

Test report

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Test report no.:

200302-AU01+W03

for:

Elatec GmbH
RFID reader / writer module
TWN4 MultiTech 2 M LF



according to:

15.209
RSS-Gen



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1 Summary of test results

System type: RFID reader / writer

47 CFR part and section	Test	Equivalent to IC radio standard(s)	Page	Result	Note(s)
15.207	AC power line conducted emissions 150 kHz to 30 MHz	RSS-210, section 3.1 RSS-Gen, section 8.8	24	Passed	1
15.215(c)	20 dB bandwidth	---	28	For information only	
2.202(a) ANSI C63.10	Occupied bandwidth (99 %)	RSS-Gen, section 6.7	30	For information only	
15.205 (a) – (c)	Restricted bands of operation	RSS-Gen section 8.10	32	Passed	
15.209	Emissions outside the operating frequency band(s) specified 9 kHz to 2 GHz	RSS-Gen, section 6.13 RSS-Gen, section 8.9			
	9 kHz to 30 MHz		35	Passed	---
	30 MHz to 1 GHz		39	Passed	---
	1 GHz to 2 GHz harmonic		42	Passed	2, 3

Notes (for information about EUT see clause 3):

- 1 Measurements to demonstrate compliance with the conducted limits are not required for devices which only employ battery power for operation and which do not operate from the AC power lines or contain provisions for operation while connected to the AC power lines. Devices that include, or make provisions for, the use of battery chargers which permit operating while charging, AC adapters or battery eliminators or that connect to the AC power lines indirectly, obtaining their power through another device which is connected to the AC power lines, shall be tested to demonstrate compliance with the conducted limits.
- 2 Not applicable if the 10th harmonic of the intentional transmitter is beyond 1 GHz (please see 47 CFR Part 15, section 15.33(a)(1), and RSS-Gen, section 6.13)
- 3 According to 47 CFR Part 15, §15.33, 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



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2 Referenced publications

<i>Publication</i>	<i>Title</i>
CFR 47 Part 2 November 2019	Code of Federal Regulations, Title 47 (Telecommunication), Part 2 (Frequency allocation and radio treaty matters; General rules and regulations) of the Federal Communication Commission (FCC)
CFR 47 Part 15 November 2019	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 March 2019	Spectrum Management and Telecommunications - Radio Standards Specification - General Requirements for Compliance of Radio Apparatus
RSS-210 Issue 10, December 2019	Spectrum Management and Telecommunications Radio Standards Specification Licence-exempt Radio Apparatus (All Frequency Bands): Category I Equipment



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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 MultiTech 2 M LF
Serial number(s): 2020158947
Applicant: Elatec GmbH
Manufacturer: Elatec GmbH
Version: Hardware: B
Software: B1.08/NKL3.08/STD2.01
Additional modifications: None
FCC ID: WP5TWN4F13
IC registration number: 7948A-TWN4F13
Power supply: DC supply
Nominal voltage: 5.00 V
Minimum voltage: 4.30 V
Maximum voltage: 5.50 V
Nominal frequency: ---
Temperature range: -25 °C to +80 °C (customer defined)
Device type: Portable Mobile Fixed



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3.2 Radio specifications

System type: RFID reader / writer

Application frequency band: n/a

Operating frequency: 125 kHz

Short description: The EUT is a RFID reader/ writer module operating at the frequency 125 kHz.

Number of RF channels: 1

Highest internal frequency: 120 MHz

Modulation: ASK

Antenna: Type: Integral Loop Antenna
Connector: external internal
 temporary none (integral antenna)

3.3 Photo documentation

For 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

<i>Device</i>	<i>Type designation</i>	<i>Serial or inventory no.</i>	<i>Manufacturer</i>
<i>EUT</i>			
RFID reader / writer module	TWN4 MultiTech 2 M LF	2020158947	Elatec
<i>Support equipment</i>			
RFID-tag	Keyfob 125 kHz	---	---
Laptop	Lifebook U772	O00632	FUJITSU
Power supply for laptop	AC adapter	O00632	FUJITSU

Table 1: Devices used for testing

<i>Port</i>	<i>Classification</i>	<i>Cable type</i>	<i>Note</i>
USB	DC power	Shielded	
USB	Signal/control	Shielded	

Table 2: Ports of EUT

4.2 Mode of operation

4.2.1 Test modes applied

EUT was powered and controlled via USB-port.

EUT was forced via test software "TWN4_NKx322_CONT108_Continuous_Mode4_125kHz.bix" to search permanent for 125 kHz tags.

As soon as a tag was detected the EUT sent the tag ID to the notebook 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).

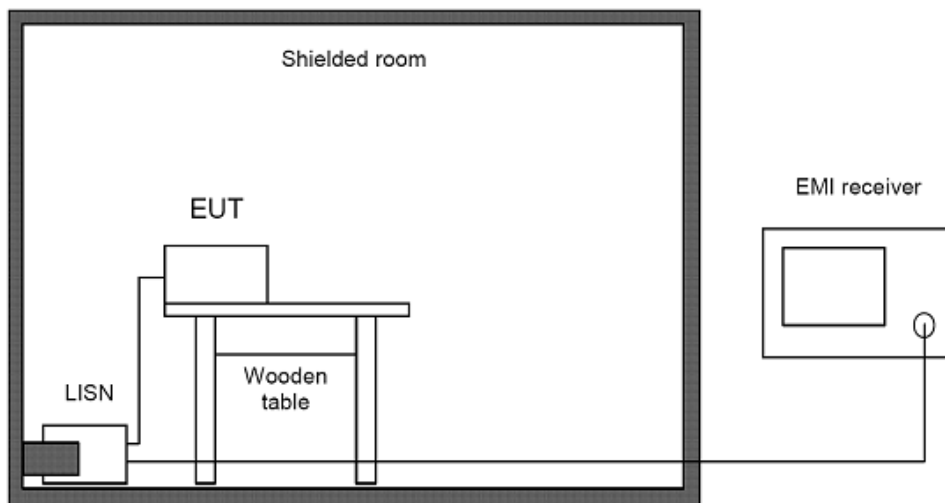


Figure 1: Setup for AC power-line conducted emissions test from 150 kHz to 30 MHz

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 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:

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

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

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:

$$f_{MHz}(300\ m) \approx 0.159\ \text{MHz}$$

$$f_{MHz}(30\ m) \approx 1.592\ \text{MHz}$$

$$f_{MHz}(3\ m) \approx 15.923\ \text{MHz}$$

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

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

Table 4: Recalculation factors for extrapolation

Prescans for radiated measurements below 30 MHz are performed in a fully anechoic room (called "CDC"). The measurement distance is 3 meters. The emissions of the EUT are recorded with an EMI test receiver configured as described in table 5.

