Test Report

Customer:

HBC-radiomatic GmbH

Haller Straße 45 - 53
74564 Crailsheim
Germany

Tel.: +49 7951 393-0
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RF test report

160050-AU01+W12

HBC-radiomatic GmbH

Remote Control

spectrum D

merlin® TUC Mode

EMV **TESTHAUS** GmbH

Gustav-Hertz-Straße 35
94315 Straubing
Tel.: +49 9421 56868-0
Fax: +49 9421 56868-100
Email: info@emv-testhaus.com

Accreditation:

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

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: 10-2016	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: 10-2016	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

2 Summary of test results

Standard	Test result
47 CFR Part 15, section 15.225	Passed

Straubing, March 20, 2017

Martin Müller Test engineer EMV **TESTHAUS** GmbH	Rainer Heller Head of EMC/Radio Department EMV **TESTHAUS** GmbH

3 Equipment under Test (EUT)

Product type:	Remote Control
Model Name:	spectrum D
Applicant:	HBC-radiomatic GmbH
Manufacturer:	HBC-radiomatic GmbH
Serial number:	727-1606005
FCC ID:	NO9SPECTRUMD
Application frequency band:	13.110 to 14.010 MHz
Frequency range:	13.560 MHz
Operating frequency:	13.560 MHz
Number of RF-channels:	1
Maximum conducted power:	2 mW (maximum RF output power of RFID chip)
Modulation:	ASK
Antenna types:	PCB antenna AB143011 ☐ detachable ☒ not detachable
Power supply:	Battery powered nominal: 6.0 VDC ± 15 %
Temperature range:	-20°C to +50°C

EUT contains transceiver module TC64327_ certified according to 47 CFR Part 90, §90.217. For further details see test report no. 150589-AU01+W01.

Model Name:	TC64327_
Manufacturer:	HBC-radiomatic GmbH
FCC ID:	NO9TC64327
Frequency range:	460.6500 MHz to 461.5625 MH
Channel spacing:	12.5 kHz
Number of RF-channels:	64
Type of modulation:	FSK
ITU emission designator:	9K12F2D
Used or generated internal frequencies:	Minimum: 16 MHz Maximum: < 500 MHz
Antenna:	Internal short dipole antenna AB158010, HBC-radiomatic GmbH maximum gain 2.15 dBi

Note: All data as specified by customer.

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 remote control for construction cranes. The frequency of 13.56 MHz is for identifying the respective crane operator.

3.3 Operation mode

According to customer's information a standard version of EUT operates as follows:
If the device is powered on, the system configuration is read from the radiomatic® iLOG. For this purpose the radiomatic® iLOG is activated for the duration of the data transfer from the RFID tag. After that, the merlin® TUC is activated for 10 seconds. If a valid merlin® TUC is detected during this time, the device switches over to the state "Radio Transmission" and check of merlin® TUC is never activated again unless the device is reactivated. If an invalid merlin® TUC is detected or if the 10 seconds are over without detecting any merlin® TUC, the device is switched off.
In the state "Radio Transmission" the radio module is transmitting and radiomatic® iLOG is activated every second for checking its presence. When the radiomatic® iLOG check is done it is deactivated again.
Therefore, simultaneous transmission of RF radio module is possible with radiomatic® iLOG only, not with merlin® TUC.

For this test report EUT was configured to continuous operation with merlin® TUC transmitting continuously and RF module TC64327_ not transmitting.

For tests concerning the transceiver module TC64327_ see test report no. 150589-AU01+W01.
For tests concerning radiomatic® iLOG mode see test report no. 160050-AU01+W14.

During the pre-tests it was observed that the "continuous-tag-searching-mode" is the respective worst- case. Therefore this mode was selected for final testing. The device was configured by manufacturer to activate the RFID reader for continuous transmission via RFID card.

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.
Remote control	spectrum D	727-1606005
RFID tag	merlin® TUC (Smart Card)	0x00520005
DC supply	Statron 3252.1	E00541
Digital multimeter	METRAHit 29S	SEB00194

3.5 Used cables

Count	Description (type / lengths / remarks)	Serial no.
2	Laboratory cable (1.5 m, unshielded)	---

4 AC power line conducted emissions

according to 47 CFR Part 15, section 15.207

Not applicable -> EUT is battery powered

5 Radiated emission measurement (<1 GHz)

according to 47 CFR Part 15, section 15.205(a), 15.209(a), 15.225(a) to (e)

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
☒	ESCI (CDC)	Rohde & Schwarz	E00001
☐	ESU 26	Rohde & Schwarz	W00002
☒	VULB 9163 (OATS)	Schwarzbeck	E00013
☒	VULB 9160 (CDC)	Schwarzbeck	E00011
☒	HFH2-Z2	Rohde & Schwarz	E00060
☒	Cable set CDC	Huber + Suhner	E00060
☒	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

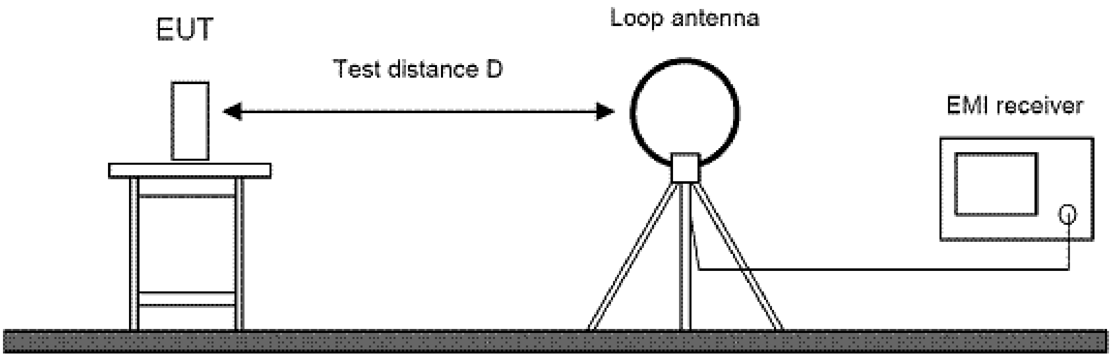
As noted in 15.205(d)(7) devices according to 15.225 are exempt from complying with restricted band requirements for the 13.36 to 13.41 MHz band. Instead they have to comply with the limits as specified in 15.225 (a) to (d):

