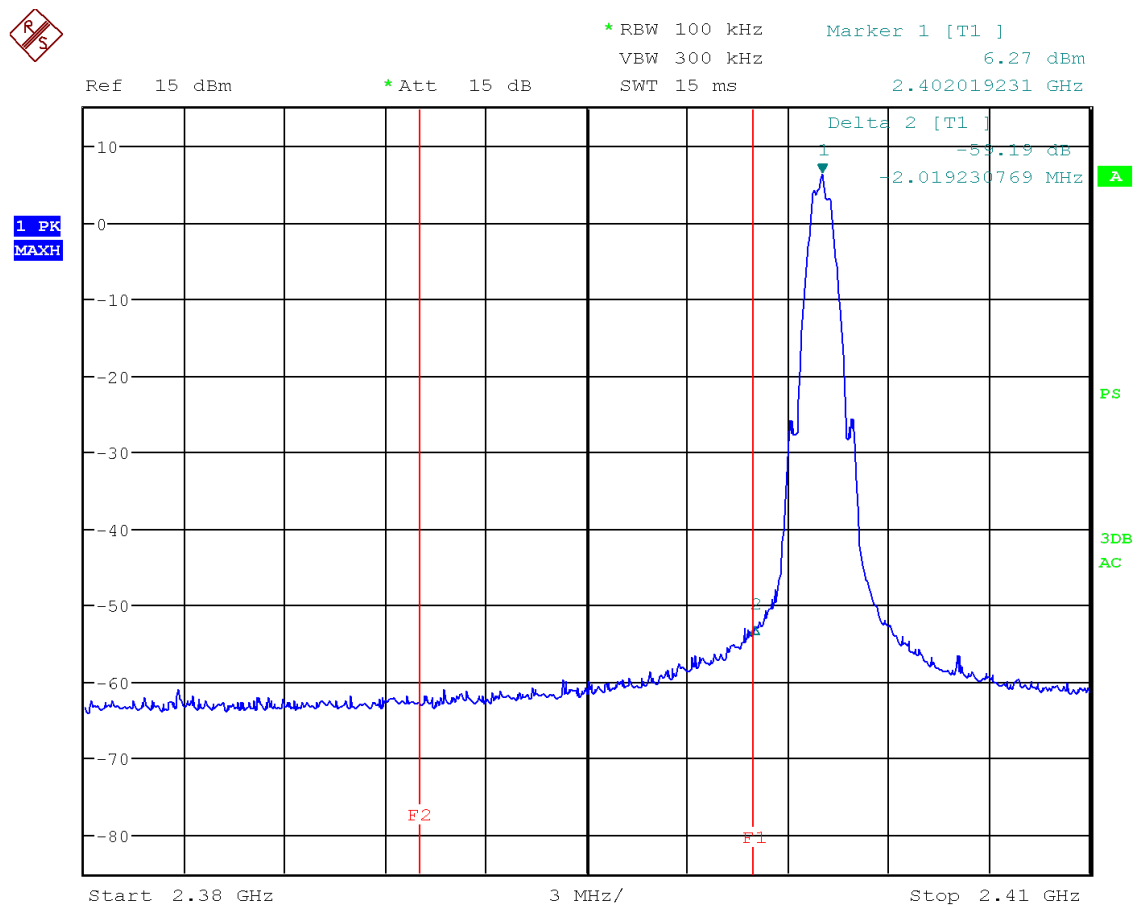


Figure 56: Chart of band-edge measurement on lowest channel, 125 kbps

Frequency (MHz)	Measured Margin (dB)	Limit of minimum margin	Result
2400.000	59.19	≥ 20	Passed

Table 36: Result of band-edge measurement on lowest channel, 125 kbps

Note(s):

1. In the limit line of the chart the antenna gain is not in consideration.
2. Conducted limit in the chart = Field strength limit at 3 m (radiated) – 95.2 dB
3. The antenna gain (Minimum 2 dBi) is in consideration in the result table.

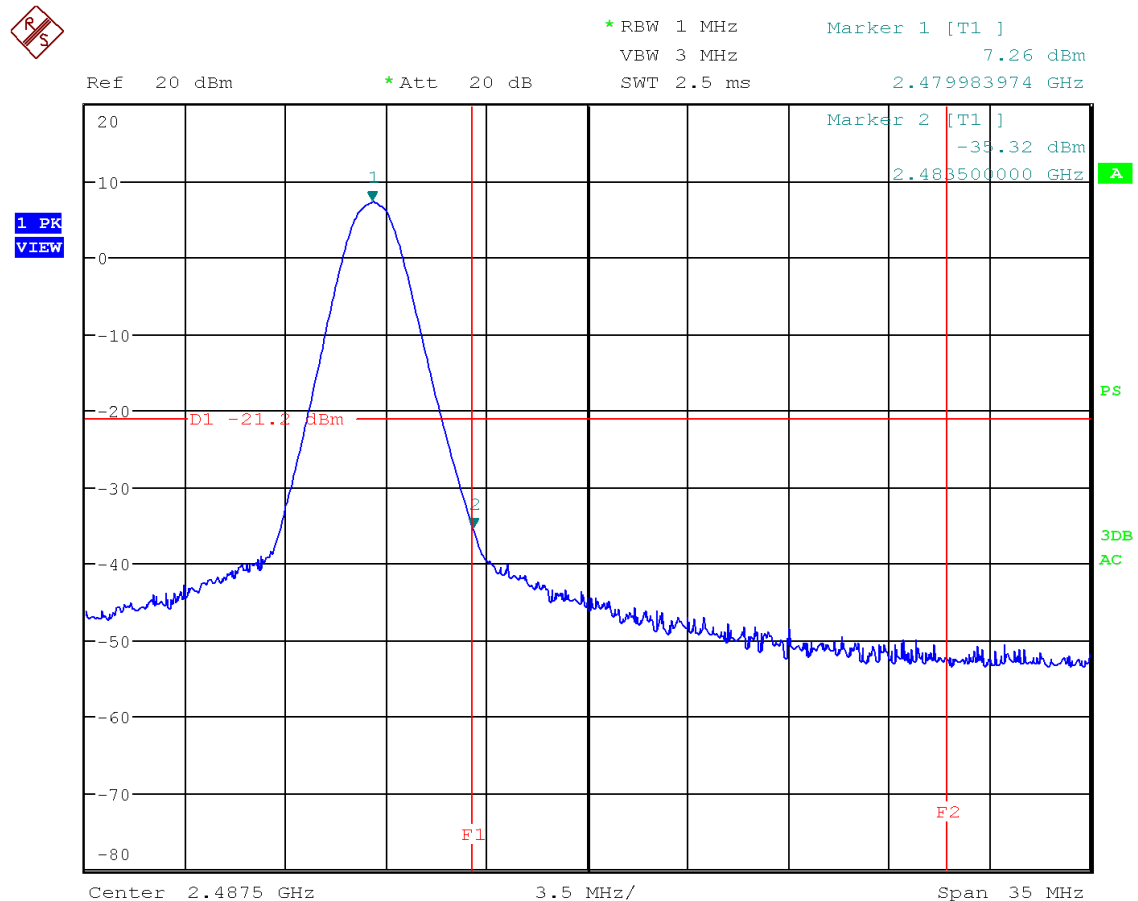


Figure 57: Chart of band-edge measurement on highest channel (PK), 125 kbps

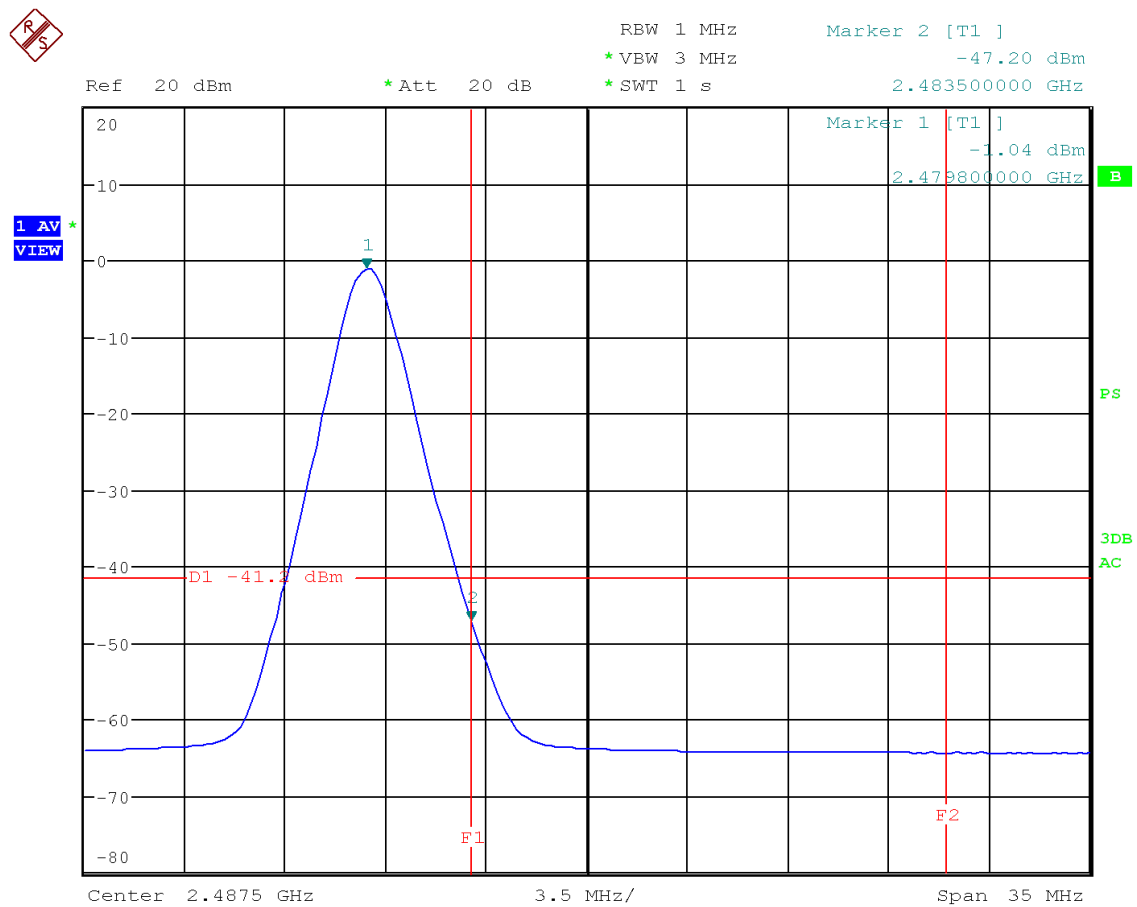


Figure 58: Chart of band-edge measurement on highest channel (AV), 125 kbps

Frequency (MHz)	Max Peak (dBm)	AV (dBm)	Limit (dBm)	Margin (dB)	Result
2483.500	-35.32	---	-23.20	12.12	Passed
2483.500	---	-47.20	-43.20	4.00	Passed

Table 37: Test results of band-edge measurements on highest channel, 125 kbps

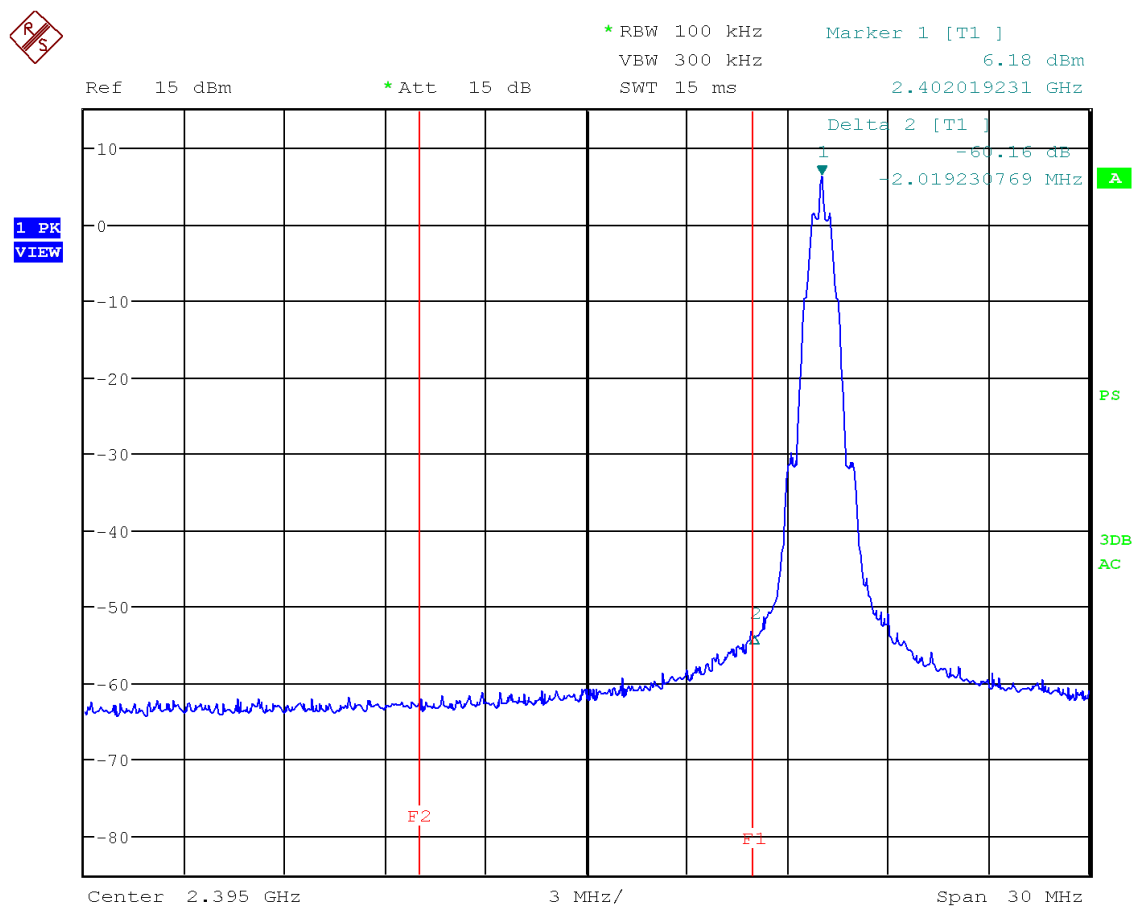


Figure 59: Chart of band-edge measurement on lowest channel, 500 kbps

Frequency (MHz)	Measured Margin (dB)	Limit of minimum margin	Result
2400.000	60.16	≥ 20	Passed

Table 38: Result of band-edge measurement on lowest channel, 500 kbps

Note(s):

1. In the limit line of the chart the antenna gain is not in consideration.
2. Conducted limit in the chart = Field strength limit at 3 m (radiated) – 95.2 dB
3. The antenna gain (Minimum 2 dBi) is in consideration in the result table.

