element

Radio Radio Radio Radio Radio Radio Radio Radio Radio Radio Radio Radio

Applicant:

Elatec GmbH
Zeppelinstraße 1
82178 Puchheim, Germany
Tel.: +49 89 5529961-0

Test report no.:

230524-AU01+W01

for:

Elatec GmbH
RFID reader / writer module
TWN4 Palon Compact S M LF HF

according to:

47 CFR Part 15, §15.225
RSS-210

Accreditation:

Deutsche Akkreditierungsstelle D-PL-12155-01-00

FCC test firm accreditation expiration date: 2025-09-19
MRA US-EU, FCC designation number: DE0010
Test firm registration number: 997268
FCC Registration Number (FRN): 0032245045
BNetzA-CAB-02/21-02/7 Valid until 2028-11-26

Recognized until 2025-03-16 by the
Department of Innovation, Science and Economic Development Canada (ISED)
as a recognized testing laboratory
CAB identifier: DE0011
Company number: 3472A

Location of Testing:

Element Materials Technology Straubing GmbH
Tel.: +49 9421 56868-0
Fax: +49 9421 56868-100
Email: info.straubing@element.com
Gustav-Hertz-Straße 35
94315 Straubing, Germany

The technical accuracy is guaranteed through the quality management of Element Materials Technology Straubing GmbH.

Table of contents

List of figures

List of tables

1 Summary of test results

System type: RFID Reader

47 CFR part and section	*Test*	*Equivalent to IC radio standard(s)*	*Result*	*Note(s)*	*Page*
15.207(a)	AC powerline conducted emissions	RSS-Gen, section 8.8	Passed	2	25
15.215(c)	20 dB bandwidth	---	Passed	---	27
---	Occupied bandwidth	RSS-Gen, section 6.7	Recorded	---	32
15.225 (a) – (c)	Operation within the band 13.110 MHz – 14.010 MHz	RSS-210 section B.6 (a) I-III	Passed	---	34
15.225(e)	Carrier frequency stability	RSS-210, section B.6 (b)	Passed	---	38
15.225(d)	Emissions below 30 MHz outside the operating frequency band(s) specified	RSS-210, section B.6 (a) IV	Passed	---	41
15.225(d)	Spurious emissions from 30 MHz to 1 GHz	RSS-210, section B.6 (a) IV	Passed	---	44
15.225(d)	Spurious emissions above 1 GHz	RSS-210, section B.6 (a) IV	Passed	3, 4	48

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 Not applicable if the 10th harmonic of the intentional transmitter is below 1 GHz (please see 47 CFR Part 15, section 15.33(a)(1), and RSS-Gen, section 6.13.2(a))

4 According to 47 CFR Part 15, §15.33 (a)(5) and RSS-Gen, section 6.13.2 (d), the frequency range of investigation for the digital device shall be used if the range of investigation determined by the highest internal frequency of the digital device is higher than the 10th harmonic of the intentional radiator

Straubing, June 4, 2024

Tested by
Konrad Graßl
Department Manager Radio

Approved by
Christian Kiermeier
Reviewer

2 Referenced publications

Publication	*Title*
CFR 47 Part 2 October 2023	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 2023	Code of Federal Regulations, Title 47 (Telecommunication), Part 15 (Radio Frequency Devices) of the Federal Communication Commission (FCC)
ANSI C63.10 June 2013	American National Standard of Procedures for Compliance Testing of Unlicensed Wireless Devices
KDB 174176 D01 June 3, 2015	AC power-line conducted emissions Frequently Asked Questions
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-210 Issue 10, December 2019 Amendment (April 2020)	Spectrum Management and Telecommunications Radio Standards Specification Licence-exempt Radio Apparatus (All Frequency Bands): Category I Equipment

3 Equipment under test (EUT)

All Information in this clause is declared by customer.

3.1 General information

Product type:	RFID reader / writer module		
Model name:	TWN4 Palon Compact S M LF HF		
Serial number(s):	Prototype		
Applicant:	Elatec GmbH		
Manufacturer:	Elatec GmbH		
Hardware version:	PRODA		
Software version:	TWN4_xKx472_CONT200_PalonPort_MODE06_13.56MHz.bix		
Short description:	EUT is a RFID reader / writer module operating at the frequencies 125 kHz and 13.56 MHz. In this test report only 13.56 MHz is in consideration.		
Additional modifications:	None		
FCC ID:	WP5TWN4F25		
IC registration number:	7948A-TWN4F25		
Designation of emissions:	649KK1D--		
Power supply:	DC supply		
	Nominal voltage:	5.00 V	
	Minimum voltage:	4.25 V	
	Maximum voltage:	5.75 V	
Temperature range:	-25 °C to +85 °C (customer defined)		
Device type:	☐ Portable	☒ Mobile	☐ Fixed

3.2 Radio specifications

System type:	RFID Reader		
Application frequency band:	13.110 MHz – 14.010 MHz		
Operating frequencies:	13.56 MHz		
Number of RF channels	1		
Highest internal frequency:	120 MHz		
Modulation	ASK		
Antenna:	Type:	PCB loop antenna	
	Connector:	☐ external	☐ internal
		☐ temporary	☒ none (integral antenna)

3.3 Photo documentation

For internal photos of the EUT see annex B. 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*
RFID reader / writer module	TWN4 Palon Compact S M LF HF	Prototype	Elatec GmbH

Table 1: EUT used for testing

Device	*Type designation*	*Serial or inventory no.*	*Manufacturer*
RFID-tag	13.56MkHz	---	Elatec GmbH
Laptop	Lifebook A531	E001053	FUJITSU
Power supply for laptop	AC adapter	E001053	FUJITSU

Table 2: Support equipment used for testing

4.2 Mode of operation

- The EUT was in continuous interrogation mode at 13.56 MHz.
- The device was powered by a laptop via USB.

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.

Floor-standing devices are placed either directly on the reference ground-plane or on insulating material (see clause 6.2.3 of ANSI C63.10-2013 for more details).

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.

5.2 AC power line conducted emission

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

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

b) The measurement equipment is connected to the LISN for the EUT and set-up according to the specifications of the test (see table 3). 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).

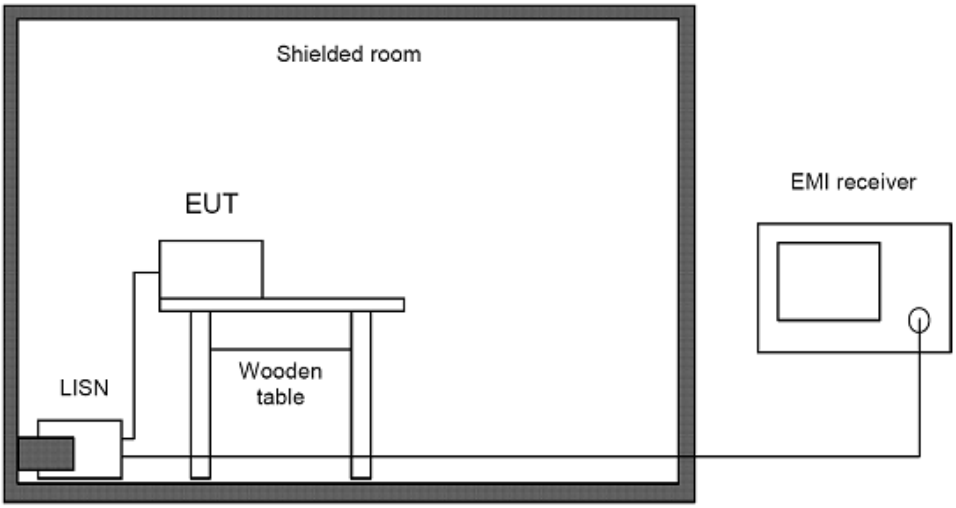


Figure 1: Setup for AC power-line conducted emissions test from 150 kHz to 30 MHz

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 4: Sample calculation

Correction factor = Artifical 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.

5.3 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 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 ≤ 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

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 6.

Frequency (f)	*Measurement receiver bandwidth*	*Step size*	*Detector type*
9 kHz ≤ f < 150 kHz	200 Hz	≤ 100 Hz	Peak Quasi-peak Aerage
150 kHz ≤ f < 30 MHz	9 kHz	≤ 4.5 kHz	Peak Quasi-peak Aerage

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

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

Table 7: 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:

5.3.1 Automatic 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 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 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.
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 ±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.
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.

5.3.2 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 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° 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.

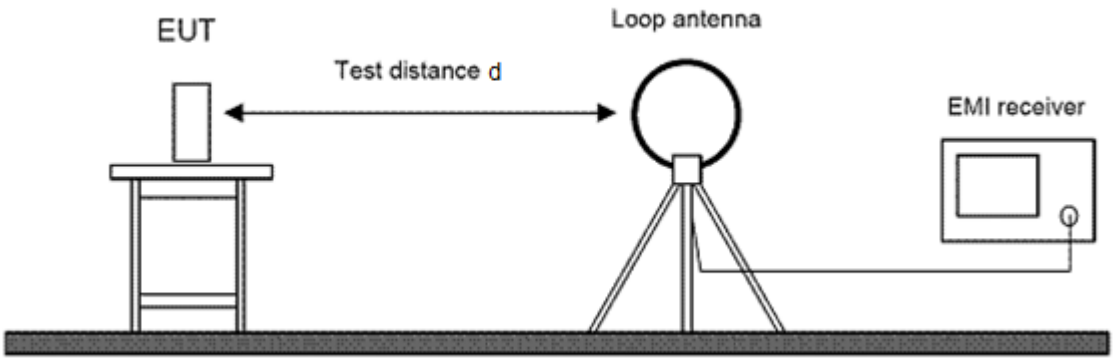


Figure 2: Setup for radiated emissions test below 30 MHz

5.4 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 8.

