Washington Laboratories, Ltd.
www.wll.com
7560 Lindbergh Drive . Gaithersburg, MD 20879
301.216.1500 . info@wll.com

FCC Certification Test Report

For the

ReconRobotics Inc.

Throwbot 2

FCC ID: UYXRSK2018-01

WLL Report# 15438-01 Rev 2
January 29, 2018
Re-issued March 13, 2018

Prepared for:

ReconRobotics Inc.
5251 W. 73rd Street, Ste. A
Edina, MN 55439

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

FCC Certification Test Report

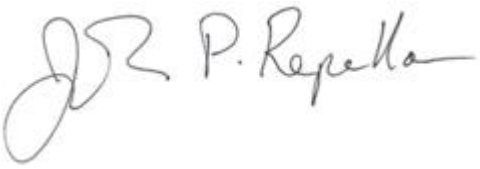
For the

ReconRobotics Inc.

Throwbot 2

WLL Report# 15438-01 Rev 2
January 29, 2018
Re-issued March 13, 2018

Prepared by:



John P. Repella
Manager, EMC & Wireless Services

Reviewed by:

Steven D. Koster
President

Abstract

This report has been prepared on behalf of ReconRobotics Inc. to support the waiver DA10-291 released Feb 23, 2010 of the FCC rules. The test report was constructed with guidance from Part 90 Subpart I--Private Land Mobile Radio Services general technical requirements section of the FCC Rules and Regulations (10/2015).

This testing was submitted to support the requested waiver DA10-291 released Feb 23, 2010 and Order of Reconsideration DA 11-675.

Testing was performed at Washington Laboratories, Ltd, 7560 Lindbergh Drive, Gaithersburg, MD 20879.

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

These tests are accredited and meet the requirements of ISO/IEC 17025:2005 as verified by the ANSI-ASQ National Accreditation Board/ANAB. Refer to certificate and scope of accreditation AT-1448.

Revision History	Reason	Date
Rev 0	Initial Release	January 29, 2018
Rev 1	Updated to address reviewers comments	February 21, 2018
Rev 2	Updated to add Audio Filter Response curves	March 13, 2018

Table of Contents

List of Tables

List of Figures

1 Introduction

1.1 Compliance Statement

The ReconRobotics Inc. Throwbot 2 was tested to the FCC Waiver DA-10-291of the requirements of Part 90 Private Land Mobile Radio Services Subpart I--Private Land Mobile Radio Services general technical requirements section of the FCC Rules and Regulations (10/2015).

1.2 Test Scope Summary

The following tests were performed using the applicable parts of the FCC rules as guidance:

Total Power	FCC Part 90.101
Emission Bandwidth	FCC Part 90.209(b)
Unwanted Radiation	FCC Part 90.210
Frequency Tolerance	FCC Part 90.213(a)
Transient Frequency Behavior	FCC Part 90.214

Additional guidance was obtained from the following references:

- TIA/EIA 603-E Land Mobile FM or PM Communications Equipment-Measurement and Performance Standards
- C63.26:2015 American National Standard for Compliance Testing of Transmitters Used in Licensed Radio Services

1.3 Contract Information

Customer:	ReconRobotics Inc. 5251 W. 73rd Street Edina, MN 55439
Purchase Order Number:	Q70077
Quotation Number:	7832

1.4 Test Dates

Testing was performed on the following date(s):	01/11/2018 to 01/26/2018, 3/13/2018

1.5 Test and Support Personnel

Washington Laboratories, Ltd.	John P. Repella, John B. Reidell
Customer Representative	Andrew Drenner, Collin Lafave

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

The results obtained relate only to the item(s) tested.

Table 1: Overview of Throwbot 2, Equipment Under Test

ITEM	DESCRIPTION
Manufacturer:	ReconRobotics Inc.
EUT Name	Throwbot 2
FCC ID:	UYXRSK2018-01
Model:	Throwbot 2
FCC Rule Parts:	Part 90
Frequency Range:	3) 6 MHz Bands: 430-436MHz, 436-442MHz, 442-448MHz Per FCC Waver DA 10-291 and DA 11-675
Output Power Mfg. Stated	250mW average, 1 W peak (per waiver)
Measured Output Power:	21.9dBm Average, 27.1dBm Peak
Modulation:	AM Video & FM Audio
Emission Bandwidth:	4.64MHz (6MHz authorized)
Keying:	Automatic
Type of Information:	NTSC Video and Audio
Number of Channels:	3 channels: 430-436 MHz, 436-442 MHz, 442-448 MHz (per waiver)
Antenna Connector	Internal mmcx (not user accessible)
Antenna Type	¼ wave whip permanently attached to chassis
Antenna Gain	N/A
Frequency Tolerance:	0.0005%
Emission Designator:	Video - 5M75C3F / Audio 250KF3E
Interface Cables:	None
Power Source & Voltage:	Rechargeable Battery, 11.3V nominal, 12.6Vmax

2.2 EUT Description

The Recon Scout robot is a surveillance robotic device meant to be deployed into settings where useful real time remote information can be transmitted from hazardous locations thereby improving the safety of personnel. The Recon Scout robot under test transmits analog audio and video information. In low light conditions the unit is capable of illuminating the surrounding area with near infrared light to aid the vision capabilities of the camera. The frequencies used for transmission occur in 6MHz bands centered at 433, 439, and 445MHz. The band is preset at time of manufacture and cannot be changed in the field. The Recon Scout broadcasts video at a preset power level which is referenced in Paragraph 7 of the FCC waiver DA 10-291, is not to exceed 0.25 W average or 1 W peak. The emission designator is C3F. The transmitter, as a whole, draws approximately 0.13 A at battery voltage (nominally 11.1V). This is used to power one 5V DC-DC switching regulator and two 3V3 LDO regulators. The final amplifier stage of this system driving a 50 Ohm load uses the 5V switching supply at 0.11 to 0.17 A.

The Recon Scout robot receives commands over a 75MHz radio receiver. The robotic platform maintains mobility through the use of two electric motors that drive each of its wheels independently. Power is supplied from a lithium polymer battery, through a smart battery safety circuit and various voltage regulators. Various sensors aid in physical navigation of the device. Onboard processing, sensor integration, auxiliary systems control, and command receiver monitoring is accomplished through the use of microcontrollers. The chassis of the system and the

external metal components are all grounded with respect to the onboard circuitry. The ground system plays an important role in antenna performance and EMI immunity. The video broadcast antenna is an approximately ¼ wave antenna constructed so as to be extremely robust to physical impacts, and yet not interfere with the mobility of the mechanical propulsion systems. The command receive antenna is similar in mechanical construction to the video broadcast antenna, but is tuned to use in receiving the 75MHz command signals the platform utilizes.

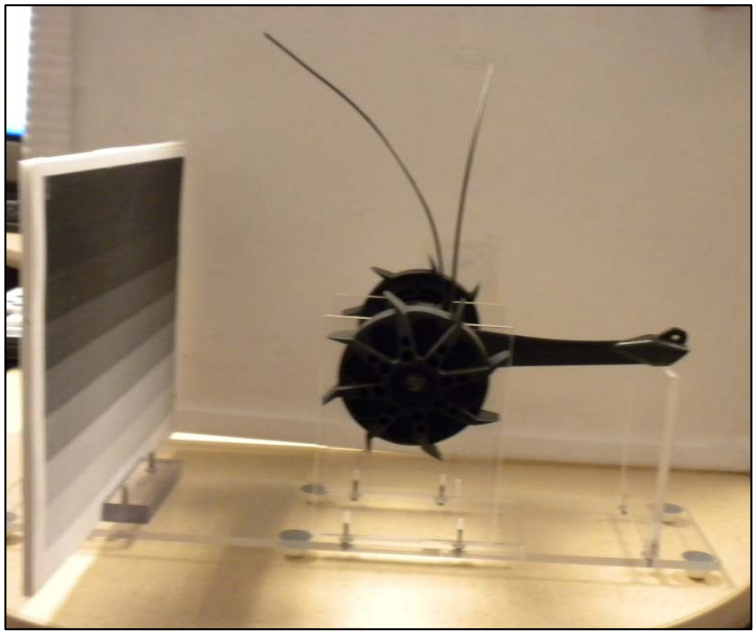
2.3 Test Configuration

The ReconRobotics Inc. Recon Scout (Throwbot 2), Equipment Under Test (EUT), was operated from a DC power supply. The devices are pre-configured with the transmit frequency (not user changeable). Three separate units were provided each unit configured to operate in one of the three 6 MHz channels, Unit A@ 442-448MHz, Unit B @ 430-436MHz, and Unit C @ 436-442MHz. The unit is intended to operate in one orientation only.

When the Throwbot 2 is introduced into its intended environment it rights itself operationally, for this reason, it was tested in only one orthogonal, its intended operational position. Worst case investigations were performed on various video photographs; the worst case results were obtained using the 0.0625" checkerboard pattern. A 1 kHz tone was introduced for the audio portion of the EUT.

When power is applied to the EUT, the robot will automatically start broadcasting at the channel indicated by the sticker on the chassis of the robot.

There are three video/audio transmission channels:
Ch. A Video 443.25MHz & VSB Audio-447.75MHz (Centered @445MHz)
Ch. B Video 431.25MHz & VSB Audio 435.75MHz (Centered @433MHz)
Ch. C Video 437.25MHz & VSB Audio 441.75MHz (Centered @439MHz)
Note: The figure below depicts a representative test setup sample.



2.4 Equipment Configuration

The EUT was comprised of the following equipment. (All Modules, PCBs, etc. listed were considered as part of the EUT, as tested.)

Table 2: Equipment Configuration

Name / Description	Model Number	Part Number	Serial Number	Rev. #
Channel A.2 – 442-448 MHz Video Carrier - 443.25 MHz Audio Carrier – 447.75 MHz	Throwbot 2 – Channel A.2	RS-TB2-A	0817AE0011	1
Channel B.2 – 430-436 MHz Video Carrier – 431.25 MHz Audio Carrier – 435.75 MHz	Throwbot 2 – Channel B.2	RS-TB2-B	0817AE0020	1
Channel C.2 – 436-442 MHz Video Carrier 437.25 MHz Audio Carrier – 441.75 MHz	Throwbot 2 – Channel C.2	RS-TB2-C	0817AE0024	1
Channel C.2 – 436-442 MHz Video Carrier 437.25 MHz Audio Carrier – 441.75 MHz	Throwbot 2 – Channel C.2	RS-TB2-C	0817AE0022	Modified for Testing

2.5 Support Equipment

The following support equipment was used during testing:

Table 3: Support Equipment

Name / Description	Manufacturer	Model Number	*Customer Supplied Calibration Data
USB Type C Charger	Google (Phihong)	Google Pixel XL Charger (TCG1000-US)	Not Applicable
Custom Power Cable for Modified Throwbot 2	ReconRobotics	NA	Not Applicable
DC Power Supply	HQ Power	PS5005U	Not Applicable

2.6 Interface Cables

Table 4: Interface Cables

Ref. ID	Port name on EUT	Cable Description or reason for no cable	Qty.	Length (m)	Shielded?	Termination Box ID & Port ID
1	USB-C Jack	USB Type C Charge Cable	1	1.8	No	Port 1 (see block diagram)
2	Non-USB-C Power Jack	Custom Power Cable for Modified Throwbot 2	1	1.8	No	Port 2 (see block diagram)

2.7 EUT Modifications

There were no modifications necessary for the EUT to comply with requirements.

2.8 Test Location

All measurements herein were performed at Washington Laboratories, Ltd. test center in Gaithersburg, MD. Washington Laboratories, Ltd. has been accepted by the FCC and approved by ANAB under Testing Certificate AT-1448 as an independent FCC test laboratory.

2.9 Measurement Uncertainty

All results reported herein relate only to the equipment tested. The basis for uncertainty calculation uses ANSI/NCSL Z540-2-1997 (2002) 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 5 below.

