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Test report no.:
200023-AU01+W03
for:
Uhlmann & Zacher GmbH
Radio module with BLE
FSMBLE

according to:
15.247
RSS-247

ilac-MRA DAkkS Deutsche Akkreditierungsstelle D-PL-12155-01-04

ilac-MRA DAkkS Deutsche Akkreditierungsstelle D-PL-12155-01-03

Accreditation:

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FCC registration number: 97268
BnetzA-CAB-02/21-02/5 Valid until 2023-11-26

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Department of Innovation, Science and Economic Development (ISED) Canada
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CAB identifier: DE0011
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The technical accuracy is guaranteed through the quality management of
Element Materials Technology Straubing GmbH.

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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)*
---	Calculated antenna gain	---	26	Recorded	---
15.207	AC power line conducted emissions 150 kHz to 30 MHz	RSS-Gen, section 8.8	29	Passed	1
15.247(a)(2)	6 dB bandwidth	RSS-247, section 5.2(a)	33	Passed	2
---	Occupied bandwidth	RSS-Gen, section 6.7	37	For reference only	---
15.247(b)	Conducted output power	RSS-247, section 5.4	41	Passed	---
15.247(e)	Power spectral density	RSS-247, section 5.2(b)	45	Passed	---
15.247(d)	Band-edge measurements	RSS-247, section 5.5	49	Passed	---
15.247(d)	Antenna-port conducted measurements	RSS-247, section 5.5	54	Passed	3
15.247(d)	Radiated emissions below 30 MHz	RSS-247, section 5.5	60	Passed	---
15.247(d)	Radiated emissions from 30 MHz to 1 GHz	RSS-247, section 5.5	63	Passed	---
15.247(d)	Radiated emissions from 1 GHz to 25 GHz (10th harmonic)	RSS-247, section 5.5	66	Passed	---
15.247(i)	Radio frequency radiation exposure	RSS-Gen, Section 3.4	---	Not performed	4

Notes (for information about EUT see clause 3):

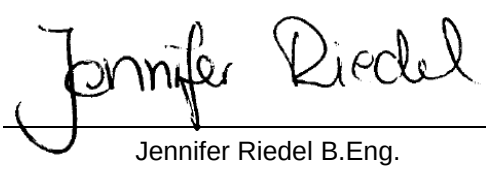
1 Measurements to demonstrate compliance with the conducted limits are not required for devices which only employ battery power for operation and which do not operate from the AC power lines or contain provisions for operation while connected to the AC power lines. Devices that include, or make provisions 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.

2 For systems using digital modulation techniques (DTS), the 6 dB bandwidth (DTS bandwidth) is regarded as the bandwidth of the emission and measuring the 20 dB bandwidth is not required.

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, October 30, 2020



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2 Referenced publications

Publication	*Title*
CFR 47 Part 2 October 2019	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 2019	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 March 2019	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:	Radio module with BLE		
Model name:	FSMBLE		
Serial number(s):	000D35AF (EUT with antenna cable) 000D35AE (EUT without antenna cable)		
Manufacturer:	Uhlmann & Zacher GmbH		
Version:	Hardware:	4.1.2	
	Software:	fsm_nrf5_DTM.hex	
Short description:	The EUT is a radio module with an integrated RF module using Bluetooth Low Energy (BLE) technique in the 2.4 GHz band.		
Additional modifications:	None		
FCC ID:	2APV6FSMBLE		
IC registration number:	24382-FSMBLE		
Emission classification:	1M05F1D		
Power supply:	DC supply		
	Nominal voltage:	12 V (see note 1)	
Device type:	☐ Portable	☐ Mobile	☒ Fixed

Note(s):
1 For all tests except AC powerline conducted emissions the EUT was powered via USB connection to the laptop.

3.2 Radio specifications

System type[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		
Antenna:	Type:	PCB antenna	
	Gain:	0.1 dBi (maximum) (see note 1)	
	Connector:	☐ external	☐ internal
		☐ temporary	☒ none (integral antenna)

Note(s):
1 For further information about the antenna gain see clause 6.1.

[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.

Channel no.	*Operating frequency*	*Channel no.*	*Operating frequency*
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

Channel	*Frequency (MHz)*
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

Device	*Type designation*	*Serial or inventory no.*	*Manufacturer*
EUT			
Radio module with BLE with antenna cable	FSMBLE	000D35AF	Uhlmann & Zacher GmbH
Radio module with BLE without antenna cable	FSMBLE	000D35AE	Uhlmann & Zacher GmbH
Peripheral devices			
Laptop	Lifebook A531	E001053	FUJITSU
Power supply for laptop	AC adapter	E001053	FUJITSU
Power supply for EUT[1]	C17-6U3	SEB01258	Hycell

Table 3: Devices used for testing

Note(s):
1 The power supply was only used for AC powerline conducted emissions.

Port	*Classification*
8 pin connector	Signal/control and DC power

Table 4: Ports of EUT and appropriate cables

4.2 Mode of operation

The EUT was DC supplied and controlled via the USB connection to the notebook.

4.2.1 Test software used for all tests

Software used during testing:
Applied Software: nRFgo Studio
Settings: - Mode (transmit)
- Channel (0 to 39)
- Modulation (PRBS9 or single carrier)
- Start test

4.2.2 Test modes applied

For the measurements except the determination of the antenna gain the testing mode “PBRS9” for modulated TX carrier is used with the carrier frequency set to the appropriate channel using “Ch = 0”, “Ch = 19” or “Ch = 39”, as applicable. For the calculated antenna gain a single carrier was used. For further details see clause 4.2.1.

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

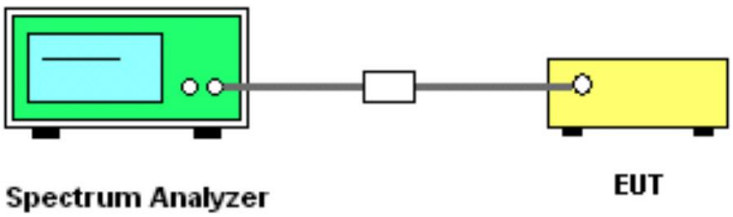

Figure 1: Setup for antenna-port conducted measurements

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 powerline conducted emissions from 150 kHz to 30 MHz are measured according to clause 6.2 of ANSI C63.10.

The test is carried out in a shielded room using a line impedance stabilization network (LISN) 50 µH/50 Ohm and an EMI test receiver which is connected to the LISN and set to a measurement bandwidth of 9 kHz in the frequency range from 150 kHz to 30 MHz.

The EUT is placed on a table and connected to the LISN. To accelerate the measurement the detector of the EMI test receiver is set to peak and the whole frequency range from 150 kHz to 30 MHz is scanned. All peak values with less than 10 dB to quasi-peak limit or exceeding the limit are marked and re-measured with quasi-peak detector.

If the values are under the average limit no additional measurement is necessary. In case there are still values between quasi-peak and average limit these values are re-measured with average detector.

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 377 Ω 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:

$d_{near\ field}$ = 47.77 / f_{MHz}, or
f_{MHz} = 47.77 / $d_{near\ field}$

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:

f_{MHz}(300 m) ≈ 0.159 MHz
f_{MHz}(30 m) ≈ 1.592 MHz
f_{MHz}(3 m) ≈ 15.923 MHz

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

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

Table 5: Recalculation factors for extrapolation

Prescans for 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 6.

Frequency (f)	*Measurement receiver bandwidth*	*Step size*	*Detector type*		
			Prescan	*Prescan with FFT*	*Final scan*
9 kHz ≤ f < 150 kHz	200 Hz	≤ 100 Hz	Peak, Average	Peak Quasi-peak, Average	Peak Quasi-peak, Average
150 kHz ≤ f < 30 MHz	9 kHz	≤ 4.5 kHz	Peak, Average	Peak Quasi-peak, Average	Peak Quasi-peak, Average

Table 6: Bandwidth and detector type for radiated emissions test below 30 MHz

Sample calculation:

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

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:
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 6).
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° in steps of 45°. 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.
f) After the last prescan, the significant maximum emissions and their table positions are determined and collected in a list.
g) With the test receiver set to the first frequency of the list, the EUT is rotated by ±45° 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.
h) Step g) is repeated for all other frequencies in the list.
i) Finally, for frequencies with critical emissions the loop antenna is rotated again to find the maximum of emission. 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 i) are repeated in two other orthogonal positions. If the EUT may be used in one position only, steps a) to i) are repeated in one orthogonal position.

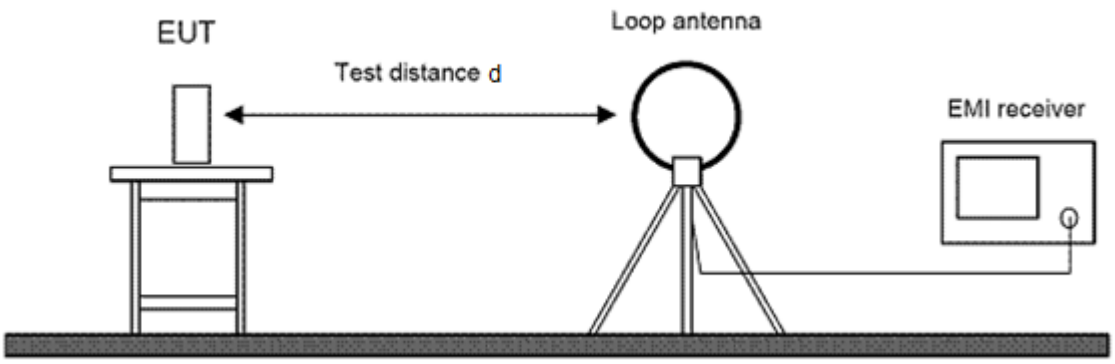

Figure 2: Setup for radiated emissions test below 30 MHz

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 7.

Frequency (f)	*Measurement receiver bandwidth*	*Step size*	*Detector type*		
			Prescan	*Prescan with FFT*	*Final scan*
30 MHz ≤ f ≤ 1 GHz	120 kHz	≤ 60 kHz	Peak	Quasi-peak	Quasi-peak

Table 7: Bandwidth and detector type for radiated emissions test from 30 MHz to 1 GHz

Sample calculation:

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

Correction factor = Antenna correction + Cable attenuation

Level = Reading value + Correction factor = 30 dBµV + 12.77 dB = 42.77 dBµV/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:

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 7).
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 60°. 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 by ±50 cm around this height and the EUT is rotated by ±60° around this table position 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.
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.

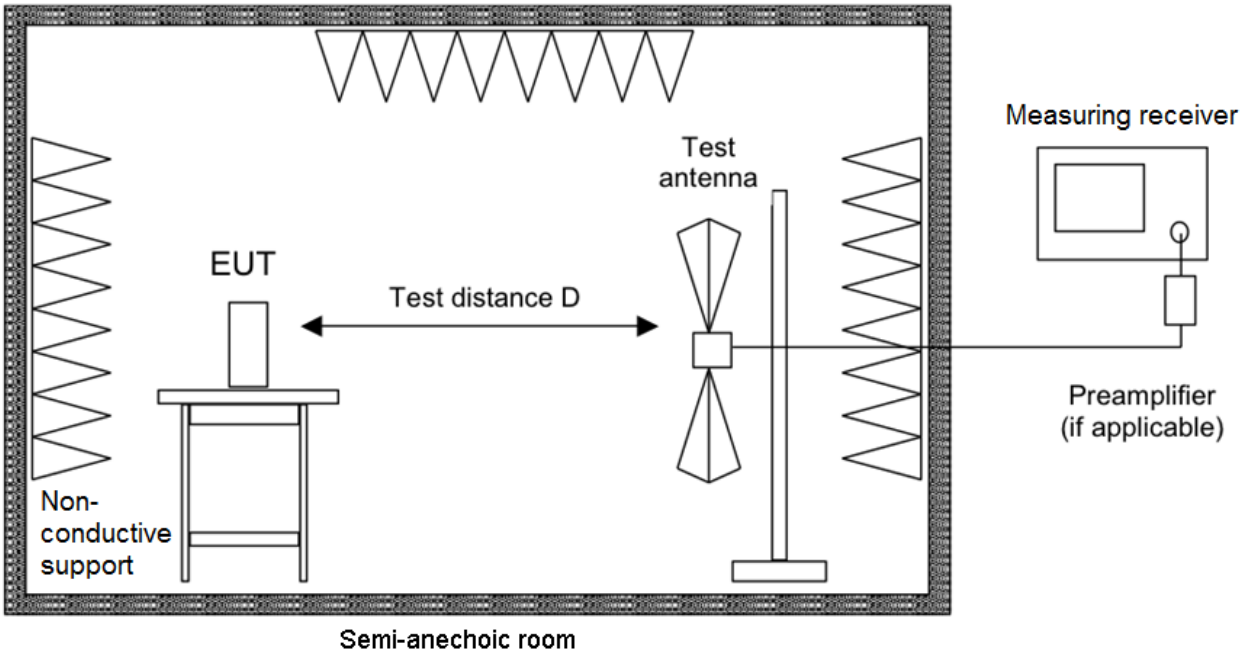

Figure 3: Setup for radiated emissions test from 30 MHz to 1 GHz

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.

Sample calculation:

Frequency (MHz)	*Reading value (dBµV)*	*Antenna correction (dB/m)*	*Correction pre-amplifier (dB)*	*Cable attenuation (dB)*	*Correction factor (Corr.) (dB)*	*Level (dBµV/m)*
2400	50.00	27.76	-34.57	3.51	-3.30	46.70

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

Level = Reading value + Correction factor = 50.00 dBµV – 3.30 dB = 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 8.

