Test report

Customer:

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EMC test report

150589-AU01+W01

FEDERAL COMMUNICATIONS COMMISSION · USA ·

HBC-radiomatic GmbH

Transceiver Module

TC64327_

EMV **TESTHAUS** GmbH

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94315 Straubing
Tel.: +49 9421 56868-0
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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 Summary of test results

47 CFR part and section	*Test*	*Page*	*Result*	*Note(s)*
90.217	Exemption from technical standards Transmitters designed to operate with a 12.5 kHz channel bandwidth are exempt from the technical requirements set out in 47 CFR Part 90, Subpart I, if they comply with the following:			
90.217	- Operating frequencies are listed in subparts B or C	18	Passed	1
90.217	- Transmitter power is not exceeding 120 mW	20	Passed	
90.217(b)	- Occupied bandwidth (-30 dB points related to the unmodulated carrier) including the bandwidth required for frequency stability is within ±25 kHz around the assigned frequency	27	Passed	
90.217(b)	- Spurious emissions are attenuated at least 30 dB below the unmodulated carrier	38		
	• Conducted spurious emissions	39	Passed	
	• Radiated spurious emissions	47	Passed	
2.1093; KDB 447498 D01, section 4.3.1	Radio frequency radiation exposure evaluation for portable devices	67	Passed	

Notes:

1 Used frequencies are listed in "Industrial/Business Pool" as defined in Subpart C, §90.35. For details about EUT see clause 3 of this test report.

Straubing, December 20, 2016

Martin Müller
Test engineer
EMV **TESTHAUS** GmbH

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

2 Referenced publications

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

Publication	*Title*
CFR 47 Part 2 October 2016	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 90 October 2016	Code of Federal Regulations, Title 47 (Telecommunication), Part 90 (Private Land Mobile Radio Services) of the Federal Communication Commission (FCC)
KDB Publication no. 412172 D01 August 7, 2015	Guidelines for determining the Effective Radiated Power (ERP) and Equivalent Isotropically Radiated Power (EIRP) of an RF transmitting system
KDB Publication no. 447498 D01 October 23, 2015	RF exposure procedures and equipment authorization policies for mobile and portable devices
ANSI/TIA-603-D June 2010	Land Mobile FM or PM Communications Equipment and Performance Standards

3 Equipment under test (EUT)

All information within this clause is provided by the customer.

Product type:	Transceiver Module		
Model name:	TC64327_		
Serial number:	Sample 3		
Manufacturer:	HBC-radiomatic GmbH		
Additional modifications:	None		
FCC ID:	NO9TC64327		
Equipment type:	Transceiver module		
Application frequency band:	460.6500 MHz to 461.5625 MHz		
Frequency range:	460.6500 MHz to 461.5625 MHz		
Operating frequencies:	See table 8		
Channel spacing:	12.5 kHz		
Channel bandwidth:	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 data:	See table 1		
Maximum RF power:	Conducted: 13.59 dBm	Radiated:	14.90 dBm
Power supply:	DC supply		
	Nominal voltage:	4.2 V	
	Minimum voltage:	3.3 V	
	Maximum voltage:	4.6 V	
	Nominal frequencies:	---	

List of antennas to be used with EUT:

Internal antennas					
HBC part number	*Antenna type*	*Frequency range*	*Gain (maximum)*	*Connector type*	*Selected for testing*
AA080004	λ/4 - antenna	405 – 480 MHz	2.15 dBi	MMCX male	
AB047010	λ/4 - antenna	405 – 480 MHz	2.15 dBi	MMCX male	
AB158010	short dipole antenna	405 – 480 MHz	2.15 dBi	MMCX male	
External antennas					
HBC part number	*Antenna type*	*Frequency range*	*Gain (maximum)*	*Connector type*	*Selected for testing*
012-01-00007	shortened half-wave antenna	440 – 470 MHz	6.15 dBi	BNC male	
AA020002	whip antenna	400 – 460 MHz	2.15 dBi	BNC male	
AA020031	λ/4 whip antenna	410 – 470 MHz	2.15 dBi	Mini-Crimp	
AA050002	omnidirectional antenna	406 – 470 MHz	2 dBi	N female	
AA060007	λ/4 mobile whip antenna	430 – 470 MHz	2.15 dBi	Mini-Crimp	
AA060015	dual frequency whip antenna	380 – 470 MHz 800 – 960 MHz	2.15 dBi	Mini-Crimp	
AA060018	whip antenna	450 – 470 MHz	6.15 dBi	Mini-Crimp	X
AA060021	λ/4 mobile whip antenna	406 – 470 MHz	2.15 dBi	Mini-Crimp	

Table 1: List of dedicated antennas

“Internal antennas” means that these antennas are mounted within the cabinet of the host, “external antennas” are mounted on the outside.
For further details on antenna parameters see appropriate data sheets available for all antennas listed above.

4 Test configuration and mode of operation

4.1 Test configuration

EUT			
Device	*Type designation*	*Serial or inventory no.*	*Manufacturer*
Transceiver Module	TC64327_	Sample 3	HBC-radiomatic
Vehicle antenna, mounted on metal plate with square area of 20 cm x 20 cm	MU 11-CX/CEL1	HBC part no.: AA060018	PROCOM
Test fixture	TC6_3	---	HBC-radiomatic
Peripheral devices			
Device	*Type designation*	*Serial or inventory no.*	*Manufacturer*
Digital multimeter	METRAHit 29S	QC3093	Gossen-Metrawatt
DC power supply	3231.1	0702007	Statron Gerätetechnik

Table 2: Devices used for testing

Port	*Classification*	*Cable type*	*Cable length*	
			used	*maximum*[1]
DC power supply of test fixture (2x)	dc power	Unshielded	0.5 m	---
Antenna cable MMCX <-> BNC	signal/control	Shielded (coax)	0.25 m	
Antenna cable BNC <-> FME	signal/control	Shielded (coax)	1.0 m	
Test cable, normal conditions	signal/control	Shielded (coax)	0.3 m	---
Test cable, extreme conditions	signal/control	Shielded (coax)	2.0 m	---

Table 3: Ports of EUT and appropriate cables

4.2 Cable attenuation

Frequency (MHz)	*Attenuation (dB)*
460.6500	0.82
461.3000	0.75
461.5625	0.72

Table 4: Attenuation of antenna cable

[1] As specified by applicant

Frequency (MHz)	*Attenuation (dB)*
460.6500	0.90
461.3000	0.90
461.5625	0.90

Table 5: Attenuation of test cable used for tests under normal conditions

Frequency (MHz)	*Attenuation (dB)*
460.6500	1.02
461.3000	1.02
461.5625	1.02

Table 6: Attenuation of test cable used for tests under extreme conditions

4.3 Mode of operation

EUT was tested in the following mode(s) of operation:

Frequency (MHz)	*Channel*	*Mode*
460.6500	low	TX with and without modulation
461.3000	mid	TX with and without modulation
461.5625	high	TX with and without modulation
460.6500	low	RX
461.3000	mid	RX
461.5625	high	RX

Table 7: List of frequencies, channels and test modes used

5 Measurement Procedures

5.1 Conducted output power

The conducted output power is measured as the conducted emission at the operating frequencies. For test setup see clause 5.5.

5.2 Radiated output power

The radiated output power is measured as the radiated emission at the operating frequencies. For test setup see clause 5.6.

5.3 Occupied bandwidth

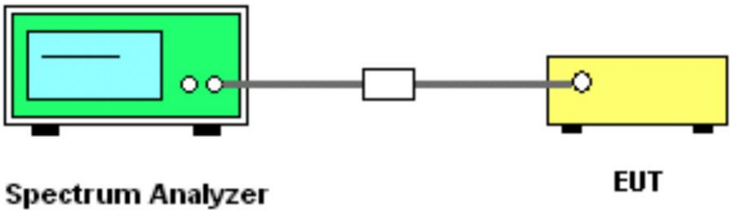


Figure 1: Test setup for occupied bandwidth

The EUT´s RF signal is coupled out by the antenna connector which is supplied by the manufacturer. The following spectrum analyzer settings are used:

- Span: centered on the actual channel and wide enough to be able to observe the spectrum and the limits
- Resolution bandwidth: 100 Hz
- Video bandwidth: 300 Hz
- Sweep: AUTO
- Detector function: peak
- Trace mode: Max hold

After trace stabilization the marker shall be set to the peak of the unmodulated carrier. This value has to be displayed as the reference line. A second display line 30 dB below the reference line is added to indicate the limit for the occupied bandwidth. The measurement has to be repeated with all kinds of modulation to find the worst case.

5.4 Frequency stability

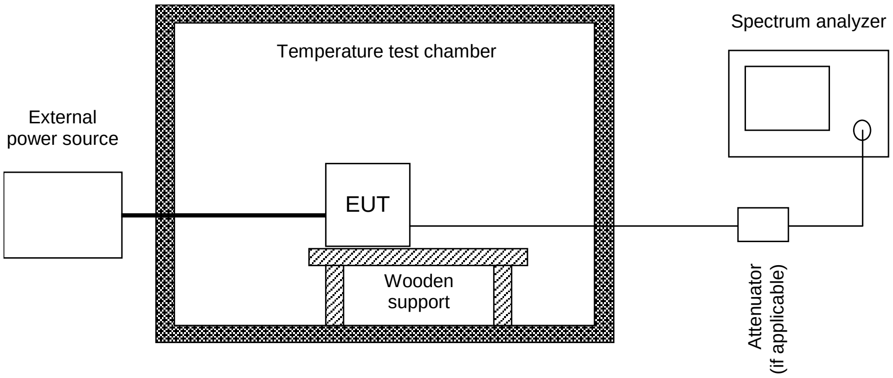


Figure 2: Test setup for frequency stability

The following procedure is used:
1) Place the EUT in the climatic chamber.
2) Set the test receiver in analyzer mode.
3) Switch on the EUT and check the correct function and the settings of the test receiver.
4) Switch off the EUT and tune the climatic chamber to a temperature of 20 °C. Wait until the thermal balance is obtained.
5) Switch on the EUT with voltage set to nominal value as specified by manufacturer.
6) Start transmitting without modulation.
7) Measure the operating frequency using frequency counter function of the test receiver.

5.4.1 Frequency stability vs. voltage

8) Set voltage to minimum value as specified by manufacturer and record the transmit frequency.
9) Increase the voltage in small steps up to maximum value as specified by manufacturer. At every step record the transmit frequency.
10) Set voltage to nominal value as specified by manufacturer.

5.4.2 Frequency stability vs. temperature

11) Switch off the EUT and tune the climatic chamber over a temperature range of at least -20 °C to 50 °C to in steps of ten degree. If the manufacturer specifies a wider range extend the temperature range accordingly. Set the lowest temperature and wait until the thermal balance is obtained. Keep voltage to nominal value as specified by manufacturer.
12) Switch on the EUT and start transmitting without modulation.
13) Measure the operating frequency and record it.
14) Repeat steps 11) to 13) for every temperature required.

5.5 Conducted emissions at antenna connector

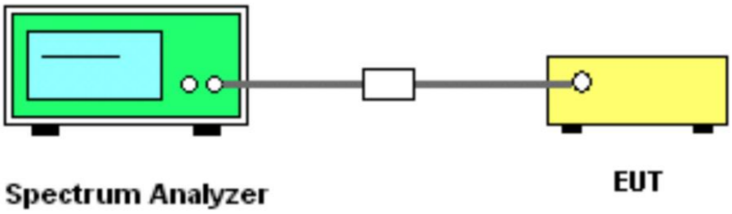


Figure 3: Test setup for conducted emission

The EUT´s RF signal is coupled out by the antenna connector which is supplied by the manufacturer. The specific losses of the signal path, which is matched to 50 Ohm, are checked within a calibration. The test receiver is set to analyzer mode with pre-selector activated. The measurement readings on the test receiver are corrected by the signal path loss.

5.6 Radiated emissions

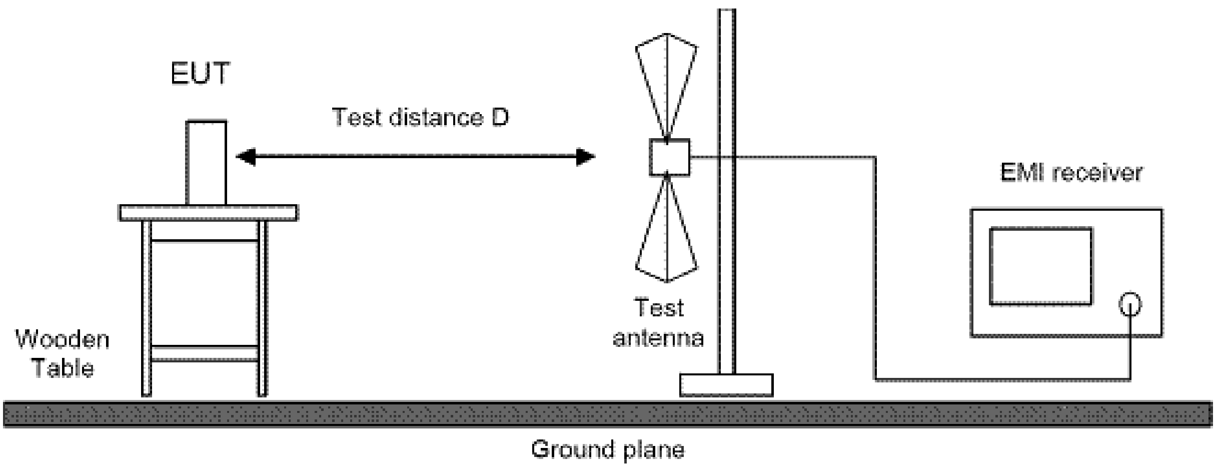


Figure 4: Setup for final radiated emission test below 1 GHz

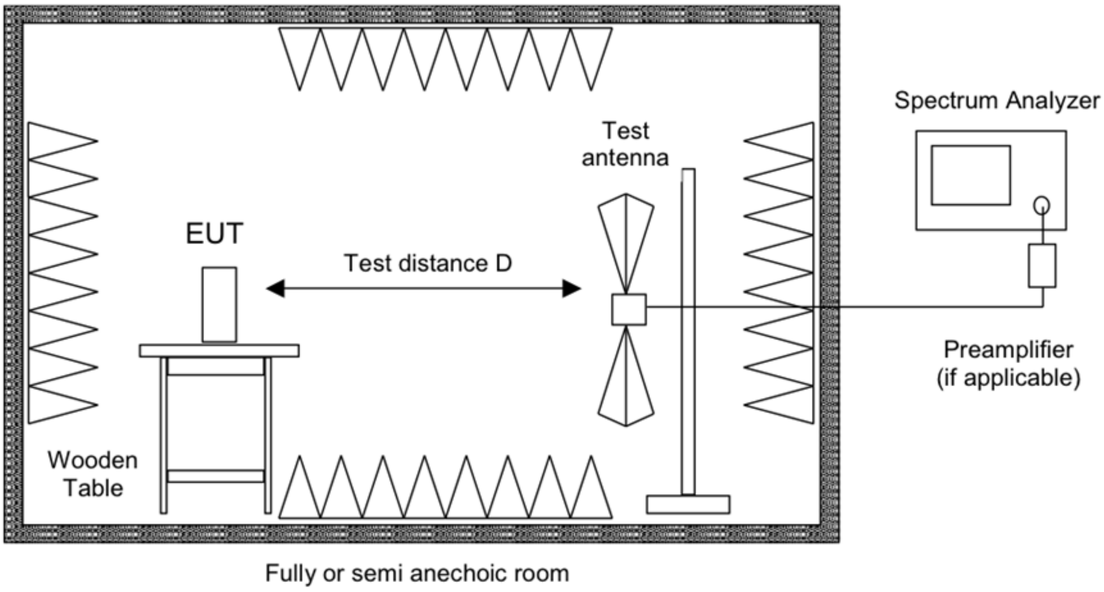


Figure 5: Setup for radiated emission test above 1 GHz

For testing below 1 GHz pre-tests are performed in a fully anechoic room (see figure 5) to find the worst case of emission. Final testing is performed using an open area test site (see figure 4). Testing above 1 GHz is performed in a semi-anechoic room with floor absorbers or a fully anechoic room (see figure 5).

In any case the following procedure is used.

15) Connect the test antenna to the test receiver directly or via external pre-amplifier. Use filters as appropriate to protect the external pre-amplifier from overload. The test receiver is set to analyzer mode with pre-selector activated.
16) Adjust the test receiver for the following settings:
    a) Resolution Bandwidth = 10 kHz for spurious emissions below 1 GHz, and 1 MHz for spurious emissions above 1GHz.
    b) Video Bandwidth = 300 kHz for spurious emissions below 1 GHz, and 3 MHz for spurious emissions above 1 GHz.
    c) Sweep Speed slow enough to maintain measurement calibration.
    d) Detector Mode = Positive Peak.
17) Place the transmitter to be tested on the turntable in the test site.
18) Turn on the transmitter.
19) Measurements shall be made from the lowest radio frequency generated in the equipment to the tenth harmonic of the carrier.
20) For each emission frequency, raise and lower the test antenna from 1 m to 4 m to obtain a maximum reading on the test receiver with the test antenna at horizontal polarization. Then the turntable is rotated by 360° to determine the maximum reading. Repeat this procedure to obtain the highest possible reading. Record this maximum reading.
21) Repeat step 20) for each spurious frequency with the test antenna polarized vertically.

22) Remove the transmitter and replace it with a substitution antenna with known gain. The center of the substitution antenna should be approximately at the same location as the center of the transmitter.
23) Feed the substitution antenna at the transmitter end with a signal generator connected to the antenna by means of a non-radiating cable. With the antennas at both ends horizontally polarized, and with the signal generator tuned to a critical spurious frequency, raise and lower the test antenna to obtain a maximum reading at the test receiver. Adjust the level of the signal generator output until the previously recorded maximum reading for this set of conditions is obtained. Record the level setting of the signal generator.
    Note: To identify critical frequencies, correction factors determined at predefined frequencies for horizontal and vertical polarization according to the procedure above are added to the reading using linear interpolation.
24) Repeat step 23) with both antennas vertically polarized for each critical spurious frequency.
25) Disconnect the cable from the substitution antenna and connect it to the test receiver. Measure the power of the signal generator set to the frequencies and levels recorded in steps 23) and 24).
26) For each frequency calculate the power in dBm into a reference ideal half-wave dipole antenna by adding the gain of the substitution antenna used relative to an ideal half-wave dipole antenna

6 Test results

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

6.1 Operating frequencies

Reference(s): 47 CFR Part 90, §90.217

Performed by:	Martin Müller	Date of test:	June 23, 2016
Result:	☒ Test passed	☐ Test not passed	

6.1.1 Requirements

To be exempt from the technical requirements set out in 47 CFR Part 90, Subpart I, transmitters shall operate on

- frequencies below 800 MHz listed in subparts B and C of 47 CFR Part 90, or
- a business category channel above 800 MHz.

