41039 Boyce Road
Fremont, CA. 94538

510-578-3500 Phone
510-440-9525 Fax

Radio Test Report

FCC Part 90 and RSS-119
(USA: 435 MHz to 470 MHz)
(Canada: 450 MHz to 470 MHz)

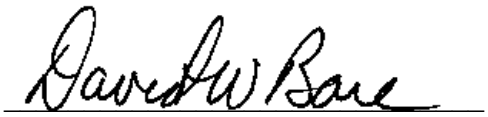
Model(s): LRS455A

IC CERTIFICATION #:	2329B-LRS455A
FCC ID:	KNYLRS455A
COMPANY:	FreeWave Technologies, Inc. 5395 Pearl Parkway Boulder, CO 80301
TEST SITE(S):	National Technical Systems 41039 Boyce Road. Fremont, CA. 94538-2435
PROJECT NUMBER:	PR109246
REPORT DATE:	July 17, 2020
REISSUE DATE:	July 27, 2020
FINAL TEST DATES:	June 4, 5 and 8, 2020
TOTAL NUMBER OF PAGES:	49

A2LA ACCREDITED
Testing Cert #0214.26

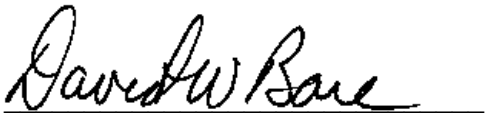
VALIDATING SIGNATORIES

PROGRAM MGR



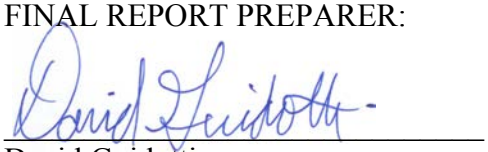
David W. Bare
Chief Engineer

TECHNICAL REVIEWER:



David W. Bare
Chief Engineer

FINAL REPORT PREPARER:



David Guidotti
Senior Technical Writer

QUALITY ASSURANCE DELEGATE

Gary Izard
Quality Assurance Representative

REVISION HISTORY

Rev#	Date	Comments	Modified By
-	July 17, 2020	First release	
1	July 27, 2020	Added details of two models of the device	dwb

TABLE OF CONTENTS

SCOPE

Tests have been performed on the FreeWave Technologies, Inc. model LRS455A, pursuant to the relevant requirements of the following standard(s) in order to obtain device certification against the regulatory requirements of the Federal Communications Commission and Innovation Science and Economic Development Canada.

- Code of Federal Regulations (CFR) Title 47 Part 2
- RSS-Gen Issue 5, April 2018
- CFR 47 Part 90 (Private Land Mobile Radio Service) Subpart I
- RSS-119, Issue 12, May 2015 (Land Mobile and Fixed Equipment Operating in the Frequency Range 27.41-960 MHz)

Conducted and radiated emissions data has been collected, reduced, and analyzed within this report in accordance with measurement guidelines set forth in the following reference standards and as outlined in National Technical Systems test procedures:

ANSI C63.26:2015
ANSI TIA-603-E
FCC KDB 971168 Licensed Digital Transmitters

The intentional radiator above has been tested in a simulated typical installation to demonstrate compliance with the relevant Innovation Science and Economic Development Canada performance and procedural standards.

Every practical effort was made to perform an impartial test using appropriate test equipment of known calibration. All pertinent factors have been applied to reach the determination of compliance.

National Technical Systems is accredited by the A2LA, certificate number 0214.26, to perform the test(s) listed in this report, except where noted otherwise.

The test results recorded herein are based on a single type test of the FreeWave Technologies, Inc. model LRS455A and therefore apply only to the tested sample. The sample was selected and prepared by Pat Reginella of FreeWave Technologies, Inc.

OBJECTIVE

The primary objective of the manufacturer is compliance with the regulations outlined in the previous section.

Prior to marketing in the USA, the device requires certification. Prior to marketing in Canada, Class I transmitters, receivers and transceivers require certification.

Certification is a procedure where the manufacturer submits test data and technical information to a certification body and receives a certificate or grant of equipment authorization upon successful completion of the certification body's review of the submitted documents. Once the equipment authorization has been obtained, the label indicating compliance must be attached to all identical units, which are subsequently manufactured.

Maintenance of compliance is the responsibility of the manufacturer. Any modification of the product which may result in increased emissions should be checked to ensure compliance has been maintained (i.e., printed circuit board layout changes, different line filter, different power supply, harnessing or I/O cable changes, etc.).

STATEMENT OF COMPLIANCE

The tested sample of FreeWave Technologies, Inc. model LRS455A complied with the requirements of the standards and frequency bands declared in the scope of this test report.

Maintenance of compliance is the responsibility of the manufacturer. Any modifications to the product should be assessed to determine their potential impact on the compliance status of the device with respect to the standards detailed in this test report.

DEVIATIONS FROM THE STANDARDS

No deviations were made from the published requirements listed in the scope of this report.

TEST RESULTS

FCC Part 90 and RSS-119

FCC	Canada	Description	Measured	Limit	Result
Transmitter Modulation, output power and other characteristics					
§2.1033 (c) (5) § 90.35		Frequency range(s)	435-470 MHz	435 – 470 MHz	Pass
	RSS-119	Frequency range(s)	450-470 MHz	450 – 470 MHz	Pass
§2.1033 (c) (6) §2.1033 (c) (7) § 2.1046 § 90.205	RSS-119	RF power output at the antenna terminals	20 dBm to 33.2 dBm	57 dBm ERP	Pass
§2.1033 (c) (6) §2.1033 (c) (7) § 2.1046 § 90.205	RSS-119	EIRP / ERP	Max 29.2 W ERP	57 dBm ERP	Pass
§2.1033 (c) (4) § 2.1047 § 90.210	RSS-119	Emission types	F1D	-	-
		Emission mask	Mask D	Within Mask	Pass
§ 2.1049 § 90.209	RSS-GEN 6.7 RSS-119	Occupied Bandwidth	7.64 & 8.89 kHz	11.25 kHz	Pass
§ 90.214	RSS-119	Transient Frequency Behavior	Within Limits	Refer to standard	Pass
Transmitter spurious emissions					
§ 2.1051 § 2.1057	RSS-119	At the antenna terminals	-36.0 dBm @ 1380.0 MHz (-16.0 dB)	-20 dBm	Pass
§ 2.1053 § 2.1057	RSS-119	Field strength	50.9 dBµV/m @ 3290.0 MHz (-24.4 dB)	-20 dBm	Pass
Other details					
§ 2.1055 § 90.213	RSS-119	Frequency stability	0.6 ppm	1.5 ppm	Pass
§ 2.1093	RSS-102	RF Exposure	See separate User Manual and MPE calculation exhibits	Warning to user	Pass
§2.1033 (c) (8)		Final radio frequency amplifying circuit's dc voltages and currents for normal operation over the power range	5.5V and 1000mA	-	-
-	-	Antenna Gain	Maximum 9.25 dBi	-	-
Notes					

EXTREME CONDITIONS

Frequency stability is determined over extremes of temperature and voltage. The extremes of voltage were 85 to 115 percent of the nominal value.

The extremes of temperature were -30°C to +50°C as specified in FCC §2.1055(a)(1).