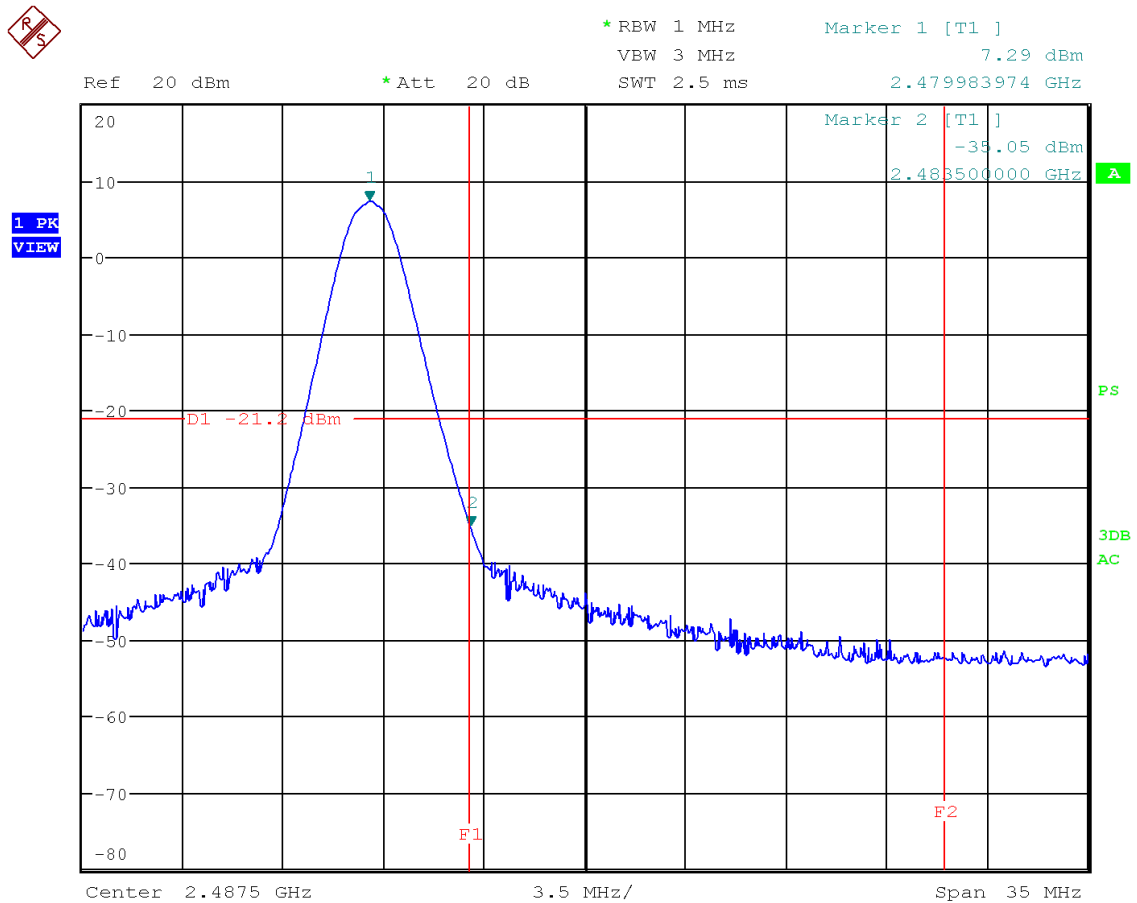


Figure 60: Chart of band-edge measurement on highest channel (PK), 500 kbps

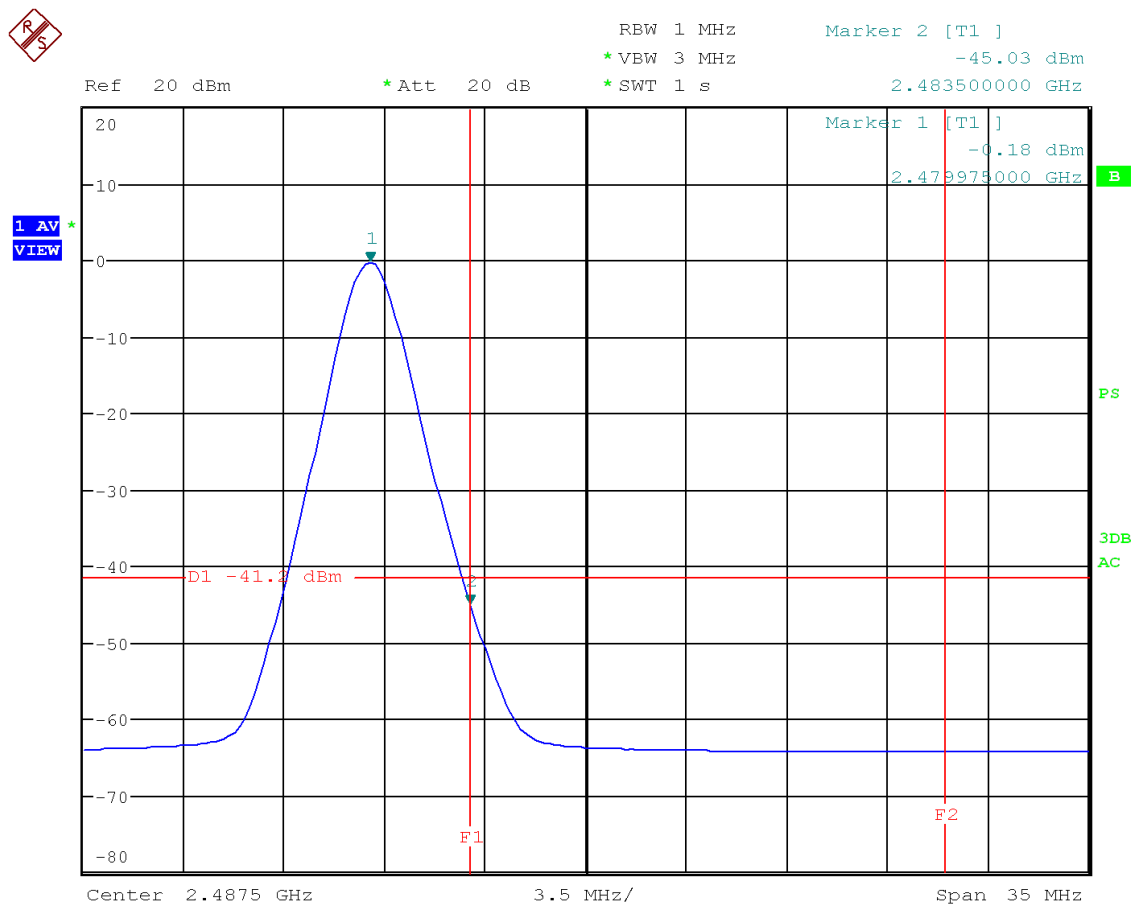


Figure 61: Chart of band-edge measurement on highest channel (AV), 500 kbps

Frequency (MHz)	Max Peak (dBm)	AV (dBm)	Limit (dBm)	Margin (dB)	Result
2483.500	-35.05	---	-23.20	11.85	Passed
2483.500	---	-45.03	-43.20	1.83	Passed

Table 39: Test results of band-edge measurements on highest channel, 500 kbps

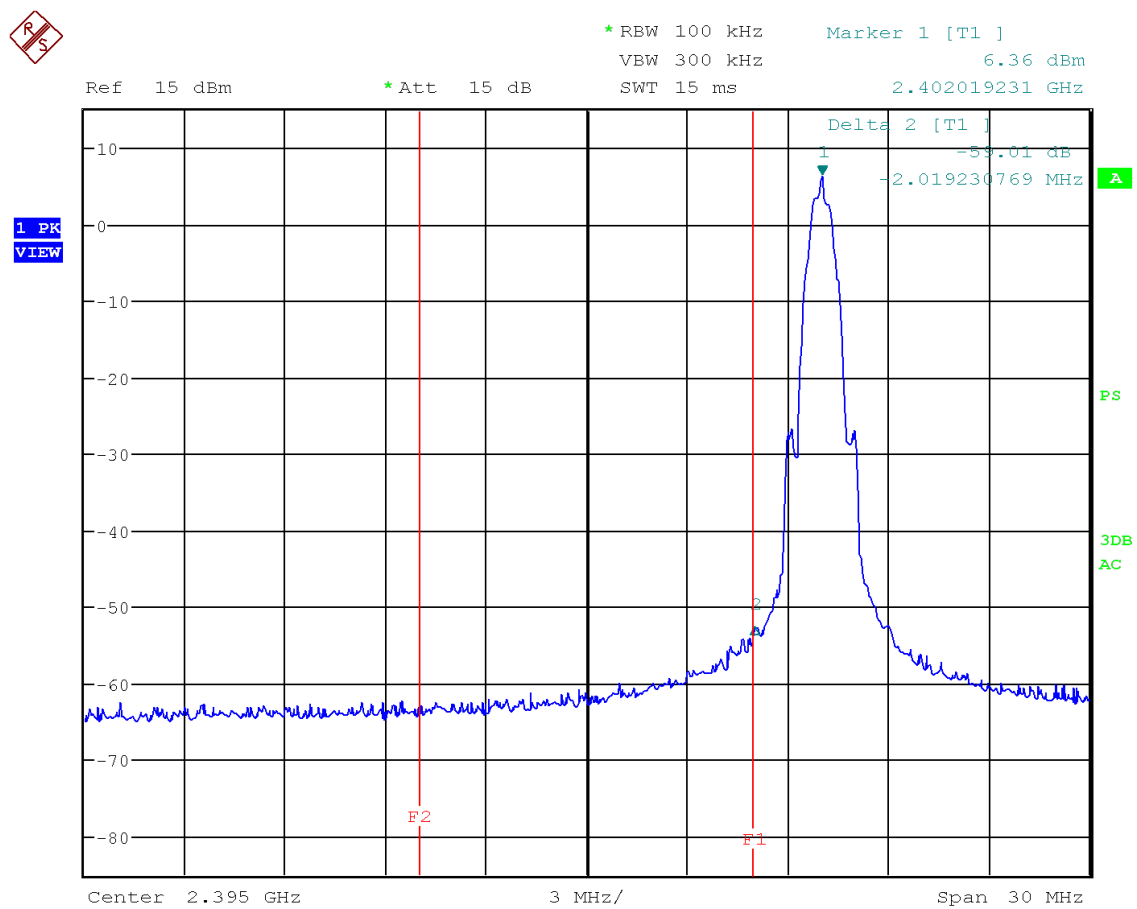


Figure 62: Chart of band-edge measurement on lowest channel, 1 Mbps

Frequency (MHz)	Measured Margin (dB)	Limit of minimum margin	Result
2400.000	59.01	≥ 20	Passed

Table 40: Result of band-edge measurement on lowest channel, 1 Mbps

Note(s):

1. In the limit line of the chart the antenna gain is not in consideration.
2. Conducted limit in the chart = Field strength limit at 3 m (radiated) – 95.2 dB
3. The antenna gain (Minimum 2 dBi) is in consideration in the result table.

