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FCC & Industry Canada Certification Test Report

(Limited Modular Approval)

For the

Mueller Systems

RFDC Radio Module
(Tested in Field Radio Host)

FCC ID: SM6-RFDC
IC: 9235A–RFDC

WLL JOB# **11547-01 Rev 3**
August 11, 2010
Re-issued March 7, 2011

Prepared for:

Mueller Systems
48 Leona Drive
Middleboro, MA, 02346 USA

Prepared By:
Washington Laboratories, Ltd.
7560 Lindbergh Drive
Gaithersburg, Maryland 20879

ACCLASS ACCREDITED TESTING

Testing Certificate AT-1448

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Prepared by:

James Ritter
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Reviewed by:

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EMC Operations Manager

Abstract

This report has been prepared on behalf of Mueller Systems to support the attached Application for Equipment Authorization. The test report and application are submitted for a limited modular Frequency Hopping Spread Spectrum Transmitter under Part 15.247 (10/2009) of the FCC Rules and Spectrum Management and Telecommunications Policy RSS-210 issue 7 of Industry Canada. This Certification Test Report documents the test configuration and test results for a Mueller Systems RFDC Radio Module.

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 Industry 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 ACLASS under Certificate AT-1448 as an independent FCC test laboratory.

The Mueller Systems RFDC Radio Module complies with the limits for a Frequency Hopping Spread Spectrum Transmitter device under FCC Part 15.247.

Revision History	Description of Change	Date
Rev 0	Initial Release	August 11, 2010
Rev 1	Corrected error in calibration date of analyzer asset 528	September 9, 2010
REV 2	Incorporation of Industry Canada Cross reference table and addition of section 5.8 Receiver spurious emissions.	September 14, 2010
Rev 3	Added Hailing Channel Data	March 7, 2011

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1 Introduction

1.1 Compliance Statement

The Mueller Systems RFDC Radio Module complies with the limits for a limited module Frequency Hopping Spread Spectrum Transmitter device under FCC Part 15.247 (10/2009) and Industry Canada RSS210 issue 8.

The Module was tested in a "field radio" host device, serial number 1100910 & 1016900535.

1.2 Test Scope

Tests for radiated and conducted (at antenna terminal) emissions were performed in the host device. All measurements were performed in accordance with FCC Public Notice DA 00-705, "Filing and Measurement Guidelines for Frequency Hopping Spread Spectrum Systems". The measurement equipment conforms to ANSI C63.2 Specifications for Electromagnetic Noise and Field Strength Instrumentation.

1.3 Contract Information

Customer:	Mueller Systems 48 Leona Drive Middleboro, MA, 02346 USA
Quotation Number:	65646

1.4 Test Dates

Testing was performed on the following date(s):	7/21/2010 to 8/03/2010 and 2/18/11

1.5 Test and Support Personnel

Washington Laboratories, LTD	James Ritter, John P. Repella, Steven Dovell, John Reidell
Client Representative	David Splitz

1.6 Abbreviations

A	**A**mpere
ac	**a**lternating **c**urrent
AM	Amplitude Modulation
Amps	**Amp**ere**s**
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

The Mueller Systems RFDC Radio Module is a 902.5- 927.35MHz FHSS technology. The system uses 2 modes of operation data mode which uses 50 channels from 902.5 to 927MHz. The system also has a hailing mode to awaken units that are sleeping (these units go into a sleep mode when inactive). The hailing frequencies consist of 50 hailing channels from 902.65 to 927.35MHz. Both of these modes use FHSS technology. The characteristics (power & bandwidth) of the hailing channels are identical to the data channels and are produced from the same RF circuitry. For more detailed information refer to the theory of operation.

Table 1: Device Summary

ITEM	DESCRIPTION
Manufacturer:	Mueller Systems
FCC ID:	SM6-RFDC
Model:	RFDC Radio Module
FCC Rule Parts:	§15.247
IC:	9235A–RFDC
Frequency Range:	902.5-927.35MHz
Maximum Output Power: (conducted at antenna port)	29.8dBm (955mW)
Modulation:	FM
Occupied Bandwidth:	43.11 kHz
Keying:	Automatic
Type of Information:	Data
Number of Channels:	50
Power Output Level	Fixed
Antenna Connector	RPSMA
Antenna Type	2.5dBi omni whip antenna
Interface:	DB9 , RPSMA connector for 902.5-927 whip antenna,
Power Source & Voltage:	120VAC
Emission Designator	43K1FXD
Highest TX Spurious Emission	7320MHz 128.7uV/m @ 3m
Highest RX Spurious Emission	126.45MHz- 30.7uV/m @ 3m

2.2 Modification

None.

2.3 Test Configuration

The RFDC Radio Module was operated from 120VAC 60Hz power. Commands were sent to the RFDC Radio Module using a dB9 port connected to a support laptop using Windows HyperTerminal program. This connection was disconnected after the test mode was set.

2.4 Testing Algorithm

The RFDC Radio Module was programmed via an external dB9 port on the EUT to a RS232 port on the support laptop. The support laptop used HyperTerminal to command the EUT to transmit on the lowest, center, and highest channels. Commands were also sent to allow the unit to transmit in a hopping fashion. The unit was preloaded with a typical data payload to transmit.

Worst case emission levels are provided in the test results data.

2.5 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 Industry 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 ACLASS under Certificate AT-1448 as an independent FCC test laboratory.

2.6 Measurements

2.6.1 References

FCC Public Notice DA 00-705, Filing and Measurement Guidelines for Frequency Hopping Spread Spectrum Systems

ANSI C63.2 Specifications for Electromagnetic Noise and Field Strength Instrumentation

2.7 Measurement Uncertainty

All results reported herein relate only to the equipment tested. The basis for uncertainty calculation uses ANSI/NCSL Z540-2-1997 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, CISPR14, FCC Part 15	2.63 dB
Radiated Emissions	CISPR11, CISPR22, 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 Antenna Port**		Test Date:	**7/27/2010**
Asset #	**Manufacturer/Model**	**Description**	**Cal. Due**
618	HP, 8563A	ANALYZER, SPECTRUM	06/04/2011
528	AGILENT, E4446A	ANALYZER, SPECTRUM	08/27/2011

Test Name: **Radiated Emissions**		Test Date:	**2/18/2011**
Asset #	**Manufacturer/Model**	**Description**	**Cal. Due**
70	HP - 85685A	PRESELECTOR RF W/OPT 8ZE	6/22/2011
72	HP - 8568B	ANALYZER SPECTRUM	6/22/2011
68	HP - 85650A	ADAPTER QP	6/22/2011
644	SUNOL SCIENCES CORPORATION - JB1 925-833-9936	BICONALOG ANTENNA	12/20/2011
425	ARA - DRG-118/A	ANTENNA DRG 1-18GHZ	9/9/2011
474	HP - 8563E	ANALYZER SPECTRUM	2/28/2011
627	AGILENT - 8449B	AMPLIFIER 1-26GHZ	5/7/2011

Test Name: **Conducted Emissions Mains**		Test Date:	**8/12/2010**
Asset #	**Manufacturer/Model**	**Description**	**Cal. Due**
68	HP - 85650A	ADAPTER QP	6/22/2011
72	HP - 8568B	ANALYZER SPECTRUM	6/22/2011
70	HP - 85685A	PRESELECTOR RF W/OPT 8ZE	6/22/2011
125	SOLAR - 8028-50-TS-24-BNC	LISN	7/10/2011
126	SOLAR - 8028-50-TS-24-BNC	LISN	7/10/2011

4 Test Summary

The Table Below shows the results of testing for compliance with a Frequency Hopping System in accordance with with FCC Part 15.247 10:2009 and RSS210 issue 8. Full results are shown in section 5.

Table 4: Test Summary Table

TX Test Summary (Frequency Hopping Spread Spectrum)			
FCC Rule Part	**IC Rule Part**	**Description**	**Result**
15.247 (a)(1)(i)	RSS-210 [A8. 1 (c)]	20dB Bandwidth	Pass
15.247 (b)(2)	RSS-210 [A8.4 (1)]	Transmit Output Power	Pass
15.247 (a)(1)	RSS-210 [A8.1 (b)]	Channel Separation	Pass
15.247 (a)(1)(i)	RSS-210 [A8. 1 (c)]	Number of Channels =50 minimum	Pass
15.247 (a)(1)(i)	RSS-210 [A8. 1 (c)]	Time of Occupancy	Pass
15.247 (d)	RSS-210 [A8. 5]	Occupied BW / Out-of-Band Emissions (Band Edge @ 20dB below)	Pass
15.205 15.209	RSS-210 Sect.2.2	General Field Strength Limits (Restricted Bands & RE Limits)	Pass
15.207	RSS-Gen [7.2.2]	AC Conducted Emissions	Pass
RX/Digital Test Summary (Frequency Hopping Spread Spectrum)			
FCC Rule Part	**IC Rule Part**	**Description**	**Result**
15.207	RSS-Gen [7.2.2]	AC Conducted Emissions	Pass
15.209	RSS-210 sect 2.6	General Field Strength Limits	Pass

5 Test Results

5.1 Duty Cycle and Time of Occupancy

In accordance with the FCC Public Notice the spurious radiated emissions measurements may be adjusted if using a duty cycle correction factor if the dwell time per channel of the hopping signal is less than 100 ms.

The duty cycle correction factor is calculated by:

20 x LOG (dwell time/100 ms)

5.1.1 Data Mode Timing

As the Maximum Dwell time of this device is 200ms no duty cycle correction is allowed.

FCC part 15.247 requires that for hopping signals with an occupied bandwidth less than 250 kHz the limit is 0.4 seconds dwell time per 20 seconds

The following figures show the plot of the dwell time and time of occupancy for the transmitter. Based on this plot, the dwell time per hop is 200ms. As the unit is on a channel once in a 20 second period the time of occupancy is 200ms per 20 seconds, thus complying with the 0.4 second requirement.

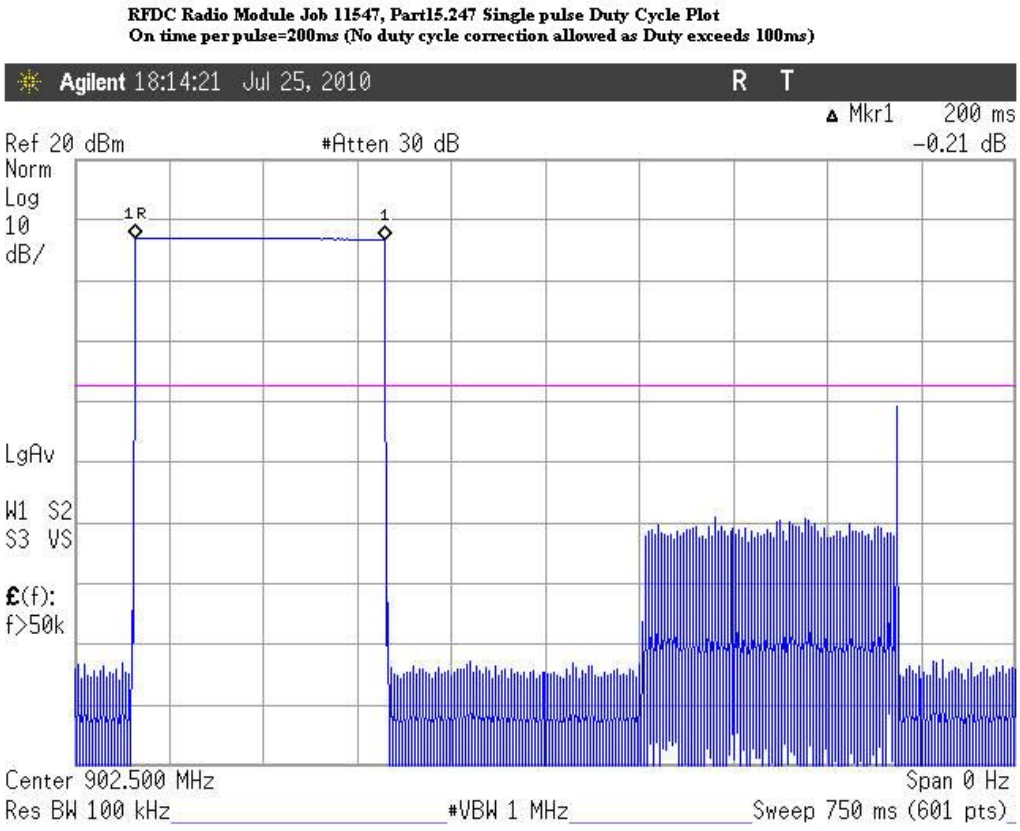

Figure 1: Duty Cycle Plot

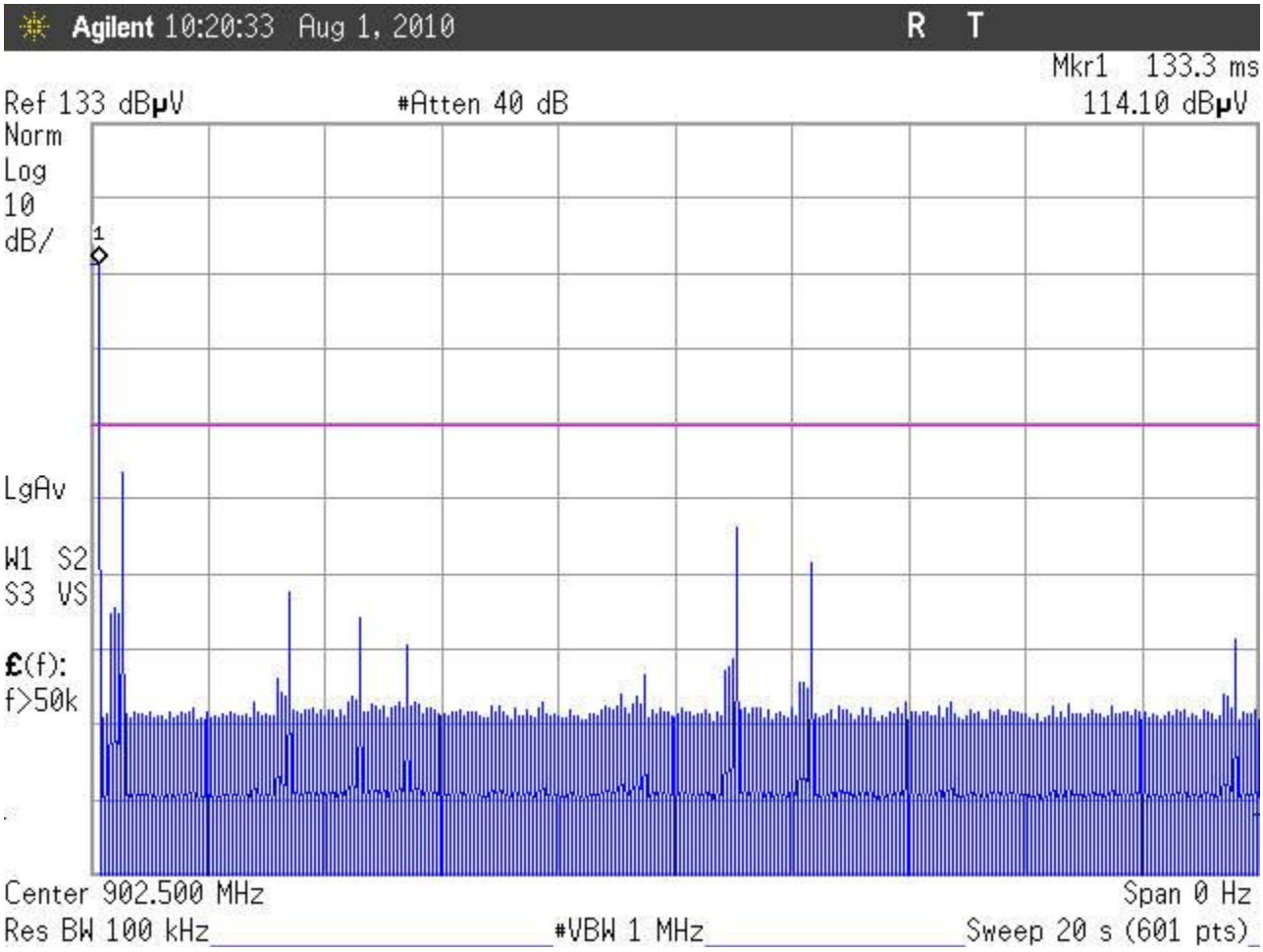

Figure 2: Time of Occupancy Plot

5.1.2 Hailing Mode Timing

As the Maximum Dwell time of this device in hailing 400ms no duty cycle correction is allowed.