MEASUREMENT UNCERTAINTIES

ISO/IEC 17025 requires that an estimate of the measurement uncertainties associated with the emissions test results be included in the report. The measurement uncertainties given below are based on a 95% confidence level (based on a coverage factor (k=2) and were calculated in accordance with NAMAS document NIS 81 and M3003.

Measurement Type	Measurement Unit	Frequency Range	Expanded Uncertainty
RF frequency	Hz	25 to 7,000 MHz	1.7×10^{-7}
RF power, conducted	dBm	25 to 7,000 MHz	± 0.52 dB
Conducted emission of transmitter	dBm	25 to 40,000 MHz	± 0.7 dB
Conducted emission of receiver	dBm	25 to 40,000 MHz	± 0.7 dB
Radiated emission (substitution method)	dBm	25 to 40,000 MHz	± 2.5 dB
Radiated emission (field strength)	dBµV/m	25 to 1,000 MHz 1 to 40 GHz	± 3.6 dB ± 6.0 dB

EQUIPMENT UNDER TEST (EUT) DETAILS

GENERAL

The FreeWave Technologies, Inc. model LRS455A is a licensed radio module which is designed to operate in the 435-470 MHz bands. Since the host unit could be placed in any position during operation, the EUT was treated as tabletop equipment during testing to simulate the end-user environment. The electrical rating of the EUT is 12VDC, 0.8 Amps.

The sample was received on June 4, 2020 and tested on June 4, 5 and 8, 2020. The EUT consisted of the following component(s):

Company	Model	Description	Serial Number	FCC ID
FreeWave Technologies, Inc.	LRS455A	Licensed radio module	4613252	KNYLRS455A

ENCLOSURE

The EUT does not have an enclosure. It measures approximately 6 cm wide by 13 cm long.

ADDITIONAL EUT DETAILS

Two models of the LRS455A module are sold, LRS455A-C and LRS455A-T. The only difference is the customer interface. LRS455A-C has a serial interface and LRS455A-T has a TTL interface. The PCB is the same size and the radio circuitry of both is identical.

MODIFICATIONS

No modifications were made to the EUT during the time the product was at National Technical Systems.

SUPPORT EQUIPMENT

The following equipment was used as support equipment for testing:

Company	Model	Description	Serial Number	FCC ID
Shenzhen Mingxin	MX15W-1200800UX	AC/DC Adapter	-	-

The following equipment was used as remote support equipment for emissions testing:

Company	Model	Description	Serial Number	FCC ID
Toshiba	Satellite L645-S4102	Laptop	1B250508W	-

EUT INTERFACE PORTS

The I/O cabling configuration during testing was as follows:

Port	Connected To	Cable(s)		
		Description	Shielded or Unshielded	Length(m)
10 pin connector	Serial DB9, Power, Reset Button	Multiwire	Unshielded	1.2
Serial DB9	Laptop USB	Multiwire	Shielded	1.8
Power	AC/DC Adapter	two wire	Unshielded	1.4
Antenna	Termination	Coax	Shielded	0.1

EUT OPERATION

During emissions testing the EUT was set to transmit a continuous modulated signal at maximum power on the selected frequency.

TESTING

GENERAL INFORMATION

Antenna port measurements were taken at the National Technical Systems test site located at 41039 Boyce Road, Fremont, CA 94538-2435.

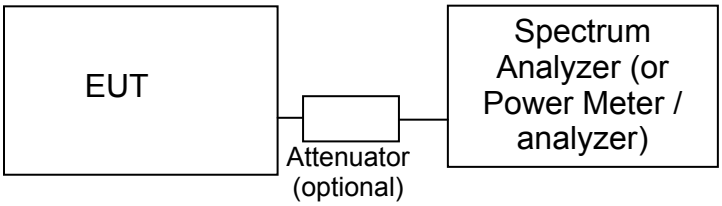
Final test measurements were taken at the test sites listed below. Pursuant to section 2.948 of the FCC's Rules and section 6.2 of RSS-GEN, NTS has been recognized as an accredited test laboratory by the Commission and Innovation, Science and Economic Development Canada. A description of the facilities employed for testing is maintained by NTS.

Site	Company / Registration Numbers		Location
	FCC	Canada	
Chamber 4	US1031	2845B (Wireless test lab #US0027)	41039 Boyce Road Fremont, CA 94538-2435
Chamber 5			

ANSI C63.4 recommends that ambient noise at the test site be at least 6 dB below the allowable limits. Ambient levels are below this requirement. The test site(s) contain separate areas for radiated and conducted emissions testing. Results from testing performed in this chamber have been correlated with results from an open area test site. Considerable engineering effort has been expended to ensure that the facilities conform to all pertinent requirements of ANSI C63.4.

RF PORT MEASUREMENT PROCEDURES

Conducted measurements are performed with the EUT's rf input/output connected to the input of a spectrum analyzer, power meter or modulation analyzer. When required an attenuator, filter and/or dc block is placed between the EUT and the spectrum analyzer to avoid overloading the front end of the measurement device. Measurements are corrected for the insertion loss of the attenuators and cables inserted between the rf port of the EUT and the measurement equipment.



Test Configuration for Antenna Port Measurements

For devices with an integral antenna the output power and spurious emissions are measured as a field strength at a test distance of (typically) 3m and then converted to an eirp using a substitution measurement (refer to RADIATED EMISSIONS MEASUREMENTS). All other measurements are made as detailed below but with the test equipment connected to a measurement antenna directed at the EUT.

OUTPUT POWER

Output power is measured using a power meter and an average sensor head, a spectrum analyzer or a power meter and peak power sensor head as required by the relevant rule part(s). Where necessary measurements are gated to ensure power is only measured over periods that the device is transmitting.

Power measurements made directly on the rf power port are, when appropriate, converted to an EIRP by adding the gain of the highest gain antenna that can be used with the device under test, as specified by the manufacturer.

BANDWIDTH MEASUREMENTS

The 6dB, 20dB and/or 26dB signal bandwidth is measured in using the bandwidths recommended by ANSI C63.4. When required, the 99% bandwidth is measured using the methods detailed in RSS-GEN. The measurement bandwidth is set to be at least 1% of the instrument's frequency span.

CONDUCTED SPURIOUS EMISSIONS

Initial scans are made using a peak detector (RBW=VBW) and using scan rates to ensure that the EUT transmits before the sweep moves out of each resolution bandwidth (for transmit mode measurements). Where the limits are expressed as an average power the spectrum analyzer is tunes to that frequency with a narrow span (wide enough to capture the emission and its sidebands) and the resolution and video bandwidths are adjusted as required by the reference measurement standards. For transmitter measurements the appropriate detector (average, peak, normal ,sample, quasi-peak) is used when making measurements for licensed devices. For receiver conducted spurious measurements the detector is set to peak.

TRANSMITTER MASK MEASUREMENTS

The transmitter mask measurements are made using resolution bandwidths as specified in the pertinent rule part(s). Where narrower bandwidths are used the measurement is corrected to account for the reduced bandwidth by either using the adjacent channel power function of the spectrum analyzer to sum the power across the required measurement bandwidth. The frequency span of the analyzer is set to ensure the fundamental signal and all significant sidebands are displayed.

The top of the mask may be set by the total output power of the signal, the power of the unmodulated signal or the peak value of the signal in the reference bandwidth being used for the mask measurement.