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			

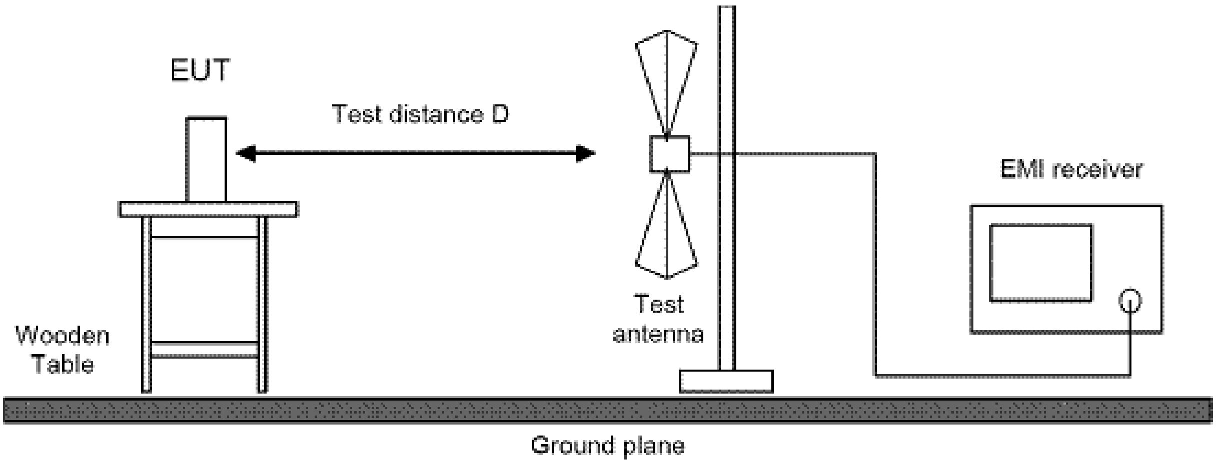
5.4 Test procedure

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



Picture 2: 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:	2017-01-03

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:

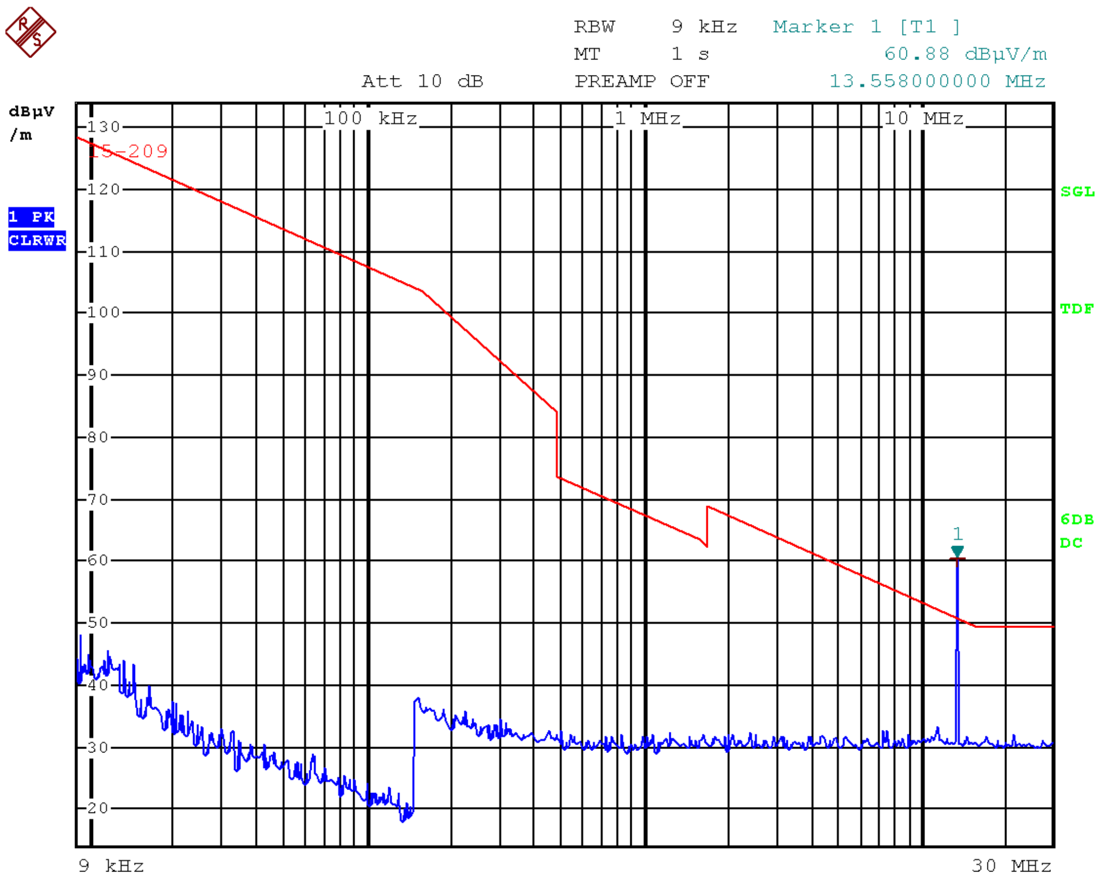
f_{MHz}(300 m) ≈ 0.159 MHz
f_{MHz}(30 m) ≈ 1.592 MHz
f_{MHz}(3 m) ≈ 15.923 MHz

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} / $d_{measure}$)

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 3, antenna in line.



