
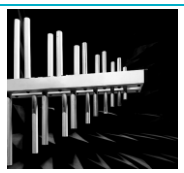
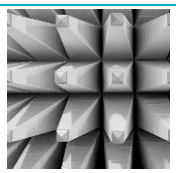

Bundesnetzagentur

BNetzA-CAB-02/21-102

TEST REPORT

Test report no.: 1-7290_23-01-02

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

Testing laboratory

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

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

Applicant

RFbeam Microwave GmbH
Schuppisstrasse 7
9016 St. Gallen / SWITZERLAND
Phone: +41 7 12 45 33 80
Contact: Ueli Giger
e-mail: giger@rfbeam.ch

Manufacturer

RFbeam Microwave GmbH
Schuppisstrasse 7
9016 St. Gallen / SWITZERLAND

Test standard/s

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

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

Test Item

Kind of test item:	**Digital K-Band Radar Sensor**
Model name:	**Phi-1**
FCC ID:	**2ASYV-PHI-1**
Frequency:	24.00 GHz – 24.25 GHz
Technology tested:	FSK
Antenna:	Integrated PCB Patch Antenna
Power supply:	3.2 V DC to 5.5 V DC by power supply
Temperature range:	-40°C to +85°C

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

Test report authorized:

Thomas Vogler

cn=Thomas Vogler, o=cetecom advanced GmbH, ou=VOG-230609, email=thomas.vogler@cetecomadvanced.com, c=DE
2024.02.28 15:33:52 +01'00'

Thomas Vogler
Lab Manager
Radio Labs

Test performed:

M. Walla

cn=Meheza Walla, o=cetecom advanced GmbH, ou=WAL-230706, email=Meheza.Walla@cetecomadvanced.com, c=DE
2024.02.28 14:55:21 +01'00'

Meheza Walla
Lab Manager
Radio Labs

1 Table of contents

2 General information

2.1 Notes and disclaimer

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

2.2 Application details

Date of receipt of order:	2024-01-04
Date of receipt of test item:	2024-02-02
Start of test:*	2024-02-06
End of test:*	2024-02-14
Person(s) present during the test:	-/-

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

2.3 Test laboratories sub-contracted

None

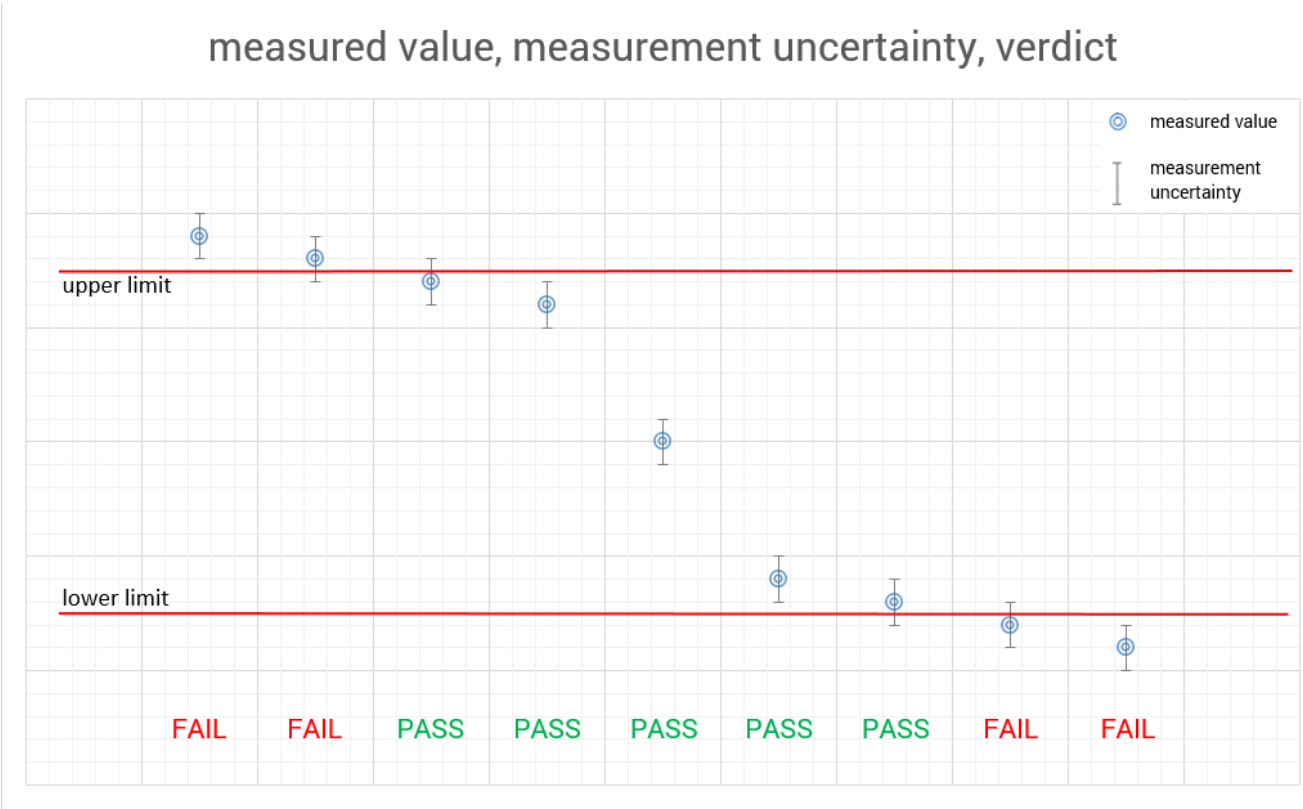
3 Test standard/s, references and accreditations

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

Guidance	Version	Description
ANSI C63.4-2014	-/-	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

4 Reporting statements of conformity – decision rule

Only the measured values related to their corresponding limits will be used to decide whether the equipment under test meets the requirements of the test standards listed in chapter 3.
The measurement uncertainty is mentioned in this test report, see chapter 9, but is not taken into account - neither to the limits nor to the measurement results. Measurement results with a smaller margin to the corresponding limits than the measurement uncertainty have a potential risk of more than 5% that the decision might be wrong.



5 Test environment

Temperature	:	T_{nom} T_{max} T_{min}	+22 °C during room temperature tests +50 °C during high temperature tests -20 °C during low temperature tests
Relative humidity content	:		49 %
Barometric pressure	:		990 hPa to 1010 hPa
Power supply	:	V_{nom} V_{max} V_{min}	3.3 V DC by external power supply 5.5 V 3.2 V

6 Test item

6.1 General description

Kind of test item	:	Digital K-Band Radar Sensor
Model name	:	Phi-1
S/N serial number	:	-/- (serial module)
Hardware status	:	A
Software status	:	N/A
Firmware status	:	01
Frequency band	:	24.00 GHz – 24.25 GHz
Type of modulation	:	FSK
Number of channels	:	5
Antenna	:	Integrated PCB Patch Antenna
Power supply	:	3.2 V DC to 5.5 V DC by power supply
Temperature range	:	-40°C to +85°C

6.2 Additional information

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

Test setup and EUT photos are included in test report: 1-7290/23-01-01_AnnexA
1-7290/23-01-01_AnnexB
1-7290/23-01-01_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).

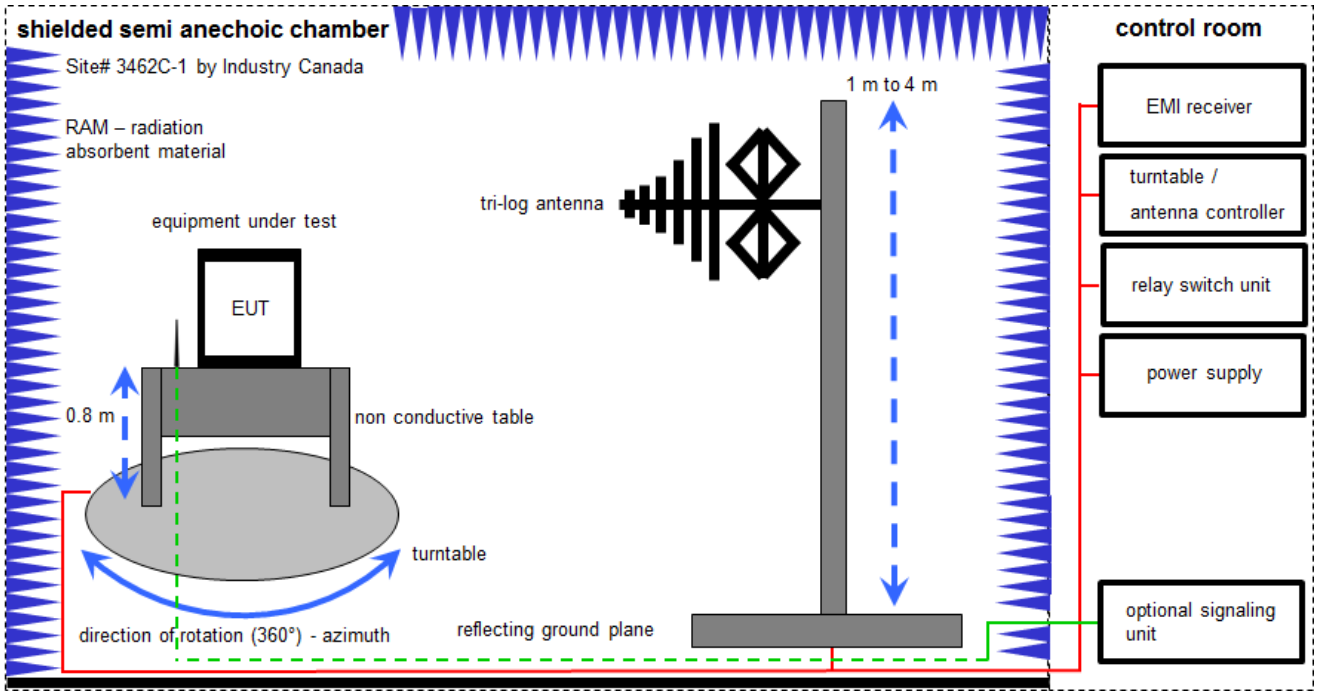
In order to simplify the identification of the equipment used at some special tests, some items of test equipment and ancillaries can be provided with an identifier or number in the equipment list below (Lab/Item).

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

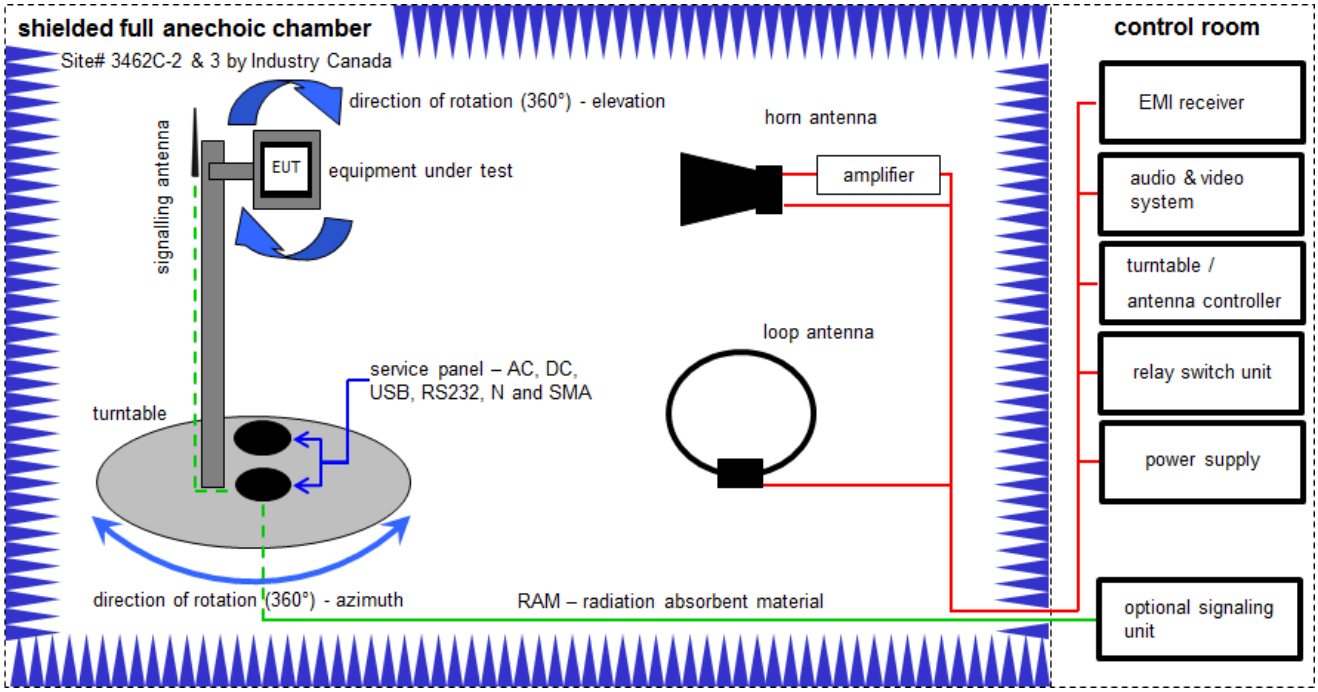
FS = UR + CL + AF
(FS-field strength; UR-voltage at the receiver; CL-loss of the cable; AF-antenna factor)

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.	Analyzer-Impedence-System	AIS16/1	Spitzenberger + Spies GmbH & Co. KG	UO2076 07/0 1023	400001751	k	19.10.2023	31.10.2025
2	n. a.	Antenna Tower	Model 2175	ETS-Lindgren	64762	300003745	izw	-/-	-/-
3	n. a.	DC power supply, 60Vdc, 50A, 1200 W	6032A	HP	2920A04466	300000580	ne	-/-	-/-
4	n. a.	EMI Test Receiver	ESR3	Rohde & Schwarz	102587	300005771	k	06.12.2023	31.12.2024
5	n. a.	Positioning Controller	Model 2090	ETS-Lindgren	64672	300003746	izw	-/-	-/-
6	n. a.	Semi anechoic chamber	3000023	MWB AG		300000551	ne	-/-	-/-
7	n. a.	Switch-Unit	3488A	HP	2719A14505	300000368	ev	-/-	-/-
8	n. a.	TRILOG Broadband Test-Antenna 30 MHz - 3 GHz	VULB9163	Schwarzbeck Mess - Elektronik	216	300003288	vIKI!	31.08.2023	31.08.2025
9	n. a.	Turntable	2089-4.0	EMCO		300004394	ne	-/-	-/-
10	n. a.	Turntable Interface-Box	Model 105637	ETS-Lindgren	44583	300003747	izw	-/-	-/-

7.2 Shielded fully anechoic chamber



Measurement distance: horn antenna 3 meter; loop antenna 3 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)

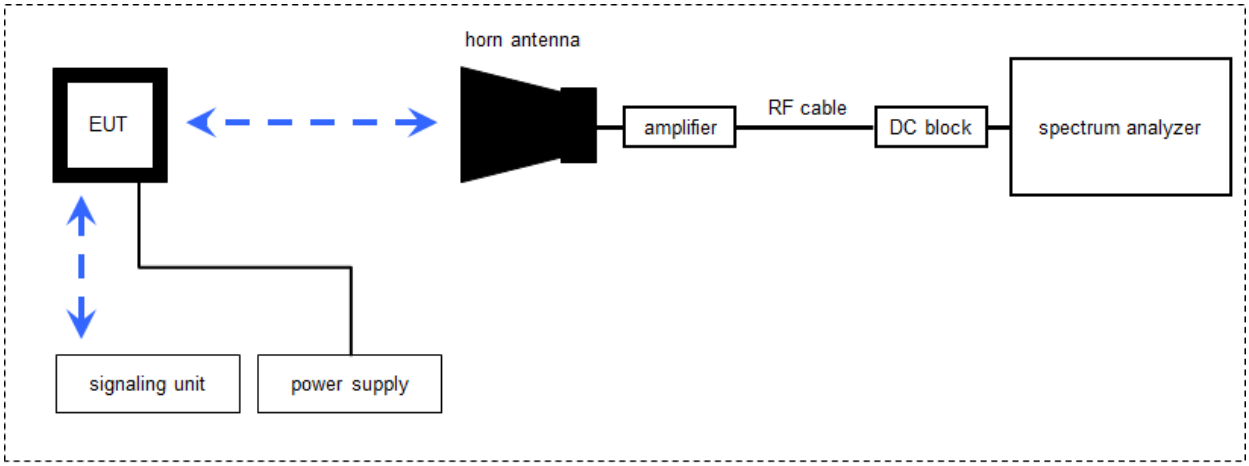
OP = AV + D - G + CA
(OP-radiated output power; AV-analyzer value; D-free field attenuation of measurement distance; G-antenna gain+amplifier gain; CA-loss signal path)

Example calculation:
OP [dBm] = -65.0 [dBm] + 50 [dB] - 20 [dBi] + 5 [dB] = -30 [dBm] (1 µW)

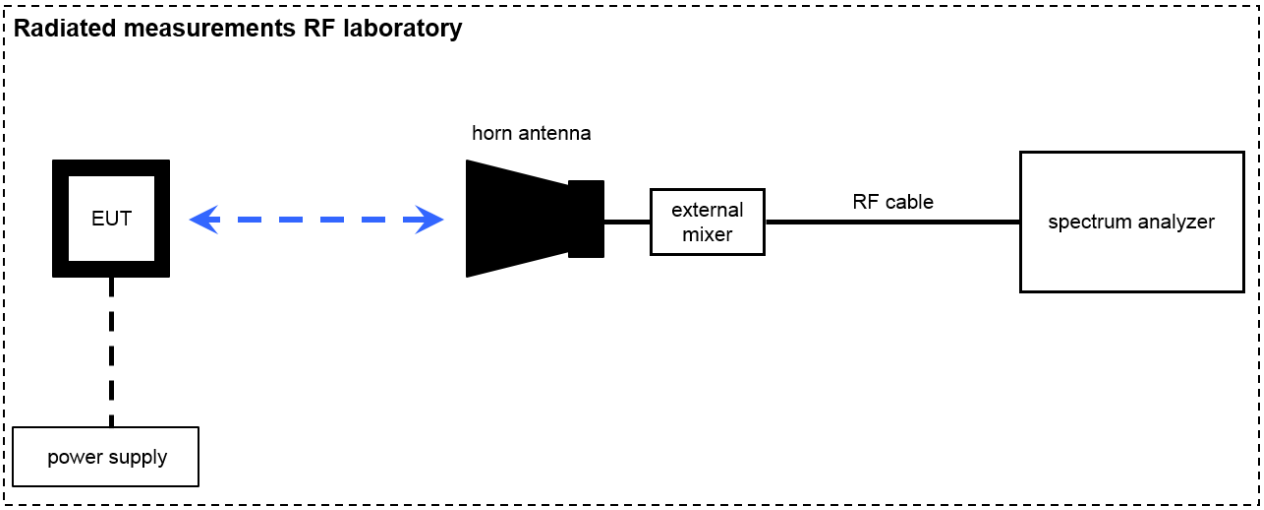
Equipment table:

No.	Lab / Item	Equipment	Type	Manufacturer	Serial No.	INV. No.	Kind of Calibration	Last Calibration	Next Calibration
1	n. a.	4U RF Switch Platform	L4491A	Agilent Technologies	MY50000037	300004509	ne	-/-	-/-
2	n. a.	Active Loop Antenna 9 kHz to 30 MHz	6502	EMCO/2	8905-2342	300000256	vIKI!	19.07.2023	31.07.2025
3	n. a.	Anechoic chamber	FAC 3/5m	MWB / TDK	87400/02	300000996	ev	-/-	-/-
4	n. a.	Broadband Amplifier 0.5-18 GHz	CBLU5184540	CERNEX	22049	300004481	ev	-/-	-/-
5	n. a.	DC power supply, 60Vdc, 50A, 1200 W	6032A	HP	2818A03450	300001040	vIKI!	05.12.2023	31.12.2026
6	n. a.	Double-Ridged Waveguide Horn Antenna 1-18.0GHz	3115	EMCO	8812-3089	300000307	vIKI!	11.02.2022	29.02.2024
7	n. a.	EMI Test Receiver 20Hz- 26,5GHz	ESU26	R&S	100037	300003555	k	11.12.2023	31.12.2024
8	n. a.	Highpass Filter	WHKX7.0/18G-8SS	Wainwright	19	300003790	ne	-/-	-/-
9	n. a.	MXG Microwave Analog Signal Generator	N5183A	Agilent Technologies	MY47420220	300003813	vIKI!	07.12.2022	31.12.2025
10	n. a.	NEXIO EMV-Software	BAT EMC V2022.0.32.0	Nexio		300004682	ne	-/-	-/-
11	n. a.	RF-Amplifier	AMF-6F06001800-30-10P-R	NARDA-MITEQ Inc	2011572	300005241	ev	-/-	-/-
12	n. a.	Switch / Control Unit	3488A	HP	*	300000199	ne	-/-	-/-
13	n. a.	Variable isolating transformer	MPL IEC625 Bus Variable isolating transformer	Erfi	91350	300001155	ne	-/-	-/-

7.3 Radiated measurements > 18 GHz



7.4 Radiated measurements > 50/85 GHz



Measurement distance: horn antenna e.g. 75 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)

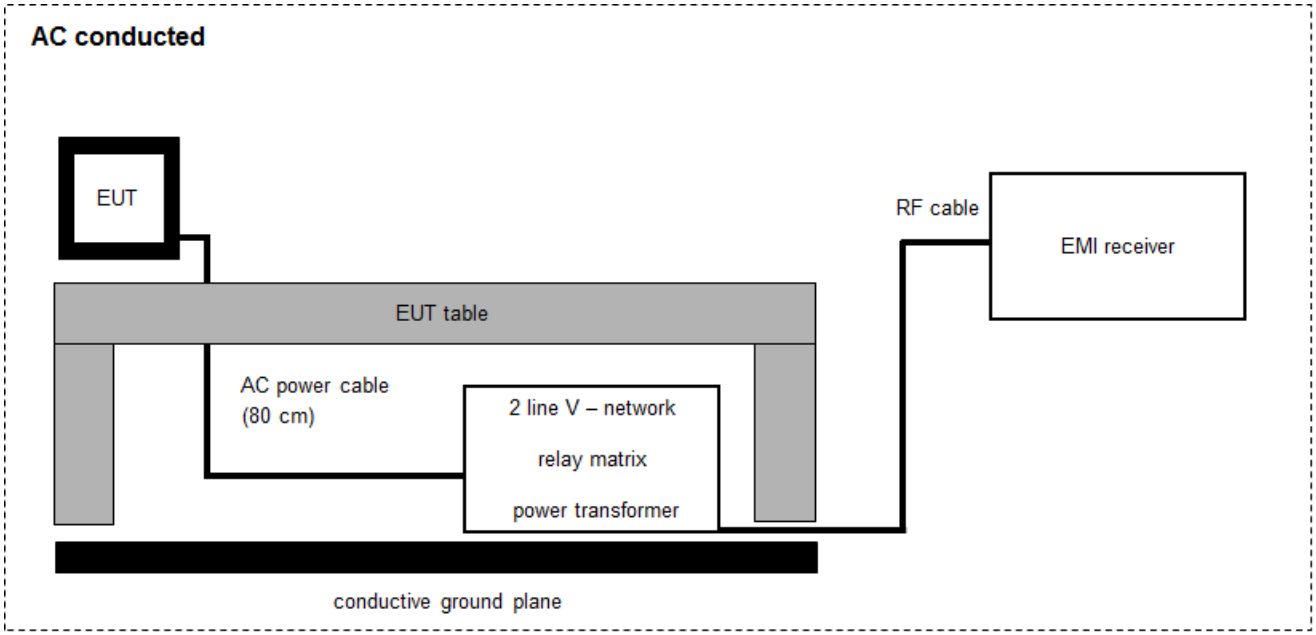
Example calculation:
OP [dBm] = -59.0 [dBm] + 44.0 [dB] - 20.0 [dBi] + 5.0 [dB] = -30 [dBm] (1 µW)

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.	Broadband LNA 18-50 GHz	CBL18503070PN	CERNEX	25240	300004948	ev	09.03.2022	08.03.2024
2	n. a.	Harmonic Mixer 3-Port, 50-75 GHz	FS-Z75	Rohde & Schwarz	101578	300005788	k	19.07.2023	31.07.2024
3	n. a.	Harmonic Mixer 3-Port, 60-90 GHz	FS-Z90	R&S	101555	300004691	k	25.08.2023	31.08.2024
4	n. a.	Harmonic Mixer 3-Port, 75-110 GHz	FS-Z110	Rohde & Schwarz	101411	300004959	k	21.07.2023	31.07.2024
5	n. a.	Harmonic Mixer 3-port, 90-140 GHz	FS-Z140	Rohde & Schwarz	101119	300005581	k	03.08.2023	31.08.2024
6	n. a.	Horn Antenna 18,0-40,0 GHz	LHAF180	Microw.Devel	39180-103-021	300001747	vlKl!	24.01.2024	23.01.2026
7	n. a.	Power supply	N5767A	Agilent Technologies	US14J1569P	300004851	vlKl!	06.12.2023	31.12.2026
8	n. a.	Signal- and Spectrum Analyzer 2 Hz - 50 GHz	FSW50	Rohde&Schwarz	101560	300006179	k	04.04.2023	30.04.2024
9	n. a.	Std. Gain Horn Antenna 18.0-26.5 GHz	638	Narda	01096	300000486	vlKl!	24.01.2024	23.01.2026
10	n. a.	Std. Gain Horn Antenna 26.5-40.0 GHz	V637	Narda	82-16	300000510	vlKl!	24.01.2024	23.01.2026
11	n. a.	Std. Gain Horn Antenna 33.0-50.1 GHz	2324-20	Flann	57	400000683	ne	-/-	-/-
12	n. a.	Std. Gain Horn Antenna 49.9-75.8 GHz	2524-20	Flann	*	300001983	ne	-/-	-/-
13	n. a.	Std. Gain Horn Antenna 60-90 GHz	COR 60_90	Thomson CSF		300000814	ev	-/-	-/-
14	n. a.	Std. Gain Horn Antenna 73.8-112 GHz	2724-20	Flann	*	300001988	ne	-/-	-/-
15	n. a.	Std. Gain Horn Antenna 92.3-140 GHz	2824-20	Flann	*	300001993	ne	-/-	-/-

7.5 AC conducted



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

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

Equipment table:

No.	Lab / Item	Equipment	Type	Manufacturer	Serial No.	INV. No.	Kind of Calibration	Last Calibration	Next Calibration
1	n. a.	Two-line V-Network (LISN) 9 kHz to 30 MHz	ESH3-Z5	R&S	892475/017	300002209	vIKI!	12.12.2023	31.12.2025
2	n. a.	RF-Filter-section	85420E	HP	3427A00162	300002214	NK!	-/-	-/-
3	n. a.	EMI Test Receiver 3.6 GHz	ESR3	Rohde & Schwarz	102981	300006318	k	08.12.2023	31.12.2024
4	n. a.	EMI Test Receiver	ESCI 3	R&S	101240	300004427	k	08.12.2023	31.12.2024
5	n. a.	Hochpass 150 kHz	EZ-25	R&S	100010	300003798	ev	-/-	-/-

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.

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 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 Summary of measurement results

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

TC identifier	Description	verdict	date	Remark
RF-Testing	FCC 47 CFR Part 15	see below	2024-02-28	-/-

Test specification clause	Test case	Temperature conditions	Power supply	Pass	Fail	NA	NP	Remark
§15.215(c) / §15.249 (b)(2)	Bandwidth and frequency stability of the wanted signal	Nominal Extreme	Nominal Extreme	☒	☐	☐	☐	complies
§15.249(b)(3)	Antenna gain & beam width	Nominal	Nominal	☐	☐	☒	☐	
§15.249(a), (b)(1), (c), (e)	Field strength of fundamental emission	Nominal	Nominal	☒	☐	☐	☐	complies
§15.209(a) / §15.249(d)	Field strength of emissions (radiated spurious)	Nominal	Nominal	☒	☐	☐	☐	complies
§15.207(a), (c)	Conducted emissions < 30 MHz	Nominal	Nominal	☒	☐	☐	☐	complies

Note: NA = Not applicable; NP = Not performed

11 Additional comments

Kind of device:

☐ Fixed, point-to-point operation system

☐ Point-to-multipoint system, omnidirectional application or multiple co-located intentional radiators transmitting the same information

☒ Other

Note:

- §15.249(b): Fixed, point-to-point operation as referred to in this paragraph shall be limited to systems employing a fixed transmitter transmitting to a fixed remote location. Point-to-multipoint systems, omnidirectional applications, and multiple co-located intentional radiators transmitting the same information are not allowed. […]

Test devices (EUT):

- S1: EUT
- S2: EUT spare
- S3: EUT for internal pictures

Associated equipment (AE):

- AE1: Evalkit PCB

Additional test modes:

☐ No test modes available

☐ Special test modes/special software (see description below)

☒ Stop-Modes (see description below)

Stop-Modes:

In addition to the normal operation mode, Stop-Modes are used in accordance with CFR 47 Part §15.31 (c) & (m), in which the frequency sweep is stopped at the following positions in the range of operation:

- Stop-Mode, low frequency: 24.135 GHz (FA)
- Stop-Mode, middle frequency: 24.175 GHz (FC)
- Stop-Mode, high frequency: 24.215 GHz (FE)

Details on test mode settings:

- Refer to customer documentation „Phi-1 - Anleitung Messungen.pdf“

Software provided by the manufacturer:

- K-PHI1_CTP-SED-0109.exe

12 Measurement results

12.1 Bandwidth and frequency stability of the wanted signal

Description:

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

Limits and provisions:

§15.215(c):
Intentional radiators operating under the alternative provisions to the general emission limits, as contained in §§15.217 through 15.257 and in subpart E of this part, must be designed to ensure that the 20 dB bandwidth of the emission, or whatever bandwidth may otherwise be specified in the specific rule section under which the equipment operates, is contained within the frequency band designated in the rule section under which the equipment is operated. In the case of intentional radiators operating under the provisions of subpart E, the emission bandwidth may span across multiple contiguous frequency bands identified in that subpart. The requirement to contain the designated bandwidth of the emission within the specified frequency band includes the effects from frequency sweeping, frequency hopping and other modulation techniques that may be employed as well as the frequency stability of the transmitter over expected variations in temperature and supply voltage. If a frequency stability is not specified in the regulations, it is recommended that the fundamental emission be kept within at least the central 80% of the permitted band in order to minimize the possibility of out-of-band operation.

