Test report

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RF test report

180872-AU01+W01

HERMOS AG

RFID Reader

LFM-LP

DAkkS Deutsche Akkreditierungsstelle D-PL-12155-01-00

EMV **TESTHAUS** GmbH

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Accreditation:

Test Firm Type “accredited”: Valid until 2019-06-05
MRA US-EU, FCC designation number: DE0010
BNetzA-CAB-02/21-02/04 Valid until 2023-11-26

Location of Testing:

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The technical accuracy is guaranteed through the quality management of EMV **TESTHAUS** GmbH.

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1 Summary of test results

System type: RFID Reader

47 CFR part and section	*Test*	*Page*	*Result*	*Note(s)*
15.207	AC power line conducted emissions 150 kHz to 30 MHz	24	Passed	---
2.202(a) ANSI C63.10	Occupied bandwidth (99 %)	28	For information only	---
15.205 (a) – (c)	Restricted bands of operation	30	Passed	---
15.209 15.33	Emissions outside the operating frequency band(s) specified 9 kHz to 2 GHz			---
	9 kHz to 30 MHz	33	Passed	---
	30 MHz to 1 GHz	37	Passed	---
	1 GHz to 2 GHz	41	Passed	1

Notes:

1. 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 then the 10th harmonic of the intentional radiator.

Straubing, December 20, 2018

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Test engineer
EMV **TESTHAUS** GmbH

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2 Referenced publications

Publication	*Title*
CFR 47 Part 2 October 2017	Code of Federal Regulations, Title 47 (Telecommunication), Part 2 (Frequency allocation and radio treaty matters; General rules and regulations) of the Federal Communication Commission (FCC)
CFR 47 Part 15 October 2017	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

3 Equipment under test (EUT)

All Information in this clause is declared by customer.

3.1 General information

Product type:	RFID Reader		
Model name:	LFM-LP		
Serial number(s):	Prototype of LFM-LP		
Applicant:	HERMOS AG		
Manufacturer:	HERMOS AG		
Version:	Hardware:	LFM_LP_RevB	
	Software:	LFMLP_1.0F03	
Additional modifications:	Ferrites L8 and L9 (Würth Elektronik, 1206, 742792118) as well as L10 and L14 (Würth Elektronik, 0805, 742792097) were mounted to the PCB by manufacturer to pass radiated emission test from 30 MHz to 1 GHz. The ferrites are indicated in schematics and internal photos. No other test was repeated with this configuration.		
FCC ID:	2AP5OLFM-LP		
Power supply:	DC supply		
	Nominal voltage:	24 V	
	Minimum voltage:	18 V	
	Maximum voltage:	30 V	
	Nominal frequency:	---	
Temperature range:	0 °C to +50°C (customer defined)		
Device type:	☐ Portable	☐ Mobile	☒ Fixed
Highest internal frequency:	120 MHz		

3.2 Radio specifications

System type:	RFID Reader		
Application frequency band:	n/a		
Frequency range used:	134.4 kHz – 134.6 kHz		
Operating frequency:	134.2 kHz		
Short description:	The EUT is a RFID Reader operating on the frequency 134.2 kHz.		
Number of RF channels	1		
Modulation	ASK		
Antenna:	Type:	Ferrite Antenna	
	Gain:	n/a	
	Connector:	☒ external	☐ internal
		☐ temporary	☐ none (integral antenna)

3.3 Photo documentation

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

4 Test configuration and mode of operation

4.1 Test configuration

Device	*Type designation*	*Serial or inventory no.*	*Manufacturer*
EUT			
RFID Reader	LFM-LP	Prototype of LFM-LP	HERMOS AG
Transponder	134.2 kHz	---	HERMOS AG
Support equipment			
Universal mains adapter	C17-6U3	1201-0013	Hycell GmbH
Notebook	B70-80	O00909	Lenovo
Notebook power supply	ADLX65NLC3A	5A10J75114	Lenovo

Table 1: Devices used for testing

4.2 Mode of operation

4.2.1 Test software used for all tests

For all tests collected in this report, the software putty.exe was used.

The COM-Settings for the communication were set as following:

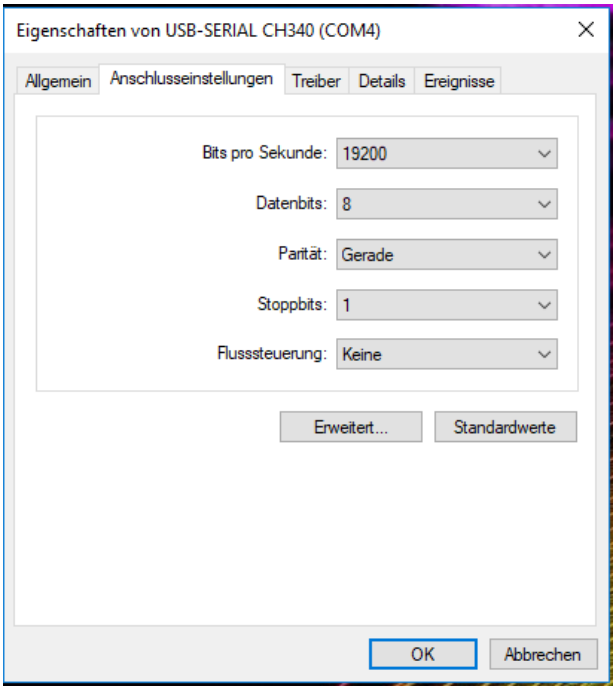

Figure 1: COM Settings

Putty settings were as following:

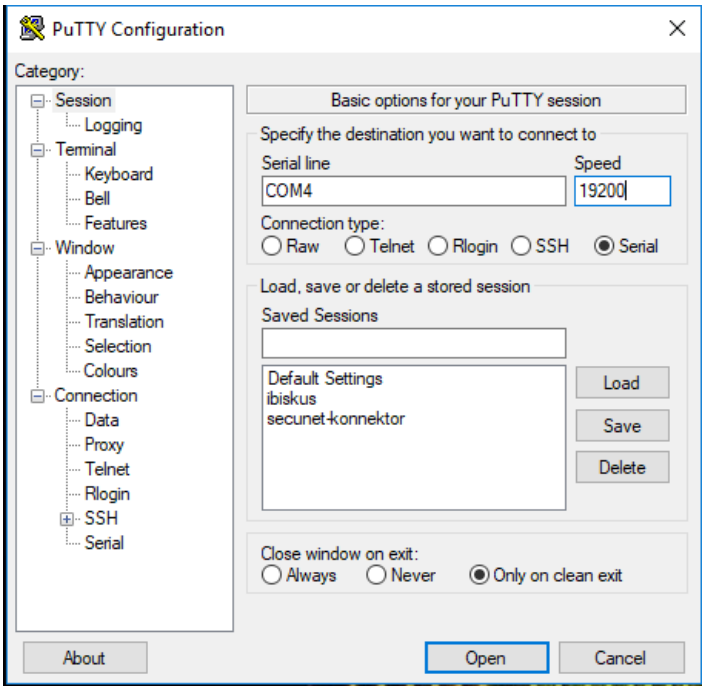

Figure 2: Putty Settings

After successful connection putty shows following response when tag is detected:

