

Test Report

Report Number:

F210861E1

Equipment under Test (EUT):

Marker Mini

Applicant:

TRUMPF Tracking Technologies

Manufacturer:

WEPTech elektronik GmbH



Deutsche
Akkreditierungsstelle
D-PL-17186-01-01
D-PL-17186-01-02
D-PL-17186-01-03

References

- [1] **ANSI C63.10-2013**, American National Standard of Procedures for Compliance Testing of Unlicensed Wireless Devices
- [2] **FCC CFR 47 Part 15**, Radio Frequency Devices
- [3] **393764 D01 UWB FAQ v02**, ULTRA-WIDEBAND (UWB) DEVICES FREQUENTLY ASKED QUESTIONS

TEST RESULT

The requirements of the tests performed as shown in the overview (clause 0) were fulfilled by the equipment under test. The complete test results are presented in the following.

“Passed” indicates that the equipment under test conforms with the relevant limits of the testing standard without taking any measurement uncertainty into account as stated in clause 1.3 of ANSI C63.10 (2013). However, the measurement uncertainty is calculated and shown in this test report.

Tested and
written by:

Signature

Reviewed and
approved by:

Signature

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The test results herein refer only to the tested sample. PHOENIX TESTLAB GmbH is not responsible for any generalisations or conclusions drawn from these test results concerning further samples. Any modification of the tested samples is prohibited and leads to the invalidity of this test report. Each page necessarily contains the PHOENIX TESTLAB Logo and the TEST REPORT NUMBER.

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1 Identification

1.1 Applicant

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Applicant represented during the test by the following person:	---

1.2 Manufacturer

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Name for contact purposes:	Mr. Jochen RIGA
Phone:	+49 63 41 92 55 - 331 / +49 160 97 72 58 61
eMail Address:	jochen.riga@weptech.de
Manufacturer represented during the test by the following person:	---

1.3 Test laboratory

The tests were carried out at: **PHOENIX TESTLAB GmbH**
Königswinkel 10
32825 Blomberg
Germany

Accredited by Deutsche Akkreditierungsstelle GmbH (DAkkS) in compliance with DIN EN ISO/IEC 17025 under Reg. No. D-PL-17186-01-05 and D-PL-17186-01-06, FCC Test Firm Designation Number DE0004, FCC Test Firm Registration Number 469623.

1.4 EUT (Equipment Under Test)

Test object: *	Tag for indoor localization
Model name: *	Marker Mini
FCC ID: *	2A2TP-2677368
Serial number: *	1910154B00301EB0
PCB identifier: *	E001-3233-02
Hardware version: *	V1.0.0
Software version: *	3.3.2
Lowest / highest internal frequency: *	32 kHz / 4500 MHz

* Declared by the applicant

Note: PHOENIX TESTLAB GmbH does not take samples. The sample used for tests is provided exclusively by the applicant.

1.5 Technical data of equipment

Channel 1	$f_c = 3.500$ GHz, 500 MHz bandwidth
Channel 2	$f_c = 4.000$ GHz, 500 MHz bandwidth
Channel 3	$f_c = 4.500$ GHz, 500 MHz bandwidth

Rated rf-output power: *	-41.3 dBm (e.i.r.p.)		
Antenna type: *	Internal PCB antenna		
Antenna gain: *	2 dBi		
Antenna connector: *	None		
Supply voltage EUT: *	$U_{nom} = 3.7$ V _{DC}	$U_{min} = 3.1$ V _{DC}	$U_{max} = 4.2$ V _{DC}
Temperature range: *	-10 °C to +55 °		
Ancillary used for test:	None		

* declared by the applicant.

Equipment used for testing	
Mobile phone *2	Samsung S9 mobile phone ¹ with the app nRF Connect V4.24.1,
Charging station*1	WTAG charger

*1 Provided by the applicant

*2 Provided by the laboratory

Identification	Connector		Length *
	EUT	Ancillary	
-	No lines are connectable to the EUT.		-
-			-

*: Length during the test if not otherwise specified.

1.6 Dates

Date of receipt of test sample:	27.05.2021
Start of test:	16.08.2021
End of test:	24.08.2021

2 Operational states

The EUT is a mobile UWB transceiver device, which is intended to be used as indoor locating device.

All measurements were carried out with an unmodified test sample mounted with a test software.

The UWB operation mode could be selected via a Bluetooth connection to a mobile phone with the app nRF Connect V4.24.1. After the operation mode is selected, the Bluetooth operation of the EUT was switched off by placing it on a charging station. Placing the device on the charger again will switch on the Bluetooth operation of the EUT.

During all measurements the EUT was supplied by a fully charged internal battery, which could be charged with wireless power transfer.

Because the EUT has no connector, all measurements were carried out radiated.

During the radiated emission measurement below 1 GHz the EUT was tested in two orthogonal directions:

Position 1: LEDs of the EUT are showing to the antenna and Position 2: LEDs of the EUT showing upwards (for details refer also the photos in annex A of this test report).

The transmit power level could be set with the test software on the mobile phone. The following power levels were used to reach the documented results:

Operation mode	Description of the operation mode	Channel	Power setting
1	Transmit continuously on 3.500 GHz	1	+2
2	Transmit continuously on 4.000 GHz	2	+3
3	Transmit continuously on 4.500 GHz	3	+1

3 Additional information

This test report contains only the results of the UWB part of the EUT.

F210861E1 contains: UWB relevant results
 F210861E2 contains: BLE relevant results
 F210861E3 contains: Simultaneous transmission of BLE and UWB relevant results

The tested sample was not labeled as required by the FCC.

4 Overview

Application	Frequency range [MHz]	FCC 47 CFR Part 15 section [2]	Status	Refer page
10 dB bandwidth	3100 - 10600	15.517 (b) 15.521 (e)	Passed	8 et seq.
Peak level of transmission	3100 - 10600	15.517 (e) 15.521 (g)	Passed	11 et seq.
Technical requirements applicable to all UWB devices.	-	15.521 (a)	Passed * ¹	-
		15.521 (b)	Refer below	-
		15.521 (f)	Not applicable * ²	-
		15.521 (i)	Noted	-
Radiated emissions (transmitter)	0.009 - 40000	15.517 (c) 15.517 (d) 15.205 (a) 15.209 (a) 15.521 (c), (d) (h)	Passed	13 et seq.
Conducted emissions on supply line	0.15 - 30	15.207 (a) 15.521 (j)	Not applicable * ³	-
Antenna requirement	-	15.521 (b) 15.203 15.517 (a) (3)	Passed * ⁴	-
External radio frequency power amplifiers and antenna modifications.	-	15.204 (a) to (d) 15.521 (b)	Passed * ⁴	-

- *¹: As declared by the applicant, the device is intended to be used in industrial applications. For details refer the installation / user manual. Therefore, the requirement could be regarded as fulfilled.
- *²: Not applicable, because the EUT is a location device and no imaging system.
- *³: Battery supplied device without any connector, the battery will be charged wireless.
- *⁴: As declared by the applicant, the EUT is intended to be used with the internal PCB antenna only. No external antennas or amplifiers could be connected to the EUT. The internal UFL-connector is intended for test purposes only – it is not reachable from outside the housing. Therefore, the requirements could be regarded as fulfilled.

5 Test results

5.1 10 dB bandwidth

5.1.1 Method of measurement (10 dB bandwidth)

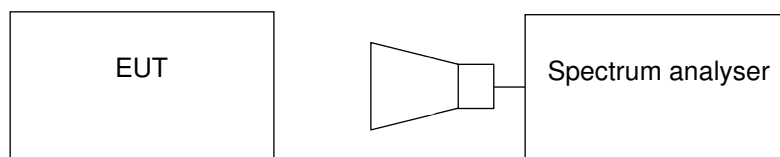
The calibration of the spectrum analyser has to be checked with the help of a known signal from a signal generator. The EUT has to be connected to the spectrum analyser via a low loss cable. If the EUT is not equipped with an antenna connector, a temporary antenna connector has to be installed. The EUT has to be switched on and the hopping function has to be disabled, the transmitter shall work with its maximum data rate.

The following spectrum analyser settings according to [1] shall be used:

- Span: App. 2 to 5 times the 10 dB bandwidth, centered on the actual hopping channel.
- Resolution bandwidth: 1 MHz.
- Video bandwidth: \geq the RBW.
- Set the reference level of the instrument as required, keeping the signal from exceeding the maximum input mixer level for linear operation.
- Sweep time: 1 ms / sweep point.
- Detector function: Peak.
- Trace mode: Max hold.

After trace stabilization the marker shall be set on the signal peak. The first display line has to be set on this value. The second display line has to be set 10 dB below the first line (or the peak marker). The frequency lines shall be set on the intersection points between the second display line and the measured curve.

Test set-up:

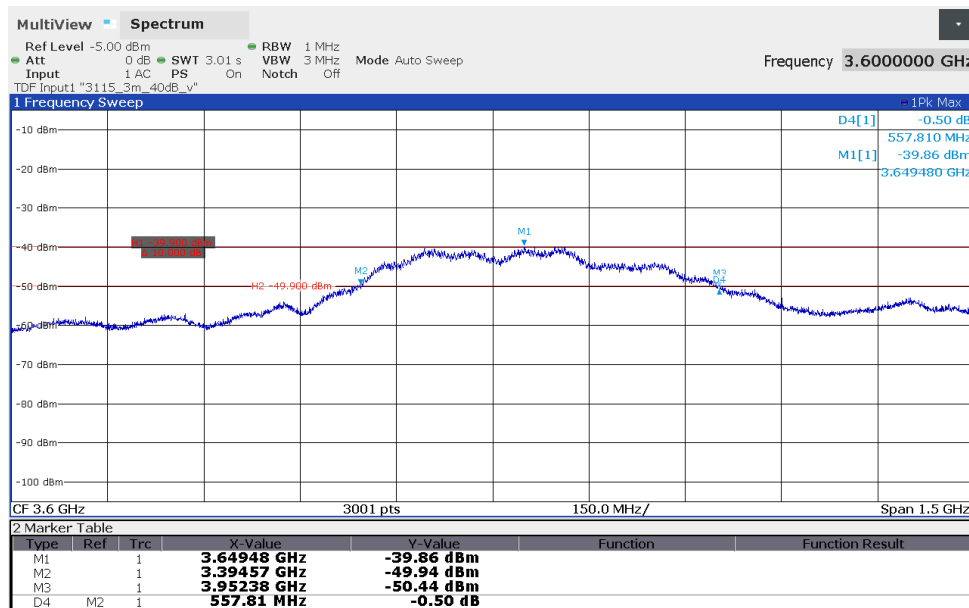


5.1.2 Test results (10 dB bandwidth)

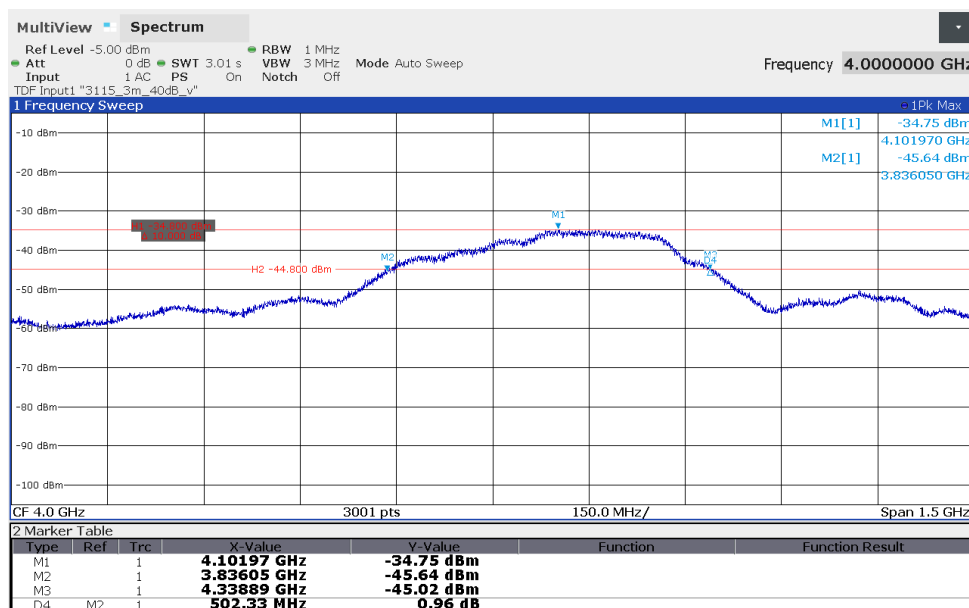
Ambient temperature:	22 °C
Relative humidity:	57 %

Date:	16.08.2021
Tested by:	Thomas KÜHN

210861_1.png: 10 dB bandwidth on channel 1:



210861_3.png: 10 dB bandwidth on channel 2:



5.2 Peak level of transmission

5.2.1 Method of measurement (peak level of transmission)

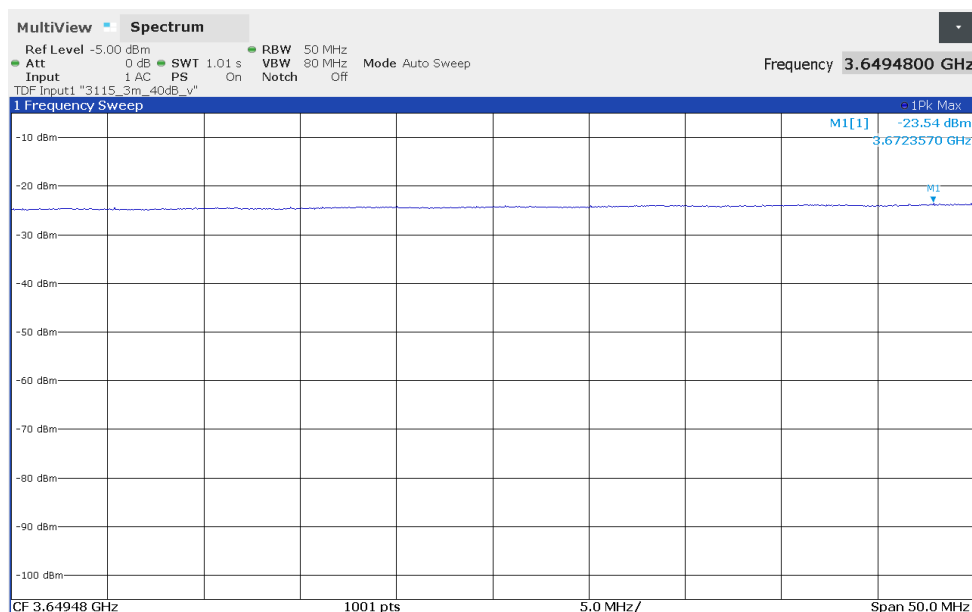
Because the EUT has no antenna connector, which presents the power delivered to the antenna, the peak value of the field strength was measured. The method of measurement is described under clause 5.3.1.4 (Preliminary and final measurement > 1 GHz) of this test report with the exception that a peak detector and a resolution bandwidth of 50 MHz within a 50 MHz span centered at highest detected average emission level.

