Test Report

Customer:

GMMC GmbH

Kehlbergstrasse 109
8054 Graz
Austria
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RF test report

160826-AU01+W02

GMMC GmbH

13.56 MHz Multi Standard - Multi Antenna Reader/Writer

SANGOMA-MSMA 2V3

EMV **TESTHAUS** GmbH

Gustav-Hertz-Straße 35
94315 Straubing
Germany
Tel.: +49 9421 56868-0
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Email: info@emv-testhaus.com

Accreditation:

FCC facility registration number: 221458
Test Firm Type “2.948 listed”: Valid until 2017-04-22
Test Firm Type “accredited”: Valid until 2017-06-09
MRA US-EU, FCC designation number: DE0010
BnetzA-CAB-02/21-02/04 Valid until 2018-11-27

Industry Canada test site numbers with registration expiry date:
3472A-1, expiring 2018-11-09
3472A-2, expiring 2018-11-12

Test Laboratory:

EMV **TESTHAUS** GmbH
Gustav-Hertz-Straße 35
94315 Straubing
Germany

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

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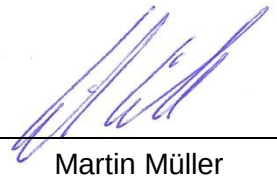
1 Test regulations

47 CFR Part 2: 10-2015	Code of Federal Regulations Part 2 (Frequency allocation and radio treaty matters; General rules and regulations) of the Federal Communication Commission (FCC)
47 CFR Part 15: 10-2015	Code of Federal Regulations Part 15 (Radio Frequency Devices) of the Federal Communication Commission (FCC)
ANSI C63.10:2013-06	American National Standard of Procedures for Compliance Testing of Unlicensed Wireless Devices
FCC KDB 174176 D01 June 3, 2015	AC power-line conducted emissions Frequently Asked Questions
FCC KDB 447498 D01 February 7, 2014	Mobile and Portable Devices RF Exposure Procedures and Equipment Authorization Policies
ICES-003 Issue 6, January 2016	Spectrum Management and Telecommunications Interference-Causing Equipment Standard Information Technology Equipment (ITE) – Limits and methods of measurement
RSS-Gen Issue 4, November 2014	Spectrum Management and Telecommunications Radio Standards Specification General Requirements and Information for the Certification of Radiocommunication Equimpment
RSS-102 Issue 5, March 2015	Spectrum Management and Telecommunications Radio Standards Specification Radio Frequency (RF) Exposure Compliance of Radiocommunication Apparatus (All Frequency Bands)
RSS-210 Issue 9, August 2016	Spectrum Management and Telecommunications Radio Standards Specification Licence-exempt Radio Apparatus (All Frequency Bands): Category I Equipment

2 Summary of test results

Standard	Test result
47 CFR Part 15, sections 15.207 and 15.225	Passed
RSS-210 Issue 9 Section 4.3 and Annex B6 (with appropriate references to RSS-Gen Issue 4)	Passed

Straubing, December 6, 2016



Martin Müller
Test engineer
EMV **TESTHAUS** GmbH

Rainer Heller
Head of EMC/Radio department
EMV **TESTHAUS** GmbH

3 Equipment under Test (EUT)

Product type:	13.56 MHz Multi Standard - Multi Antenna Reader/Writer
Model Name:	SANGOMA-MSMA 2V3
Applicant:	GMMC GmbH
Manufacturer:	GMMC GmbH
Serial number:	#1
FCC ID:	2AKHW-SANGMSMA1
IC certification number:	22202-SANGMSMA1
Application frequency band:	13.110 to 14.010 MHz
Frequency range:	13.560 MHz
Operating frequency:	13.560 MHz
Number of RF-channels:	1
Modulation:	ASK
Antenna types:	PCB antenna
	☒ detachable ☐ not detachable
Power supply:	USB powered nominal: 5.0 VDC ± 15 %
Temperature range:	0°C to +65°C

Remark:
The tests were performed with 120V AC / 60Hz.

3.1 Photo documentation

For external photos of the EUT see annex B, for internal ones see annex C.
For photos taken during testing and including EUT-positions see annex A.

3.2 Short description of the EUT

EUT is a RFID reader/writer operating at the frequency of 13.56 MHz.

3.3 Operation mode

During the pre-tests it was observed that the “continuous-wave-mode” is the respective worst-case. Therefore this mode was selected for final testing.

The EUT was tested in 3 orthogonal positions. This is documented in annex A.

3.4 Configuration

The following peripheral devices and interface cables were connected during the tests:

Device	Model:	Serial or inventory no.
13.56 MHz Multi Standard - Multi Antenna Reader/Writer	SANGOMA-MSMA 2V3	#1
RFID antenna	Jay	---
Notebook	Lifebook A531	E00521
Power supply notebook	ADP-65JH AD	S26113-E557-V55-01
DC power supply [1]	Statron 3231.1	E00017
AC power supply (120V / 60Hz)	61602	ABP000000730

Note1: Used for test “carrier frequency stability” only.

3.5 Used cables

Count	Description (type / lengths / remarks)	Serial no.
1	USB cable (shielded / 0.3 m)	---
2	DC power supply cable (unshielded / 1.5 m) [2]	---

Note2: Used for test “carrier frequency stability” only.

4 AC power line conducted emissions

according to 47 CFR Part 15, section 15.207, and RSS-210, section 3.1 with RSS-Gen, section 8.8

4.1 Test location

Description	Manufacturer	Inventory No.
Shielded room	Siemens - Matsushita	E00107

4.2 Test instruments

	Description	Manufacturer	Inventory No.
☒	ESCS 30	Rohde & Schwarz	E00003
☐	ESU 26	Rohde & Schwarz	W00002
☐	ESCI	Rohde & Schwarz	E00001
☐	ESH3-Z2	Rohde & Schwarz	E00028
☒	ESH2-Z5	Rohde & Schwarz	E00004
☐	ESH2-Z5	Rohde & Schwarz	E00005
☒	Cable set shielded room	Huber + Suhner	E00424

4.3 Limits

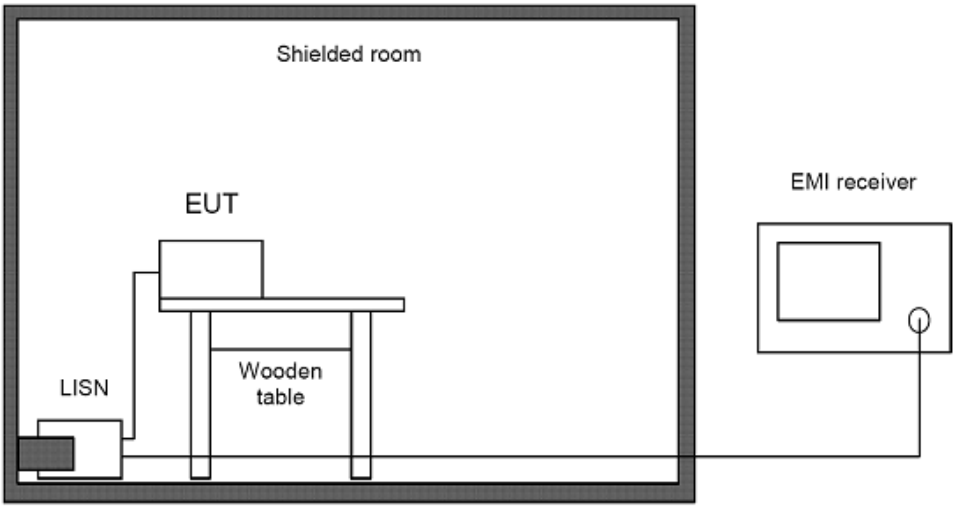
Frequency [MHz]	Quasi-peak [dBµV]	Avarage [dBµV]
0.15 – 0.5	66 – 56	56 – 46
0.5 – 5.0	56	46
5 – 30	60	50

4.4 Test procedure

1. The tests of conducted emission were carried out in a shielded room using a line impedance stabilization network (LISN) 50 µH/50 Ohms and an EMI test receiver.
2. The EMI test receiver was connected to the LISN and set to a measurement bandwidth of 9 kHz in the frequency range from 0.15 MHz to 30 MHz.
3. The EUT was placed on a wooden table and connected to the LISN.
4. To accelerate the measurement the detector of the EMI test receiver was set to peak and the whole frequency range form 0.15 MHz to 30 MHz was scanned.
5. After that all peaks values with less margin than 10 dB to quasi-peak limit or exceeding the limit were marked and re-measured with quasi-peak detector.
6. If after that all values are under the average limit no addition measurement is necessary. In case there are still values between quasi-peak and average limit then these values were re-measured with average detector.
7. These measurements were done on all power lines.

According to ANSI C63.10, section 6.2.2 testing of intentional radiators with detachable antennas shall be done with a dummy load otherwise the tests should be done with connected antenna and if adjustable fully extended.

