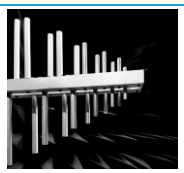
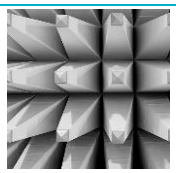

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Bundesnetzagentur

BNetzA-CAB-02/21-102

TEST REPORT

Test report no.: 1-0764/20-01-02

ilac-MRA DAkkS Deutsche Akkreditierungsstelle D-PL-12076-01-05

Testing laboratory

CTC advanced GmbH
Untertuerkheimer Strasse 6 – 10
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Phone: + 49 681 5 98 - 0
Fax: + 49 681 5 98 - 9075
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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 starting with the registration number: D-PL-12076-01.

Applicant

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Phone: +33 02 98 454368
Contact: Frantz Bodereau
e-mail: frantz.bodereau@zf.com

Manufacturer

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201814, Shanghai / CHINA

ZF Automotive Systems Poland Sp. z o.o.,
ul. Ekonomiczna 19
42-271 Częstochowa / POLAND

Test standard/s

CFR 47 Part 95, Subpart M	The 76-81 GHz Band Radar Service
CFR 47 Part 2, Subpart J	Frequency allocations and radio treaty matters; general rules and regulations

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

Test Item

Kind of test item:	**76 GHz Automotive Radar**
Type:	**MRGEN21**
FCC ID:	**S9I-MRGEN21**
Frequency:	76.0 GHz – 77.0 GHz
Antenna:	Integrated antenna
Power supply:	8.0 to 16.0 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:

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Test performed:

F. Heussner

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Frank Heussner
Testing Manager
Radio Communications & EMC

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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. CTC 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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2.2 Application details

Date of receipt of order:	2020-09-30
Date of receipt of test item:	2021-10-01
Start of test:*	2021-10-18
End of test:*	2021-11-17
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 and references

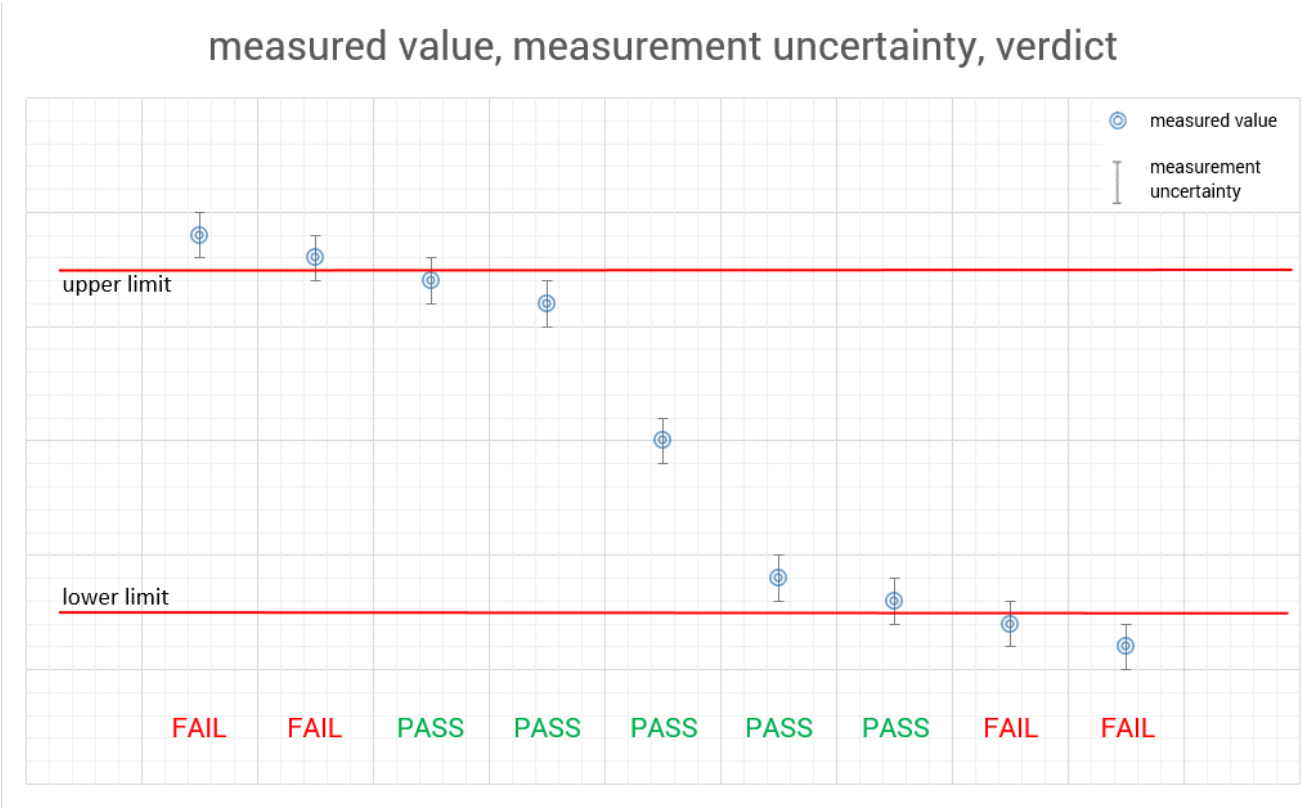
Test standard	Date	Description
CFR 47 Part 95, Subpart M	-/-	The 76-81 GHz Band Radar Service
CFR 47 Part 2, Subpart J	-/-	Frequency allocations and radio treaty matters; general rules and regulations

Guidance	Version	Description
ANSI C63.4-2014	-/-	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
ANSI C63.26-2015	-/-	American National Standard for Compliance Testing of Transmitters Used in Licensed Radio Services
KDB 653005 D01	v01r01 2019-04	Equipment Authorization Guidance for 76-81 GHz Radar Devices

Accreditation	Description
D-PL-12076-01-05	Telecommunication FCC requirements https://www.dakks.de/as/ast/d/D-PL-12076-01-05e.pdf

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 3.
The measurement uncertainty is mentioned in this test report, see chapter 9, 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	:		not relevant for this kind of testing
Power supply	:	V_{nom} V_{max} V_{min}	12.0 V DC by external power supply 16.0 V 8.0 V

6 Test item

6.1 General description

Kind of test item	:	76 GHz Automotive Radar
Type	:	MRGEN21
S/N serial number	:	TOY21175BRT20010
Hardware status	:	BD3.0
Software status	:	T2_R11
Frequency band	:	76.0 GHz – 77.0 GHz
Type of modulation	:	FMCW
Number of modes	:	3
Antenna	:	Integrated antenna
Power supply	:	8.0 to 16.0 V DC by external power supply
Temperature range	:	-40°C to +85°C

6.2 Additional information

Operating modes as declared by manufacturer:

Modulation mode	Detection Range	Accuracy	Bandwidth [MHz]
Long Range High Speed	220 m	≤ 0.1 m	150MHz (eff)* ≈ 210MHz (chirp)**
Mid-Range Mid. Speed	154 m	≤ 0.07 m	215MHz (eff)* ≈ 300MHz (chirp)**
Short Range Low Speed	90 m	≤ 0.04 m	375MHz (eff)* ≈ 520MHz (chirp)**

* refers to the bandwidth used by the radar ADC; ** is referred to the bandwidth of the modulated RF signal

The operating modes were set with the help of special software and according to the document "PRO_MEM_2165_A.pdf".

The 3 modulations were tested.

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: 1-0764/20-01-01_AnnexA
1-0764/20-01-01_AnnexB
1-0764/20-01-01_AnnexD

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7 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).

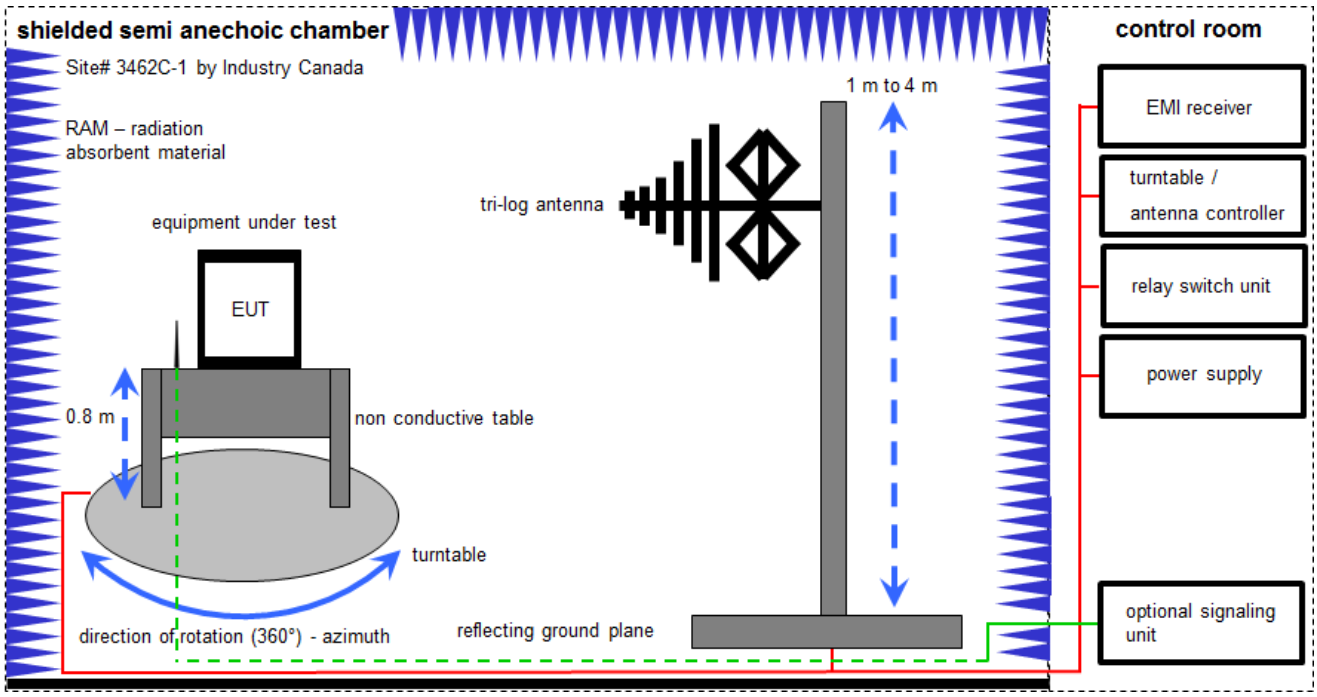
In order to simplify the identification of the equipment used at some special tests, some items of test equipment and ancillaries can be provided with an identifier or number in the equipment list below (Lab/Item).

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
vlkI!	Attention: extended calibration interval			
NK!	Attention: not calibrated		*)	next calibration ordered / currently in progress

7.1 Shielded semi anechoic chamber

The radiated measurements are performed in vertical and horizontal plane in the frequency range from 30 MHz 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 conform to 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

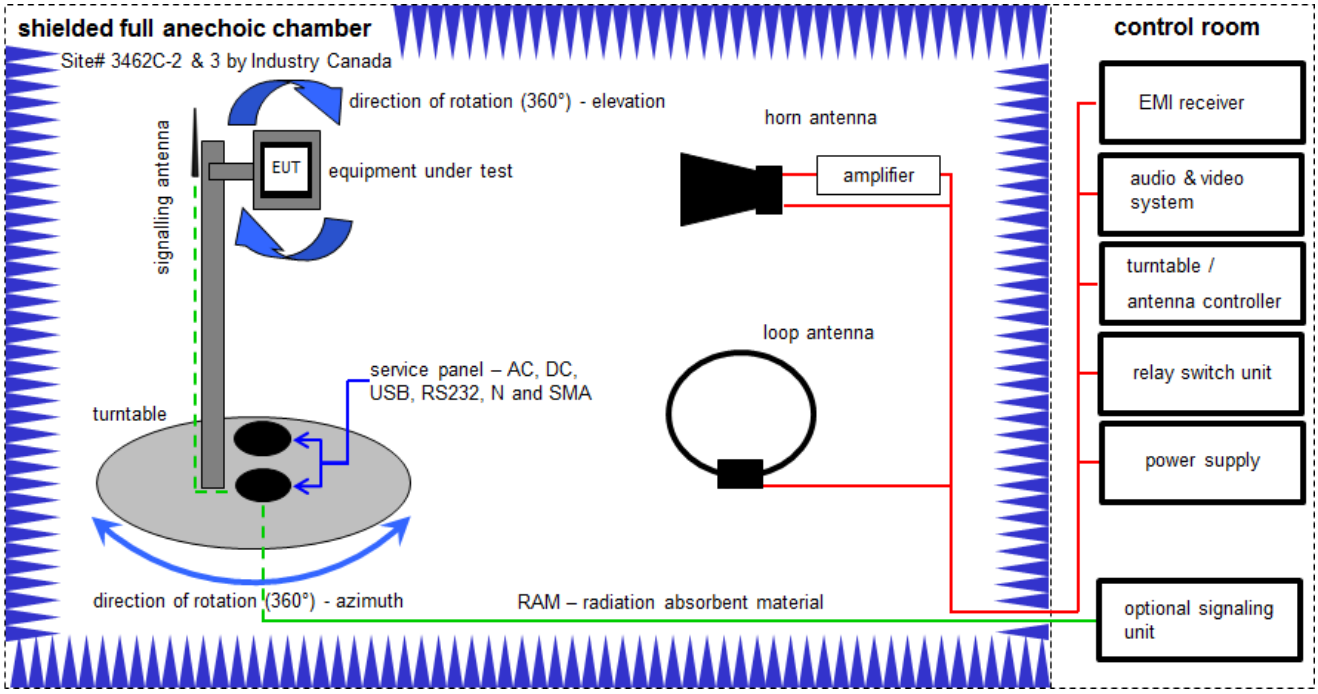
FS = UR + CL + AF
(FS-field strength; UR-voltage at the receiver; CL-loss of the cable; AF-antenna factor)