FCC part 15.247 requires that for hopping signals with an occupied bandwidth less than 250 kHz the limit is 0.4 seconds dwell time per 20 seconds

The following figures show the plot of the dwell time and time of occupancy for the transmitter. Based on this plot, the dwell time per hop is 400ms. As the unit is on a hailing channel once in a 20 second period the time of occupancy is 400ms per 20 seconds, thus complying with the 0.4 second requirement.

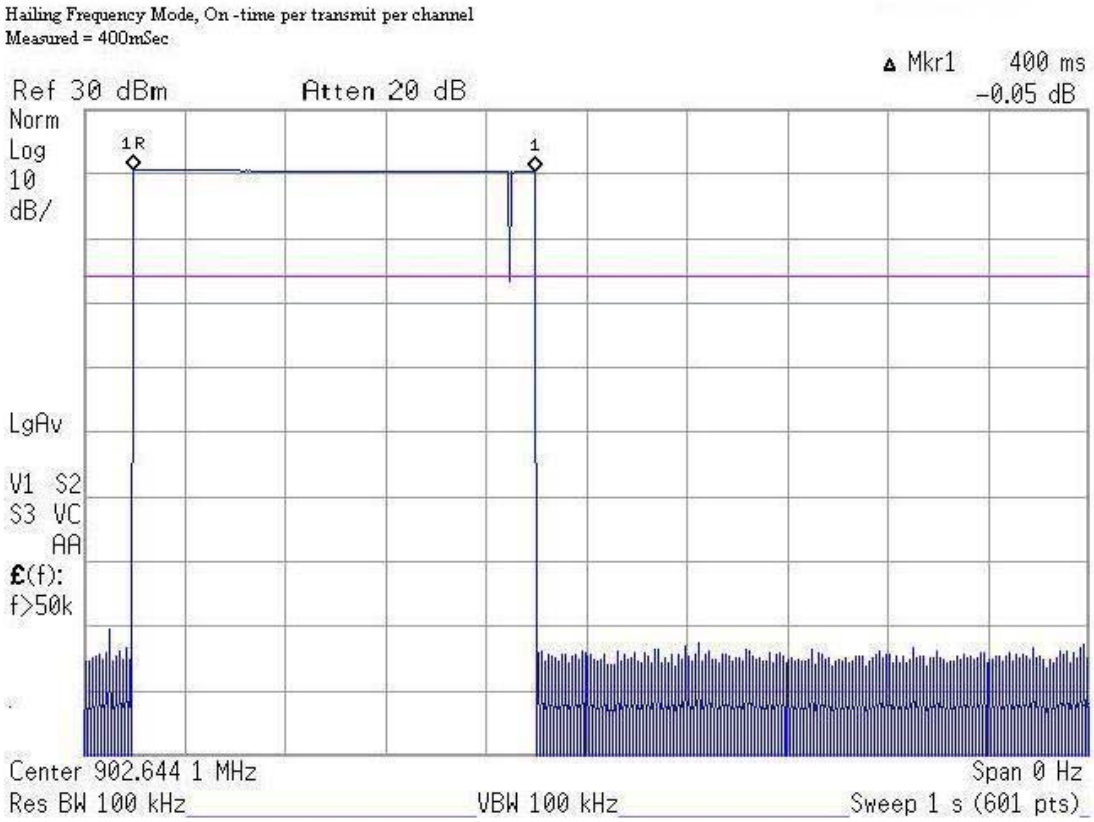

Figure 3 Hailing Channel Duty Cycle Plot

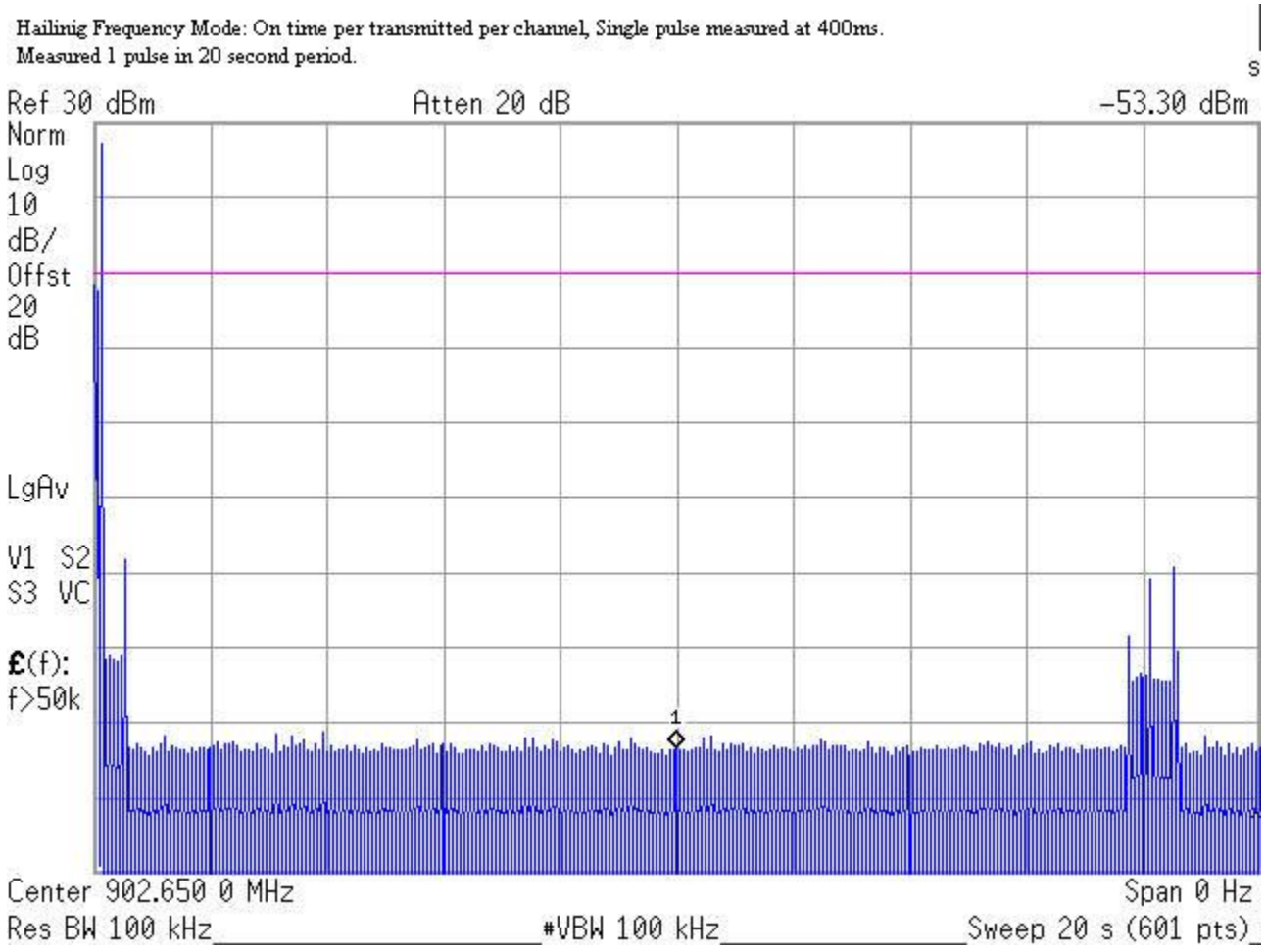

Figure 4 Hailing Channel Time of Occupancy Plot

5.2 RF Power Output: (FCC Part §2.1046)

To measure the output power the hopping sequence was stopped while the frequency dwelled on the lowest, middle and highest channel. The output from the transmitter was connected to an attenuator and then to the input of the RF Spectrum Analyzer. The analyzer offset was adjusted to compensate for the attenuator, cable, and other losses in the system.

Table 5: Data Channel RF Power Output

Frequency	Level	Limit	Pass/Fail
Low Channel: 902.5MHz	29.76dBm	30dBm	Pass
Mid Channel: 915.0MHz	29.84dBm	30dBm	Pass
High Channel: 927.0MHz	29.76dBm	30dBm	Pass

Table 6 Hailing Channel RF Power Output

Frequency	Level	Limit	Pass/Fail
Low Channel: 902.65MHz	28.32dBm	30dBm	Pass
Center Channel: 915.35MHz	29.00dBm	30dBm	Pass
High Channel: 927.35MHz	28.32dBm	30dBm	Pass