5.2.2 Test results (peak level of transmission)

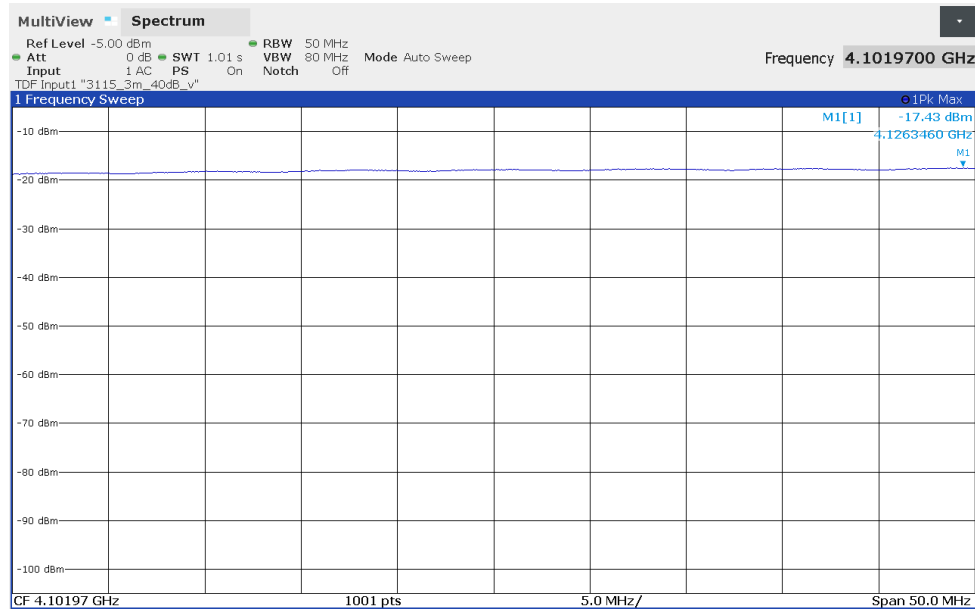
Ambient temperature:	22 °C
Relative humidity:	57 %

Date:	16.08.2021
Tested by:	Thomas KÜHN

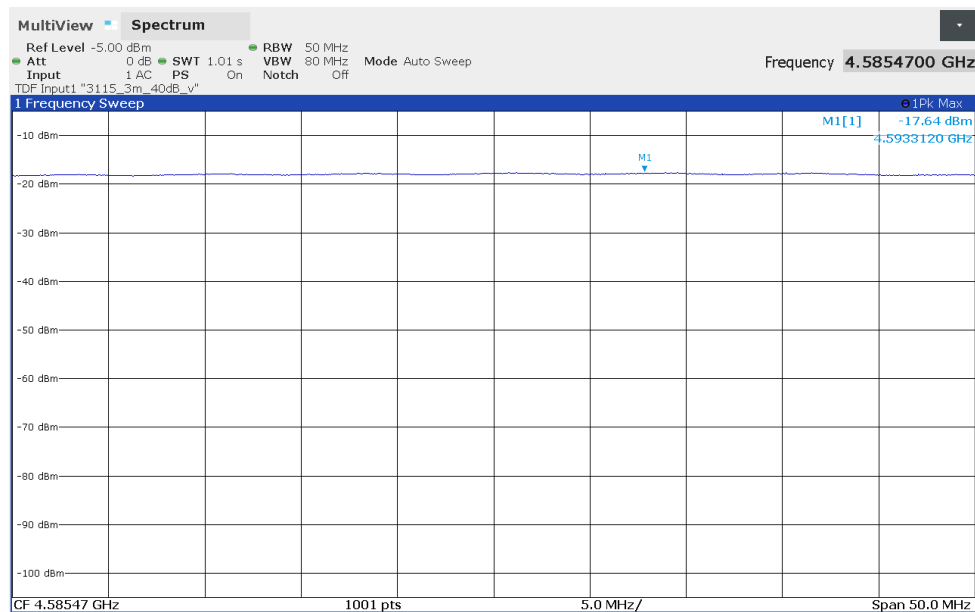
210861_2.png: Peak level of transmission on channel 1:



210861_4.png: Peak level of transmission on channel 2:



210861_6.png: Peak level of transmission on channel 3:



Channel No.	Channel frequency [MHz]	Frequency of max. level [MHz]	Bandwidth [kHz]	Height [cm]	Turn table [deg]	Turn device [deg]	Pol.	Peak level (EIRP) [dBm]	Limit [dBm]	Margin [dB]
1	3575	3672.357	50000	150	0	0	Vert.	-23.5	0.0	23.5
2	4000	4126.346	50000	150	26	0	Vert.	-17.4	0.0	17.4
3	4500	4593.312	50000	150	90	4	Vert.	-17.6	0.0	17.6

Measurement uncertainty ± 3.0 dB

Test: Passed

Test equipment (please refer to chapter 6 for details)

12 – 21, 28

5.3 Radiated emissions

5.3.1 Method of measurement (radiated emissions)

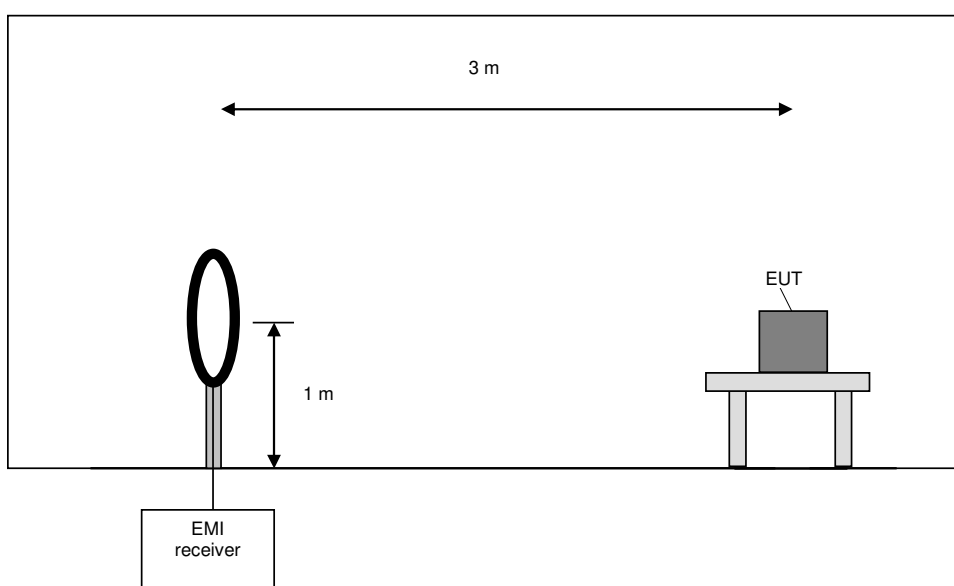
5.3.1.1 Preliminary measurement 9 kHz to 30 MHz

In the first stage a preliminary measurement is performed in an anechoic chamber with a measuring distance of 3 meters. Table-top devices are set up on a non-conducting support with a size of 1 m by 1.5 m and a height of 80 cm. Floor-standing devices are placed directly on the turntable / ground plane. The setup of the equipment under test is in accordance to [1].

The frequency range 9 kHz to 30 MHz is monitored with an EMI receiver while the system and its cables are manipulated to find out the configuration with the maximum emission levels if applicable. The EMI receiver is set to MAX hold mode. The EUT and the measuring antenna are rotated around their vertical axis to find the maximum emission levels.

The resolution bandwidth of the EMI receiver is set to the following values:

Frequency range	Resolution bandwidth
9 kHz to 150 kHz	200 Hz
150 kHz to 30 MHz	9 kHz



Procedure preliminary measurement:

Pre-scans are performed in the frequency range 9 kHz to 150 kHz and 150 kHz to 30 MHz.

The following procedure is used:

- 1) Monitor the frequency range with the measuring antenna facing the EUT and an EUT / turntable azimuth of 0 °.
- 2) Manipulate the system cables to produce the maximum levels of emissions.
- 3) Rotate the EUT by 360 ° to maximize the detected signals.
- 4) Measure the frequencies of the highest detected emissions with a lower span and resolution bandwidth to increase the accuracy and note the frequency values.
- 5) If the EUT is portable or ceiling mounted, repeat steps 1 to 4 with other orientations (x,y,z) of the EUT.
- 6) Rotate the measuring antenna and repeat steps 1 to 5.

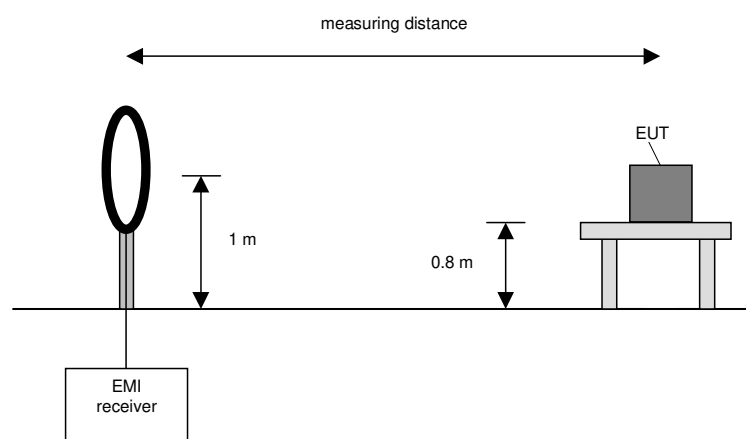
5.3.1.2 Final measurement 9 kHz to 30 MHz

In the second stage a final measurement is performed on an open area test site with no conducting ground plane in a measuring distances of 3 m, 10 m or 30 m. In the case where larger measuring distances are required the results are extrapolated based on the values measured on the closer distances according to section 15.31 (f) (2) [2]. The final measurement is performed with an EMI receiver set to Quasi-Peak detector, except for the frequency bands 9 kHz to 90 kHz and 110 kHz to 490 kHz where an Average detector is used according section 15.209 (d) [2].

At the frequencies, which were detected during the preliminary measurements, the final measurement is performed while rotating the EUT and the measuring antenna in the range of 0 ° to 360 ° around their vertical axis until the maximum level value is found.

The resolution bandwidth of the EMI receiver is set to the following values:

Frequency range	Resolution bandwidth
9 kHz to 150 kHz	200 Hz
150 kHz to 30 MHz	9 kHz



Procedure final measurement:

The following procedure is used:

- 1) Monitor the selected frequencies from the preliminary measurement with the measuring antenna facing the EUT and an EUT azimuth of 0 °.
- 2) Rotate the EUT by 360 ° to maximize the detected signals.
- 3) Rotate the measuring antenna and repeat steps 1 to 2 until the maximum value is found and note it.
- 4) If the EUT is portable or ceiling mounted, repeat steps 1 to 3 with other orientations (x,y,z) of the EUT.

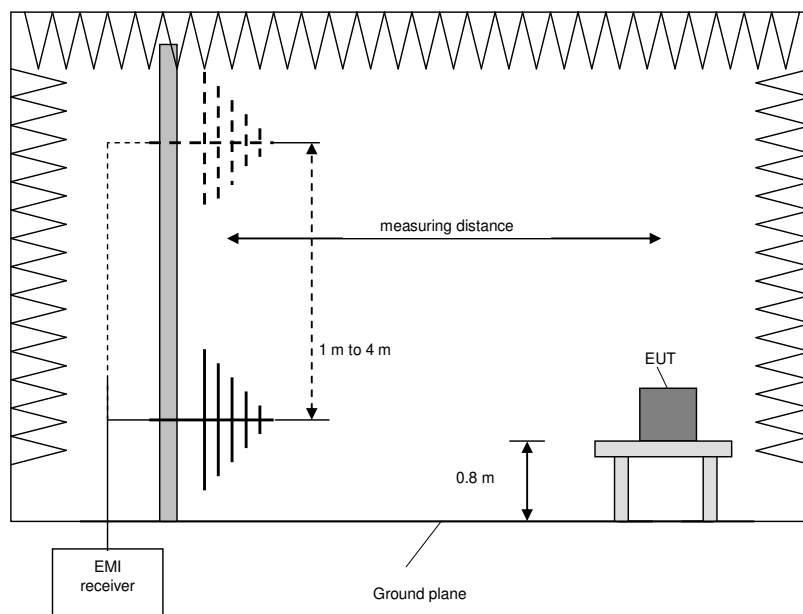
5.3.1.3 Preliminary and final measurement 30 MHz to 1 GHz

The preliminary and final measurements are performed in a semi-anechoic chamber with a metal ground plane in a 3 m distance.

During the tests the EUT is rotated in the range of 0 ° to 360 °, the measuring antenna is set to horizontal and vertical polarization and raised and lowered in the range from 1 m to 4 m to find the maximum level of emissions.

The resolution bandwidth of the EMI Receiver is set to the following values:

Test	Frequency range	Step-size	Resolution bandwidth	Detector
Preliminary measurement	30 MHz to 1 GHz	30 kHz	120 kHz	Peak Average
Frequency peak search	± 120 kHz	10 kHz	120 kHz	Peak
Final measurement	30 MHz to 1 GHz	-	120 kHz	QuasiPeak



Procedure preliminary measurement:

The following procedure is used:

- 1) Set the measuring antenna to 1 m height.
- 2) Monitor the frequency range at horizontal polarization of the measuring antenna and an EUT / turntable azimuth of 0 °.
- 3) Rotate the EUT by 360° to maximize the detected signals.
- 4) Repeat steps 2 to 3 with the vertical polarization of the measuring antenna.
- 5) Increase the height of the measuring antenna for 0.5 m and repeat steps 2 to 4 until the final height of 4 m is reached.
- 6) The highest values for each frequency are saved by the software, including the measuring antenna height and polarization and the turntable azimuth for that value.

Procedure final measurement:

The following procedure is used:

- 1) Select the highest frequency peaks (lowest margin to the limit) for the final measurement.
- 2) The software determines the exact peak frequencies by doing a partial scan with reduced step size of the pre-scan of the selected peaks.
- 3) If the EUT is portable or ceiling mounted, find the worst-case EUT orientation (x,y,z) for the final test.
- 4) The worst-case measuring antenna height is found via varying the height by +/- 0.5 m from the value obtained in the preliminary measurement while monitoring the emission level.
- 5) The worst-case turntable position is found via varying the turntable azimuth by +/- 30° from the value obtained in the preliminary measurement while monitoring the emission level.
- 6) The final measurement is performed at the worst-case measuring antenna height and the worst-case turntable azimuth.
- 7) Steps 2 to 6 are repeated for each frequency peak selected in step 1.

