Test report

Customer:

Continental Automotive GmbH
Regensburg

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RF test report

190628-AU01+W02

Continental Automotive GmbH

Tire pressure monitoring system

TIS-15N

EMV **TESTHAUS** GmbH

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Germany
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Accreditation:

FCC test firm accreditation expiration date: 2021-05-30
MRA US-EU, FCC designation number: DE0010
FCC registration number: 97268
BnetzA-CAB-02/21-02/5 Valid until 2023-11-26

Recognized on March 14th, 2019 by the
Department of Innovation, Science and Economic Development (ISED) Canada
as a wireless testing laboratory
CAB identifier: DE0011
ISED#: 3472A

Location of Testing:

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

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

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1 Summary of test results

47 CFR part and section	*Test*	*Equivalent to IC radio standard(s)*	*Page*	*Result*	*Note(s)*
15.207(a)	AC power line conducted emissions 150 kHz to 30 MHz	RSS-Gen, 8.8	---	Not applicable	---
15.231(e)	Field strength of the fundamental wave	RSS-210, A1.2a	16	Passed	---
15.231(b)/ (e)	Spurious emissions (magnetic field) 9 kHz – 30 MHz	RSS-210, A1.2b	19	Passed	---
15.231(b)/ (e)	Spurious emissions radiated (electrical field) 30 MHz – 10th harmonic	RSS-210, A1.2 b	19	Passed	---
15.231(b)2	Correction for pulse operation (duty cycle)	RSS-Gen 8.2	28	Passed	---
15.231(c)	20 dB bandwidth	RSS-Gen, 6.7	30	Passed	---
	Occupied bandwidth (99%)	RSS-Gen, 6.7			---
15.231(e)	Duration of transmission and silent period	RSS-Gen 8.2	33	Passed	---

Straubing, September 5, 2019

Jennifer Riedel
Test engineer
EMV **TESTHAUS** GmbH

Konrad Graßl
Head of radio department
EMV **TESTHAUS** GmbH

2 Referenced publications

The tests were performed according to following standards:

FCC Rules and Regulations Part 15, Subpart A – General (November, 2017)	
Part 15, Subpart A, Section 15.31	Measurement Standards
Part 15, Subpart A, Section 15.33	Frequency range of radiated measurements
Part 15, Subpart A, Section 15.35	Measurement detector functions and bandwidths
FCC Rules and Regulations Part 15, Subpart C – Intentional Radiators (November, 2017)	
Part 15, Subpart C, Section 15.203	Antenna Requirement
Part 15, Subpart C, Section 15.204	External radio frequency power amplifiers and antenna modifications
Part 15, Subpart C, Section 15.205	Restricted bands of operation
Part 15, Subpart C, Section 15.207	Conducted limits
Part 15, Subpart C, Section 15.209	Radiated emission limits, general requirements
Part 15, Subpart C, Section 15.231	Periodic operation in the band 40.66 MHz - 40.7 MHz and above 70 MHz
ANSI C63.10: 2013	Procedures for Compliance Testing of Unlicensed Wireless Devices
RSS-210 – Licence-Exempt Radio Apparatus: Category I Equipment (August, 2016)	
Annex A 1.1	*Types of Momentarily Operated Devices*
Annex A 1.2	*Field Strengths*
Annex A 1.3	*Bandwidth of Momentary Signals*
RSS-Gen Issue 5 – General Requirements for Compliance of Radio Apparatus	
Section 6.7	Occupied bandwidth (or 99% emission bandwidth) and x dB bandwidth

3 Equipment under test (EUT)

Product type:	Tire pressure monitoring system	
Model name:	TIS-15N	
Serial number(s):	N/A	
Applicant:	Continental Automotive GmbH	
Manufacturer:	Continental Automotive GmbH	
Version:	Hardware:	TIS-15N
	Software:	TIS-15N
Additional modifications:	None	
Short description:	The EUT is a tire pressure monitoring system.	
FCC ID:	KR5TIS-15N	
IC registration number:	7812D-TIS15N	
Frequency range:	Above 70 MHz	
Operating frequencies:	433.92 MHz	
Channel spacing:	not specified	
Number of RF channels:	1	
System type:	RF Transmitter	
Modulation type(s):	FSK, ASK	
Antenna type(s):	PCB antenna	
Antenna gain(s):	-25.6 dBi	
Power supply:	Leclanché or lithium battery supply	
	Nominal voltage:	3.6 V
	Minimum voltage:	2.8 V
	Maximum voltage:	3.7 V
Device type:	☐ Portable	☒ Mobile ☐ Fixed

4 Test configuration and mode of operation

4.1 Test configuration

Device	*Type designation*	*Serial or inventory no.*	*Manufacturer*
EUT			
Tire pressure monitoring system	TIS-15N	N/A	Continental Automotive GmbH
Support equipment			
Trigger tool	LF Trigger Tool	N/A	Continental Automotive GmbH

Table 1: Devices used for testing

4.2 Mode of operation

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

Test mode/ EUT	*Behavior*
Repetition of FSK frames	FSK-modulated transmission at 433.92 MHz
Repetition of ASK frames	ASK-modulated transmission at 433.92 MHz
16 s periodic emission	Periodic emission at 433.92 MHz

5 Measurement Procedures

5.1 20 dB bandwidth

The 20 dB bandwidth test method refers to section 6.9.2 of ANSI C63.10 and shall be as follows:

Spectrum analyzer settings:
Spectrum analyzer center frequency = nominal EUT channel center frequency
Span = between two times and five times the OBW
IF filter bandwidth (3 dB RBW) = between 1 % to 5 % of the OBW
VBW ≥ 3 x RBW
Detector function = peak
Trace mode = max hold
Reference level: more than 10·log(OBW/RBW) dB above peak of spectral envelope

Measure the maximum width of the emission that is constrained by the frequencies associated with the two markers (upper and lower frequencies) that are at or slightly below the 20 dB down amplitude relative to the maximum level measured in the fundamental emission.
If possible, use the automatic bandwidth measurement capability of the spectrum analyzer using the X dB bandwidth mode with X set to 20 dB. Submit this plot(s).
The 20 dB bandwidth is the frequency difference between the two markers.

For test setup see clause 5.4.

5.2 Occupied bandwidth (99%)

The occupied bandwidth test method refers to section 6.9.3 of ANSI C63.10 and shall be as follows.

Spectrum analyzer settings:
Span = between 1.5 times and 5.0 times of the OBW, centered on a channel
RBW ≥ in the range of 1% to 5% of the OBW
VBW ≥ approximately three times the RBW
Sweep time = auto coupled
Detector function = peak
Trace mode = max hold
Reference level: more than 10·log(OBW/RBW) dB above peak of spectral envelope

Use the 99% power bandwidth function of the spectrum analyzer and report the measured bandwidth.

For test setup see clause 5.4.

5.3 Spurious radiated emissions 9 kHz to 10th harmonic

For test setup and test method see clause 5.4.

5.4 Radiated emissions

5.4.1 Radiated emissions below 30 MHz

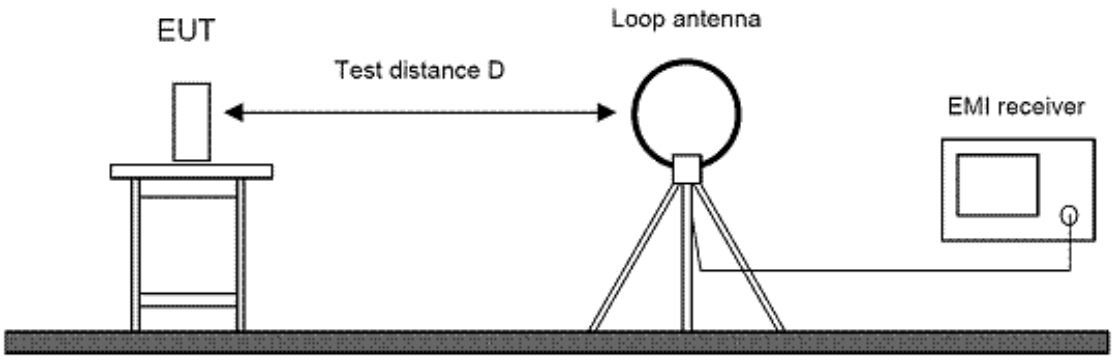

Figure 1: Setup for radiated emission test below 30 MHz

Sample calculation:

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

Correction factor = Antenna correction + Cable attenuation

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

The test method for radiated emissions below 30 MHz refers to section 6.4 of ANSI C63.10 and shall be as follows:

1. EUT is configured according to ANSI C63.10. It is placed on the turntable 0.8 meter above ground. The receiving antenna is located 3 meters from the EUT. The test setup is placed inside a compact diagnostic chamber.
2. EUT and all peripherals are powered on.
3. The loop antenna is set in parallel with the antenna of the EUT.
4. The EMI receiver performs a scan from 9 kHz to 30 MHz with peak detector and measurement bandwidth set to 200 Hz for frequencies up to 150 kHz and 9 or 10 kHz for frequencies above.
5. The turn table is rotated to 8 different positions (360° / 8).
6. The antenna is set in line with the antenna of the EUT and steps 4 and 5 are repeated.

7. Then the test setup is placed in an OATS with 3 m distance and all peak values over the limit or with less margin than 10 dB are marked and re-measured with a quasi-peak detector except for the frequency bands 9 to 90 kHz and 110 to 490 k Hz, where average detector applies.
8. The turntable is rotated by 360 degrees to determine the position of the highest radiation.
9. The highest value for each frequency is recorded.