FREQUENCY STABILITY

The EUT is placed inside a temperature chamber with all support and test equipment located outside of the chamber. The temperature is varied across the specified frequency range in 10 degree increments with frequency measurements made at each temperature step. The EUT is allowed enough time to stabilize at each temperature variation.

The spectrum analyzer is configured to give a 5- or 6-digit display for the marker-frequency function. The spectrum analyzer's built-in frequency counter is used to measure the maximum deviation of the fundamental frequency at each temperature. Where possible the device is set to transmit an unmodulated signal. Where this is not possible the frequency drift is determined by finding a stable point on the signal (e.g. the null at the centre of an OFDM signal) or by calculating a centre frequency based on the upper and lower XdB points (where X is typically 6dB or 10dB) on the signal’s skirts.

TRANSIENT FREQUENCY BEHAVIOR:

The TIA/EIA 603 procedure is used to determine compliance with transient frequency timing requirements as the radio is keyed on and off.

The EUTs rf output is connected via a combiner/splitter to the test receiver/spectrum analyzer and to a diode detector. The test receiver or spectrum analyzer video output is connected to an oscilloscope, which is triggered by the output from the diode detector.

Plots showing Ton, T1, and T2 are made when turning on the transmitter and showing T3 when turning off the transmitter.

RADIATED EMISSIONS MEASUREMENTS

Transmitter radiated spurious emissions are initially measured as a field strength. The eirp or erp limit as specified in the relevant rule part(s) is converted to a field strength at the test distance and the emissions from the EUT are then compared to that limit. Emissions within 20dB of this limit are the subjected to a substitution measurement.

All radiated emissions measurements are performed in two phases. A preliminary scan of emissions is conducted in either an anechoic chamber or on an OATS during which all significant EUT frequencies are identified with the system in a nominal configuration. At least two scans are performed across the complete frequency range of interest and at each operating frequency identified in the reference standard. One or more of these is with the antenna polarized vertically while the one or more of these is with the antenna polarized horizontally. Initial scans are made using a peak detector (RBW=VBW) and using scan rates to ensure that the EUT transmits before the sweep moves out of each resolution bandwidth (for transmit mode).

During the preliminary scans, the EUT is rotated through 360°, the antenna height is varied and cable positions are varied to determine the highest emission relative to the limit. For transmitter spurious emissions, where the limit is expressed as an effective radiated power, the eirp or erp is converted to a field strength limit.

Final measurements are made in a semi-anechoic chamber at the significant frequencies observed during the preliminary scan(s) using the same process of rotating the EUT and raising/lowering the measurement antenna to find the highest level of the emission. The field strength is recorded and, for receiver spurious emissions, compared to the field strength limit. For the final measurement the appropriate detectors (average, peak, normal, sample, quasi-peak) are used. For receiver measurements below 1GHz the detector is a Quasi-Peak detector, above 1GHz a peak detector is used and the peak value (RB=VB=1MHz) and average value (RB=1MHz, VB=10Hz) are recorded.

For transmitter spurious emissions, the radiated power of all emissions within 20dB of the calculated field strength limit are determined using a substitution measurement. The substitution measurement is made by replacing the EUT with an antenna of known gain (typically a dipole antenna or a double-ridged horn antenna), connected to a signal source. The output power of the signal generator is adjusted until the maximum field strength from the substitution antenna is similar to the field strength recorded from the EUT. The erp of the EUT is then calculated.

INSTRUMENTATION

An EMI receiver as specified in CISPR 16-1-1 is used for radiated emissions measurements. The receivers used can measure over the frequency range of 9 kHz up to 7000 MHz. These receivers allow both ease of measurement and high accuracy to be achieved. The receivers have Peak, Average, and CISPR (Quasi-peak) detectors built into their design so no external adapters are necessary.

For measurements above the frequency range of the receivers and for all conducted measurements a spectrum analyzer is utilized because it provides visibility of the entire spectrum along with the precision and versatility required to support engineering analysis.

Measurement bandwidths for the test instruments are set in accordance with the requirements of the standards referenced in this document.

Software control is used to correct the measurements for transducer factors (e.g. antenna) and the insertion loss of cables, attenuators and other series elements to obtain the final measurement value. This provides faster, more accurate readings by performing the conversions described under Sample Calculations within the Test Procedures section of this report. Results are exported in a graphic and/or tabular format, as appropriate.

FILTERS/ATTENUATORS

External filters and precision attenuators are often connected between the EUT antenna port or receiving antenna and the test receiver. This eliminates saturation effects and non-linear operation due to high amplitude transient events.

ANTENNAS

A combination of biconical, log periodic or bi-log antennas are used to cover the range from 30 MHz to 1000 MHz. Broadband antennas or tuned dipole antennas are used over the entire 25 to 1000 MHz frequency range as the reference antenna for substitution measurements.

Above 1000 MHz, a dual-ridge guide horn antenna or octave horn antenna are used as reference and measurement antennas.

The antenna calibration factors are included in site factors that are programmed into the test receivers and instrument control software when measuring the radiated field strength.

ANTENNA MAST AND EQUIPMENT TURNTABLE

The antennas used to measure the radiated electric field strength are mounted on a non-conductive antenna mast equipped with a motor-drive to vary the antenna height.

Table mounted devices are placed on a non-conductive table at a height of 80 or 150 centimeters above the floor depending on the frequency being measured. Floor mounted equipment is placed on the ground plane if the device is normally used on a conductive floor or separated from the ground plane by insulating material from 3 to 12 mm if the device is normally used on a non-conductive floor. The EUT is positioned on a motorized turntable to allow it to be rotated during testing to determine the angel with the highest level of emissions.

SAMPLE CALCULATIONS

SAMPLE CALCULATIONS - CONDUCTED SPURIOUS EMISSIONS

Measurements are compared directly to the conducted emissions specification limit (decibel form). The calculation is as follows:

$$R_r - S = M$$

where:

R_r = Measured value in dBm
S = Specification Limit in dBm
M = Margin to Specification in +/- dB

SAMPLE CALCULATIONS –RADIATED FIELD STRENGTH

Measurements of radiated field strength are compared directly to the specification limit (decibel form). The receiver and/or control software corrects for cable loss, preamplifier gain, and antenna factor. The calculations are in the reverse direction of the actual signal flow, thus cable loss is added and the amplifier gain is subtracted. The Antenna Factor converts the voltage at the antenna coaxial connector to the field strength at the antenna elements.

A distance factor is sued when measurements are made at a test distance that is different to the specified limit distance by using the following formula:

$$F_d = 20*LOG_{10} (D_m/D_s)$$

where:

F_d = Distance Factor in dB

D_m = Measurement Distance in meters

D_s = Specification Distance in meters

For electric field measurements below 30MHz the extrapolation factor is either determined by making measurements at multiple distances or a theoretical value is calculated using the formula:

$$F_d = 40*LOG_{10} (D_m/D_s)$$

The margin of a given emission peak relative to the limit is calculated as follows:

$$R_c = R_r + F_d$$

and

$$M = R_c - L_s$$

where:

R_r = Receiver Reading in dBuV/m

F_d = Distance Factor in dB

R_c = Corrected Reading in dBuV/m

L_s = Specification Limit in dBuV/m

M = Margin in dB Relative to Spec

SAMPLE CALCULATIONS –RADIATED POWER

The erp/eirp limits for transmitter spurious measurements are converted to a field strength in free space using the following formula:

$$E = \frac{\sqrt{30\ P\ G}}{d}$$

where:

E = Field Strength in V/m
P = Power in Watts
G = Gain of isotropic antenna (numeric gain) = 1
D = measurement distance in meters

The field strength limit is then converted to decibel form (dBuV/m) and the margin of a given emission peak relative to the limit is calculated (refer to SAMPLE CALCULATIONS –RADIATED FIELD STRENGTH).