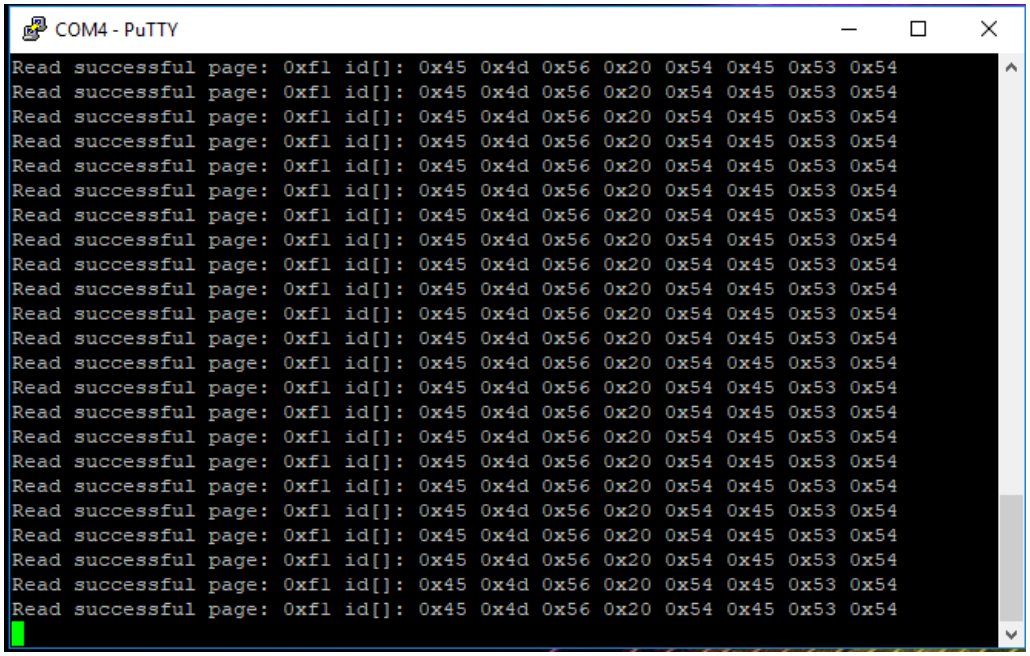

Figure 3: Read tag successful

If no tag is detected putty shows following response:

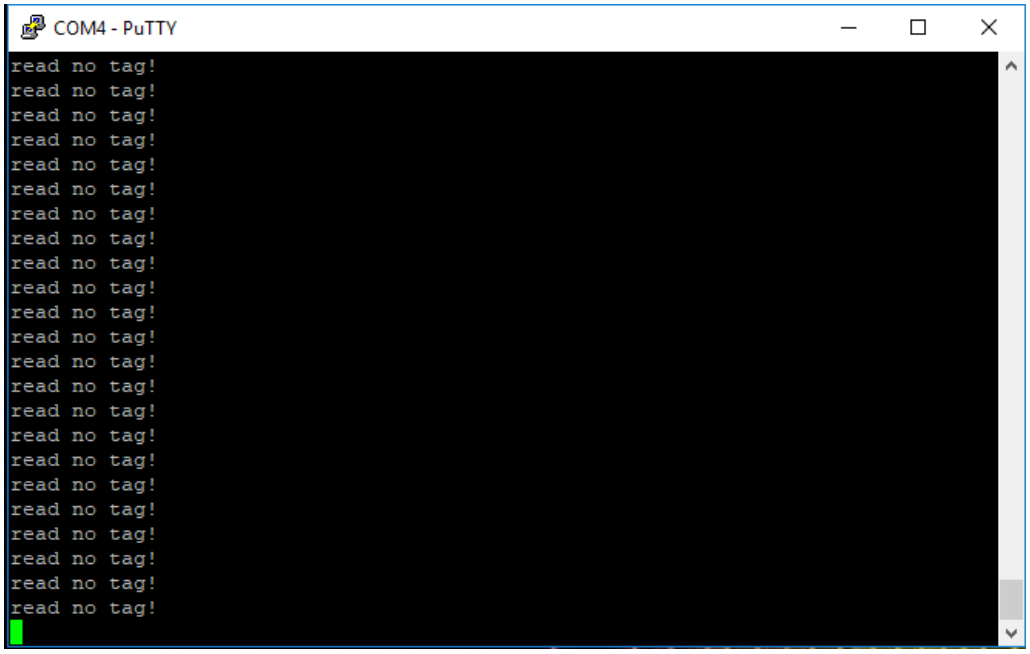

Figure 4: No tag detected

4.2.2 Test modes applied

The EUT was configured by manufacturer to start reading searching / reading the tag as soon as the device is powered.
For information if the worst-case of the single measurements was with or without tag, look at the respective test.

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 6.3.3 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.

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 2: 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 2). 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).

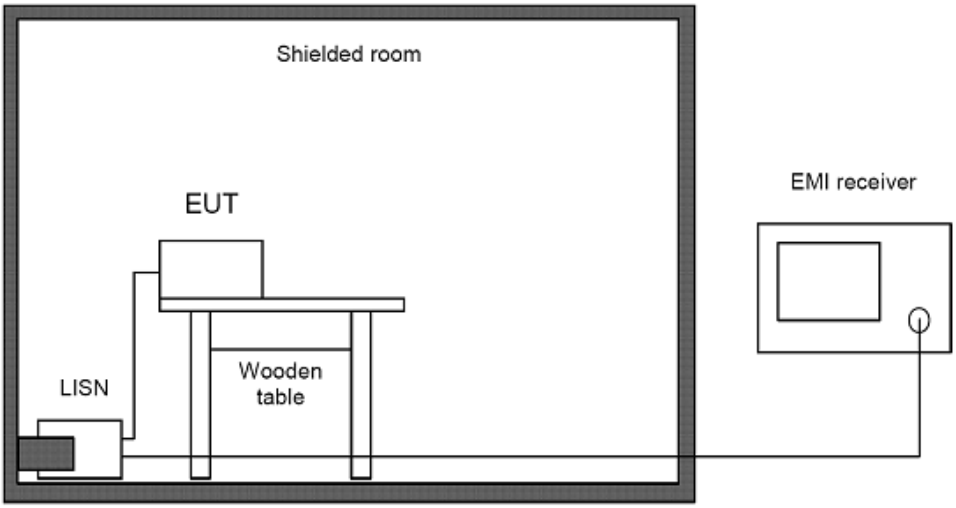

Figure 5: Setup for AC power-line conducted emissions test from 150 kHz to 30 MHz

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

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

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

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

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

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

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

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

Table 3: 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 4.

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

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 4).
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.

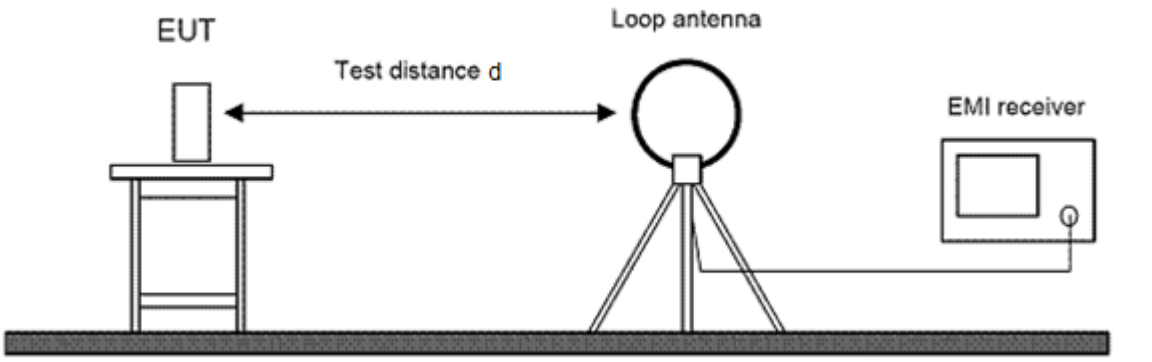

Figure 6: Setup for radiated emissions test below 30 MHz

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 5.