Example calculation:
FS [dBµV/m] = 12.35 [dBµV/m] + 1.90 [dB] + 16.80 [dB/m] = 31.05 [dBµV/m] (35.69 µV/m)

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.	Semi anechoic chamber	300023	MWB AG	-/-	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	318	300003696	vlKI!	30.09.2021	29.09.2023
8	n. a.	EMI Test Receiver	ESR3	Rohde & Schwarz	102587	300005771	k	10.12.2020	09.12.2021
9	n. a.	PC	TecLine	F+W	-/-	300004388	ne	-/-	-/-

7.2 Shielded 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)

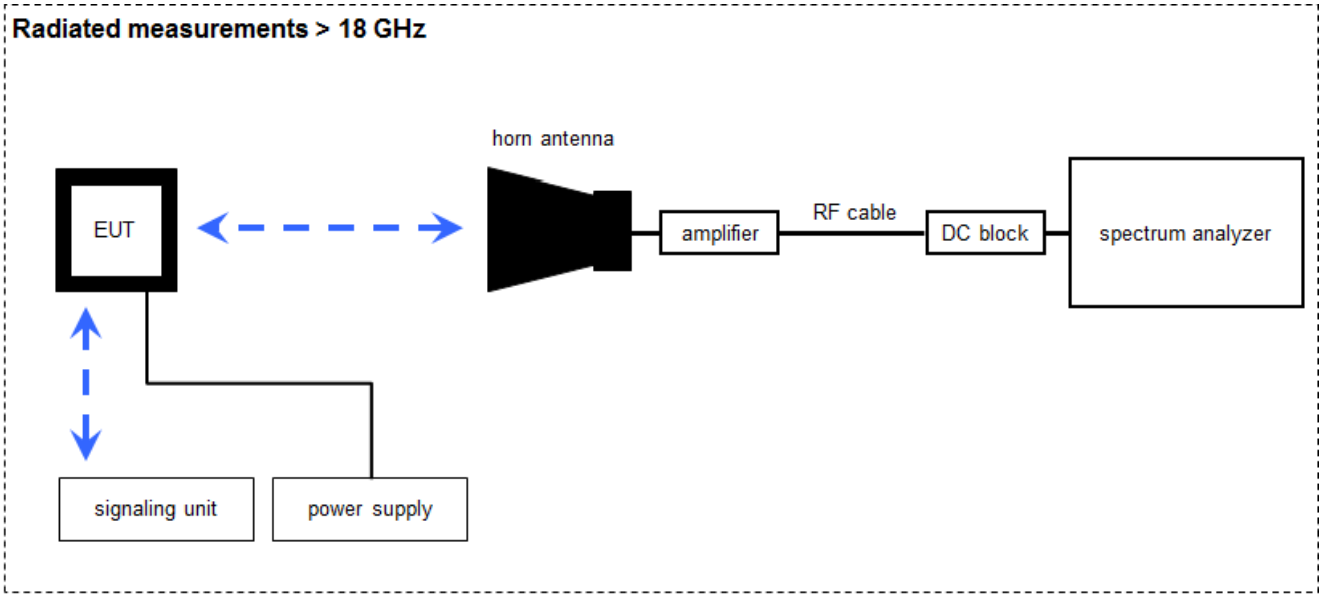
OP = AV + D - G + CA
(OP-radiated output power; AV-analyzer value; D-free field attenuation of measurement distance; G-antenna gain+amplifier gain; CA-loss signal path)

Example calculation:
OP [dBm] = -39.0 [dBm] + 57.0 [dB] - 12.0 [dBi] + (-36.0) [dB] = -30 [dBm] (1 µW)

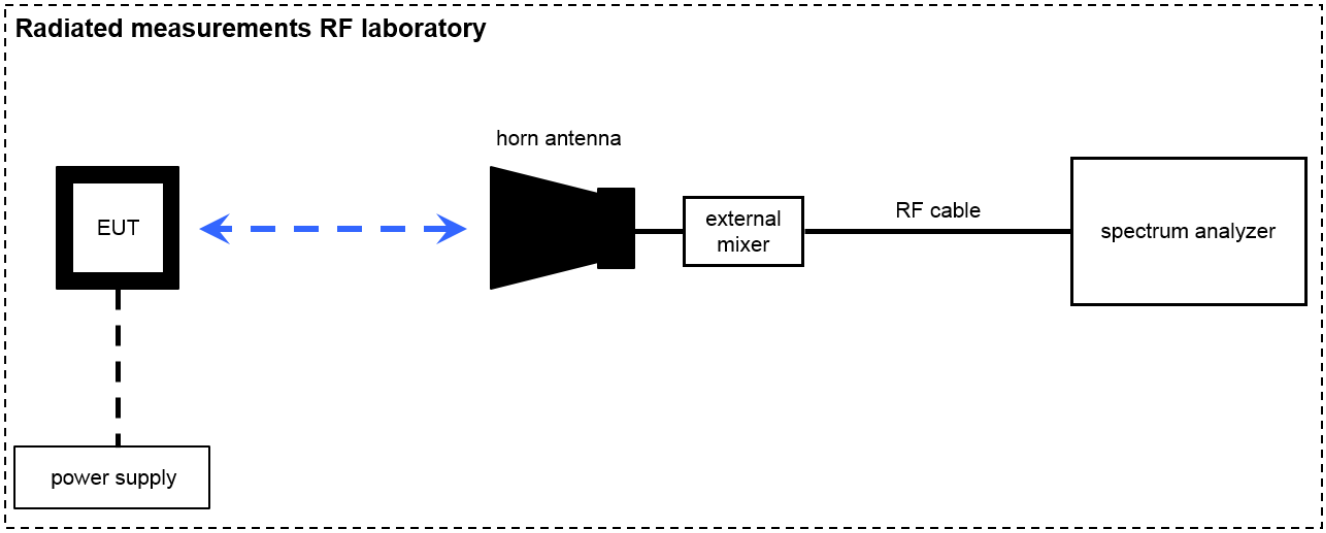
Equipment table:

No.	Lab / Item	Equipment	Type	Manufacturer	Serial No.	INV. No.	Kind of Calibration	Last Calibration	Next Calibration
1	n. a.	DC power supply, 60Vdc, 50A, 1200 W	6032A	HP	2818A03450	300001040	vIKI!	09.12.2020	08.12.2023
2	n. a.	Active Loop Antenna 9 kHz to 30 MHz	6502	EMCO	2210	300001015	vIKI!	13.06.2019	12.06.2022
3	n. a.	Anechoic chamber	FAC 3/5m	MWB / TDK	87400/02	300000996	ev	-/-	-/-
4	n. a.	TRILOG Broadband Test-Antenna 30 MHz - 3 GHz	VULB9163	Schwarzbeck Mess - Elektronik	371	300003854	vIKI!	14.01.2020	13.01.2022
5	n. a.	Double-Ridged Waveguide Horn Antenna 1-18.0GHz	3115	EMCO	9107-3697	300001605	vIKI!	12.03.2021	11.03.2023
6	n. a.	Switch / Control Unit	3488A	HP	*	300000199	ne	-/-	-/-
7	n. a.	Variable isolating transformer	MPL IEC625 Bus Variable isolating transformer	Erfi	91350	300001155	ne	-/-	-/-
8	n. a.	EMI Test Receiver 20Hz- 26,5GHz	ESU26	R&S	100037	300003555	k	11.12.2020	10.12.2021
9	n. a.	Highpass Filter	WHKX7.0/18G-8SS	Wainwright	19	300003790	ne	-/-	-/-
10	n. a.	Broadband Amplifier 0.5-18 GHz	CBLU5184540	CERNEX	22049	300004481	ev	-/-	-/-
11	n. a.	Broadband Amplifier 5-13 GHz	CBLU5135235	CERNEX	22010	300004491	ev	-/-	-/-
12	n. a.	4U RF Switch Platform	L4491A	Agilent Technologies	MY50000037	300004509	ne	-/-	-/-
13	n. a.	NEXIO EMV-Software	BAT EMC V3.16.0.49	EMCO		300004682	ne	-/-	-/-
14	n. a.	PC	ExOne	F+W		300004703	ne	-/-	-/-
15	n. a.	RF-Amplifier	AMF-6F06001800-30-10P-R	NARDA-MITEQ Inc	2011572	300005241	ev	-/-	-/-

7.3 Radiated measurements > 18 GHz



7.4 Radiated measurements > 50/85 GHz



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.

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!	18.02.2019	17.02.2022
2	n. a.	Std. Gain Horn Antenna 18.0-26.5 GHz	638	Narda		300000486	vIKI!	21.01.2020	20.01.2022
3	n. a.	Std. Gain Horn Antenna 26.5-40.0 GHz	V637	Narda	82-16	300000510	vIKI!	23.01.2020	22.01.2022
4	n.a.	Std. Gain Horn Antenna 33.0-50.1 GHz	2324-20	Flann	57	400000683	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	09.03.2020	08.03.2022
13	n. a.	Harmonic Mixer 3-Port, 60-90 GHz	FS-Z90	R&S	102152	300006202	k	21.01.2021	20.01.2022
14	n.a.	Harmonic Mixer 3-port, 90-140 GHz	FS-Z140	Rohde & Schwarz	101119	300005581	k	22.07.2021	21.07.2022
15	n.a.	Harmonic Mixer 3-port, 75-110 GHz	FS-Z110	Rohde & Schwarz	101411	300004959	k	15.06.2021	14.06.2022
16	n.a.	Harmonic Mixer 3-port, 110-170 GHz	FS-Z170	Rohde & Schwarz	100014	300004156	k	11.06.2021	10.06.2022
17	n. a.	Harmonic Mixer 3-Port, 140-220 GHz	SAM-220	Radiometer Physics GmbH	200001	300004157	k	22.07.2021	21.07.2022
18	n. a.	Harmonic Mixer 3-Port, 220-325 GHz	SAM-325	Radiometer Physics GmbH	100002	300004158	k	22.07.2021	21.07.2022
19	n. a.	Spectrum Analyzer 2 Hz - 50 GHz	FSW50	R&S	101332	300005935	k	05.03.2021	04.03.2022
20	n.a.	Spectrum Analyzer 2 Hz - 85 GHz	FSW85	R&S	101333	300005568	k	30.06.2021	29.06.2022
21	n. a.	Temperature Test Chamber	T-40/50	CTS GmbH	064023	300003540	ev	08.05.2020	07.05.2022

8 Sequence of testing

8.1 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.

8.2 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.

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8.3 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.

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8.4 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.

8.5 Sequence of testing radiated spurious above 50/85 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.

9 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 40 GHz)	± 1 dB
Radiated unwanted emissions in the spurious domain (up to 40 GHz)	± 3 dB
Conducted unwanted emissions in the spurious domain (40 to 50 GHz)	± 4 dB
Radiated unwanted emissions in the spurious domain (40 to 50 GHz)	± 4 dB
Conducted unwanted emissions in the spurious domain (50 to 300 GHz)	± 5 dB
Radiated unwanted emissions in the spurious domain (50 to 300 GHz)	± 5 dB
DC and low frequency voltages	± 3 %
Temperature	± 1 °C
Humidity	± 3 %

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10 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	47 CFR Part 95 Subpart M	see below	2021-12-09	-/-

Test specification clause	Test case	Temperature conditions	Power source voltages	C	NC	NA	NP	Results (max.)
§2.1046 §95.3367 (a) / (b)	Radiated power	Nominal	Nominal	☒	☐	☐	☐	-/-
§2.1047	Modulation characteristics	-/-	-/-	☒	☐	☐	☐	-/-
§2.1049	Occupied bandwidth (99% bandwidth)	Nominal	Nominal	☒	☐	☐	☐	-/-
§2.1051	Spurious emissions at antenna terminals	Nominal	Nominal	☐	☐	☒	☐	see note
§2.1053 §95.3379 (a)(1) §95.3379 (a)(2) §95.3379 (a)(3)	Field strength of emissions (radiated spurious)	Nominal	Nominal	☒	☐	☐	☐	-/-
§2.1055 §95.3379 (b)	Frequency stability	Nominal and Extreme	Nominal and Extreme	☒	☐	☐	☐	-/-

Note: C = Compliant; NC = Not compliant; NA = Not applicable; NP = Not performed

See FCC's Millimeter Wave Test Procedures:
I. A radiated method of measurements in order to demonstrate compliance with the various regulatory requirements has been chosen in consideration of test equipment availability and the limitations of many external harmonic mixers. A conducted method of measurement could be employed if EUT and mixer waveguides both are accessible and of the same type (WG number) and if waveguide sections and transitions can be found. Another potential problem is that the peak power output of devices operating under Sections 15.253 and 15.255 may exceed the +20 dBm input power limit of many commercially available mixers. For these reasons a radiated method is preferred.

11 Measurement results

11.1 Radiated power

Description:

The fundamental radiated emission limits within the 76-81 GHz band are expressed in terms of Equivalent Isotropically Radiated Power (EIRP) and are as shown below.

