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Radio Testing of the

Piaggio Fast Forward, Inc.

FCW Radar System
Part Number: F02129-FCW

In accordance with CFR 47 Part 95 Subpart M and RSS-251 Issue 2 July 2018

Piaggio Fast Forward, Inc.
52 Roland St.
Charlestown MA 02129

COMMERCIAL-IN-CONFIDENCE

Date: July 2023
Document Number: 72189104A Issue 02 | Version Number: 01

RESPONSIBLE FOR	NAME	DATE	SIGNATURE
Authorized Signatory	Ferdinand S. Custodio	July 06, 2023	

Signatures in this approval box have checked this document in line with the requirements of TÜV SÜD document control rules.

EXECUTIVE SUMMARY
A sample of this product was tested and found to be in compliance with CFR 47 Part 95 Subpart M and RSS-251 Issue 2 July 2018.

A2LA Cert. No. 2955.13

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REPORT ON	Radio Testing of the Piaggio Fast Forward, Inc. Model F02129-FCW FCW Radar System
TEST REPORT NUMBER	72189104A
TEST REPORT DATE	July 2023
PREPARED FOR	Piaggio Fast Forward, Inc. 52 Roland St. Charlestown MA 02129
CONTACT PERSON	Dr. David Bonyuet Senior Manager, Electrical Engineering d.bonyuet@piaggiofastforward.com 617-543-0690
PREPARED BY	Joe Salvador **Name** Authorized Signatory Title: Wireless/RF Test Engineer
APPROVED BY	Ferdinand S. Custodio **Name** Authorized Signatory Title: Senior EMC Test Engineer / Wireless Team Lead
DATED	July 6, 2023

Revision History

72189104A Piaggio Fast Forward, Inc. FCW Radar System Model F02129-FCW					
DATE	OLD REVISION	NEW REVISION	REASON	PAGES AFFECTED	APPROVED BY
07/06/2023	—	Initial Release			Ferdinand S. Custodio
09/13/2023	Initial Release	Issue 2	Updated Average power measurement as Band Power	15	Ferdinand S. Custodio

CONTENTS

SECTION 1

REPORT SUMMARY

Radio Testing of the
Piaggio Fast Forward, Inc.
FCW Radar System Model F02129-FCW

1.1 INTRODUCTION

The information contained in this report is intended to show verification of the Piaggio Fast Forward, Inc. FCW Radar System Model F02129-FCW to the requirements of CFR 47 Part 95 Subpart M and RSS-251 Issue 2 July 2018.

Objective	To perform Radio testing to determine the Equipment Under Test's (EUT's) compliance with the test specification, for the series of tests carried out.
Manufacturer	Piaggio Fast Forward, Inc.
EUT	FCW Radar System
Part Number	F02129-FCW
Serial Number(s)	PPFCW1000-002
FCC ID	2AY6H-101572
ISED Number	27808-101572
Number of Samples Tested	1
Test Specification/Issue/Date	• CFR 47 Part 95 Subpart M (October 1, 2020). • RSS-251 Issue 2 July 2018 Vehicular Radar and Airport Fixed or Mobile Radar in the 76-81 GHz Frequency Band
Start of Test	June 11, 2023
Finish of Test	June 27, 2023
Name of Engineer(s)	Joe Salvador, JS
Related Document(s)	• ANSI C63.10-2013. American National Standard of Procedures for Compliance testing of Unlicensed Wireless Devices. • FCW Software Configuration Procedure for TUV Test.pdf • Preliminary Forward Collision Warning Radar Design Document.docx

1.2 BRIEF SUMMARY OF RESULTS

A brief summary of the tests carried out in accordance with CFR 47 Part 95 Subpart M and RSS-251 Issue 2 July 2018 are shown below:

Part 2	Part 95 Subpart M	RSS-251 / RSS-Gen*	Test Description	Result
§2.1046	§95.3367 (b)	9	Radiated Power Limits – Peak Power (EIRP)	Compliant
	§95.3367 (a)	8	Radiated Power Limits – Average Power (EIRP)	Compliant
§2.1049		6.7*	Occupied Bandwidth	Compliant
§2.1047		6b	Modulation Characteristics	N/A
§2.1053	§95.3379	10 and 6.13*	Unwanted Emissions Limits	Compliant
§2.1055	§95.3379 (b)	11	Frequency Stability	Compliant

N/A -Not verified. Declared by the Manufacturer as part of the Operational Description exhibit. See also Technical Description section of this test report (Section 1.3.2).

1.3 PRODUCT INFORMATION

1.3.1 EUT General Description

The Equipment Under Test (EUT) is Piaggio Fast Forward, Inc. Part Number: F02129-FCW FCW Radar System as shown in the photographs below. The EUT warns the rider against collisions that may occur due to being too close to a front vehicle. FCW is intended to provide the rider with long range detection abilities. FCW is intended to detect vehicles to the front of the subject vehicle and warn the rider if reducing the speed is recommended.

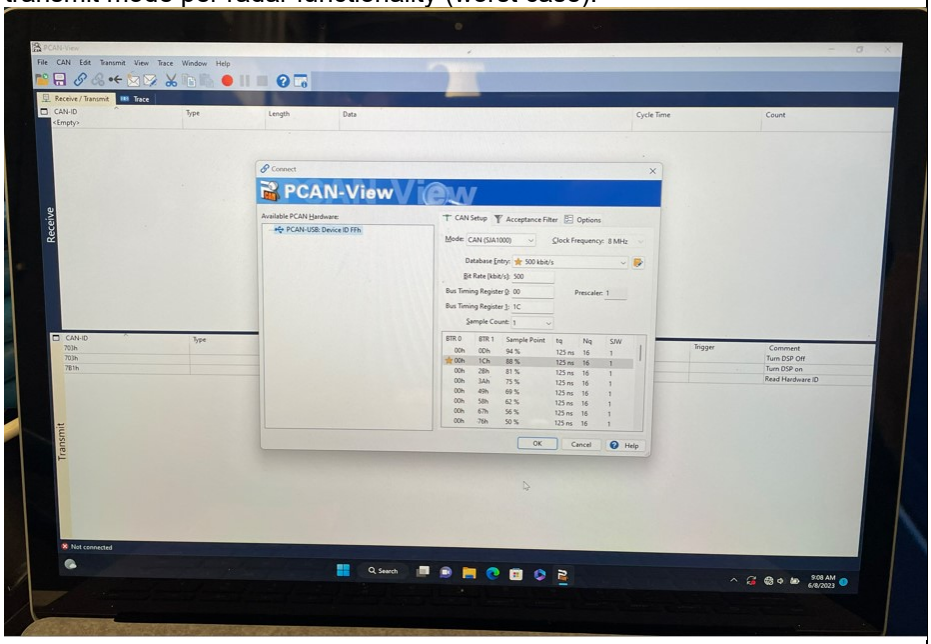
1.3.2 Technical Description

EUT Description	FCW Radar System
Model Number	F02129-FCW
Serial Number	PPFCW1000-002
Input Voltage	13.5VDC (8 – 16.5VDC Operating Range)
Frequency Range	76.88 to 76.95 GHz
Modulation Type	FMCW
Modulation Characteristic	Sawtooth
Chirp Time	50 µs Single chirp
Type of Equipment	☐ Fixed ☒ Mobile ☐ Portable

Bandwidth	80 MHz
No. of TX antennas	22
No. of RX antennas	23
Rated Power	30dBmi EIRP
Single TX antenna gain	9.5dBi
Effective antenna gain	23dBi (including MIMO combining)
Transmission duration	8msec
Frame duration	67msec
TX antenna beamwidth	± 20°

1.4 EUT TEST CONFIGURATION

1.4.1 Test Configuration Description

Test Configuration	Description
Default	The EUT only has one working mode, with a fixed power level. There are no modulation and/or duty cycle adjustments. The EUT is connected to a support laptop running PCAN-View through a PCAN-USB adapter. There are three (3) CAN-ID messages provided to program the EUT: 703h to turn ON and OFF the radar and 7B1 to verify if the FCW Radar is still functioning and answering commands. Testing was performed in default configuration of continuous transmit mode per radar functionality (worst case). 

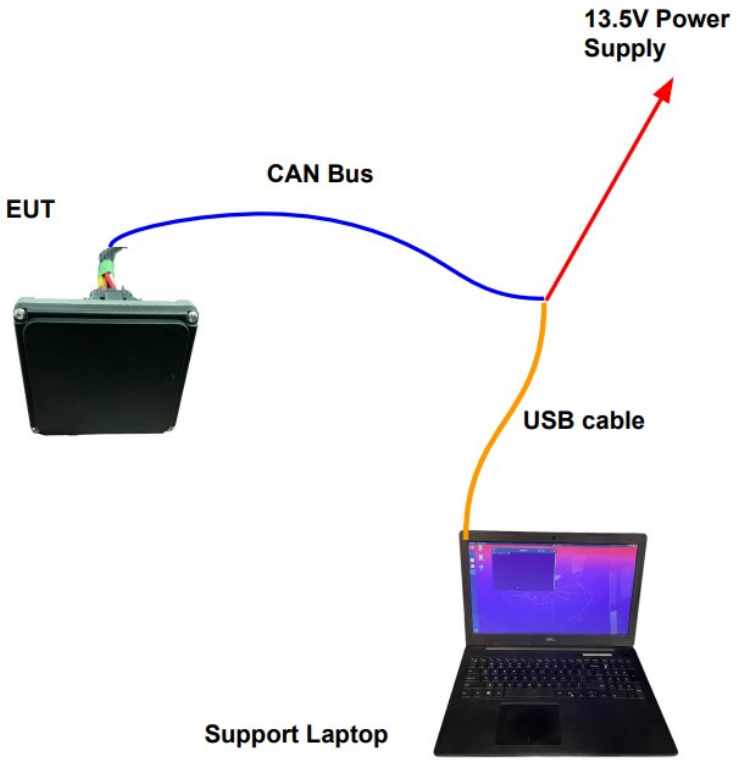
1.4.2 EUT Exercise Software

PCAN-View Version 5.0.5.871 (x64).

1.4.3 Support Equipment and I/O cables

Manufacturer	Equipment/Cable	Description
Microsoft	Support Laptop	Model Surface 1867 S/N 021909794257
phytools	PCAN-USB Adapter	Model IPEH-002021 S/N N/A
-	Custom cable	Cable assy to interface EUT with the PCAN-USB adapter. It has Molex connector for the EUT, serial for the adapter, manual switch, LED and DC connector for the AC adapter
TRIAD	Switching Mode Power Supply	Model 812WSU120-1000 S/N N/A

1.4.4 Simplified Test Configuration Diagram



1.5 DEVIATIONS FROM THE STANDARD

No deviations from the applicable test standards or test plan were made during testing.

1.6 MODIFICATION RECORD

Description of Modification	Modification Fitted By	Date Modification Fitted
Serial Number: No modifications		
None	—	—

The table above details modifications made to the EUT during the test programme. The modifications incorporated during each test (if relevant) are recorded on the appropriate test pages.

1.7 TEST METHODOLOGY

All measurements contained in this report were conducted with ANSI C63.10-2013. American National Standard of Procedures for Compliance testing of Unlicensed Wireless Devices.

For conducted and radiated emissions, the equipment under test (EUT) was configured to measure its highest possible emission level. This level was based on the maximized cable configuration from exploratory testing per ANSI C63.10-2013. The test modes were adapted according to the Operating Instructions provided by the manufacturer/client.

1.8 TEST FACILITY LOCATION

1.8.1 TÜV SÜD America Inc. (Mira Mesa)

10040 Mesa Rim Road, San Diego, CA 92121-2912 (32.901268,-117.177681). Phone: 858 678 1400 FAX: 858 546 0364

1.8.2 TÜV SÜD America Inc. (Rancho Bernardo)

16936 Via Del Campo, San Diego, CA 92127-1708 (33.018644,-117.092409). Phone: 858 678 1400 Fax: 858 546 0364.

1.9 TEST FACILITY REGISTRATION

1.9.1 FCC – Designation No.: US1146

TÜV SÜD America Inc. (San Diego), is an accredited test facility with the site description report on file and has met all the requirements specified in §2.948 of the FCC rules. The acceptance letter from the FCC is maintained in our files and the Designation is US1146.

1.9.2 Innovation, Science and Economic Development Canada (IC) Registration No.: 3067A-1 & 22806-1

The 10m Semi-anechoic chamber of TÜV SÜD America Inc. (San Diego Rancho Bernardo) has been registered by Certification and Engineering Bureau of Innovation, Science and Economic Development Canada for radio equipment testing with Registration No. 3067A-1.

The 3m Semi-anechoic chamber of TÜV SÜD America Inc. (San Diego Mira Mesa) has been registered by Certification and Engineering Bureau of Innovation, Science and Economic Development Canada for radio equipment testing with Registration No. 22806-1.

1.9.3 BSMI – Laboratory Code: SL2-IN-E-028R (US0102)

TÜV Product Service Inc. (San Diego) is a recognized EMC testing laboratory by the BSMI under the MRA (Mutual Recognition Arrangement) with the United States. Accreditation includes CNS 13438 up to 6GHz.

1.9.4 NCC (National Communications Commission - US0102)

TÜV SÜD America Inc. (San Diego) is listed as a Foreign Recognized Telecommunication Equipment Testing Laboratory and is accredited to ISO/IEC 17025 (A2LA Certificate No.2955.13) which under APEC TEL MRA Phase 1 was designated as a Conformity Assessment Body competent to perform testing of equipment subject to the Technical Regulations covered under its scope of accreditation including RTTE01, PLMN01 and PLMN08 for TTE type of testing and LP002 for Low-Power RF Device type of testing.

1.9.5 VCCI – Registration No. A-0280 and A-0281

TÜV SÜD America Inc. (San Diego) is a VCCI registered measurement facility which includes radiated field strength measurement, radiated field strength measurement above 1GHz, mains port interference measurement and telecommunication port interference measurement.

1.9.6 RRA – Identification No. US0102

TÜV SÜD America Inc. (San Diego) is National Radio Research Agency (RRA) recognized laboratory under Phase I of the APEC Tel MRA.