Frequency (f)	*Resolution bandwidth*	*Video bandwidth*	Sweep time	*Trace detector(s)*	*Trace mode(s)*	*Test*
f ≥ 1 GHz	1 MHz	3 MHz	AUTO	Max Peak, Average	Clear Write	Searching
					Max Hold	Recording

Table 8: 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 a semi-anechoic chamber (SAC) with RF absorbing material on the floor between measurement antenna and EUT. 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*	
			Prescan	*Final scan*
f ≥ 1 GHz	1 MHz	≤ 500 kHz	Peak, Average	Peak, Average

Table 9: 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:

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 9).
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 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) The EUT is rotated in a horizontal plane through 360° in steps of 30°. 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 by ±50 cm around this height and the EUT is rotated by ±30° around this table position 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.
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.

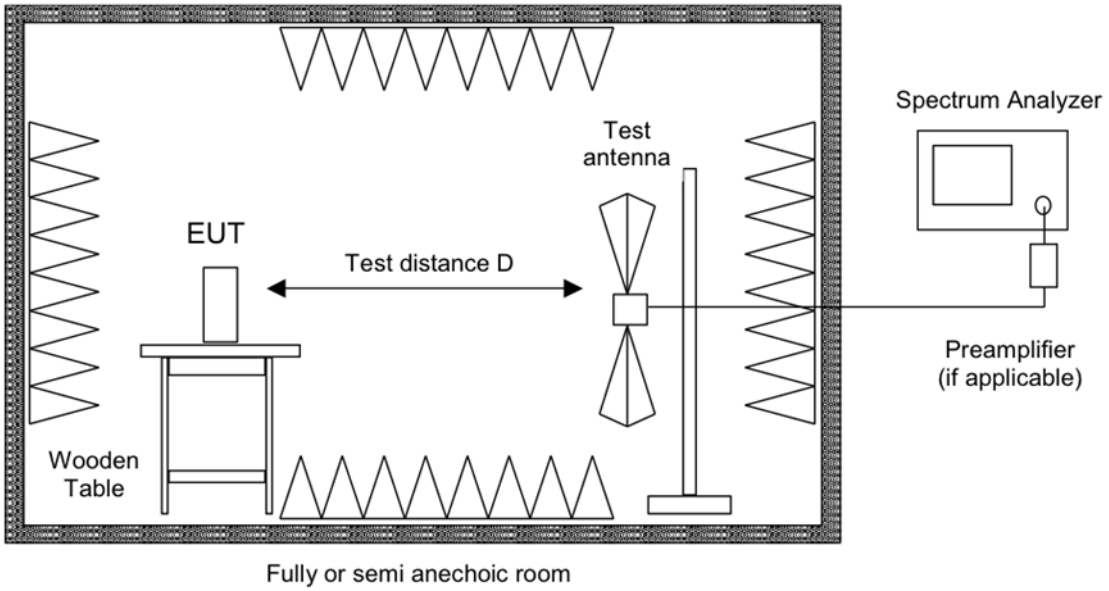

Figure 4: Setup for radiated emissions test above 1 GHz

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) ≥ 3 x 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 ≥ 3 x RBW, centered on a channel
b) RBW ≥ DTS bandwidth
c) VBW ≥ 3 x RBW
d) Sweep time = auto coupled
e) Detector function = peak
f) Trace mode = max hold
g) Reference level = more than 10·log(OBW/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 kHz ≤ RBW ≤ 100 kHz
c) VBW ≥ 3 x RBW
d) Sweep time = auto coupled or ≥ span/RBW in seconds, whichever is greater
e) Detector function = peak
f) Trace mode = max hold
g) Reference level = more than 10·log(OBW/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 6.

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

Ambient temperature	*Ambient humidity*	*Ambient pressure*
15°C to 35°C	30 % to 75 %	86 kPa to 106 kPa

6.1 Calculated antenna gain

Performed by:	Jennifer Riedel B. Eng.	Date(s) of test:	September 3, 2020
Result[2]:	☒ Test passed	☐ Test not passed	

6.1.1 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
Horn antenna	BBHA 9120D	Schwarzbeck	W00053
Cable set FS-SAC	RF cable(s)	Teledyne Reynolds Huber + Suhner Teledyne Reynolds	E00435 E00307 E00433

[2] For information about measurement uncertainties see page 73.

6.1.2 Limits

The antenna gain is recorded for this test report, so no limit applies.

6.1.3 Test procedure

The antenna gain is measured using the

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

6.1.4 Test results

Test distance:	☐ 3 m	☐ 10 m	☒ 1.5 m
EUT position:	☒ Position X	☒ Position Y	☒ Position Z

Note(s):
1 The antenna gain is calculated as the difference between the E.I.R.P. and the maximum conducted output power.
2 For the measurement a single carrier is used.
3 Premeasurements were performed to declare the worst case which is documented below.
4 The measurements were made at a measurement distance of 1.5 m. However, the measured field strength was referenced to the field strength at a measurement distance of 3 m (Offset – 6 dB).
5 The E.I.R.P. is calculated as defined in clause 12.7.3 of ANSI C63.10-2013:

$$EIRP[dBm] = E\left[\frac{dB\mu V}{m}\right] - 95.2$$

Channel	*Field strength (dBµV/m) at 3 m*	*E.I.R.P. (dBm)*	*Conducted output power (dBm)*	*Calculated antenna gain (dBi)*	*Result*
low	92.77	-2.43	-2.53	0.10	Recorded
middle	92.62	-2.58	-2.24	-0.34	Recorded
high	92.82	-2.38	-1.61	-0.77	Recorded

Table 10: Results of calculated antenna gain, EUT position Z, antenna polarisation vertical

6.2 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:	September 23, 2020
Result[3]:	☒ Test passed	☐ Test not passed	

6.2.1 Test equipment

Type	*Designation*	*Manufacturer*	*Inventory no.*
Shielded room	P92007	Siemens Matsushita	E00107
EMI test receiver	ESR 7	Rohde & Schwarz	E00739
Artificial mains network	ESH2-Z5	Rohde & Schwarz	E00004
Attenuator (10 dB)	50FHB-010-10	JFW Industries	E00471
Test software	EMC32-EB (V10.35)	Rohde & Schwarz	E00777

[3] For information about measurement uncertainties see page 73.

6.2.2 Limits

According to 15.207(a) and RSS-Gen section 8.8:
For intentional radiators that are 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 Table 11.

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

Table 11: Limits for AC powerline conducted emissions according to 15.207(a) and RSS-Gen, section 8.8

*Decreases with the logarithm of the frequency

6.2.3 Test procedure

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

6.2.4 Test results

Note(s):
1 The test was performed at 120 V and 60 Hz.
2 No assessable emissions were detected.

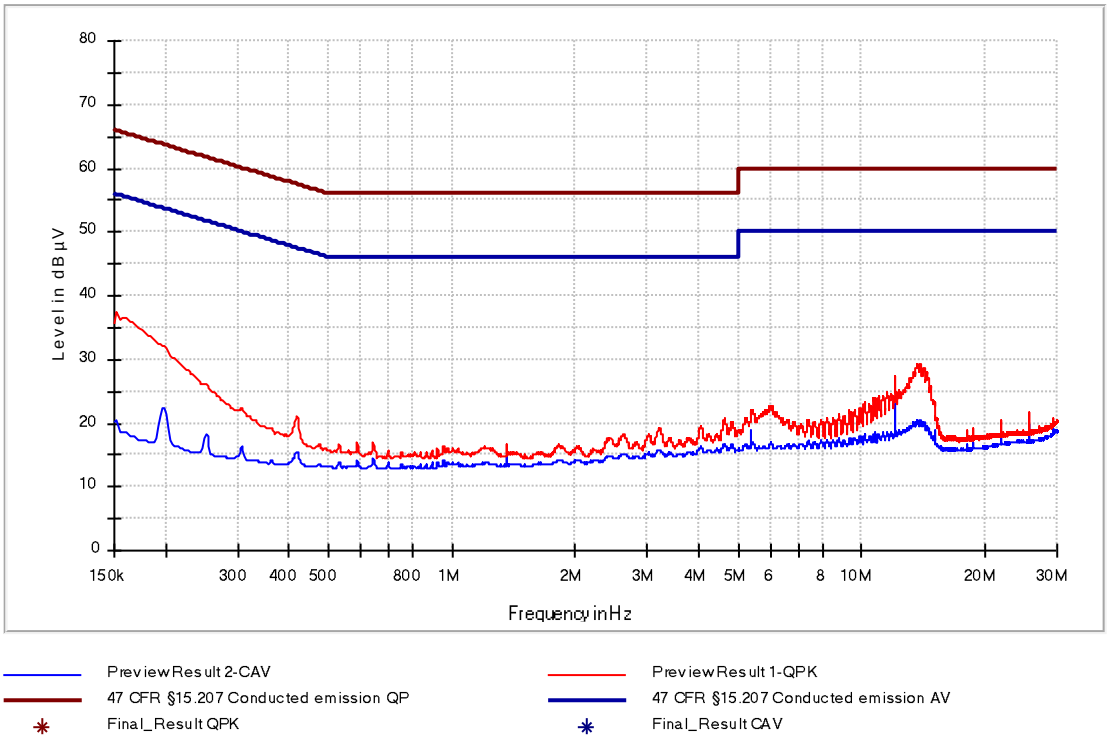

Figure 5: Chart of AC powerline conducted emissions on L1

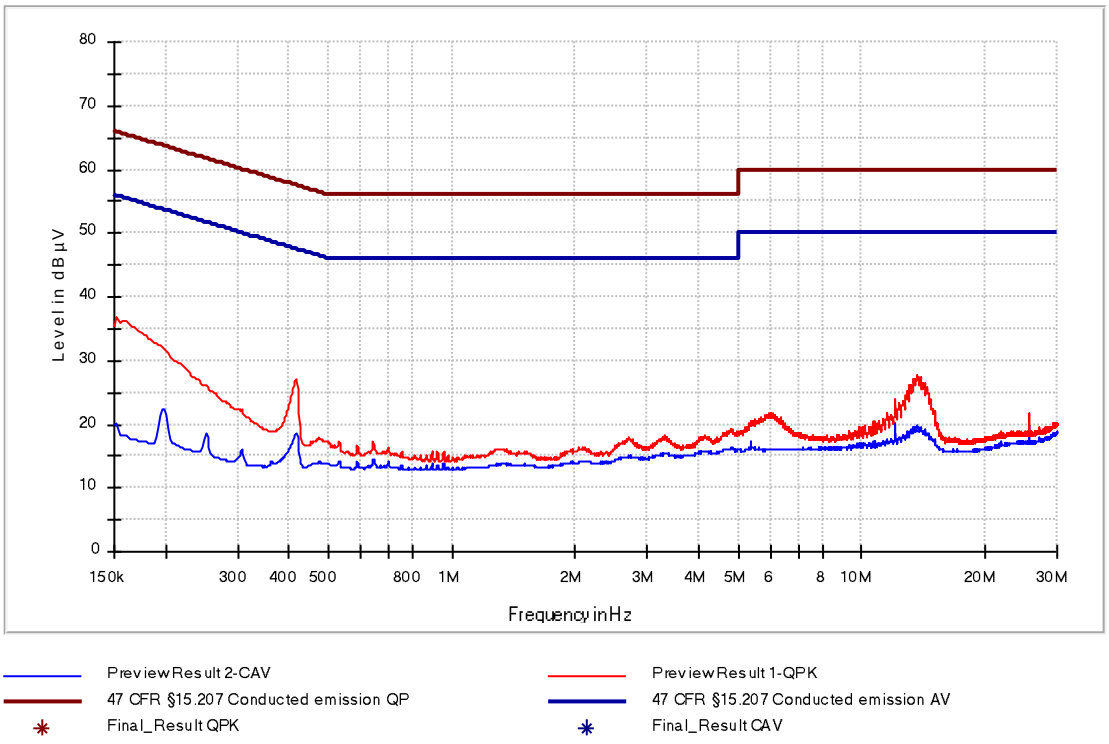

Figure 6: Chart of AC powerline conducted emissions on N

6.3 6 dB bandwidth

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

Performed by:	Jennifer Riedel	Date(s) of test:	September 3, 2020
Result[4]:	☒ Test passed	☐ Test not passed	

6.3.1 Test equipment

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

[4] For information about measurement uncertainties see page 73.

6.3.2 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.

6.3.3 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.