Designated frequency bands of §15.249				
Kind of device	Fundamental frequency [GHz]	f_L [GHz]	f_H [GHz]	Bandwidth [MHz]
Fixed, point-to-point system (see also 15.249(b)(2))	24.05–24.25	> 24.05	< 24.25	< 200
Other	0.902 – 0.928	> 0.902	< 0.928	< 26 MHz
Other	2.400 – 2.4835	> 2.400	< 2.4835	< 83.5 MHz
Other	5.725 – 5.875	> 5.725	< 5.875	< 150 MHz
Other	**24.0 – 24.25**	**> 24.0**	**< 24.25**	**<250 MHz**

15.249(b): Fixed point-to-point systems
[…] Fixed, point-to-point operation is permitted in the 24.05–24.25 GHz band subject to the following conditions: […]

(2) The frequency tolerance of the carrier signal shall be maintained within ±0.001% of the operating frequency over a temperature variation of −20 degrees to +50 degrees C at normal supply voltage, and for a variation in the primary supply voltage from 85% to 115% of the rated supply voltage at a temperature of 20 degrees C. For battery operated equipment, the equipment tests shall be performed using a new battery. […]

Measurement:

Measurement parameter	
Detector:	Pos-Peak
Resolution bandwidth:	1 MHz
Video bandwidth:	3 MHz
Trace-Mode:	Max Hold

Measurement procedures:

- Bandwidth: ANSI C63.10-2013 6.9
- Frequency stability: ANSI C63.10-2013 6.8

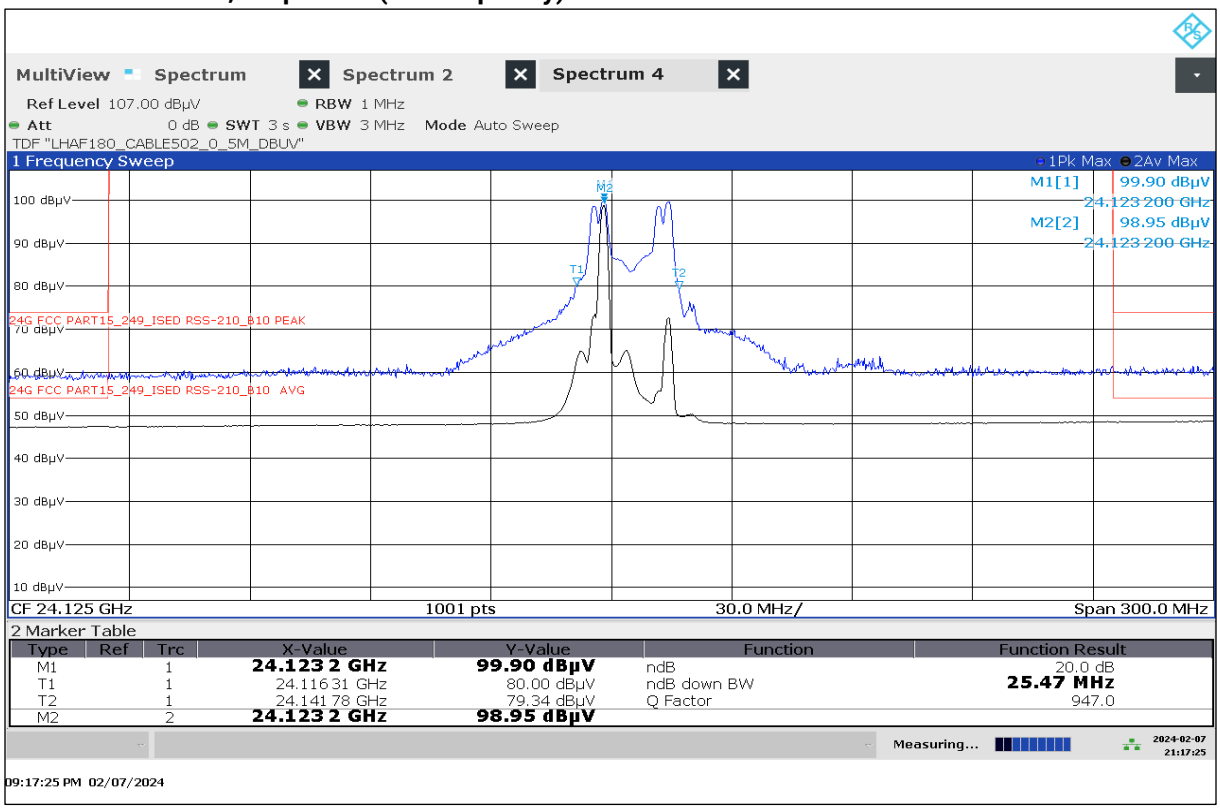
Measurement results:

20 dB bandwidth at normal conditions:

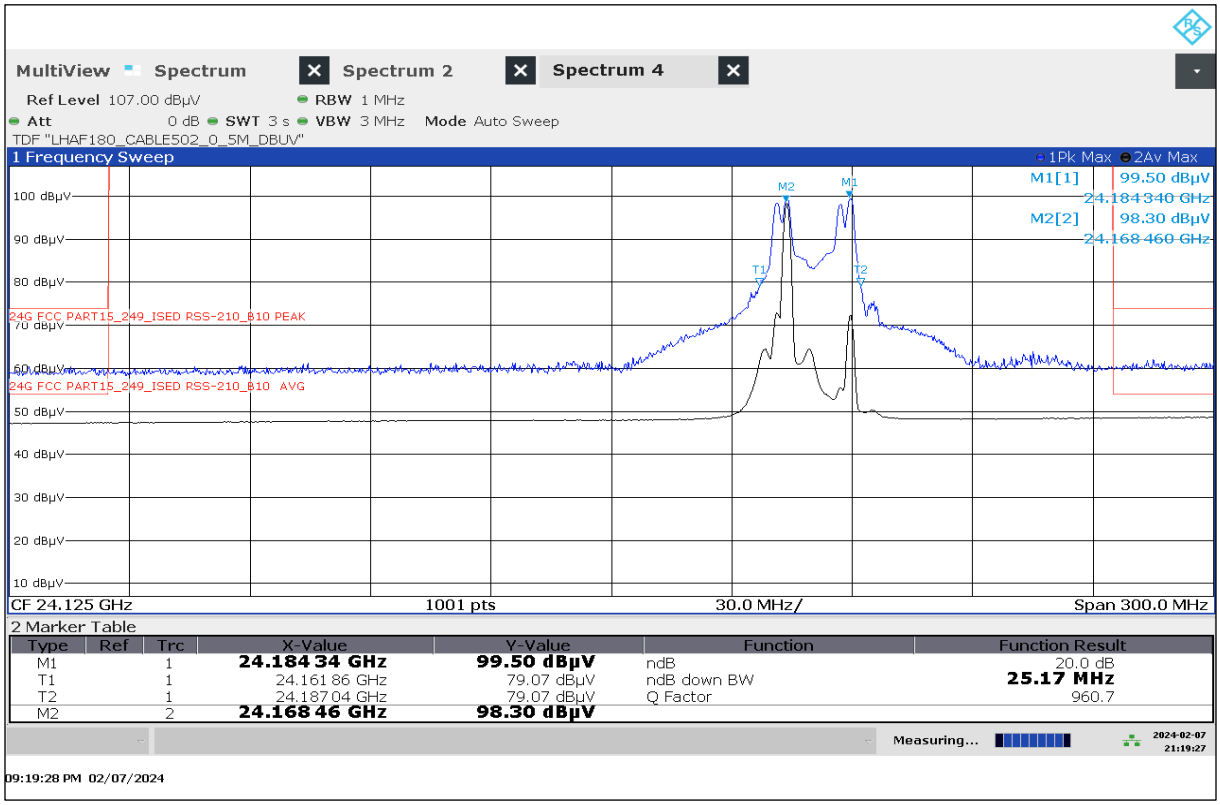
Channels	Test condition	f_L [GHz]	f_H [GHz]	Bandwidth [MHz]
FA – 24.135 GHz	T_{nom} / V_{nom}	24.116 310	24.141 780	25.5
FC – 24.175 GHz	T_{nom} / V_{nom}	24.161 860	24.187 040	25.2
FE – 24.215 GHz	T_{nom} / V_{nom}	24.204 420	24.229 600	25.2

Verdict: Compliant

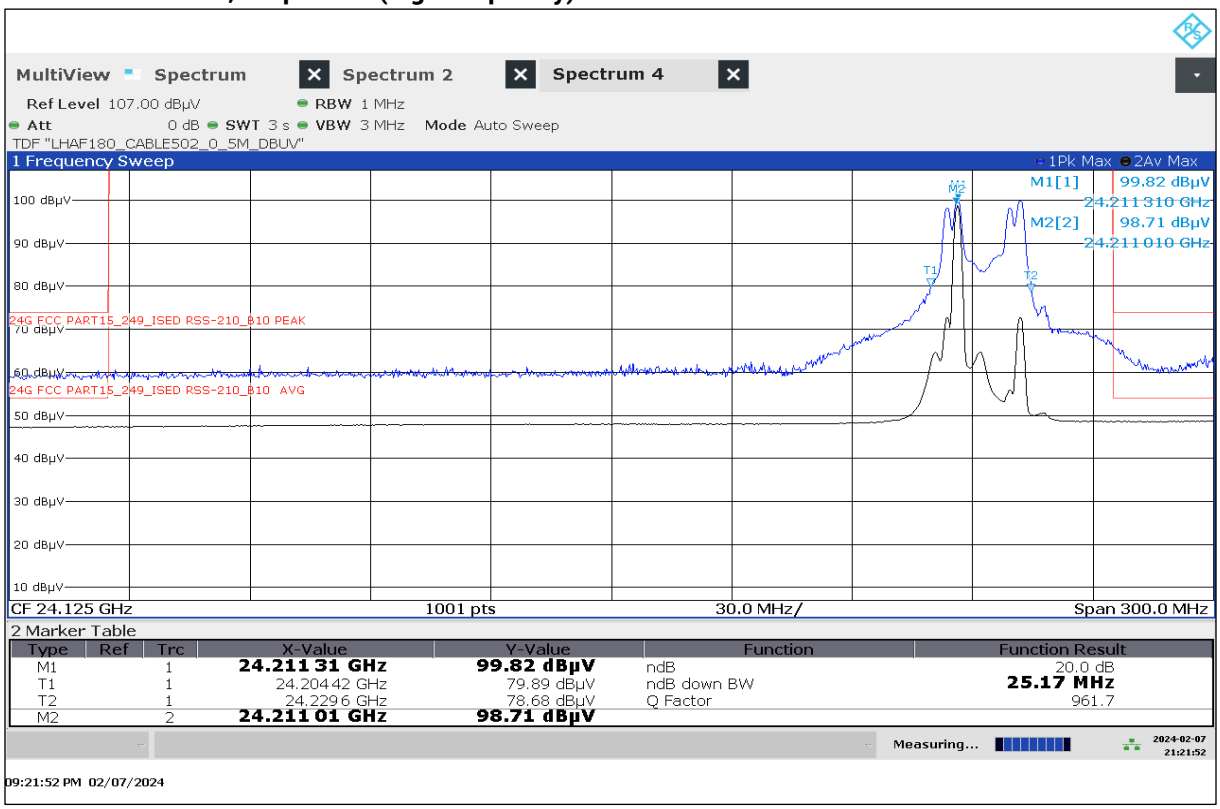
Plot 1: 20dB bandwidth, Stop Mode (low frequency)



Plot 2: 20dB bandwidth, Stop Mode (middle frequency)



Plot 3: 20dB bandwidth, Stop Mode (high frequency)



Frequency stability / tolerance:

Bandwidth measurement for frequency stability tests: 20 dB bandwidth

Test condition Stop Mode (low frequency)	Frequency f_L [GHz]	Frequency f_H [GHz]	Bandwidth [MHz]	Carrier frequency* [GHz]	Frequency tolerance* [ppm]
-20 °C / V_{nom}	24.100 120	24.124 100	24.0	-/-	-/-
-10 °C / V_{nom}	24.104 620	24.130 390	25.8	-/-	-/-
0 °C / V_{nom}	24.110 910	24.136 390	25.5	-/-	-/-
10 °C / V_{nom}	24.113 910	24.139 390	25.5	-/-	-/-
20 °C / V_{nom}	24.116 310	24.141 780	25.5	-/-	-/-
20 °C / V_{min}	24.116 310	24.142 080	25.8	-/-	-/-
20 °C / V_{max}	24.116 610	24.141 780	25.2	-/-	-/-
30 °C / V_{nom}	24.116 610	24.142 380	25.8	-/-	-/-
40 °C / V_{nom}	24.116 010	24.141 180	25.2	-/-	-/-
50 °C / V_{nom}	24.113 610	24.138 490	24.9	-/-	-/-

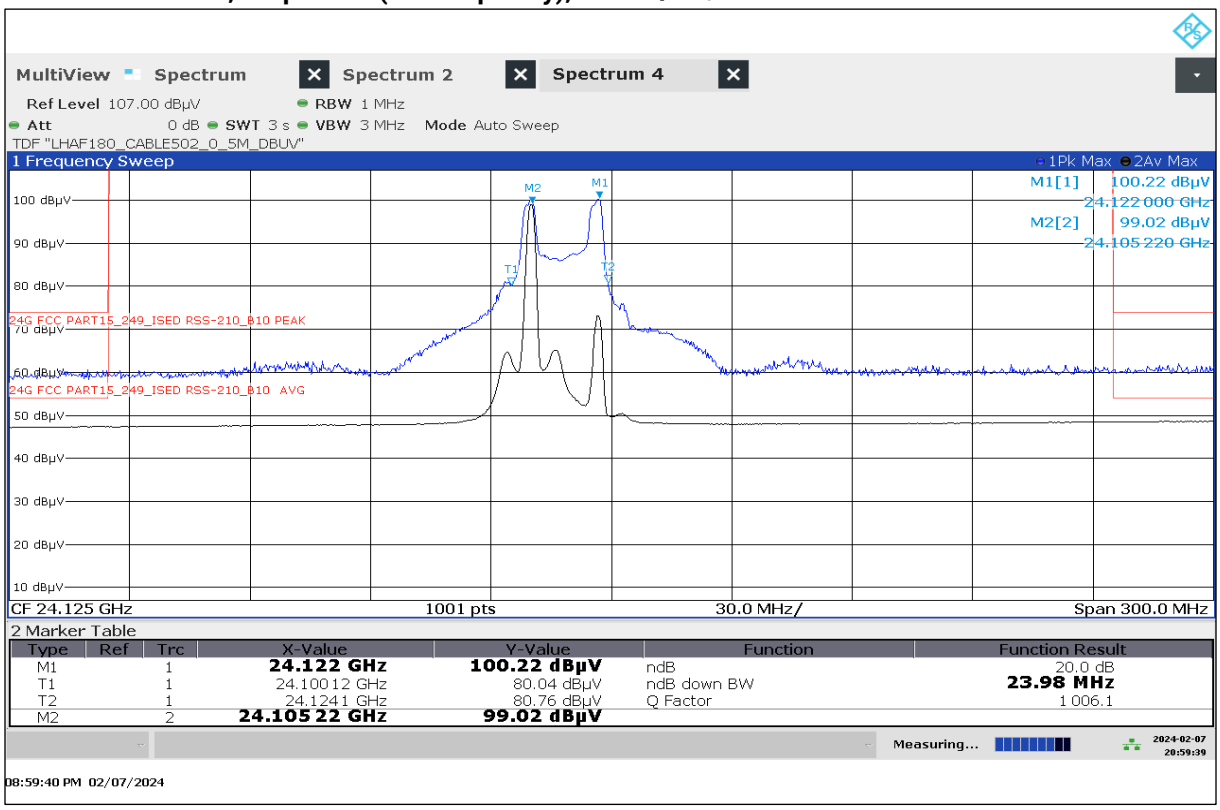
Test condition Stop Mode (middle frequency)	Frequency f_L [GHz]	Frequency f_H [GHz]	Bandwidth [MHz]	Carrier frequency* [GHz]	Frequency tolerance* [ppm]
-20 °C / V_{nom}	24.144 780	24.170 550	25.8	-/-	-/-
-10 °C / V_{nom}	24.151 370	24.176 850	25.5	-/-	-/-
0 °C / V_{nom}	24.156 770	24.182 540	25.8	-/-	-/-
10 °C / V_{nom}	24.159 470	24.185 240	25.8	-/-	-/-
20 °C / V_{nom}	24.161 860	24.187 040	25.2	-/-	-/-
20 °C / V_{min}	24.161 860	24.187 040	25.2	-/-	-/-
20 °C / V_{max}	24.161 560	24.186 740	25.2	-/-	-/-
30 °C / V_{nom}	24.162 160	24.187 040	24.9	-/-	-/-
40 °C / V_{nom}	24.160 660	24.185 540	24.9	-/-	-/-
50 °C / V_{nom}	24.157 370	24.182 240	24.9	-/-	-/-

Test condition Stop Mode (high frequency)	Frequency f_L [GHz]	Frequency f_H [GHz]	Bandwidth [MHz]	Carrier frequency* [GHz]	Frequency tolerance* [ppm]
-20 °C / V_{nom}	24.190 330	24.214 010	23.7	-/-	-/-
-10 °C / V_{nom}	24.195 430	24.220 900	25.5	-/-	-/-
0 °C / V_{nom}	24.200 220	24.225 700	25.5	-/-	-/-
10 °C / V_{nom}	24.203 520	24.228 400	24.9	-/-	-/-
20 °C / V_{nom}	24.204 420	24.229 600	25.2	-/-	-/-
20 °C / V_{min}	24.204 720	24.229 600	24.9	-/-	-/-
20 °C / V_{max}	24.204 420	24.229 600	25.2	-/-	-/-
30 °C / V_{nom}	24.204 720	24.229 600	24.9	-/-	-/-
40 °C / V_{nom}	24.202 920	24.227 200	24.3	-/-	-/-
50 °C / V_{nom}	24.199 630	24.224 200	24.6	-/-	-/-

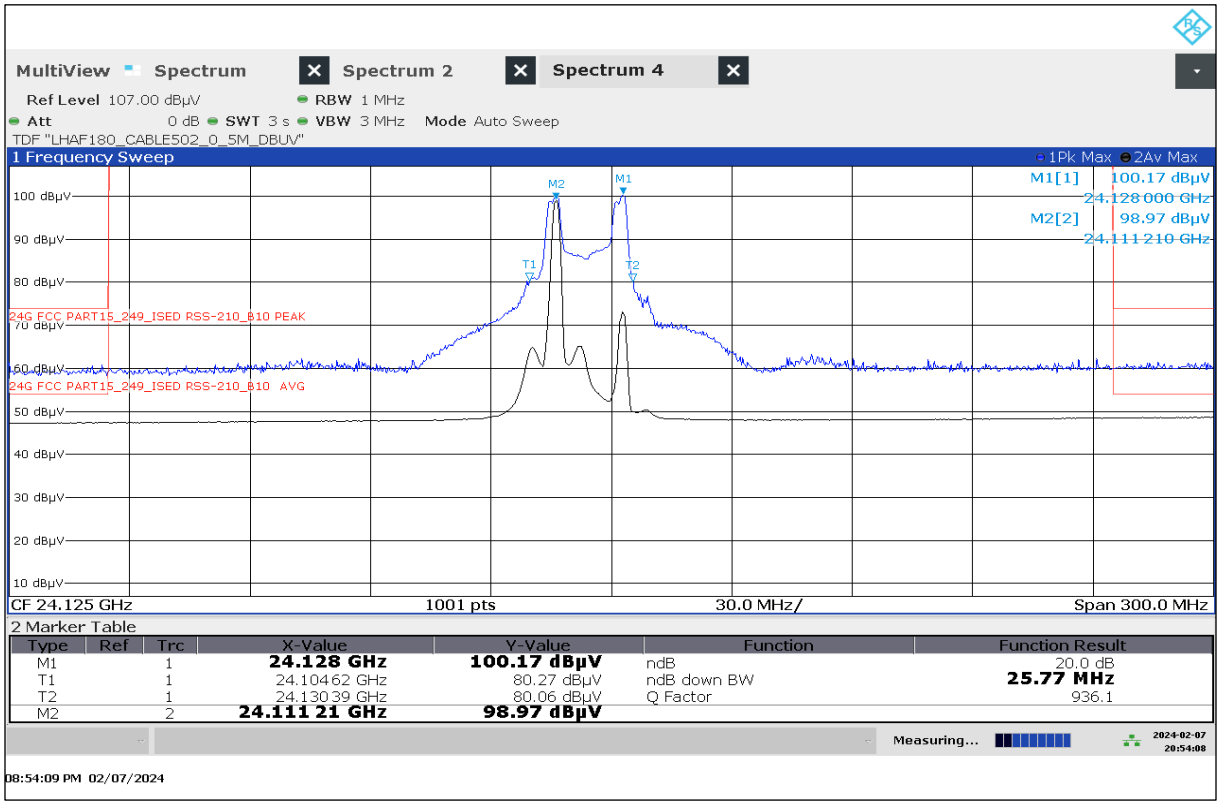
Note: *only required for fixed point-to-point systems

Verdict: Compliant

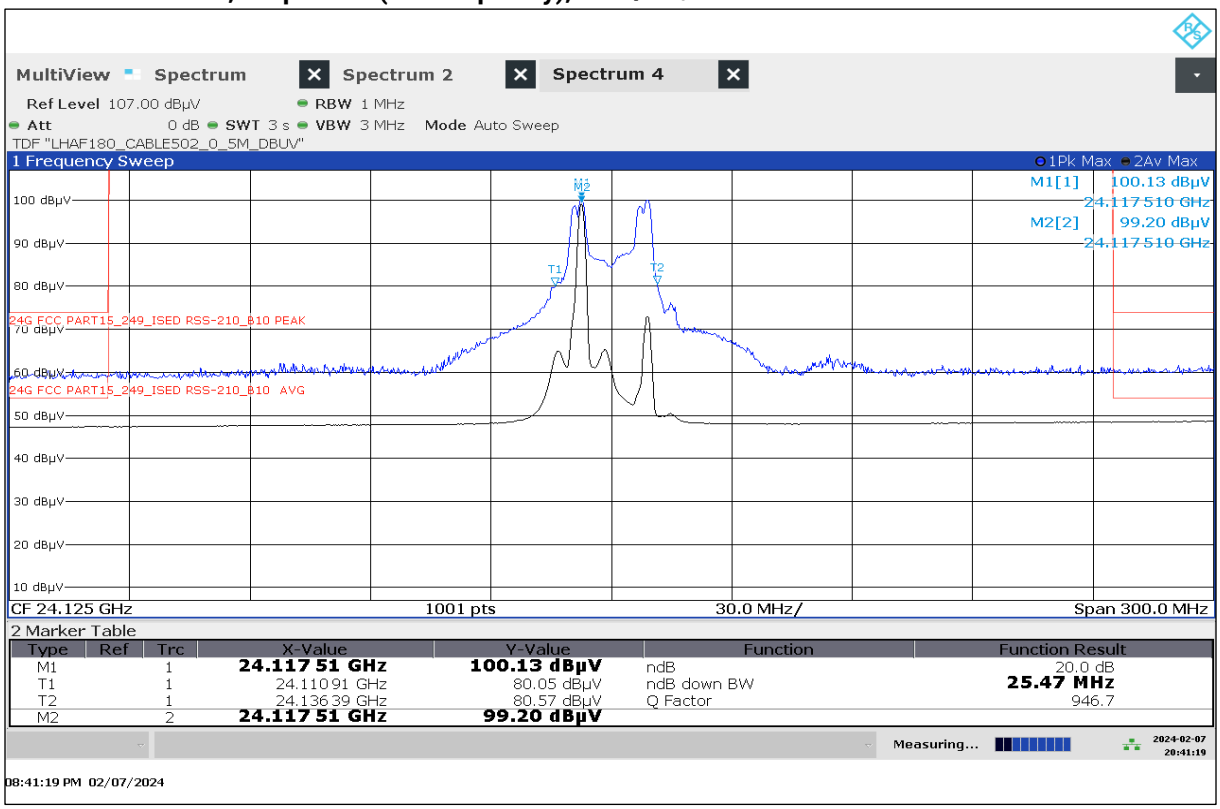
Plot 4: 20dB bandwidth, Stop Mode (low frequency), -20 °C / V_{nom}



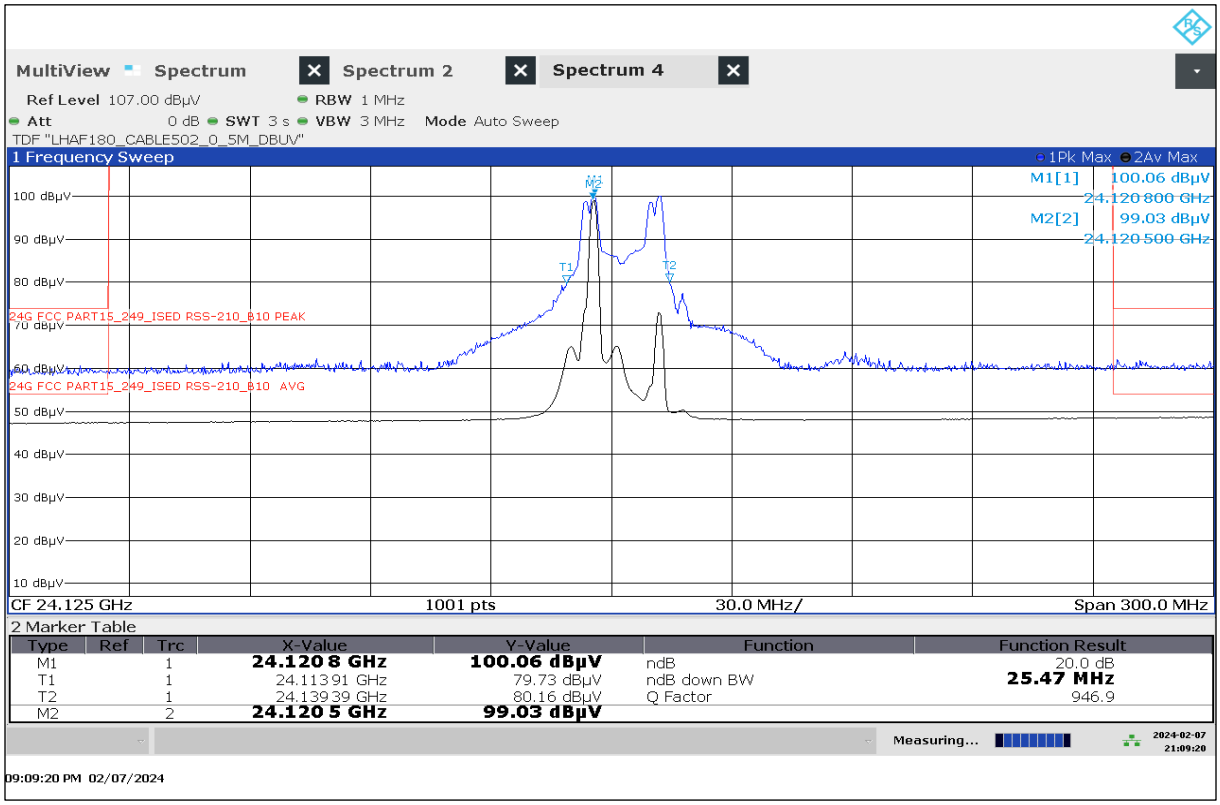
Plot 5: 20dB bandwidth, Stop Mode (low frequency), -10 °C / V_{nom}



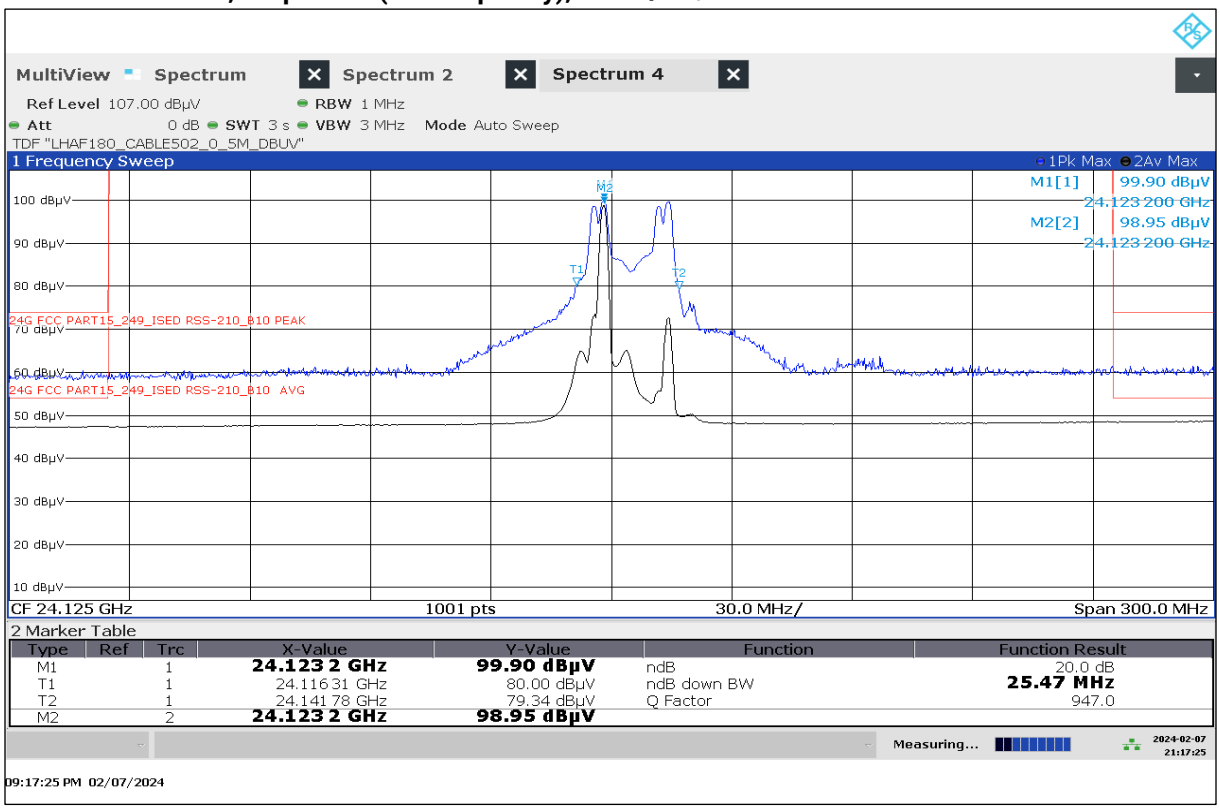
Plot 6: 20dB bandwidth, Stop Mode (low frequency), 0 °C / V_{nom}



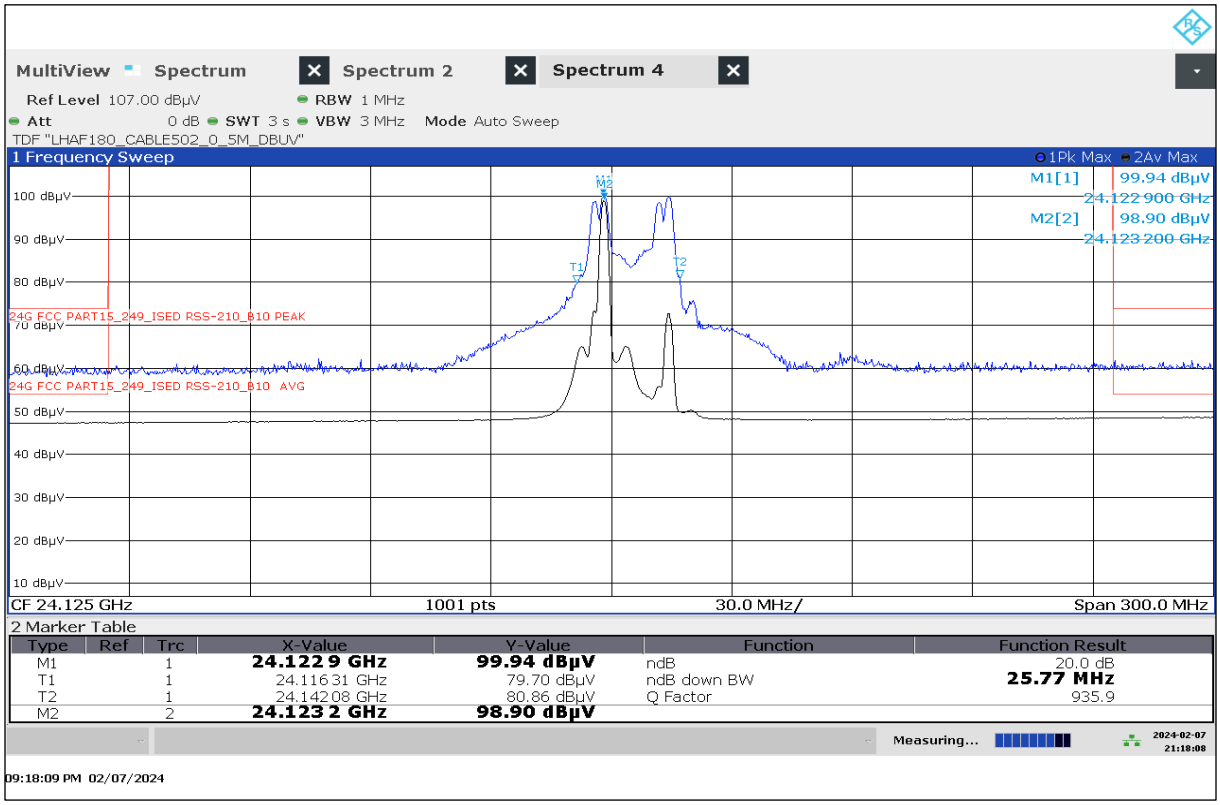
Plot 7: 20dB bandwidth, Stop Mode (low frequency), 10 °C / V_{nom}



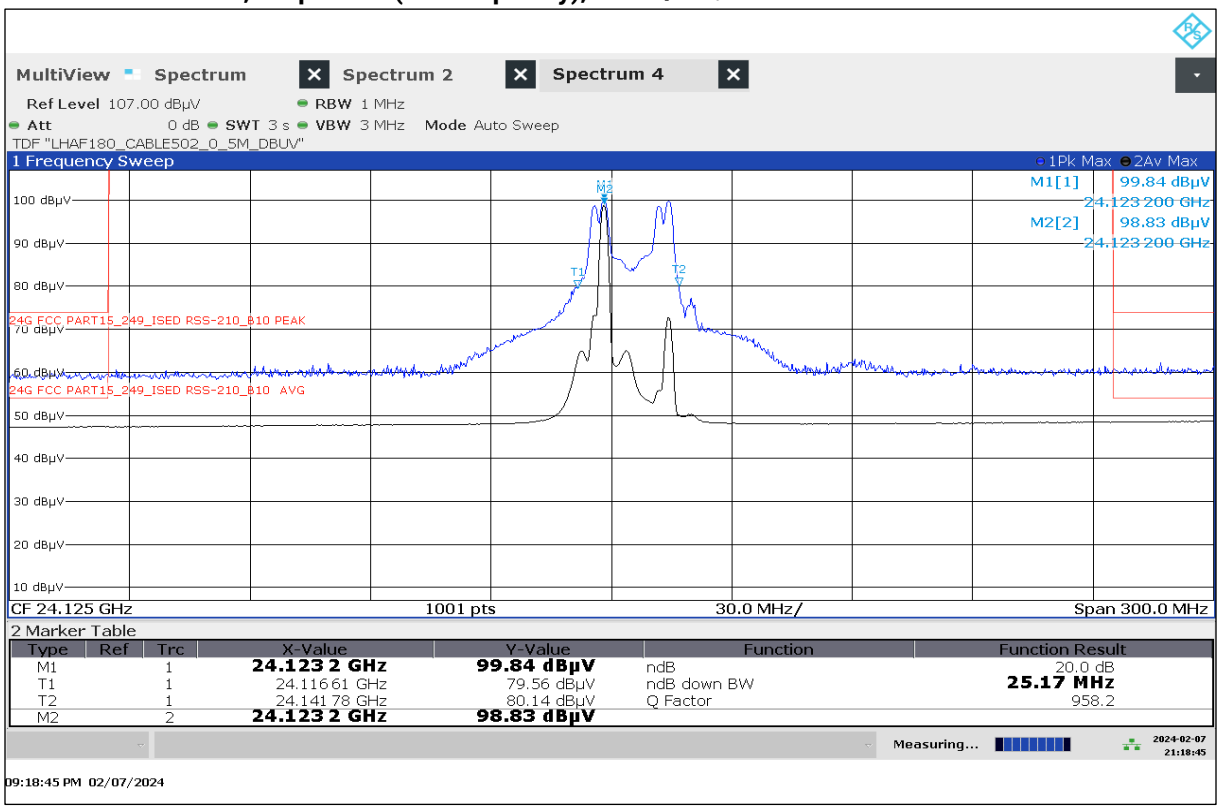
Plot 8: 20dB bandwidth, Stop Mode (low frequency), 20 °C / V_{nom}