5.4.2 Radiated emissions from 30 MHz to 1 GHz

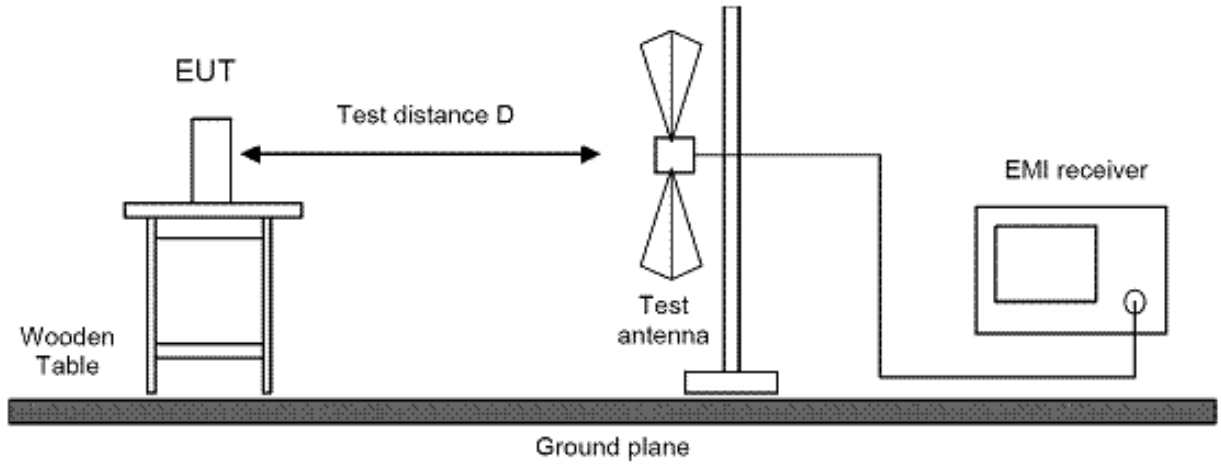

Figure 2: Setup for radiated emission test from 30 MHz to 1 GHz

Sample calculation:

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

Correction factor = Antenna correction + Cable attenuation

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

The test method for radiated emissions from 30 MHz to 1 GHz refers to section 6.5 of ANSI C63.10 and shall be as follows:

1. EUT is configured according to ANSI C63.10. It is placed on the turntable 0.8 meter above ground. The receiving antenna is located 3 meters from the EUT. The test setup is placed inside a compact diagnostic chamber.
2. EUT and all peripherals are powered on.
3. The broadband antenna is set to vertical polarization.
4. The EMI receiver performs a scan from 30 MHz to 1000 MHz with peak detector and measurement bandwidth set to 120 kHz.
5. The turn table is rotated to 6 different positions (360° / 6).

6. The antenna polarization is changed to horizontal and steps 4 and 5 are repeated.
7. Then the test setup is placed in an OATS at 3 m distance and all peak values over the limit or with less margin than 10 dB are marked and re-measured with a quasi-peak detector.
8. The turntable is rotated by 360 degrees to determine the position of the highest radiation.
9. The height of the broadband receiving antenna is varied between 1 meter and 4 meters above ground to find the maximum emission field strength of both horizontal and vertical polarization.
10. The highest value for each frequency is recorded.

5.4.3 Radiated emissions above 1 GHz

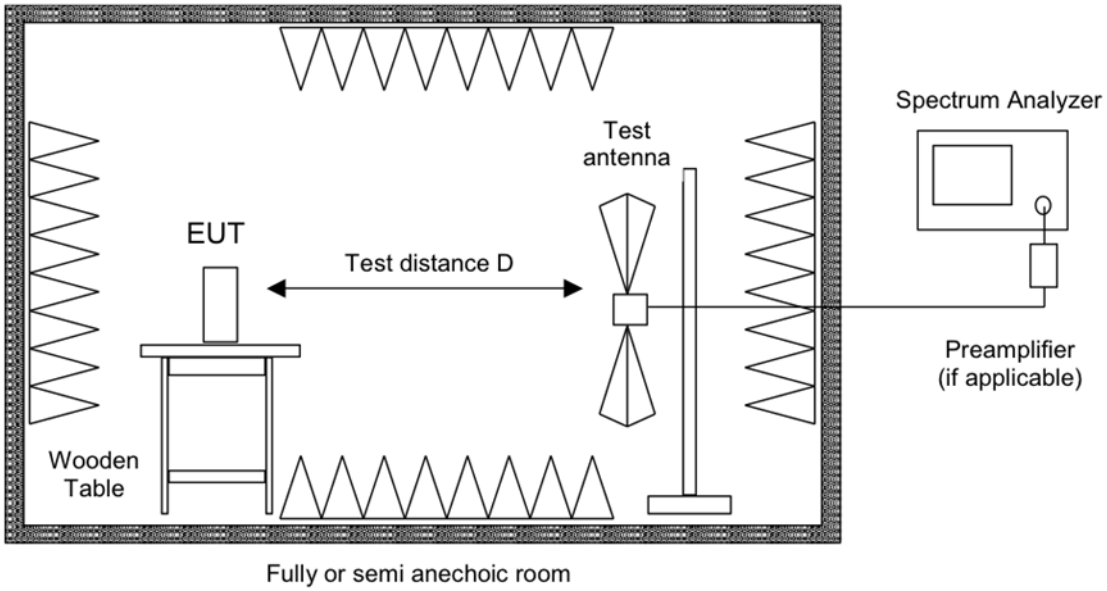

Figure 3: Setup for radiated emission test above 1 GHz

Sample calculation:

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

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

Level = Reading value + Correction factor = 50.00 dBµV - 14.92 dB/m = 35.08 dBµV/m

The test method for radiated emissions above 1 GHz refers to section 6.6 of ANSI C63.10 and shall be as follows:

1. EUT is configured according to ANSI C63.10. It is placed on the turntable 1.5 meter above ground. The test setup is placed inside a semi-anechoic chamber with RF absorbers on the floor.
2. EUT and all peripherals are powered on.
3. To identify the critical frequencies, extrapolatory radiated emission tests are performed at a closer distance than 3 meters (e.g. 1 meter). The critical frequencies found are noted.
4. For pre-scan the receiving antenna is located 3 meters from the EUT.
5. The broadband horn antenna is set to vertical polarization.
6. The EMI receiver performs a scan from 1 GHz to the 10^{th} harmonic of the fundamental frequency with peak and average detector activated simultaneously and measurement bandwidth set to 1 MHz. The trace data is recorded using the max hold function.
7. The turntable is rotated in steps of 15°.
8. After a full turn by 360° the antenna polarization is changed to horizontal and steps 4 and 5 are repeated.
9. After the scan all peak values over the limit or with less margin than 10 dB are marked. If critical frequencies recorded during extrapolatory radiated emission tests are not contained, they are added to this list.
10. Emission levels at listed frequencies are maximized by moving the turntable and varying the antenna height until maximum of emission is found.
11. The turntable is rotated by 360 degrees to determine the position of the highest radiation.
12. The height of the broadband receiving antenna is varied between 1 meter and the upper height above ground to find the maximum emission field strength of both horizontal and vertical polarization. For equipment that is tested in multiple orientations, the upper height is limited to 2.5 meters or 0.5 meters above the top of the EUT, whichever is higher. For all other equipment the upper height is 4 meters.
13. The highest value for each frequency is recorded.

6 Test results

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

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

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

6.1 Field strength of fundamental wave

47 CFR part and section: 15.231(e)

Measurement procedure: See 5.3

Result ☒ Test passed ☐ Test not passed

6.1.1 Test equipment

	Type	*Designation*	*Manufacturer*	*Inventory no.*
☐	Compact Diagnostic Chamber (CDC)	VK041.0174	Albatross Projects	E00026
☐	Open Area Test Site (OATS)	---	EMV **TESTHAUS**	E00354
☒	Semi Anechoic Chamber (SAC)	---	Albatross Projects	E00716
☐	Anechoic Chamber (AC)	---	EMV **TESTHAUS**	E00100
☐	EMI test receiver (CDC)	ESCI 3	Rohde & Schwarz	E00001
☐	EMI test receiver	ESU 26	Rohde & Schwarz	W00002
☐	EMI test receiver (SAC)	ESR 7	Rohde & Schwarz	E00739
☐	EMI test receiver (OATS)	ESCI 3	Rohde & Schwarz	E00552
☒	EMI test receiver	ESW 44	Rohde & Schwarz	E00895
☐	Preamplifier	AMF-5D-00501800	Miteq	W00089
☐	Preamplifier	AMF-6F-16002650	Miteq	W00090
☐	Preamplifier	ALS05749	MIWEKO	W01007
☐	Loop antenna	HFH2-Z2	Rohde & Schwarz	E00060
☐	TRILOG broadband antenna (CDC)	VULB 9163	Schwarzbeck	E00012
☐	TRILOG broadband antenna (OATS)	VULB 9163	Schwarzbeck	E00013
☒	TRILOG broadband antenna (SAC)	VULB 9162	Schwarzbeck	E00643
☐	Horn antenna	BBHA 9120D	Schwarzbeck	W00052
☐	Horn antenna	BBHA 9120D	Schwarzbeck	W00053
☐	Horn antenna	BBHA 9170	Schwarzbeck	W00054
☒	Cable set of SAC	RF cable(s)	Huber + Suhner	E00755 E01033 E01034
☐	Measurement software	E10	ib comPLAN	E00443
☒	Measurement software	EMC 32	Rohde & Schwarz	E00777

6.1.2 Limit according to 15.231(e)

Frequency [MHz]	*Field strength Fs [µV/m]*	*Field strength [dBµV/m]*	*Measurement distance d [m]*
40.66 – 40.70	1000	60	3
70 – 130	500	54.0	3
130 – 174	500 to 1500*	54.0 to 63.5*	3
174 – 260	1500	63.5	3
260 – 470	1500 to 5000*	63.5 to 74.0*	3
Above 470	5000	74.0	3

*Linear interpolation

6.1.3 Test procedure

The field strength of fundamental wave is measured using the test procedure as described in clause 5.3.

