Washington Laboratories, Ltd.

FCC PART 15.247 & RSS-247 CERTIFICATION TEST REPORT

for the

Wi-Fi device

FCC ID: YSD-5840-SS-1920

IC ID: 24752-SS1920

REPORT# 15414-01 REV 2

Prepared for:

Reutech Radar Systems

PO Box 686

Stellenbosch, Capetown 7599

Prepared By:

Washington Laboratories, Ltd.

7560 Lindbergh Drive

Gaithersburg, Maryland 20879

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SEPTEMBER 06, 2019

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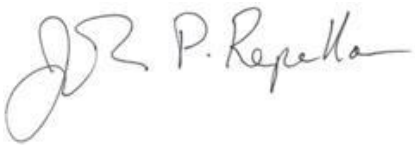

John P. Repella
Manager, EMC & Wireless Services

Reviewed by:

Steven Koster
President

ABSTRACT

This report has been prepared on behalf of Reutech Radar Systems to support the attached Application for Equipment Authorization. The test report and application are submitted for a Digital Transmission System (DTS) Transmitter under Part 15.247 of the FCC Rules and Regulations and Spectrum Management and Telecommunications Policy and under RSS-247 of Innovation, Science and Economic Development Canada (ISED). This Certification Test Report documents the test configuration and test results for the Reutech Radar Systems Wi-Fi device.

This device is applying for a **Limited Modular Approval** as it does not meet all 8 criteria (no shield is supplied over the RF circuitry).

Testing was performed on an Open Area Test Site (OATS) of Washington Laboratories, Ltd, 7560 Lindbergh Drive, Gaithersburg, MD 20879. 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. The ISED Canada OATS numbers are 3035A-1 and 3035A-2 for Washington Laboratories, Ltd. Site 1 and Site 2, respectively. Washington Laboratories, Ltd. has been accepted by the FCC and approved by ANAB under Certificate AT-1448 as an independent FCC test laboratory.

The Reutech Radar Systems Wi-Fi device complies with the limits for a Digital Transmission System (DTS) Transmitter device under FCC Part 15.247 and Innovation, Science and Economic Development Canada (ISED) RSS-247.

Revision History	Description of Change	Date
Rev 0	Initial Release	May 8, 2019
Rev 1	After ACB comments	August 1, 2019
Rev 2	Additional Comments from ACB	September 5, 2019

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1 INTRODUCTION

1.1 COMPLIANCE STATEMENT

The Reutech Radar Systems Wi-Fi device complies with the limits for a Digital Transmission System (DTS) Transmitter device under FCC Part 15.247 and ISED Canada RSS-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.

1.3 CONTRACT INFORMATION

Customer:	Reutech Radar Systems
Address	PO Box 686
	Stellenbosch, Capetown 7599
Purchase Order Number:	PO44384
Quotation Number:	70341

1.4 TEST DATES

Testing was performed on the following date(s): 12-15 Dec. 2018, July 18, 2019, & Sept. 6, 2019

1.5 TEST AND SUPPORT PERSONNEL

Washington Laboratories, LTD	Mike Violette, John P. Repella
Customer Representative	Bryn Jones

1.6 ABBREVIATIONS

A	**A**mpere
ac	**a**lternating **c**urrent
AM	Amplitude Modulation
Amps	Amperes
b/s	**b**its per **s**econd
BW	**B**and**W**idth
CE	**C**onducted **E**mission
cm	**C**enti**m**eter
CW	**C**ontinuous **W**ave
dB	**d**eci**B**el
dc	**d**irect **c**urrent
EMI	**E**lectro**m**agnetic **I**nterference
EUT	**E**quipment **U**nder **T**est
FM	**F**requency **M**odulation
G	**g**iga – prefix for 10^9 multiplier
Hz	**H**ertz
IF	**I**ntermediate **F**requency
k	**k**ilo – prefix for 10^3 multiplier
LISN	**L**ine **I**mpedance **S**tabilization **N**etwork
M	**M**ega – prefix for 10^6 multiplier
m	**M**eter
μ	**m**icro – prefix for 10^{-6} multiplier
NB	**N**arrow**b**and
QP	**Q**uasi-**P**eak
RE	**R**adiated **E**missions
RF	**R**adio **F**requency
rms	**r**oot-**m**ean-**s**quare
SN	**S**erial **N**umber
S/A	**S**pectrum **A**nalyzer
V	**V**olt

2 EQUIPMENT UNDER TEST

2.1 EUT IDENTIFICATION & DESCRIPTION

Table 1: Device Summary

Item	WiFi Communications device to operate Subsurface Profiler and receive and present data from Subsurface Profiler
Manufacturer:	Reutech Radar Systems
FCC ID:	YSD-5840-SS-1920
ISED ID:	24752-SS1920
Model:	Wi-Fi device
Serial Number of Unit Tested	None
FCC Rule Parts:	§15.247
ISED Rule Parts:	RSS-247
Frequency Range:	2412-2462 MHz
Maximum Output Power:	15.62 dBm (36.5 mW)
Modulation:	DSSS, OFDM, MCS1-7
Occupied Bandwidth (99%):	>17000kHz for all modulations
FCC Emission Designator:	DSSS: 14M1G1D OFDM: 16M7G1D WCS: 17M8G1D
Keying:	Automatic
Type of Information:	Data
Number of Channels:	11
Power Output Level	Fixed
Highest TX Spurious Emission:	129.8uV/m@2400 MHz
Antenna Connector	N/A
Antenna Type	PCB Trace
Interface Cables:	None
Maximum Data Rate	64MBps
Power Source & Voltage:	From host, 5VDC

The Reutech Radar Systems Wi-Fi device is used in the Subsurface Profiler (SSP), which is a system used in underground tunnels to image inside walls and floors to detect anomalies in the underlying structure. The SSP communicates via the WiFi Device to a table PC that is set up in a peer-to-peer mode for communications.

It contains the following clocks and oscillators:

Frequency (MHz)	Source
40MHz	Vectron VC-820-EAE-FAAN-40M000000 Crystal Oscillator (XO) Used by the DDS and CC3100 Wi-Fi
10MHz	Vectron VC-820-EAE-FAAN-40M000000 Crystal Oscillator (XO) via AD9513 800 MHz Clock Distribution IC Used by the STM32F407 Processor
1.25MHz	Vectron VC-820-EAE-FAAN-40M000000 Crystal Oscillator (XO) via AD9513 800 MHz Clock Distribution IC Used by the LT8601 DC/DC converter

2.2 TEST CONFIGURATION

The Wi-Fi device was configured to operate at highest, center and lowest modulations of the available channels (WiFi Channels 1-11). The following modes can be accessed from the test software that is available from the RF Chip manufacturer (Texas Instruments).

Modulation
1 Mbps (DSSS)
2 Mbps (DSSS)
5.5 Mbps (DSSS)
11 Mbps (DSSS)
6 Mbps (OFDM)
12 Mbps (OFDM)
18 Mbps (OFDM)

24 Mbps (OFDM)
36 Mbps (OFDM)
48 Mbps (OFDM)
54 Mbps (OFDM)
MCS 0
MCS 1
MCS 2
MCS 3
MCS 4
MCS 5
MCS 6
MCS 7
MCS 8

MCS: Modulation coding schemes are designated phase shift keying techniques.

The following modulation modes were tested at lower, middle and high channels, representing maximum and minimum modulation data rate of each type.

Mode	Modulation
1	1 Mbps (DSSS)
2	11 Mbps (CCK)
4	54 Mbps (OFDM)
7	MCS 7

2.3 TESTING ALGORITHM

The device was tested using application software from Texas Instruments. This allowed the test for each available channel. Non-modulated mode was not accessible by the tool, so all measurements were taken with modulation enabled.

2.4 TEST LOCATION

All measurements herein were performed at Washington Laboratories, Ltd. test center in Gaithersburg, 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. The ISED Canada OATS numbers are 3035A-1 and 3035A-2 for Washington Laboratories, Ltd. Site 1 and Site 2, respectively. Washington Laboratories, Ltd. has been accepted by the FCC and approved by ANAB under Testing Certificate AT-1448 as an independent FCC test laboratory.

2.5 MEASUREMENTS

2.5.1 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

ANSI C63.26 (Dec 2015) American National Standard for Compliance Testing of Transmitters Used in Licensed Radio Services

2.6 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 u_c = standard uncertainty

a, b, c,.. = individual uncertainty elements

$Div_{a, b, c}$ = 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

$k \leq 2$ for 95% coverage (ANSI/NCSL Z540-2 Annex G)

u_c = 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 2 below.

Table 2: 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

3 TEST EQUIPMENT

Table 3 shows a list of the test equipment used for measurements along with the calibration information.

Table 3: Test Equipment List

Test Name:	**Conducted Emissions Voltage**	Test Date:	**12/14/2018**
Asset #	**Manufacturer/Model**	**Description**	**Cal. Due**
528	AGILENT - E4446A	3HZ - 44GHZ ANALYZER SPECTRUM	12/19/2018
125	SOLAR - 8028-50-TS-24-BNC	LISN	5/23/2019
126	SOLAR - 8028-50-TS-24-BNC	LISN	5/23/2019
53	HP - 11947A	LIMITER TRANSIENT	2/1/2019
00330	WLL	COAX CABLE RG-223	4/6/2020

Test Name:	**Radiated Emissions**	Test Date:	**12/13/2018**
Asset #	**Manufacturer/Model**	**Description**	**Cal. Due**
823	AGILENT - N9010A	EXA SPECTRUM ANALYZER	4/30/2018
559	HP - 8447D	AMPLIFIER	2/12/2019
627	AGILENT - 8449B	AMPLIFIER 1-26GHZ	11/7/2017
644	SUNOL SCIENCES CORPORATION - JB1 925-833-9936	BICONALOG ANTENNA	1/16/2020
Site 1 cable set	WLL	COAX CABLE SET	2/19/2019
4	ARA/DRG-118/A	ANTENNA DRG 1-18GHZ	6/14/2019
210	NARDA/V638	HORN STANDARD GAIN 18-26.5 GHZ	6/7/2019
849	AH Systems /SAC-18G-16	HF Coaxial Cable 20MHz to 18GHz	1/18/2019

00885	UTIFLEX MICRO COAX/UFA2108-0-360-100300	0.5M SMA-SMA RF COAXIAL CABLE	4/9/2020

Test Name:	**Antenna Port Conducted Emissions**	Test Date:	**09/06/2019**
Asset #	**Manufacturer/Model**	**Description**	**Cal. Due**
00528	AGILENT/PSA E4446A	3Hz-44GHz SPECTRUM ANALYZER	02/07/2020
00885	UTIFLEX MICRO COAX/UFA2108-0-360-100300	0.5M SMA-SMA RF COAXIAL CABLE	4/9/2020

125	SOLAR - 8028-50-TS-24-BNC	LISN	5/23/2019
126	SOLAR - 8028-50-TS-24-BNC	LISN	5/23/2019
53	HP - 11947A	LIMITER TRANSIENT	2/1/2019

4 TEST SETUP

The following figure shows the test setup.

EUT CABLE SPECTRUM ANALYZER

The EUT was connected to the input of a spectrum analyzer through cable and necessary attenuation. Attenuation factors were compensated for in the analyzer settings.

5 TEST RESULTS

The Table Below shows the results of testing for compliance with a Digital Transmission System in accordance with FCC Part 15.247 10/2014 and RSS-247 Issue 1. Full test results are shown in subsequent sub-sections.

Table 4: Test Summary Table

Digital Transmission System (DTS) TX Test Summary			
FCC Rule Part	**IC Rule Part**	**Description**	**Result**
15.247(a) (2)	RSS-247 [5.2 (1)]	6dB Bandwidth	Pass
15.247 (b)(3)	RSS-247 [5.4 (4)]	Transmit Output Power	Pass
15.247 (e)	RSS-247 [5.2 (2)]	Power Spectral Density	Pass
15.247 (d)	RSS-247 [5.5]	Out-of-Band Emissions (Band Edge @ 20dB below)	Pass
15.205 15.209	RSS-Gen [8.9/8.10]	General Field Strength Limits (Restricted Bands & RE Limits)	Pass
15.207	RSS-Gen [8.8]	AC Conducted Emissions*	Pass

*** SUPPLIED WITH BATTERY CHARGER**

5.1 DUTY CYCLE:

The spectrum analyzer was set to 0 span mode and the total ON and OFF times were measured.

Figure 1. On Time of Transmit Pulse

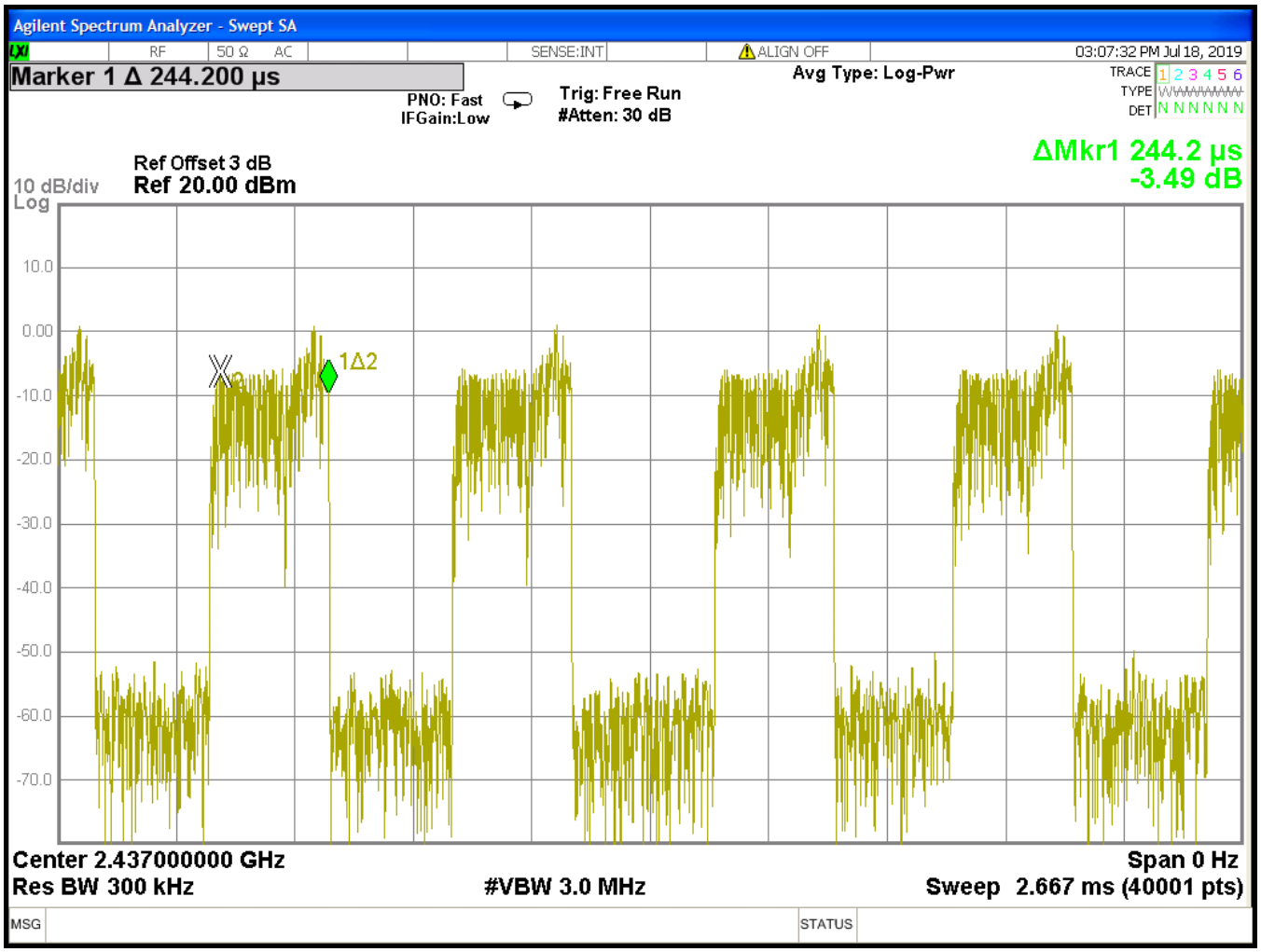
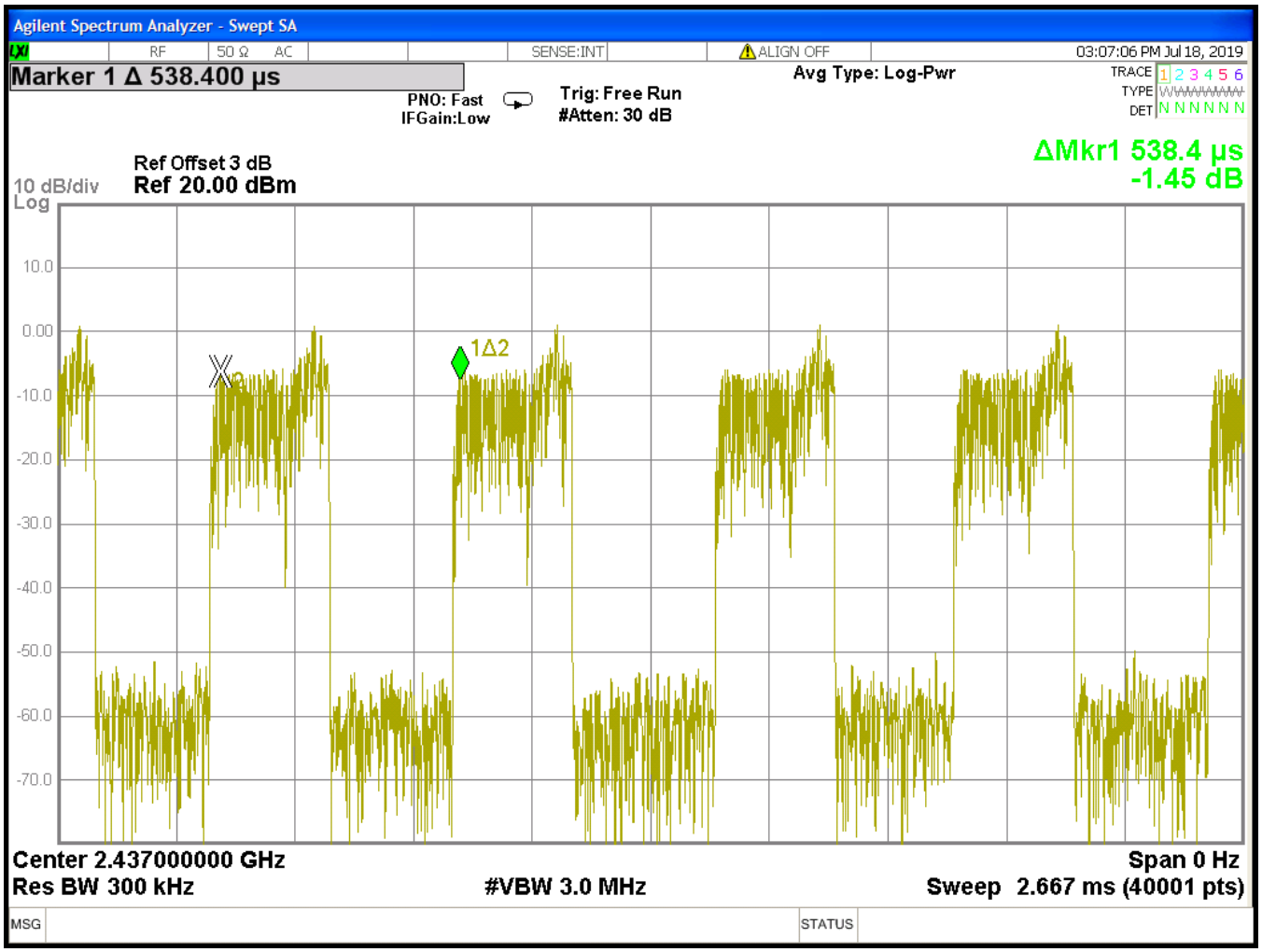


Figure 2. Total Time of Transmit Pulse



The total pulse time is 538us and the transmit time is 242us. The duty cycle is:

$$D = 242/538 = 0.449 = -6.9\text{dB}$$

5.2 OCCUPIED BANDWIDTH:

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

For Direct Sequence Spread Spectrum Systems, FCC Part 15.247 requires the minimum 6 dB bandwidth be at least 500 kHz.

5.2.1 Measurement Method:

The occupied bandwidth was measured over the span of the emission using the spectrum analyzer's built-in algorithm. The 6dB OBW was measured.

Table 5 provides a summary of the Occupied Bandwidth Results.

Table 5: Occupied Bandwidth Results

Frequency	Bandwidth	Limit	Pass/Fail
Low Channel 2412 MHz	>14000kHz	≥500kHz	Pass
Center Channel 2437 MHz	>14000kHz	≥500kHz	Pass
High Channel 2462 MHz	>14000kHz	≥500kHz	Pass

Table 6: 6db Occupied Bandwidth Measurement Summary

Frequency	Mode 1 (MHz)	Mode 2 (MHz)	Mode 4 (MHz)	Mode 7 (MHz)
Low Channel 2412 MHz	9.201	9.680	16.434	17.698
Center Channel 2437 MHz	9.214	9.708	16.432	17.616
High Channel 2462 MHz	9.201	9.632	16.184	17.708

Table 7: 99% Power Bandwidth Measurement Summary

Frequency	Mode 1 (MHz)	Mode 2 (MHz)	Mode 4 (MHz)	Mode 7 (MHz)
Low Channel 2412 MHz	14.0406	14.1348	16.6464	17.8137
Center Channel 2437 MHz	14.0581	14.3110	16.6625	17.7728
High Channel 2462 MHz	14.0244	14.4236	16.5902	17.8113