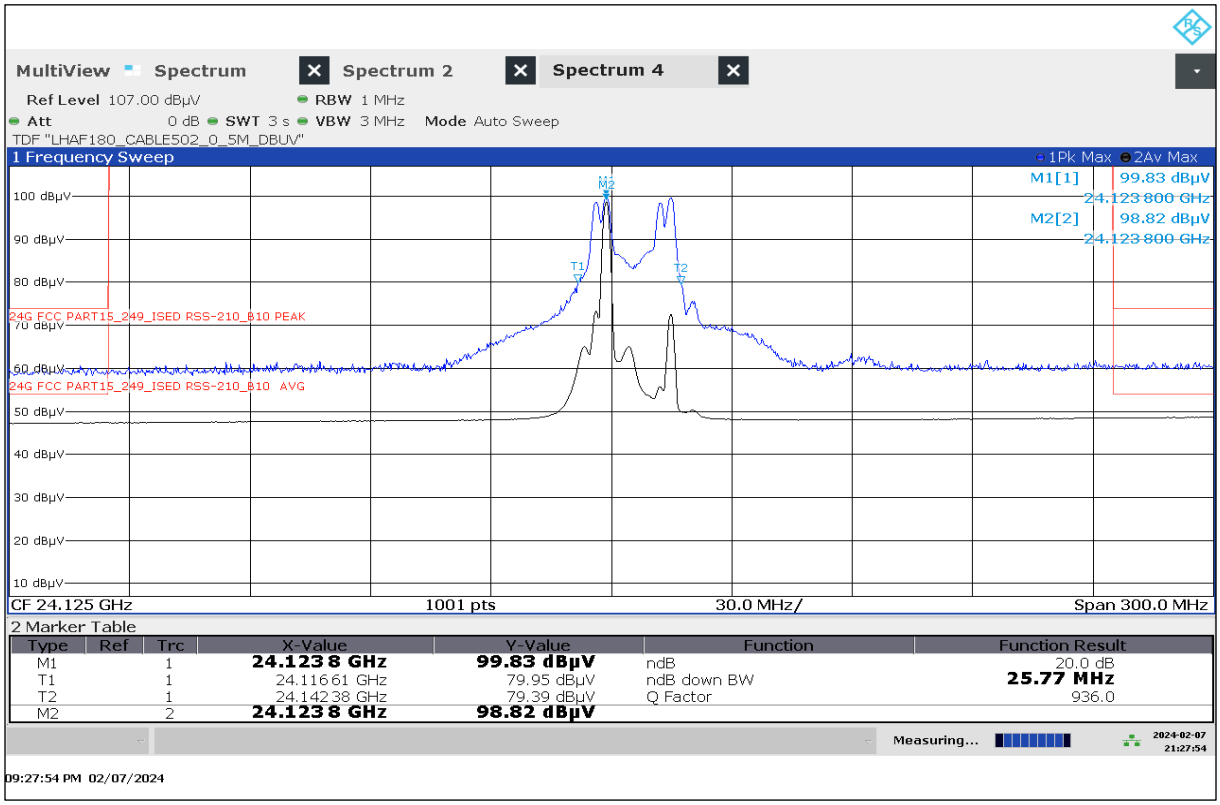
Plot 9: 20dB bandwidth, Stop Mode (low frequency), 20 °C / V_{min}



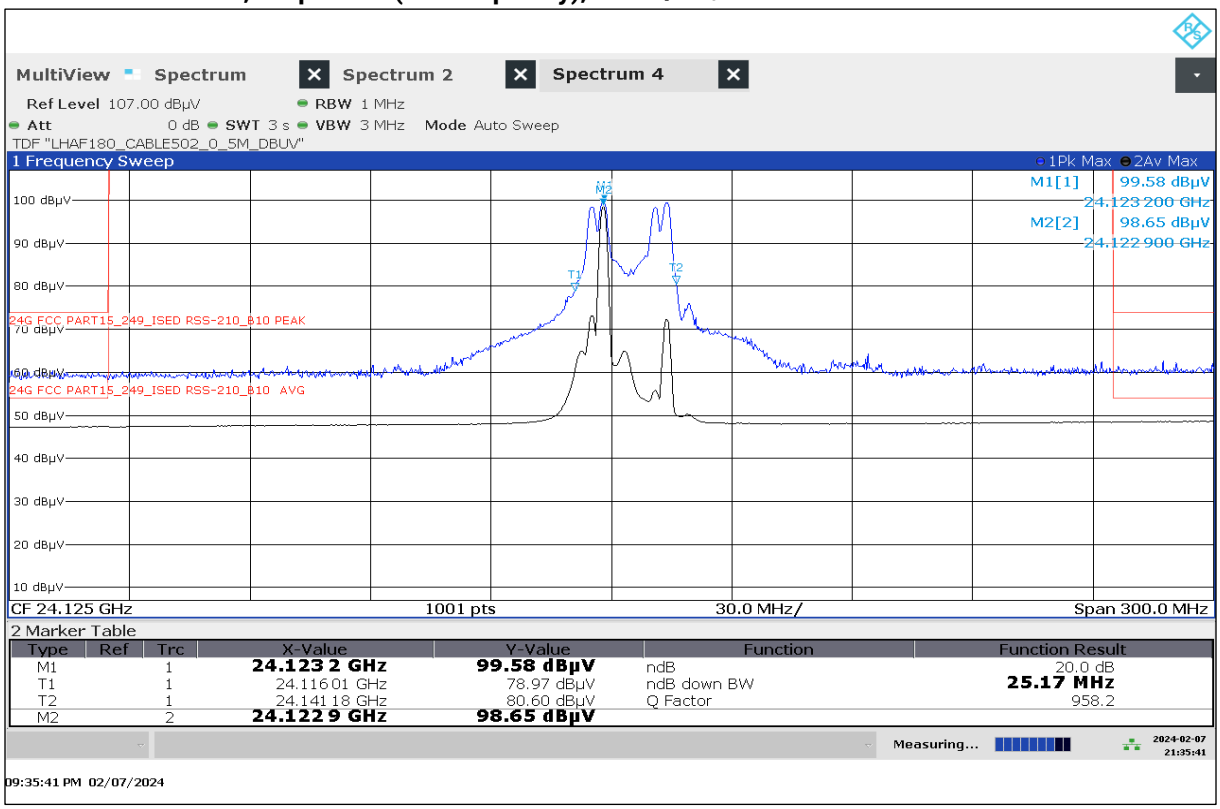
Plot 10: 20dB bandwidth, Stop Mode (low frequency), 20 °C / V_{max}



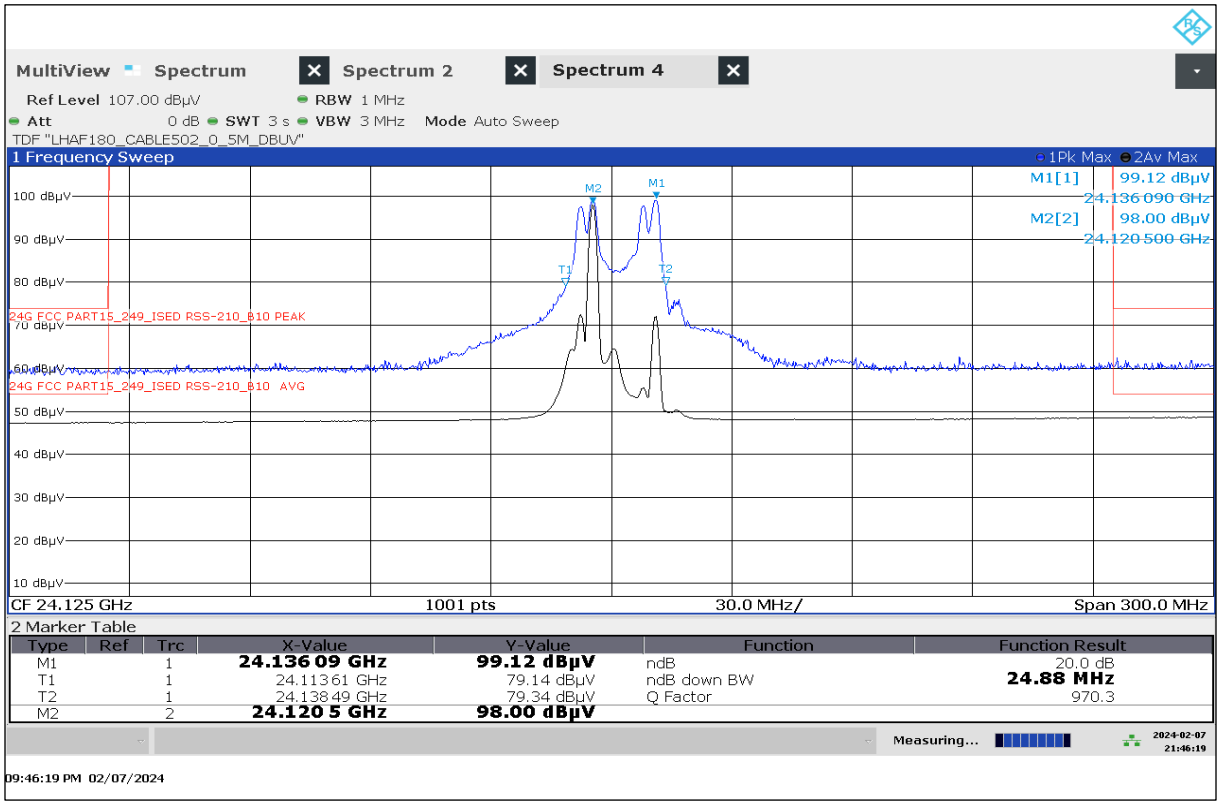
Plot 11: 20dB bandwidth, Stop Mode (low frequency), 30 °C / V_{nom}



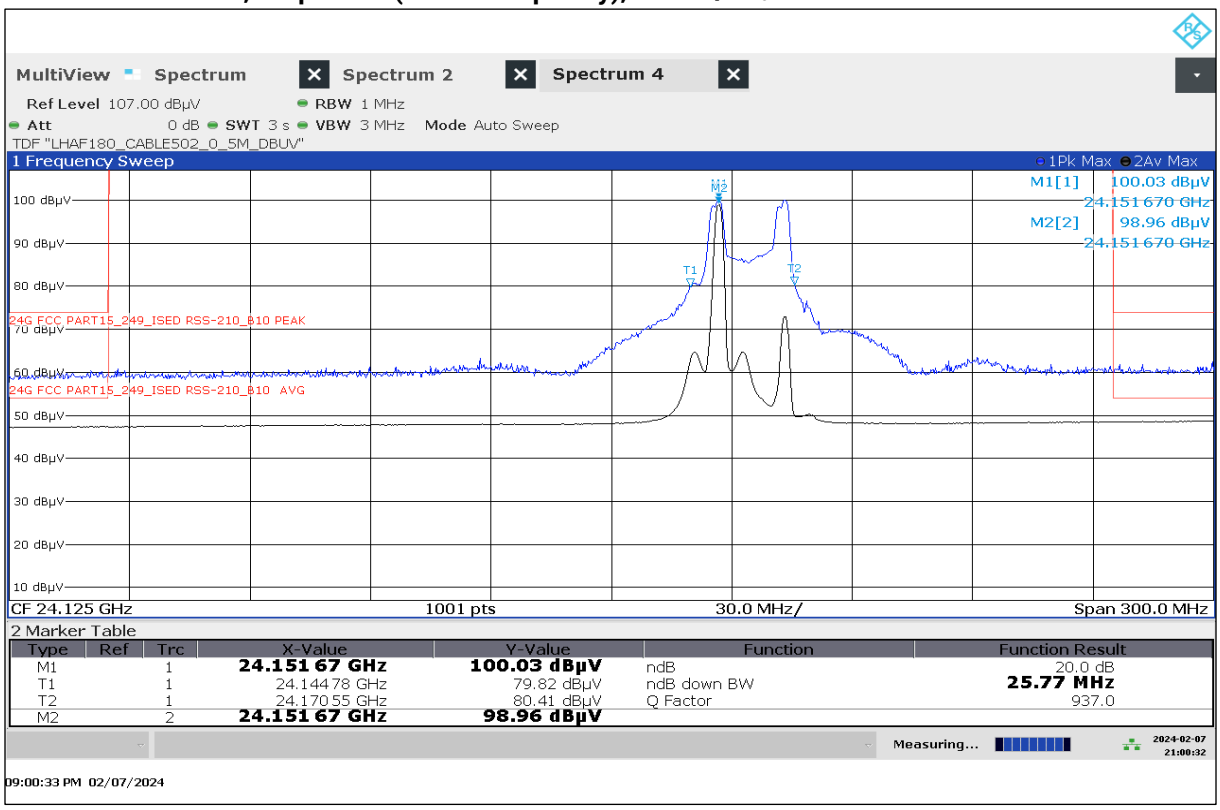
Plot 12: 20dB bandwidth, Stop Mode (low frequency), 40 °C / V_{nom}



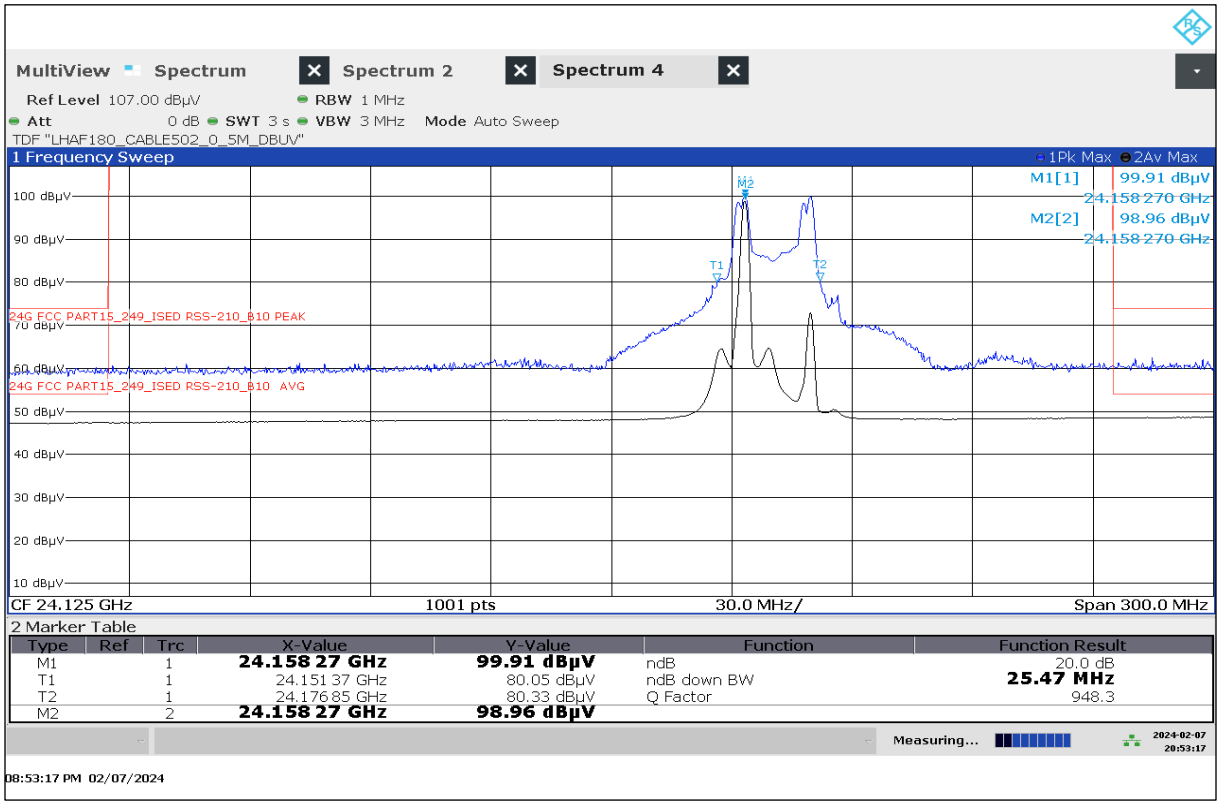
Plot 13: 20dB bandwidth, Stop Mode (low frequency), 50 °C / V_{nom}



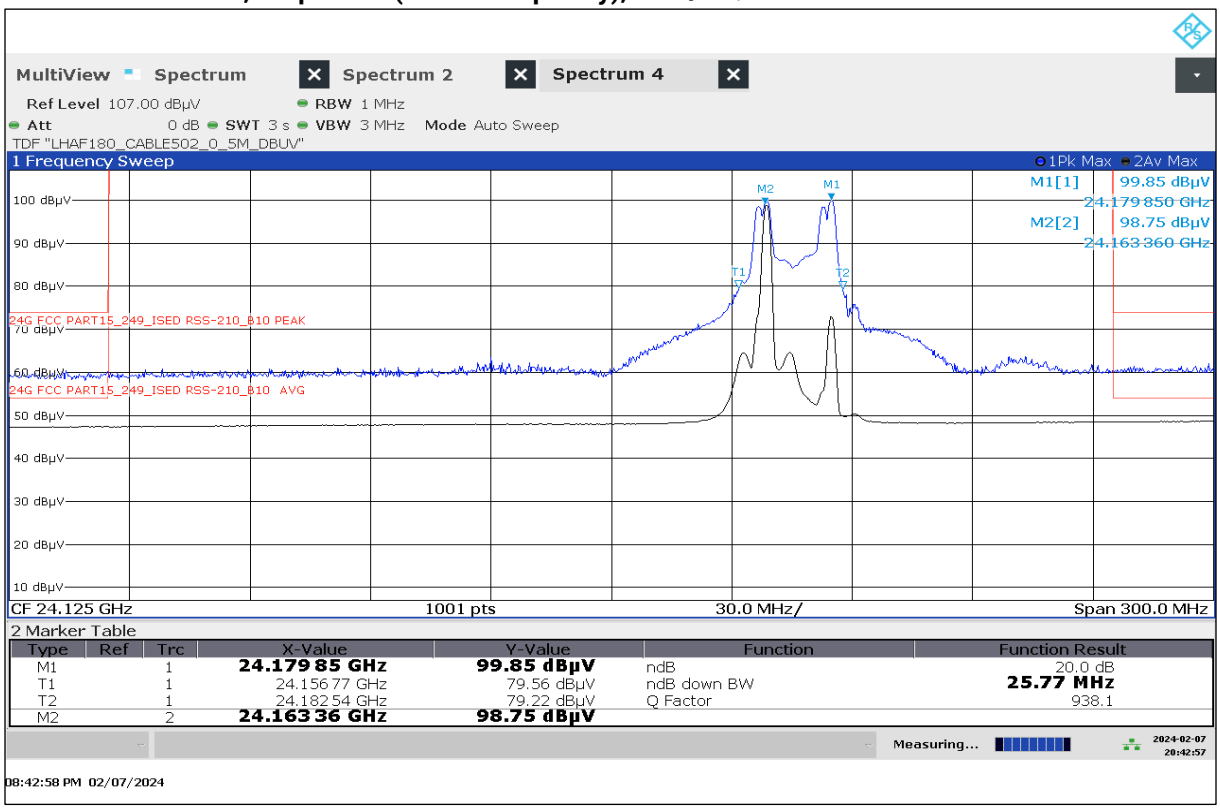
Plot 14: 20dB bandwidth, Stop Mode (middle frequency), -20 °C / V_{nom}



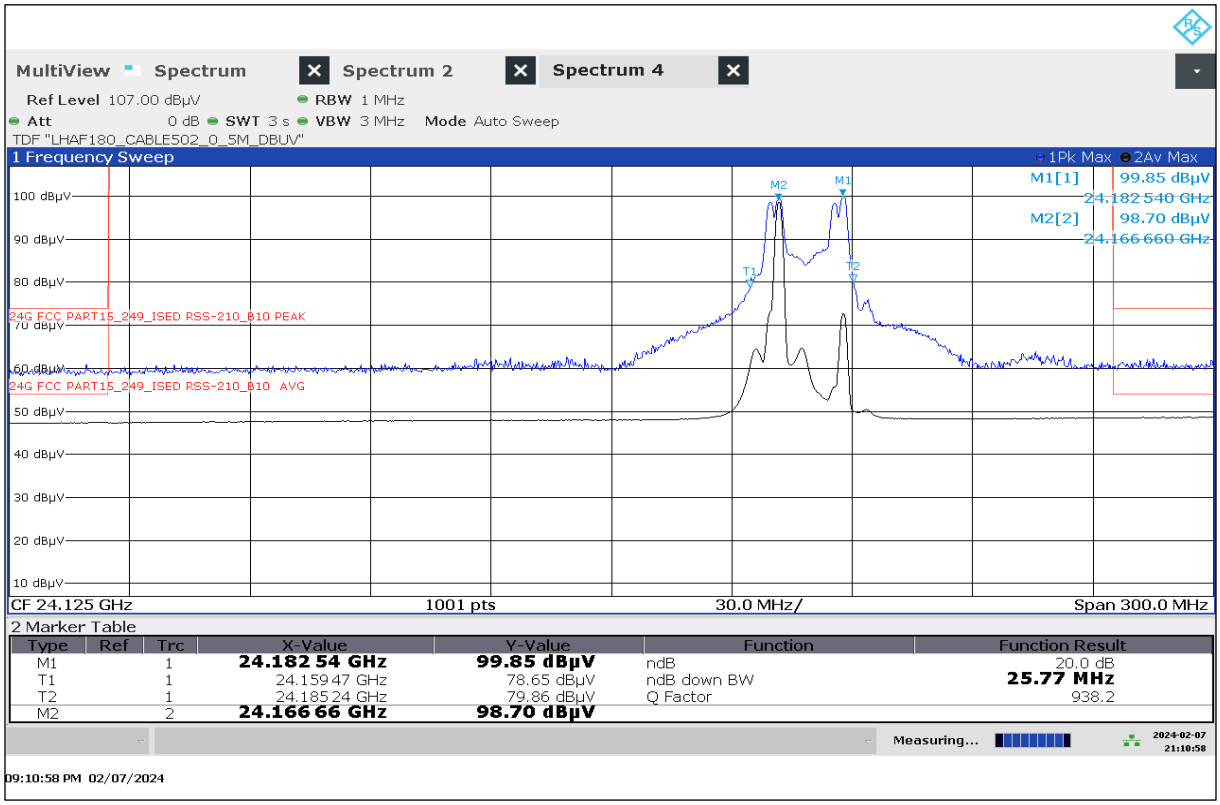
Plot 15: 20dB bandwidth, Stop Mode (middle frequency), -10 °C / V_{nom}



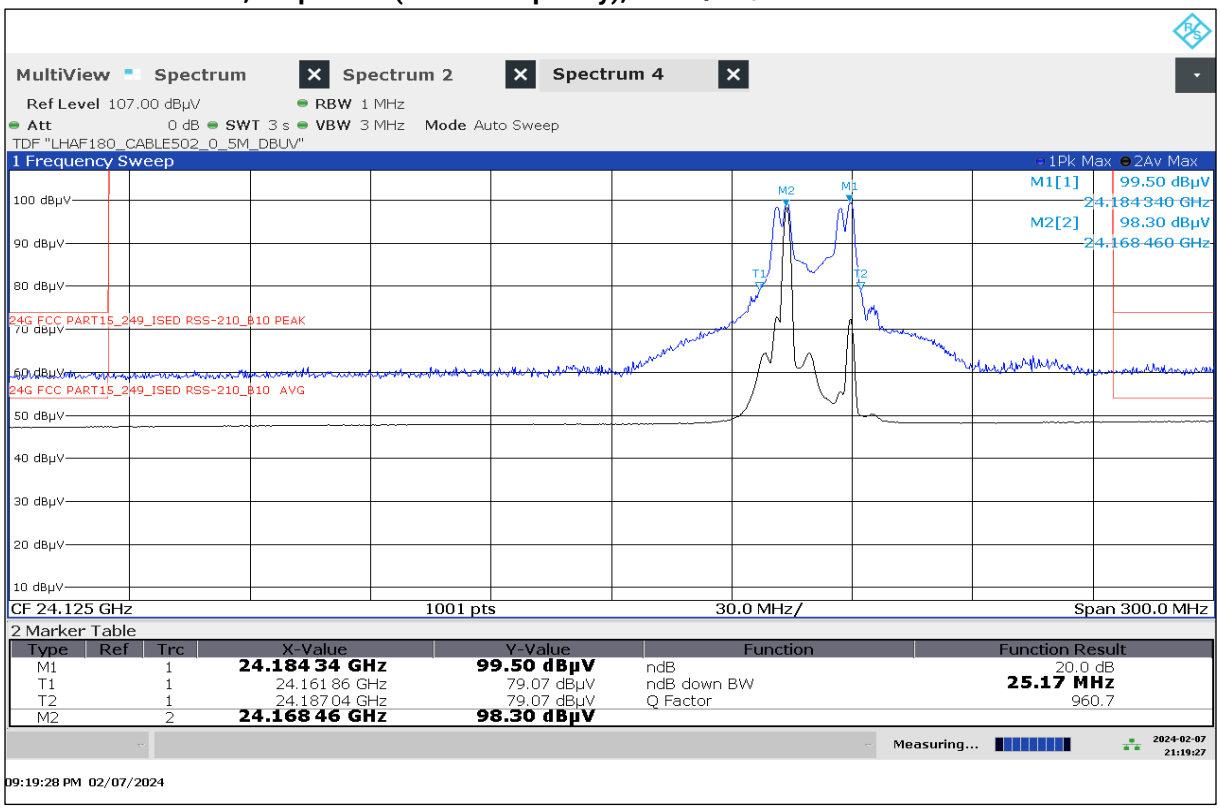
Plot 16: 20dB bandwidth, Stop Mode (middle frequency), 0 °C / V_{nom}



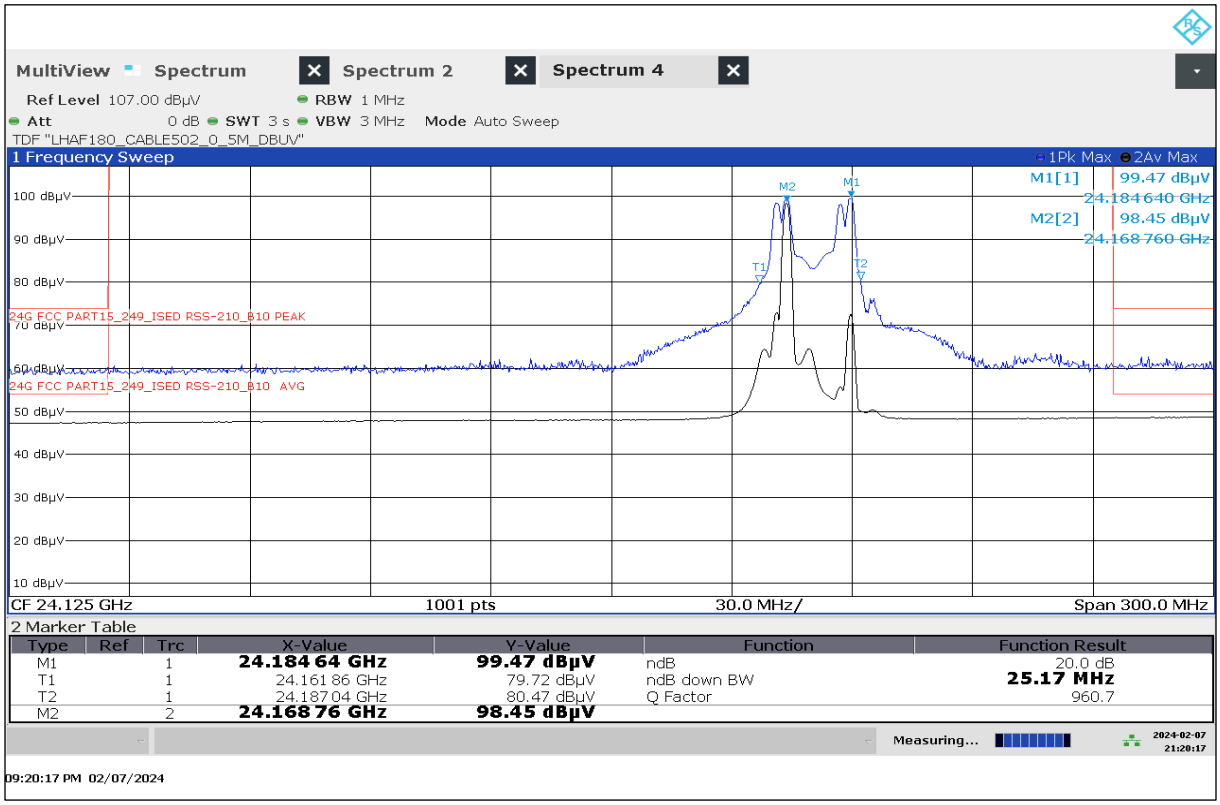
Plot 17: 20dB bandwidth, Stop Mode (middle frequency), 10 °C / V_{nom}



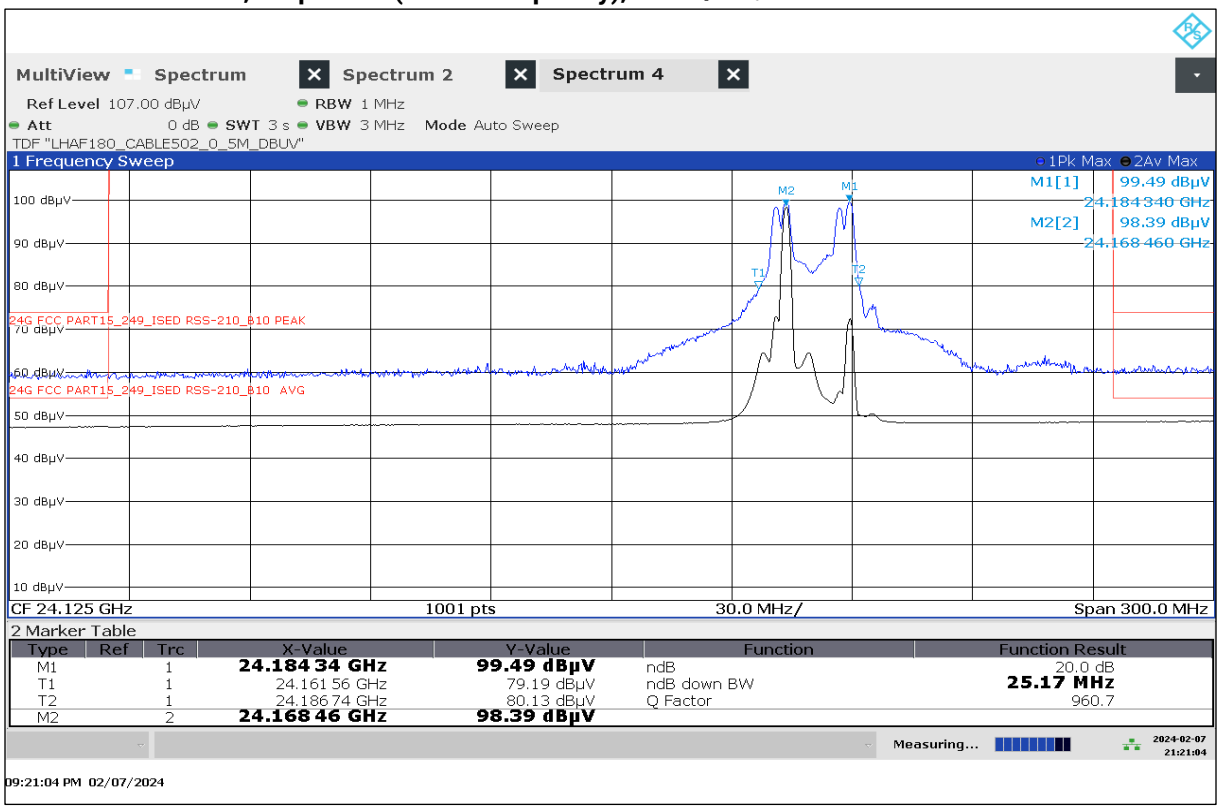
Plot 18: 20dB bandwidth, Stop Mode (middle frequency), 20 °C / V_{nom}