Measurement:

Parameters	
Detector:	RMS / Pos-Peak
Sweep time:	72.5 s
Resolution bandwidth:	1 MHz
Video bandwidth:	3 MHz
Trace-Mode:	Max Hold

Limits: **FCC §95.3367 (a) (b)**

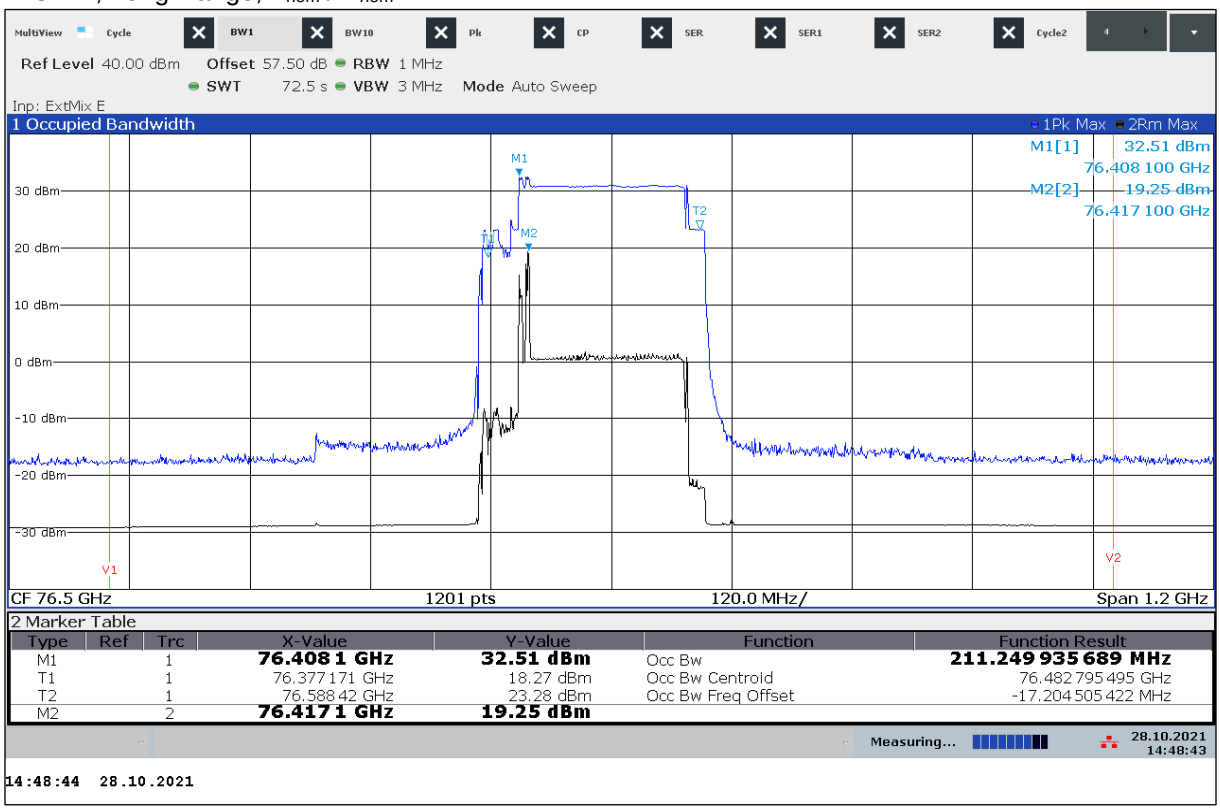
Frequency	Measurement distance	EIRP
76.0 - 81.0 GHz	3.0 m	88 µW/cm^2 → 50 dBm (Average) 279 µW/cm^2 → 55 dBm (PEAK)

Measurement results:

Modulation / Test conditions		Channel power Radiated mean power (eirp) [dBm]	Radiated peak power (eirp) [dBm]	Radiated power spectral density [dBm]
Long Range High Speed (150 MHz)	T_{nom} / V_{nom}	25.98	32.51	19.25
Mid-Range Mid. Speed (215 MHz)	T_{nom} / V_{nom}	24.72	32.65	17.90
Short Range Low Speed (375 MHz)	T_{nom} / V_{nom}	24.69	32.49	18.81

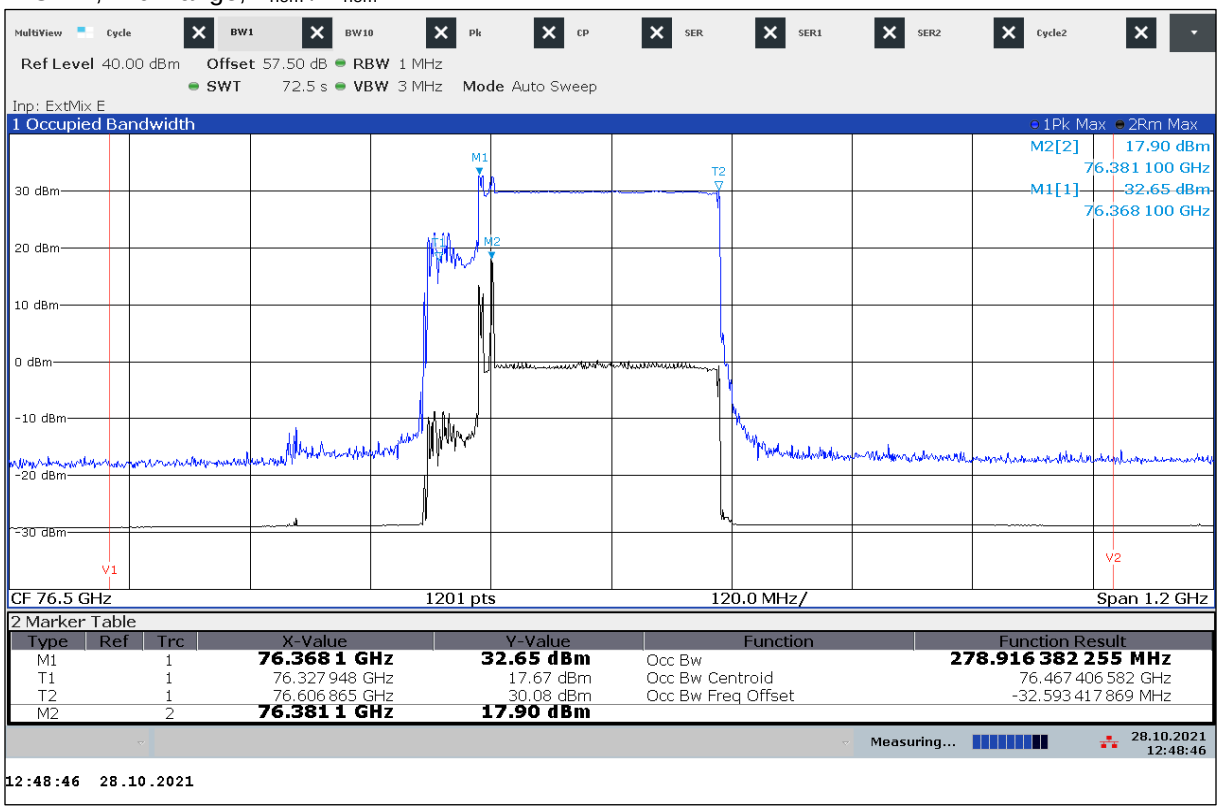
Plot 1: EIRP Mean Power (Channel Power), Long Range, T_{nom} / V_{nom}

Plot 2: OBW, Long Range, T_{nom} / V_{nom}

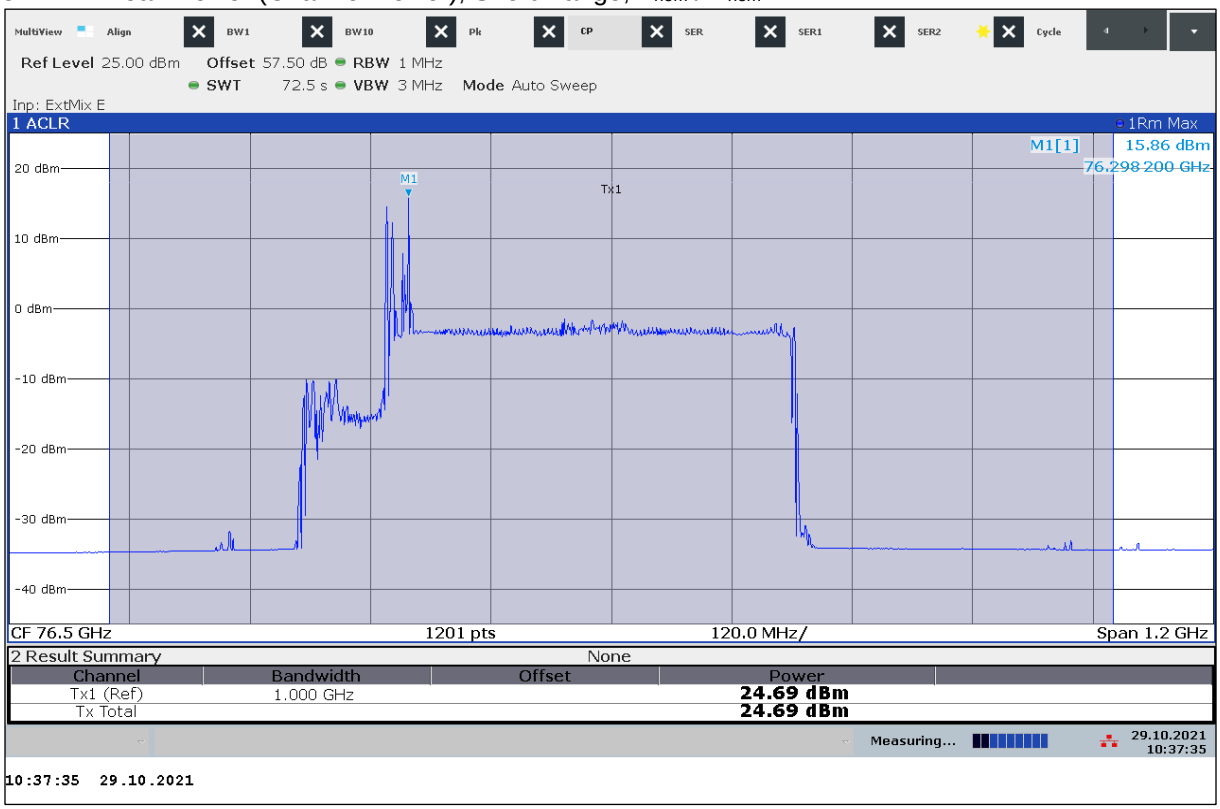


Plot 3: EIRP Mean Power (Channel Power), Mid Range, T_{nom} / V_{nom}

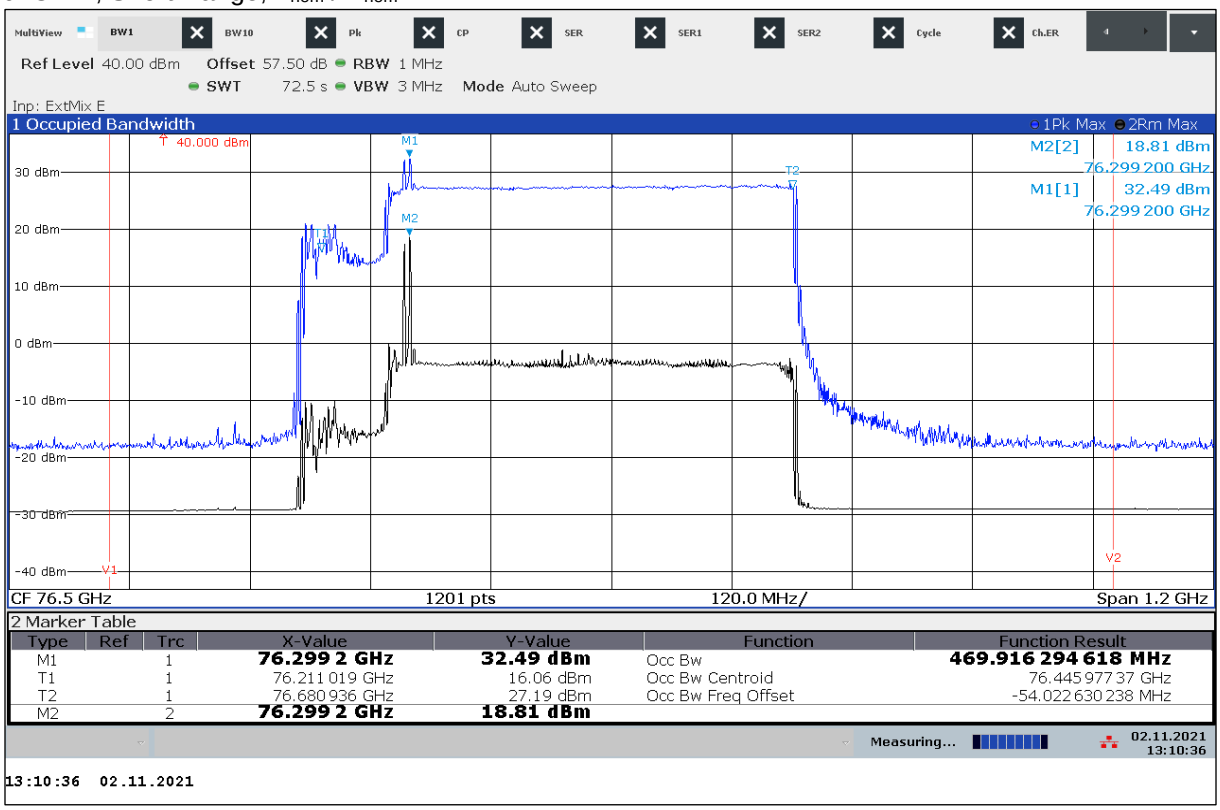
Plot 4: OBW, Mid Range, T_{nom} / V_{nom}



Plot 5: EIRP Mean Power (Channel Power), Short Range, T_{nom} / V_{nom}



Plot 6: OBW, Short Range, T_{nom} / V_{nom}



11.2 Modulation characteristics

Description:

§2.1047 (d) *Other types of equipment.* A curve or equivalent data which shows that the equipment will meet the modulation requirements of the rules under which the equipment is to be licensed.

Comments from manufacturer on modulation characteristics according to KDB:

Referenced document: *ZF_MRGen21_Product_data_sheet.pdf*

4.4.2 Modulation

Main radar modulation parameters:

Bandwidth Min	150MHz (eff) => 1 m
Bandwidth Max	365MHz (eff) => 0.4 m
Cycle time	60 ms
RF Frequency	77 GHz
Number of Rx channels	4
Number of Tx	3
Sampling rate	5 Msamples/s IQ
Number of chirps	256
Number of samples per chirp	256 IQ
Chirp repetition time	66 – 94 us
Speed ambiguity (+/-)	37.5 – 53.5 kph
Speed resolution	0.4 km/h

The proposed parameters contain 3 variants for the Bandwidth, i.e., range resolution of 0.4, 0.7, or 1 m. This will depend on the host vehicle speed, to have more resolution at lower speeds, and increase the maximum detection range at higher speeds.