6.1.4 Test Result

Performed by:	Jennifer Riedel	Date of test:	August 28, 2019	
Test distance:	☐ 1 m	☐ 1.5 m	☒ 3 m	☐ ….. m
Polarization:	☐ horizontal	☒ vertical		
EUT Position:	☒ Position X	☐ Position Y	☐ Position Z	

f [MHz]	*Level PK [dBµV/m]*	*Limit PK [dBµV/m]*	*Margin PK [dB]*	*Duty cycle factor [dB]*	*Level AV [dBµV/m]*	*Limit AV [dBµV/m]*	*Margin AV [dB]*
433.880	79.78	94.0	14.22	-19.97	59.81	74.0	14.19

Table 2: Test result of field strength of fundamental wave for FSK modulation

f [MHz]	*Level PK [dBµV/m]*	*Limit PK [dBµV/m]*	*Margin PK [dB]*	*Duty cycle factor [dB]*	*Level AV [dBµV/m]*	*Limit AV [dBµV/m]*	*Margin AV [dB]*
433.920	79.64	94.0	14.36	-19.97	59.67	74.0	14.33

Table 3: Test result of field strength of fundamental wave for ASK modulation

6.2 Spurious radiated emissions 9 kHz to 10th harmonic

47 CFR part and section: 15.231(b)/ (e)

Measurement procedure: See 5.3

Result ☒ Test passed ☐ Test not passed

Remark: According to 15.231 (b) 3 the measurements are referred to the limits according 15.209.

6.2.1 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)	---	Albatross Projects	E00716
☐	Anechoic Chamber (AC)	---	EMV **TESTHAUS**	E00100
☐	EMI test receiver (CDC)	ESCI 3	Rohde & Schwarz	E00001
☐	EMI test receiver	ESU 26	Rohde & Schwarz	W00002
☒	EMI test receiver (SAC)	ESR 7	Rohde & Schwarz	E00739
☐	EMI test receiver (OATS)	ESCI 3	Rohde & Schwarz	E00552
☒	EMI test receiver	ESW 44	Rohde & Schwarz	E00895
☐	Preamplifier	AMF-5D-00501800	Miteq	W00089
☐	Preamplifier	AMF-6F-16002650	Miteq	W00090
☒	Preamplifier	ALS05749	MIWEKO	W01007
☒	Loop antenna	HFH2-Z2	Rohde & Schwarz	E00060
☐	TRILOG broadband antenna (CDC)	VULB 9163	Schwarzbeck	E00012
☐	TRILOG broadband antenna (OATS)	VULB 9163	Schwarzbeck	E00013
☒	TRILOG broadband antenna (SAC)	VULB 9162	Schwarzbeck	E00643
☒	Horn antenna	BBHA 9120D	Schwarzbeck	W00052
☐	Horn antenna	BBHA 9120D	Schwarzbeck	W00053
☐	Horn antenna	BBHA 9170	Schwarzbeck	W00054
☒	Cable set of SAC	RF cable(s)	Huber + Suhner	E00755 E01033 E01034
☐	Measurement software	E10	ib comPLAN	E00443
☒	Measurement software	EMC 32	Rohde & Schwarz	E00777

6.2.2 Limits

According to §15.231 (e):
Intentional radiators may operate at a periodic rate exceeding that specified in paragraph (a) of this section and may be employed for any type of operation, including operation prohibited in paragraph (a) of this section, provided the intentional radiator complies with the provisions of paragraphs (b) through (d) of this section, except the field strength table in paragraph (b) of this section is replaced by the following:

Fundamental frequency (MHz)	Field strength of fundamental (microvolts/meter)	Field strength of spurious emission (microvolts/meter)
40.66-40.70	1,000	100
70-130	500	50
130-174	500 to 1,500[1]	50 to 150[1]
174-260	1,500	150
260-470	1,500 to 5,000[1]	150 to 500[1]
Above 470	5,000	500

Table 4: Radiated emission limits according to §15.231

According to §15.231 (b) 3:
Spurious emissions shall be attenuated to the average (or, alternatively, CISPR quasi-peak) limits shown in this table or to the general limits shown in §15.209, whichever limit permits a higher field strength.

Frequency (MHz)	Field strength (microvolts/meter)	Measurement distance (meters)
0.009-0.490	2400/F(kHz)	300
0.490-1.705	24000/F(kHz)	30
1.705-30.0	30	30
30-88	100**	3
88-216	150**	3
216-960	200**	3
Above 960	500	3

Table 5: General radiated emission limits according to §15.209

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.

6.2.3 Test procedure

The emissions below 30 MHz are measured using the test procedure for radiated measurements as described in clause 5.4.1.

The emissions from 30 MHz to 1 GHz are measured using the test procedure for radiated measurements as described in clause 5.4.2.

The emissions from 1 GHz to 10th harmonics are measured using the test procedure for radiated measurements as described in clause 5.4.3.

6.2.4 Test results from 9 kHz to 30 MHz

Performed by:	Jennifer Riedel	Date of test:	August 28, 2019

Test distance:	Prescan:	☒ 3 m		
	Final scan:	☒ 3 m	☐ 10 m	☐ ….. m
Polarization:	☒ parallel	☒ in line	☐ angle: ….°	
EUT Position:	☒ Position X	☒ Position Y	☒ Position Z	

Frequency range	*Step size*	*IF Bandwidth*	*Detector*	
			Prescan	*Final scan*
9 kHz – 90 kHz	100 Hz	200 Hz	PK	AV
90 kHz – 110 kHz	100 Hz	200 Hz	PK	QPK
110 kHz – 150 kHz	100 Hz	200 Hz	PK	AV
150 kHz – 490 kHz	4.5 kHz	9 kHz	PK	AV
490 kHz – 30 MHz	4.5 kHz	9 kHz	PK	QPK

Note 1: In this test report only the chart of the worst case position and antenna polarization is shown. These are found through premeasurements.

Note 2: Premeasurements have shown that FSK-modulation is the worst case, so only the chart of the FSK-modulation is in this test report.

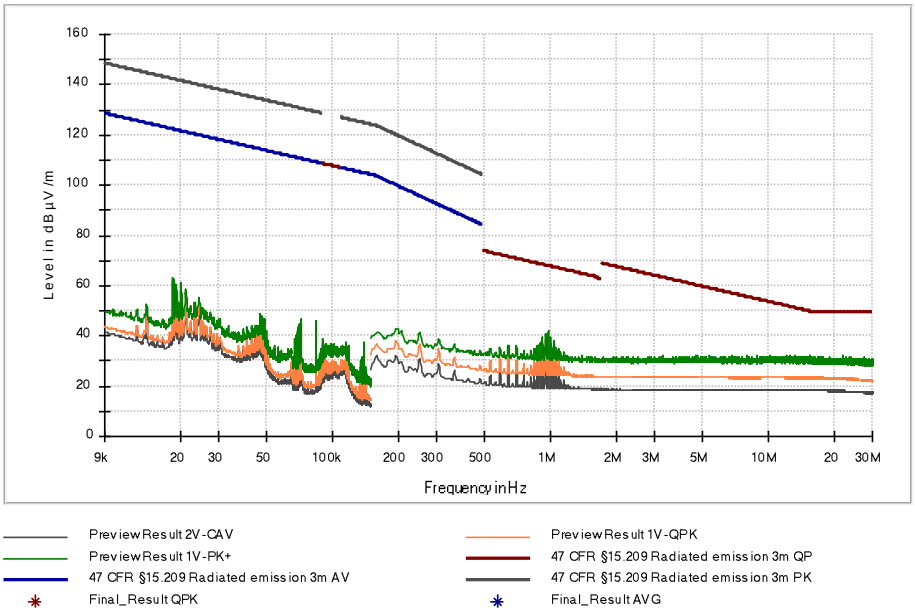

Figure 4: Chart of spurious radiated emission test 9 kHz - 30 MHz in position X and antenna parallel to the EUT at 3 m

Note: No assessable emissions were detected.

6.2.5 Test results from 30 MHz to 1 GHz

Performed by:	Jennifer Riedel	Date of test:	August 28, 2019	
Test distance:	Prescan:	☒ 3 m		
	Final scan:	☒ 3 m	☐ 10 m	☐ ….. m
Polarization:	☒ horizontal	☒ vertical		
EUT Position:	☒ Position X	☒ Position Y	☒ Position Z	

Frequency range	*Step size*	*IF Bandwidth*	*Detector*	
			Prescan	*Final scan*
30 MHz – 1 GHz	50 kHz	100 kHz	PK	PK

Note 1: In this test report only the chart of the worst case position and antenna polarization is shown. These are found through premeasurements.

