FCC & ISED CANADA CERTIFICATION TEST REPORT

for the

Vubiq HaulPass V10g H

FCC ID: 2ADJ9-V10G-H

IC ID: 12497A-V10GH

REPORT# 15763 -01 REV 1

Prepared for:

Vubiq Networks Inc.

9231 Irvine Blvd

Irvine, CA 92618

Prepared By:

Washington Laboratories, Ltd.

7560 Lindbergh Drive

Gaithersburg, Maryland 20879

Testing Certificate AT-1448

FCC & ISED Canada Certification Test Report

for the

Vubiq Networks Inc.

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FCC ID: 2ADJ9-V10G-H

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OCTOBER 18, 2018

WLL REPORT# 15763 -01 REV 1

Prepared by:

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Test Engineer

Reviewed by:

Steven D. Koster

President

Revision History	Description of Change	Date
Rev 0	Initial Release	SEPTEMER 24, 2018
Rev 1	Reply to TCB comments	October 12, 2018
Rev 2	Reply to TCB comments	October 18, 2018

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1 INTRODUCTION

1.1 COMPLIANCE STATEMENT

The Vubiq HaulPass V10g complies with the requirements of FCC Part 15.255 and ISED RSS210 Issue 9, Annex J.

1.2 CONTRACT INFORMATION

Customer:	Vubiq Networks, Inc.
Address	9231 Irvine Blvd
	Irvine, CA 92618
Purchase Order Number:	VPO63634
Quotation Number:	70966

1.3 TEST DATES

Testing was performed on the following date(s): September 10-14, 2018

1.4 TEST AND SUPPORT PERSONNEL

Washington Laboratories, LTD	Mike Violette
Customer Representative	Michael Klett

2 EQUIPMENT UNDER TEST

2.1 EUT IDENTIFICATION & DESCRIPTION

The Vubiq Networks Inc. Vubiq HaulPass V10g H is a point-to-point millimeter wave radio link. It is intended for multi-gigabit data communications.

Table 1: Device Summary

Item	Multi-Gigabit Radio Link
Manufacturer:	Vubiq Networks Inc.
FCC ID:	2ADJ9-V10G-H
ISED ID:	12497A-V10GH
Model:	Vubiq HaulPass V10g H
Serial Number of Unit Tested	N/A
FCC Rule Parts:	§15.255
ISED Rule Parts:	RSS-210 Issue 9 Annex J
Frequency Range:	62.75GHz Channel
Maximum Output Power:	6.9mW Max Rated: 15mW (11.8 dBm)
Modulation:	400 Mbd (BPSK), 800 Mbd (BPSK), 1600 Mbd (BPSK, QPSK, 8PSK, 16QAM, 32QAM, 64 QAM, 128 QAM). Modes are automatically selected as a function of available link budget.
Emissions Bandwidth (6dB):	>349MHz
ISED Emissions Designators:	BPSK (400 Mbd): 480MG7D BPSK2 (800 Mbd): 960MG7D BPSK3 (1600Mbd): 1G9G7D QPSK (1600Mbd): 960MG7D 8PSK (1600 Mbd): 640MG7D 16QAM (1600 Mbd): 800MW7D 32QAM (1600 Mbd): 640MW7D 64QAM (1600 Mbd): 533MW7D

	128 QAM (1600 Mbd): 370MW7D
Keying:	N/A
Type of Information:	Data
Number of Channels:	One
Highest TX Spurious Emission:	None detected to 200 GHz System noise floor = 70.1dBuV/m @ 3m
Antenna Connector	N/A
Antenna Type	Integrated Array, 38.5dBi
Interface Cables:	Ethernet
Maximum Data Rate	10GBPS
Power Source & Voltage:	POE, 48VDC

2.2 EMISSION DESIGNATOR

According to the NTIA Redbook Annex J, the necessary bandwidth for PSK and QAM modulations are found from the following formula

https://www.ntia.doc.gov/files/ntia/publications/redbook/2017-09/J_17_9.pdf

$$Bn = 2RK/\log 2(S)$$

Where Bn is the necessary bandwidth to transmit the data at a given rate R. K is an overall numerical factor which varies according to the emission and which depends on the allowable signal distortion. S is the number of equivalent non-redundant signaling states.

K for PSK systems varies between 0.5 and 1. For these calculations we use a K =0.6. For QAM systems, K is typically 1.

The necessary bandwidths for each modulation type are shown in the following table.

Table 2. Necessary Bandwidths

Modulation	R	K	S	Bn MHz
BPSK	400	0.6	2	480
BPSK2	800	0.6	2	960
BPSK3	1600	0.6	2	1920
QPSK	1600	0.6	4	960
8PSK	1600	0.6	8	640
16QAM	1600	1	16	800.0
32QAM	1600	1	32	640.0
64QAM	1600	1	64	533.3
128QAM	1600	1	128	457.1

2.3 TEST CONFIGURATION

The Vubiq HaulPass V10g H was configured for 2.5 Gbps and 10 Gbps Ethernet interface modes, independent of RF modulation, with max baud rates set for each modulation mode.

The Vubiq HaulPass V10g H was commanded to transmit at maximum power with all available the modulations adjusted for testing.

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

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

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

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 3 below.

Table 3: 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 4 shows a list of the test equipment used for measurements along with the calibration information.

Table 4: Test Equipment List

Test Name:	**Radiated Frequency Stability Part 15.209**	**Test Date:**	**09/11/2018**
Asset #	**Manufacturer/Model**	**Description**	**Cal. Due**
644	SUNOL SCIENCES CORPORATION - JB1 925-833-9936	BICONALOG ANTENNA	1/16/2020
4	ARA - DRG-118/A	ANTENNA DRG 1-18GHZ	12/14/2018
276	ELECTRO-METRICS - BPA-1000	RF PRE-AMPLIFIER	2/7/2019
823	AGILENT - N9010A	EXA SPECTRUM ANALYZER	4/21/2019
627	AGILENT - 8449B	AMPLIFIER 1-26GHZ	11/7/2019
Test Name:	Conducted Emissions	Test Date:	09/11/2018
Asset #	Manufacturer/Model	Description	Cal. Due
823	AGILENT - N9010A	EXA SPECTRUM ANALYZER	4/21/2019
Test Name:	**Radiated Frequency Stability Part 15.255**	**Test Date:**	**9/10-9/11/2018**
83	AGILENT - 11970U	MIXER HARMONIC 40 - 60GHz	CNR
54	AGILENT - 11970V	MIXER HARMONIC 50-75GHz	CNR
210	NARDA - V638	HORN STANDARD GAIN	CNR
209	NARDA - V637	HORN STANDARD GAIN	CNR
528	AGILENT - E4446A	3HZ - 44GHz ANALYZER SPECTRUM	12/19/2018
209	NARDA - V637	HORN STANDARD GAIN	CNR
210	NARDA - V638	HORN STANDARD GAIN	CNR
	OMLM12HW	60-90 GHz Mixer	CNR
	OML M08HW	90-140 GHz Mixer	CNR
	OML Gband	140-220 GHz Mixer	CNR

4 TEST RESULTS

4.1 §15.255 OPERATION WITHIN THE BAND 57-71 GHZ: OUTPUT POWER

(c) Within the 57-71 GHz band, emission levels shall not exceed the following equivalent isotropically radiated power (EIRP):

(1) Products other than fixed field disturbance sensors and short-range devices for interactive motion sensing shall comply with one of the following emission limits, as measured during the transmit interval:

(i) The average power of any emission shall not exceed 40 dBm and the peak power of any emission shall not exceed 43 dBm; or

(ii) For fixed point-to-point transmitters located outdoors, the average power of any emission shall not exceed 82 dBm and shall be reduced by 2 dB for every dB that the antenna gain is less than 51 dBi. The peak power of any emission shall not exceed 85 dBm and shall be reduced by 2 dB for every dB that the antenna gain is less than 51 dBi.

A) The provisions in this paragraph (c) for reducing transmit power based on antenna gain shall not require that the power levels be reduced below the limits specified in paragraph (c)(1)(i) of this section.

(B) The provisions of §15.204(c)(2) and (4) that permit the use of different antennas of the same type and of equal or less directional gain do not apply to intentional radiator systems operating under this provision. In lieu thereof, intentional radiator systems shall be certified using the specific antenna(s) with which the system will be marketed and operated. Compliance testing shall be performed using the highest gain and the lowest gain antennas for which certification is sought and with the intentional radiator operated at its maximum available output power level. The responsible party, as defined in §2.909 of this chapter, shall supply a list of acceptable antennas with the application for certification.

Section (ii) applies to the EUT. A single, fixed antenna is used, and the gain is 38.5dBi, so the maximum average power limit is:

$$\text{Maximum Power} = 82-2*(51-38.5) = 82-25 = 57 \text{ dBm}$$

Radiated measurements were perform as the unit has an integral array antenna per ANSI C63.10:2013, using the maximization techniques of Section 9.9 of ANSI C63.10. Power measurements per Section 9.10 of ANSI C63.10 were made on an unmodulated carrier in the band and occupied bandwidth measurements were performed on the different modulated signals. **The measurements were performed at 3-meter distance in an anechoic chamber boresight to the antenna array and as PEAK power measurements. No ground reflections at these frequencies and tight antenna patterns.** The measurements were collected using diode mixers to down-convert the mmWave signal to the in-band operation of the spectrum analyzer.

The external mixer devices operate as non-linear diode downconverters. The Local Oscillator (LO) output of the spectrum analyzer is coupled into the LO input of the mixer. The LO is applied to a high frequency diode that rectifies the lO input, producing many harmonic products. The mixer design is such that the "nth" harmonic that is produced is mixed with the incoming mmWave energy. The mixed product appears at the Intermediate Frequency (IF) of the spectrum analyzer and the image is displayed on the analyzer as appearing "in-band". Software routines convert the frequency range that is displayed to the mmWave measurement bands. For the HP mixers that we employ (up to 90 GHz) the LO and IF are separate connections. For the OML mixers that we use, a diplexer is used to send a combined LO/IF signal to the input of the mixer. The diplexer is used to couple the IF (321.4 MHz) into the analyzer and provide the LO (3.6-5.4 GHz) on a single coaxial cable.

The down conversion is lossy, which limits the sensitivity of the measurements at millimeter wave frequencies.

In addition, the non-linear operation of the mixers produces many artifacts which can be difficult to manage. The spectrum analyzer employs a software algorithm (Signal Identification) that helps to suppress the artifacts but works best for very close measurements to the carrier. Out of band, the suppression is not ideal.

To convert the raw spectrum analyzer radiated data into a form that can be compared with the FCC/ISED 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), the CL (in dB) 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/ISED limit.

Example:
Spectrum Analyzer Voltage: VdBµV
Antenna Correction Factor: AFdB/m
Mixer Conversion Loss: CFdB
Cable Correction Factor: CLdB
Pre-Amplifier Gain (if applicable): GdB
Electric Field: E*meas*dBµV/m = V dBµV + AFdB/m + CFdB + CLdB - GdB
To convert to linear units of measure: EdBµV/m/20 Inv log

The calculation of EIRP is performed per Equation (22) of ANSI C63.10, viz

$$EIRP = E_{meas} + 20Log(d_{meas}) – 104.7$$

Where

EIRP is the equivalent Isotropic Radiated Power in dBm
E_{meas} is the measured field strength at distance d_{meas}.

The unmodulated signal power was measured as follows with the carrier set 500 MHz below the center channel. This is the normal mode for measuring output power.

Table 5. Fundamental Power Measurement (Peak Measurement)

Freq GHz	Spec An dBuV	AF dB/m	CF dB	CL dB	E-Field dBuV/m
62.75	55.9	48.5	35.2	2.5	142.1

The EIRP is then found as:

$$EIRP = 142.1 + 9.54 – 104.7 = 46.9 \text{ dB}$$

The Gain of the transmit array is Gt = 38.5dBi and the familiar EIRP formula, EIRP = PtGt, is used to compute the output Power, Pout.

This results in a conducted output power of:

$$Pout = EIRP – Gt = 8.4\text{dBm}$$
$$Pout = 6.9 \text{ mW}$$

This is within a few dB of the manufacturer's stated output power of 15 mW (or 11.8dBm) and complies with the limit of 56dBm. The V10g H version of this radio has less than the power of the V10G L version.

Table 6. Radiated Power Results

Freq GHz	Average Power Limit (dBm)	EIRP (Peak) dBm	Power 10.1 dBm	Margin dB	Result
62.25	57	46.9	8.4	10.1	Pass

A plot of the unmodulated carrier is provided in the following Figure. To produce this mode for power measurement, the carrier is offset from the center channel by minus 500MHz.

Per 15.255(e) the peak conducted output power limit is 500mW. The EUT has a measured output power of 6.9mW.

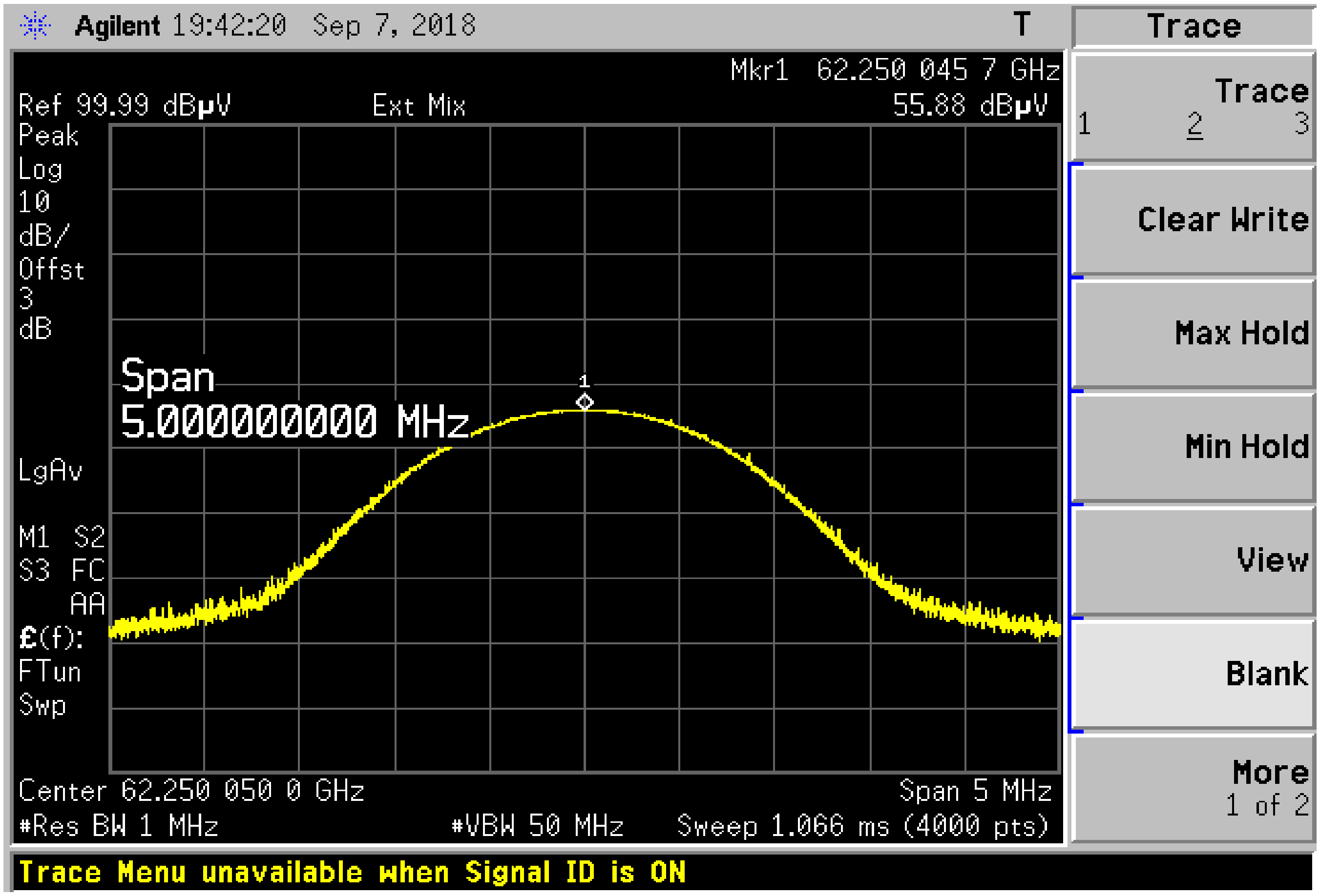

Figure 1. Unmodulated Carrier. Maximum Power

Figure 2. Measurement of Fundamental @ 3m

4.2 §15.255 OPERATION WITHIN THE BAND 57-71 GHZ: SPURIOUS EMISSIONS

(1) The power density of any emissions outside the 57-71 GHz band shall consist solely of spurious emissions.

(2) Radiated emissions below 40 GHz shall not exceed the general limits in §15.209.

(3) Between 40 GHz and 200 GHz, the level of these emissions shall not exceed 90 pW/cm² at a distance of 3 meters. This is converted to volts-per-meter according to the following formula, which defines the power spectral density in terms of electric field and the free-space wave impedance.

$$S\ W/m^2 = E^2/377$$

Where,

S is the power density in watts-per-square meter

E is the electric field in volt-per-meter and

377 is the free space impedance

This can be expressed as in terms of E-field as:

$$E = SQRT[(S/377)]$$

Converting the units, we find that

$$W/m^2 = 10^{12}pW/10^4cm^2$$

or

$$1\ W/m^2 = 10^8pW/cm^2$$

further,

$$EV/m = 10^6uV/m$$

hence,

$$EV/m = SQRT[(10^8pW/cm^2*377)]$$

And the spurious emission electric field limit, in uV/m is:

$$EuV/m = SQRT[(10^8pW/cm^2*377)]*10^6$$

Such that $90pW/cm^2$ is equal to **85dBuV/m.**

To reach this sensitivity at these frequencies requires that a reduced test distance be used to measure the radiated spurious emissions. Per ANSI C63.10, we estimate that a 0.1m test distance is adequate to discern spurious emissions from the EUT with sufficient margin to the limit, per section 9.8 of ANSI C63.10 to measure the spurious emissions over the frequency range of 40 GHz to 200 GHz.

Spurious emissions were measured from the EUT using the maximization procedure of ANSI C63.10.

(4) The levels of the spurious emissions shall not exceed the level of the fundamental emission.

To cope with system sensitivity issues at frequencies above 60 GHz, it is necessary to perform extremely close scans of the system.

The following table shows the performance of the mixer/horn combination used to measure spurious emissions. The total conversion losses are in excess of >80dB, thus, the test distance is collapsed from 3m to a distance where emissions, if present, can be detected.

At a distance of 0.02, the losses can just be overcome to make measurements. At the upper band, computing the equivalent electric field at the 6th harmonic (~180GHz), the system noise floor is approximately 13dBuV and combined conversion losses are 106.2dB. This level equates to an inferred field strength of:

E-field = 13+106 = 121dBuV/m

This provides an estimated 8 dB of headroom to the inferred limit.