DATE: 27/10/2021 REVISION: 0.1 1.10 DOC#: Confidential PAGE: 8 of 19	MRGen21 Core Project Product Data Sheet	ZF

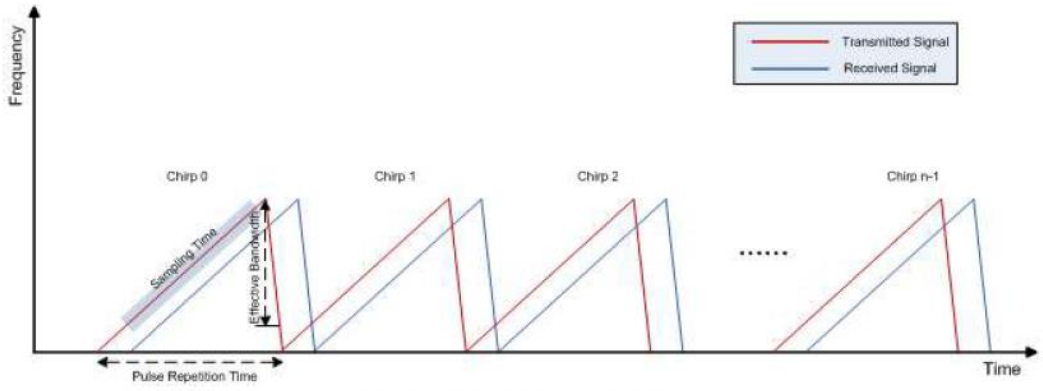


Figure 4: Single Chirp Timing

We use a modulation scheme based on a coherent train of linearly frequency modulated pulses which is also known as fast chirp-sequence modulation as shown in **Figure 4**.

11.3 Occupied bandwidth

Description:

§2.1049 The occupied bandwidth, that is the frequency bandwidth such that, below its lower and above its upper frequency limits, the mean powers radiated are each equal to 0.5 percent of the total mean power radiated by a given emission.

Measurement:

Parameters	
Detector:	Pos. Peak
Sweep time:	72.5 s
Resolution bandwidth:	1 MHz
Video bandwidth:	3 MHz
Trace-Mode:	Max Hold
Measurement uncertainty:	Span/1000

Limits: **FCC §95.3379 (b)**

Frequency range	f(lowest) > 76.0 GHz	f(highest) < 81.0 GHz

Measurement results:

Modulations / Test conditions		99% Occupied Bandwidth		OBW [MHz]
		f_L [GHz]	f_H [GHz]	
Long Range High Speed (150 MHz)	T_{nom} / V_{nom}	76.377 171	76.588 420	211.2
Mid-Range Mid. Speed (215 MHz)	T_{nom} / V_{nom}	76.327 948	76.606 865	278.9
Short Range Low Speed (375 MHz)	T_{nom} / V_{nom}	76.211 019	76.680 936	469.9

Refer to plot 2, 4, 6

11.4 Field strength of spurious emissions

Description:

The power density of any emissions outside the 76-81 GHz band shall consist solely of spurious emissions and shall not exceed the following:

Limits: **FCC §95.3379**

FCC		
CFR Part 95.3379 (a) (1) / CFR Part 95.3379 (a) (3)		
Radiated Spurious Emissions		
Emissions radiated outside of the specified frequency bands, except for harmonics, shall be attenuated by at least 50 dB below the level of the fundamental or to the general radiated emission limits in § 15.209, whichever is the lesser attenuation.		
Frequency [MHz]	Field Strength [dBµV/m]	Measurement distance
0.009 – 0.490	2400/F[kHz]	300
0.490 – 1.705	24000/F[kHz]	30
1.705 – 30.0	30	30
30 88	30.0	10
88 – 216	33.5	10
216 – 960	36.0	10
960 – 40 000	54.0	3

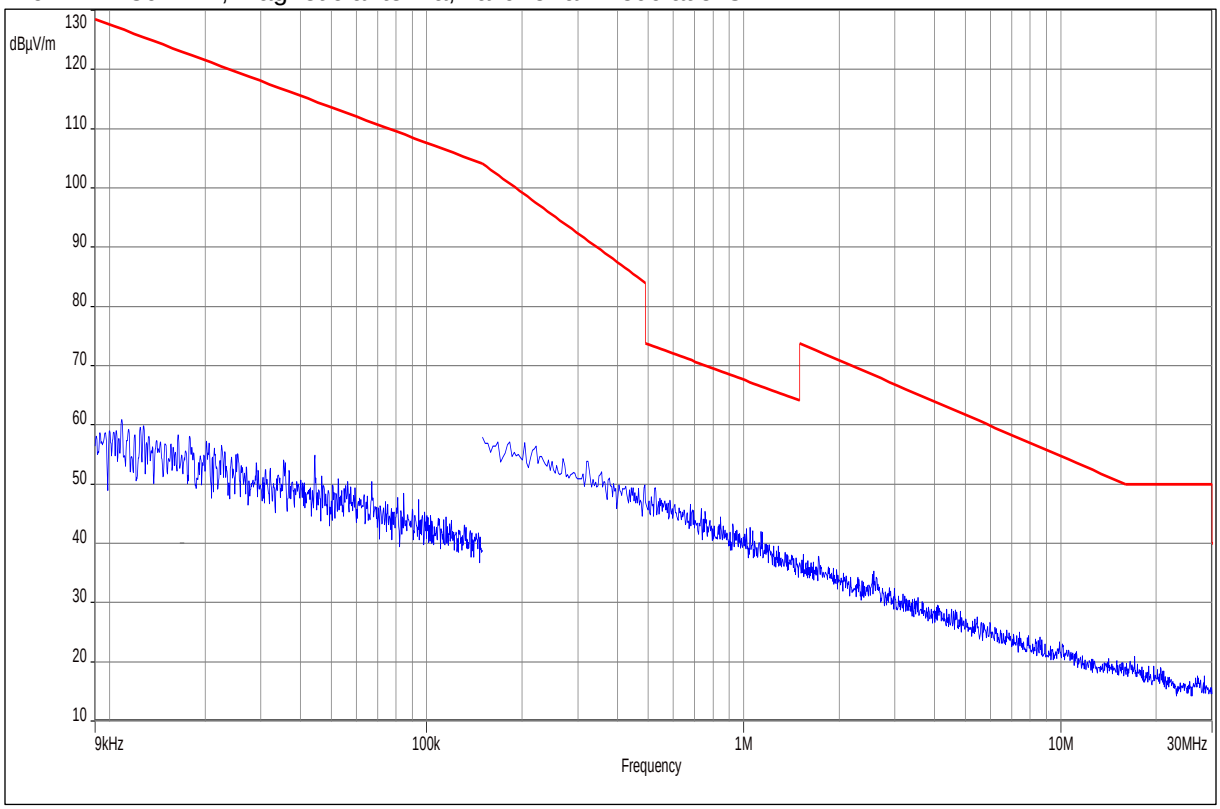
Limits: **FCC §95.3379 (a) (2) (i) + (ii)**

Frequency Range [GHz]	Measurement distance	Power Density
40 – 200	3.0 m	600 pW/cm^2 → -1.7 dBm
200 – 231	3.0 m	1000 pW/cm^2 → +0.5 dBm

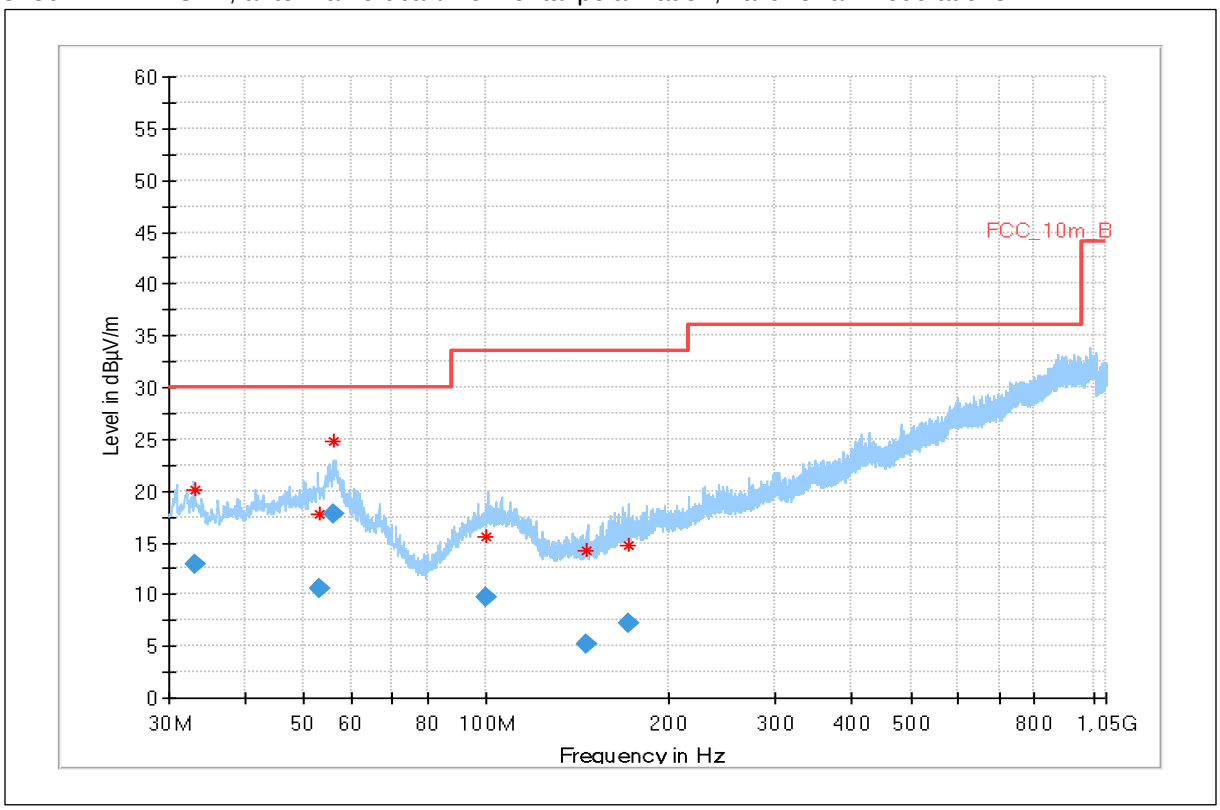
Measurement results:

Frequency in [GHz]	Detector	Bandwidth [kHz]	Level [dBµV]	Distance [m]	Limit [dBµV]	Margin [dB]
No critical peak found!						

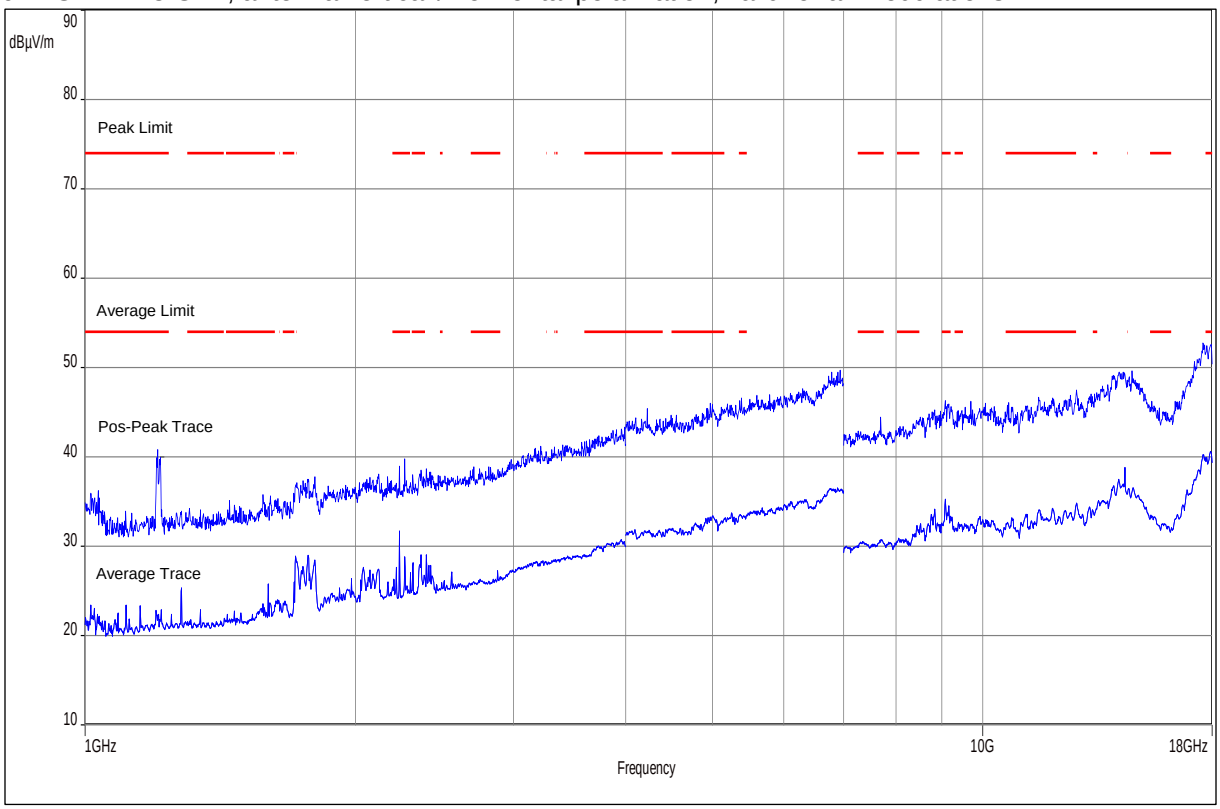
Plot 7: 9 kHz – 30 MHz, Magnetic antenna, valid for all modulations



