FCC PART 15.247 SINGLE MODULAR TRANSMITTER APPROVAL

TEST REPORT

for the

GALLIUM RADIO

FCC ID: 2AI6Y-GALLIUM2400

WLL REPORT # 17337-01 REV 1

Prepared for:

Intelligent Automation Inc.
15400 Calhoun Dr.
Rockville, Maryland 20850

Prepared By:

Washington Laboratories, Ltd.
4840 Winchester Boulevard
Frederick, Maryland 21703

Testing Certificate AT-1448

FCC Part 15.247 Single Modular Transmitter Approval

Test Report

for the

Intelligent Automation Inc.

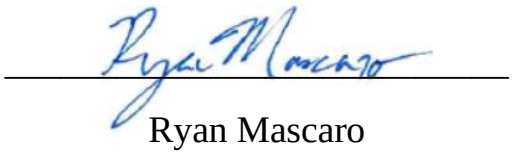
Gallium Radio

FCC ID: 2AI6Y-GALLIUM2400

November 19, 2021

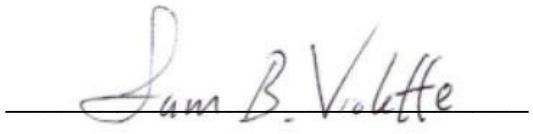
WLL Report# 17337-01 Rev 1

Prepared by:



Ryan Mascaro
RF Test Engineer

Reviewed by:



Samuel Violette
Vice President

Abstract

This report has been prepared on behalf of Intelligent Automation Inc. to support the attached Application for a Single Modular Transmitter Approval. The test report and application are submitted for a Digital Transmission System (DTS) Transmitter under Part 15.247 and 15.212 of the FCC Rules. This Single Modular Transmitter Approval Test Report documents the test configuration and test results for the Intelligent Automation Inc., Gallium Radio. The information provided on this report is only applicable to device herein documented, as the EUT.

The radiated portion of the testing was performed on an Open Area Test Site (OATS) of Washington Laboratories, Ltd., located at 4840 Winchester Boulevard, Frederick MD 21703. Site description and site attenuation data have been placed on file with the FCC's Sampling and Measurements Branch at the FCC laboratory in Columbia, MD.

Washington Laboratories, Ltd. has been accepted by the FCC and approved by ANAB under Certificate AT-1448 as an independent FCC test laboratory.

The Intelligent Automation Inc., Gallium Radio complies with the requirements for a Digital Transmission System (DTS) Transmitter (Single Modular Transmitter Approval) under FCC Part 15.247.

Revision History	Description of Change	Date
Rev 0	Initial Release	November 19, 2021
Rev 1	ACB Comments, Dated: 12/14/2021	December 15, 2021

Table of Contents

List of Tables

List of Figures

1 Introduction

1.1 Compliance Statement

The Intelligent Automation Inc., Gallium Radio complies with the requirements for a Digital Transmission System (DTS) Transmitter (Single Modular Transmitter Approval) under FCC Part 15.247.

1.2 Test Scope

Tests for radiated and conducted (at antenna terminal) emissions were performed. All measurements were performed in accordance with C63.10 "ANSI Procedures for Compliance Testing of Unlicensed Wireless Devices". The measurement equipment conforms to ANSI C63.2 Specifications for Electromagnetic Noise and Field Strength Instrumentation.

The table below shows the series and results of testing for compliance with a Digital Transmission System Full test results are shown in subsequent report sub-sections.

Table 1: FCC Test Summary Table

FCC Rule Part	Description	Result
15.247(a)(2)	6 dB Bandwidth	Pass
15.247 (b)(3)	Transmit Output Power	Pass
15.247(e)	Power Spectral Density	Pass
15.247(d)	Out-of-Band Emissions (Band Edge @ 20 dB below)	Pass
15.205 15.209	General Field Strength Limits (Restricted Bands & RE Limits)	Pass
15.207	AC Conducted Emissions	Pass

1.3 Contract Information

Customer:	Intelligent Automation Inc.
Purchase Order Number:	09002.00.034-102021
Quotation Number:	73043

1.4 Test and Support Personnel

Washington Laboratories, LTD	Ryan Mascaro
Customer Representative	Shahin Farrokhnia

1.5 Test Dates

11/15/2021 – 11/17/2021 (also see Section 4 of this report)

1.6 Test Location

All measurements herein were performed at Washington Laboratories, Ltd. test center in Frederick, MD. Site description and site attenuation data have been placed on file with the FCC's Sampling and Measurements Branch at the FCC laboratory in Columbia, MD. Washington Laboratories, Ltd. has been accepted by the FCC and approved by ANAB under Testing Certificate AT-1448 as an independent FCC test laboratory.

1.7 Testing Algorithm

The Gallium Radio was provided to the test laboratory, mounted to a plastic test-jig. The EUT is designed to transmit in two output power modes, which were [at the time of testing] configurable via a selector knob. The two transmit modes are (1) Low Power Mode – which transmits at the radio's minimum power setting, and (2) High Power Mode – which transmits at the radio's maximum power setting. The EUT low, center, and high channels were tunable through the support laptop's interface. Prior to all testing, the transmitter power was adjusted [via software] to an attenuation setting of 10.5 dB. This setting achieved the reported transmit output power of < 30 dBm, and the reported PSD of < 8 dBm. The attenuation was not adjusted at any time during testing. The EUT was tested in a manner that produced the worst cast emission levels, which are provided in the test results data section(s) of this report.

2 Test Results

2.1 Occupied (DTS) Bandwidth

Occupied bandwidth was performed by measuring the output of the EUT antenna port with a spectrum analyzer, corrected for any cable/attenuator loss.

For a DTS device, FCC Part 15.247 requires the minimum 6 dB bandwidth be at least 500 kHz.

2.1.1 Measurement Method

This test was performed as specified in ANSI C63.10, Section 11.8.1 "Option 1" for DTS bandwidth.

Table 2: Occupied Bandwidth Spectrum Analyzer Settings

Resolution Bandwidth	Video Bandwidth
100 kHz	300 kHz

In a fully modulated mode, the OBW was measured as shown in Figures 1 through Figure 6.

Table 3 provides a summary of the test results.

Table 3: Occupied Bandwidth Summary

EUT Power Mode/Setting	Channel Name	Frequency (MHz)	6 dB OBW (MHz)	Pass/Fail
Low Power Setting (Minimum Power)	Low	2403.5	5.068	Pass
	Center	2440.0	5.067	Pass
	High	2478.5	5.083	Pass
High Power Setting (Maximum Power)	Low	2403.5	5.088	Pass
	Center	2440.0	5.087	Pass
	High	2478.5	5.203	Pass

Figure 1: Low Channel, Occupied Bandwidth – Low Power Mode

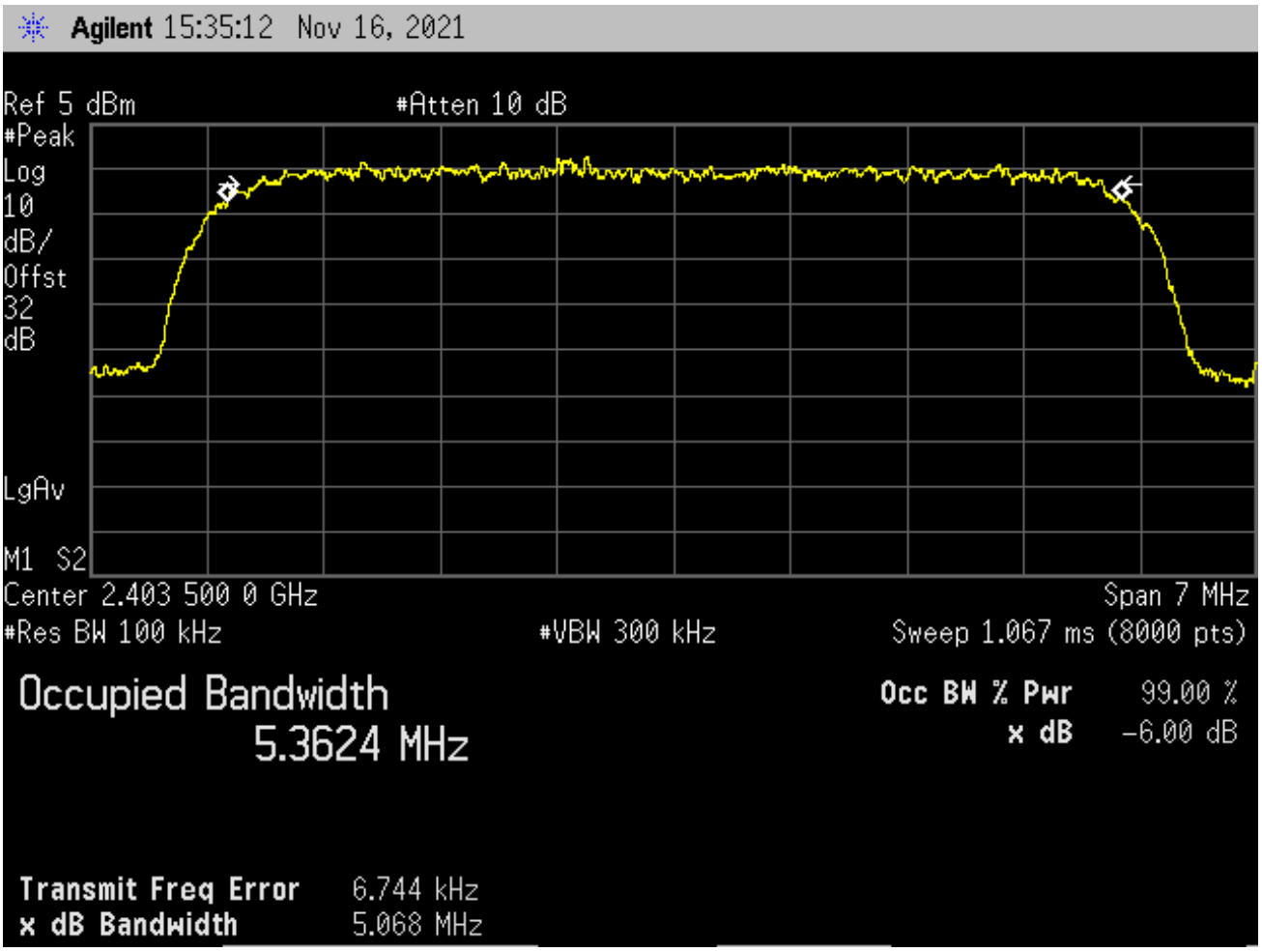


Figure 2: Center Channel, Occupied Bandwidth – Low Power Mode

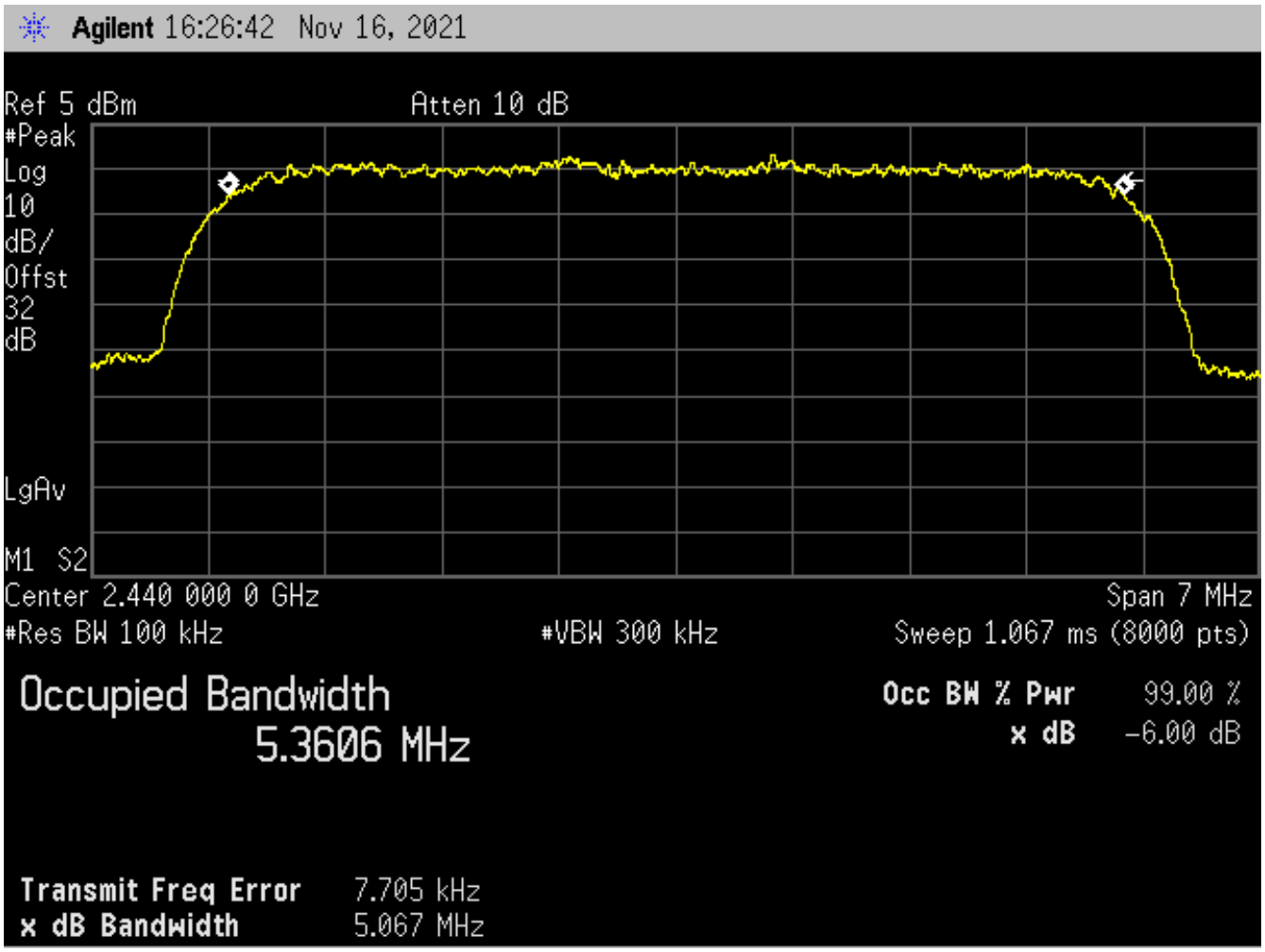


Figure 3: High Channel, Occupied Bandwidth – Low Power Mode

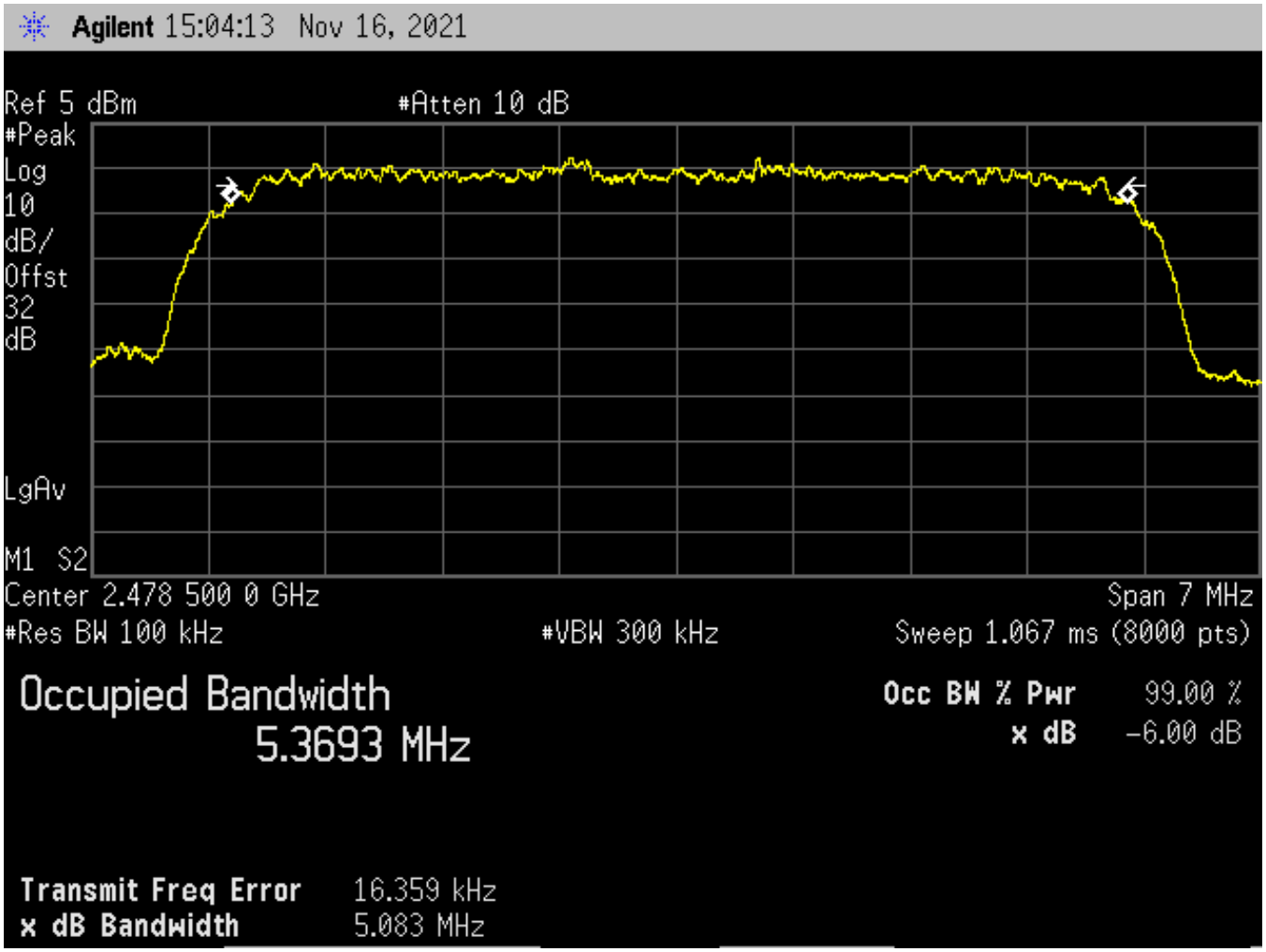


Figure 4: Low Channel, Occupied Bandwidth – High Power Mode

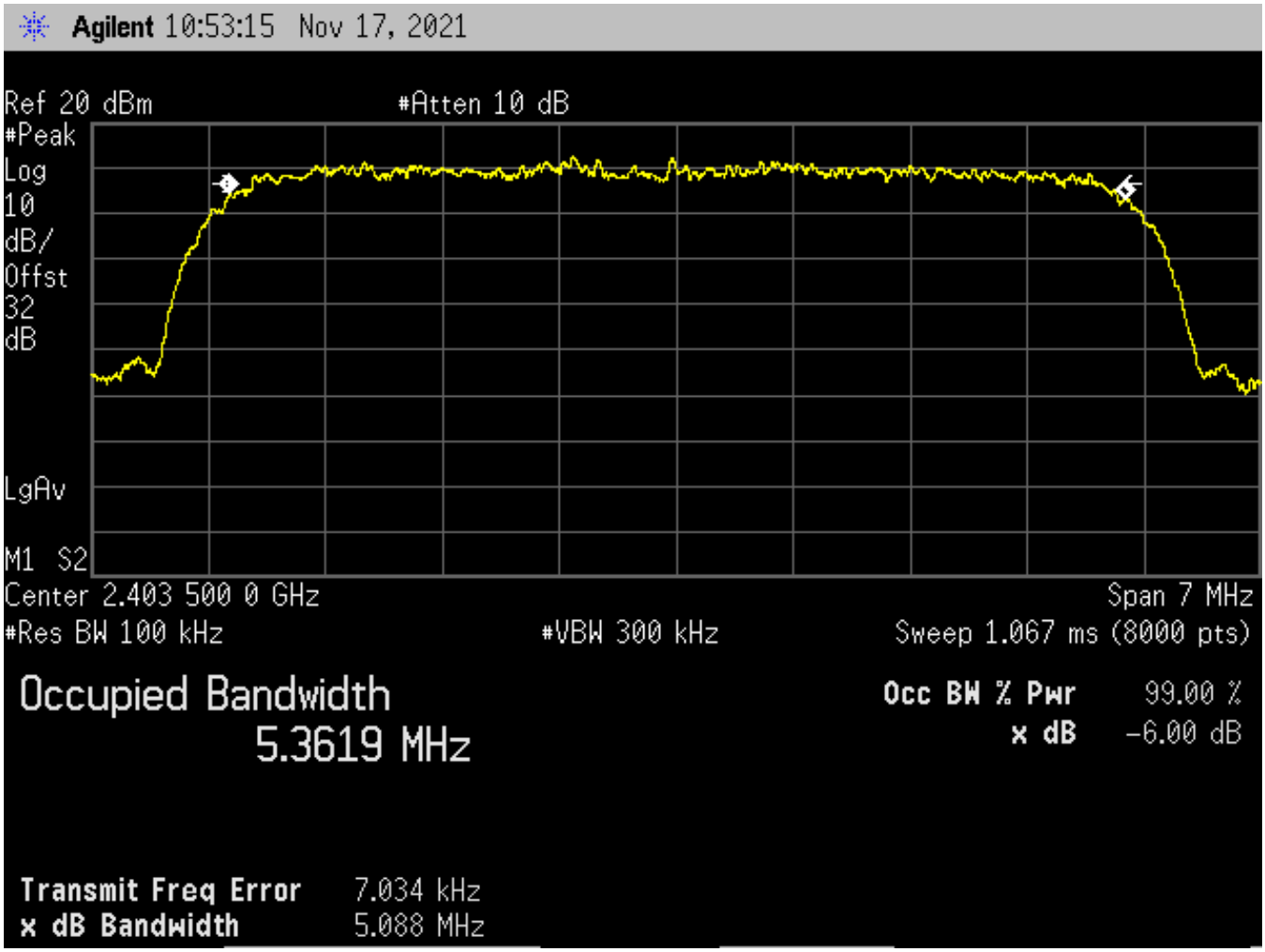


Figure 5: Center Channel, Occupied Bandwidth – High Power Mode

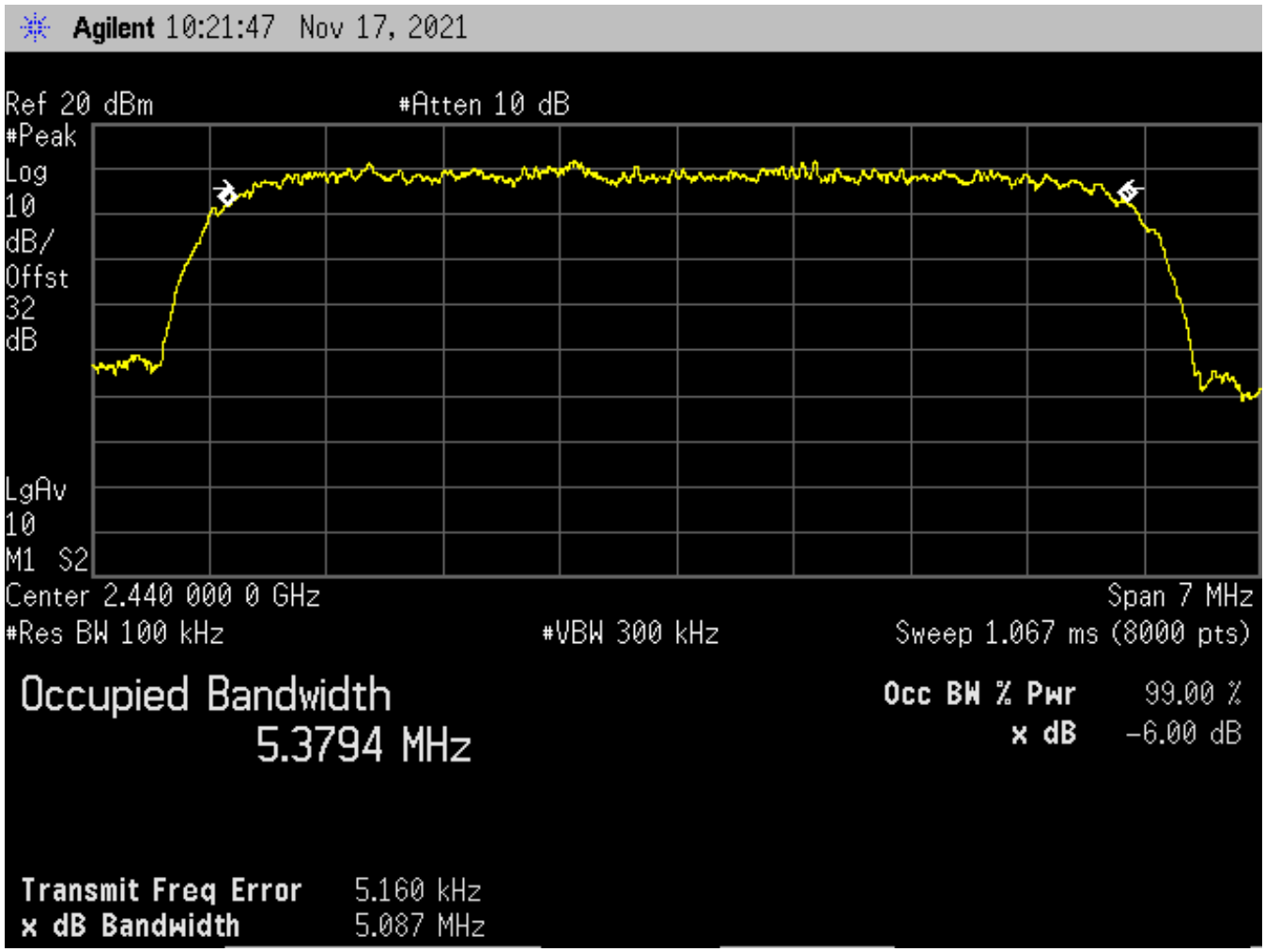
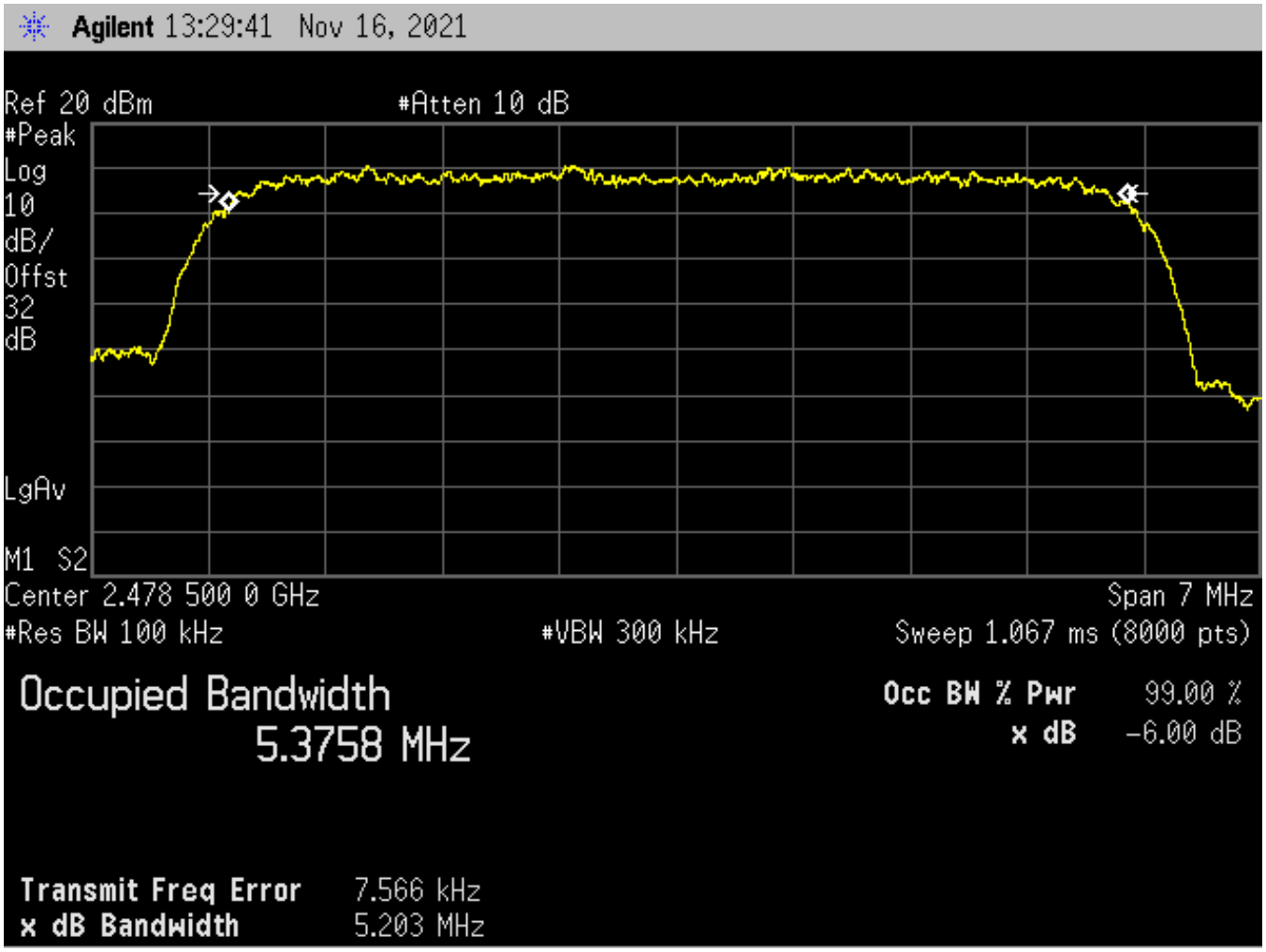


Figure 6: High Channel, Occupied Bandwidth – High Power Mode



2.2 RF Power Output

RF Power Output was performed by measuring the output of the EUT antenna port with a spectrum analyzer, corrected for any cable/attenuator loss.

For a DTS device, FCC Part 15.247 requires the maximum conducted output power to be < 30 dBm (1W).

2.2.1 Measurement Method

This test was performed as specified in ANSI C63.10, Section 11.9.1.1, "RBW ≥ DTS bandwidth" for Maximum peak conducted output power.

Table 4: Spectrum Analyzer Settings

Resolution Bandwidth	Video Bandwidth
8 MHz	50 MHz

In a CW mode, the peak output power was measured as shown in Figures 7 through Figure 12.

Table 5 provides a summary of the test results.

Table 5: RF Power Output Summary

EUT Power Mode/Setting	Channel Name	Frequency (MHz)	Peak Power (dBm)	Pass/Fail
Low Power Setting (Minimum Power)	Low	2403.5	12.16	Pass
	Center	2440.0	11.97	Pass
	High	2478.5	11.82	Pass
High Power Setting (Maximum Power)	Low	2403.5	26.16	Pass
	Center	2440.0	25.83	Pass
	High	2478.5	25.04	Pass