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

Table 5: Bandwidth and detector type for radiated emissions test below 30 MHz

Sample calculation:

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

Correction factor = Antenna correction + Cable attenuation

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

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

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

- a) The loop antenna is positioned with its plane perpendicular to the ground with the lowest height of the antenna 1 m above the ground.
- b) The EUT is placed in its standard position on a turntable capable of rotation through 360° in the horizontal plane and arranged as tabletop or floor-standing equipment, as applicable. The EUT is switched on.
- c) The measurement equipment is connected to the loop antenna and set-up according to the specifications of the test (see table 5).
- d) The EUT is turned to a position likely to get the maximum and the test antenna is rotated to detect the maximum of the fundamental in this EUT position.
- e) Then the EUT is rotated in a horizontal plane through 360° in steps of 45°. Starting at 0°, at each table position the spectrum for the full frequency range is recorded. If the emission at a certain frequency is higher than the levels already recorded, the current table position is noted as the maximum position.
- f) After the last prescan, the significant maximum emissions and their table positions are determined and collected in a list.
- g) With the test receiver set to the first frequency of the list, the EUT is rotated by ±45° around the table position found during prescans while measuring the emission level continuously. For final scan, the worst-case table position is set and the maximum emission level is recorded.
- h) Step g) is repeated for all other frequencies in the list.
- i) Finally, for frequencies with critical emissions the loop antenna is rotated again to find the maximum of emission. At least, frequency and level of the six highest emissions relative to the

limit have to be recorded. However, emissions more than 20 dB below the limit do not need to be reported.

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

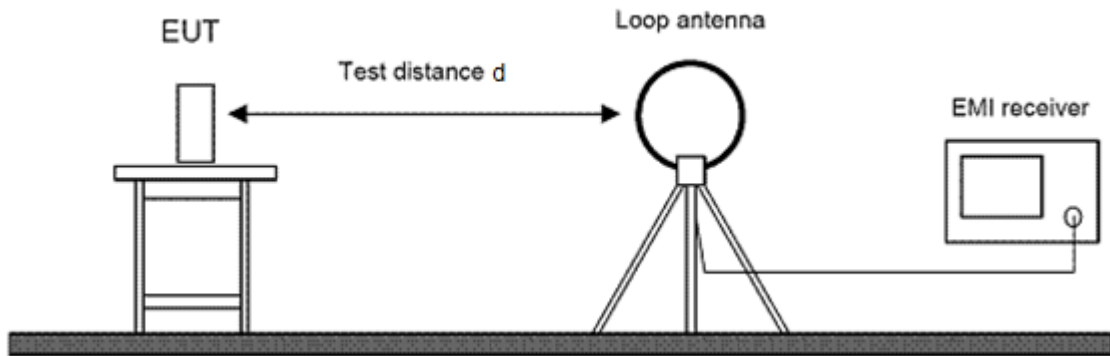


Figure 2: Setup for radiated emissions test below 30 MHz

5.4 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 6.

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

Sample calculation:

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

Correction factor = Antenna correction + Cable attenuation

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

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

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

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

- a) The measurement antenna is oriented initially for vertical polarization.
- b) The EUT is placed in its standard position on a turntable capable of rotation through 360° in the horizontal plane and arranged as tabletop or floor-standing equipment, as applicable. The EUT is switched on.
- c) The measurement equipment is connected to the measurement antenna and set-up according to the specifications of the test (see table 6).
- d) The table position is set to 0°.
- e) The antenna height is set to 1 m.
- f) The spectrum for the full frequency range is recorded. If the emission at a certain frequency is higher than the levels already recorded, the polarization and height of the measurement antenna as well as the current table position are noted as the maximum position.
- g) The antenna height is increased to 4 m in steps of 50 cm. At each height, step f) is repeated.
- h) The polarization of the measurement antenna is changed to horizontal.
- i) The antenna height is decreased from 4 m to 1 m in steps of 50 cm. At each height, step f) is repeated.
- j) The EUT is rotated in a horizontal plane through 360° in steps of 60°. At each table position, steps e) to i) are repeated.
- k) After the last prescan, the significant maximum emissions with their polarizations and heights of the measurement antenna as well as their table positions are determined and collected in a list.
- l) With the test receiver set to the first frequency of the list, the measurement antenna is set to the polarization and height and the table is moved to the position as determined during prescans.
- m) The antenna is moved by ± 50 cm around this height and the EUT is rotated by $\pm 60^\circ$ around this table position while measuring the emission level continuously.
- n) For final scan, the worst-case positions of antenna and table are set and the maximum emission level is recorded.
- o) Steps l) to n) are repeated for all other frequencies in the list. At least, frequency and level of the six highest emissions relative to the limit have to be recorded. However, emissions more than 20 dB below the limit do not need to be reported.

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



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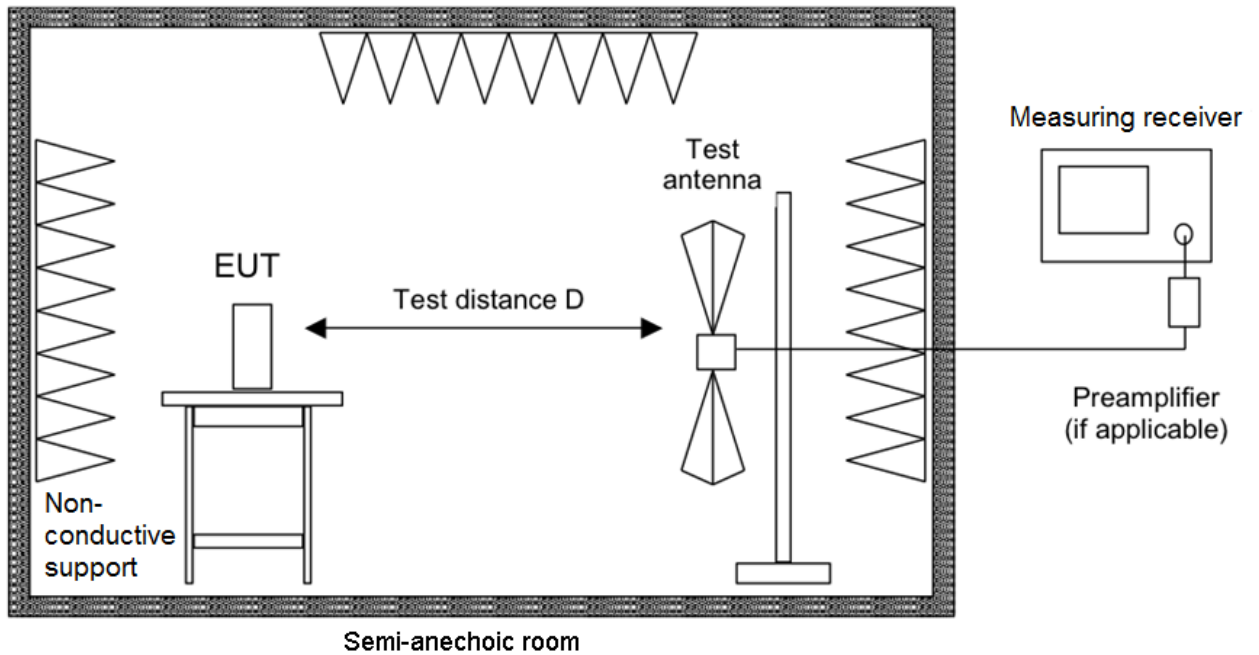


Figure 3: Setup for radiated emissions test from 30 MHz to 1 GHz

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.

Sample calculation:

Frequency (MHz)	Reading value (dB μ V)	Antenna correction (dB/m)	Correction pre- amplifier (dB)	Cable attenuation (dB)	Correction factor (Corr.) (dB/m)	Level (dB μ V/m)
2400	50.00	27.76	-47.91	5.24	-14.92	35.08

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

Level = Reading value + Correction factor = 50.00 dB μ V - 14.92 dB/m = 35.08 dB μ V/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 7.

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

Table 7: 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 a semi-anechoic chamber (SAC) with RF absorbing material on the floor between measurement antenna and EUT. The measurement distance is 3 meters. The emissions of the EUT are recorded with an EMI test receiver configured as described in table 8.

