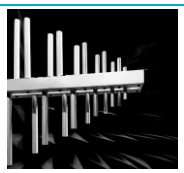
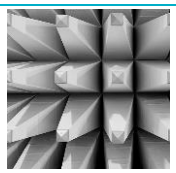



Bundesnetzagentur

BNetzA-CAB-02/21-102

TEST REPORT

Test report no.: 1-2991/21-01-03_Draft

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

Topgolf Sweden AB
Svardvagen 3A
18233 Danderyd / SWEDEN
Phone: +46 707 778758
Contact: Jonas Norlander
e-mail: jonas.norlander@topgolf.com

Manufacturer

Topgolf Sweden AB
Svardvagen 3A
18233 Danderyd / SWEDEN

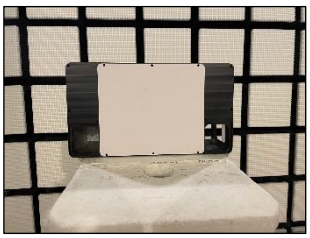
Test standard/s

FCC - Title 47 CFR Part 90	Private Land Mobile Radio Services
Subpart F	Radiolocation Service

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

Test Item

Kind of test item:	**Ball Tracking Radar**
Model name:	**Toptracer**
FCC ID:	**2A3E9-PTRSHV1**
Frequency:	10.35 – 10.40 GHz 10.40 – 10.45 GHz 10.45 – 10.50 GHz
Antenna:	Integrated patch antenna
Power supply:	12 V to 28 V DC or 100 to 240 V AC, 50/60 Hz – 1.5A max
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:

Thomas Vogler

cn=Thomas Vogler, o=CTC advanced GmbH, ou=VOG-161125, email=thomas.vogler@ctcadvanced.com, c=DE
2021.11.17 17:32:48 +01'00'

Thomas Vogler
Lab Manager
Radio Communications

Test performed:

M. Walla

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2021.11.17 15:53:20 +01'00'

Meheza Walla
Lab Manager
Radio Communications

1 Table of contents

1 Table of contents 2
2 General information 3
2.1 Notes and disclaimer 3
2.2 Application details 3
2.3 Test laboratories sub-contracted 3
3 Test standard/s, references and accreditations 4
4 Reporting statements of conformity – decision rule 5
5 Test environment 6
6 Test item 6
6.1 General description 6
6.2 Additional information 6
7 Description of the test setup 7
7.1 Shielded semi anechoic chamber 8
7.2 Shielded fully anechoic chamber 10
7.3 Radiated measurements > 18 GHz 12
8 Sequence of testing 13
8.1 Sequence of testing radiated spurious 9 kHz to 30 MHz 13
8.2 Sequence of testing radiated spurious 30 MHz to 1 GHz 14
8.3 Sequence of testing radiated spurious 1 GHz to 18 GHz 15
8.4 Sequence of testing radiated spurious above 18 GHz 16
9 Measurement uncertainty 17
10 Summary of measurement results 18
11 Measurement results 19
11.1 RF Output Power 19
11.2 Occupied bandwidth (99% bandwidth) 29
11.3 Field strength of emissions radiation and emission mask 31
11.4 Conducted spurious emissions < 30 MHz 50
11.5 Frequency Stability 53
12 Glossary 59
13 Document history 60
14 Accreditation Certificate – D-PL-12076-01-05 61

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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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In no case this test report can be considered as a Letter of Approval.

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

2.2 Application details

Date of receipt of order:	2021-09-07
Date of receipt of test item:	2021-09-17
Start of test:*	2021-09-20
End of test:*	2021-11-02
Person(s) present during the test:	-/-

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

2.3 Test laboratories sub-contracted

None

3 Test standard/s, references and accreditations

Test standard	Date	Description
FCC - Title 47 CFR Part 90		Private Land Mobile Radio Services
Subpart F		Radiolocation Service

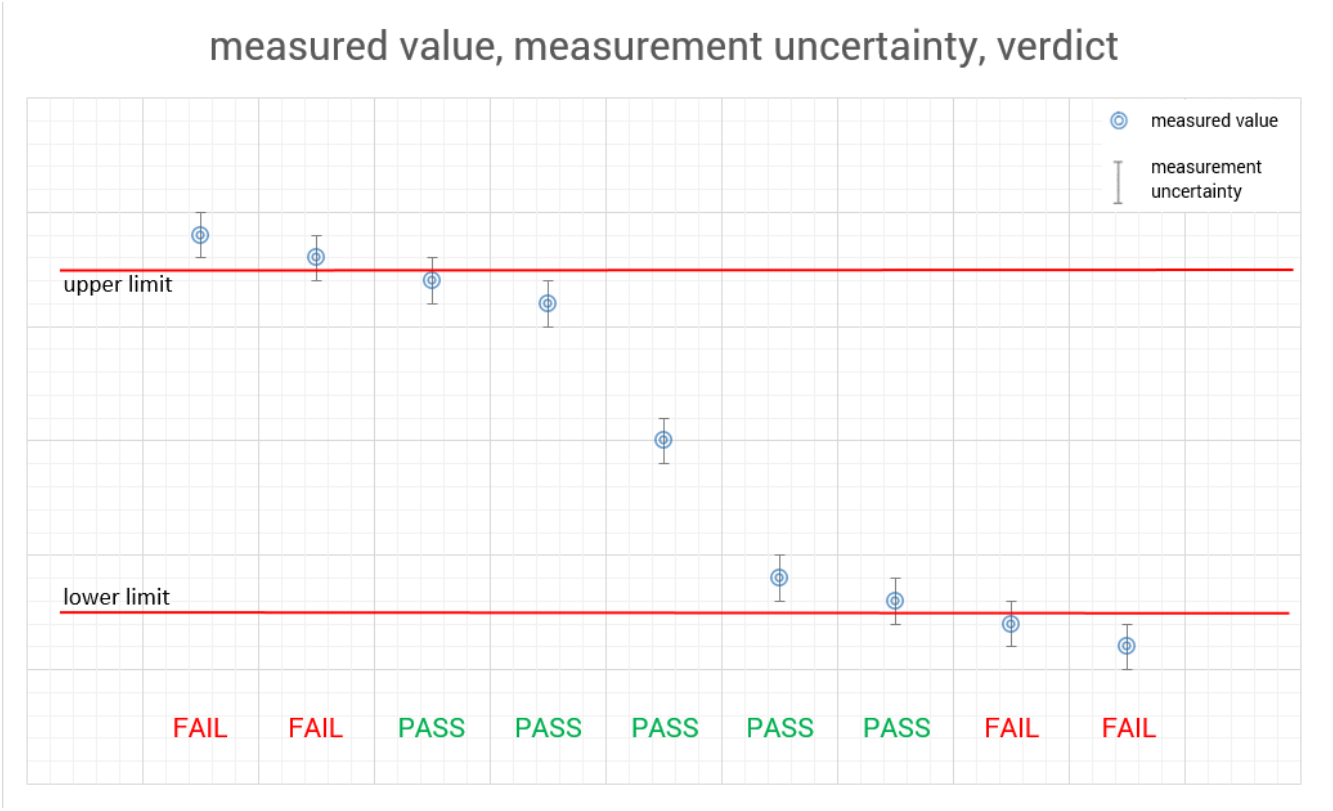
Guidance	Version	Description
ANSI C63.26-2015	-/-	American National Standard for Compliance Testing of Transmitters Used in Licensed Radio Services

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

FCC designation number: DE0002

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 9.
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 +50 °C during high temperature tests -20 °C during low temperature tests
Relative humidity content	:		55 %
Barometric pressure	:		1021 hpa
Power supply	:	V_{nom} V_{max} V_{min}	24.0 V DC from power supply or 100-240 V AC, 50/60 Hz, 1.5A max 28.0 V 12.0 V

6 Test item

6.1 General description

Kind of test item	:	Ball Tracking Radar
Model name	:	Toptracer
S/N serial number	:	-/-
Hardware status	:	Frontend: R2A; Backend: R3A; Antenna: 9xE
Software status	:	-/-
Frequency band	:	10.35 – 10.40 GHz 10.40 – 10.45 GHz 10.45 – 10.50 GHz
Type of modulation	:	FMCW
Number of channels	:	3
Antenna	:	Integrated patch antenna
Power supply	:	12 V to 28 V DC or 100 to 240 V AC, 50/60 Hz – 1.5A max
Temperature range	:	-20°C to +50°C

6.2 Additional information

Special test software was used to change from normal operation mode to CW.

The power settings: VVA Code 1023

Test setup and EUT photos are included in test report: 1-2991/21-01-01_AnnexA
1-2991/21-01-01_AnnexB
1-2991/21-01-01_AnnexD

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).

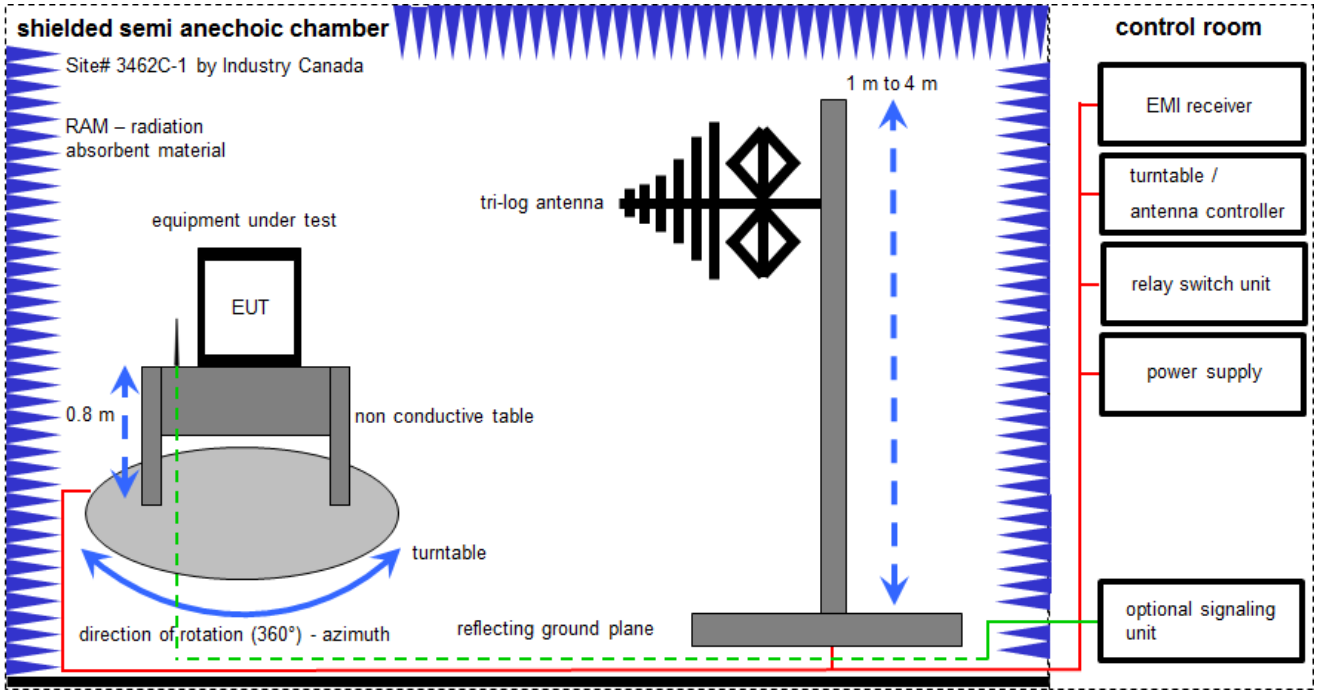
In order to simplify the identification of the equipment used at some special tests, some items of test equipment and ancillaries can be provided with an identifier or number in the equipment list below (Lab/Item).

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
vlkl!	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

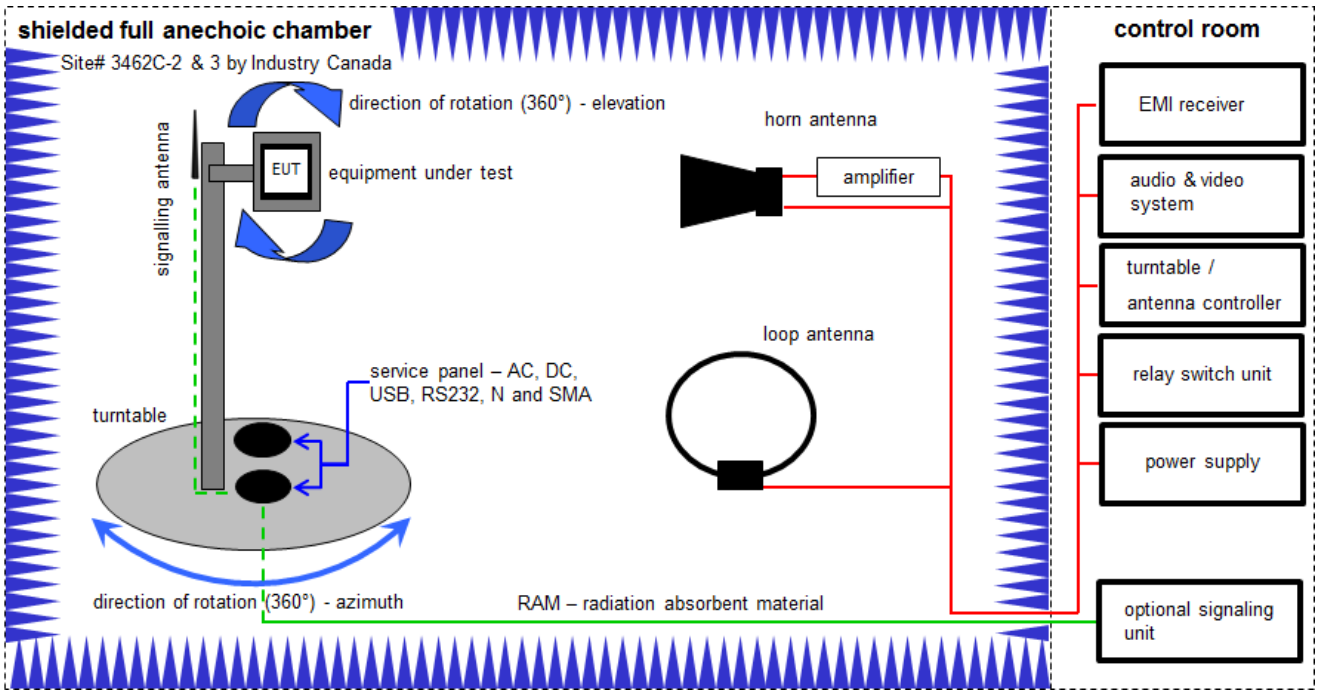
FS = UR + CL + AF
(FS-field strength; UR-voltage at the receiver; CL-loss of the cable; AF-antenna factor)

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	295	300003787	vlKl!	21.04.2021	20.04.2023
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)

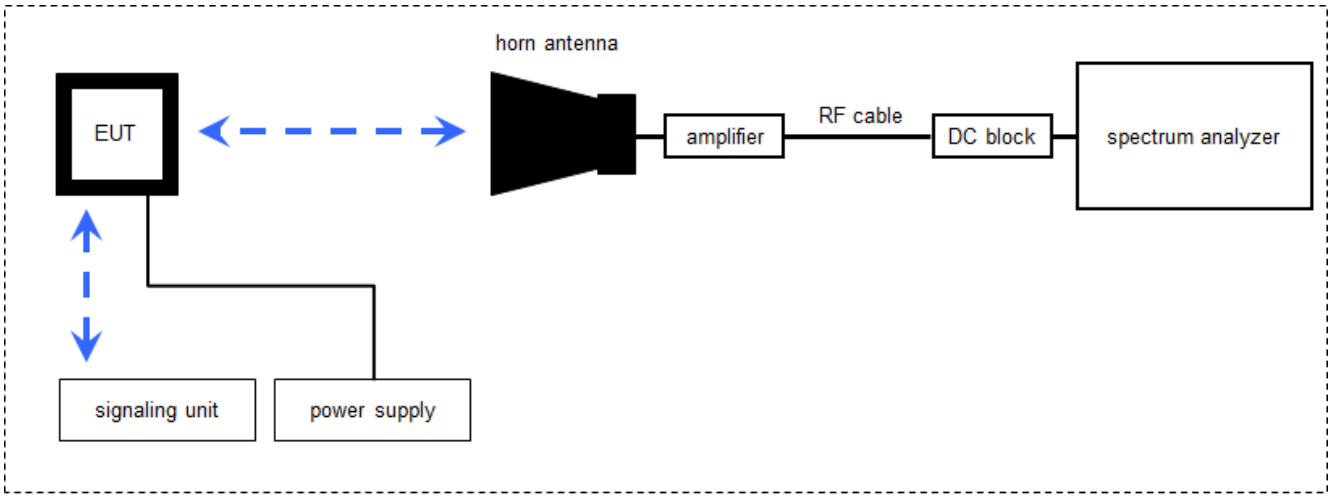
OP = AV + D - G + CA
(OP-radiated output power; AV-analyzer value; D-free field attenuation of measurement distance; G-antenna gain+amplifier gain; CA-loss signal path)

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.	Anechoic chamber	FAC 3/5m	MWB / TDK	87400/02	300000996	ev	-/-	-/-
3	n. a.	Double-Ridged Waveguide Horn Antenna 1-18.0GHz	3115	EMCO	9107-3697	300001605	vIKI!	12.03.2021	11.03.2023
4	n. a.	Switch / Control Unit	3488A	HP	*	300000199	ne	-/-	-/-
5	n. a.	Variable isolating transformer	MPL IEC625 Bus Variable isolating transformer	Erfi	91350	300001155	ne	-/-	-/-
6	n. a.	EMI Test Receiver 20Hz- 26,5GHz	ESU26	R&S	100037	300003555	k	11.12.2020	10.12.2021
7	n. a.	Highpass Filter	WHKX7.0/18G-8SS	Wainwright	19	300003790	ne	-/-	-/-
8	n. a.	Broadband Amplifier 0.5-18 GHz	CBLU5184540	CERNEX	22049	300004481	ev	-/-	-/-
9	n. a.	Broadband Amplifier 5-13 GHz	CBLU5135235	CERNEX	22010	300004491	ev	-/-	-/-
10	n. a.	4U RF Switch Platform	L4491A	Agilent Technologies	MY50000037	300004509	ne	-/-	-/-
11	n. a.	NEXIO EMV-Software	BAT EMC V3.16.0.49	EMCO		300004682	ne	-/-	-/-
12	n. a.	PC	ExOne	F+W		300004703	ne	-/-	-/-
13	n. a.	RF-Amplifier	AMF-6F06001800-30-10P-R	NARDA-MITEQ Inc	2011572	300005241	ev	-/-	-/-
14	n. a.	Active Loop Antenna 9 kHz to 30 MHz	6502	EMCO	2210	300001015	vIKI!	13.06.2019	12.06.2022

7.3 Radiated measurements > 18 GHz



Measurement distance: horn antenna e.g. 25 cm

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

Example calculation:
FS [dBµV/m] = 40.0 [dBµV/m] + (-60.1) [dB] + 36.74 [dB/m] = 16.64 [dBµV/m] (6.79 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] = -59.0 [dBm] + 44.0 [dB] - 20.0 [dBi] + 5.0 [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	Spectrum Analyzer	FSW50	Rohde & Schwarz	101560	300006179	k	05.03.2021	04.03.2022
2	n. a	Broadband LNA 18-50 GHz	CBL18503070PN	CERNEX	25240	300004948	ev	09.03.2020	08.03.2022
3	n. a	Horn Antenna 18,0-40,0 GHz	LHAF180	Microw.Devel	39180-103-021	300001747	vlKl!	18.02.2019	17.02.2022
4	n. a	Std. Gain Horn Antenna 18.0-26.5 GHz	638	Narda	01096	300000486	vlKl!	21.01.2020	20.01.2022
5	n. a	Std. Gain Horn Antenna 26.5-40.0 GHz	V637	Narda	82-16	300000510	vlKl!	23.01.2020	22.01.2022
6	n. a	Std. Gain Horn Antenna 33.0-50.1 GHz	2324-20	Flann	57	400000683	ne	-/-	-/-
8	n. a	Std. Gain Horn Antenna 49.9-75.8 GHz	2524-20	Flann	*	300001986	ne	-/-	-/-

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.

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 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 90	see table	2021-11-17	-/-

Test specification clause	Test case	Temperature conditions	Power source voltages	C	NC	NA	NP	Results (max.)
§90.205 (r) §90.103 (b)	RF Output Power	Nominal	Nominal	☒	☐	☐	☐	
§90.103 (b)	Occupied bandwidth (99% bandwidth)	Nominal	Nominal	☒	☐	☐	☐	
§90.210 (c) (3)	Field strength of spurious radiation and Emission masks	Nominal	Nominal	☒	☐	☐	☐	complies
§90.213	Frequency stability	Nominal Extreme	Nominal Extreme	☒	☐	☐	☐	Complies

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

11 Measurement results

11.1 RF Output Power

§ 90.205 Power and antenna height limits

Applicants for licenses must request and use no more power than the actual power necessary for satisfactory operation. Except where otherwise specifically provided for, the maximum power that will be authorized to applicants whose license applications for new stations are filed after August 18, 1995 is as follows:

(r) All other frequency bands. Requested transmitter power will be considered and authorized on a case by case basis.

§ 90.103 Radiolocation Service

(b) Frequencies available. The following table indicates frequencies available for assignment to stations in the Radiolocation Service, together with the class of station(s) to which they are normally assigned, and the specific assignment limitations, which are explained in paragraph (c) of this section:

RADIOLOCATION SERVICE FREQUENCY TABLE

Frequency or band	Class of station(s)	Limitation
	Kilohertz	
70 to 90	Radiolocation land or mobile.	1
90 to 110	Radiolocation land	2
110 to 130	Radiolocation land or mobile.	1
1705 to 1715	do	4, 5, 6
1715 to 1750	do	5, 6
1750 to 1800	do	5, 6
3230 to 3400	do	6, 8
	Megahertz	
420 to 450	do	21
2450 to 2500	do	9, 22, 23
2900 to 3100	do	10, 11
3100 to 3300	do	12
3300 to 3500	do	12, 13
3500 to 3550	do	12
3550 to 3650	do	30
5250 to 5350	do	12
5350 to 5460	do	10, 14
5460 to 5470	do	10, 15
5470 to 5600	do	10, 11
5600 to 5650	do	10, 16
8500 to 9000	do	12, 17
9000 to 9200	do	10, 14
9200 to 9300	do	12
9300 to 9500	do	10, 15, 18
9500 to 10,000	do	12
10,000 to 10,500	do	12, 13, 19
10,500 to 10,550	do	20, 22, 24
13,400 to 13,750	do	12
13,750 to 14,000	do	29
15,700 to 17,300	do	
24,050 to 24,250	do	12, 22, 24
33,400 to 36,000	do	12
78,000–81,000	do	30

(12) This frequency is shared with and is on a secondary basis to the Government Radiolocation Service.

(13) Operations in this band are limited to survey operations using transmitters with a peak power not to exceed 5 watts into the antenna.

(19) Operations in this band are on a secondary basis to the Amateur Radio Service (part 97). Pulsed emissions are prohibited.