Figure 7: Low Channel, RF Peak Power Output – Low Power Mode

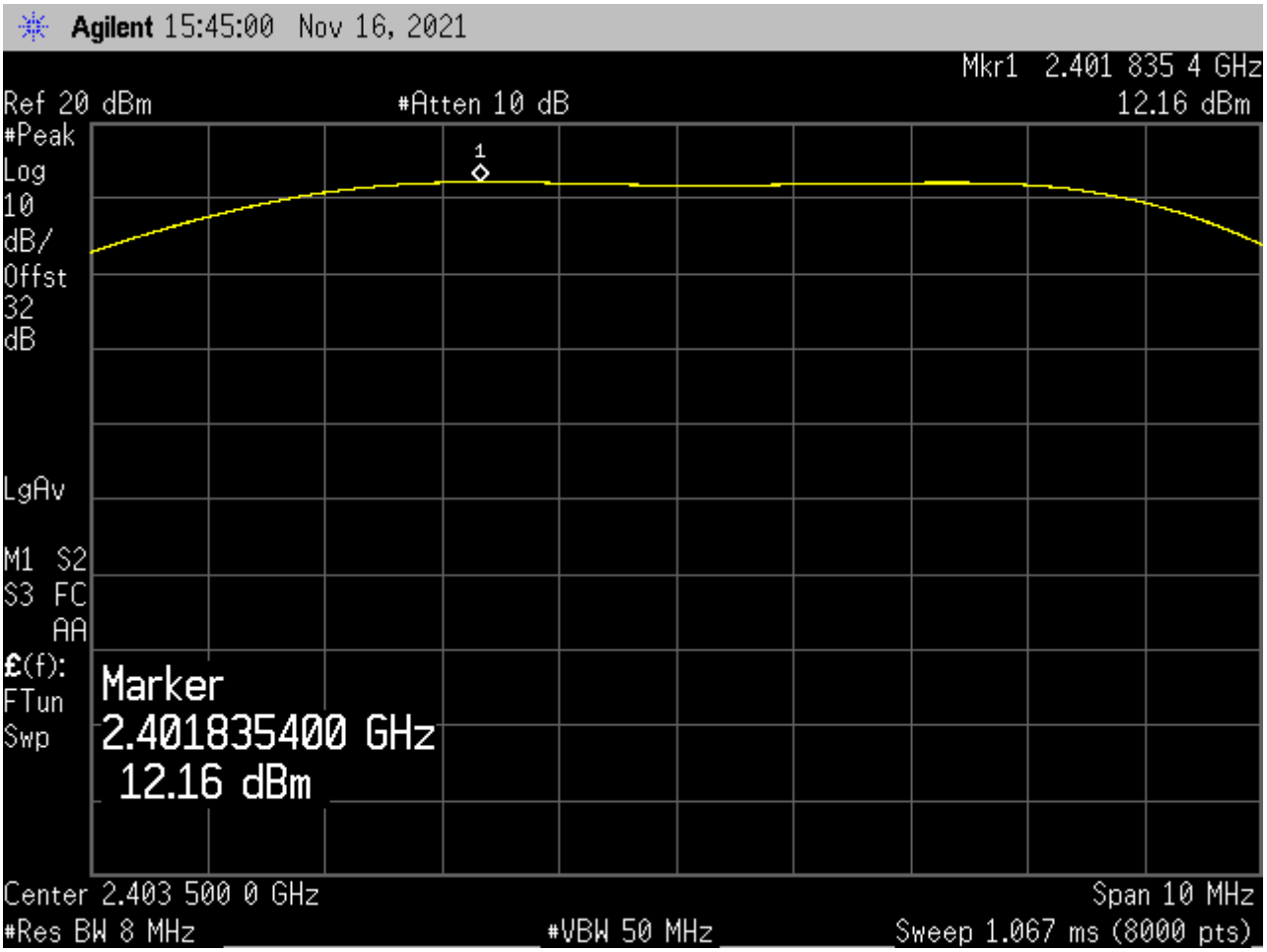


Figure 8: Center Channel, RF Peak Power Output – Low Power Mode

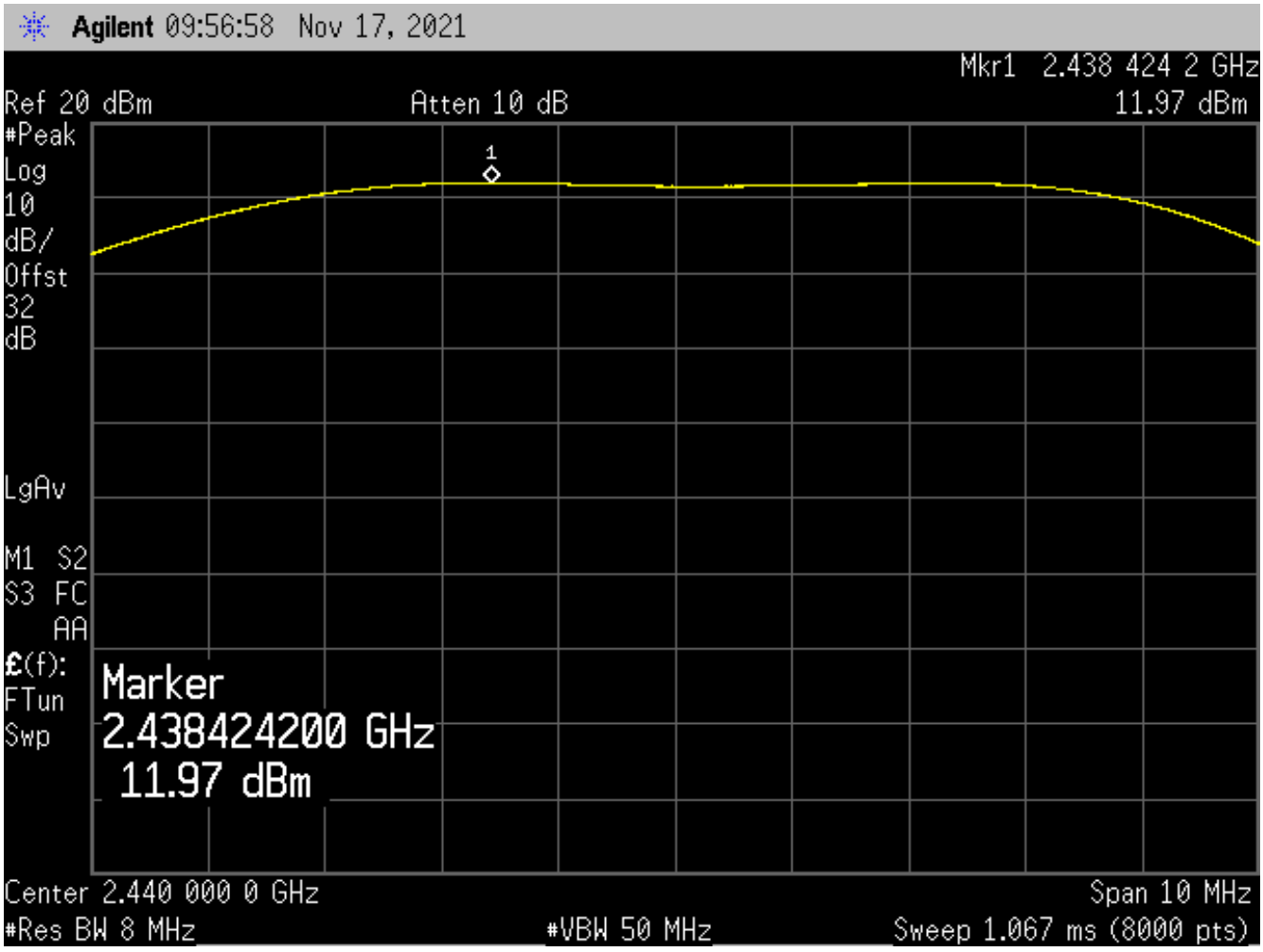


Figure 9: High Channel, RF Peak Power Output – Low Power Mode

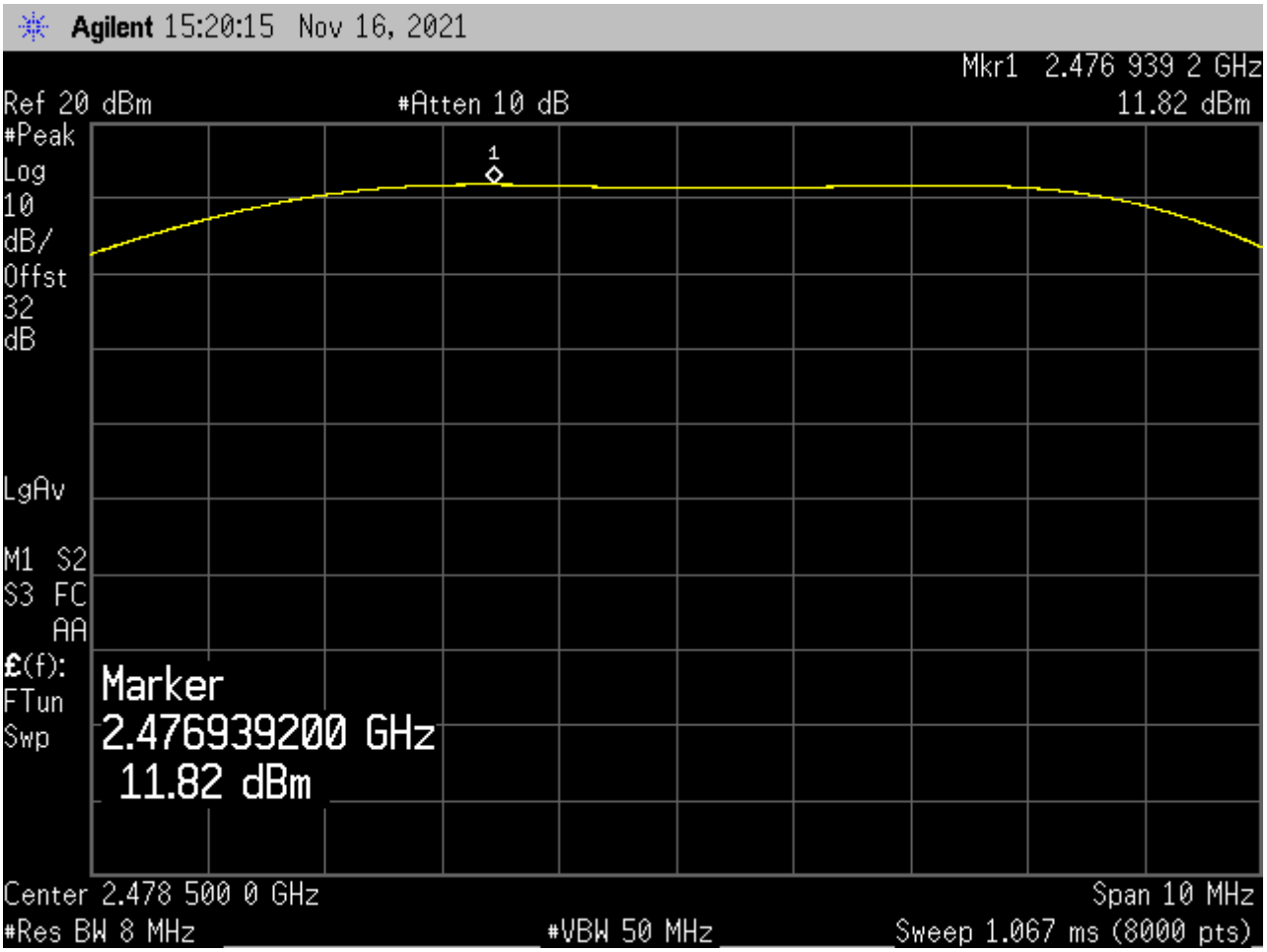


Figure 10: Low Channel, RF Peak Power Output – High Power Mode

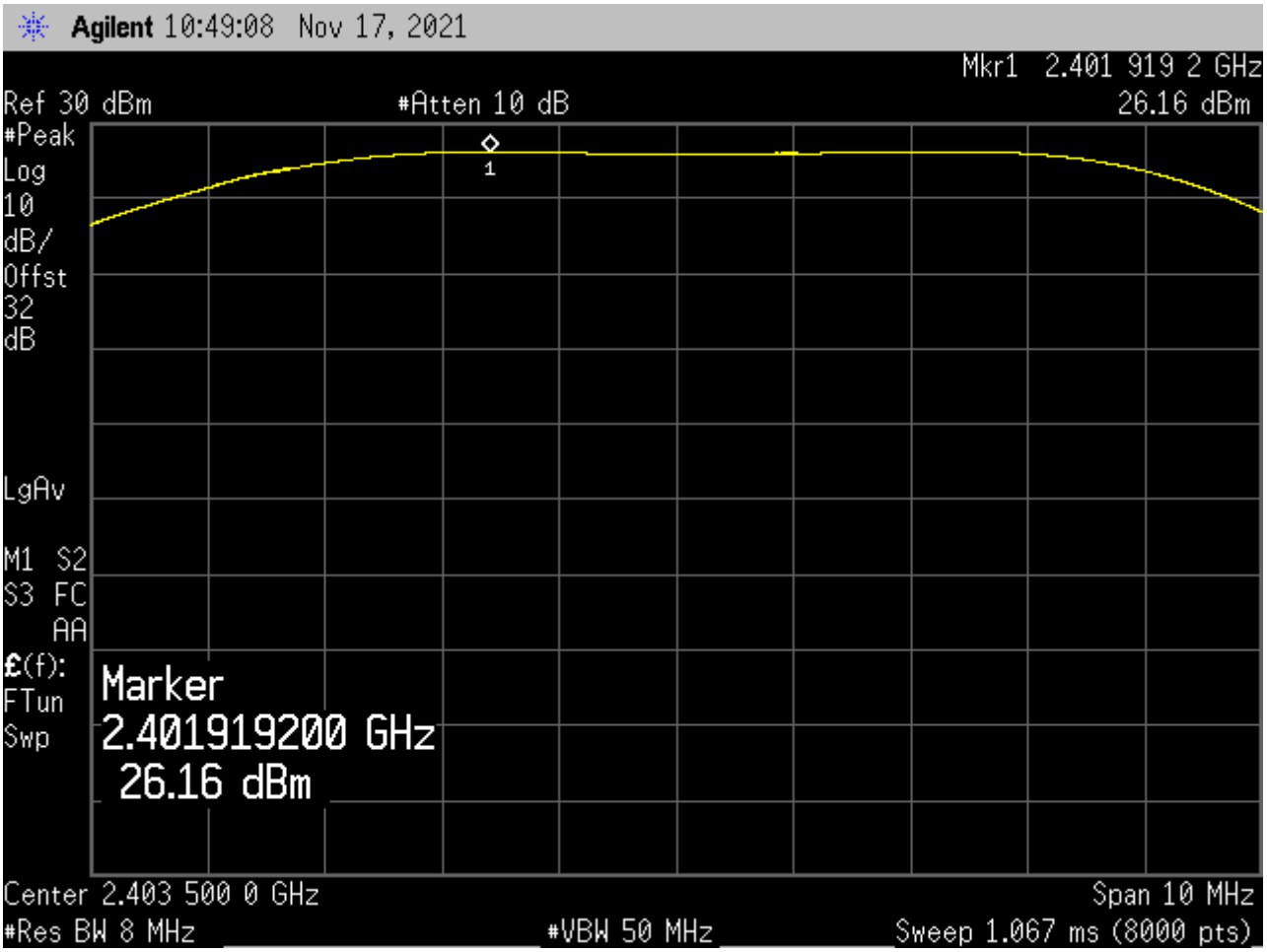


Figure 11: Center Channel, RF Peak Power Output – High Power Mode

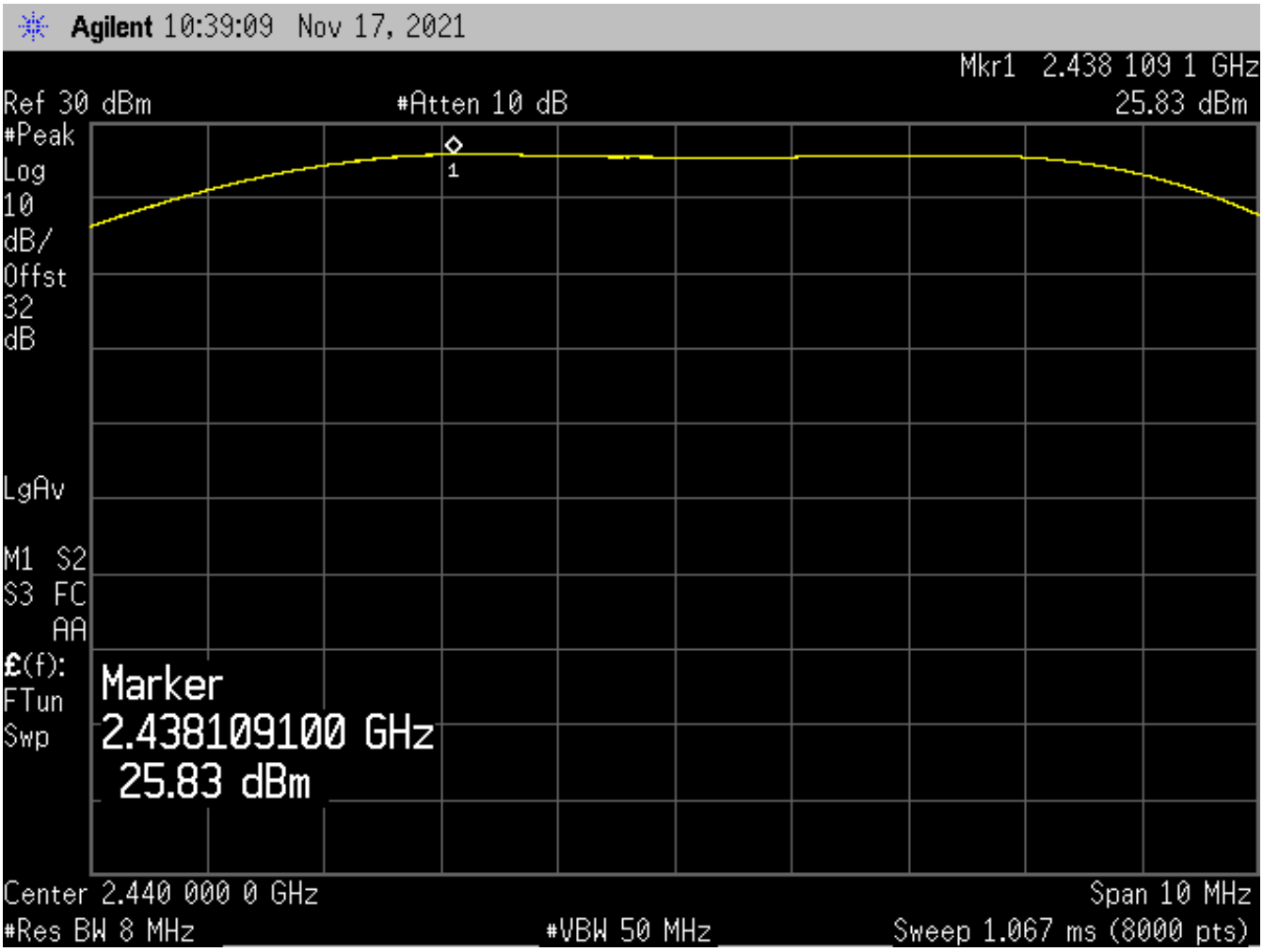
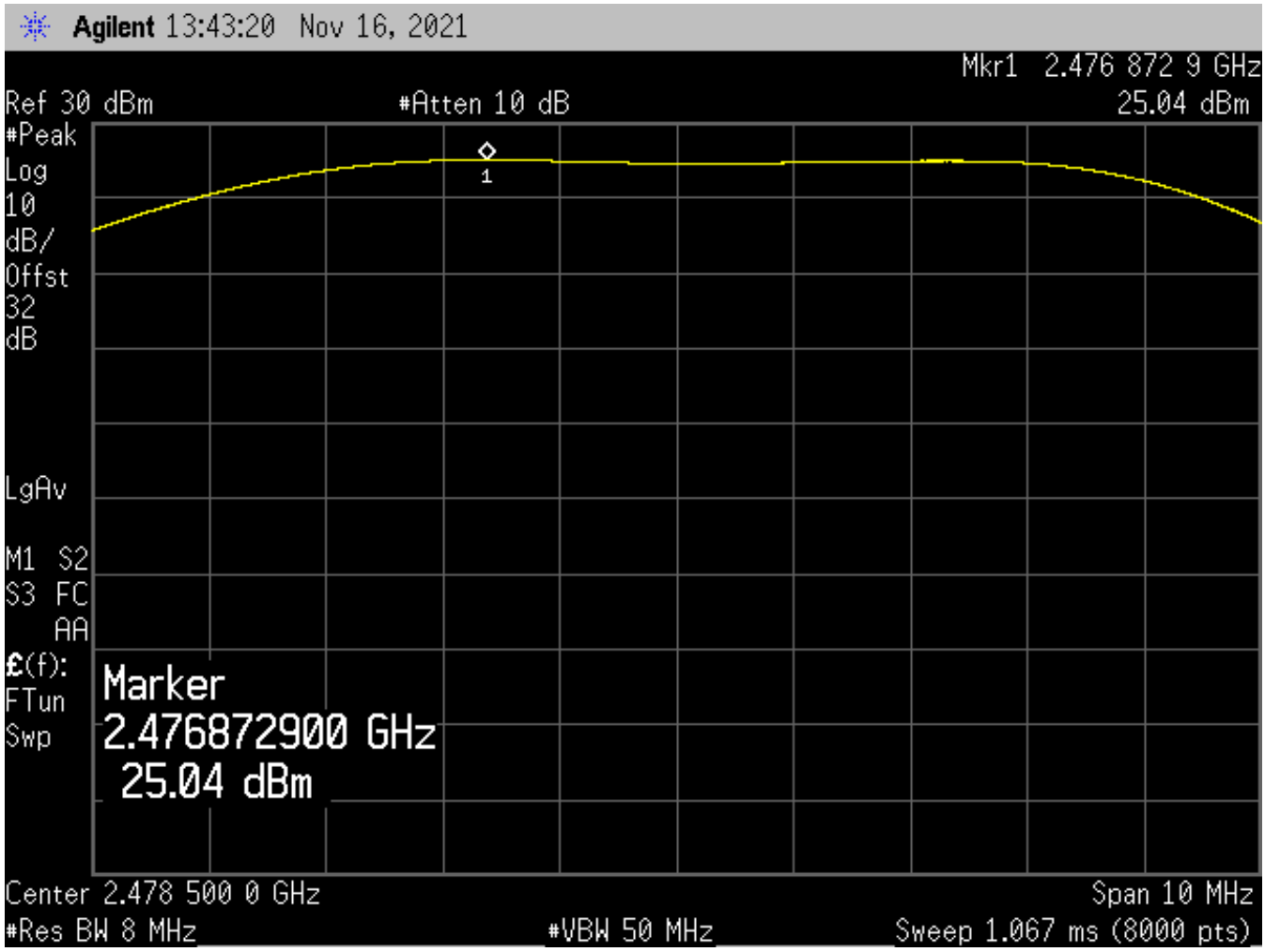


Figure 12: High Channel, RF Peak Power Output – High Power Mode



2.3 Power Spectral Density

Power Spectral Density (PSD) was performed by measuring the output of the EUT antenna port with a spectrum analyzer, corrected for any cable/attenuator loss.

For a DTS device, FCC Part 15.247 requires the maximum PSD to be < 8 dBm, in any 3 kHz bandwidth.

2.3.1 Measurement Method

This test was performed as specified in ANSI C63.10, Section 11.10.2, "Peak PSD" for Maximum power spectral density level in the fundamental emission

In a fully modulated mode, the peak PSD was measured as shown in Figures 13 through Figure 18.

Table 6 provides a summary of the test results.

Table 6: Power Spectral Density Summary

EUT Power Mode/Setting	Channel Name	Frequency (MHz)	Peak PSD (dBm)	Pass/Fail
Low Power Setting (Minimum Power)	Low	2403.5	-10.78	Pass
	Center	2440.0	-11.70	Pass
	High	2478.5	-11.98	Pass
High Power Setting (Maximum Power)	Low	2403.5	3.47	Pass
	Center	2440.0	3.09	Pass
	High	2478.5	2.28	Pass

