
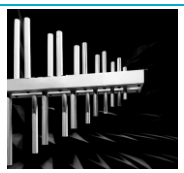
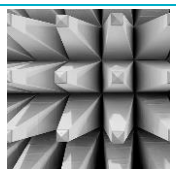

TEST REPORT

Test report no.: 1-3181-21-01-09_TR1-R01

DAkkS Deutsche Akkreditierungsstelle D-PL-12047-01-00

Testing laboratory

cetecom advanced GmbH
Untertuerkheimer Strasse 6 – 10
66117 Saarbruecken / Germany
Phone: + 49 681 5 98 - 0
Fax: + 49 681 5 98 - 9075
Internet: https://cetecomadvanced.com
e-mail: mail@cetecomadvanced.com

Accredited Testing Laboratory:
The testing laboratory (area of testing) is accredited according to DIN EN ISO/IEC 17025 (2018-03) by the Deutsche Akkreditierungsstelle GmbH (DAkkS).
The accreditation is valid for the scope of testing procedures as stated in the accreditation certificate with the registration number:
D-PL-12047-01-00.
ISED Testing Laboratory Recognized Listing Number: DE0001
FCC designation number: DE0002

Applicant

ifm electronic gmbh
Friedrichsstraße 1
45128 Essen / GERMANY
Phone: +49 201 2422-0
Contact: Holger Wenzel
e-mail: Holger.Wenzel@ifm.com

Manufacturer

ifm electronic gmbh
Friedrichsstraße 1
45128 Essen / GERMANY

Test standard/s

FCC - Title 47 CFR Part 15	FCC - Title 47 of the Code of Federal Regulations; Chapter I; Part 15 - Radio frequency devices

For further applied test standards please refer to section 3 of this test report.

Test Item

Kind of test item:	**Area Radar, 60 GHz**
Model name:	**R2D103, R2D102, R2D111 (TR24)**
FCC ID:	UN6-R2D1
Frequency:	60.0 GHz – 64.0 GHz
Antenna:	Integrated antenna
Power supply:	9.0 V – 32.0 V DC by external power supply
Temperature range:	-40°C to +85°C

This test report is electronically signed and valid without handwritten signature. For verification of the electronic signatures, the public keys can be requested at the testing laboratory.

Test report authorized:

Thomas Vogler

cn=Thomas Vogler, o=cetecom advanced GmbH, ou=VOG-230609, email=thomas.vogler@cetecomadvanced.com, c=DE
2024.10.08 10:39:31 +02'00'

Thomas Vogler
Lab Manager
Radio Labs

Test performed:

M. Walla

cn=Meheza Walla, o=cetecom advanced GmbH, ou=WAL-230706, email=Meheza.Walla@cetecomadvanced.com, c=DE
2024.10.07 19:20:58 +02'00'

Meheza Walla
Lab Manager
Radio Labs

1 Table of contents

2 General information

2.1 Notes and disclaimer

The test results of this test report relate exclusively to the test item specified in this test report. cetecom advanced GmbH does not assume responsibility for any conclusions and generalizations drawn from the test results with regard to other specimens or samples of the type of the equipment represented by the test item.
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This test report is electronically signed and valid without handwritten signature. For verification of the electronic signatures, the public keys can be requested at the testing laboratory.

2.2 Application details

Date of receipt of order:	2021-12-20
Date of receipt of test item:	2024-06-07
Start of test:*	2024-06-10
End of test:*	2024-06-28
Person(s) present during the test:	-/-

*Date of each measurement, if not shown in the plot, can be requested. Dates are stored in the measurement software.

2.3 Test laboratories sub-contracted

None

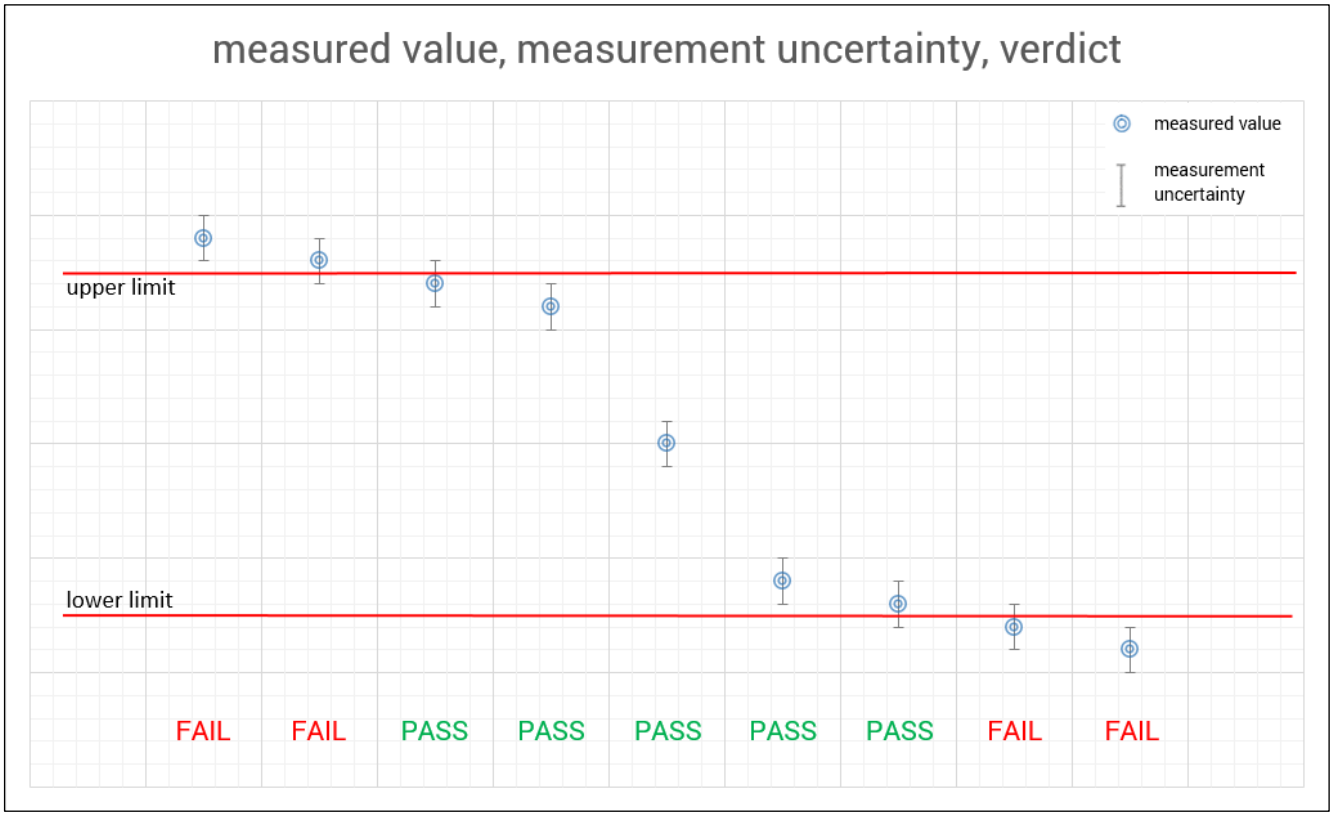
3 Test standard/s, references and accreditations

Test standard	Date	Description
FCC - Title 47 CFR Part 15		FCC - Title 47 of the Code of Federal Regulations; Chapter I; Part 15 - Radio frequency devices

Guidance	Version	Description
ANSI C63.4-2017	-/-	American National Standard for Methods of Measurement of Radio-Noise Emissions from Low-Voltage Electrical and Electronic Equipment in the Range of 9 kHz to 40 GHz
ANSI C63.10-2013	-/-	American National Standard of Procedures for Compliance Testing of Unlicensed Wireless Devices

4 Reporting statements of conformity – decision rule

Only the measured values related to their corresponding limits will be used to decide whether the equipment under test meets the requirements of the test standards listed in chapter 11.
The measurement uncertainty is mentioned in this test report, see chapter 7, but is not taken into account - neither to the limits nor to the measurement results. Measurement results with a smaller margin to the corresponding limits than the measurement uncertainty have a potential risk of more than 5% that the decision might be wrong."



5 Test environment

Temperature	:	T_{nom} T_{max} T_{min}	+22 °C during room temperature tests +85 °C during high temperature tests -40 °C during low temperature tests
Relative humidity content	:		55 %
Barometric pressure	:		1021 hpa
Power supply	:	V_{nom} V_{max} V_{min}	24.0 V DC by external power supply 32.0 V 9.0 V

6 Test item

6.1 General description

Kind of test item	:	Area Radar, 60 GHz
Model name	:	R2D103, R2D102, R2D111 (TR24)
S/N serial number	:	100001991356 (Internal Photos) 100001991371 (EUT)
Hardware status	:	PV2.9
Software status frontend	:	V1.022
Software status backend	:	V2.3.3
Frequency band	:	60.0 GHz – 64.0 GHz
Type of modulation	:	FMCW
Antenna	:	Integrated antenna
Power supply	:	9.0 V – 32.0 V DC by external power supply
Temperature range	:	-40°C to +85°C

6.2 Additional information

The content of the following annexes is defined in the QA. It may be that not all of the listed annexes are necessary for this report, thus some values in between may be missing.

Test setup and EUT photos are included in test report:

- 1-3181-21-01-09_TR1-A101-R01 (External photographs of EUT)
- 1-3181-21-01-09_TR1-A102-R01 (Internal photographs of EUT)
- 1-3181-21-01-09_TR1-A103-R01 (Test set-up photographs)
- Note: The referenced photos show EUT delivered by the customer in this project, not necessarily the exact one used for the specific tests. EUT identification shown in the photos may differ.

Operating mode as declared by the manufacturer:
radar modulation mode is identified internally as "Mode 4, Emitted power reduction".
Users cannot select another mode (fixed mode)

6.3 Additional comments

Reference documents: Document incl. antenna gain information in terms of data sheets and/or test reports (from customer)

Refer to "20240627_ISR2301_Simulation_Tx_Antenna_Gain.pdf"
from InnoSent GmbH for radar frontend ISR-2301.

Special test descriptions: None

Configuration descriptions:

This test report is valid for the following electrically identical models with the same radio frontend:

Variant	HW status	SW status frontend	SW status backend	Remarks
R2D103 (tested)	M04288AA	V1.022	V2.3.3	backend: CAN bus interface (Communication via CAN J1939)
R2D102	M04286AA	V1.022		backend: IO-Link interface, standard analysis software
R2D111	M04287AA	V1.022		HW identical to R2D102, special analysis software

See also “Customer Declaration on Electrically Identical Models” in chapter 14.

7 Summary of measurement results

☒	**No deviations from the technical specifications were ascertained**
☐	There were deviations from the technical specifications ascertained
☐	This test report is only a partial test report. The content and verdict of the performed test cases are listed below.

TC identifier	Description	verdict	date	Remark
RF-Testing	FCC 47 CFR Part 15 (dated 2023-08-23)	see below	2024-10-07	-/-

Test specification clause	Test case	Temperature conditions	Power supply	Pass	Fail	NA	NP	Remark
47 CFR 15.215(b) & (c), 47 CFR 15.255(f)	Occupied bandwidth & Frequency stability	Nominal Extreme	Nominal Extreme	☒	☐	☐	☐	complies
47 CFR 15.255(b)(3) & (c)	Radiated power (EIRP)	Nominal	Nominal	☒	☐	☐	☐	complies
47 CFR 15.255(c)(2) 47 CFR 15.255(e)	Peak transmitter conducted output power	Nominal	Nominal	☒	☐	☐	☐	complies
47 CFR 15.255(b)(3), 47 CFR 15.255(c)	Time domain requirements	Nominal	Nominal	☒	☐	☐	☐	complies
47 CFR 15.255(d)	Spurious emissions radiated	Nominal	Nominal	☒	☐	☐	☐	complies
47 CFR 15.207	Conducted emissions < 30 MHz (AC power line)	Nominal	Nominal	☒	☐	☐	☐	complies

Note: NA = Not applicable; NP = Not performed

8 Basic information of the DUT & selection of applicable rule parts

Basic information of the DUT:

Operation condition:

☐ Operation on aircraft (47 CFR 15.255(b))

☐ Unmanned aircraft (47 CFR 15.255(b)(3))

☐ Not unmanned aircraft

☒ No operation on aircraft

Note: Operation under the provisions of this section is not permitted for equipment used on satellites (47 CFR 15.255(a)).

Kind of DUT:

☐ Devices other than field disturbance sensors and other than fixed point-to-point transmitters located outdoors

☐ Fixed point-to-point transmitters located outdoors

☒ Field disturbance sensors/radars

☐ Pulsed field disturbance sensors/radars

☒ Other than pulsed field disturbance sensors/radars
Note: FMCW signal

Frequency band:

☐ Operating within band 59.3 – 71.0 GHz (47 CFR 15.255(b)(2)(iii))

☐ Operating within band 60 – 64 GHz (47 CFR 15.255(b)(3))

☐ Operating within band 57 – 71 GHz (47 CFR 15.255(c)(1) / (c)(2))

☐ Operating within band 57.0 – 59.4 GHz (47 CFR 15.255(c)(2)(i))

☐ Operating within band 57.0 – 61.56 GHz (47 CFR 15.255(c)(2)(ii))

☒ Operating within band 57 – 64 GHz (47 CFR 15.255(c)(2)(iii) / (c)(3))
Note: FMCW signal

☐ Operating within band 61.0 – 61.5 GHz (47 CFR 15.255(c)(2)(v))

Note: See results in chapter 13.1

Selection of applicable rule parts:

Applicable rule parts and limits depend on the basic information of the DUT (see chapter 8).
The comparison of the basic information of the DUT with the rule parts lead to the following conclusions:

Rule Part	Applicable?	
	Yes	No
47 CFR 15.255:		
(a) **General:** Operation under the provisions of this section is not permitted for equipment used on **satellites**.	☒	
(b) **Operation on aircraft:** Operation on aircraft is permitted under the following conditions:	☐	☒
(1) When the aircraft is on the ground.	☐	☒
(2) While airborne, only in closed exclusive on-board communication networks within the aircraft, with the following exceptions:	☐	☒
(i) Equipment shall not be used in wireless avionics intra-communication (WAIC) applications where external structural sensors or external cameras are mounted on the outside of the aircraft structure.	☐	☒
(ii) Except as permitted in paragraph (b)(3) of this section, equipment shall not be used on aircraft where there is little attenuation of RF signals by the body/fuselage of the aircraft.	☐	☒
(iii) **Field disturbance sensor/radar** devices may only operate in the frequency band **59.3–71.0 GHz** while installed in passengers' personal portable electronic equipment (e.g., smartphones, tablets) and shall comply with paragraph (b)(2)(i) of this section, and relevant requirements of paragraphs (c)(2) through (c)(4) of this section.	☐	☒
(3) **Field disturbance sensors/radar** devices deployed on **unmanned aircraft** may operate within the frequency band **60–64 GHz**, provided that the transmitter not exceed 20 dBm peak EIRP. The sum of continuous transmitter off-times of at least two milliseconds shall equal at least 16.5 milliseconds within any contiguous interval of 33 milliseconds. Operation shall be limited to a maximum of 121.92 meters (400 feet) above ground level.	☐	☒
(c) **Radiated power limits:** Within the **57–71 GHz band**, emission levels shall not exceed the following equivalent isotropically radiated power (EIRP):	☒	
(1) **Devices other than field disturbance sensors** shall comply with one of the following power limits, as measured during the transmit interval:	☐	☒
(i) The average power of any emission shall not exceed 40 dBm and the peak power of any emission shall not exceed 43 dBm; or	☐	☒
(ii) For **fixed point-to-point transmitters located outdoors**, the average power of any emission shall not exceed 82 dBm, and shall be reduced by 2 dB for every dB that the antenna gain is less than 51 dBi. The peak power of any emission shall not exceed 85 dBm, and shall be reduced by 2 dB for every dB that the antenna gain is less than 51 dBi.	☐	☒
(A) The provisions in this paragraph (c) for reducing transmit power based on antenna gain shall not require that the power levels be reduced below the limits specified in paragraph (c)(1)(i) of this section.	☐	☒
(B) The provisions of § 15.204(c)(2) and (4) that permit the use of different antennas of the same type and of equal or less directional gain do not apply to intentional radiator systems operating under this provision. In lieu thereof, intentional radiator systems shall be certified using the specific antenna(s) with which the system will be marketed and operated. Compliance testing shall be performed using the highest gain and the lowest gain antennas for which certification is sought and with the intentional radiator operated at its maximum available output power level. The responsible party, as defined in § 2.909 of this chapter, shall supply a list of acceptable antennas with the application for certification.	☐	☒

(2) **Field disturbance sensors/radars** shall not exceed −10 dBm peak conducted output power and 10 dBm peak EIRP except that field disturbance sensors/radars that limit their operation to all or part of the specified frequency band may operate without being subject to a transmitter conducted output power limit if they operate in compliance with paragraph (b)(3) of this section or with one or more of the provisions below:	☒	☐
(i) **57.0–59.4 GHz**: the peak EIRP level shall not exceed 20 dBm for **indoor operation** or 30 dBm for **outdoor operation**;	☐	☒
(ii) **57.0–61.56 GHz**: the peak EIRP shall not exceed 3 dBm except that the peak EIRP shall not exceed 20 dBm if the sum of continuous transmitter off-times of at least two milliseconds equals at least 16.5 milliseconds within any contiguous interval of 33 milliseconds;	☐	☒
(iii) **57.0–64.0 GHz:**	☒	☐
(A) The peak EIRP shall not exceed 14 dBm, and the sum of continuous transmitter off-times of at least two milliseconds shall equal at least 25.5 milliseconds within any contiguous interval of 33 milliseconds, except as specific in paragraph (c)(2)(iii)(B) of this section;	☐	☒
(B) The peak EIRP shall not exceed 20 dBm, and the sum of continuous transmitter off-times of at least two milliseconds shall equal at least 16.5 milliseconds within any contiguous interval of 33 milliseconds when operated outdoors:	☒	☐
(1) As part of a **temporary or permanently fixed application**; or	☒	☐
(2) When being used in **vehicular applications to perform specific tasks of moving something or someone, except for in-cabin applications**;	☒	☐
(iv) A **field disturbance sensor** may operate in any of the modes in the above sub-sections so long as the device operates in only one mode at any time and does so for at least 33 milliseconds before switching to another mode.	☒	☐
(v) **61.0–61.5 GHz:** For **field disturbance sensors/radars** that occupy 500 MHz bandwidth or less that are contained wholly **within the frequency band 61.0–61.5 GHz**, the average power of any emission, measured during the transmit interval, shall not exceed 40 dBm, and the peak power of any emission shall not exceed 43 dBm. In addition, the average power of any emission **outside of the 61.0–61.5 GHz band**, measured during the transmit interval, but still within the 57–71 GHz band, shall not exceed 10 dBm, and the peak power of any emission shall not exceed 13 dBm.	☐	☒
(3) For **pulsed field disturbance sensors/radars** operating in the 57–64 GHz band that have a maximum pulse duration of 6 ns, the average EIRP shall not exceed 13 dBm and the transmit duty cycle shall not exceed 10% during any 0.3 µs time window. In addition, the average integrated EIRP within the frequency band **61.5–64.0 GHz** shall not exceed 5 dBm in any 0.3 µs time window. Peak emissions shall not exceed 20 dB above the maximum permitted average emission limit applicable to the equipment under test. The radar bandwidth is the frequency band bounded by the points that are 10 dB below the highest radiated emission, as based on the complete transmission system including the antenna	☐	☒
(4) The provisions in § 15.35(b) and (c) that require emissions to be averaged over a 100 millisecond period and that limits the peak power to 20 dB above the average limit do not apply to devices operating under paragraphs (c)(2) and (3) of this section.	☐	☒
(d) Limits on spurious emissions:	☒	
(1) The power density of any emissions outside the 57–71 GHz band shall consist solely of spurious emissions.	☒	
(2) Radiated emissions below 40 GHz shall not exceed the general limits in § 15.209.	☒	
(3) Between 40 GHz and 200 GHz, the level of these emissions shall not exceed 90 pW/cm^2 at a distance of 3 meters.	☒	
(4) The levels of the spurious emissions shall not exceed the level of the fundamental emission.	☒	
(e) Limits on transmitter conducted output power.	☐	☒