6.3.4 Test results

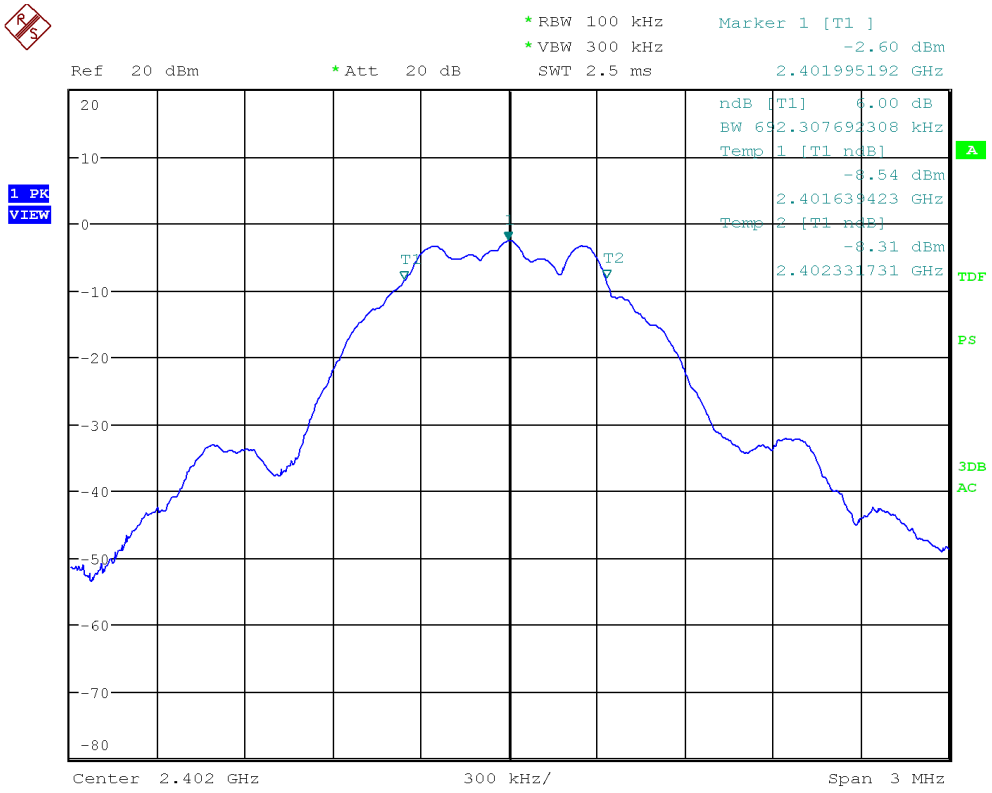

Figure 7: Chart of 6 dB bandwidth test on lowest channel

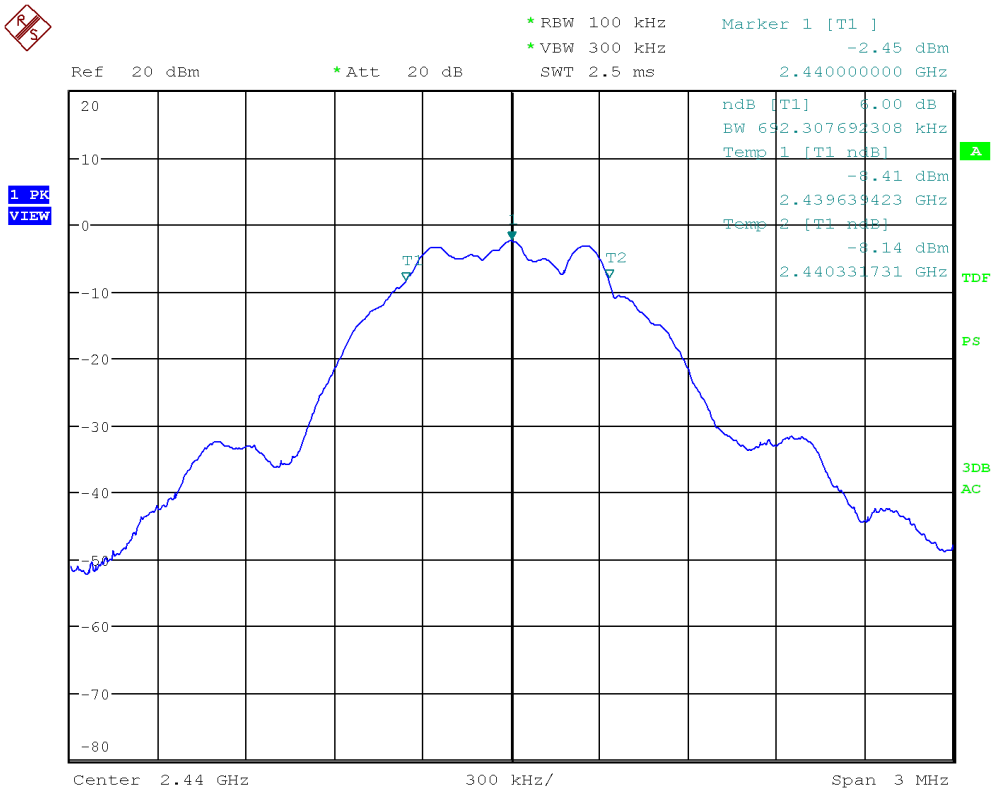

Figure 8: Chart of 6 dB bandwidth test on middle channel

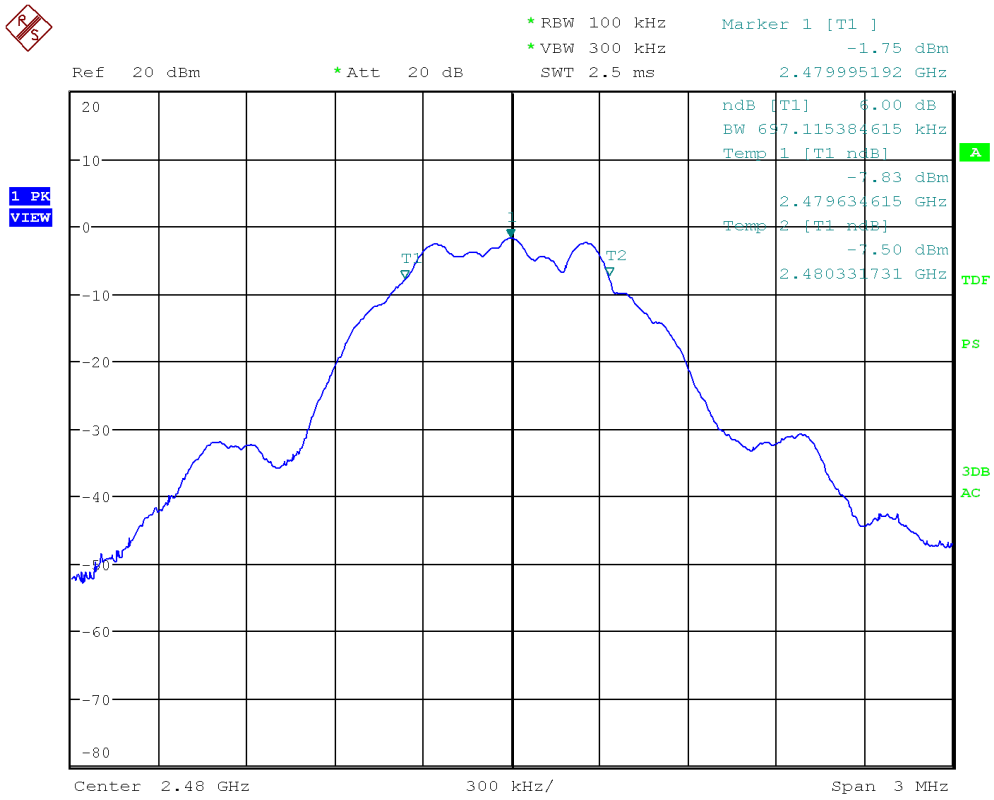

Figure 9: Chart of 6 dB bandwidth test on highest channel

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	692.308	≥ 500	2401.639	2400.000	2402.332	2483.500	Passed
middle	692.308	≥ 500	2439.639	2400.000	2440.332	2483.500	Passed
high	697.115	≥ 500	2479.635	2400.000	2480.332	2483.500	Passed

Table 12: Results of 6 dB bandwidth test

6.4 Occupied bandwidth

Section(s) in 47 CFR Part 15:	Requirement(s): Reference(s):	KDB 558074 D01, section 5.2 ANSI C63.10, clause 6.9
Section(s) in RSS:	Requirement(s): Reference(s):	RSS-Gen, section 6.7 KDB 558074 D01, section 5.2 ANSI C63.10, clause 6.9

Performed by:	Jennifer Riedel	Date(s) of test:	September 3, 2020
Result[5]:	☒ Test passed	☐ Test not passed	

6.4.1 Test equipment

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

[5] For information about measurement uncertainties see page 73.

6.4.2 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.

6.4.3 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.

6.4.4 Test results

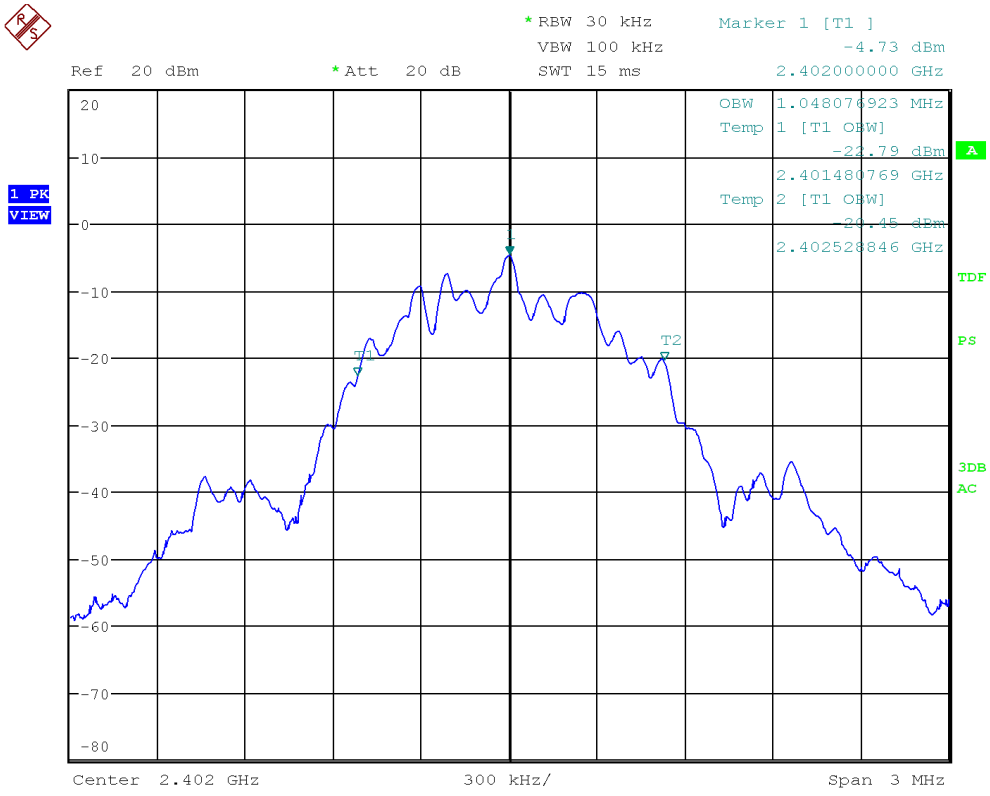

Figure 10: Chart of occupied bandwidth test on lowest channel

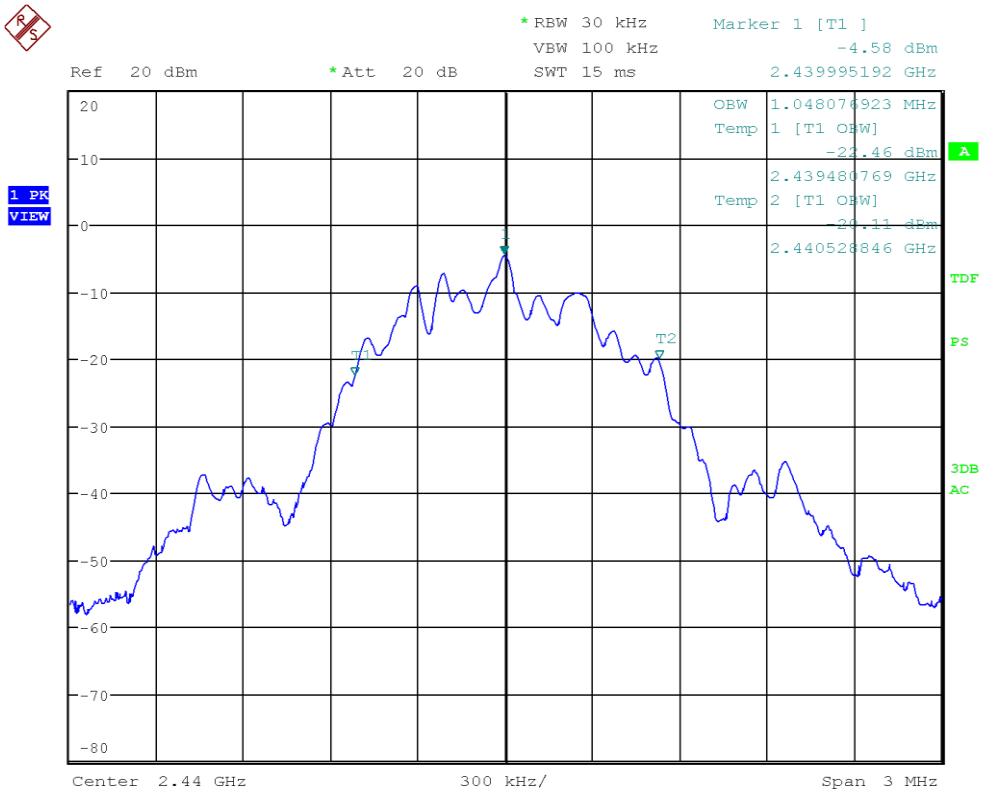

Figure 11: Chart of occupied bandwidth test on middle channel

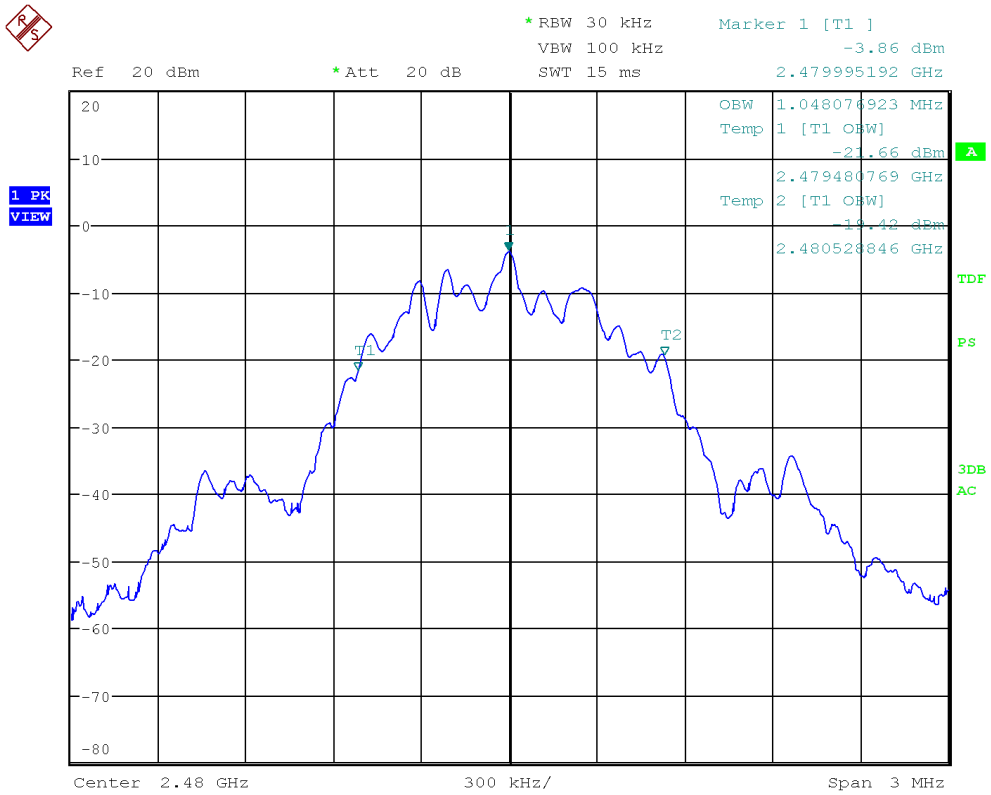

Figure 12: Chart of occupied bandwidth test on highest channel

Channel	*99 % occupied bandwidth (kHz)*	*Result*
low	1048.077	Recorded
middle	1048.077	Recorded
high	1048.077	Recorded

Table 13: Results of occupied bandwidth test

6.5 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:	Jennifer Riedel	Date(s) of test:	September 3, 2020
Result[6]:	☒ Test passed	☐ Test not passed	

6.5.1 Test equipment

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

[6] For information about measurement uncertainties see page 73.