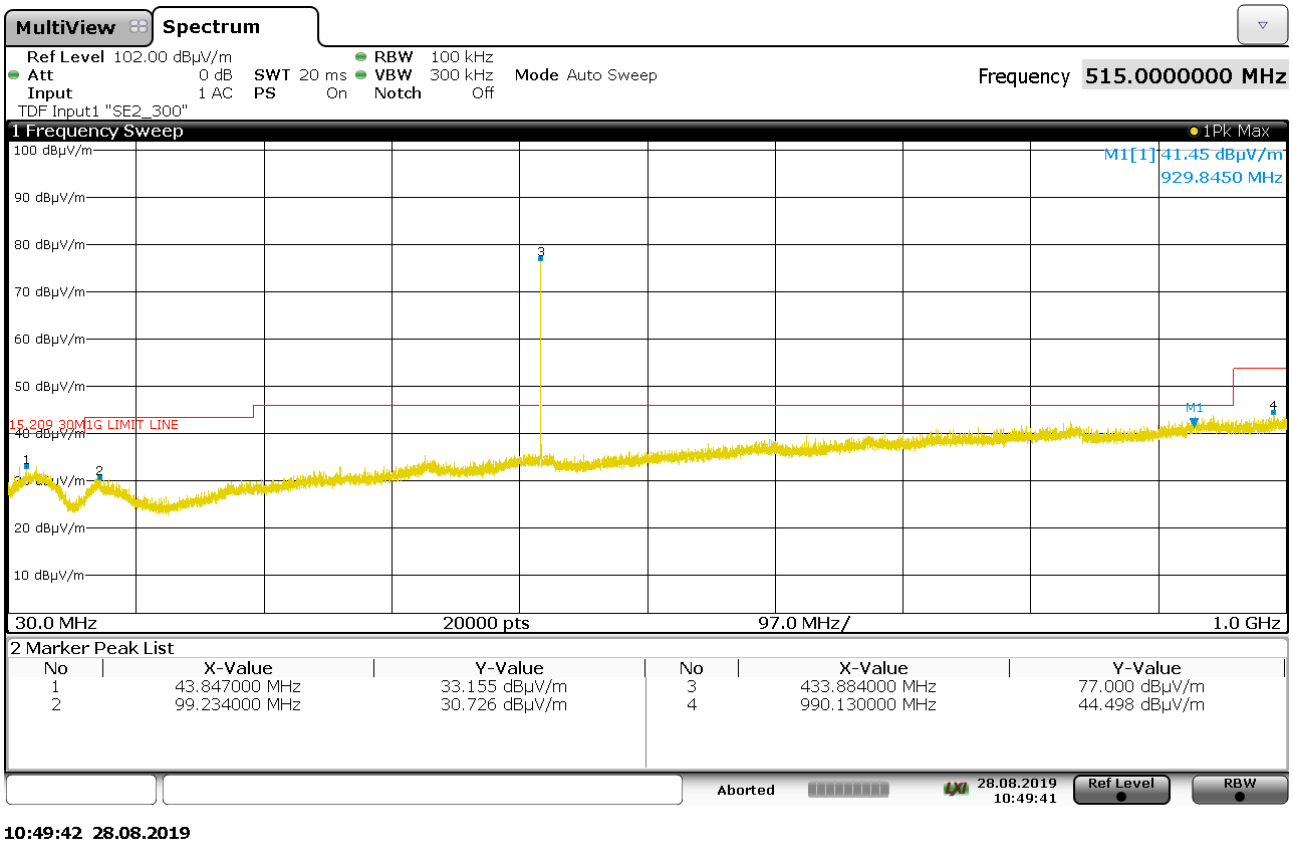

Figure 5: Chart of spurious radiated emission test 30 MHz - 1 GHz of FSK-modulation in position X and polarization V at 3 m

Note: Except of the fundamental no assessable emissions could be detected. The fundamental wave is evaluated in clause 6.2.

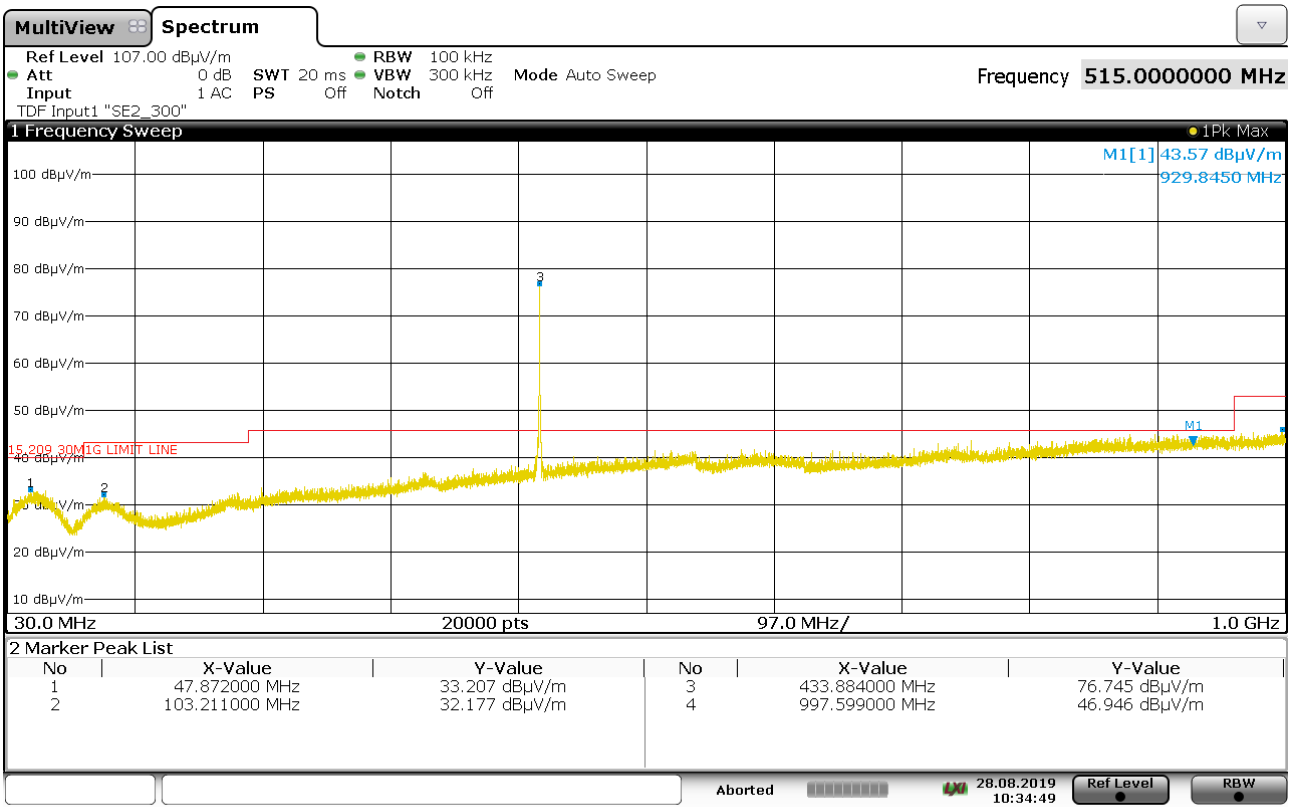

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Figure 6: Chart of spurious radiated emission test 30 MHz - 1 GHz of ASK-modulation in position X and polarization V at 3 m

Note: Except of the fundamental no assessable emissions could be detected. The fundamental wave is evaluated in clause 6.2.

6.2.6 Test results from 1 GHz to 10th harmonic

Performed by:	Jennifer Riedel	Date of test:	August 28, 2019	
Test distance:	Prescan:	☐ 1 m	☒ 3 m	☐ ….. m
	Final scan:	☒ 3 m	☐ 10 m	☐ ….. m
Polarization:	☒ horizontal	☒ vertical		
EUT Position:	☒ Position X	☒ Position Y	☒ Position Z	

Frequency range	*Step size*	*IF Bandwidth*	*Detector*	
			Prescan	*Final scan*
1 GHz – 5 GHz	250 kHz	1 MHz	PK	PK

Note 1: In this test report only the chart of the worst case position and antenna polarization is shown. These are found through premeasurements. The table results are the final measurements of the emissions detected in the premeasurements which are shown in this test report.

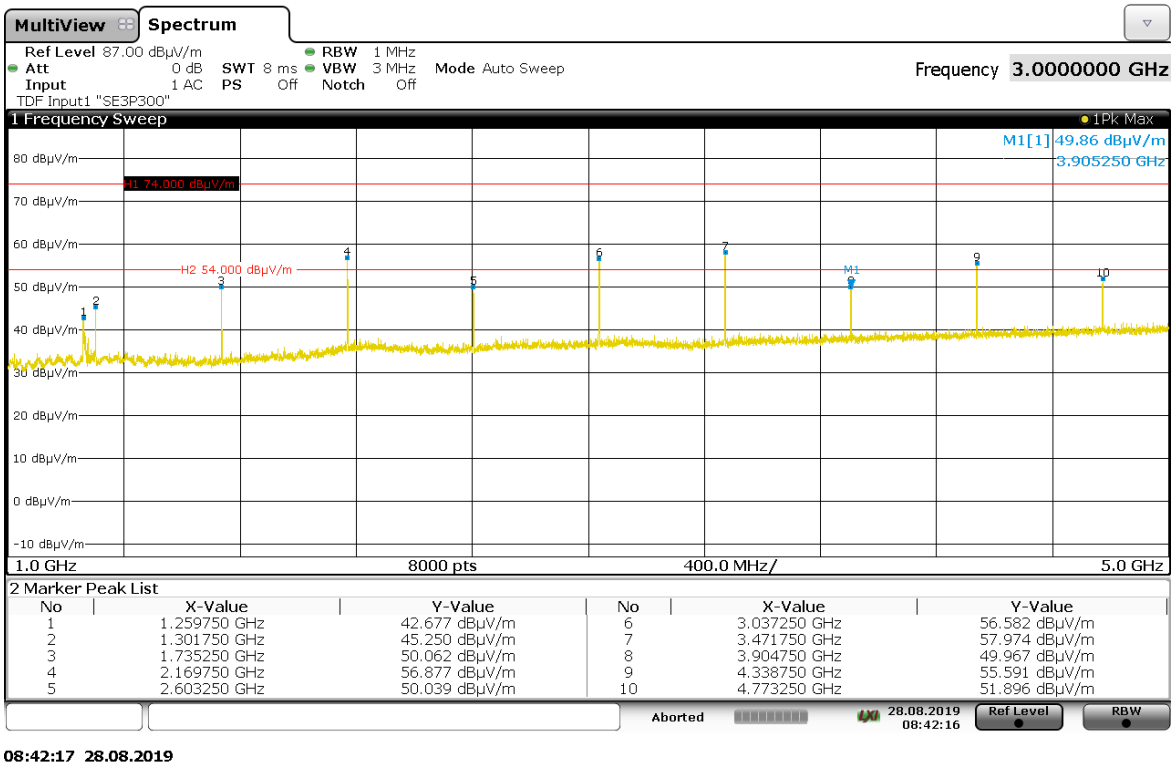

Figure 7: Chart of spurious radiated emission final test 1 GHz to 5 GHz of FSK-modulation in position X and horizontal polarization at 3 m

Frequency (MHz)	MaxPeak (dBµV/m)	Average (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Bandwidth (kHz)	Height (cm)	Pol	Azimuth (deg)
1259.750	43.43	---	74.00	30.57	1000.000	248.0	H	175.0
1301.750	46.49	---	74.00	27.51	1000.000	100.0	H	355.0
1735.250	50.04	---	74.00	23.96	1000.000	100.0	H	13.0
2169.750	57.14	---	74.00	16.86	1000.000	155.0	H	290.0
2169.750	---	37.17[1]	54.00	16.83	---	---	---	---
2603.250	51.37	---	74.00	22.63	1000.000	190.0	H	30.0
3037.250	56.62	---	74.00	17.38	1000.000	200.0	H	115.0
3037.250	---	36.65[1]	54.00	17.35	---	---	---	---
3471.750	59.34	---	74.00	14.66	1000.000	110.0	H	150.0
3471.750	---	39.37[1]	54.00	14.63	---	---	---	---
3904.750	50.37	---	74.00	23.63	1000.000	100.0	H	220.0
4338.750	55.57	---	74.00	18.43	1000.000	250.0	H	320.0
4338.750	---	35.60[1]	54.00	18.40	---	---	---	---
4773.250	52.15	---	74.00	21.85	1000.000	240.0	H	333.0

Table 6: Test result of spurious radiated emissions wave for FSK modulation

Note 1: The average value is calculated as the difference between the peak value and the duty cycle correction factor which is determined as described in clause 6.3.