Figure 3. 2412 MHz OBW MODE 1

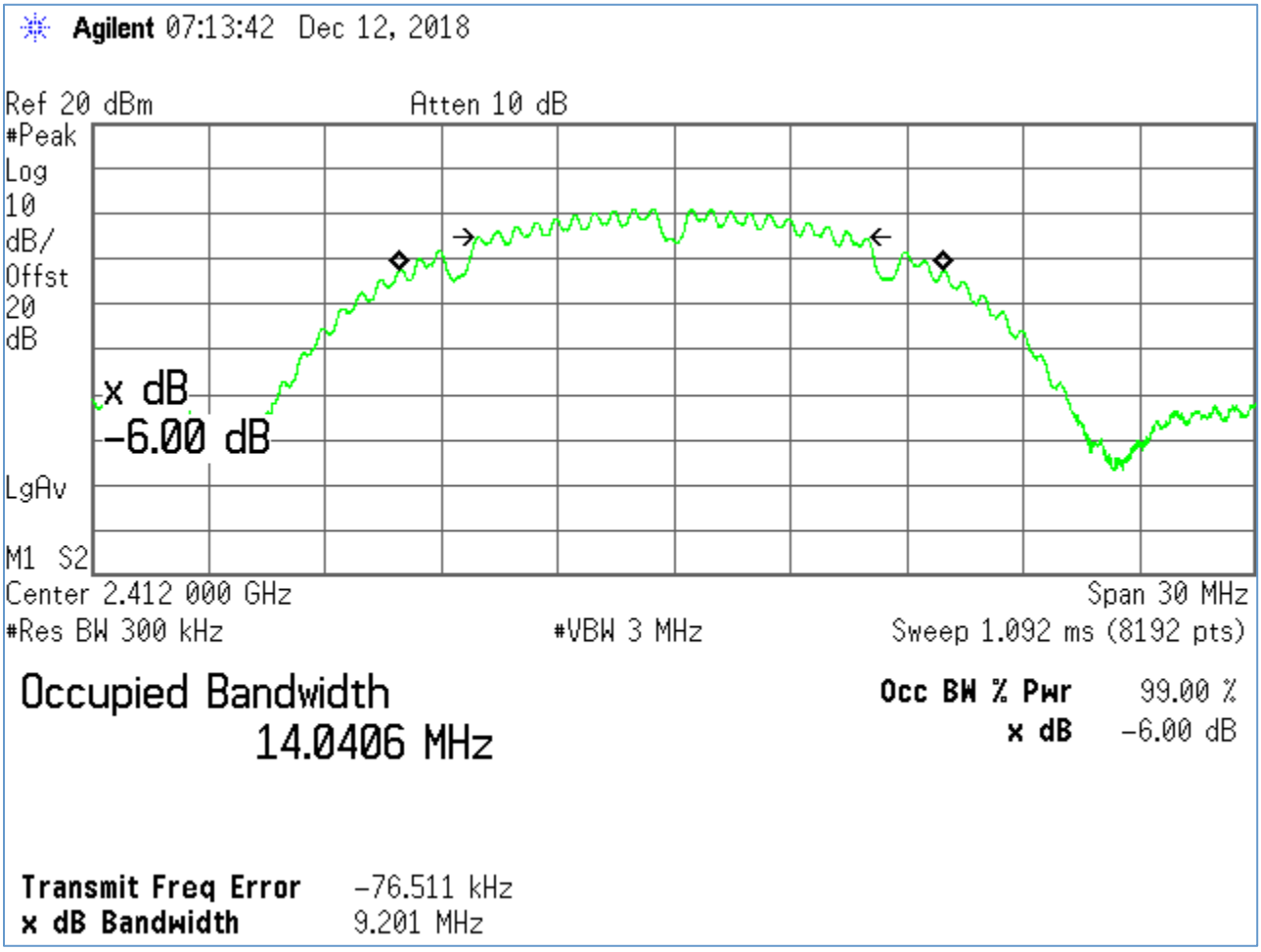


Figure 4. 2412 MHz OBW MODE 2

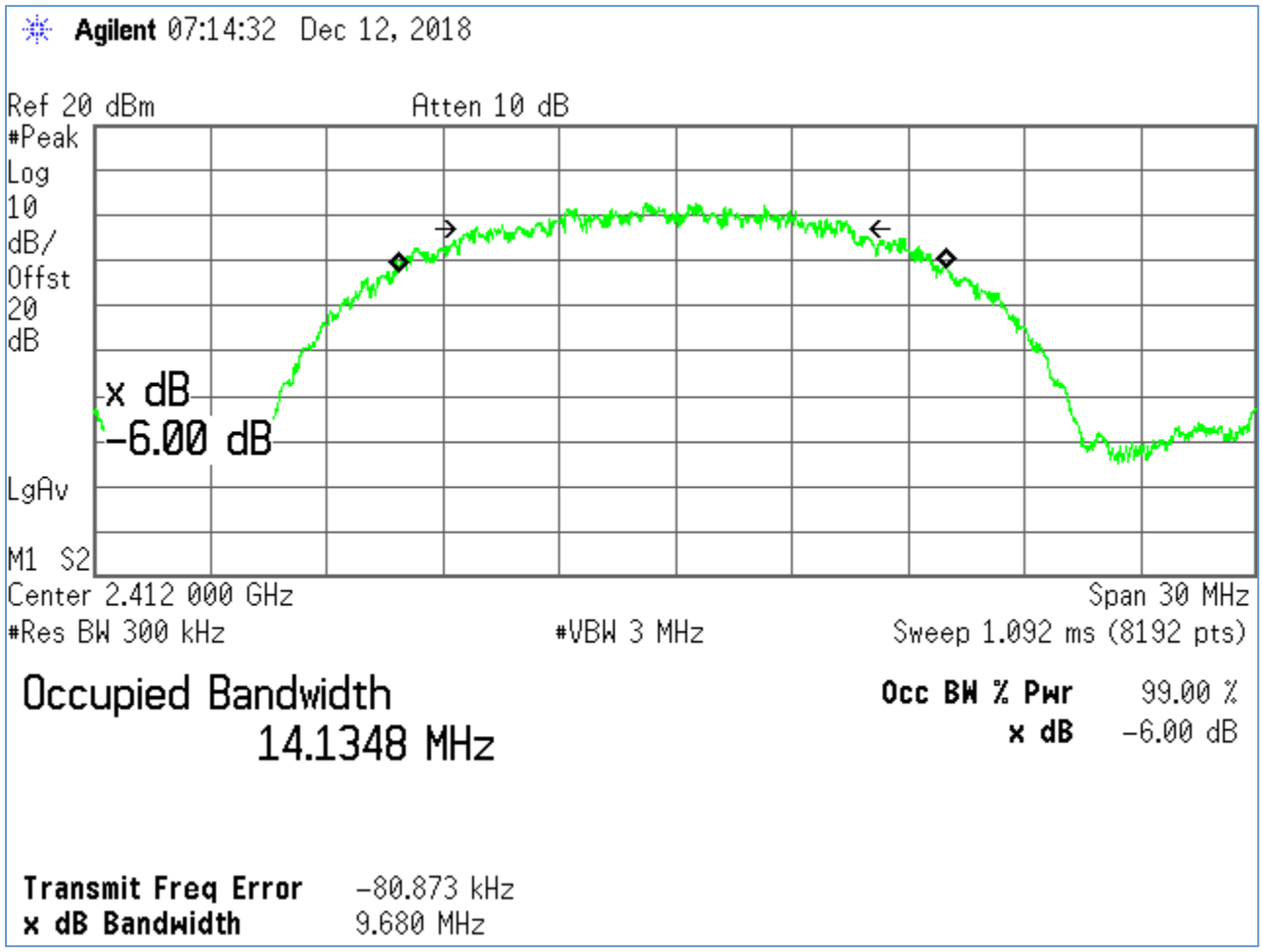


Figure 5. 2412 MHz OBW MODE 4

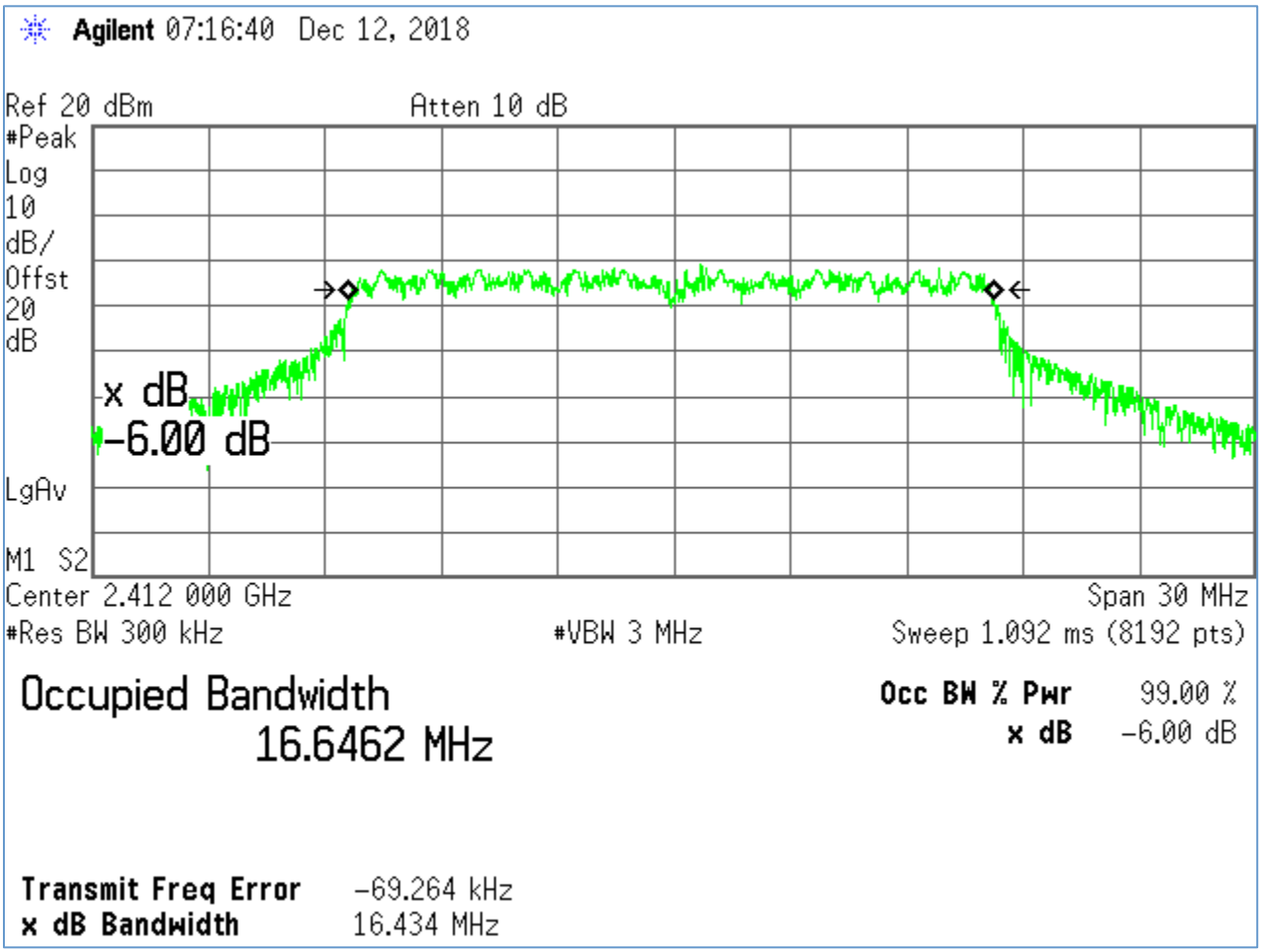


Figure 6. 2412 MHz OBW MODE 7

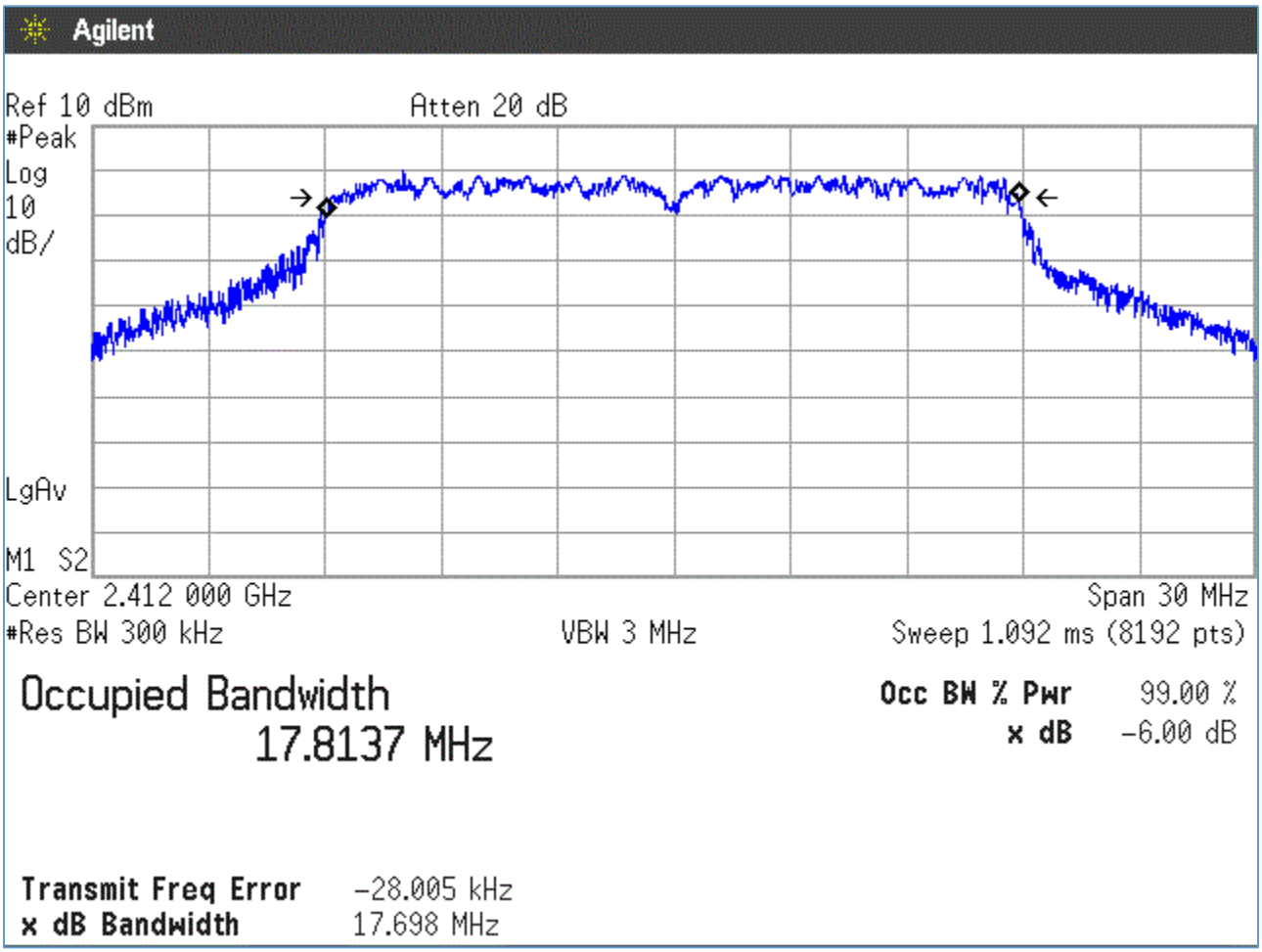


Figure 7. 2437 MHz OBW MODE 1

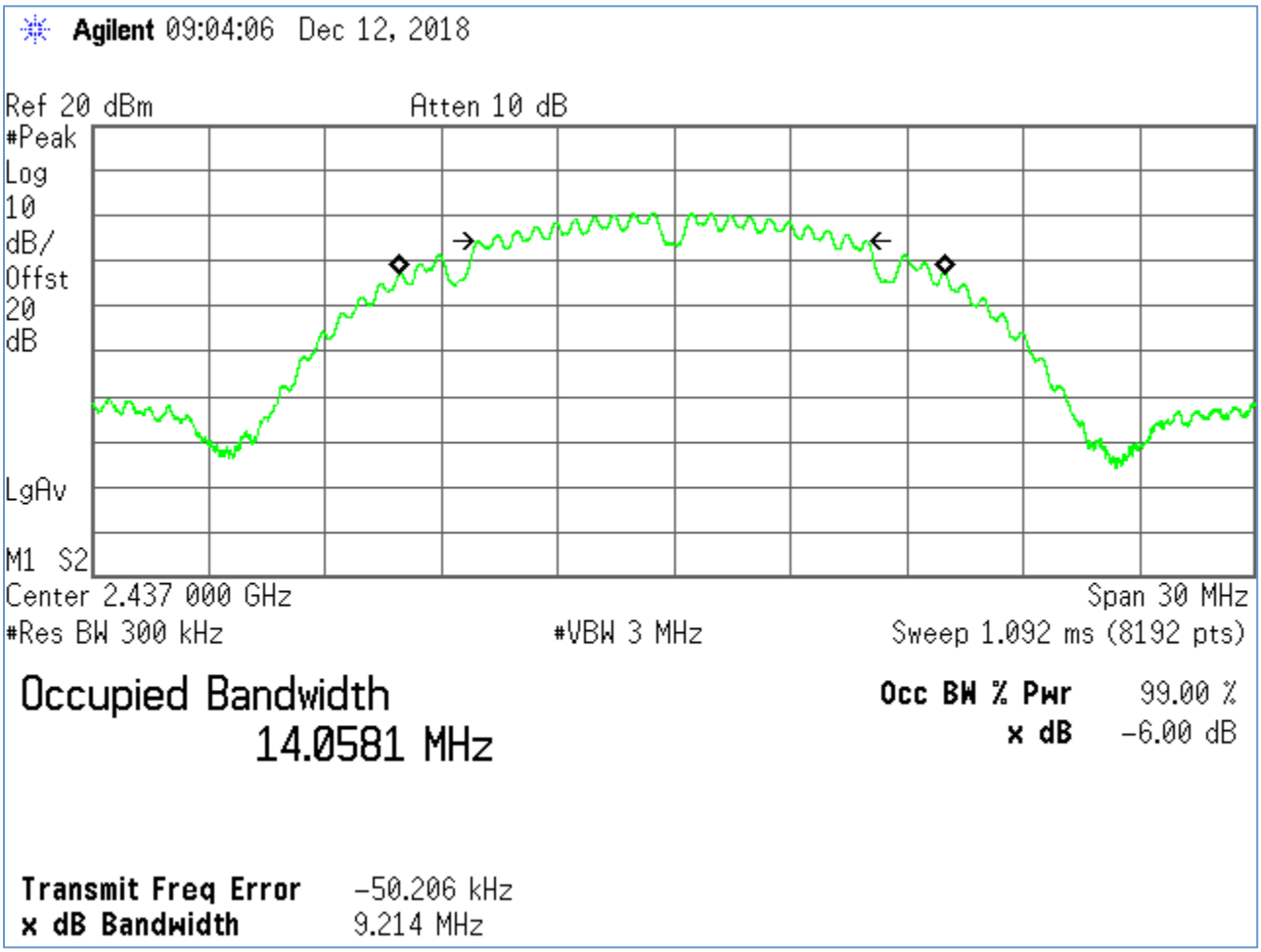


Figure 8. 2437 MHz OBW MODE 2

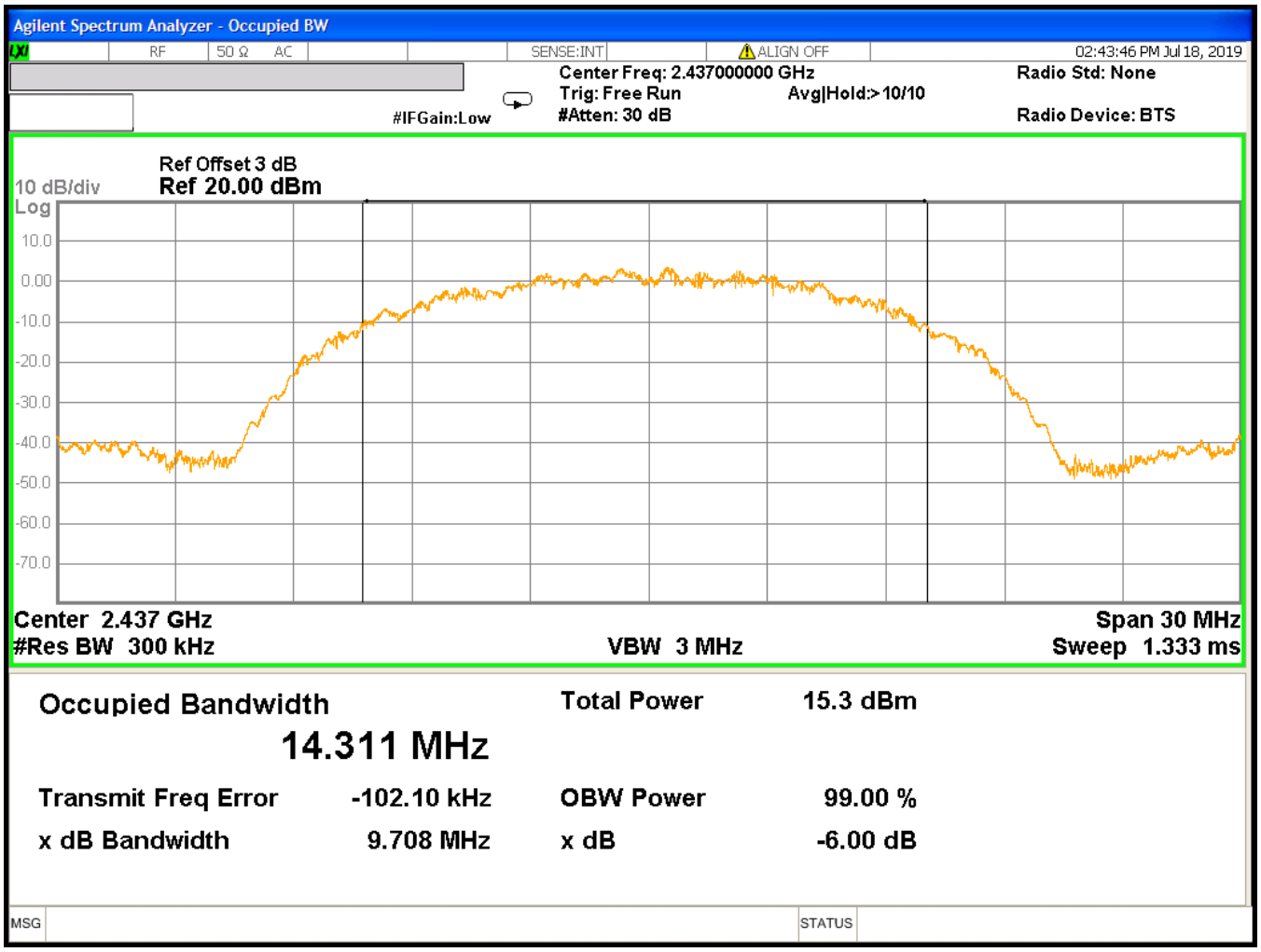


Figure 9. 2437 MHz OBW MODE 4

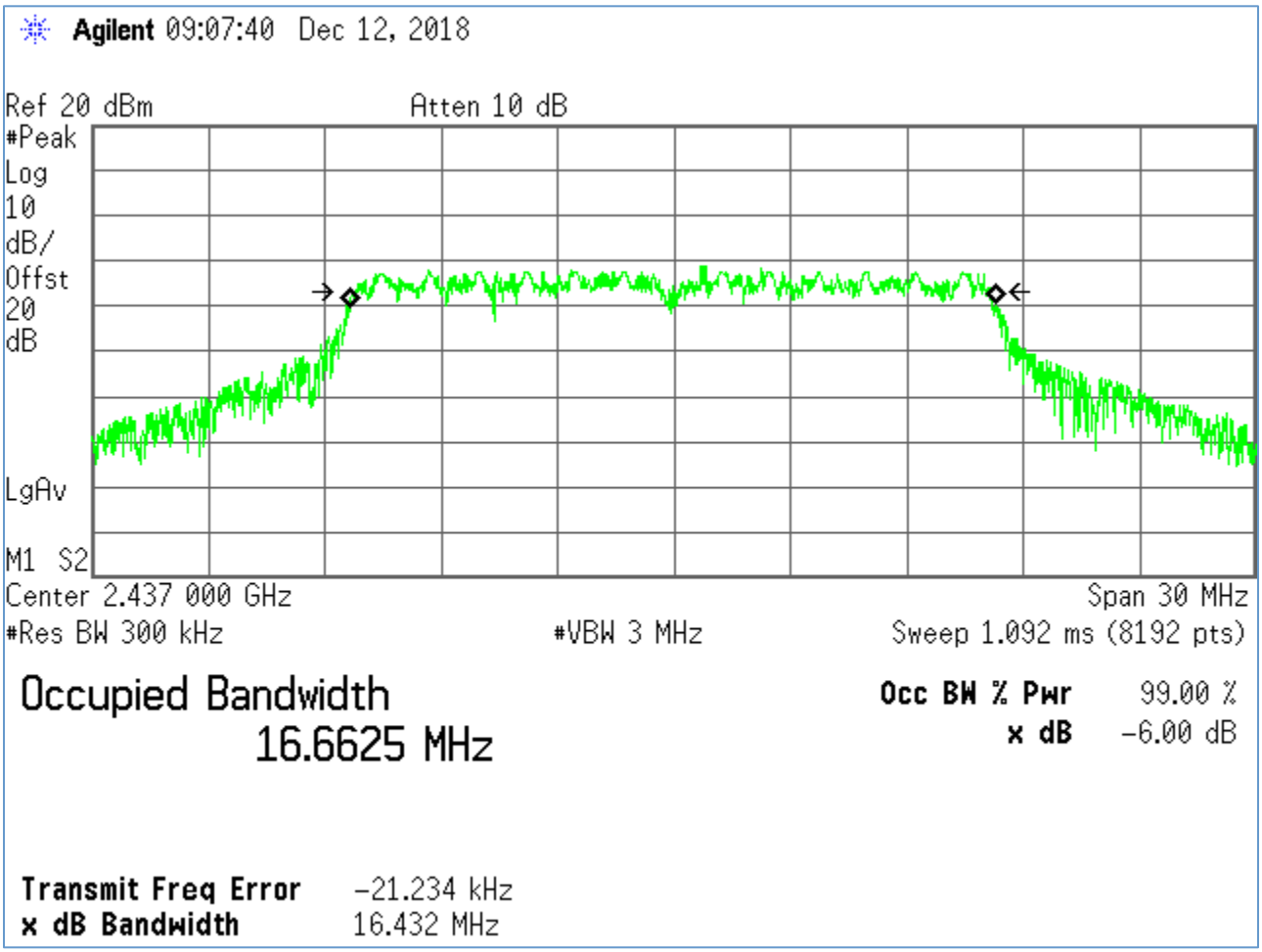


Figure 10. 2437 MHz OBW MODE 7

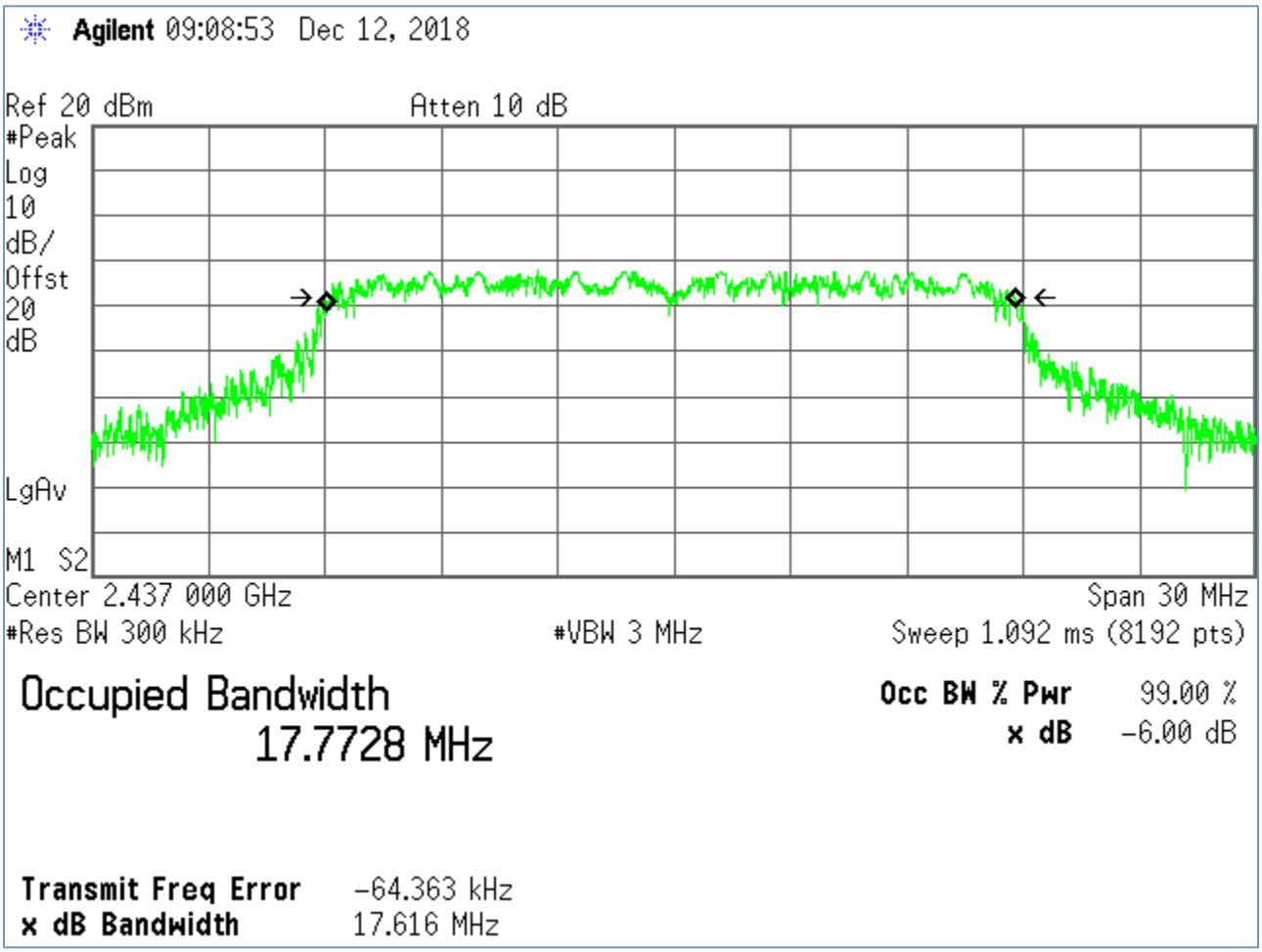


Figure 11. 2462 MHz OBW MODE 1

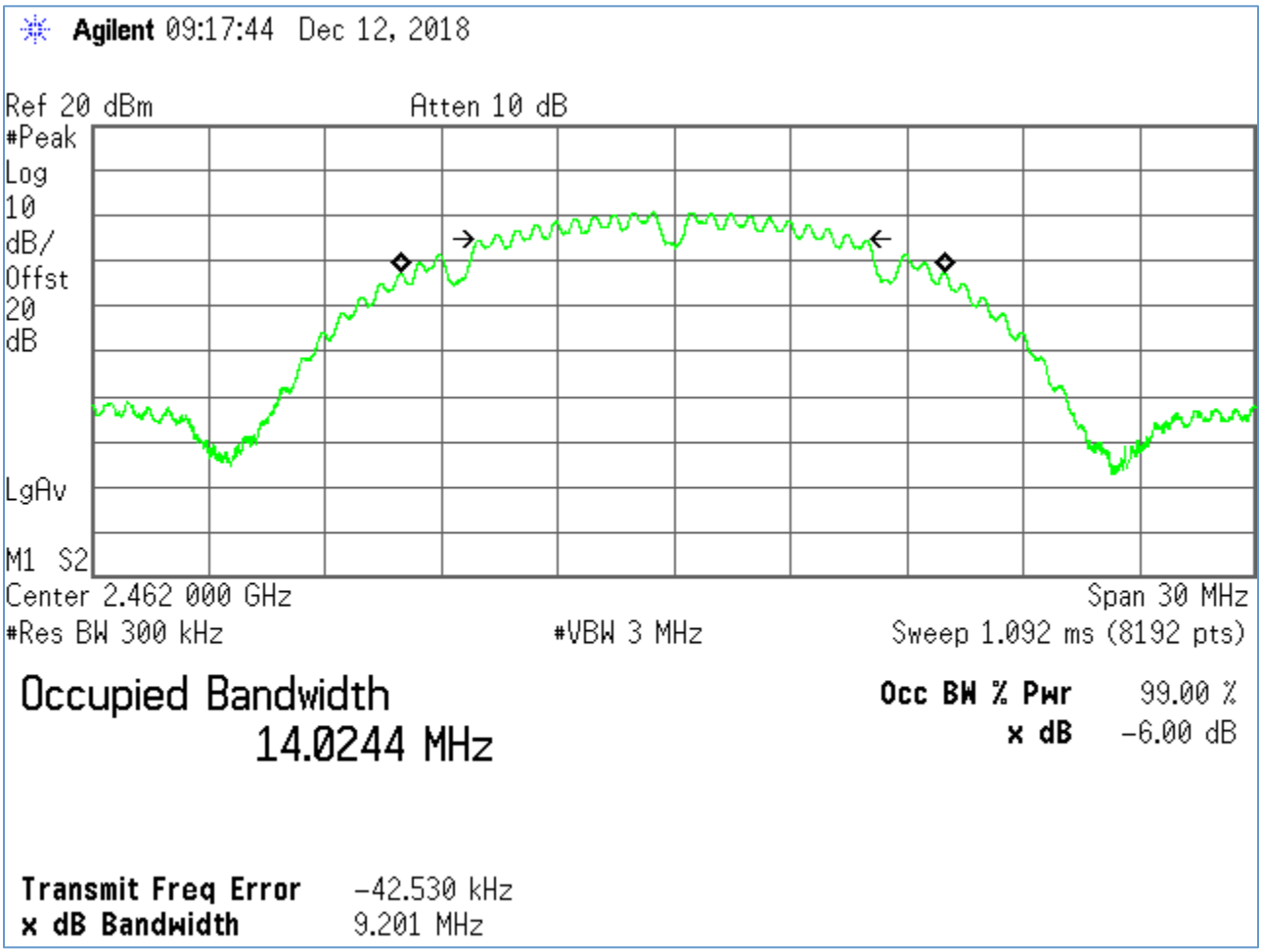


Figure 12. 2462 MHz OBW MODE 2