6.5.2 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.

6.5.3 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.

6.5.4 Test results

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

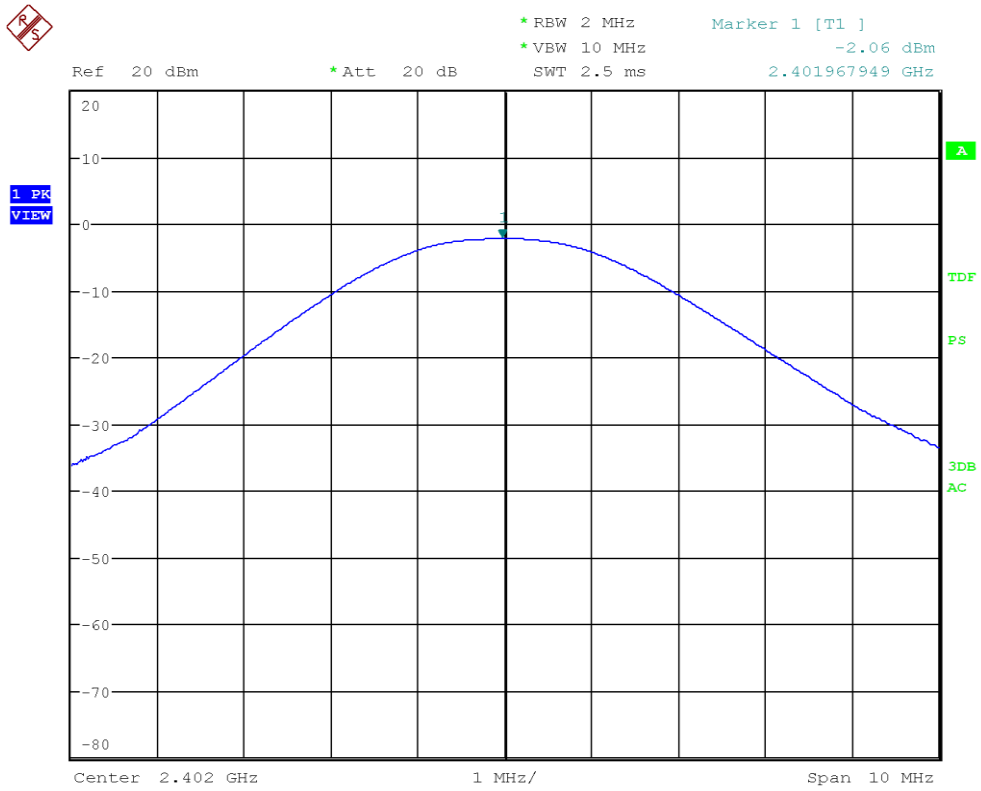

Figure 13: Chart of conducted output power on lowest channel

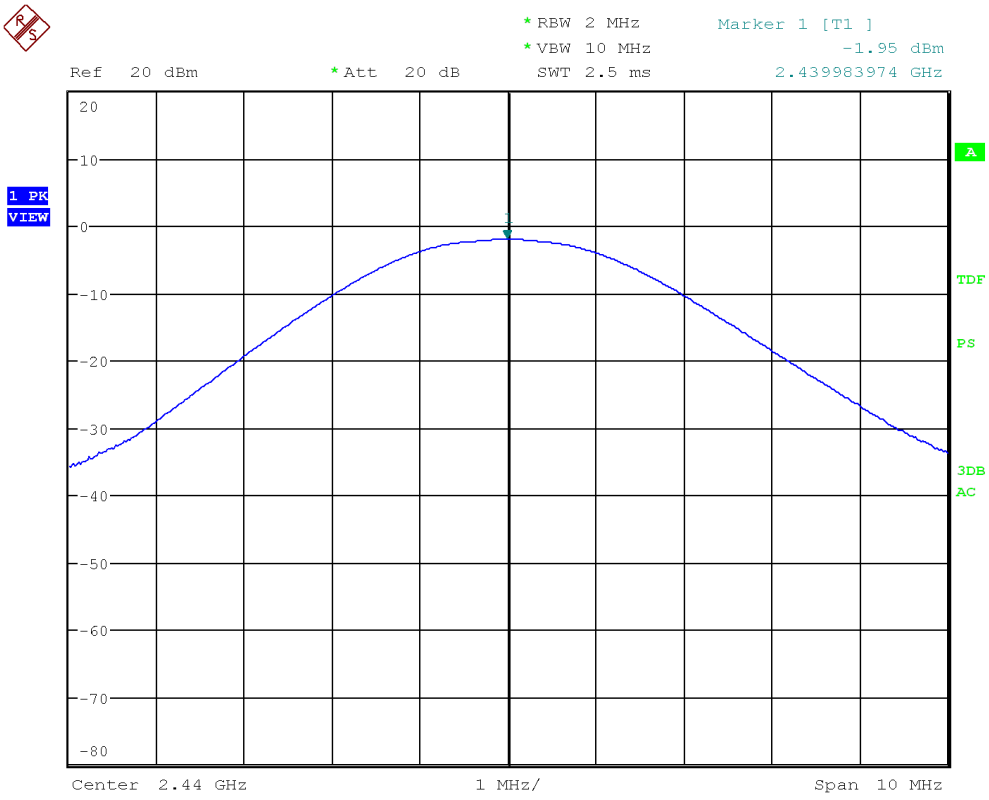

Figure 14: Chart of conducted output power on middle channel

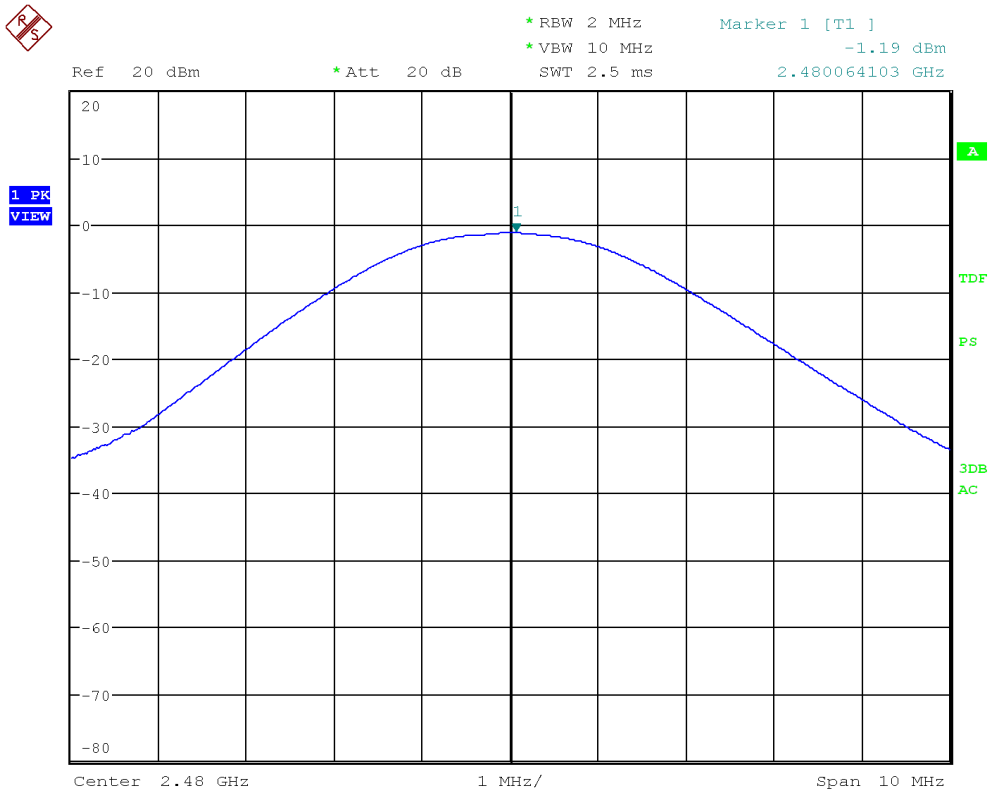

Figure 15: Chart of conducted output power on highest channel

Channel	*Conducted output power (dBm)*	*Limit (dBm)*	*Margin (dB)*	*Results*
low	-2.06	30.00	32.06	Passed
middle	-1.95	30.00	31.95	Passed
high	-1.19	30.00	31.19	Passed

Table 14: Results of conducted output power

6.6 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	Date(s) of test:	September 3, 2020
Result[7]:	☒ Test passed	☐ Test not passed	

6.6.1 Test equipment

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

[7] For information about measurement uncertainties see page 73.

6.6.2 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.

6.6.3 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.

