Electromagnetic Compatibility Test Report

Tests Performed on a GoTenna, Inc.

goTenna Pro, Model 37337

Radiometrics Document RP-8728A1

ACCREDITED
TESTING CERT #1495.01

Product Detail:
FCC ID: 2ABVK37337 Equipment type: 150-479 MHz Transceiver
Test Standards:
US CFR Title 47, Chapter I, FCC Part 2 and 90 FCC Parts 2, 15, and 90 CFR Title 47: 2018

Tests Performed For:	*Test Facility:*
goTenna, Inc. 81 Willoughby St., Ste. 302 Brooklyn, NY 11201	**Radiometrics Midwest Corporation** 12 East Devonwood Romeoville, IL 60446 Phone: (815) 293-0772

Test Date(s): (Month-Day-Year)
October 23, 2017 to February 6, 2018

Document RP-8728A1 Revisions:

Rev.	Issue Date	Affected Sections	Revised By
0	February 16, 2018		

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1 ADMINISTRATIVE DATA

Equipment Under Test:	
A goTenna, Inc. goTenna Pro Model: 37337; Serial Number: 22 This will be referred to as the EUT in this Report	
Date EUT Received at Radiometrics: (Month-Day-Year)	*Test Date(s): (Month-Day-Year)*
October 20, 2017	October 23, 2017 to February 6, 2018
Test Report Written and authorized By:	*Test Witnessed By:*
Joseph Strzelecki Senior EMC Engineer	The tests were not witnessed by personnel from goTenna, Inc.
Radiometrics' Personnel Responsible for Test:	*Test Report Approved By*
Joseph Strzelecki 02/16/2018 Date Joseph Strzelecki Senior EMC Engineer NARTE EMC-000877-NE Richard L. Tichgelaar EMC Technician	Chris W. Carlson Director of Engineering NARTE EMC-000921-NE

2 TEST SUMMARY AND RESULTS

The EUT (Equipment Under Test) is a goTenna Pro, Model 37337, manufactured by goTenna, Inc. The detailed test results are presented in a separate section. The following is a summary of the test results.

Transmitter Requirements

Environmental Phenomena	Frequency Range	FCC Section	Test Result
RF Power Output	450-479MHz	2.1046 90.205	Pass
Occupied Bandwidth Test; Emissions Masks	450-479Hz	2.1049 90.209	Pass
Spurious RF Conducted Emissions	1-4700 MHz	2.1051 90.210	Pass
Field Strength of Spurious Radiation	30-4700 MHz	2.1053	Pass
Frequency Vs. Temperature	450-479MHz	2.1055 90.213	Pass
Frequency Vs. Voltage	450-479MHz	2.1055 90.213	Pass
Transient Frequency Behavior	450-479MHz	90.214	Pass
Radiated Emissions Receive Mode	30-2000 MHz	15	Pass

3 EQUIPMENT UNDER TEST (EUT) DETAILS

3.1 EUT Description

The EUT is a goTenna Pro, manufactured by GoTenna, Inc. The RF communications link is encrypted in both directions. The EUT was in good working condition during the tests, with no known defects.

4 TESTED SYSTEM DETAILS

4.1 Tested System Configuration

The system was configured for testing in a typical fashion. The testing was performed in conditions as close as possible to installed conditions. Wiring was consistent with manufacturer's recommendations. The networking radio was tested as a stand-alone device. The identification for all equipment used in the tested system, is:

Tested System Configuration List

Item	Description	Type*	Manufacturer	Model Number	Serial Number(s)
1	goTenna Pro Mesh Networking Radio	E	goTenna, Inc.	37337	01, 02 06, 22, 23, 24, 25
2	USB power Supply	P	Apple	A1401	LPS 0012ADU00

* Type: E = EUT; P = Peripheral

4.2 Special Accessories

No special accessories were used during the tests in order to achieve compliance.

4.3 Equipment Modifications

No modifications were made to the EUT at Radiometrics' test facility in order to comply with the standards listed in this report.

5 TEST SPECIFICATIONS AND RELATED DOCUMENTS

Document	Date	Title
FCC CFR Title 47	2018	Code of Federal Regulations Title 47, Chapter 1, Federal Communications Commission, Part 15 & 90 - Radio Frequency Devices
ANSI C63.4-2014	2014	Methods of Measurement of Radio Noise Emissions from Low-Voltage Electrical and Electronic Equipment in the Range of 9 kHz to 40 GHz
TIA-603-E	2016	Land Mobile FM or PM Communications Equipment – Measurement and Performance Standards

6 RADIOMETRICS' TEST FACILITIES

The results of these tests were obtained at Radiometrics Midwest Corp. in Romeoville, Illinois, USA. Radiometrics is accredited by A2LA (American Association for Laboratory Accreditation) to conform to ISO/IEC 17025: 2005 "General Requirements for the Competence of Calibration and Testing Laboratories". Radiometrics' Lab Code is 121191 and Certification Number is 1495.01. A copy of the accreditation can be accessed on our web site (www.radiomet.com). Radiometrics accreditation status can be verified at A2LA's web site (www.a2la2.org).

The following is a list of shielded enclosures located in Romeoville, Illinois used during the tests:

Chamber A: Is an anechoic chamber that measures 24' L X 12' W X 12' H. The walls and ceiling are fully lined with ferrite absorber tiles. The floor has a 10' x 10' section of ferrite absorber tiles located in the center. Panashield of Rowayton, Connecticut manufactured the chamber. The enclosure is NAMAS certified.

Chamber B: Is a shielded enclosure that measures 20' L X 12' W X 8' H. Erik A. Lindgren & Associates of Chicago, Illinois manufactured the enclosure.

Chamber C: Is a shielded enclosure that measures 17' L X 10' W X 8' H. Lindgren RF Enclosures Inc. of Addison, Illinois manufactured the enclosure.

Chamber E: Is a custom made anechoic chamber that measures 52' L X 30' W X 18' H. The walls and ceiling are fully lined with RF absorber. Pro-shield of Collinsville, Oklahoma manufactured the chamber.

A separate ten-foot long, brass plated, steel ground rod attached via a 6 inch copper braid grounds each of the above chambers. Each enclosure is also equipped with low-pass power line filters.

The FCC has accepted these sites as test site number US1065. The FCC test site Registration Number is 732175. Details of the site characteristics are on file with the Industry Canada as site number IC 3124A.

7 DEVIATIONS AND EXCLUSIONS FROM THE TEST SPECIFICATIONS

There were no deviations or exclusions from the test specifications.

8 CERTIFICATION

Radiometrics Midwest Corporation certifies that the data contained herein was taken under conditions that meet or exceed the requirements of the test specification. The results relate only to the EUT listed herein. Any modifications made to the EUT subsequent to the indicated test date will invalidate the data and void this certification.

9 TEST EQUIPMENT TABLE

RMC ID	Manufacturer	Description	Model No.	Serial No.	Frequency Range	Cal Period	Cal Date
ANT-03	Tensor	Biconical Antenna	4104	2231	20-250MHz	24 Mo.	12/07/15 12/06/17
ANT-04	Tensor	Biconical Antenna	4104	2246	20-250MHz	24 Mo.	05/16/16
ANT-06	EMCO	Log-Periodic Ant.	3146	1248	200-1000MHz	24 Mo.	12/05/17
ANT-08	RMC	Log-Periodic Ant.	LP1000	1002	200-1000MHz	24 Mo.	10/06/16
ANT-13	EMCO	Horn Antenna	3115	2502	1.0-18GHz	24 Mo.	12/28/16

RMC ID	Manufacturer	Description	Model No.	Serial No.	Frequency Range	Cal Period	Cal Date
ANT-36	Ailtech (Eaton)	Horn Antenna	96001	2013	1.0-18GHz	24 Mo.	11/02/16
ATT-53	Weinschel	Attenuator (20 dB)	23-20-34	CG7857	DC-18 GHz	12 Mo	09/26/16
CAB-106A	Teledyne	Coaxial Cable	N/A	1090	DC-2 GHz	24 Mo.	04/21/16
CAB-1090	Teledyne	Coaxial Cable	N/A	1090	DC-18 GHz	24 Mo.	04/19/16
CAB-160B	Teledyne	Coaxial Cable	N/A	1090	DC-18 GHz	24 Mo.	04/21/16
CDT-01	Wiltron	Crystal RF Detector	75N50	CDT-01	DC-18GHz	N/A	NCR
COM-01	Anaren	Coupler	10023-3	COM-01	250-1000MHz	N/A	NCR
DIR-19	Narda	Directional Coupler	3000-10	01174	200-500MHz	N/A	NCR
DMM-10	Keithley	DMM	2010	0773679	DC-10 kHz	24 Mo	12/06/16
PWM-01	Boonton	Power Meter	4230	22503	50kHz-18GHz	24 Mo.	12/26/17
REC-11	HP / Agilent	Spectrum Analyzer	E7405A	US39110103	9Hz-26.5GHz	24 Mo.	03/23/16
REC-20	HP / Agilent	Spectrum Analyzer	85460A/84562A	33330A00135 3410A00178	30Hz-6GHz	24 Mo.	08/03/17
REC-21	Agilent	Spectrum Analyzer	E7405A	MY45118341	9Hz-26.5 GHz	24 Mo.	12/22/15 01/06/18
REC-43	Adventest	Spectrum Analyzer	U3772	150800305	9Hz-43GHz	12 Mo.	04/19/17
SCP-02	Tektronix	Oscilloscope	TDS784A	B040258	DC-1GHz	24 Mo.	12/16/16
SIG-31	Rohde & Schwarz	Vector Signal Generator	SMJ 100A	101395	100kHz-6GHz	12 Mo.	08/25/17
THM-03	Fluke	Temp/Humid Meter	971	95850465	N/A	12 Mo.	02/20/17

Note: All calibrated equipment is subject to periodic checks.
NCR – No Calibration Required. Device monitored by calibrated equipment. N/A: Not Applicable.
All Equipment calibration was current while it was being used for the tests.

10 TEST SECTIONS

10.1 Peak Output Power

The peak power was measured by connecting the EUT antenna port to the spectrum analyzer via a low loss coaxial cable and an appropiate power attenuator.

Model	37337	Specification	FCC part 90.205
Serial Number	22	Test Date	January 22, 2018
Test Personnel	Joseph Strzelecki	Test Location	Chamber B
Test Equipment	Attenuator ATT-54; REC-21; PWM-01		

TX Freq MHz	Reading dBm	Attenuator dB	Cable Loss dB	Total dBm	Peak Power Watts
150	16.05	19.73	0.13	35.91	3.899
162	15.93	19.73	0.13	35.79	3.793
173.3	15.95	19.73	0.14	35.82	3.819
450	16.02	19.71	0.25	35.98	3.963
465	15.90	19.71	0.25	35.86	3.855
470	15.92	19.71	0.26	35.89	3.882
479	15.97	19.71	0.26	35.94	3.926

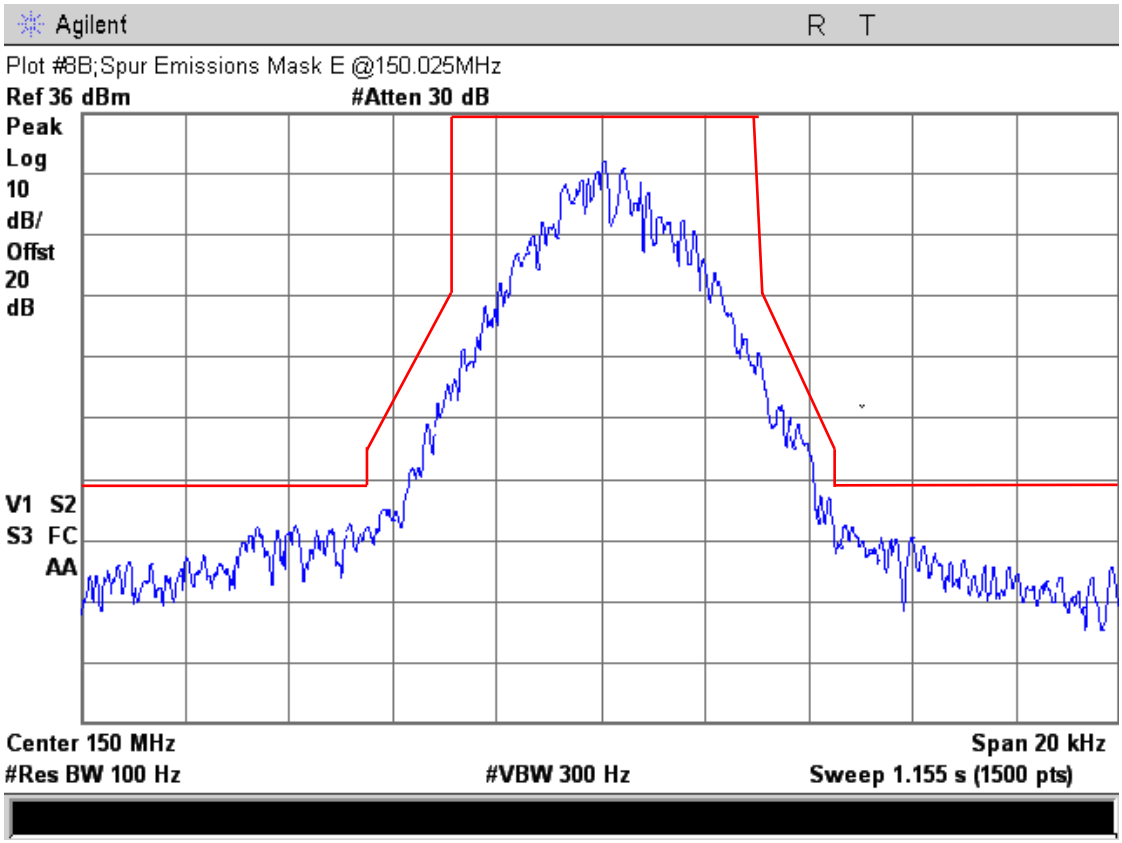
Judgement: Pass

10.2 Occupied Bandwidth; Emissions Masks

Model	37337	Specification	FCC Part 90.209 & 90.2105
Test Date	November 2 to 8, 2017	Test Personnel	Richard Tichgelaar
Test Equipment	Spectrum Analyzer (REC-21)		

The spectrum analyzer was set to the MAX HOLD mode to record the worst case of the modulation. The EUT was transmitting at its maximum data rate. The trace was allowed to stabilize.

Emission Masks:



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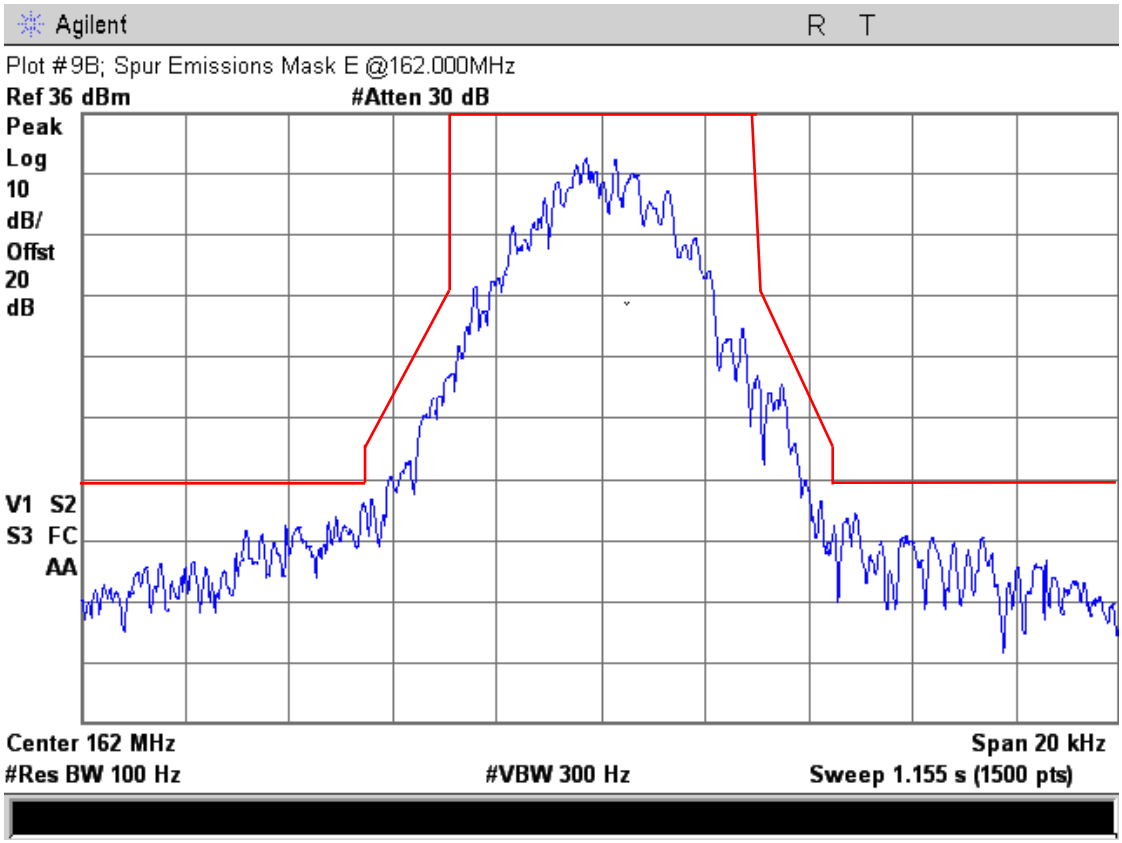

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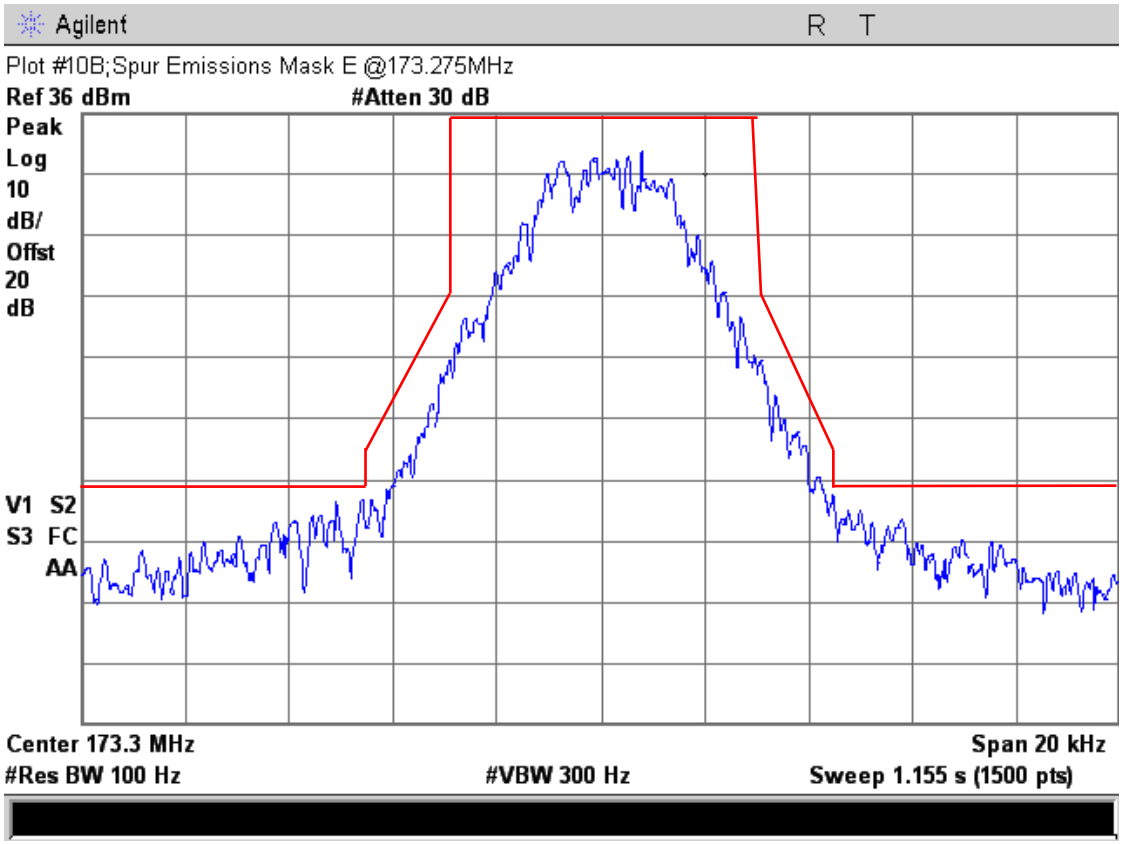

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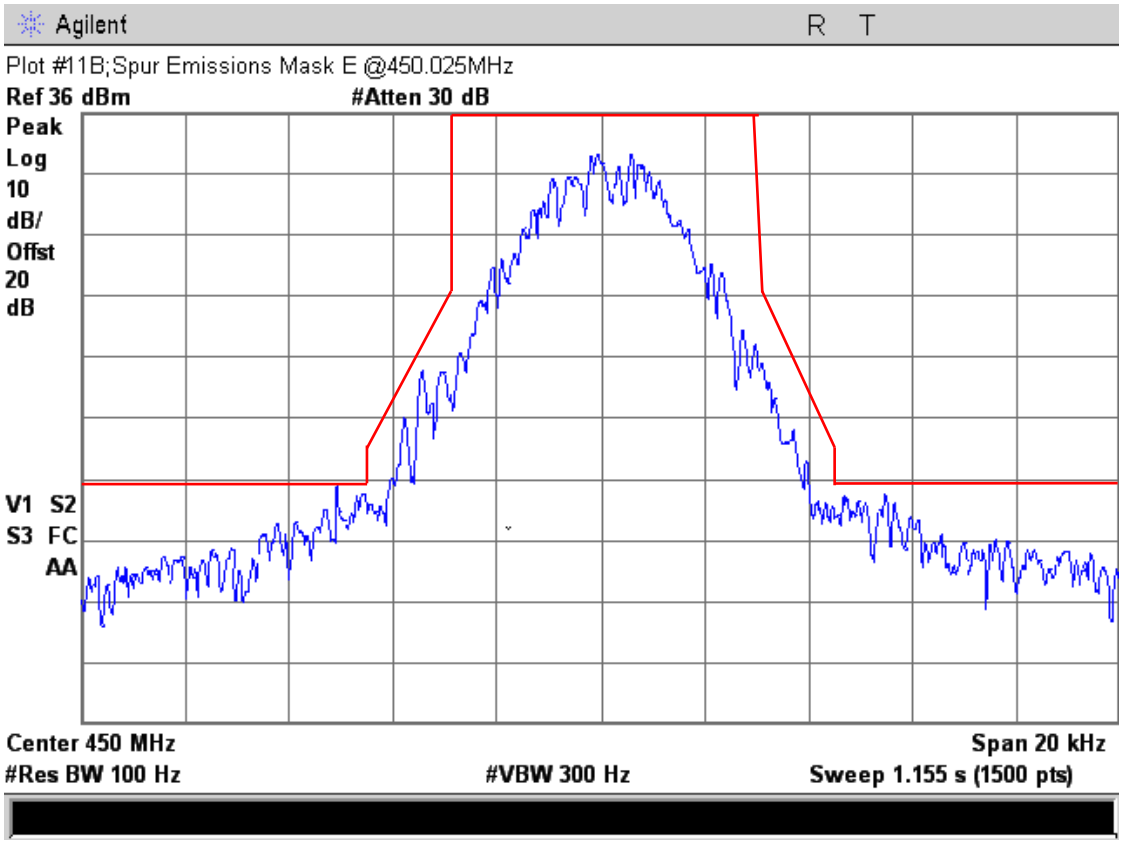

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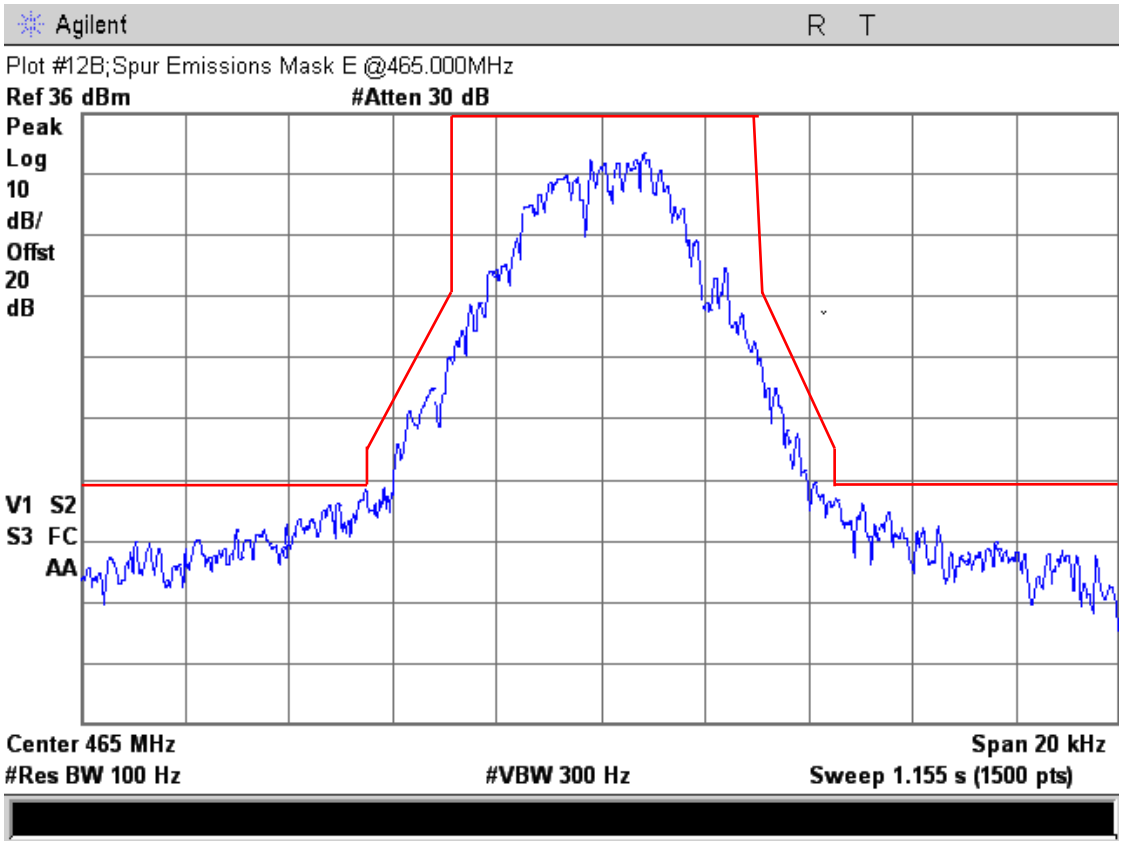

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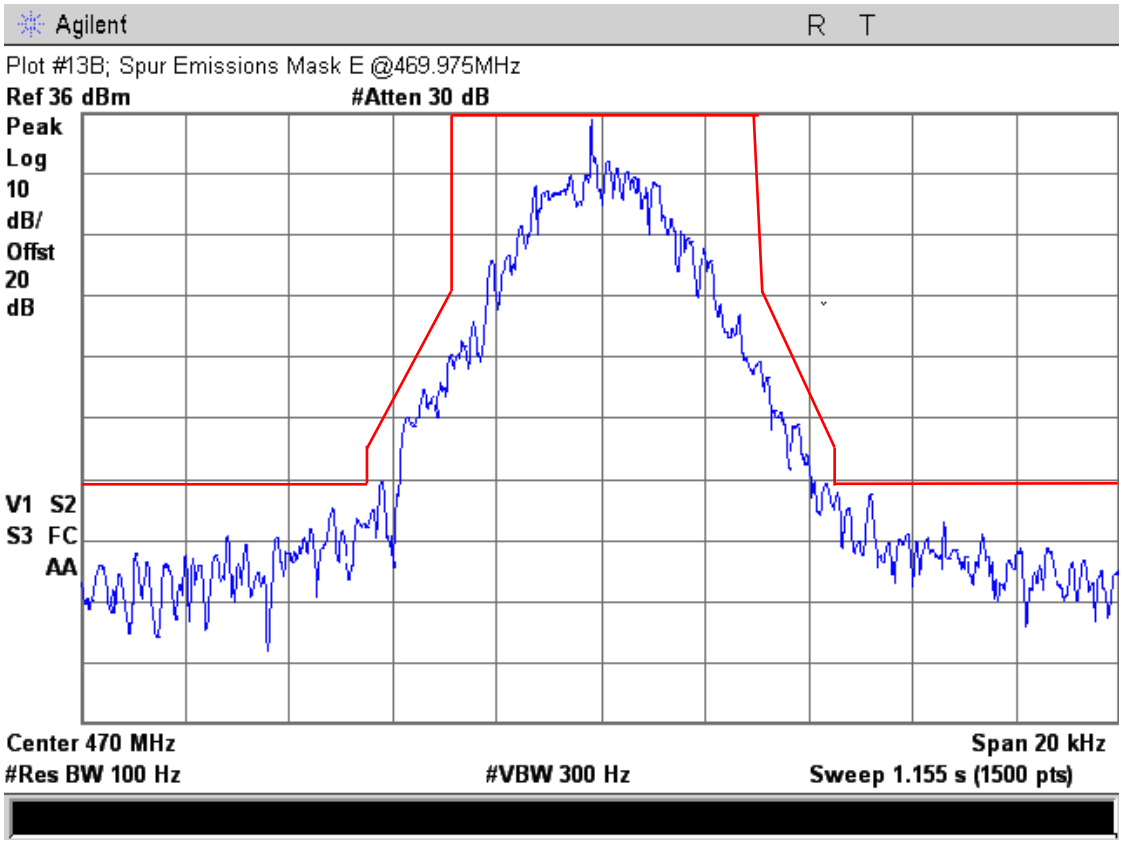

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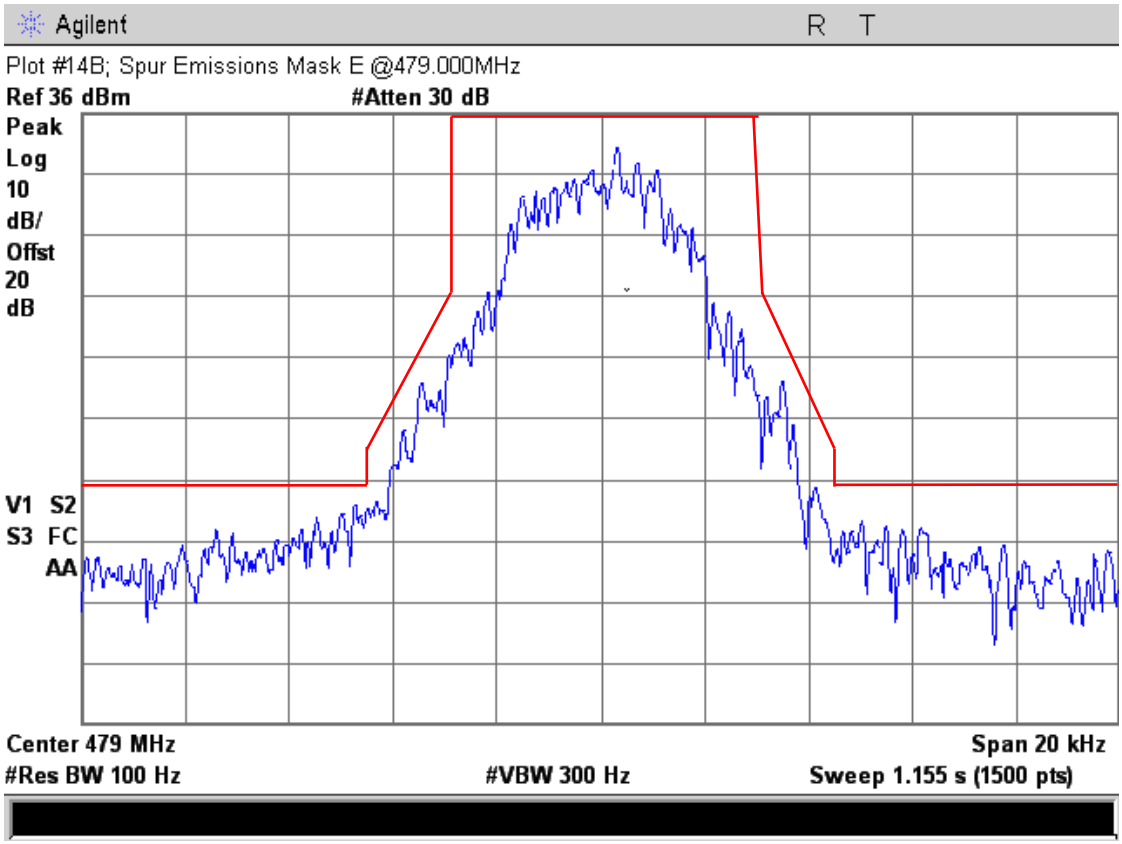

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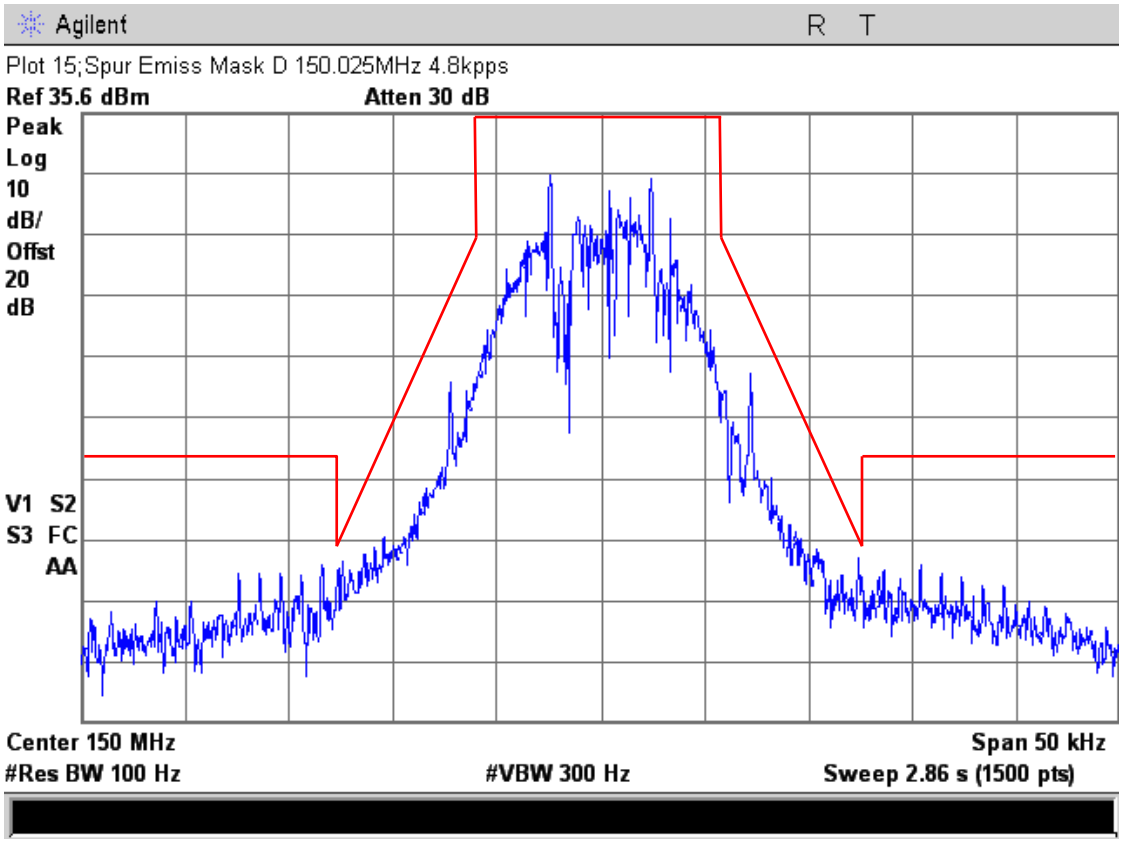

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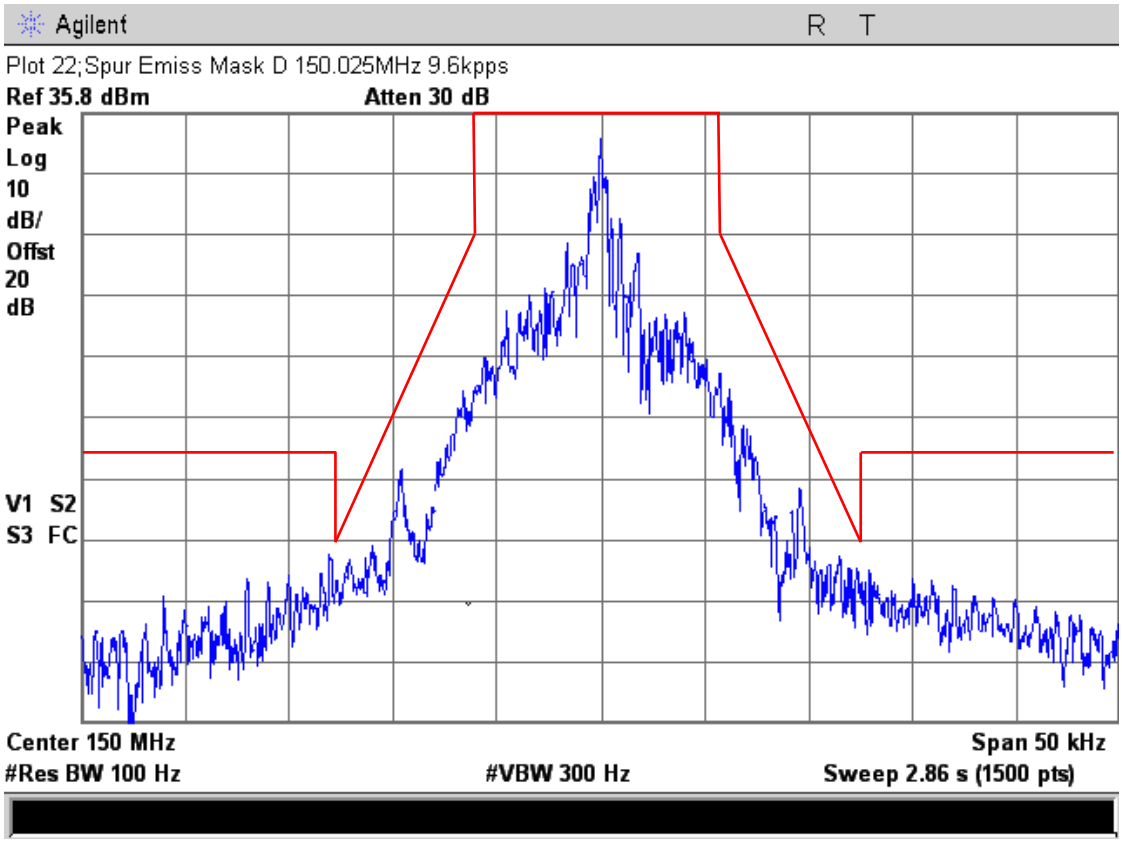