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

Table 8: Bandwidth and detector type for final radiated emissions test above 1 GHz

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

The horn antenna is mounted on a support capable of allowing the antenna to be used in either horizontal or vertical polarization and to be moved in a scan height range between 1 m and the scan height upper range defined in clause 6.6.3.3 of ANSI C63.10. When the EUT is manipulated through three different orientations, the scan height upper range for the measurement antenna is limited to 2.5 m above the ground plane or 0.5 m above the top of the EUT, whichever is higher. Otherwise, the scan height upper range is 4 m above the ground plane. To keep the emission signal within the illumination area of the 3 dB beamwidth of the measurement antenna, the automatic tilt function of the antenna support device is used to point the antenna at an angle toward the source of the emission.

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

- a) The measurement antenna is oriented initially for vertical polarization.
- b) The EUT is placed in its standard position on a turntable capable of rotation through 360° in the horizontal plane and arranged as tabletop or floor-standing equipment, as applicable. The EUT is switched on.
- c) The measurement equipment is connected to the measurement antenna and set-up according to the specifications of the test (see table 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 the scan height upper range in steps of 50 cm. At each height, step f) is repeated.
- h) The polarization of the measurement antenna is changed to horizontal.
- i) The antenna height is decreased from the scan height upper range to 1 m in steps of 50 cm. At each height, step f) is repeated.
- j) The EUT is rotated in a horizontal plane through 360° in steps of 30°. At each table position, steps e) to i) are repeated.
- k) After the last prescan, the significant maximum emissions with their polarizations and heights of the measurement antenna as well as their table positions are determined and collected in a list.
- l) With the test receiver set to the first frequency of the list, the measurement antenna is set to the polarization and height and the table is moved to the position as determined during prescans.
- m) The antenna is moved by ± 50 cm around this height and the EUT is rotated by $\pm 30^\circ$ around this table position while measuring the emission level continuously.
- n) For final scan, the worst-case positions of antenna and table are set and the maximum emission level is recorded.
- o) Steps l) to n) are repeated for all other frequencies in the list. At least, frequency and level of the six highest emissions relative to the limit have to be recorded. However, emissions more than 20 dB below the limit do not need to be reported.

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



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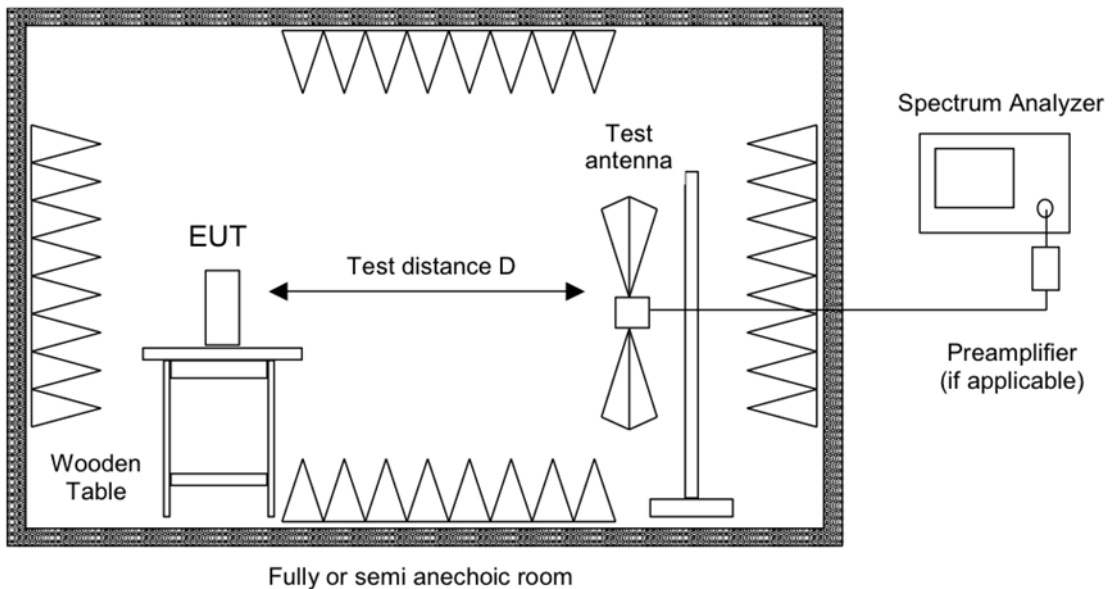


Figure 4: Setup for radiated emissions test above 1 GHz

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 $[10 \log (20 \text{ dB bandwidth/RBW})]$ 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 Restricted bands of operation

The EUT was placed in a fully anechoic chamber and the testing was performed in accordance with ANSI C63.10 and 47 CFR Part 15, section 15.35. The measurement distance was 3 m. To find the closest margin of the spectrum to the limit mask adapted to the test distance the EUT was rotated by 360 degrees with detector of the test receiver set to peak. The loop antenna placed in a fixed height of 1 meter was rotated by 360 degrees to get the maximum of emission. In case of exceeding the limits the detector is switched to quasi peak for final testing in position of maximum emission.

6 Test results

This clause gives details about the test results as collected in the summary of test results on page 6.

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

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

6.1 AC power line conducted emissions 150 kHz to 30 MHz

Section(s) in 47 CFR Part 15: Requirement(s): 15.207
 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: Andreas Menacher Date of test: June 9, 2020

Result¹: Test passed Test not passed

6.1.1 Test equipment

Type	Designation	Manufacturer	Inventory no.
Shielded room	P92007	Siemens Matsushita	E00107
EMI test receiver (OATS)	ESCI 3	Rohde & Schwarz	E00001
Artificial mains network	ESH2-Z5	Rohde & Schwarz	E00005
Attenuator (10 dB)	50FHB-010-10	JFW Industries	E00471
Test software	EMC32-EB (V10.35)	Rohde & Schwarz	E00777

6.1.2 Limits

As specified in section 15.209 of 47 CFR Part 15, the emissions from an intentional radiator shall not exceed the conducted limits as specified in table 9.

Frequency of emission [MHz]	Conducted limit	
	Quasi-peak [dB μ V]	Average [dB μ V]
0.15 – 0.5	66 to 56*	56 to 46*
0.5 – 5.0	56	46
5 – 30	60	50

Table 9: AC power-line conducted limits

* Decreases with the logarithm of the frequency.

¹ For information about measurement uncertainties see page 73.

6.1.3 Test procedure

AC power line conducted emissions are measured using the test procedure as described in clause 5.2.

6.1.4 Test results

Frequency range	Step size	IF Bandwidth	Detector		Measurement Time		Preamplifier
			Prescan	Final scan	Prescan	Final scan	
150 kHz – 30 MHz	≤ 4.5 kHz	9 kHz	PK, AV	QP, AV	10 ms	1 s	Off

Note: The notebook was powered with 120 V / 60 Hz.