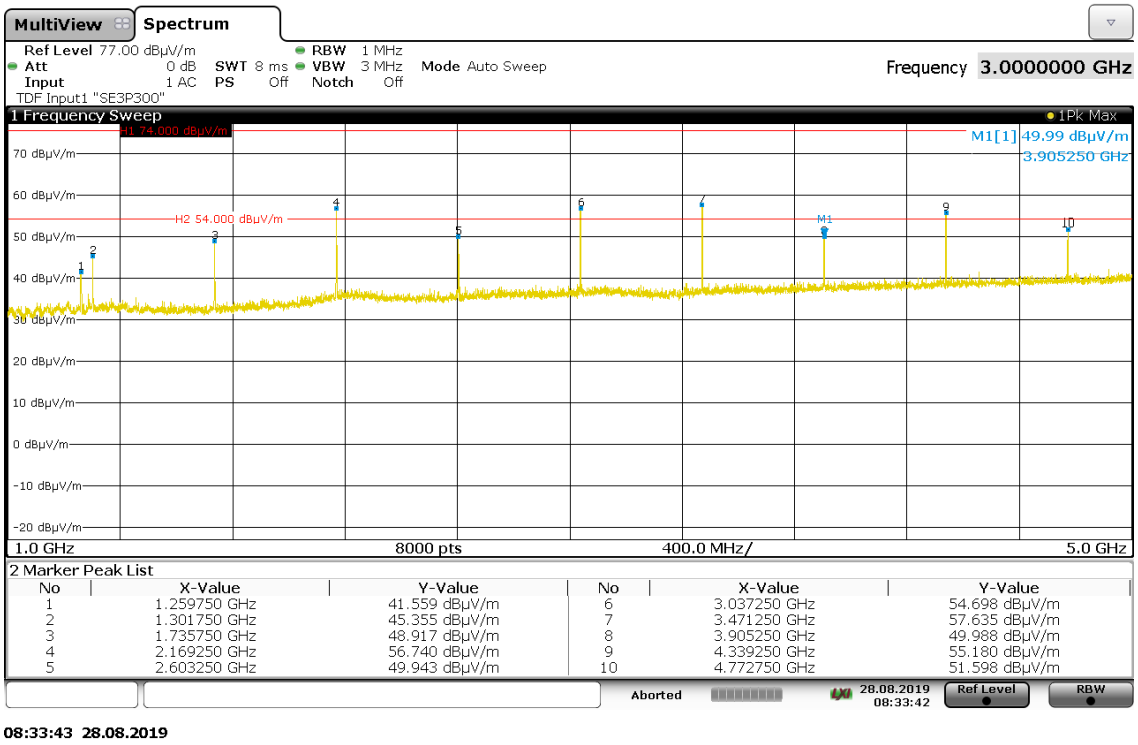

Figure 8: Chart of spurious radiated emission final test 1 GHz to 5 GHz of ASK-modulation in position X and horizontal polarization at 3 m

Frequency (MHz)	MaxPeak (dBµV/m)	Average (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Bandwidth (kHz)	Height (cm)	Pol	Azimuth (deg)
1259.750	41.56	---	74.00	32.44	1000.000	140.0	H	170.0
1301.750	45.36	---	74.00	28.64	1000.000	105.0	H	340.0
1735.750	48.92	---	74.00	25.08	1000.000	100.0	H	20.0
2169.250	56.74	---	74.00	17.26	1000.000	155.0	H	280.0
2169.250	---	36.77[1]	54.00	17.23	---	---	---	---
2603.250	49.94	---	74.00	24.06	1000.000	185.0	H	32.0
3037.250	54.70	---	74.00	19.30	1000.000	190.0	H	120.0
3037.250	---	34.73[1]	54.00	19.27	---	---	---	---
3471.250	57.64	---	74.00	16.36	1000.000	110.0	H	145.0
3471.250	---	37.67[1]	54.00	16.33	---	---	---	---
3905.250	49.99	---	74.00	24.01	1000.000	110.0	H	230.0
4339.250	55.18	---	74.00	18.82	1000.000	245.0	H	325.0
4339.250	---	35.21[1]	54.00	18.79	---	---	---	---
4772.750	51.60	---	74.00	22.40	1000.000	235.0	H	325.0

Table 7: Test result of spurious radiated emissions wave for ASK modulation

Note 1: The average value is calculated as the difference between the peak value and the duty cycle correction factor which is determined as described in clause 6.3.

6.3 Correction for pulse operation (duty cycle)

47 CFR part and section: 15.231(b)2

Measurement procedure: See 5.2

Result ☒ Test passed ☐ Test not passed

6.3.1 Test equipment

	Type	*Designation*	*Manufacturer*	*Inventory no.*
☐	Laboratory environment	---	---	---
☒	Compact Diagnostic Chamber (CDC)	VK041.0174	Albatross Projects	E00026
☐	EMI test receiver	ESCI 3	Rohde & Schwarz	E00001
☐	EMI test receiver	ESU 26	Rohde & Schwarz	W00002
☒	EMI test receiver	ESR 7	Rohde & Schwarz	E00739
☐	EMI test receiver	ESW 44	Rohde & Schwarz	E00895
☒	Measuring antenna set	---	---	A00088

6.3.2 Applicable standard

According to FCC Part 15C, Section 15.35(c):
The emissions from intentional radiators shall not exceed the effective field strength limits.

6.3.3 Test procedure

The duty cycle is measured using stimulus signal from a car key as used in real application.
The duty cycle factor (dB) is calculated applying the following formula:

$$KE = 20\lg\frac{tiB * p}{\mathrm{Tw}}$$

K_E	pulse operation correction factor	(dB)
t_{iw}	pulse duration for one complete pulse track	(ms)
t_{ib}	pulse duration for one pulse	(ms)
T_w	a period of the pulse track	(ms)
P	number of pulses in one train	(ms)

6.3.4 Test results

Performed by:	Jennifer Riedel	Date of test:	August 12, 2019

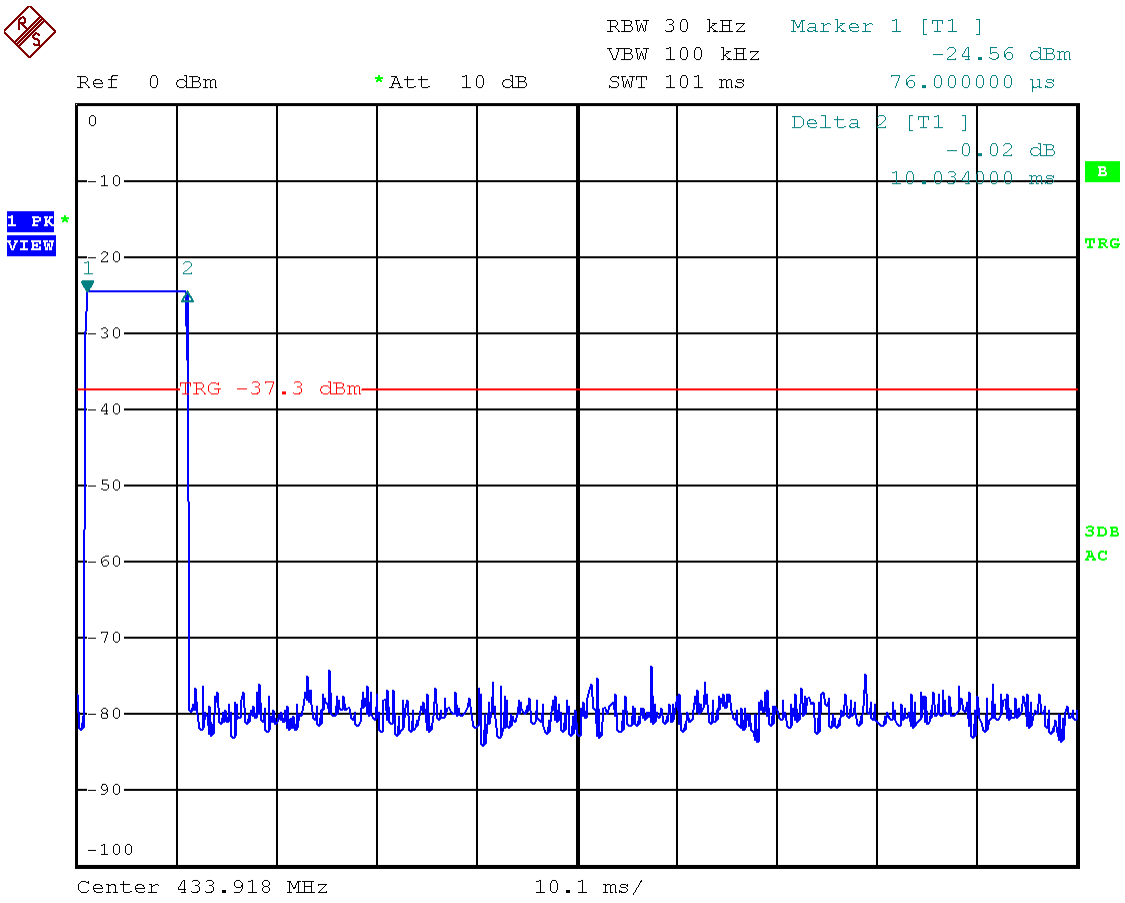

Figure 9: Detailed view of signal in 100 ms (Trigger-offset -1 ms)