Measurement:

Output Power	
Detector:	Pos-Peak
Sweep time:	1s
Resolution bandwidth:	1 MHz
Video bandwidth:	3 MHz
Span:	60 MHz
Trace-Mode:	Max Hold

Power Meter	
Detector:	RMS
Sweep time:	1s
Resolution bandwidth:	1 MHz
Video bandwidth:	3 MHz
Bandwidth:	50 MHz
Trace-Mode:	Clear Write

Result:

With Power Meter:

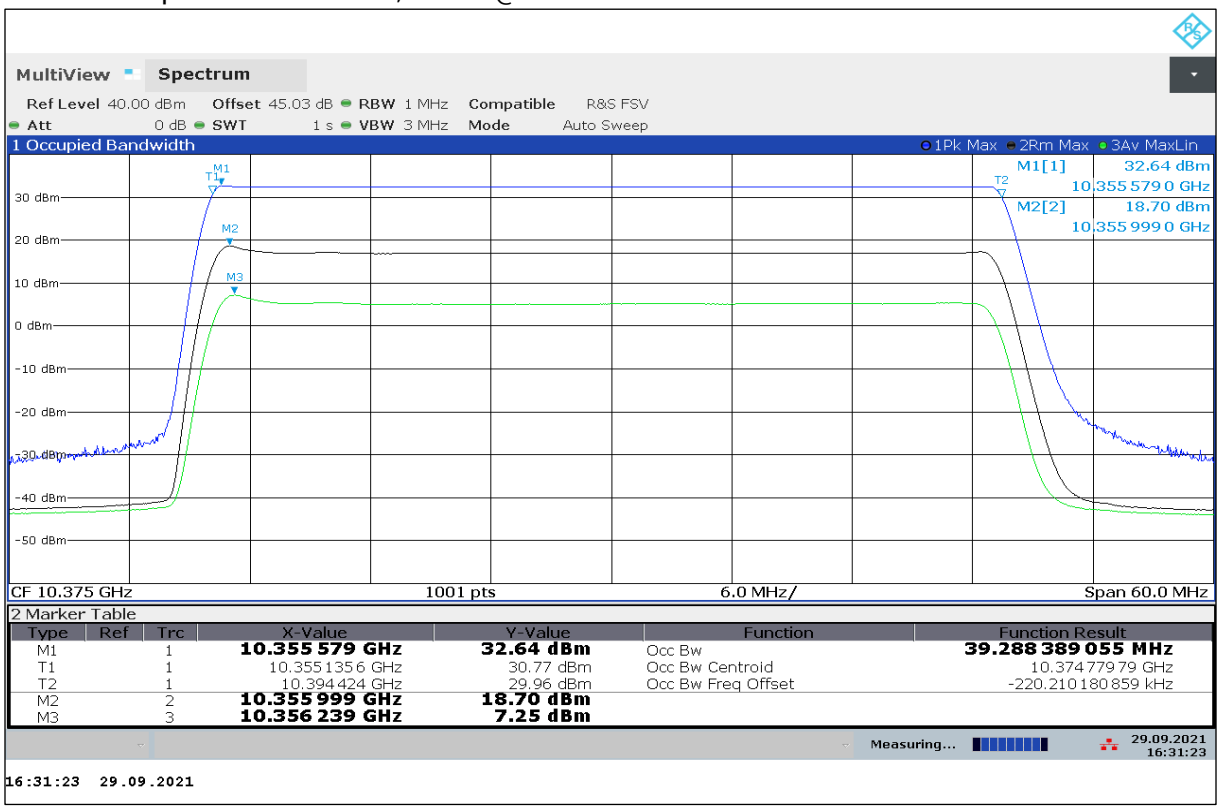
Test condition T_{nom} / V_{nom}	**FMCW @ 10.35 GHz– 10.40 GHz**	**FMCW @ 10.40 GHz– 10.45 GHz**	**FMCW @ 10.45 GHz– 10.50 GHz**
Power meter Conducted	18.0	18.0	17.8

With SA:

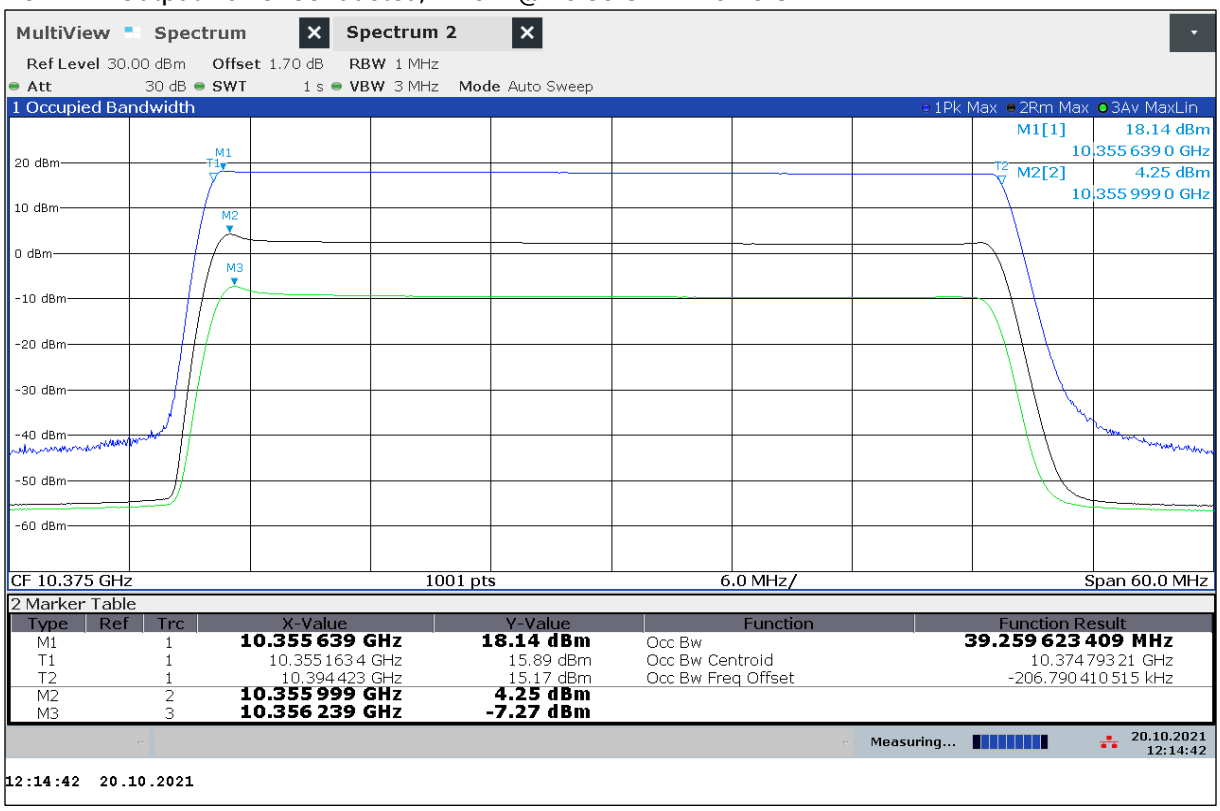
Test condition T_{nom} / V_{nom}	**FMCW @ 10.35 GHz– 10.40 GHz**	**FMCW @ 10.40 GHz– 10.45 GHz**	**FMCW @ 10.45 GHz– 10.50 GHz**
Output Power Radiated	32.6	32.7	32.9
Output Power Conducted	18.1	18.0	17.8
Channel Power Conducted	18.0	18.0	17.7

Test condition T_{nom} / V_{nom}	**CW @ 10.375 GHz**	**CW @ 10.425 GHz**	**CW @ 10.475 GHz**
Output Power Radiated	32.7	32.8	33.0
Output Power Conducted	18.1	18.2	17.5

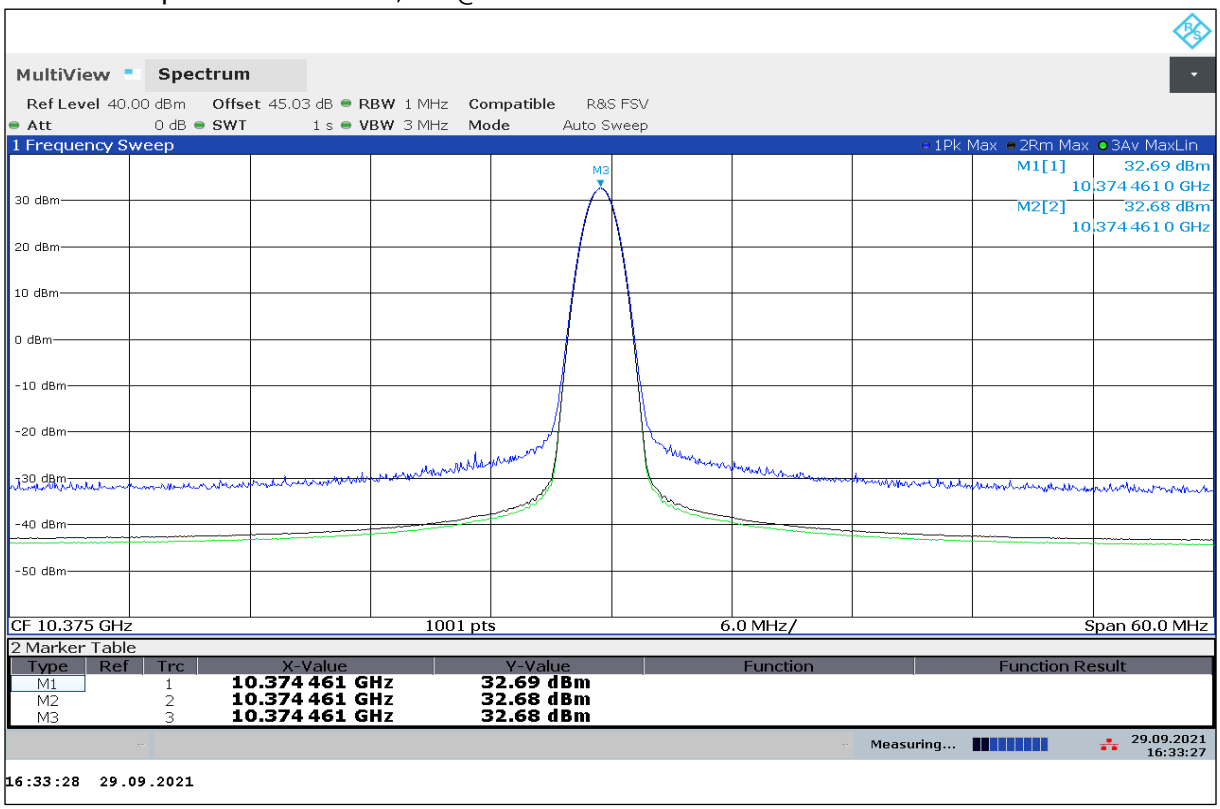
Plot No. 1: RF Output Power Radiated, FMCW @ 10.35 GHz– 10.40 GHz



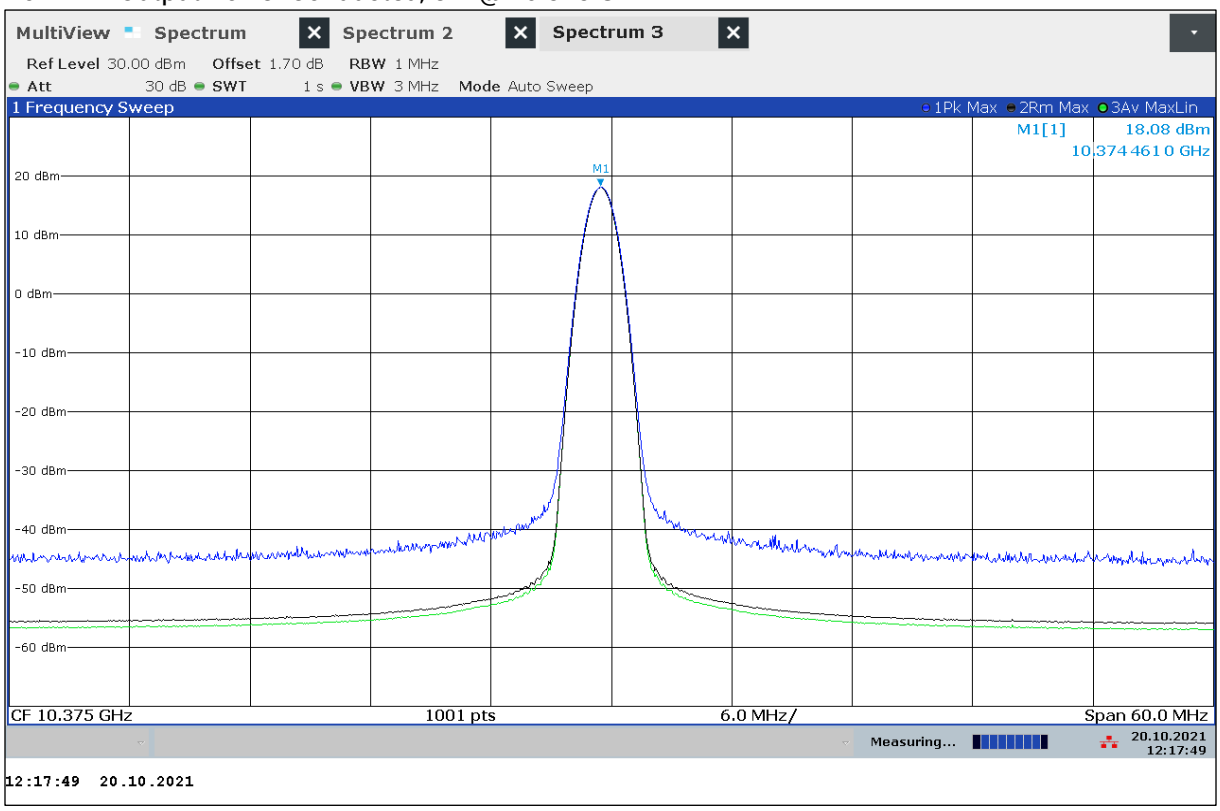
Plot No. 2: RF Output Power Conducted, FMCW @ 10.35 GHz– 10.40 GHz



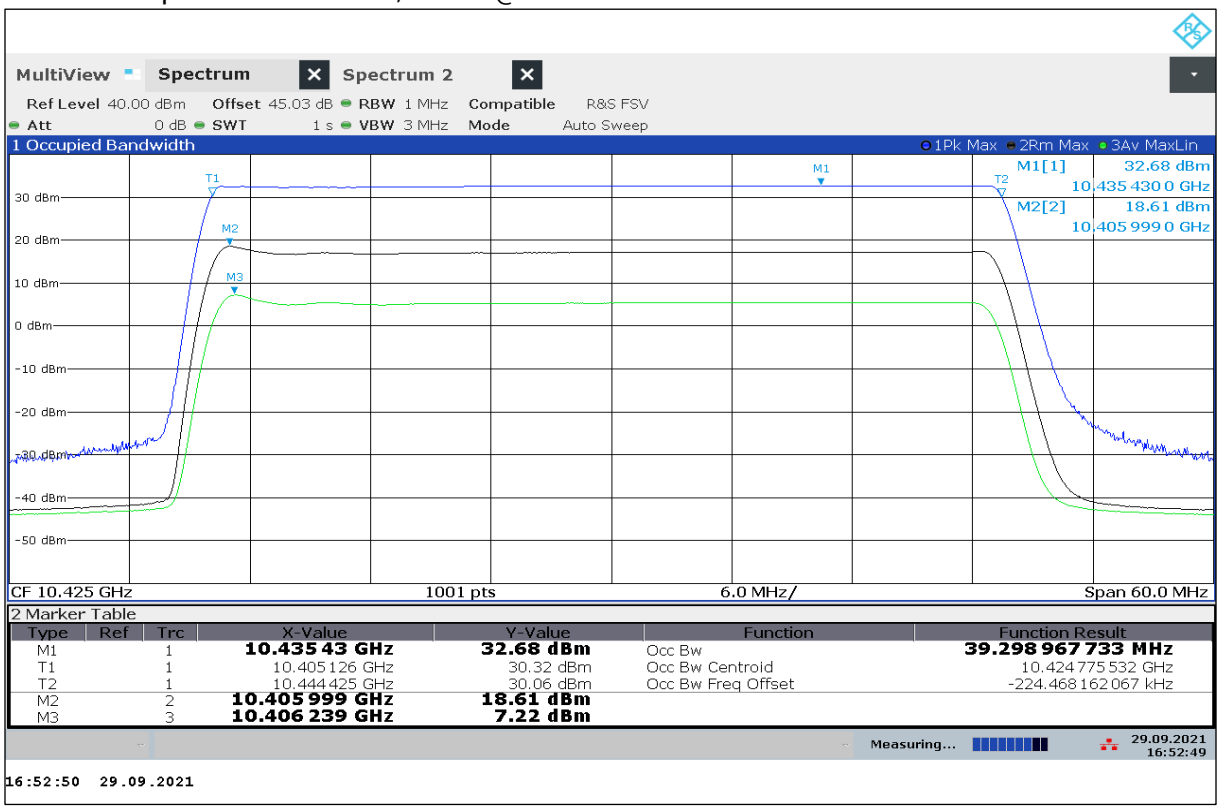
Plot No. 3: RF Output Power Radiated, CW @ 10.375 GHz



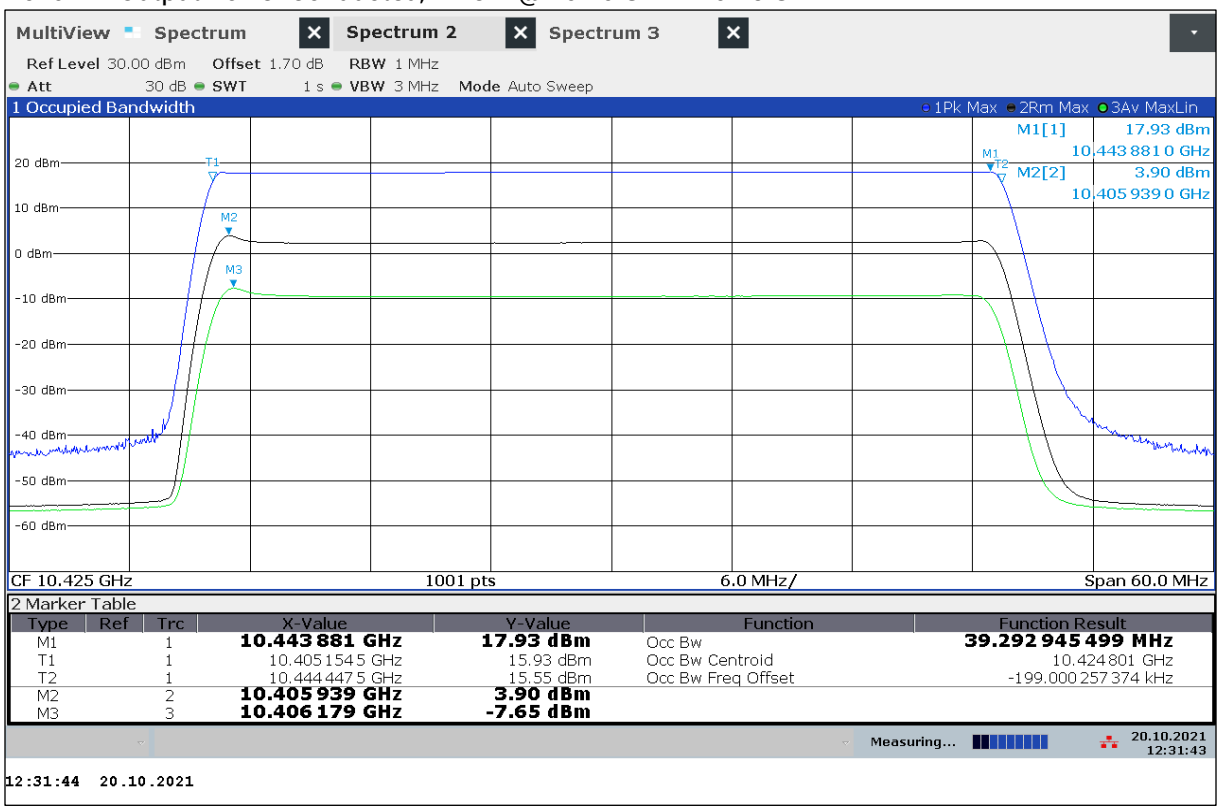
Plot No. 4: RF Output Power Conducted, CW @ 10.375 GHz



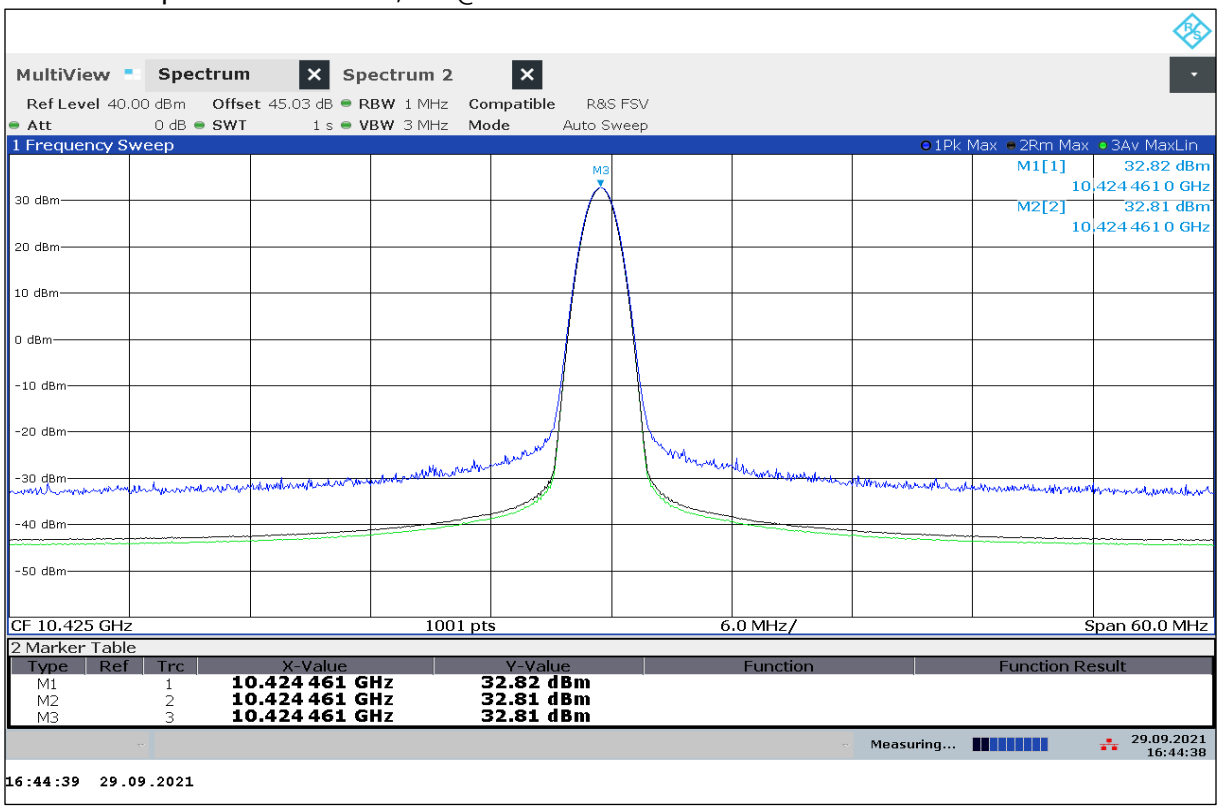
Plot No. 5: RF Output Power Radiated, FMCW @ 10.40 GHz– 10.45 GHz



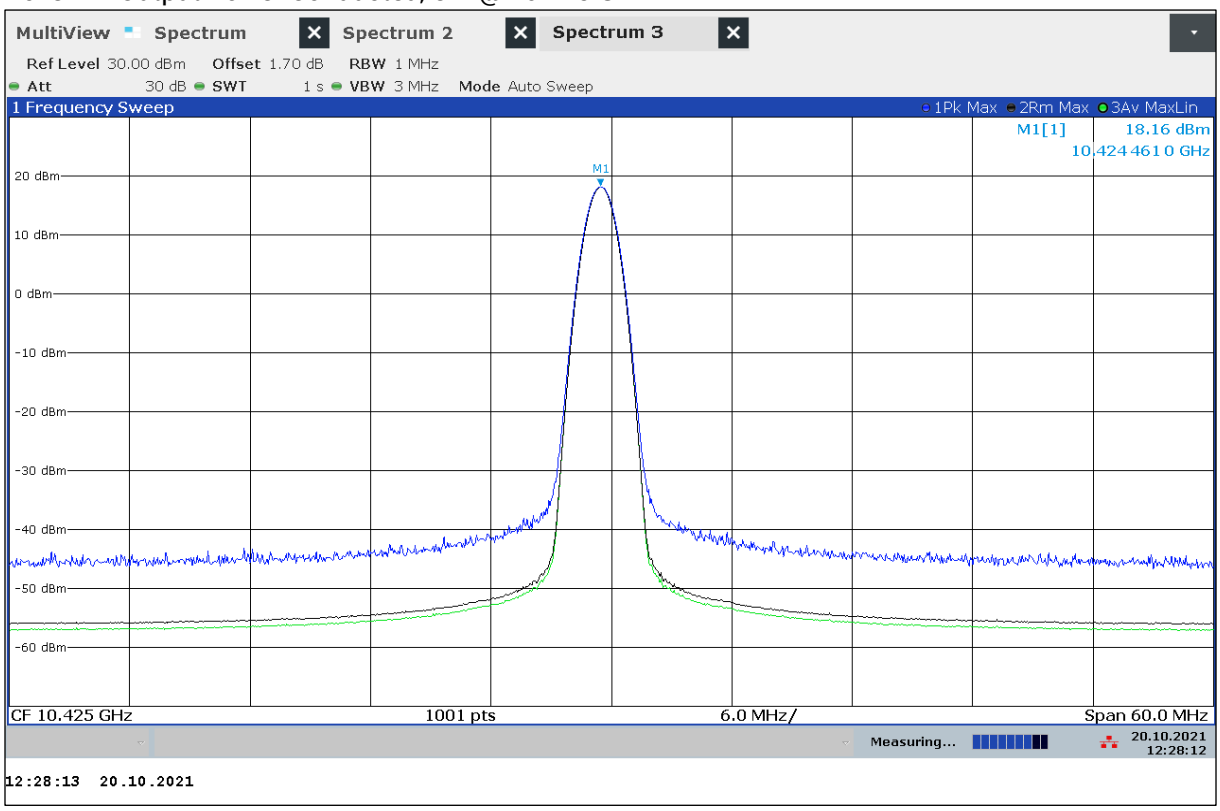
Plot No. 6: RF Output Power Conducted, FMCW @ 10.40 GHz– 10.45 GHz