4.5 Test setup

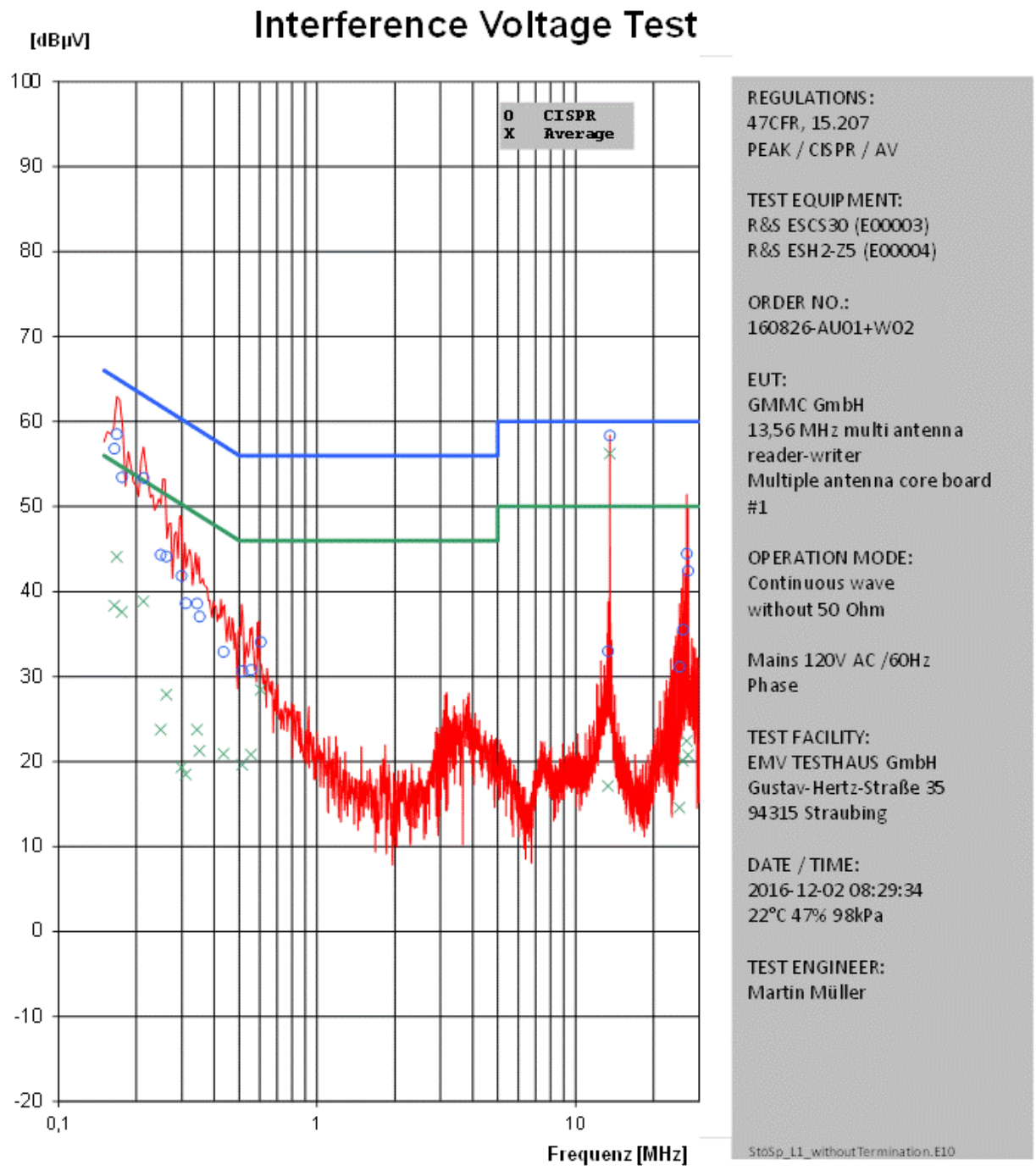


Picture 1: Outline of conducted emission test setup

Comments: All peripheral devices were additionally decoupled by means of a line stabilization network.

4.6 Test results

Temperature:	20°C	Humidity:	41%
Tested by:	Martin Müller	Test date:	2016-12-02

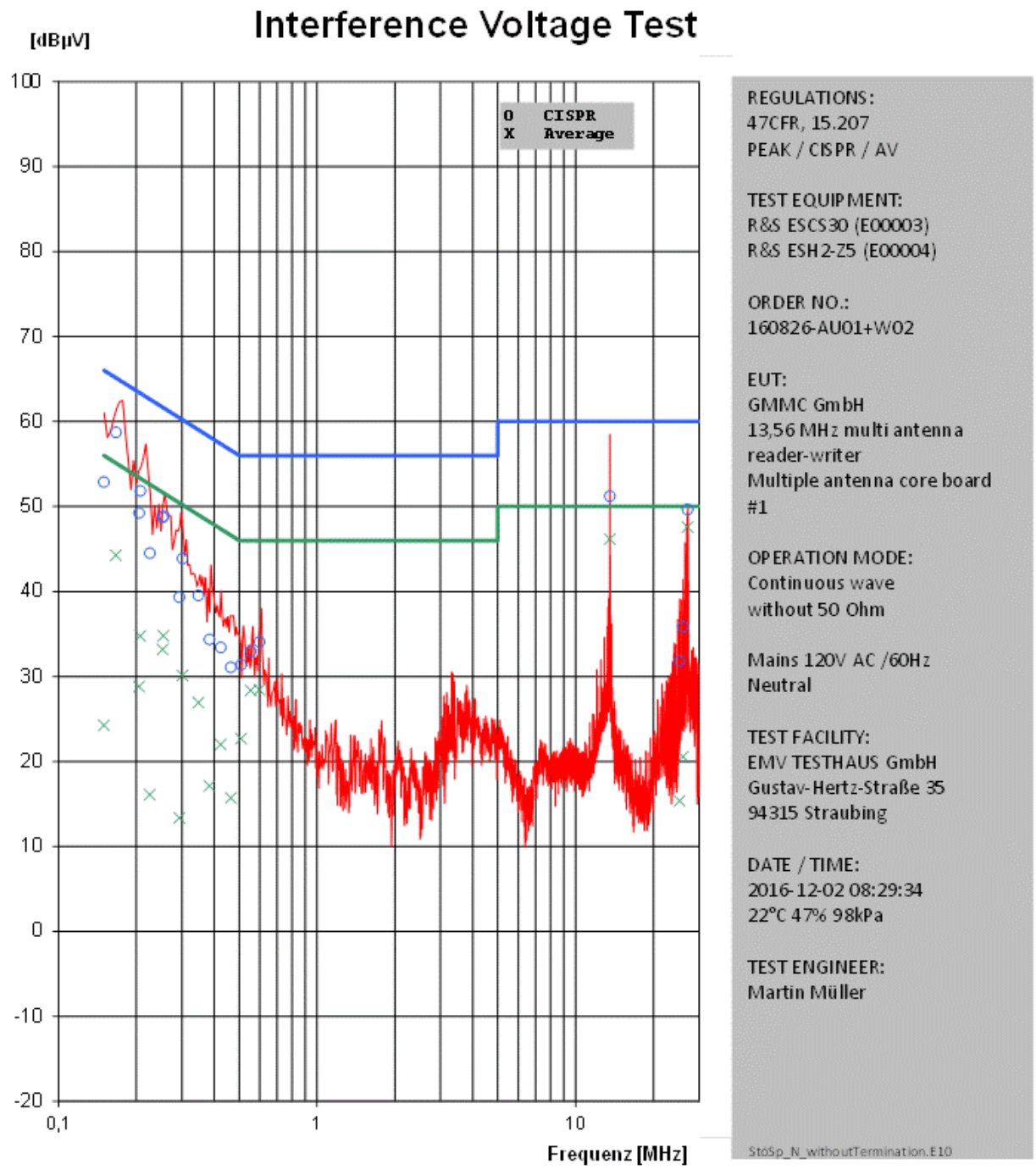


Picture 2: Graphic - Conducted emission on mains, phase 1 (without termination)

Interference Voltage Test

Freq. [MHz]	U_CISPR [dBµV]	Limit [dBµV]	delta_U [dB]	U_AV [dBµV]	Limit [dBµV]	delta_U [dB]	Corr. [dB]	Remark
0,16	56,8	65,2	8,4	38,3	55,2	16,9	0,0	
0,17	58,5	65,1	6,5	44,1	55,1	11,0	0,0	
0,18	53,4	64,7	11,2	37,6	54,7	17,1	0,0	
0,21	53,4	63,1	9,7	38,9	53,1	14,2	0,0	
0,25	44,3	61,8	17,5	23,7	51,8	28,1	0,0	
0,26	44,1	61,4	17,3	27,9	51,4	23,5	0,0	
0,30	41,8	60,3	18,4	19,3	50,3	31,0	0,0	
0,31	38,6	59,9	21,3	18,5	49,9	31,5	0,0	
0,34	38,6	59,1	20,5	23,7	49,1	25,4	0,0	
0,35	37,1	58,9	21,9	21,3	48,9	27,7	0,0	
0,43	32,9	57,2	24,3	20,9	47,2	26,3	0,0	
0,52	30,6	56,0	25,4	19,6	46,0	26,4	0,0	
0,56	30,8	56,0	25,2	20,8	46,0	25,2	0,0	
0,61	34,1	56,0	21,9	28,4	46,0	17,6	0,0	
13,35	33,0	60,0	27,0	17,1	50,0	32,9	0,0	
13,56	58,3	60,0	1,7	56,2	50,0	**-6,2**	0,0	
25,22	31,1	60,0	28,9	14,6	50,0	35,4	0,0	
26,06	35,5	60,0	24,5	20,1	50,0	29,9	0,0	
26,91	44,4	60,0	15,6	22,4	50,0	27,6	0,0	
27,20	42,4	60,0	17,6	20,8	50,0	29,2	0,0	

Picture 3: Table - Conducted emission on mains, phase 1 (without termination)