(1) Except as specified in paragraph (e)(2) of this section, the peak transmitter conducted output power of **devices other than field disturbance sensors/radars** shall not exceed 500 mW. Depending on the gain of the antenna, it may be necessary to operate the intentional radiator using a lower peak transmitter output power in order to comply with the EIRP limits specified in paragraph (c) of this section.	☐	☒
(2) **Devices other than field disturbance sensors/radars** with an emission bandwidth of less than 100 megahertz must limit their peak transmitter conducted output power to the product of 500 mW times their emission bandwidth divided by 100 megahertz. For the purposes of this paragraph, emission bandwidth is defined as the instantaneous frequency range occupied by a steady state radiated signal with modulation, outside which the radiated power spectral density never exceeds 6 dB below the maximum radiated power spectral density in the band, as measured with a 100 kilohertz resolution bandwidth spectrum analyzer. The center frequency must be stationary during the measurement interval, even if not stationary during normal operation (e.g., for frequency hopping devices).	☐	☒
(f) Frequency stability: Fundamental emissions must be contained within the frequency bands specified in this section during all conditions of operation. Equipment is presumed to operate over the temperature range −20 to + 50 degrees Celsius with an input voltage variation of 85% to 115% of rated input voltage, unless justification is presented to demonstrate otherwise.	☒	
(g) Radio frequency radiation exposure: Radio frequency devices operating under the provisions of this part are subject to the radio frequency radiation exposure requirements specified in §§ 1.1307(b), 1.1310, 2.1091, and 2.1093 of this chapter, as appropriate. Applications for equipment authorization of mobile or portable devices operating under this section must contain a statement confirming compliance with these requirements. Technical information showing the basis for this statement must be submitted to the Commission upon request.	☒	
(h) Group installation: Any transmitter that has received the necessary FCC equipment authorization under the rules of this chapter may be mounted in a group installation for simultaneous operation with one or more other transmitter(s) that have received the necessary FCC equipment authorization, without any additional equipment authorization. However, no transmitter operating under the provisions of this section may be equipped with external phase-locking inputs that permit beam-forming arrays to be realized.	☒	
(i) Compliance measurement: Measurement procedures that have been found to be acceptable to the Commission in accordance with § 2.947 of this chapter may be used to demonstrate compliance.	☒	
(1) For purposes of demonstrating compliance with this section, corrections to the transmitter conducted output power may be made due to the antenna and circuit loss.	☒	
(2) Compliance measurements of **frequency-agile field disturbance sensors/radars** shall be performed with any related frequency sweep, step, or hop function activated.	☐	☒
47 CFR 15.215		
(c) Intentional radiators operating under the alternative provisions to the general emission limits, as contained in §§ 15.217 through 15.257 and in subpart E of this part, 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. In the case of intentional radiators operating under the provisions of subpart E, the emission bandwidth may span across multiple contiguous frequency bands identified in that subpart. 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. If a frequency stability is not specified in the regulations, it is recommended that the fundamental emission be kept within at least the central 80% of the permitted band in order to minimize the possibility of out-of-band operation.	☒	

47 CFR 15.209	☒	
47 CFR 15.207		
(a) Except as shown in paragraphs (b) and (c) of this section, for an intentional radiator that is designed to be connected to the public utility (AC) power line, the radio frequency voltage that is conducted back onto the AC power line on any frequency or frequencies, within the band 150 kHz to 30 MHz, shall not exceed the limits in the table of this paragraph (see chapter 13.5), as measured using a 50 µH/50 ohms line impedance stabilization network (LISN). Compliance with the provisions of this paragraph shall be based on the measurement of the radio frequency voltage between each power line and ground at the power terminal. The lower limit applies at the boundary between the frequency ranges.	☒	
(c) Measurements to demonstrate compliance with the conducted limits are not required for devices which **only employ battery power** for operation and which do not operate from the AC power lines or contain provisions for operation while connected to the AC power lines. Devices that include, or make provisions for, the use of battery chargers which permit operating while charging, AC adapters or battery eliminators or that connect to the AC power lines indirectly, obtainig their power through another device which is connected to the AC power lines, shall be tested to demonstrate compliance with the conducted limits.	☒	☐

9 Sequence of testing

9.1 Sequence of testing radiated spurious 9 kHz to 30 MHz

Setup

- The equipment is set up to simulate normal operation mode as described in the user manual or defined by the manufacturer.
- If the EUT is a tabletop system, it is placed on a table with 0.8 m height.
- If the EUT is a floor standing device, it is placed directly on the turn table.
- Auxiliary equipment and cables are positioned to simulate normal operation conditions as described in ANSI C 63.4.
- The AC power port of the EUT (if available) is connected to a power outlet below the turntable.
- Measurement distance is 3 m (see ANSI C 63.4) – see test details.
- EUT is set into operation.

Premeasurement*

- The turntable rotates from 0° to 315° using 45° steps.
- The antenna height is 1 m.
- At each turntable position the analyzer sweeps with positive-peak detector to find the maximum of all emissions.

Final measurement

- Identified emissions during the pre-measurement are maximized by the software by rotating the turntable from 0° to 360°.
- Loop antenna is rotated about its vertical axis for maximum response at each azimuth about the EUT. (For certain applications, the loop antenna plane may also need to be positioned horizontally at the specified distance from the EUT)
- The final measurement is done in the position (turntable and elevation) causing the highest emissions with quasi-peak (as described in ANSI C 63.4).
- Final levels, frequency, measuring time, bandwidth, turntable position, correction factor, margin to the limit and limit will be recorded. A plot with the graph of the premeasurement and the limit is stored.

*)Note: The sequence will be repeated three times with different EUT orientations.

9.2 Sequence of testing radiated spurious 30 MHz to 1 GHz

Setup

- The equipment is set up to simulate normal operation mode as described in the user manual or defined by the manufacturer.
- If the EUT is a tabletop system, a table with 0.8 m height is used, which is placed on the ground plane.
- If the EUT is a floor standing device, it is placed on the ground plane with insulation between both.
- Auxiliary equipment and cables are positioned to simulate normal operation conditions as described in ANSI C 63.4.
- The AC power port of the EUT (if available) is connected to a power outlet below the turntable.
- Measurement distance is 10 m or 3 m (see ANSI C 63.4) – see test details.
- EUT is set into operation.

Premeasurement

- The turntable rotates from 0° to 315° using 45° steps.
- The antenna is polarized vertical and horizontal.
- The antenna height changes from 1 m to 3 m.
- At each turntable position, antenna polarization and height the analyzer sweeps three times in peak to find the maximum of all emissions.

Final measurement

- The final measurement is performed for at least six highest peaks according to the requirements of the ANSI C63.4.
- Based on antenna and turntable positions at which the peak values are measured the software maximize the peaks by changing turntable position ± 45° and antenna height between 1 and 4 m.
- The final measurement is done with quasi-peak detector (as described in ANSI C 63.4).
- Final levels, frequency, measuring time, bandwidth, antenna height, antenna polarization, turntable angle, correction factor, margin to the limit and limit are recorded. A plot with the graph of the premeasurement with marked maximum final results and the limit is stored.

9.3 Sequence of testing radiated spurious 1 GHz to 18 GHz

Setup

- The equipment is set up to simulate normal operation mode as described in the user manual or defined by the manufacturer.
- If the EUT is a tabletop system, a 2-axis positioner with 1.5 m height is used.
- If the EUT is a floor standing device, it is placed directly on the turn table.
- Auxiliary equipment and cables are positioned to simulate normal operation conditions as described in ANSI C 63.4.
- The AC power port of the EUT (if available) is connected to a power outlet below the turntable.
- Measurement distance is 3 m (see ANSI C 63.4) – see test details.
- EUT is set into operation.

Premeasurement

- The turntable rotates from 0° to 315° using 45° steps.
- The antenna is polarized vertical and horizontal.
- The antenna height is 1.5 m.
- At each turntable position and antenna polarization the analyzer sweeps with positive peak detector to find the maximum of all emissions.

Final measurement

- The final measurement is performed for at least six highest peaks according to the requirements of the ANSI C63.4.
- Based on antenna and turntable positions at which the peak values are measured the software maximizes the peaks by rotating the turntable from 0° to 360°. This measurement is repeated for different EUT-table positions (0° to 150° in 30°-steps) and for both antenna polarizations.
- The final measurement is done in the position (turntable, EUT-table and antenna polarization) causing the highest emissions with Peak and RMS detector (as described in ANSI C 63.4).
- Final levels, frequency, measuring time, bandwidth, turntable position, EUT-table position, antenna polarization, correction factor, margin to the limit and limit are recorded. A plot with the graph of the premeasurement with marked maximum final results and the limit is stored.

9.4 Sequence of testing radiated spurious above 18 GHz

Setup

- The equipment is set up to simulate normal operation mode as described in the user manual or defined by the manufacturer.
- Auxiliary equipment and cables are positioned to simulate normal operation conditions as described in ANSI C 63.4.
- The AC power port of the EUT (if available) is connected to a power outlet.
- The measurement distance is as appropriate (e.g. 0.5 m).
- The EUT is set into operation.

Premeasurement

- The test antenna is handheld and moved carefully over the EUT to cover the EUT's whole sphere and different polarizations of the antenna.

Final measurement

- The final measurement is performed at the position and antenna orientation causing the highest emissions with Peak and RMS detector (as described in ANSI C 63.4).
- Final levels, frequency, measuring time, bandwidth, correction factor, margin to the limit and limit are recorded. A plot with the graph of the premeasurement and the limit is stored.

9.5 Sequence of testing radiated spurious above 50 GHz with external mixers

Setup

- The equipment is set up to simulate normal operation mode as described in the user manual or defined by the manufacturer.
- Auxiliary equipment and cables are positioned to simulate normal operation conditions as described in ANSI C 63.4.
- The AC power port of the EUT (if available) is connected to a power outlet.
- The measurement distance is as appropriate for far field (e.g. 0.25 m).
- The EUT is set into operation.

Premeasurement

- The test antenna with external mixer is handheld and moved carefully over the EUT to cover the EUT's whole sphere and different polarizations of the antenna.
- Caution is taken to reduce the possible overloading of the external mixer.

Final measurement

- The final measurement is performed at the position and antenna orientation causing the highest emissions with Peak and RMS detector (as described in ANSI C 63.4).
- As external mixers may generate false images care is taken to ensure that any emission measured by the spectrum analyzer does indeed originate in the EUT. Signal identification feature of spectrum analyzer is used to eliminate false mixer images (i.e., it is not the fundamental emission or a harmonic falling precisely at the measured frequency).
- Final levels, frequency, measuring time, bandwidth, correction factor, margin to the limit and limit are recorded. A plot with the graph of the premeasurement and the limit is stored.

10 Description of the test setup

Typically, the calibrations of the test apparatus are commissioned to and performed by an accredited calibration laboratory. The calibration intervals are determined in accordance with the DIN EN ISO/IEC 17025. In addition to the external calibrations, the laboratory executes comparison measurements with other calibrated test systems or effective verifications. Weekly chamber inspections and range calibrations are performed. Where possible, RF generating and signaling equipment as well as measuring receivers and analyzers are connected to an external high-precision 10 MHz reference (GPS-based or rubidium frequency standard).

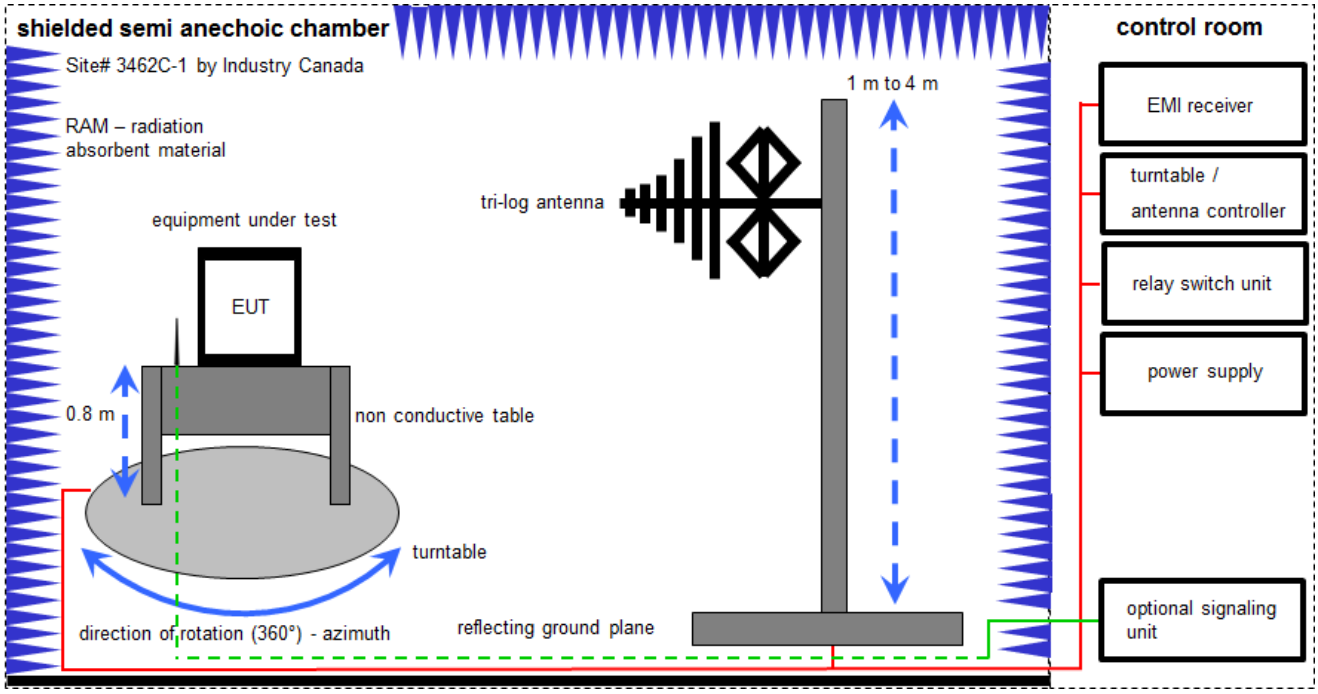
In order to simplify the identification of the equipment used at some special tests, some items of test equipment and ancillaries can be provided with an identifier or number in the equipment list below (Lab/Item).

Agenda: Kind of Calibration

k	calibration / calibrated		EK	limited calibration
ne	not required (k, ev, izw, zw not required)		zw	cyclical maintenance (external cyclical maintenance)
ev	periodic self verification		izw	internal cyclical maintenance
Ve	long-term stability recognized		g	blocked for accredited testing
vlkl!	Attention: extended calibration interval			
NK!	Attention: not calibrated		*)	next calibration ordered / currently in progress

10.1 Shielded semi anechoic chamber

The radiated measurements are performed in vertical and horizontal plane in the frequency range from 9 kHz to 1 GHz in semi-anechoic chambers. The EUT is positioned on a non-conductive support with a height of 0.80 m above a conductive ground plane that covers the whole chamber. The receiving antennas are confirmed with specifications ANSI C63. These antennas can be moved over the height range between 1.0 m and 4.0 m in order to search for maximum field strength emitted from EUT. The measurement distances between EUT and receiving antennas are indicated in the test setups for the various frequency ranges. For each measurement, the EUT is rotated in all three axes until the maximum field strength is received. The wanted and unwanted emissions are received by spectrum analyzers where the detector modes and resolution bandwidths over various frequency ranges are set according to requirement ANSI C63.

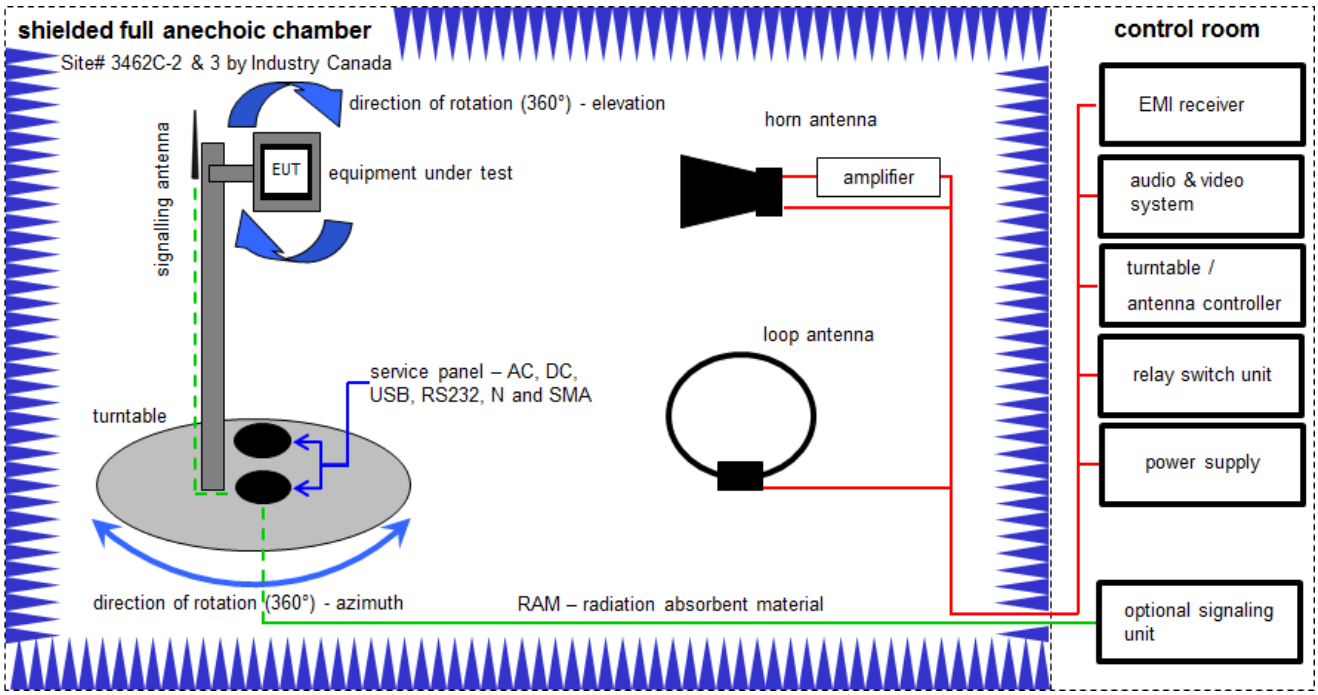


Measurement distance: tri-log antenna 10 meter

Equipment table:

No.	Lab / Item	Equipment	Type	Manufacturer	Serial No.	INV. No.	Kind of Calibration	Last Calibration	Next Calibration
1	n. a.	Switch-Unit	3488A	HP	2719A14505	300000368	ev	-/-	-/-
2	n. a.	DC power supply, 60Vdc, 50A, 1200 W	6032A	HP	2920A04466	300000580	ne	-/-	-/-
3	n. a.	Meßkabine 1	HF-Absorberhalle	MWB AG 300023		300000551	ne	-/-	-/-
4	n. a.	Antenna Tower	Model 2175	ETS-Lindgren	64762	300003745	izw	-/-	-/-
5	n. a.	Positioning Controller	Model 2090	ETS-Lindgren	64672	300003746	izw	-/-	-/-
6	n. a.	Turntable Interface-Box	Model 105637	ETS-Lindgren	44583	300003747	izw	-/-	-/-
7	n. a.	TRILOG Broadband Test-Antenna 30 MHz - 3 GHz	VULB9163	Schwarzbeck Mess - Elektronik	216	300003288	vIKI!	31.08.2023	31.08.2025
8	n. a.	Switch-Unit	3488A	HP	2719A14505	300000368	ev	-/-	-/-
9	n. a.	EMI Test Receiver	ESR3	Rohde & Schwarz	102587	300005771	k	06.12.2023	31.12.2024

10.2 Radiated measurements fully anechoic chamber



Measurement distance: horn antenna 3 meter; loop antenna 3 meter / 1 meter

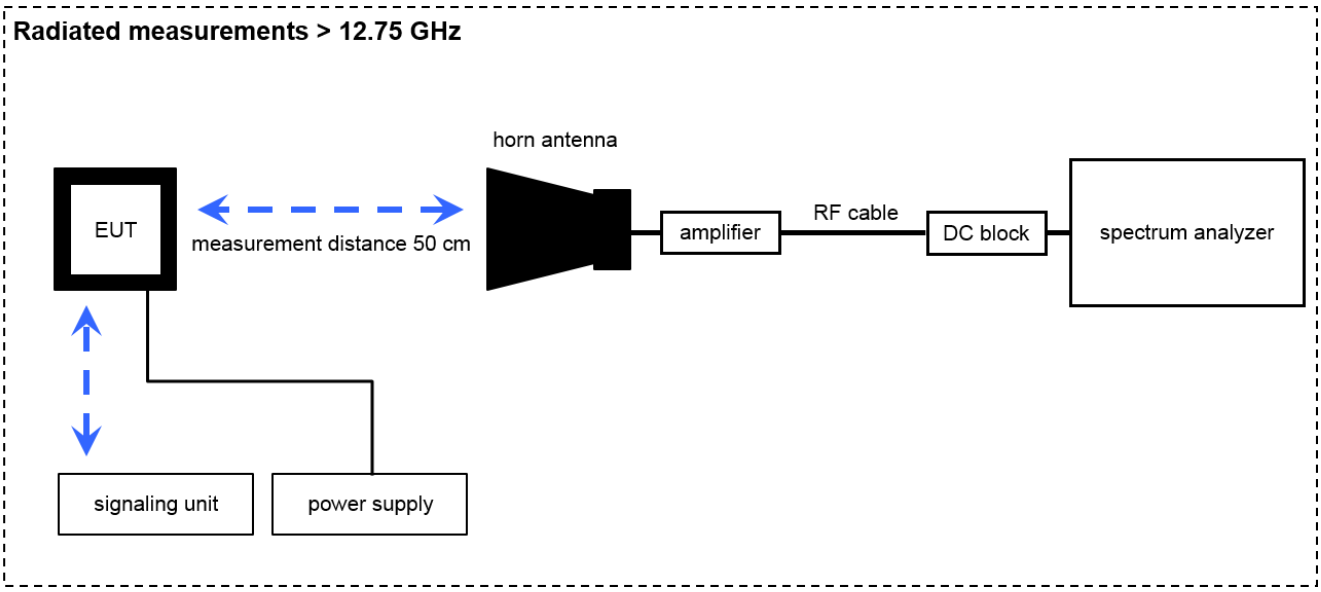
FS = UR + CA + AF
(FS-field strength; UR-voltage at the receiver; CA-loss of the signal path; AF-antenna factor)

Example calculation:
FS [dBµV/m] = 40.0 [dBµV/m] + (-35.8) [dB] + 32.9 [dB/m] = 37.1 [dBµV/m] (71.61 µV/m)