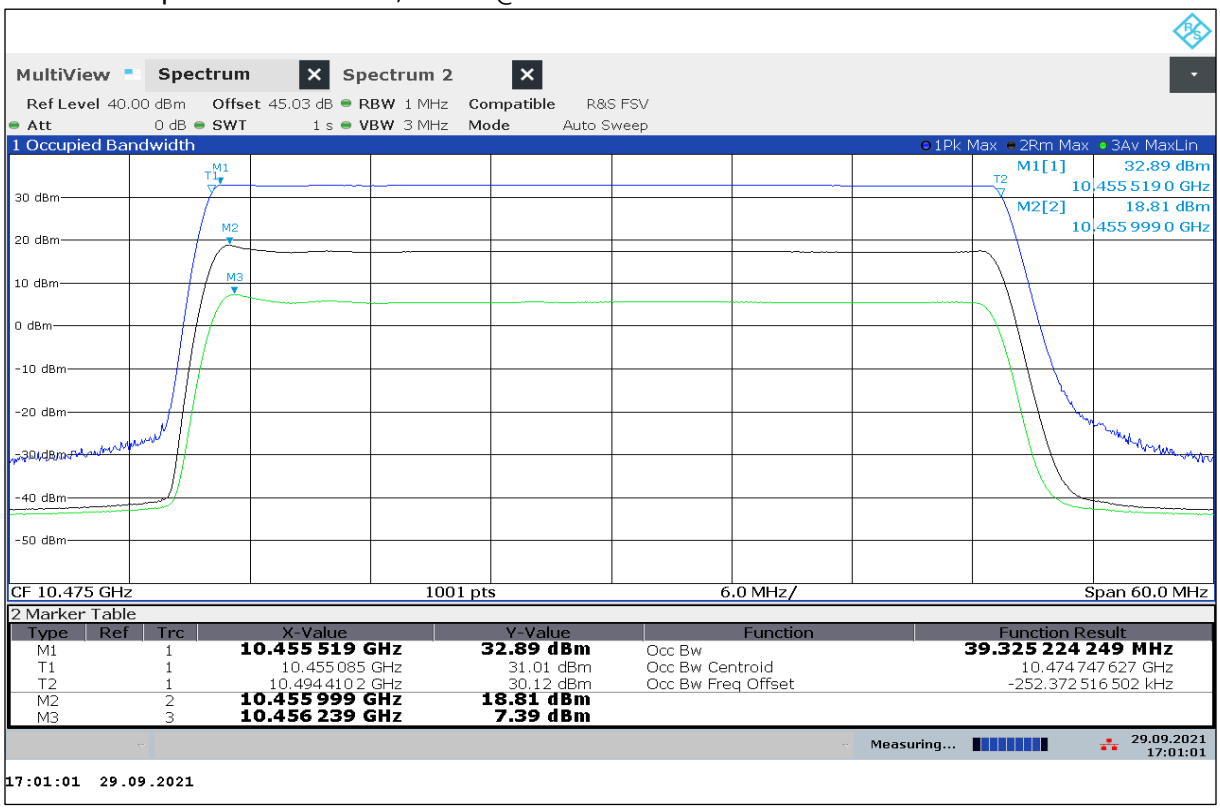
Plot No. 7: RF Output Power Radiated, CW @ 10.425 GHz



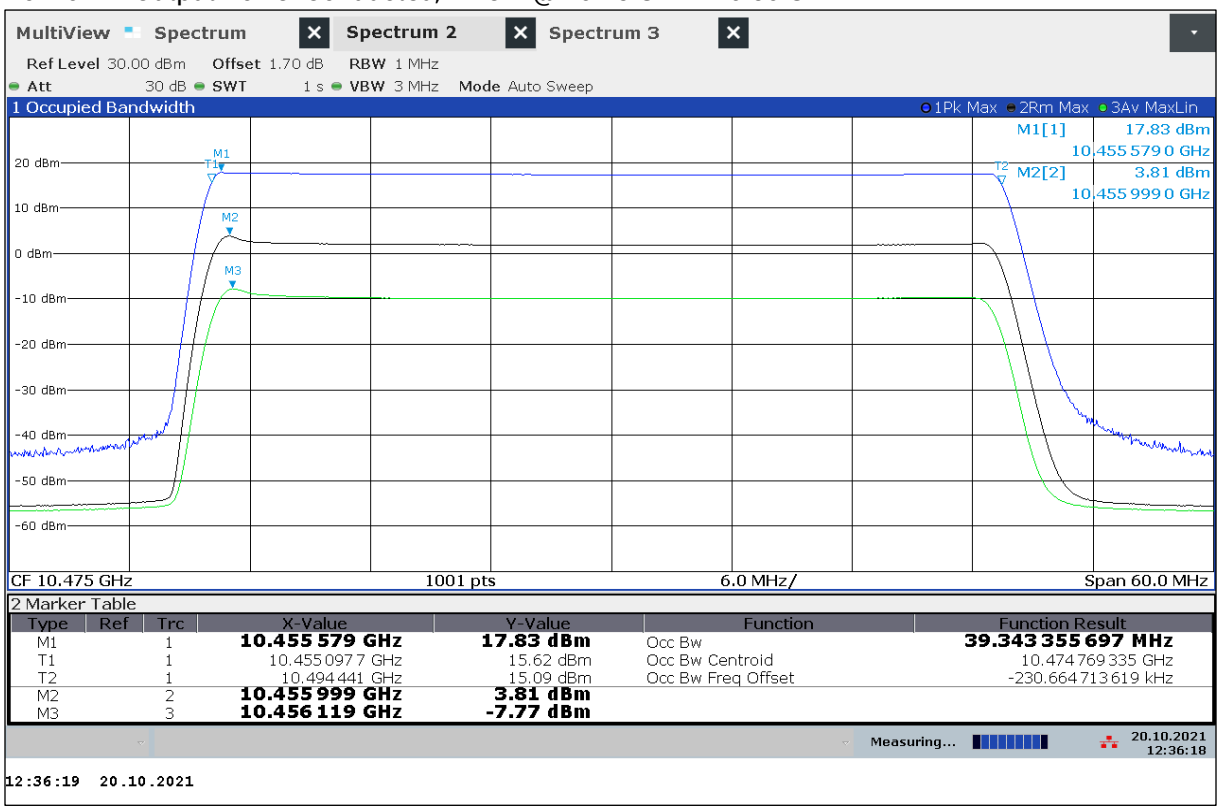
Plot No. 8: RF Output Power Conducted, CW @ 10.425 GHz



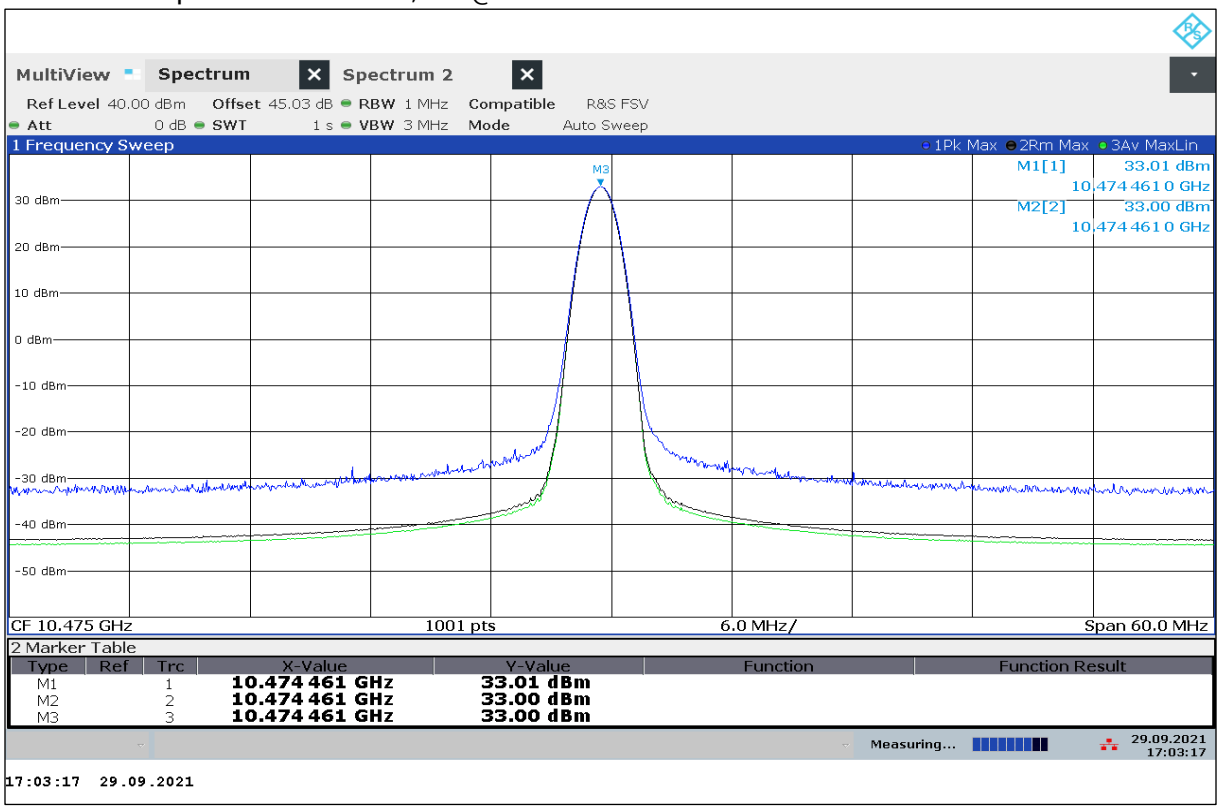
Plot No. 9: RF Output Power Radiated, FMCW @ 10.45 GHz– 10.50 GHz



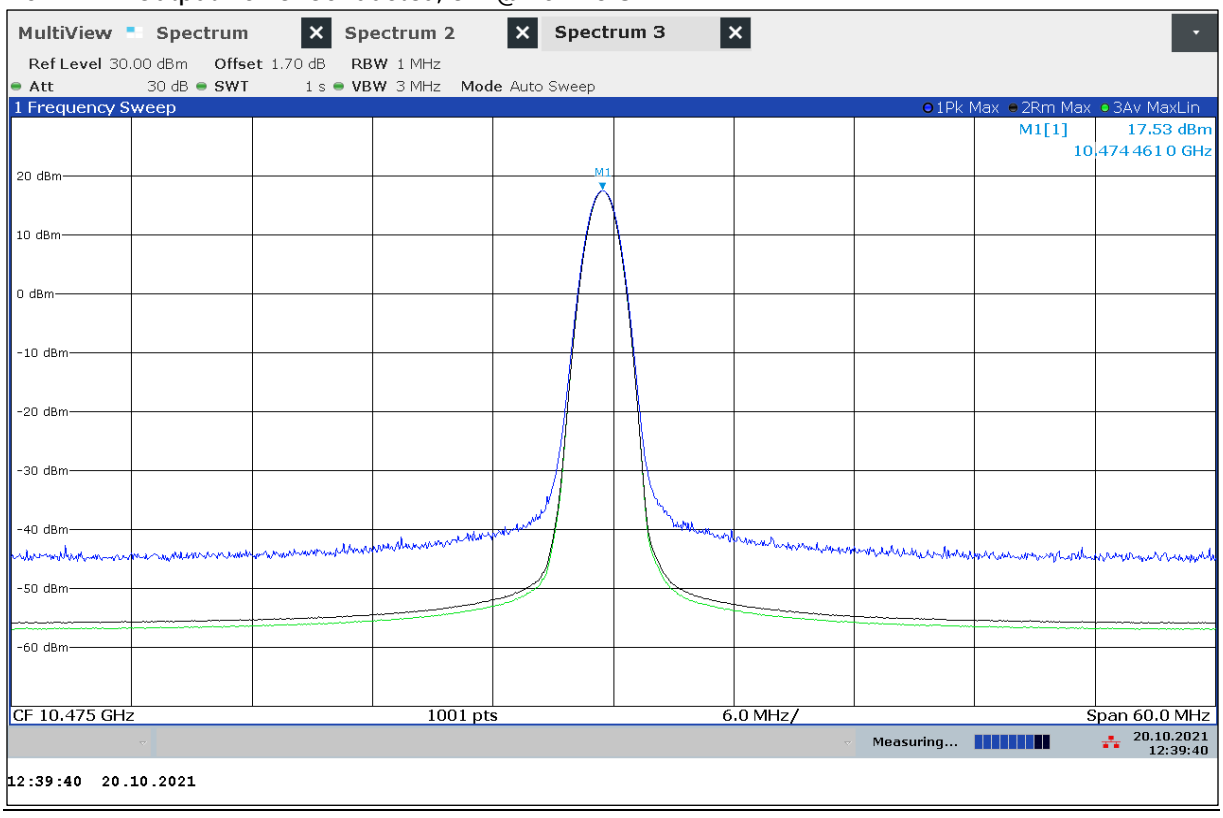
Plot No. 10: RF Output Power Conducted, FMCW @ 10.45 GHz– 10.50 GHz



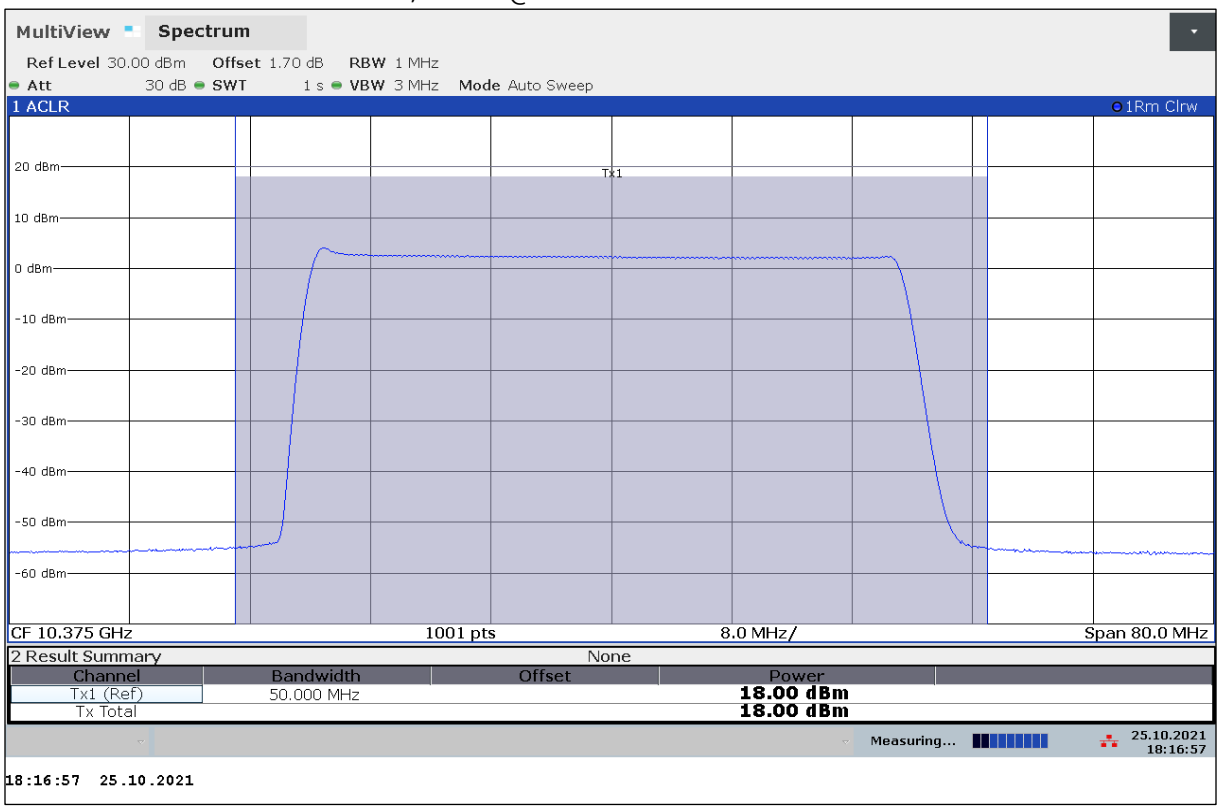
Plot No. 11: RF Output Power Radiated, CW @ 10.475 GHz



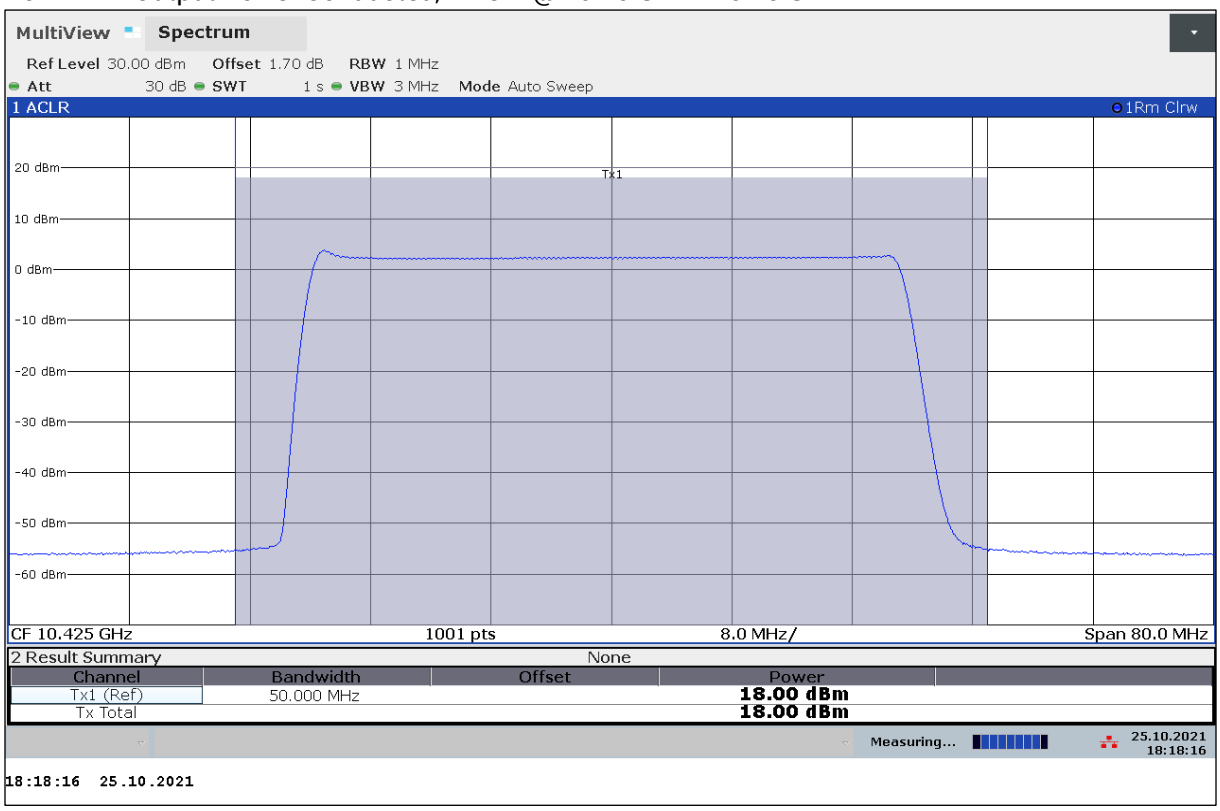
Plot No. 12: RF Output Power Conducted, CW @ 10.475 GHz



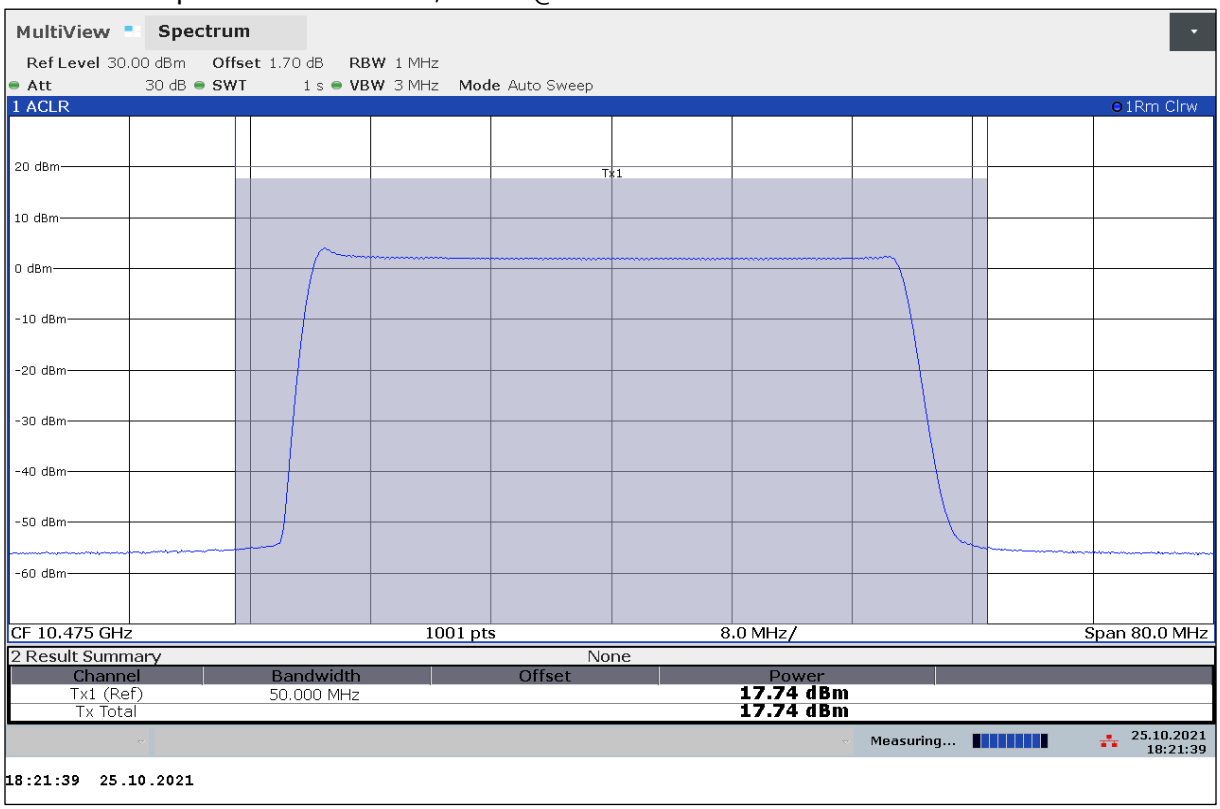
Plot No. 13: Channel Power Conducted, FMCW @ 10.35 GHz– 10.40 GHz



Plot No. 14: RF Output Power Conducted, FMCW @ 10.40 GHz– 10.45 GHz



Plot No. 15: RF Output Power Conducted, FMCW @ 10.45 GHz– 10.50 GHz



11.2 Occupied bandwidth (99% bandwidth)

§ 90.103 Radiolocation Service

(b) Frequencies available. The following table indicates frequencies available for assignment to stations in the Radiolocation Service, together with the class of station(s) to which they are normally assigned, and the specific assignment limitations, which are explained in paragraph (c) of this section:

RADIOLOCATION SERVICE FREQUENCY TABLE

Frequency or band	Class of station(s)	Limitation
Kilohertz		
70 to 90	Radiolocation land or mobile.	1
90 to 110	Radiolocation land	2
110 to 130	Radiolocation land or mobile.	1
1705 to 1715	do	4, 5, 6
1715 to 1750	do	5, 6
1750 to 1800	do	5, 6
3230 to 3400	do	6, 8
Megahertz		
420 to 450	do	21
2450 to 2500	do	9, 22, 23
2900 to 3100	do	10, 11
3100 to 3300	do	12
3300 to 3500	do	12, 13
3500 to 3550	do	12
3550 to 3650	do	30
5250 to 5350	do	12
5350 to 5460	do	10, 14
5460 to 5470	do	10, 15
5470 to 5600	do	10, 11
5600 to 5650	do	10, 16
8500 to 9000	do	12, 17
9000 to 9200	do	10, 14
9200 to 9300	do	12
9300 to 9500	do	10, 15, 18
9500 to 10,000	do	12
10,000 to 10,500	do	12, 13, 19
10,500 to 10,550	do	20, 22, 24
13,400 to 13,750	do	12
13,750 to 14,000	do	29
15,700 to 17,300	do	
24,050 to 24,250	do	12, 22, 24
33,400 to 36,000	do	12
78,000–81,000	do	30

(12) This frequency is shared with and is on a secondary basis to the Government Radiolocation Service.

(13) Operations in this band are limited to survey operations using transmitters with a peak power not to exceed 5 watts into the antenna.

(19) Operations in this band are on a secondary basis to the Amateur Radio Service (part 97). Pulsed emissions are prohibited.