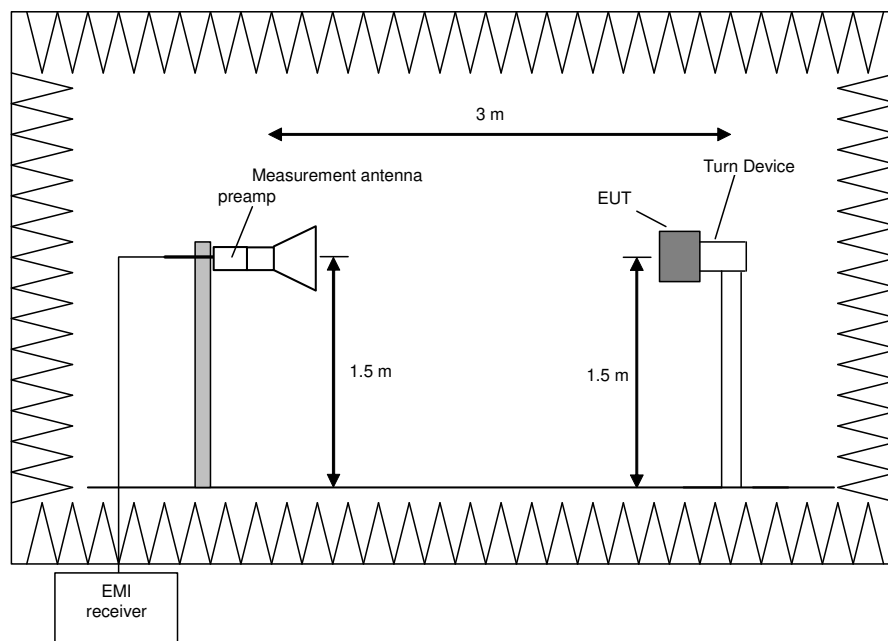
5.3.1.4 Preliminary and final measurement > 1 GHz

The preliminary and final measurements are performed in a fully anechoic chamber. Table-top devices are set up on a non-conducting turn device at the height of 1.5 m. The setup of the equipment under test is in accordance to [1].

The frequency range is divided into different sub-ranges depending on the frequency range of the used horn antenna. The frequency range 30 MHz to 1 GHz is monitored with an EMI receiver which is set to MAX hold mode. The EUT is rotated in the range of 0 ° to 360 ° and the measuring antenna is set to horizontal and vertical polarisation to find the maximum levels of emissions. After these steps, the measurement is repeated after reorientating the EUT in 30 ° steps according to [1].

The resolution bandwidth of the EMI receiver is set to the following values:

Frequency range	Resolution bandwidth
1 GHz to 4 GHz	1 MHz
4 GHz to 12 GHz	1 MHz
12 GHz to 18 GHz	1 MHz
18 GHz to 26.5 GHz	1 MHz
26.5 GHz to 40 GHz	1 MHz
40 GHz to 60 GHz	1 MHz
50 GHz to 75 GHz	1 MHz
75 GHz to 110 GHz	1 MHz



Procedure preliminary measurement:

Pre-scans are performed in the frequency range 1 to 110 GHz.

The following procedure is used:

- 1) Monitor the frequency range at horizontal polarisation of the measuring antenna and an EUT / turntable azimuth of 0 °.
- 2) Rotate the EUT by 360° to maximize the detected signals.
- 3) Repeat steps 1 to 2 with the vertical polarisation of the measuring antenna.
- 4) Repeat steps 1 to 3 with the EUT reorientated by an angle of 30° (60°, 90°, 120° and 150°), according to 6.6.5.4 in [1].
- 5) Measure the frequencies of the detected emissions with a lower span and resolution bandwidth to increase the accuracy and note the resulting frequencies.
- 6) The highest emissions (smallest margin to the limit) will be used for the final measurement.

Procedure of measurement:

The following procedure is used:

- 1) Set the turntable and the turn device to the position which leads to the highest emission for the first frequency identified in the preliminary measurements.
- 2) Set the measurement antenna to the polarisation which leads to the highest emission for the first frequency identified in the preliminary measurements.
- 3) Set the spectrum analyser to EMI mode with Peak and Average detector activated.
- 4) Rotate the turntable from 0° to 360° to find the EUT angle that results in the highest emission level.
- 5) Note the highest displayed peak and average values.
- 6) Repeat steps 1 to 5 for each frequency detected during the preliminary measurements.

5.3.2 Test results (radiated emissions)

5.3.2.1 Preliminary radiated emission measurement (9 kHz to 10 GHz)

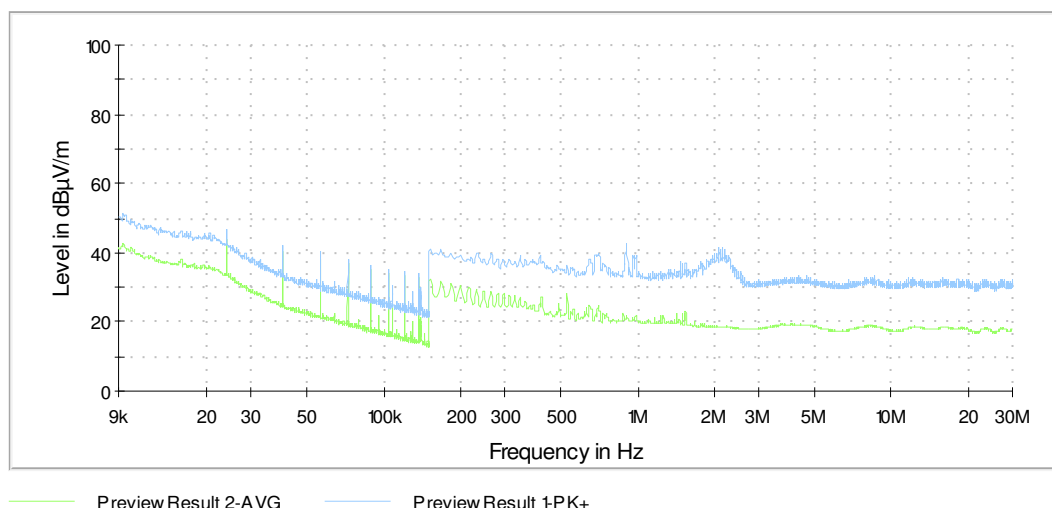
Ambient temperature:	22 °C
Relative humidity:	58 %

Date:	18.08.2021
Tested by:	Thomas KÜHN

Position of EUT:	The EUT was set-up on a non-conducting table of a height of 0.8 m for measurements below 1 GHz and on a turn device of a height of 1.5 m for measurements above 1 GHz and. The distance between EUT and antenna was 3 m (9 kHz to 1 GHz and 3.1 GHz to 10.6 GHz) and 1 m (all other frequency ranges).
Cable guide:	For detail information of test set-up refer to the pictures in annex A of this test report.
Test record:	All results are shown in the following.
Supply voltage:	During all measurements the EUT was supplied by a fully charged battery.
Frequency range:	The preliminary measurement was carried out in the frequency range 9 kHz to 40 GHz according to [2].
Remark:	As preliminary measurements has shown, the results below 1 GHz are not depending on the transmitter operation mode. Therefore, they were documented as transmitter independent emissions below.

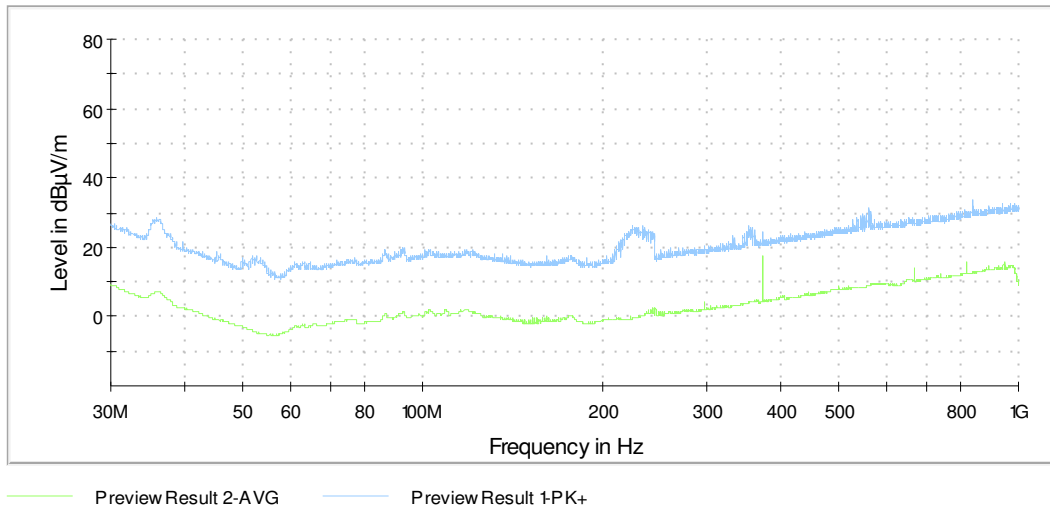
Transmitter independent emissions below 1 GHz:

210861 9k 30M: Spurious emissions from 9 kHz to 30 MHz (operation mode 3):



All emissions were below -52.0 dBμV/m (measured with peak detector at 3 m distance). The peaks found were caused by the turntable and camera of the test site, not by the EUT. So, no final measurement was carried out on the outdoor test site.

210861 30M 1G: Spurious emissions from 30 MHz to 1 GHz (operation mode 3):



The following frequencies were found in the frequency range 30 MHz to 960 MHz:

- 35.790 MHz, 233.220 MHz, 352.690 MHz, 371.260 MHz, 560.410 MHz and 837.430 MHz.

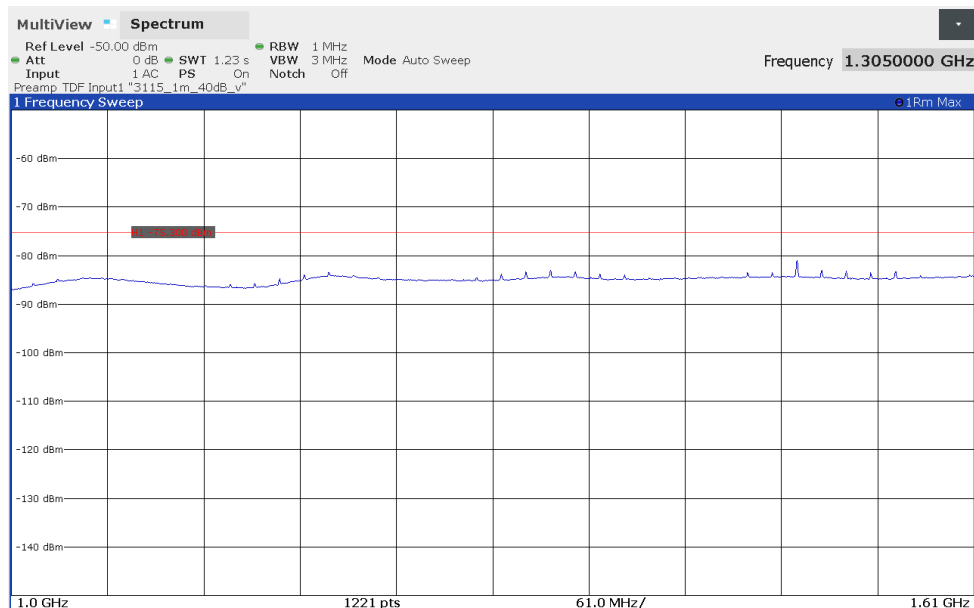
The following frequency was found in the frequency range 960 MHz to 1 GHz:

- 971.950 MHz (highest peak, noise floor of the measuring system).

On these frequencies a final measurement has to be carried out. The result is presented in the following.

Transmitter operates on channel 1 (operation mode 1):

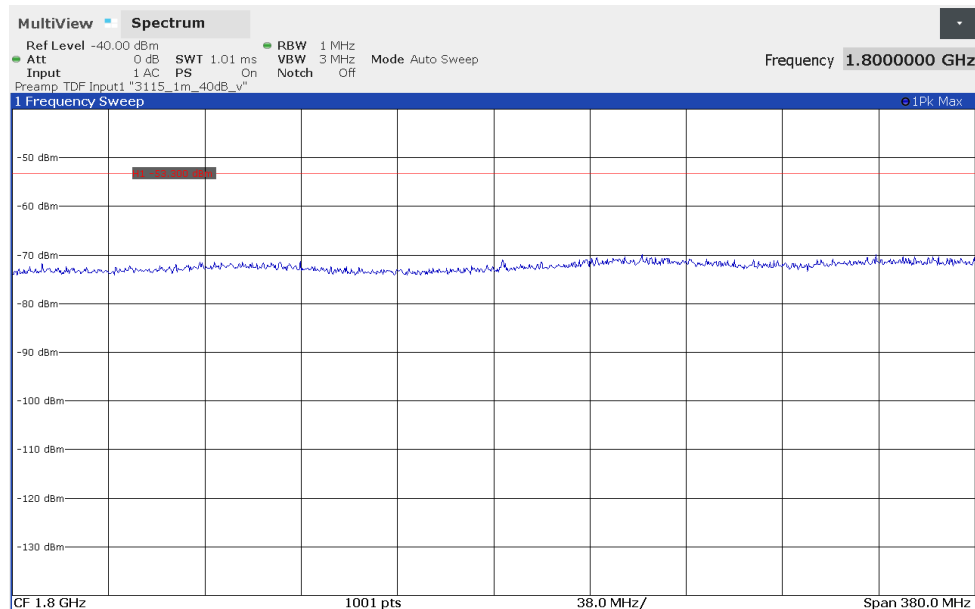
210861 10.png: Transmitter spurious emissions from 1 GHz to 1.61 GHz (operation mode 1):



The following frequency was found: 1497.840 MHz.

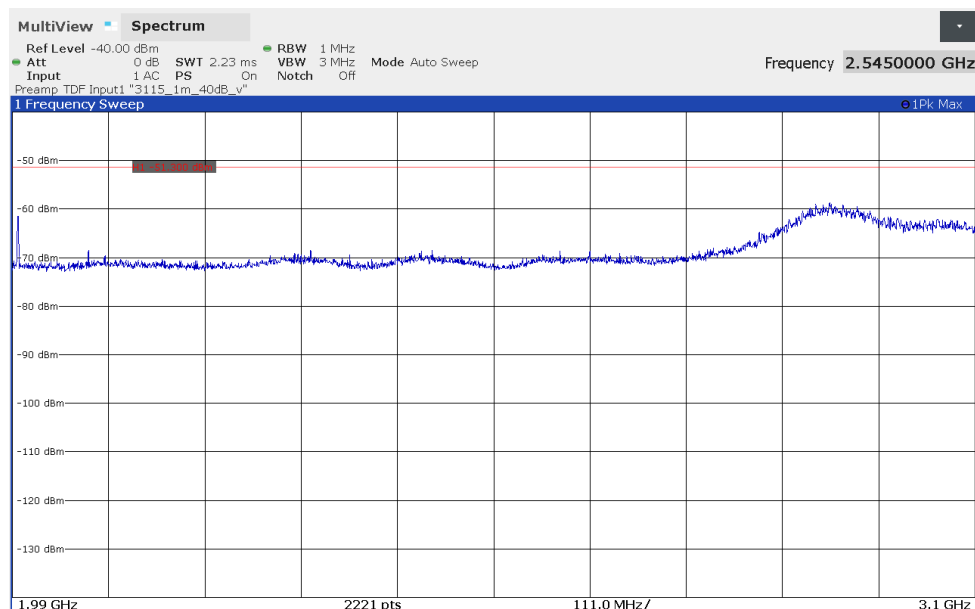
On this frequency a final measurement has to be carried out. The result is presented in the following. All other emissions were below -83.1 dBm. This value is already below the rms AV-limit of -75.3 dBm.