The duration of the burst is 10.034 ms.

$$KE = 20lg\frac{10.034\,ms}{100\,ms} = -19.97\,dB \rightarrow 19.97\,dB\,max.$$

6.4 20 dB bandwidth

47 CFR part and section: 15.231(c)

Measurement procedure (DTS): See 5.1

Result ☒ Test passed ☐ Test not passed

6.4.1 Test equipment

Type	*Designation*	*Manufacturer*	*Inventory no.*
☐ Laboratory environment	---	---	---
☒ Compact Diagnostic Chamber (CDC)	VK041.0174	Albatross Projects	E00026
☒ EMI test receiver	ESCI 3	Rohde & Schwarz	E00001
☐ EMI test receiver	ESU 26	Rohde & Schwarz	W00002
☐ EMI test receiver	ESW 44	Rohde & Schwarz	E00895
☒ Measuring antenna set	---	---	A00088

6.4.2 Limits according to FCC Part 15C Section 15.231(c):

Frequency [MHz]	*20 dB BW limit dependent of the carrier [%]*
70 – 900	0.25
Above 900	0.50

6.4.3 Test procedure

The 20 dB bandwidth is measured using the test procedure as described in clause 5.1.

6.4.4 Test results

Performed by:	Jennifer Riedel	Date of test:	August 12, 2019

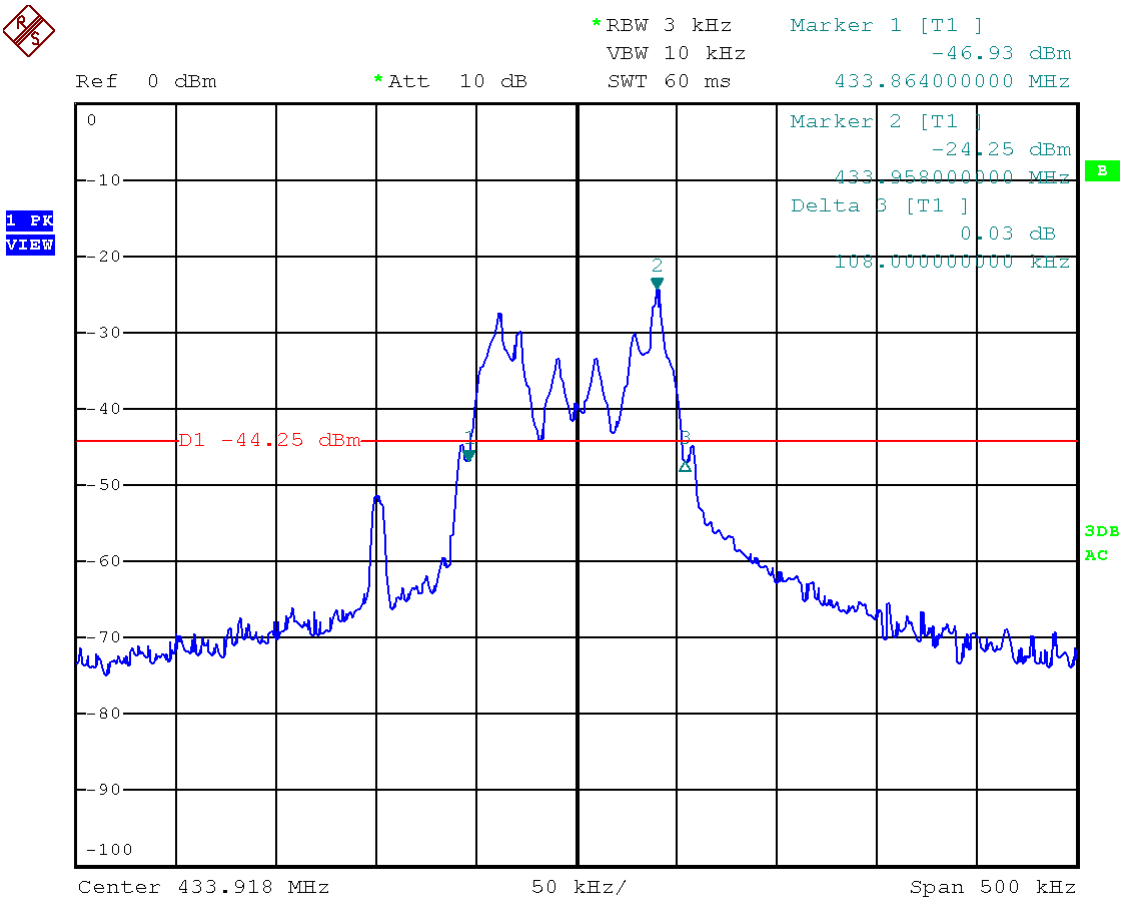

Figure 10: Chart of 20 dB bandwidth test for FSK-modulation

f [MHz]	*20dB-BW [kHz]*	*f_{lower} [MHz]*	*f_{upper} [MHz]*	*Limit [MHz]*	*Result*
433.958	108.0	433.864	433.972	1.085	Passed

Table 8: Final results of 20 dB bandwidth for FSK-modulation

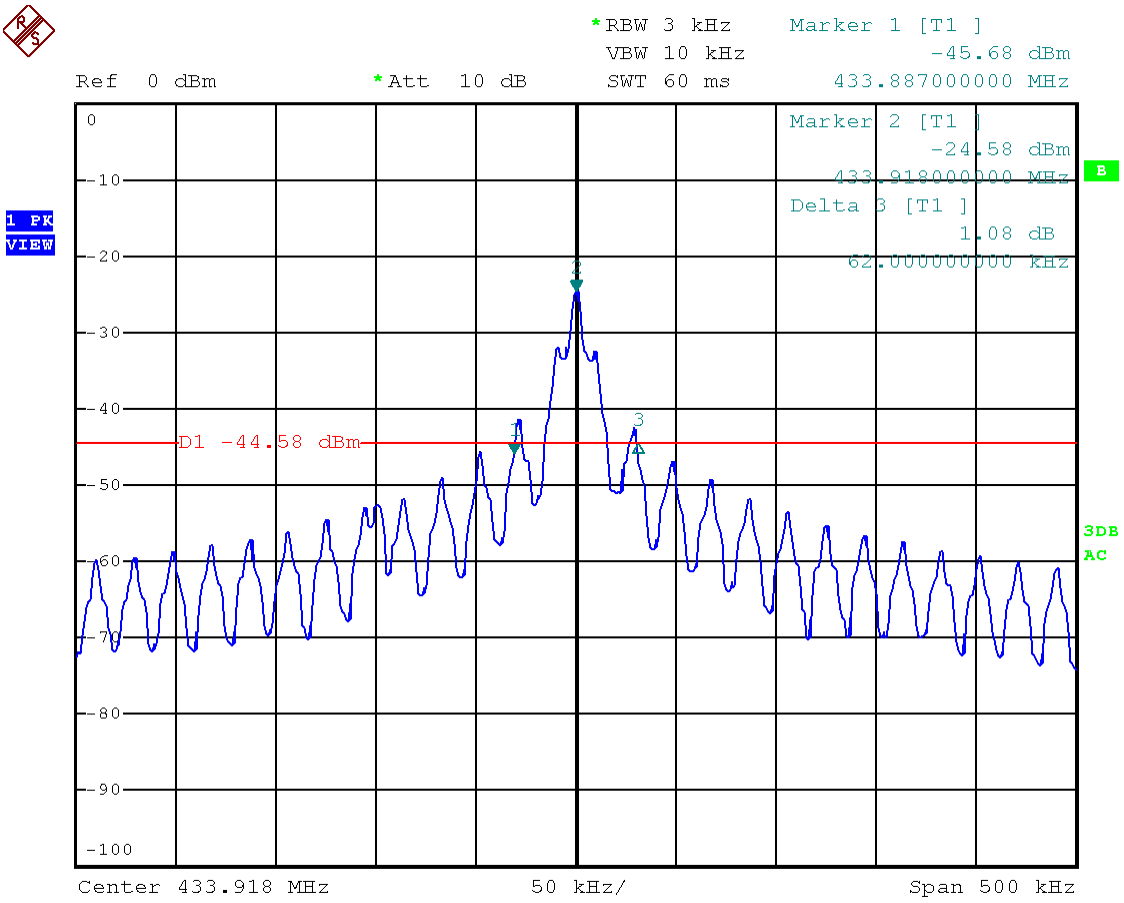

Figure 11: Chart of 20 dB bandwidth test for ASK-modulation

f [MHz]	*20dB-BW [kHz]*	f_{lower} *[MHz]*	f_{upper} *[MHz]*	*Limit [MHz]*	*Result*
433.918	62.00	433.887	433.949	1.085	Passed

Table 9: Final results of 20 dB bandwidth for ASK-modulation

6.5 Occupied bandwidth

47 CFR part and section: ---

Equivalent to IC radio standard(s) RSS-Gen, 6.7

Measurement procedure: See 5.2

Result ☒ Test passed ☐ Test not passed

6.5.1 Test equipment

Type	*Designation*	*Manufacturer*	*Inventory no.*
☐ Laboratory environment	---	---	---
☒ Compact Diagnostic Chamber (CDC)	VK041.0174	Albatross Projects	E00026
☐ EMI test receiver	ESCI 3	Rohde & Schwarz	E00001
☐ EMI test receiver	ESU 26	Rohde & Schwarz	W00002
☒ EMI test receiver	ESR 7	Rohde & Schwarz	E00739
☐ EMI test receiver	ESW 44	Rohde & Schwarz	E00895
☒ Measuring antenna set	---	---	A00088

6.5.2 Limits

None -> results recorded for setting the proper reference level.