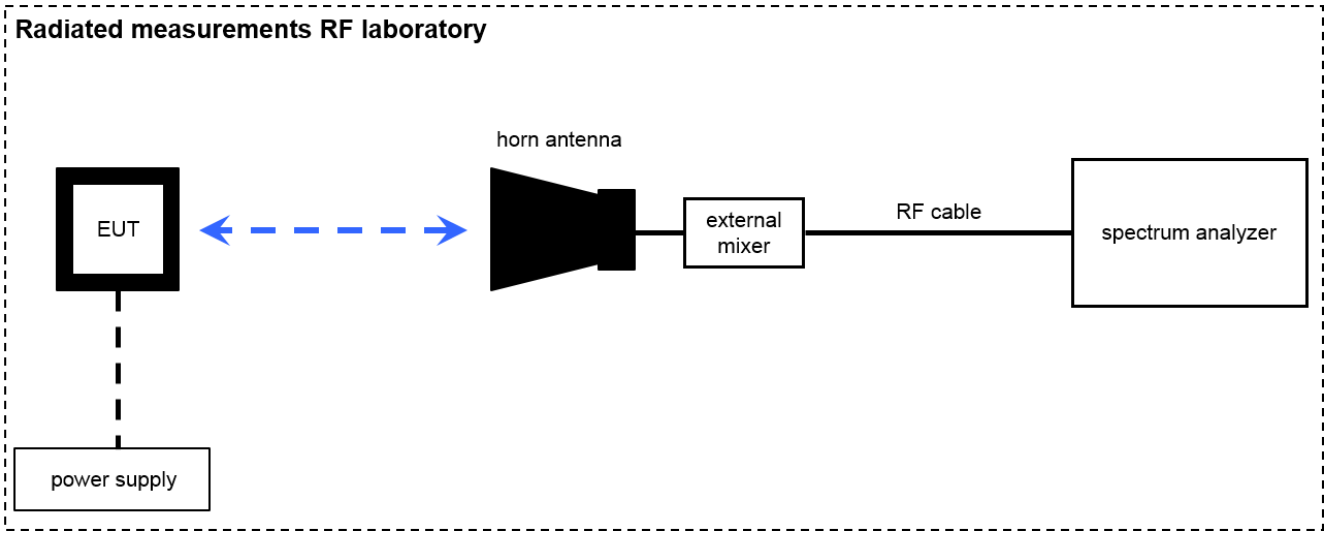
Equipment table (Chamber C):

No.	Equipment	Type	Manufacturer	Serial No.	INV. No.	Kind of Calibration	Last Calibration	Next Calibration
1	Double-Ridged Waveguide Horn Antenna 1-18.0GHz	3115	EMCO	9107-3696	300001604	vIKI!	20.03.2023	19.03.2025
2	Highpass Filter	WHK1.1/15G-10SS	Wainwright	37	400000148	ne	-/-	-/-
3	Highpass Filter	WHKX7.0/18G-8SS	Wainwright	18	300003789	ne	-/-	-/-
4	Band Reject Filter	WRCG2400/2483-2375/2505-50/10SS	Wainwright	26	300003792	ne	-/-	-/-
5	TRILOG Broadband Test-Antenna 30 MHz - 3 GHz	VULB9163	Schwarzbeck Mess - Elektronik	295	300003787	vIKI!	23.05.2023	31.05.2025
6	Broadband Amplifier 0.5-18 GHz	CBLU5184540	CERNEX	22051	300004483	ev	-/-	-/-
7	4U RF Switch Platform	L4491A	Agilent Technologies	MY50000032	300004510	ne	-/-	-/-
8	NEXIO EMV-Software	BAT EMC V2022.0.22.0	Nexio	-/-	300004682	ne	-/-	-/-
9	Anechoic chamber	-/-	TDK	-/-	300003726	ne	-/-	-/-
10	EMI Test Receiver 9kHz-26,5GHz	ESR26	Rohde & Schwarz	101376	300005063	k	15.01.2024	31.01.2025

10.3 Radiated measurements 18 GHz to 50 GHz in test lab



10.4 Radiated measurements > 50 GHz in test lab

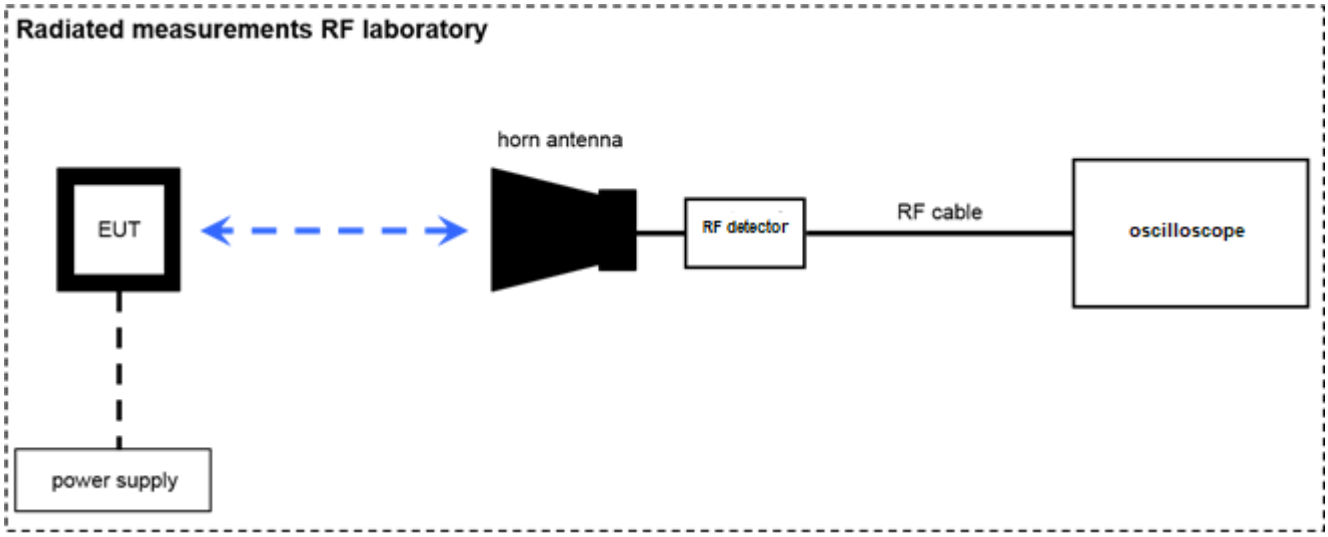


OP = AV + D - G
(OP-rad. output power; AV-analyzer value; D-free field attenuation of measurement distance; G-antenna gain)

Example calculation:
OP [dBm] = -54.0 [dBm] + 64.0 [dB] - 20.0 [dBi] = -10 [dBm] (100 µW)

Note: conversion loss of mixer is already included in analyzer value.

10.5 Radiated measurements with RF detector > 50 GHz in test lab

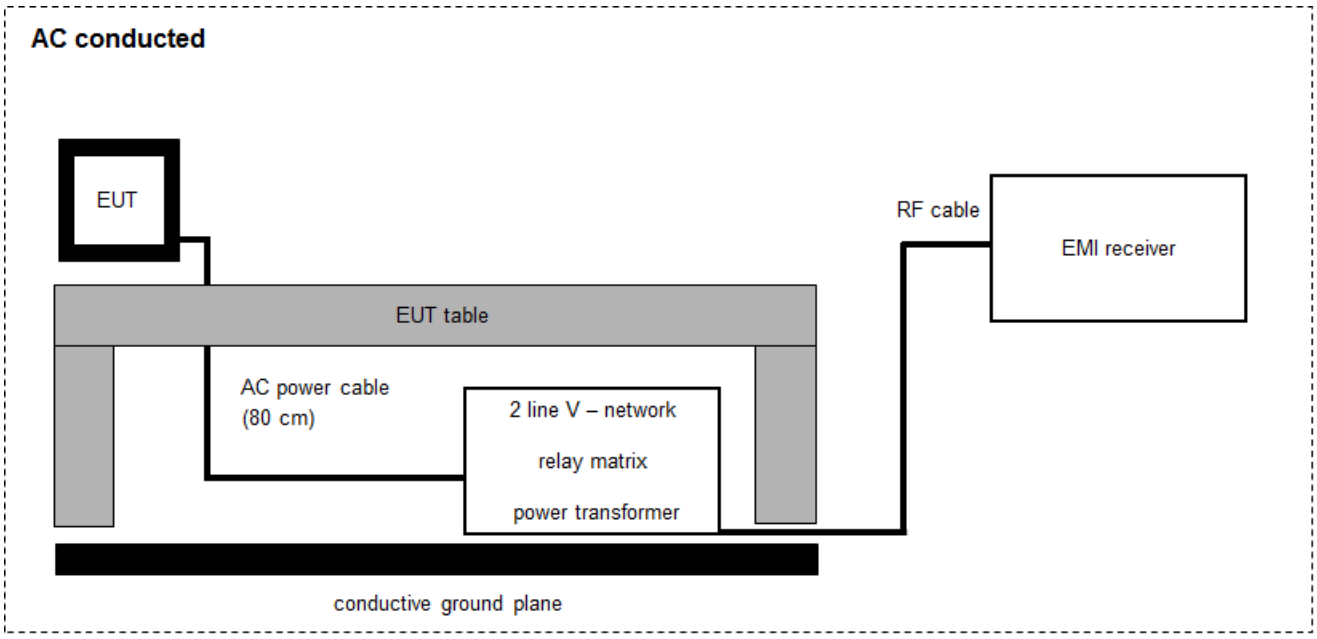


Note: EUT is replaced by reference source for substitution measurement

Equipment table:

No.	Lab / Item	Equipment	Type	Manufacturer	Serial No.	INV. No.	Kind of Calibration	Last Calibration	Next Calibration
1	n.a.	Horn Antenna 18.0-40.0 GHz	LHAF180	Microw.Devel	39180-103-021	300001747	vIKI!	24.01.2024	23.01.2026
2	n. a.	Std. Gain Horn Antenna 18.0-26.5 GHz	638	Narda		300000486	vIKI!	24.01.2024	23.01.2026
3	n. a.	Std. Gain Horn Antenna 26.5-40.0 GHz	V637	Narda	82-16	300000510	vIKI!	24.01.2024	23.01.2026
4	n.a.	Std. Gain Horn Antenna 40-60 GHz	2424-20	Flann	76	400001981	ne	-/-	-/-
5	n. a.	Std. Gain Horn Antenna 49.9-75.8 GHz	2524-20	Flann	*	300001983	ne	-/-	-/-
6	n. a.	Std. Gain Horn Antenna 60-90 GHz	COR 60_90	Thomson CSF		300000814	ev	-/-	-/-
7	n. a.	Std. Gain Horn Antenna 73.8-112 GHz	2724-20	Flann	*	300001988	ne	-/-	-/-
8	n.a.	Std. Gain Horn Antenna 92.3-140 GHz	2824-20	Flann		300001993	ne	-/-	-/-
9	n. a.	Std. Gain Horn Antenna 114-173 GHz	2924-20	Flann	*	300001999	ne	-/-	-/-
10	n. a.	Std. Gain Horn Antenna 145-220 GHz	3024-20	Flann	*	300002000	ne	-/-	-/-
11	n. a.	Std. Gain Horn Antenna 217-330 GHz	32240-20	Flann	233278	300004960	ne	-/-	-/-
12	n. a.	Broadband LNA 18-50 GHz	CBL18503070PN	CERNEX	25240	300004948	ev	22.04.2024	21.04.2026
13	n. a.	Harmonic Mixer 3-Port, 50-75 GHz	FS-Z75	Rohde & Schwarz	101578	300005788	k	19.07.2023	31.07.2024
14	n. a.	Harmonic Mixer 3-Port, 60-90 GHz	FS-Z90	R&S	101555	300004691	k	25.08.2023	31.08.2024
15	n. a.	Harmonic Mixer 3-Port, 75-110 GHz	FS-Z110	R&S	101411	300004959	k	21.07.2023	31.07.2024
16	n.a.	Harmonic Mixer 3-port, 90-140 GHz	FS-Z140	Rohde & Schwarz	101119	300005581	k	03.08.2023	31.08.2024
17	n. a.	Harmonic Mixer 3-Port, 110-170 GHz	FS-Z170	Radiometer Physics GmbH	100014	300004156	k	21.07.2023	31.07.2024
18	n. a.	Harmonic Mixer 3-Port, 140-220 GHz	SAM-220	Radiometer Physics GmbH	200001	300004157	k	02.08.2023	31.08.2024
19	n. a.	Harmonic Mixer 3-Port, 220-325 GHz	SAM-325	Radiometer Physics GmbH	100002	300004158	k	02.08.2023	31.08.2024
20	n. a.	Spectrum Analyzer 2 Hz - 85 GHz	FSW85	R&S	101333	300005568	k	02.08.2023	31.08.2024
21	n.a.	Power Supply	E3632A	Agilent Technologies	MY40001320	400000396	ev	14.12.2021	31.12.2024
22	n. a.	Temperature Test Chamber	VT 4002	Heraeus Voetsch	521/84193	300003889	ev	09.05.2022	30.11.2024
23	n. a.	Synthesized Sweeper 10 MHz - 40 GHz	83640A	HP	3119A00458	300002266	vIKI!	05.12.2023	31.12.2025

10.6 AC power-line conducted emissions



FS = UR + CF + VC
(FS-field strength; UR-voltage at the receiver; CR-loss of the cable and filter; VC-correction factor of the ISN)

Example calculation:
FS [dBµV/m] = 37.62 [dBµV/m] + 9.90 [dB] + 0.23 [dB] = 47.75 [dBµV/m] (244.06 µV/m)

Equipment table:

No.	Lab / Item	Equipment	Type	Manufacturer	Serial No.	INV. No.	Kind of Calibration	Last Calibration	Next Calibration
1	-/-	Two-line V-Network (LISN) 9 kHz to 30 MHz	ESH3-Z5	R&S	892475/017	300002209	vIKI!	12.12.2023	31.12.2025
2	-/-	RF-Filter-section	85420E	HP	3427A00162	300002214	NK!	-/-	-/-
3	-/-	EMI Test Receiver	ESCI 3	R&S	101240	300004427	k	08.12.2023	31.12.2024
4	-/-	Hochpass 150 kHz	EZ-25	R&S	100010	300003798	ev	-/-	-/-

11 Measurement uncertainty

Test case	Uncertainty
Equivalent isotropically radiated power (e.i.r.p.)	Conducted value ± 1 dB Radiated value ± 3 dB
Permitted range of operating frequencies	± 100 kHz
Conducted unwanted emissions in the spurious domain (up to 18 GHz)	± 1 dB
Radiated unwanted emissions in the spurious domain (up to 18 GHz)	± 3 dB
Conducted unwanted emissions in the spurious domain (18 to 40 GHz)	± 4 dB
Radiated unwanted emissions in the spurious domain (18 to 40 GHz)	± 4 dB
Conducted unwanted emissions in the spurious domain (40 to 50 GHz)	± 4.5 dB
Radiated unwanted emissions in the spurious domain (40 to 50 GHz)	± 4.5 dB
Conducted unwanted emissions in the spurious domain (above 50 GHz)	± 5 dB
Radiated unwanted emissions in the spurious domain (above 50 GHz)	± 5 dB
DC and low frequency voltages	± 3 %
Temperature	± 1 °C
Humidity	± 3 %

12 Far field consideration for measurements above 18 GHz

Far field distance calculation:

$D_{ff} = 2 \times D^2 / \lambda$

with

D_{ff}	Far field distance
D	Antenna dimension
λ	wavelength

Spurious emission measurements:

Antenna frequency range in GHz	Highest measured frequency in GHz	D in cm	λ in cm	D_{ff} in cm
18-26	26	3.4	1.15	20.04
26-40	40	2.2	0.75	12.91
40-50	50	2.77	0.60	25.58
50-75	75	1.85	0.40	17.11
75-110	110	1.24	0.27	11.28
110-170	170	0.85	0.18	8.19
170-220	220	0.68	0.14	6.78

In band measurement (EIRP, OBW):

Antenna frequency range in GHz	Highest measured frequency in GHz	Antenna dimension in cm	Wavelength in cm	far field distance in cm
50-75	71	5	0.46	116

13 Measurement results

13.1 Occupied bandwidth & emission bandwidth & frequency stability

Description:

Measurement of the bandwidth and the frequency stability of the wanted signal (fundamental emission) under temperature and supply voltage variations.

Limits and provisions:

Selection of applicable rule parts: see 8

Bandwidth & Applicable limits of designated frequency band			
Applicable	**Rule part**	**Method of bandwidth measurement**	**Limit of designated frequency band**
☐	15.255(b)(2)(iii)	20 dB bandwidth or 99% bandwidth	59.3 - 71.0 GHz
☐	15.255(b)(3)	20 dB bandwidth or 99% bandwidth	60 - 64 GHz
☐	15.255(c)(1)(i)	20 dB bandwidth or 99% bandwidth	57 - 71 GHz
☐	15.255(c)(1)(ii)	20 dB bandwidth or 99% bandwidth	57 - 71 GHz
☐	15.255(c)(2)	20 dB bandwidth or 99% bandwidth	57 - 71 GHz
☐	15.255(c)(2)(i)	20 dB bandwidth or 99% bandwidth	57.0 - 59.4 GHz
☐	15.255(c)(2)(ii)	20 dB bandwidth or 99% bandwidth	57.0 - 61.56 GHz
☒	15.255(c)(2)(iii)	20 dB bandwidth or 99% bandwidth	**57.0 - 64.0 GHz**
☐	15.255(c)(2)(v)	20 dB bandwidth or 99% bandwidth	61.0 - 61.5 GHz
☐	15.255(c)(3)	10 dB bandwidth	57 - 64 GHz
☐	15.255(e)(2)	6 dB emission bandwidth (EBW_{6dB})	None (required for calculation in chapter 8)

Note:

- Definition of 6dB emission bandwidth (15.255(e)(2)): the instantaneous frequency range occupied by a steady state radiated signal with modulation, outside which the radiated power spectral density never exceeds 6 dB below the maximum radiated power spectral density in the band, as measured with a 100 kilohertz resolution bandwidth spectrum analyzer. The center frequency must be stationary during the measurement interval, even if not stationary during normal operation (e.g., for frequency hopping devices).