Table 5: Expanded Uncertainty List

Scope	Standard(s)	Expanded Uncertainty
Radiated Emissions	FCC Part 15	±4.55 dB

3 Test Equipment

Test Name:	**Temperature Stability**	Test Date:	**1/11/2018**
Asset #	**Manufacturer/Model**	**Description**	**Cal. Due**
641	HQ POWER - NONE	0-50V 5AMP DC SUPPLY	Cal in Test
823	AGILENT - N9010A	EXA SPECTRUM ANALYZER	12/21/2018
776	TENNY - TJR-A-WS4	1.22 CUFT	05/22/2018
774	FLUKE - 115	TRUE RMS MULTIMETER	04/26/2018

Test Name:	**Radiated Emissions**	Test Date:	**1/26/2018**
823	AGILENT - N9010A	EXA SPECTRUM ANALYZER	12/21/2018
382	SUNOL SCIENCES CORPORATION - JB1	ANTENNA BICONLOG	10/31/2018
29	EMCO - 3146A	ANTENNA LOG PERIODIC	12/13/2018
425	ARA - DRG-118/A	ANTENNA DRG 1-18GHZ	11/23/2018
4	ARA - DRG-118/A	ANTENNA DRG 1-18GHZ	12/14/2018
771	TEKTRONIX - TDS1012C-EDU	2 CH DIGITAL STORAGE OSCILLOSCOPE	8/9/2018

Test Name:	**Modulation Characteristics**	Test Date:	**1/15/2018**
Asset #	**Manufacturer/Model**	**Description**	**Cal. Due**
771	TEKTRONIX - TDS1012C-EDU	2 CH DIGITAL STORAGE OSCILLOSCOPE	8/9/2018
735	HEWLET PACKARD - 8920A	RF COMM TEST SET 0.4 -1000MHz	Cal in Test
833	KEITHLY - 3390	ARB WAVEFORM GENERATOR	Cal in Test
641	HQ POWER - NONE	0-50V 5AMP DC SUPPLY	Cal in Test
29	EMCO - 3146A	ANTENNA LOG PERIODIC	12/13/2018

4 Rule Declarations from Manufacturer

Application of the Waiver DA 10-291 to part 90 of The Commission's Rules is declared by the manufacturer and the Order of Reconsideration DA 11-675.

5 Test Results

5.1 Total Power [FCC Waiver DA 10-291 Paragraph 7]

5.1.1 Test Method

The EUT was tested in band for radiated emissions on an open air test site (OATS) using the substitution method specified in TIA-603-E section 2.2.12 Unwanted Emissions with the following 2 exceptions:
1) Instead of replacing the EUT antenna with a non-reacting load the EUT antenna was left in place. This produces a worst case reading (combined case and antenna).

2) A resolution bandwidth of 8MHz and a video bandwidth of 50MHz were used for measurements conducted on this device. This was done to fully encompass the entire NTSC signal. Each of the three EUT's was the set to transmit at its preconfigured transmit frequency. This level was recorded for the EIRP power.

3) The video resolution bandwidth of the measuring instrument was the reduced to 10Hz and the peak of the resulting signal was compared to the average limits for each of the units.

4) The maximum amplitude of the EIRP signal was obtained with the 0.0625" checkerboard pattern.

A sample from the substitution tables is provided below to clarify them.

Frequency (MHz)	Polarity	Azimuth	Ant. Height (m)	Spurious Level (dBuV)	EIRP Level (dBm)	Margin (dB)
(a)	(b1)	(b2)	(b3)	(c)	(h)	(k)

Sub. Sig. Gen. Level (dBm)	Sub. Power Level (dBm)	Sub. Ant. Factor (dB)	Sub. Ant. Gain (dB)
(d)	(e)	(f)	(g)

Column Key:

a. Frequency of detected emission
b. (1-3) Position of EUT and height/ polarization of receive antenna at maximum emission level
c. Maximum field strength level of EUT emission on receiver without any corrections
d. Level of Signal Generator attached to a substitution antenna that produced field strength identical to the EUT emission.
e. Signal Generator level at Substitution antenna (d minus any cable/connector losses)
f. Antenna Factor of substitution antenna used to get Antenna Gain
g. Substitution Antenna Gain
h. EIRP level of emission per TIA-603-E (column e plus column g) Note : numbers may have fractional differences due to rounding.
k. Level of EUT EIRP (column i) compared to EIRP limit (Column j). Minus numbers indicate level below limit.

5.1.2 Test Limit

FCC Waiver DA 10-291 Paragraph 7 states an operating power not to exceed 250mW (23.98dBm) average power and a 1W (30dBm) peak power.

5.1.3 Test Results

The test results are shown in Table 6 & 7.

5.1.4 Test Summary

The EIRP Total power complies with the requirements as per FCC Waiver DA 10-291 Paragraph 7.

Table 6: EIRP Power (Average Measurements)

Frequency (MHz)	Polarity (H/V)	Azimuth (Degree)	Ant. Height (m)	SA Level (dBuV)	Corr Factors (dB)	Corr. Level (dBuV/m)	EIRP (dBm)	Ave Limit (dBm)	Margin (dB)	Peak or Average	Comments
443.25	V	45.0	1.2	97.6	18.9	116.5	21.2	24.0	-2.8	AVG	Horizontal
431.25	V	0.0	1.2	95.6	20.2	115.8	20.5	24.0	-3.5	AVG	Horizontal
437.25	V	0.0	1.2	97.1	19.6	116.8	21.5	24.0	-2.5	AVG	Horizontal
443.25	V	0.0	1.2	93.1	18.9	111.9	16.7	24.0	-7.3	AVG	Tail Up
431.25	V	90.0	1.2	90.7	20.2	110.8	15.6	24.0	-8.4	AVG	Tail Up
437.25	V	90.0	1.2	93.6	19.6	113.2	18.0	24.0	-6.0	AVG	Tail Up
443.25	V	0.0	1.2	90.0	18.9	108.9	13.6	24.0	-10.4	AVG	On Side
431.25	V	270.0	1.2	88.1	20.2	108.2	13.0	24.0	-11.0	AVG	On Side
437.25	V	0.0	1.2	89.5	19.6	109.1	13.9	24.0	-10.1	AVG	On Side
443.25	H	90.0	1.2	89.6	18.9	108.5	13.2	24.0	-10.8	AVG	Horizontal
431.25	H	90.0	1.2	88.3	20.2	108.5	13.2	24.0	-10.8	AVG	Horizontal
437.25	H	270.0	1.2	88.4	19.6	108.1	12.8	24.0	-11.2	AVG	Horizontal
443.25	H	350.0	1.2	98.3	18.9	117.2	21.9	24.0	-2.1	AVG	Tail Up
431.25	H	0.0	1.2	97.0	20.2	117.1	21.9	24.0	-2.1	AVG	Tail Up
437.25	H	0.0	1.2	97.5	19.6	117.1	21.9	24.0	-2.1	AVG	Tail Up
443.25	H	315.0	1.2	90.5	18.9	109.4	14.2	24.0	-9.8	AVG	On Side
431.25	H	315.0	1.2	88.6	20.2	108.8	13.5	24.0	-10.5	AVG	On Side
437.25	H	315.0	1.2	88.0	19.6	107.6	12.4	24.0	-11.6	AVG	On Side

Table 7: EIRP Power (Peak Measurements)

Frequency (MHz)	Polarity (H/V)	Azimuth (Degree)	Ant. Height (m)	SA Level (dBuV)	Corr Factors (dB)	Corr. Level (dBuV/m)	EIRP (dBm)	Peak Limit (dBm)	Margin (dB)	Peak or Average	Comments
443.25	V	45.0	1.2	102.8	18.9	121.7	26.4	30.0	-3.6	Peak	Horizontal
431.25	V	0.0	1.2	100.6	20.2	120.8	25.5	30.0	-4.5	Peak	Horizontal
437.25	V	0.0	1.2	102.4	19.6	122.0	26.8	30.0	-3.2	Peak	Horizontal
443.25	V	0.0	1.2	97.1	18.9	116.0	20.7	30.0	-9.3	Peak	Tail Up
431.25	V	90.0	1.2	96.4	20.2	116.5	21.3	30.0	-8.7	Peak	Tail Up
437.25	V	90.0	1.2	96.4	19.6	116.1	20.8	30.0	-9.2	Peak	Tail Up
443.25	V	0.0	1.2	95.0	18.9	113.9	18.6	30.0	-11.4	Peak	On Side
431.25	V	270.0	1.2	93.1	20.2	113.3	18.0	30.0	-12.0	Peak	On Side
437.25	V	0.0	1.2	94.5	19.6	114.2	18.9	30.0	-11.1	Peak	On Side
443.25	H	90.0	1.2	95.3	18.9	114.2	18.9	30.0	-11.1	Peak	Horizontal
431.25	H	90.0	1.2	94.1	20.2	114.2	19.0	30.0	-11.0	Peak	Horizontal
437.25	H	270.0	1.2	94.1	19.6	113.8	18.5	30.0	-11.5	Peak	Horizontal
443.25	H	350.0	1.2	103.5	18.9	122.4	27.1	30.0	-2.9	Peak	Tail Up
431.25	H	0.0	1.2	101.4	20.2	121.6	26.3	30.0	-3.7	Peak	Tail Up
437.25	H	0.0	1.2	102.4	19.6	122.0	26.7	30.0	-3.3	Peak	Tail Up
	H										
443.25	H	315.0	1.2	94.8	18.9	113.7	18.4	30.0	-11.6	Peak	On Side
431.25	H	315.0	1.2	93.7	20.2	113.8	18.6	30.0	-11.4	Peak	On Side
437.25	H	315.0	1.2	92.5	19.6	112.1	16.9	30.0	-13.1	Peak	On Side

5.2 Emission Bandwidth [FCC Waiver DA 10-291 Paragraph 7]

5.2.1 Test Method

The emission bandwidth test was performed as an occupied bandwidth measurement. A spectrum analyzer was tuned to the center of the transmit frequency. The span of the analyzer was the reduced to approximately 2 to 3 times the span of the Tx signal. The resolution bandwidth of the device was lowered to approximately 1% of the estimated occupied bandwidth. The span between points on each side of the Tx signal corresponding to 20dB below the peak were then recorded as the emission bandwidth. The 0.0625" checkerboard pattern was used for test as worst case. The results are based on a 20dB bandwidth measurement of the video and audio carrier (together).

5.2.2 Test Limit

As per FCC Waiver DA10-291, the emissions bandwidth must not exceed 6MHz.

5.2.3 Test Results

Figure 1 shows the plot of the occupied bandwidth. The recorded level is 4.616MHz. Figure 2 shows a sample of the occupied bandwidth of the video signal alone, and is supplied for reference to the measurement value. Table 8 summarizes the measured bandwidths of the video signal with different test patterns. The test patterns shown in table 8 are black and white test patterns as these provided worst case results. The 0.0625" checkerboard pattern was used for test as worst case.

5.2.4 Test Summary

Table 8 below shows the maximum measured bandwidths for the video signal for different standardized video patterns. This data was investigative to determine which standardized pattern produced worst case operating conditions.