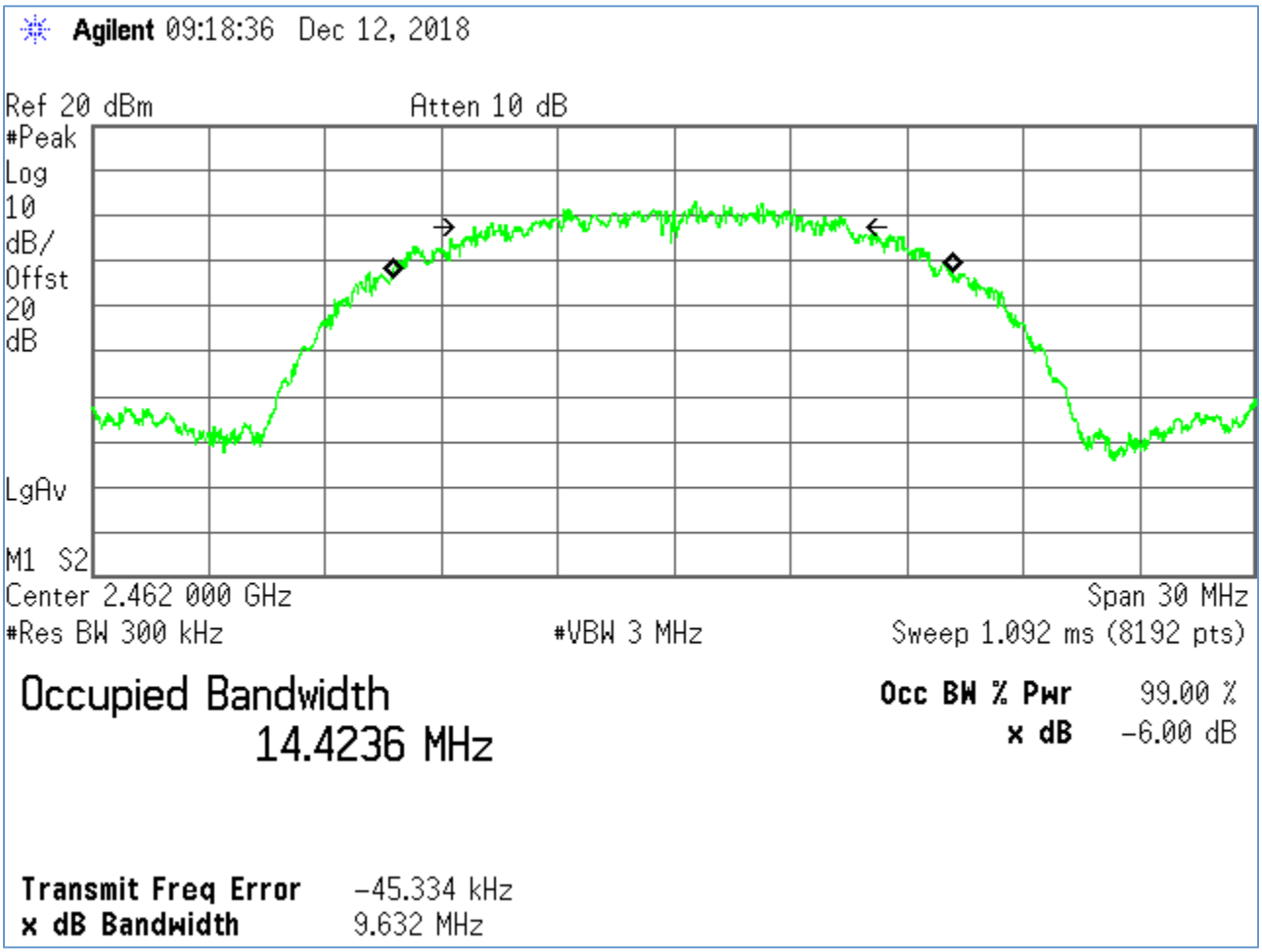


Figure 13. 2462 MHz OBW MODE 4

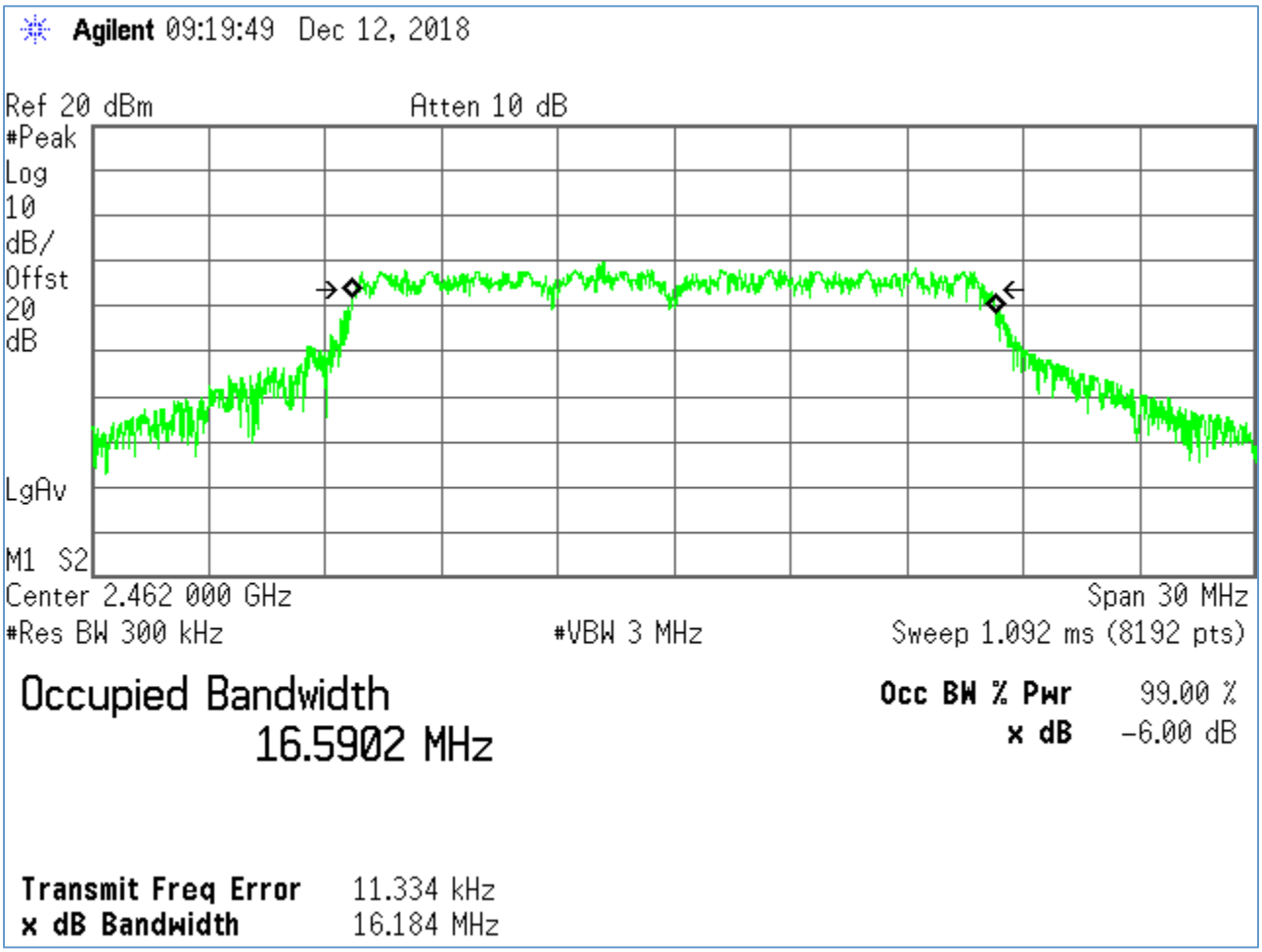
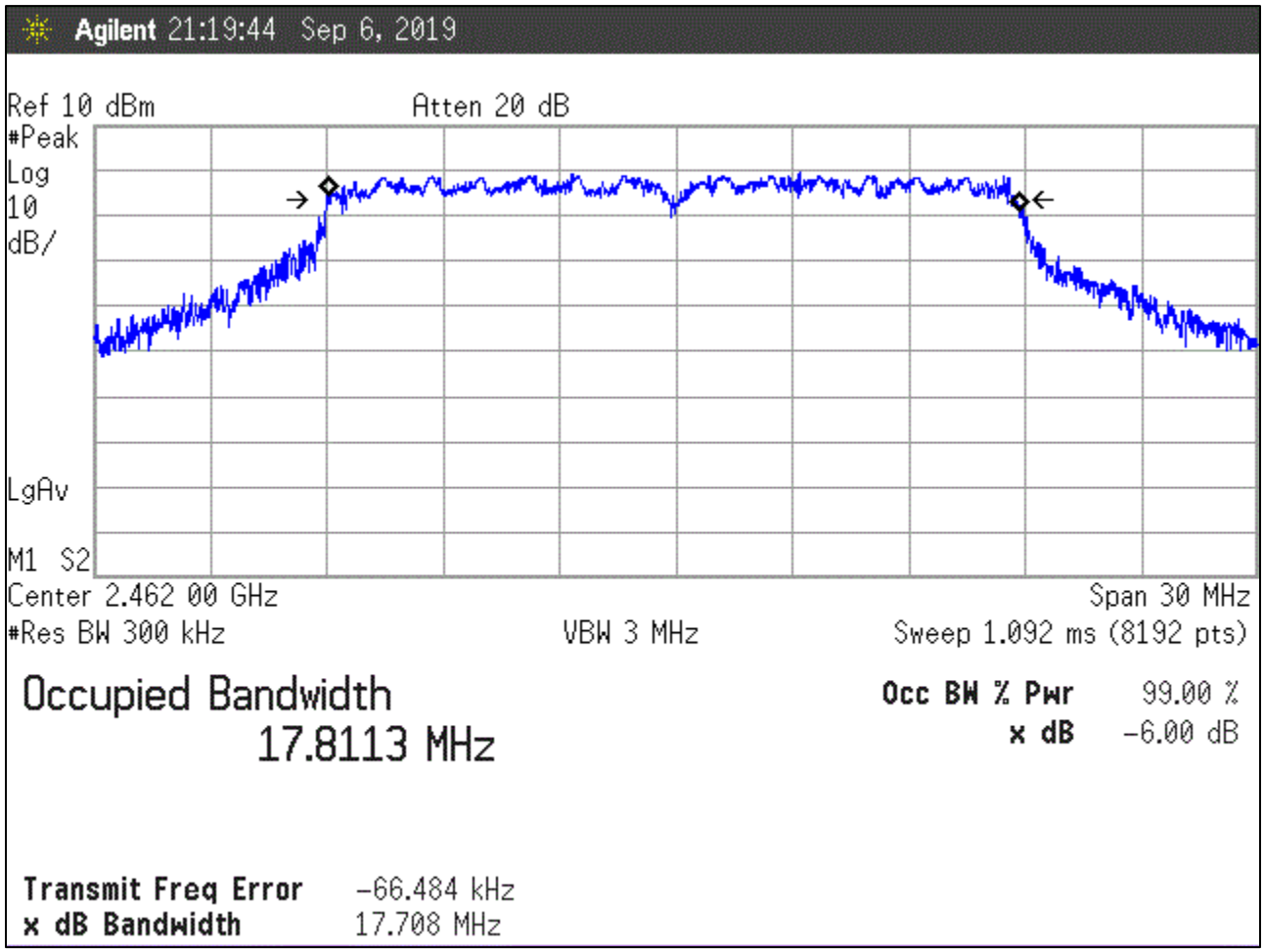


Figure 14. 2462 MHz OBW MODE 7



5.3 RF POWER OUTPUT CHANNEL POWER:

To measure the output power the unit was set to dwell on the low, high and middle channel with a continuous transmit. Testing was performed using the spectrum analyzer's channel power function with the integration bandwidth set to the occupied bandwidth of the modulated signal.

Table 8: RF Power Output Summary (Maximum)

Frequency	Level (dBm)	Limit (dBm)	Pass/Fail
Low Channel: 2412MHz	14.67	30 dBm	Pass
Center Channel: 2437MHz	15.62	30 dBm	Pass
High Channel: 2462MHz	13.89	30 dBm	Pass