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

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 5).
d) The table position is set to 0°.
e) The antenna height is set to 1 m.

f) The spectrum for the full frequency range is recorded. If the emission at a certain frequency is higher than the levels already recorded, the polarization and height of the measurement antenna as well as the current table position are noted as the maximum position.
g) The antenna height is increased to 4 m in steps of 50 cm. At each height, step f) is repeated.
h) The polarization of the measurement antenna is changed to horizontal.
i) The antenna height is decreased from 4 m to 1 m in steps of 50 cm. At each height, step f) is repeated.
j) The EUT is rotated in a horizontal plane through 360° in steps of 60°. At each table position, steps e) to i) are repeated.
k) After the last prescan, the significant maximum emissions with their polarizations and heights of the measurement antenna as well as their table positions are determined and collected in a list.
l) With the test receiver set to the first frequency of the list, the measurement antenna is set to the polarization and height and the table is moved to the position as determined during prescans.
m) The antenna is moved by ±50 cm around this height and the EUT is rotated by ±60° around this table position while measuring the emission level continuously.
n) For final scan, the worst-case positions of antenna and table are set and the maximum emission level is recorded.
o) Steps l) to n) are repeated for all other frequencies in the list. At least, frequency and level of the six highest emissions relative to the limit have to be recorded. However, emissions more than 20 dB below the limit do not need to be reported.

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

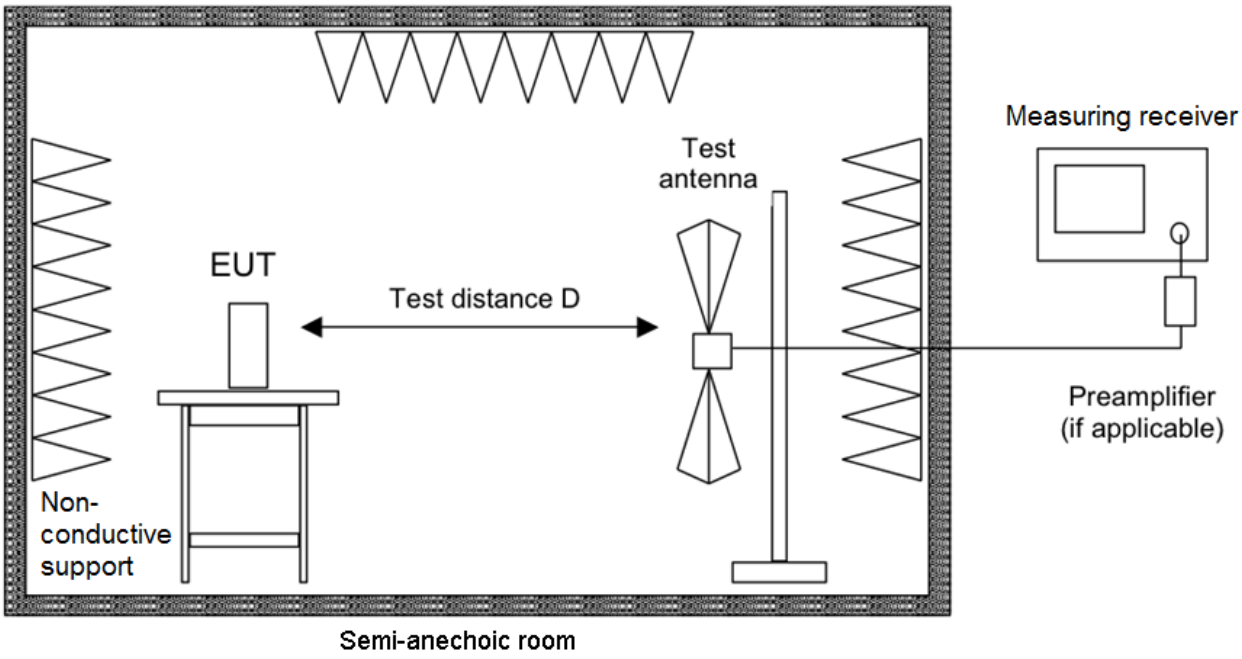

Figure 7: Setup for radiated emissions test from 30 MHz to 1 GHz

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.

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 6.

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

Table 6: 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 7.

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

Table 7: 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 7).
d) The table position is set to 0°.
e) The antenna height is set to 1 m.
f) The spectrum for the full frequency range is recorded. If the emission at a certain frequency is higher than the levels already recorded, the polarization and height of the measurement antenna as well as the current table position are noted as the maximum position.
g) The antenna height is increased to the scan height upper range in steps of 50 cm. At each height, step f) is repeated.
h) The polarization of the measurement antenna is changed to horizontal.
i) The antenna height is decreased from the scan height upper range to 1 m in steps of 50 cm. At each height, step f) is repeated.
j) The EUT is rotated in a horizontal plane through 360° in steps of 30°. At each table position, steps e) to i) are repeated.
k) After the last prescan, the significant maximum emissions with their polarizations and heights of the measurement antenna as well as their table positions are determined and collected in a list.
l) With the test receiver set to the first frequency of the list, the measurement antenna is set to the polarization and height and the table is moved to the position as determined during prescans.
m) The antenna is moved by ±50 cm around this height and the EUT is rotated by ±30° around this table position while measuring the emission level continuously.
n) For final scan, the worst-case positions of antenna and table are set and the maximum emission level is recorded.

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

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

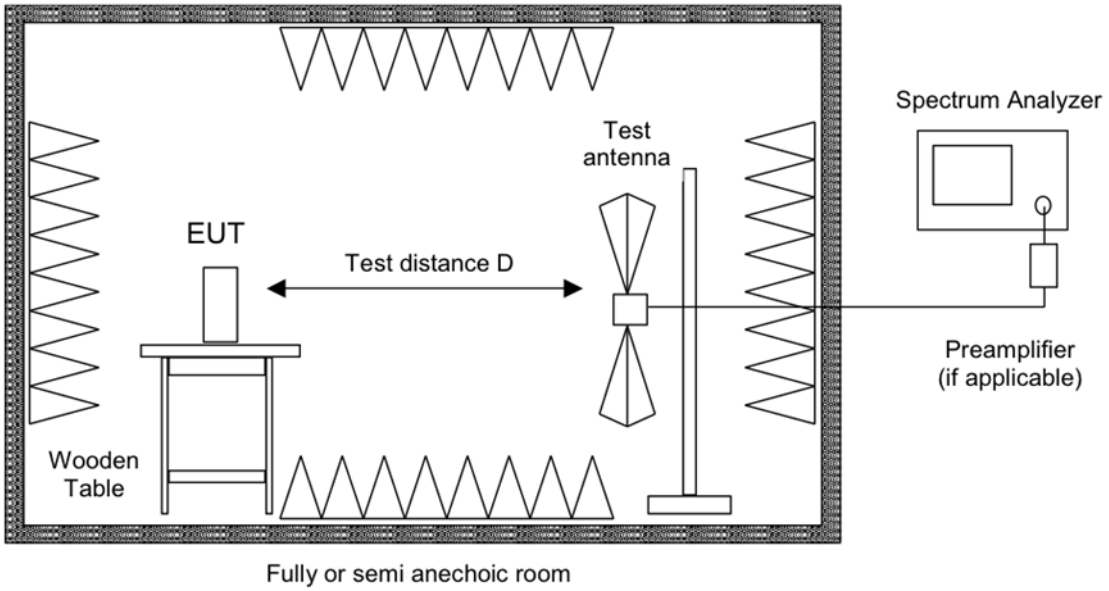

Figure 8: Setup for radiated emissions test above 1 GHz

5.6 Bandwidth measurements

5.6.1 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.