210861_11.png: Transmitter spurious emissions from 1.61 GHz to 1.99 GHz (operation mode 1):



All emissions were below -69.8 dBm (measured with peak detector). This peak value is already below the rms AV-limit of -53.3 dBm. Therefore, no final measurement was carried out in this frequency range.

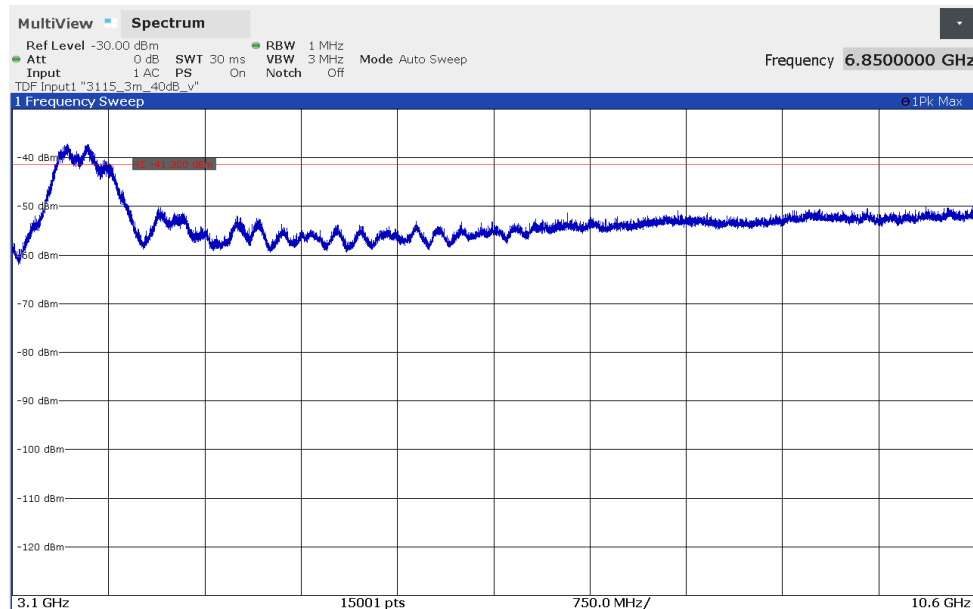
210861_12.png: Transmitter spurious emissions from 1.99 GHz to 3.1 GHz (operation mode 1):



The following frequencies were found: 1996.700 MHz and 2938.820 MHz.

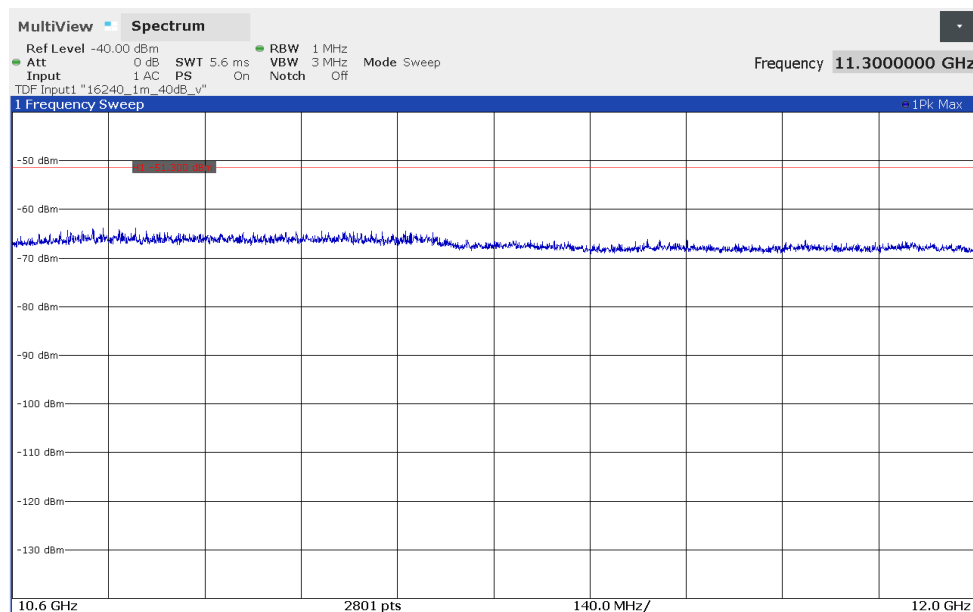
On these frequencies a final measurement has to be carried out. The result is presented in the following. All other emissions were below -63.3 dBm (measured with peak detector). This peak value is already below the rms AV-limit of -51.3 dBm.

210861_9.png: Transmitter spurious emissions from 3.1 GHz to 10.6 GHz (operation mode 1):



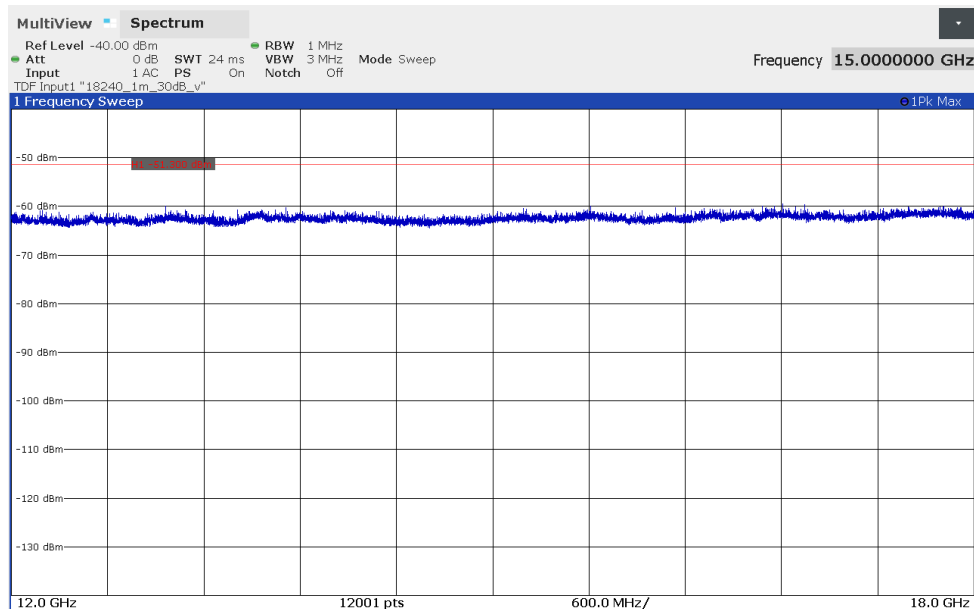
The following frequencies were found: 3485.101 MHz (wanted signal) and 4258.870 MHz. On these frequencies a final measurement has to be carried out. The result is presented in the following. All other emissions were below -49.9 dBm (measured with peak detector). This peak value is already below the rms AV-limit of -41.3 dBm.

210861_27.png: Transmitter spurious emissions from 10.6 GHz to 12 GHz (operation mode 1):



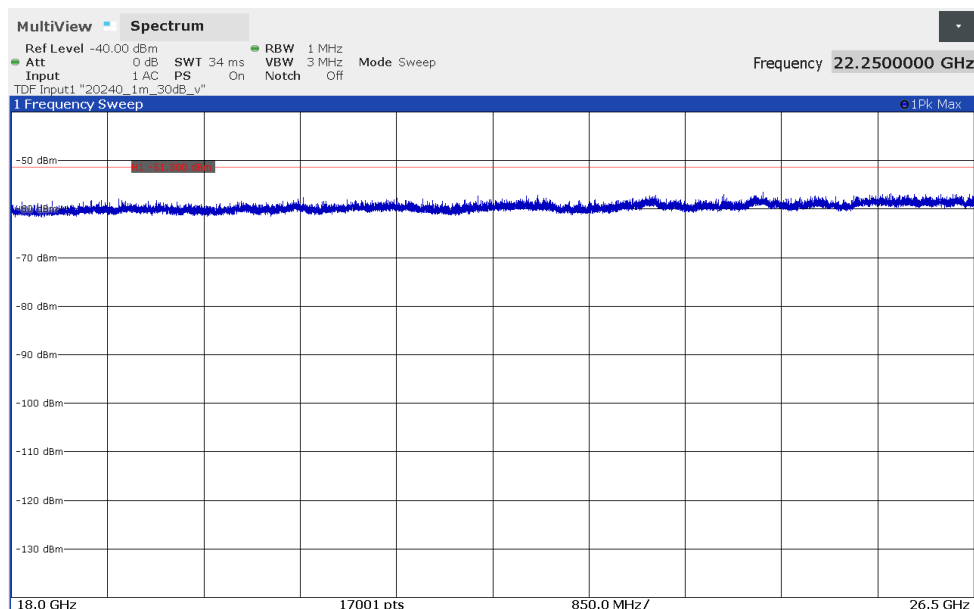
All emissions were below -63.8 dBm (measured with peak detector). This peak value is already below the rms AV-limit of -51.3 dBm. Therefore, no final measurement was carried out in this frequency range.

210861_28.png: Transmitter spurious emissions from 12 GHz to 18 GHz (operation mode 1):



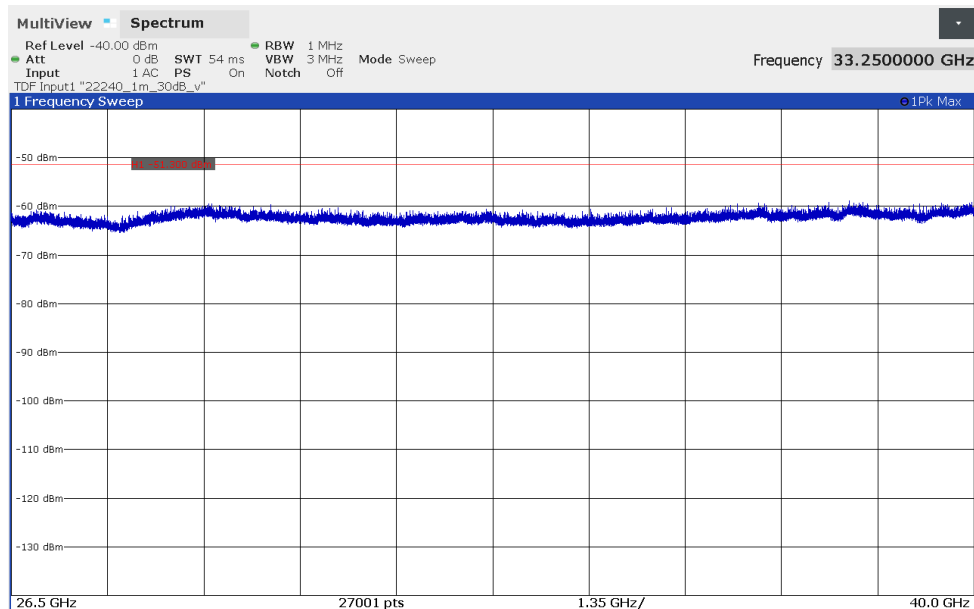
All emissions were below -59.5 dBm (measured with peak detector). This peak value is already below the rms AV-limit of -51.3 dBm. Therefore, no final measurement was carried out in this frequency range.

210861_29.png: Transmitter spurious emissions from 18 GHz to 26.5 GHz (operation mode 1):



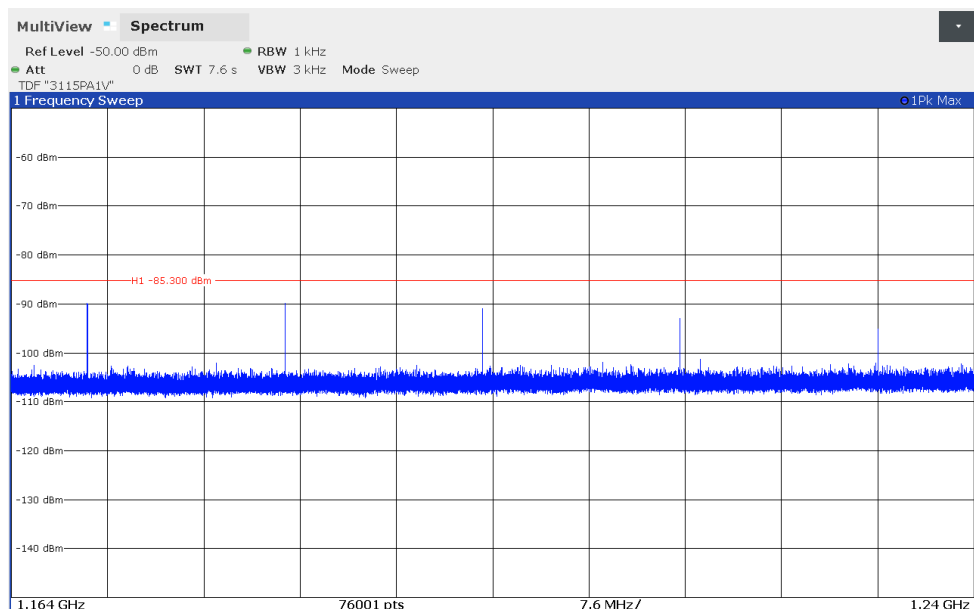
All emissions were below -56.5 dBm (measured with peak detector). This peak value is already below the rms AV-limit of -51.3 dBm. Therefore, no final measurement was carried out in this frequency range.

210861_30.png: Transmitter spurious emissions from 26.5 GHz to 40 GHz (operation mode 1):



All emissions were below -59.0 dBm (measured with peak detector). This peak value is already below the rms AV-limit of -51.3 dBm. Therefore, no final measurement was carried out in this frequency range.

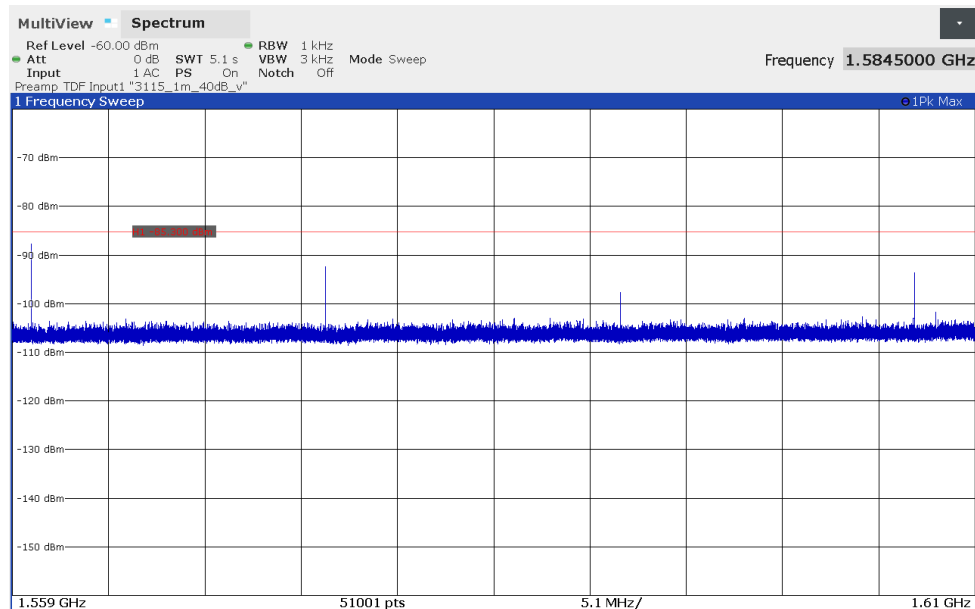
210861_13.png: Transmitter spurious emissions from 1.164 GHz to 1.240 GHz (operation mode 1):



The following frequency was found: 1185.600 MHz.

