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FCC Certification Test Report
For the
Mueller Systems
MIHUBXR-R

FCC ID: SM6-HUBXRR
IC ID: 9235A- HUBXRR

WLL JOB# **12823-01 Rev. 2**
April 29, 2013
Last revised May 14, 2013

Prepared for:

Mueller Systems
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ACLASS ACCREDITED TESTING

Testing Certificate AT-1448

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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 Frequency Hopping Spread Spectrum Transmitter under Part 15.247 (10/2010) of the FCC Rules and Industry Canada RSS-210 Issue 8. This Certification Test Report documents the test configuration and test results for a Mueller Systems transmitter.

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 MIHUBXR-R complies with the limits for a Frequency Hopping Spread Spectrum Transmitter device under FCC Part 15.247 and Industry Canada RSS-210 Issue 8..

As the name of the EUT has been revised from MiHub1.75XR to MIHUBXR-R any references to the MiHub1.75XR shown in photographs or plots refer to the MIHUBXR-R.

Revision History	Description of Change	Date
Rev 0	Initial Release	April 13, 2013
Rev 1	Updated EUT name	April 29, 2013
Rev 2	Changed EUT name to MIHUBXR-R and placed note in abstract section about references to MiHub1.75XR.	May 14, 2013

Table of Contents

Abstract ii
1 Introduction 1
1.1 Compliance Statement 1
1.2 Test Scope 1
1.3 Contract Information 1
1.4 Test Dates 1
1.5 Test and Support Personnel 1
1.6 Abbreviations 2
2 Equipment Under Test 3
2.1 EUT Identification & Description 3
2.2 Modification 4
2.3 Test Configuration 4
2.4 Testing Algorithm 4
2.5 Test Location 4
2.6 Measurements 4
2.7 Measurement Uncertainty 4
3 Test Equipment 7
4 Test Summary 8
5 Test Results 9
5.1 Duty Cycle and Time of Occupancy 9
5.2 RF Power Output: (FCC Part §2.1046) 16
5.3 Occupied Bandwidth: (FCC Part §2.1049) 29
5.4 Channel Spacing and Number of Hop Channels (FCC Part §15.247(a)(1) 39
5.5 Conducted Spurious Emissions at Antenna Terminals (FCC Part §2.1051) 44
5.6 Radiated Spurious Emissions: (FCC Part §2.1053) 93
5.7 AC Conducted Emissions (FCC Pt.15.207) 101
5.8 Receiver Radiated Emissions 103

List of Tables

Table 1: Device Summary 3
Table 2: Equipment Configuration 3
Table 3: Expanded Uncertainty List 6
Table 4: Test Equipment List 7
Table 5: Test Summary Table 8
Table 6: Data Channel RF Power Output 16
Table 7 Hailing Channel RF Power Output 16
Table 8 Data Channel Occupied Bandwidth Results 29
Table 9: Hailing Channel Occupied Bandwidth Results 29
Table 10: Channel spacing and number of hopping channels summary 39
Table 11: Radiated Emission Test Data, Low Frequency Data (<1GHz) 94
Table 12: Radiated Emission Test Data, Short Cable, High Frequency Data (>1GHz) 95
Table 13: Radiated Emission Test Data, Long Cable, High Frequency Data (>1GHz) 98
Table 14: Conducted Emissions Data 120VAC, Transmit On 102
Table 15: Receiver Radiated Emission Test Data 104

List of Figures

Figure 1: Duty Cycle Plot (Data Mode 9.6kbps) 10
Figure 2: Time of Occupancy Plot (Data Mode 9.6kbps) 11
Figure 3: Duty Cycle Plot (Data Mode 28.8bps) 12
Figure 4: Time of Occupancy Plot (Data Mode 28.8kbps) 13
Figure 5 Hailing Channel Duty Cycle Plot 14
Figure 6 Hailing Channel Time of Occupancy Plot 15
Figure 7: Data Channel RF Peak Power, Long Cable, Low Channel 17
Figure 8: Data Channel RF Peak Power, Long Cable, Center Channel 18
Figure 9: Data Channel RF Peak Power, Long Cable, High Channel 19
Figure 10: Data Channel RF Peak Power, Short Cable, Low Channel 20
Figure 11: Data Channel RF Peak Power, Short Cable, Center Channel 21
Figure 12: Data Channel RF Peak Power, Short Cable, High Channel 22
Figure 13 Hailing Channel RF Peak Power, Long Cable, Low Channel 23
Figure 14 Hailing Channel RF Peak Power, Long Cable, Center Channel 24
Figure 15 Hailing Channel RF Peak Power, Long Cable, High Channel 25
Figure 16 Hailing Channel RF Peak Power, Short Cable, Low Channel 26
Figure 17 Hailing Channel RF Peak Power, Short Cable, Center Channel 27
Figure 18 Hailing Channel RF Peak Power, Short Cable, High Channel 28
Figure 19: Data Channel Occupied Bandwidth, 9.6kbps, Low Channel 30
Figure 20: Data Channel Occupied Bandwidth, 9.6kbps, Center Channel 31
Figure 21: Data Channel Occupied Bandwidth, 9.6kbps, High Channel 32
Figure 22: Data Channel Occupied Bandwidth, 28.8kbps, Low Channel 33
Figure 23: Data Channel Occupied Bandwidth, 28.8kbps, Center Channel 34
Figure 24: Data Channel Occupied Bandwidth, 28.8kbps, High Channel 35
Figure 25 Hailing Channel Occupied Bandwidth, Low Channel 36
Figure 26 Hailing Channel Occupied Bandwidth, Center Channel 37
Figure 27 Hailing Channel Occupied Bandwidth, High Channel 38
Figure 28: Data Channel Spacing, 250 kHz 40
Figure 29: Data Channel Number of Channels 41
Figure 30: Hailing Channel Spacing 42
Figure 31: Number of Hailing Channels 43
Figure 32: Lower Band-edge, Hailing, Long Cable, 9.6kbps, TX-902.65MHz 45
Figure 33: Upper Band-edge, Hailing, Long Cable, 9.6kbps, TX-927.35MHz 46
Figure 34: Lower Band-edge, Hailing, Long Cable, 9.6kbps, Hopping 47
Figure 35: Upper Band-edge, Hailing, Long Cable, 9.6kbps, Hopping 48
Figure 36: Lower Band-edge, Hailing, Short Cable, 9.6kbps, TX-902.65MHz 49
Figure 37: Upper Band-edge, Hailing, Short Cable, 9.6kbps, TX-927.35MHz 50
Figure 38: Lower Band-edge, Hailing, Short Cable, 9.6kbps, Hopping 51
Figure 39: Upper Band-edge, Hailing, Short Cable, 9.6kbps, Hopping 52
Figure 40: Lower Band-edge, Data, Long Cable, 9.6kbps, TX-902.5MHz 53
Figure 41: Upper Band-edge, Data, Long Cable, 9.6kbps, TX-927MHz 54
Figure 42: Lower Band-edge, Data, Long Cable, 9.6kbps, Hopping 55
Figure 43: Upper Band-edge, Data, Long Cable, 9.6kbps, Hopping 56

Figure 44: Lower Band-edge, Data, Short Cable, 9.6kbps, TX-902.5MHz 57
Figure 45: Upper Band-edge, Data, Short Cable, 9.6kbps, TX-927MHz..... 58
Figure 46: Lower Band-edge, Data, Short Cable, 9.6kbps, Hopping 59
Figure 47: Upper Band-edge, Data, Short Cable, 9.6kbps, Hopping..... 60
Figure 48: Lower Band-edge, Data, Long Cable, 28.8kbps, TX-902.5MHz 61
Figure 49: Upper Band-edge, Data, Long Cable, 28.8kbps, TX-927MHz..... 62
Figure 50: Lower Band-edge, Data, Long Cable, 28.8kbps, Hopping 63
Figure 51: Upper Band-edge, Data, Long Cable, 28.8kbps, Hopping..... 64
Figure 52: Lower Band-edge, Data, Short Cable, 28.8kbps, TX-902.5MHz 65
Figure 53: Upper Band-edge, Data, Short Cable, 28.8kbps, TX-927MHz..... 66
Figure 54: Lower Band-edge, Data, Short Cable, 28.8kbps, Hopping 67
Figure 55: Upper Band-edge, Data, Short Cable, 28.8kbps, Hopping..... 68
Figure 56. MIHUBXR-R Spurious Emissions TX = 902.5MHz Long Cable - 30MHz - 890MHz 69
Figure 57. MIHUBXR-R Spurious Emissions TX = 902.5MHz Long Cable - 890MHz - 940MHz 70
Figure 58. MIHUBXR-R Spurious Emissions TX = 902.5MHz Long Cable - 940MHz - 5GHz 71
Figure 59. MIHUBXR-R Spurious Emissions TX = 902.5MHz Long Cable - 5GHz - 10GHz . 72
Figure 60. MIHUBXR-R Spurious Emissions TX = 902.5MHz Short Cable 30M - 890MHz.... 73
Figure 61. MIHUBXR-R Spurious Emissions TX = 902.5MHz Short Cable 890M - 940MHz.. 74
Figure 62. MIHUBXR-R Spurious Emissions TX = 902.5MHz Short Cable 940M - 5GHz 75
Figure 63. MIHUBXR-R Spurious Emissions TX = 902.5MHz Short Cable 5G - 10GHz..... 76
Figure 64. MIHUBXR-R Spurious Emissions TX = 915MHz Long Cable - 30MHz - 890MHz77
Figure 65. MIHUBXR-R Spurious Emissions TX = 915MHz Long Cable - 890MHz - 940MHz 78
Figure 66. MIHUBXR-R Spurious Emissions TX = 915MHz Long Cable - 940MHz - 5GHz . 79
Figure 67. MIHUBXR-R Spurious Emissions TX = 915MHz Long Cable - 5GHz - 10GHz 80
Figure 68. MIHUBXR-R Spurious Emissions TX = 915MHz Short Cable 30M - 890MHz..... 81
Figure 69. MIHUBXR-R Spurious Emissions TX = 915MHz Short Cable 890M - 940MHz..... 82
Figure 70. MIHUBXR-R Spurious Emissions TX = 915MHz Short Cable 940M - 5GHz 83
Figure 71. MIHUBXR-R Spurious Emissions TX = 915MHz Short Cable - 5GHz - 10GHz.... 84
Figure 72. MIHUBXR-R Spurious Emissions TX = 927.35MHz Long Cable - 30MHz - 890MHz 85
Figure 73. MIHUBXR-R Spurious Emissions TX = 927.35MHz Long Cable - 890MHz - 940MHz 86
Figure 74. MIHUBXR-R Spurious Emissions TX = 927.35MHz Long Cable - 940MHz - 5GHz 87
Figure 75. MIHUBXR-R Spurious Emissions TX = 927.35MHz Long Cable - 5GHz - 10GHz 88
Figure 76. MIHUBXR-R Spurious Emissions TX = 927.35MHz Short Cable - 30MHz - 890MHz 89
Figure 77. MIHUBXR-R Spurious Emissions TX = 927.35MHz Short Cable - 890MHz - 940MHz 90
Figure 78. MIHUBXR-R Spurious Emissions TX = 927.35MHz Short Cable - 940MHz - 5GHz 91
Figure 79. MIHUBXR-R Spurious Emissions TX = 927.35MHz Long Cable - 5GHz - 10GHz 92

1 Introduction

1.1 Compliance Statement

The Mueller Systems MIHUBXR-R complies with the limits for a Frequency Hopping Spread Spectrum Transmitter device under FCC Part 15.247 (10/2010) and Industry Canada RSS-210 Issue 8. .

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:	801661

1.4 Test Dates

Testing was performed on the following date(s):	1/8/2013 to 4/2/13

1.5 Test and Support Personnel

Washington Laboratories, LTD	James Ritter, Steven Dovell
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 MIHUBXR-R 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-HUBXRR
IC ID:	9235A- HUBXRR
Model:	MIHUBXR-R
FCC Rule Parts:	§15.247
Frequency Range:	902.5-927.35MHz
Maximum Output Power: (conducted at antenna port)	29.6 dBm (912mW)
Modulation:	FM
Occupied Bandwidth:	59.8kHz
Keying:	Automatic
Type of Information:	Data
Number of Channels:	50 Hailing Channels and 50 Data Channels
Antenna Connector	N
Antenna Type	6dBi Omni
Interface:	N connector for 902.5-927 whip antenna,
Power Source & Voltage:	120VAC
Highest TX Spurious Emission	2707.5MHz @ 226.6uV/m
Highest RX Spurious Emission	431.53MHz @ 89.4uV/m

Table 2: Equipment Configuration

Name / Description	Model Number	Part Number	Serial Number	Revision
Polyphase Lightning Arrestor	CGXZ+15NFNF-A	LT2012000185076	N/A	N/A
Radio/meter	MS-G-AC-B-G-R	MS-G-AC-B-G-R	11000227	N/A
Amplifier/Filter	MS-G-EX-ANT-Kit-R	MS-G-EX-ANT-Kit-R	12345678	N/A

2.2 Modification

None.

2.3 Test Configuration

The MIHUBXR-R was operated as a standalone unit connected to 120VAC mains. Commands were sent to the MIHUBXR-R using a 3 pin to USB port connected to a support laptop using Windows HyperTerminal program.

2.4 Testing Algorithm

The MIHUBXR-R was programmed via an external 3 pin programming port on the EUT to a USB 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.

The amplifier is auto-correcting to provide a constant output to the antenna regardless of the TX input power, thus the testing was conducted with a short cable between the amplifier and the TX unit (High power into amplifier) and a long high loss cable simulating 200ft (low power into amplifier). The power of the TX unit never changes and the power level to the amplifier is due to cable losses only as the amplifier may be mounted at various distances from the TX unit (on poles).

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 3 below.

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

Table 4: Test Equipment List

Test Name:	**Conducted Antenna Port**	Test Date:	**3/12/2013 & 4/1/2013**
Asset #	**Manufacturer/Model**	**Description**	**Cal. Due**
220595	AGILENT - 8565EC	SPECTRUM ANALYZER 30HZ - 40GHZ	01/28/2014
00528	AGILENT - E4446A	ANALYZER SPECTRUM	8/30/2013
728	AGILENT - 8564EC	SPECTRUM ANALYZER 30HZ - 40GHZ	5/15/2013

Test Name:	**Radiated Emissions**	Test Date:	**03/27/2013**
Asset #	**Manufacturer/Model**	**Description**	**Cal. Due**
823	AGILENT - N9010A	EXA SPECTRUM ANALYZER	1/26/2014
382	SUNOL SCIENCES CORPORATION - JB1	ANTENNA BICONLOG	6/26/2014
728	AGILENT - 8564EC	SPECTRUM ANALYZER 30HZ - 40GHZ	5/15/2013
4	ARA - DRG-118/A	ANTENNA DRG 1-18GHZ	2/20/2015
742	PENN ENGINEERING - WR284	2.2-4.15GHZ BANDPASS FILTER	5/29/2014
627	AGILENT - 8449B	AMPLIFIER 1-26GHZ	5/24/2013
767	MEGAPHASE - EM18-NK5NK-600	LOW LOSS ARMORED CABLE DC-18GHZ N-N FACTORY FORMED RA	6/19/2013
281	ITC - 21A-3A1	WAVEGUIDE 4.51-10.0GHZ	5/29/2014

Test Name:	**Conducted Emissions Voltage**	Test Date:	**03/13/2013**
Asset #	**Manufacturer/Model**	**Description**	**Cal. Due**
124	SOLAR - 8012-50-R-24-BNC	LISN	6/28/2013
69	HP - 85650A	ADAPTER QP	6/27/2013
802	HP - 8568B	SPECTRUM ANALYZER	4/27/2013
71	HP - 85685A	PRESELECTOR RF	6/27/2013
53	HP - 11947A	LIMITER TRANSIENT	3/19/2014

4 Test Summary

The Table Below shows the results of testing for compliance with a Frequency Hopping System in accordance with FCC Part 15.247 10/2010 and Industry Canada RSS-210 Issue 8.. Full results are shown in section 5.

Table 5: 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 RSS-Gen 7.2.2	General Field Strength Limits (Restricted Bands & RE Limits)	Pass
15.207	RSS-Gen [7.2.4]	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 2.5	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 approximately 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 198.6ms. As the unit is on a channel twice in a 20 second period the time of occupancy is 397.2ms per 20 seconds, thus complying with the 0.4 second requirement.