Maximum measured power

Figure 15. 2412 MHz Channel PWR MODE 1

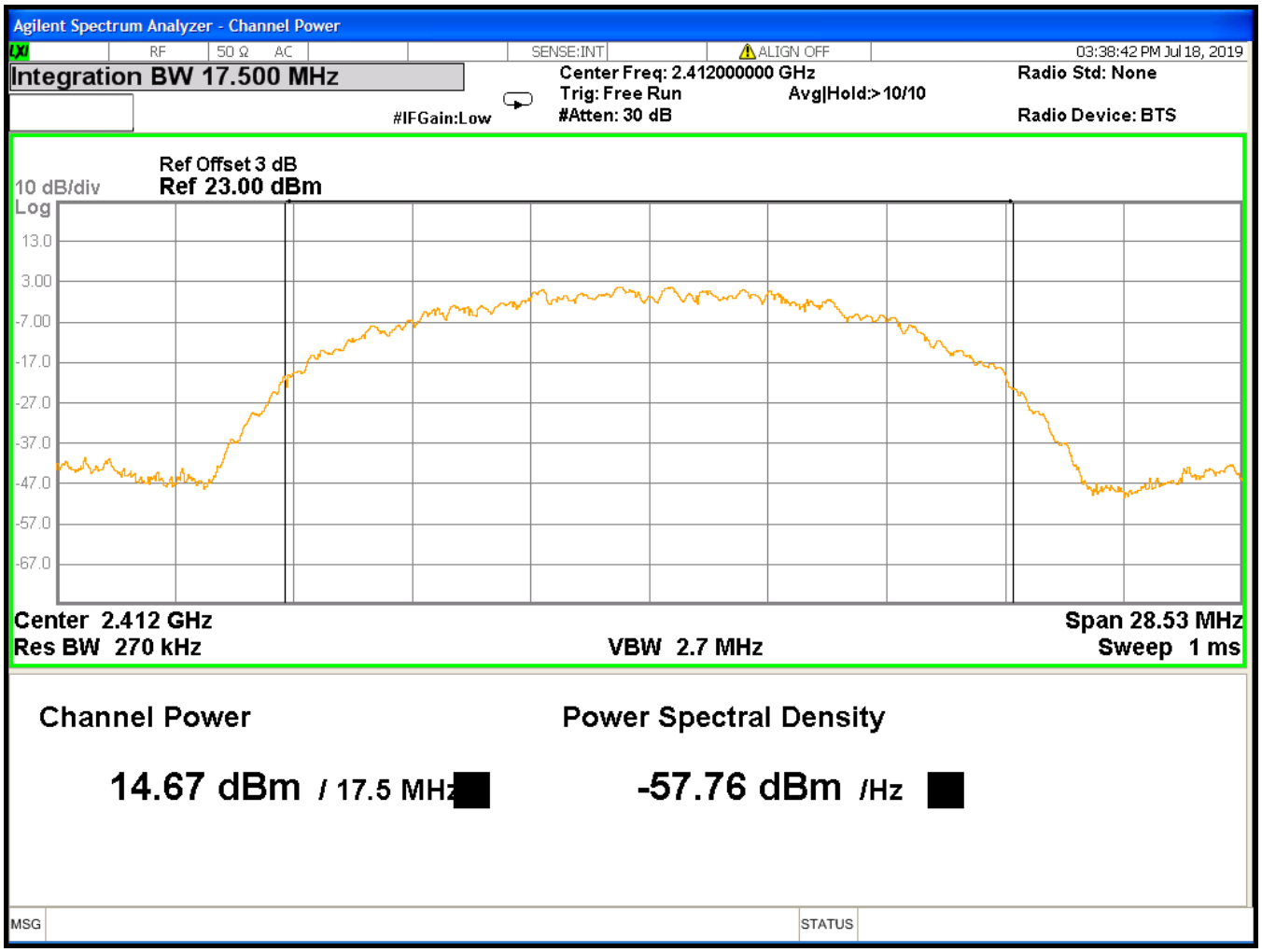


Figure 16. 2412 MHz Channel PWR MODE 2

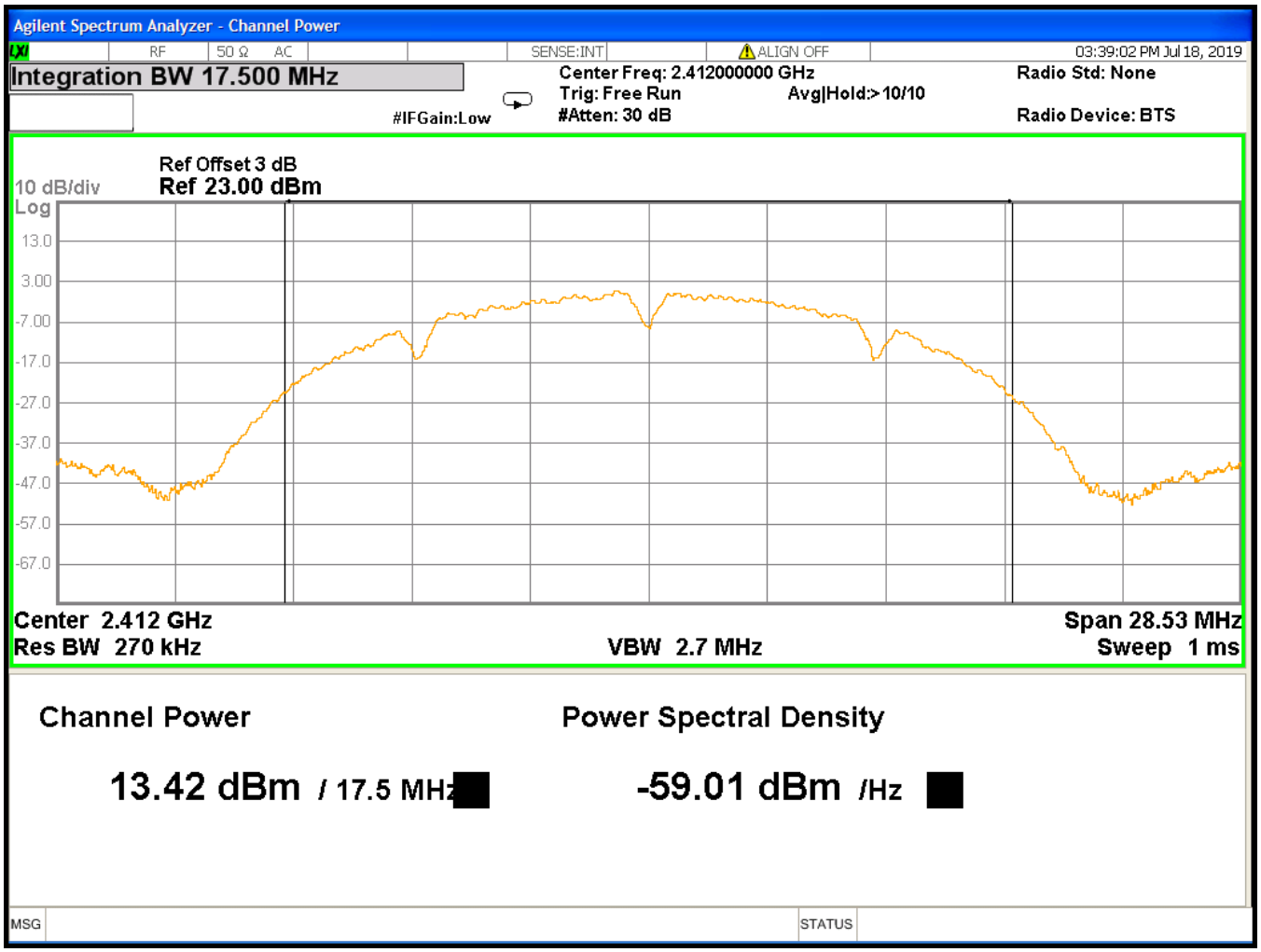


Figure 17. 2412 MHz Channel PWR MODE 4

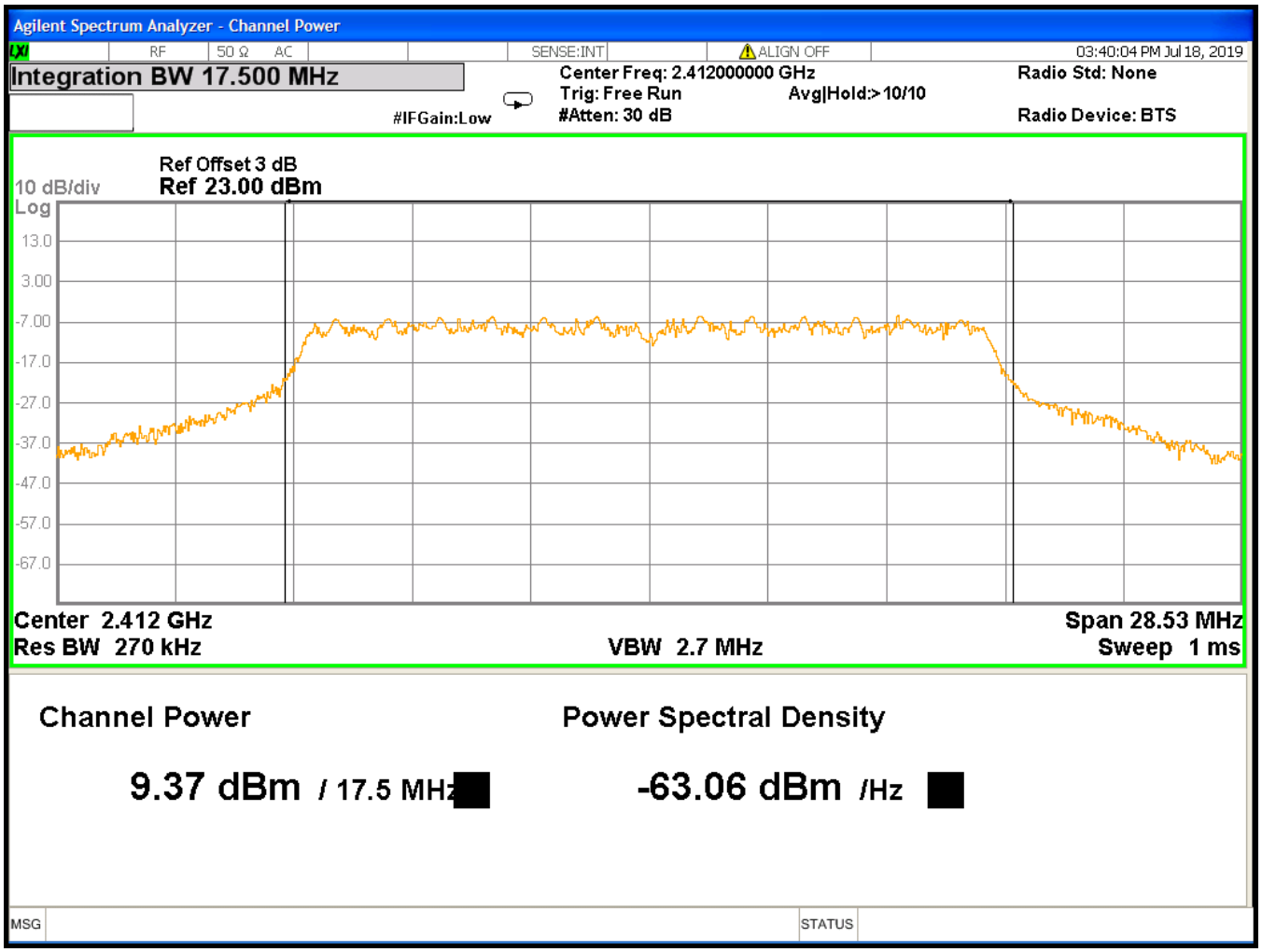


Figure 18. 2412 MHz Channel PWR MODE 7

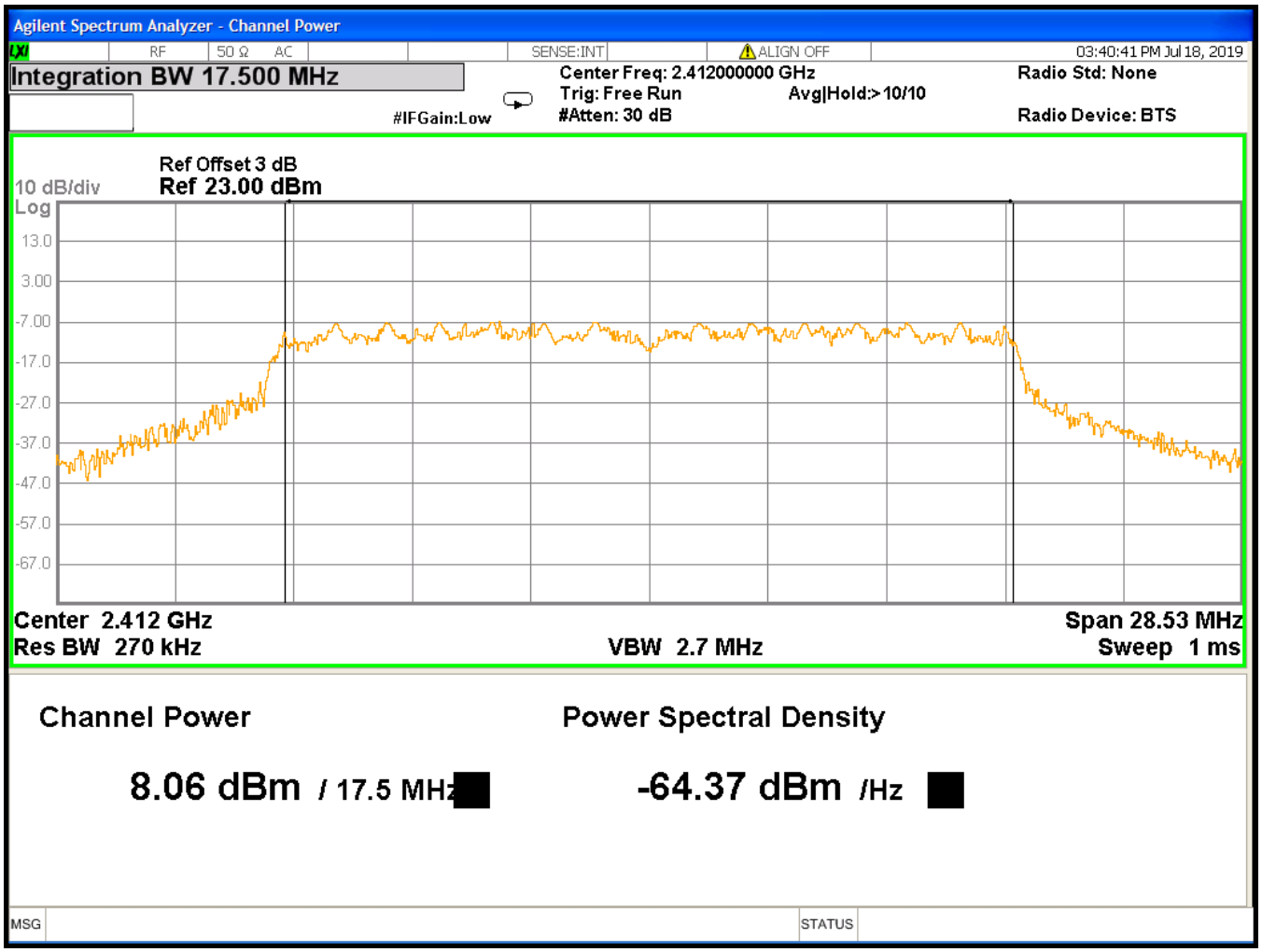


Figure 19. 2437 MHz Channel PWR MODE 1

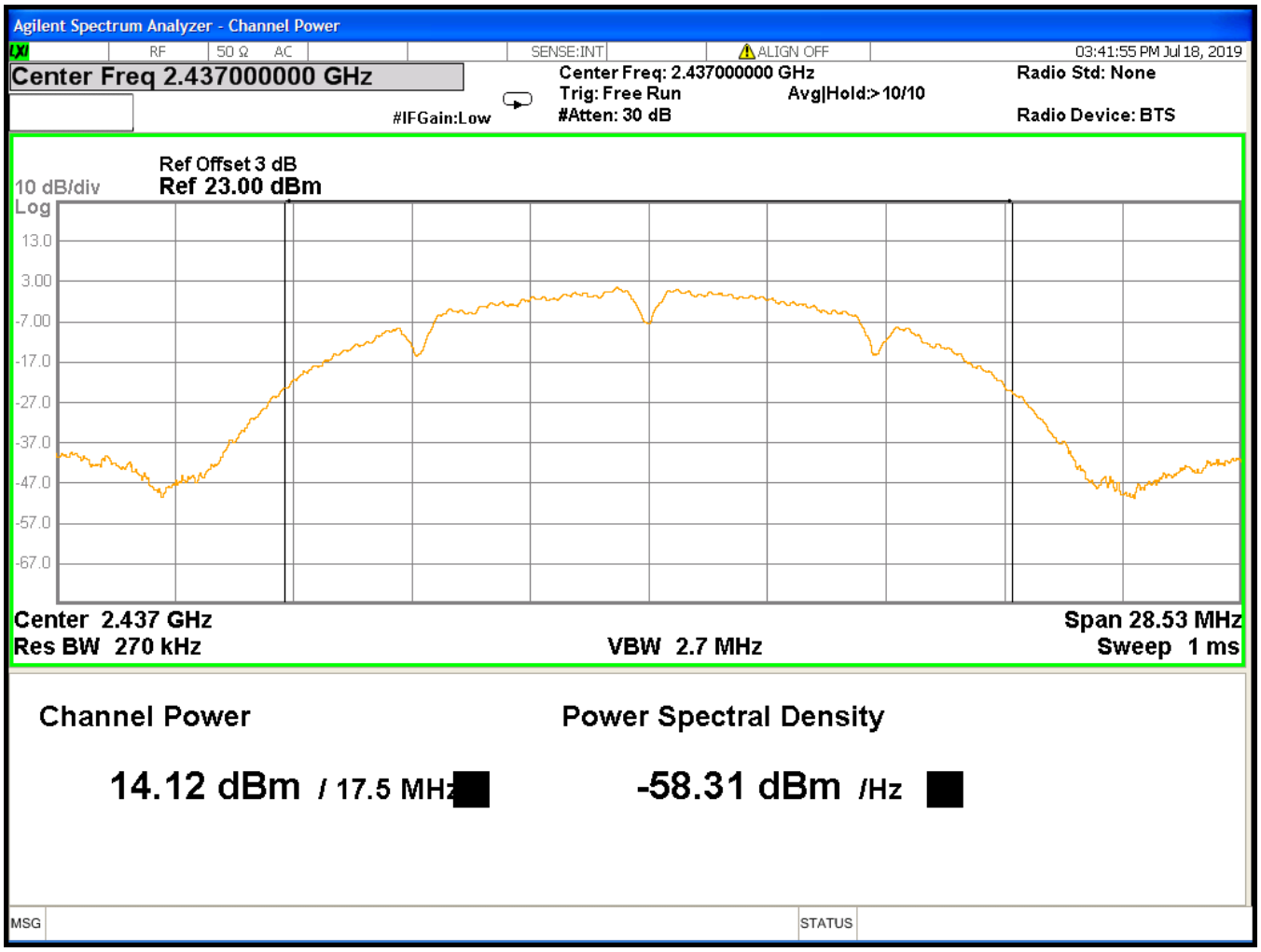


Figure 20. 2437 MHz Channel PWR MODE 2

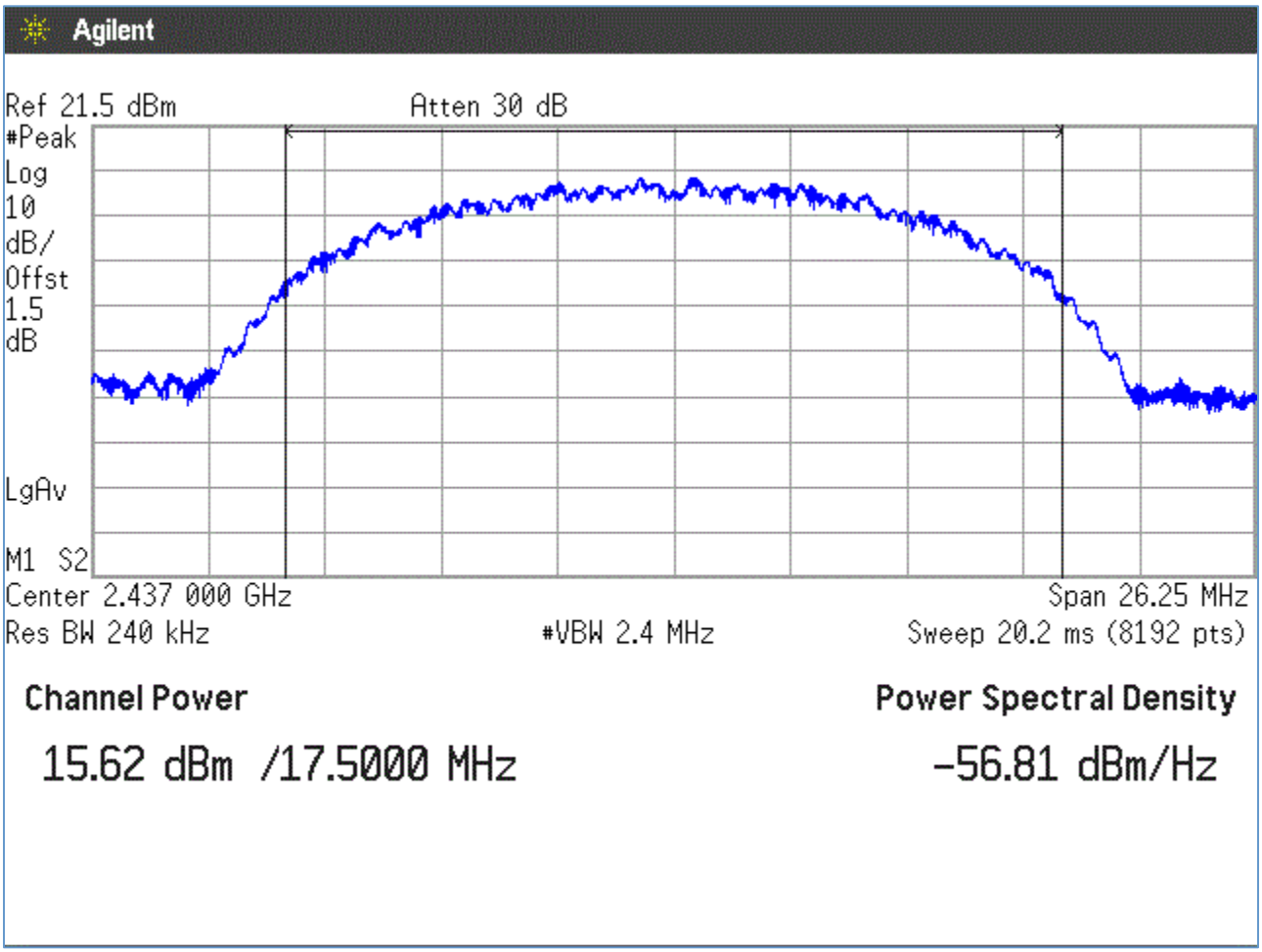


Figure 21. 2437 MHz Channel PWR MODE 4

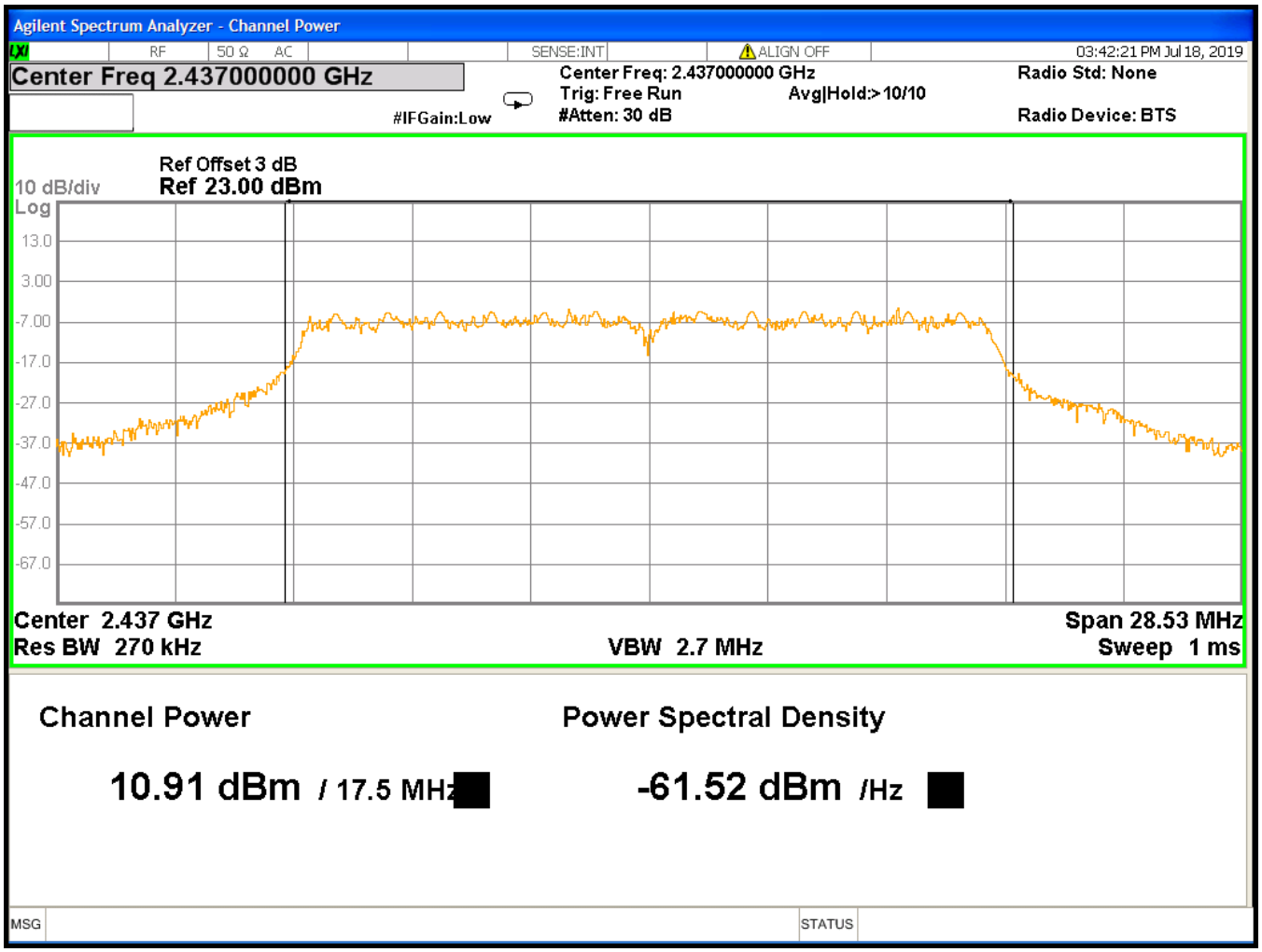


Figure 22. 2437 MHz Channel PWR MODE 7

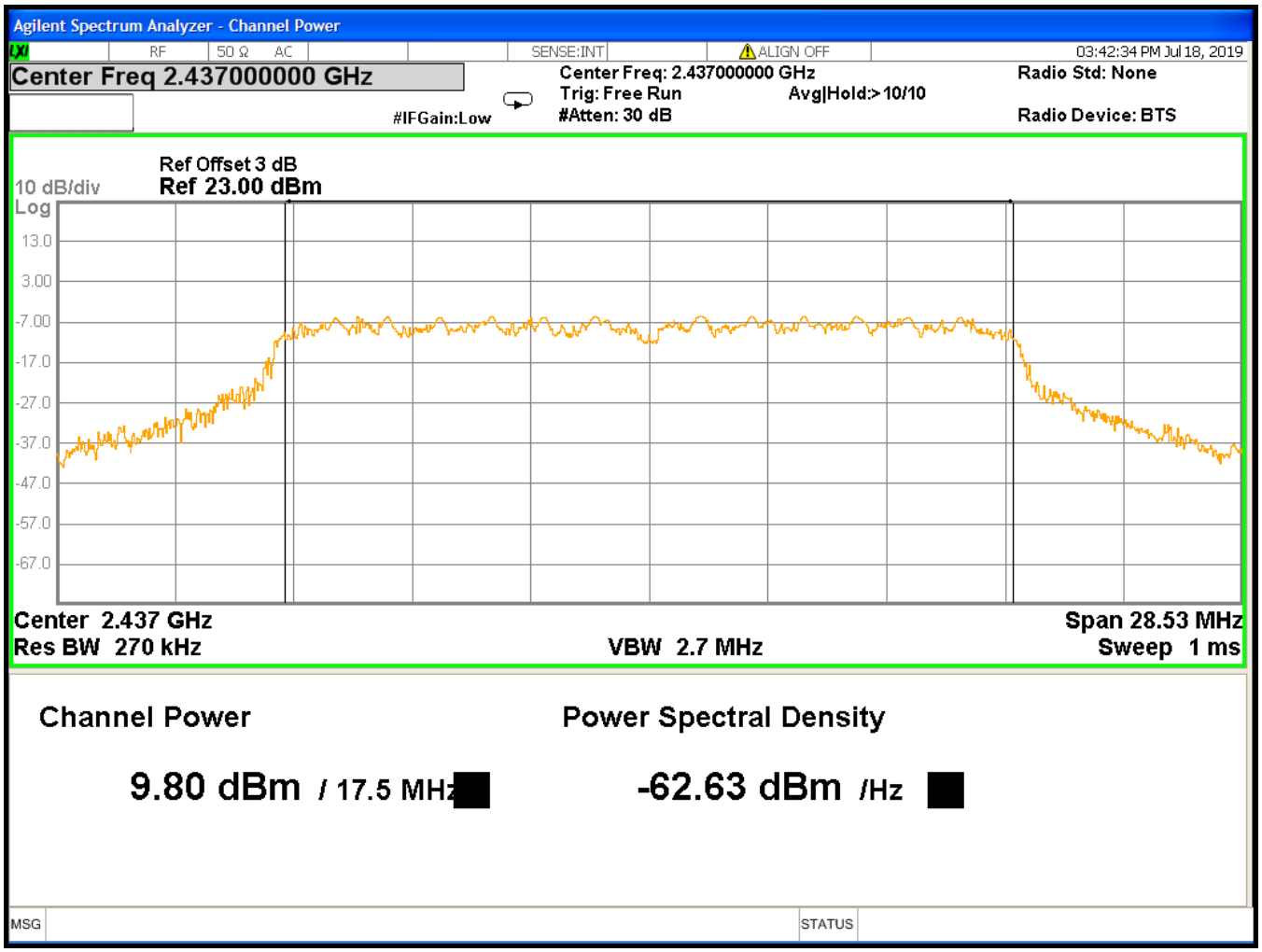


Figure 23. 2462 MHz Channel PWR MODE 1

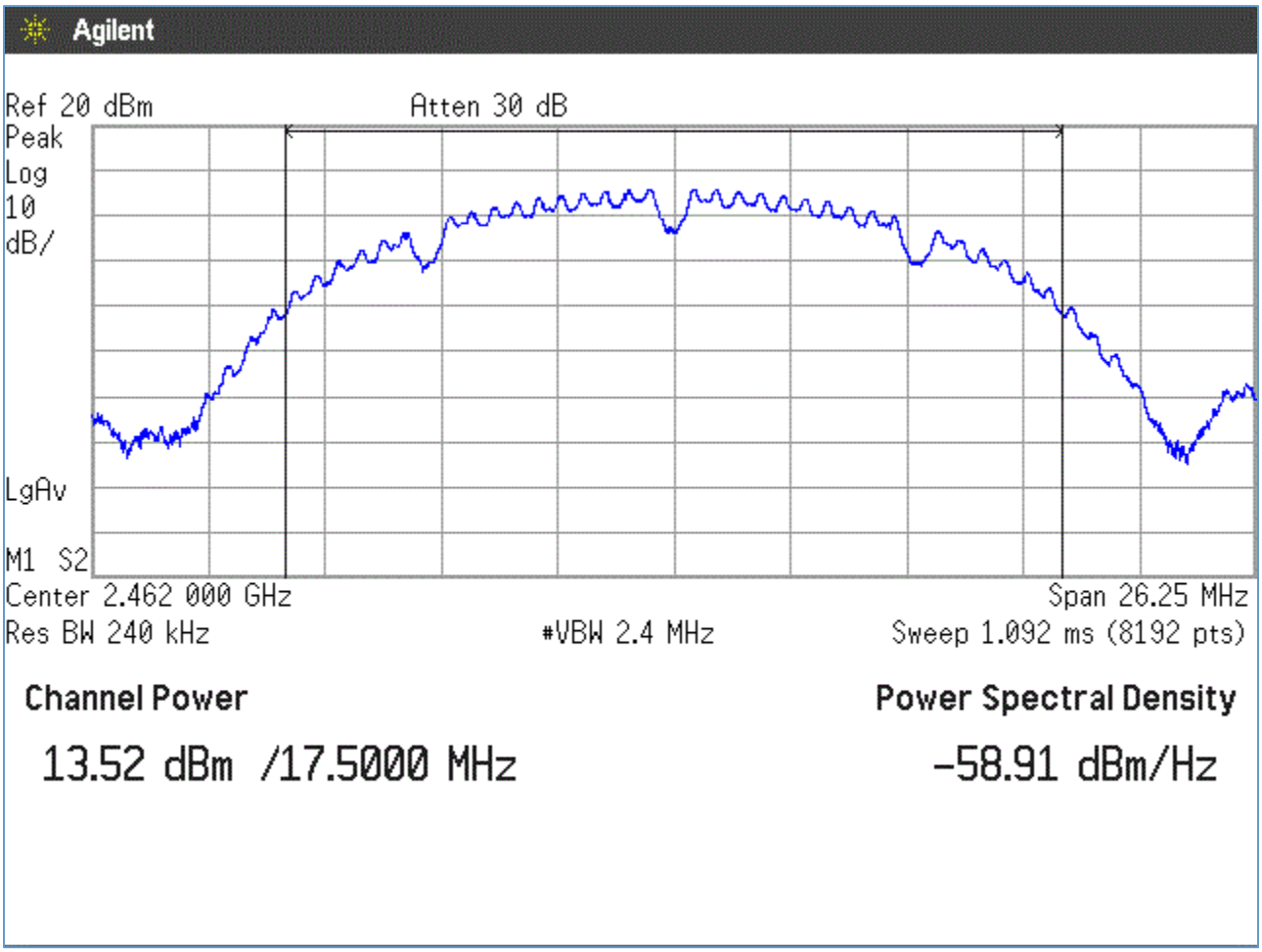


Figure 24. 2462 MHz Channel PWR MODE 2

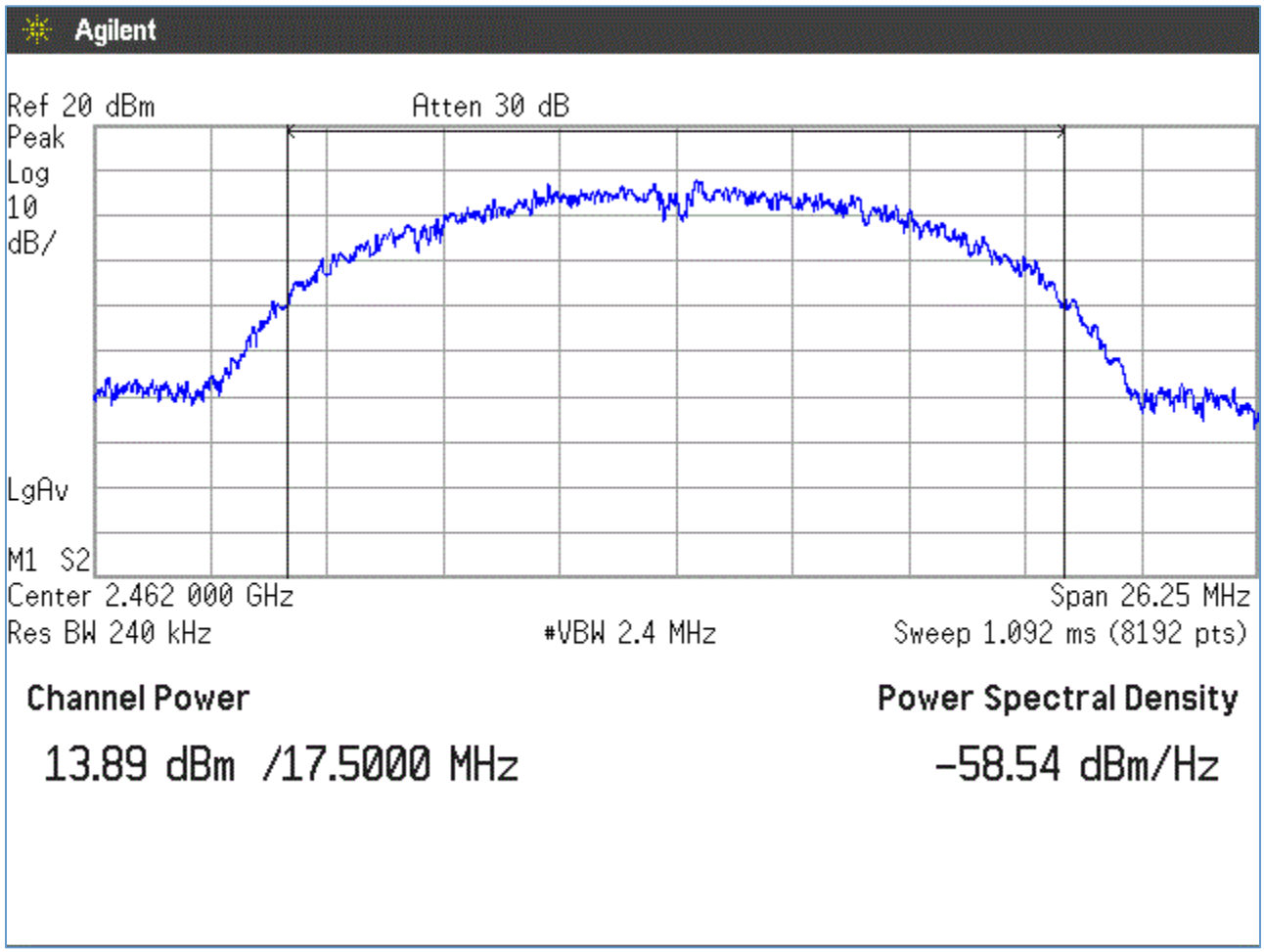


Figure 25. 2462 MHz Channel PWR MODE 4