Measurement:

Measurement parameter	
Detector:	Pos-Peak
Resolution bandwidth:	50 MHz
Video bandwidth:	80 MHz
Trace-Mode:	Max Hold

Measurement procedures:

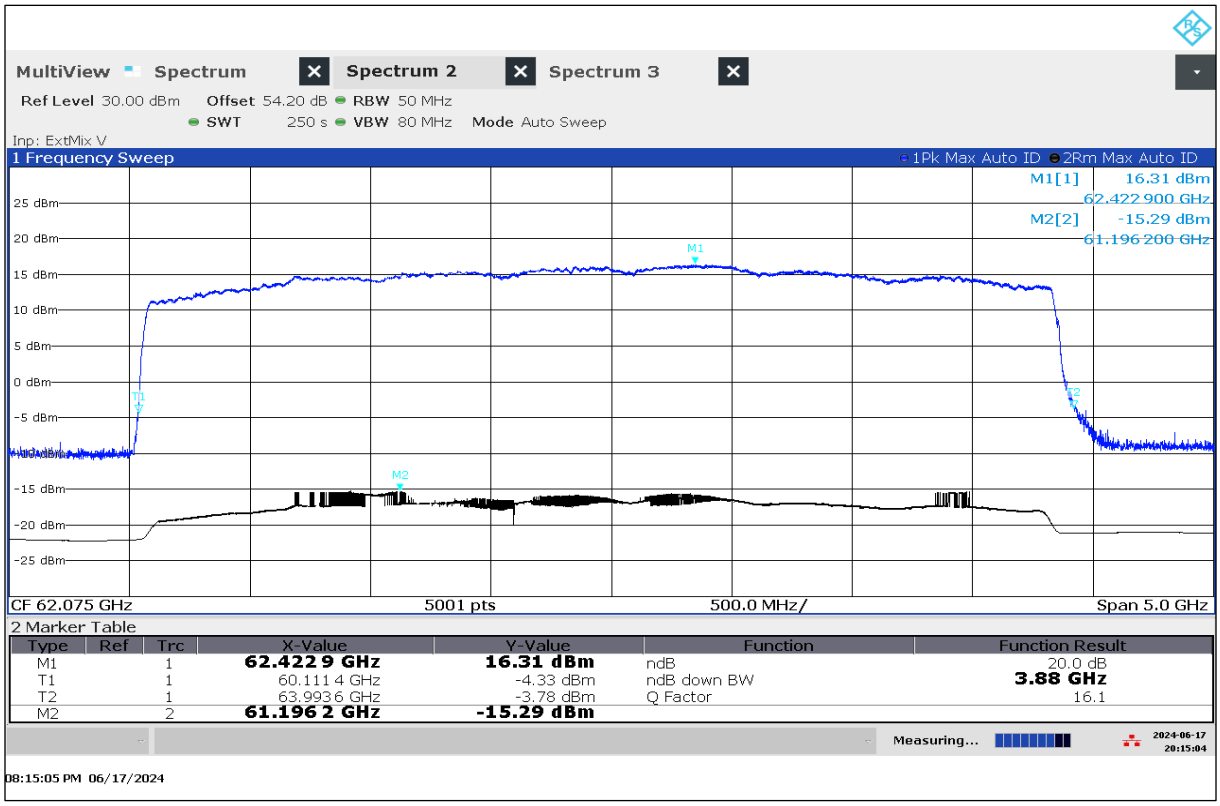
- Bandwidth: ANSI C63.10-2020 6.9 / 9.3 / 9.4
- Frequency stability: ANSI C63.10-2020 6.8 / 9.5

Measurement results:

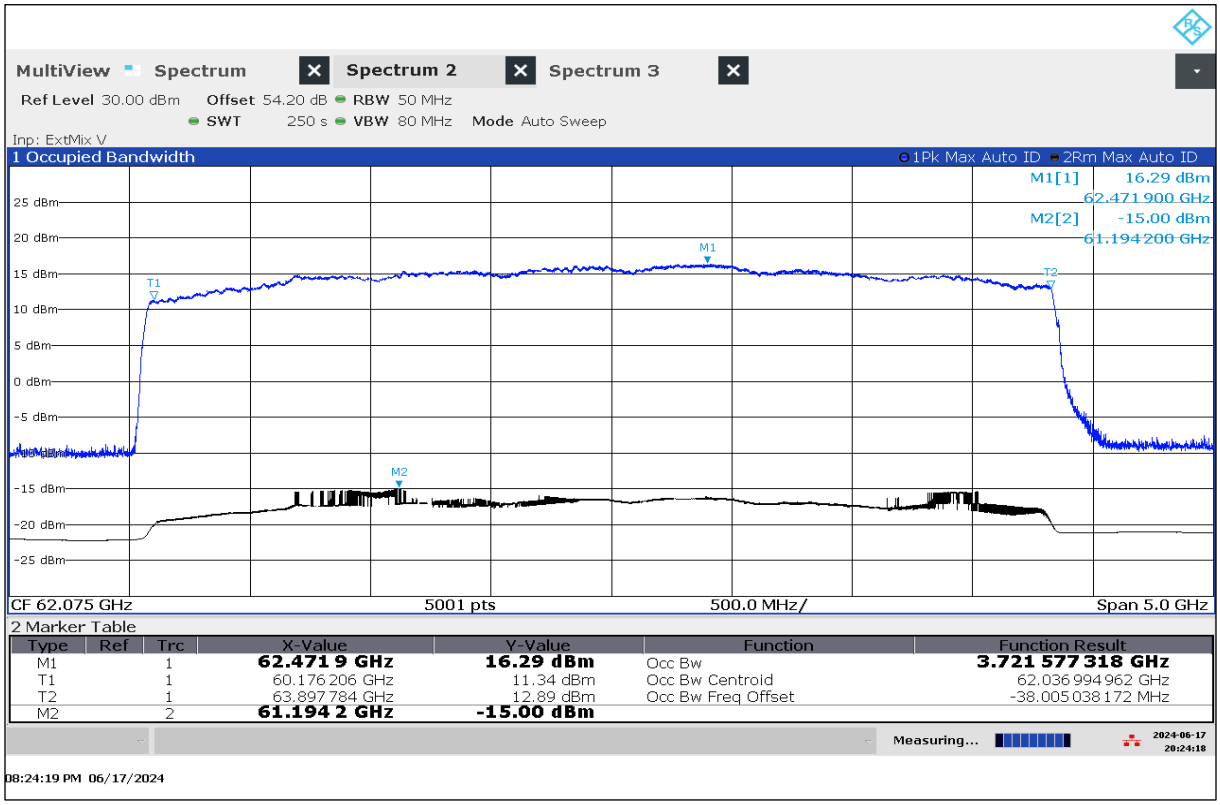
Test condition T_{nom} / V_{nom}	F_L in GHz	F_H in GHz	OBW in GHz
N20 dB OBW	60.111 400	63.993 600	3.88
99% OBW	60.176 206	63.897 784	3.72

Verdict: **Compliant**

Plot 1: N20 dB OBW, T_{nom} / V_{nom}



Plot 2: 99% OBW, T_{nom} / V_{nom}



Frequency stability (15.255(f)):

Measurement:

Measurement parameter	
Detector:	Pos-Peak
Resolution bandwidth:	40 MHz
Video bandwidth:	80 MHz
Trace-Mode:	Max Hold

Measurement procedures:

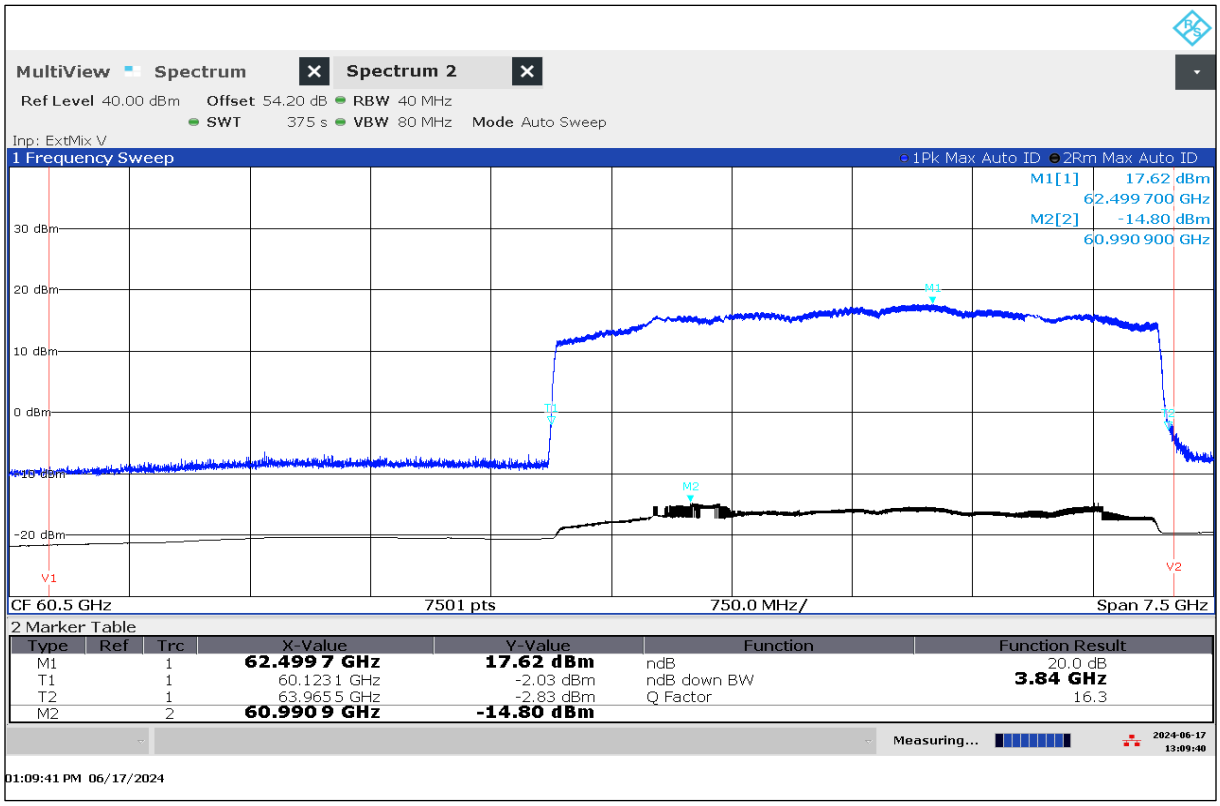
- Bandwidth: ANSI C63.10-2020 6.9 / 9.3 / 9.4
- Frequency stability: ANSI C63.10-2020 6.8 / 9.5

Bandwidth measurement for frequency stability tests: 20 dB bandwidth (Worst-case scenario)

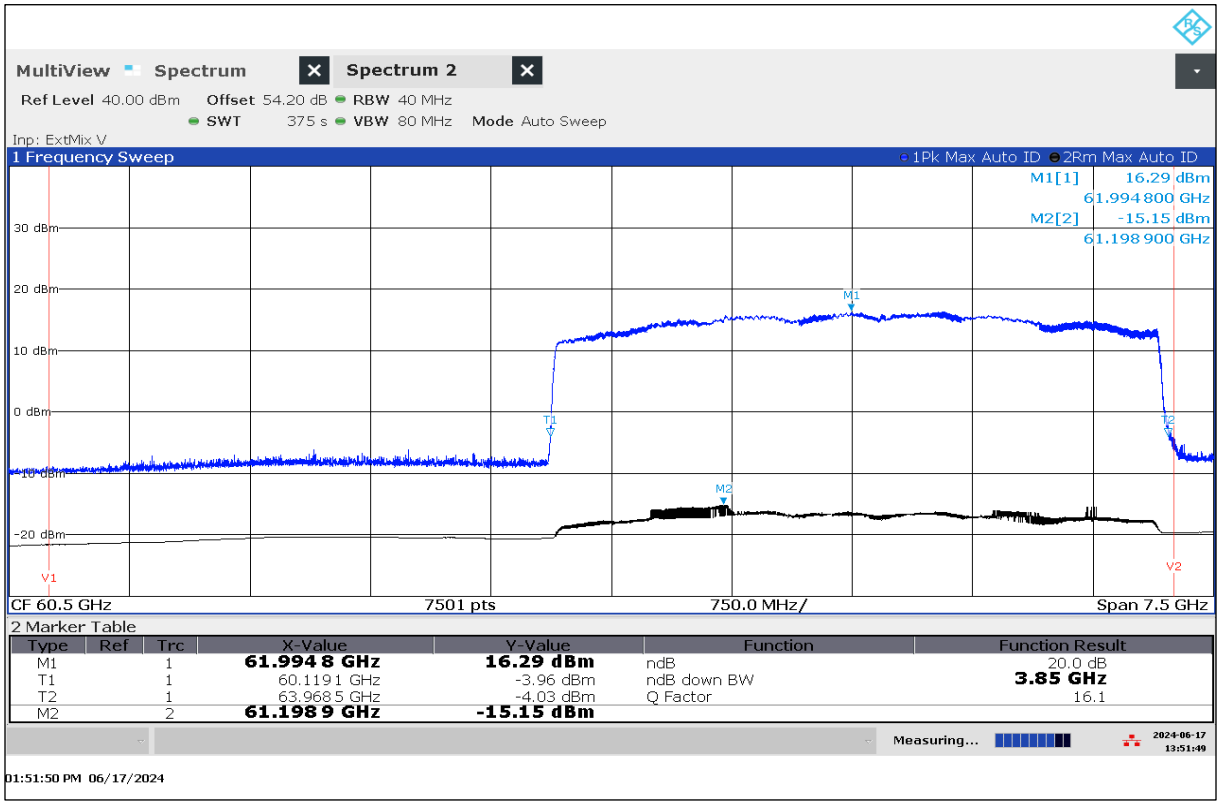
Test condition	Frequency f_L [GHz]	Frequency f_H [GHz]	Bandwidth [GHz]
-40 °C / V_{nom}	60.123 100	63.965 500	3.84
-20 °C / V_{nom}	60.119 100	63.968 500	3.85
-10 °C / V_{nom}	60.120 100	63.971 500	3.85
0 °C / V_{nom}	60.119 100	63.968 500	3.85
10 °C / V_{nom}	60.121 100	63.970 500	3.85
20 °C / $V_{min-max}$	60.121 100	63.971 500	3.85
30 °C / V_{nom}	60.121 100	63.975 500	3.85
40 °C / V_{nom}	60.118 100	63.967 500	3.85
50 °C / V_{nom}	60.120 100	63.966 500	3.85
85 °C / V_{nom}	60.118 100	63.969 500	3.85