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

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

Table 9: Sample calculation

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:

5.4.1 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 8).
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) 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.

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

5.4.2 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 8).
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 while the EUT is rotated in a horizontal plane through 360° continuously. 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.
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) After the last prescan, the significant maximum emissions with their polarizations and heights of the measurement antenna 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.
l) The worst-case positions of antenna and table and the maximum emission level are recorded.
m) Steps k) to l) are repeated for all other frequencies in the list.

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

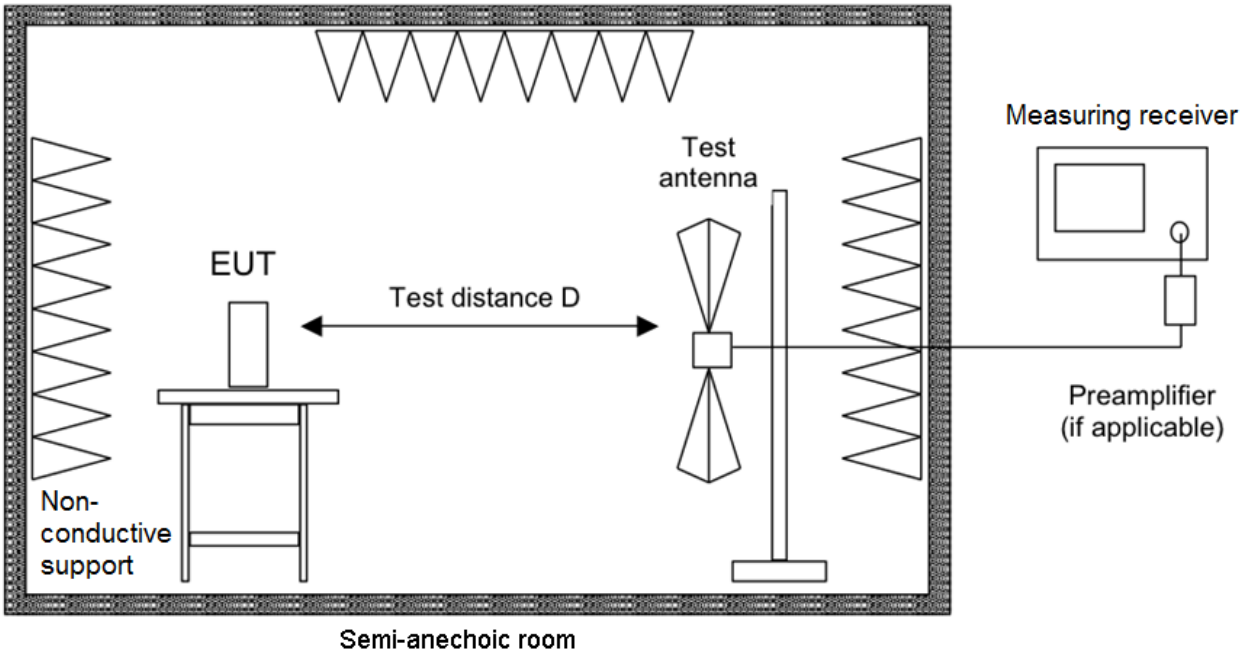


Figure 3: Setup for radiated emissions test from 30 MHz to 1 GHz

5.5 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 10: 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

5.5.1 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 11.

Frequency (f)	*Resolution bandwidth*	*Video bandwidth*	Sweep time	*Trace detector(s)*
f ≥ 1 GHz	1 MHz	3 MHz	AUTO	Max Peak, Average

Table 11: 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.

5.5.2 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 12.

Frequency (f)	*Measurement receiver bandwidth*	*Step size*	*Detector type*	
			Prescan	*Final scan*
f ≥ 1 GHz	1 MHz	≤ 500 kHz	Peak, Average	Peak, Average

Table 12: 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:

5.5.2.1 Automatic 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 12).
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 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 from 1 m to 4 m around this height and the EUT is rotated through 360° around while measuring the emission level continuously.
n) 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.

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

5.5.2.2 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 12).
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 while the EUT is rotated in a horizontal plane through 360° continuously. The measurement is performed with peak detector and max hold.
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 k) to l) are repeated for all other frequencies in the list.

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

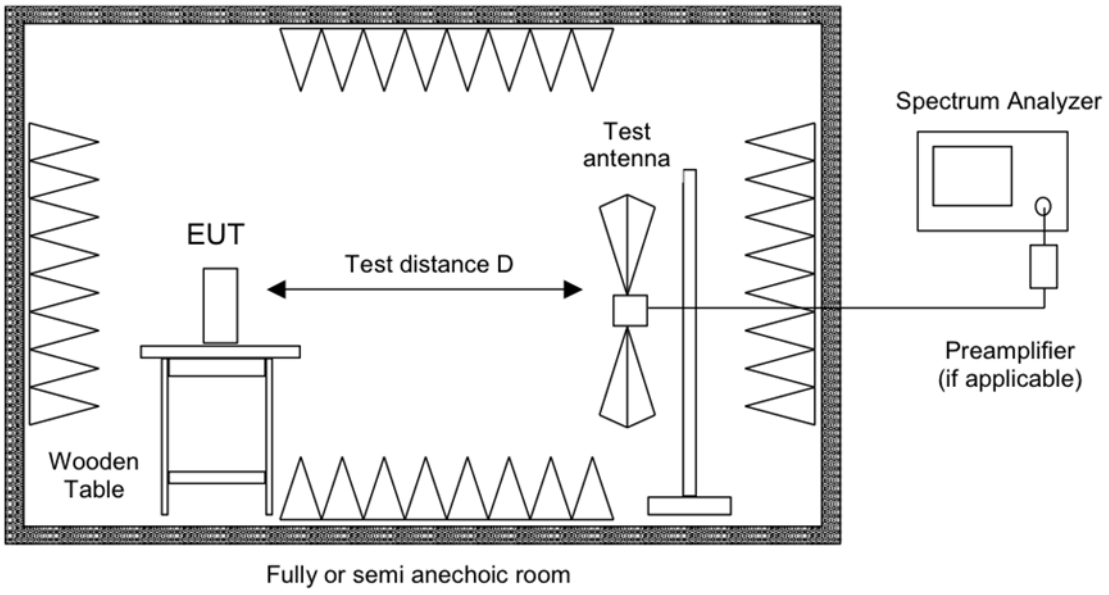


Figure 4: Setup for radiated emissions test above 1 GHz

5.6 Bandwidth measurements

5.6.1 20 dB bandwidth of the emission

The 20 dB bandwidth of the emission is measured according to clause 6.9.2 of ANSI C63.10 as the width of the spectral envelope of the modulated signal, at an amplitude level reduced by a ratio of 20 dB down from the reference value.

The spectrum analyzer center frequency is set to the nominal EUT channel center frequency. The span range for the EMI receiver or spectrum analyzer is between two times and five times the 20 dB bandwidth. The nominal IF filter bandwidth (3 dB RBW) shall be in the range of 1 % to 5 % of the 20 dB bandwidth and the video bandwidth (VBW) shall be approximately three times RBW.

The reference level of the instrument is set as required, keeping the signal from exceeding the maximum input mixer level for linear operation. In general, the peak of the spectral envelope shall be more than [10 log (20 dB bandwidth/RBW)] below the reference level.

5.6.2 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.

5.7 Carrier frequency stability

1. If possible EUT is operating providing an unmodulated carrier. The peak detector of the spectrum analyzer is selected and resolution as well as video bandwidth are set to values appropriate to the shape of the spectrum of the EUT. The frequency counter mode of the spectrum analyzer is used to maximize the accuracy of the measured frequency tolerance.
   If an unmodulated carrier is not available a significant and stable point on the spectrum is selected and the span is reduced to a value that delivers an accuracy which shall be better than 1% of the maximum frequency tolerance allowed for the carrier signal. This method may be performed as long as the margin to the frequency tolerance allowed is larger than the uncertainty of the measured frequency tolerance.
2. The carrier frequency is measured depending on the variation in the primary supply voltage from 85% to 115% of the rated supply voltage at a temperature of 20 C.
   For battery operated equipment an external supply voltage can be used and set at the battery nominal voltage, and again at the battery operating end point voltage which must be specified by the equipment manufacturer. Alternatively, tests shall be performed using a new battery.
3. The carrier frequency is measured over a temperature variation of -20 degrees to +50 degrees C at normal supply voltage.

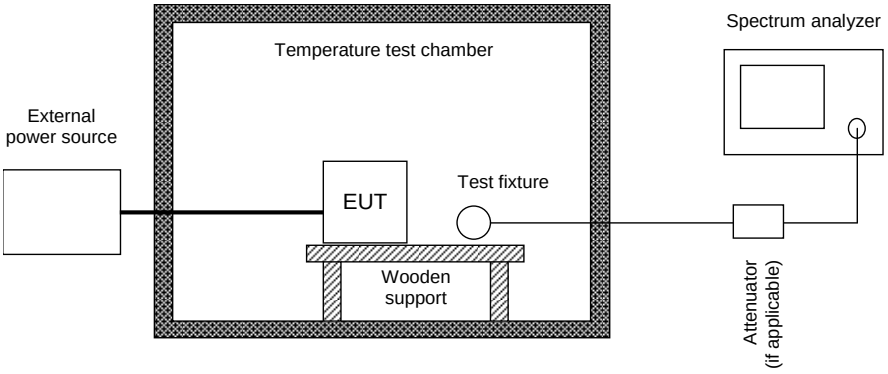


Figure 5: Test setup for carrier frequency stability measurement

6 Test results

This clause gives details about the test results as collected in the summary of test results on page 5.