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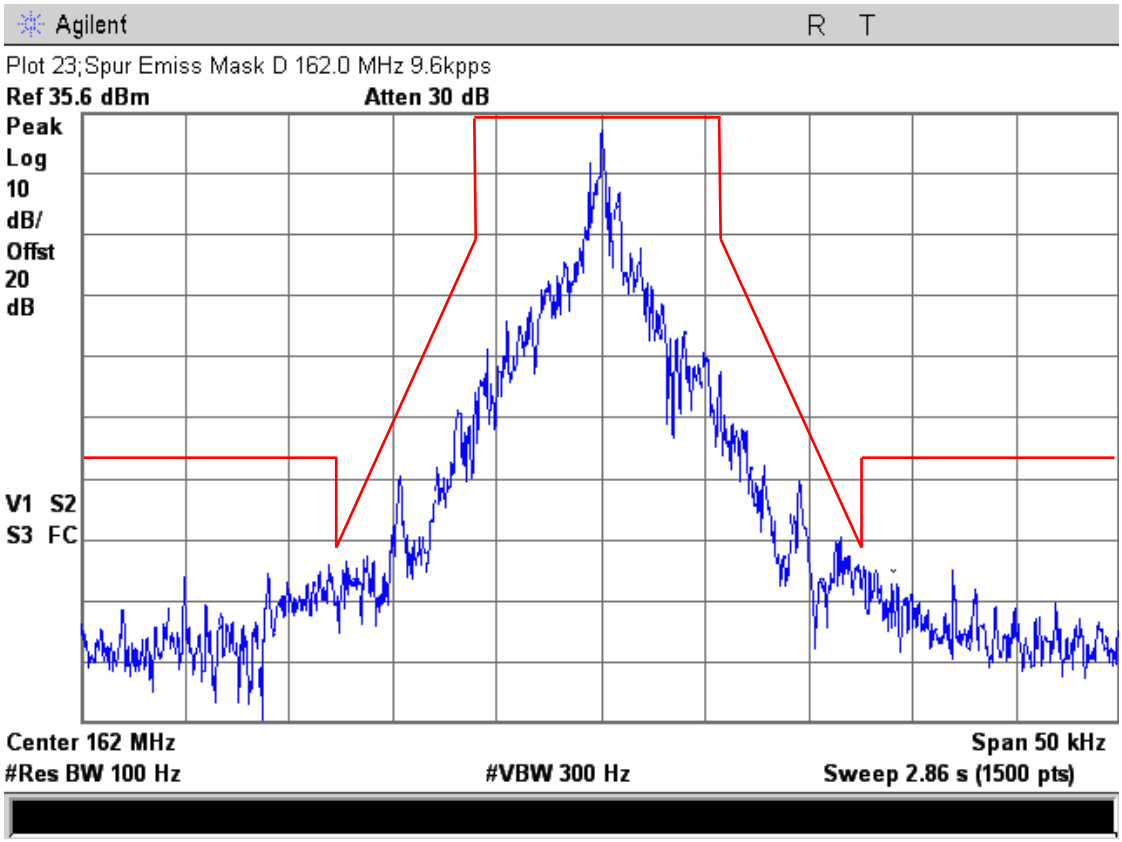

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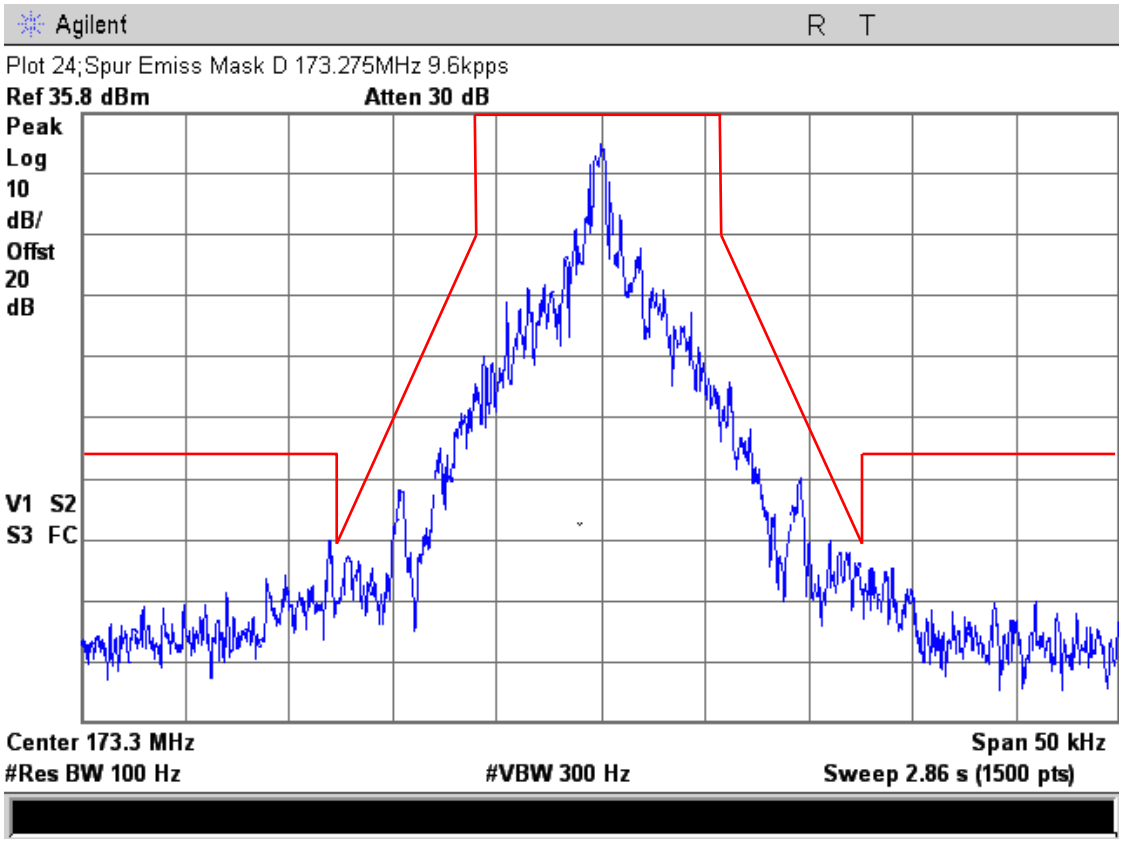

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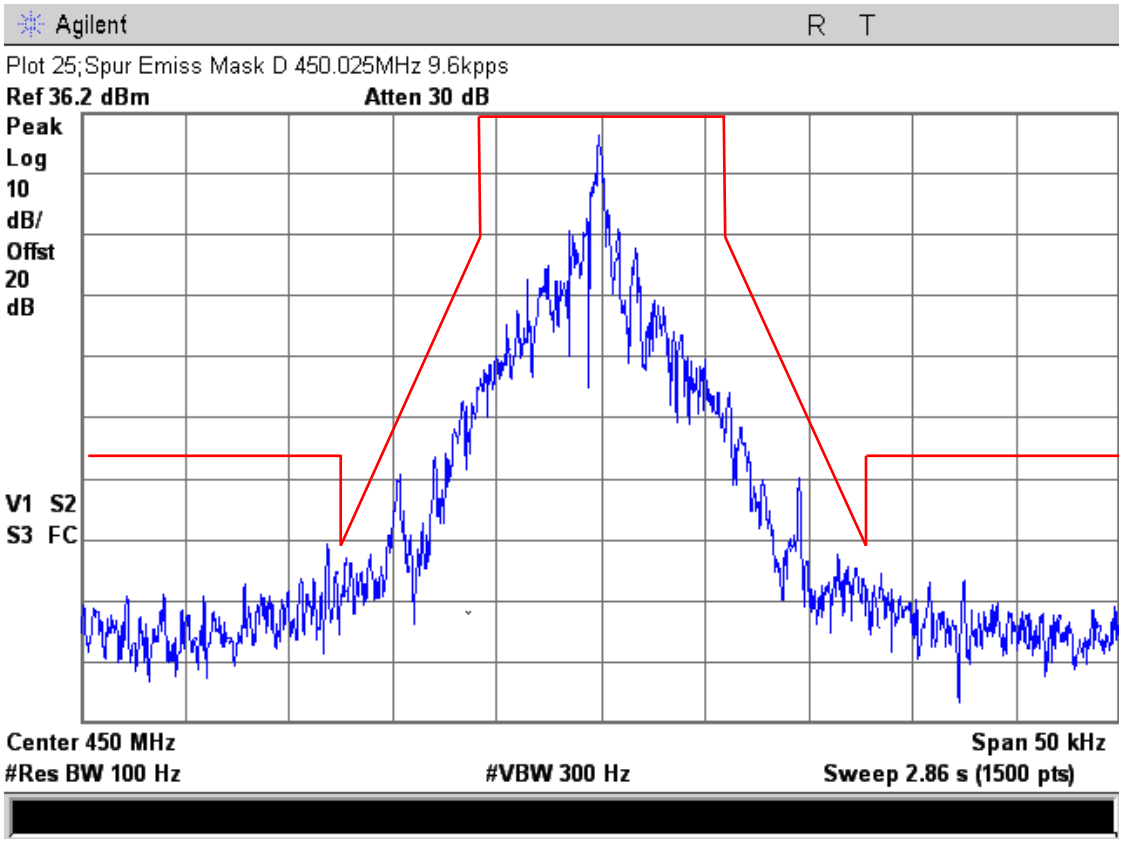

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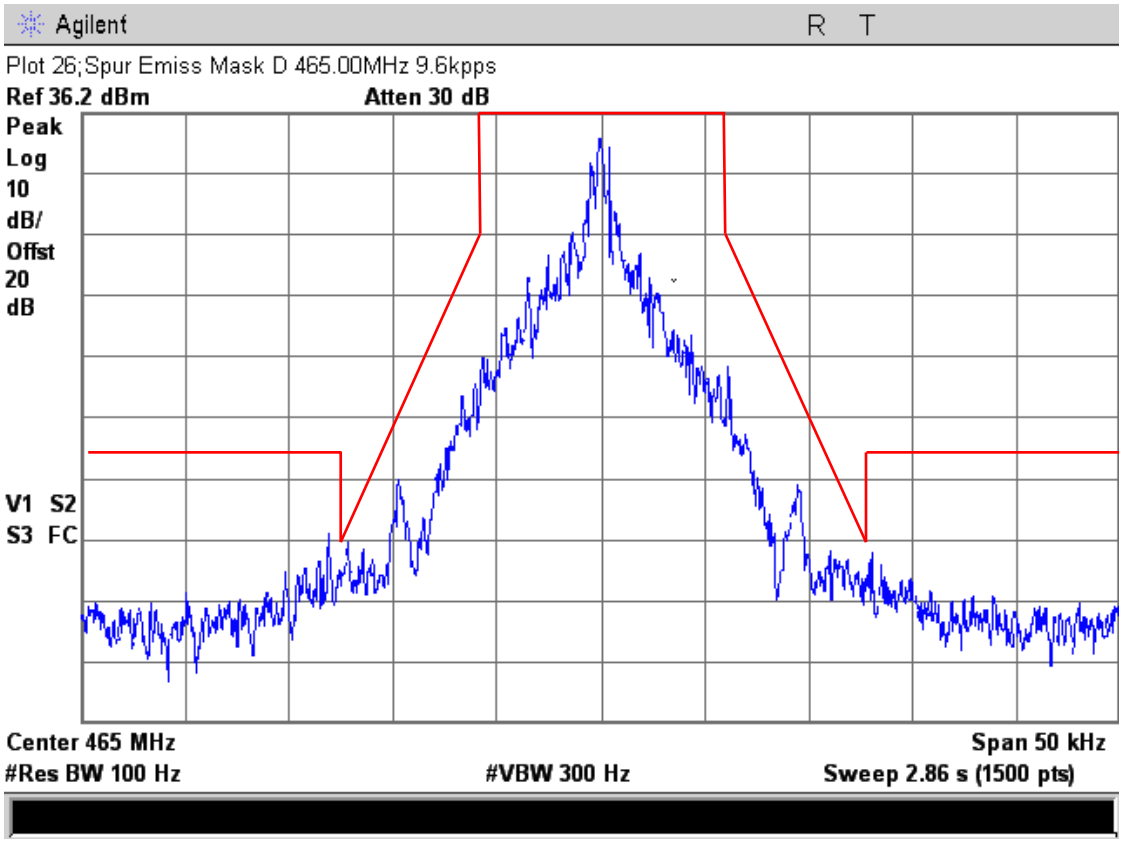

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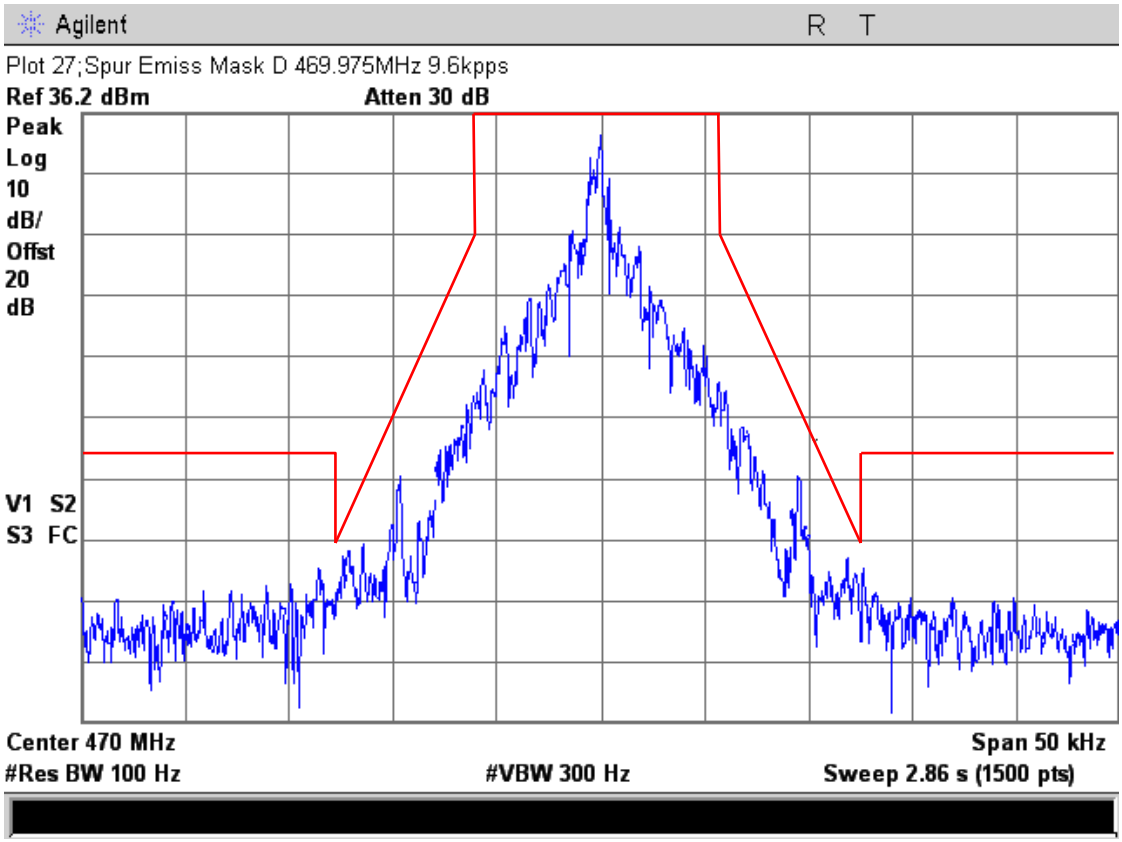

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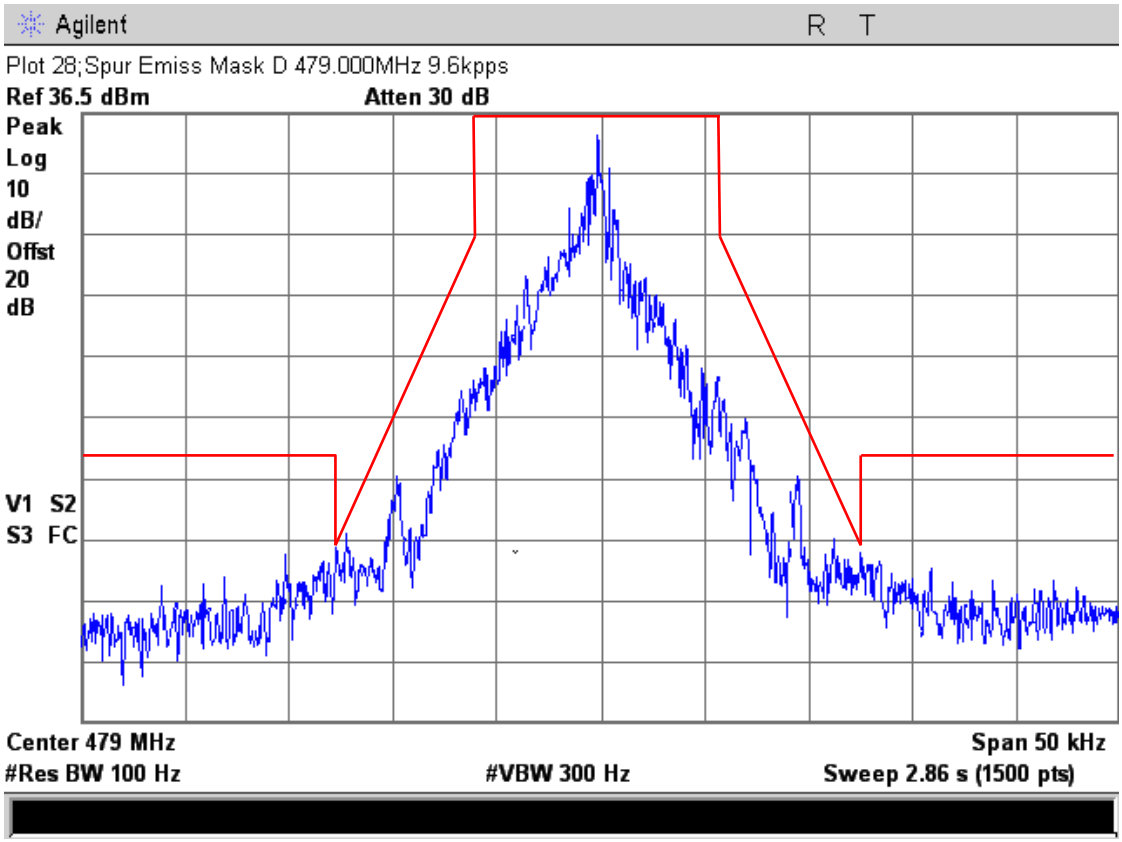

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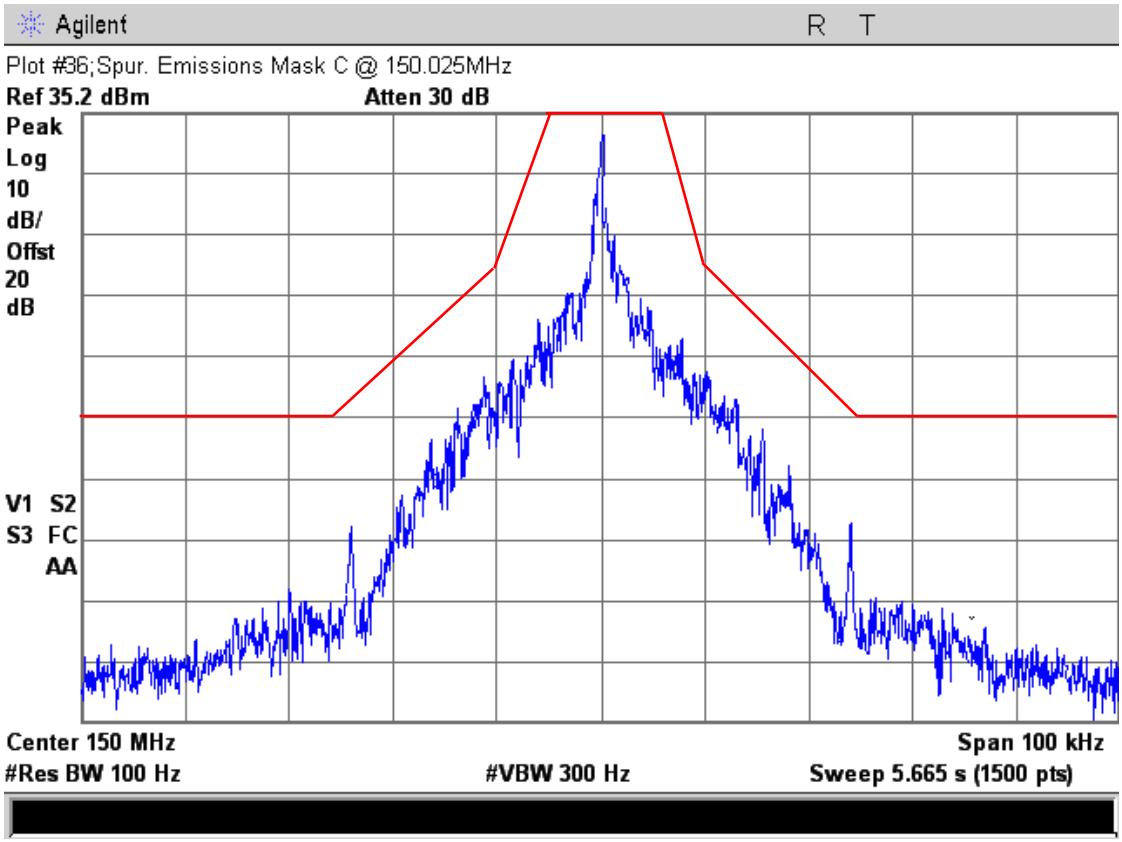

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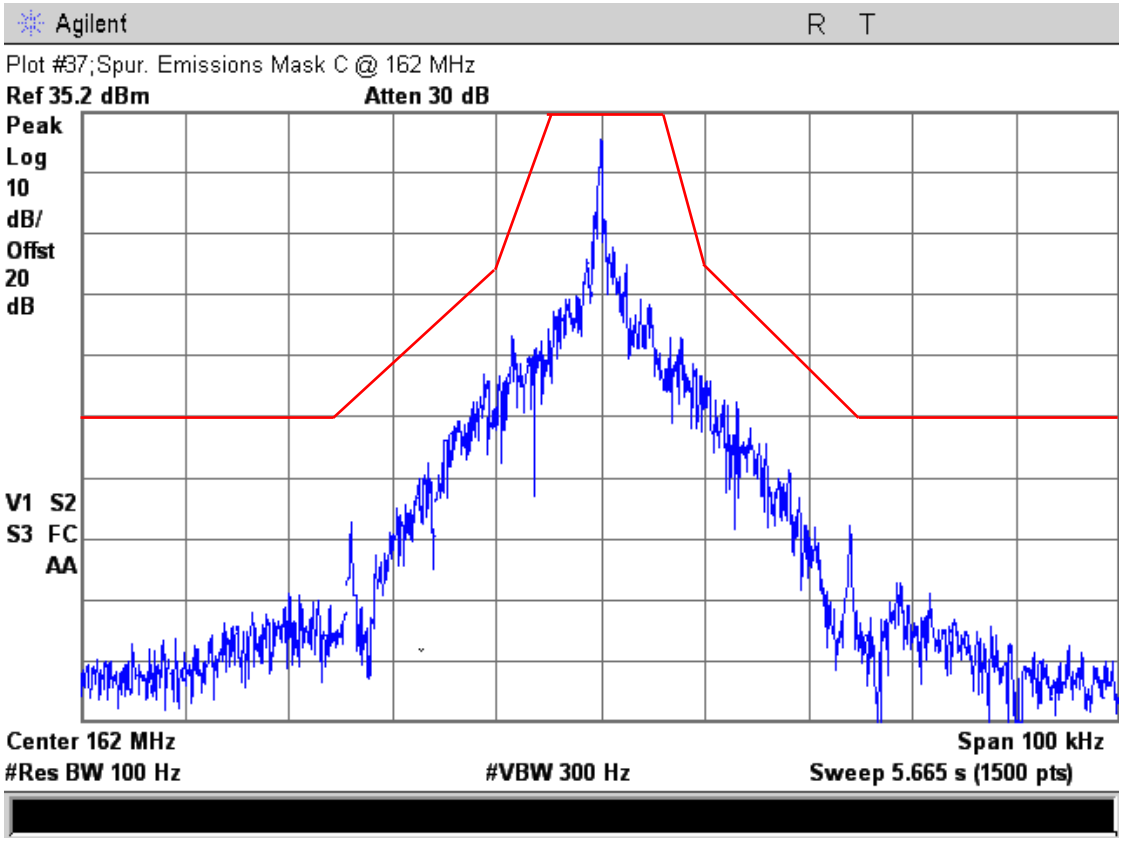

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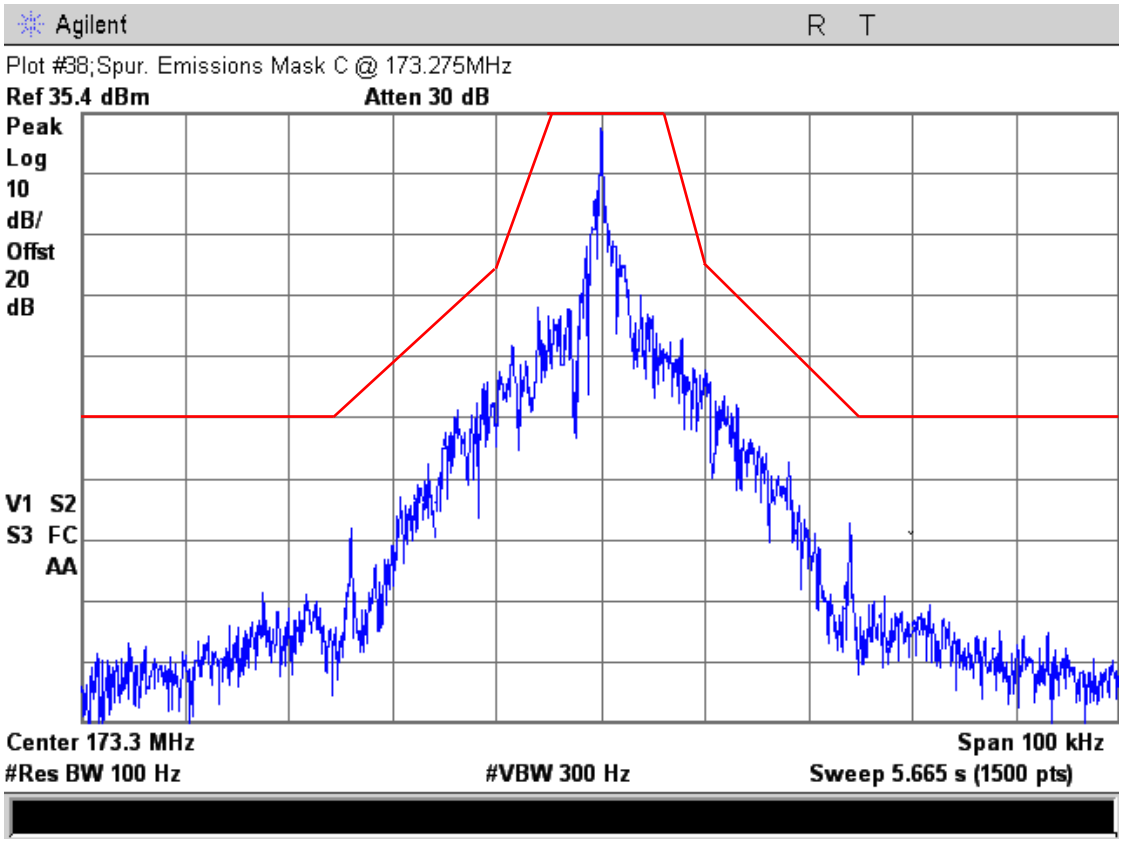

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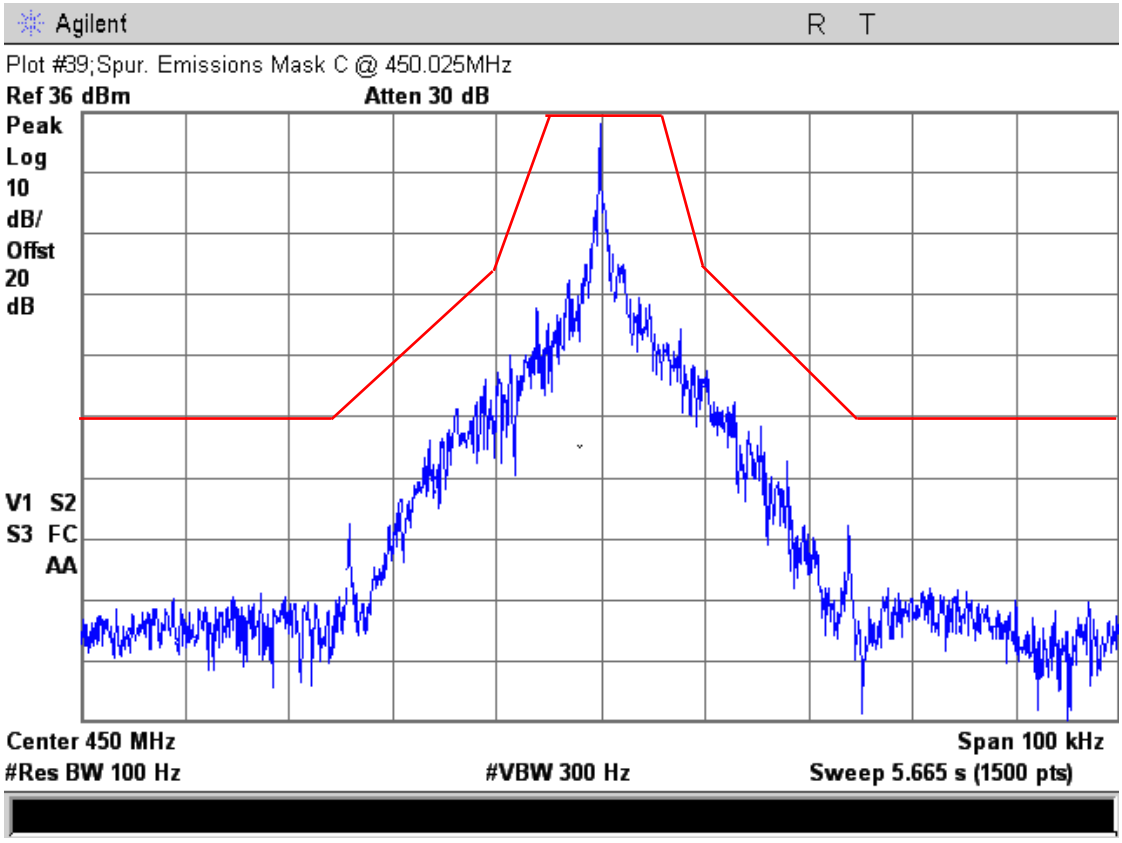

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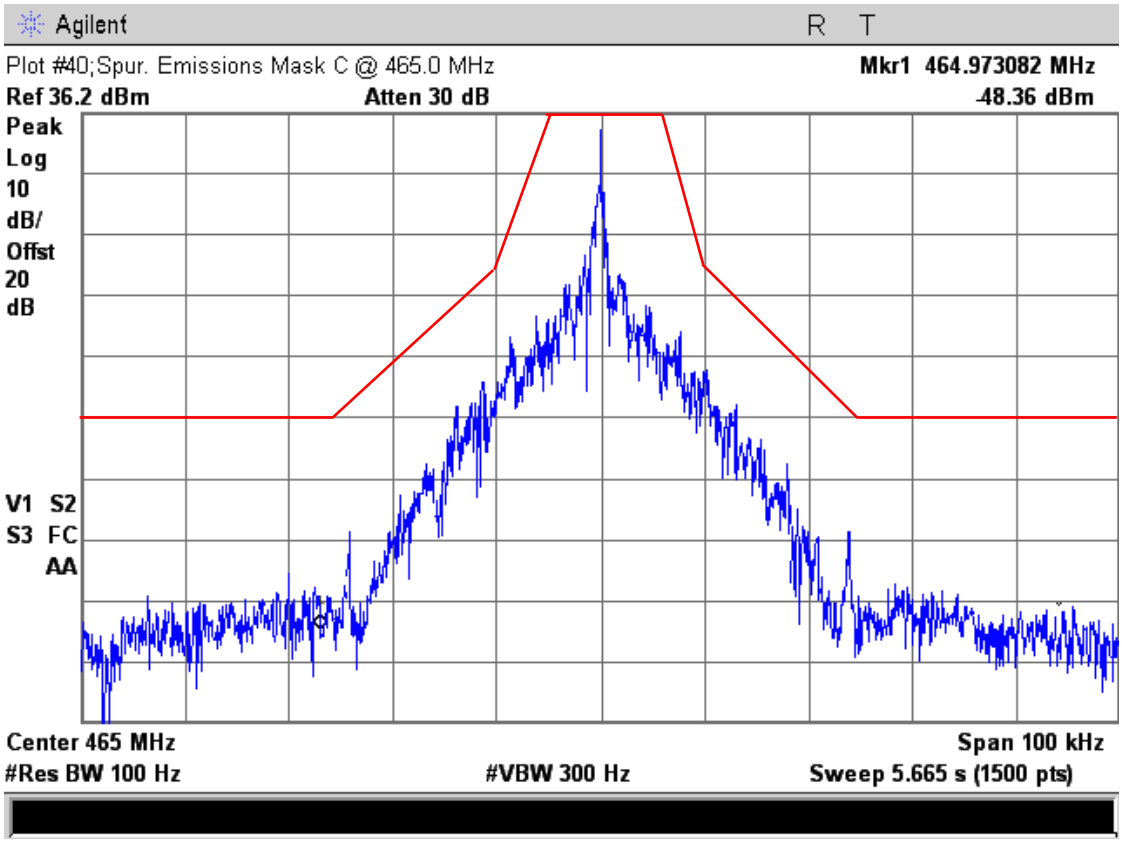

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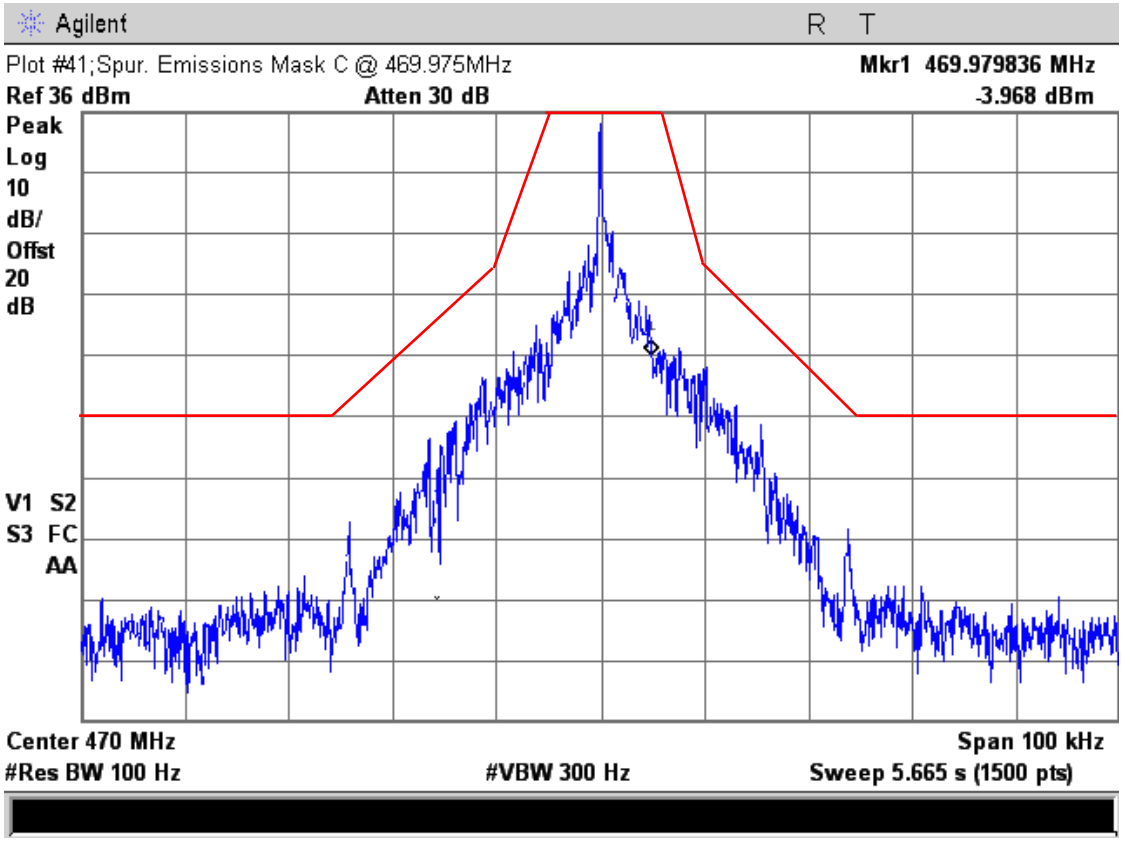