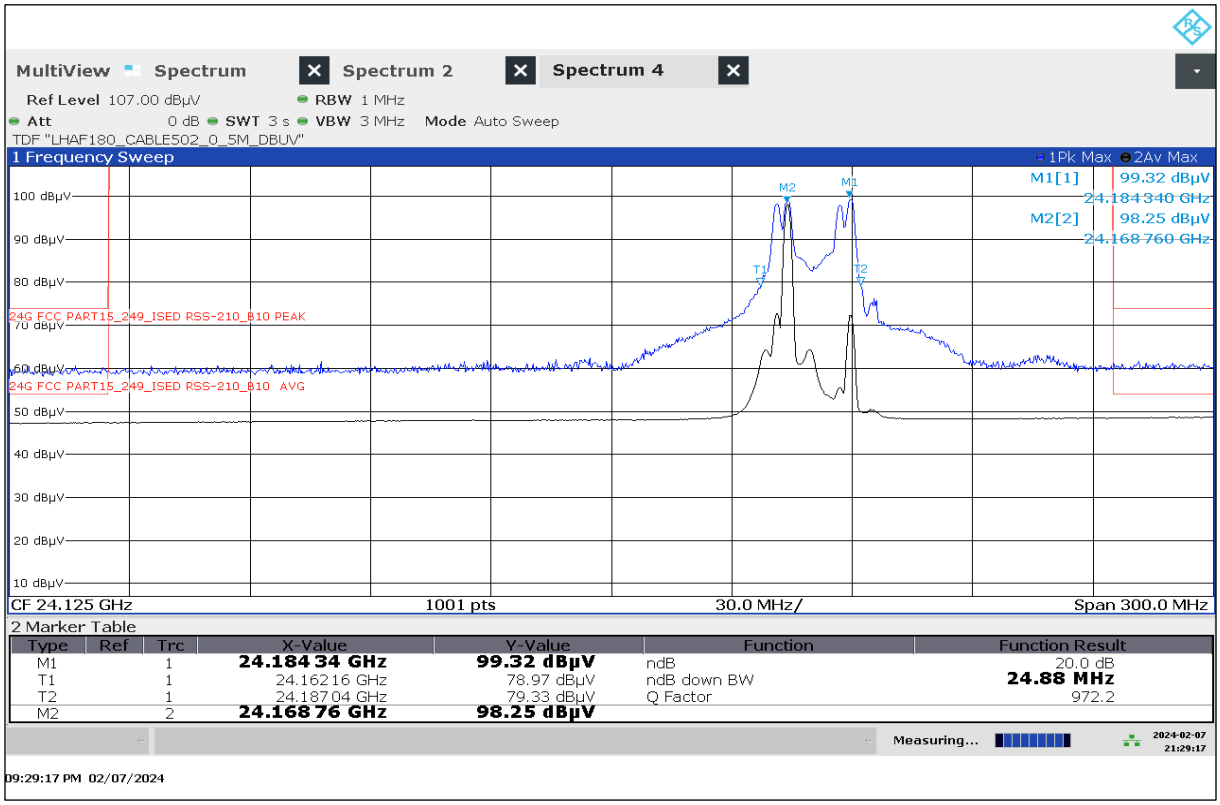
Plot 19: 20dB bandwidth, Stop Mode (middle frequency), 20 °C / V_{min}



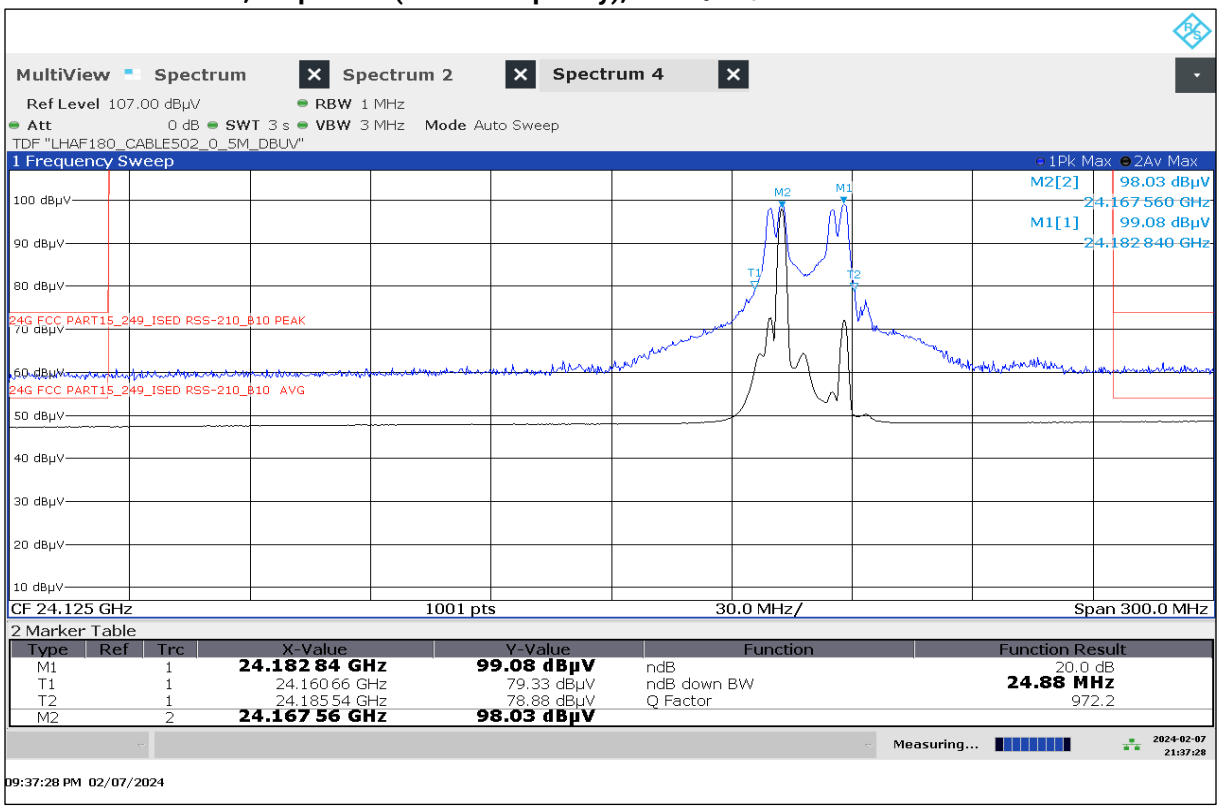
Plot 20: 20dB bandwidth, Stop Mode (middle frequency), 20 °C / V_{max}



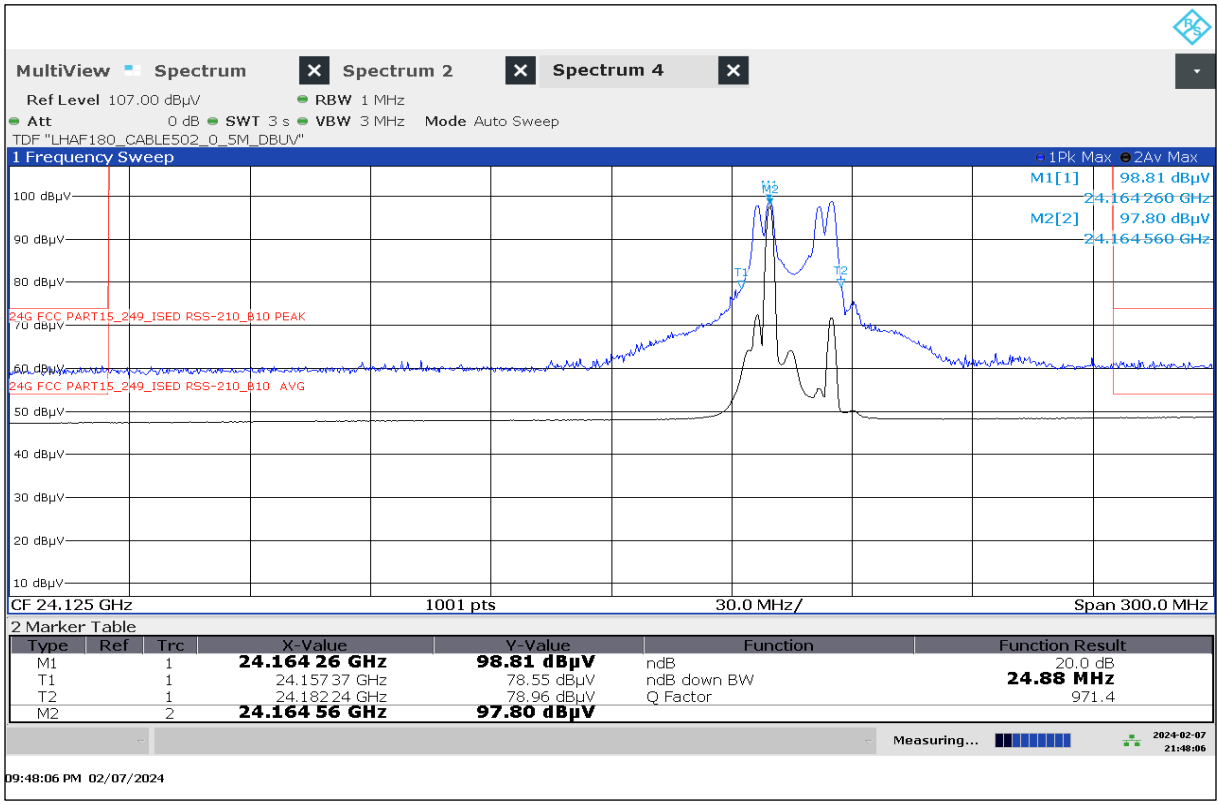
Plot 21: 20dB bandwidth, Stop Mode (middle frequency), 30 °C / V_{nom}



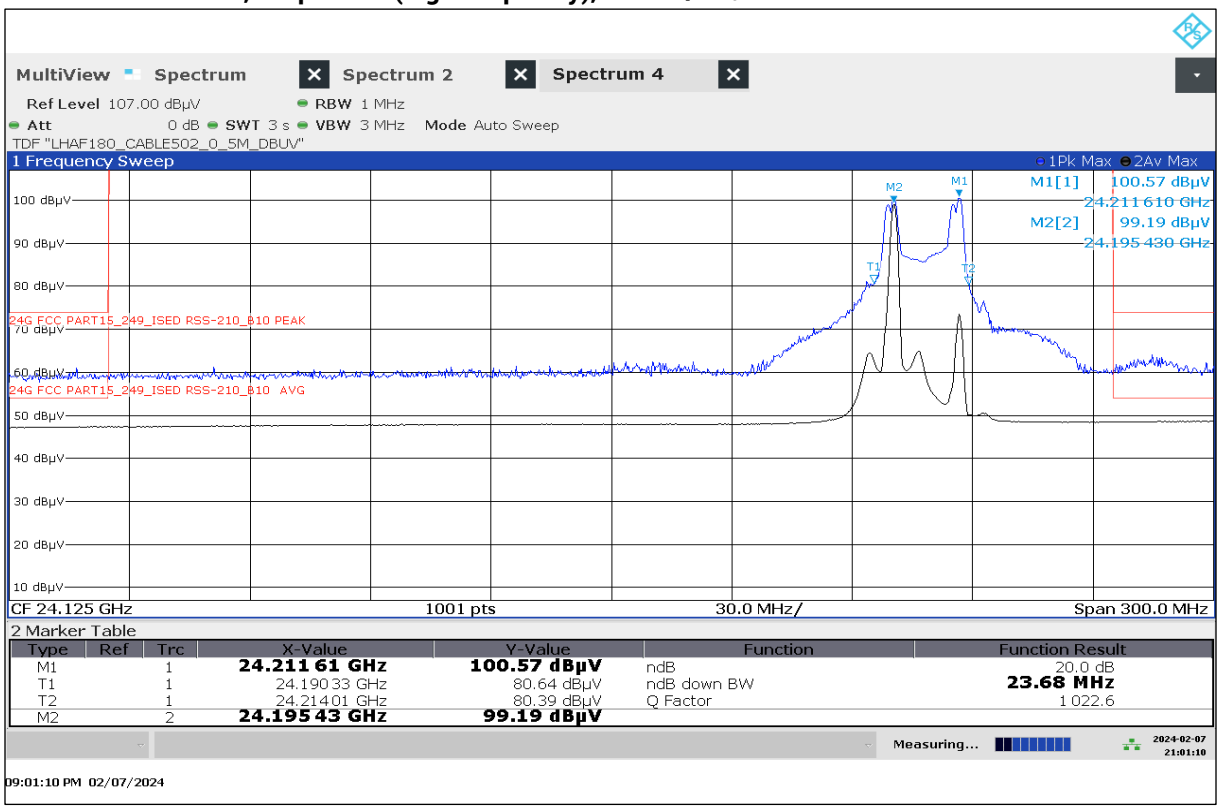
Plot 22: 20dB bandwidth, Stop Mode (middle frequency), 40 °C / V_{nom}



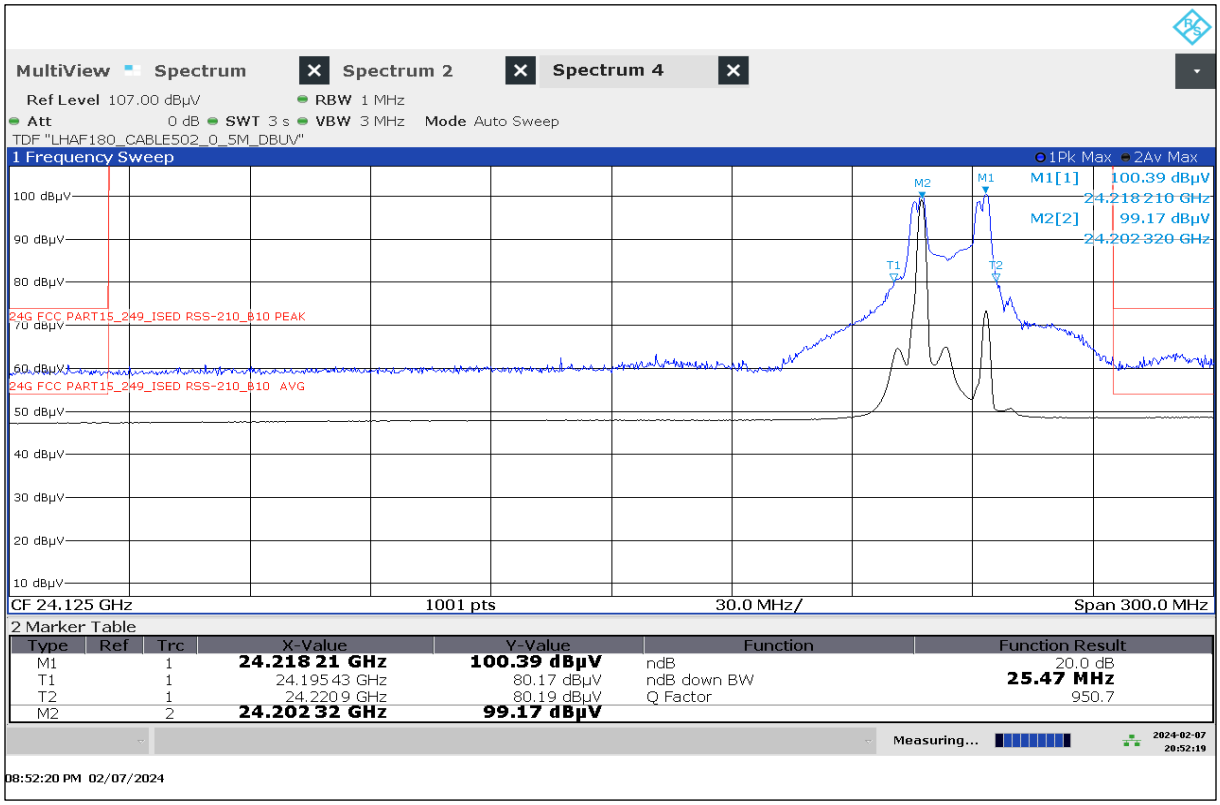
Plot 23: 20dB bandwidth, Stop Mode (middle frequency), 50 °C / V_{nom}



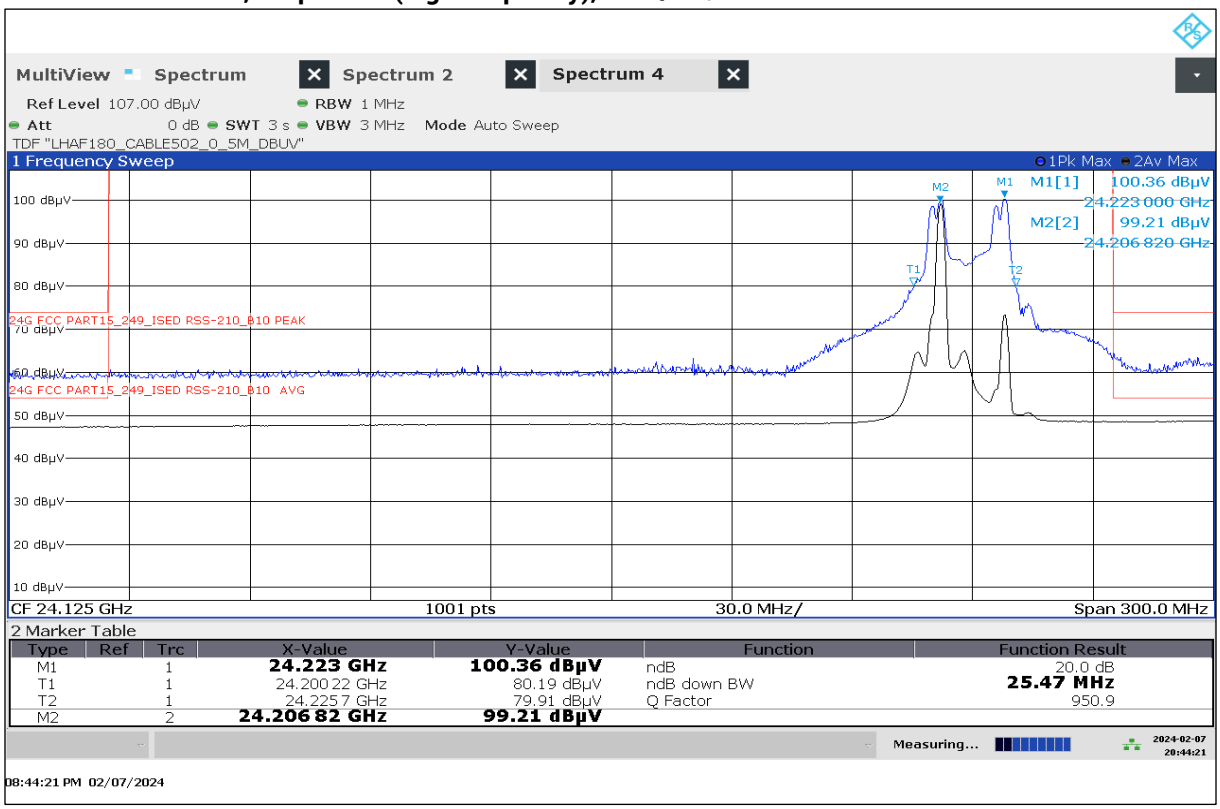
Plot 24: 20dB bandwidth, Stop Mode (high frequency), -20 °C / V_{nom}



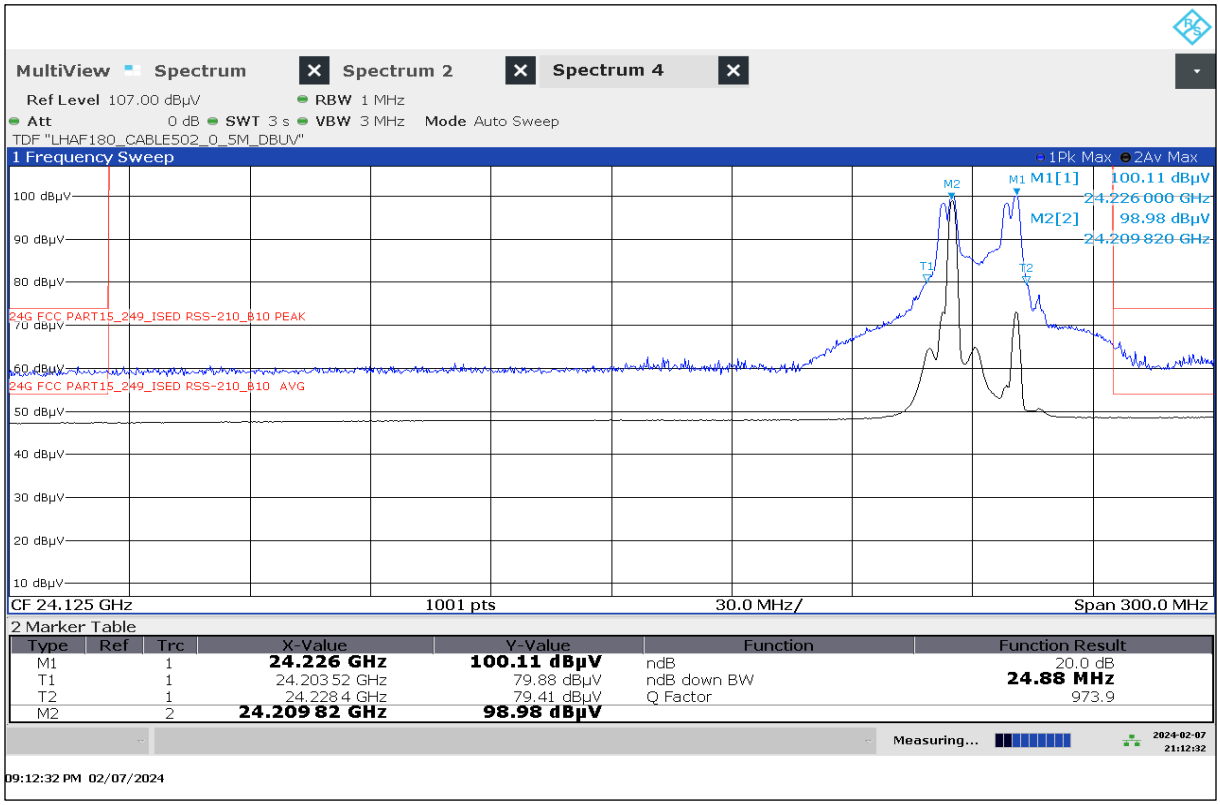
Plot 25: 20dB bandwidth, Stop Mode (high frequency), -10 °C / V_{nom}



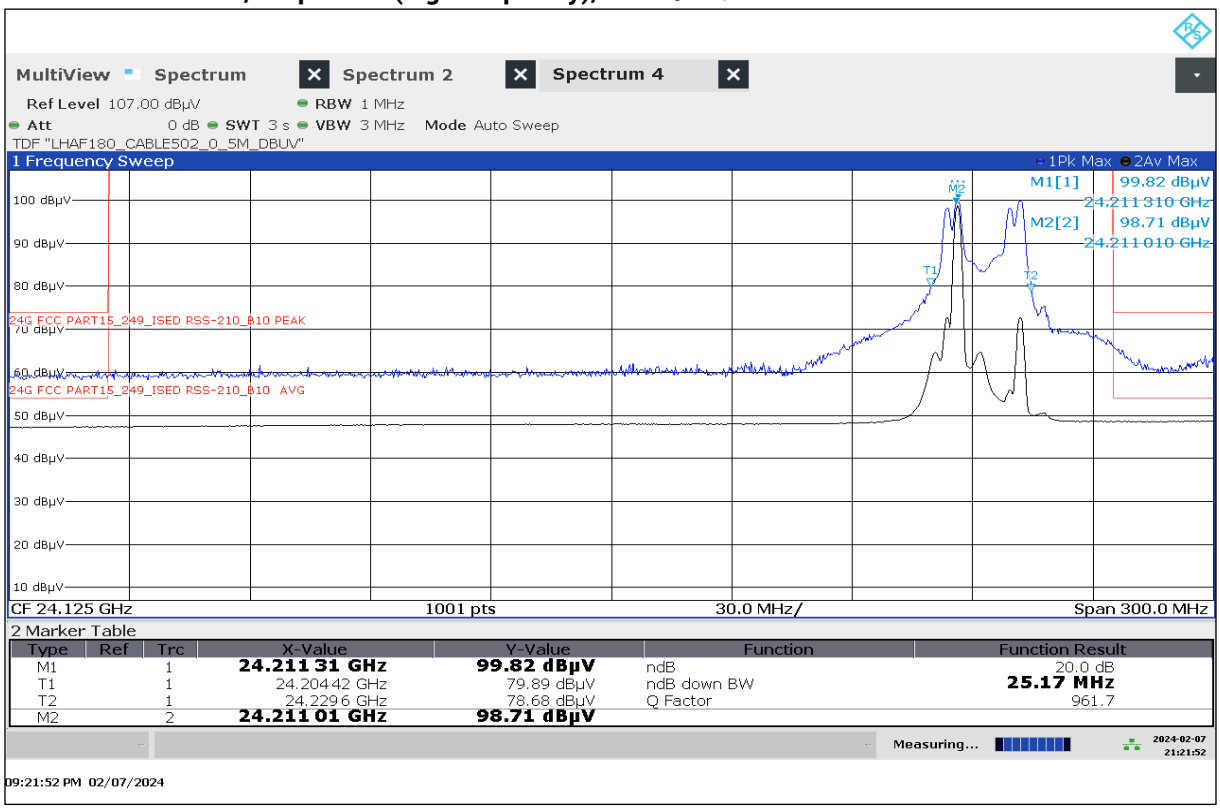
Plot 26: 20dB bandwidth, Stop Mode (high frequency), 0 °C / V_{nom}



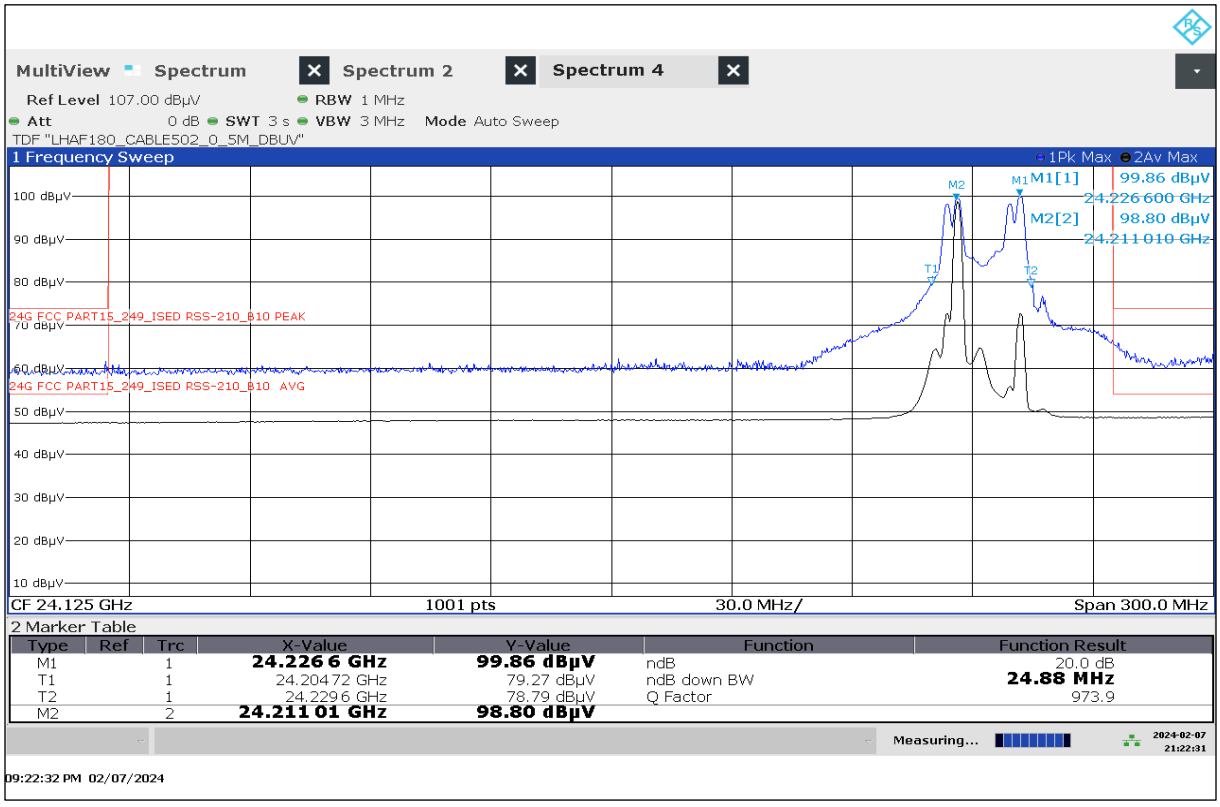
Plot 27: 20dB bandwidth, Stop Mode (high frequency), 10 °C / V_{nom}



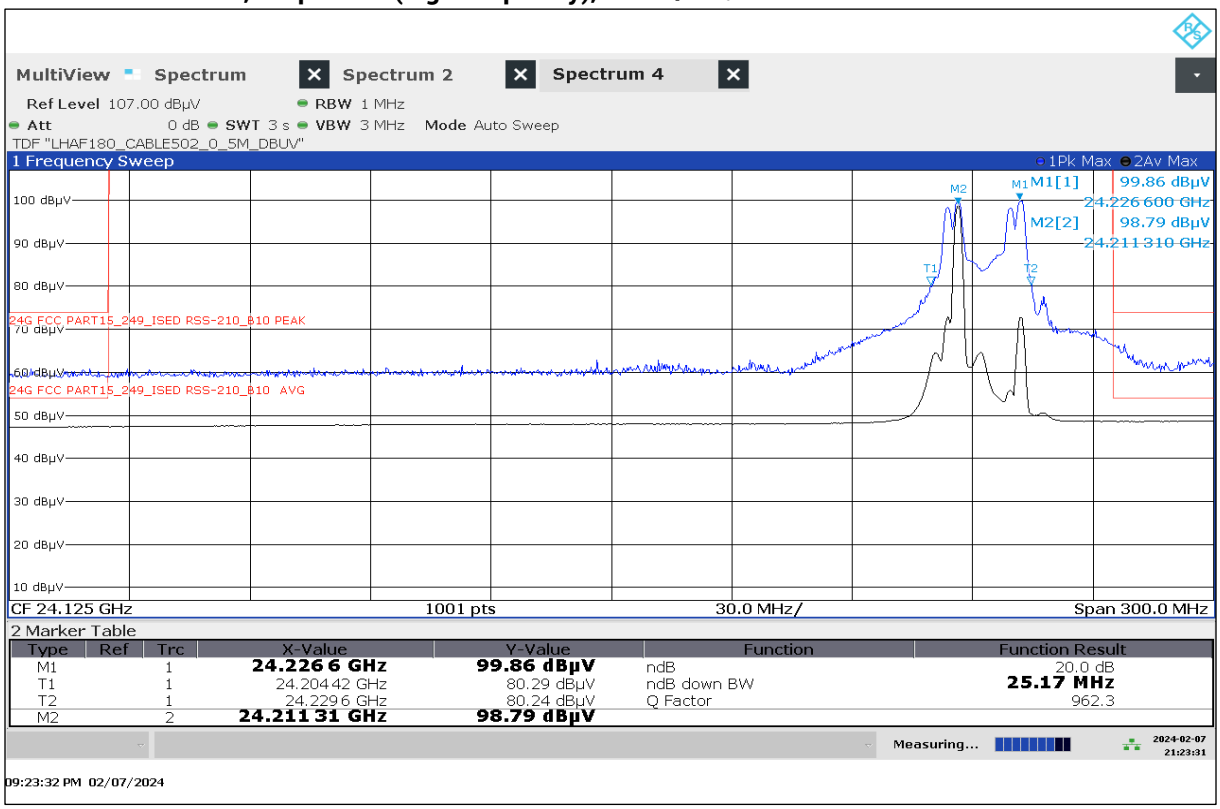
Plot 28: 20dB bandwidth, Stop Mode (high frequency), 20 °C / V_{nom}



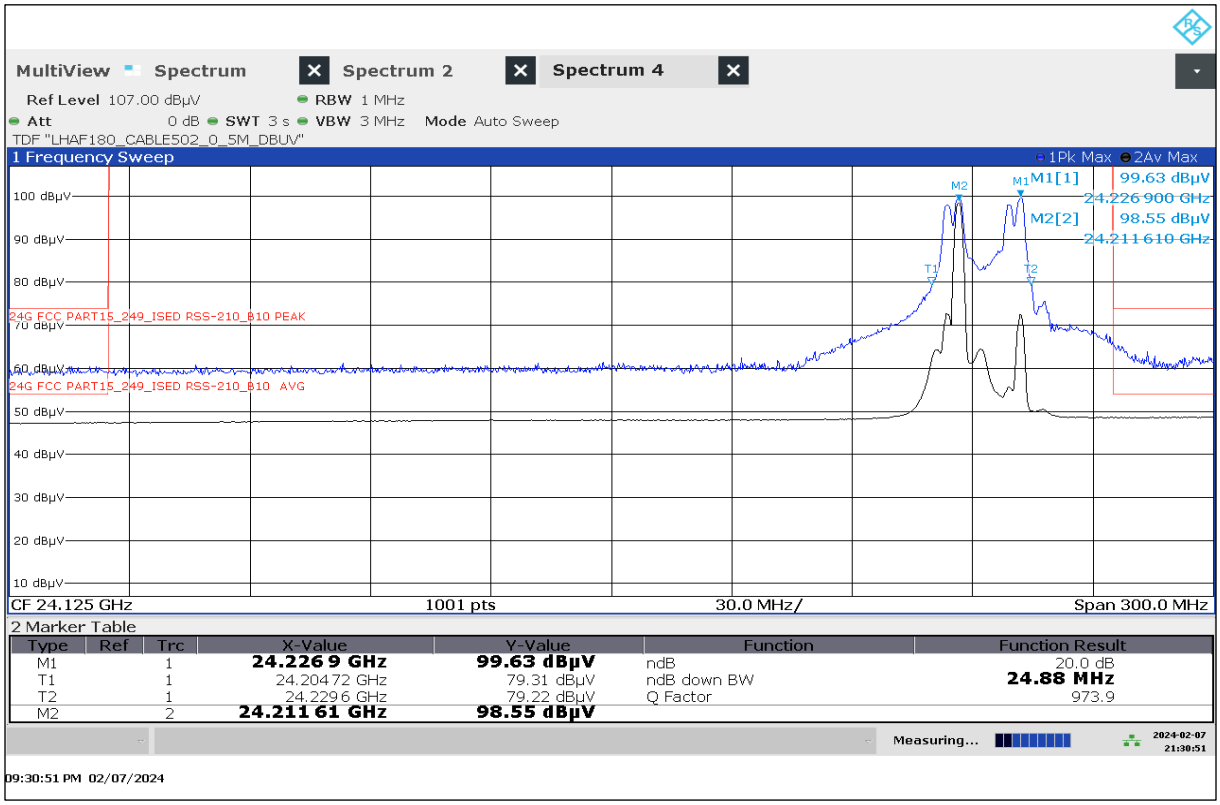
Plot 29: 20dB bandwidth, Stop Mode (high frequency), 20 °C / V_{min}



