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220365-AU01+W04

AwEasy-Charger

47 CFR Part 15, §15.209

Accreditation:

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1 Summary of test results

47 CFR part and section	Test	Page	Result	Note(s)
15.207(a)	AC power line conducted emissions	23	Passed	---
15.209(a)	Radiated emissions below 30 MHz	29	Passed	---
15.209(a)	Radiated emissions from 30 MHz to 1 GHz	32	Passed	---
15.209(a)	Radiated emissions > 1 GHz	---	Passed	2

Note(s):

- 1 For information about EUT see clause 3.
- 2 The highest internal frequency of the BLE probe is 2.5 GHz. Tests > 1 GHz are only applicable in charging mode. The appropriate tests are documented in the test report 220365-AU01+W09 of the test laboratory Element Materials Technology Straubing GmbH.

Straubing, June 20, 2023



Tested by
Konrad Graßl
Department Manager Radio



Approved by
Rainer Heller Dipl.-Ing. (FH)
Reviewer

2 Referenced publications

In this report, any reference to publications without stating the issue date explicitly refers to the versions as listed below.

<i>Publication</i>	<i>Title</i>
CFR 47 Part 2 October 2022	Code of Federal Regulations Part 2 (Frequency allocation and radio treaty matters; General rules and regulations) of the Federal Communication Commission (FCC)
CFR 47 Part 15 October 2022	Code of Federal Regulations Part 15 (Radio Frequency Devices) of the Federal Communication Commission (FCC)
ANSI C63.10:2013-06	American National Standard of Procedures for Compliance Testing of Unlicensed Wireless Devices
FCC KDB 174176 D01 June 3, 2015	AC power-line conducted emissions Frequently Asked Questions

3 Equipment under test (EUT)

All Information in this clause is declared by customer.

3.1 General information

Product type:	QI charger for BLE probe		
Model name:	AwEasy-Charger		
Serial number:	n/a		
Manufacturer:	Rotronic AG		
Version:	Hardware:	KE_052_013_v100	
	Software:	No FW / complies with WPC 1.2 standard	
Additional modifications:	None		
FCC ID:	2AG4J-AWEY		
Highest internal frequency:	205 kHz		
Power supply:	DC supply		
	Nominal voltage:	5.0 V	
Device type:	<input type="checkbox"/> Portable	<input checked="" type="checkbox"/> Mobile	<input type="checkbox"/> Fixed

3.2 Radio specifications

Application(s):	Wireless Power Transmission (WPT) including inherent radio communication functionality or radio determination via the WPT interface or port at the specific WPT frequency ranges		
Operating frequency range(s):	140.1 kHz to 174.7 kHz		
Modulation:	ASK (Backscatter modulation)		
Antenna:	Type:	Power transmitter:	WE-WPCC Wireless Power Transfer Transmitter Coil (760308101104)
		Power receiver:	WPC Wireless Power Transfer Receiver Coil (ID#3004)
	Size:	Power transmitter:	20.5 mm Ø / 14 turns
		Power receiver:	19.0 ± 1 mm Ø / 25 turns
Connector:	<input type="checkbox"/> external <input type="checkbox"/> internal		
	<input type="checkbox"/> temporary <input checked="" type="checkbox"/> none (internal antenna)		

4 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.

5 Test configuration and mode of operation

5.1 Test configuration

<i>Device</i>	<i>Type designation</i>	<i>Serial or inventory no.</i>	<i>Manufacturer</i>
QI charger for BLE probe	AwEasy-Charger	n/a	Rotronic AG

Table 1: EUT used for testing

<i>Device</i>	<i>Type designation</i>	<i>Serial or inventory no.</i>	<i>Manufacturer</i>
Power adapter for charger	PS1006-050SIB150	---	Powertron Electronics Corp.
BLE probe	AwEasy	n/a	Rotronic AG

Table 2: Support equipment used for testing

5.2 Mode of operation

Standby mode:

- charger only

Charging mode:

- the charger is attached to the load, communicates with the load and makes energy transmission

Note:

1. There is only 1 charging position, the Charger and the Load are held together with a magnet.

6 Test procedures

6.1 General specifications

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 6.3.3 of ANSI C63.4-2014 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.

6.2 AC power-line conducted emissions

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

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

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

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

Table 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:

- The EUT is arranged as tabletop or floor-standing equipment, as applicable, and connected to a line impedance stabilization network (LISN) with 50 μH / 50 Ω. If required, a second LISN of the same type and terminated by 50 Ω is used for peripheral devices. The EUT is switched on.
- The measurement equipment is connected to the LISN for the EUT and set-up according to the specifications of the test (see table 3). At the LISN, the neutral line is selected to be tested.
- 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).

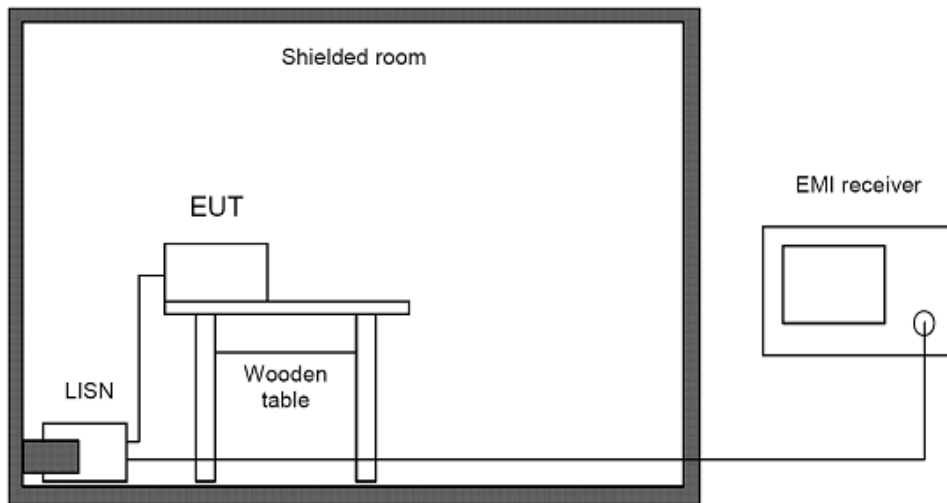


Figure 1: Setup for AC power-line conducted emissions test from 150 kHz to 30 MHz

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 = Artificial mains network correction + Cable attenuation + 10 dB

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

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

6.3 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 377Ω as described in clause 4.3.1 of ANSI C63.10. This results in an additional correction of 51.53 dB.

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

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

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

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

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

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

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

Table 5: Recalculation factors for extrapolation

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 \leq f < 150 kHz	200 Hz	$\leq 100 \text{ Hz}$	Peak Quasi-peak Average
150 kHz \leq f < 30 MHz	9 kHz	$\leq 4.5 \text{ kHz}$	Peak Quasi-peak Average

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

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

Table 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:

6.3.1 Automatic test method

- The loop antenna is positioned with its plane perpendicular to the ground with the lowest height of the antenna 1 m above the ground.
- The EUT is placed in its standard position on a turntable capable of rotation through 360° in the horizontal plane and arranged as tabletop or floor-standing equipment, as applicable. The EUT is switched on.
- The measurement equipment is connected to the loop antenna and set-up according to the specifications of the test (see table 6).
- The EUT is turned to a position likely to get the maximum and the test antenna is rotated to detect the maximum of the fundamental in this EUT position.
- Then the EUT is rotated in a horizontal plane through 360° in steps of 20°. Starting at 0°, at each table position the spectrum for the full frequency range is recorded. If the emission at a certain frequency is higher than the levels already recorded, the current table position is noted as the maximum position.
- After the last prescan, the significant maximum emissions and their table positions are determined and collected in a list.
- With the test receiver set to the first frequency of the list, the EUT is rotated by ±180° around the table position found during prescans while measuring the emission level continuously. For final scan, the worst-case table position is set and the maximum emission level is recorded.
- Step g) is repeated for all other frequencies in the list.