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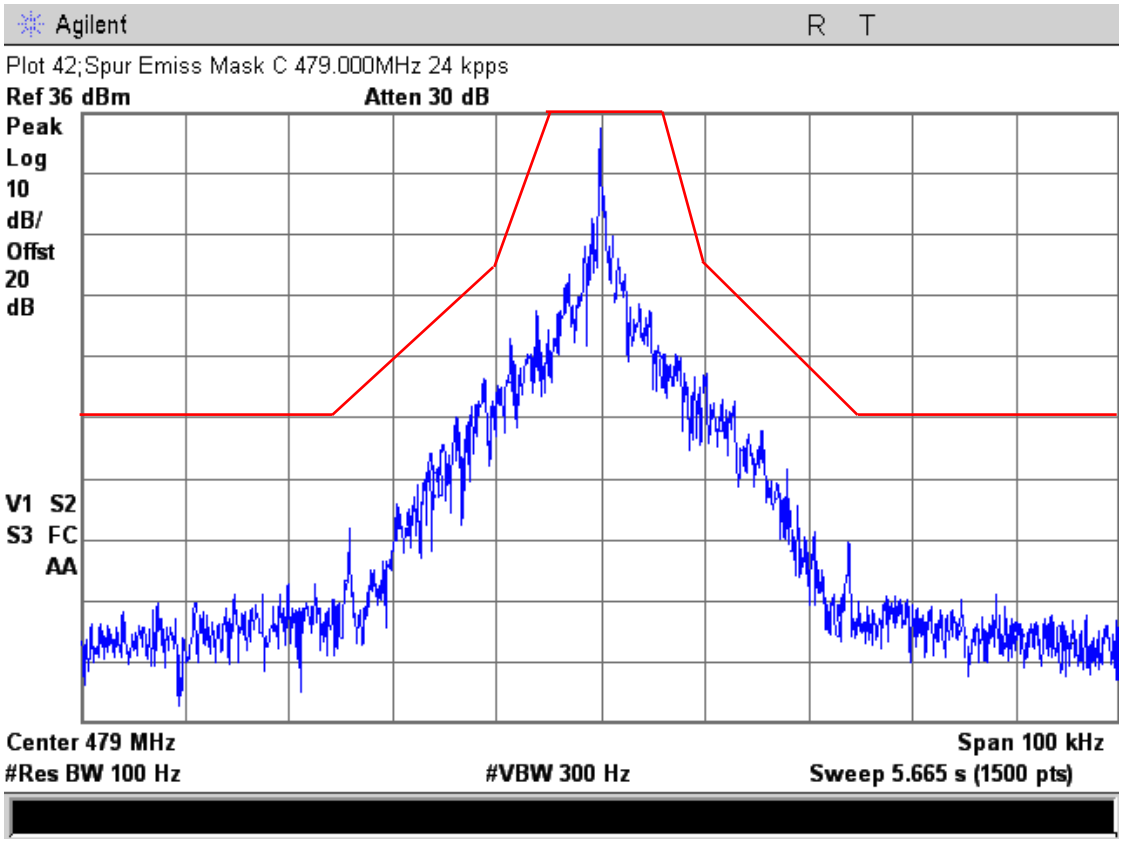

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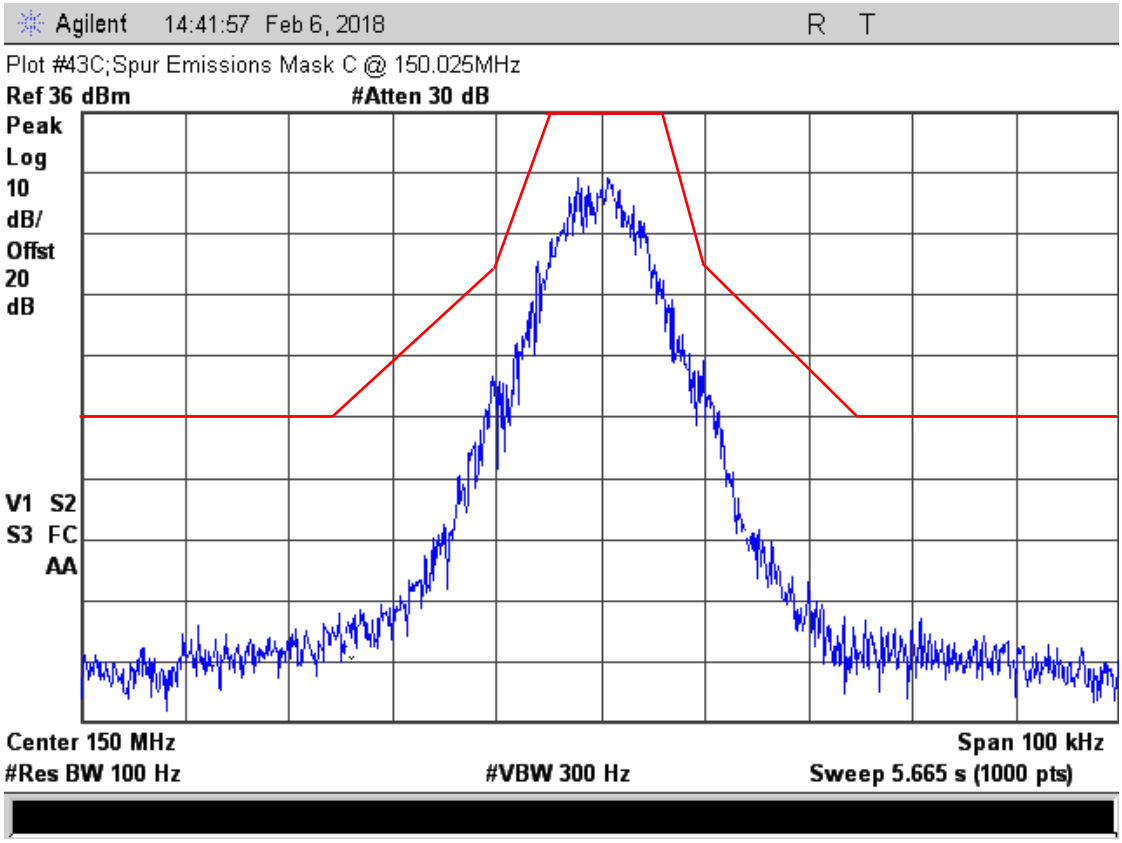

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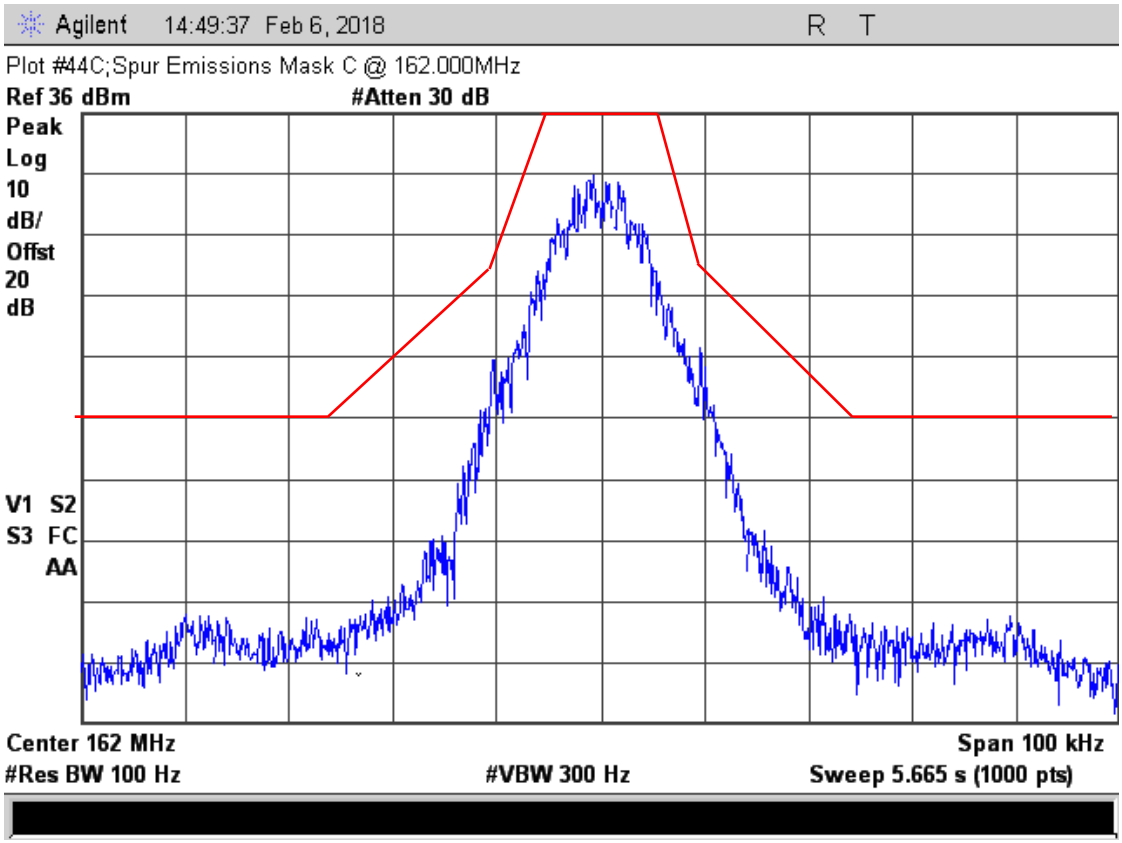

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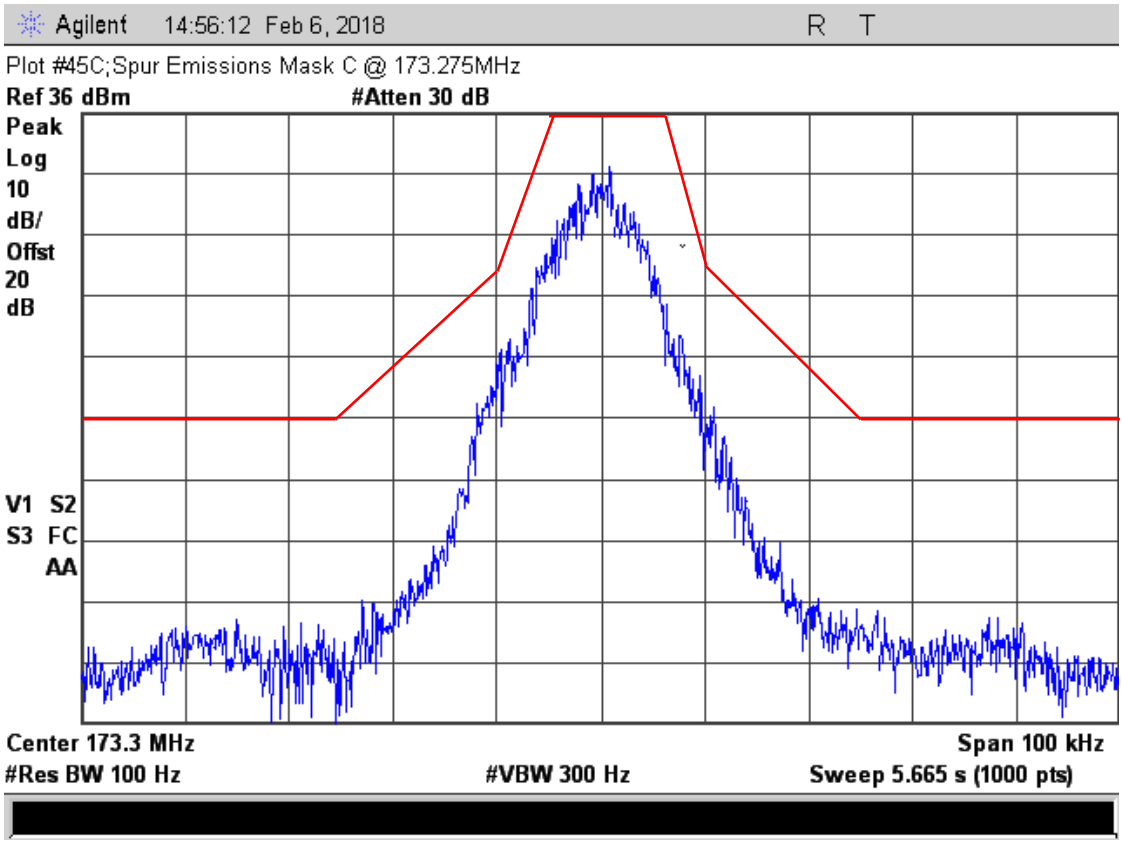

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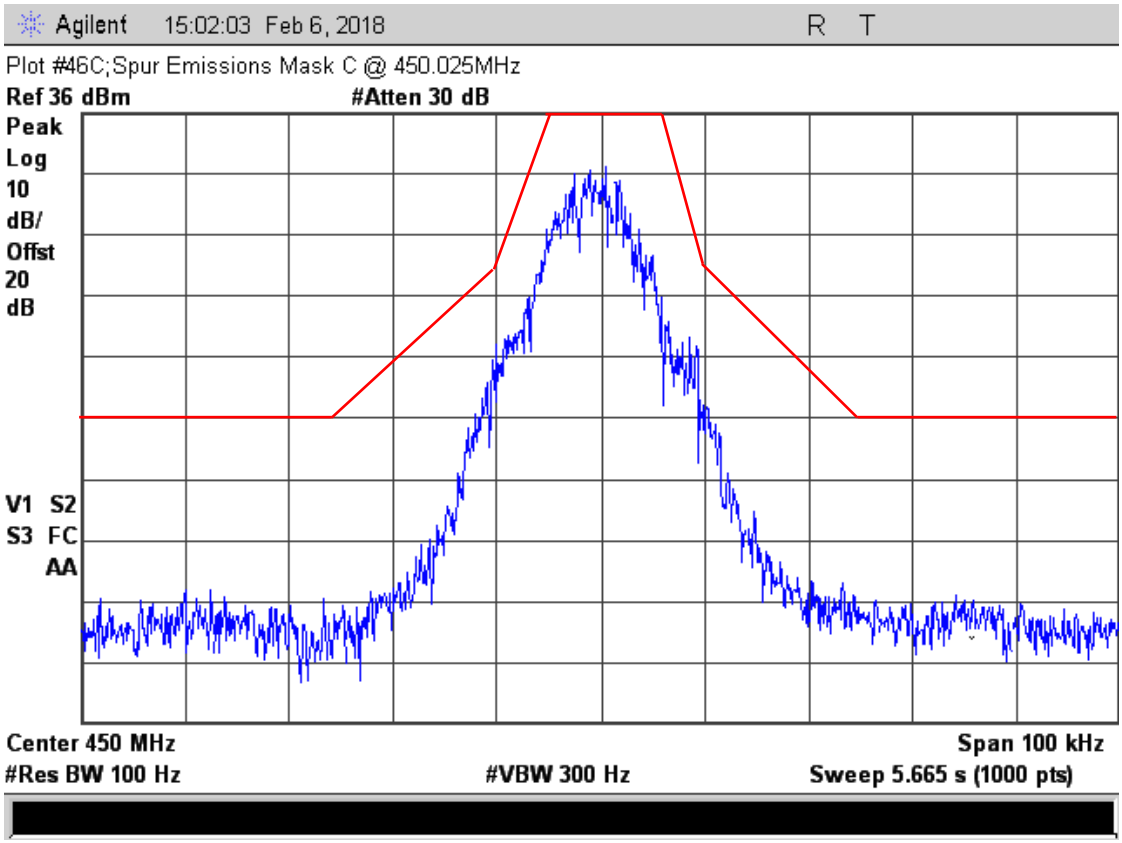

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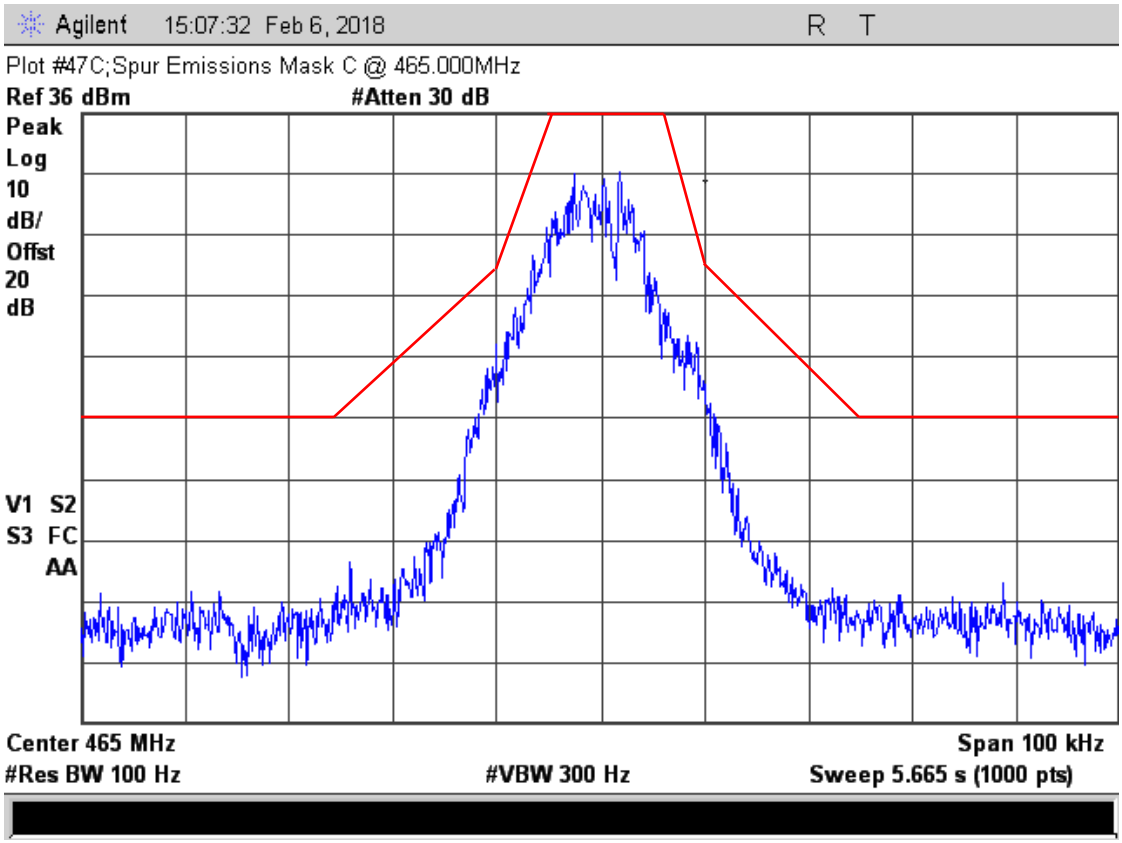

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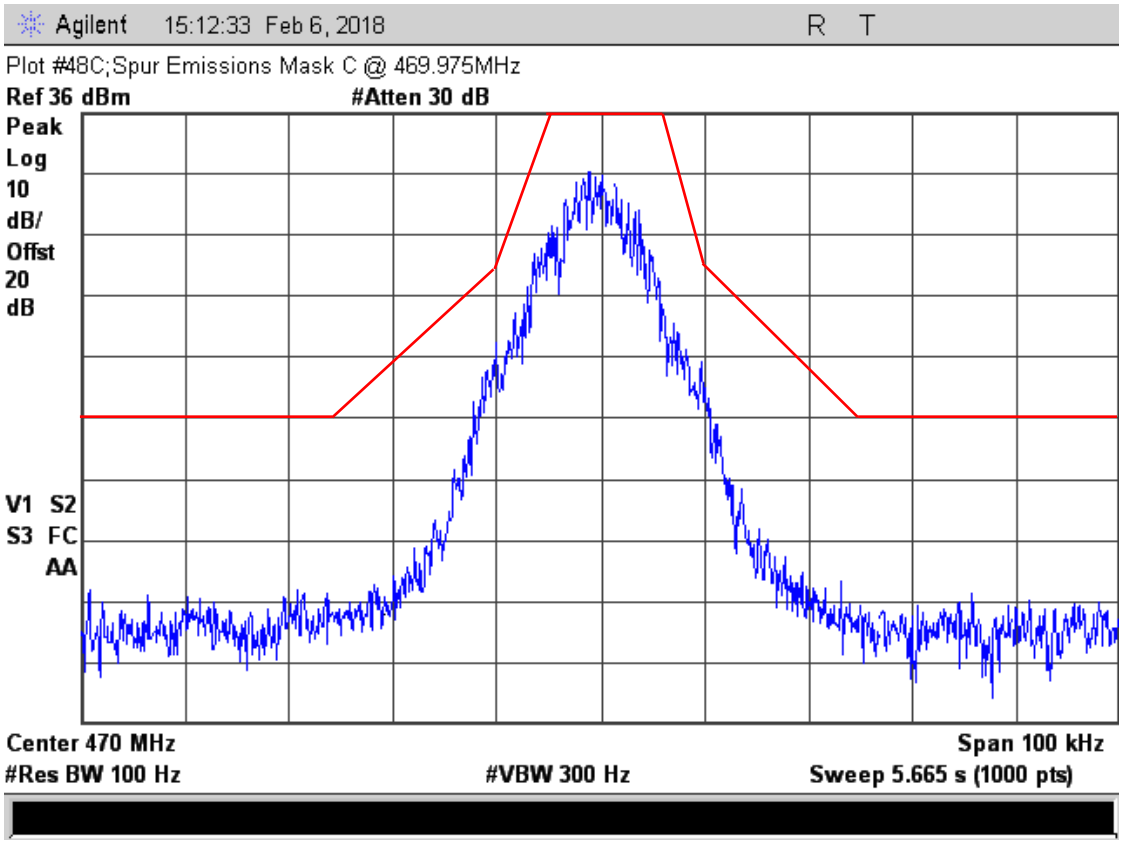

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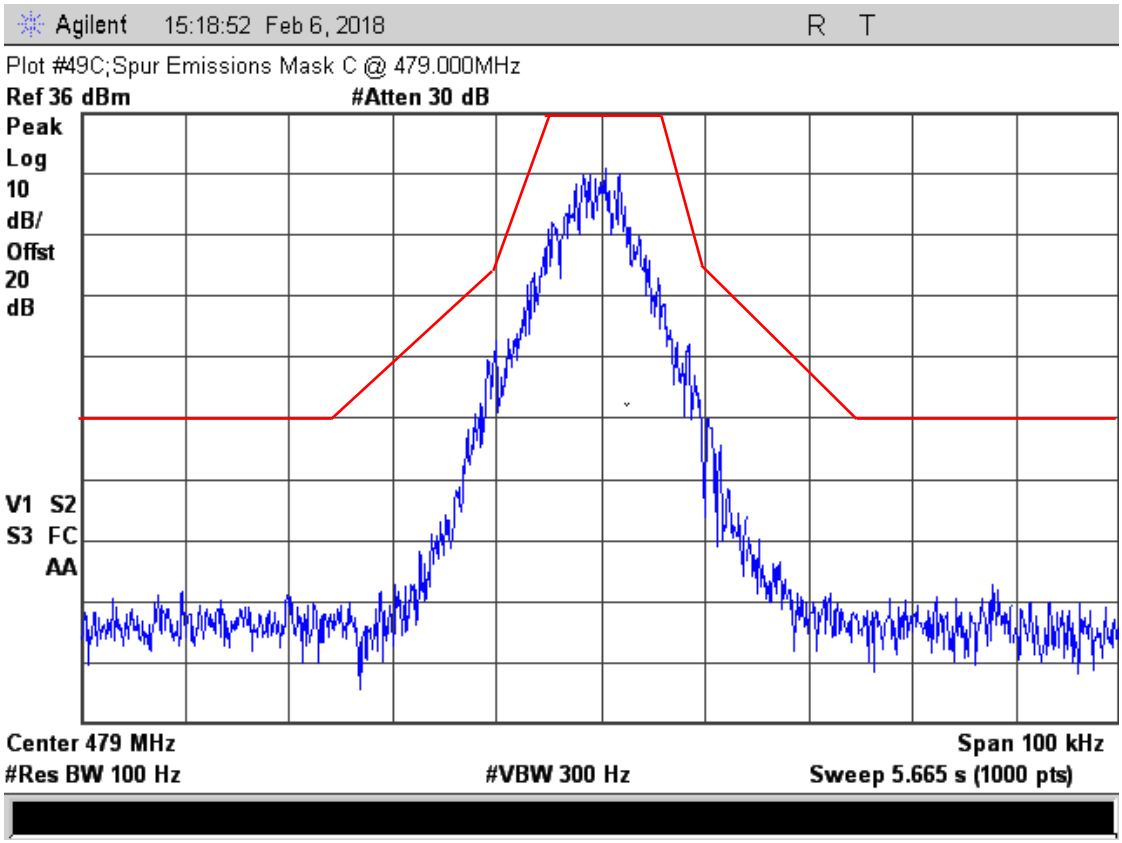

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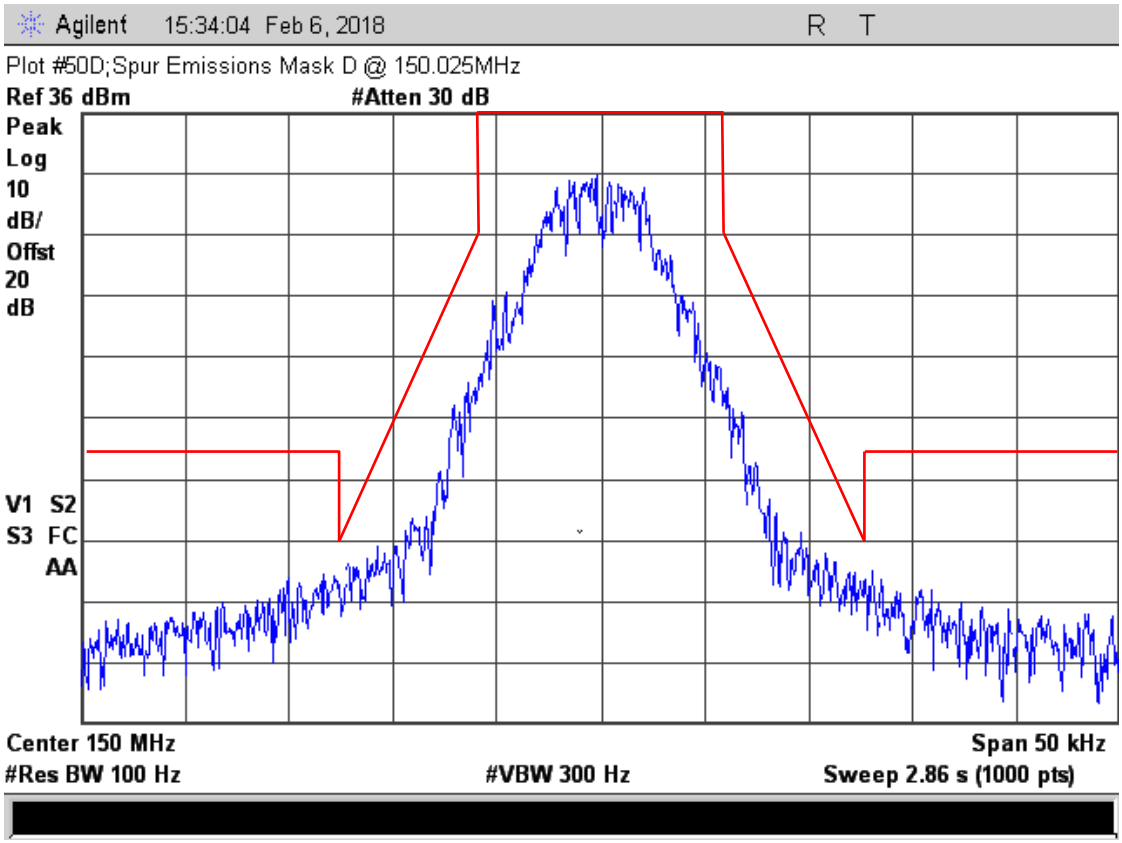

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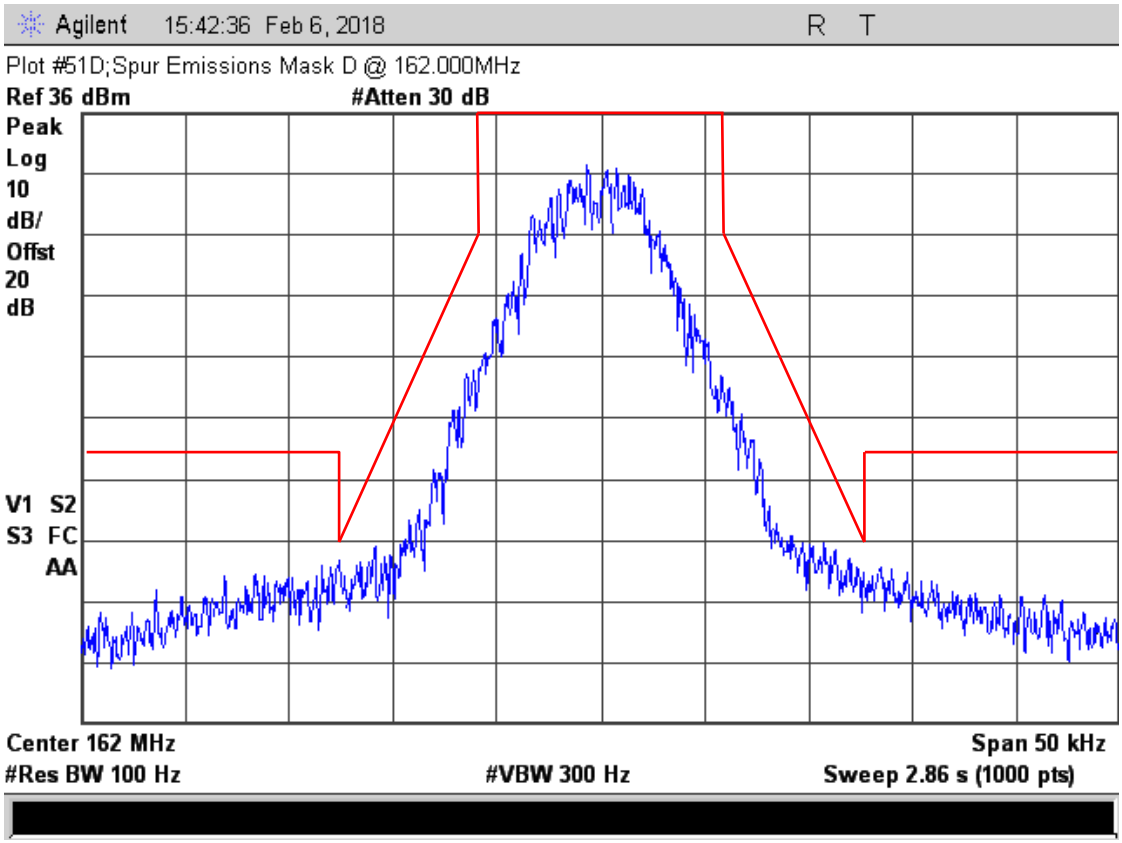

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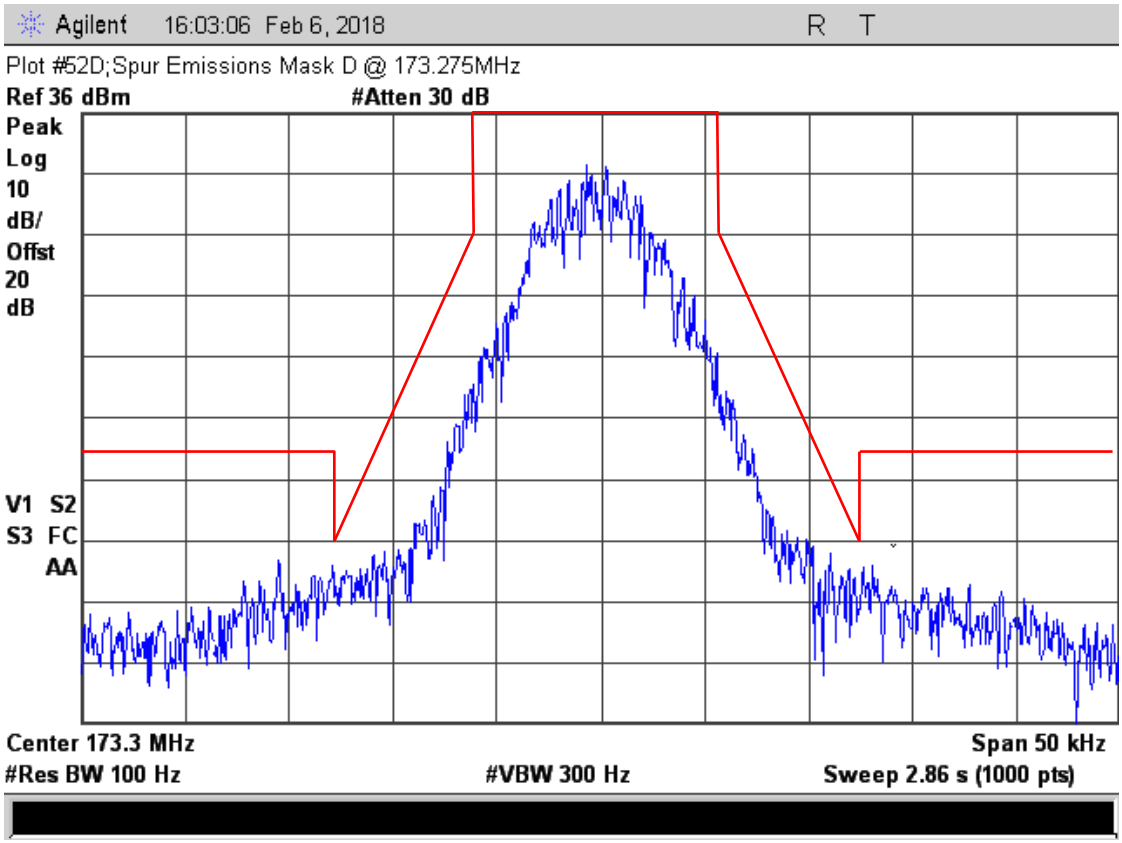

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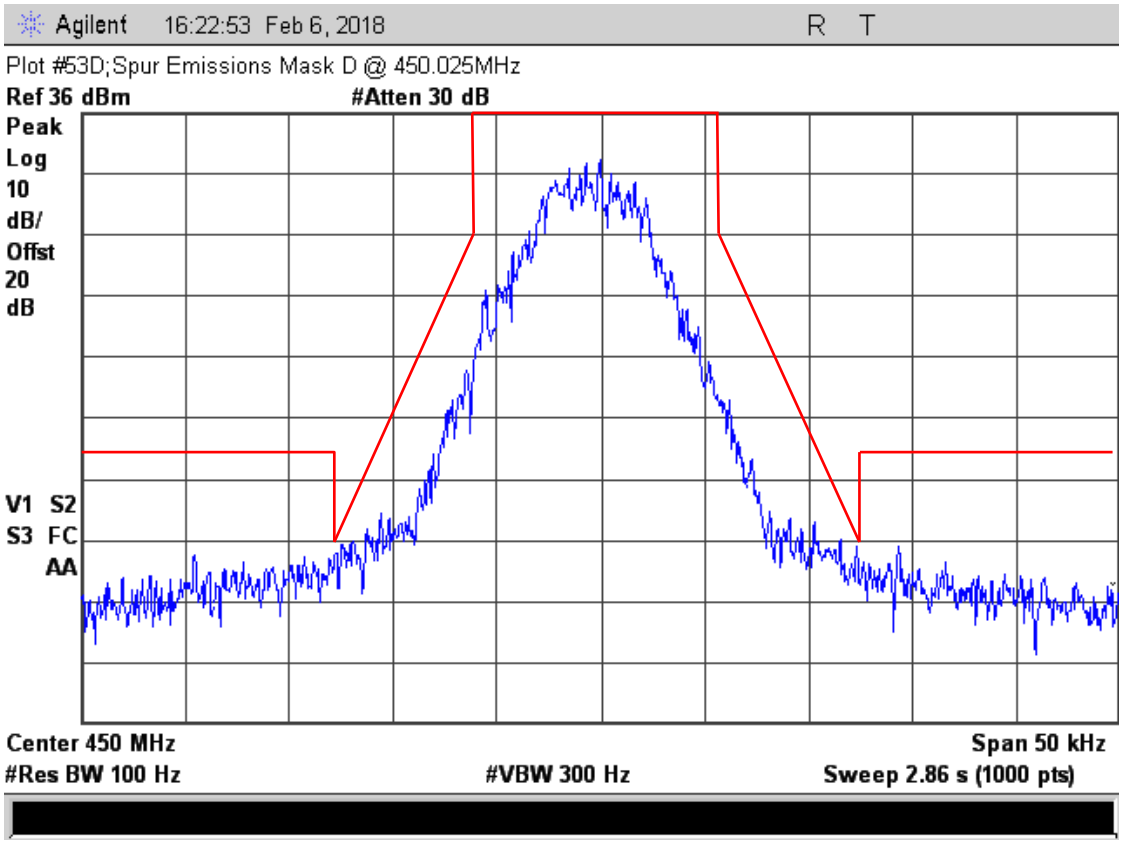

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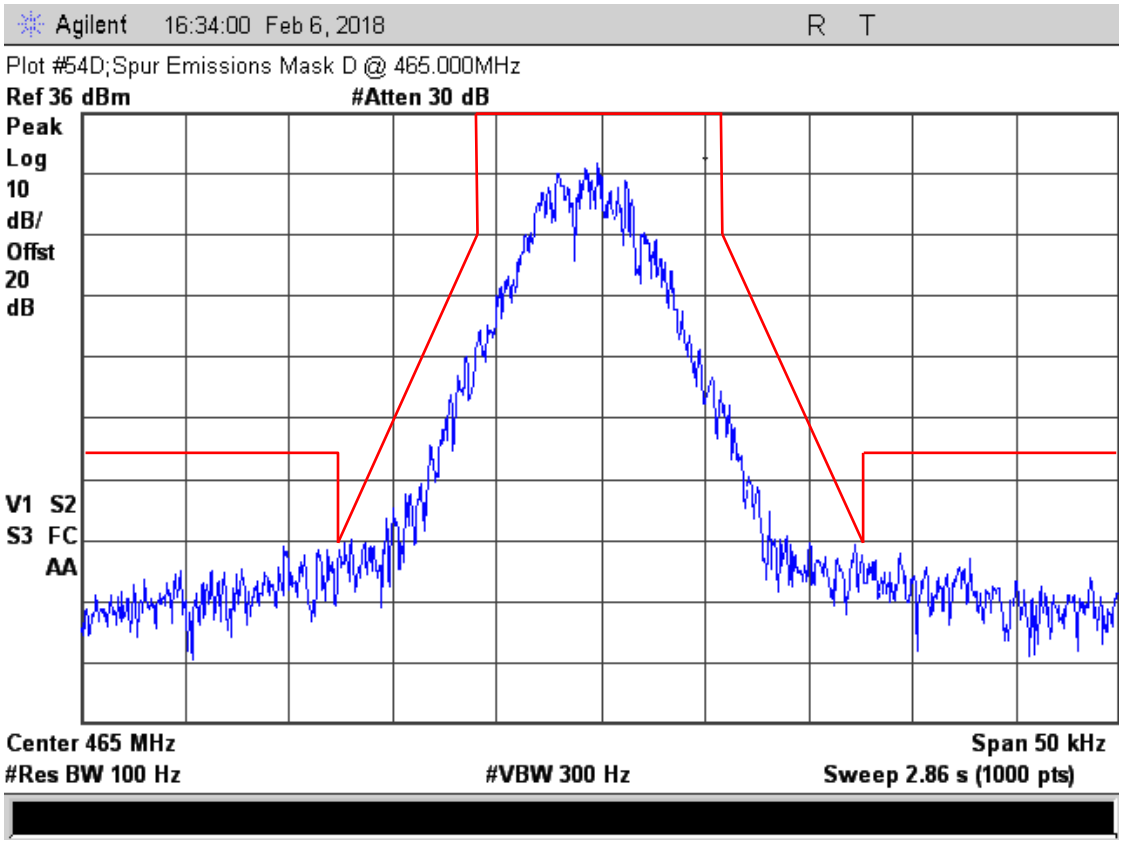