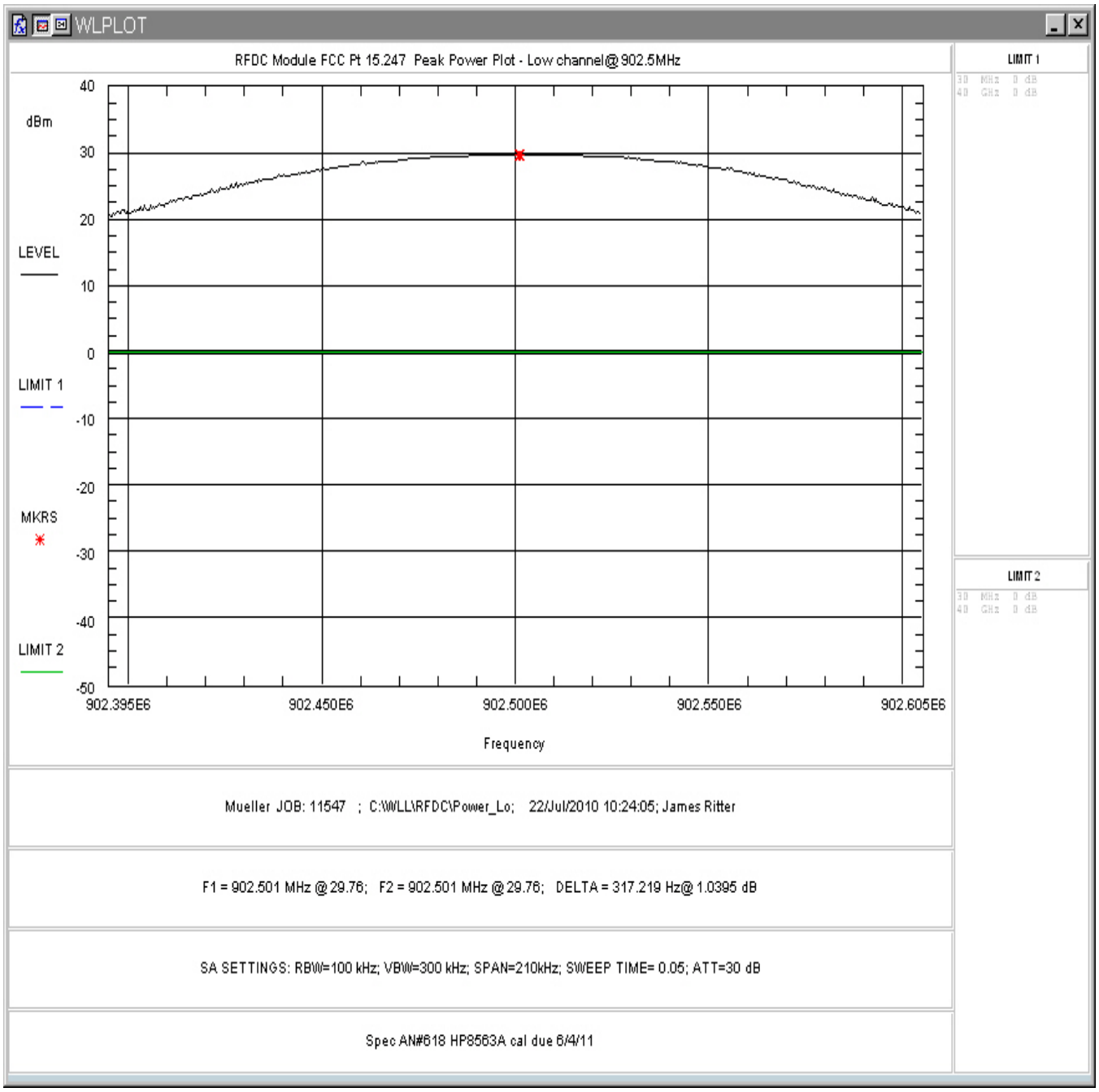

Figure 5: Data Channel RF Peak Power, Low Channel

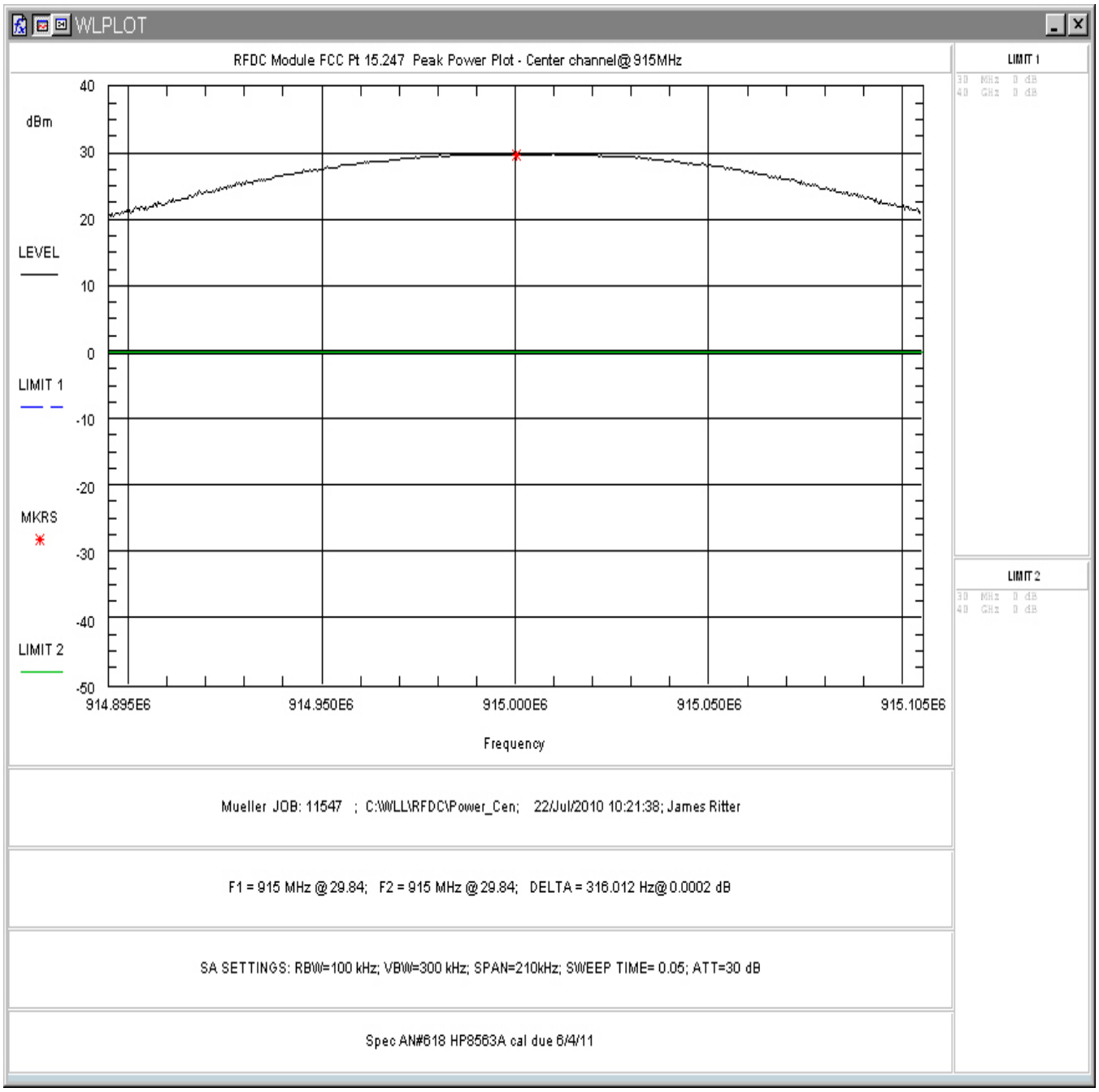

Figure 6: Data Channel RF Peak Power, Mid Channel

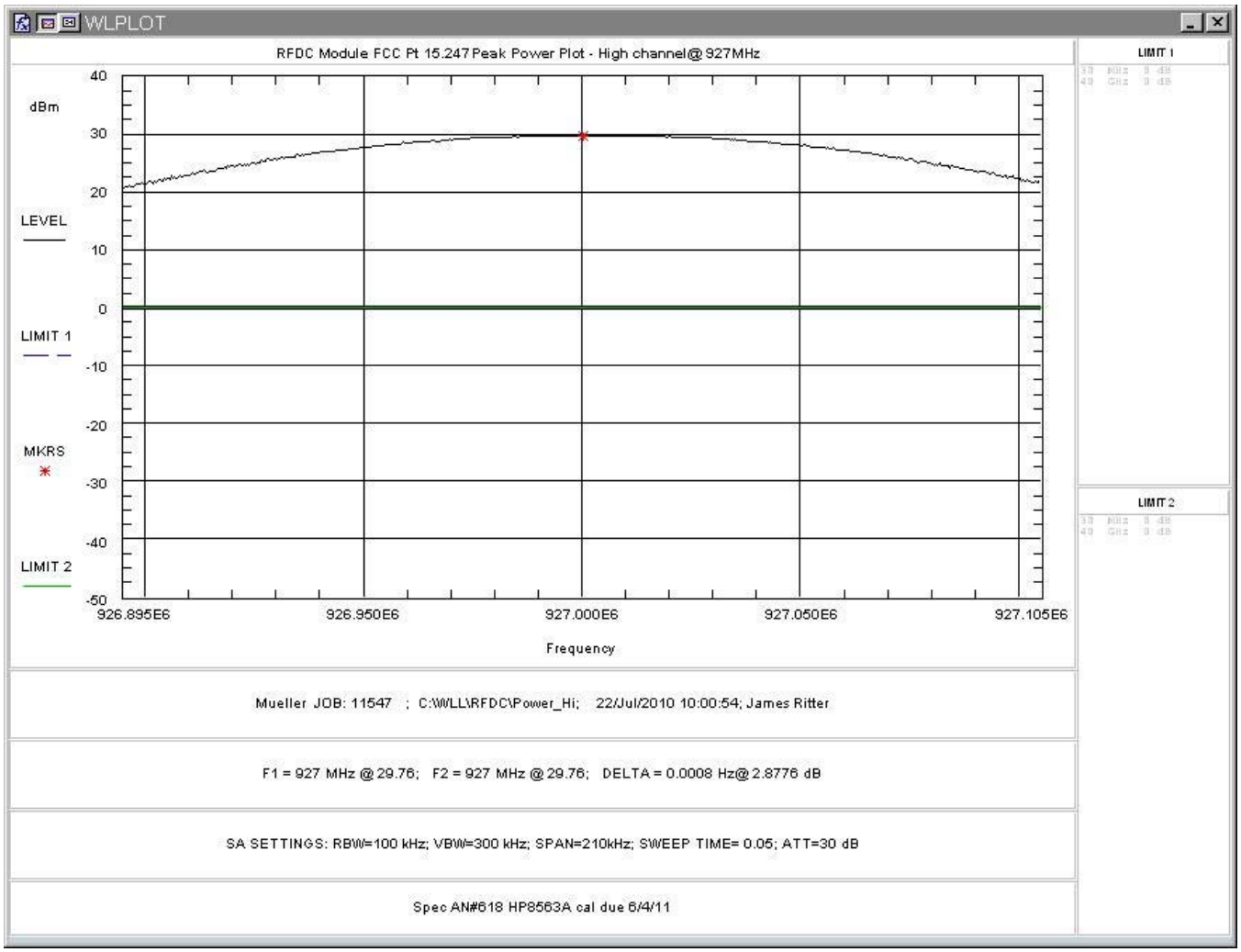

Figure 7: Data Channel RF Peak Power, High Channel

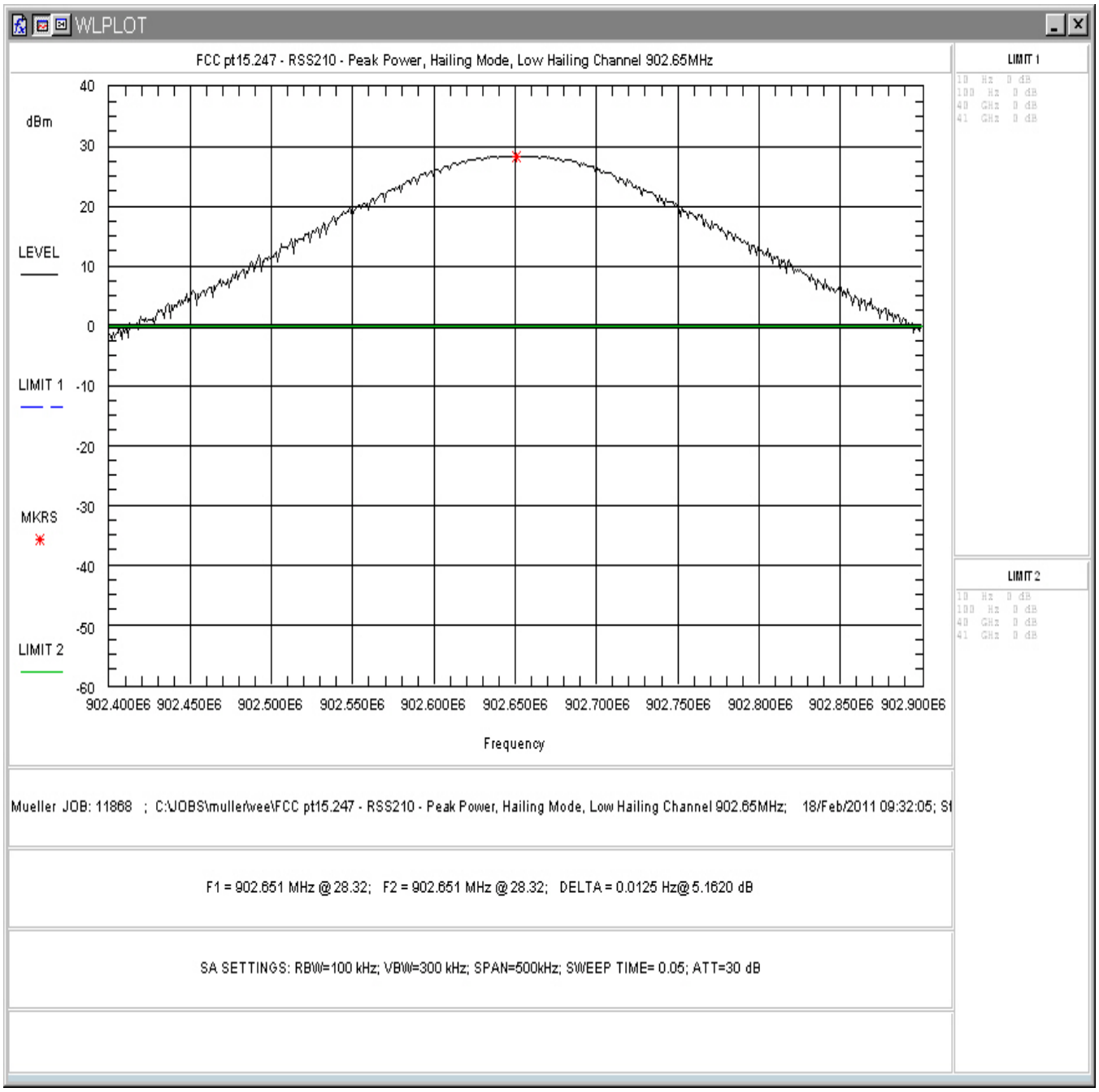

Figure 8 Hailing Channel RF Peak Power, Low Channel

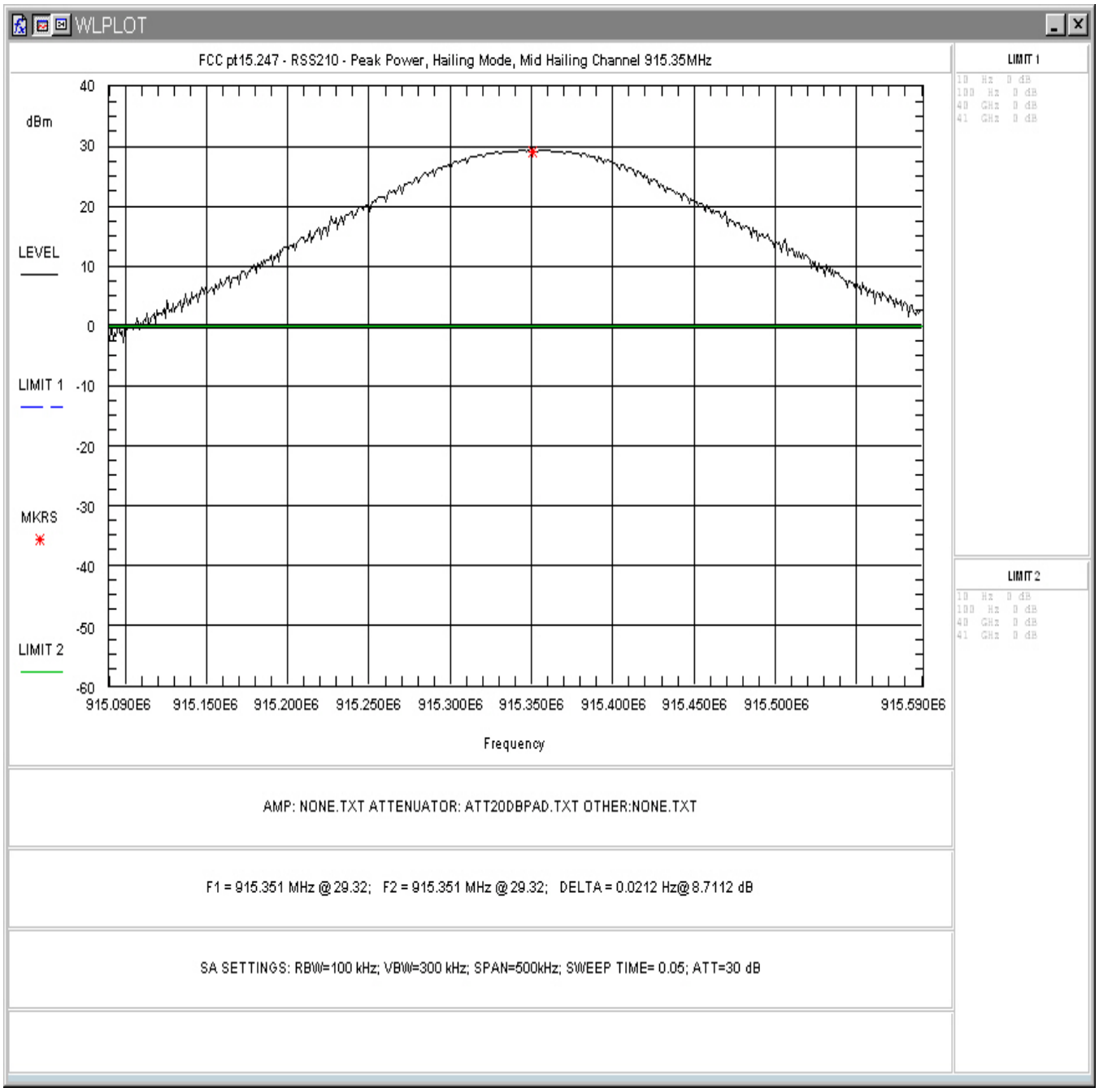

Figure 9 Hailing Channel RF Peak Power, Center Channel

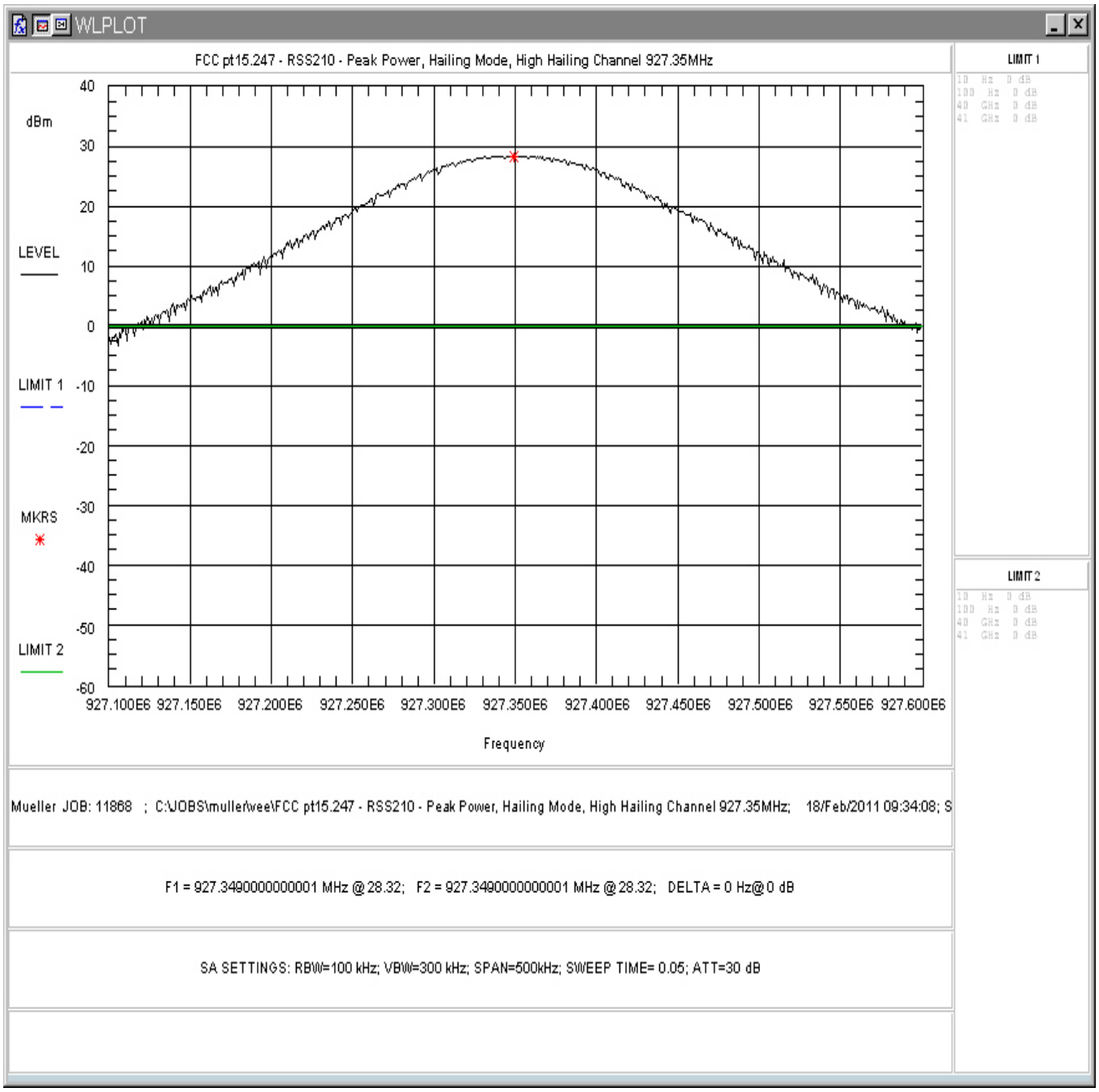

Figure 10 Hailing Channel RF Peak Power, High Channel

5.3 Occupied Bandwidth: (FCC Part §2.1049)

Occupied bandwidth was performed by coupling the output of the EUT to the input of a spectrum analyzer.

For Frequency Hopping Spread Spectrum Systems, operating in the 902-928MHz frequency range, FCC Part 15.247 requires that devices with occupied bandwidths less than 250kHz have a minimum of 50 hopping channels.

At full modulation, the occupied bandwidth was measured as shown:

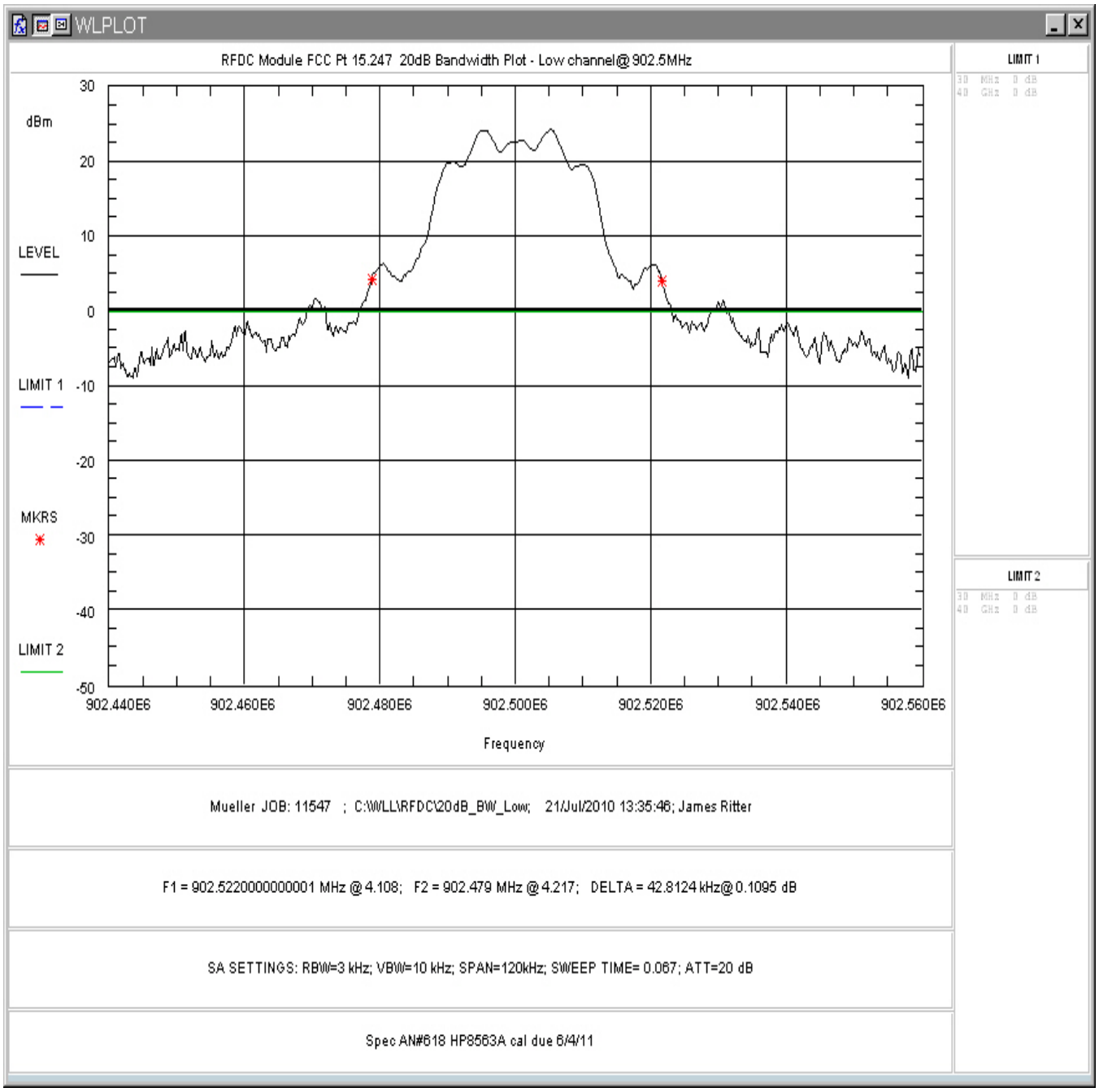

Figure 11: Data Channel Occupied Bandwidth, Low Channel

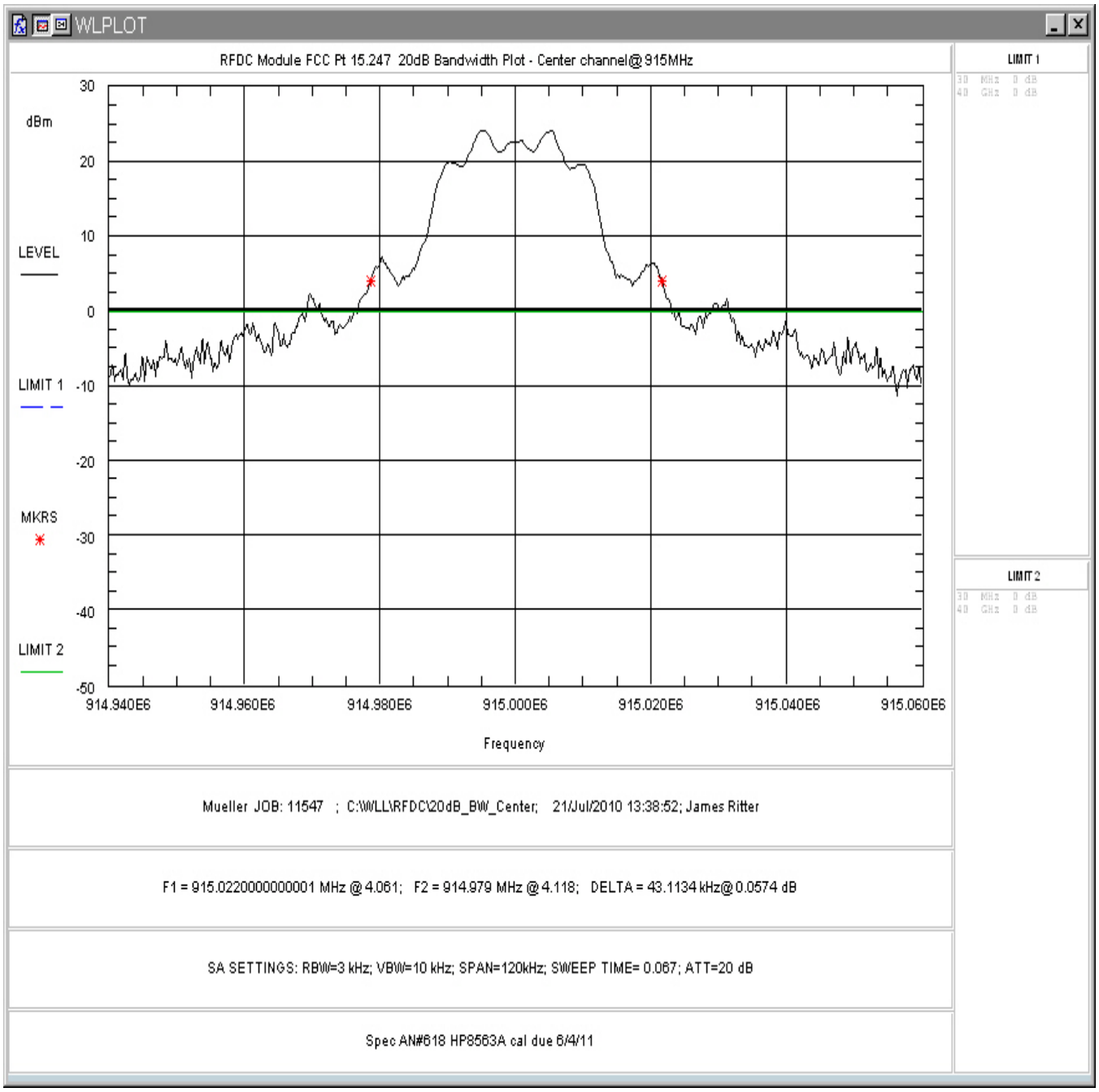

Figure 12: Data Channel Occupied Bandwidth, Mid Channel

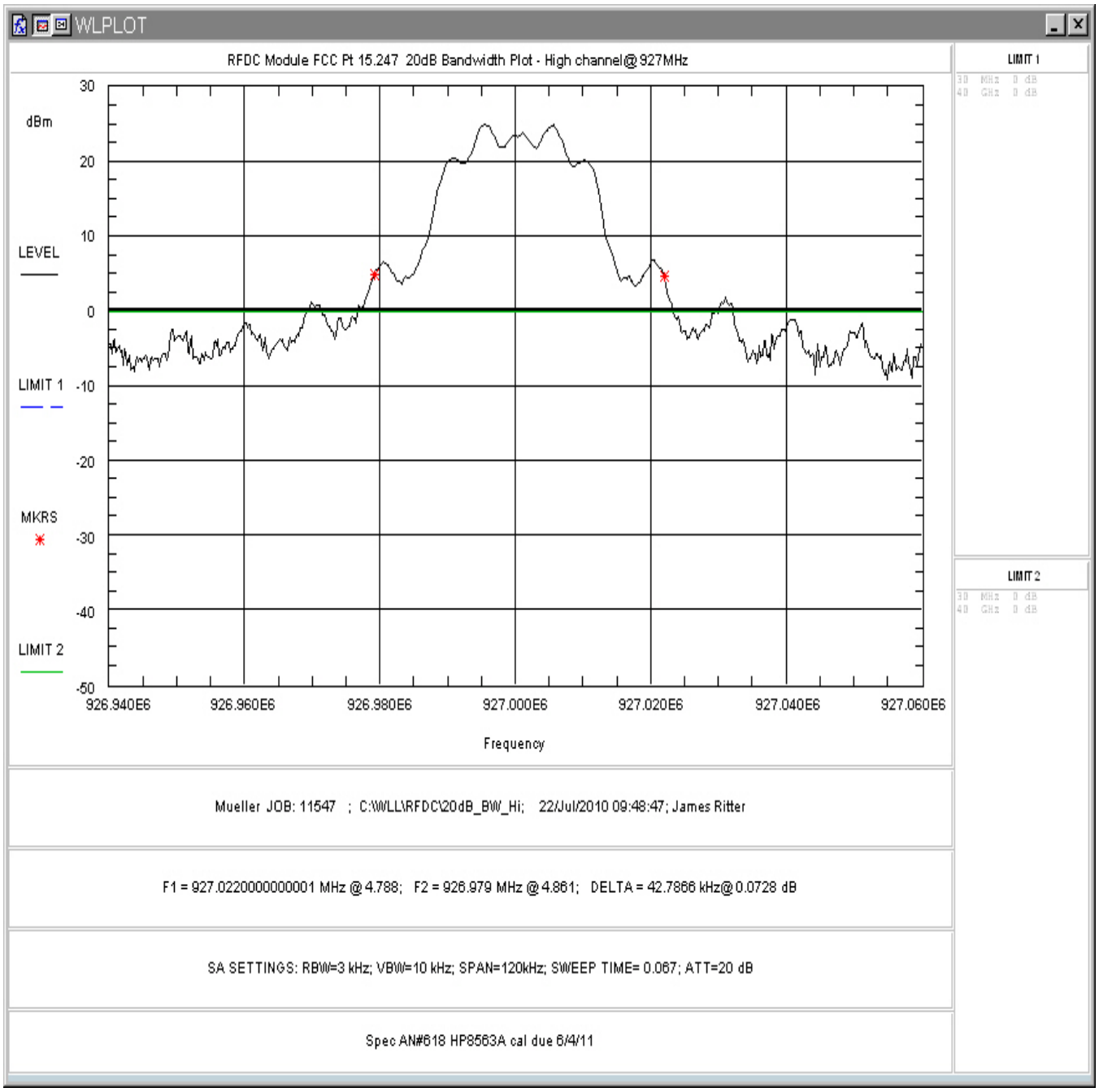

Figure 13: Data Channel Occupied Bandwidth, High Channel

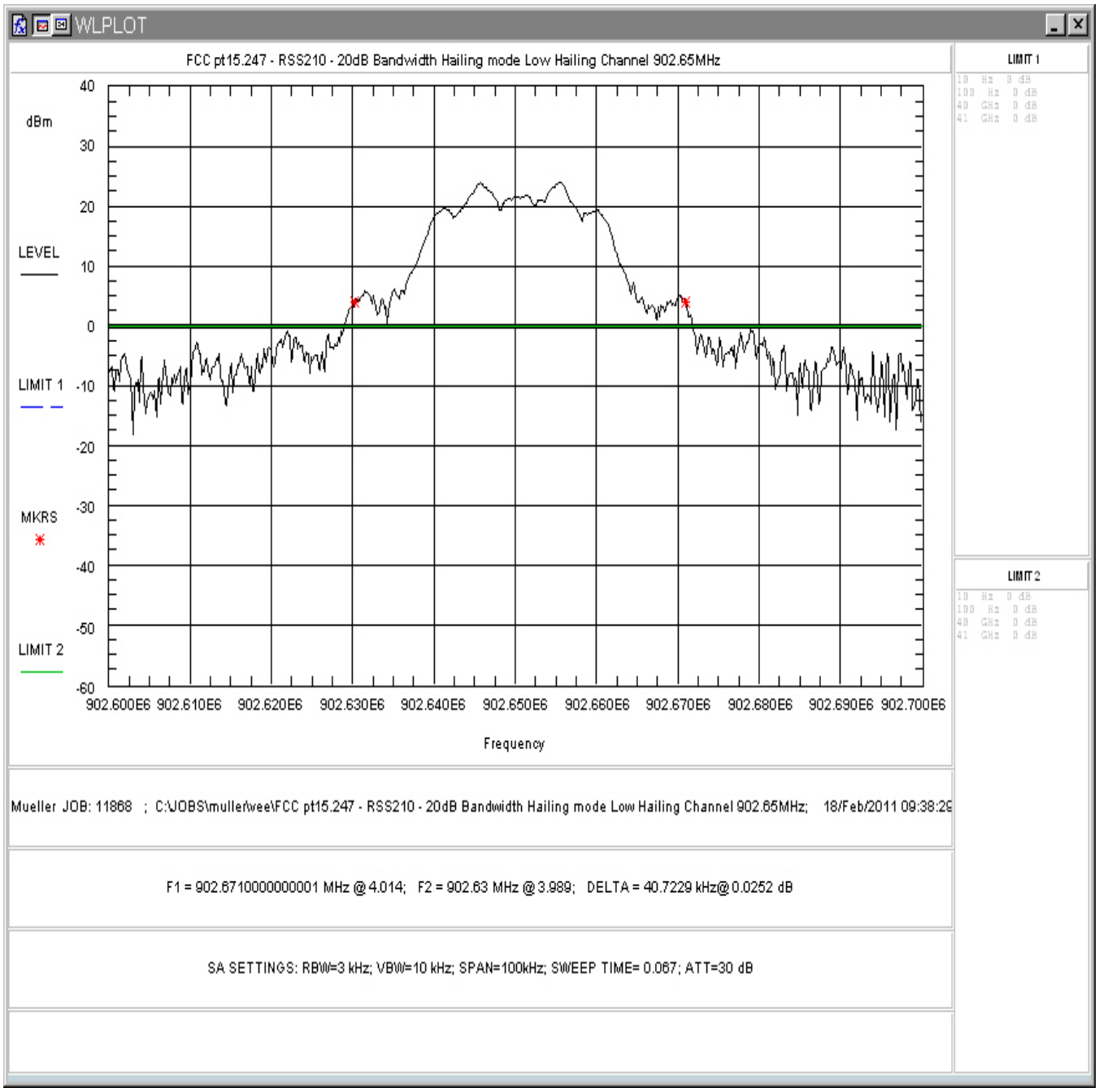

Figure 14 Hailing Channel Occupied Bandwidth, Low Channel

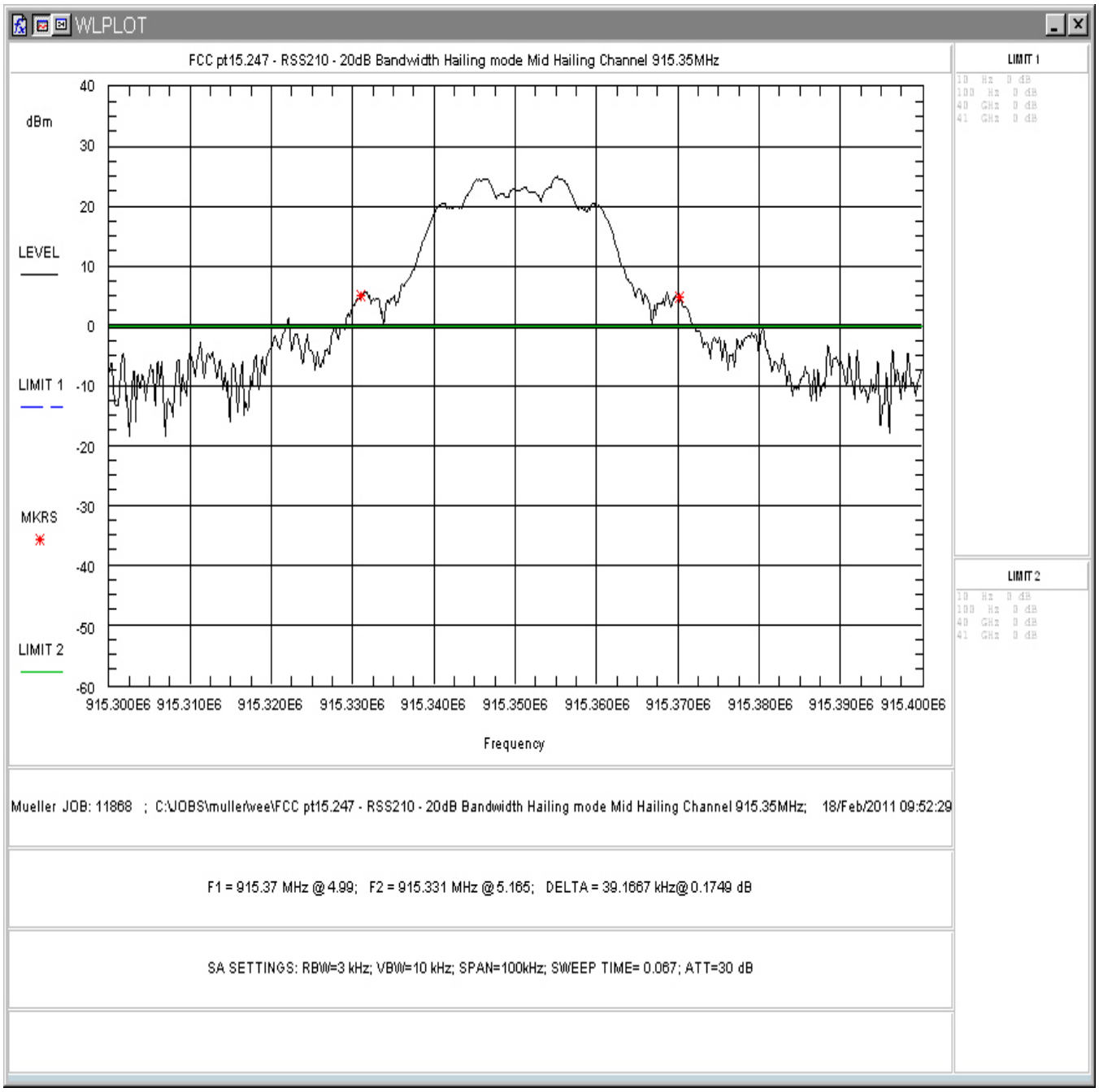

Figure 15 Hailing Channel Occupied Bandwidth, Center Channel

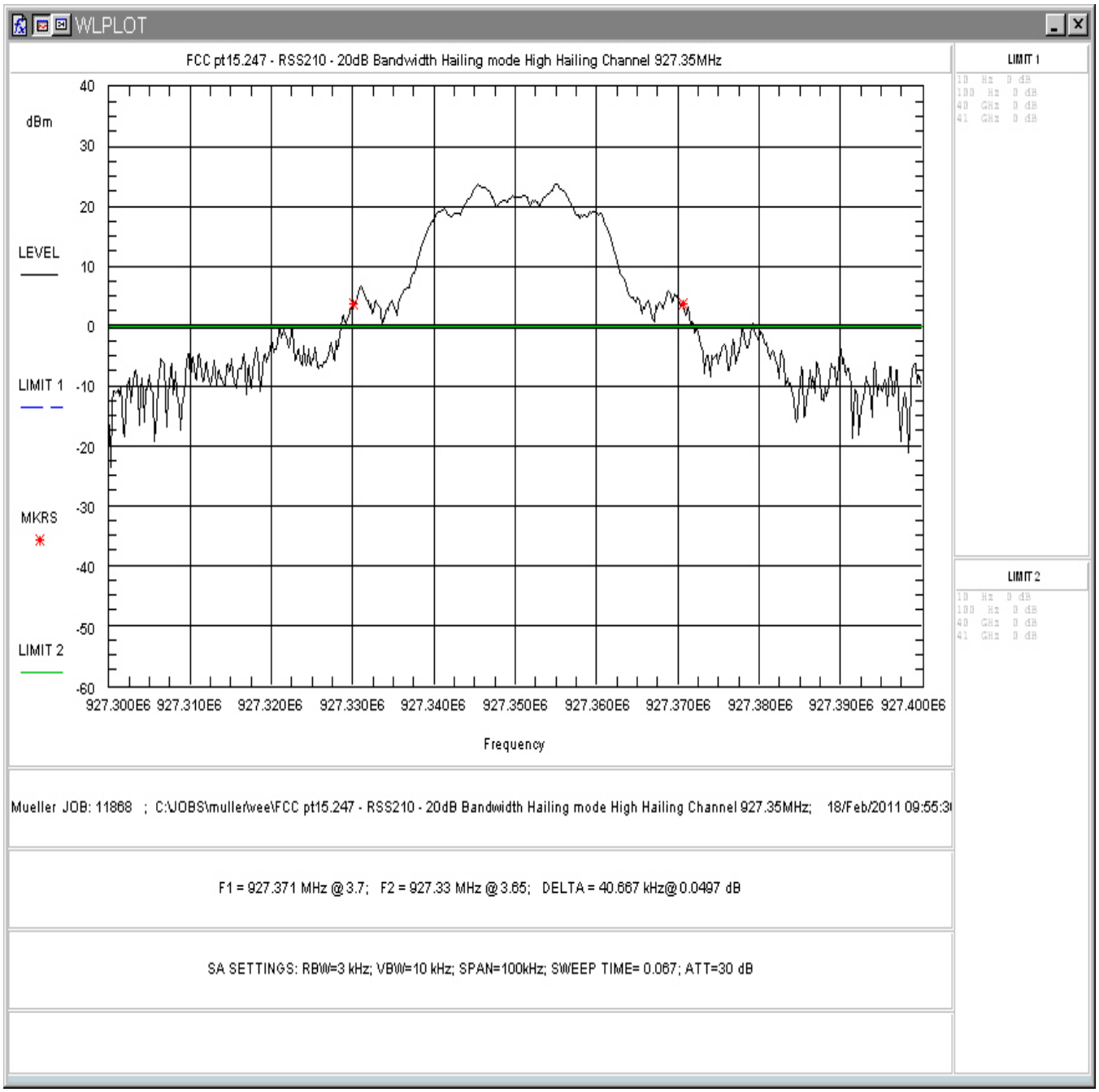

Figure 16 Hailing Channel Occupied Bandwidth, High Channel

Table 7 provides a summary of the Occupied Bandwidth Results.

Table 7: Occupied Bandwidth Results

Frequency	Bandwidth
Low Channel: 902.5MHz	42.81 kHz
Mid Channel: 915.0MHz	43.11 kHz
High Channel: 927.0MHz	42.79 kHz

Table 8 Hailing Channel Occupied Bandwidth Results

Frequency	Bandwidth
Low Channel: 902.65MHz	40.7229 kHz
Center Channel: 915.35MHz	39.1667 kHz
High Channel: 927.35MHz	40.667 kHz

5.4 Channel Spacing and Number of Hop Channels (FCC Part §15247(a)(1)

Per the FCC requirements, frequency hopping systems operating in the 902-928MHz shall have hopping channel carrier frequencies separated by a minimum of 25kHz or the 20 dB bandwidth, whichever is greater. The maximum 20dB bandwidth measured is 43.11 kHz so the channel spacing must be more than 43.11 kHz. In addition, Part 15.247 requires that devices with occupied bandwidths less than 250kHz have a minimum of 50 hopping channels.

The EUT antenna was removed and the cable was connected directly into a spectrum analyzer through a calibrated cable and attenuator. An offset was programmed into the spectrum analyzer to compensate for the loss of the external attenuator/cable. The spectrum analyzer resolution bandwidth was set to 100 kHz and the video bandwidth was set to 300 kHz. The channel spacing of 2 adjacent channels was measured using a spectrum analyzer span setting of 2MHz. Also, the number of hopping channels was measured within the 902-928MHz frequency range.

The following are plots of the channel spacing and number of hopping channels data. The channel spacing was measured to be 250kHz and the number of hopping channels is 50.