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

6.3.2 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: by using the bargraph max hold function of the measurement receiver the turntable is set in the worst case position of the fundamental emission. In this position the measurement was performed with the scan table method.

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

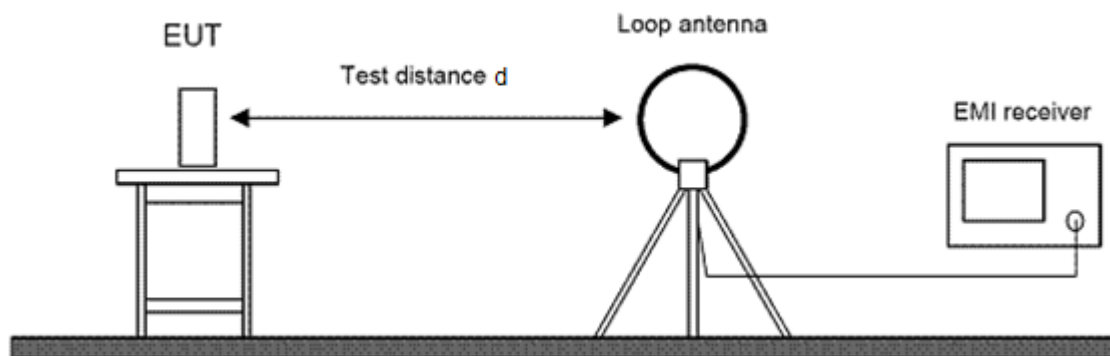


Figure 2: Setup for radiated emissions test below 30 MHz

6.4 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.

<i>Frequency (f)</i>	<i>Measurement receiver bandwidth</i>	<i>Step size</i>	<i>Detector type</i>		
			<i>Prescan</i>	<i>Prescan with FFT</i>	<i>Final scan</i>
30 MHz ≤ 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

<i>Frequency</i> (MHz)	<i>Reading value</i> (dBμV)	<i>Antenna correction</i> (dB/m)	<i>Cable attenuation</i> (dB)	<i>Correction factor (Corr.)</i> (dB)	<i>Level</i> (dBμV/m)
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:

6.4.1 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) For final scan, the worst-case positions of antenna and table are set and the maximum emission level is recorded. At least, frequency and level of the six highest emissions relative to the limit have to be recorded. However, emissions more than 20 dB below the limit do not need to be reported.
- o) Steps l) to n) are repeated for all other frequencies in the list.

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

6.4.2 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. The measurement is performed with peak detector and max hold.
- g) The antenna height is increased to 4 m in steps of 50 cm. At each height, step f) is repeated or the measurement is stopped after all heights were measured.
- h) The polarization of the measurement antenna is changed to horizontal.
- i) The antenna height is decreased from 4 m to 1 m in steps of 50 cm. At each height, step f) is repeated.
- j) The EUT is rotated in a horizontal plane through 360° continuously. At each table position, steps e) to i) are repeated.
- k) After the last prescan, the significant maximum emissions with their polarizations and heights of the measurement antenna are determined and collected in a list.
- h) Final scan: the test receiver is set in the bargraph max hold function and is set to the first frequency of the list, the EUT is rotated by 360° and the antenna is moved from 1 m to 4 m while measuring the emission level continuously. The worst-case table position and the maximum emission level is recorded.
- l) Step l) is repeated for all other frequencies in the list. At least, frequency and level of the six highest emissions relative to the limit have to be recorded. However, emissions more than 20 dB below the limit do not need to be reported.

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

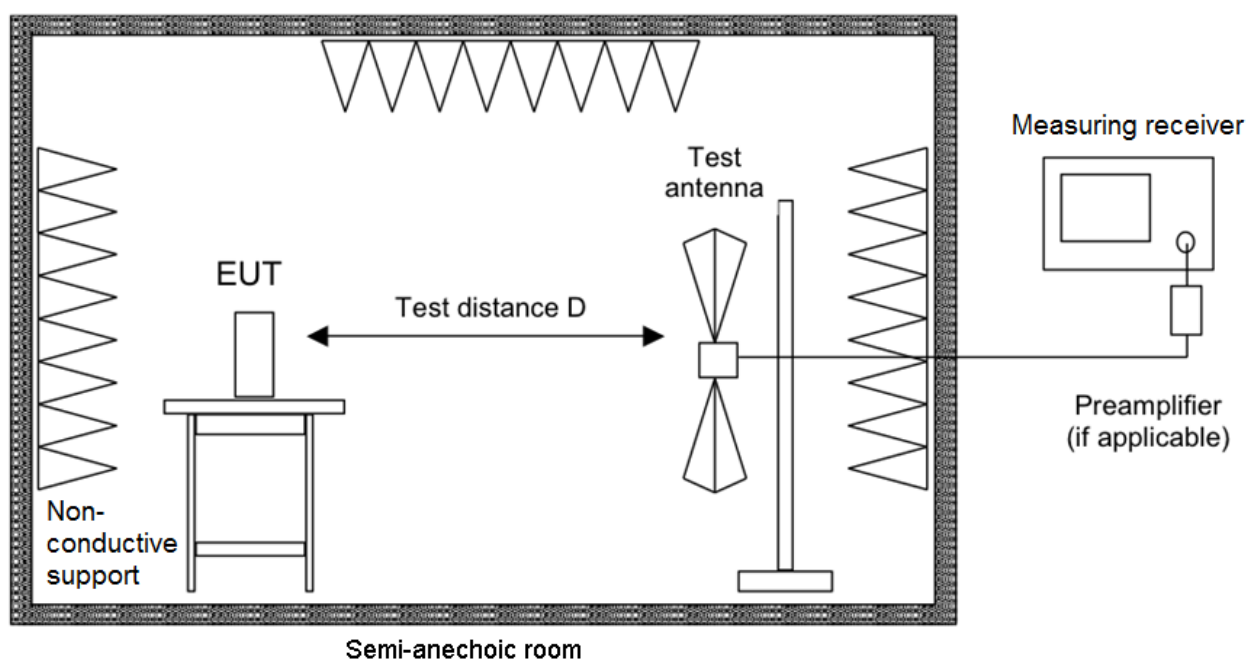


Figure 3: Setup for radiated emissions test from 30 MHz to 1 GHz

6.5 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

6.5.1 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.