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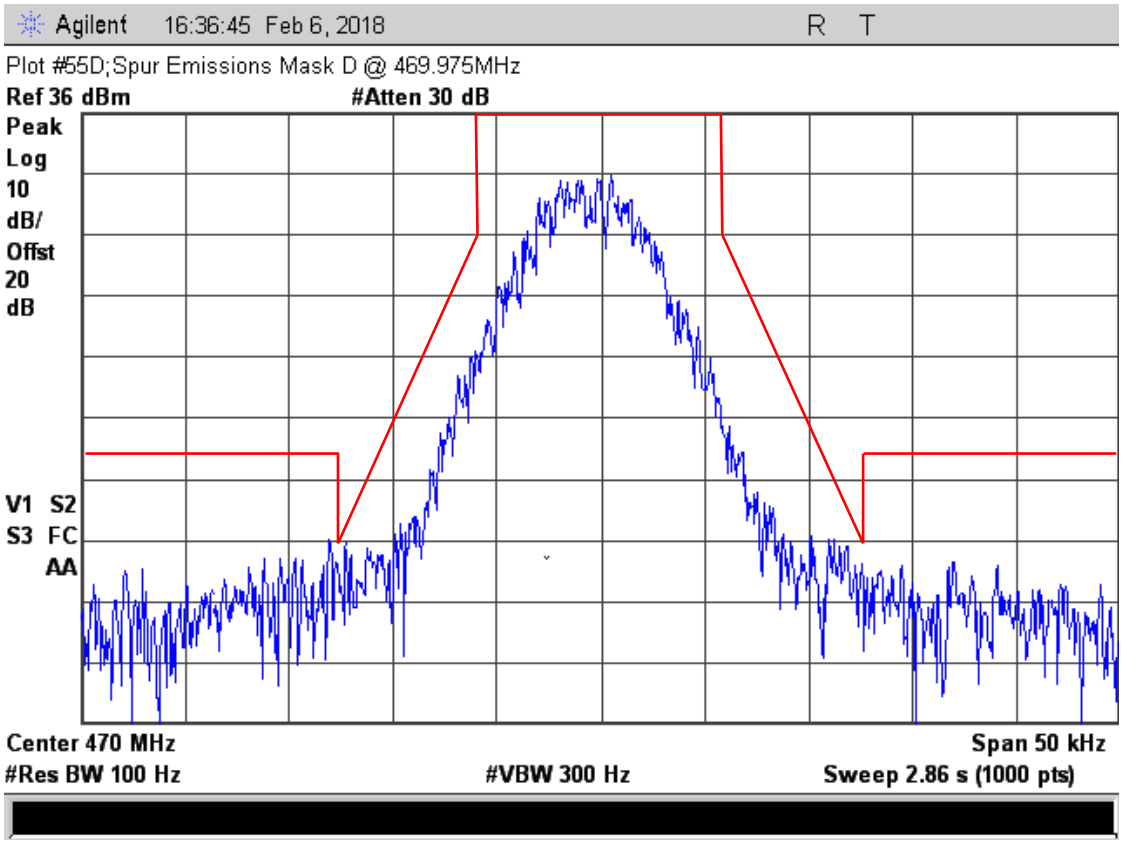

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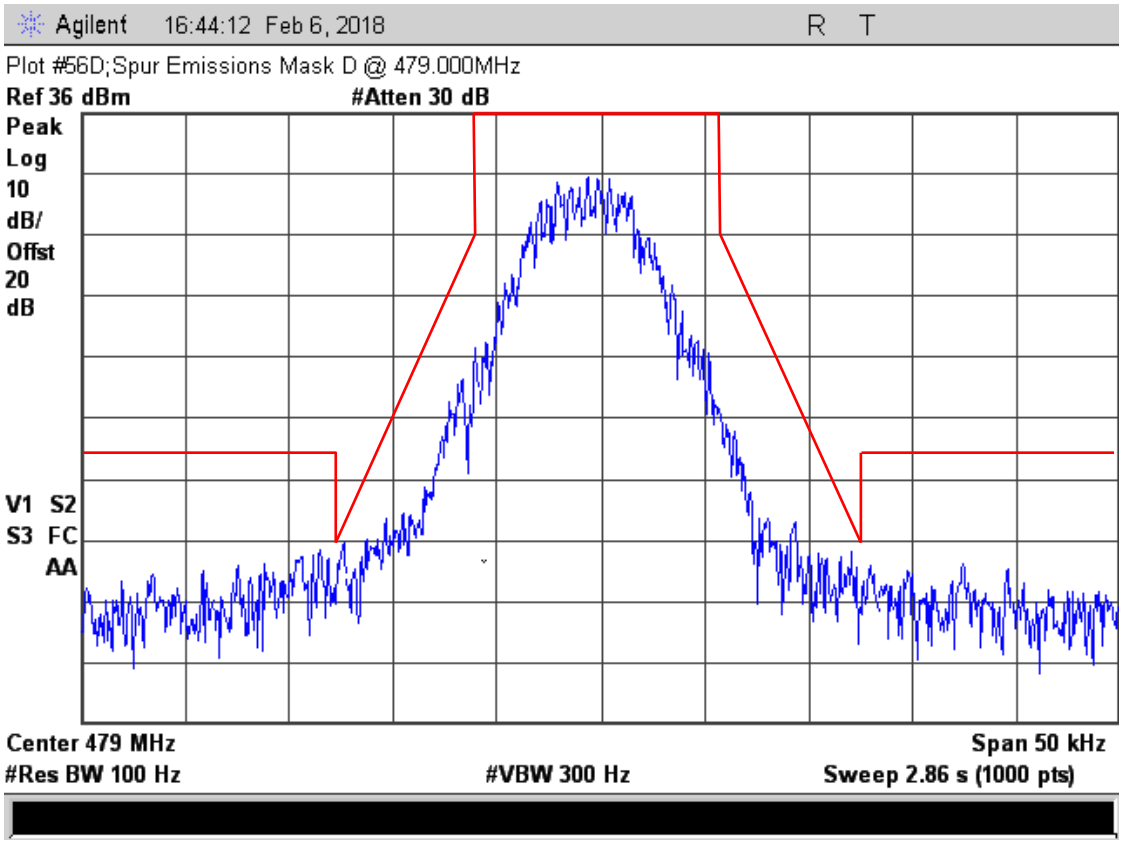
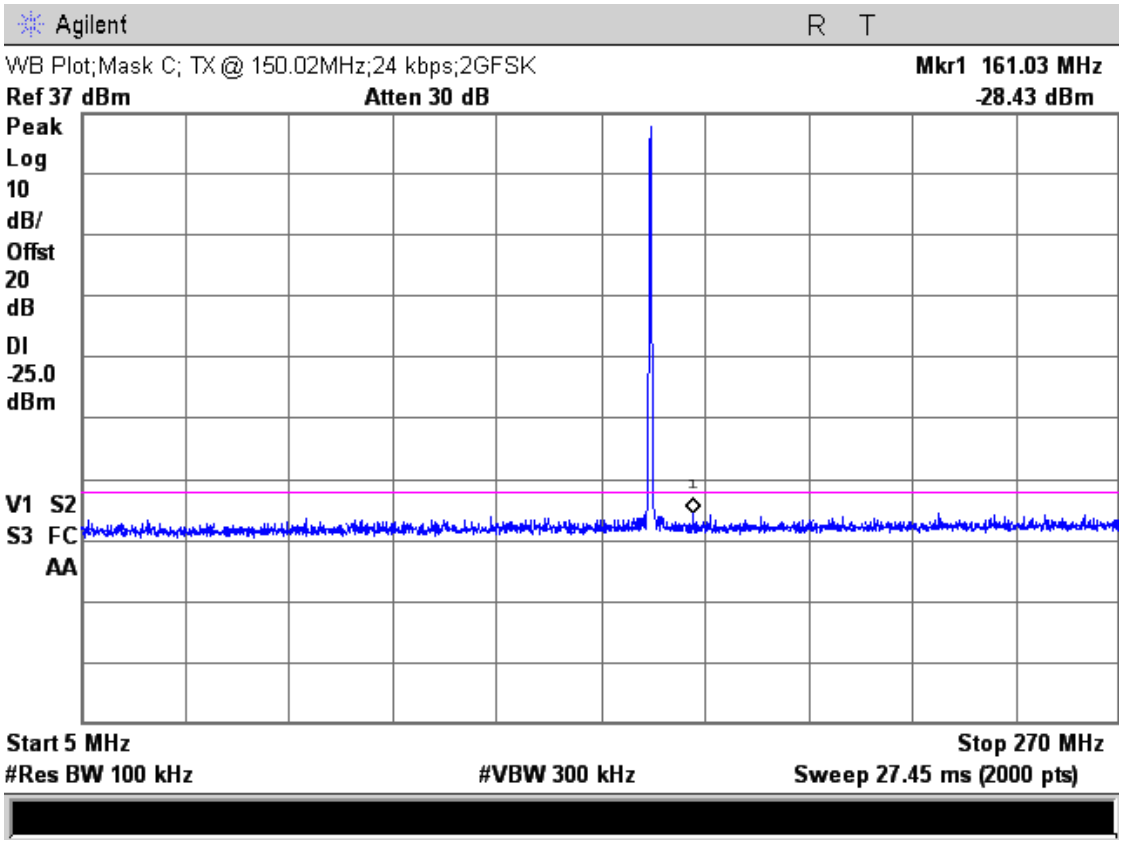
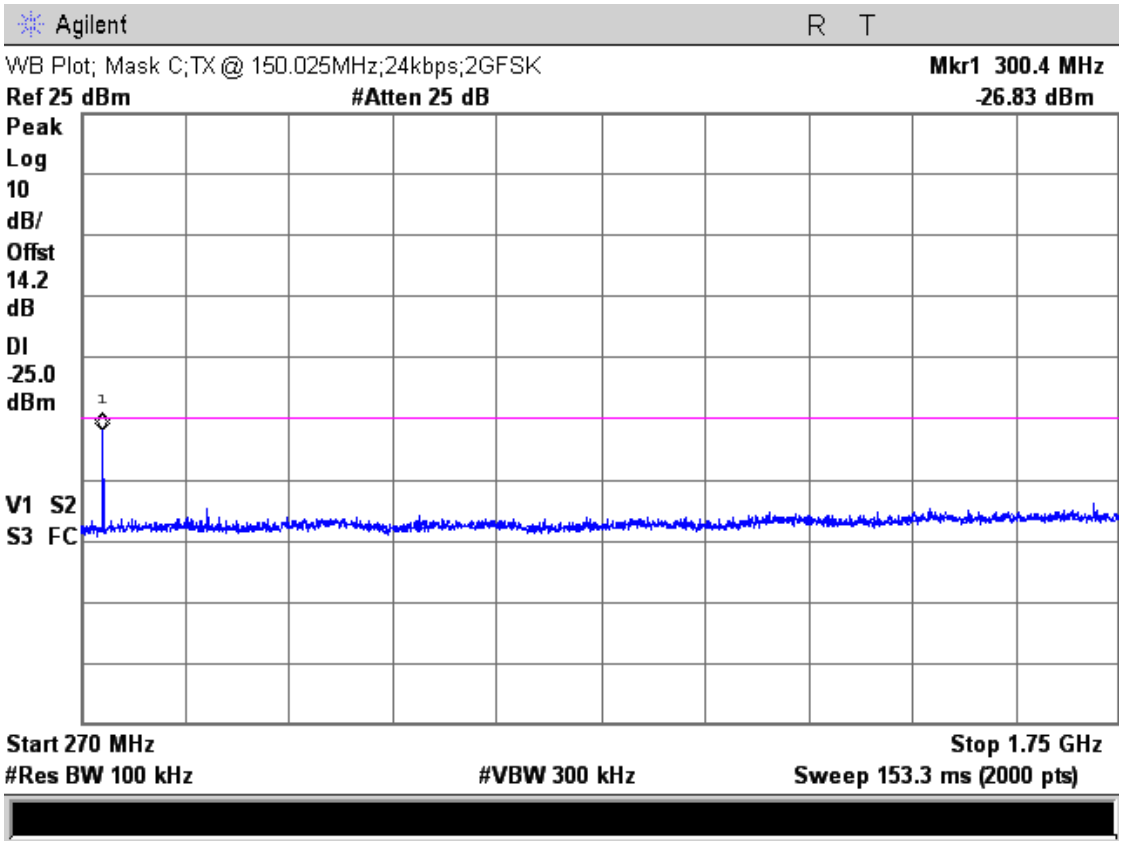


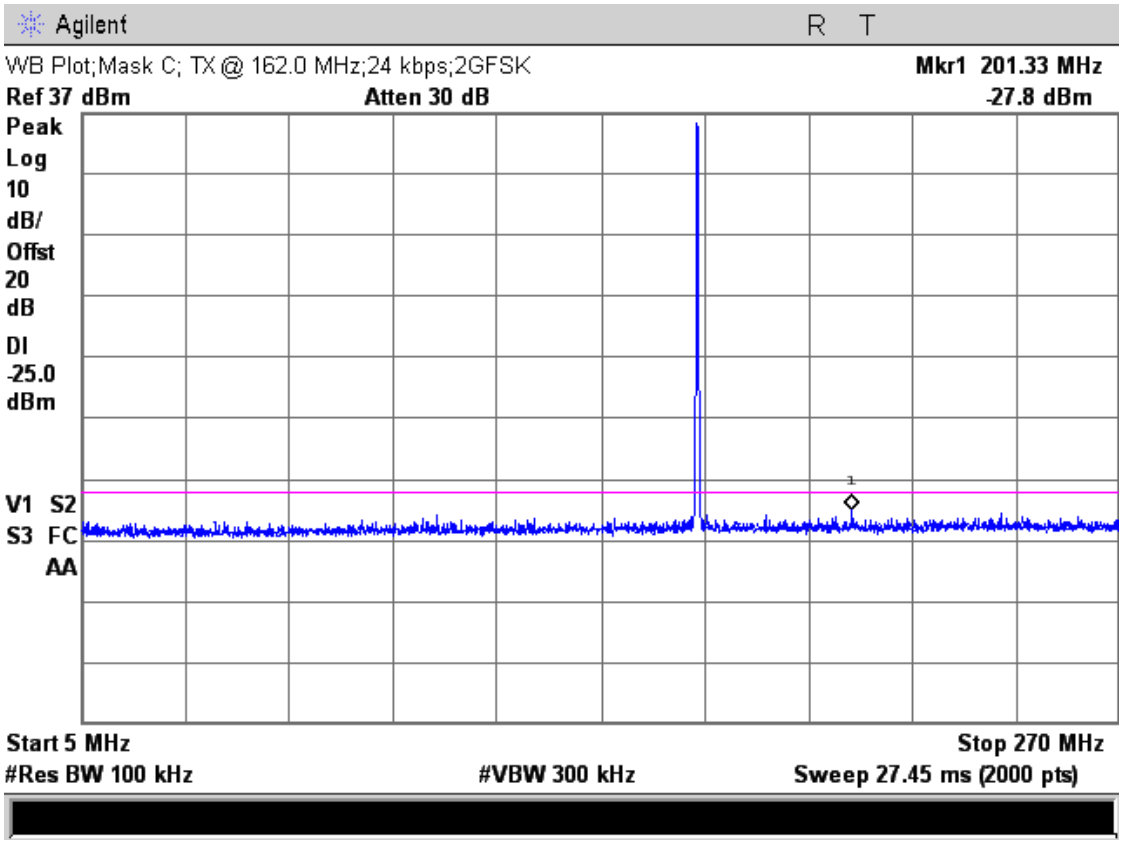
9.6 kbps; 4GFSK; Mask D



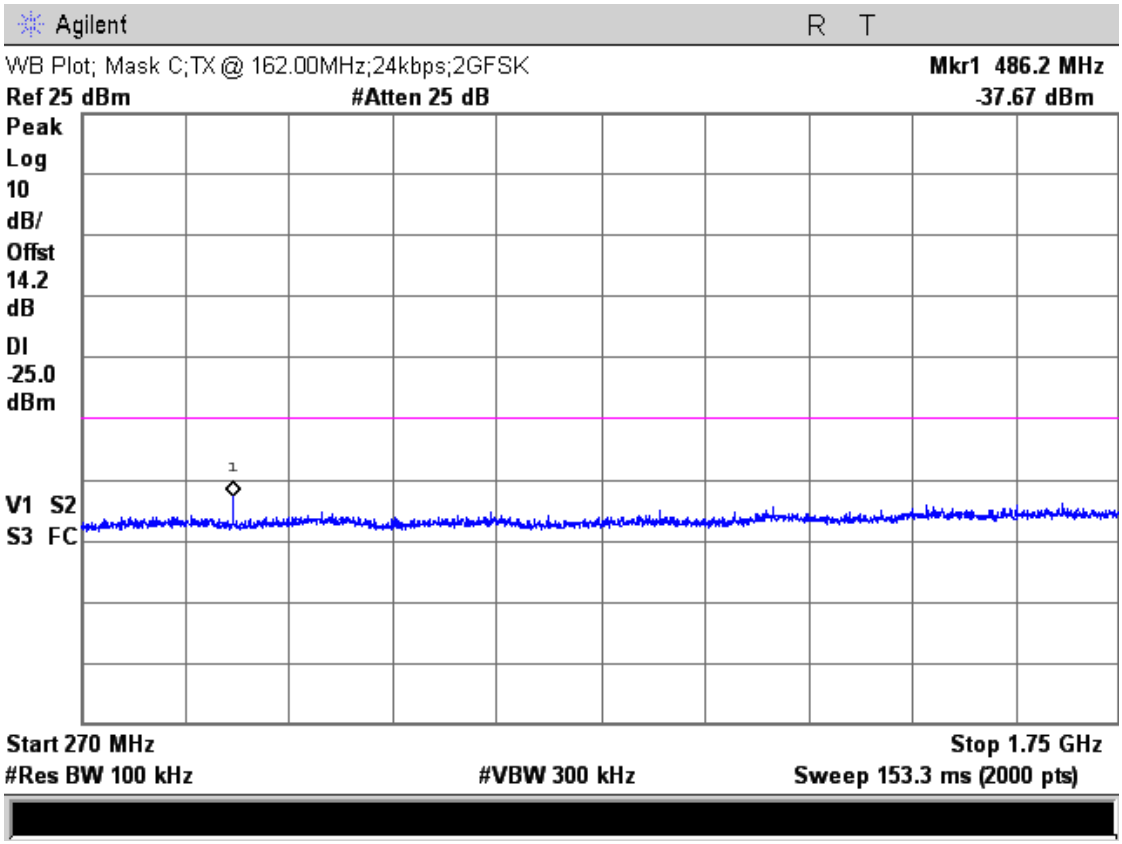
150 MHz; Worst case Mask E limit (Limit of 55*LOG(P in Watts)) or -25 dBm



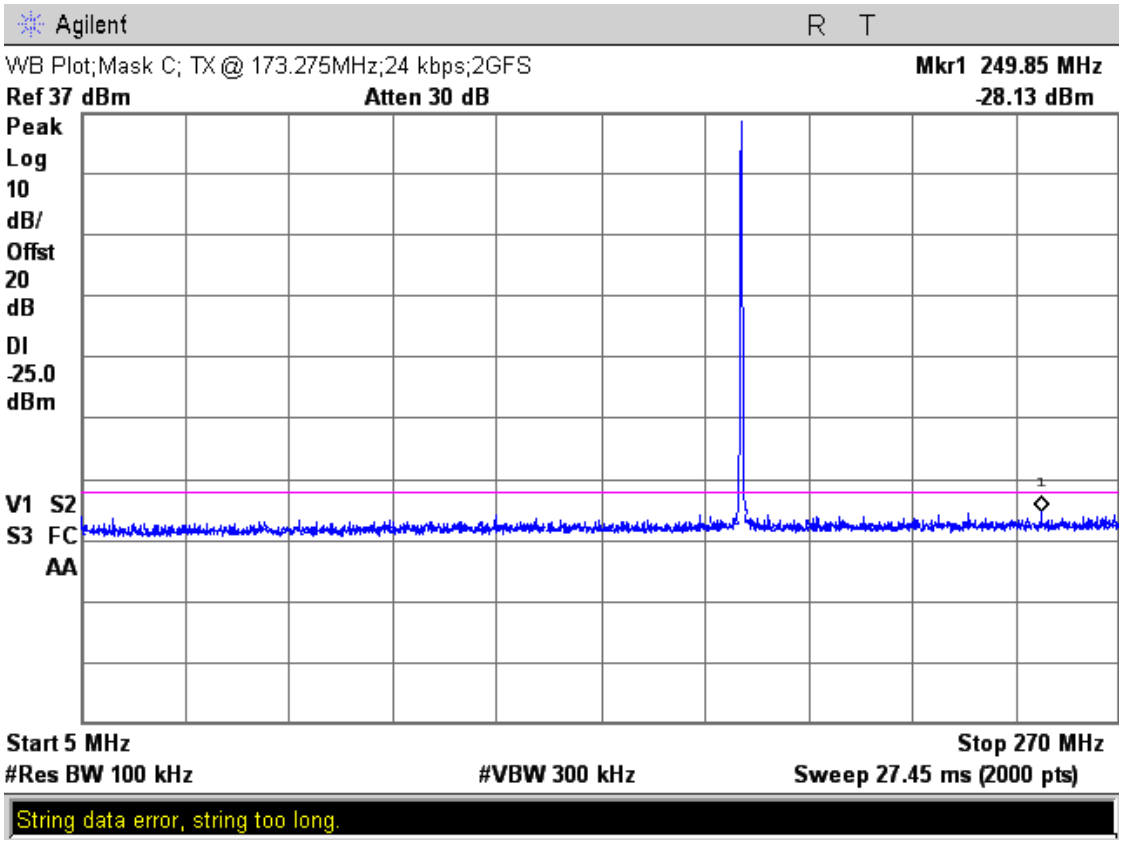
150 MHz; Worst case Mask E limit (Limit of 55*LOG(P in Watts)) or -25 dBm



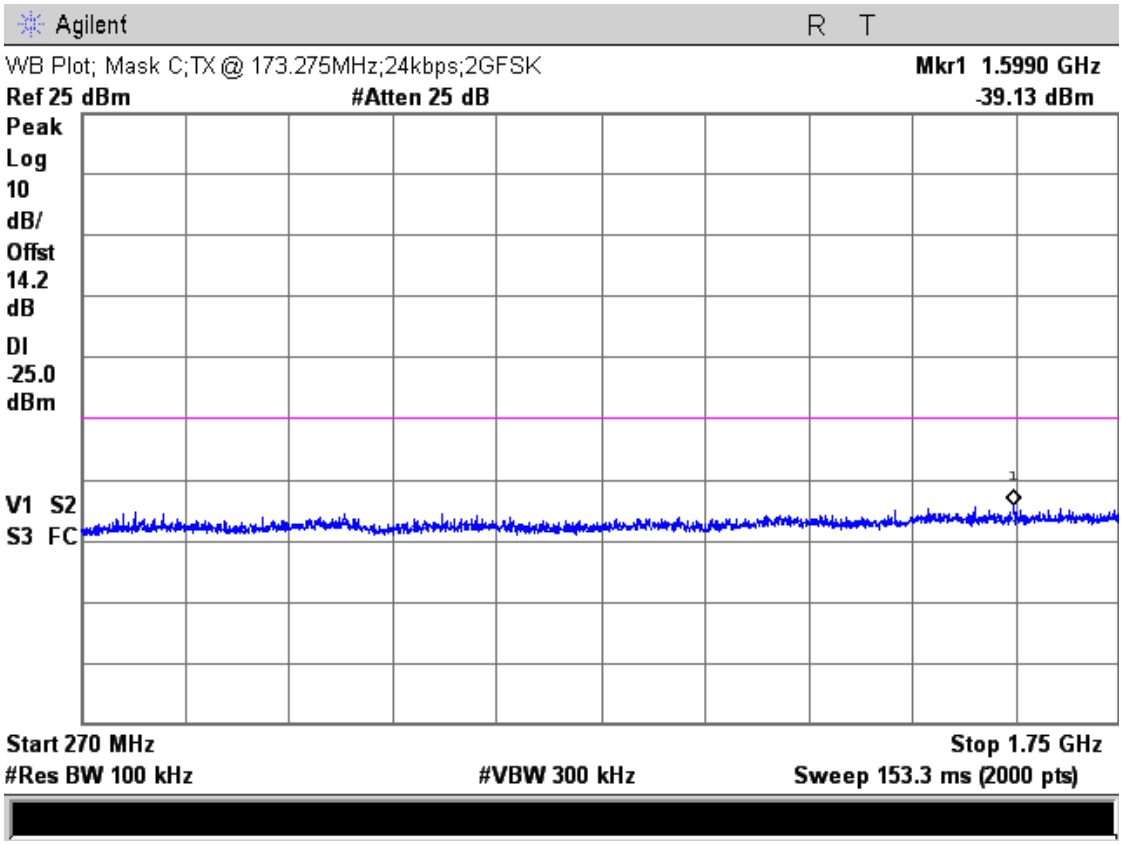
162 MHz; Worst case Mask E limit (Limit of 55*LOG(P in Watts)) or -25 dBm



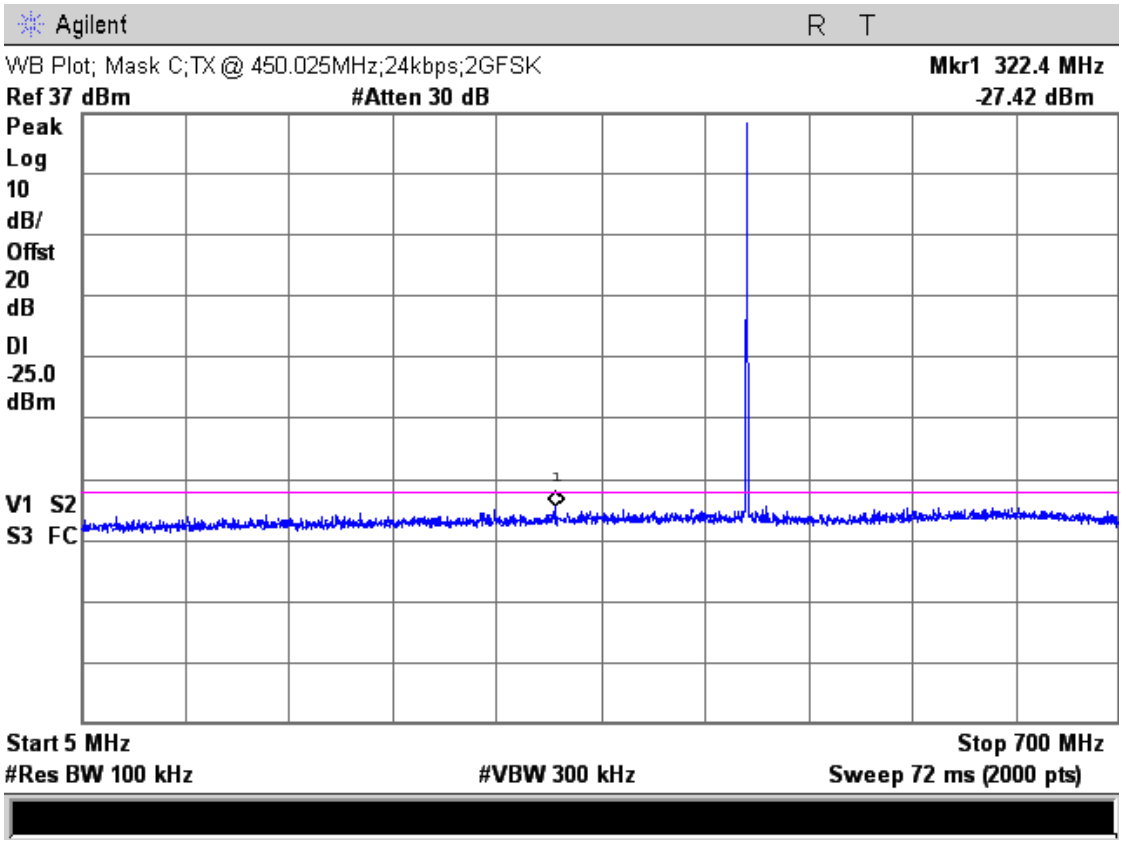
162 MHz; Worst case Mask E limit (Limit of 55*LOG(P in Watts)) or -25 dBm



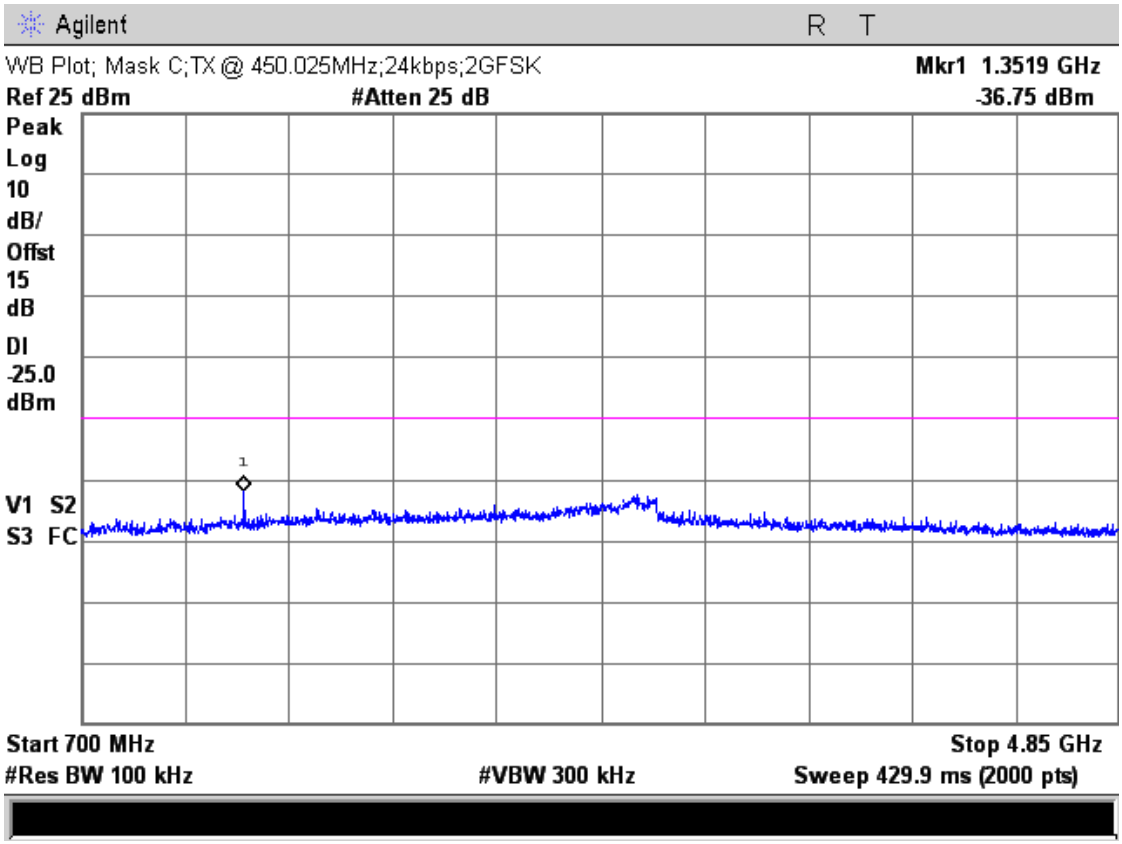
173.3 MHz; Worst case Mask E limit (Limit of 55*LOG(P in Watts)) or -25 dBm



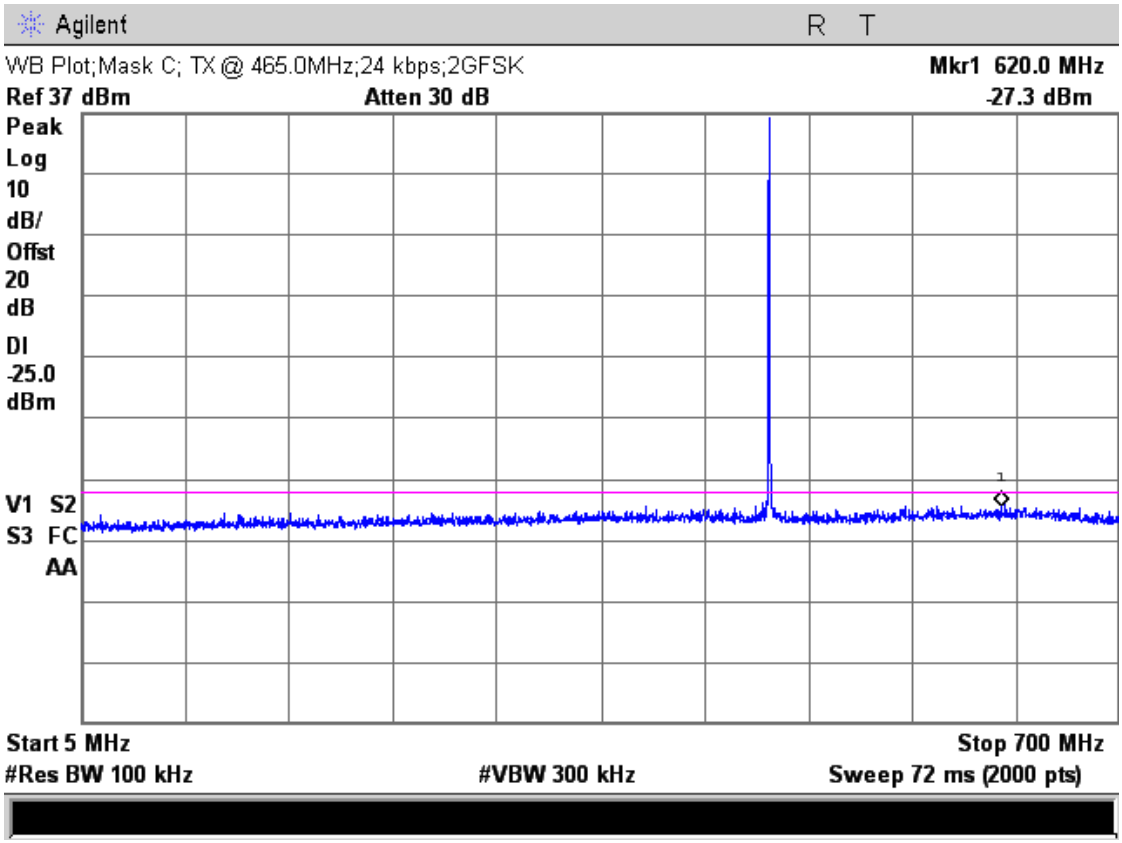
173.3 MHz; Worst case Mask E limit (Limit of 55*LOG(P in Watts)) or -25 dBm



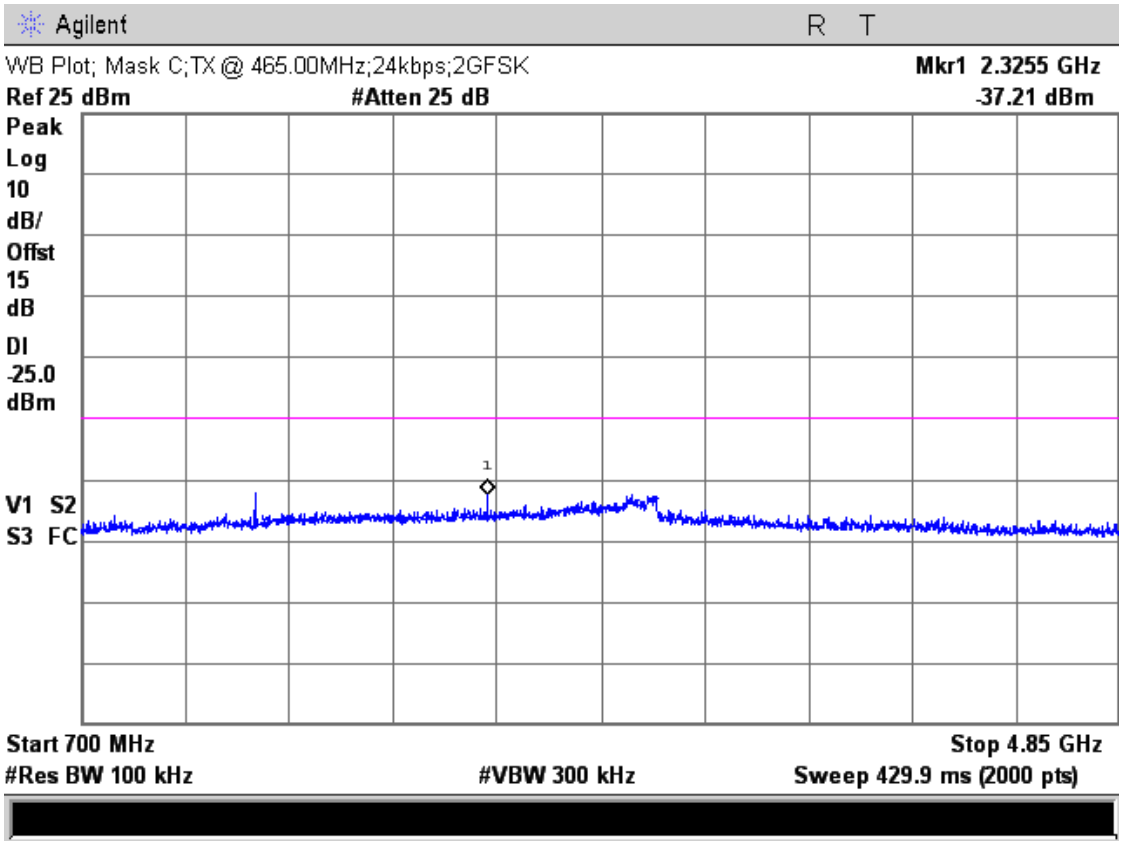
450 MHz; Worst case Mask E limit (Limit of 55*LOG(P in Watts)) or -25 dBm