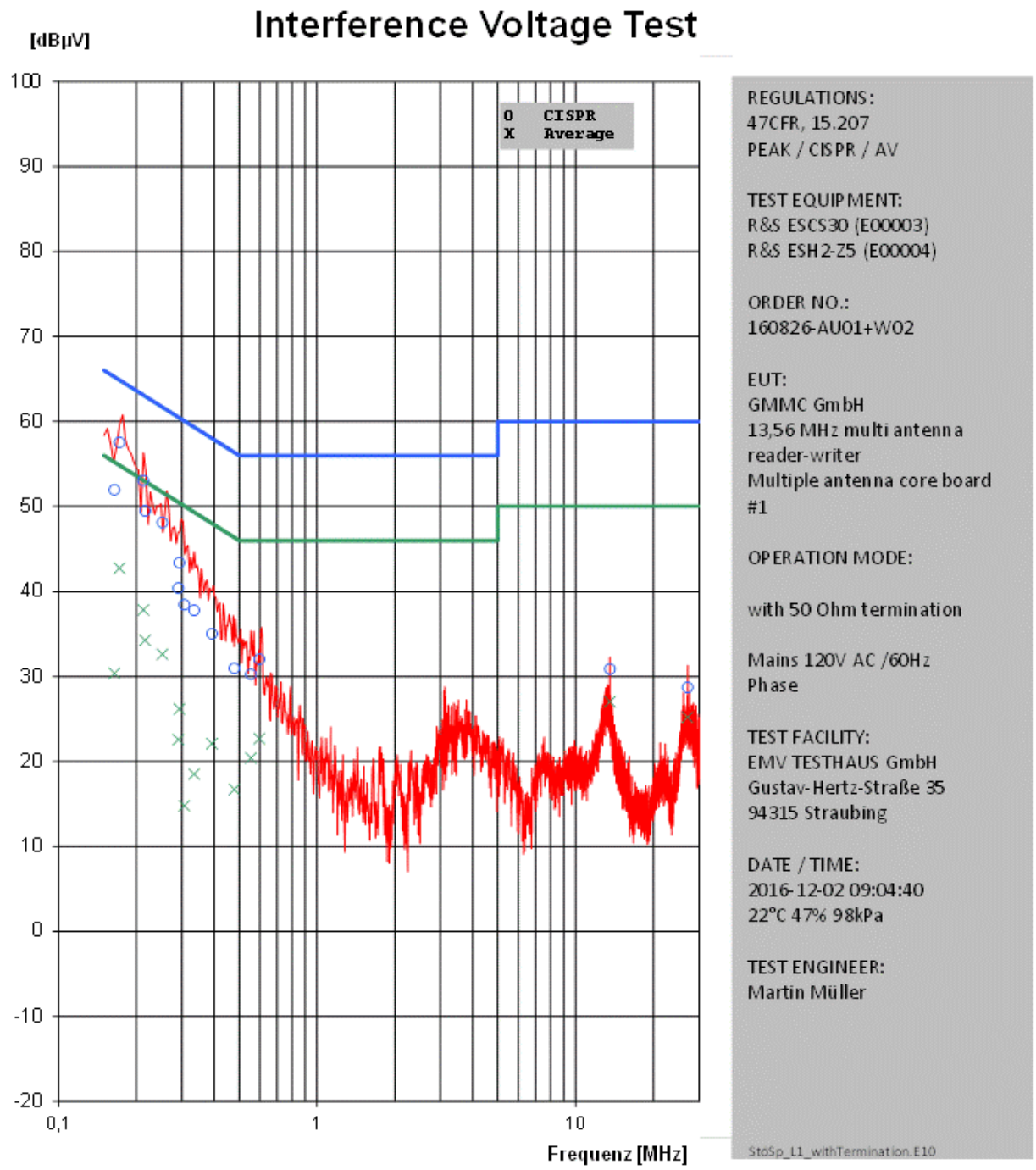


Picture 4: Graphic - Conducted emission on mains, neutral (without termination)

Interference Voltage Test

Freq. [MHz]	U_CISPR [dBµV]	Limit [dBµV]	delta_U [dB]	U_AV [dBµV]	Limit [dBµV]	delta_U [dB]	Corr. [dB]	Remark
0,15	52,9	66,0	13,1	24,2	56,0	31,8	0,0	
0,17	58,7	65,1	6,4	44,3	55,1	10,9	0,0	
0,21	49,2	63,4	14,2	28,8	53,4	24,6	0,0	
0,21	51,8	63,3	11,5	34,7	53,3	18,6	0,0	
0,23	44,5	62,6	18,1	16,1	52,6	36,5	0,0	
0,25	48,8	61,6	12,8	34,8	51,6	16,8	0,0	
0,25	48,7	61,7	12,9	33,2	51,7	18,5	0,0	
0,29	39,3	60,4	21,1	13,3	50,4	37,1	0,0	
0,30	43,9	60,2	16,3	30,1	50,2	20,1	0,0	
0,35	39,5	59,0	19,5	26,9	49,0	22,1	0,0	
0,38	34,4	58,2	23,8	17,1	48,2	31,1	0,0	
0,42	33,4	57,4	24,0	22,0	47,4	25,4	0,0	
0,46	31,1	56,6	25,6	15,7	46,6	30,9	0,0	
0,51	31,4	56,0	24,7	22,7	46,0	23,3	0,0	
0,55	32,9	56,0	23,1	28,4	46,0	17,7	0,0	
0,60	34,1	56,0	22,0	28,4	46,0	17,6	0,0	
13,56	51,2	60,0	8,8	46,2	50,0	3,8	0,0	
25,22	31,8	60,0	28,2	15,3	50,0	34,7	0,0	
26,06	35,8	60,0	24,2	20,6	50,0	29,5	0,0	
27,12	49,6	60,0	10,4	47,6	50,0	2,4	0,0	

Picture 5: Table - Conducted emission on mains, neutral (without termination)

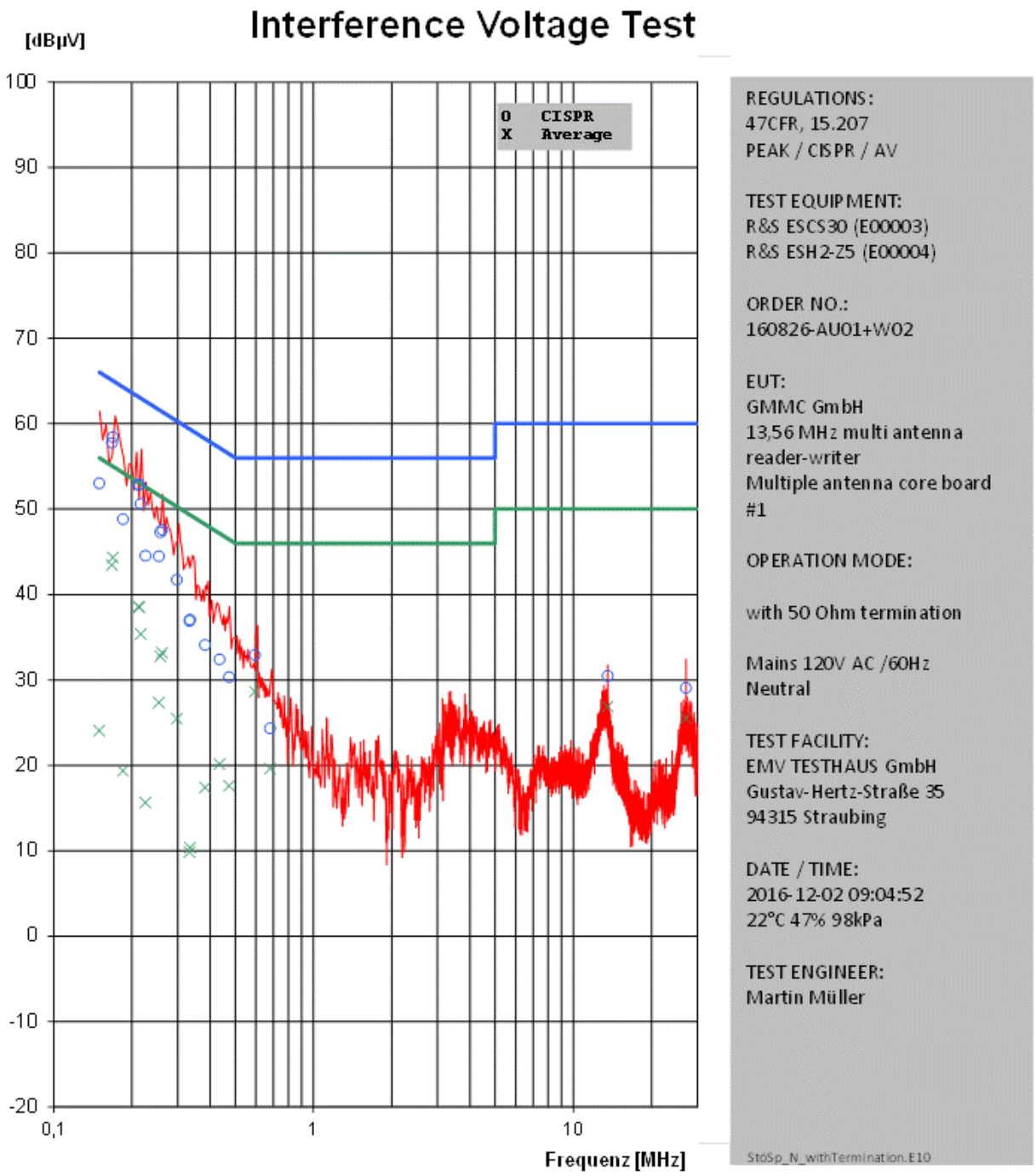


Picture 6: Graphic - Conducted emission on mains, phase 1 (with termination 50 Ω)

Interference Voltage Test

Freq. [MHz]	U_CISPR [dBµV]	Limit [dBµV]	delta_U [dB]	U_AV [dBµV]	Limit [dBµV]	delta_U [dB]	Corr. [dB]	Remark
0,16	52,0	65,2	13,3	30,4	55,2	24,9	0,0	
0,17	57,5	64,9	7,3	42,7	54,9	12,1	0,0	
0,21	53,0	63,1	10,0	37,8	53,1	15,3	0,0	
0,22	49,5	63,0	13,5	34,2	53,0	18,7	0,0	
0,25	48,1	61,7	13,6	32,6	51,7	19,1	0,0	
0,29	40,4	60,5	20,1	22,5	50,5	28,0	0,0	
0,29	43,4	60,4	17,0	26,2	50,4	24,3	0,0	
0,31	38,4	60,1	21,6	14,8	50,1	35,3	0,0	
0,33	37,8	59,3	21,6	18,5	49,3	30,8	0,0	
0,39	35,0	58,0	23,0	22,1	48,0	25,9	0,0	
0,48	30,9	56,4	25,4	16,7	46,4	29,7	0,0	
0,56	30,3	56,0	25,8	20,4	46,0	25,6	0,0	
0,60	32,0	56,0	24,0	22,7	46,0	23,3	0,0	
13,56	30,9	60,0	29,2	27,0	50,0	23,0	0,0	
27,12	28,7	60,0	31,3	25,2	50,0	24,8	0,0	

Picture 7: Table - Conducted emission on mains, phase 1 (with termination 50 Ω)



Picture 8: Graphic - Conducted emission on mains, neutral (with termination 50 Ω)

Interference Voltage Test

Freq. [MHz]	U_CISPR [dBµV]	Limit [dBµV]	delta_U [dB]	U_AV [dBµV]	Limit [dBµV]	delta_U [dB]	Corr. [dB]	Remark
								StöSp_N_withTermination_E10
0,15	53,0	66,0	13,0	24,1	56,0	31,9	0,0	
0,17	58,4	65,0	6,6	44,3	55,0	10,7	0,0	
0,17	57,7	65,1	7,3	43,4	55,1	11,6	0,0	
0,19	48,8	64,3	15,5	19,4	54,3	34,9	0,0	
0,21	52,9	63,1	10,2	38,5	53,1	14,6	0,0	
0,21	52,8	63,1	10,3	38,6	53,1	14,5	0,0	
0,22	50,6	63,0	12,3	35,4	53,0	17,6	0,0	
0,23	44,5	62,6	18,1	15,6	52,6	37,0	0,0	
0,25	44,5	61,6	17,2	27,3	51,6	24,3	0,0	
0,26	47,3	61,5	14,2	32,8	51,5	18,8	0,0	
0,26	47,6	61,4	13,8	33,2	51,4	18,2	0,0	
0,30	41,7	60,3	18,6	25,5	50,3	24,8	0,0	
0,34	37,1	59,3	22,3	10,3	49,3	39,0	0,0	
0,33	36,9	59,4	22,5	9,8	49,4	39,5	0,0	
0,38	34,1	58,2	24,1	17,4	48,2	30,8	0,0	
0,43	32,4	57,2	24,8	20,1	47,2	27,0	0,0	
0,47	30,3	56,4	26,1	17,6	46,4	28,9	0,0	
0,59	32,9	56,0	23,1	28,6	46,0	17,4	0,0	
0,68	24,3	56,0	31,7	19,6	46,0	26,4	0,0	
13,56	30,5	60,0	29,5	26,9	50,0	23,1	0,0	
27,12	29,1	60,0	31,0	25,5	50,0	24,5	0,0	

Picture 9: Table - Conducted emission on mains, neutral (with termination 50 Ω)

5 Radiated emission measurement (<1 GHz)

according to 47 CFR Part 15, section 15.205(a), 15.209(a), 15.225(a) to (e), and RSS-210, section 4.3 and Annex B6 with RSS-Gen, sections 8.10 and 8.9

5.1 Test Location

☒ Scan with peak detector in 3 m CDC.