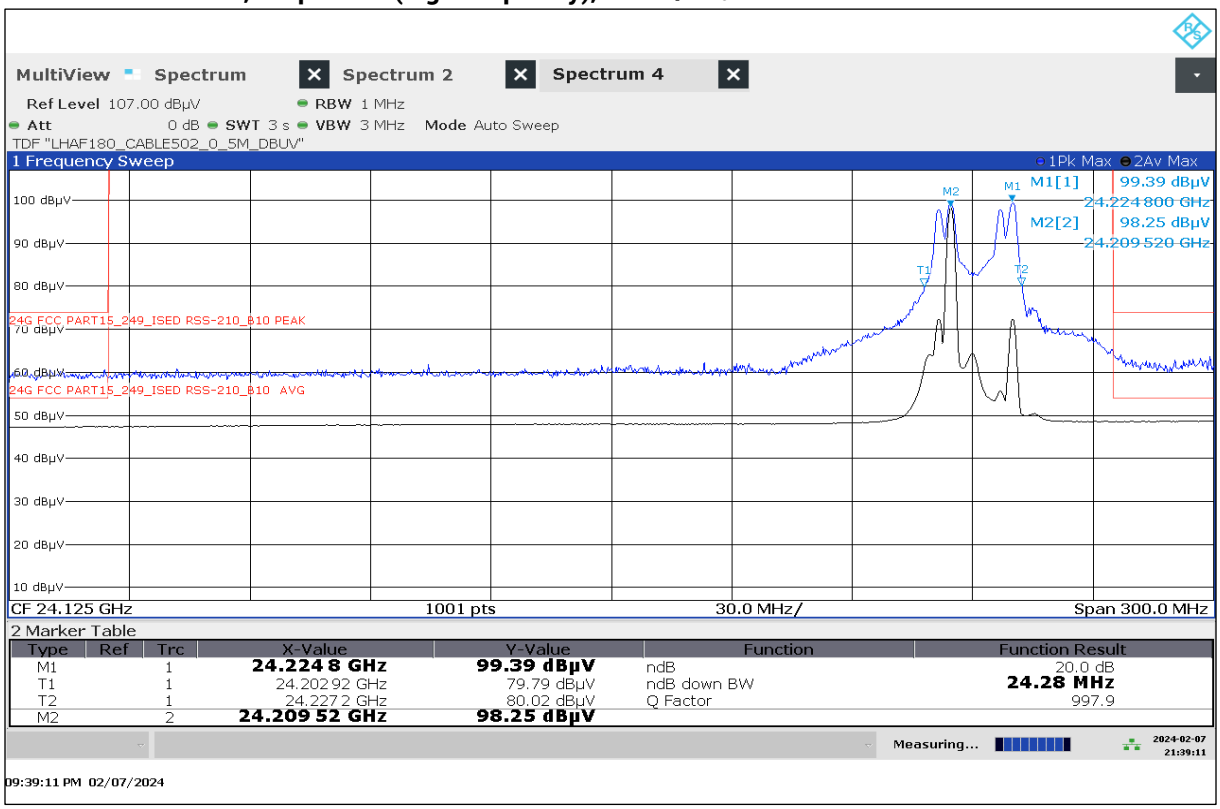
Plot 30: 20dB bandwidth, Stop Mode (high frequency), 20 °C / V_{max}



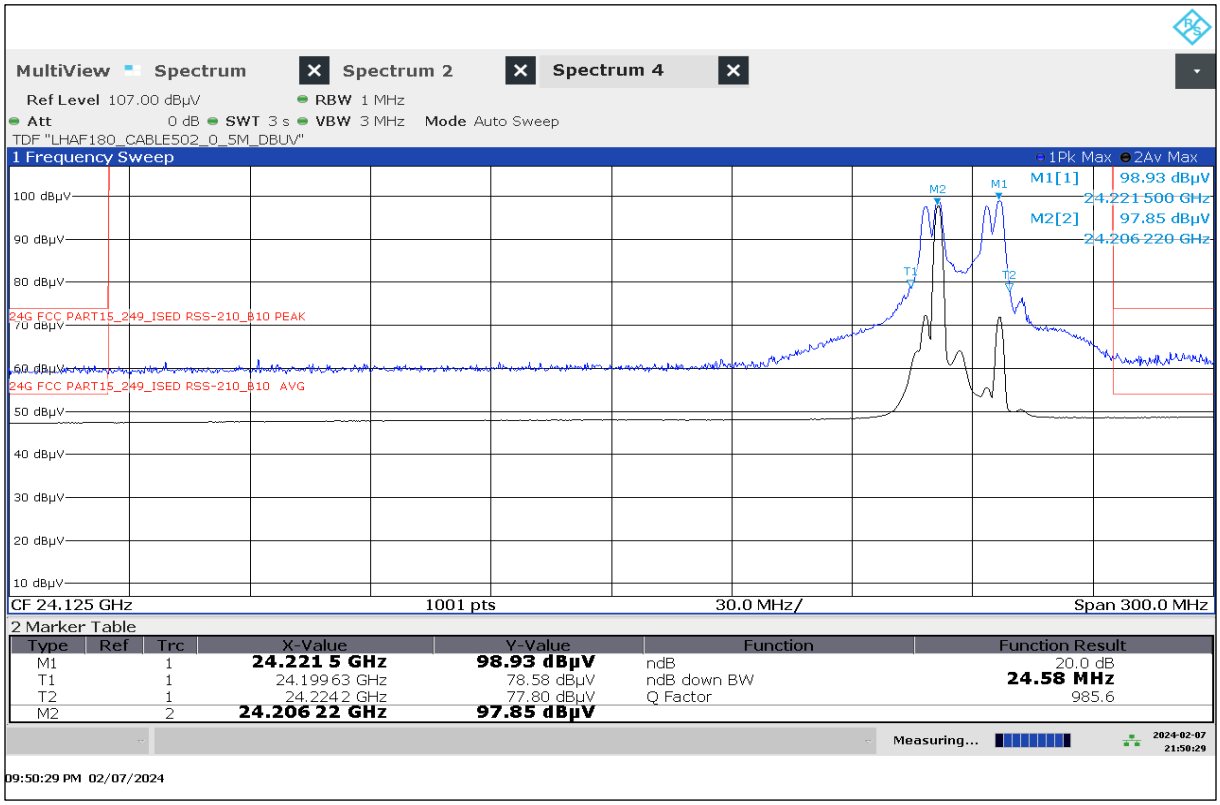
Plot 31: 20dB bandwidth, Stop Mode (high frequency), 30 °C / V_{nom}



Plot 32: 20dB bandwidth, Stop Mode (high frequency), 40 °C / V_{nom}



Plot 33: 20dB bandwidth, Stop Mode (high frequency), 50 °C / V_{nom}



12.2 Antenna gain & beam width

Description:

Information on the minimum antenna gain and maximum beam width.

Limits and provisions:

15.249(b): Fixed point-to-point systems
[…] Fixed, point-to-point operation is permitted in the 24.05–24.25 GHz band subject to the following conditions: […]

(3) Antenna gain must be at least 33 dBi. Alternatively, the main lobe beamwidth must not exceed 3.5 degrees. The beamwidth limit shall apply to both the azimuth and elevation planes. At antenna gains over 33 dBi or beamwidths narrower than 3.5 degrees, power must be reduced to ensure that the field strength does not exceed 2500 millivolts/meter.

Option 1: Antenna gain requirement			
Kind of device	Antenna gain [dBi]	Limit on minimum antenna gain [dBi]	Margin [dB]
Other	**Not required**	**No limit**	-/-

Option 2: Beam width requirement		
Kind of device	Beam width of the main lobe [°]	Limit on maximum beam width [°]
Other	Not required	No limit

Verdict: Not required

12.3 Field strength of fundamental emission

Description:

Measurement of the maximum radiated field strength of the wanted signal (fundamental emission).

Limits and provisions:

15.249(b): Fixed point-to-point systems
[…] Fixed, point-to-point operation is permitted in the 24.05–24.25 GHz band subject to the following conditions: […]

(1) The field strength of emissions in this band shall not exceed 2500 millivolts/meter.

Kind of device	Fundamental frequency (GHz)	Field strength of fundamental (mV/m)
Fixed point-to-point system	24.05-24.25	2500

§15.249 (a):
Except as provided in paragraph (b) of this section, the field strength of emissions from intentional radiators operated within these frequency bands shall comply with the following:

Kind of device	Fundamental frequency (GHz)	Field strength of fundamental (mV/m)
Other	0.902-0.928	50
Other	2.400-2.4835	50
Other	5.725-5.875	50
Other	**24.0-24.25**	**250**

§15.249 (c):
Field strength limits are specified at a distance of 3 meters.

§15.249 (e):
As shown in § 15.35(b), for frequencies above 1000 MHz, the field strength limits in paragraphs (a) and (b) of this section are based on average limits. However, the peak field strength of any emission shall not exceed the maximum permitted average limits specified above by more than 20 dB under any condition of modulation.

For point-to-point operation under paragraph (b) of this section, the peak field strength shall not exceed 2500 millivolts/meter at 3 meters along the antenna azimuth.

§15.35(b):
Unless otherwise specified, on any frequency or frequencies above 1000 MHz, the radiated emission limits are based on the use of measurement instrumentation employing an average detector function. Unless otherwise specified, measurements above 1000 MHz shall be performed using a minimum resolution bandwidth of 1 MHz. When average radiated emission measurements are specified in this part, including average emission measurements below 1000 MHz, there also is a limit on the peak level of the radio frequency emissions. Unless otherwise specified, e.g., see §§ 15.250, 15.252, 15.253(d), 15.255, 15.256, and 15.509 through 15.519, the limit on peak radio frequency emissions is 20 dB above the maximum permitted average emission limit applicable to the equipment under test. This peak limit applies to the total peak emission level radiated by the device, e.g., the total peak power level. Note that the use of a pulse desensitization correction factor may be needed to determine the total peak emission level. The instruction manual or application note for the measurement instrument should be consulted for determining pulse desensitization factors, as necessary.

§15.31 (c):
Except as otherwise indicated in §15.256, for swept frequency equipment, measurements shall be made with the frequency sweep stopped at those frequencies chosen for the measurements to be reported.

Applicable limits according to §15.249 (b):

Kind of device	Fundamental frequency (GHz)	Field strength of fundamental		Measurement distance	Power delivered to the antenna
		average value	peak value		
Other	24.0-24.25	108 dBµV/m	128 dBµV/m	3 m	-/-

Measurement:

Measurement parameter	
Detector:	Peak / Linear average
Resolution bandwidth:	1 MHz
Video bandwidth:	3 MHz
Trace-Mode:	Max Hold

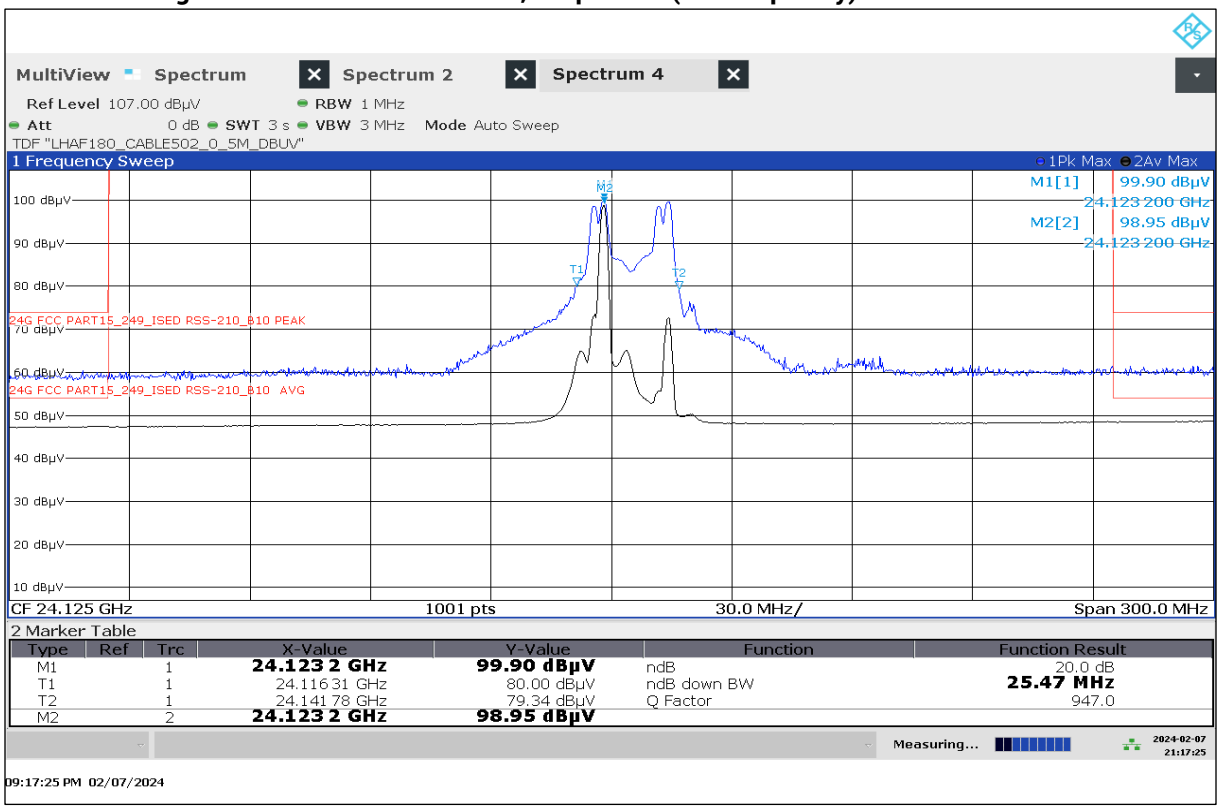
Measurement results:

Mode	Frequency [GHz]	Field strength of fundamental @ 3m [dBµV/m]	Applicable limit	Margin [dB]	Plot
		Average value			
FA	24.135	98.95	108 dBµV/m	9.05	14
FC	24.175	98.30		9.70	15
FE	24.215	98.71		9.29	16

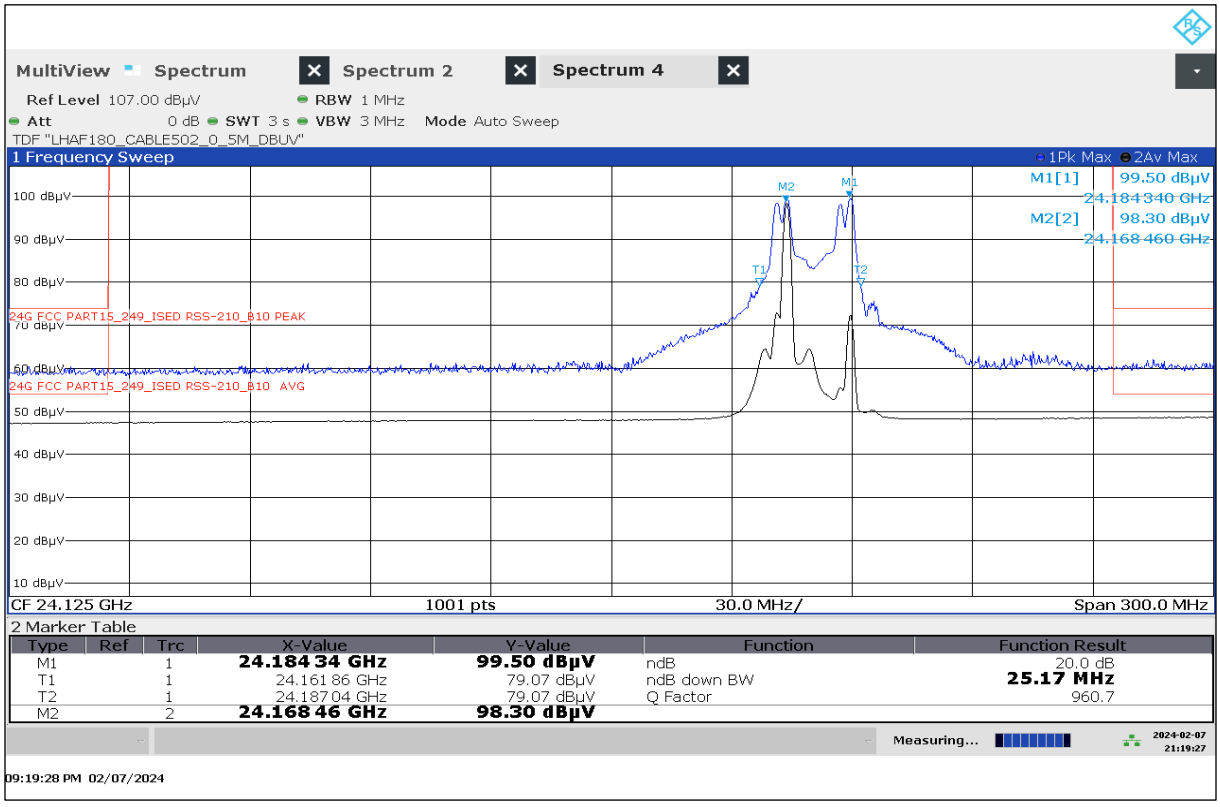
EUT	Frequency [GHz]	Field strength of fundamental @ 3m [dBµV/m]	Applicable limit	Margin [dB]	Plot
		Peak value			
FA	24.135	99.90	128 dBµV/m	28.1	14
FC	24.175	99.50		28.5	15
FE	24.215	99.82		28.2	16

Verdict: Compliant

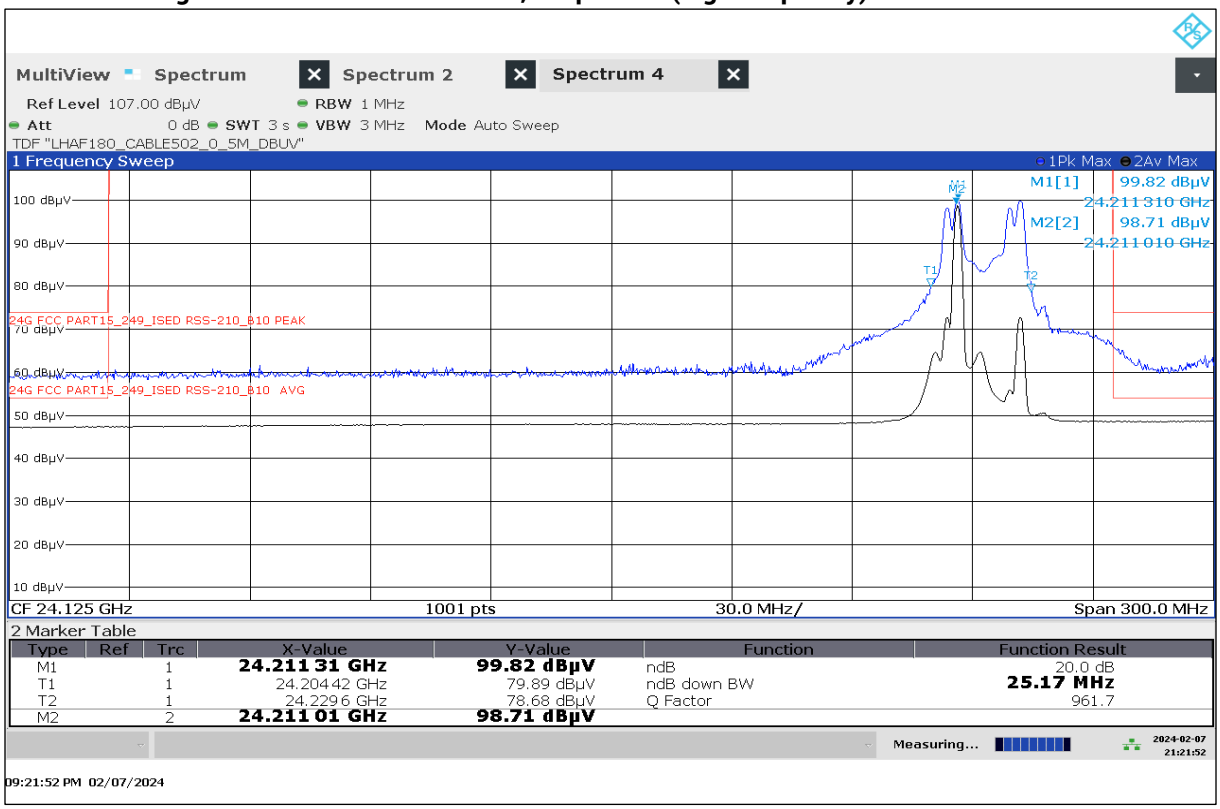
Plot 34: Field strength of fundamental emission, Stop Mode (low frequency)



Plot 35: Field strength of fundamental emission, Stop Mode (middle frequency)



Plot 36: Field strength of fundamental emission, Stop Mode (high frequency)



12.4 Field strength of emissions (radiated outside of the specified frequency bands)

Description:

Measurement of the field strength of emissions radiated outside of the specified frequency bands (in transmit mode).

Limits and provisions:

§15.249 (a):
Except as provided in paragraph (b) of this section, the field strength of emissions from intentional radiators operated within these frequency bands shall comply with the following:

Fundamental frequency (GHz)	Field strength of harmonics (mV/m)
0.902-0.928	0.5
2.400-2.4835	0.5
5.725-5.875	0.5
24.0-24.25	2.5

§15.249 (c):
Field strength limits are specified at a distance of 3 meters.

§15.249 (c):
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.

§15.249 (e):
As shown in § 15.35(b), for frequencies above 1000 MHz, the field strength limits in paragraphs (a) and (b) of this section are based on average limits. However, the **peak field strength** of any emission shall not exceed the maximum permitted average limits specified above by more than **20 dB** under any condition of modulation. […]

§15.205(d)(9):
Devices operated in the 24.0–24.25 GHz band under § 15.249 are exempt from complying with the requirements of this section for the 48.0–48.5 GHz and 72.0–72.75 GHz bands only, and shall not exceed the limits specified in § 15.249(a).

§15.209 (a):
Except as provided elsewhere in this subpart, the emissions from an intentional radiator shall not exceed the field strength levels specified in the following table

Frequency (MHz)	Field Strength (µV/m)	Measurement distance (m)
0.009 – 0.490	2400/F(kHz)	300
0.490 – 1.705	24000/F(kHz)	30
1.705 – 30.0	30	30
30 88	100**	3
88 – 216	150**	3
216 – 960	200**	3
Above 960	500	3

** Except as provided in paragraph (g), fundamental emissions from intentional radiators operating under this section shall not be located in the frequency bands 54–72 MHz, 76–88 MHz, 174–216 MHz or 470–806 MHz. However, operation within these frequency bands is permitted under other sections of this part, e.g., §§ 15.231 and 15.241

§15.209(b):
In the emission table above, the tighter limit applies at the band edges.

§15.209(c):
The level of any unwanted emissions from an intentional radiator operating under these general provisions shall not exceed the level of the fundamental emission. For intentional radiators which operate under the provisions of other sections within this part and which are required to reduce their unwanted emissions to the limits specified in this table, the limits in this table are based on the frequency of the unwanted emission and not the fundamental frequency. However, the level of any unwanted emissions shall not exceed the level of the fundamental frequency.

§15.209(d):
The emission limits shown in the above table are based on measurements employing a CISPR quasi-peak detector except for the frequency bands 9–90 kHz, 110–490 kHz and above 1000 MHz. Radiated emission limits in these three bands are based on measurements employing an average detector.

§15.31 (c):
Except as otherwise indicated in §§ 15.255 and 15.256, for swept frequency equipment, measurements shall be made with the frequency sweep stopped at those frequencies chosen for the measurements to be reported.

§15.33(a):
For an intentional radiator, the spectrum shall be investigated from the lowest radio frequency signal generated in the device, without going below 9 kHz, up to at least the frequency shown in this paragraph: […]

(2) If the intentional radiator operates at or above 10 GHz and below 30 GHz: to the fifth harmonic of the highest fundamental frequency or to 100 GHz, whichever is lower.

Calculation of limits according to §15.249 (c) :

$$E_{pot} = E_{fund} - 50\ dB$$

- E_{pot}: Potential limit according to §15.249 (c)
- E_{fund}: Measured field strength of fundamental emission @ 3m (see chapter 12.3)

EUT	Measured field strength of fundamental emission @ 3m [dBµV/m]	Potential limit according to §15.249 (c) [dBµV/m]	Limit according to §15.209 [dBµV/m]
	average value	average value	average value
1	98.95	48.95	54 (f > 1GHz)

Note:
- The limit value with the lesser attenuation compared to the fundamental field strength applies.
- The level of any unwanted emissions shall not exceed the level of the fundamental frequency.

Applicable limits according to §15.249 (a),(c):

EUT	Harmonics		Emissions radiated outside of the specified frequency bands (except for harmonics)	
	average value	peak value	average value	peak value
1	68 dBµV/m	88 dBµV/m	54 dBµV/m	74 dBµV/m

Measurement:

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

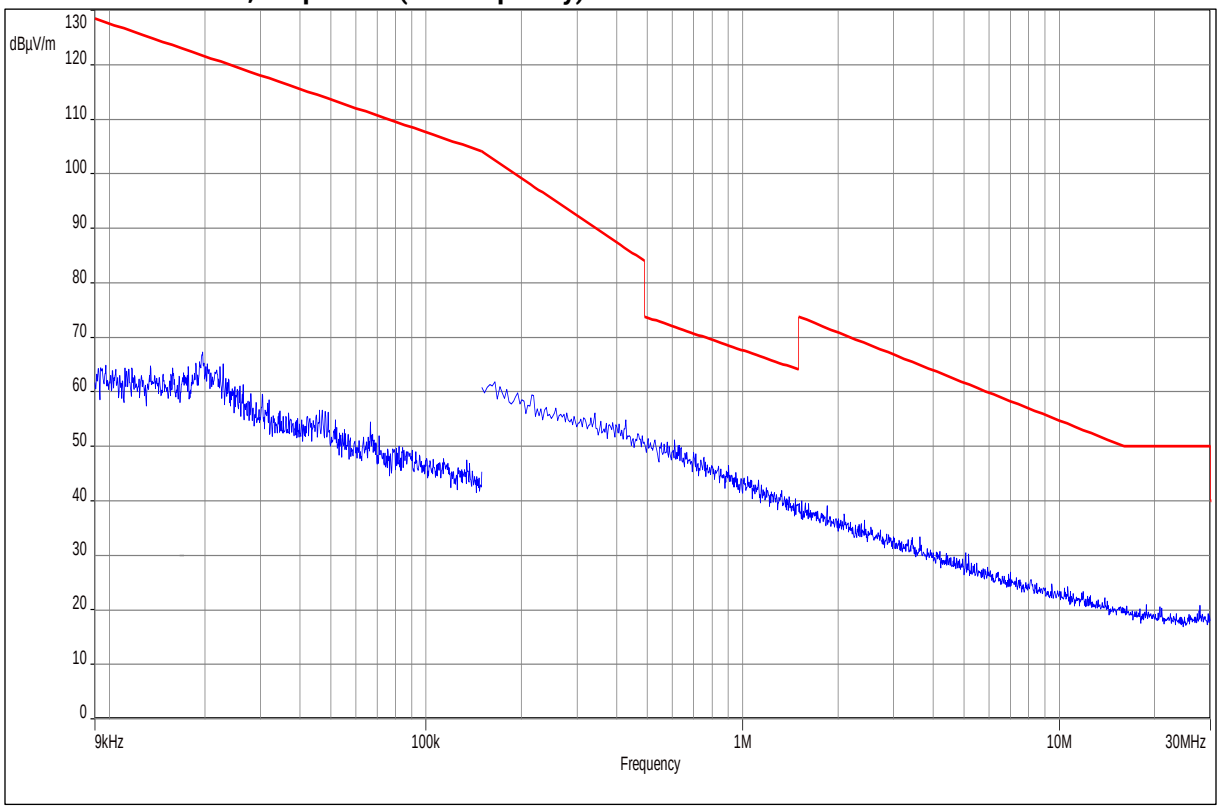
Measurement results:

Emissions radiated outside of the specified frequency bands:

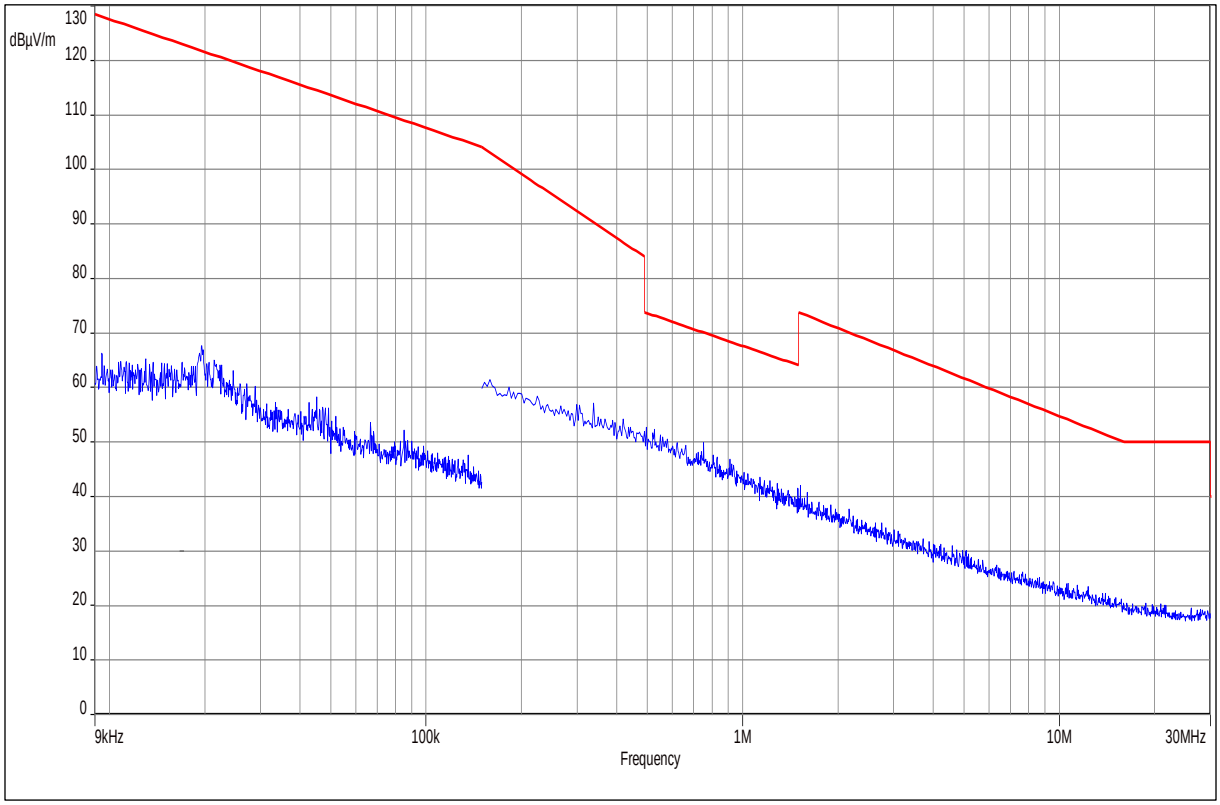
Frequency f [MHz]	Detector	Measured level [dBµV/m]	Limit [dBµV/m]	Margin [dB]
Please refer to the following plots for more information on the level of spurious emissions				
96.673 708 (worst Case)	Peak	65.00	88	23.0
	Average	59.64	68	8.36

