



TEST REPORT

Test report no.: 1-7426/18-07-02

Testing laboratory

CTC advanced GmbH

Untertuerkheimer Strasse 6 – 10

66117 Saarbruecken / Germany

Phone: + 49 681 5 98 - 0

Fax: + 49 681 5 98 - 9075

Internet: <https://www.ctcadvanced.com>

e-mail: mail@ctcadvanced.com

Accredited Testing Laboratory:

The testing laboratory (area of testing) is accredited according to DIN EN ISO/IEC 17025 (2018-03) by the Deutsche Akkreditierungsstelle GmbH (DAkkS)

The accreditation is valid for the scope of testing procedures as stated in the accreditation certificate starting with the registration number: D-PL-12076-01.

Applicant

ASTYX GmbH

Caroline-Herschel-Str. 2

85521 Ottobrunn / GERMANY

Phone: +49 (0) 89 201 804 0

Contact: Serhat Ay & Sigmund Ott

e-mail: serhat.ay@getcruise.com &

sigmund.ott@getcruise.com

Phone: +49 173 2127350 & +49 173 2112952

Manufacturer

ASTYX GmbH

Caroline-Herschel-Str. 2

85521 Ottobrunn / GERMANY

Test standard/s

CFR 47 Part 95, The 76-81 GHz Band Radar Service
Subpart M

CFR 47 Part 2, Frequency allocations and radio treaty matters; general rules and regulations
Subpart J

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

Test Item

Kind of test item: 77GHz Radar for Autonomous Drive Applications

Model name: HiRes 6455

FCC ID: 2ASKB-HIRES55V3P1

Frequency: 76 – 81 GHz

Antenna: Integrated patch antenna

Power supply: 10 V to 16 V DC

Temperature range: -20°C to +50°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:



Meheza Walla
Lab Manager
Radio Communications

Test performed:



Sebastian Janoschka
Lab Manager
Radio Communications

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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:	2020-12-02
Date of receipt of test item:	2020-12-16
Start of test:*	2021-01-25
End of test:*	2021-02-10
Person(s) present during the test:	-/-

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

2.3 Test laboratories sub-contracted

None

3 Test standard/s, references and accreditations

Test standard	Date	Description
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-12076-01-05.pdf

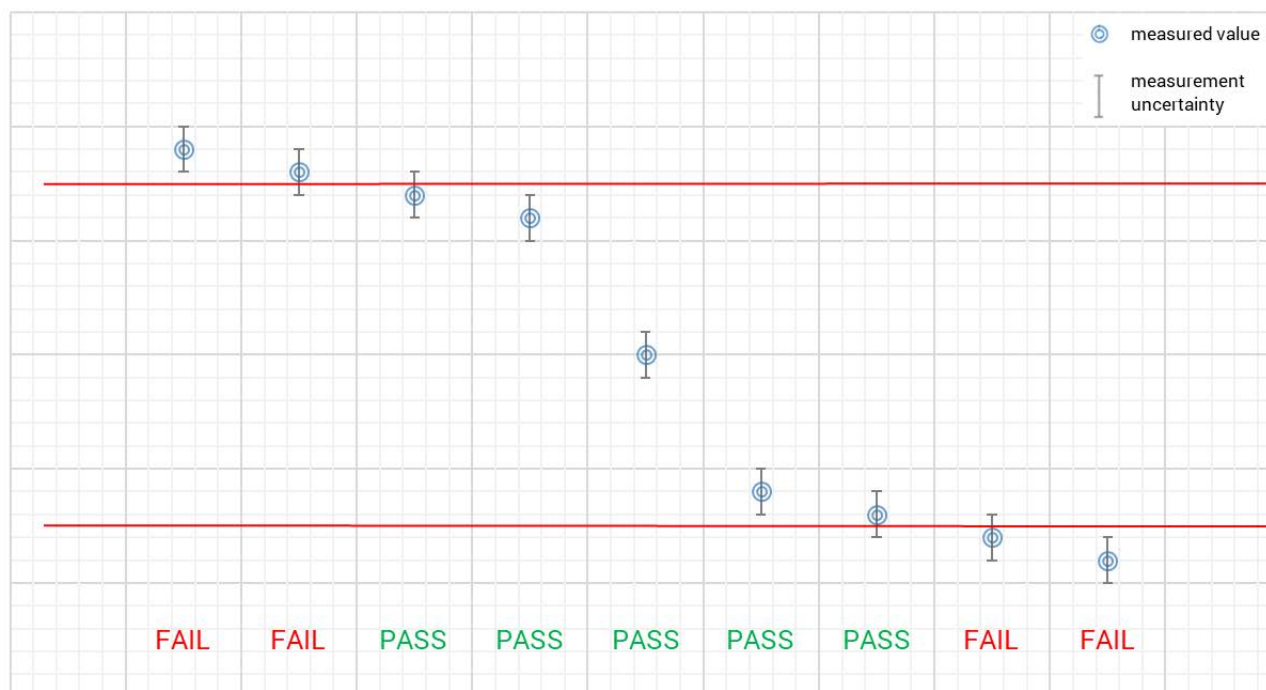


4 Reporting statements of conformity – decision rule

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."

measured value, measurement uncertainty, verdict



5 Test environment

Temperature	T_{nom}	+23 °C during room temperature tests
	T_{max}	+50 °C during high temperature tests
	T_{min}	-20 °C during low temperature tests
Relative humidity content		47 %
Barometric pressure		1019 hpa
Power supply	V_{nom}	12 V DC
	V_{max}	16 V
	V_{min}	10 V

6.1 General description

Kind of test item	:	77GHz Radar for Autonomous Drive Applications
Model name	:	HiRes 6455
S/N serial number	:	1104
Hardware status	:	ST 6455 1100B
Software status	:	SW 8.2.0 with Mode 3, 5 & 6
Frequency band	:	76 – 81 GHz
Type of modulation	:	FMCW
Number of channels	:	1
Antenna	:	Integrated patch antenna
Power supply	:	10 V to 16 V DC
Temperature range	:	-20°C to +50°C

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:

1-7426/18-07-01_AnnexA
1-7426/18-07-01_AnnexB
1-7426/18-07-01_AnnexD

Tests were performed on 3 modulations, Mode 3, Mode 5 and Mode 6

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).

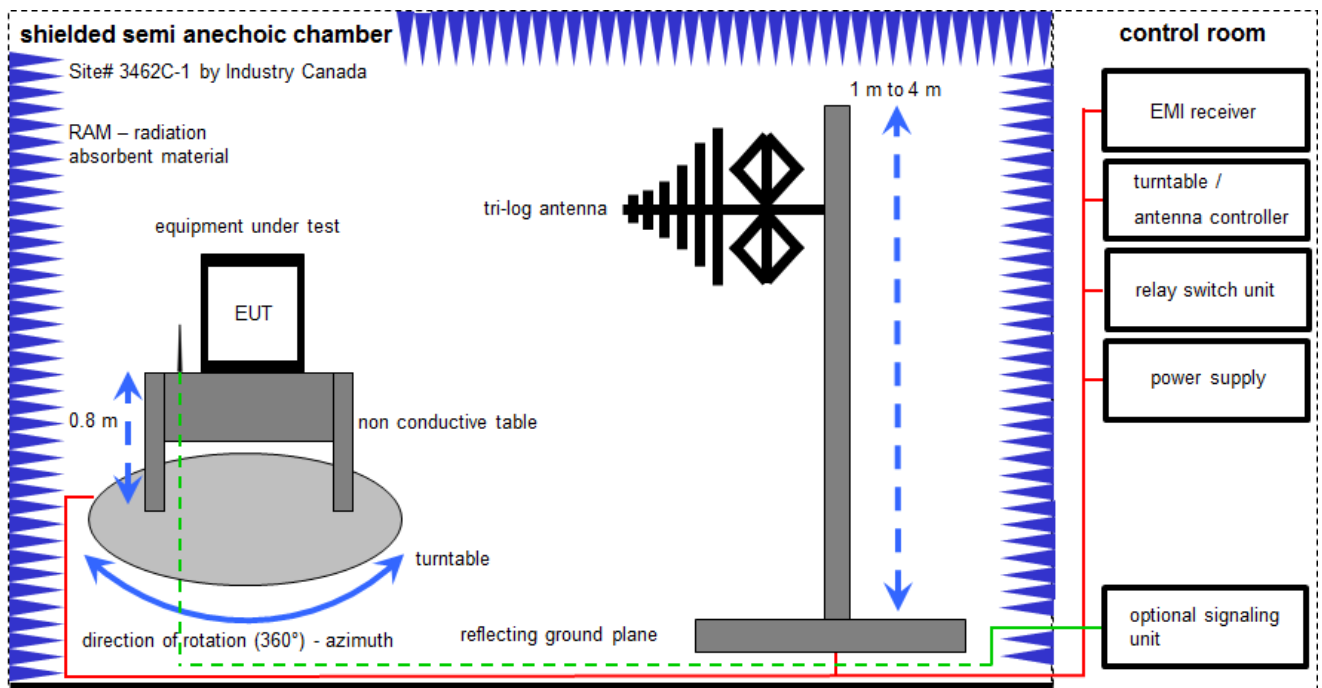
In order to simplify the identification of the equipment used at some special tests, some items of test equipment and ancillaries can be provided with an identifier or number in the equipment list below (Lab/Item).

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
vlk!	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)

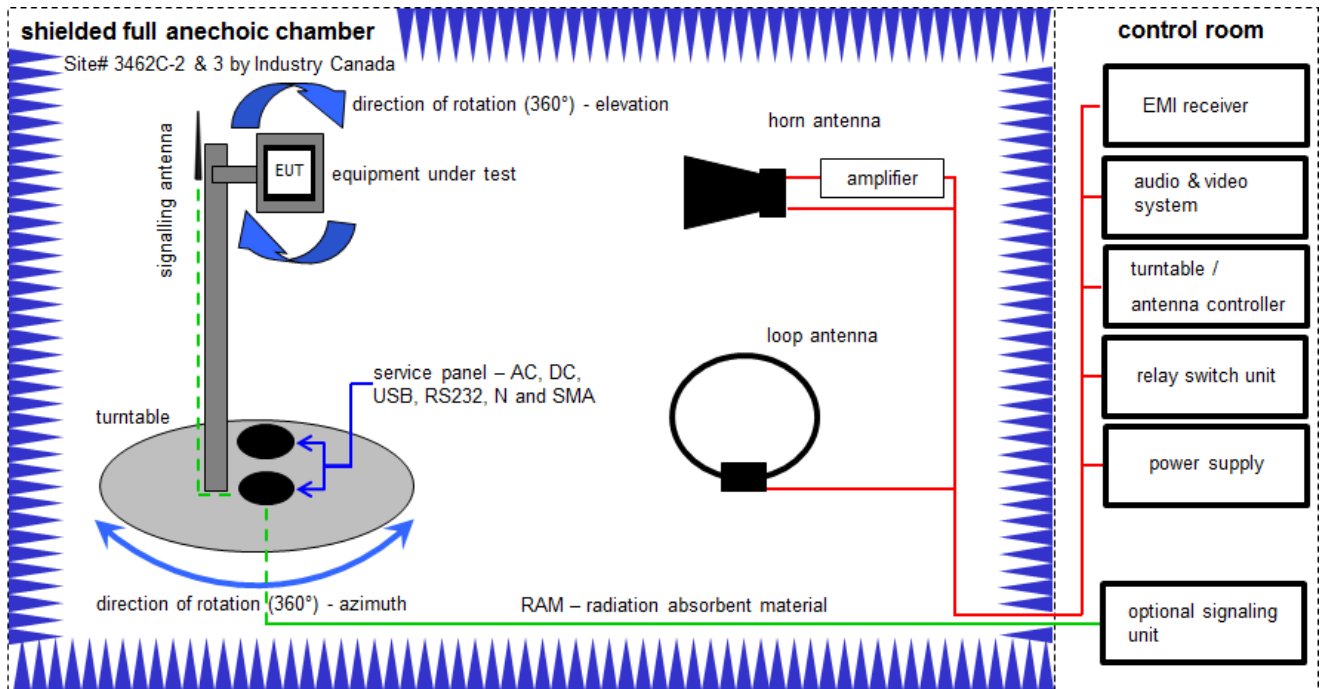
Example calculation:

$$FS \text{ [dB}\mu\text{V/m]} = 12.35 \text{ [dB}\mu\text{V/m]} + 1.90 \text{ [dB]} + 16.80 \text{ [dB/m]} = 31.05 \text{ [dB}\mu\text{V/m]} \text{ (35.69 } \mu\text{V/m)}$$

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.	Meßkabine 1	HF-Absorberhalle	MWB AG 300023		300000551	ne	-/-	-/-
4	n. a.	EMI Test Receiver	ESCI 3	R&S	100083	300003312	k	09.12.2020	08.12.2021
5	n. a.	Antenna Tower	Model 2175	ETS-Lindgren	64762	300003745	izw	-/-	-/-
6	n. a.	Positioning Controller	Model 2090	ETS-Lindgren	64672	300003746	izw	-/-	-/-
7	n. a.	Turntable Interface-Box	Model 105637	ETS-Lindgren	44583	300003747	izw	-/-	-/-
8	n. a.	TRILOG Broadband Test-Antenna 30 MHz - 3 GHz	VULB9163	Schwarzbeck Mess - Elektronik	295	300003787	vKII	19.02.2019	18.02.2021
9	n. a.	Switch-Unit	3488A	HP	2719A14505	300000368	ev	-/-	-/-
10	n. a.	EMI Test Receiver	ESR3	Rohde & Schwarz	102587	300005771	k	10.12.2020	09.06.2022

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:

$$FS \text{ [dB}\mu\text{V/m]} = 40.0 \text{ [dB}\mu\text{V/m]} + (-35.8) \text{ [dB]} + 32.9 \text{ [dB/m]} = 37.1 \text{ [dB}\mu\text{V/m]} (71.61 \mu\text{V/m})$$

$$OP = AV + D - G + CA$$

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

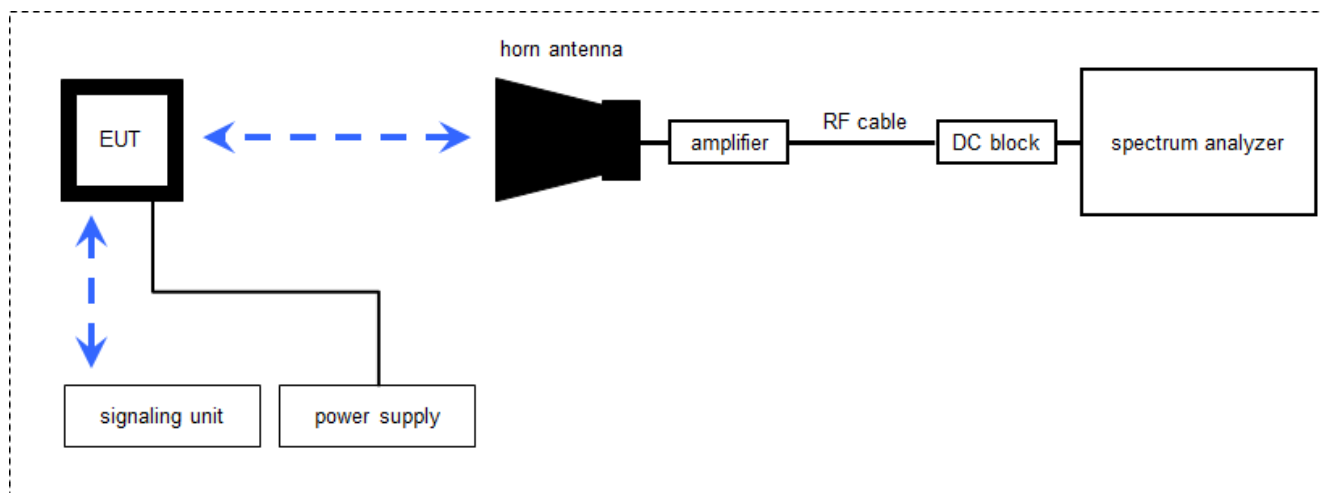
Example calculation:

$$OP \text{ [dBm]} = -39.0 \text{ [dBm]} + 57.0 \text{ [dB]} - 12.0 \text{ [dBi]} + (-36.0) \text{ [dB]} = -30 \text{ [dBm]} (1 \mu\text{W})$$

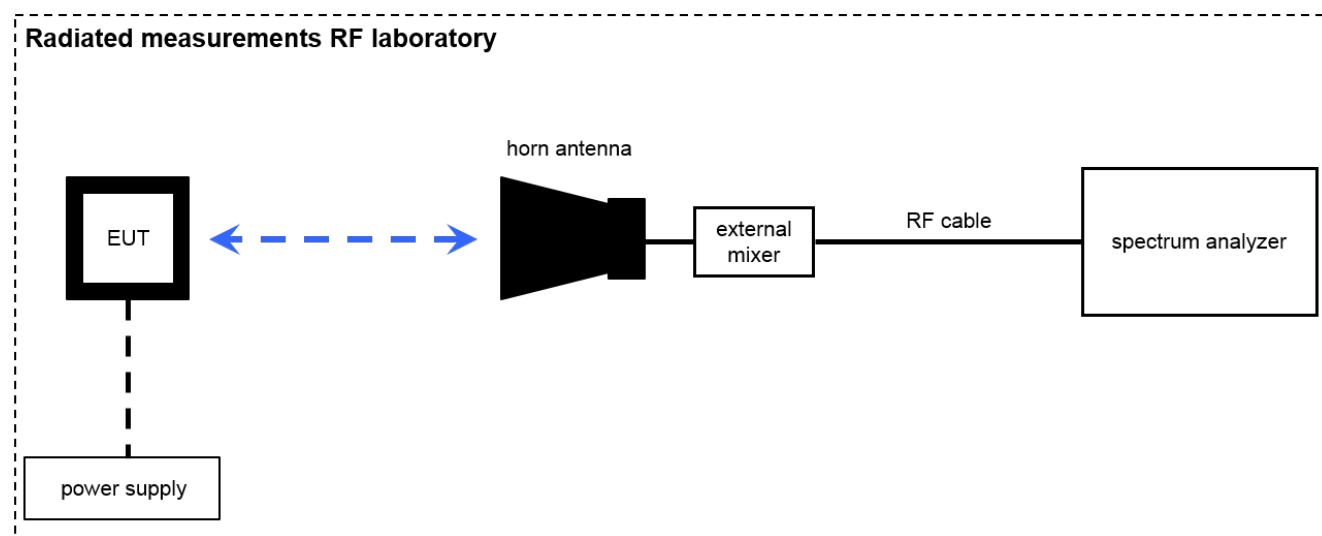
Equipment table:

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	vKI!	09.12.2020	08.12.2023
2	n. a.	Active Loop Antenna 9 kHz to 30 MHz	6502	EMCO	2210	300001015	vKI!	13.06.2019	12.06.2021
3	n. a.	Anechoic chamber	FAC 3/5m	MWB / TDK	87400/02	300000996	ev	-/-	-/-
4	n. a.	Double-Ridged Waveguide Horn Antenna 1-18.0GHz	3115	EMCO	9107-3697	300001605	vKI!	27.12.2019	26.02.2021
5	n. a.	Switch / Control Unit	3488A	HP	*	300000199	ne	-/-	-/-
6	n. a.	Variable isolating transformer	MPL IEC625 Bus Variable isolating transformer	Erfi	91350	300001155	ne	-/-	-/-
7	n. a.	EMI Test Receiver 20Hz- 26,5GHz	ESU26	R&S	100037	300003555	k	11.12.2020	10.12.2021
8	n. a.	Highpass Filter	WHKX7.0/18G-8SS	Wainwright	19	300003790	ne	-/-	-/-
9	n. a.	Broadband Amplifier 0.5-18 GHz	CBLU5184540	CERNEX	22049	300004481	ev	-/-	-/-
10	n. a.	Broadband Amplifier 5-13 GHz	CBLU5135235	CERNEX	22010	300004491	ev	-/-	-/-
11	n. a.	4U RF Switch Platform	L4491A	Agilent Technologies	MY50000037	300004509	ne	-/-	-/-
12	n. a.	NEXIO EMV-Software	BAT EMC V3.16.0.49	EMCO		300004682	ne	-/-	-/-
13	n. a.	PC	ExOne	F+W		300004703	ne	-/-	-/-
14	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:

$$OP \text{ [dBm]} = -54.0 \text{ [dBm]} + 64.0 \text{ [dB]} - 20.0 \text{ [dBi]} = -10 \text{ [dBm]} \text{ (100 } \mu\text{W)}$$

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	vKI!	18.02.2019	17.02.2022
2	n. a.	Std. Gain Horn Antenna 18.0-26.5 GHz	638	Narda		300000486	vKI!	21.01.2020	20.01.2022
3	n. a.	Std. Gain Horn Antenna 26.5-40.0 GHz	V637	Narda	82-16	300000510	vKI!	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.	Standard Gain Horn 325-500 GHz	570240-20 1785-2a	Flann	273569	300006097	ev	25.05.2020	24.05.2022
13	n. a.	Broadband LNA 18-50 GHz	CBL18503070PN	CERNEX	25240	300004948	ev	09.03.2020	08.03.2022
14	n. a.	Harmonic Mixer 3-Port, 50-75 GHz	FS-Z75	Rohde & Schwarz	101578	300005788	k	17.06.2020	16.06.2021
15	n. a.	Harmonic Mixer 3-Port, 60-90 GHz	FS-Z90	R&S	101555	300004691	k	08.07.2020	07.07.2021
16	n. a.	Harmonic Mixer 3-Port, 75-110 GHz	FS-Z110	R&S	101411	300004959	k	19.06.2020	18.06.2021
17	n.a.	Harmonic Mixer 3-port, 90-140 GHz	FS-Z140	Rohde & Schwarz	101119	300005581	k	09.07.2020	08.07.2021
18	n. a.	Harmonic Mixer 3-Port, 110-170 GHz	FS-Z170	Radiometer Physics GmbH	100014	300004156	k	28.05.2020	27.05.2021
19	n. a.	Harmonic Mixer 3-Port, 140-220 GHz	SAM-220	Radiometer Physics GmbH	200001	300004157	k	14.07.2020	13.07.2021
20	n. a.	Harmonic Mixer 3-Port, 220-325 GHz	SAM-325	Radiometer Physics GmbH	100002	300004158	k	23.07.2020	22.07.2021
21	n.a.	Harmonic Mixer 325-500GHz	FS-Z500	Radiometer Physics GmbH	101016	300006096	k	25.05.2020	24.05.2021
22	n. a.	Spectrum Analyzer 2 Hz - 85 GHz	FSW85	R&S	101333	300005568	k	17.06.2020	16.06.2021
23	n. a.	Spectrum Analyzer	FSW50	Rohde & Schwarz	101332	300005935	k	26.02.2020	25.02.2021
24	n.a.	Std. Gain Horn Antenna 90-140 GHz	COR 90_140	Thomson CSF		300000799	ev	-/-	-/-
25	n.a.	F-Band Positive Amplitude Detector	SFD-903144-08SF-P1	Sage Millimeter Inc.	07354-1	300006119	ev	-/-	-/-
26	n.a.	SG Extension Module 110 - 170 GHz	E8257DV06	VDI	US53250018	300005540	ev	-/-	-/-
27	n.a.	Std. Gain Horn Antenna 114-173 GHz	2924-20	Flann	*	300001999	ne	-/-	-/-
28	n.a.	Synthesized Sweeper 10 MHz - 40 GHz	83640A	HP	3119A00458	300002266	vKI!	13.12.2019	12.12.2021
29	n.a.	2.5 GHz Digital Phosphor Oscilloscope	DPO7254	Tektronix	B022702	300003573	vKI!	07.12.2020	06.12.2022

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 $\pm 45^\circ$ 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.

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.

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 18 GHz)	± 1 dB
Radiated unwanted emissions in the spurious domain (up to 18 GHz)	± 3 dB
Conducted unwanted emissions in the spurious domain (18 to 40 GHz)	± 4 dB
Radiated unwanted emissions in the spurious domain (18 to 40 GHz)	± 4 dB
Conducted unwanted emissions in the spurious domain (40 to 50 GHz)	± 4.5 dB
Radiated unwanted emissions in the spurious domain (40 to 50 GHz)	± 4.5 dB
Conducted unwanted emissions in the spurious domain (above 50 GHz)	± 5 dB
Radiated unwanted emissions in the spurious domain (above 50 GHz)	± 5 dB
DC and low frequency voltages	± 3 %
Temperature	± 1 °C
Humidity	± 3 %

10 Far field consideration for measurements above 18 GHz

Far field distance calculation:

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

with

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

Spurious emission measurements:

Antenna frequency range in GHz	Highest measured frequency in GHz	D in cm	λ in cm	D_{ff} in cm
18-26	26	3.4	1.15	20.04
26-40	40	2.2	0.75	12.91
40-50	50	2.77	0.60	25.58
50-75	75	1.85	0.40	17.11
75-110	110	1.24	0.27	11.28
90-140	140	1.02	0.22	9.72
110-170	170	0.85	0.18	8.19
140-220	220	0.68	0.14	6.78
220-325	325	0.43	0.09	4.01
325-500	500	0.26	0.06	2.22

11 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	2021-02-12	-/-

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 Extreme	Nominal 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.