Verdict: **Compliant**

Plot 3: OBW, -40 °C / V_{nom}

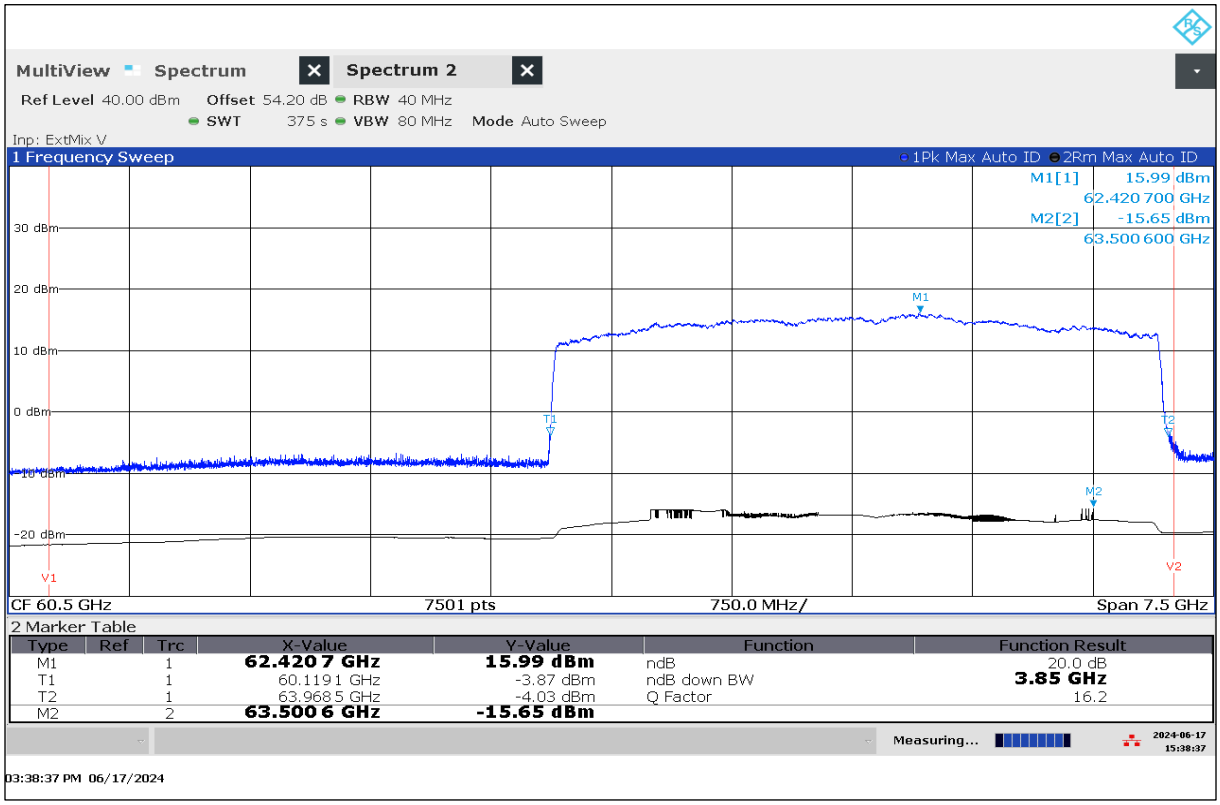


Plot 4: OBW, -20 °C / V_{nom}

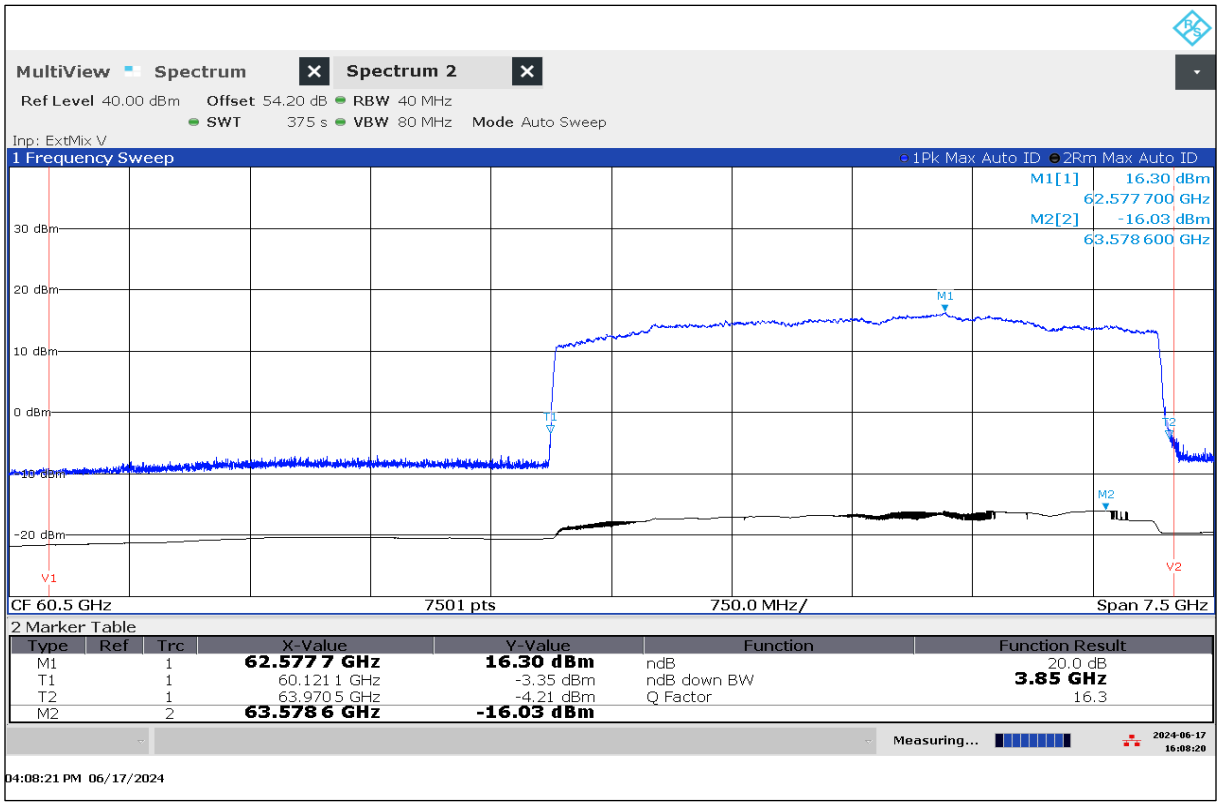


Plot 5: OBW, -10 °C / V_{nom}

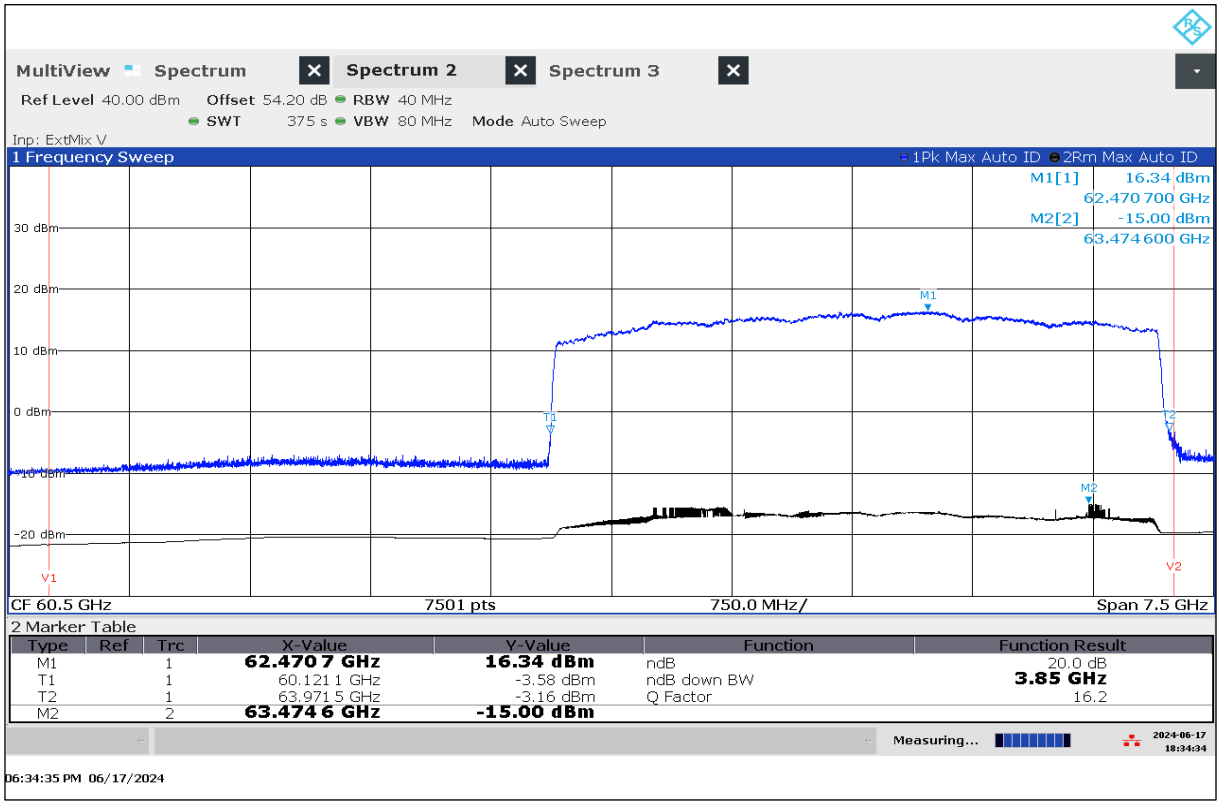
Plot 6: OBW, 0 °C / V_{nom}



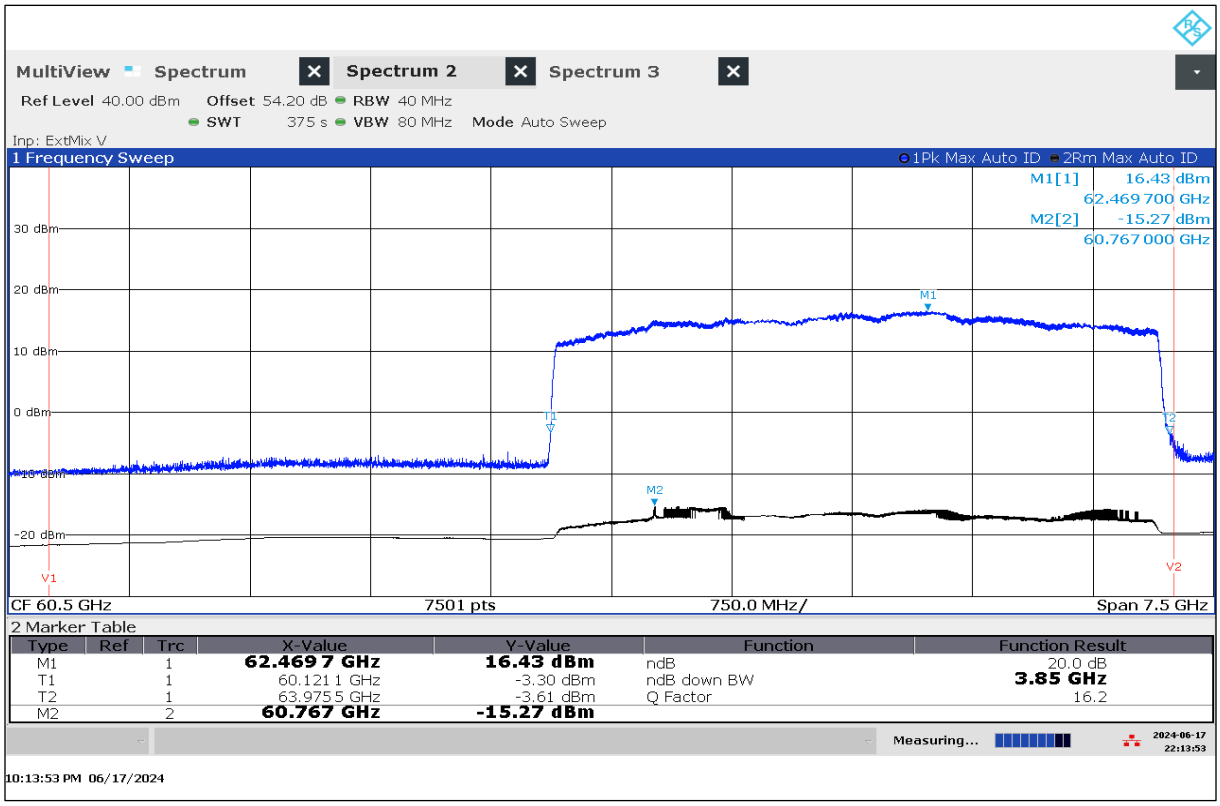
Plot 7: OBW, 10 °C / V_{nom}



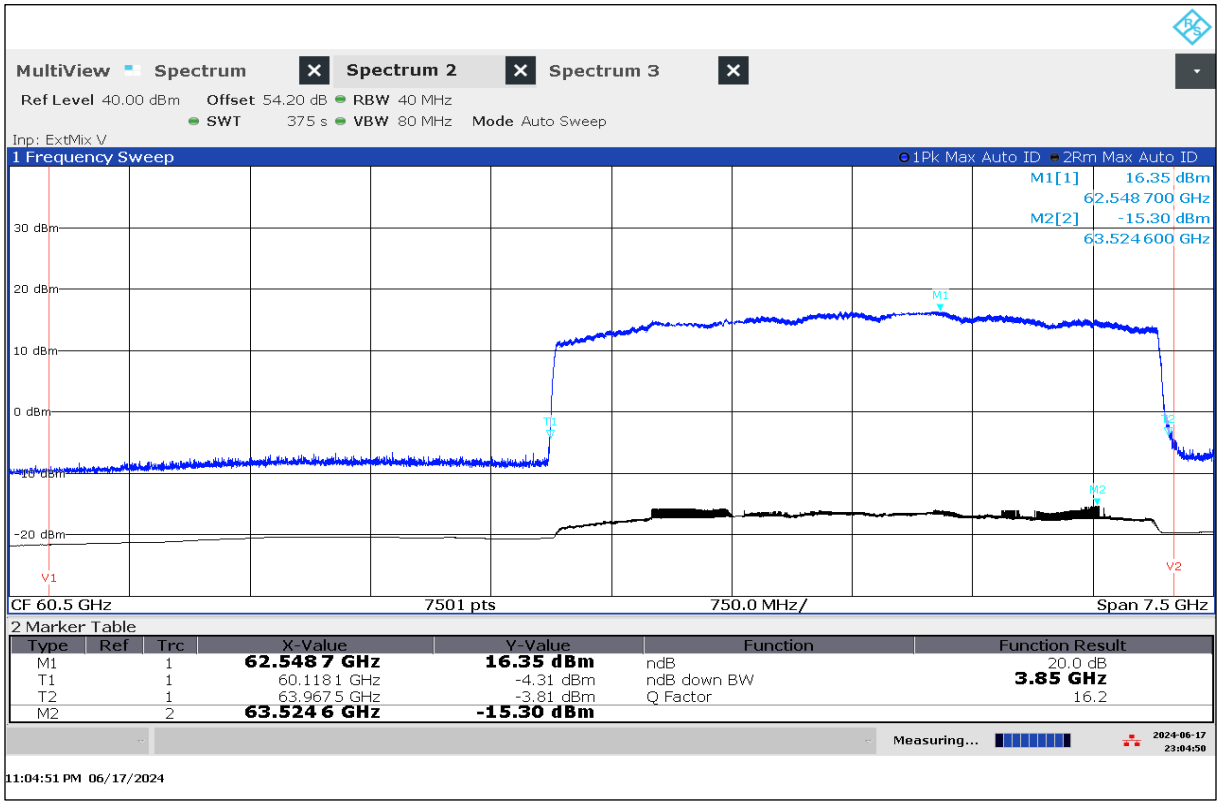
Plot 8: OBW, 20 °C / $V_{min-max}$



Plot 9: OBW, 30 °C / V_{nom}

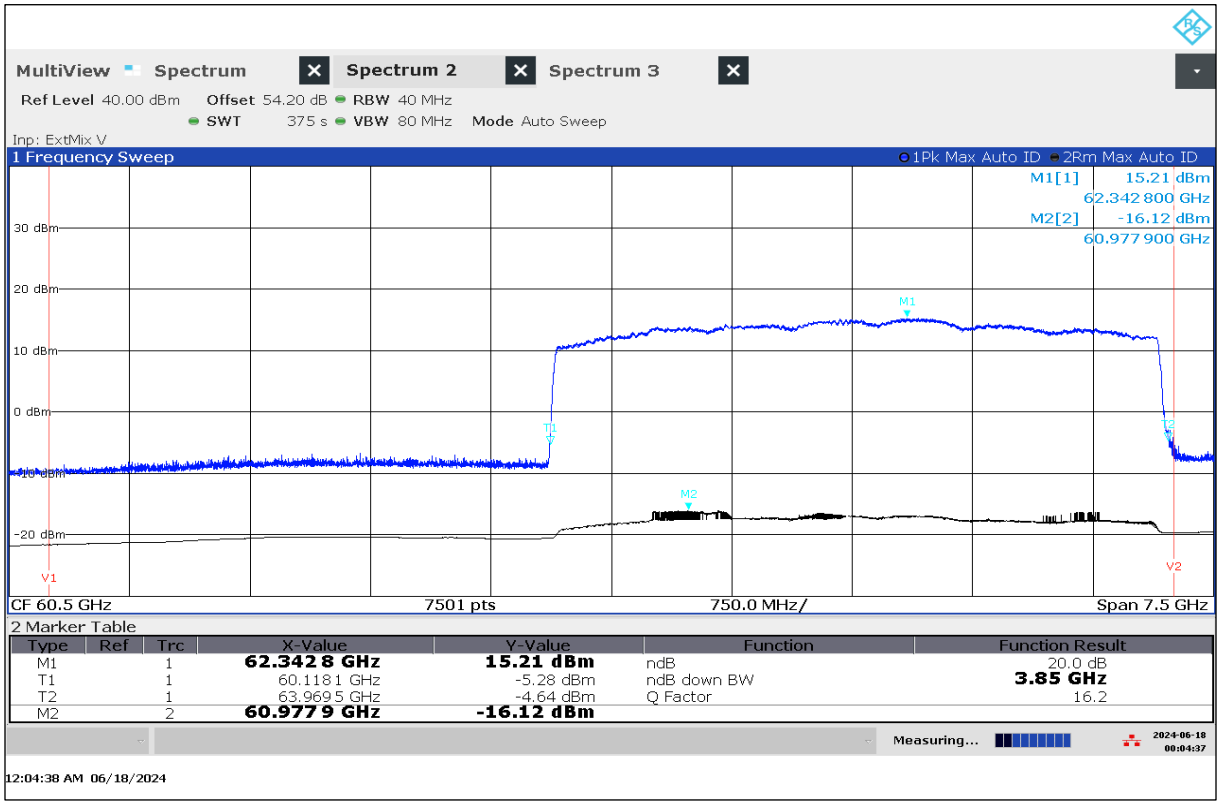


Plot 10: OBW, 40 °C / V_{nom}



Plot 11: OBW, 50 °C / V_{nom}

Plot 12: OBW, 85 °C / V_{nom}



13.2 Radiated power (EIRP)

Description:

Measurement of the maximum radiated E.I.R.P. of the wanted signal.

Limits and provisions:

Selection of applicable rule parts: see 8

Applicable limits of radiated power (EIRP)			
Applicable	**Rule part**	**Limit average EIRP**	**Limit peak EIRP**
☐	15.255(b)(3)	none	20 dBm
☐	15.255(c)(1)(i)	40 dBm (see note 1)	43 dBm
☐	15.255(c)(1)(ii)	Calculation depending on EUT antenna gain (see note 1, 2.1 & 2.3)	Depending on EUT antenna gain (see note 1, 2.2 & 2.3)
☐	15.255(c)(2)	none	10 dBm
☐	15.255(c)(2)(i)	none	20 dBm (indoor) 30 dBm (outdoor)
☐	15.255(c)(2)(ii)	none	3 dBm (general) 20 dBm (+ off-time requirement)
☐	15.255(c)(2)(iii)(A)	none	14 dBm (+ off-time requirement)
☒	15.255(c)(2)(iii)(B)	none	**20 dBm (+ off-time requirement)**
☐	15.255(c)(2)(v)	40 dBm (within 61-61.5 GHz) (see note 1) 10 dBm (outside 61-61.5 GHz, but within 57-71GHz) (see note 1)	43 dBm (within 61.0-61.5 GHz) 13 dBm (outside 61-61.5 GHz, but within 57-71GHz)
☐	15.255(c)(3)	13 dBm (average EIRP during any 0.3 µs time window) (+ time domain requirement) 5 dBm (average integrated EIRP within 61.5–64.0 GHz in any 0.3 µs time window)	applicable average limit + 20 dB

Measurement results:

Method	Test condition	Peak E.I.R.P.	Limit Peak E.I.R.P
Spectrum analyzer	T_{nom} / V_{nom}	16.31 dBm	20 dBm
RF detector	T_{nom} / V_{nom}	16.55 dBm	20 dBm

Verdict: **Compliant**

Measurement:

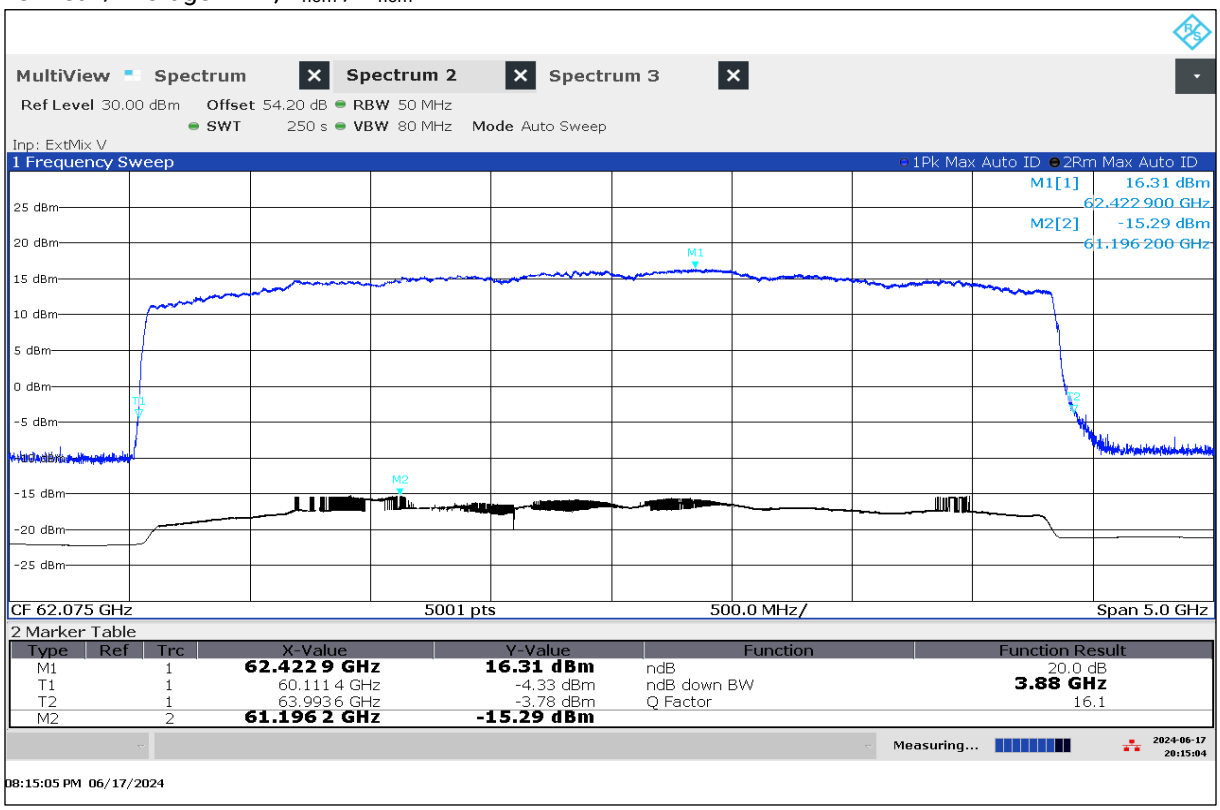
Spectrum analyzer:

Measurement parameter	
Detector:	Pos-Peak
Resolution bandwidth:	50 MHz
Video bandwidth:	80 MHz
Trace-Mode:	Max Hold

Measurement procedures:

- Fundamental emission using an RF detector: ANSI C63.10-2020 9.8

Plot 13: Peak/Average EIRP, T_{nom} / V_{nom}



RF detector:

Measurement parameter	
Detector:	Pos-Peak (RF-Detector)
Video bandwidth:	≥ 10 MHz

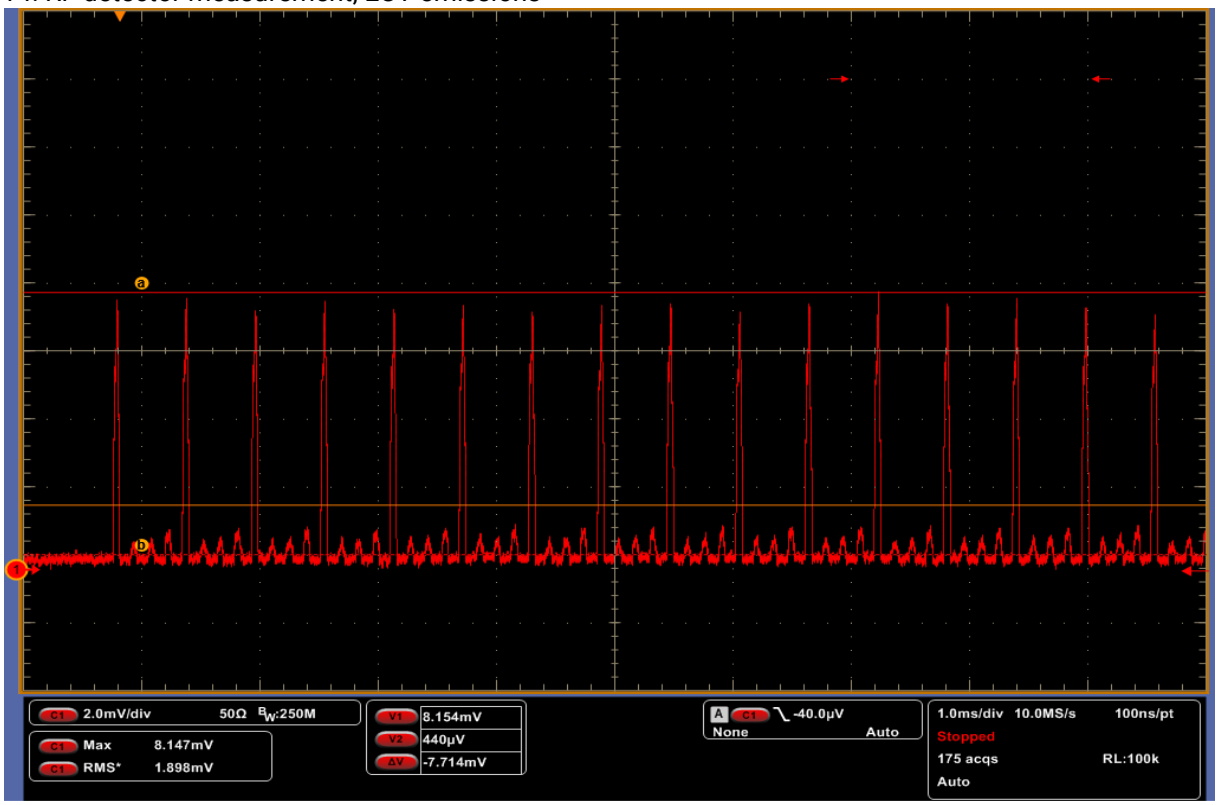
Measurement procedures:

- Fundamental emission using an RF detector: ANSI C63.10-2020 9.9

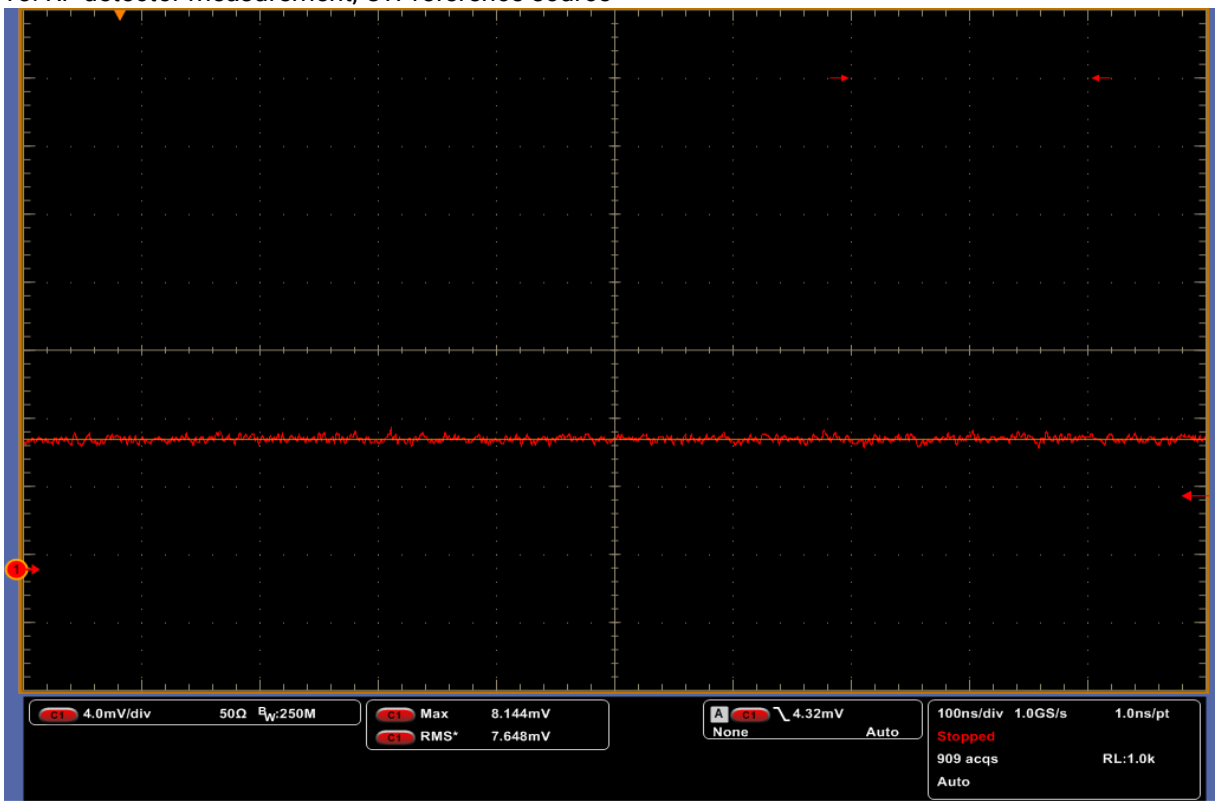
Description of the Peak E.I.R.P. measurement by substitution method:

1) EUT emission measured with RF-detector and oscilloscope: • Measurement distance d = 1.0 m	V = 8.147 mV
2) Substitution of EUT by a cw reference source: • Frequency f = 62.2 GHz • Adjustment of rotary attenuator so that equal voltage value is measured	V = 8.144 mV
3) Measurement of the conducted output power P_{cond} of the cw reference source (without horn antenna)	-3.55 dBm
4) Antenna gain of horn antenna G_{ant}	20.1 dBi
5) Calculation of Peak E.I.R.P • Peak E.I.R.P = P_{cond} + G_{ant}	16.55 dBm