1.9.7 OFCA – U.S. Identification No. US0102

TÜV SÜD America Inc. (San Diego) is recognized by Office of the Communications Authority (OFCA) under Appendix B, Phase I of the APEC Tel MRA.

SECTION 2

TEST DETAILS

Radio Testing of the
Piaggio Fast Forward, Inc.
FCW Radar System Model F02129-FCW

2.1 RADIATED POWER LIMITS

2.1.1 Specification Reference

Part 2.1046(a), Part 95 Subpart M §95.3367(a) (b) and RSS-251 Sec. 8.0 and Section 9.0

2.1.2 Standard Applicable

The fundamental radiated emission limits within the 76-81 GHz band are expressed in terms of Equivalent Isotopically Radiated Power (EIRP) and are as follows:

(a) The maximum power (EIRP) within the 76-81 GHz band shall not exceed 50 dBm based on measurements employing a power averaging detector with a 1 MHz Resolution Bandwidth (RBW).

(b) The maximum peak power (EIRP) within the 76-81 GHz band shall not exceed 55 dBm based on measurements employing a peak detector with a 1 MHz RBW

2.1.3 Equipment Under Test and Modification State

Serial No: PPFCW1000-002 / Default Test Configuration

2.1.4 Date of Test/Initial of test personnel who performed the test

June 14, 2023 / JS

2.1.5 Test Equipment Used

The major items of test equipment used for the above tests are identified in Section 3.1.

2.1.6 Environmental Conditions

Test performed at TÜV SÜD America Inc. Mira Mesa facility

Ambient Temperature	27.7 °C
Relative Humidity	45.4 %
ATM Pressure	100.5 kPa

2.1.7 Additional Observations

- This is a radiated test.
- Test distance of 3 m was used for the fundamental emissions measurement.
- Offset is for the free space loss of the relevant frequency being investigated otherwise antenna gain is programmed as a transducer factor (TDF) while mixer conversion loss is programmed in the SA mixer setup.
- The FMCW chirps correction factor was calculated using the formula:

$$\mathrm{CF_{chirp}} = 5 \times \log\left(1 + \mathrm{K} \times \left(\frac{\mathrm{Span}}{\mathrm{t} \times \mathrm{RBW}^2}\right)^2\right)$$

- Guidance for calculating the correction factor is from Application Note 1EF107-1E Rohde & Schwarz Peak and Mean Power measurements on wideband FMCW radar signals.

- Sample calculation for FMCW chirps correction factor:

$$CF_{chirp} = 5 \times \log\left(1 + K \times \left(\frac{Span}{t \times RBW^2}\right)^2\right)$$

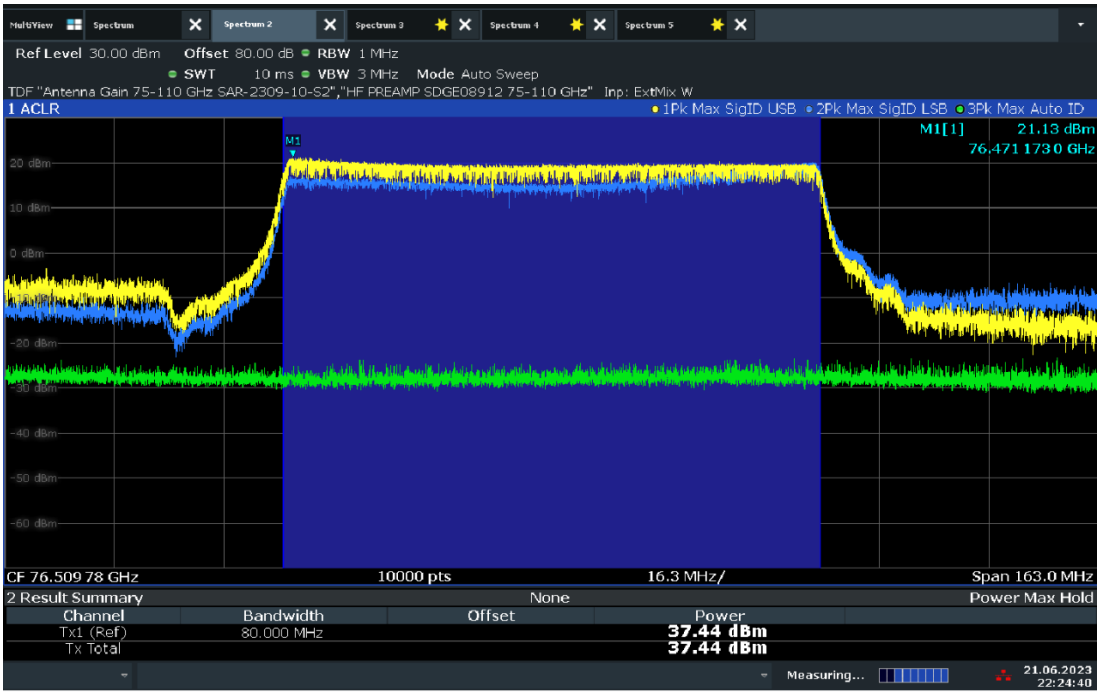
$$CF_{chirp} = 5 \times \log\left(1 + 0.1947 \times \left(\frac{80000\ MHz}{50\mu s \times 1MHz^2}\right)^2\right)$$

$$CF_{chirp} = 4.29\ dB$$

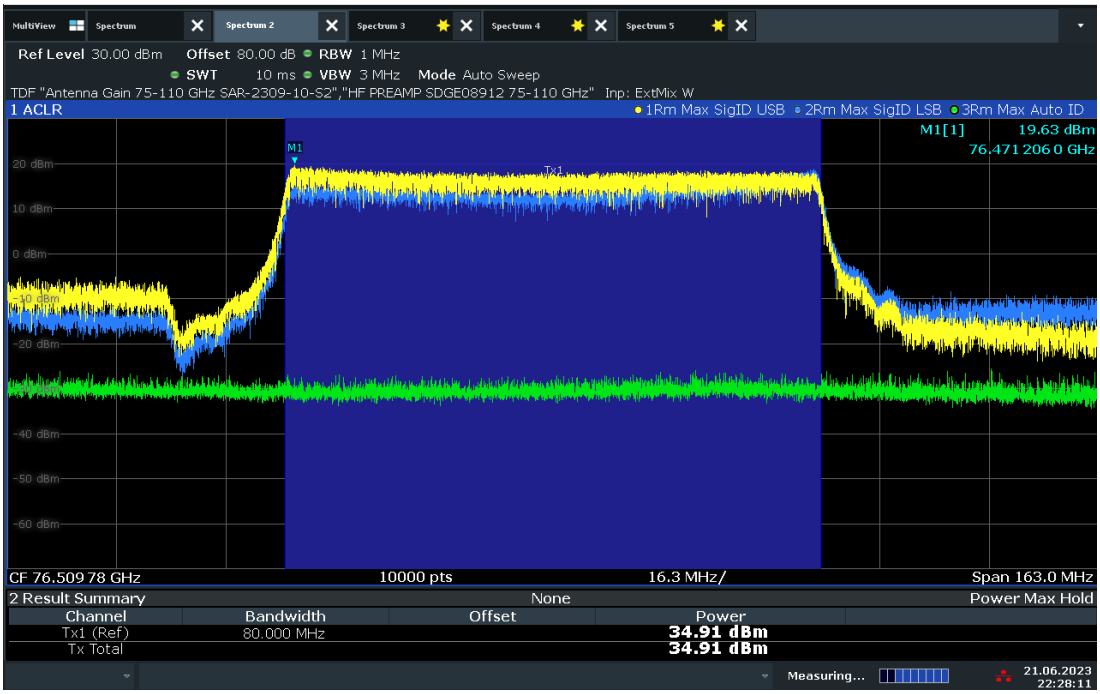
2.1.8 Test Results

Detector	Measured	FMCW Chirps Correction Factor	Corrected Level (EIRP)	EIRP Limit
Peak	21.13 dBm	4.29 dB	25.42	55 dBm
Average (Band Power)	34.91 dBm	-	34.91 dBm	50 dBm

2.1.9 Test Plots



Peak Power EIRP



Average Band Power EIRP (Max Hold)

2.2 OCCUPIED BANDWIDTH

2.2.1 Specification Reference

Part 2.1049 and RSS-GEN Issue 5 Section 6.7

2.2.2 Standard Applicable

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

2.2.3 Equipment Under Test and Modification State

Serial No: PPFCW1000-002 / Default Test Configuration

2.2.4 Date of Test/Initial of test personnel who performed the test

June 23, 2023 / JS

2.2.5 Test Equipment Used

The major items of test equipment used for the above tests are identified in Section 3.1.

2.2.6 Environmental Conditions

Test performed at TÜV SÜD America Inc. Mira Mesa facility

Ambient Temperature	28.8 °C
Relative Humidity	41.2 %
ATM Pressure	99.9 kPa

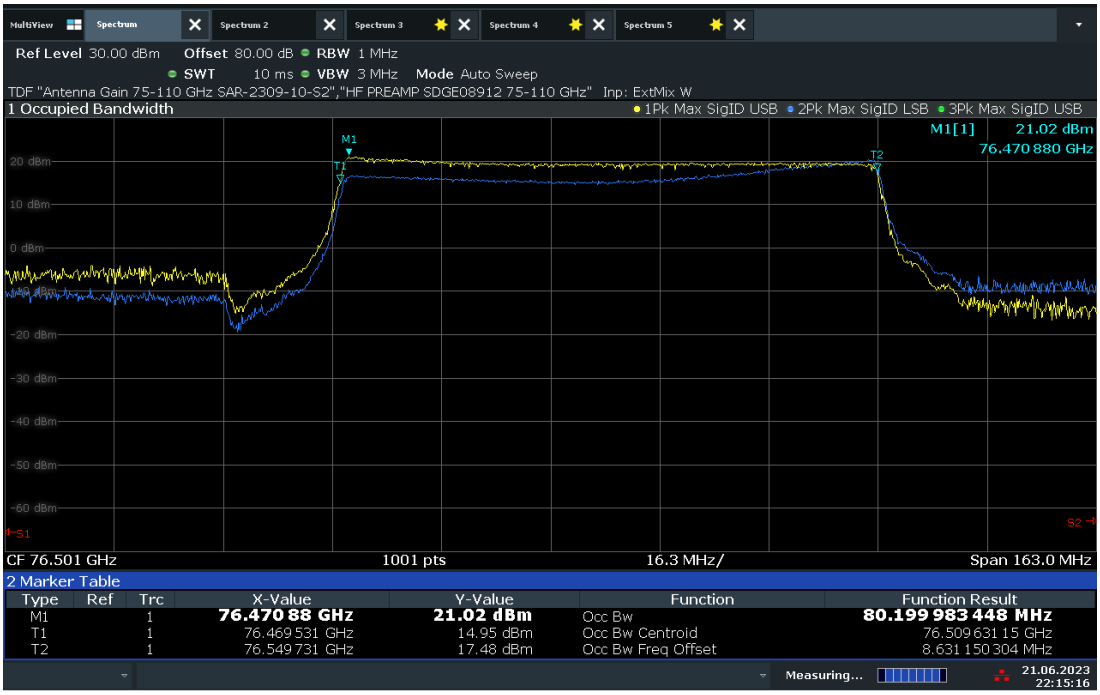
2.2.7 Additional Observations

- This is a radiated test.
- Span is wide enough to capture the channel transmission.
- VBW > RBW.
- Trace is max hold.
- Detector is peak.
- Sweep time is set to Auto.
- 99% OBW measurement function of the spectrum analyzer was used for this test.
- RBW is between 1% to 5% of the anticipated OBW.

2.2.8 Test Results

99% OBW	80.2 MHz

2.2.9 Test Plot



99% OBW

2.3 UNWANTED EMISSIONS LIMITS

2.3.1 Specification Reference

Part 2.1053, FCC Part 95 Subpart M §95.3379 and RSS-251 Section 10

2.3.2 Standard Applicable

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

(1) Radiated emissions below 40 GHz shall not exceed the field strength as shown in the following emissions table.

Frequency (MHz)	Field strength (microvolts/meter)	Measurement distance (meters)
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

(i) In the emissions table in paragraph (a)(1) of this section, the tighter limit applies at the band edges.

(ii) The limits in the table in paragraph (a)(1) of this section are based on the frequency of the unwanted emissions and not the fundamental frequency. However, the level of any unwanted emissions shall not exceed the level of the fundamental frequency.

(iii) The emissions limits shown in the table in paragraph (a)(1) of this section are based on measurements employing a CISPR quasi-peak detector except for the frequency bands 9.0-90.0 kHz, 110.0-490.0 kHz, and above 1000 MHz. Radiated emissions limits in these three bands are based on measurements employing an average detector with a 1 MHz RBW.

(2) The power density of radiated emissions outside the 76-81 GHz band above 40.0 GHz shall not exceed the following, based on measurements employing an average detector with a 1 MHz RBW:

(i) For radiated emissions outside the 76-81 GHz band between 40 GHz and 200 GHz from field disturbance sensors and radar systems operating in the 76-81 GHz band: 600 pW/cm2 at a distance of 3 meters from the exterior surface of the radiating structure.

(ii) For radiated emissions above 200 GHz from field disturbance sensors and radar systems operating in the 76-81 GHz band: 1000 pW/cm2 at a distance of 3 meters from the exterior surface of the radiating structure.

(3) For field disturbance sensors and radar systems operating in the 76-81 GHz band, the spectrum shall be investigated up to 231.0 GHz.

For radar devices that operate solely in the 76-77 GHz band (i.e. the occupied bandwidth is entirely contained in the 76-77 GHz band), an unwanted emissions limit of 0 dBm/MHz shall apply for the unwanted emission that fall in the 73.5-76 GHz band. Outside of the 73.5-76 GHz band, the unwanted emission limits prescribed in table 1 shall apply.