6.5.2 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
$f \geq 1 \text{ GHz}$	1 MHz	$\leq 500 \text{ kHz}$	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:

6.5.2.1 Automatic measurement method

- The measurement antenna is oriented initially for vertical polarization.
- The EUT is placed in its standard position on a turntable capable of rotation through 360° in the horizontal plane and arranged as tabletop or floor-standing equipment, as applicable. The EUT is switched on.
- The measurement equipment is connected to the measurement antenna and set-up according to the specifications of the test (see table 12).
- The table position is set to 0°.
- The antenna height is set to 1 m.
- The spectrum for the full frequency range is recorded. If the emission at a certain frequency is higher than the levels already recorded, the polarization and height of the measurement antenna as well as the current table position are noted as the maximum position.
- The antenna height is increased to the scan height upper range in steps of 50 cm. At each height, step f) is repeated.
- The polarization of the measurement antenna is changed to horizontal.
- The antenna height is decreased from the scan height upper range to 1 m in steps of 50 cm. At each height, step f) is repeated.
- The EUT is rotated in a horizontal plane through 360° in steps of 20°. At each table position, steps e) to i) are repeated.
- After the last prescan, the significant maximum emissions with their polarizations and heights of the measurement antenna as well as their table positions are determined and collected in a list.
- With the test receiver set to the first frequency of the list, the measurement antenna is set to the polarization and height and the table is moved to the position as determined during prescans.
- The antenna is moved from 1 m to 4 m around this height and the EUT is rotated through 360° around while measuring the emission level continuously.
- The worst-case positions of antenna and table and the maximum emission level are recorded.

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

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

6.5.2.2 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 EUT is rotated in a horizontal plane through 360° The spectrum for the full frequency range is recorded using the peak detector.
- g) The antenna height is increased to the scan height upper range in steps of 50 cm. At each height, step f) is repeated.
- h) The polarization of the measurement antenna is changed to horizontal.
- i) The antenna height is decreased from the scan height upper range to 1 m in steps of 50 cm. At each height, step f) is repeated.
- j) After the last prescan, the significant maximum emissions with their polarizations are determined and collected in a list.
- k) For the final scan the test receiver is set to the first frequency of the list. By using the bargraph max hold function of the measurement receiver the emission in consideration is maximised by rotating the EUT in the horizontal plane through 360° and moving the antenna from 1 m to 4 m (2.5 m).
- l) The worst-case positions of antenna and table and the maximum emission level are recorded.
- m) Steps l) to n) are repeated for all other frequencies in the list. At least, frequency and level of the six highest emissions relative to the limit have to be recorded. However, emissions more than 20 dB below the limit do not need to be reported.

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

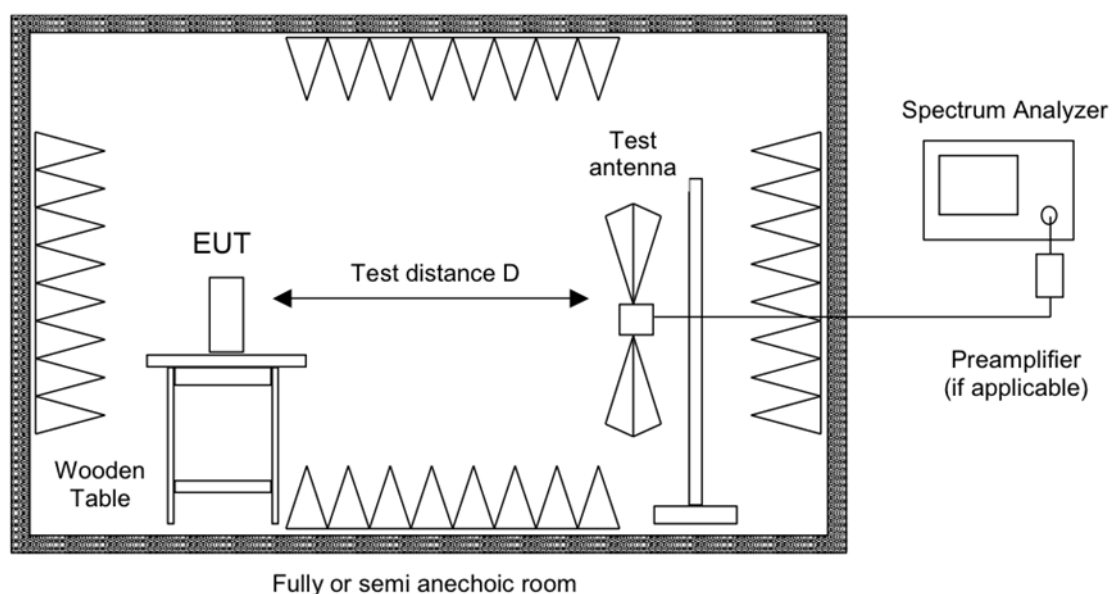


Figure 4: Setup for radiated emissions test above 1 GHz

6.6 Bandwidth measurements

6.6.1 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.

7 Test results

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

For information about measurement uncertainties see page 38.

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

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

Note(s):

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

7.1 AC power line conducted emissions

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

Performed by: Konrad Graßl Date of test: December 9, 2022

Result: ☒ Test passed ☐ Test not passed

7.1.1 Test equipment

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

7.1.2 Limits

According to §15.207(a):

Except as shown in paragraphs (b) and (c) of this section, for an intentional radiator that is designed to be connected to the public utility (AC) power line, the radio frequency voltage that is conducted back onto the AC power line on any frequency or frequencies, within the band 150 kHz to 30 MHz, shall not exceed the limits in the following table, as measured using a 50 μ H / 50 ohms line impedance stabilization network (LISN). Compliance with the provisions of this paragraph shall be based on the measurement of the radio frequency voltage between each power line and ground at the power terminal. The lower limit applies at the boundary between the frequency ranges.

According to §15.207(c):

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

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

Table 13: Limits for AC powerline conducted emissions according to § 15.207(a)

*Decreases with the logarithm of the frequency

7.1.3 Test procedure

AC power line conducted emissions are measured using the test procedure as described in clause 6.2.

7.1.4 Test results

7.1.4.1 Test results for standby mode

Note(s):