☒ Final CISPR measurement with quasi peak detector on 3 m open area test site.

Description	Manufacturer	Inventory No.
CDC	Albatross Projects	E00026
Open area test site (OATS)	EMV **TESTHAUS** GmbH	E00354

5.2 Test instruments

	Description	Manufacturer	Inventory No.
☒	ESCI (OATS)	Rohde & Schwarz	E00552
☐	ESU 26	Rohde & Schwarz	W00002
☒	ESCI (CDC)	Rohde & Schwarz	E00001
☒	VULB 9163 (OATS)	Schwarzbeck	E00013
☒	VULB 9160 (CDC)	Schwarzbeck	E00011
☒	HFH2-Z2	Rohde & Schwarz	E00060
☒	Cable set CDC	Huber + Suhner	E00459, E00460
☒	Cable set OATS 3 m	Huber + Suhner	E00453, E00456, E00458
☐	Cable set OATS 10 m	Huber + Suhner	E00453, E00455, E00458

5.3 Limits

The field strength of any emissions appearing outside of the 13.110 to 14.010 MHz band including spurious emissions falling into restricted bands as specified in 15.205(a) shall not exceed the general radiated emission limits as specified in 15.209.

Frequency [MHz]	Field strength Fs [µV/m]	Field strength [dBµV/m]	Measurement distance d [m]
0.009 – 0.490	266.6 – 4.9	48.5 – 13.8	300
0.490 – 1.705	48.98 – 14.08	33.8 – 22.97	30
1.705 – 30.0	30	29.54	30
30 – 88	100	40	3
88 – 216	150	43.5	3
216 - 960	200	46	3
Above 960	500	54	3

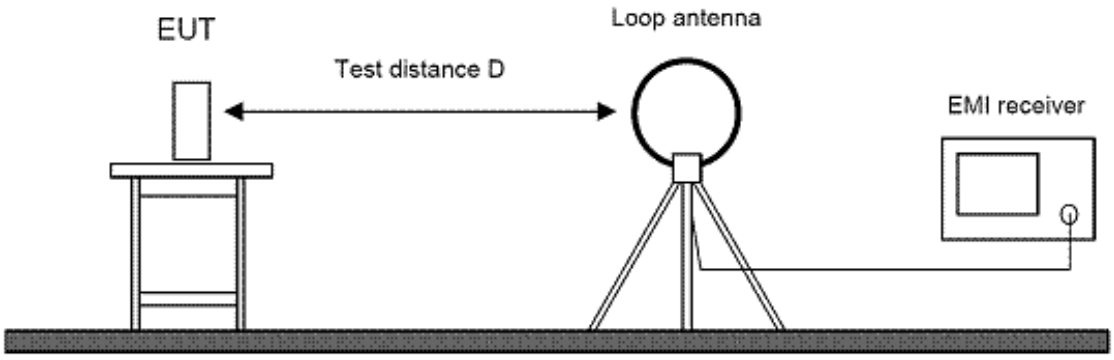
As noted in 15.205(d)(7) devices according to 15.225 are exempt from complying with restricted band requirements for the 13.36 to 13.41 MHz band. Instead they have to comply with the limits as specified in 15.225 (a) to (d):

Frequency [MHz]	Field strength Fs [µV/m]	Field strength [dBµV/m]	Measurement distance d [m]
13.553 - 13.567	15,848	84	30
13.410 - 13.553	334	50.47	30
13.567 - 13.710	334	50.47	30
13.110 - 13.410	106	40.51	30
13.710 - 14.010	106	40.51	30
f < 13.110	according to limits in §15.209		
f > 14.010			

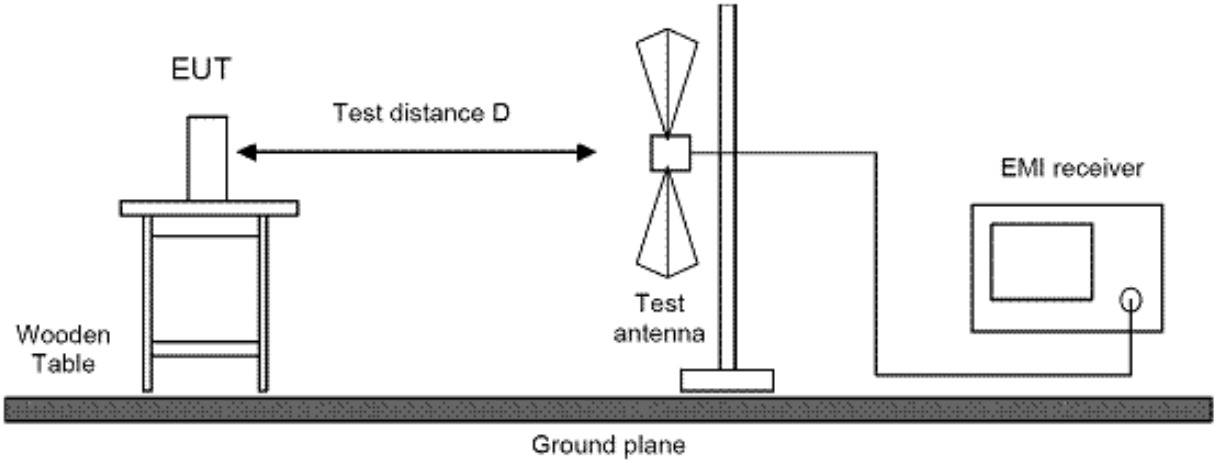
5.4 Test procedure

1. EUT was configured according to ANSI C63.10. It was placed on the top of the turntable 0.8 meter above ground. The receiving antenna was placed 3 meters from the turntable. The test setup was placed inside a compact diagnostic chamber.
2. EUT and all peripherals were powered on.
3. The broadband antenna was set to vertical polarization.
4. The EMI receiver performed a scan from 30 MHz to 1000 MHz with peak detector peak and measurement bandwidth set to 120 kHz.
5. The turn table was rotated to 6 different positions (360° / 6) and the antenna polarization was changed to horizontal.
6. Test procedure at step 4 and 5 was repeated.
7. The test setup was then placed in an OATS at 3 m distance and all peak values over or with less margin to the limit than 6dB were marked and re-measured with a quasi-peak detector.
8. The turntable was rotated by 360 degrees to determine the position of the highest radiation.
9. The height of the broadband receiving antenna was varied between one meter and four meters above ground to find the maximum emission field strength of both horizontal and vertical polarization. The highest value was recorded.
10. For emissions below 30 MHz measurements were done using a loop antenna. Prescan was performed with peak detector and final measurements with quasi-peak except for the frequency bands 9 to 90 kHz and 110 to 490 k Hz where average detector applies. Antenna height was not changed during this test. Appropriate CISPR bandwidths of 200 Hz for frequencies up to 150 kHz and 9 or 10 kHz for frequencies above were used.

5.5 Test setup



Picture 10: Test setup for radiated emission measurement (< 30 MHz)



Picture 11: Test setup for radiated emission measurement (< 1 GHz)

5.6 Test deviation

There is no deviation from the standards referred to.

5.7 Test results

Temperature:	20°C	Humidity:	41%
Tested by:	Martin Müller	Test date:	2016-12-02

Radiated Emission Measurement 9 kHz - 30 MHz

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

$d_{near\ field}$ = 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 for determining the recalculation factor:

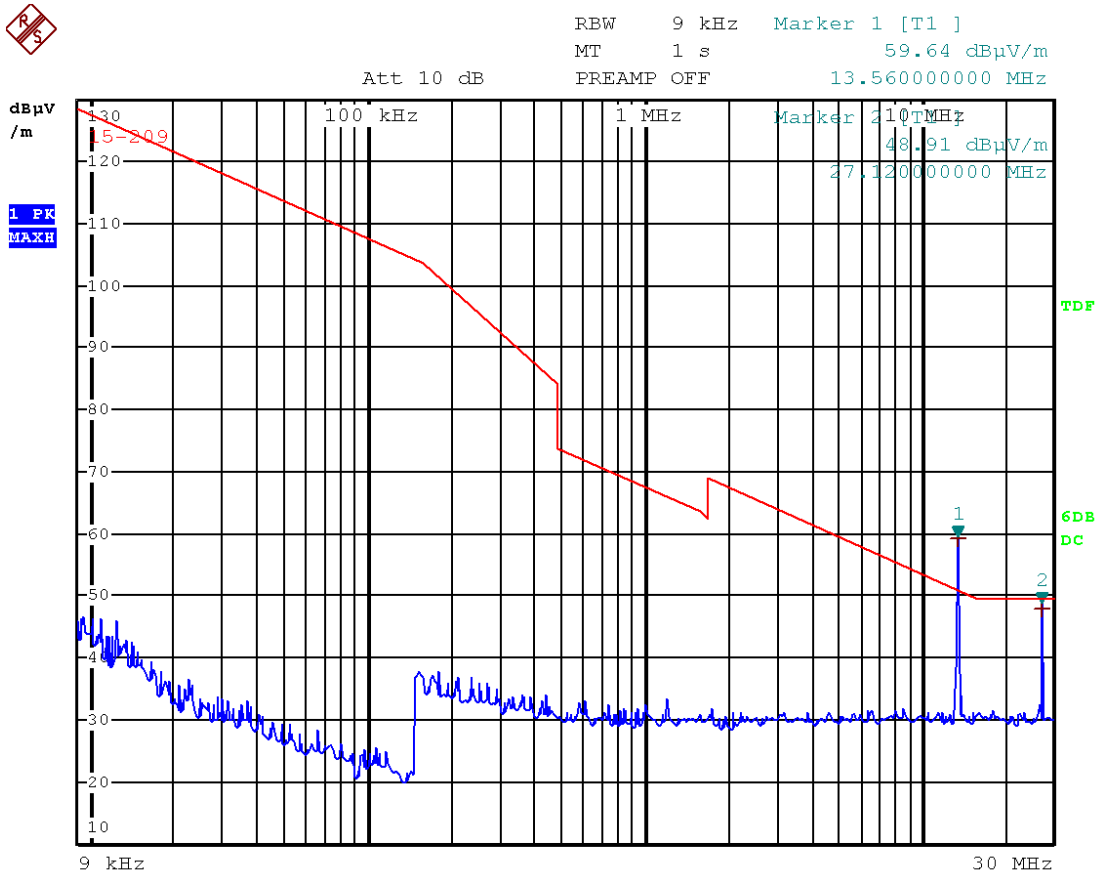
f_{MHz}(300 m) ≈ 0.159 MHz
f_{MHz}(30 m) ≈ 1.592 MHz
f_{MHz}(3 m) ≈ 15.923 MHz