Measurement parameter	
Detector:	Pos-Peak
Sweep time:	1s
Resolution bandwidth:	1 MHz
Video bandwidth:	3 MHz
Span:	60 MHz
Trace-Mode:	Max Hold

Result:

Test condition T_{nom} / V_{nom}	FMCW @ 10.35 GHz– 10.40 GHz	FMCW @ 10.40 GHz– 10.45 GHz	FMCW @ 10.45 GHz– 10.50 GHz
99% OBW Radiated	39.3 MHz	39.3 MHz	39.3 MHz
99% OBW Conducted	39.3 MHz	39.3 MHz	39.3 MHz

Note: for corresponding plots refer to chapter 11.1, plot No. 1, 2, 5, 6, 9, 10

11.3 Field strength of emissions radiation and emission mask

§ 90.210 Emission masks

Except as indicated elsewhere in this part, transmitters used in the radio services governed by this part must comply with the emission masks outlined in this section. Unless otherwise stated, per paragraphs (d)(4), (e)(4), and (o) of this section, measurements of emission power can be expressed in either peak or average values provided that emission powers are expressed with the same parameters used to specify the unmodulated transmitter carrier power. For transmitters that do not produce a full power unmodulated carrier, reference to the unmodulated transmitter carrier power refers to the total power contained in the channel bandwidth. Unless indicated elsewhere in this part, the table in this section specifies the emission masks for equipment operating under this part.

APPLICABLE EMISSION MASKS

Frequency band (MHz)	Mask for equipment with audio low pass filter	Mask for equipment without audio low pass filter
Below 25[1]	A or B	A or C
25–50	B	C
72–76	B	C
150–174[2]	B, D, or E	C, D or E
150 paging only	B	C
220–222	F	F
421–512[2 5]	B, D, or E	C, D, or E
450 paging only	B	G
806–809/851–854[6]	B	H
809–824/854–869[3 5]	B	G
896–901/935–940	I	J
902–928	K	K
929–930	B	G
4940–4990 MHz	L or M	L or M
5850–5925[4].		
All other bands	B	C

[1] Equipment using single sideband J3E emission must meet the requirements of Emission Mask A. Equipment using other emissions must meet the requirements of Emission Mask B or C, as applicable.
[2] Equipment designed to operate with a 25 kHz channel bandwidth must meet the requirements of Emission Mask B or C, as applicable. Equipment designed to operate with a 12.5 kHz channel bandwidth must meet the requirements of Emission Mask D, and equipment designed to operate with a 6.25 kHz channel bandwidth must meet the requirements of Emission Mask E.
[3] Equipment used in this licensed to EA or non-EA systems shall comply with the emission mask provisions of § 90.691 of this chapter.
[4] DSRCS Roadside Units equipment in the 5850–5925 MHz band is governed under subpart M of this part.
[5] Equipment may alternatively meet the Adjacent Channel Power limits of § 90.221.
[6] Transmitters utilizing analog emissions that are equipped with an audio low-pass filter must meet Emission Mask B. All transmitters utilizing digital emissions and those transmitters using analog emissions without an audio low-pass filter must meet Emission Mask H.

(c) *Emission Mask C.* For transmitters that are not equipped with an audio low-pass filter, the power of any emission must be attenuated below the unmodulated carrier output power (P) as follows:

(1) On any frequency removed from the center of the authorized bandwidth by a displacement frequency (f^d in kHz) of more than 5 kHz, but not more than 10 kHz: At least 83 log (f^d/5) dB;

(2) On any frequency removed from the center of the authorized bandwidth by a displacement frequency (f^d in kHz) of more than 10 kHz, but not more than 250 percent of the authorized bandwidth: At least 29 log (f^{d2}/11) dB or 50 dB, whichever is the lesser attenuation;

(3) On any frequency removed from the center of the authorized bandwidth by more than 250 percent of the authorized bandwidth: At least 43 + 10 log (P) dB.

Results:

TX Spurious Emissions Radiated [dBm]								
FMCW @ 10.35 GHz– 10.40 GHz			FMCW @ 10.40 GHz– 10.45 GHz			FMCW @ 10.45 GHz– 10.50 GHz		
Frequency [GHz]	Detector Peak	Level [dBm]	Frequency [GHz]	Detector Peak	Level [dBm]	Frequency [GHz]	Detector Peak	Level [dBm]
21.0	Cond.	-/-	21.0	Cond.	-/-	21.1	Cond.	-/-
21.0	Rad.	-32.1	21.0	Rad.	-31.6	21.1	Rad.	-31.5
31.1	Cond.	-26.1	31.2	Cond.	-29.8	31.4	Cond.	-31.9
31.5	Rad.	-24.7	31.6	Rad.	-26.0	31.6	Rad.	-23.5
41.5	Cond.	-/-	41.7	Cond.	-/-	41.5	Cond.	-/-
41.5	Rad.	-30.6	41.7	Rad.	-26.2	41.9	Rad.	-25.1

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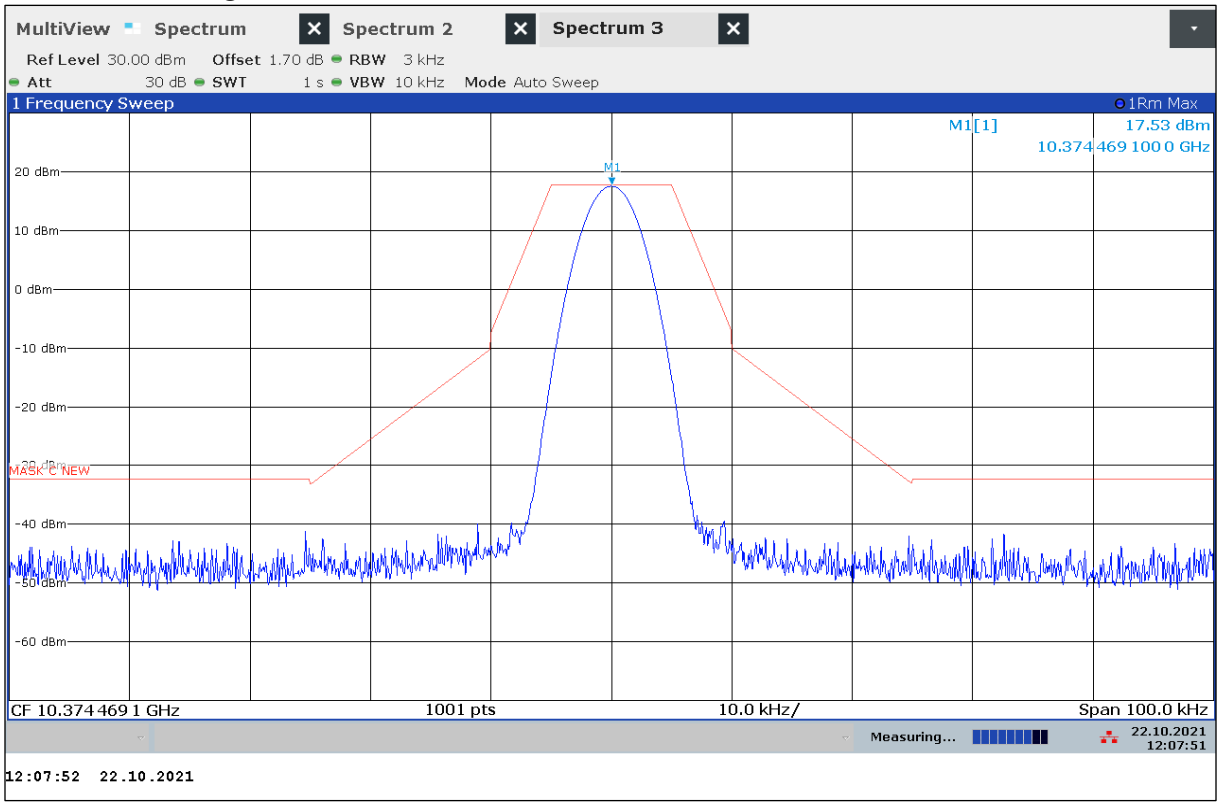
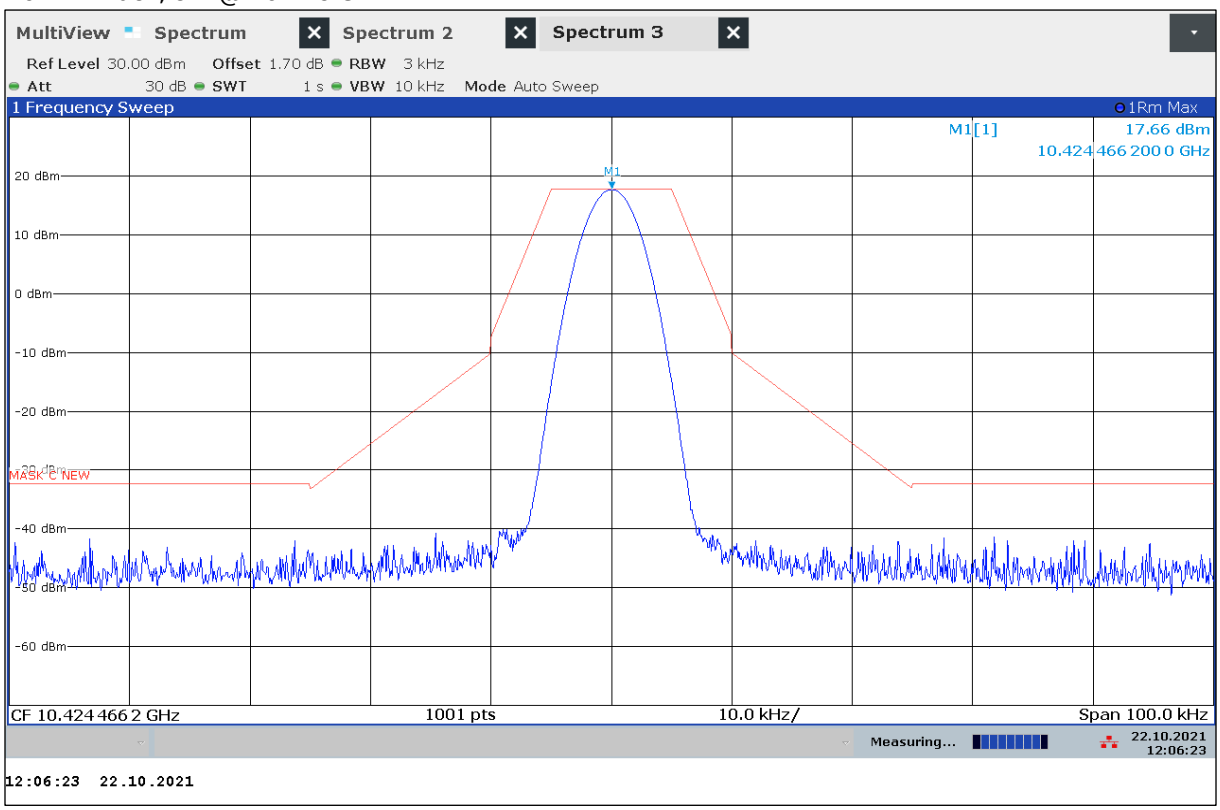
Conducted Measurement

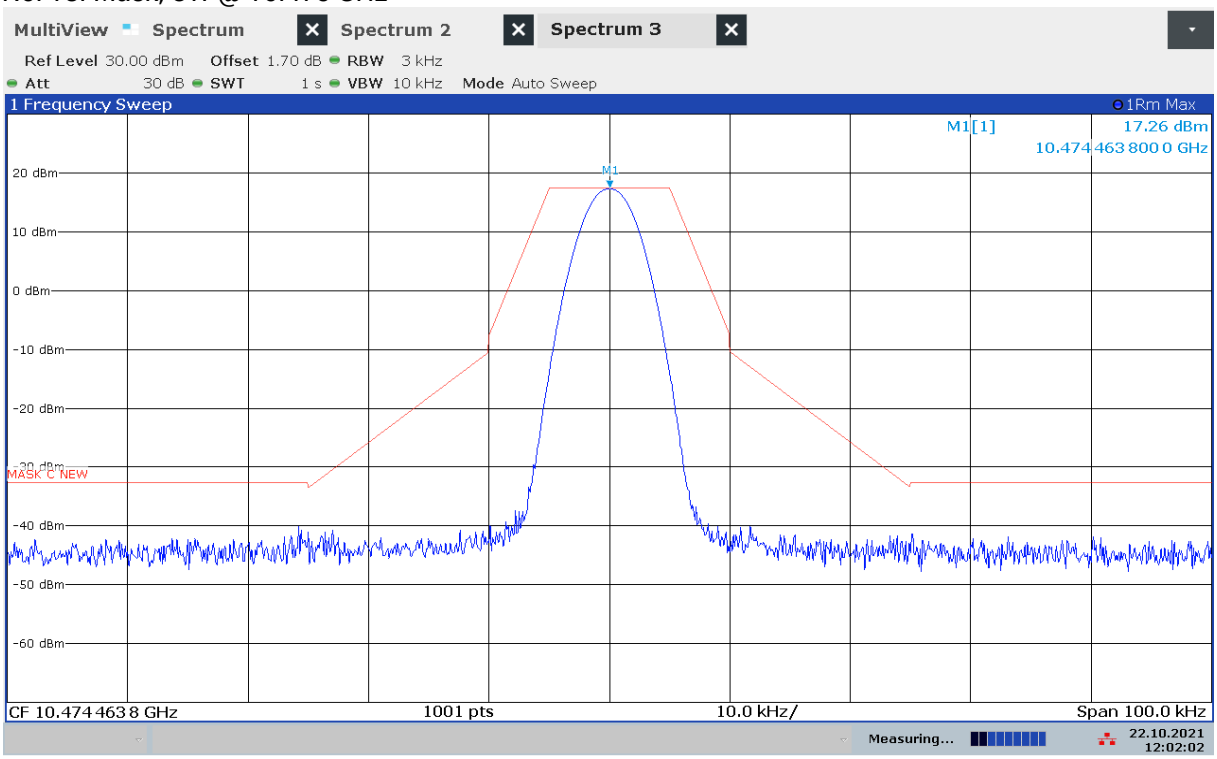
Plot No. 16: Mask, CW @ 10.375 GHz



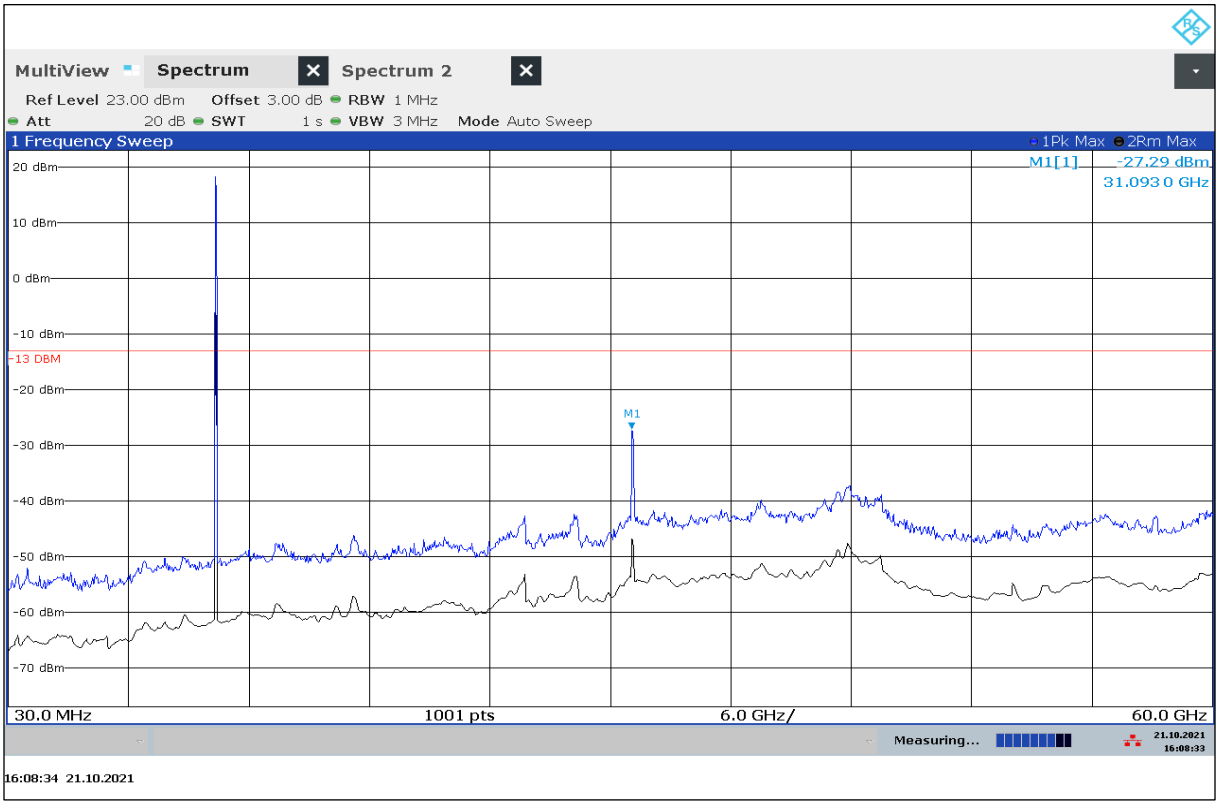
Plot No. 17: Mask, CW @ 10.425 GHz



Plot No. 18: Mask, CW @ 10.475 GHz

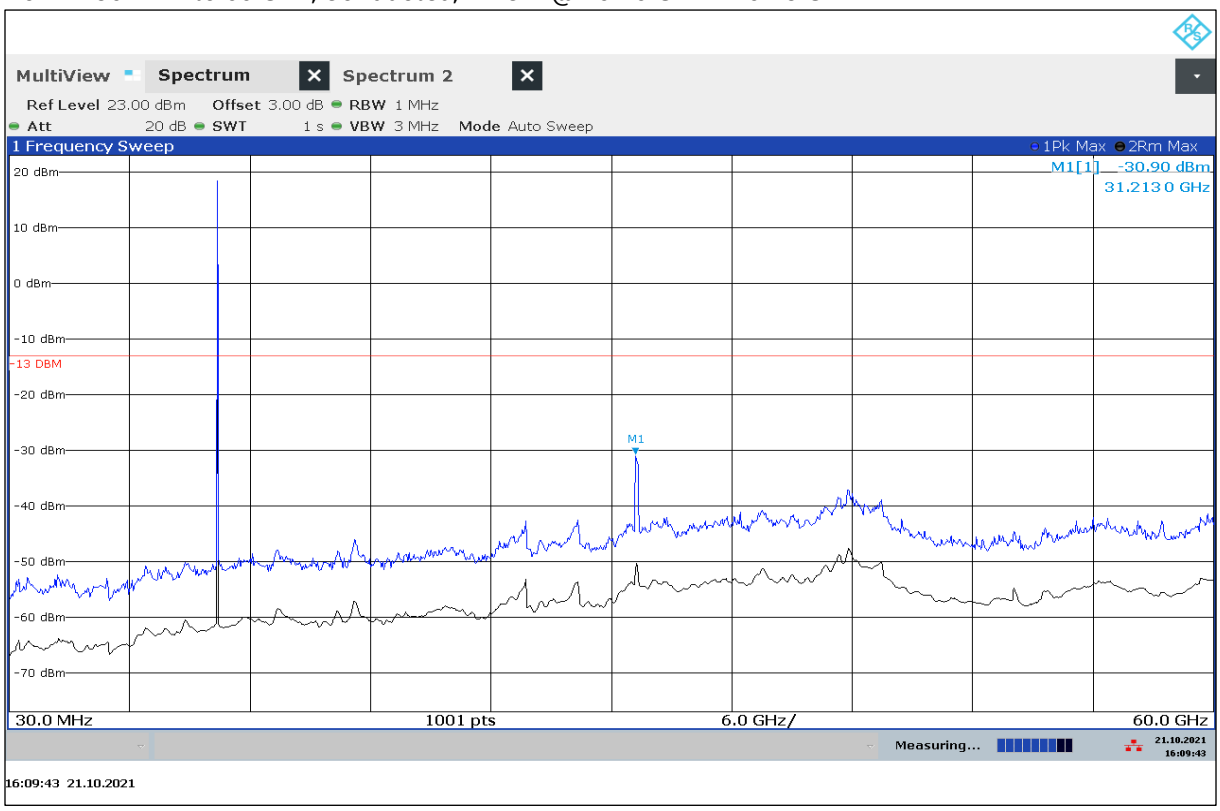


Plot No. 19: 30 MHz to 60 GHz, Conducted, FMCW @ 10.35 GHz– 10.40 GHz



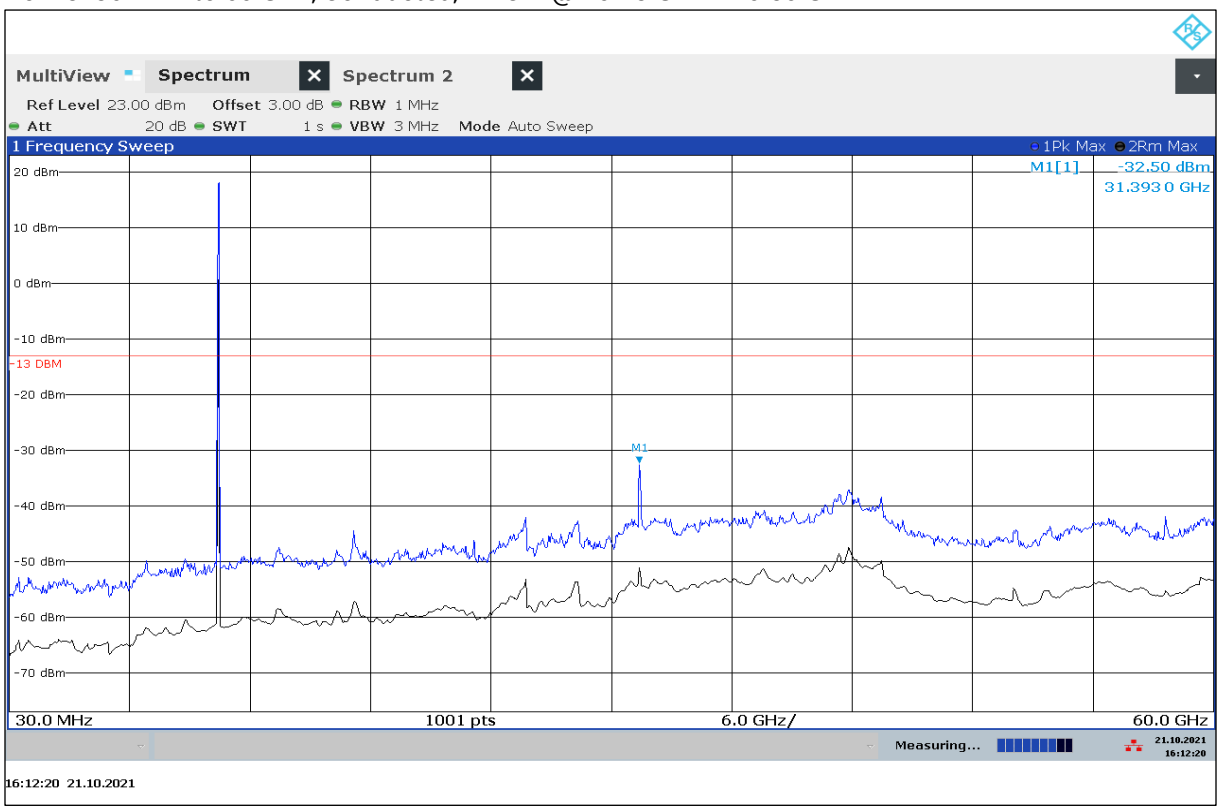
Plot No. 20: 31 GHz, Conducted, FMCW @ 10.35 GHz– 10.40 GHz

Plot No. 21: 30 MHz to 60 GHz, Conducted, FMCW @ 10.40 GHz– 10.45 GHz



Plot No. 22: 31 GHz, Conducted, FMCW @ 10.40 GHz– 10.45 GHz

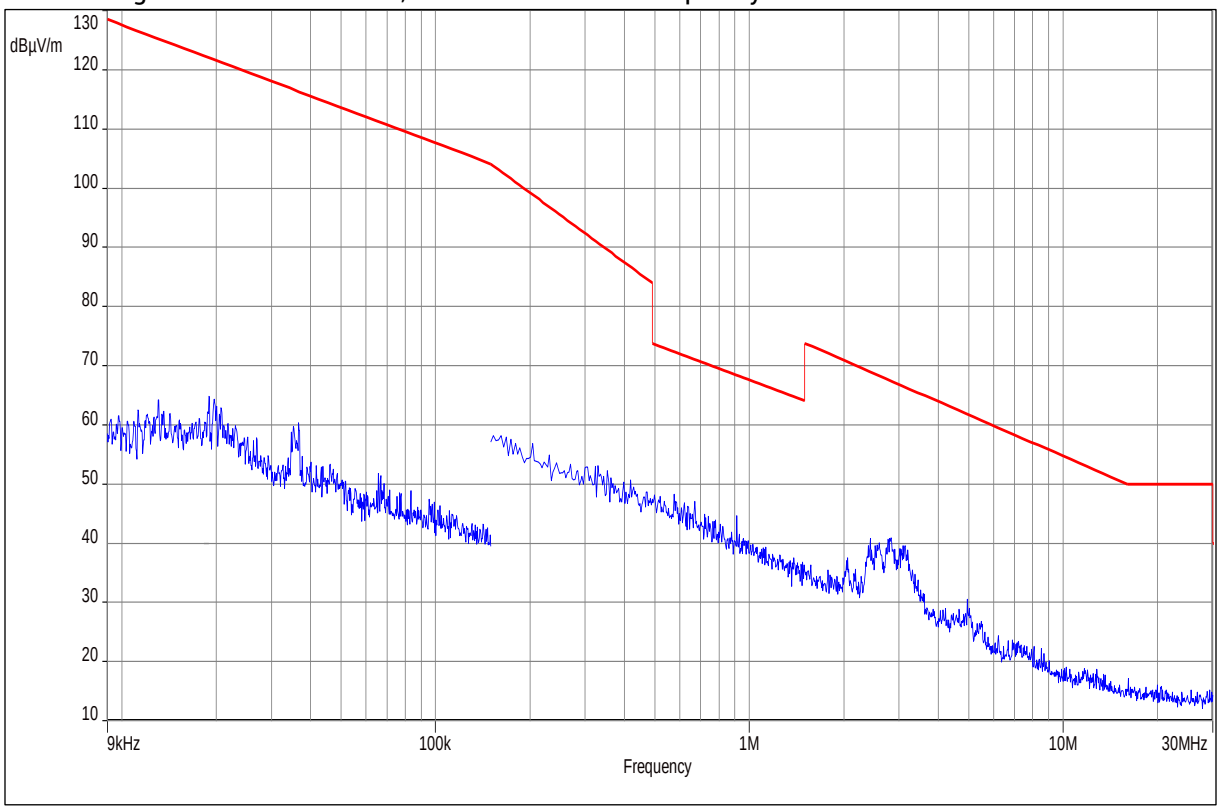
Plot No. 23: 30 MHz to 60 GHz, Conducted, FMCW @ 10.45 GHz– 10.50 GHz