Figure 13: Low Channel, Power Spectral Density – Low Power Mode

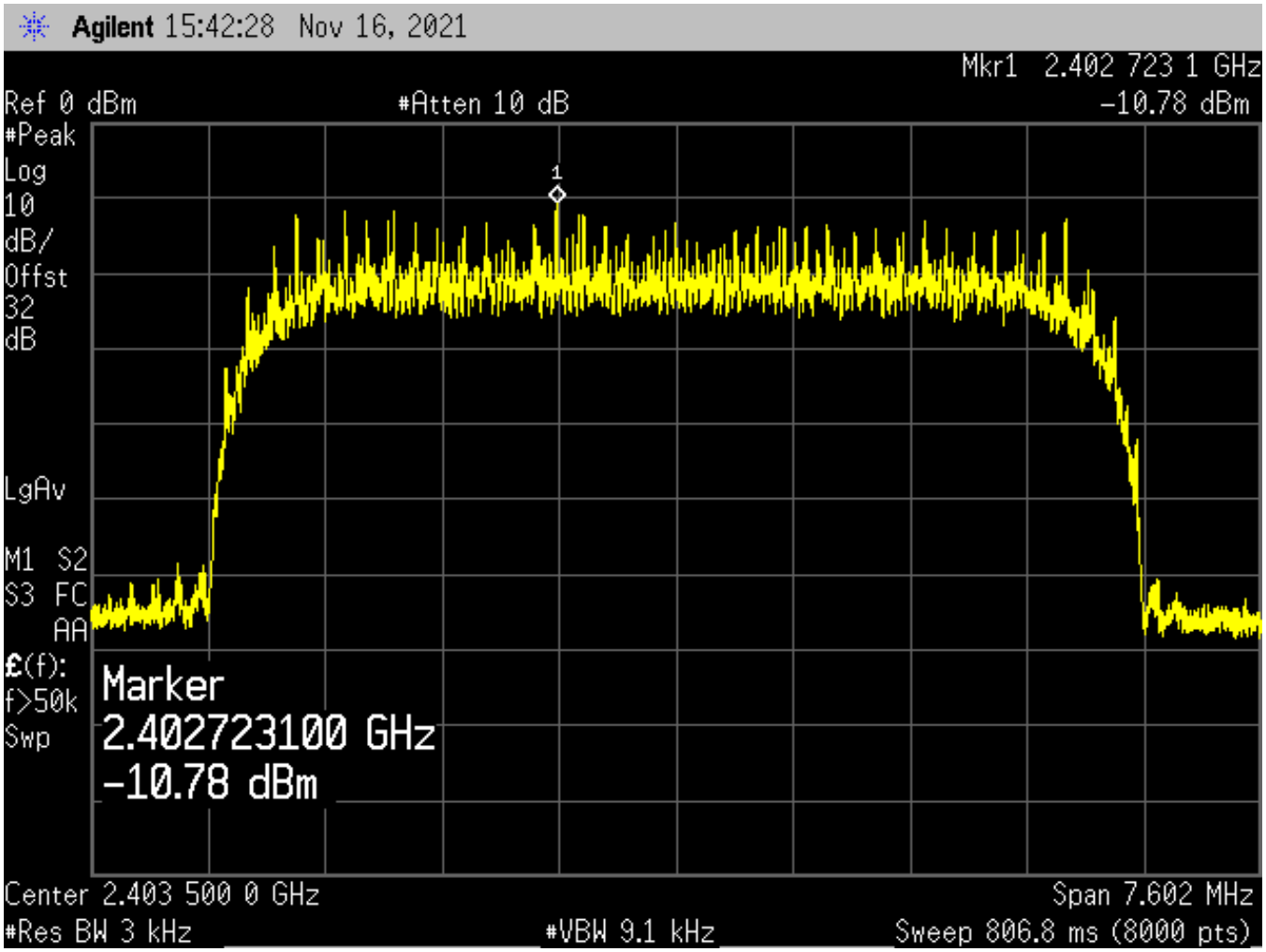


Figure 14: Center Channel, Power Spectral Density – Low Power Mode

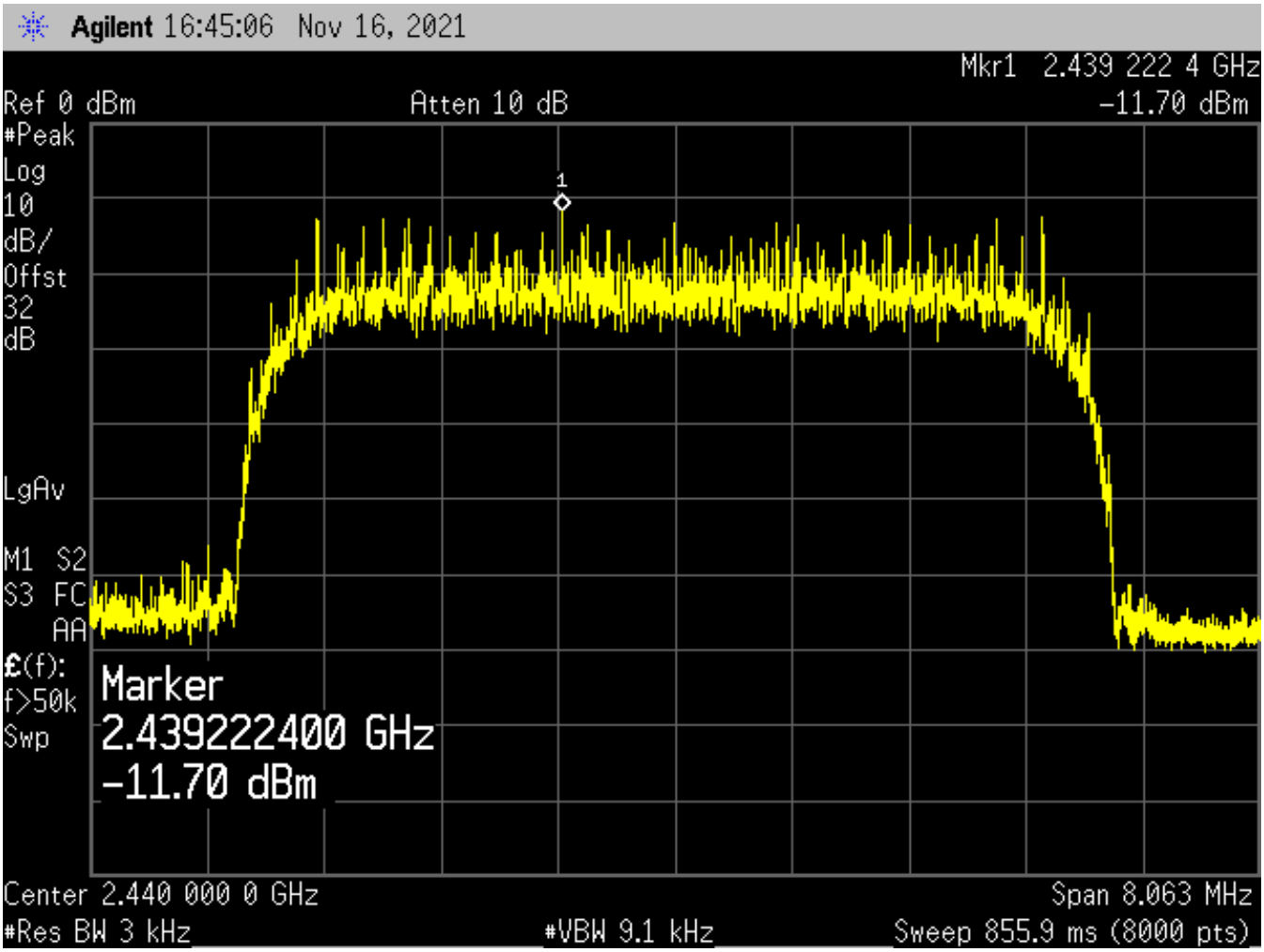


Figure 15: High Channel, Power Spectral Density – Low Power Mode

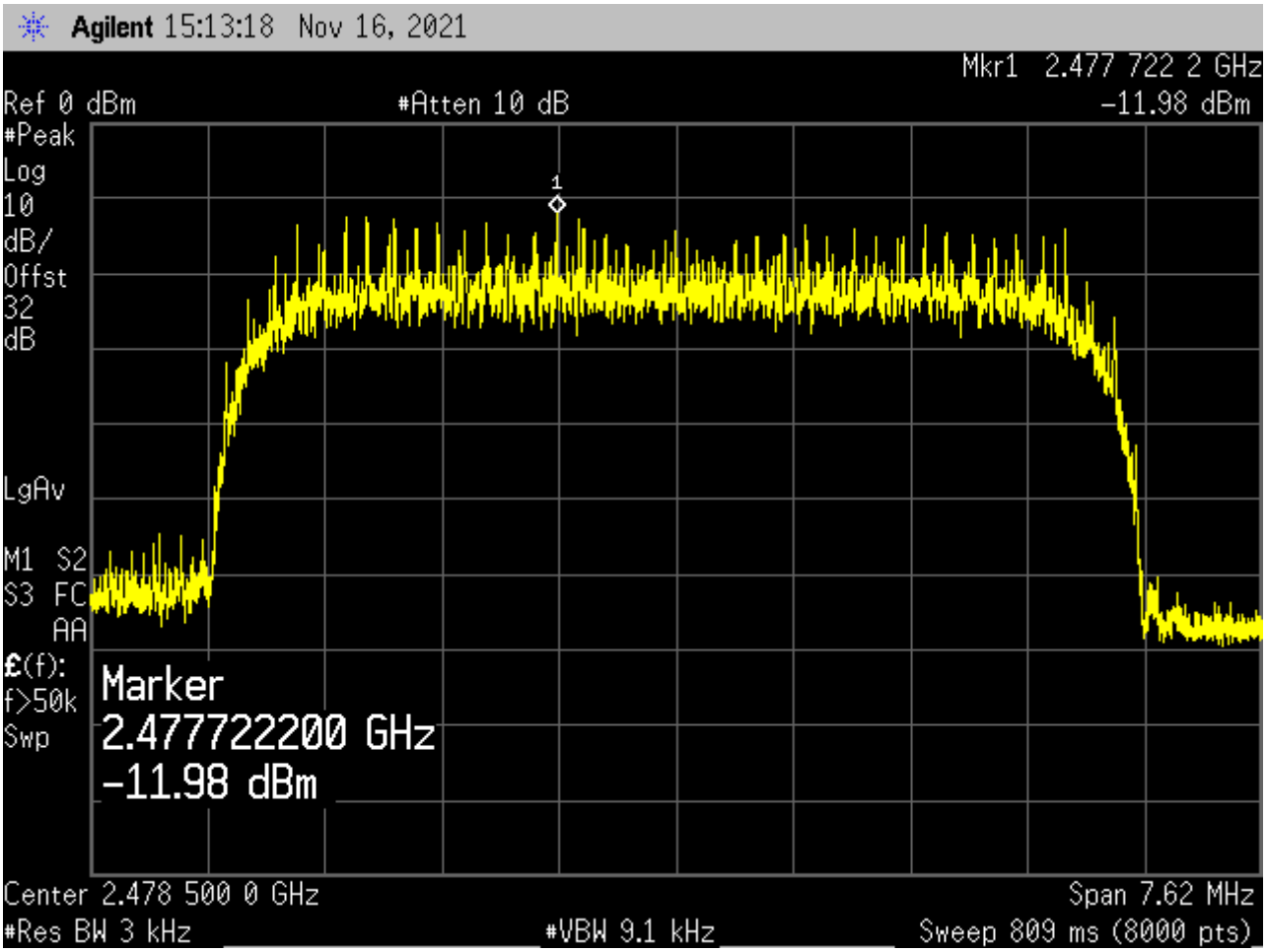


Figure 16: Low Channel, Power Spectral Density – High Power Mode

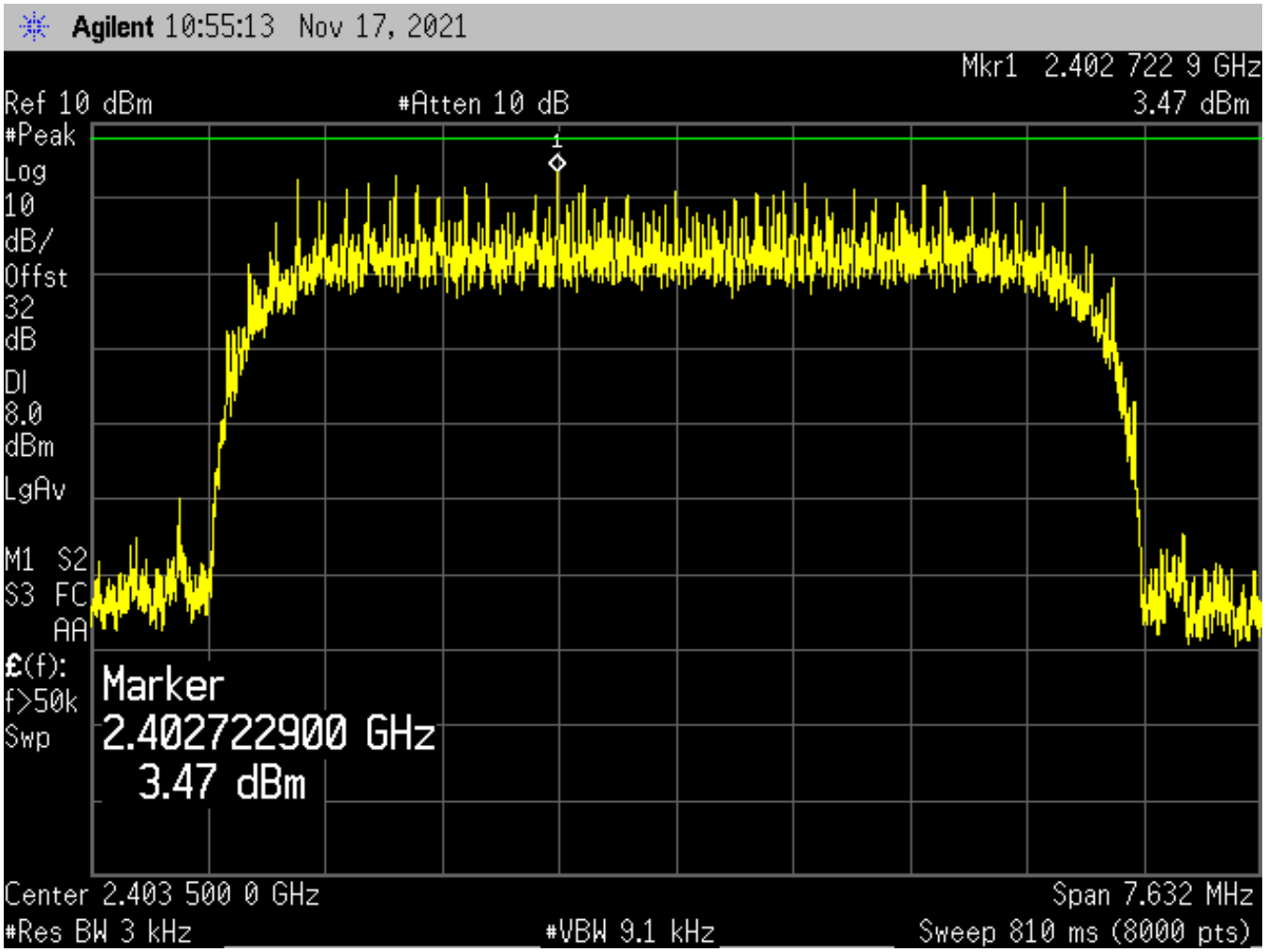


Figure 17: Center Channel, Power Spectral Density – High Power Mode

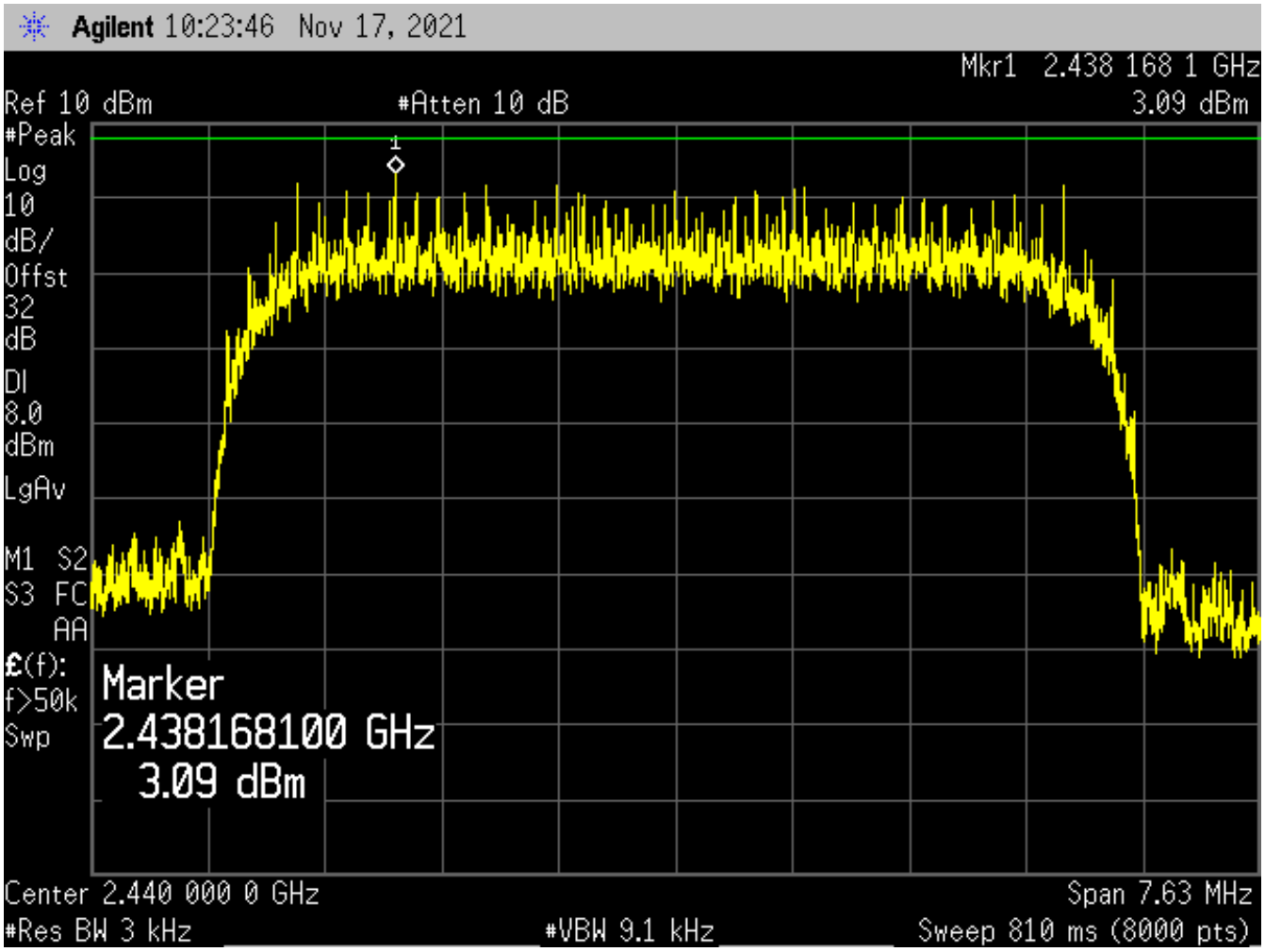
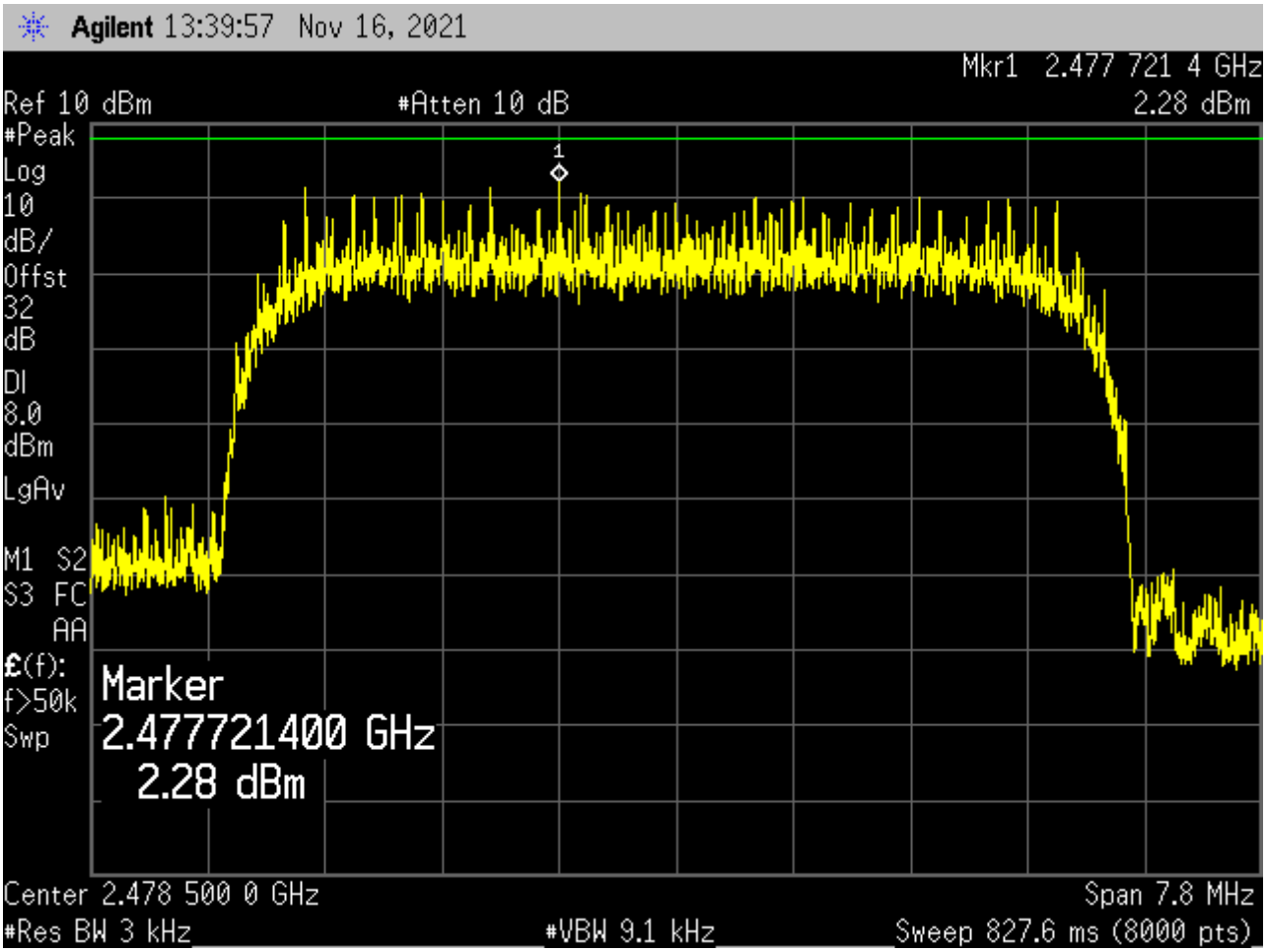


Figure 18: High Channel, Power Spectral Density – High Power Mode



2.4 Conducted Band Edge

In accordance with FCC Public Notice DA-00-705 close-up plots of the low cannel, and of the high channel, with respect to the nearest authorized band-edge, are provided below.

2.4.1 Measurement Method

In any 100 kHz bandwidth outside the frequency band in which the spread spectrum or digitally modulated intentional radiator is operating, the radio frequency power that is produced by the intentional radiator shall be at least 20 dB below that in the 100 kHz bandwidth within the band that contains the highest level of the desired power, based on either an RF conducted or a radiated measurement, provided the transmitter demonstrates compliance with the peak conducted power limits.

Table 7: Band Edge – Spectrum Analyzer Settings

Resolution Bandwidth	Video Bandwidth
100 kHz	300 kHz

Table 8: Band Edge Summary

EUT Power Mode/Setting	Channel Name	Frequency (MHz)	Band Edge (dBc)	Pass/Fail
Low Power Setting (Minimum Power)	Low	2403.5	46.38	Pass
	High	2478.5	44.91	Pass
High Power Setting (Maximum Power)	Low	2403.5	46.90	Pass
	High	2478.5	51.40	Pass

Figure 19: Low Channel, Lower Band Edge – Low Power Mode

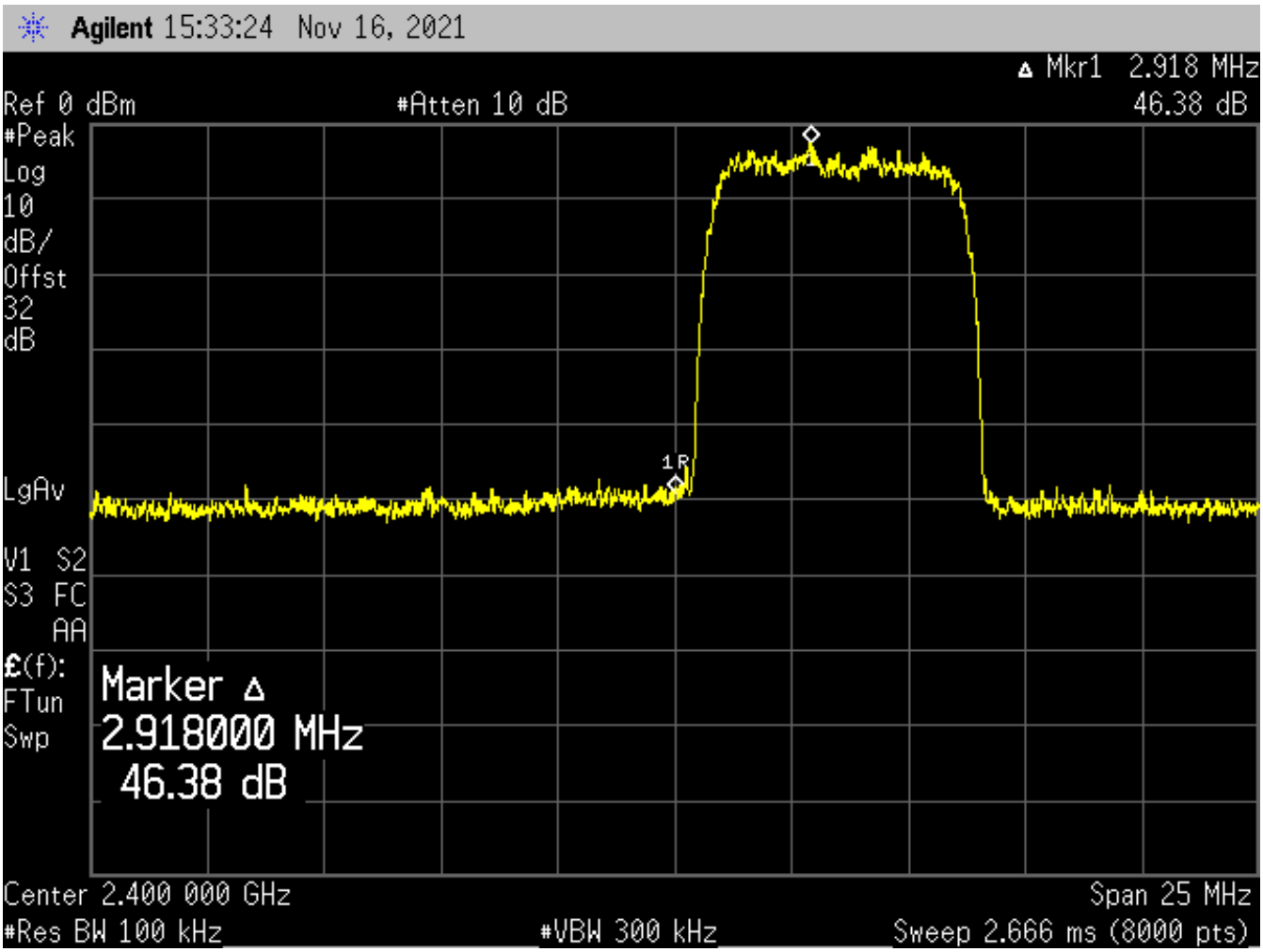


Figure 20: High Channel, Upper Band Edge – Low Power Mode

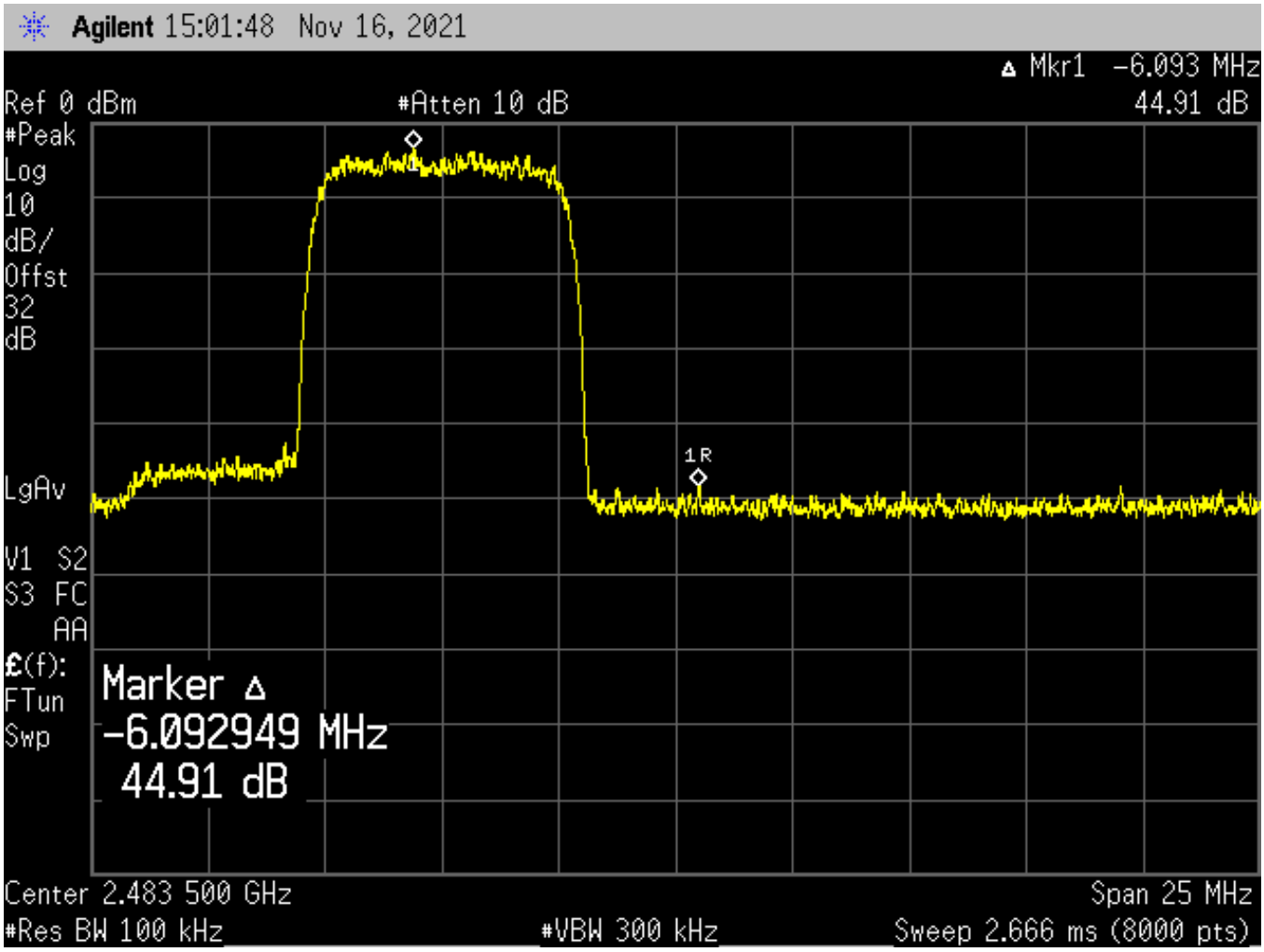


Figure 21: Low Channel, Lower Band Edge – High Power Mode

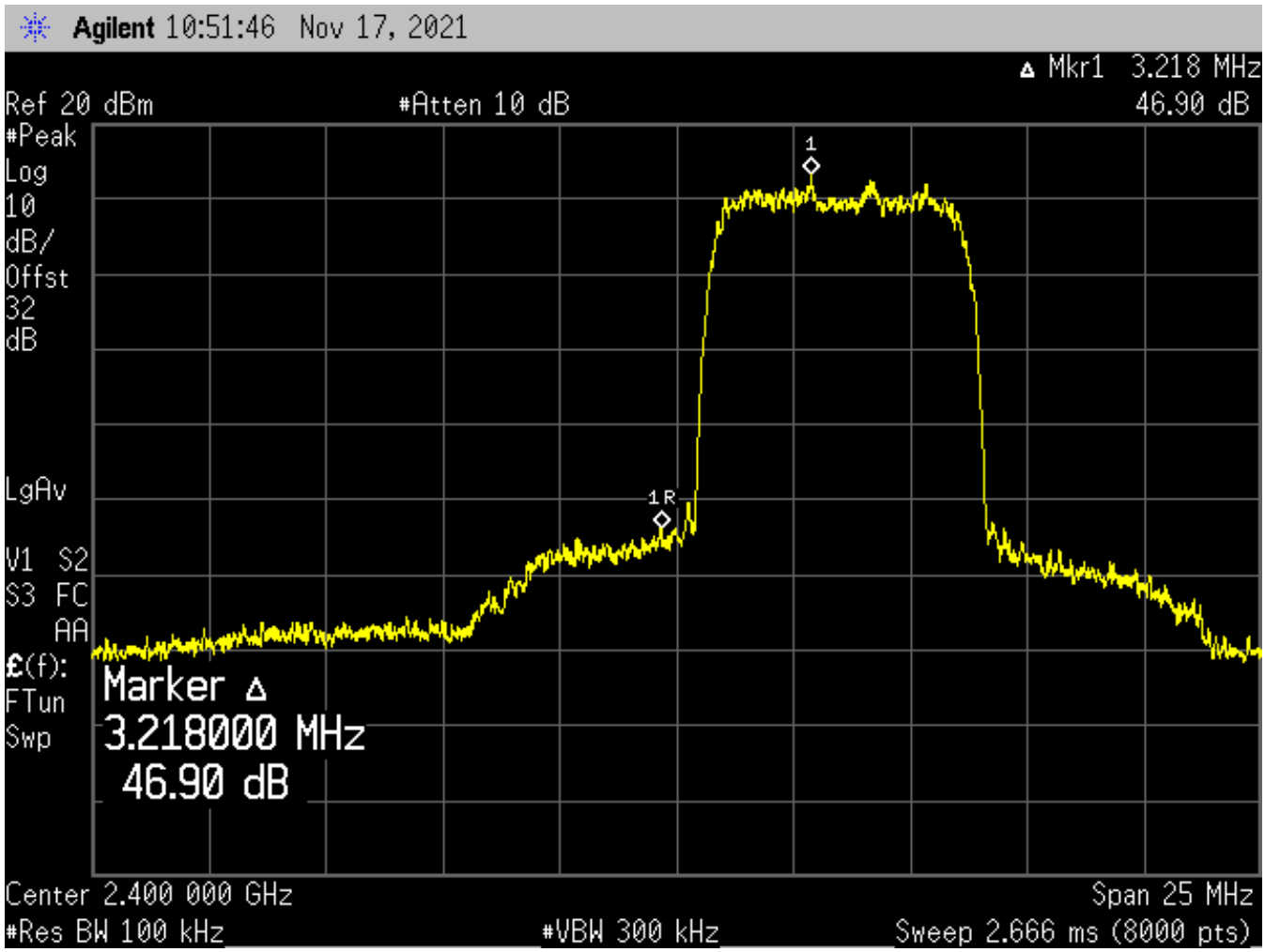
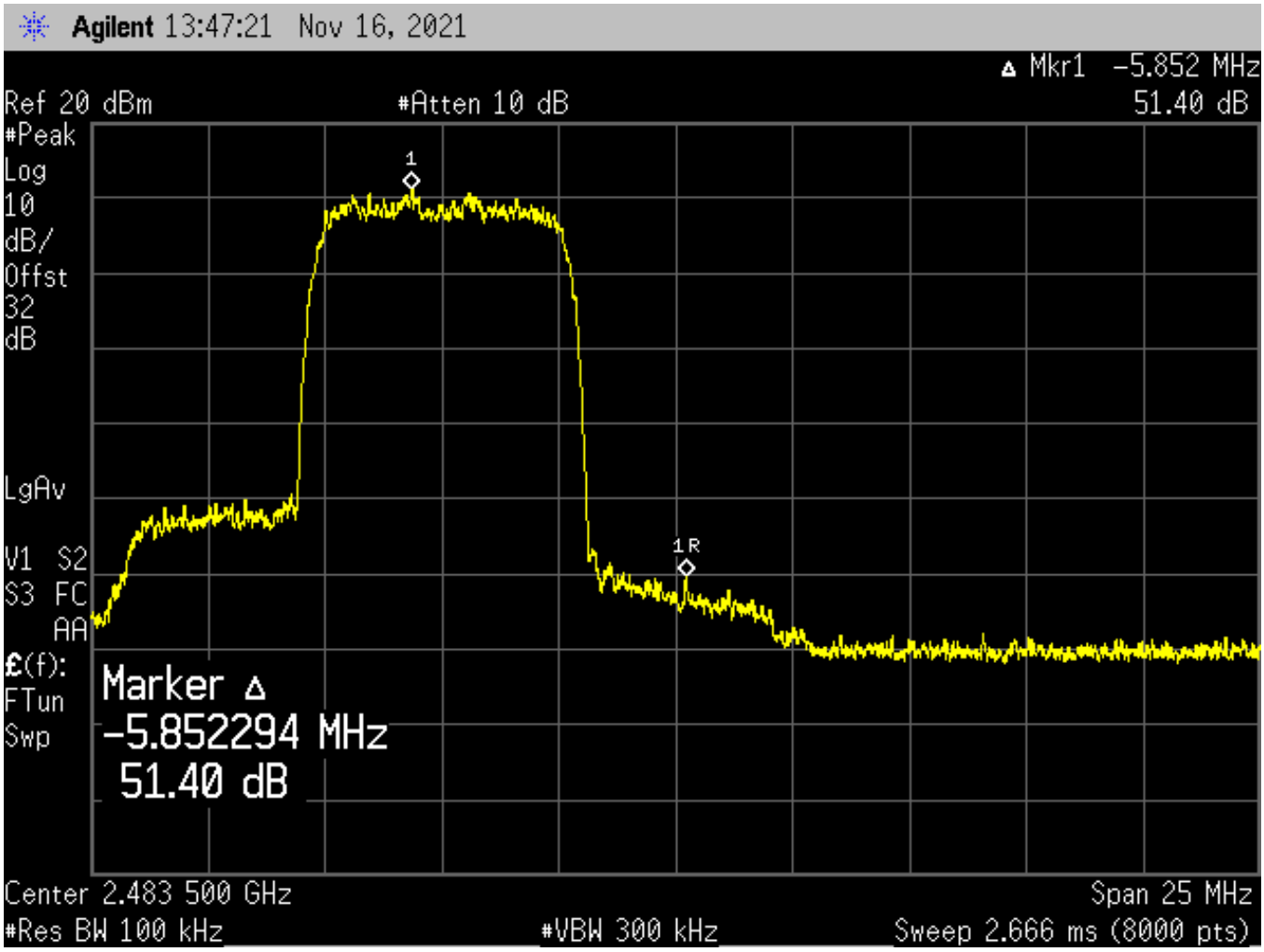


Figure 22: High Channel, Upper Band Edge – High Power Mode



2.5 Conducted Spurious Emissions

The EUT must comply with requirements for spurious emissions. Per §15.247(d) – all spurious emissions in any 100 kHz bandwidth outside the frequency band in which the spread spectrum device is operating shall be attenuated 20 dB below the highest power level in a 100 kHz bandwidth within the band containing the highest level of the desired power.

2.5.1 Measurement Method

Per ANSI C63.10, Section 11.11, "Emissions in non-restricted frequency bands" this test may be performed at the antenna port, via a conducted manner. The spectrum analyzer resolution bandwidth was set to 100 kHz and the video bandwidth was set to 300 kHz. The amplitude of the EUT carrier frequency was measured to determine the emissions limit (20 dB below the carrier frequency amplitude). The emissions outside of the allocated frequency band were then scanned from 30 MHz up to the 10th harmonic of the fundamental carrier.

The EUT complies with the requirements for Spurious emissions at the antenna port.

The final spurious emissions test data is presented in Figure 23 through Figure 46.

Table 9: Spurious Emissions Summary

EUT Power Mode/Setting	Channel Name	Frequency (MHz)	Test Range (MHz)	Pass/Fail
Low Power Setting (Minimum Power)	Low	2403.5	30 – 25,000	Pass
	Center	2440.0	30 – 25,000	Pass
	High	2478.5	30 – 25,000	Pass
High Power Setting (Maximum Power)	Low	2403.5	30 – 25,000	Pass
	Center	2440.0	30 – 25,000	Pass
	High	2478.5	30 – 25,000	Pass