12 Measurement results

12.1 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:	Pos-Peak / RMS
Sweep time:	Pulse repetition time x pts
Resolution bandwidth:	1 MHz
Video bandwidth:	3 MHz
Trace-Mode:	Max Hold

Limits:

FCC §95.3367 (a) (b)

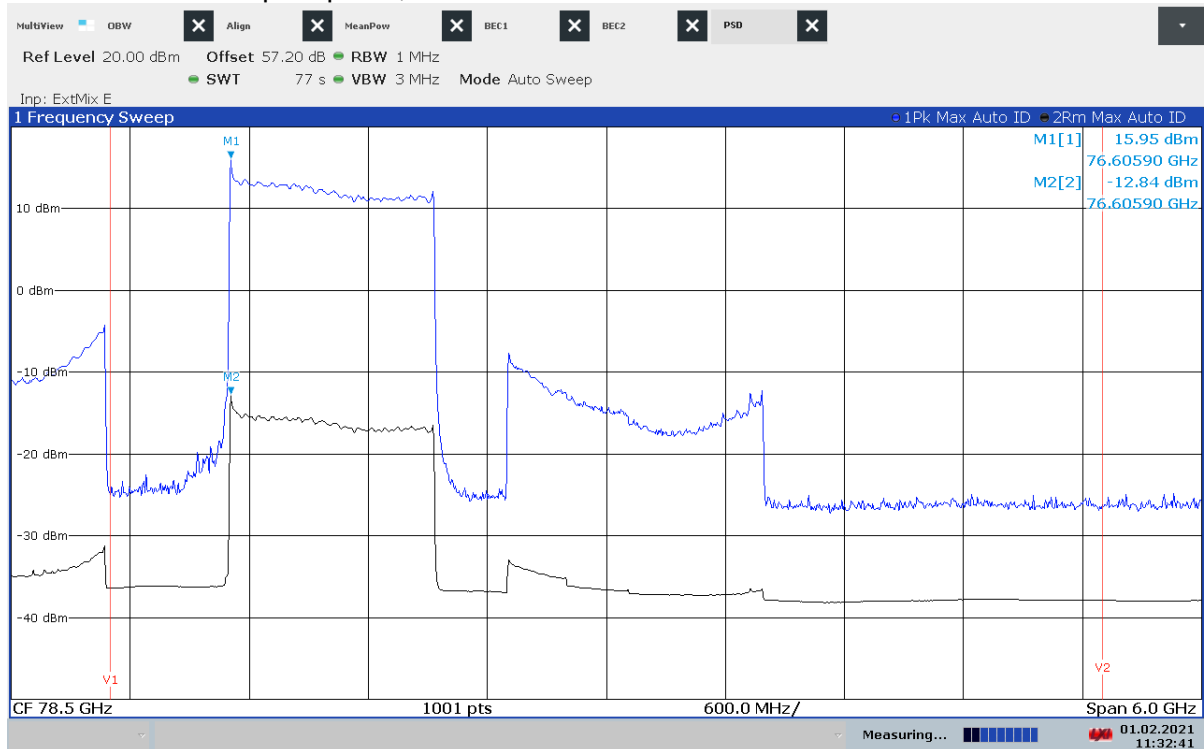
Frequency	Measurement distance	EIRP
76.0 - 81.0 GHz	3.0 m	$88 \mu\text{W}/\text{cm}^2 \rightarrow 50 \text{ dBm (Average)}$ $279 \mu\text{W}/\text{cm}^2 \rightarrow 55 \text{ dBm (PEAK)}$

Measurement results:

Mode	Radiated peak power (eirp) [dBm]	Power spectral density [dBm/MHz]	Channel power [dBm]
Mode 3	15.95	-12.84	13.71
Mode 5	14.51	-17.50	12.76
Mode 6	15.45	-14.54	16.11

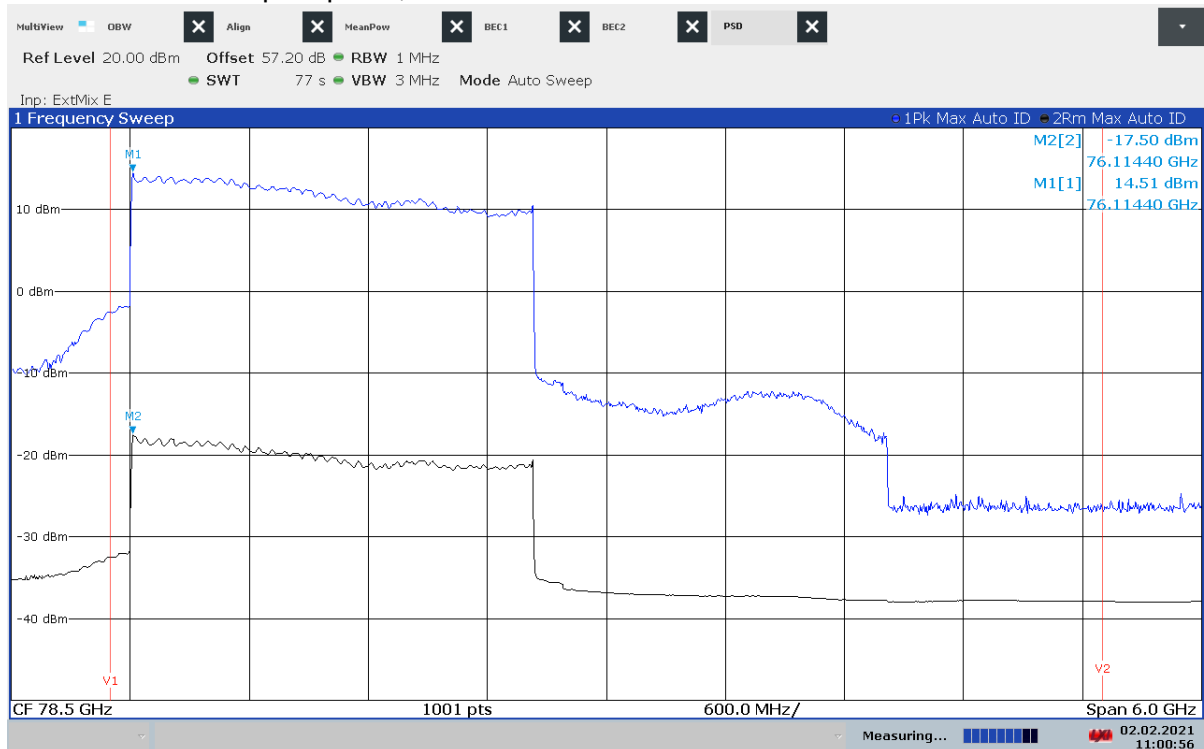
Note: Voltage variation does not affect the radiated signal

Plot 1: Mode 3 – Radiated peak power, PSD



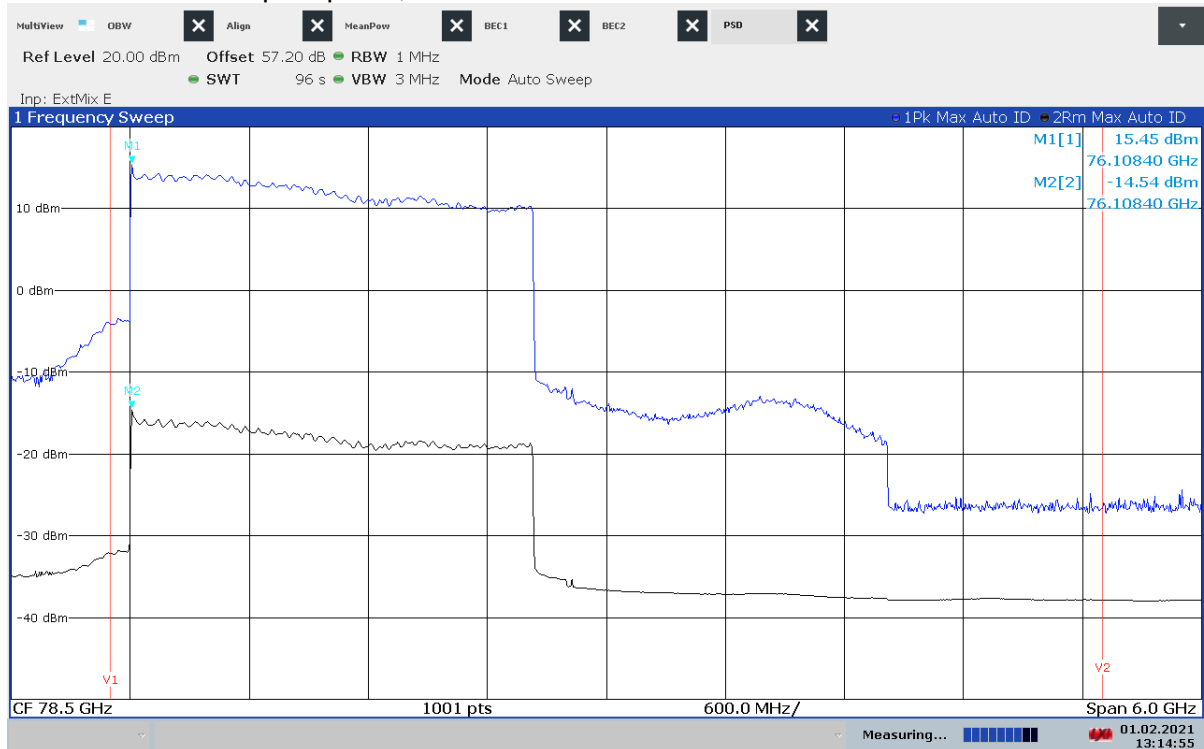
11:32:41 01.02.2021

Plot 2: Mode 5 – Radiated peak power, PSD



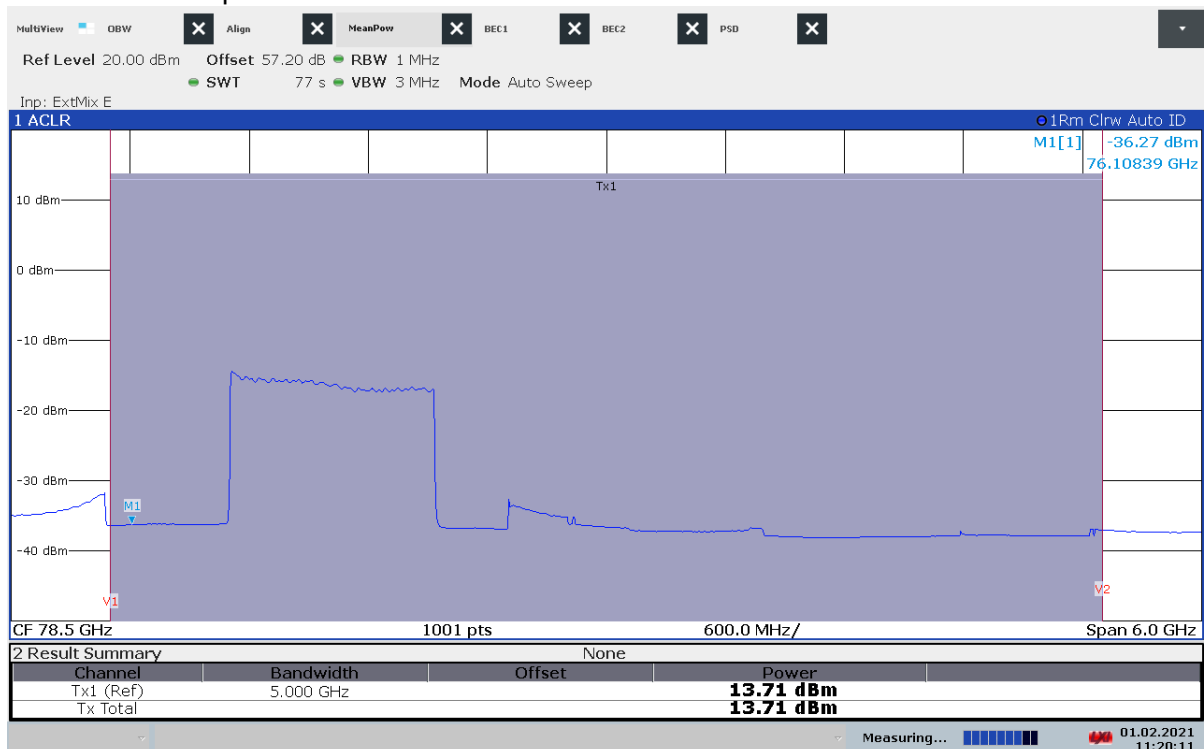
11:00:56 02.02.2021

Plot 3: Mode 6 – Radiated peak power, PSD



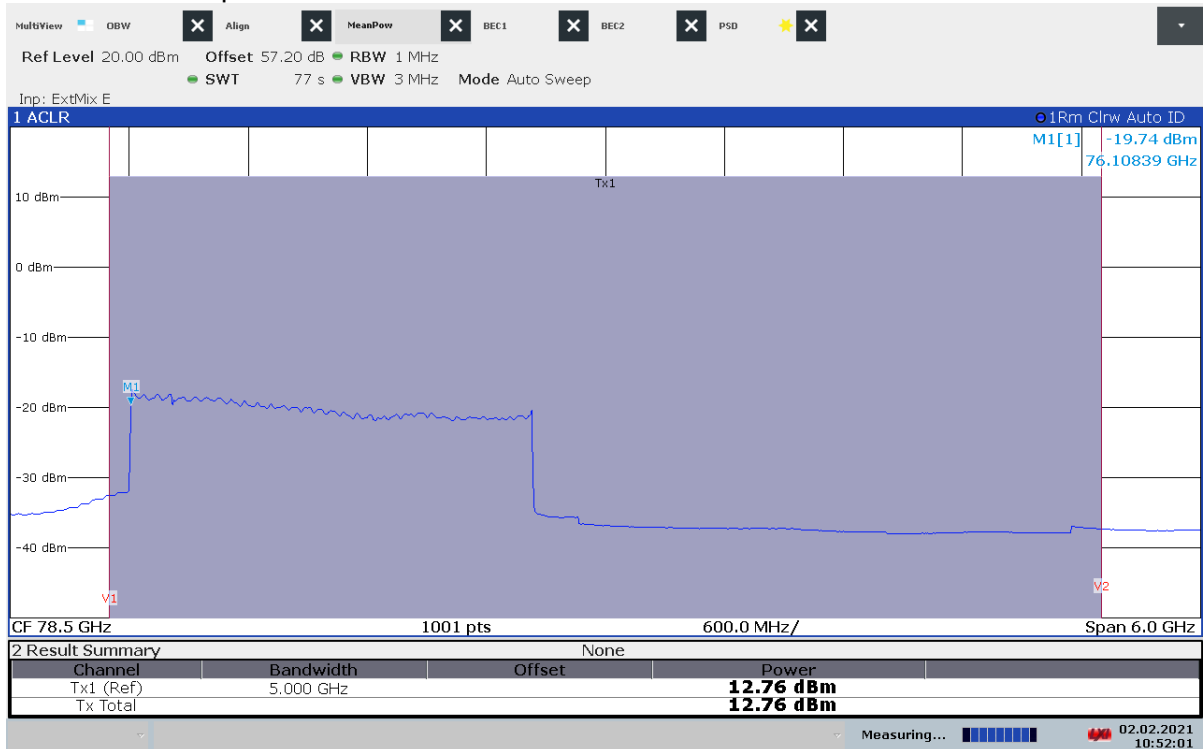
13:14:56 01.02.2021

Plot 4: Mode 3 – Mean power



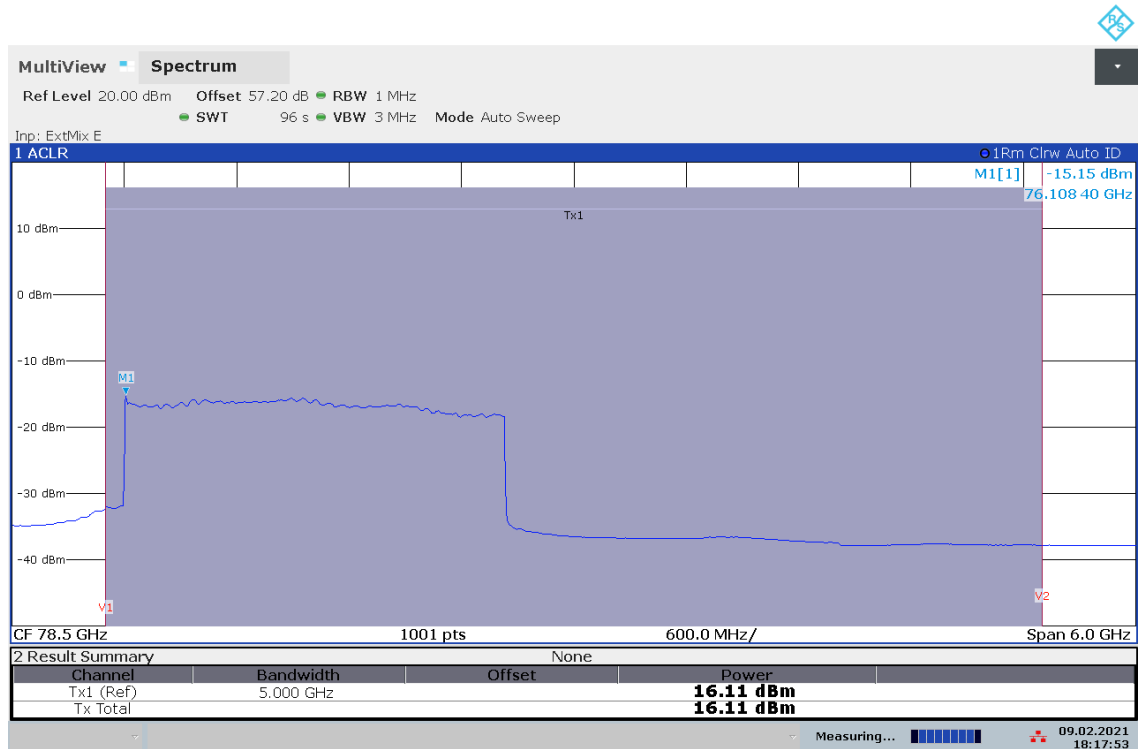
11:20:11 01.02.2021

Plot 5: Mode 5 – Mean power



10:52:01 02.02.2021

Plot 6: Mode 6 – Mean power



18:17:53 09.02.2021

12.2 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:

Parameter	Mode 3	Mode 5	Mode 6
Duty Cycle %	15.5	9.2	18.4
Timing RF on (ms)	12.0	12.0	23.9
Timing RF off (ms)	65.0	118.0	106.1
Power	Constant during RF on	Constant during RF on	Constant during RF on
Steepness of Ramps (GHz/s)	24414.1	24414.1	24414.1
Calibration	N/A	N/A	N/A
Antenna Beam Steering (Tx)	No	No	No
Characteristic	Linear FMCW	Linear FMCW	Linear FMCW
Sweep Bandwidth (GHz)	1	1	2
Sweep Rate (kHz)	21.4	10.7	10.7
Sweep Time (us)	42.4	83.3	83.3

12.3 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:	Pulse repetition time x pts
Resolution bandwidth:	1 MHz
Video bandwidth:	3 MHz
Trace-Mode:	Max Hold
Measurement uncertainty	Span/1000

Limits:

FCC §95.3379 (b)

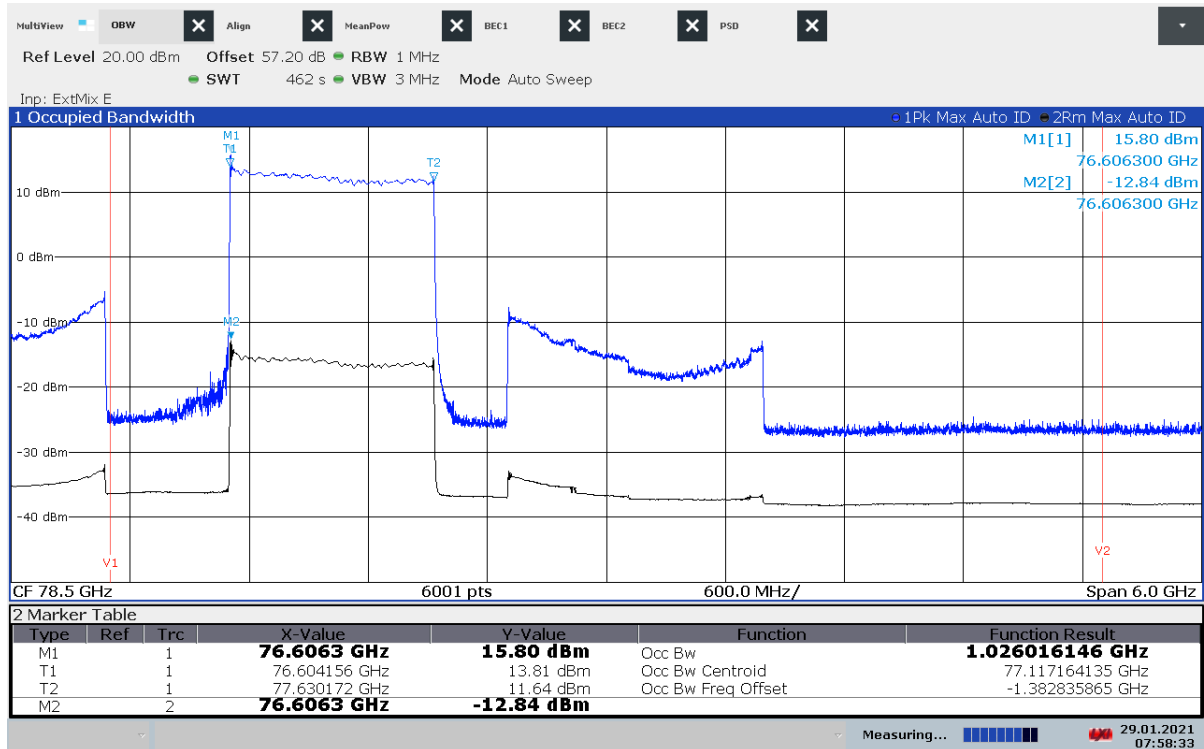
Frequency range	f(lowest) > 76.0 GHz	f(highest) < 81.0 GHz
-----------------	----------------------	-----------------------

Measurement results:

Mode	Operating Frequency Range		
	f _L [GHz]	f _H [GHz]	OBW [MHz]
Mode 3	76.6041	77.6301	1026.0
Mode 5	76.1042	78.1234	2019.1
Mode 6	76.1044	78.1229	2018.5

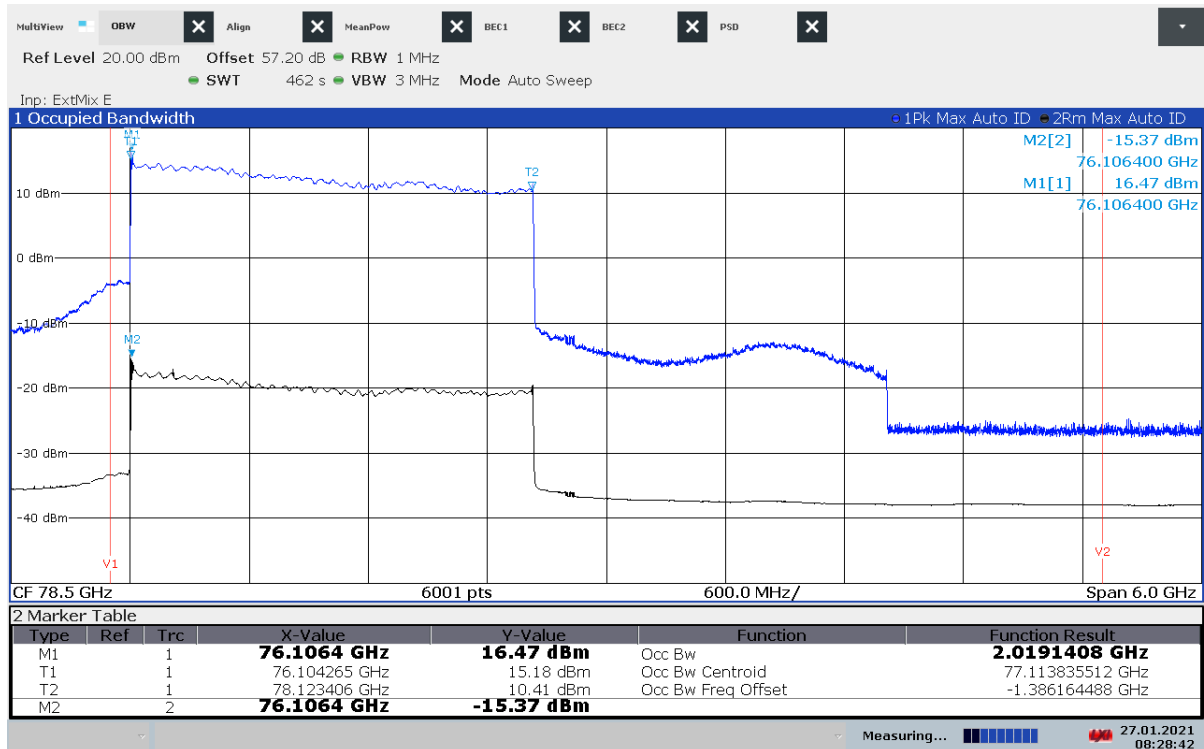
Note: Voltage variation does not affect the radiated signal

Plot 7: Mode 3 – OBW



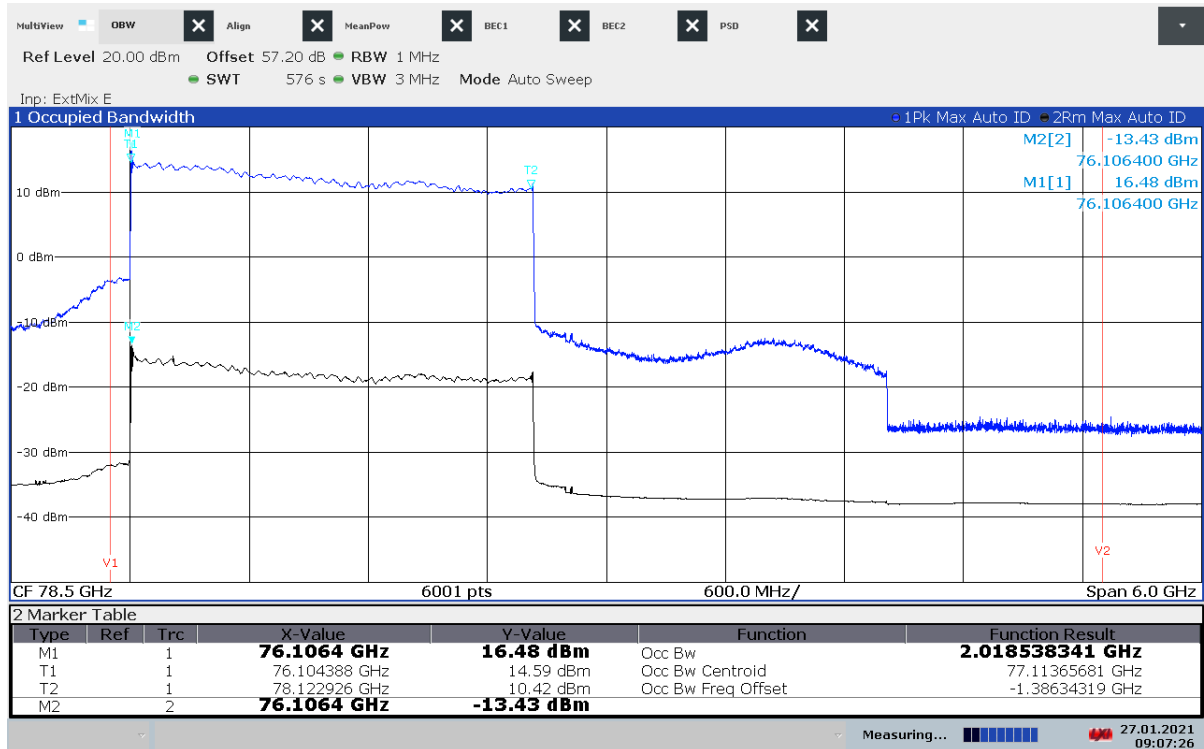
07:58:34 29.01.2021

Plot 8: Mode 5 – OBW



08:28:42 27.01.2021

Plot 9: Mode 6 – OBW



09:07:27 27.01.2021

12.4 Band edge compliance

Description:

Investigation of the emission limits at the band edge.