For 9 kHz ≤ f ≤ 159 kHz and 490 kHz < f ≤ 1.592 MHz:
Recalculation factor = $-40 \log(d_{limit} / d_{measure})$
For 159 kHz < f ≤ 490 kHz and 1.592 MHz < f ≤ 15.923 MHz:
Recalculation factor = $-40 \log(d_{near\ field} / d_{measure}) - 20 \log(d_{limit} / d_{near\ field})$
For f > 15.923 MHz:
Recalculation factor = $-20 \log(d_{limit} / d_{near\ field})$

The limits in the graphics and value lists are derived from the general radiated emission limits as specified in 15.209 using the recalculation factor as described above.

Frequency range	Step size	IF Bandwidth	Detector		Measurement Time		Preamplifier
			Prescan	Final scan	Prescan	Final scan	
9 kHz – 90 kHz	80 Hz	200 Hz	PK	AV	1 ms	1 s	off
90 kHz – 110 kHz	80 Hz	200 Hz	PK	QPK	1 ms	1 s	off
110 kHz – 150 kHz	80 Hz	200 Hz	PK	AV	1 ms	1 s	off
150 kHz – 490 kHz	4 kHz	9 kHz	PK	AV	1 ms	1 s	off
490 kHz – 30 MHz	4 kHz	9 kHz	PK	QPK	1 ms	1 s	off

The following picture shows the worst-case-emissions for the spurious emissions at EUT-position 1, antenna parallel.



Picture 12: Radiated emission 9 kHz – 30 MHz @ 3m distance

Frequency [MHz]	Measured value [dBµV/m]	Detector	Recalculation factor [dB]	Field strength [dBµV/m]	Limit [dBµV/m]	Margin [dB]	Result
13.560	59.35	QPK	-21.40	37.95	---	---	Carrier
27.120	47.99	QPK	-24.63	23.36	29.54	-6.18	Pass

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

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

Recalculation factor = -40 log($d_{near\ field}$ / $d_{measure}$) - 20 log(d_{limit} / $d_{near\ field}$)

f_{MHz} [MHz]	$d_{near\ field}$ [m]	$d_{measure}$ [m]	d_{limit} [m]	Recalculation factor [dB]
13.560	3.523	3.000	30.000	-21.40

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

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

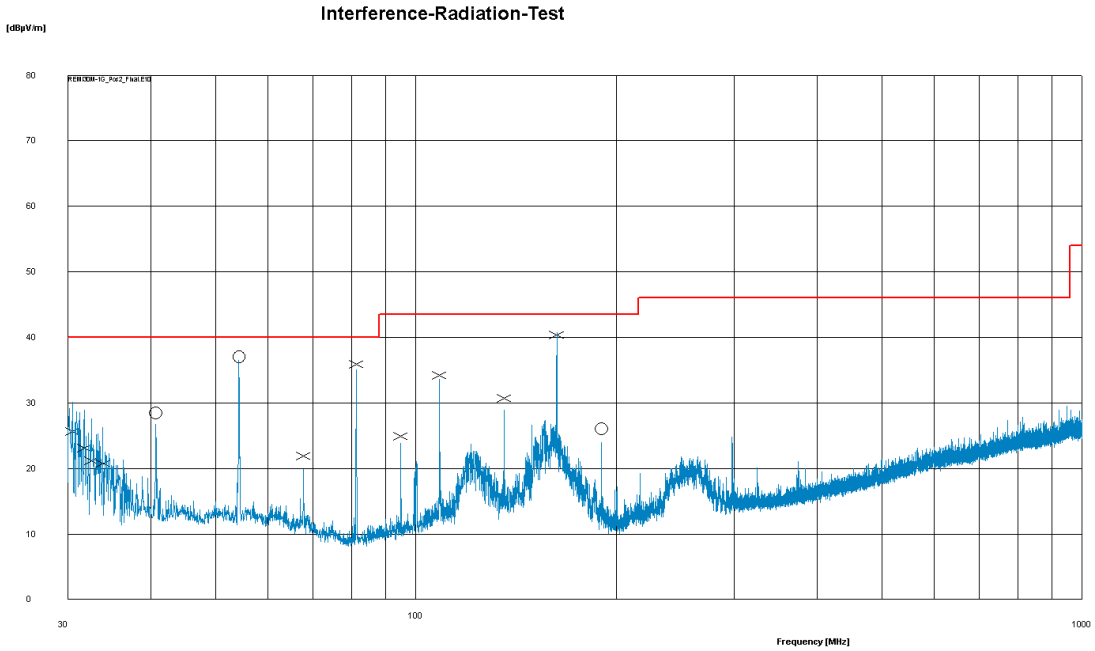
Recalculation factor = -20 log(d_{limit} / $d_{nearfield}$)

f_{MHz} [MHz]	$d_{near\ field}$ [m]	$d_{measure}$ [m]	d_{limit} [m]	Recalculation factor [dB]
27.120	1.761	3.000	30.000	-24.63

Radiated Emission Measurement 30 MHz - 1000 MHz

Frequency range	*Polari-sation*	*Step size*	*IF Band-width*	*Detector*		*Measurement Time*		*Pre-amplifier*
				Prescan	*Final scan*	*Prescan*	*Final scan*	
30 MHz – 1 GHz	H / V	60 kHz	120 kHz	PK	QPK	1 ms	1 s	20 dB

The following pictures show the worst-case-emissions at EUT-position 2.



f [MHz]	E_{final} [dBV/m]	Limit [dBµV/m]	Height [cm]	TT [°]	Polarisation	Result
30.54	25.65	40.00	100	301.0	V	Pass
31.80	23.13	40.00	100	282.2	V	Pass
32.58	21.15	40.00	100	201.2	V	Pass
33.90	20.73	40.00	100	281.6	V	Pass
40.68	28.46	40.00	250	350.2	H	Pass
54.24	37.07	40.00	261	330.6	H	Pass
67.80	21.90	40.00	100	252.8	V	Pass
81.36	35.92	40.00	109	262.8	V	Pass
94.92	24.92	43.52	100	291.9	V	Pass
108.48	34.18	43.52	100	282.4	V	Pass
135.60	30.69	43.52	100	301.0	V	Pass
162.72	40.34	43.52	117	271.8	V	Pass
189.84	26.08	43.52	250	39.5	H	Pass

Picture 13: Radiated emission 30 MHz - 1000MHz @ 3m distance

Spectrum Mask

Test procedure

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 15.225 (a) to (d). 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.

Test result

Temperature:	20°C	Humidity:	41%
Tested by:	Martin Müller	Test date:	2016-12-01

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

$d_{near\ field}$ = 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 for determining the recalculation factor:

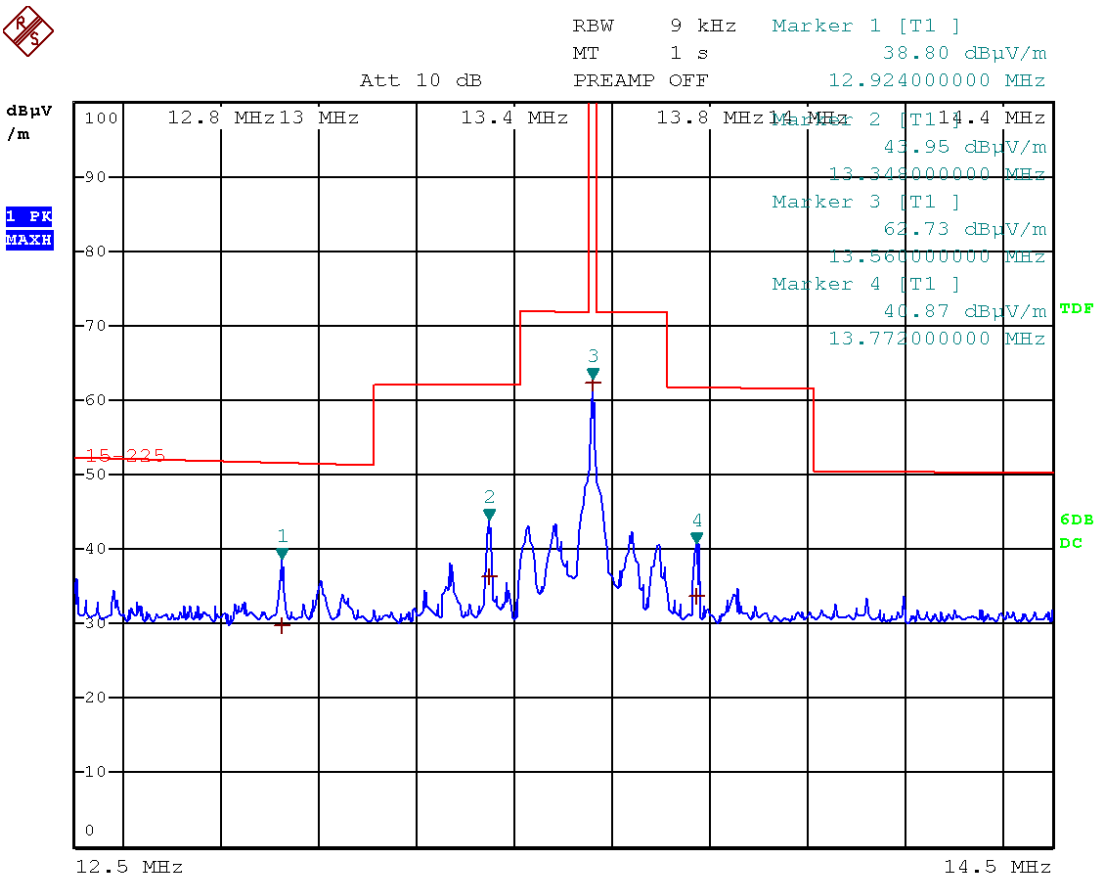
f_{MHz}(300 m) ≈ 0.159 MHz
f_{MHz}(30 m) ≈ 1.592 MHz
f_{MHz}(3 m) ≈ 15.923 MHz

For 9 kHz ≤ f ≤ 159 kHz and 490 kHz < f ≤ 1.592 MHz:
Recalculation factor = $-40 \log(d_{limit} / d_{measure})$
For 159 kHz < f ≤ 490 kHz and 1.592 MHz < f ≤ 15.923 MHz:
Recalculation factor = $-40 \log(d_{near\ field} / d_{measure}) - 20 \log(d_{limit} / d_{near\ field})$
For f > 15.923 MHz:
Recalculation factor = $-20 \log(d_{limit} / d_{near\ field})$

The limits in the graphics and value lists are derived from the general radiated emission limits as specified in 15.209 using the recalculation factor as described above.