2.3.3 Equipment Under Test and Modification State

Serial No: PPFCW1000-002 / Default Test Configuration

2.3.4 Date of Test/Initial of test personnel who performed the test

June 11 to 23, 2023 / JS

2.3.5 Test Equipment Used

The major items of test equipment used for the above tests are identified in Section 3.1.

2.3.6 Environmental Conditions

Test performed at TÜV SÜD America Inc. Mira Mesa facility

Ambient Temperature	22.8 – 27.8 °C
Relative Humidity	39.6 – 42.9 %
ATM Pressure	100.1– 100.5 kPa

2.3.7 Additional Observations

- This is a radiated test.
- The spectrum was searched from 30MHz to 231GHz.
- Measurement was done using EMC32 automated software for below 40GHz. Reported level is the actual level with all the correction factors factored in. Correction Factor column is for informational purposes only. See below table for sample computation at 30MHz:

Measuring equipment raw measurement (dbµV) @ 30 MHz			24.4
Correction Factor (dB)	Asset# 1066 (cable)	0.3	-12.6
	Asset# 1172 (cable)	0.3	
	Asset# 1016 (preamplifier)	-30.7	
	Asset# 1175(cable)	0.3	
	Asset# 1002 (antenna)	17.2	
Reported QuasiPeak Final Measurement (dbµV/m) @ 30MHz			**11.8**

- For measurements above 40GHz, the corresponding transducer factor (TDF) were programmed directly to the Spectrum Analyzer (e.g. antenna gain, LNA and the free space loss).
- Measurement above 40GHz are maximized by hand and the worst case plot (max hold) presented.
- Tests distances and frequency ranges performed are summarized below:

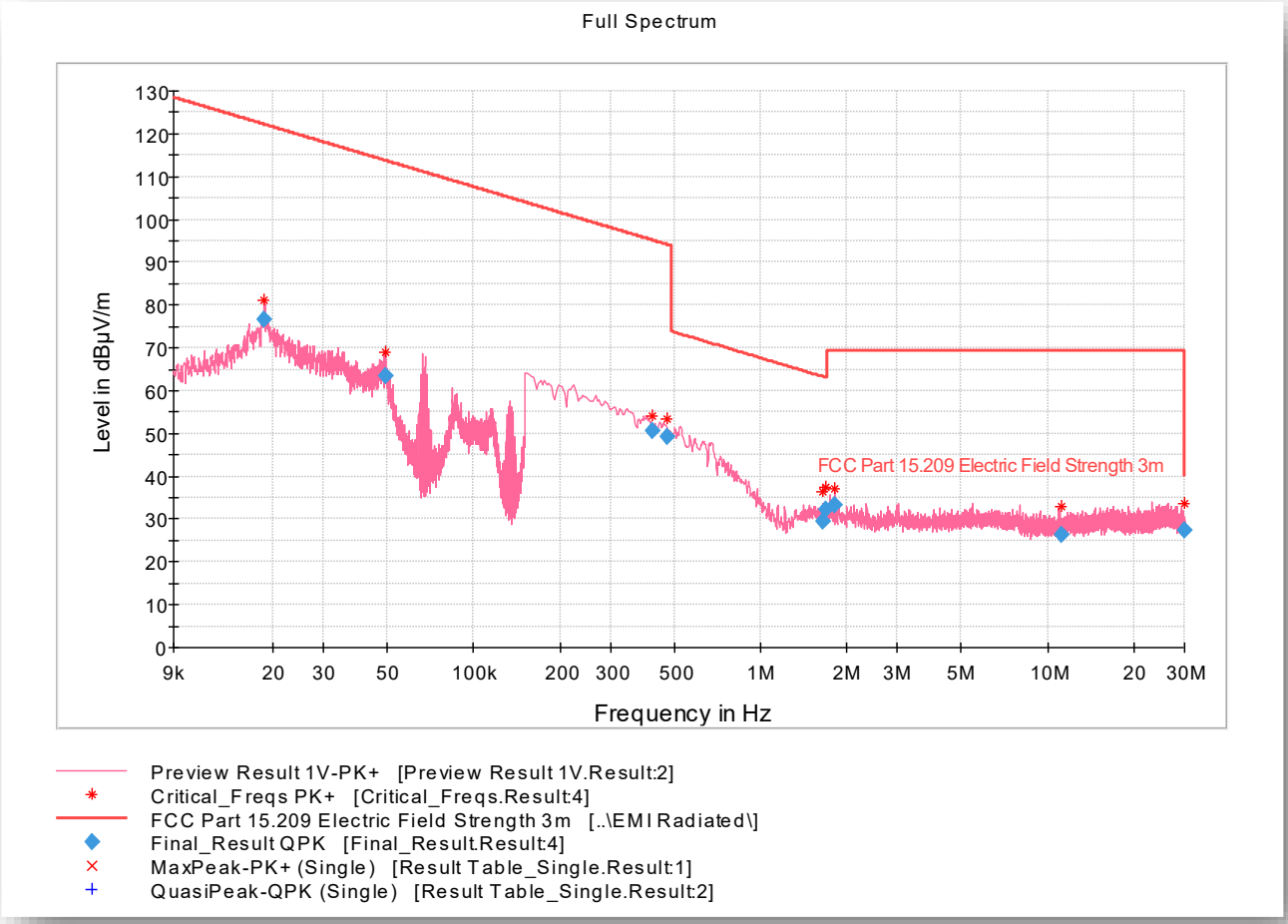
Frequency Range	Test Distance
30 MHz to 1GHz	3 meters
1 GHz to 18 GHz	3 meters
18 GHz to 26 GHz	3 meters
26 GHz to 40 GHz	3 meters

40 GHz to 60 GHz	3 meters
60 GHz to 75 GHz	3 meters
75 GHz to 81 GHz	3 meters
81 GHz to 110 GHz	1 meter
110 GHz to 160 GHz	1 meter
140 GHz to 220 GHz	1 meter
220 GHz to 231 GHz	0.2 meter

2.3.8 Test Results

Complies. See attached plots.

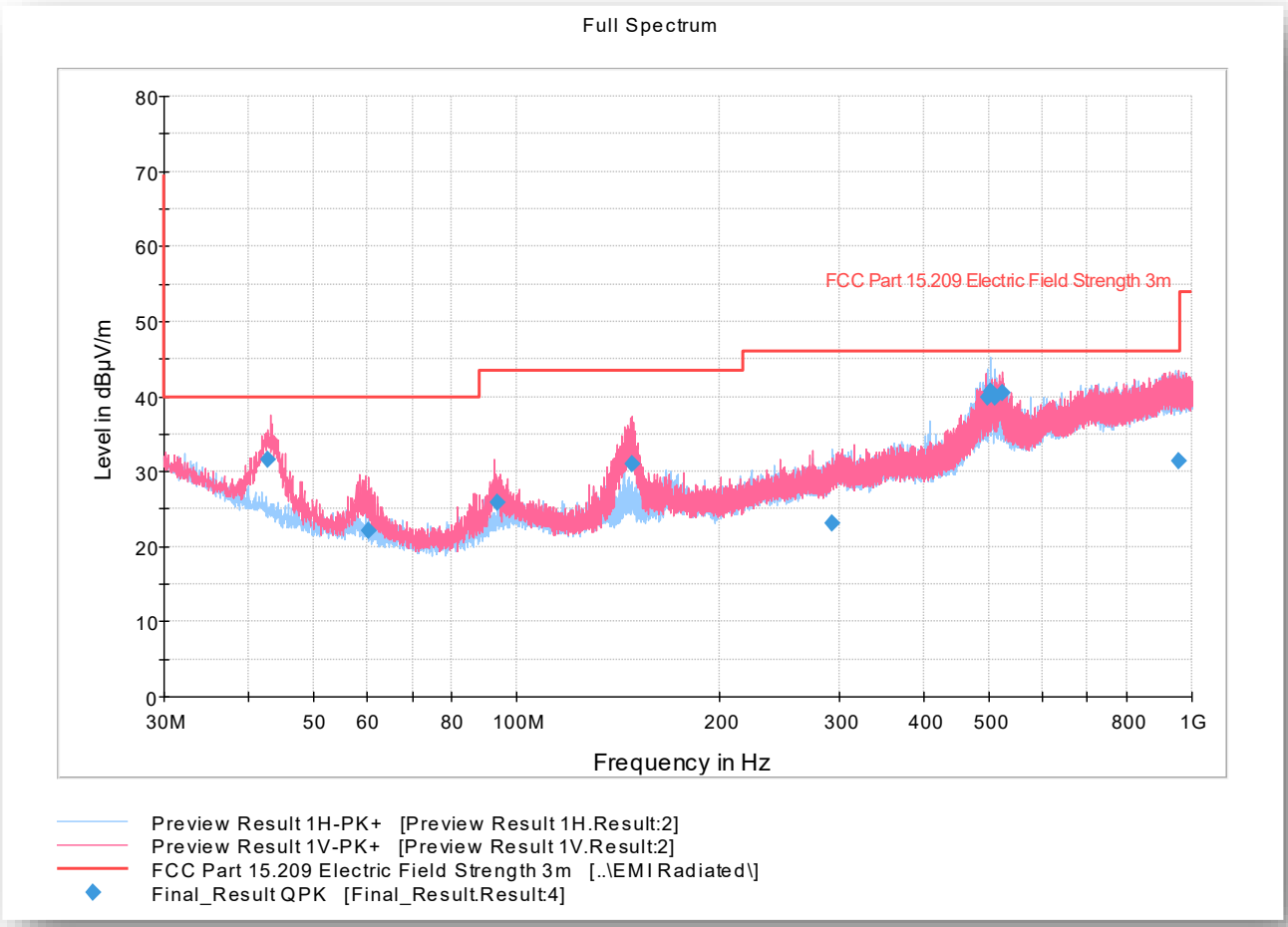
2.3.9 Below 30MHz Radiated Emission Test



Quasi-Peak Data

Frequency (MHz)	QuasiPeak (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Meas. Time (ms)	Bandwidth (kHz)	Pol	Height (cm)	Azimuth (degrees)	Corr. (dB/m)
0.018700	76.56	122.16	45.60	1000.0	0.200	400.0	H	324.0	22
0.049054	63.54	113.79	50.25	1000.0	0.200	400.0	H	228.0	20
0.417730	50.51	95.19	44.68	1000.0	9.000	400.0	H	358.0	19
0.474625	49.27	94.08	44.81	1000.0	9.000	400.0	H	60.0	20
1.653238	29.36	63.23	33.86	1000.0	9.000	400.0	H	306.0	20
1.678620	32.25	63.10	30.85	1000.0	9.000	400.0	H	173.0	20
1.821502	33.17	69.50	36.33	1000.0	9.000	400.0	H	312.0	20
11.141610	26.33	69.50	43.17	1000.0	9.000	400.0	H	16.0	21
29.946115	27.30	69.50	42.20	1000.0	9.000	400.0	H	60.0	25

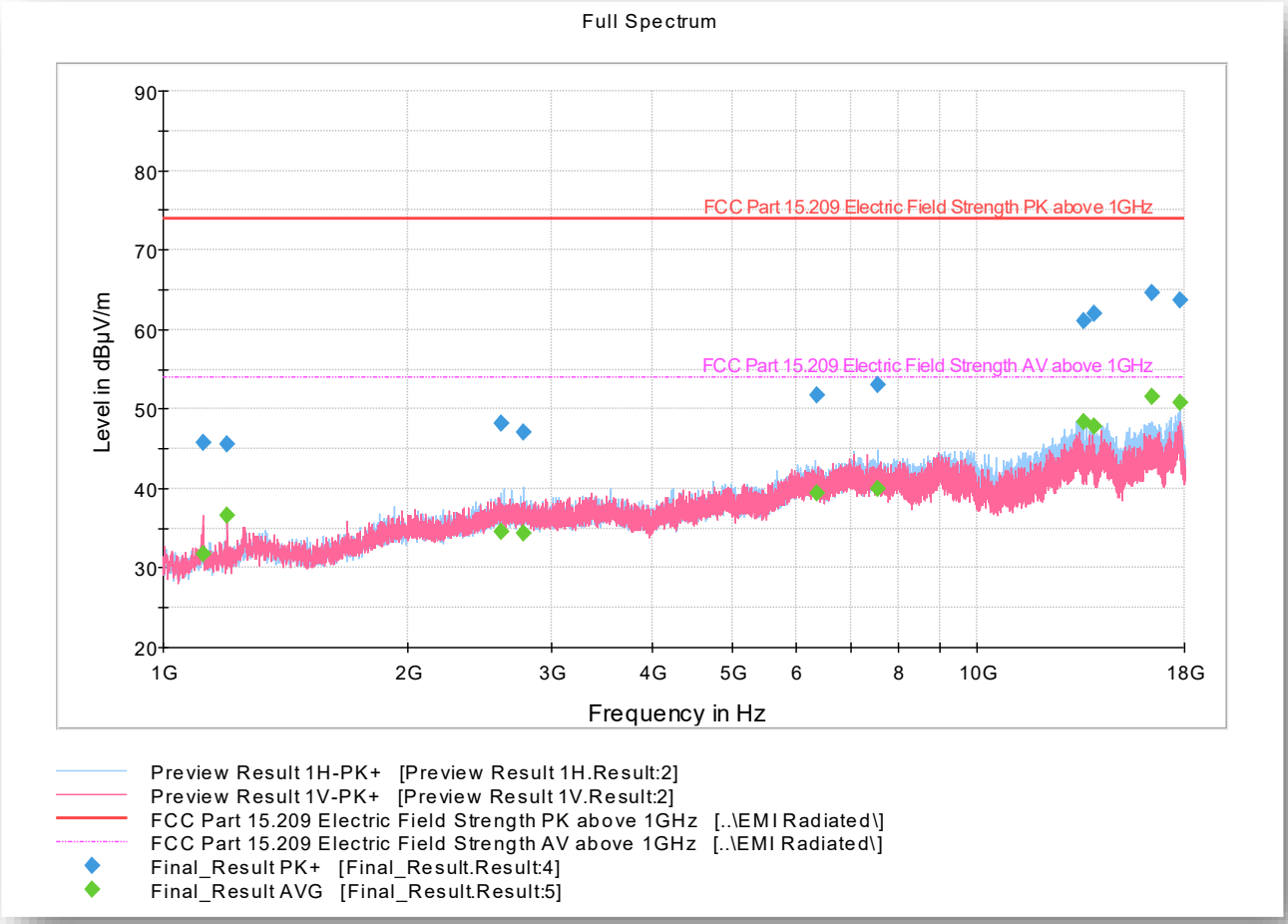
2.3.10 30MHz to 1GHz Radiated Emission Test