Table 7. Conversion losses for Mixer/Horn Combinations > 60 GHz

FREQ (GHz)	Wavelength	Gain dB	AF dB/m	Con Loss dB	Total dB	Limit dBuV/m	Limit dBuV/m
						@3m	@0.02m
60	0.0050	24	41.67	45.00	86.67	85.00	128.52
80	0.0038	24	44.17	45.00	89.17	85.00	128.52
100	0.0030	24	46.11	50.00	96.11	85.00	128.52
120	0.0025	24	47.69	50.00	97.69	85.00	128.52
140	0.0021	24	49.03	55.00	104.03	85.00	128.52
160	0.0019	24	50.19	55.00	105.19	85.00	128.52
180	0.0017	24	51.21	55.00	106.21	85.00	128.52
200	0.0015	24	52.13	60.00	112.13	85.00	128.52

Plots of the radiated spurious emissions measurements are shown in the following figures.

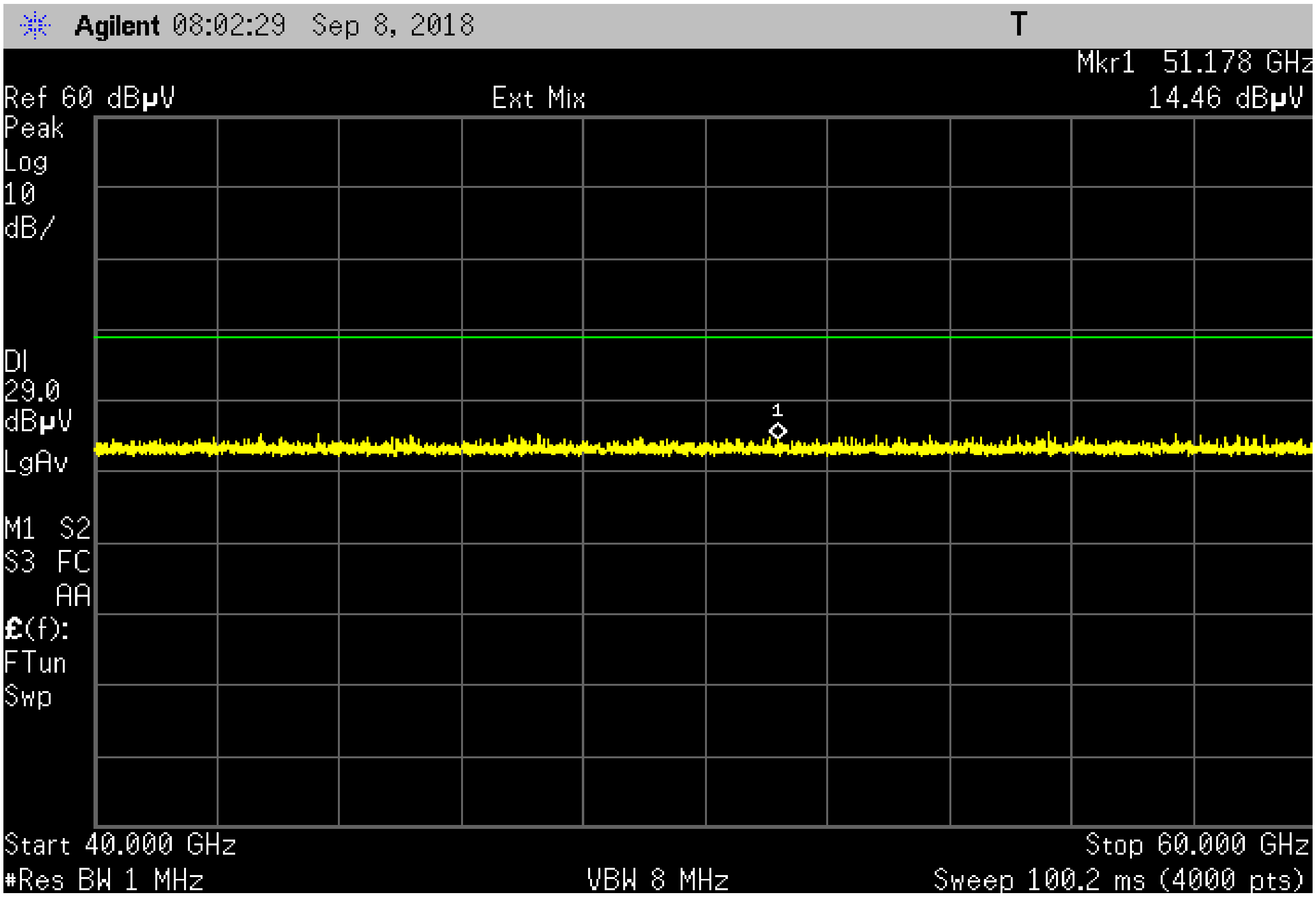

Figure 3. Spurious Emissions 40-60 GHz

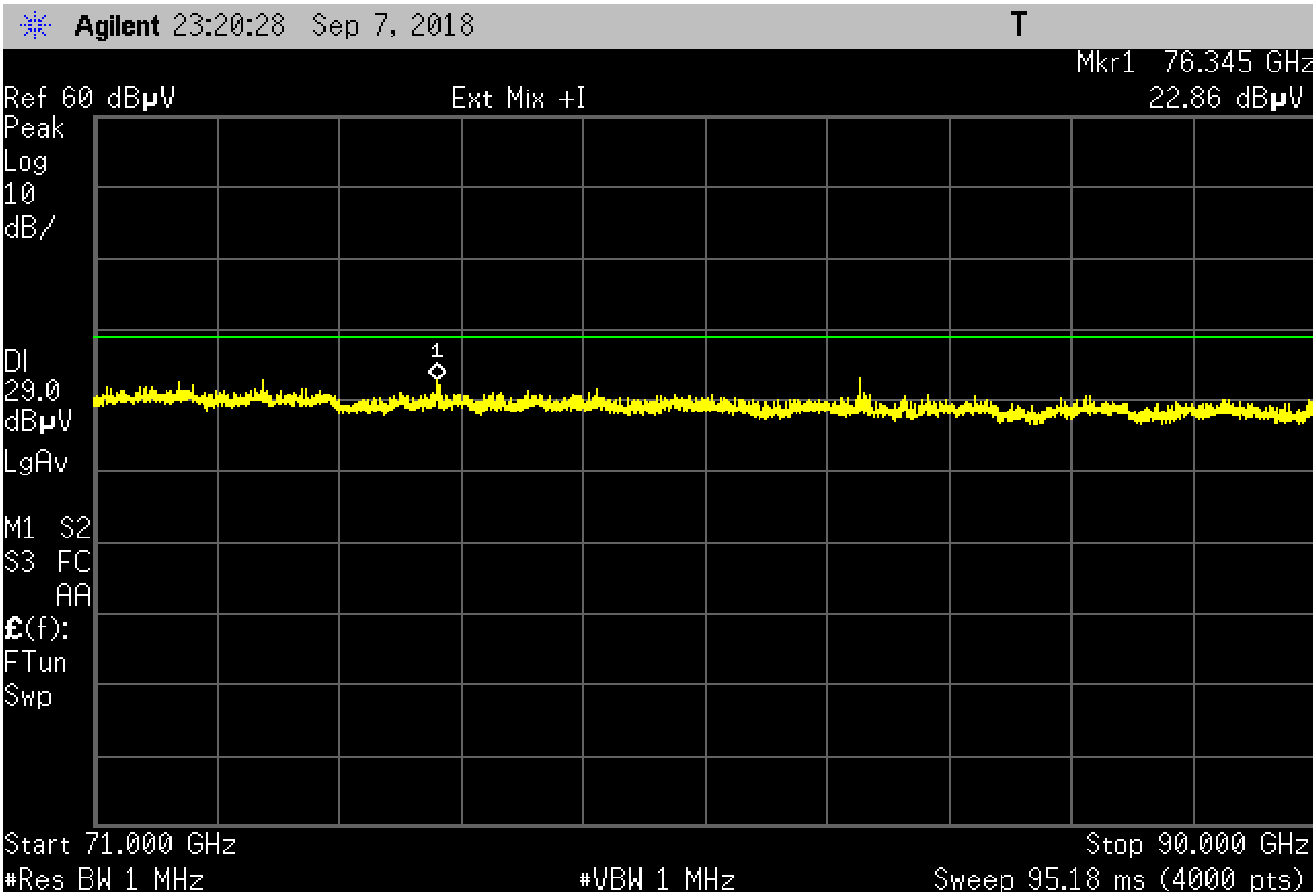

Figure 4. Spurious Emissions 71-90 GHz

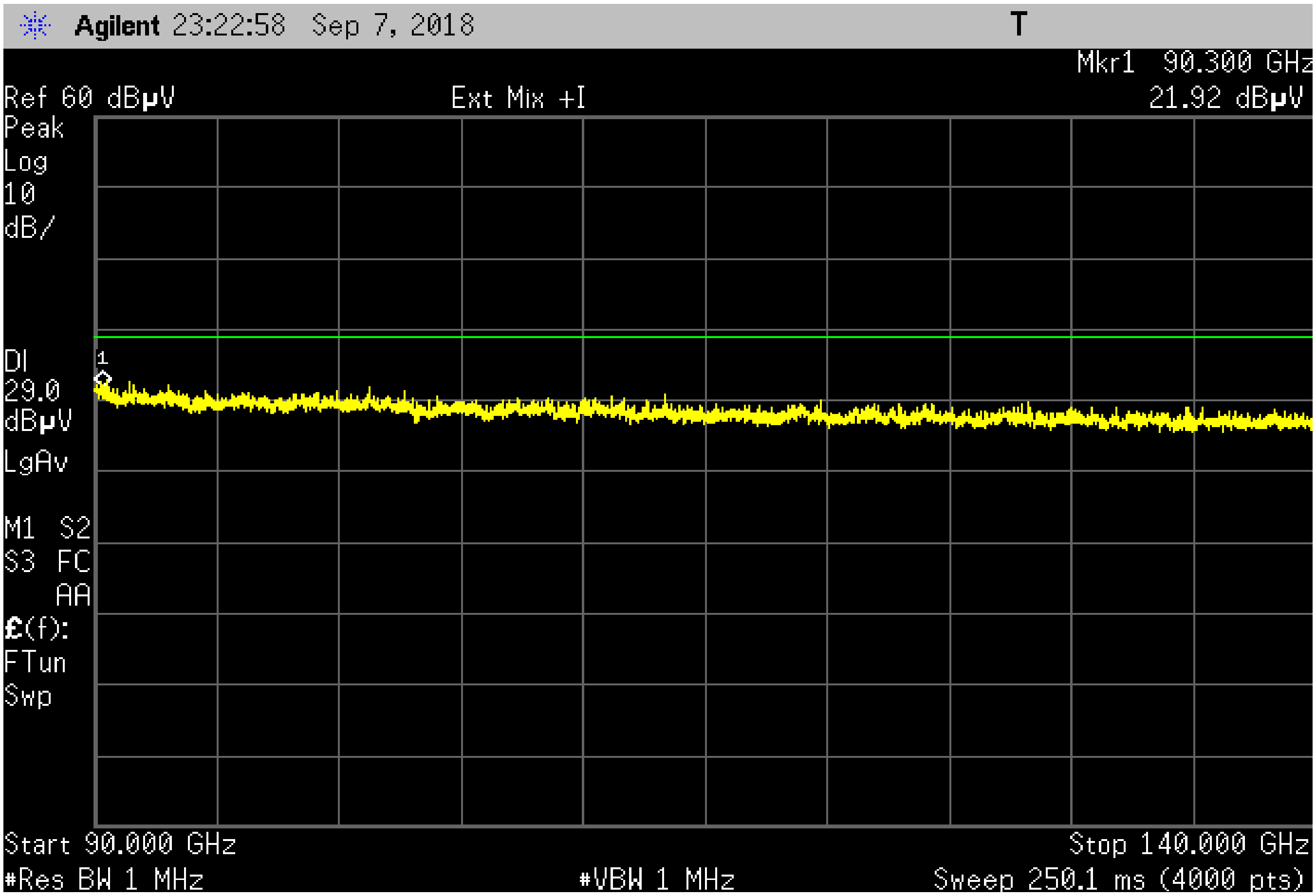

Figure 5. Spurious Emissions 90-140 GHz

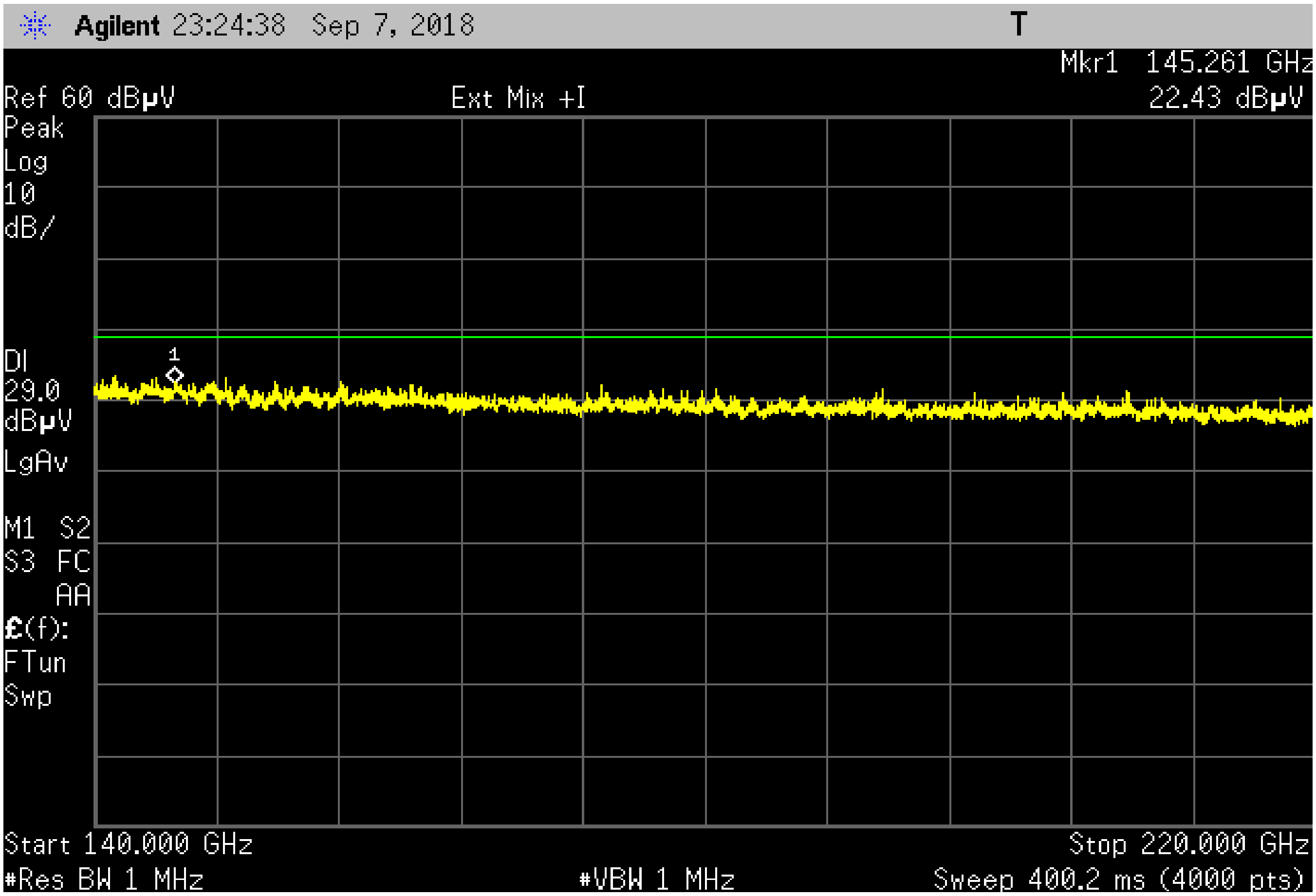

Figure 6. Spurious Emissions 140-220 GHz

No spurious emissions were detected, hence, the spurious emissions did not exceed the level of the fundamental emissions and were found to comply with the spurious emissions limits.

The worst-case radiated field strength emission at 145.3 GHz is the noise floor of the measurement system. The computed value of the field is:

@ 145.3 GHz (using the conversion losses from Table 7)

VdBuV/m + CONVERSION LOSS = 22.4+104 = 126.4 dBuV/m

Note that the imputed limit at the scan distance of 0.02 m is 128.5 dBuV/m, which is a margin of 2.1dB.

The equivalent field strength at 3 meters is 128.5 - 20log(3/0.02) = 82.8 dBuV/m.

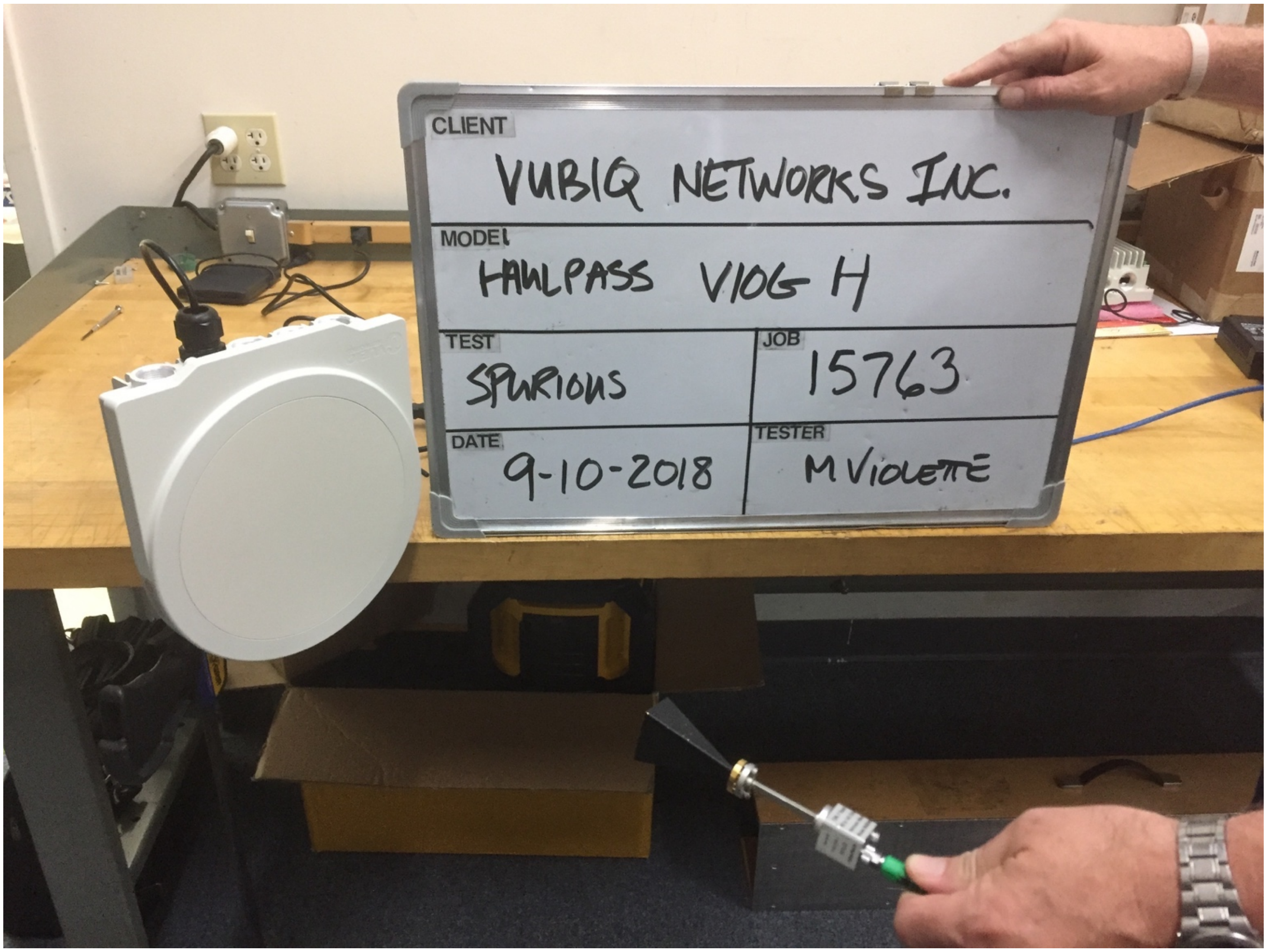

Figure 7. Spurious Emissions Measurement

4.3 §15.255 Operation within the band 57-71 GHz: Emissions Bandwidth

The requirements for emission bandwidth are stated below:

(1) Transmitters with an emission bandwidth of less than 100 MHz must limit their peak transmitter conducted output power to the product of 500 mW times their emission bandwidth divided by 100 MHz. For the purposes of this paragraph, emission bandwidth is defined as the instantaneous frequency range occupied by a steady state radiated signal with modulation, outside which the radiated power spectral density never exceeds 6 dB below the maximum radiated power spectral density in the band, as measured with a 100 kHz resolution bandwidth spectrum analyzer. The center frequency must be stationary during the measurement interval, even if not stationary during normal operation (e.g., for frequency hopping devices).