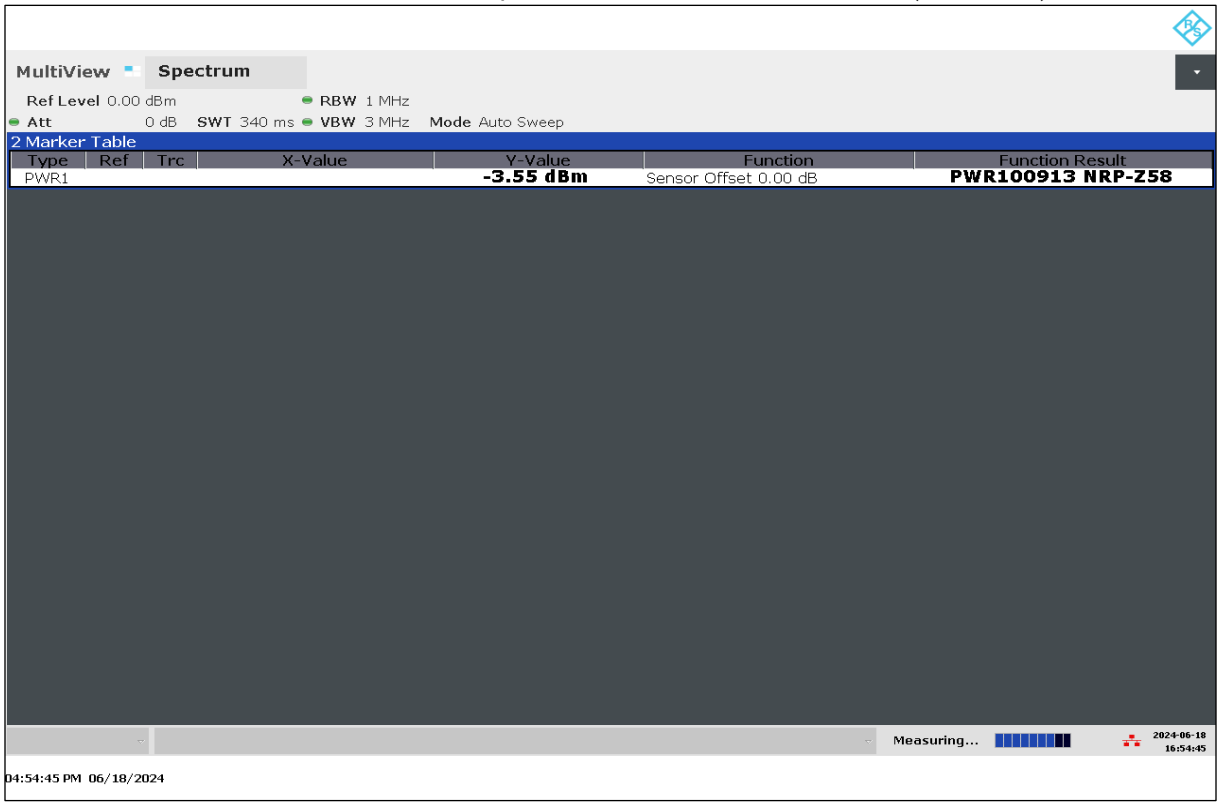
Plot 14: RF detector measurement, EUT emissions



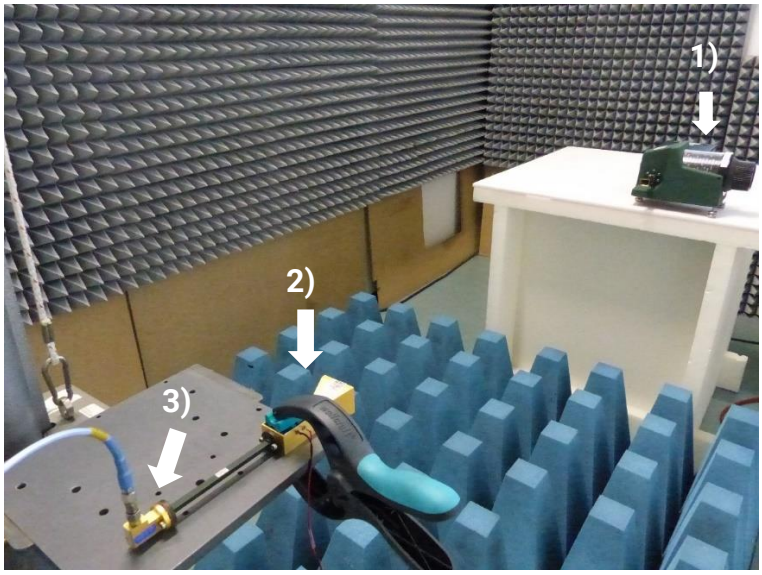
Plot 15: RF detector measurement, CW reference source



Plot 16: RF detector measurement, Conducted power of the CW reference source (read value)



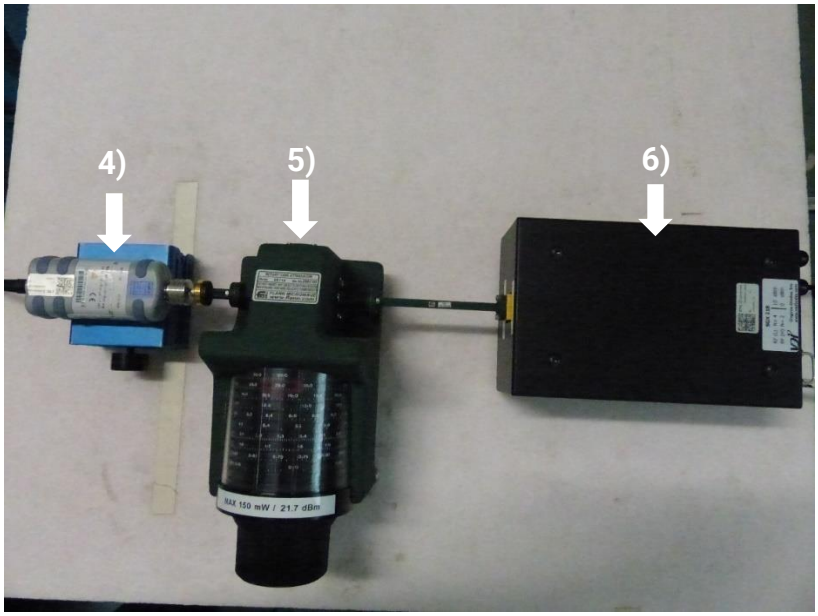
Setup of the substitution:



1) CW reference source:
SG Extension Module 50 - 75 GHz & Rotary Attenuator & Std. Gain Horn Antenna 49.9-75.8 GHz

2) Low Noise Amplifier Waveguide & Std. Gain Horn Antenna 50-75 GHz

3) RF Detector



4) Power Meter Sensor

5) Rotary Attenuator

6) SG Extension Module 50 - 75 GHz (connected to Synthesized Sweeper 10 MHz - 40 GHz)

13.3 Time domain requirements: Continuous transmitter off-times & transmit duty cycle

Description:

Measurement of the time domain parameter.

Limits and provisions:

Selection of applicable rule parts: see 8

Applicable time domain requirements		
Applicable	**Rule part**	**Time domain requirement**
☐	15.255(b)(3)	sum of continuous transmitter off-times of at least two milliseconds shall equal at least 16.5 milliseconds within any contiguous interval of 33 milliseconds
☐	15.255(c)(2)(ii)	Peak EIRP ≤ 3 dBm: none
		Peak EIRP ≤ 20 dBm: sum of continuous transmitter off-times of at least two milliseconds equals at least 16.5 milliseconds within any contiguous interval of 33 milliseconds
☐	15.255(c)(2)(iii)(A)	sum of continuous transmitter off-times of at least two milliseconds shall equal at least 25.5 milliseconds within any contiguous interval of 33 milliseconds
☒	15.255(c)(2)(iii)(B)	**sum of continuous transmitter off-times of at least two milliseconds shall equal at least 16.5 milliseconds within any contiguous interval of 33 milliseconds**
☐	15.255(c)(3)	maximum pulse duration of 6 ns; transmit duty cycle shall not exceed 10% during any 0.3 µs time window
☐	other	none

Note:

- Continuous transmitter off-times:
  Off-times are only taken into account if they are larger than the specified minimum value (e.g. 2 ms).
  Off-times smaller than the specified minimum value are not considered when checking the specified limit (e.g. "at least 25.5 ms within any contiguous interval of 33 ms").

Measurement:

Measurement parameter	
Detector:	Pos-Peak (RF-Detector)
Video bandwidth:	10 MHz
Trace-Mode:	Max Hold

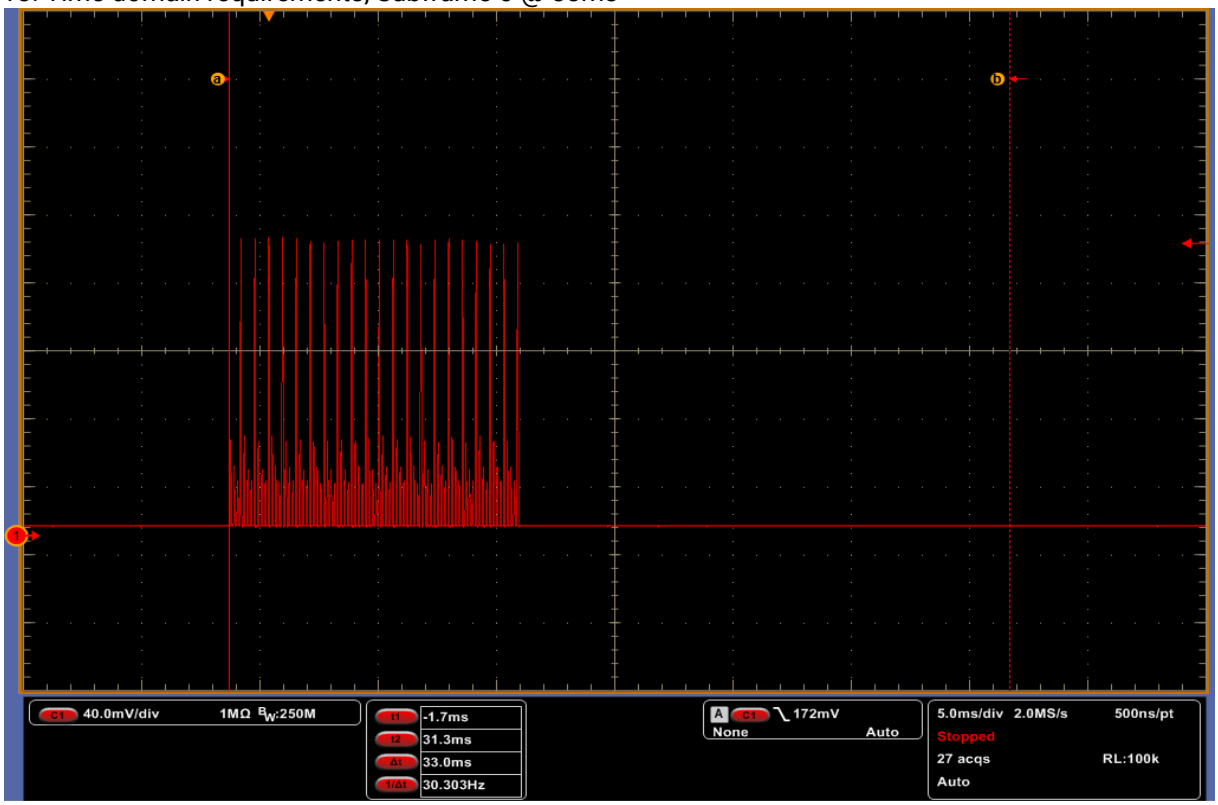
Measurement results:

Frame	Maximum sum of continuous transmitter off-times of at least two milliseconds within any contiguous interval of 33 milliseconds.	
	Measured value	Limit
Frame 0	20.7 ms	At least 16.5 ms
Farme 1	16.8 ms	At least 16.5 ms

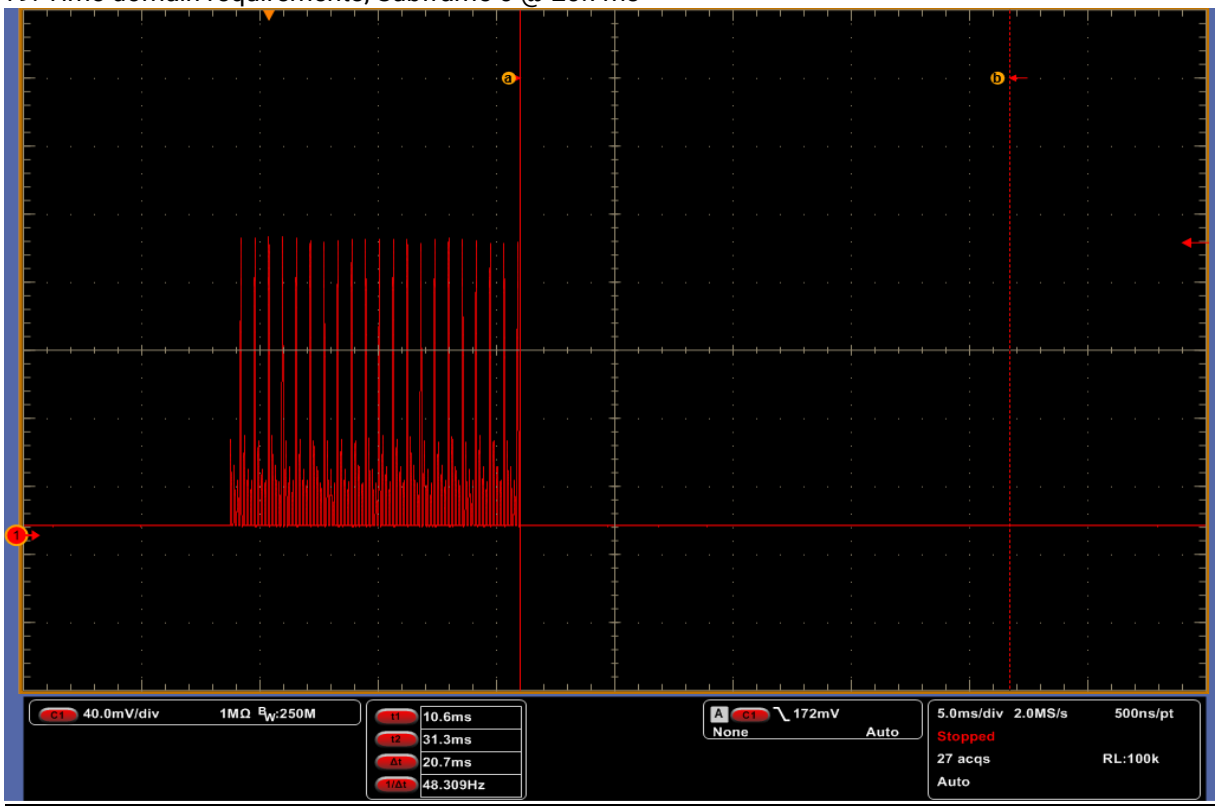
Verdict: **Compliant**

Plot 17: Time domain requirements, Off-times @ 200us

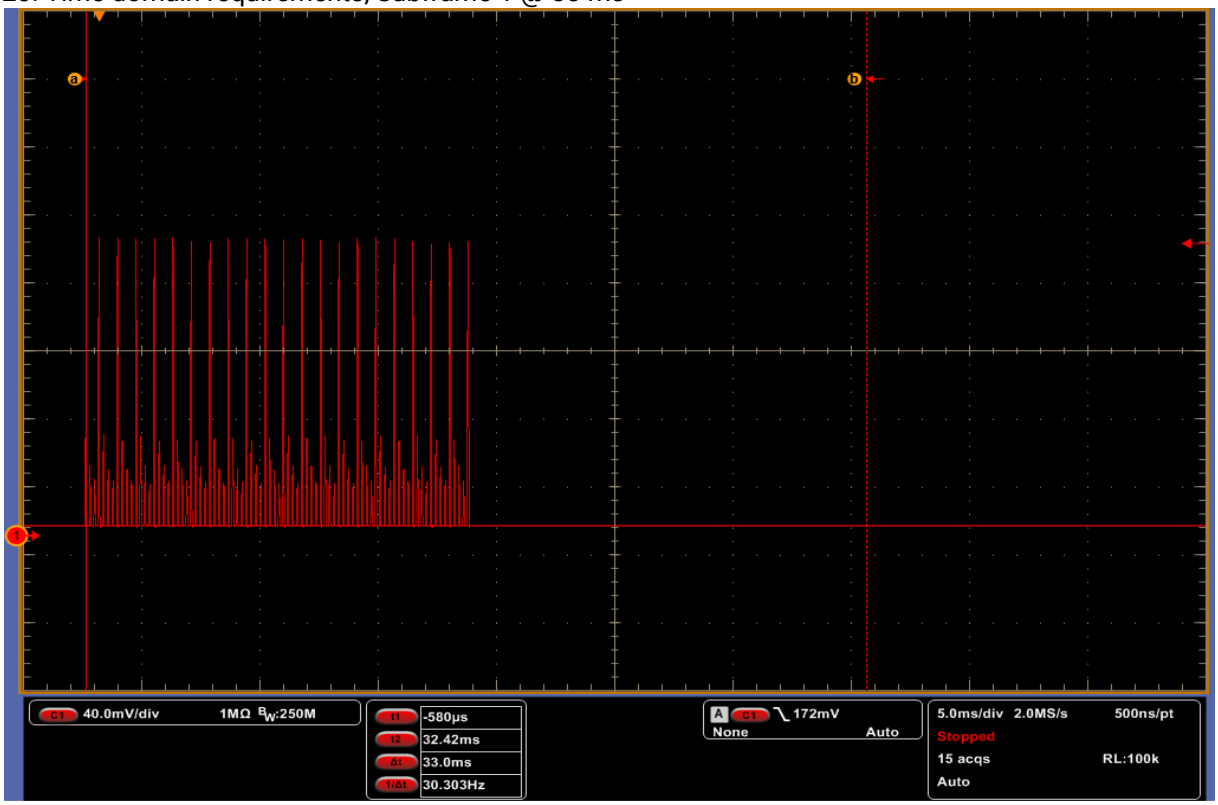
Plot 18: Time domain requirements, Subframe 0 @ 33ms



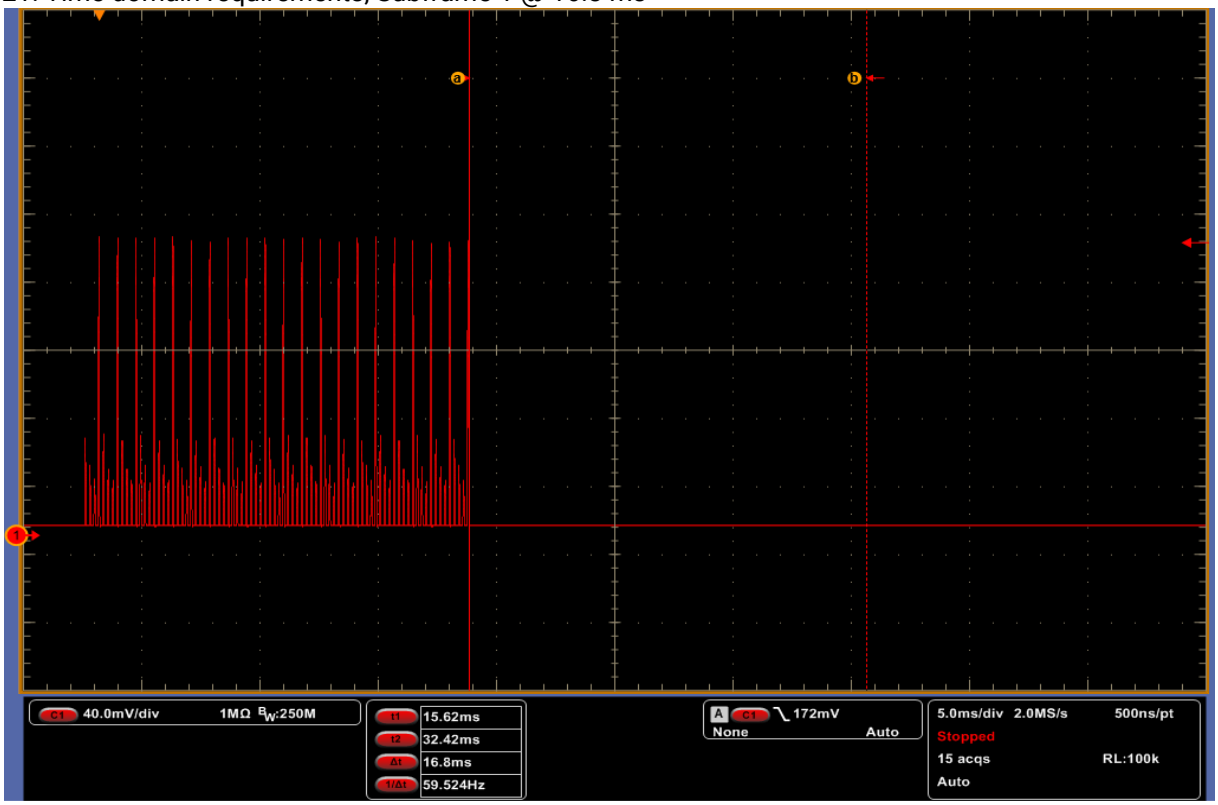
Plot 19: Time domain requirements, Subframe 0 @ 20.7ms



Plot 20: Time domain requirements, Subframe 1 @ 33 ms



Plot 21: Time domain requirements, Subframe 1 @ 16.8 ms



13.4 Spurious emissions radiated

Description:

Measurement of the radiated spurious emissions.