Plot No. 24: 31 GHz, Conducted, FMCW @ 10.45 GHz– 10.50 GHz

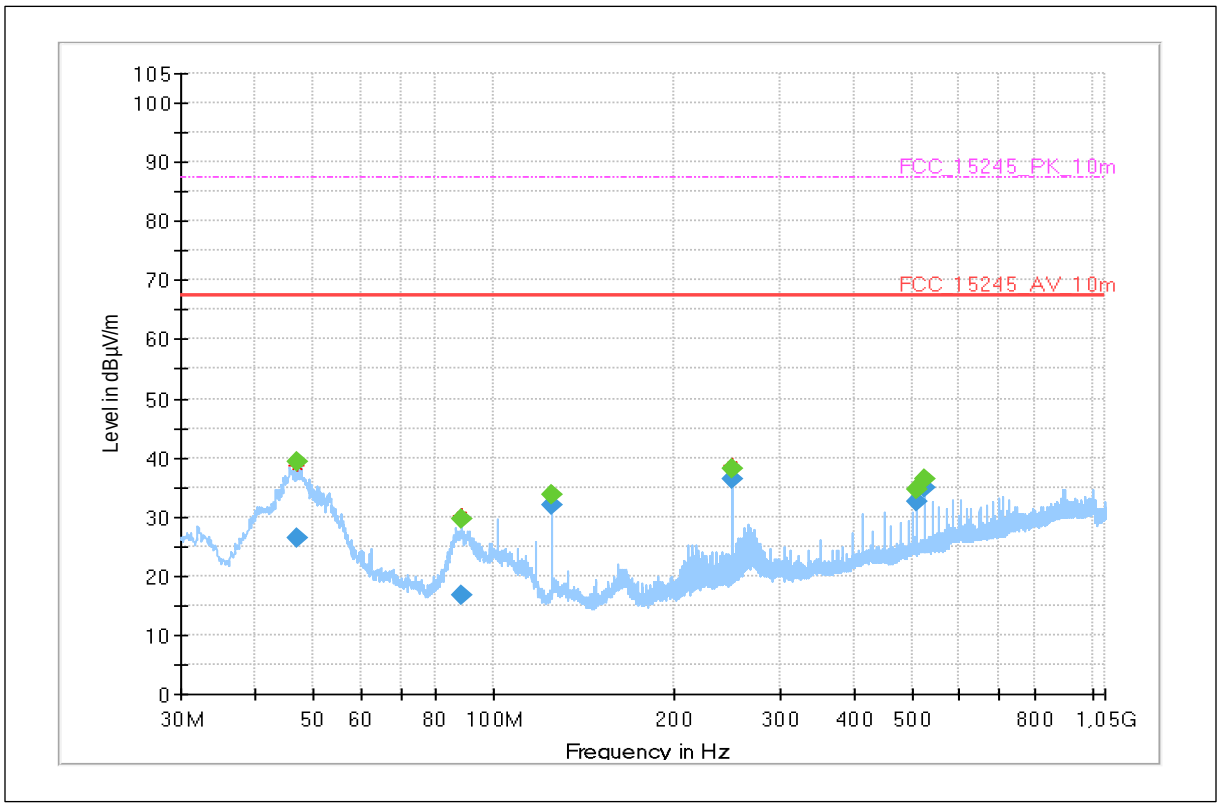
Radiated Measurements

Plot No. 25: Magnetic: 9 kHz - 30 MHz, valid for all FMCW Frequency bands



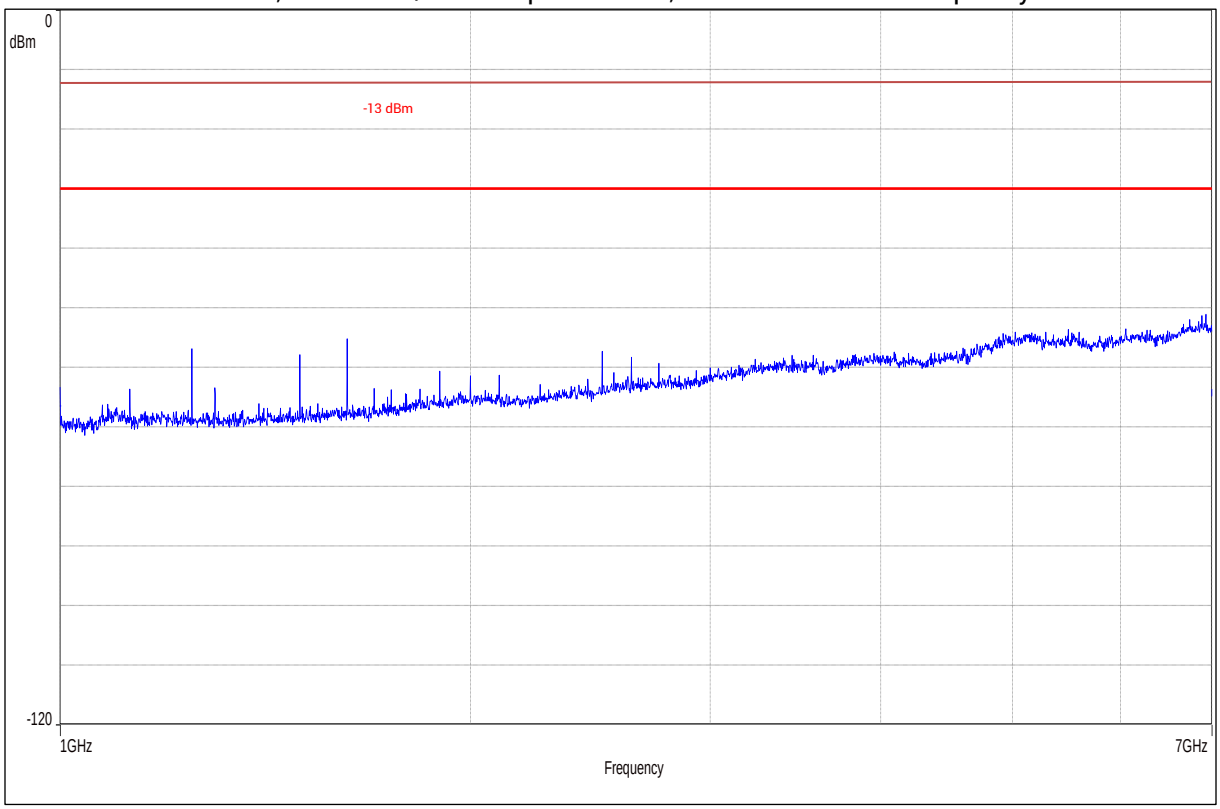
The -13 dBm Limit corresponds to 82 dBuV @ 3m Average Limit
and 102 dBuV @ 3m Peak Limit. Therefore, all limits are met.

Plot No. 26: 30 MHz to 1 GHz, horizontal / vertical polarization, valid for all FMCW Frequency bands

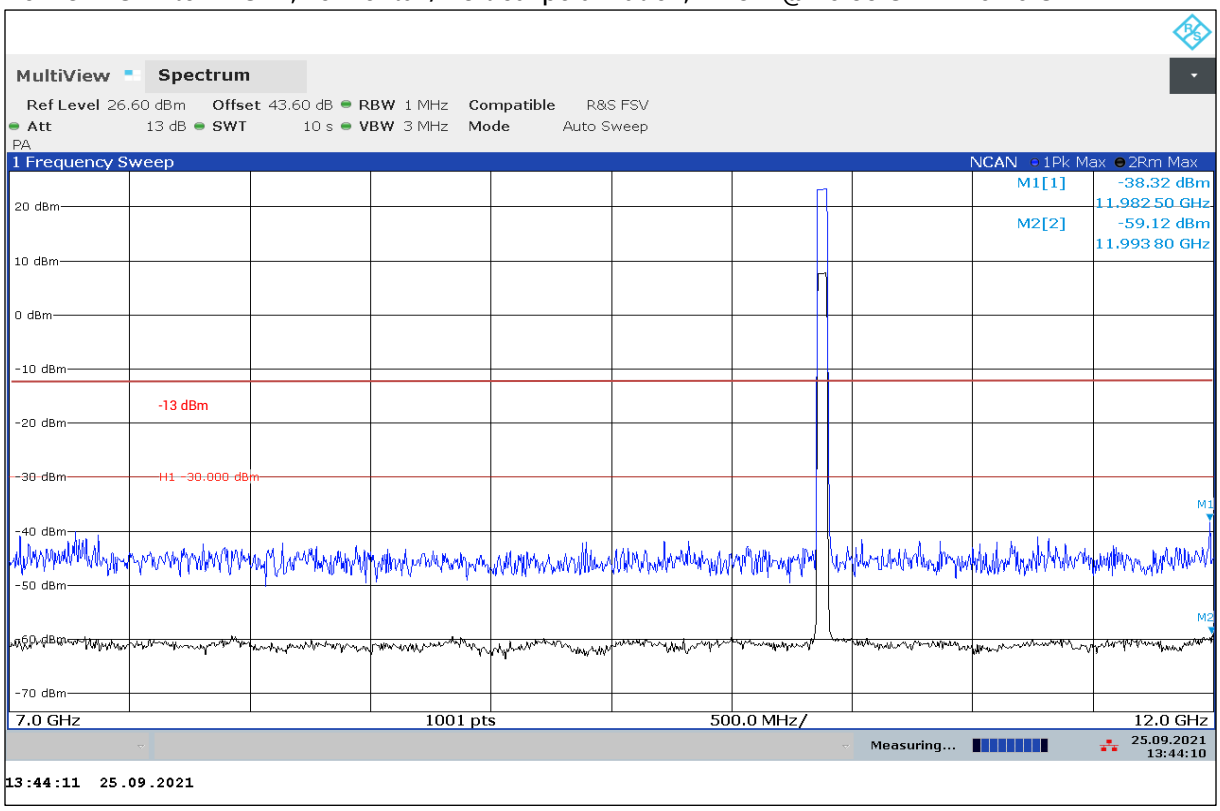


The -13 dBm Limit corresponds to 72 dBuV @ 10m Average Limit
and 92 dBuV @ 10m Peak Limit. Therefore, all limits are met.

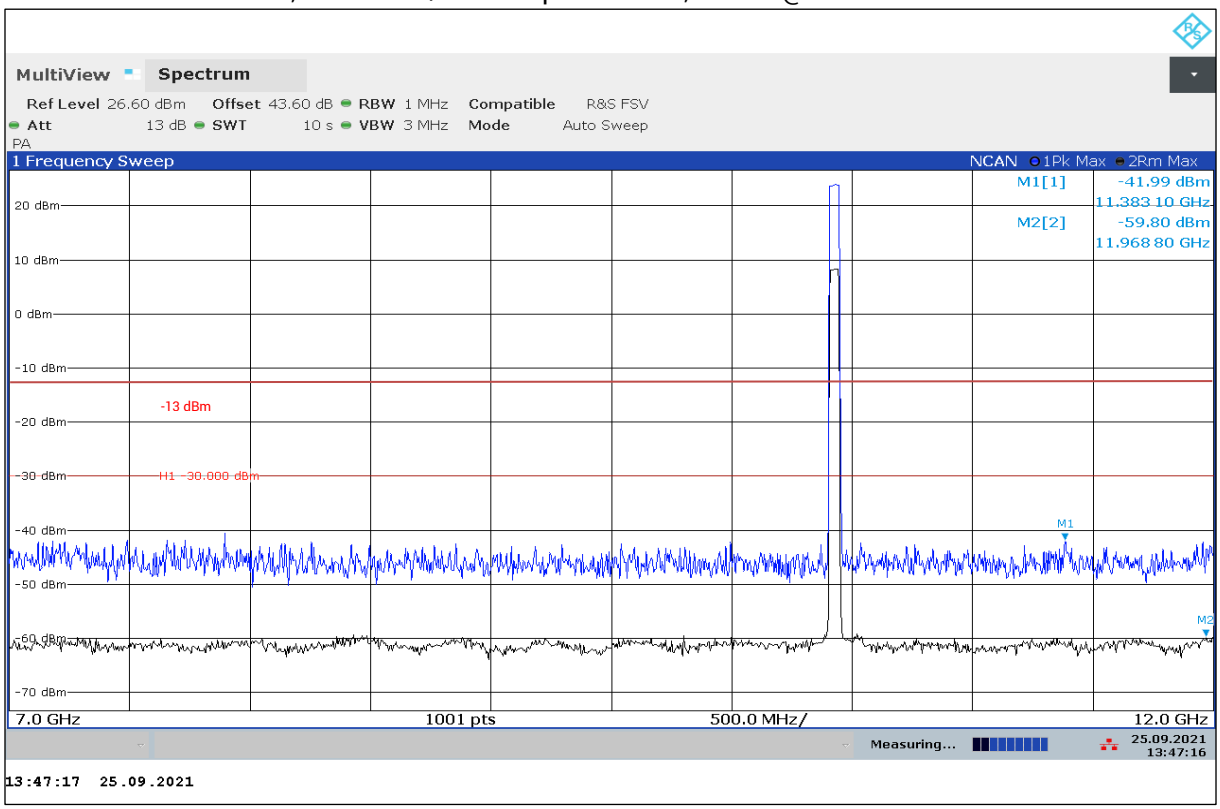
Plot No. 27: 1 GHz to 7 GHz, horizontal / vertical polarization, valid for all FMCW Frequency bands



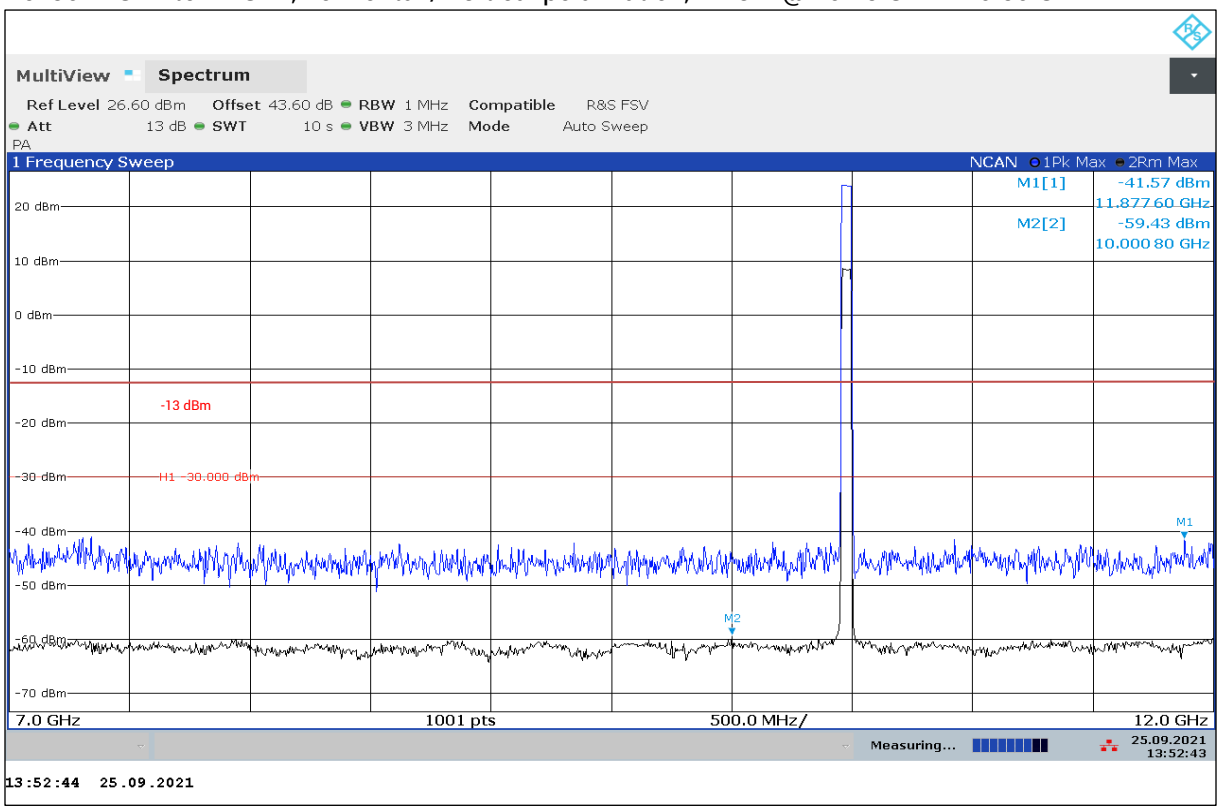
Plot No. 28: 7 GHz to 12 GHz, horizontal / vertical polarization, FMCW @ 10.35 GHz – 10.40 GHz



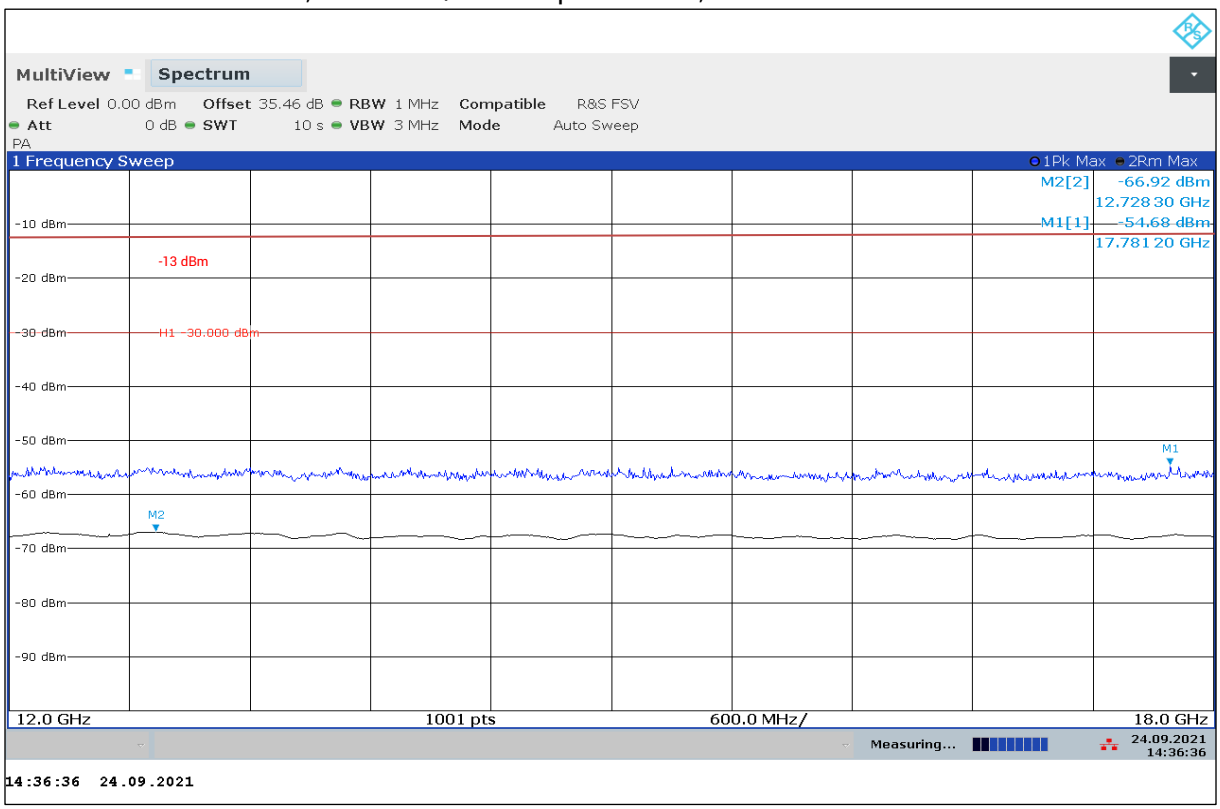
Plot No. 29: 7 GHz to 12 GHz, horizontal / vertical polarization, FMCW @ 10.40 GHz– 10.45 GHz



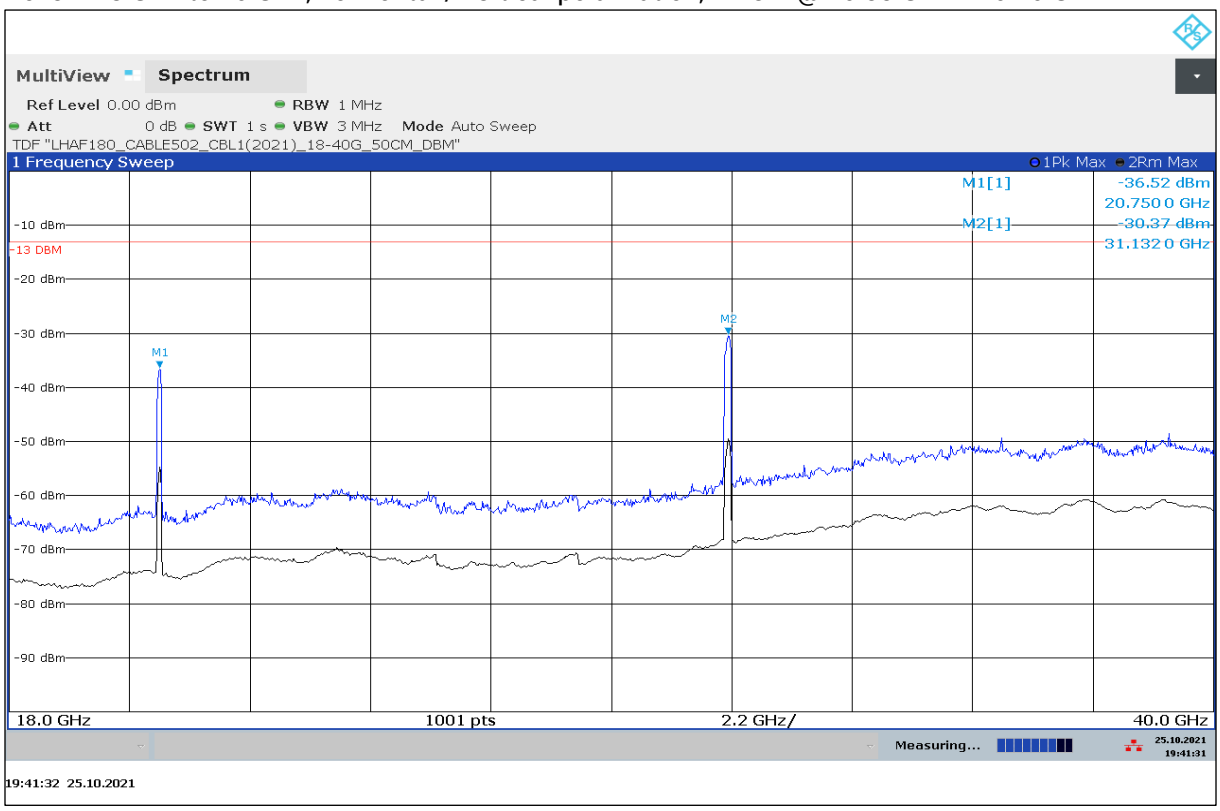
Plot No. 30: 7 GHz to 12 GHz, horizontal / vertical polarization, FMCW @ 10.45 GHz– 10.50 GHz