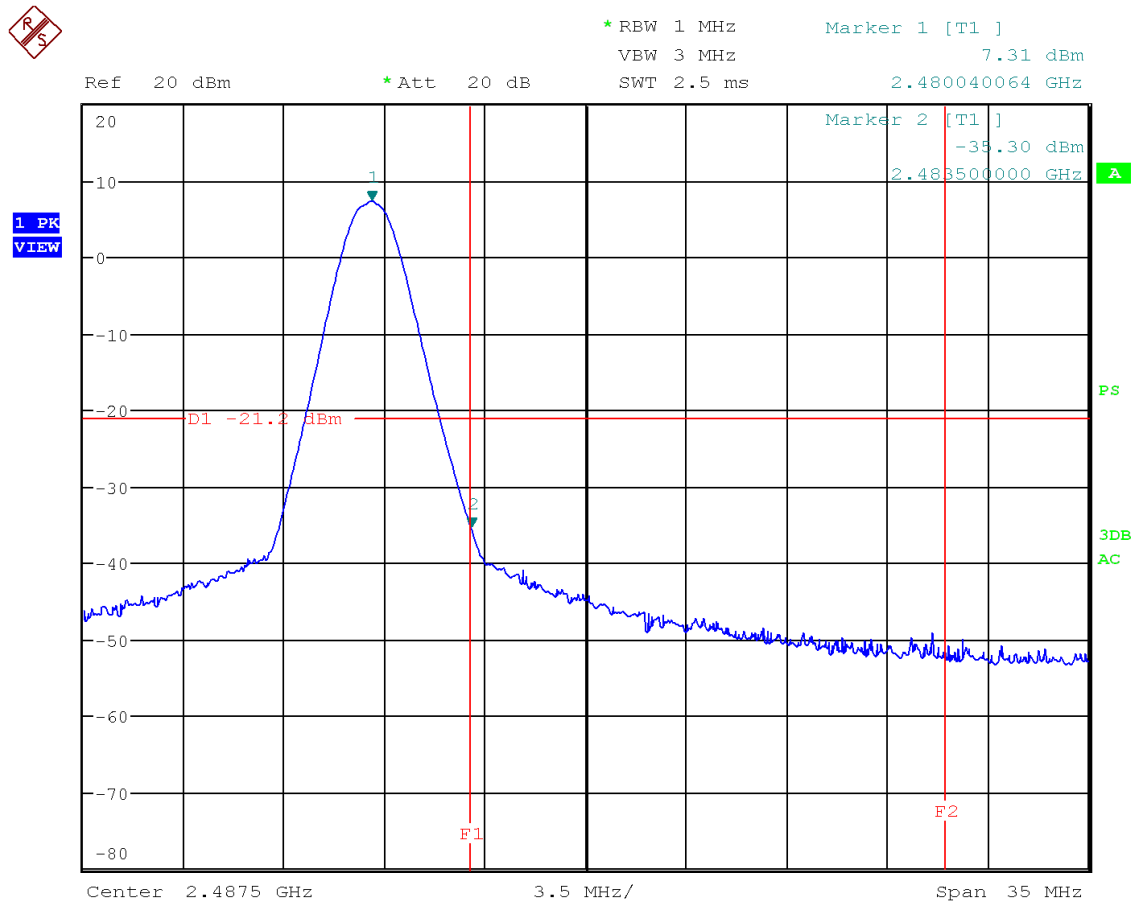


Figure 63: Chart of band-edge measurement on highest channel (PK), 1 Mbps

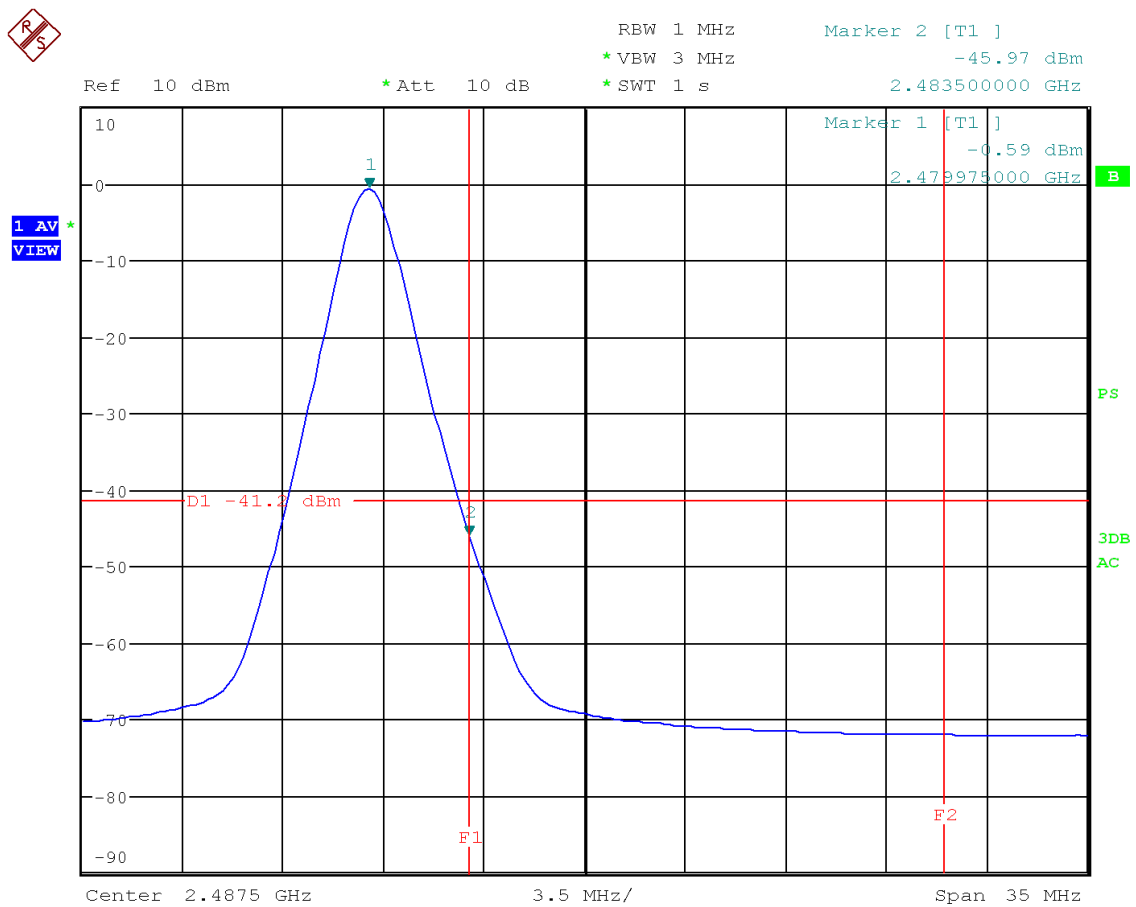


Figure 64: Chart of band-edge measurement on highest channel (AV), 1 Mbps

Frequency (MHz)	Max Peak (dBm)	AV (dBm)	Limit (dBm)	Margin (dB)	Result
2483.500	-35.30	---	-23.20	12.10	Passed
2483.500	---	-45.97	-43.20	2.77	Passed

Table 41: Test results of band-edge measurements on highest channel, 1 Mbps

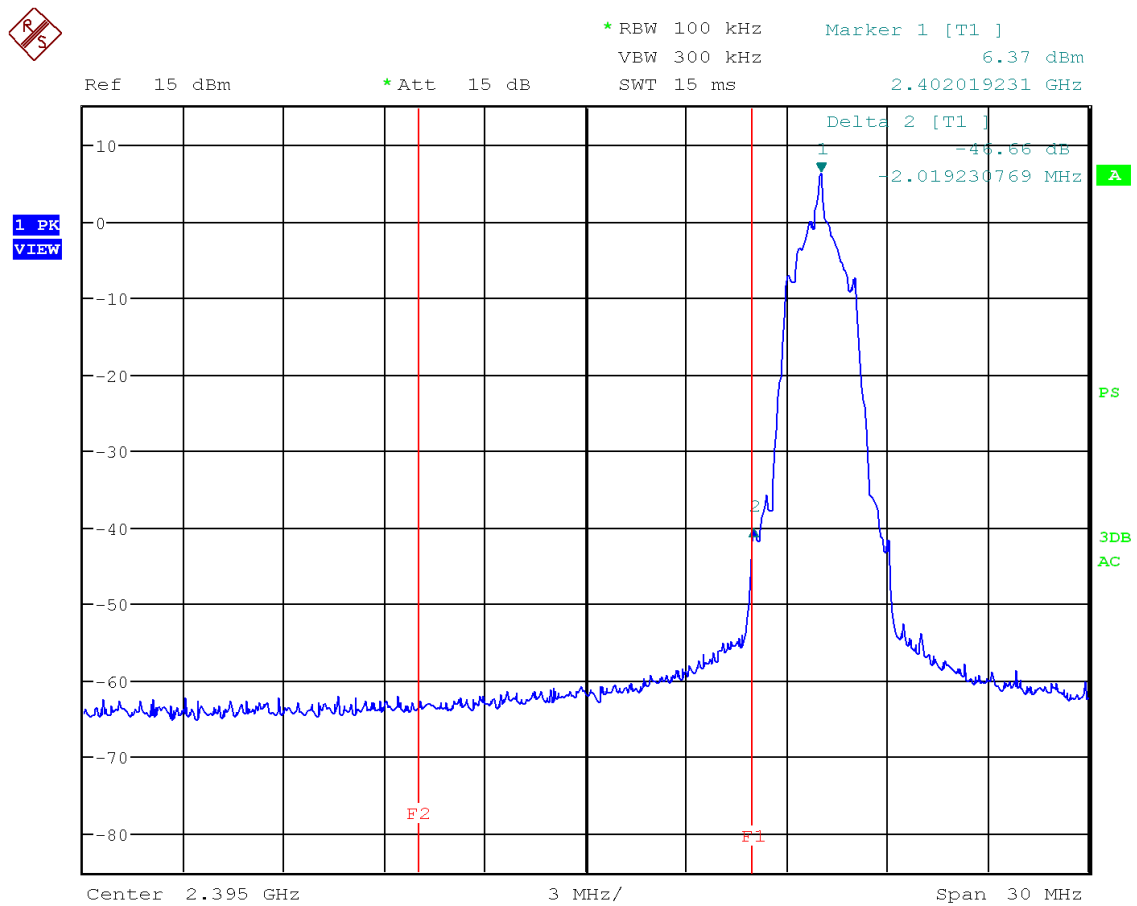


Figure 65: Chart of band-edge measurement on lowest channel, 2 Mbps

Frequency (MHz)	Measured Margin (dB)	Limit of minimum margin	Result
2400.000	46.66	≥ 20	Passed

Table 42: Result of band-edge measurement on lowest channel, 2 Mbps

Note(s):

1. In the limit line of the chart the antenna gain is not in consideration.
2. Conducted limit in the chart = Field strength limit at 3 m (radiated) – 95.2 dB
3. The antenna gain (Minimum 2 dBi) is in consideration in the result table.