On this frequency a final measurement has to be carried out. The result is presented in the following. All other emissions were below -91.7 dBm (measured with peak detector). This peak value is already below the rms AV-limit of -85.3 dBm.

210861_14.png: Transmitter spurious emissions from 1.559 GHz to 1.610 GHz (operation mode 1):

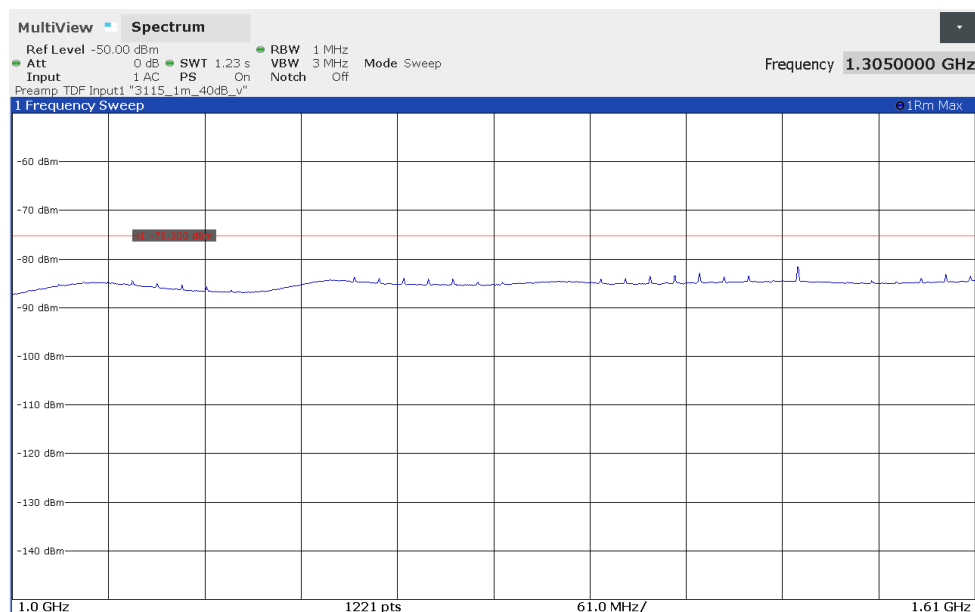


The following frequency was found: 1560.000 MHz.

On this frequency a final measurement has to be carried out. The result is presented in the following. All other emissions were below -92.4 dBm (measured with peak detector). This peak value is already below the rms AV-limit of -85.3 dBm.

Transmitter operates on channel 2 (operation mode 2):

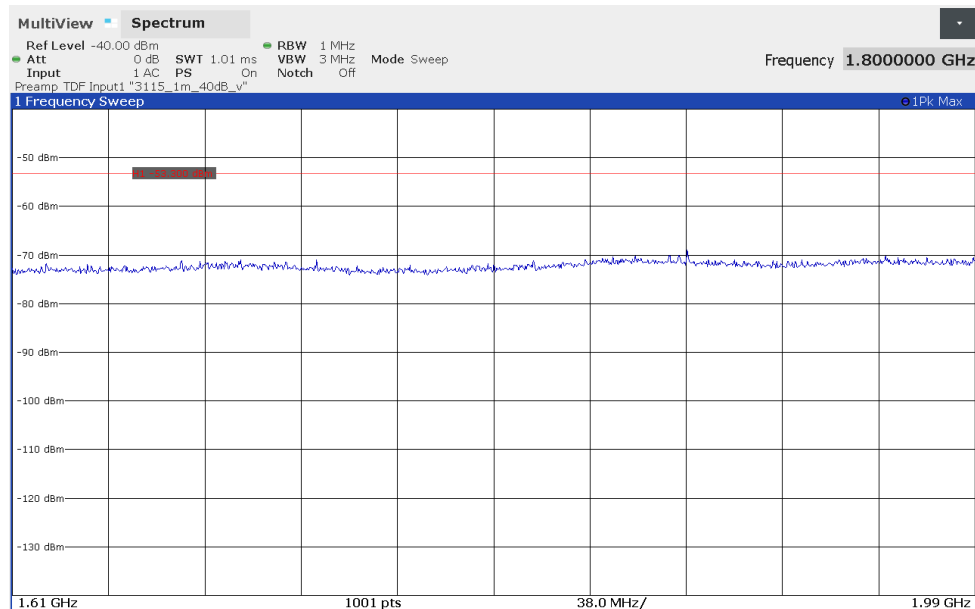
210861_15.png: Transmitter spurious emissions from 1 GHz to 1.61 GHz (operation mode 2):



The following frequency was found: 1497.840 MHz.

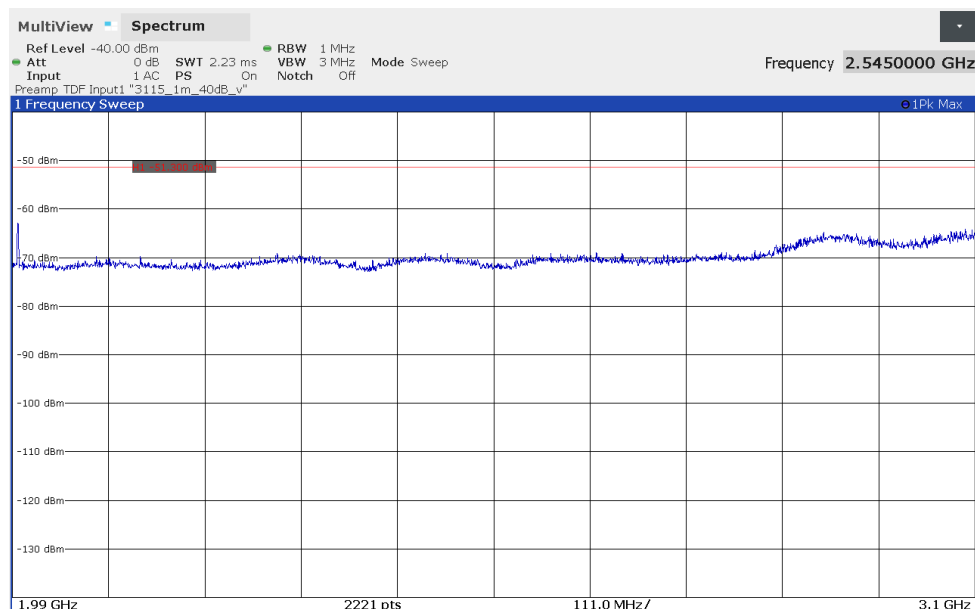
On this frequency a final measurement has to be carried out. The result is presented in the following. All other emissions were below -82.2 dBm. This value is already below the rms AV-limit of -75.3 dBm.

210861_16.png: Transmitter spurious emissions from 1.61 GHz to 1.99 GHz (operation mode 2):



All emissions were below -69.0 dBm (measured with peak detector). This peak value is already below the rms AV-limit of -53.3 dBm. Therefore, no final measurement was carried out in this frequency range.

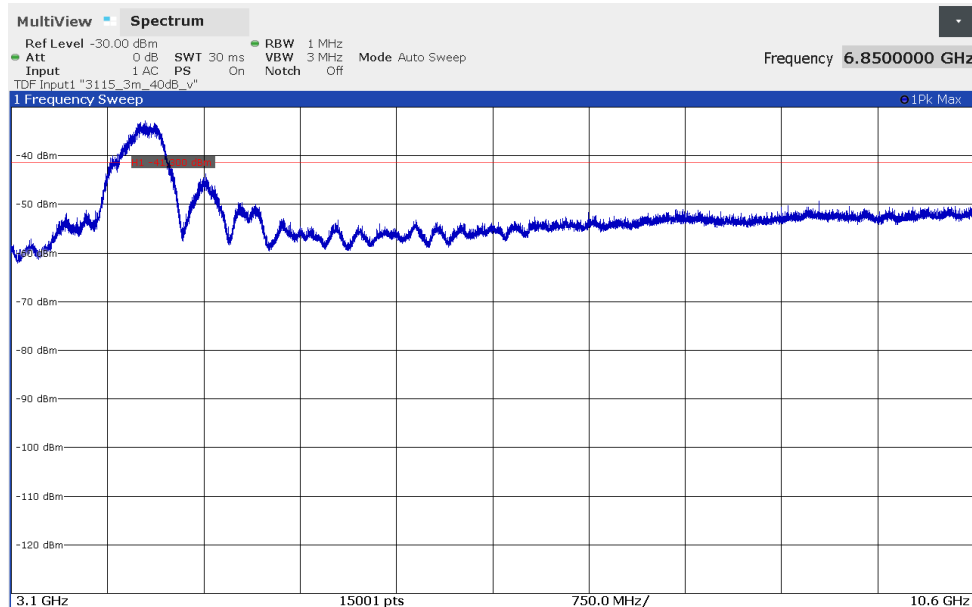
210861_17.png: Transmitter spurious emissions from 1.99 GHz to 3.1 GHz (operation mode 2):



The following frequency was found: 1996.760 MHz.

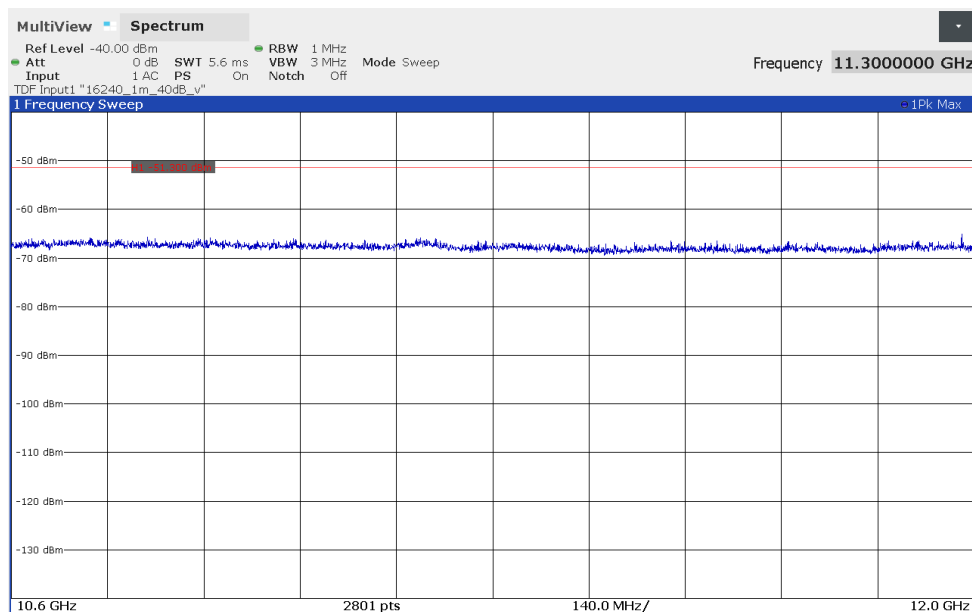
On this frequency a final measurement has to be carried out. The result is presented in the following. All other emissions were below -64.1 dBm (measured with peak detector). This peak value is already below the rms AV-limit of -51.3 dBm.

210861_8.png: Transmitter spurious emissions from 3.1 GHz to 10.6 GHz (operation mode 2):



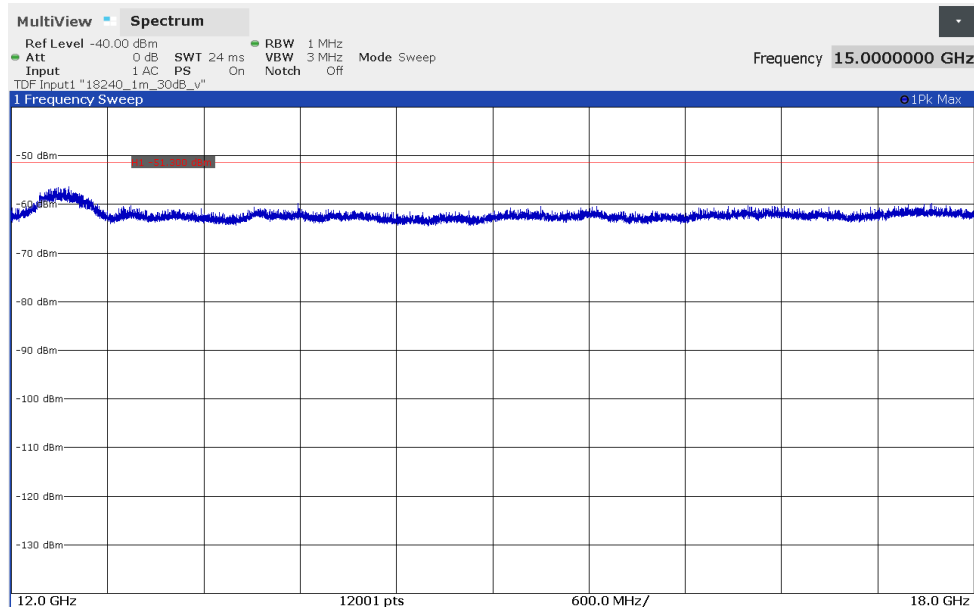
The following frequencies were found: 4093.970 MHz (wanted signal) and 4597.870 MHz. On these frequencies a final measurement has to be carried out. The result is presented in the following. All other emissions were below -49.1 dBm (measured with peak detector). This peak value is already below the rms AV-limit of -41.3 dBm.

210861_26.png: Transmitter spurious emissions from 10.6 GHz to 12 GHz (operation mode 2):



All emissions were below -65.0 dBm (measured with peak detector). This peak value is already below the rms AV-limit of -51.3 dBm. Therefore, no final measurement was carried out in this frequency range.