Limits and provisions:

Selection of applicable rule parts: see 8

47CFR Part 15.209(a)		
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
47 CFR 15.255(d)		
Frequency (GHz)	Power density [pW/cm2]	Equivalent isotropically radiated power: EIRP [dBm]
Below 40	See §15.209	-/-
40 - 200	90 @ distance of 3 m	-10
The power density of any emissions outside the 57-71 GHz band shall consist solely of spurious emissions.		
The levels of the spurious emissions shall not exceed the level of the fundamental emission.		
47 CFR 15.33(a)(3)		
If the intentional radiator operates at or above 30 GHz: to the fifth harmonic of the highest fundamental frequency or to 200 GHz, whichever is lower, unless specified otherwise elsewhere in the rules.		

Limit conversion (ANSI C63.10-2020 9.2.3):

$EIRP[dBm] = 10 \times \log(4 \times \pi \times d^2 \times PD[W/m^2])$

- Power density at the distance specified by the limit: PD [W/m²]
- Equivalent isotropically radiated power: EIRP [dBm]
- Distance at which the power density limit is specified: d [m]

According to this formula, an emission limit of PD = 90 pW/cm² at a distance of d = 3 m corresponds to an equivalent isotropically radiated power of EIRP = -10 dBm.

Measurement:

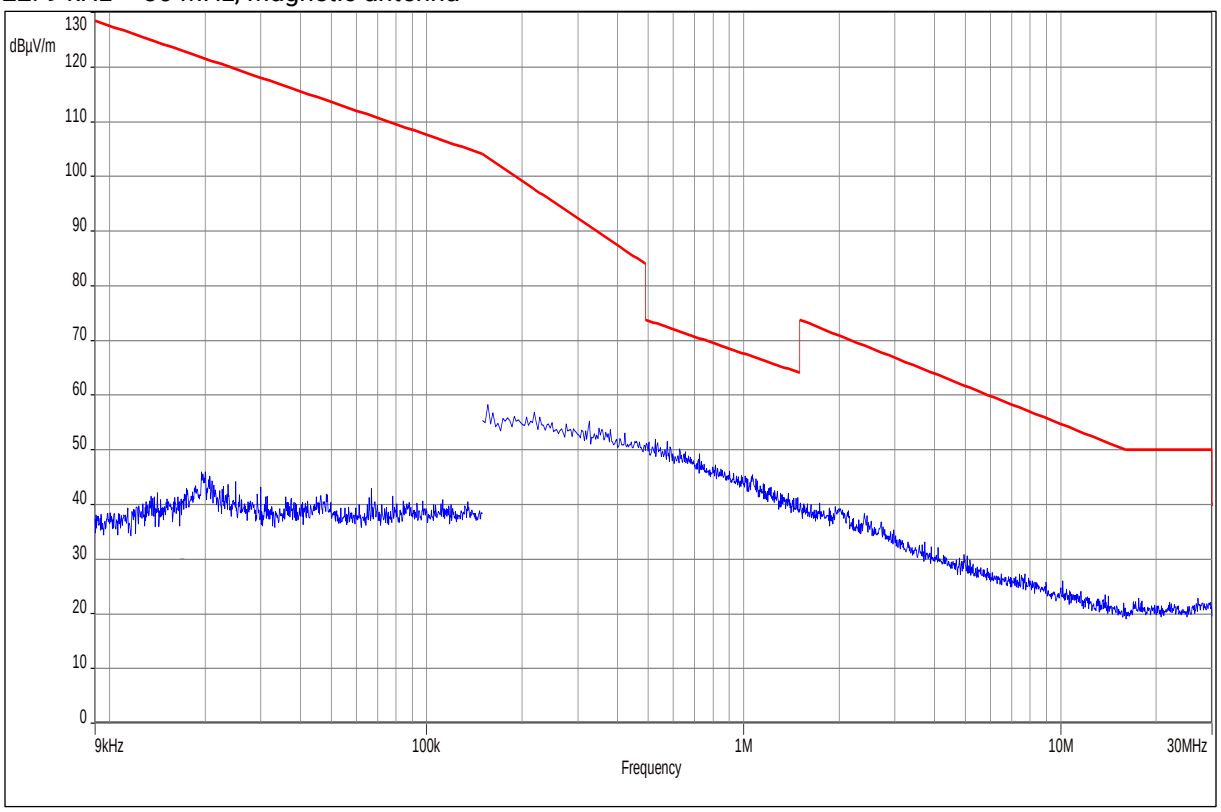
Measurement parameter	
Detector:	Quasi Peak / Pos-Peak / RMS
Resolution bandwidth:	F < 1 GHz: 100 kHz F > 1 GHz: 1 MHz
Video bandwidth:	F < 1 GHz: 300 kHz F > 1 GHz: 3 MHz
Trace-Mode:	Max Hold

Measurement results:

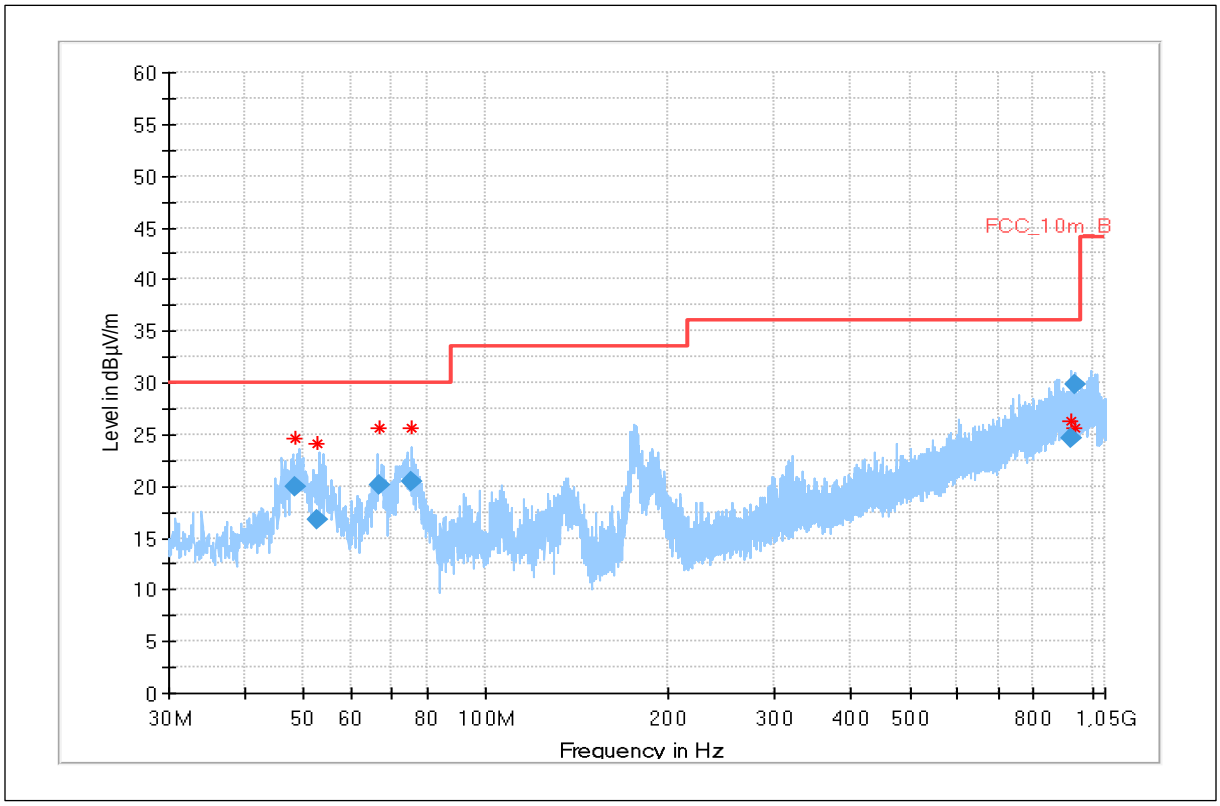
Frequency [GHz]	Detector	Bandwidth [MHz]	Level	Limit	Margin [dB]
-/-	-/-	-/-	-/-	-/-	-/-
Please refer to the following plots for more information on the level of spurious emissions					

Verdict: Compliant

Plot 22: 9 kHz – 30 MHz, Magnetic antenna

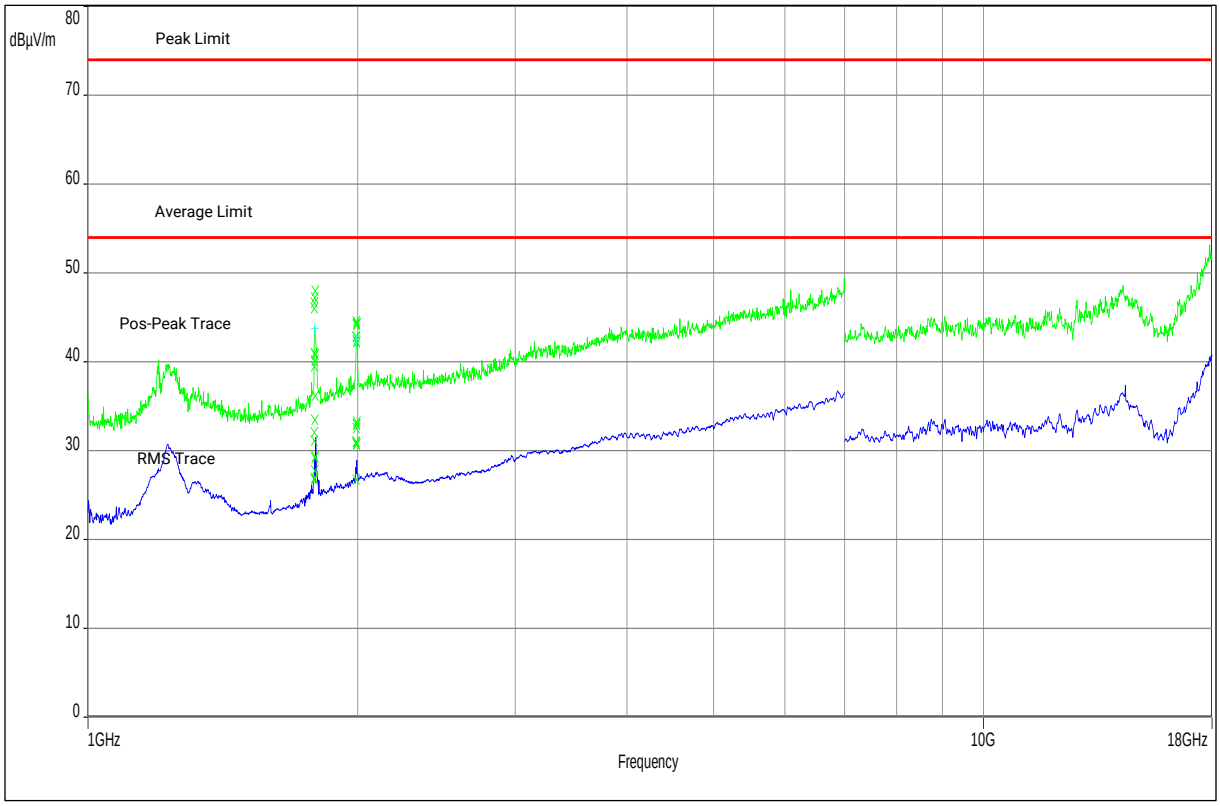


Plot 23: 30 MHz – 1 GHz, antenna vertical / horizontal

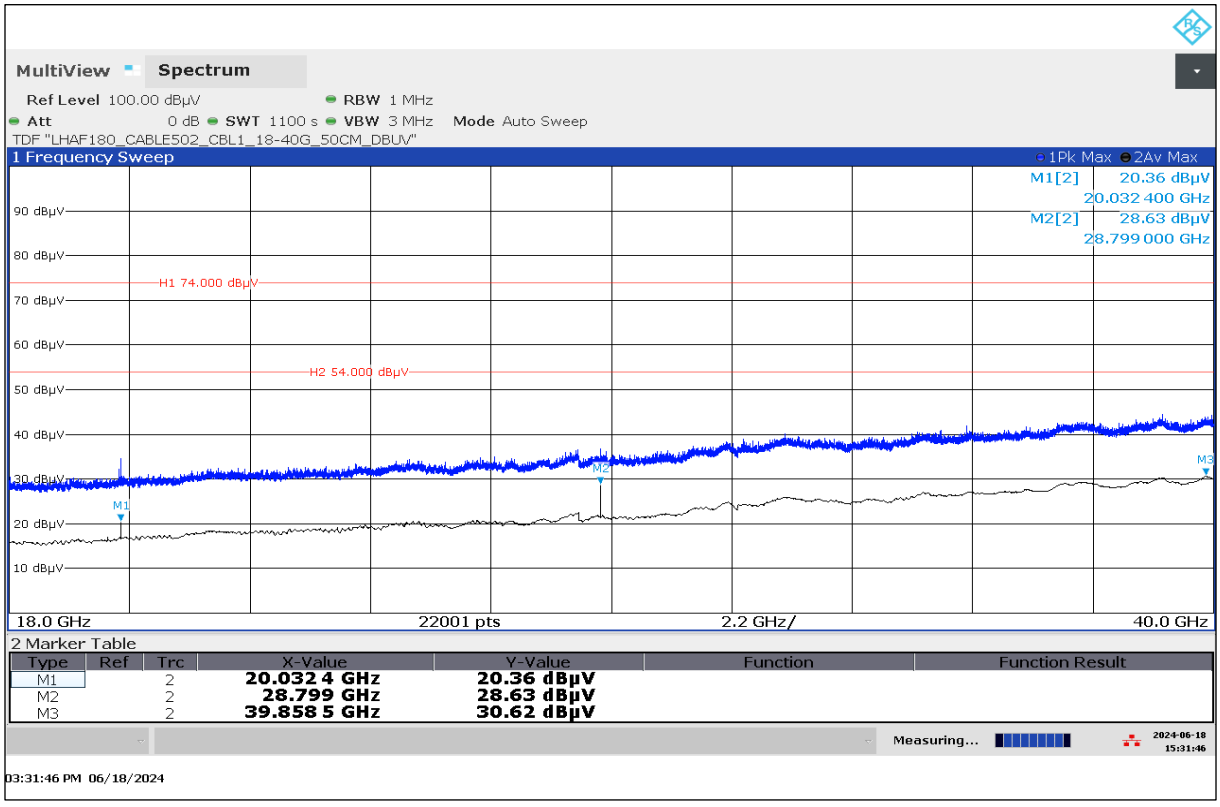


Frequency (MHz)	QuasiPeak (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Meas. Time (ms)	Bandwidth (kHz)	Height (cm)	Pol	Azimuth (deg)	Corr. (dB/m)
48.626	19.97	30.0	10.0	1000	120.0	195.0	V	20	15
52.789	16.71	30.0	13.3	1000	120.0	104.0	V	-25	15
66.843	20.06	30.0	9.9	1000	120.0	195.0	V	66	12
75.404	20.44	30.0	9.6	1000	120.0	180.0	V	65	9
925.374	24.69	36.0	11.3	1000	120.0	195.0	V	142	25
938.246	29.85	36.0	6.2	1000	120.0	195.0	H	-37	25

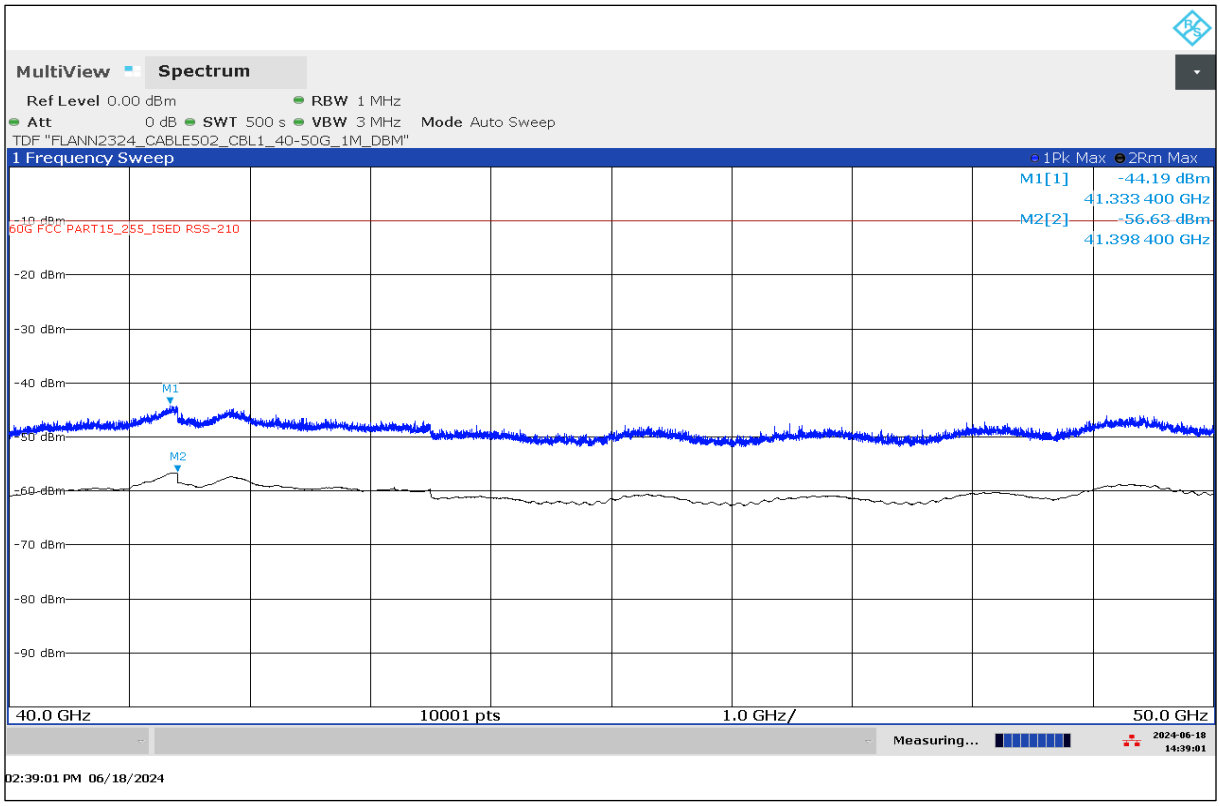
Plot 24: 1 GHz – 18 GHz, antenna vertical / horizontal



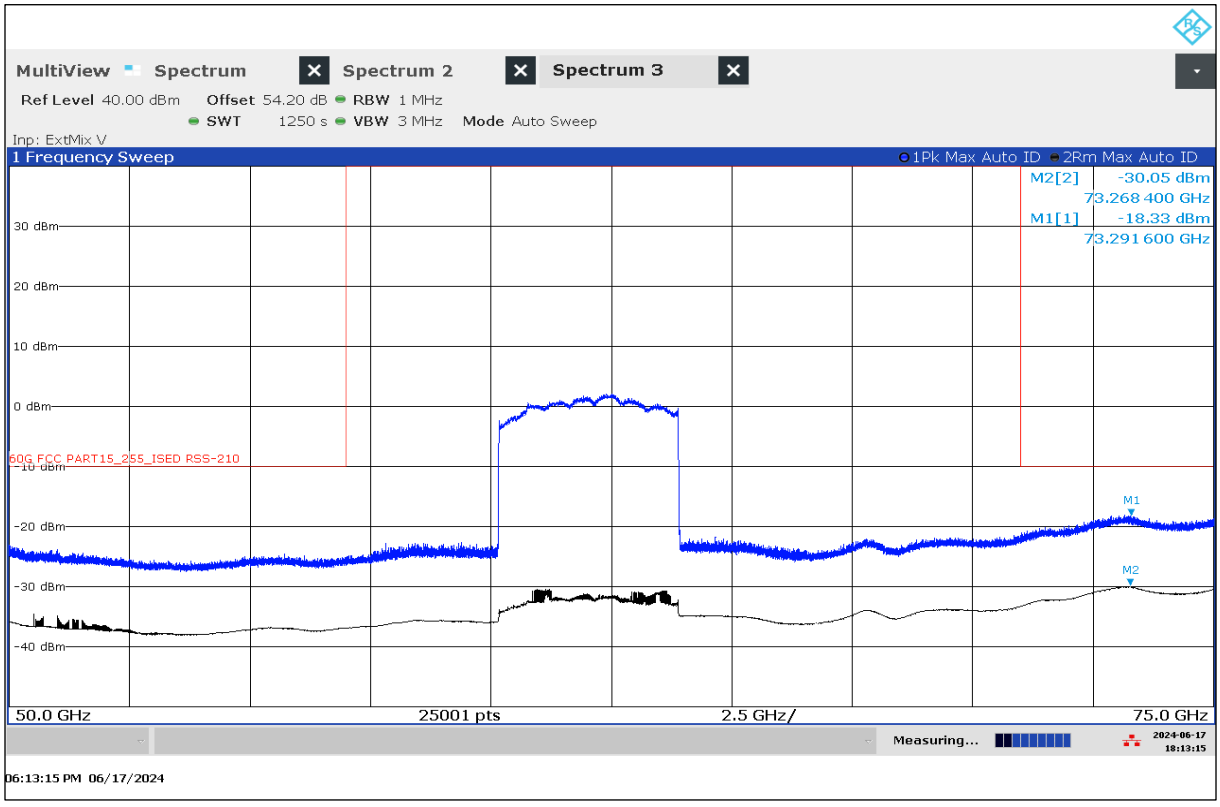
Plot 25: 18 GHz – 40 GHz, antenna vertical / horizontal