When substitution measurements are required (all signals with less than 20dB of margin relative to the calculated field strength limit) the eirp of the spurious emission is calculated using:

$$P_{EUT} = P_S - (E_S - E_{EUT})$$

and

$$P_S = G + P_{in}$$

where:

P_S = effective isotropic radiated power of the substitution antenna (dBm)
P_{in} = power input to the substitution antenna (dBm)
G = gain of the substitution antenna (dBi)
E_S = field strength the substitution antenna (dBm) at eirp P_S
E_{EUT} = field strength measured from the EUT

Where necessary the effective isotropic radiated power is converted to effective radiated power by subtracting the gain of a dipole (2.2dBi) from the eirp value.

Appendix A Test Equipment Calibration Data

Manufacturer	Description	Model	Asset #	Calibrated	Cal Due
Radiated Emissions, 30 - 1,000 MHz, 04-Jun-20					
National Technical Systems	NTS EMI Software (rev 2.10)	N/A	WC022452	N/A	
Sunol Sciences	Biconilog, 30-3000 MHz	JB3	WC064454	3/11/2019	3/11/2021
Hewlett Packard	9KHz-1300MHz pre-amp	8447F	WC064718	12/2/2019	12/2/2020
Rhode & Schwarz	EMI Test Receiver 20Hz-26.5GHz	ESI	WC071498	5/4/2020	5/4/2021
Radiated Emissions, 1,000 - 5,000 MHz, 05-Jun-20					
National Technical Systems	NTS EMI Software (rev 2.10)	N/A	WC022452	N/A	
EMCO	Horn Antenna	3115	WC062583	7/9/2018	7/9/2020
Hewlett Packard	Microwave Preamplifier, 1-26.5GHz	8449B	WC064574	7/19/2019	7/19/2020
Rohde & Schwarz	EMI Test Receiver, 20 Hz-7 GHz	ESIB 7	WC064989	11/4/2019	11/4/2020
Radio Antenna Port (Power and Spurious Emissions), 05-Jun-20					
National Technical Systems	NTS EMI Software (rev 2.10)	N/A	WC022452	N/A	
National Technical Systems	NTS Mask Software (rev 3.9)	N/A	WC022701	N/A	
National Technical Systems	NTS Capture Analyzer Software (rev 4.0)	N/A	WC022706	N/A	
Agilent Technologies	PSA Spectrum Analyzer	E4446A	WC055650	7/18/2019	7/18/2020
Rohde & Schwarz	Peak Power Sensor 100 uW - 2 Watts (w/ 20 dB pad, SN BJ5155)	NRV-Z32	WC064459	6/28/2019	6/28/2020
Rohde & Schwarz	Power Meter, Dual Channel	NRVD	WC064893	6/7/2019	6/7/2020
Transient Frequency Behavior, 08-Jun-20					
Tektronix	Oscilloscope (Digital)	TDS5104	WC055595	11/11/2019	11/11/2020
Rohde & Schwarz	Peak Power Sensor 100 uW - 2 Watts (w/ 20 dB pad, SN BJ5155)	NRV-Z32	WC064459	6/28/2019	6/28/2020
Rohde & Schwarz	Power Meter, Dual Channel	NRVD	WC064893	6/7/2019	7/7/2020
Rohde & Schwarz	EMI Test Receiver, 20 Hz-7 GHz	ESIB 7	WC064989	11/4/2019	11/4/2020
Hewlett Packard	Signal Generator 0.1 - 1040MHz	8657A	WC071517	N/A	
Radio Antenna Port (Power and Spurious Emissions), 08-Jun-20					
Rohde & Schwarz	Spectrum Analyzer	FSQ26	WC055662	7/4/2019	7/4/2020
Watlow	Environmental Chamber Controller	F4DH-CCCC-21RG	WC066185	6/6/2020	6/6/2021
Watlow	Limit Controller	Limit 97	WC071533	N/A	
Envirotronics	EMC Chamber #10 (Lab #3)	SH16C	WC071534	N/A	

Appendix B Test Data

TL109246-RANA Pages 21 - 48

Client:	FreeWave Technologies, Inc.	PR Number:	PR109246
Product	LRS455A	T-Log Number:	TL109246-RANA
System Configuration:	-	Project Manager:	Deepa Shetty
Contact:	Michael Vidales	Project Engineer:	David Bare
Emissions Standard(s):	FCC Parts 15 & 90, RSS-119	Class:	-
Immunity Standard(s):	-	Environment:	Radio

EMC Test Data

For The

FreeWave Technologies, Inc.

Product

LRS455A

Date of Last Test: 6/8/2020

Client:	FreeWave Technologies, Inc.	PR Number:	PR109246
Model:	LRS455A	T-Log Number:	TL109246-RANA
		Project Manager:	Deepa Shetty
Contact:	Michael Vidales	Project Engineer:	David Bare
Standard:	FCC Parts 15 & 90, RSS-119	Class:	N/A

RSS 119 and FCC Part 90

Power, Occupied Bandwidth, Frequency Stability and Spurious Emissions

Test Specific Details

Objective: The objective of this test session is to perform final qualification testing of the EUT with respect to the specification listed above.

General Test Configuration

With the exception of the radiated spurious emissions tests, all measurements are made with the EUT's rf port connected to the measurement instrument via an attenuator or dc-block if necessary. All amplitude measurements are adjusted to account for the attenuation between EUT and measuring instrument. For frequency stability measurements the EUT was placed inside an environmental chamber.

Radiated measurements are made with the EUT located on a non-conductive table, 3m from the measurement antenna.

Radiated emissions tests above 1 GHz to FCC Part 90 were performed with floor absorbers in place in accordance with the test methods of ANSI C63.4 and CISPR 16-1-4.

Ambient Conditions:

Temperature:	19 - 23 °C
Rel. Humidity:	39 - 44 %

Modifications Made During Testing

No modifications were made to the EUT during testing

Deviations From The Standard

No deviations were made from the requirements of the standard.

Client:	FreeWave Technologies, Inc.	PR Number:	PR109246
Model:	LRS455A	T-Log Number:	TL109246-RANA
		Project Manager:	Deepa Shetty
Contact:	Michael Vidales	Project Engineer:	David Bare
Standard:	FCC Parts 15 & 90, RSS-119	Class:	N/A

Summary of Results

Run #			Test Performed	Limit	Pass / Fail	Result / Margin
1			Output Power	500W ERP	Pass	33.2 dBm (Max 29.2 W ERP)
2			Spectral Mask	Within Mask	Pass	Within Mask
3			99% or Occupied Bandwidth	11.25 kHz	Pass	7.64 & 8.89 kHz
4			Spurious Emissions (conducted)	-20dBm	Pass	-36.0 dBm @ 1380.0 MHz (-16.0 dB)
5			Spurious emissions (radiated)	-20dBm	Pass	50.9 dBµV/m @ 3290.0 MHz (-24.4 dB)
6			Transient Frequency Behavior	t_1: 10ms t_2: 25ms t_3:10ms	Pass	Within Limits
7			Modulation limitation	N/A	-	-
8			Frequency Stability	2.5 ppm / 1.5 ppm	Pass	0.6

Test Notes

RSS-119 and SRSP-501 only allow operation from 450-470 MHz. FCC §2.106 pages 28 and 29 and Part 90 allow operation over the full 435-470 MHz band.