The emissions were measured in each of the modulation modes. The use of the "signal identification" function precludes the use of the TRACE function on the spectrum analyzer because of the system design. Hence, "MAX HOLD" and "VIEW" functions are not available in this mode.

If we turn Signal ID OFF, then artifacts appear in the signal and the trace representation is not valid.

Trace Menu unavailable when Signal ID is ON

The nature of the signal is such that the modulation envelope is constantly changing, so a snapshot of the data are provided.

The following is a summary of the 6dB bandwidth for the various modulations types:

Table 8. Summary of 6dB Bandwiths

Modulation	Data Rate Mbd	6 dB Bandwidth MHz
BPSK	400	392.3
BPSK2	800	250.6
BPSK3	1600	354.1
QPSK	1600	352.6
8PSK	1600	352.6
16QAM	1600	348.8
32QAM	1600	350.3
64QAM	1600	384.1
128QAM	1600	459.9

Sample plots of various modulations provided below. The market-delta function on the analyzer display is a best approximation of the 6dB emission bandwidths given the nature of the signal and the limitations of the analyzer.

All emissions in a 6dB bandwidth were measured to **be in excess of 100 MHz**, hence, no power limitations apply to the system.

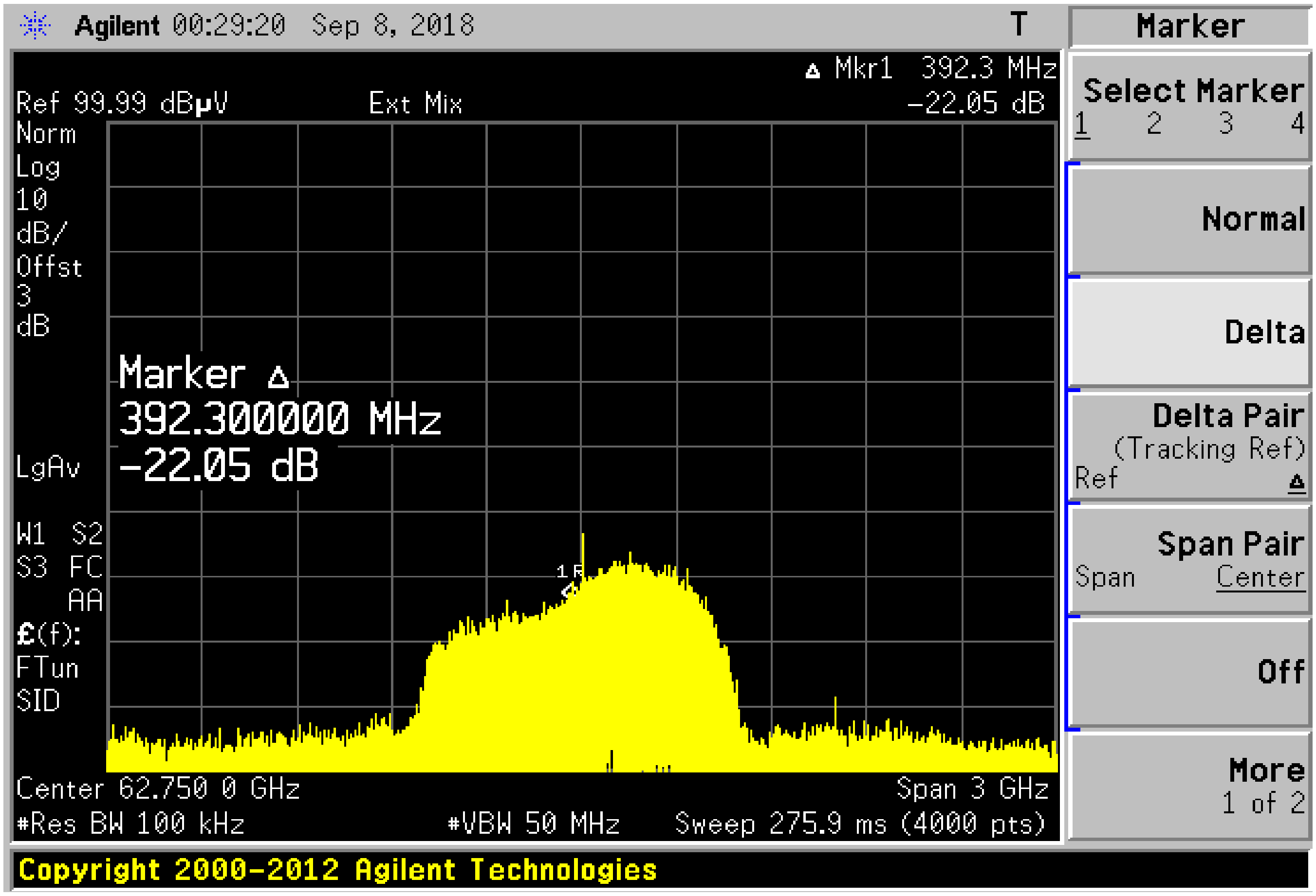

Figure 8. Emission Bandwidth BPSK

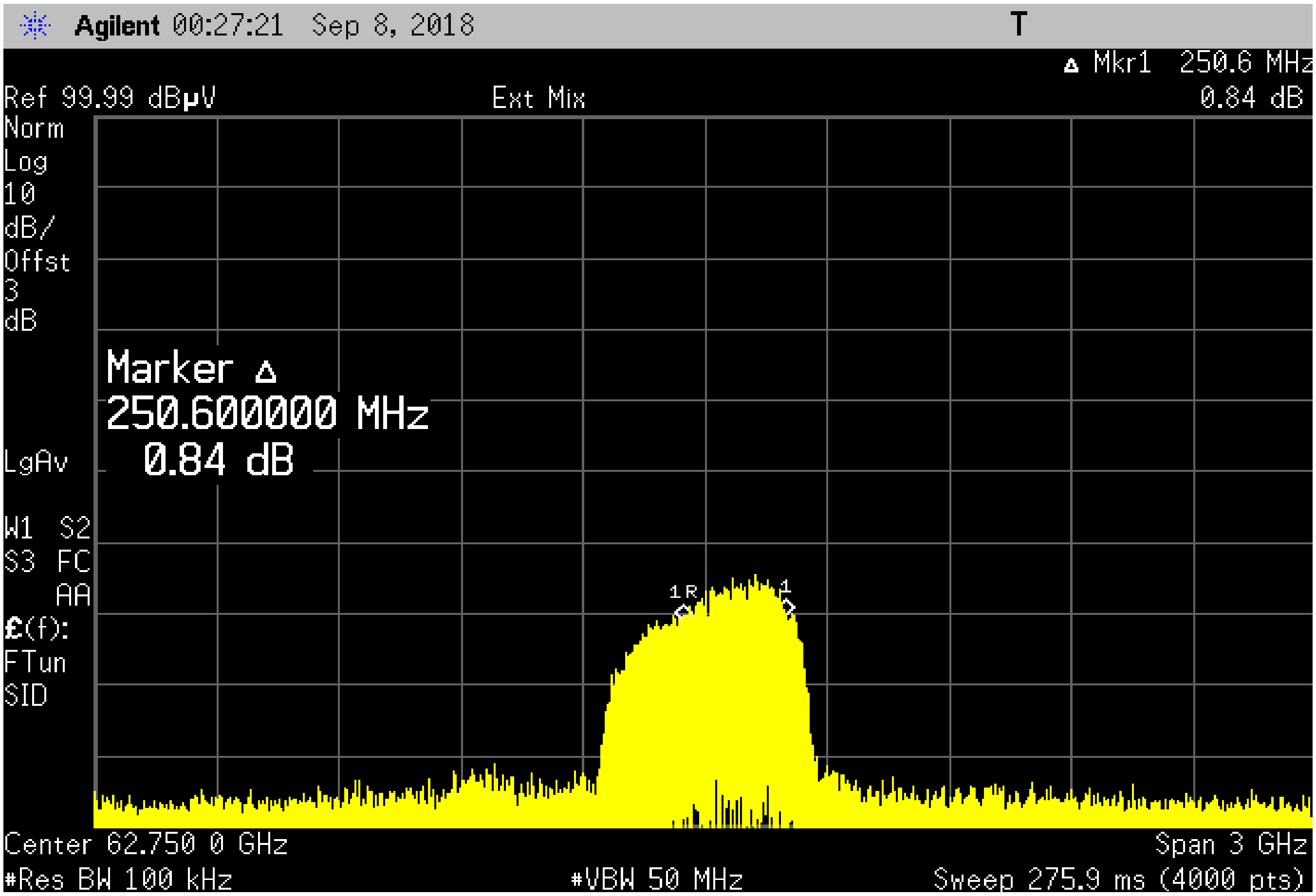