For information about measurement uncertainties see page 54.

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 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:	Konrad Graßl	Date of test:	January 30, 2024
Result:	☒ Test passed	☐ Test not passed	

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	ENV432	Rohde & Schwarz	E01733
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 µH / 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 µH / 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 (dBµV)*	
	Quasi-peak	*Average*
0.15-0.5	66 to 56*	56 to 46*
0.5-5	56	46
5-30	60	50

Table 13: Limits for AC powerline conducted emissions according to § 15.207 and RSS-Gen

*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 5.2.

6.1.4 Test results

Note(s):
1. The test was performed at 120 V and 60 Hz.

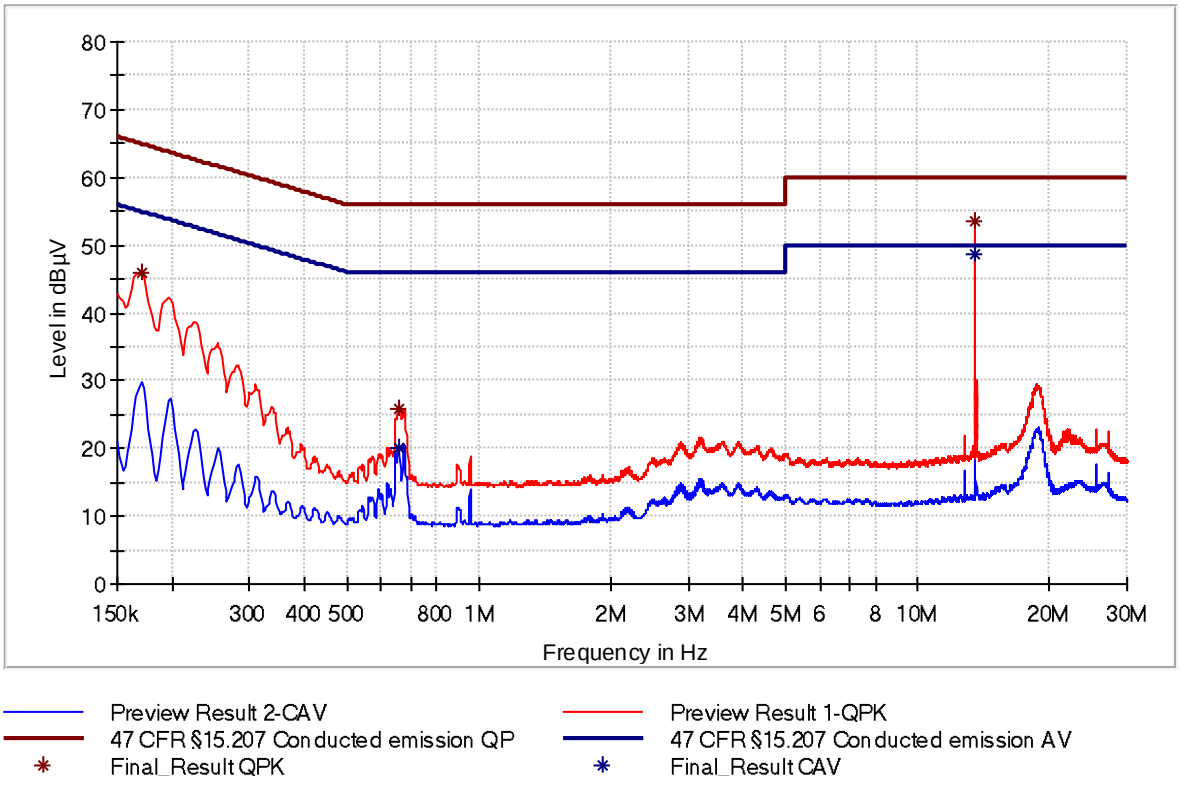


Figure 6: Chart of AC powerline conducted emissions on L1

Frequency (MHz)	*QuasiPeak (dBµV)*	*Average (dBµV)*	*Limit (dBµV)*	*Margin (dB)*	*Line*	*PE*	*Corr. (dB)*	*Result*
0.170	45.9	-	65.0	19.1	L1	GND	20.3	Passed
0.659	-	20.2	46.0	25.8	L1	GND	20.3	Passed
0.659	26.0	-	56.0	30.0	L1	GND	20.3	Passed
13.560	-	48.6	50.0	1.4	L1	GND	20.9	Passed
13.560	53.5	-	60.0	6.5	L1	GND	20.9	Passed

Table 14: Results of AC powerline conducted emissions on L1

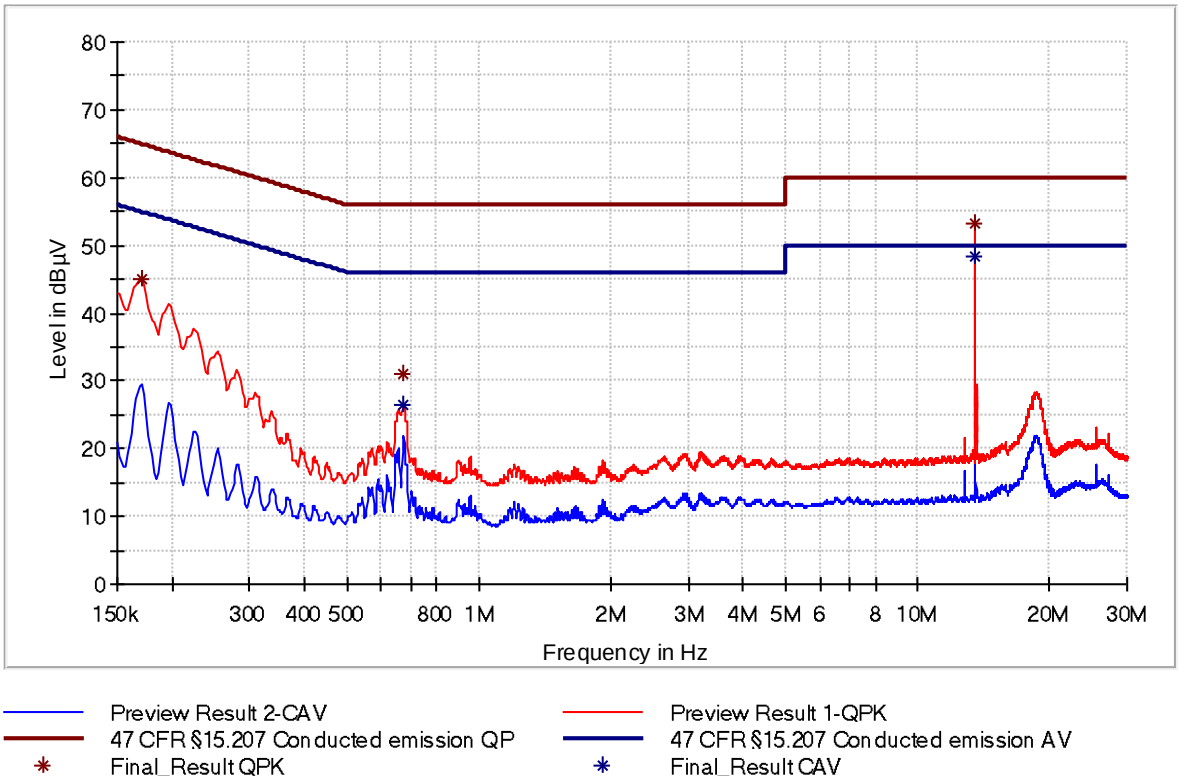


Figure 7: Chart of AC powerline conducted emissions on N

Frequency (MHz)	*QuasiPeak (dBµV)*	*Average (dBµV)*	*Limit (dBµV)*	*Margin (dB)*	*Line*	*PE*	*Corr. (dB)*	*Result*
0.170	45.1	-	65.0	19.9	N	GND	20.3	Passed
0.674	-	26.5	46.0	19.5	N	GND	20.3	Passed
0.674	31.0	-	56.0	25.0	N	GND	20.3	Passed
13.560	-	48.3	50.0	1.7	N	GND	21.1	Passed
13.560	53.1	-	60.0	6.9	N	GND	21.1	Passed

Table 15: Results of AC powerline conducted emissions on N

6.2 20 dB bandwidth

Section(s) in 47 CFR Part 15:	Requirement(s):	15.215(c)	
	Reference(s):	ANSI C63.10 , clause 6.9	

Performed by:	Konrad Graßl	Date(s) of test:	February 23, 2024
Result:	☒ Test passed	☐ Test not passed	

6.2.1 Test equipment

Type	*Designation*	*Manufacturer*	*Inventory no.*
EMI test receiver	ESR 7	Rohde & Schwarz	E01549
Field probe	RF-R 400-1	Langer EMV-Technik	E00270

6.2.2 Limits

According to §15.215(c):
Intentional radiators operating under the alternative provisions to the general emission limits must be designed to ensure that the 20 dB bandwidth of the emission, or whatever bandwidth may otherwise be specified in the specific rule section under which the equipment operates, is contained within the frequency band designated in the rule section under which the equipment is operated. The requirement to contain the designated bandwidth of the emission within the specified frequency band includes the effects from frequency sweeping, frequency hopping and other modulation techniques that may be employed as well as the frequency stability of the transmitter over expected variations in temperature and supply voltage. If a frequency stability is not specified in the regulations, it is recommended that the fundamental emission be kept within at least the central 80% of the permitted band in order to minimize the possibility of out-of-band operation.