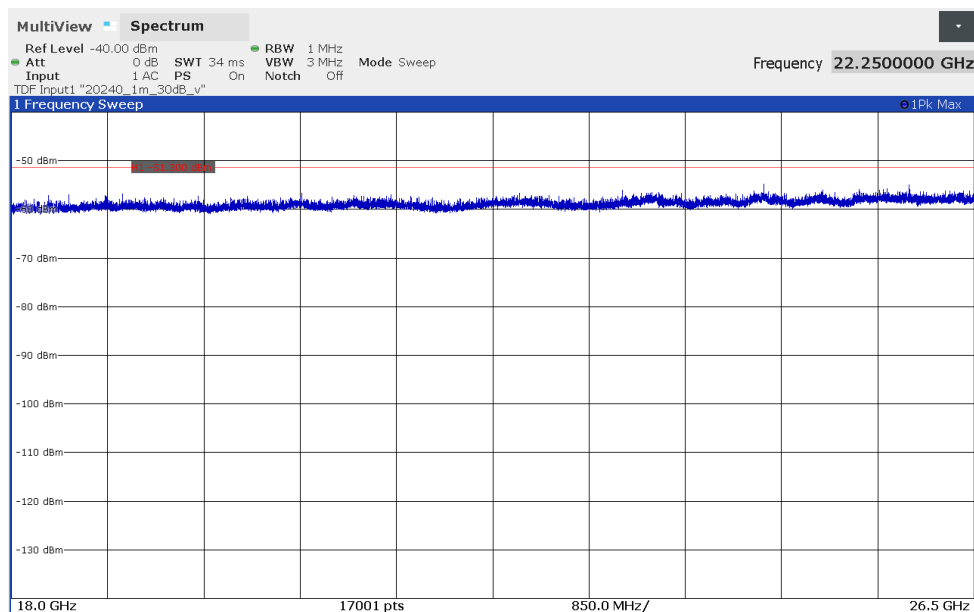
210861_33.png: Transmitter spurious emissions from 12 GHz to 18 GHz (operation mode 2):



The following frequencies were found: 12287.790 MHz.

On these frequencies a final measurement has to be carried out. The result is presented in the following. All other emissions were below -59.9 dBm (measured with peak detector). This peak value is already below the rms AV-limit of -51.3 dBm.

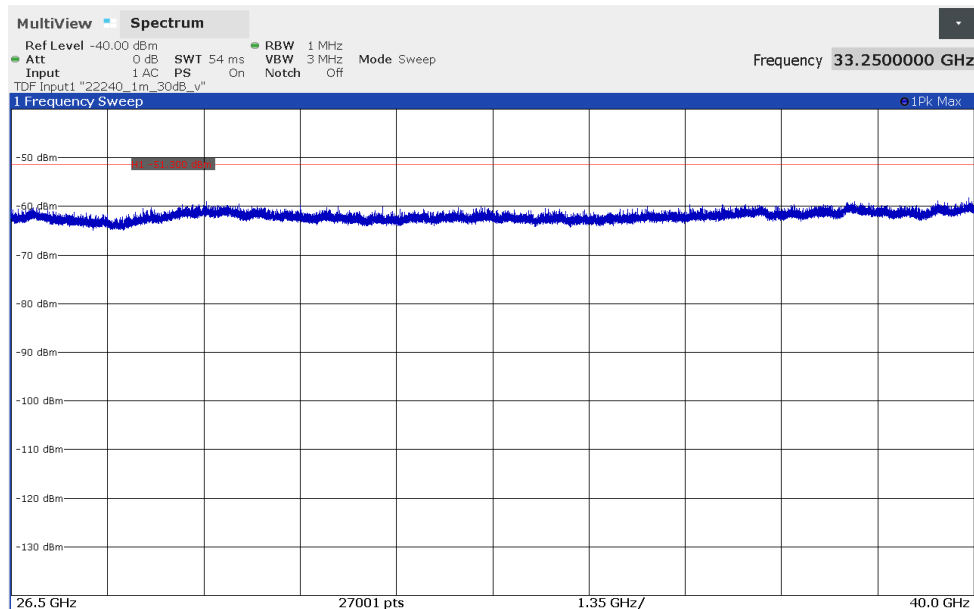
210861_32.png: Transmitter spurious emissions from 18 GHz to 26.5 GHz (operation mode 2):



The following frequency was found: 24652.840 MHz.

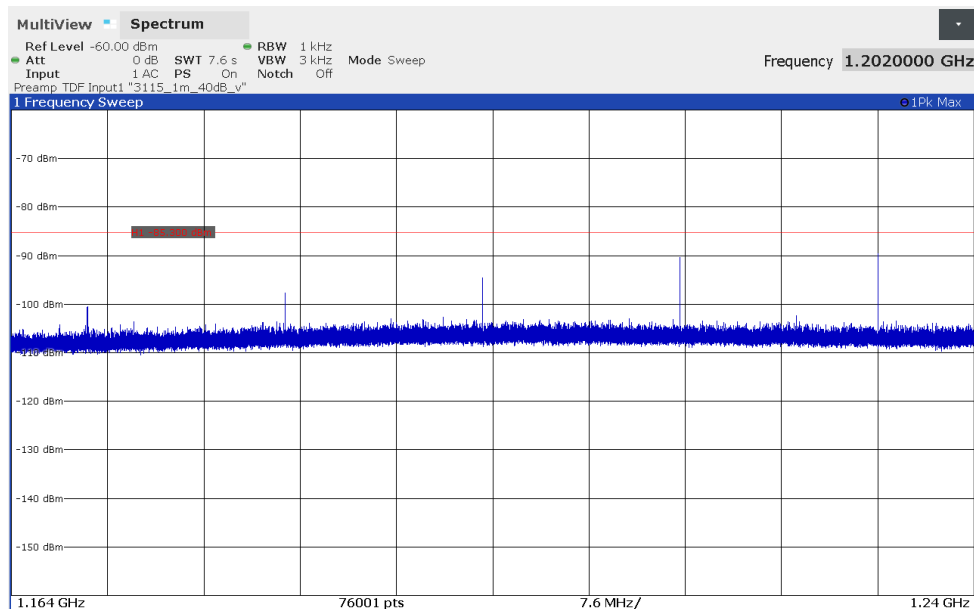
On this frequency a final measurement has to be carried out. The result is presented in the following. All other emissions were below -55.5 dBm (measured with peak detector). This peak value is already below the rms AV-limit of -51.3 dBm.

210861_31.png: Transmitter spurious emissions from 26.5 GHz to 40 GHz (operation mode 2):



All emissions were below -58.2 dBm (measured with peak detector). This peak value is already below the rms AV-limit of -51.3 dBm. Therefore, no final measurement was carried out in this frequency range.

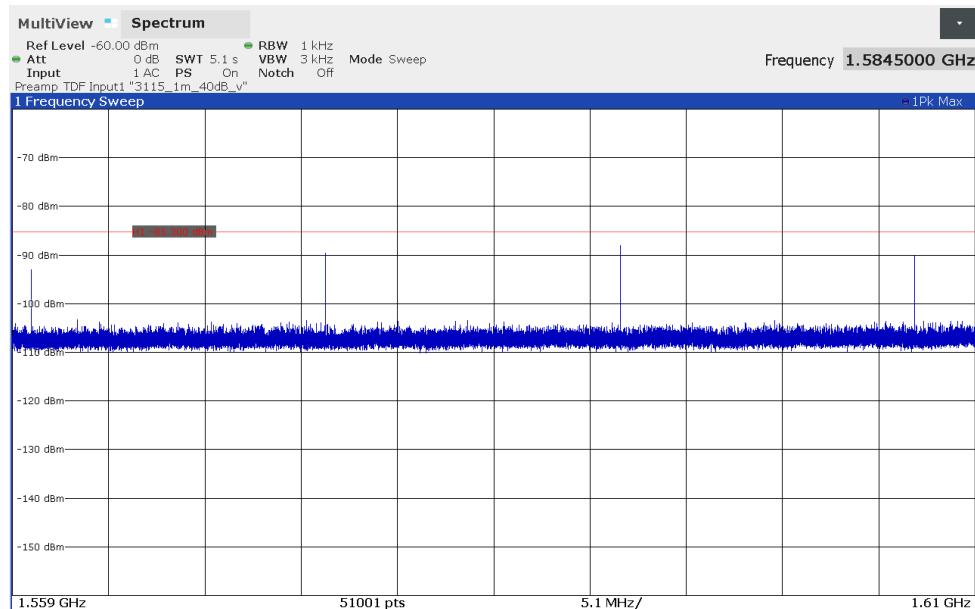
210861_18.png: Transmitter spurious emissions from 1.164 GHz to 1.240 GHz (operation mode 2):



The following frequency was found: 1232.400 MHz.

On this frequency a final measurement has to be carried out. The result is presented in the following. All other emissions were below -90.4 dBm (measured with peak detector). This peak value is already below the rms AV-limit of -85.3 dBm.

210861_19.png: Transmitter spurious emissions from 1.559 GHz to 1.610 GHz (operation mode 2):

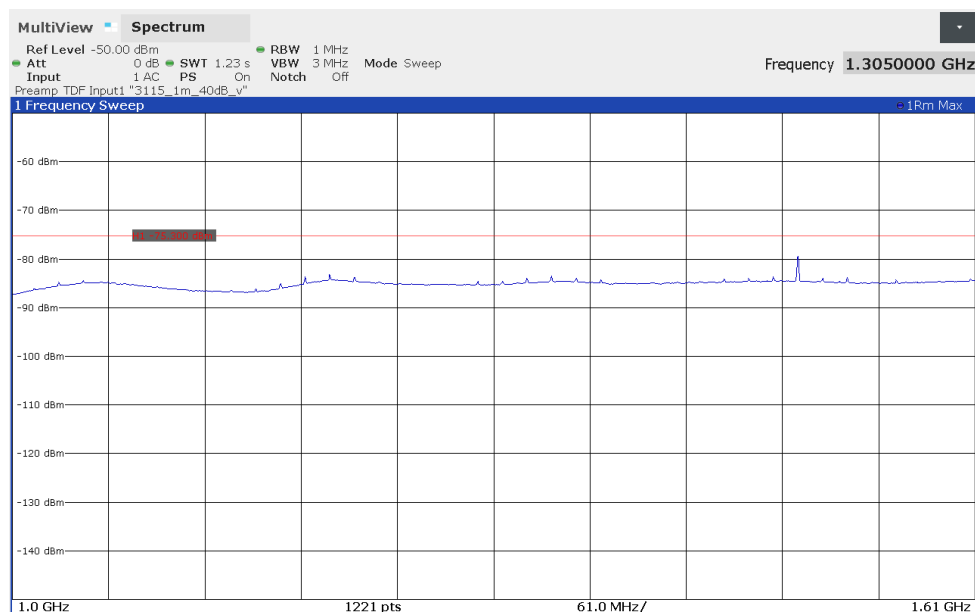


The following frequency was found: 1591.120 MHz.

On this frequency a final measurement has to be carried out. The result is presented in the following. All other emissions were below -89.6 dBm (measured with peak detector). This peak value is already below the rms AV-limit of -85.3 dBm.

Transmitter operates on channel 3 (operation mode 3):

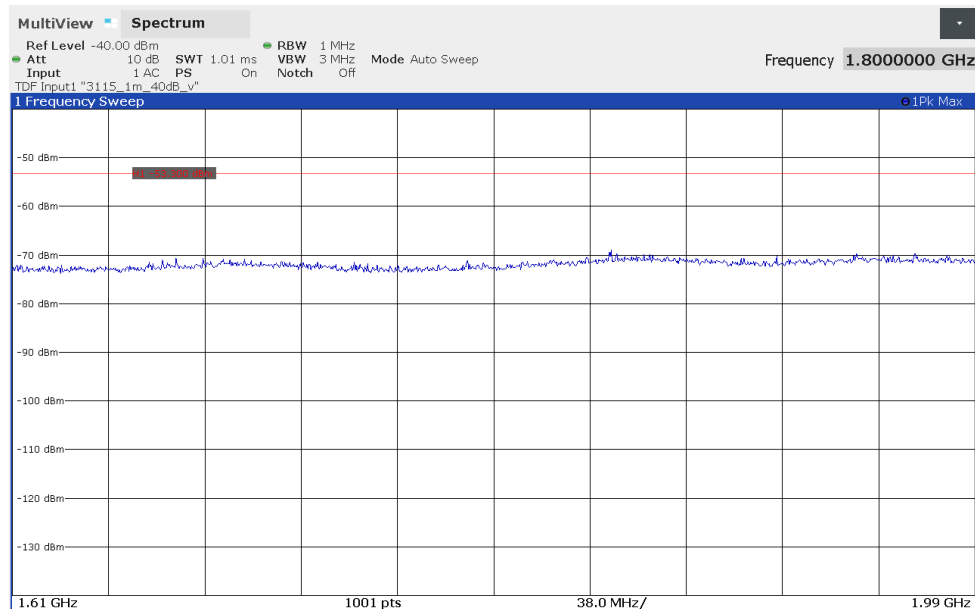
210861_20.png: Transmitter spurious emissions from 1 GHz to 1.61 GHz (operation mode 3):



The following frequency was found: 1497.840 MHz.

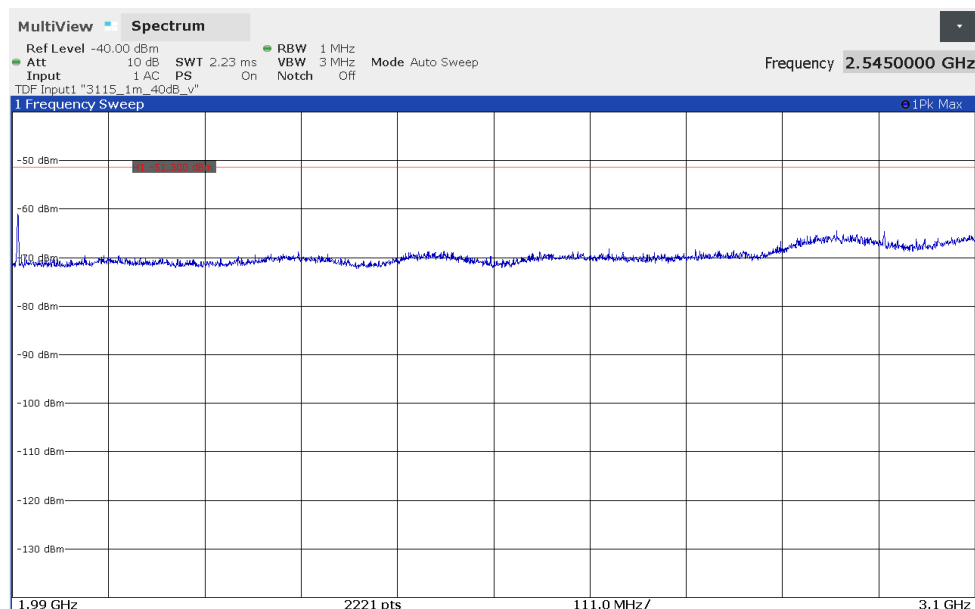
On this frequency a final measurement has to be carried out. The result is presented in the following. All other emissions were below -83.5 dBm. This value is already below the rms AV-limit of -75.3 dBm.

210861_21.png: Transmitter spurious emissions from 1.61 GHz to 1.99 GHz (operation mode 3):



All emissions were below -69.0 dBm (measured with peak detector). This peak value is already below the rms AV-limit of -53.3 dBm. Therefore, no final measurement was carried out in this frequency range.