Picture 3: 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**	**Result**
13.558	60.88	PK	-21.40	39.48	---	---	Carrier
13.558	60.57	QP	-21.40	39.17	84.00	-44.83	Carrier

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}

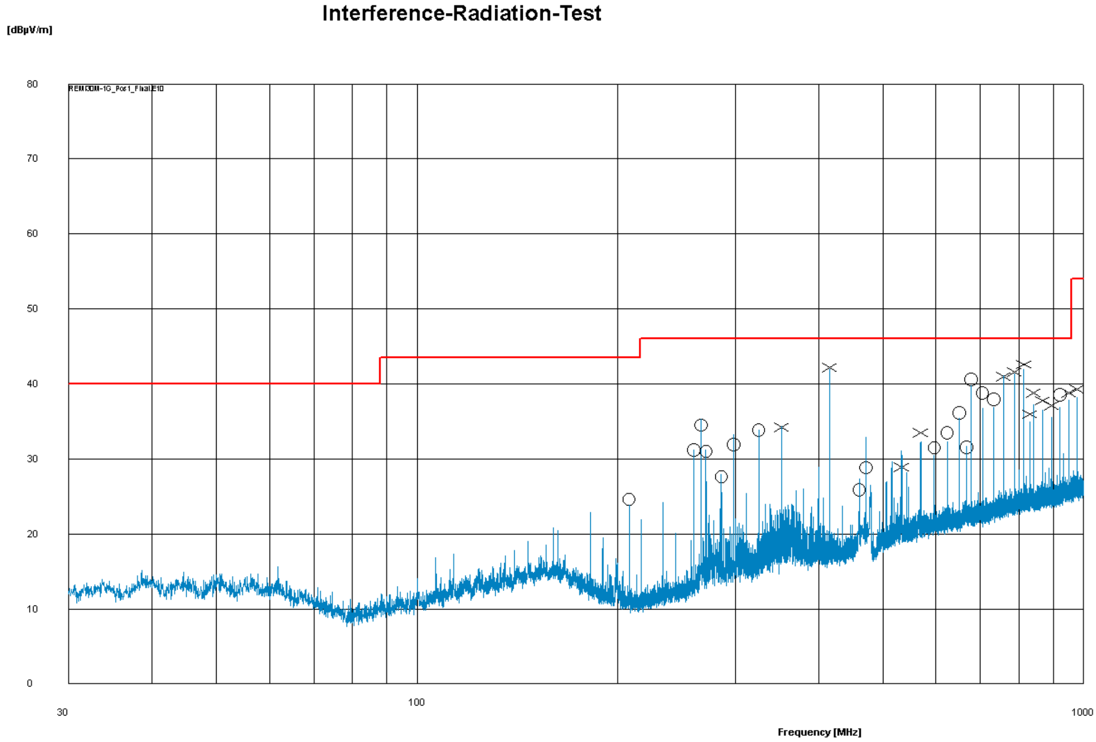
Recalculation factor = -40 log($d_{near\ field}$ / $d_{measure}$) - 20 log(d_{limit} / $d_{near\ field}$)

f_{MHz} [MHz]	$d_{near\ field}$ [m]	$d_{measure}$ [m]	d_{limit} [m]	Recalculation factor [dB]
13.558	3.523	3.0	30.0	-21.40

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 1.



f [MHz]	E_{final} [dBV/m]	Limit [dBµV/m]	Height [cm]	TT [°]	Polarisation	Result
208.02	24.60	43.52	250	269.0	H	Pass
259.98	31.17	46.02	250	358.5	H	Pass
266.64	34.52	46.02	250	359.7	H	Pass
271.20	30.98	46.02	250	4.7	H	Pass
286.02	27.65	46.02	250	339.5	H	Pass
298.32	31.90	46.02	250	4.3	H	Pass
325.44	33.84	46.02	250	9.5	H	Pass
352.56	34.19	46.02	100	287.6	V	Pass
415.62	42.20	46.02	139	80.4	V	Pass
460.62	25.86	46.02	250	351.0	H	Pass
471.30	28.84	46.02	250	324.3	H	Pass
533.22	28.92	46.02	100	145.8	V	Pass
569.52	33.49	46.02	100	88.0	V	Pass
596.64	31.51	46.02	250	51.3	H	Pass
623.70	33.50	46.02	250	48.8	H	Pass
650.82	36.14	46.02	250	67.6	H	Pass
666.60	31.55	46.02	250	277.1	H	Pass
677.94	40.62	46.02	103	83.1	H	Pass
705.06	38.78	46.02	250	72.1	H	Pass
732.18	37.96	46.02	250	327.0	H	Pass
759.30	40.98	46.02	183	43.7	V	Pass
786.42	41.59	46.02	165	72.5	V	Pass
813.54	42.57	46.02	146	83.2	V	Pass
831.30	35.96	46.02	100	277.0	V	Pass
840.66	38.80	46.02	100	193.6	V	Pass
867.78	37.78	46.02	100	174.9	V	Pass
894.90	37.13	46.02	100	185.1	V	Pass
921.30	38.56	46.02	250	359.7	H	Pass
949.14	38.79	46.02	100	229.7	V	Pass
976.26	39.27	53.98	100	177.7	V	Pass

Table 1: 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.

5.8 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:

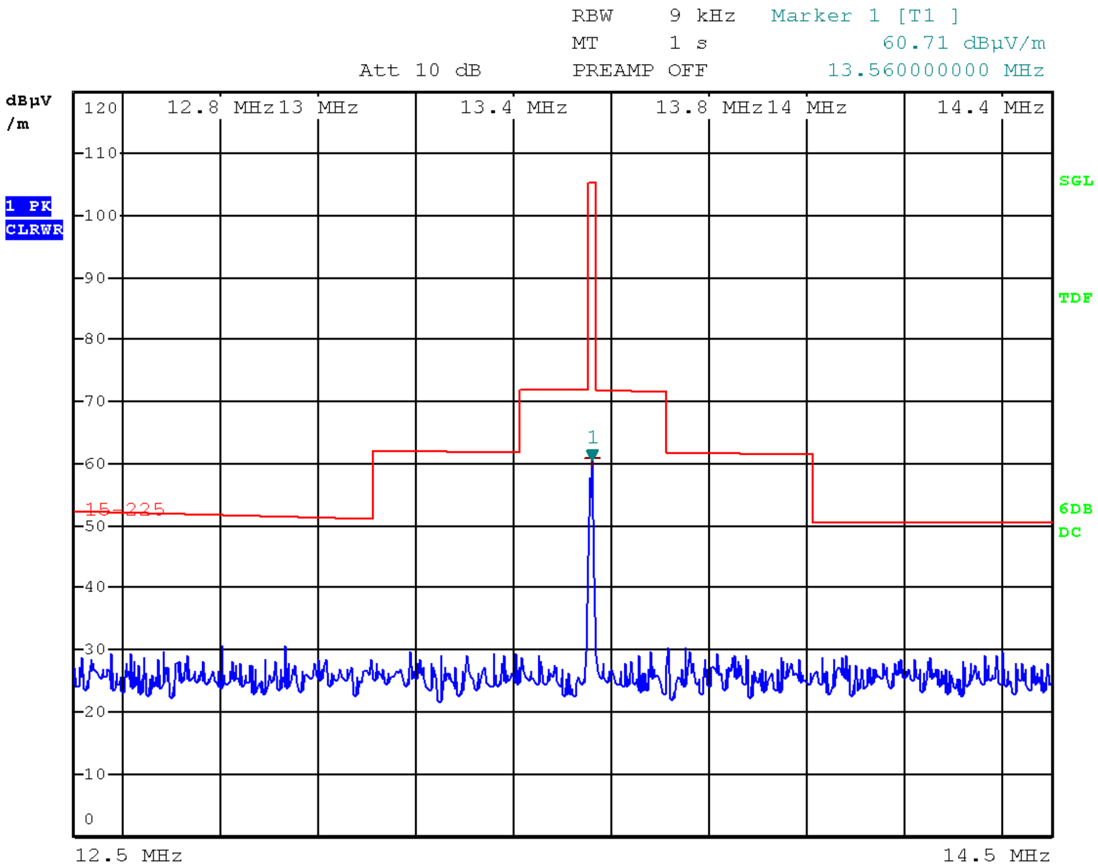
f_{MHz}(300 m) ≈ 0.159 MHz
f_{MHz}(30 m) ≈ 1.592 MHz
f_{MHz}(3 m) ≈ 15.923 MHz