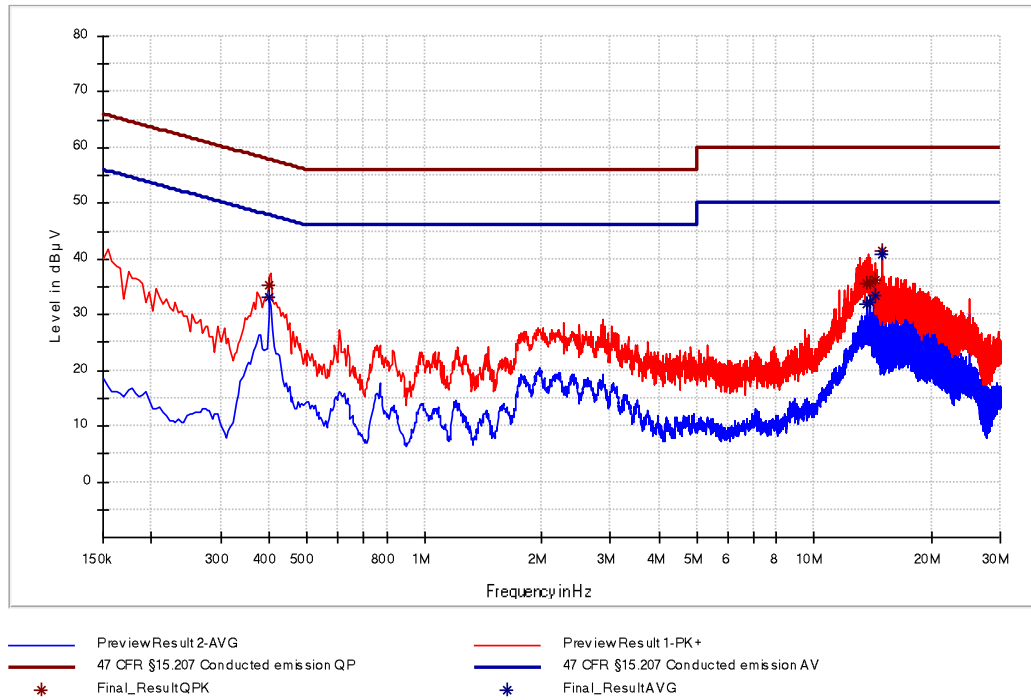


Figure 5: Chart of AC power-line conducted emissions test – phase L1

Frequency (MHz)	QuasiPeak (dBµV)	Average (dBµV)	Limit (dBµV)	Margin (dB)	Line	PE
0.401000	---	33.19	47.83	14.64	L1	GND
0.401000	35.40	---	57.83	22.43	L1	GND
13.701000	---	32.06	50.00	17.94	L1	GND
13.701000	35.58	---	60.00	24.42	L1	GND
13.889000	35.58	---	60.00	24.42	L1	GND
13.889000	---	32.29	50.00	17.71	L1	GND
14.357000	36.29	---	60.00	23.71	L1	GND
14.357000	---	33.32	50.00	16.68	L1	GND
15.001000	---	40.81	50.00	9.19	L1	GND
15.001000	41.41	---	60.00	18.59	L1	GND

Figure 6: Final results of AC power-line conducted emissions test – phase L1

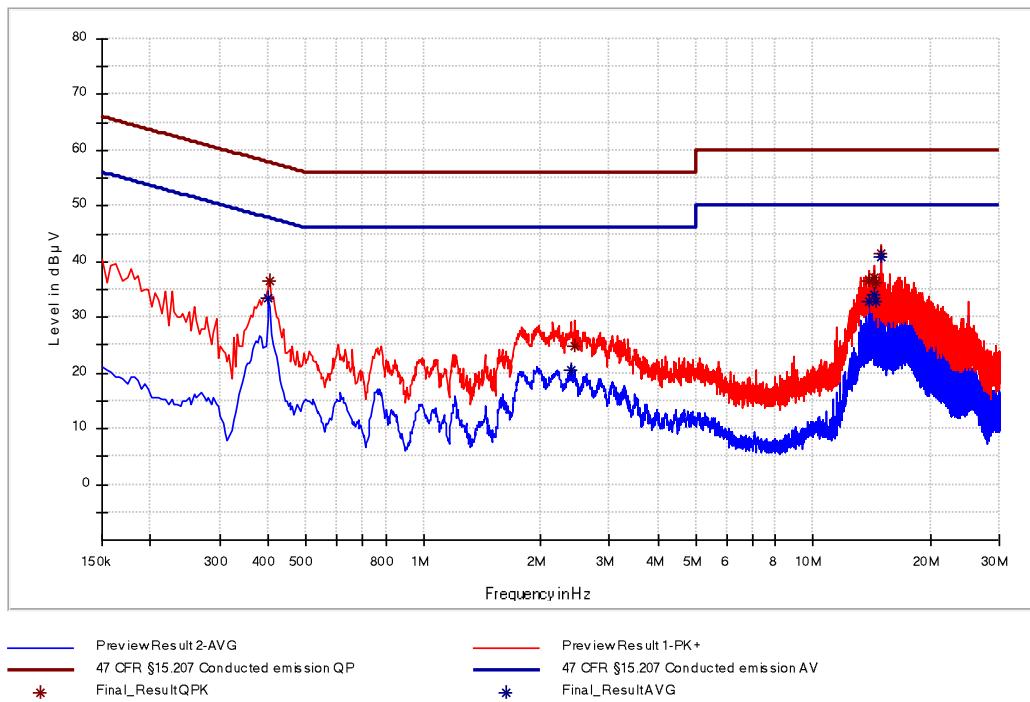


Figure 7: Chart of AC power-line conducted emissions test – phase N

Frequency (MHz)	QuasiPeak (dBµV)	Average (dBµV)	Limit (dBµV)	Margin (dB)	Line	PE
0.401000	---	33.56	47.83	14.27	N	GND
0.405000	36.40	---	57.75	21.35	N	GND
2.401000	---	20.55	46.00	25.45	N	GND
2.437000	24.71	---	56.00	31.29	N	GND
13.889000	---	32.90	50.00	17.10	N	GND
13.889000	36.46	---	60.00	23.54	N	GND
14.357000	37.18	---	60.00	22.82	N	GND
14.357000	---	34.01	50.00	15.99	N	GND
14.545000	36.37	---	60.00	23.63	N	GND
14.545000	---	32.97	50.00	17.03	N	GND
15.001000	---	40.84	50.00	9.16	N	GND
15.001000	41.42	---	60.00	18.58	N	GND

Figure 8: Final results of AC power-line conducted emissions test – phase 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: Andreas Menacher Date(s) of test: June 10, 2020

Result²: Test passed Test not passed

6.2.1 Test equipment

Type	Designation	Manufacturer	Inventory no.
EMI test receiver	ESU 26	Rohde & Schwarz	W00002
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 test procedure as described in clause 5.6.1.

² For information about measurement uncertainties see page 92.