1. No assessable emissions could be detected.

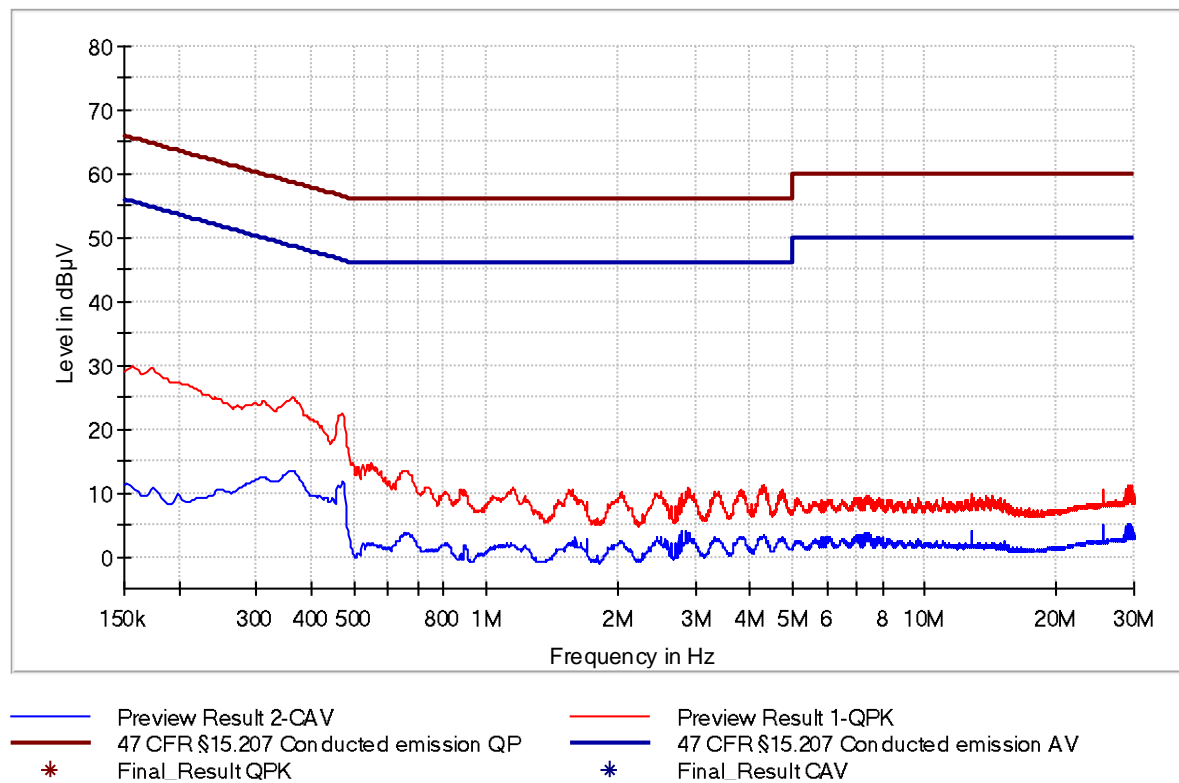


Figure 5: Chart of AC powerline conducted emissions on L1

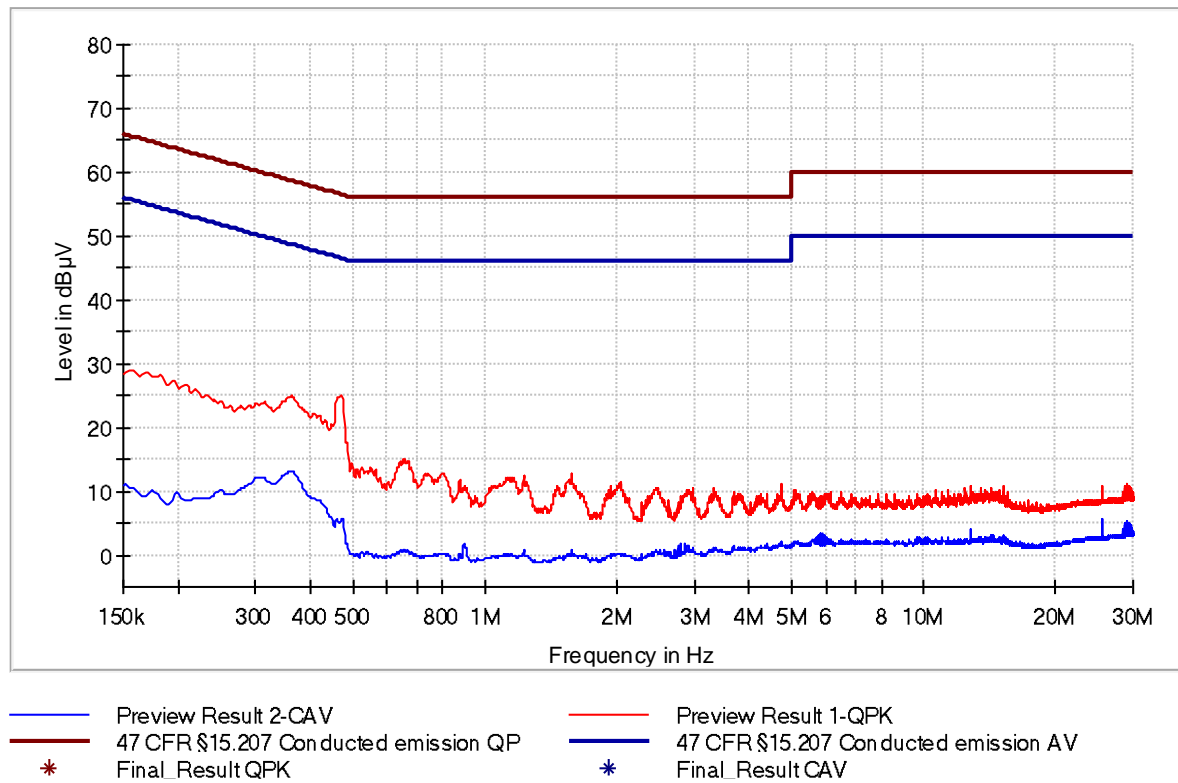


Figure 6: Chart of AC powerline conducted emissions on N

7.1.4.2 Test results for charging mode

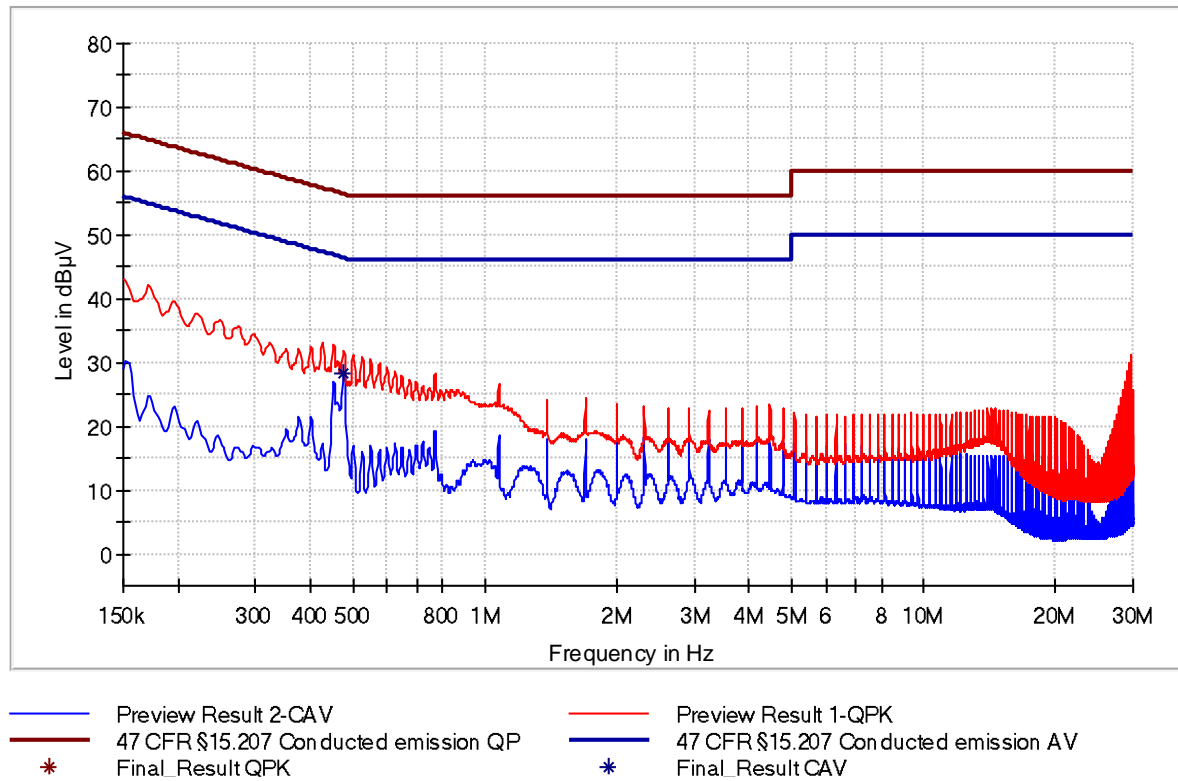


Figure 7: Chart of AC powerline conducted emissions on L1

Frequency (MHz)	QuasiPeak (dBμV)	Average (dBμV)	Limit (dBμV)	Margin (dB)	Meas. Time (ms)	Bandwidth (kHz)	Line	PE	Corr. (dB)
0.476250	---	28.30	46.40	18.10	1000.0	9.000	L1	GND	10.1