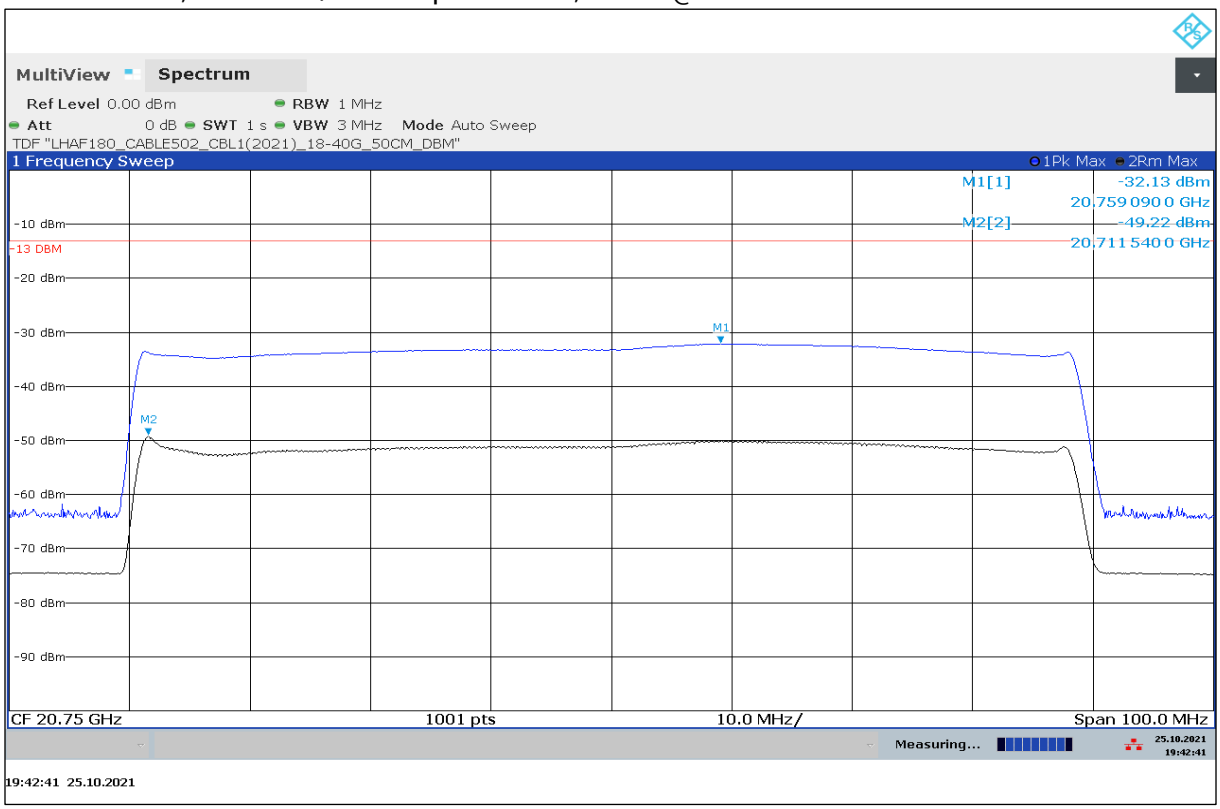
Plot No. 31: 12 GHz to 18 GHz, horizontal / vertical polarization, valid for all FMCWs



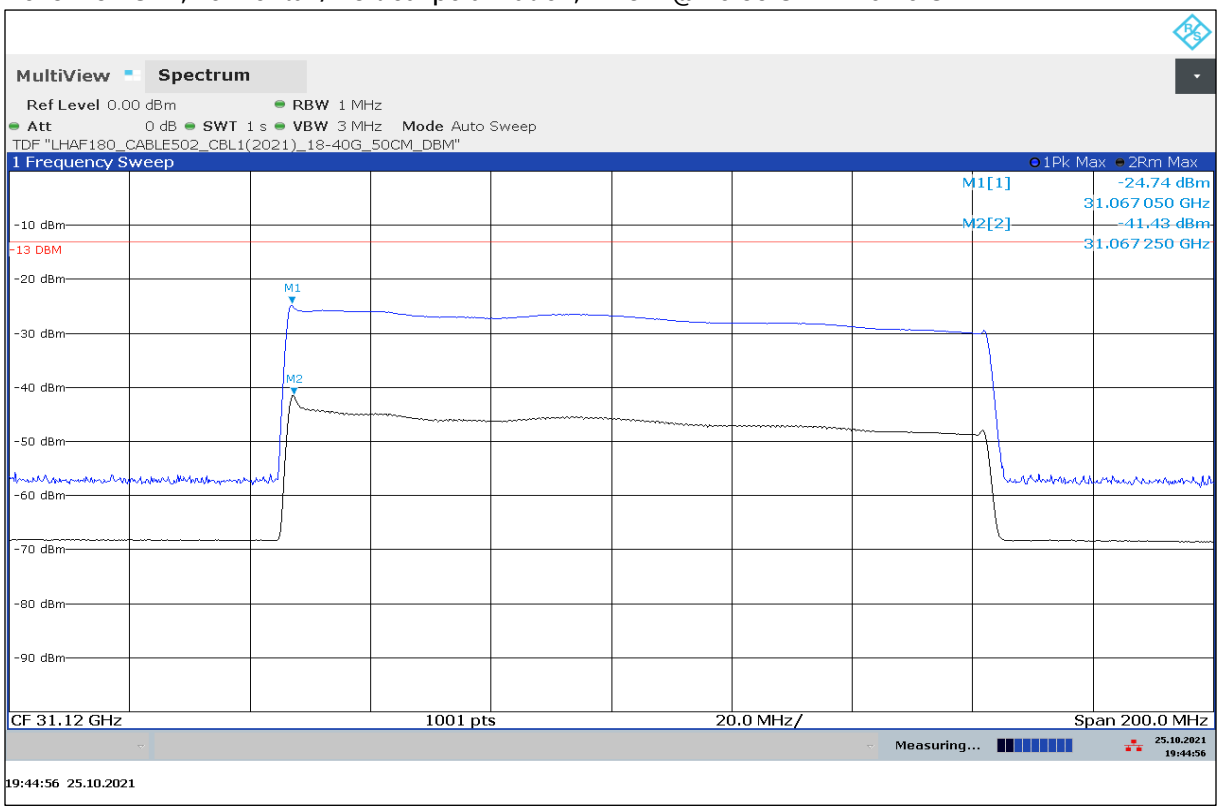
Plot No. 32: 18 GHz to 40 GHz, horizontal / vertical polarization, FMCW @ 10.35 GHz – 10.40 GHz



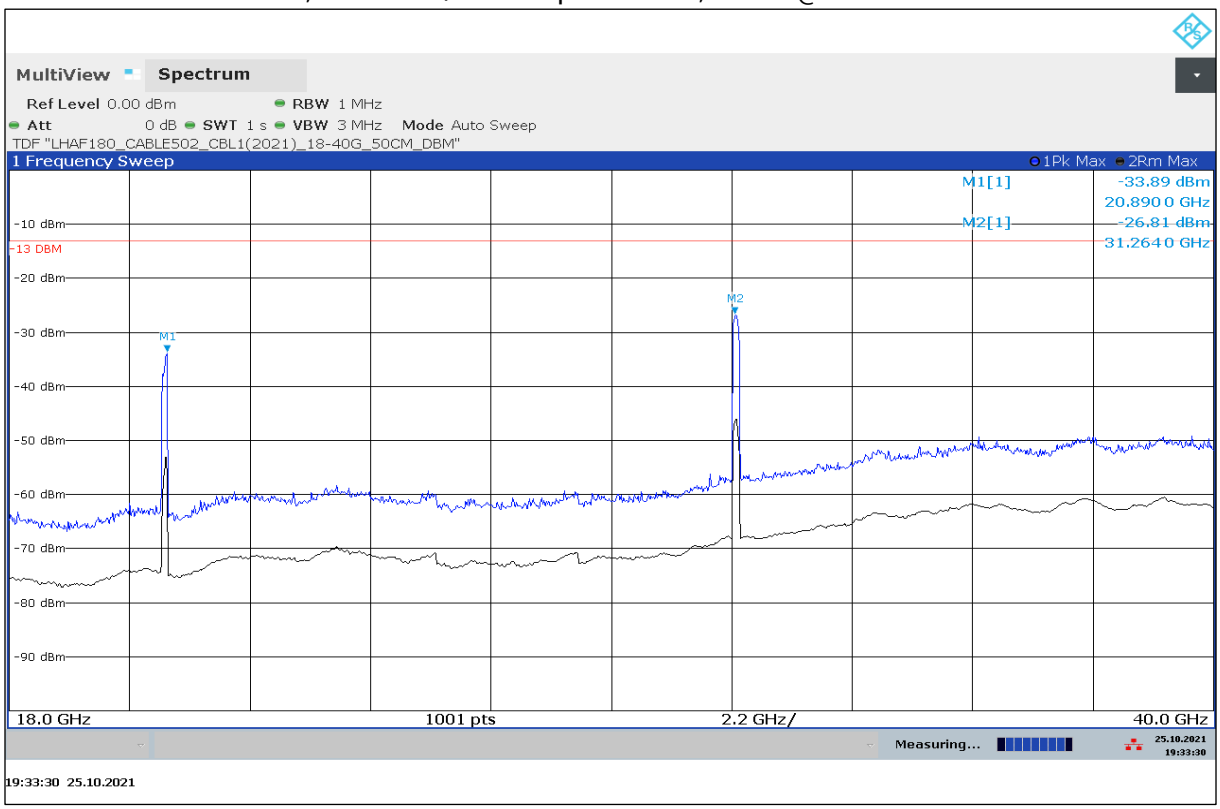
Plot No. 33: 21 GHz, horizontal / vertical polarization, FMCW @ 10.35 GHz– 10.40 GHz



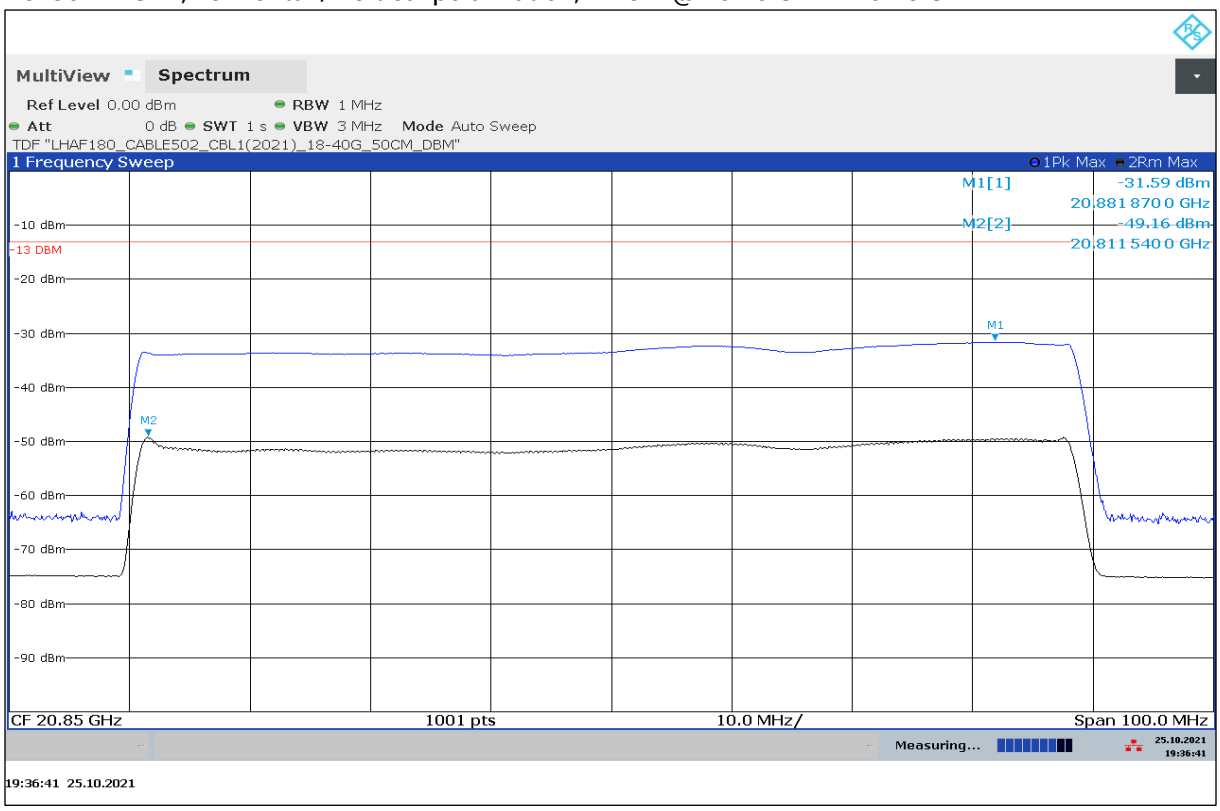
Plot No. 34: 31 GHz, horizontal / vertical polarization, FMCW @ 10.35 GHz– 10.40 GHz



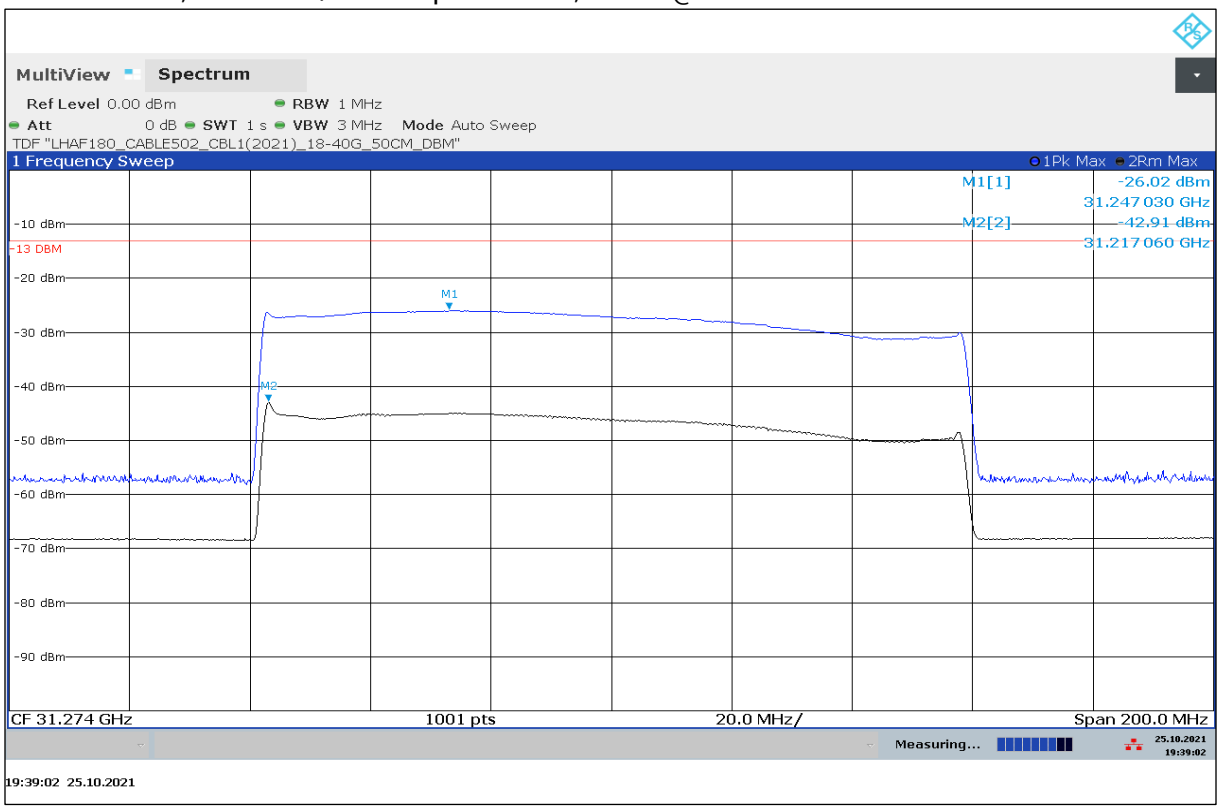
Plot No. 35: 18 GHz to 40 GHz, horizontal / vertical polarization, FMCW @ 10.40 GHz– 10.45 GHz



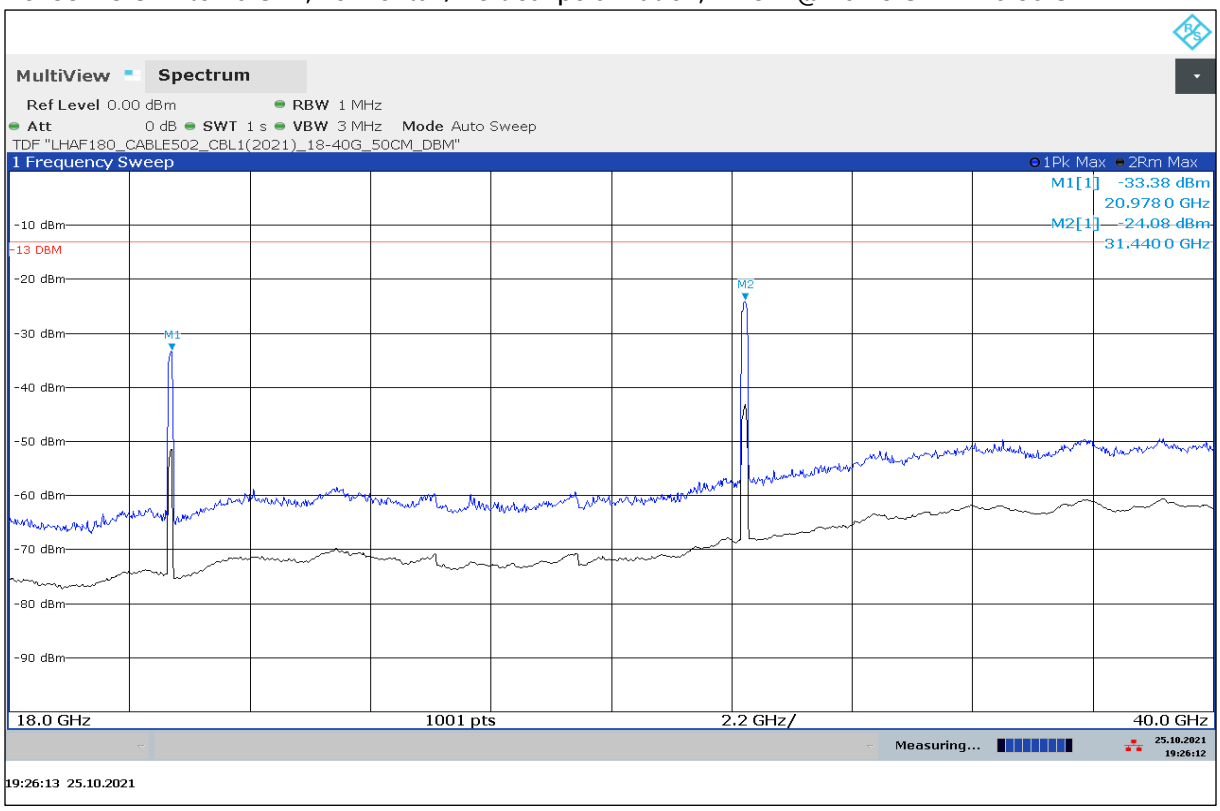
Plot No. 36: 21 GHz, horizontal / vertical polarization, FMCW @ 10.40 GHz– 10.45 GHz



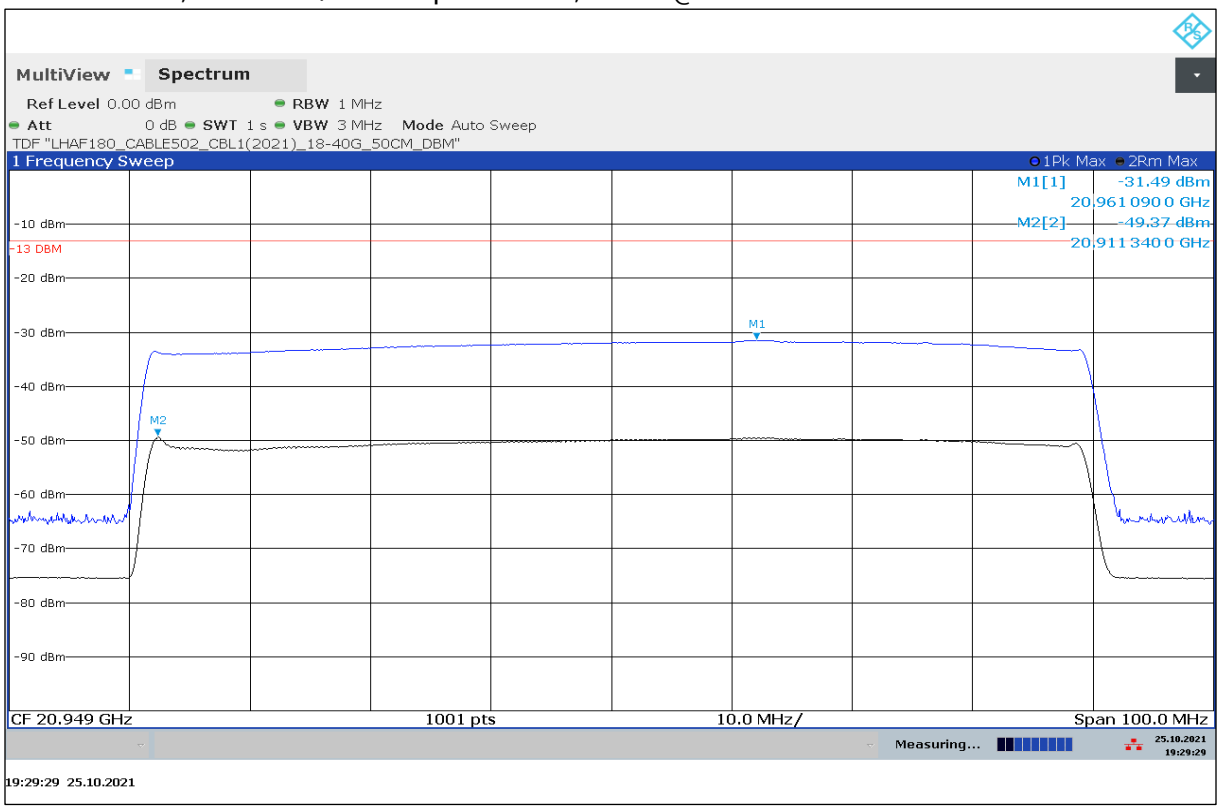
Plot No. 37: 31 GHz, horizontal / vertical polarization, FMCW @ 10.40 GHz– 10.45 GHz



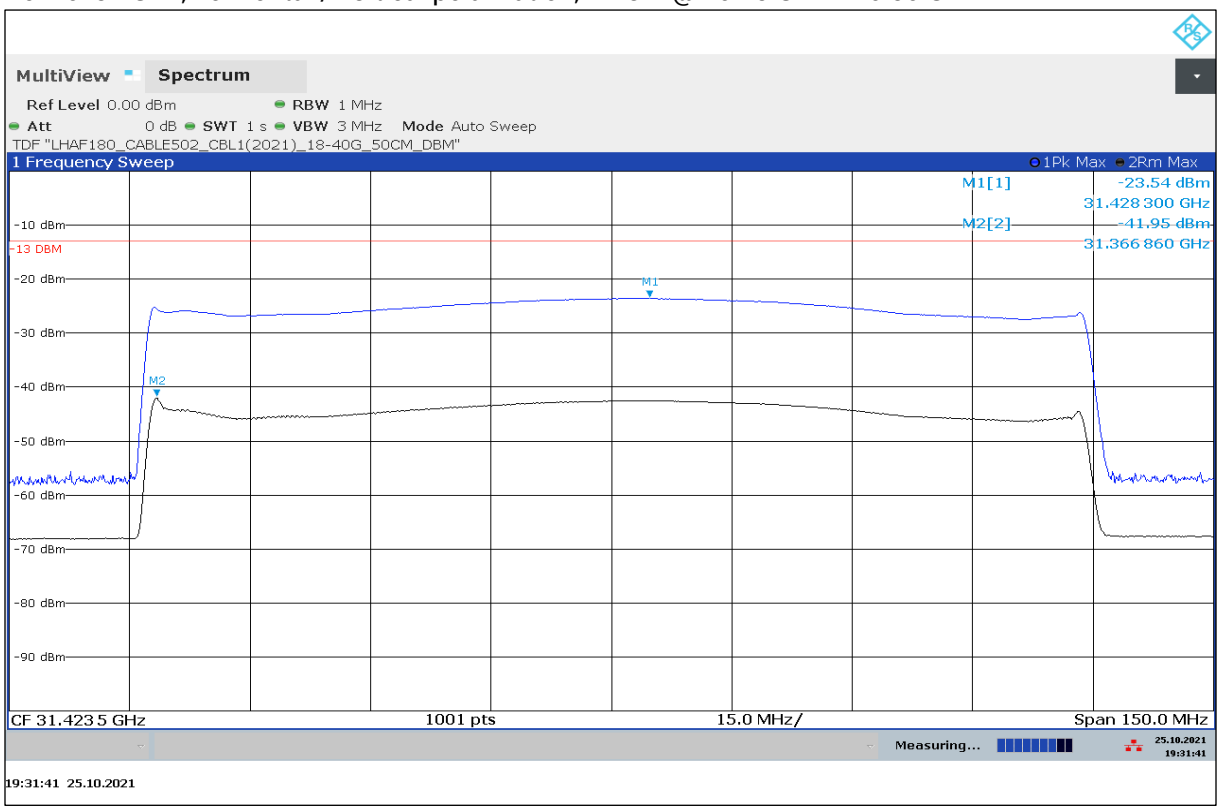
Plot No. 38: 18 GHz to 40 GHz, horizontal / vertical polarization, FMCW @ 10.45 GHz– 10.50 GHz