6.2.3 Test procedure

The 20 dB bandwidth is measured using the conducted measurement procedure using a test fixture with the analyzer settings as described in clause 5.6.1 at normal conditions.
Any required results for maximum 20 dB bandwidth under extreme conditions are obtained by addition and subtraction of the upper and lower frequency error results (see clause 6.5.4) to each bandwidth measurement obtained in this test.

6.2.4 Test results

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

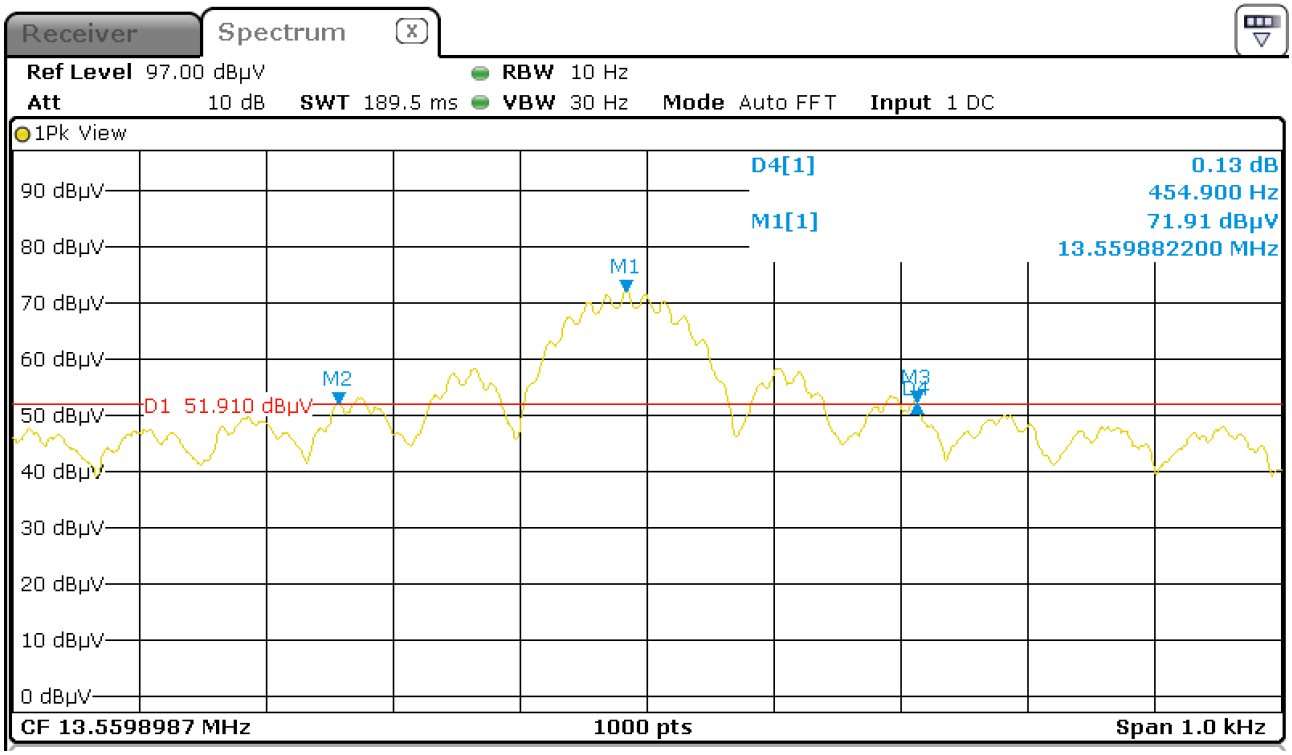


Figure 8: Chart of 20 dB bandwidth tests at normal conditions, with tag

20 dB bandwidth	*Band edge left*		*Band edge right*		*Result*
	Frequency	*Limit*	*Frequency*	*Limit*	
(kHz)	*(MHz)*	*(MHz)*	*(MHz)*	*(MHz)*	
0.455	13.559656	>13.553000	13.560111	<13.5670000	Passed

Table 16: Results of 20 dB bandwidth tests at normal conditions, with tag

$f_{assigned}$ (MHz)	Index	f_{-20dB} (MHz)	Δf_T (kHz)	Δf_U (kHz)	$f_{-20dB(T, U)}$ (MHz)	Limit (MHz)	Margin (kHz)	Result
13.560000	low	13.559656	0.000	0.000	13.559656	>13.553000	6.656	Passed
	high	13.560111	0.140	0.000	13.560251	<13.567000	6.749	Passed
	Bandwidth	0.455 kHz			0.595 kHz			

Table 17: Results of 20 dB bandwidth tests at extreme conditions, with tag

with:
- $f_{-20dB(low)}$ = lower frequency in MHz where emission is at least 20 dB below the carrier at normal conditions
- $f_{-20dB(high)}$ = upper frequency in MHz where emission is at least 20 dB below the carrier at normal conditions
- $f_{assigned}$ = assigned frequency in MHz
- $\Delta f_{T(low)}$ = maximum absolute value of negative frequency offset to frequency at normal conditions caused by temperature variation in kHz
- $\Delta f_{T(high)}$ = maximum absolute value of positive frequency offset to frequency at normal conditions caused by temperature variation in kHz
- $\Delta f_{U(low)}$ = maximum absolute value of negative frequency offset to frequency at normal conditions caused by voltage variation in kHz
- $\Delta f_{U(high)}$ = maximum absolute value of positive frequency offset to frequency at normal conditions caused by voltage variation in kHz
- $f_{-20dB(T, U)}$ = frequency in MHz where emission is at least 20 dB below the carrier, including offset caused by variations of temperature and supply voltage as recorded in clause 6.5.4

Measured -20 dB emission bandwidth:
At normal conditions: 0.455 kHz
Including variations in temperature and supply voltage: 0.595 kHz

6.3 Occupied bandwidth

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

Performed by:	Konrad Graßl	Date(s) of test:	December 20, 2023
Result:	☒ Recorded	☐ Not recorded	

6.3.1 Test equipment

Type	*Designation*	*Manufacturer*	*Inventory no.*
EMI test receiver	ESR 7	Rohde & Schwarz	E01549
Field probe	RF-R 400-1	Langer EMV-Technik	E00270

6.3.2 Limits

According to 2.1049(i):
Transmitters designed for other types of modulation—when modulated by an appropriate signal of sufficient amplitude to be representative of the type of service in which used. A description of the input signal should be supplied.

According to RSS-Gen, section 6.7:
There is no limit specified, the occupied bandwidth has to be recorded and reported.

6.3.3 Test procedure

Occupied bandwidth is measured using the

☐ radiated measurement procedure with the analyzer settings as described in clause 5.6.2.

☒ conducted measurement procedure using a test fixture with the analyzer settings as described in clause 5.6.2.

6.3.4 Test results

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

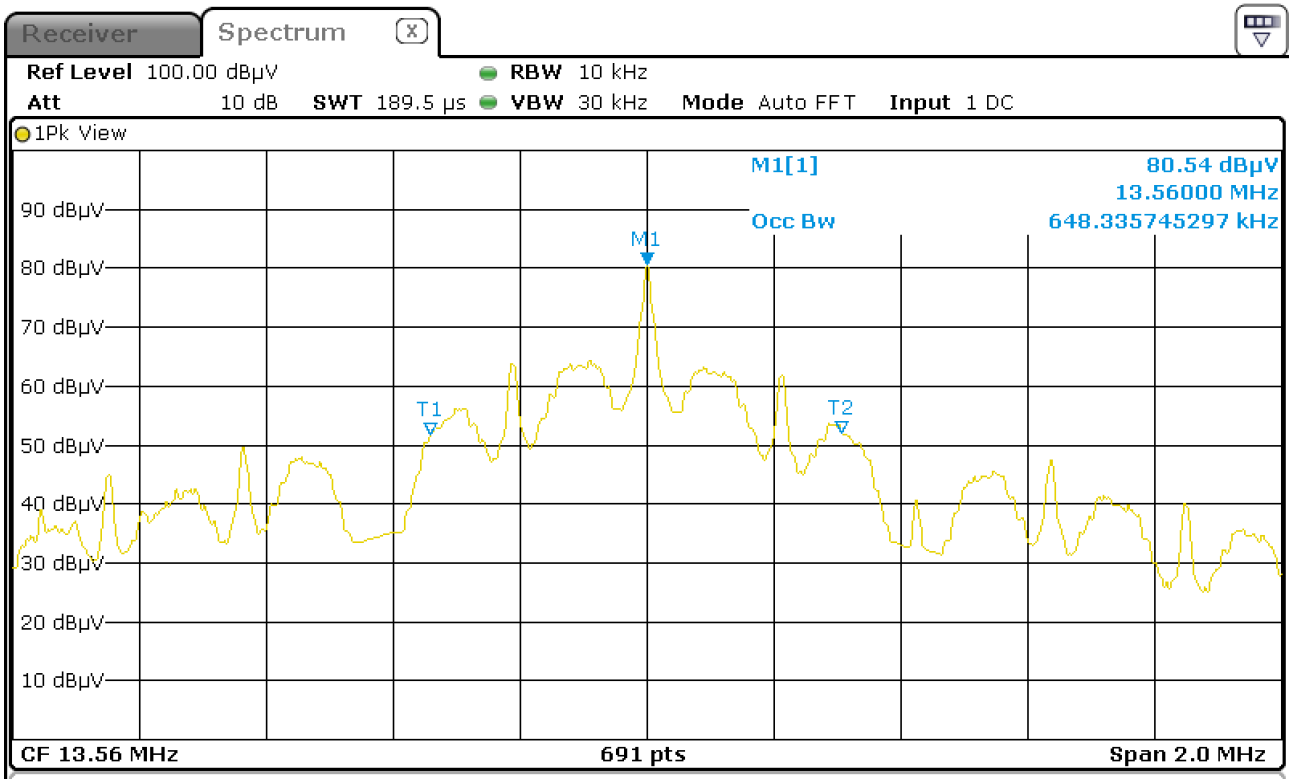


Figure 9: Chart of occupied bandwidth test, with tag

99% bandwidth (kHz)	*Lower frequency (MHz)*	*Higher frequency (MHz)*	*Result*
648.3	13.2184	13.8668	Recorded