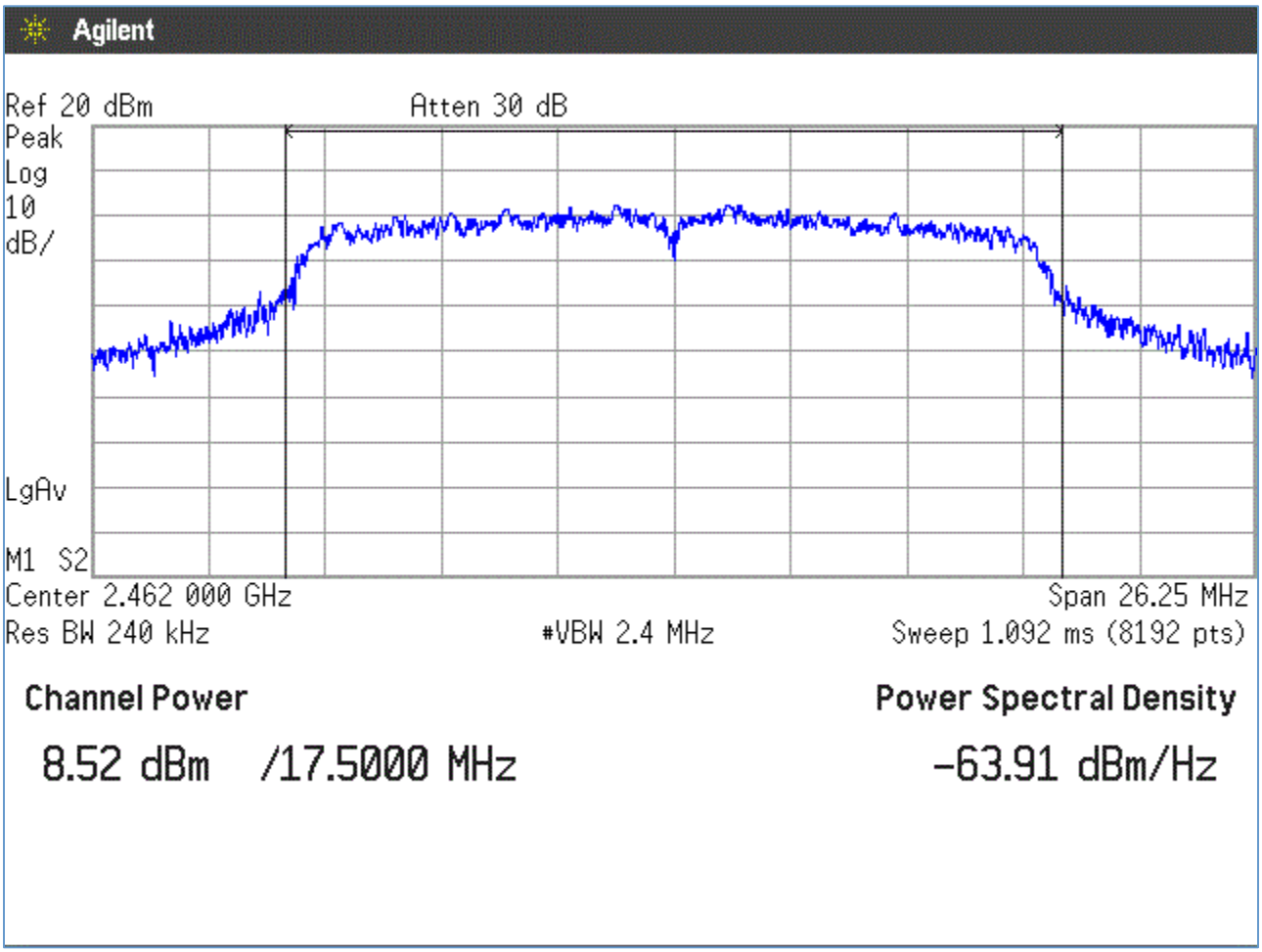
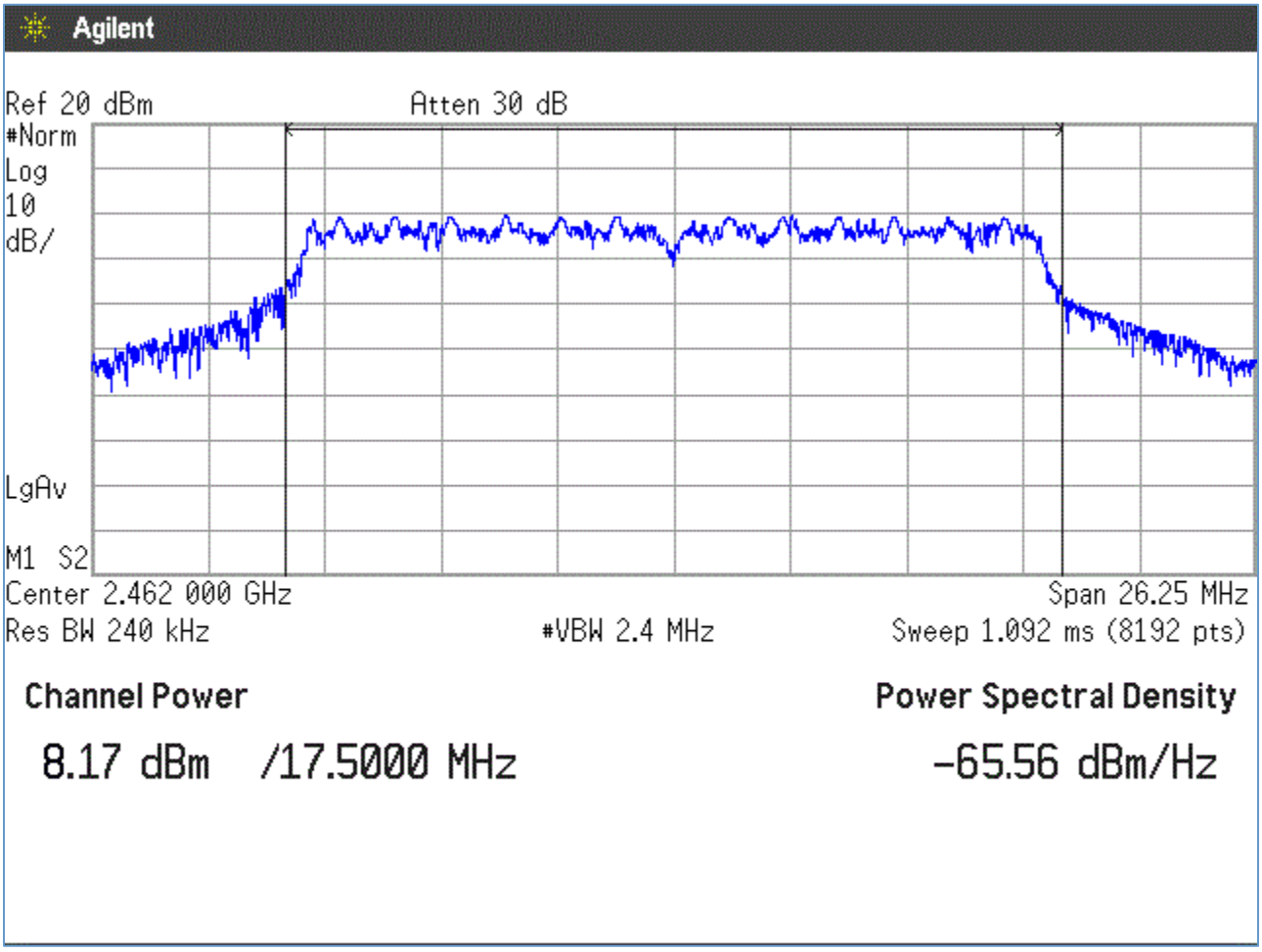


Figure 26. 2462 MHz Channel PWR MODE 7



5.4 POWER SPECTRAL DENSITY

Measurements for power spectral density were taken at the antenna port in accordance with ANSI C63.10. The spectrum analyzer was set to peak detect mode with a RBW of 3kHz ,VBW of 30kHz across a zero span at the peak of maximum power in the band.

The highest level detected across any 3 kHz band for continuous transmission was then recorded and compared to the limit 8dBm. The following table and plots give the results for power spectral density testing.

Table 9: Power Spectral Density(Worst Case)

Frequency	Peak Level (dBm)	Limit (dBm)	Pass/Fail
Low Channel: 2412MHz	-9.17	8	Pass
Center Channel: 2437MHz	-7.58	8	Pass
High Channel: 2462MHz	-8.46	8	Pass

Note: All modes tested, Mode 2 represents worst case.