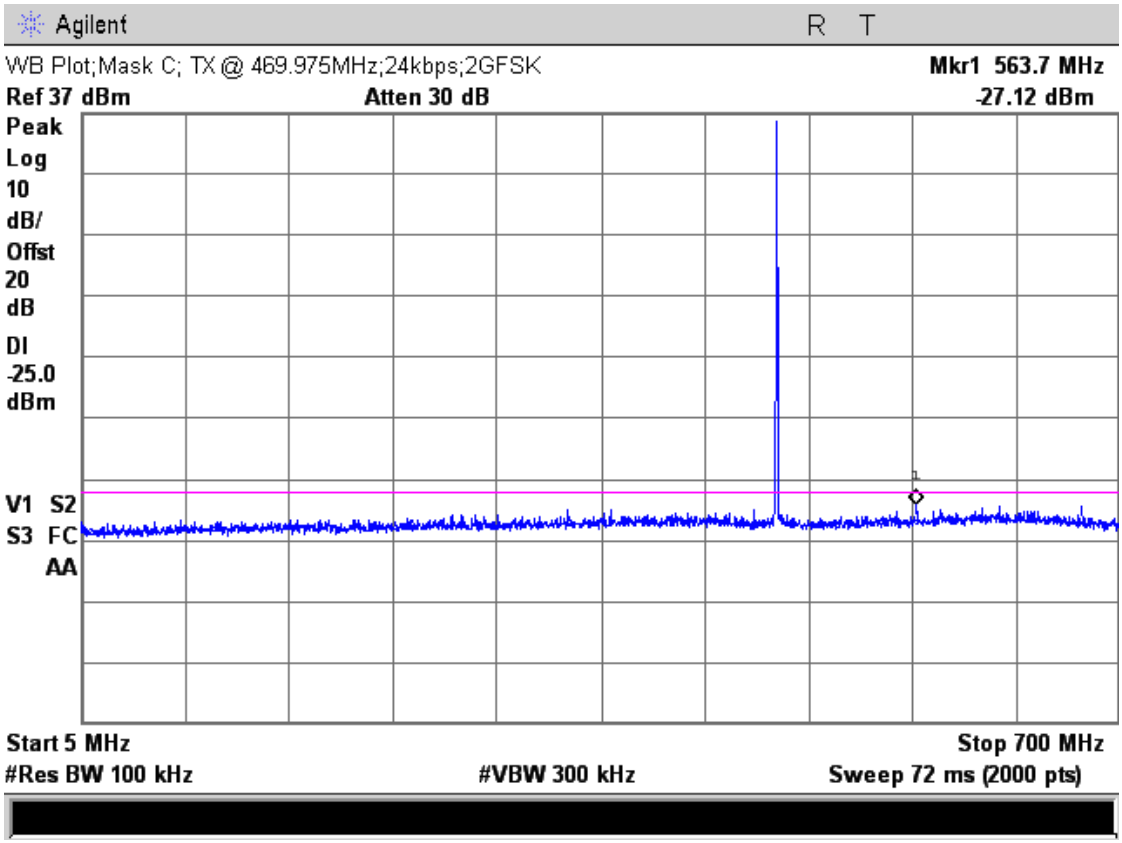
450 MHz; Worst case Mask E limit (Limit of 55*LOG(P in Watts)) or -25 dBm



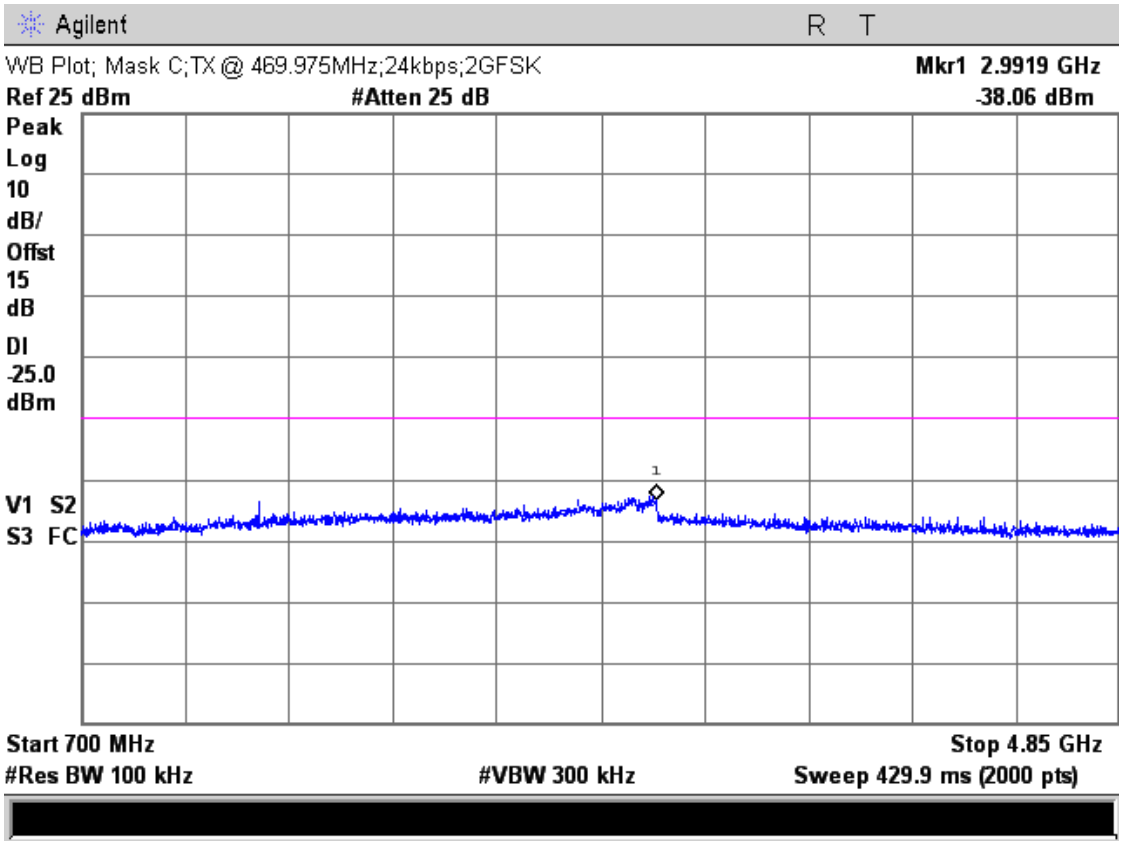
465 MHz; Worst case Mask E limit (Limit of 55*LOG(P in Watts)) or -25 dBm



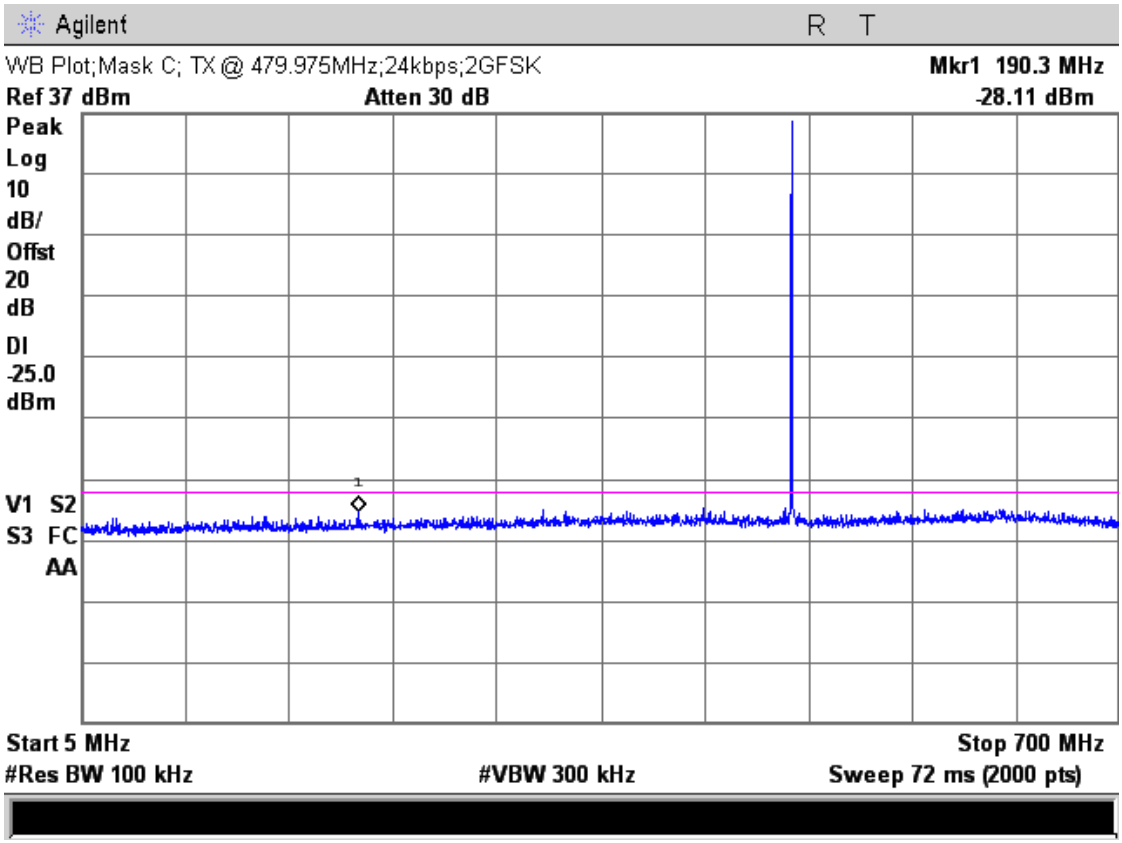
465 MHz; Worst case Mask E limit (Limit of 55*LOG(P in Watts)) or -25 dBm



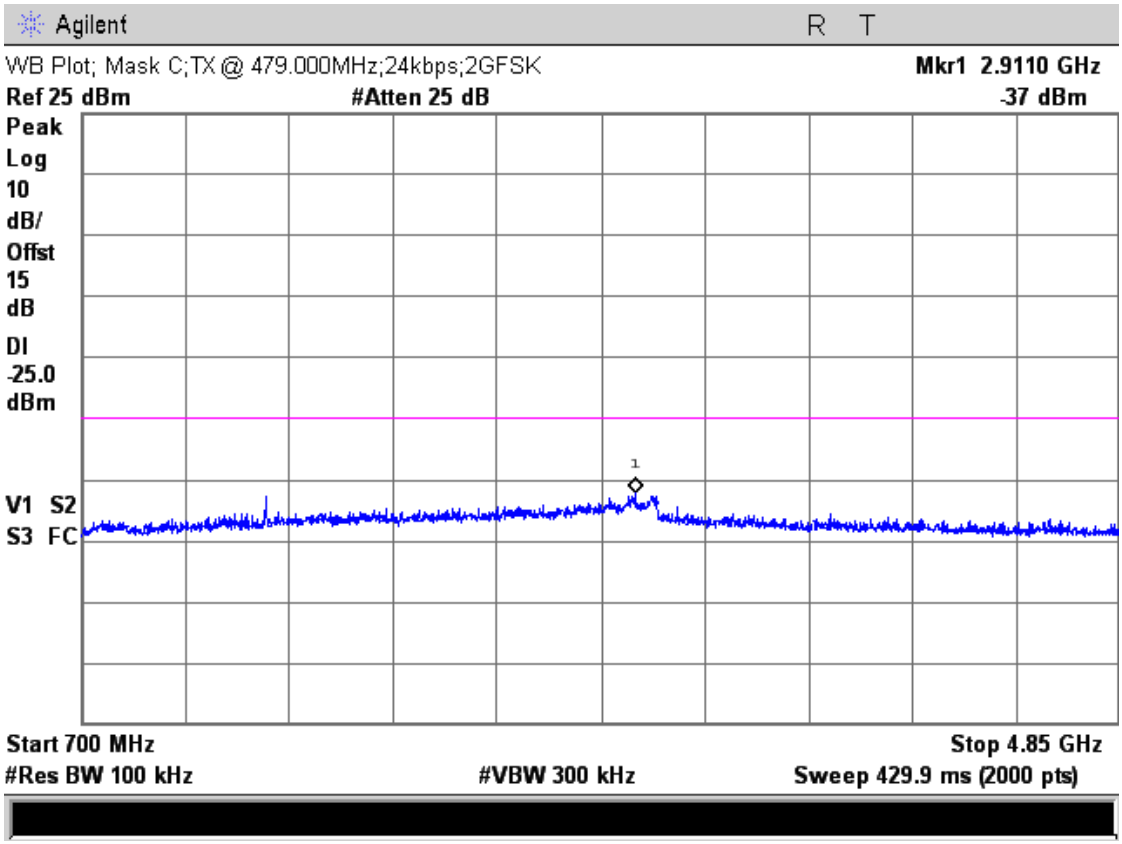
470 MHz; Worst case Mask E limit (Limit of 55*LOG(P in Watts)) or -25 dBm



450 MHz; Worst case Mask E limit (Limit of 55*LOG(P in Watts)) or -25 dBm



479 MHz; Worst case Mask E limit (Limit of 55*LOG(P in Watts)) or -25 dBm

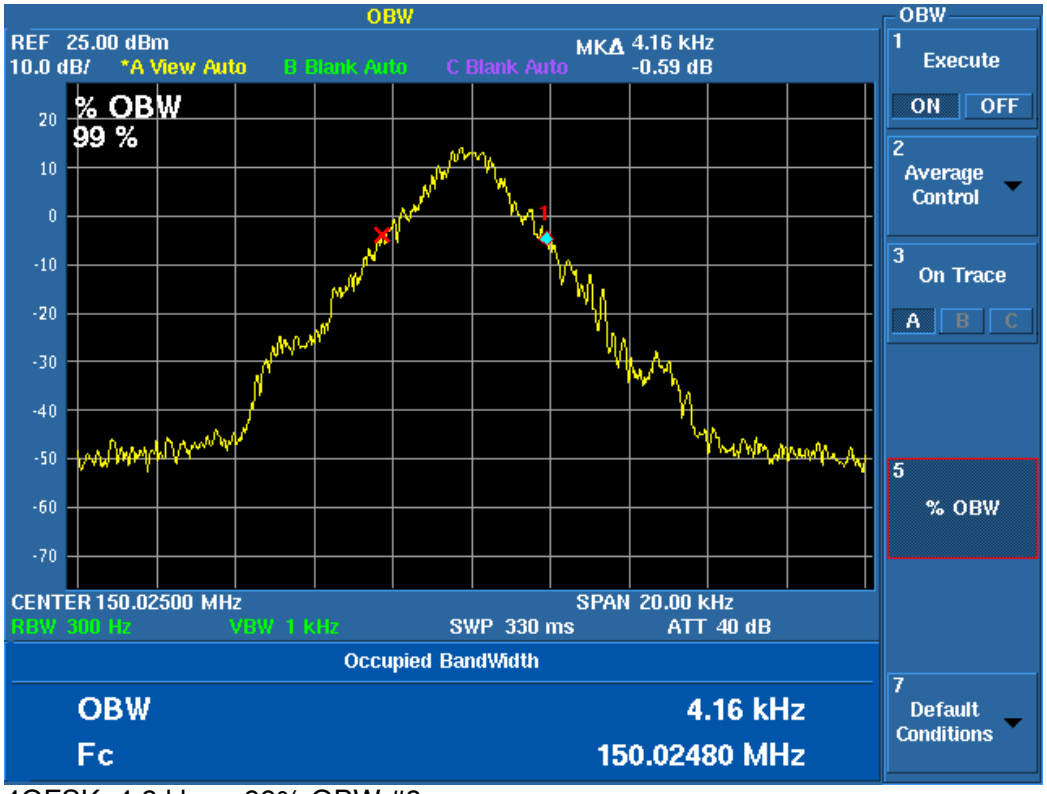


479 MHz; Worst case Mask E limit (Limit of 55*LOG(P in Watts)) or -25 dBm
Judgement: Pass

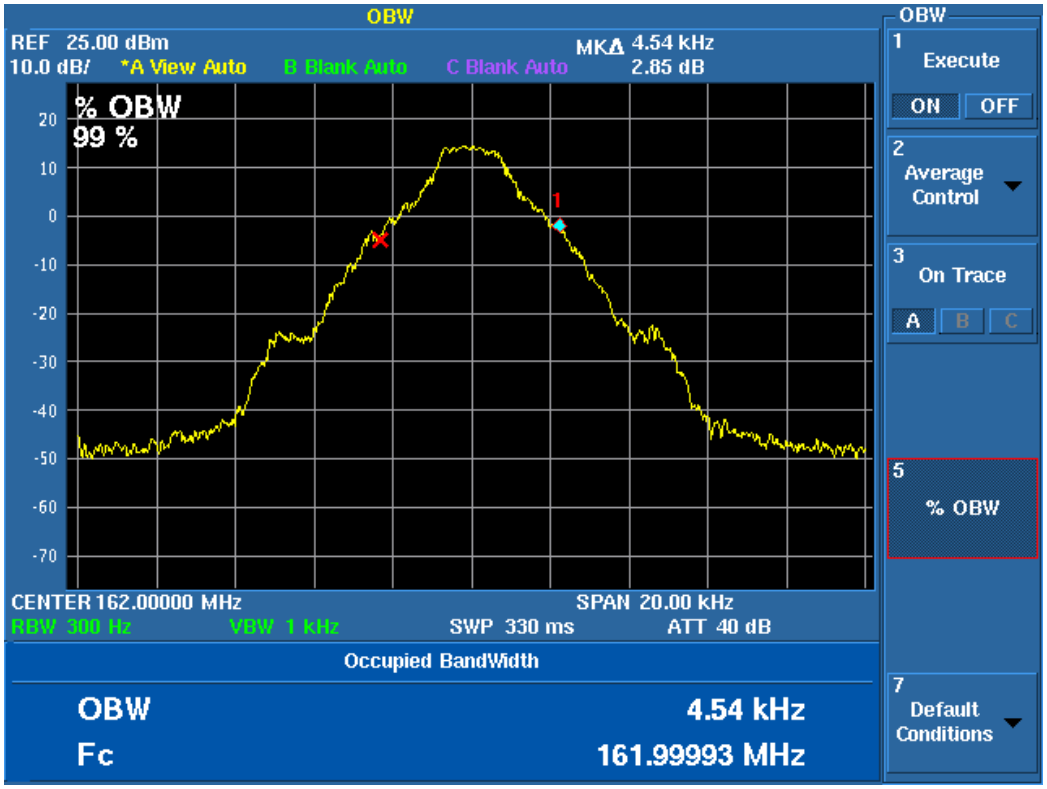
10.3 Occupied Bandwidth

Model	37337	Specification	FCC part 90
Test Date	November 9, 2017	Test Personnel	Richard Tichgelaar
Test Equipment	Spectrum Analyzer (REC-43)		

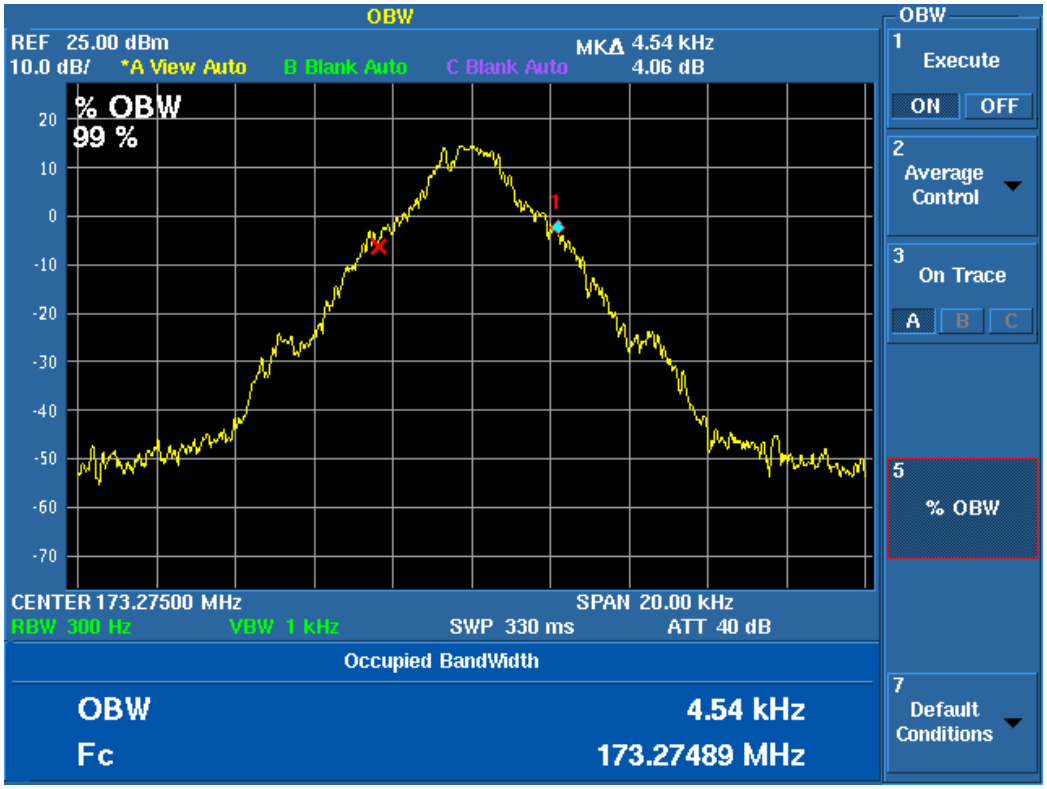
Channel MHz	6.25 kHz 4.8 kbps	12.5 kHz 9.6 kbps	25 kHz 24 kbps	25 kHz 19.2 kbps	12.5 kHz 9.6 kbps
	99% OBW; All results in kHz				
150.025	4.16	5.4	8.32	11.68	7.24
162.000	4.54	5.28	8.36	11.80	7.36
173.300	4.54	5.38	8.48	11.64	7.04
450.0250	4.44	5.4	8.20	11.56	7.20
465.000	4.56	5.32	8.20	11.80	7.28
469.975	4.54	5.4	7.76	11.68	7.12
479.000	4.42	5.38	8.20	11.56	7.24