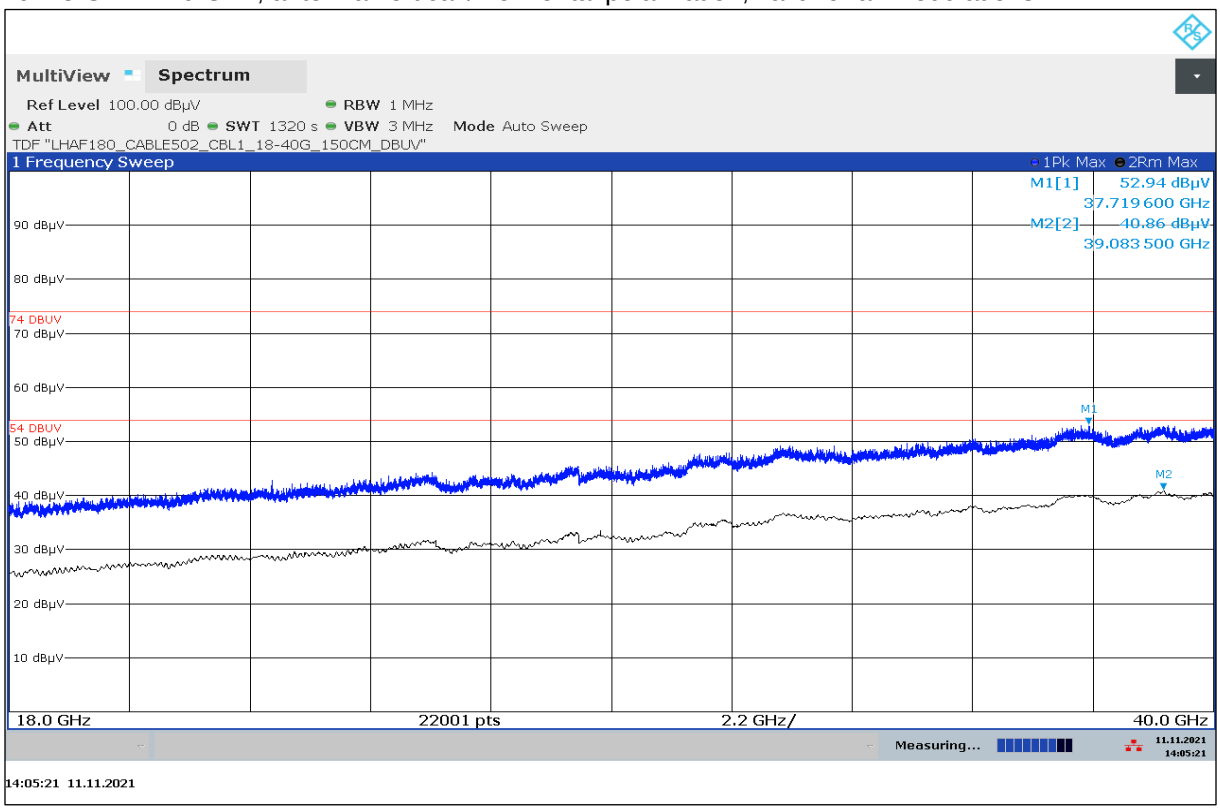
Plot 8: 30 MHz – 1 GHz, antenna vertical / horizontal polarization, valid for all modulations



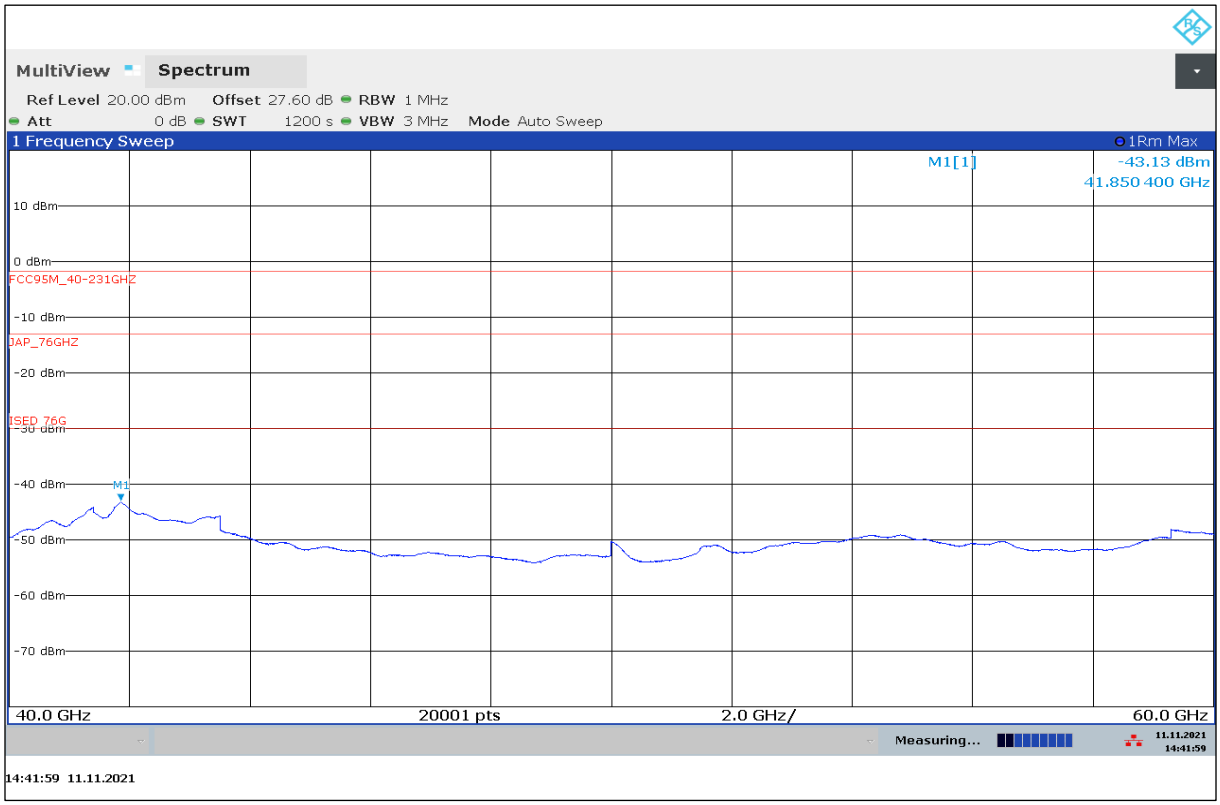
Plot 9: 1 GHz – 18 GHz, antenna vertical / horizontal polarization, valid for all modulations



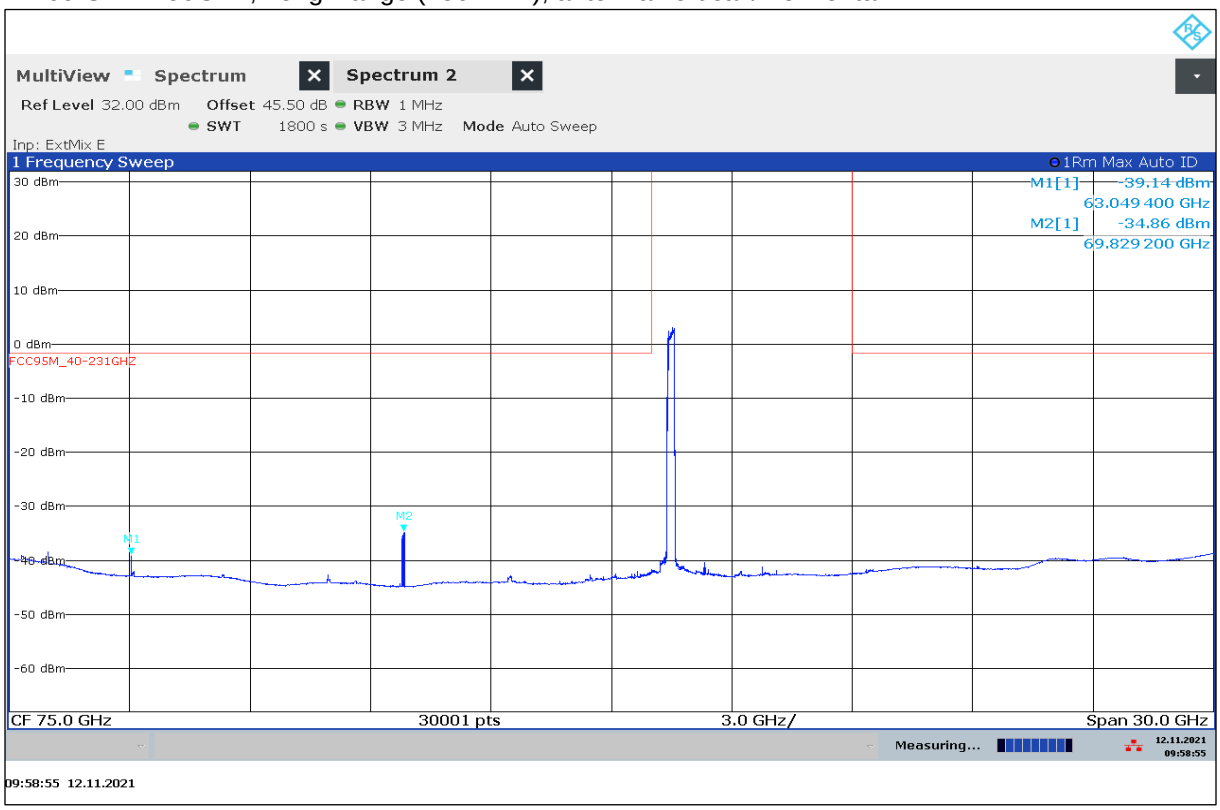
Plot 10: 18 GHz – 40 GHz, antenna vertical / horizontal polarization, valid for all modulations



Plot 11: 40 GHz – 60 GHz, antenna vertical / horizontal, valid for all modulations

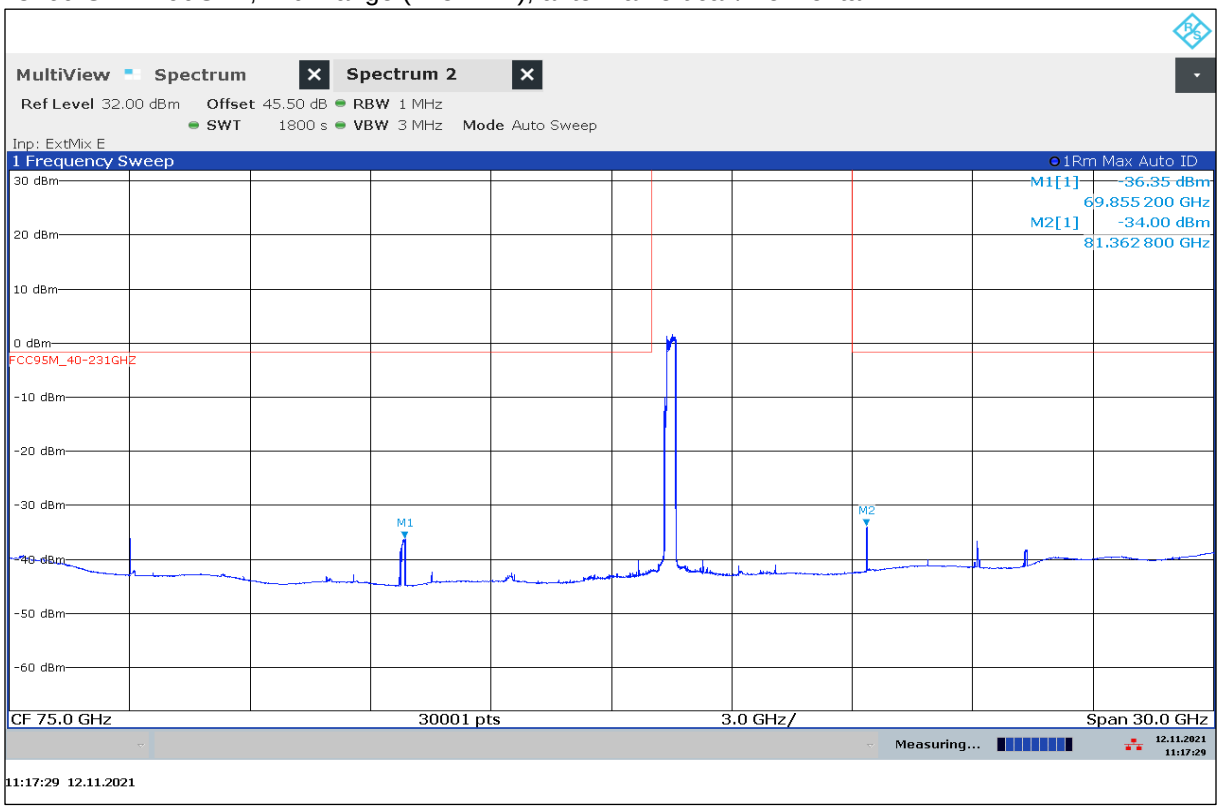


Plot 12: 60 GHz – 90GHz, Long Range (150 MHz), antenna vertical / horizontal



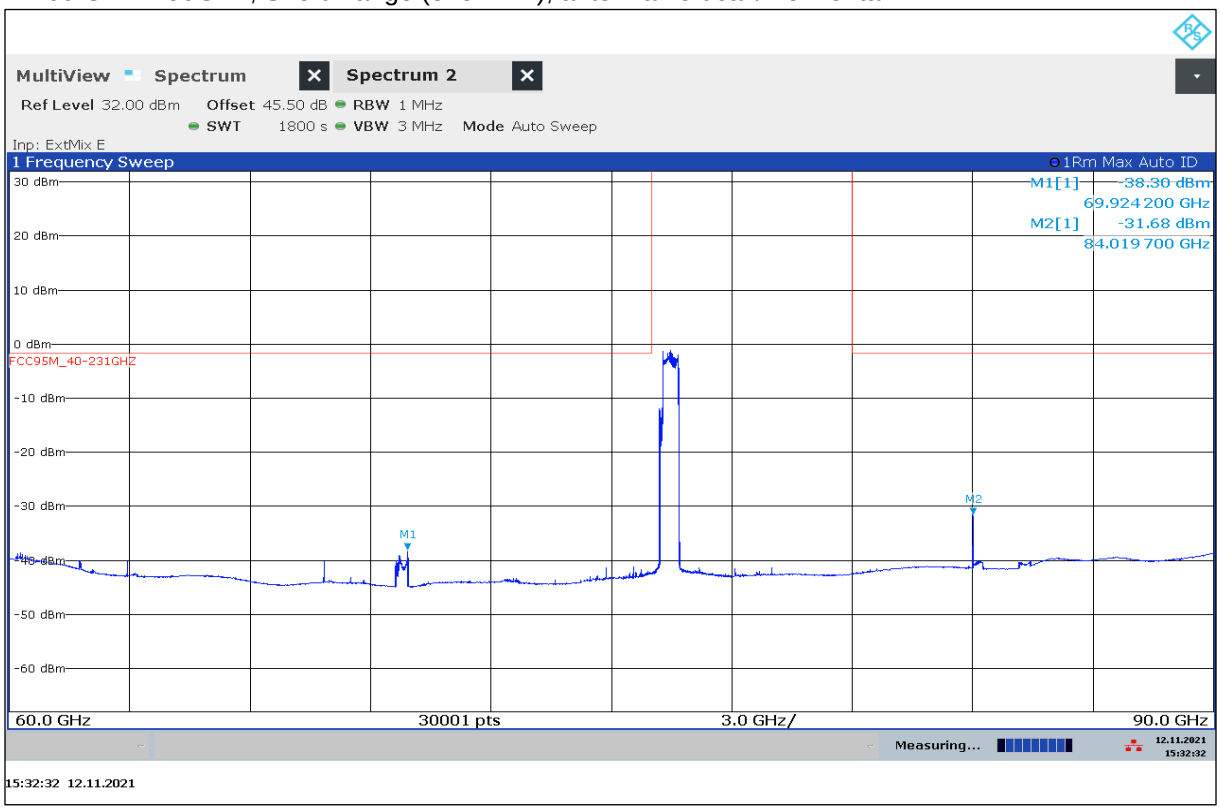
Marker show mixer products produced by harmonic mixer.