Note: The Data channel plan for this unit has a typical channel spacing of 500kHz between channels, however, 2 channels have been removed at 909MHz and 921MHz. These channels have been replaced with 2 channels at 902.25MHz and 908.25MHz thus giving a 250kHz channel spacing between 904MHz -904.5MHz and 908MHz-908.5MHz. This still remains in compliance. Both the standard spacing and the spacing between the 2 bands above are shown.

In addition the hailing channels are not evenly dispersed within the band with the closest hailing channels spaced 150 kHz apart.

Table 9: Channel spacing and number of hopping channels summary

Test	Result	Limit	Pass/Fail
Channel spacing	250kHz channel spacing between 904MHz -904.5MHz and 908MHz-908.5MHz. 500kHz between other channels	43.11kHz Minimum	Pass
Number of Channels	50 channels	50 channels minimum	Pass
Hailing Channel Spacing	The closest channels are spaced 150kHz	43.11kHz Minimum	Pass
Number of Hailing Channels	50 channels	50 channels minimum	Pass

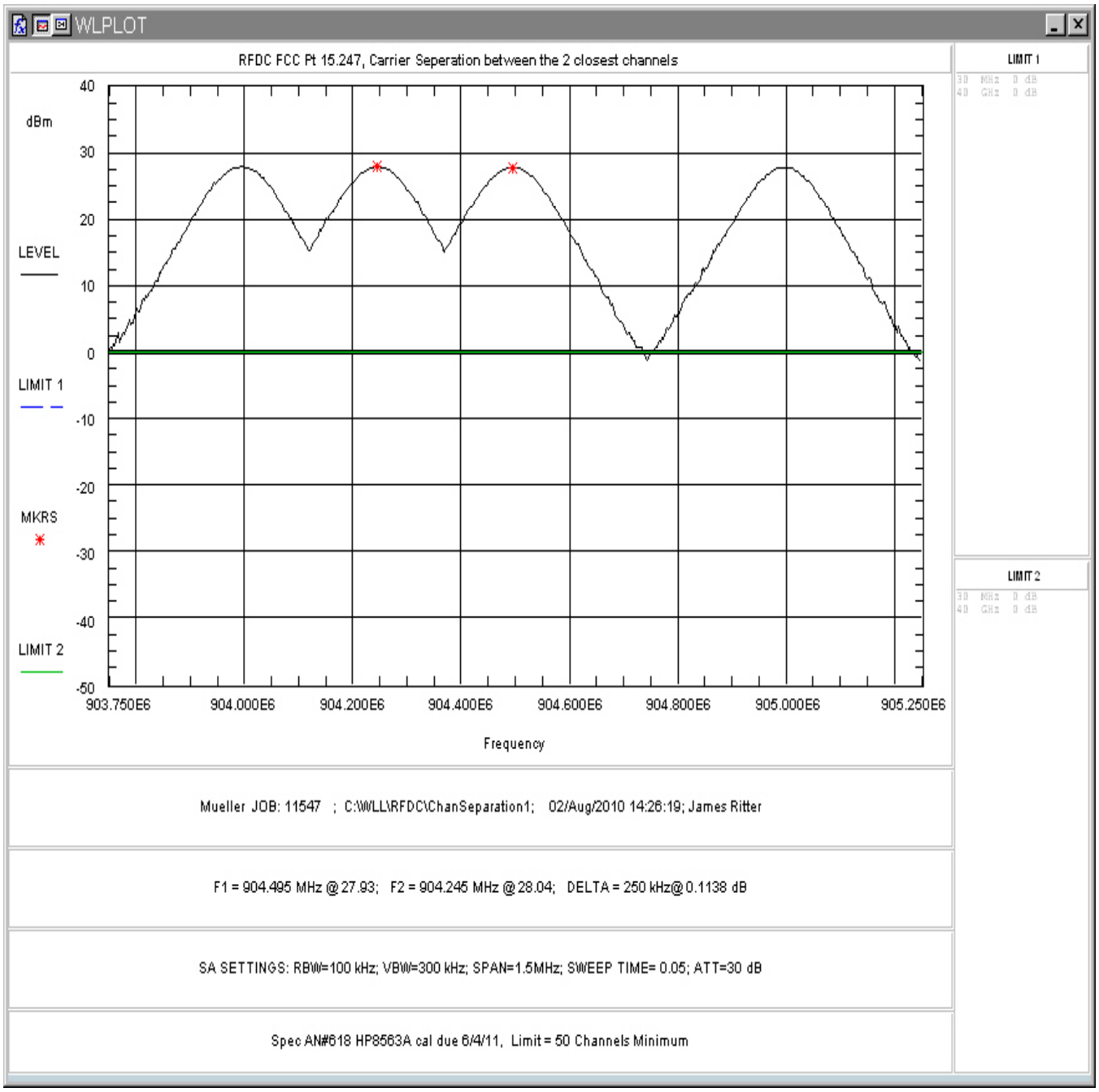

Figure 17: Data Channel Spacing, 250 kHz

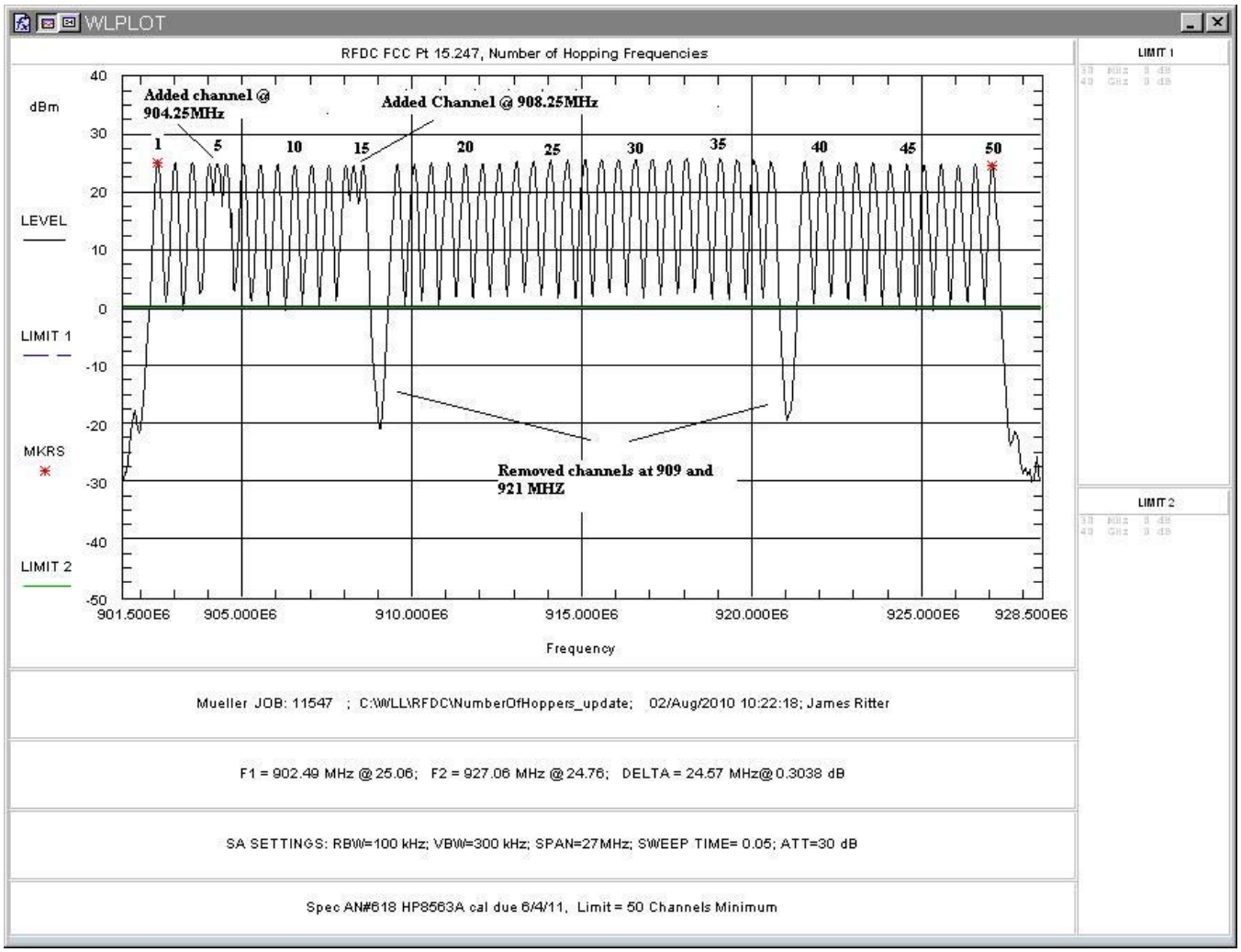

Figure 18:Data Channel Number of Channels

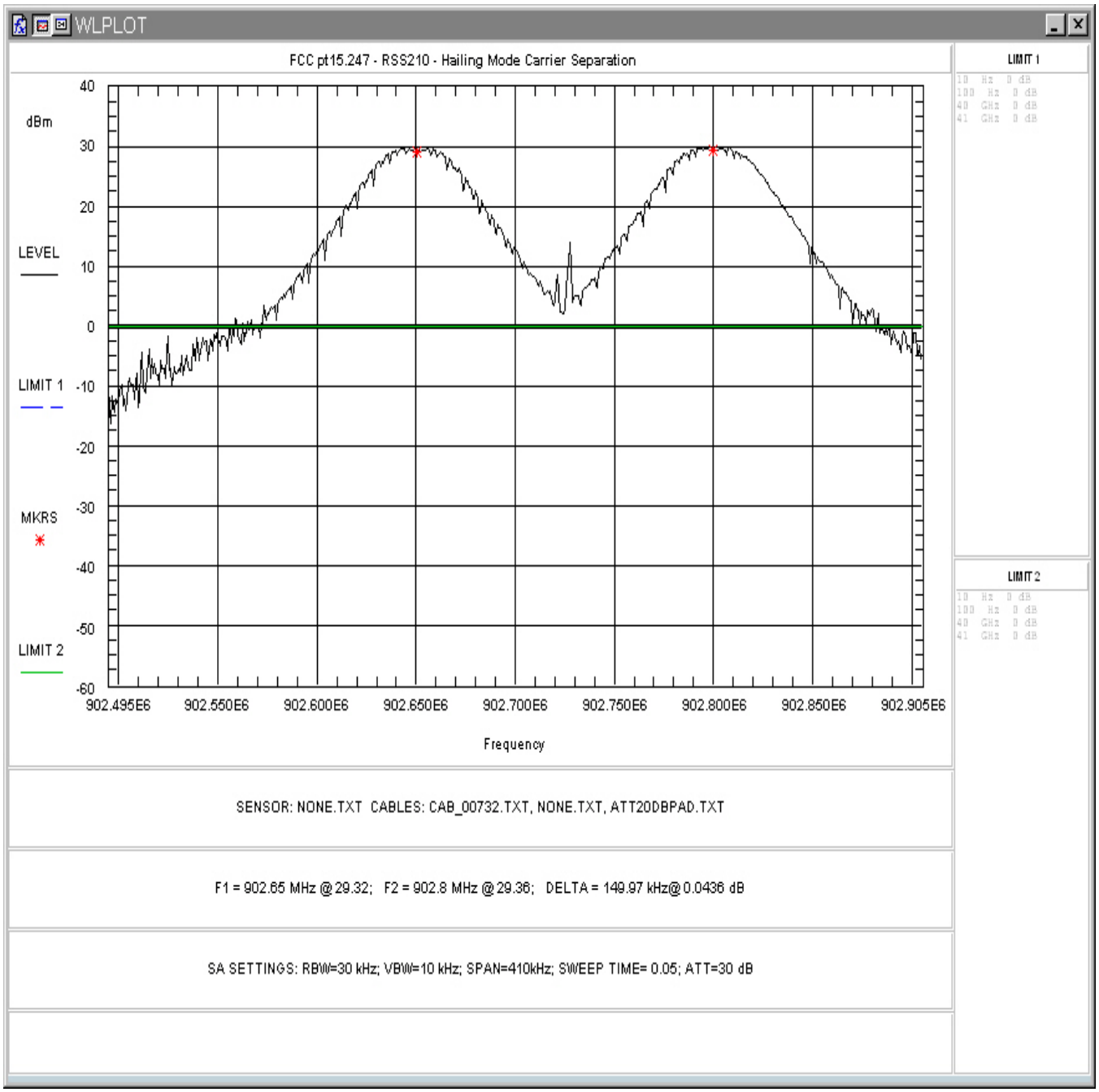

Figure 19 Hailing Channel Spacing

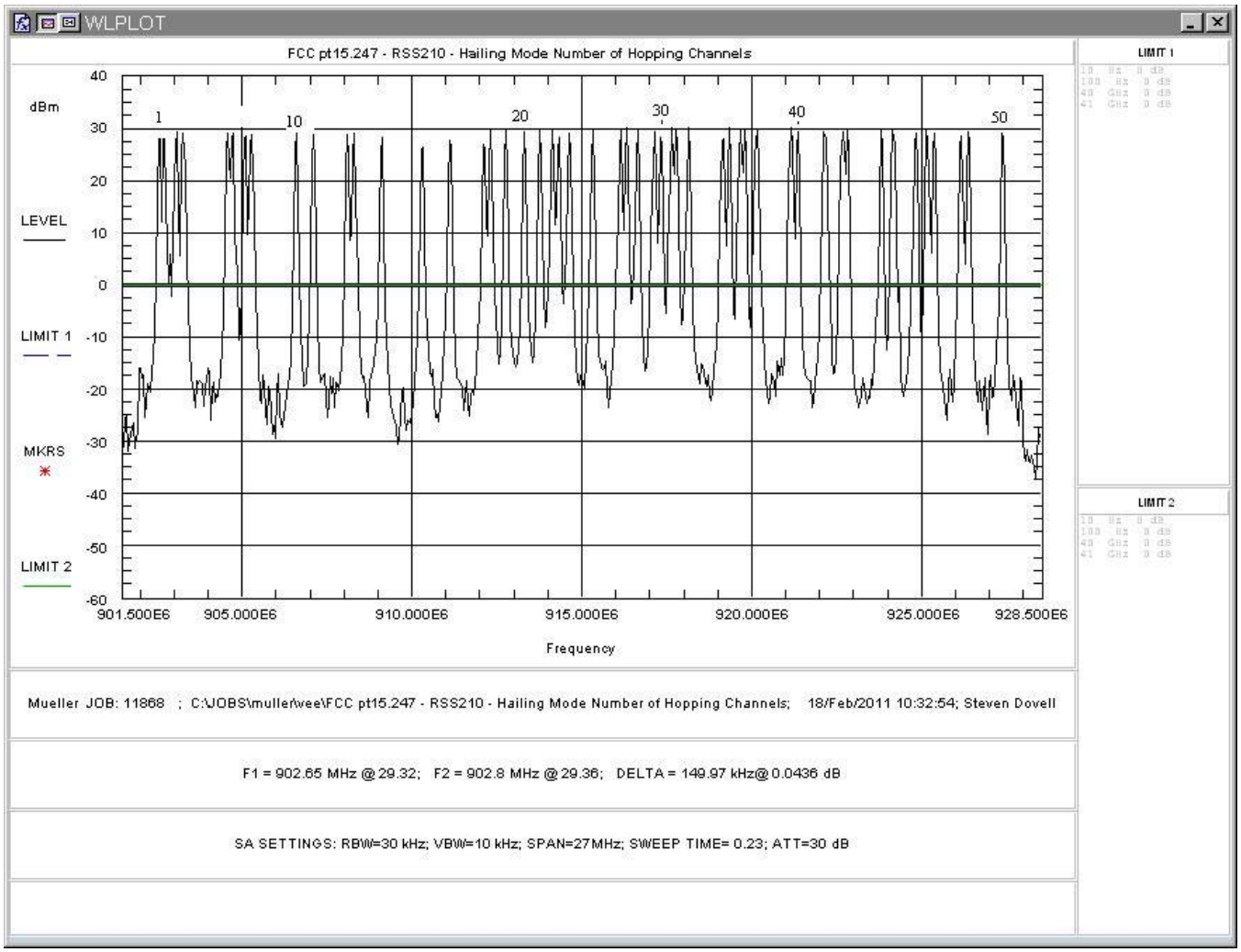

Figure 20 Number of Hailing Channels

5.5 Conducted Spurious Emissions at Antenna Terminals (FCC Part §2.1051)

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

The EUT antenna was removed and the cable was connected directly into a spectrum analyzer through a suitable attenuator. An offset was programmed into the spectrum analyzer to compensate for the loss of the external attenuator. 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 maximum modulated transmit frequency amplitude). The emissions outside of the allocated frequency band were then scanned from 30 MHz up to the tenth harmonic of the carrier.