Figure 9. Emission Bandwidth BPSK2

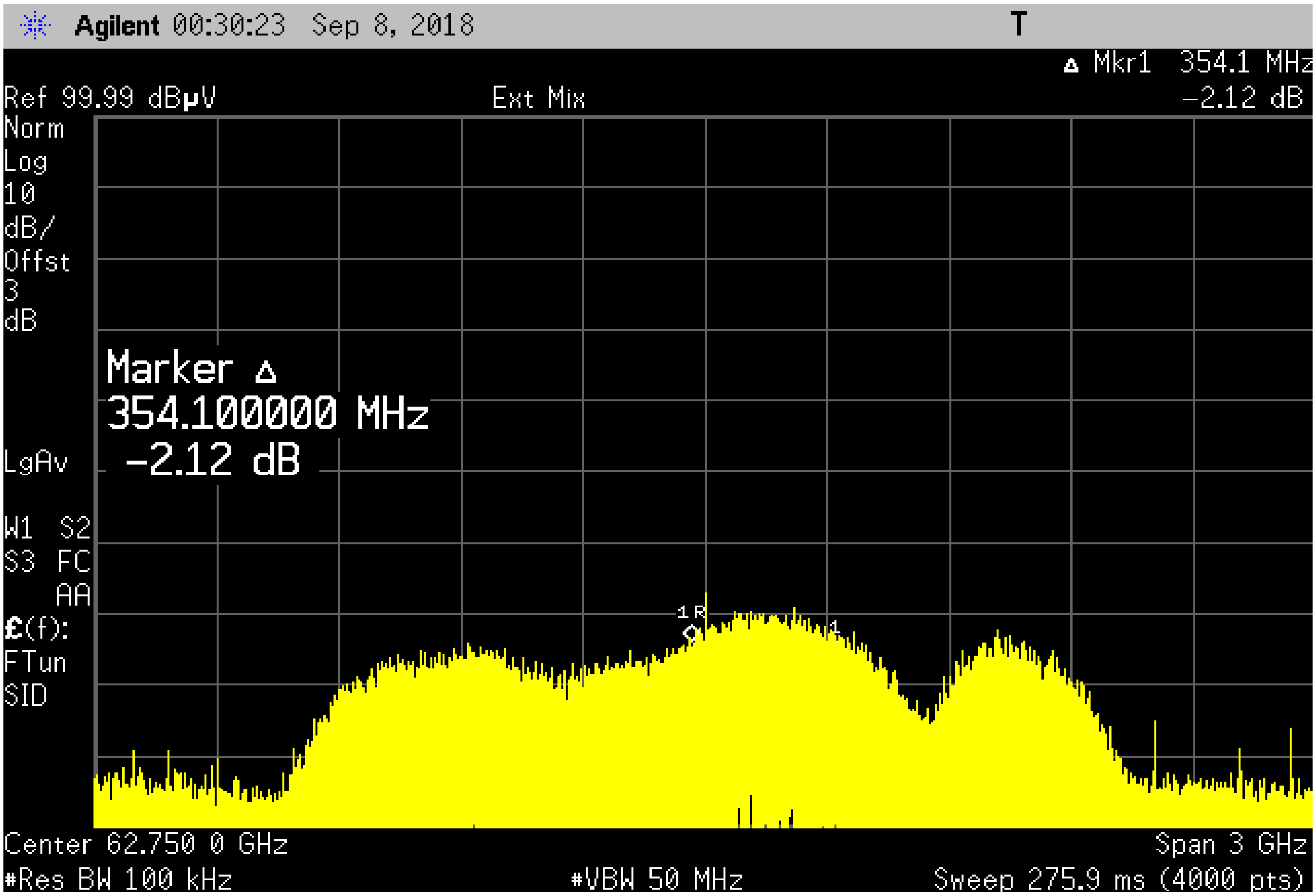

Figure 10. Emission Bandwidth BPSK3

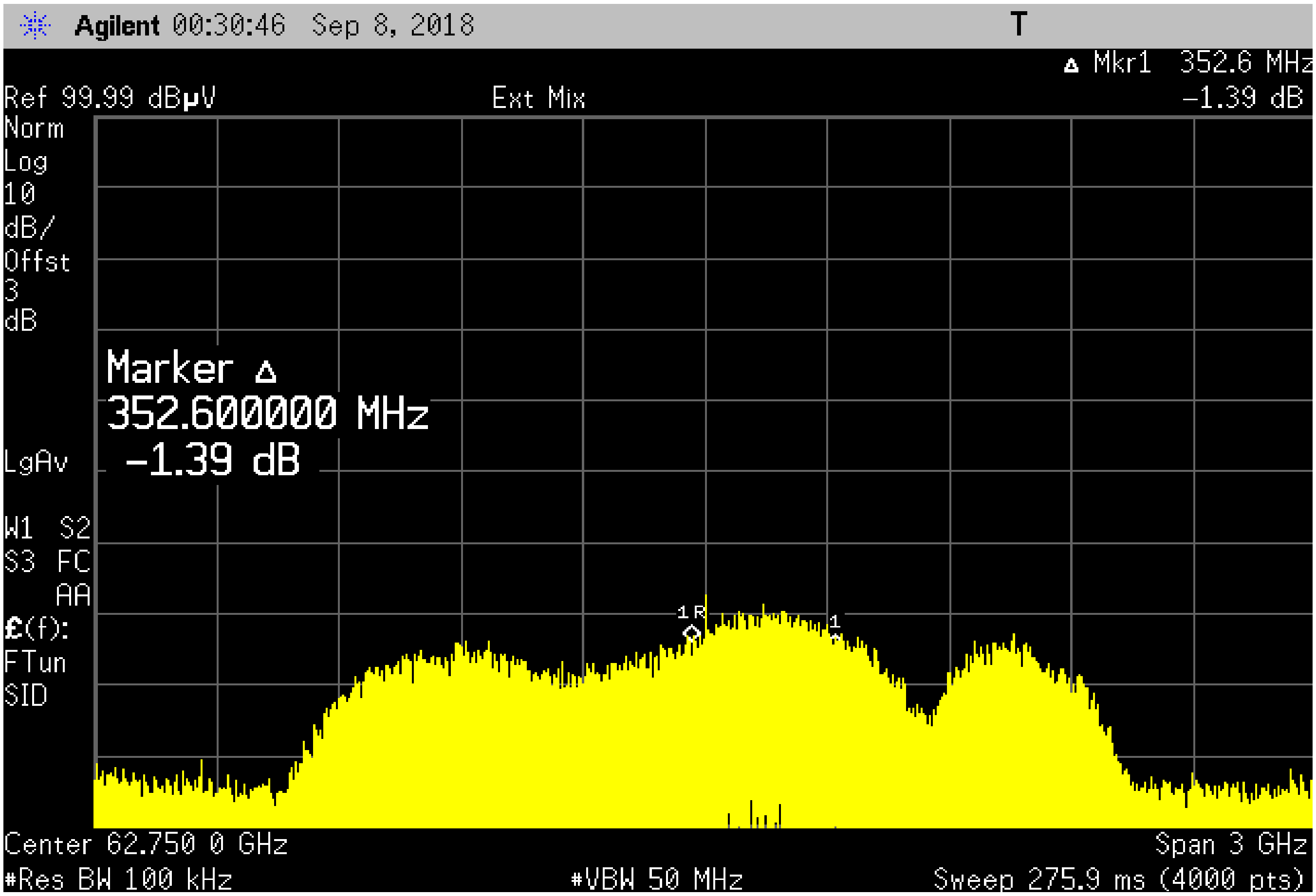

Figure 11. Emission Bandwidth QPSK

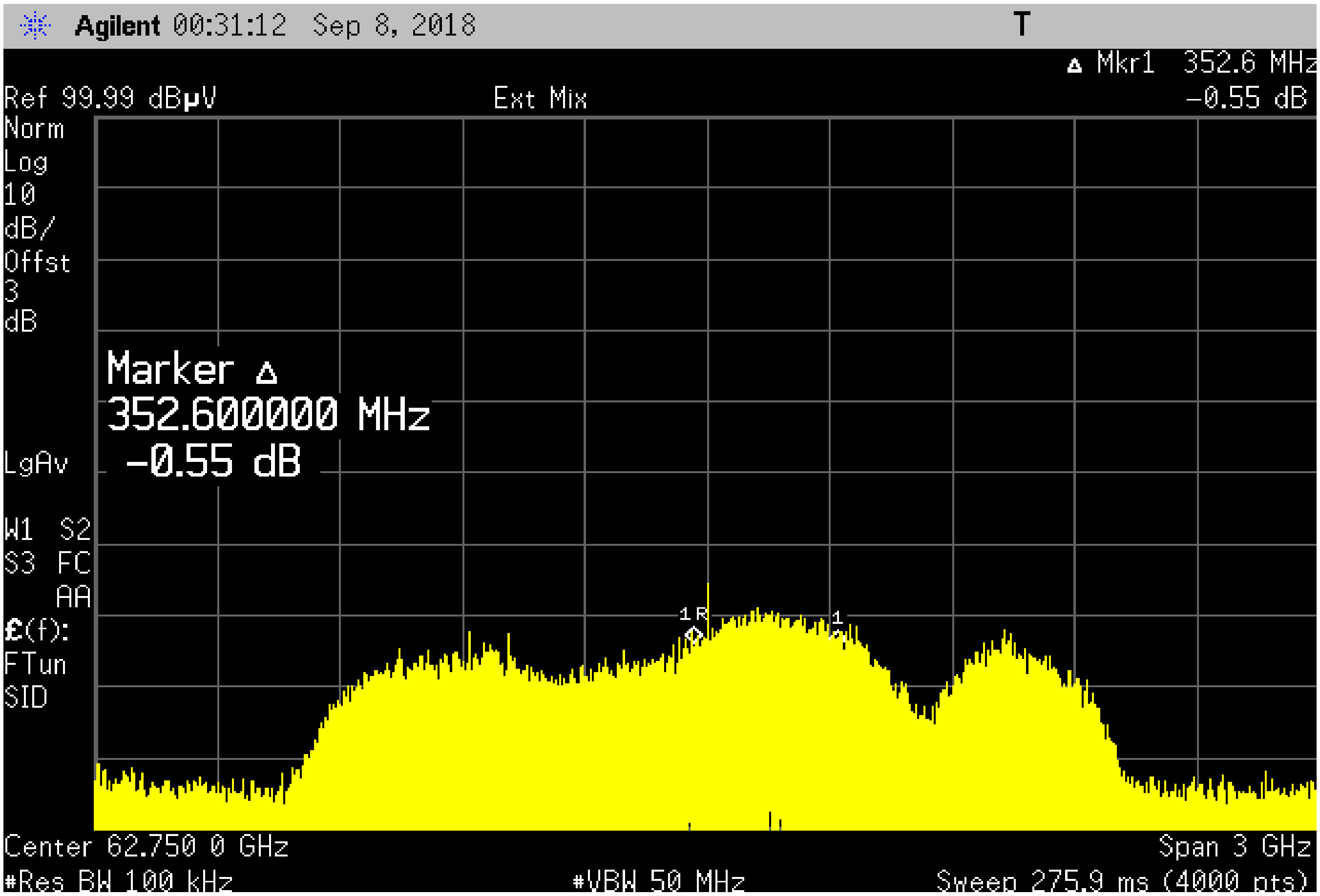

Figure 12. Emission Bandwidth 8PSK

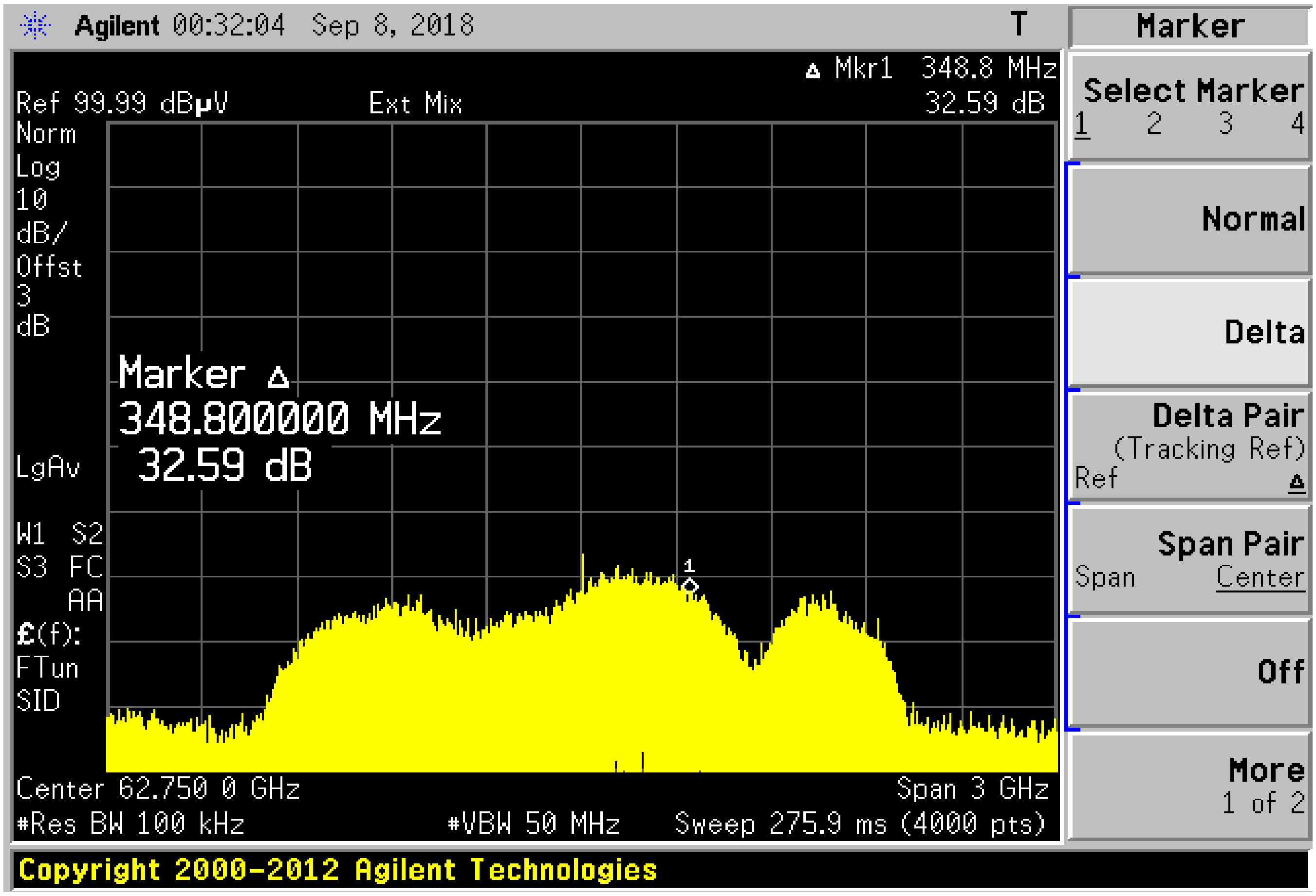

Figure 13. Emission Bandwidth 16QAM

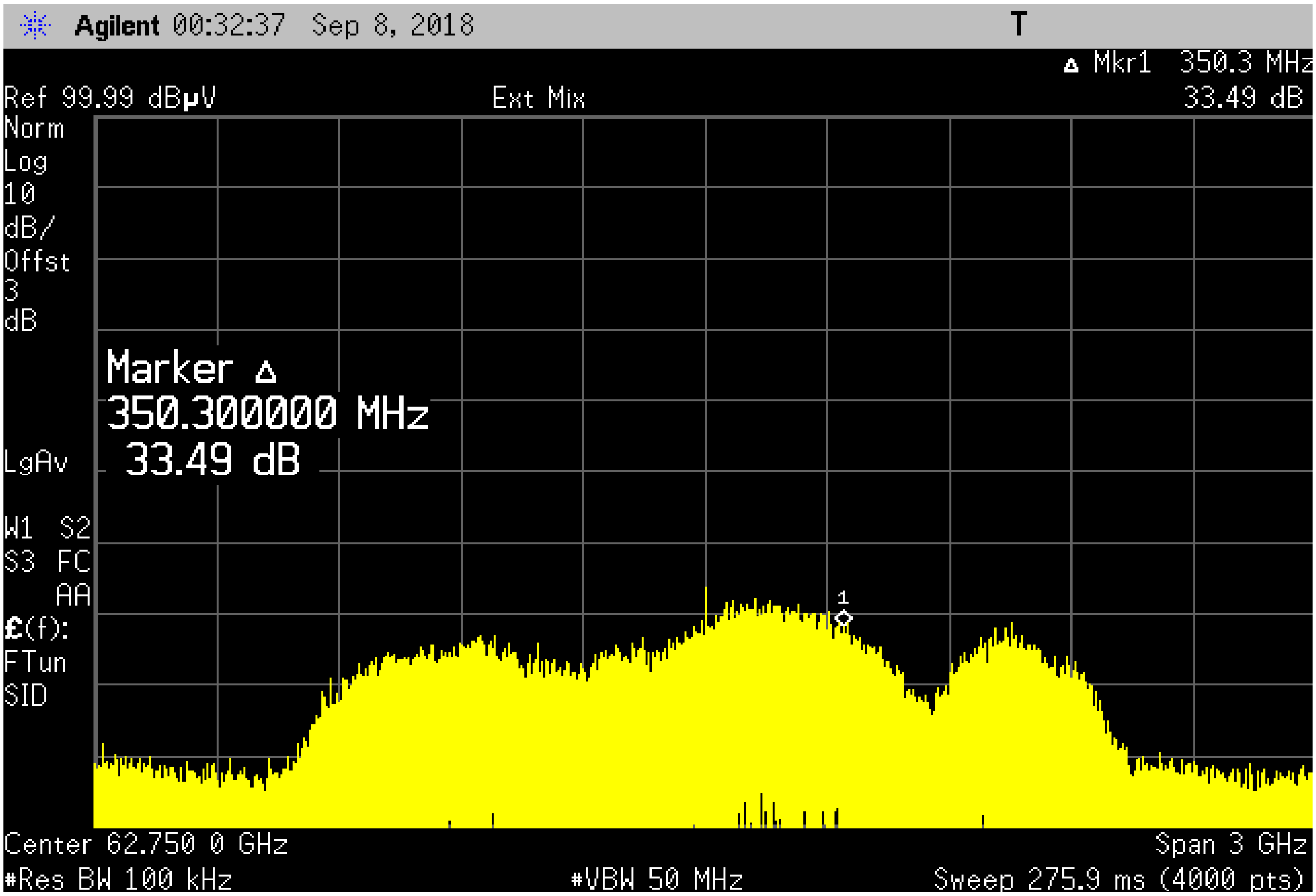

Figure 14. Emission Bandwidth 32QAM

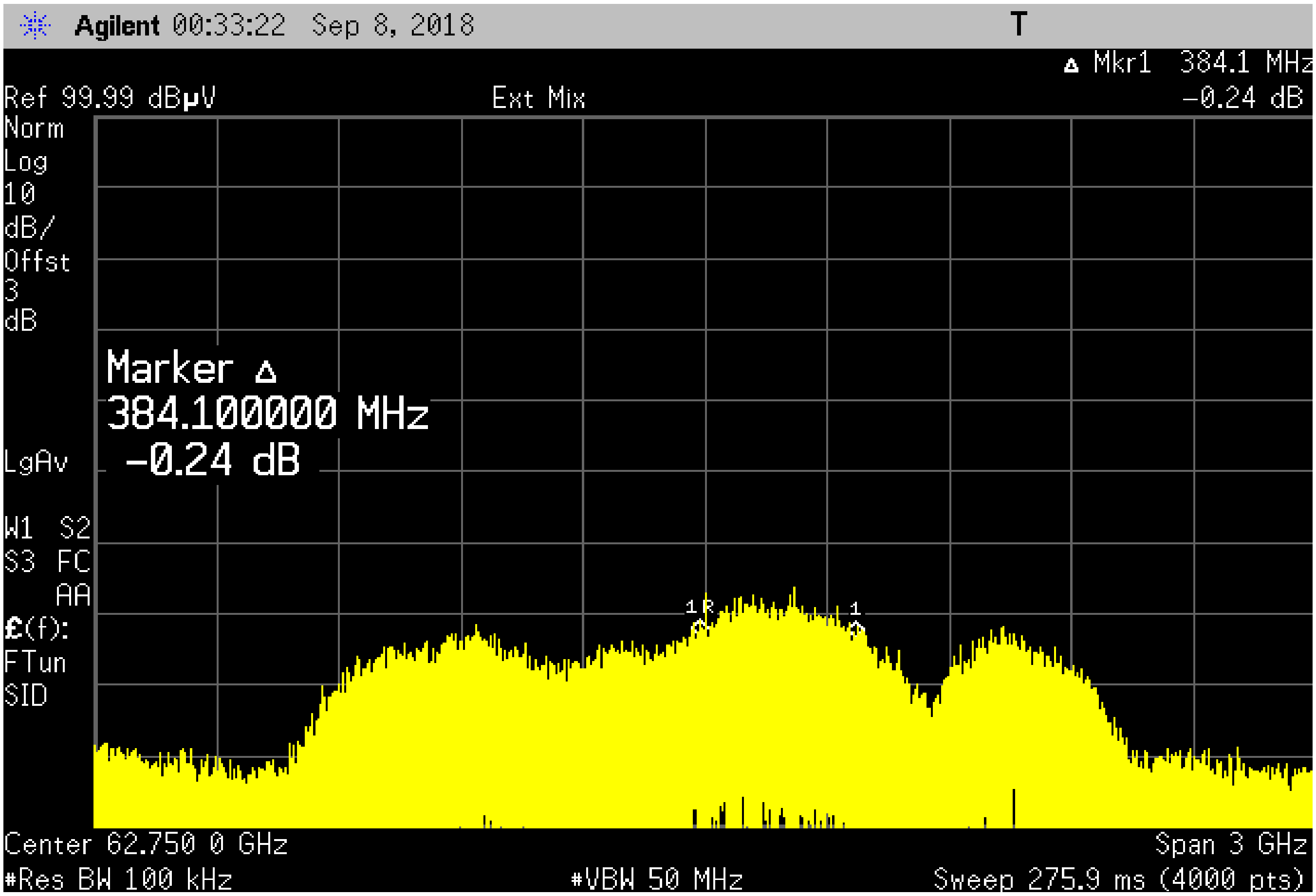

Figure 15. Emission Bandwidth 64QAM

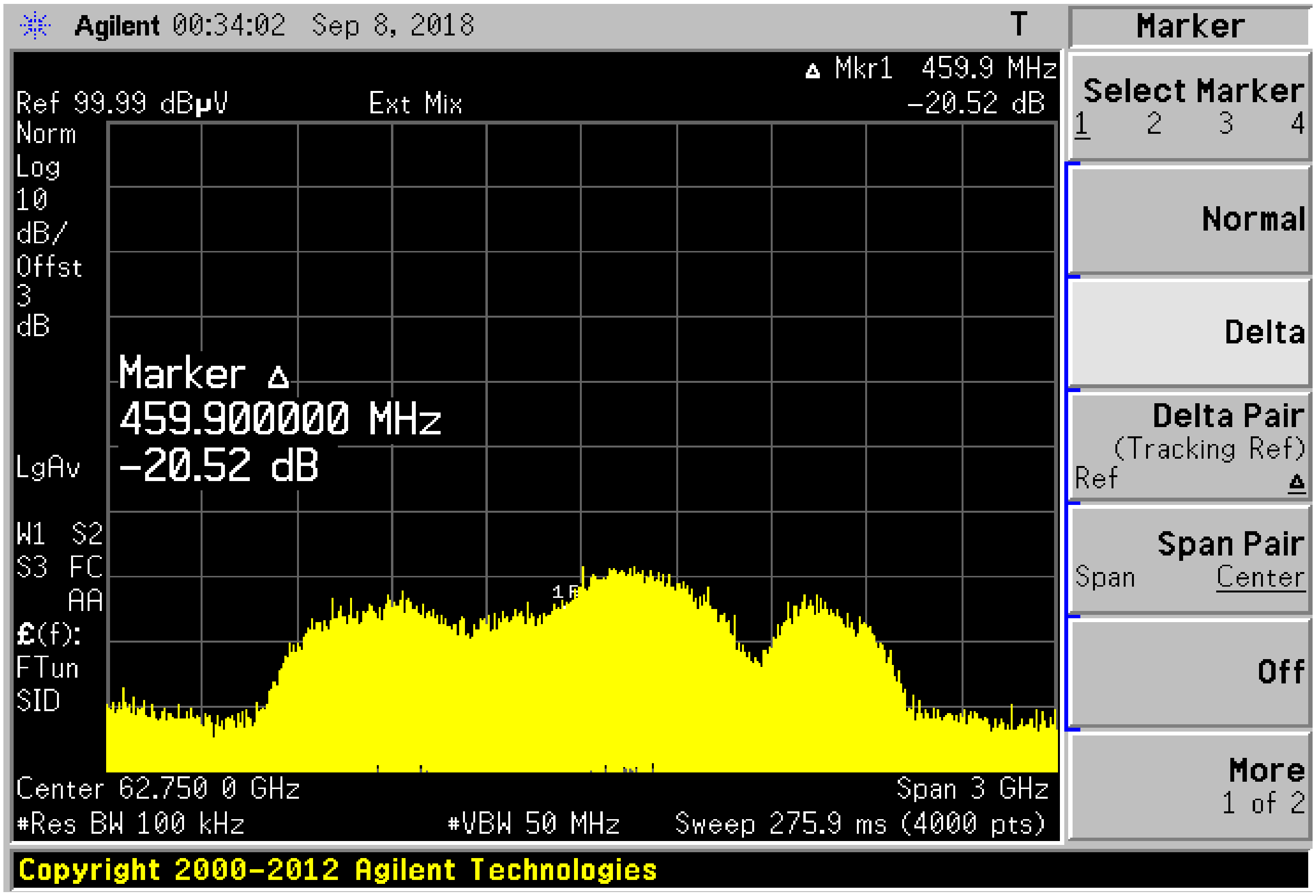

Figure 16. Emission Bandwidth 128 QAM

Further, measurements were made of the 99% bandwidth and the band edge compliance are verified by by a conducted measurement. The data are shown below. The band edge shows compliance with the 90pW/cm^2 by converting the power density to an equivalent conducted power from an isotropic source.

This calculation derives an equivalent power limit of -9.92 dBm. This is compared with the conducted power at the band edge.

$P = P_d \, 4 \pi D^2 / G$ Assume G = 1 (isotropic)

Pd	D	Pmax	Pmax	Pmax
(pW/cm^2)	(cm)	(W)	(mW)	(dBm)
90	300	0.000102	0.102	-9.92

The following plots show the 99% BW with a marker C at the bandedge. The following table shows the results of the equivalent field strength as represented as a conducted power.