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 5.

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

Result[1]	☒ 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
☐	Test software	EMC32-MEB (V10.35)	Rohde & Schwarz	E00778
☐	Test software	EMC32-MEB (V10.35)	Rohde & Schwarz	E01073

6.1.2 Limits

As specified in section 15.207 of 47 CFR Part 15, the emissions from an intentional radiator shall not exceed the conducted limits as specified in table 8.

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

Table 8: AC power-line conducted limits

[1] For information about measurement uncertainties see page 85.

* Decreases with the logarithm of the frequency.

6.1.3 Test procedure

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

Remark: The AC power line conducted emissions were measured at the AC-power input port of the representative power switch. The nominal input supply was 120V / 60 Hz.

6.1.4 Test results

Performed by:	Andreas Menacher	Date(s) of test:	November 2, 2018
Climatic conditions:	Ambient temperature 22 °C	Relative humidity 35 %	Barometric pressure 977 hPa

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

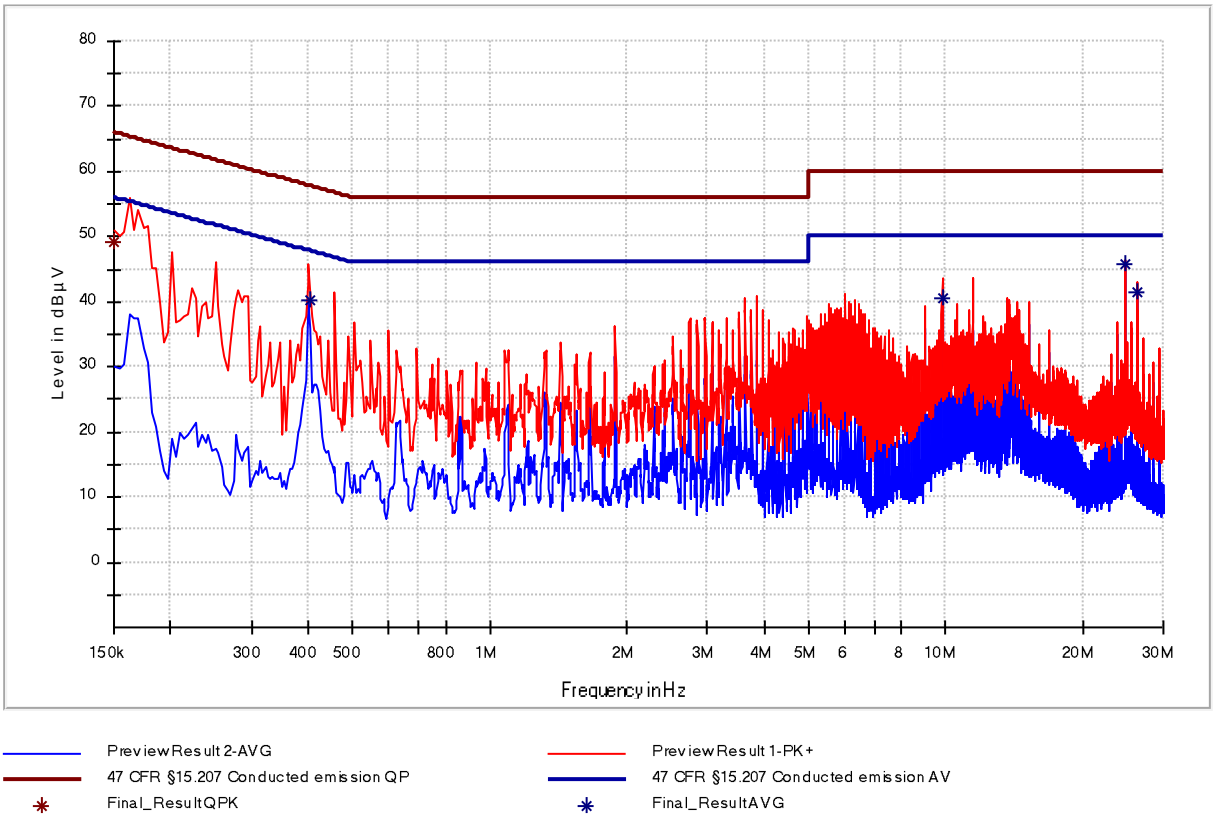

Figure 9: Chart of AC power-line conducted emissions test – phase L1

Frequency (MHz)	QuasiPeak (dBµV)	Average (dBµV)	Limit (dBµV)	Margin (dB)	Meas. Time (ms)	Bandwidth (kHz)	Line	PE	Corr. (dB)
0.150000	49.08	---	66.00	16.92	1000.0	9.000	L1	GND	10.1
0.405000	---	40.30	47.75	7.45	1000.0	9.000	L1	GND	10.1
9.825000	---	40.43	50.00	9.57	1000.0	9.000	L1	GND	11.3
24.749000	---	45.92	50.00	4.08	1000.0	9.000	L1	GND	12.5
26.317000	---	41.39	50.00	8.61	1000.0	9.000	L1	GND	12.5