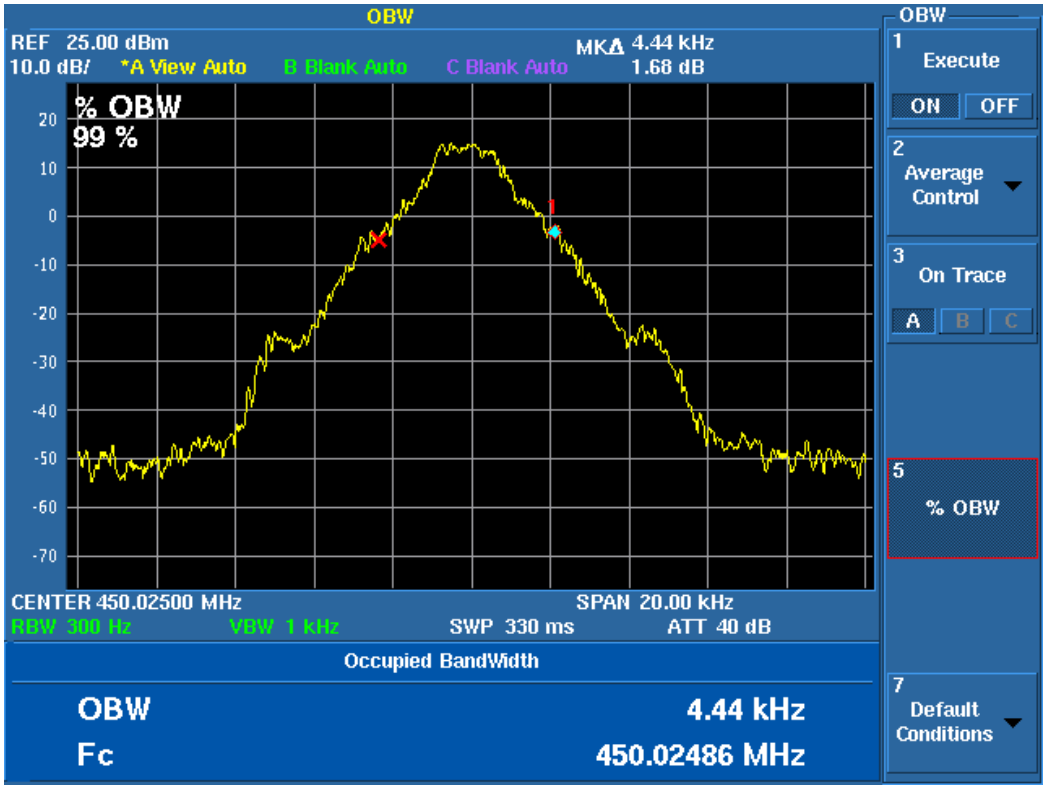
4GFSK; 4.8 kbps; 99% OBW #8



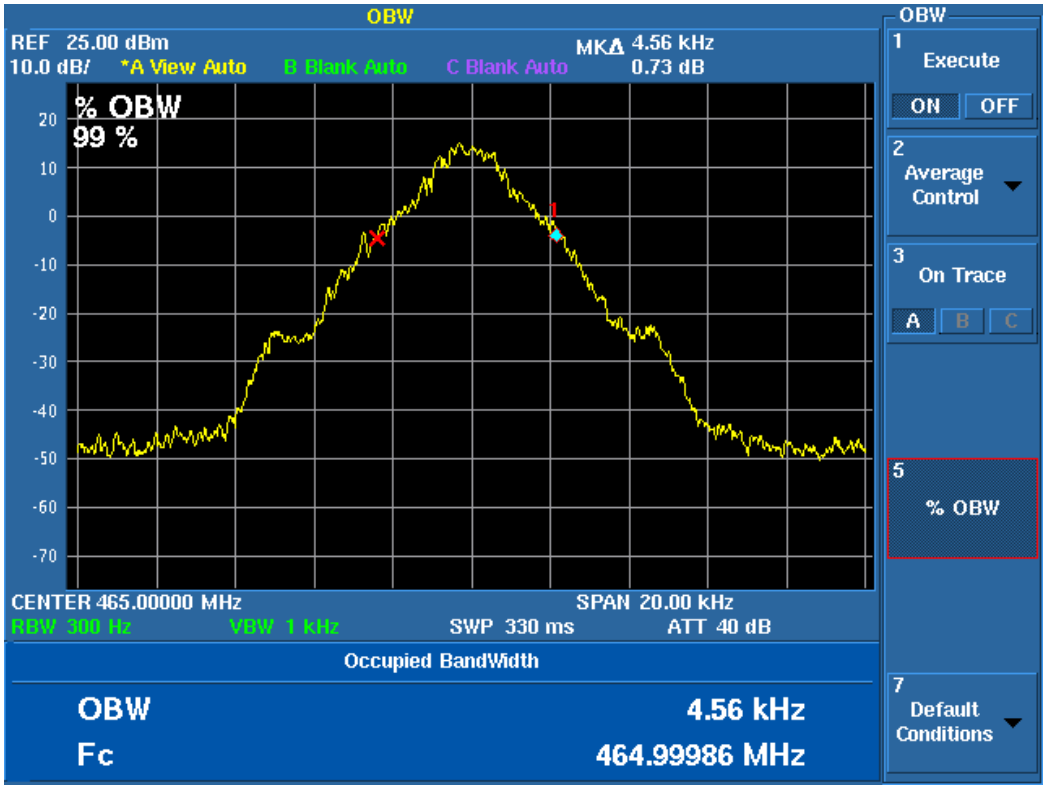
4GFSK; 4.8 kbps; 99% OBW #9



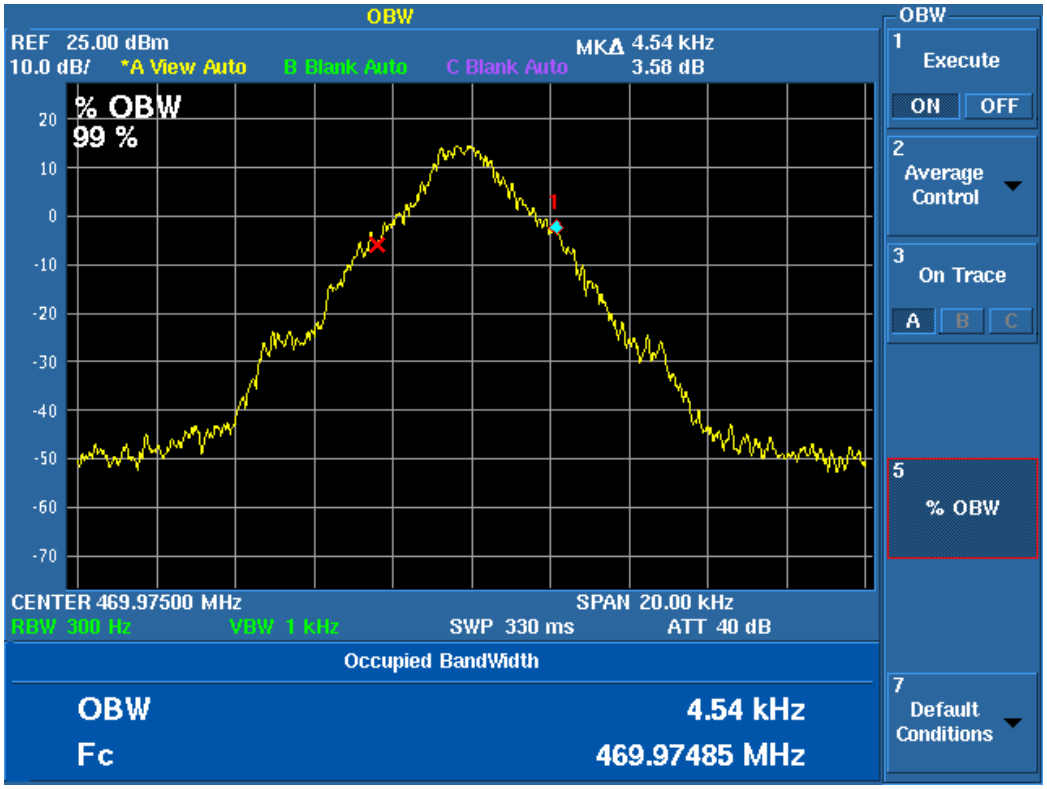
4GFSK; 4.8 kbps; 99% OBW #10



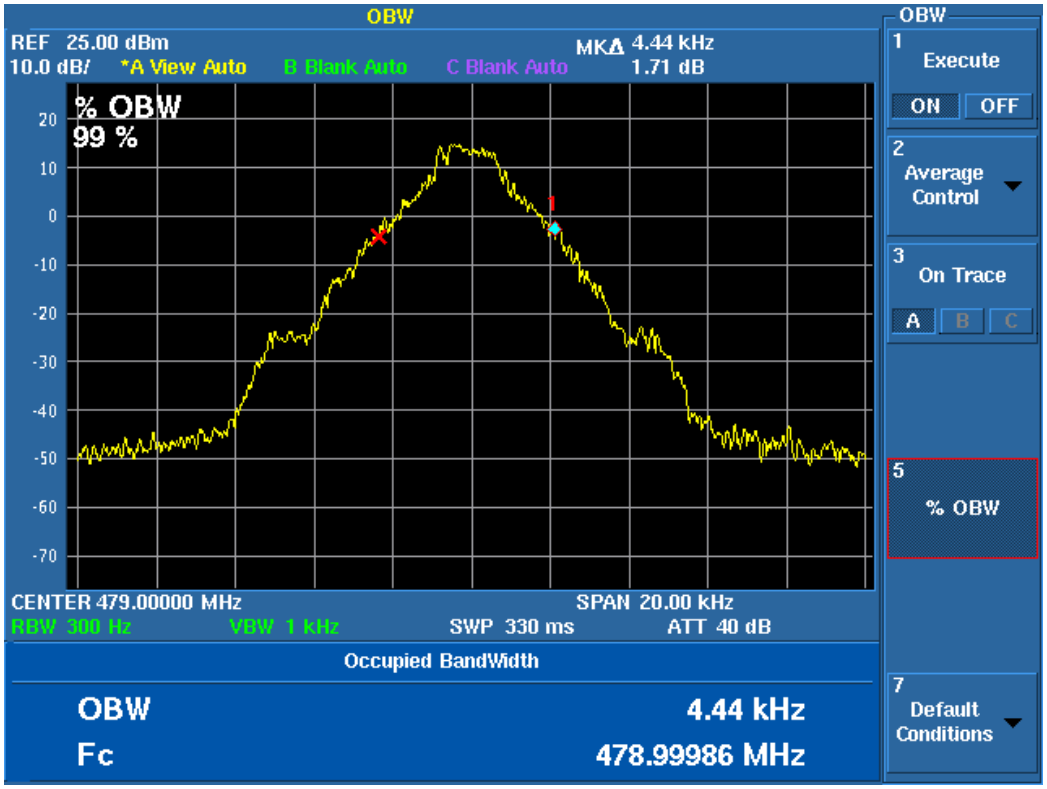
4GFSK; 4.8 kbps; 99% OBW #11



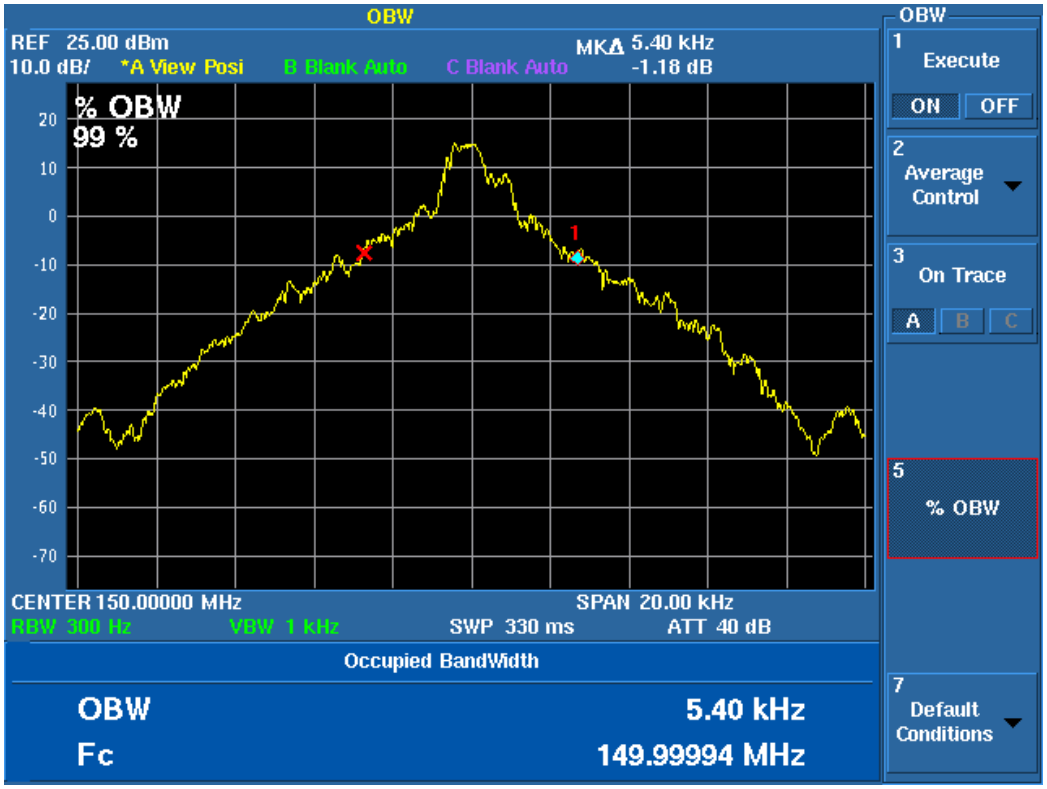
4GFSK; 4.8 kbps; 99% OBW #12



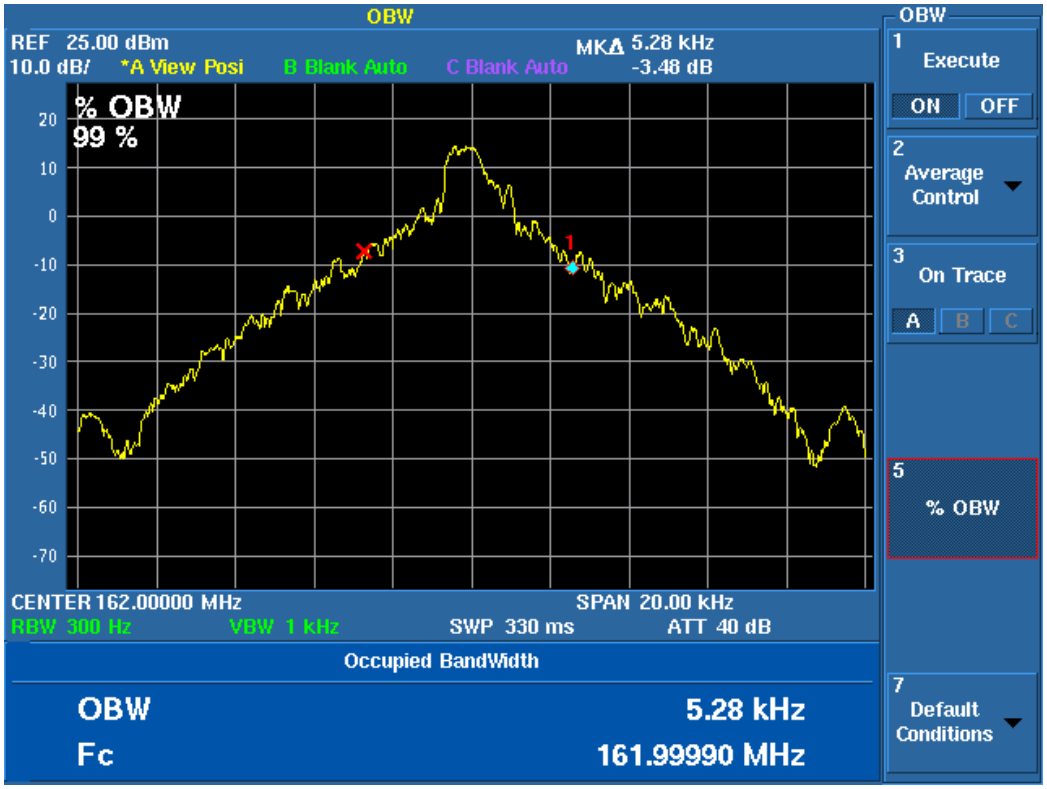
4GFSK; 4.8 kbps; 99% OBW #13



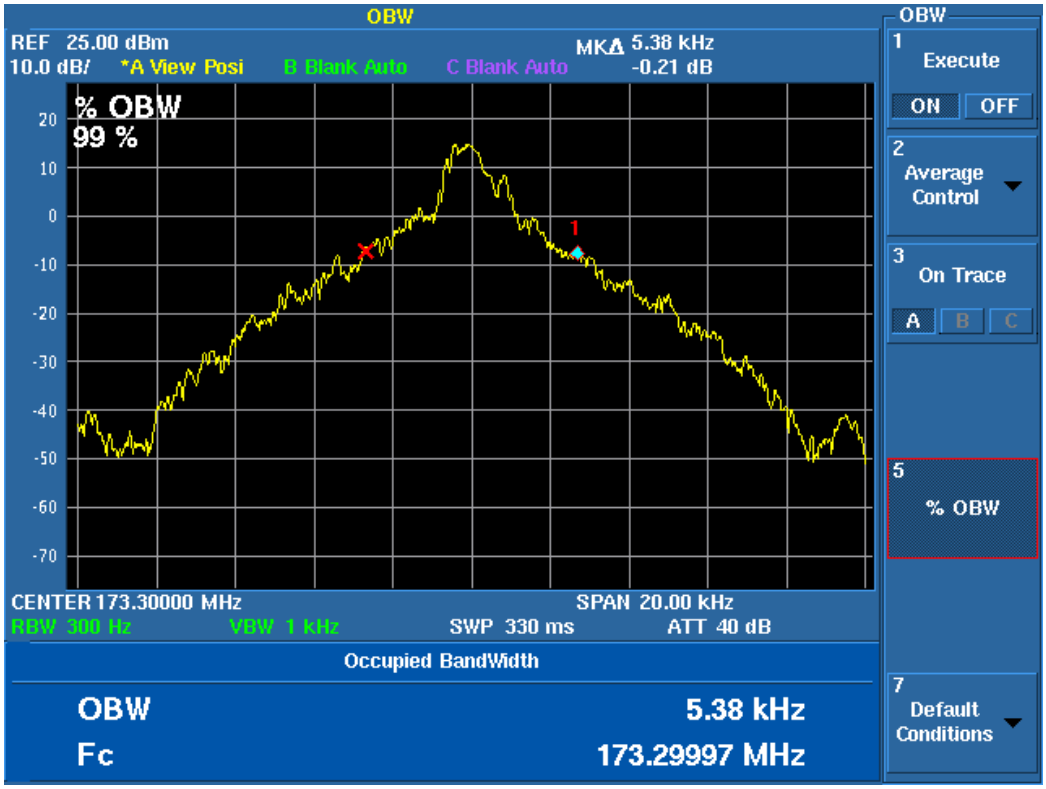
4GFSK; 4.8 kbps; 99% OBW #14



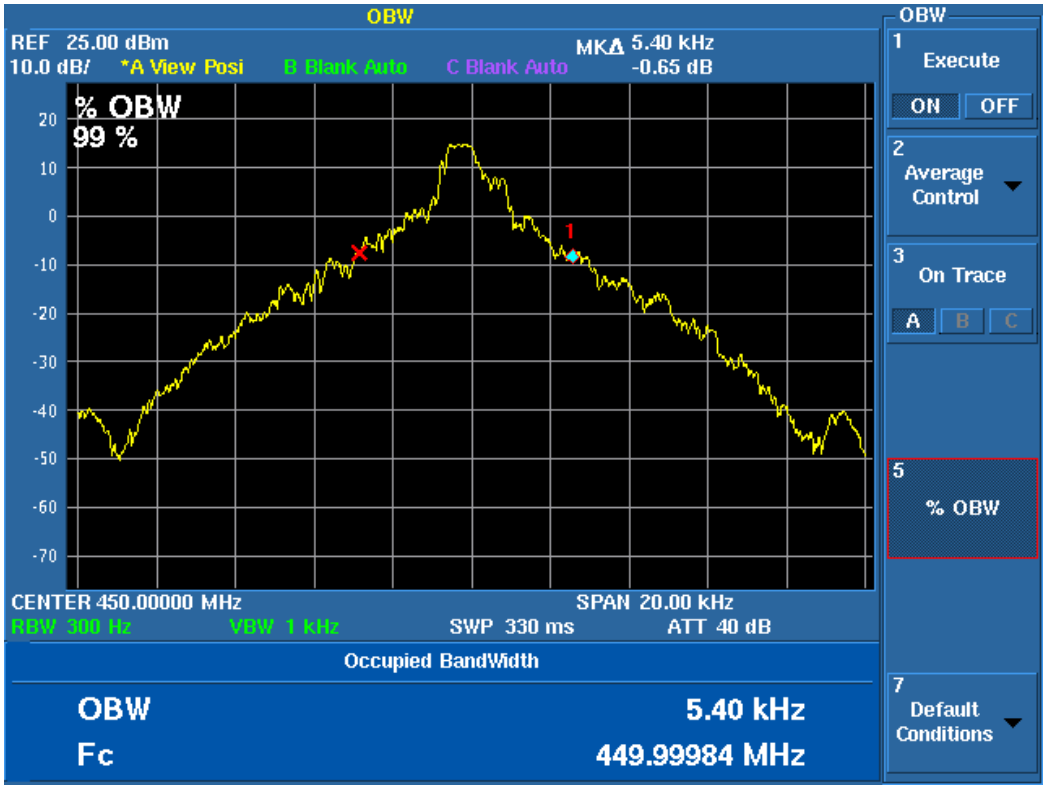
2GFSK; 9.6 kbps; 99% OBW #22



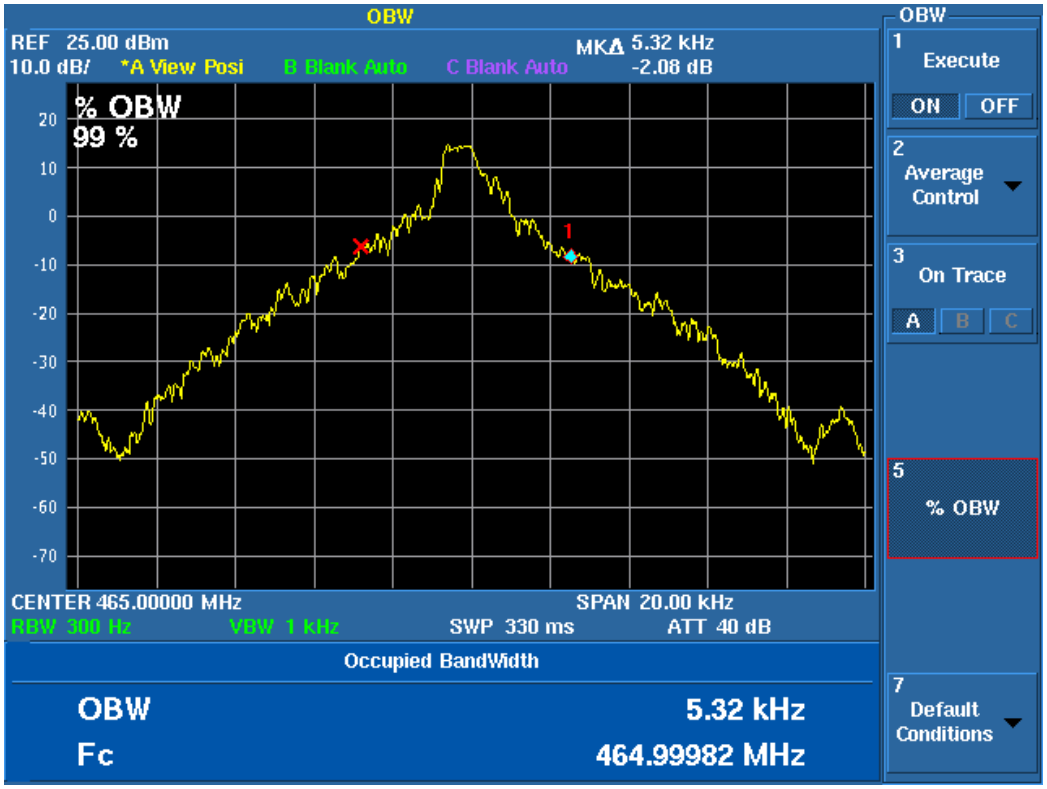
2GFSK; 9.6 kbps; 99% OBW #23



2GFSK; 9.6 kbps; 99% OBW #24



2GFSK; 9.6 kbps; 99% OBW #25



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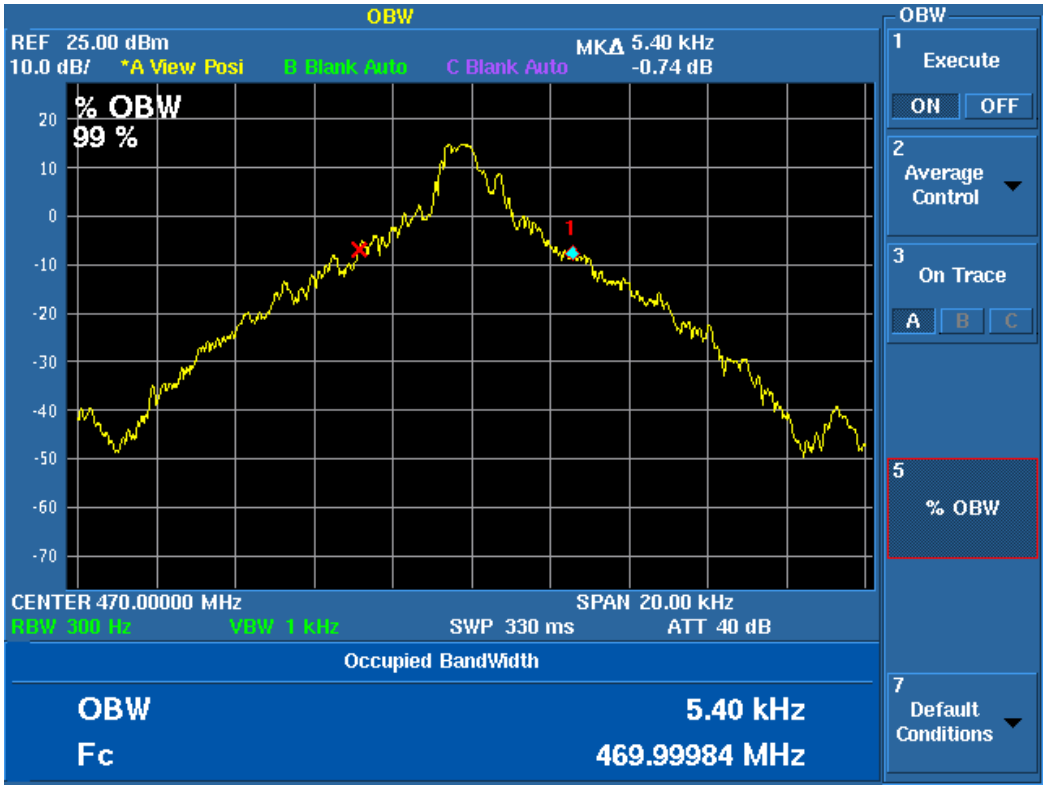
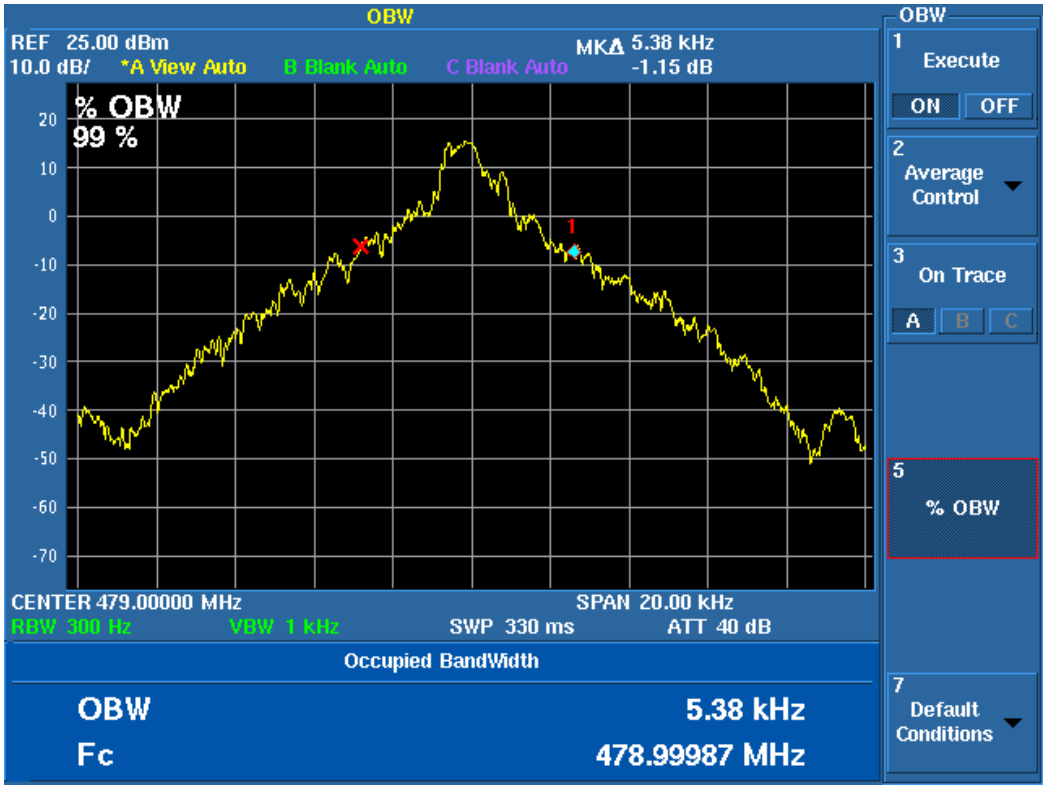
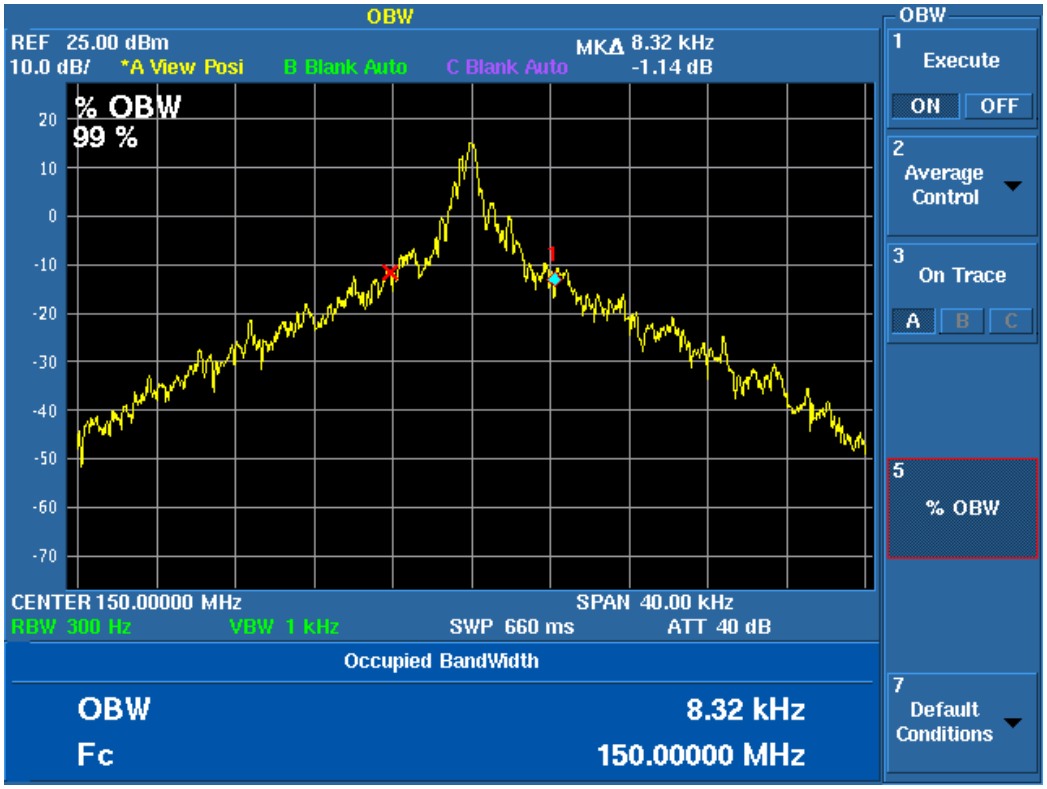


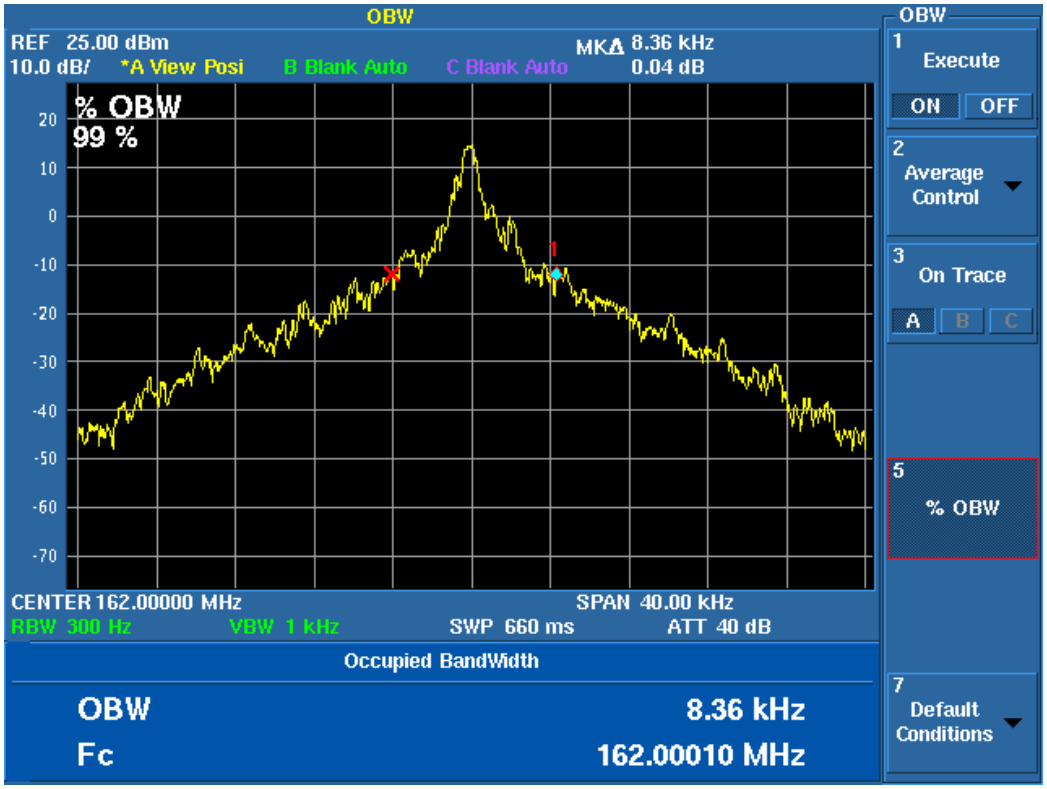
2GFSK; 9.6 kbps; 99% OBW #27



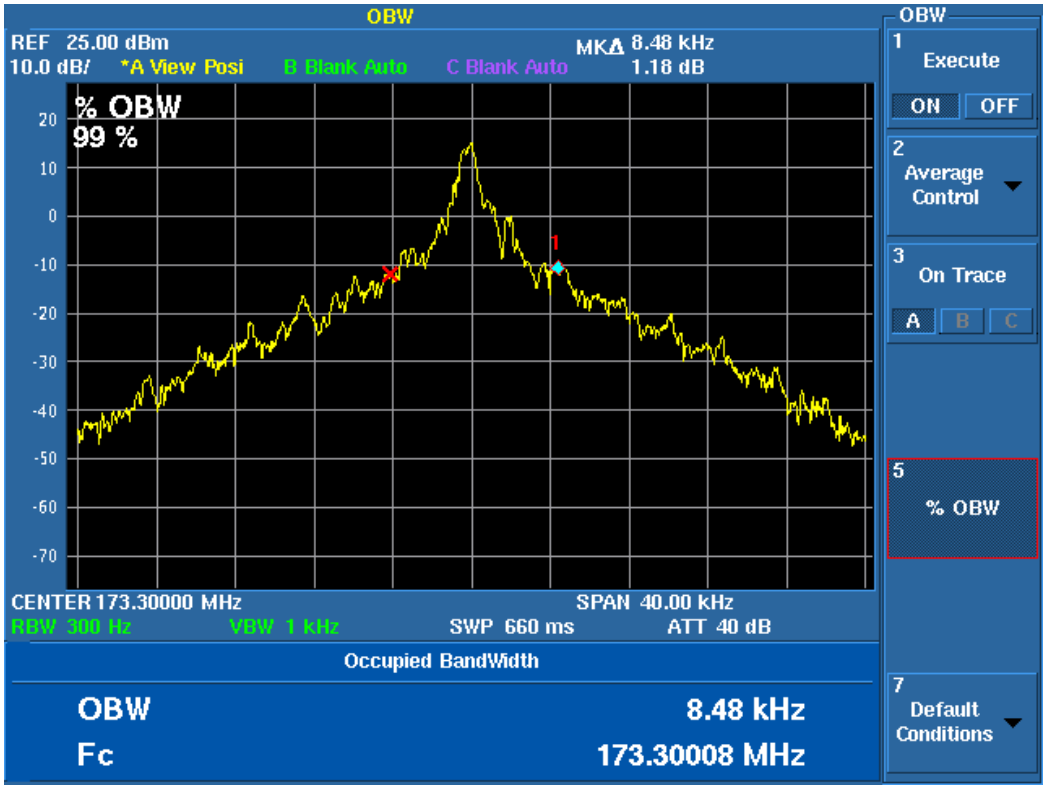
2GFSK; 9.6 kbps; 99% OBW #28



2GFSK; 24 kbps; 99% OBW #36



2GFSK; 24 kbps; 99% OBW #37



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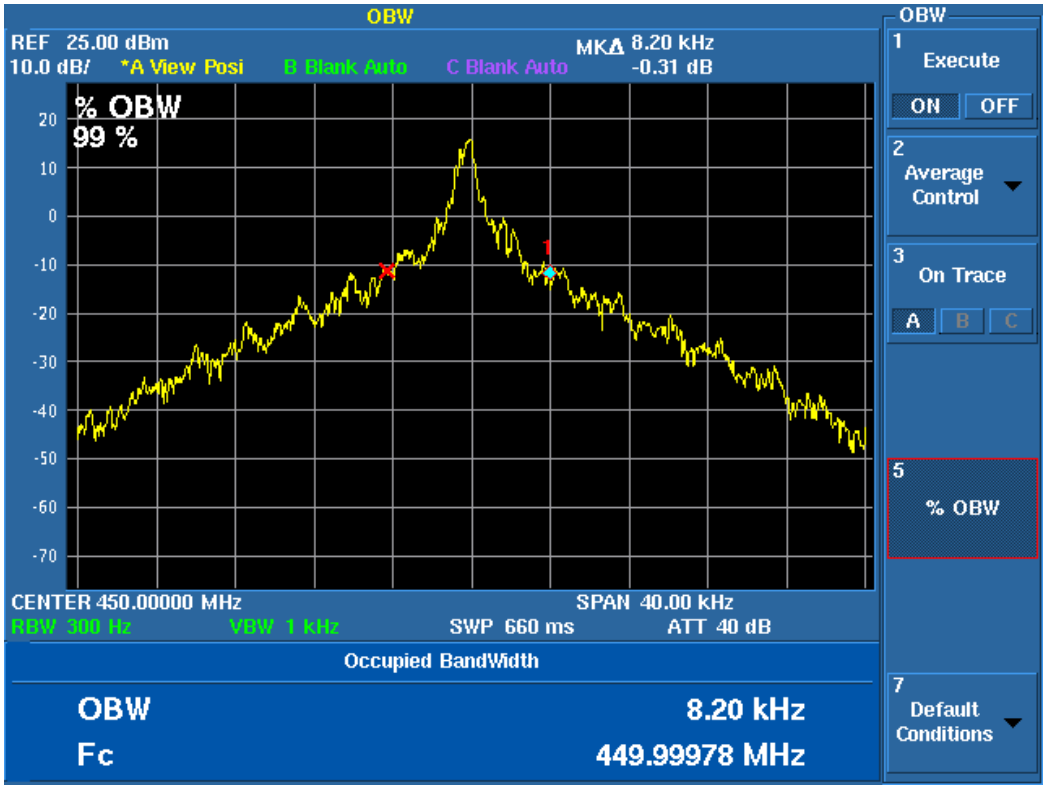
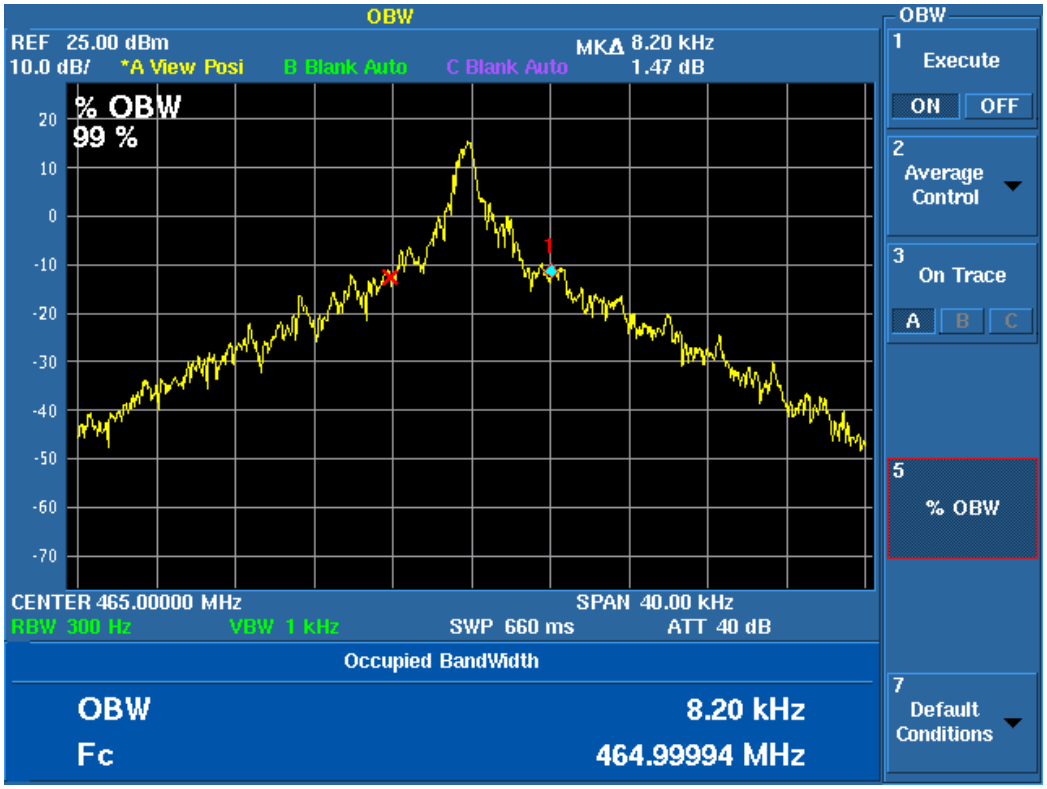
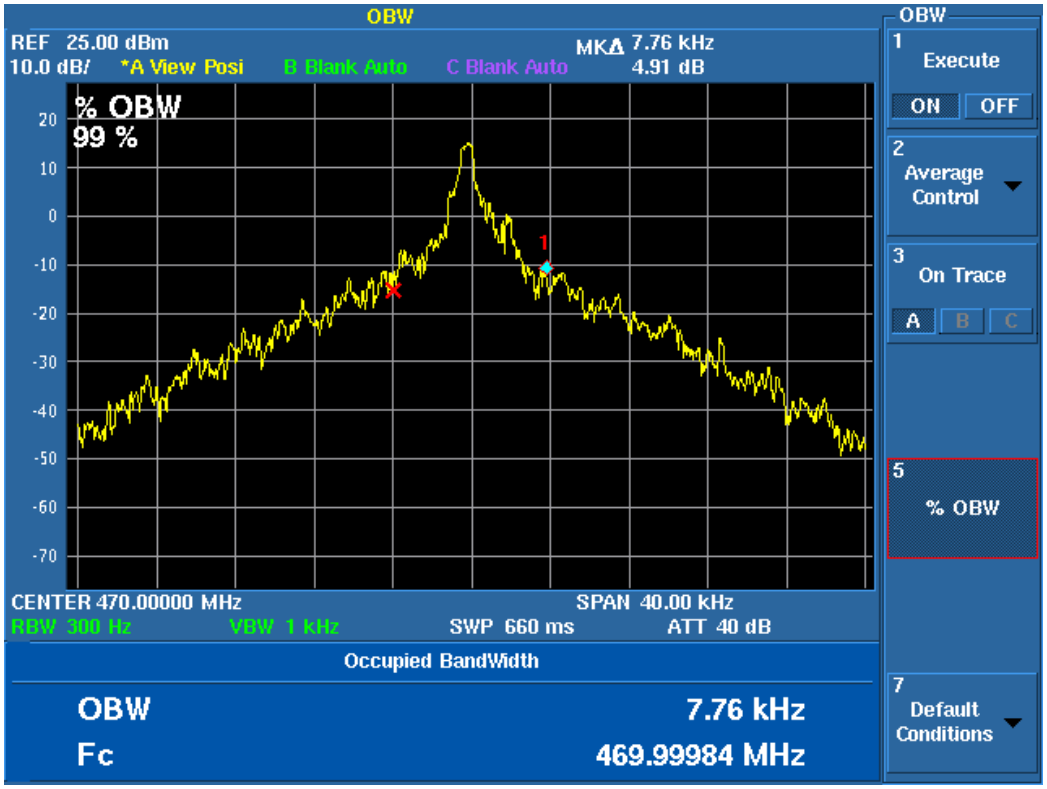


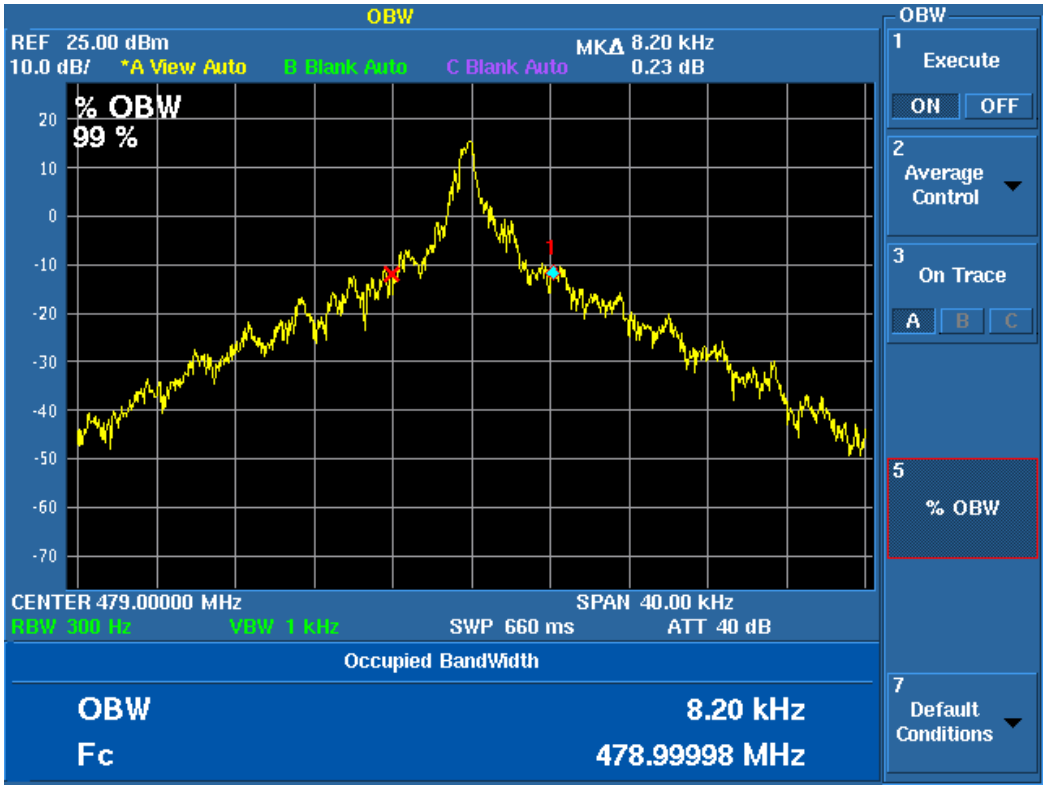
2GFSK; 24 kbps; 99% OBW #39



2GFSK; 25 kbps; 99% OBW #40

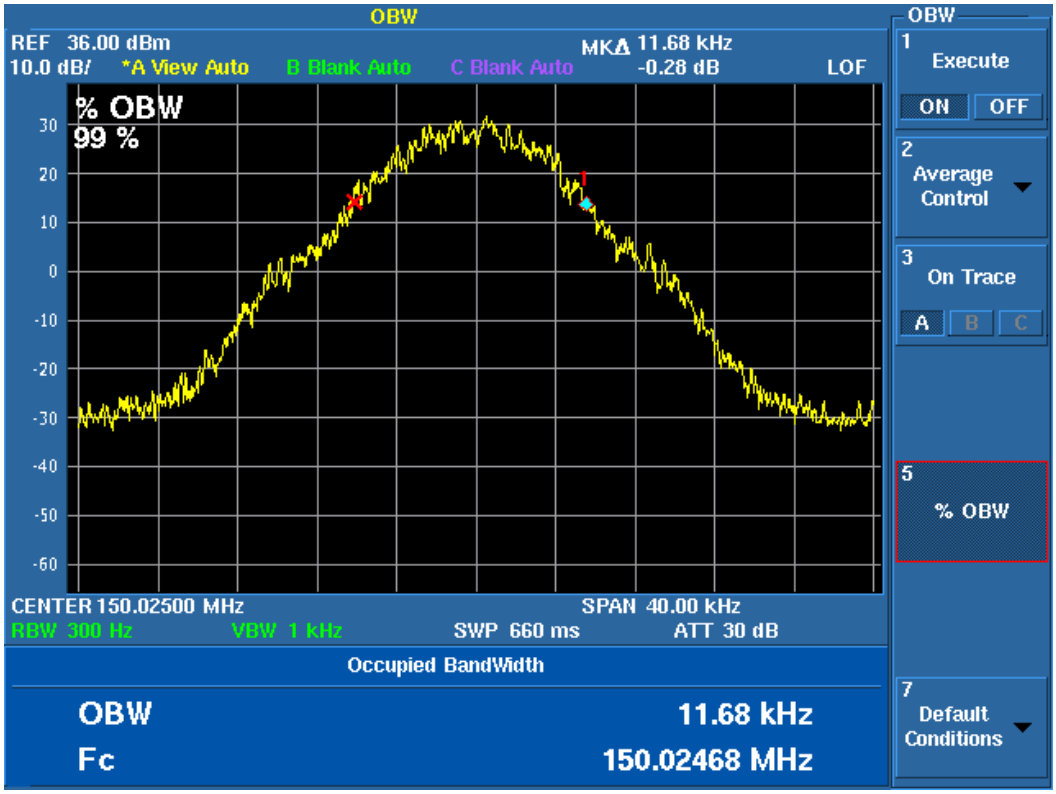


2GFSK; 25 kbps; 99% OBW #41

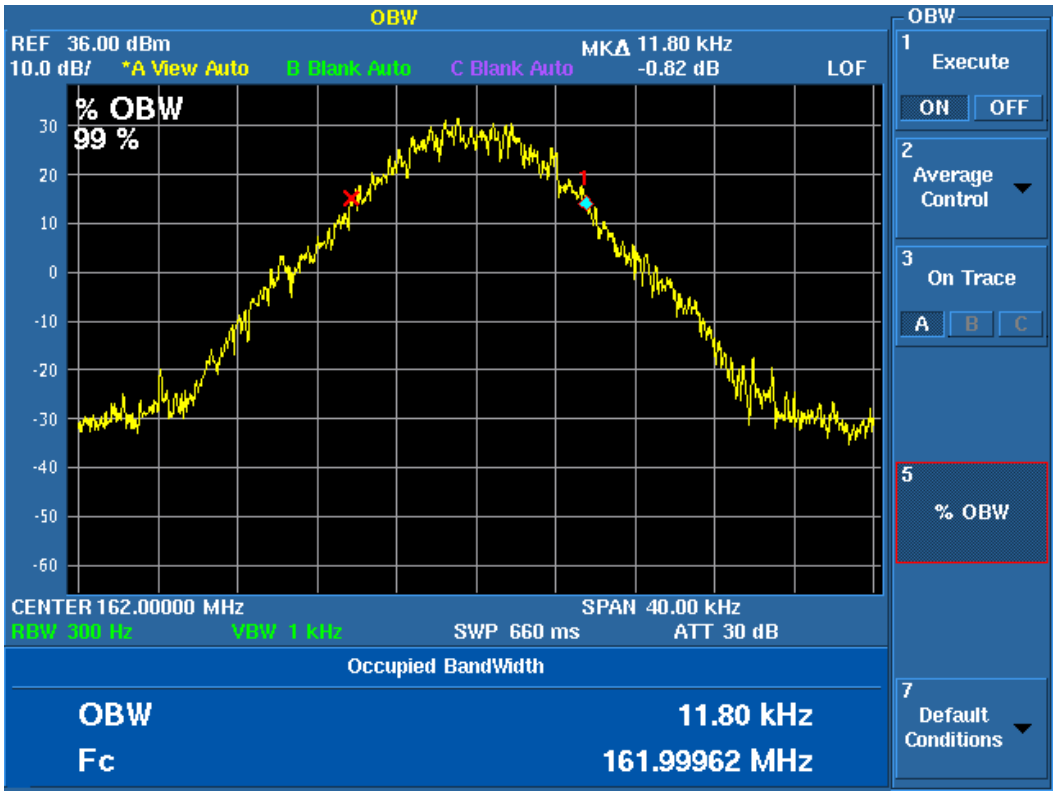


2GFSK; 25 kbps; 99% OBW #42

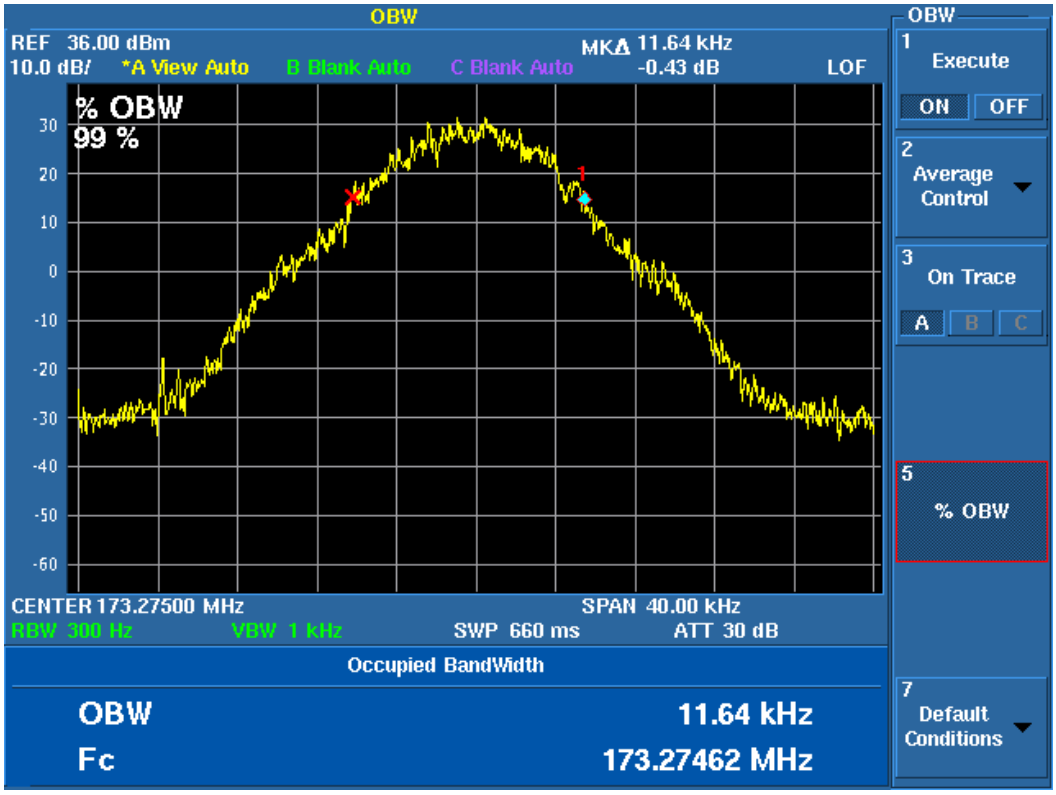
Test Date	February 6, 2018	Test Personnel	Richard Tichgelaar