6.2.4 Test results

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

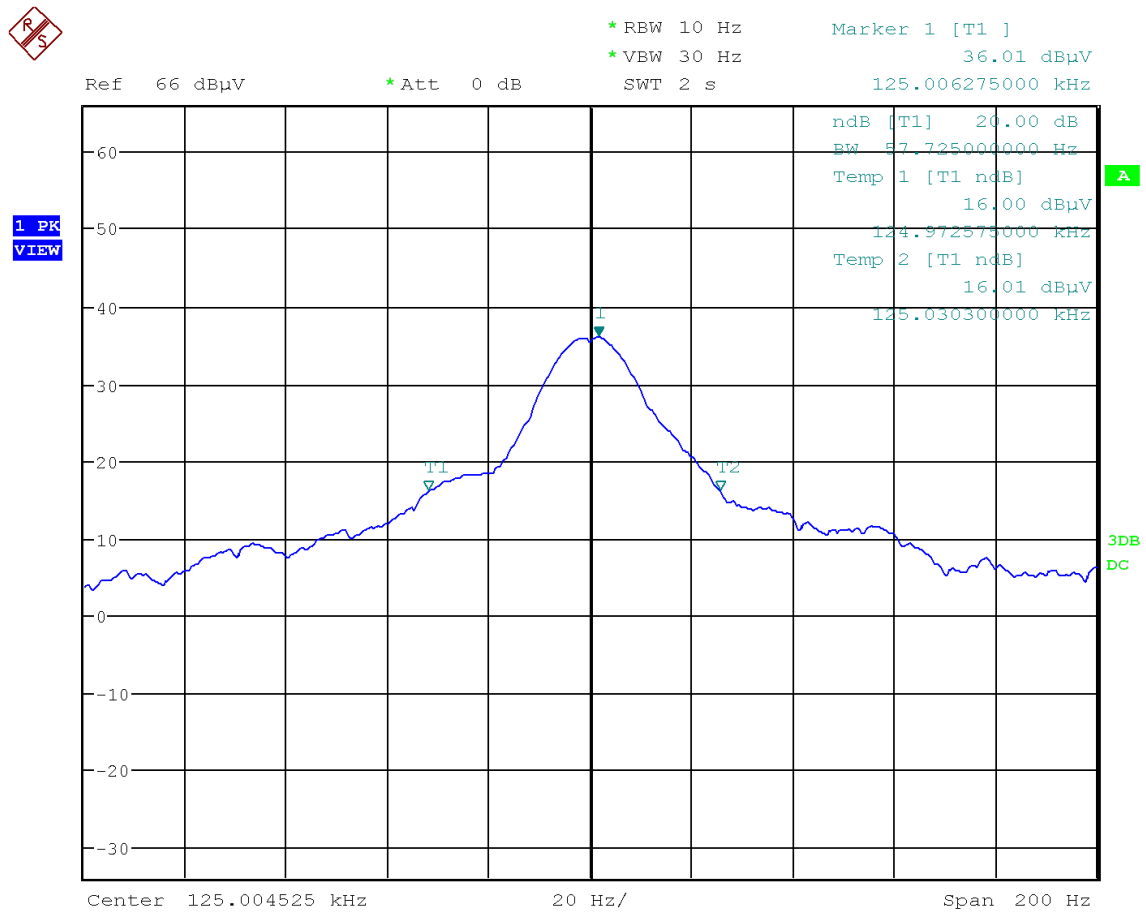


Figure 9: Chart of 20 dB bandwidth test, with tag

20 dB bandwidth [kHz]	Band edge left Frequency [MHz]	Band edge right Frequency [MHz]	Result
0.058	0.124972	0.125030	Recorded

Table 10: Results of 20 dB bandwidth tests, with tag

6.3 Occupied bandwidth

Section(s) in 47 CFR Part 15: Requirement(s): 2.202(a)
Reference(s): ANSI C63.10, clause 6.9

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

Performed by: Andreas Menacher Date(s) of test: June 10, 2020

Result³: Test passed Test not passed

6.3.1 Test equipment

Type	Designation	Manufacturer	Inventory no.
EMI test receiver	ESU 26	Rohde & Schwarz	W00002
Field probe	RF-R 400-1	Langer EMV-Technik	E00270

6.3.2 Limits

Although there is no limit specified, the occupied bandwidth has to be recorded and reported.

6.3.3 Test procedure

The occupied bandwidth is measured using the test procedure as described in clause 5.6.2.

³ For information about measurement uncertainties see page 76.

6.3.4 Test results

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

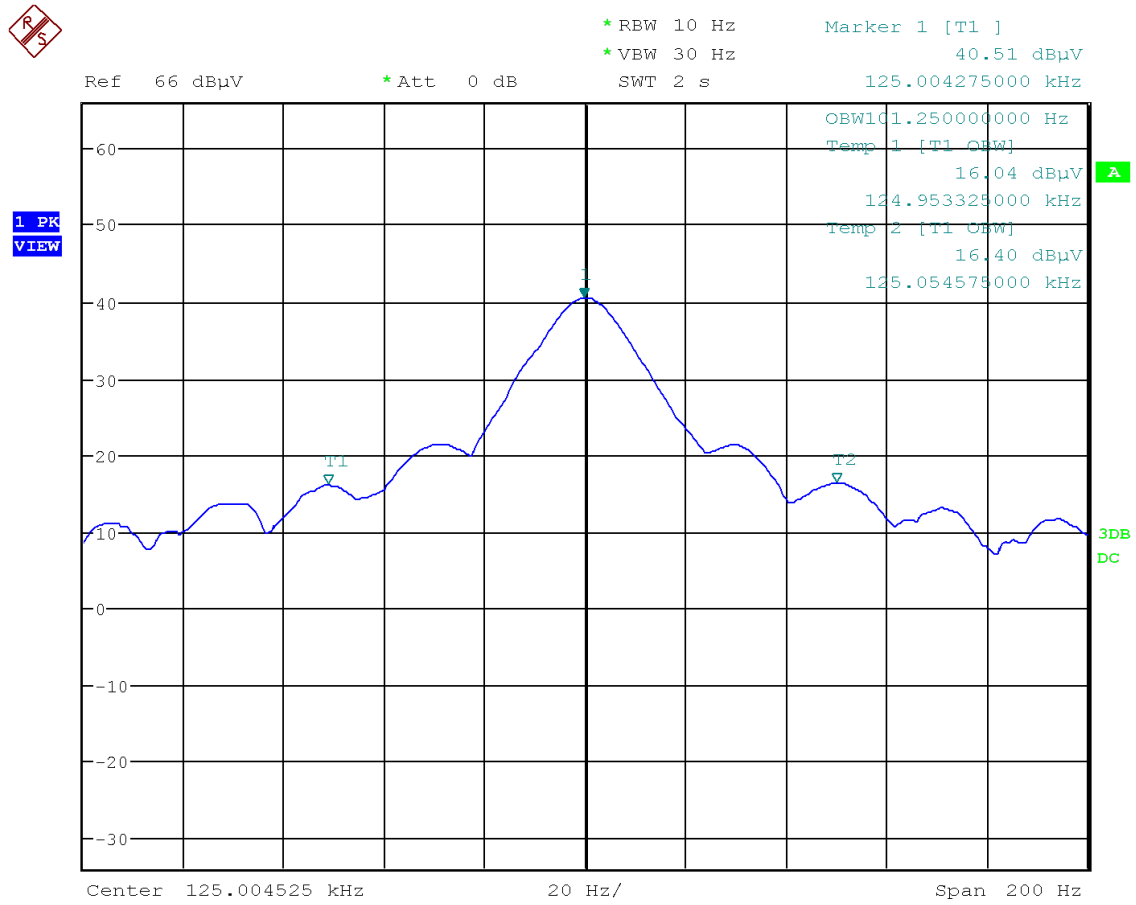


Figure 10: Chart of occupied bandwidth test, without tag

99% bandwidth [kHz]	Band edge left Frequency [MHz]	Band edge right Frequency [MHz]	Result
0.101	0.124953	0.125054	Recorded

Table 11: Results of occupied bandwidth test, without tag

6.4 Restricted band of operation from 0.090 MHz to 0.110 MHz

Section(s) in 47 CFR Part 15: Requirement(s): 15.205(a)-(c)
 Reference(s): ANSI C63.10, section 12.7.2

Section(s) in RSS: Requirement(s): RSS-Gen, section 8.10
 Reference(s): ANSI C63.10, section 12.7.2

Performed by: Andreas Menacher Date(s) of test: June 9, 2020

Result⁴: 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	ESR 7	Rohde & Schwarz	E00739
Loop antenna	HFH2-Z2	Rohde & Schwarz	E00060
Cable set CDC	RF cable(s)	Huber + Suhner AME HF-Technik AME HF-Technik Stabo	E00446 E00920 E00921 E01215
Test software	EMC32-EB (V10.35)	Rohde & Schwarz	E00777

⁴ For information about measurement uncertainties see page 76.