Figure 10: Final results of AC power-line conducted emissions test – phase L1

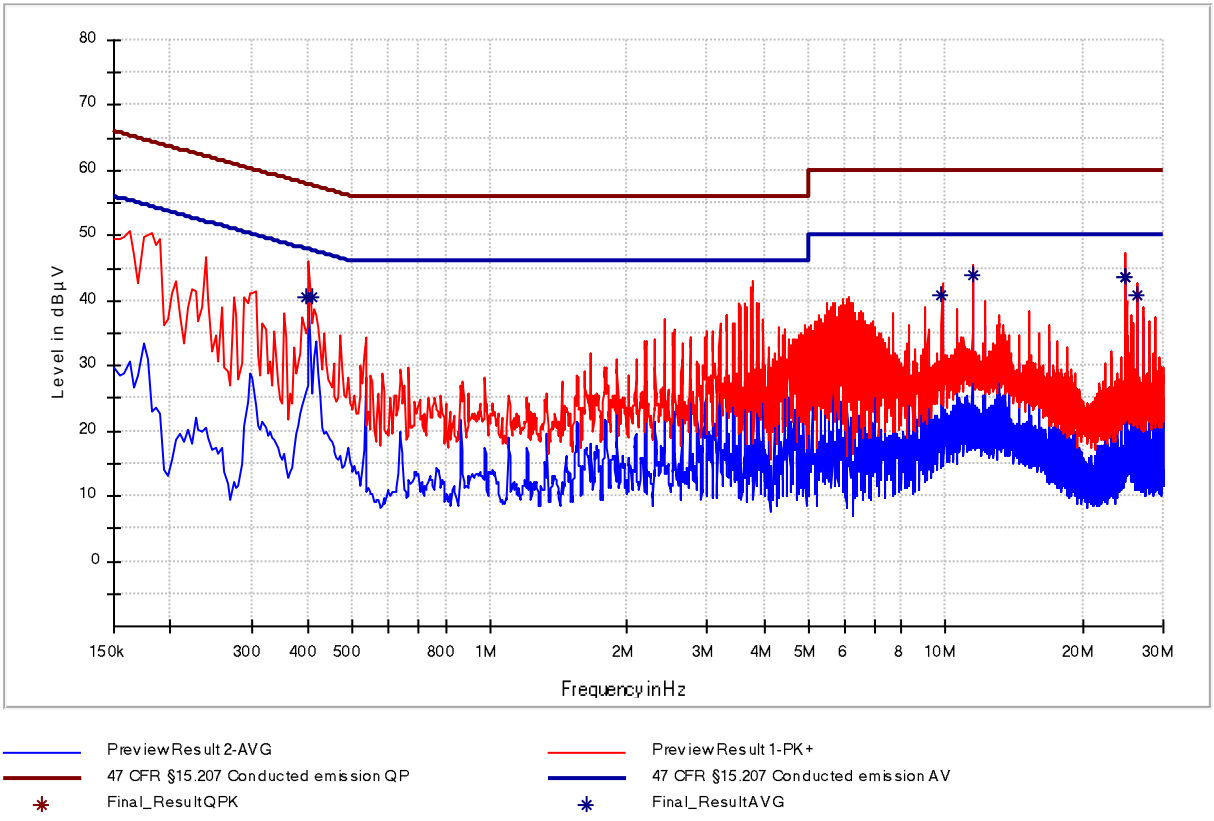

Figure 11: Chart of AC power-line conducted emissions test – phase N

Frequency (MHz)	QuasiPeak (dBµV)	Average (dBµV)	Limit (dBµV)	Margin (dB)	Meas. Time (ms)	Bandwidth (kHz)	Line	PE	Corr. (dB)
0.396000	---	40.45	47.94	7.49	1000.0	9.000	N	GND	10.1
0.409000	---	40.45	47.67	7.36	1000.0	9.000	N	GND	10.1
9.780000	---	40.73	50.00	9.27	1000.0	9.000	N	GND	11.5
11.428000	---	44.06	50.00	5.94	1000.0	9.000	N	GND	11.7
24.750000	---	43.78	50.00	6.22	1000.0	9.000	N	GND	12.5
24.795000	---	43.78	50.00	6.22	1000.0	9.000	N	GND	12.5
26.316000	---	40.93	50.00	9.07	1000.0	9.000	N	GND	12.5

Figure 12: Final results of AC power-line conducted emissions test – phase N

6.2 Occupied bandwidth

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

Performed by:	Andreas Menacher	Date(s) of test:	November 5, 2018
Climatic conditions:	Ambient temperature 21.0 °C	Relative humidity 34.8% to 35.4%	Barometric pressure 974.5 to 975.2 hPa
Result[2]:	☒ Test passed	☐ Test not passed	

6.2.1 Test equipment

	Type	*Designation*	*Manufacturer*	*Inventory no.*
☒	EMI test receiver (CDC)	ESCI 3	Rohde & Schwarz	E00552
☒	Field probe	RF-R 400-1	Langer EMV-Technik	E00270

6.2.2 Limits

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

6.2.3 Test procedure

The occupied bandwidth is measured using the test procedure as described in clause 5.6.1.

[2] For information about measurement uncertainties see page 76.

6.2.4 Test results

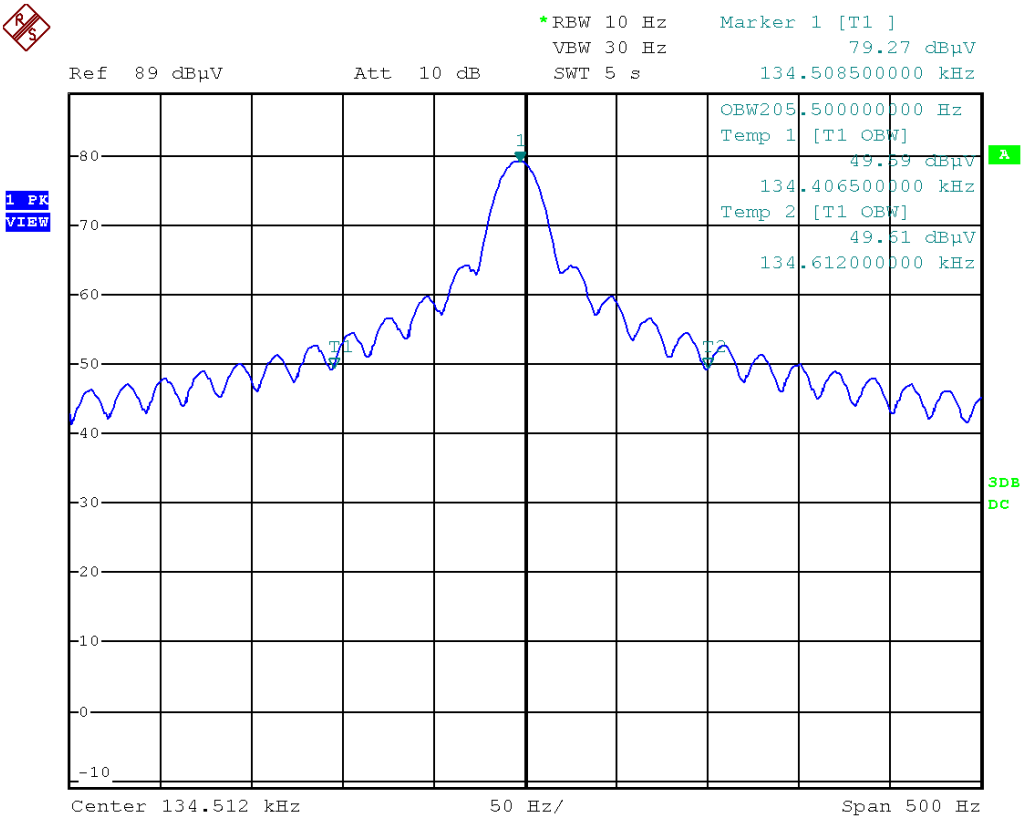

Figure 13: Chart of occupied bandwidth test

99% bandwidth	*Band edge left*		*Band edge right*		*Result*
	Frequency	*Limit*	*Frequency*	*Limit*	
[Hz]	*[kHz]*	*[kHz]*	*[kHz]*	*[kHz]*	
205.500	134.407	---	134.612	---	Recorded

Table 9: Results of occupied bandwidth test

Remark:
Occupied bandwidth was measured with and without tag.
There was no difference regarding the occupied bandwidth if a tag was used or not.
The plot shown in the test report is the plot of the measurement with tag.

6.3 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	

Performed by:	Andreas Menacher	Date(s) of test:	November 2, 2018
Climatic conditions:	Ambient temperature 22.0 °C	Relative humidity 35 %	Barometric pressure 977 hPa
Result[3]:	☒ Test passed	☐ Test not passed	

6.3.1 Test equipment

	Type	*Designation*	*Manufacturer*	*Inventory no.*
☒	Compact Diagnostic Chamber (CDC)	VK041.0174	Albatross Projects	E00026
☐	Open area test site (OATS)	---	EMV **TESTHAUS**	E00354
☒	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
☒	Test software	EMC32-MEB (V10.35)	Rohde & Schwarz	E00778
☐	Test software	EMC32-MEB (V10.35)	Rohde & Schwarz	E01073

[3] For information about measurement uncertainties see page 76.

6.3.2 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.

6.3.3 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.