Figure 23: Low Channel, Conducted Spurious Plot 1 – Low Power Mode

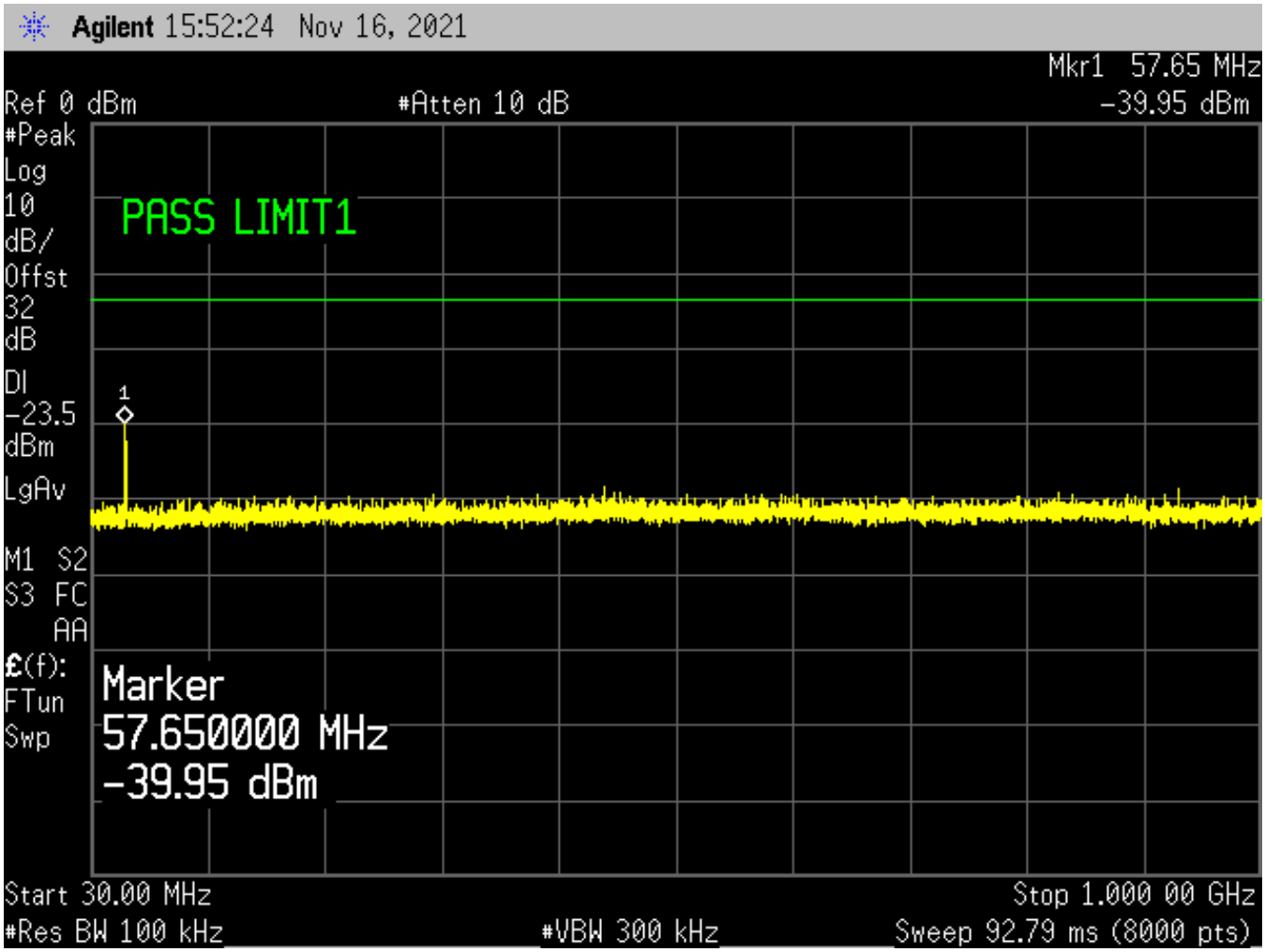


Figure 24: Low Channel, Conducted Spurious Plot 2 – Low Power Mode

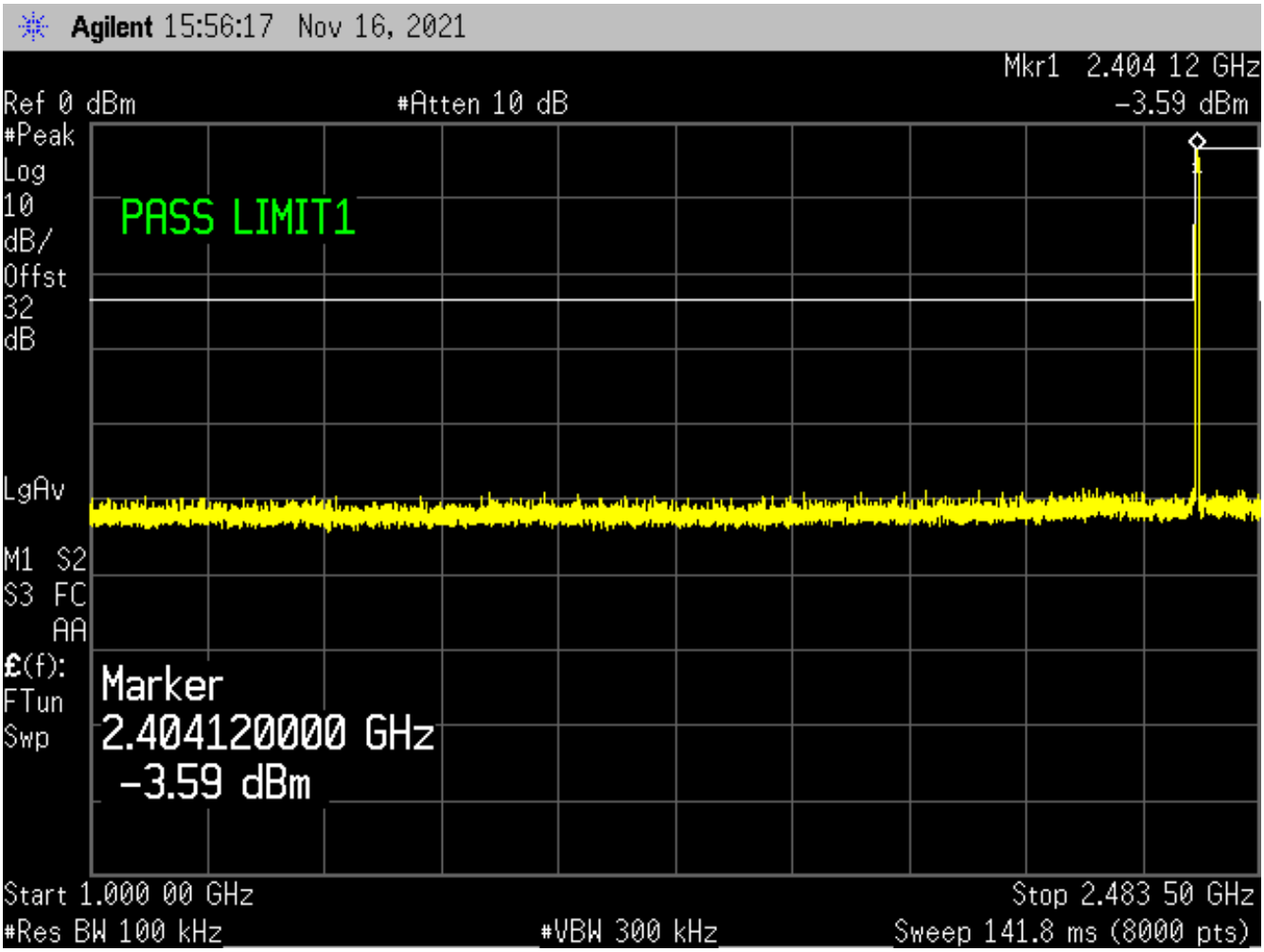


Figure 25: Low Channel, Conducted Spurious Plot 3 – Low Power Mode

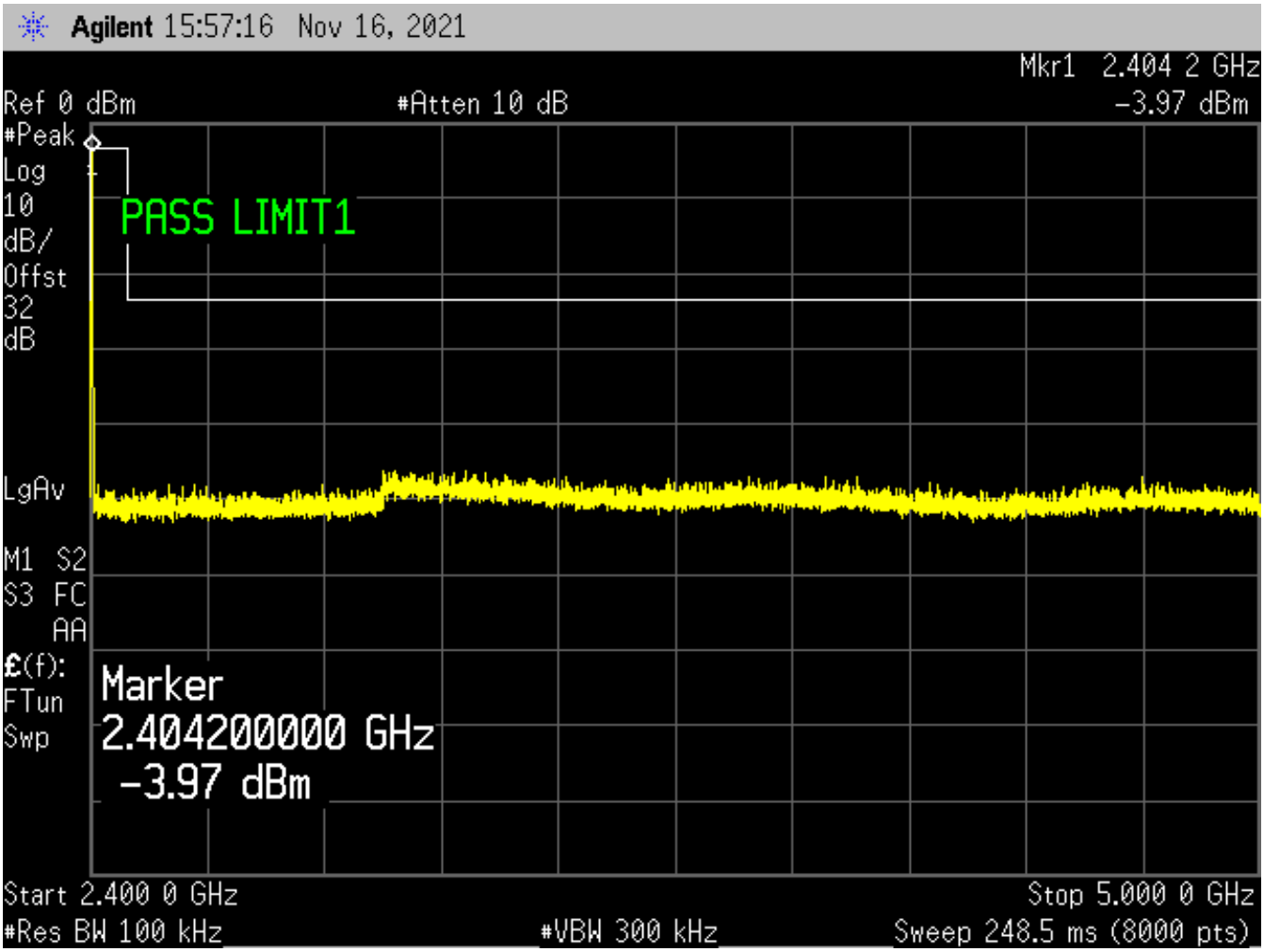


Figure 26: Low Channel, Conducted Spurious Plot 4 – Low Power Mode

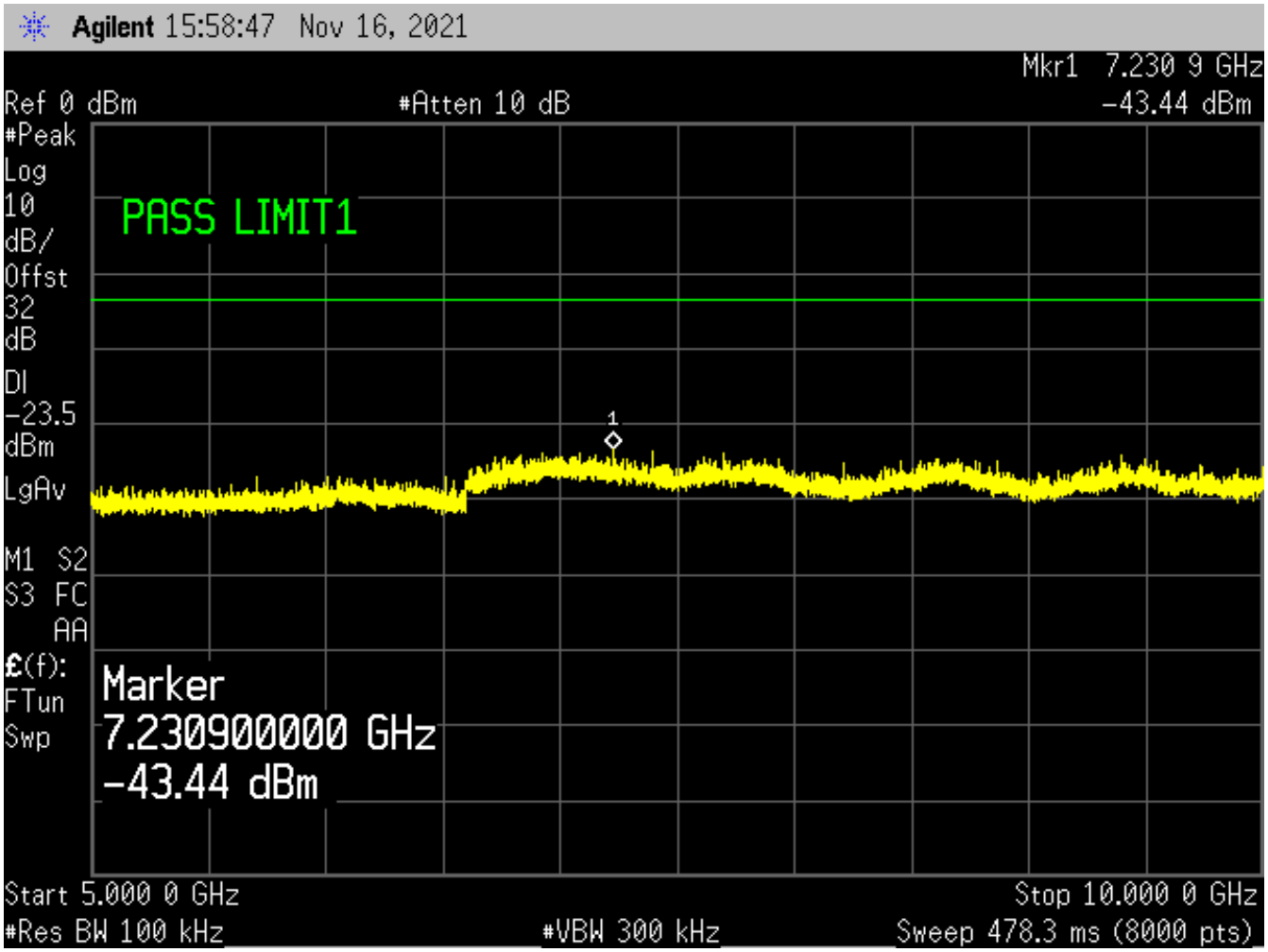


Figure 27: Low Channel, Conducted Spurious Plot 5 – Low Power Mode

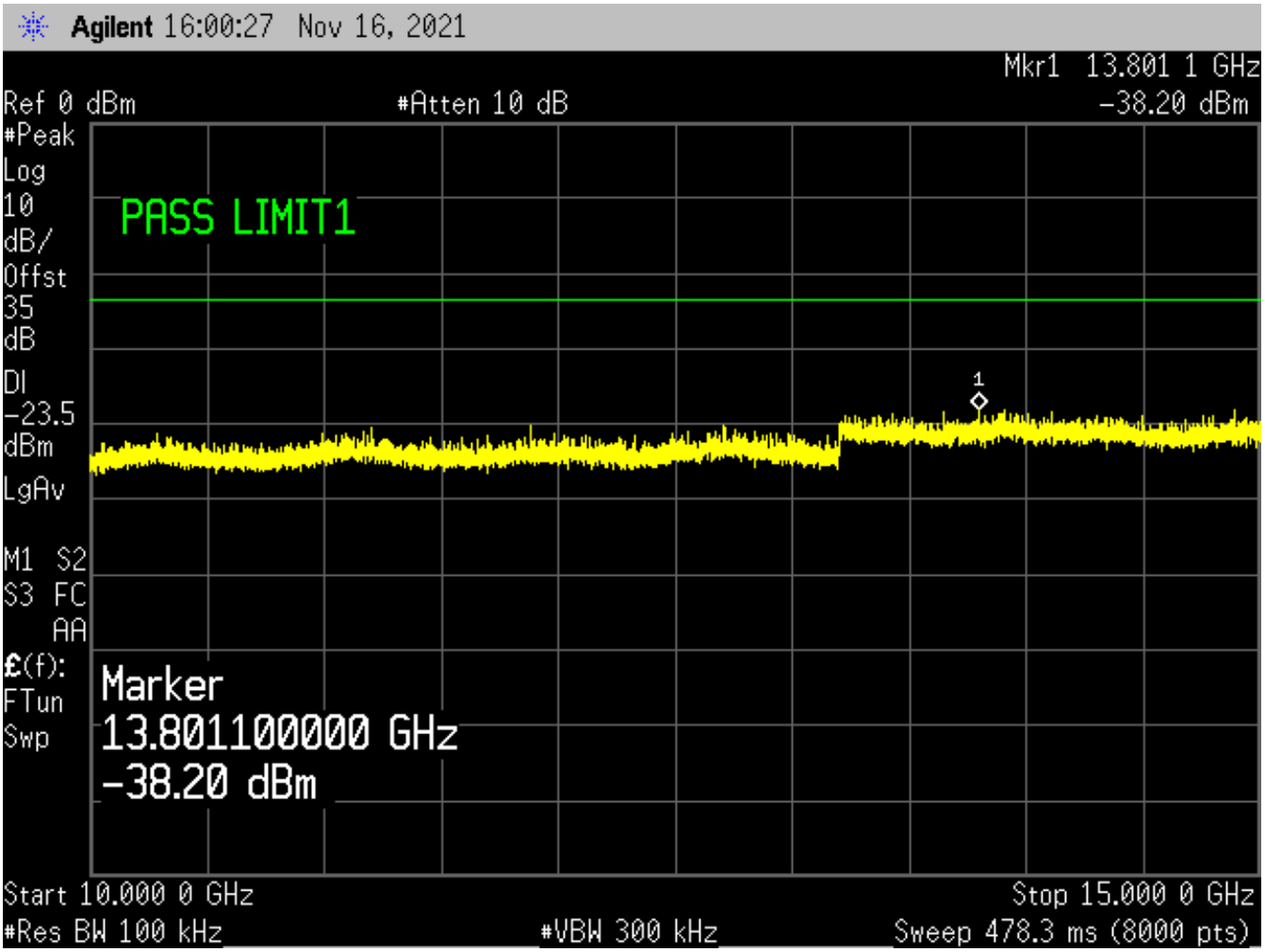


Figure 28: Low Channel, Conducted Spurious Plot 6 – Low Power Mode

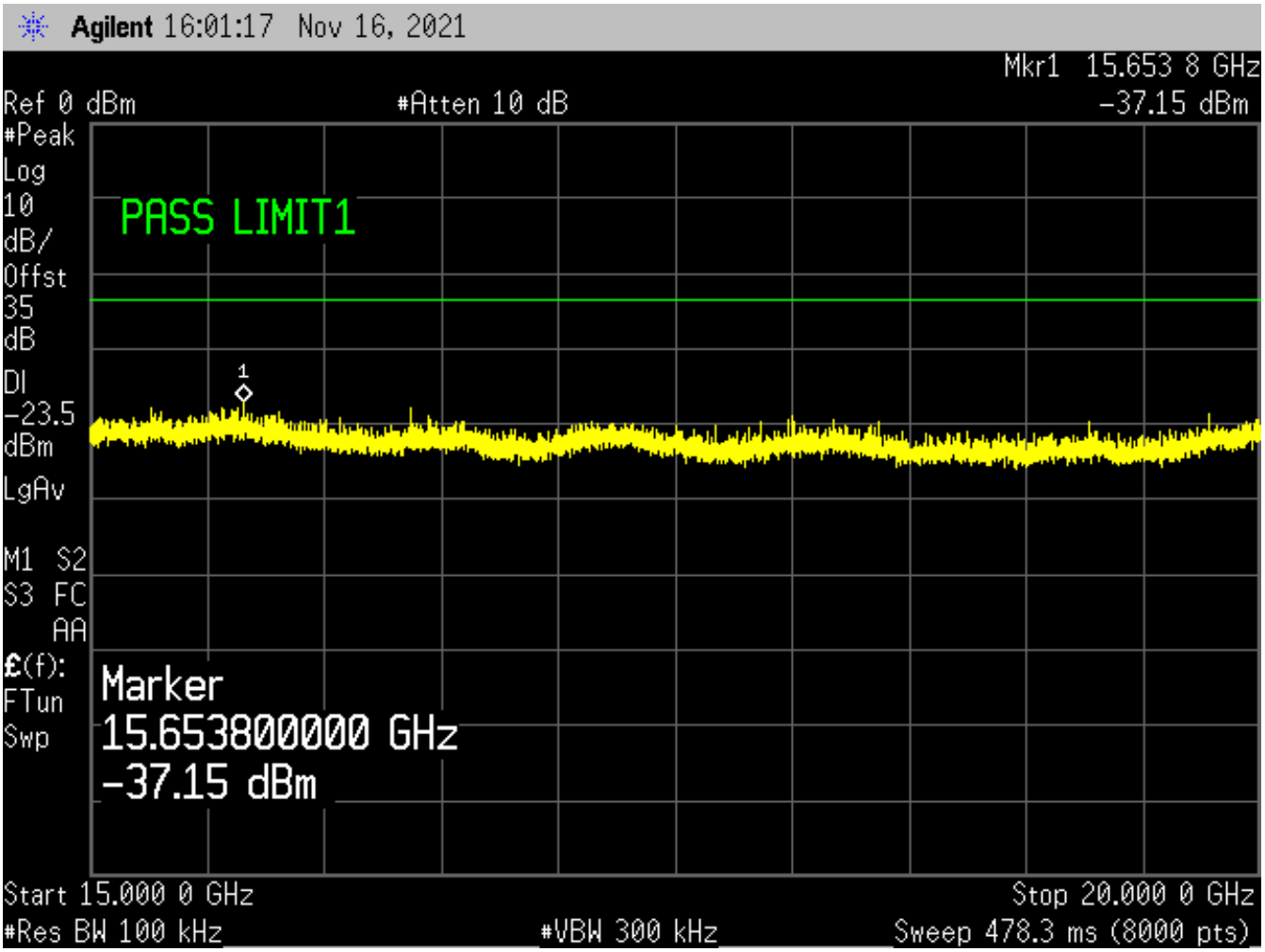


Figure 29: Low Channel, Conducted Spurious Plot 7 – Low Power Mode

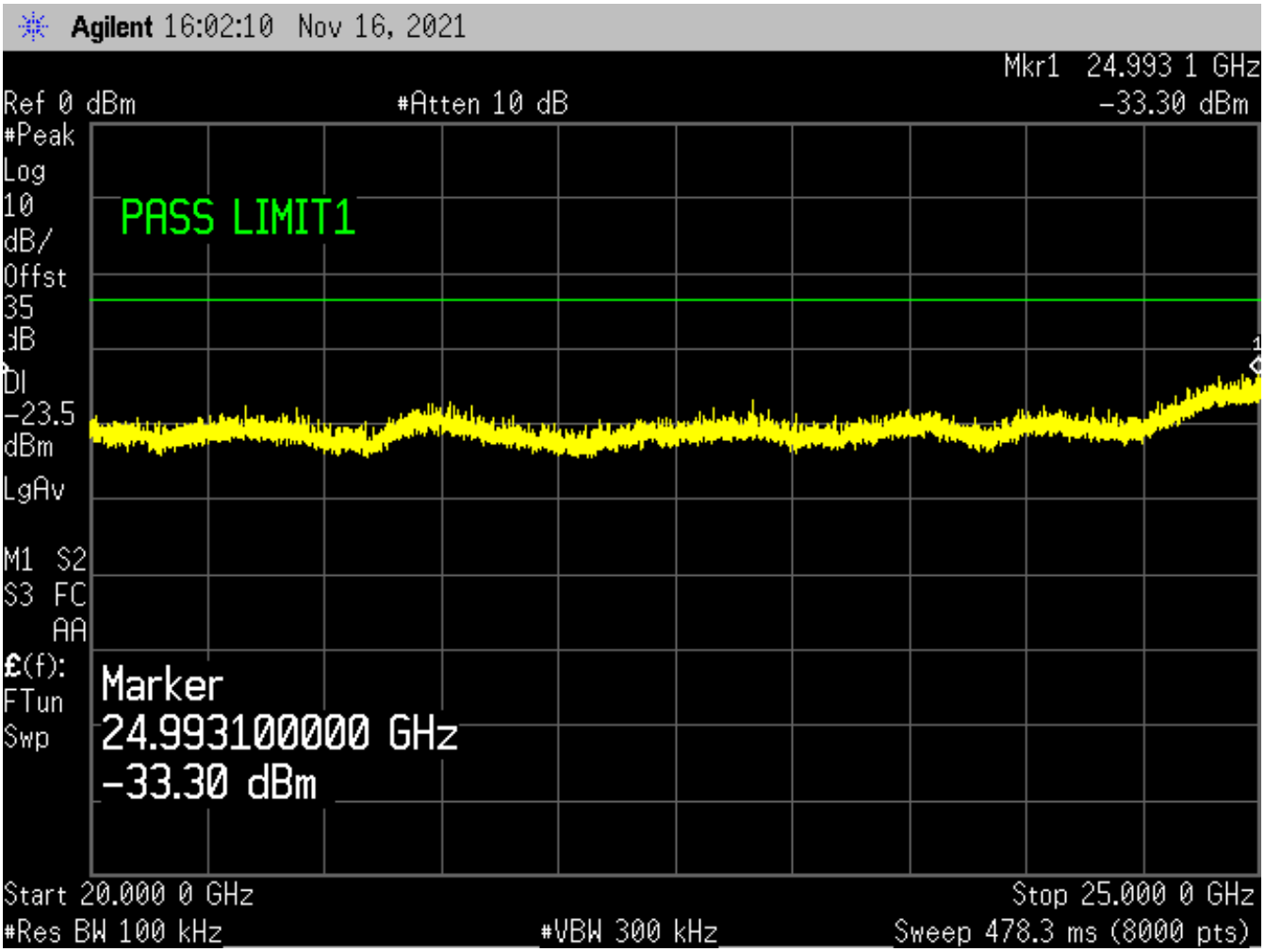


Figure 30: Center Channel, Conducted Spurious Plot 1 – Low Power Mode

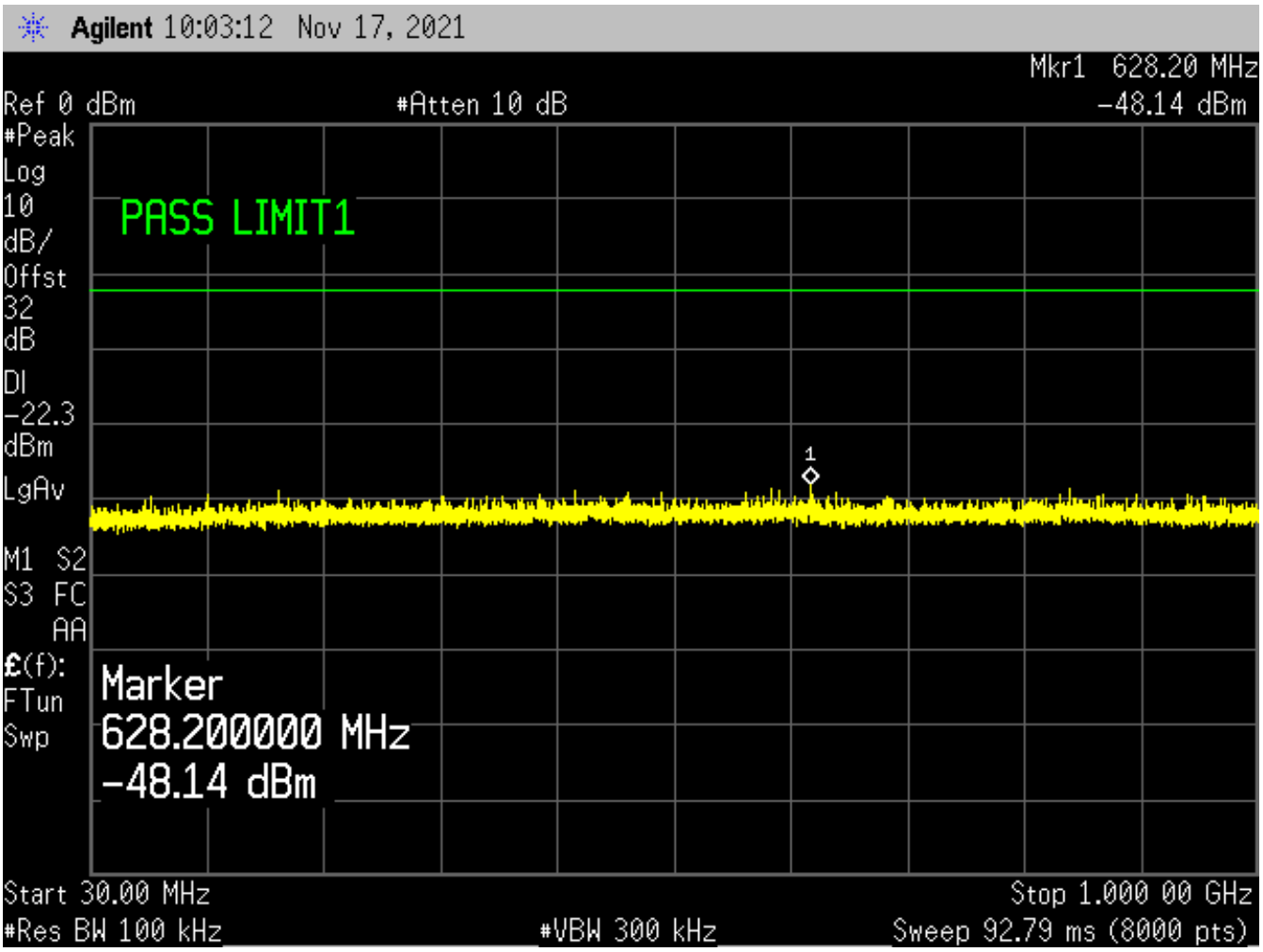


Figure 31: Center Channel, Conducted Spurious Plot 2 – Low Power Mode

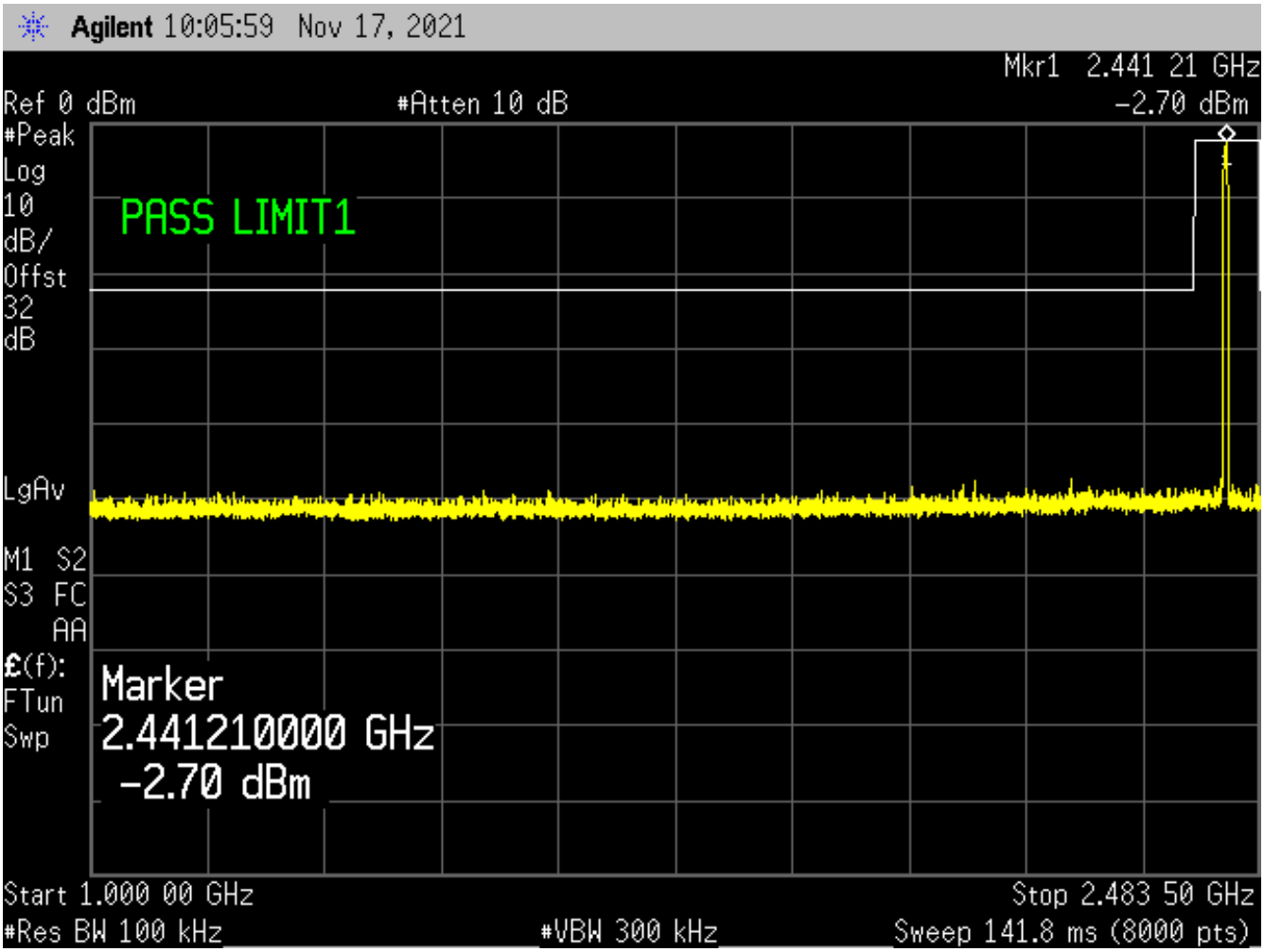


Figure 32: Center Channel, Conducted Spurious Plot 3 – Low Power Mode

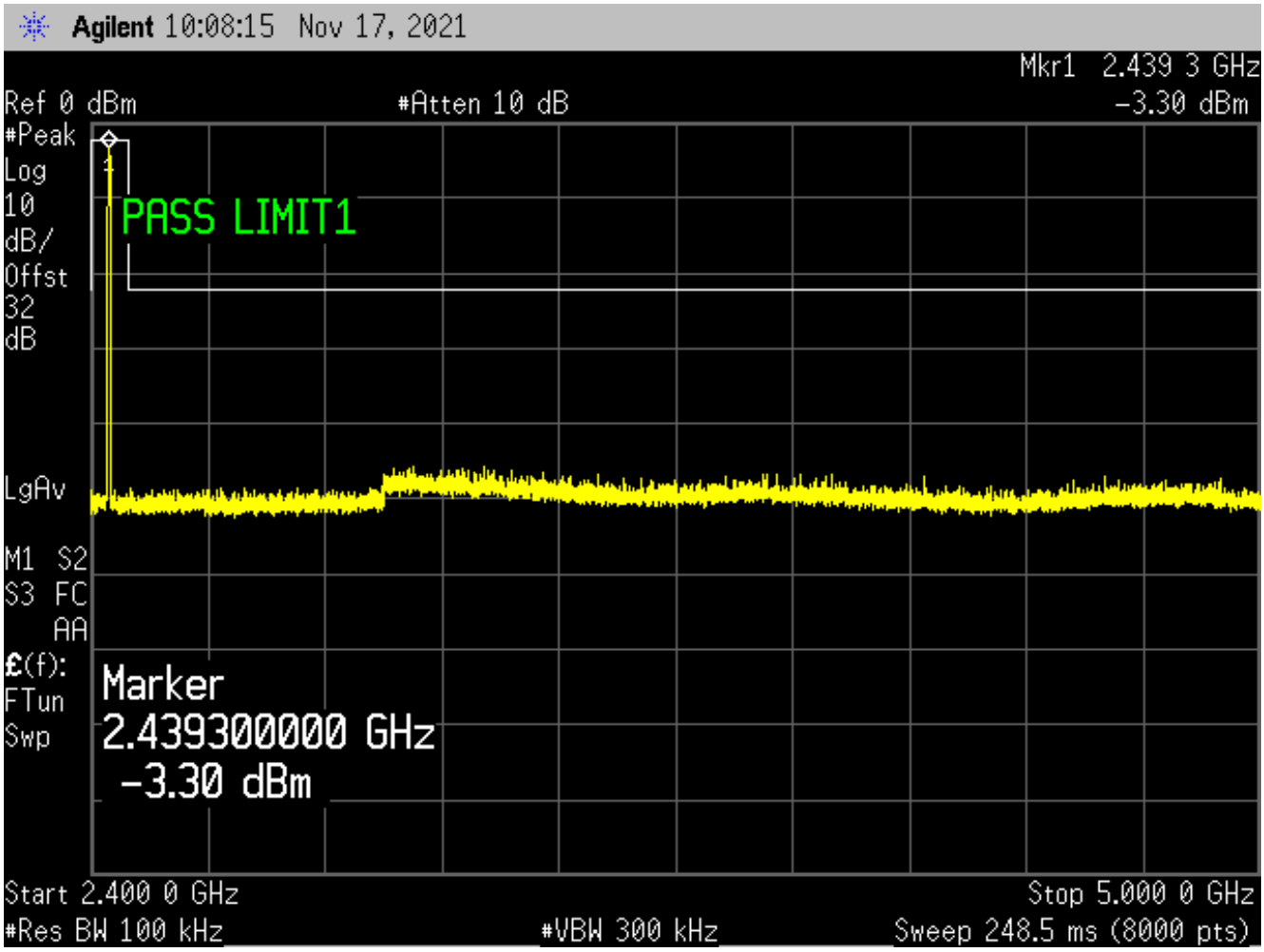