Client:	FreeWave Technologies, Inc.	PR Number:	PR109246
Model:	LRS455A	T-Log Number:	TL109246-RANA
		Project Manager:	Deepa Shetty
Contact:	Michael Vidales	Project Engineer:	David Bare
Standard:	FCC Parts 15 & 90, RSS-119	Class:	N/A

Run #1: Output Power

Date of Test: 6/5/2020 Config. Used: 1

Test Engineer: David Bare Config Change: None

Test Location: Fremont Chamber #5 EUT Voltage: 12 VDC

Cable Loss: 0.0 dB Attenuator: 20.0 dB Total Loss: 20.0 dB

Cable ID(s): None Attenuator IDs: WC072235

Power Setting[2]	Frequency (MHz)	Output Power (dBm) [1]	Output Power mW	Max Ant Gain (dBi)	Result	ERP dBm	ERP W
10	435	32.9	1949.8	9.25	Pass	44.4	27.227
10	450	33.2	2089.3	9.25	Pass	44.7	29.174
10	460	33.2	2089.3	9.25	Pass	44.7	29.174
10	470	33.1	2041.7	9.25	Pass	44.6	28.510

Note 1:	Output power measured using a peak power meter
Note 2:	Power setting - the software power setting used during testing, included for reference only
Note 3:	435 MHz not used in Canada

Client:	FreeWave Technologies, Inc.	PR Number:	PR109246
Model:	LRS455A	T-Log Number:	TL109246-RANA
		Project Manager:	Deepa Shetty
Contact:	Michael Vidales	Project Engineer:	David Bare
Standard:	FCC Parts 15 & 90, RSS-119	Class:	N/A

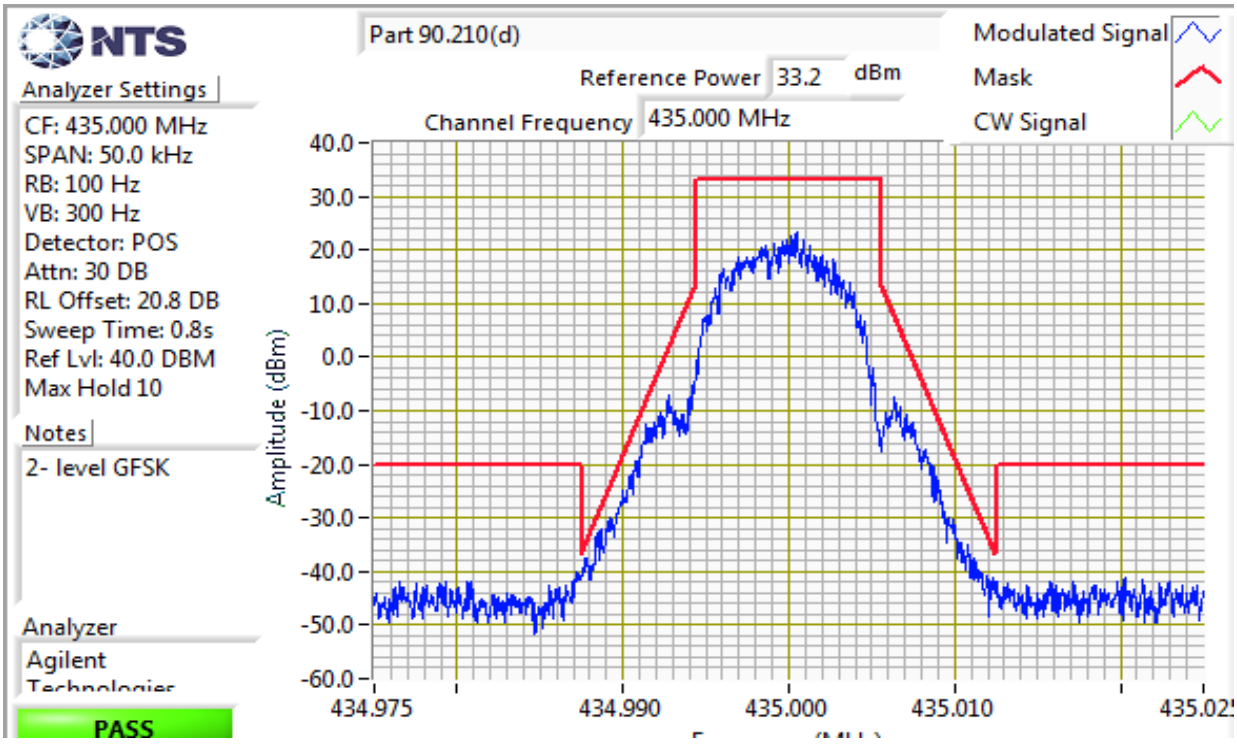
Run #2: Spectral Mask, FCC Part 90/RSS-119 Mask D

Date of Test: 6/5/2020 Config. Used: 1

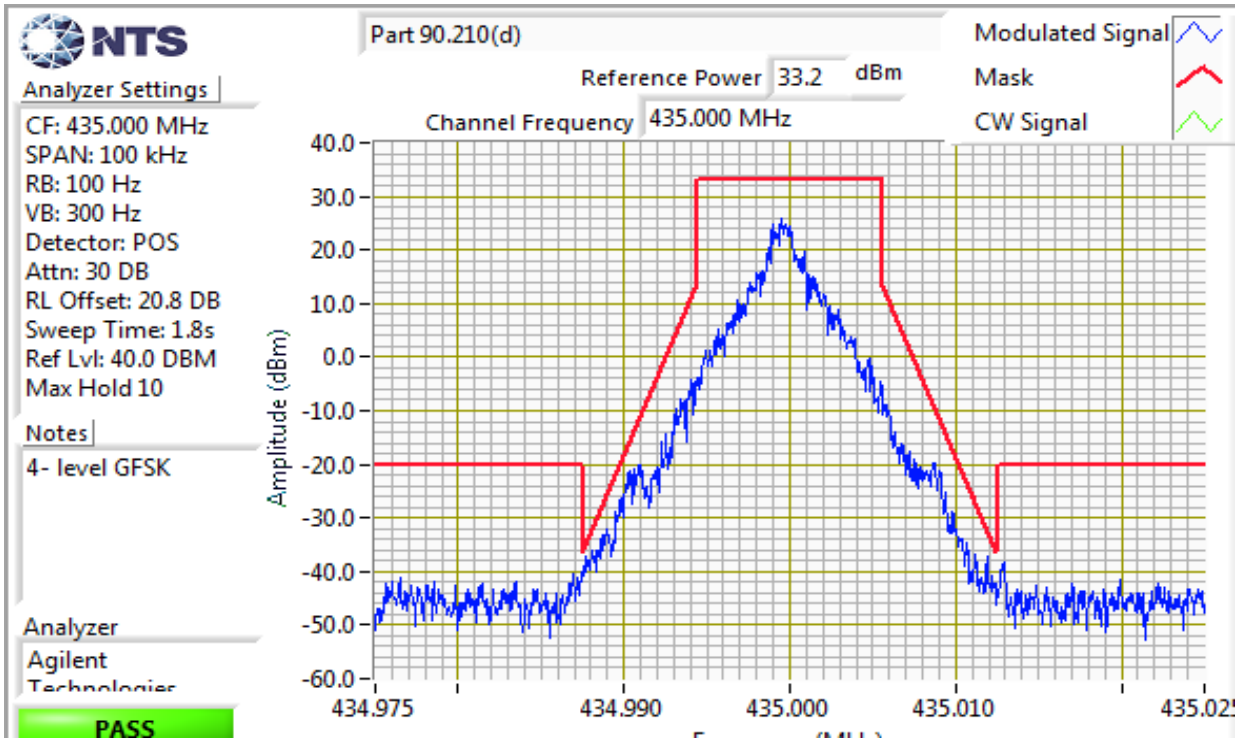
Test Engineer: David Bare Config Change: None