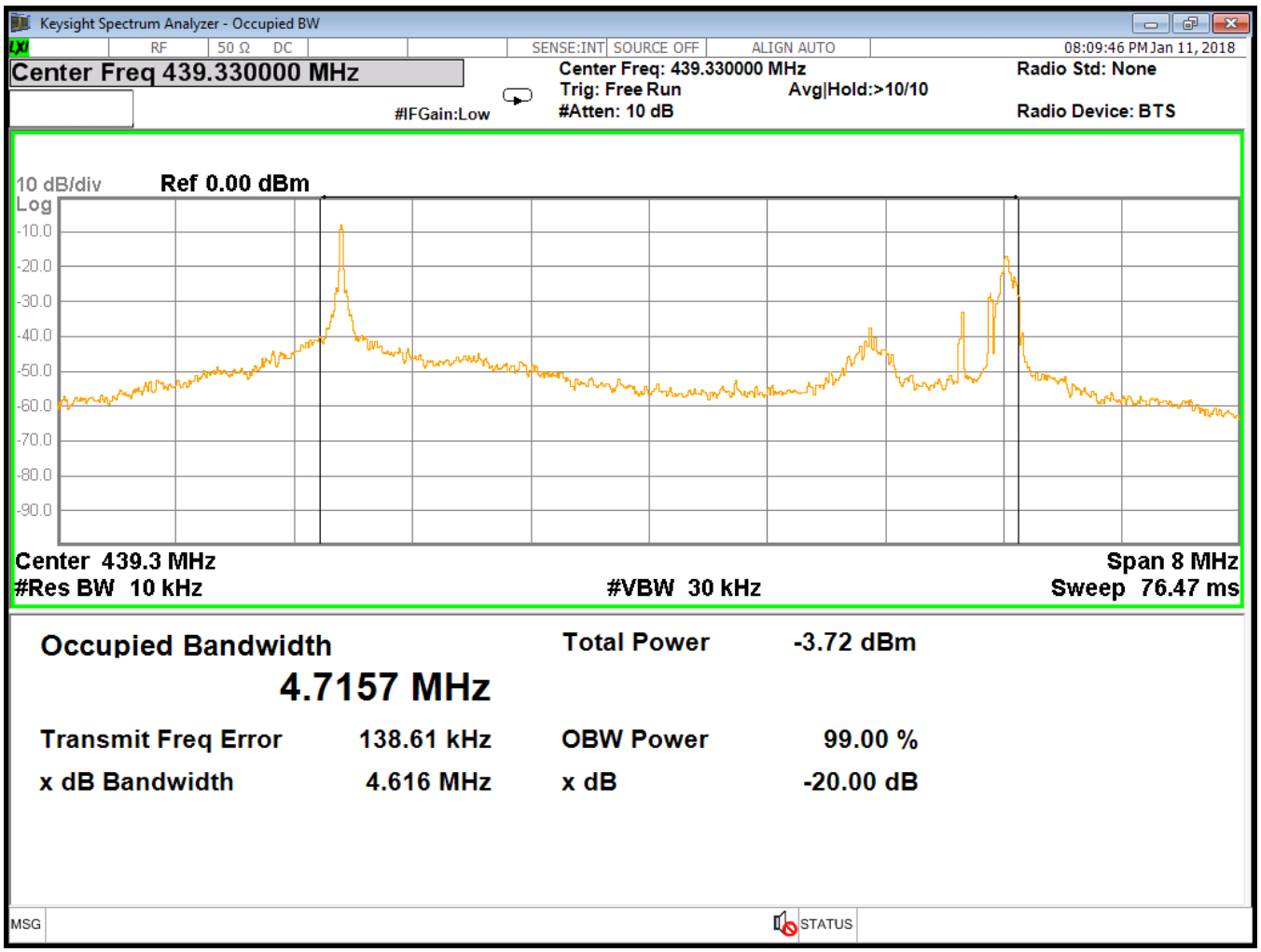


Figure 1: 20dB/99% Occupied bandwidth

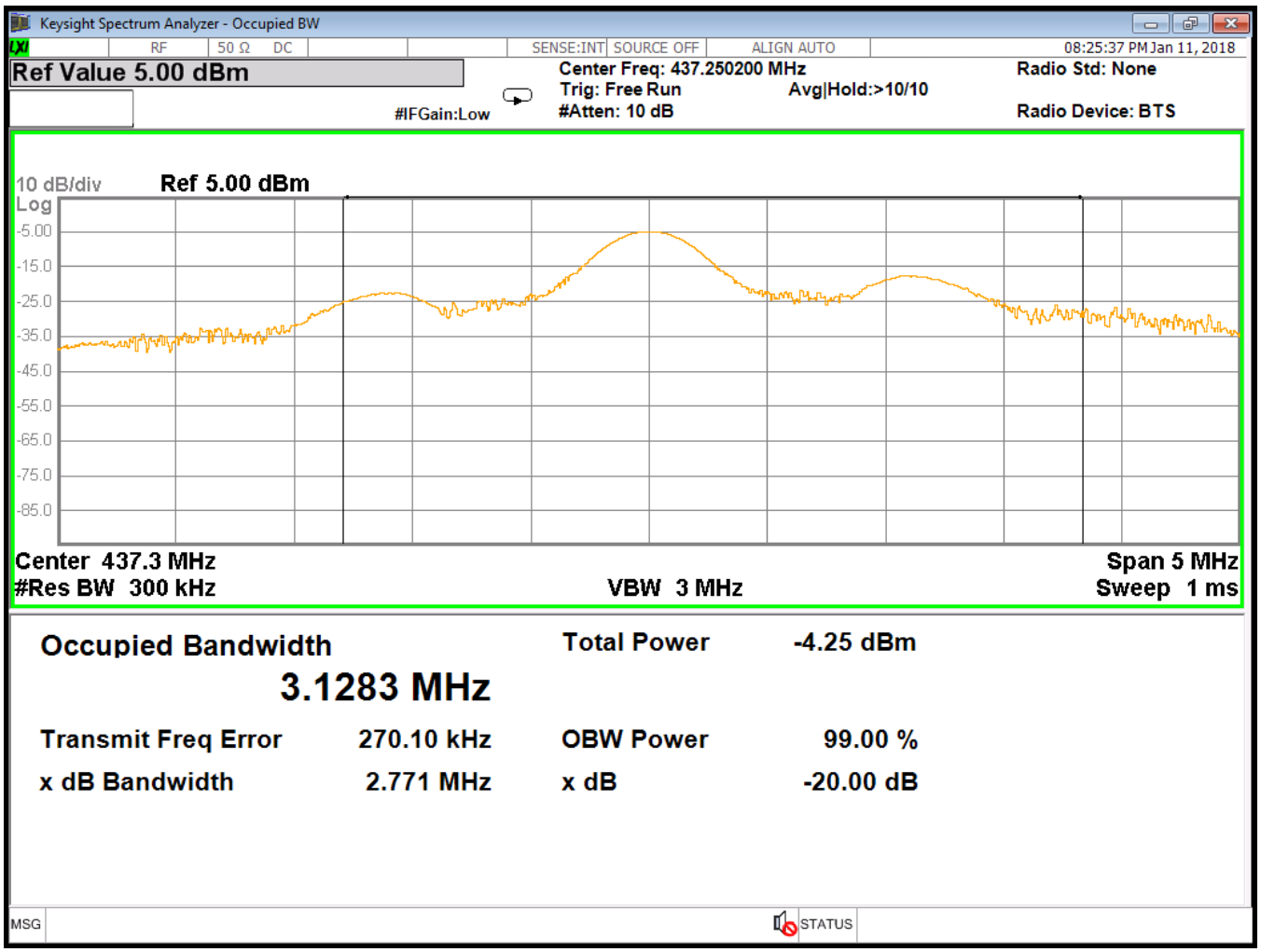


Figure 2: 20dB Occupied bandwidth (Video only)

Table 8: Video Signal Bandwidth Summary (for reference only)

Video Pattern	20dB BW (MHz)
0.125 Checkerboard	2.686
0.25" Checkerboard	2.133
0.5" Checkerboard	2.387
1.0" Checkerboard	2.441
0.0625" Checkerboard	2.771
0.125" Horizontal Bars	2.393
0.0625" Horizontal Bars	2.144
0.125” Vertical Bars	2.567
1” Vertical Bars	2.302
Vertical Gradation Gray Scale	2.266
Horizontal Gradation Gray Scale	2.344
Standard TV Test Pattern	2.469
1” Color Bar	2.222
Standard Eye Chart	2.235

The chart of 20dB video bandwidth is used to determine the worst case video pattern and all test were then completed with this pattern.

5.3 Unwanted Radiation [FCC Part 90.210 (b)(1)(2)(3)]

5.3.1 Test Method

The EUT was tested in band for radiated emissions on an open air test site (OATS) using the substitution method specified in TIA-603-E section 2.2.12 Unwanted Emissions with the following exception:

Instead of replacing the EUT antenna with a non-reacting load the EUT antenna was left in place. This produces a worst case reading (combined case and antenna).

In addition the EUT was tested out of band (>250 % of authorized bandwidth) for radiated emissions on an open air test site (OATS) using a substitution method The EUT was placed on motorized turntable for radiated testing on a 3-meter open field test site. The emissions from the EUT were measured continuously at every azimuth by rotating the turntable. Receiving antennas were mounted on an antenna mast to determine the height of maximum emissions. The EUT was tested in 3 orthogonal positions for compliance and the worst case emissions are presented here. A resolution bandwidth of 100 kHz was used for radiated measurements below <1GHz, Measurements above 1GHz used a resolution bandwidth of 1MHz. The EUT antenna was in place for these readings. Due to the narrow nature of the separate audio and video signals and the proximity to the part 90 mask a 3.9 kHz resolution bandwidth was used inside of the band.

At least 43 + 10 log10 (P) dB (-13dBm) on any frequency removed from the center of the authorized bandwidth by more than 250%. The authorized bandwidth used was 6MHz.

5.3.2 Test Results

The reference emissions measurements are shown in Figure 3 thru 11 which depict the various NTSC signal parameters and a summary list is stated in Table 8. Radiated results and band edge measurements are shown in Tables 10-15 respectively. The data listed in tables 10-12 correspond to the center channel of the three units (Unit C-439 MHz) which operates in the following band 436-442MHz. These emissions represent the worst case emissions as measured with 0.0625" checkerboard pattern and a 1 kHz tone.

5.3.3 Test Summary

The EUT complied with the requirements of FCC Part [90.210 b (1) (2) (3)]. The EUT additionally complied with the requirements of a typical NTSC signal. 6 MHz was used as the authorized bandwidth from the assigned frequency. The plots per emissions Mask B (used to demonstrate the emission characteristics since no masks seemed appropriate to this type of transmitter) indicate compliance to the -13dBm spurious limit at the band edges. The 3 units tested had assigned center frequencies of 445, 433, and 439MHz.