Table 18: Results of occupied bandwidth test, with tag

6.4 Operation within the band 13.110 MHz – 14.010 MHz

Section(s) in 47 CFR Part 15:	Requirement(s):	15.225 (a)-(c)
	Reference(s):	ANSI C63.10, section 6.4
Section(s) in RSS:	Requirement(s):	RSS-210, section B.6 (a) I-III
	Reference(s):	ANSI C63.10, section 6.4

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

6.4.1 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)	AME HF-Technik stabo Elektronik GmbH AME HF-Technik AME HF-Technik	E01474 E01215 E00920 E01284

6.4.2 Limits

According to § 15.225(a)-(c):
The field strength of any emissions within the band 13.553-13.567 MHz shall not exceed 15848 microvolts/meter at 30 meters.

Within the bands 13.410-13.553 MHz and 13.567-13.710 MHz, the field strength of any emissions shall not exceed 334 microvolts/meter at 30 meters.

Within the bands 13.110-13.410 MHz and 13.710-14.010 MHz the field strength of any emissions shall not exceed 106 microvolts/meter at 30 meters.

According to RSS-210 section B.6 I-III:
The field strength of any emissions shall not exceed the following limits:
15.848 mV/m (84 dBµV/m) at 30 m, within the band 13.553-13.567 MHz
334 µV/m (50.5 dBµV/m) at 30 m, within the bands 13.410-13.553 MHz and 13.567-13.710 MHz
106 µV/m (40.5 dBµV/m) at 30 m, within the bands 13.110-13.410 MHz and 13.710-14.010 MHz

In case of measurements that 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 above using the recalculation factor as described in clause 5.3.

6.4.3 Test procedure

The emission within the band 13.110 MHz – 14.010 MHz is measured using the

☒ manual measurement procedure as described in clause 5.3.
☐ automatic measurement procedure as described in clause clause 5.3.

6.4.4 Test results

Test distance:	☒ 3 m		
Antenna alignment:	☒ in parallel	☒ in line	
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. The chart shows the calculated limit at 3 m.

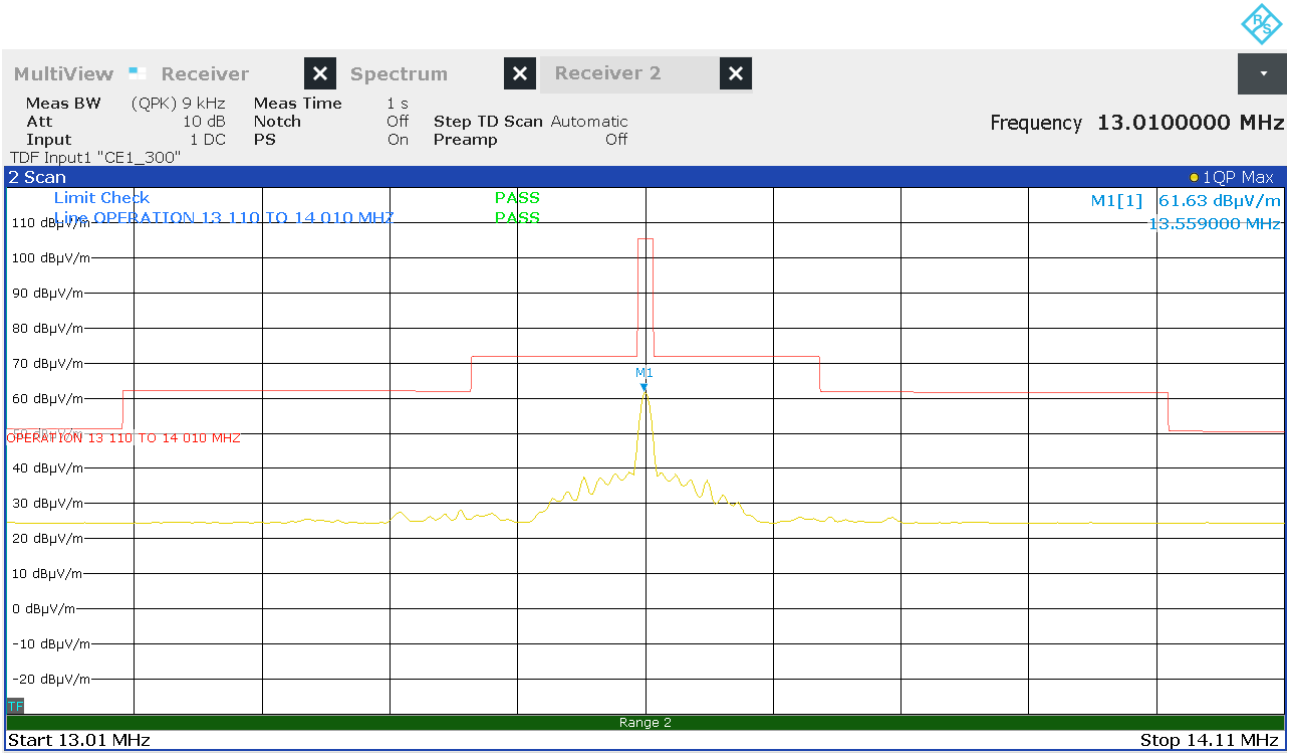


Figure 10: Chart of emission within the band 13.110 MHz to 14.010 MHz, EUT in position Y, without tag, antenna in line at 3 m distance

Freq. (MHz)	*EUT Pos.*	*Det.*	*Field strength (dBµV/m at 3 m)*	*Rec. factor*	*Calc. field strength (dBµV/ m)*	*at dist. (m)*	*Limit (dBµV/ m)*	*at dist. (m)*	*Mar. (dB)*	*Pol*	*Azim. (deg)*	*Corr. (dB/m)*	*Res*
13.559	Y	QP	61.6	-21.4	40.2	30	84.0	30	43.8	I	90	19.5	P

Table 19: Results of emission within the band 13.110 MHz to 14.010 MHz, without tag

with:

	Freq.	=	Frequency
	EUT Pos.	=	EUT Position
	Det.	=	Detector
	Rec. factor		Recalculation factor
	Calc.		Calculated
	at dis		at distance
	Mar.		Margin
	Pol.	=	Polarization of the measurement antenna
	I		Polarization of the measurement antenna in line
	O		Polarization of the measurement antenna parallel
	Azim. (deg)	=	Azimuth (degree)
	Corr.	=	Correction factor
	Res.		Result
	P		Passed
	Np		Not passed

6.5 Carrier frequency stability

Section(s) in 47 CFR Part 15:	Requirement(s):	15.225(e)
	Reference(s):	ANSI C63.10, section 6.8
Section(s) in RSS:	Requirement(s):	RSS-210, annex B6 (b)
	Reference(s):	RSS-Gen, section 6.11

Performed by:	Konrad Graßl	Date(s) of test:	February 14, 2024
Result:	☒ Test passed	☐ Test not passed	

6.5.1 Test equipment

Type	*Designation*	*Manufacturer*	*Inventory no.*
EMI test receiver	ESR 7	Rohde & Schwarz	E01549
Field probe	RF-R 400-1	Langer EMV-Technik	E00270
Climatic chamber (990 l)	VC 4100	Vötsch Industrietechnik	C00014
Multimeter	METRAHit 2+	Gossen Metrawatt	W01452
Power supply	3231.1	Statron	E01235
USB measurement box	---	ELEMENT STRAUBING	SEB01231