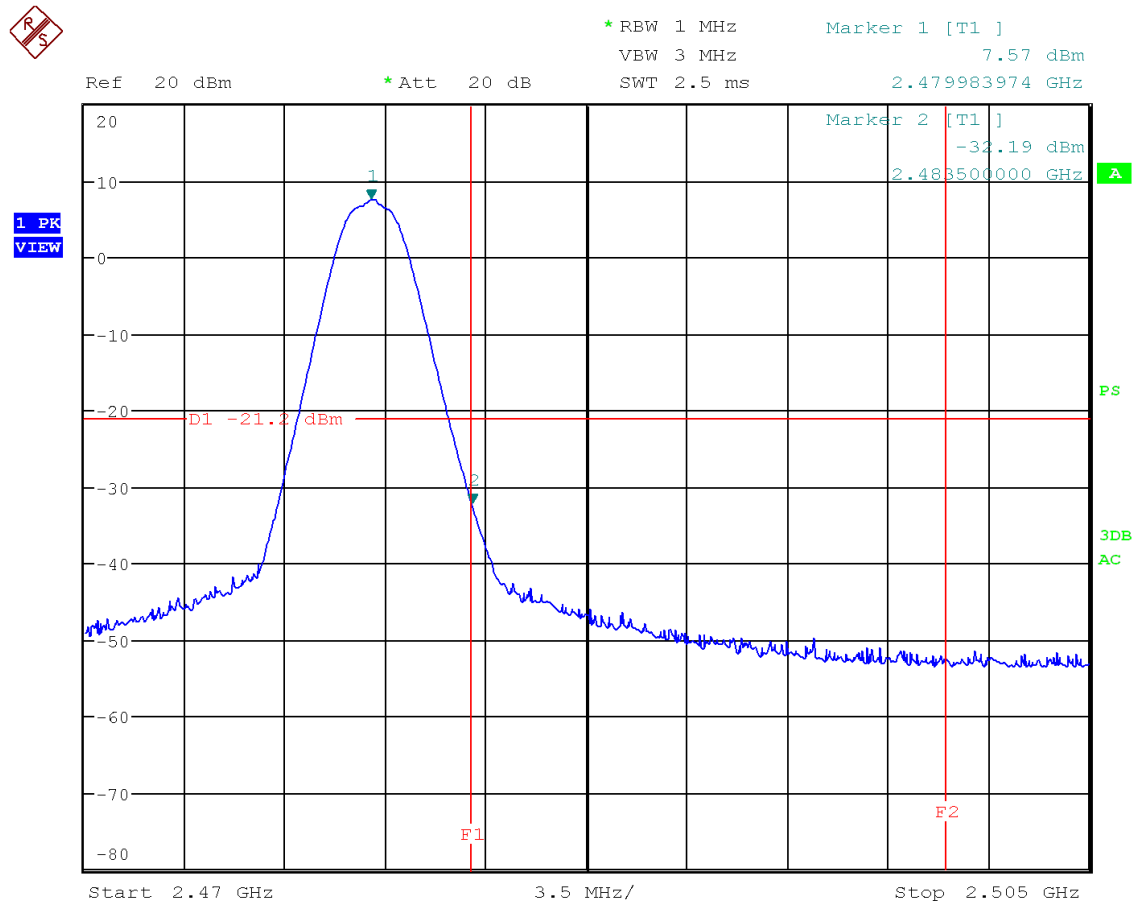


Figure 66: Chart of band-edge measurement on highest channel (PK), 2 Mbps

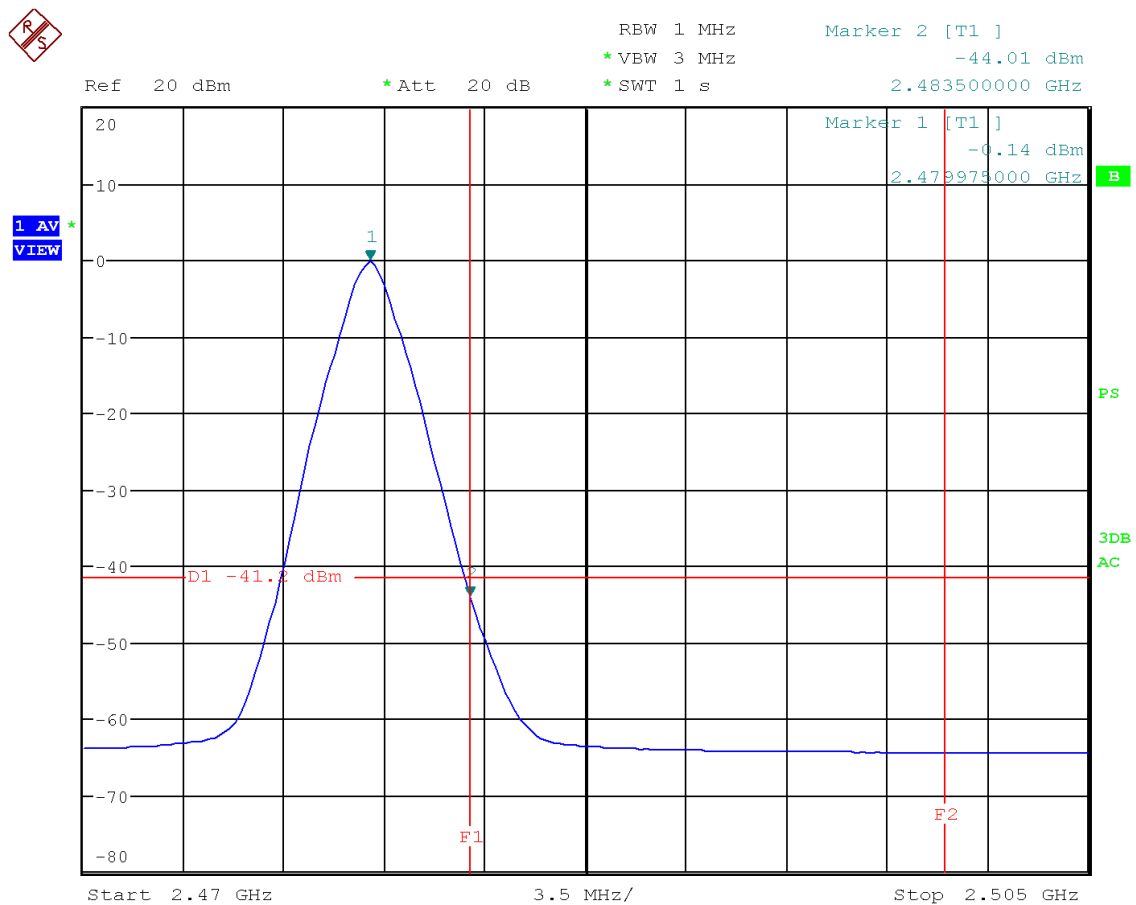


Figure 67: Chart of band-edge measurement on highest channel (AV), 2 Mbps

Frequency (MHz)	Max Peak (dBm)	AV (dBm)	Limit (dBm)	Margin (dB)	Result
2483.500	-32.19	---	-23.20	8.99	Passed
2483.500	---	-44.01	-43.20	0.81	Passed

Table 43: Test results of band-edge measurements on highest channel, 2 Mbps

6.7 Antenna-port conducted measurements

Section(s) in 47 CFR Part 15:	Requirement(s): Reference(s):	15.247(d) KDB 558074 D01, clauses 8.6 ANSI C63.10, clause 11.12.2
Section(s) in RSS:	Requirement(s): Reference(s):	RSS-247, section 5.5 KDB 558074 D01, clauses 8.6 ANSI C63.10, clause 11.12.2

Performed by:	Jennifer Riedel B. Eng.	Date(s) of test:	February 3, 2023
Result:	☒ Test passed	☐ Test not passed	

6.7.1 Test equipment

Type	Designation	Manufacturer	Inventory no.
EMI test receiver	ESU 26	Rohde & Schwarz	W00002

6.7.2 Limits

According to §15.247(d) and RSS-247 section 5.5:

In any 100 kHz bandwidth outside of 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.

In addition, radiated emissions which fall in the restricted bands (see table 35) must also comply with the radiated emission limits specified in §15.209(a) and RSS-Gen section 8.10.

Frequency (MHz)	Field strength		Measurement distance (m)
	($\mu\text{V}/\text{m}$)	($\text{dB}\mu\text{V}/\text{m}$)	
0.009 – 0.490	2400/F(kHz) (266.67 – 4.90)	48.52 – 13.80	300
0.490 – 1.705	24000/F(kHz) (48.98 – 14.08)	33.80 – 22.97	30
1.705 – 30	30	29.54	30
30 – 88	100	40.00	3
88 – 216	150	43.52	3
216 – 960	200	46.02	3
Above 960	500	53.98	3

Table 44: General radiated emission limits from 9 kHz to 25 GHz according to §15.209

Frequency (MHz)	Magnetic field strength		Measurement distance (m)
	($\mu\text{A/m}$)	($\text{dB}\mu\text{A/m}$)	
0.009 – 0.490	6.37/F(kHz)	-2.999 – -37.721	300
0.490 – 1.705	63.7/F(kHz)	-17.721 – -28.636	30
1.705 – 30	0.08	-21.94	30

Table 45: General radiated emission limits from 9 kHz to 30 MHz according to RSS-Gen section 8.9

Frequency (MHz)	Field strength		Measurement distance (m)
	($\mu\text{V/m}$)	($\text{dB}\mu\text{V/m}$)	
30 – 88	100	40.00	3
88 – 216	150	43.52	3
216 - 960	200	46.02	3
Above 960	500	53.98	3

Table 46: General radiated emission limits from 30 MHz to 25 GHz according to RSS-Gen section 8.9

In case of measurements are performed at other distances than that specified in the requirements, the limits in the charts and tables reported with the test results are derived from the general radiated emission limits as listed in table 59 using the recalculation factor as described in clause 5.3.

6.7.3 Test procedure

The emissions from 9 kHz to 25 GHz are measured using the

- ☒ test procedure for conducted measurements as described in clause 5.2.
- ☐ test procedure for radiated measurements as described in clause 5.3.

6.7.4 Test results

Note(s)

- 1 The power limit lines in all charts are calculated from the field strength limits at 3 m measurement distance with an antenna gain of 0 dBi. The maximum antenna gain is 1.1 dBi. According to ANSI C63.10 clause 11.12.2.6, the gain of the transmitting antenna must be added to the measured output power, either the maximum in-band gain of the antenna across all operating bands or 2 dBi, whichever is greater.
- 2 The measured output power values were corrected by 2 dB.
- 3 The operating frequency band from 2400 MHz to 2483.5 MHz is not shown in the charts because it is not in consideration in this clause.
- 4 According to clause 6.6.4.3, note 1 of ANSI C63.10, if the maximized peak measured value complies with the average limit, than it is unnecessary to perform an average measurement.
- 5 The band edge measurements are in consideration in clause 6.6.

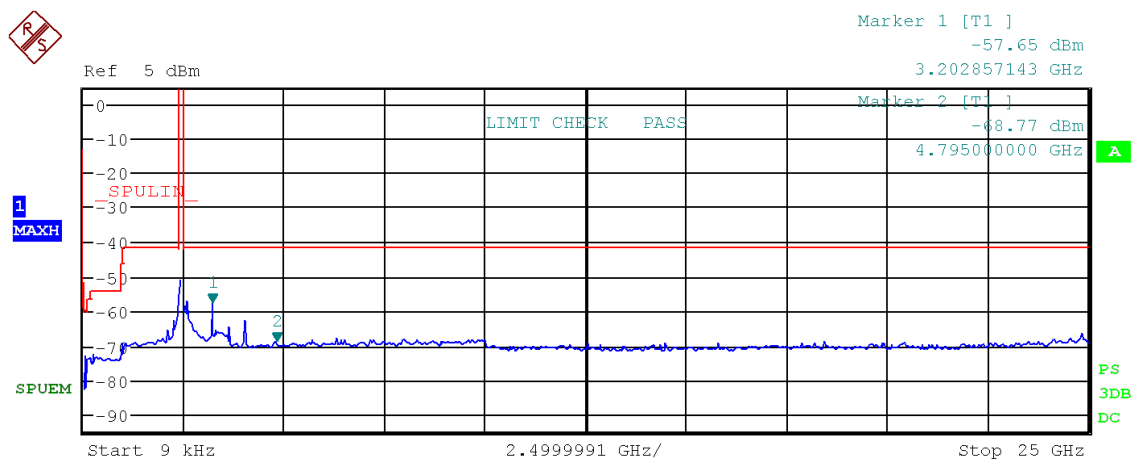


Figure 68: Chart of emissions test from 9 kHz to 25 GHz on lowest channel, 125 kbps, PK-detector

Frequency (MHz)	Level (dBm)	Detector	Limit (dBm)	Margin (dB)
47.207	-71.24	PK	-59.90	11.34
2389.537	-51.45	PK	-21.20	30.25
2559.571	-55.44	PK	-21.20	34.24
3202.857	-55.65	PK	-21.20	34.45
4000.000	-60.92	PK	-21.20	39.72
4795.000	-66.77	PK	-21.20	45.57

Table 47: Results of emissions test from 9 kHz to 25 GHz on lowest channel, 125 kbps

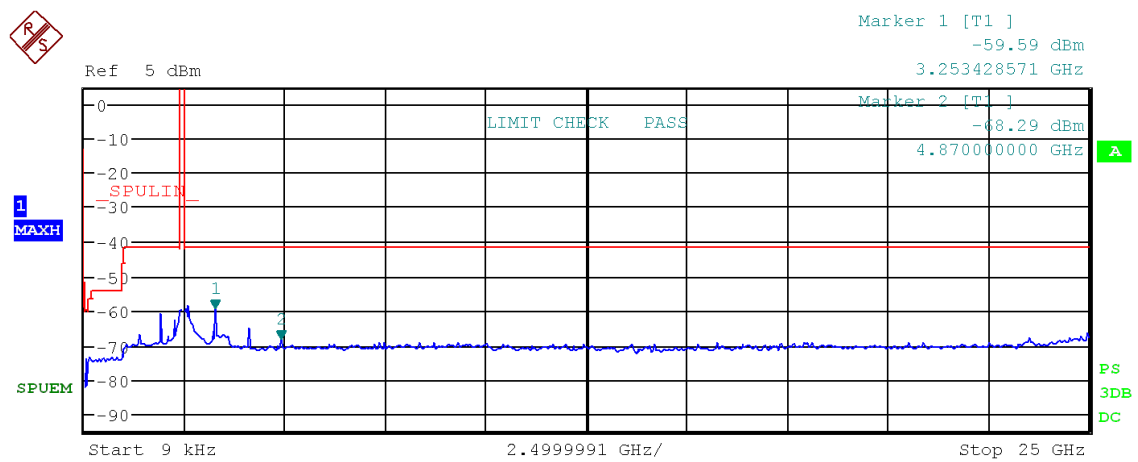


Figure 69: Chart of emissions test from 9 kHz to 25 GHz on middle channel, 125 kbps, PK-detector

Frequency (MHz)	Level (dBm)	Detector	Limit (dBm)	Margin (dB)
33.248	-72.04	PK	-59.90	12.14
2389.073	-58.03	PK	-21.20	36.83
2559.571	-56.42	PK	-21.20	35.22
3253.429	-57.59	PK	-21.20	36.39
4060.000	-64.13	PK	-21.20	42.93
4870.000	-66.29	PK	-21.20	45.09

Table 48: Results of emissions test from 9 kHz to 25 GHz on middle channel, 125 kbps

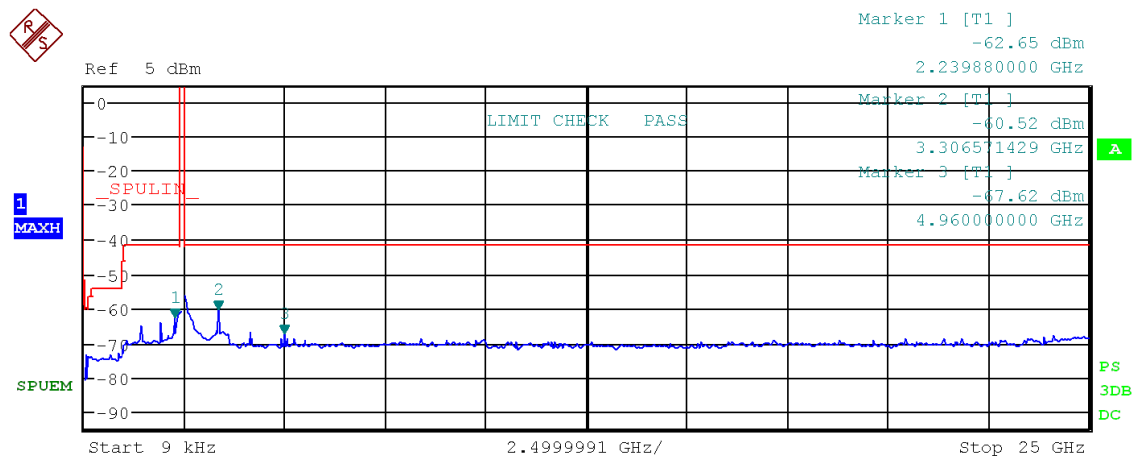


Figure 70: Chart of emissions test from 9 kHz to 25 GHz on highest channel, 125 kbps, PK-detector