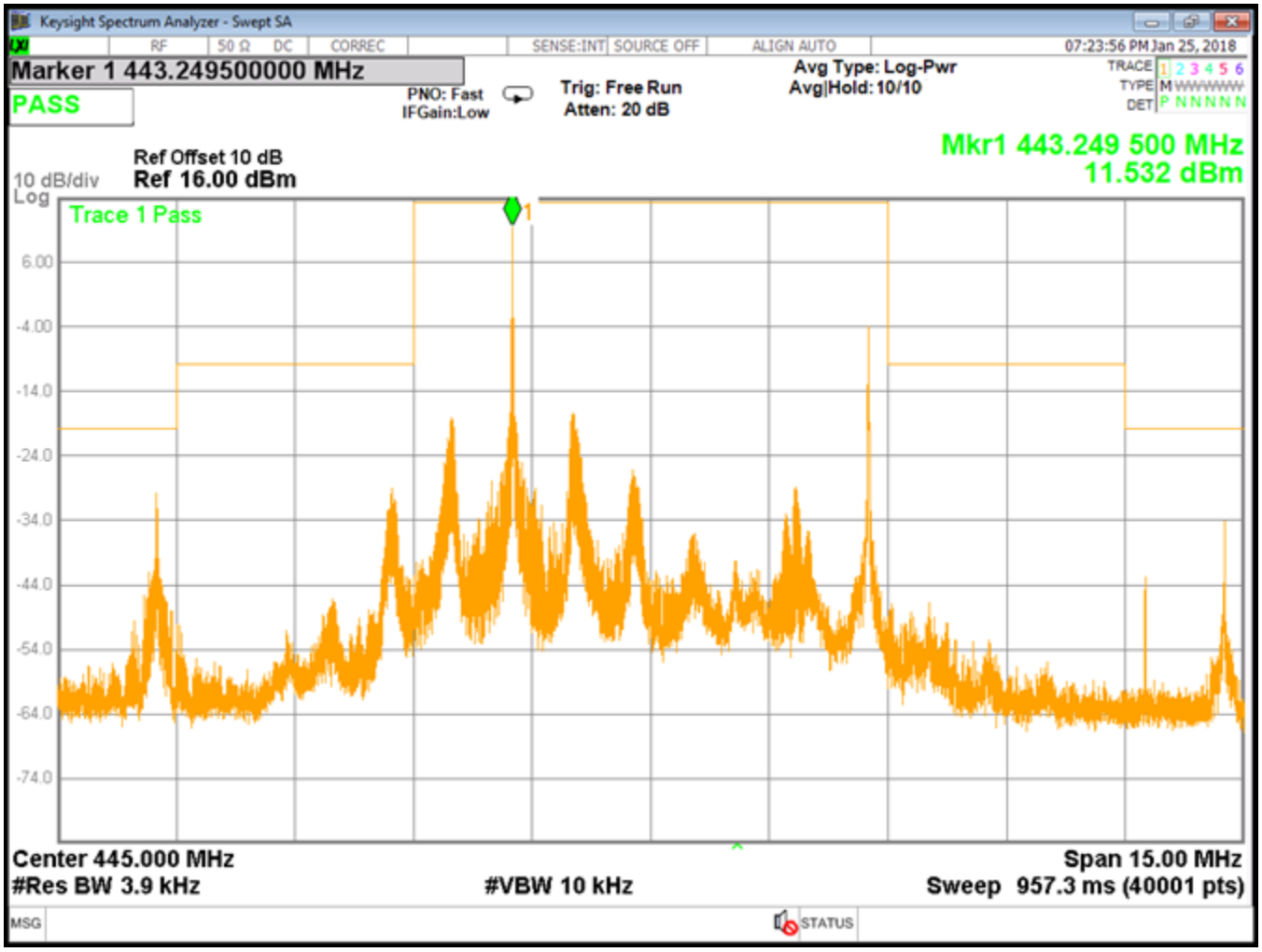


Figure 3: In-Band Emissions Mask, Unit A

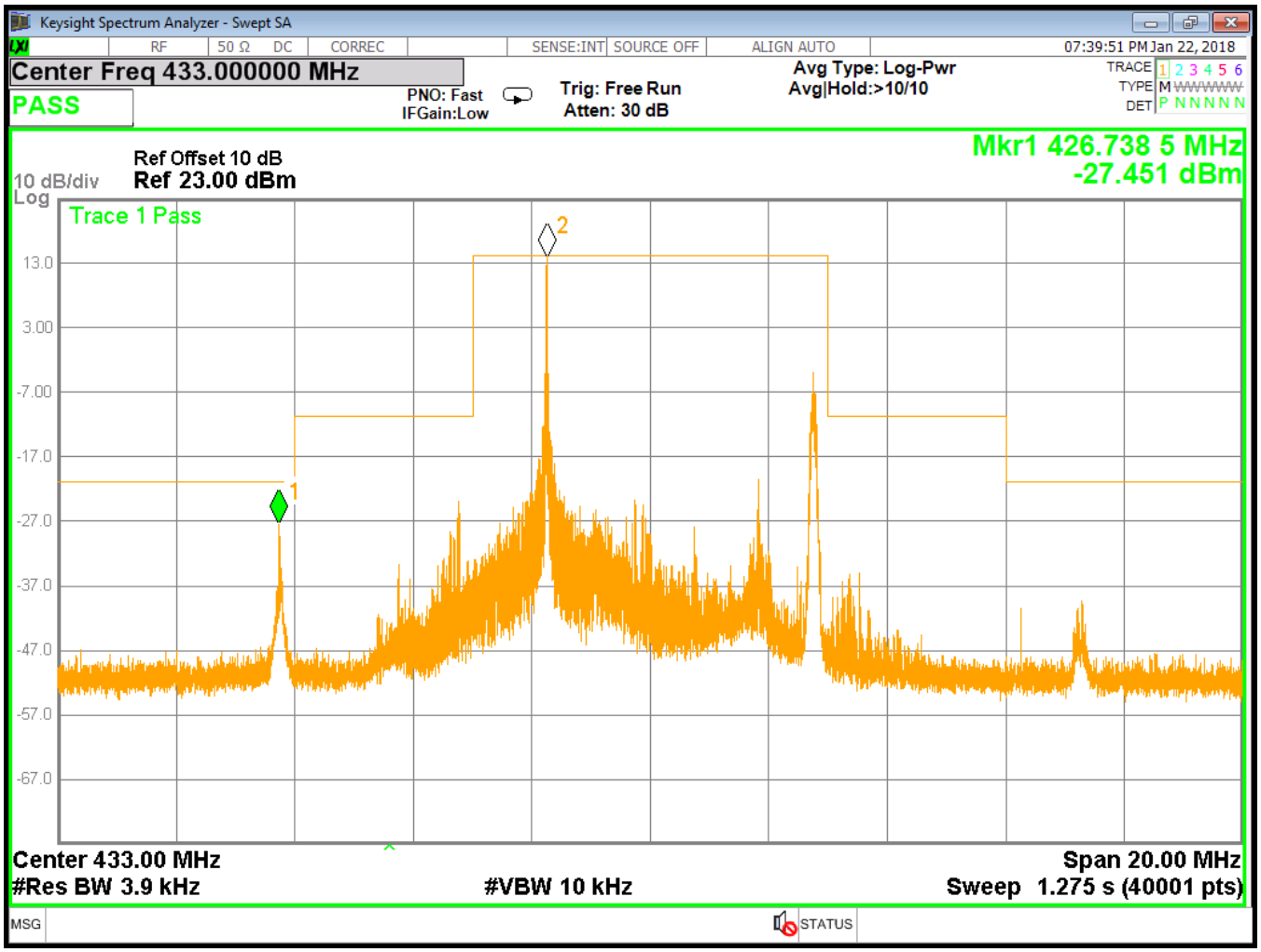


Figure 4: In-Band Emissions Mask, Unit B

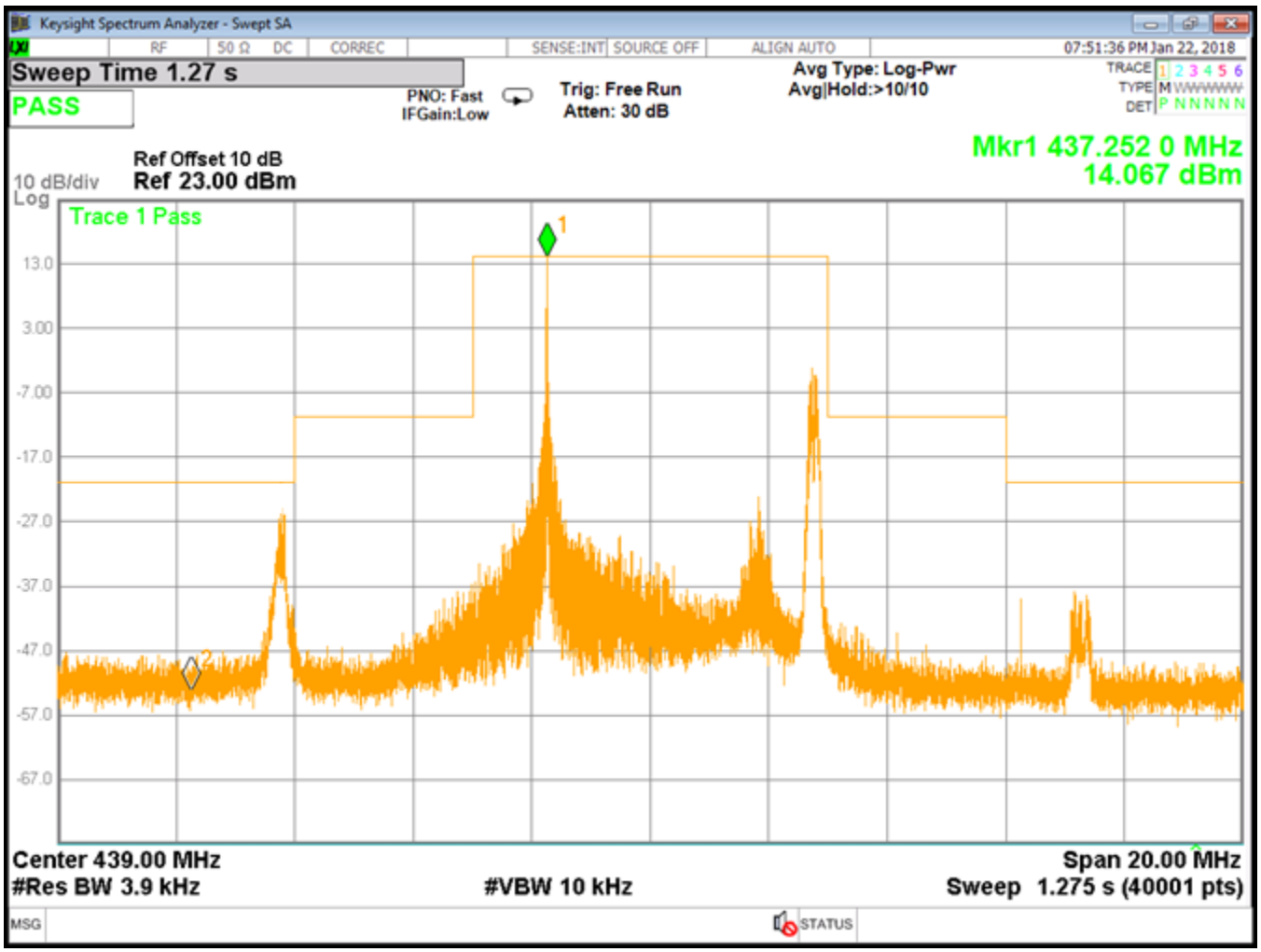


Figure 5: In-Band Emissions Mask, Unit C

Table 9: NTSC Signal Characteristics Summary

	Center of Channel (MHz)	Video Carrier Δ from Lower Bound (MHz)	Video Carrier Δ from Color Carrier (MHz)	Audio Carrier Δ from Upper Bound (MHz)	Video Carrier Δ from Audio Carrier (MHz)
Unit A	445	1.248	3.582	0.260	4.5
Unit B	433	1.254	3.589	0.248	4.5
Unit C	439	1.253	3.583	0.248	4.5