Measurement:

Parameters	
Detector:	RMS
Sweep time:	100 s
Resolution bandwidth:	1 MHz
Video bandwidth:	3 MHz
Trace-Mode:	Max Hold

Limits:

FCC §95.3379 (a) (2) (i) + (ii) / ANSI C63.10-2013 / 6.10

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

Limits:

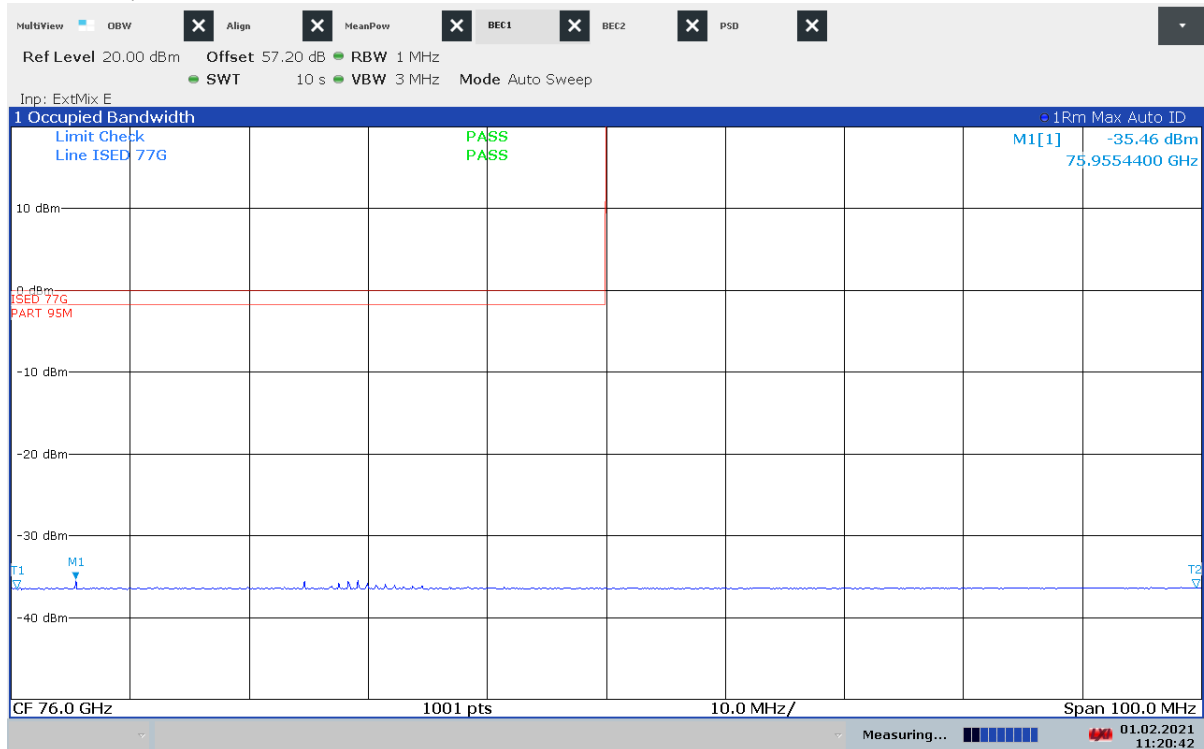
FCC §95.3379 (b)

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

Measurement results:

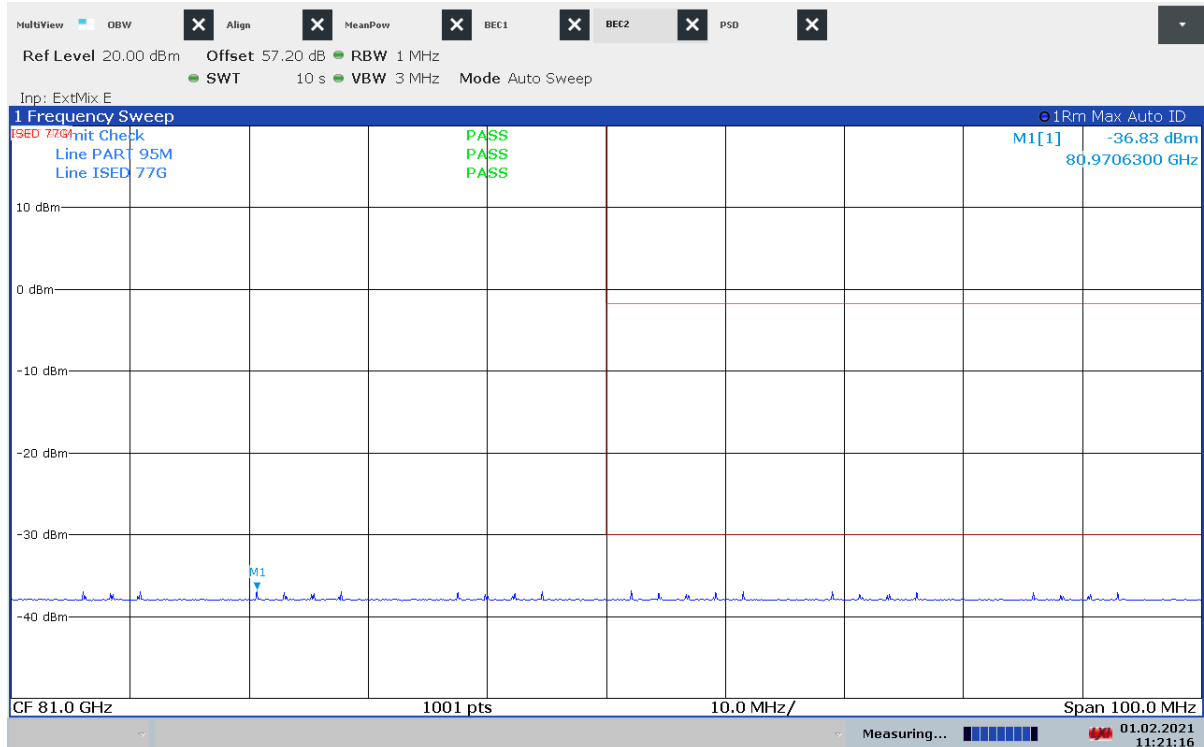
See plots below, EUT complies

Plot 10: Mode 3, BEC



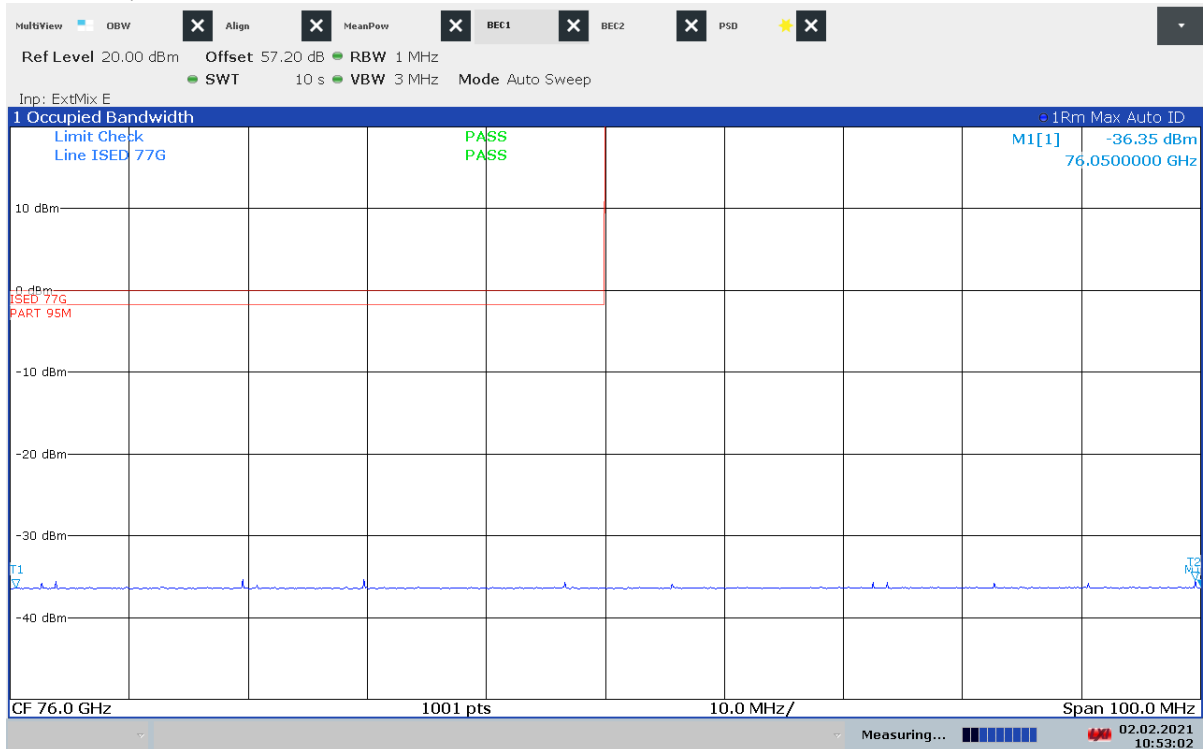
11:20:43 01.02.2021

Plot 11: Mode 3, BEC



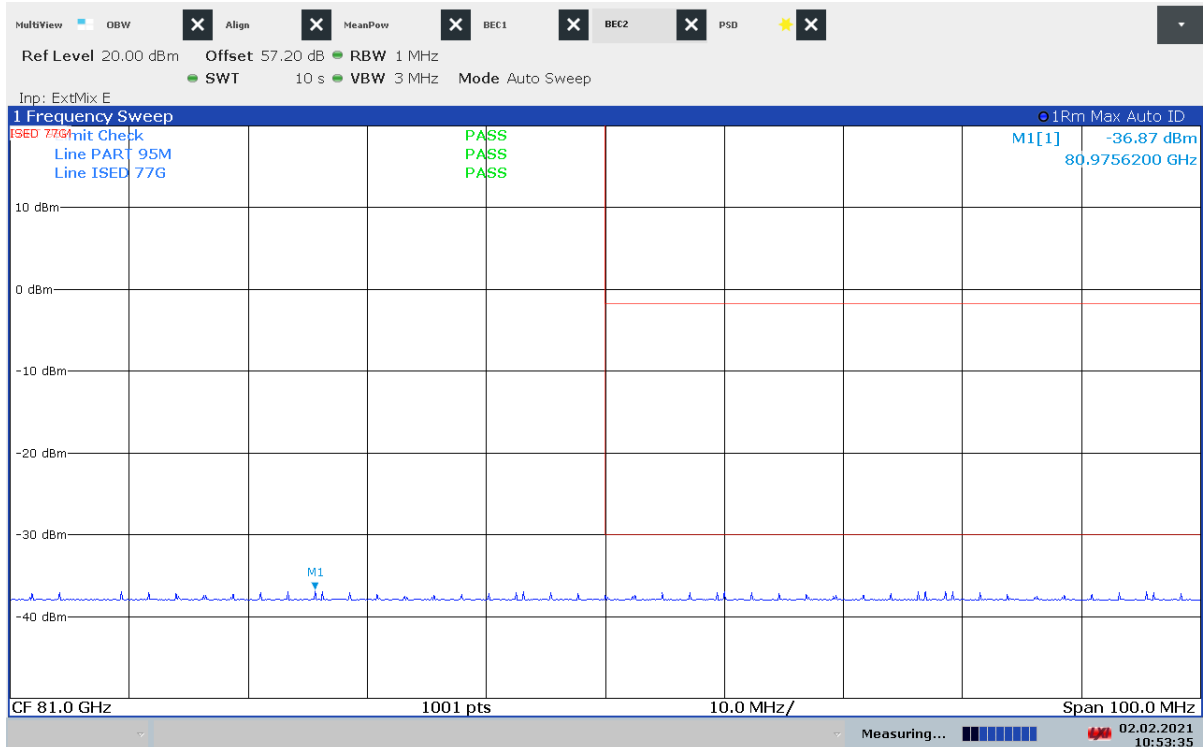
11:21:16 01.02.2021

Plot 12: Mode 5, BEC



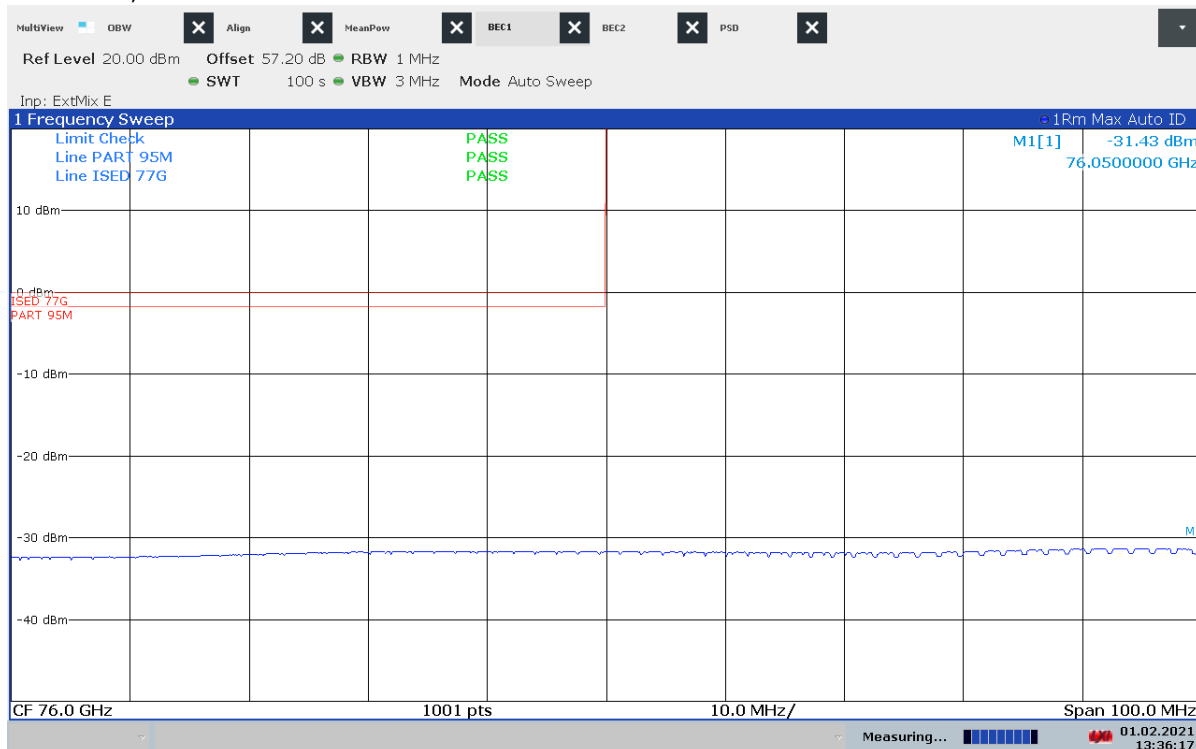
10:53:02 02.02.2021

Plot 13: Mode 5, BEC



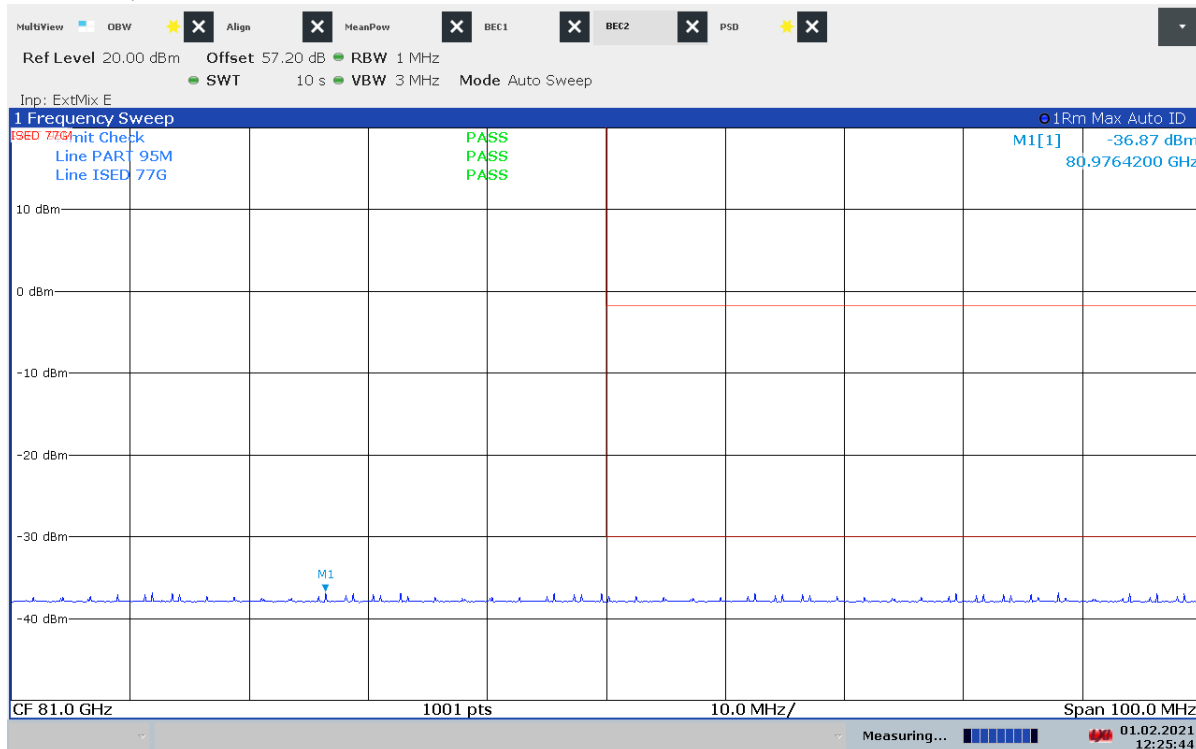
10:53:35 02.02.2021

Plot 14: Mode 6, BEC



13:36:18 01.02.2021

Plot 15: Mode 6, BEC



12:25:45 01.02.2021

12.5 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:

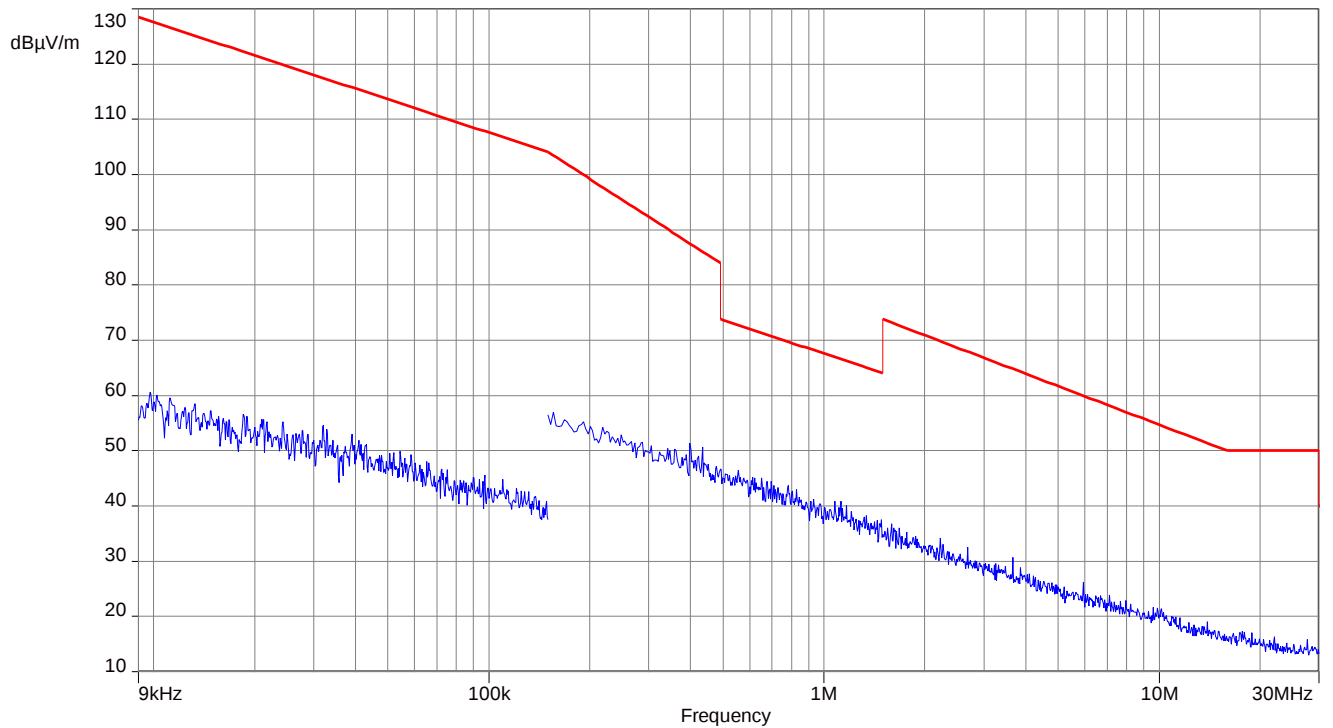
FCC §95.3379 (a) (2) (i) + (ii)

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

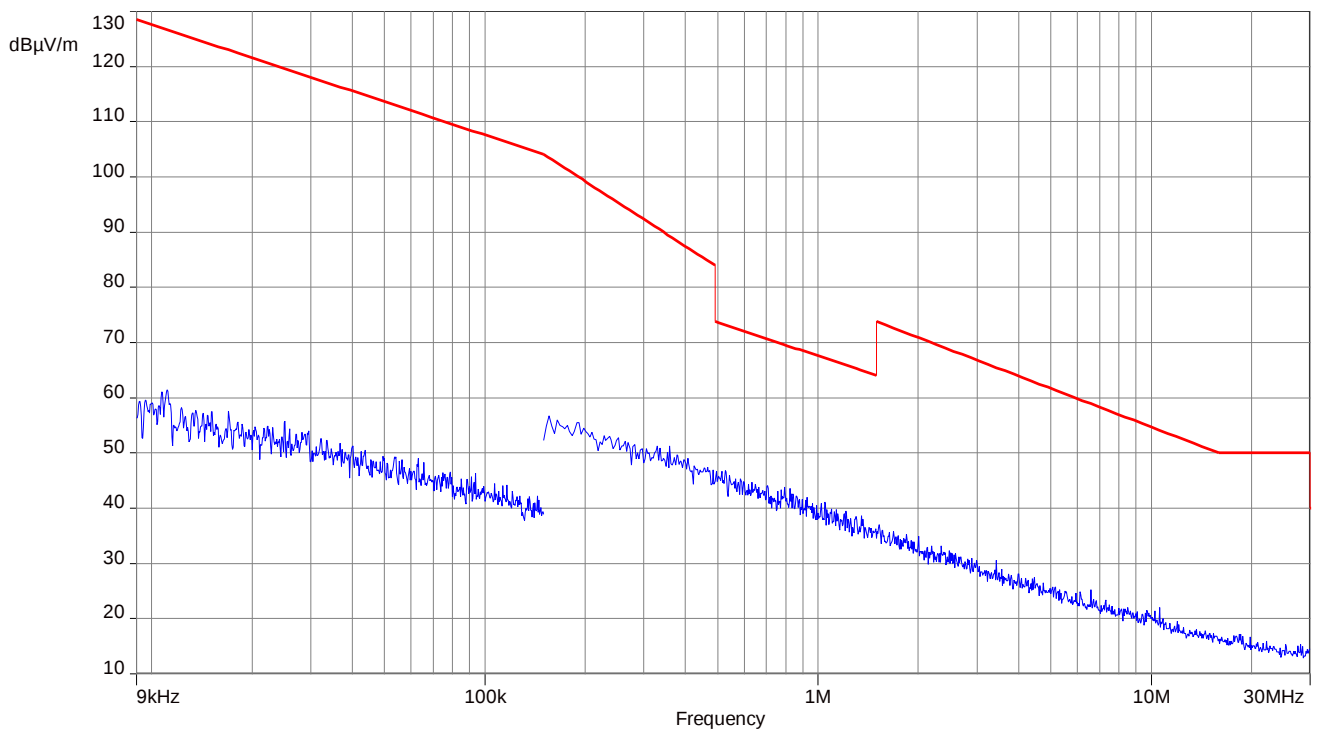
Measurement results:

Frequency	Detector	Bandwidth	Level [dB μ V]	Distance [m]	Limit [dB μ V]	Margin [dB]
250 MHz – Mode 5	QPK	120 kHz	12.35	10	36	23.7
300 MHz – Mode 5	QPK	120 kHz	9.54	10	36	26.5
38.6 GHz – Mode 3	AVG	1 MHz	50.29	3	54	3.7
39.0 GHz – Mode 5	AVG	1 MHz	48.1	3	54	5.9
39.0 GHz – Mode 6	AVG	1 MHz	50.1	3	54	3.9

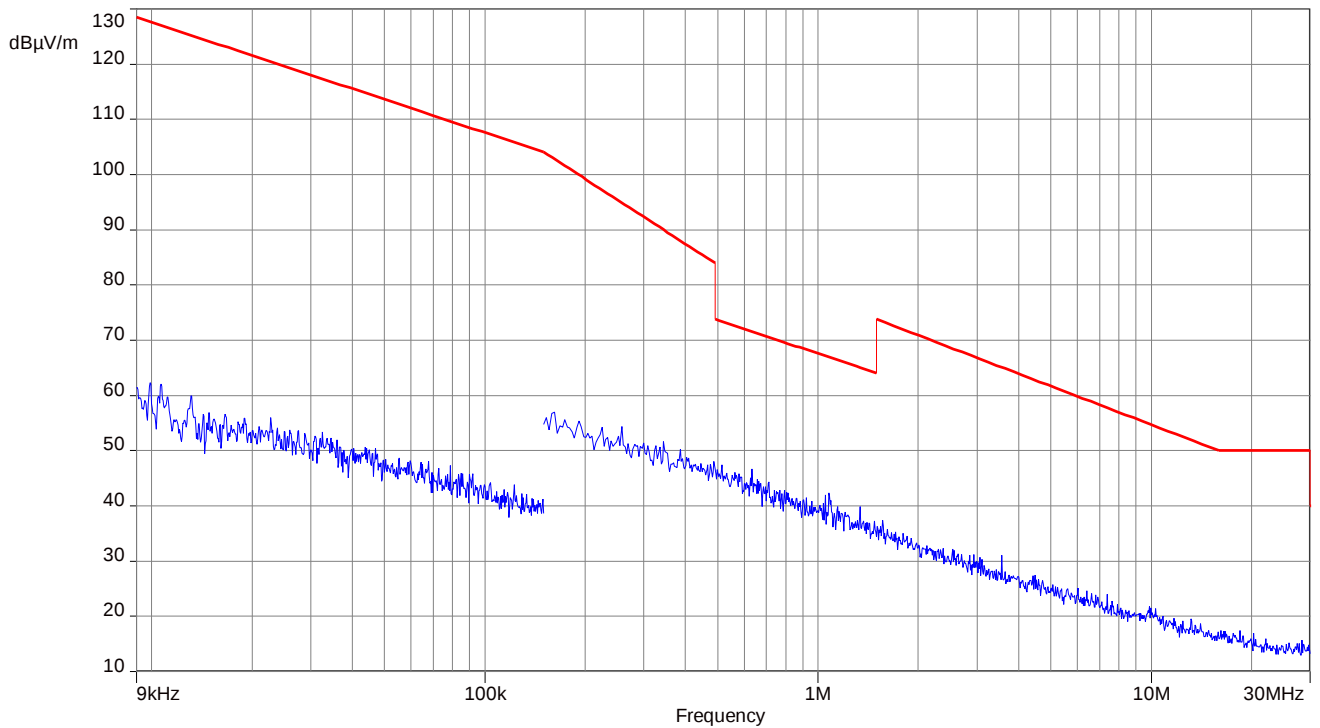
Plot 16: 9 kHz – 30 MHz, Magnetic antenna, Mode 3



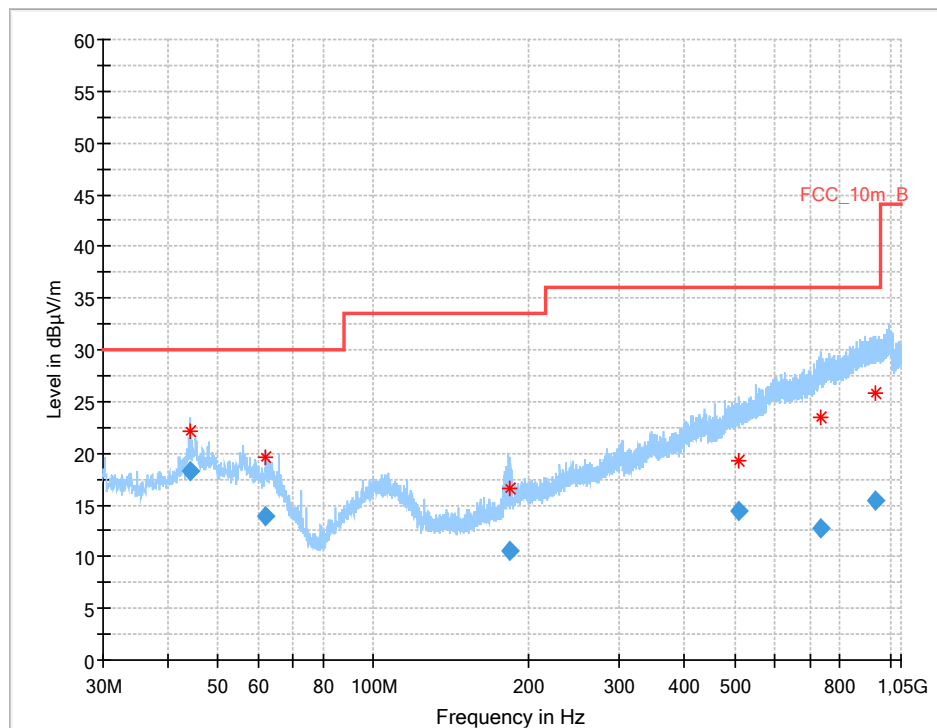
Plot 17: 9 kHz – 30 MHz, Magnetic antenna, Mode 5



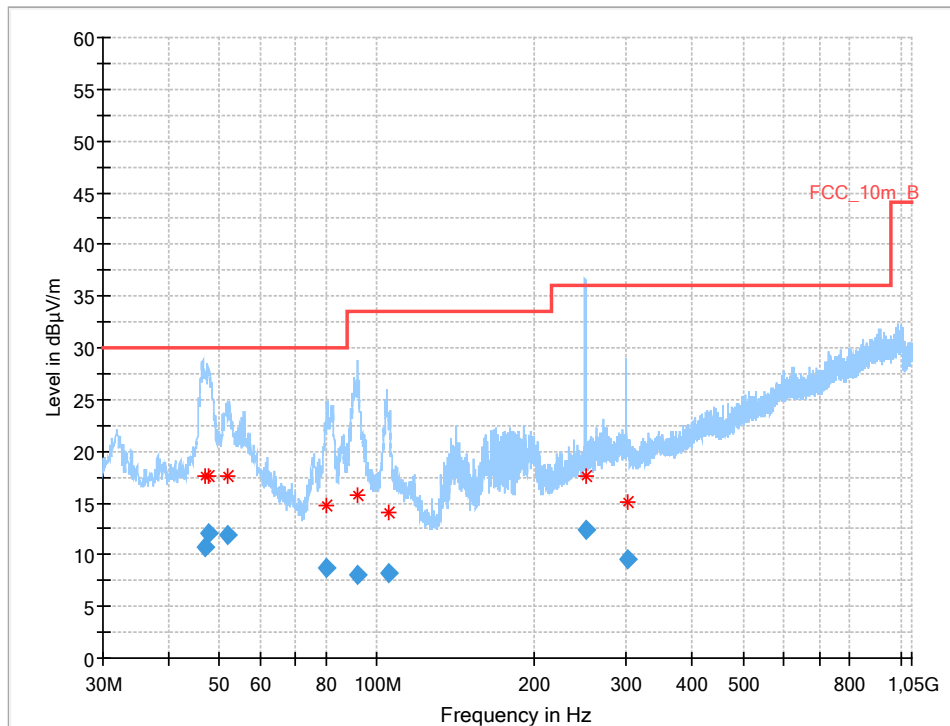
Plot 18: 9 kHz – 30 MHz, Magnetic antenna, Mode 6