Plot 13: 60 GHz – 90GHz, Mid-Range (215 MHz), antenna vertical / horizontal



Marker show mixer products produced by harmonic mixer.

Plot 14: 60 GHz – 90GHz, Short Range (375 MHz), antenna vertical / horizontal

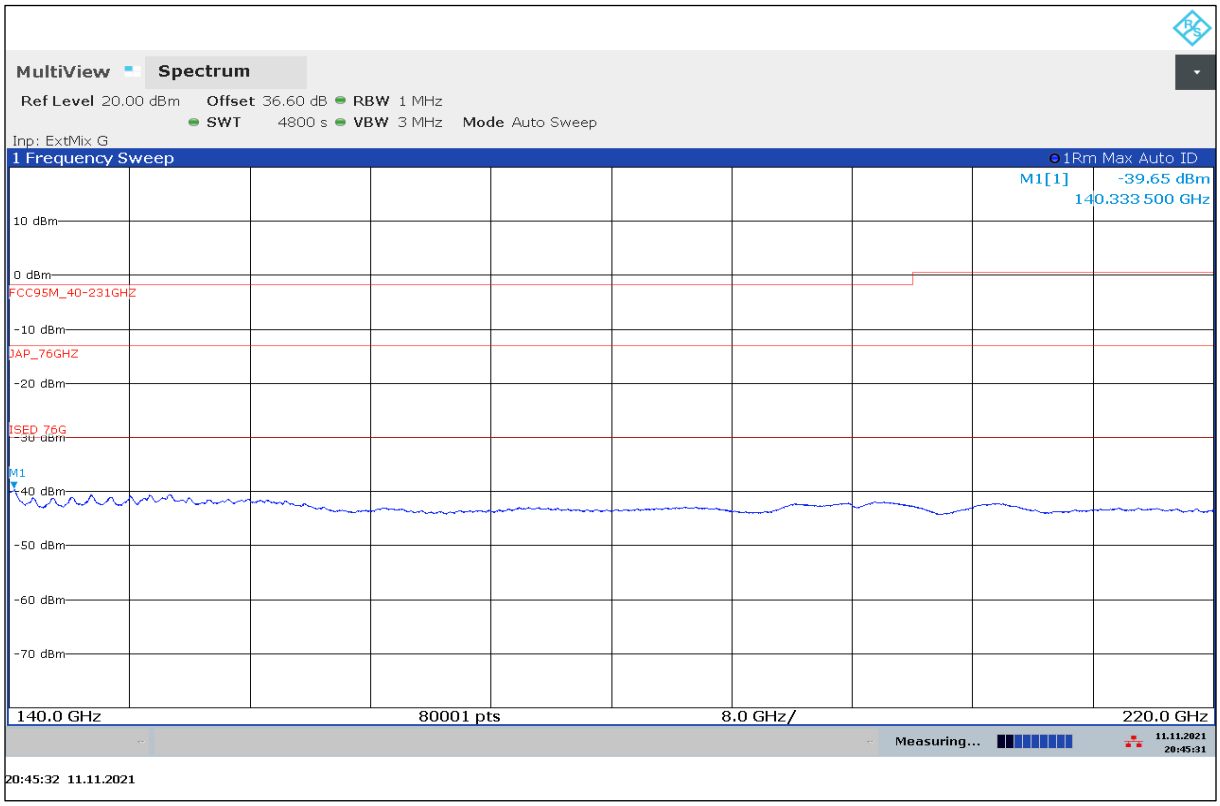


Marker show mixer products produced by harmonic mixer.

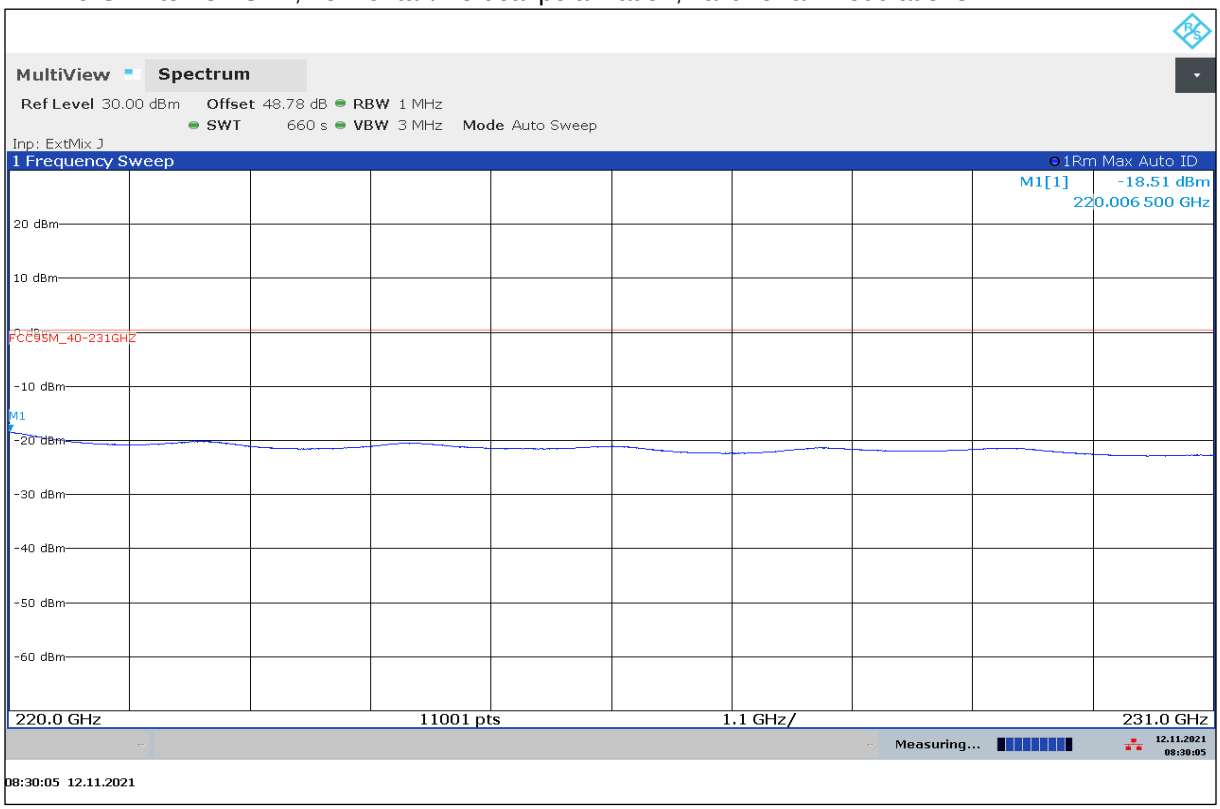
Plot 15: 90 GHz – 140 GHz, antenna vertical / horizontal, valid for all modulations

Marker show mixer products produced by harmonic mixer.

Plot 16: 140 GHz – 220 GHz, antenna vertical / horizontal, valid for all modulations



Plot 17: 220 GHz to 231 GHz, horizontal / vertical polarization, valid for all modulations



11.5 Frequency stability

Description:

§95.3379 (b) 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.

Limits: **FCC §95.3379 (b)**

Frequency range	f(lowest) > 76.0 GHz	f(highest) < 81.0 GHz

Measurement results:

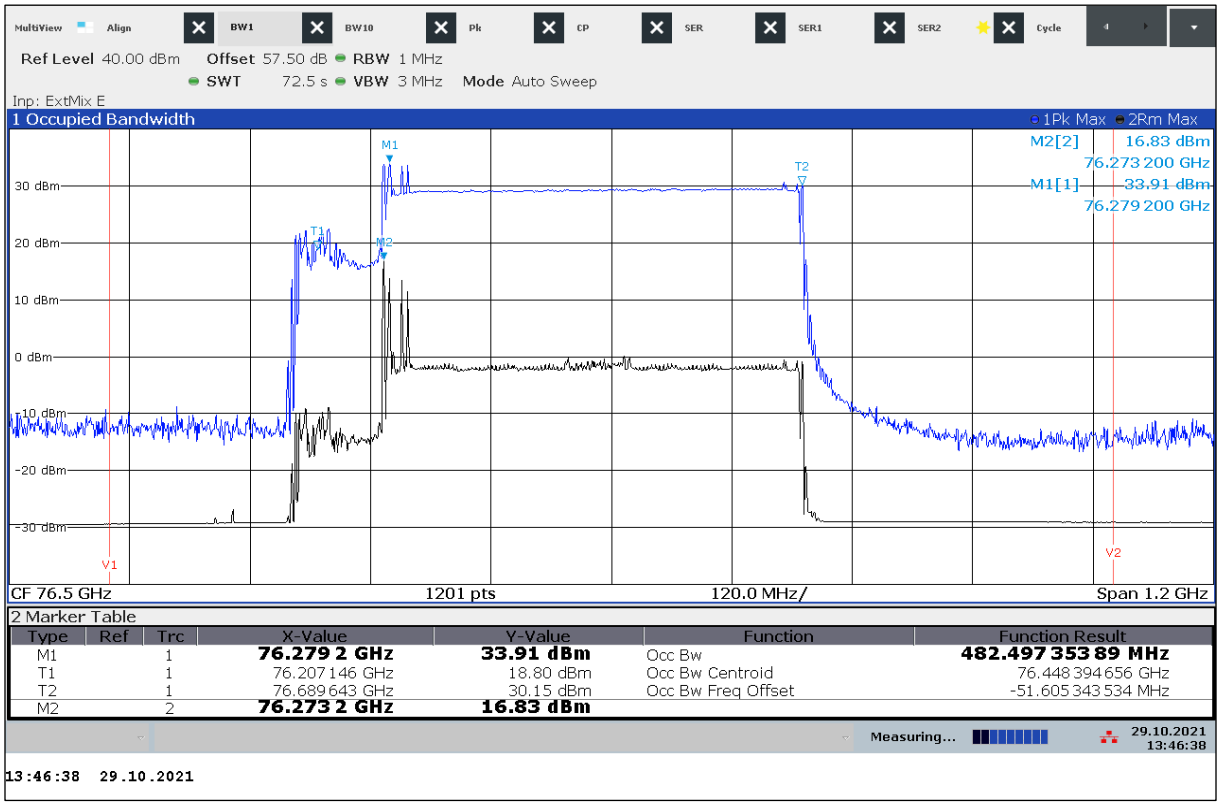
Temperature variation:

Modulation	Temperature in °C	f_L in GHz	f_H in GHz
Short Range Low Speed (375 MHz)	-40	76.207 146	76.689 643
	-20	76.206 338	76.682 895
	-10	76.208 651	76.683 778
	0	76.207 199	76.682 116
	10	76.204 139	76.682 364
	20	76.211 019	76.680 936
	30	76.212 069	76.680 638
	40	76.204 297	76.679 413
	50	76.202 606	76.679 614
	85	76.202 452	76.680 671