Figure 33: Center Channel, Conducted Spurious Plot 4 – Low Power Mode

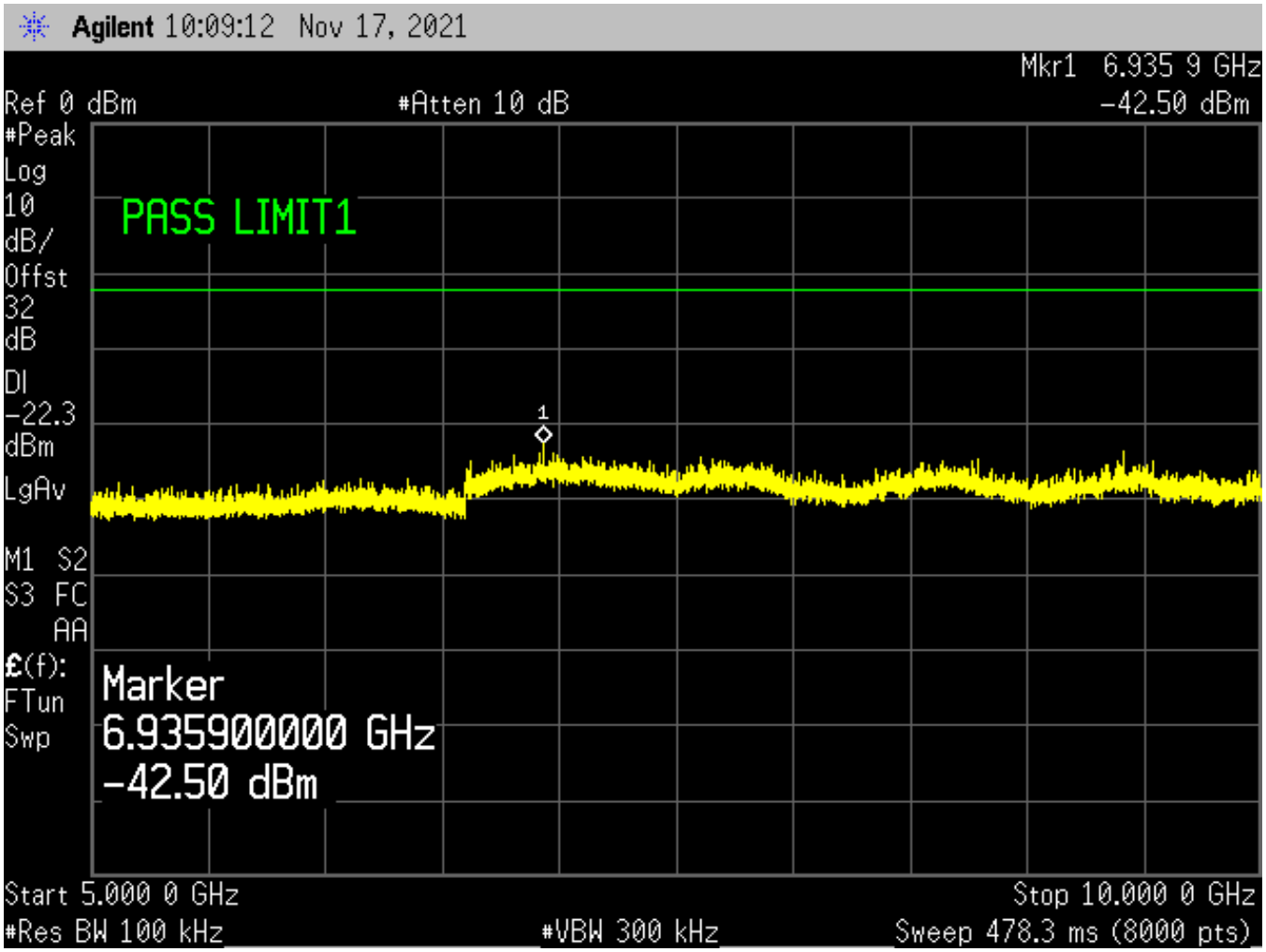


Figure 34: Center Channel, Conducted Spurious Plot 5 – Low Power Mode

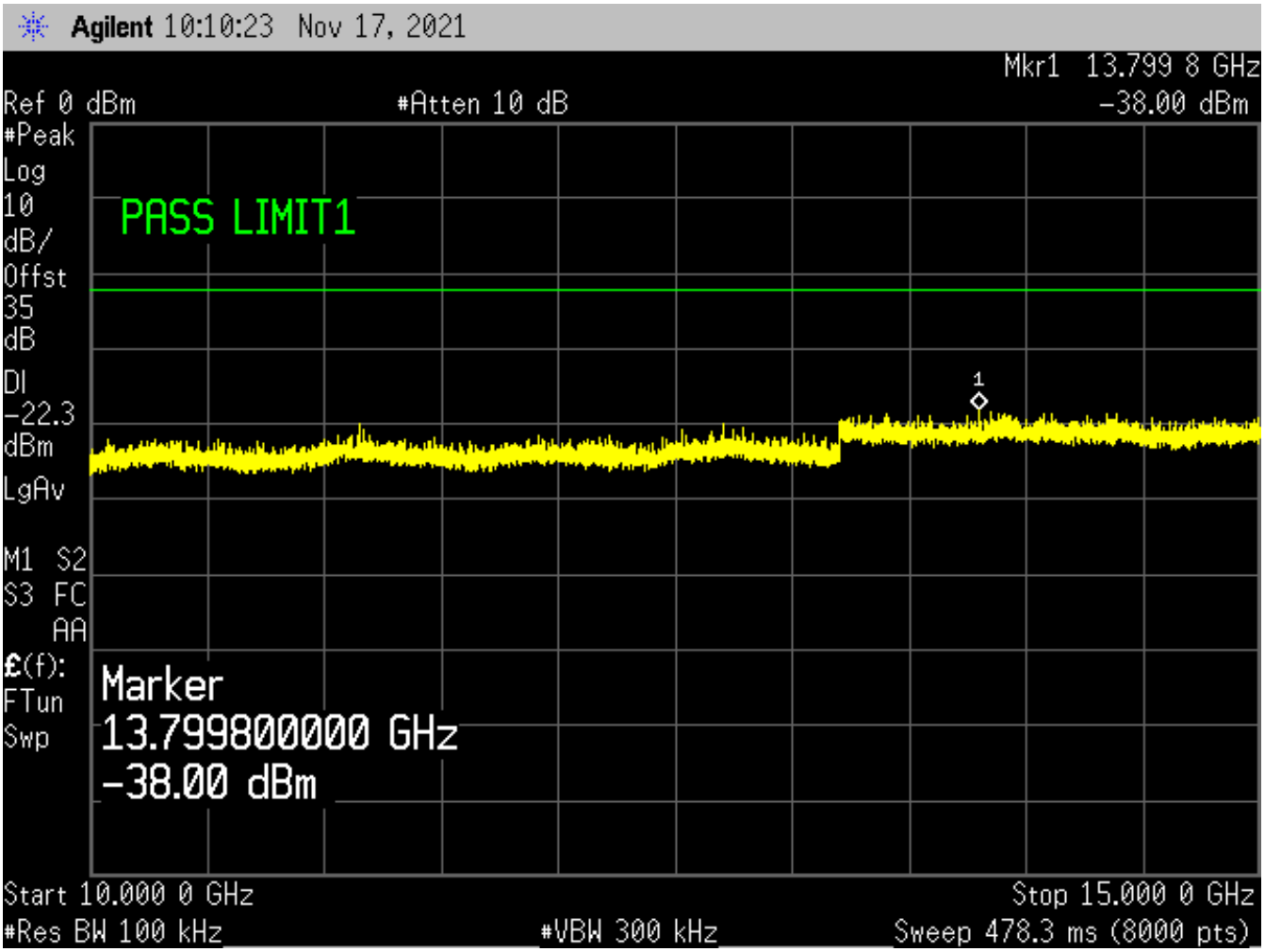


Figure 35: Center Channel, Conducted Spurious Plot 6 – Low Power Mode

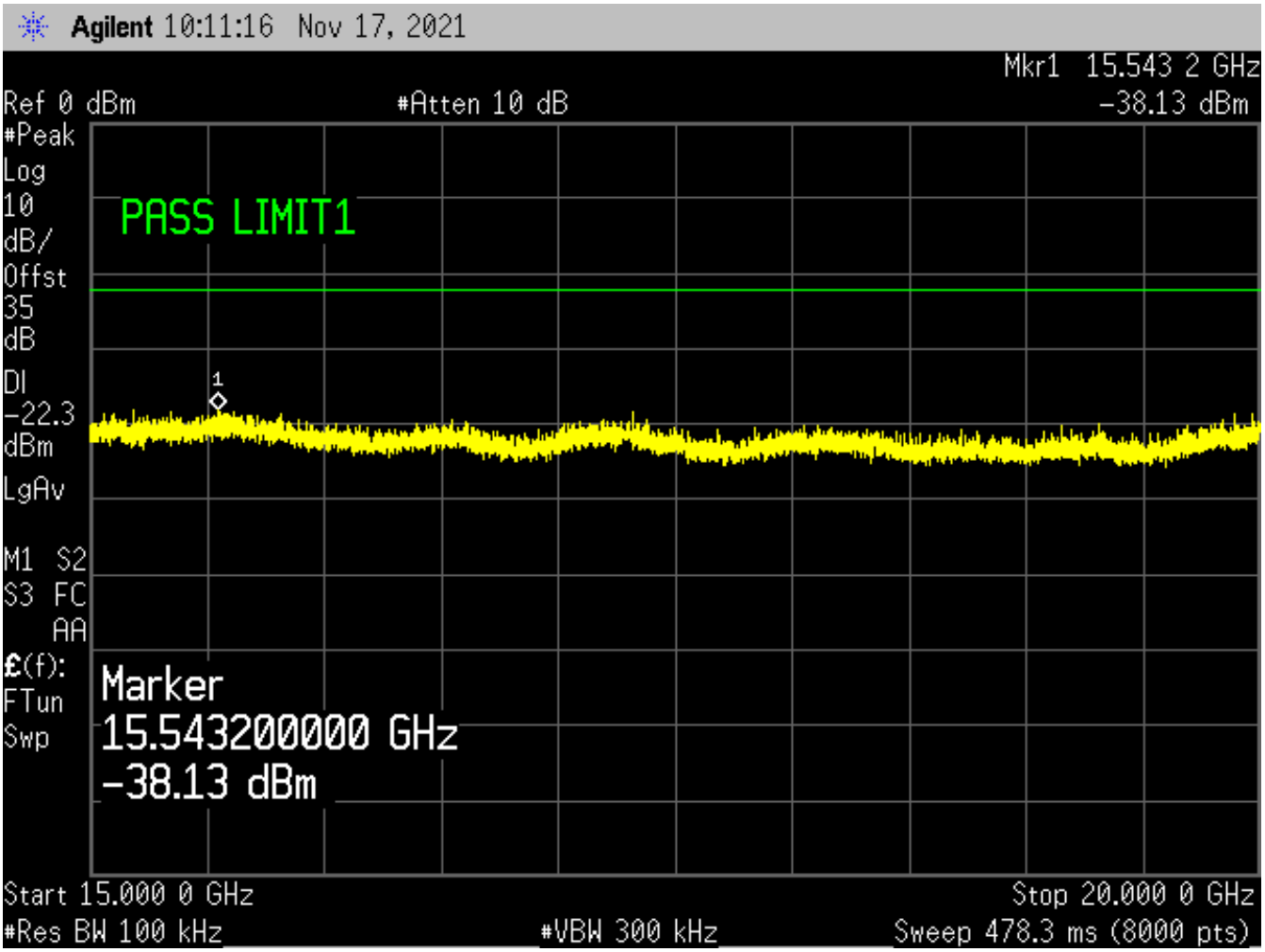


Figure 36: Center Channel, Conducted Spurious Plot 7 – Low Power Mode

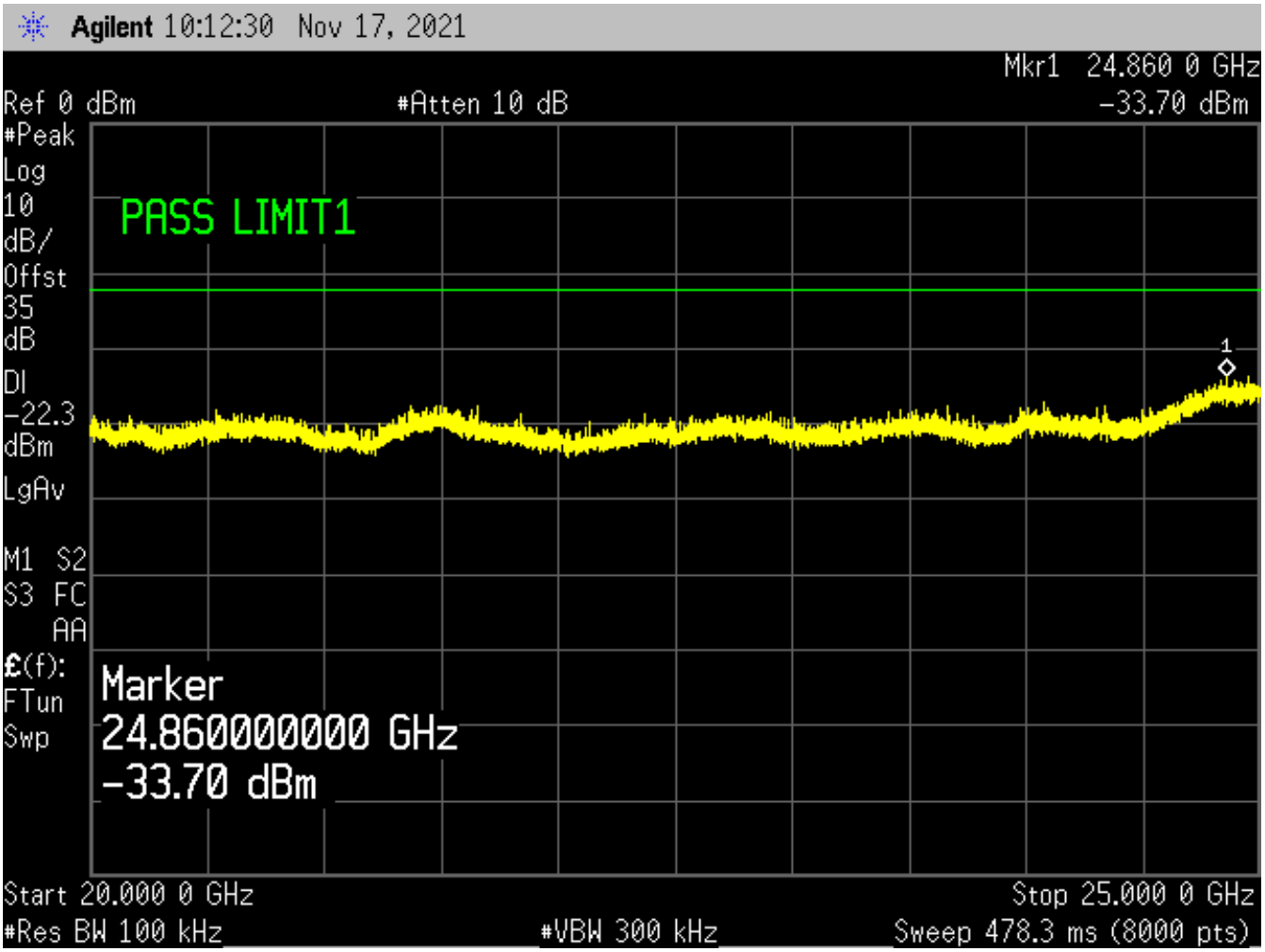


Figure 37: High Channel, Conducted Spurious Plot 1 – Low Power Mode

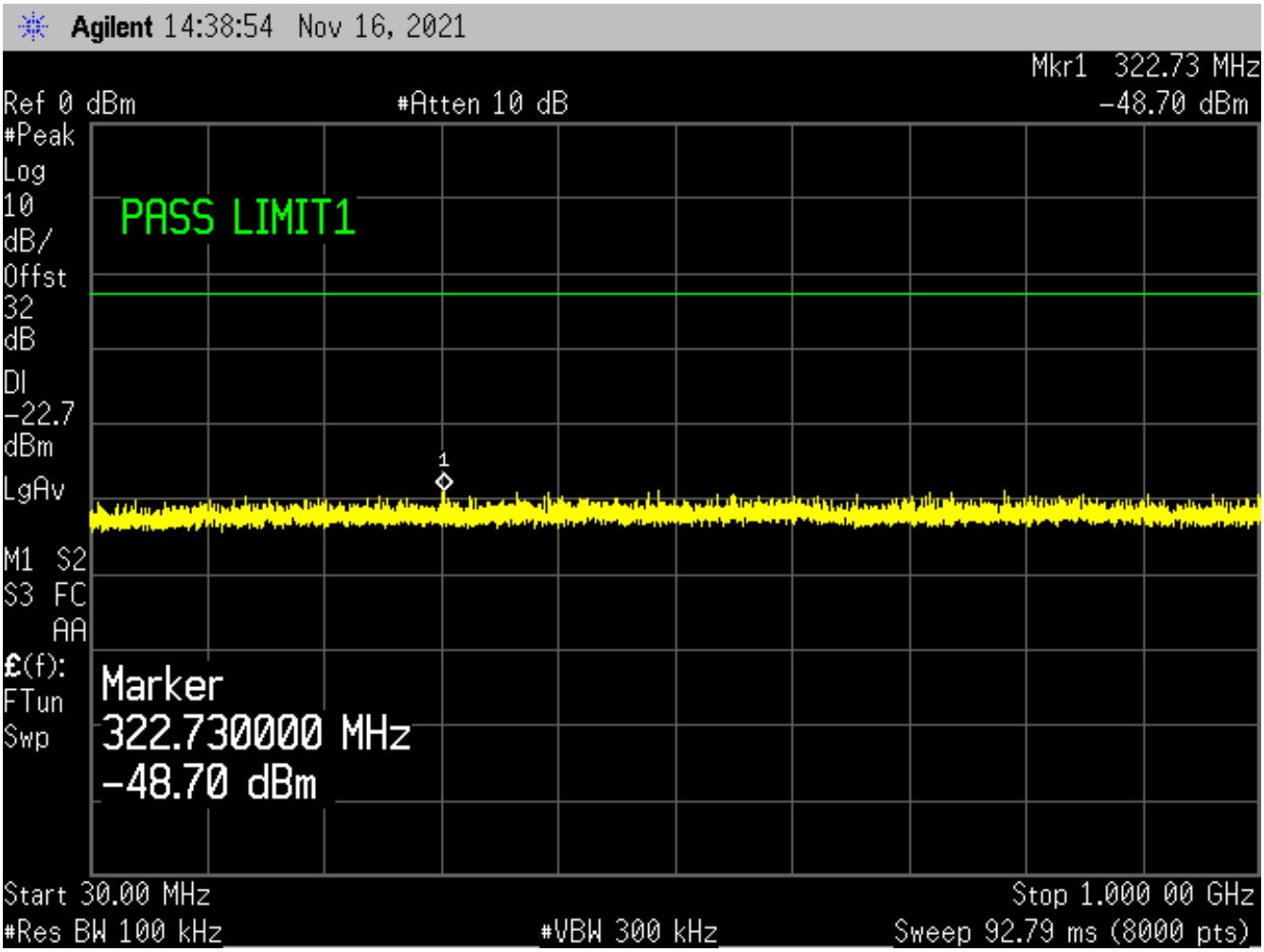


Figure 38: High Channel, Conducted Spurious Plot 2 – Low Power Mode

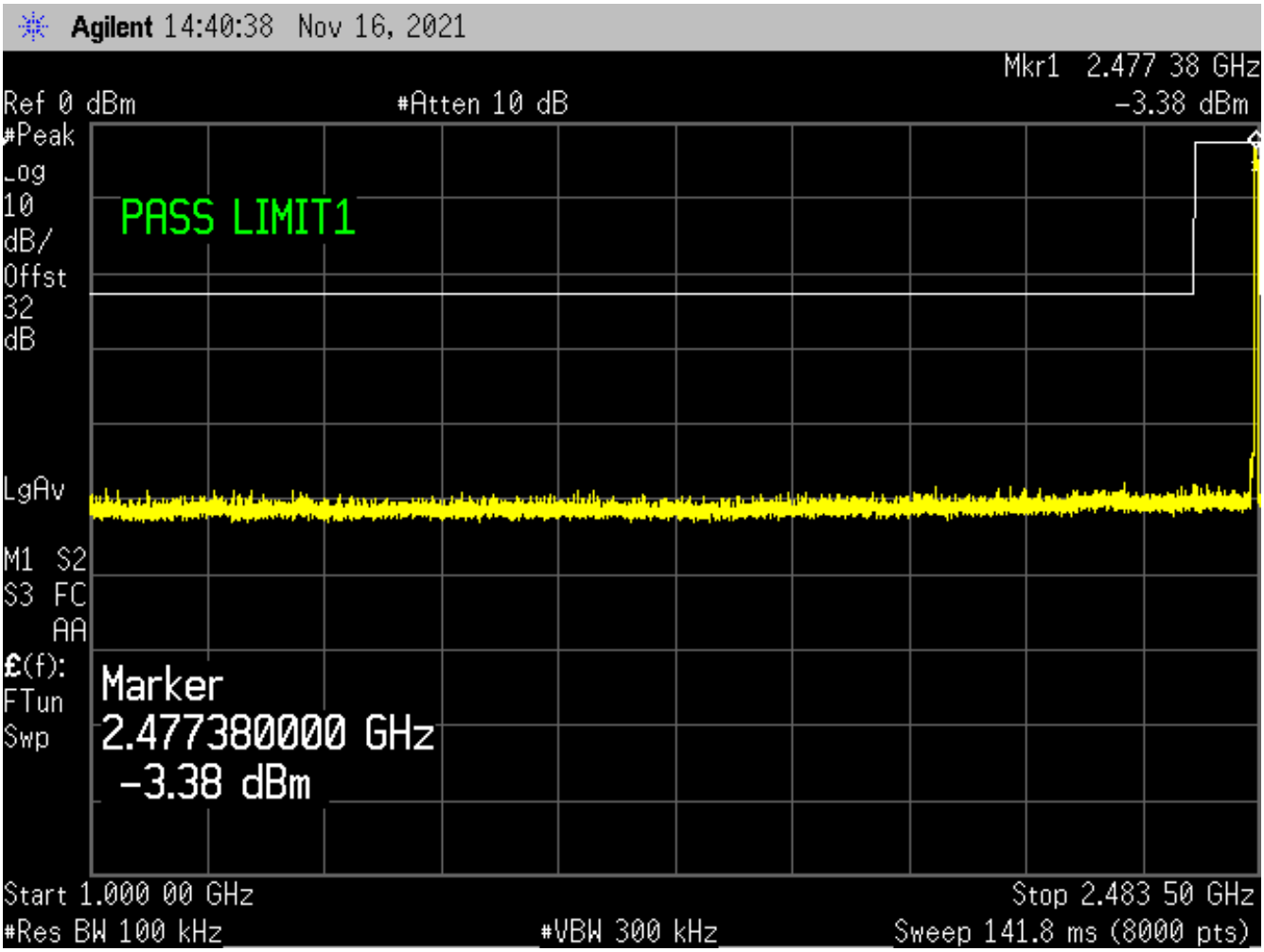


Figure 39: High Channel, Conducted Spurious Plot 3 – Low Power Mode

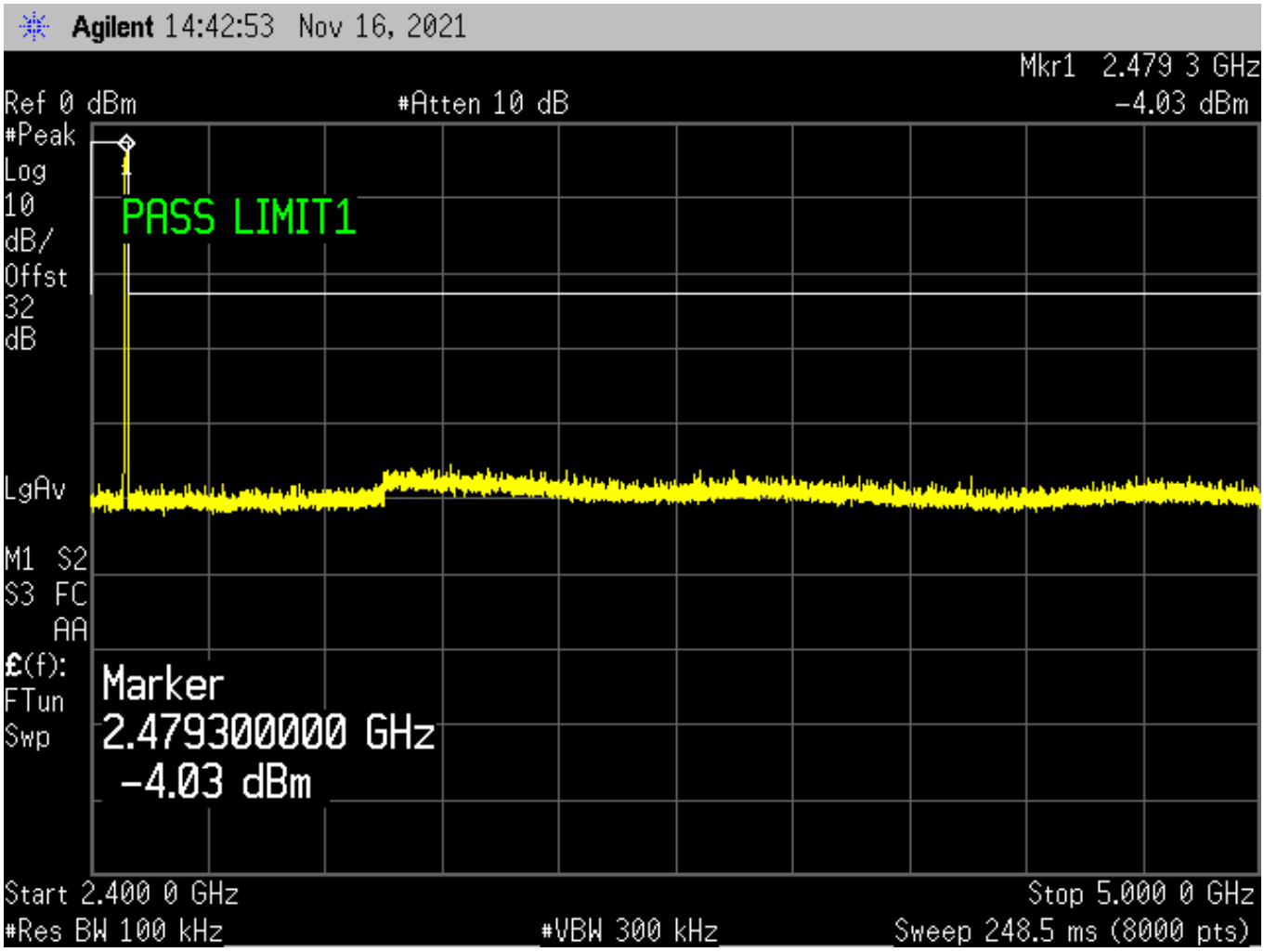


Figure 40: High Channel, Conducted Spurious Plot 4 – Low Power Mode

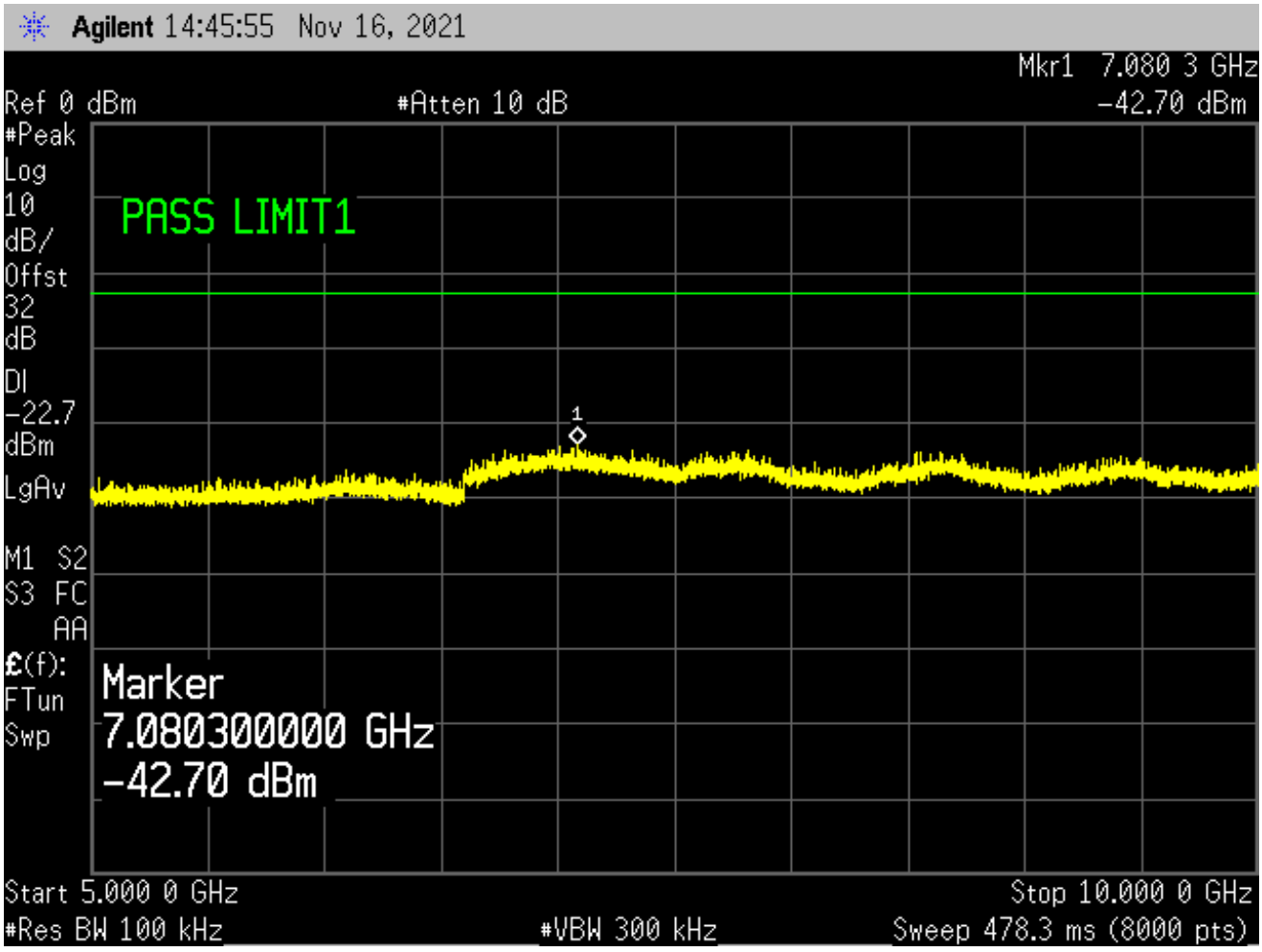


Figure 41: High Channel, Conducted Spurious Plot 5 – Low Power Mode

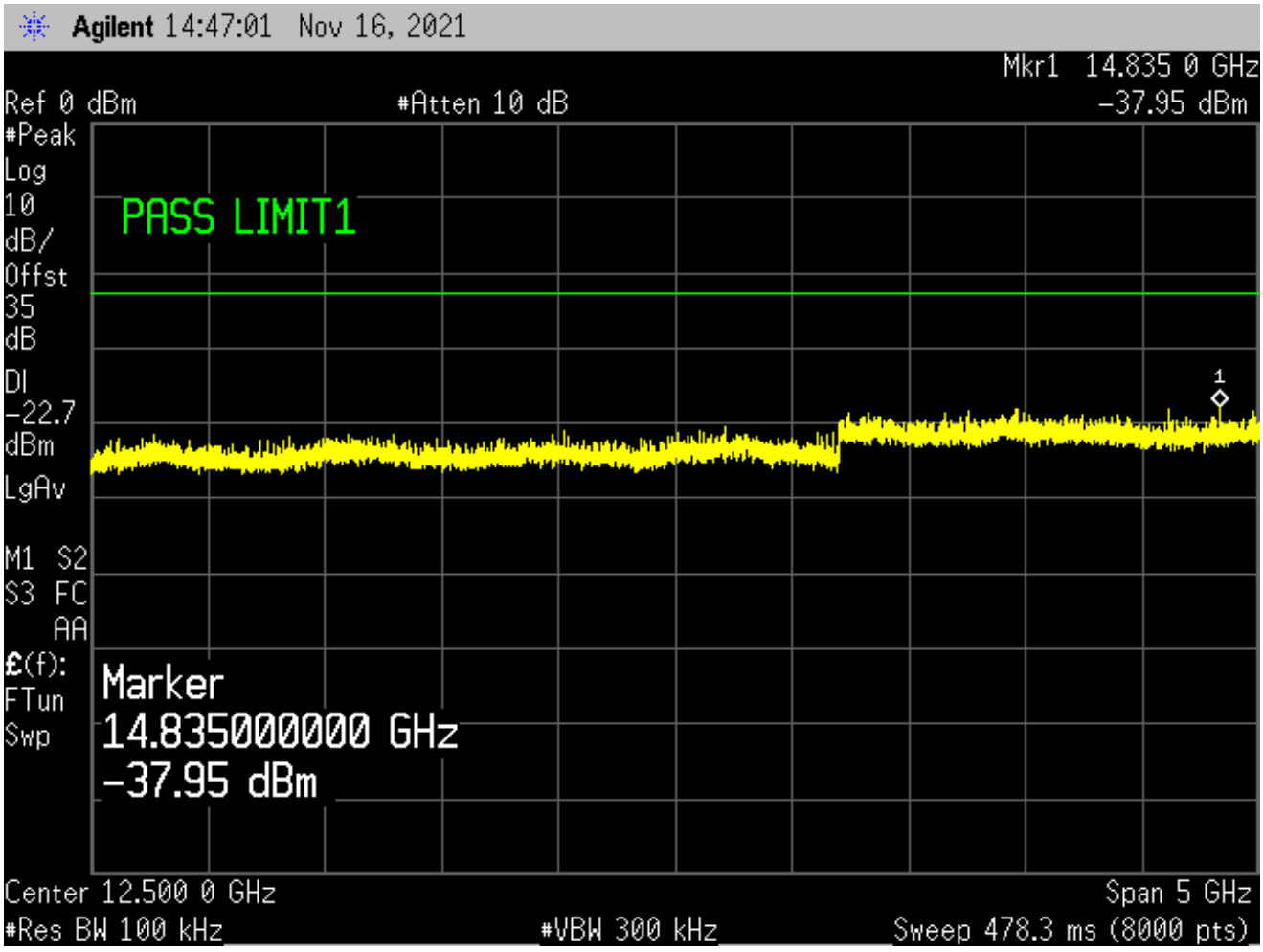


Figure 42: High Channel, Conducted Spurious Plot 6 – Low Power Mode

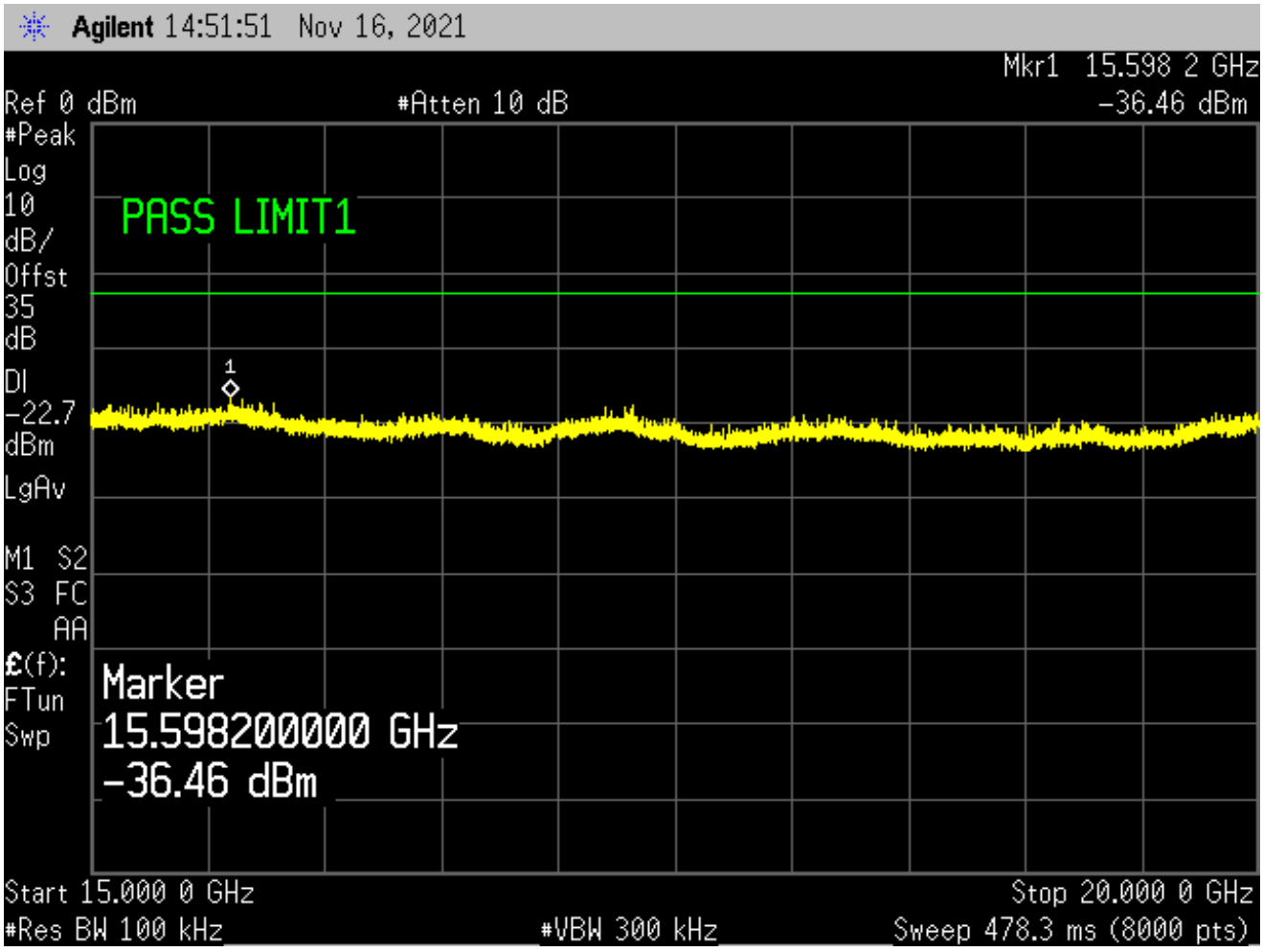
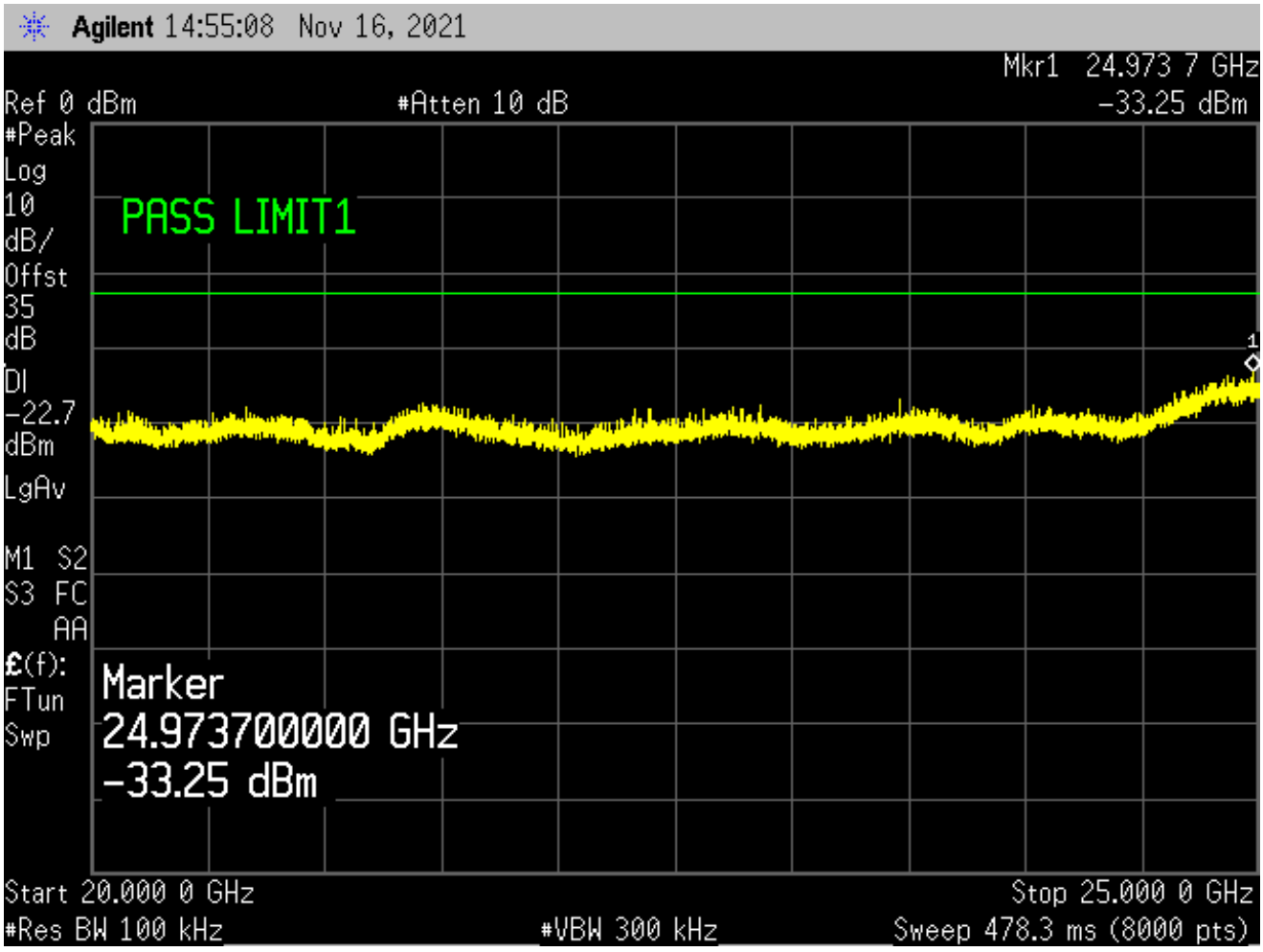