Dwell time per hop =198.6ms; Limit 0.4sec per 20 sec

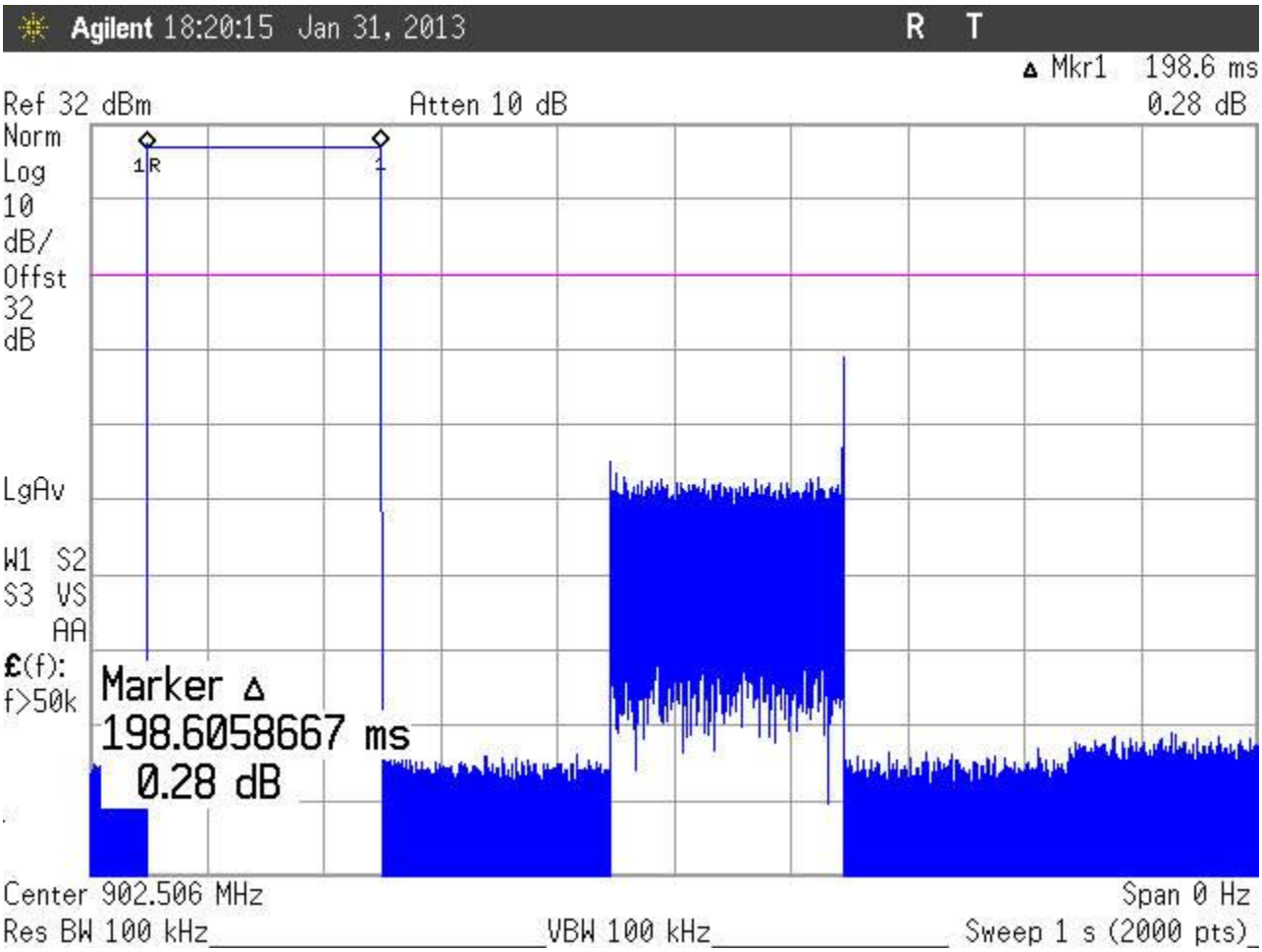

Figure 1: Duty Cycle Plot (Data Mode 9.6kbps)

Time of Occupancy per 20 seconds: 2 pulses of 198.6ms per 20 seconds = 397.2ms.

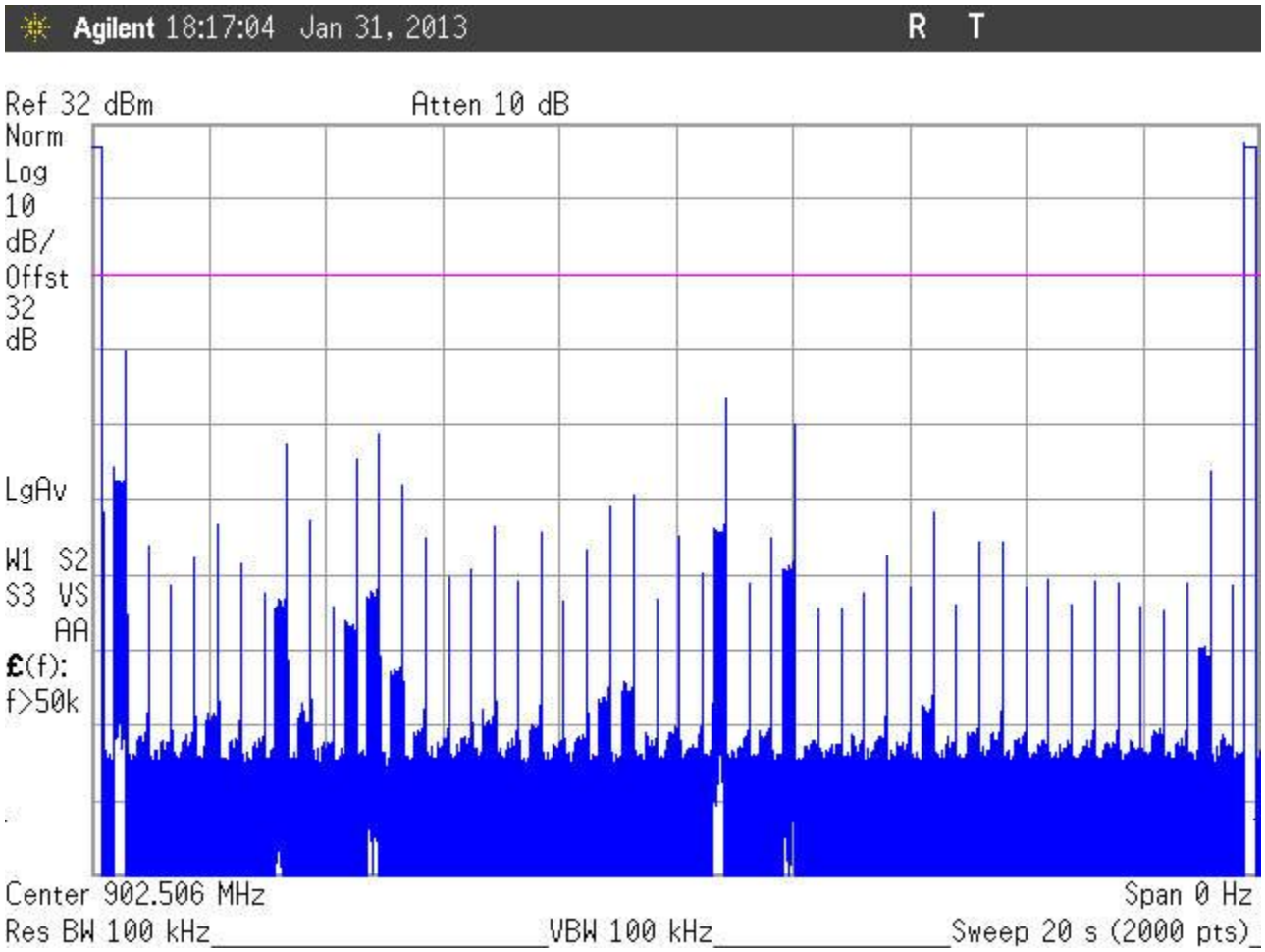

Figure 2: Time of Occupancy Plot (Data Mode 9.6kbps)

Dwell time per hop =66.04ms; Limit 0.4sec

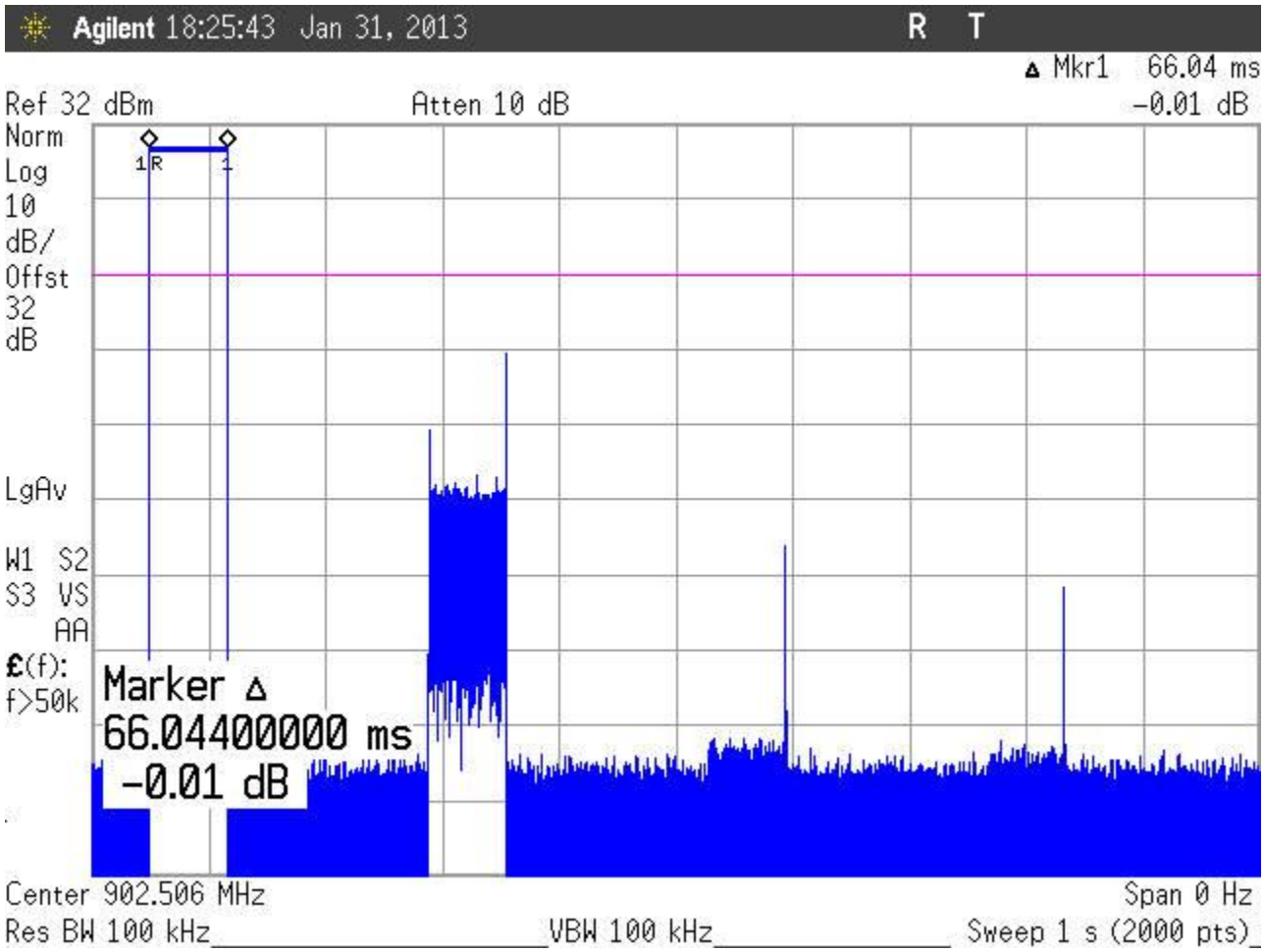

Figure 3: Duty Cycle Plot (Data Mode 28.8bps)

Time of Occupancy per 20 seconds: 2 pulses of 66.04ms per 20 seconds = 132.08ms.

Limit = 0.4sec per 20 seconds maximum

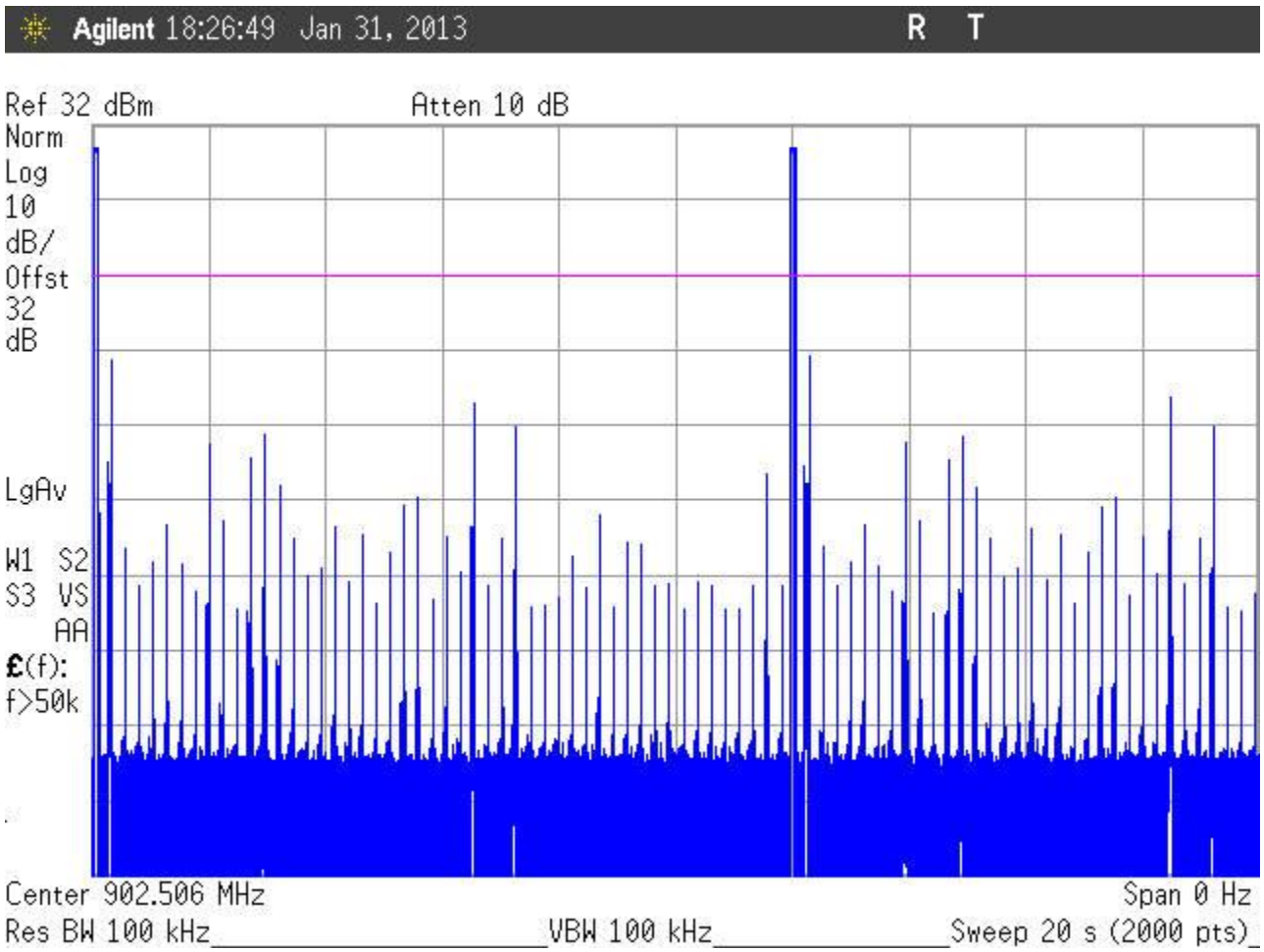

Figure 4: Time of Occupancy Plot (Data Mode 28.8kbps)

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 393.2ms. As the unit is on a hailing channel once in a 20 second period the time of occupancy is 393.2ms per 20 seconds, thus complying with the 0.4 second requirement.

Dwell time per hop =393.2ms; Limit 0.4sec

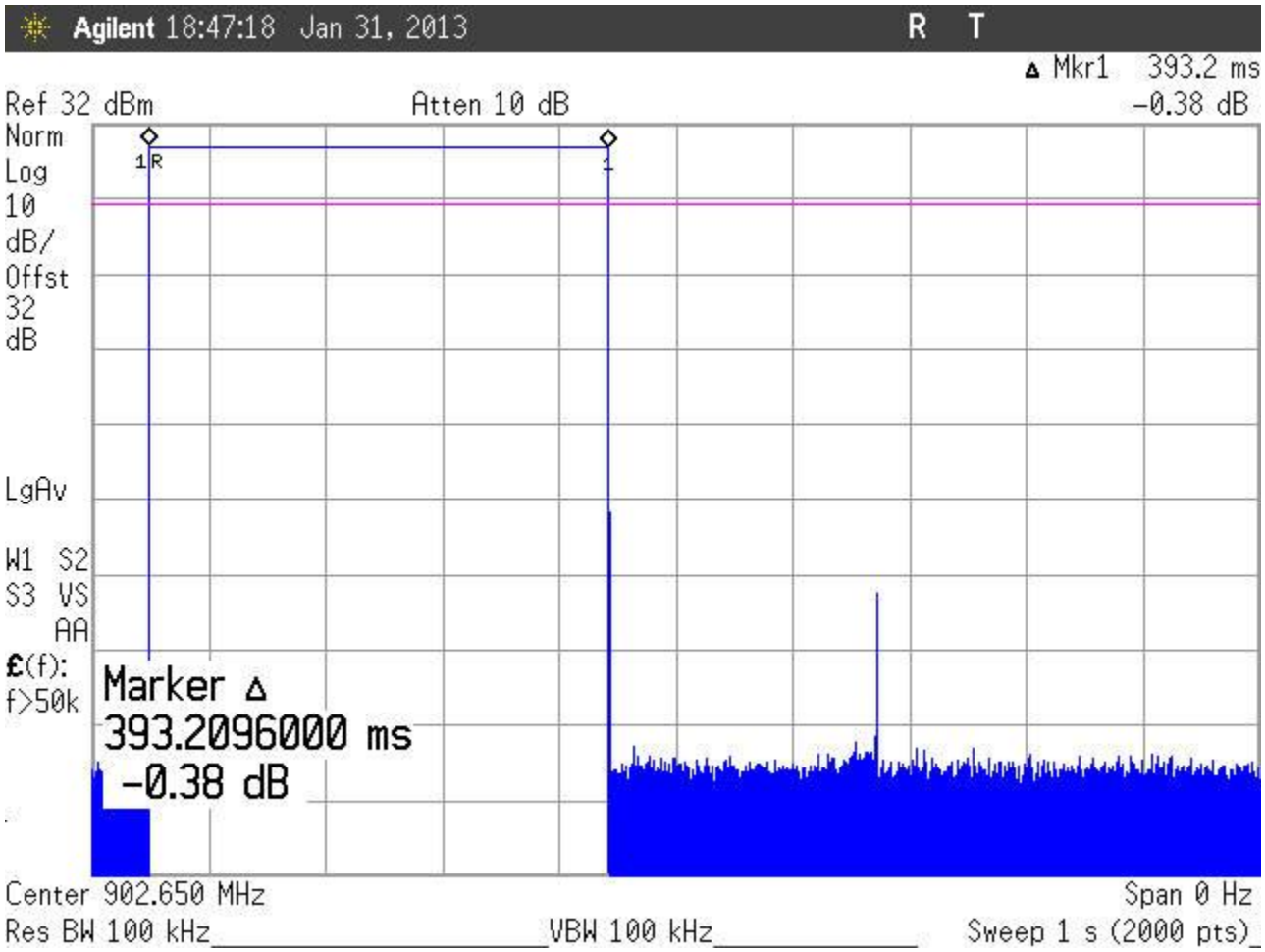

Figure 5 Hailing Channel Duty Cycle Plot

Time of Occupancy per 20 seconds: 1 pulse of 393.2ms per 20 seconds = 393.2ms.