6.1.2 Results

Frequency (MHz)	*Listed*	*Used*	*Channels*	*Tested*
460.6500	X	X	01 – 04	X
460.6625	X			
460.6750	X			
460.6875	X			
460.7000	X	X	05 – 08	
460.7125	X			
460.7250	X			
460.7375	X			
460.7500	X	X	09 – 12	
460.7625	X			
460.7750	X			
460.7875	X			
460.8000	X	X	13 – 16	
460.8125	X			
460.8250	X			
460.8375	X			
460.8500	X	X	17 – 20	
460.8625	X			
460.8750	X			
460.8875	X			
460.9000	X			
460.9125	X			
460.9250	X			
460.9375	X			
460.9500	X			
460.9625	X			
460.9750	X			
460.9875	X			
461.0000	X			
461.0125	X			
461.0250	X	X	21 – 24	
461.0375	X			
461.0500	X			
461.0625	X			
461.0750	X			
461.0875	X			
461.1000	X			

Frequency (MHz)	*Listed*	*Used*	*Channels*	*Tested*
461.1125	X			
461.1250	X	X	25 – 28	
461.1375	X			
461.1500	X	X	29 – 32	
461.1625	X			
461.1750	X			
461.1875	X			
461.2000	X			
461.2125	X			
461.2250	X			
461.2375	X			
461.2500	X			
461.2625	X			
461.2750	X			
461.2875	X			
461.3000	X	X	33 – 36	X
461.3125	X			
461.3250	X			
461.3375	X			
461.3500	X	X	37 – 40	
461.3625	X			
461.3750	X	X	41 – 44	
461.3875	X			
461.4000	X	X	45 – 48	
461.4125	X			
461.4250	X			
461.4375	X			
461.4500	X	X	49 – 52	
461.4625	X			
461.4750	X			
461.4875	X			
461.5000	X	X	53 – 56	
461.5125	X			
461.5250	X	X	57 – 60	
461.5375	X			
461.5500	X			
461.5625	X	X	61 – 64	X

Table 8: List of operating frequencies used

Notes:

1. All possible frequencies as defined by operating frequency range and channel spacing are considered. If used they have to be listed.
2. Any frequency listed in subpart B or C is indicated accordingly. All frequencies above are part of the “Industrial/Business Pool” as defined in Subpart C, §90.35.

6.2 Maximum output power

Reference(s): 47 CFR Part 90, §90.217

6.2.1 Measurement procedures

The maximum output power is measured
☒ conducted at antenna connector according to measurement procedure “Conducted output power” described in clause 5.1
☒ radiated as effective radiated power (ERP) according to measurement procedure “Radiated output power” described in clause 5.2
with the transmitter operating unmodulated.

6.2.2 Requirements

To be exempt from the technical requirements set out in 47 CFR Part 90, Subpart I, transmitters shall have an output power not exceeding 120 milliwatts (20.79 dBm).

6.2.3 Maximum conducted output power

Performed by:	Martin Müller	Date of test:	June 23, 2016
Climatic conditions:	Ambient temperature 25 °C	Relative humidity 53 %	Barometric pressure 98 kPa
Result[2]:	☒ Test passed	☐ Test not passed	

6.2.3.1 Test equipment

Type	Designation	Manufacturer	Inventory no.
☐ Compact Diagnostic Chamber (CDC)	VK041.0174	Albatross Projects	E00026
☐ Semi-anechoic chamber (SAC)	SAC3	Albatross Projects	E00716
☐ EMI test receiver (CDC)	ESCI 3	Rohde & Schwarz	E00001
☐ EMI test receiver (OATS)	ESCI 3	Rohde & Schwarz	E00552
☐ EMI test receiver (SAC)	ESR 7	Rohde & Schwarz	E00739
☒ EMI test receiver	ESU 26	Rohde & Schwarz	W00002
☐ Measurement software	E10 v1.4.12	EMV **TESTHAUS**	W00053
☐ Measurement software	EMC32 V10	Rohde & Schwarz	E00777, E00778

[2] For information about measurement uncertainties see page 58

6.2.3.2 Test results

The maximum conducted output power P_{cond} is calculated according to:

$$P_{cond}\ [\text{dBm}] = P_{meas}\ [\text{dBm}] + A_{cable}\ [\text{dB}]$$

with: P_{meas} = measured power in dBm

A_{cable} = attenuation of test cable in dB (see table 5)

Frequency (MHz)	*P_{meas} (dBm)*	*Detector*	*A_{cable} (dB)*	*P_{cond} (dBm)*	*Limit (dBm)*	*Margin (dB)*	*Result*
460.6500	12.12	Peak	0.90	13.02	20.79	7.77	Passed
461.3000	12.69	Peak	0.90	13.59	20.79	7.20	Passed
461.5620	12.43	Peak	0.90	13.33	20.79	7.46	Passed

Table 9: Test results of maximum conducted output power

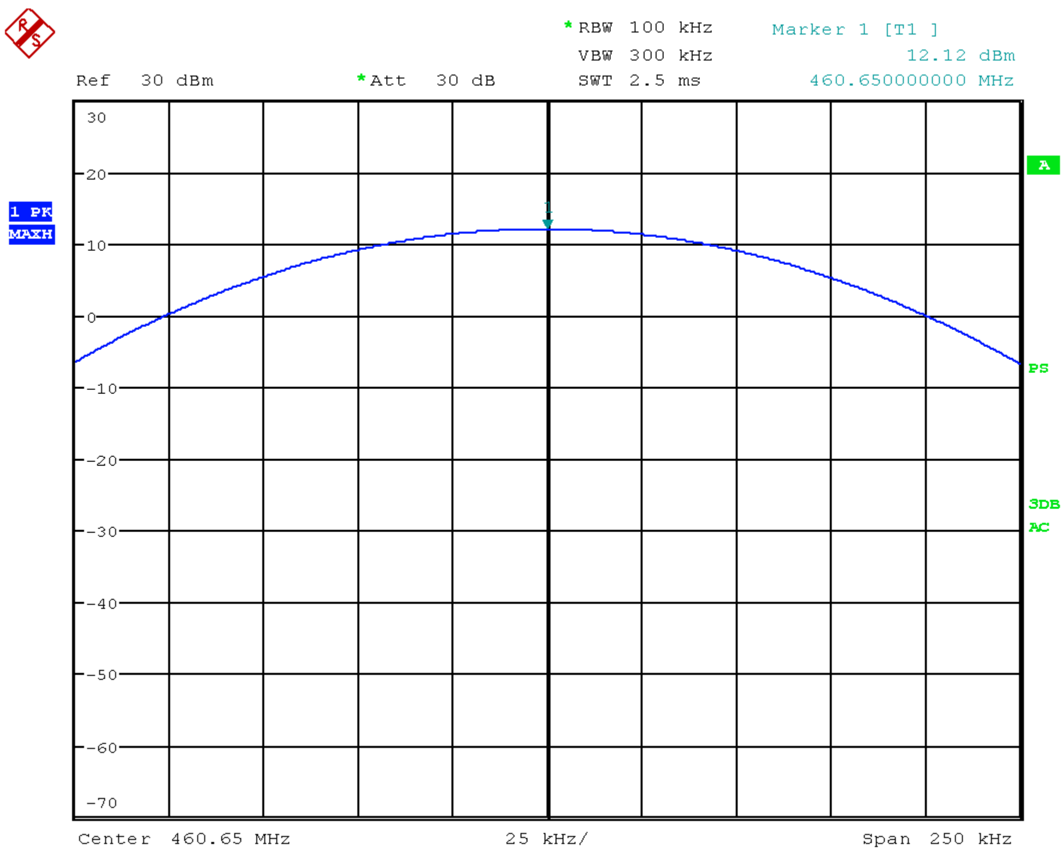


Figure 6: Chart of maximum conducted output power test – bottom channel

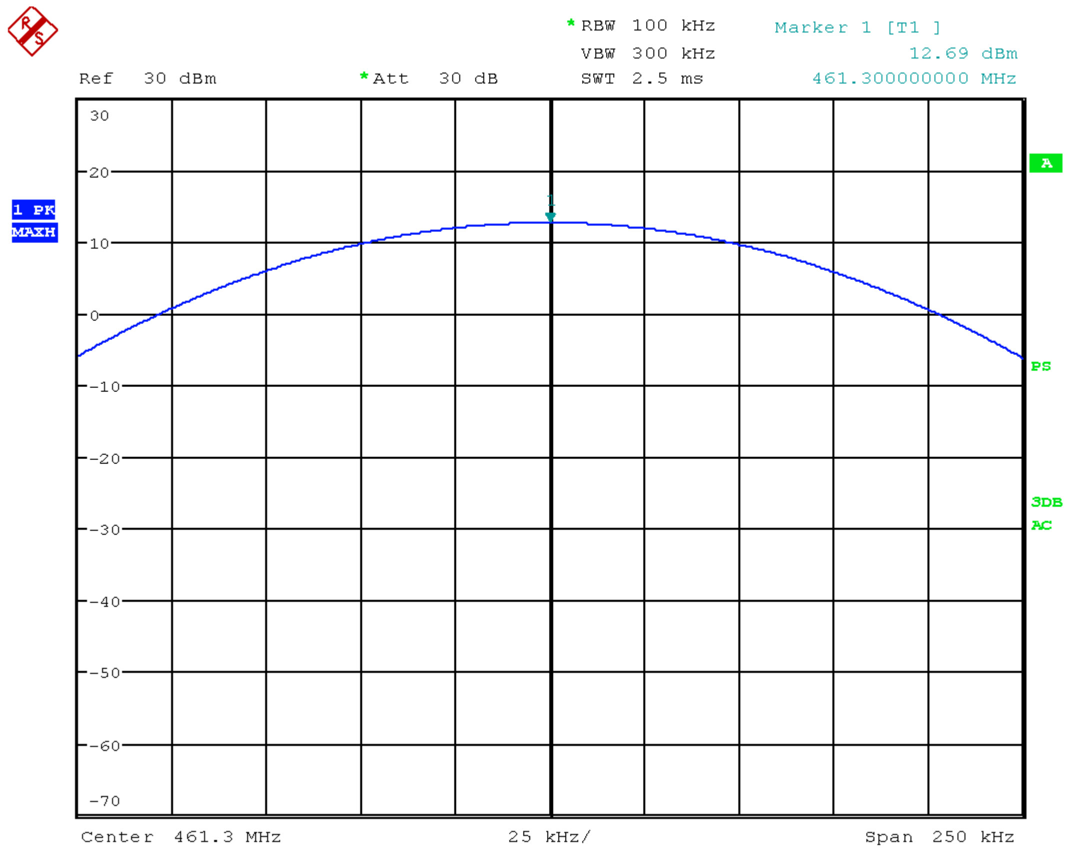


Figure 7: Chart of maximum conducted output power test – middle channel

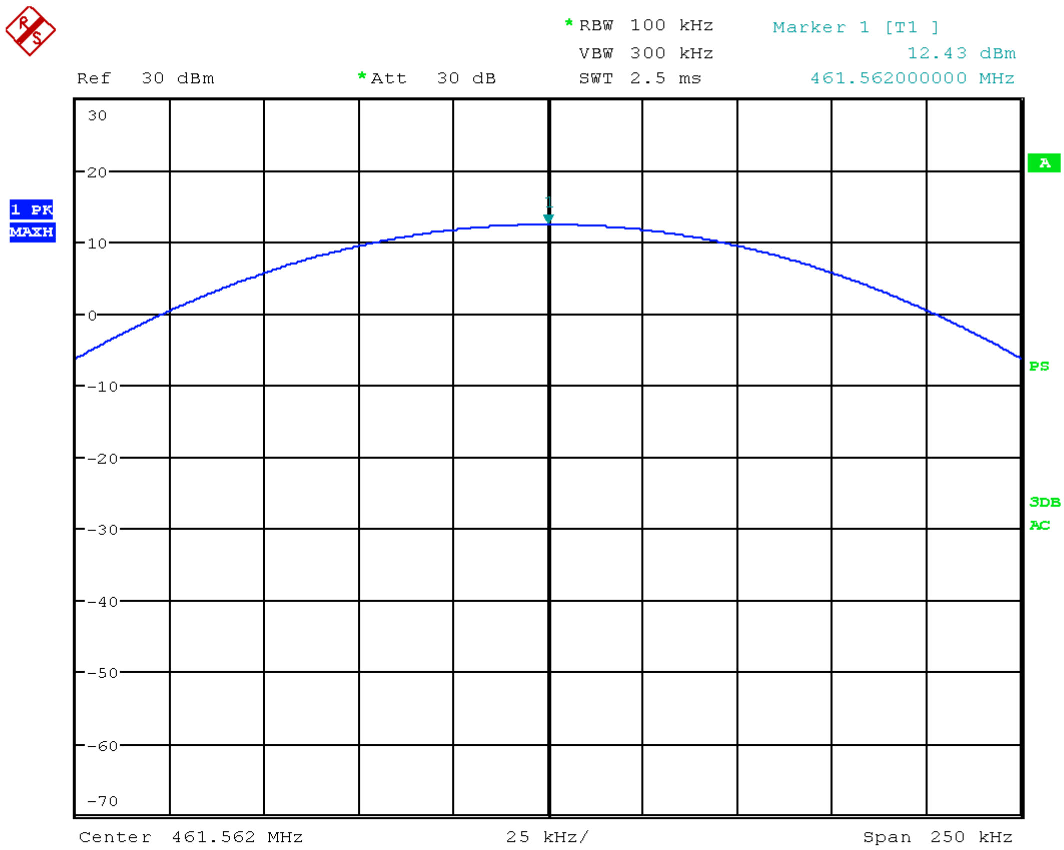


Figure 8: Chart of maximum conducted output power test – top channel

6.2.4 Maximum radiated output power

Performed by:	Martin Müller	Date of test:	June 23, 2016
Climatic conditions:	Ambient temperature 25 °C	Relative humidity 53 %	Barometric pressure 98 kPa
Result[3]:	☒ Test passed	☐ Test not passed	

6.2.4.1 Test equipment

Type	Designation	Manufacturer	Inventory no.
☐ Compact Diagnostic Chamber (CDC)	VK041.0174	Albatross Projects	E00026
☒ Open area test site (OATS)	---	EMV **TESTHAUS**	E00354
☐ Semi-anechoic chamber (SAC)	SAC3	Albatross Projects	E00716
☐ EMI test receiver (CDC)	ESCI 3	Rohde & Schwarz	E00001
☒ EMI test receiver (OATS)	ESCI 3	Rohde & Schwarz	E00552
☐ EMI test receiver (SAC)	ESR 7	Rohde & Schwarz	E00739
☐ EMI test receiver	ESU 26	Rohde & Schwarz	W00002
☐ Preamplifier (500 MHz - 18 GHz)	AMF-5D-00501800-28-13P	Miteq	W00089
☐ Loop antenna	HFH2-Z2	Rohde & Schwarz	E00060
☐ TRILOG broadband antenna (CDC)	VULB 9160	Schwarzbeck	E00011
☒ TRILOG broadband antenna (OATS)	VULB 9163	Schwarzbeck	E00013
☐ TRILOG broadband antenna (SAC)	VULB 9162	Schwarzbeck	E00643
☐ Horn antenna	BBHA 9120D	Schwarzbeck	W00053
☐ Horn antenna	BBHA 9170	Schwarzbeck	W00055
☐ Measurement software	E10 v1.4.12	EMV **TESTHAUS**	W00053
☐ Measurement software	EMC32 V10	Rohde & Schwarz	E00777, E00778

[3] For information about measurement uncertainties see page 58

6.2.4.2 Test results

The maximum radiated output power P_{ERP} is measured as the maximum effective radiated power (ERP). It is calculated according to:

$$P_{ERP} \text{ [dBm]} = P_{meas} \text{ [dBm]} + C_{sub} \text{ [dB]}$$

with: P_{meas} = measured power in dBm
C_{sub} = substitution factor determined without EUT

Frequency (MHz)	*EUT position*	Antenna *polarization*	*height (cm)*	*Table position (°)*	P_{meas} *(dBm)*	*Detector*	C_{sub} *(dB)*	P_{ERP} *(dBm)*	*Limit (dBm)*	*Margin (dB)*	*Result*
460.6540	1H	horizontal	106	191	-19.83	Peak	34.56	14.73	20.79	6.06	Passed
461.3050	1V	vertical	172	126	-21.83	Peak	36.41	14.58	20.79	6.21	Passed
461.5690	1H	horizontal	195	236	-19.65	Peak	34.55	14.90	20.79	5.89	Passed

Table 10: Test results of maximum radiated output power

6.3 Occupied bandwidth (-30 dB)

Reference(s): 47 CFR Part 90, §90.217(b)

Performed by:	Martin Müller	Date of test:	June 24, 2016
Climatic conditions:	Ambient temperature 24 °C	Relative humidity 51 %	Barometric pressure 98 kPa
Result[4]:	☒ 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
☐	Semi-anechoic chamber (SAC)	SAC3	Albatross Projects	E00716
☒	Climatic chamber	VC³ 4034	Vötsch Industrietechnik	C00015
☐	EMI test receiver (CDC)	ESCI 3	Rohde & Schwarz	E00001
☐	EMI test receiver (OATS)	ESCI 3	Rohde & Schwarz	E00552
☐	EMI test receiver (SAC)	ESR 7	Rohde & Schwarz	E00739
☒	EMI test receiver	ESU 26	Rohde & Schwarz	W00002
☐	Preamplifier (500 MHz - 18 GHz)	AMF-5D-00501800-28-13P	Miteq	W00089
☐	Loop antenna	HFH2-Z2	Rohde & Schwarz	E00060
☐	TRILOG broadband antenna (CDC)	VULB 9160	Schwarzbeck	E00011
☐	TRILOG broadband antenna (OATS)	VULB 9163	Schwarzbeck	E00013
☐	TRILOG broadband antenna (SAC)	VULB 9162	Schwarzbeck	E00643
☐	Horn antenna	BBHA 9120D	Schwarzbeck	W00053
☐	Horn antenna	BBHA 9170	Schwarzbeck	W00055
☐	Measurement software	E10 v1.4.12	EMV **TESTHAUS**	W00053
☐	Measurement software	EMC32 V10	Rohde & Schwarz	E00777, E00778

[4] For information about measurement uncertainties see page 58

6.3.2 Measurement procedures

The occupied bandwidth is specified as the frequency range where the modulated spectrum is attenuated 30 dB below the unmodulated carrier (-30 dB points) extended by the bandwidth required for frequency stability. Tests are performed according to measurement procedures “Occupied bandwidth” described in clause 5.3 and “Frequency stability” described in clause 5.4.

6.3.3 Requirements

To be exempt from the technical requirements set out in 47 CFR Part 90, Subpart I, for transmitters designed to operate with a 12.5 kHz channel bandwidth, the sum of the bandwidth occupied by the emitted signal plus the bandwidth required for frequency stability shall be adjusted so that any emission appearing on a frequency 25 kHz or more removed from the assigned frequency is attenuated at least 30 dB below the unmodulated carrier.

6.3.4 Test results

The offset from the assigned frequency caused by the occupied bandwidth *OBW* is calculated according to:

$$\Delta f_{OBW(low)} \text{ [kHz]} = f_{-30dB(low)} \text{ [kHz]} - f_{assigned} \text{ [kHz]} - \Delta f_{temp(low)} \text{ [kHz]} - \Delta f_{volt(low)} \text{ [kHz]}$$

$$\Delta f_{OBW(high)} \text{ [kHz]} = f_{-30dB(high)} \text{ [kHz]} - f_{assigned} \text{ [kHz]} + \Delta f_{temp(high)} \text{ [kHz]} + \Delta f_{volt(high)} \text{ [kHz]}$$

with:

$f_{-30dB(low)}$ = lower frequency in kHz where emission is at least 30 dB below the unmodulated carrier

$f_{-30dB(high)}$ = upper frequency in kHz where emission is at least 30 dB below the unmodulated carrier

$f_{assigned}$ = assigned frequency in kHz

$\Delta f_{temp(low)}$ = maximum absolute value of negative frequency offset to frequency at nominal conditions caused by temperature variation in kHz

$\Delta f_{volt(low)}$ = maximum absolute value of negative frequency offset to frequency at nominal conditions caused by voltage variation in kHz

$\Delta f_{temp(high)}$ = maximum absolute value of positive frequency offset to frequency at nominal conditions caused by temperature 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 assigned (kHz)	Index	f -30dB (kHz)	Δf temp (kHz)	Δf volt (kHz)	Δf OBW (kHz)	Limit (kHz)	Margin (kHz)	Result
460650.000	low	460645.329	1.007	0.022	-5.700	-25	19.300	Passed
	high	460655.377	0.645	0.110	6.132	25	18.868	Passed
461300.000	low	461295.240	0.960	0.023	-5.743	-25	19.257	Passed
	high	461305.288	0.701	0.056	6.045	25	18.955	Passed
461562.000	low	461557.769	0.956	0.027	-5.214	-25	19.786	Passed
	high	461567.817	0.701	0.033	6.551	25	18.449	Passed

Table 11: Test results for occupied bandwidth

6.3.4.1 Identification of -30 dB points

The -30 dB points for occupied bandwidth are measured at nominal conditions.