Quasi-Peak Data

Frequency (MHz)	QuasiPeak (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Meas. Time (ms)	Bandwidth (kHz)	Height (cm)	Pol	Azimuth (deg)	Corr. (dB/m)
42.784333	31.61	40.00	8.39	1000.0	120.000	100.0	V	199.0	16
60.102667	22.22	40.00	17.78	1000.0	120.000	118.0	V	11.0	13
93.372667	25.97	43.50	17.53	1000.0	120.000	162.0	V	146.0	15
147.879667	30.98	43.50	12.52	1000.0	120.000	100.0	V	251.0	15
293.460667	23.15	46.00	22.85	1000.0	120.000	125.0	H	-11.0	20
498.448000	39.87	46.00	6.13	1000.0	120.000	165.0	H	219.0	25
503.271333	40.74	46.00	5.26	1000.0	120.000	162.0	H	123.0	25
510.180667	39.83	46.00	6.17	1000.0	120.000	175.0	H	138.0	25
522.758000	40.43	46.00	5.57	1000.0	120.000	169.0	V	171.0	26
956.303333	31.49	46.00	14.51	1000.0	120.000	110.0	V	137.0	31

2.3.11 From 1GHz to 18GHz Radiated Emission Test



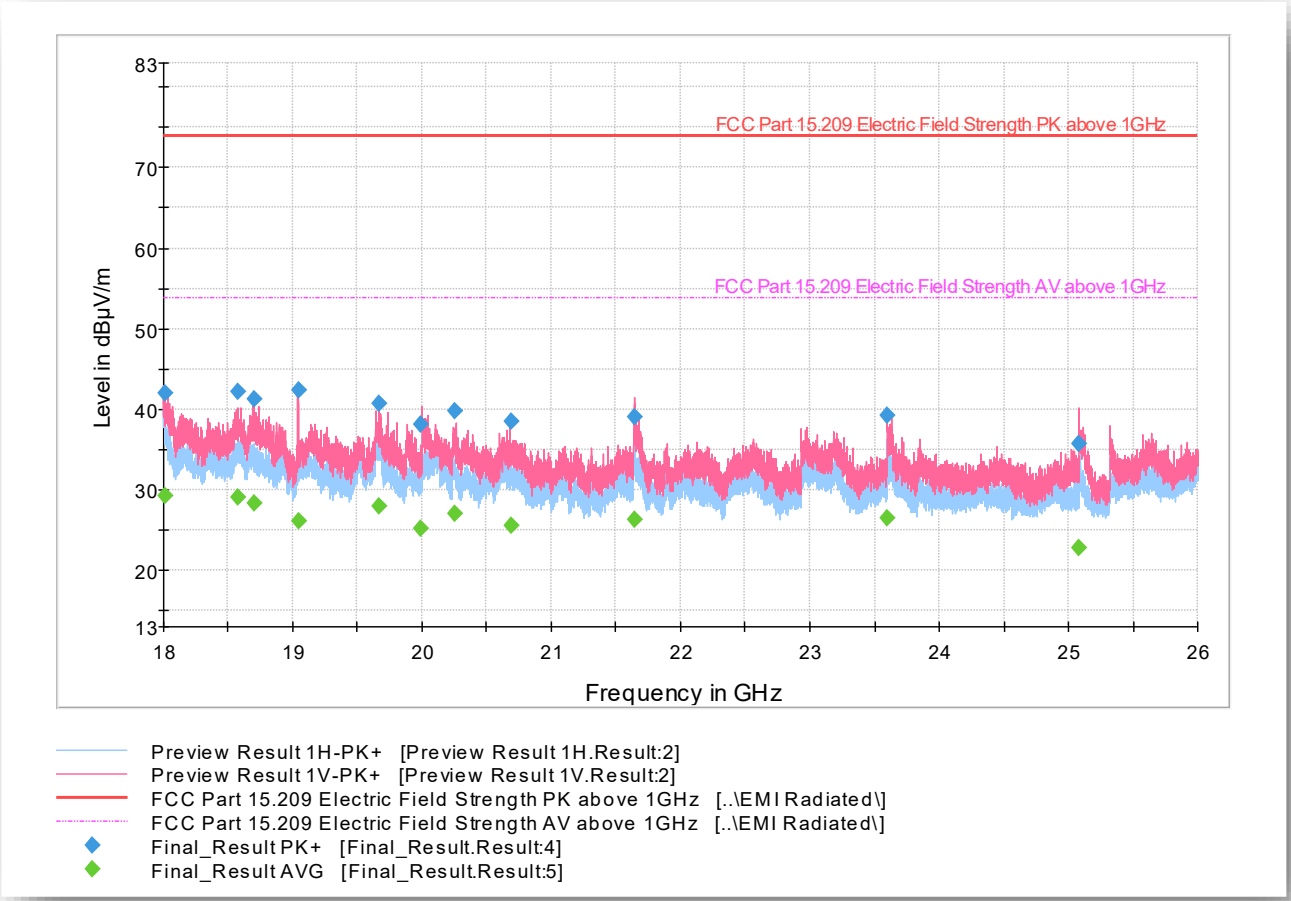
Peak Data

Frequency (MHz)	MaxPeak (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Meas. Time (ms)	Bandwidth (kHz)	Height (cm)	Pol	Azimuth (deg)	Corr. (dB/m)
1120.46666	45.76	73.90	28.14	1000.0	1000.000	335.0	V	208.0	-1
1200.06666	45.62	73.90	28.28	1000.0	1000.000	236.0	V	72.0	-1
2603.60000	48.23	73.90	25.67	1000.0	1000.000	320.0	H	9.0	5
2768.93333	47.12	73.90	26.78	1000.0	1000.000	315.0	H	17.0	5
6353.30000	51.81	73.90	22.09	1000.0	1000.000	175.0	H	23.0	9
7539.20000	53.02	73.90	20.88	1000.0	1000.000	255.0	H	30.0	11
13529.0333	61.10	73.90	12.80	1000.0	1000.000	242.0	H	295.0	18
13953.5666	62.06	73.90	11.84	1000.0	1000.000	250.0	H	73.0	18
16405.7333	64.57	73.90	9.33	1000.0	1000.000	169.0	H	52.0	21
17782.5000	63.68	73.90	10.22	1000.0	1000.000	140.0	H	284.0	23

Average Data

Frequency (MHz)	Average (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Meas. Time (ms)	Bandwidth (kHz)	Height (cm)	Pol	Azimuth (deg)	Corr. (dB/m)
1120.46666	31.79	53.90	22.11	1000.0	1000.000	335.0	V	208.0	-1
1200.06666	36.64	53.90	17.26	1000.0	1000.000	247.0	V	60.0	-1
2603.60000	34.59	53.90	19.31	1000.0	1000.000	320.0	H	9.0	5
2768.93333	34.35	53.90	19.55	1000.0	1000.000	315.0	H	17.0	5
6353.30000	39.42	53.90	14.48	1000.0	1000.000	175.0	H	23.0	9
7539.20000	39.94	53.90	13.96	1000.0	1000.000	255.0	H	30.0	11
13529.0333	48.30	53.90	5.60	1000.0	1000.000	242.0	H	295.0	18
13953.5666	47.86	53.90	6.04	1000.0	1000.000	250.0	H	73.0	18
16405.7333	51.48	53.90	2.42	1000.0	1000.000	169.0	H	52.0	21
17782.5000	50.73	53.90	3.17	1000.0	1000.000	140.0	H	284.0	23

2.3.12 18GHz to 26GHz Radiated Emission Test



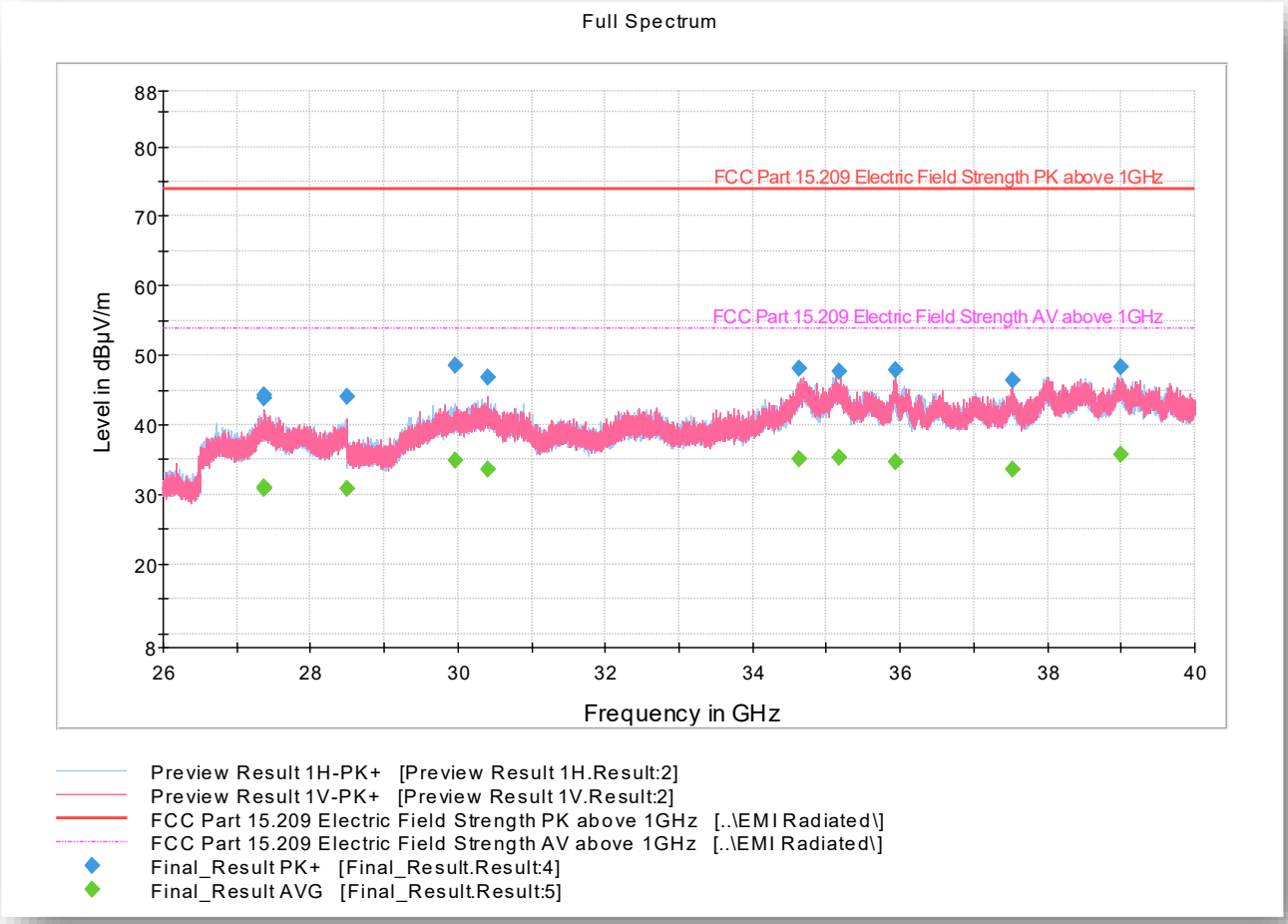
Peak Data

Frequency (MHz)	MaxPeak (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Meas. Time (ms)	Bandwidth (kHz)	Height (cm)	Pol	Azimuth (deg)	Corr. (dB/m)
18007.9463	42.03	73.90	31.87	1000.0	1000.000	154.0	V	105.0	-2
18579.9875	42.09	73.90	31.81	1000.0	1000.000	162.0	V	96.0	-3
18699.3735	41.26	73.90	32.64	1000.0	1000.000	162.0	V	71.0	-3
19041.2815	42.41	73.90	31.49	1000.0	1000.000	162.0	V	68.0	-3
19670.9410	40.64	73.90	33.26	1000.0	1000.000	141.0	V	47.0	-3
19989.8595	38.06	73.90	35.84	1000.0	1000.000	162.0	V	90.0	-3
20252.8820	39.72	73.90	34.18	1000.0	1000.000	162.0	V	144.0	-4
20688.9650	38.44	73.90	35.46	1000.0	1000.000	162.0	V	140.0	-3
21647.9585	38.98	73.90	34.92	1000.0	1000.000	162.0	V	14.0	-2
23600.8365	39.15	73.90	34.75	1000.0	1000.000	162.0	V	47.0	-1
25083.2520	35.71	73.90	38.19	1000.0	1000.000	156.0	V	117.0	-1

Average Data

Frequency (MHz)	Average (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Meas. Time (ms)	Bandwidth (kHz)	Height (cm)	Pol	Azimuth (deg)	Corr. (dB/m)
18007.9463	29.27	53.90	24.63	1000.0	1000.000	154.0	V	105.0	-2
18579.9875	29.02	53.90	24.88	1000.0	1000.000	162.0	V	96.0	-3
18699.3735	28.30	53.90	25.60	1000.0	1000.000	162.0	V	71.0	-3
19041.2815	26.08	53.90	27.82	1000.0	1000.000	162.0	V	68.0	-3
19670.9410	27.99	53.90	25.91	1000.0	1000.000	141.0	V	47.0	-3
19989.8595	25.25	53.90	28.65	1000.0	1000.000	162.0	V	90.0	-3
20252.8820	27.06	53.90	26.84	1000.0	1000.000	162.0	V	144.0	-4
20688.9650	25.49	53.90	28.41	1000.0	1000.000	162.0	V	140.0	-3
21647.9585	26.24	53.90	27.66	1000.0	1000.000	162.0	V	14.0	-2
23600.8365	26.49	53.90	27.41	1000.0	1000.000	162.0	V	47.0	-1
25083.2520	22.86	53.90	31.04	1000.0	1000.000	156.0	V	117.0	-1