6.4.2 Limits

As specified in section 15.205(a)-(c) of 47 CFR Part 15:

Except as provided in paragraphs (d) and (e) of this section, the field strength of emissions appearing within these frequency bands shall not exceed the limits shown in §15.209. At frequencies equal to or less than 1000 MHz, compliance with the limits in §15.209 shall be demonstrated using measurement instrumentation employing a CISPR quasi-peak detector. Above 1000 MHz, compliance with the emission limits in §15.209 shall be demonstrated based on the average value of the measured emissions. The provisions in §15.35 apply to these measurements.

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 above using the recalculation factor as described in clause 5.3.

6.4.3 Test procedure

The emission within the restricted band of operation from 0.090 MHz – 0.110 MHz is measured using the test procedure as described in clause 5.7.

6.4.4 Test results

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

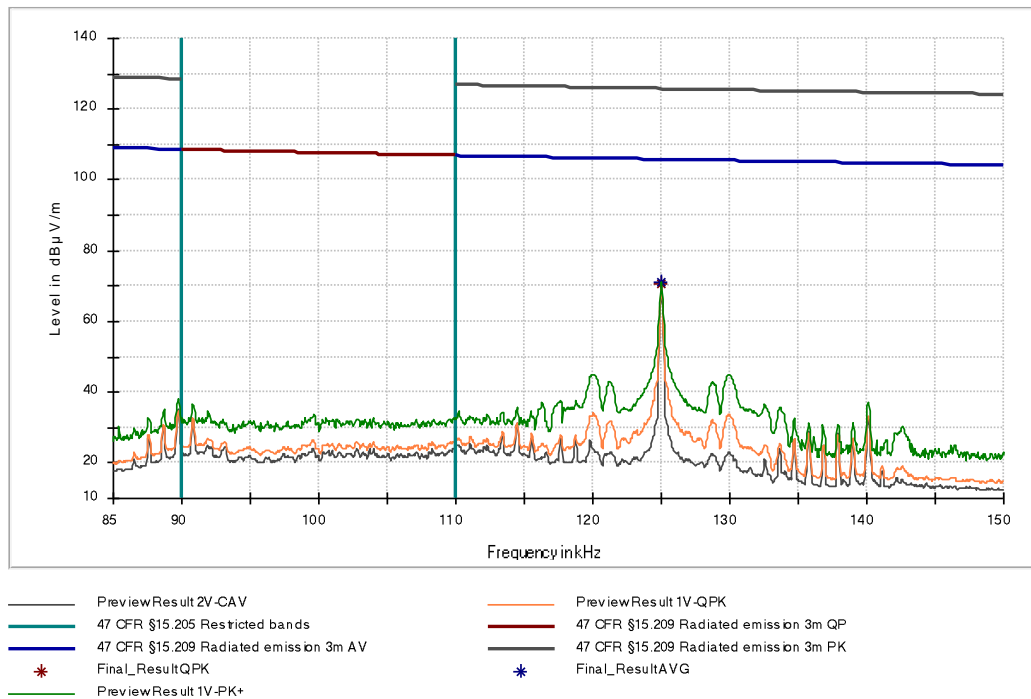


Figure 11: Chart of restricted band of operation, EUT position Z, without tag, antenna parallel at 3 m

Note: No assessable emission could be detected.

6.5 Emissions outside the operating frequency band(s) specified

6.5.1 Emissions below 30 MHz

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

Section(s) in RSS: Requirement(s): RSS-Gen, section 6.13
Reference(s): ANSI C63.10, clause 6.4

Performed by: Andreas Menacher Date of test: June 9, 2020

Result⁵: Test passed Test not passed

6.5.1.1 Test equipment

Type	Designation	Manufacturer	Inventory no.
Compact Diagnostic Chamber (CDC)	VK041.0174	Albatross Projects	E00026
EMI test receiver	ESR 7	Rohde & Schwarz	E00739
Loop antenna	HFH2-Z2	Rohde & Schwarz	E00060
Cable set CDC	RF cable(s)	Huber + Suhner AME HF-Technik AME HF-Technik Stabo	E00446 E00920 E00921 E01215
Test software	EMC32-EB (V10.35)	Rohde & Schwarz	E00777

⁵ For information about measurement uncertainties see page 73.

6.5.1.2 Limits

Frequency [MHz]	Field strength		Measurement distance [m]
	[μ V/m]	[dB μ 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 12: General radiated emission limits up to 30 MHz according to §15.209

Frequency [MHz]	Field strength		Measurement distance [m]
	[μ A/m]	[dB μ A/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 13: General radiated emission limits up to 30 MHz according to RSS Gen

In case of measurements are performed at other distances than that specified in the requirements, the limits in the charts and tables reported with the test results are derived from the general radiated emission limits as listed in table 12 and Table 13, using the recalculation factor as described in clause 5.3.

6.5.1.3 Test procedure

The emissions below 30 MHz are measured using the

- test procedure for radiated measurements as described in clause 5.3.

6.5.1.4 Test results

Test distance: 3 m

Antenna alignment: in parallel in line

EUT position: Position X Position Y Position Z

Frequency range	Step size	IF Bandwidth	Detector		Measurement Time		Preamplifier
			Prescan	Final scan	Prescan	Final scan	
9 kHz – 150 kHz	50 Hz	200 Hz	QP, PK, CAV	QP, PK, AV	1 s	1 s	Off
150 kHz – 30 MHz	2.25 kHz	9 kHz	QP, PK, CAV	QP, PK, AV	1 s	1 s	Off

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

Note 2: The limits in CFR 47, Part 15, Subpart C, paragraph 15.209(a), are identical to those in RSS-Gen section 8.9, Table 6, since the measurements are performed in terms of magnetic field strength and converted to electric field strength levels (as reported in the table) using the free space impedance of 377 Ohms. For example, the measurement at frequency X kHz resulted in a level of Y dBuV/m, which is equivalent to $Y - 51.5 = Z$ dBuA/m, which has the same margin, W dB, to the corresponding RSS-Gen Table 6 limit as it has to 15.209(a) limit.