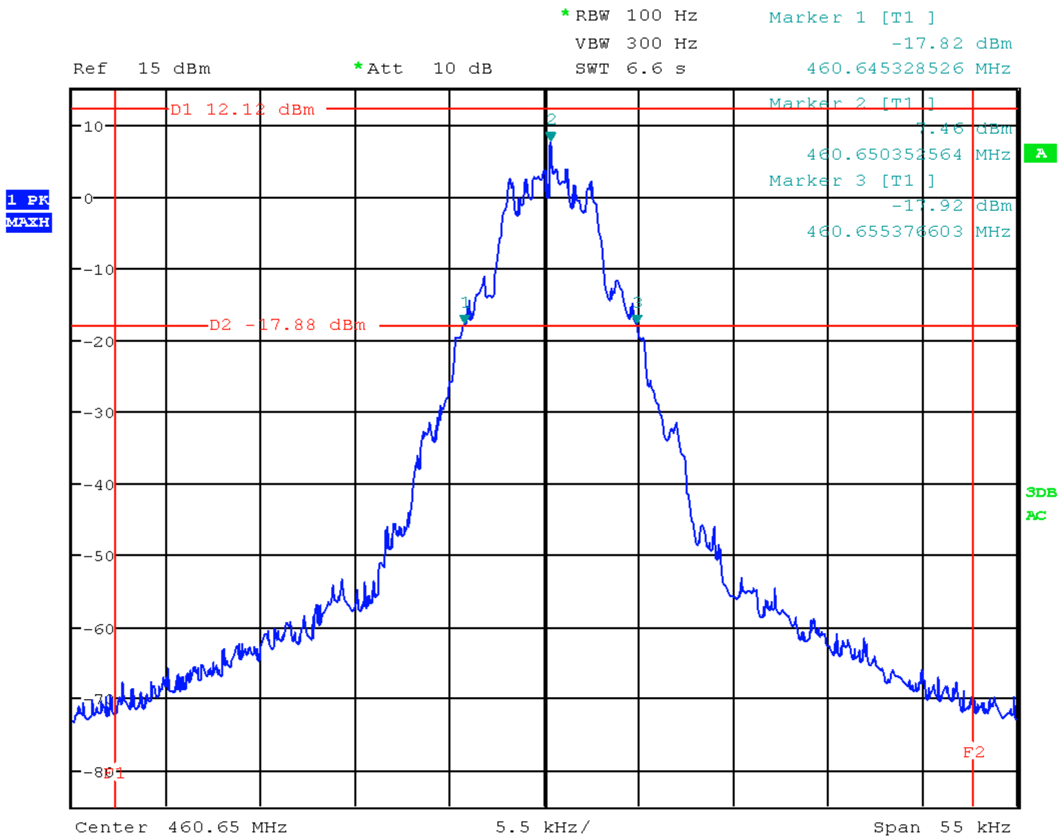


Figure 9: Chart of -30 dB points for occupied bandwidth test – bottom channel

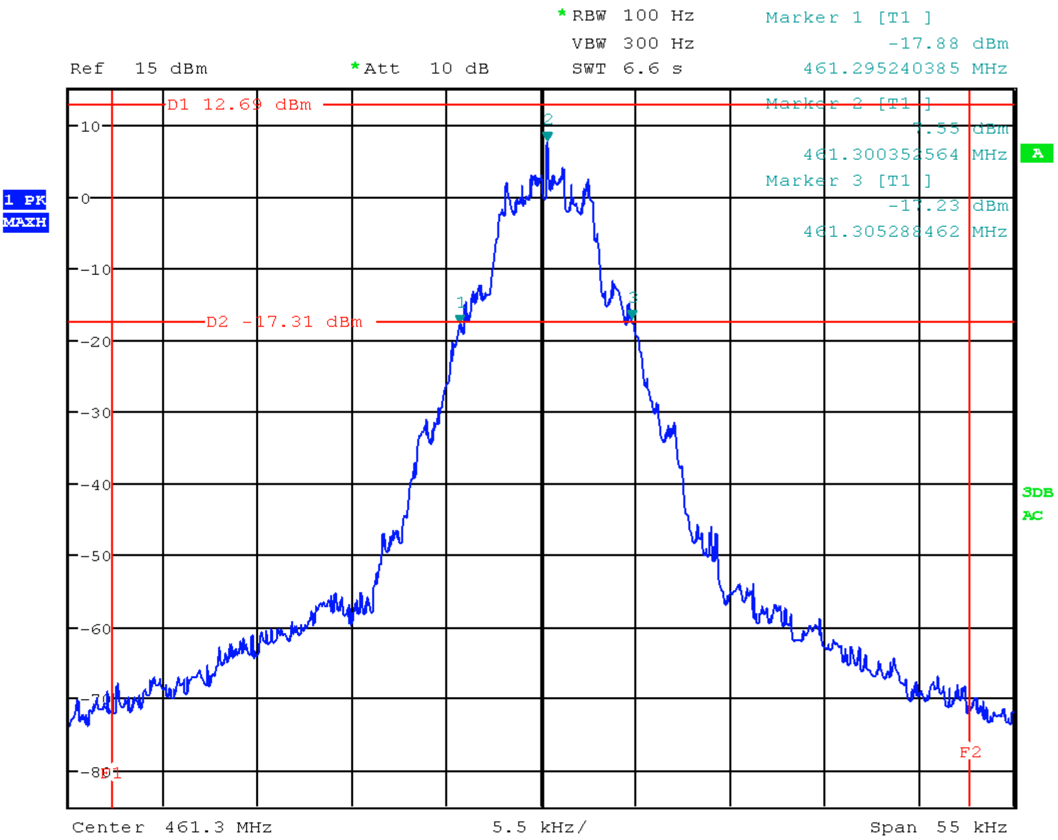


Figure 10: Chart of -30 dB points for occupied bandwidth test – middle channel

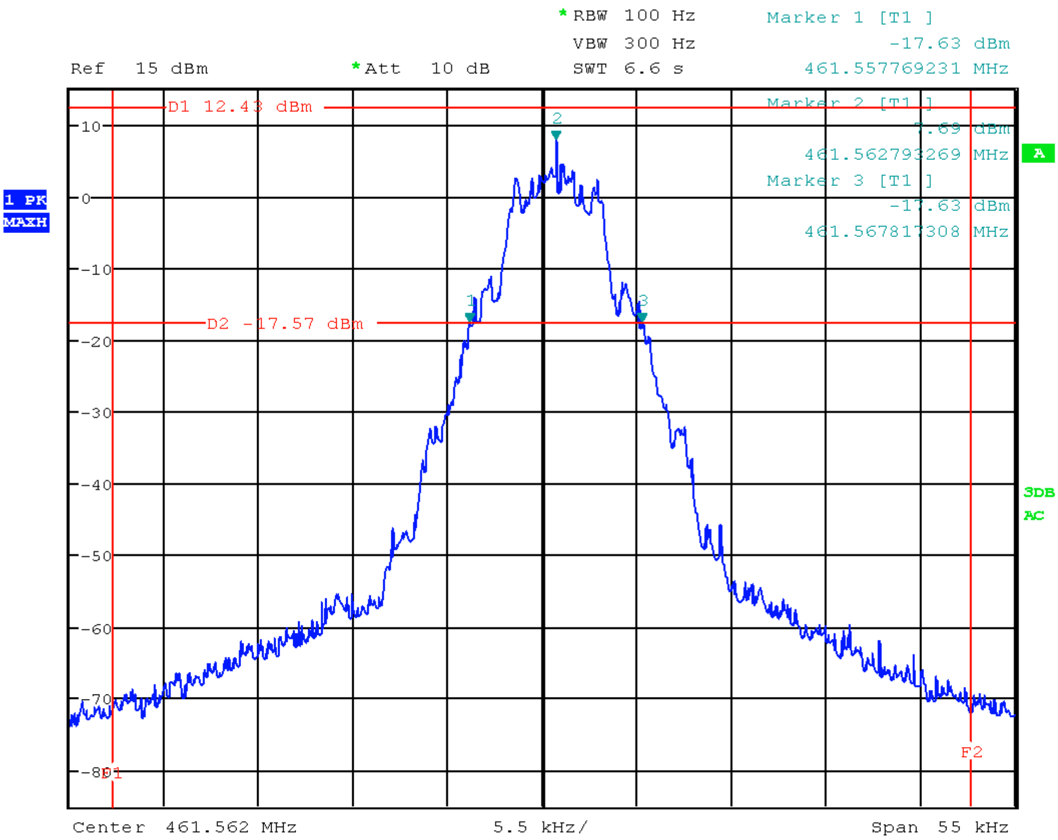
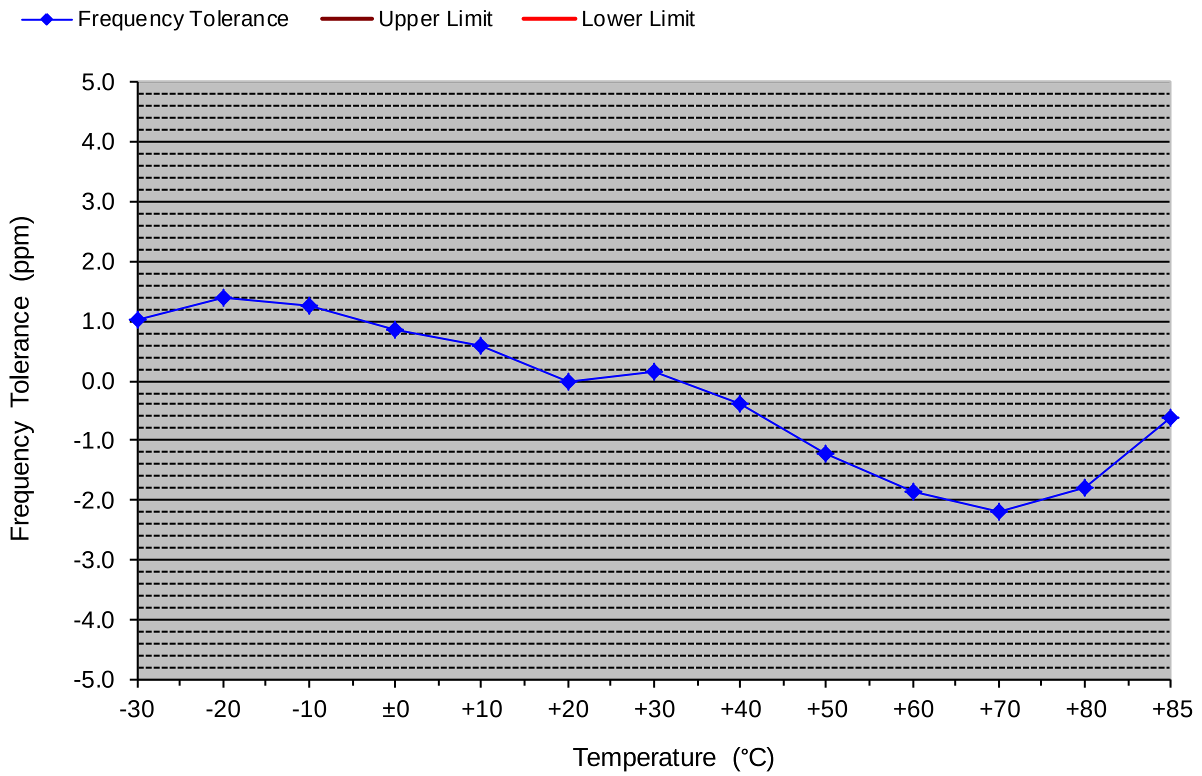


Figure 11: Chart of -30 dB points for occupied bandwidth test – top channel

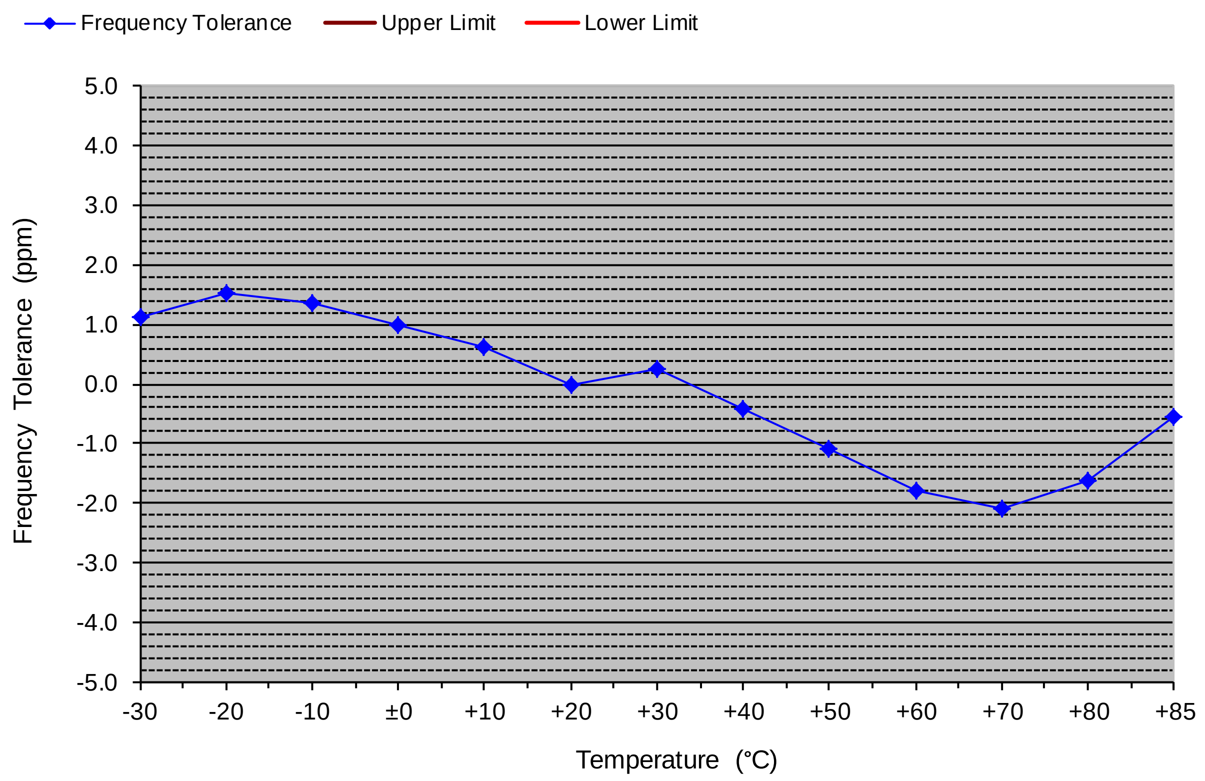
6.3.4.2 Frequency stability vs. temperature

The frequency stability vs. temperature is measured with nominal voltage supply.



Supply voltage:	4.2 V	Frequency under nominal conditions:		460.650061 MHz		
Temperature (°C)	Frequency (MHz)	Frequency Tolerance (Hz)	(ppm)	Upper Limit (ppm)	Lower Limit (ppm)	Margin (ppm)
-30	460.650528	467	1.0			
-20	460.650706	645	1.4			
-10	460.650635	574	1.2			
±0	460.650453	392	0.9			
+10	460.650331	270	0.6			
+20	460.650061	0	0.0			
+30	460.650124	63	0.1			
+40	460.649887	-174	-0.4			
+50	460.649499	-562	-1.2			
+60	460.649204	-857	-1.9			
+70	460.649054	-1007	-2.2			
+80	460.649243	-818	-1.8			
+85	460.649769	-292	-0.6			

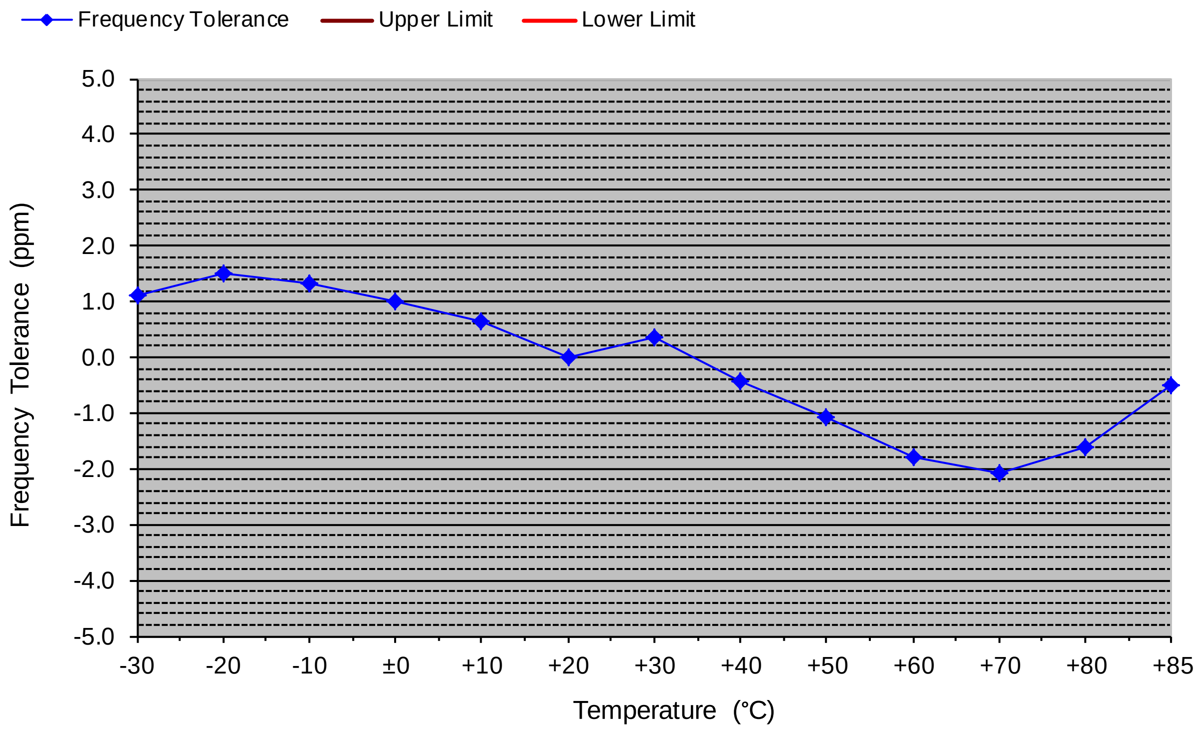
Table 12: Test results for frequency stability vs. temperature – bottom channel



Supply voltage: 4.2 V Frequency under nominal conditions: 461.300012 MHz

Temperature (°C)	Frequency (MHz)	Frequency Tolerance (Hz)	(ppm)	Upper Limit (ppm)	Lower Limit (ppm)	Margin (ppm)
-30	461.300531	519	1.1			
-20	461.300713	701	1.5			
-10	461.300634	622	1.3			
±0	461.300462	450	1.0			
+10	461.300306	294	0.6			
+20	461.300012	0	0.0			
+30	461.300133	121	0.3			
+40	461.299821	-191	-0.4			
+50	461.299504	-508	-1.1			
+60	461.299192	-820	-1.8			
+70	461.299052	-960	-2.1			
+80	461.299257	-755	-1.6			
+85	461.299753	-259	-0.6			