Figure 27. 2412 MHz PSD MODE 1

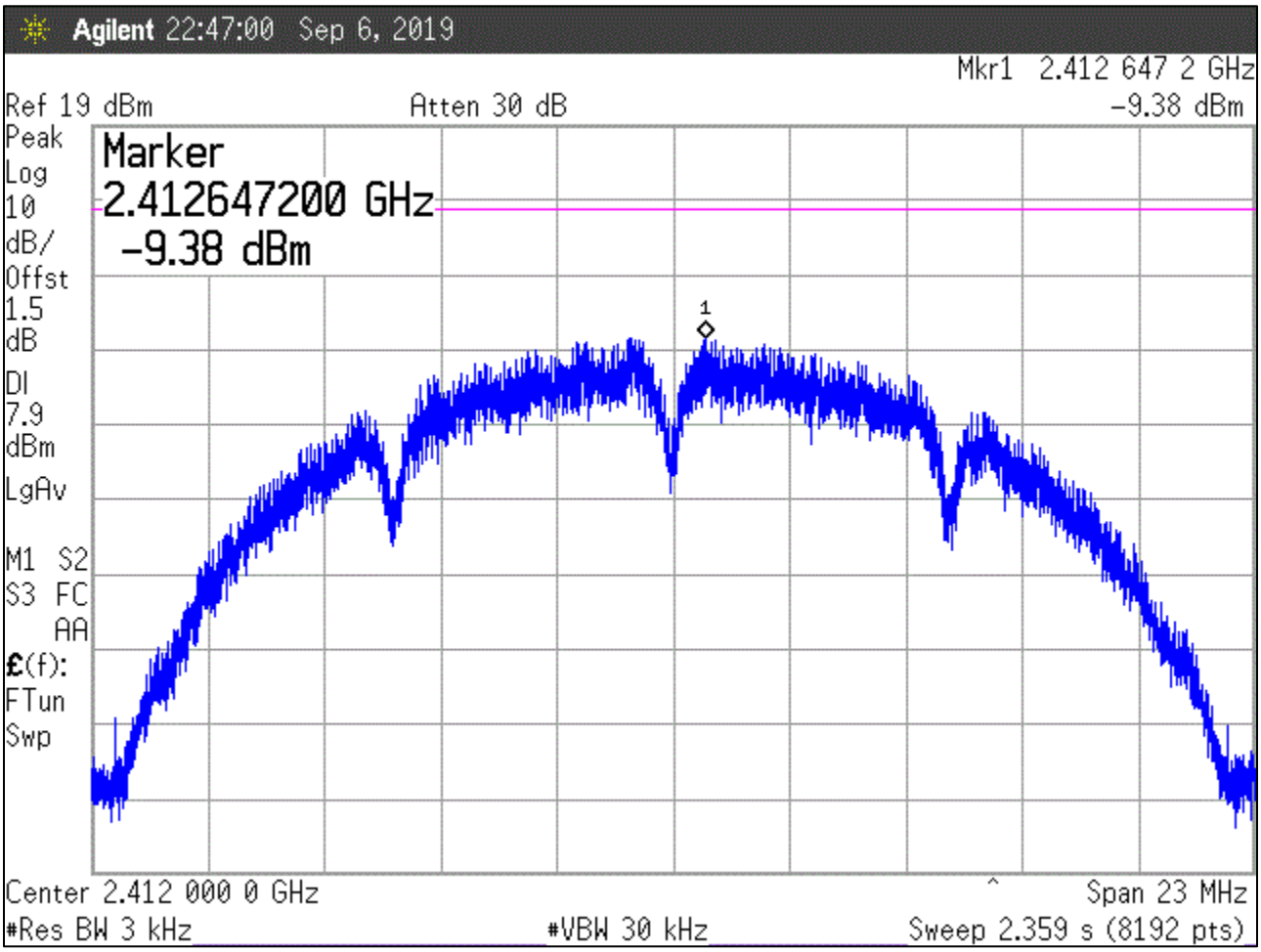


Figure 28. 2412 MHz PSD MODE 2

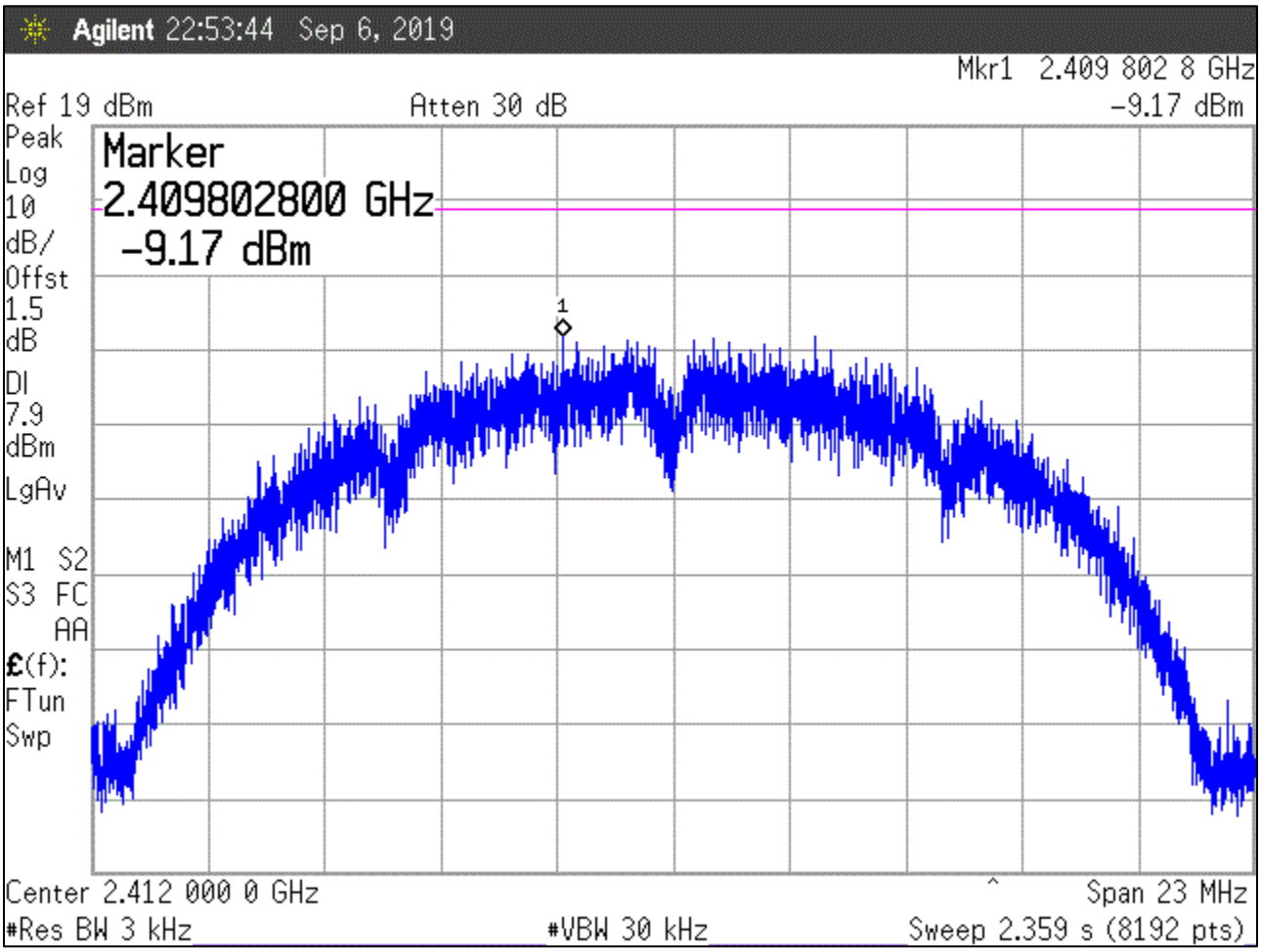


Figure 29. 2412 MHz PSD MODE 4

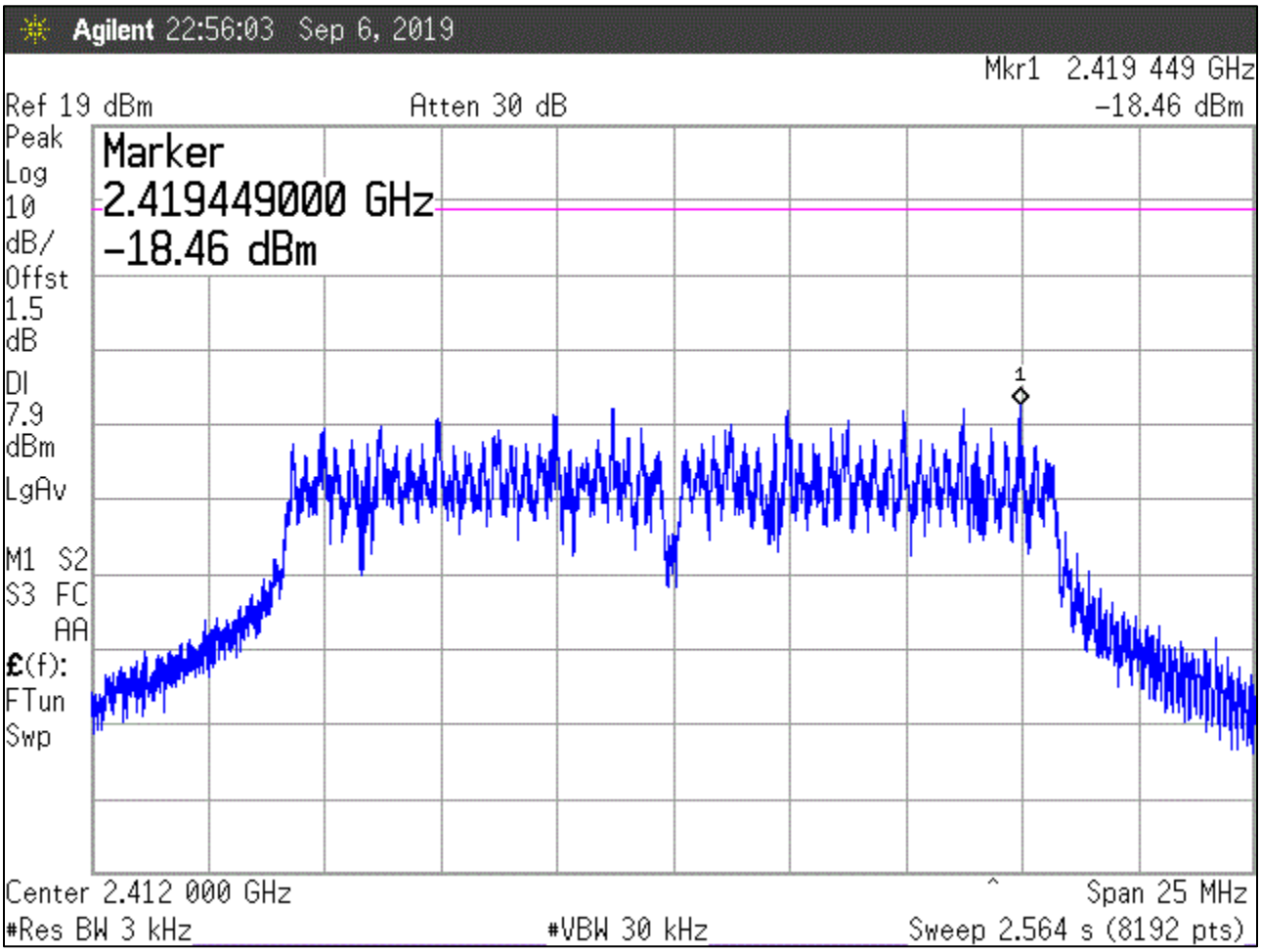


Figure 30. 2412 MHz PSD MODE 7

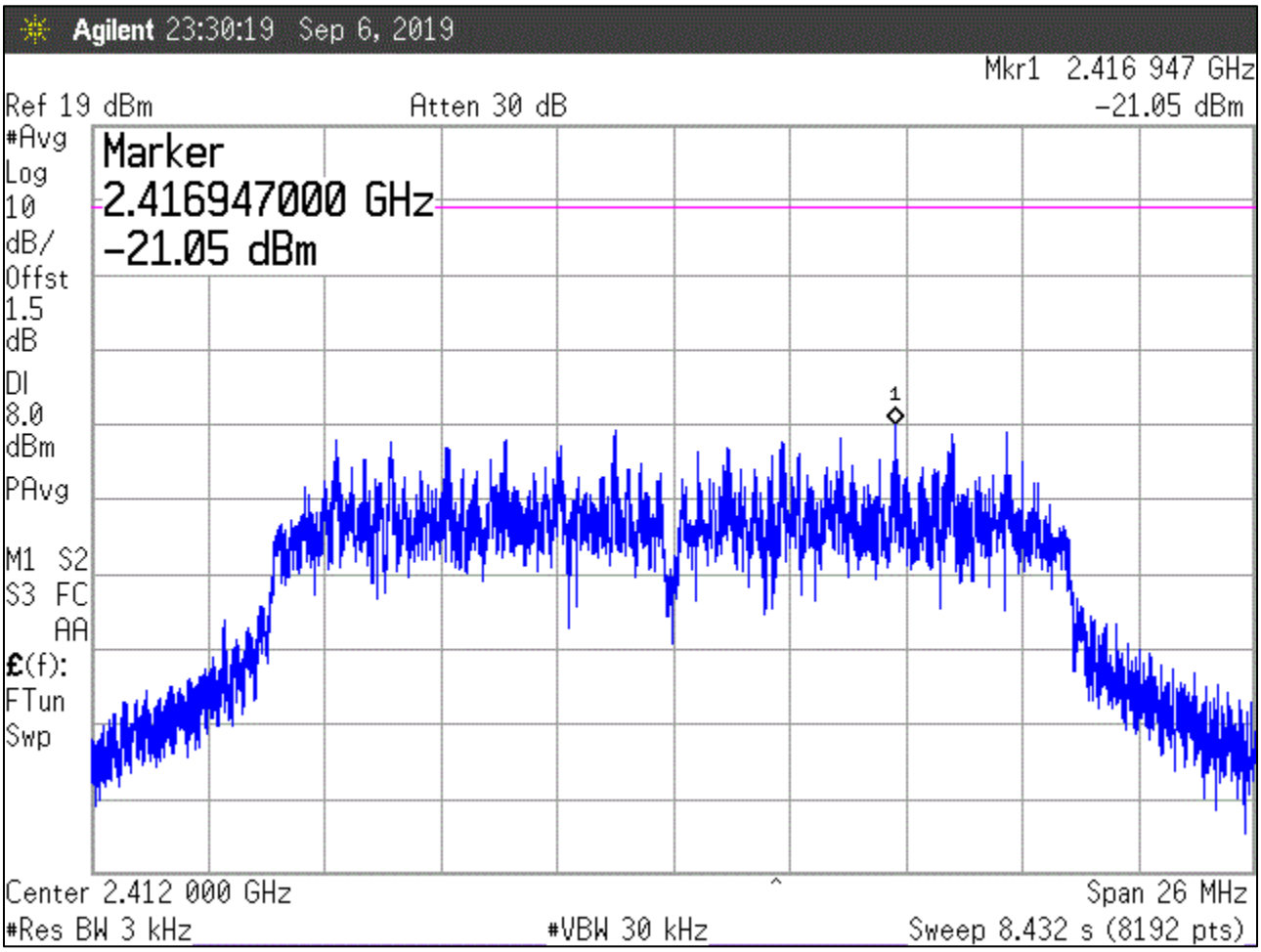


Figure 31. 2437 MHz PSD MODE 1

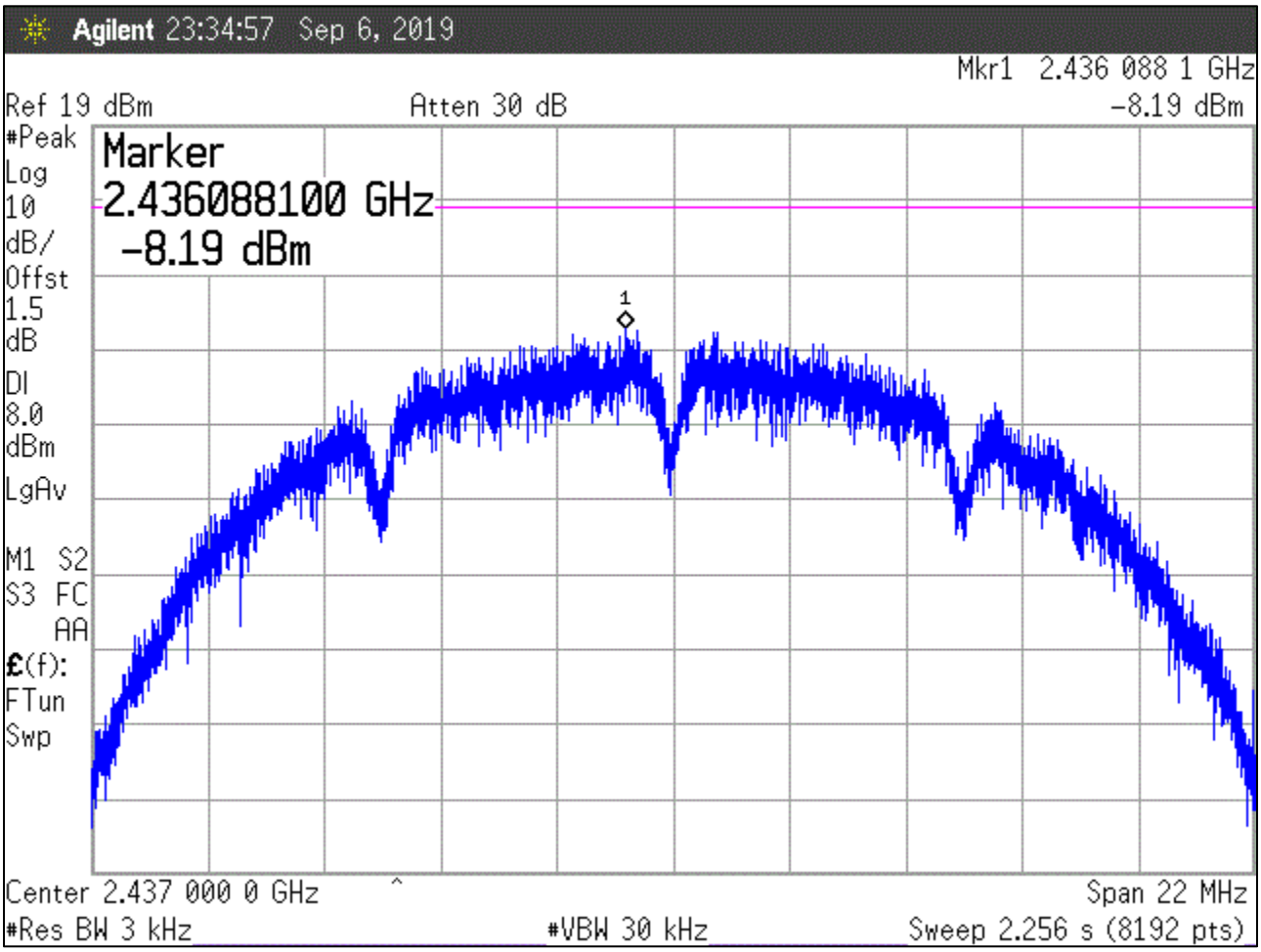


Figure 32. 2437 MHz PSD MODE 2

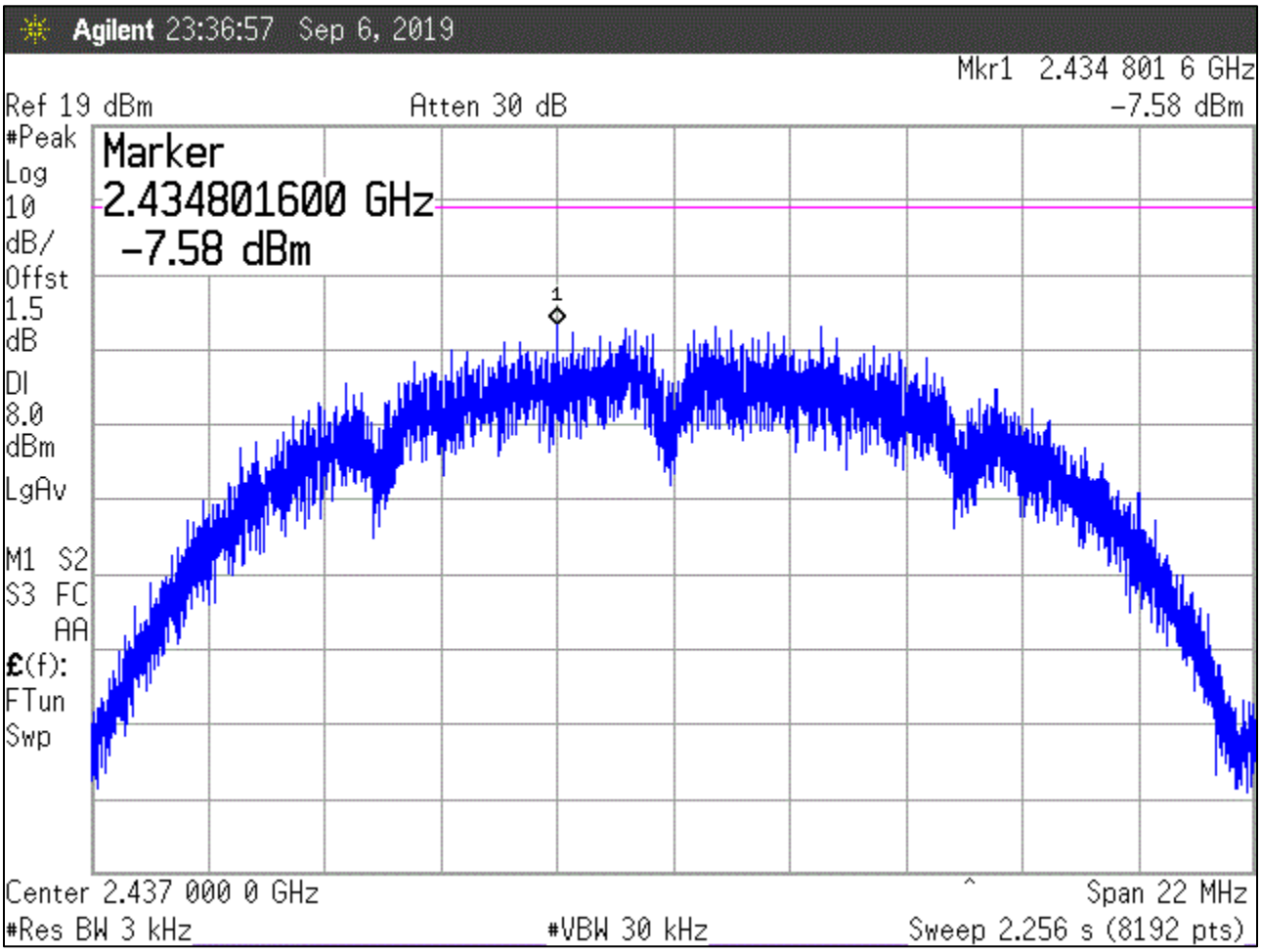


Figure 33. 2437 MHz PSD MODE 4

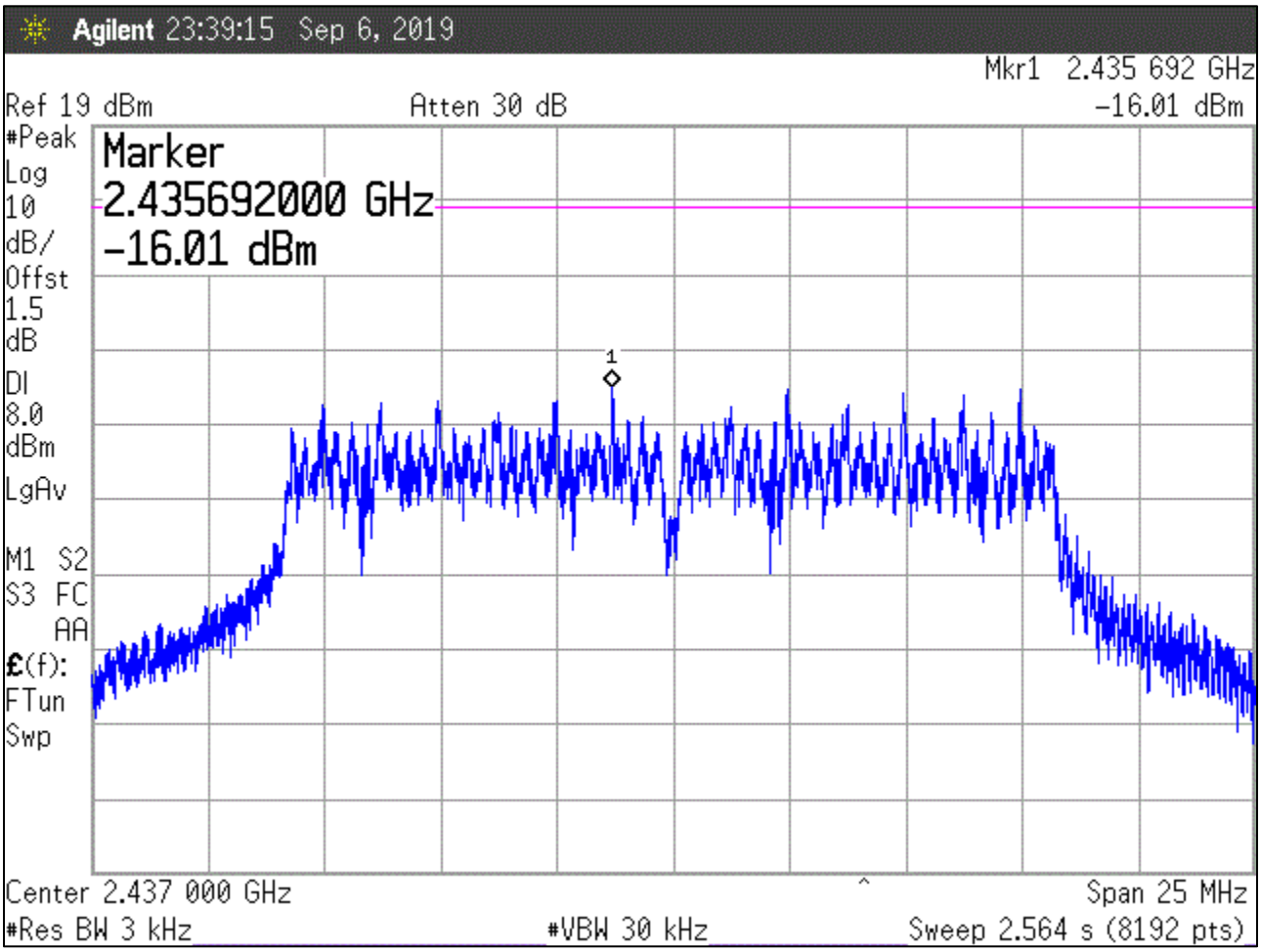


Figure 34. 2437 MHz PSD MODE 7

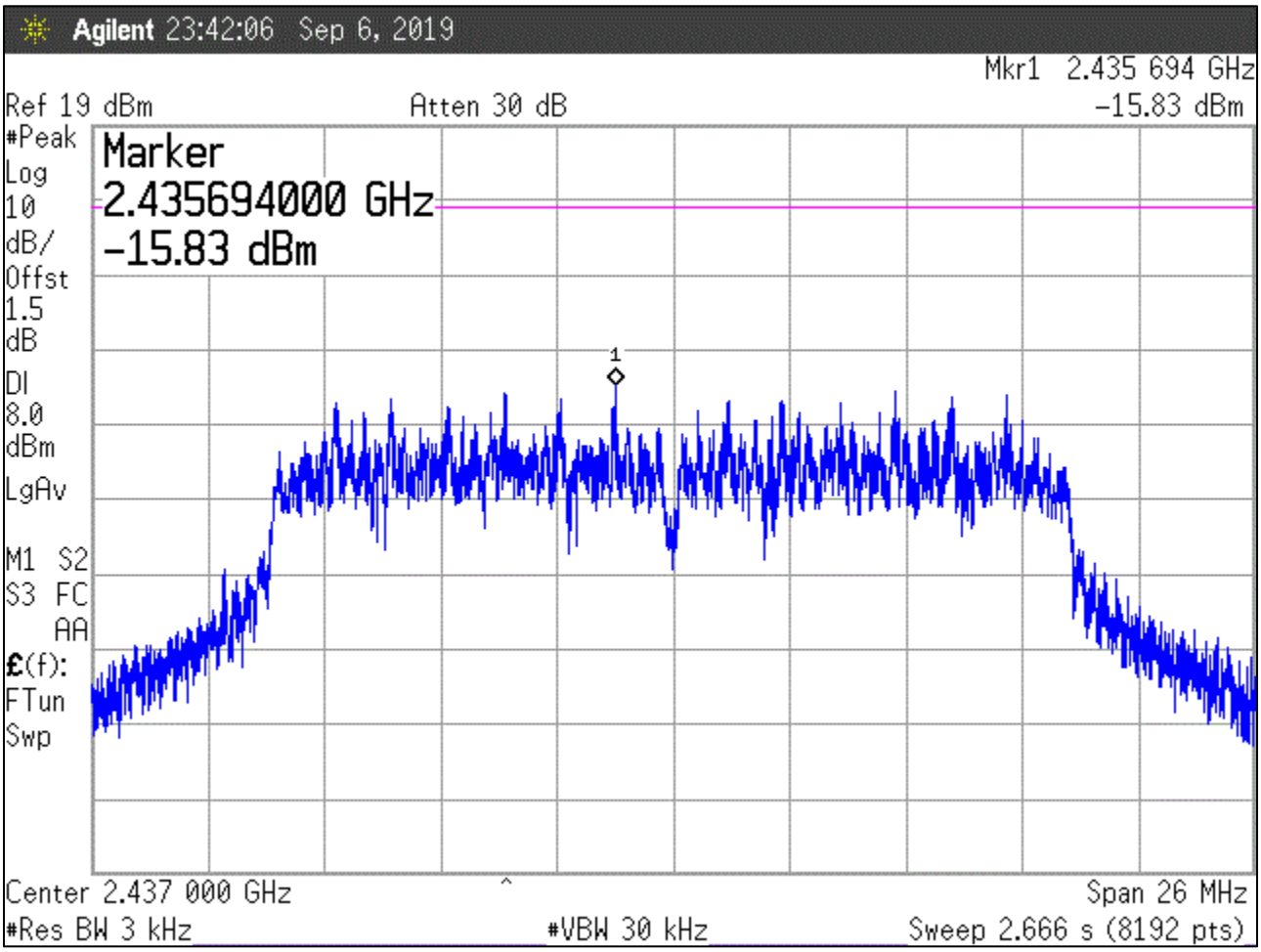


Figure 35. 2462 MHz PSD MODE 1

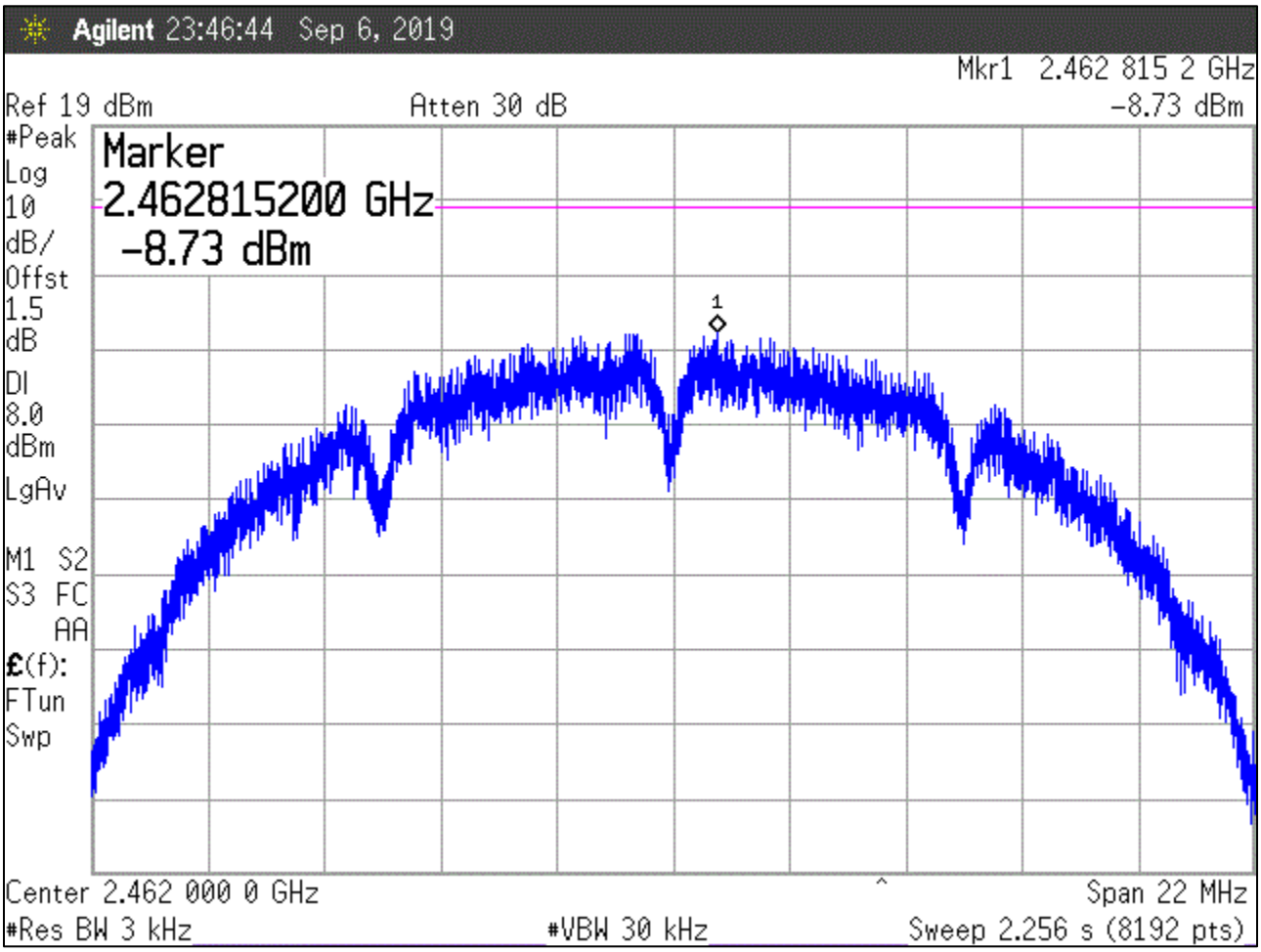


Figure 36. 2462 MHz PSD MODE 2

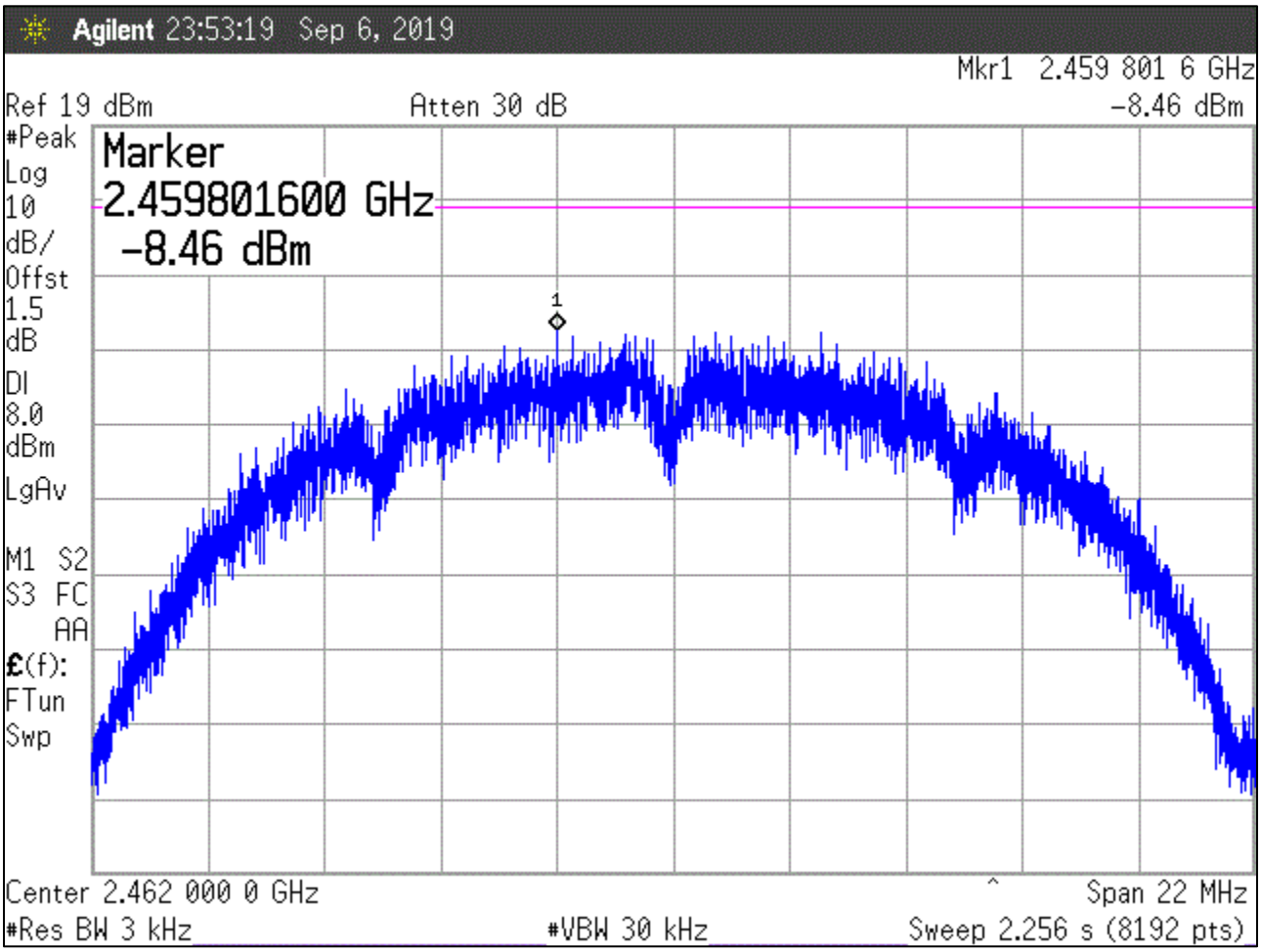


Figure 37. 2462 MHz PSD MODE 4

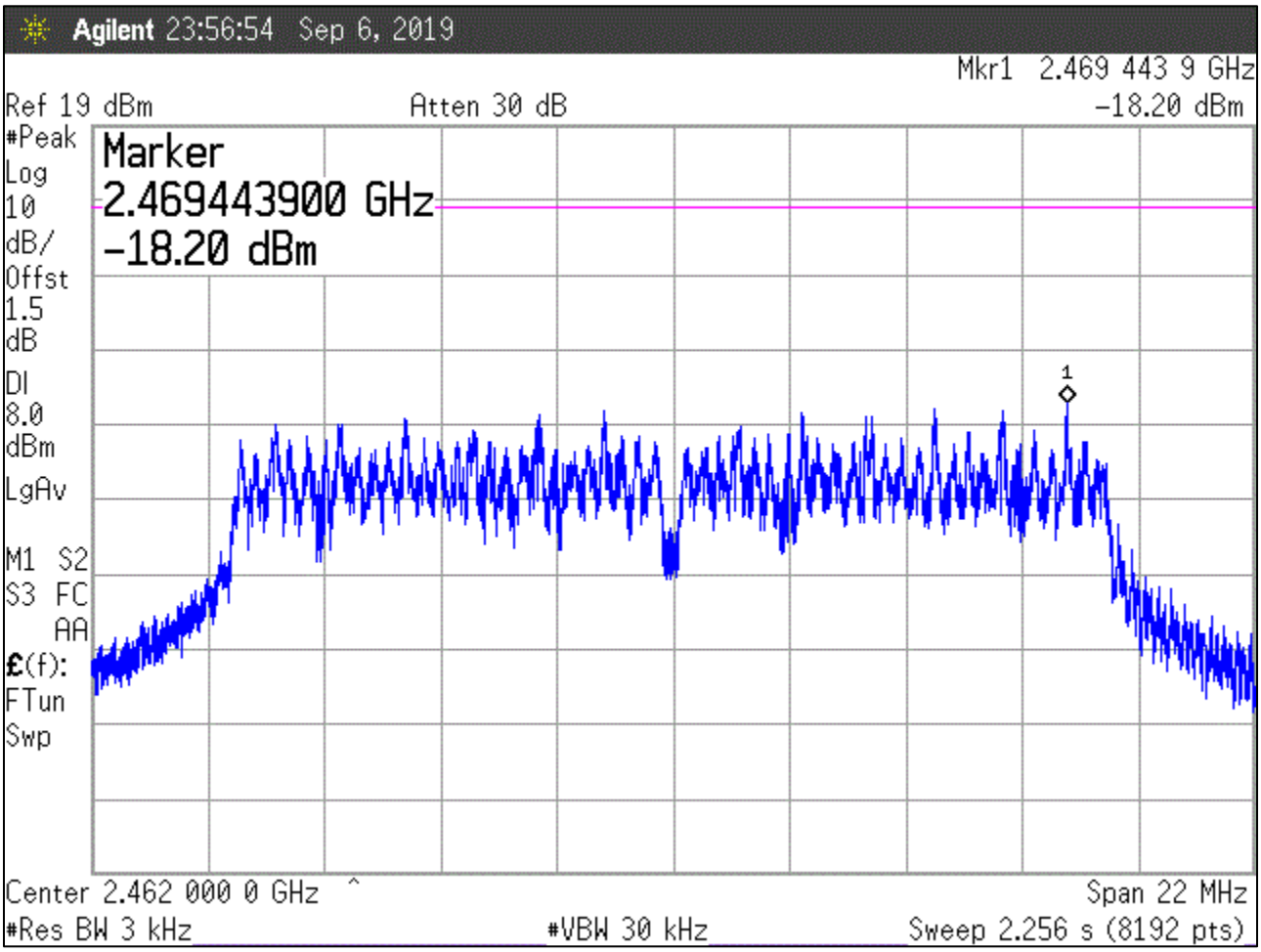
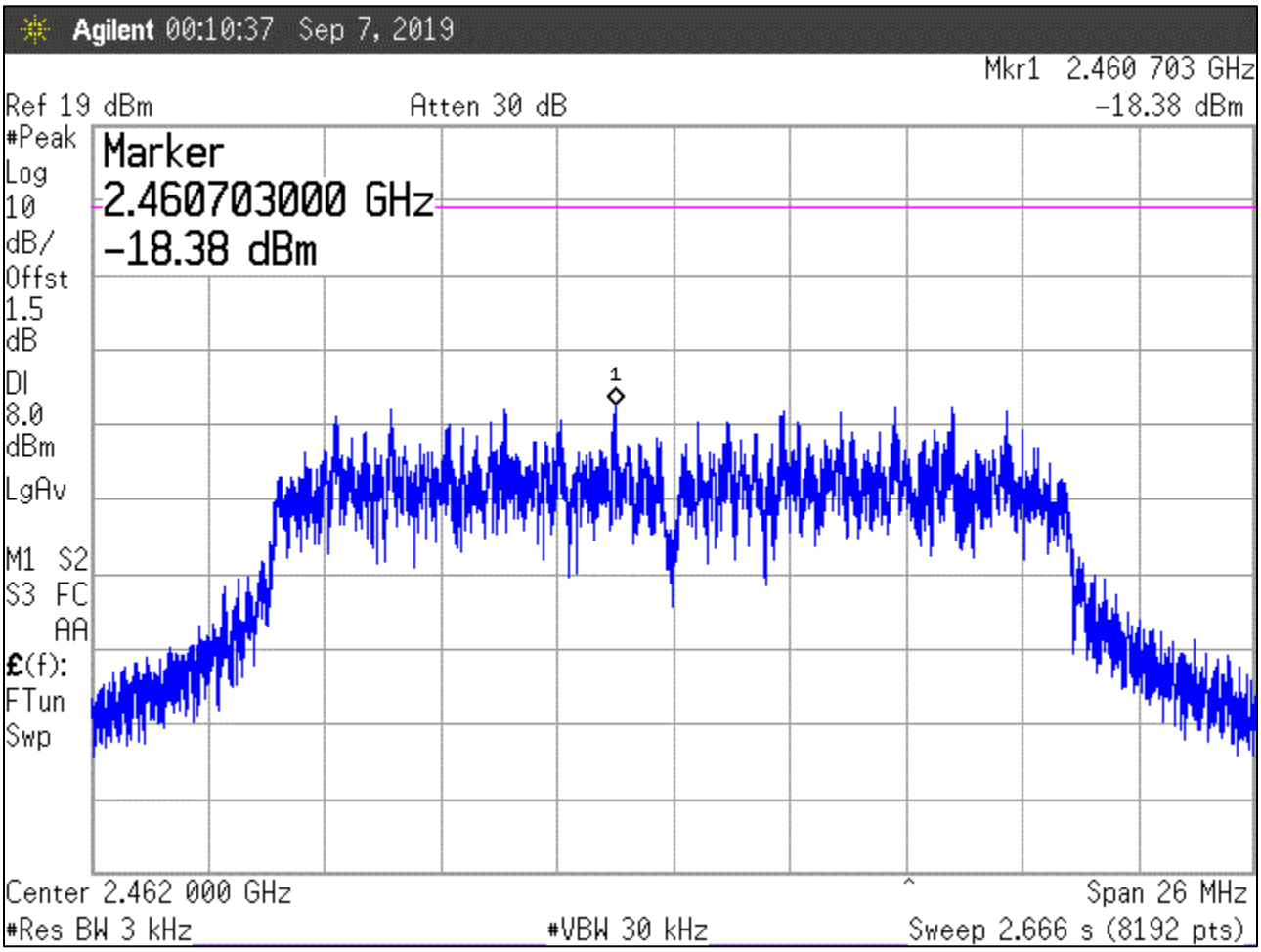


Figure 38. 2462 MHz PSD MODE 7



5.5 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.

Per ANSI C63.10 section 11.11 "Emissions in non-restricted frequency bands" this test may be performed in an antenna port 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 tenth harmonic of the carrier.

To decrease the number of test segments due to limited spectrum analyzer "points" the RBW was set to 3 MHz above 2.4GHz. This is a worst-case condition as the RBW is greater than the minimum required.

It should be noted that all modes were tested, and Mode 2 was found to be the worst case. Conducted spurious emissions for mode 2 are presented in this report.