Table 9. Band Edge Measurements Summary

TX Freq (GHz)	Filename (.scc)	Mod (type)	Sym Rate (Mbaud)	Spurious @ 64 GHz (dBm)	Limit (dBm)	Margin dBm
62.75	high0	128 QAM	1599	-30.86	-9.90	20.96
62.75	high1	64 QAM	1599	-33.86	-9.90	23.96
62.75	high2	32 QAM	1599	-32.86	-9.90	22.96
62.75	high3	16 QAM	1599	-32.86	-9.90	22.96
62.75	high4	8 PSK	1599	-32.86	-9.90	22.96
62.75	high5	QPSK	1599	-36.86	-9.90	26.96
62.75	high6	BPSK	1599	-34.86	-9.90	24.96
62.75	high7	BPSK	800	-39.86	-9.90	29.96
62.75	high8	BPSK	400	-41.86	-9.90	31.96

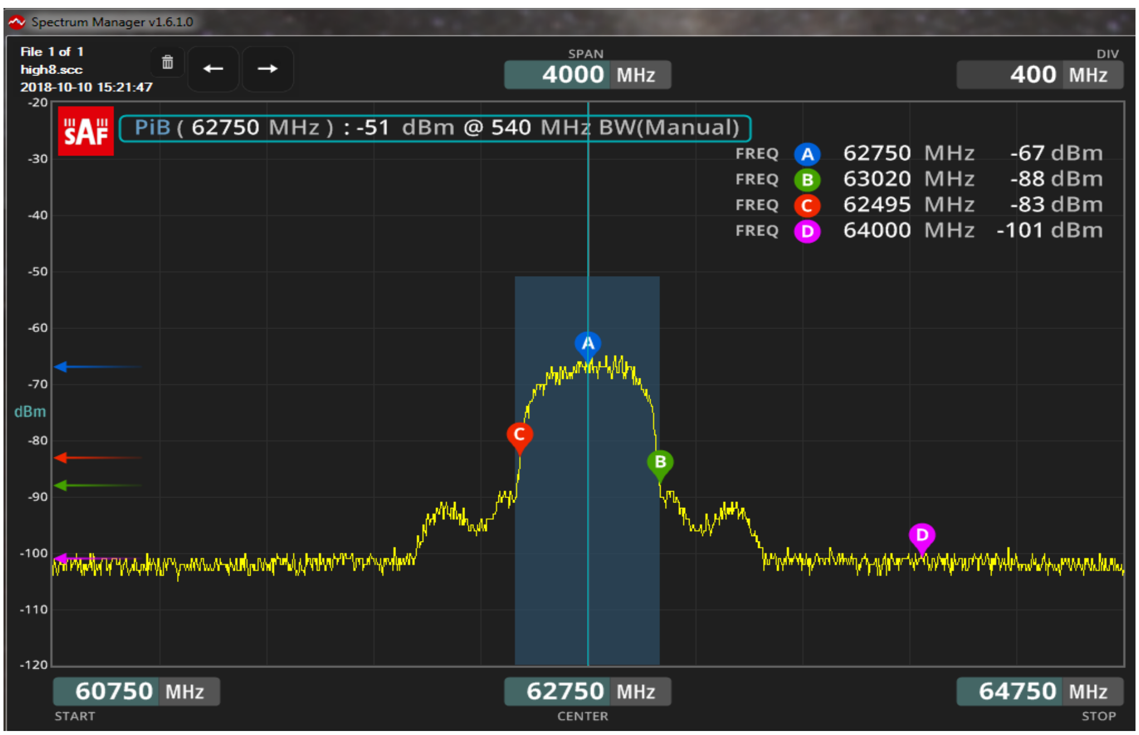

Figure 17. 99% Bandwidth BPSK

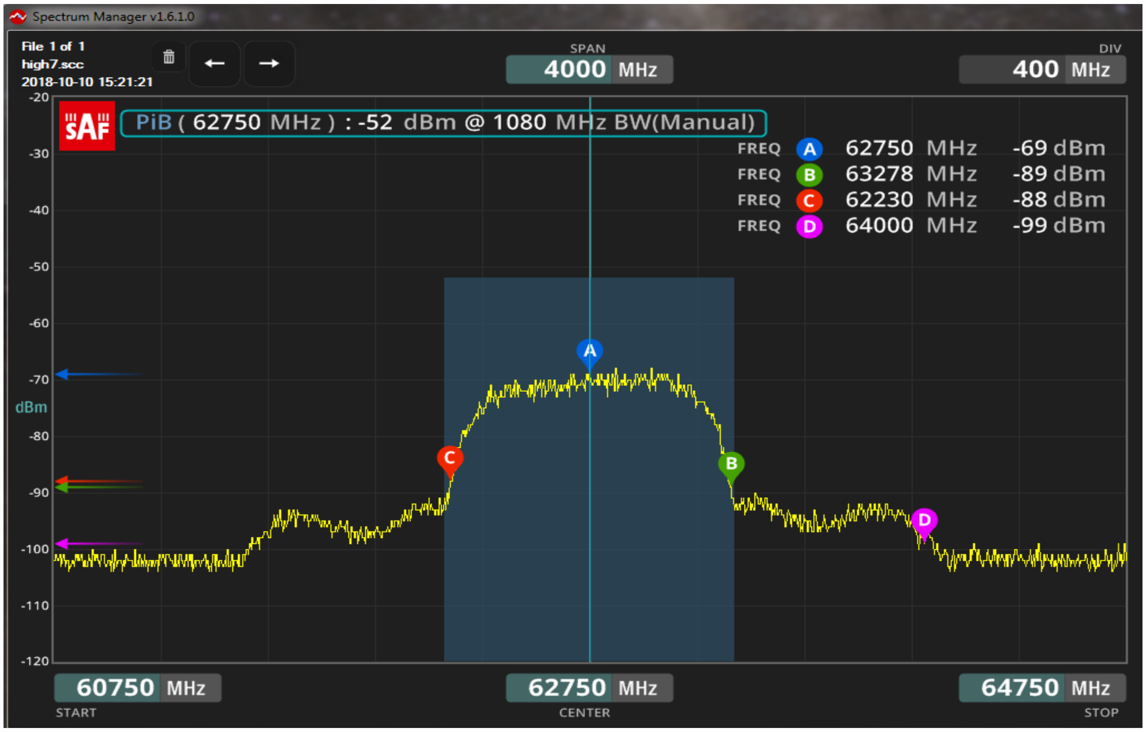

Figure 18. 99% Bandwidth BPSK2

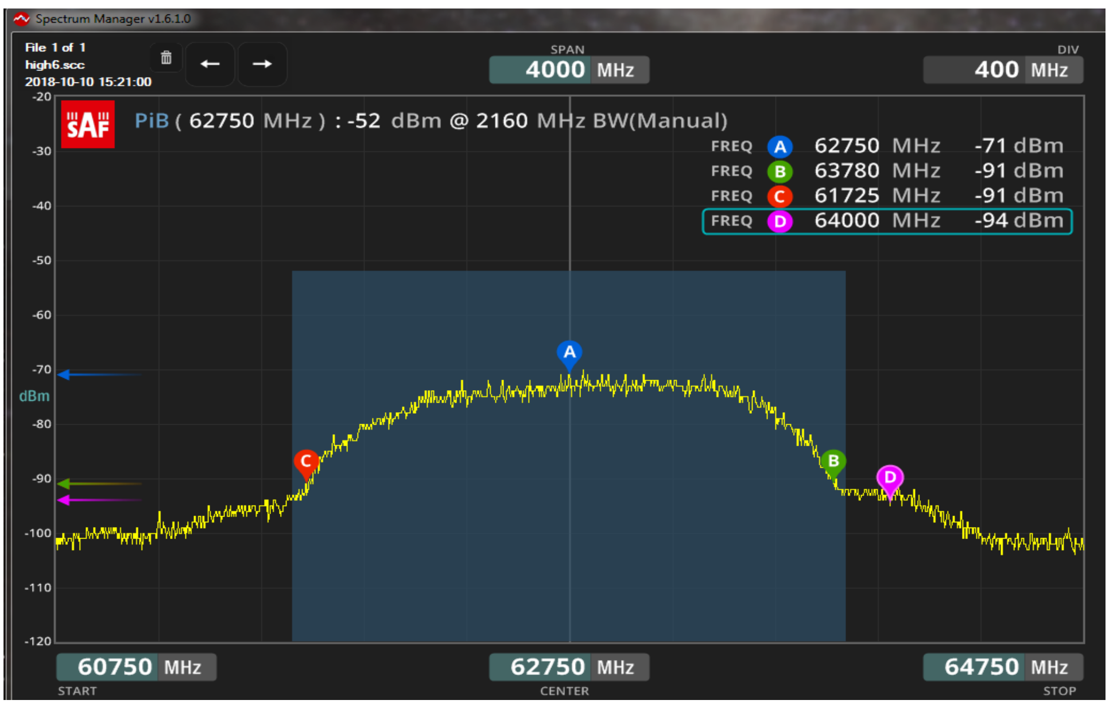

Figure 19. 99% Bandwidth BPSK3

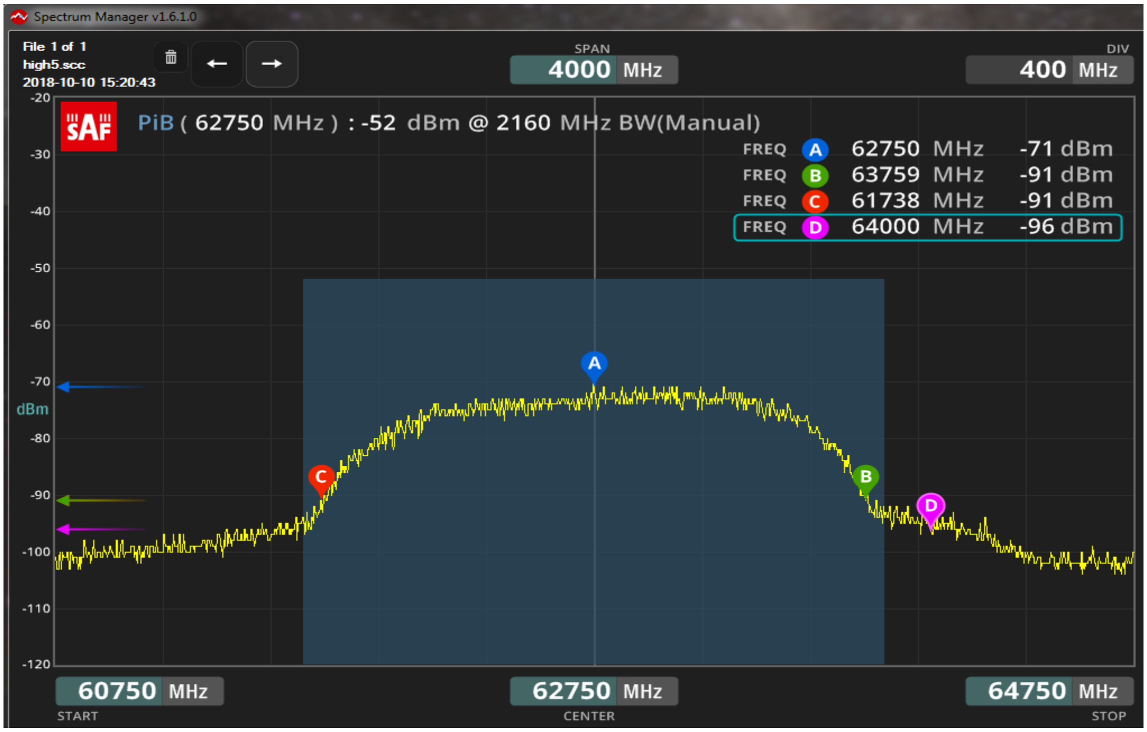

Figure 20. 99% Bandwidth QPSK

Figure 21. 99% Bandwidth 8PSK

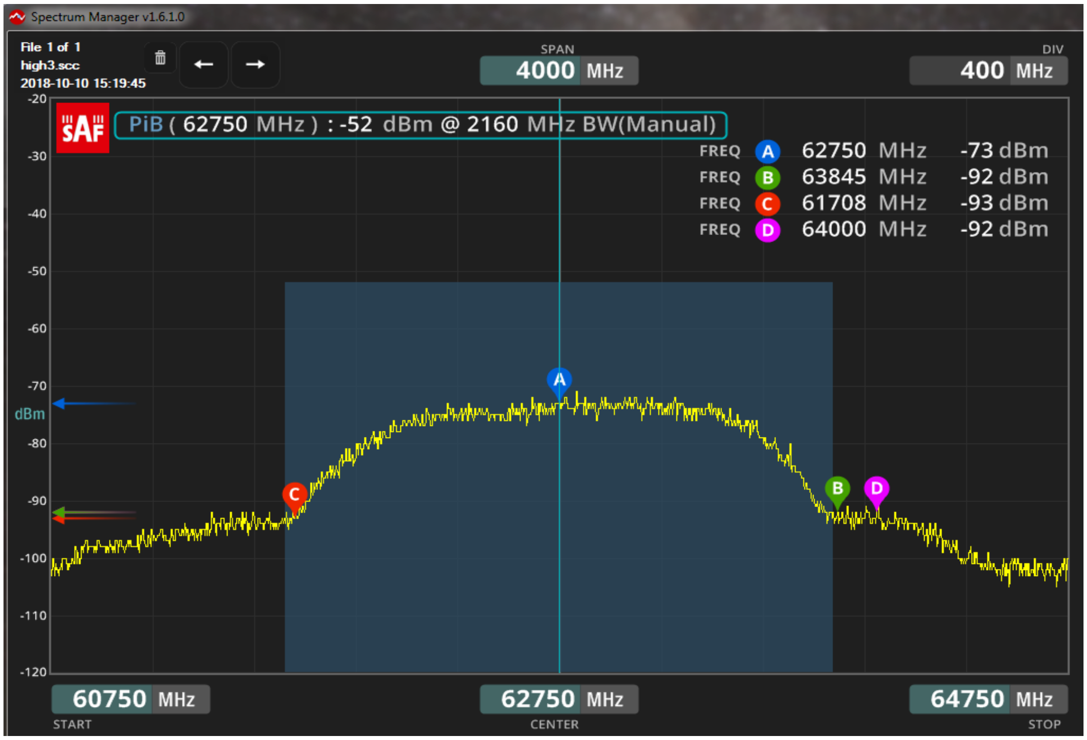

Figure 22. 99% Bandwidth 16 QAM

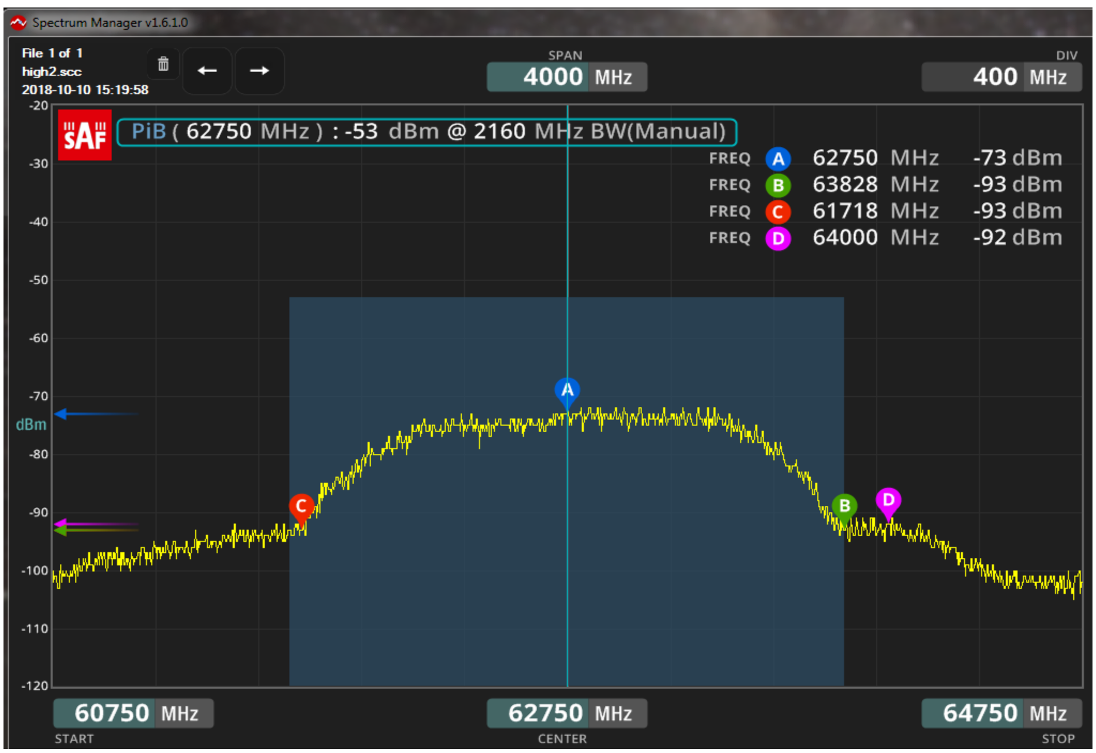

Figure 23. 99% Bandwidth 32 QAM

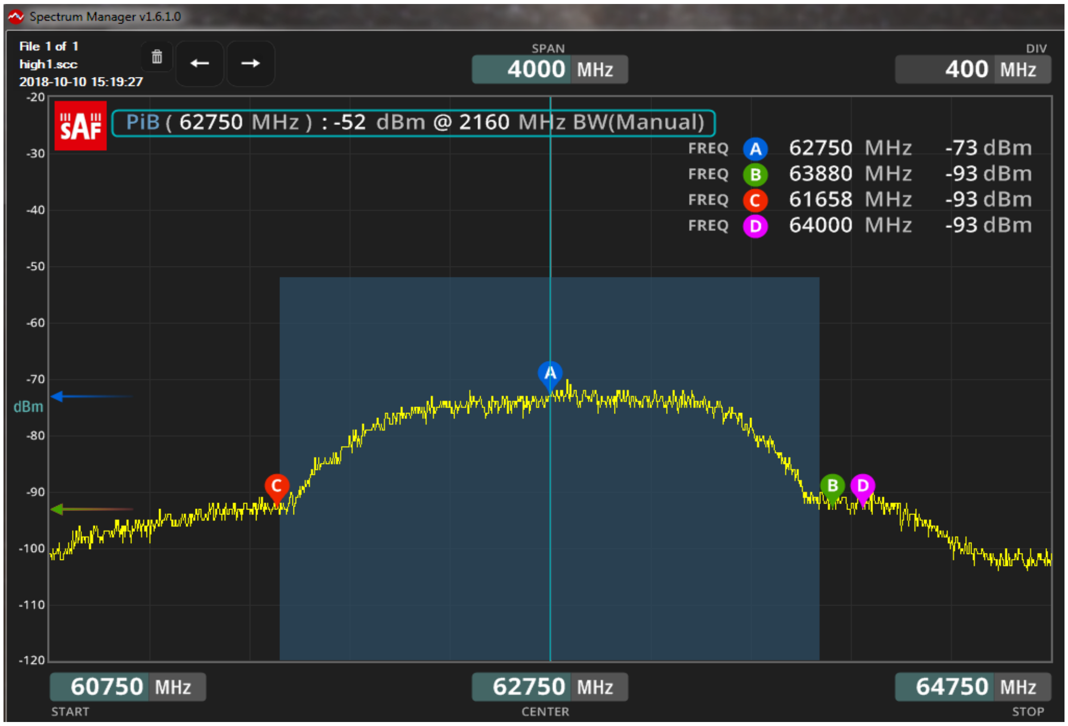

Figure 24. 99% Bandwidth 64QAM

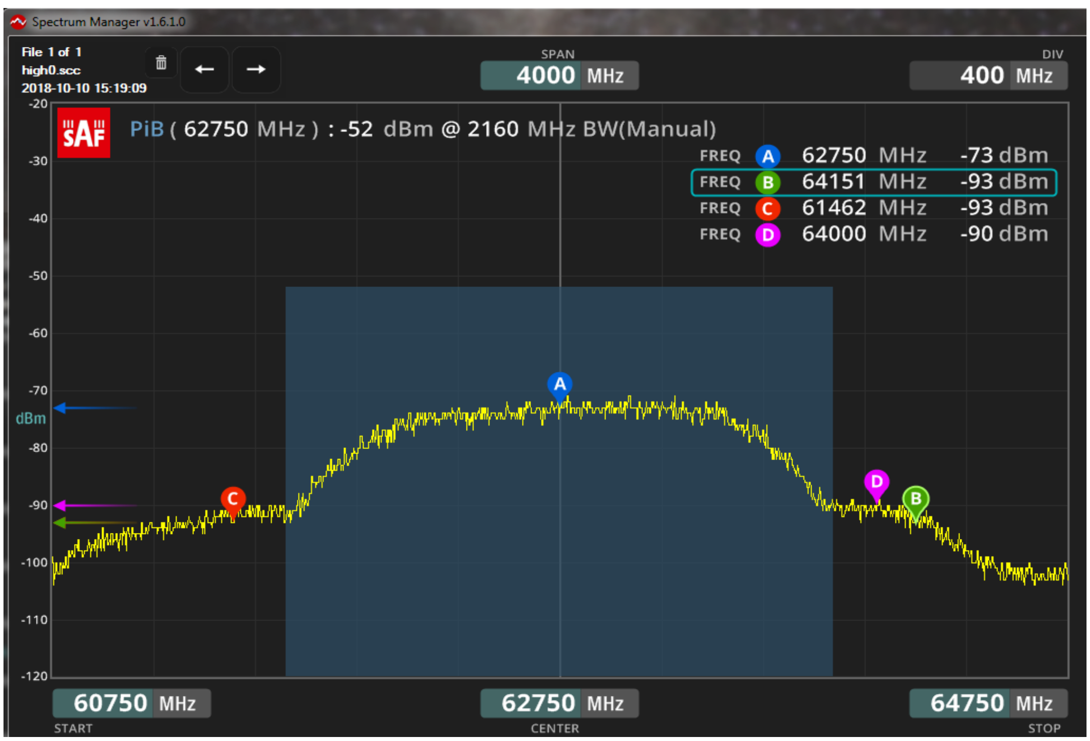

Figure 25. 99% Bandwidth 128QAM

4.4 §15.255 Operation within the band 57-71 GHz: Frequency Stability

Frequency stability requirements are as stated below:

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

The equipment specification calls for an operating range of -40C to +55C. Temperature stability measurements were performed over this range. Measurements were performed at the following temperatures:

Ambient: (24C), 55C, 40C, 30C, 20C, 10C, 0C, -10C, -20C, -30C, -40C

Measurement of the signal was performed at ambient temperature with a supply voltage variation of -15% and 115%. The resulst are show in the following figures.

The radio was then setup inside a temperature chamber and the temperature set to 50C and the spectrum sampled. The system was then brought to 40C and the spectrum re-measured. This was repeated for increments of 10C to the lower specified operating temperature of -40C.

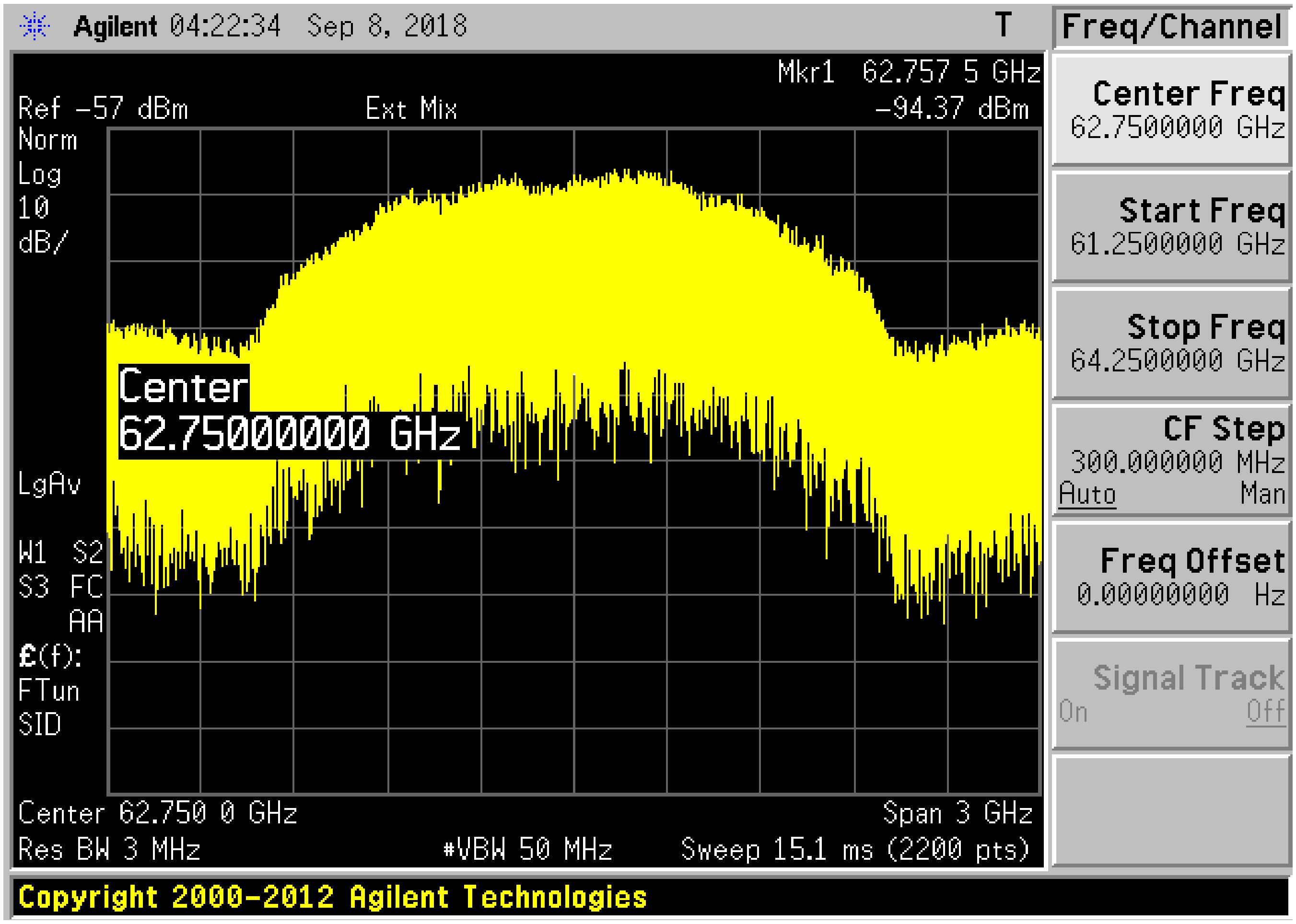

Figure 26. Frequency Stability 24C, 125VAC Input

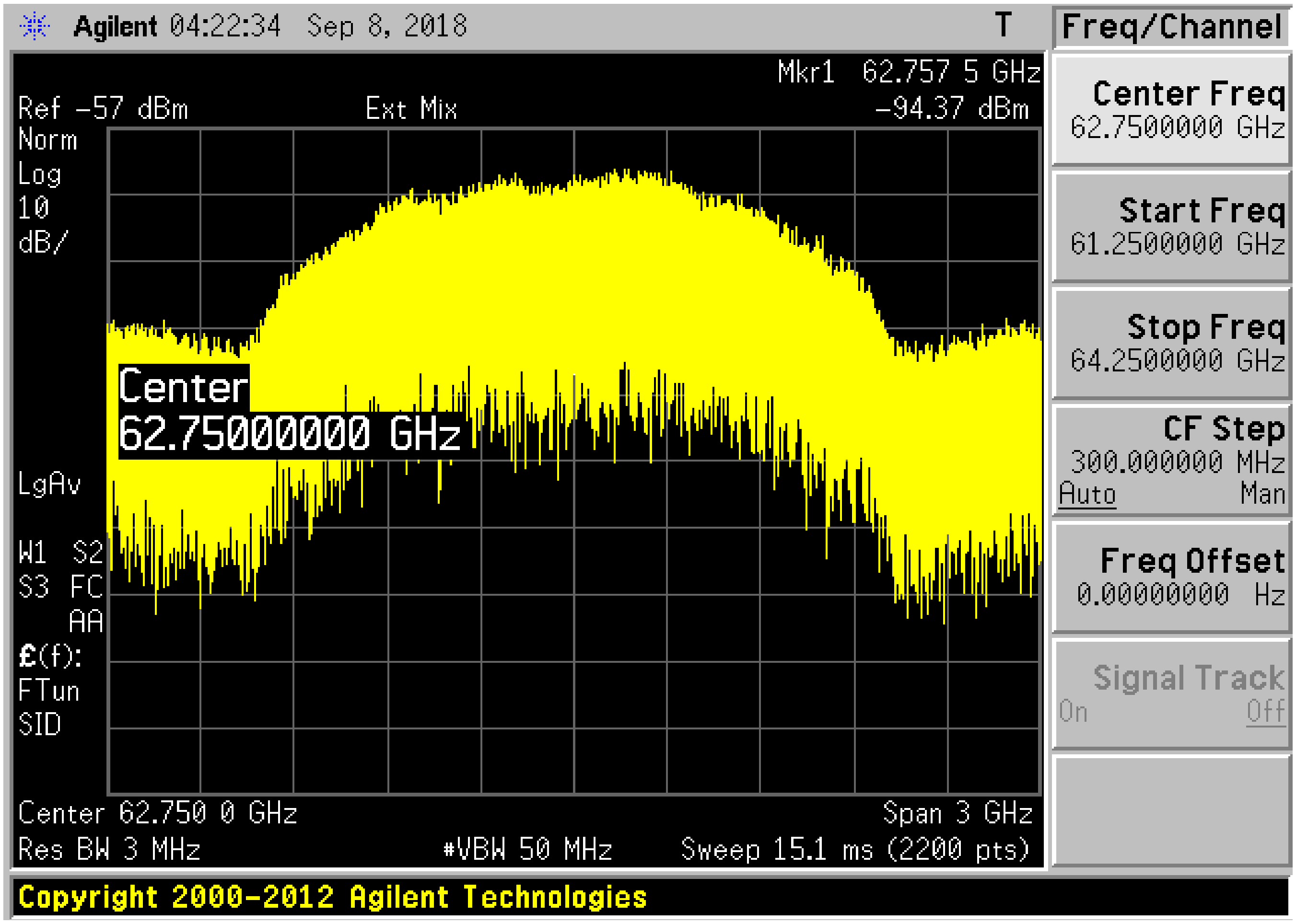

Figure 27. Frequency Stability 24C, 102VAC Input

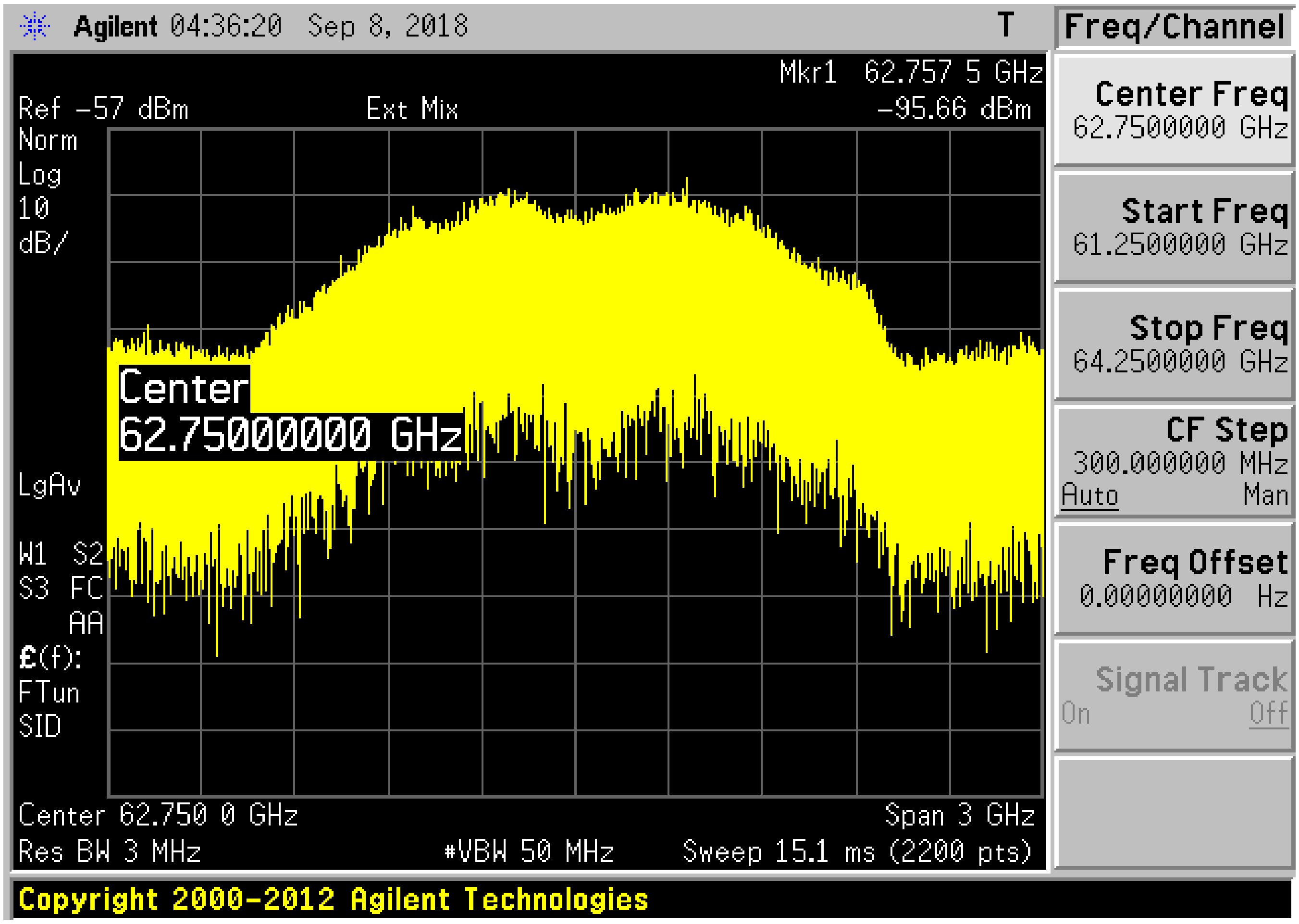

Figure 28. Frequency Stability 24C, 138VAC Input

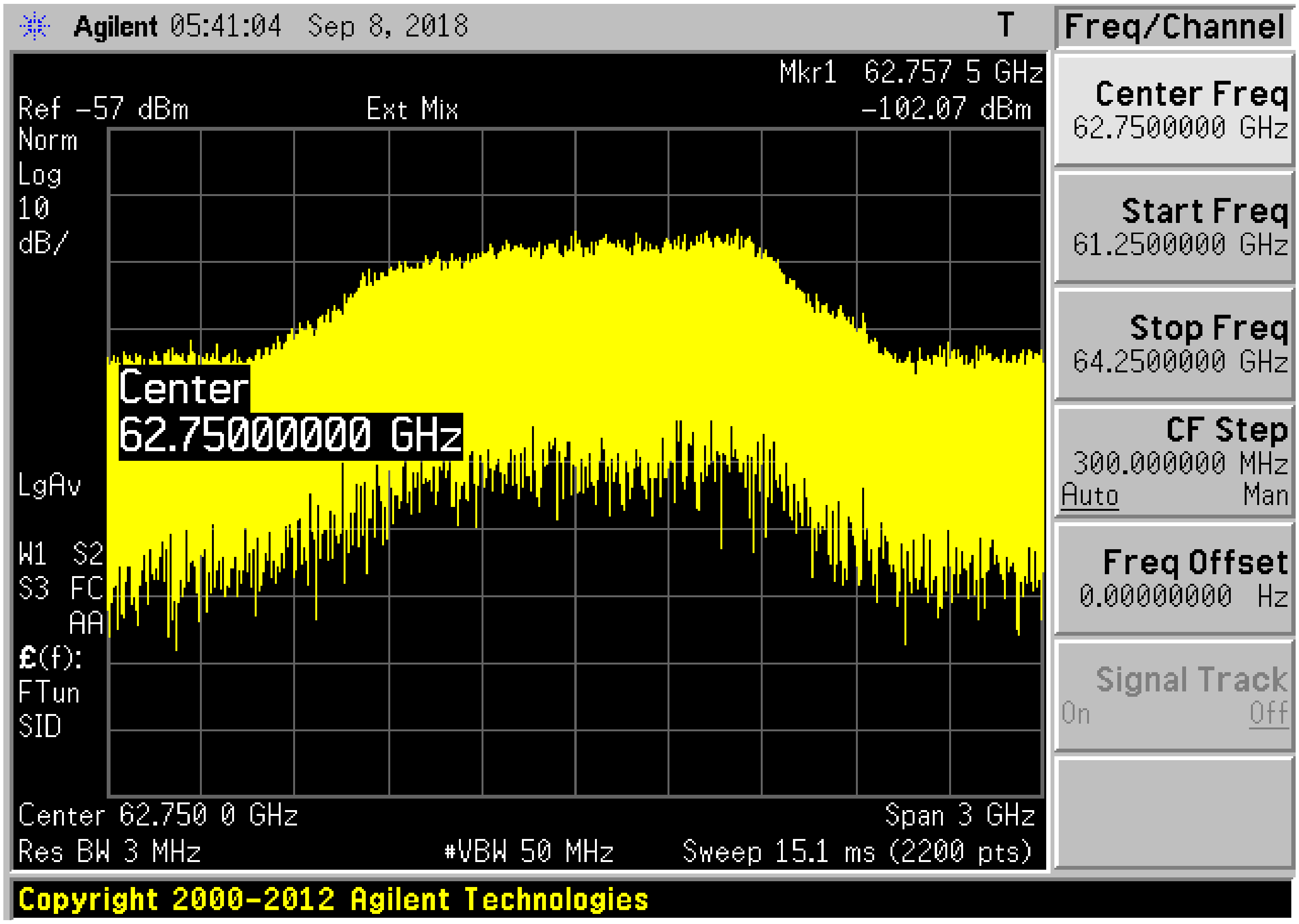

Figure 29. Frequency Stability 55C, 125VAC Input

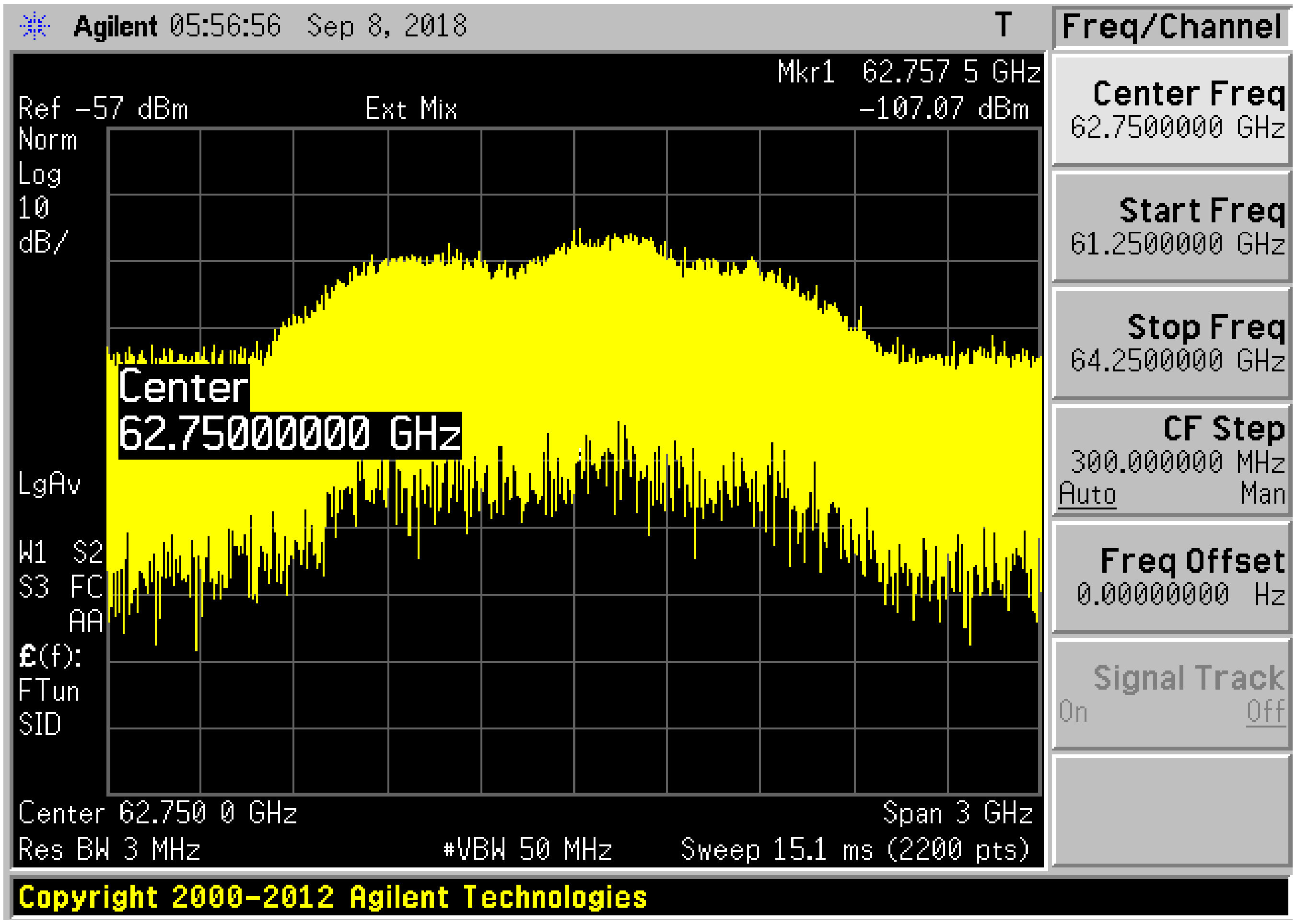

Figure 30. Frequency Stability 40C, 125VAC Input

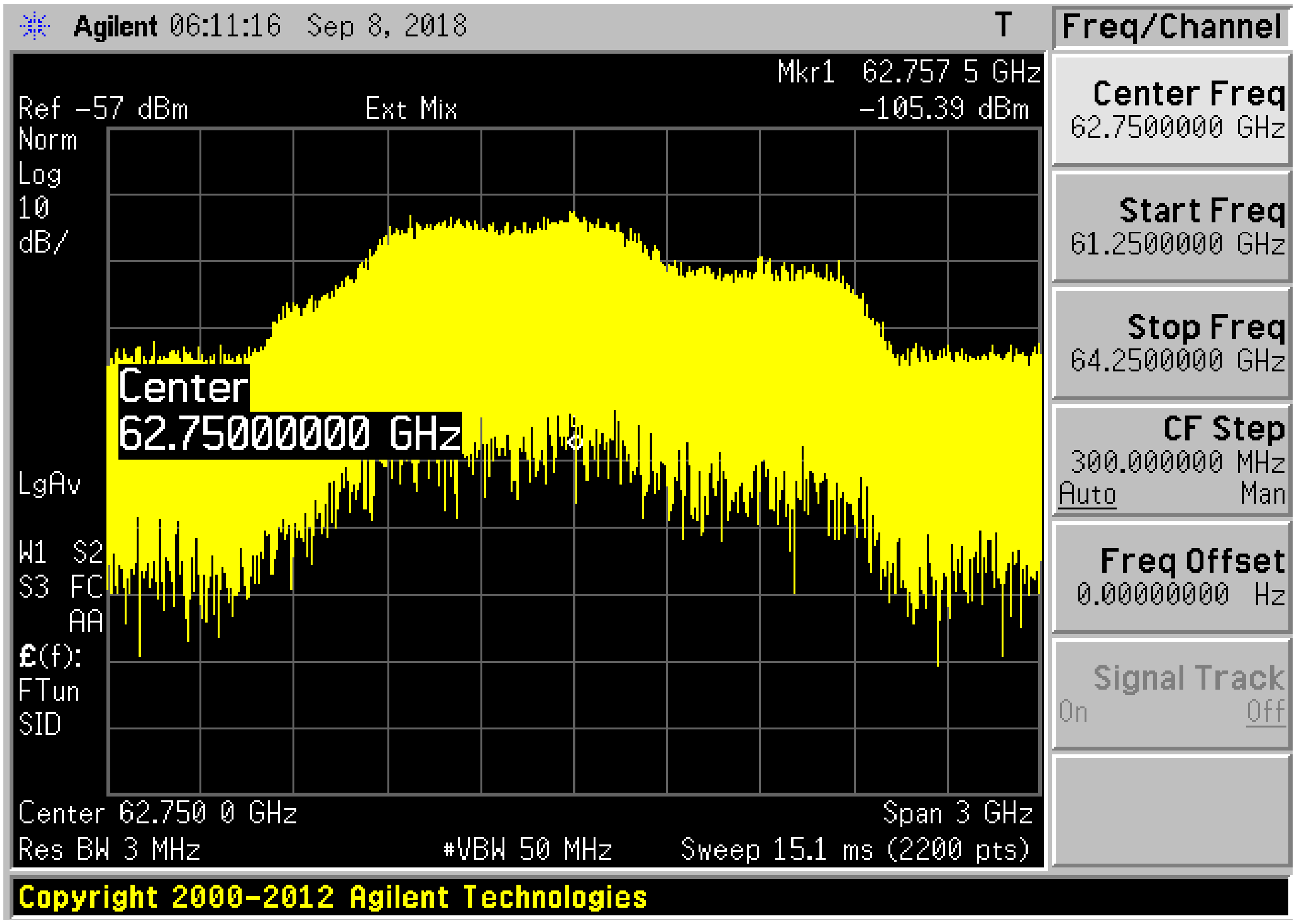

Figure 31. Frequency Stability 30C, 125VAC Input

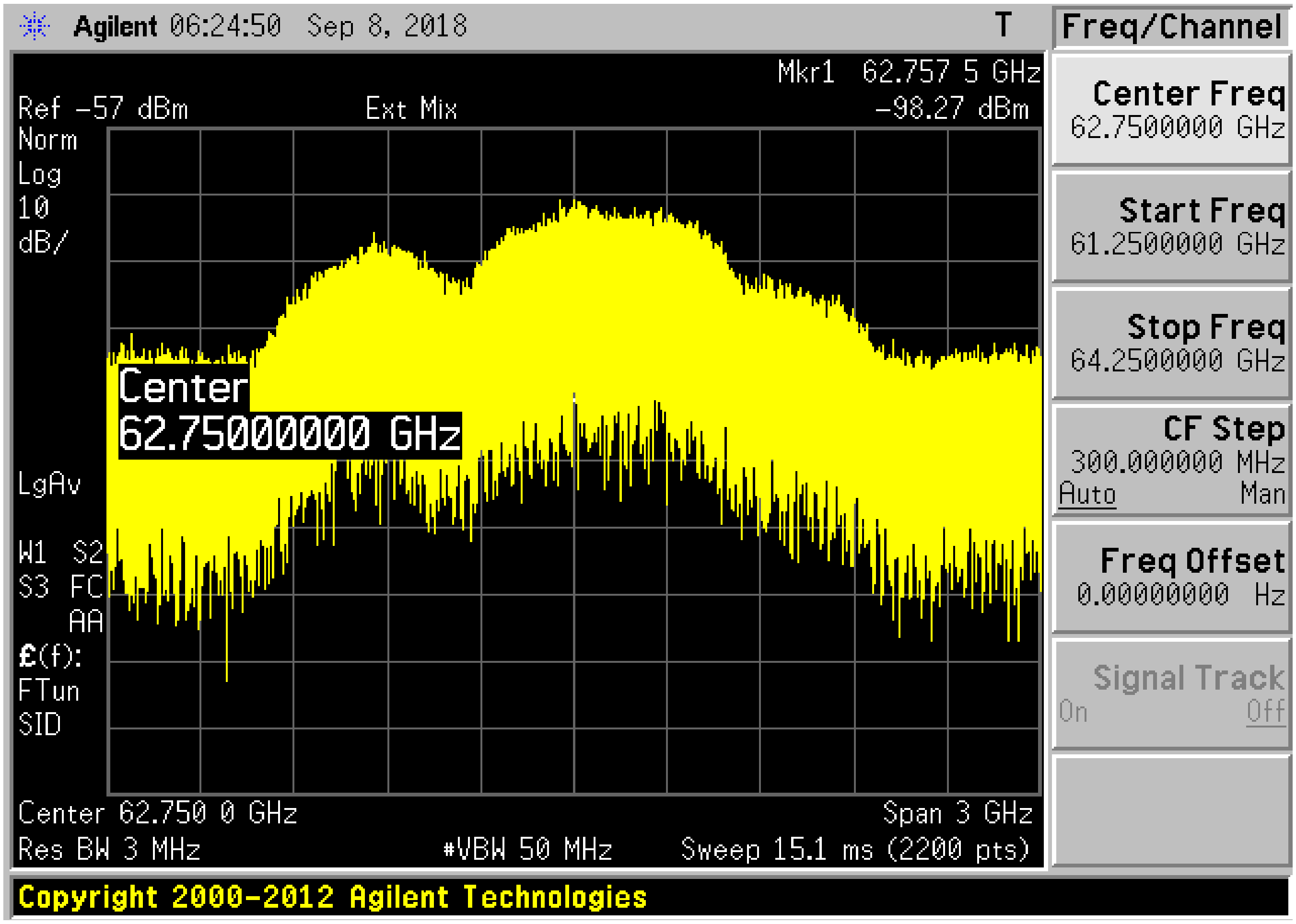