2.3.13 26GHz to 40GHz Radiated Emission Test

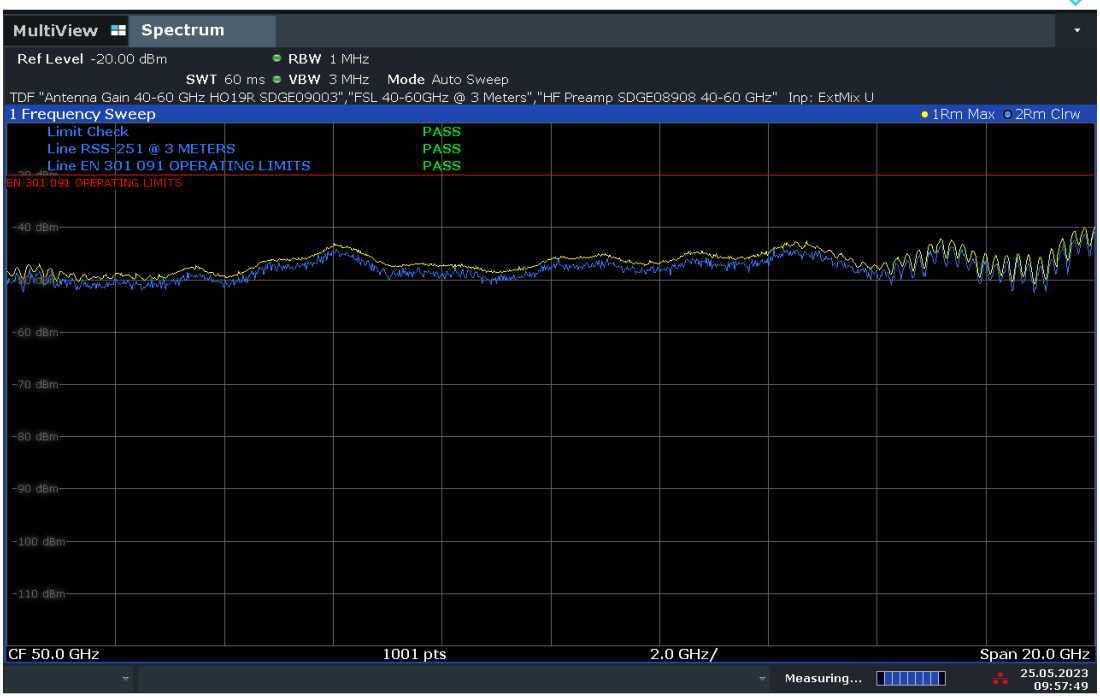


Peak Data

Frequency (MHz)	MaxPeak (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Meas. Time (ms)	Bandwidth (kHz)	Height (cm)	Pol	Azimuth (deg)	Corr. (dB/m)
27374.6365	43.89	73.90	30.01	1000.0	1000.000	146.0	V	184.0	4
27375.7576	44.24	73.90	29.66	1000.0	1000.000	175.0	V	184.0	4
28493.5646	44.05	73.90	29.85	1000.0	1000.000	175.0	V	225.0	5
29964.6053	48.56	73.90	25.34	1000.0	1000.000	175.0	H	226.0	8
30407.7253	46.73	73.90	27.17	1000.0	1000.000	175.0	V	357.0	7
34632.3819	48.04	73.90	25.86	1000.0	1000.000	159.0	H	309.0	8
35175.4834	47.75	73.90	26.15	1000.0	1000.000	140.0	V	280.0	8
35931.3273	47.81	73.90	26.09	1000.0	1000.000	123.0	V	79.0	8
37527.7819	46.39	73.90	27.51	1000.0	1000.000	152.0	V	294.0	8
38991.4450	48.36	73.90	25.54	1000.0	1000.000	175.0	H	166.0	9

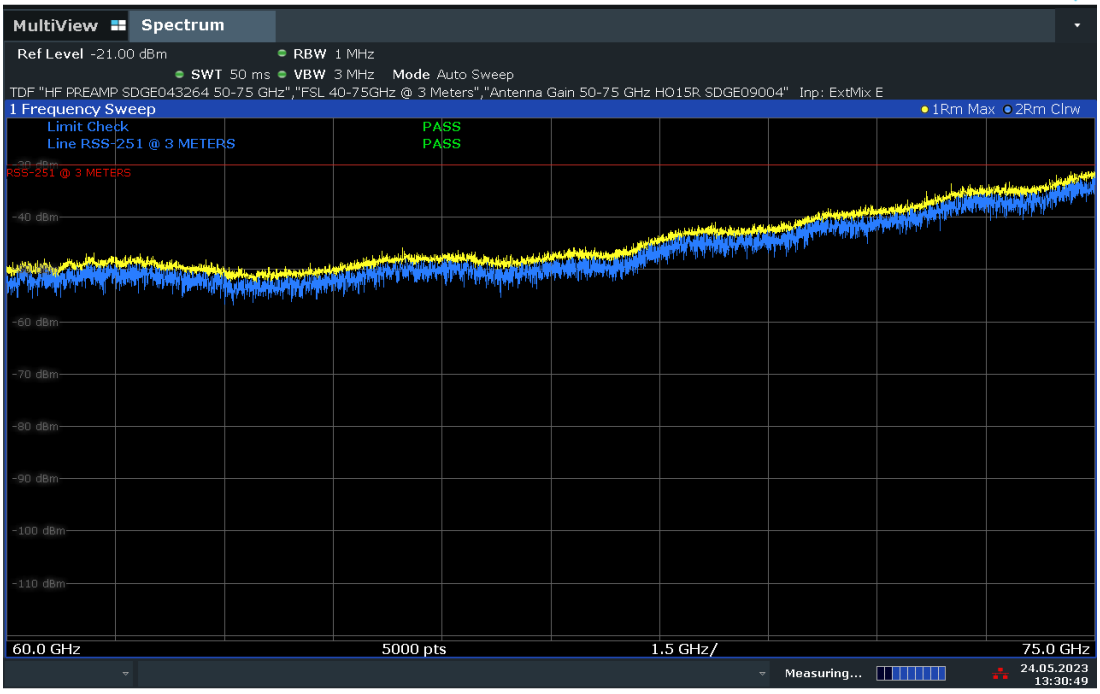
Average Data

Frequency (MHz)	Average (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Meas. Time (ms)	Bandwidth (kHz)	Height (cm)	Pol	Azimuth (deg)	Corr. (dB/m)
27374.6365	30.95	53.90	22.95	1000.0	1000.000	146.0	V	184.0	4
27375.7576	30.87	53.90	23.03	1000.0	1000.000	175.0	V	184.0	4
28493.5646	30.74	53.90	23.16	1000.0	1000.000	175.0	V	225.0	5
29964.6053	34.80	53.90	19.10	1000.0	1000.000	175.0	H	226.0	8
30407.7253	33.59	53.90	20.31	1000.0	1000.000	175.0	V	357.0	7
34632.3819	35.04	53.90	18.86	1000.0	1000.000	159.0	H	309.0	8
35175.4834	35.28	53.90	18.62	1000.0	1000.000	140.0	V	280.0	8
35931.3273	34.70	53.90	19.20	1000.0	1000.000	123.0	V	79.0	8
37527.7819	33.67	53.90	20.23	1000.0	1000.000	152.0	V	294.0	8
38991.4450	35.74	53.90	18.16	1000.0	1000.000	175.0	H	166.0	9