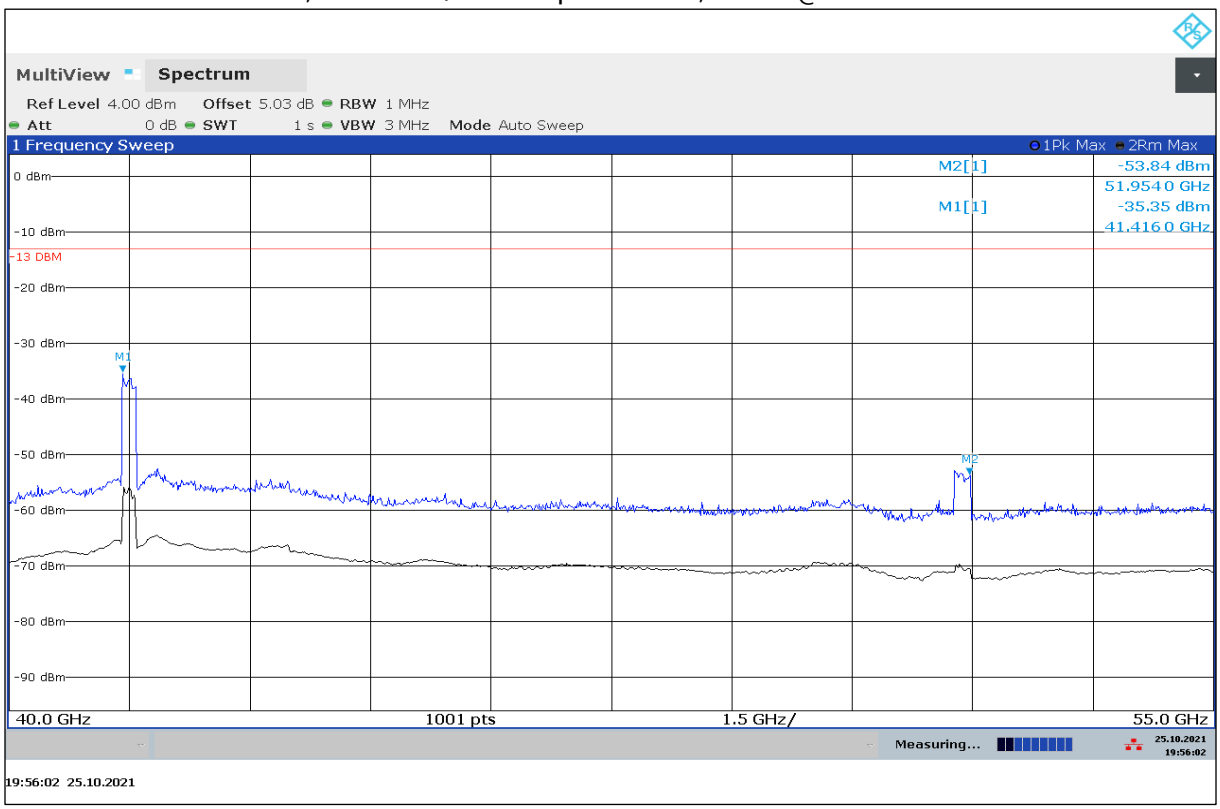
Plot No. 39: 21 GHz, horizontal / vertical polarization, FMCW @ 10.45 GHz– 10.50 GHz



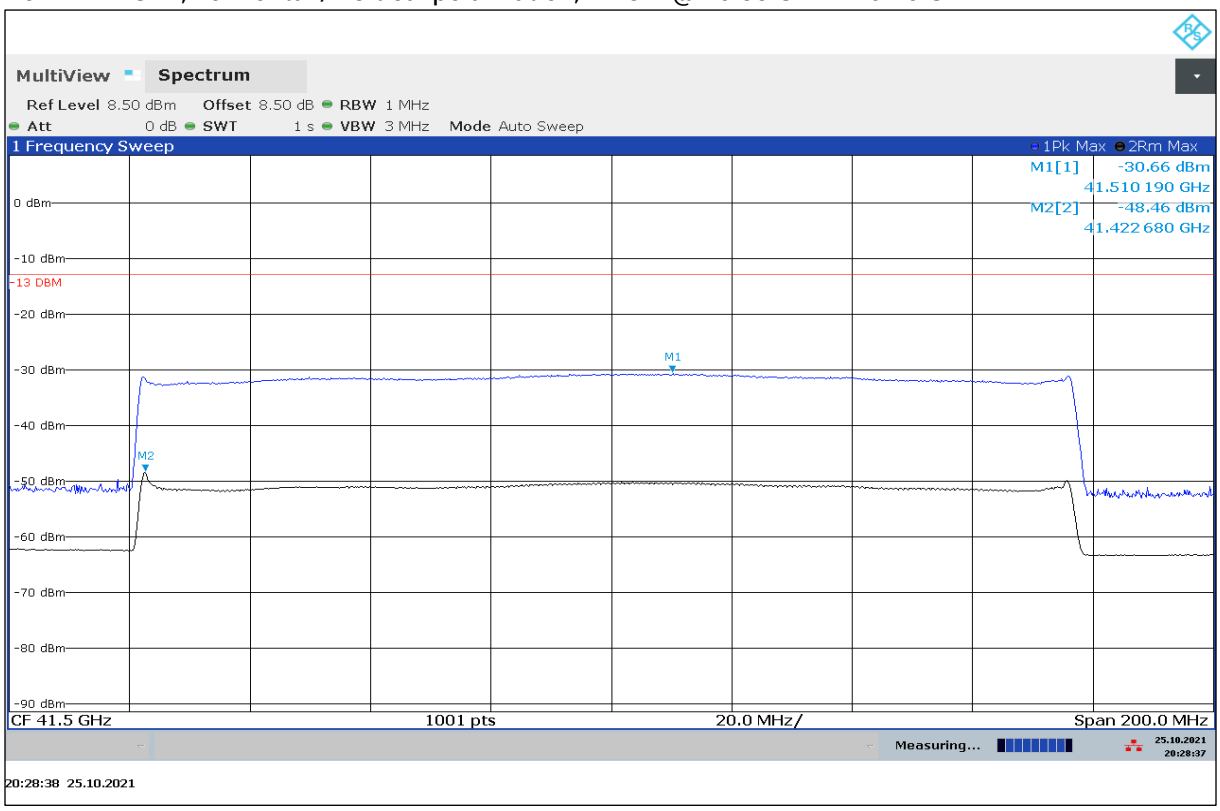
Plot No. 40: 31 GHz, horizontal / vertical polarization, FMCW @ 10.45 GHz– 10.50 GHz



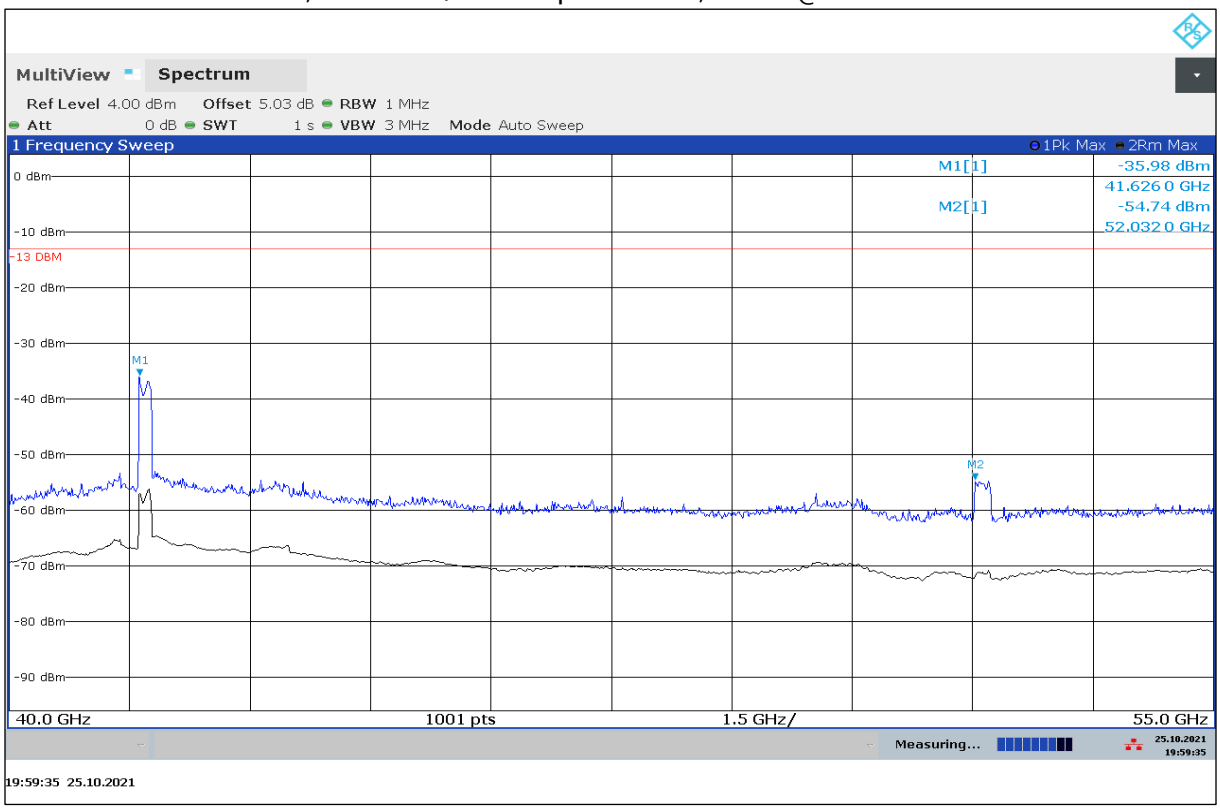
Plot No. 41: 40 GHz to 55 GHz, horizontal / vertical polarization, FMCW @ 10.35 GHz– 10.40 GHz



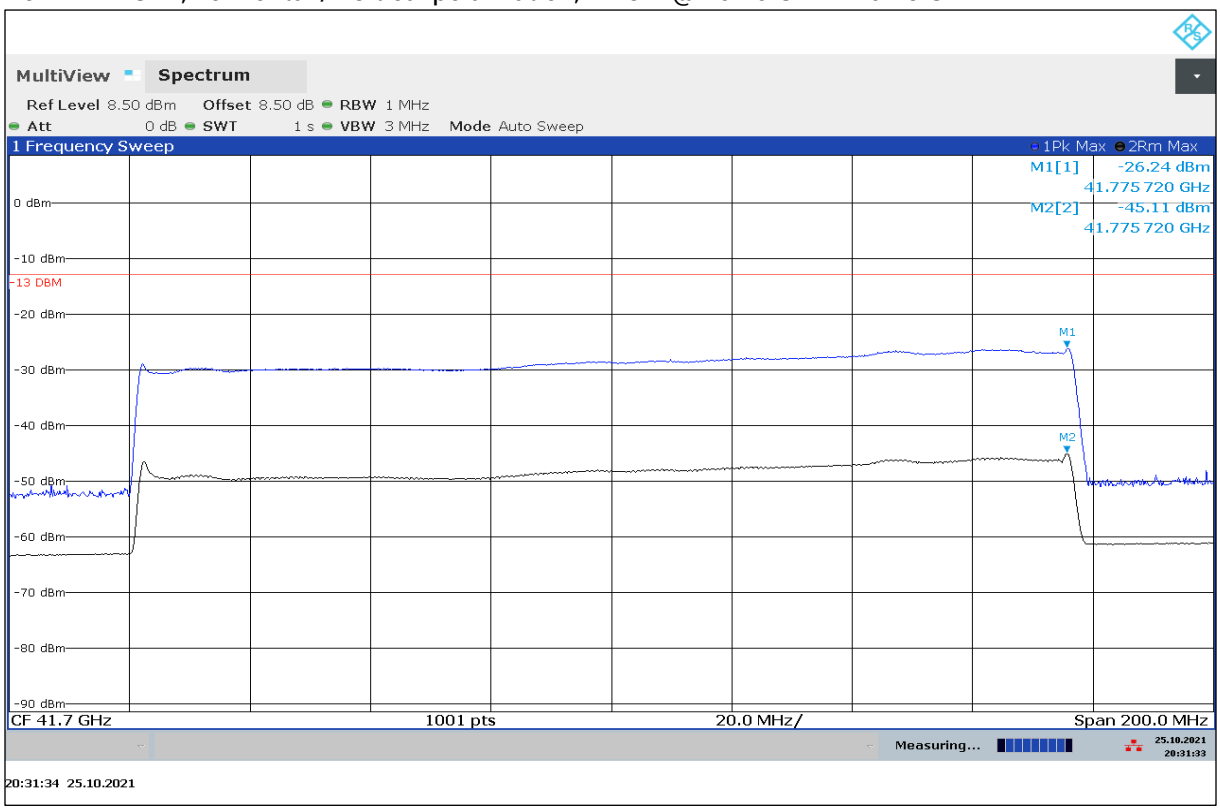
Plot No. 42: 41 GHz, horizontal / vertical polarization, FMCW @ 10.35 GHz– 10.40 GHz



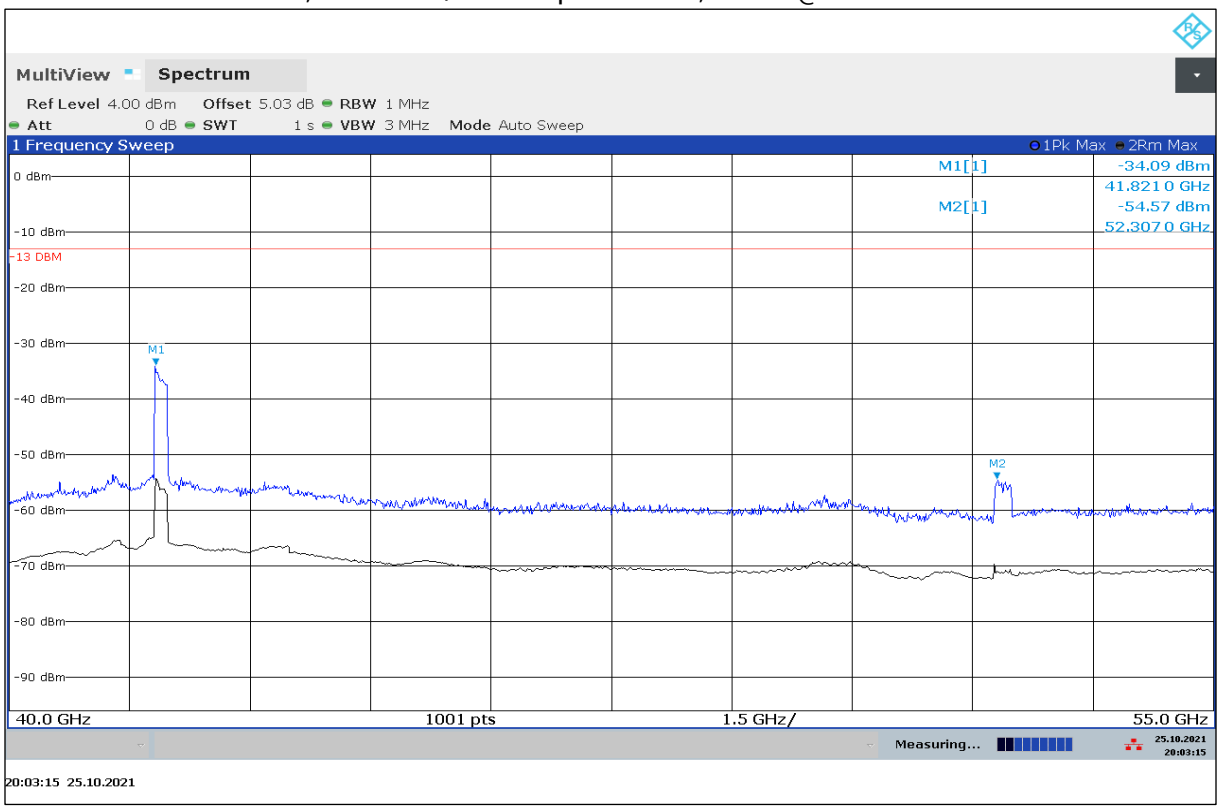
Plot No. 43: 40 GHz to 55 GHz, horizontal / vertical polarization, FMCW @ 10.40 GHz– 10.45 GHz



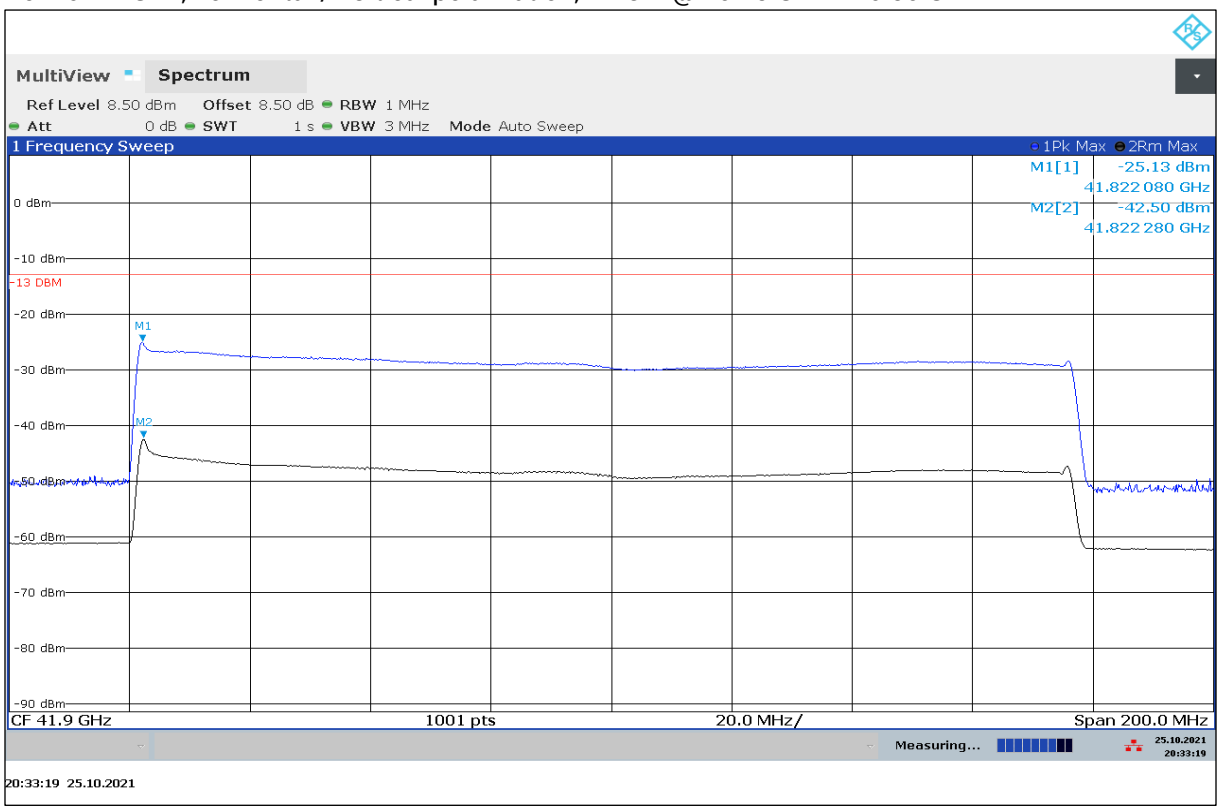
Plot No. 44: 42 GHz, horizontal / vertical polarization, FMCW @ 10.40 GHz– 10.45 GHz



Plot No. 45: 40 GHz to 55 GHz, horizontal / vertical polarization, FMCW @ 10.45 GHz– 10.50 GHz



Plot No. 46: 42 GHz, horizontal / vertical polarization, FMCW @ 10.45 GHz– 10.50 GHz



11.4 Conducted spurious emissions < 30 MHz

Description:

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

Measurement:

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

Limits:

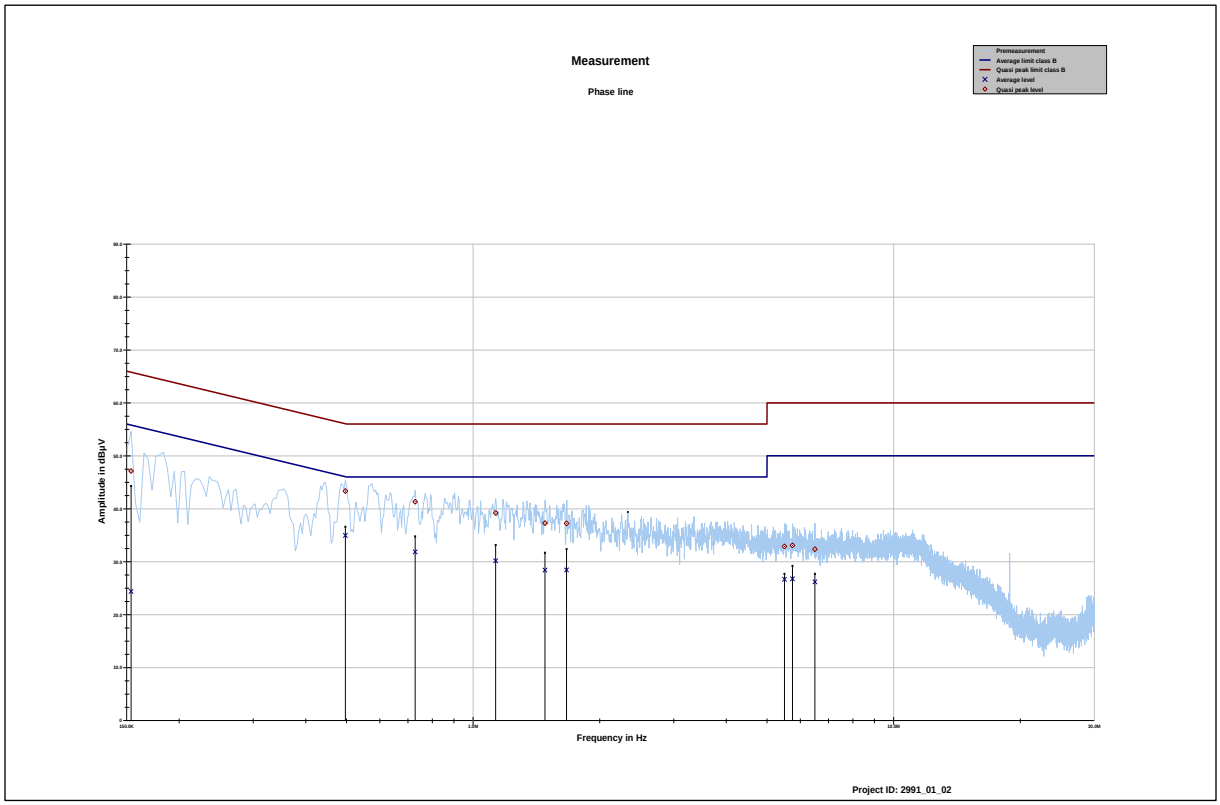
FCC		IC
CFR Part 15.207(a)		RSS-Gen 8.8
Conducted Spurious Emissions < 30 MHz		
Frequency (MHz)	Quasi-Peak (dBµV/m)	Average (dBµV/m)
0.15 – 0.5	79 to 69* (Class A) 66 to 56* (Class B)	79 to 69* (Class A) 56 to 46* (Class B)
0.5 – 5	73 (Class A) 56 (Class B)	63 (Class A) 46 (Class B)
5 – 30.0	73 (Class A) 60 (Class B)	63 (Class A) 50 (Class B)

*Decreases with the logarithm of the frequency

Measurement results:

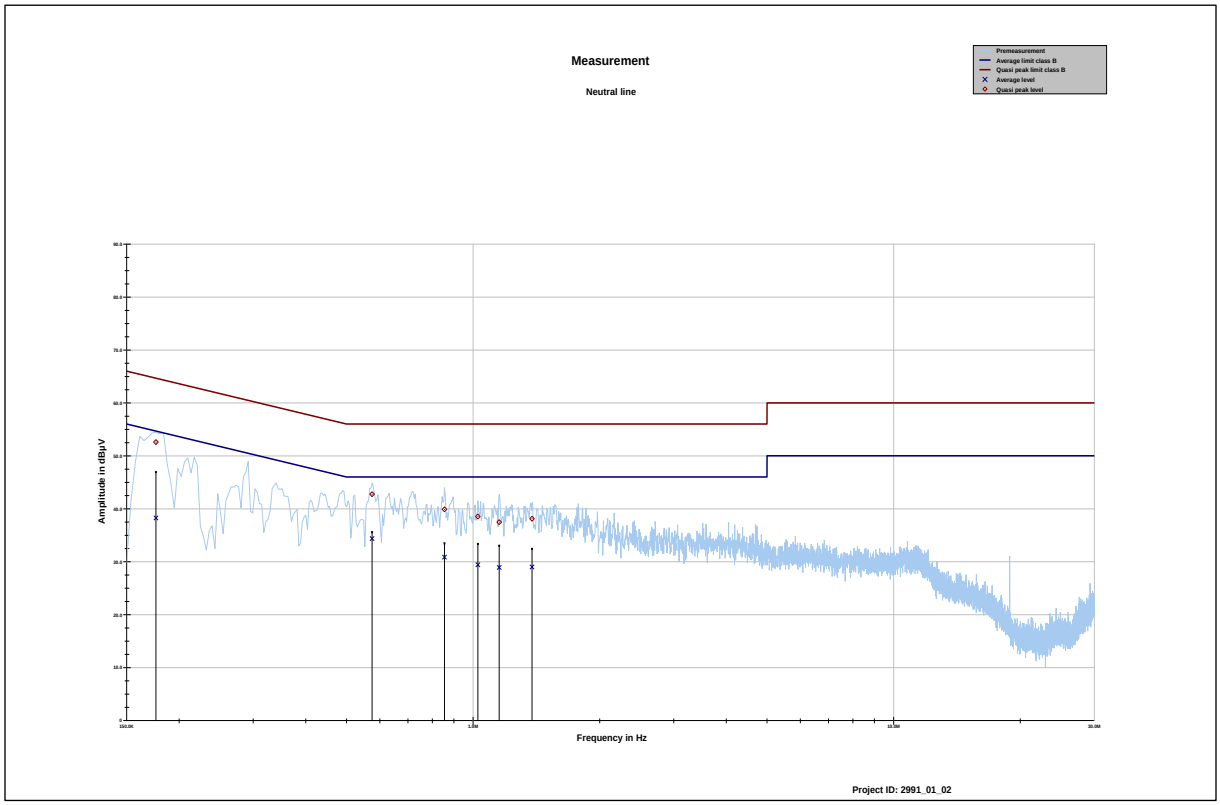
See plots below.