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} / $d_{measure}$)

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 3, antenna in line.



Picture 4: 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**
13.560	60.71	PK	-21.40	39.31	---	---	---
13.560	60.66	QP	-21.40	39.26	84.00	44.74	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

6 Radiated emission measurement (>1 GHz)

according to 47 CFR Part 15, section 15.209(a)

6.1 Test Location

☒ Scan with average and max peak detector in 3 m anechoic chamber

☒ Final measurement with average and max peak detector in 3 anechoic chamber.

Description	Manufacturer	Inventory No.
Anechoic chamber	EMV Testhaus GmbH	E00100

6.2 Test instruments

	Description	Manufacturer	Inventory No.
☒	ESU26	Rohde & Schwarz	W00002
☒	AMF-5D-00501800-28-13P	Miteq	W00089
☐	AMF-6F-16002650-25-10P	Miteq	W00090
☒	BBHA 9120D	Schwarzbeck	W00053
☐	BBHA 9170	Schwarzbeck	W00055
☐	COSB 4-1-26	Conformitas	W00091
☒	Cable set AC 3 m	Huber + Suhner	E00435 E00319 E00873

6.3 Limits

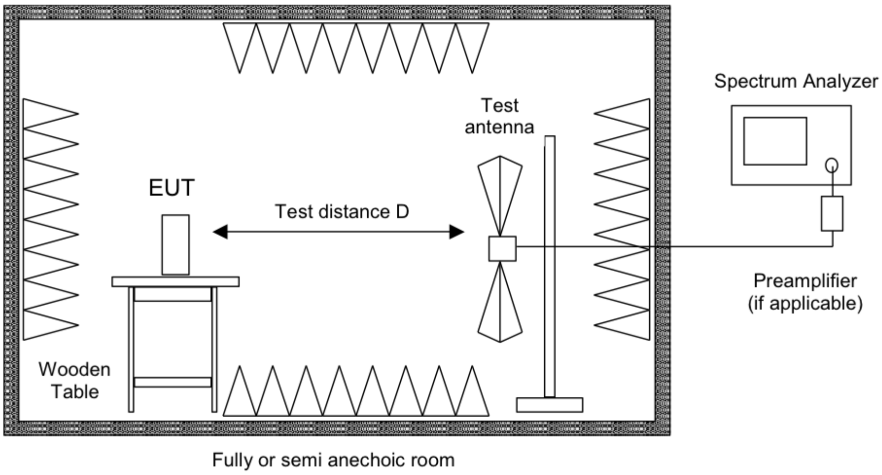
Emissions radiated outside of the specified frequency bands, except for harmonics, shall be attenuated by at least 50 dB below the level of the fundamental or to the general radiated emission limits in §15.209, whichever is the lesser attenuation.
Limit for field strength of harmonics is 54 dBµV/m (500 µV/m).
In case of emission falling into restricted bands specified on 15.205(a), limit according to 15.209(a) in table below applies.

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

6.4 Test procedure

1. Configure the EUT according to ANSI C63.10. The EUT was placed on the top of the turntable 1.5 meter above ground. The receiving antenna was placed 3 meters from the turntable. The test setup was placed inside a fully anechoic chamber.
2. Power on the EUT and all peripherals.
3. The broadband antenna was set to vertical polarization.
4. The EMI receiver performed a scan from 1000 MHz to 10^{th} harmonic of the fundamental frequency with the detector set to peak and the measurement bandwidth set to 1 MHz (VBW ≥ 3 MHz). The trace data was recorded with the receiver Max Hold function.
5. The turn table was rotated in intervals of 15°.
6. After a full 360°-turn the antenna polarization was changed to horizontal and the test was repeated at step 4 and 5.
7. After the scan suspicious frequencies were selected and maximized by moving turntable and variation of antenna height until maximum of emission was found.
8. Then the RBW was set to 1 MHz and the VBW was reduced to a minimum of 10 Hz (1 kHz by default) to get average values determined by video averaging.
9. The receiving antenna was set to vertical polarization.
10. The turntable was rotated by 360 degrees to determine the position of the highest radiation.
11. The receiving antenna was then set to horizontal polarization and the measurement was repeated at step 9.
12. The highest recorded level was noted.