6.3.4 Test results

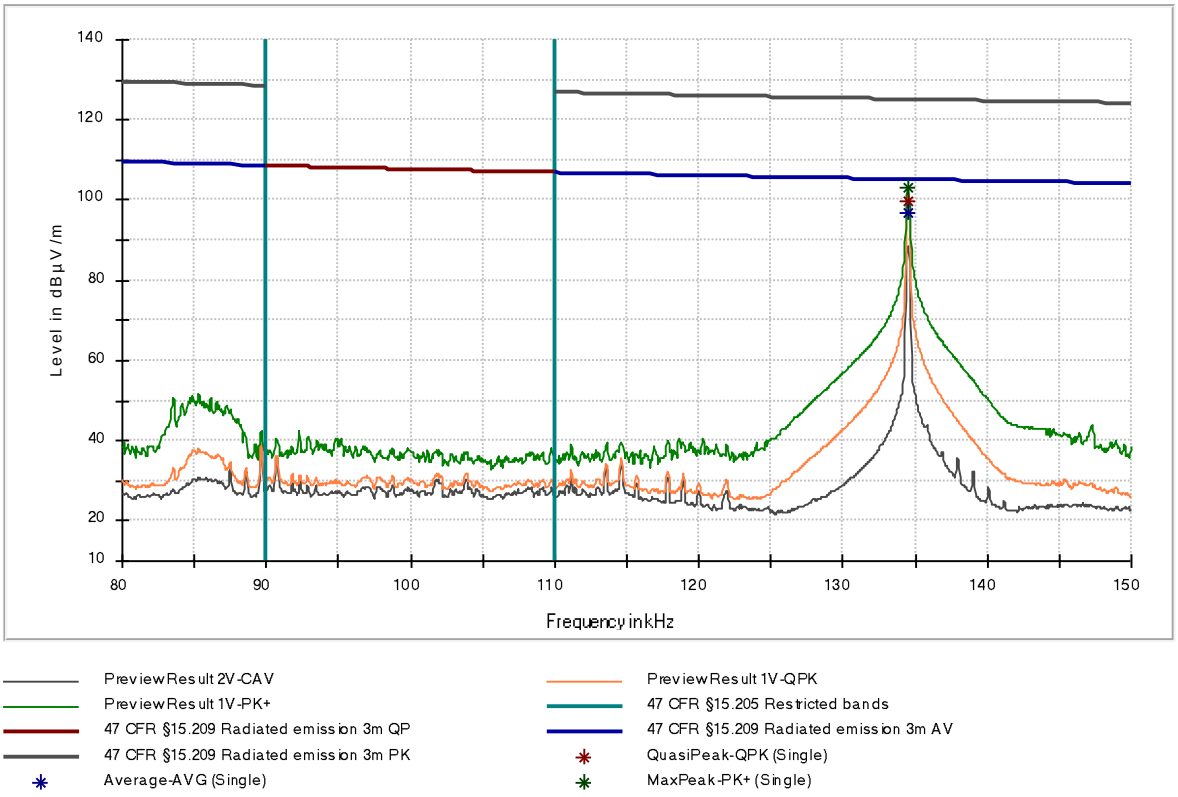

Figure 14: Restricted band of operation @ 3 m distance

Recalculation factor is determined according to ANSI C63.10, section 6.4.4.2 “Extrapolation from the measurement of a single point”:

Recalculation factor = $-40 \log(d_{limit} / d_{measure})$

f_{MHz} [MHz]	$d_{measure}$ [m]	d_{limit} [m]	Recalculation factor [dB]
0.134	3.000	300.000	-80

6.4 Radiated emissions

6.4.1 Emissions below 30 MHz

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

Result[4]: ☒ Test passed ☐ Test not passed

6.4.1.1 Test equipment

	Type	*Designation*	*Manufacturer*	*Inventory no.*
☒	Compact Diagnostic Chamber (CDC)	VK041.0174	Albatross Projects	E00026
☐	Open area test site (OATS)	---	EMV TESTHAUS	E00354
☒	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
☒	Test software	EMC32-MEB (V10.35)	Rohde & Schwarz	E00778
☐	Test software	EMC32-MEB (V10.35)	Rohde & Schwarz	E01073

[4] For information about measurement uncertainties see page 92.

6.4.1.2 Limits

Frequency	*Field strength*		*Measurement distance*
[MHz]	*[µV/m]*	*[dBµV/m]*	*[m]*
0.009 – 0.490	2400/F(kHz) (266.67 – 4.90)	48.52 – 13.80	300
0.490 – 1.705	24000/F(kHz) (48.98 – 14.08)	33.80 – 22.97	30
1.705 – 30	30	29.54	30

Table 10: 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 10 using the recalculation factor as described in clause 5.3.

6.4.1.3 Test procedure

The emissions below 30 MHz are measured using the

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

6.4.1.4 Test results

Performed by:	Andreas Menacher	Date(s) of test:	November 2, 2018
Climatic conditions:	Ambient temperature 22.0 °C	Relative humidity 35.0 %	Barometric pressure 977 hPa
Test distance:	☒ 3 m	☐ 10 m	☐ ….. m
Antenna alignment:	☒ in parallel	☐ in line	☐ angle ….. °
EUT position[5]:	☒ Position 1	☒ Position 2	☒ Position 3

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	2 s	1 s	Off
150 kHz – 30 MHz	2.25 kHz	9 kHz	QP, PK, CAV	QP, PK, AV	2 s	1 s	Off