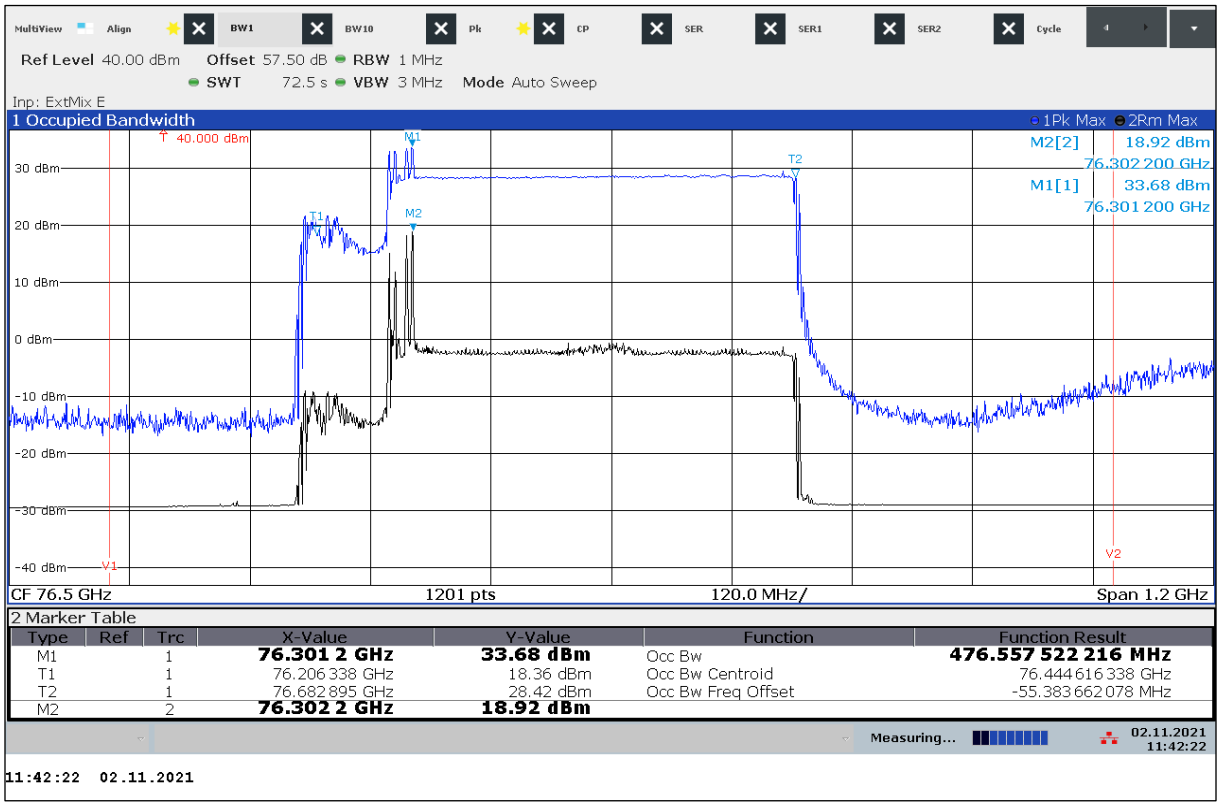
Voltage variation:

Voltage variation of rated input voltage	f_L in GHz	f_H in GHz
< 85 % of U	Voltage variation does not affect the radiated signal	
> 115 % of U		