Test Location: Fremont Chamber #5 EUT Voltage: 12 VDC

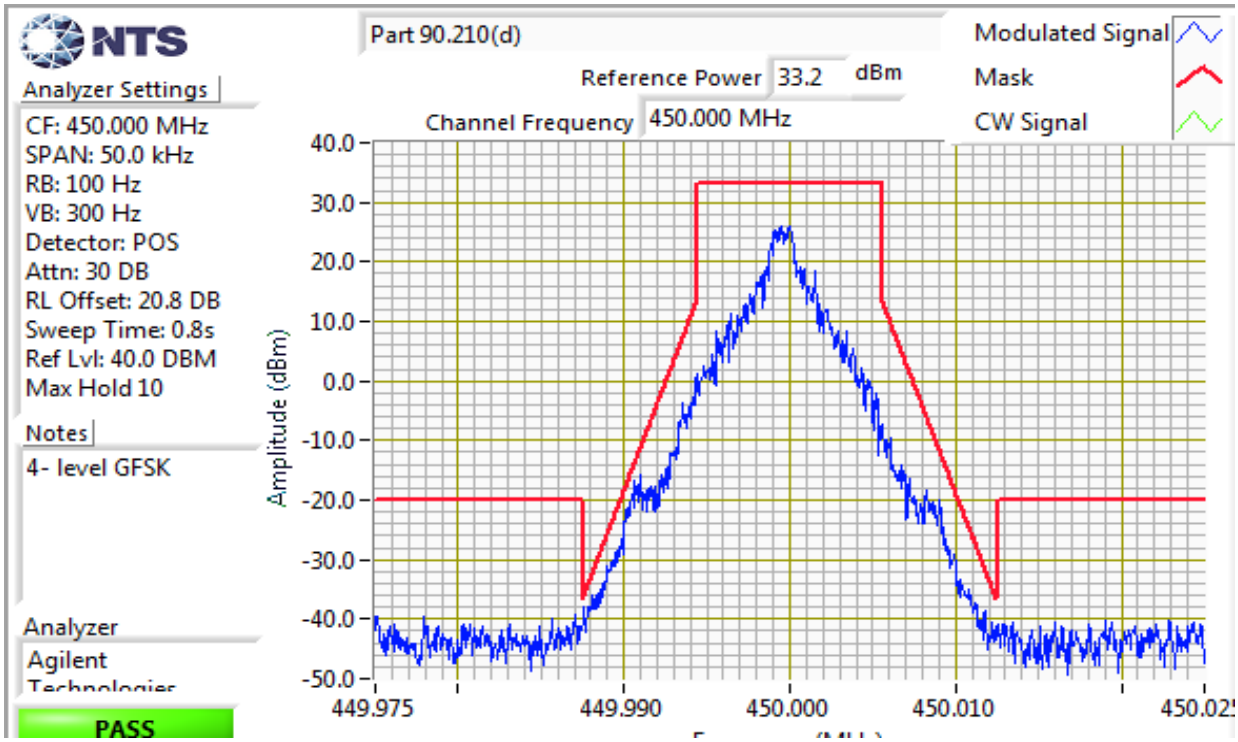
Note 1:	Reference level for Mask is equal to maximim peak power from Run 1
Note 2:	435 MHz not used in Canada



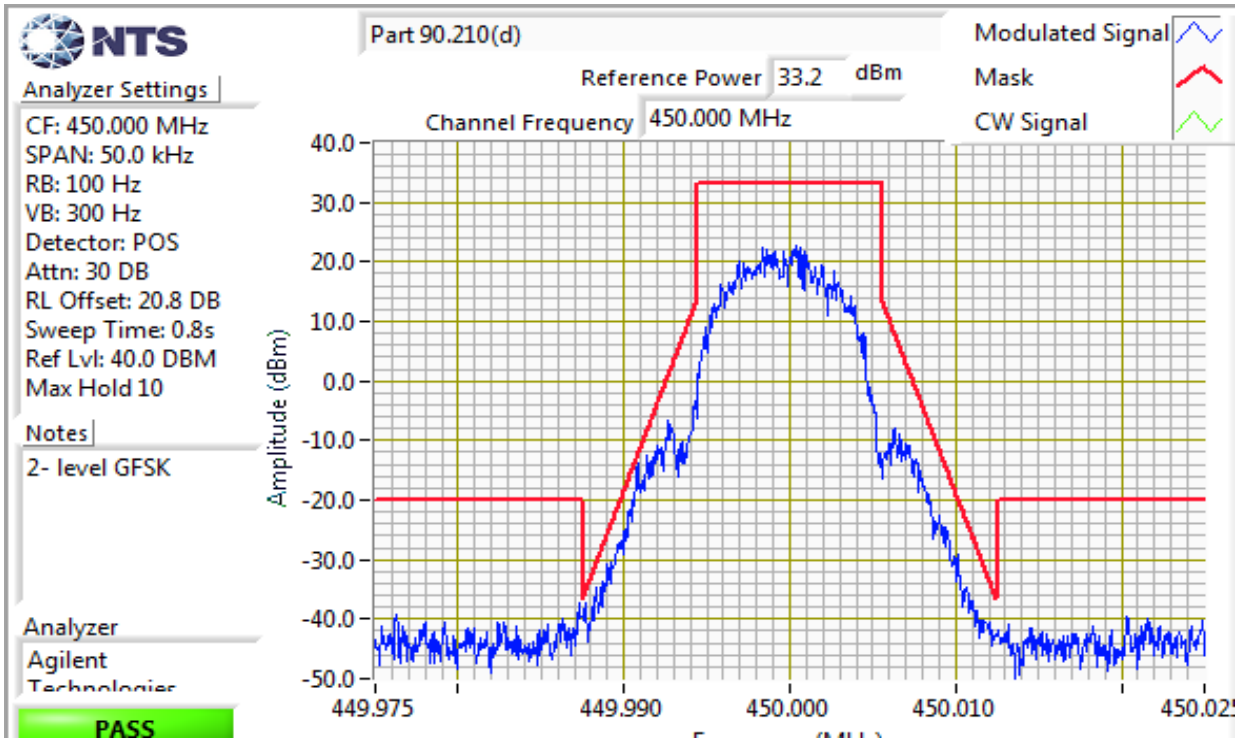
Client:	FreeWave Technologies, Inc.	PR Number:	PR109246
Model:	LRS455A	T-Log Number:	TL109246-RANA
		Project Manager:	Deepa Shetty
Contact:	Michael Vidales	Project Engineer:	David Bare
Standard:	FCC Parts 15 & 90, RSS-119	Class:	N/A