Frequency range	Step size	IF Bandwidth	Detector		Measurement Time		Preamplifier
			Prescan	Final scan	Prescan	Final scan	
490 kHz – 30 MHz	4 kHz	9 kHz	PK	QPK	1 ms	1 s	off

The following picture shows the worst-case-emissions for spectrum mask at EUT-position 2, antenna in line.



Picture 14: Spectrum mask for 13.56 MHz @ 3m distance

Frequency [MHz]	Measured value [dBµV/m]	Detector	Recalculation factor [dB]	Field strength [dBµV/m]	Limit [dBµV/m]	Margin [dB]	Result
12.924	38.80	PK	-21.81	16.99	---	---	Pass
12.924	29.86	QPK	-21.81	8.05	29.54	-21.49	Pass
13.348	43.95	PK	-21.53	22.42	---	---	Pass
13.348	36.46	QPK	-21.53	14.93	40.51	-25.58	Pass
13.560	62.73	PK	-21.40	41.33	---	---	Pass
13.560	62.46	QPK	-21.40	41.06	84.00	-42.94	Pass
13.772	40.87	PK	-21.26	19.61	---	---	Pass
13.772	33.80	QPK	-21.26	12.54	40.51	-27.97	Pass

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

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

Recalculation factor = -40 log($d_{near\ field}$ / $d_{measure}$) - 20 log(d_{limit} / $d_{near\ field}$)

f_{MHz} [MHz]	$d_{near\ field}$ [m]	$d_{measure}$ [m]	d_{limit} [m]	Recalculation factor [dB]
12.924	3.696	3.000	30.000	-21.81
13.348	3.579	3.000	30.000	-21.53
13.560	3.523	3.000	30.000	-21.40
13.772	3.469	3.000	30.000	-21.26

6 Radiated emission measurement (>1 GHz)

according to 47 CFR Part 15, section 15.209(a), RSS-210, section 4.3 with RSS-Gen, section 8.9

Remark:

This measurement needs not to be applied because

- the intentional radiator operates below 10 GHz and tenth harmonic of the highest fundamental frequency is lower than 1 GHz (see 47 CFR Part 15, section 15.33(a)(1), and RSS-Gen, section 6.13), and
- the digital part of the device does not generate or use internal frequencies higher than 108 MHz (see 47 CFR Part 15 section 15.33(b)(1), and RSS-Gen, section 2.3.3 with ICES-003, section 6.2).

7 Carrier frequency stability

according to CFR 47 Part 15, section 15.225(e), and RSS-210, Annex B6 with RSS-Gen, section 6.11

7.1 Test Location

	Description	Manufacturer	Inventory No.
☐	Climatic chamber VC 4100	Vötsch Industrietechnik	C00014
☒	Climatic chamber VC³ 4034	Vötsch Industrietechnik	C00015

7.2 Test instruments

	Description	Manufacturer	Inventory No.
☐	ESU 26	Rohde & Schwarz	W00002
☒	ESCI 3	Rohde & Schwarz	E00552
☒	RF-R 400-1	Langer EMV-Technik	E00270

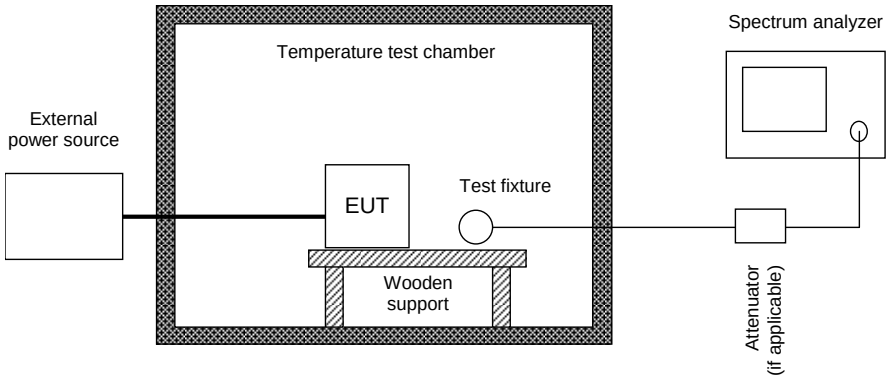
7.3 Limits

The frequency tolerance of the carrier signal shall be maintained within ±0.01% (100 ppm) of the operating frequency over a temperature variation of -20 degrees to +50 degrees C at normal supply voltage, and for a variation in the primary supply voltage from 85% to 115% of the rated supply voltage at a temperature of 20 degrees C.
For battery operated equipment, the equipment tests shall be performed using a new battery. Alternatively, an external supply voltage can be used and set at the battery nominal voltage, and again at the battery operating end point voltage which must be specified by the equipment manufacturer.

7.4 Test procedure

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

7.5 Test setup



Picture 15: Test setup for carrier frequency stability measurement

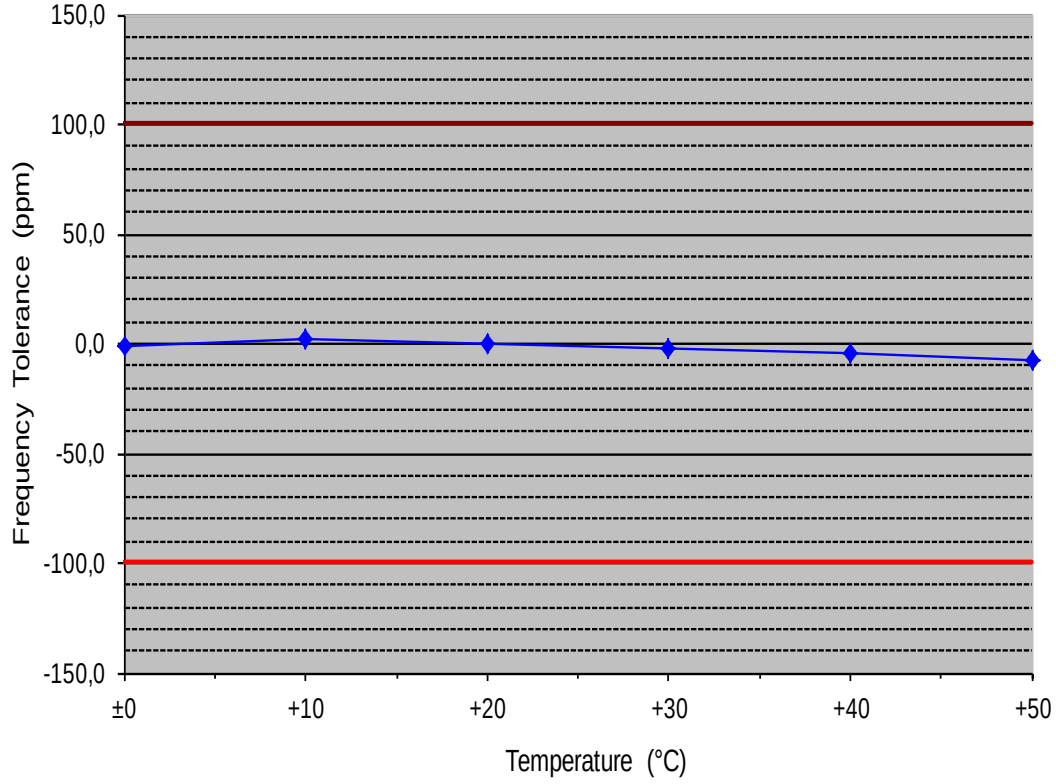
7.6 Test deviation

There is no deviation from the standards referred to.

Test result

Temperature:	20°C	Humidity:	41%
Tested by:	Martin Müller	Test date:	2016-12-05

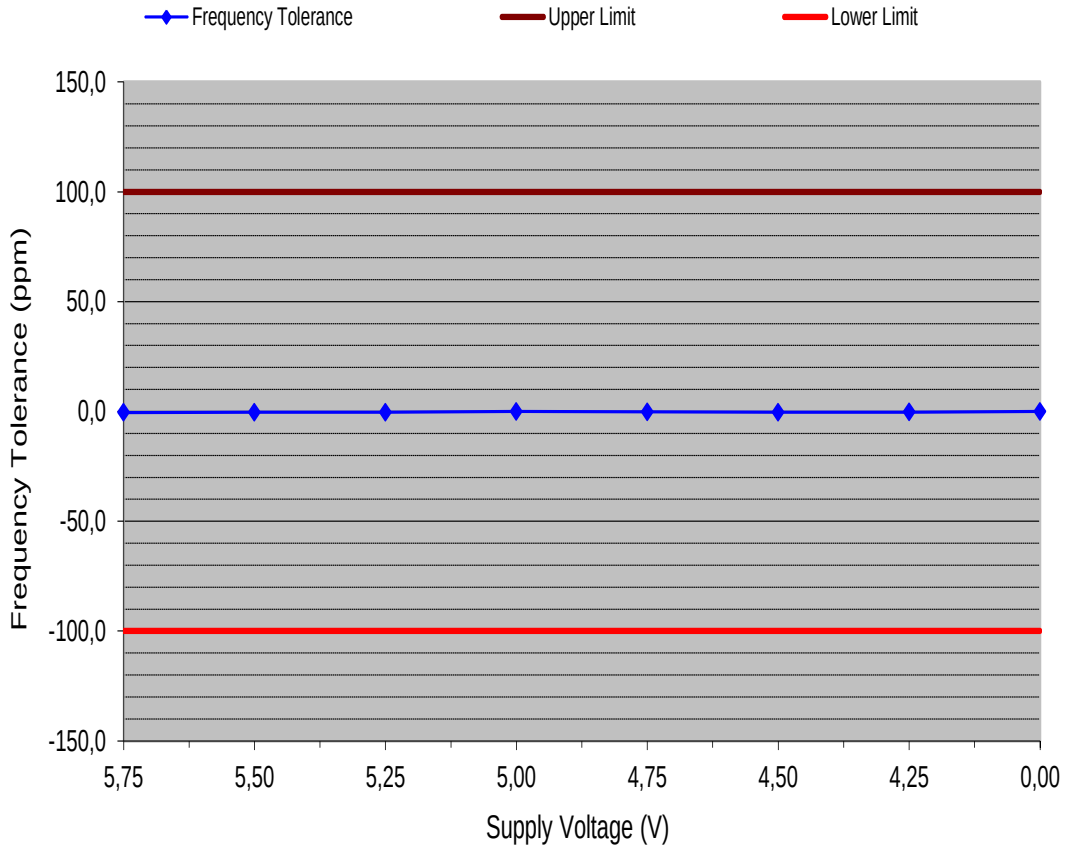
Carrier frequency stability vs. temperature