Figure 43: High Channel, Conducted Spurious Plot 7 – Low Power Mode



This Page Intentionally Left Blank

Figure 44: Low Channel, Conducted Spurious Plot 1 – High Power Mode

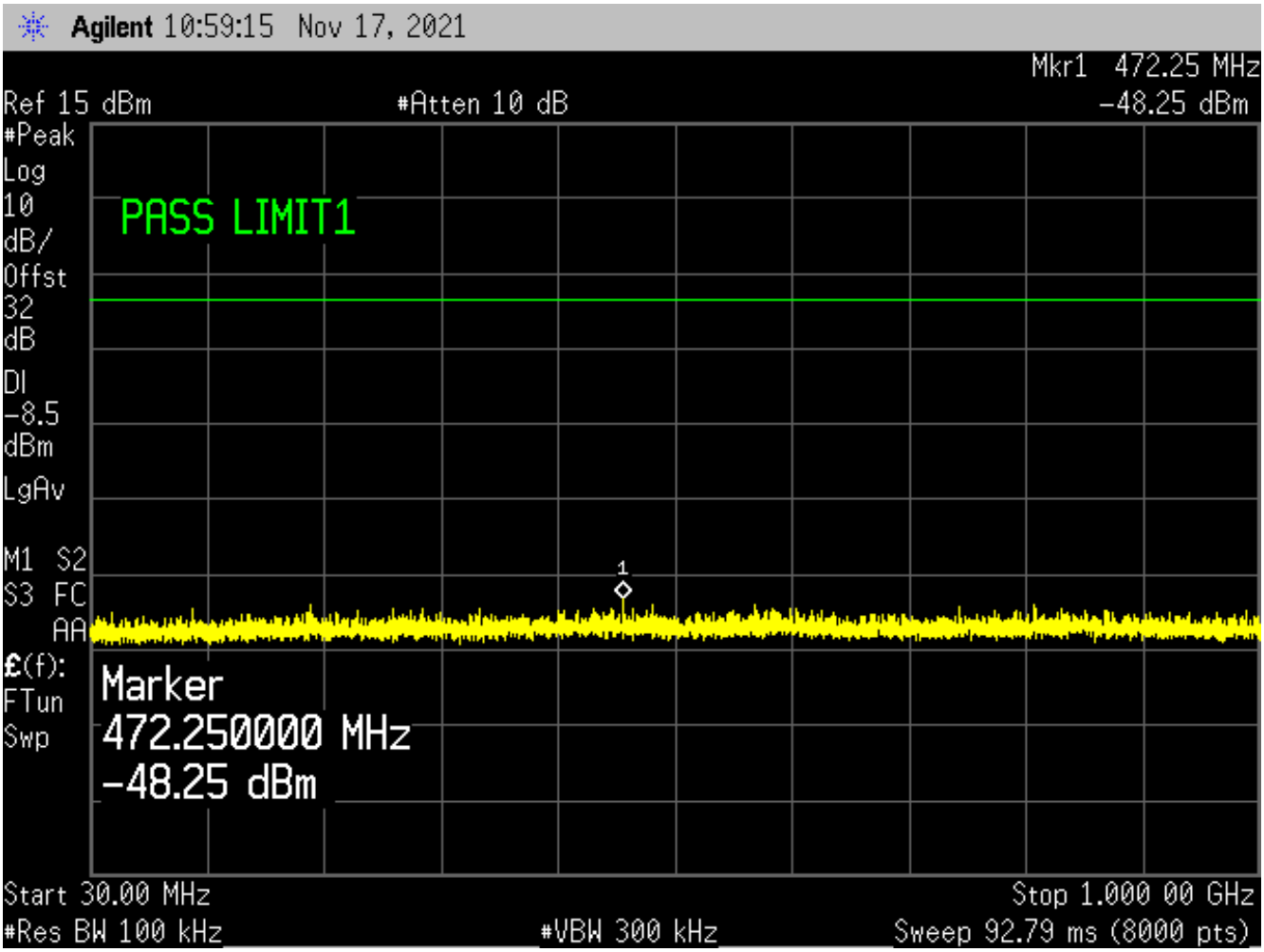


Figure 45: Low Channel, Conducted Spurious Plot 2 – High Power Mode

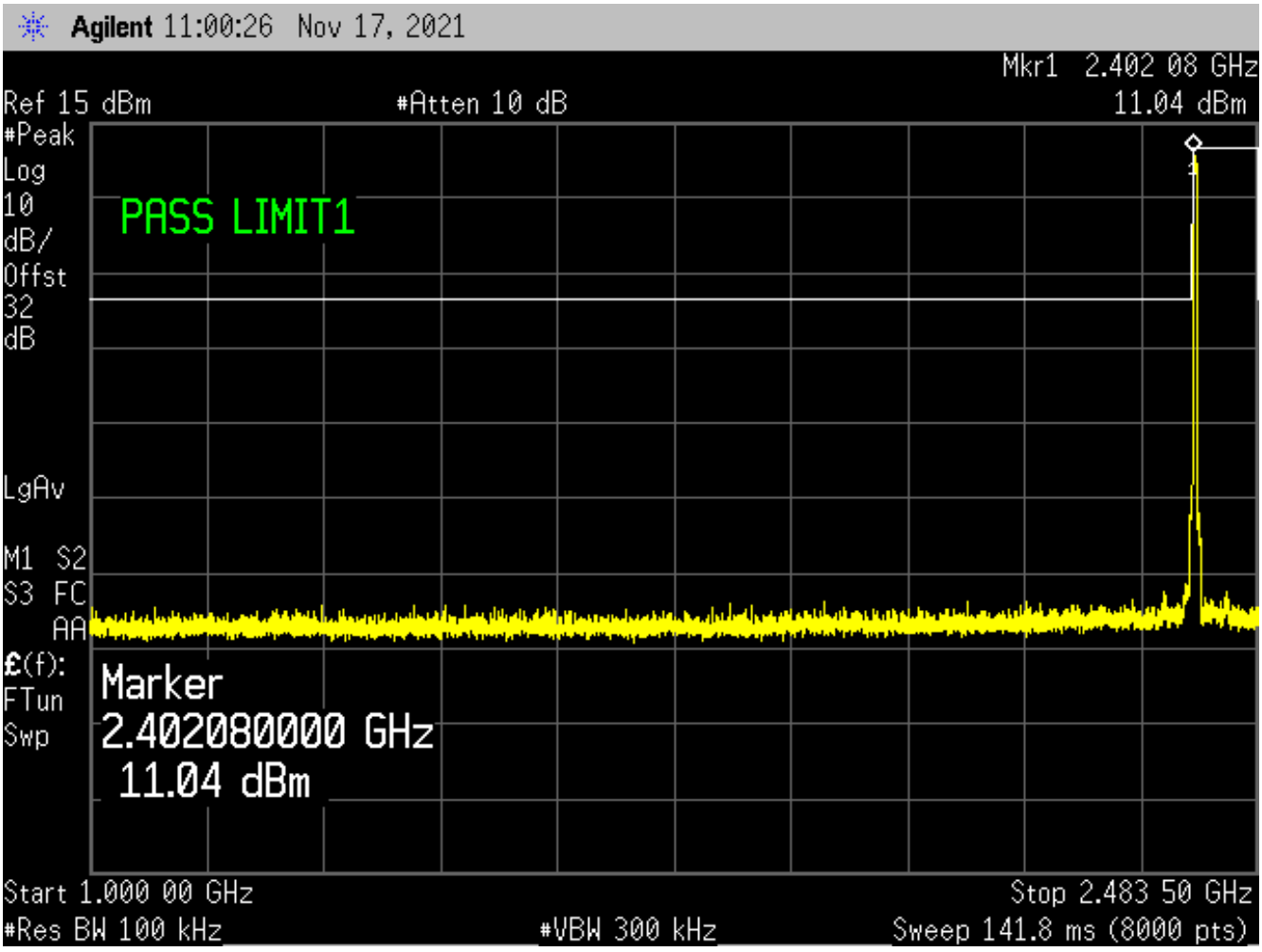


Figure 46: Low Channel, Conducted Spurious Plot 3 – High Power Mode

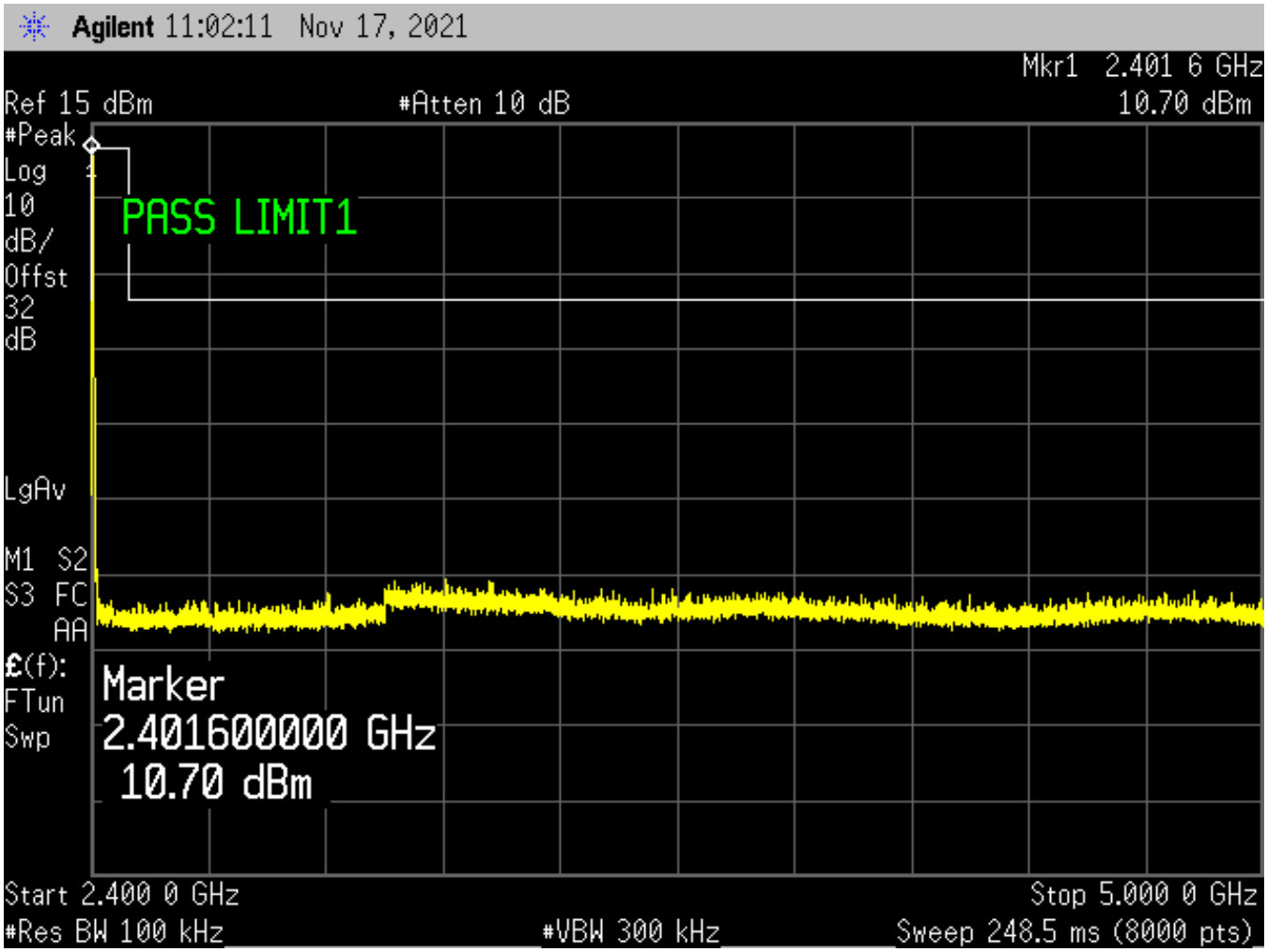


Figure 47: Low Channel, Conducted Spurious Plot 4 – High Power Mode

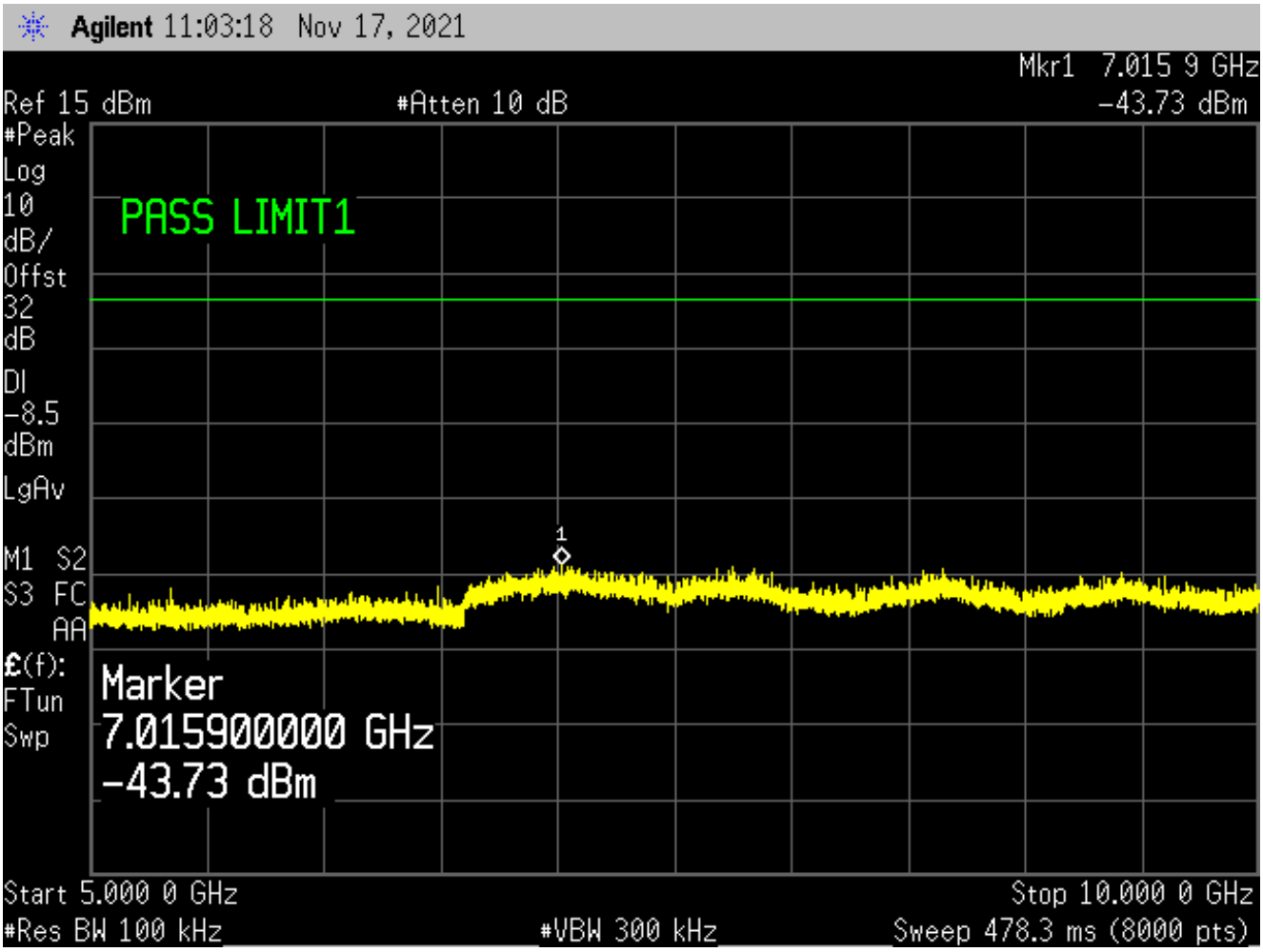


Figure 48: Low Channel, Conducted Spurious Plot 5 – High Power Mode

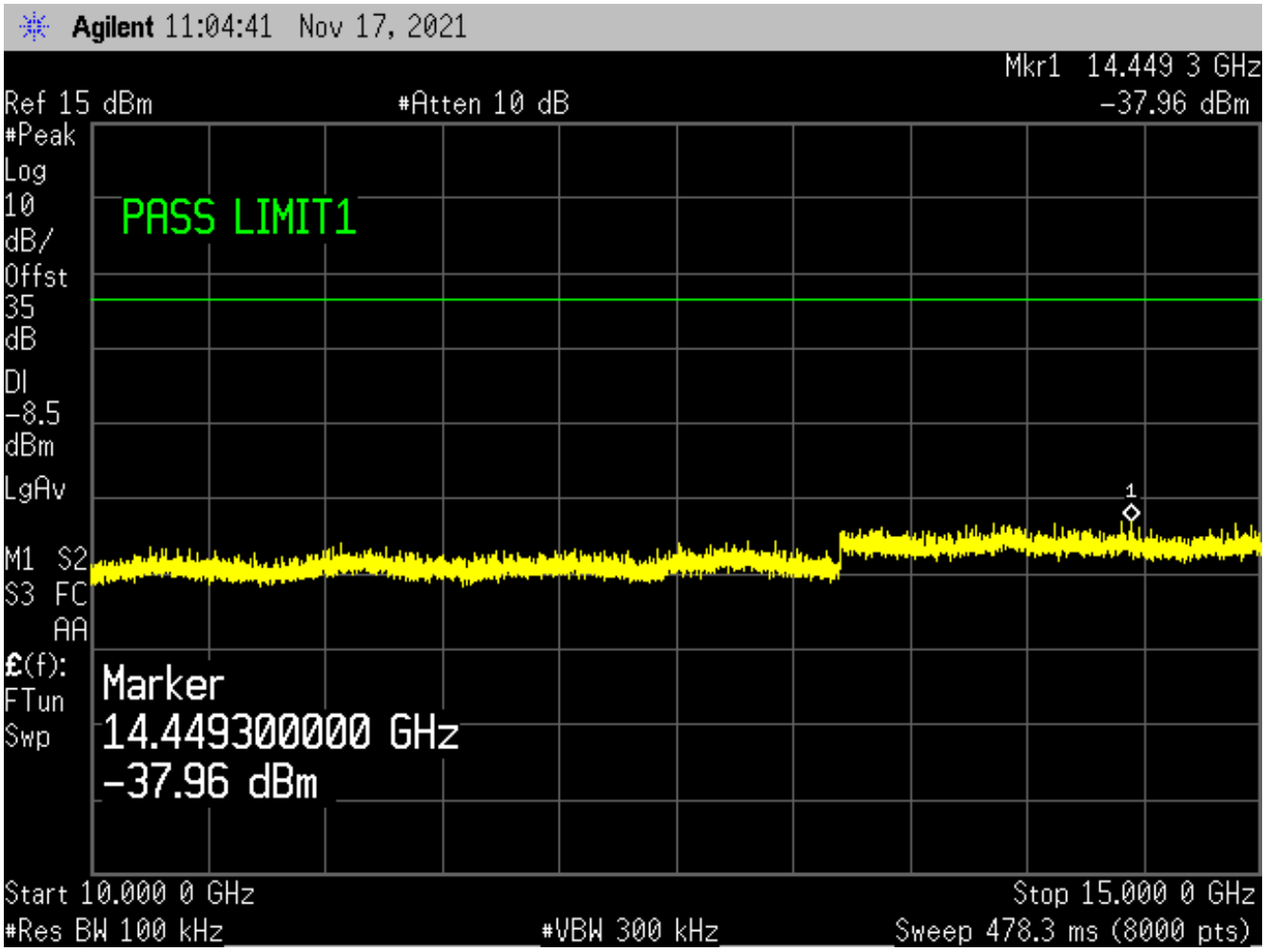


Figure 49: Low Channel, Conducted Spurious Plot 6 – High Power Mode

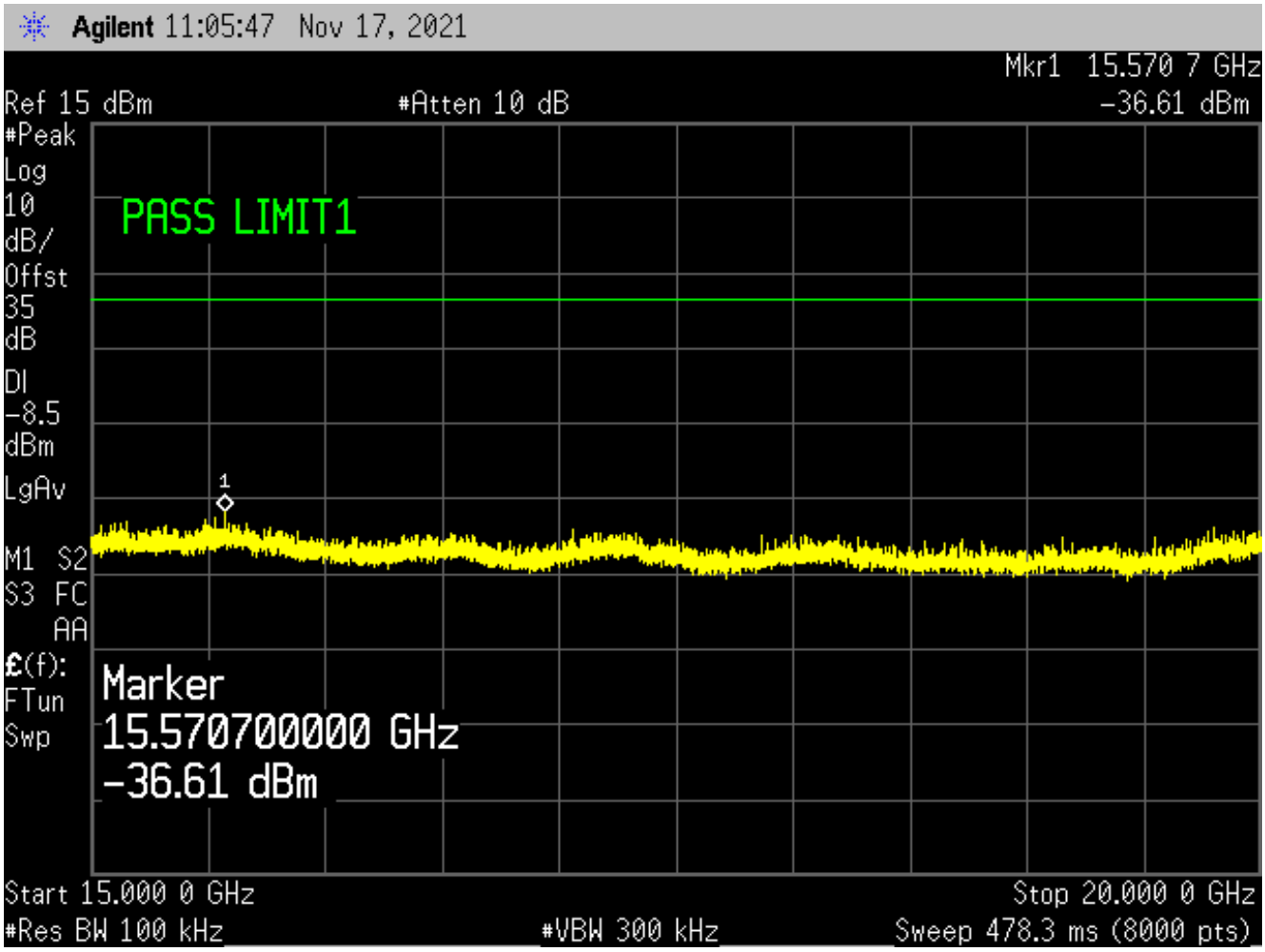


Figure 50: Low Channel, Conducted Spurious Plot 7 – High Power Mode

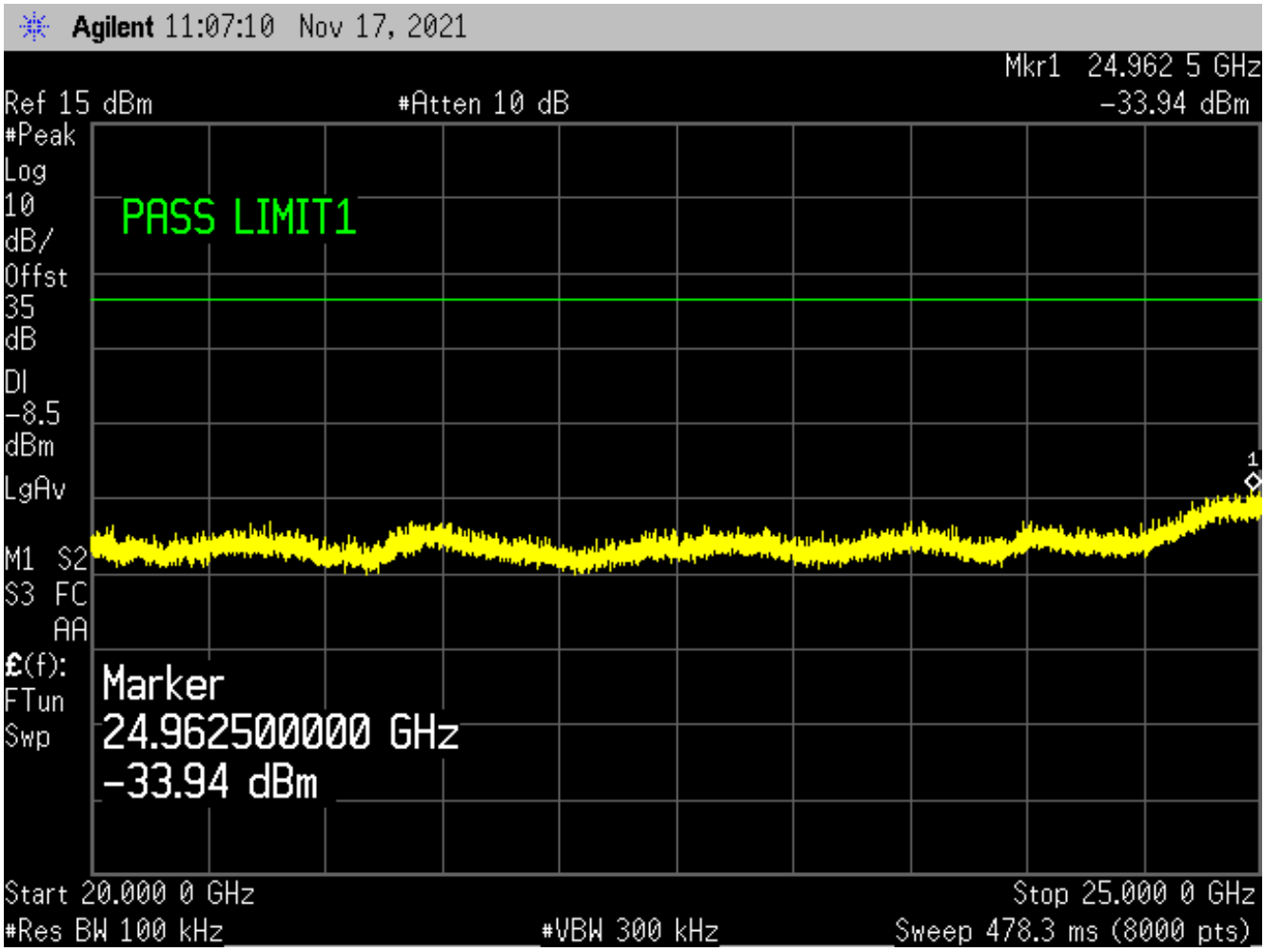


Figure 51: Center Channel, Conducted Spurious Plot 1 – High Power Mode

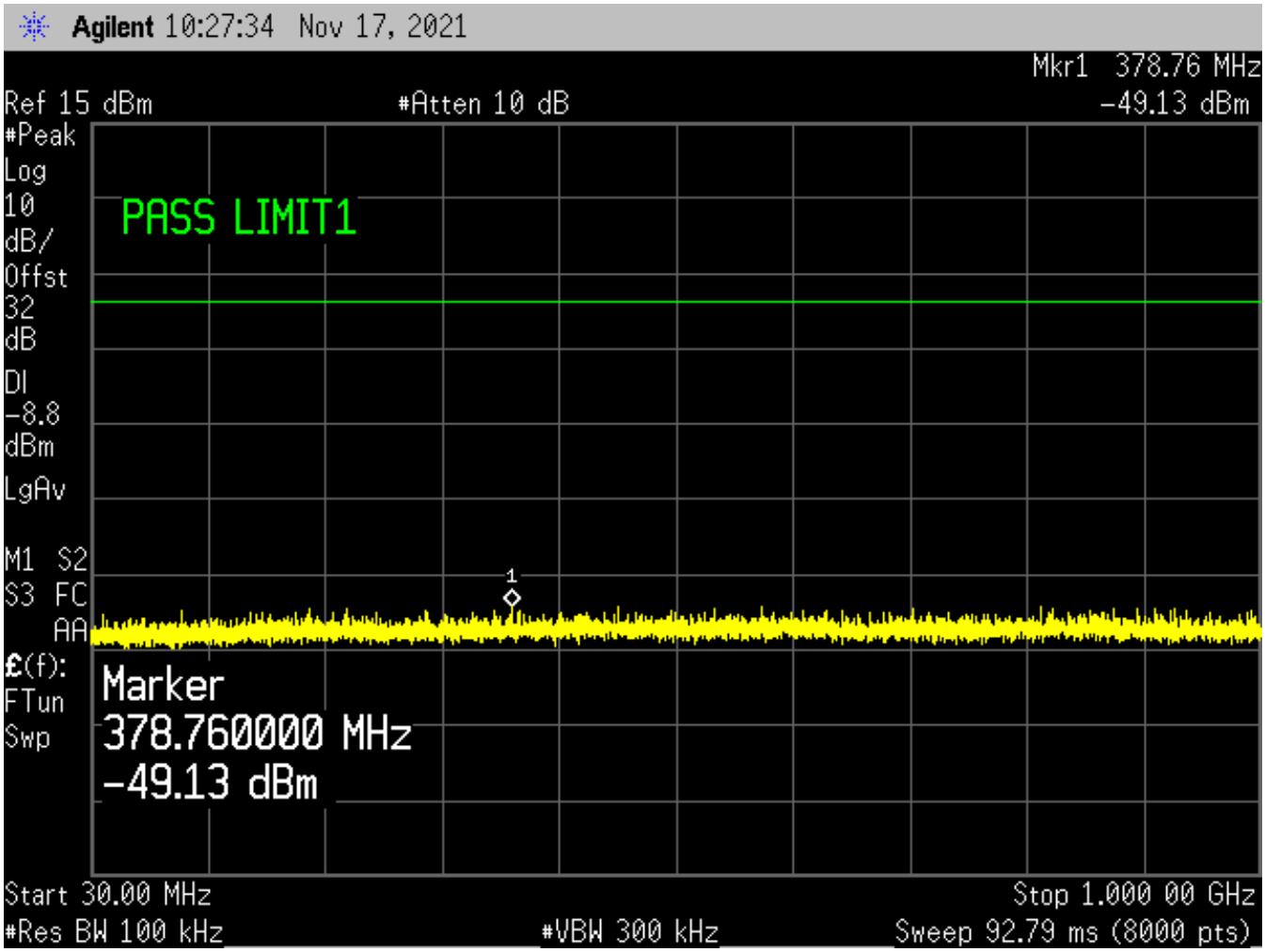


Figure 52: Center Channel, Conducted Spurious Plot 2 – High Power Mode

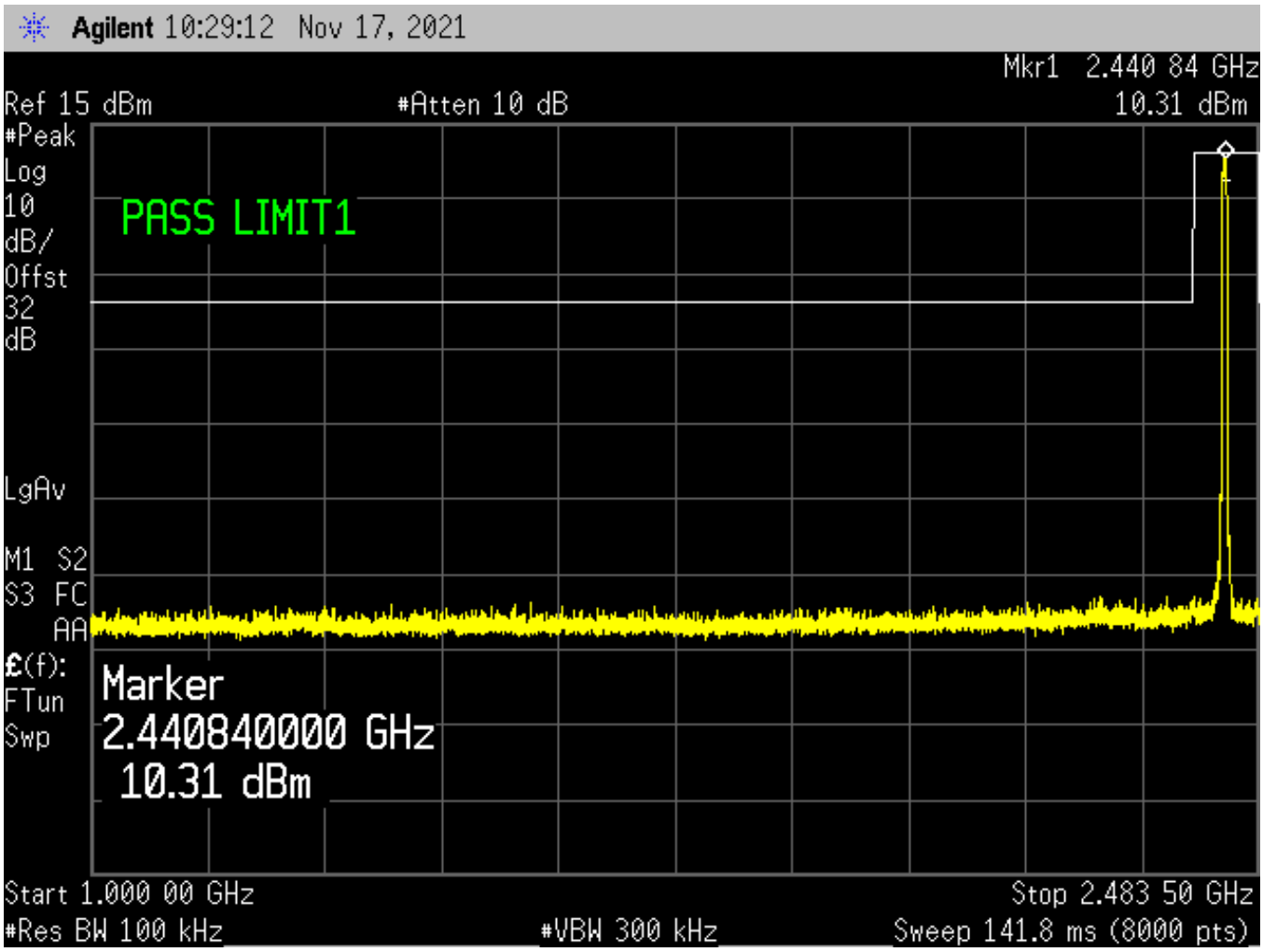


Figure 53: Center Channel, Conducted Spurious Plot 3 – High Power Mode