Limit = 0.4sec per 20 seconds maximum0020

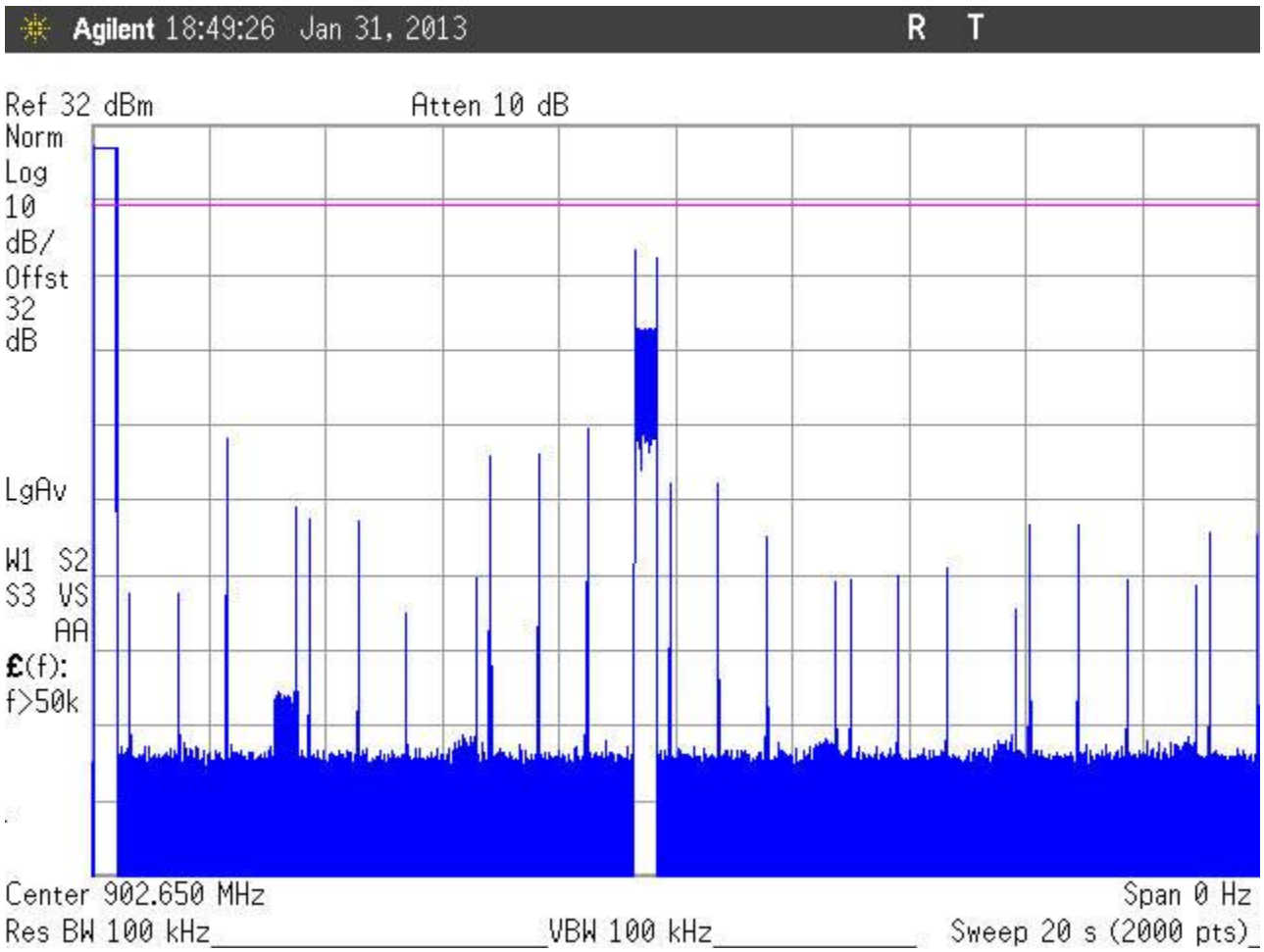

Figure 6 Hailing Channel Time of Occupancy Plot

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.

The power out to the amplifier was tested in 2 configurations. With a short RF cable between the TX Unit & Amplifier and with a long Hi loss RF cable between the TX unit & Amplifier (simulating 200ft of cable).

Table 6: Data Channel RF Power Output

Frequency	Power Level (Long cable) (dBm)	Power Level (Short Cable) (dBm)	Limit (dBm)	Pass/Fail
Low Channel: 902.5MHz	29	29	30	Pass
Center Channel: 915.0MHz	29.6	29.5	30	Pass
High Channel: 927.0MHz	29.2	29.2	30	Pass

Table 7 Hailing Channel RF Power Output

Frequency	Power Level (Long cable) (dBm)	Power Level (Short Cable) (dBm)	Limit (dBm)	Pass/Fail
Low Channel: 902.65MHz	29.0	29	30	Pass
Center Channel: 915.35MHz	29.5	29.6	30	Pass
High Channel: 927.35MHz	29.2	29.2	30	Pass