6.5 Test setup



Picture 5: Test setup for radiated emission measurement (> 1 GHz)

6.6 Test deviation

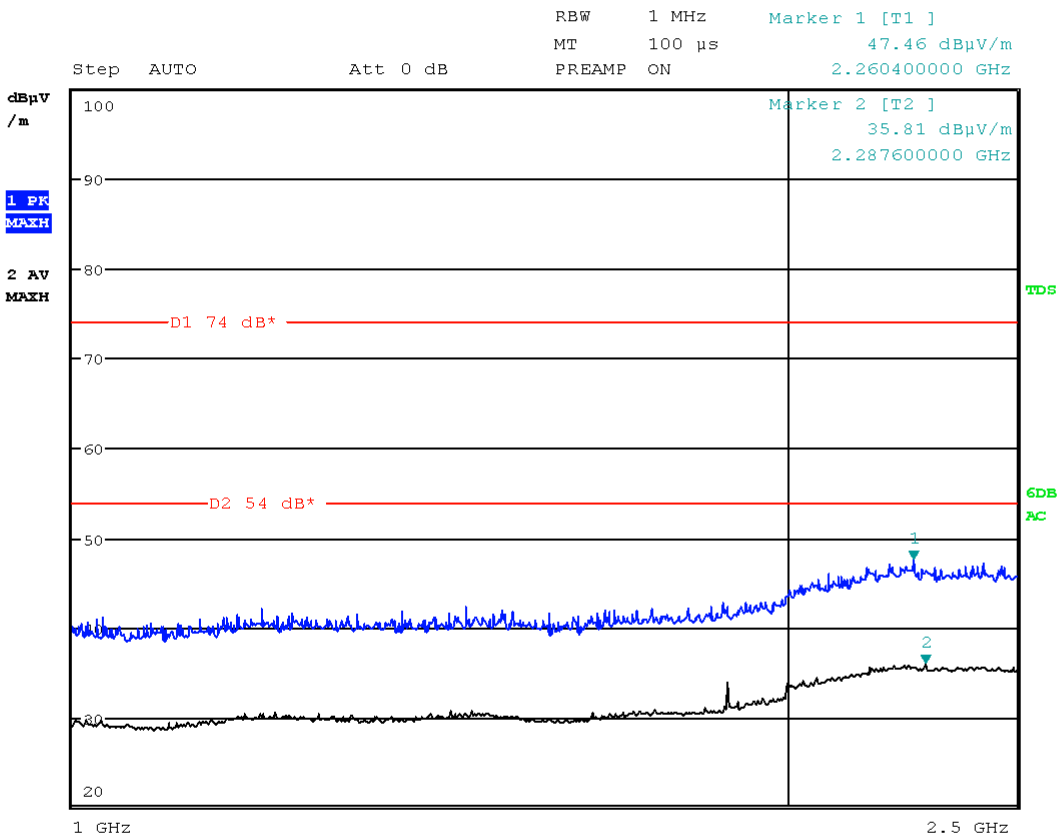
There is no deviation from the standards referred to.

6.7 Test results

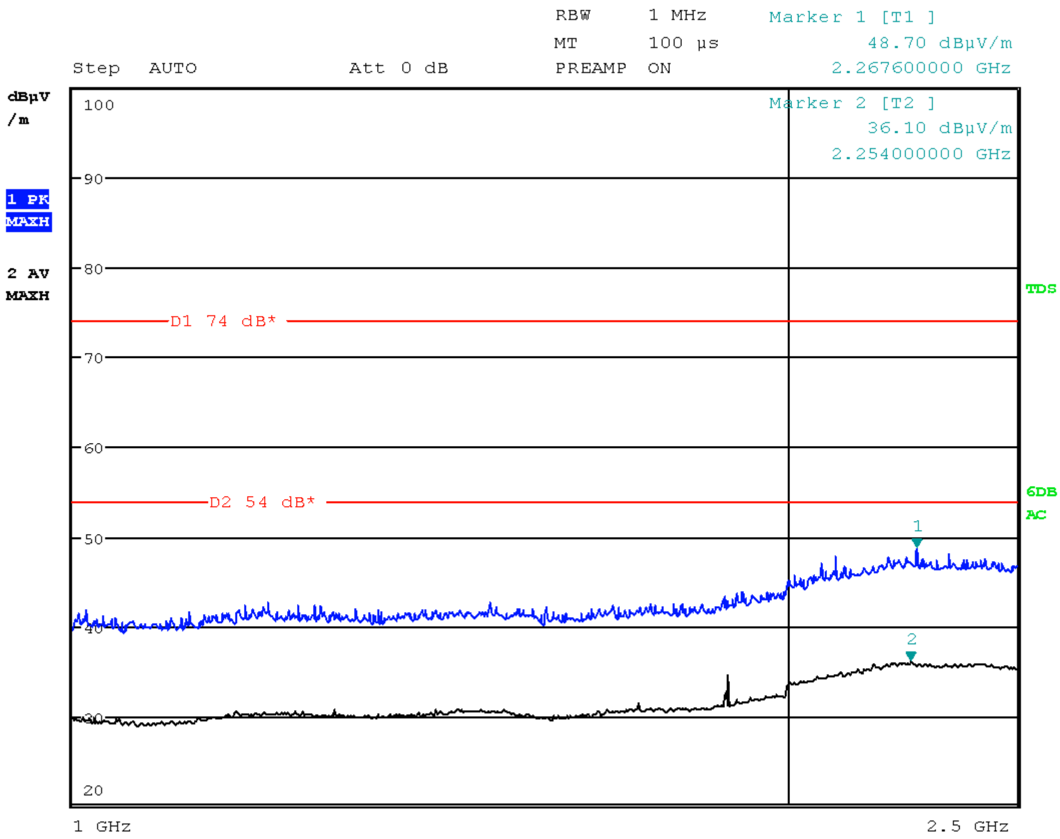
Temperature:	20°C	Humidity:	41%
Tested by:	Martin Müller	Test date:	2017-01-19

Frequency range	*Polari-sation*	*Step size*	*IF Band-width*	*Detector*		*Measurement Time*		*Pre-amplifier*
				Prescan	*Final scan*	*Prescan*	*Final scan*	
1 GHz - 2.5 GHz	H / V	400 kHz	1 MHz	PK / AV	PK / AV	1 ms	1 s	0 dB

The following pictures show the worst-case-emissions at EUT-position 1.