Supply voltage:	5 V	Frequency under nominal conditions:	13,560577 MHz

Temperature (°C)	Frequency (MHz)	Frequency Tolerance (Hz)	Frequency Tolerance (ppm)	Upper Limit (ppm)	Lower Limit (ppm)	Margin (ppm)
±0	13,560569	-8	-0,6	+100,0	-100,0	99,4
+10	13,560605	28	2,1	+100,0	-100,0	97,9
+20	13,560577	0	0,0	+100,0	-100,0	100,0
+30	13,560553	-24	-1,8	+100,0	-100,0	98,2
+40	13,560513	-64	-4,7	+100,0	-100,0	95,3
+50	13,560476	-101	-7,4	+100,0	-100,0	**92,6**
+60	13,560498	-79	-5,8	+100,0	-100,0	94,2
+65	13,560505	-72	-5,3	+100,0	-100,0	94,7

Carrier frequency stability vs. supply voltage



Temperature:	+20 °C	Battery End Point:	Not applicable
Frequency under nominal conditions:	13,560577 MHz		

Supply Voltage (V)	Frequency (MHz)	Frequency Tolerance (Hz)	Frequency Tolerance (ppm)	Upper Limit (ppm)	Lower Limit (ppm)	Margin (ppm)
5,75	13,560570	-7	-0,5	+100,0	-100,0	**99,5**
5,50	13,560571	-6	-0,4	+100,0	-100,0	99,6
5,25	13,560572	-5	-0,4	+100,0	-100,0	99,6
5,00	13,560577	0	0,0	+100,0	-100,0	100,0
4,75	13,560574	-3	-0,2	+100,0	-100,0	99,8
4,50	13,560572	-5	-0,4	+100,0	-100,0	99,6
4,25	13,560573	-4	-0,3	+100,0	-100,0	99,7

8 Bandwidths

according to CFR 47 Part 2, section 2.202(a), and RSS-Gen, section 6.6

8.1 Test Location

See clause 5.1 on page 20.

8.2 Test instruments

See clause 5.2 on page 20.

8.3 Limits

The bandwidths are recorded only. There are no limits specified in CFR 47 Part 15, section 15.225, and RSS-210, Annex B6

8.4 Test setup

See clause 5.5 on page 23.

8.5 Test deviation

There is no deviation from the standards referred to.

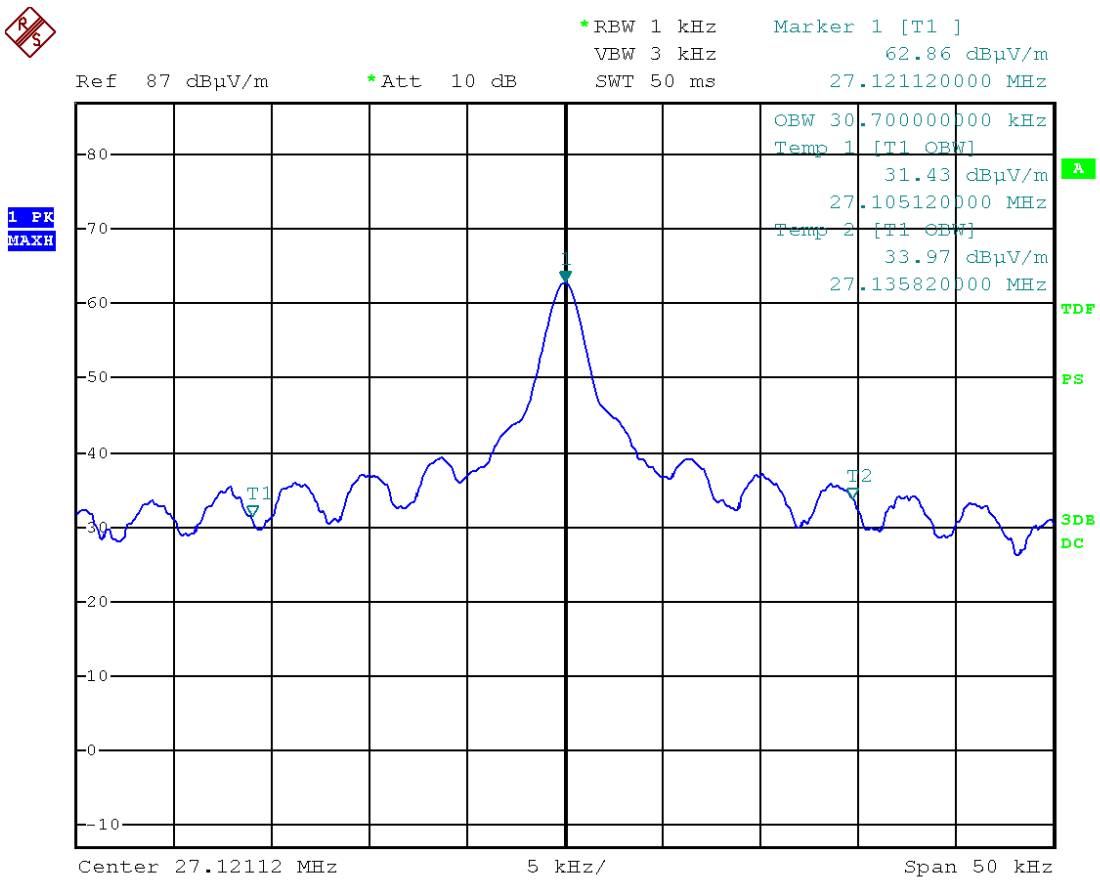
8.6 Test results

Temperature:	20°C	Humidity:	41%
Tested by:	Martin Müller	Test date:	2016-12-01

Occupied bandwidth (99 %)

Test procedure

When an occupied bandwidth value is not specified in the applicable RSS, the transmitted signal bandwidth to be reported is to be its 99% emission bandwidth, as calculated or measured. The transmitter shall be operated at its maximum carrier power measured under normal test conditions.
The span of the analyzer shall be set to capture all products of the modulation process, including the emission skirts. The resolution bandwidth shall be set to as close to 1% of the selected span as is possible without being below 1%. The video bandwidth shall be set to 3 times the resolution bandwidth. Video averaging is not permitted. Where practical, a sampling detector shall be used given that a peak or peak hold may produce a wider bandwidth than actual.
The trace data points are recovered and directly summed in linear terms. The recovered amplitude data points, beginning at the lowest frequency, are placed in a running sum until 0.5% of the total is reached and that frequency recorded. The process is repeated for the highest frequency data points. This frequency is recorded. The span between the two recorded frequencies is the occupied bandwidth. For this purpose the appropriate measurement function of the spectrum analyzer is used.



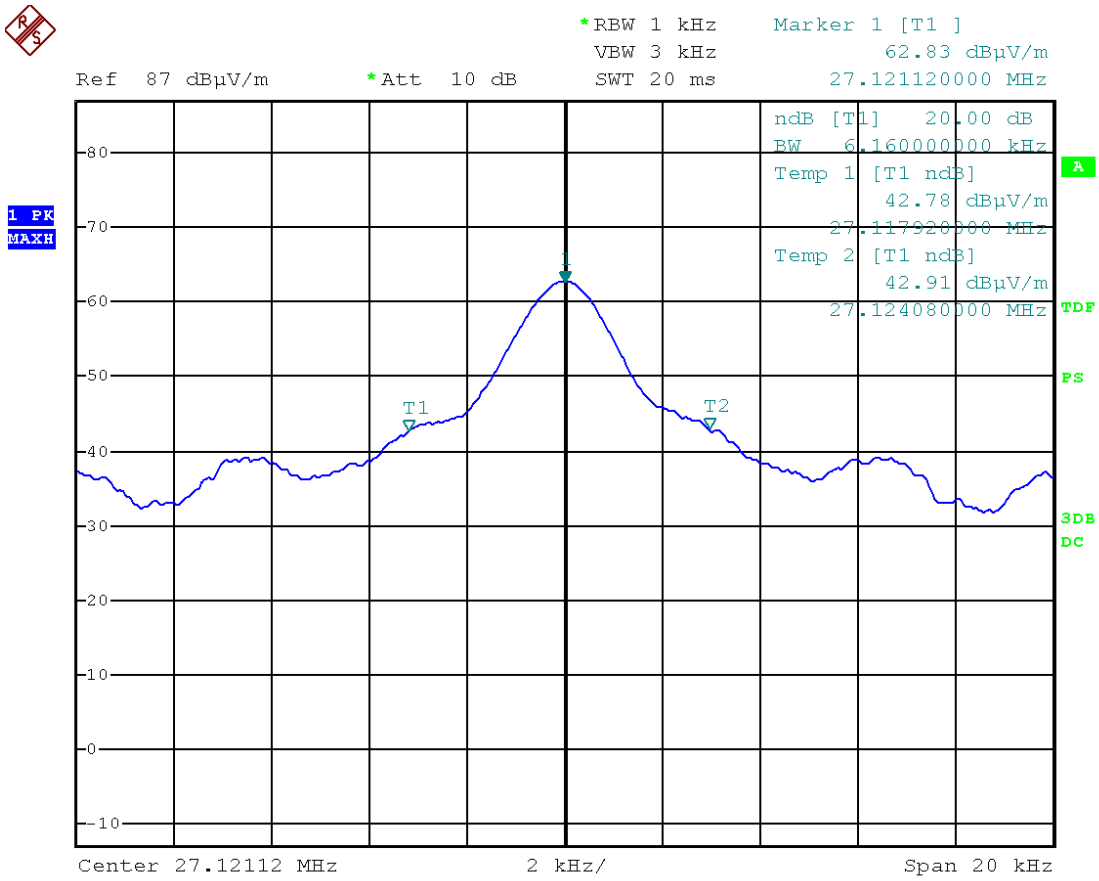
Picture 16: Occupied bandwidth (99 %)

Measured occupied bandwidth (99 %): 30.700 kHz

-20 dB emission bandwidth

Test procedure

Where indicated, the -20 dB emission bandwidth is defined as the frequency range between two points, one above and one below the carrier frequency, at which the spectral density of the emission is attenuated 20 dB below the maximum in-band spectral density of the modulated signal. Spectral density (power per unit bandwidth) is to be measured with a detector of resolution bandwidth equal to approximately 1.0% of the emission bandwidth.