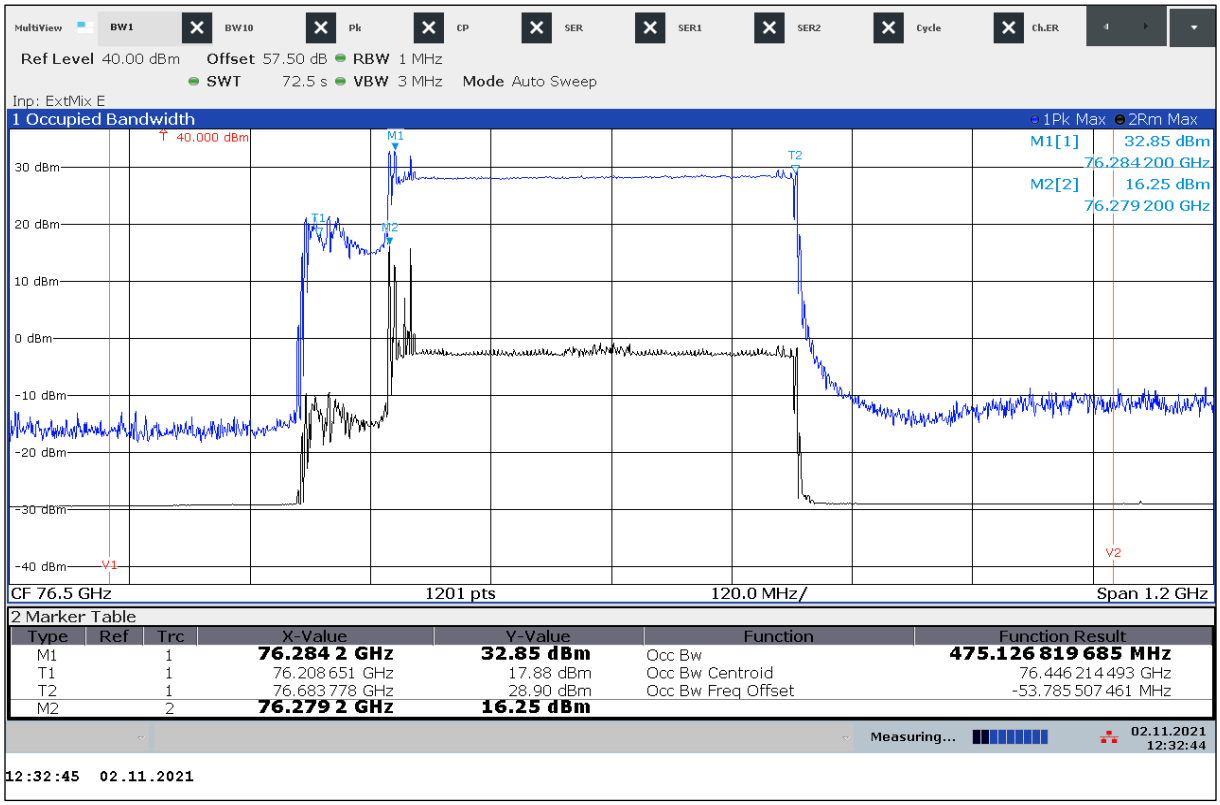
Plot 18: OBW, T_{min} / V_{nom}



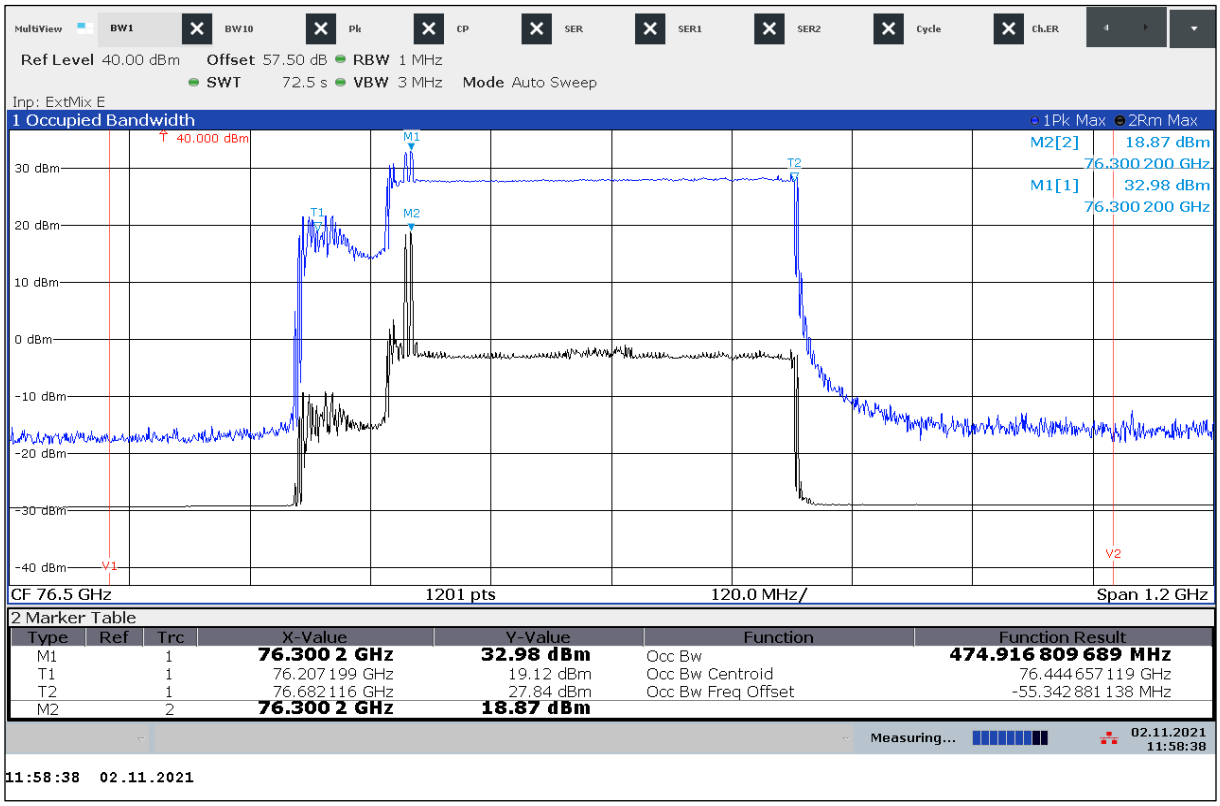
Plot 19: OBW, -20 °C / V_{nom}



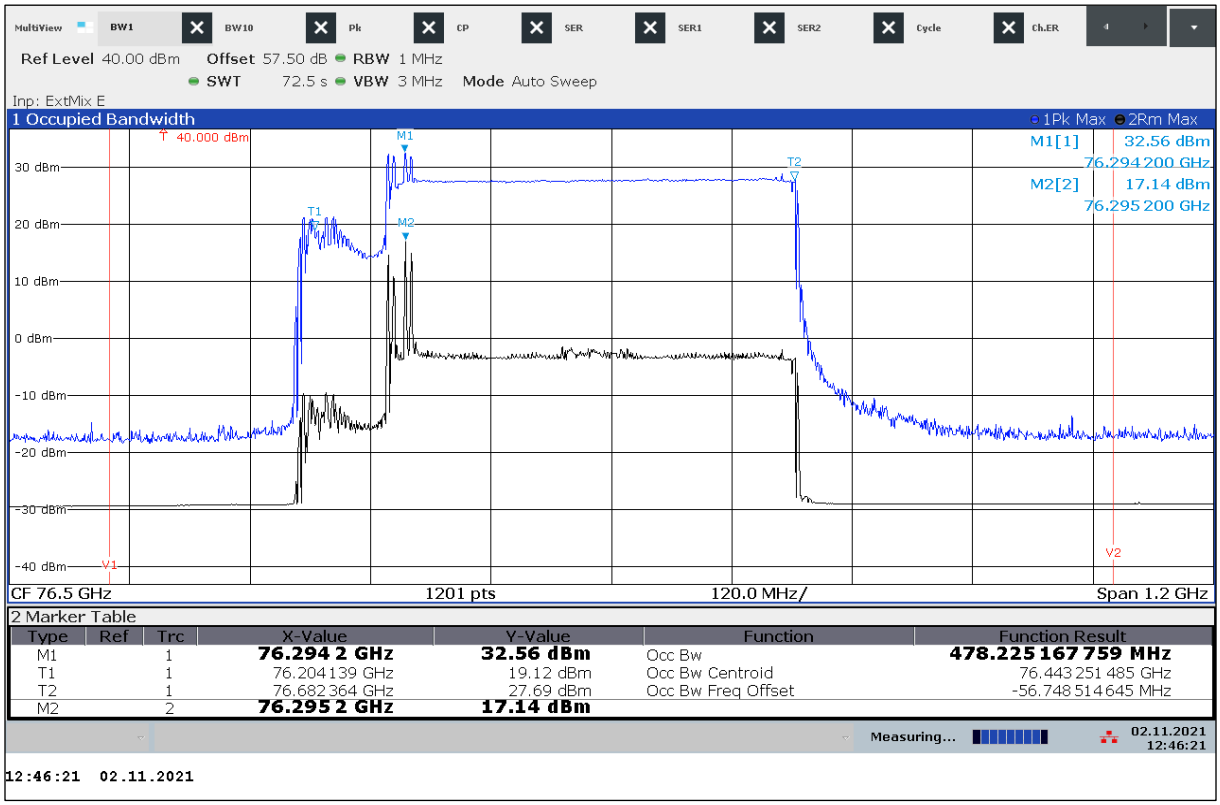
Plot 20: OBW, -10 °C / V_{nom}



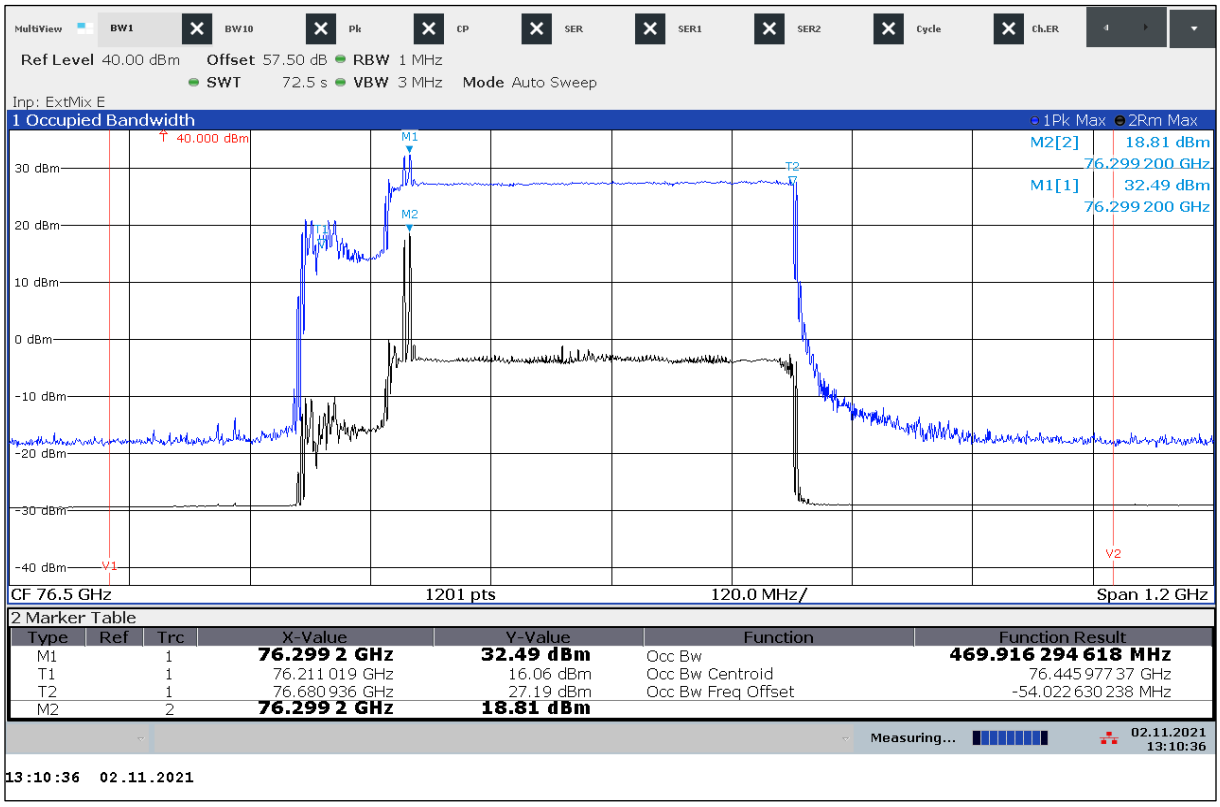
Plot 21: OBW, 0 °C / V_{nom}



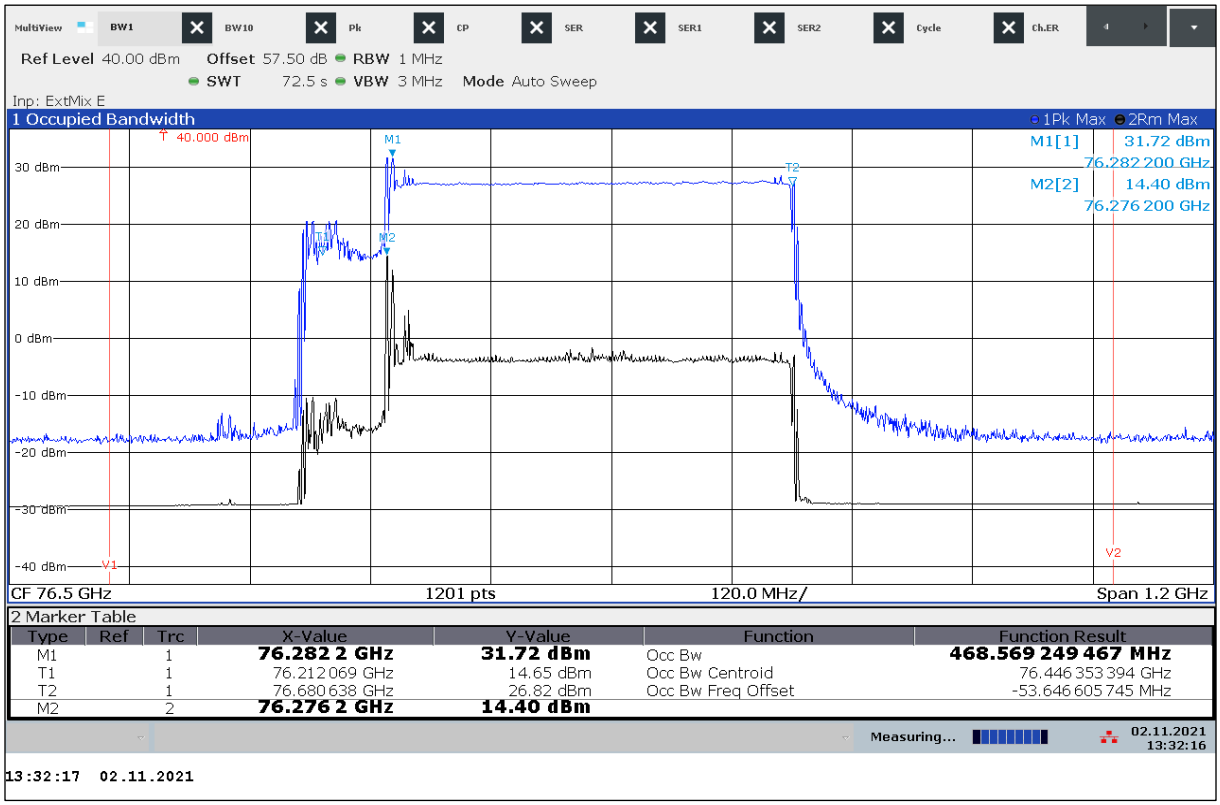
Plot 22: OBW, +10 °C / V_{nom}



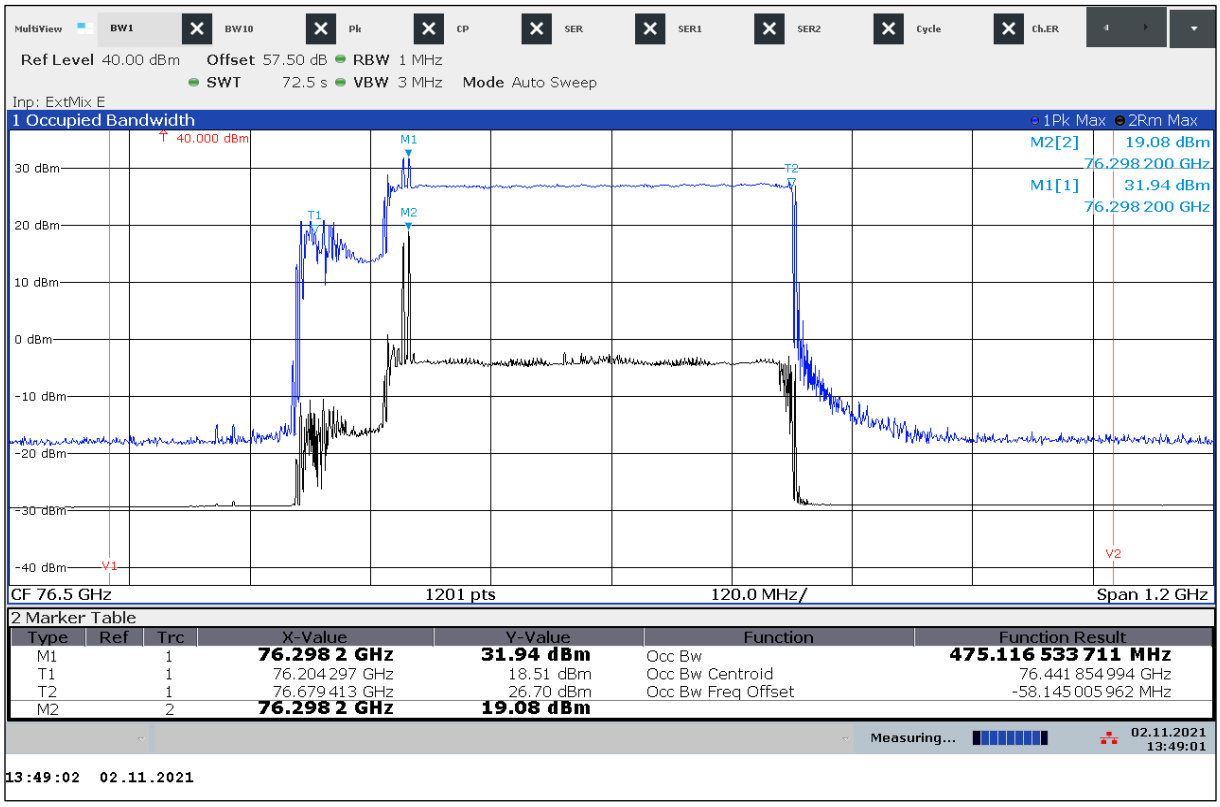
Plot 23: OBW, +20 °C / V_{nom}



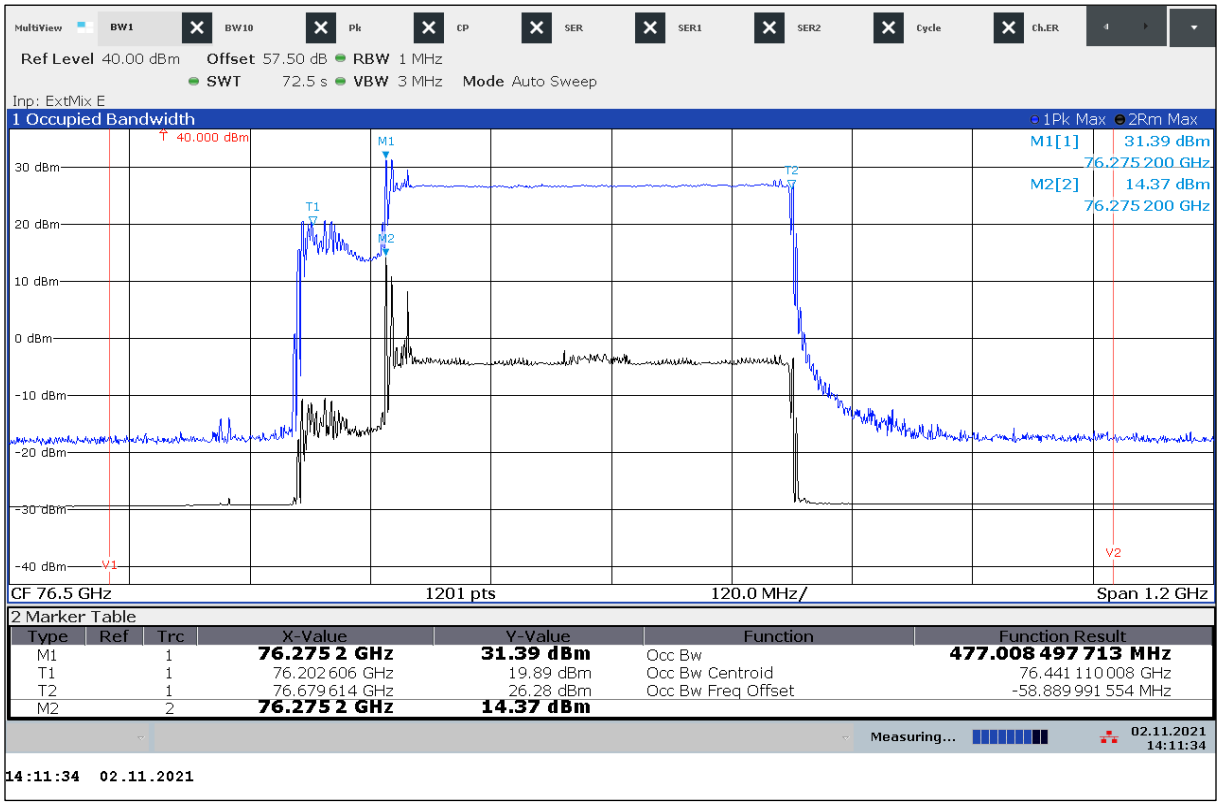
Plot 24: OBW, +30 °C / V_{nom}



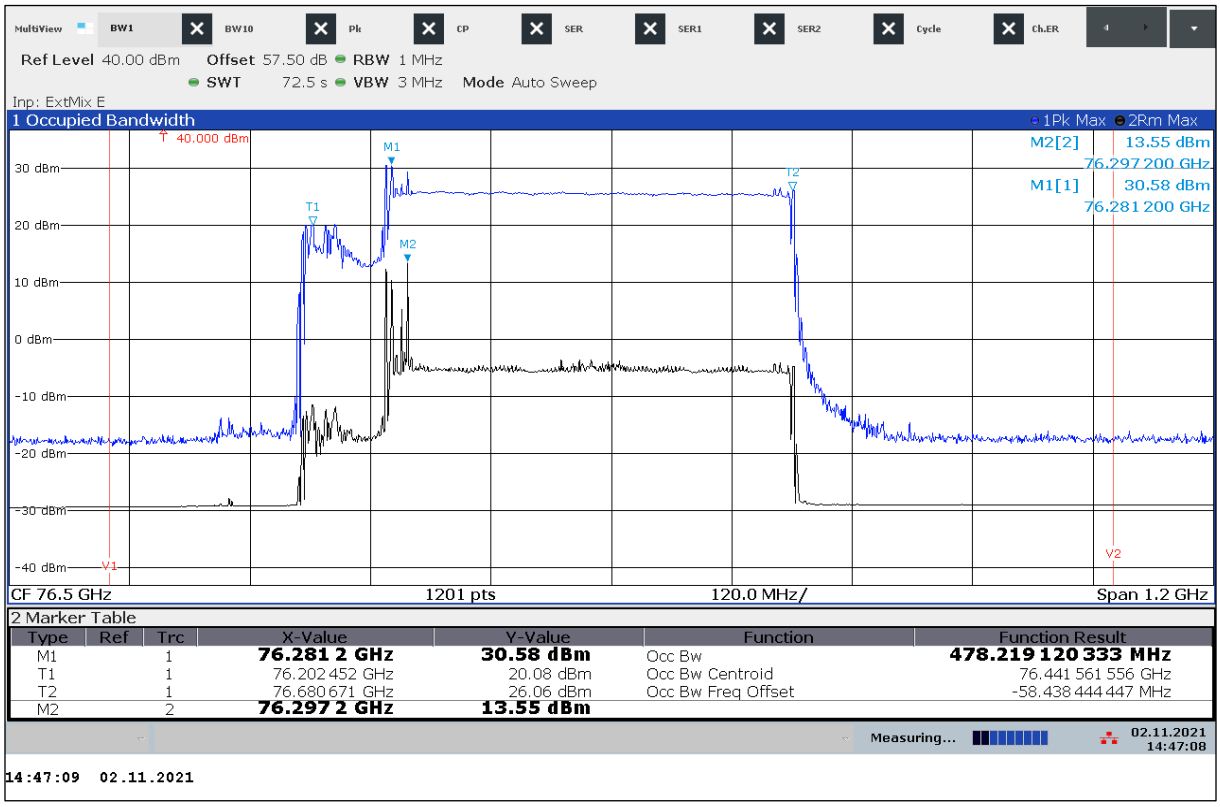
Plot 25: OBW, +40 °C / V_{nom}



Plot 26: OBW, +50 °C / V_{nom}



Plot 27: OBW, T_{max} / V_{nom}



12 Glossary

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

13 Document history

Version	Applied changes	Date of release
-/-	Initial release	2021-12-09

14 Accreditation Certificate – D-PL-12076-01-05

first page	last page

Note: The current certificate annex is published on the websites (link see below).

https://www.dakks.de/files/data/as/pdf/D-PL-12076-01-05e.pdf

or
https://ctcadvanced.com/app/uploads/2020/06/D-PL-12076-01-05_TCB_USA.pdf

END OF TEST REPORT