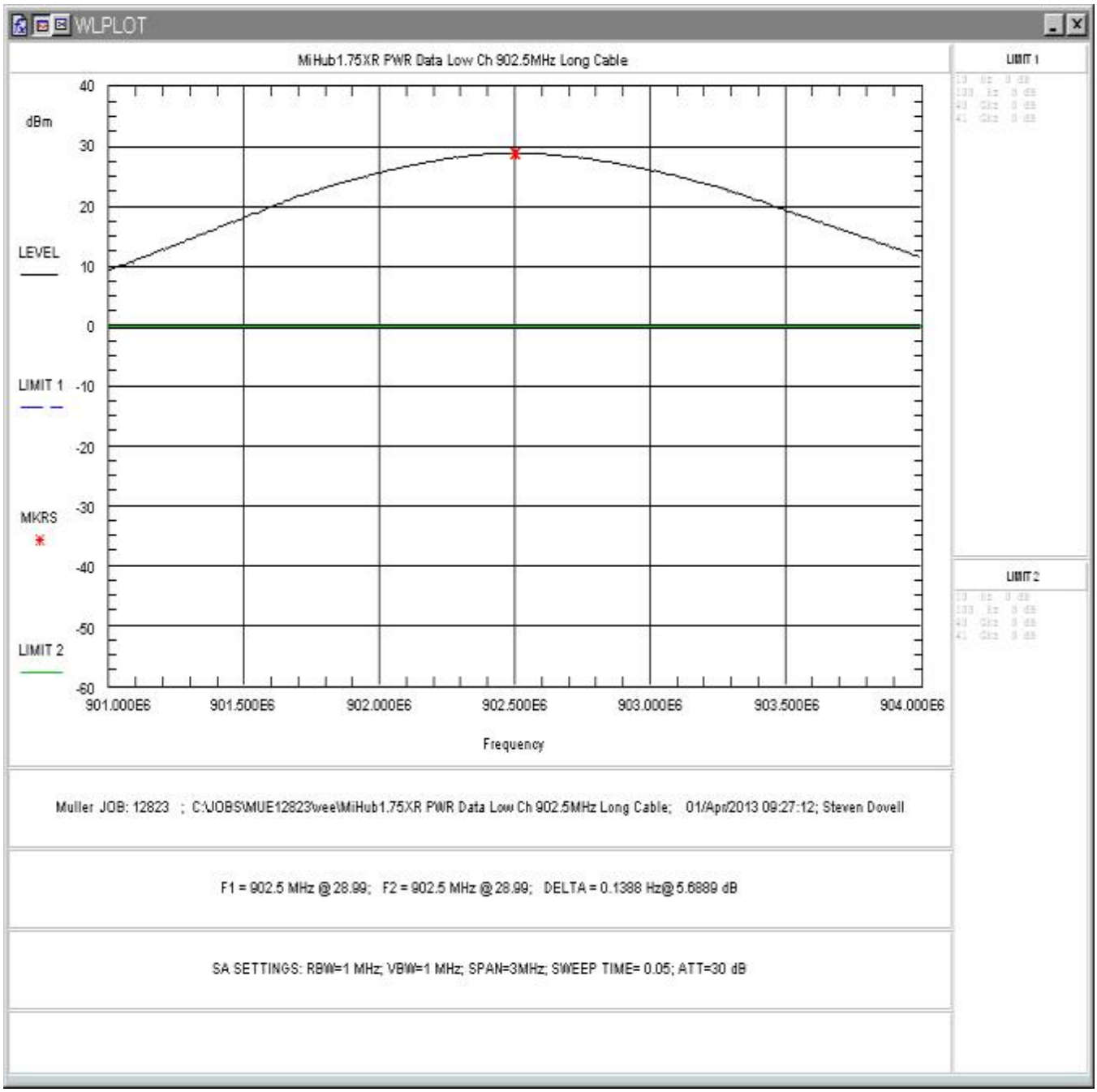

Figure 7: Data Channel RF Peak Power, Long Cable, Low Channel

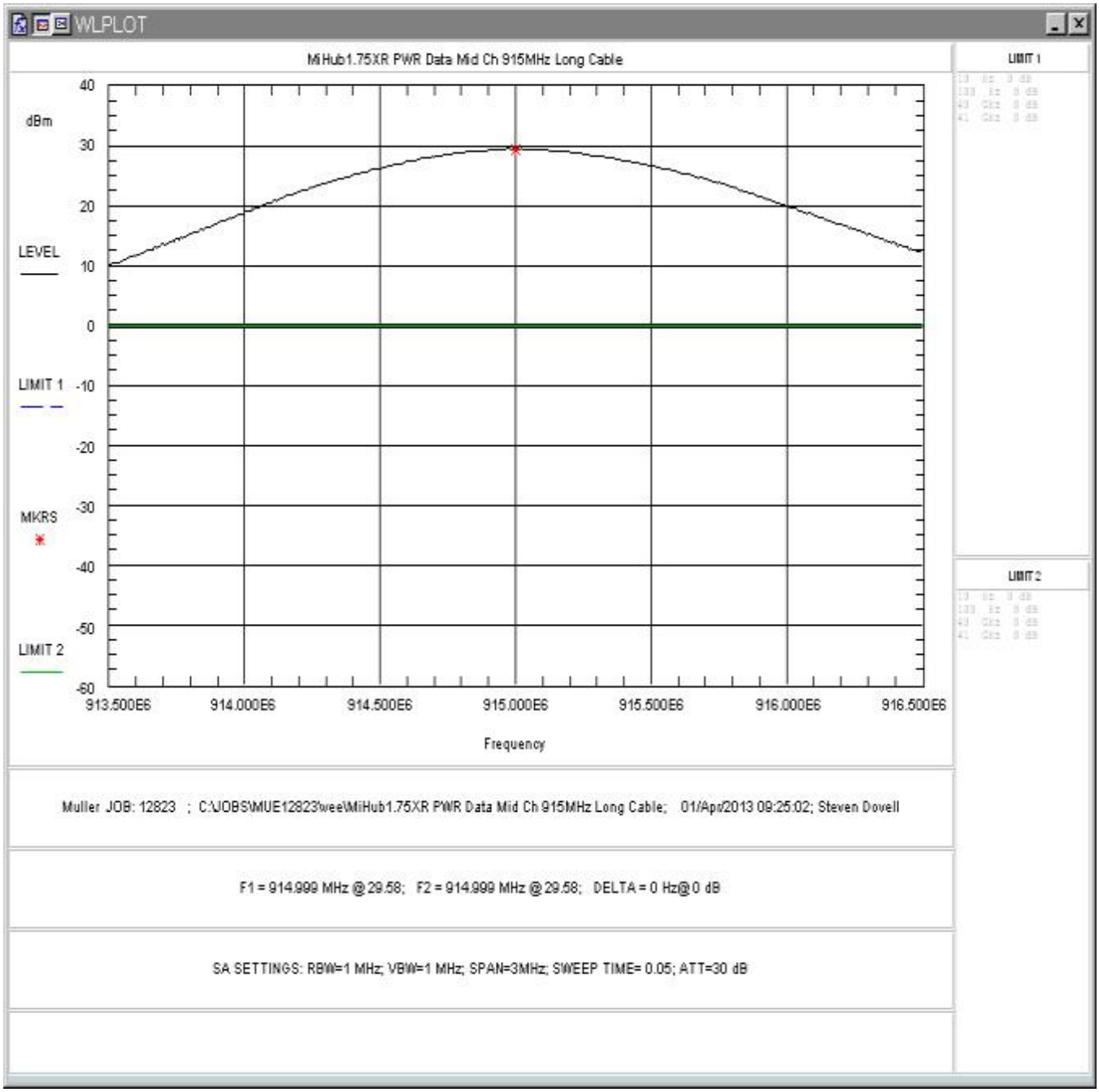

Figure 8: Data Channel RF Peak Power, Long Cable, Center Channel

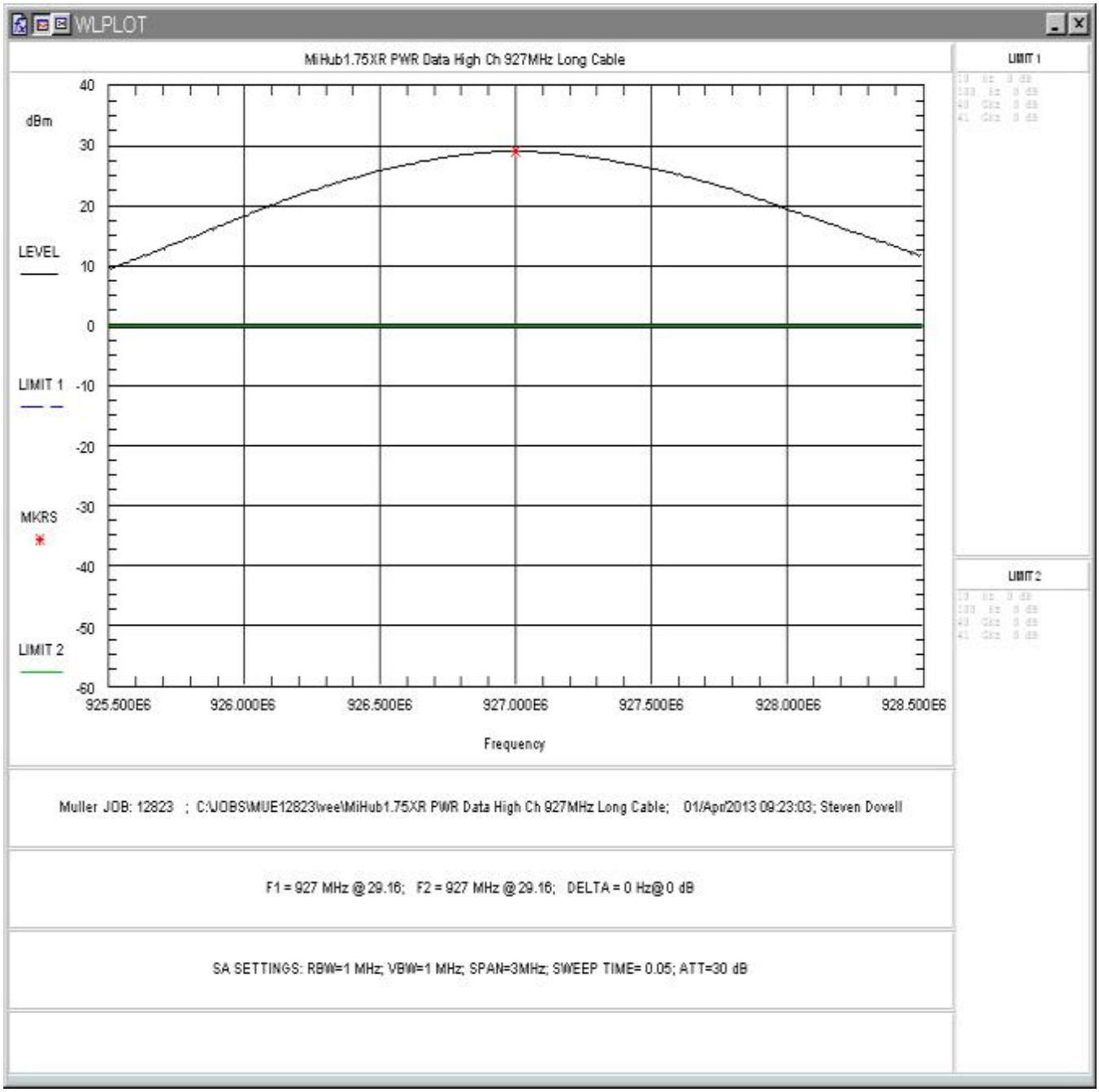

Figure 9: Data Channel RF Peak Power, Long Cable, High Channel

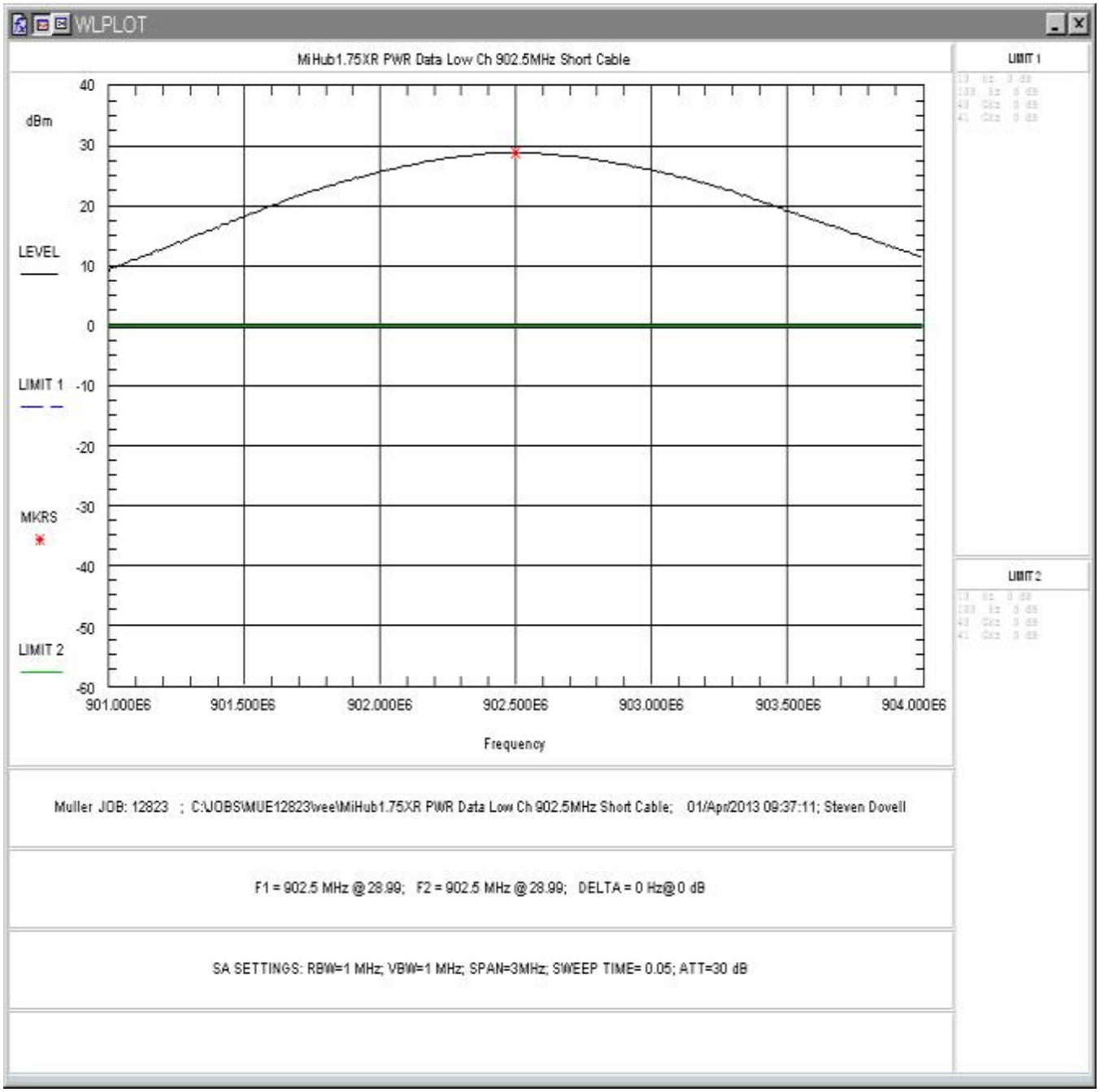

Figure 10: Data Channel RF Peak Power, Short Cable, Low Channel

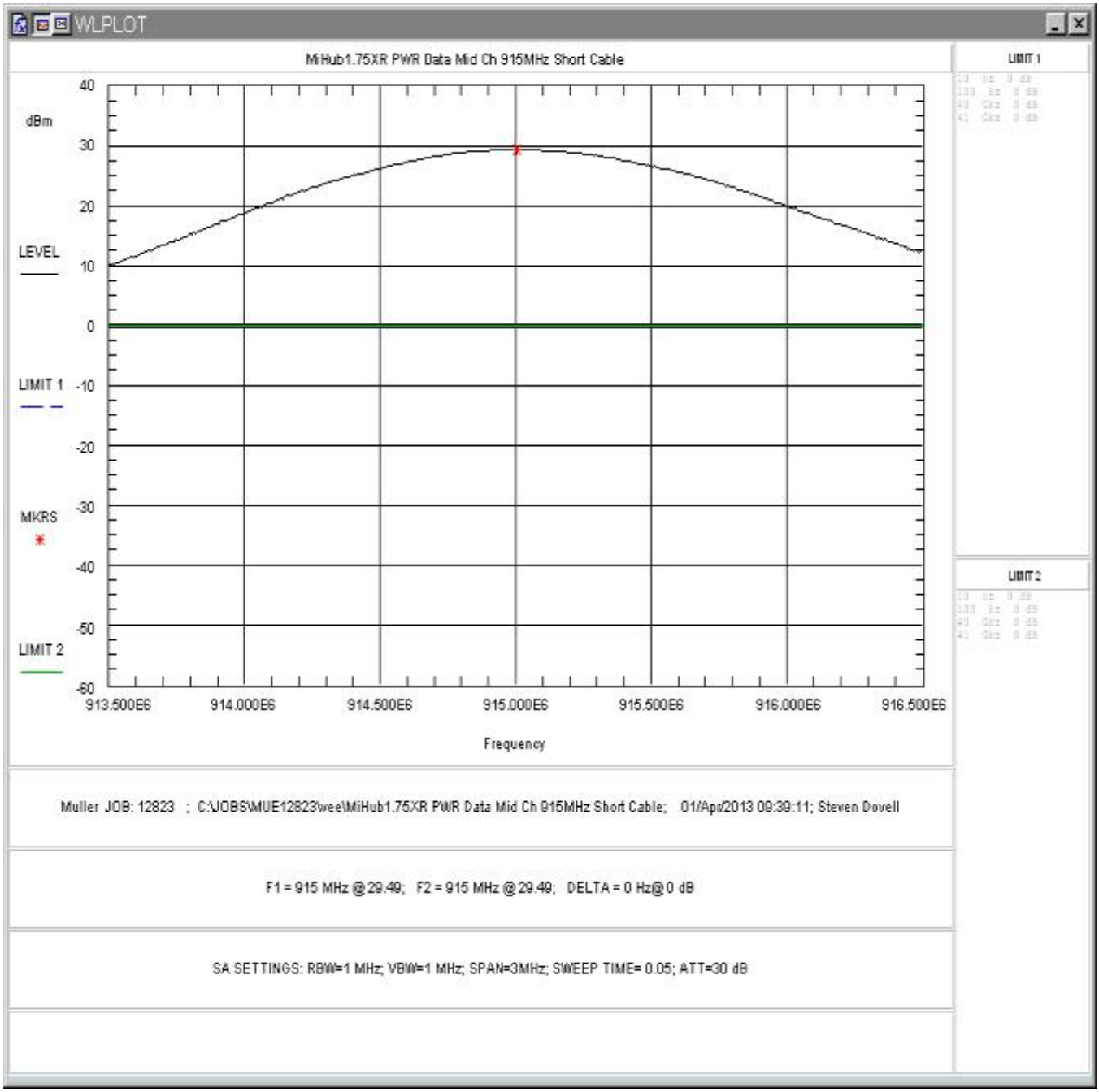

Figure 11: Data Channel RF Peak Power, Short Cable, Center Channel

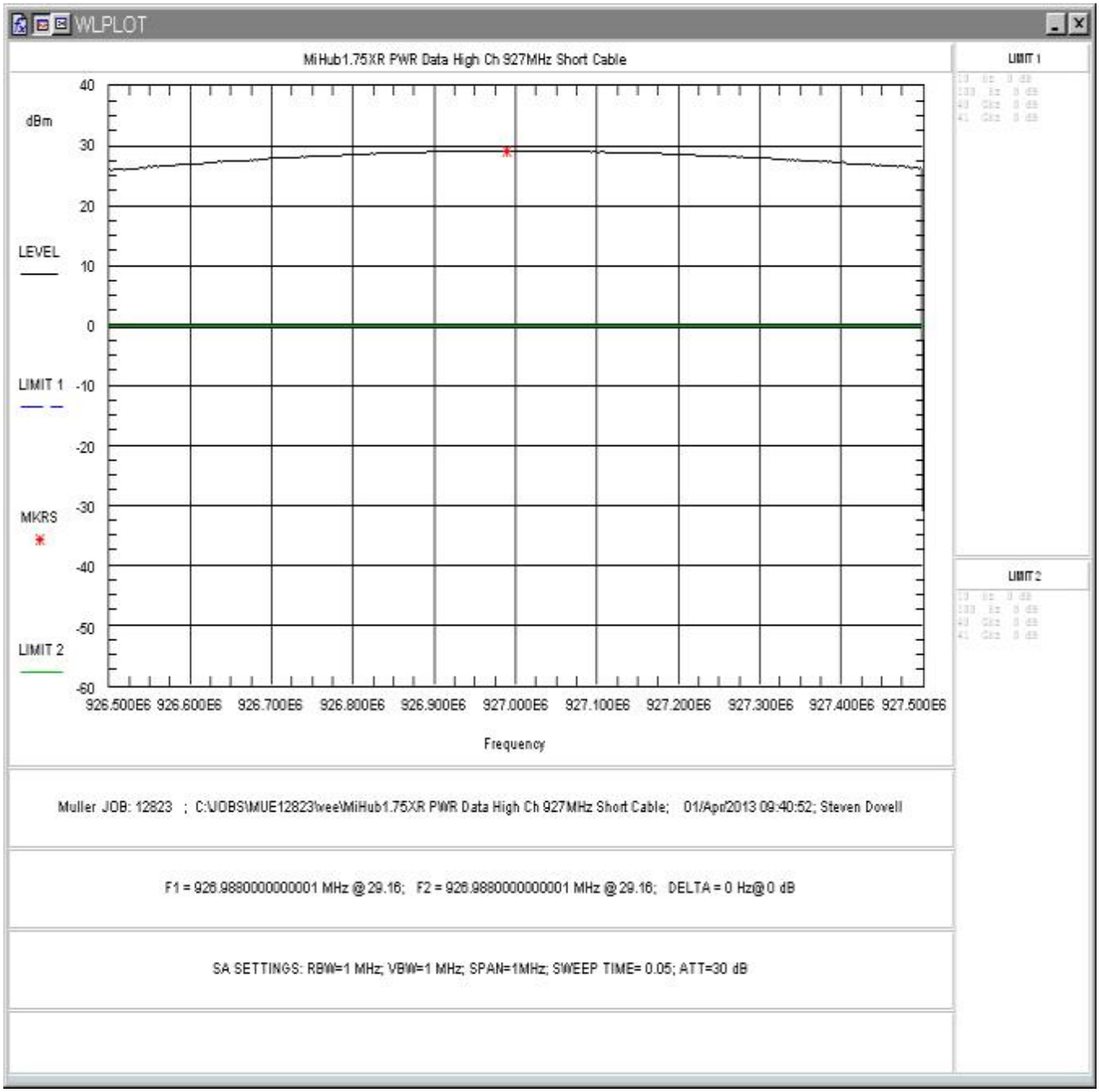

Figure 12: Data Channel RF Peak Power, Short Cable, High Channel

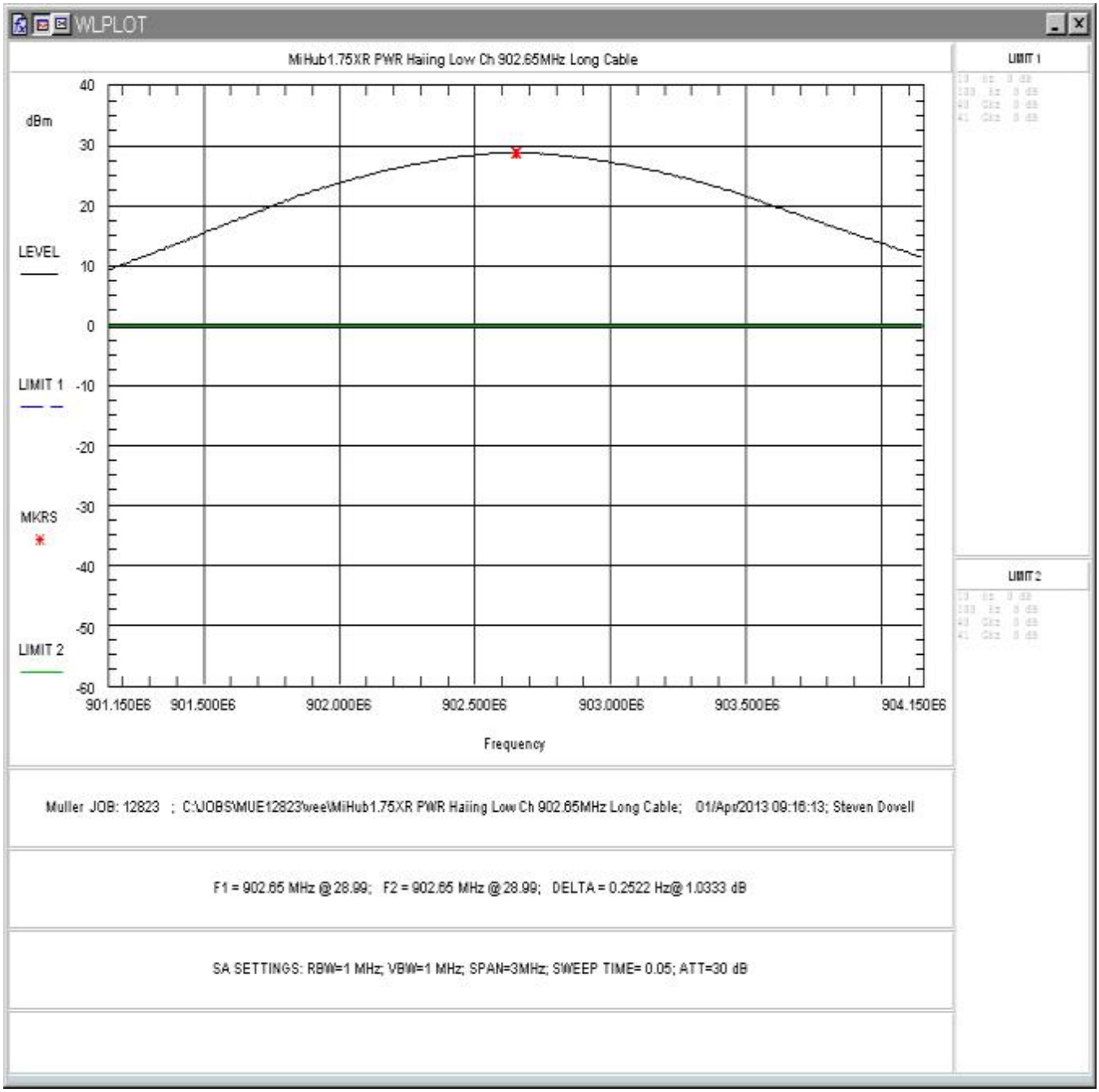