Table 14: Results of AC powerline conducted emissions on L1

Note(s):

1. No assessable emissions could be detected.

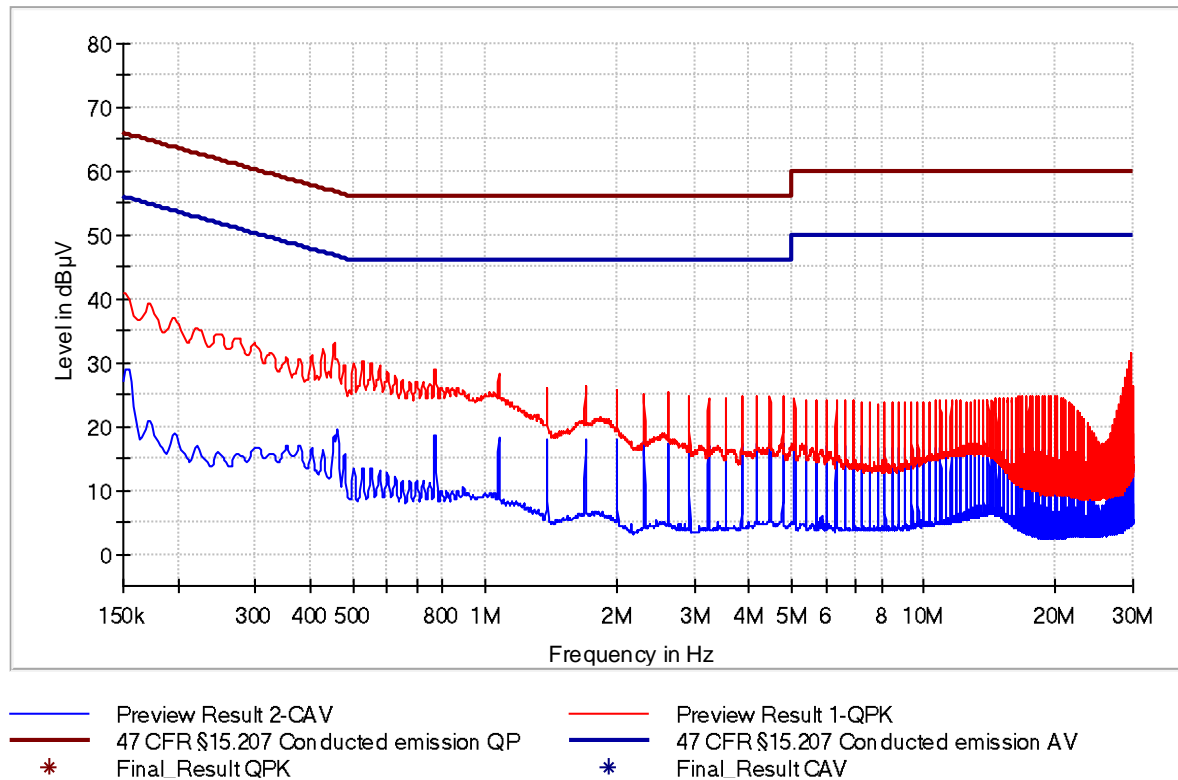


Figure 8: Chart of AC powerline conducted emissions on N

7.2 Radiated emissions below 30 MHz

Section(s) in 47 CFR Part 15: Requirement: 15.209(a)
Reference(s): ANSI C63.10, clause 6.4

Performed by: Konrad Graßl Date of test: June 14, 2023
June 15, 2023

Result: ☒ Test passed ☐ Test not passed

7.2.1 Test equipment

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

7.2.2 Limits

According to § 15.209(a):

Except as provided elsewhere in subpart 15.209 the emissions from an intentional radiator shall not exceed the field strength levels specified in the following table:

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

Table 15: General radiated emission limits up to 30 MHz according to §15.209

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 15 using the recalculation factor as described in clause 6.3.

7.2.3 Test procedure

Radiated emissions below 30 MHz are measured using the manual test procedure as described in clause 6.3.

7.2.4 Test results

7.2.4.1 Test results for standby mode

Test distance:	<input checked="" type="checkbox"/> 3 m	<input type="checkbox"/> 10 m	<input type="checkbox"/> m
Antenna alignment:	<input checked="" type="checkbox"/> in parallel	<input checked="" type="checkbox"/> in line	<input type="checkbox"/> angle °
EUT position:	<input checked="" type="checkbox"/> Position 1	<input checked="" type="checkbox"/> Position 2	<input checked="" type="checkbox"/> Position 3
	<input type="checkbox"/> Position 4	<input type="checkbox"/> Position 5	<input type="checkbox"/> Position 6

Note(s):

1. Pre-measurements were performed to declare the worst-case which is documented below.

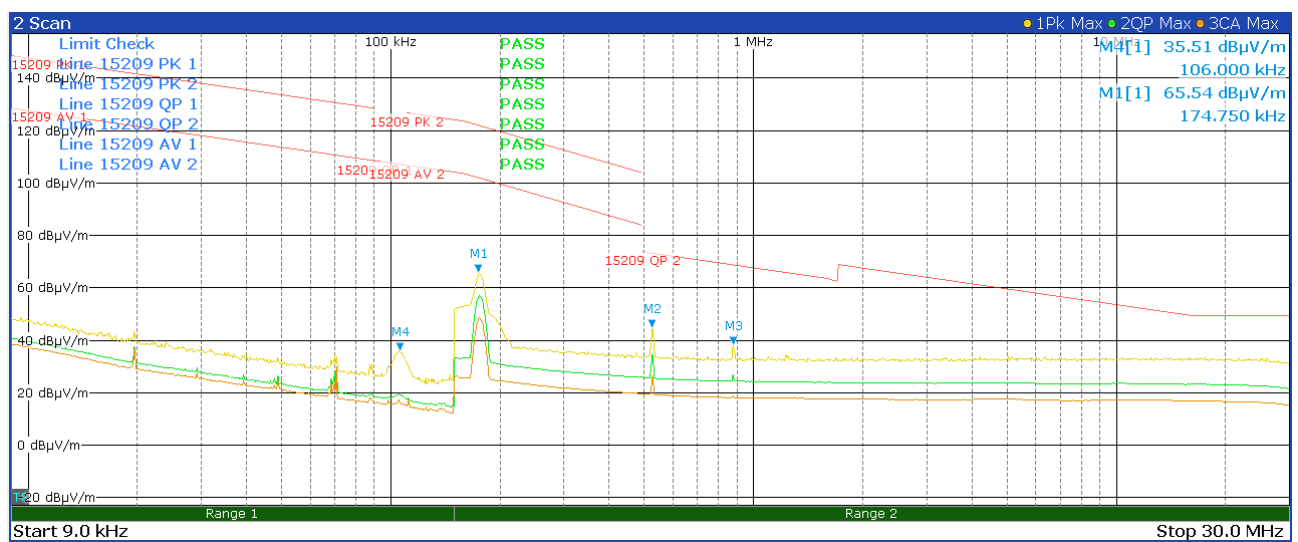


Figure 9: Chart of radiated emissions test below 30 MHz, EUT position 2, antenna in line, Pk