Frequency (MHz)	Level (dBm)	Detector	Limit (dBm)	Margin (dB)
44.809	-71.81	PK	-59.90	11.91
2239.880	-60.65	PK	-21.20	39.45
2389.537	-58.81	PK	-21.20	37.61
2501.286	-54.43	PK	-21.20	33.23
3306.571	-58.52	PK	-21.20	37.32
4120.000	-65.06	PK	-21.20	43.86
4960.000	-65.62	PK	-21.20	44.42

Table 49: Results of emissions test from 9 kHz to 25 GHz on highest channel, 125 kbps

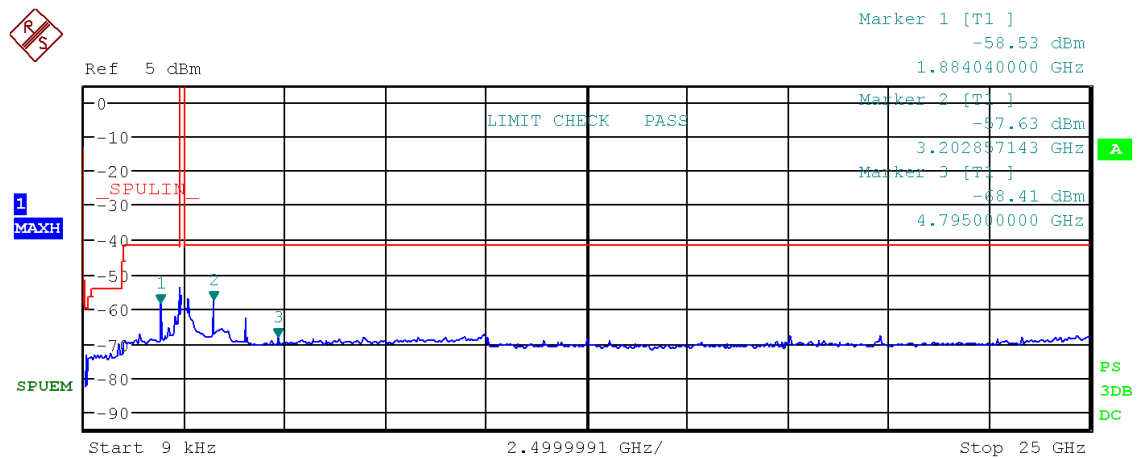


Figure 71: Chart of emissions test from 9 kHz to 25 GHz on lowest channel, 500 kbps, PK-detector

Frequency (MHz)	Level (dBm)	Detector	Limit (dBm)	Margin (dB)
39.976	-71.83	PK	-59.90	11.93
1884.040	-56.53	PK	-21.20	35.33
2382.123	-52.12	PK	-21.20	30.92
3202.857	-55.63	PK	-21.20	34.43
4000.000	-61.07	PK	-21.20	39.87
4795.000	-66.41	PK	-21.20	45.21

Table 50: Results of emissions test from 9 kHz to 25 GHz on lowest channel, 500 kbps

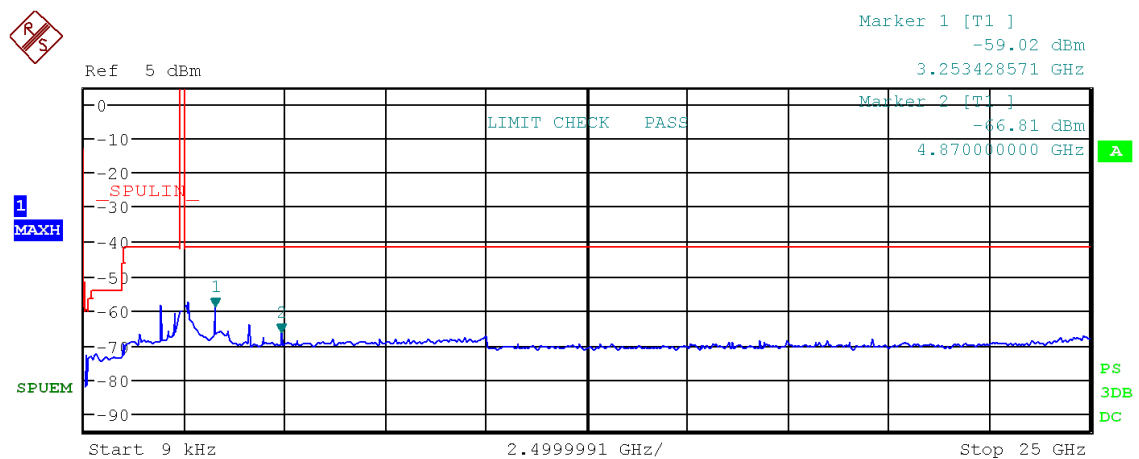


Figure 72: Chart of emissions test from 9 kHz to 25 GHz on middle channel, 500 kbps, PK-detector

Frequency (MHz)	Level (dBm)	Detector	Limit (dBm)	Margin (dB)
39.241	-71.02	PK	-59.90	11.12
1883.113	-56.42	PK	-21.20	35.22
2559.571	-55.56	PK	-21.20	34.36
3253.429	-57.02	PK	-21.20	35.82
4060.000	-62.44	PK	-21.20	41.24
4870.000	-64.81	PK	-21.20	43.61

Table 51: Results of emissions test from 9 kHz to 25 GHz on middle channel, 500 kbps

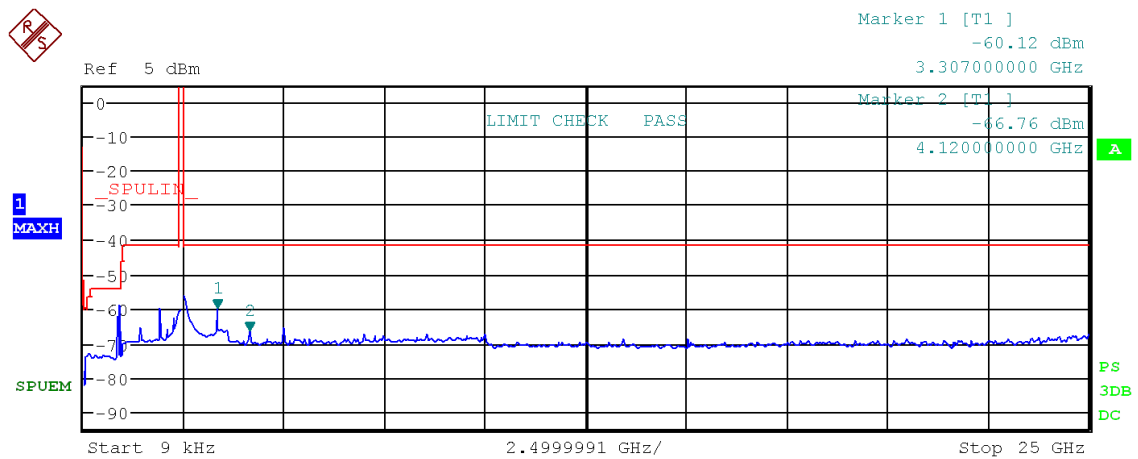


Figure 73: Chart of emissions test from 9 kHz to 25 GHz on highest channel, 500 kbps, PK-detector

Frequency (MHz)	Level (dBm)	Detector	Limit (dBm)	Margin (dB)
60.779	-71.91	PK	-59.90	12.01
861.494	-57.07	PK	-53.90	3.17
1897.013	-57.82	PK	-21.20	36.62
2502.142	-54.13	PK	-21.20	32.93
3307.000	-58.12	PK	-21.20	36.92
4120.000	-64.76	PK	-21.20	43.56
4960.000	-64.66	PK	-21.20	43.46

Table 52: Results of emissions test from 9 kHz to 25 GHz on highest channel, 500 kbps

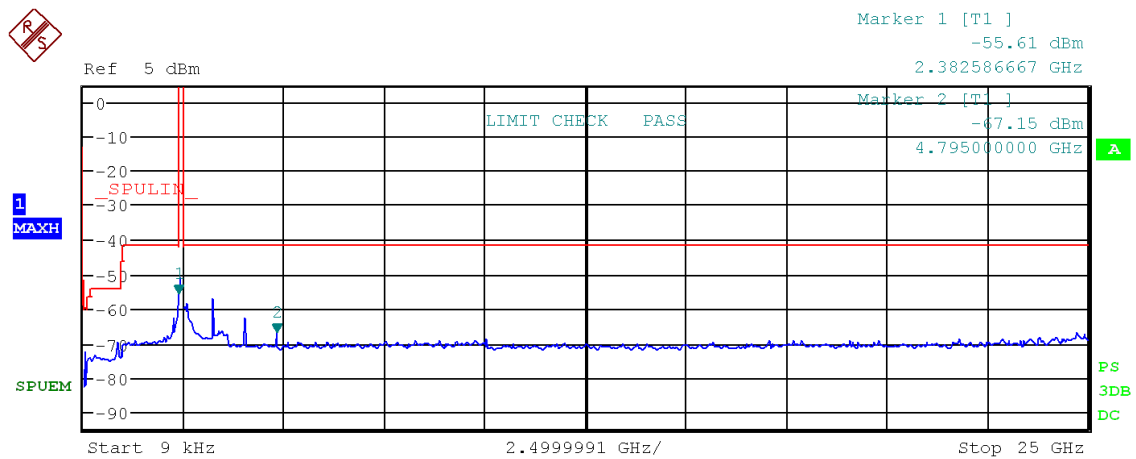


Figure 74: Chart of emissions test from 9 kHz to 25 GHz on lowest channel, 1 Mbps, PK-detector

Frequency (MHz)	Level (dBm)	Detector	Limit (dBm)	Margin (dB)
39.976	-70.90	PK	-59.90	11.00
2382.587	-53.61	PK	-21.20	32.41
2388.610	-49.32	PK	-21.20	28.12
3202.857	-54.99	PK	-21.20	33.79
4000.000	-60.70	PK	-21.20	39.50
4795.000	-65.15	PK	-21.20	43.95

Table 53: Results of emissions test from 9 kHz to 25 GHz on lowest channel, 1 Mbps

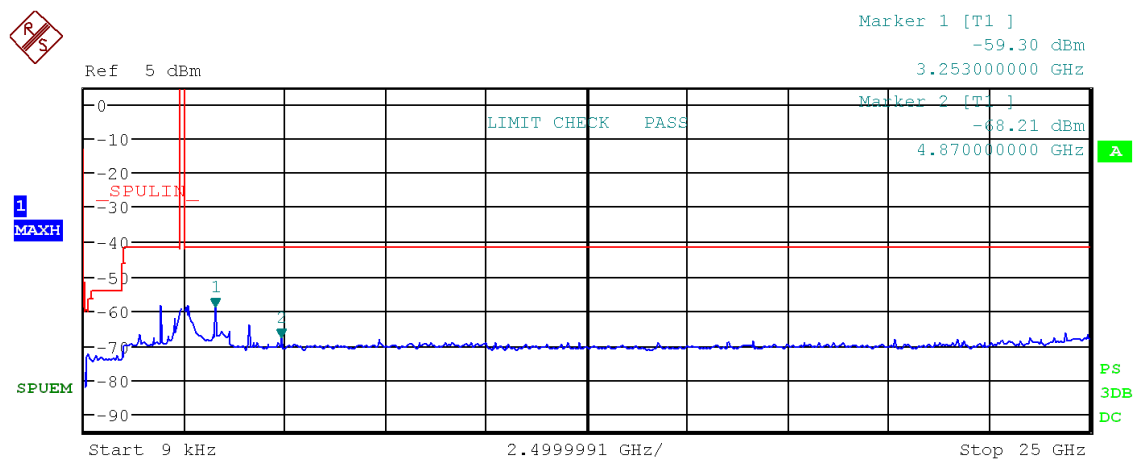


Figure 75: Chart of emissions test from 9 kHz to 25 GHz on middle channel, 1 Mbps, PK-detector

Frequency (MHz)	Level (dBm)	Detector	Limit (dBm)	Margin (dB)
66.192	-71.49	PK	-59.90	11.59
1896.087	-56.58	PK	-21.20	35.38
2560.000	-56.65	PK	-21.20	35.45
3253.000	-57.30	PK	-21.20	36.10
4060.000	-62.41	PK	-21.20	41.21
4870.000	-66.21	PK	-21.20	45.01

Table 54: Results of emissions test from 9 kHz to 25 GHz on middle channel, 1 Mbps