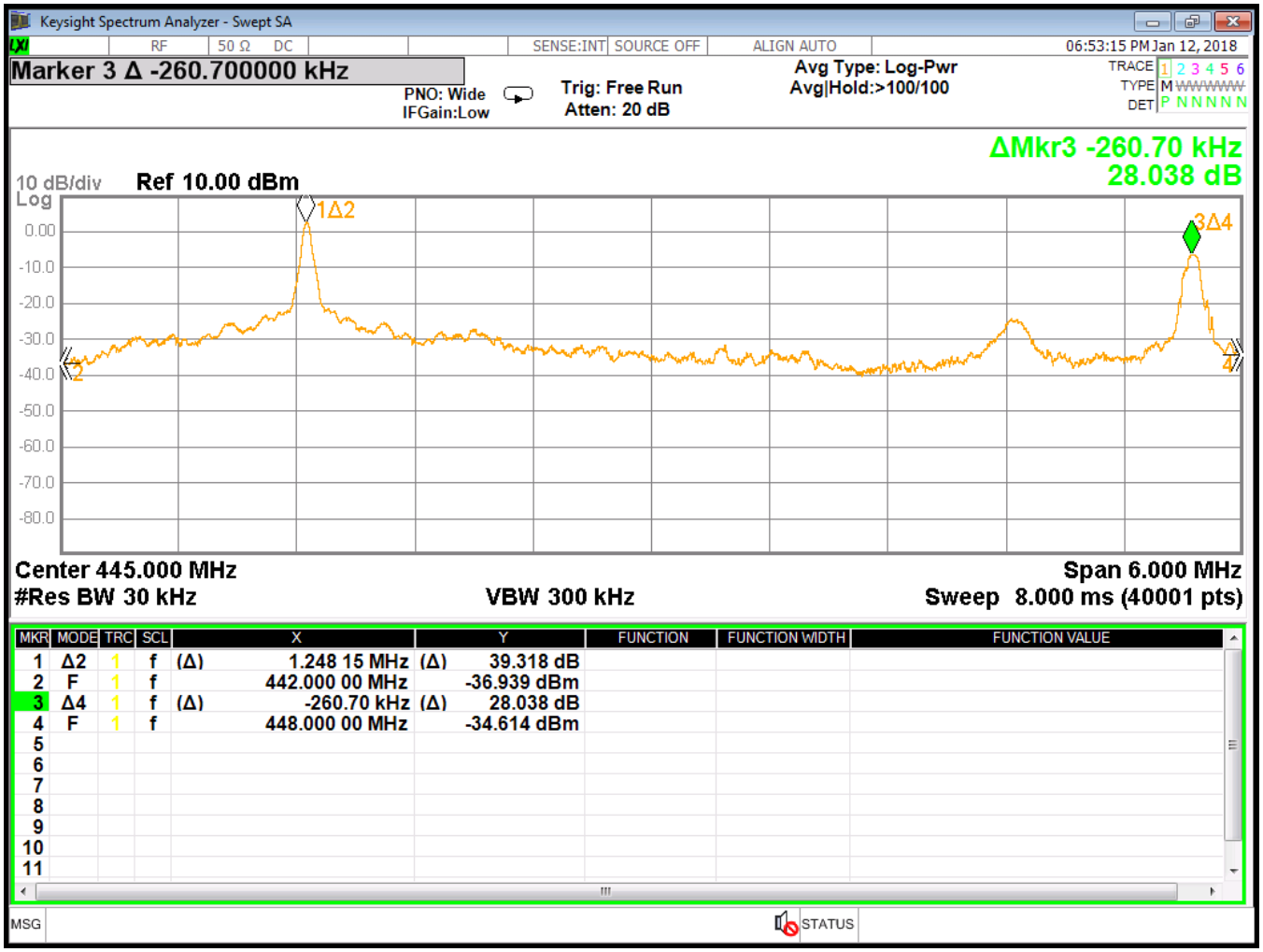


Figure 6: NTSC Signal Parameters, Unit A

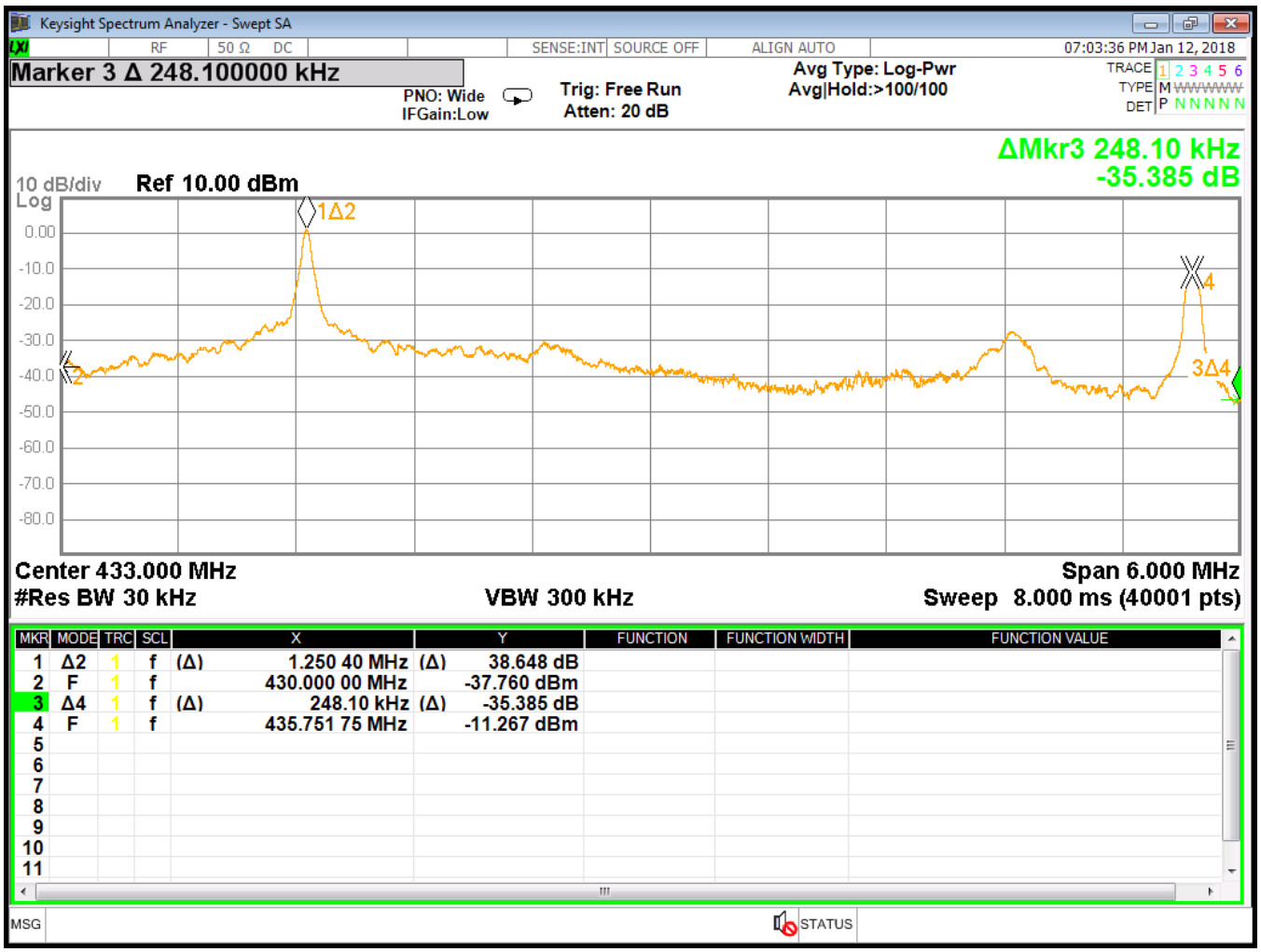


Figure 7: NTSC Signal Parameters, Unit B

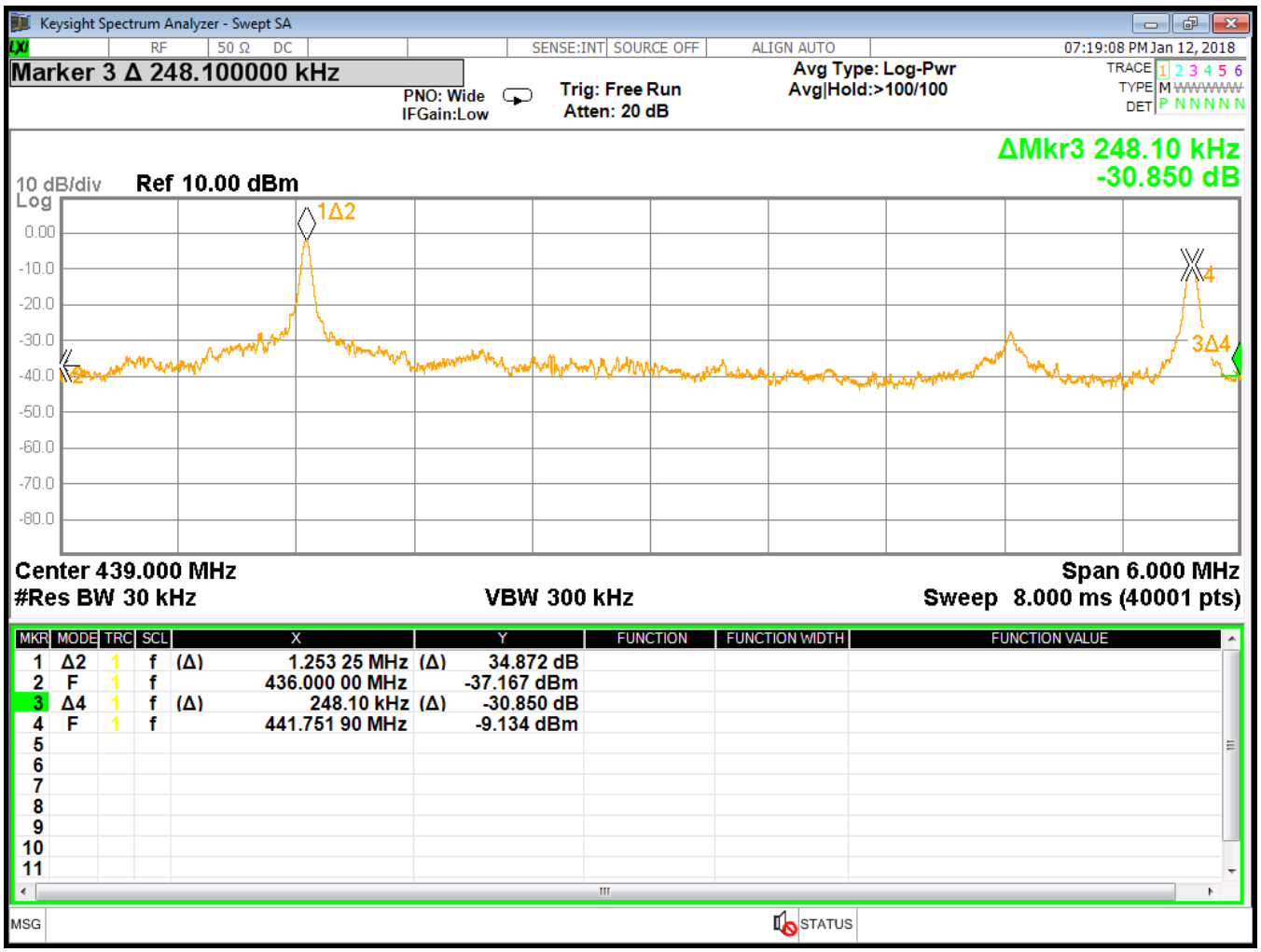


Figure 8: NTSC Signal Parameters, Unit C

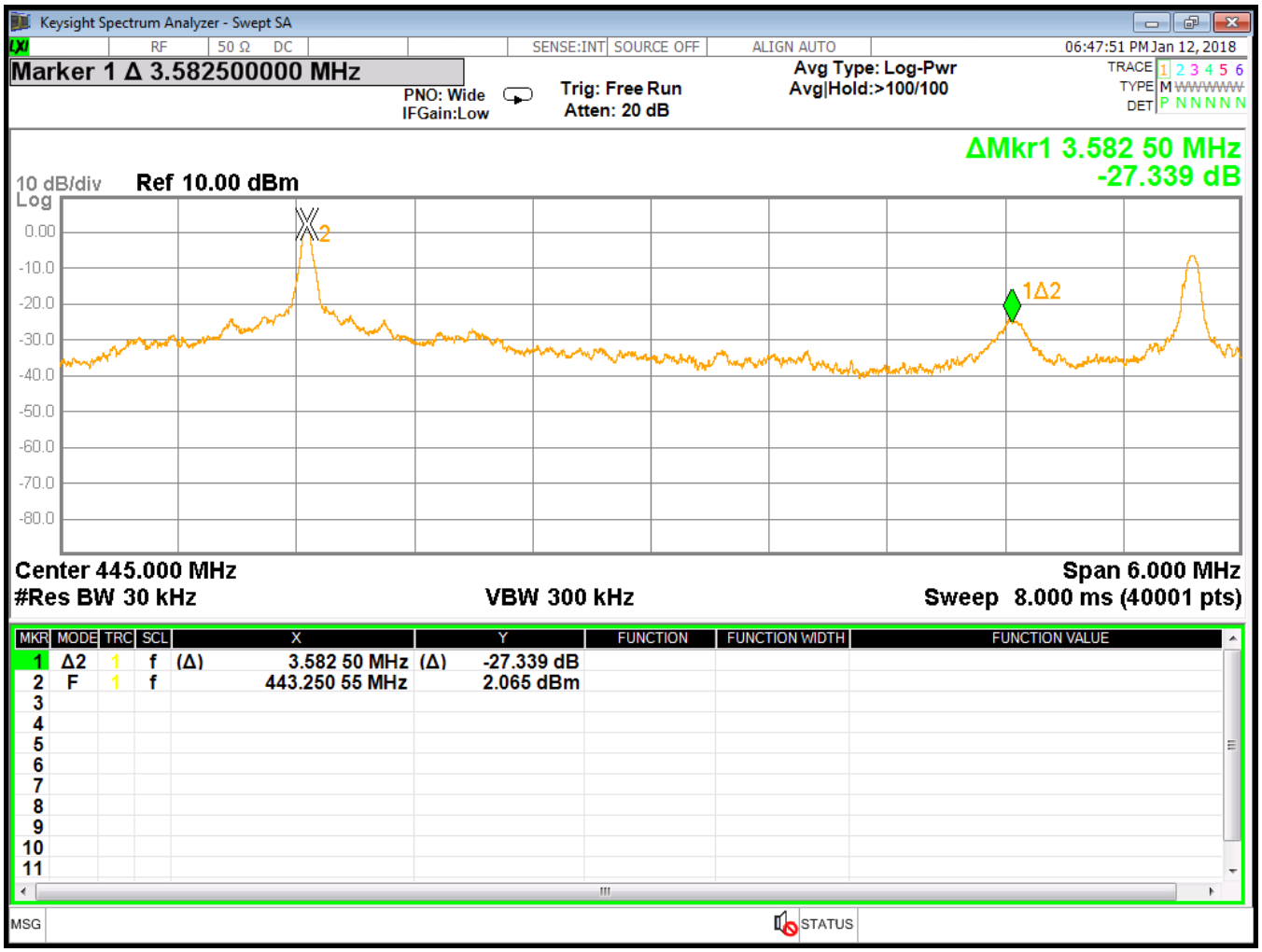


Figure 9: NTSC Signal Parameters, Unit A

Figure 10: NTSC Signal Parameters, Unit B

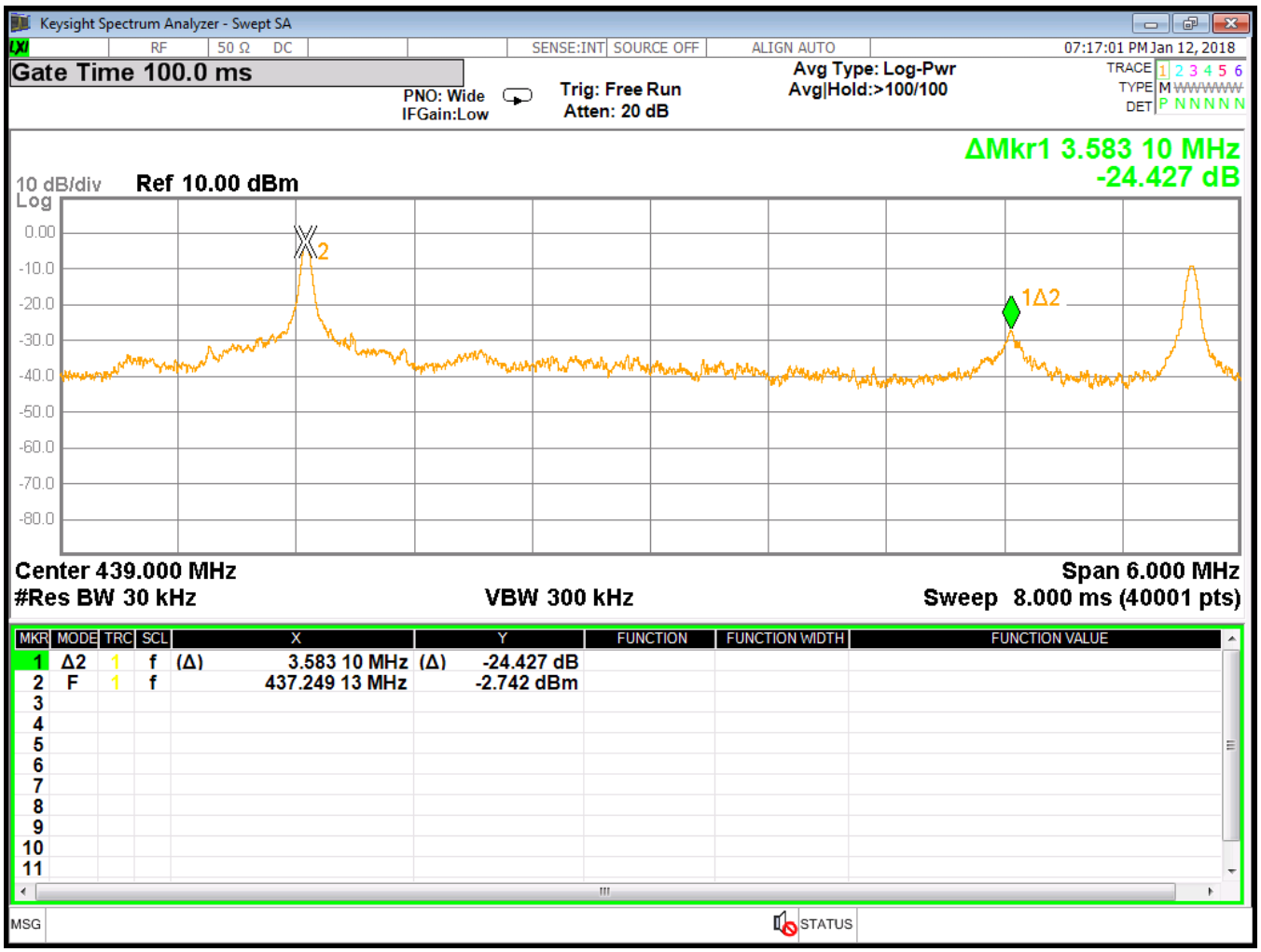


Figure 11: NTSC Signal Parameters, Unit C

Table 10: Unwanted Radiated Emissions (Unit Flat)