Verdict: Compliant

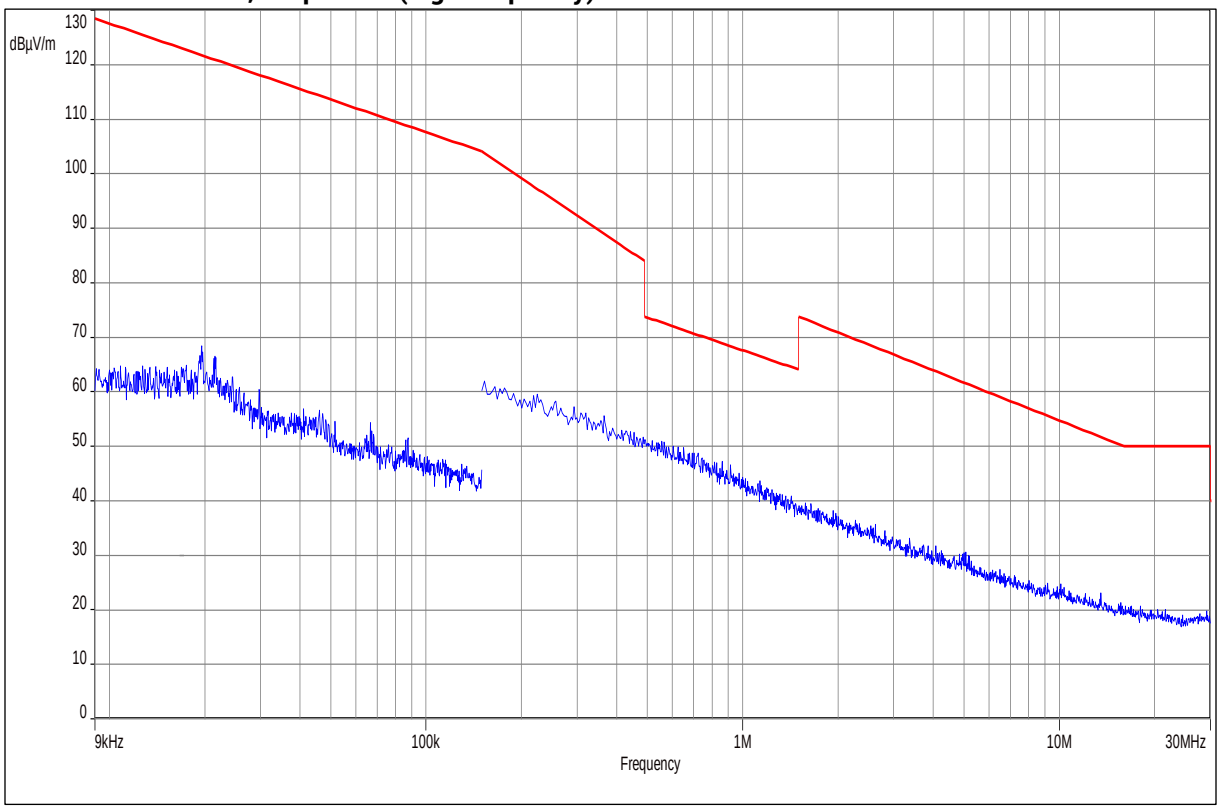
Plot 37: 9 kHz to 30 MHz, Stop Mode (low frequency)



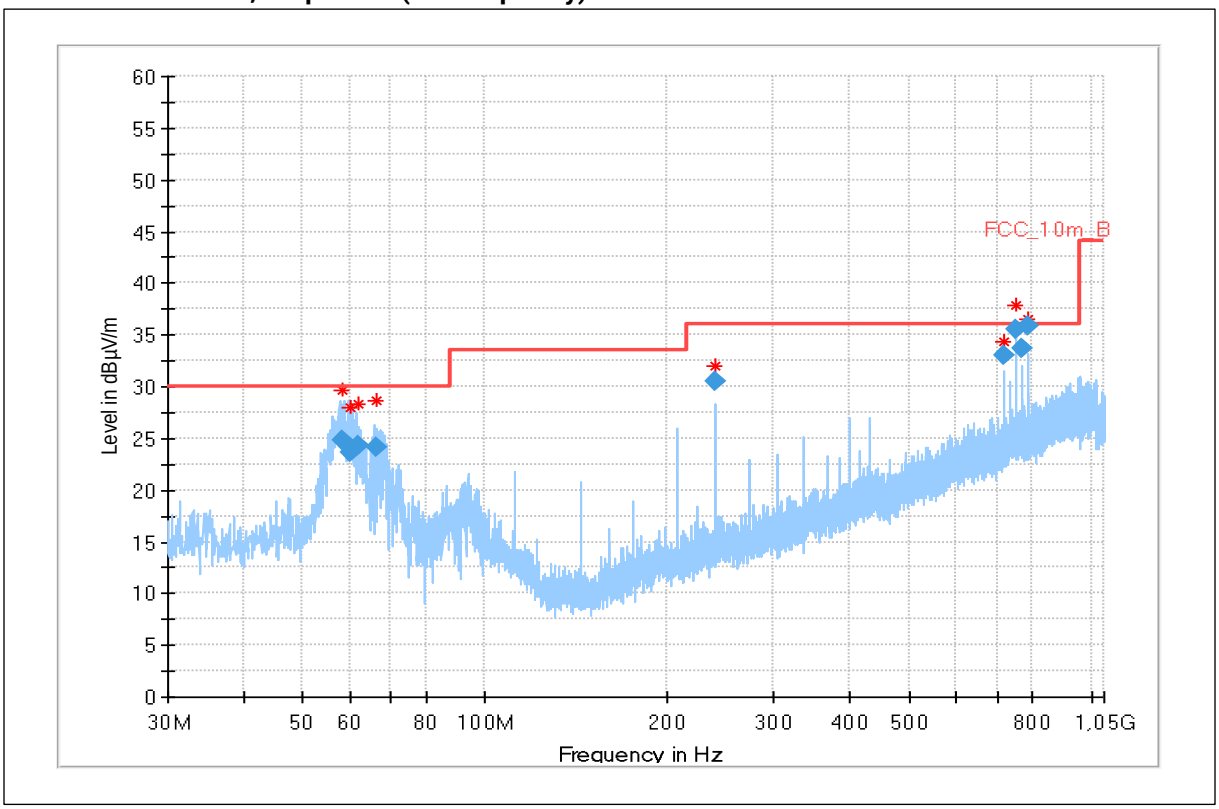
Plot 38: 9 kHz to 30 MHz, Stop Mode (middle frequency)



Plot 39: 9 kHz to 30 MHz, Stop Mode (high frequency)

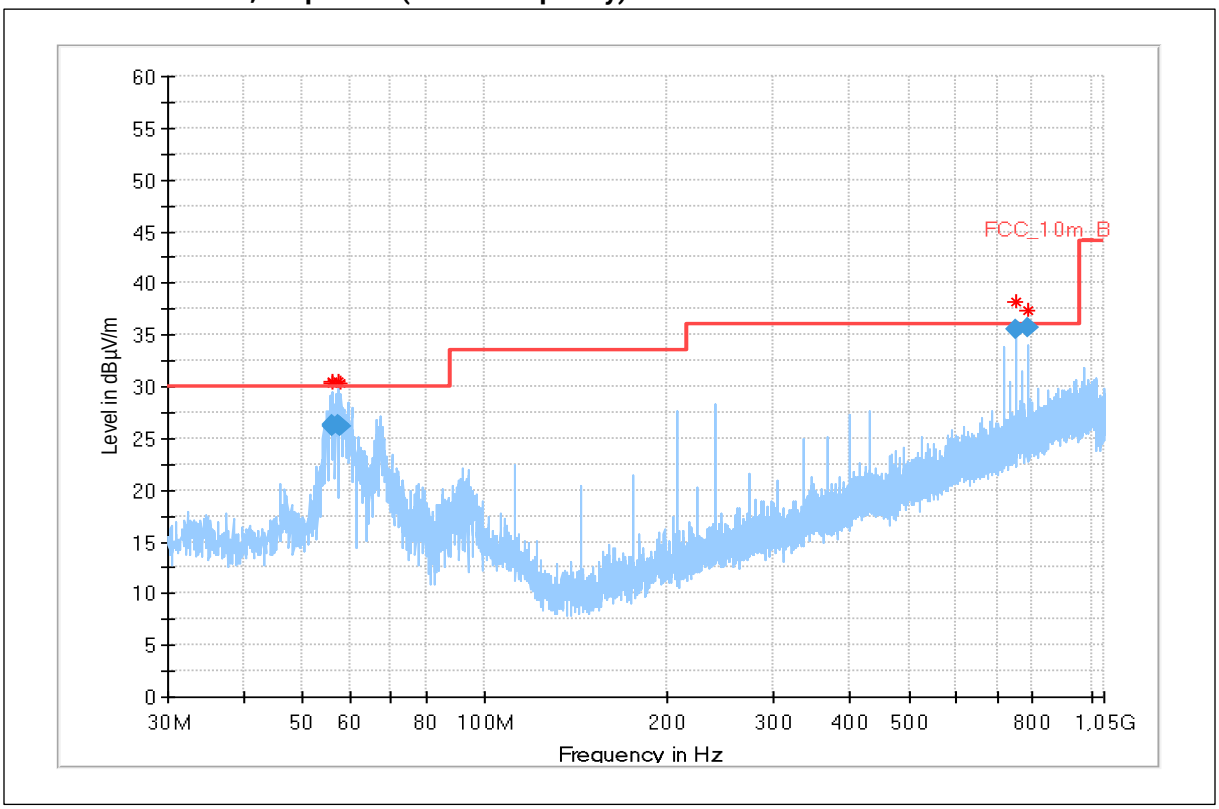


Plot 40: 30 MHz to 1 GHz, Stop Mode (low frequency)



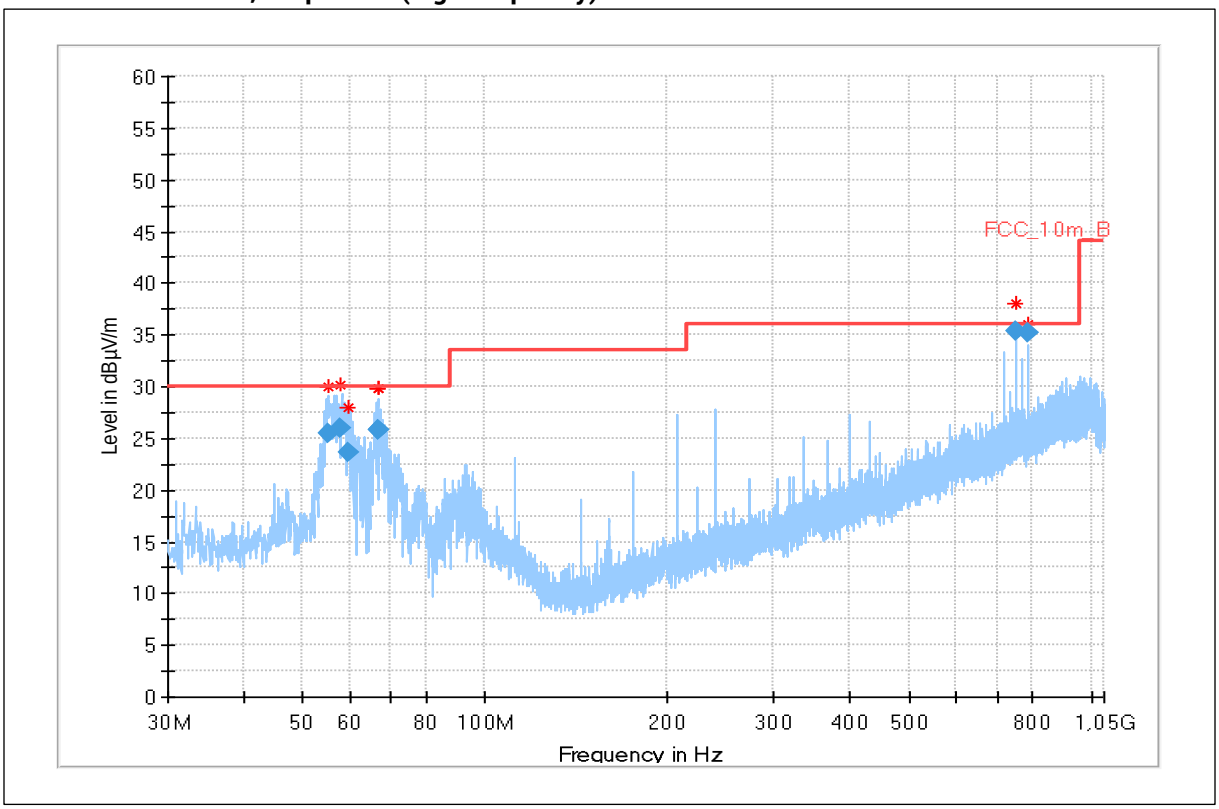
Frequency (MHz)	QuasiPeak (dBµV/m	Limit (dBµV/m)	Margin (dB)	Meas. Time (ms)	Bandwidth (kHz)	Height (cm)	Pol	Azimuth (deg)	Corr. (dB/m)
58.240	24.80	30.0	5.2	1000	120.0	170.0	V	94	15
59.776	23.64	30.0	6.4	1000	120.0	98.0	V	52	14
61.870	24.31	30.0	5.7	1000	120.0	102.0	V	97	13
66.184	24.11	30.0	5.9	1000	120.0	195.0	V	111	12
240.001	30.50	36.0	5.5	1000	120.0	195.0	H	179	14
719.993	33.02	36.0	3.0	1000	120.0	139.0	H	65	23
751.991	35.47	36.0	0.5	1000	120.0	107.0	H	52	23
767.997	33.66	36.0	2.3	1000	120.0	125.0	H	61	24
783.981	35.94	36.0	0.1	1000	120.0	127.0	H	232	23

Plot 41: 30 MHz to 1 GHz, Stop Mode (middle frequency)



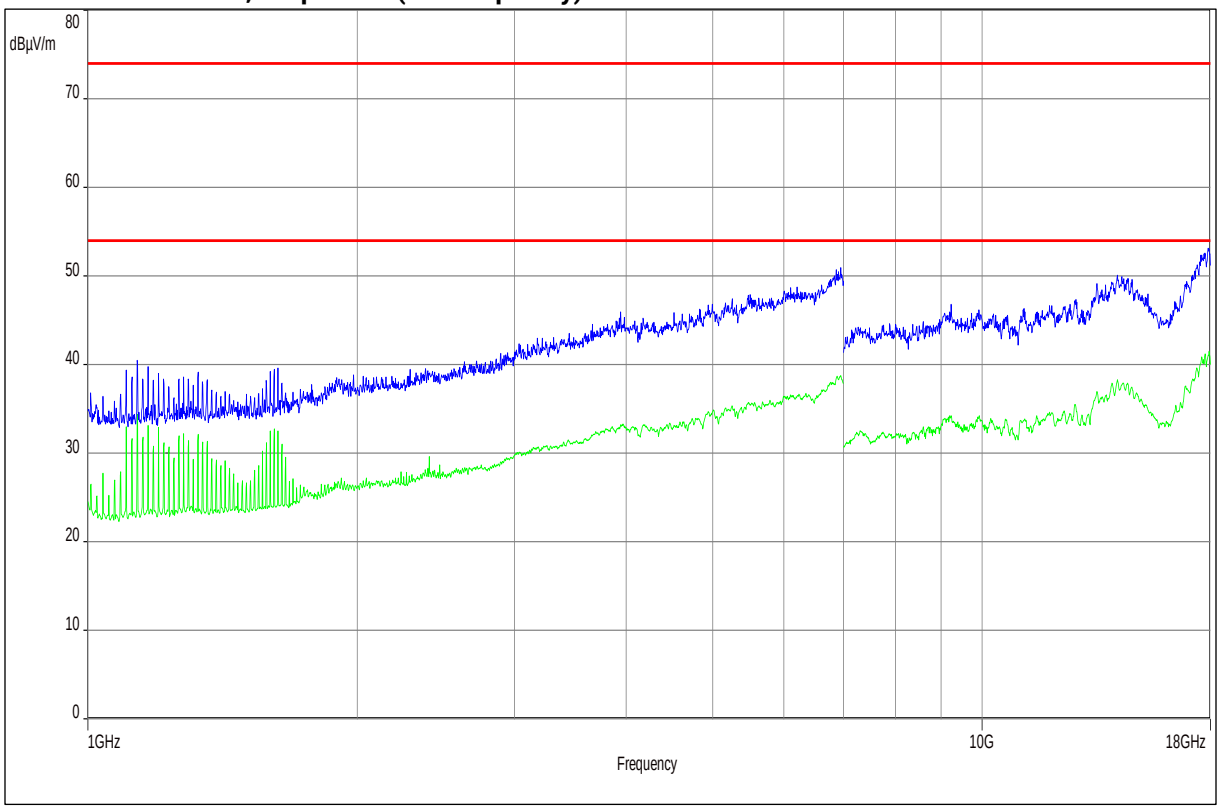
Frequency (MHz)	QuasiPeak (dBµV/m	Limit (dBµV/m)	Margin (dB)	Meas. Time (ms)	Bandwidth (kHz)	Height (cm)	Pol	Azimuth (deg)	Corr. (dB/m)
56.005	26.26	30.0	3.7	1000	120.0	101.0	V	60	16
56.148	26.09	30.0	3.9	1000	120.0	105.0	V	65	16
57.339	26.31	30.0	3.7	1000	120.0	101.0	V	54	15
57.533	26.15	30.0	3.9	1000	120.0	101.0	V	65	15
751.988	35.48	36.0	0.5	1000	120.0	102.0	H	78	23
783.993	35.73	36.0	0.3	1000	120.0	123.0	H	246	23

Plot 42: 30 MHz to 1 GHz, Stop Mode (high frequency)

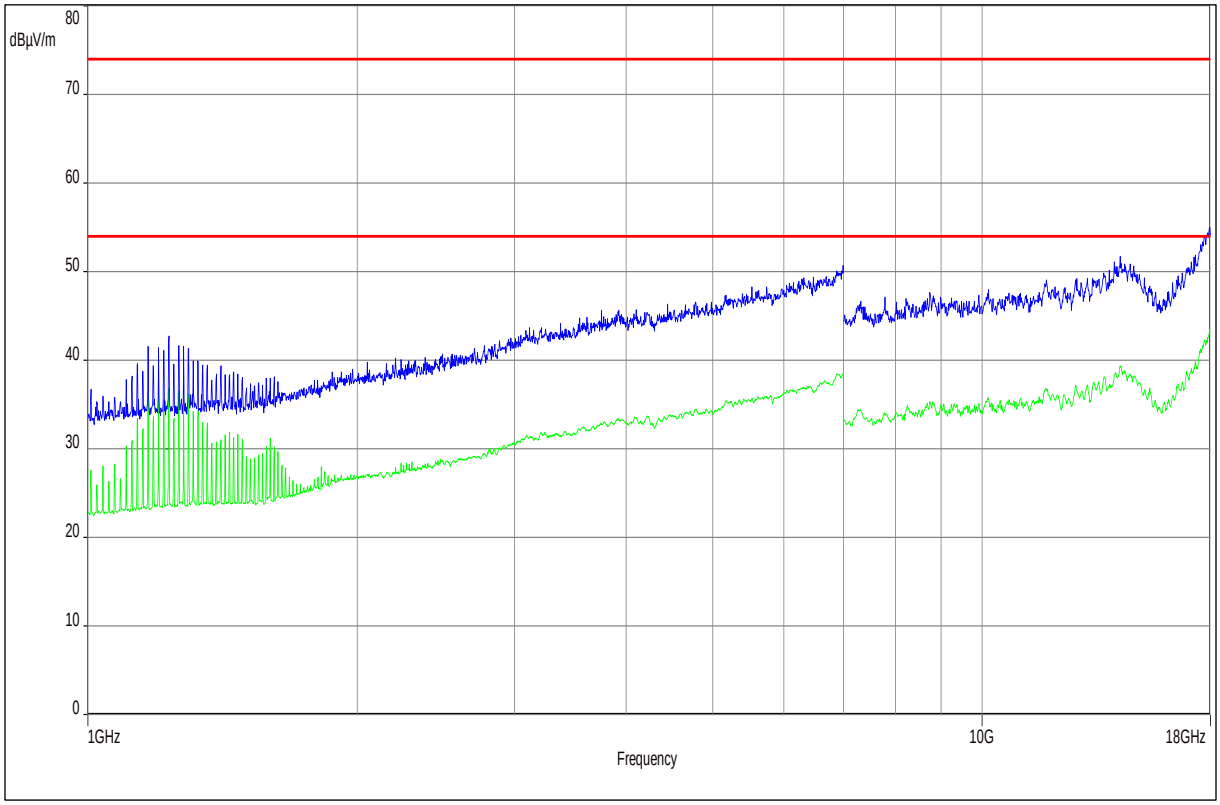


Frequency (MHz)	QuasiPeak (dBµV/m	Limit (dBµV/m)	Margin (dB)	Meas. Time (ms)	Bandwidth (kHz)	Height (cm)	Pol	Azimuth (deg)	Corr. (dB/m)
55.010	25.52	30.0	4.5	1000	120.0	118.0	V	53	15
57.587	25.97	30.0	4.0	1000	120.0	102.0	V	66	15
59.644	23.63	30.0	6.4	1000	120.0	101.0	V	232	14
66.638	25.81	30.0	4.2	1000	120.0	102.0	V	84	12
66.848	25.81	30.0	4.2	1000	120.0	101.0	V	119	12
751.992	35.30	36.0	0.7	1000	120.0	110.0	H	81	23
783.997	35.23	36.0	0.8	1000	120.0	124.0	H	76	23

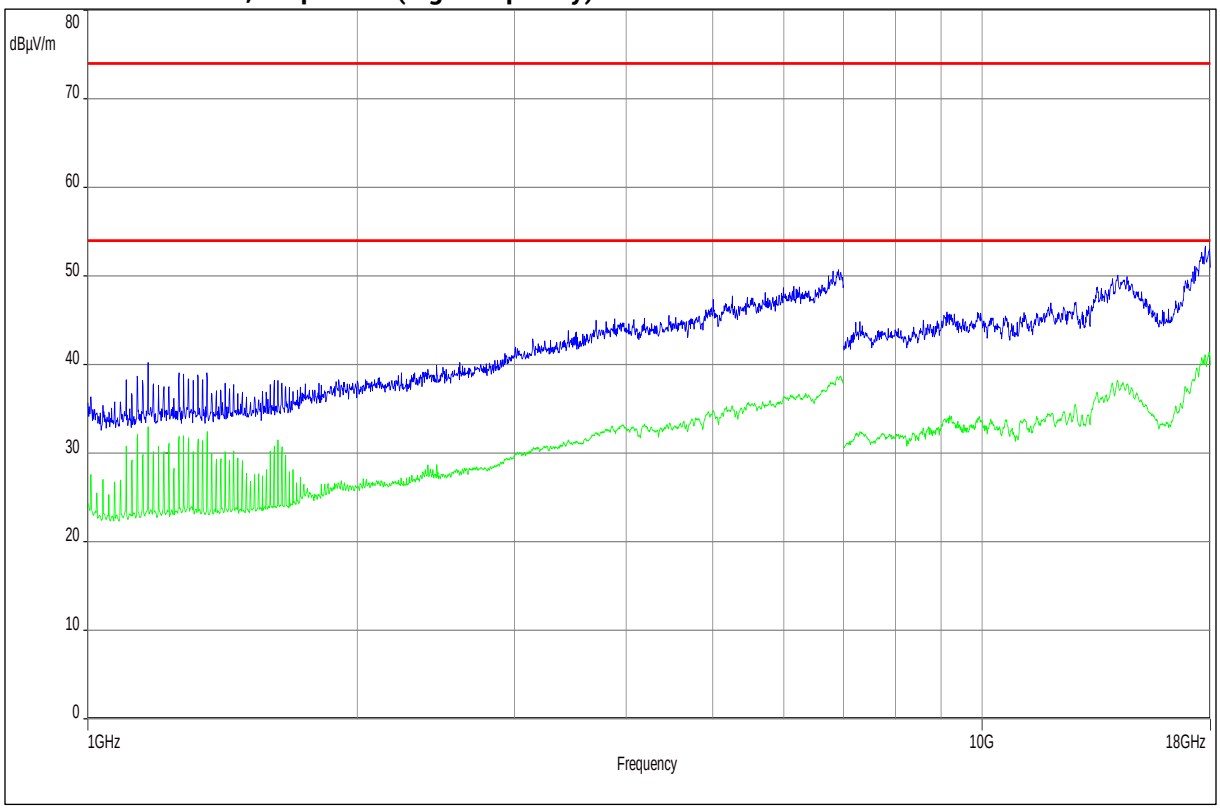
Plot 43: 1 GHz to 18 GHz, Stop Mode (low frequency)



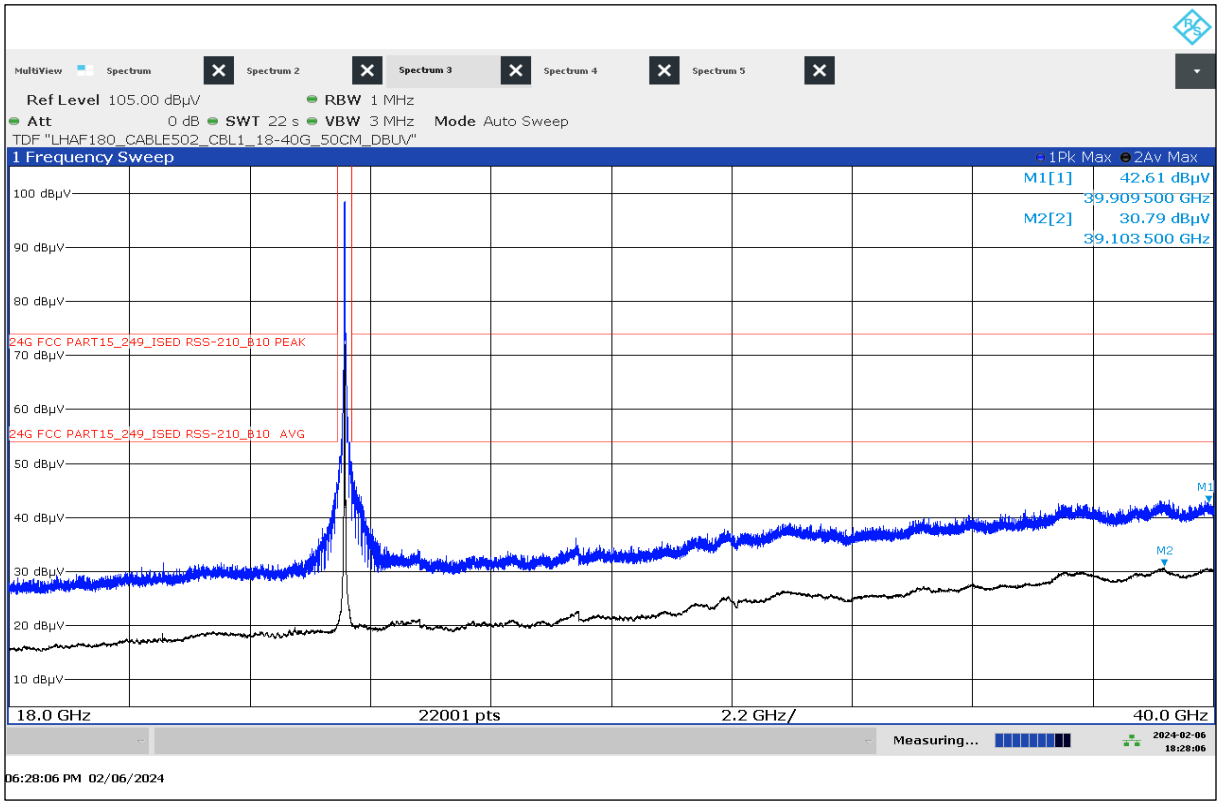
Plot 44: 1 GHz to 18 GHz, Stop Mode (middle frequency)



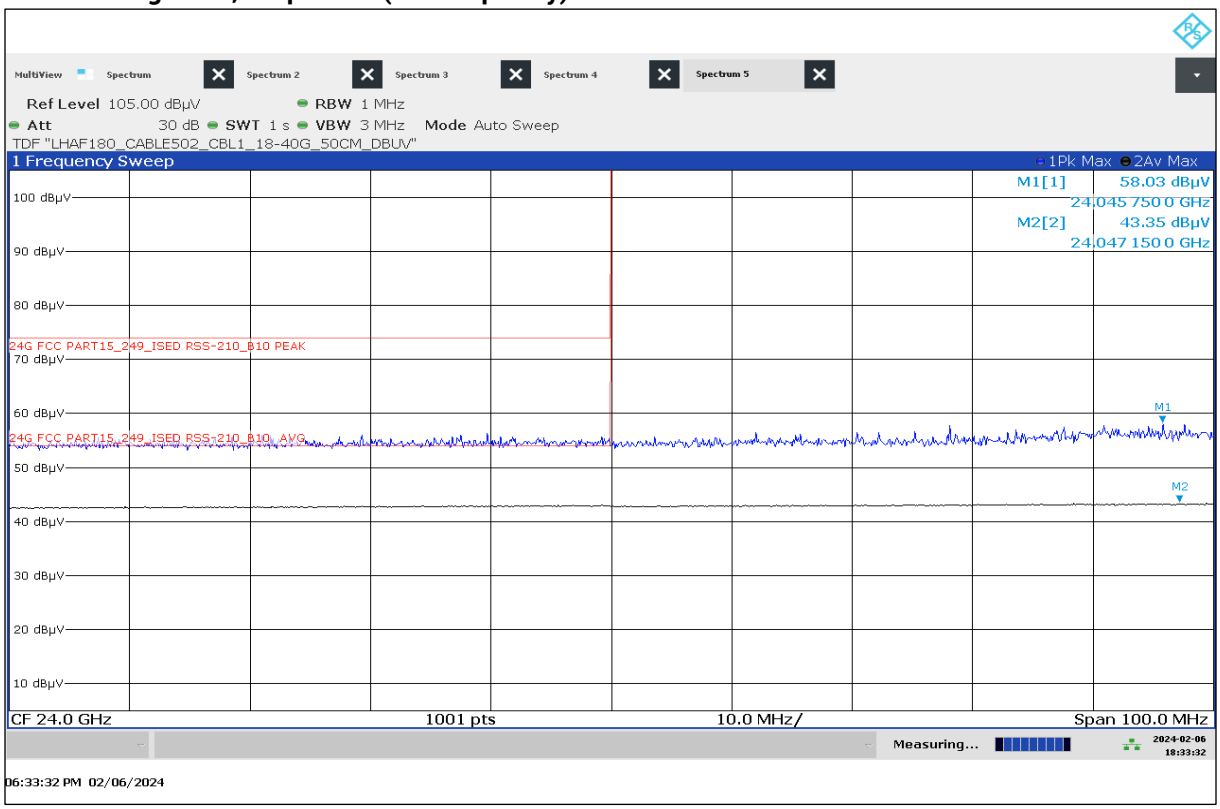
Plot 45: 1 GHz to 18 GHz, Stop Mode (high frequency)



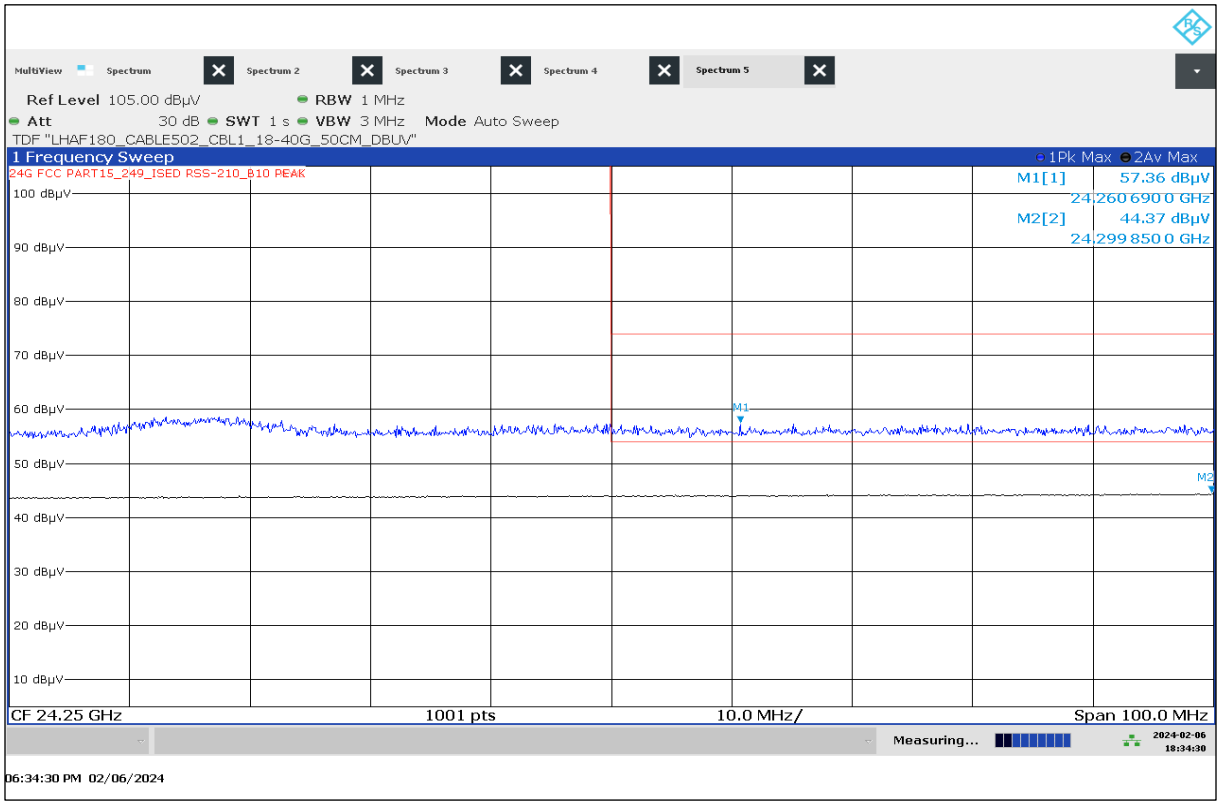
Plot 46: 18 GHz to 40 GHz, Stop Mode (low frequency)