Close-up plots of the 902-928MHz band edges are provided in both the hopping and non-hopping modes to show compliance at both of these points.

The following are plots of the conducted spurious emissions data.

5.5.1 Data Mode Conducted Spurious

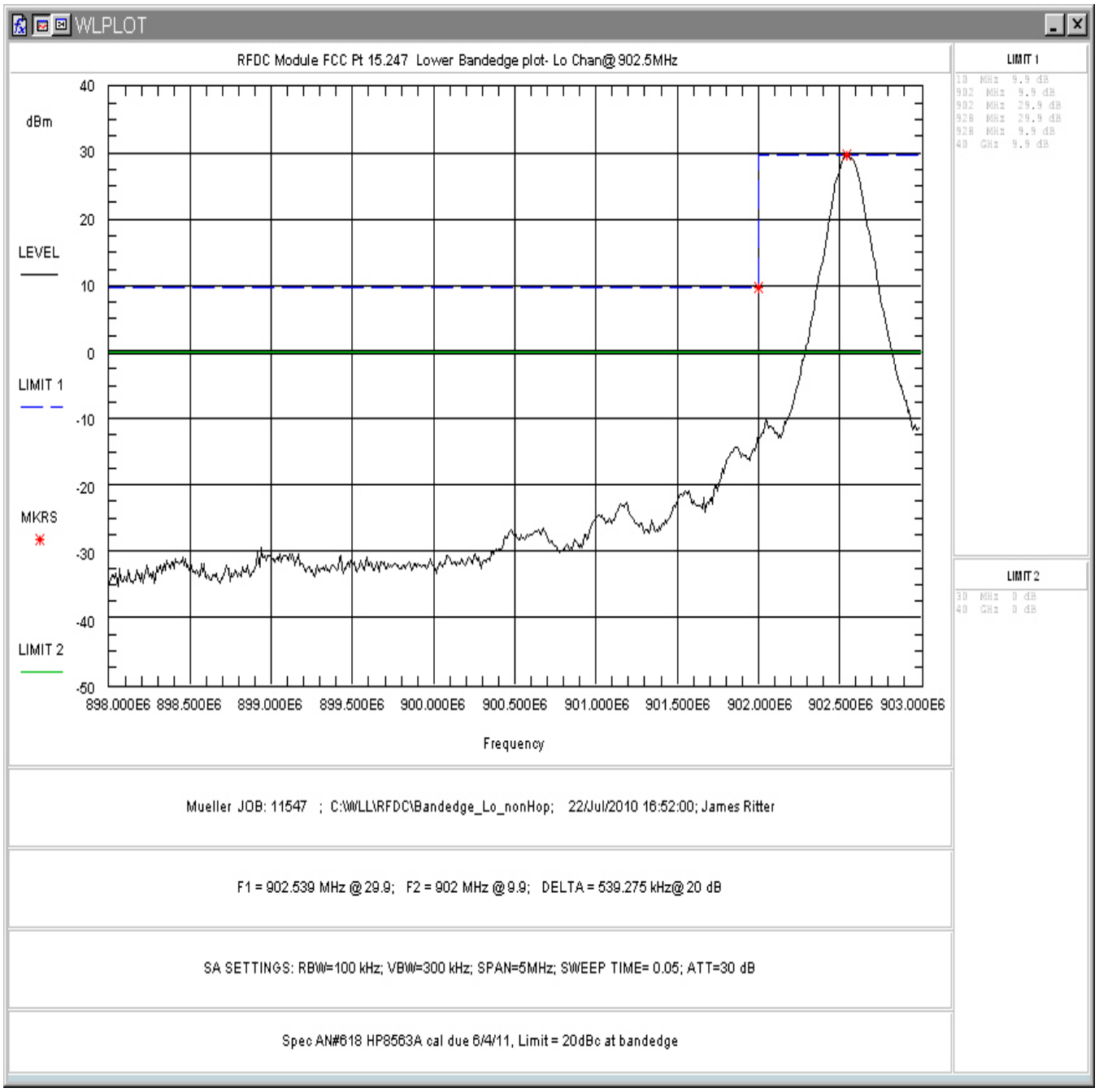

Figure 21: Lower Band Edge Plot, Low Channel

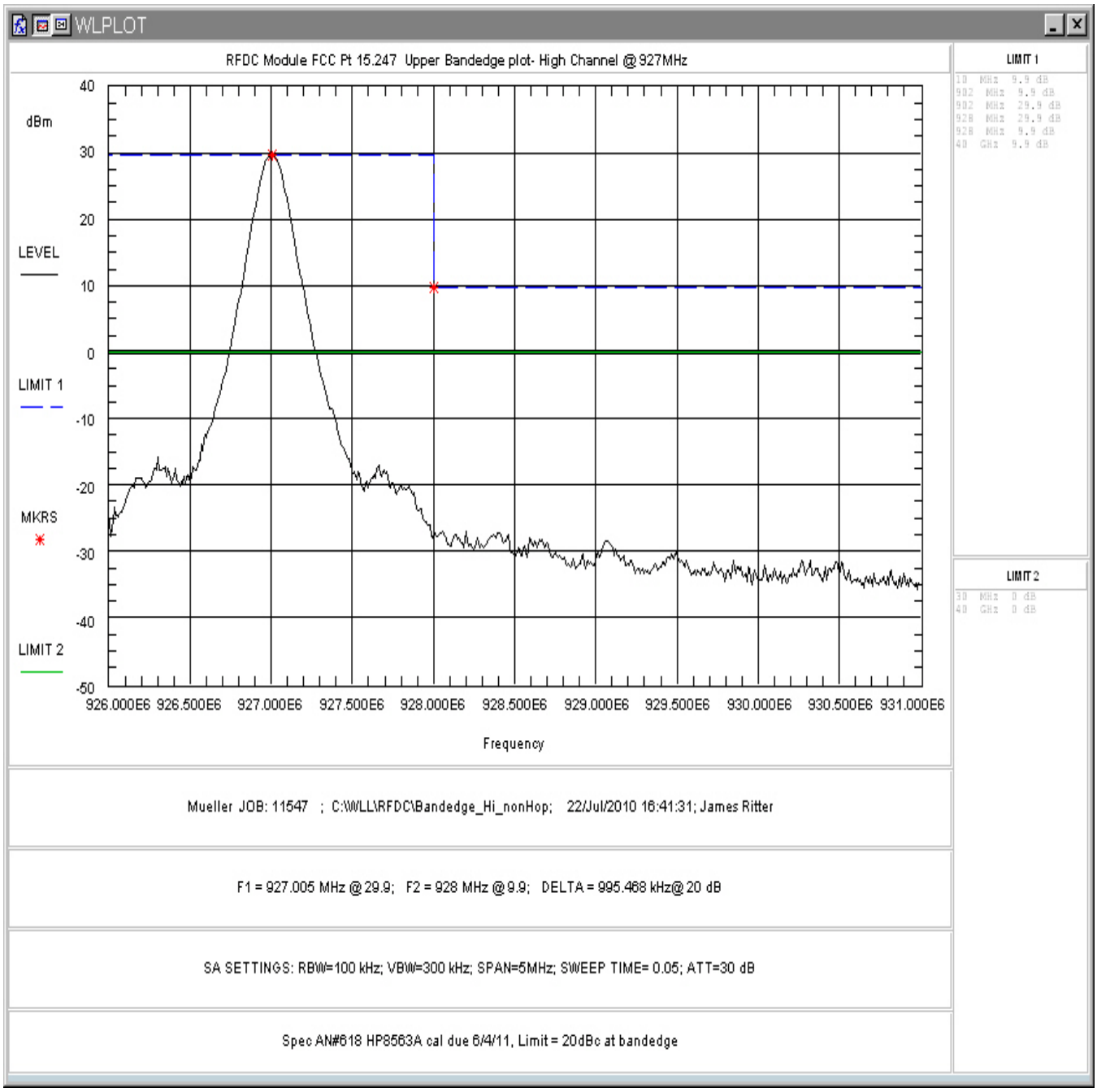

Figure 22: Upper Band Edge Plot, High Channel

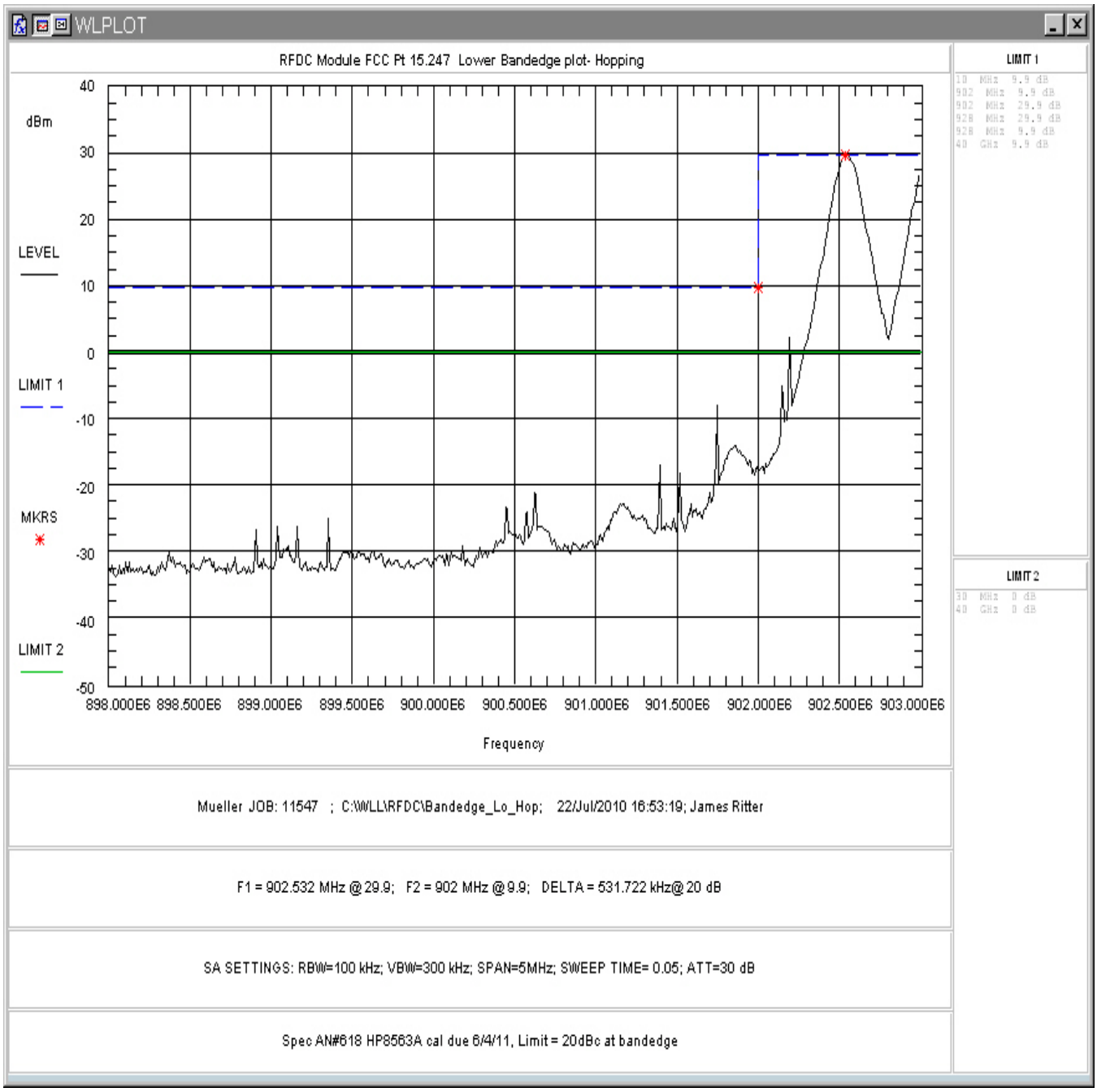