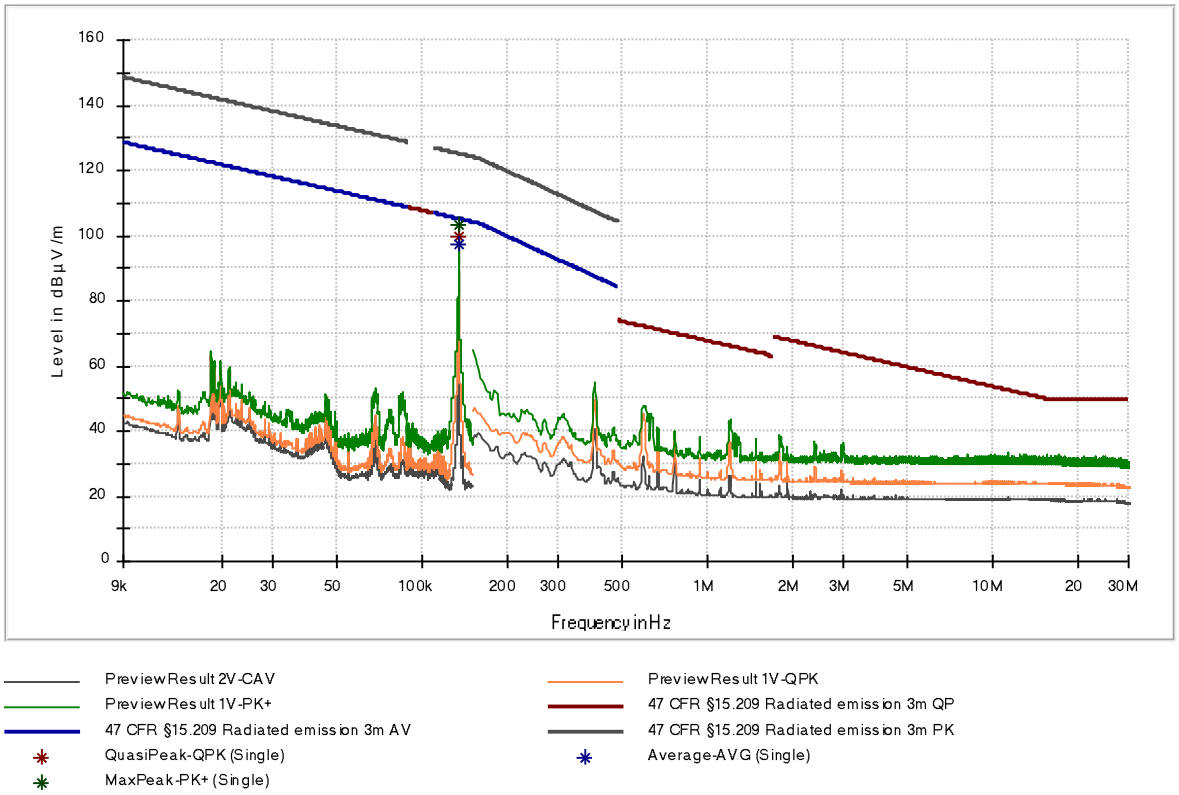

Figure 15: Chart of emissions test below 30 MHz without tag in position 2

[5] Exploratory measurements are performed in all positions as indicated. However, the figures and result tables within this test report show the worst case position, only.

Frequency [MHz]	Measured value [dBµV/m]	Detector	Recalculation factor [dB]	Field strength [dBµV/m]	Limit [dBµV/m]	Margin	Result
0.13450	103.22	PK	-80.0	23.22	45.05	21.83	Pass
0.13450	99.66	QP	-80.0	19.66	---	---	
0.13450	97.04	AV	-80.0	17.04	25.05	8.01	Pass

Recalculation factor is determined according to ANSI C63.10, section 6.4.4.2 “Extrapolation from the measurement of a single point”:

Recalculation factor = $-40 \log(d_{limit} / d_{measure})$

f_{MHz} [MHz]	$d_{measure}$ [m]	d_{limit} [m]	Recalculation factor [dB]
0.134	3.000	300.000	-80

6.4.2 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

Result[6]: ☒ Test passed ☐ Test not passed

6.4.2.1 Test equipment

	Type	*Designation*	*Manufacturer*	*Inventory no.*
☒	Semi-anechoic chamber (SAC)	SAC3	Albatross Projects	E00716
☒	EMI test receiver	ESR 7	Rohde & Schwarz	E00739
☐	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-EB (V10.35)	Rohde & Schwarz	E00777
☐	Test software	EMC32-MEB (V10.35)	Rohde & Schwarz	E00778
☐	Test software	EMC32-MEB (V10.35)	Rohde & Schwarz	E01073

[6] For information about measurement uncertainties see page 92.

6.4.2.2 Limits

Frequency	*Field strength*		*Measurement distance*
[MHz]	*[µV/m]*	*[dBµV/m]*	*[m]*
30 – 88	100	40.00	3
88 – 216	150	43.52	3
216 - 960	200	46.02	3
Above 960	500	53.98	3

Table 11: General radiated emission limits ≥ 30 MHz according to §15.209

6.4.2.3 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.

6.4.2.4 Test results

Performed by:	Andreas Menacher	Date(s) of test:	December 5, 2018
Climatic conditions:	Ambient temperature 21 °C	Relative humidity 35 %	Barometric pressure 977 hPa
Test distance:	☒ 3 m	☐ 10 m	☐ ….. m
EUT position[7]:	☒ Position 1	☒ Position 2	☒ Position 3

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

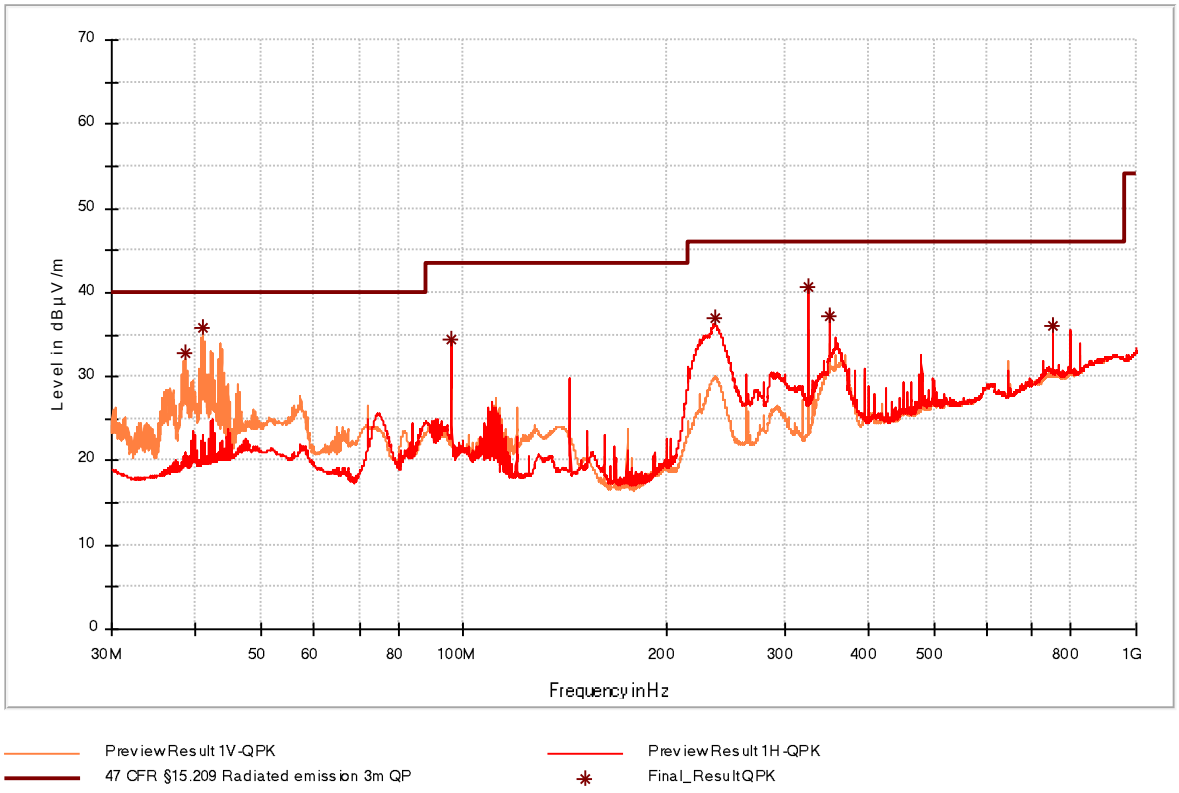

Figure 16: Chart of emissions test from 30 MHz to 1 GHz with tag in position 2

[7] Exploratory measurements are performed in all positions as indicated. However, the figures and result tables within this test report show the worst case position, only.