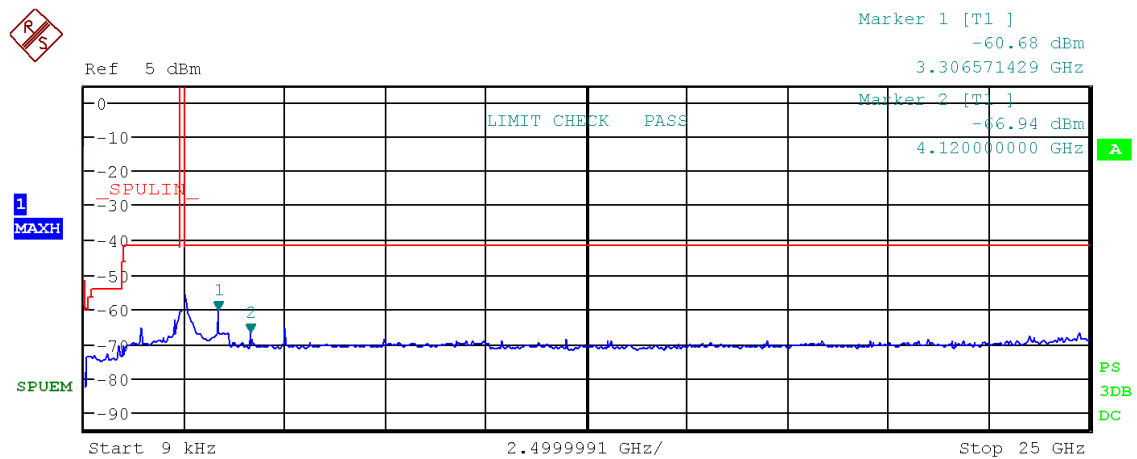


Figure 76: Chart of emissions test from 9 kHz to 25 GHz on highest channel, 1 Mbps, PK-detector

Frequency (MHz)	Level (dBm)	Detector	Limit (dBm)	Margin (dB)
56.061	-72.17	PK	-59.90	12.27
2387.220	-58.80	PK	-21.20	37.60
2500.429	-53.86	PK	-21.20	32.66
3306.571	-58.68	PK	-21.20	37.48
4120.000	-64.94	PK	-21.20	43.74
4960.000	-63.76	PK	-21.20	42.56

Table 55: Results of emissions test from 9 kHz to 25 GHz on highest channel, 1 Mbps

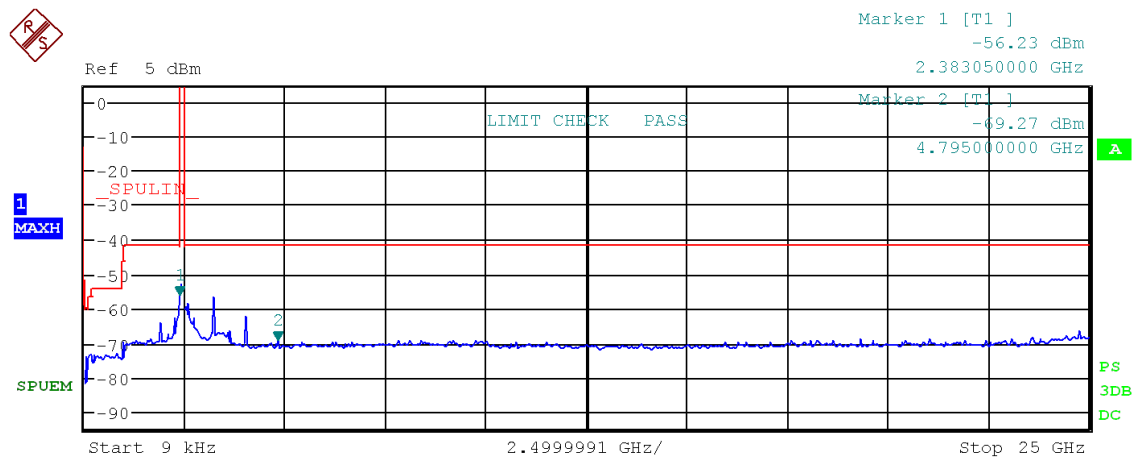


Figure 77: Chart of emissions test from 9 kHz to 25 GHz on lowest channel, 2 Mbps, PK-detector

Frequency (MHz)	Level (dBm)	Detector	Limit (dBm)	Margin (dB)
37.733	-72.00	PK	-59.90	12.10
2383.050	-54.23	PK	-21.20	33.03
2388.610	-50.91	PK	-21.20	29.71
3202.857	-54.84	PK	-21.20	33.64
4000.000	-60.58	PK	-21.20	39.48
4795.000	-67.27	PK	-21.20	46.07

Table 56: Results of emissions test from 9 kHz to 25 GHz on lowest channel, 2 Mbps

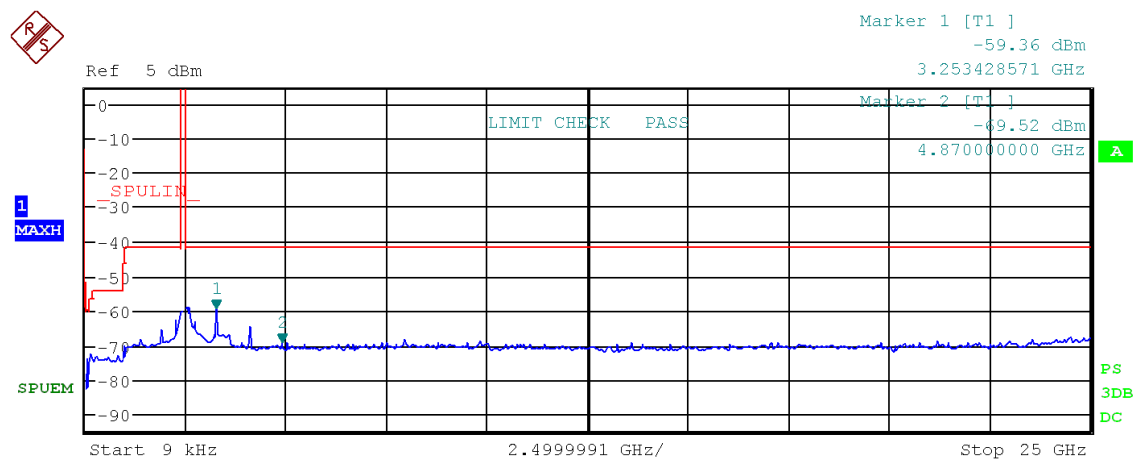


Figure 78: Chart of emissions test from 9 kHz to 25 GHz on middle channel, 2 Mbps, PK-detector

Frequency (MHz)	Level (dBm)	Detector	Limit (dBm)	Margin (dB)
67.004	-72.04	PK	-59.90	12.14
2380.733	-58.59	PK	-21.20	37.39
2559.571	-56.96	PK	-21.20	35.76
3253.429	-57.36	PK	-21.20	36.16
4060.000	-62.77	PK	-21.20	41.57
4870.000	-67.52	PK	-21.20	46.32

Table 57: Results of emissions test from 9 kHz to 25 GHz on middle channel, 2 Mbps

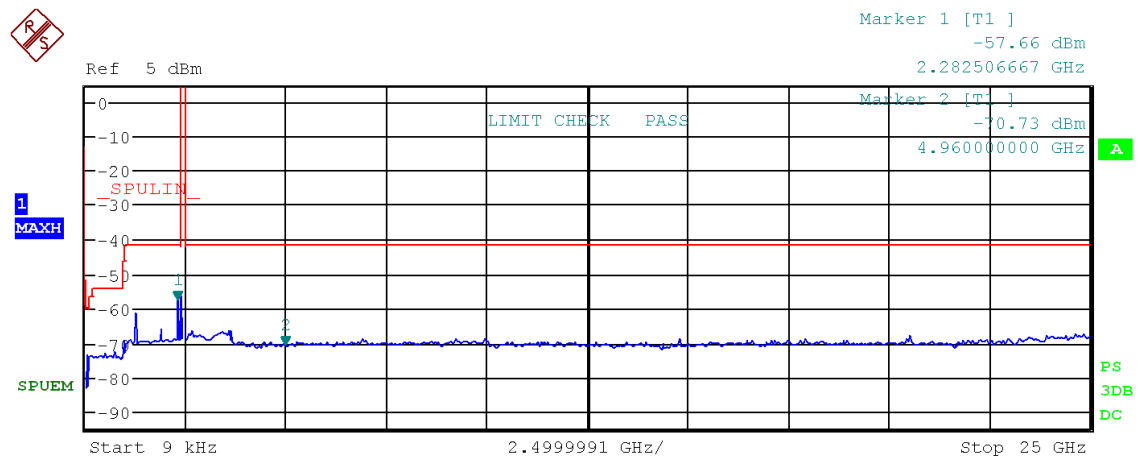


Figure 79: Chart of emissions test from 9 kHz to 25 GHz on highest channel, 2 Mbps, PK-detector

Frequency (MHz)	Level (dBm)	Detector	Limit (dBm)	Margin (dB)
38.661	-71.46	PK	-59.90	11.56
2282.507	-55.66	PK	-21.20	34.46
2371.003	-54.36	PK	-21.20	33.16
3572.714	-64.64	PK	-21.20	43.44
4960.000	-68.73	PK	-21.20	47.53

Table 58: Results of emissions test from 9 kHz to 25 GHz on highest channel, 2 Mbps

6.8 Radiated emissions below 30 MHz

Section(s) in 47 CFR Part 15:	Requirement(s):	15.247(d)
	Reference(s):	KDB 558074 D01, clauses 8.5 and 8.6 ANSI C63.10, clause 6.4
Section(s) in RSS:	Requirement(s):	RSS-247, section 5.5
	Reference(s):	KDB 558074 D01, clauses 8.5 and 8.6 ANSI C63.10, clause 6.4

Performed by:	Konrad Graßl	Date(s) of test:	July 12, 2023
Result:	☒ Test passed	☐ Test not passed	

6.8.1 Test equipment

Type	Designation	Manufacturer	Inventory no.
Compact Diagnostic Chamber (CDC)	VK041.0174	Albatross Projects	E00026
EMI test receiver	ESW 44	Rohde & Schwarz	E00895
Loop antenna	HFH2-Z2	Rohde & Schwarz	E00060
Cable set CDC	RF cable(s)	Huber + Suhner AME HF-Technik AME HF-Technik Stabo	E00446 E00920 E00921 E01215

6.8.2 Limits

According to §15.247(d) and RSS-247 section 5.5:

In any 100 kHz bandwidth outside of 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.

In addition, radiated emissions which fall in the restricted bands (see table 35) must also comply with the radiated emission limits specified in §15.209(a) and RSS-Gen section 8.10.

For the frequency range 9 kHz to 30 MHz, these limits are shown in table 59 and Table 60.

Frequency (MHz)	Field strength		Measurement distance (m)
	($\mu\text{V/m}$)	($\text{dB}\mu\text{V/m}$)	
0.009 – 0.490	2400/F(kHz) (266.67 – 4.90)	48.52 – 13.80	300
0.490 – 1.705	24000/F(kHz) (48.98 – 14.08)	33.80 – 22.97	30
1.705 – 30	30	29.54	30

Table 59: General radiated emission limits up to 30 MHz according to §15.209

Frequency (MHz)	Magnetic field strength		Measurement distance (m)
	($\mu\text{A/m}$)	($\text{dB}\mu\text{A/m}$)	
0.009 – 0.490	6.37/F(kHz)	-2.999 – -37.721	300
0.490 – 1.705	63.7/F(kHz)	-17.721 – -28.636	30
1.705 – 30	0.08	-21.94	30

Table 60: General radiated emission limits from 9 kHz to 30 MHz according to section 8.9 of RSS-Gen

In case of measurements are performed at other distances than that specified in the requirements, the limits in the charts and tables reported with the test results are derived from the general radiated emission limits as listed in table 59 using the recalculation factor as described in clause 5.3.

6.8.3 Test procedure

The emissions below 30 MHz are measured using the

- ☐ test procedure for conducted measurements as described in clause 5.2.
- ☒ test procedure for radiated measurements as described in clause 5.4.2.

The following parameters are set:

Frequency range	IF Bandwidth	Preamplifier
9 kHz – 150 kHz	200 Hz	Off
150 kHz – 30 MHz	9 kHz	Off

Figure 80: Chart of emissions test below 30 MHz on lowest channel, 1 Mbps, EUT position Y, antenna in line to the EUT

6.9 Radiated emissions from 30 MHz to 1 GHz

Section(s) in 47 CFR Part 15:	Requirement(s):	15.247(d)
	Reference(s):	KDB 558074 D01, clauses 8.4 and 8.5 ANSI C63.10, clause 6.5
Section(s) in RSS:	Requirement(s):	RSS-247, section 5.5
	Reference(s):	KDB 558074 D01, clauses 8.4 and 8.5 ANSI C63.10, clause 6.5

Performed by:	Konrad Graßl	Date(s) of test:	June 20, 2023
Result:	☒ Test passed	☐ Test not passed	

6.9.1 Test equipment

Type	Designation	Manufacturer	Inventory no.
Semi-anechoic chamber (SAC)	SAC3	Albatross Projects	E00716
EMI test receiver	ESR 7	Rohde & Schwarz	E00739
TRILOG broadband antenna (SAC)	VULB 9162	Schwarzbeck	E00643
Cable set SAC	RF cable(s)	Huber + Suhner	E00755 E01033 E01034
Test software	EMC32-(M)EB, V10.60.20	Rohde & Schwarz	E00777, E00778 or E01073

6.9.2 Limits

According to §15.247(d) and RSS-247 section 5.5:

In any 100 kHz bandwidth outside of 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.

In addition, radiated emissions which fall in the restricted bands (see table 35) must also comply with the radiated emission limits specified in §15.209(a) and RSS-Gen section 8.10.

For frequencies equal to and above 30 MHz, these limits are shown in table 61.