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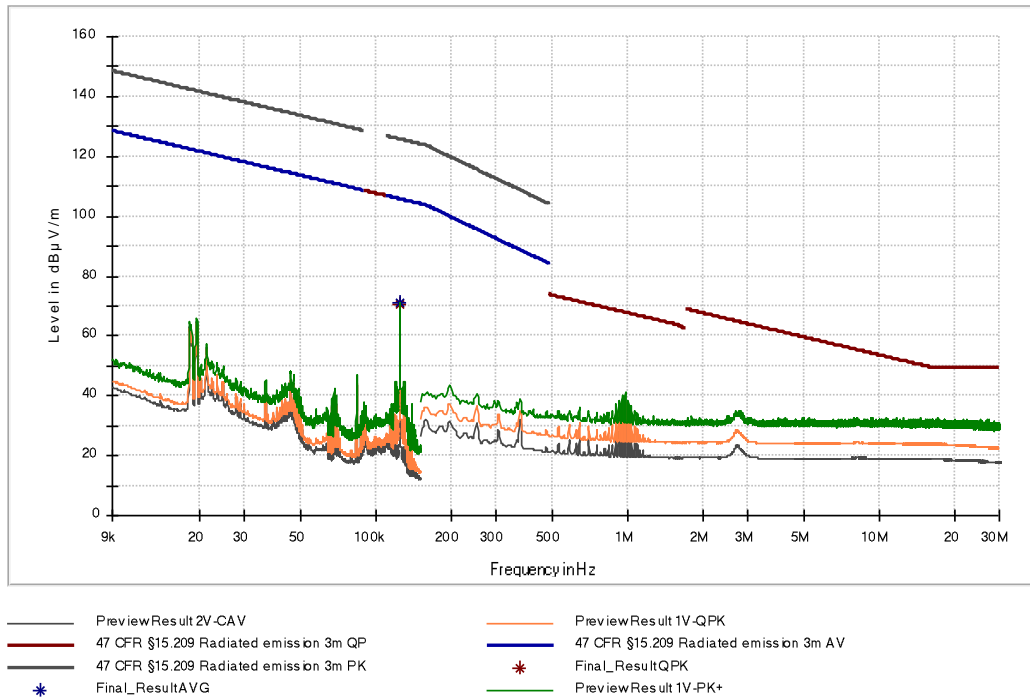


Figure 12: Chart of emissions test below 30 MHz, EUT position Z, without tag, antenna parallel at 3 m

Frequency (MHz)	Measured value (dBµV/m) at 3 m	Recalculation factor (dB)	Field strength (dBµV/m) at 300 m	Limit (dBµV/m) at 300 m	Margin (dB)	Detector	Azimuth (deg)	Result
0.125000	71.22	-80.00	-8.78	45.67	54.45	PK	0.0	Pass
0.125000	71.08	-80.00	-8.92	25.67	34.59	AV	0.0	Pass

Table 14: Final results of test below 30 MHz, EUT position Z, without tag, antenna parallel at 3 m

6.5.2 Emissions from 30 MHz to 1 GHz

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

Section(s) in RSS: Requirement(s): RSS-247, section 5.5
 RSS-Gen, section 6.13
 Reference(s): ANSI C63.10, clause 6.5

Performed by: Andreas Menacher Date of test: June 8, 2020

Result⁶: Test passed Test not passed

6.5.2.1 Test equipment

Type	Designation	Manufacturer	Inventory no.
Semi-anechoic chamber (SAC)	SAC3	Albatross Projects	E00716
EMI test receiver	ESW 44	Rohde & Schwarz	E00895
TRILOG broadband antenna (SAC)	VULB 9162	Schwarzbeck	E00643
Cable set SAC	RF cable(s)	Huber + Suhner	E00755 E01033 E01034
Test software	EMC32-MEB (V10.35)	Rohde & Schwarz	E00778

⁶ For information about measurement uncertainties see page 73.

6.5.2.2 Limits

Frequency [MHz]	Field strength		Measurement distance [m]
	[μ V/m]	[dB μ 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 15: General radiated emission limits \geq 30 MHz according to §15.209

6.5.2.3 Test procedure

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

- test procedure for radiated measurements as described in clause 5.4.

6.5.2.4 Test results

Test distance: 3 m

EUT position: Position X Position Y Position Z

Frequency range	Step size	IF Bandwidth	Detector		Measurement Time		Preamplifier
			Prescan	Final scan	Prescan	Final scan	
30 MHz – 1 GHz	30 kHz	120 kHz	QP	QP	1 s	1 s	20 dB

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

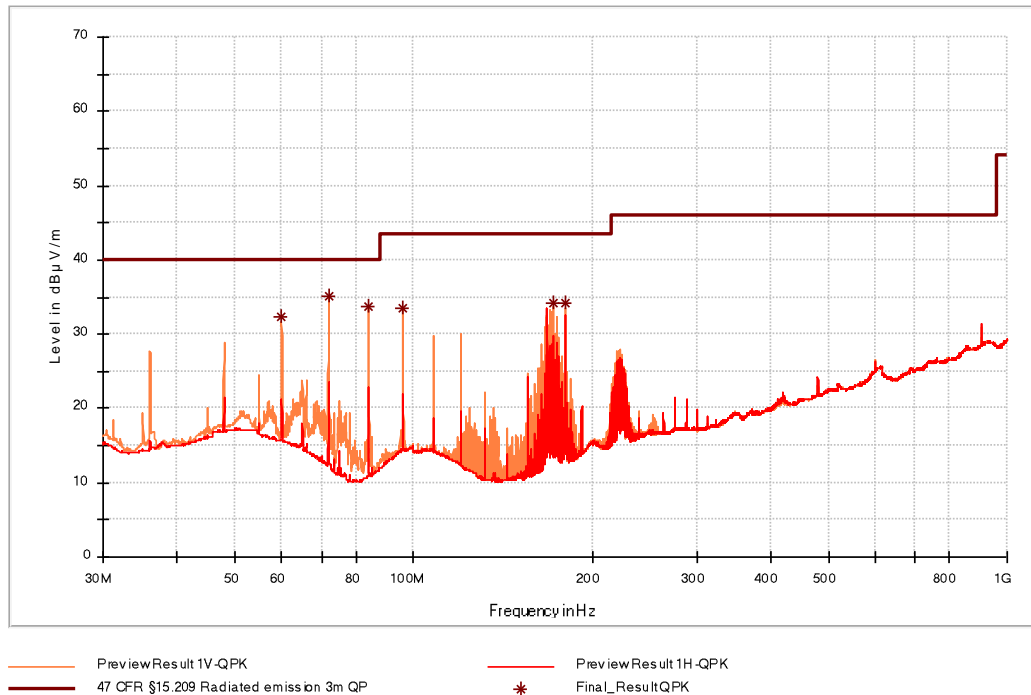


Figure 13: Chart of emissions test from 30 MHz to 1 GHz, EUT position Y, with tag at 3 m

Frequency (MHz)	Measured value QuasiPeak (dBµV/m) at 3m	Limit (dBµV/m) at 3m	Margin (dB)	Height (cm)	Polarization	Azimuth (deg)	Result
60.000000	32.28	40.00	7.72	100.0	V	169.0	Pass
72.000000	35.21	40.00	4.79	102.0	V	169.0	Pass
84.000000	33.81	40.00	6.19	112.0	V	102.0	Pass
96.000000	33.59	43.52	9.93	101.0	V	110.0	Pass
172.170000	34.24	43.52	9.28	102.0	V	135.0	Pass
180.000000	34.09	43.52	9.43	102.0	V	135.0	Pass

Table 16: Final results of emissions test from 30 MHz to 1 GHz, EUT position Y, with tag, at 3 m

6.5.3 Emissions from 1 GHz to 2 GHz

Section(s) in 47 CFR Part 15: Requirement(s): 15.209
 Reference(s): ANSI C63.10, clause 6.6

Section(s) in RSS: Requirement(s): RSS-247, section 5.5
 RSS-Gen, section 6.13
 Reference(s): ANSI C63.10, clause 6.6

Performed by: Andreas Menacher Date of test: June 8, 2020

Result⁷: Test passed Test not passed

6.5.3.1 Test equipment

Type	Designation	Manufacturer	Inventory no.
Free space semi-anechoic chamber (FS-SAC)	FS-SAC	EMV TESTHAUS	E00100
EMI test receiver	ESU 26	Rohde & Schwarz	W00002
EMI test receiver	ESW 44	Rohde & Schwarz	E00895
Preamplifier (1 GHz - 18 GHz)	ALS05749	Aldetec	W01007
Horn antenna	BBHA 9120D	Schwarzbeck	W00053
Cable set FS-SAC	RF cable(s)	Teledyne Reynolds Huber + Suhner Teledyne Reynolds	E00435 E00307 E00433
Test software	EMC32-MEB (V10.35)	Rohde & Schwarz	E00778

⁷ For information about measurement uncertainties see page 73.