Frequency (MHz)	QuasiPeak (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Meas. Time (ms)	Bandwidth (kHz)	Height (cm)	Pol	Azimuth (deg)
38.610000	32.91	40.00	7.09	1000.0	120.000	100.0	V	98.0
41.040000	35.89	40.00	4.11	1000.0	120.000	100.0	V	94.0
95.850000	34.32	43.50	9.18	1000.0	120.000	329.0	H	76.0
236.340000	37.03	46.00	8.97	1000.0	120.000	128.0	H	9.0
324.990000	40.67	46.00	5.33	1000.0	120.000	101.0	H	175.0
350.010000	37.24	46.00	8.76	1000.0	120.000	102.0	H	175.0
750.000000	35.96	46.00	10.04	1000.0	120.000	102.0	H	175.0

Table 12: Final results of emissions test from 30 MHz to 1 GHz with tag in position 2

6.4.3 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

Result[8]: ☒ Test passed ☐ Test not passed

6.4.3.1 Test equipment

	Type	*Designation*	*Manufacturer*	*Inventory no.*
☒	Semi-anechoic chamber (SAC)	SAC3	Albatross Projects	E00716
☒	EMI test receiver	ESW 44	Rohde & Schwarz	E00895
☒	Preamplifier (1 GHz - 18 GHz)	ALS05749	Aldetec	W01007
☒	Horn antenna	BBHA 9120D	Schwarzbeck	W00052
☒	Cable set SAC	RF cable(s)	Huber + Suhner	E00755 E01033 E01034
☒	Test software	EMC32-EB (V10.35)	Rohde & Schwarz	E00777
☐	Test software	EMC32-MEB (V10.35)	Rohde & Schwarz	E00778
☐	Test software	EMC32-MEB (V10.35)	Rohde & Schwarz	E01073

[8] For information about measurement uncertainties see page 92.

6.4.3.2 Limits

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

Table 13: General radiated emission limits above 960 MHz according to §15.209

6.4.3.3 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.

6.4.3.4 Test results

Performed by:	Andreas Menacher	Date(s) of test:	October 31, 2018
Climatic conditions:	Ambient temperature 25 °C	Relative humidity 35%	Barometric pressure 977 hPa
Test distance:	Final tests:	☒ 3 m	☐ 1 m
EUT position[9]:	☒ Position 1	☒ Position 2	☒ 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

[9] Exploratory measurements are performed in all positions as indicated. However, the figures and result tables within this test report show the worst case position, only.

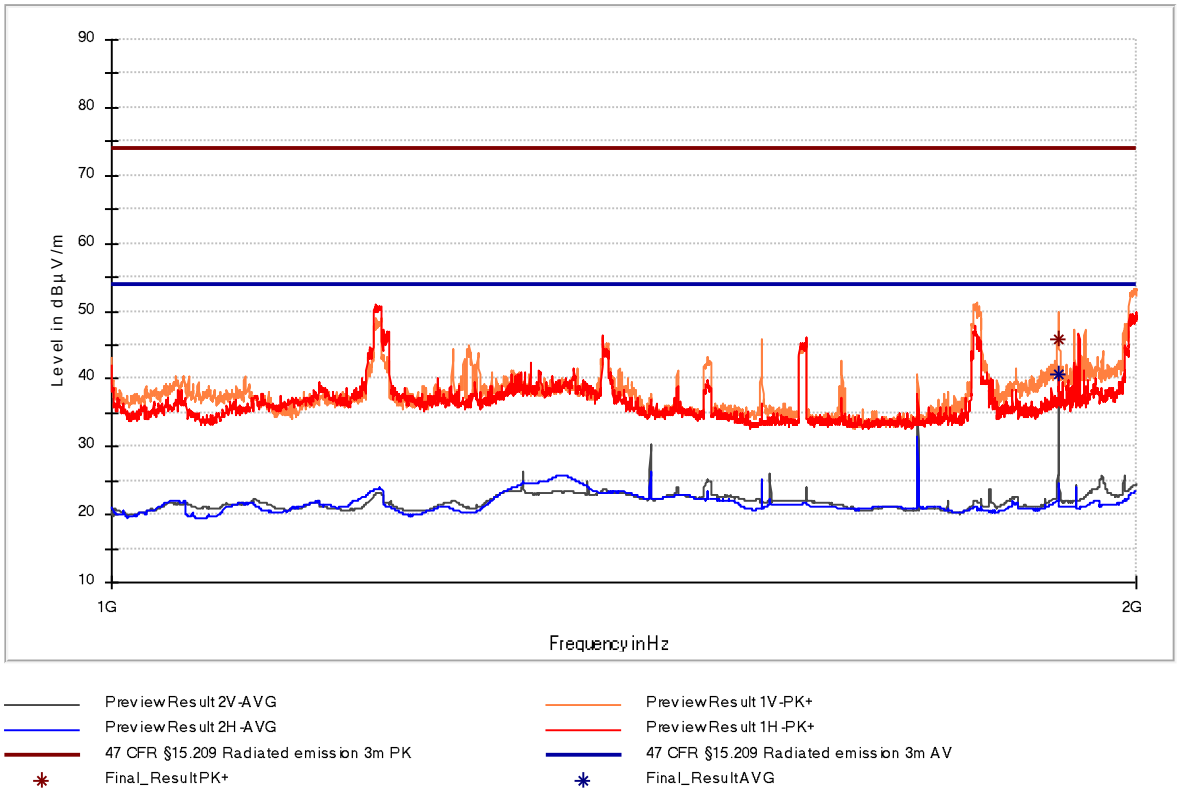

Figure 17: Chart of emissions test from 1 GHz to 2 GHz with tag in position 2

Frequency (MHz)	MaxPeak (dBµV/m)	Average (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Meas. Time (ms)	Bandwidth (kHz)	Height (cm)	Pol	Azimuth (deg)
1897.500000	45.70	---	74.00	28.30	1000.0	1000.000	143.0	V	354.0
1897.500000	---	40.61	54.00	13.39	1000.0	1000.000	143.0	V	354.0

Table 14: Final results of emissions test from 1 GHz to 2 GHz with tag in position 2

7 Equipment calibration status

Description	*Modell number*	*Serial number*	*Inventory number(s)*	*Last calibration*	*Next calibration*
EMI test receiver	ESCI 3	100328	E00552	2018-10	2020-10
EMI test receiver	ESW44	101538	E00895	2018-04	2019-04
EMI test receiver	ESR7	101059	E00739	2018-05	2019-05
Preamplifier (1 GHz - 18 GHz)	ALS05749	001	W01007	2018-01	2019-01
Loop antenna	HFH2-Z2	871398/0050	E00060	2018-10	2020-10
TRILOG broadband antenna (SAC3)	VULB 9162	9162-041	E00643	2018-03	2021-03
Horn antenna	BBHA 9120D	9120D-592	W00052	2017-04	2020-04
Magnetic field probe	RF-R 400-1	02.2030	E00270	N/A (see note 1)	
Artificial mains network	ESH2-Z5	893406/009	E00005	2018-10	2020-10
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	2018-04	2019-04
	LCF12-50J	---	E01215	2018-04	2019-04
	LMR400	1718020006	E00920	2018-01	2019-01
	RG214 Hiflex	171802007	E00921	2018-01	2019-01
Cable set anechoic chamber	262-0942-1500	005	E00435	2017-10	2018-10
	SF104EA/2x11PC35-42/5m	11144/4EA	E00307	2017-12	2018-12
	262-0942-1500	003	E00433	2017-10	2018-10
Cable set of semi-anechoic chamber SAC3	SF104EA/11PC35/11PC35/10000MM	501347/4EA	E00755	2017-12	2018-12
	SF104E/11PC35/11PC35/2000MM	507410/4E	E01033	2017-12	2018-12
	SF104E/11PC35/11PC35/2000MM	507411/4E	E01034	2017-09	2018-09

Note 1: Used for relative measurements only (see test instruments for “Occupied bandwidth” clause 6.2)

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

Revision	*Date*	*Issued by*	*Description of modifications*
0	2018-12-20	Andreas Menacher	First edition