6.5.3 Test procedure

The occupied bandwidth is measured using the test procedure as described in clause 5.2.

6.5.4 Test results

Performed by:	Jennifer Riedel	Date of test:	August 12, 2019

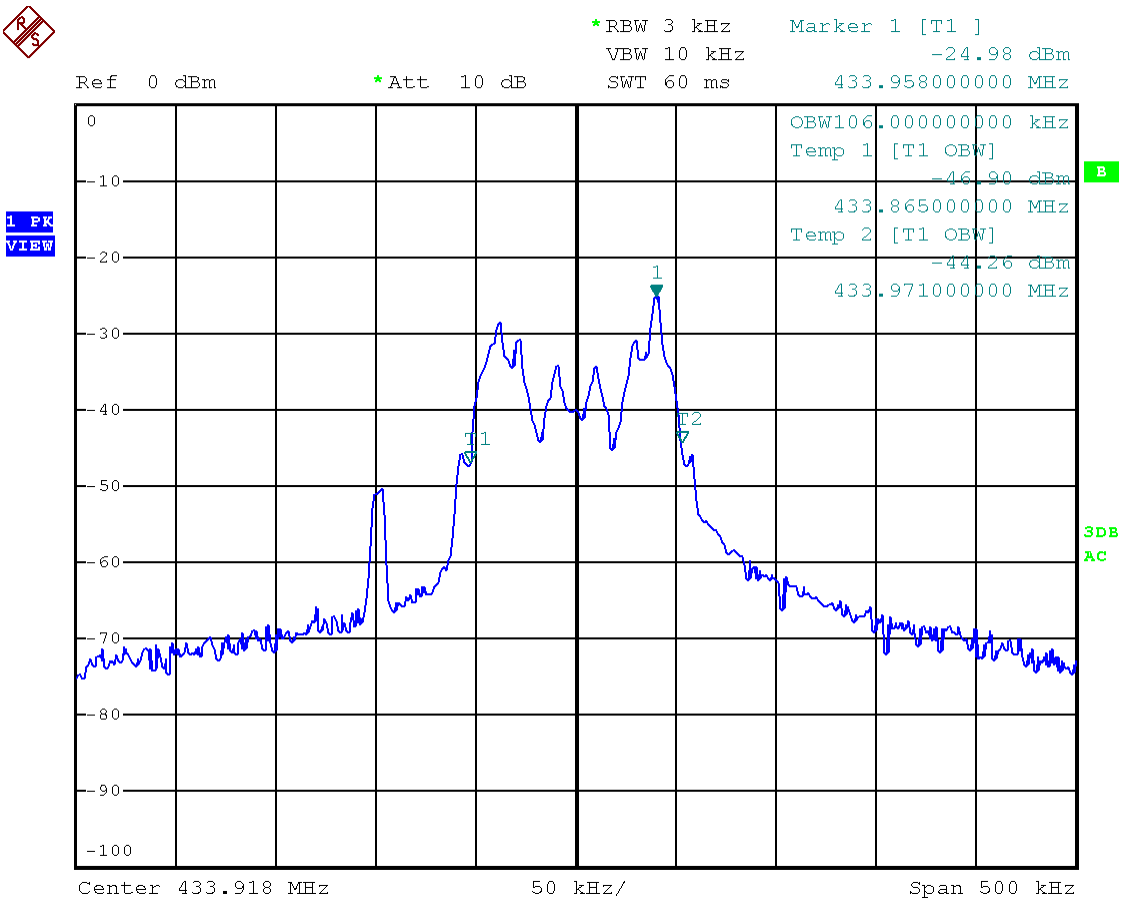

Figure 12: Chart of occupied bandwidth test of FSK-modulation

f [MHz]	*Occ. BW [kHz]*	f_{lower} *[MHz]*	f_{upper} *[MHz]*	*Result*
433.958	106.0	433.865	433.971	No limit

Table 10: Final results of occupied bandwidth test of FSK-modulation

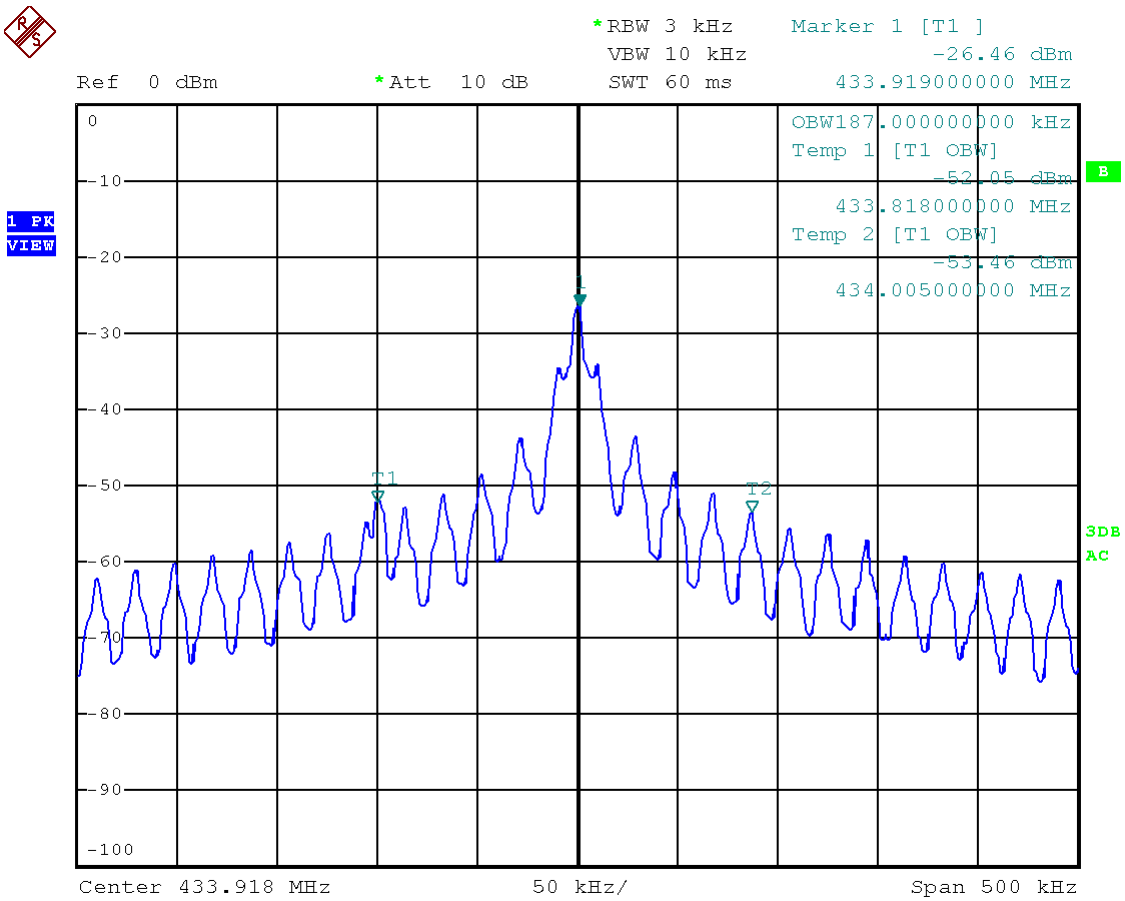

Figure 13: Chart of occupied bandwidth test of ASK-modulation

f [MHz]	*Occ. BW [kHz]*	*f_{lower} [MHz]*	*f_{upper} [MHz]*	*Result*
433.919	187.0	433.818	434.005	No limit

Table 11: Final results of occupied bandwidth test of ASK-modulation

6.6 Duration of transmission and silent period

47 CFR part and section: 15.231(e)

Measurement procedure: See 5.2

Result ☒ Test passed ☐ Test not passed

6.6.1 Test equipment

	Type	*Designation*	*Manufacturer*	*Inventory no.*
☐	Laboratory environment	---	---	---
☐	Compact Diagnostic Chamber (CDC)	VK041.0174	Albatross Projects	E00026
☐	EMI test receiver	ESCI 3	Rohde & Schwarz	E00001
☒	EMI test receiver	ESU 26	Rohde & Schwarz	W00002
☐	EMI test receiver	ESR 7	Rohde & Schwarz	E00739
☐	EMI test receiver	ESW 44	Rohde & Schwarz	E00895
☒	Measurement antenna 900 MHz	CV-800FE	Create Japan	A00088

6.6.2 Applicable standard

According to FCC Part 15C, Section 15.231(e):
The duration of each transmission of intentional radiators operating at a periodic rate shall not be greater than one second and the silent period between transmissions shall be at least 30 times the duration of the transmission but in no case less than 10 seconds.

6.6.3 Test procedure

The duration of transmission is measured with the spectrum analyzer. The signal is modulated; the marker of the analyzer is set to maximum amplitude at normal temperature and zero span. The analyzer is set to video triggered, the marker is set to the edges in order to measure the duration time and silent period and then recorded.

6.6.4 Test results

Performed by:	Jennifer Riedel	Date of test:	August 12, 2019

Limit according to FCC Part 15C, Section 15.231(e):
The duration of each transmission shall not be greater than one second and the silent period between transmissions shall be at least 30 times the duration of the transmission but in no case less than 10 seconds.

Remark: The EUT was activated automatically with a sending interval of 16 s, which is the normal sending interval, it is also selected for the test. The transmission duration is always the same (2.81 ms).