6.5.2 Limits

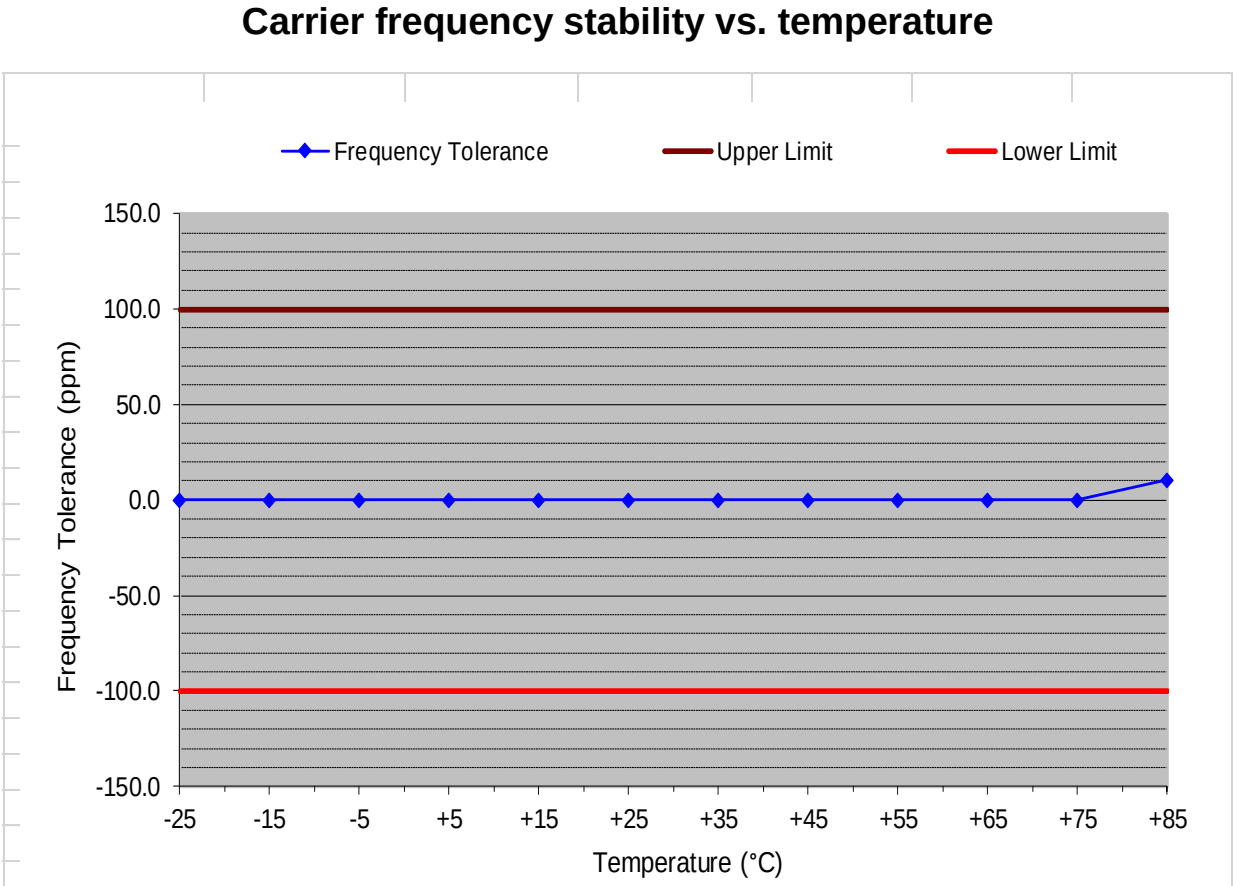
According to §15.225 (e):
The frequency tolerance of the carrier signal shall be maintained within ±0.01% of the operating frequency over a temperature variation of -20 degrees to +50 degrees C at normal supply voltage, and for a variation in the primary supply voltage from 85% to 115% of the rated supply voltage at a temperature of 20 degrees C. For battery operated equipment, the equipment tests shall be performed using a new battery. Alternatively, an external supply voltage can be used and set at the battery nominal voltage, and again at the battery operating end point voltage which must be specified by the equipment manufacturer.

According to RSS-210 section B.6 (b):
The carrier frequency stability shall not exceed ±100 ppm.

6.5.3 Test procedure

The carrier frequency stability is measured using the test procedure as described in clause 5.7.

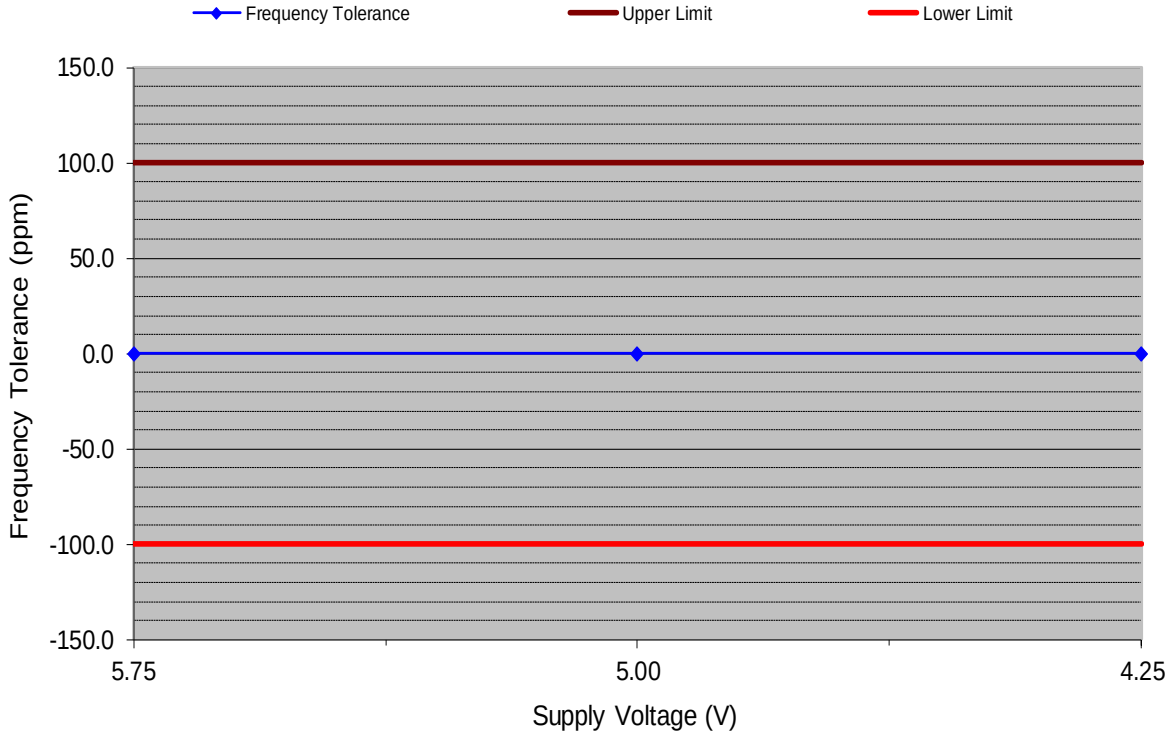
6.5.4 Test results



Supply voltage:	5 V	Frequency under nominal conditions:			13.55993 MHz	
Temperature (°C)	Frequency (MHz)	Frequency Tolerance (Hz)	(ppm)	Upper Limit (ppm)	Lower Limit (ppm)	Margin (ppm)
-25	13.559930	0	0.0	+100.0	-100.0	**100.0**
-15	13.559930	0	0.0	+100.0	-100.0	**100.0**
-5	13.559930	0	0.0	+100.0	-100.0	**100.0**
+5	13.559930	0	0.0	+100.0	-100.0	**100.0**
+15	13.559930	0	0.0	+100.0	-100.0	**100.0**
+25	13.559930	0	0.0	+100.0	-100.0	**100.0**
+35	13.559930	0	0.0	+100.0	-100.0	**100.0**
+45	13.559930	0	0.0	+100.0	-100.0	**100.0**
+55	13.559930	0	0.0	+100.0	-100.0	**100.0**
+65	13.559930	0	0.0	+100.0	-100.0	**100.0**
+75	13.559930	0	0.0	+100.0	-100.0	**100.0**
+85	13.560070	140	10.3	+100.0	-100.0	89.7

Result: Passed

Carrier frequency stability vs. supply voltage



Temperature: +25 °C
Frequency under normal conditions: 13.55993 MHz

Supply Voltage (V)	Frequency (MHz)	Frequency Tolerance (Hz)	Frequency Tolerance (ppm)	Upper Limit (ppm)	Lower Limit (ppm)	Margin (ppm)
5.75	13.559930	0	0.0	+100.0	-100.0	100.0
5.00	13.559930	0	0.0	+100.0	-100.0	100.0
4.25	13.559930	0	0.0	+100.0	-100.0	100.0

Result: Passed

6.6 Emissions below 30 MHz outside the operating frequency band(s) specified

Section(s) in 47 CFR Part 15:	Requirement(s): Reference(s):	15.225 (d) ANSI C63.10, clause 6.4
Section(s) in RSS:	Requirement(s): Reference(s):	RSS-210, section B.6 (a) IV ANSI C63.10, clause 6.4

Performed by:	Konrad Graßl	Date of test:	December 19, 2023
Result:	☒ Test passed	☐ Test not passed	

6.6.1 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)	AME HF-Technik stabo Elektronik GmbH AME HF-Technik AME HF-Technik	E01474 E01215 E00920 E01284

6.6.2 Limits

According to §15.225(d):
The field strength of any emissions appearing outside of the 13.110-14.010 MHz band shall not exceed the general radiated emission limits in §15.209.

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

According to RSS-210, section B.6 (a) IV:
RSS-Gen general field strength limits for frequencies outside the band 13.110-14.010 MHz.

Frequency	*Field strength*		*Measurement distance*
(MHz)	*(µA/m)*	*(dBµA/m)*	*(m)*
0.009 – 0.490	6.37/F(kHz) (0.708 – 0.013)	-2.999 – -37.721	300
0.490 – 1.705	63.7/F(kHz) (0.13 – 0.037)	-17.721 – -28.636	30
1.705 – 30	0.08	-21.94	30

Table 21: General radiated emission limits up to 30 MHz according to section 8.9 of RSS-Gen

In case of measurements that 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 20 and Table 21, using the recalculation factor as described in clause 5.3.

6.6.3 Test procedure

The radiated emissions below 30 MHz are measured using the

☒ manual measurement procedure as described in clause 5.3.
☐ automatic measurement procedure as described in clause 5.3.