Frequency (MHz)	Polarity (H/V)	Azimuth (Degree)	Ant. Height (m)	SA Level (dBuV)	Corr Factors (dB)	Corr. Level (dBuV/m)	EIRP (dBm)	Limit (dBm)	Margin (dB)	Peak or Average	Comments
419.24	V	0.0	1.2	19.9	20.5	40.5	-54.8	-13.0	-41.8	Peak	
423.70	V	0.0	1.2	26.7	20.8	47.5	-47.8	-13.0	-34.8	Peak	
446.25	V	0.0	1.2	48.1	19.7	67.9	-27.4	-13.0	-14.4	Peak	
450.75	V	0.0	1.2	26.7	19.6	46.3	-49.0	-13.0	-36.0	Peak	
865.50	V	0.0	1.2	29.6	26.9	56.5	-38.8	-13.0	-25.8	Peak	
870.01	V	0.0	1.2	36.5	26.7	63.2	-32.0	-13.0	-19.0	Peak	
874.50	V	0.0	1.2	52.7	26.8	79.5	-15.8	-13.0	-2.8	Peak	
879.00	V	0.0	1.2	48.2	26.6	74.8	-20.5	-13.0	-7.5	Peak	
883.51	V	0.0	1.2	36.3	26.3	62.6	-32.7	-13.0	-19.7	Peak	
1311.77	V	0.0	1.2	48.2	27.8	76.0	-19.3	-13.0	-6.3	Peak	
1316.25	V	0.0	1.2	43.7	27.8	71.5	-23.8	-13.0	-10.8	Peak	
1320.70	V	0.0	1.2	29.0	27.8	56.8	-38.4	-13.0	-25.4	Peak	
1749.20	V	0.0	1.2	27.5	28.7	56.1	-39.1	-13.0	-26.1	Peak	
423.70	H	0.0	1.5	25.3	20.8	46.1	-49.2	-13.0	-36.2	Peak	
428.25	H	0.0	1.5	41.3	21.1	62.4	-32.9	-13.0	-19.9	Peak	
446.25	H	0.0	1.5	44.3	19.7	64.0	-31.3	-13.0	-18.3	Peak	
450.75	H	0.0	1.5	21.2	19.6	40.7	-54.5	-13.0	-41.5	Peak	
865.50	H	0.0	1.5	26.4	26.9	53.3	-42.0	-13.0	-29.0	Peak	
870.01	H	0.0	1.5	33.2	26.7	59.9	-35.3	-13.0	-22.3	Peak	
874.50	H	0.0	1.5	47.4	26.8	74.2	-21.1	-13.0	-8.1	Peak	
879.00	H	0.0	1.5	45.8	26.6	72.4	-22.9	-13.0	-9.9	Peak	
883.51	H	0.0	1.5	29.9	26.3	56.2	-39.1	-13.0	-26.1	Peak	
1311.77	H	0.0	1.5	42.1	27.8	69.9	-25.4	-13.0	-12.4	Peak	
1316.25	H	0.0	1.5	38.8	27.8	66.6	-28.7	-13.0	-15.7	Peak	
1320.70	H	0.0	1.5	26.5	27.8	54.3	-41.0	-13.0	-28.0	Peak	
1749.20	H	0.0	1.5	23.5	28.7	52.2	-43.1	-13.0	-30.1	Peak	

Table 11: Unwanted Radiated Emissions (Unit Tail Up)

Frequency (MHz)	Polarity (H/V)	Azimuth (Degree)	Ant. Height (m)	SA Level (dBuV)	Corr Factors (dB)	Corr. Level (dBuV/m)	EIRP (dBm)	Limit (dBm)	Margin (dB)	Peak or Average	Comments
423.70	V	0.0	1.2	21.1	20.8	41.9	-53.4	-13.0	-40.4	Peak	
428.25	V	0.0	1.2	38.8	21.1	59.9	-35.4	-13.0	-22.4	Peak	
446.25	V	0.0	1.2	48.3	19.7	68.0	-27.3	-13.0	-14.3	Peak	
450.75	V	0.0	1.2	27.2	19.6	46.8	-48.5	-13.0	-35.5	Peak	
865.50	V	0.0	1.2	18.6	26.9	45.5	-49.8	-13.0	-36.8	Peak	
870.01	V	0.0	1.2	36.6	26.7	63.3	-31.9	-13.0	-18.9	Peak	
874.50	V	0.0	1.2	48.5	26.8	75.3	-20.0	-13.0	-7.0	Peak	
879.00	V	0.0	1.2	45.6	26.6	72.2	-23.1	-13.0	-10.1	Peak	
883.51	V	0.0	1.2	31.8	26.3	58.1	-37.2	-13.0	-24.2	Peak	
1311.77	V	0.0	1.2	40.1	27.8	67.9	-27.4	-13.0	-14.4	Peak	
1316.25	V	0.0	1.2	37.6	27.8	65.4	-29.9	-13.0	-16.9	Peak	
1320.70	V	0.0	1.2	26.5	27.8	54.3	-41.0	-13.0	-28.0	Peak	
1749.20	V	0.0	1.2	23.5	28.7	52.2	-43.1	-13.0	-30.1	Peak	
423.70	H	90.0	1.5	27.4	20.8	48.2	-47.1	-13.0	-34.1	Peak	
428.25	H	90.0	1.5	32.8	21.1	53.9	-41.4	-13.0	-28.4	Peak	
446.25	H	90.0	1.5	43.4	19.7	63.1	-32.1	-13.0	-19.1	Peak	
450.75	H	90.0	1.5	34.2	19.6	53.8	-41.5	-13.0	-28.5	Peak	
865.50	H	90.0	1.5	19.7	26.9	46.6	-48.7	-13.0	-35.7	Peak	
870.01	H	90.0	1.5	41.3	26.7	68.0	-27.2	-13.0	-14.2	Peak	
874.50	H	90.0	1.5	50.2	26.8	76.9	-18.3	-13.0	-5.3	Peak	
879.00	H	90.0	1.5	47.9	26.6	74.5	-20.8	-13.0	-7.8	Peak	
883.51	H	90.0	1.5	33.7	26.3	60.0	-35.3	-13.0	-22.3	Peak	
1311.77	H	90.0	1.5	47.9	27.8	75.7	-19.6	-13.0	-6.6	Peak	
1316.25	H	90.0	1.5	42.3	27.8	70.1	-25.2	-13.0	-12.2	Peak	
1320.70	H	90.0	1.5	30.1	27.8	57.9	-37.4	-13.0	-24.4	Peak	
1749.20	H	90.0	1.5	28.3	28.7	57.0	-38.3	-13.0	-25.3	Peak	

Table 12: Unwanted Radiated Emissions (Unit Wheels Up)

Frequency (MHz)	Polarity (H/V)	Azimuth (Degree)	Ant. Height (m)	SA Level (dBuV)	Corr Factors (dB)	Corr. Level (dBuV/m)	EIRP (dBm)	Limit (dBm)	Margin (dB)	Peak or Average	Comments
423.70	V	0.0	1.2	20.6	20.8	41.4	-53.8	-13.0	-40.8	Peak	
428.25	V	0.0	1.2	41.8	21.1	62.9	-32.4	-13.0	-19.4	Peak	
446.25	V	0.0	1.2	44.2	19.7	63.9	-31.3	-13.0	-18.3	Peak	
450.75	V	0.0	1.2	29.3	19.6	48.9	-46.4	-13.0	-33.4	Peak	
870.01	V	0.0	1.2	30.5	26.7	57.2	-38.0	-13.0	-25.0	Peak	
874.50	V	0.0	1.2	45.4	26.8	72.1	-23.1	-13.0	-10.1	Peak	
879.00	V	0.0	1.2	39.7	26.6	66.3	-28.9	-13.0	-15.9	Peak	
883.51	V	0.0	1.2	25.5	26.3	51.8	-43.5	-13.0	-30.5	Peak	
1311.77	V	0.0	1.2	41.8	27.8	69.6	-25.7	-13.0	-12.7	Peak	
1316.25	V	0.0	1.2	41.4	27.8	69.2	-26.1	-13.0	-13.1	Peak	
1320.70	V	0.0	1.2	28.4	27.8	56.2	-39.1	-13.0	-26.1	Peak	
1749.20	V	0.0	1.2	32.8	28.7	61.5	-33.8	-13.0	-20.8	Peak	
423.70	H	45.0	1.5	25.9	20.8	46.7	-48.6	-13.0	-35.6	Peak	
428.25	H	45.0	1.5	29.7	21.1	50.8	-44.5	-13.0	-31.5	Peak	
446.25	H	45.0	1.5	41.1	19.7	60.9	-34.4	-13.0	-21.4	Peak	
450.75	H	45.0	1.5	32.8	19.6	52.4	-42.9	-13.0	-29.9	Peak	
865.50	H	45.0	1.5	22.7	26.9	49.6	-45.7	-13.0	-32.7	Peak	
870.01	H	45.0	1.5	45.4	26.7	72.1	-23.1	-13.0	-10.1	Peak	
874.50	H	45.0	1.5	51.5	26.8	78.3	-17.0	-13.0	-4.0	Peak	
879.00	H	45.0	1.5	47.8	26.6	74.4	-20.9	-13.0	-7.9	Peak	
883.51	H	45.0	1.5	37.4	26.3	63.7	-31.6	-13.0	-18.6	Peak	
1311.77	H	45.0	1.5	47.3	27.8	75.1	-20.2	-13.0	-7.2	Peak	
1316.25	H	45.0	1.5	45.2	27.8	73.0	-22.3	-13.0	-9.3	Peak	
1320.70	H	45.0	1.5	38.5	27.8	66.3	-29.0	-13.0	-16.0	Peak	
1749.20	H	45.0	1.5	37.5	28.7	66.2	-29.1	-13.0	-16.1	Peak	

Table 13: Band Edge Measurements (Unit Flat)

Frequency (MHz)	Polarity (H/V)	Azimuth (Degree)	Ant. Height (m)	SA Level (dBuV)	Corr Factors (dB)	Corr. Level (dBuV/m)	EIRP (dBm)	Limit (dBm)	Margin (dB)	Peak or Average	Comments
Unit A											
442.00	V	0.0	1.2	59.5	19.0	78.5	-16.8	-13.0	-3.8	Peak	
448.00	V	0.0	1.2	52.6	18.6	71.2	-24.1	-13.0	-11.1	Peak	
Unit B											
430.00	V	0.0	1.2	58.3	20.2	78.5	-16.7	-13.0	-3.7	Peak	
436.00	V	0.0	1.2	46.4	19.8	66.2	-29.1	-13.0	-16.1	Peak	
Unit C											
436.00	V	0.0	1.2	59.3	19.8	79.2	-16.1	-13.0	-3.1	Peak	
442.00	V	0.0	1.2	53.0	19.0	72.0	-23.3	-13.0	-10.3	Peak	
Unit A											
442.00	H	0.0	1.5	53.9	19.0	72.9	-22.3	-13.0	-9.3	Peak	
448.00	H	0.0	1.5	45.9	18.6	64.5	-30.7	-13.0	-17.7	Peak	
Unit B											
430.00	H	0.0	1.5	51.0	20.2	71.2	-24.0	-13.0	-11.0	Peak	
436.00	H	0.0	1.5	42.8	19.8	62.6	-32.7	-13.0	-19.7	Peak	
Unit C											
436.00	H	0.0	1.5	49.6	19.8	69.5	-25.8	-13.0	-12.8	Peak	
442.00	H	0.0	1.5	45.3	19.0	64.3	-31.0	-13.0	-18.0	Peak	

Table 14: Band Edge Measurements (Unit, Wheels Up)