Plot No. 47: Phase line



Frequency	Quasi peak level	Margin quasi peak	Limit QP	Average level	Margin average	Limit AV
MHz	dBµV	dB	dBµV	dBµV	dB	dBµV
0.202237	40.35	23.17	63.518	28.07	26.44	54.508
0.377606	34.42	23.92	58.332	22.03	27.47	49.497
0.687300	25.81	30.19	56.000	16.41	29.59	46.000
3.224550	28.91	27.09	56.000	20.95	25.05	46.000
3.403650	27.22	28.78	56.000	21.42	24.58	46.000
3.765581	27.14	28.86	56.000	21.82	24.18	46.000
18.873413	39.99	20.01	60.000	40.13	9.87	50.000

Plot No. 48: Neutral line



Frequency	Quasi peak level	Margin quasi peak	Limit QP	Average level	Margin Average	Limit AV
MHz	dBµV	dB	dBµV	dBµV	dB	dBµV
0.150000	45.60	20.40	66.000	31.82	24.18	56.000
0.314175	38.77	21.08	59.859	25.14	26.17	51.309
0.545512	32.51	23.49	56.000	20.51	25.49	46.000
3.373800	22.38	33.62	56.000	11.87	34.13	46.000
3.735731	20.33	35.67	56.000	12.17	33.83	46.000
3.847669	13.08	42.92	56.000	7.40	38.60	46.000
18.873413	40.14	19.86	60.000	40.29	9.71	50.000

11.5 Frequency Stability

§ 90.213 Frequency Stability

(a) Unless noted elsewhere, transmitters used in the services governed by this part must have a minimum frequency stability as specified in the following table.

MINIMUM FREQUENCY STABILITY

[Parts per million (ppm)]

Frequency range (MHz)	Fixed and base stations	Mobile stations	
		Over 2 watts output power	2 watts or less output power
Below 25	[1 2 3] 100	100	200
25–50	20	20	50
72–76	5	.....	50
150–174	[5 11] 5	[6] 5	[4 6] 50
216–220	1.0	.....	1.0
220–222 [12]	0.1	1.5	1.5
421–512	[7 11 14] 2.5	[8] 5	[8] 5
806–809	[14] 1.0	1.5	1.5
809–824	[14] 1.5	2.5	2.5
851–854	1.0	1.5	1.5
854–869	1.5	2.5	2.5
896–901	[14] 0.1	1.5	1.5
902–928	2.5	2.5	2.5
902–928 [13]	2.5	2.5	2.5
929–930	1.5	.....	.....
935–940	0.1	1.5	1.5
1427–1435	[9] 300	300	300
Above 2450 [10]	.....	.....	.....

1 Fixed and base stations with over 200 watts transmitter power must have a frequency stability of 50 ppm except for equipment used in the Public Safety Pool where the frequency stability is 100 ppm.

2 For single sideband operations below 25 MHz, the carrier frequency must be maintained within 50 Hz of the authorized carrier frequency.

3 Travelers information station transmitters operating from 530-1700 kHz and transmitters exceeding 200 watts peak envelope power used for disaster communications and long distance circuit operations pursuant to §§ 90.242 and 90.264 must maintain the carrier frequency to within 20 Hz of the authorized frequency.

4 Stations operating in the 154.45 to 154.49 MHz or the 173.2 to 173.4 MHz bands must have a frequency stability of 5 ppm.

5 In the 150-174 MHz band, fixed and base stations with a 12.5 kHz channel bandwidth must have a frequency stability of 2.5 ppm. Fixed and base stations with a 6.25 kHz channel bandwidth must have a frequency stability of 1.0 ppm.

6 In the 150-174 MHz band, mobile stations designed to operate with a 12.5 kHz channel bandwidth or designed to operate on a frequency specifically designated for itinerant use or designed for low-power operation of two watts or less, must have a frequency stability of 5.0 ppm. Mobile stations designed to operate with a 6.25 kHz channel bandwidth must have a frequency stability of 2.0 ppm.

7 In the 421-512 MHz band, fixed and base stations with a 12.5 kHz channel bandwidth must have a frequency stability of 1.5 ppm. Fixed and base stations with a 6.25 kHz channel bandwidth must have a frequency stability of 0.5 ppm.

8 In the 421-512 MHz band, mobile stations designed to operate with a 12.5 kHz channel bandwidth must have a frequency stability of 2.5 ppm. Mobile stations designed to operate with a 6.25 kHz channel bandwidth must have a frequency stability of 1.0 ppm.

9 Fixed stations with output powers above 120 watts and necessary bandwidth less than 3 kHz must operate with a frequency stability of 100 ppm. Fixed stations with output powers less than 120 watts and using time-division multiplex, must operate with a frequency stability of 500 ppm.

10 Frequency stability for DSRCS equipment in the 5895-5925 MHz band is specified in subpart M of this part. For all other equipment, frequency stability is to be specified in the station authorization.

11 Paging transmitters operating on paging-only frequencies must operate with frequency stability of 5 ppm in the 150-174 MHz band and 2.5 ppm in the 421-512 MHz band.

12 Mobile units may utilize synchronizing signals from associated base stations to achieve the specified carrier stability.

13 Fixed non-multilateration transmitters with an authorized bandwidth that is more than 40 kHz from the band edge, intermittently operated hand-held readers, and mobile transponders are not subject to frequency tolerance restrictions.

14 Control stations may operate with the frequency tolerance specified for associated mobile frequencies.

(b) For the purpose of determining the frequency stability limits, the power of a transmitter is considered to be the maximum rated output power as specified by the manufacturer.

Measurement results:

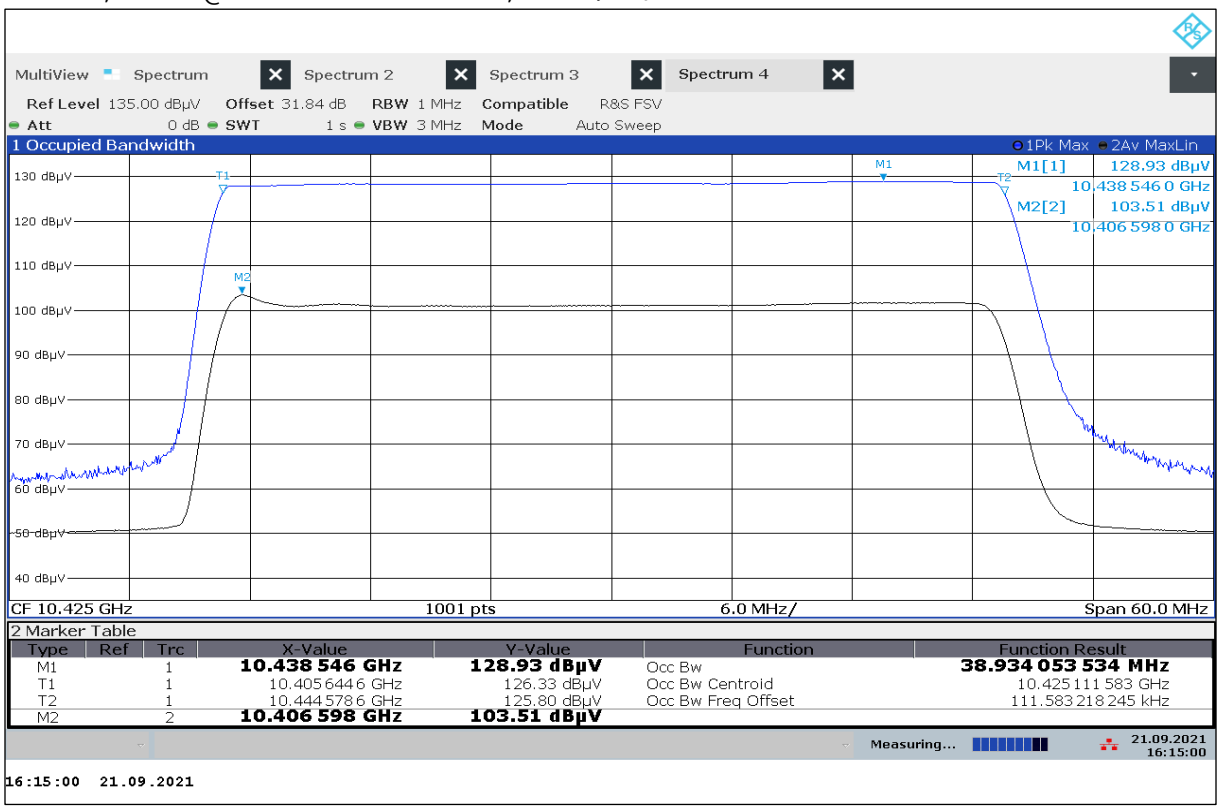
Temperature variation

Mode	Temperature in °C	f_L in GHz	f_H in GHz	Bandwidth [MHz]
FMCW @ 10.40–10.45 G	-20 °C / V_{nom}	10.405 644	10.444 578	38.9
	-10 °C / V_{nom}	10.405 377	10.444 543	39.2
	0 °C / V_{nom}	10.405 214	10.444 466	39.2
	10 °C / V_{nom}	10.405 290	10.444 504	39.2
	20 °C / $V_{min-max}$	10.405 184	10.444 463	39.3
	30 °C / V_{nom}	10.405 095	10.444 431	39.3
	40 °C / V_{nom}	10.405 095	10.444 431	39.3
	50 °C / $V_{min-max}$	10.405 068	10.444 422	39.3

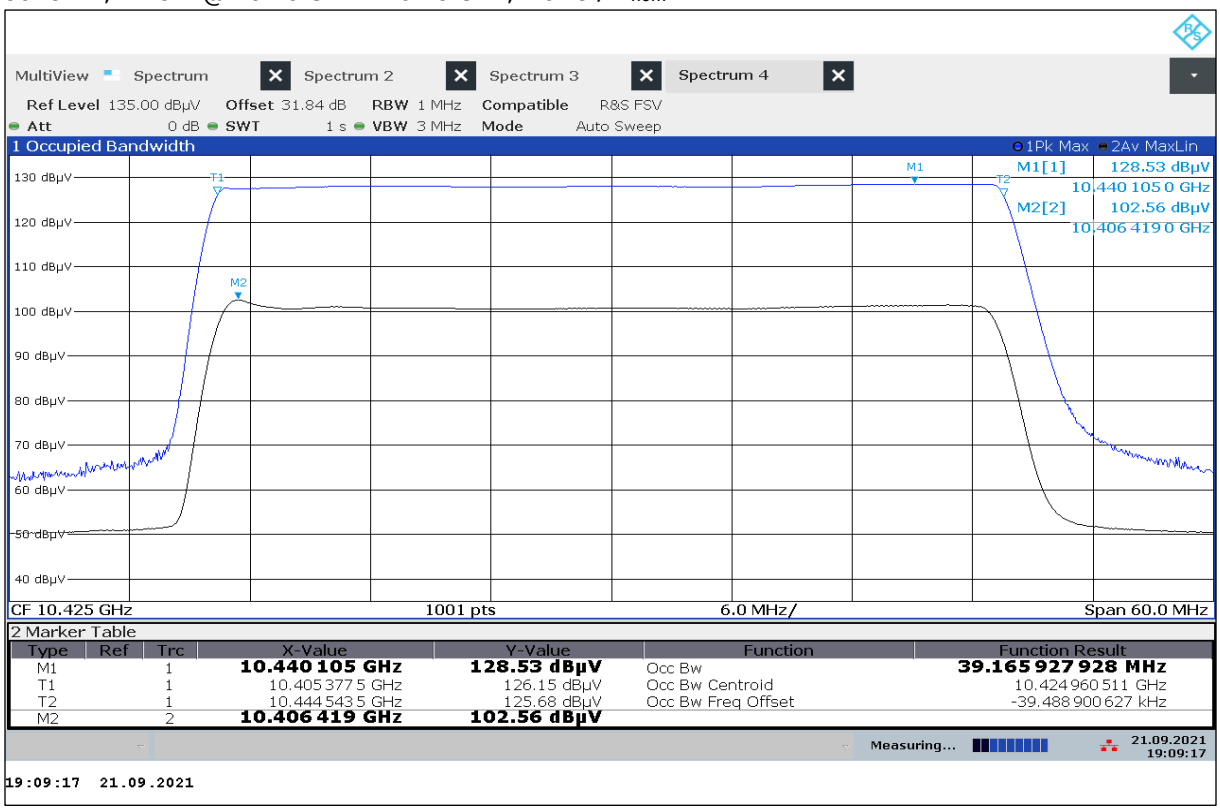
Voltage variation

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	

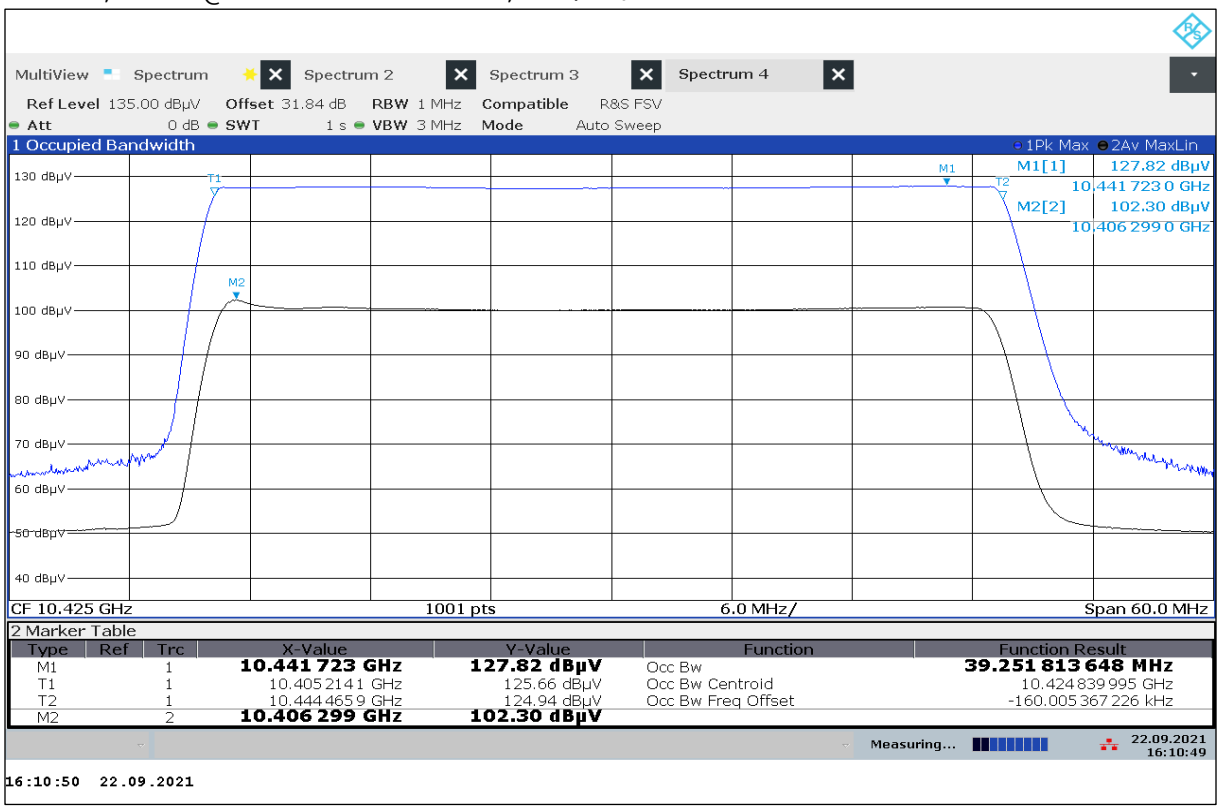
Plot 49: OBW, FMCW @ 10.40 GHz– 10.45 GHz, -20 °C / V_{nom}



Plot 50: OBW, FMCW @ 10.40 GHz– 10.45 GHz, -10 °C / V_{nom}



Plot 51: OBW, FMCW @ 10.40 GHz– 10.45 GHz, 0 °C / V_{nom}

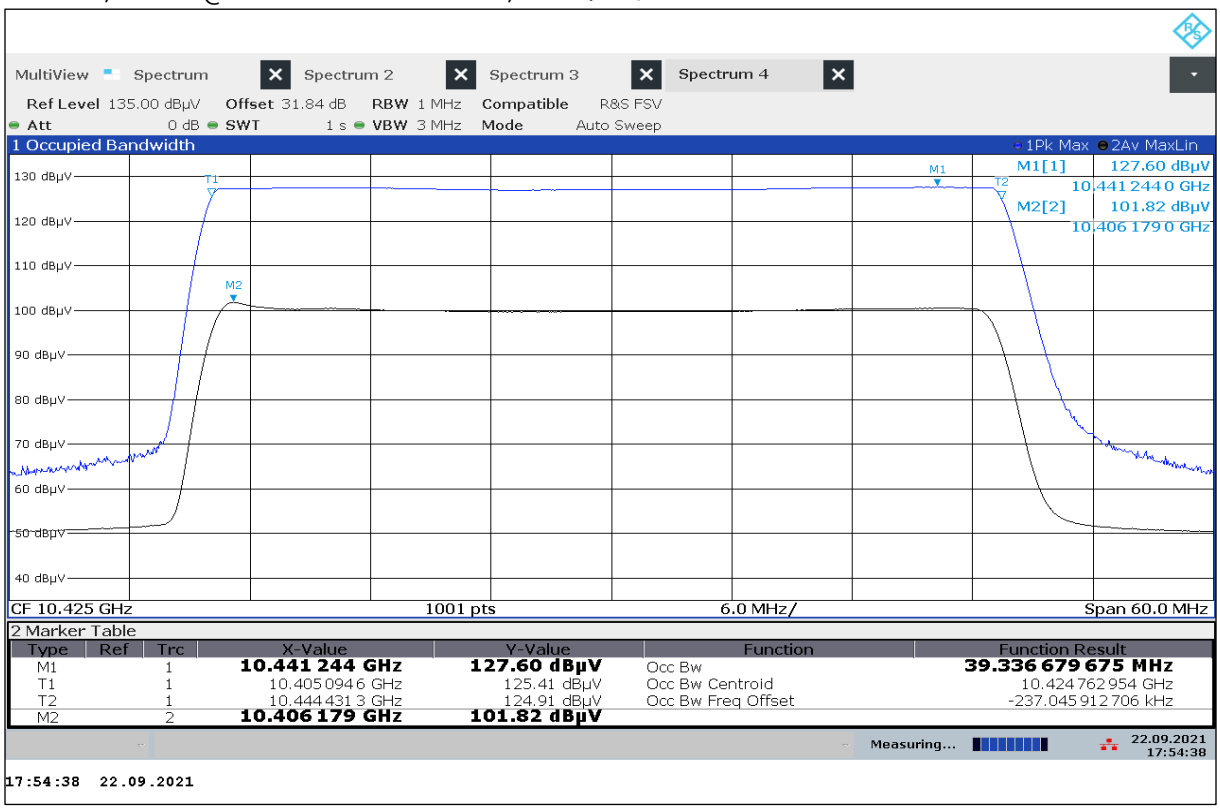


Plot 52: OBW, FMCW @ 10.40 GHz– 10.45 GHz, 10 °C / V_{nom}

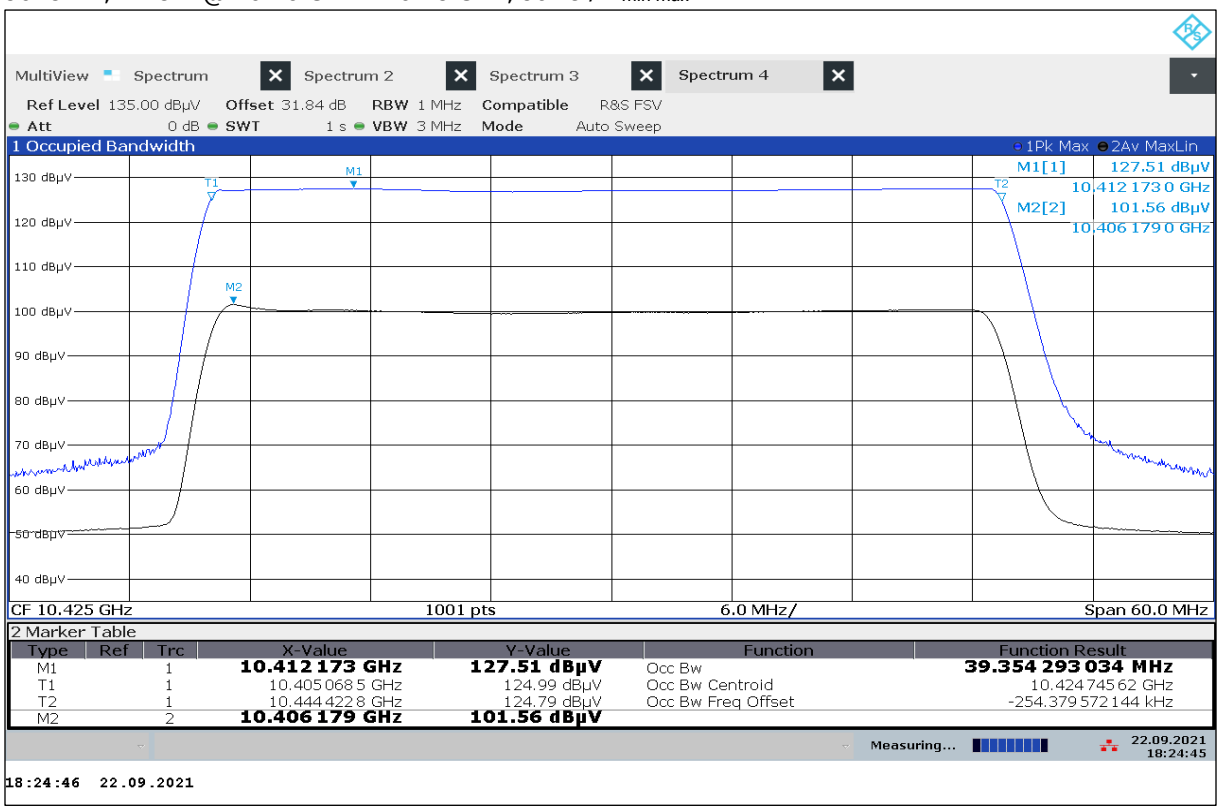
Plot 53: OBW, FMCW @ 10.40 GHz– 10.45 GHz, 20 °C / $V_{min-max}$

Plot 54: OBW, FMCW @ 10.40 GHz– 10.45 GHz, 30 °C / V_{nom}

Plot 55: OBW, FMCW @ 10.40 GHz– 10.45 GHz, 40 °C / V_{nom}



Plot 56: OBW, FMCW @ 10.40 GHz– 10.45 GHz, 50 °C / $V_{min-max}$



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 - DRAFT	2021-10-26
-/-	Minor changes	2021-11-17

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

first page

DAkkS
Deutsche Akkreditierungsstelle

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 order Dipl.-Ing. (FH) Ralf Egner
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

See notes overleaf.

last page

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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.

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

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

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