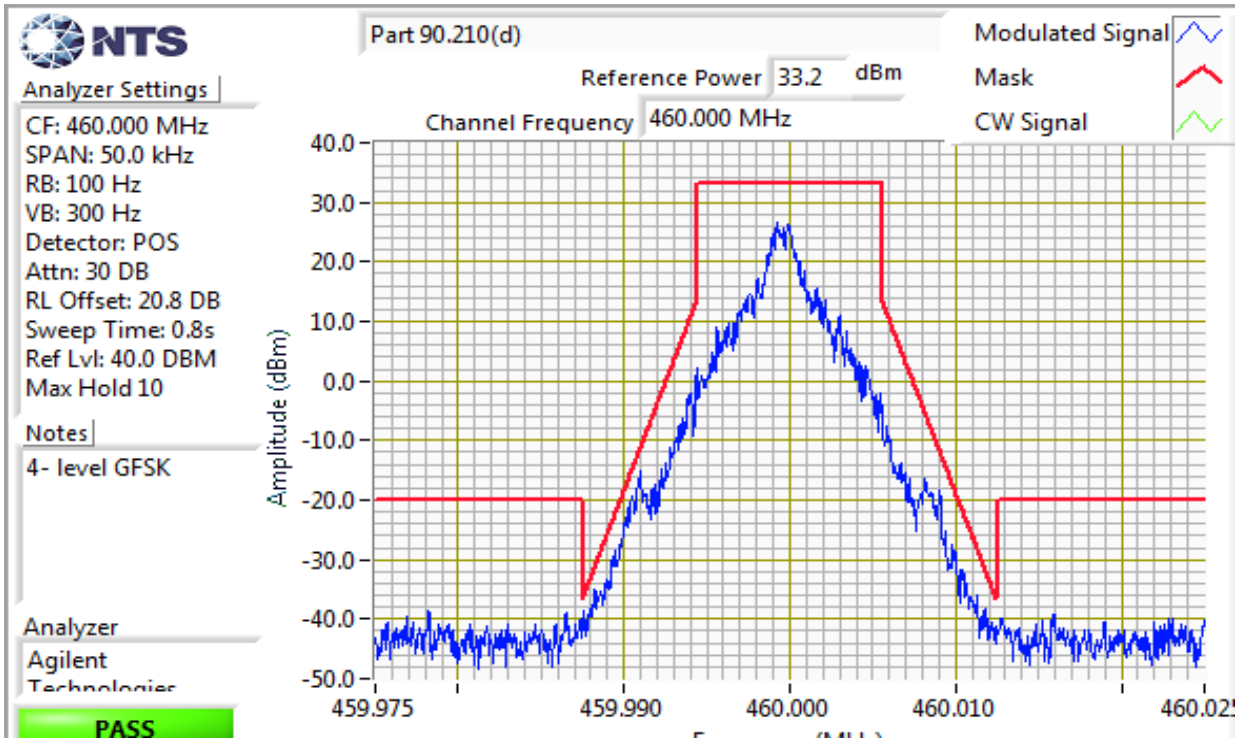
Client:	FreeWave Technologies, Inc.	PR Number:	PR109246
Model:	LRS455A	T-Log Number:	TL109246-RANA
		Project Manager:	Deepa Shetty
Contact:	Michael Vidales	Project Engineer:	David Bare
Standard:	FCC Parts 15 & 90, RSS-119	Class:	N/A



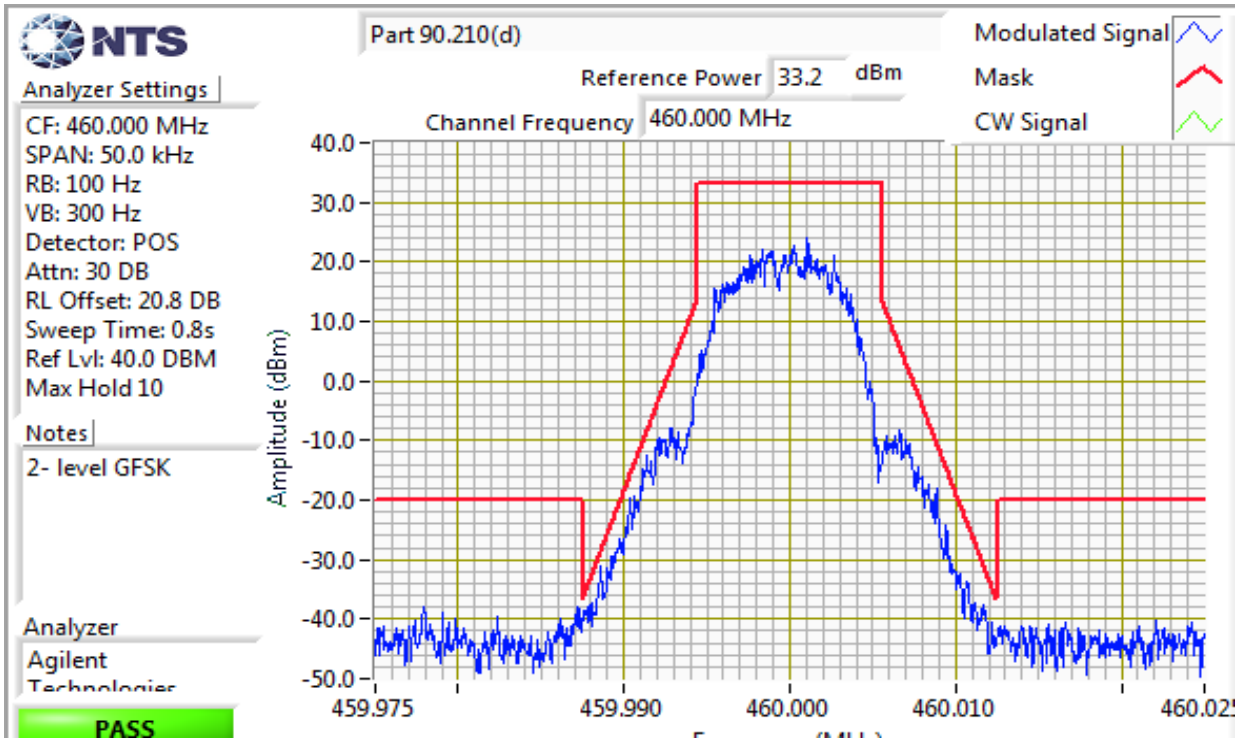
Client:	FreeWave Technologies, Inc.	PR Number:	PR109246
Model:	LRS455A	T-Log Number:	TL109246-RANA
		Project Manager:	Deepa Shetty
Contact:	Michael Vidales	Project Engineer:	David Bare
Standard:	FCC Parts 15 & 90, RSS-119	Class:	N/A