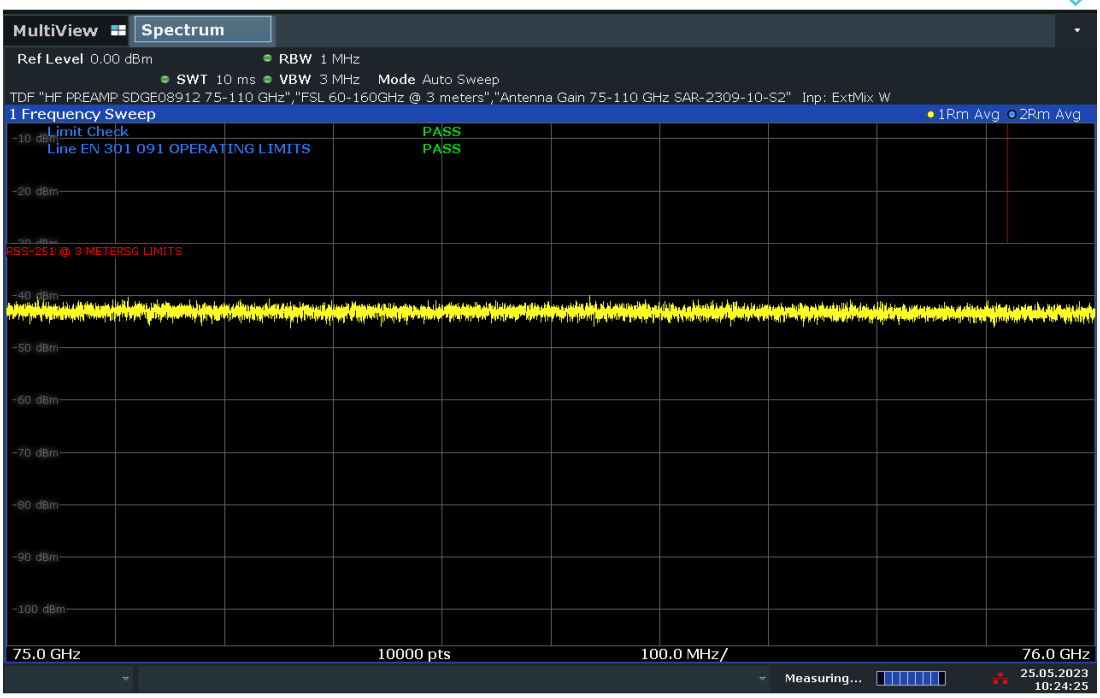
09:57:50 25.05.2023

40-60 GHz



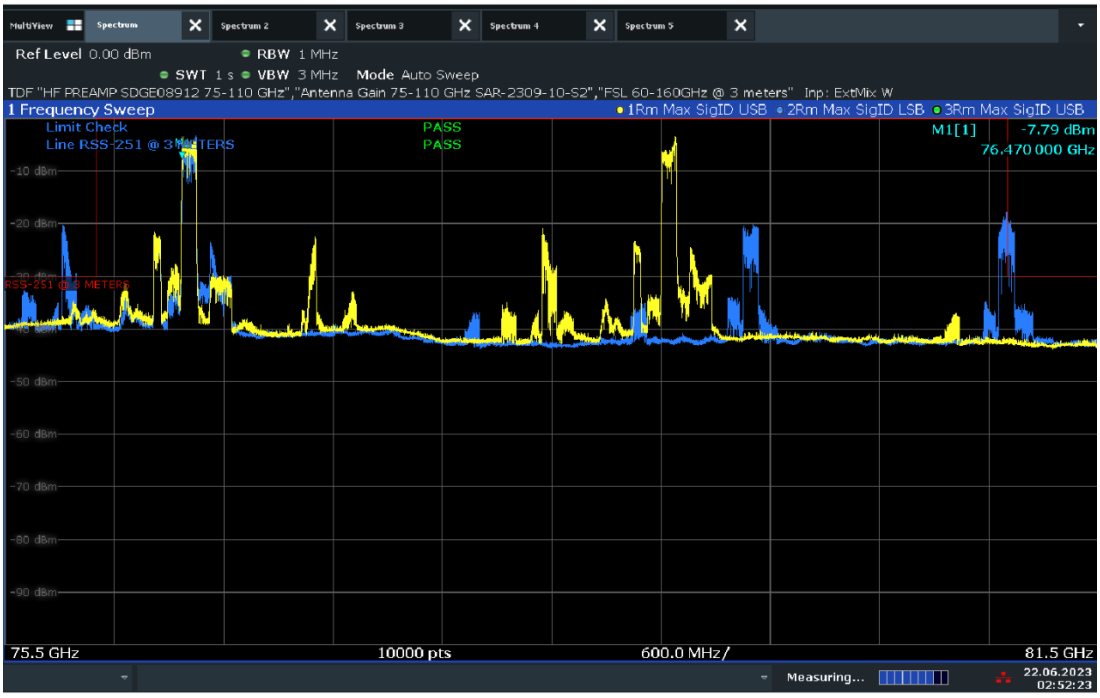
13:30:49 24.05.2023

60 to 75GHz



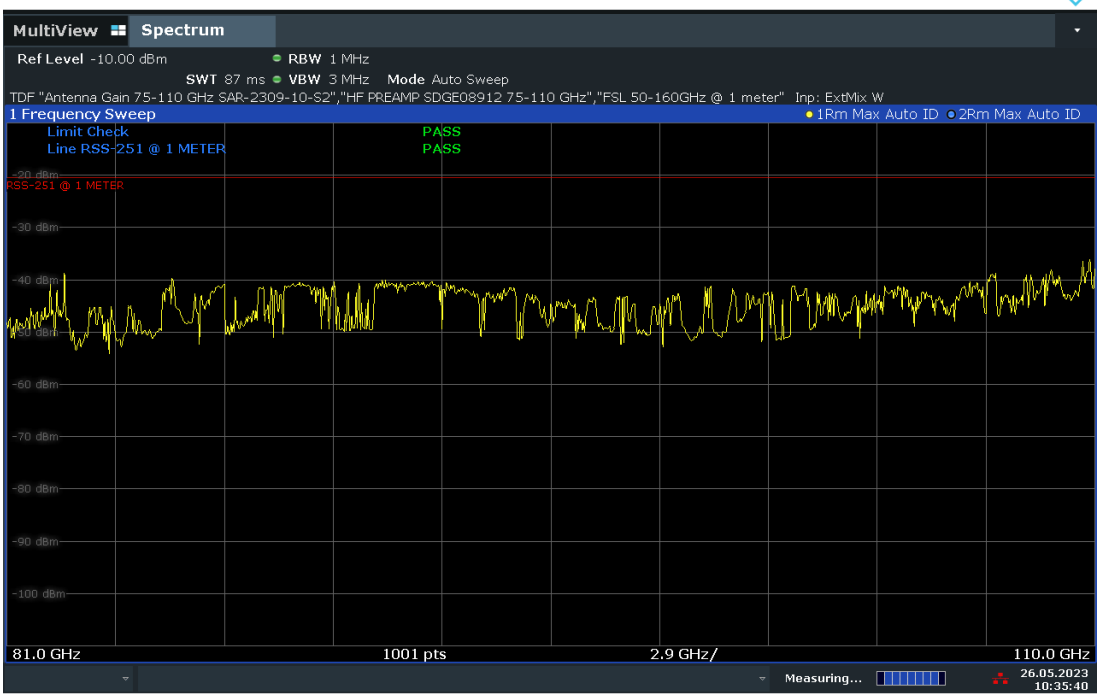
10:24:26 25.05.2023

75-76GHz



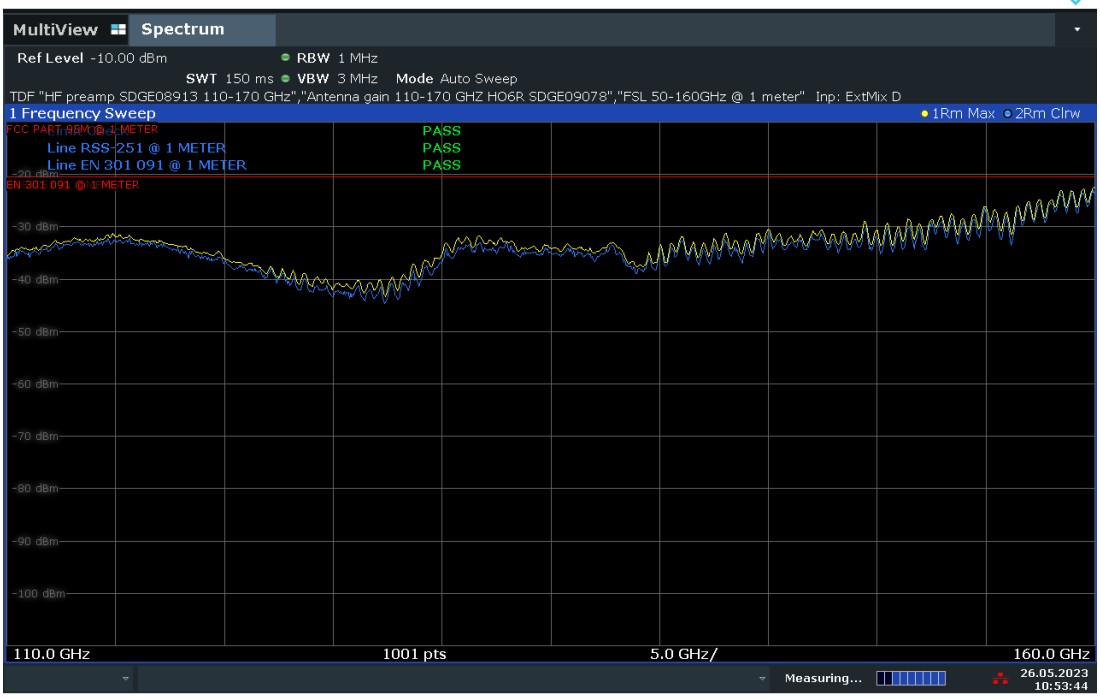
76-81GHz in band

Test Note: When using Signal ID function, traces not common to both Yellow and Blue traces are by-products of the mixing and are not real.



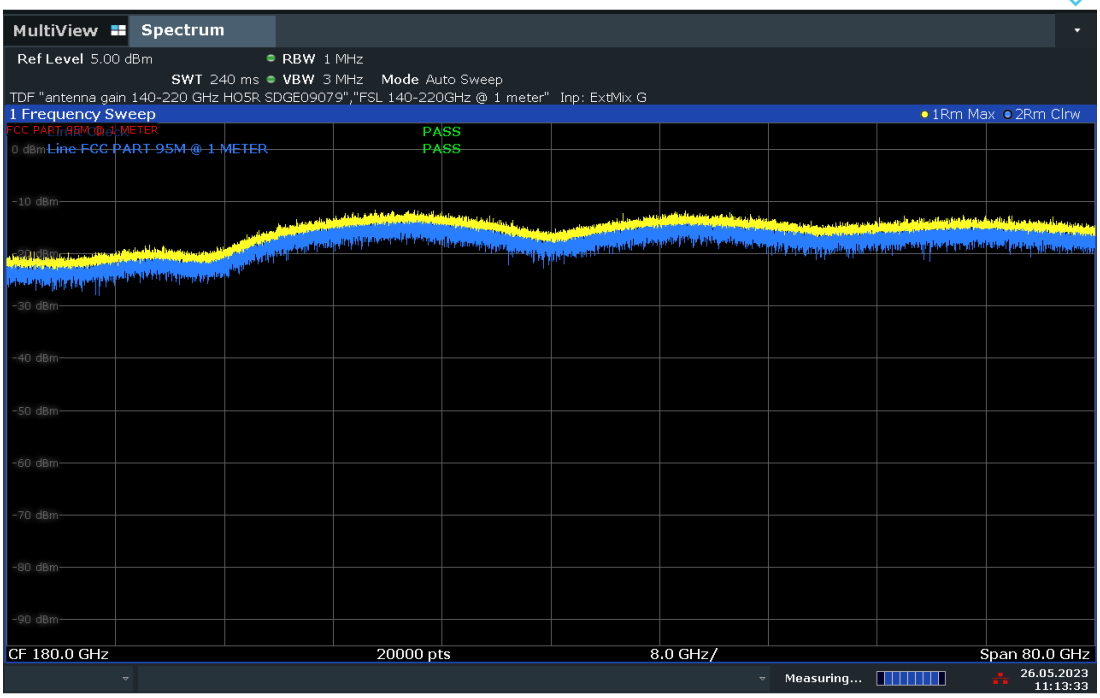
10:35:40 26.05.2023

81 to 110GHz



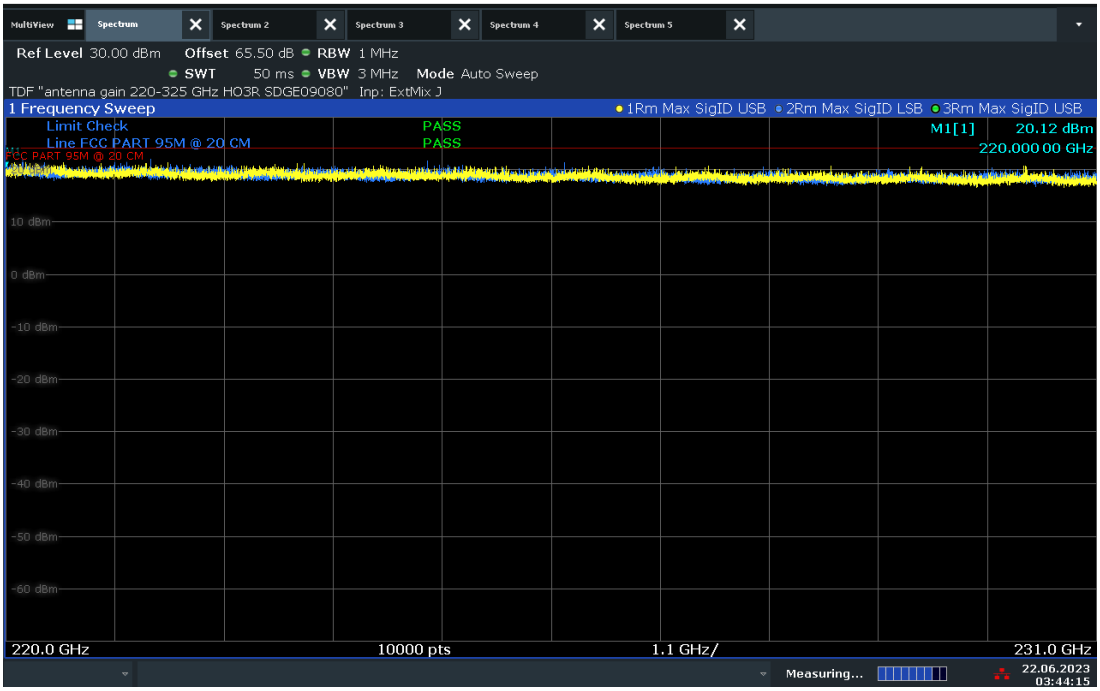
10:53:44 26.05.2023

110 to 160 GHz



11:13:33 26.05.2023

140 to 220 GHz



220 to 231 GHz

2.4 FREQUENCY STABILITY

2.4.1 Specification Reference

Part 2.1055, FCC Part 95 Subpart M §95.3379(b) and RSS-251 Section 11

2.4.2 Standard Applicable

Fundamental emissions must be contained within the frequency bands specified in this section during all conditions of operation. Equipment is presumed to operate over the temperature range −20 to +50 degrees Celsius with an input voltage variation of 85% to 115% of rated input voltage, unless justification is presented to demonstrate otherwise.

2.4.3 Equipment Under Test and Modification State

Serial No: PPFCW1000-002 / Default Test Configuration

2.4.4 Date of Test/Initial of test personnel who performed the test

June 17, 2023 / JS

2.4.5 Test Equipment Used

The major items of test equipment used for the above tests are identified in Section 3.1.

2.4.6 Environmental Conditions

Test performed at TÜV SÜD America Inc. Mira Mesa facility

Ambient Temperature	25.0 °C
Relative Humidity	49.4 %
ATM Pressure	100.1 kPa

2.4.7 Additional Observations

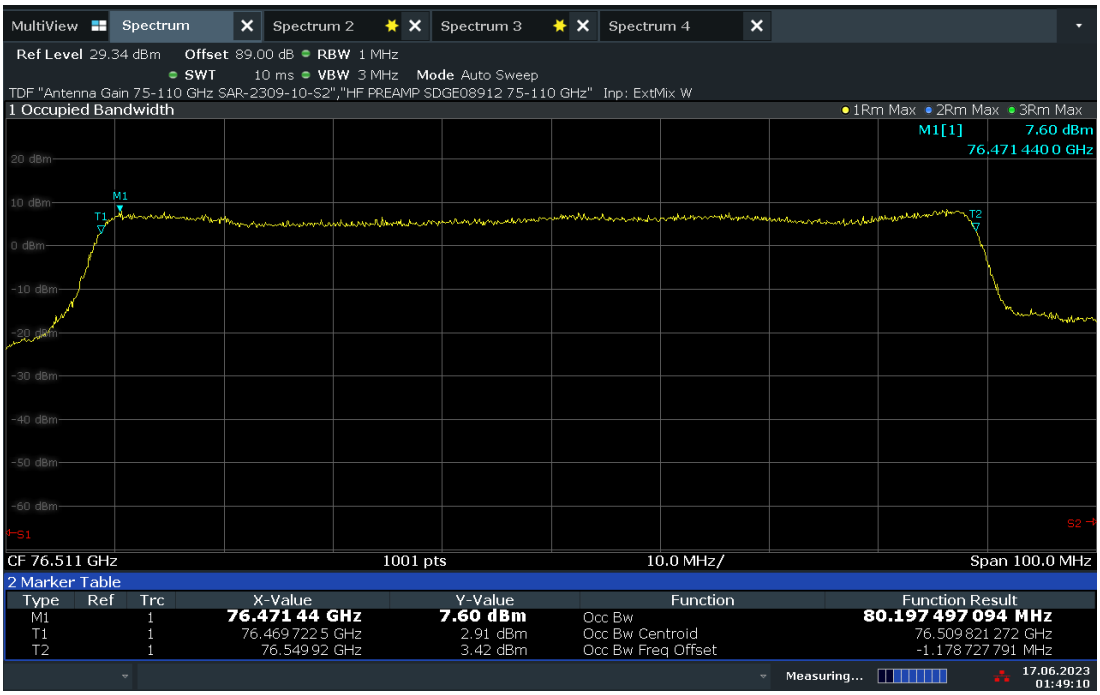
- EUT has no antenna port available. The measurements under this section were performed using radiated measurement method.
- Temperature range used is -20°C to +50°C. During test the EUT spectrum was monitored in the entire temperature range at 10 °C intervals.
- RBW is 1 MHz while VBW is 3 MHz
- Detector is Peak
- Trace is Max Hold
- The OBW function of the Spectrum Analyzer is used for this test. The edges (T1 and T2) were observed verifying they stayed within 76 and 81GHz band during the entire test.