Table 13: Test results for frequency stability vs. temperature – middle channel



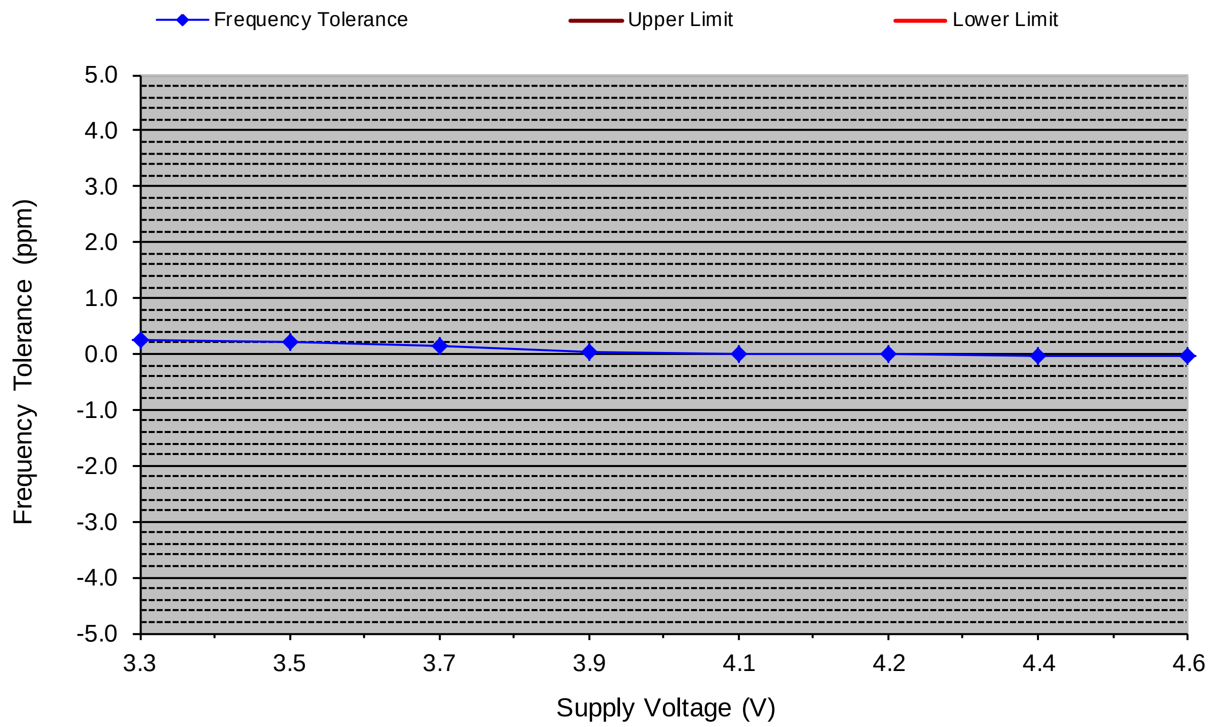
Supply voltage: 4.2 V Frequency under nominal conditions: 461.56251 MHz

Temperature (°C)	Frequency (MHz)	Frequency Tolerance (Hz)	Frequency Tolerance (ppm)	Upper Limit (ppm)	Lower Limit (ppm)	Margin (ppm)
-30	461.563029	519	1.1			
-20	461.563211	701	1.5			
-10	461.563128	618	1.3			
±0	461.562972	462	1.0			
+10	461.562803	293	0.6			
+20	461.562510	0	0.0			
+30	461.562669	159	0.3			
+40	461.562314	-196	-0.4			
+50	461.562017	-493	-1.1			
+60	461.561691	-819	-1.8			
+70	461.561554	-956	-2.1			
+80	461.561764	-746	-1.6			
+85	461.562271	-239	-0.5			

Table 14: Test results for frequency stability vs. temperature – top channel

6.3.4.3 Frequency stability vs. voltage

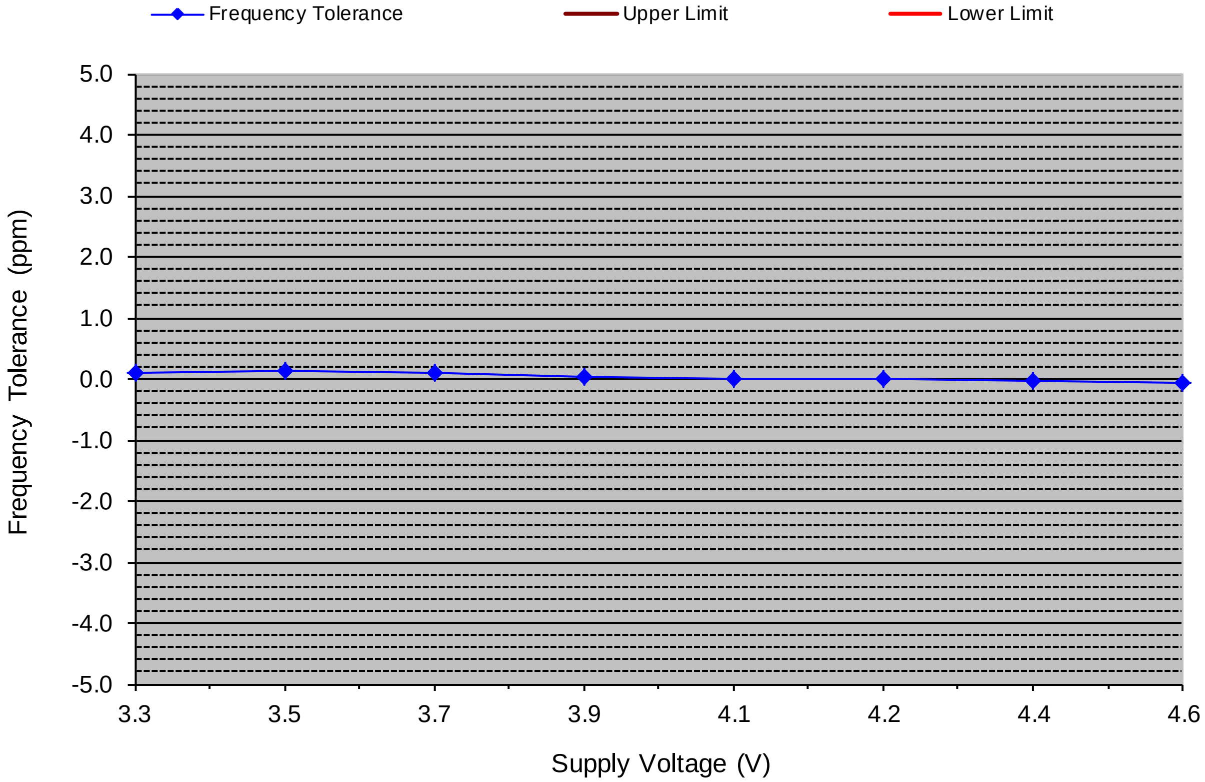
The frequency stability vs. voltage is measured at nominal temperature.



Temperature:	+20 °C	Battery End Point:	Not applicable
Frequency under nominal conditions:	460.650061 MHz		

Supply Voltage (V)	Frequency (MHz)	Frequency Tolerance (Hz)	Frequency Tolerance (ppm)	Upper Limit (ppm)	Lower Limit (ppm)	Margin (ppm)
3.3	460.650171	110	0.2			
3.5	460.650161	100	0.2			
3.7	460.650127	66	0.1			
3.9	460.650083	22	0.0			
4.1	460.650068	7	0.0			
4.2	460.650061	0	0.0			
4.4	460.650047	-14	0.0			
4.6	460.650039	-22	0.0			

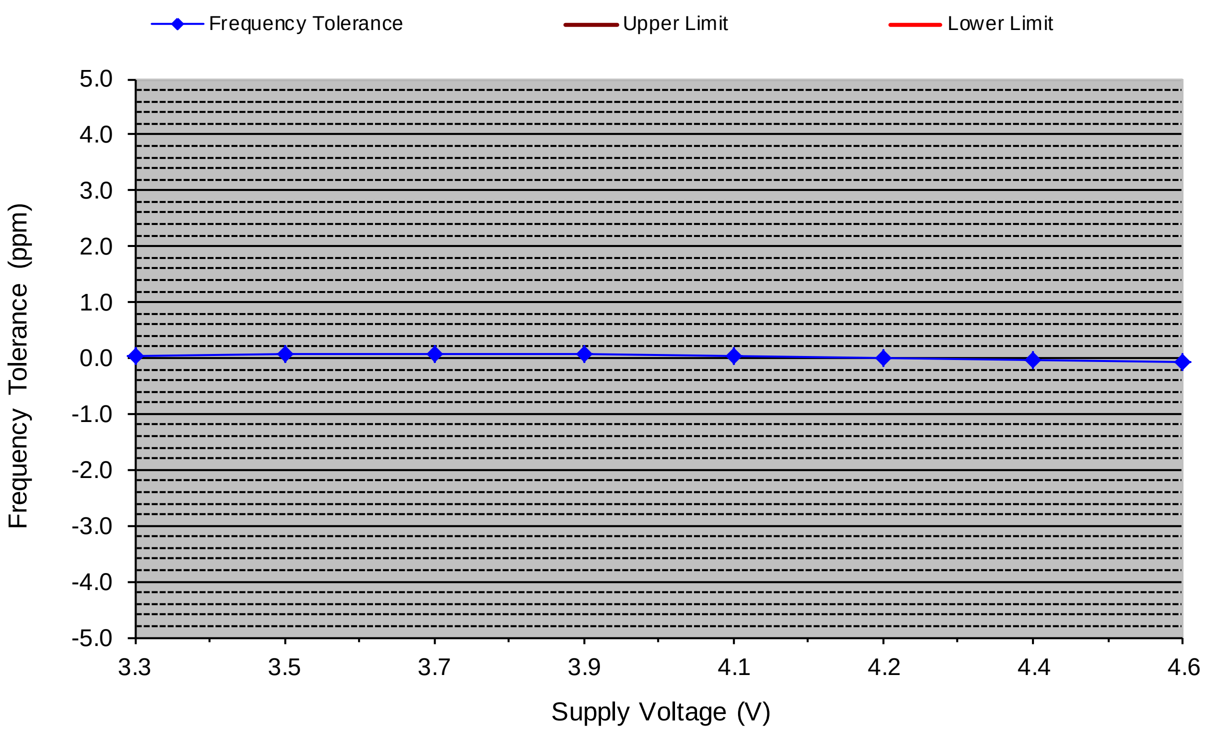
Table 15: Test results for frequency stability vs. voltage – bottom channel



Temperature:	+20 °C		Battery End Point:		Not applicable
Frequency under nominal conditions:	461.300015 MHz				

Supply Voltage (V)	Frequency (MHz)	Frequency Tolerance (Hz)	Frequency Tolerance (ppm)	Upper Limit (ppm)	Lower Limit (ppm)	Margin (ppm)
3.3	461.300065	50	0.1			
3.5	461.300071	56	0.1			
3.7	461.300058	43	0.1			
3.9	461.300034	19	0.0			
4.1	461.300017	2	0.0			
4.2	461.300015	0	0.0			
4.4	461.300001	-14	0.0			
4.6	461.299992	-23	0.0			

Table 16: Test results for frequency stability vs. voltage – middle channel



Temperature:	+20 °C		Battery End Point:		Not applicable
Frequency under nominal conditions:	461.56251 MHz				

Supply Voltage (V)	Frequency (MHz)	Frequency Tolerance (Hz)	Frequency Tolerance (ppm)	Upper Limit (ppm)	Lower Limit (ppm)	Margin (ppm)
3.3	461.562531	21	0.0			
3.5	461.562543	33	0.1			
3.7	461.562542	32	0.1			
3.9	461.562535	25	0.1			
4.1	461.562522	12	0.0			
4.2	461.562510	0	0.0			
4.4	461.562501	-9	0.0			
4.6	461.562483	-27	-0.1			

Table 17: Test results for frequency stability vs. voltage – top channel

6.4 Spurious emissions

Reference(s): 47 CFR Part 90, §90.217(b)

6.4.1 Measurement procedures

Spurious emissions are measured
☒ conducted at antenna connector according to measurement procedure “Conducted emissions at antenna connector” described in clause 5.5
☒ radiated as effective radiated power (ERP) according to measurement procedure “Radiated emissions” described in clause 5.6
with the transmitter operating modulated.

6.4.2 Requirements

Spurious emissions must be attenuated at least 30 dB below the unmodulated carrier.

For radiated measurements from 10 MHz to 30 MHz calculation of electric field strength limit according to KDB 412172, formula 2, is used:

$$ERP = \frac{(E \cdot d)^2}{30 \cdot 1.64} \Leftrightarrow E = \frac{\sqrt{ERP \cdot 30 \cdot 1.64}}{d} \Leftrightarrow E = \frac{\sqrt{2.871 \cdot 10^{-5}\, W \cdot 30 \cdot 1.64}}{3\, m}$$

$$\Rightarrow E = 0.01253\, \frac{V}{m} \Leftrightarrow E = 81.96\, dB\mu V/m$$

with:

E	=	electric field strength in V/m		
ERP	=	effective radiated power in W	=	14.58 dBm - 30 dB = -15.42 dBm
			=	$2.871 \cdot 10^{-5}$ W (lowest ERP level according to table 10 was selected for worst-case limit)
d	=	measurement distance in meters	=	3 m

6.4.3 Conducted spurious emissions

Performed by:	Martin Müller	Date of test:	July 12, 2016
Climatic conditions:	Ambient temperature 27 °C	Relative humidity 51 %	Barometric pressure 98 kPa
Result[5]:	☒ Test passed	☐ Test not passed	

6.4.3.1 Test equipment

Type	Designation	Manufacturer	Inventory no.
☐ Compact Diagnostic Chamber (CDC)	VK041.0174	Albatross Projects	E00026
☐ Anechoic chamber		EMV **TESTHAUS**	E00100
☐ EMI test receiver (CDC)	ESCI 3	Rohde & Schwarz	E00001
☒ EMI test receiver	ESU 26	Rohde & Schwarz	W00002
☐ Measurement software	E10 v1.4.12	EMV **TESTHAUS**	W00053
☐ Measurement software	EMC32 V10	Rohde & Schwarz	E00777, E00778

6.4.3.2 Test results

Conducted spurious emissions P_{cond} are calculated according to:

$$P_{cond}\ [\text{dBm}] = P_{meas}\ [\text{dBm}] + A_{cable}\ [\text{dB}]$$

with: P_{meas} = measured power in dBm
A_{cable} = attenuation of test cable in dB (see table 5)

Note: For power levels of the unmodulated carrier see table 9.

[5] For information about measurement uncertainties see page 58

6.4.3.2.1 TX mode

Frequency (MHz)	*P_{meas} (dBm)*	*Detector*	*A_{cable} (dB)*	*P_{cond} (dBm)*	*Limit (dBm)*	*Margin (dB)*	*Result*
460.6400	11.81	Peak	0.90	12.71	20.79	8.08	Carrier
461.3200	11.61	Peak	0.90	12.51	20.79	8.28	Carrier
461.5600	12.10	Peak	0.90	13.00	20.79	7.79	Carrier

Table 18: Results of conducted spurious emissions test – TX

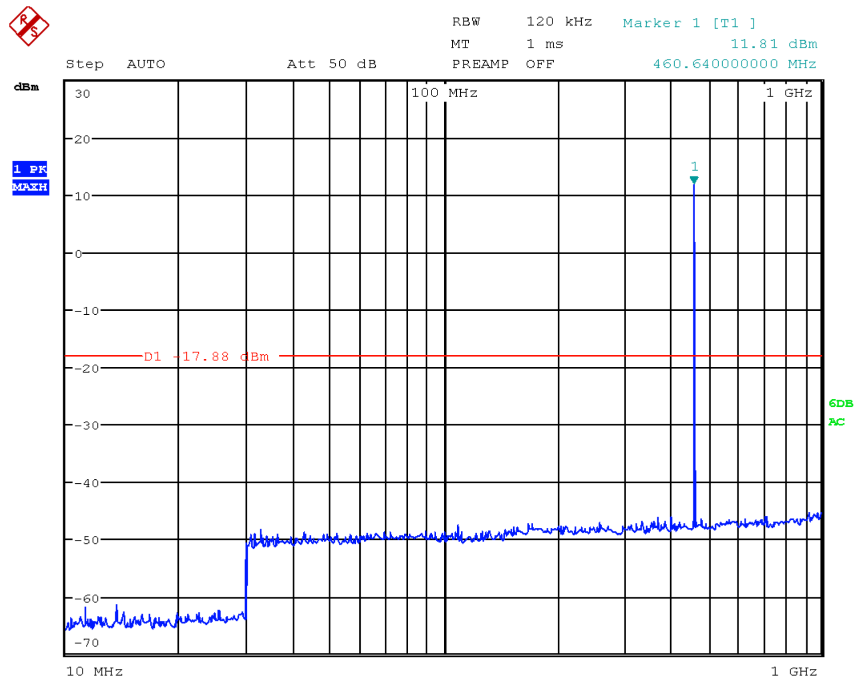


Figure 12: Chart of conducted spurious emissions test 10 MHz to 1 GHz – bottom channel – TX

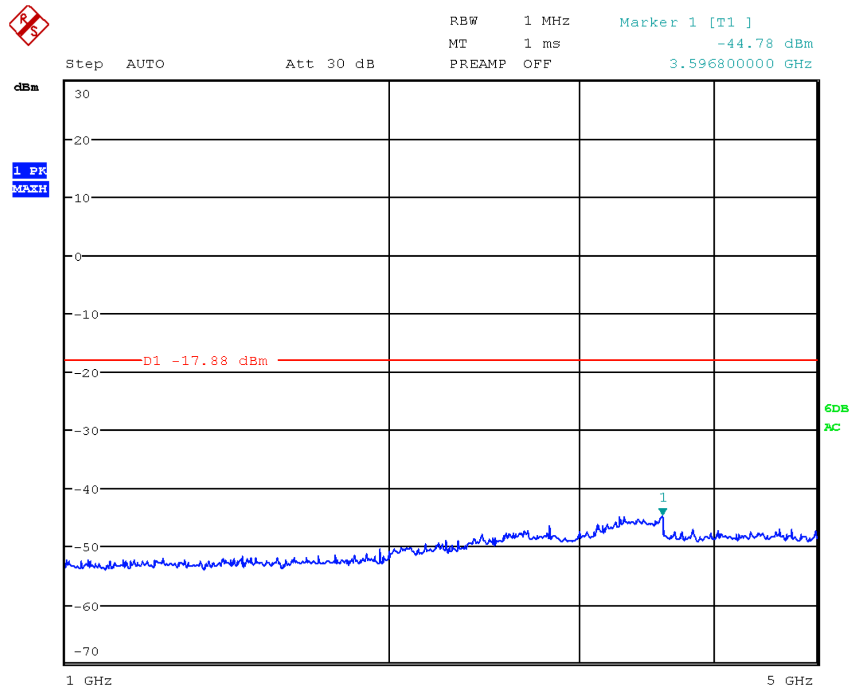


Figure 13: Chart of conducted spurious emissions test 1 GHz to 5 GHz – bottom channel – TX

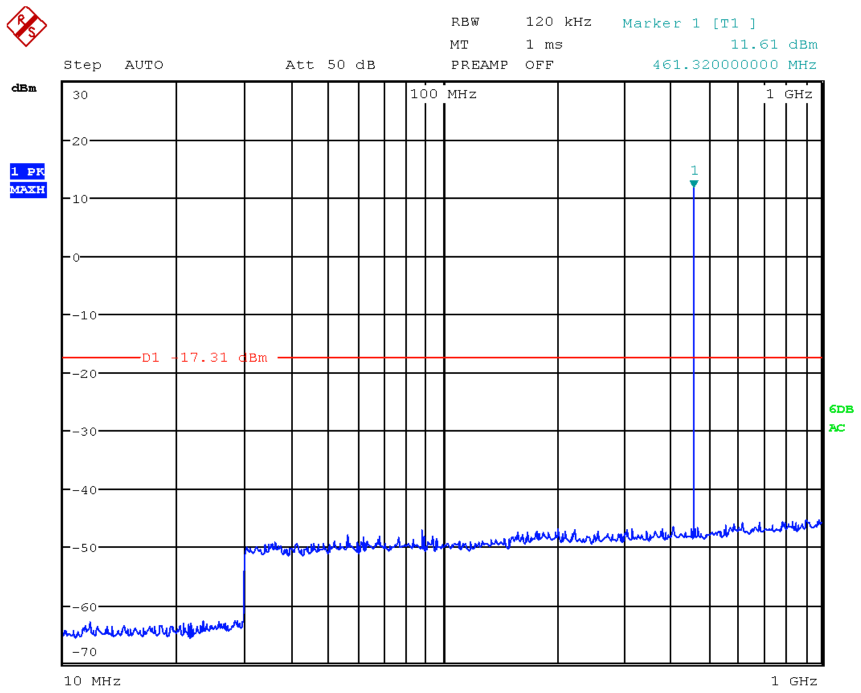


Figure 14: Chart of conducted spurious emissions test 10 MHz to 1 GHz – middle channel – TX