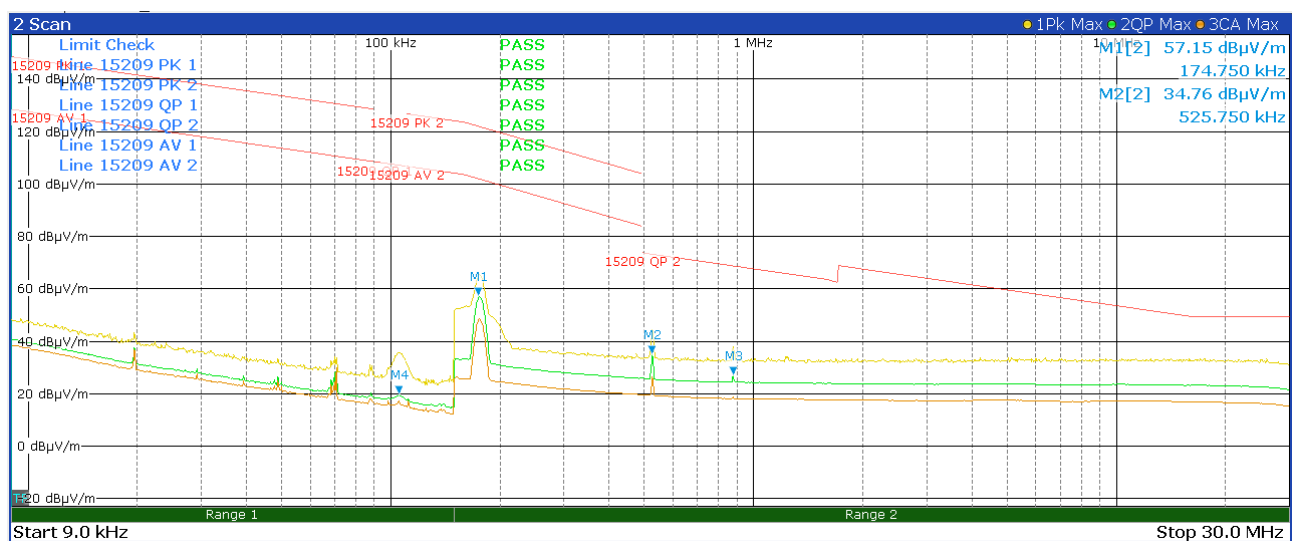


Figure 10: Chart of radiated emissions test below 30 MHz, EUT position 2, antenna in line, QP

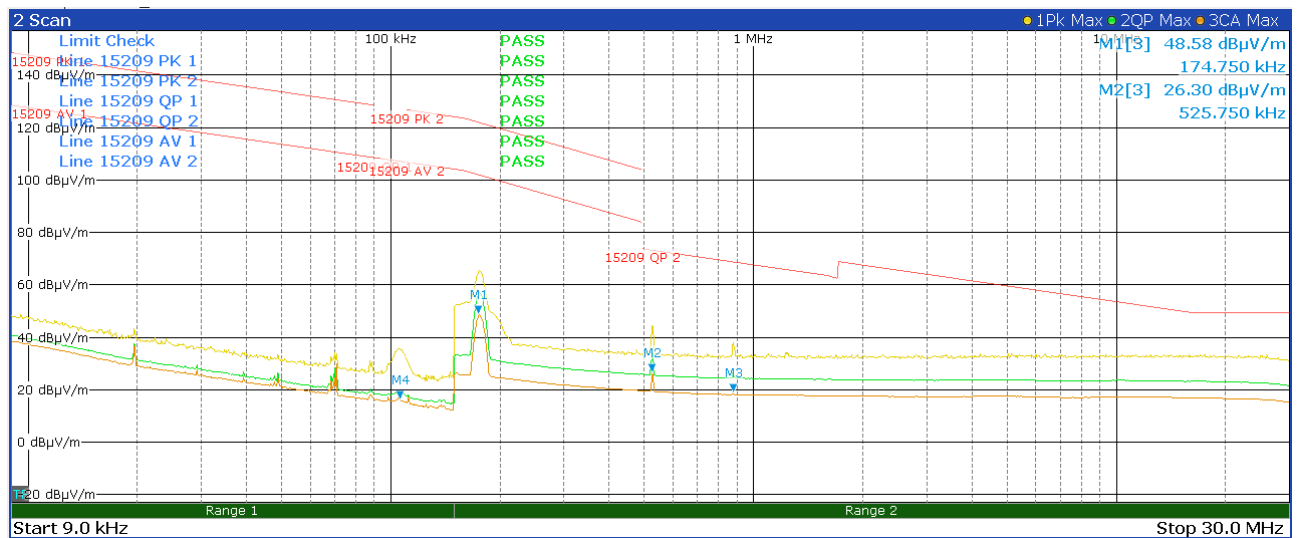


Figure 11: Chart of radiated emissions test below 30 MHz, EUT position 2, antenna in line, AV

Frequency (MHz)	Field strength (dBμV/m at 3 m)	Det.	Calculated field strength (dBμV/m)	at dist. (m)	Limit (dBμV/m)	at dist. (m)	Margin (dB)	Azimuth (deg)	Corr. (dB/m)	Result
0.1747	65.5	Pk	-13.7	300	42.8	300	56.5	90	20.0	passed
0.1747	48.6	AV	-30.6	300	22.8	300	53.4	90	20.0	passed
0.5257	34.8	QP	-5.2	30	13.2	30	18.4	90	20.0	passed

Table 16: Final results of radiated emissions test below 30 MHz, EUT position 2, antenna in line

7.2.4.2 Test results for charging mode

Test distance:	<input checked="" type="checkbox"/> 3 m	<input type="checkbox"/> 10 m	<input type="checkbox"/> m
Antenna alignment:	<input checked="" type="checkbox"/> in parallel	<input checked="" type="checkbox"/> in line	<input type="checkbox"/> angle °
EUT position:	<input type="checkbox"/> Position 1	<input type="checkbox"/> Position 2	<input type="checkbox"/> Position 3
	<input checked="" type="checkbox"/> Position 4	<input checked="" type="checkbox"/> Position 5	<input checked="" type="checkbox"/> Position 6

Note(s):

1. Pre-measurements were performed to declare the worst-case which is documented below.

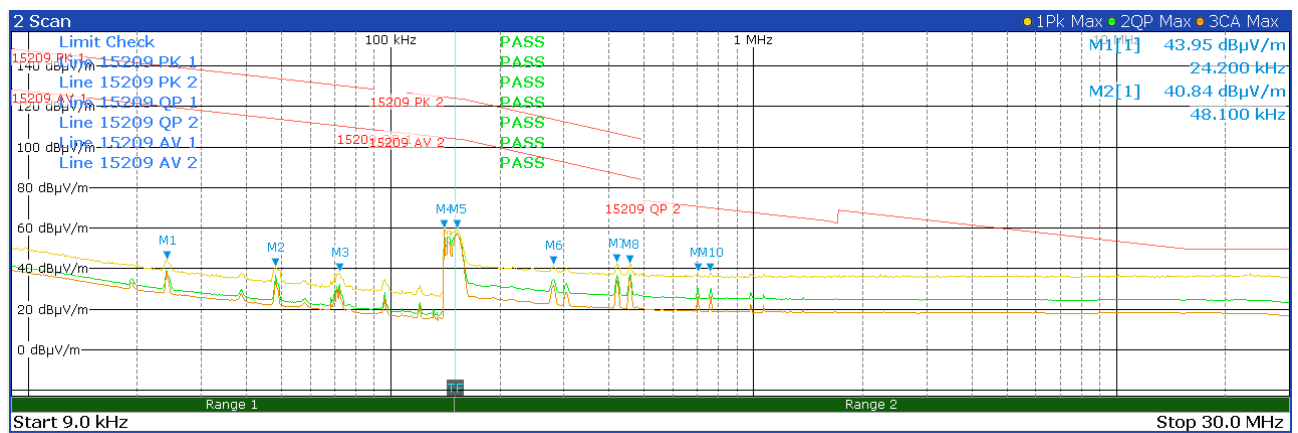


Figure 12: Chart of radiated emissions test below 30 MHz, EUT position 4, antenna parallel, Pk