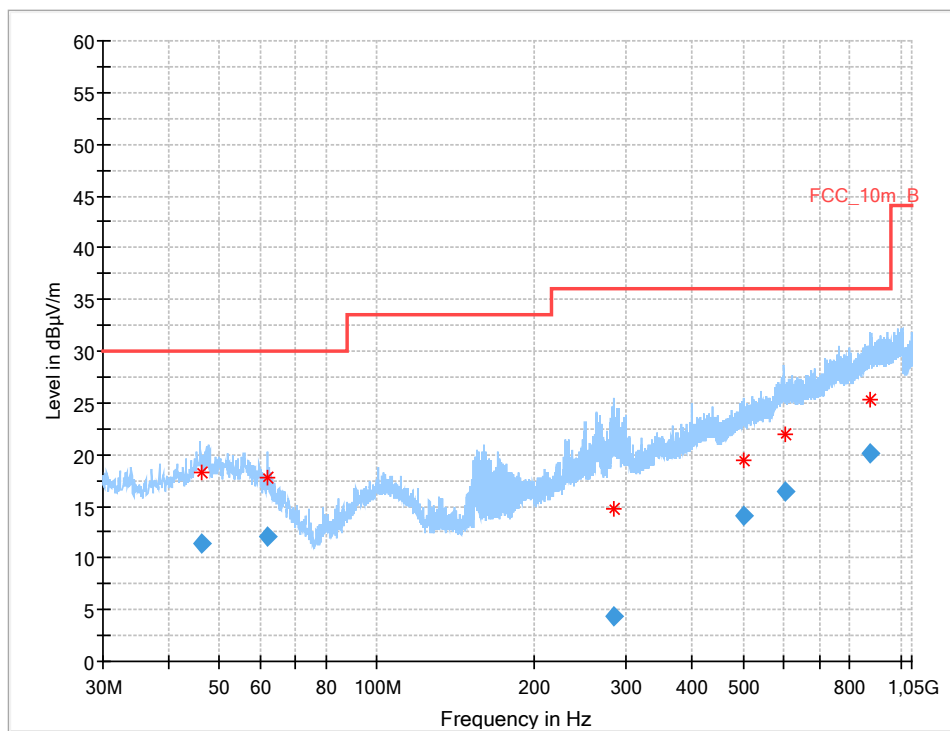
Plot 19: 30 MHz – 1 GHz, vertical / horizontal polarization, Mode 3



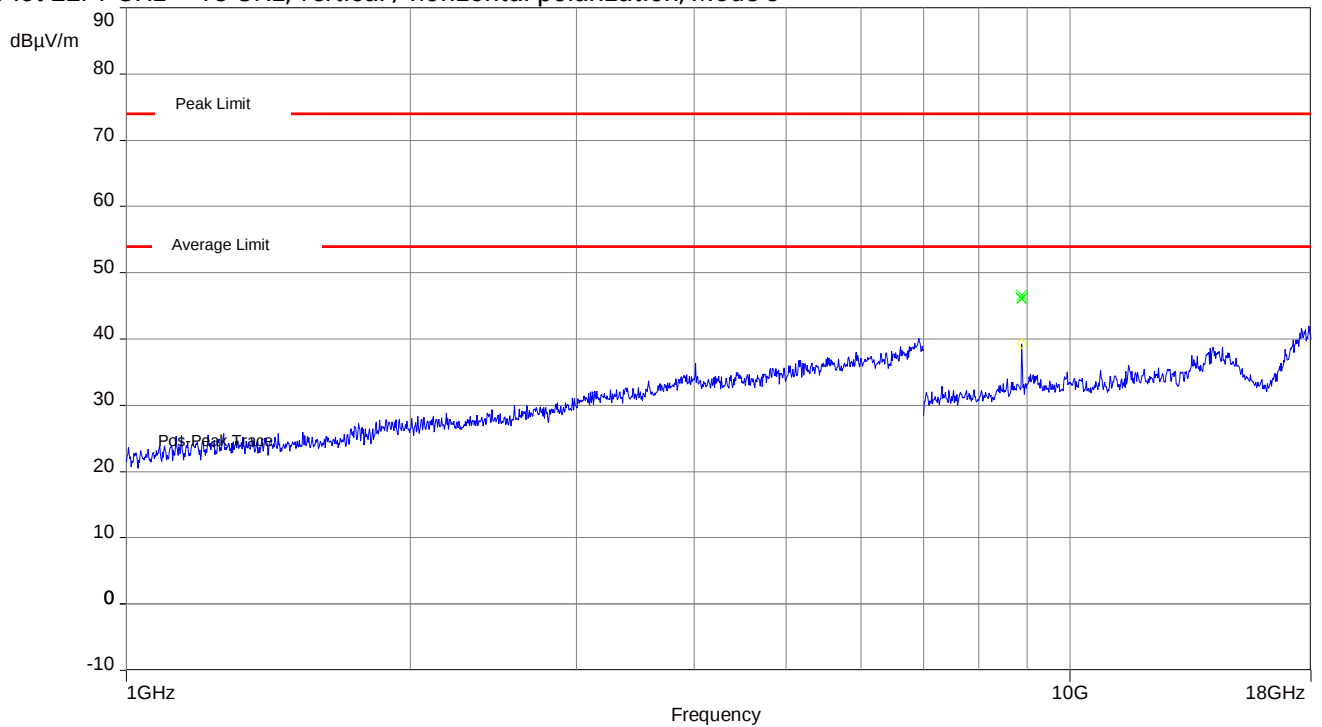
Plot 20: 30 MHz – 1 GHz, vertical / horizontal polarization, Mode 5



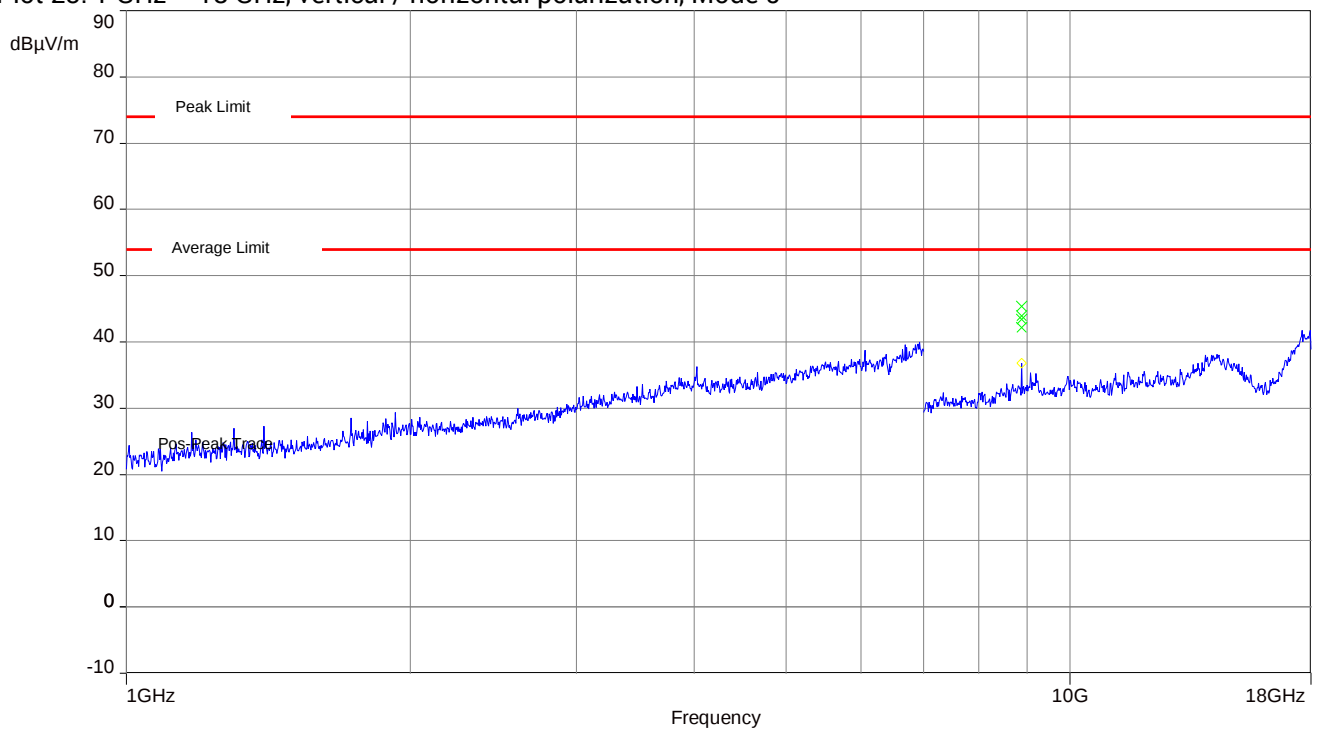
Plot 21: 30 MHz – 1 GHz, vertical / horizontal polarization, Mode 6



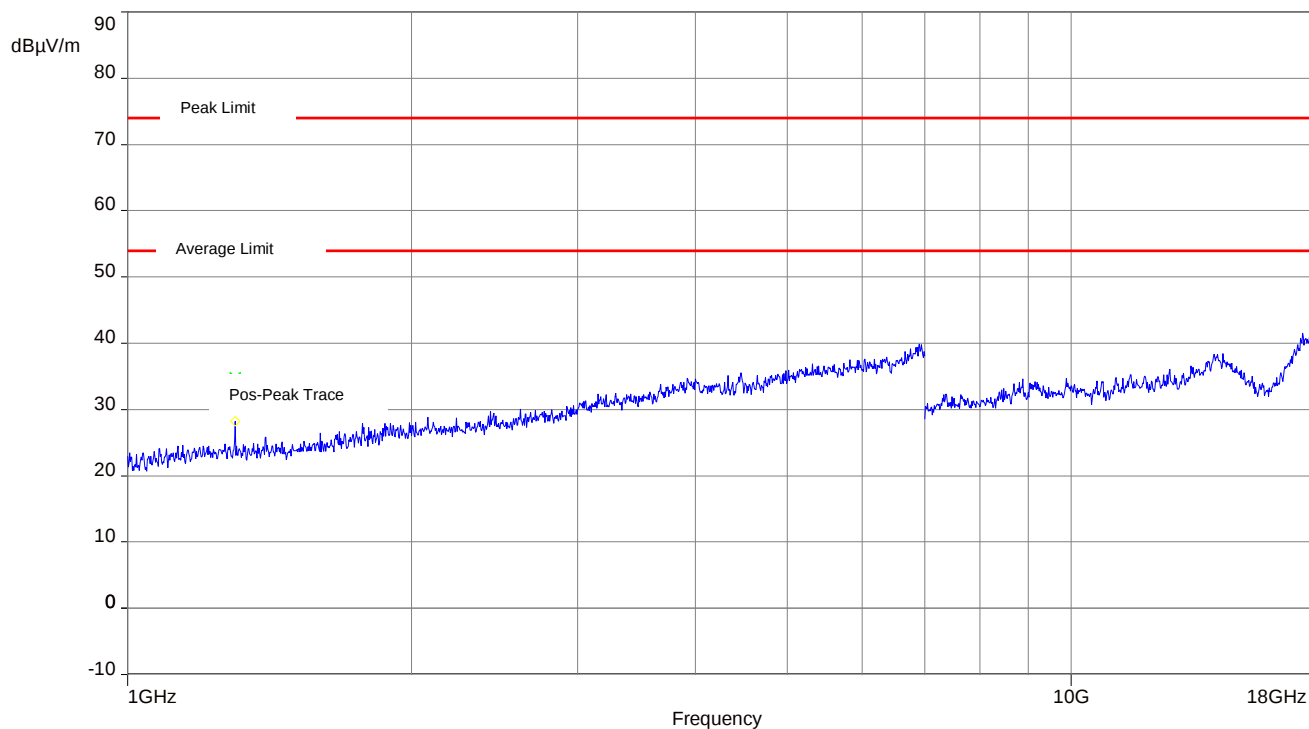
Plot 22: 1 GHz – 18 GHz, vertical / horizontal polarization, Mode 3



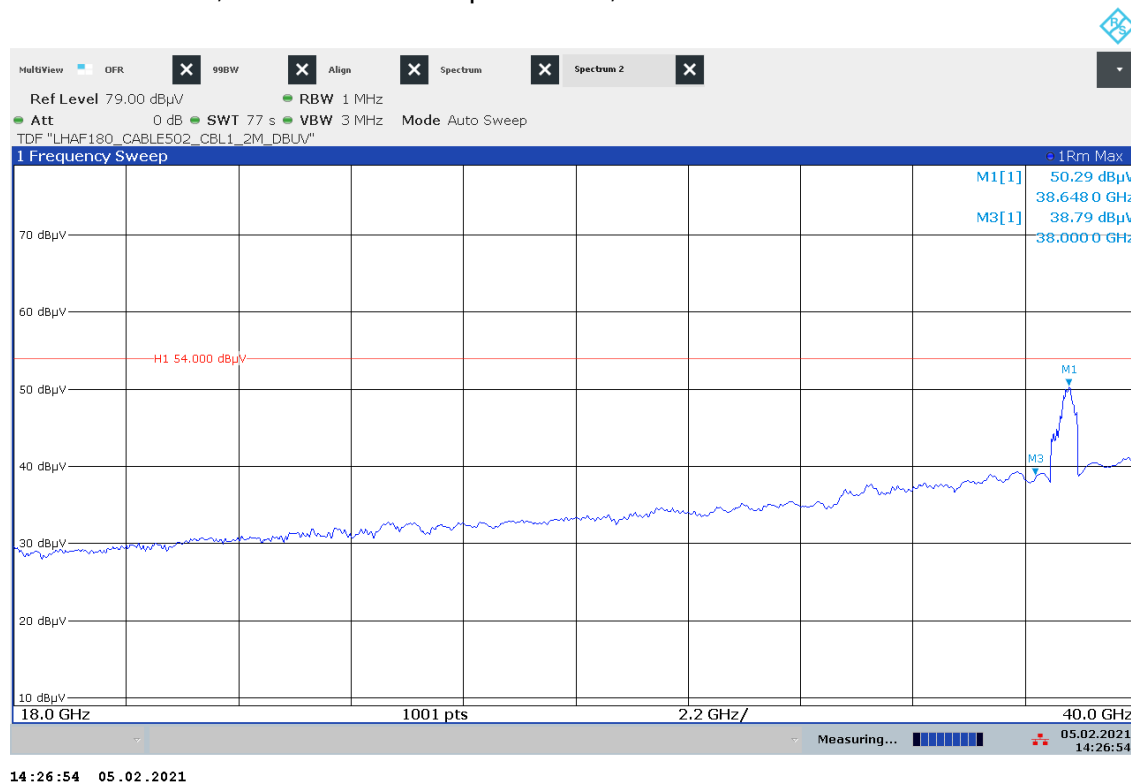
Plot 23: 1 GHz – 18 GHz, vertical / horizontal polarization, Mode 5



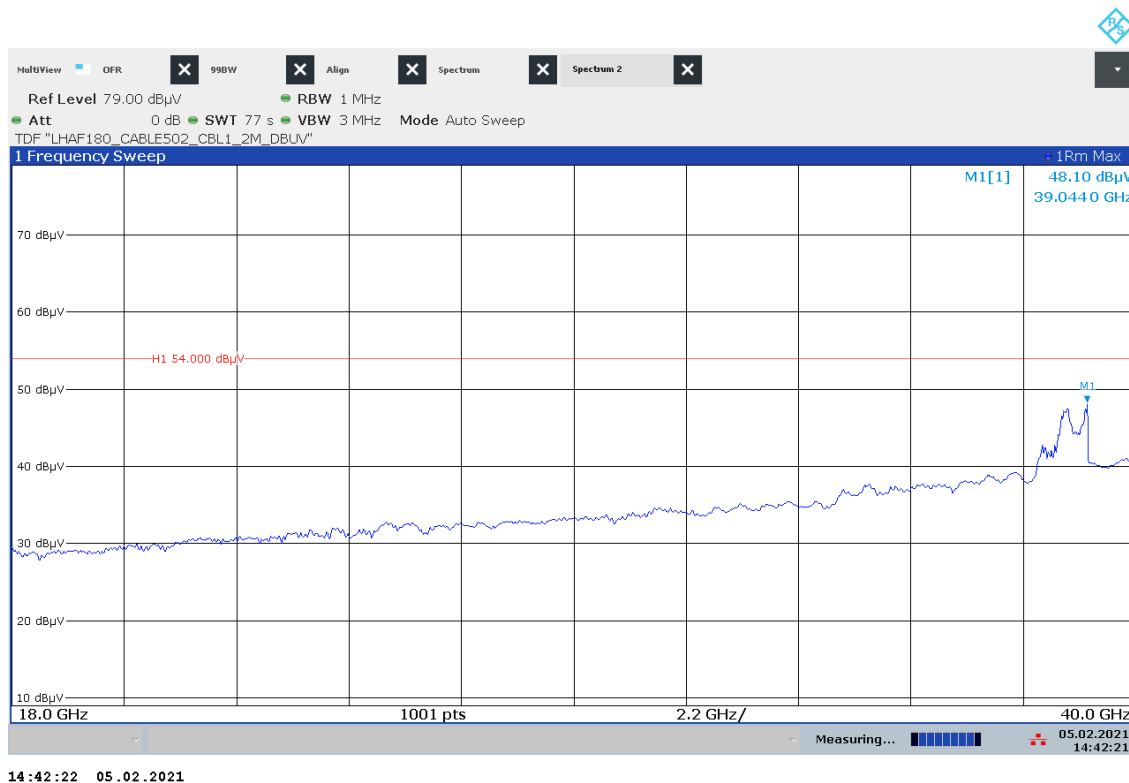
Plot 24: 1 GHz – 18 GHz, vertical / horizontal polarization, Mode 6



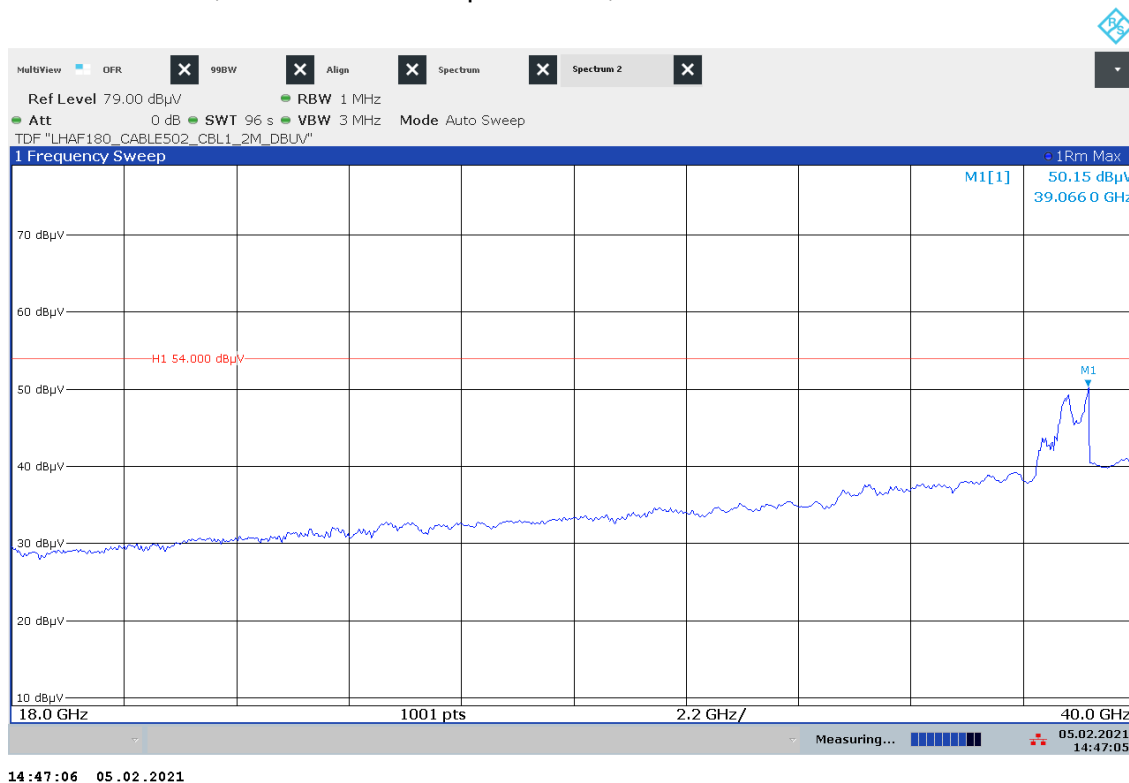
Plot 25: 18 GHz – 40 GHz, vertical / horizontal polarization, Mode 3



Plot 26: 18 GHz – 40 GHz, vertical / horizontal polarization, Mode 5



Plot 27: 18 GHz – 40 GHz, vertical / horizontal polarization, Mode 6

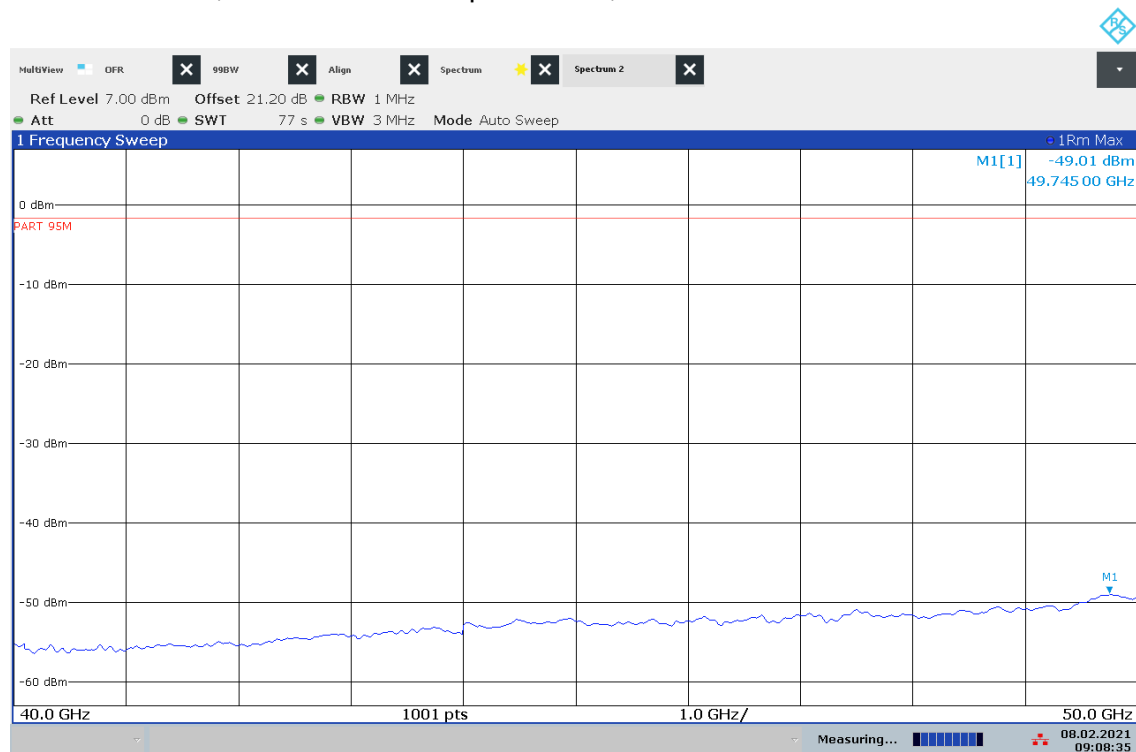


Plot 28: 40 GHz – 50 GHz, vertical / horizontal polarization, Mode 3



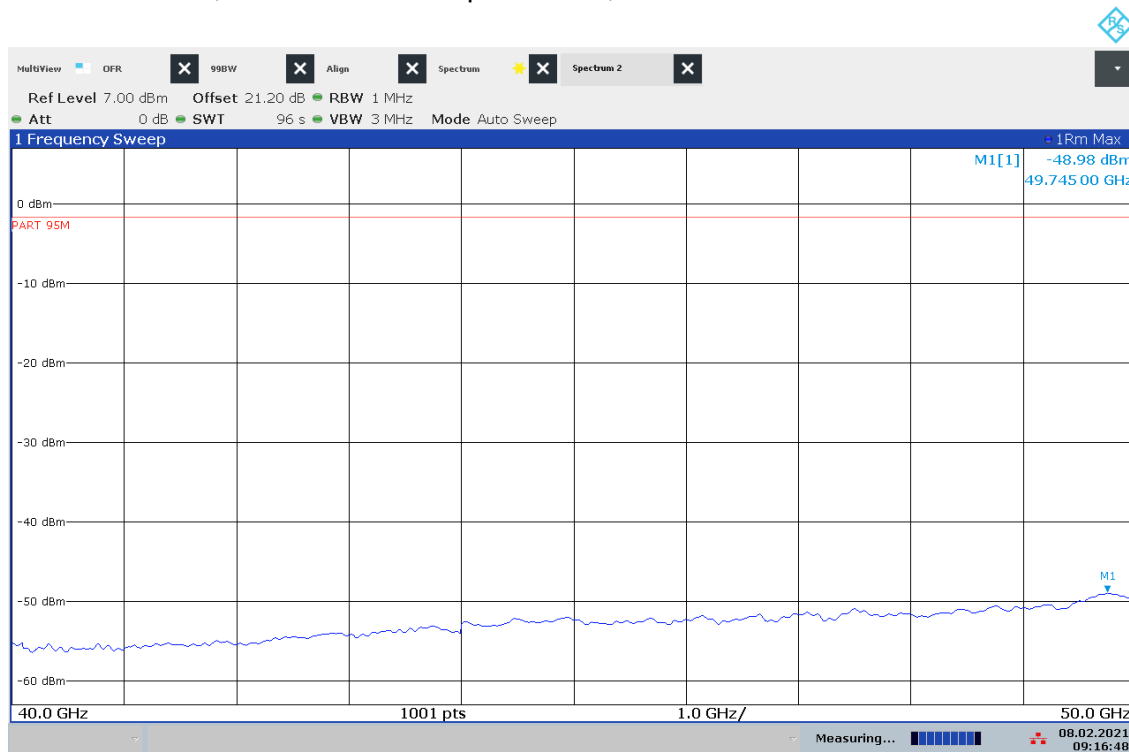
09:00:45 08.02.2021

Plot 29: 40 GHz – 50 GHz, vertical / horizontal polarization, Mode 5

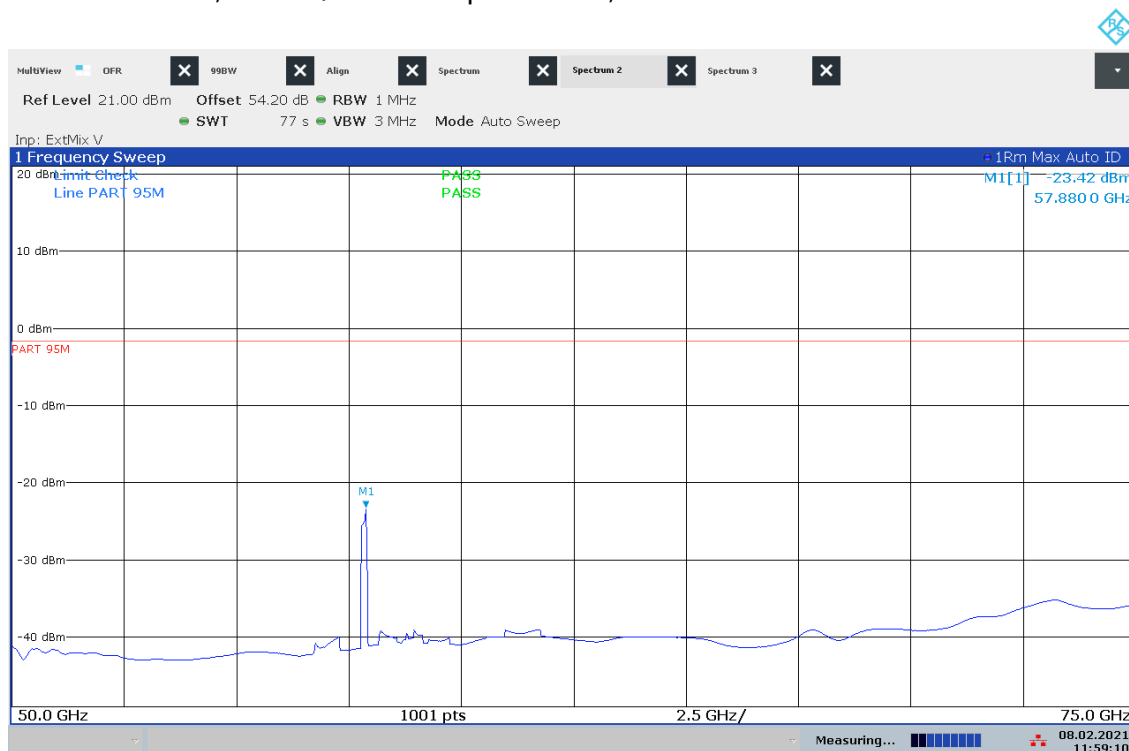


09:08:35 08.02.2021

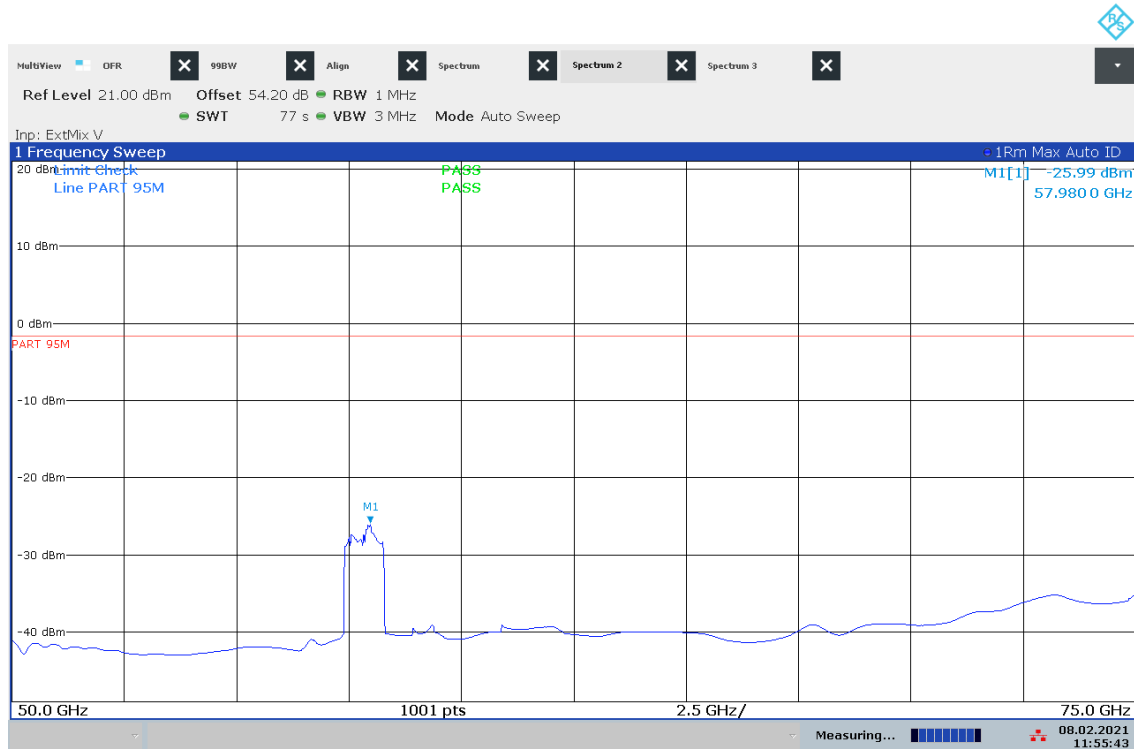
Plot 30: 40 GHz – 50 GHz, vertical / horizontal polarization, Mode 6