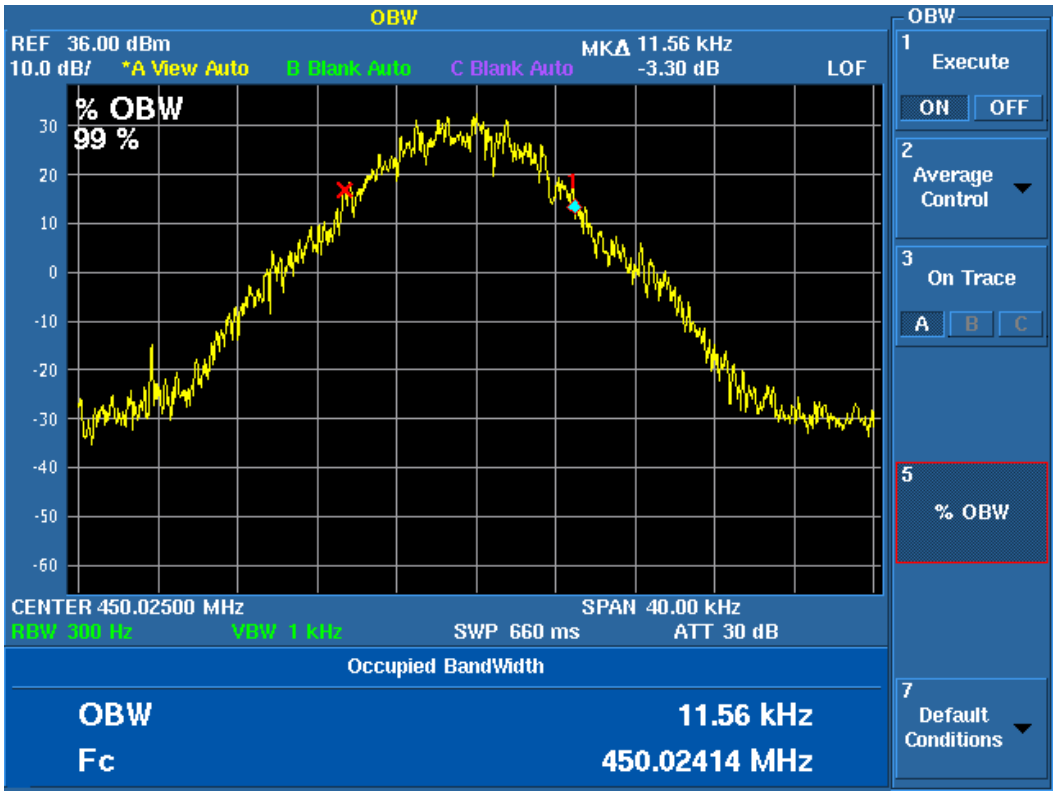
4GFSK; 19.2 kbps; 99% OBW #43



4GFSK; 19.2 kbps; 99% OBW #44



4GFSK; 19.2 kbps; 99% OBW #45



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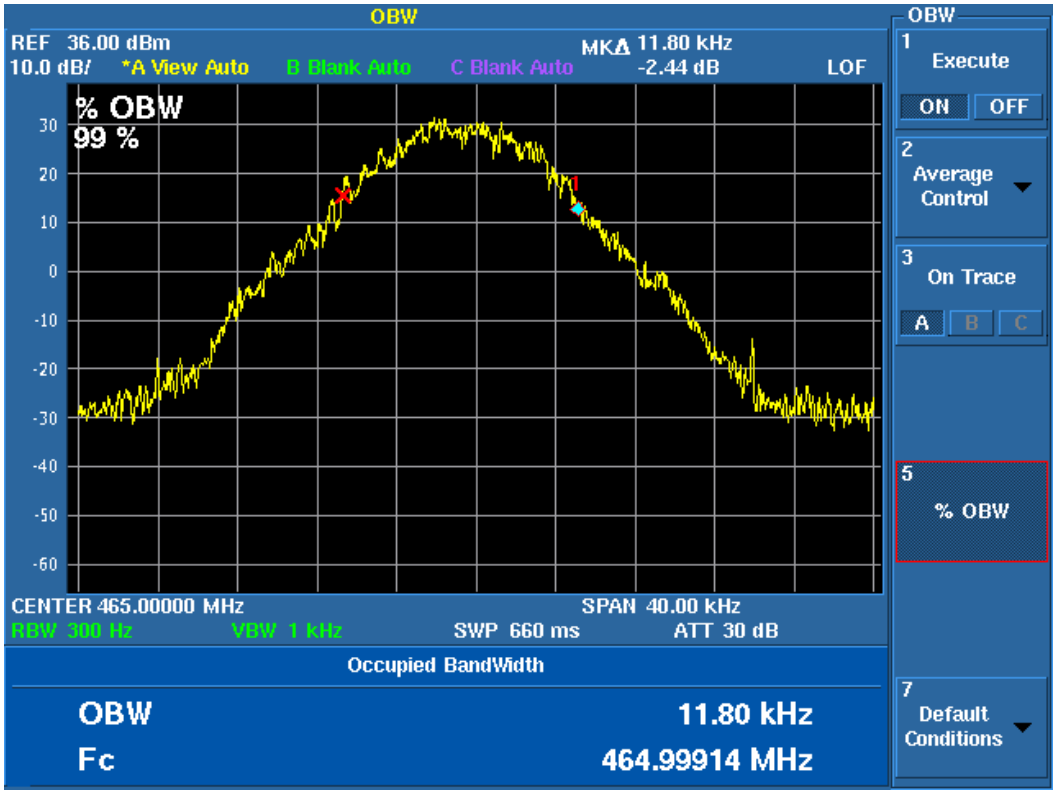

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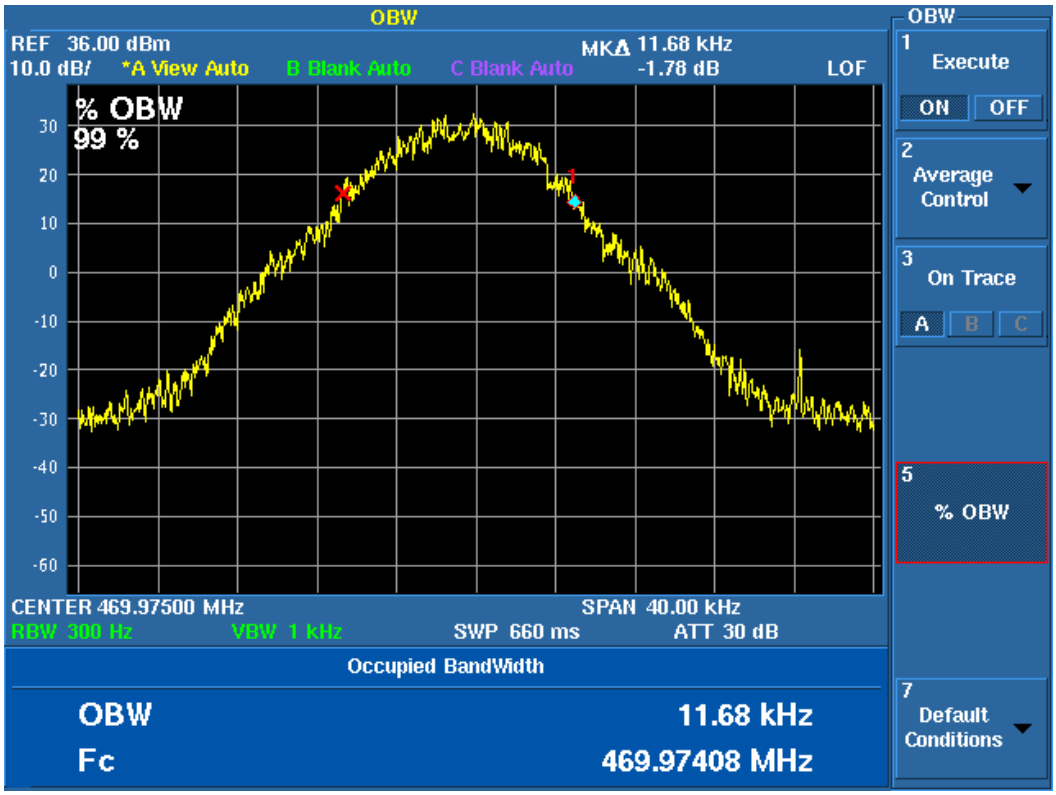

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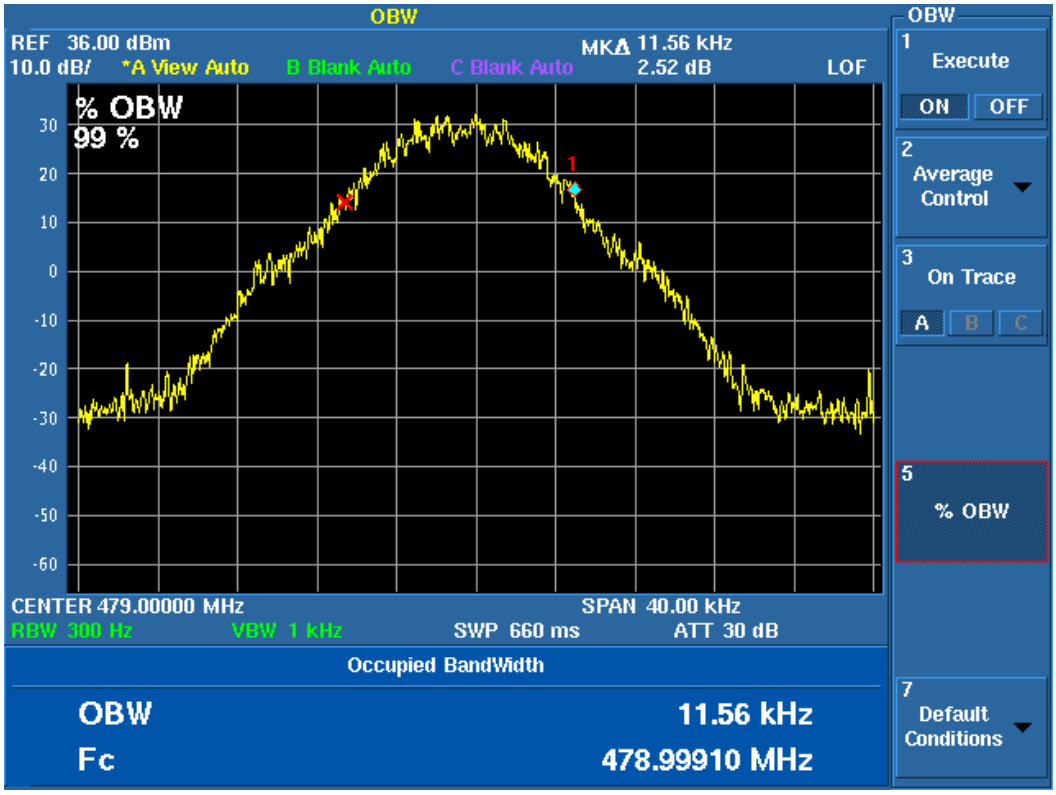

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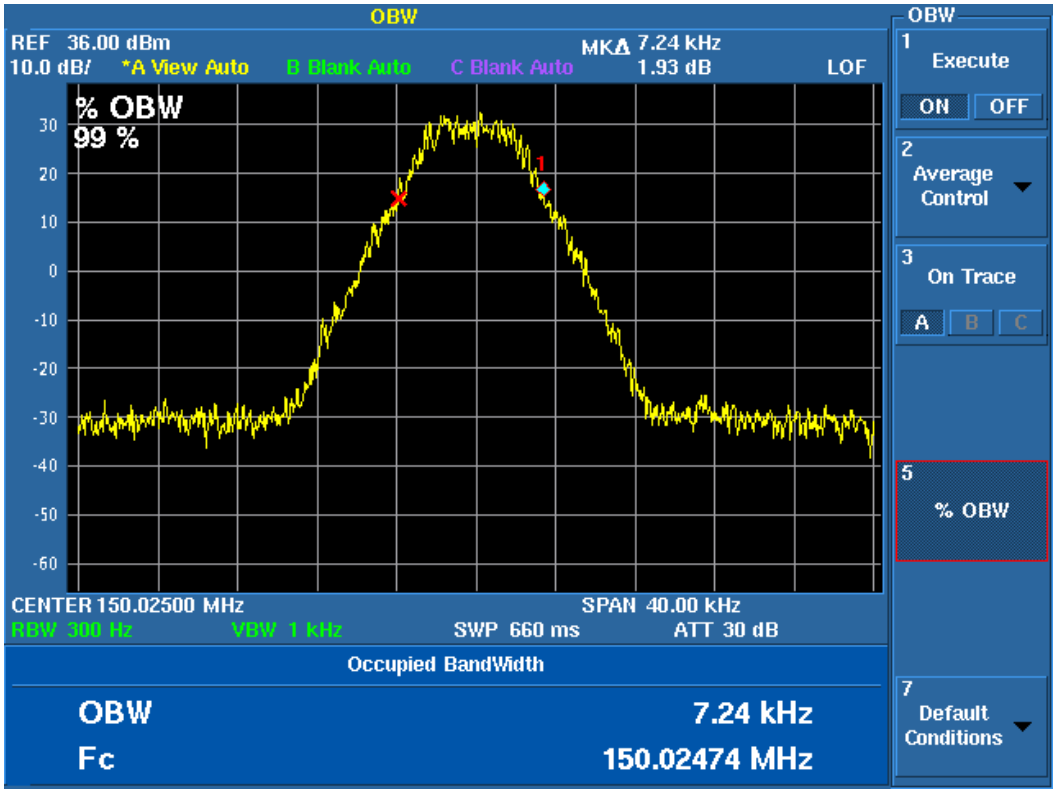
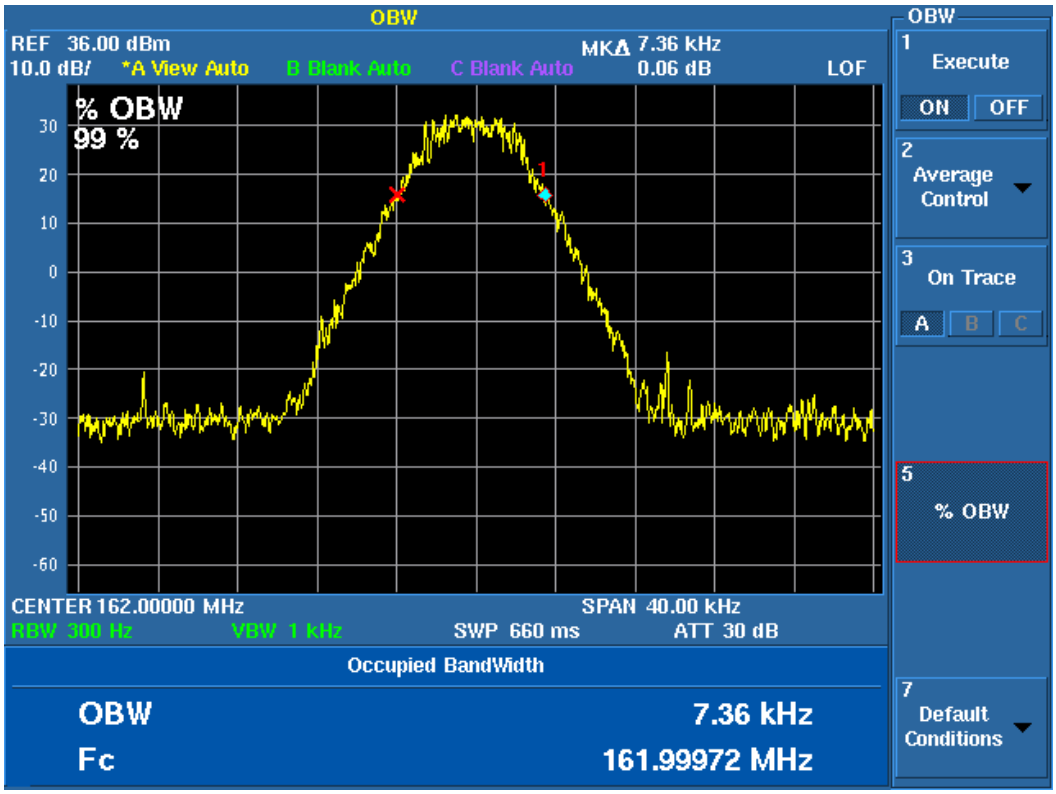
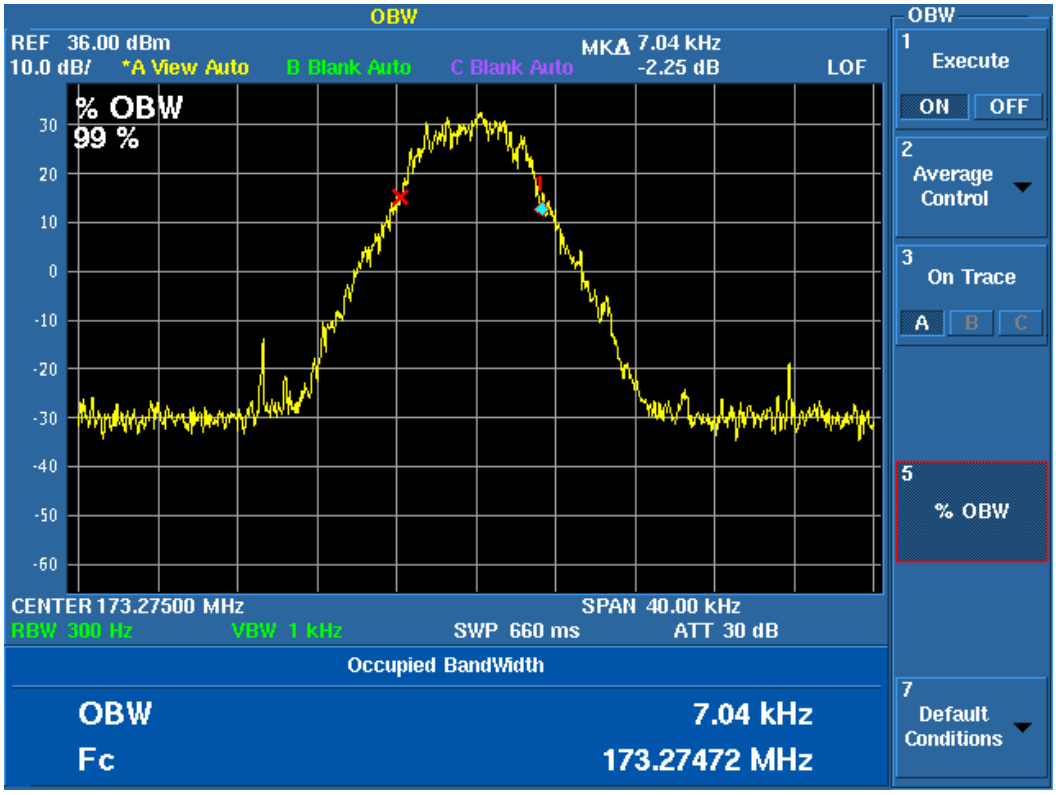
#017



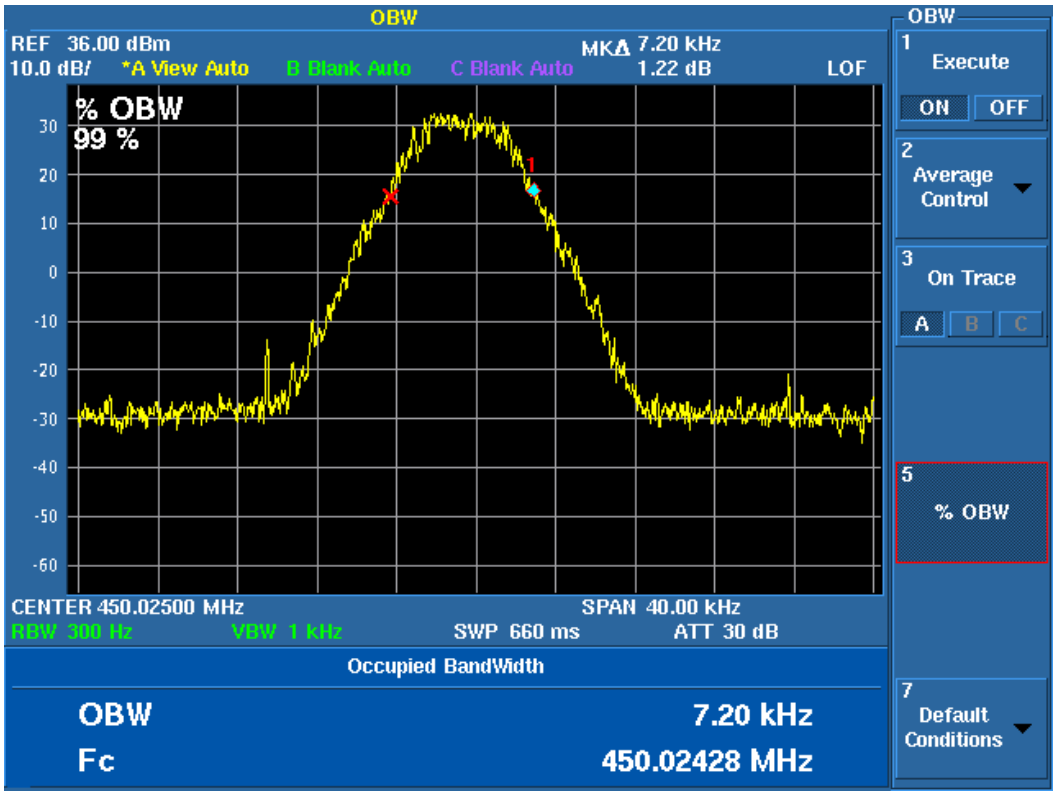
4GFSK; 9.6 kbps; 99% OBW #50



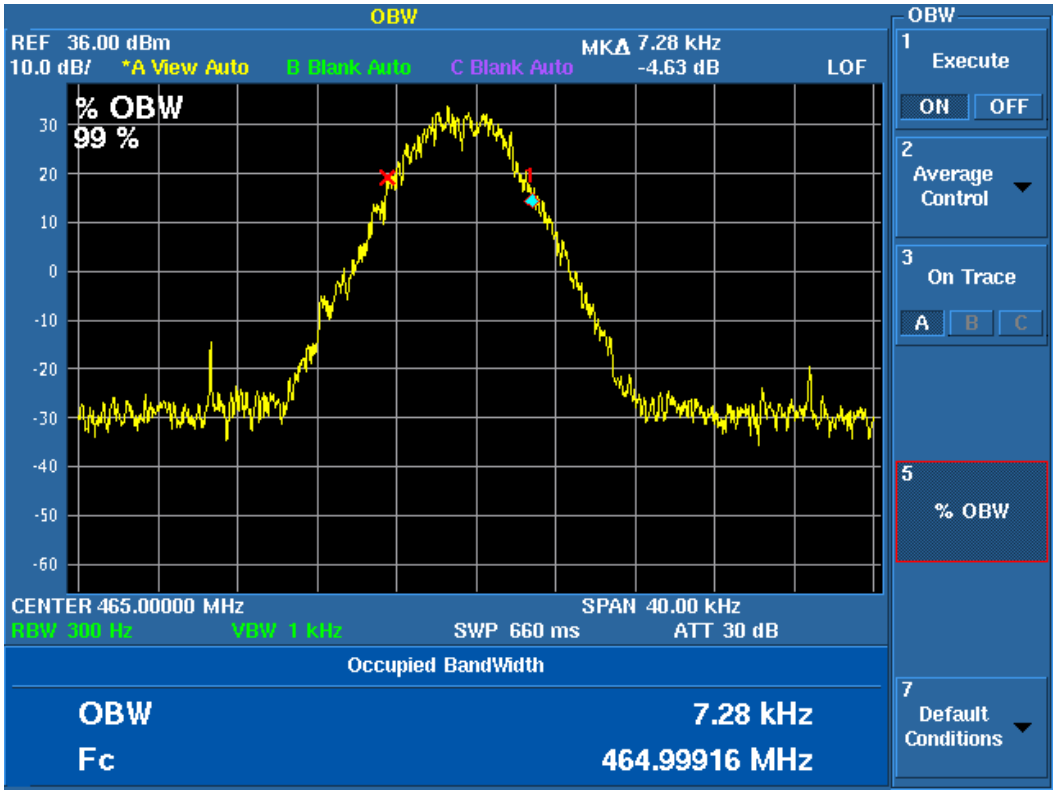
4GFSK; 9.6 kbps; 99% OBW #51



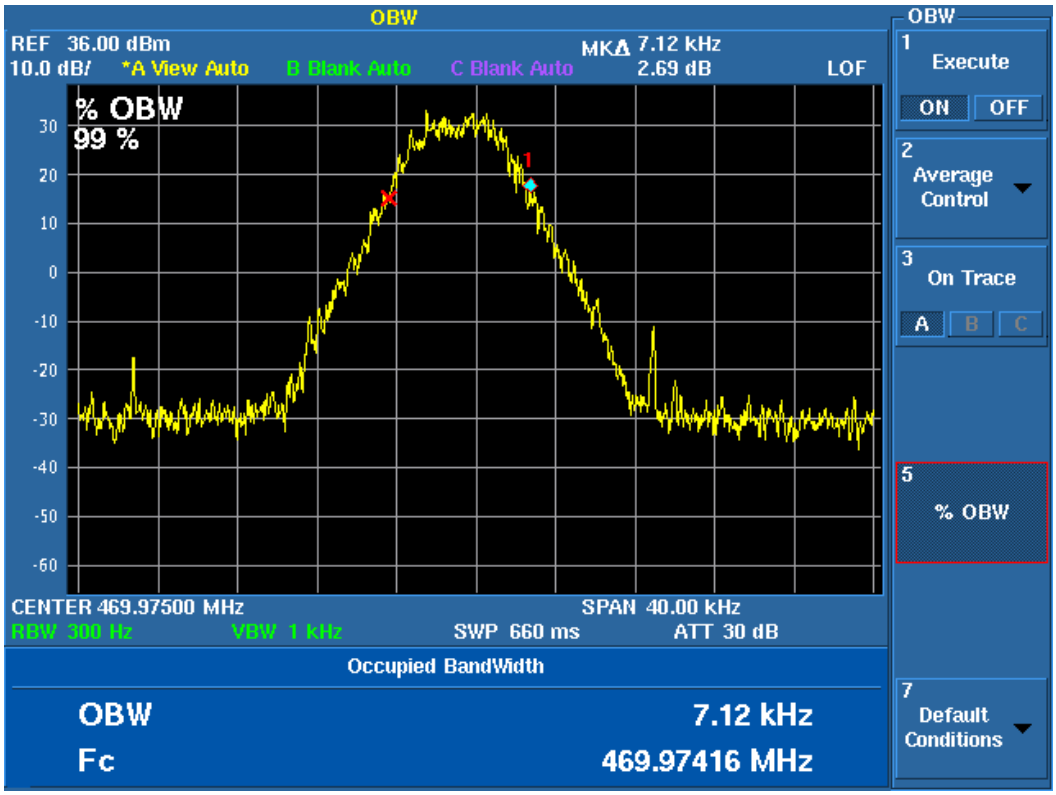
4GFSK; 9.6 kbps; 99% OBW #52



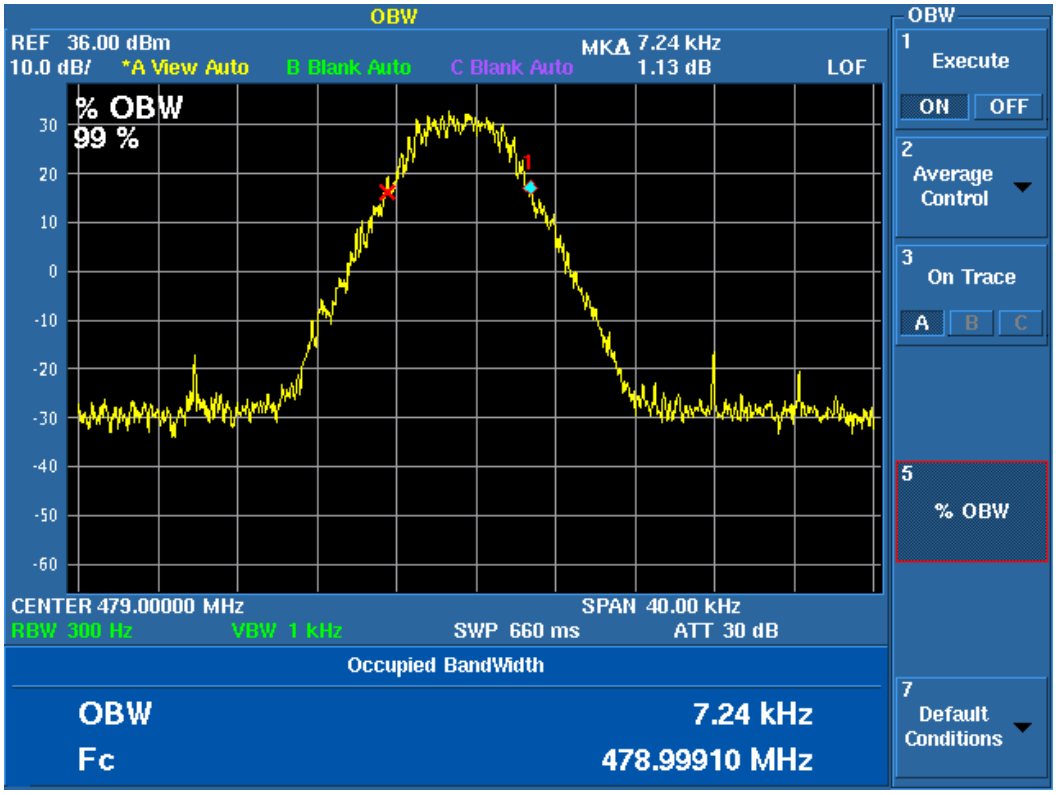
4GFSK; 9.6 kbps; 99% OBW #53



4GFSK; 9.6 kbps; 99% OBW #54



4GFSK; 9.6 kbps; 99% OBW #55



4GFSK; 9.6 kbps; 99% OBW #56

10.4 Field Strength of Unwanted Spurious Radiation

10.4.1 Test Procedures

Radiated emission measurements in the Restricted bands were performed with linearly polarized broadband antennas. The results obtained with these antennas can be correlated with results obtained with a tuned dipole antenna. A 10 dB linearity check is performed prior to start of testing in order to determine if an overload condition exists. From 30 to 4700 MHz, a spectrum analyzer with a preselector was used for measurement. Radiated emissions measurements were performed at the anechoic chamber at a test distance of 3 meters. The entire frequency range from 30 to 4700 MHz was slowly scanned and the emissions in the restricted frequency bands were recorded. Measurements were performed using the peak detector function.

The spectrum analyzer was adjusted for the following settings:

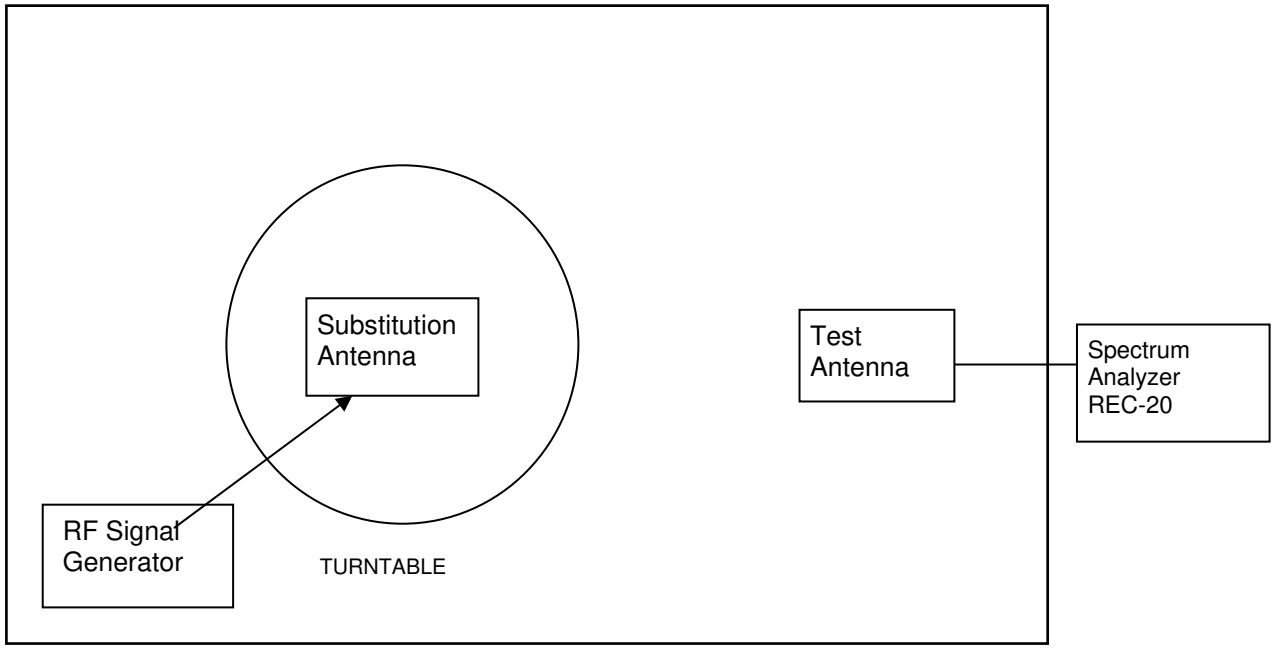
1) Resolution Bandwidth = 100 kHz for spurious emissions below 1 GHz, and 1 MHz for spurious emissions above 1GHz.
2) Video Bandwidth = 300 kHz for spurious emissions below 1 GHz, and 3 MHz for spurious emissions above 1 GHz.
3) Sweep Speed slow enough to maintain measurement calibration.
4) Detector Mode = Positive Peak.

The transmitter to be tested was placed on the turntable in the standard test site, or an FCC listed site compliant with ANSI C63.4. The transmitter is transmitting into a non-radiating load that is placed on the turntable. Measurements were made from the lowest radio frequency generated in the equipment to the tenth harmonic of the carrier. The transmitter was keyed during the tests.

For each spurious frequency, the test antenna was raised and lowered from 1 m to 4m to obtain a maximum reading on the spectrum analyzer with the test antenna at horizontal polarity. Then the turntable was rotated 360°to determine the maximum reading. This procedure was repeated to obtain the highest possible reading. This maximum reading was recorded.

Each measurement was repeated for each spurious frequency with the test antenna polarized vertically.

Figure 1. Drawing of Radiated Emissions Setup



ANSI C63.4 Listed Test Site

Notes:
- Test Antenna height varied from 1 to 4 meters
- Distance from antenna to tested system is 3 meters
- Not to Scale

Frequency MHz	Test Antenna	Substitution Antenna	Receiver to Coupler	Signal Generator
30 - 200	ANT-04	ANT-03	REC-20	SIG-31
200 - 1000	ANT-08	ANT-06	REC-20	SIG-31
1000-5000	ANT-13	ANT-36	REC-20	SIG-31

The transmitter was removed and replaced with a broadband substitution antenna. The substitution antenna is calibrated so that the gain relative to a dipole is known. The center of the substitution antenna was approximately at the same location as the center of the transmitter.

The substitution antenna was fed at the transmitter end with a signal generator connected to the antenna by means of a non-radiating cable. With the antennas at both ends horizontally polarized, and with the signal generator tuned to a particular spurious frequency, the test antenna was raised and lowered to obtain a maximum reading at the spectrum analyzer. The level of the signal generator output was adjusted until the previously recorded maximum reading for this set of conditions was obtained.

The measurements were repeated with both antennas horizontally and vertically polarized for each spurious frequency.

The power in dBm into a reference ideal half-wave dipole antenna was calculated by reducing the readings obtained in steps k) and l) by the power loss in the cable between the generator and the antenna, and further corrected for the gain of the substitution antenna used relative to an ideal half-wave dipole antenna by the following formula:
Pd(dBm) = *Pg*(dBm) – *cable loss* (dB) + *antenna gain* (dB)

where:
Pd is the dipole equivalent power and
Pg is the generator output power into the substitution antenna.
The *Pd* levels record in step m) are the absolute levels of radiated spurious emissions in dBm.

Any emission must be attenuated below the power (P) of the highest emission contained within the authorized bandwidth as follows:

On any frequency removed from the center of the authorized bandwidth by a displacement frequency (fd in kHz) of more than 6.25 kHz: At least 55 + 10 log (P) dB.

Since by mathematical definition, P(dBm) – (55+10xLOG P(W)) = -25 dBm, the limit for spurious emissions was set to -25 dBm equivalent radiated power.