Figure 39. 2412 MHz SPURS 30-2.4G MODE 2

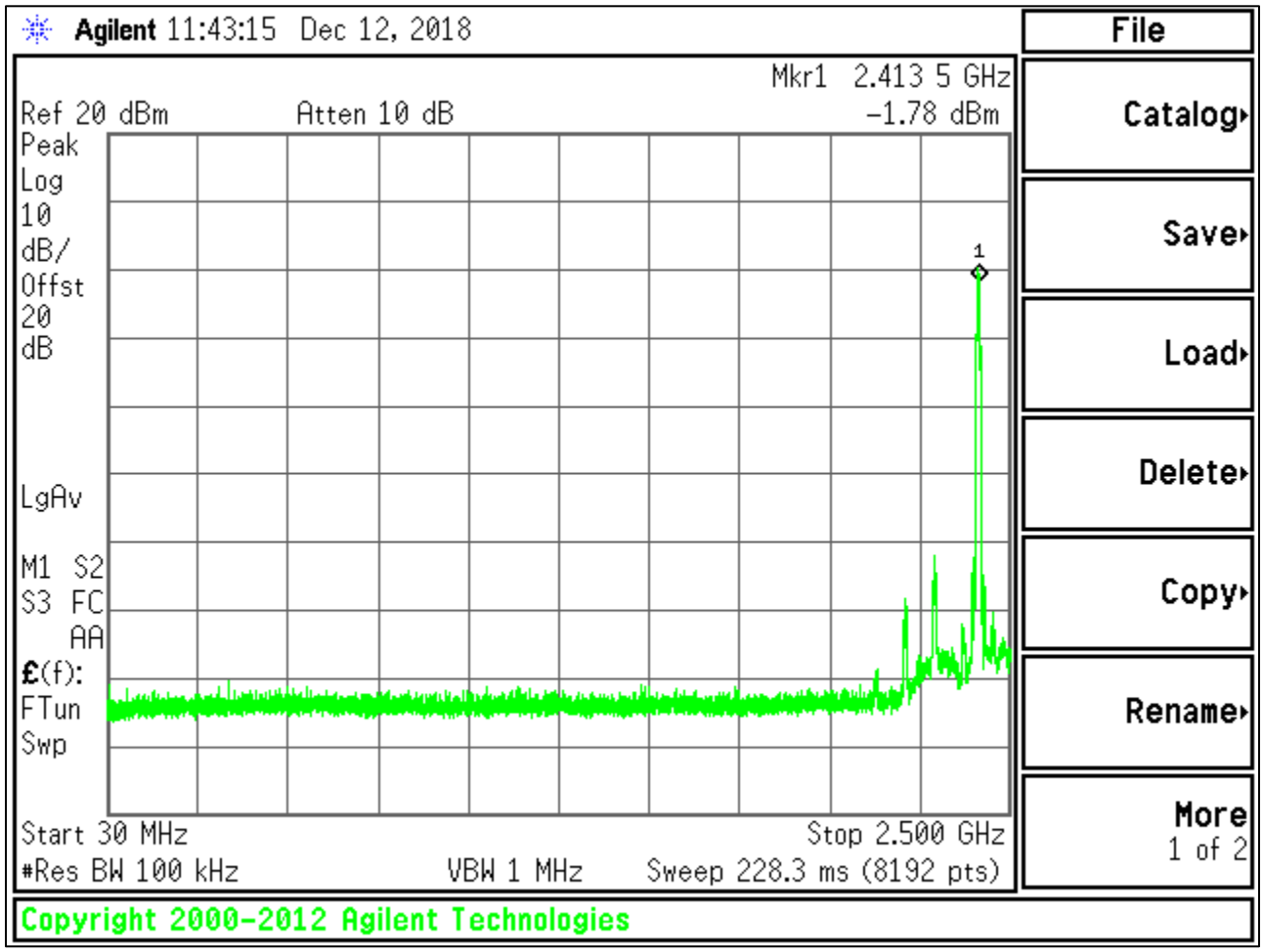


Figure 40. 2412 MHz SPURS 2.4-10G MODE 2

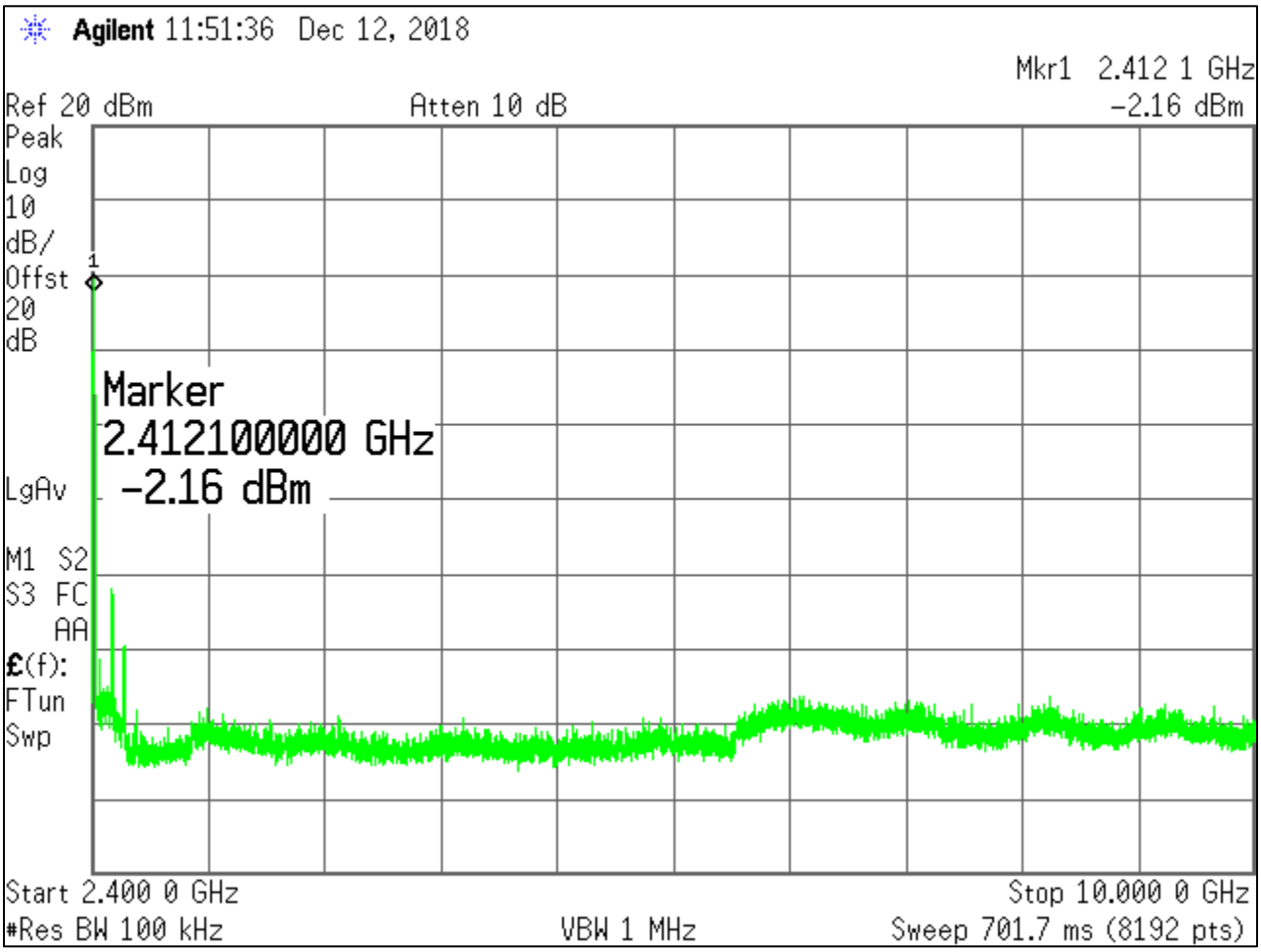


Figure 41. 2412 MHz SPURS 10-20G MODE 2

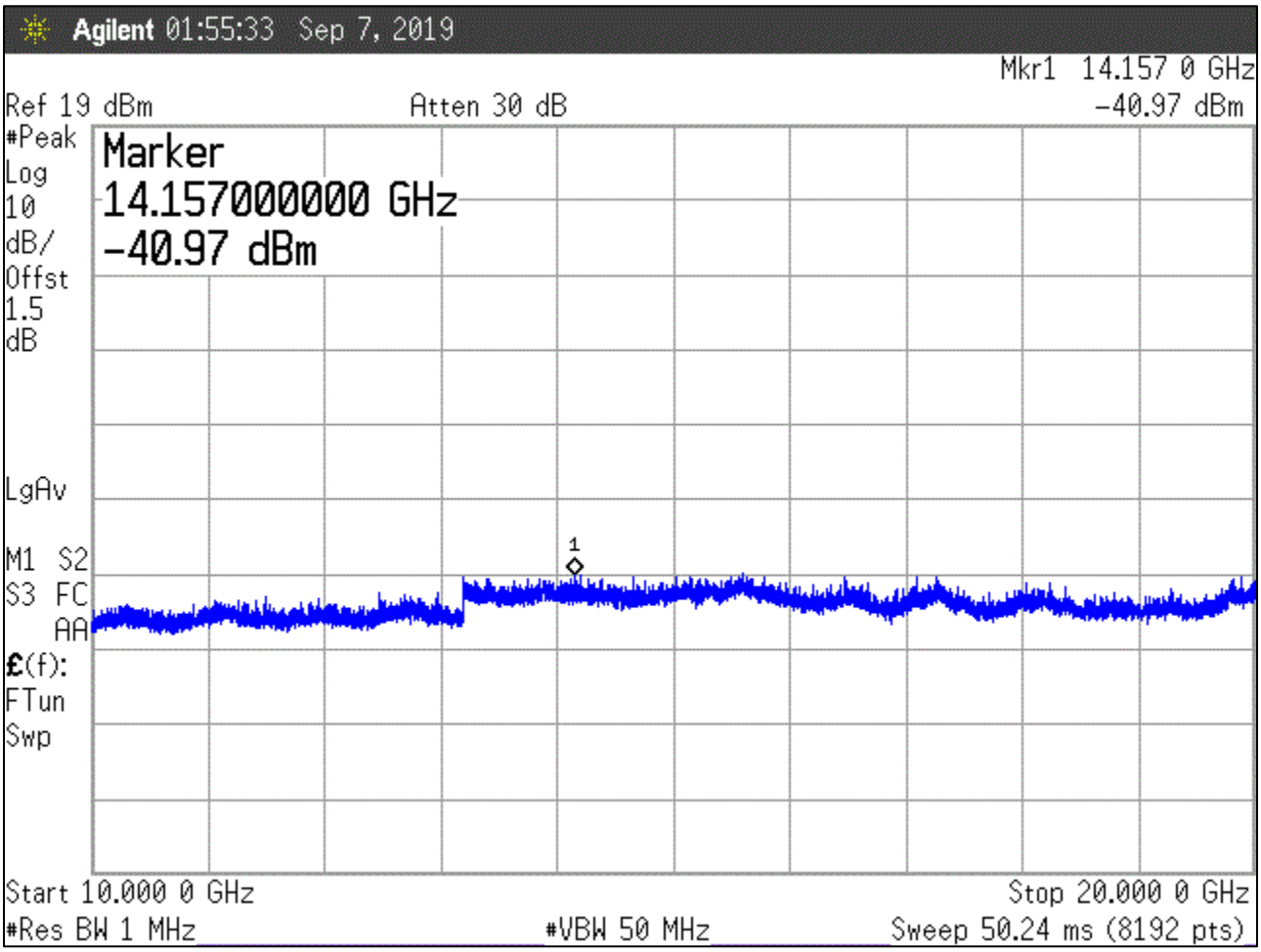


Figure 42. 2412 MHz SPURS 20-25G MODE 2

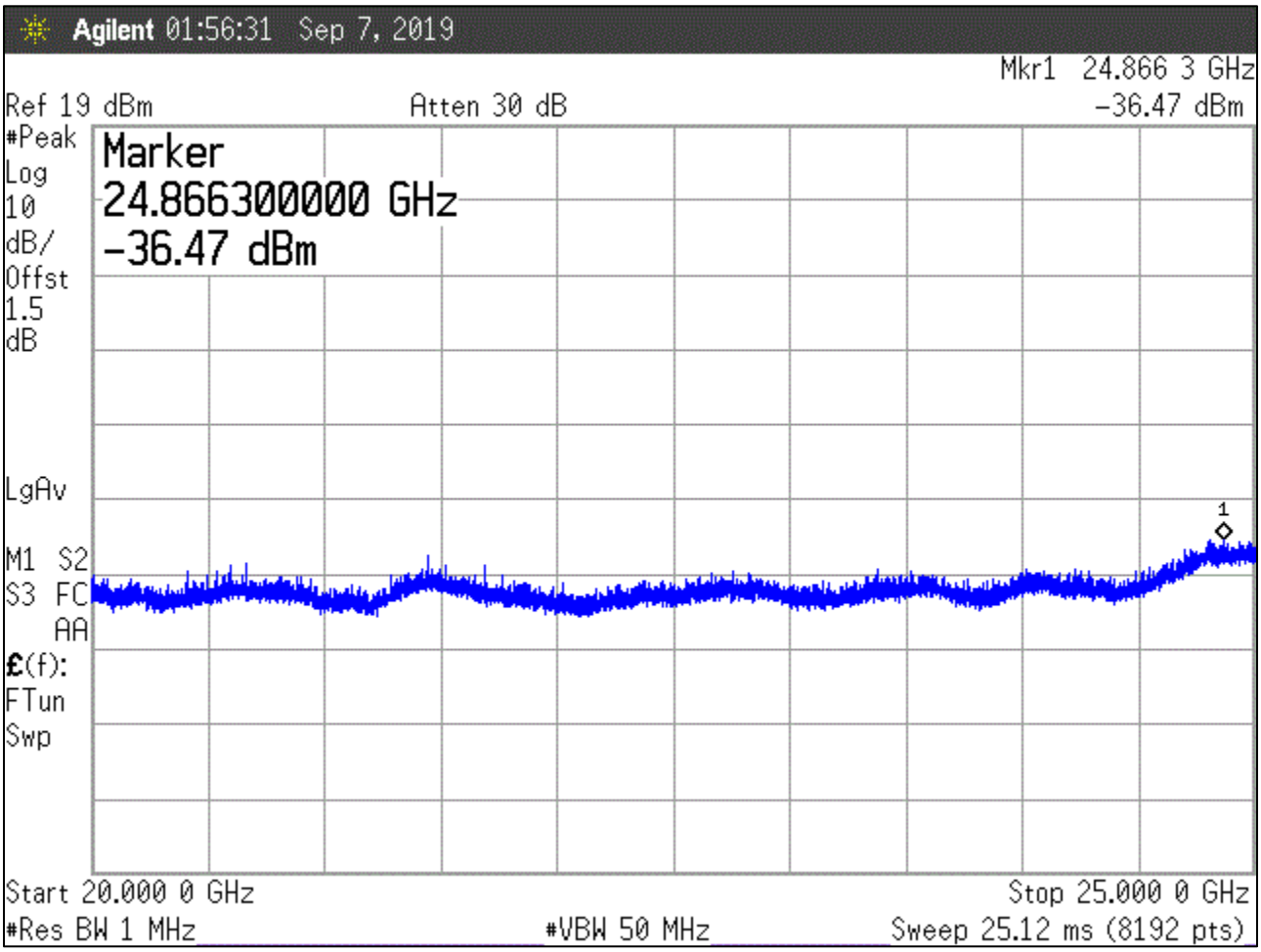


Figure 43. 2437 MHz SPURS 30-2.4G MODE 2

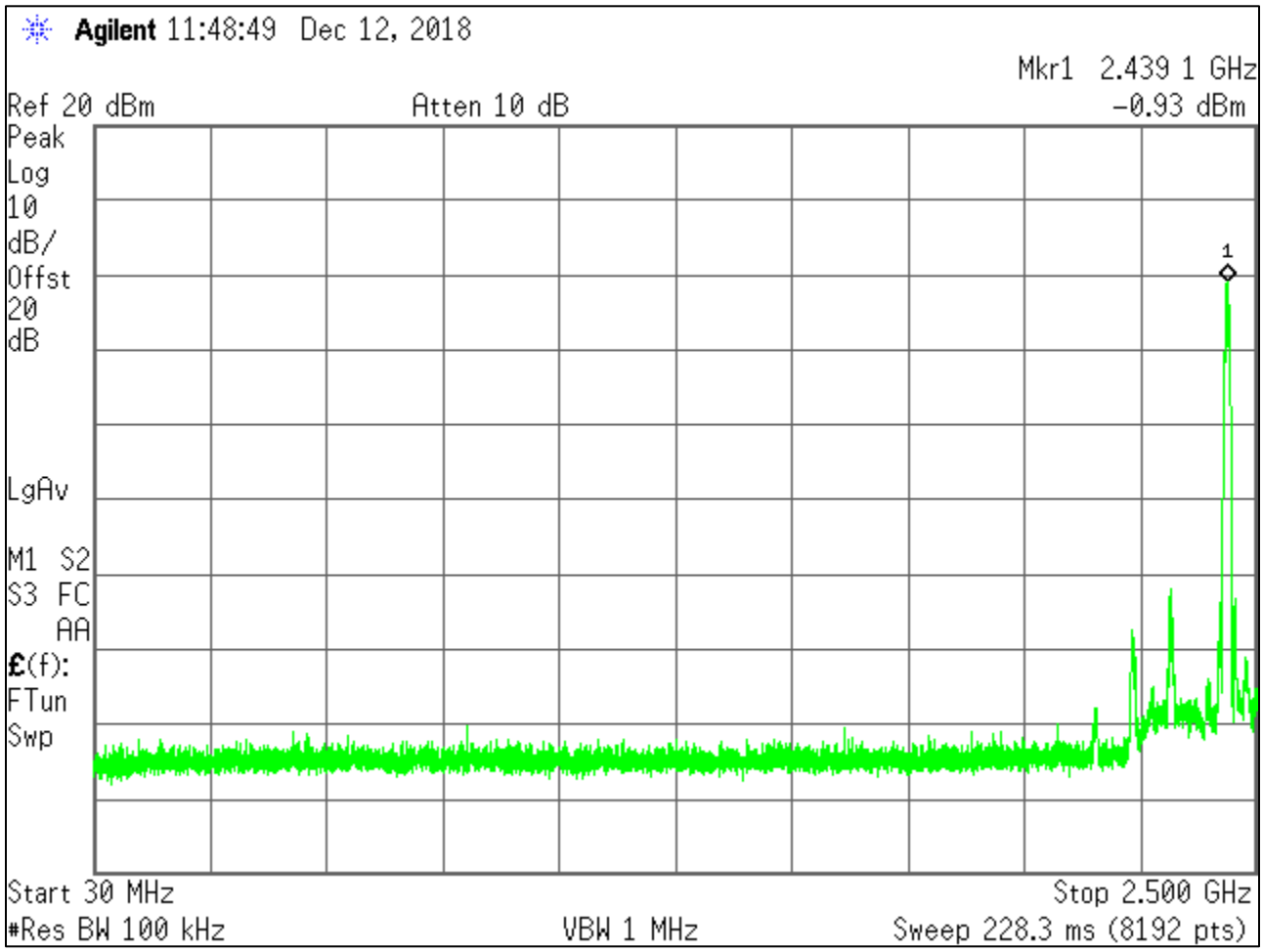


Figure 44. 2437 MHz SPURS 2.4-10G MODE 2

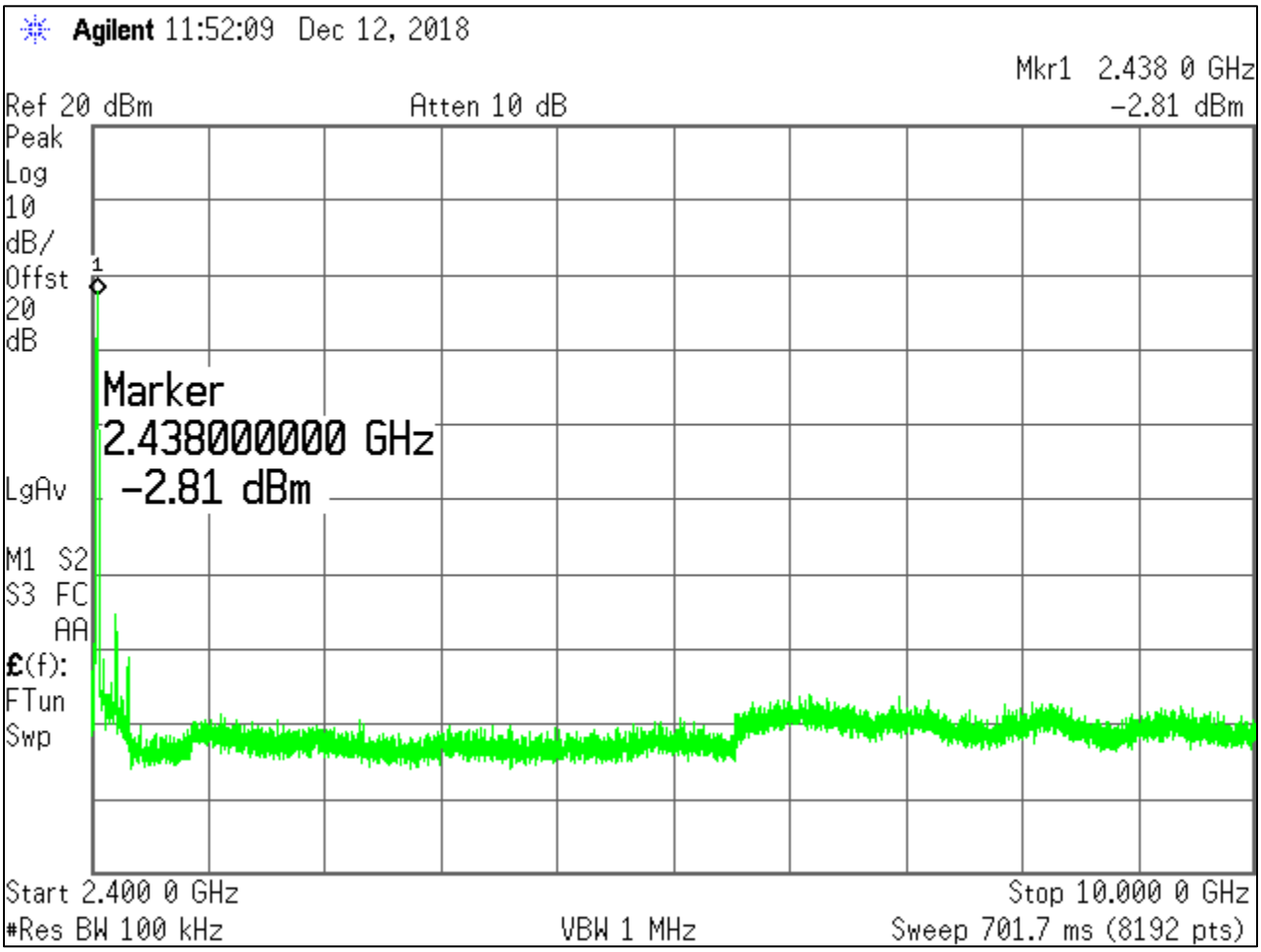


Figure 45. 2437 MHz SPURS 10-20G MODE 2

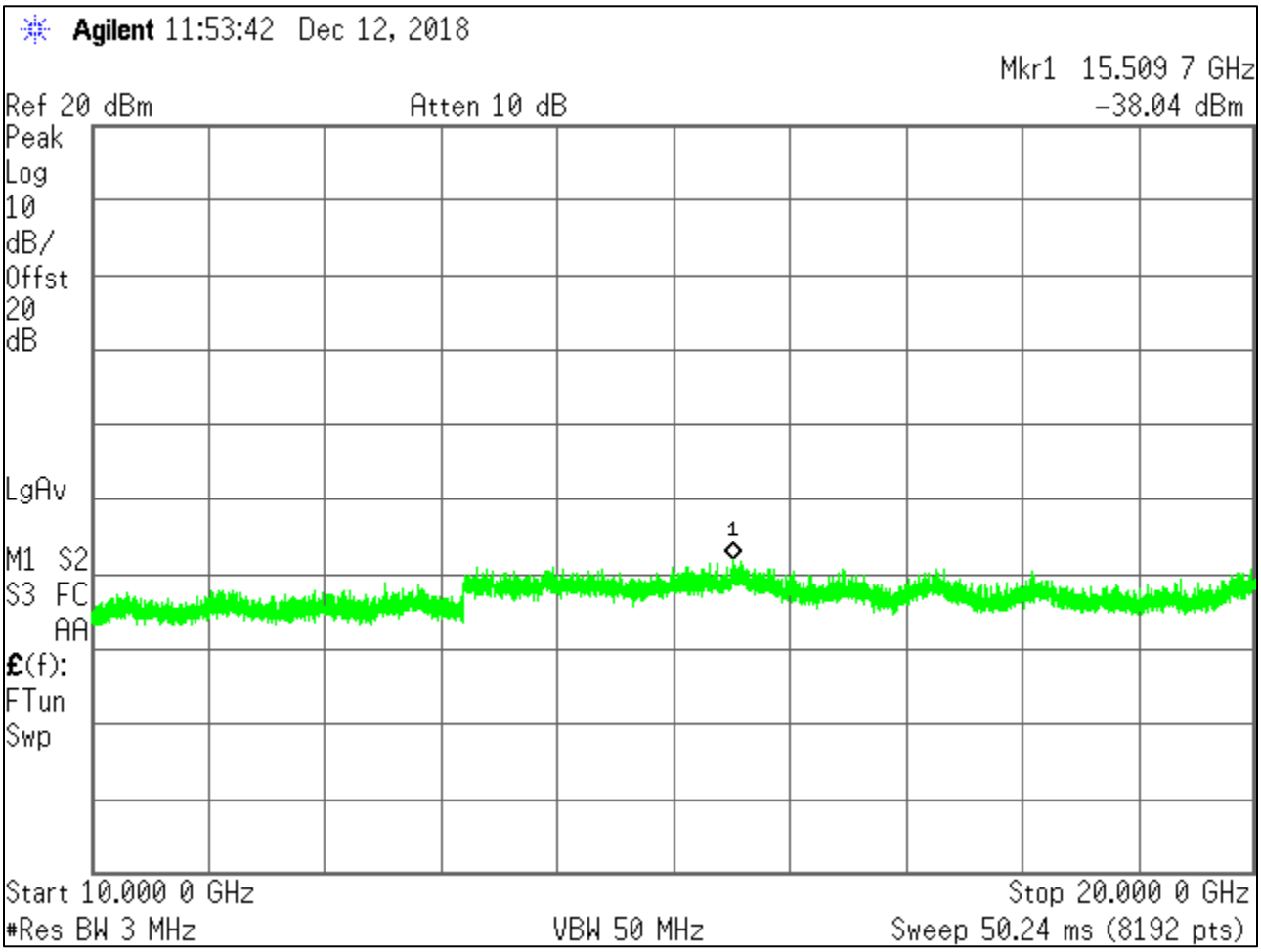


Figure 46. 2437 MHz SPURS 20-25G MODE 2

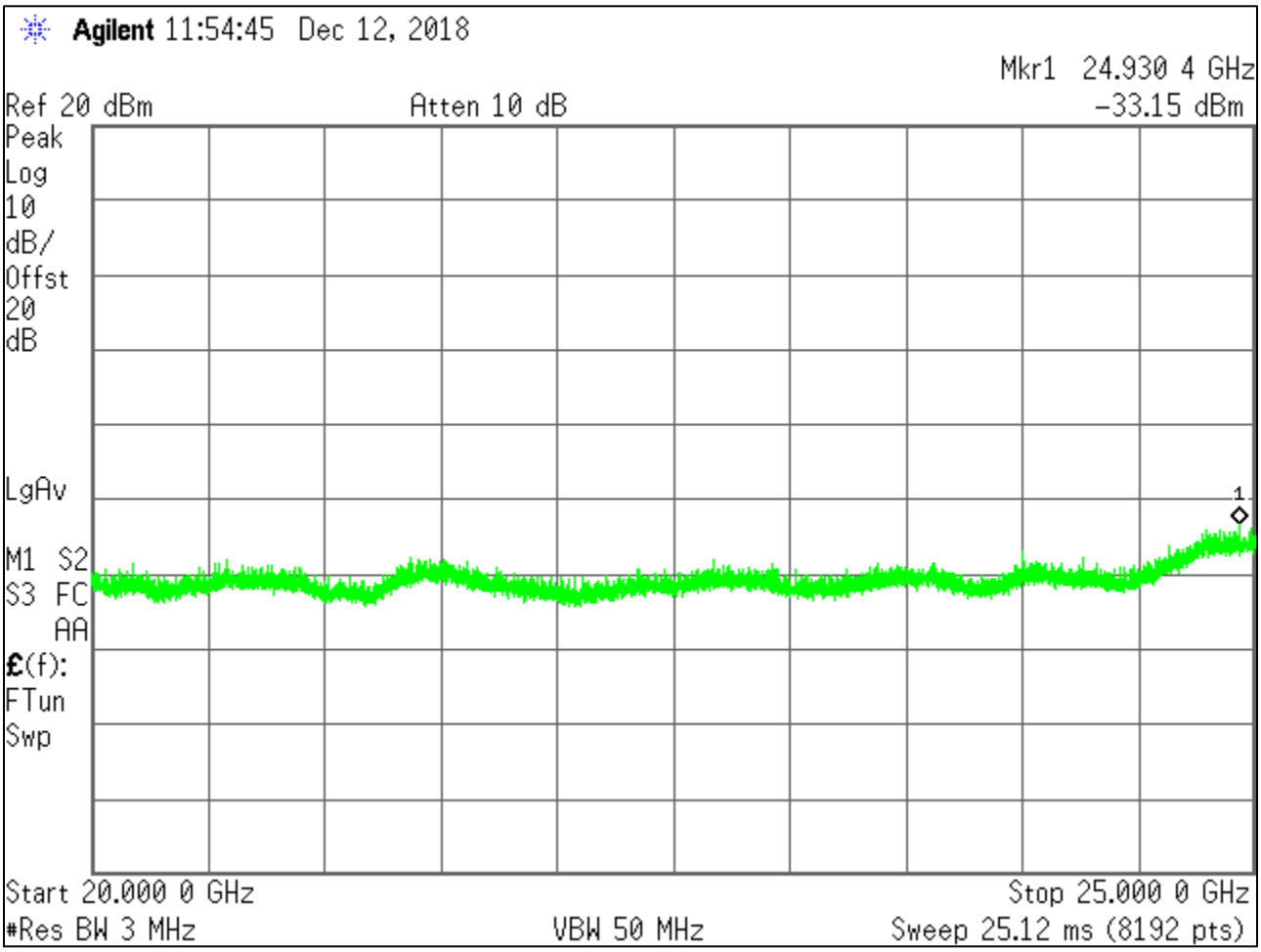


Figure 47. 2462 MHz SPURS 30-2.4G MODE 2

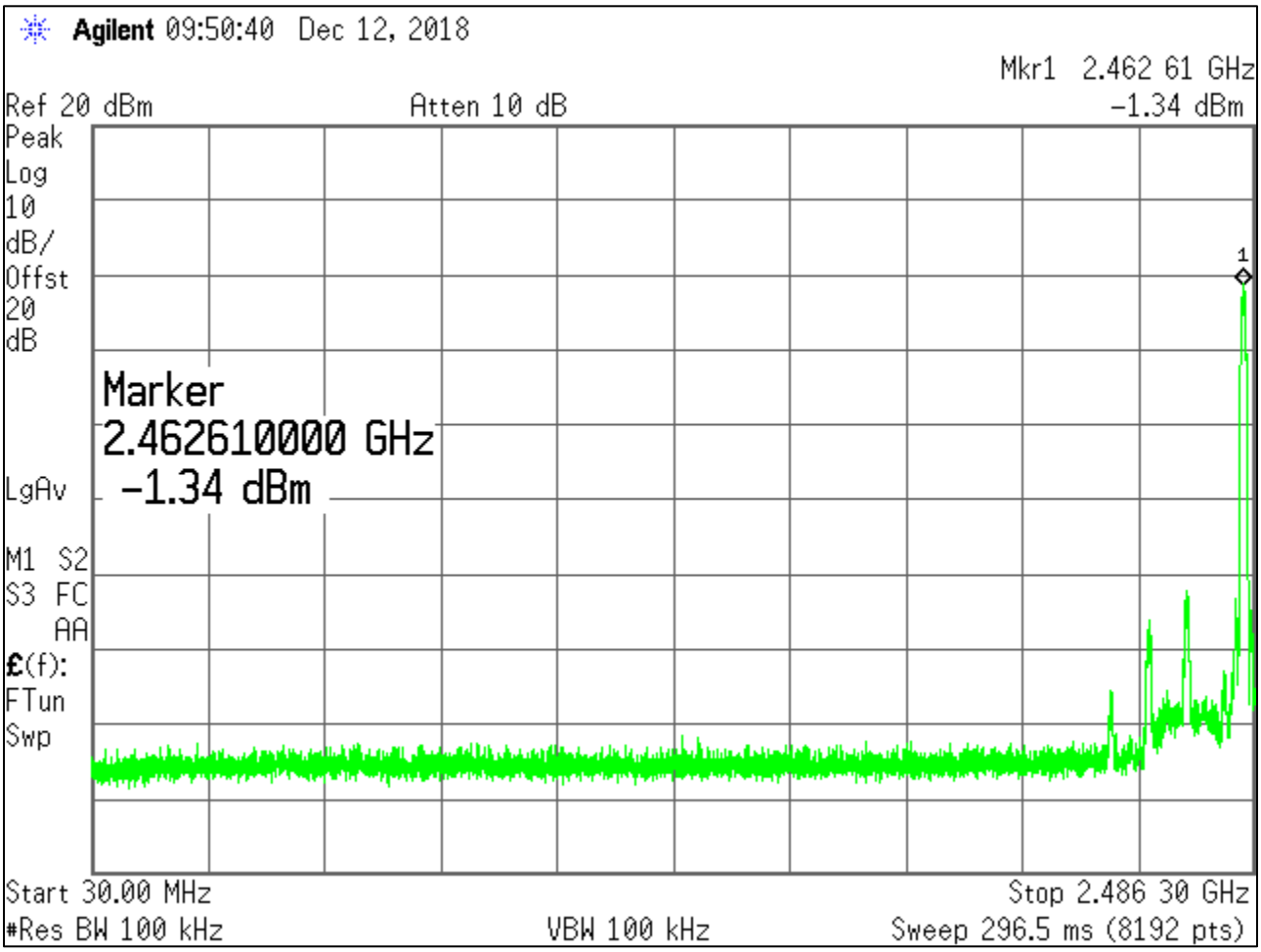


Figure 48. 2462 MHz SPURS 2.4-10G MODE 2

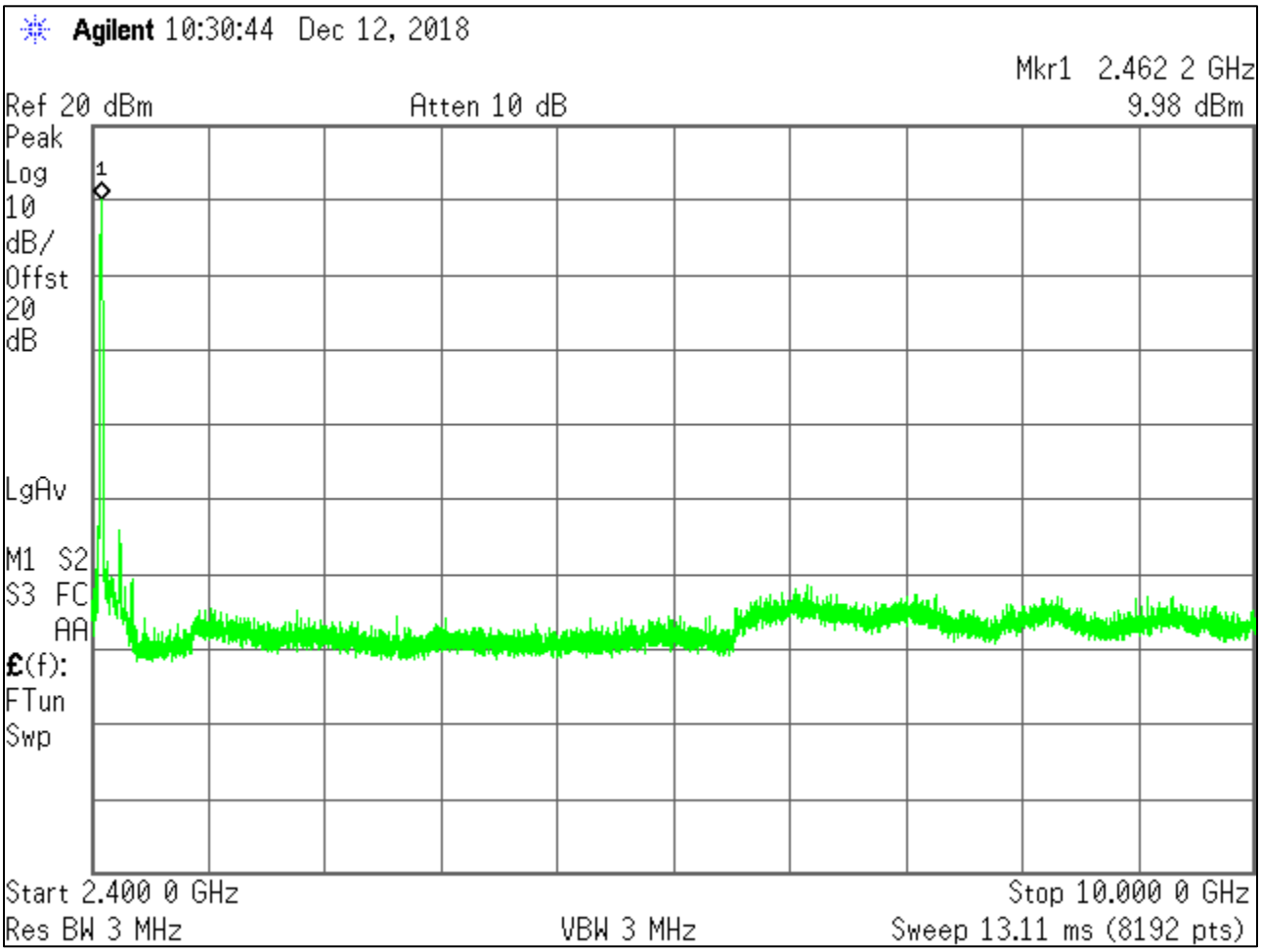


Figure 49. 2462 MHz SPURS 10-20G MODE 2

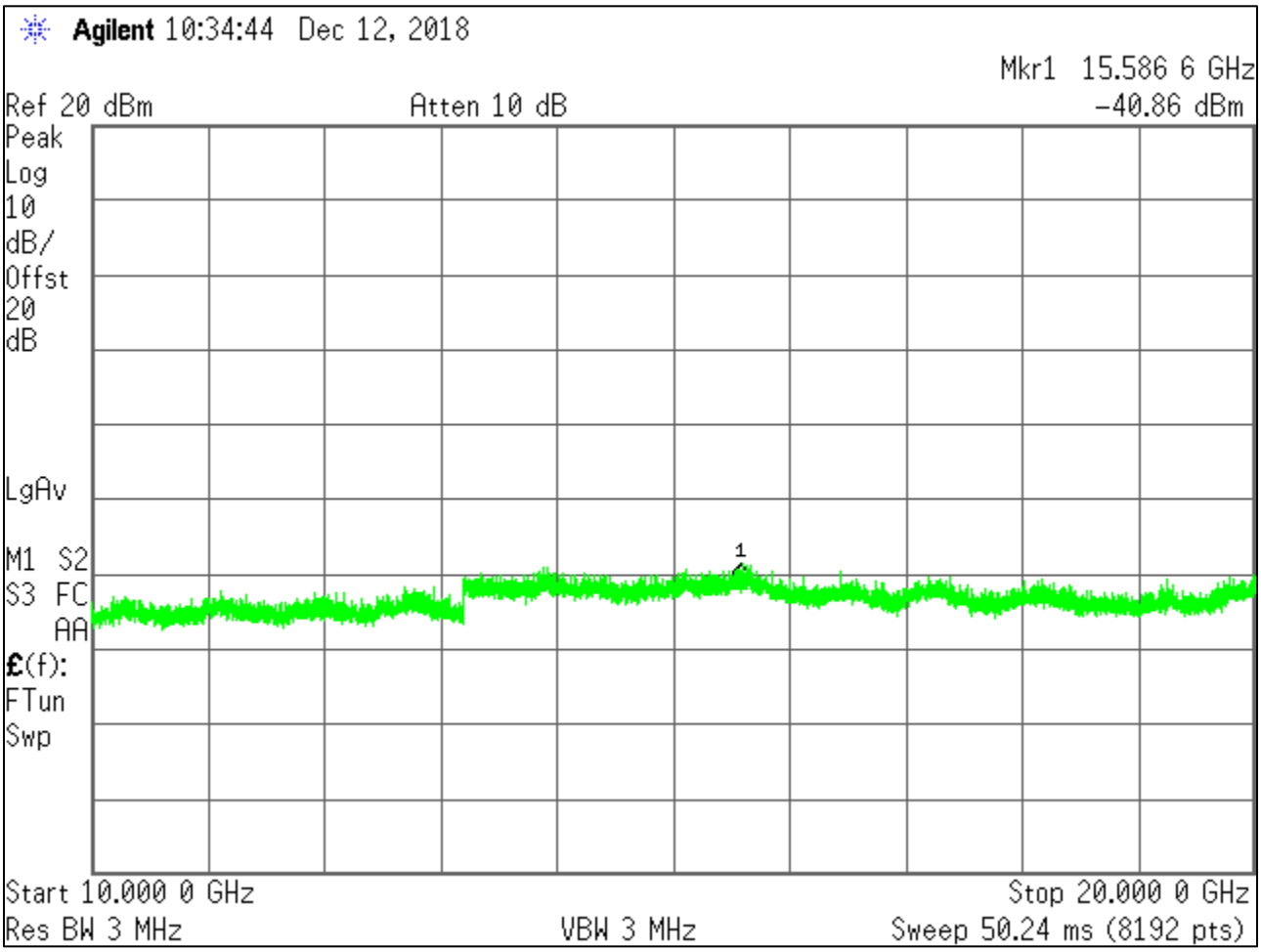
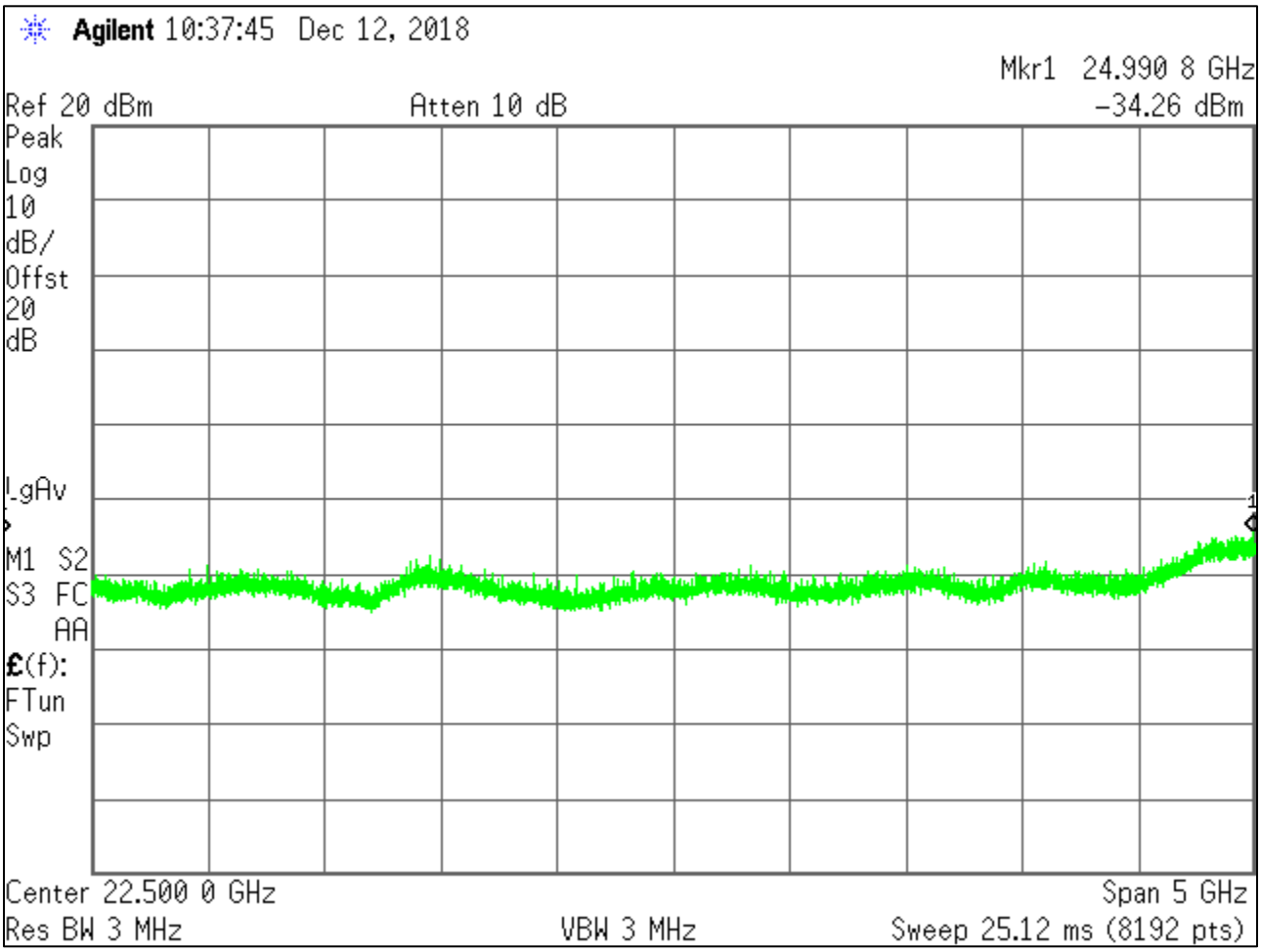


Figure 50. 2462 MHz SPURS 20-25G MODE 2



5.6 BAND EDGE CONDUCTED EMISSIONS

Measurements at the upper and lower band edges were made with the same procedure above. The results are provided below.