Plot 31: 50 GHz – 75 GHz, vertical / horizontal polarization, Mode 3

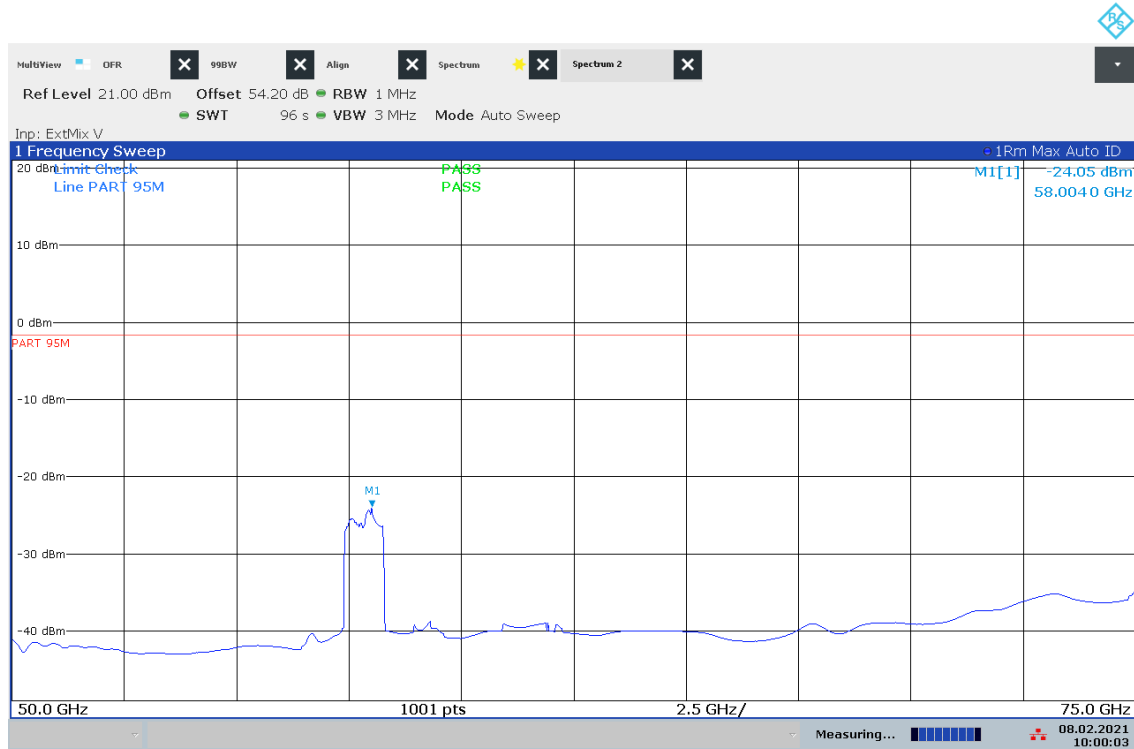


Plot 32: 50 GHz – 75 GHz, vertical / horizontal polarization, Mode 5



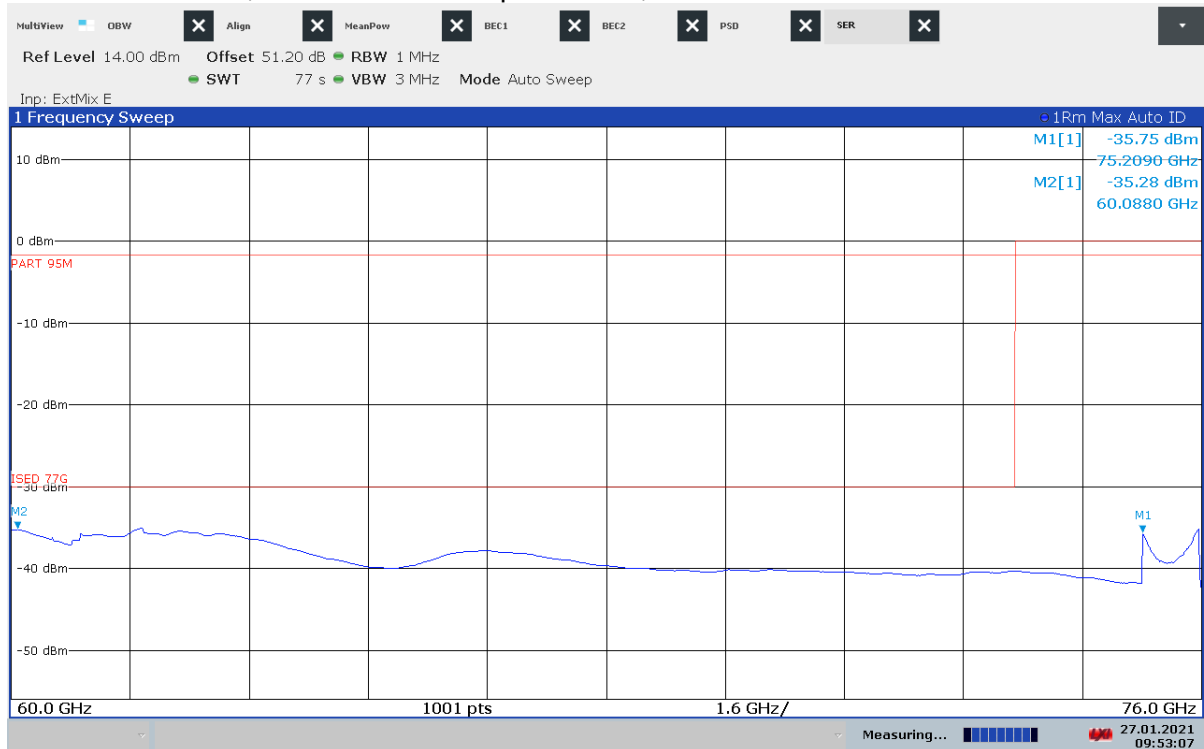
11:55:43 08.02.2021

Plot 33: 50 GHz – 75 GHz, vertical / horizontal polarization, Mode 6



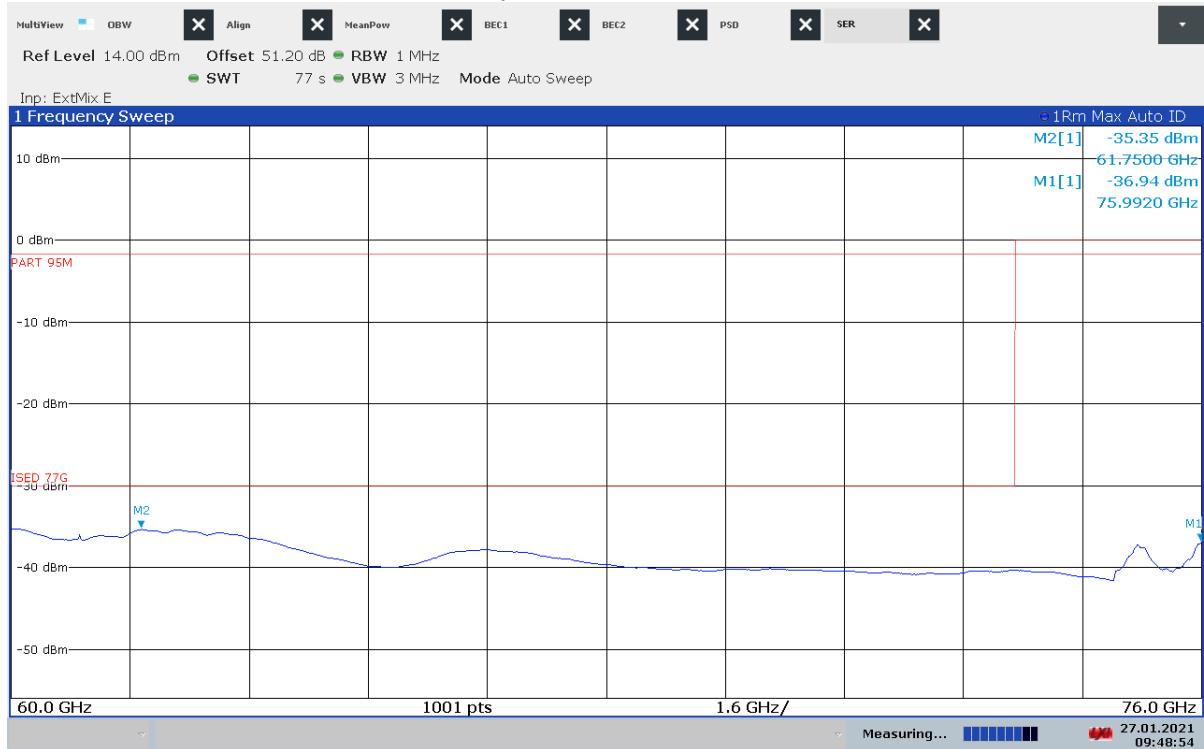
10:00:03 08.02.2021

Plot 34: 60 GHz – 76 GHz, vertical / horizontal polarization, Mode 3



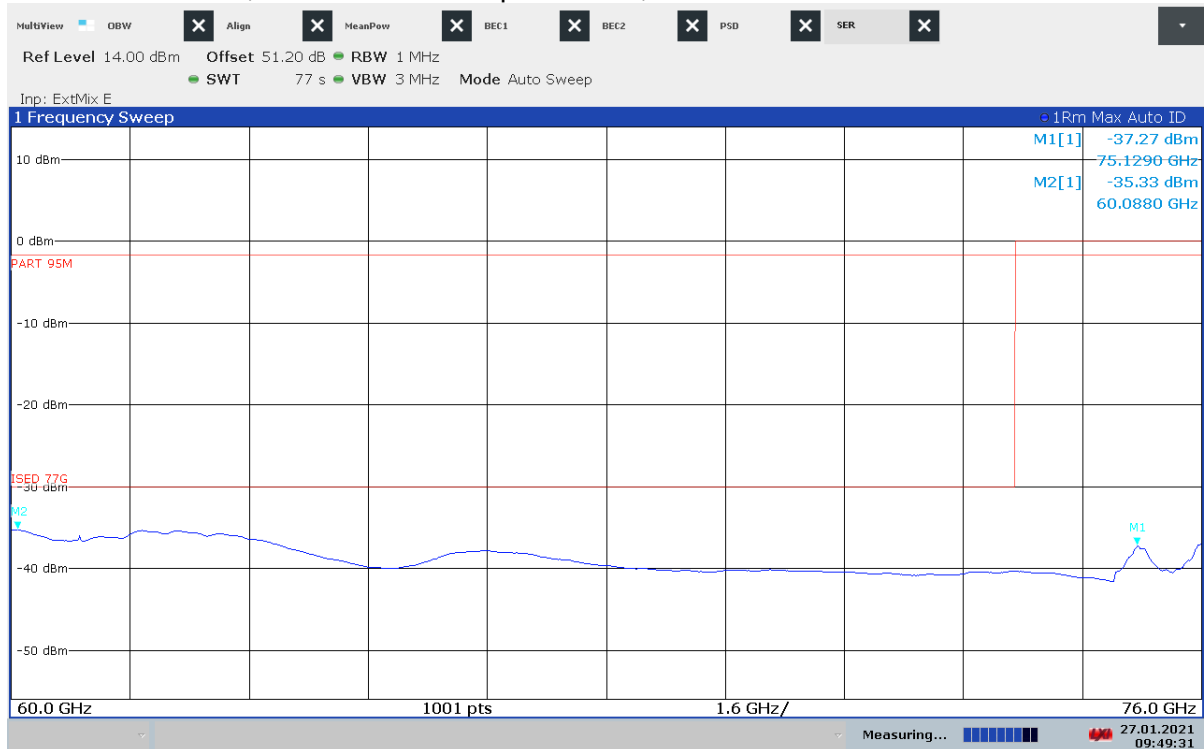
09:53:07 27.01.2021

Plot 35: 60 GHz – 76 GHz, vertical / horizontal polarization, Mode 5



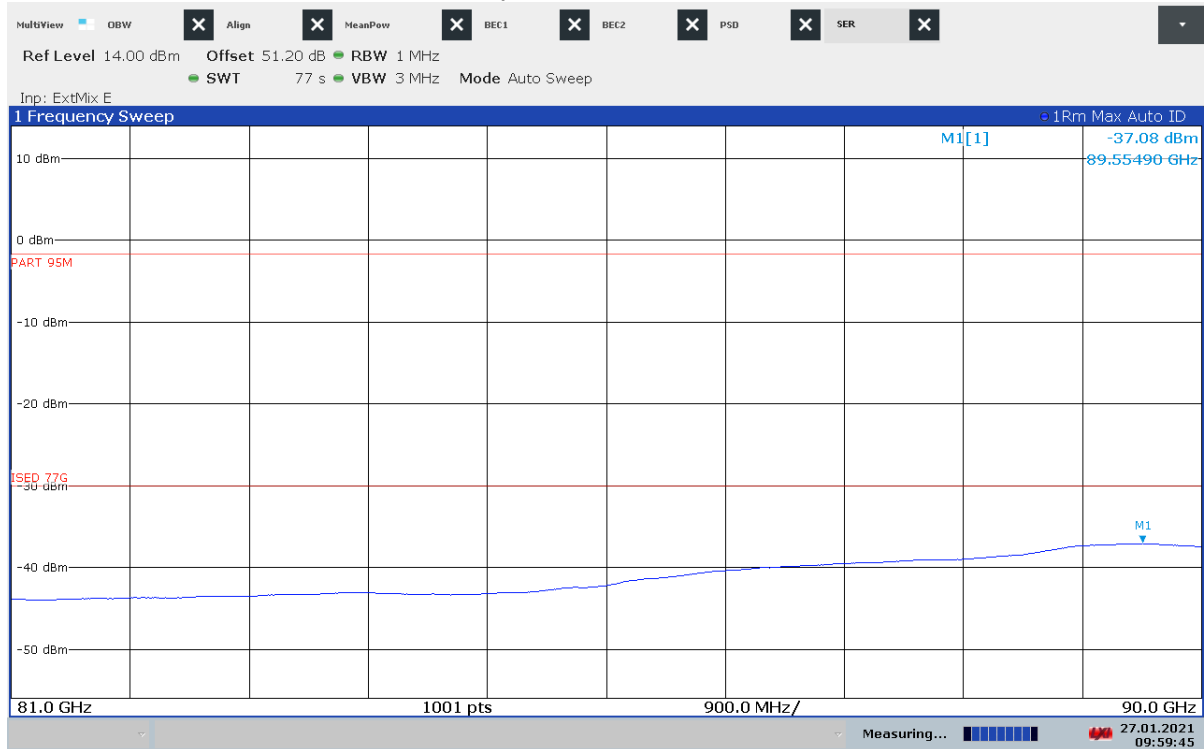
09:48:55 27.01.2021

Plot 36: 60 GHz – 76 GHz, vertical / horizontal polarization, Mode 6



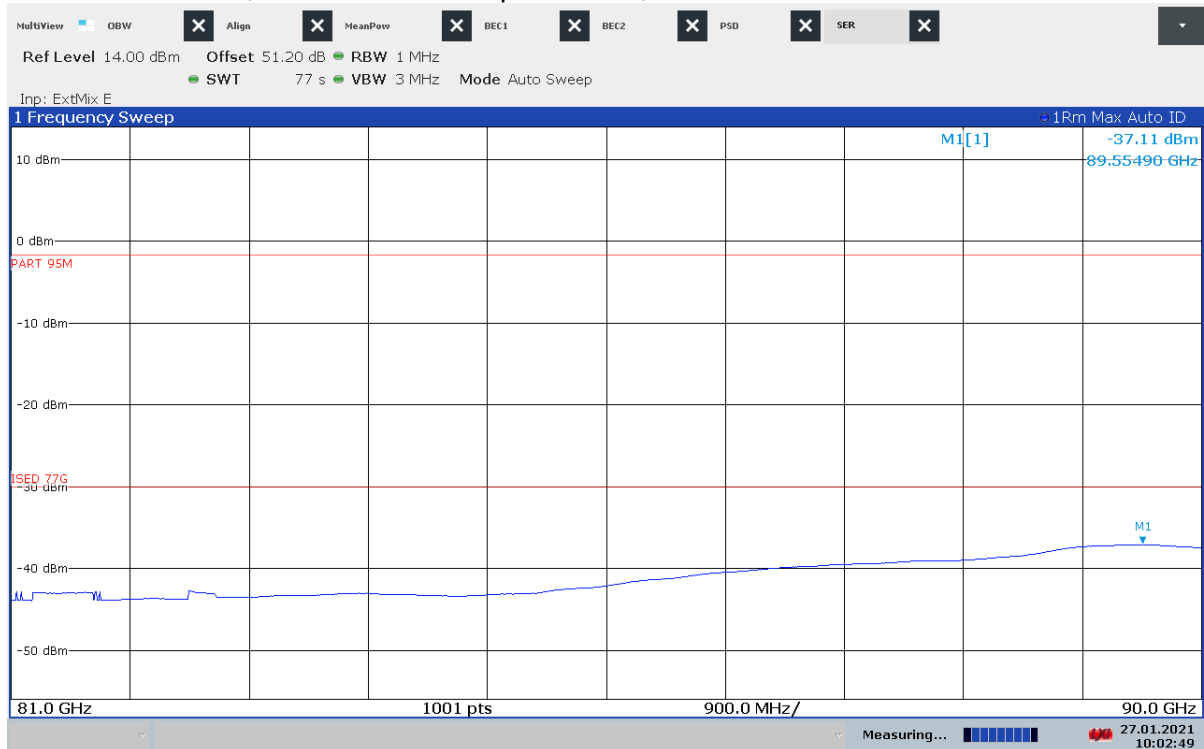
09:49:31 27.01.2021

Plot 37: 81 GHz – 90 GHz, vertical / horizontal polarization, Mode 3



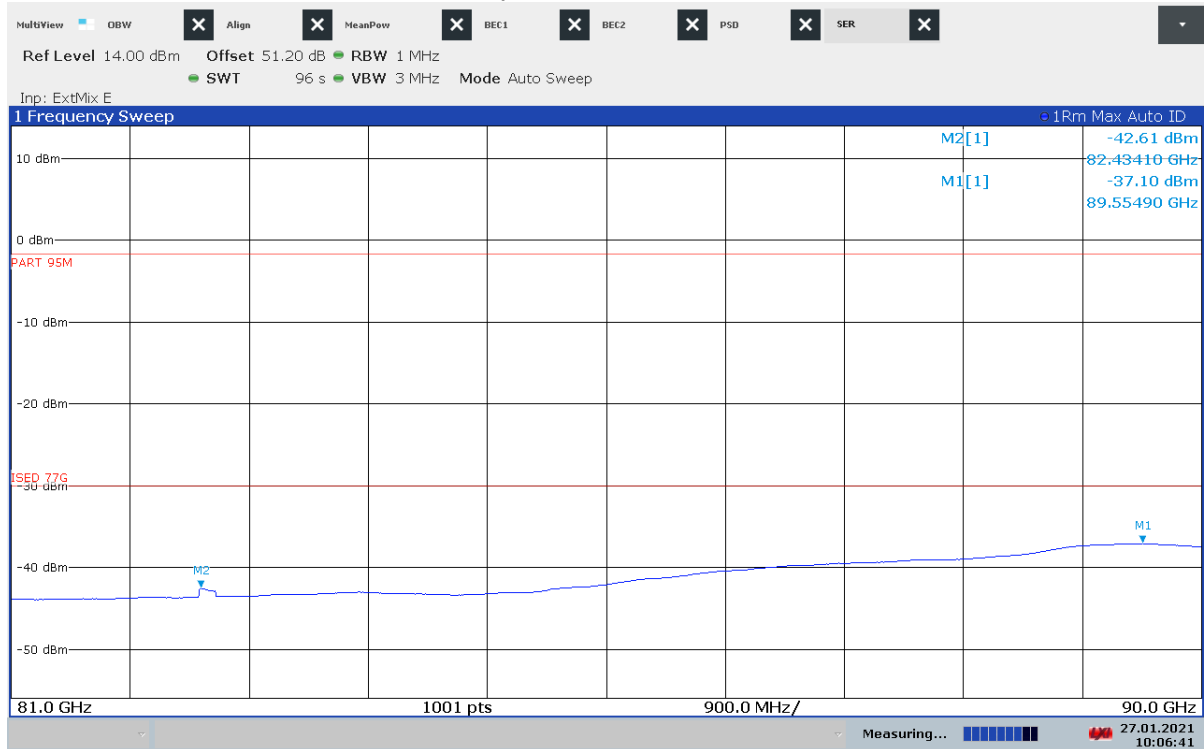
09:59:46 27.01.2021

Plot 38: 81 GHz – 90 GHz, vertical / horizontal polarization, Mode 5

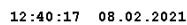
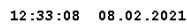


10:02:50 27.01.2021

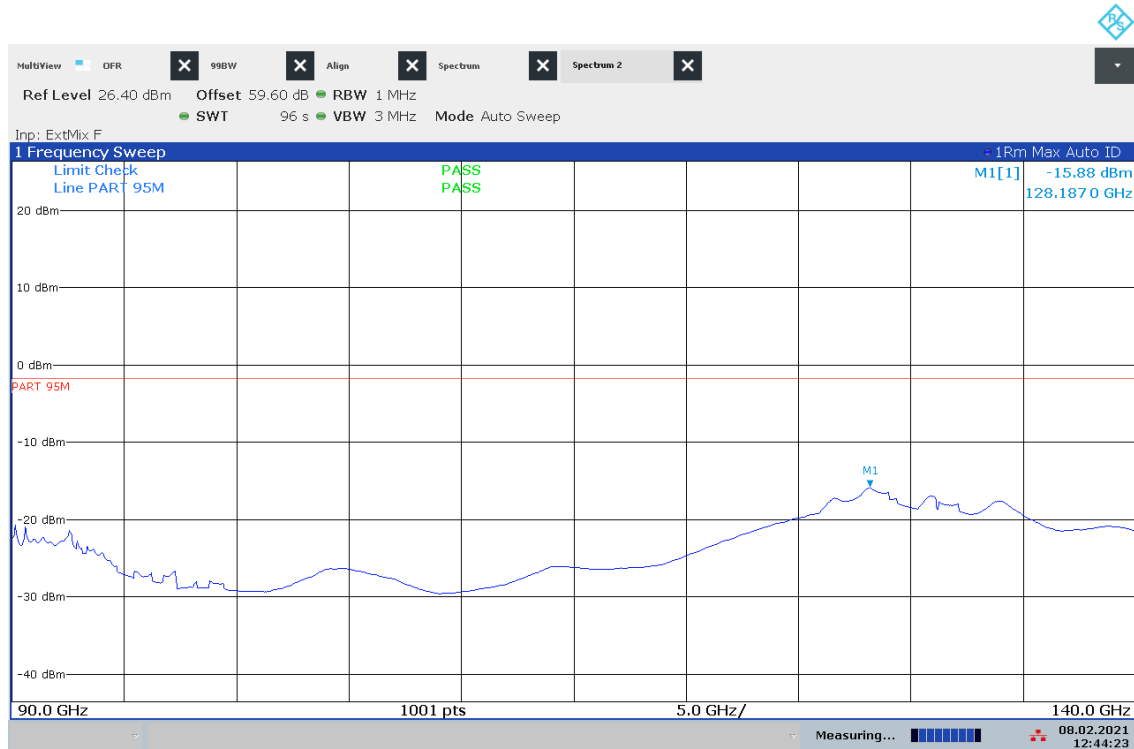
Plot 39: 81 GHz – 90 GHz, vertical / horizontal polarization, Mode 6