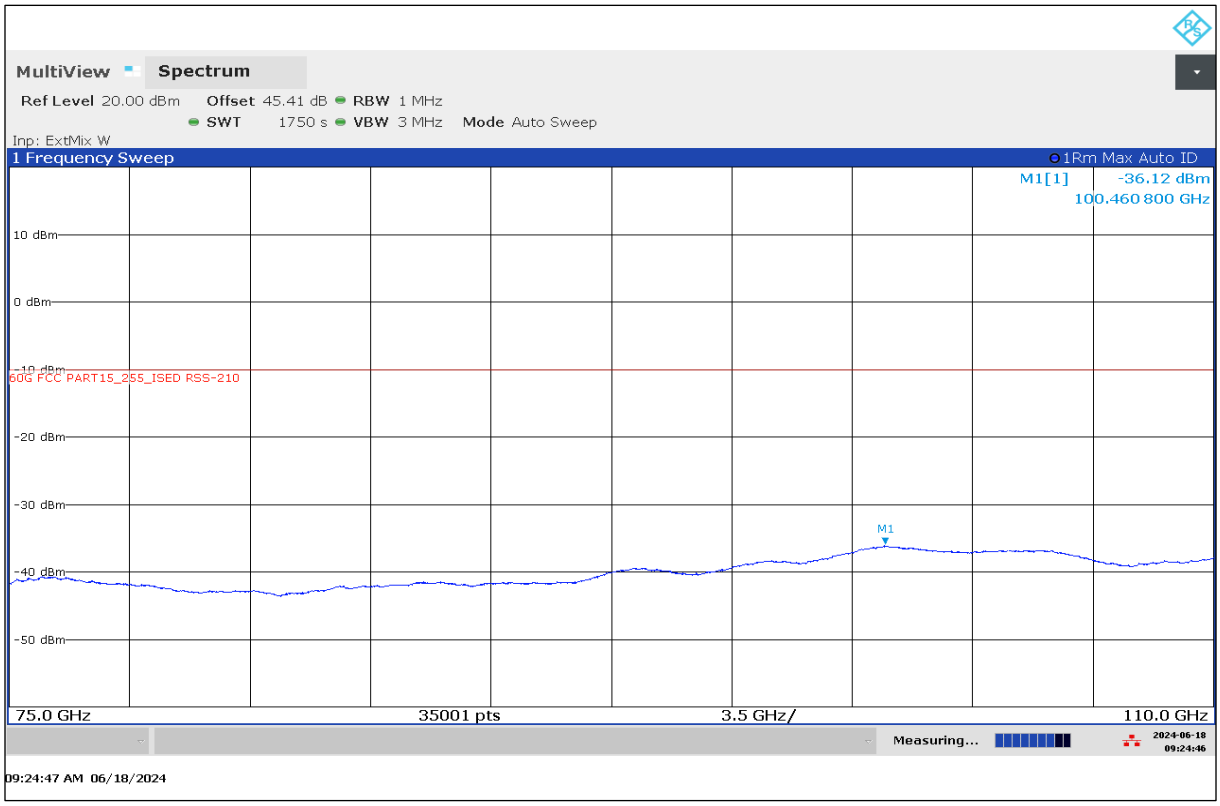
Plot 26: 40 GHz – 50 GHz, antenna vertical / horizontal



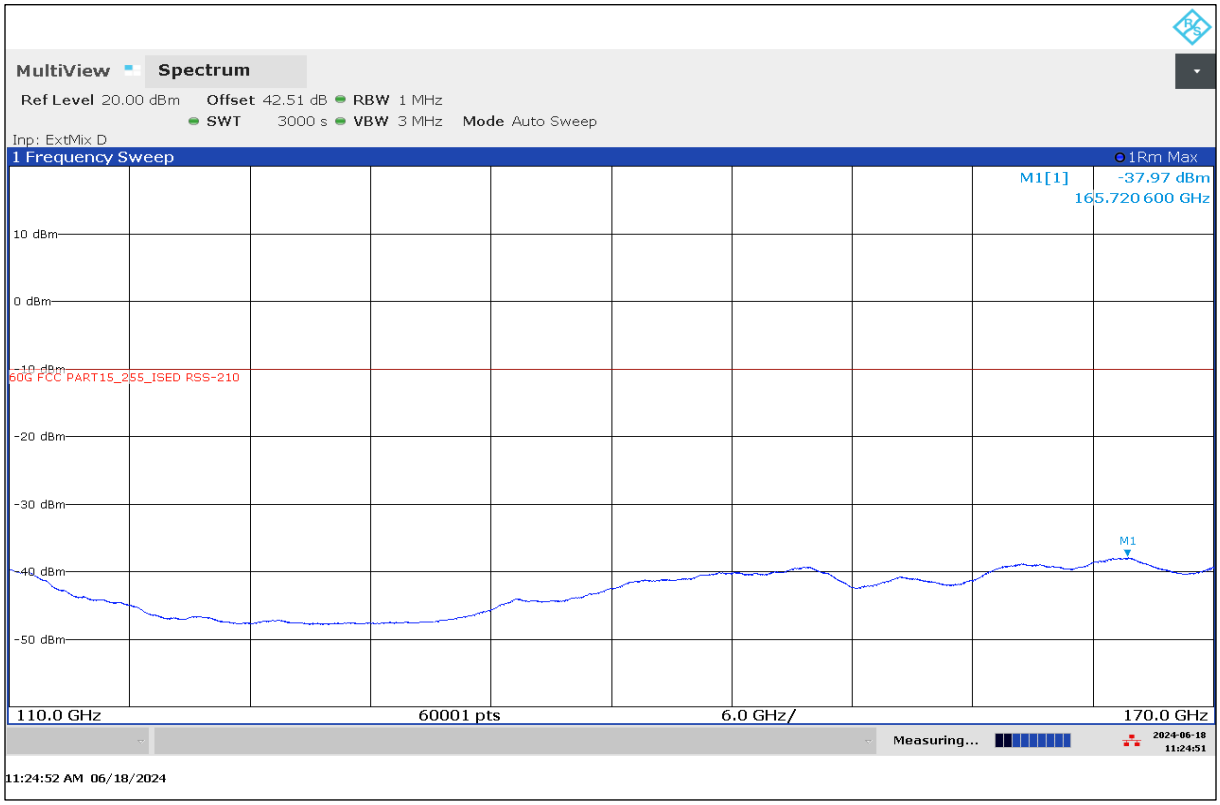
Plot 27: 50 GHz – 75 GHz, antenna vertical / horizontal



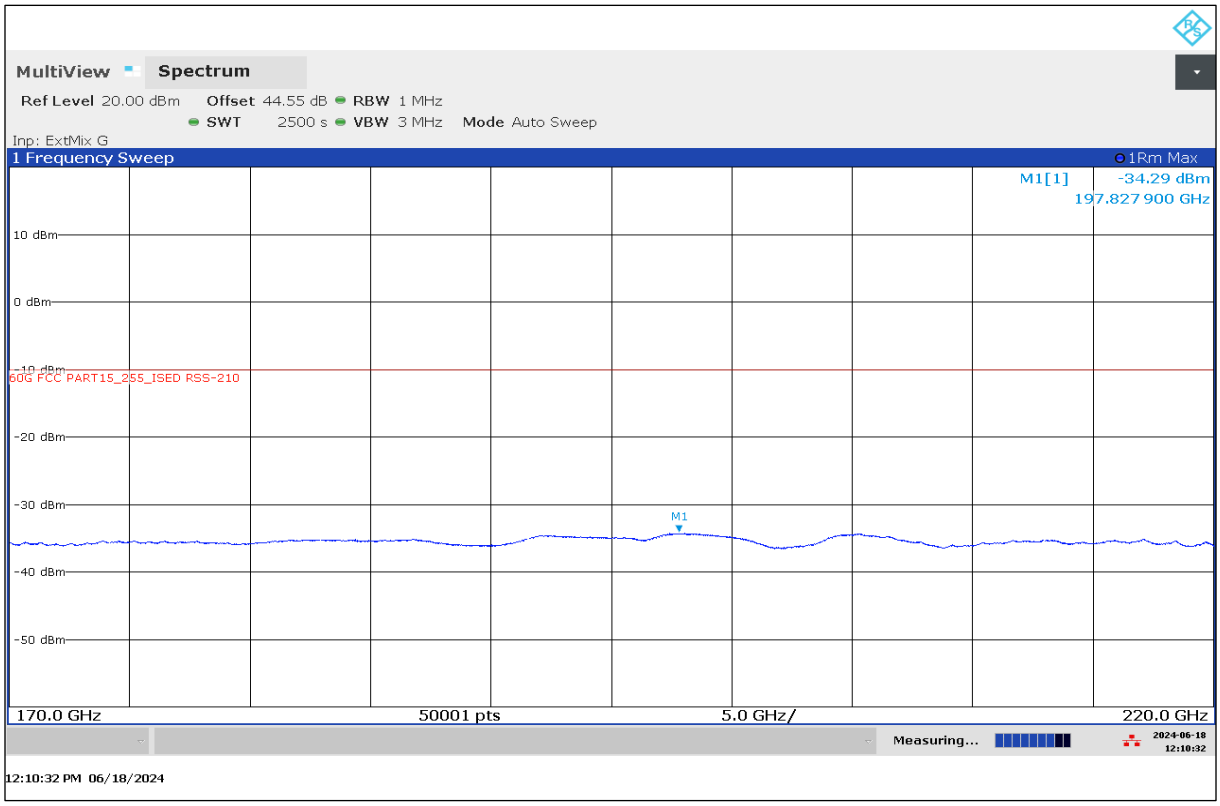
Plot 28: 75 GHz – 110 GHz, antenna vertical / horizontal



Plot 29: 110 GHz – 170 GHz, antenna vertical / horizontal



Plot 30: 170 GHz – 220 GHz, antenna vertical / horizontal



13.5 Conducted emissions < 30 MHz (AC power line)

Description:

Measurement of the conducted spurious emissions in transmit mode below 30 MHz. Both power lines, phase and neutral line, are measured. Found peaks are re-measured with average and quasi peak detection to show compliance to the limits.

Measurement:

Parameter	
Detector:	Peak - Quasi Peak / Average
Sweep time:	Auto
Video bandwidth:	F < 150 kHz: 200 Hz F > 150 kHz: 9 kHz
Resolution bandwidth:	F < 150 kHz: 1 kHz F > 150 kHz: 100 kHz
Span:	9 kHz to 30 MHz
Trace-Mode:	Max Hold

Limits and provisions:

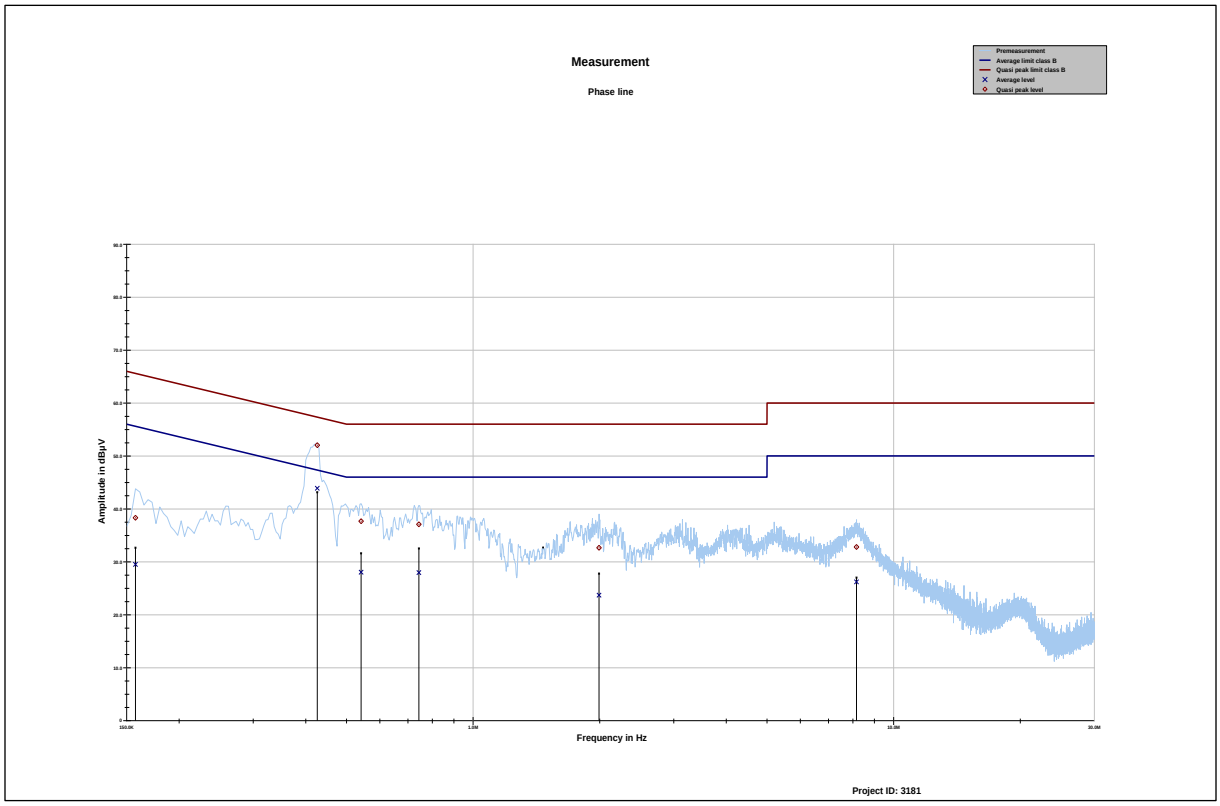
Selection of applicable rule parts: see 8

47 CFR 15.207(a)		
Frequency of emission (MHz)	Conducted limit (dBµV)	
	Quasi-peak	Average
0.15 – 0.5	66 to 56*	56 to 46*
0.5 – 5	56	46
5 – 30	60	50

* Decreases with the logarithm of the frequency

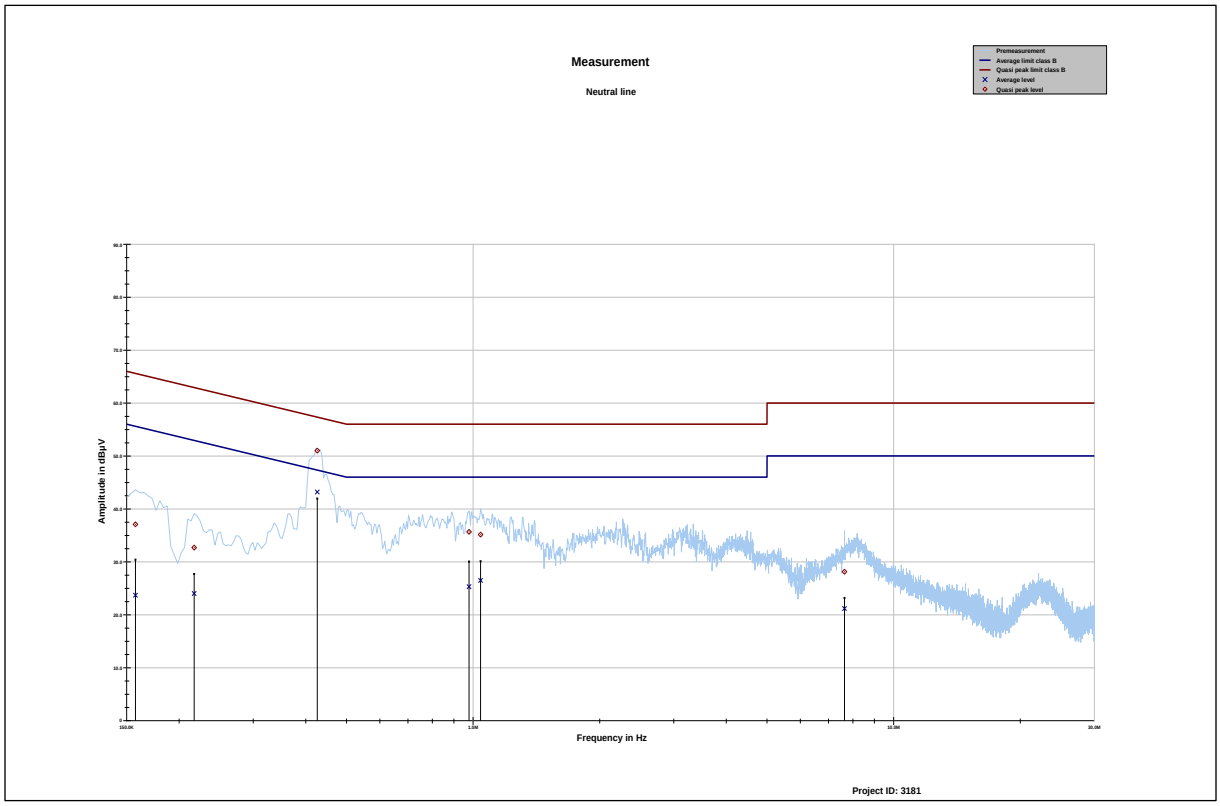
Verdict: **Compliant**

Plot 31: Phase line



Frequency	Quasi peak level	Margin quasi peak	Limit QP	Average level	Margin Average	Limit AV
MHz	dBµV	dB	dBµV	dBµV	dB	dBµV
0.157463	38.32	27.27	65.597	29.51	26.28	55.787
0.426113	52.03	5.30	57.328	43.90	4.21	48.111
0.541781	37.66	18.34	56.000	28.04	17.96	46.000
0.743269	37.08	18.92	56.000	27.96	18.04	46.000
1.993237	32.65	23.35	56.000	23.70	22.30	46.000
8.160994	32.80	27.20	60.000	26.20	23.80	50.000

Plot 32: Neutral line



Frequency	Quasi peak level	Margin quasi peak	Limit QP	Average level	Margin Average	Limit AV
MHz	dBµV	dB	dBµV	dBµV	dB	dBµV
0.157463	37.08	28.52	65.597	23.70	32.08	55.787
0.217163	32.69	30.24	62.927	24.01	30.08	54.081
0.426113	50.99	6.33	57.328	43.18	4.93	48.111
0.978337	35.66	20.34	56.000	25.30	20.70	46.000
1.041769	35.14	20.86	56.000	26.49	19.51	46.000
7.642350	28.13	31.87	60.000	21.17	28.83	50.000

14 Customer Declaration on Electrically Identical Models

ifm efector gmbh · Postfach 12 62 · 88061 Tettnang · Germany

ifm efector gmbh
ifm-Straße 1
88069 Tettnang
Germany
Phone +49 7542 518-0
Telefax +49 7542 518-1290
E-mail info@ifm.com
Internet www.ifm.com

Declaration on Electrically Identical Models

We, ifm efector gmbh, declare on our sole responsibility the following family of radar devices to be identical in hardware and software part concerning the transmitter of the device that effect the radio frequency emissions:

R2D102, R2D111, R2D103, working in the frequency band 60 .. 64 GHz

The only differences between the models within this family are the backend hardware with its specific software for communication via different protocols, output drivers and error management:

- R2D102 and R2D111 are identical in hardware, backend software is different for different radar raw data evaluation and communication via IO Link
- R2D103 with different backend hardware and different backend software for radar raw data evaluation and communication via CAN J1939

The radar frontend component which transmits the radio frequency is the same within the family cited above (same material number).

We attest that above differences are not relevant for any RF behaviour subject to regulatory items.

Place and date: Tettnang, 12.08.2024

Name: Michael Hamma (Technical Manager)

Signature: i.V. Michael Hamma

15 Glossary

AVG	Average
C	Compliant
C/N_0	Carrier to noise-density ratio, expressed in dB-Hz
CAC	Channel availability check
CW	Clean wave
DC	Duty cycle
DFS	Dynamic frequency selection
DSSS	Dynamic sequence spread spectrum
DUT	Device under test
EN	European Standard
ETSI	European Telecommunications Standards Institute
EMC	Electromagnetic Compatibility
EUT	Equipment under test
FCC	Federal Communications Commission
FCC ID	Company Identifier at FCC
FHSS	Frequency hopping spread spectrum
FVIN	Firmware version identification number
GNSS	Global Navigation Satellite System
GUE	GNSS User Equipment
HMN	Host marketing name
HVIN	Hardware version identification number
HW	Hardware
IC	Industry Canada
Inv. No.	Inventory number
MC	Modulated carrier
NA	Not applicable
NC	Not compliant
NOP	Non occupancy period
NP	Not performed
OBW	Occupied bandwidth
OC	Operating channel
OCW	Operating channel bandwidth
OFDM	Orthogonal frequency division multiplexing
OOB	Out of band
OP	Occupancy period
PER	Packet error rate
PMN	Product marketing name
PP	Positive peak
QP	Quasi peak
RLAN	Radio local area network
S/N or SN	Serial number
SW	Software
UUT	Unit under test
WLAN	Wireless local area network

16 Document history

Version	Applied changes	Date of release
R01	Initial release	2024-10-07

########## END OF TEST REPORT ##########