Frequency (MHz)	Polarity (H/V)	Azimuth (Degree)	Ant. Height (m)	SA Level (dBuV)	Corr Factors (dB)	Corr. Level (dBuV/m)	EIRP (dBm)	Limit (dBm)	Margin (dB)	Peak or Average	Comments
Unit A											
442.00	V	45.0	1.5	53.3	19.0	72.3	-22.9	-13.0	-9.9	Peak	
448.00	V	45.0	1.2	46.1	18.6	64.7	-30.5	-13.0	-17.5	Peak	
Unit B											
430.00	V	45.0	1.2	55.6	20.2	75.8	-19.5	-13.0	-6.5	Peak	
436.00	V	45.0	1.2	45.3	19.8	65.2	-30.1	-13.0	-17.1	Peak	
Unit C											
436.00	V	45.0	1.2	55.8	19.8	75.6	-19.6	-13.0	-6.6	Peak	
442.00	V	45.0	1.2	44.9	19.0	63.9	-31.3	-13.0	-18.3	Peak	
Unit A											
442.00	H	315.0	1.5	59.8	19.0	78.8	-16.5	-13.0	-3.5	Peak	
448.00	H	315.0	1.5	52.5	18.6	71.1	-24.2	-13.0	-11.2	Peak	
Unit B											
430.00	H	315.0	1.5	60.1	20.2	80.3	-15.0	-13.0	-2.0	Peak	
436.00	H	315.0	1.5	51.4	19.8	71.3	-24.0	-13.0	-11.0	Peak	
Unit C											
436.00	H	315.0	1.5	60.4	19.8	80.3	-15.0	-13.0	-2.0	Peak	
442.00	H	315.0	1.5	51.9	19.0	71.0	-24.3	-13.0	-11.3	Peak	

Table 15: Band Edge Measurements (Unit, Tail Up)

Frequency (MHz)	Polarity (H/V)	Azimuth (Degree)	Ant. Height (m)	SA Level (dBuV)	Corr Factors (dB)	Corr. Level (dBuV/m)	EIRP (dBm)	Limit (dBm)	Margin (dB)	Peak or Average	Comments
Unit A											
442.00	V	0.0	1.2	50.4	19.0	69.4	-25.9	-13.0	-12.9	Peak	
448.00	V	0.0	1.2	42.2	18.6	60.8	-34.4	-13.0	-21.4	Peak	
Unit B											
430.00	V	0.0	1.2	51.8	20.2	72.0	-23.3	-13.0	-10.3	Peak	
436.00	V	0.0	1.2	42.0	19.8	61.8	-33.4	-13.0	-20.4	Peak	
Unit C											
436.00	V	45.0	1.2	49.7	19.8	69.6	-25.7	-13.0	-12.7	Peak	
442.00	V	45.0	1.2	44.4	19.0	63.4	-31.8	-13.0	-18.8	Peak	
Unit A											
442.00	H	270.0	1.5	54.5	19.0	73.5	-21.8	-13.0	-8.8	Peak	
448.00	H	270.0	1.5	47.1	18.6	65.7	-29.5	-13.0	-16.5	Peak	
Unit B											
430.00	H	270.0	1.5	59.5	20.2	79.7	-15.6	-13.0	-2.6	Peak	
436.00	H	270.0	1.5	49.3	19.8	69.1	-26.1	-13.0	-13.1	Peak	
Unit C											
436.00	H	270.0	1.5	59.1	19.8	79.0	-16.3	-13.0	-3.3	Peak	
442.00	H	270.0	1.5	49.7	19.0	68.7	-26.6	-13.0	-13.6	Peak	

5.4 Voice Scrambling [FCC Part 90.212]

Voice scrambling is not permitted and therefore not applicable to this device.

5.5 Frequency Tolerance [FCC Part 90.213(a)]

5.5.1 Test Method

The EUT was placed in a calibrated temperature chamber. A receive antenna was placed in the temperature chamber with the device connected to a frequency counter outside the chamber. All three units were tested in accordance with Part 90. Discussion below provides an example of one configuration.

The EUT was set to transmit at 439 MHz where the video carrier was located at 437.25MHz and the audio carrier was located at 441.75MHz. The video carrier was selected as the measurement point (437.25MHz). A frequency reading was taken with the temperature at ambient (22C). The EUT was turned off and the temperature chamber set to -30 Celsius after 1 hour at this temperature the unit was turned on, allowed to settle and a frequency reading was taken. The unit was turned back off and the temperature changed to -20 C. This process was repeated in 10 degree increments up to 50 Degrees Celsius allowing the unit to stabilize for 1 hour at each level before turning on the unit and recording the frequency. At each level the frequency recorded was compared to the ambient reading with the amount of deviation in Hz compared to the part 90 limit.

5.5.2 Test Limit

Part 90.213(a) states that transmitters with 2 watts or less must have a frequency tolerance of not more than 0.0005%.

5.5.3 Test Results

The test results are stated below in Table 13 and Table 14.

5.5.4 Test Summary

The EUT complied with the requirements of Part 90.213(a).

Table 16: Frequency Tolerance vs. Temperature

Unit A

Temperature (Centigrade)	Frequency (MHz)	Difference (Hz)	Deviation (%)
Ambient	443.250233	0	0
-30	443.251963	1730	0.00039
-20	443.251952	1719	0.00039
-10	443.251478	1245	0.00028
0	443.251441	1208	0.00027
10	443.251063	830	0.00019
20	443.250652	419	0.00009
30	443.250002	-231	-0.00005
40	443.249778	-455	-0.00010
50	443.249185	-1048	-0.00024

Unit B

Temperature (Centigrade)	Frequency (MHz)	Difference (Hz)	Deviation (%)
Ambient	431.249164	0	0
-30	431.251165	2001	0.00046
-20	431.250134	970	0.00022
-10	431.250225	1061	0.00025
0	431.250056	892	0.00021
10	431.249954	790	0.00018
20	431.249545	381	0.00009
30	431.249004	-160	-0.00004
40	431.248969	-195	-0.00005
50	431.247952	-1212	-0.00028

Unit C

Temperature (Centigrade)	Frequency (MHz)	Difference (Hz)	Deviation (%)
Ambient	437.250229	0	0
-30	437.250805	576	0.00013
-20	437.25155	1321	0.00030
-10	437.251989	1760	0.00040
0	437.252162	1933	0.00044
10	437.251554	1325	0.00030
20	437.250621	392	0.00009
30	437.249577	-652	-0.00015
40	437.249029	-1200	-0.00027
50	437.248836	-1393	-0.00032

Table 17: Frequency Tolerance vs. Battery Voltage

Unit C

Voltage (Volts)	Frequency (MHz)	Difference (Hz)	Deviation (%)	Voltage (Volts)
At rated	437.250229	0	0	11.1
At 85%	437.249962	-267	-0.00006	9.435
At 115%	437.249858	-371	-0.00008	12.765

5.6 Transient Frequency Behavior [FCC Part 90.214]

ReconRobotics believes Section 90.214 does not apply because (1) the rule provides transient specifications for 6.25, 12.5, and 25 kHz bandwidth radios, but does not include any requirements for the bandwidth at which the EUT operates and (2) the intent of the rule is to control transient behavior when a two-way radio is keyed, the EUT is not keyed but remains on throughout a mission (up to approximately one hour maximum).

5.7 Audio Frequency Response & Modulation Characteristics (2.1047)

The audio frequency response was measured in accordance with TIA/EIA-603. The audio signal was fed directly into the microphone circuit with the microphone removed. The audio low pass filter testing was performed per the method given in TIA-603.

5.7.1 Test Limit

There are no applicable limits associated with these measurements. The only consideration is maintaining the modulation of the signal within the band edge and meeting the -13dBm limit at 250% of the center frequency.

5.7.2 Test Results

The test results are shown below in Figure 13 thru Figure 16. The test set-up diagram is shown in Figure 12.

5.7.3 Test Summary

The furthest peak from the audio carrier that rose above the non-modulated waveform was less than 228 kHz from the center of the audio carrier and at least 24dB below the luminance carrier peak (the limit of part 90 [43+10Log10(P) down)] would require this signal to be 7.2dB below the carrier minimum at the band-edge).