Picture 17: -20 dB emission bandwidth

Measured -20 dB emission bandwidth: 6.160 kHz

9 Estimation of RF radiation exposure for mobile devices

according to 47 CFR Part 2, section 2.1091, and RSS-102, sections 3.2 and 4

This estimation follows the general guidelines for RF Exposure according to KDB 447498.

As noted in §2.1091(b) a mobile device is defined as “a transmitting device designed to be used in other than fixed locations and to generally be used in such a way that a **separation distance of at least 20 centimeters** is normally maintained between the transmitter's radiating structure(s) and the body of the user or nearby persons.”
According to §2.1091(c) the limits to be used for evaluation are defined in §1.1310.

As specified in §1.1310(d)(2) at operating frequencies less than or equal to 6 GHz, the limits for maximum permissible exposure (MPE), derived from whole-body SAR limits and listed in Table 1 of §1.1310(e) may be used.

Table 1 below shows the limits for Maximum Permissible Exposure (MPE) to radiofrequency electromagnetic fields.

Frequency range (MHz)	Electric field strength (V/m)	Magnetic field strength (A/m)	Power density (mW/cm^2)	Averaging time (minutes)
(A) Limits for Occupational/Controlled Exposure				
0.3 - 3.0	614	1.63	*100	6
3.0 - 30	1842/f	4.89/f	$*900/f^2$	6
30 - 300	61.4	0.163	1.0	6
300 - 1500			f/300	6
1500 - 100000			5	6
(B) Limits for General Population/Uncontrolled Exposure				
0.3 - 1.34	614	1.63	*100	30
1.34 - 30	824/f	2.19/f	$*180/f^2$	30
30 - 300	27.5	0.073	0.2	30
300 - 1500			f/1500	30
1500 - 100000			1.0	30

Table 1: Limits for maximum permissible exposure (MPE) according to table 1 of §1.1310(e)

Notes:
1. f = frequency in MHz.
2. * = Plane-wave equivalent power density.

Appropriate RF Field Strength Limits for Devices Used by the General Public (Uncontrolled Environment) can be found in table 4 of RSS-102, section 4:

Frequency Range (MHz)	Electric Field (V/m rms)	Magnetic Field (A/m rms)	Power Density (W/m^2)	Reference Period (minutes)
0.003-10	83	90	-	Instantaneous*
0.1-10	-	0.73/f	-	6**
1.1-10	$87/f^{0.5}$	-	-	6**
10-20	27.46	0.0728	2	6
20-48	$58.07/f^{0.25}$	$0.1540/f^{0.25}$	$8.944/f^{0.5}$	6
48-300	22.06	0.05852	1.291	6
300-6000	$3.142\ f^{0.3417}$	$0.008335\ f^{0.3417}$	$0.02619\ f^{0.6834}$	6
6000-15000	61.4	0.163	10	6
15000-150000	61.4	0.163	10	$616000/f^{1.2}$
150000-300000	$0.158\ f^{0.5}$	$4.21 \times 10^{-4}\ f^{0.5}$	$6.67 \times 10^{-5}\ f$	$616000/f^{1.2}$
Note: f is frequency in MHz. *Based on nerve stimulation (NS). ** Based on specific absorption rate (SAR).				

Table 2: RF field strength limits according to table 4 of RSS-102

Maximum peak value of electric field strength measured at 13.560 MHz in a distance of 3 m:
$E_{meas}(3\ m)$ = 62.73 dBµV/m (see picture 14)

Although expressed in “dBµV/m” the source of the field strength is magnetic and the value is recorded with a loop antenna measuring magnetic field. Using wave impedance in free space of about $120 \cdot \pi\ \Omega$ (51.5 dB) magnetic field strength results in:
$H_{meas}(3\ m) = E_{meas}(3\ m)$ - 51.5 dB = 62.73 dBµV/m -51.5 dB = 11.23 dBµA/m

Worst case field strength is calculated for a separation distance of 20 centimeters.

Using an extrapolation factor of 40 dB/decade ($\sim r^{-2}$) results in:
$E_{calc}(20\ cm) = 62.73\ dB\mu V/m - 40 \cdot \log(0.2\ m / 3\ m) = 62.73\ dB\mu V/m + 47.04\ dB$
E_{calc} (20 cm) = 109.77 dBµV/m = 0.308 V/m

Using an extrapolation factor of 60 dB/decade ($\sim r^{-3}$) results in:
E_{calc} (20 cm) = 62.73 dBµV/m - 60 · log(0.2 m / 3 m) = 62.73 dBµV/m + 70.56 dB
E_{calc} (20 cm) = 133.29 dBµV/m = 4.618 V/m

Using an extrapolation factor of 40 dB/decade ($\sim r^{-2}$) results in:
$H_{calc}(20\ cm) = 11.23\ dB\mu A/m - 40 \cdot \log(0.2\ m / 3\ m) = 11.23\ dB\mu A/m + 47.04\ dB$
$H_{calc}(20\ cm) = 58.27\ dB\mu A/m = 819.41 \cdot 10^{-6}\ A/m$

Using an extrapolation factor of 60 dB/decade ($\sim r^{-3}$) results in:
$H_{calc}(20\ cm) = 11.23\ dB\mu A/m - 60 \cdot \log(0.2\ m / 3\ m) = 11.23\ dB\mu A/m + 70.56\ dB$
$H_{calc}(20\ cm) = 81.79\ dB\mu A/m = 0.0123\ A/m$

Worst case power density is calculated for a separation distance of 20 centimeters by using the respective field strenghts for an extrapolation factor of 60 dB/decade (~ r^{-3}):

$S_{calc}(20\ cm) = E_{calc}\ (20\ cm) \cdot H_{calc}(20\ cm) = 4.618\ V/m \cdot 0.0123\ A/m$
$S_{calc}(20cm) = \underline{0.0568\ W/m^2} = \underline{0.0057\ mW/cm^2}$

Comparing the calculated results to the limits for general population/uncontrolled exposure at 13.56 MHz shows that even with worst case calculation using peak values the limits are kept.

E-field			
E_{calc}(20 cm) (V/m)	Limit 47 CFR Par 1, §1.1310(e) (V/m)		Limit RSS-102, table 2 (V/m)
4.618	60.77		27.46
H-field			
H_{calc}(20 cm) (A/m)	Limit 47 CFR Par 1, §1.1310(e) (A/m)		Limit RSS-102, table 2 (A/m)
0.0123	0.1615		0.0728
Power density			
S_{calc}(20 cm) (mW/cm^2)	Limit 47 CFR Par 1, §1.1310(e) (mW/cm^2)	S_{calc}(20 cm) (W/m^2)	Limit RSS-102, table 2 (W/m^2)
0.0057	0.9789	0.0568	2

Table 3: Calculated results @ 13.56 MHz compared to RF field strength limits

10 Equipment calibration status

Description	Modell number	Serial number	Inventory number(s)	Last calibration	Next calibration
Test receiver	ESCI 3	100013	E00001	2016-02	2018-02
Test receiver	ESCI 3	100328	E00552	2016-09	2018-09
Test receiver	ESCS 30	825442/0002	E00003	2016-04	2018-04
LISN	ESH2-Z5	893406/009	E00005	2016-02	2018-02
Loop antenna	HFH2-Z2	871398/0050	E00060	2016-09	2018-09
Broadband antenna	VULB 9160	9160-3050	E00011	2015-09	2017-09
Broadband antenna	VULB 9163	9163-114	E00013	2015-09	2017-09
Magnetic field probe	RF-R 400-1	02-2030	E00270	N/A (see note 1)	
Shielded room	P92007	B83117C1109T211	E00107	N/A	
Compact diagnostic chamber (CDC)	VK041.0174	D62128-A502-A69-2-0006	E00026	N/A	
Open area test site (OATS)	---	---	E00354	2015-10	2017-10
Climatic chamber 340 l	VC³ 4034	58566123250010	C00015	2016-10	2018-10
Cable set shielded room	Cable no. 30	---	E00424	2016-07	2018-07
Cable set CDC	Cables no. 37 and 38	---	E00459 E00460	2015-05	2017-05
Cable set OATS 3 m	Cables no. 19, 34 and 36	---	E00453 E00456 E00458	2015-11	2017-11

Table 4: Equipment calibration status

Note 1: Used for relative measurements only (see test instruments for “Carrier frequency stability”, clause 7.2)

Note 2: Expiration date of measurement facility registration (OATS) by
- FCC (registration number 221458): 2017-04
- Industry Canada (test sites number 3472A-1 and 3472A-2): 2018-11

Note 3: Expiration date of test firm accreditation for OATS and SAC:
FCC test firm type “accredited”: 2017-06

11 Measurement uncertainty

Description	Max. deviation	k=
Conducted emission AMN (9kHz to 30 MHz)	± 3.8 dB	2
Radiated emission open field (3 m) (30 MHz to 300 MHz) (300MHz to 1 GHz)	 ± 5.4 dB ± 5.9 dB	2
Radiated emission absorber chamber (> 1000 MHz)	± 4.5 dB	2

Table 5: Measurement uncertainty

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.

12 Revision History

Date	Description	Person	Revision
2016-12-06	First edition	M. Müller	0