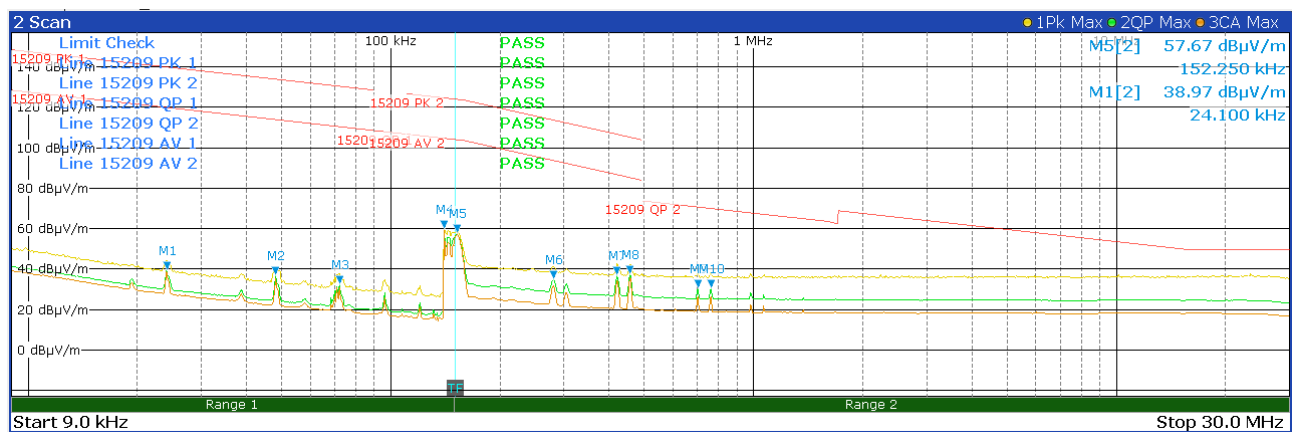


Figure 13: Chart of radiated emissions test below 30 MHz, EUT position 4, antenna parallel, QP

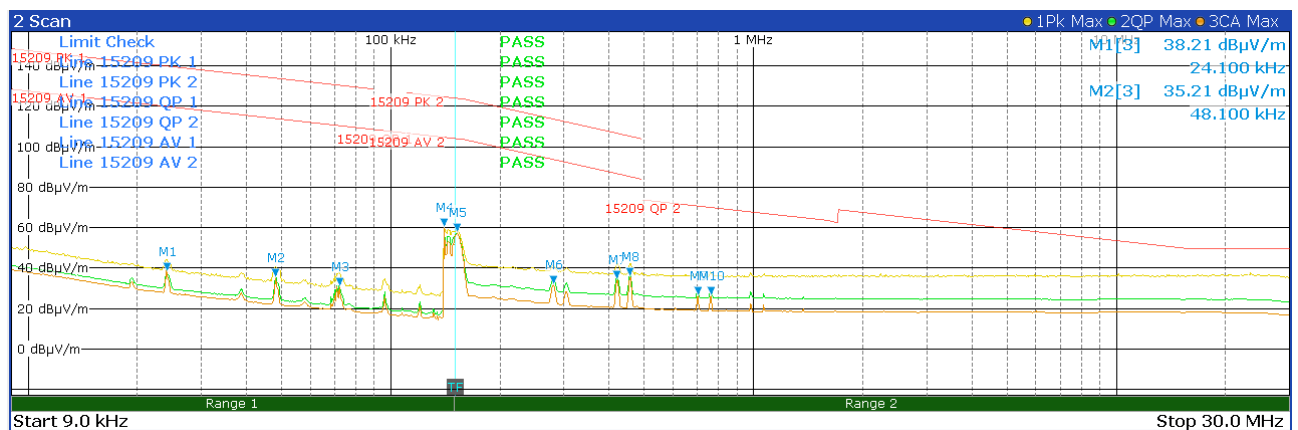


Figure 14: Chart of radiated emissions test below 30 MHz, EUT position 4, antenna parallel, AV

Frequency (MHz)	Field strength (dBμV/m at 3 m)	Det.	Calculated field strength (dBμV/m)	at dist. (m)	Limit (dBμV/m)	at dist. (m)	Margin (dB)	Azimuth (deg)	Corr. (dB/m)	Result
0.1401	59.9	Pk	-20.1	300	44.7	300	64.8	85	20.0	passed
0.1401	59.7	AV	-20.3	300	24.7	300	45.0	85	20.0	passed
0.1522	59.4	Pk	-20.6	300	44.0	300	64.6	85	20.0	passed
0.1522	57.3	AV	-22.7	300	24.0	300	46.7	85	20.0	passed
0.2805	41.5	Pk	-37.7	300	38.6	300	76.3	85	20.0	passed
0.2805	31.7	AV	-47.5	300	18.6	300	66.1	85	20.0	passed
0.4200	42.6	Pk	-36.6	300	35.1	300	71.7	85	20.0	passed
0.4200	34.3	AV	-44.9	300	15.1	300	60.0	85	20.0	passed
0.4560	42.1	Pk	-37.1	300	34.4	300	71.5	85	20.0	passed
0.4560	35.6	AV	-43.6	300	14.4	300	58.0	85	20.0	passed
0.7012	30.3	QP	-9.7	30	10.7	30	20.4	85	20.0	passed
0.7620	30.3	QP	-9.7	30	10.0	30	19.7	85	20.0	passed

Table 17: Final results of radiated emissions test below 30 MHz, EUT position 4, antenna parallel

7.3 Radiated emissions from 30 MHz to 1 GHz

Section(s) in 47 CFR Part 15: Requirement: 15.209(a)
Reference(s): ANSI C63.10, clause 6.5

Performed by:	Konrad Graßl	Date of test:	June 16, 2023
Result:	<input checked="" type="checkbox"/> Test passed	<input type="checkbox"/> Test not passed	

7.3.1 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

7.3.2 Limits

According to § 15.209(a):

Except as provided elsewhere in subpart 15.209 the emissions from an intentional radiator shall not exceed the field strength levels specified in the following table:

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

Table 18: General radiated emission limits ≥ 30 MHz according to §15.209

7.3.3 Test procedure

Radiated emissions from 30 MHz to 1 GHz are measured using the automatic test procedure as described in clause 6.4.