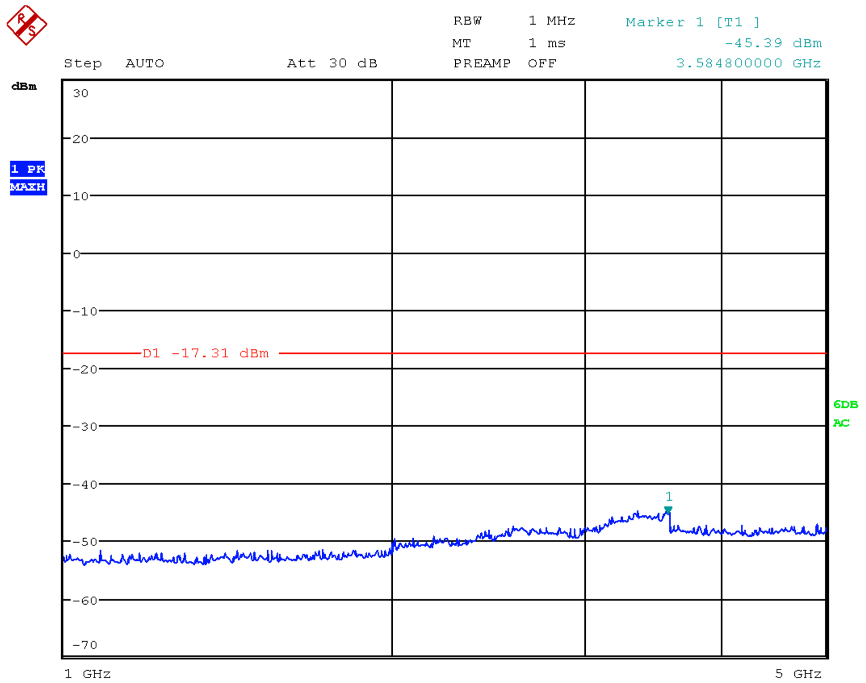


Figure 15: Chart of conducted spurious emissions test 1 GHz to 5 GHz – middle channel – TX

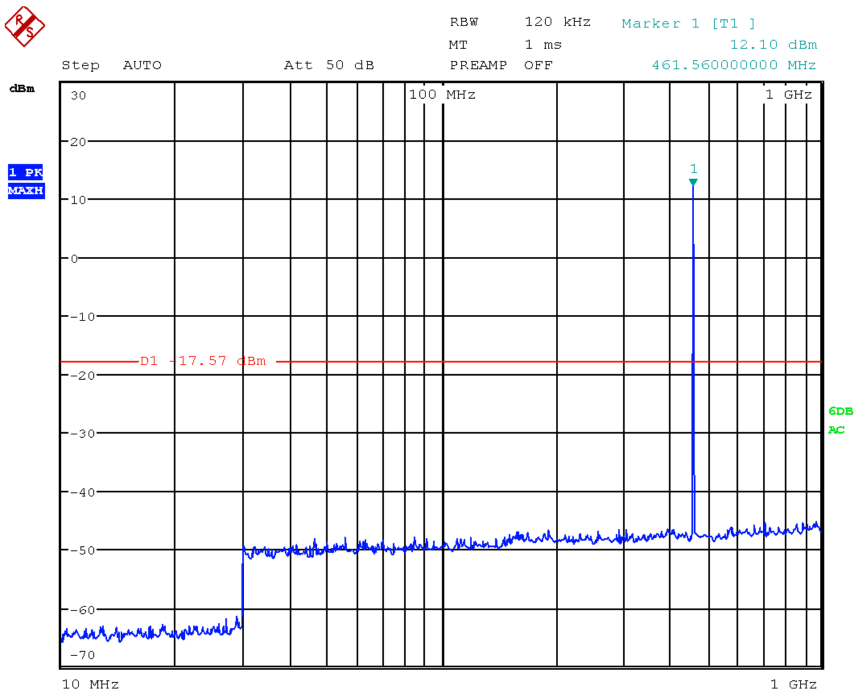


Figure 16: Chart of conducted spurious emissions test 10 MHz to 1 GHz – top channel – TX

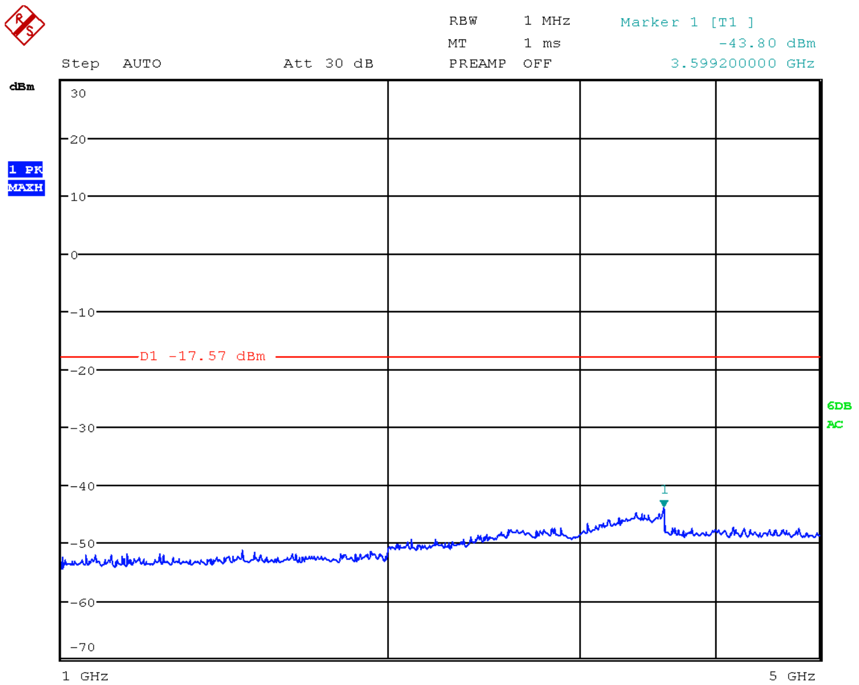


Figure 17: Chart of conducted spurious emissions test 1 GHz to 5 GHz – top channel – TX

6.4.3.2.2 RX mode

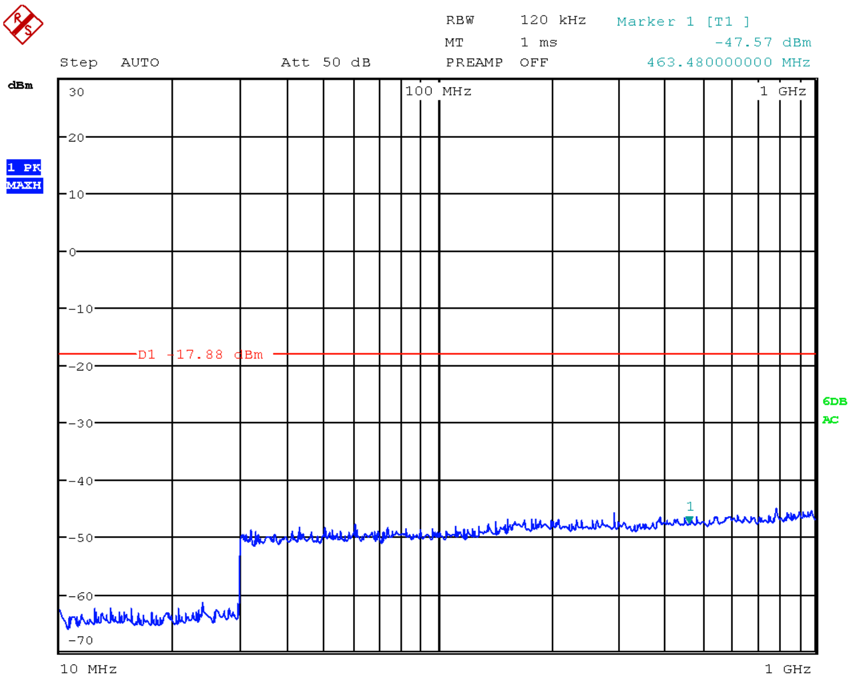


Figure 18: Chart of conducted spurious emissions test 10 MHz to 1 GHz – bottom channel – RX

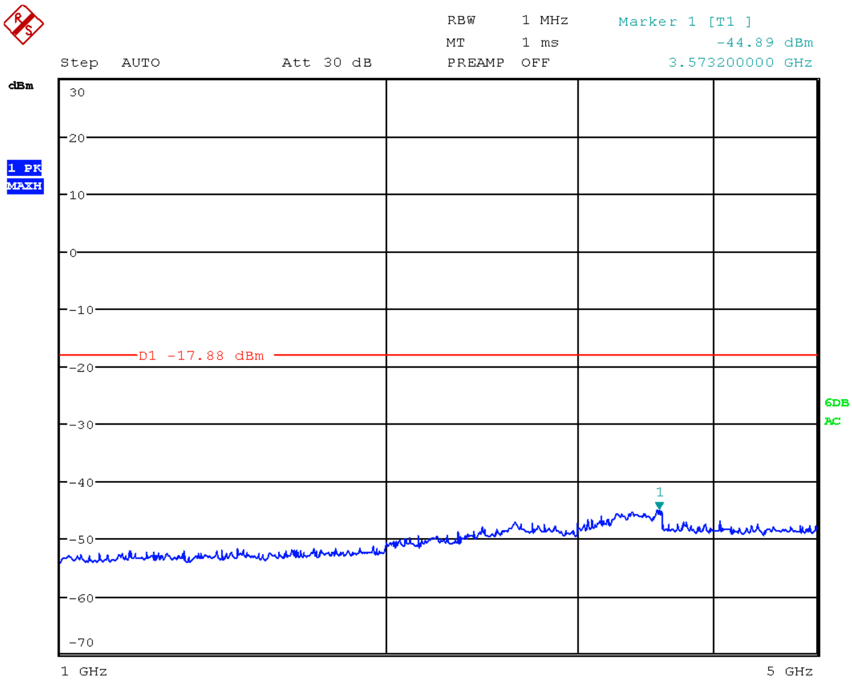


Figure 19: Chart of conducted spurious emissions test 1 GHz to 5 GHz – bottom channel – RX

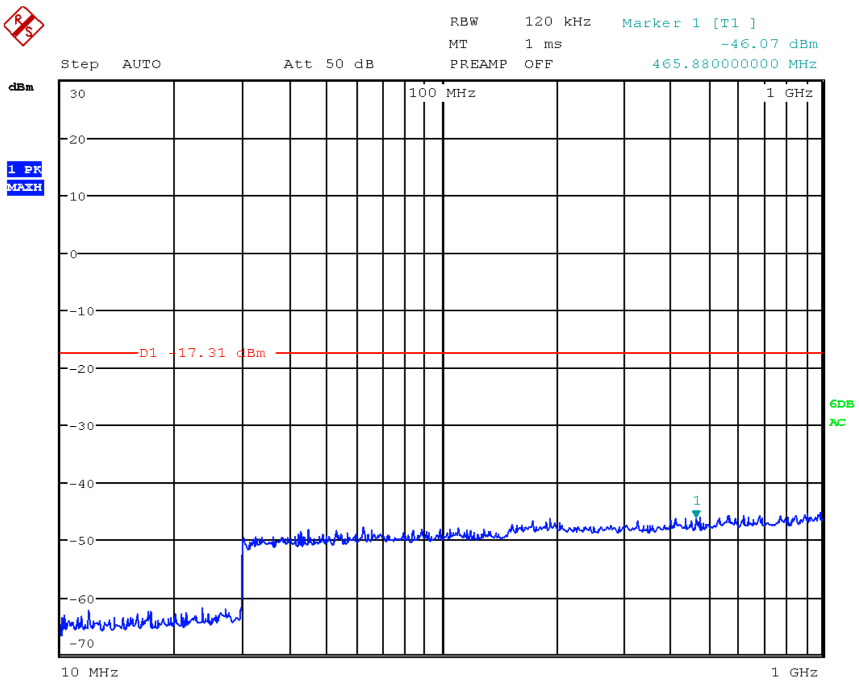


Figure 20: Chart of conducted spurious emissions test 10 MHz to 1 GHz – middle channel – RX

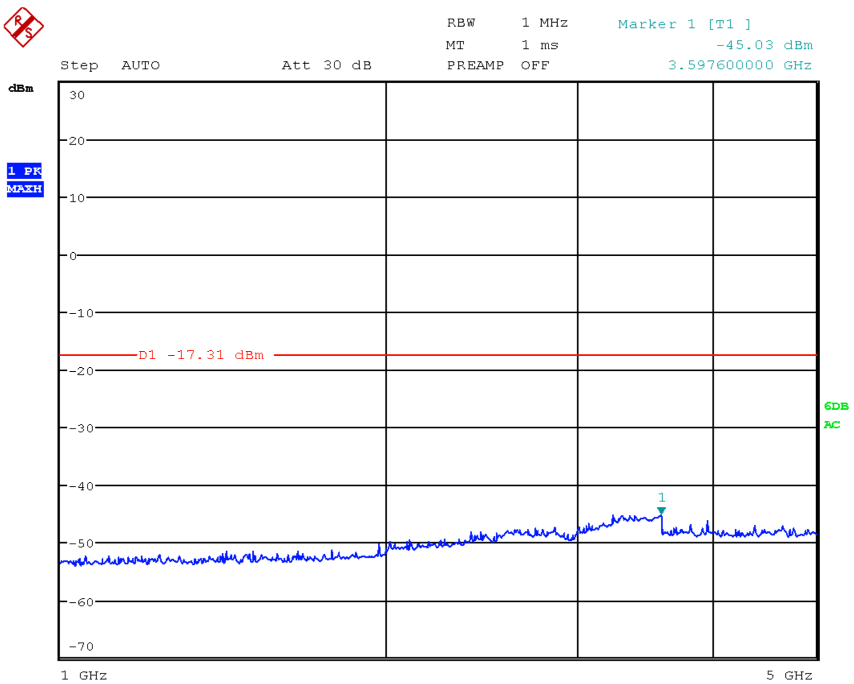


Figure 21: Chart of conducted spurious emissions test 1 GHz to 5 GHz – middle channel – RX

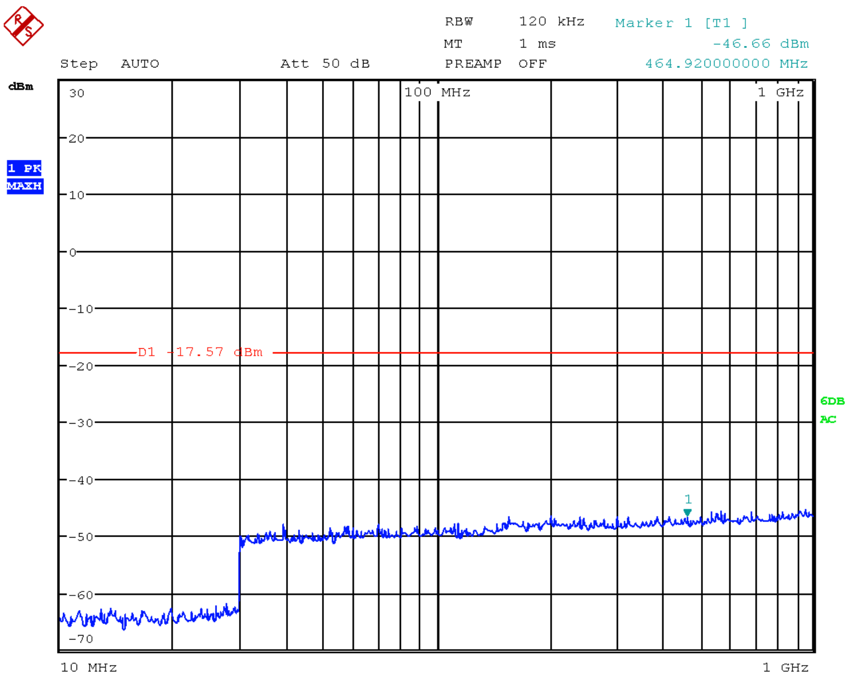


Figure 22: Chart of conducted spurious emissions test 10 MHz to 1 GHz – top channel – RX

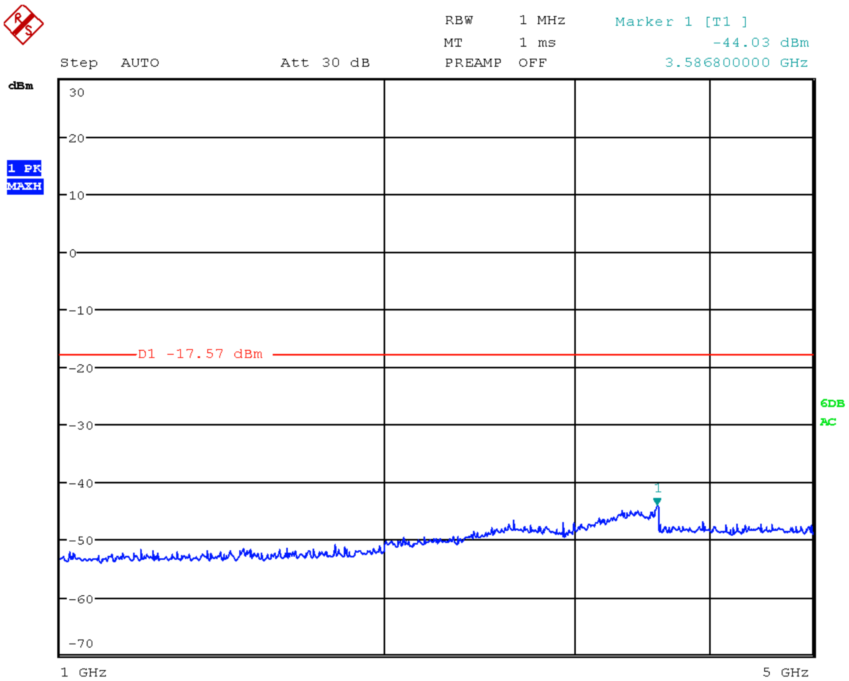


Figure 23: Chart of conducted spurious emissions test 1 GHz to 5 GHz – top channel – RX

6.4.4 Radiated spurious emissions

Performed by:	Martin Müller	Date of test:	July 12, 2016
Climatic conditions:	Ambient temperature 28 °C	Relative humidity 54 %	Barometric pressure 98 kPa
Result[6]:	☒ Test passed	☐ Test not passed	

6.4.4.1 Test equipment

Type	Designation	Manufacturer	Inventory no.
☒ Compact Diagnostic Chamber (CDC)	VK041.0174	Albatross Projects	E00026
☒ Open area test site (OATS)	---	EMV **TESTHAUS**	E00354
☐ Anechoic chamber		EMV **TESTHAUS**	E00100
☐ Semi-anechoic chamber (SAC)	SAC3	Albatross Projects	E00716
☒ EMI test receiver (CDC)	ESCI 3	Rohde & Schwarz	E00001
☒ EMI test receiver (OATS)	ESCI 3	Rohde & Schwarz	E00552
☐ EMI test receiver (SAC)	ESR 7	Rohde & Schwarz	E00739
☒ EMI test receiver	ESU 26	Rohde & Schwarz	W00002
☒ Preamplifier (500 MHz - 18 GHz)	AMF-5D-00501800-28-13P	Miteq	W00089
☒ High pass filter	WHK10-900-1000-8000-40SS	Wainwright Instruments	W00700
☒ Loop antenna	HFH2-Z2	Rohde & Schwarz	E00060
☒ TRILOG broadband antenna (CDC)	VULB 9160	Schwarzbeck	E00011
☒ TRILOG broadband antenna (OATS)	VULB 9163	Schwarzbeck	E00013
☐ TRILOG broadband antenna (SAC)	VULB 9162	Schwarzbeck	E00643
☐ Horn antenna	BBHA 9120D	Schwarzbeck	W00053
☐ Horn antenna	BBHA 9170	Schwarzbeck	W00055
☒ Measurement software	E10 v1.4.12	EMV **TESTHAUS**	W00053
☐ Measurement software	EMC32 V10	Rohde & Schwarz	E00777, E00778

[6] For information about measurement uncertainties see page 58

6.4.4.2 Test results

Radiated spurious emissions P_{ERP} are measured as the maximum effective radiated power (ERP). It is calculated according to:

$$P_{ERP} \text{ [dBm]} = P_{meas} \text{ [dBm]} + C_{sub} \text{ [dB]}$$

with: P_{meas} = measured power in dBm
C_{sub} = substitution factor determined without EUT

Note: For electric field strength limit in the frequency range 10 MHz to 30 MHz see clause 6.4.2.
For ERP levels of the unmodulated carrier see table 10.