10:06:41 27.01.2021

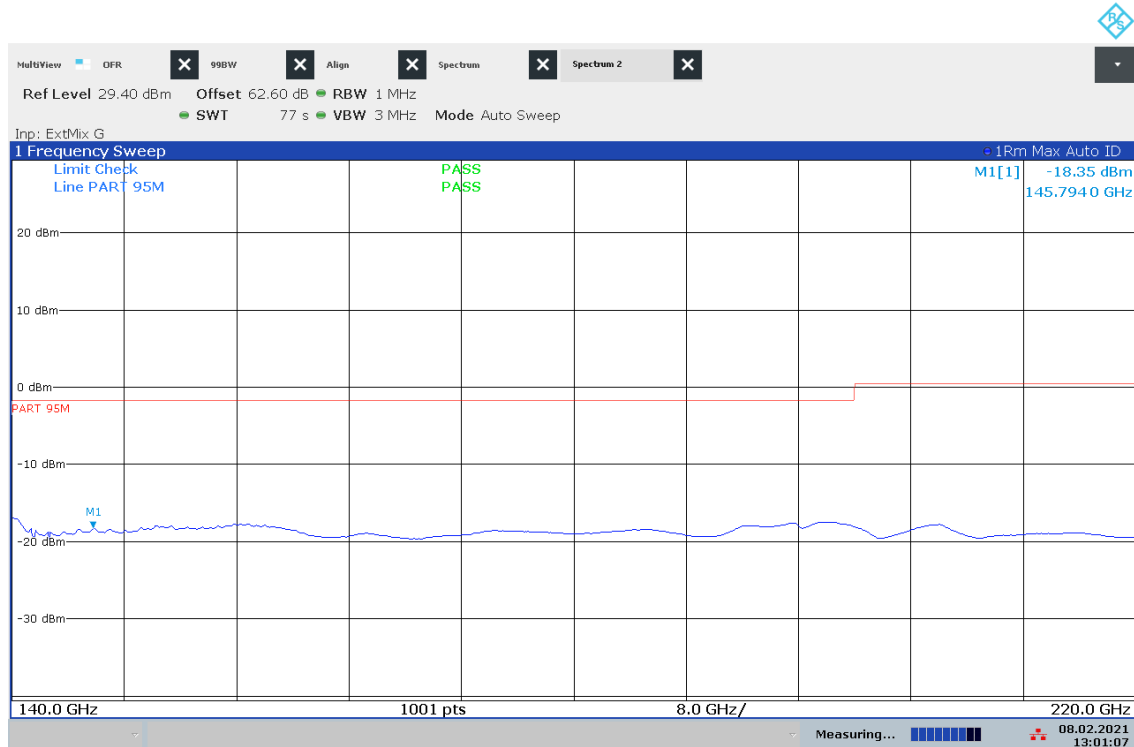


Plot 42: 90 GHz – 140 GHz, vertical / horizontal polarization, Mode 6



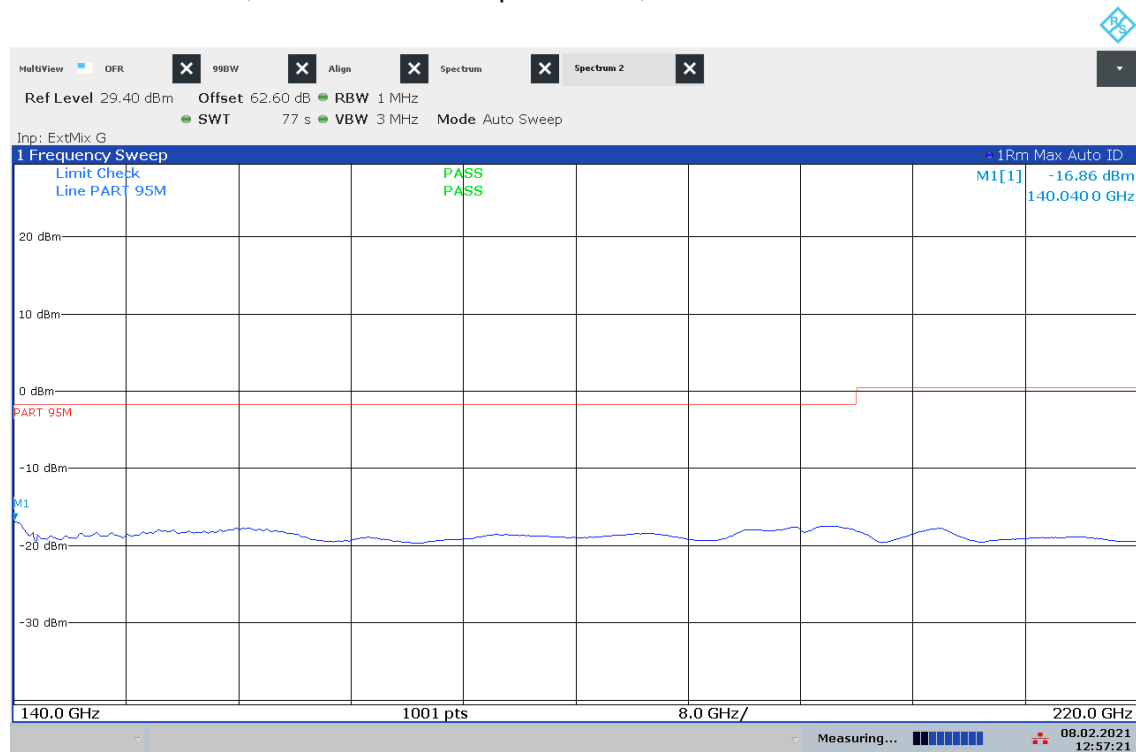
12:44:23 08.02.2021

Plot 43: 140 GHz – 220 GHz, vertical / horizontal polarization, Mode 3



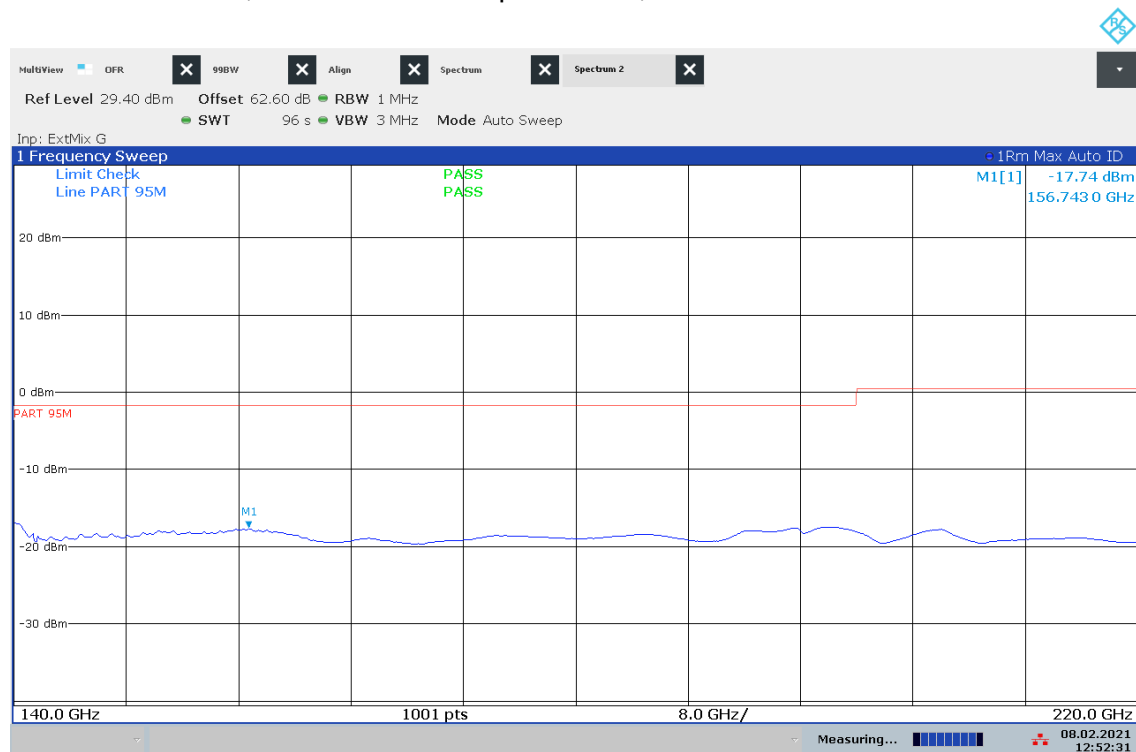
13:01:07 08.02.2021

Plot 44: 140 GHz – 220 GHz, vertical / horizontal polarization, Mode 5



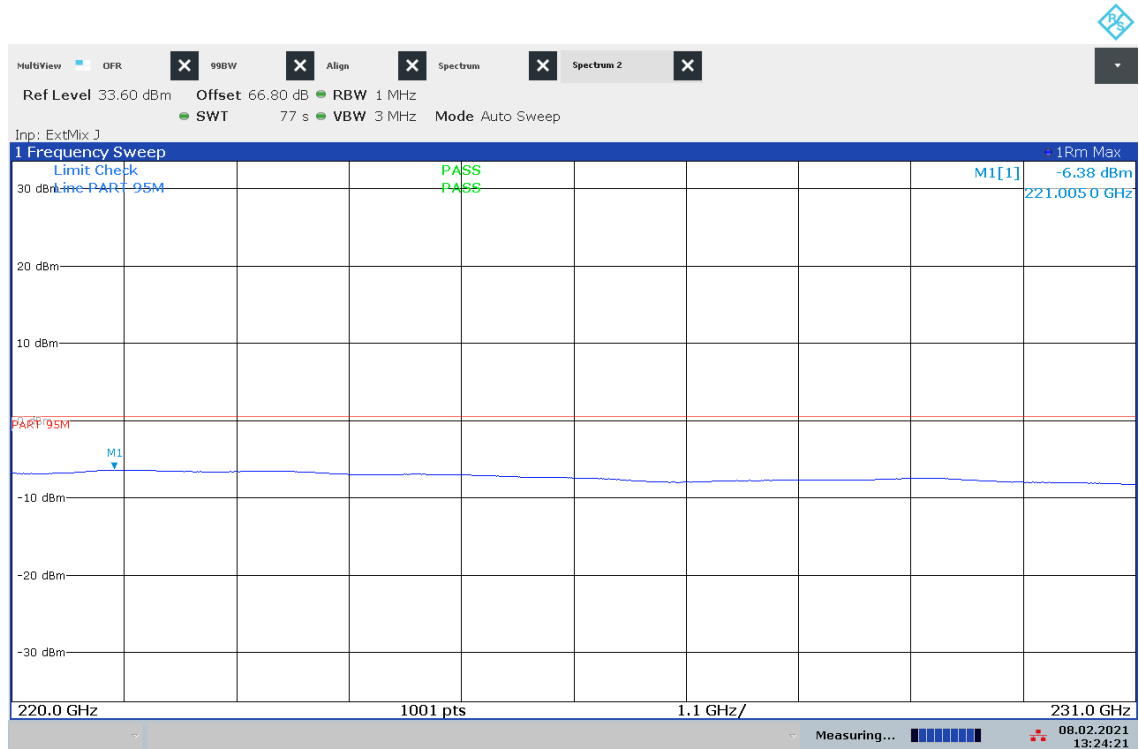
12:57:21 08.02.2021

Plot 45: 140 GHz – 220 GHz, vertical / horizontal polarization, Mode 6



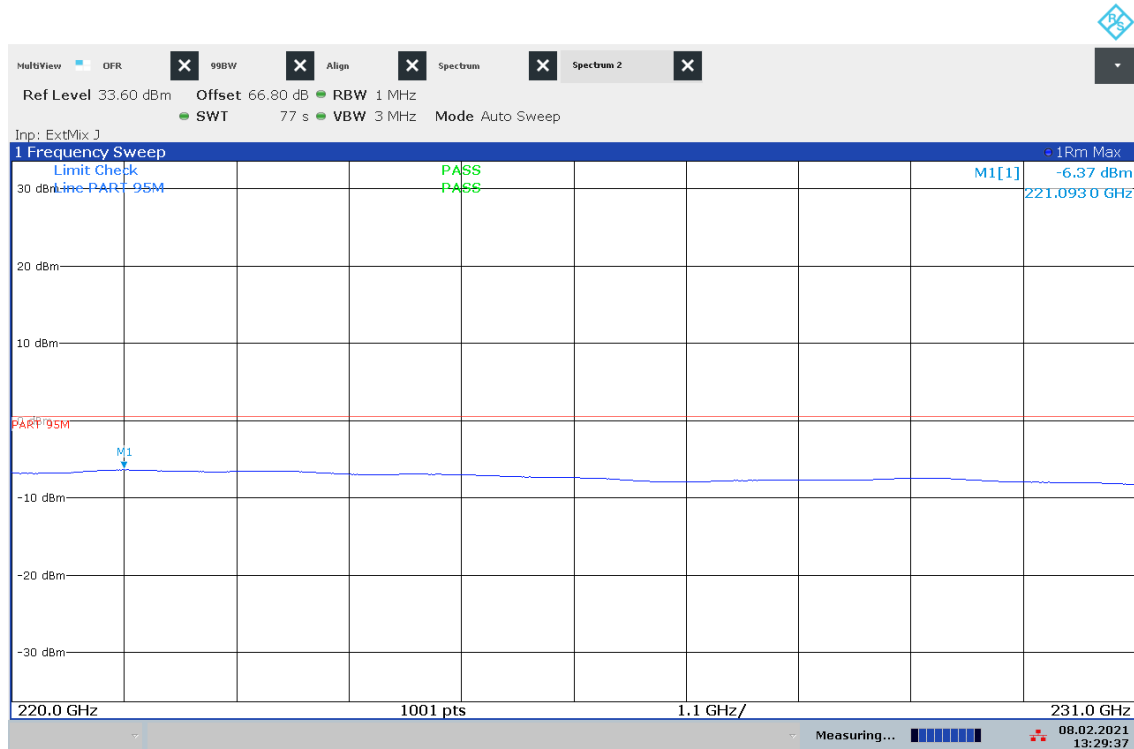
12:52:32 08.02.2021

Plot 46: 220 GHz – 231 GHz, vertical / horizontal polarization, Mode 3



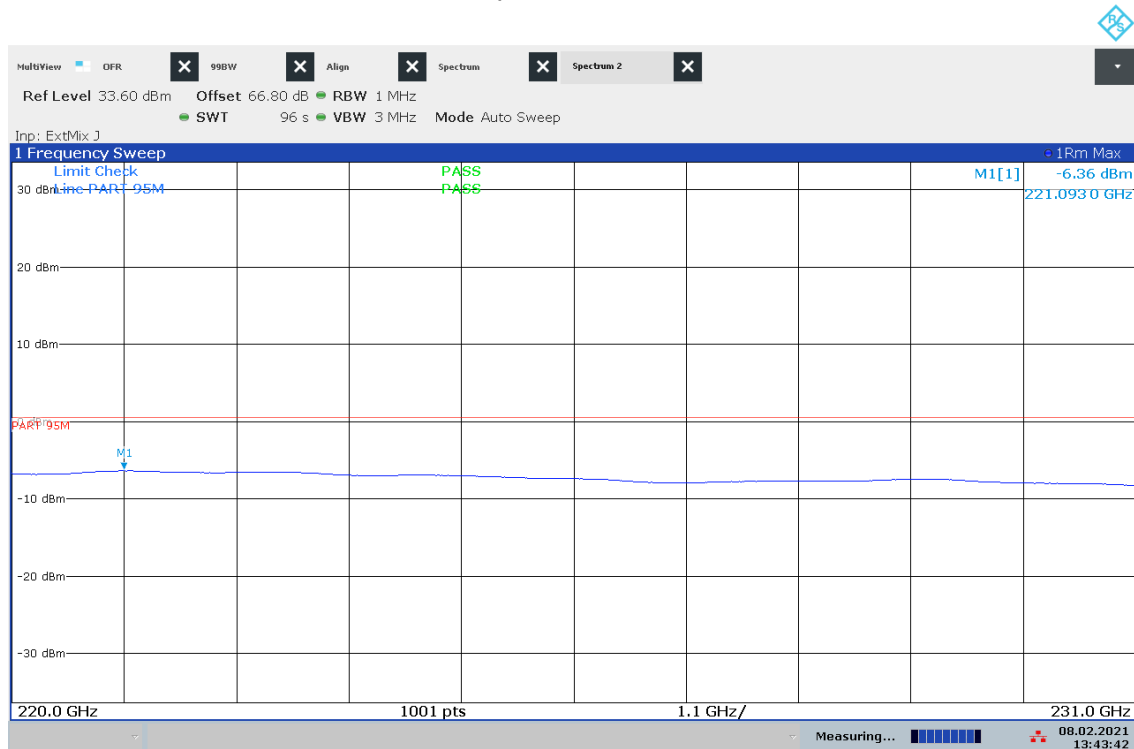
13:24:22 08.02.2021

Plot 47: 220 GHz – 231 GHz, vertical / horizontal polarization, Mode 5



13:29:37 08.02.2021

Plot 48: 220 GHz – 231 GHz, vertical / horizontal polarization, Mode 6



13:43:42 08.02.2021

12.6 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
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Temperature variation, Mode 3

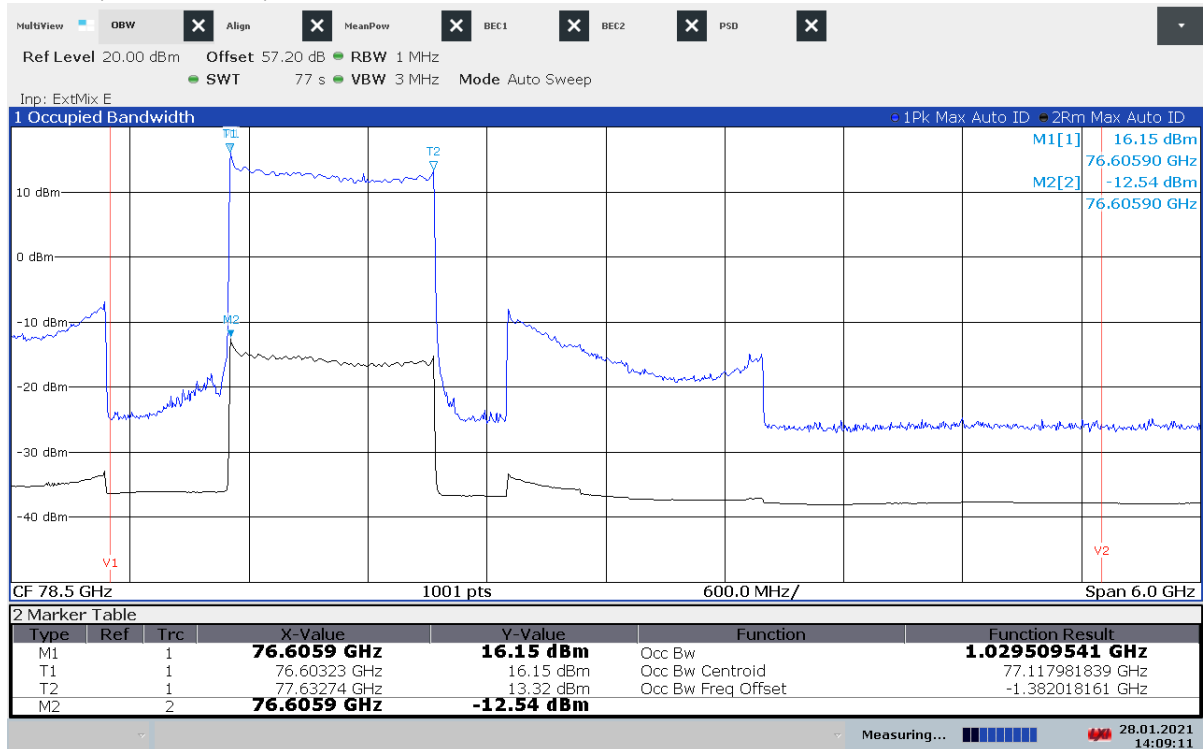
Test conditions	Operating Frequency Range		Bandwidth [MHz]
	f _L [GHz]	f _H [GHz]	
-20 / V _{nom}	76.60323	77.63274	1029.5
-10 / V _{nom}	76.60359	77.62747	1023.9
0 / V _{nom}	76.60378	77.63042	1026.6
10 / V _{nom}	76.60315	77.63120	1028.1
20 / V _{nom}	76.55798	77.63331	1075.3
30 / V _{min}	76.60309	77.62786	1024.8
40 / V _{max}	76.59731	77.62988	1032.6
50 / V _{nom}	76.59387	77.63218	1038.3

Temperature variation, Mode 5

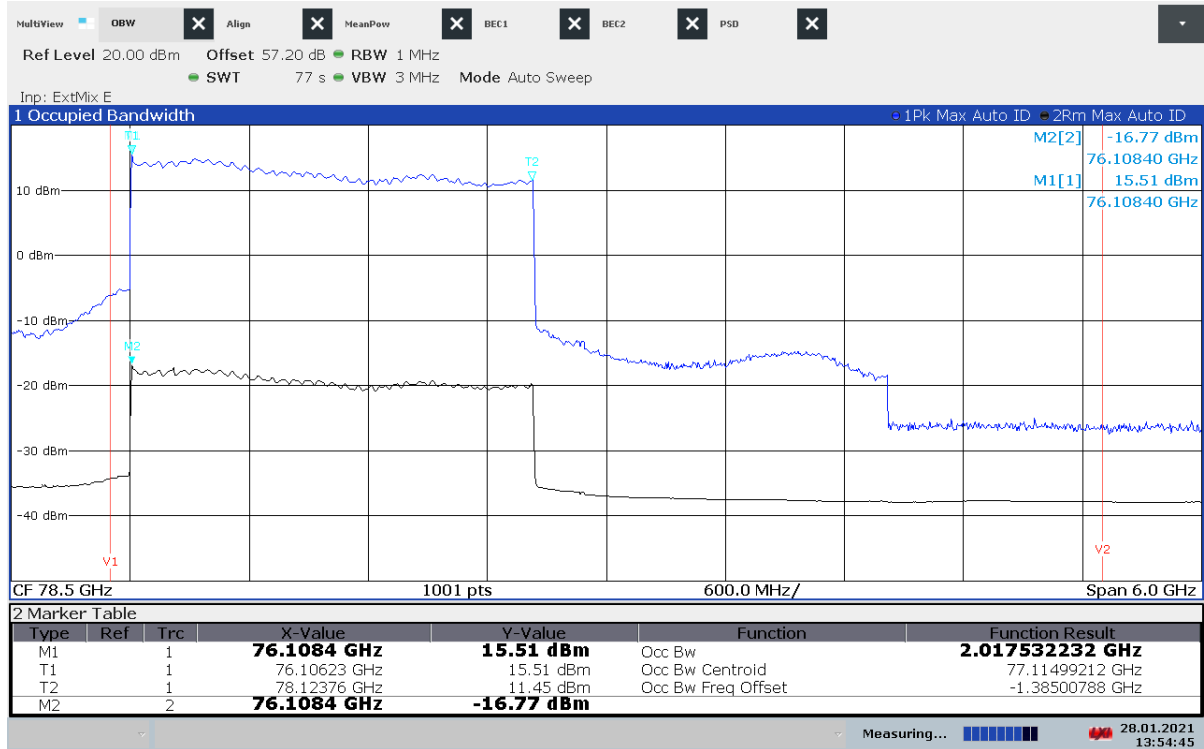
Test conditions	Operating Frequency Range		Bandwidth [MHz]
	f _L [GHz]	f _H [GHz]	
-20 / V _{nom}	76.10623	78.12376	2017.5
-10 / V _{nom}	76.10628	78.12332	2017.0
0 / V _{nom}	76.10514	78.12322	2018.1
10 / V _{nom}	76.10930	78.12293	2013.6
20 / V _{nom}	76.07816	78.12576	2047.6
30 / V _{min}	76.10627	78.12052	2014.3
40 / V _{max}	76.10013	78.11979	2019.7
50 / V _{nom}	76.09011	78.12447	2034.4

Temperature variation, Mode 6

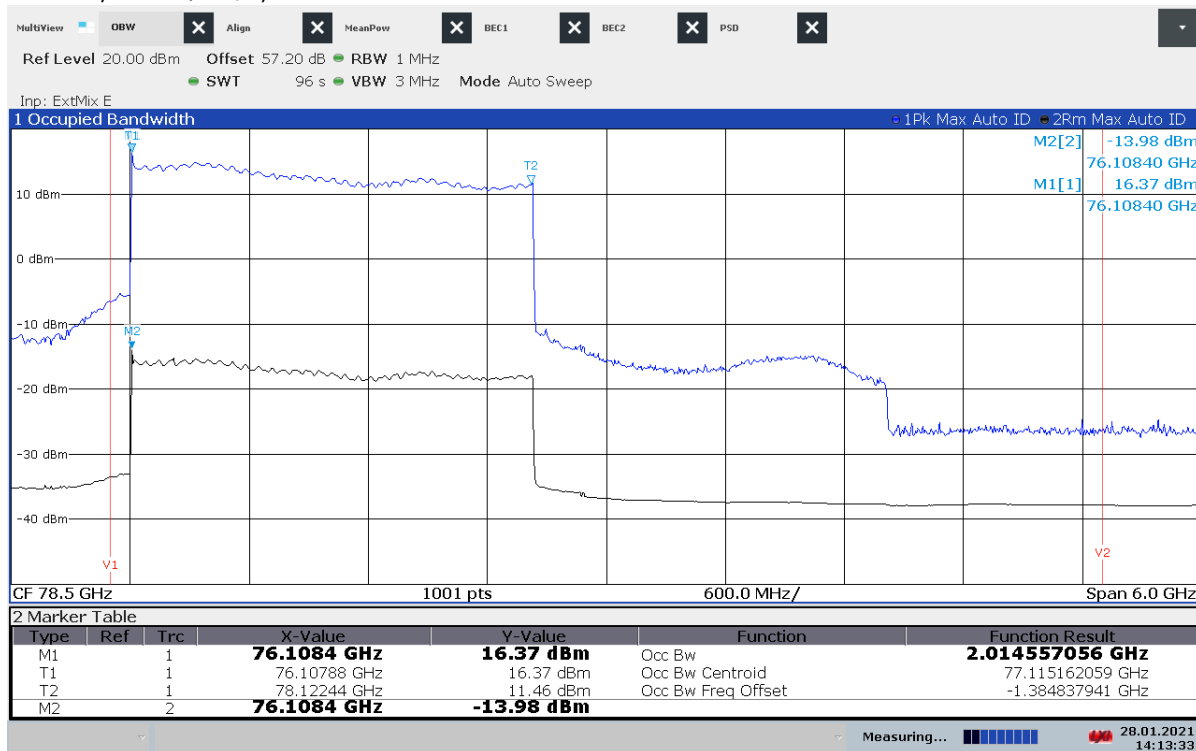
Test conditions	Operating Frequency Range		Bandwidth [MHz]
	f _L [GHz]	f _H [GHz]	
-20 / V _{nom}	76.10788	78.12244	2014.6
-10 / V _{nom}	76.10776	78.12249	2014.7
0 / V _{nom}	76.10703	78.12331	2016.3
10 / V _{nom}	76.10339	78.12445	2021.1
20 / V _{nom}	76.10059	78.12454	2023.9
30 / V _{min}	76.10577	78.12196	2016.2
40 / V _{max}	76.10057	78.12293	2022.4
50 / V _{nom}	76.05850	78.12468	2066.2