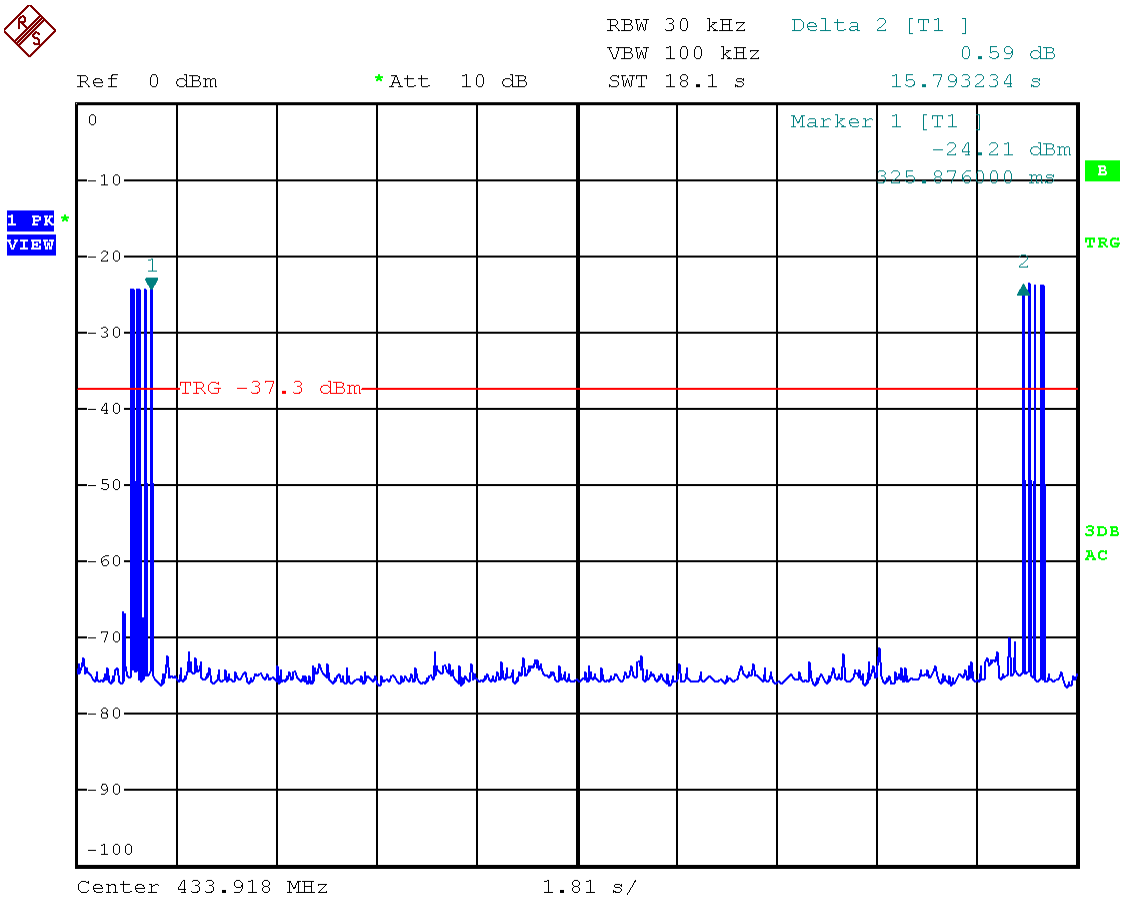

Figure 14: Test protocol of signal deactivation in 18.1 s (trigger offset -0.1 s)

The four bursts are considered as one transmission.
There are two transmissions in a sweep time of 18 s. The silent period between the two transmissions is 15.793 s which is more than at least 30 times the duration of the transmission respectively more than 10 s.

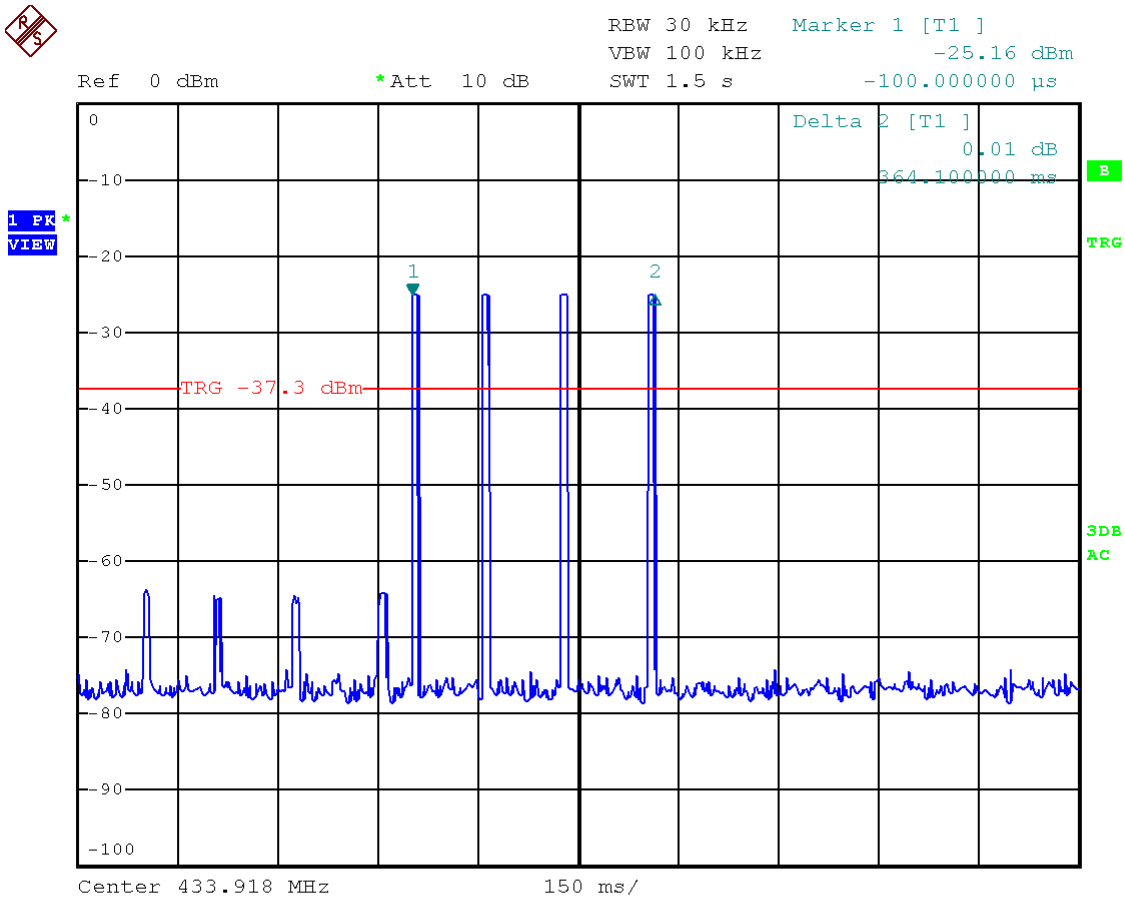

Figure 15: Test protocol of transmission duration of one transmission (trigger offset -0.5 s)

The duration of one transmission is 364.1 ms which is less than the maximum permitted duration time of one second of each transmission.

7 Equipment calibration status

Description	*Modell number*	*Serial number*	*Inventory number(s)*	*Last calibration*	*Next calibration*
EMI test receiver	ESW44	101538	E00895	2019-07	2020-07
EMI test receiver	ESR7	101059	E00739	2019-08	2020-08
EMI test receiver	ESCI 3	100013	E00001	2018-05	2020-05
EMI test receiver	ESU26	100026	W00002	2018-06	2020-06
Preamplifier (1 GHz - 18 GHz)	ALS05749	001	W01007	2019-01	2020-01
Loop antenna	HFH2-Z2	871398/0050	E00060	2018-10	2020-10
TRILOG broadband antenna (SAC3)	VULB 9162	9162-041	E00643	2018-03	2021-03
Horn antenna	BBHA 9120D	9120D-592	W00052	2017-04	2020-04
Horn antenna	BBHA 9170	9170-332	W00054	2017-04	2020-04
Measuring antenna set	---	---	A00088	N/A[1]	
Shielded room	P92007	B 83117 C 1109 T 211	E00107	N/A	
Compact diagnostic chamber (CDC)	VK041.0174	D62128-A502-A69-2-0006	E00026	N/A	
Semi-anechoic chamber (SAC) with floor absorbers	FS-SAC	---	E00100	2018-03	2021-03
Semi-anechoic chamber (SAC)	SAC3	C62128-A520-A643-x-0006	E00716	2018-03	2021-03
Cable set CDC	RG214/U	---	E00446	2019-04	2020-04
	LCF12-50J	---	E01215	2019-04	2020-04
	LMR400	1718020006	E00920	2019-01	2020-01
	RG214 Hiflex	171802007	E00921	2019-01	2020-01
Cable set anechoic chamber	262-0942-1500	005	E00435	2018-10	2019-10
	SF104EA/2x11PC35-42/5m	11144/4EA	E00307	2018-12	2019-12
	262-0942-1500	003	E00433	2018-10	2019-10
Cable set of semi-anechoic chamber SAC3	SF104EA/11PC35/11PC35/10000MM	501347/4EA	E00755	2018-12	2019-12
	SF104E/11PC35/11PC35/2000MM	507410/4E	E01033	2018-12	2019-12
	SF104E/11PC35/11PC35/2000MM	507411/4E	E01034	2018-09	2019-09

Table 12: Equipment calibration status

Note 1: Only used for relative measurements.

8 Measurement uncertainties

Description	*Max. deviation*	*k=*
Conducted emission AMN (9kHz to 30 MHz)	± 4.1 dB	2
Carrier frequency separation Number of hopping frequencies Time of occupancy (dwell time)	± 5.0 %	2
Bandwidth tests	± 2.0 %	2
Maximum conducted output power	± 1.5 dB	2
Power spectral density	± 3.0 dB	2
Spurious RF conducted emissions	± 3.0 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 anechoic chamber (> 1000 MHz)	± 4.5 dB	2

Table 13: 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.

9 Revision history

Revision	*Date*	*Issued by*	*Description of modifications*
0	2019-09-05	Jennifer Riedel	First edition

10 Additional documents

☒ Annex A: Pictures of test setup and EUT-positions
☒ Annex B: Pictures of EUT (external)
☒ Annex C: Pictures of EUT (internal)