6.4.4.2.1 TX mode

Frequency (MHz)	*EUT posi-tion*	*Antenna polari-zation*	*height (cm)*	*Table position (°)*	*P_{meas} (dBm)*	*Detector*	*C_{sub} (dB)*	*P_{ERP} (dBm)*	*Limit (dBm)*	*Margin (dB)*	*Result*
Bottom channel											
460.6200	1H	horizontal	107	191	-21.85	Peak	34.58	12.72	20.79	8.07	Passed
921.3000	1H	vertical	150	85	-95.10	Peak	42.58	-52.52	-15.27	37.25	Passed
Middle channel											
461.2800	1H	horizontal	110	183	-20.74	Peak	34.58	13.84	20.79	6.95	Passed
922.6200	1H	vertical	150	248	-94.82	Peak	42.55	-52.27	-15.42	36.85	Passed
Top channel											
461.5800	1H	horizontal	106	195	-20.40	Peak	34.58	14.19	20.79	6.60	Passed
923.1000	1H	vertical	150	87	-97.61	Peak	42.54	-55.07	-15.10	39.97	Passed

Table 19: Results of radiated spurious emissions test 10 MHz to 5 GHz – TX

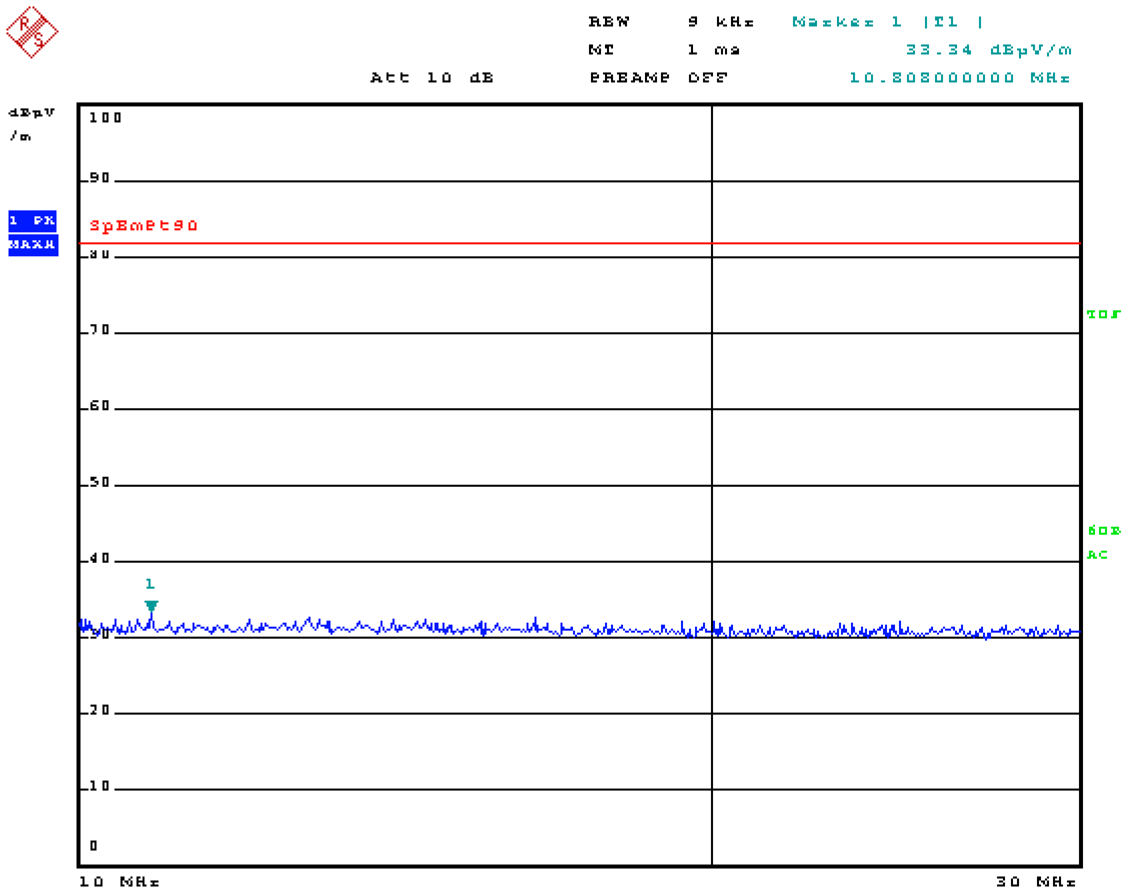


Figure 24: Chart of radiated spurious emissions test 10 MHz to 30 MHz – bottom channel – TX

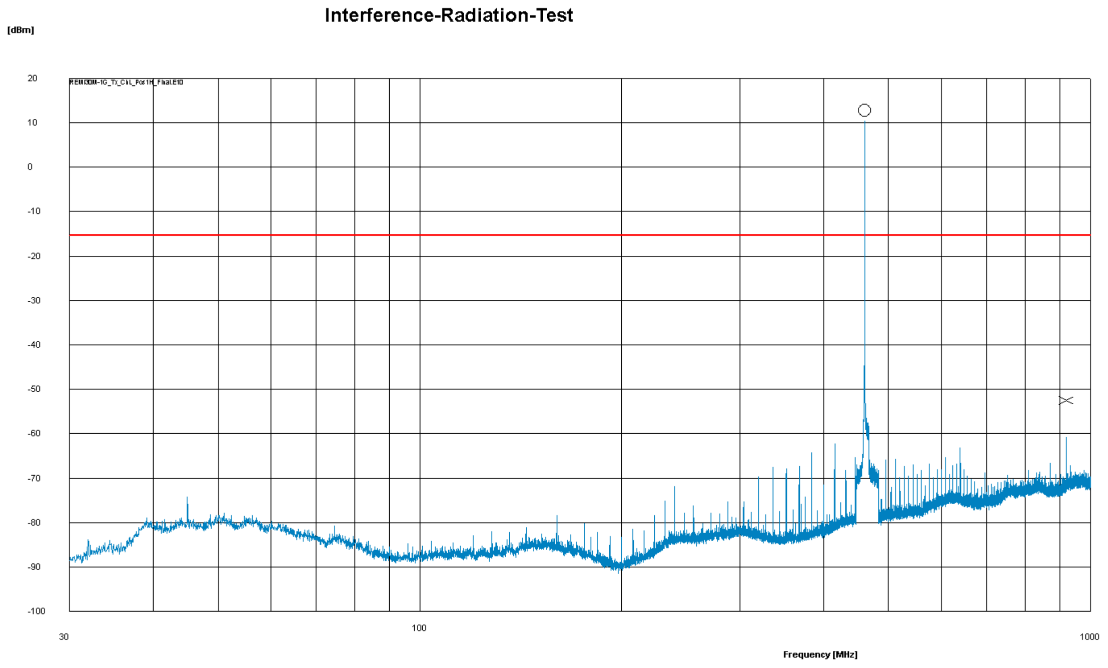


Figure 25: Chart of radiated spurious emissions test 30 MHz to 1 GHz – bottom channel – TX

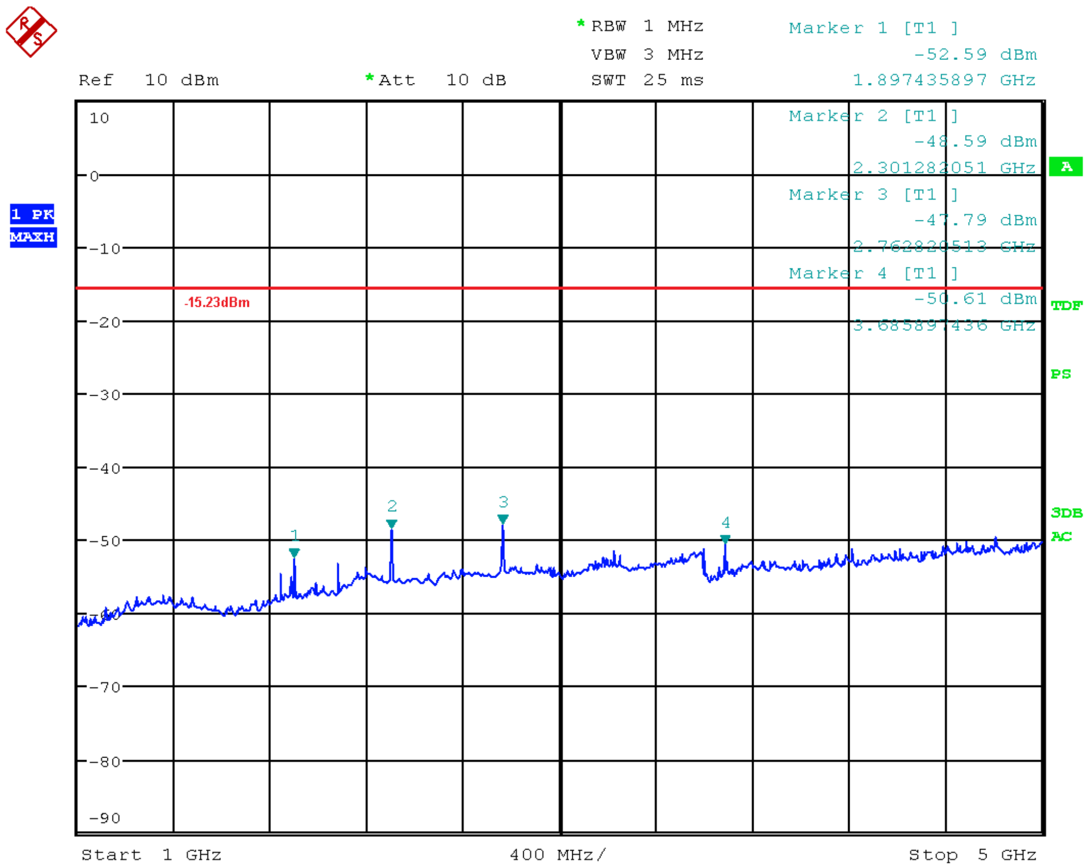


Figure 26: Chart of radiated spurious emissions test 1 GHz to 5 GHz – bottom channel – TX

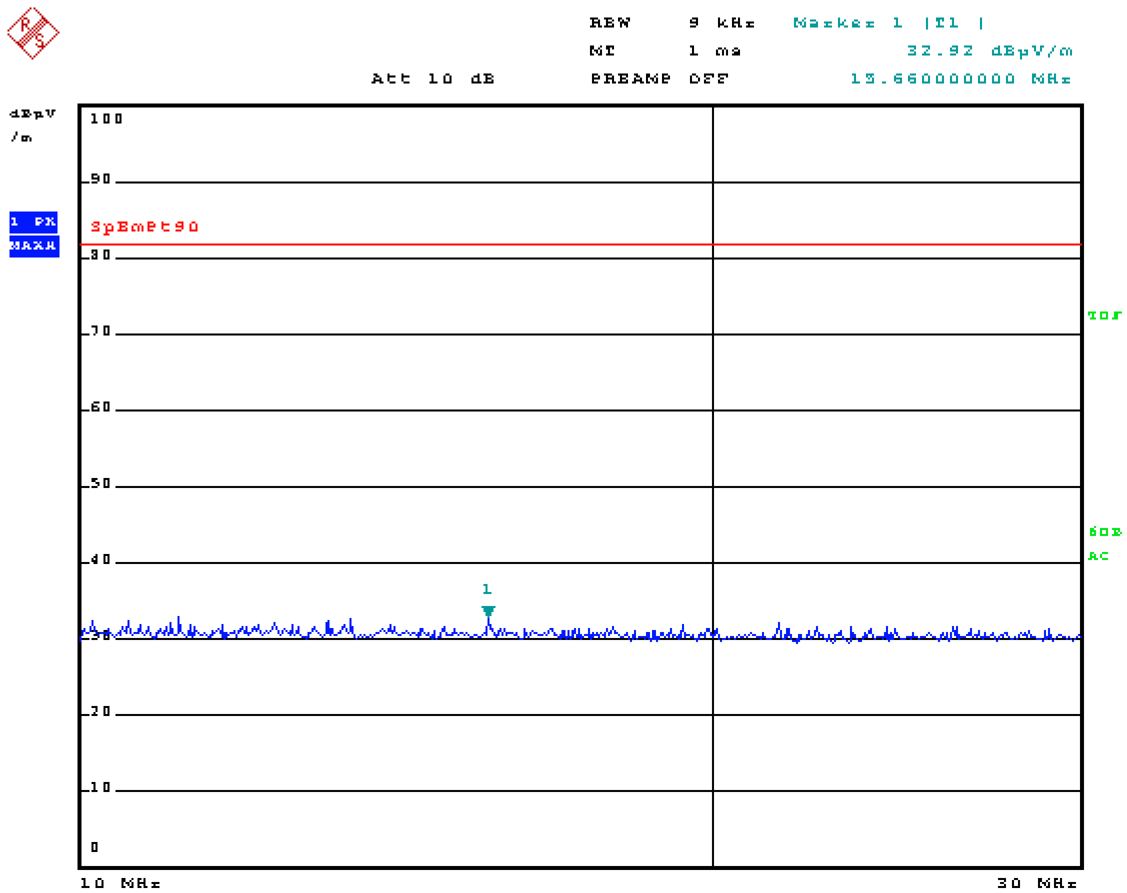


Figure 27: Chart of radiated spurious emissions test 10 MHz to 30 MHz – middle channel – TX

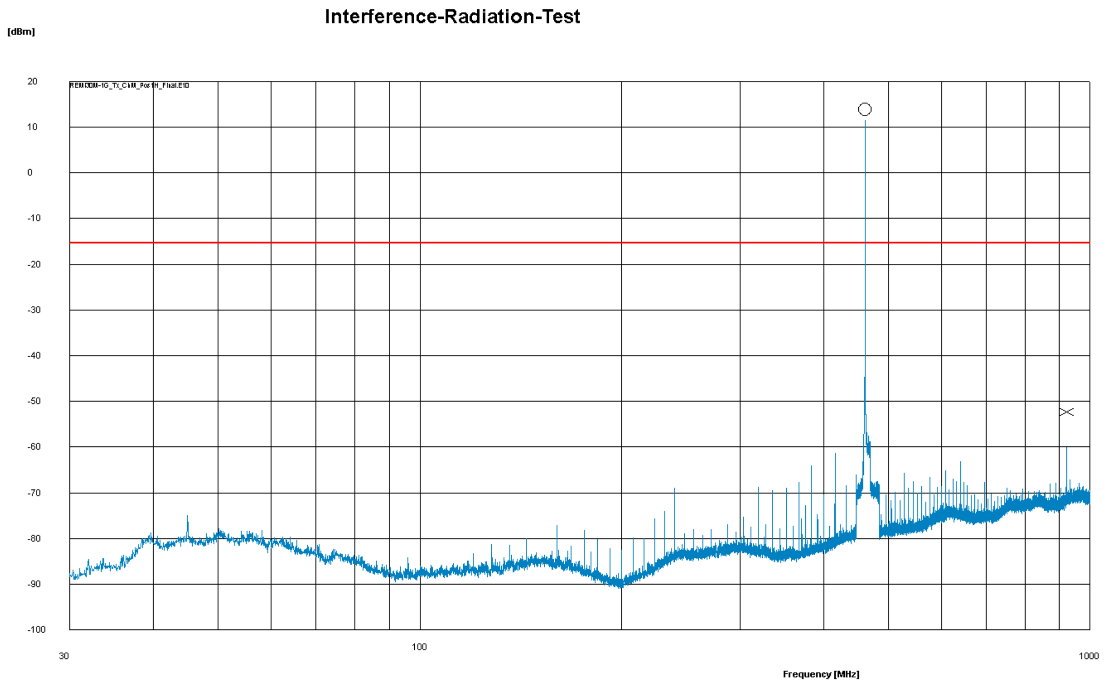


Figure 28: Chart of radiated spurious emissions test 30 MHz to 1 GHz – middle channel – TX

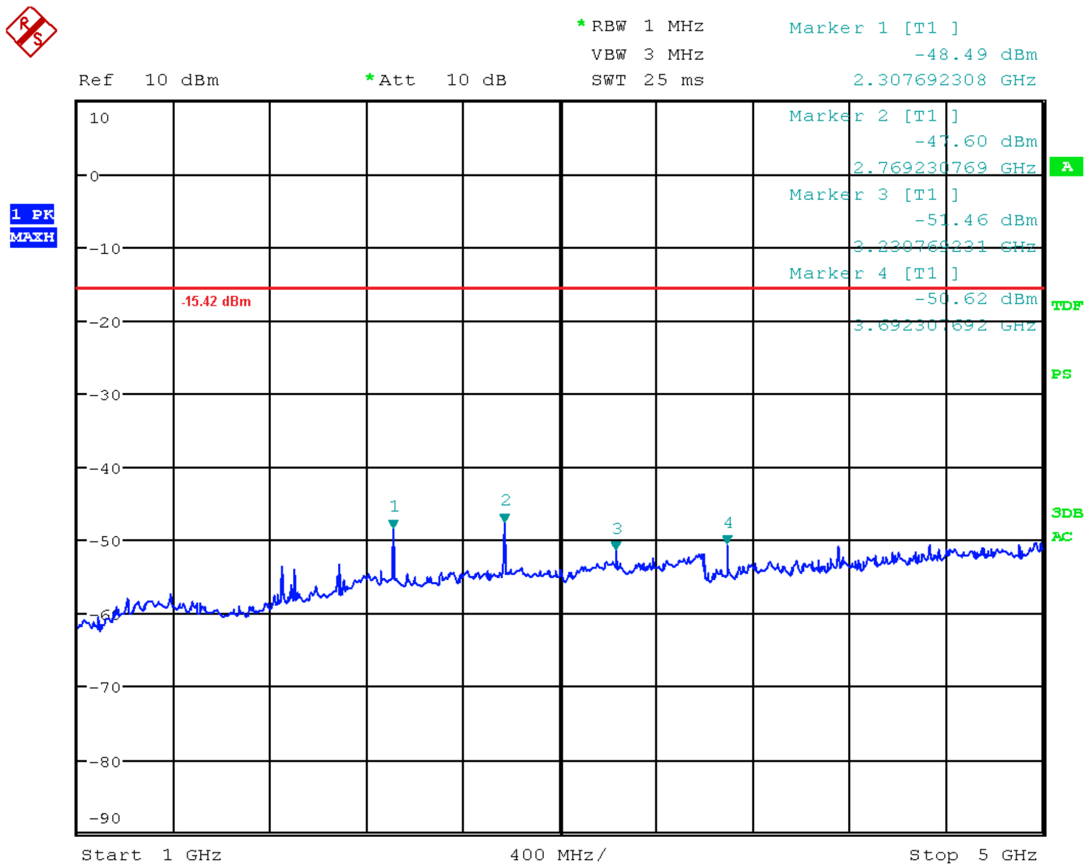


Figure 29: Chart of radiated spurious emissions test 1 GHz to 5 GHz – middle channel – TX