Plot 49: OBW, -20 °C / V_{nom}, Mode 3

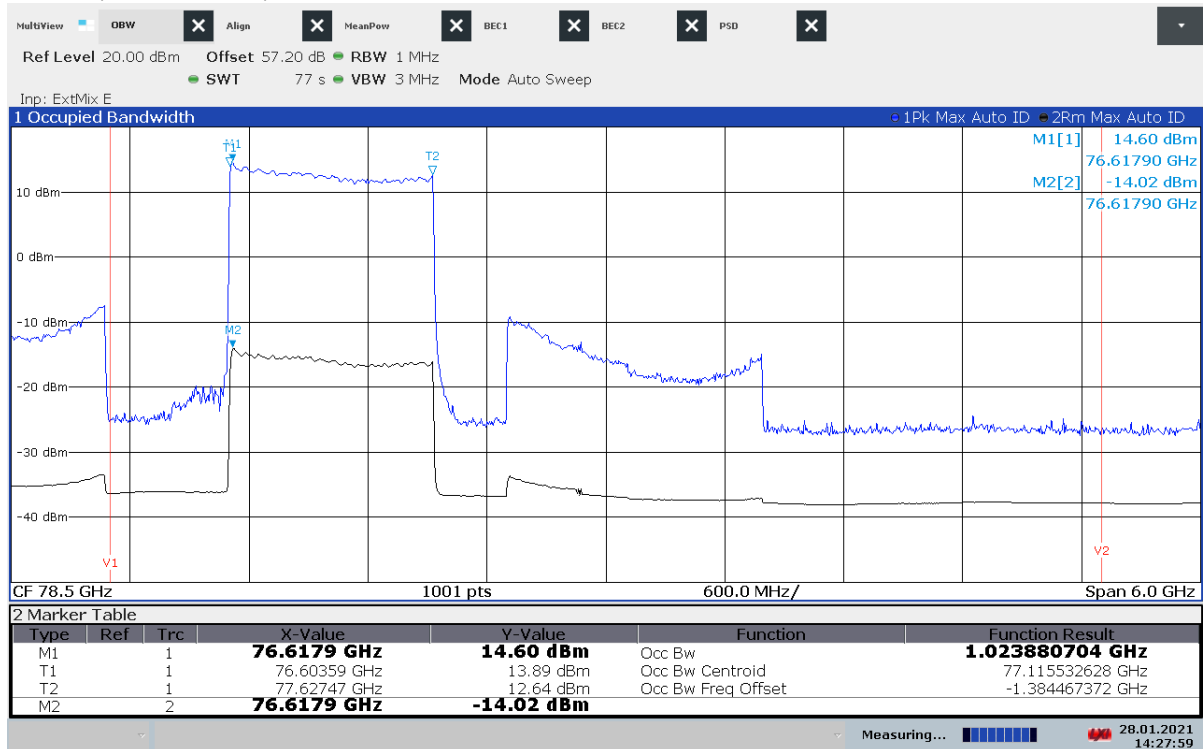
14:09:12 28.01.2021

Plot 50: OBW, -20 °C / V_{nom}, Mode 5

13:54:46 28.01.2021

Plot 51: OBW, -20 °C / V_{nom}, Mode 6

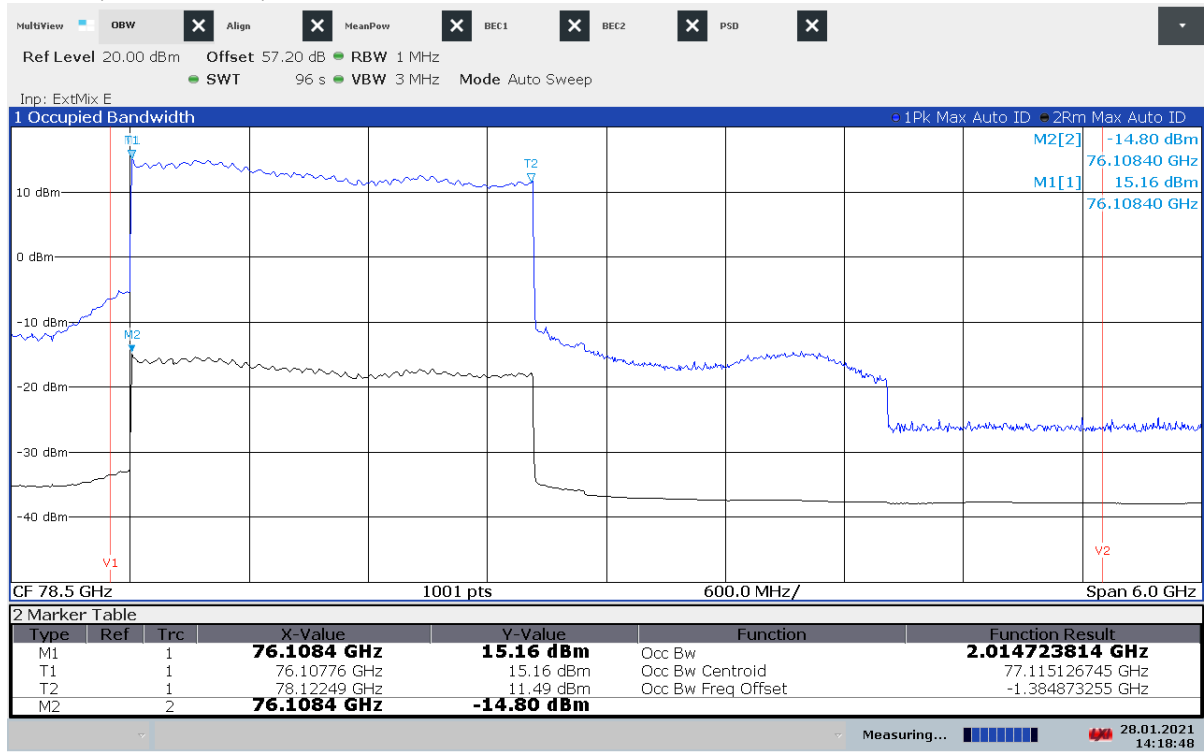
14:13:33 28.01.2021

Plot 52: OBW, -10 °C / V_{nom}, Mode 3

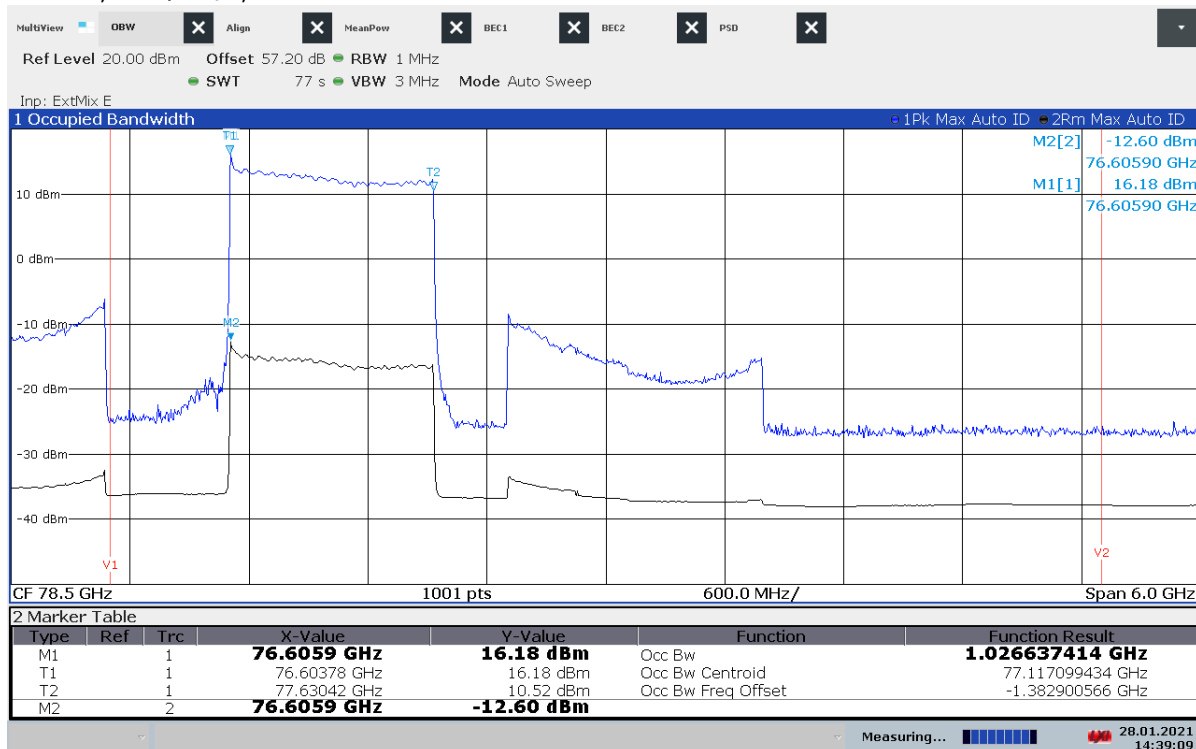
14:28:00 28.01.2021

Plot 53: OBW, -10 °C / V_{nom}, Mode 5

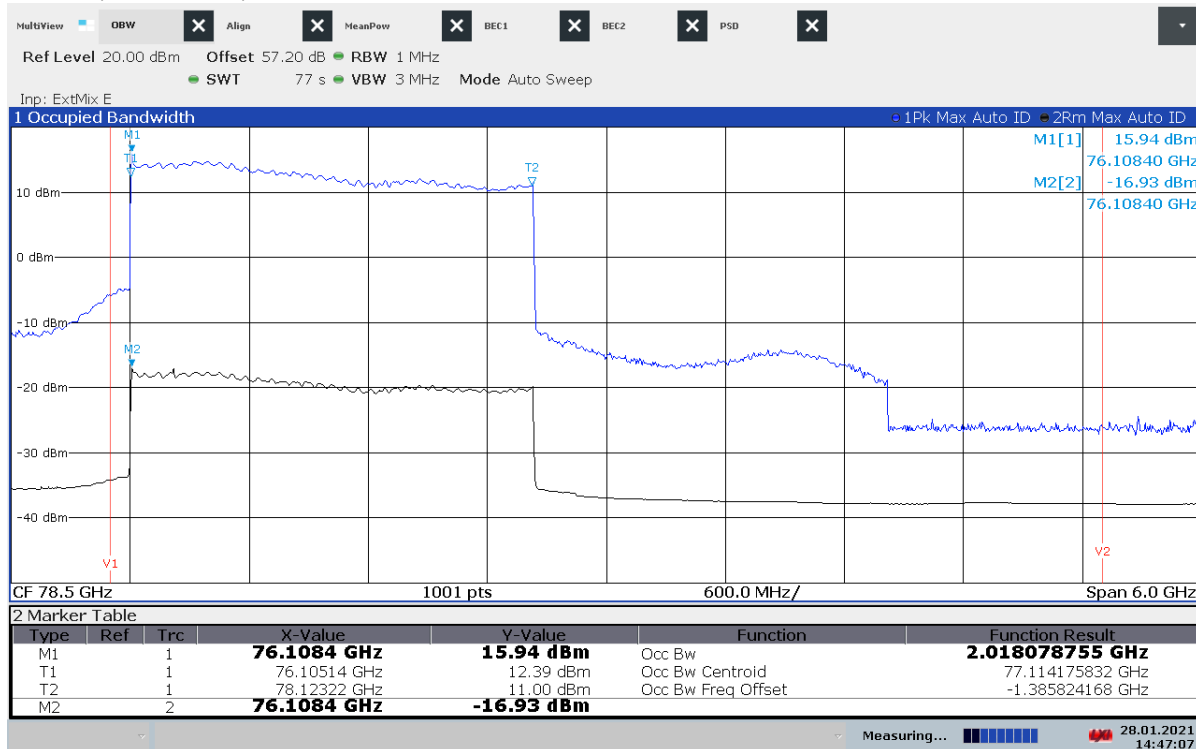
14:25:01 28.01.2021

Plot 54: OBW, -10 °C / V_{nom}, Mode 6

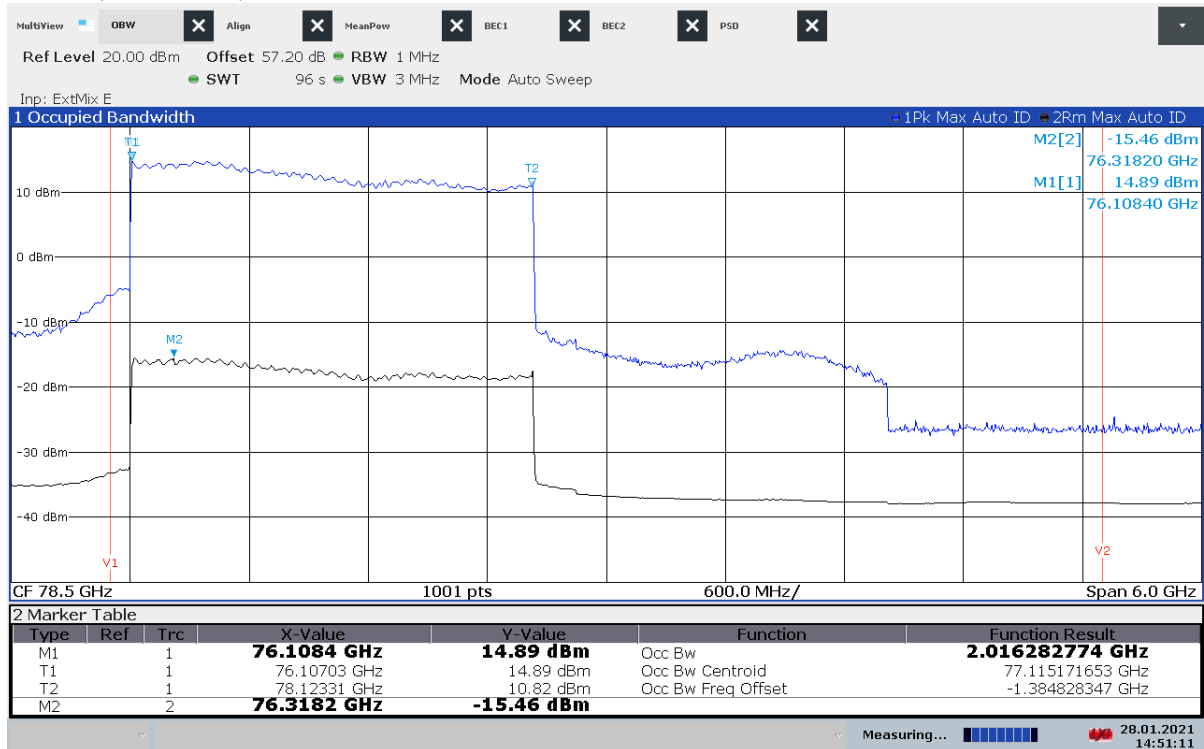
14:18:48 28.01.2021

Plot 55: OBW, 0 °C / V_{nom}, Mode 3

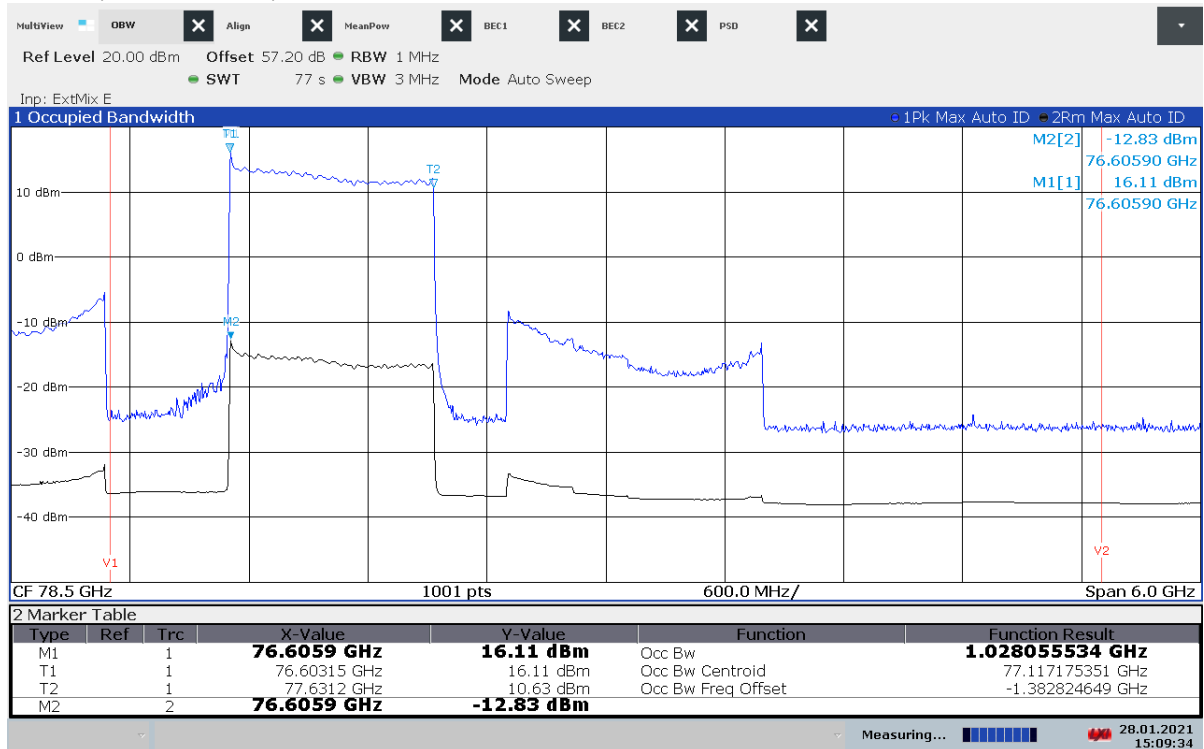
14:39:09 28.01.2021

Plot 56: OBW, 0 °C / V_{nom}, Mode 5

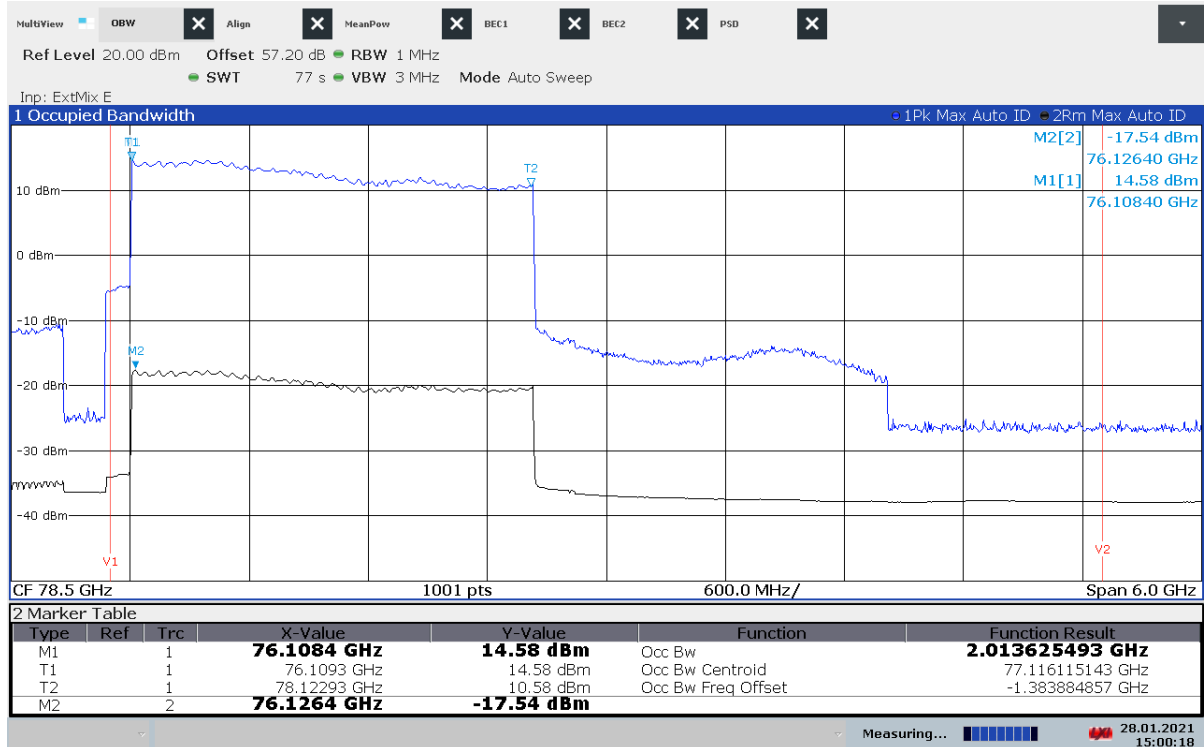
14:47:07 28.01.2021

Plot 57: OBW, 0 °C / V_{nom}, Mode 6

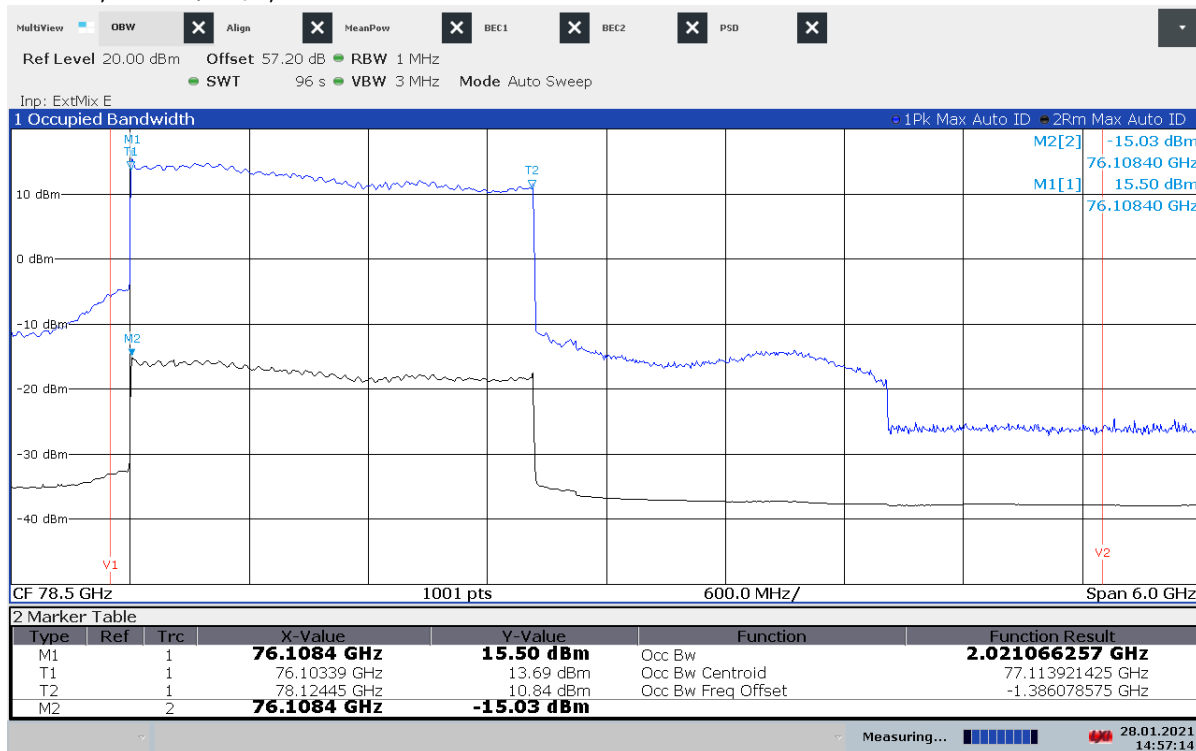
14:51:11 28.01.2021

Plot 58: OBW, +10 °C / V_{nom}, Mode 3

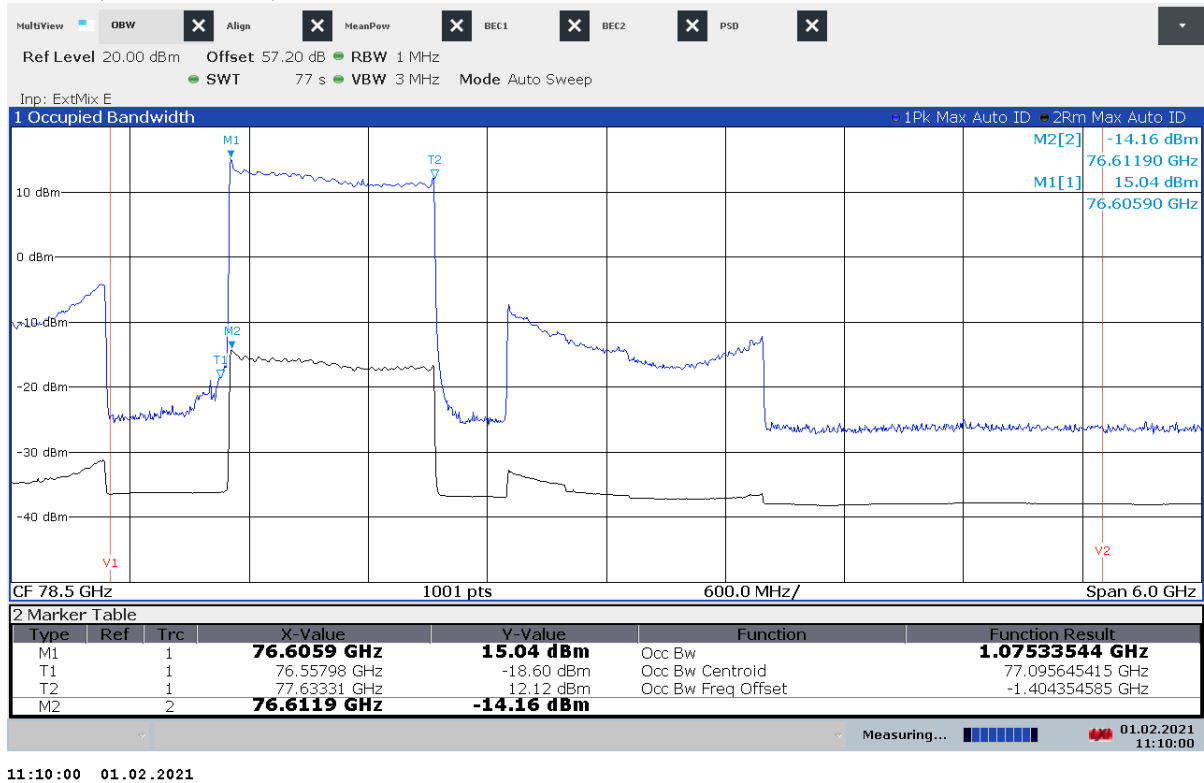
15:09:34 28.01.2021

Plot 59: OBW, +10 °C / V_{nom}, Mode 5

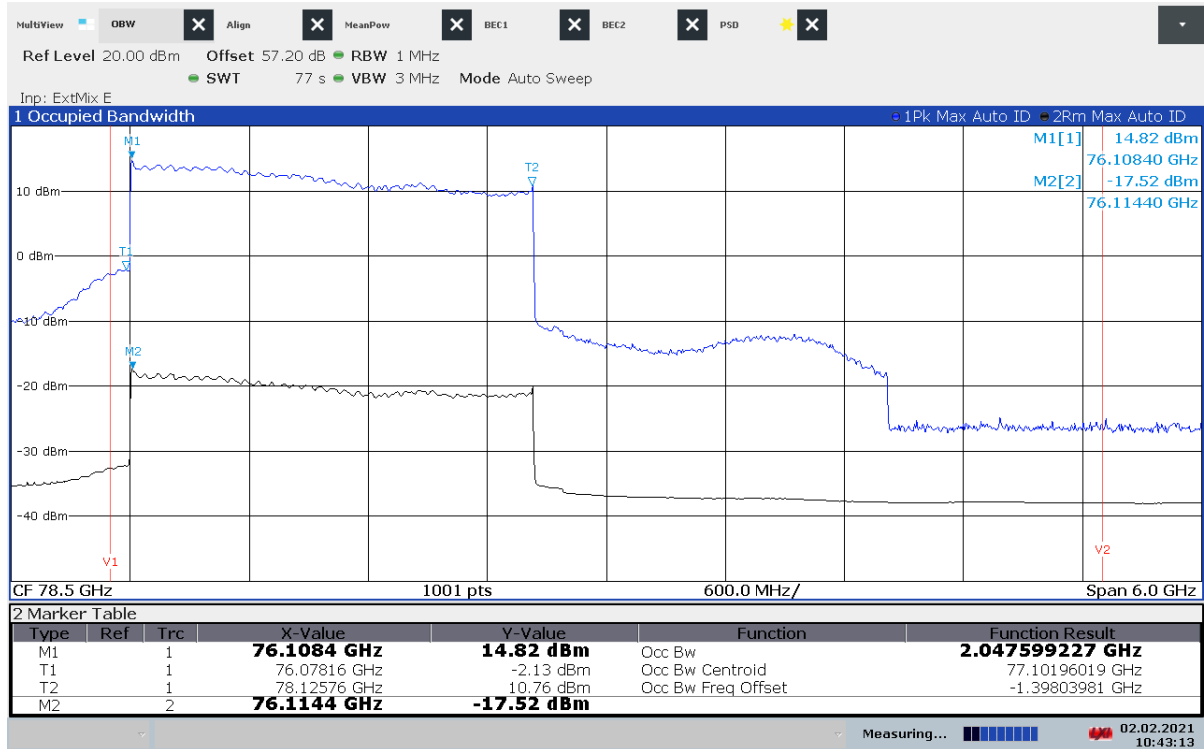
15:00:19 28.01.2021

Plot 60: OBW, +10 °C / V_{nom}, Mode 6

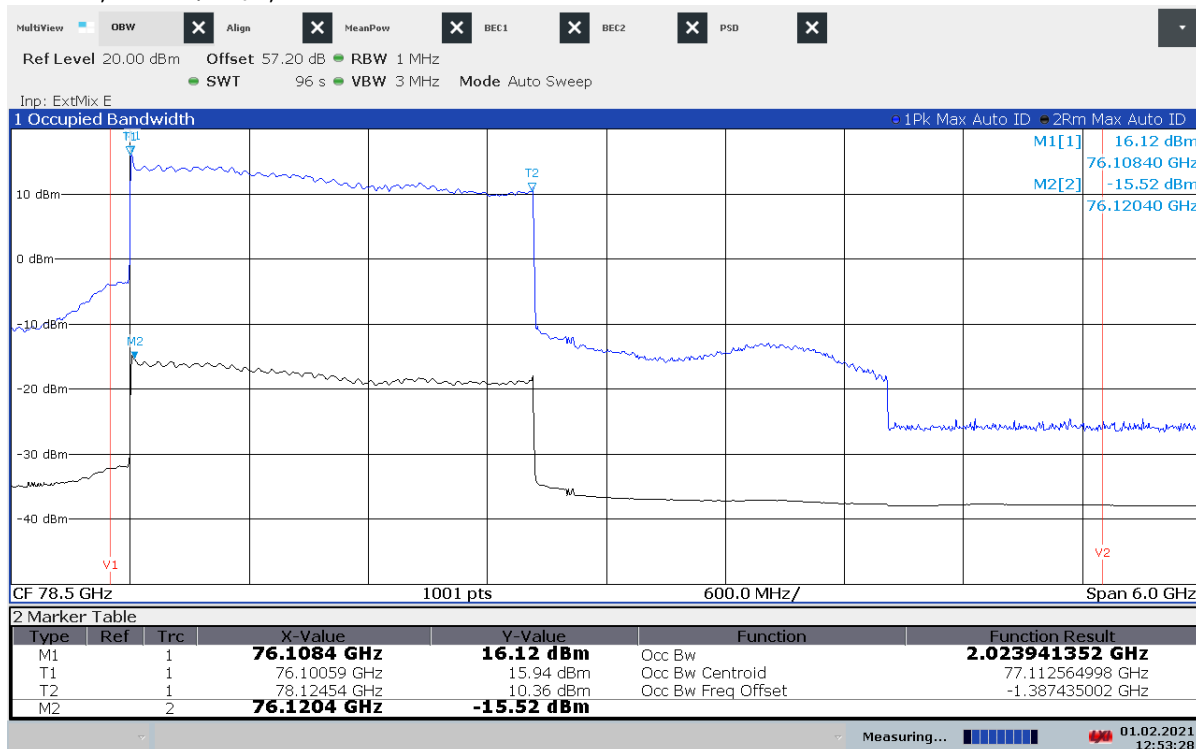
14:57:14 28.01.2021

Plot 61: OBW, +20 °C / V_{nom} , Mode 3

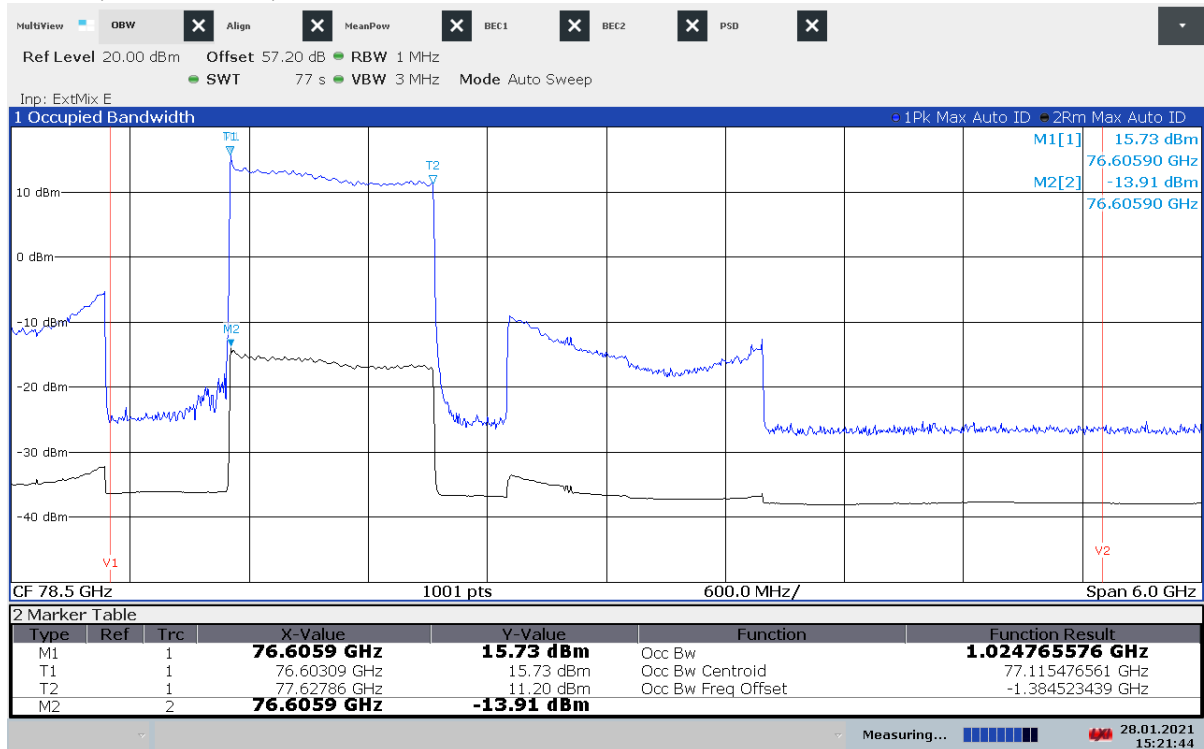
11:10:00 01.02.2021

Plot 62: OBW, +20 °C / V_{nom} , Mode 5

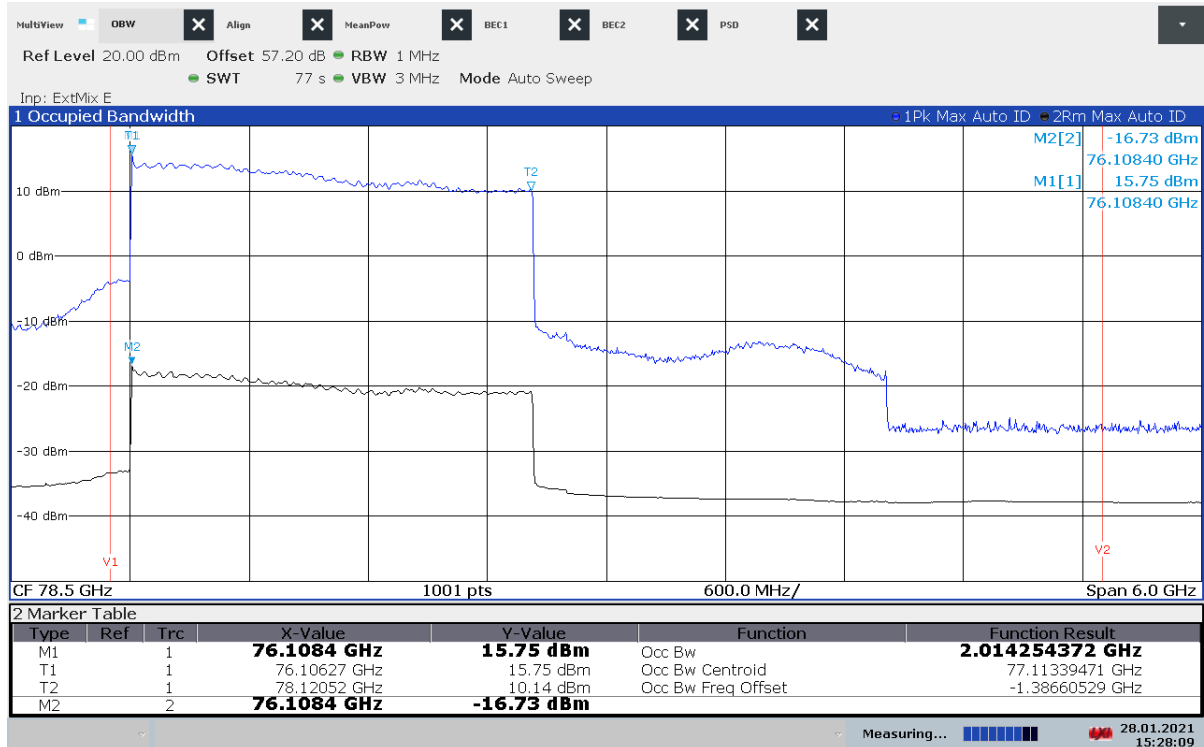
10:43:13 02.02.2021

Plot 63: OBW, +20 °C / V_{nom}, Mode 6

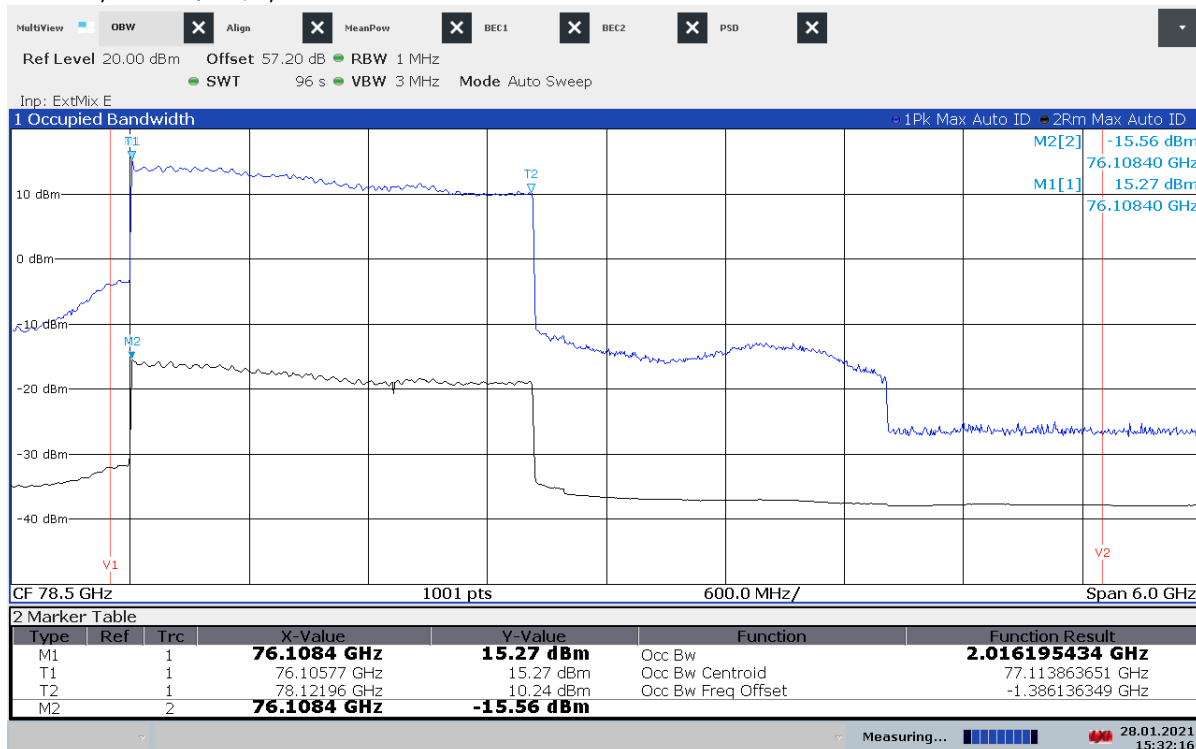
12:53:29 01.02.2021

Plot 64: OBW, +30 °C / V_{nom} , Mode 3

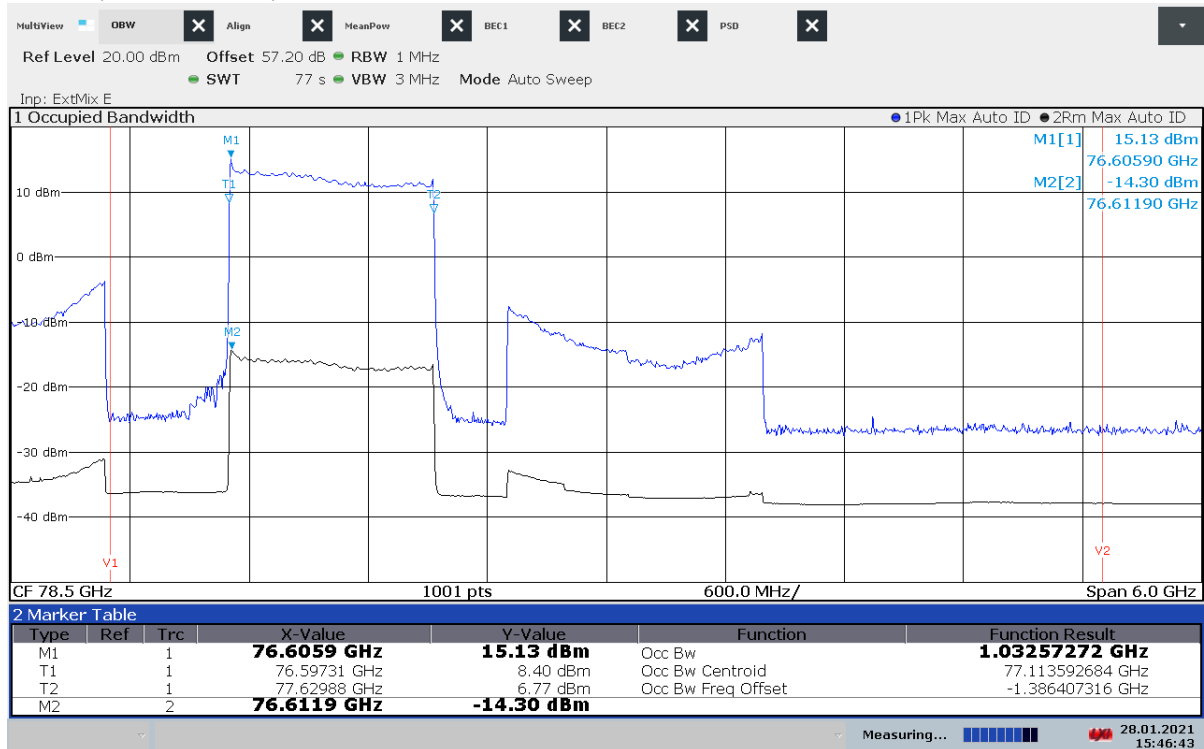
15:21:45 28.01.2021

Plot 65: OBW, +30 °C / V_{nom} , Mode 5

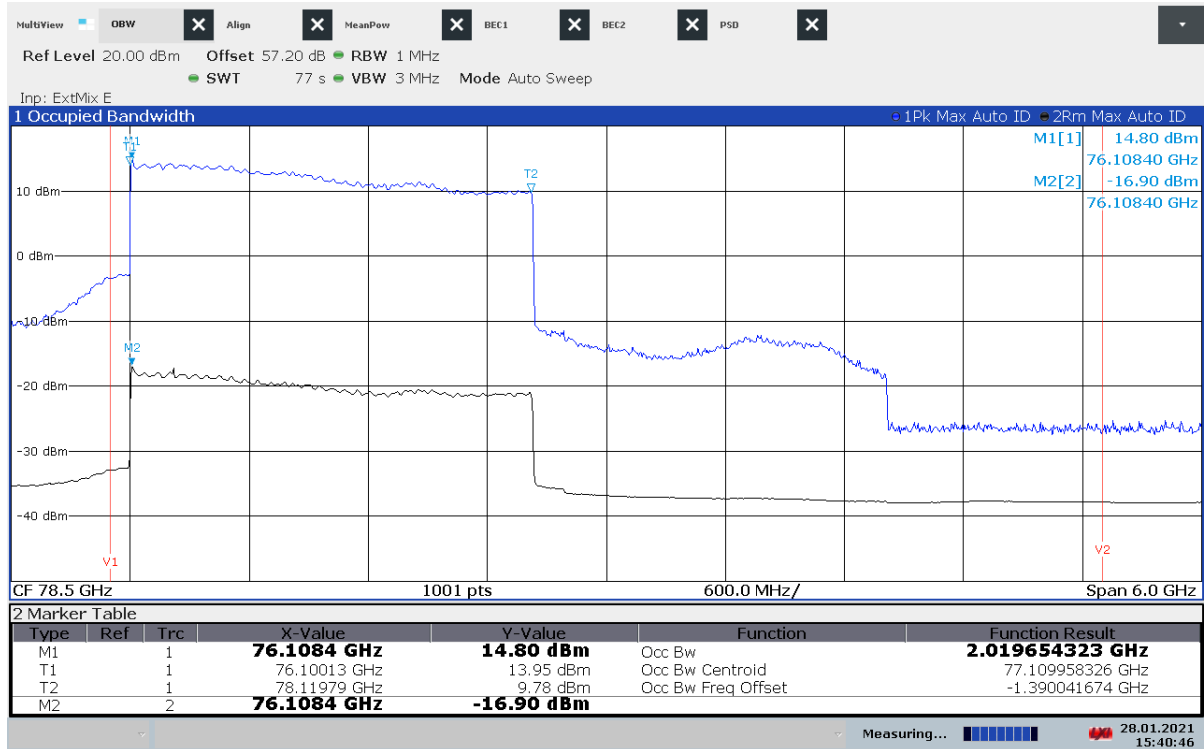
15:28:10 28.01.2021

Plot 66: OBW, +30 °C / V_{nom}, Mode 6

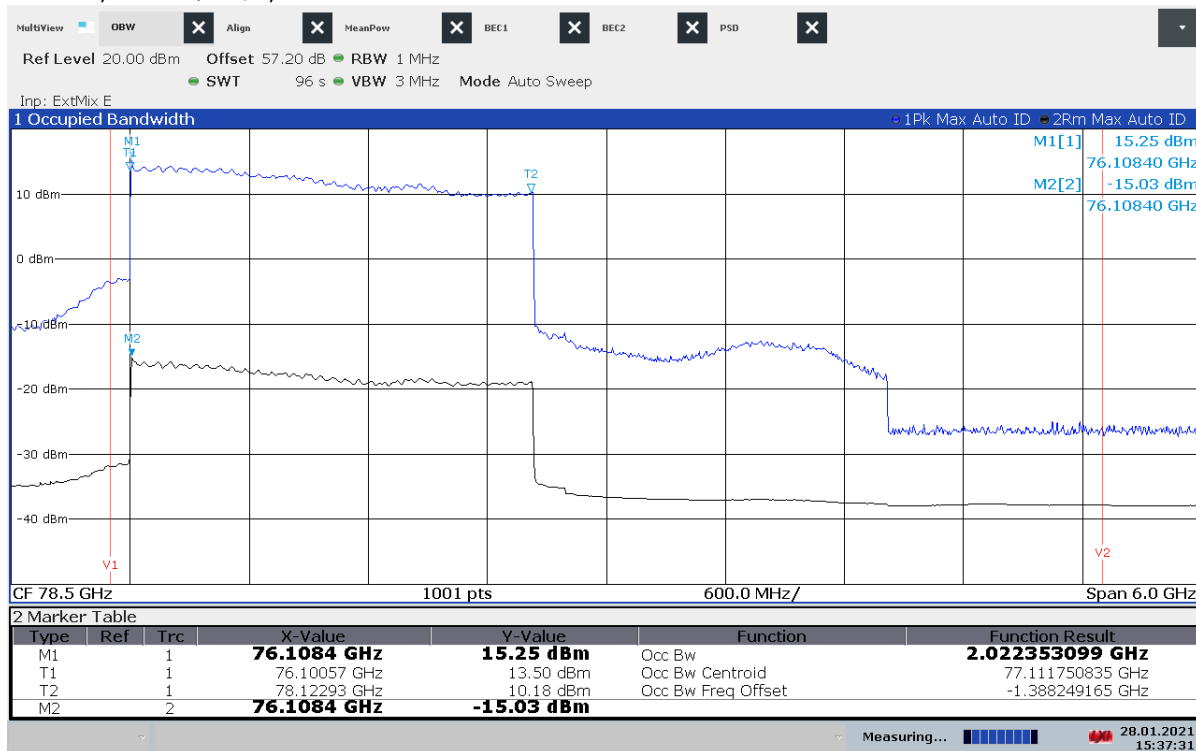
15:32:17 28.01.2021

Plot 67: OBW, +40 °C / V_{nom} , Mode 3

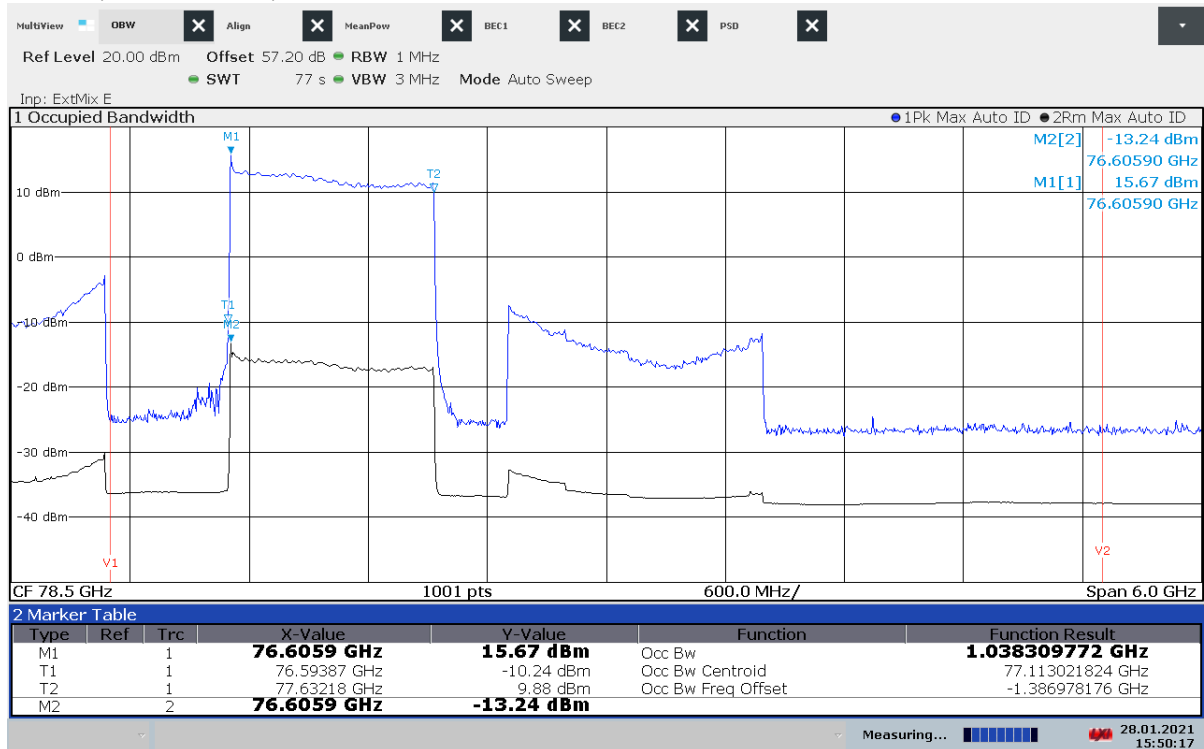
15:46:44 28.01.2021

Plot 68: OBW, +40 °C / V_{nom} , Mode 5

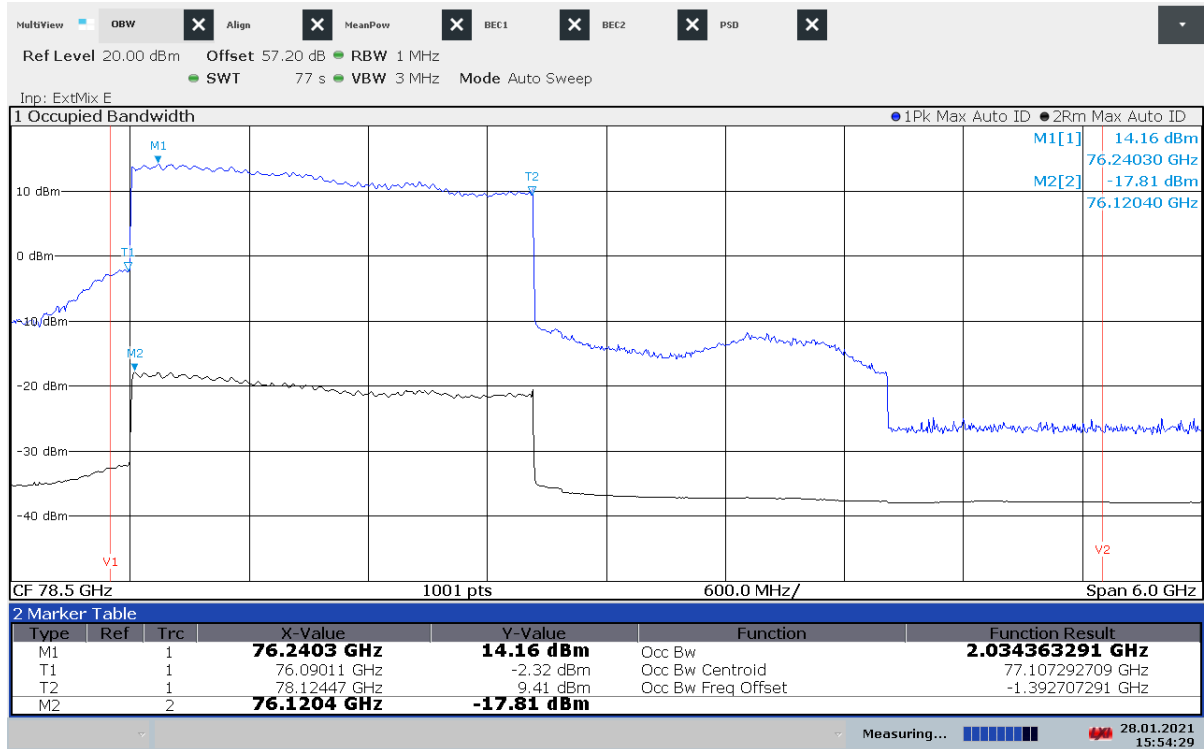
15:40:47 28.01.2021

Plot 69: OBW, +40 °C / V_{nom}, Mode 6

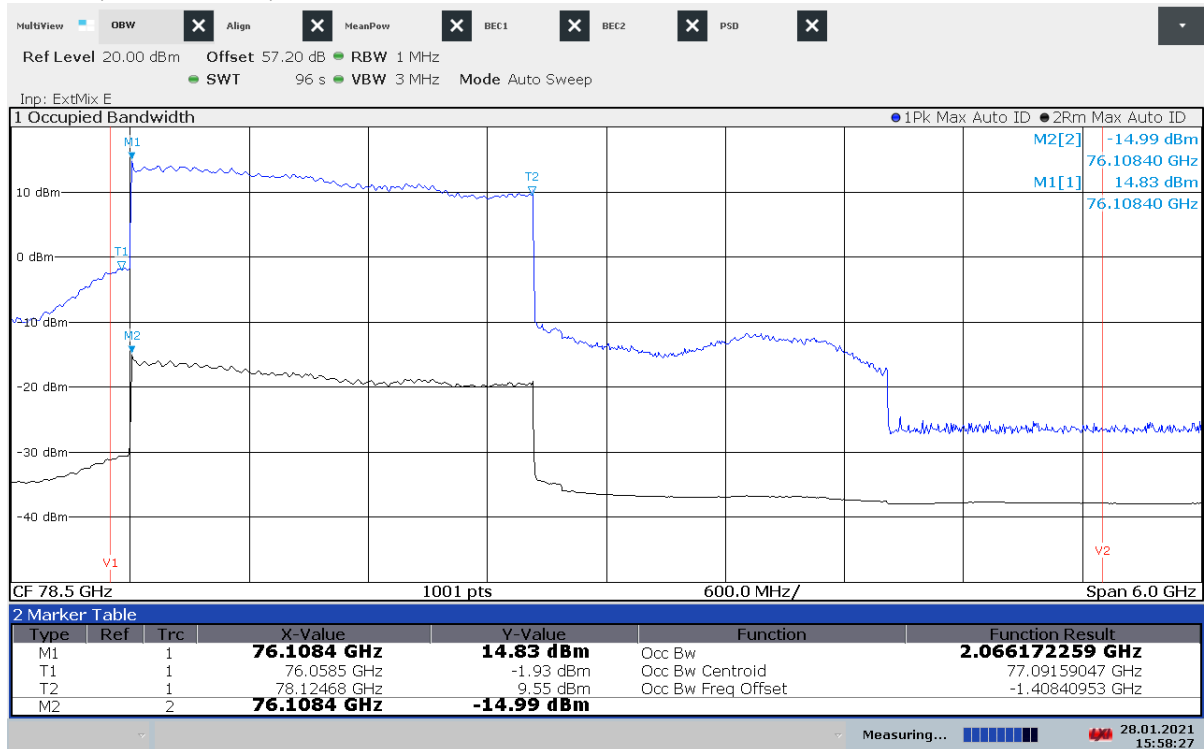
15:37:32 28.01.2021

Plot 70: OBW, +50 °C / V_{nom} , Mode 3

15:50:18 28.01.2021

Plot 71: OBW, +50 °C / V_{nom} , Mode 5

15:54:29 28.01.2021

Plot 72: OBW, +50 °C / V_{nom}, Mode 6

15:58:27 28.01.2021

13 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/N₀	Carrier to noise-density ratio, expressed in dB-Hz

14 Document history

Version	Applied changes	Date of release
-/-	Initial release	2021-02-12

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

first page

last page



Deutsche Akkreditierungsstelle GmbH

Entrusted according to Section 8 subsection 1 AkkStelleG in connection with Section 1 subsection 1 AkkStelleGBV
Signatory to the Multilateral Agreements of EA, ILAC and IAF for Mutual Recognition