Figure 13 Hailing Channel RF Peak Power, Long Cable, Low Channel

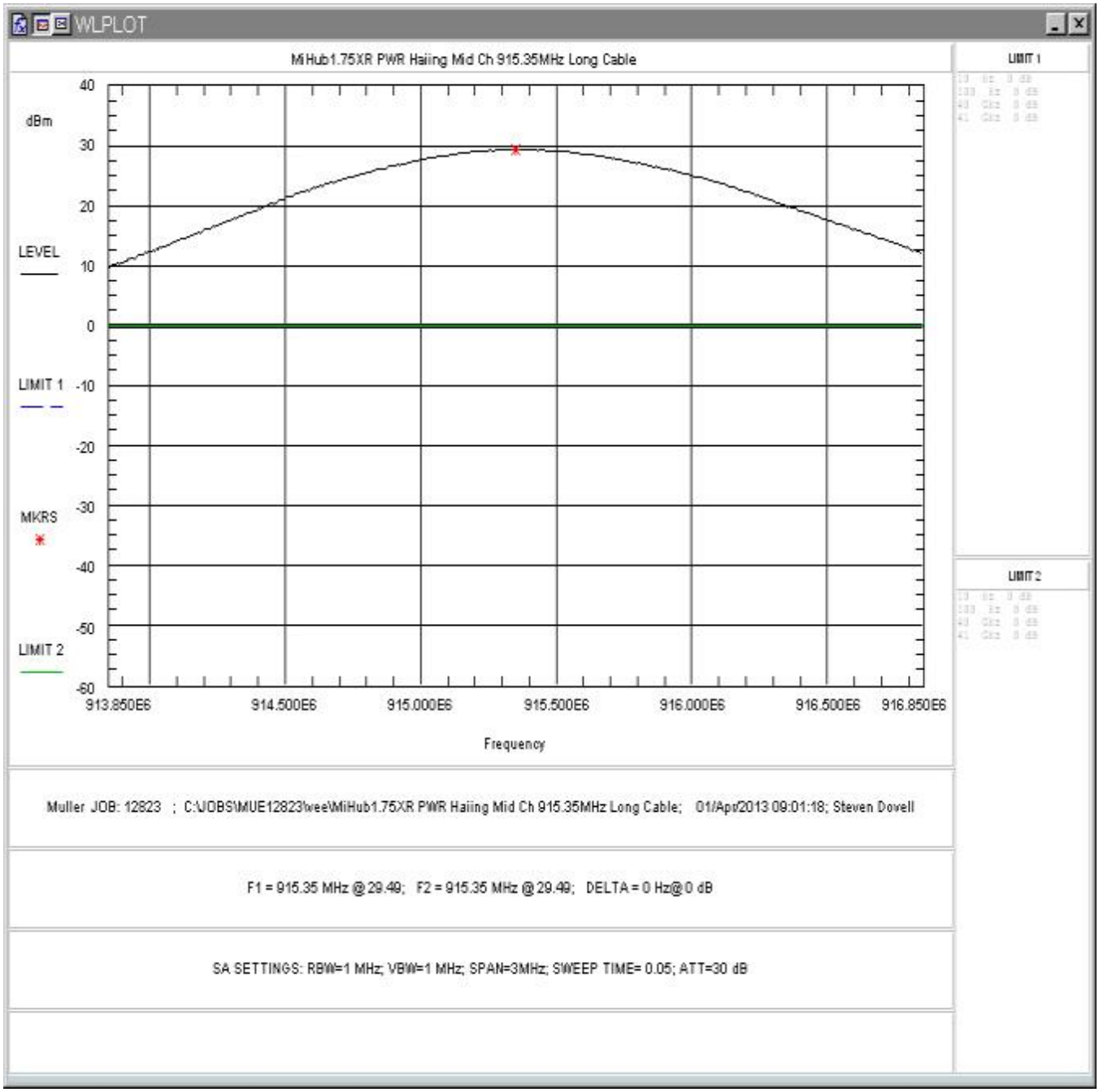

Figure 14 Hailing Channel RF Peak Power, Long Cable, Center Channel

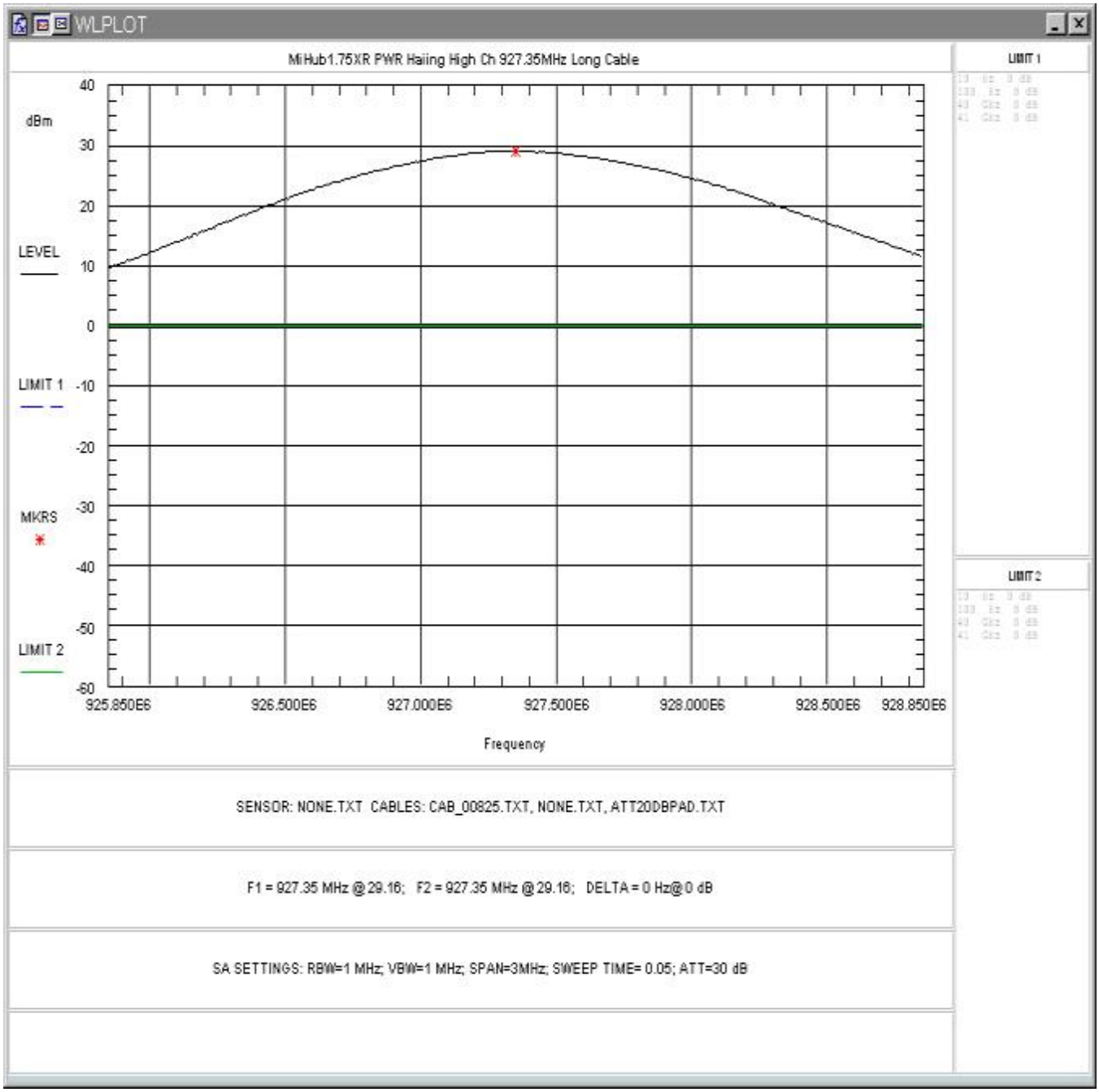

Figure 15 Hailing Channel RF Peak Power, Long Cable, High Channel

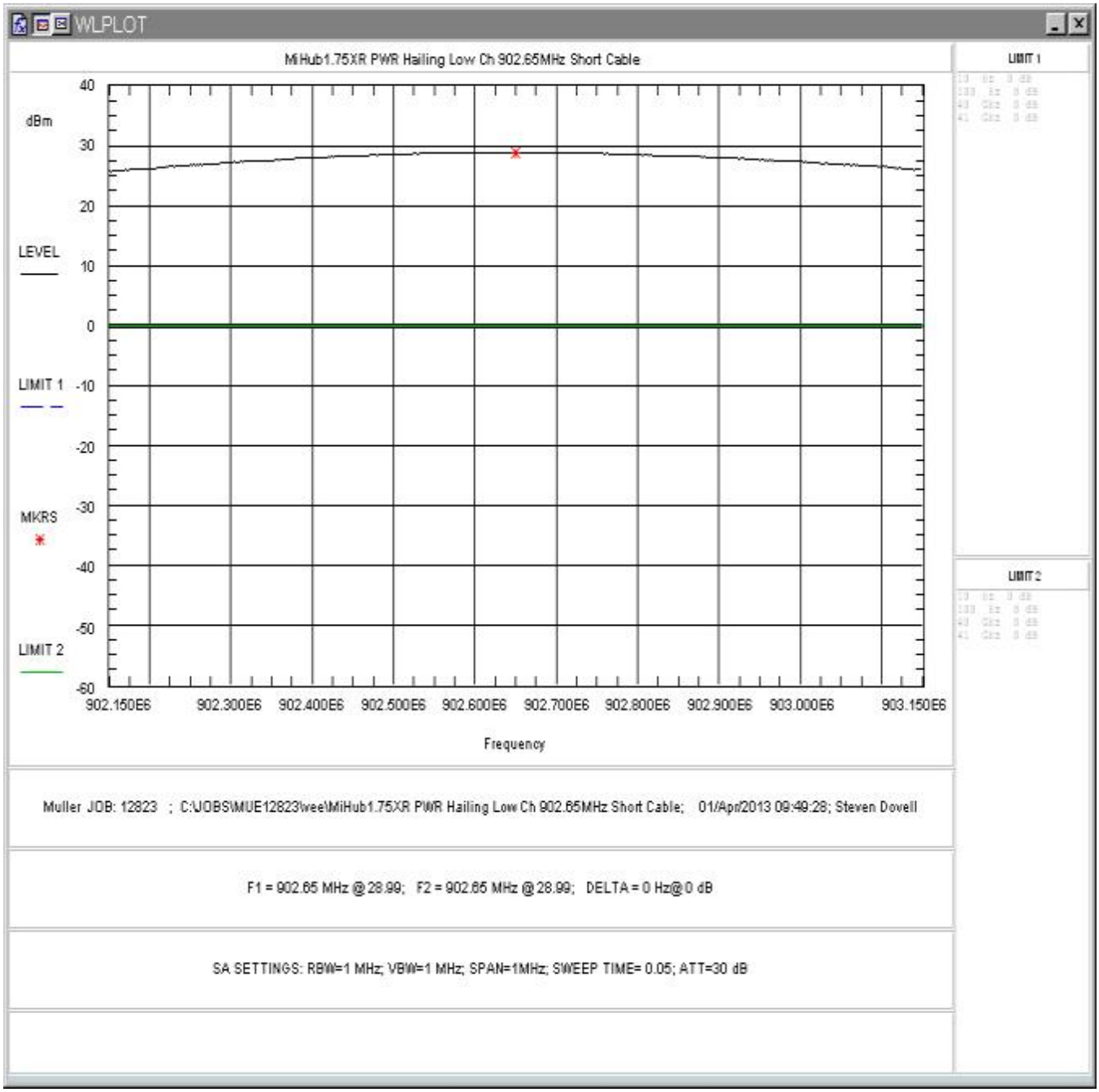

Figure 16 Hailing Channel RF Peak Power, Short Cable, Low Channel

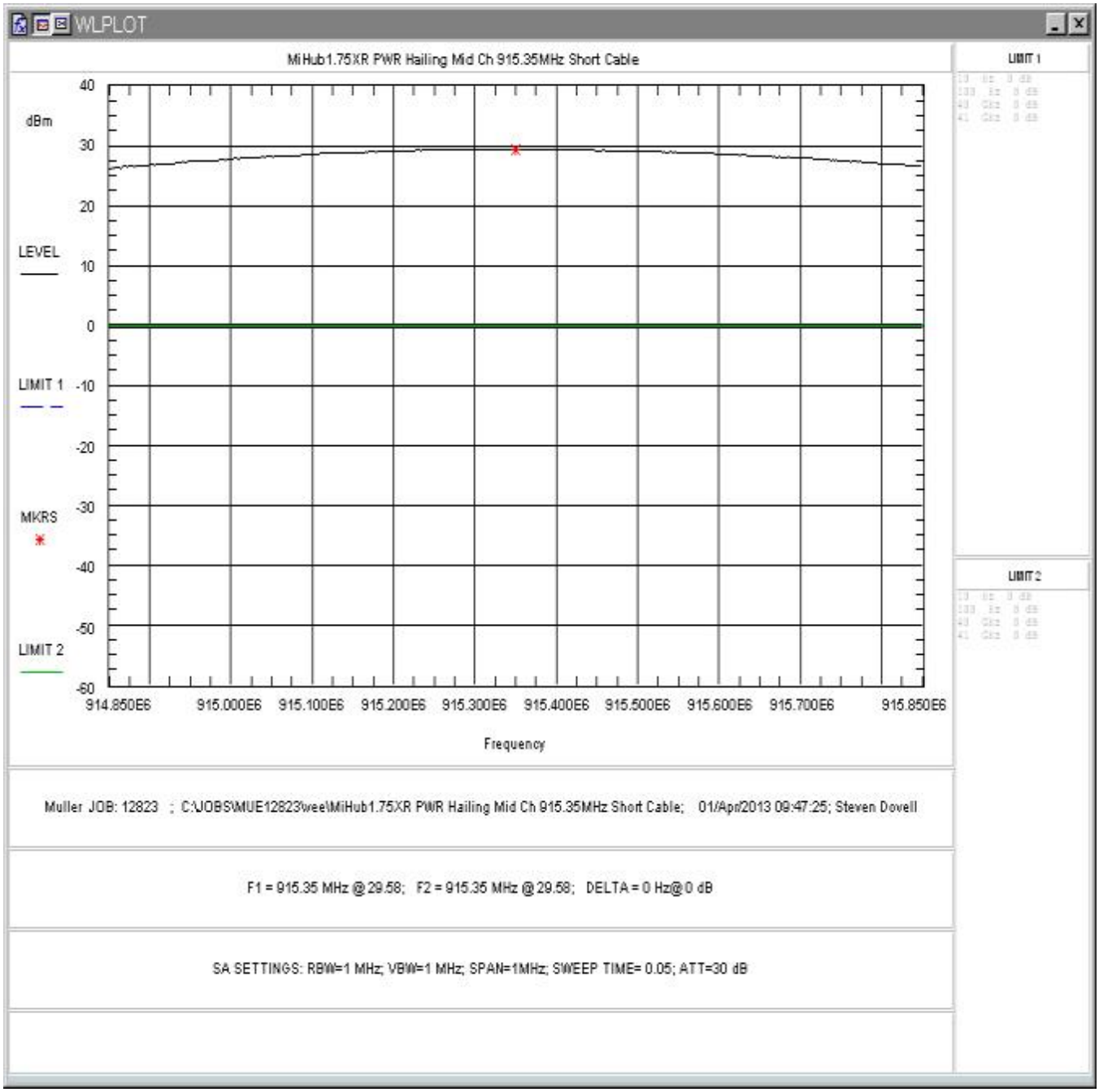

Figure 17 Hailing Channel RF Peak Power, Short Cable, Center Channel

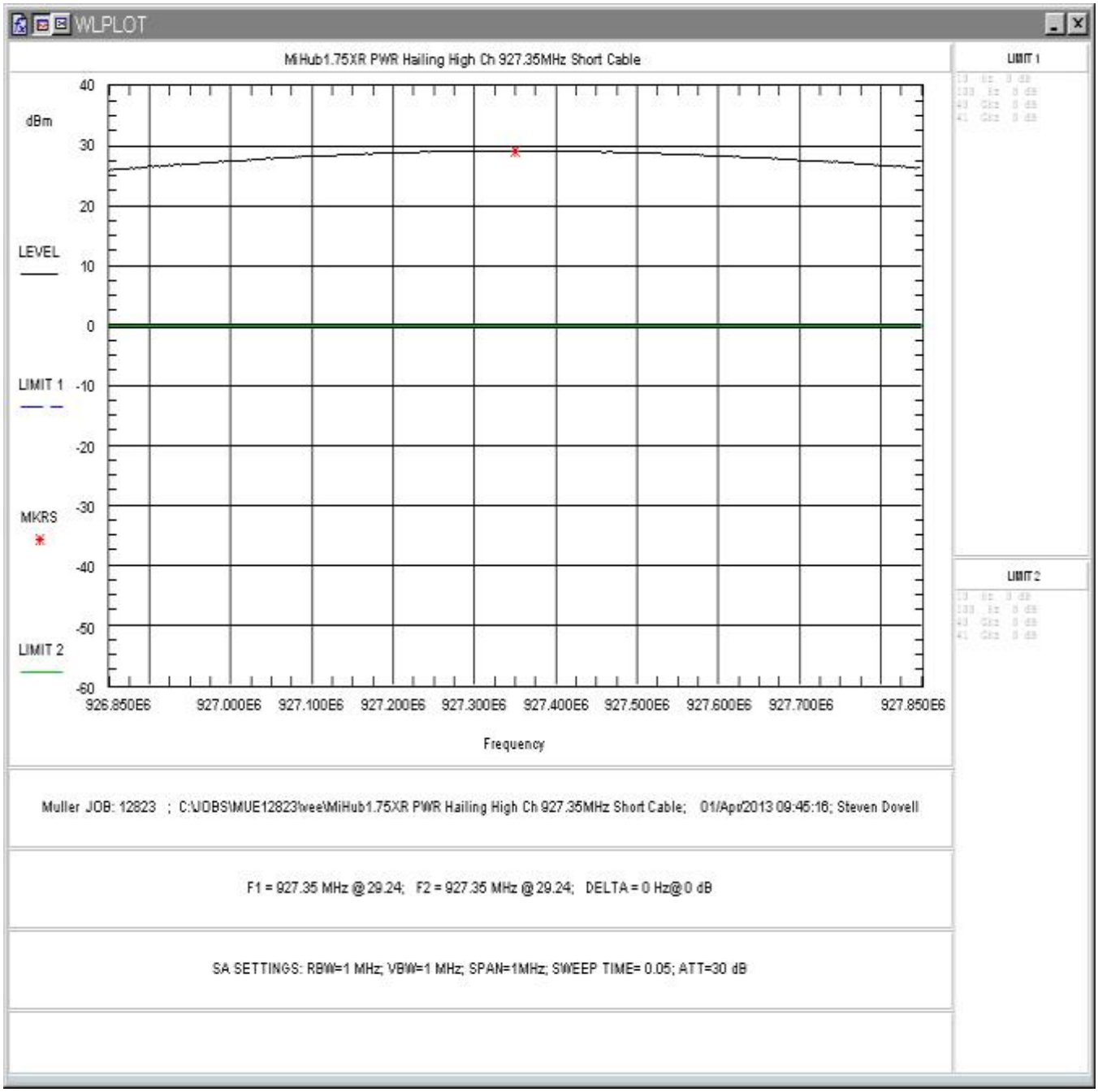

Figure 18 Hailing Channel RF Peak Power, Short Cable, High Channel

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 250 kHz have a minimum of 50 hopping channels.