Figure 32. Frequency Stability 20C, 125VAC Input

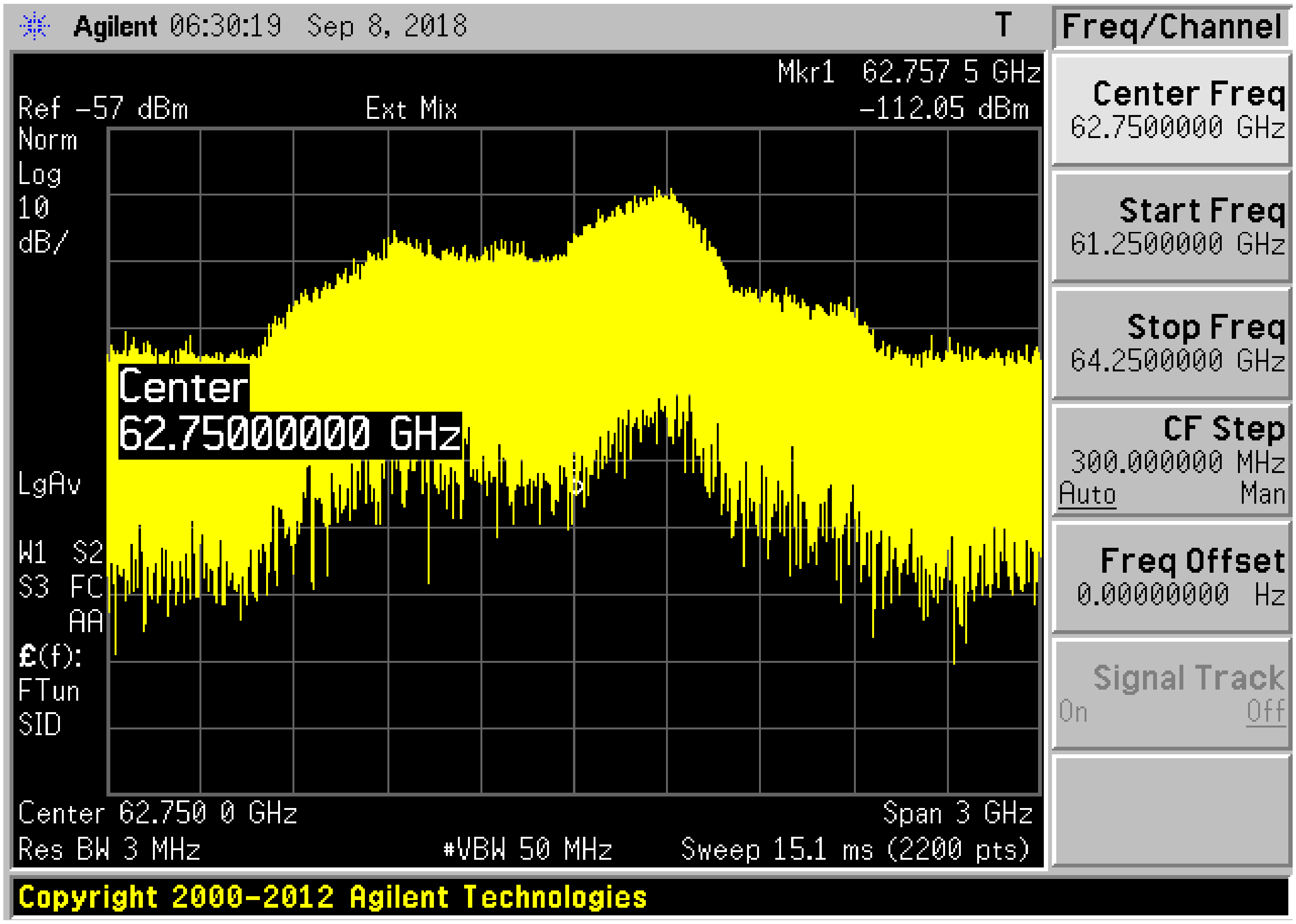

Figure 33. Frequency Stability 10C, 125VAC Input

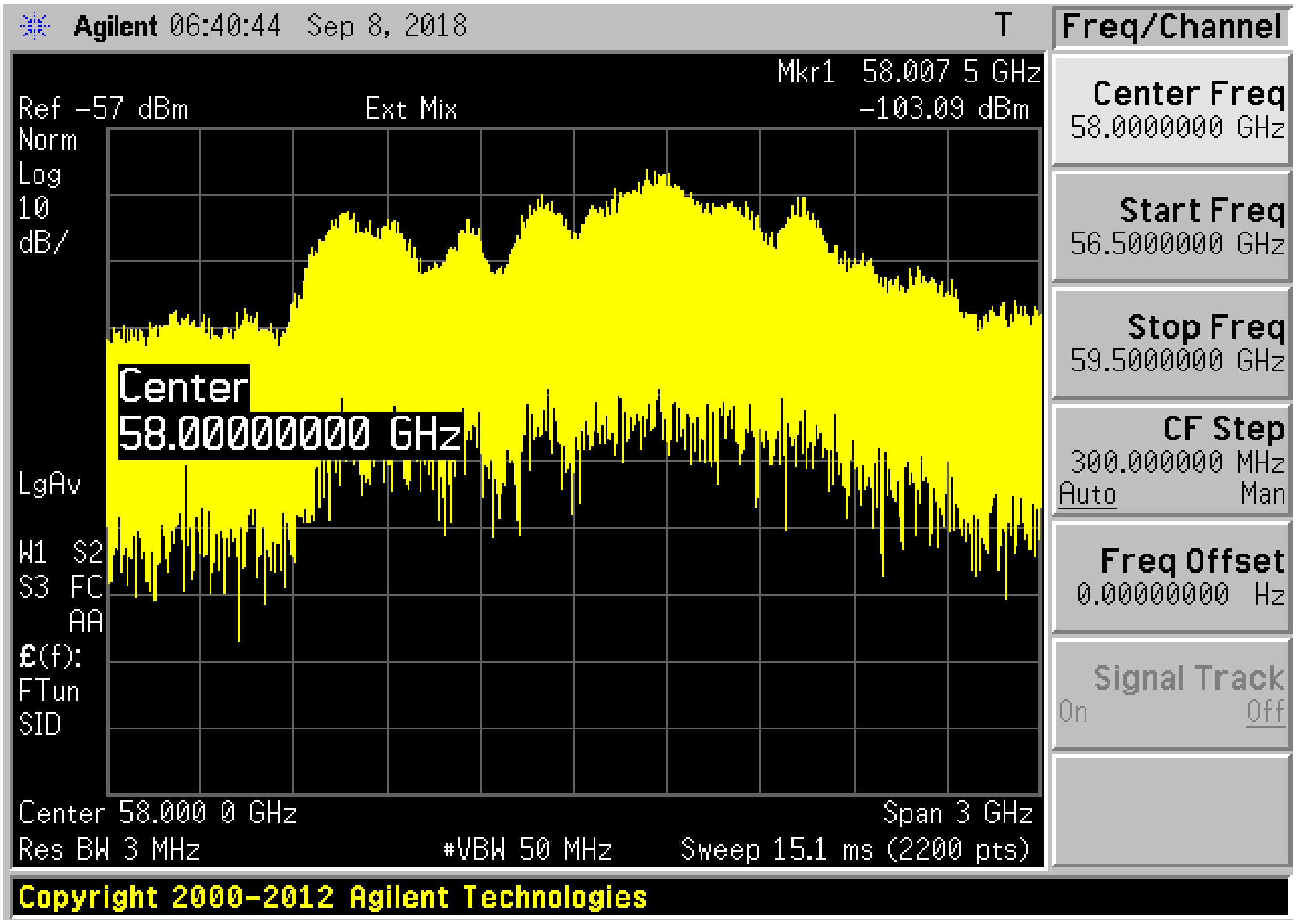

Figure 34. Frequency Stability 0C, 125VAC Input

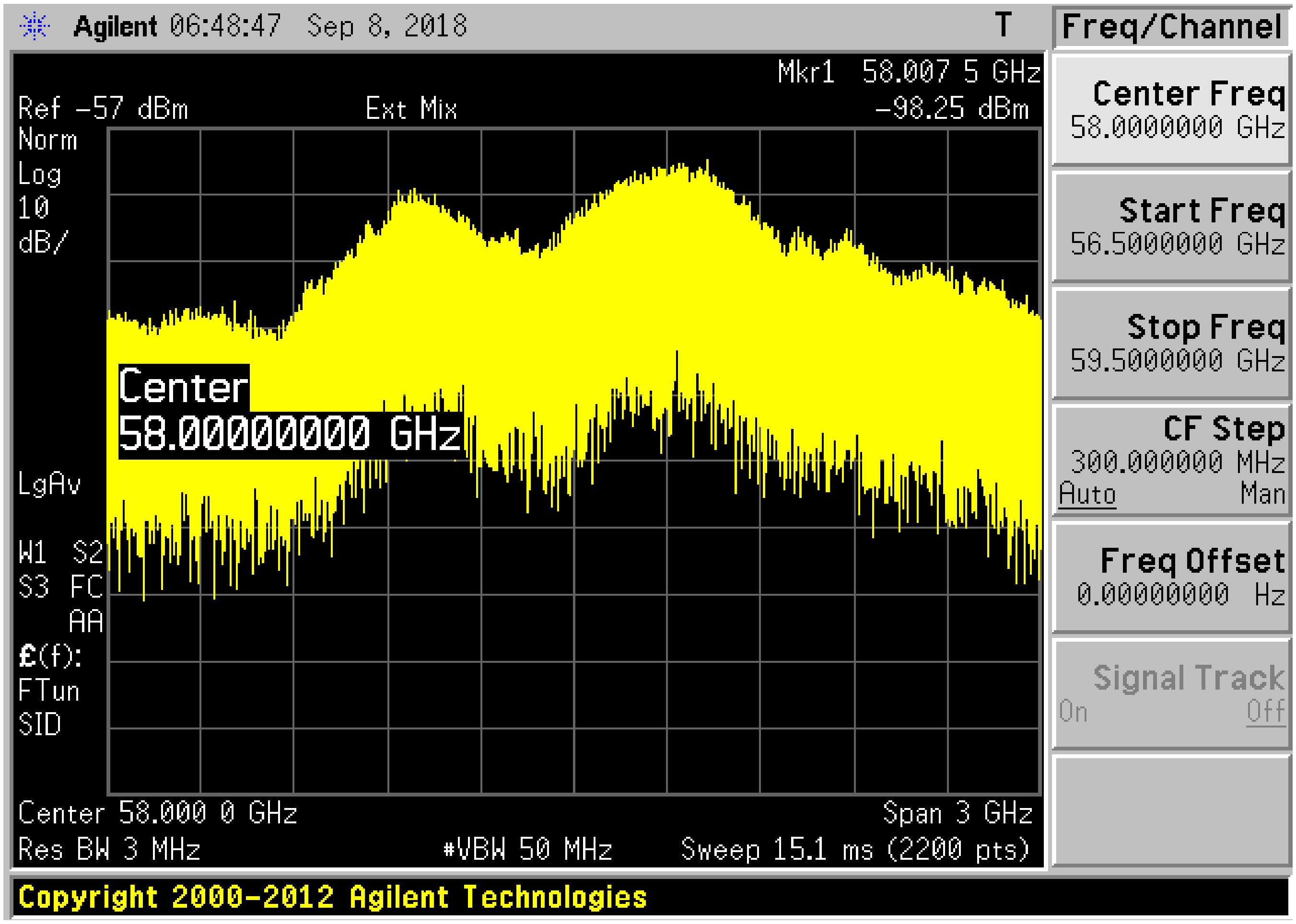

Figure 35. Frequency Stability -10C, 125VAC Input

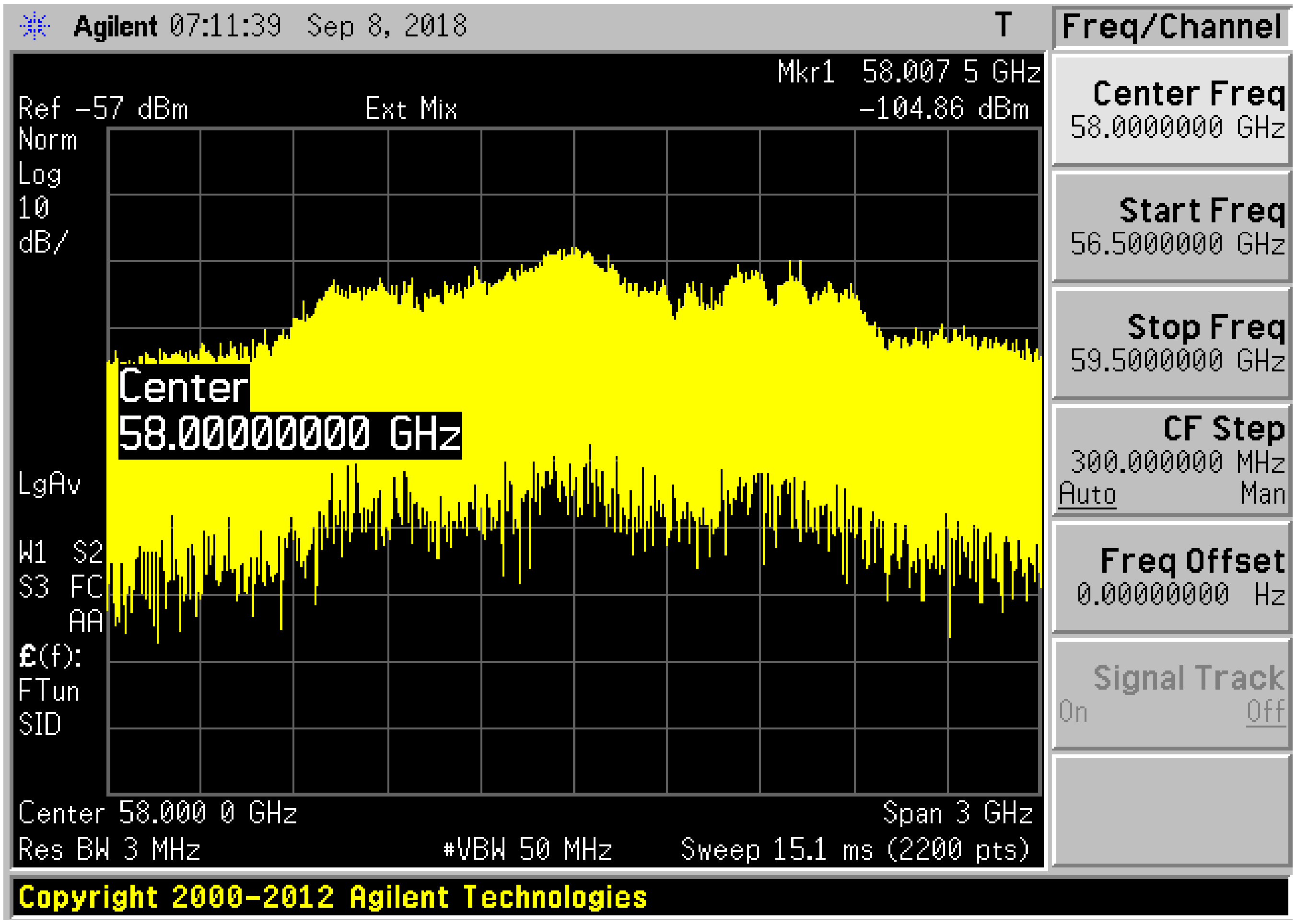

Figure 36. Frequency Stability -20C, 125VAC Input

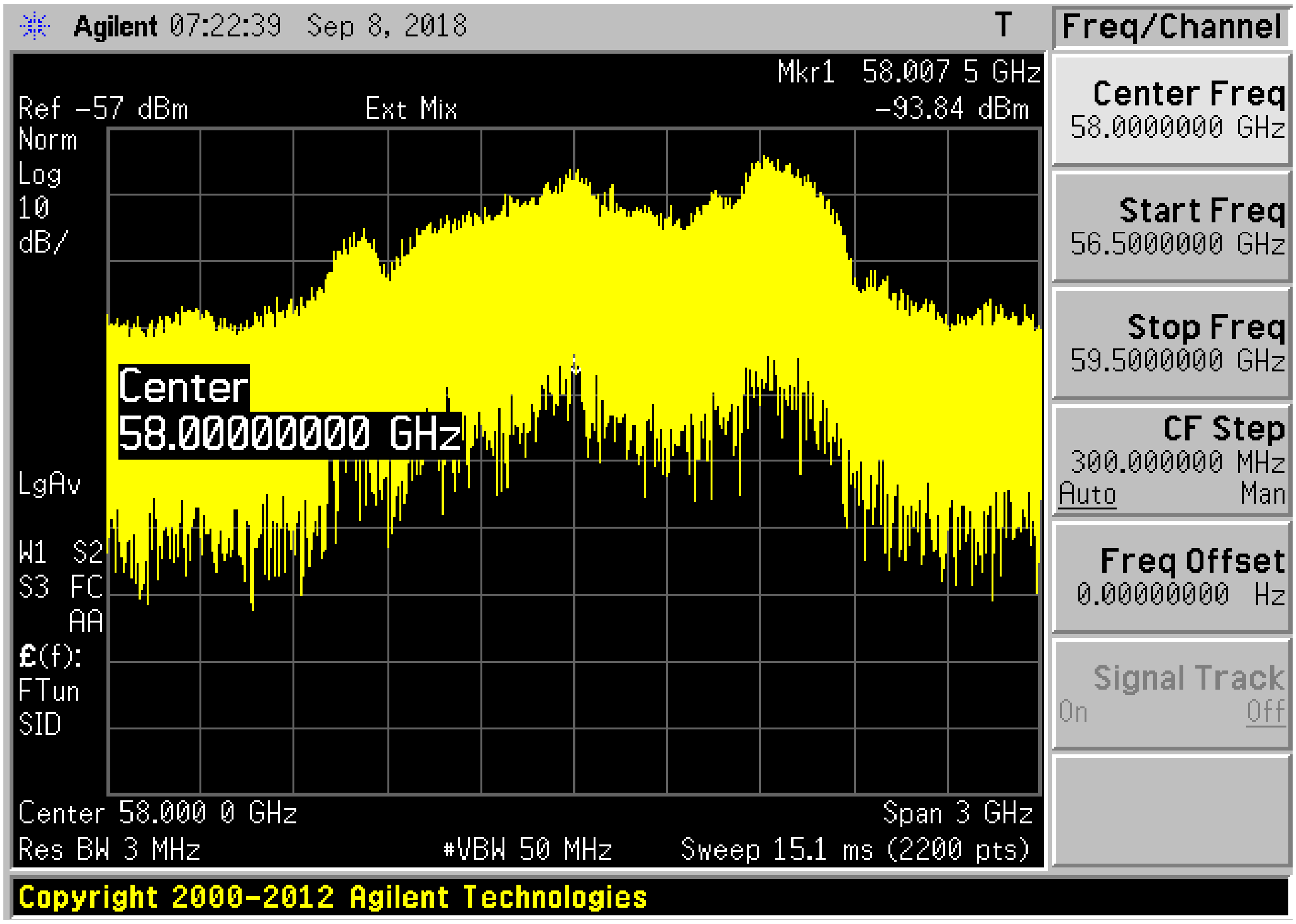

Figure 37. Frequency Stability -30C, 125VAC Input

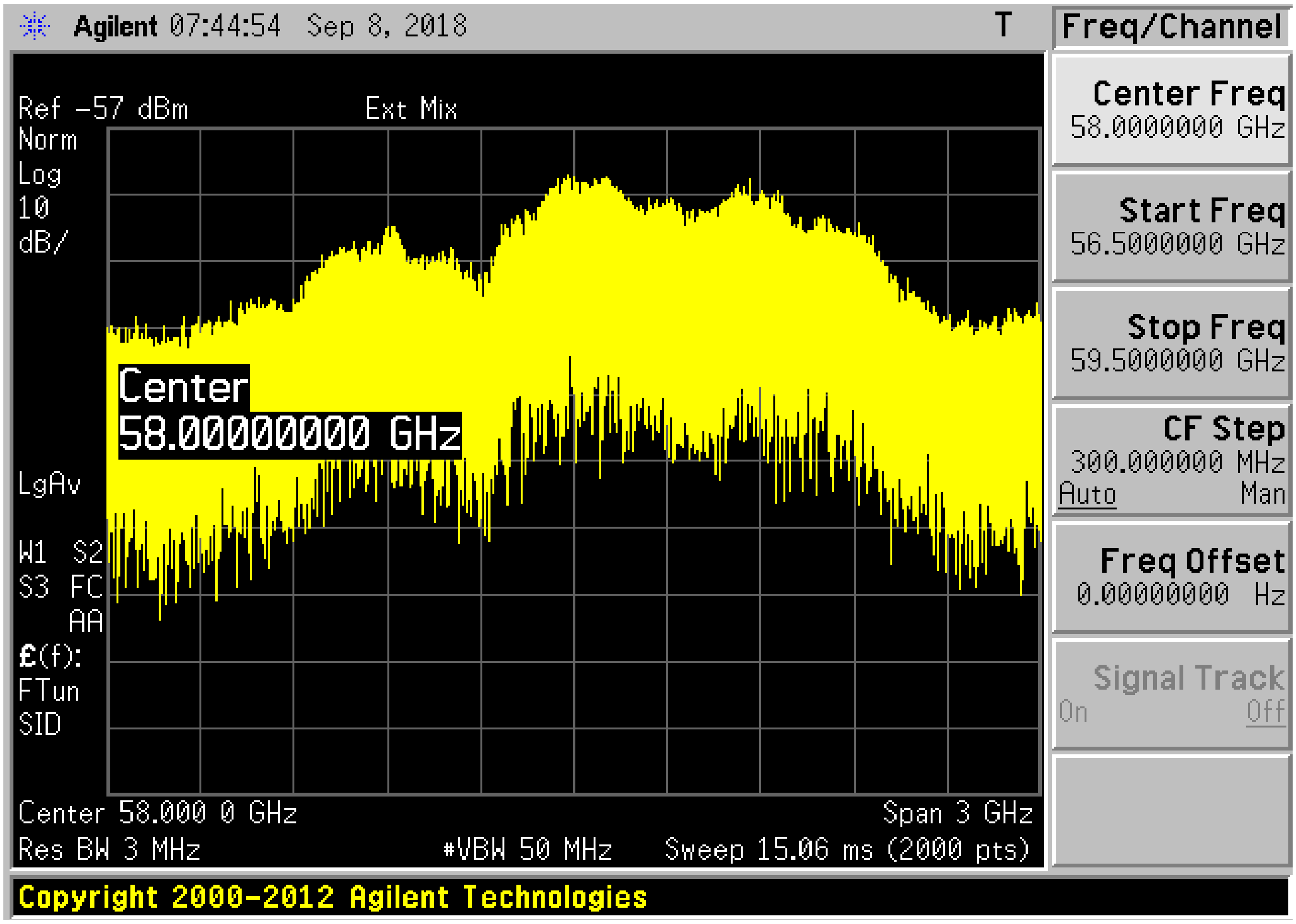

Figure 38. Frequency Stability -40C, 125VAC Input

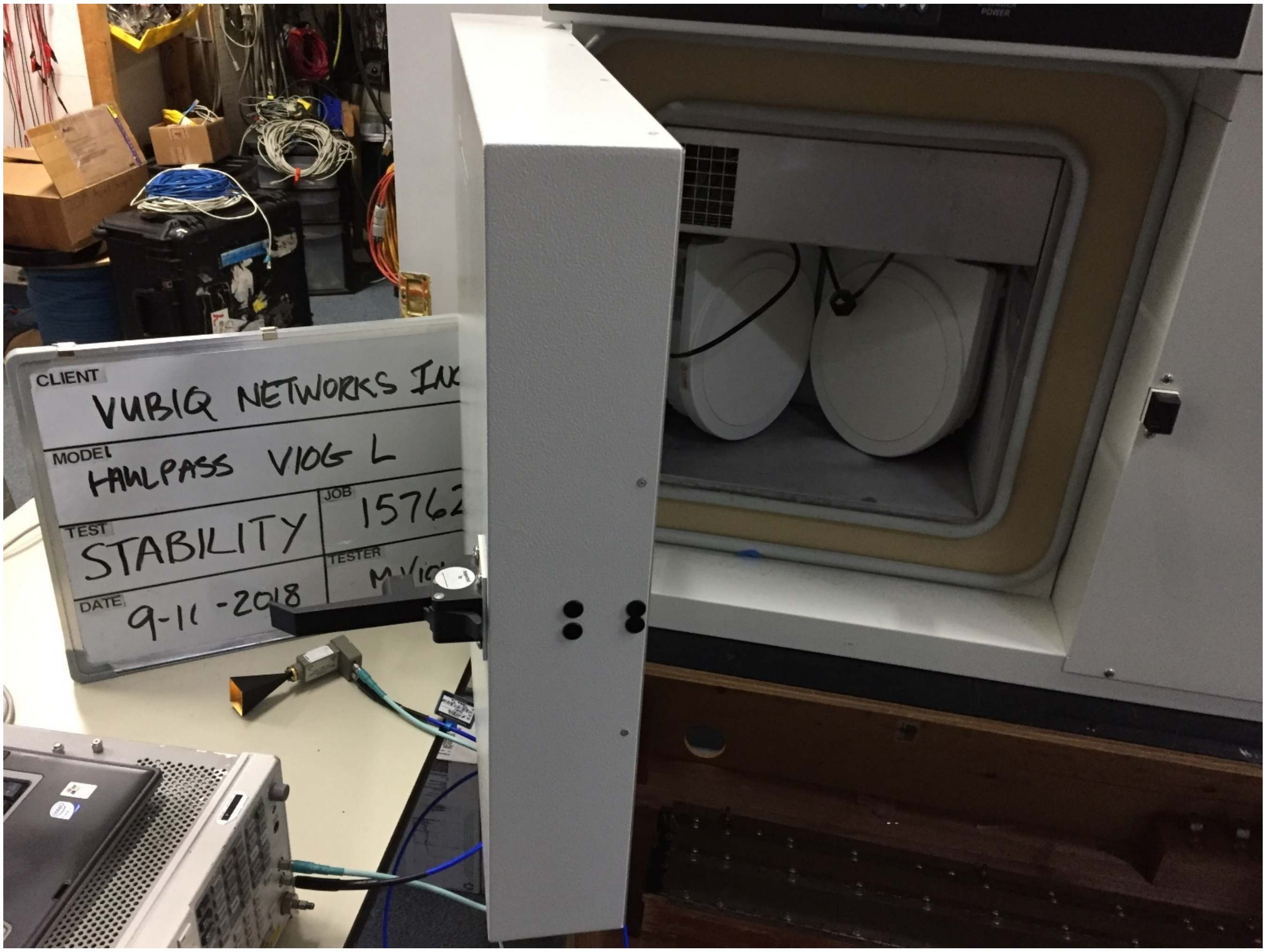

Figure 39. Frequency Stability