Picture 6: Radiated emission > 1 GHz, vertical



Picture 7: Radiated emission > 1 GHz, horizontal

7 Carrier frequency stability

according to CFR 47 Part 15, section 15.225(e)

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

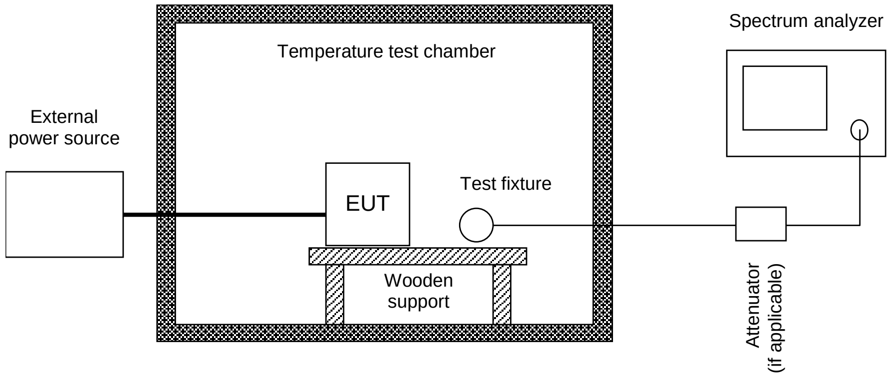
7.3 Limits

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 8: Test setup for carrier frequency stability measurement

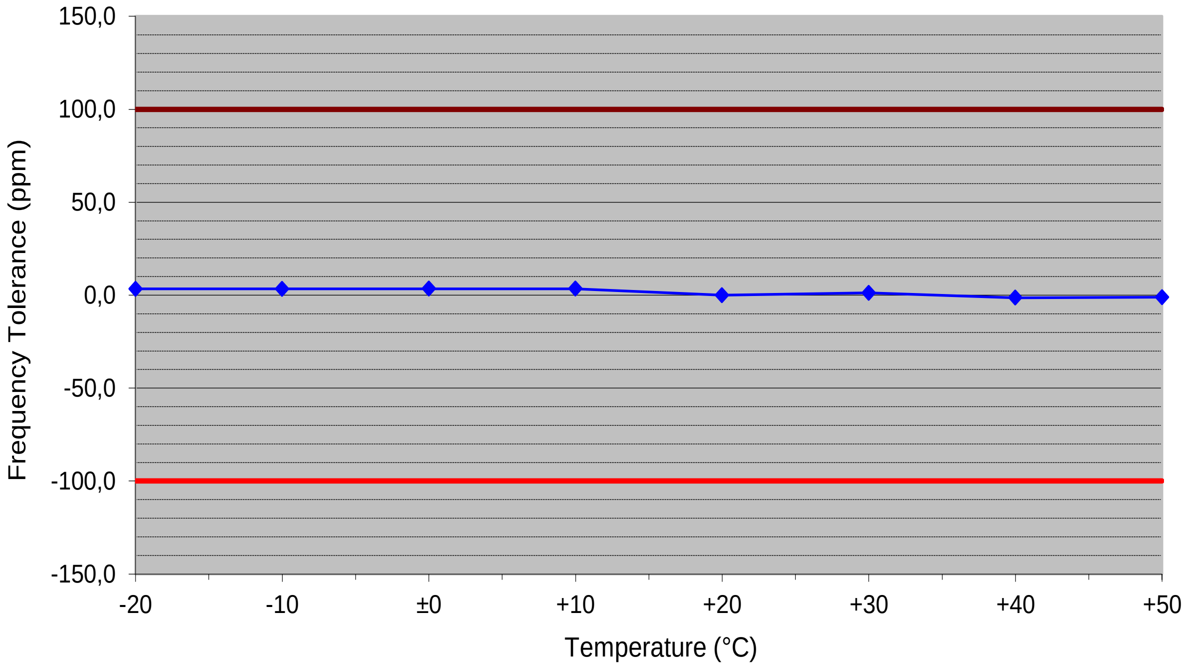
7.6 Test deviation

There is no deviation from the standards referred to.

7.7 Test result

Temperature:	20°C	Humidity:	41%
Tested by:	Martin Müller	Test date:	2017-01-18

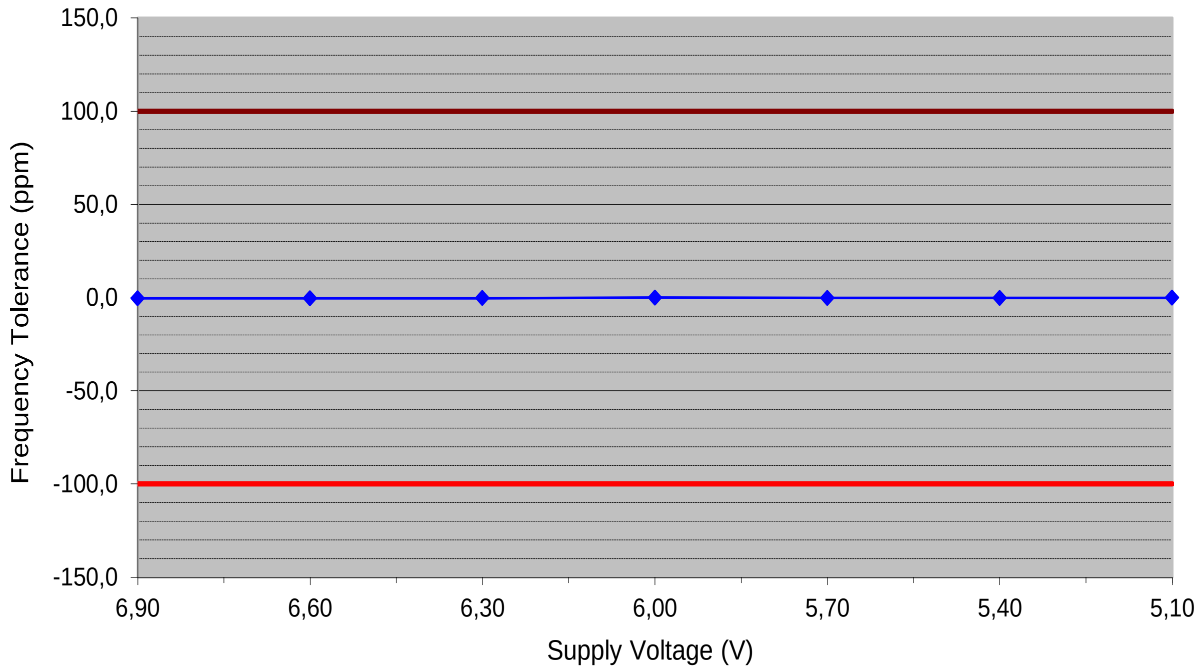
Carrier frequency stability vs. temperature