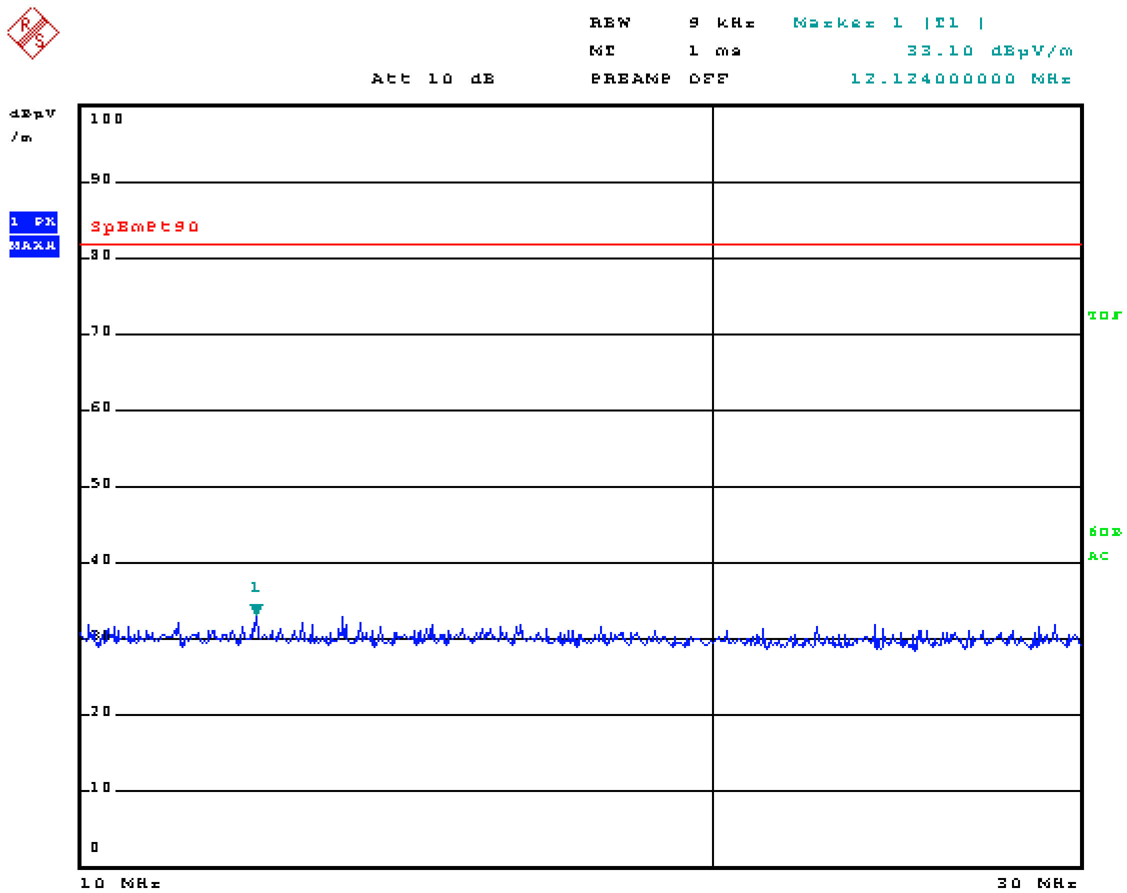


Figure 30: Chart of radiated spurious emissions test 10 MHz to 30 MHz – top channel – TX

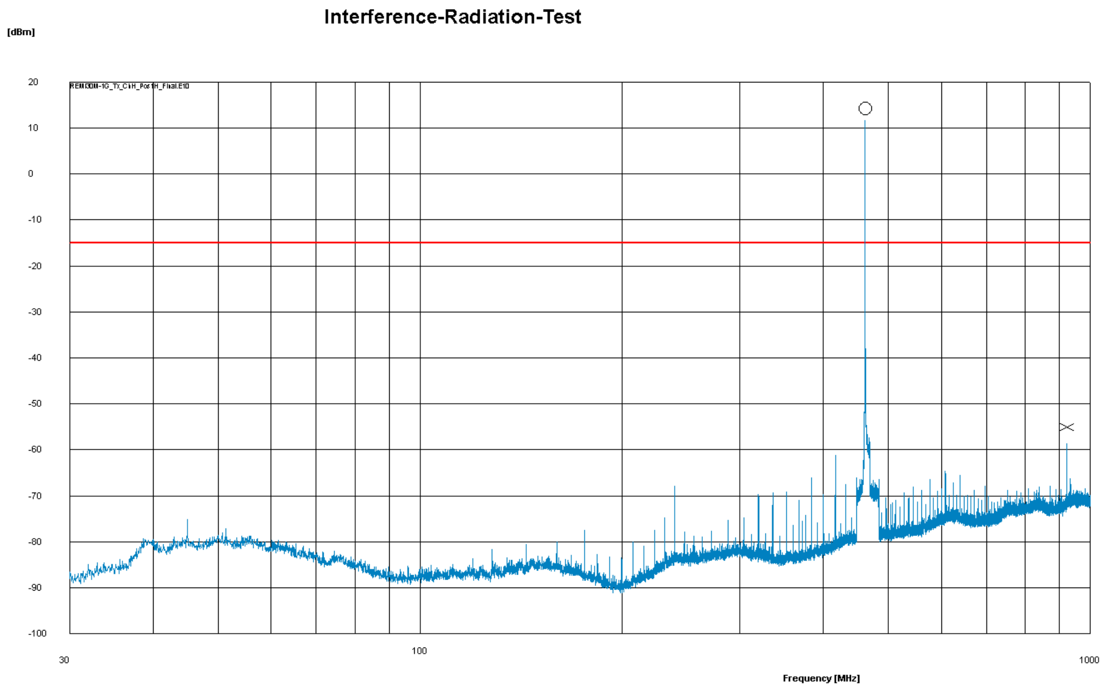


Figure 31: Chart of radiated spurious emissions test 30 MHz to 1 GHz – top channel – TX

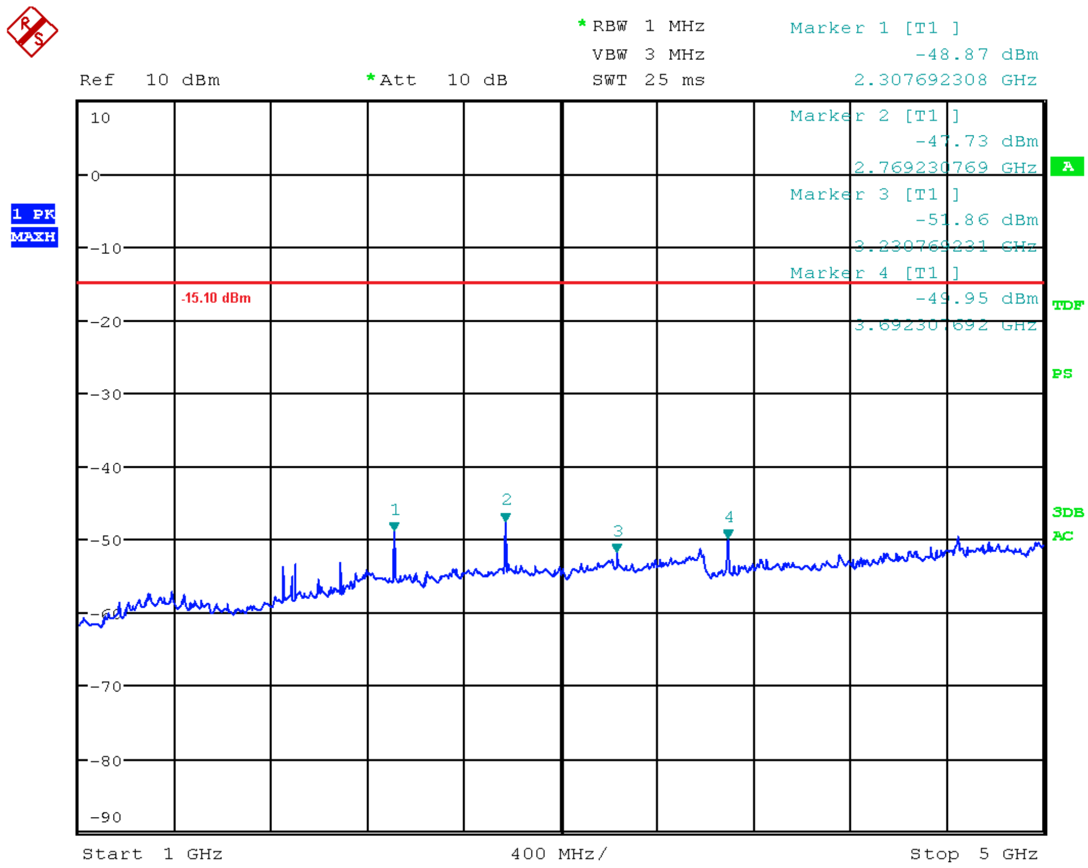


Figure 32: Chart of radiated spurious emissions test 1 GHz to 5 GHz – top channel – TX

6.4.4.2.2 RX mode

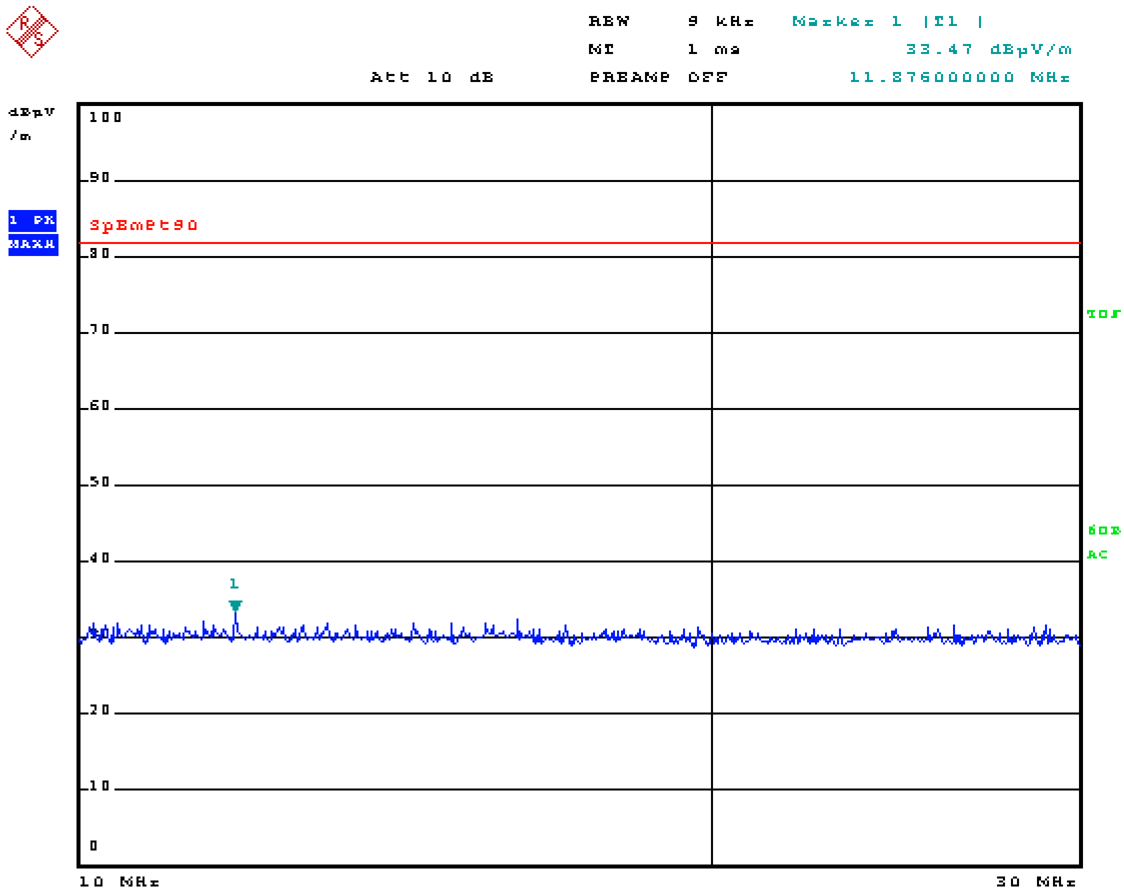


Figure 33: Chart of radiated spurious emissions test 10 MHz to 30 MHz – bottom channel – RX

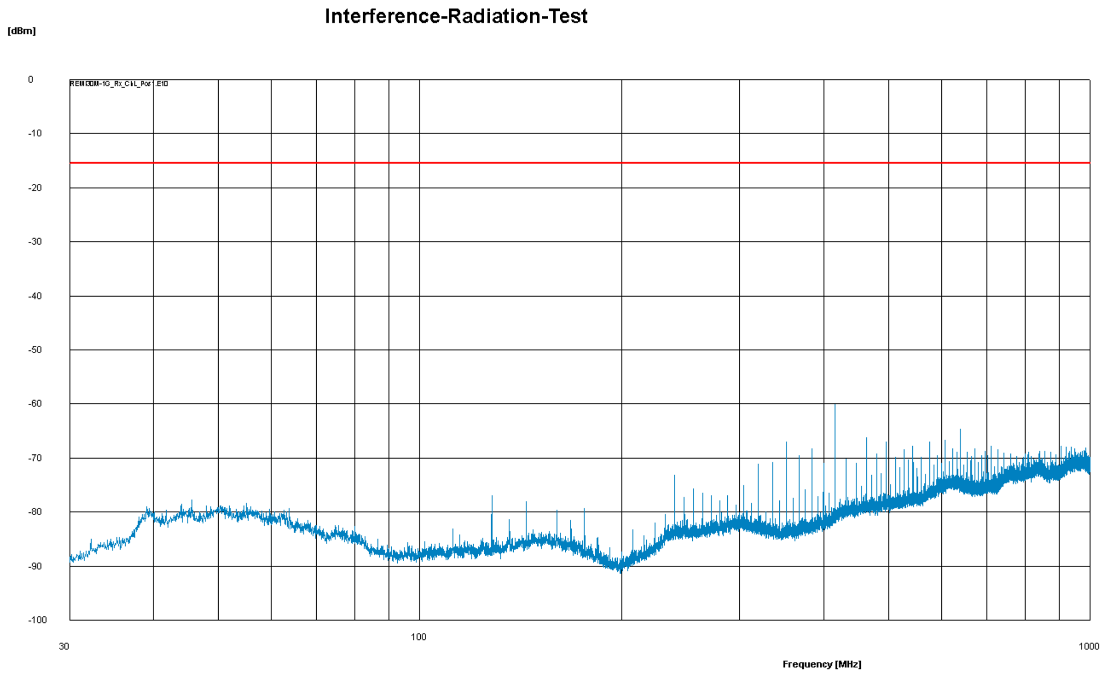


Figure 34: Chart of radiated spurious emissions test 30 MHz to 1 GHz – bottom channel – RX

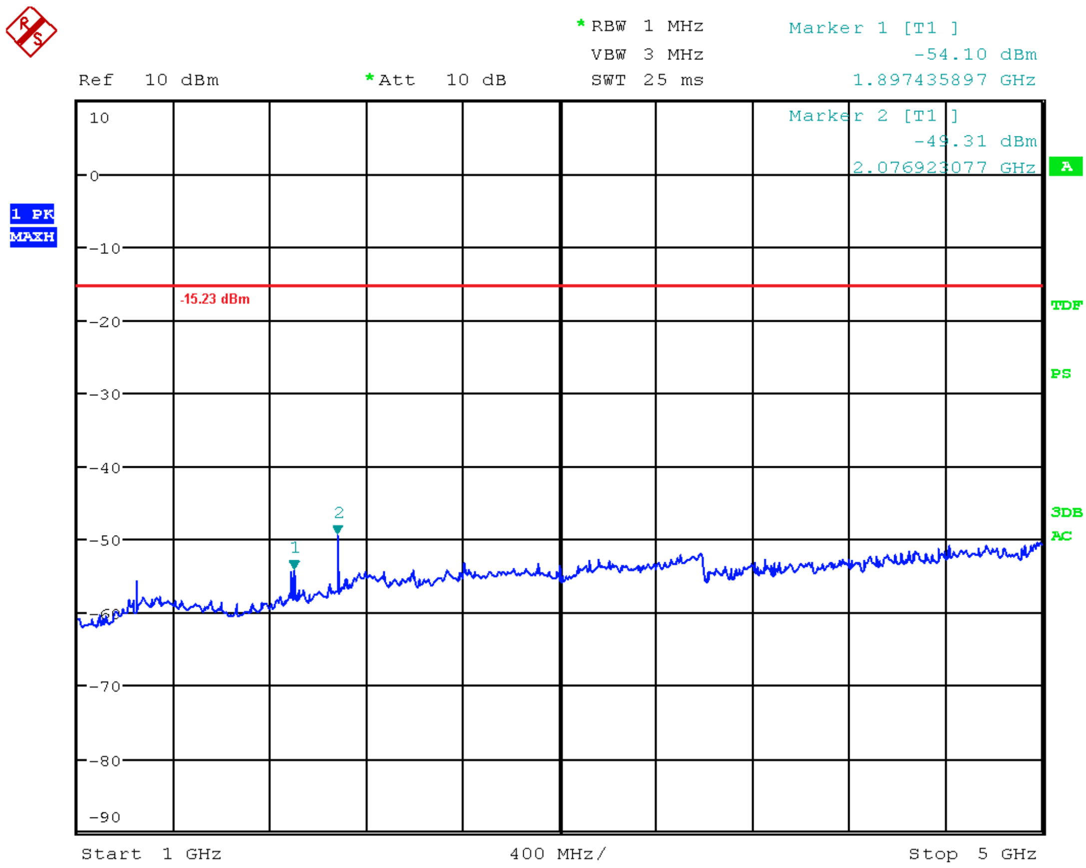


Figure 35: Chart of radiated spurious emissions test 1 GHz to 5 GHz – bottom channel – RX