Figure 51. 2412 MHz LWR Band Edge MODE 1

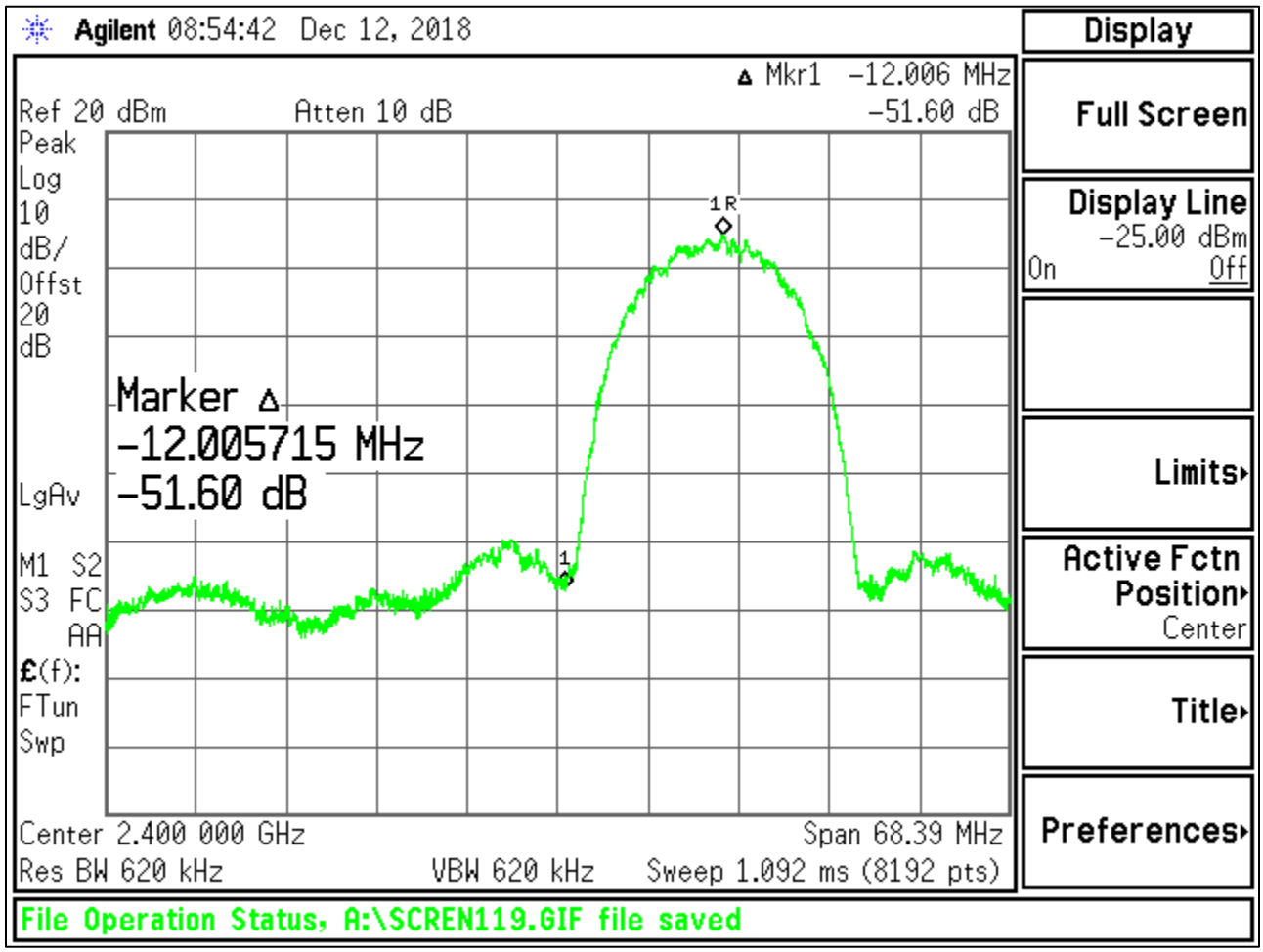


Figure 52. 2412 MHz LWR Band Edge MODE 2

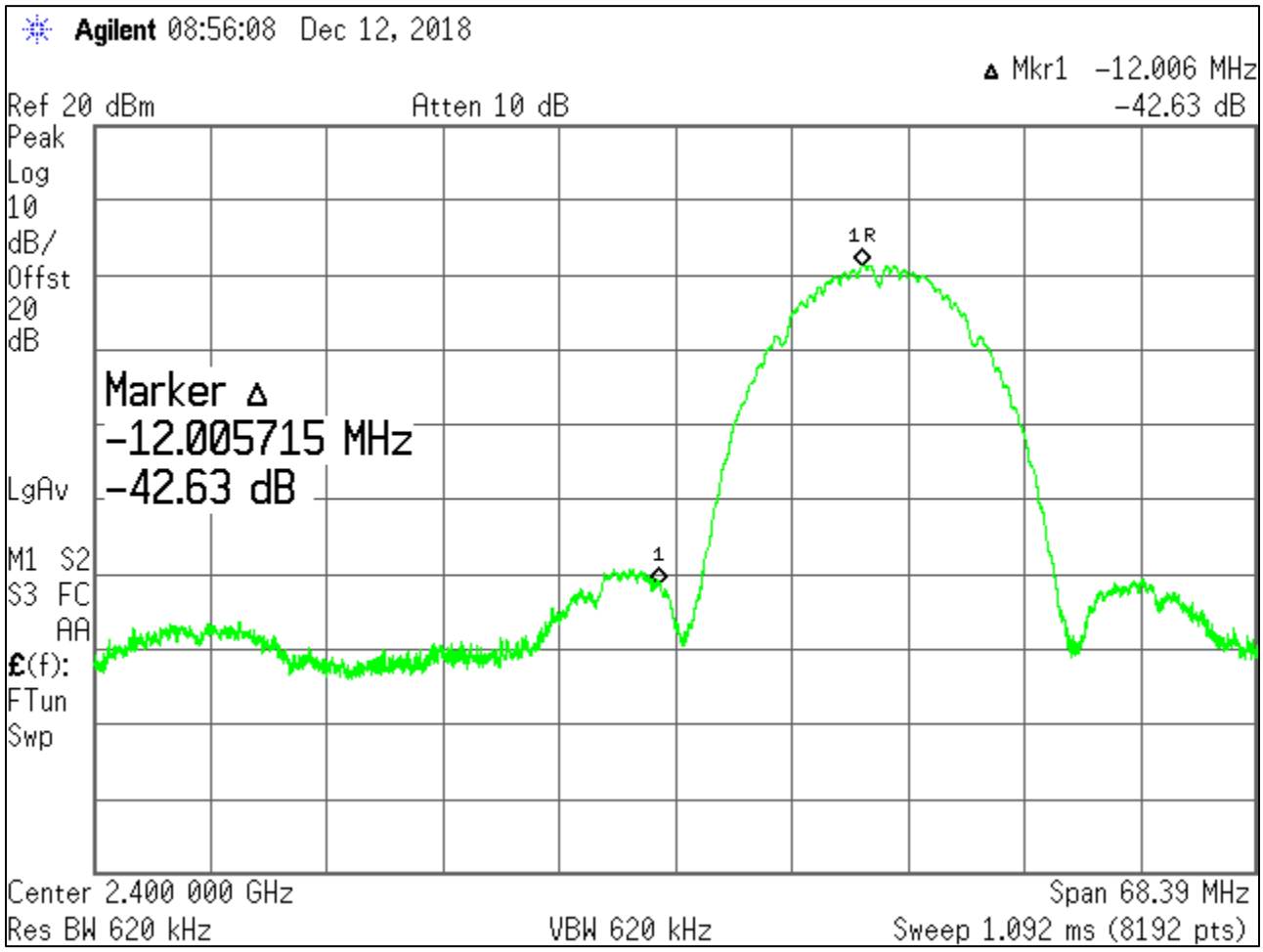


Figure 53. 2412 MHz LWR Band Edge MODE 4

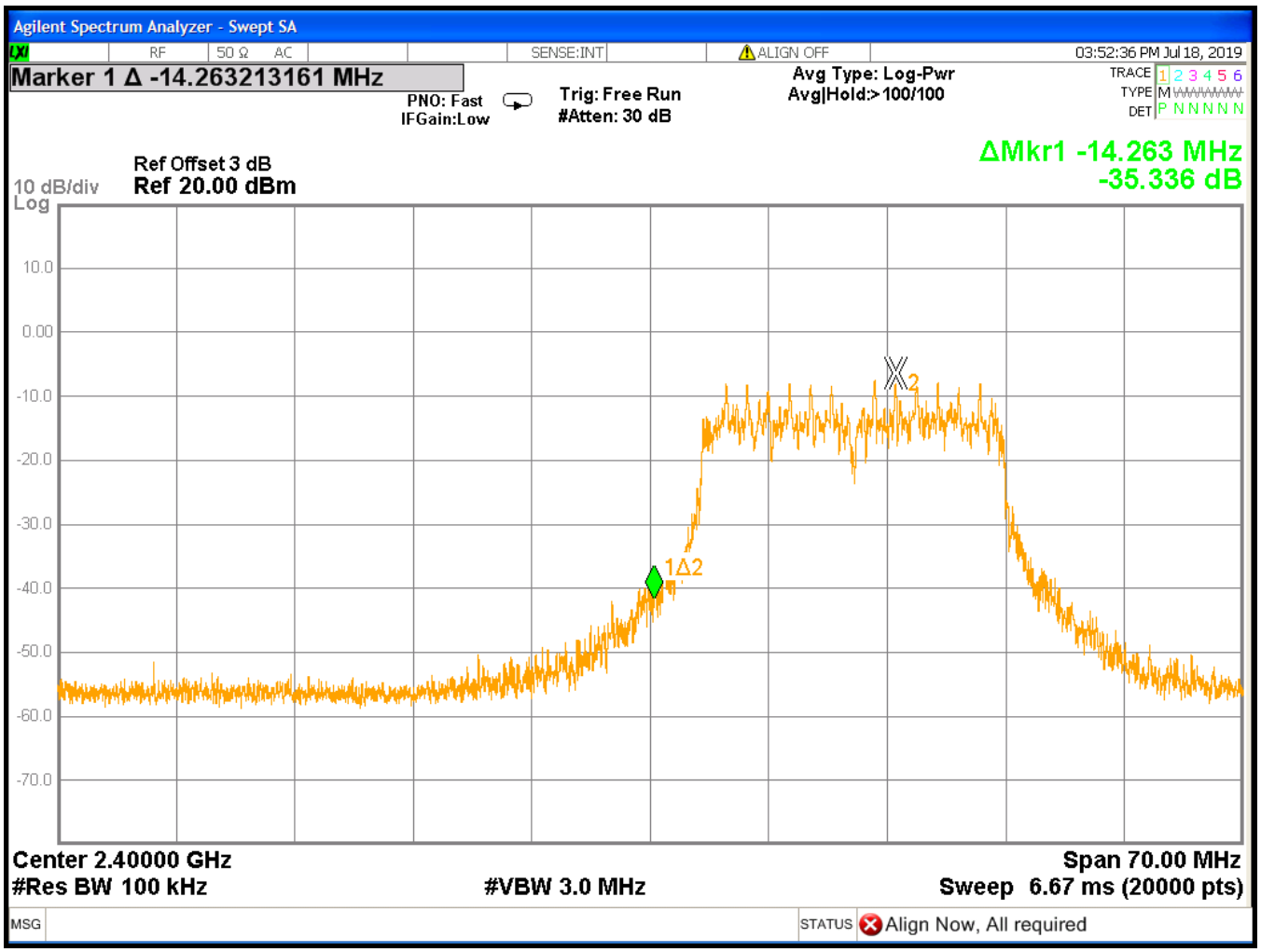


Figure 54. 2412 MHz LWR Band Edge MODE 7

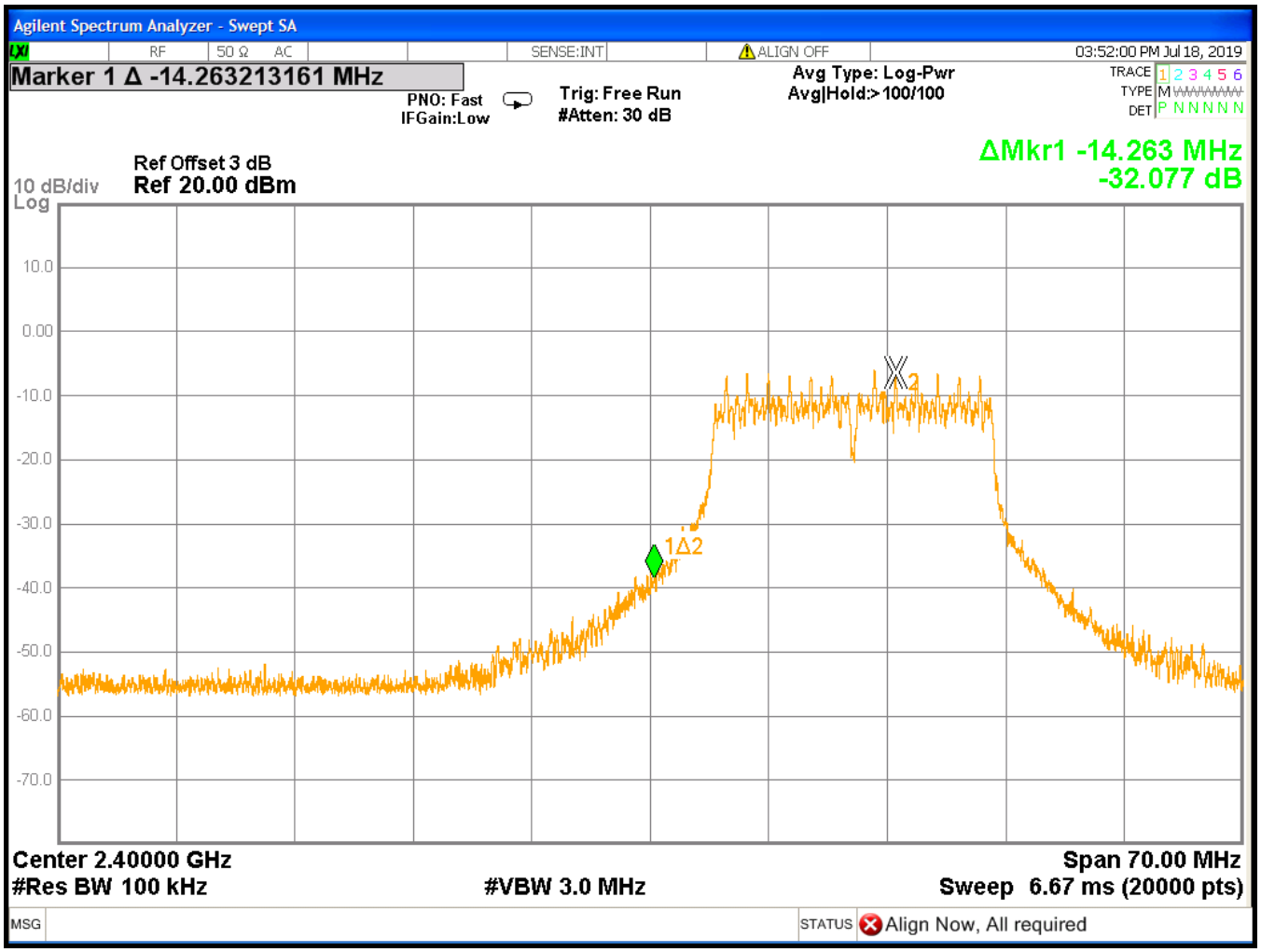


Figure 55. 2462 MHz UPR Band Edge MODE 1

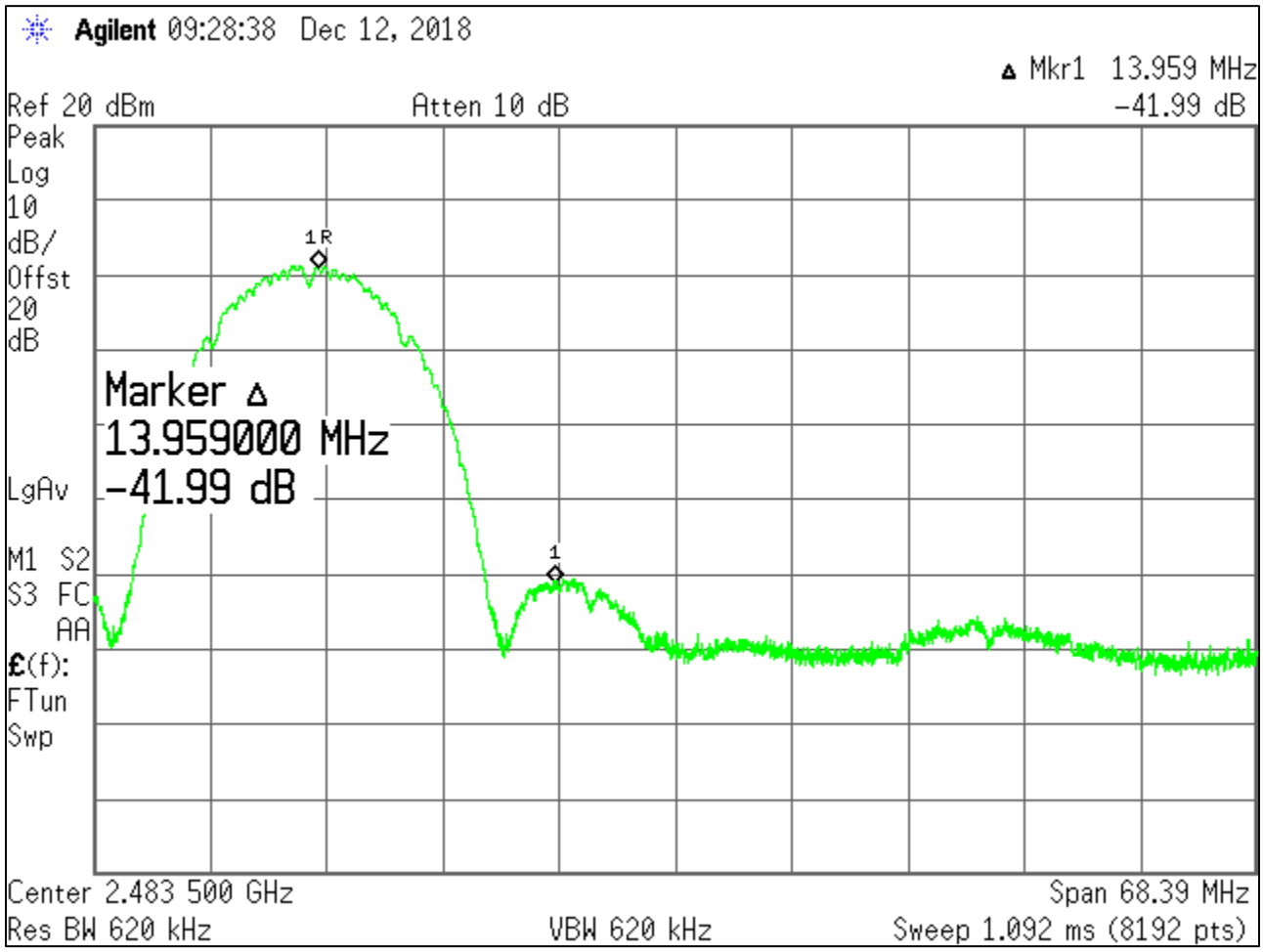


Figure 56. 2462 MHz UPR Band Edge MODE 2

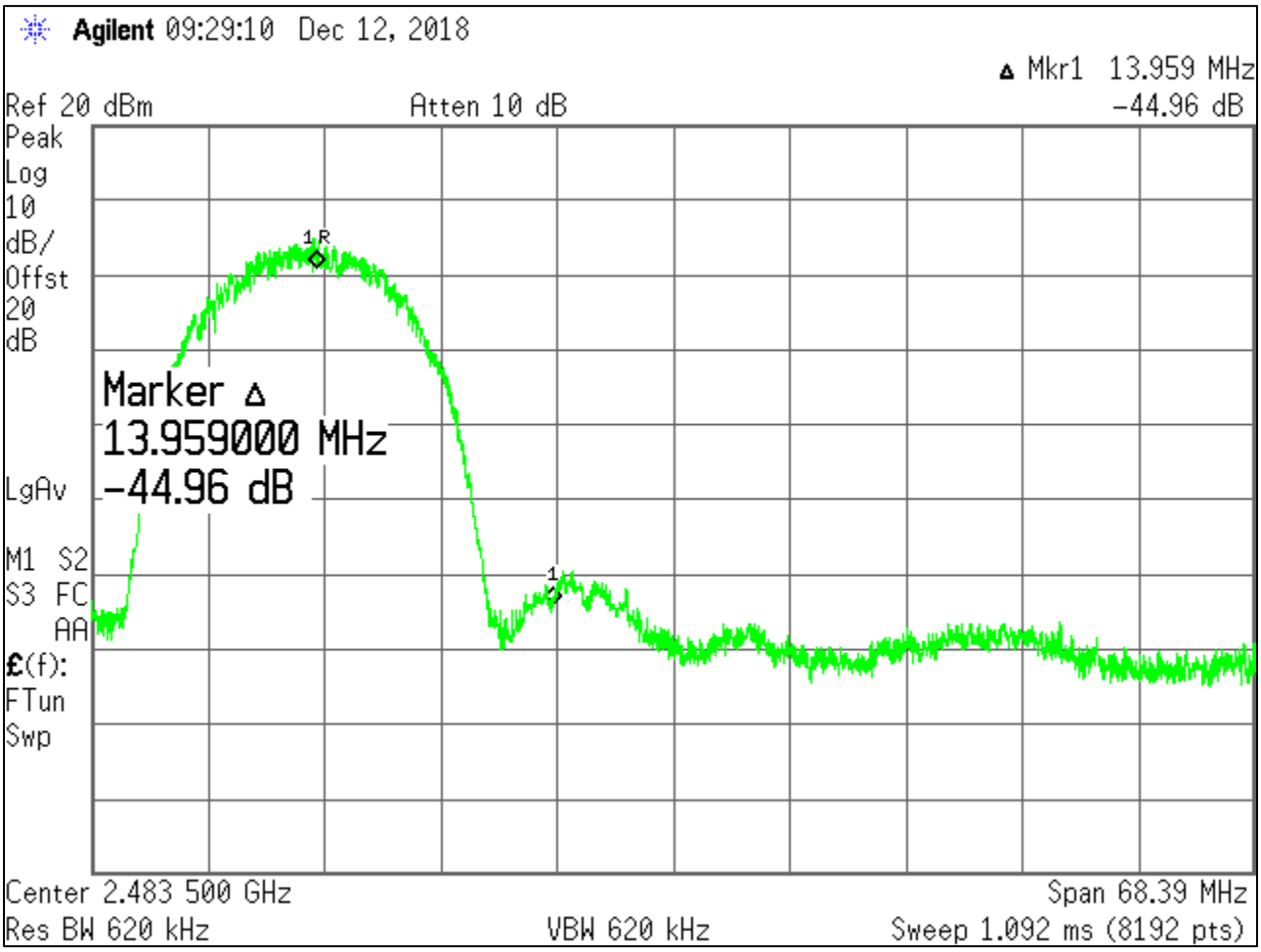


Figure 57. 2462 MHz UPR Band Edge MODE 4

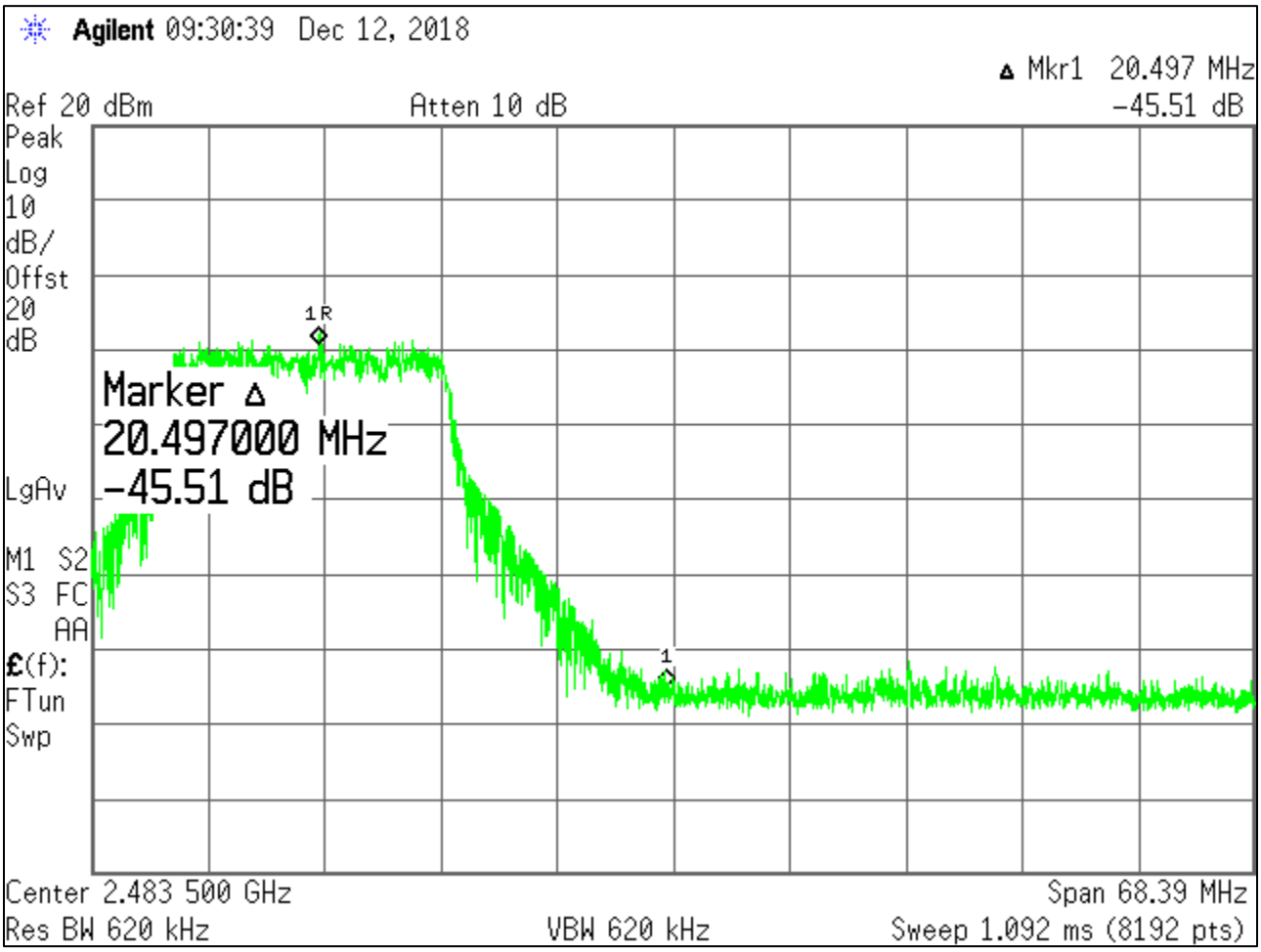
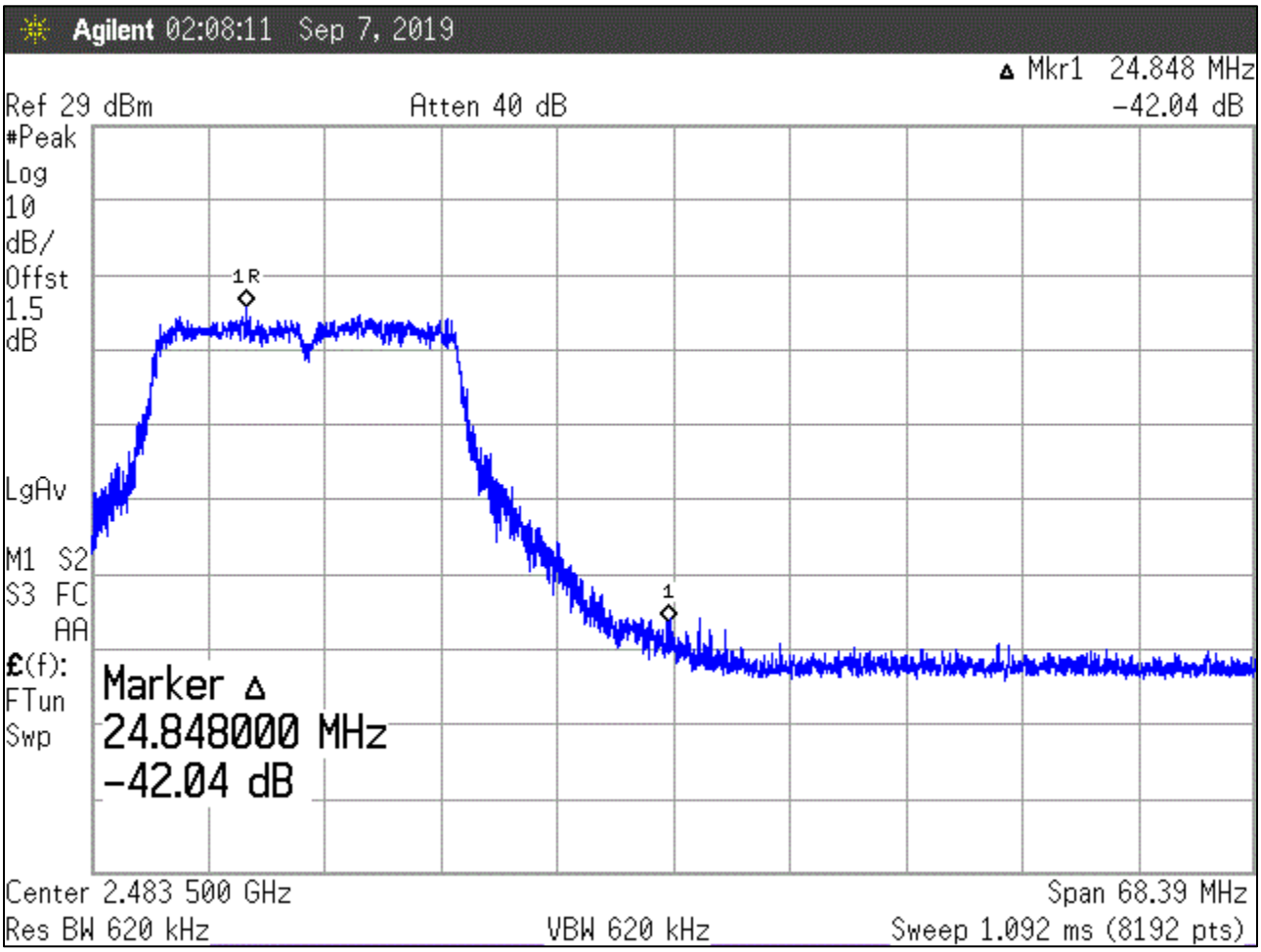


Figure 58. 2462 MHz UPR Band Edge MODE 7



5.7 SPURIOUS RADIATED EMISSIONS

5.7.1 Requirements

Compliance Standard: FCC Part 15.209.

FCC Compliance Limits		
Frequency Range	Limit (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
>960MHz	300 µV/m	500 µV/m

5.7.2 Test Procedure

The requirements of FCC Part 15 and ICES-003 call for the EUT to be placed on an 80 cm high 1 X 1.5 meters non-conductive motorized turntable for radiated testing on a3-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 output of the antenna was connected to the input of the spectrum analyzer and the emissions in the frequency range of 30 MHz to 1 GHz were measured. 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 or peak, as appropriate. Above 1GHz average measurement are 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 1GHz were performed using a measurement bandwidth of 1MHz with a video bandwidth setting of 10 Hz for the average measurement.

The device was set in MODE 2, which, during investigation represents the worst-case radiated spurious emissions condition.

5.7.3 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 = V dBµV + AFdB/m + CFdB - GdB
To convert to linear units of measure: EdBµV/m/20 Inv log

5.7.4 Test Data

The EUT complied with the Radiated Emissions requirements. Table 10 provides the test results for radiated emissions.

Emissions were checked in three orientations and the worst-case results are provided herein.

Table 10: Radiated Emission Test Data

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)	Comments
57.20	V	270.00	1.00	48.28	-15.9	41.4	100.0	-7.7	Peak
80.00	V	0.00	1.00	46.24	-14.9	37.1	100.0	-8.6	Peak
77.40	V	180.00	1.00	43.70	-14.6	28.4	100.0	-10.9	Peak
110.60	V	180.00	1.00	43.33	-9.8	47.4	150.0	-10.0	Peak
225.39	V	90.00	1.00	36.25	-10.7	19.0	200.0	-20.4	Peak
433.35	V	0.00	1.74	34.24	-5.2	28.4	200.0	-17.0	Peak
2402.00	V	180.00	1.00	42.39	-0.1	129.8	500.0	-11.7	AVG
2483.50	V	180.00	1.30	39.05	-0.9	81.0	500.0	-15.8	AVG
2483.5	V	180.0	1.30	47.20	-0.9	206.5	5000.0	-27.7	Peak
3600.00	V	0.00	1.00	32.10	1.9	50.2	5000.0	-40.0	AVG
4924.00	V	0.00	1.00	31.50	6.4	78.1	500.0	-16.1	AVG
4924.00	V	0.00	1.00	37.50	6.4	156.7	5000.0	-30.1	Peak
12310.00	V	0.00	1.00	31.00	17.3	260.5	5000.0	-25.7	Peak
14760.00	V	0.00	1.00	30.90	22.4	462.3	500.0	-0.7	Peak
57.21	H	0.00	1.74	42.78	-15.9	22.0	100.0	-13.2	Peak
77.43	H	0.00	2.02	47.70	-14.6	45.0	100.0	-6.9	Peak
110.59	H	90.00	1.67	39.08	-9.8	29.0	150.0	-14.3	Peak
80.00	H	0.00	1.17	41.08	-14.9	20.5	100.0	-13.8	Peak
228.86	H	0.00	1.00	35.93	-10.4	18.8	200.0	-20.5	Peak
445.49	H	180.00	3.21	37.00	-5.1	39.4	200.0	-14.1	Peak
2402.00	H	0.00	1.00	39.10	-0.1	88.9	500.0	-15.0	AVG
2483.50	H	180.00	1.00	35.70	-0.9	55.1	500.0	-19.2	AVG
2483.50	H	180.00	1.00	43.50	-0.9	149.6	50000	-30.5	Peak
3600.00	H	180.00	1.00	31.60	1.9	47.3	500.0	-20.5	AVG
4924.00	H	0.00	1.00	32.00	6.4	82.8	500.0	-15.6	Peak
4924.00	H	0.00	1.00	36.00	6.4	131.8	5000.0	-31.6	
12310.00	H	180.00	1.00	31.00	17.3	260.5	500.0	-5.7	Peak
14760.00	H	0.00	1.00	30.10	22.4	421.7	500.0	-1.5	Peak

Emissions were scanned to 25GHz.

5.8 AC CONDUCTED EMISSIONS

The EUT is powered by rechargeable batteries. The charger was measured for compliance to the conducted emissions requirements of FCC Part 15B.

5.8.1 Requirements

Test Arrangement: Table Top

Compliance Standard: FCC Part 15 (10/2018), Class B

FCC Compliance Limits		
Frequency	**Quasi-peak**	**Average**
0.15 - 0.5MHz	66 to 56dBµV	56 to 46dBµV
0.5 - 5MHz	56dBµV	46dBµV
5 - 30MHz	60dBµV	50dBµV

5.8.2 Test Procedure

The requirements of FCC Part 15 call for the EUT to be placed on an 80 cm high 1 X 1.5 m non-conductive table above a ground plane. Power to the EUT was provided through a Solar Corporation 50 ohm/50 mH 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.

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.

At frequencies where quasi-peak or peak measurements comply with the average limit, no average measurements need be performed.

5.8.3 Test Data

The EUT complied with the Class B Conducted Emissions requirements. The following provides the test results for phase and neutral line power line conducted emissions.

5.8.4 Conducted Data Reduction and Reporting

At frequencies where quasi-peak or peak measurements comply with the average limit, no average measurements need be performed. The Conducted emissions level to be compared to the FCC limit is calculated as shown in the following example.

Example:

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

5.8.5 Test Data

The EUT complied with the Class B Conducted Emissions requirements. This charger operates on 120VAC. The following tables provide the test results for phase and neutral line power line conducted emissions.

Conducted Emissions was tested with the device charging batteries.

Table 11: Conducted Emissions Data

NEUTRAL

Frequency (MHz)	Level QP (dBµV)	Level AVG (dBµV)	Cable Loss (dB)	LISN Corr (dB)	Level QP Corr (dBµV)	Level Corr Avg (dBµV)	Limit QP (dBµV)	Limit AVG (dBµV)	Margin QP (dB)	Margin AVG (dB)
0.186	33.5	19.3	10.2	0.2	43.9	29.7	64.2	54.2	-20.3	-24.5
0.415	20.7	11.3	10.2	0.3	31.2	21.8	57.5	47.5	-26.3	-25.7
0.757	20.8	9.6	10.3	0.2	31.3	20.1	56.0	46.0	-24.7	-25.9
1.009	30.4	14.5	10.3	0.3	40.9	25.0	56.0	46.0	-15.1	-21.0
1.158	24.4	10.5	10.3	0.3	34.9	21.0	56.0	46.0	-21.1	-25.0
2.220	25.5	8.6	10.1	0.3	35.9	19.0	56.0	46.0	-20.1	-27.0

PHASE

Frequency (MHz)	Level QP (dBµV)	Level AVG (dBµV)	Cable Loss (dB)	LISN Corr (dB)	Level QP Corr (dBµV)	Level Corr Avg (dBµV)	Limit QP (dBµV)	Limit AVG (dBµV)	Margin QP (dB)	Margin AVG (dB)
0.833	21.8	10.5	10.3	0.1	32.2	20.9	56.0	46.0	-23.8	-25.1
1.450	24.4	10.5	10.2	0.3	34.9	21.0	56.0	46.0	-21.1	-25.0
1.482	24.8	8.7	10.2	0.3	35.3	19.2	56.0	46.0	-20.7	-26.8
2.490	23.7	8.9	10.1	0.3	34.1	19.3	56.0	46.0	-21.9	-26.7
9.514	19.8	10.7	11.1	0.2	31.1	22.0	60.0	50.0	-28.9	-28.0
10.904	21.7	12.3	11.2	0.3	33.1	23.7	60.0	50.0	-26.9	-26.3