2.4.8 Test Results

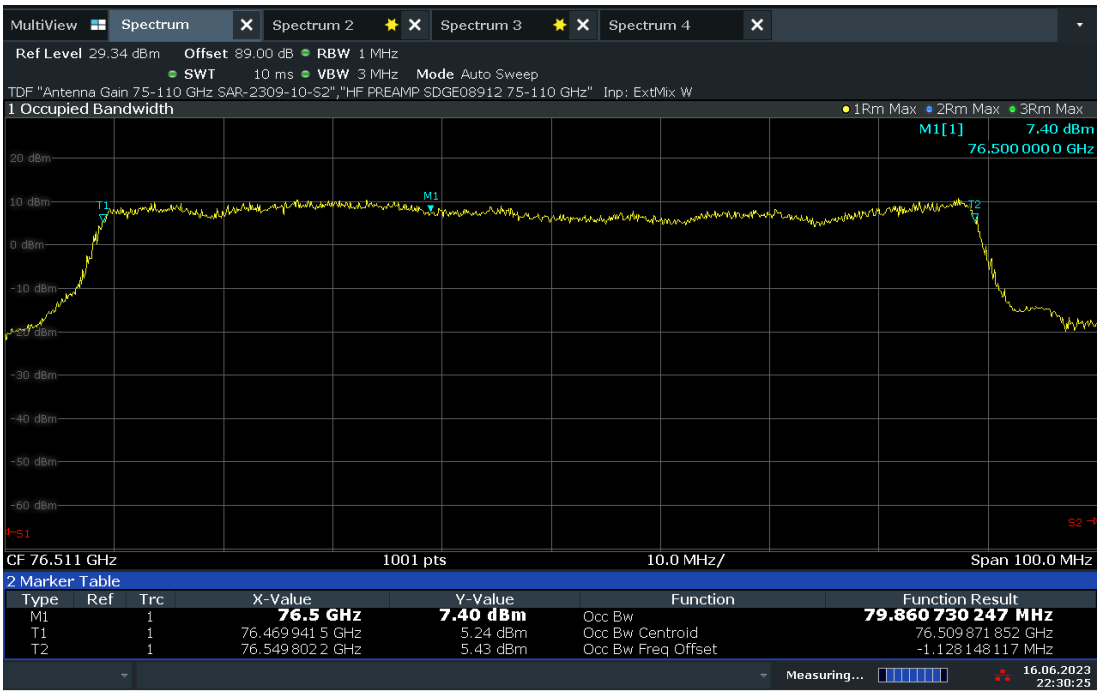
Complies. See attached plots.

Condition	Fundamental Emissions
50C	Stable
40C	Stable
30C	Stable
20C	Stable
10C	Stable
0C	Stable
-10C	Stable
-20C	Stable

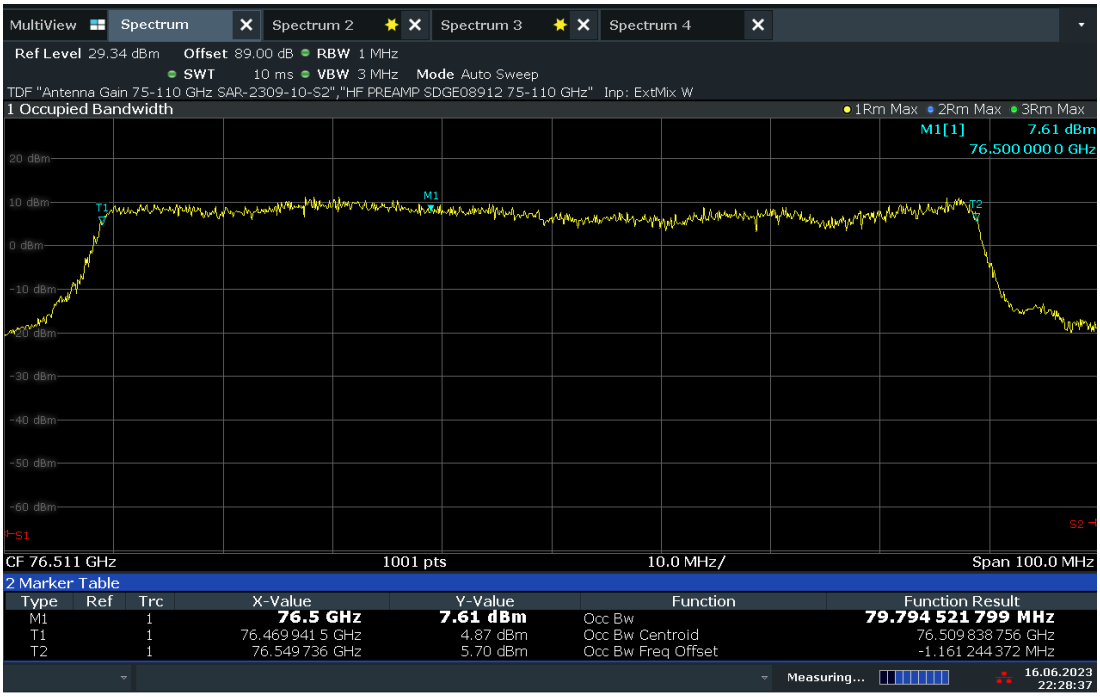
2.4.9 Test Results



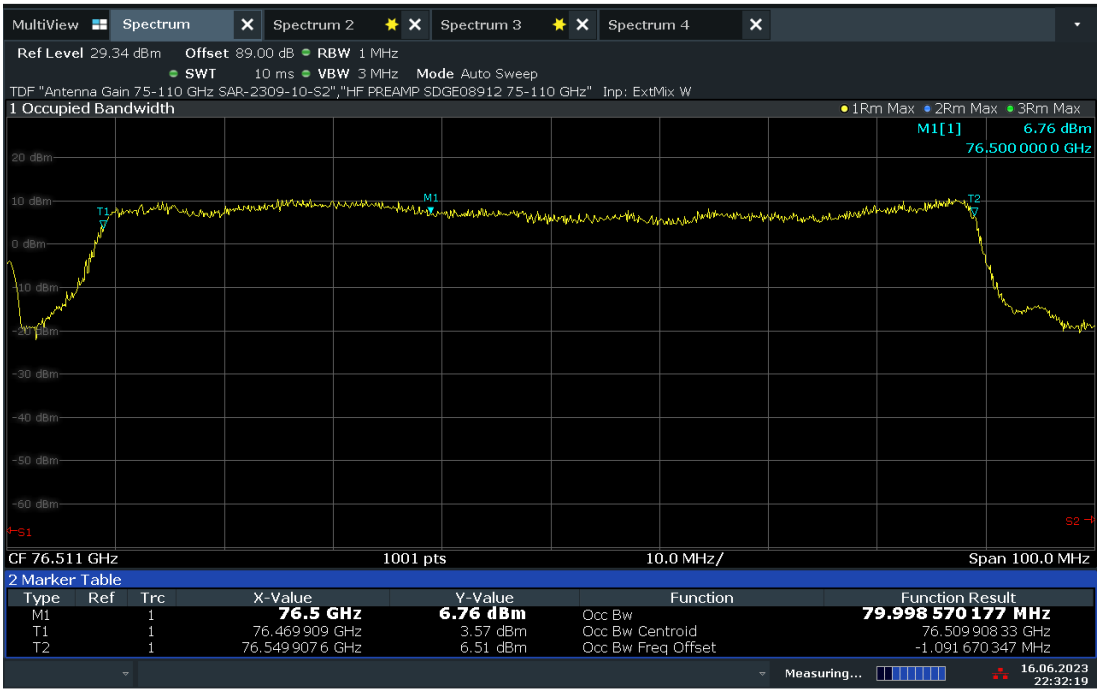
50°C @ 13.5V



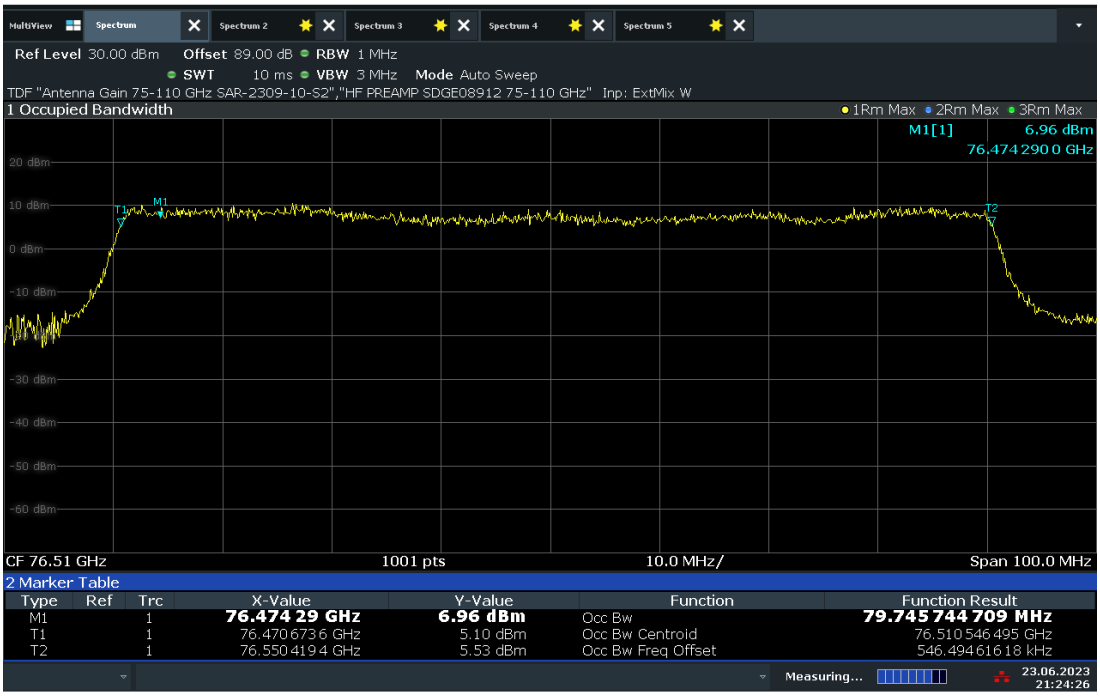
20°C @ 8V



20°C @ 13.5V



20°C @ 16.5V



-20°C @ 13.5V

SECTION 3

TEST EQUIPMENT USED

3.1 TEST EQUIPMENT USED

List of absolute measuring and other principal items of test equipment.

ID Number (SDGE/SDRB)	Test Equipment	Type	Serial Number	Manufacturer	Cal Date	Cal Due Date
Radiated Emission						
1049	EMI Test Receiver	ESU40	100133	Rohde & Schwarz	09/21/22	09/21/23
46797	Preamplifier	PA-122	181925	Com Power	12/03/22	12/03/23
1033	BiConiLog Antenna	3142C	00044556	ETS Lindgren	10/05/21	10/05/23
7575	1-18GHz DRG Horn	3117	155511	ETS Lindgren	08/08/21	08/08/24
40815	Pre-amplifier (18-40 GHz)	19D18	15G27	Spacek Labs	08/21/22	08/21/23
9001	18-26 GHz Antenna	HO42S	101	Custom Microwave Inc.	09/23/21	09/21/23
9002	26-40GHz Antenna	HO28S	102	Custom Microwave Inc.	09/23/21	09/21/23
9003	Horn antenna (40-60 GHz)	HO19R	103	Custom Microwaves	08/30/22	08/30/24
9004	Horn antenna (50-75 GHz)	HO15R	104	Custom Microwaves	08/30/22	08/30/24
9005	Horn antenna (75-110 GHz)	SAR-2309-10-S2	10104-01	Sage Millimeter, Inc.	08/30/22	08/30/24
9078	110-170GHz Antenna	HO6R	N/A	Custom Microwave Inc.	08/30/22	08/30/24
7637	Harmonics mixer (40-60 GHz)	FS-Z60	100009	Rohde & Schwarz	07/29/20	07/23/23
51288	Harmonics mixer (50-75 GHz)	FS-Z75	102099	Rohde & Schwarz	07/29/20	07/29/23
7633	Harmonics mixer (75-110 GHz)	HM-110-7	101000	Radiometer Physics	07/29/20	07/23/23
7634	Harmonics mixer (110-170 GHz)	HM-170	0062	Radiometer Physics	02/22/21	07/29/23
Miscellaneous						
43003	True RMS Multimeter	85 III	69880143	Fluke	01/09/23	01/09/24
6610	Environmental Chamber	SH27	18021	Espec	01/13/23	01/13/24
6798	Temp/Humidity Data Logger	OM-24 USB	20000226	Omega	09/13/22	09/13/23
	Test Software	EMC32	V10.50.40	Rohde & Schwarz	N/A	

3.2 MEASUREMENT UNCERTAINTY

Calculation of Measurement Uncertainty per CISPR 16-4-2:2011 with Corr. 1

3.2.1 Radiated Measurements (Below 1GHz)

	Input Quantity (Contribution) X_i	Value		Prob. Dist.	Divisor	$u_i(x)$	$u_i(x)^2$
1	Receiver reading	0.10	dB	Normal, k=1	1.000	0.10	0.01
2	Attenuation: antenna-receiver	0.20	dB	Normal, k=2	2.000	0.10	0.01
3	Antenna factor AF	0.58	dB	Normal, k=2	2.000	0.29	0.08
4	Receiver sinewave accuracy	0.15	dB	Normal, k=2	2.000	0.08	0.01
5	Receiver pulse amplitude	1.50	dB	Rectangular	1.732	0.87	0.75
6	Receiver pulse repetition rate	1.50	dB	Rectangular	1.732	0.87	0.75
7	Noise floor proximity	0.50	dB	Rectangular	1.732	0.29	0.08
8	Mismatch: antenna-receiver	0.95	dB	U-shaped	1.414	0.67	0.45
9	AF frequency interpolation	0.30	dB	Rectangular	1.732	0.17	0.03
10	AF height deviations	0.10	dB	Rectangular	1.732	0.06	0.00
11	Directivity difference at 3 m	3.12	dB	Rectangular	1.732	1.80	3.24
12	Phase center location at 3 m	1.00	dB	Rectangular	1.732	0.58	0.33
13	Cross-polarization	0.90	dB	Rectangular	1.732	0.52	0.27
14	Balance	0.00	dB	Rectangular	1.732	0.00	0.00
15	Site imperfections	3.99	dB	Triangular	2.449	1.63	2.65
16	Separation distance at 3 m	0.30	dB	Rectangular	1.732	0.17	0.03
17	Effect of setup table material	0.57	dB	Rectangular	1.732	0.33	0.11
18	Table height at 3 m	0.10	dB	Normal, k=2	2.000	0.05	0.00
19	Near-field effects	0.00	dB	Triangular	2.449	0.00	0.00
20	Effect of ambient noise on OATS	0.00	dB				0.00
	Combined standard uncertainty			Normal	2.97	dB	
	Expanded uncertainty			Normal, k=2	**5.94**	**dB**	