6.6.4 Test results

Test distance:	☒ 3 m		
Antenna alignment:	☒ in parallel (O)	☒ in line (I)	
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. No assessable emissions could be detected.
3. The operation frequency at 13.56 MHz is not in consideration in this test.

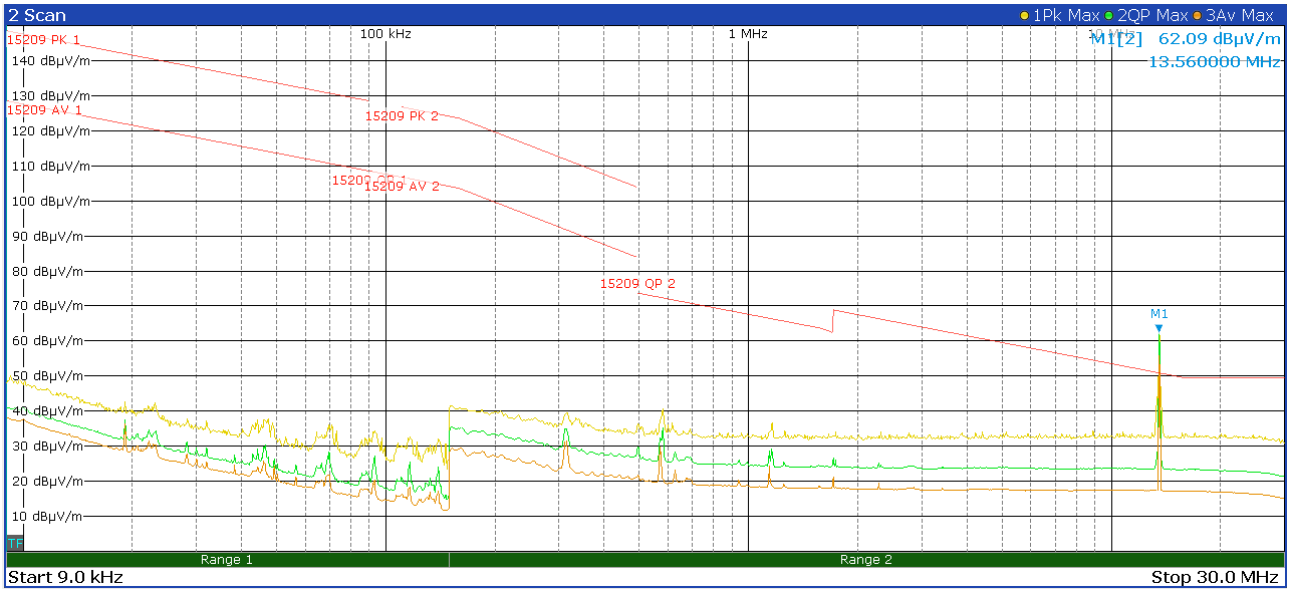


Figure 11: Chart of radiated emissions test below 30 MHz, EUT position Y, antenna polarization in line, without tag

6.7 Spurious emissions from 30 MHz to 1 GHz

Section(s) in 47 CFR Part 15:	Requirement(s):	15.225 (d)
	Reference(s):	ANSI C63.10, clause 6.5
Section(s) in RSS:	Requirement(s):	RSS-210, section B.6 (a) IV
	Reference(s):	ANSI C63.10, clause 6.5

Performed by:	Konrad Graßl	Date of test:	December 13, 2023
Result:	☒ Test passed	☐ Test not passed	

6.7.1 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

6.7.2 Limits

According to §15.225(d):
The field strength of any emissions appearing outside of the 13.110-14.010 MHz band shall not exceed the general radiated emission limits in §15.209.

According to RSS-210, section B.6 (a) IV:
RSS-Gen general field strength limits for frequencies outside the band 13.110-14.010 MHz.

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 22: General radiated emission limits ≥ 30 MHz according to §15.209 and RSS-Gen

6.7.3 Test procedure

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

☐ manual measurement procedure as described in clause 5.4.
☒ automatic measurement procedure as described in clause 5.4.

6.7.4 Test results

Test distance:	☒ 3 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.

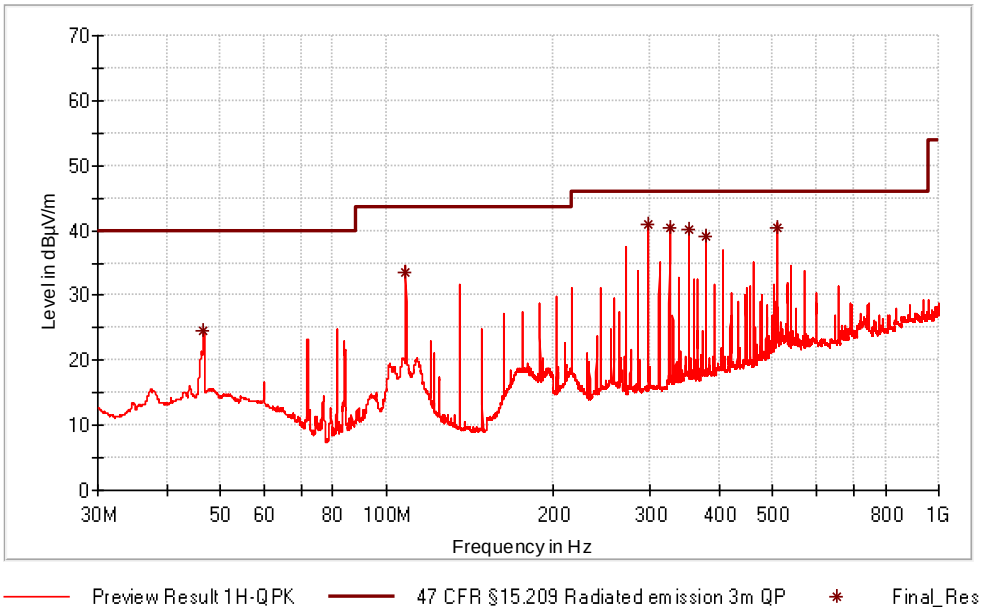


Figure 12: Chart of radiated emissions test from 30 MHz to 1 GHz, EUT position X, antenna polarization horizontal, without tag

Freq. (MHz)	*EUT Pos.*	*Det.*	*Field strength (dBµV/m at 3 m)*	*Limit (dBµV/m) at 3 m*	*Margin (dB)*	*Height (cm)*	*Pol.*	*Azim. (deg)*	*Corr. (dB/m)*	*Result*
46.680	X	QP	24.5	40.0	15.5	135	H	0	14.7	Passed
108.480	X	QP	33.5	43.5	10.0	258	H	197	12.6	Passed
298.320	X	QP	40.9	46.0	5.1	100	H	69	15.1	Passed
325.440	X	QP	40.4	46.0	5.7	100	H	257	15.8	Passed
352.56	X	QP	40.1	46.0	5.9	100	H	248	16.9	Passed
379.68	X	QP	39.1	46.0	7.0	100	H	232	17.2	Passed
510.00	X	QP	40.4	46.0	5.6	146	H	52	19.7	Passed

Table 23: Results of radiated emissions test from 30 MHz to 1 GHz, without tag

with:
Freq. = Frequency
EUT Pos. = EUT Position
Det. = Detector
Pol. = Polarization of the measurement antenna
Azim. (deg) = Azimuth (degree)
Corr. = Correction factor

6.8 Spurious emissions above 1 GHz

Section(s) in 47 CFR Part 15:	Requirement(s):	15.225 (d)
	Reference(s):	ANSI C63.10, clause 6.6
Section(s) in RSS:	Requirement(s):	RSS-210, section B.6 (a) IV
	Reference(s):	ANSI C63.10, clause 6.6

Performed by:	Konrad Graßl	Date of test:	February 26, 2024
Result:	☒ Test passed	☐ Test not passed	

6.8.1 Test equipment

Type	*Designation*	*Manufacturer*	*Inventory no.*
Free space semi-anechoic chamber (FS-SAC)	FS-SAC	ELEMENT STRAUBING	E00100
EMI test receiver	ESW 44	Rohde & Schwarz	E00895
Preamplifier (0.5 GHz - 18 GHz)	BBV 9718 B	Schwarzbeck	W01325
Horn antenna	BBHA 9120D	Schwarzbeck	W00053
Cable set FS-SAC	RF cable(s)	Teledyne Reynolds Huber + Suhner Teledyne Reynolds	E00435 E00307 E00433

6.8.2 Limits

According to §15.225(d):
The field strength of any emissions appearing outside of the 13.110-14.010 MHz band shall not exceed the general radiated emission limits in §15.209.

According to RSS-210, section B.6 (a) IV:
RSS-Gen general field strength limits for frequencies outside the band 13.110-14.010 MHz.

Frequency	*Field strength*		*Measurement distance*
(MHz)	*(µV/m)*	*(dBµV/m)*	*(m)*
Above 960	500	54	3

Table 24: General radiated emission limits above 960 MHz according to §15.209 and RSS-Gen

6.8.3 Test procedure

The radiated emissions above 1 GHz are measured using the

☒ manual measurement procedure as described in clause 5.5.
☐ automatic measurement procedure as described in clause clause 5.5.

6.8.4 Test results

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

Note(s):

1 The measurements from 1 GHz to 2 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 Pre-measurements were performed to declare the worst case which is documented below. The table results are the final measurements of the emissions detected in the pre-measurements which are shown in this test report.

3 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.