Figure 23: Lower Band Edge Plot, Hopping Mode

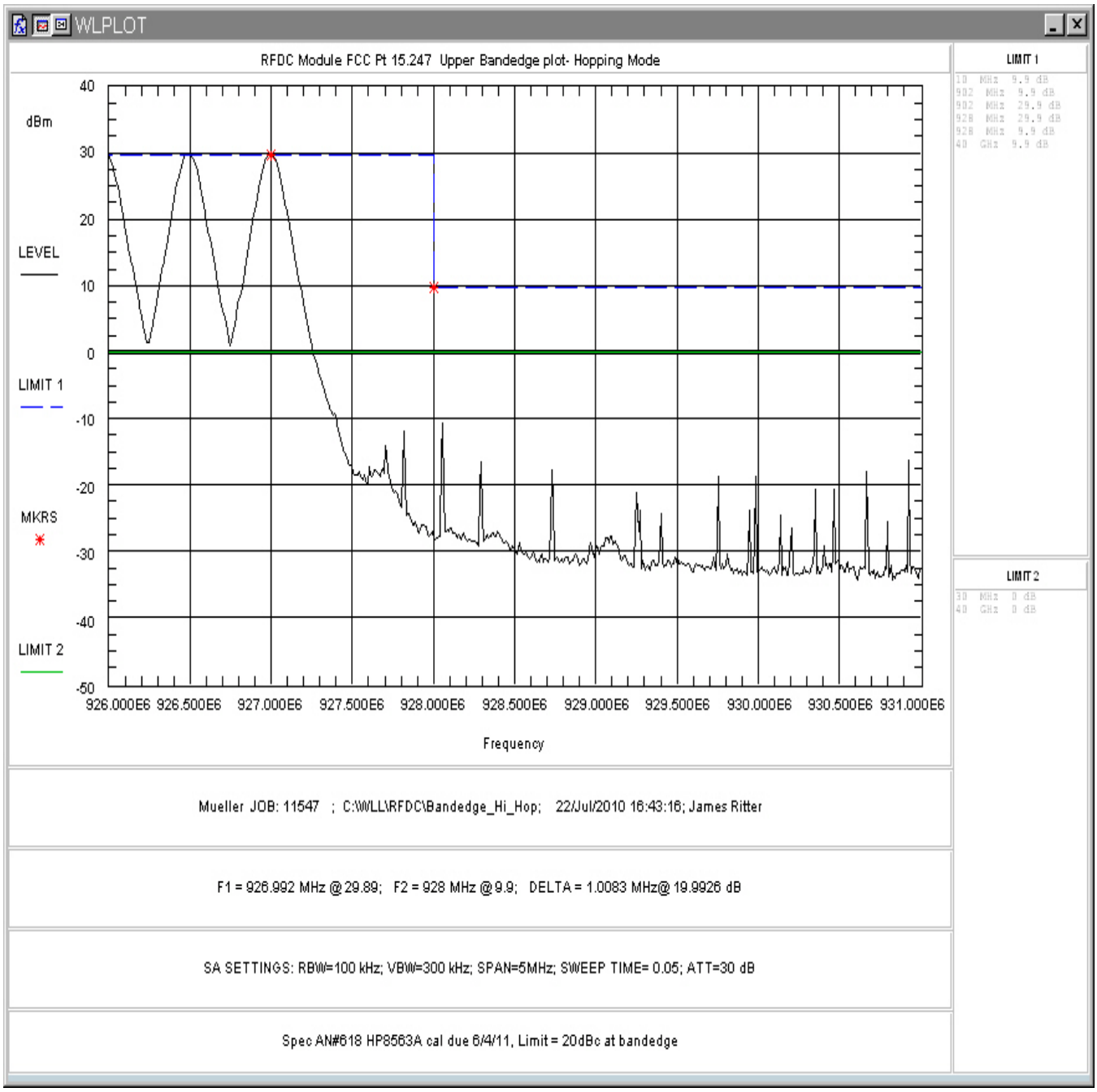

Figure 24: Upper Band Edge Plot, Hopping Mode

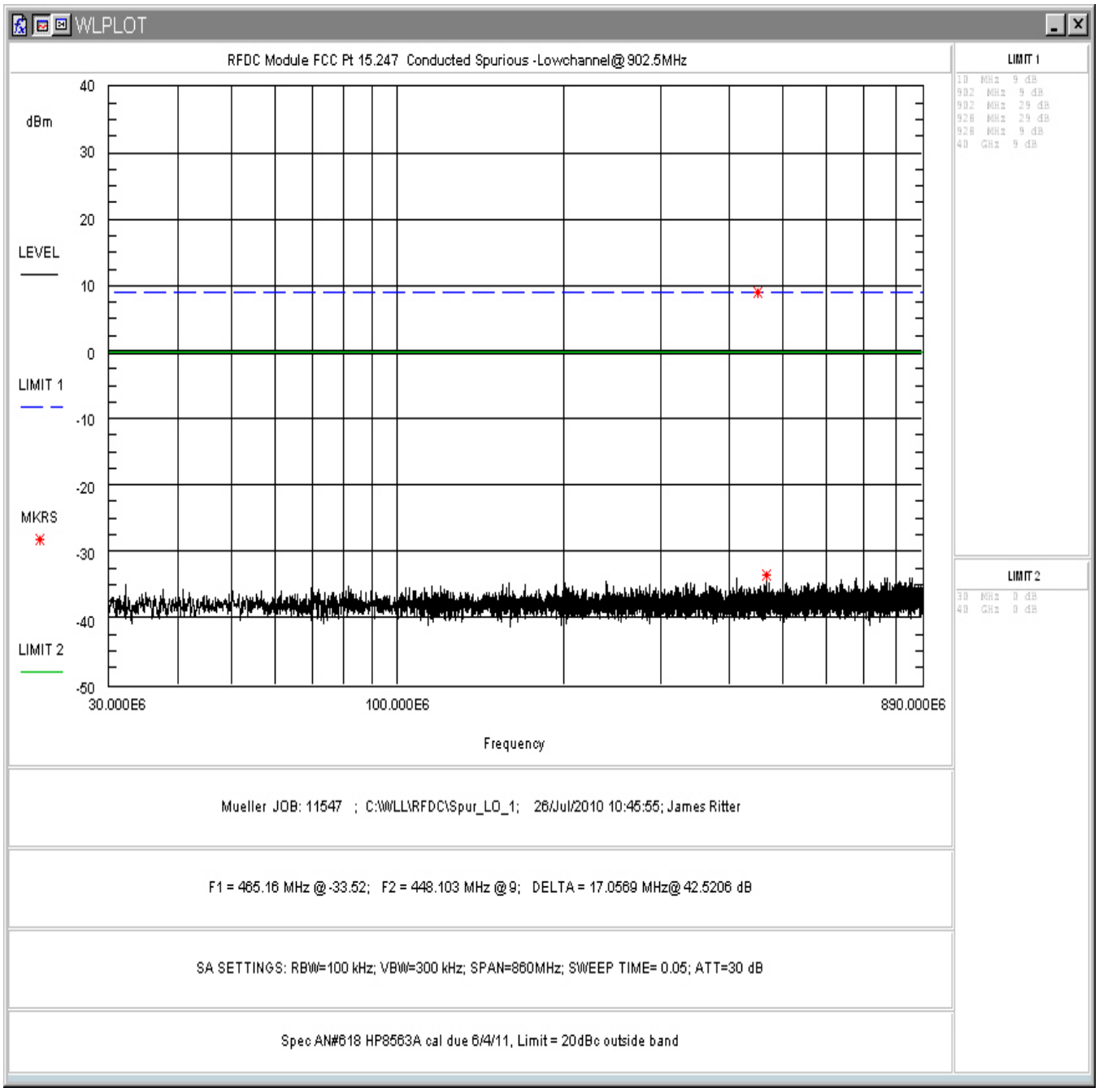

Figure 25: Conducted Spurious Emissions, Low Data Channel 30 - 890MHz

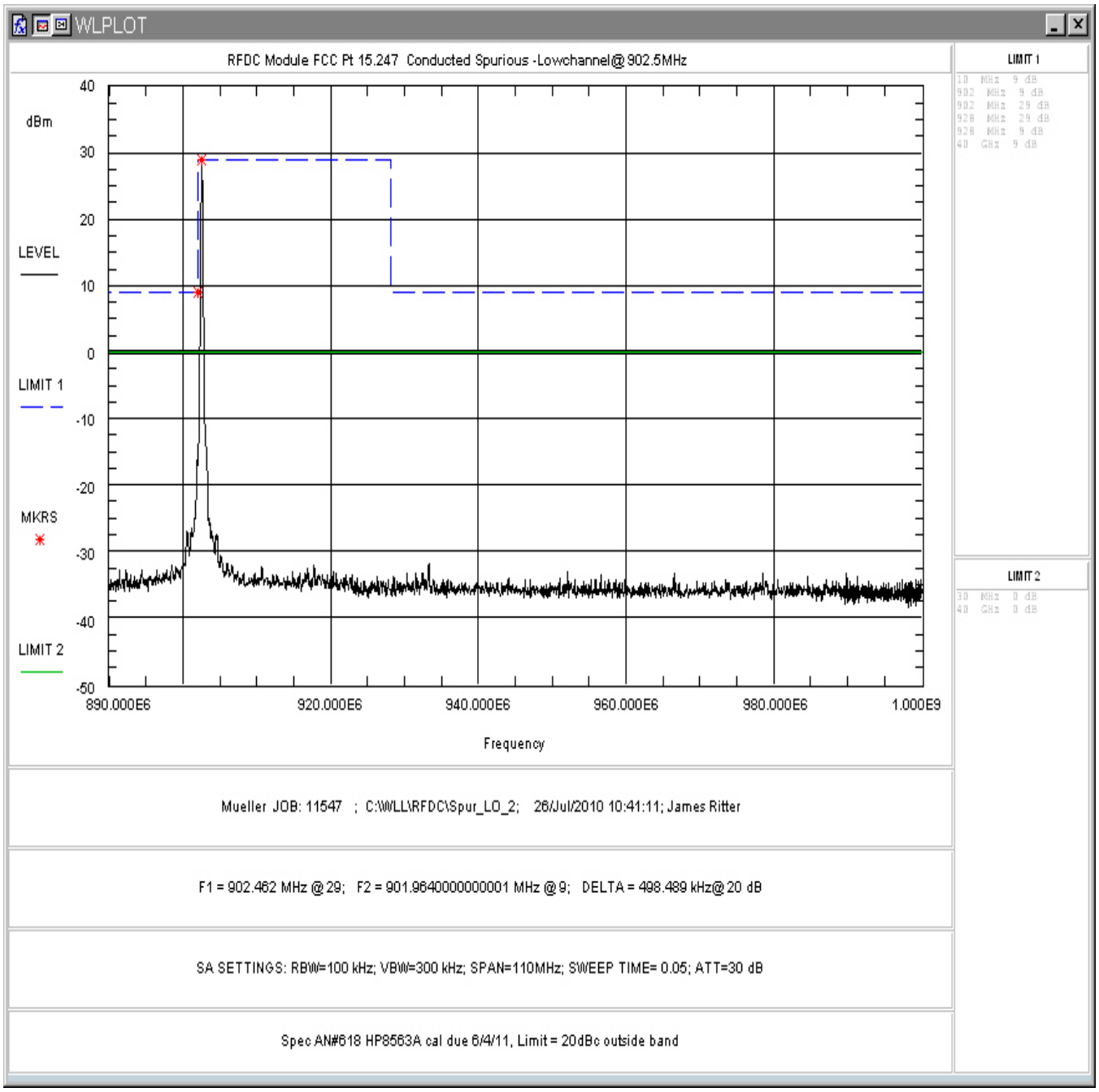

Figure 26: Conducted Spurious Emissions, Low Data Channel 890-1000MHz

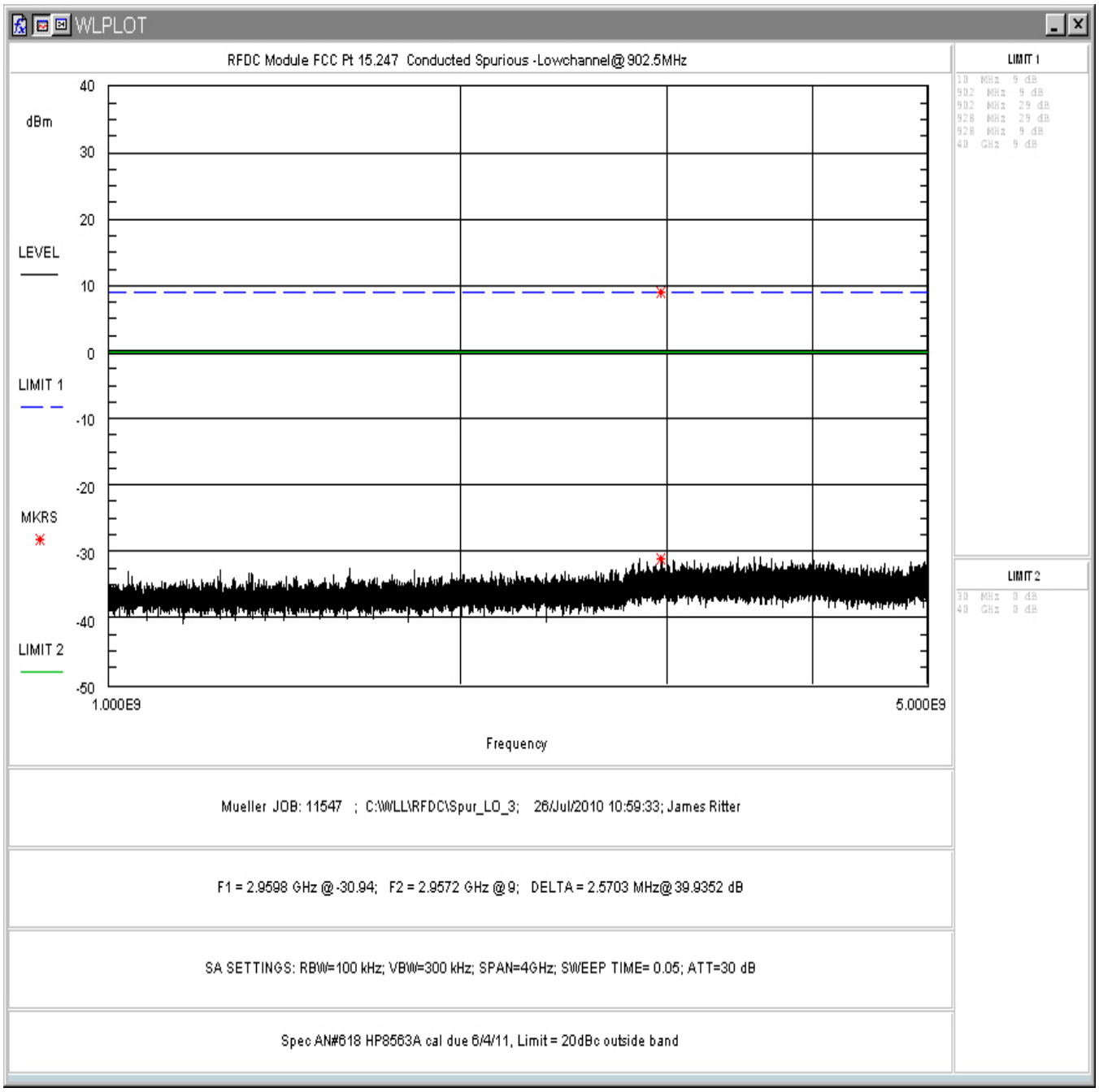

Figure 27: Conducted Spurious Emissions, Low Data Channel 1-5GHz