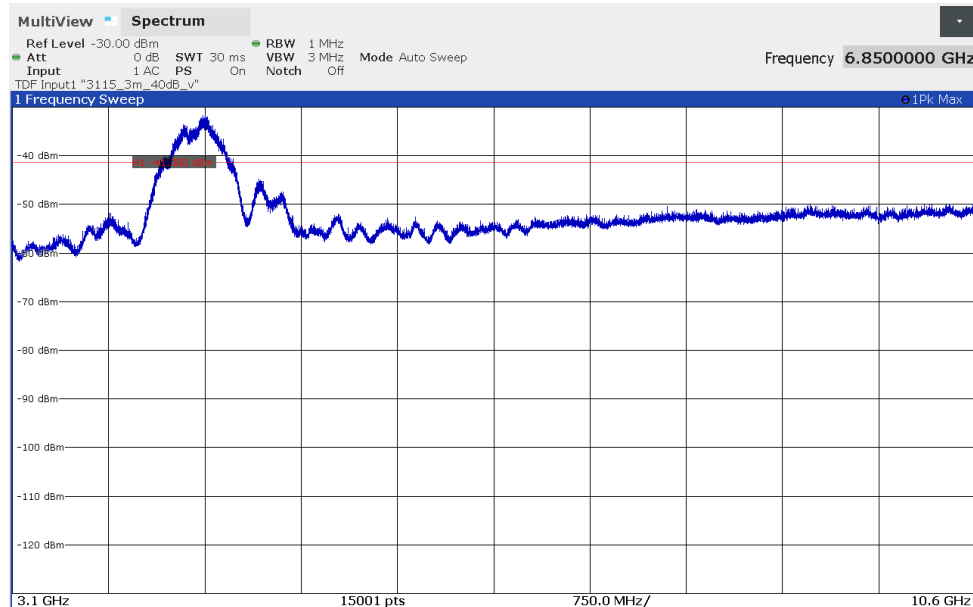
210861_22.png: Transmitter spurious emissions from 1.99 GHz to 3.1 GHz (operation mode 3):



The following frequency was found: 1996.800 MHz.

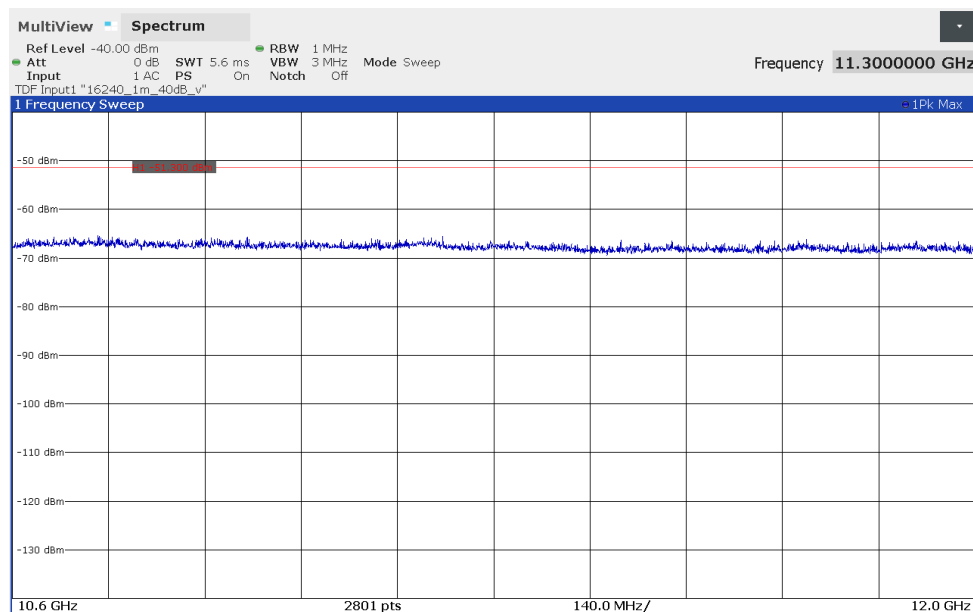
On this frequency a final measurement has to be carried out. The result is presented in the following. All other emissions were below -64.5 dBm (measured with peak detector). This peak value is already below the rms AV-limit of -51.3 dBm.

210861_7.png: Transmitter spurious emissions from 3.1 GHz to 10.6 GHz (operation mode 3):



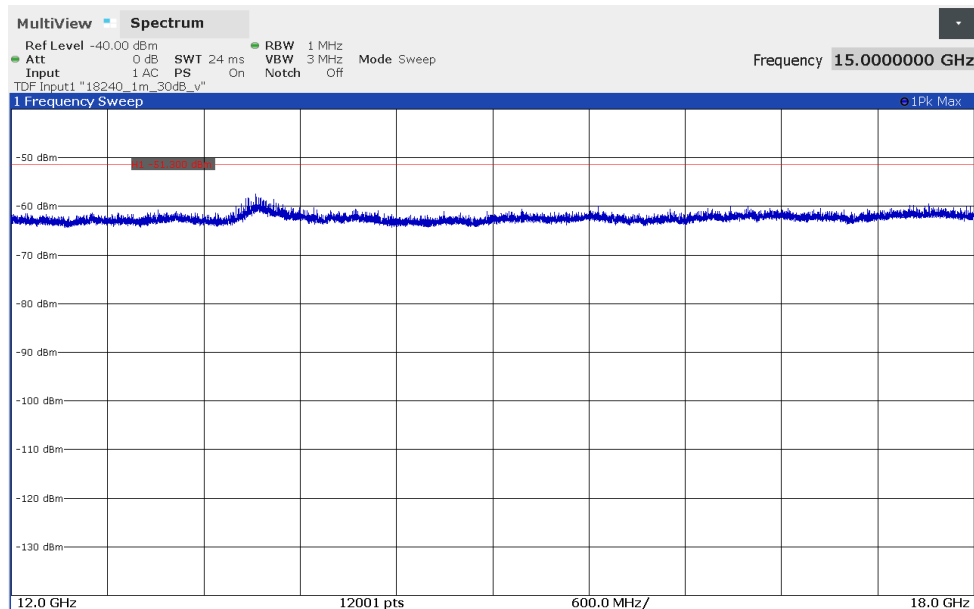
The following frequencies were found: 4586.470 MHz (wanted signal) and 5023.320 MHz. On these frequencies a final measurement has to be carried out. The results are presented in the following. All other emissions were below -49.9 dBm (measured with peak detector). This peak value is already below the rms AV-limit of -41.3 dBm.

210861_25.png: Transmitter spurious emissions from 10.6 GHz to 12 GHz (operation mode 3):



All emissions were below -65.3 dBm (measured with peak detector). This peak value is already below the rms AV-limit of -51.3 dBm. Therefore, no final measurement was carried out in this frequency range.

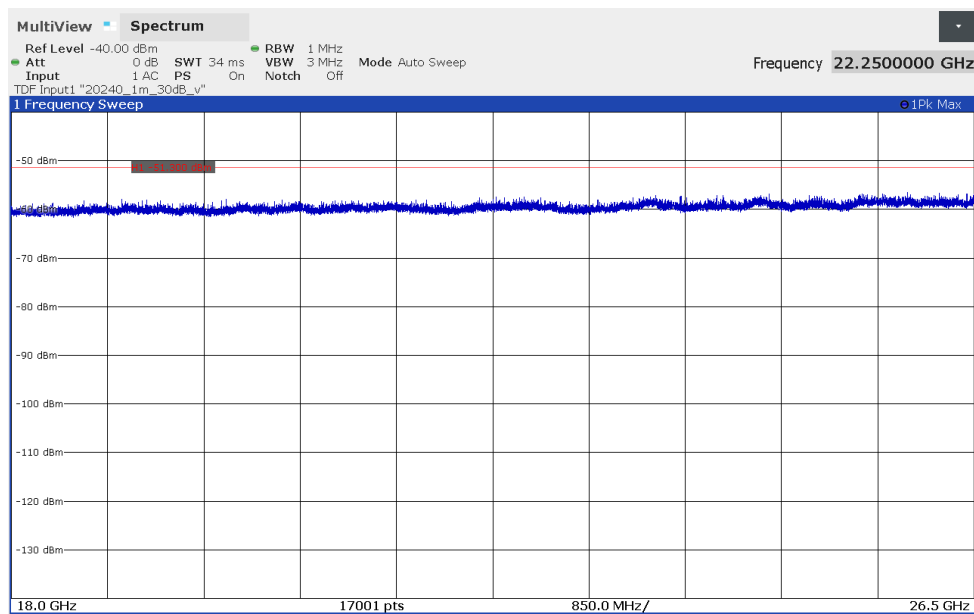
210861_34.png: Transmitter spurious emissions from 12 GHz to 18 GHz (operation mode 3):



The following frequency was found: 13509.630 MHz.

On this frequency a final measurement has to be carried out. The result is presented in the following. All other emissions were below -59.5 dBm (measured with peak detector). This peak value is already below the rms AV-limit of -51.3 dBm.

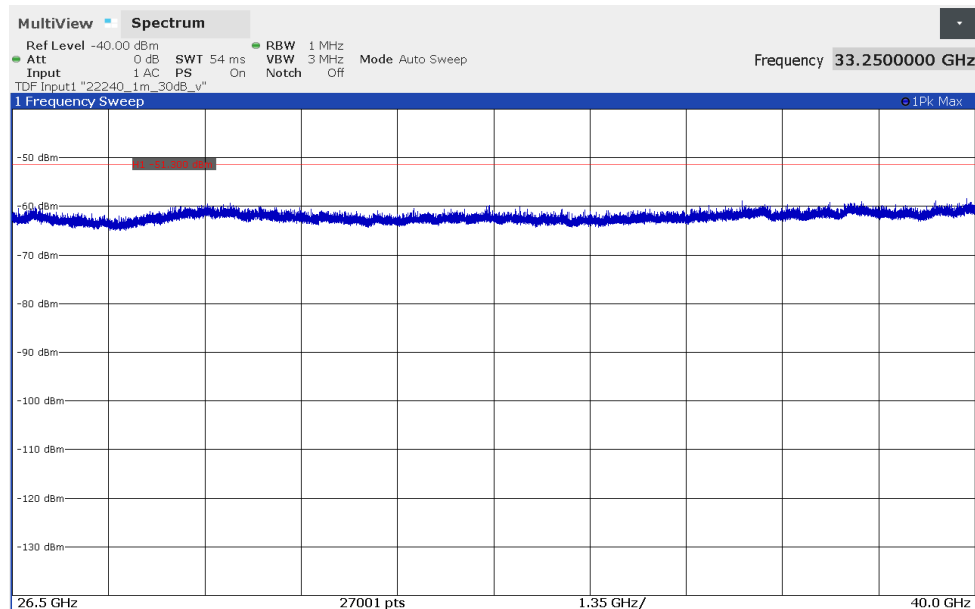
210861_35.png: Transmitter spurious emissions from 18 GHz to 26.5 GHz (operation mode 3):



The following frequency was found: 25913.770 MHz.

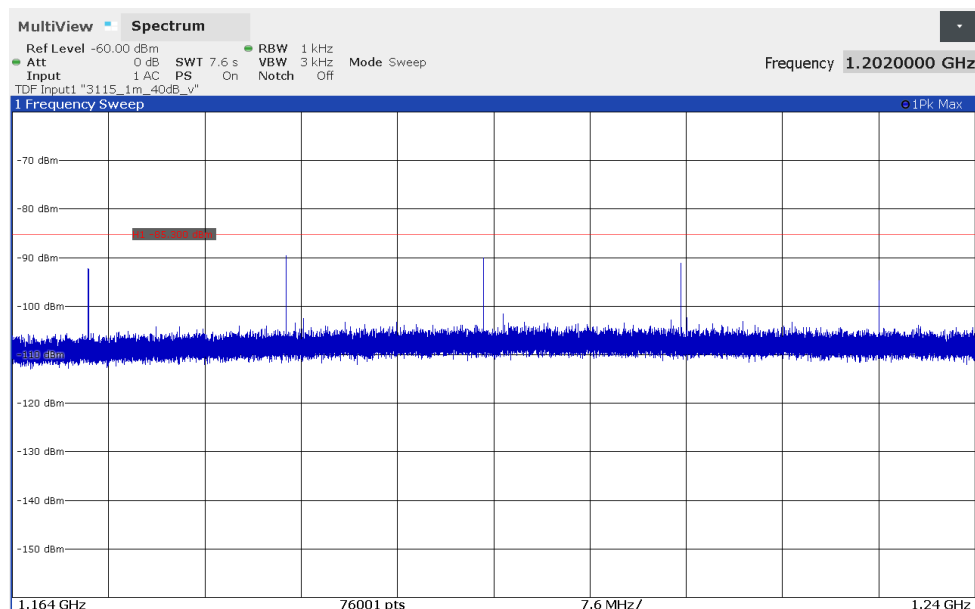
On this frequency a final measurement has to be carried out. The result is presented in the following. All other emissions were below -57.8 dBm (measured with peak detector). This peak value is already below the rms AV-limit of -51.3 dBm. Therefore, no final measurement was carried out in this frequency range.

210861_36.png: Transmitter spurious emissions from 26.5 GHz to 40 GHz (operation mode 3):



All emissions were below -58.4 dBm (measured with peak detector). This peak value is already below the rms AV-limit of -51.3 dBm. Therefore, no final measurement was carried out in this frequency range.

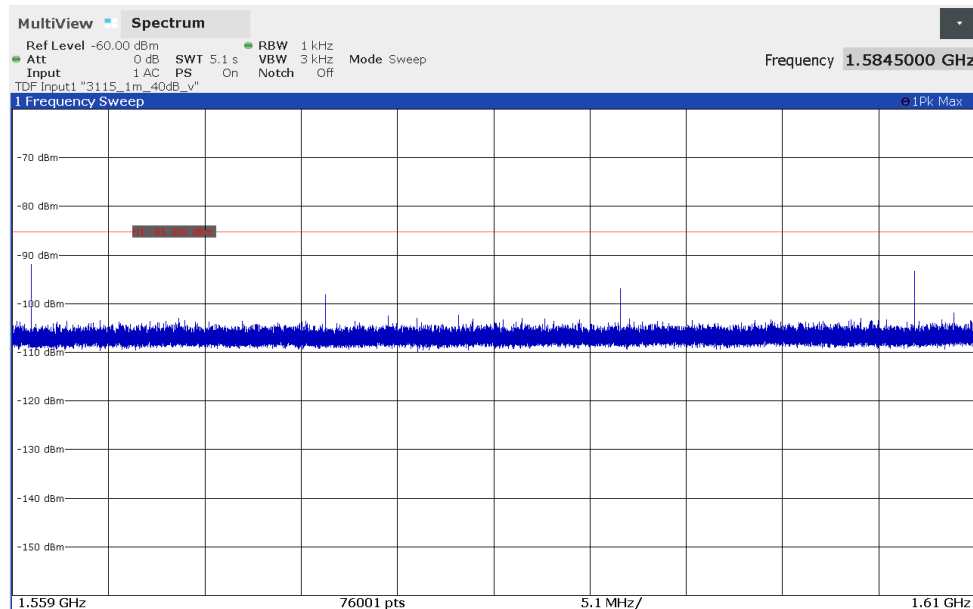
210861_23.png: Transmitter spurious emissions from 1.164 GHz to 1.240 GHz (operation mode 3):



The following frequency was found: 1185.600 MHz.