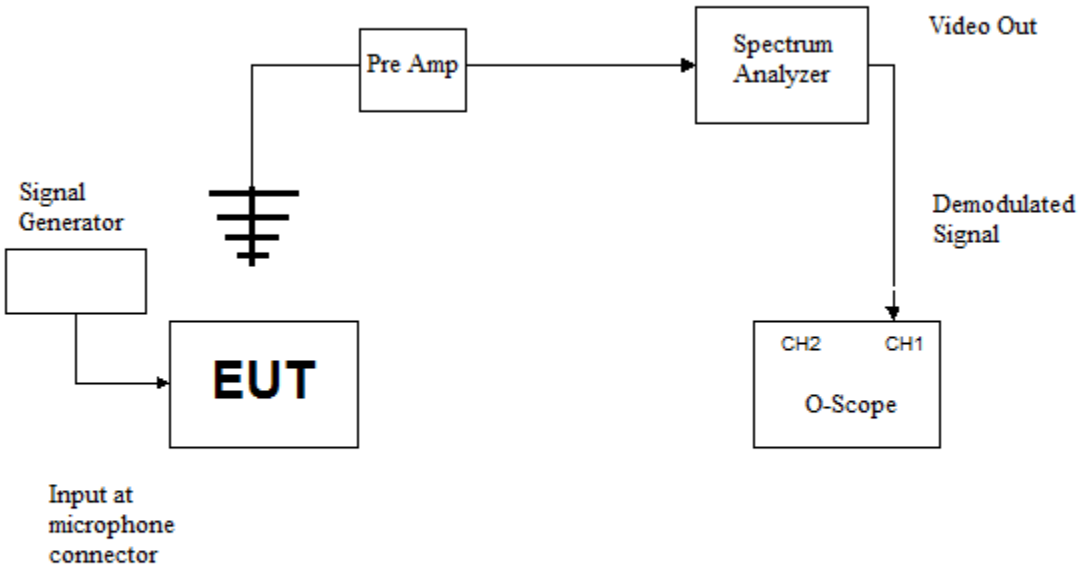


Figure 12: Test Set-up Diagram

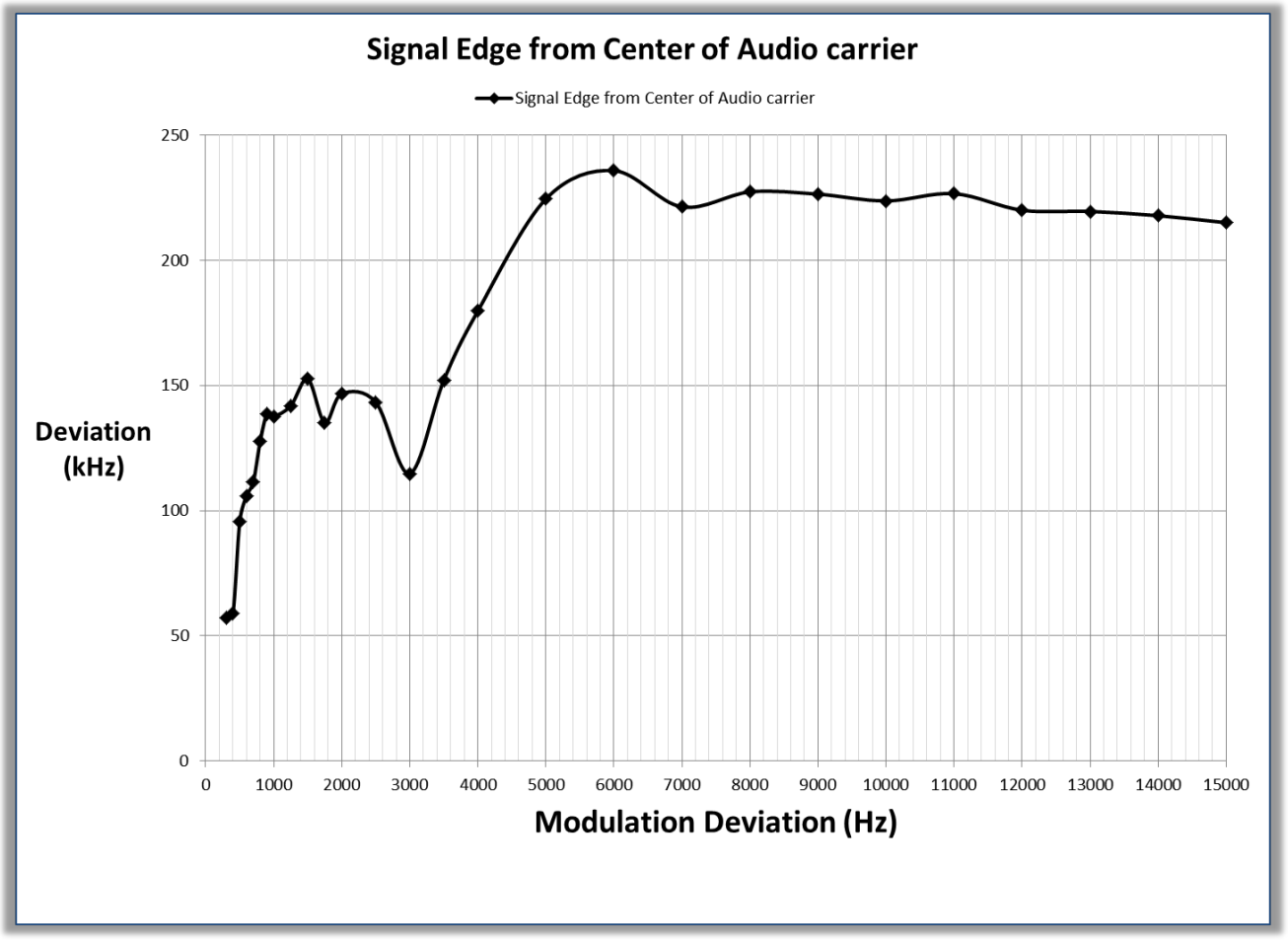


Figure 13: Signal Edge from Center of Audio Carrier Frequency

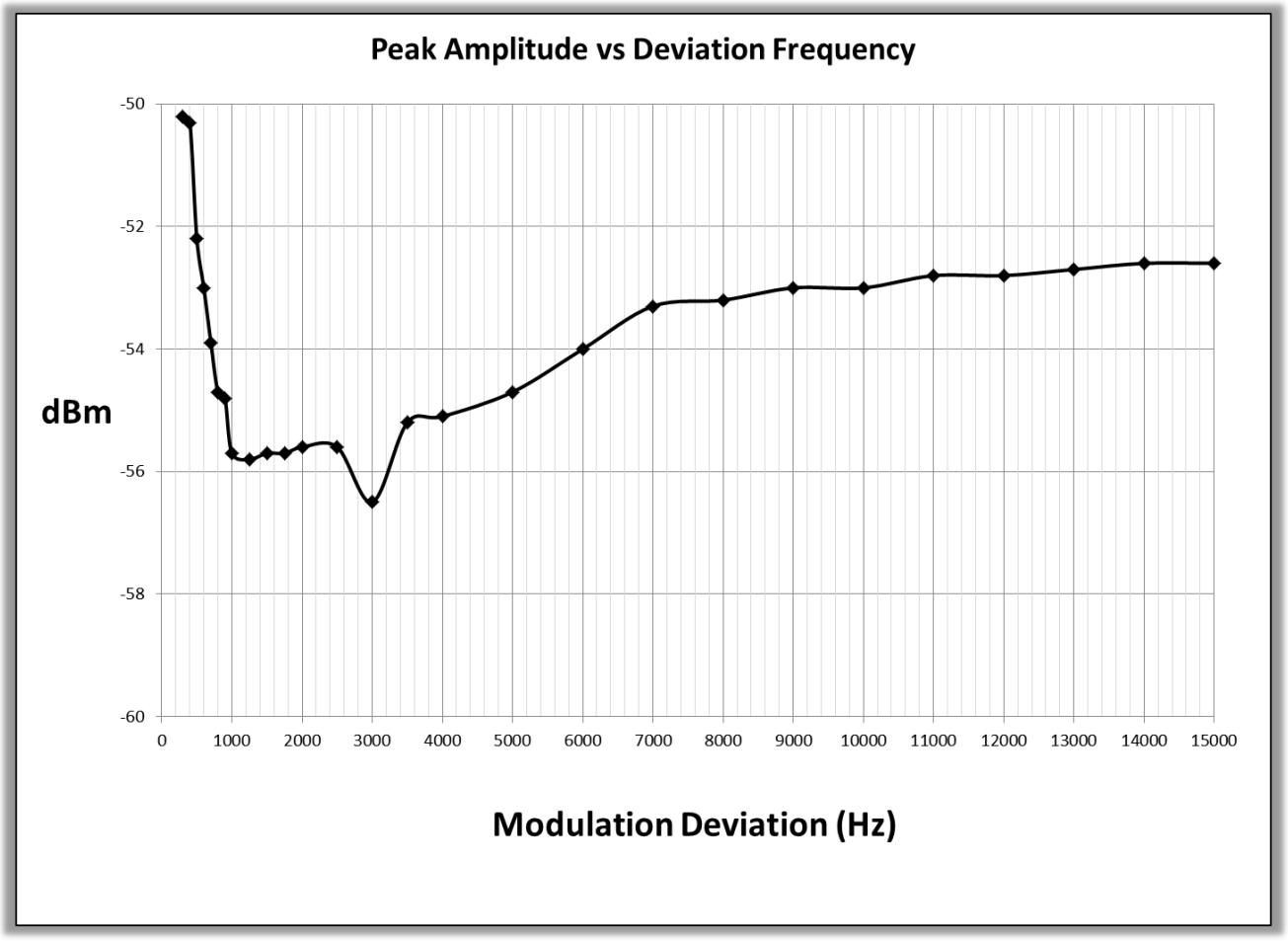


Figure 14: Peak Signal Amplitude vs Modulation Frequency

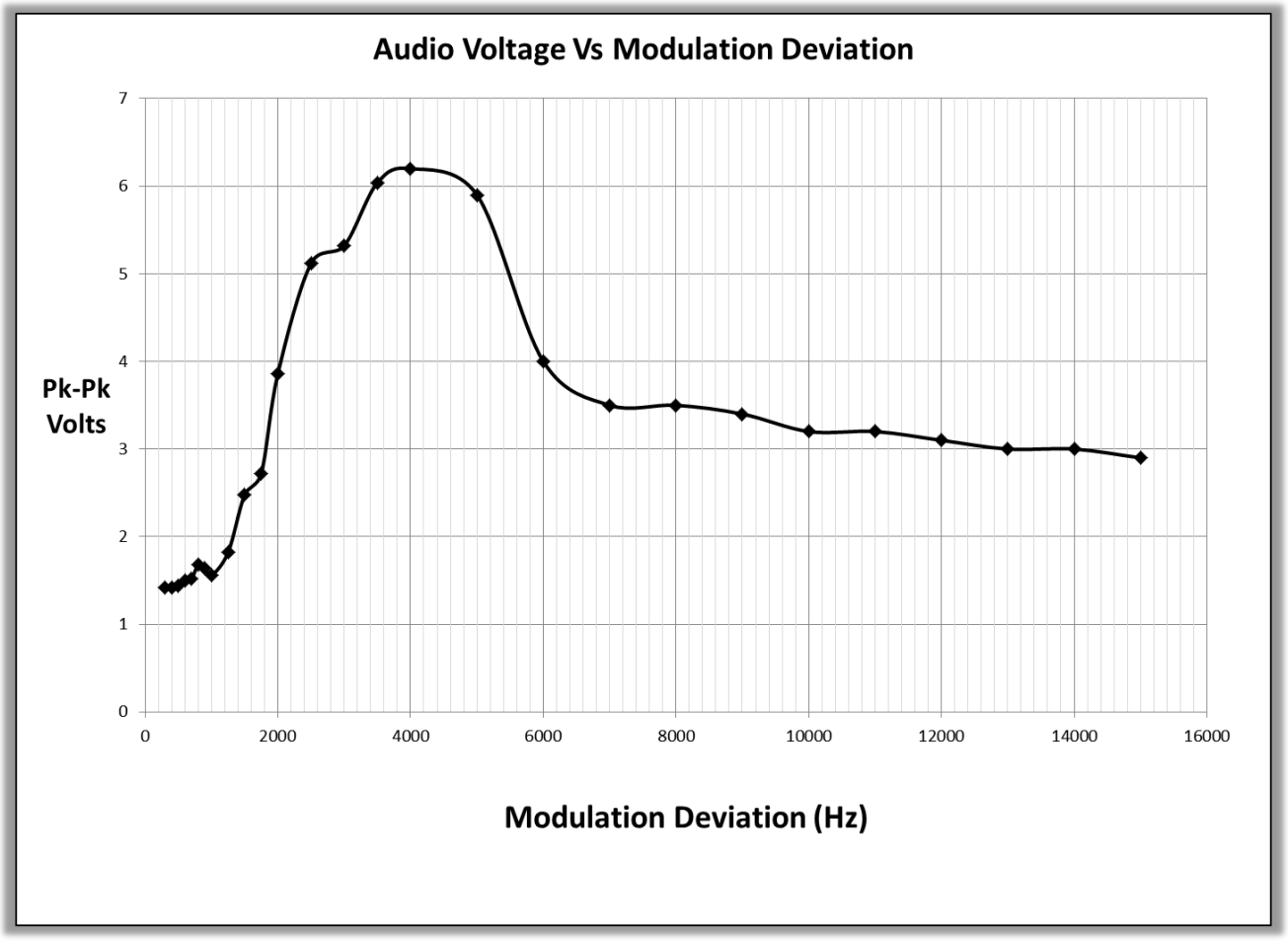


Figure 15: Measured Output Voltage vs Modulation Frequency

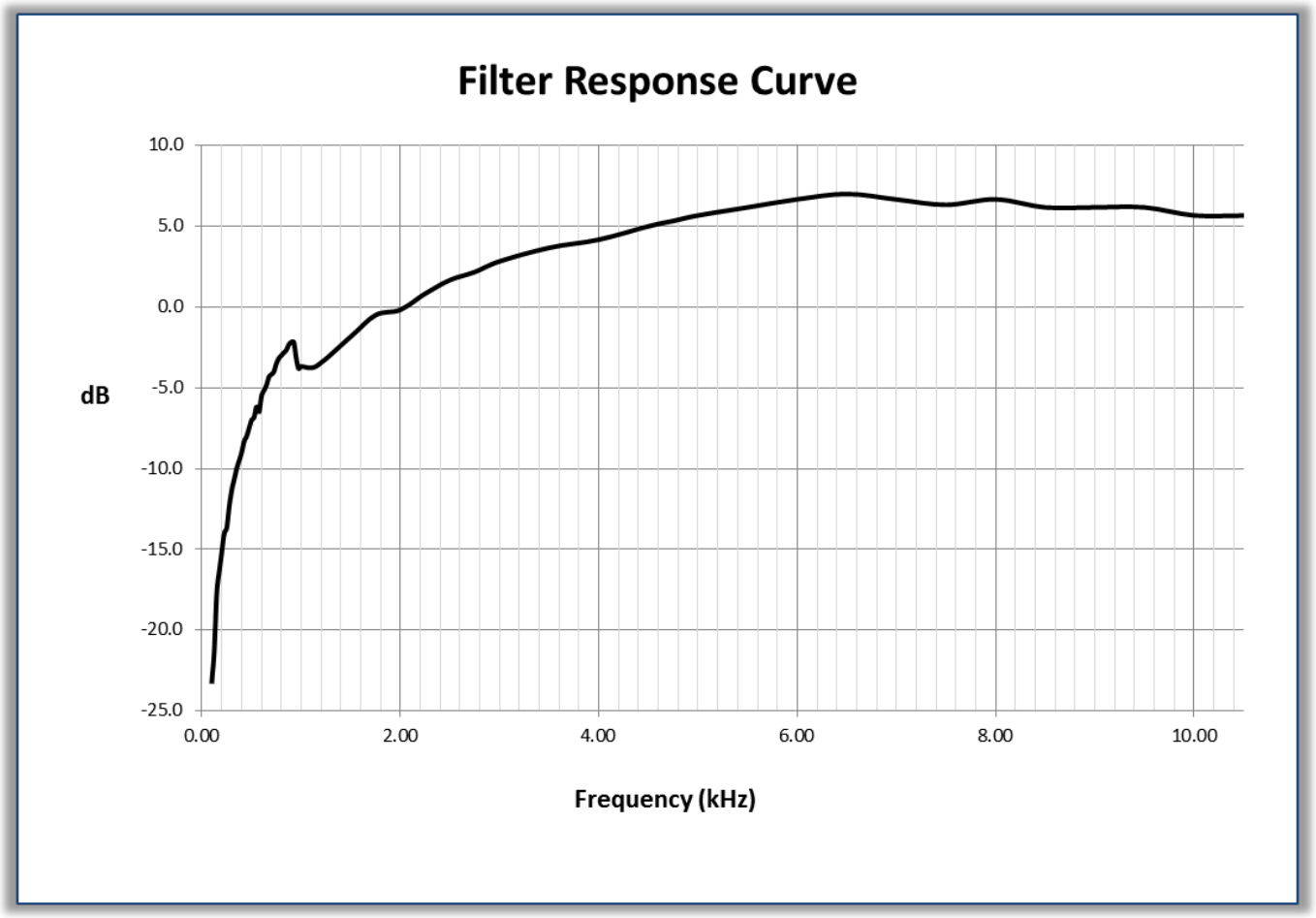


Figure 16: Filter Response Curve