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6.5.3.2 Limits

Frequency [MHz]	Field strength		Measurement distance [m]
	[μ V/m]	[dB μ V/m]	
Above 960	500	53.98	3

Table 17: General radiated emission limits above 960 MHz according to §15.209

6.5.3.3 Test procedure

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

- test procedure for radiated measurements as described in clause 5.5.

6.5.3.4 Test results

Test distance:	Final tests:	<input checked="" type="checkbox"/> 3 m	<input type="checkbox"/> 1 m
EUT position:	<input checked="" type="checkbox"/> Position 1	<input checked="" type="checkbox"/> Position 2	<input checked="" type="checkbox"/> Position 3

Frequency range	Step size	IF Bandwidth	Detector		Measurement Time		Pre-amplifier	Distance
			Prescan	Final scan	Prescan	Final scan		
1 GHz – 2 GHz	250 kHz	1 MHz	PK + AV	PK + AV	1.5 s	0.1 s	External	3 m

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

Note 2: No assessable emissions could be detected.

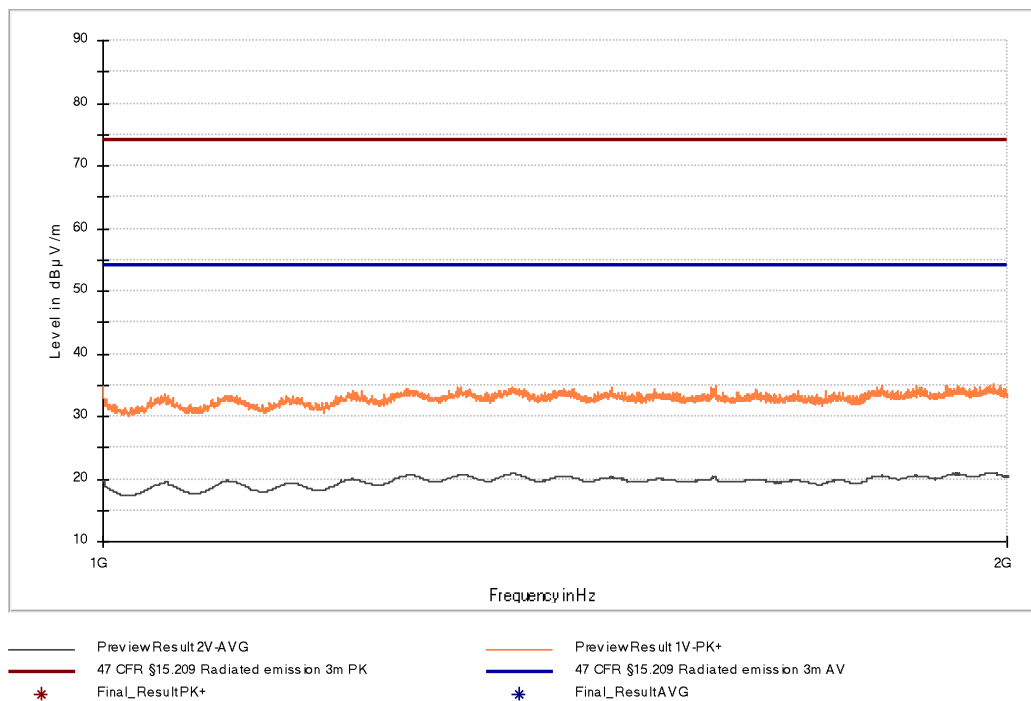


Figure 14: Chart of emissions test from 1 GHz to 7 GHz, EUT position Y, without tag, antenna vertical, at 3 m

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Equipment calibration status

Description	Modell number	Serial number	Inventory number(s)	Last calibration	Next calibration
EMI test receiver	ESW44	101538	E00895	2019-07	2020-07
EMI test receiver	ESU26	100026	W00002	2020-06	2022-06
EMI test receiver	ESR7	101059	E00739	2019-08	2020-08
EMI test receiver	ESCI3	100013	E00001	2020-05	2022-05
Preamplifier (1 GHz - 18 GHz)	ALS05749	001	W01007	2020-03	2021-03
Loop antenna	HFH2-Z2	871398/0050	E00060	2018-10	2020-10
LISN	ESH2-Z5	893406/009	E00005	2018-10	2020-10
Field probe	RF-R 400-1	02-2030	E00270	see Note 1	
TRILOG broadband antenna (SAC3)	VULB 9162	9162-041	E00643	2018-03	2021-03
Horn antenna	BBHA 9120D	9120D-593	W00053	2019-09	2022-09
Shielded room	P92007	B 83117 C 1109 T 211	E00107	N/A	
Compact diagnostic chamber (CDC)	VK041.0174	D62128-A502- A69-2-0006	E00026	N/A	
Semi-anechoic chamber (SAC) with floor absorbers	FS-SAC	---	E00100	2018-03	2021-03
Semi-anechoic chamber (SAC)	SAC3	C62128-A520- A643-x-0006	E00716	2018-03	2021-03
Cable set CDC	RG214/U	---	E00446	2020-04	2021-04
	LCF12-50J	---	E01215	2020-01	2021-01
	LMR400	1718020006	E00920	2020-01	2021-01
	RG214 Hiflex	171802007	E00921	2019-10	2020-10
	SF104EA/2x11PC 35-42/5m	11144/4EA	E00307	2019-12	2020-12
	262-0942-1500	003	E00433	2019-10	2020-10
Cable set of semi-anechoic chamber SAC3	SF104EA/11PC35 /11PC35/10000M M	501347/4EA	E00755	2019-08	2020-08
	SF104E/11PC35/1 1PC35/2000MM	507410/4E	E01035	2020-04	2021-04
	SF104E/11PC35/1 1PC35/2000MM	507411/4E	E01034	2020-01	2021-01

Note 1: Only used for relative measurements (clause 6.2, 6.3).



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8 Measurement uncertainties

Description	Uncertainty	k=
AC power line conducted emission	± 4.1 dB	2
Carrier frequency separation Number of hopping frequencies Time of occupancy (dwell time)	± 5.0 %	2
Bandwidth tests	± 2.0 %	
Maximum conducted output power (conducted)	± 1.5 dB	
Power spectral density (conducted)	± 2.9 dB	
Conducted spurious emissions	± 2.9 dB	
Radiated emissions in semi-anechoic chamber		
9 kHz to 30 MHz	± 4.8 dB	2
30 MHz to 300 MHz	± 5.4 dB	2
300MHz to 1 GHz	± 4.7 dB	2
Radiated emissions in semi-anechoic chamber with RF absorbing material on the floor or fully anechoic room		
1 GHz to 25 GHz	± 4.5 dB	2

Comment: The uncertainty stated is the expanded uncertainty obtained by multiplying the standard uncertainty by the coverage factor k. For a confidence level of 95 % the coverage factor k is 2.

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

9

Revision history

<i>Revision</i>	<i>Date</i>	<i>Issued by</i>	<i>Description of modifications</i>
0	2020-06-10	Andreas Menacher	First edition