3.2.2 Radiated Emission Measurements (1GHz to 18GHz)

	Input Quantity (Contribution) X_i	Value	Prob. Dist.	Divisor	$u_i(x)$	$u_i(x)^2$
1	Receiver reading	0.10 dB	Normal, k=1	1.000	0.10	0.01
2	Attenuation: antenna-receiver	0.30 dB	Normal, k=2	2.000	0.15	0.02
3	Antenna factor AF	0.20 dB	Normal, k=2	2.000	0.10	0.01
4	Receiver sinewave accuracy	0.47 dB	Normal, k=2	2.000	0.24	0.06
5	Receiver pulse amplitude	0.15 dB	Normal, k=2	2.000	0.08	0.01
6	Receiver pulse repetition rate	1.21 dB	Rectangular	1.732	0.70	0.49
7	Noise floor proximity	0.70 dB	Rectangular	1.732	0.40	0.16
8	Mismatch: antenna-receiver	1.41 dB	U-shaped	1.414	1.00	0.99
9	AF frequency interpolation	1.30 dB	U-shaped	1.414	0.92	0.85
10	AF height deviations	0.30 dB	Rectangular	1.732	0.17	0.03
11	Directivity difference at 3 m	1.50 dB	Rectangular	1.732	0.87	0.75
12	Phase center location at 3 m	0.30 dB	Rectangular	1.732	0.17	0.03
13	Cross-polarisation	0.90 dB	Rectangular	1.732	0.52	0.27
14	Balance	5.53 dB	Triangular	2.000	4.89	1.13
15	Site imperfections	1.57 dB	Rectangular	1.732	0.91	0.82
16	Separation distance at 3 m	0.30 dB	Rectangular	1.732	0.17	0.03
17	Effect of setup table material	0.00 dB	Normal, k=2	2.000	0.00	0.00
18	Table height at 3 m	0.90 dB	Rectangular	1.732	0.52	0.27
19	Near-field effects	0.00 dB	Triangular	2.449	0.00	0.00
20	Effect of ambient noise on OATS	0.00 dB				0.00
	Combined standard uncertainty		Normal	2.38 dB		
	Expanded uncertainty		Normal, k=2	**4.76 dB**		

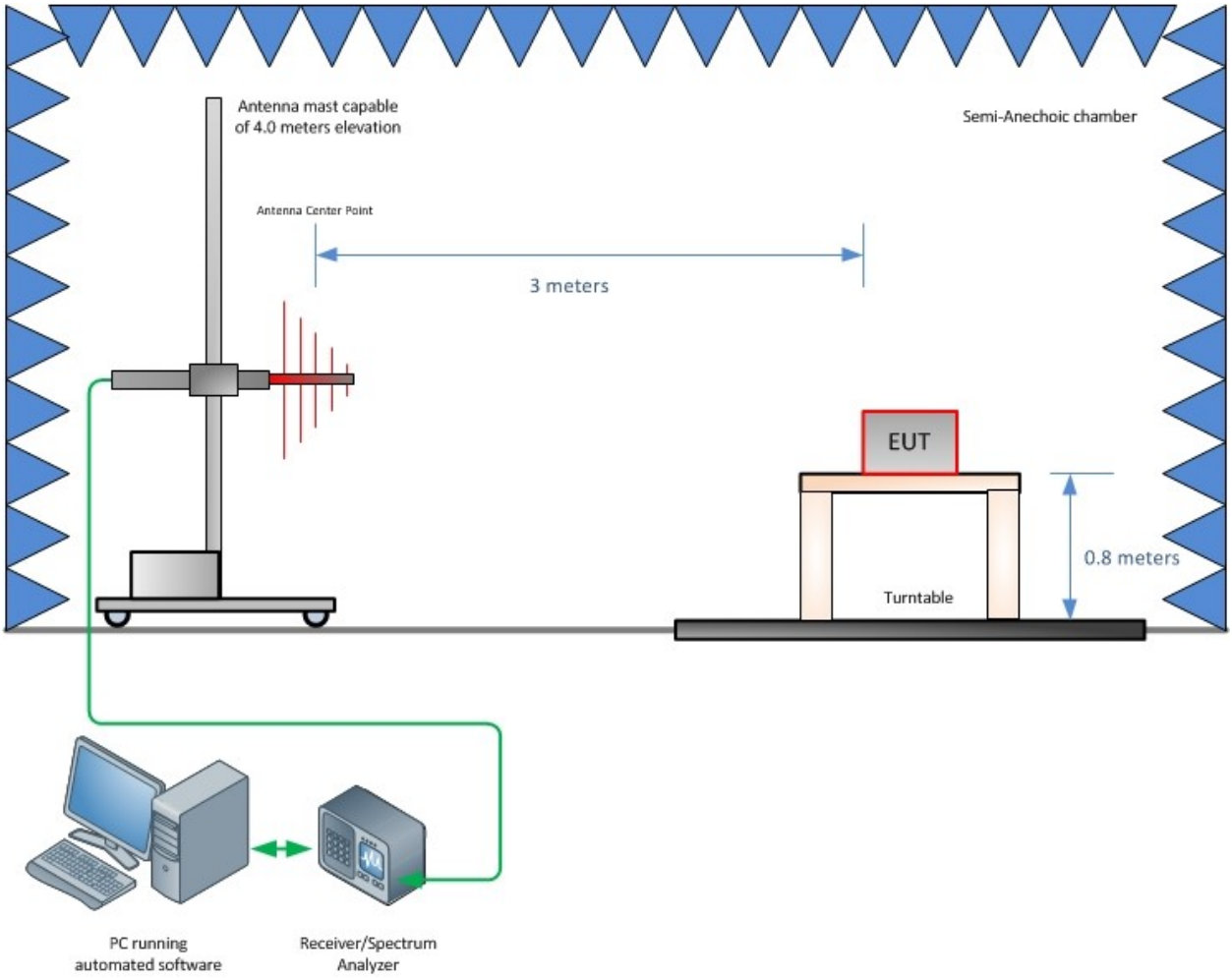
3.2.3 Radiated Emission Measurements (High Frequency Setup)

	Input Quantity (Contribution) X_i	Value	Prob. Dist.	Divisor	$u_i(x)$	$u_i(x)^2$
1	Receiver reading	0.10 dB	Normal, k=1	1.000	0.10	0.01
2	Attenuation: antenna-receiver	0.30 dB	Normal, k=2	2.000	0.15	0.02
3	Preamplifier Gain	0.50 dB	Normal, k=2	2.000	0.25	0.06
4	Antenna Gain	0.75 dB	Normal, k=2	2.000	0.38	0.14
5	Sinewave accuracy	0.15 dB	Normal, k=2	2.000	0.08	0.01
6	Mixer Operation	1.21 dB	Rectangular	1.732	0.70	0.49
7	Instability of preamp gain	1.21 dB	Rectangular	1.732	0.70	0.49
8	Noise floor proximity	0.70 dB	Rectangular	1.732	0.40	0.16
9	Mismatch: antenna-preamplifier	1.41 dB	U-shaped	1.414	1.00	0.99
10	Mismatch: preamplifier-receiver	1.30 dB	U-shaped	1.414	0.92	0.85
11	AF frequency interpolation	0.30 dB	Rectangular	1.732	0.17	0.03
12	Cross-polarisation	0.90 dB	Rectangular	1.732	0.52	0.27
	Combined standard uncertainty		Normal	1.88 dB		
	Expanded uncertainty		Normal, k=2	**3.75 dB**		

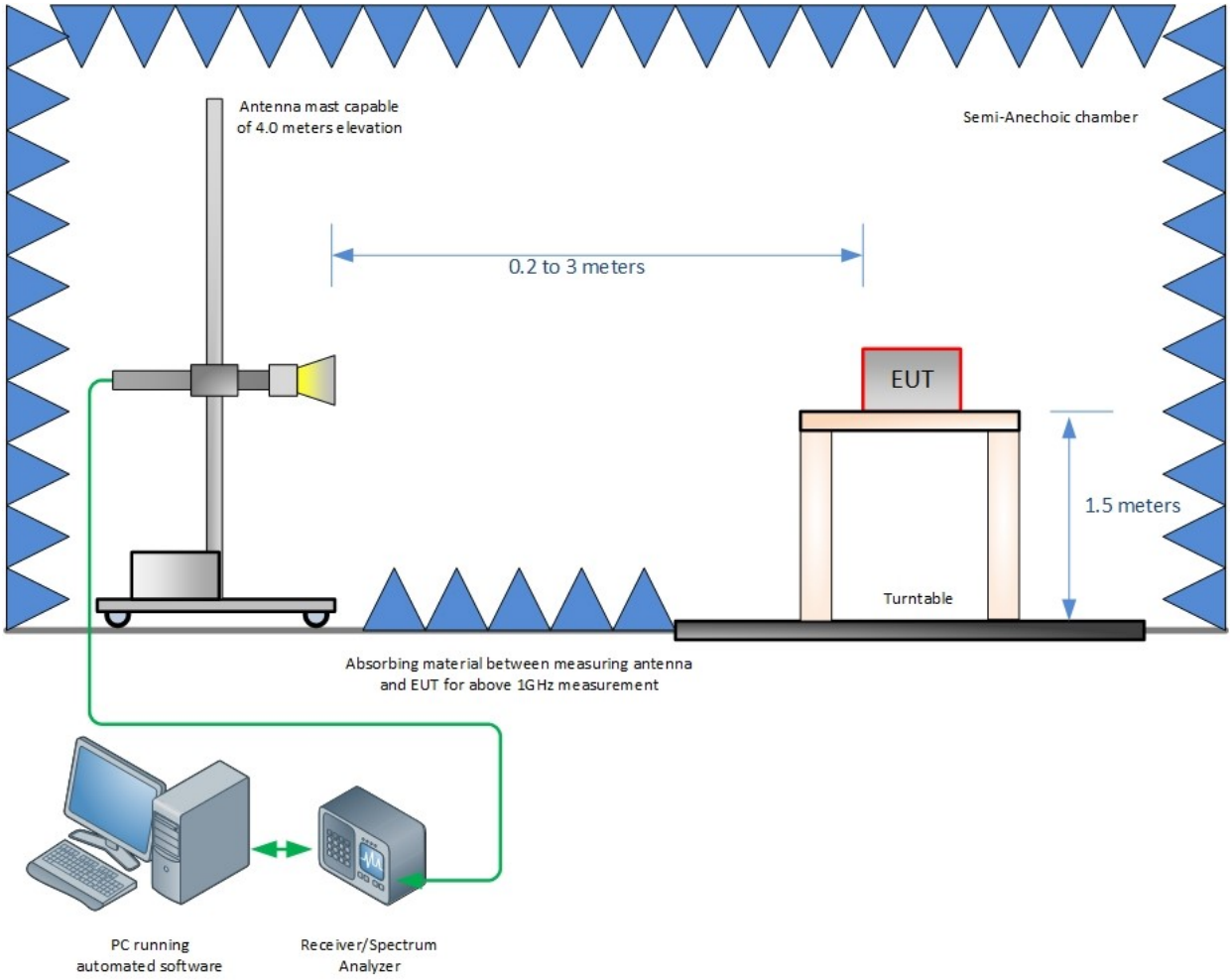
SECTION 4

DIAGRAM OF TEST SETUP

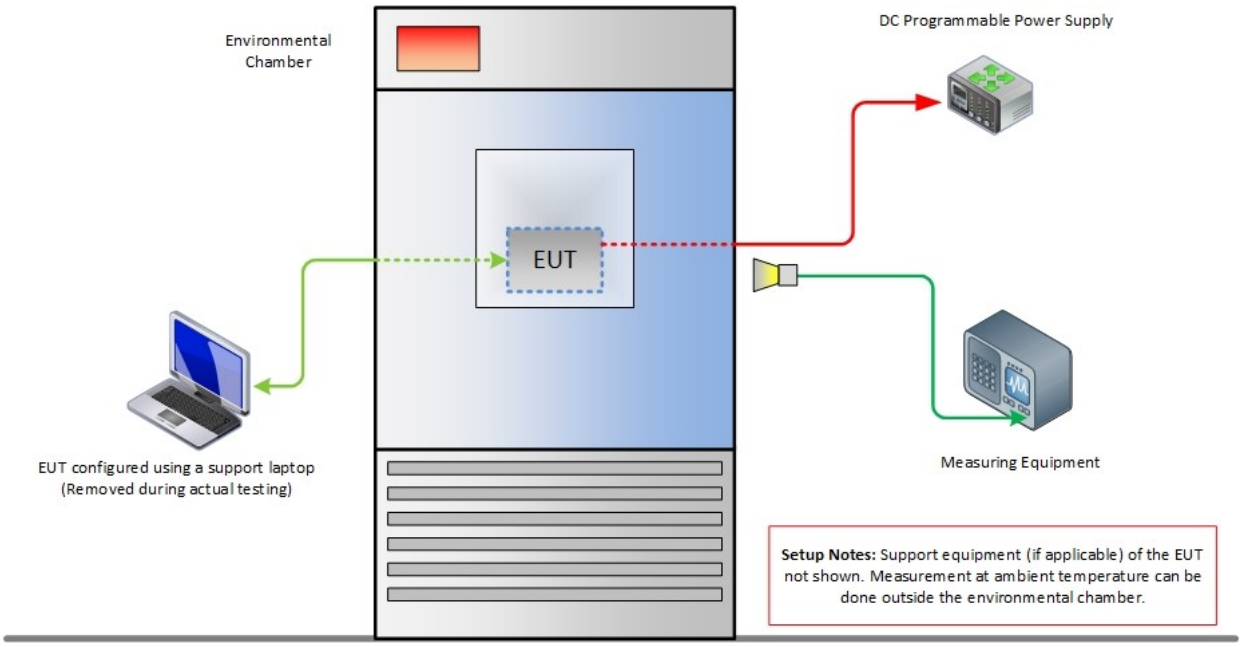
4.1 TEST SETUP DIAGRAM



Radiated Emission Test Setup (Below 1GHz)



Radiated Emission Test Setup (Above 1GHz)



Extreme Test Conditions Test Setup

SECTION 5

ACCREDITATION, DISCLAIMERS AND COPYRIGHT

5.1 ACCREDITATION, DISCLAIMERS AND COPYRIGHT

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