6.6.4 Test results

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

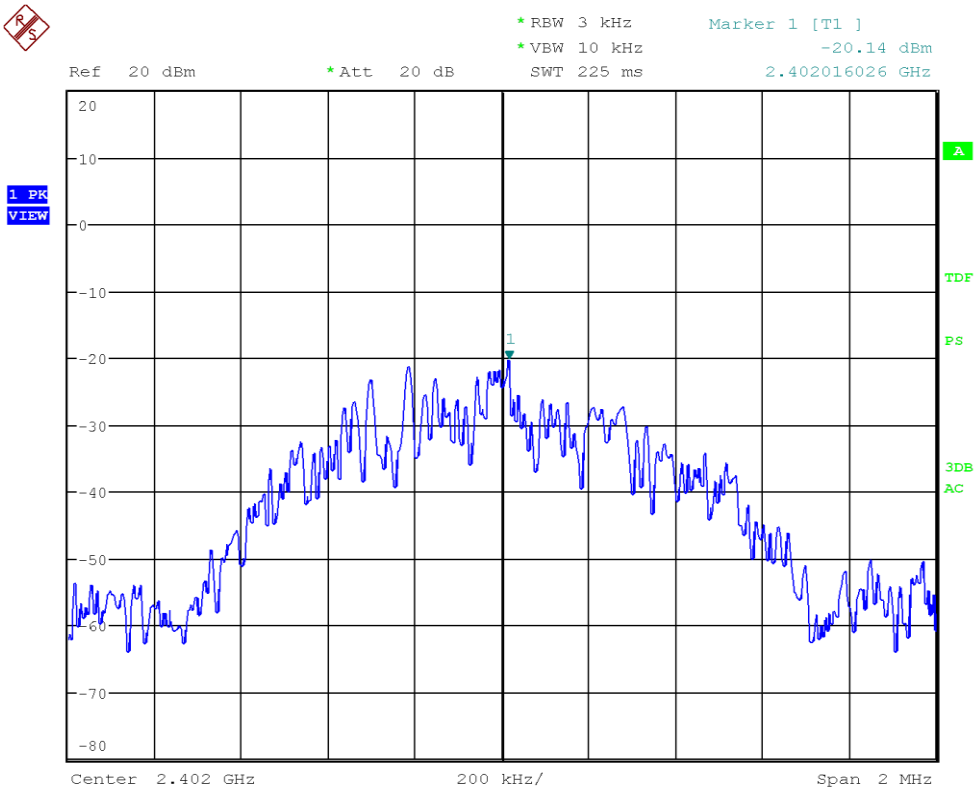

Figure 16: Chart of power spectral density on lowest channel

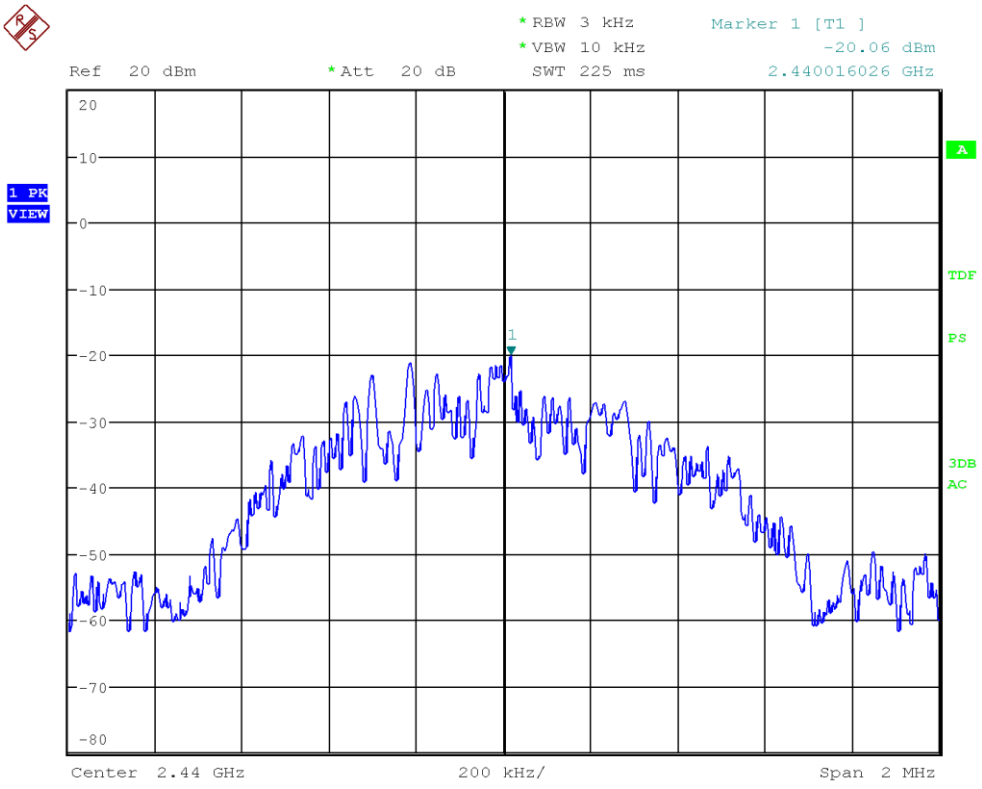

Figure 17: Chart of power spectral density on middle channel

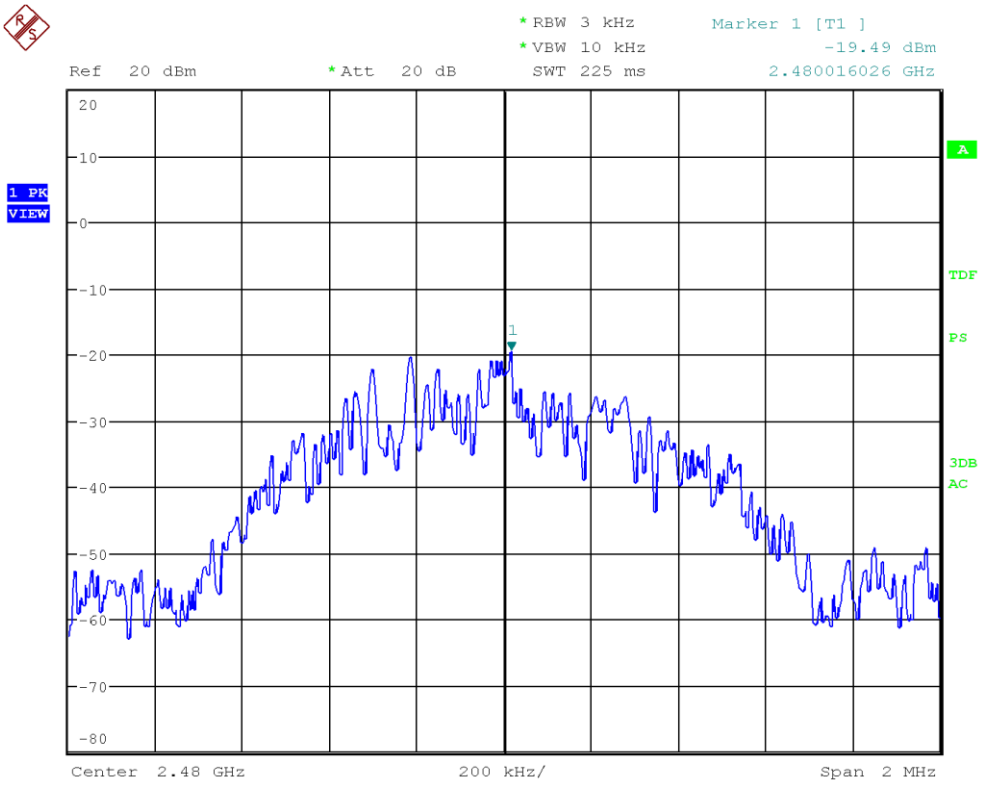

Figure 18: Chart of power spectral density on highest channel

Channel	*Power spectral density (dBm/MHz)*	*Limit (dBm/MHz)*	*Margin (dB)*	*Results*
low	-20.14	8.00	28.14	Passed
middle	-20.06	8.00	28.06	Passed
high	-19.49	8.00	27.49	Passed

Table 15: Results of conducted power spectral density

6.7 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	Date(s) of test:	September 4, 2020
Result[8]:	☒ Test passed	☐ Test not passed	

6.7.1 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
Horn antenna	BBHA 9120D	Schwarzbeck	W00053
Cable set FS-SAC	RF cable(s)	Teledyne Reynolds Huber + Suhner Teledyne Reynolds	E00435 E00307 E00433

[8] For information about measurement uncertainties see page 73.

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 16) 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 16: Restricted bands of operation according to §15.205 and RSS-Gen section 8.10

6.7.3 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.

6.7.4 Test results

Test distance:	☐ 3 m	☐ 10 m	☒ 1.5 m
EUT position:	☒ Position X	☒ Position Y	☒ Position Z

Note(s):
1 Premeasurements were performed to declare the worst case which is documented below.

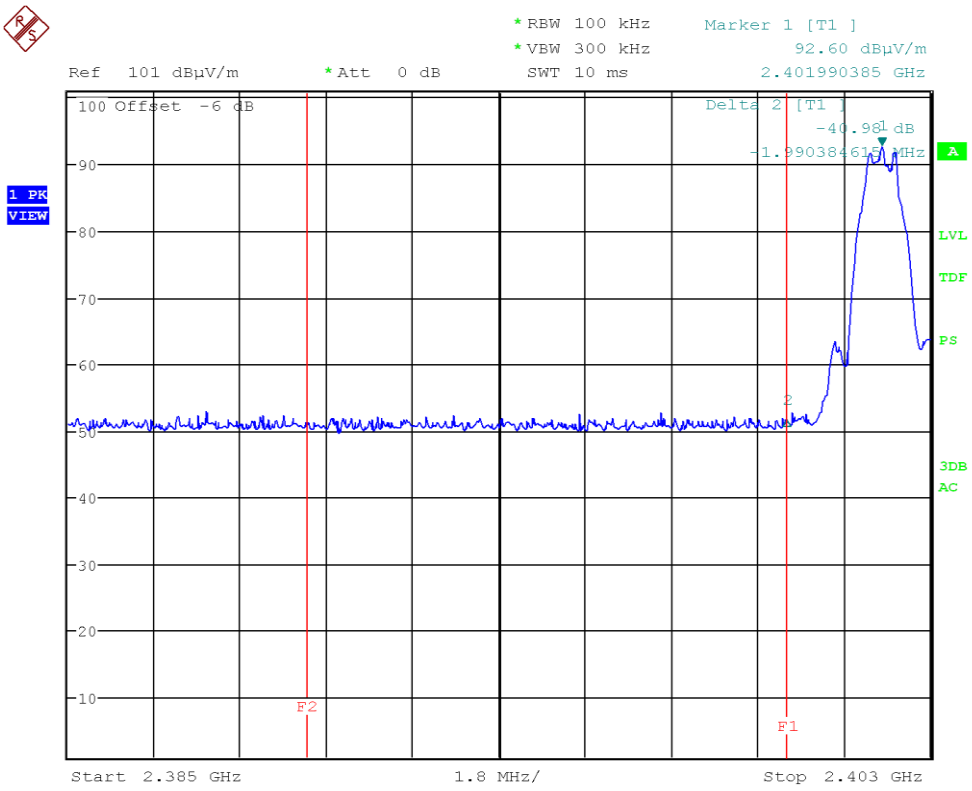

Figure 19: Chart of band-edge measurement on lowest channel, EUT position Z, antenna polarization vertical

Frequency (MHz)	*Measured Margin (dB)*	*Limit of minimum margin (dB)*	*Result*
2400.000	40.98	≥ 20	Passed

Table 17: Test results of band-edge measurements on lowest channel, EUT position Z, antenna polarization vertical

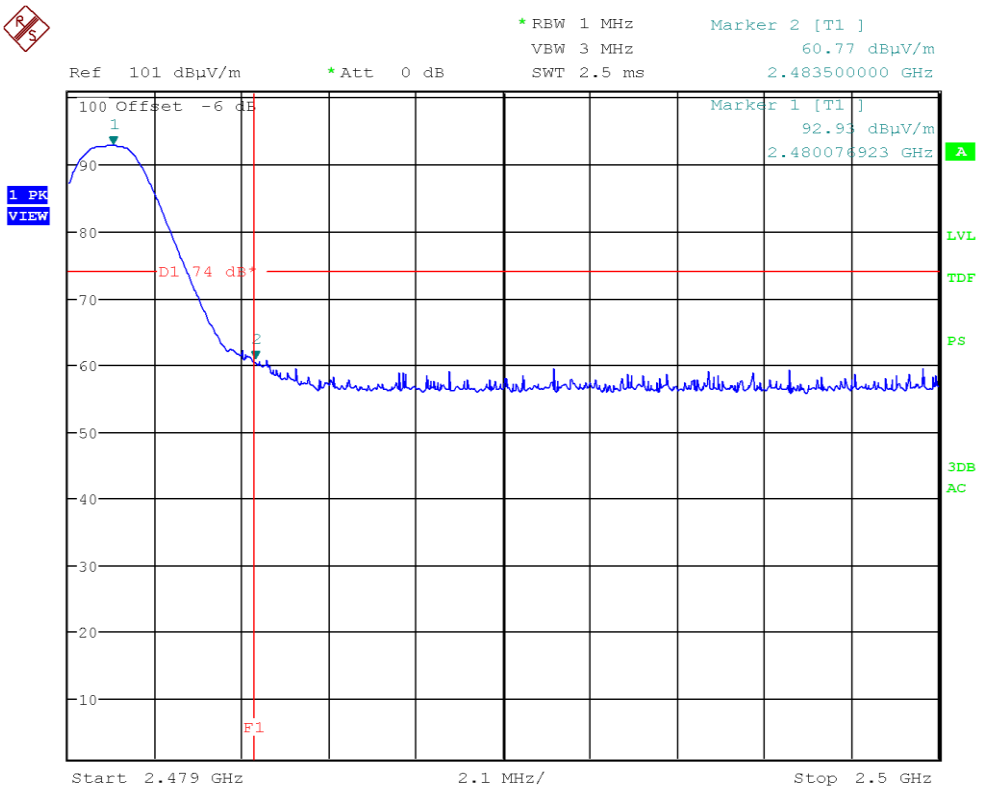

Figure 20: Chart of band-edge measurement on highest channel (PK), EUT position Z, antenna polarization vertical

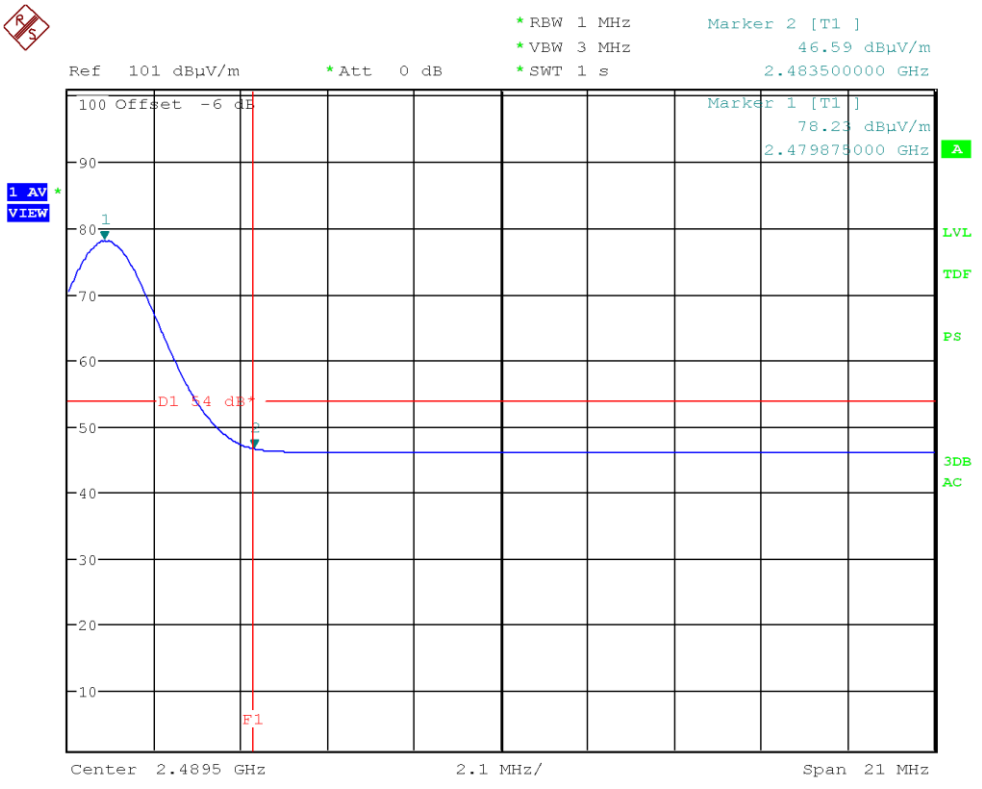

Figure 21: Chart of band-edge measurement on highest channel (AV), EUT position Z, antenna polarization vertical

Frequency (MHz)	*Max Peak (dBµV/m)*	*AV (dBµV/m)*	*Limit (dBµV/m)*	*Margin (dB)*	*Result*
2483.500	60.77	---	74.00	13.23	Passed
2483.500	---	46.59	54.00	7.41	Passed

Table 18: Test results of band-edge measurements on highest channel, EUT position Z, antenna polarization vertical

6.8 Antenna-port conducted measurements

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

Performed by:	Jennifer Riedel	Date(s) of test:	September 3, 2020
Result[9]:	☒ Test passed	☐ Test not passed	

6.8.1 Test equipment

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

[9] For information about measurement uncertainties see page 73.