The Hailing channels operate at a single transmission rate 9.6kbps, the data channels can operate at either 9.6 or 28.8kbps (negotiated by network). The Occupied bandwidth was verified in all available data rates.

Table 8 and Table 9 provide a summary of the Occupied Bandwidth Results.

Table 8 Data Channel Occupied Bandwidth Results

Frequency	9.6kbps Bandwidth (kHz)	28.8kbps Bandwidth (kHz)
Low Channel: 902.5MHz	39.6	59.5
Mid Channel: 915.0MHz	39.7	59.6
High Channel: 927.0MHz	39.9	59.8

Table 9: Hailing Channel Occupied Bandwidth Results

Frequency	9.6kbps Bandwidth (kHz)
Low Channel: 902.65MHz	39.6
Mid Channel: 915.35MHz	39.8
High Channel: 927.35MHz	39.9

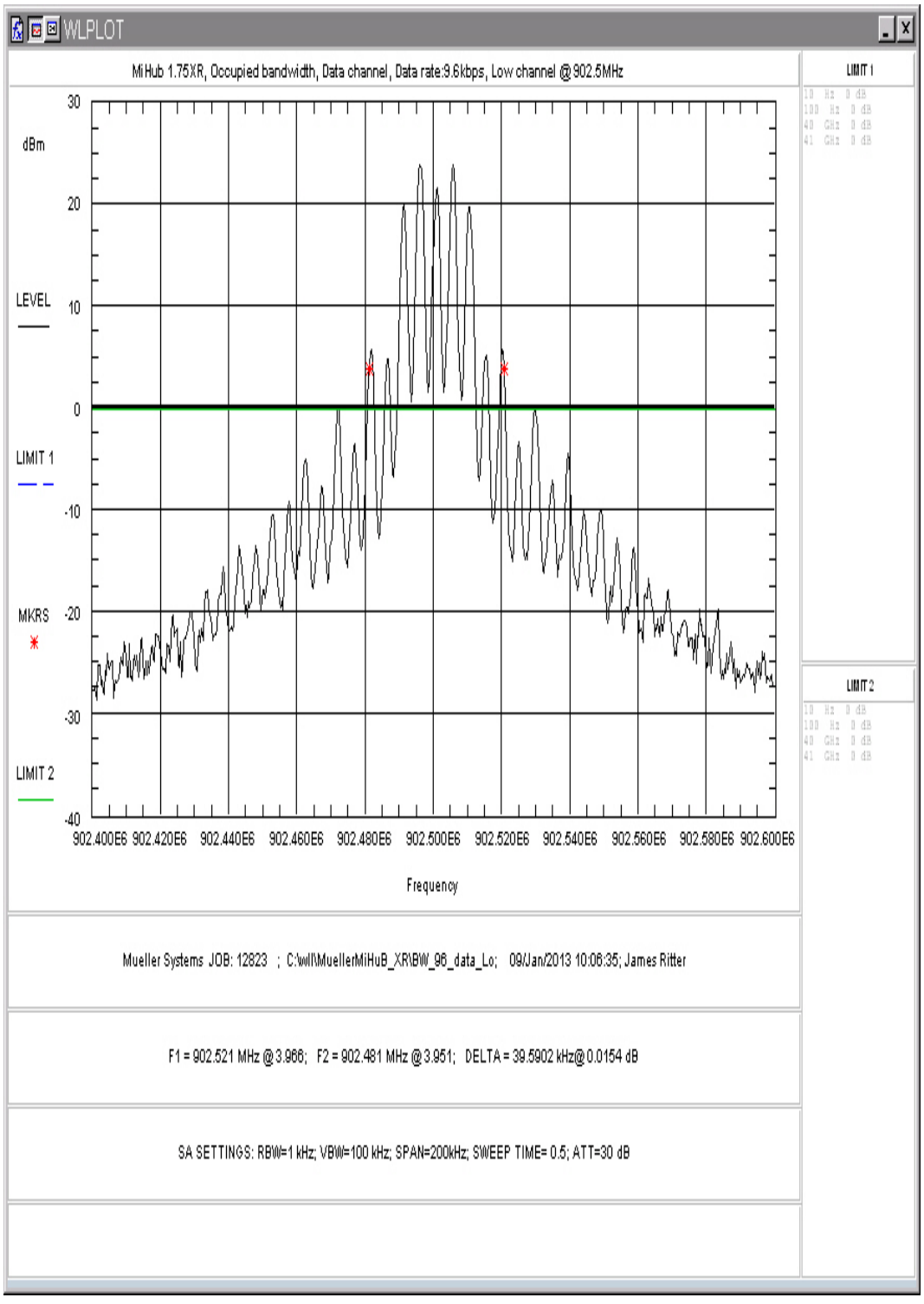

Figure 19: Data Channel Occupied Bandwidth, 9.6kbps, Low Channel

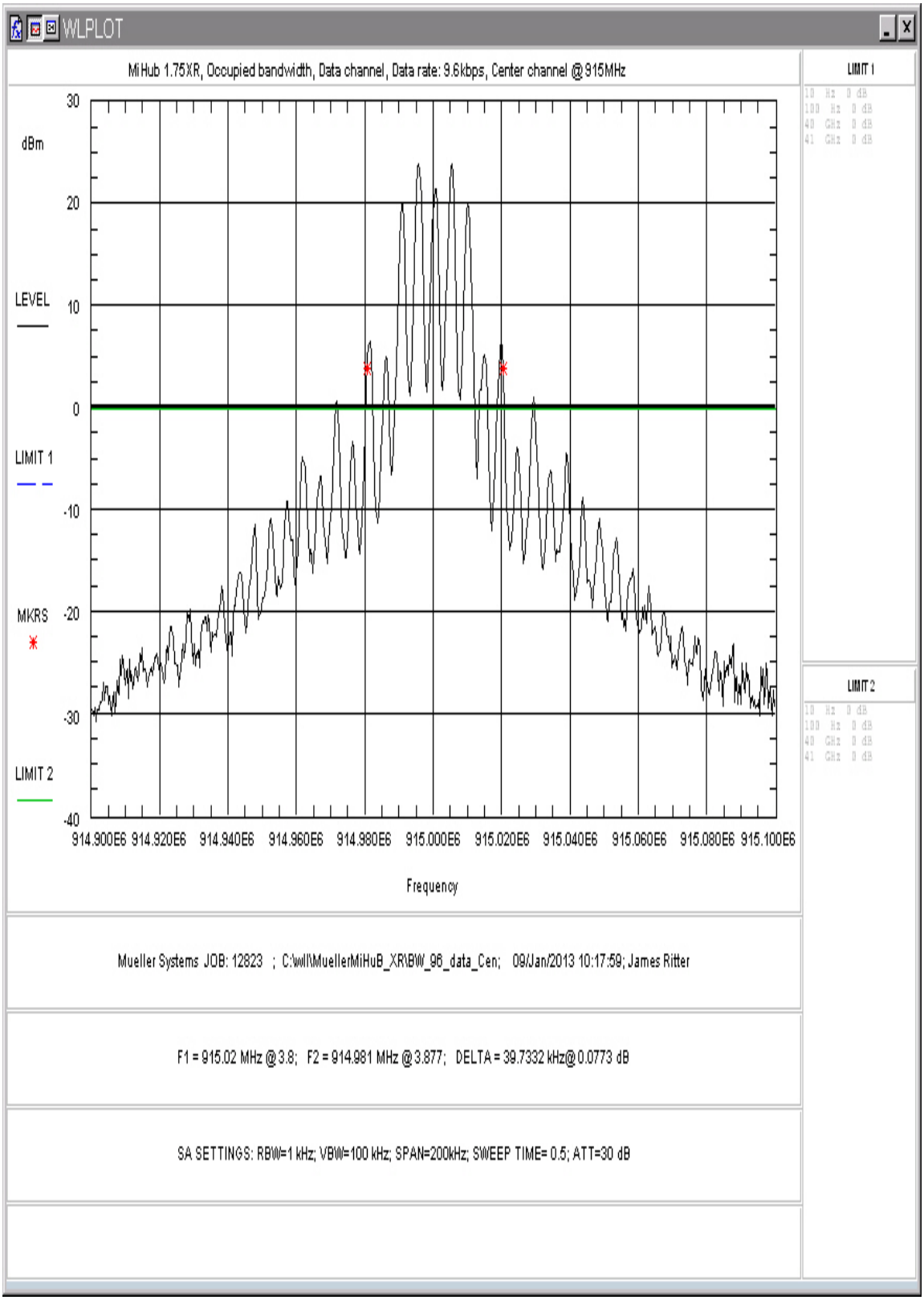

Figure 20: Data Channel Occupied Bandwidth, 9.6kbps, Center Channel

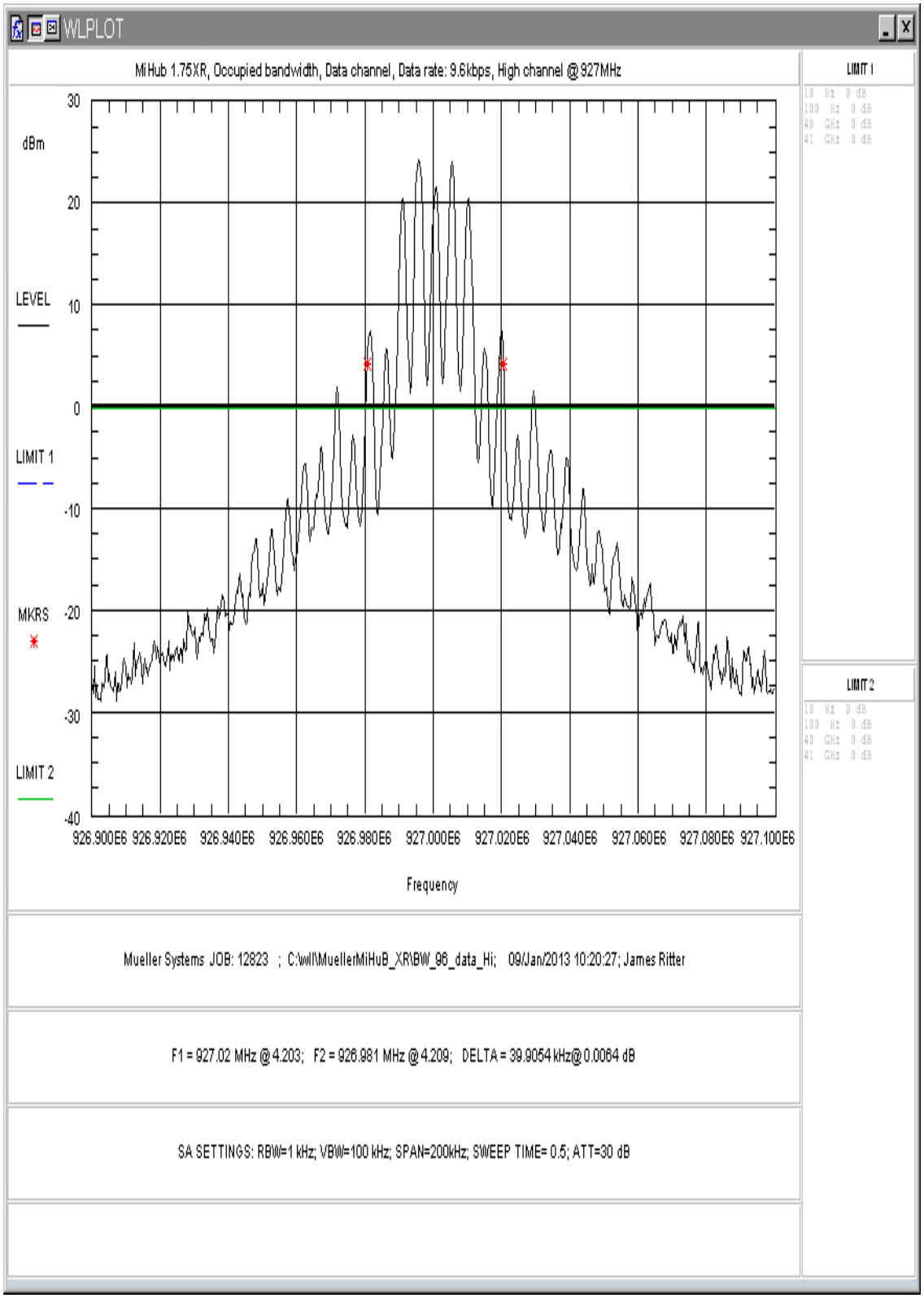

Figure 21: Data Channel Occupied Bandwidth, 9.6kbps, High Channel

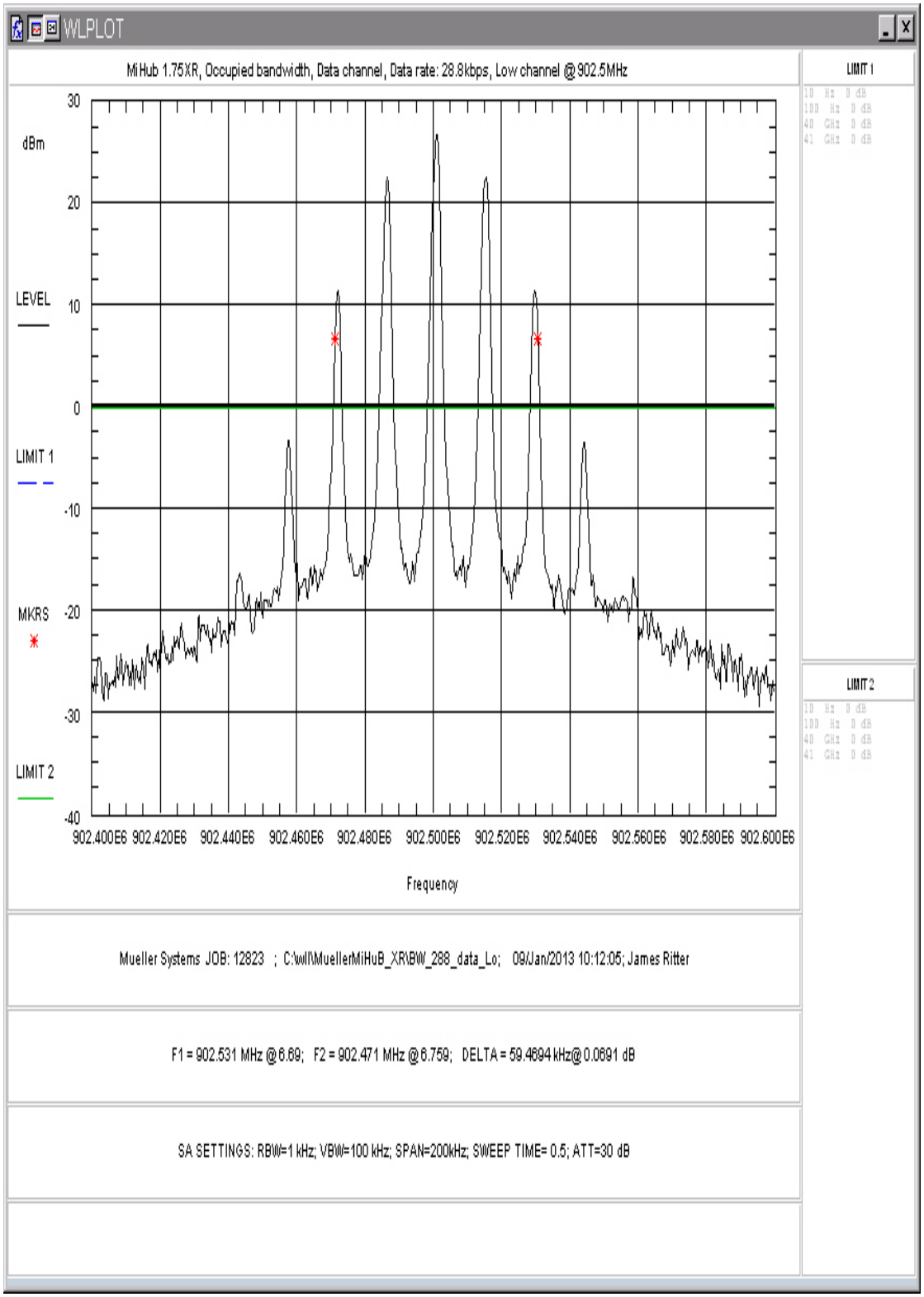

Figure 22: Data Channel Occupied Bandwidth, 28.8kbps, Low Channel

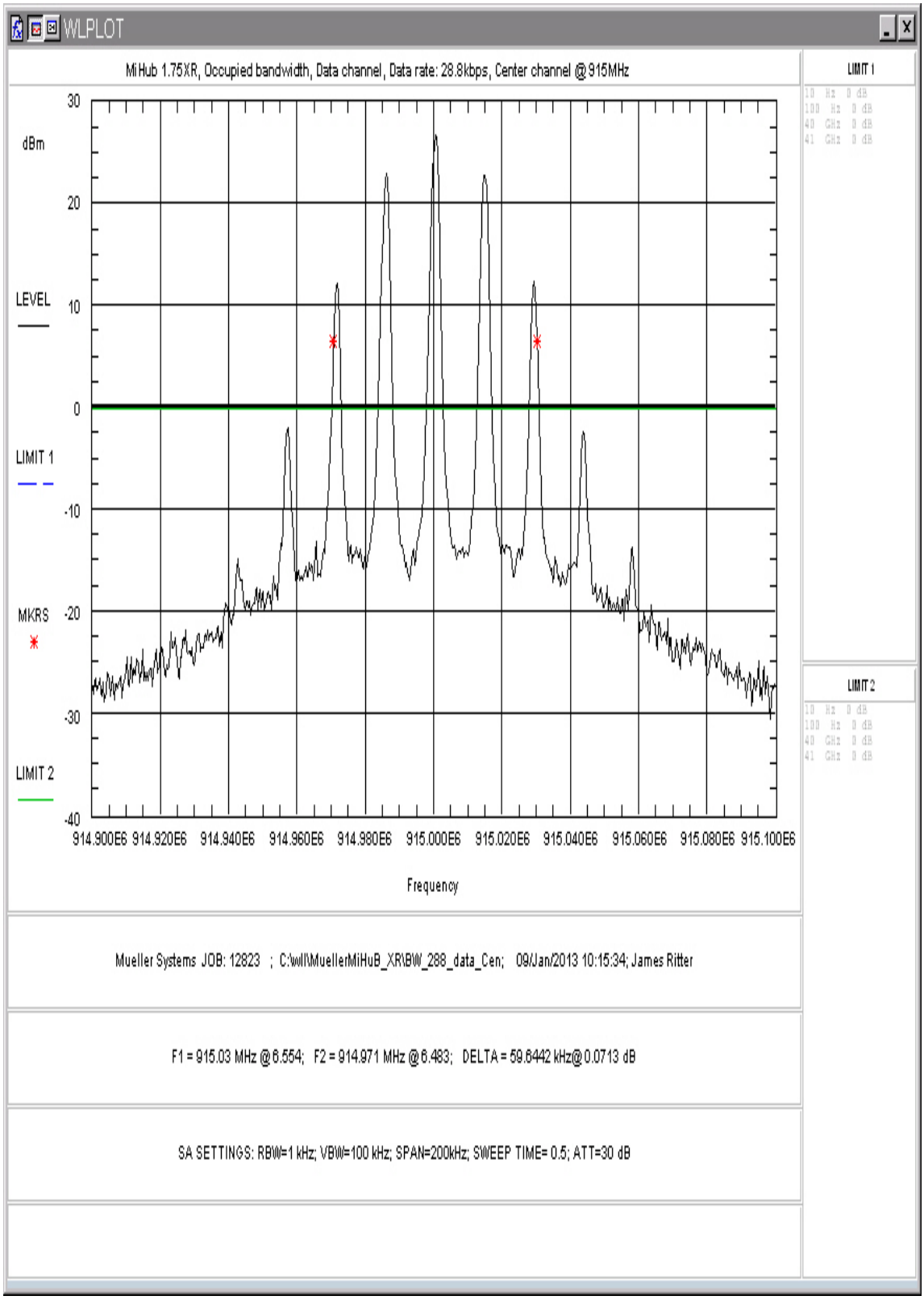