Accreditation



The Deutsche Akkreditierungsstelle GmbH attests that the testing laboratory

CTC advanced GmbH
Untertürkheimer Straße 6-10, 66117 Saarbrücken

is competent under the terms of DIN EN ISO/IEC 17025:2018 to carry out tests in the following fields:

Telecommunication (FCC Requirements)

The accreditation certificate shall only apply in connection with the notice of accreditation of 09.06.2020 with the accreditation number D-PL-12076-01. It comprises the cover sheet, the reverse side of the cover sheet and the following annex with a total of 05 pages.

Registration number of the certificate: D-PL-12076-01-05

Frankfurt am Main, 09.06.2020

by  **Dr. rer. oec. Dipl.-Ing. (FH) Ralf Egnor**
Head of Division

The certificate together with its annex reflects the status at the time of the date of issue. The current status of the scope of accreditation can be found in the database of accredited bodies of Deutsche Akkreditierungsstelle GmbH.
<https://www.dakks.de/en/content/accredited-bodies-dakks>
Annexes omitted.

Deutsche Akkreditierungsstelle GmbH

Office Berlin
Spittelmarkt 10
10117 Berlin

Office Frankfurt am Main
Europa-Allee 52
60327 Frankfurt am Main

Office Braunschweig
Bundesallee 100
38116 Braunschweig

The publication of extracts of the accreditation certificate is subject to the prior written approval by Deutsche Akkreditierungsstelle GmbH (DAkKS). Exempted is the unchanged form of separate disseminations of the cover sheet by the conformity assessment body mentioned overleaf.

No impression shall be made that the accreditation also extends to fields beyond the scope of accreditation attested by DAkKS.

The accreditation was granted pursuant to the Act on the Accreditation Body (AkkStelleG) of 31 July 2009 (Federal Law Gazette I p. 2625) and the Regulation (EC) No 765/2008 of the European Parliament and of the Council of 9 July 2008 setting out the requirements for accreditation and market surveillance relating to the marketing of products (Official Journal of the European Union L 218 of 9 July 2008, p. 30). DAkKS is a signatory to the Multilateral Agreements for Mutual Recognition of the European co-operation for Accreditation (EA), International Accreditation Forum (IAF) and International Laboratory Accreditation Cooperation (ILAC). The signatories to these agreements recognise each other's accreditations.

The up-to-date state of membership can be retrieved from the following websites:
EA: www.european-accreditation.org
ILAC: www.ilac.org
IAF: www.iaf.nu

Note: The current certificate annex is published on the website (link see below) of the Accreditation Body DAkKS or may be received by CTC advanced GmbH on request

<https://www.dakks.de/as/ast/d/D-PL-12076-01-05e.pdf>

END OF TEST REPORT