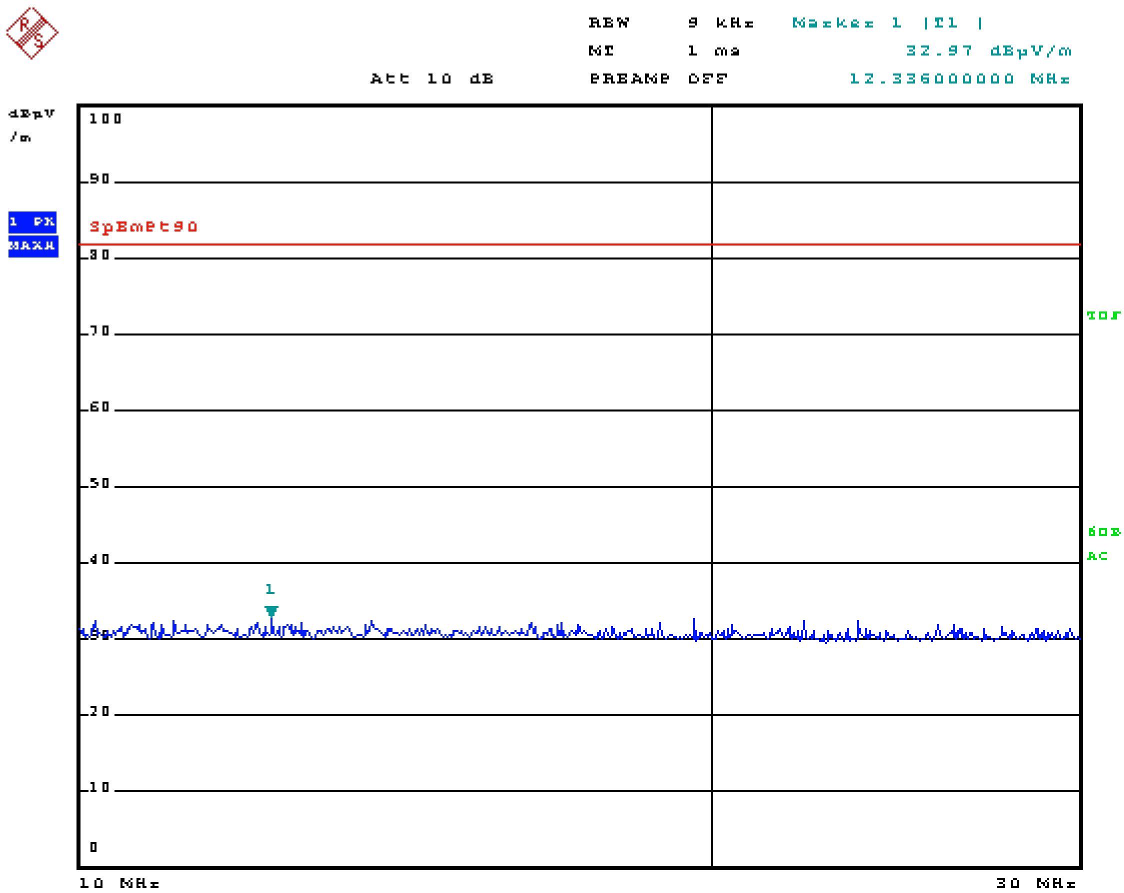


Figure 36: Chart of radiated spurious emissions test 10 MHz to 30 MHz – middle channel – RX

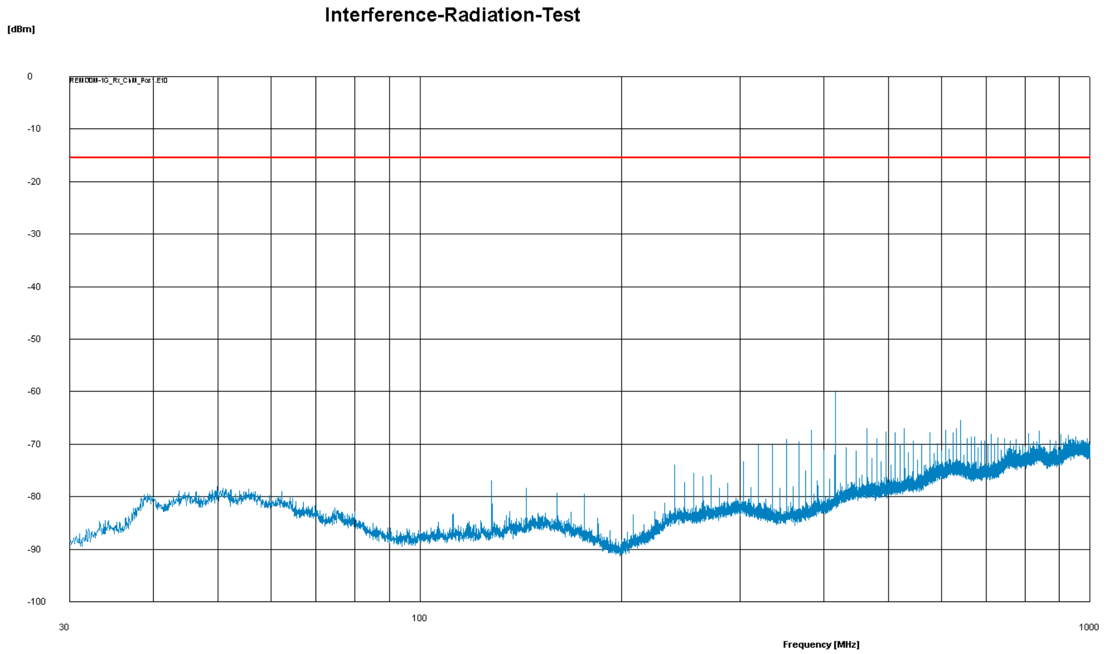


Figure 37: Chart of radiated spurious emissions test 30 MHz to 1 GHz – middle channel – RX

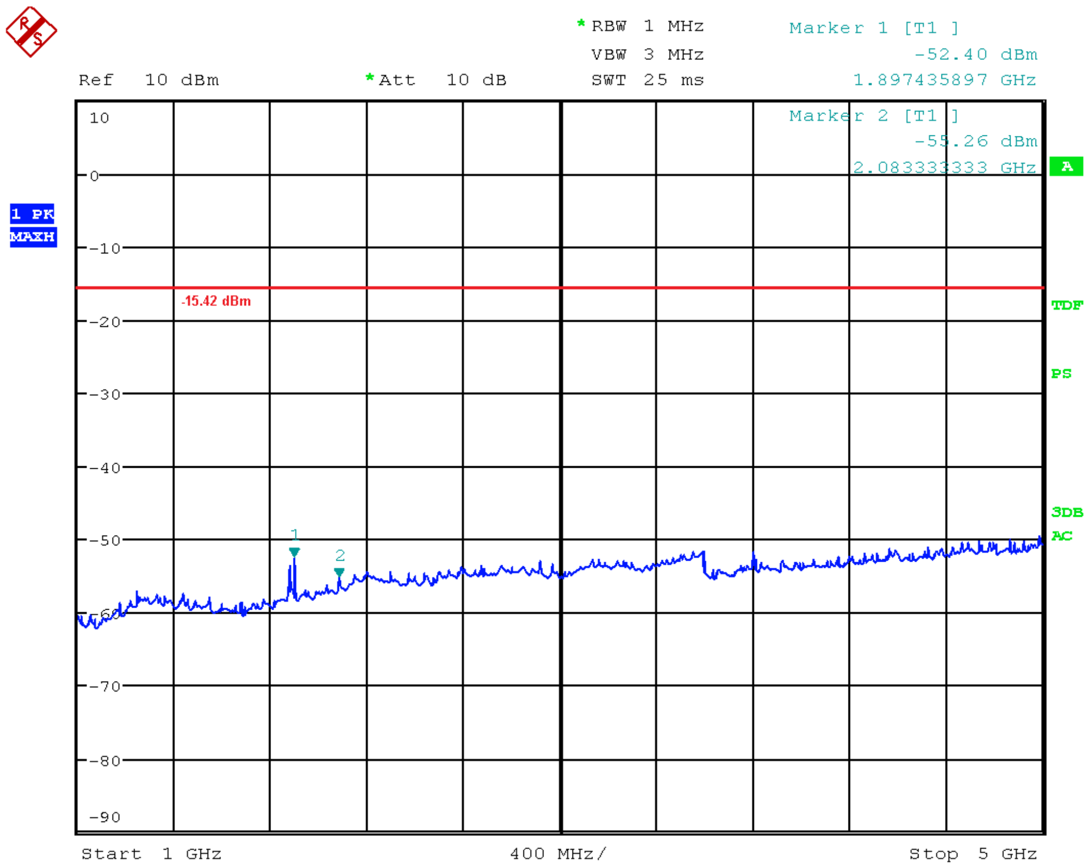


Figure 38: Chart of radiated spurious emissions test 1 GHz to 5 GHz – middle channel – RX

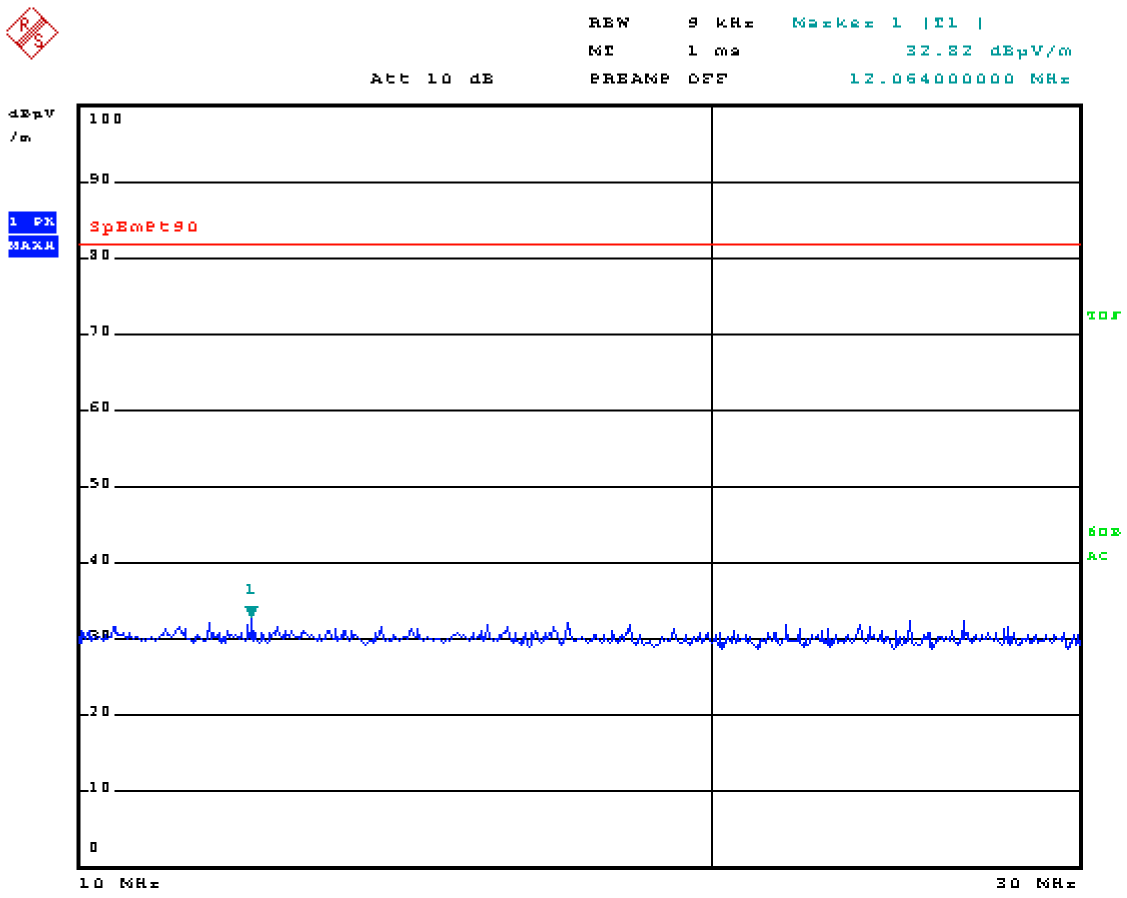


Figure 39: Chart of radiated spurious emissions test 10 MHz to 30 MHz – top channel – RX

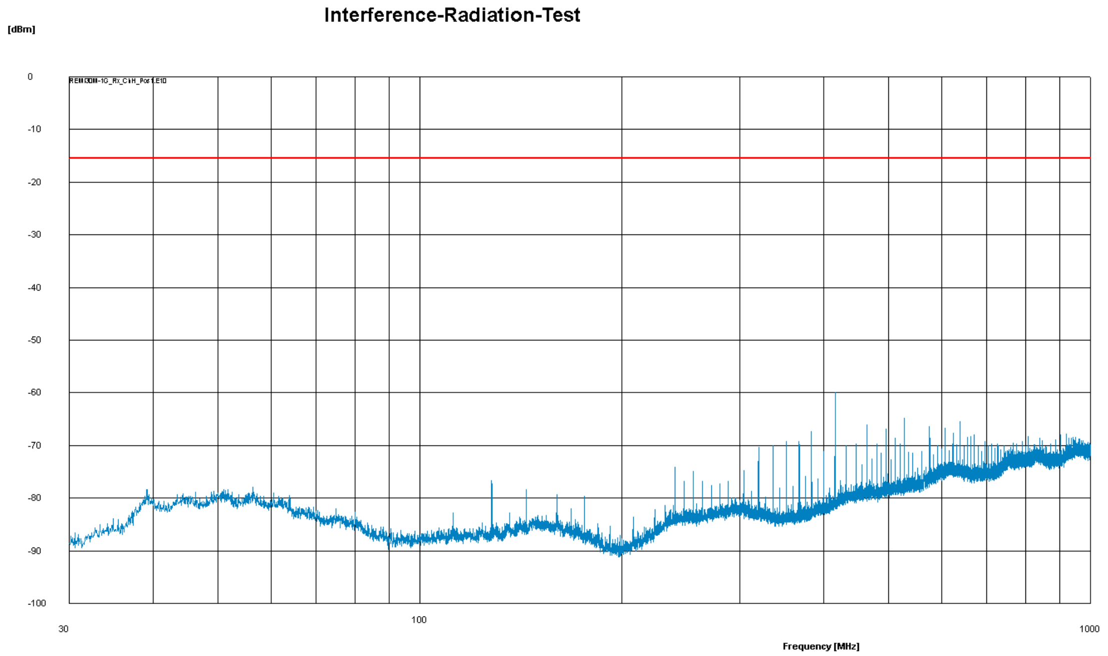


Figure 40: Chart of radiated spurious emissions test 30 MHz to 1 GHz – top channel – RX

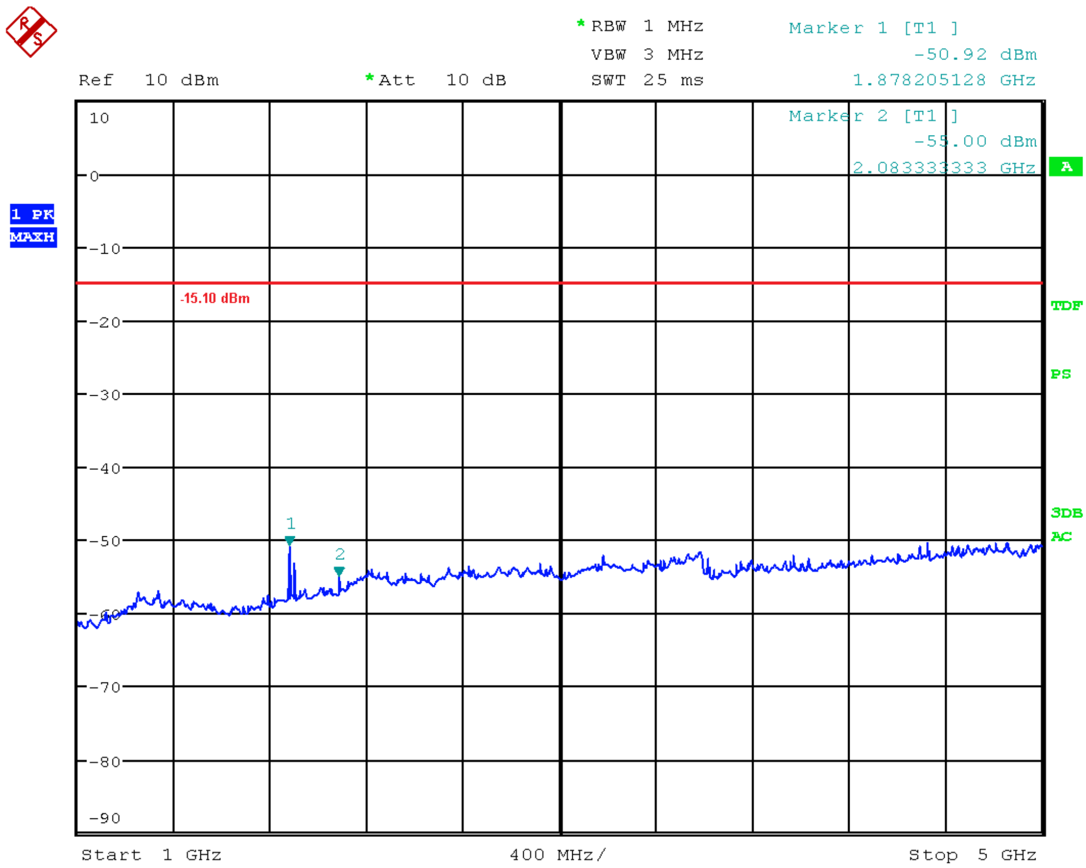


Figure 41: Chart of radiated spurious emissions test 1 GHz to 5 GHz – top channel – RX

6.5 Radio frequency radiation exposure evaluation for portable devices

Reference(s):	47 CFR Part 2, §2.1093 KDB 447498 D01, section 4.3.1

Performed by:	Martin Müller	Date of test:	July 25, 2016
Result:	☒ Test passed	☐ Test not passed	

6.5.1 Data of equipment under test (EUT)

Antenna connector (see clause 3):	☒ permanent	☐ temporary	☐ none
Antenna detachable:	☒ yes	☐ no	
Tune-up function:	☒ yes	☐ no	
Maximum antenna gain (see clause 3):	logarithmic 6.15 dBi	numeric 4.12	
Maximum conducted output power (see clause 6.2.3.2):	logarithmic 13.59 dBm	numeric 22.9 mW	
Maximum conducted output power for tune-up:	logarithmic 13.90 dBm	numeric 24.5 mW	
Maximum operation frequency (see clause 3):	461.5625 MHz		
Minimum test separation distance:	6 mm		

6.5.2 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 4.3.1, have to be kept. For 100 MHz to 6 GHz and test separation distances ≤ 50 mm, the 1 g and 10 g SAR test exclusion thresholds are determined by the following equation:

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

with: $P_{conducted}$ = source-based time-averaged maximum conducted output power in mW, adjusted for tune-up tolerance

f = RF channel transmit frequency in GHz

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

6.5.3 Results

$$\frac{P_{conducted}(mW) \cdot \sqrt{f(GHz)}}{d_{min}(mm)} \leq 3.0 \quad \Leftrightarrow \quad \frac{25 \cdot \sqrt{0.4615625}}{6} \leq 3.0$$

$$\Leftrightarrow \quad 2.8 \leq 3.0 \ \checkmark$$

Notes:
1 Power and distance are rounded to the nearest mW and mm before calculation.
2 The result is rounded to one decimal place for comparison.

7 Measurement uncertainties

Description	*Maimum deviation*	*k=*
Conducted emission AMN 150kHz to 30 MHz	± 4.1 dB	2
Radiated emission open field or semi-anechoic chamber 9 kHz to 30 MHz 30 MHz to 300 MHz 300MHz to 1 GHz	 ± 4.8 dB ± 5.4 dB ± 5.9 dB	2
Radiated emission absorber chamber 1 GHz to max. 18 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.

8 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	2014-07	2016-07
Test receiver	ESU 26	100026	W00002	2016-04	2018-04
Loop antenna	HFH2-Z2	871398/0050	E00060	2014-07	2016-07
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	E00053	2014-03	2017-03
Preamplifier	AMF-5D-00501800	1319793	W00089	2015-05	2017-05
Climatic chamber	VC³ 4034	58566123250010	C00015	2014-09	2016-09
Compact diagnostic chamber (CDC)	VK041.0174	D62128-A502-A69-2-0006	E00026	N/A (for pre-tests only)	
Anechoic chamber	FS-SAC	---	E00100	2015-10	2017-10
Open area test site (OATS)	OATS	---	E00354	2015-10	2017-10
Semi-anechoic chamber (SAC)	P26726	C62128-A520-A643-x-0006	E00716	2015-03	2017-03
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

Note: Expiration date of measurement facility registration (OATS) by FCC (registration number 221458) is 2017-04.

9 Additional documents

☒ Annex A: Pictures of test setups
☒ Annex B: External pictures of EUT
☒ Annex C: Internal pictures of EUT

10 Revision history

Revision	*Date*	*Issued by*	*Description of modifications*
0	2016-12-20	Martin Müller	First edition