Figure 23: Data Channel Occupied Bandwidth, 28.8kbps, Center Channel

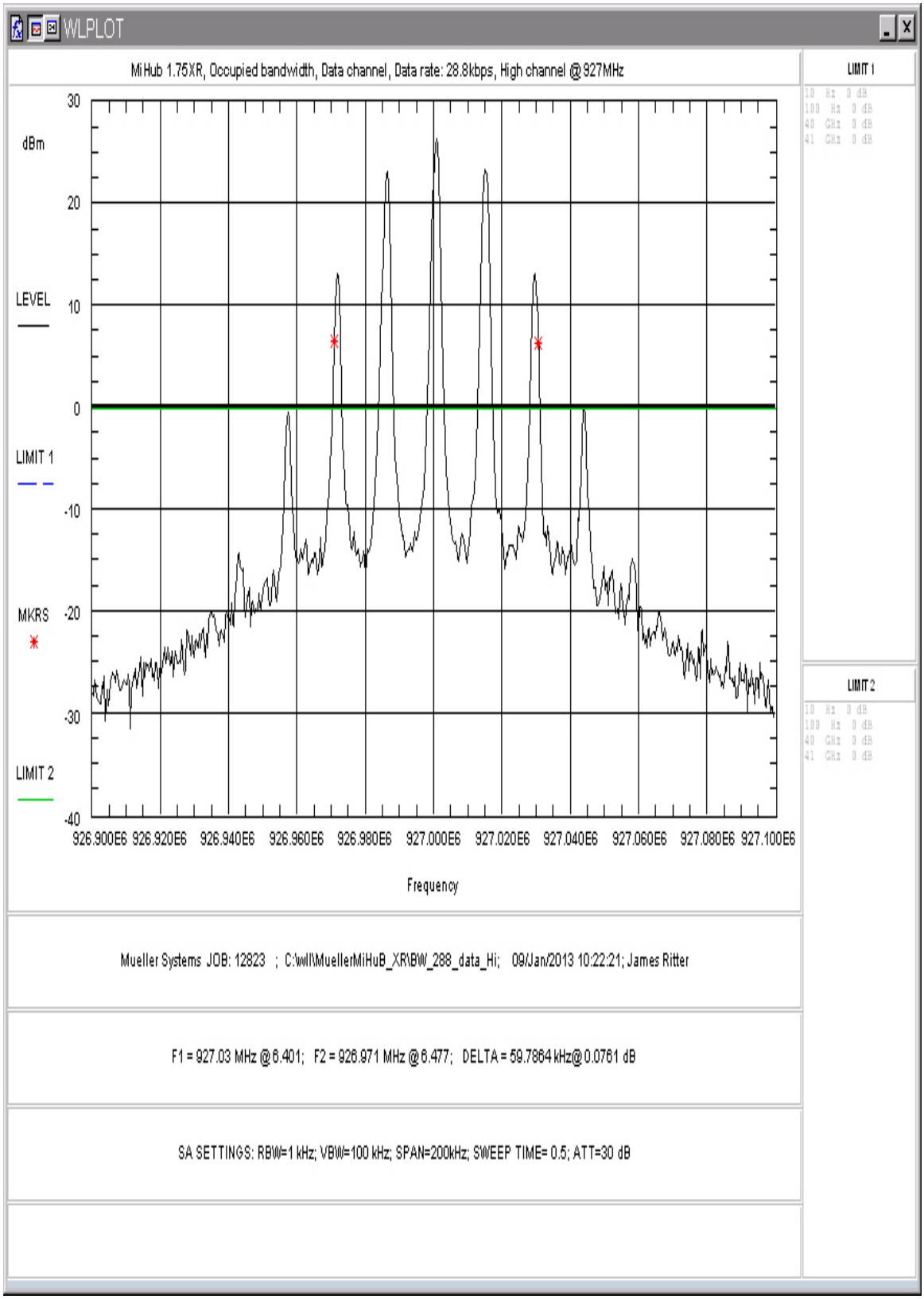

Figure 24: Data Channel Occupied Bandwidth, 28.8kbps, High Channel

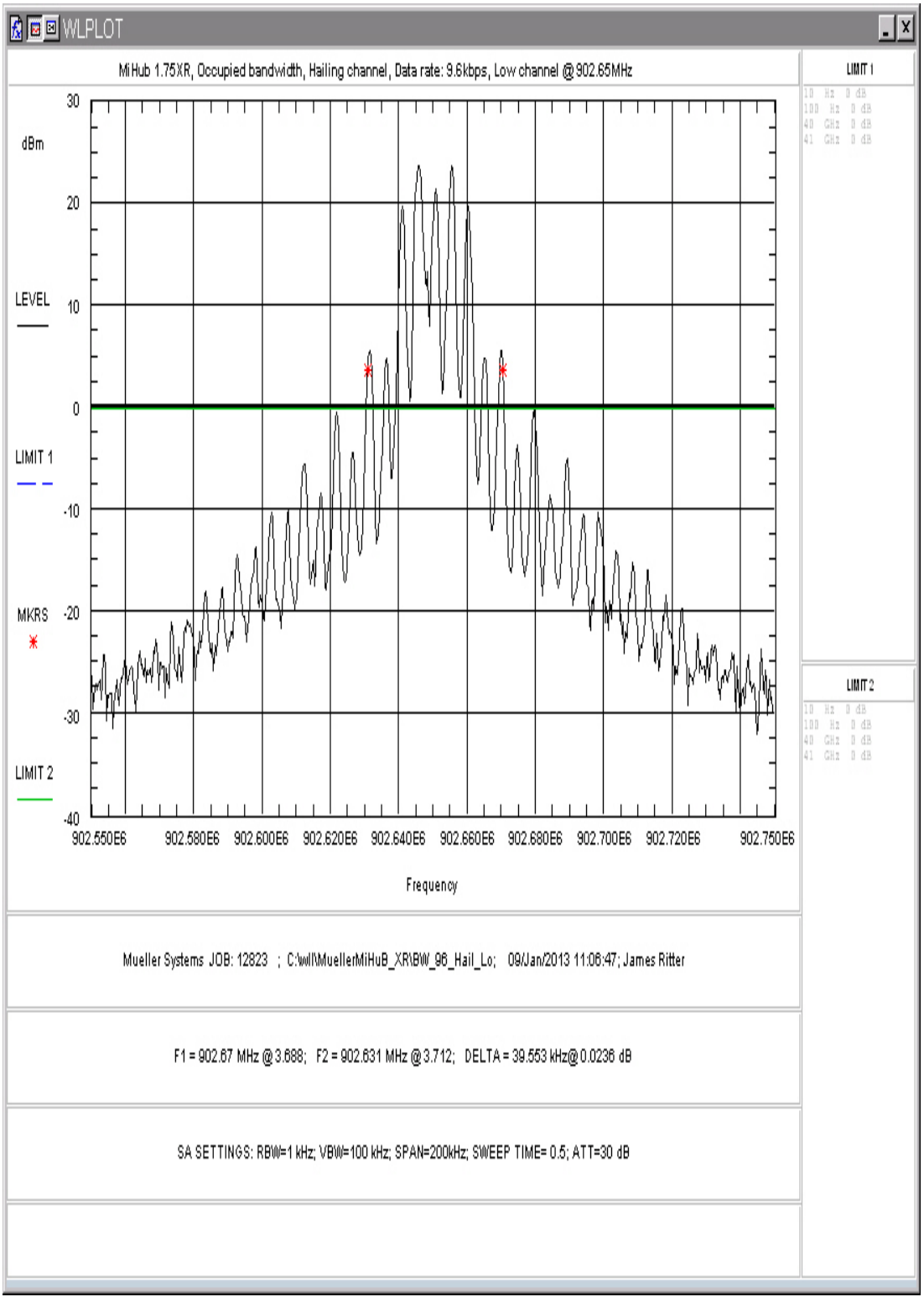

Figure 25 Hailing Channel Occupied Bandwidth, Low Channel

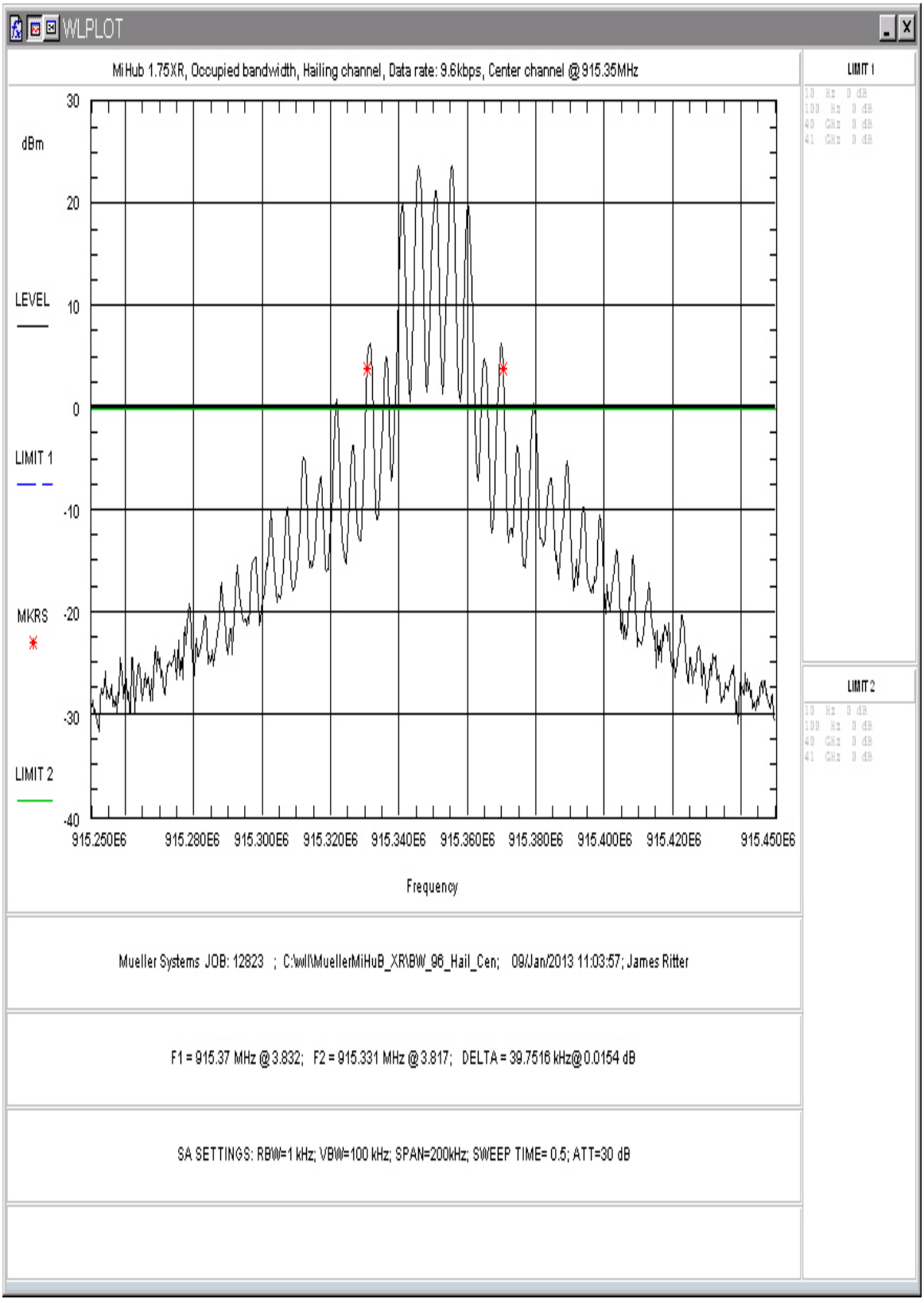

Figure 26 Hailing Channel Occupied Bandwidth, Center Channel

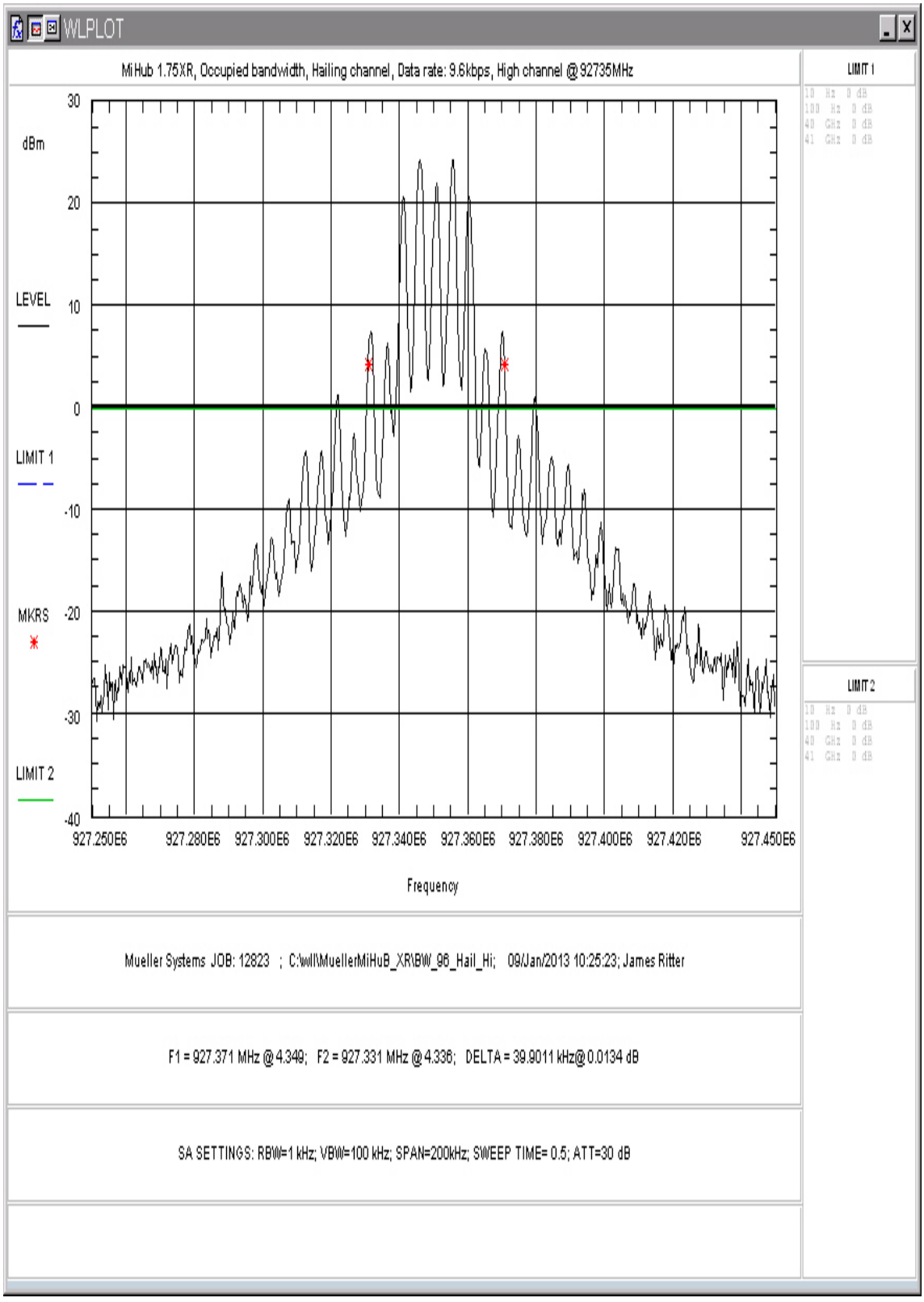

Figure 27 Hailing Channel Occupied Bandwidth, High Channel

5.4 Channel Spacing and Number of Hop Channels (FCC Part §15.247(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 25 kHz or the 20 dB bandwidth, whichever is greater. The maximum 20dB bandwidth measured is 59.8 kHz for Data channels (28.8kbps mode) and 39.9 kHz for hailing mode. The channel spacing must be more than 59.8 kHz for Data mode and 39.9 kHz for Hailing mode. In addition, Part 15.247 requires that devices with occupied bandwidths less than 250 kHz 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 (minimum) for Data channels and 150kHz (minimum) for Hailing channels and the number of hopping channels is 50 for each mode of operation.