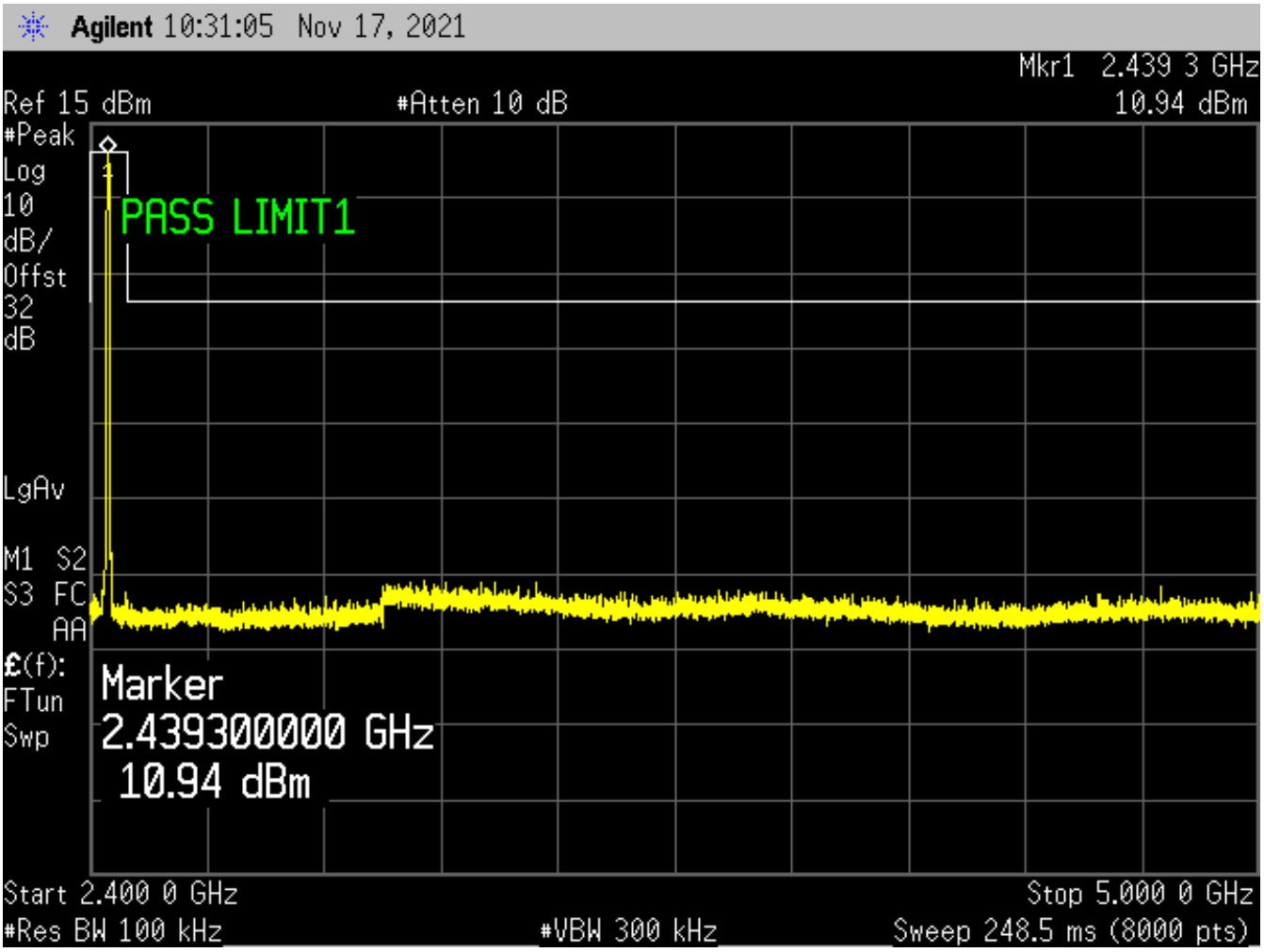


Figure 54: Center Channel, Conducted Spurious Plot 4 – High Power Mode

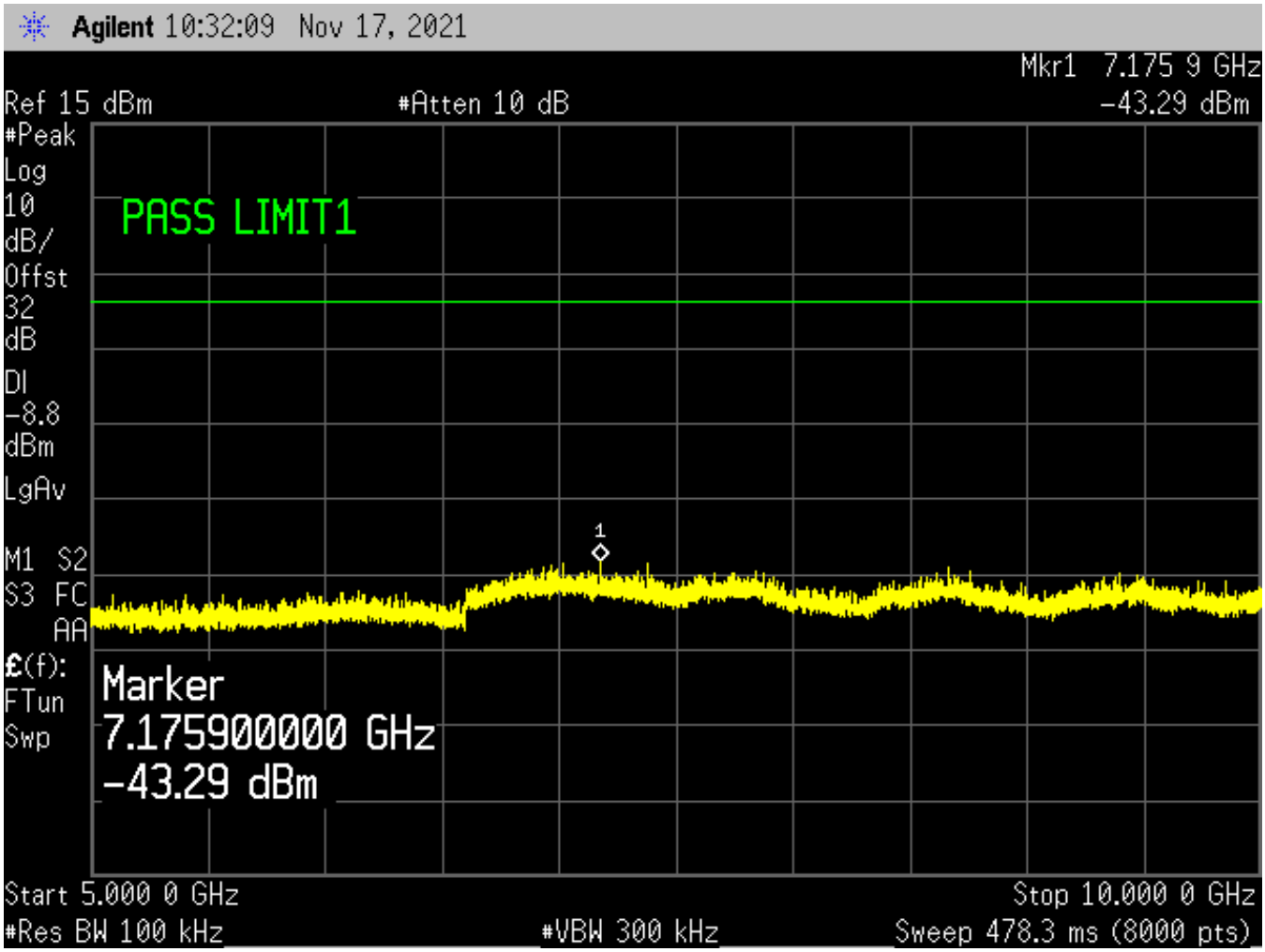


Figure 55: Center Channel, Conducted Spurious Plot 5 – High Power Mode

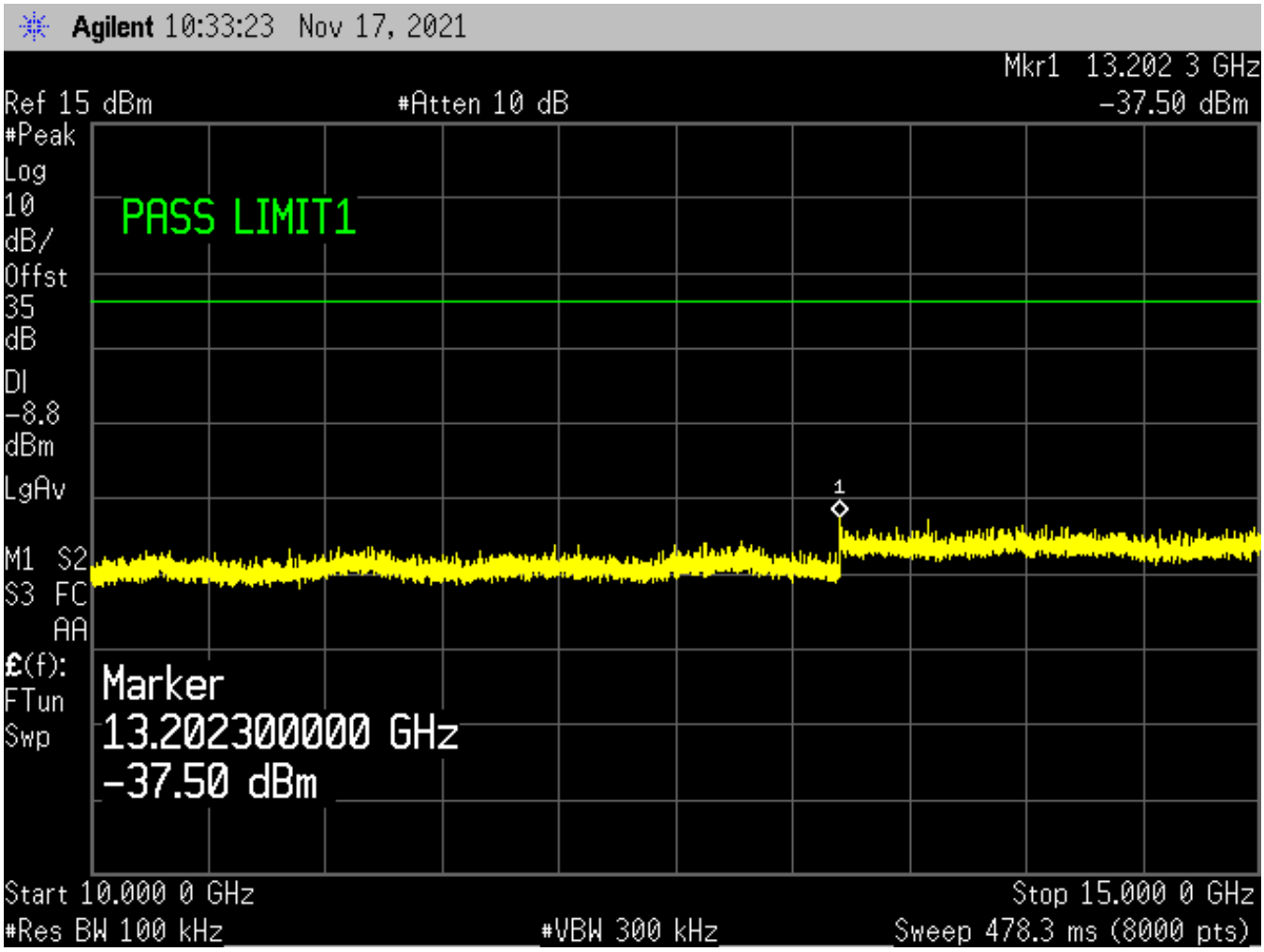


Figure 56: Center Channel, Conducted Spurious Plot 6 – High Power Mode

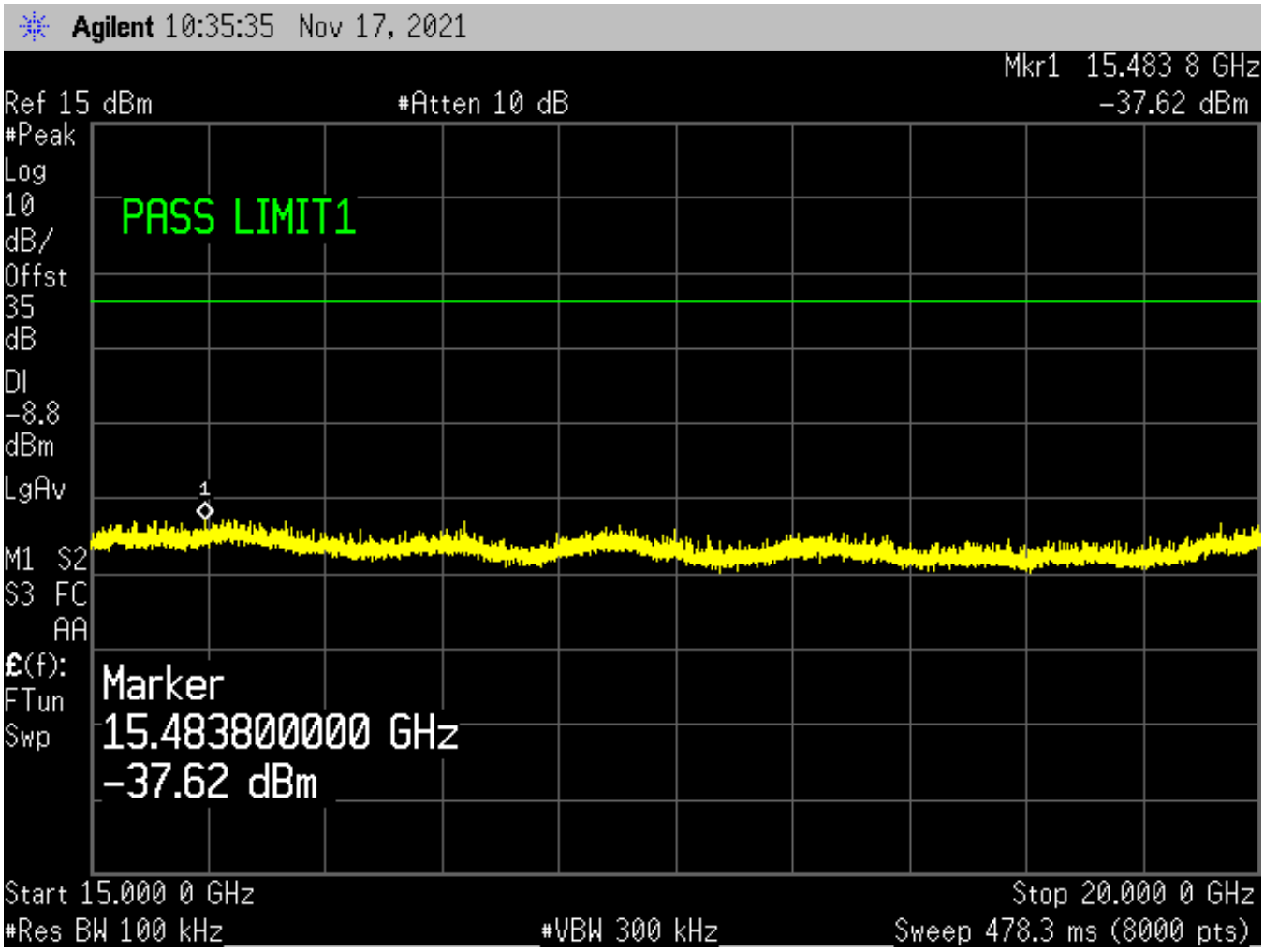


Figure 57: Center Channel, Conducted Spurious Plot 7 – High Power Mode

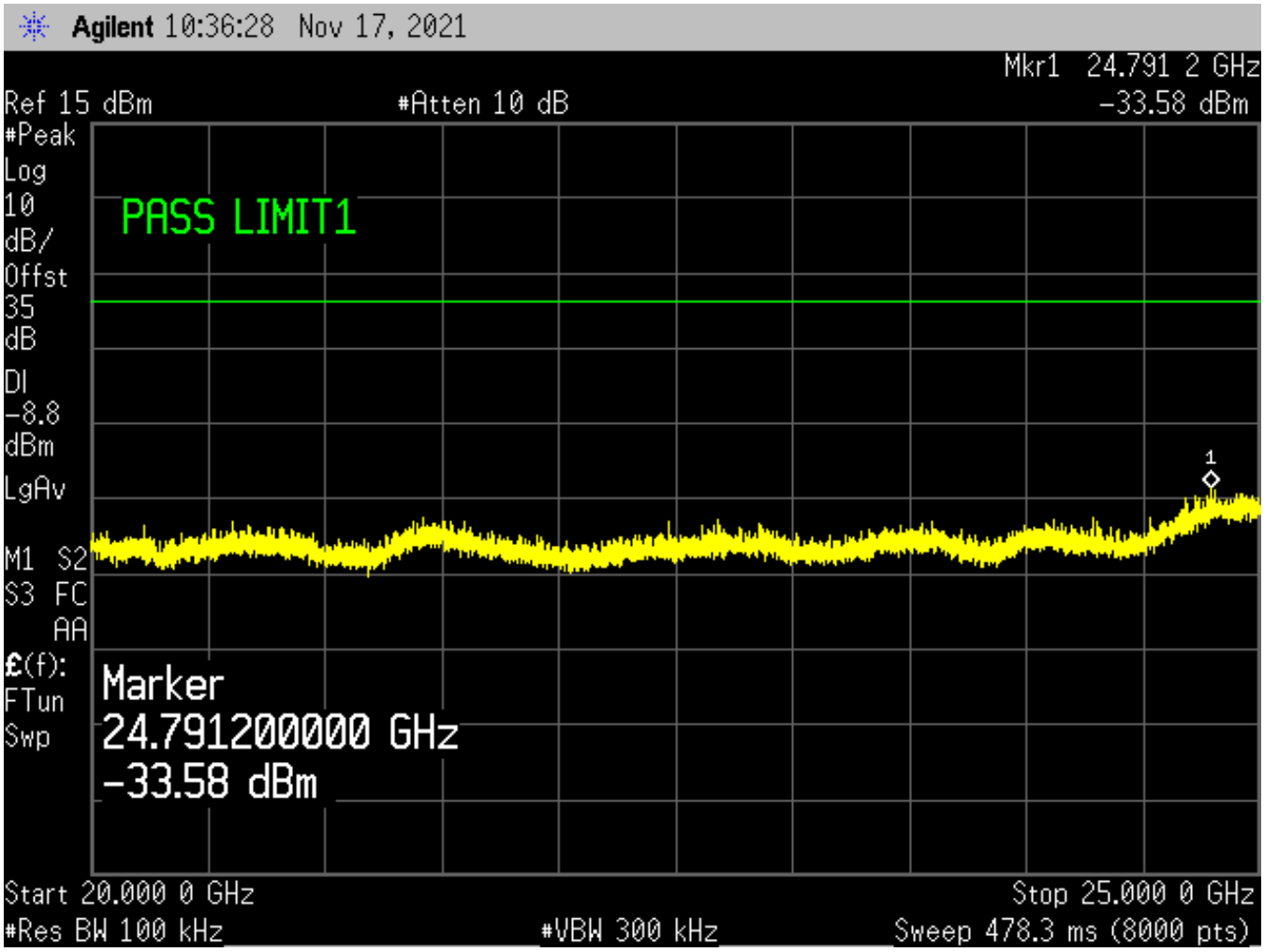


Figure 58: High Channel, Conducted Spurious Plot 1 – High Power Mode

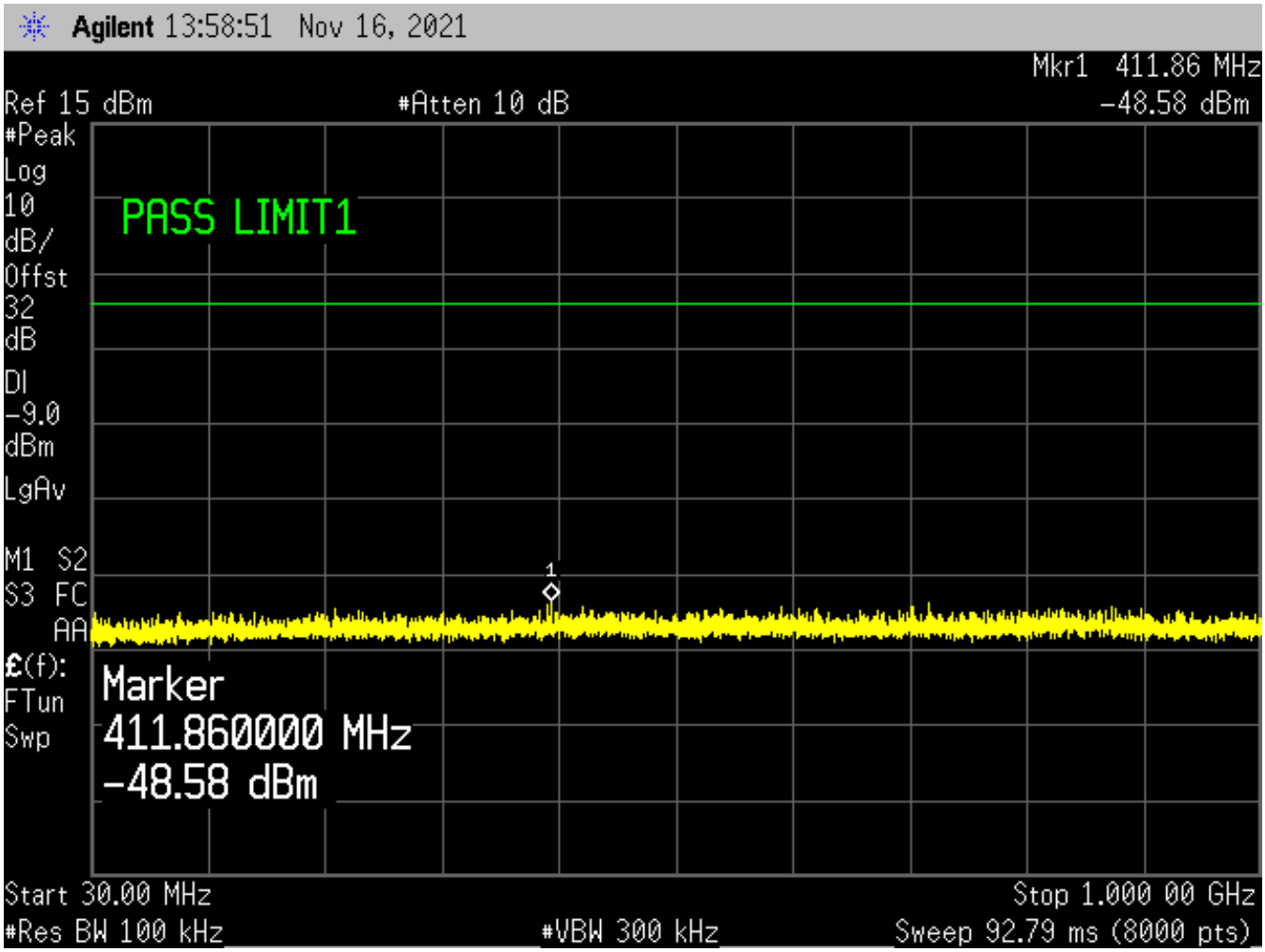


Figure 59: High Channel, Conducted Spurious Plot 2 – High Power Mode

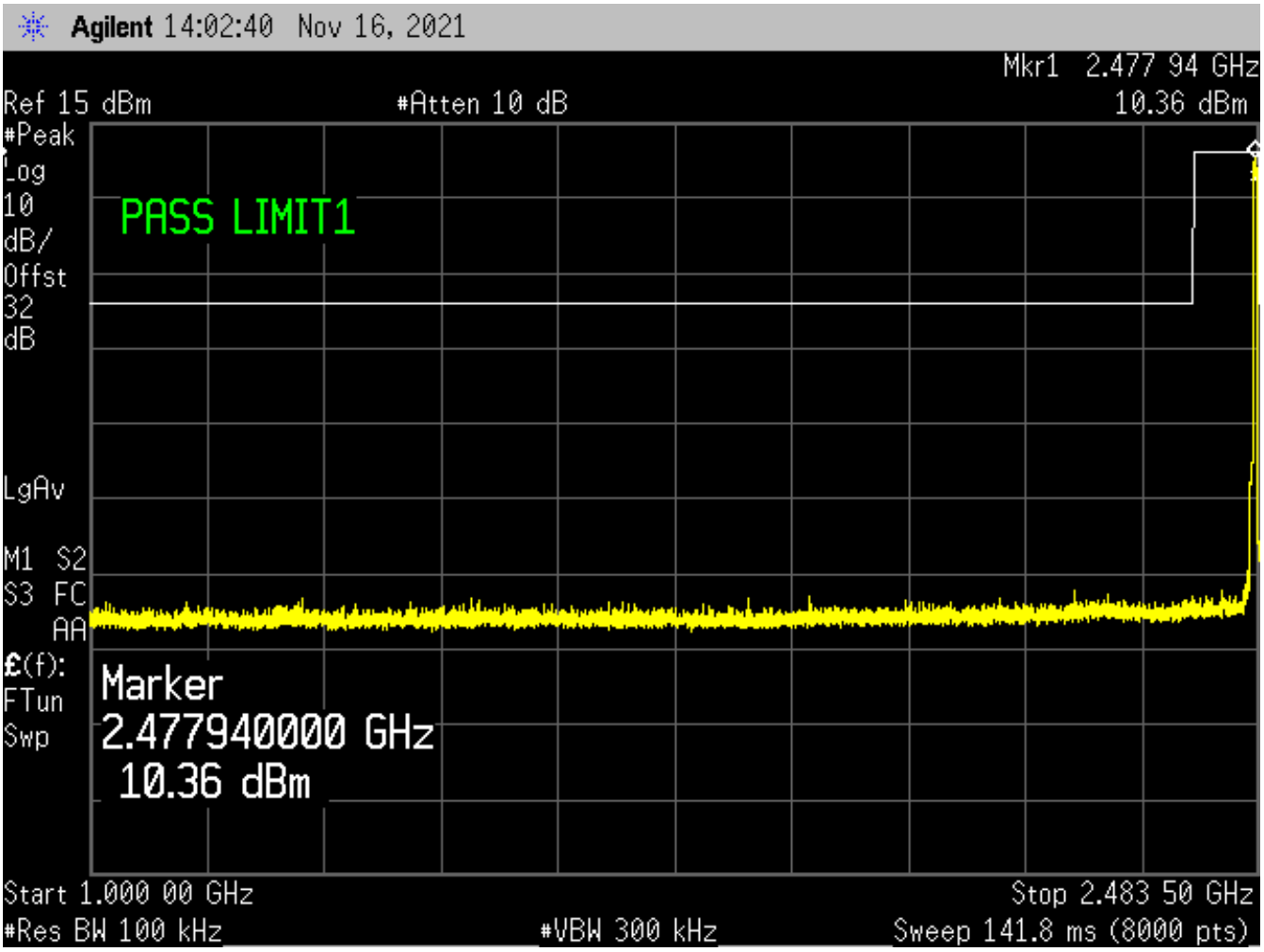


Figure 60: High Channel, Conducted Spurious Plot 3 – High Power Mode

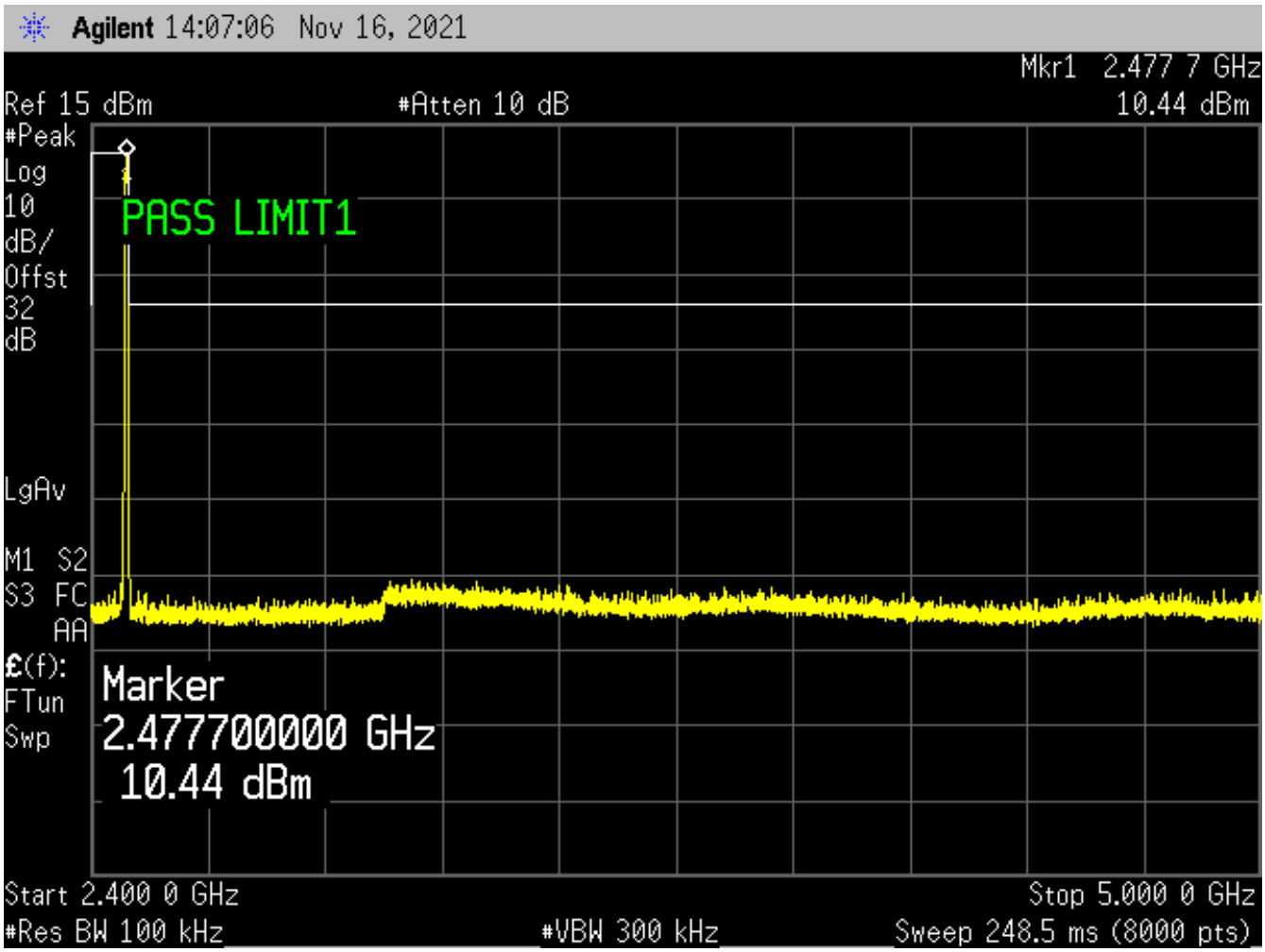


Figure 61: High Channel, Conducted Spurious Plot 4 – High Power Mode

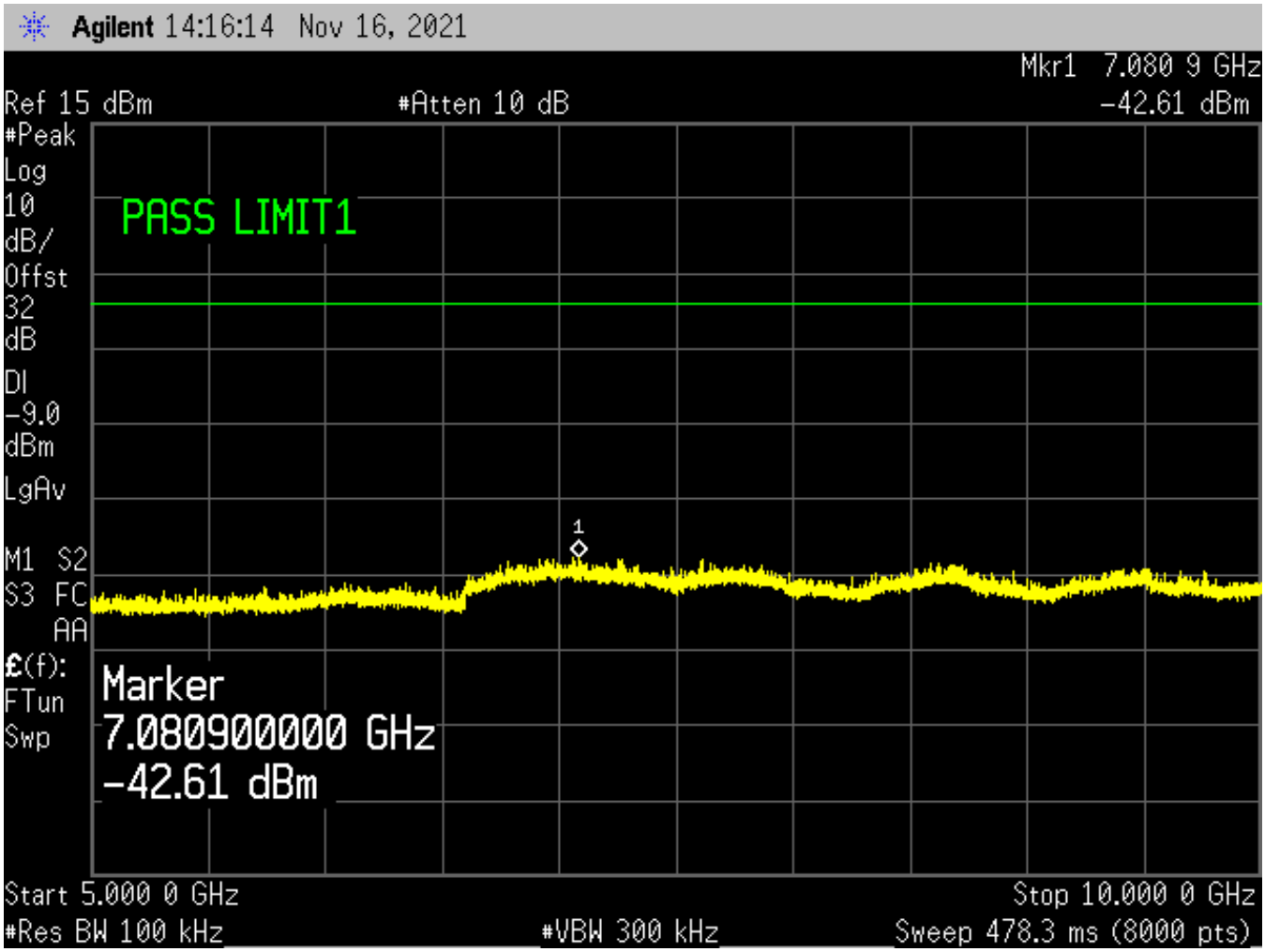


Figure 62: High Channel, Conducted Spurious Plot 5 – High Power Mode

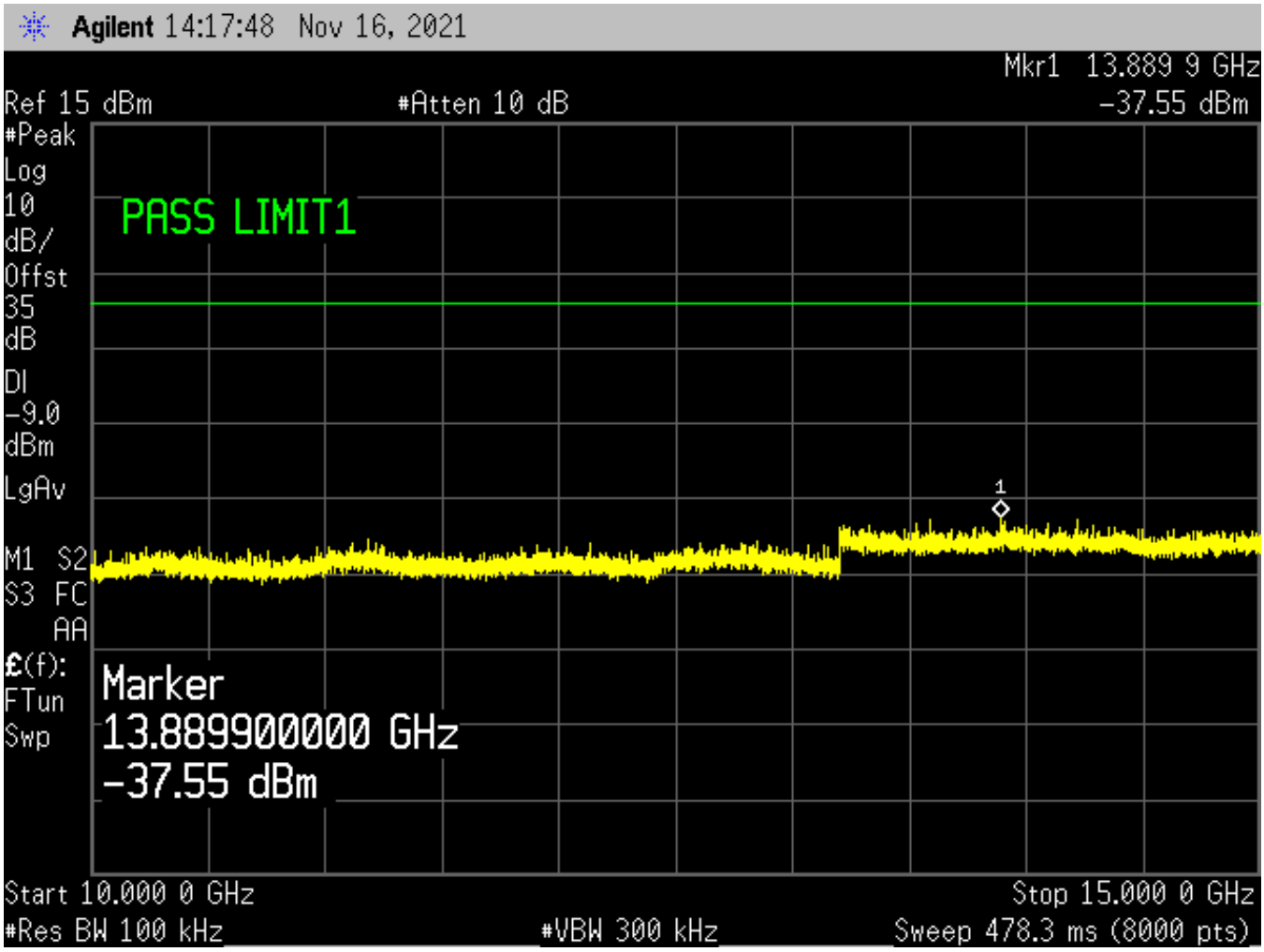


Figure 63: High Channel, Conducted Spurious Plot 6 – High Power Mode

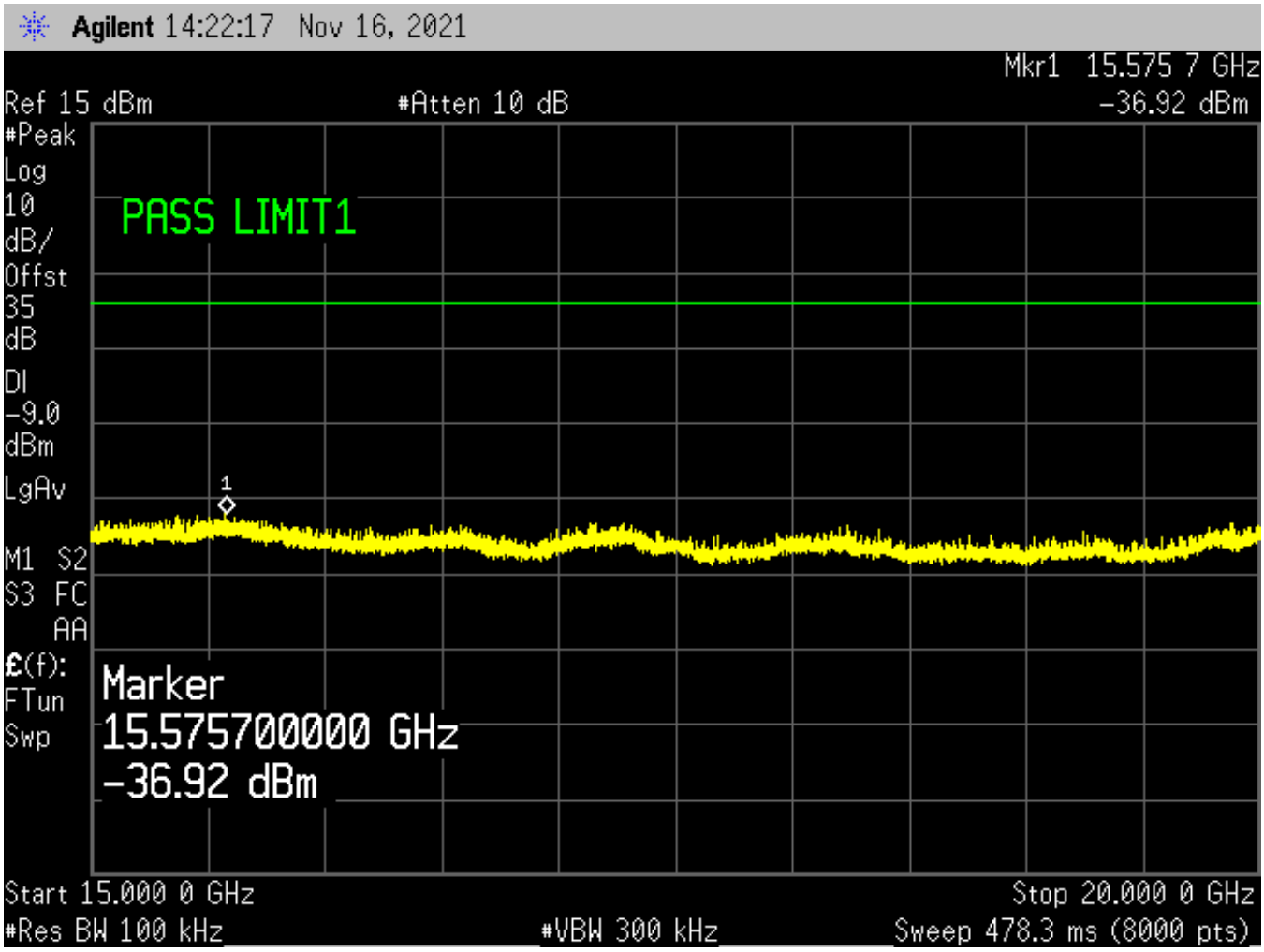
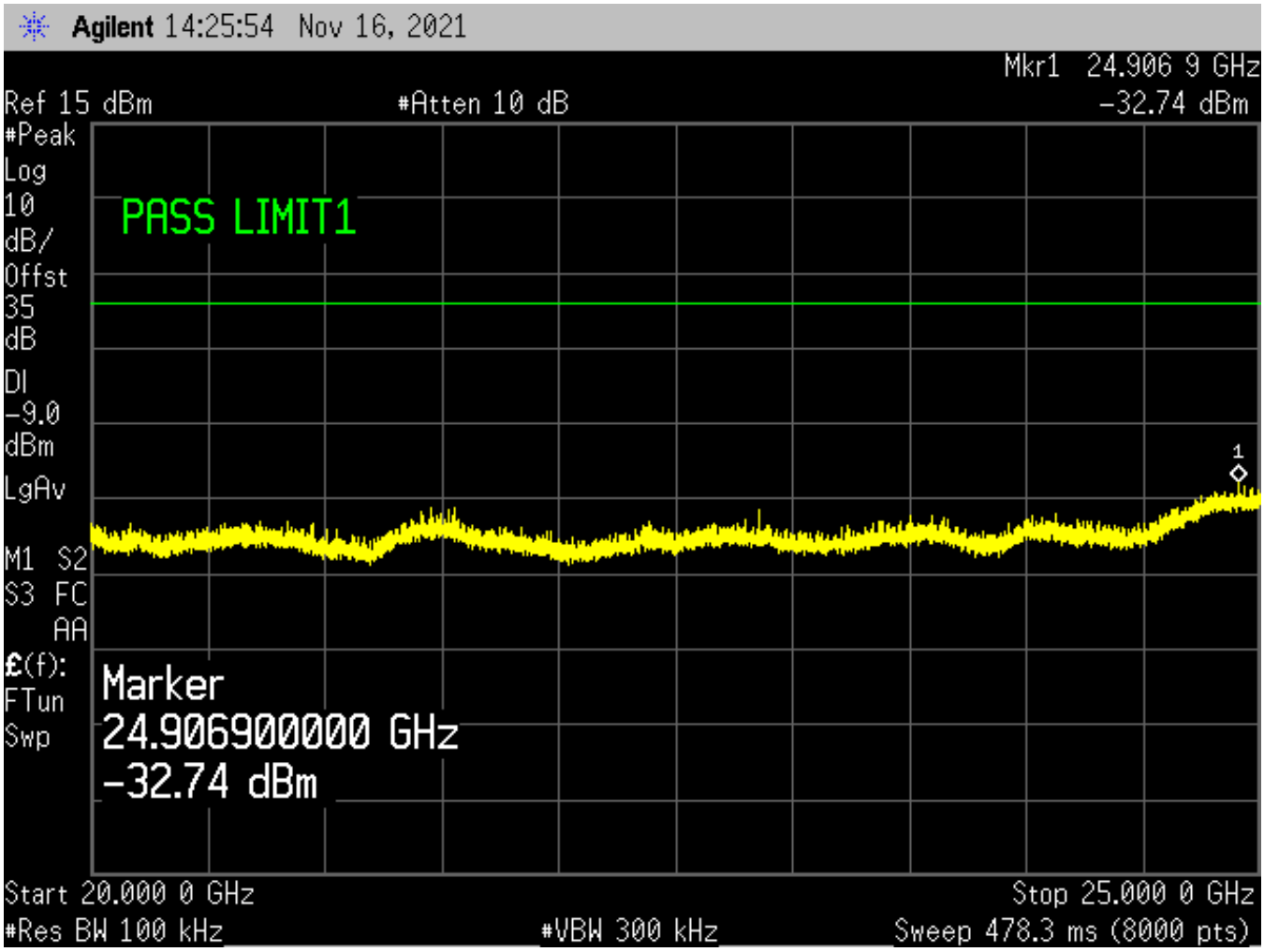