On this frequency a final measurement has to be carried out. The result is presented in the following. All other emissions were below -90.4 dBm (measured with peak detector). This peak value is already below the rms AV-limit of -85.3 dBm.

210861_24.png: Transmitter spurious emissions from 1.559 GHz to 1.610 GHz (operation mode 3):



The following frequency was found: 1560.000 MHz.

On this frequency a final measurement has to be carried out. The result is presented in the following. All other emissions were below -93.1 dBm (measured with peak detector). This peak value is already below the rms AV-limit of -85.3 dBm.

Test equipment (please refer to chapter 6 for details)

1 – 17, 19, 22, 23, 26 – 31, 33

5.3.2.2 Final radiated emission measurement (30 MHz to 1 GHz)

Ambient temperature:	21 °C
Relative humidity:	44 %

Date:	24.08.2021
Tested by:	Thomas KÜHN

Position of EUT: The EUT was set-up on a turn device of a height of 1.5 m. The distance between EUT and antenna was 3 m.

Cable guide: For detail information of test set-up refer to the pictures in annex A of this test report.

Test record: All results are shown in the following.

Supply voltage: During all measurements the EUT was supplied by a fully charged battery.

Test results: The test results above 30 MHz and below 960 MHz were calculated with the following formula:
 Result [dBμV/m] = reading [dBμV] + correction [dB] (cable loss, antenna factor and used attenuator)
 The test results above 960 MHz and below 1 GHz were calculated with the following formula:
 Result [dBμV/m] = reading [dBμV] + correction [dB] (cable loss, antenna factor and used attenuator) – 95.2 dB (according to 15.503 (k) [2])

The results of the standard subsequent measurement inside a semi anechoic chamber are indicated in the table below. The limits as well as the measured results (levels) refer to the above-mentioned standard while taking account of the specified requirements for a 3 m measuring distance.

Result measured with the Quasi-peak detector above 30 MHz and below 960 MHz:

Frequency [MHz]	Result [dBμV/m]	Limit [dBμV/m]	Margin [dB]	Meas. Time [ms]	Bandwidth [kHz]	Height [cm]	Pol.	Azimuth [deg]	Pos.	Corr. [dB]
35.790	21.5	40.0	18.5	1000	120	404	Vert.	267	1	22.6
233.220	7.0	46.0	39.0	1000	120	284	Hor.	188	1	16.9
352.690	10.9	46.0	35.1	1000	120	125	Vert.	-3	1	20.7
371.260	19.4	46.0	26.6	1000	120	342	Vert.	352	2	21.2
560.410	15.7	46.0	30.3	1000	120	143	Hor.	188	1	25.3
837.430	19.6	46.0	26.4	1000	120	383	Vert.	-21	1	29.4

Result measured with the RMS detector above 960 MHz and below 1 GHz:

Frequency [MHz]	Result [dBm]	Limit [dBm]	Margin [dB]	Correction [dB]	Conversion from dBμV/m to dBm	Meas. Time [ms]	Bandwidth [kHz]	Height [cm]	Azimuth [deg]	Pol.	Pos.
971.950*	-80.2	-75.3	4.9	30.7	95.2	1000	120	323	55	Hor.	2

*: Highest peak (noise floor of the measuring system) within the frequency range 960 MHz to 1 GHz.

Measurement uncertainty ±4.8 dB

Test: Passed

Test equipment (please refer to chapter 6 for details)
1 – 8, 10, 11

5.3.2.3 Final radiated emission measurement (1 GHz to 40 GHz)

Ambient temperature:	22 °C
Relative humidity:	65 %

Date:	19.08.2021
Tested by:	Thomas KÜHN

Position of EUT: The EUT was set-up on a turn device of a height of 1.5 m. The distance between EUT and antenna was 1 m, except the range 3.1 GHz to 10.6 GHz, where 3 m distance was used.

Cable guide: For detail information of test set-up refer to the pictures in annex A of this test report.

Test record: All results are shown in the following.

Supply voltage: During all measurements the EUT was supplied by a fully charged battery.

Transmit on channel 1								
Frequency [MHz]	RMS average [dBm]	Limit [dBm]	Margin [dB]	Bandwidth * [kHz]	Pol.	Azimuth [deg]	Elevation [deg]	Result
1185.600	-89.3	-85.3	4.0	1	Vert.	200	0	Passed
1497.840	-81.0	-75.3	5.7	1000	Vert.	265	120	Passed
1560.000	-87.8	-85.3	2.5	1	Vert.	200	0	Passed
1996.700	-64.5	-51.3	13.2	1000	Vert.	260	0	Passed
2938.820	-61.5	-51.3	10.2	1000	Vert.	185	30	Passed
3485.101	-47.3	-41.3	6.0	1000	Vert.	0	0	Passed
4258.870	-58.7	-41.3	17.4	1000	Vert.	45	0	Passed
Transmit on channel 2								
Frequency [MHz]	RMS average [dBm]	Limit [dBm]	Margin [dB]	Bandwidth * [kHz]	Pol.	Azimuth [deg]	Elevation [deg]	Result
1232.400	-91.0	-85.3	5.7	1	Vert.	10	120	Passed
1497.840	-81.0	-75.3	5.7	1000	Vert.	265	120	Passed
1591.120	-87.0	-85.3	1.7	1	Vert.	195	0	Passed
1996.760	-64.7	-51.3	13.2	1000	Vert.	260	0	Passed
4093.970	-41.8	-41.3	0.5	1000	Vert.	26	0	Passed
4597.870	-53.5	-41.3	12.2	1000	Hor.	270	90	Passed
12287.790	-65.0	-51.3	13.7	1000	Hor.	245	90	Passed
24652.840	-68.4	-51.3	17.1	1000	Vert.	70	0	Passed
Transmit on channel 3								
Frequency [MHz]	RMS average [dBm]	Limit [dBm]	Margin [dB]	Bandwidth * [kHz]	Pol.	Azimuth [deg]	Elevation [deg]	Result
1185.600	-89.3	-85.3	4.0	1	Vert.	200	0	Passed
1497.840	-81.0	-75.3	5.7	1000	Vert.	265	120	Passed
1560.000	-91.2	-85.3	5.9	1	Vert.	195	0	Passed
1996.800	-62.4	-51.3	11.1	1000	Hor.	270	60	Passed
4586.470	-41.4	-41.3	0.1	1000	Vert.	90	4	Passed
5023.320	-53.4	-41.3	12.1	1000	Hor.	310	120	Passed
13509.630	-63.4	-51.3	10.1	1000	Hor.	245	90	Passed
25913.770	-69.1	-51.3	17.8	1000	Hor.	55	120	Passed

Measurement uncertainty ± 4.1 dB

Test equipment (please refer to chapter 6 for details)
12 – 21, 23 – 33

5.3.2.4 Radiated emissions according to 15.209 [2]

According to 15.521 [2], the emissions of the digital circuit of the EUT have to comply with the limits according to 15.209 [2]. Refer clause 5.3.2.2 for the emission results below 960 MHz, which already comply with these limits.

Because it was not possible to differ between UWB emissions and emissions from the digital circuit of the EUT, the EIRP results from clause 5.3.2.3 of this test report were converted to field strength values with the following formula (according to [1]):

$$E = \text{EIRP} - 20\log(d_{\text{Meas}}) + 104.7$$

Transmit on channel 1									
Frequency [MHz]	RMS average *2 [dBm]	Measurement distance [m]	Calculated field strength [dBμV/m]	Limit acc. 15.209 [dBμV/m]	Margin [dB]	Pol.	Azimuth [deg]	Elevation [deg]	Result
971.95	-80.2	3	15.0	54.0	39.0	Hor.	55	-90	Passed
1497.840	-81.0	1	23.7	54.0	30.3	Vert.	265	120	Passed
1996.700	-64.5	1	40.2	54.0	13.8	Vert.	260	0	Passed
2938.820	-61.5	1	43.2	54.0	10.8	Vert.	185	30	Passed
3485.101 *2	-47.3	3	47.9	54.0	6.1	Vert.	0	0	Passed
4258.870	-58.7	3	36.5	54.0	17.5	Vert.	45	0	Passed
Transmit on channel 2									
Frequency [MHz]	RMS average *2 [dBm]	Measurement distance [m]	Calculated field strength [dBμV/m]	Limit acc. 15.209 [dBμV/m]	Margin [dB]	Pol.	Azimuth [deg]	Elevation [deg]	Result
971.95	-80.2	3	15.0	54.0	39.0	Hor.	55	-90	Passed
1497.840	-81.0	1	23.7	54.0	30.3	Vert.	265	120	Passed
1996.760	-64.7	1	40.0	54.0	14.0	Vert.	260	0	Passed
4093.970 *2	-41.8	3	53.4	54.0	0.6	Vert.	26	0	Passed
4597.870	-53.5	3	41.7	54.0	12.3	Hor.	270	90	Passed
12287.790	-65.0	1	39.7	54.0	14.3	Hor.	245	90	Passed
24652.840	-68.4	1	36.3	54.0	17.7	Vert.	70	0	Passed
Transmit on channel 3									
Frequency [MHz]	RMS average *2 [dBm]	Measurement distance [m]	Calculated field strength [dBμV/m]	Limit acc. 15.209 [dBμV/m]	Margin [dB]	Pol.	Azimuth [deg]	Elevation [deg]	Result
971.95	-80.2	3	15.0	54.0	39.0	Hor.	55	-90	Passed
1497.840	-81.0	1	23.7	54.0	30.3	Vert.	265	120	Passed
1996.800	-62.4	1	42.3	54.0	11.7	Hor.	270	60	Passed
4586.470 *1	-41.4	3	53.8	54.0	0.2	Vert.	90	4	Passed
5023.320	-53.4	3	41.8	54.0	12.2	Hor.	310	120	Passed
13509.630	-63.4	1	41.3	54.0	12.7	Hor.	245	90	Passed
25913.770	-69.1	1	35.6	54.0	18.4	Hor.	55	120	Passed

Measurement uncertainty ±4.1 dB

*1: Wanted signal of the UWB device, no spurious emission.

*2: Preliminary measurements shown that the peak emission levels comply with AV limits

Test equipment (please refer to chapter 6 for details)

12 – 21, 23 – 33

6 Test equipment and ancillaries used for tests

No.	Test equipment	Type	Manufacturer	Serial No.	PM. No.	Cal. Date	Cal. due
1	Semi anechoic chamber M276	SAC5-2	Albatross Projects	C62128-A540-A138-10-0006	483227	Calibration not necessary	
2	RF Switch Matrix	OSP220	Rohde & Schwarz		482976	Calibration not necessary	
3	Turntable	TT3.0-3t	Maturo	825/2612/.01	483224	Calibration not necessary	
4	Controller	NCD	Maturo	474/2612.01	483226	Calibration not necessary	
5	Antenna support	BAM 4.5-P-10kg	Maturo	222/2612.01	483225	Calibration not necessary	
6	System software EMC32 M276	EMC32	Rohde & Schwarz	100970	482972	Calibration not necessary	
7	Antenna (Bilog) with 6 dB attenuator	HL562E	Rohde & Schwarz	101079	482978	18.03.2021	03.2024
8		2	Weinschel	BG0931	483499		
9	Loop antenna	HFH2-Z2	Rohde & Schwarz	100417	481912	25.02.2021	02.2022
10	EMI Test receiver ESW	ESW44	Rohde & Schwarz	101828	482979	14.11.2019	11.2021
11	Cable C417	Sucoflex 118	Huber+Suhner	500654/118	-	Calibration not necessary	
12	Fully anechoic chamber M20	B83117-E2439-T232	Albatross Projects	103	480303	Calibration not necessary	
13	EMI Receiver / Spectrum Analyser	ESW44	Rohde & Schwarz	101635	482467	06.07.2021	07.2023
14	Turntable	DS420HE	Deisel	420/620/80	480315	Calibration not necessary	
15	Controller	MCU	Maturo	MCU/043/971107	480832	Calibration not necessary	
16	Positioner	TDF 1.5- 10Kg	Maturo	15920215	482034	Calibration not necessary	
17	Antenna (Horn)	3115	EMCO	9609-4918	480183	23.02.2021	02.2024
18	Antenna (Horn)	3115	EMCO	6761	480368	06.02.2020	02.2023
19	Antenna support	AS620P	Deisel	620/375	480325	Calibration not necessary	
20	CW signal generator	PSG E8257D	Keysight	MY60020218	483359	03.08.2020	08.2021
21	RF-cable No.38	Sucoflex 106B	Suhner	0563/6B	480670	Calibration not necessary	
22	RF-cable No.36	Sucoflex 106B	Suhner	0587/6B	480865	Calibration not necessary	
23	Standard gain horn antenna	18240-20	Flann	483	480294	Calibration not necessary	
24	Standard gain horn antenna	18240-20	Flann	482	480295	Calibration not necessary	
25	Standard gain horn antenna	20240-20	Flann	410	480296	Calibration not necessary	
26	Standard gain horn antenna	20240-20	Flann	411	480297	Calibration not necessary	
27	Standard gain horn antenna	22240-20	Flann	469	480299	Calibration not necessary	
28	Preamplifier 100 MHz – 16 GHz	AFS6-00101600-23-10P-6-R	MITEQ	2011215	482333	13.02.2020	02.2022
29	Preamplifier 12 GHz - 18 GHz	JS3-12001800-16-5A	MITEQ	571667	480343	13.02.2020	02.2022
30	Preamplifier 18 GHz - 26 GHz	JS4-18002600-20-5A	MITEQ	658697	480342	13.02.2020	02.2022

No.	Test equipment	Type	Manufacturer	Serial No.	PM. No.	Cal. Date	Cal. due
31	Preamplifier 26 GHz - 40 GHz	JDM2- 26004000-25- 10P	MITEQ	128746	482806	17.02.2020	02.2022
32	RF-cable 1 m	Insulated Wire	Insulated Wire	-	480300	Calibration not necessary	
33	RF-cable 2m	Insulated Wire	Insulated Wire	-	480302	Calibration not necessary	

7 Test site Verification

Test equipment	PM. No.	Frequency range	Type of validation	According to	Val. Date	Val Due
Semi anechoic chamber M276	483227	30 – 1000 MHz	NSA/RSM	CISPR 16-1-4 + Cor1:2010 + A1:2012 +A2:2017	03.03.2021	02.03.2023
Fully anechoic chamber M20	480303	1 -18 GHz	SVSWR	CISPR 16-1-4 Amd. 1	18.08.2020	17.08.2022

8 Report history

Report Number	Date	Comment
F210861E1	25.02.2022	Document created
F210861E1, 2 nd version	25.03.2022	Requirements of 15.521 [2] are clearly addressed and Clause 5.3.2.4 inserted

9 List of annexes

Annex A Test setup photos

8 pages