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 16) must also comply with the radiated emission limits specified in §15.209(a) and RSS-Gen section 8.10.

Frequency	*Field strength*		*Measurement distance*
(MHz)	*(µV/m)*	*(dBµV/m)*	*(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 19: General radiated emission limits from 9 kHz to 25 GHz according to §15.209

Frequency	*Magnetic field strength*		*Measurement distance*
(MHz)	*(µA/m)*	*(dBµA//m)*	*(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 20: General radiated emission limits from 9 kHz to 30 MHz according to RSS-Gen section 8.9

Frequency	*Field strength*		*Measurement distance*
(MHz)	*(µV/m)*	*(dBµV/m)*	*(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 21: 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 25 using the recalculation factor as described in clause 5.3.

6.8.3 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.

6.8.4 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 0.1 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 2 dBi was added to the measured output power.

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.

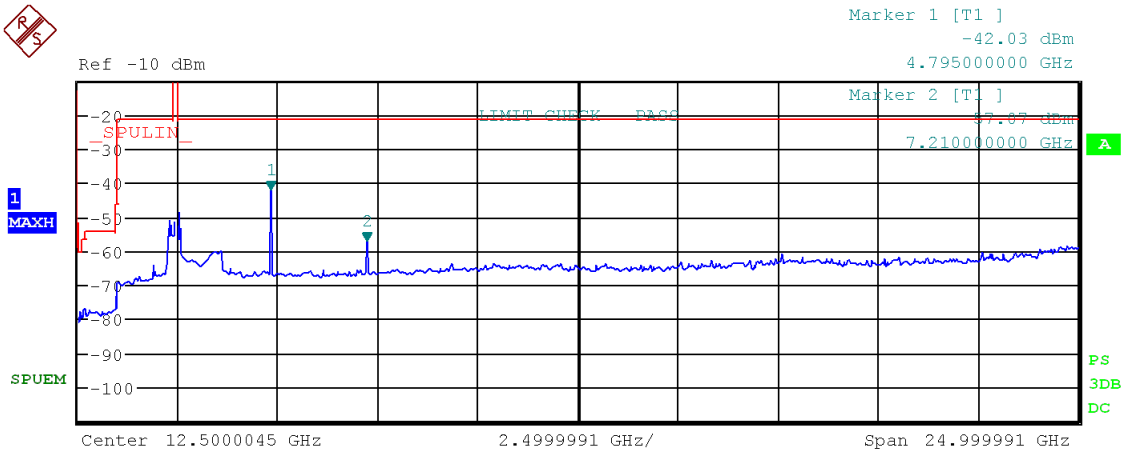

Figure 22: Chart of emissions test from 9 kHz to 25 GHz on lowest channel, PK-detector

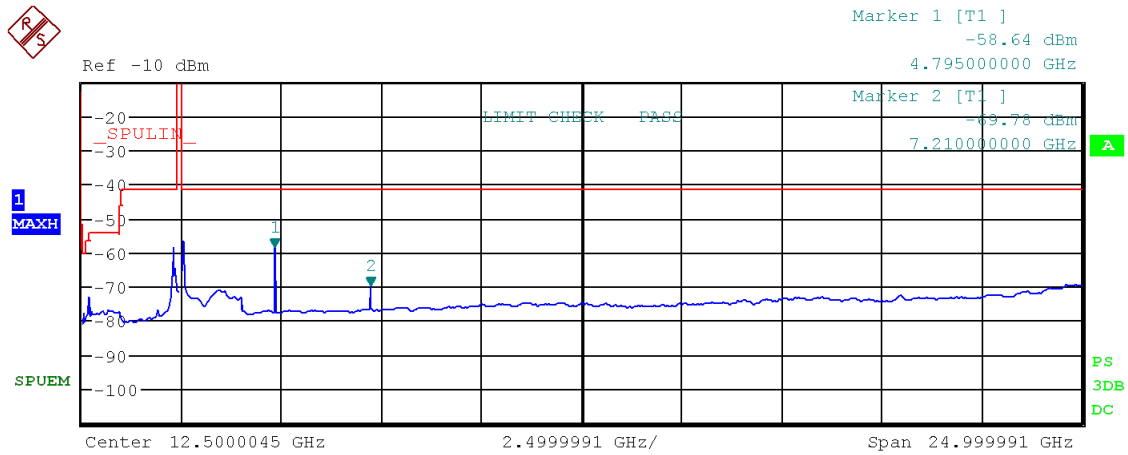

Figure 23: Chart of emissions test from 9 kHz to 25 GHz on lowest channel, AV-detector

Frequency (MHz)	*Level (dBm)*	*Detector*	*Limit (dBm)*	*Margin (dB)*
2274.167	-49.28	PK	-21.20	28.08
2274.167	-56.47	AV	-41.20	15.27
2530.000	-46.66	PK	-21.20	25.46
2530.000	-54.84	AV	-41.20	13.64
4795.000	-40.03	PK	-21.20	18.83
4795.000	-56.64	AV	-41.20	15.44
7210.000	-55.07	PK	-21.20	33.87
7210.000	-67.78	AV	-41.20	26.58

Table 22: Results of emissions test from 9 kHz to 25 GHz on lowest channel

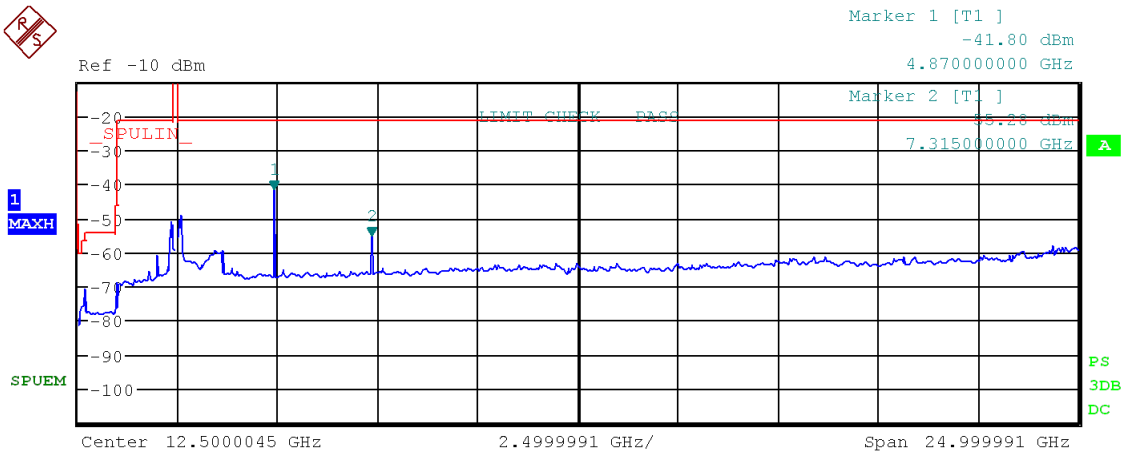

Figure 24: Chart of emissions test from 9 kHz to 25 GHz on middle channel, PK-detector

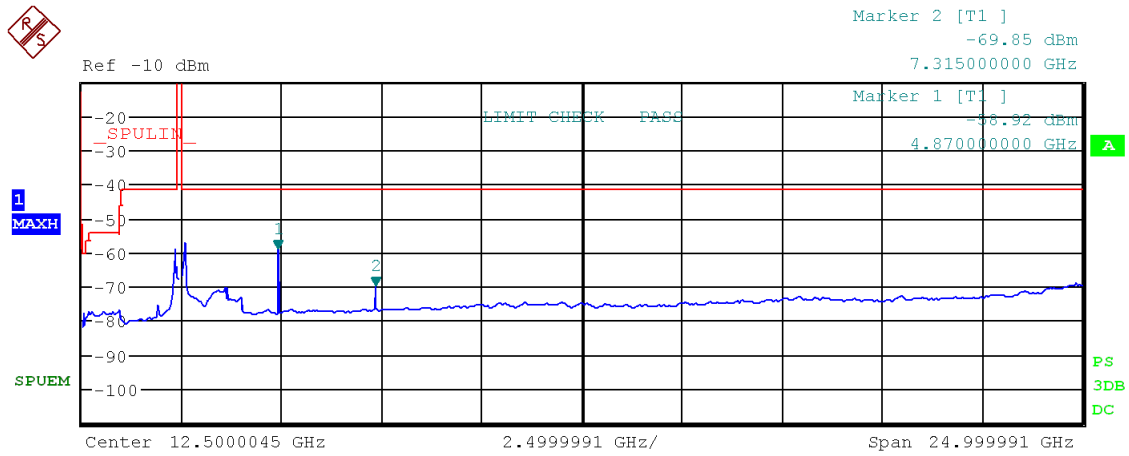

Figure 25: Chart of emissions test from 9 kHz to 25 GHz on middle channel, AV-detector

Frequency (MHz)	*Level (dBm)*	*Detector*	*Limit (dBm)*	*Margin (dB)*
2312.160	-49.13	PK	-21.20	27.93
2312.160	-56.94	AV	-41.20	15.74
2568.143	-47.39	PK	-21.20	26.19
2568.143	-55.09	AV	-41.20	13.89
4870.000	-39.80	PK	-21.20	18.60
4870.000	-56.92	AV	-41.20	15.72
7315.000	-53.28	PK	-21.20	32.08
7315.000	-67.85	AV	-41.20	26.65

Table 23: Results of emissions test from 9 kHz to 25 GHz on middle channel

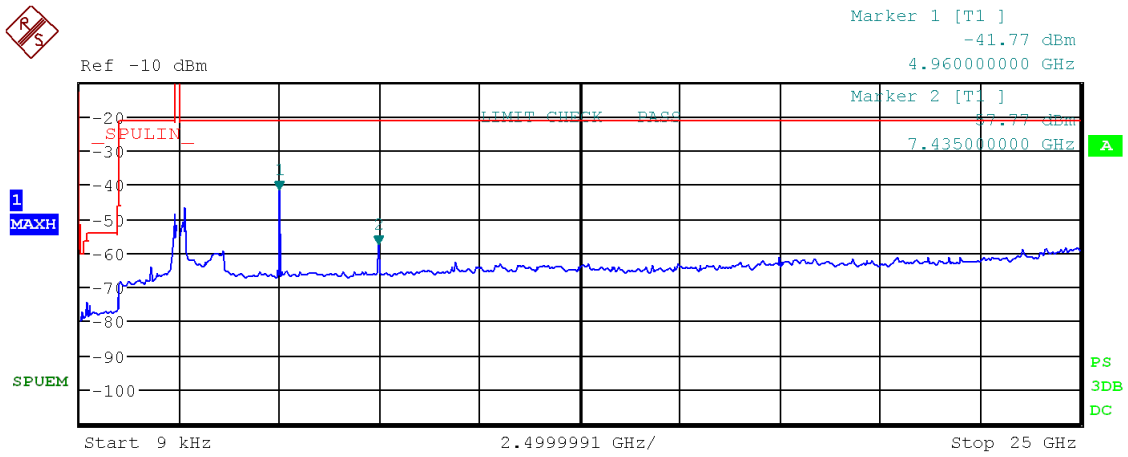

Figure 26: Chart of emissions test from 9 kHz to 25 GHz on highest channel, PK-detector

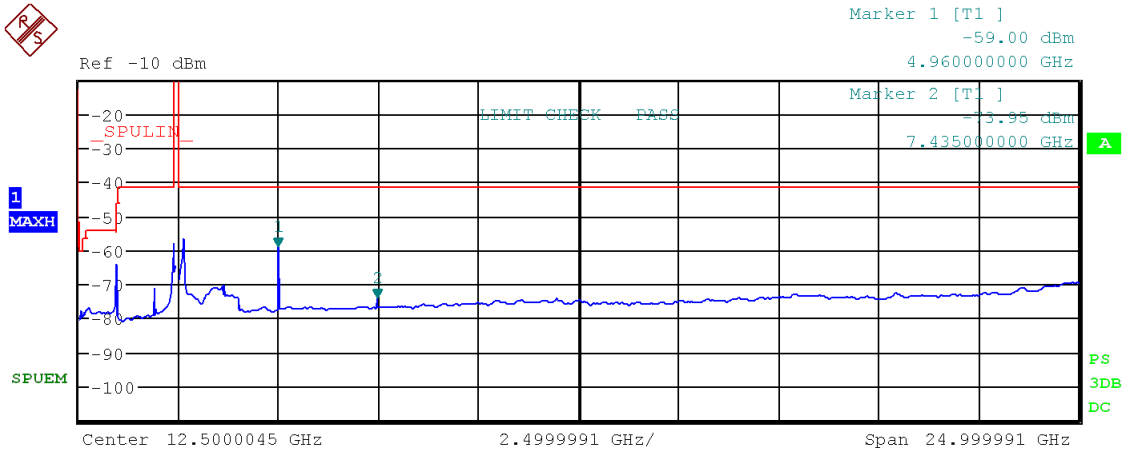

Figure 27: Chart of emissions test from 9 kHz to 25 GHz on highest channel, AV-detector

Frequency (MHz)	*Level (dBm)*	*Detector*	*Limit (dBm)*	*Margin (dB)*
2352.007	-46.84	PK	-21.20	25.64
2352.007	-56.01	AV	-41.20	14.81
2608.000	-45.01	PK	-21.20	23.81
2608.000	-54.67	AV	-41.20	13.47
4960.000	-39.77	PK	-21.20	18.57
4960.000	-57.00	AV	-41.20	15.80
7435.000	-55.77	PK	-21.20	34.57
7435.000	-71.95	AV	-41.20	30.75

Table 24: Results of emissions test from 9 kHz to 25 GHz on highest channel

6.9 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:	Jennifer Riedel	Date(s) of test:	September 7, 2020
Result[10]:	☒ Test passed	☐ Test not passed	

6.9.1 Test equipment

Type	*Designation*	*Manufacturer*	*Inventory no.*
Compact Diagnostic Chamber (CDC)	VK041.0174	Albatross Projects	E00026
EMI test receiver	ESR 7	Rohde & Schwarz	E00739
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
Test software	EMC32-EB (V10.35)	Rohde & Schwarz	E00777

[10] For information about measurement uncertainties see page 73.