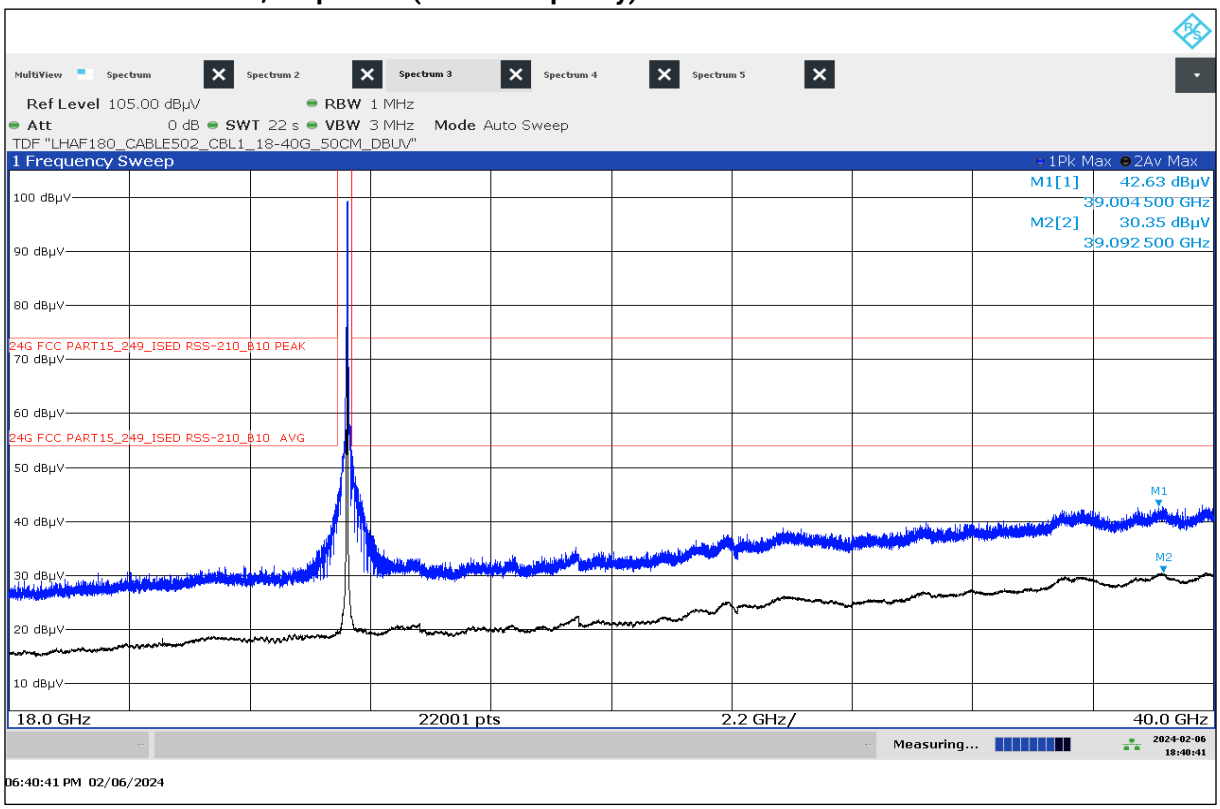
Plot 47: Band Edge Low, Stop Mode (low frequency)



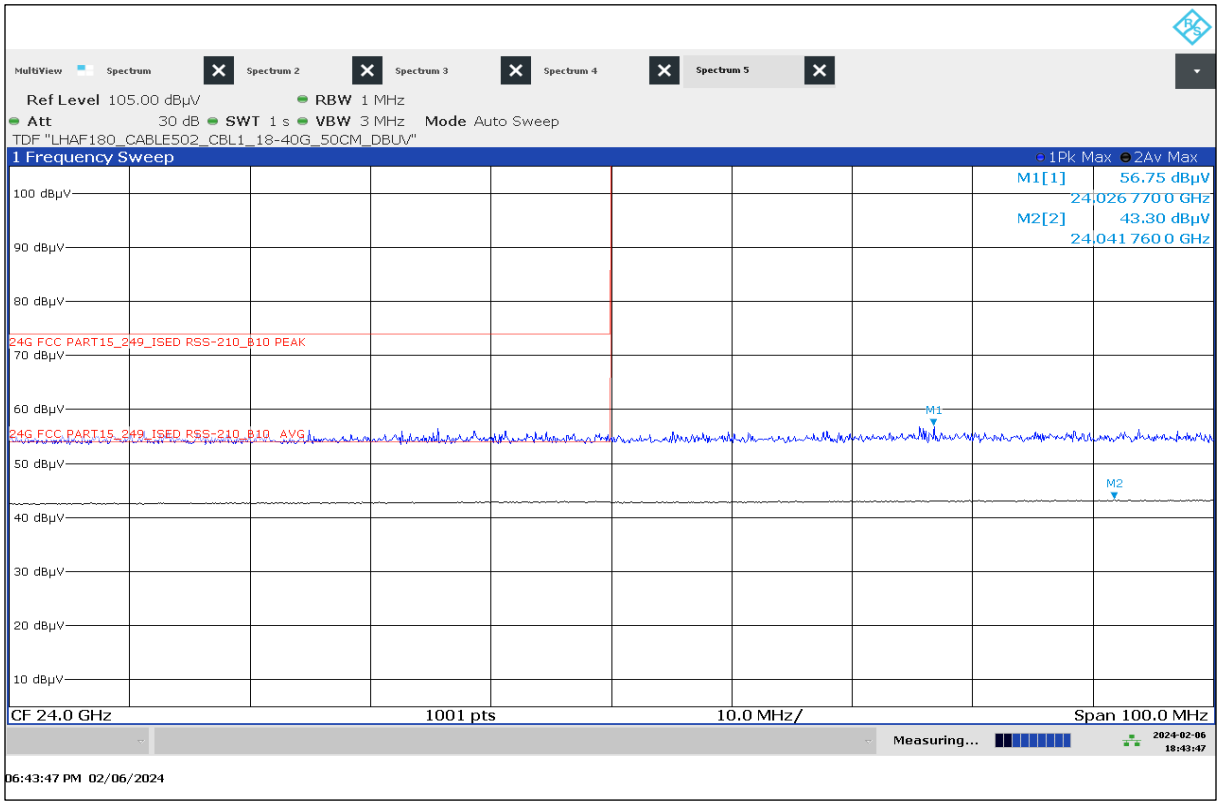
Plot 48: Band Edge High, Stop Mode (low frequency)



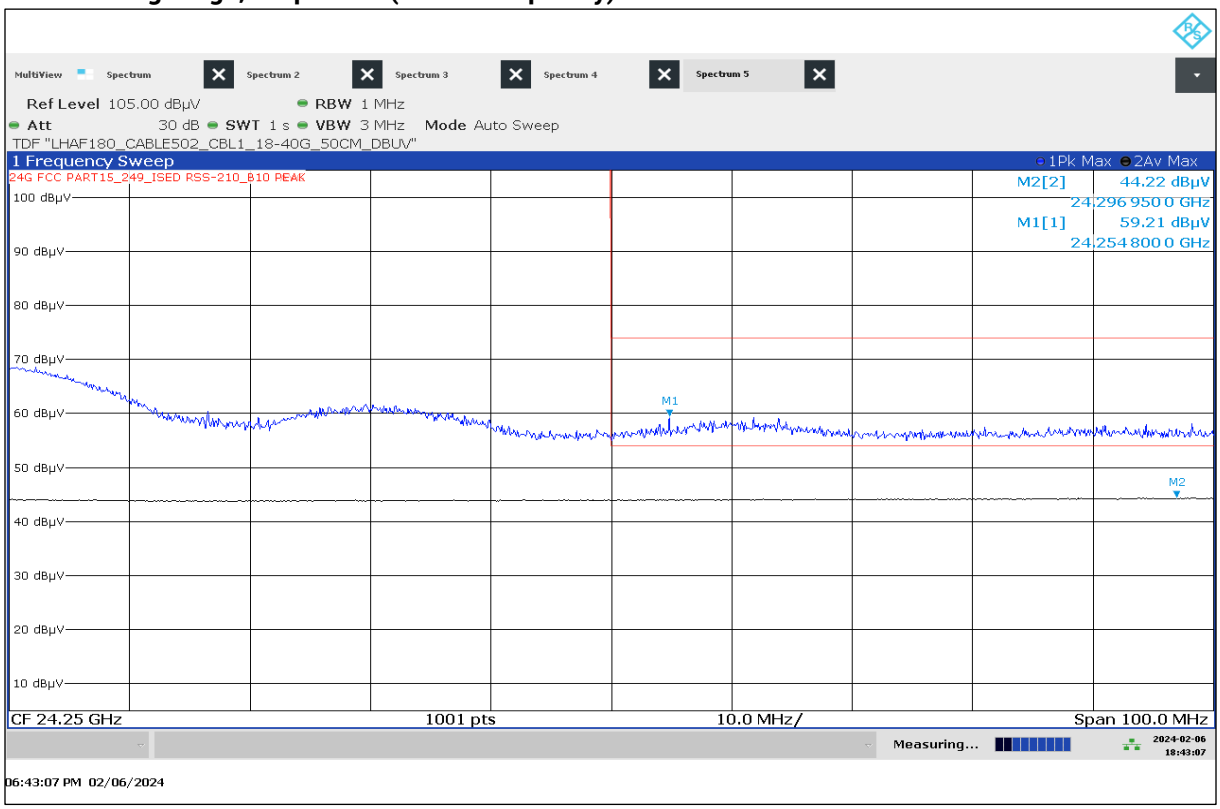
Plot 49: 18 GHz to 40 GHz, Stop Mode (middle frequency)



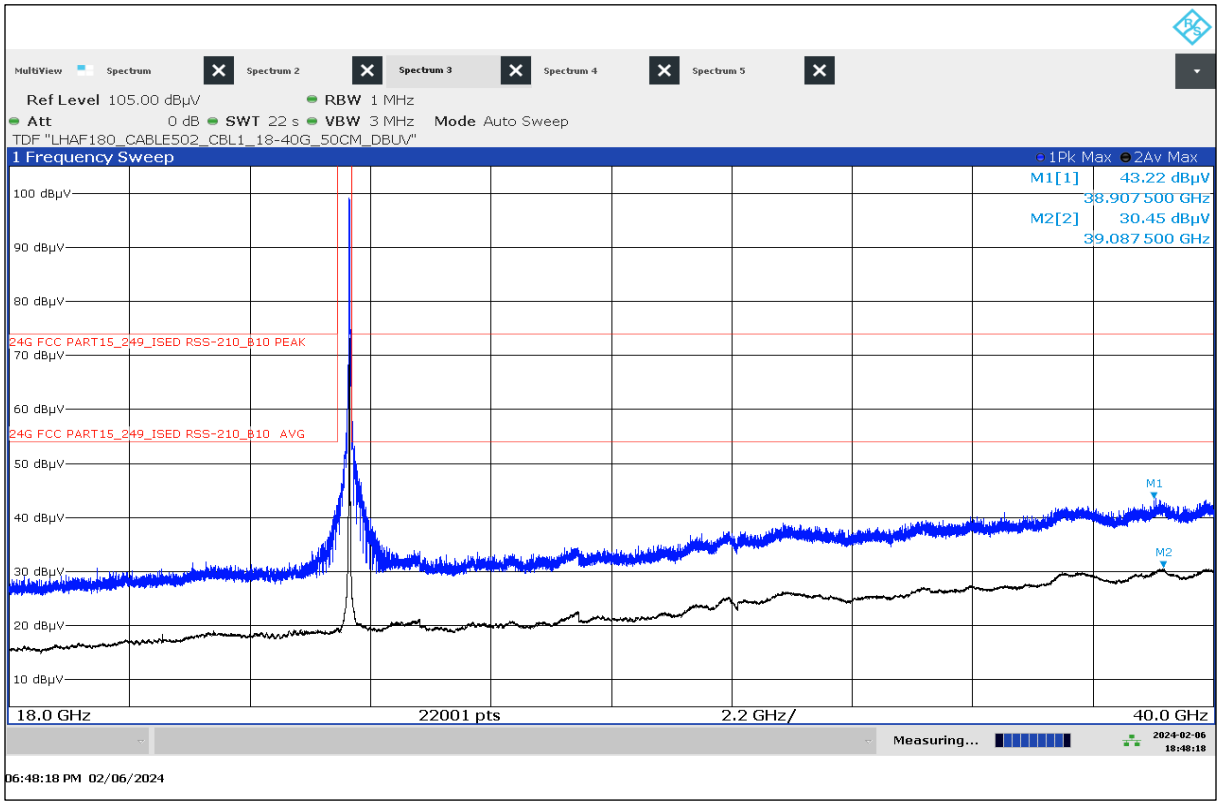
Plot 50: Band Edge Low, Stop Mode (middle frequency)



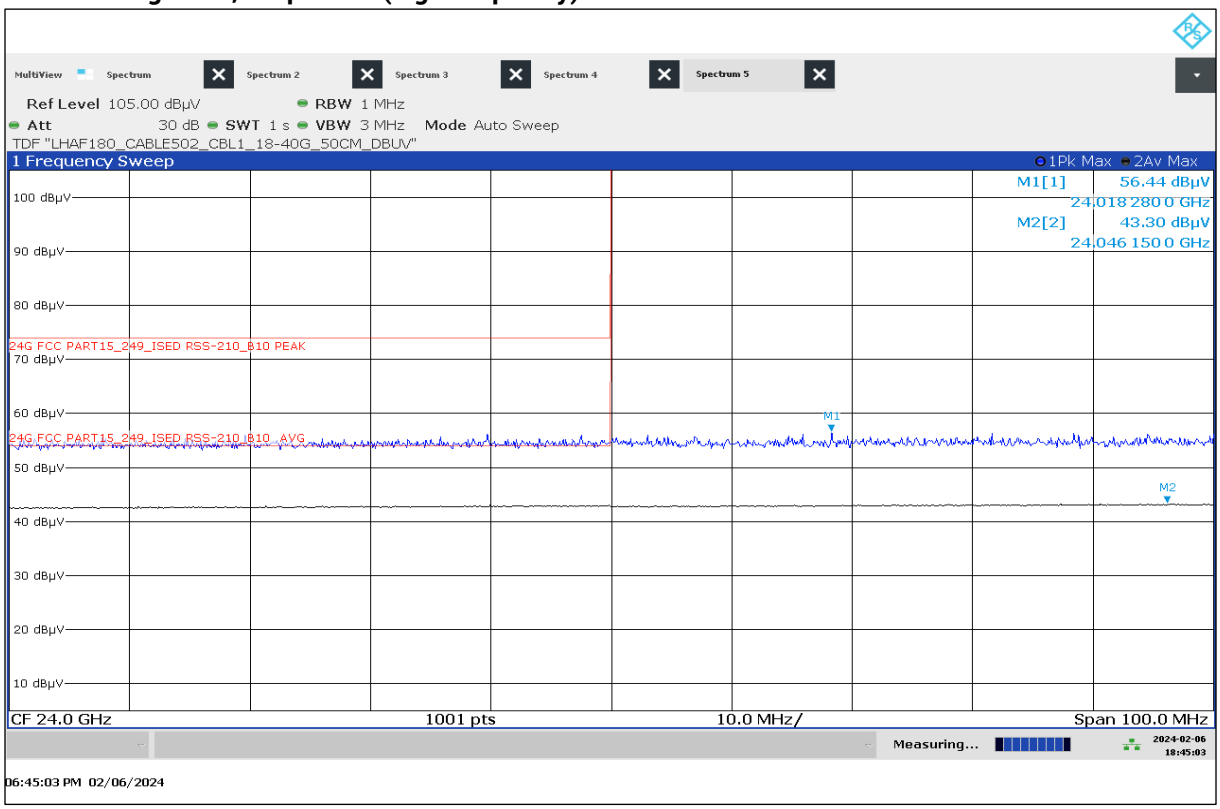
Plot 51: Band Edge High, Stop Mode (middle frequency)



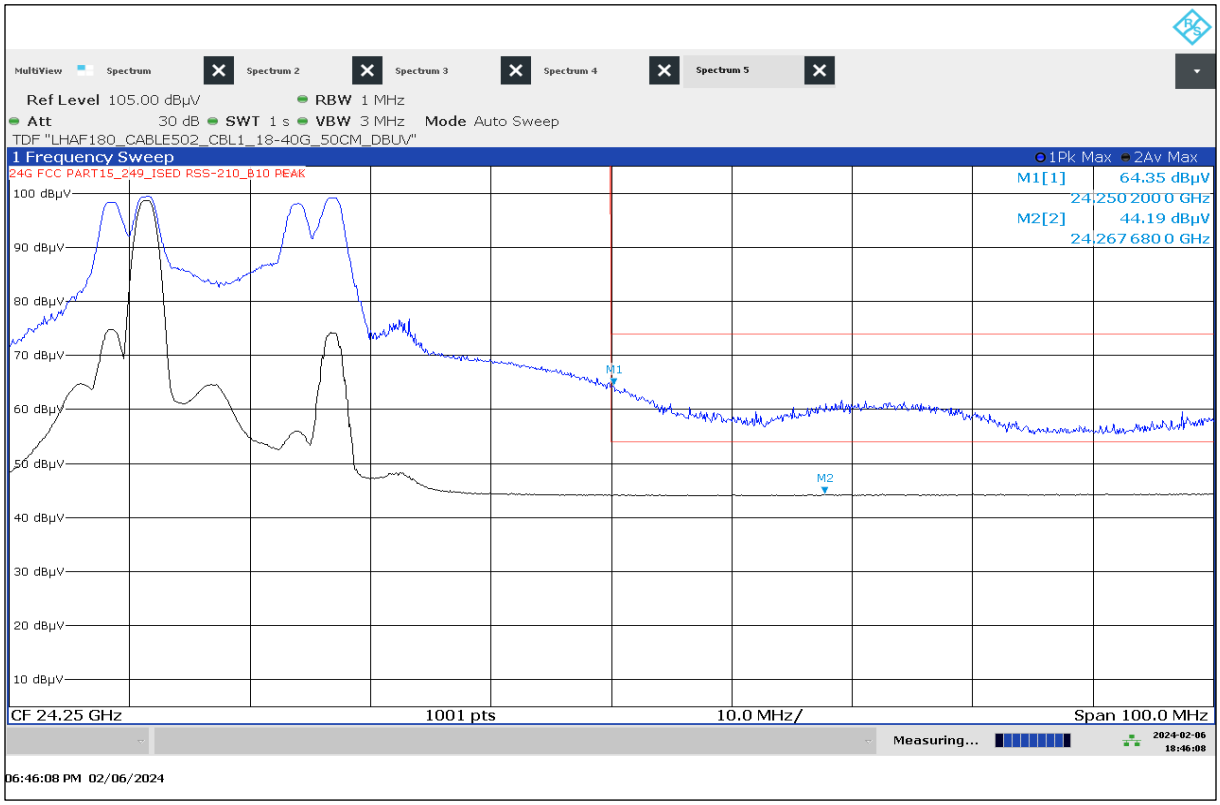
Plot 52: 18 GHz to 40 GHz, Stop Mode (high frequency)



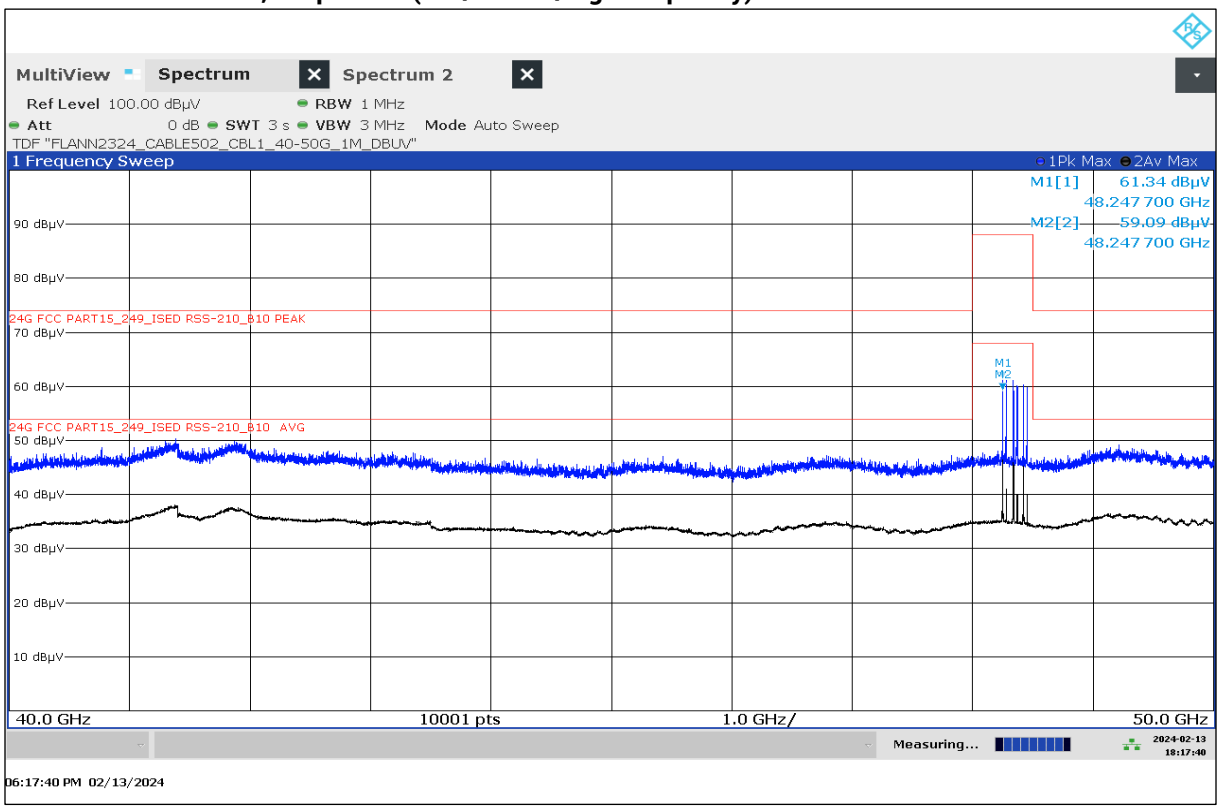
Plot 53: Band Edge Low, Stop Mode (high frequency)



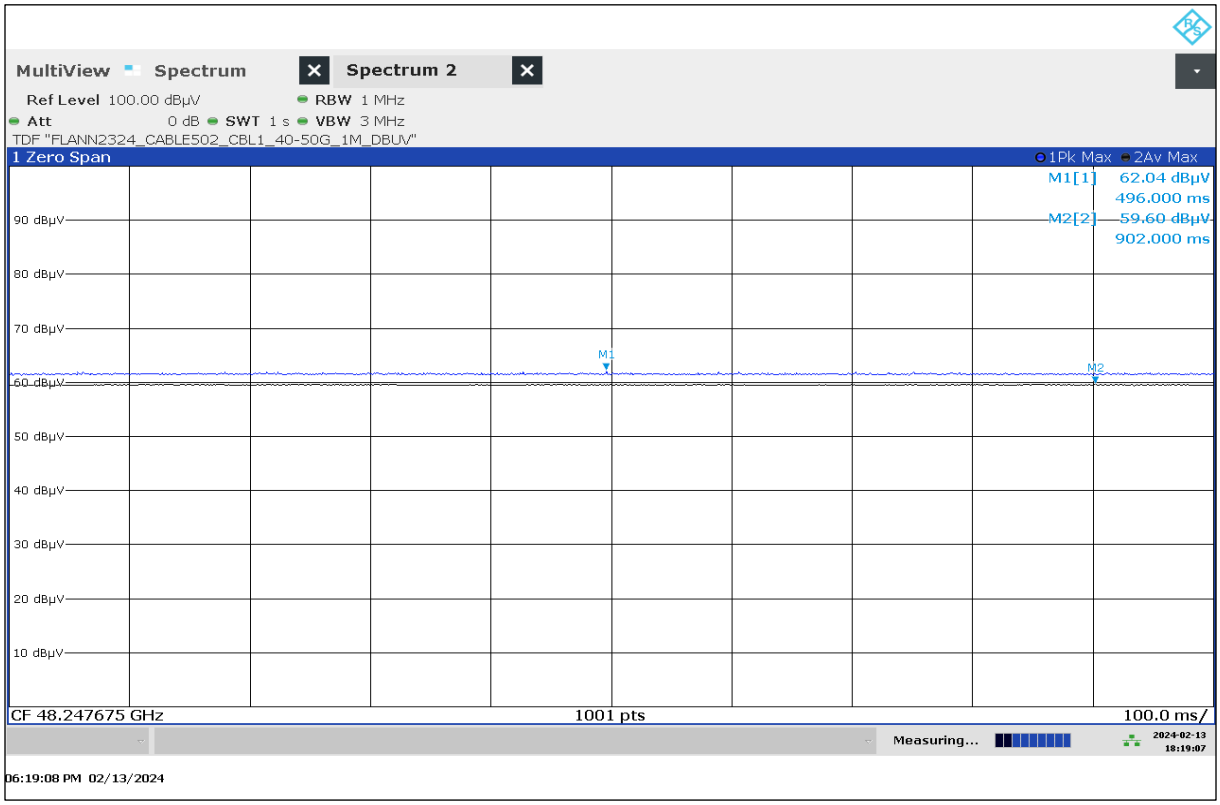
Plot 54: Band Edge High, Stop Mode (high frequency)



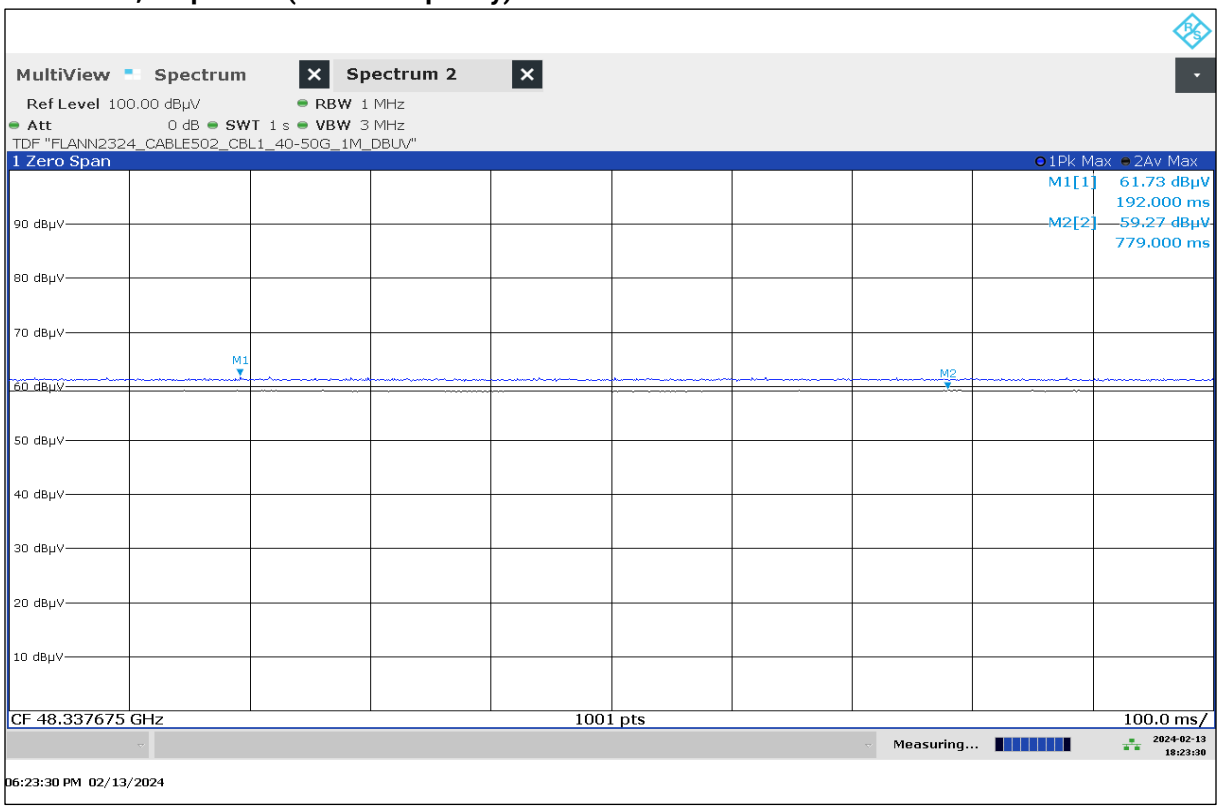
Plot 55: 40 GHz to 50 GHz, Stop Mode (low/middle/high frequency)



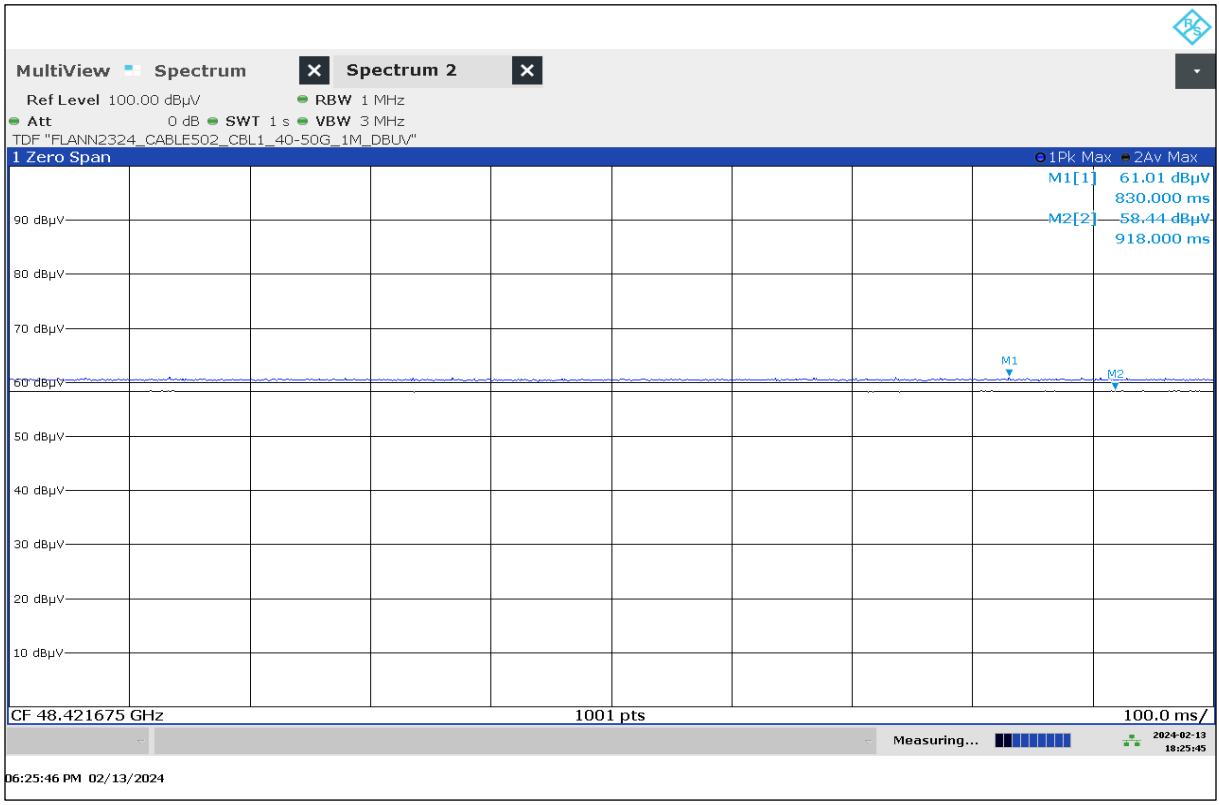
Plot 56: 48 GHz, Stop Mode (low frequency)