<i>Frequency (MHz)</i>	<i>Field strength</i>		<i>Measurement distance (m)</i>
	<i>(μV/m)</i>	<i>(dBμV/m)</i>	
30 – 88	100	40.00	3
88 – 216	150	43.52	3
216 - 960	200	46.02	3
Above 960	500	53.98	3

Table 61: General radiated emission limits $\geq$ 30 MHz according to §15.209 and RSS-Gen section 8.9

6.9.3 Test procedure

The emissions from 30 MHz to 1 GHz are measured using the

- ☐ test procedure for conducted measurements as described in clause 5.2.
- ☒ test procedure for radiated measurements as described in clause 5.5.1.

The following parameters are set:

<i>Frequency range</i>	<i>IF Bandwidth</i>	<i>Preamplifier</i>
30 MHz – 1 GHz	120 kHz	20 dB

6.9.4 Test results

Test distance:	☒ 3 m	☐ 10 m	☐ m
Polarization:	☒ horizontal	☒ vertical	
EUT position:	☒ Position X	☒ Position Y	☒ Position Z

Note(s)

- 1 Pre-measurements were performed to declare the worst case which is documented below.
- 2 Pre-measurements have shown that there are no differences between the tested channels in the range of 30 MHz to 1 GHz, so the final measurement was only performed on channel low.
- 3 According to clause 6.7 the worst case data rate is 1 Mbps.
- 4 According to clause 4.1.4.2.1 of ANSI C63.10: As an alternative to CISPR quasi-peak measurements or average measurements, a test laboratory may demonstrate compliance with the emission limits using measuring equipment employing a peak detector function as long as the equivalent or greater bandwidths as indicated for CISPR quasi-peak measurements or average measurements, as applicable, are employed.
- 5 The antenna port was terminated with 50 ohm.

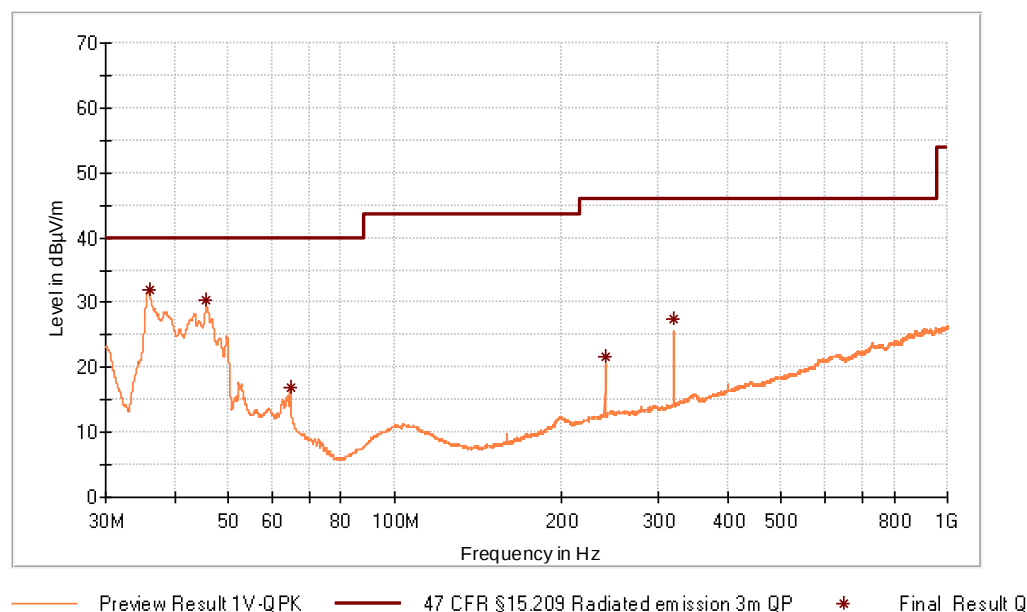


Figure 81: Chart of emissions test from 30 MHz to 1 GHz on lowest channel, 1 Mbps, EUT position X, antenna polarization vertical

Frequency (MHz)	EUT pos.	Field strength (dBμV/m at 3 m)	Detector	Limit (dBμV/m) at 3 m	Margin (dB)	Height (cm)	Pol.	Azimuth (deg)	Corr. (dB/m)	Result
35.940	X	31.89	QP	40.00	8.11	100.0	V	0.0	12.0	Passed
45.660	X	30.32	QP	40.00	9.68	100.0	V	356.0	14.6	Passed
64.710	X	16.90	QP	40.00	23.10	113.0	V	1.0	12.3	Passed
240.000	X	21.62	QP	46.00	24.38	100.0	V	2.0	13.9	Passed
320.010	X	27.36	QP	46.00	18.64	124.0	V	189.0	15.6	Passed

Table 62: Results of emissions test from 30 MHz to 1 GHz on lowest channel, 1 Mbps

6.10 Radiated emissions from 1 GHz to 25 GHz (10th harmonic)

Section(s) in 47 CFR Part 15:	Requirement(s):	15.247(d)
	Reference(s):	KDB 558074 D01, clauses 8.4 and 8.5 ANSI C63.10, clause 6.6
Section(s) in RSS:	Requirement(s):	RSS-247, section 5.5
	Reference(s):	KDB 558074 D01, clauses 8.4 and 8.5 ANSI C63.10, clause 6.6

Performed by:	Jennifer Riedel B. Eng.	Date(s) of test:	February 9, 2023
Result:	☒ Test passed ☐ Test not passed		

6.10.1 Test equipment

Type	Designation	Manufacturer	Inventory no.
Free space semi-anechoic chamber (FS-SAC)	FS-SAC	ELEMENT STRAUBING	E00100
EMI test receiver	ESU 26	Rohde & Schwarz	W00002
Preamplifier (0.5 GHz - 18 GHz)	BBV 9718 B	Schwarzbeck	W01325
Preamplifier (17 GHz – 40 GHz)	BBV 9721	Schwarzbeck	W01350
Horn antenna	BBHA 9120D	Schwarzbeck	W00053
Horn antenna	BBHA 9170	Schwarzbeck	W00055
Cable set FS-SAC	RF cable(s)	Teledyne Reynolds Huber + Suhner Teledyne Reynolds	E00435 E00307 E00433

6.10.2 Limits

According to §15.247(d) and RSS-247 section 5.5:

In any 100 kHz bandwidth outside of 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.

In addition, radiated emissions which fall in the restricted bands (see table 35) must also comply with the radiated emission limits specified in §15.209(a) and RSS-Gen section 8.10.

For frequencies above 960 MHz, these limits are shown in table 63.

Frequency (MHz)	Field strength		Measurement distance (m)
	($\mu\text{V/m}$)	(dB $\mu\text{V/m}$)	
Above 960	500	54	3

Table 63: General radiated emission limits above 960 MHz according to §15.209 and RSS-Gen

6.10.3 Test procedure

The emissions from 1 GHz to 25 GHz are measured using the

- ☐ test procedure for conducted measurements as described in clause 5.2.
- ☒ test procedure for radiated measurements as described in clause 5.6.2.2.

6.10.4 Test results

Test distance:	Exploratory tests:	☐ 1 m	☒ 0.5 m
	Final tests:	☐ 3 m	☒ 1.5 m
EUT position:	☒ Position X	☒ Position Y	☒ Position Z

Note(s):

- 1 The measurements from 1 GHz to 17 GHz are made at a measurement distance of 1.5 m. However, the limit lines for these tests are referenced to the limit lines at a measurement distance of 3 m (Offset – 6 dB).
- 2 The exploratory measurements from 17 GHz to 25 GHz are made at a measurement distance of 0.5 m. However, the limit lines for these tests are referenced to the limit lines at a measurement distance of 3 m (Offset – 15.6 dB).
- 3 Pre-measurements were performed to declare the worst case which is documented below. The table results show the final measurements of the emissions detected in the pre-measurements which are shown in this test report.
- 4 According to clause 6.6.4.3, note 1 of ANSI C63.10, if the maximized peak measured value complies with the average limit, than it is unnecessary to perform an average measurement.
- 5 According to clause 6.7 the worst case data rate is 1 Mbps.
- 6 The antenna port was terminated with 50 ohm.

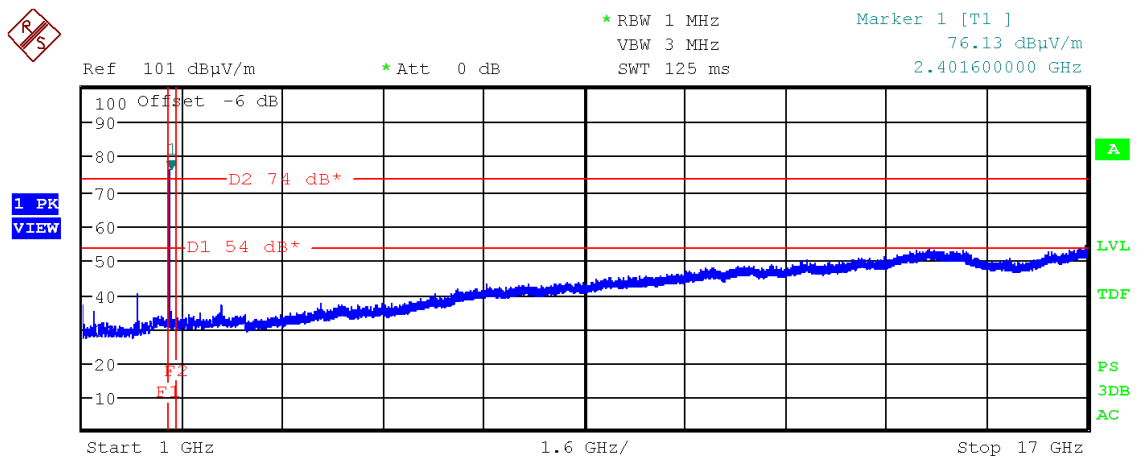


Figure 82: Chart of radiated emissions pre-measurement from 1 GHz to 17 GHz on lowest channel, 1 Mbps, EUT position Y, antenna polarization horizontal

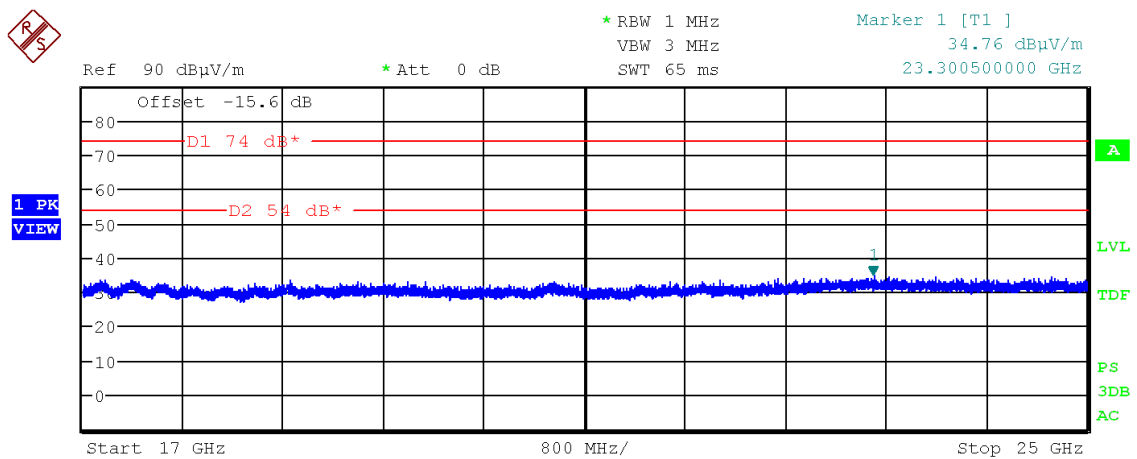


Figure 83: Chart of exploratory emissions measurement from 17 GHz to 25 GHz on lowest channel, 1 Mbps

Frequency (MHz)	EUT Pos.	Field strength (dBμV/m) at 3 m	Detector	Limit (dBμV/m) at 3 m	Margin (dB)	Height (cm)	Pol.	Azimuth (deg)	Result
14484.506	Y	54.58	PK	74.00	19.42	100.0	H	328.0	Passed
14484.506	Y	41.87	AV	54.00	12.13	100.0	H	328.0	Passed
16687.760	Y	54.56	PK	74.00	19.44	100.0	H	210.0	Passed
16712.199	Y	41.60	AV	54.00	12.40	100.0	H	210.0	Passed

Table 64: Results of radiated emissions test from 1 GHz to 25 GHz on lowest channel, 1 Mbps