7.3.4 Test results

7.3.4.1 Test results for standby mode

Test distance:	<input checked="" type="checkbox"/> 3 m	<input type="checkbox"/> 10 m	<input type="checkbox"/> m
Polarization:	<input checked="" type="checkbox"/> horizontal	<input checked="" type="checkbox"/> vertical	
EUT position:	<input checked="" type="checkbox"/> Position 1	<input checked="" type="checkbox"/> Position 2	<input checked="" type="checkbox"/> Position 3
	<input type="checkbox"/> Position 4	<input type="checkbox"/> Position 5	<input type="checkbox"/> Position 6

Note(s):

1. Pre-measurements were performed to declare the worst-case which is documented below.

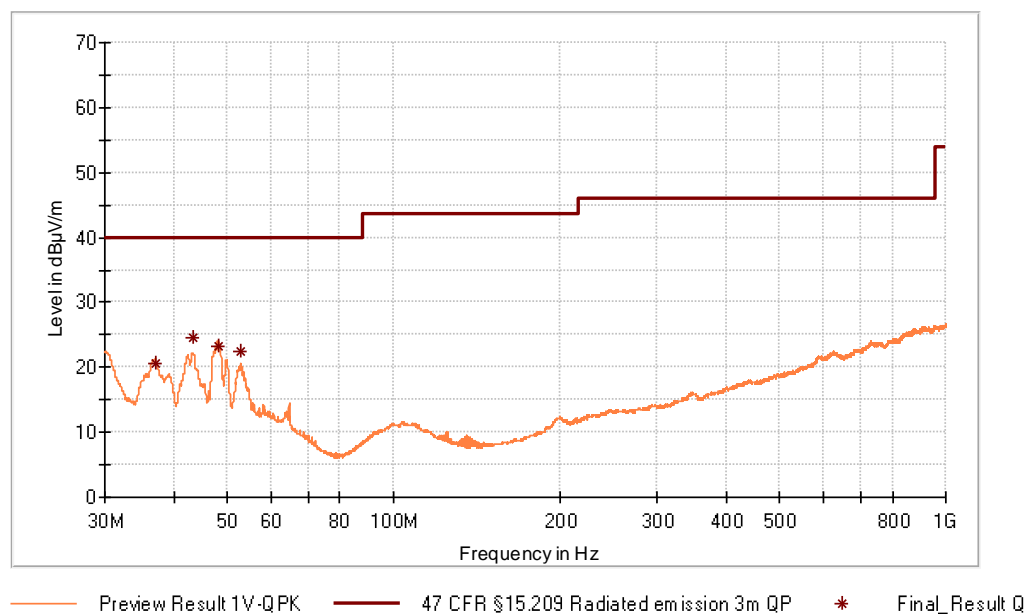


Figure 15: Chart of radiated emissions test from 30 MHz to 1 GHz, EUT position 2, antenna vertical

Frequency (MHz)	Field strength (dBμV/m at 3 m)	Limit (dBμV/m at 3 m)	Margin (dB)	Height (cm)	Pol.	Azimuth (deg)	Corr. (dB/m)	Result
36.990	20.6	40.0	19.4	113	V	145	12.4	Passed
43.320	24.5	40.0	15.5	100	V	331	14.2	Passed
48.060	23.2	40.0	16.8	113	V	315	14.7	Passed
52.770	22.5	40.0	27.5	100	V	51	14.6	Passed

Table 19: Results of radiated emissions test from 30 MHz to 1 GHz, EUT position 2, antenna vertical

7.3.4.2 Test results for charging mode

Test distance:	<input checked="" type="checkbox"/> 3 m	<input type="checkbox"/> 10 m	<input type="checkbox"/> m
Polarization:	<input checked="" type="checkbox"/> horizontal	<input checked="" type="checkbox"/> vertical	
EUT position:	<input type="checkbox"/> Position 1	<input type="checkbox"/> Position 2	<input type="checkbox"/> Position 3
	<input checked="" type="checkbox"/> Position 4	<input checked="" type="checkbox"/> Position 5	<input checked="" type="checkbox"/> Position 6

Note(s):

1. Pre-measurements were performed to declare the worst-case which is documented below.

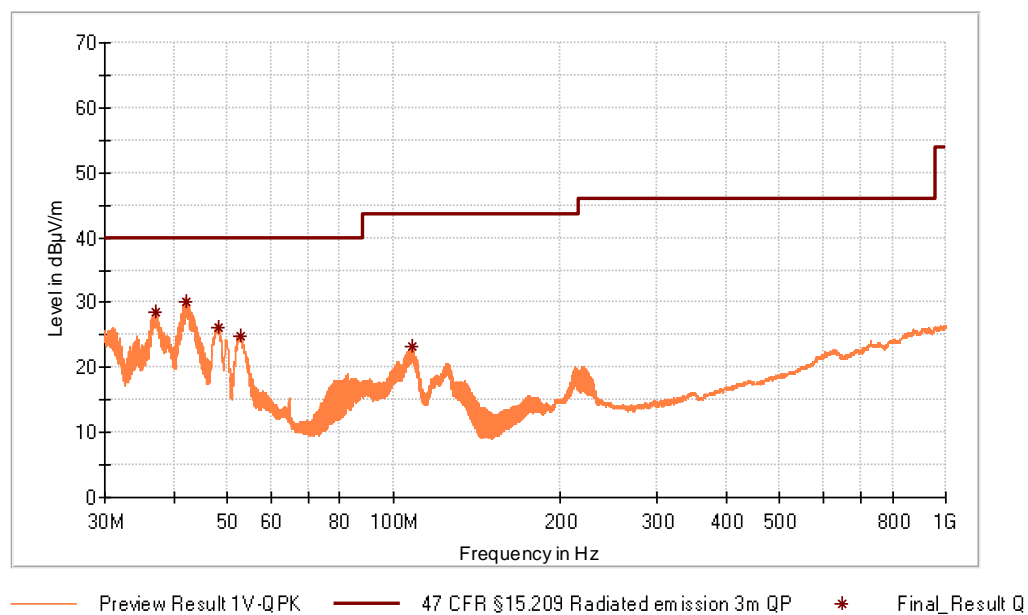


Figure 16: Chart of radiated emissions test from 30 MHz to 1 GHz, EUT position 4, antenna vertical

Frequency (MHz)	Field strength (dBμV/m at 3 m)	Limit (dBμV/m at 3 m)	Margin (dB)	Height (cm)	Pol.	Azimuth (deg)	Corr. (dB/m)	Result
37.080	28.6	40.0	11.4	100	V	0	12.5	Passed
42.270	30.8	40.0	9.2	100	V	0	14.1	Passed
48.06	26.1	40.0	13.9	113	V	0	14.7	Passed
52.770	24.5	40.0	15.5	100	V	60	14.6	Passed
108.060	23.9	40.0	16.1	100	V	52	12.7	Passed

Table 20: Results of radiated emissions test from 30 MHz to 1 GHz, EUT position 4, antenna vertical

8 Equipment calibration status

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

Note(s)

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

9 Measurement uncertainties

Description	Uncertainty	U_{Limit}	Note(s)	k=
AC power line conducted emission	± 3.0 dB	± 3.4 dB	2b), 3b)	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
- 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 $TUR \geq 1:1$). That means, compliance is based on the recorded level by the lab irrespective of the expanded measurement uncertainty value but with a limitation to it.
- 5 All used test instruments as well as the test accessories are calibrated at regular intervals.

10 Revision history

<i>Revision</i>	<i>Date</i>	<i>Issued by</i>	<i>Description of modifications</i>
0	2023-06-20	Konrad Graßl	First edition

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