10.4.2 Spurious Radiated Emissions Test Results

Model	37337	Specification	FCC Part 90.210
Serial Number	22	Test Date	November 1, 2017
Test Distance	3 Meters	Notes	Transmit Mode

	Tx	Measured	Equivalent Radiated power			Margin Under Limit	
Harmonic	Freq	Freq	Vertical	Horizontal	Limit	Vertical	Horizontal
#	MHz	MHz	dBm	dBm	dBm	dB	dB
2	150.0	300.05	-28.9	-30.1	-25.0	3.8	5.1
3	150.0	450.08	-33.0	-27.6	-25.0	8.0	2.6
4	150.0	600.10	-33.6	-45.2	-25.0	8.6	20.2
5	150.0	750.13	-39.4	-40.4	-25.0	14.4	15.4
6	150.0	900.15	-41.2	-44.0	-25.0	16.2	19.0
7	150.0	1050.18	-61.3	-60.2	-25.0	36.3	35.2
8	150.0	1200.20	-60.4	-59.3	-25.0	35.4	34.3
9	150.0	1350.23	-62.4	-60.9	-25.0	37.4	35.9
10	150.0	1500.25	-57.4	-58.4	-25.0	32.4	33.4
2	162.0	324.00	-35.9	-30.9	-25	10.9	5.9
3	162.0	486.00	-30.1	-39.1	-25	5.1	14.1
4	162.0	648.00	-35.2	-36.5	-25	10.2	11.5
5	162.0	810.00	-51.1	-43.7	-25	26.1	18.7
6	162.0	972.00	-40.7	-45.4	-25	15.7	20.4

	Tx	Measured	Equivalent Radiated power			Margin Under Limit	
Harmonic	Freq	Freq	Vertical	Horizontal	Limit	Vertical	Horizontal
#	MHz	MHz	dBm	dBm	dBm	dB	dB
7	162.0	1134.00	-59.1	-58.6	-25	34.1	33.6
8	162.0	1296.00	-57.5	-55.8	-25	32.5	30.8
9	162.0	1458.00	-58.6	-57.9	-25	33.6	32.9
10	162.0	1620.00	-57.2	-57.0	-25	32.2	32.0
2	173.3	346.60	-40.5	-32.7	-25	15.5	7.7
3	173.3	519.90	-34.9	-48.1	-25	9.9	23.1
4	173.3	693.20	-46.1	-36.5	-25	21.1	11.5
5	173.3	866.50	-49.6	-44.9	-25	24.6	19.9
6	173.3	1039.80	-55.4	-54.6	-25	30.4	29.6
7	173.3	1213.10	-58.3	-54.6	-25	33.3	29.6
8	173.3	1386.40	-58.7	-58.5	-25	33.7	33.5
9	173.3	1559.70	-56.2	-55.4	-25	31.2	30.4
10	173.3	1733.00	-53.7	-54.7	-25	28.7	29.7
2	450.0	900.05	-38.2	-43.9	-25	13.2	18.9
3	450.0	1350.08	-29.4	-29.1	-25	4.4	4.1
4	450.0	1800.10	-37.2	-40.3	-25	12.2	15.3
5	450.0	2250.13	-30.6	-29.1	-25	5.6	4.1
6	450.0	2700.15	-39.1	-37.2	-25	14.1	12.2
7	450.0	3150.18	-41.2	-43.4	-25	16.2	18.4
8	450.0	3600.20	-47.0	-46.6	-25	22.0	21.6
9	450.0	4050.23	-47.0	-47.3	-25	22.0	22.3
10	450.0	4500.25	-45.8	-46.0	-25	20.8	21.0
2	465.0	930.00	-37.0	-43.8	-25	12.0	18.8
3	465.0	1395.00	-29.8	-29.4	-25	4.8	4.4
4	465.0	1860.00	-36.9	-39.6	-25	11.9	14.6
5	465.0	2325.00	-30.4	-28.9	-25	5.4	3.9
6	465.0	2790.00	-38.7	-37.4	-25	13.7	12.4
7	465.0	3255.00	-41.1	-42.1	-25	16.1	17.1
8	465.0	3720.00	-45.5	-45.1	-25	20.5	20.1
9	465.0	4185.00	-47.6	-46.8	-25	22.6	21.8
10	465.0	4650.00	-46.1	-45.9	-25	21.1	20.9
2	470.0	469.98	-25.0	-25.0	37	62.0	62.0
3	470.0	939.95	-40.6	-45.7	-25	15.6	20.7
4	470.0	1409.93	-29.3	-29.7	-25	4.3	4.7
5	470.0	1879.90	-39.9	-40.1	-25	14.9	15.1
6	470.0	2349.88	-31.1	-34.0	-25	6.1	9.0
7	470.0	2819.85	-40.5	-41.5	-25	15.5	16.5
8	470.0	3289.83	-45.2	-44.0	-25	20.2	19.0
9	470.0	3759.80	-45.7	-45.8	-25	20.7	20.8
10	470.0	4229.78	-45.8	-45.2	-25	20.8	20.2
2	479.0	958.00	-38.3	-42.4	-25	13.3	17.4
3	479.0	1437.00	-29.1	-29.0	-25	4.1	4.0
4	479.0	1916.00	-41.1	-38.3	-25	16.1	13.3
5	479.0	2395.00	-31.1	-34.3	-25	6.1	9.3
6	479.0	2874.00	-40.9	-42.5	-25	15.9	17.5
7	479.0	3353.00	-46.6	-45.4	-25	21.6	20.4
8	479.0	3832.00	-46.4	-46.4	-25	21.4	21.4
9	479.0	4311.00	-46.8	-46.3	-25	21.8	21.3
10	479.0	4790.00	-46.5	-45.3	-25	21.5	20.3

Judgment: Passed by at least 2.6 dB.
No other spurious radiated emissions were detected within 10 dB of the limits from 30 MHz to 4.7 GHz.

10.5 Frequency Stability

10.5.1 Frequency Stability Vs Temperature

The chamber was then set to the lowest temperature. The transmitter was in the chamber and allowed to stabilize for 15 minutes. The transmitter was then keyed and the frequency was recorded. The chamber was then incremented in 10°C steps with a minimum of 15 minute stabilization period for each temperature measurement. The transmitter was off during the temperature transitions.

10.5.2 Frequency Stability Vs Supply Voltage

The EUT was allowed to stabilize with the nominal primary power supply voltage applied. The primary input voltage was varied.

10.5.3 Test Results for Frequency Stability

Model	37337	Specification	FCC Part 90.213
Serial Number	22	Test Date	November 16, 2017
Test Personnel	Rich Tichgelaar	Test Location	Chamber B
Test Equipment	Spectrum Analyzer (REC-21); Temperature Chamber TC-01 Digital Multimeter (DMM-08)		
Notes	15 minutes at each Temperature; 1 min at each voltage		
Nominal Frequency	162.0000 or 460.0000 MHz		

Volts	Freq.	Deviation	
DC	(MHz)	Hz	PPM
7.0	161.999941	2	0.01
7.3	161.999940	1	0.01
7.6	161.999939	0	0.00
7.9	161.999939	0	0.00
8.2	161.999940	1	0.01

Test Requirements: Limit is 2 ppm
Judgement: Pass

Temp	Freq.	Deviation	
Deg. C	(MHz)	Hz	PPM
50	161.999928	-16	-0.10
40	161.999942	-2	-0.02
30	161.999947	3	0.02
20	161.999944	0	0.00
10	161.999968	24	0.15
0	161.999980	36	0.22
-10	162.000021	77	0.47
-20	162.000043	99	0.61
-30	162.000042	98	0.60

Test Requirements: Limit is 2 ppm
Judgement: Pass

Volts	Freq.	Deviation	
DC	(MHz)	Hz	PPM
7.0	464.999825	-9	-0.02
7.3	464.999831	-2	0.00
7.6	464.999832	-1	0.00
7.9	464.999833	0	0.00
8.2	464.999834	1	0.00

Test Requirements: Limit is 1 ppm
Judgement: Pass

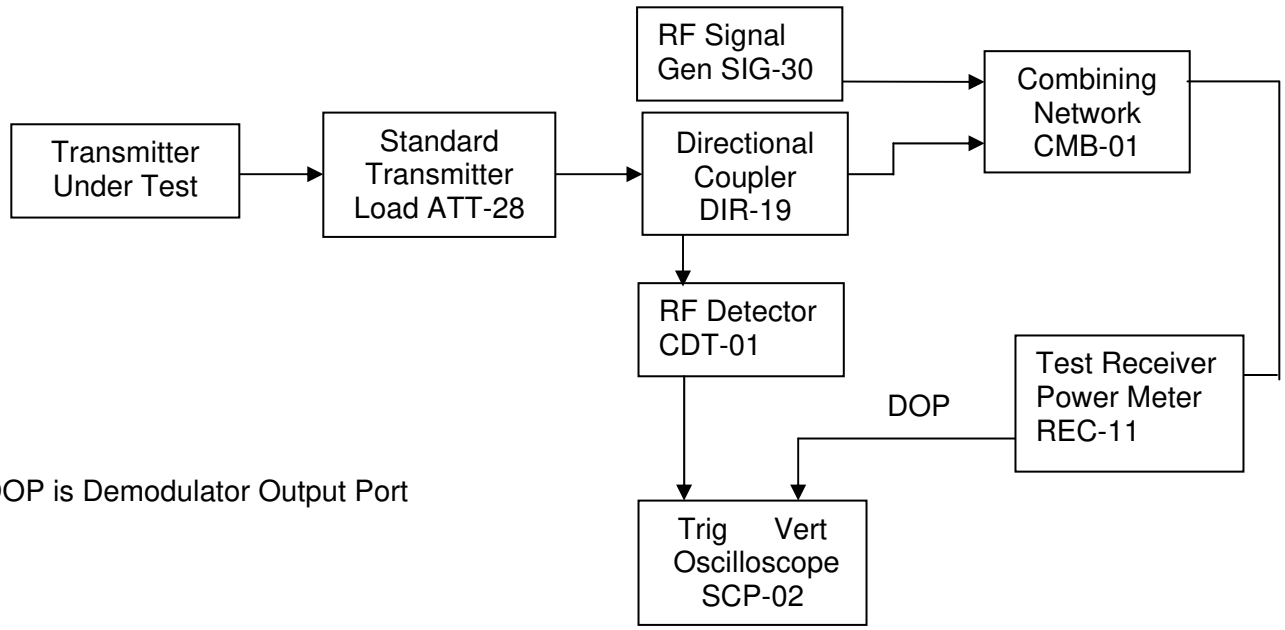
Temp	Freq.	Deviation	
Deg. C	(MHz)	Hz	PPM
50	464.999767	-83	-0.18
40	464.999826	-24	-0.05
30	464.999846	-4	-0.01
20	464.999850	0	0.00
10	464.999891	41	0.09
0	464.999920	69	0.15
-10	464.999978	128	0.28
-20	465.000088	238	0.51
-30	465.000084	234	0.50

Test Requirements: Limit is 1 ppm
Judgement: Pas

10.6 Transient Frequency Behavior

10.6.1 Test method

The test was performed in accordance to TIA-603-D Section 2.2.19.3 Alternate Method of Measurement (Using a Test Receiver). The equipment was connected as shown below.



DOP is Demodulator Output Port

10.6.2 Limits of transient frequency

Time intervals [1,2]	Maximum Frequency Difference [3]	150 to 174 MHz Equipment Operating on 6.25 kHz Channels	421 to 512 MHz Equipment Operating on 6.25 kHz Channels
t_1 [4]	±6.25 kHz	5.0 mSec	10.0 mSec
t_2	±3.125 kHz	20.0 mSec	25.0 mSec
t_3 [4]	±6.25 kHz	5.0 mSec	10.0 mSec

[1] t_{on} is the instant when a 1 kHz test signal is completely suppressed, including any capture time due to phasing.

t_1 is the time period immediately following t_{on}.

t_2 is the time period immediately following t_1.

t_3 is the time period from the instant when the transmitter is turned off until t_{off}.

t_{off} is the instant when the 1 kHz test signal starts to rise.

[2] During the time from the end of t_2 to the beginning of t_3, the frequency difference must not exceed the limits specified in § 90.213.

[3] Difference between the actual transmitter frequency and the assigned transmitter frequency.

[4] If the transmitter carrier output power rating is 6 watts or less, the frequency difference during this time period may exceed the maximum frequency difference for this time period.

10.6.3 Test Results

Model	37337	Specification	FCC part 90.213
Serial Number	22	Test Date	November 28, 2017
Test Personnel	Joseph Strzelecki Rich Tichgelaar	Test Location	Chamber B

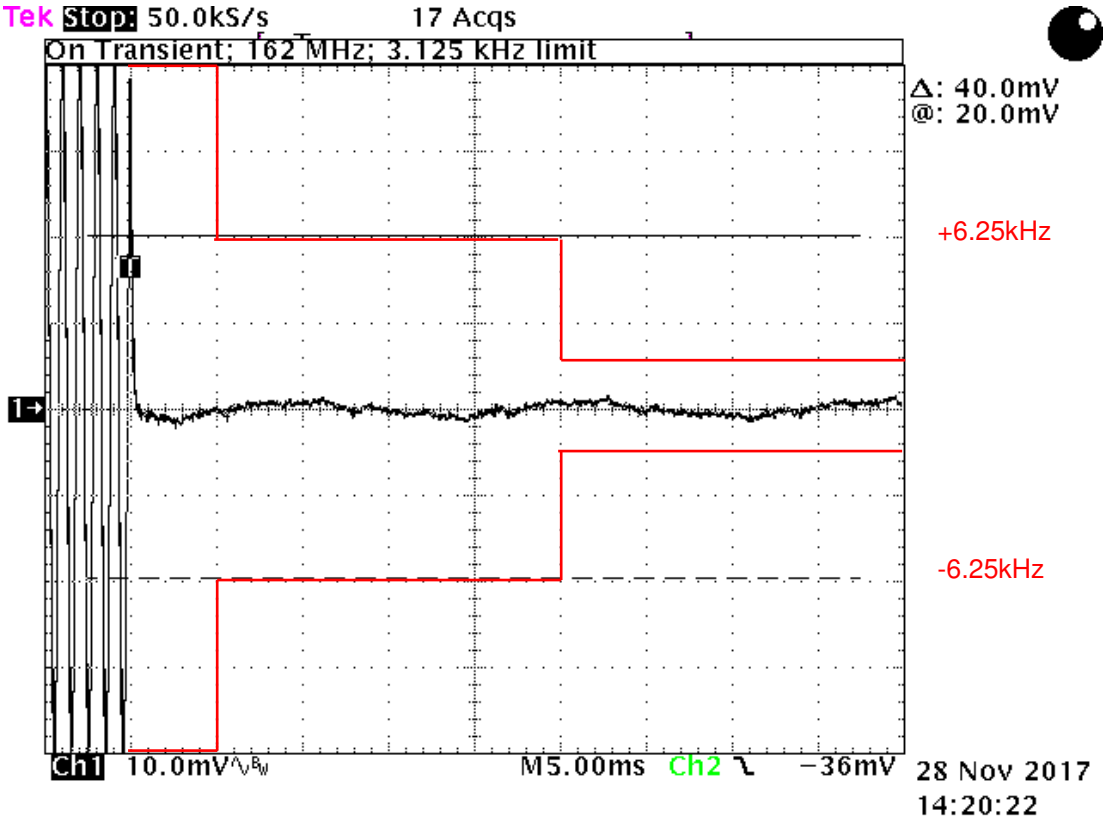
Freq MHz	Channel BW	Limits for Time interval/Freq difference						Test Result
		t_1		t_2		t_3		
		mSec	kHz	mSec	kHz	mSec	kHz	
162.000	6.25	5	6.25	20	3.125	5	6.25*	Pass
465.000	6.25	10	6.25	25	3.125	10	6.25*	Pass

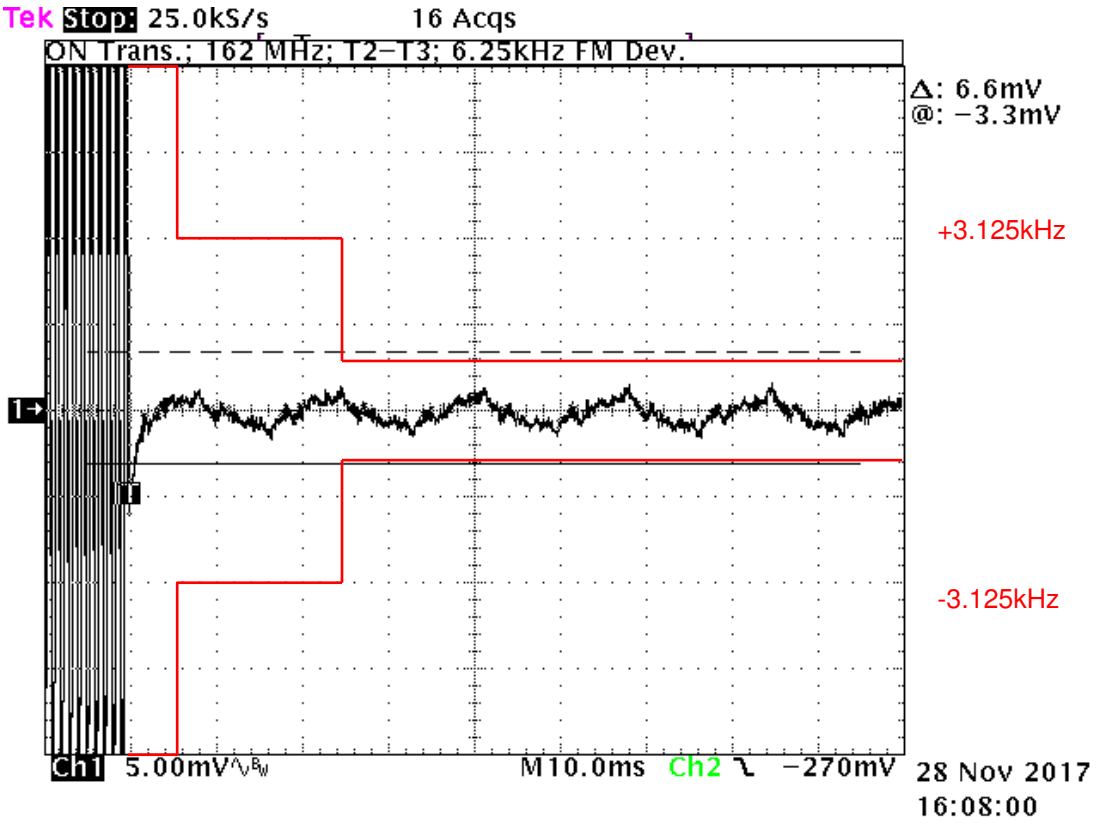
Judgement: Pass

*Since the transmitter carrier output power is less than 6 watts, the frequency difference during the t3 time period may exceed the maximum frequency difference for this time period.

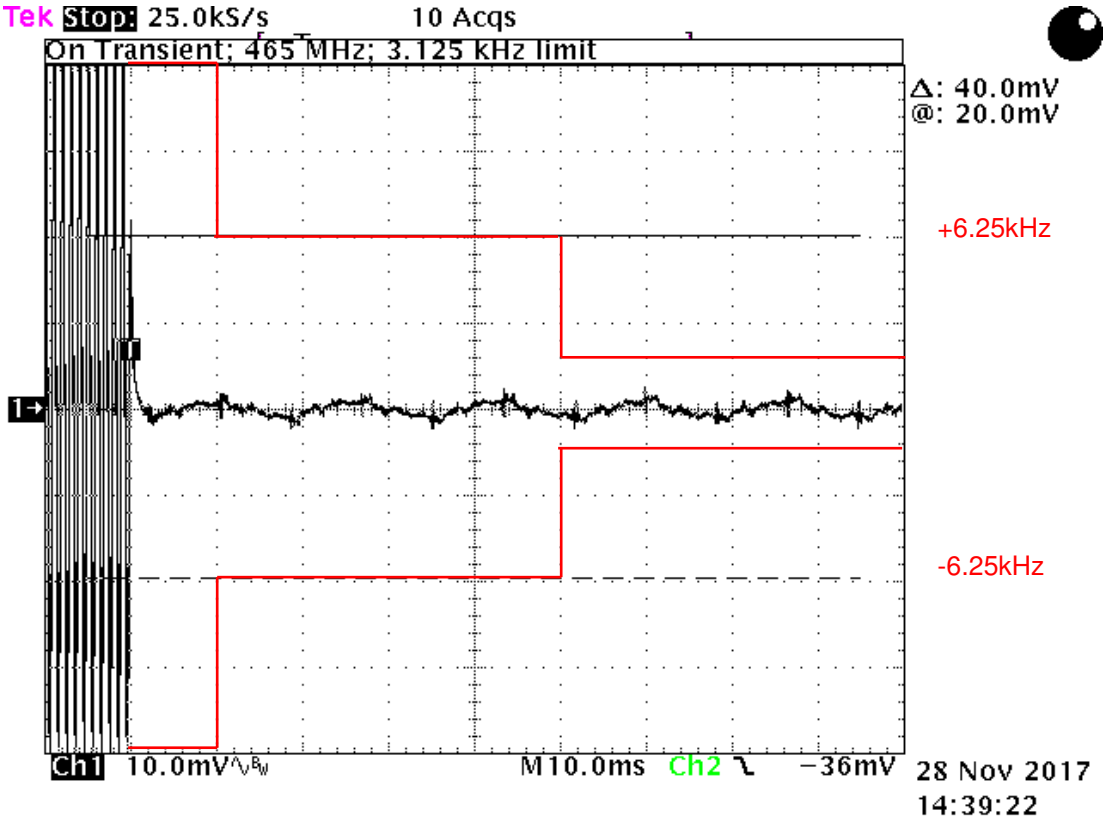
10.6.4 Results for Time Periods t1 and t2

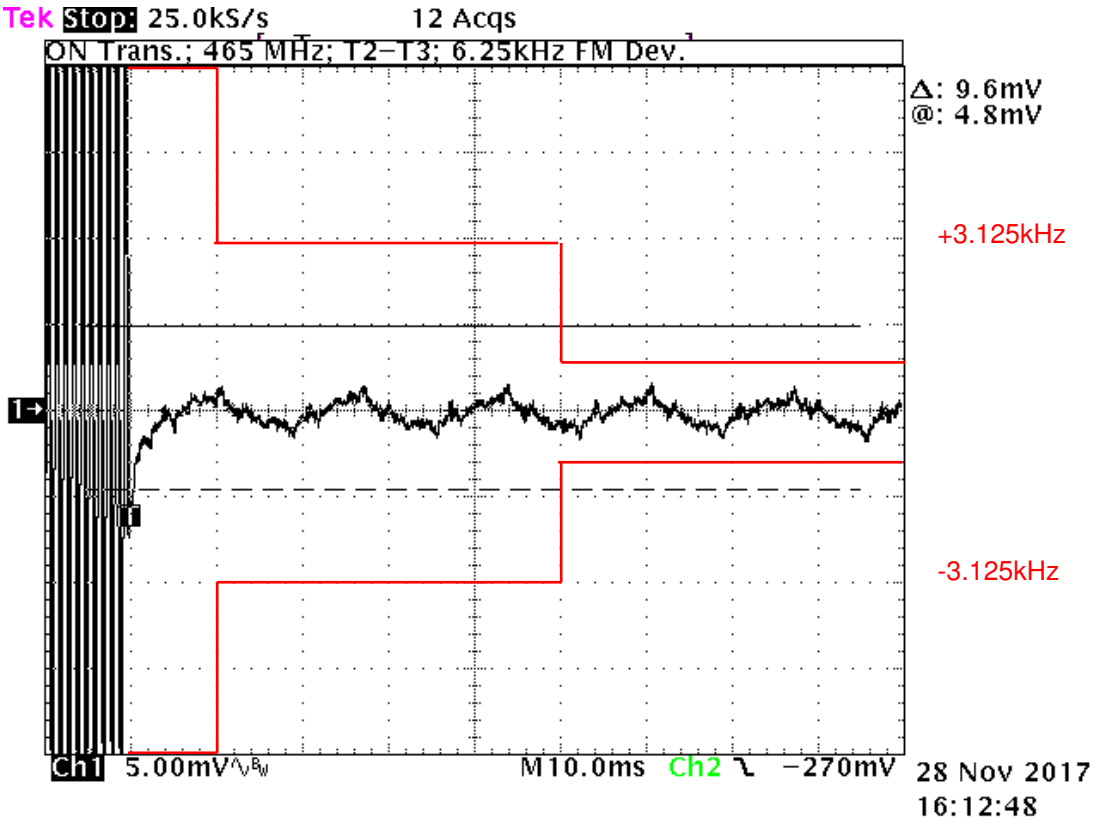
The following shows the off to on State.





At 162 MHz, it passed the limits for 6.25 kHz Channel devices, so the 12.5 and 25 kHz device limits are not shown.



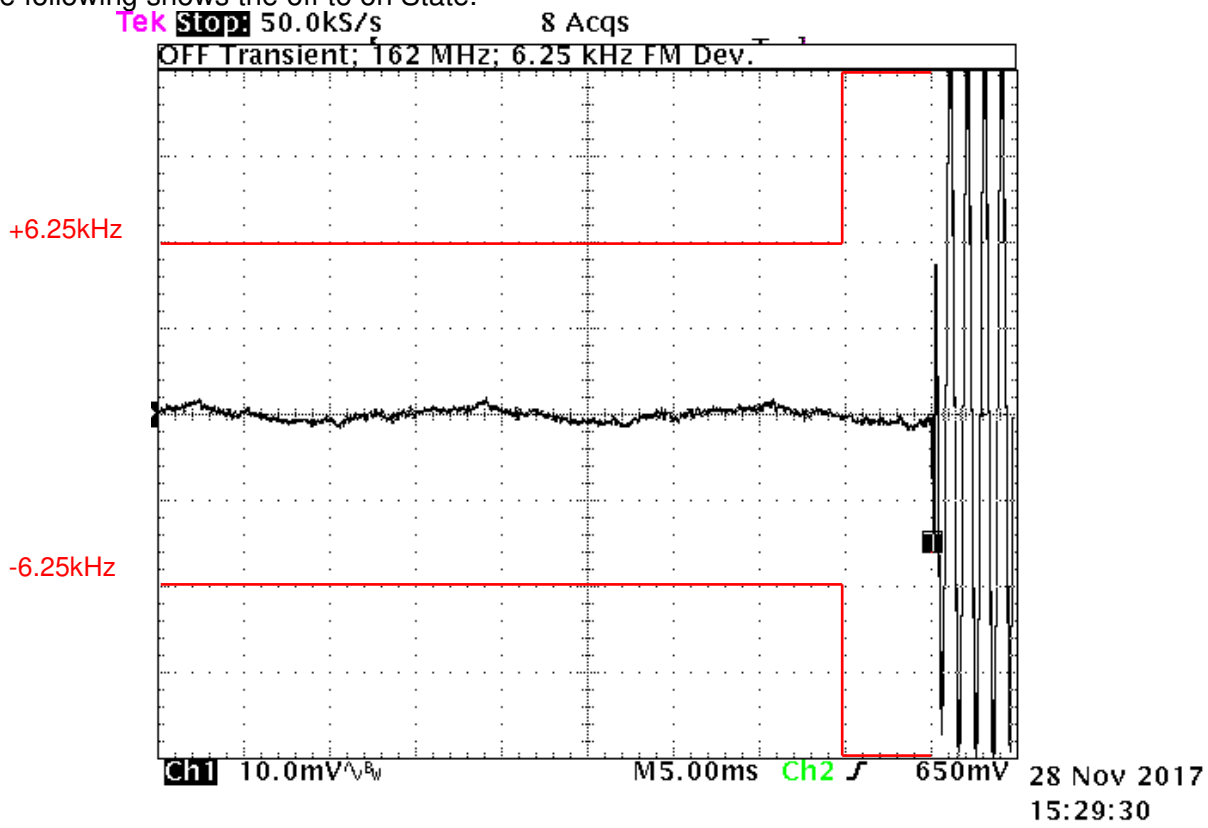


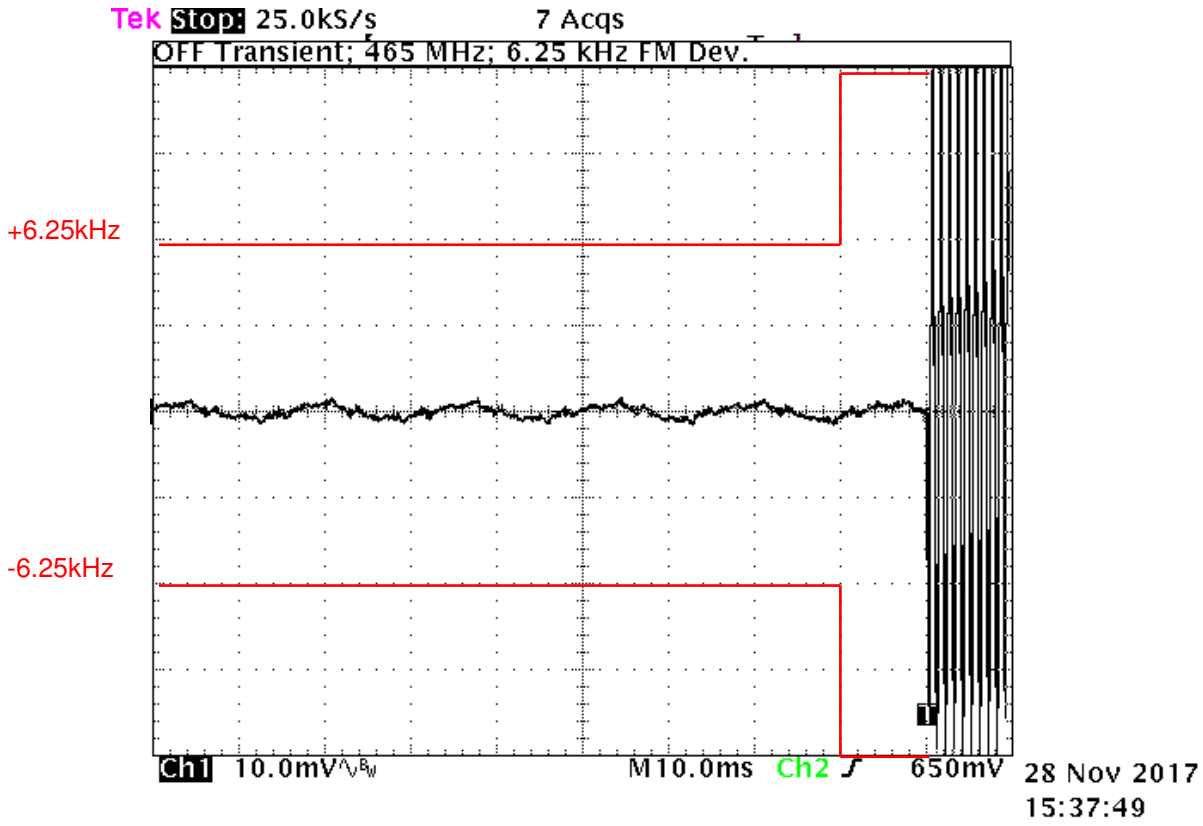
Judgement: Pass

10.6.5 Results for Time Period t3

Since the transmitter carrier output power is less than 6 watts, the frequency difference during the t3 time period may exceed the maximum frequency difference for this time period.

The following shows the off to on State.





Judgement: Pass

10.7 Radiated Emissions (Receive Mode)

Radiated emission measurements were performed with linearly polarized broadband antennas. The results obtained with these antennas can be correlated with results obtained with a tuned dipole antenna. The radiated emission measurements were performed with a spectrum analyzer. The bandwidth used from 150 kHz to 30 MHz is 9 or 10 kHz and the bandwidth from 30 MHz to 1000 MHz is 100 or 120 kHz. Above 1 GHz, a 1 MHz bandwidth is used. A 10-dB linearity check is performed prior to start of testing in order to determine if an overload condition exists.

From 30 to 2000 MHz, an Anritsu spectrum analyzer was used. Final radiated emissions measurements were performed inside of an anechoic chamber at a test distance of 3 meters. The anechoic chamber is designated as Chamber E. This Chamber meets the Site Attenuation requirements of ANSI C63.4 and CISPR 16-1. Chamber E is located at 12 East Devonwood Ave. Romeoville, Illinois EMI test lab.

The entire frequency range from 30 to 2000 MHz was slowly scanned with particular attention paid to those frequency ranges which appeared high. Measurements were performed using two antenna polarizations, (vertical and horizontal). The worst-case emissions were recorded. All measurements may be performed using either the peak, average or quasi-peak detector functions. If the peak detector data exceeds or is marginally close to the limits, the measurements are repeated using a quasi-peak detector or average function as required by the specification for final determination of compliance.

The detected emission levels were maximized by rotating the EUT, adjusting the positions of all cables, and by scanning the measurement antenna from 1 to 4 meters above the ground.

10.7.1 Radiated Emissions Field Strength Sample Calculation

The field strength is calculated by adding the Antenna Factor and Cable Loss, and by subtracting the Amplifier Gain from the measured reading. The basic equation is as follows:

FS = RA + AF + CF - AG

Where: FS = Field Strength
RA = Receiver Amplitude
AF = Antenna Factor
CF = Cable Attenuation Factor
AG = Amplifier Gain

10.7.2 Spurious Radiated Emissions Test Results (Receive Mode)

Model	37337	Specification	FCC Part 15 Subpart B
Serial Number	22	Test Date	October 27, 2017
Tested by	Richard Tichgelaar	Test Distance	3 Meters
Abbreviations	Pol = Antenna Polarization; V = Vertical; H = Horizontal; P = peak; Q = QP		
Notes	Corr. Factors = Cable Loss – Preamp Gain; Internal preamp below 1 GHz.		
Configuration	Receive Mode		

All emissions except Fundamental and harmonics

Freq. MHz	Meter Reading dBuV	Dect.	Ant. Pol.	Ant Factor	Cable & Amp Factors	Dist. Fact dB	EUT dBuV/m	Limit dBuV/m	Margin Under Limit dB	Note
30.0	7.1	P	H	11.1	0.5	0.0	18.7	40.0	21.3	
32.2	13.5	P	H	11.3	0.5	0.0	25.3	40.0	14.7	
33.0	15.4	P	H	11.3	0.5	0.0	27.2	40.0	12.8	
34.7	16.8	P	H	11.5	0.5	0.0	28.8	40.0	11.2	
36.0	13.2	P	H	11.6	0.5	0.0	25.3	40.0	14.7	
48.9	11.4	P	H	11.5	0.6	0.0	23.5	40.0	16.5	
134.1	9.7	P	H	11.6	1.0	0.0	22.3	43.5	21.2	
191.3	8.8	P	H	17.0	1.1	0.0	26.9	43.5	16.6	
200.0	8.1	P	H	11.0	1.2	0.0	20.2	43.5	23.3	
202.0	8.6	P	H	16.2	1.2	0.0	26.0	43.5	17.5	
328.4	8.8	P	H	13.7	1.5	0.0	24.0	46.0	22.0	
432.5	9.3	P	H	15.6	1.8	0.0	26.6	46.0	19.4	
500.0	7.1	P	H	17.8	1.9	0.0	26.8	46.0	19.2	
502.0	9.3	P	H	17.8	1.9	0.0	29.0	46.0	17.0	
656.3	8.4	P	H	20.2	2.2	0.0	30.8	46.0	15.2	
805.0	9.1	P	H	20.5	2.6	0.0	32.2	46.0	13.8	
907.5	8.4	P	H	22.1	2.6	0.0	33.1	46.0	12.9	
1690.0	40.7	P	H	25.9	-32.3	0.0	34.2	74.0	39.8	1
1832.5	40.6	P	H	26.8	-31.9	0.0	35.5	74.0	38.5	1
1977.5	40.1	P	H	27.2	-31.7	0.0	35.6	74.0	38.4	1
30.0	7.7	P	V	11.1	0.5	0.0	19.3	40.0	20.7	
42.0	16.7	P	V	12.0	0.5	0.0	29.2	40.0	10.8	
64.4	10.7	P	V	8.0	0.7	0.0	19.3	40.0	20.7	
113.4	8.2	P	V	12.5	0.9	0.0	21.6	43.5	21.9	
130.2	9.0	P	V	11.8	1.0	0.0	21.8	43.5	21.7	
182.2	9.3	P	V	17.0	1.1	0.0	27.4	43.5	16.1	
202.0	8.7	P	V	16.2	1.2	0.0	26.1	43.5	17.4	
208.3	12.6	P	V	10.4	1.2	0.0	24.2	43.5	19.3	
246.8	12.5	P	V	10.9	1.3	0.0	24.7	46.0	21.3	

Freq. MHz	Meter Reading dBuV	Dect.	Ant. Pol.	Ant Factor	Cable & Amp Factors	Dist. Fact dB	EUT dBuV/m	Limit dBuV/m	Margin Under Limit dB	Note
353.3	8.2	P	V	14.1	1.6	0.0	23.9	46.0	22.1	
410.6	9.9	P	V	15.0	1.7	0.0	26.6	46.0	19.4	
457.5	12.0	P	V	16.0	1.8	0.0	29.8	46.0	16.2	
501.3	7.4	P	V	17.8	1.9	0.0	27.1	46.0	18.9	
502.0	10.5	P	V	17.8	1.9	0.0	30.2	46.0	15.8	
612.5	8.1	P	V	18.6	2.1	0.0	28.9	46.0	17.1	
772.5	9.5	P	V	21.7	2.4	0.0	33.6	46.0	12.4	
883.8	8.7	P	V	21.7	2.6	0.0	33.0	46.0	13.0	
992.5	9.0	P	V	23.3	2.8	0.0	35.1	54.0	18.9	
1440.0	42.2	P	V	25.0	-32.5	0.0	34.7	74.0	39.3	1
1832.5	41.7	P	V	26.8	-31.9	0.0	36.6	74.0	37.4	1
1957.5	42.3	P	V	27.2	-31.7	0.0	37.9	74.0	36.1	1

Note 1: Peak Reading under the Average limit, therefore no Average reading is required.
Judgment: Passed by at least 10 dB

11 MEASUREMENT INSTRUMENTATION UNCERTAINTY

Measurement	Uncertainty
Radiated Emissions, E-field, 3 meters, 30 to 1000 MHz	5.3 dB
Radiated Emissions, E-field, 3 meters, 1 to 6 GHz	5.5 dB
99% Occupied Bandwidth using REC-43	1% of frequency span
Conducted power PWM-01 at 460 MHz	0.14 dB
Amplitude measurement 1-5000 MHz; REC-11	1.5 dB
Temperature THM-02	0.6 Deg. C

The uncertainties represent expanded uncertainties expressed at approximately the 95% confidence level using a coverage factor of k=2 in accordance with CISPR 16-4-2.