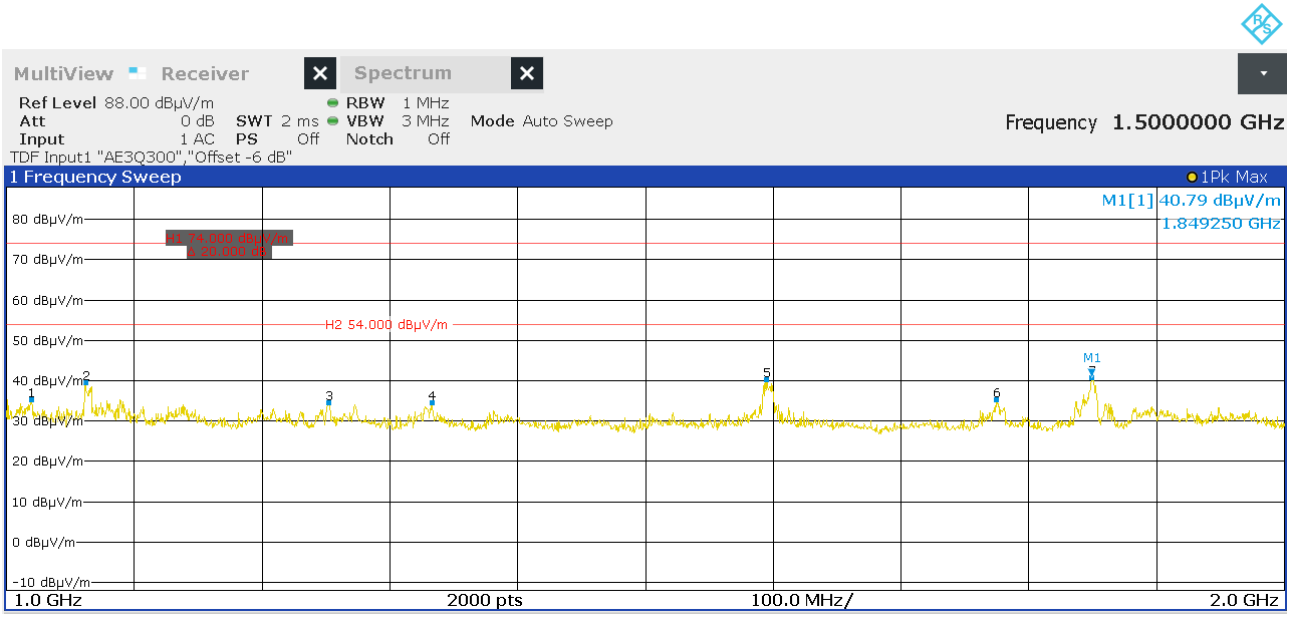


Figure 13: Chart of emissions pre-measurement from 1 GHz to 2 GHz, EUT position X, antenna polarization vertical, with tag

Freq. (MHz)	*EUT Pos.*	*Det.*	*Level (dBµV/m) at 3 m*	*Peak limit (dBµV/m) at 3 m*	*Mar. (dB)*	*Average limit (dBµV/m) at 3 m*	*Mar. (dB)*	*Height (cm)*	*Pol.*	*Azim. (deg)*	*Corr. (dB/m)*	*Res.*
1065.25	X	Pk	42.1	74.0	31.9	54.0	11.9	110	V	300	-7.2	P
1594.75	X	Pk	44.5	74.0	29.5	54.0	9.5	150	V	312	-6.1	P
1774.75	X	Pk	36.3	74.0	37.7	54.0	17.7	225	V	286	-5.0	P
1849.25	X	Pk	44.3	74.0	29.7	54.0	9.7	161	V	176	-4.4	P

Table 25: Results of radiated emissions test > 1 GHz, with tag,

with:
Freq. = Frequency
EUT Pos. = EUT Position
Det. = Detector
Mar. = Margin
Pol. = Polarization of the measurement antenna
Azim. (deg) = Azimuth (degree)
Corr. = Correction factor
Res. = Result
P = Passed
Np = Not passed

7 Equipment calibration status

Description	*Model number*	*Serial number*	*Inventory number(s)*	*Last calibration*	*Next calibration*
EMI test receiver	ESW44	101538	E00895	2023-11-23	2024-11-23
EMI test receiver	ESU26	100026	W00002	2023-06-28	2024-06-28
EMI test receiver	ESR7	101059	E00739	2023-02-13	2024-02-13
EMI test receiver	ESR7	102170	E01549	2023-07-06	2024-07-06
Preamplifier (1 GHz to 18 GHz)	ALS05749	001	W01007	2023-05-04	2024-05-04
Preamplifier (1 GHz to 18 GHz)	BBV 9718 B	00032	W01325	2022-12-05	2024-06-05
Preamplifier (18 GHz to 40 GHz)	BBV 9721	43	W01350	2023-09-07	2024-09-07
Attenuator (10 dB)	HFP 50	---	E00355	2022-12-07	2024-06-07
Artificial mains network (AMN) with artificial hand connection	ENV432	101487	E01733	2023-11-14	2024-11-14
Artificial mains network (AMN) with artificial hand connection	ESH2-Z5	881362/037	E00004	See note 1	
Loop antenna	HFH2-Z2	871398/0050	E00060	2023-11-07	2024-11-07
RF field probe set	---	---	E00270	See note 2	
TRILOG broadband antenna	VULB 9162	9162-041	E00643	2021-04-02	2024-04-02
Double ridged broadband horn antenna	BBHA 9120D	9120D-593	W00053	2022-09-27	2025-09-27
Broadband Horn Antenna	BBHA 9170	9170-331	W00055	2022-08-26	2025-08-26
Shielded room	P92007	B 83117 C 1109 T 211	E00107	---	---
Compact diagnostic chamber (CDC)	VK041.0174	D62128-A502-A69-2-0006	E00026	2021-10-21	2024-10-21
Semi-anechoic chamber (SAC) with floor absorbers	FS-SAC	---	E00100	2024-02-21	2027-02-21
Semi-anechoic chamber (SAC)	SAC3	C62128-A520-A643-x-0006	E00716	2023-01-03	2026-01-03
Cable set no. 1 for shielded room	RG 223/U	---	E00741	2022-12-07	2024-06-07
	RG 223/U	---	E00804	2022-12-07	2024-06-07
Cable set no. 2 for shielded room	RG223/U	1718020004	E00918	2023-01-25	2024-07-25
	RG223/U	1718020001	E00915	2023-01-03	2024-07-03
	RG223/U - 30cm	1829042001	E01282	2023-01-03	2024-07-03
	RG223/U	1718020002	E00916	2023-01-03	2024-07-03
	RG 223/U - 150cm	1829042023	E01309	2023-01-03	2024-07-03
Cable set CDC	RG214 Hiflex - 500cm	1922032022	E01474	2023-01-03	2024-07-03
	LCF12-50J-N-N-7300	---	E01215	2023-01-03	2024-07-03
	LMR400 - 350cm	1718020006	E00920	2023-01-03	2024-07-03
	S04272B - 200cm	1829042003	E01284	2023-01-03	2024-07-03
Cable set anechoic chamber	262-0942-1500	005	E00435	2022-12-14	2024-06-14
	SF104EA/11PC35/11PC35/5000MM	501696/4EA	E01032	202308-29	2025-02-28
	262-0942-1500	003	E00433	2022-12-14	2024-06-14

Description	*Model number*	*Serial number*	*Inventory number(s)*	*Last calibration*	*Next calibration*
Cable set no. 1 for semi-anechoic chamber SAC3	SF104E/11PC35/11PC35/2000MM	507411/4E	E01034	2023-01-03	2024-07-03
	SF104E/11PC35/11PC35/2000MM	511258/4E	E01435	2023-01-03	2024-07-03
	SF104EA/11PC35/11PC35/10000MM	502177/4EA	E01439	2023-01-03	2024-07-03
Cable set no. 2 for semi-anechoic chamber SAC3	SF104EA/11PC35/11PC35/5000MM	501696/4EA	E01032	2023-08-29	2025-02-28
Cable for testing up to 40 GHz	SF102/11SK/11SK/2000MM	510845/2	E01441	2023-01-24	2024-07-24
Multimeter	METRAHit 2+	DE1133	W01452	2023-05-10	2024-05-10
Climatic chamber (990 l)	VC 4100	59566102680010	C00014	2023-04-26	2024-04-26
Climatic chamber (340 l)	VC³ 4034	58566123250010	C00015	2023-04-20	2024-04-20

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 stability	±0.1 ppm	±0.5 ppm	2a), 3d)	2
Bandwidth tests	± 2.0 %	± 5 %	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):

1 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.

2 The values of the measurement uncertainty as listed above are calculated according to
   a) ETSI TR 100 028-1 V1.4.1 and ETSI TR 100 028-2 V1.4.1
   b) CISPR 16-4-2:2011-06 + A1:2014-02 + A2:2018-08

3 The limits for the measurement uncertainty as listed above are
   a) derived from ETSI EN 300 328 V2.1.1
   b) equal to U_{CISPR} taken from CISPR 16-4-2:2011-06 + A1:2014-02 + A2:2018-08
   c) defined by the test laboratory
   d) derived from ETSI EN 300 220-1 V3.1.1

4 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 ≥ 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.

5 All used test instruments as well as the test accessories are calibrated at regular intervals.

9 Revision history

Revision	*Date*	*Issued by*	*Description of modifications*
0	2024-06-04	Konrad Graßl	First edition

Template: RF_15.225_RSS-210_V1.9