Supply voltage: 6 V Frequency under nominal conditions: 13,559256 MHz

Temperature (°C)	Frequency (MHz)	Frequency Tolerance (Hz)	(ppm)	Upper Limit (ppm)	Lower Limit (ppm)	Margin (ppm)
-20	13,559302	46	3,4	+100,0	-100,0	96,6
-10	13,559301	45	3,3	+100,0	-100,0	96,7
±0	13,559303	47	3,5	+100,0	-100,0	**96,5**
+10	13,559303	47	3,5	+100,0	-100,0	**96,5**
+20	13,559256	0	0,0	+100,0	-100,0	100,0
+30	13,559272	16	1,2	+100,0	-100,0	98,8
+40	13,559237	-19	-1,4	+100,0	-100,0	98,6
+50	13,559241	-15	-1,1	+100,0	-100,0	98,9

Carrier frequency stability vs. supply voltage



Temperature:	+20 °C	Battery End Point:	Not applicable
Frequency under nominal conditions:	13,559256 MHz		

Supply Voltage (V)	Frequency (MHz)	Frequency Tolerance (Hz)	Frequency Tolerance (ppm)	Upper Limit (ppm)	Lower Limit (ppm)	Margin (ppm)
6,90	13,559251	-5	-0,4	+100,0	-100,0	**99,6**
6,60	13,559251	-5	-0,4	+100,0	-100,0	**99,6**
6,30	13,559252	-4	-0,3	+100,0	-100,0	99,7
6,00	13,559256	0	0,0	+100,0	-100,0	100,0
5,70	13,559253	-3	-0,2	+100,0	-100,0	99,8
5,40	13,559253	-3	-0,2	+100,0	-100,0	99,8
5,10	13,559254	-2	-0,1	+100,0	-100,0	99,9

8 Bandwidths

according to CFR 47 Part 2, section 2.202(a) and CFR 47 Part 15, section 15.215

8.1 Test Location

See clause 5.1 on page 11.

8.2 Test instruments

See clause 5.2 on page 11.

8.3 Limits

According to section 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.

8.4 Test setup

See clause 5.5 on page 14.

8.5 Test deviation

There is no deviation from the standards referred to.

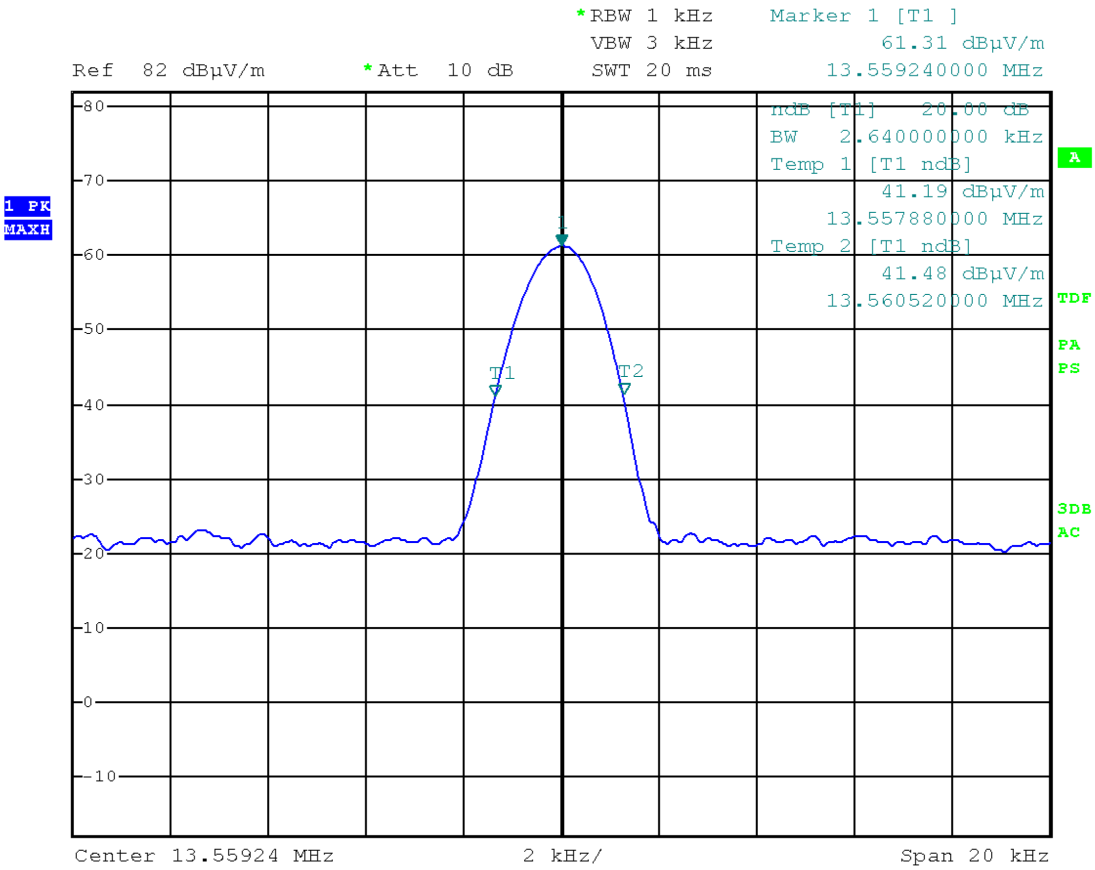
8.6 Test results

Temperature:	20°C	Humidity:	41%
Tested by:	Martin Müller	Test date:	2017-01-03

-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 9: -20 dB emission bandwidth

$f_{assigned}$ (MHz)	Index	f_{-20dB} (MHz)	Δf_T (kHz)	Δf_U (kHz)	$f_{-20dB(T, U)}$ (MHz)	Limit (MHz)	Margin (kHz)	Result
13.560000	low	13.557880	0.019	0.005	13.557856	13.110000	447.856	Passed
	high	13.560520	0.047	0.000	13.560567	14.010000	449.433	Passed
	Bandwidth	2.640 kHz			2.711 kHz			

with:

- $f_{-20dB(low)}$ = lower frequency in MHz where emission is at least 20 dB below the carrier
- $f_{-20dB(high)}$ = upper frequency in MHz where emission is at least 30 dB below the carrier
- $f_{assigned}$ = assigned frequency in kHz
- $\Delta f_{T(low)}$ = maximum absolute value of negative frequency offset to frequency at nominal conditions caused by temperature variation in kHz
- $\Delta f_{U(low)}$ = maximum absolute value of negative frequency offset to frequency at nominal conditions caused by voltage variation in kHz
- $\Delta f_{T(high)}$ = maximum absolute value of positive frequency offset to frequency at nominal conditions caused by temperature variation in kHz
- $\Delta f_{U(high)}$ = maximum absolute value of positive frequency offset to frequency at nominal conditions caused by voltage variation in kHz
- $\Delta f_{volt(high)}$ = maximum absolute value of positive frequency offset to frequency at nominal conditions caused by voltage variation in kHz
- $f_{-20dB(T, U)}$ = frequency in MHz where emission is at least 20 dB below the carrier, including offset caused by variations of temperature and supply voltage as recorded in clause 7.7

Measured -20 dB emission bandwidth:
At nominal conditions: 2.640 kHz
Including variations in temperature and supply voltage: 2.711 kHz

9 Radio frequency radiation exposure evaluation for portable devices

according to 47 CFR Part 2, section 2.1093 and KDB 447498 D01, section 4.3.1

9.1 Data of equipment under test (EUT)[1]

Antenna connector (see clause 3):	☐ permanent ☒ none	☐ temporary
Antenna detachable:	☐ yes	☒ no
Tune-up function:	☐ yes	☒ no
Maximum conducted output power (see clause 3):	logarithmic 3.01 dBm	numeric 2.00 mW
Maximum operation frequency (see clause 3):	13.560 MHz	
Minimum test separation distance:	6 mm	
Simultaneous transmission (see clause 3.3):	none	

9.2 Standalone Requirements for EUT

9.2.1 Requirements

To be excluded from SAR tests set out in 47 CFR Part 2, §2.1093, the limits of the general guidelines for RF Exposure as described in KDB 447498 D01, section 4.3.1c)2) have to be kept by transmitters operating below 100 MHz with test separation distances ≤ 50 mm. For calculation the following equations apply:

$$P_{c2}\,(mW) = \frac{1}{2} \cdot P_{c1}\,(mW)$$ Formula 4.3.1c)2)

$$P_{c1}\,(mW) = P_{b1}\,(mW) \cdot \left(1 + \log\left(\frac{100}{f\,(MHz)}\right)\right)$$ Formula 4.3.1c)1)

$$P_{b1}\,(mW) = P_a\,(mW) + (d_{min}(mm) - 50\,mm) \cdot \frac{f_0(MHz)}{150}$$ Formula 4.3.1b)1)

[1] As specified by customer.

$$\frac{P_{conducted}(mW) \cdot \sqrt{f(GHz)}}{d_{min}(mm)} \leq 3.0$$

Formula 4.3.1a)

$$\Rightarrow P_a\,(mW) = \frac{3.0 \cdot d_0(mm)}{\sqrt{f_0(GHz)}}$$

9.2.2 Results

$$P_a\,(mW) = \frac{3.0 \cdot 50\,mm}{\sqrt{0.1\,GHz}} \Leftrightarrow P_a\,(mW) = 474\,mW$$

Formula 4.3.1a) with:
d_0 = 50 mm, f_0 = 100 MHz

$$P_{b1}\,(mW) = 474\,mW + (6\,mm - 50\,mm) \cdot \frac{100}{150}$$
$$\Leftrightarrow P_{b1}\,(mW) = 445\,mW$$

Formula 4.3.1b)1) with:
d_{min} = 6 mm, f_0 = 100 MHz

$$P_{c1}\,(mW) = 445\,mW \cdot \left(1 + \log\left(\frac{100}{13.56}\right)\right)$$
$$\Leftrightarrow P_{c1}\,(mW) = 831\,mW$$

Formula 4.3.1c)1) with:
f = 13.56 MHz

$$P_{c2}\,(mW) = \frac{1}{2} \cdot 831\,mW \Leftrightarrow P_{c2}\,(mW) = 415\,mW$$

Formula 4.3.1c)2)

$$\Rightarrow P_{conducted}\,(mW) = 2\,mW \ll P_{c2}\,(mW) = 415\,mW$$

with:

	$P_{conducted}$	=	source-based time-averaged maximum conducted output power in mW, adjusted for tune-up tolerance
	P_i	=	conducted output power in mW as calculated in step “i” of section 4.3.1, i. e. steps a), b)1), c)1) and c)2).
	f	=	RF channel transmit frequency in GHz or MHz as indicated
	f_0	=	reference frequency in GHz or MHz as indicated
	d_{min}	=	minimum test separation distance in mm determined by the smallest distance from the antenna and radiating structures or outer surface of the device, according to the host form factor, exposure conditions and platform requirements, to any part of the body or extremity of a user or bystander
	d_0	=	reference distance in mm

Notes:
1 Power and distance are rounded to the nearest mW and mm before calculation.
2 Power is rounded to the nearest mW with every step.

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	ESU 26	100026	W00002	2016-04	2018-04
Preamplifier	AMF-5D-00501800-28-13P	1319793	W00089	2015-06	2017-06
Loop antenna	HFH2-Z2	871398/0050	E00060	2016-09	2018-09
Broadband antenna	VULB 9160	9160-3050	E00011	N/A (for pre-tests only)	
Broadband antenna	VULB 9163	9163-114	E00013	2015-09	2017-09
Broadband horn antenna	BBHA 9120D	9120D-593	W00053	2014-03	2017-03
Magnetic field probe	RF-R 400-1	02-2030	E00270	N/A (see note 1)	
Compact diagnostic chamber (CDC)	VK041.0174	D62128-A502-A69-2-0006	E00026	N/A (for pre-tests only)	
Open area test site (OATS)	---	---	E00354	2016-10	2018-10
Anechoic chamber (AC)	FS-SAC	---	E00100	2015-10	2017-10
Climatic chamber 340 l	VC³ 4034	58566123250010	C00015	2016-10	2018-10
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
Cable set AC 3 m	Cables no. 05, 11 and 63	---	E00435 E00319 E00873	2015-10	2017-10

Table 2: Equipment calibration status

Note 1: Used for relative measurements only (see test instruments for "Carrier frequency stability", clause 7)

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 3: 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
2017-03-20	First edition	M. Müller	0