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.

In addition the hailing channels are not evenly dispersed within the band with the closest hailing channels spaced 150 kHz apart. Worst case spacing is shown in plots below.

Table 10: Channel spacing and number of hopping channels summary

Test	Result	Limit	Pass/Fail
Data Channel spacing	250kHz channel spacing between 904MHz - 904.5MHz and 908MHz-908.5MHz. 500kHz between other channels	59.8 kHz Minimum	Pass
Number of Channels	50 channels	50 channels minimum	Pass
Hailing Channel Spacing	The closest channels are spaced 150kHz	39.9 kHz Minimum	Pass
Number of Hailing Channels	50 channels	50 channels minimum	Pass

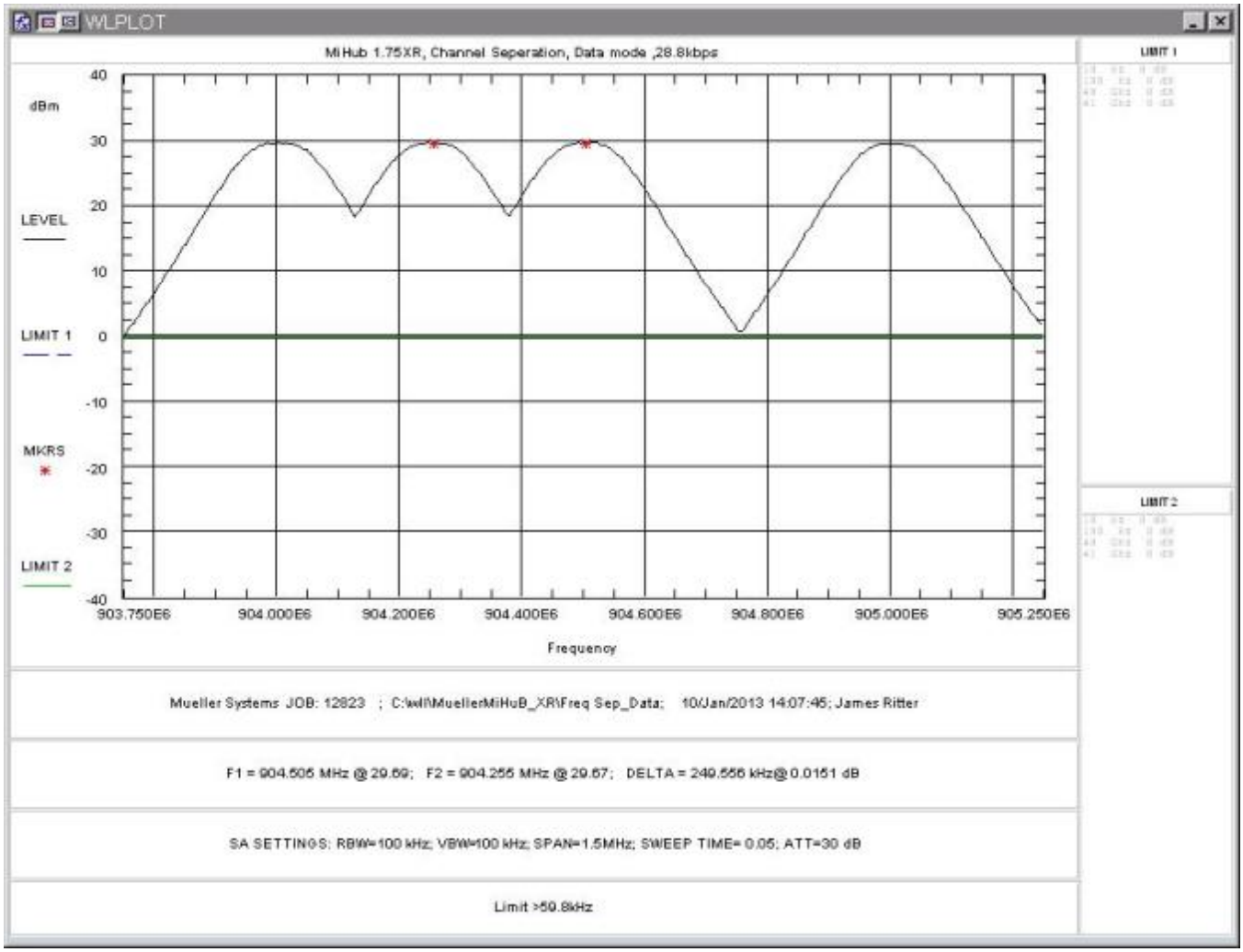

Figure 28: Data Channel Spacing, 250 kHz

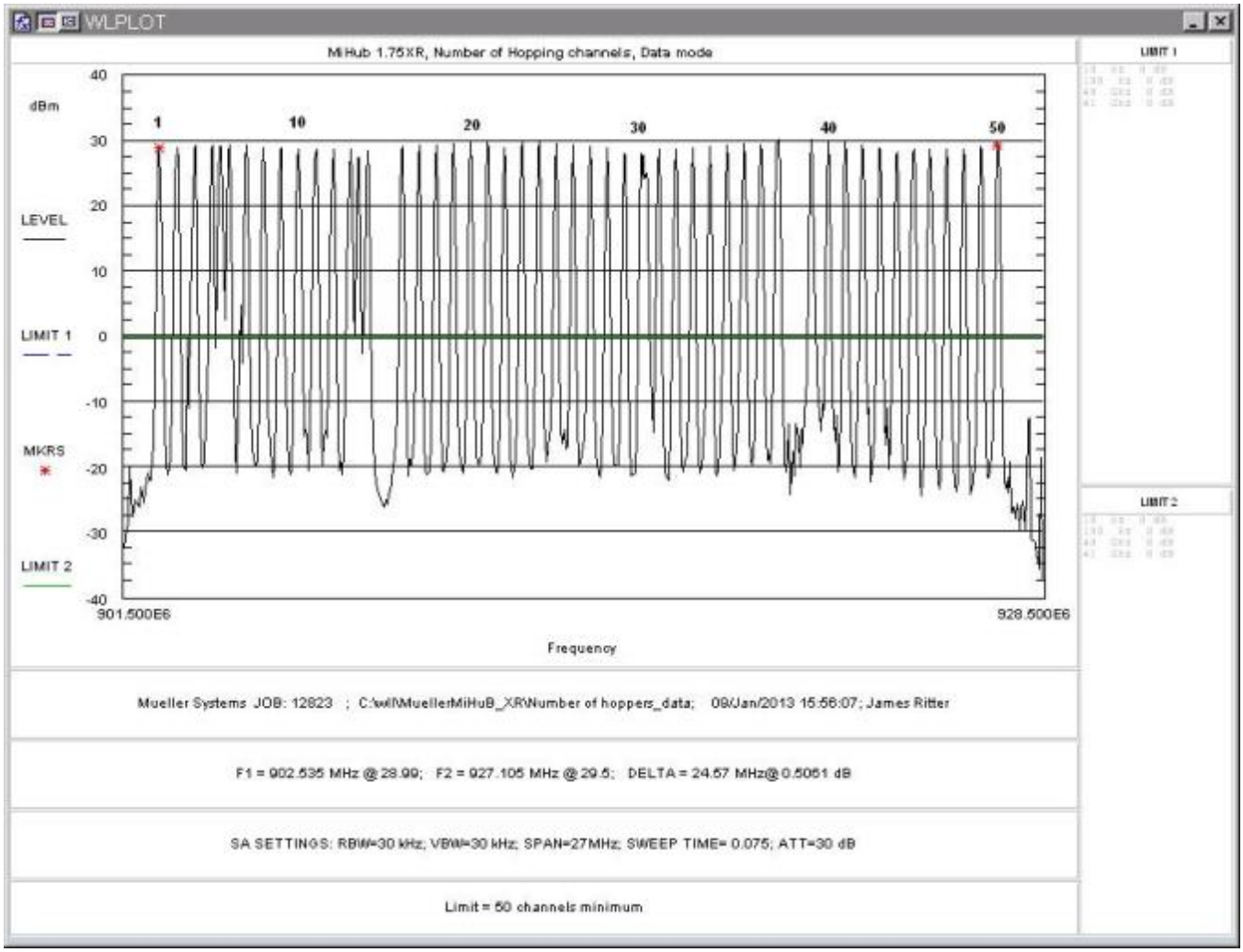

Figure 29: Data Channel Number of Channels

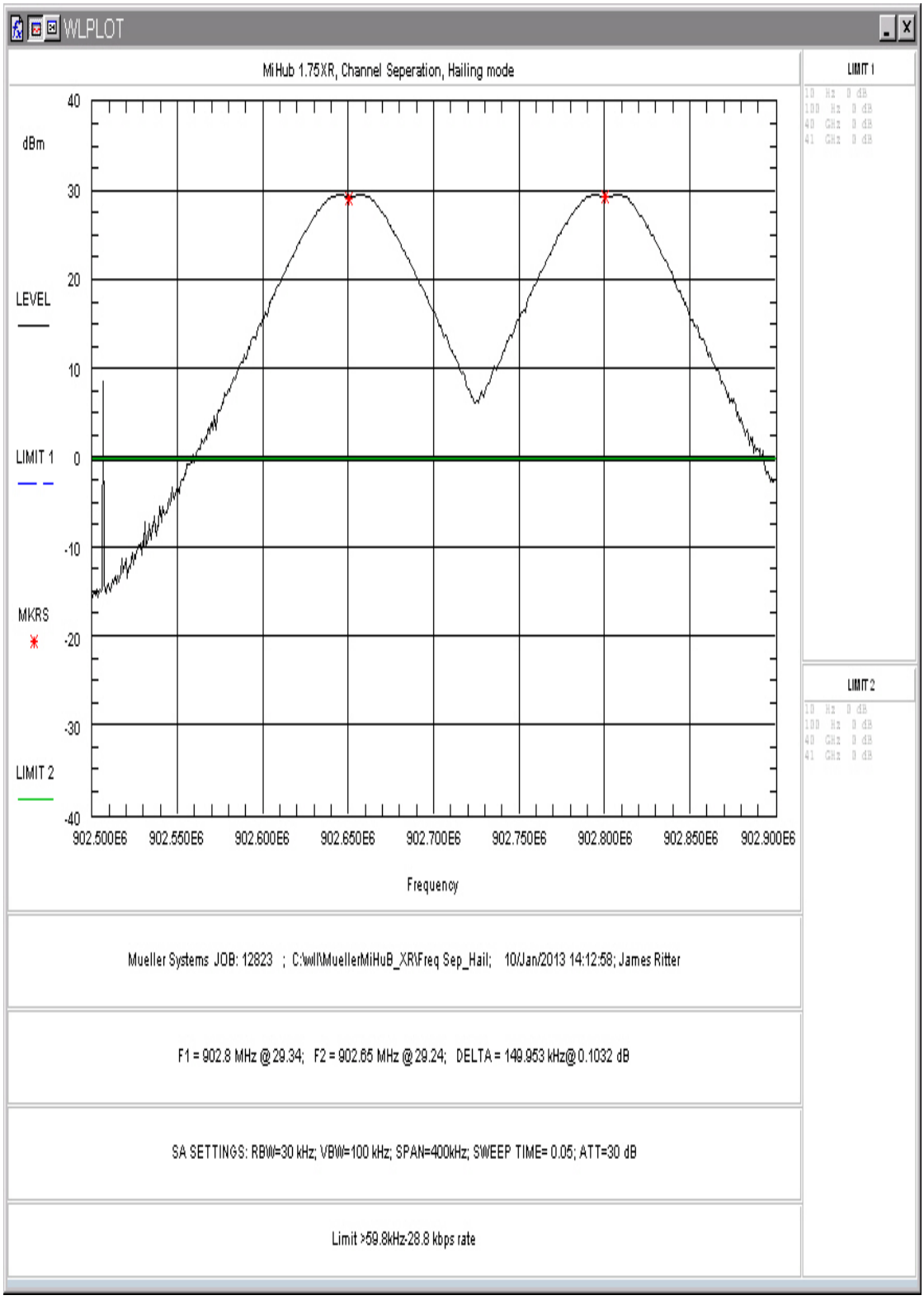

Figure 30: Hailing Channel Spacing

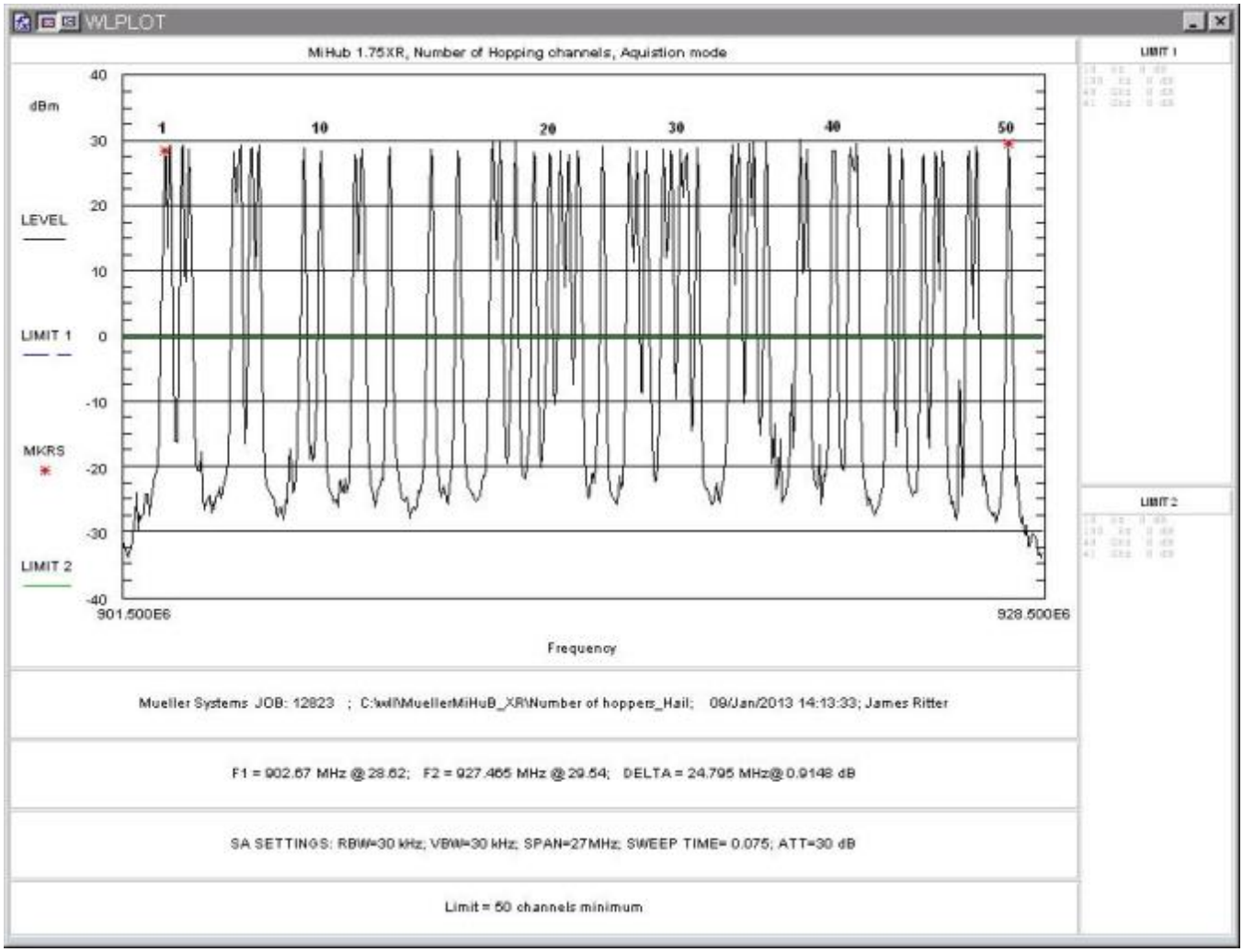

Figure 31: Number of Hailing Channels