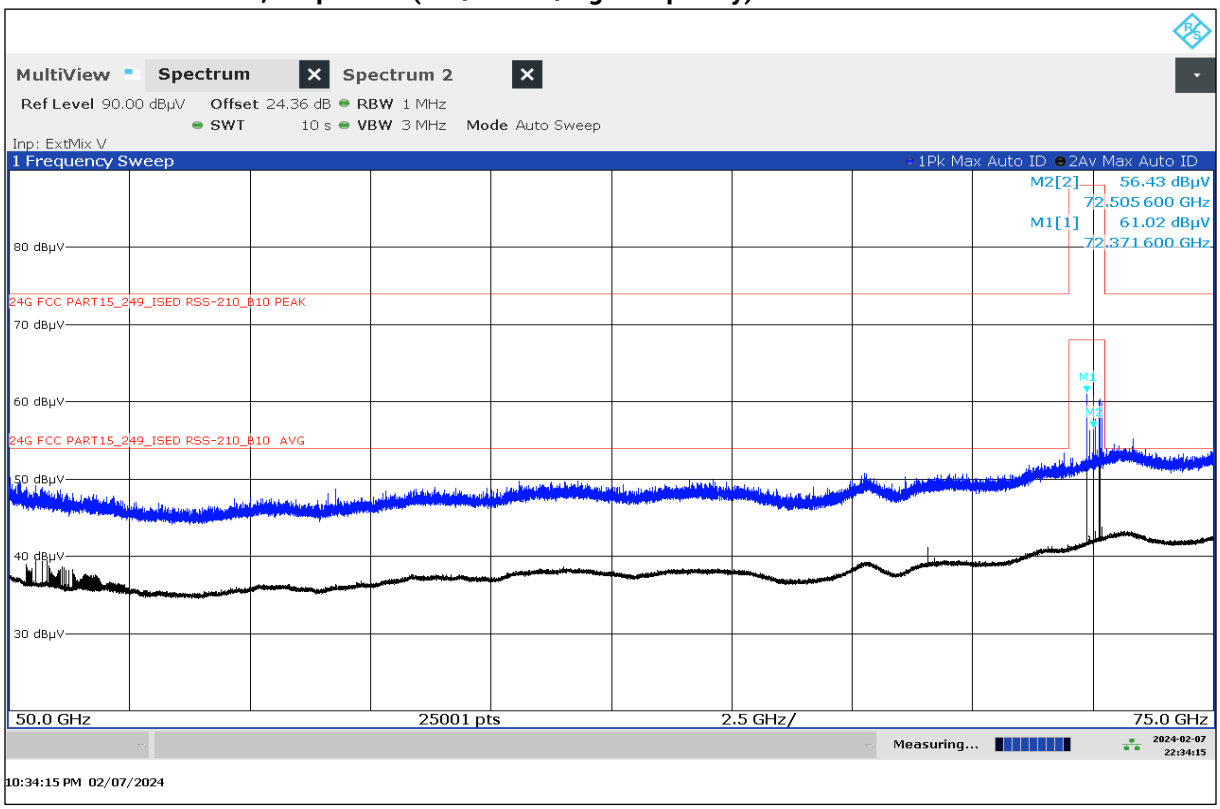
Plot 57: 48 GHz, Stop Mode (middle frequency)



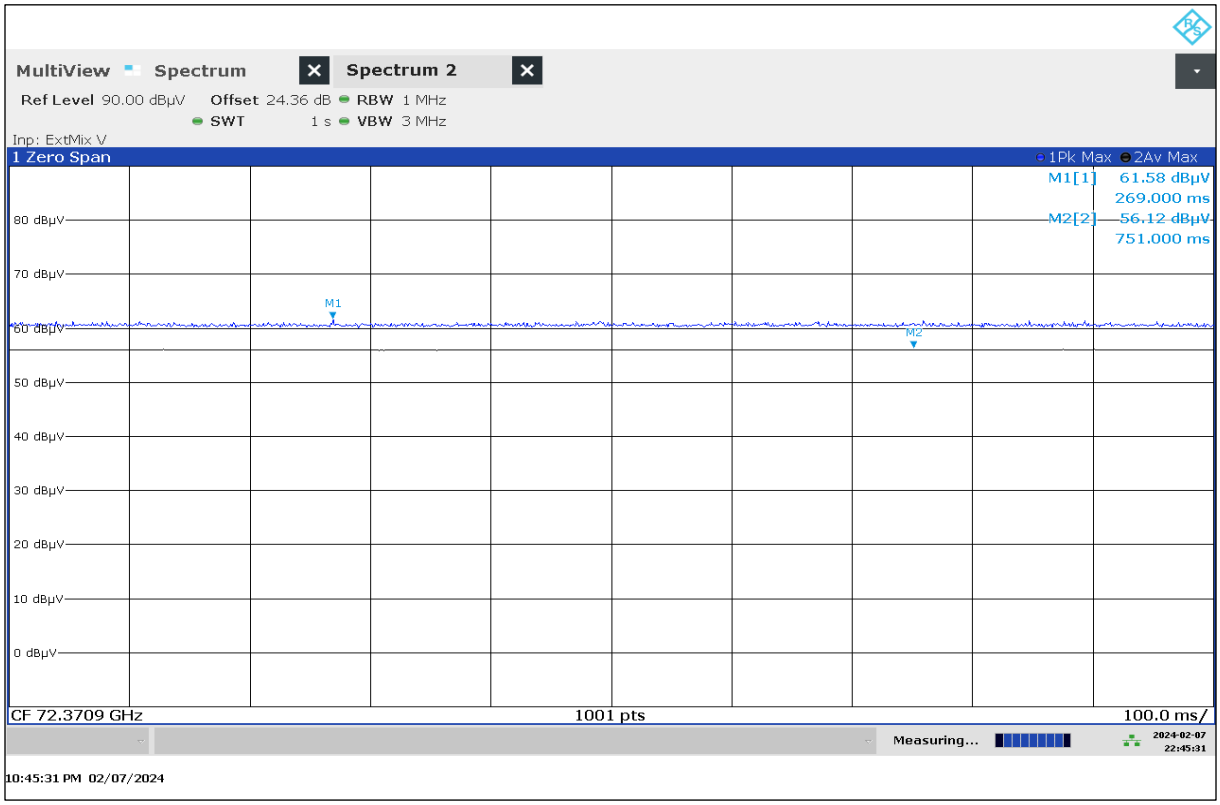
Plot 58: 48 GHz, Stop Mode (high frequency)



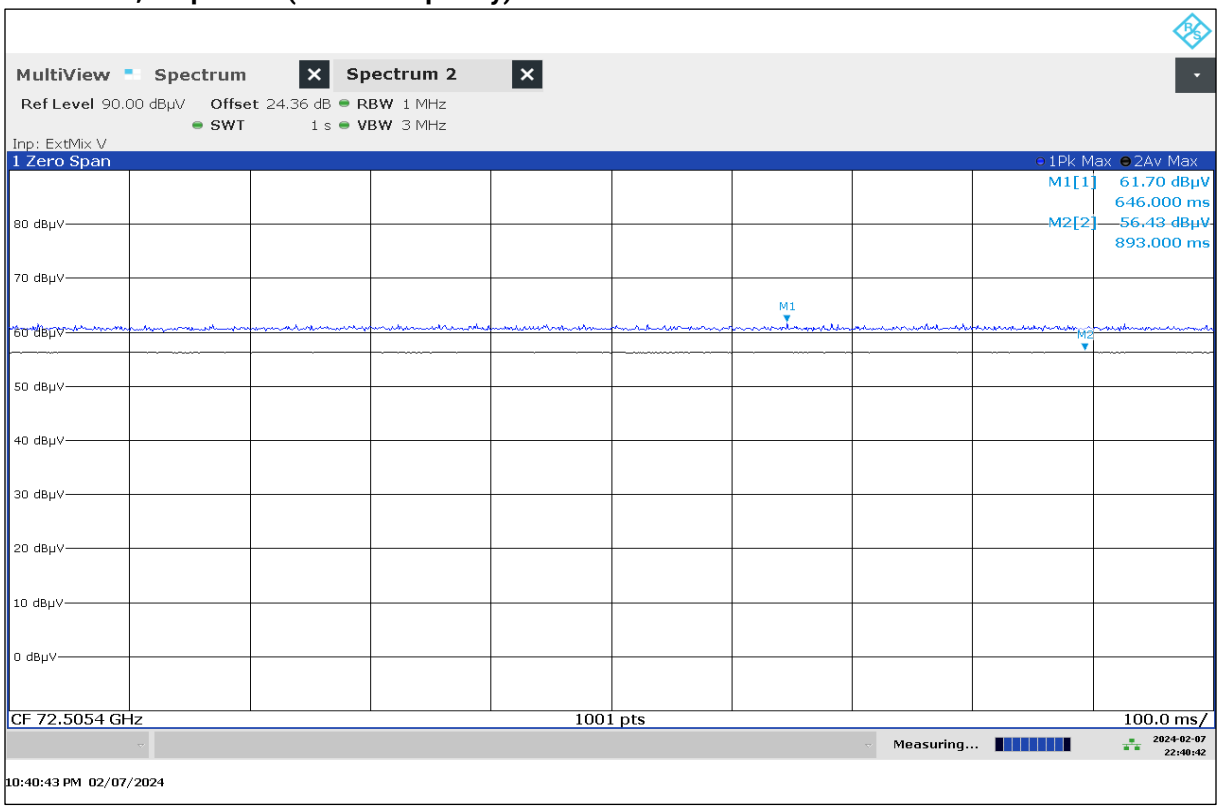
Plot 59: 50 GHz to 75 GHz, Stop Mode (low/middle/high frequency)



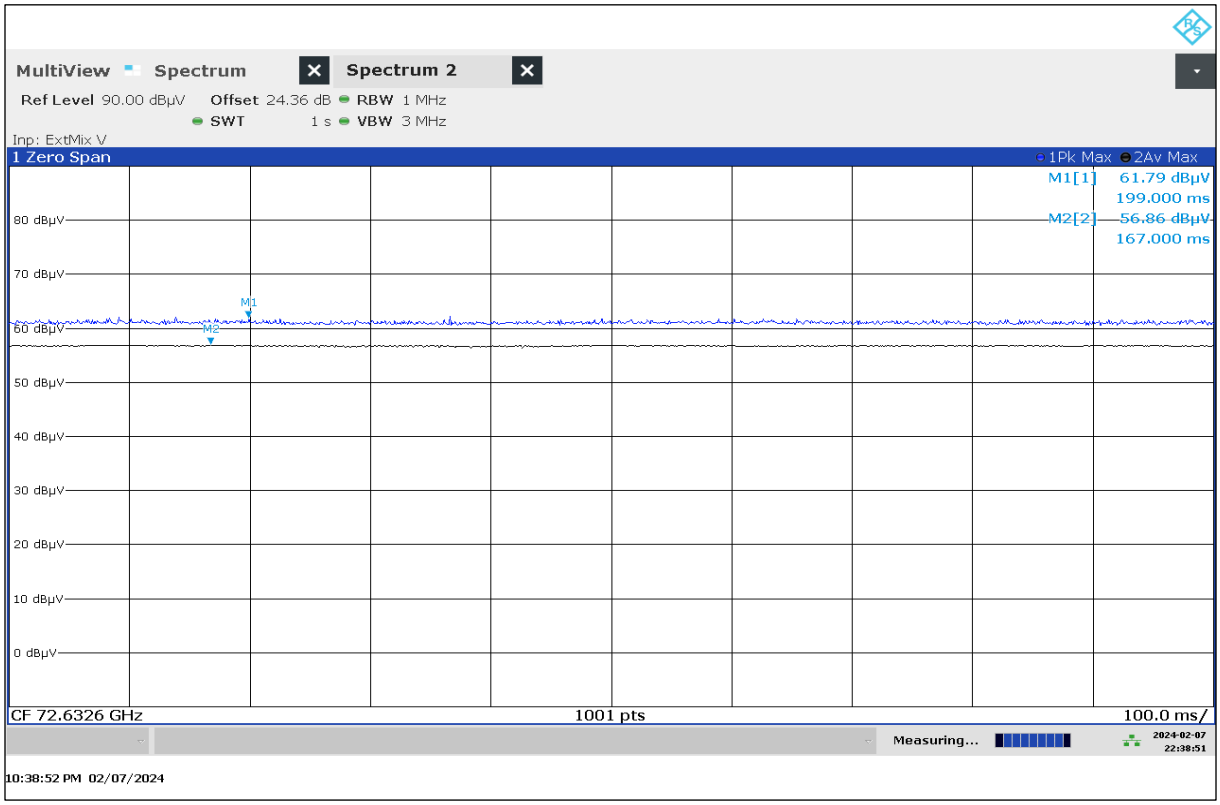
Plot 60: 72 GHz, Stop Mode (low frequency)



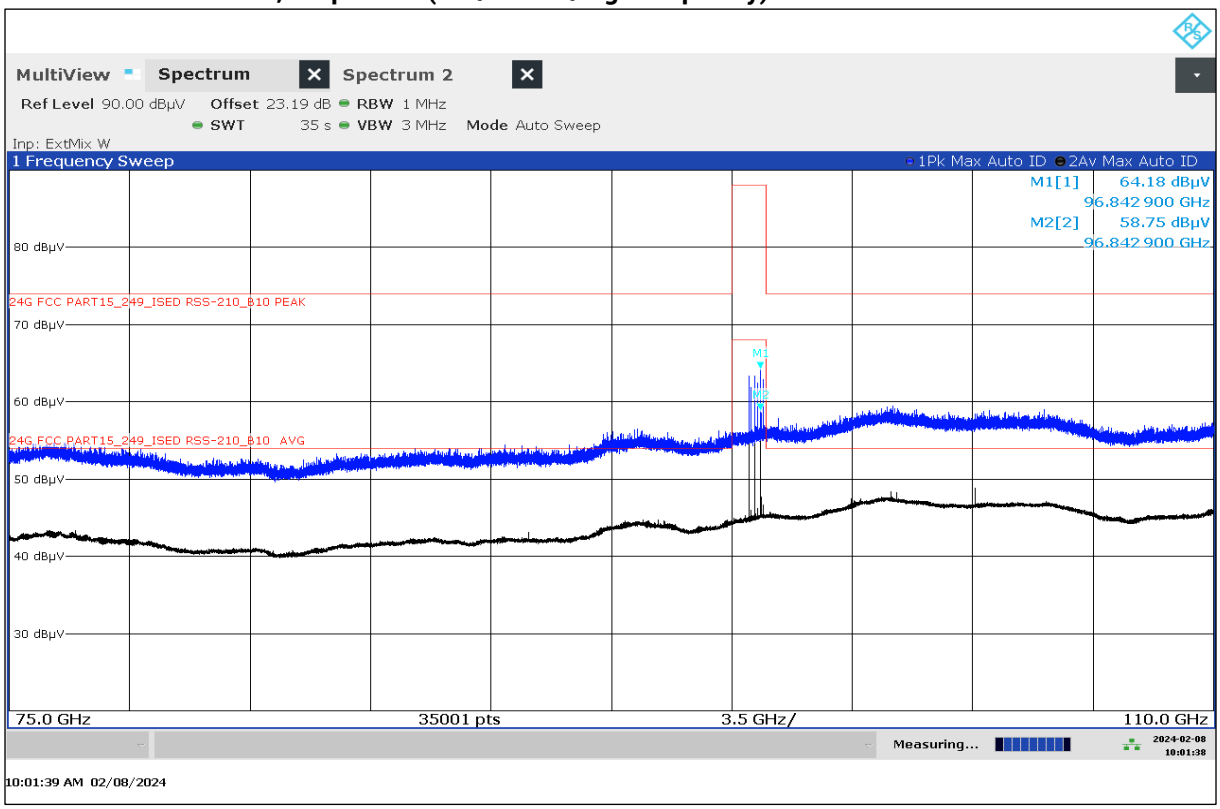
Plot 61: 72 GHz, Stop Mode (middle frequency)



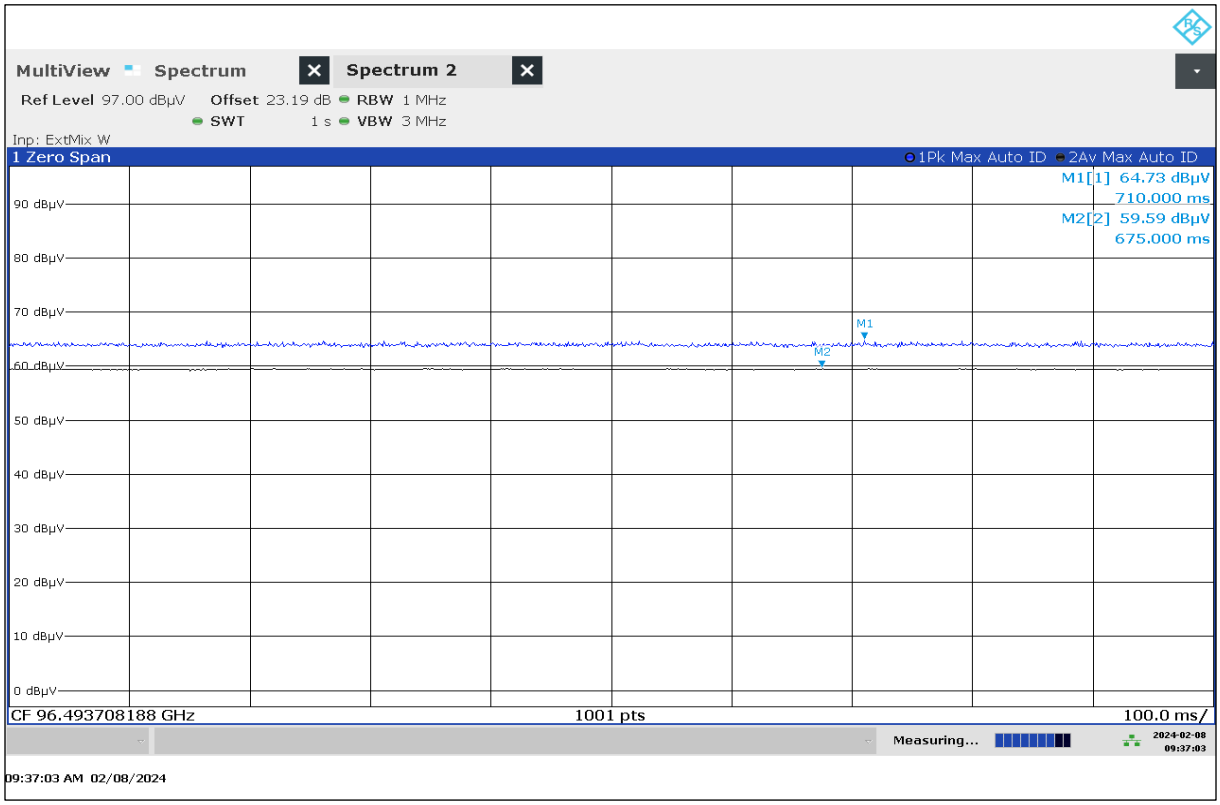
Plot 62: 72 GHz, Stop Mode (high frequency)



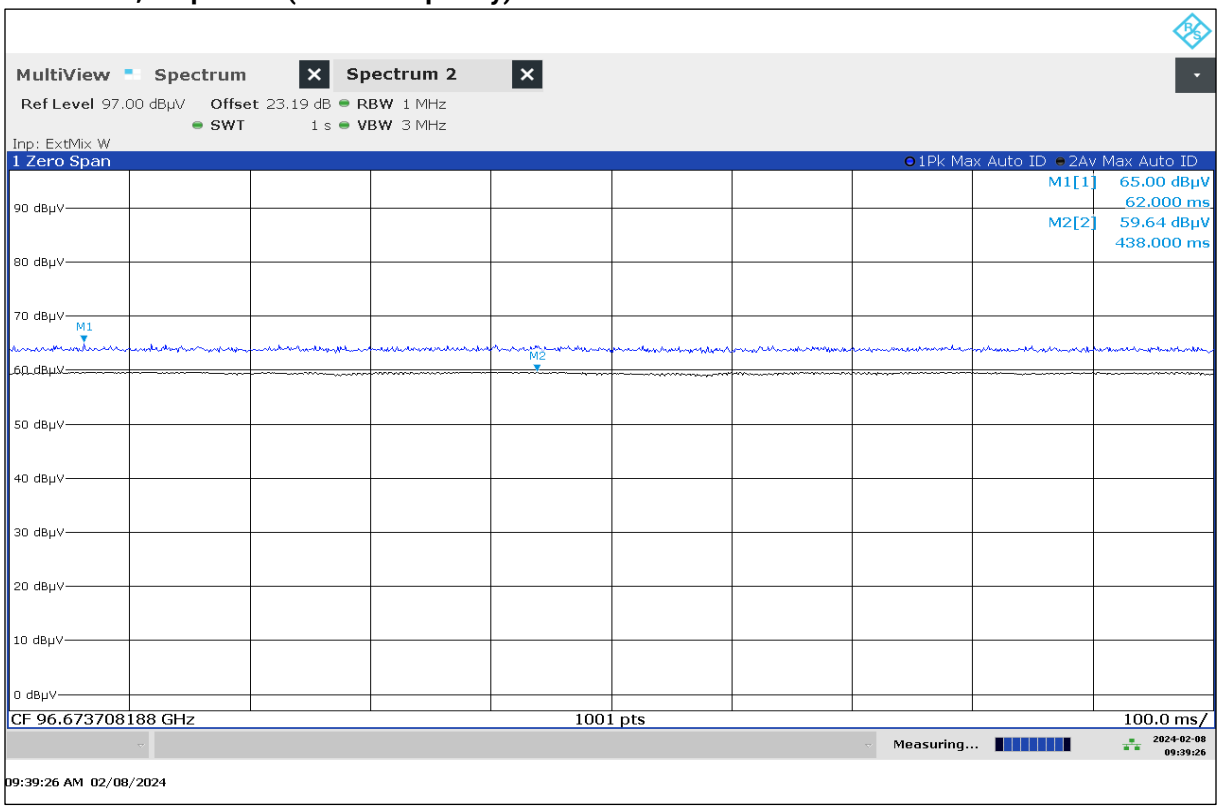
Plot 63: 75 GHz to 110 GHz, Stop Mode (low/middle/high frequency)



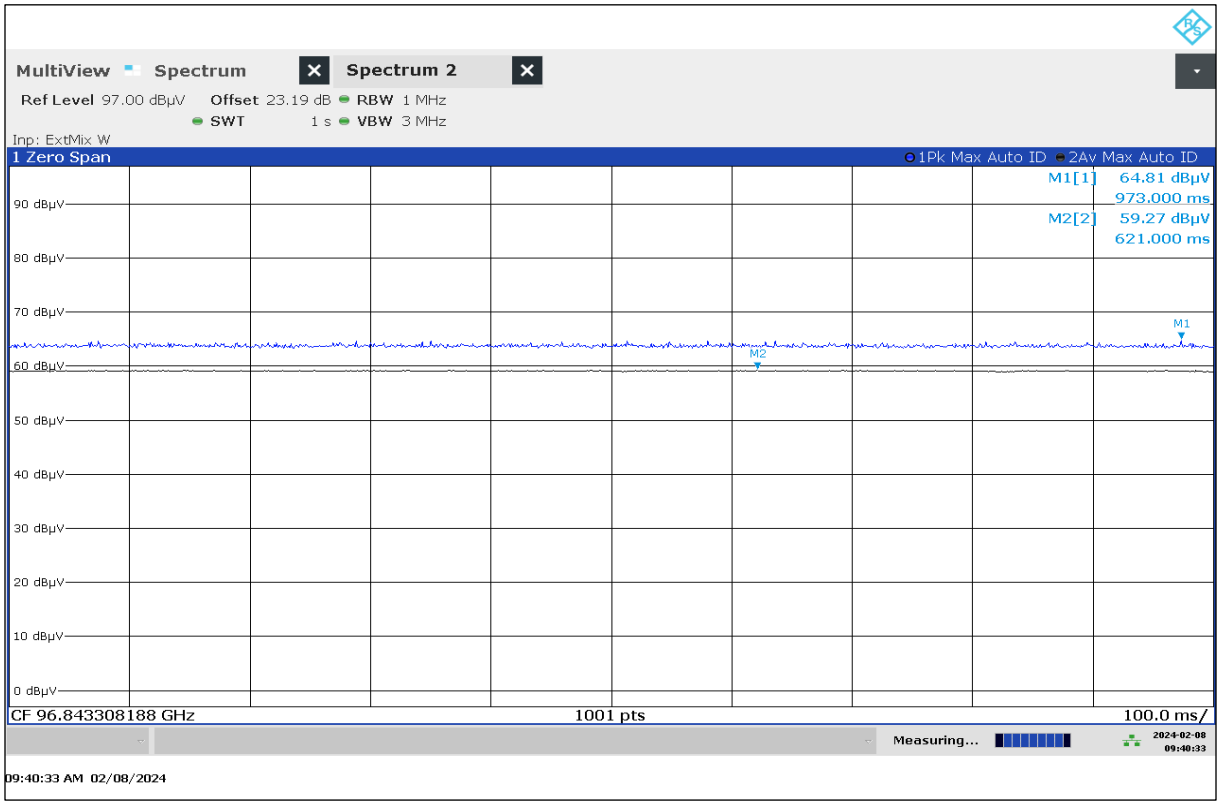
Plot 64: 96 GHz, Stop Mode (low frequency)



Plot 65: 96 GHz, Stop Mode (middle frequency)



Plot 66: 96 GHz, Stop Mode (high frequency)



12.5 Conducted emissions < 30MHz (AC power line)

Description:

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

Limits and provisions:

§15.207(a):
Except as shown in paragraphs (b) and (c) of this section, for an intentional radiator that is designed to be connected to the public utility (AC) power line, the radio frequency voltage that is conducted back onto the AC power line on any frequency or frequencies, within the band 150 kHz to 30 MHz, shall not exceed the limits in the following table, as measured using a 50 µH/50 ohms line impedance stabilization network (LISN). Compliance with the provisions of this paragraph shall be based on the measurement of the radio frequency voltage between each power line and ground at the power terminal. The lower limit applies at the boundary between the frequency ranges.

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

* Decreases with the logarithm of the frequency

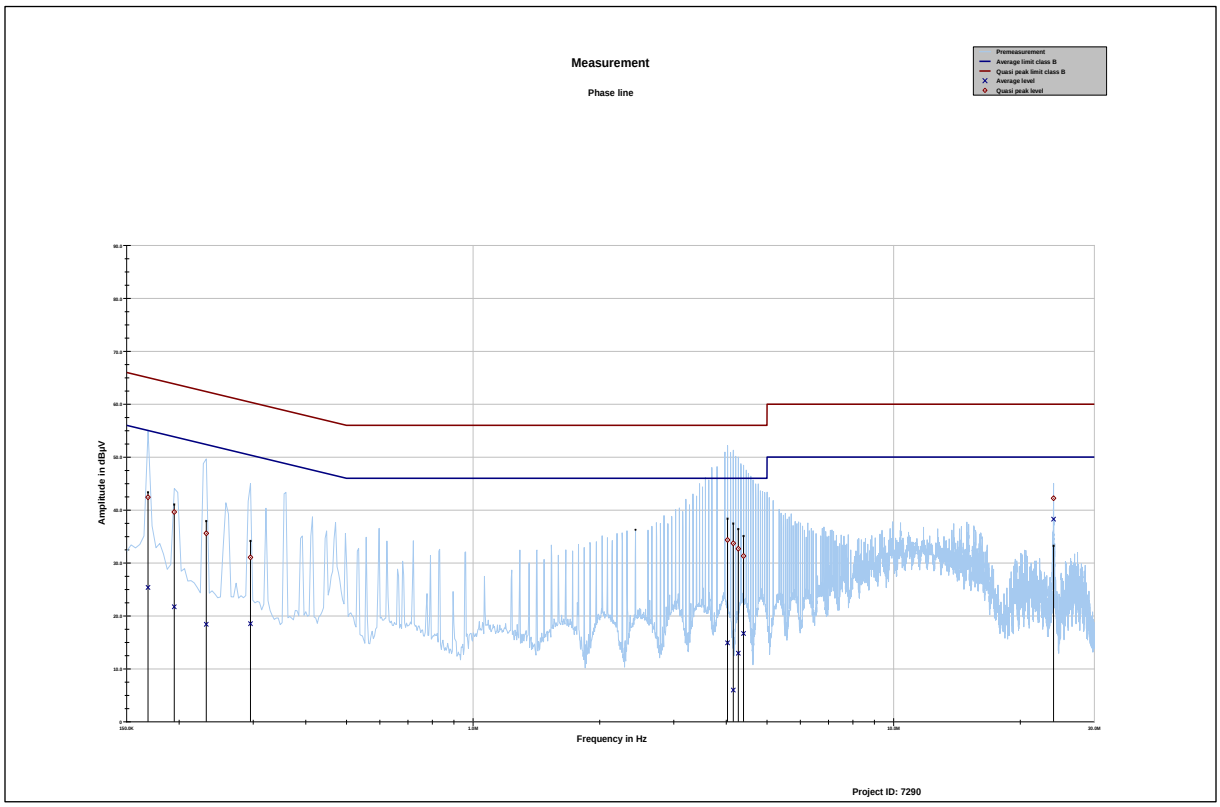
§15.207(c):
Measurements to demonstrate compliance with the conducted limits are not required for devices which only employ battery power for operation and which do not operate from the AC power lines or contain provisions for operation while connected to the AC power lines. Devices that include, or make provisions for, the use of battery chargers which permit operating while charging, AC adapters or battery eliminators or that connect to the AC power lines indirectly, obtainig their power through another device which is connected to the AC power lines, shall be tested to demonstrate compliance with the conducted limits.

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

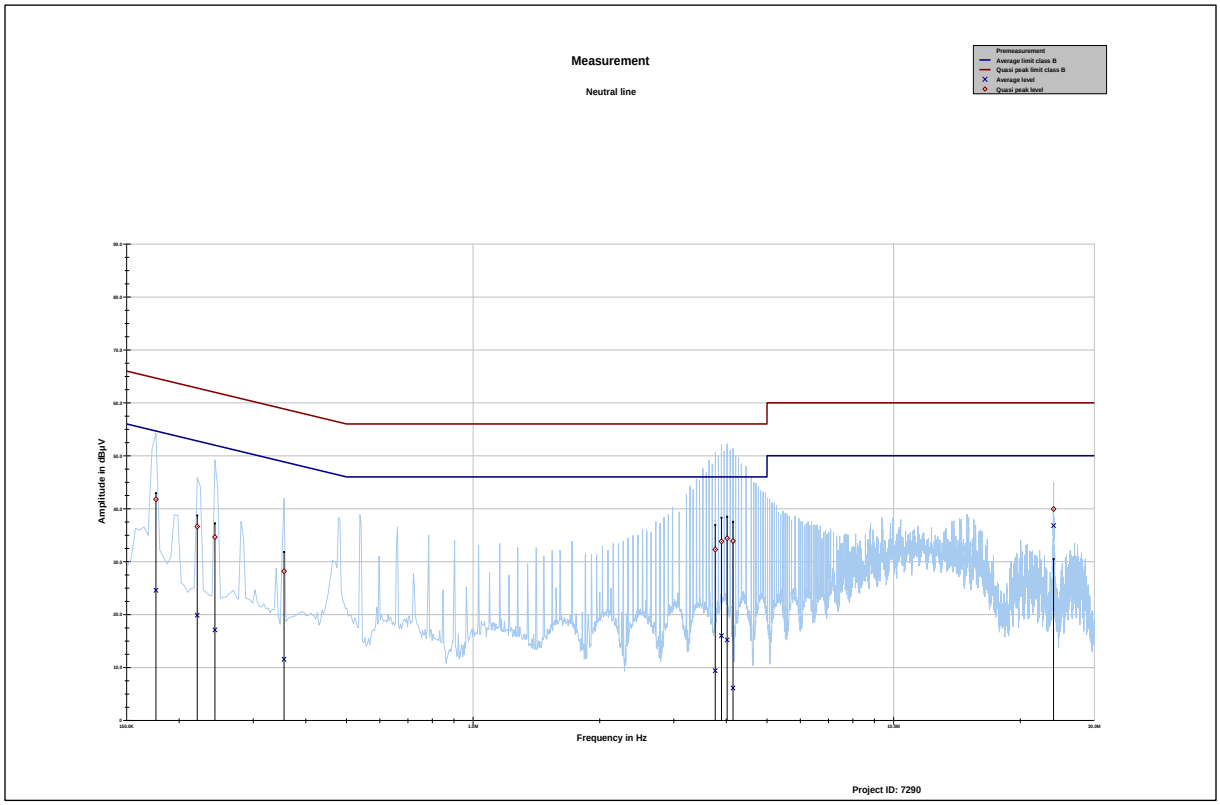
Measurement results:

Plot 67: Phase line



Frequency	Quasi peak level	Margin quasi peak	Limit QP	Average level	Margin average	Limit AV
MHz	dBµV	dB	dBµV	dBµV	dB	dBµV
0.168656	42.42	22.60	65.026	25.38	30.09	55.467
0.194775	39.63	24.20	63.830	21.72	33.00	54.721
0.232088	35.61	26.77	62.375	18.42	35.24	53.655
0.295519	31.06	29.31	60.368	18.53	33.31	51.842
4.026769	34.34	21.66	56.000	14.90	31.10	46.000
4.157362	33.73	22.27	56.000	5.98	40.02	46.000
4.273031	32.69	23.31	56.000	12.95	33.05	46.000
4.396162	31.32	24.68	56.000	16.67	29.33	46.000
24.003881	42.23	17.77	60.000	38.29	11.71	50.000

Plot 68: Neutral line



Frequency	Quasi peak level	Margin quasi peak	Limit QP	Average level	Margin Average	Limit AV
MHz	dBµV	dB	dBµV	dBµV	dB	dBµV
0.176119	41.77	22.90	64.667	24.58	30.67	55.254
0.220894	36.64	26.14	62.785	19.87	34.11	53.974
0.243281	34.63	27.35	61.983	17.10	36.24	53.335
0.355219	28.18	30.66	58.840	11.54	38.59	50.137
3.765581	32.27	23.73	56.000	9.38	36.62	46.000
3.896175	33.81	22.19	56.000	16.00	30.00	46.000
4.019306	34.41	21.59	56.000	15.21	30.79	46.000
4.149900	33.89	22.11	56.000	6.12	39.88	46.000
24.007613	39.94	20.06	60.000	36.79	13.21	50.000

Verdict: Compliant

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/N_0	Carrier to noise-density ratio, expressed in dB-Hz

14 Document history

Version	Applied changes	Date of release
-/-	Initial release - DRAFT	2024-02-23
-/-	Initial release	2024-02-28

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