Figure 64: High Channel, Conducted Spurious Plot 7 – High Power Mode



2.6 Radiated Emissions

2.6.1 Requirements

Compliance Standard: FCC Part 15, Class B

FCC Compliance Limits		
Frequency Range	Limit Class (distance)	
	Class A (10 meter)	Class B (3 meter)
30 – 88 MHz	90 µV/m	100 µV/m
88 – 216 MHz	150 µV/m	150 µV/m
216 – 960 MHz	210 µV/m	200 µV/m
> 960 MHz	300 µV/m	500 µV/m

2.6.2 Test Procedure

The requirements of FCC Part 15 call for the EUT to be placed on a 1 X 1.5 meters non-conductive motorized turntable, at a height of 80cm for measurements below 1 GHz, and a height of 1.5m for measurements above 1 GHz; for radiated testing on a 3-meter open field test site.

The emissions from the EUT were measured continuously at every azimuth by rotating the turntable. Bi-conical and log periodic broadband antennas were mounted on an antenna mast to determine the height of maximum emissions. The height of the antenna was varied between 1 and 4 meters. The frequency range of 30 MHz to 25 GHz was measured for all unintentional radiated emissions. The peripherals were placed on the table in accordance with ANSI C63.4. Cables were varied in position to produce maximum emissions. Both the horizontal and vertical field components were measured.

The output from the antenna was connected, via a preamplifier, to the input of the spectrum analyzer. The detector function was set to quasi-peak for compliance measurements below 1 GHz. For measurements above 1 GHz, both the peak and average measurement was recorded. The measurement bandwidth of the spectrum analyzer system was set to at least 120 kHz, with all post-detector filtering no less than 10 times the measurement bandwidth. Frequencies above 1 GHz were performed using a measurement bandwidth of 1 MHz with a video bandwidth setting of 10 Hz for the average measurement.

Environmental Conditions during Radiated Emissions Testing

Ambient Temperature:	14 °C
Relative Humidity:	60 %

2.6.3 Radiated Data Reduction and Reporting

To convert the raw spectrum analyzer radiated data into a form that can be compared with the FCC limits, it is necessary to account for various calibration factors that are supplied with the antennas and other measurement accessories. These factors are included into the antenna factor (AF) column of the table and in the cable factor (CF) column of the table. The AF (in dB/m) and the CF (in dB) is algebraically added to the raw Spectrum Analyzer Voltage in dBµV to obtain the Radiated Electric Field in dBµV/m. This logarithm amplitude is converted to a linear amplitude, then compared to the FCC limit.

Example:

Spectrum Analyzer Voltage:	VdBµV
Antenna Correction Factor:	AFdB/m
Cable Correction Factor:	CFdB
Pre-Amplifier Gain (if applicable):	GdB
Electric Field:	EdBµV/m = VdBµV + AFdB/m + CFdB - GdB
Convert to linear units of measure:	EdBµV/m/20 Inv log

2.6.4 Test Data

The EUT complies with the Radiated Emissions requirements of FCC Part 15.

The frequency range of 30 MHz to 25 GHz was investigated.

The 2.4 GHz transmitter was evaluated in both the vertical and horizontal EUT polarities, to determine the worst-case orientation that produced the highest fundamental field strength. This data is provided in Table 10.

For measurements of frequencies below 1000 MHz, the EUT was positioned in a polarity that matched that of the receive antenna, as this produced the was the worst-case field strength. The EUT low channel was tuned for testing below 1000 MHz, as representative of all channels. The low channel (2403.5 MHz) produced to highest transmitter power measurement, as denoted in Section 2.2 of this report.

For testing above 1000 MHz, the EUT was scanned at the low, center, and high transmit channels; out to the 10th harmonic. The same polarity matching scheme, as noted above, was used in this frequency range.

For all radiated emissions testing, the EUT was set to a transmit in the High-Power Mode.

AMB indicates that the measurement was taken at the noise floor.

Spur indicates that an emission was detected (at 3m) from the EUT.

Worst case emission levels are reported below.

Table 10: Radio Fundamental, EUT Antenna-Axis Evaluation

Frequency (MHz)	Polarity H/V	Azimuth (Degree)	Ant. Height (m)	SA Level (dBuV)	Corr Factors (dB)	Corr. Level (uV/m)	Detector	Comments
2440.00	V	180.0	1.6	110.3	3.5	488821.0	Peak	EUT Vertical
2440.00	V	0.0	1.8	106.9	3.5	331703.4	Peak	EUT Horizontal
2440.00	H	180.0	1.7	104.1	3.5	242019.2	Peak	EUT Vertical
2440.00	H	0.0	1.8	108.9	3.5	419710.5	Peak	EUT Horizontal

* when the EUT external antenna is polarity matched to that of the OATS receive antenna, the highest field strength of the transmitter center channel was recorded. This shall be the EUT positioning scheme used for all radiated emissions testing. Please see Section 2.6.4 above.

During this evaluation of radiated emissions, both the high-power mode and the low-power mode were evaluated. Both power modes were investigated at the fundamental, first harmonic, and at the restricted band edges. There were no emissions detected from the low-power mode that exceeded the levels of emissions from the high-power mode.

Table 11: Radiated Emissions Test Data – All Channels (30 MHz to 1000 MHz)

Frequency (MHz)	Polarity H/V	Azimuth (Degree)	Ant. Height (m)	SA Level (dBuV)	Corr Factors (dB)	Corr Level (uV/m)	Limit (uV/m)	Margin (dB)	Detector
40.00	V	180	1.9	39.6	-10.2	29.6	100	-10.6	QP
41.60	V	180	1.9	40.4	-11.3	28.5	100	-10.9	QP
77.60	V	0	1.7	47.9	-16.0	39.3	100	-8.1	QP
80.00	V	90	2.0	47.3	-16.3	35.7	100	-9.0	QP
143.00	V	0	1.6	40.6	-11.1	30.0	150	-14.0	QP
165.00	V	0	1.3	40.0	-11.8	25.6	150	-15.4	QP
250.00	V	90	1.6	44.7	-11.9	43.5	200	-13.2	QP
693.00	V	0	1.4	41.0	-2.7	82.3	200	-7.7	QP
40.00	H	180	1.9	38.4	-10.2	25.8	100	-11.8	QP
41.60	H	180	1.9	40.8	-11.3	29.9	100	-10.5	QP
77.60	H	0	1.7	47.0	-16.0	35.4	100	-9.0	QP
80.00	H	90	2.0	46.3	-16.3	31.8	100	-10.0	QP
143.00	H	0	1.6	41.1	-11.1	31.8	150	-13.5	QP
165.00	H	0	1.3	39.9	-11.8	25.3	150	-15.5	QP
250.00	H	90	1.6	44.5	-11.9	42.5	200	-13.4	QP
693.00	H	0	1.4	40.2	-2.7	75.0	200	-8.5	QP

Table 12: Radiated Spurious Emissions Test Data – Low Channel

Frequency (MHz)	Polarity H/V	Azimuth (Degree)	Ant. Height (m)	SA Level (dBuV)	Corr Factors (dB)	Corr. Level (uV/m)	Limit (uV/m)	Margin (dB)	Detector	Comments
2390.00	V	0.0	1.7	61.8	3.1	1763.1	5000.0	-9.1	Peak	Restricted BE
2390.00	V	180.0	1.8	48.6	3.1	386.2	500.0	-2.2	AVG	
2403.50	V	180.0	1.8	115.3	3.2	842894.1	Fundamental		Peak	Radio
2403.50	V	0.0	1.8	113.7	3.2	701573.3			AVG	
4807.00	V	180.0	1.8	45.0	12.3	734.2	5000.0	-16.7	Peak	Spur
4807.00	V	180.0	1.7	31.3	12.3	151.1	500.0	-10.4	AVG	Spur
7210.50	V	135.0	1.8	45.7	19.6	1847.5	5000.0	-8.6	Peak	AMB
7210.50	V	0.0	1.8	31.6	19.6	363.6	500.0	-2.8	AVG	AMB
9614.00	V	0.0	1.8	45.7	23.7	2931.0	5000.0	-4.6	Peak	AMB
9614.00	V	180.0	1.8	25.0	23.7	271.5	500.0	-5.3	AVG	AMB
12017.50	V	135.0	1.8	45.5	27.2	4304.0	5000.0	-1.3	Peak	AMB
12017.50	V	90.0	1.8	24.6	27.2	388.0	500.0	-2.2	AVG	AMB
2390.00	H	90.0	1.8	60.5	3.1	1526.8	5000.0	-10.3	Peak	Restricted BE
2390.00	H	180.0	1.8	48.6	3.1	385.3	500.0	-2.3	AVG	
2403.50	H	180.0	1.8	108.0	3.2	363976.2	Fundamental		Peak	Radio
2403.50	H	90.0	1.7	102.7	3.2	197730.2			AVG	
4807.00	H	0.0	1.8	46.3	12.3	851.7	5000.0	-15.4	Peak	Spur
4807.00	H	90.0	1.7	32.3	12.3	169.7	500.0	-9.4	AVG	Spur
7210.50	H	180.0	1.8	44.5	19.6	1601.7	5000.0	-9.9	Peak	AMB
7210.50	H	180.0	1.8	30.7	19.6	327.0	500.0	-3.7	AVG	AMB
9614.00	H	180.0	1.8	43.9	23.7	2400.6	5000.0	-6.4	Peak	AMB
9614.00	H	90.0	1.8	24.2	23.7	247.7	500.0	-6.1	AVG	AMB
12017.50	H	180.0	1.7	44.8	27.2	3957.0	5000.0	-2.0	Peak	AMB
12017.50	H	180.0	1.7	25.1	27.2	411.0	500.0	-1.7	AVG	AMB

Table 13: Radiated Spurious Emissions Test Data – Center Channel

Frequency (MHz)	Polarity H/V	Azimuth (Degree)	Ant. Height (m)	SA Level (dBuV)	Corr Factors (dB)	Corr. Level (uV/m)	Limit (uV/m)	Margin (dB)	Detector	Comments
2440.00	V	180.0	1.6	110.3	3.5	488821.0	Fundamental		Peak	Radio
2440.00	V	180.0	1.6	105.0	3.5	266993.0			AVG	
4880.00	V	180.0	1.8	46.0	12.4	827.2	5000.0	-15.6	Peak	Spur
4880.00	V	180.0	1.8	36.5	12.4	279.3	500.0	-5.1	AVG	Spur
7320.00	V	0.0	1.8	46.4	19.6	1998.8	5000.0	-8.0	Peak	Spur
7320.00	V	0.0	1.8	32.6	19.6	405.8	500.0	-1.8	AVG	Spur
9760.00	V	180.0	1.7	47.3	23.7	3567.6	5000.0	-2.9	Peak	AMB
9760.00	V	180.0	1.8	28.0	23.7	386.7	500.0	-2.2	AVG	AMB
12200.00	V	0.0	1.8	41.7	27.3	2813.0	5000.0	-5.0	Peak	AMB
12200.00	V	135.0	1.8	21.0	27.3	259.5	500.0	-5.7	AVG	AMB
2440.00	H	180.0	1.7	104.1	3.5	242019.2	Fundamental		Peak	Radio
2440.00	H	180.0	1.7	100.0	3.5	150141.2			AVG	
4880.00	H	135.0	1.8	45.4	12.4	774.6	5000.0	-16.2	Peak	Spur
4880.00	H	180.0	1.8	33.0	12.4	185.4	500.0	-8.6	AVG	Spur
7320.00	H	90.0	1.7	46.5	19.6	2008.0	5000.0	-7.9	Peak	Spur
7320.00	H	180.0	1.8	33.1	19.6	428.3	500.0	-1.3	AVG	Spur
9760.00	H	180.0	1.7	46.1	23.7	3089.4	5000.0	-4.2	Peak	AMB
9760.00	H	135.0	1.8	28.6	23.7	413.9	500.0	-1.6	AVG	AMB
12200.00	H	90.0	1.8	40.2	27.3	2366.8	5000.0	-6.5	Peak	AMB
12200.00	H	180.0	1.8	20.8	27.3	253.8	500.0	-5.9	AVG	AMB

Table 14: Radiated Spurious Emissions Test Data – High Channel

Frequency (MHz)	Polarity H/V	Azimuth (Degree)	Ant. Height (m)	SA Level (dBuV)	Corr Factors (dB)	Corr. Level (uV/m)	Limit (uV/m)	Margin (dB)	Detector	Comments
2478.50	V	90.0	1.5	113.5	3.8	732727.1	Fundamental		Peak	Radio
2478.50	V	90.0	1.5	105.0	3.8	275386.3			AVG	
2483.50	V	90.0	1.4	61.9	3.8	1938.3	5000.0	-8.2	Peak	Restricted BE
2483.50	V	90.0	1.4	48.2	3.8	400.3	500.0	-1.9	AVG	
4957.00	V	0.0	1.6	53.9	12.4	2064.9	5000.0	-7.7	Peak	AMB
4957.00	V	0.0	1.6	39.0	12.4	371.4	500.0	-2.6	AVG	AMB
7435.50	V	0.0	1.6	45.9	19.4	1841.7	5000.0	-8.7	Peak	AMB
7435.50	V	0.0	1.6	31.0	19.4	331.3	500.0	-3.6	AVG	AMB
9914.00	V	0.0	1.6	46.1	24.2	3258.5	5000.0	-3.7	Peak	AMB
9914.00	V	0.0	1.6	28.6	24.2	436.5	500.0	-1.2	AVG	AMB
12392.50	V	0.0	1.6	40.2	27.6	2467.8	5000.0	-6.1	Peak	AMB
12392.50	V	0.0	1.6	20.8	27.6	264.7	500.0	-5.5	AVG	AMB
2478.50	H	180.0	1.6	109.8	3.8	478566.5	Fundamental		Peak	Radio
2478.50	H	180.0	1.6	101.2	3.8	177804.3			AVG	
2483.50	H	90.0	1.5	60.8	3.8	1707.8	5000.0	-9.3	Peak	Restricted BE
2483.50	H	90.0	1.5	48.0	3.8	391.2	500.0	-2.1	AVG	
4957.00	H	0.0	1.6	52.5	12.4	1757.5	5000.0	-9.1	Peak	AMB
4957.00	H	0.0	1.6	39.1	12.4	375.7	500.0	-2.5	AVG	AMB
7435.50	H	0.0	1.6	45.7	19.4	1808.1	5000.0	-8.8	Peak	AMB
7435.50	H	0.0	1.6	31.6	19.4	355.8	500.0	-3.0	AVG	AMB
9914.00	H	0.0	1.6	45.7	24.2	3116.9	5000.0	-4.1	Peak	AMB
9914.00	H	0.0	1.6	25.0	24.2	288.7	500.0	-4.8	AVG	AMB
12392.50	H	0.0	1.6	41.7	27.6	2933.0	5000.0	-4.6	Peak	AMB
12392.50	H	0.0	1.6	21.0	27.6	270.6	500.0	-5.3	AVG	AMB

2.7 AC Conducted Emissions

2.7.1 Requirements

Compliance Standard: FCC Part 15, Class B

FCC Compliance Limits				
Frequency Range	Class A		Class B	
	Quasi-peak	Average	Quasi-peak	Average
0.15 – 0.5 MHz	79 dBµV	66 dBµV	66 to 56 dBµV	56 to 46 dBµV
0.5 – 5 MHz	79 dBµV	66 dBµV	56 dBµV	46 dBµV
0.5 – 30 MHz	73 dBµV	60 dBµV	60 dBµV	50 dBµV

2.7.2 Test Procedure

The requirements of FCC Part 15 call for the EUT to be placed on an 80cm-high 1 X 1.5-meter non-conductive table above a ground plane. Power to the EUT was provided through a Solar Corporation 50 Ω/50 µH Line Impedance Stabilization Network bonded to a 3 X 2-meter ground plane. The LISN has its AC input supplied from a filtered AC power source. Power was supplied to the peripherals through a second LISN. The peripherals were placed on the table in accordance with ANSI C63.4. Power and data cables were moved about to obtain maximum emissions.

The 50 Ω output of the LISN was connected to the input of the spectrum analyzer and the emissions in the frequency range of 150 kHz to 30 MHz were measured. The detector function was set to quasi-peak, peak, or average as appropriate, and the resolution bandwidth during testing was at least 9 kHz, with all post-detector filtering no less than 10 times the resolution bandwidth. For average measurements, the post-detector filter was set to 10 Hz.

These emissions must meet the limits specified in §15.107 for quasi-peak and average measurements. At frequencies where quasi-peak or peak measurements comply with the average limit, no average measurements need be performed.

Environmental Conditions during Conducted Emissions Testing

Ambient Temperature:	18 °C
Relative Humidity:	45 %

2.7.3 Conducted Data Reduction and Reporting

The comparison between the AC voltage conducted emission levels and the FCC limit is calculated as shown in the following example:

Spectrum Analyzer Voltage: VdBµV
LISN Correction Factor: LISN dB
Cable Correction Factor: CF dB
Electric Field: EdBµV = VdBµV + LISN dB + CF dB

2.7.4 Test Data

The EUT complies with the Class B, AC Conducted Emissions requirements.

The EUT was tested in both the Low-Power and High-Power modes.

The EUT was set to a transmit enabled mode for this test.

The final test data appears in Table 15 and Table 16.

Table 15: Conducted Voltage Emissions Test Data – Low Power Mode

NEUTRAL										
Frequency (MHz)	**Level QP (dBµV)**	**Level AVG (dBµV)**	**Cable Loss (dB)**	**LISN Corr (dB)**	**Level QP Corr (dBµV)**	**Level Avg Corr (dBµV)**	**Limit QP (dBµV)**	**Limit AVG (dBµV)**	**Margin QP (dB)**	**Margin AVG (dB)**
0.150	44.9	31.6	10.2	0.6	55.7	42.4	66.0	53.0	-10.3	-10.6
0.196	42.1	37.5	10.2	0.5	52.8	48.2	63.8	50.8	-11.0	-2.6
0.466	33.5	27.0	10.2	0.3	44.0	37.5	56.6	43.6	-12.6	-6.1
4.120	26.0	17.4	10.5	0.4	37.0	28.4	56.0	43.0	-19.0	-14.6
10.900	25.0	16.8	11.2	0.7	36.9	28.7	60.0	47.0	-23.1	-18.3
25.110	21.1	14.0	11.7	2.3	35.1	28.0	60.0	47.0	-24.9	-19.0
PHASE / L1										
Frequency (MHz)	**Level QP (dBµV)**	**Level AVG (dBµV)**	**Cable Loss (dB)**	**LISN Corr (dB)**	**Level QP Corr (dBµV)**	**Level Avg Corr (dBµV)**	**Limit QP (dBµV)**	**Limit AVG (dBµV)**	**Margin QP (dB)**	**Margin AVG (dB)**
0.150	45.3	32.9	10.2	0.5	55.9	43.5	66.0	53.0	-10.1	-9.5
0.175	41.9	29.9	10.2	0.4	52.5	40.5	64.7	51.7	-12.3	-11.3
0.461	34.7	26.5	10.2	0.3	45.2	37.0	56.7	43.7	-11.5	-6.7
0.661	25.0	18.1	10.3	0.3	35.5	28.6	56.0	43.0	-20.5	-14.4
3.999	25.1	18.3	10.5	0.4	36.0	29.2	56.0	43.0	-20.0	-13.8
17.579	32.5	17.9	11.4	0.8	44.7	30.1	60.0	47.0	-15.3	-16.9
26.479	20.4	15.0	11.8	2.2	34.4	29.0	60.0	47.0	-25.6	-18.0

Table 16: Conducted Voltage Emissions Test Data – High Power Mode

NEUTRAL										
Frequency (MHz)	**Level QP (dBµV)**	**Level AVG (dBµV)**	**Cable Loss (dB)**	**LISN Corr (dB)**	**Level QP Corr (dBµV)**	**Level Avg Corr (dBµV)**	**Limit QP (dBµV)**	**Limit AVG (dBµV)**	**Margin QP (dB)**	**Margin AVG (dB)**
0.151	48.6	37.0	10.2	0.6	59.4	47.8	65.9	52.9	-6.5	-5.1
0.478	35.0	28.7	10.2	0.3	45.5	39.2	56.4	43.4	-10.9	-4.2
0.940	26.4	19.0	10.3	0.3	37.0	29.6	56.0	43.0	-19.0	-13.4
4.025	24.3	17.9	10.5	0.4	35.3	28.8	56.0	43.0	-20.7	-14.2
14.932	22.6	16.1	11.3	0.9	34.9	28.4	60.0	47.0	-25.1	-18.6
25.431	17.5	13.0	11.7	2.4	31.6	27.1	60.0	47.0	-28.4	-19.9
PHASE / L1										
Frequency (MHz)	**Level QP (dBµV)**	**Level AVG (dBµV)**	**Cable Loss (dB)**	**LISN Corr (dB)**	**Level QP Corr (dBµV)**	**Level Avg Corr (dBµV)**	**Limit QP (dBµV)**	**Limit AVG (dBµV)**	**Margin QP (dB)**	**Margin AVG (dB)**
0.150	48.3	36.5	10.2	0.5	59.0	47.1	66.0	53.0	-7.0	-5.9
0.207	38.3	26.2	10.2	0.3	48.8	36.7	63.3	50.3	-14.5	-13.6
0.475	37.0	31.0	10.2	0.3	47.5	41.5	56.4	43.4	-8.9	-1.9
0.699	26.3	20.2	10.3	0.3	36.8	30.7	56.0	43.0	-19.2	-12.3
0.937	27.7	22.5	10.3	0.3	38.3	33.1	56.0	43.0	-17.7	-9.9
4.284	25.3	20.0	10.6	0.4	36.3	31.0	56.0	43.0	-19.7	-12.0
14.150	23.0	16.9	11.3	0.7	35.0	28.9	60.0	47.0	-25.0	-18.1

3 Equipment Under Test

3.1 EUT Identification & Description

The Intelligent Automation Inc., Gallium Radio is a 2.4 GHz radio module device that transmits and receives proprietary waveform/protocol (Niquist) with ad-hoc network and ranging features.

3.2 Test Configuration

The Gallium Radio was powered by a provided 120 VAC wall-wart power supply, which delivered the final 12 VDC to the radio package. The transmitter was mounted to a plastic test-jig and the settings of the transmitter were configurable through the use of a support laptop. The EUT was configured for testing, as depicted in Figure 65. Table 17 provides further details pertaining to the EUT.

Figure 65: EUT Test-Jig Diagram – As Tested

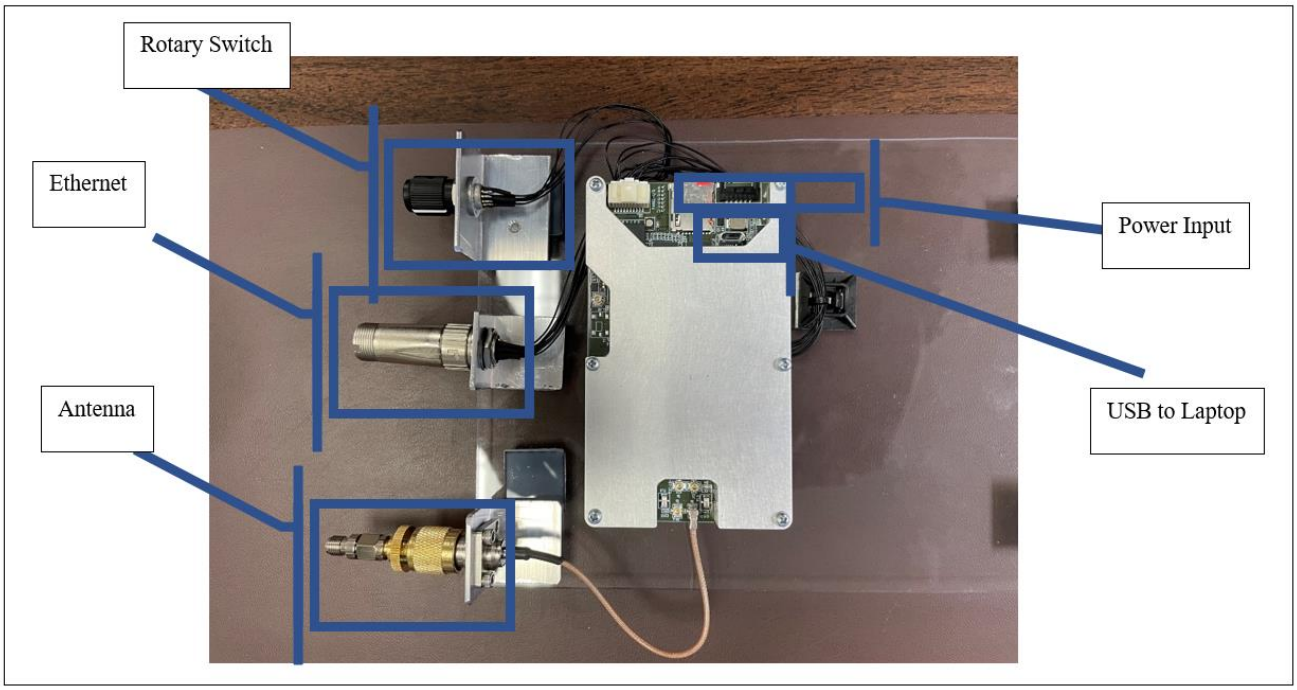


Table 17: Radio Device Summary

Manufacturer:	Intelligent Automation Inc.
FCC ID:	2AI6Y-GALLIUM2400
EUT Name:	Gallium Radio
Serial Number of Unit Tested:	110420210005
FCC Rule Part:	§15.247
TX Frequency Range:	2403.5 – 2478.5 MHz
Maximum Peak Output Power:	26.16 dBm (413 mW)
Modulation:	QPSK
6dB Occupied Bandwidth:	5.067 MHz
FCC Emission Designator:	5M07G1DN
Keying:	Automatic
Type of Information:	TCP/IP Data
Number of Channels:	Not Specified by Applicant
Power Output Level Settings:	2 Modes (Min & Max)
Antenna Connector:	U.FL at PCB; RP-TNC at external connection
Antenna Type	Arcadian: RQWD-9/24-RTM, 1/4 Wave (2.5 dBi)
Maximum Potential EIRP:	dBm (as tested)
Interface Cables:	See Table 21 of this Report
Maximum Data Rate	5 Mbps
Software/Firmware:	Normal Operation, REV 1.0 (test settings: 10dB Tx Attn.)
Pulsed Transmitter:	No
Transmitter Timing/Duty Cycle:	N/A, None
Power Source & Voltage:	12 VDC from 120 VAC Wall-Adapter
Highest TX Spurious Emission:	7320 MHz (3m, Radiated); 405.8 uV/m (AVG)

Table 18: System Configuration List

Name / Description	Model Number	Part Number	Serial Number	Revision
Gallium Radio	1	SPWNiQ-1	110420210005	1.0

Table 19: Support Equipment

Item	Model/Part Number	Serial Number
Laptop	Dell, XPS-13	N/A
USB Cable	Micro-USB, 20cm	N/A
Radio Antenna	Arcadian, RQWD-9/24-RTM	N/A

Table 20: Cable Configuration

Port Identification	Connector Type	Cable Length	Shielded (Y/N)	Termination Point
Panel IO, J4	Custom	15cm	Yes	Circ. Ethernet; Rotary Switch
Power Input, J13	Custom	1.5m	Yes	120 VAC Adapter
RF1	U.FL to RP-TNC	10cm	Yes	Antenna

3.3 Measurements

3.3.1 References

ANSI C63.2 (Jan-2016) Specifications for Electromagnetic Noise and Field Strength Instrumentation

ANSI C63.4 (Jan 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 (Jun 2013) American National Standard of Procedures for Compliance Testing of Unlicensed Wireless Devices

3.4 Measurement Uncertainty

All results reported herein relate only to the equipment tested. The basis for uncertainty calculation uses ANSI/NCSL Z540-2-1997 (R2002) with a type B evaluation of the standard uncertainty. Elements contributing to the standard uncertainty are combined using the method described in Equation 1 to arrive at the total standard uncertainty. The standard uncertainty is multiplied by the coverage factor to determine the expanded uncertainty which is generally accepted for use in commercial, industrial, and regulatory applications and when health and safety are concerned (see Equation 2). A coverage factor was selected to yield a 95% confidence in the uncertainty estimation.

Equation 1: Standard Uncertainty

$$u_c = \pm\sqrt{\frac{a^2}{div_a{}^2} + \frac{b^2}{div_b{}^2} + \frac{c^2}{div_c{}^2} + ...}$$

Where uc = standard uncertainty
a, b, c,.. = individual uncertainty elements
Diva, b, c = the individual uncertainty element divisor based on the probability distribution
Divisor = 1.732 for rectangular distribution
Divisor = 2 for normal distribution
Divisor = 1.414 for trapezoid distribution

Equation 2: Expanded Uncertainty

$$U = ku_c$$

Where:
U = expanded uncertainty
k = coverage factor
k ≤ 2 for 95% coverage (ANSI/NCSL Z540-2 Annex G)
uc = standard uncertainty

The measurement uncertainty complies with the maximum allowed uncertainty from CISPR 16-4-2. Measurement uncertainty is not used to adjust the measurements to determine compliance. The expanded uncertainty values for the various scopes in the WLL accreditation are provided in Table 21 below.

Table 21: Expanded Uncertainty List

Scope	Standard(s)	Expanded Uncertainty
Conducted Emissions	CISPR11, CISPR22, CISPR32, CISPR14, FCC Part 15	± 2.63 dB
Radiated Emissions	CISPR11, CISPR22, CISPR32, CISPR14, FCC Part 15	± 4.55 dB

4 Test Equipment

Table 22 shows a list of the test equipment used for measurements, along with the calibration information.

Table 22: Test Equipment List

Test Name:	**Benchtop RF Emissions**	Test Date: 11/16/2021 – 11/17/2021	
Asset #	**Manufacturer/Model**	**Description**	**Cal. Due**
00528	AGILENT, E4446A	SPECTRUM ANALYZER	3/18/2022
00806	MINI-CIRCUITS	HF COAXIAL CABLE, SMA	5/10/2022

Test Name:	**Radiated Emissions**	Test Date: 11/15/2021 – 11/16/2021	
Asset #	**Manufacturer/Model**	**Description**	**Cal. Due**
00528	AGILENT, E4446A	4SPECTRUM ANALYZER	3/18/2022
00644	SUNOL SCIENCES CORP.	BICONALOG ANTENNA	11/9/2022
00425	ARA, DRG-118/A	HF HORN ANTENNA	8/18/2022
00955	JUNKOSHA, MWX322	18M HF COAXIAL CABLE	5/10/2022
00865	STORM 874-0101-036	HF COAXIAL CABLE, SMA	6/17/2022
00276	ELECTRO-METRICS, BPA	RF PRE-AMPLIFIER	6/8/2022
00522	HP, 8449B	RF PRE-AMPLIFIER	6/4/2022
00742	PENN ENG., WR284	WAVEGUIDE PASS FILTER	1/18/2022
00281	ITC. 21A-3A1	WAVEGUIDE PASS FILTER	1/18/2022
00721	WEINSCHEL, DS109	TUNABLE ATTENUATOR	Cal. Before Use

Test Name:	**AC Conducted Emissions**	Test Date: 11/17/2021	
Asset #	**Manufacturer/Model**	**Description**	**Cal. Due**
00528	AGILENT, E4446A	SPECTRUM ANALYZER	3/18/2022
00895	HP, 11947A	TRANSIENT LIMITER	2/18/2022
00330	WLL, CE CABLE	RF COAXIAL CABLE, BNC	5/12/2022
00419	EMCO, 3810/2	LISN	5/11/2022