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 16) 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 25 and Table 26.

Frequency	*Field strength*		*Measurement distance*
(MHz)	*(µV/m)*	*(dBµV/m)*	*(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 25: General radiated emission limits up to 30 MHz according to §15.209

Frequency	*Magnetic field strength*		*Measurement distance*
(MHz)	*(µA/m)*	*(dBµA//m)*	*(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 26: General radiated emission limits from 9 kHz to 30 MHz 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 25 using the recalculation factor as described in clause 5.3.

6.9.3 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 5.3.

The following parameters are set:

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

6.9.4 Test results

Test distance:	☒ 3 m	☐ 10 m	☐ ….. m
Antenna alignment:	☒ in parallel	☒ in line	☐ angle ….. °
EUT position:	☒ Position X	☒ Position Y	☒ Position Z

Note(s):
1 Premeasurements were performed to declare the worst case which is documented below.
2 No assessable emissions could be detected.
3 Premeasurements have shown that there are no differences between the tested channels below 30 MHz, so the final measurement was only performed on channel low.
4 The measurements were performed with the EUT with antenna cable, terminated with 50 Ohm.

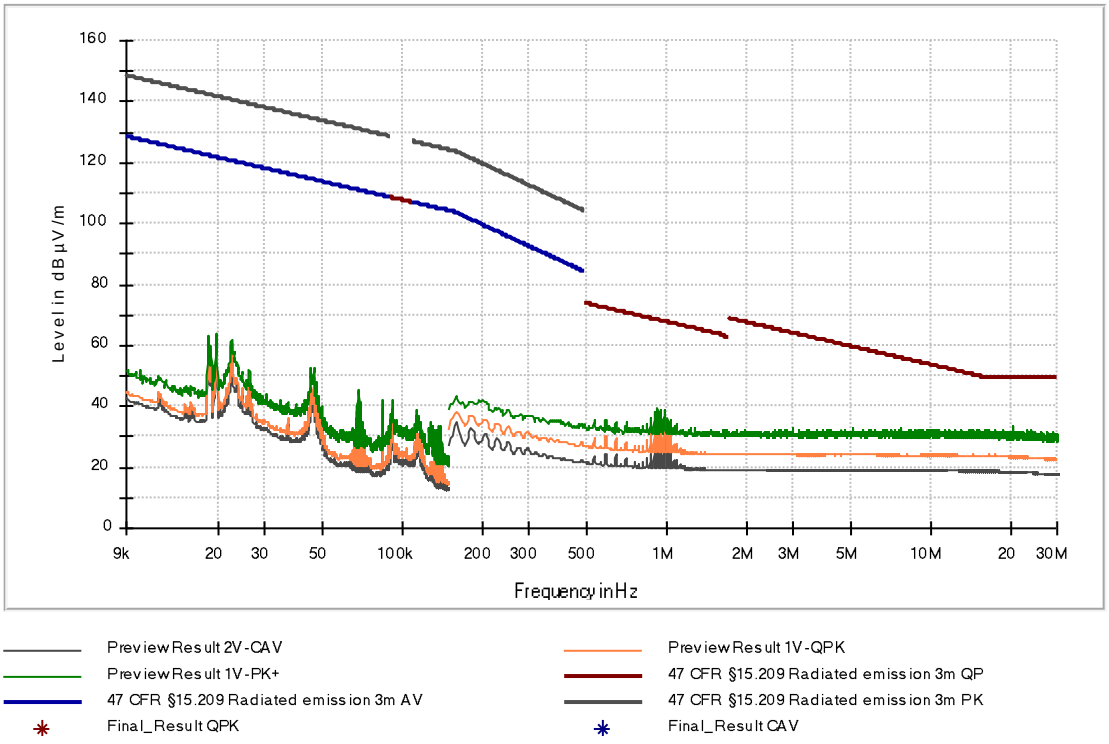

Figure 28: Chart of emissions test below 30 MHz on lowest channel, EUT position Y, antenna parallel to the EUT

6.10 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:	Jennifer Riedel	Date(s) of test:	September 7, 2020
Result[11]:	☒ Test passed	☐ Test not passed	

6.10.1 Test equipment

Type	*Designation*	*Manufacturer*	*Inventory no.*
Semi-anechoic chamber (SAC)	SAC3	Albatross Projects	E00716
EMI test receiver	ESW 8	Rohde & Schwarz	N/A
TRILOG broadband antenna (SAC)	VULB 9162	Schwarzbeck	E00643
Cable set SAC	RF cable(s)	Huber + Suhner	E00755 E01033 E01034
Test software	EMC32-MEB (V10.35)	Rohde & Schwarz	E00778

[11] For information about measurement uncertainties see page 73.

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 16) 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 27.

Frequency	*Field strength*		*Measurement distance*
(MHz)	*(µV/m)*	*(dBµV/m)*	*(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 27: General radiated emission limits ≥ 30 MHz according to §15.209 and RSS-Gen section 8.9

6.10.3 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.

The following parameters are set:

Frequency range	*IF Bandwidth*	*Preamplifier*
30 MHz – 1 GHz	120 kHz	20 dB

6.10.4 Test results

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

Note(s)
1 Premeasurements were performed to declare the worst case which is documented below.
2 Premeasurements 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 The measurements were performed with the EUT with antenna cable, terminated with 50 Ohm.

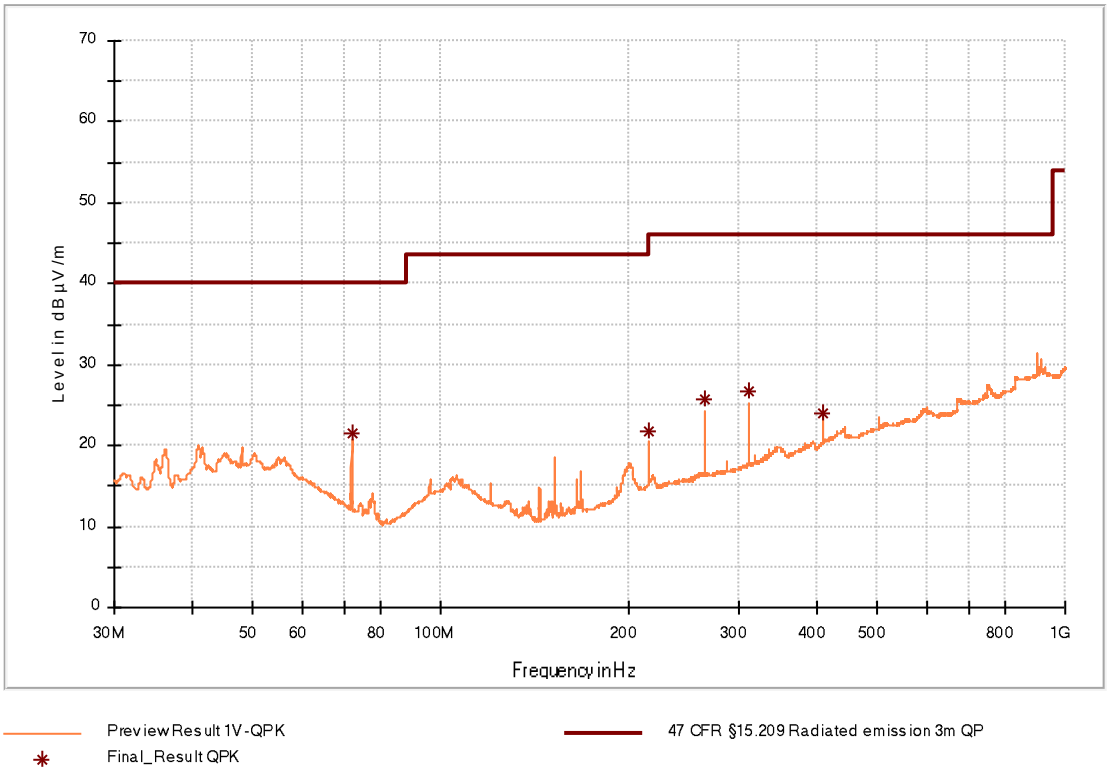

Figure 29: Chart of emissions test from 30 MHz to 1 GHz on lowest channel, EUT position Y, antenna polarization vertical

Frequency (MHz)	*QuasiPK (dBµV/m)*	*Limit (dBµV/m)*	*Margin (dB)*	*Meas. Time (ms)*	*Bandwidth (kHz)*	*Height (cm)*	*Pol.*	*Azimuth (deg)*	*Corr. (dB/m)*
72.000000	21.48	40.00	18.52	1000.0	120.000	112.0	V	162.0	9.9
216.000000	21.65	43.50	21.85	1000.0	120.000	100.0	V	154.0	12.7
264.000000	25.68	46.00	20.32	1000.0	120.000	162.0	V	187.0	14.5
312.000000	26.66	46.00	19.34	1000.0	120.000	100.0	V	222.0	15.4
408.000000	24.01	46.00	21.99	1000.0	120.000	100.0	V	239.0	17.9

Table 28: Results of emissions test from 30 MHz to 1 GHz on lowest channel, EUT position Y, antenna polarization vertical

6.11 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	Date(s) of test:	September 4, 2020
Result[12]:	☒ Test passed	☐ Test not passed	

6.11.1 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
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

[12] For information about measurement uncertainties see page 73.

6.11.2 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 16) 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 29.

Frequency	*Field strength*		*Measurement distance*
(MHz)	*(µV/m)*	*(dBµV/m)*	*(m)*
Above 960	500	53.98	3

Table 29: General radiated emission limits above 960 MHz according to §15.209 and RSS-Gen

6.11.3 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.

The following parameters are set:

Frequency range	*IF Bandwidth*	*Preamplifier*
1 GHz – 25 GHz	1 MHz	External

6.11.4 Test results

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

Note(s):

1 The measurements from 1 GHz to 25 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 Premeasurements were performed to declare the worst case which is documented below. The table results are the final measurements of the emissions detected in the premeasurements which are shown in this test report.

3 According to ANSI C63.10-2013 clause 6.6.4.3 note 2, if the maximized peak measured value complies with the average limit, then it is unnecessary to perform an average measurement.

4 The measurements were performed with the EUT with antenna cable, terminated with 50 Ohm.

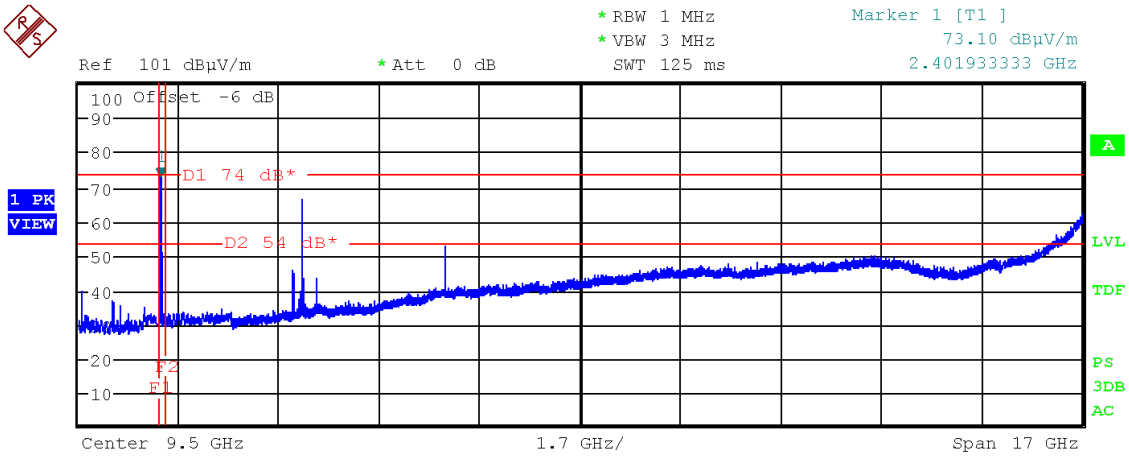

Figure 30: Chart of emissions test from 1 GHz to 18 GHz on lowest channel, EUT position Z, antenna polarization vertical

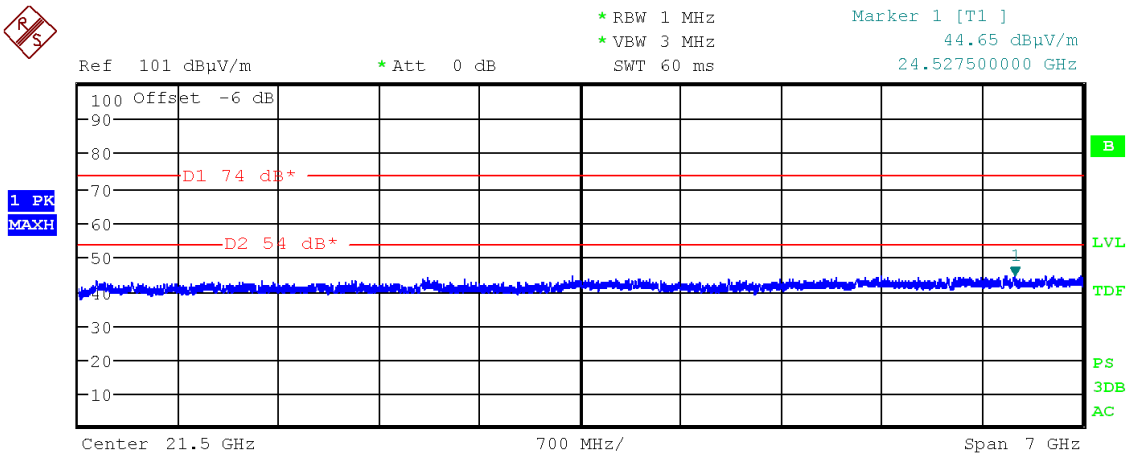

Figure 31: Chart of emission test from 18 GHz to 25 GHz on lowest channel, EUT position Z, antenna polarization vertical