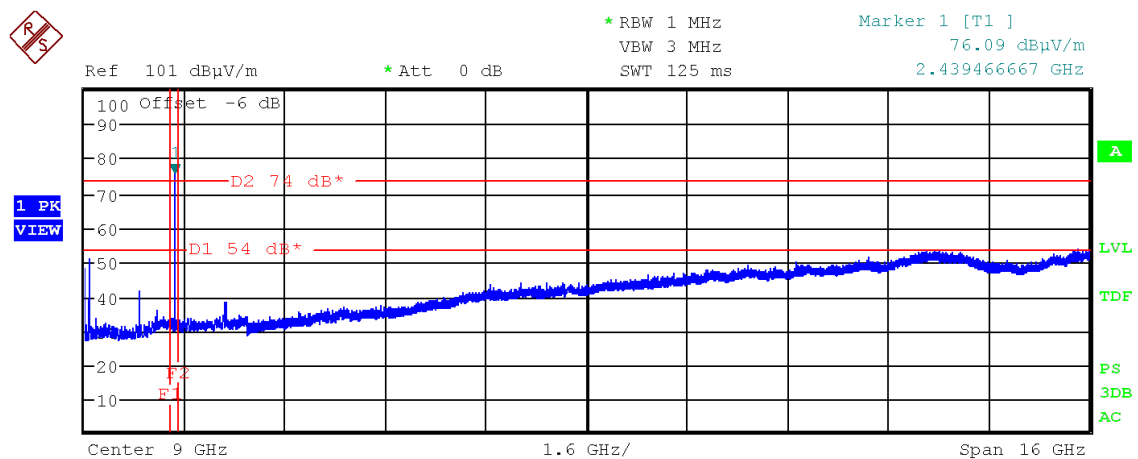


Figure 84: Chart of radiated emissions pre-measurement from 1 GHz to 17 GHz on middle channel, 1 Mbps, EUT position Y, antenna polarization horizontal

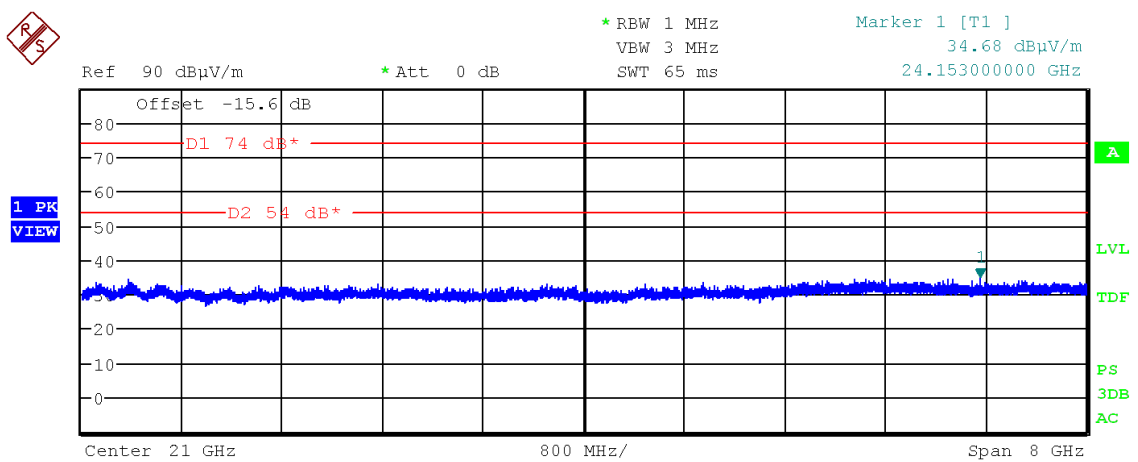


Figure 85: Chart of exploratory emissions measurement from 17 GHz to 25 GHz on middle channel, 1 Mbps

Frequency (MHz)	EUT Pos.	Level (dBμV/m) at 3 m	Detector	Limit (dBμV/m) at 3 m	Margin (dB)	Height (cm)	Pol.	Azimuth (deg)	Result
1011.058	Y	43.77	PK	74.00	30.89	180.0	H	0	Passed
14517.917	Y	54.08	PK	74.00	19.92	100.0	H	200.0	Passed
14521.571	Y	41.92	AV	54.00	12.08	100.0	H	200.0	Passed
16988.077	Y	54.80	PK	74.00	19.20	100.0	H	293.0	Passed
16989.583	Y	43.56	AV	54.00	10.44	100.0	H	293.0	Passed

Table 65: Results of radiated emissions test from 1 GHz to 25 GHz on middle channel, 1 Mbps

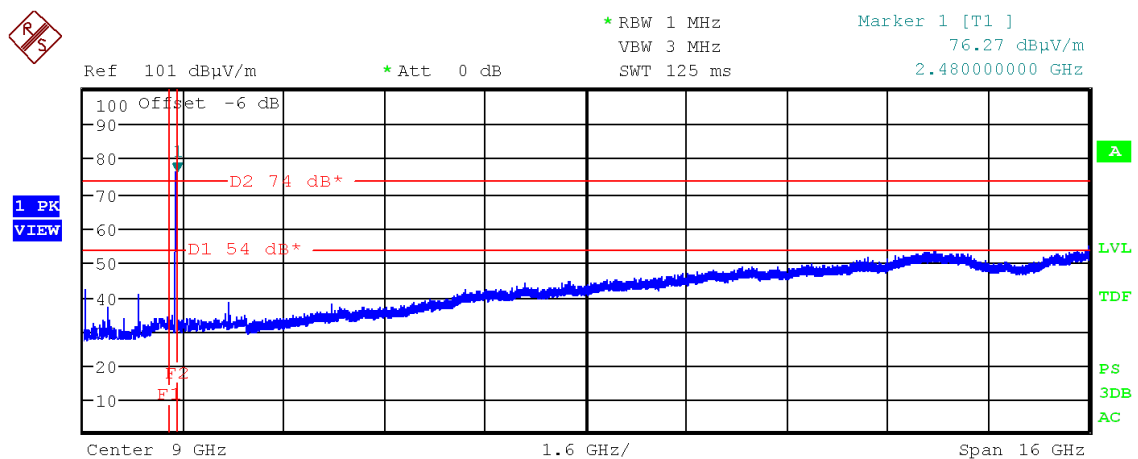


Figure 86: Chart of emissions test from 1 GHz to 17 GHz on highest channel, 1 Mbps, EUT position Y, antenna polarization horizontal

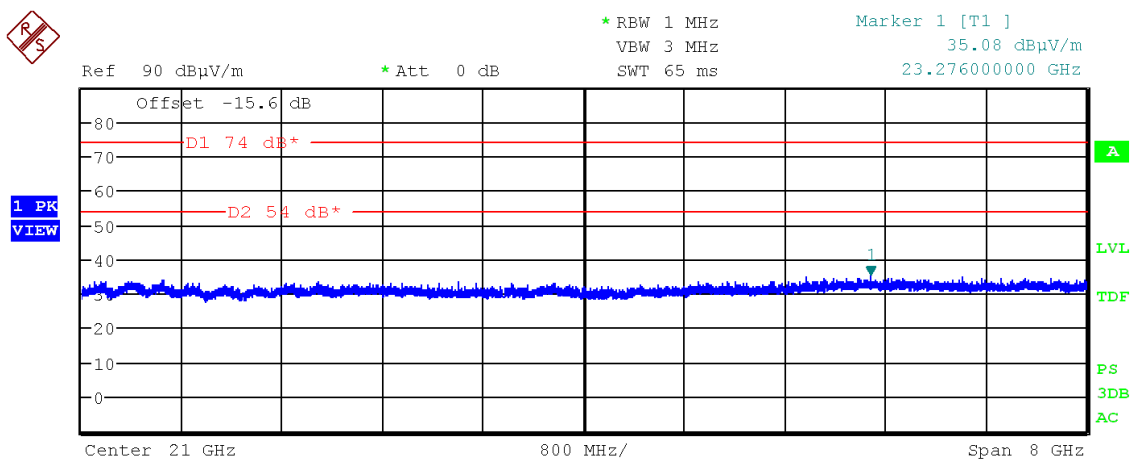


Figure 87: Chart of exploratory emission test from 17 GHz to 25 GHz on highest channel, 1 Mbps, at 0.5 m

Frequency (MHz)	EUT Pos.	Level (dBμV/m) at 3 m	Detector	Limit (dBμV/m) at 3 m	Margin (dB)	Height (cm)	Pol.	Azimuth (deg)	Result
14521.128	Y	54.77	PK	74.00	19.23	150.0	H	0	Passed
14521.026	Y	41.92	AV	54.00	12.08	150.0	H	0	Passed
16969.327	Y	55.18	PK	74.00	18.82	200.0	H	125.0	Passed
16971.314	Y	42.48	AV	54.00	11.52	200.0	H	125.0	Passed

Table 66: Results of emissions test from 1 GHz to 25 GHz on highest channel, 1 Mbps

7 Equipment calibration status

Description	Modell number	Serial number	Inventory number(s)	Last calibration	Next calibration
EMI test receiver	ESW44	101538	E00895	2022-08	2024-08
EMI test receiver	ESU26	100026	W00002	2022-06	2024-06
EMI test receiver	ESR7	101059	E00739	2022-08	2024-08
Preamplifier (1 GHz – 18 GHz)	BBV 9718 B	00032	W01325	2022-09	2023-10
Preamplifier (18 GHz – 40 GHz)	BBV 9721	43	W01350	2022-11	2023-11
Preamplifier (1 GHz - 18 GHz)	ALS05749	001	W01007	2023-03	2024-03
Loop antenna	HFH2-Z2	871398/0050	E00060	2021-10	2023-10
LISN	ESH2-Z5	881362/037	E00004	Note 1	
LISN	ESH2-Z5	893406/009	E00005	2021-10	2023-10
Field probe	RF-R 400-1	02-2030	E00270	Note 2	
TRILOG broadband antenna (SAC3)	VULB 9162	9162-041	E00643	2021-03	2024-03
Horn antenna	BBHA 9120D	9120D-592	W00053	2022-09	2025-09
Horn antenna	BBHA 9170	9170-332	W00055	2022-08	2023-08
Shielded room	P92007	B 83117 C 1109 T 211	E00107	N/A	
Compact diagnostic chamber (CDC)	VK041.0174	D62128-A502-A69-2-0006	E00026	N/A	
Semi-anechoic chamber (SAC) with floor absorbers	FS-SAC	---	E00100	2021-03	2024-03
Semi-anechoic chamber (SAC)	SAC3	C62128-A520-A643-x-0006	E00716	2021-03	2024-03
Cable set CDC	RG214/U	---	E00446	2023-01	2024-07
	LCF12-50J	---	E01215	2023-01	2024-07
	LMR400	1718020006	E00920	2023-01	2024-07
	RG214 Hiflex	171802007	E00921	2023-01	2024-07
Cable set anechoic chamber	262-0942-1500	005	E00435	2022-04	2023-10
	SF104EA/2x11PC 35-42/5m	11144/4EA	E00307	2023-01	2024-07
	262-0942-1500	003	E00433	2022-04	2023-10
Cable set of semi-anechoic chamber SAC3	SF104EA/11PC35/11PC35/10000M M	501347/4EA	E00755	2023-01	2024-07
	SF104E/11PC35/11PC35/2000MM	507410/4E	E01035	2023-01	2024-07
	SF104E/11PC35/11PC35/2000MM	507411/4E	E01034	2023-01	2024-07

Note(s)

1. Only used for decoupling of support equipment.
2. Only used for relative measurements.

8 Measurement uncertainties

Description	Uncertainty	U_{Limit}	Note(s)	k=
AC power line conducted emission	± 3.0 dB	± 3.4 dB	2b), 3b)	2
Carrier frequency separation	± 1.5 %	± 5 %	2a), 3a)	2
Number of hopping frequencies	± 1.5 %	± 5 %	2a), 3a)	2
Time of occupancy (dwell time)	± 1.5 %	± 5 %	2a), 3a)	2
Bandwidth tests	± 2.0 %	± 5 %	2a), 3a)	2
Maximum conducted output power (conducted)	± 2.9 dB	± 3.0 dB	2a), 3a)	2
Power spectral density (conducted)	± 2.9 dB	± 3.0 dB	2a), 3a)	2
Conducted spurious emissions	± 2.9 dB	± 3.0 dB	2a), 3a)	2
Radiated emissions				
from 9 kHz to 30 MHz	± 3.8 dB	± 4.0 dB	2b), 3b)	2
from 30 MHz to 1 GHz	± 6.1 dB	± 6.3 dB	2b), 3b)	2
from 1 GHz to 6 GHz	± 4.6 dB	± 5.2 dB	2b), 3b)	2
from 6 GHz to 18 GHz	± 5.0 dB	± 5.5 dB	2b), 3b)	2
from 18 GHz to 26.5 GHz	± 5.4 dB	± 6.0 dB	2b), 3c)	2
from 26.5 GHz to 40 GHz	± 6.2 dB	± 6.5 dB	2b), 3c)	2

Note(s):

- The uncertainty stated is the expanded uncertainty obtained by multiplying the standard uncertainty by the coverage factor k. For a confidence level of 95 % the coverage factor k is 2.
- The values of the measurement uncertainty as listed above are calculated according to
 - ETSI TR 100 028-1 V1.4.1 and ETSI TR 100 028-2 V1.4.1
 - CISPR 16-4-2:2011-06 + A1:2014-02 + A2:2018-08
- The limits for the measurement uncertainty as listed above are
 - derived from ETSI EN 300 328 V2.1.1
 - equal to U_{CISPR} taken from CISPR 16-4-2:2011-06 + A1:2014-02 + A2:2018-08
 - defined by the test laboratory
- Simple acceptance is applied as the decision rule while keeping the specified limits (U_{Limit}) for the expanded measurement uncertainty (i.e. Test Uncertainty Ratio $TUR \geq 1:1$). That means, compliance is based on the recorded level by the lab irrespective of the expanded measurement uncertainty value but with a limitation to it.
- All used test instruments as well as the test accessories are calibrated at regular intervals.

9 Revision history

<i>Revision</i>	<i>Date</i>	<i>Issued by</i>	<i>Description of modifications</i>
0	2023-07-18	Konrad Graßl	First edition

Template: RF_15.247_RSS-247_V1.7