Frequency (MHz)	*EUT Pos.*	*Level (dBµV/m)*	*Detec-tor*	*Limit (dBµV/m)*	*Margin (dB)*	*Height (cm)*	*Pol.*	*Azimuth (deg)*	*Corr. (dB/m)*
4804.000	Z	66.90	PK	74.00	7.10	150.00	V	48.00	1.1
4804.000	Z	52.56	AV	54.00	1.44	150.00	V	48.00	1.1
7206.000	Z	52.42	PK	74.00	21.58	200.00	V	280.00	8.9
17978.000	Z	62.54	PK	74.00	11.46	250.00	V	10.00	18.3
17978.000	Z	51.21	AV	54.00	2.79	250.00	V	10.00	18.3

Table 30: Results of emissions test from 1 GHz to 25 GHz on lowest channel

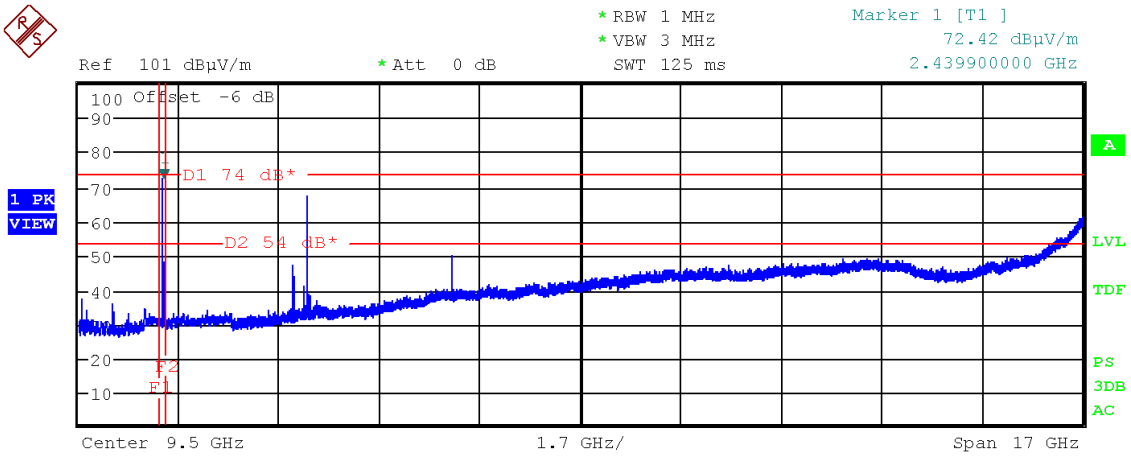

Figure 32: Chart of emissions test from 1 GHz to 18 GHz on middle channel, EUT position Z, antenna polarization vertical

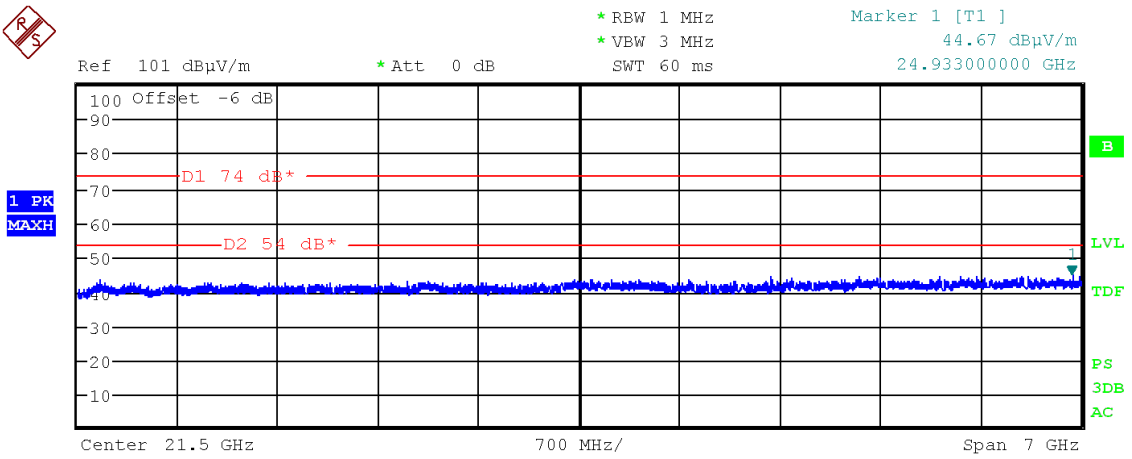

Figure 33: Chart of emission test from 18 GHz to 25 GHz on middle channel, EUT position Z, antenna polarization vertical

Frequency (MHz)	*EUT Pos.*	*Level (dBµV/m)*	*Detec-tor*	*Limit (dBµV/m)*	*Margin (dB)*	*Height (cm)*	*Pol.*	*Azimuth (deg)*	*Corr. (dB/m)*
4880.000	Z	67.29	PK	74.00	6.71	150.00	V	40.00	0.9
4880.000	Z	52.65	AV	54.00	1.35	150.00	V	40.00	0.9
7320.000	Z	51.67	PK	74.00	22.33	100.00	V	45.00	8.7
17978.000	Z	62.54	PK	74.00	11.46	250.00	V	10.00	18.3
17978.000	Z	51.21	AV	54.00	2.79	250.00	V	10.00	18.3

Table 31: Results of emissions test from 1 GHz to 25 GHz on middle channel

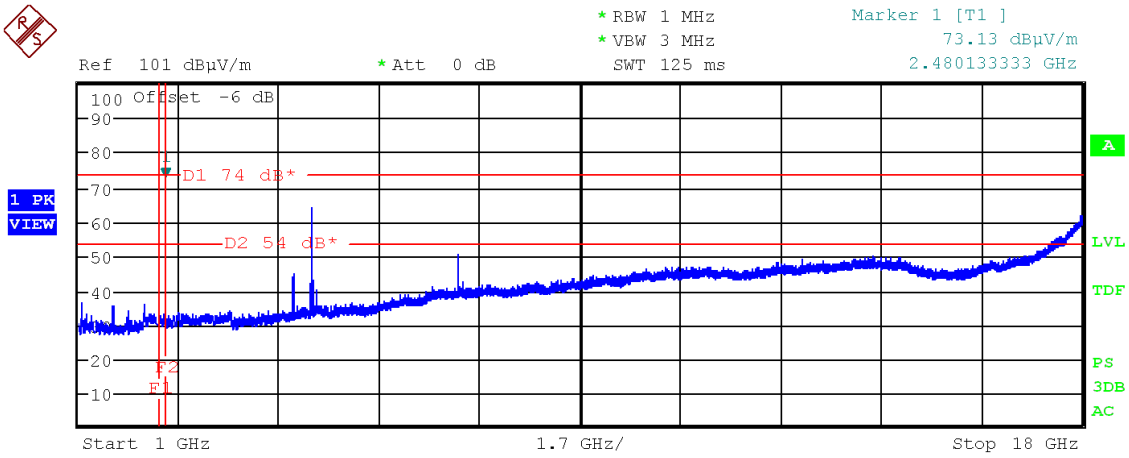

Figure 34: Chart of emissions test from 1 GHz to 18 GHz on highest channel, EUT position Z, antenna polarization vertical

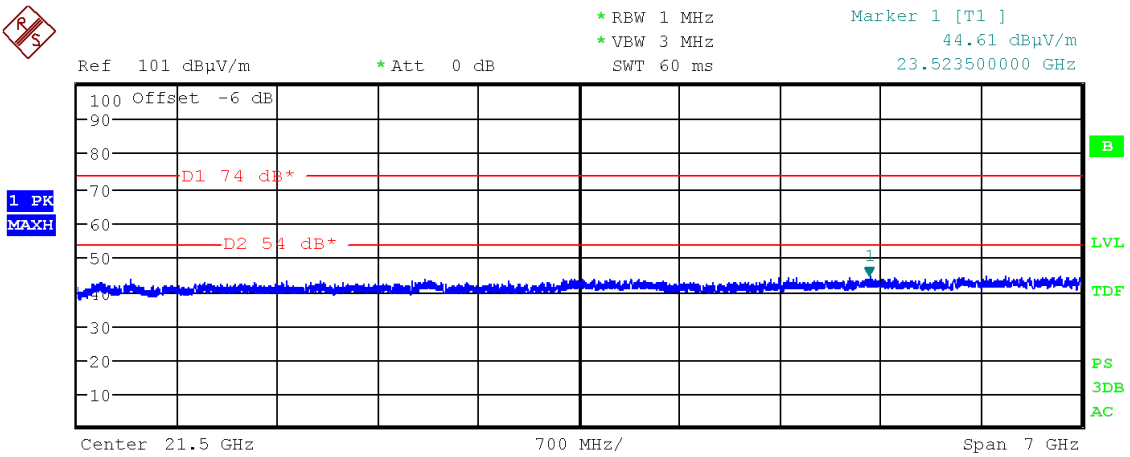

Figure 35: Chart of emission test from 18 GHz to 25 GHz on highest channel, EUT position Z, antenna polarization vertical

Frequency (MHz)	*EUT Pos.*	*Level (dBµV/m)*	*Detec-tor*	*Limit (dBµV/m)*	*Margin (dB)*	*Height (cm)*	*Pol.*	*Azimuth (deg)*	*Corr. (dB/m)*
4960.000	Z	64.85	PK	74.00	9.15	100.00	V	55.00	1.3
4960.000	Z	49.63	AV	54.00	4.37	100.00	V	55.00	1.3
7440.000	Z	51.47	PK	74.00	22.53	150.00	V	280.00	9.3
17993.000	Z	63.27	PK	74.00	10.73	100.00	V	280.00	18.2
17993.000	Z	51.37	AV	54.00	2.63	100.00	V	280.00	18.2

Table 32: Results of emissions test from 1 GHz to 25 GHz on highest channel

7 Equipment calibration status

Description	*Modell number*	*Serial number*	*Inventory number(s)*	*Last calibration*	*Next calibration*
EMI test receiver	ESW44	101538	E00895	2020-08	2022-08
EMI test receiver	ESU26	100026	W00002	2020-06	2022-06
EMI test receiver	ESW8	101284	N/A	2020-08	2022-08
EMI test receiver	ESR7	101059	E00739	2019-08	2021-08
EMI test receiver	ESCI3	100328	E00552	2018-10	2020-10
EMI test receiver	ESCI3	100013	E00001	2020-05	2022-05
Preamplifier (1 GHz - 18 GHz)	BBV 9718 B	00032	W01325	2019-09	2020-10
Preamplifier (18 GHz - 40 GHz)	BBV 9721	43	W01350	2019-11	2020-11
Preamplifier (1 GHz - 18 GHz)	ALS05749	001	W01007	2019-01	2020-01
Loop antenna	HFH2-Z2	871398/0050	E00060	2018-10	2020-10
LISN	ESH2-Z5	881362/037	E00004	Note 1	
LISN	ESH2-Z5	893406/009	E00005	2018-10	2020-10
Field probe	RF-R 400-1	02-2030	E00270	Note 2	
TRILOG broadband antenna (SAC3)	VULB 9162	9162-041	E00643	2018-03	2021-03
Horn antenna	BBHA 9120D	9120D-592	W00053	2019-09	2023-09
Horn antenna	BBHA 9170	9170-332	W00055	2019-06	2023-06
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	2018-03	2021-03
Semi-anechoic chamber (SAC)	SAC3	C62128-A520-A643-x-0006	E00716	2018-03	2021-03
Cable set CDC	RG214/U	---	E00446	2020-04	2021-04
	LCF12-50J	---	E01215	2020-04	2021-04
	LMR400	1718020006	E00920	2020-01	2021-01
	RG214 Hiflex	171802007	E00921	2020-01	2021-01
Cable set anechoic chamber	262-0942-1500	005	E00435	2019-10	2020-10
	SF104EA/2x11PC35-42/5m	11144/4EA	E00307	2019-12	2020-12
	262-0942-1500	003	E00433	2019-10	2020-10
Cable set of semi-anechoic chamber SAC3	SF104EA/11PC35/11PC35/10000MM	501347/4EA	E00755	2019-12	2020-12
	SF104E/11PC35/11PC35/2000MM	507410/4E	E01035	2019-12	2020-12
	SF104E/11PC35/11PC35/2000MM	507411/4E	E01034	2020-09	2021-09

Note(s)
1. Only used for decoupling of support equipment.
2. Only used for relative measurements.

8 Measurement uncertainties

Description	*Uncertainty*	*k=*
AC power line conducted emission	± 3.4 dB	2
Carrier frequency separation Number of hopping frequencies Time of occupancy (dwell time)	± 5.0 %	2
Bandwidth tests	± 2.0 %	2
Maximum conducted output power (conducted)	± 2.9 dB	2
Power spectral density (conducted)	± 2.9 dB	2
Conducted spurious emissions	± 2.9 dB	2
Radiated emissions in semi-anechoic chamber		
9 kHz to 30 MHz	± 2.6 dB	2
30 MHz to 1 GHz	± 6.1 dB	2
1 GHz to 6 GHz	± 4.6 dB	2
6 GHz to 18 GHz	± 5.0 dB	2
18 GHz to 26.5 GHz	± 5.4 dB	2
26.5 GHz to 40 GHz	± 6.2 dB	2

Comment: 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.

Test related measurement uncertainties have to be taken into consideration when evaluating the test results. All used test instrument as well as the test accessories are calibrated at regular intervals.

9 Revision history

Revision	*Date*	*Issued by*	*Description of modifications*
0	2020-10-30	Jennifer Riedel B. Eng.	First edition