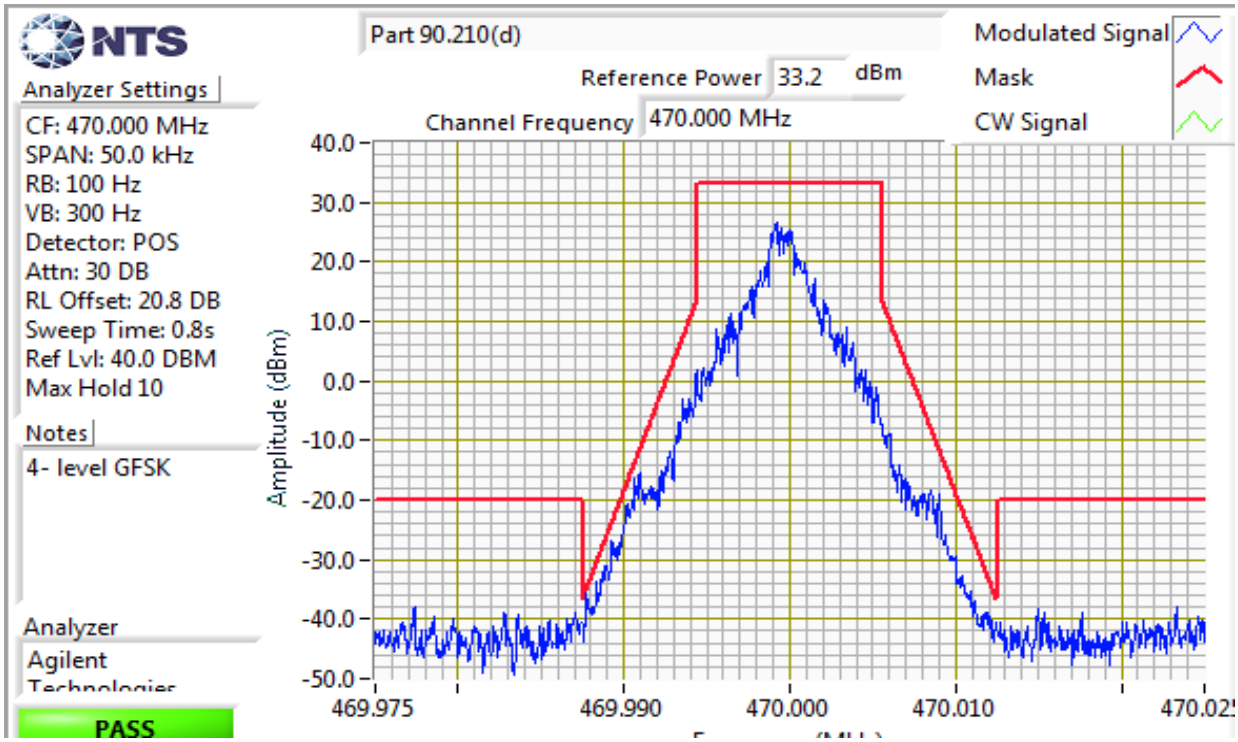
Client:	FreeWave Technologies, Inc.	PR Number:	PR109246
Model:	LRS455A	T-Log Number:	TL109246-RANA
		Project Manager:	Deepa Shetty
Contact:	Michael Vidales	Project Engineer:	David Bare
Standard:	FCC Parts 15 & 90, RSS-119	Class:	N/A



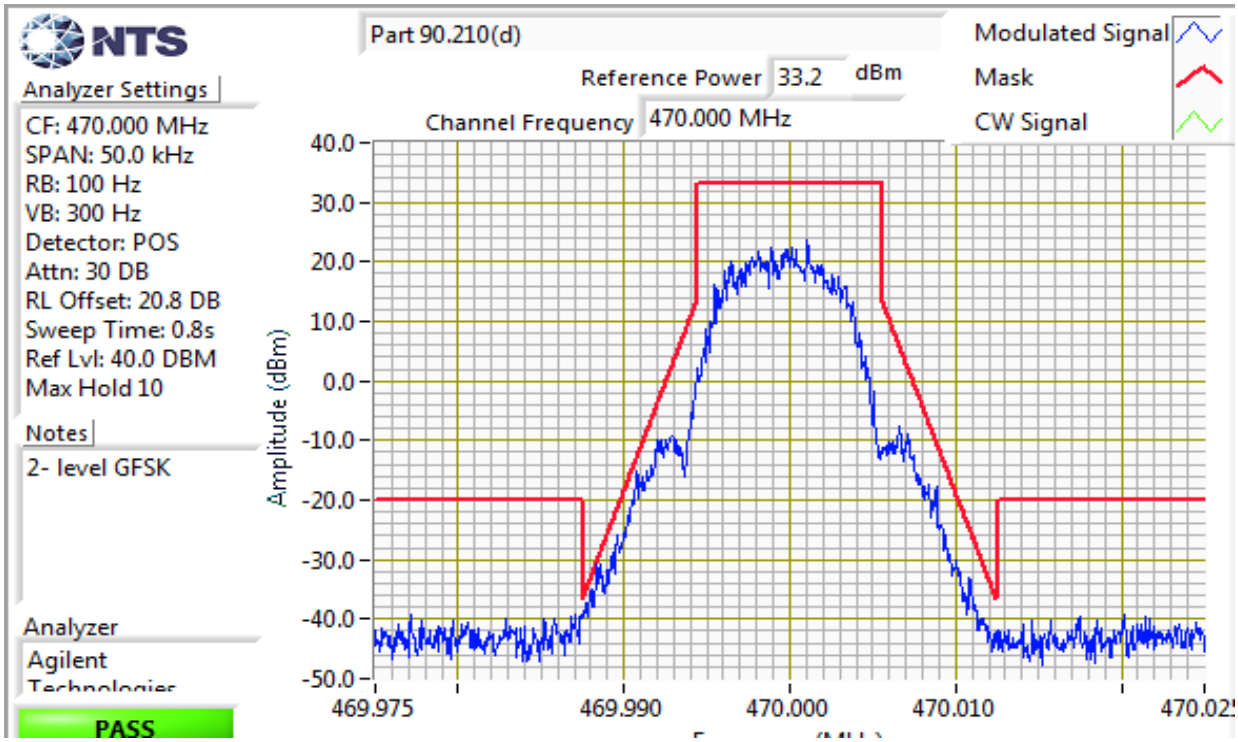
Client:	FreeWave Technologies, Inc.	PR Number:	PR109246
Model:	LRS455A	T-Log Number:	TL109246-RANA
		Project Manager:	Deepa Shetty
Contact:	Michael Vidales	Project Engineer:	David Bare
Standard:	FCC Parts 15 & 90, RSS-119	Class:	N/A



Client:	FreeWave Technologies, Inc.	PR Number:	PR109246
Model:	LRS455A	T-Log Number:	TL109246-RANA
		Project Manager:	Deepa Shetty
Contact:	Michael Vidales	Project Engineer:	David Bare
Standard:	FCC Parts 15 & 90, RSS-119	Class:	N/A



Client:	FreeWave Technologies, Inc.	PR Number:	PR109246
Model:	LRS455A	T-Log Number:	TL109246-RANA
		Project Manager:	Deepa Shetty
Contact:	Michael Vidales	Project Engineer:	David Bare
Standard:	FCC Parts 15 & 90, RSS-119	Class:	N/A



Client:	FreeWave Technologies, Inc.	PR Number:	PR109246
Model:	LRS455A	T-Log Number:	TL109246-RANA
		Project Manager:	Deepa Shetty
Contact:	Michael Vidales	Project Engineer:	David Bare
Standard:	FCC Parts 15 & 90, RSS-119	Class:	N/A

Run #3: Signal Bandwidth

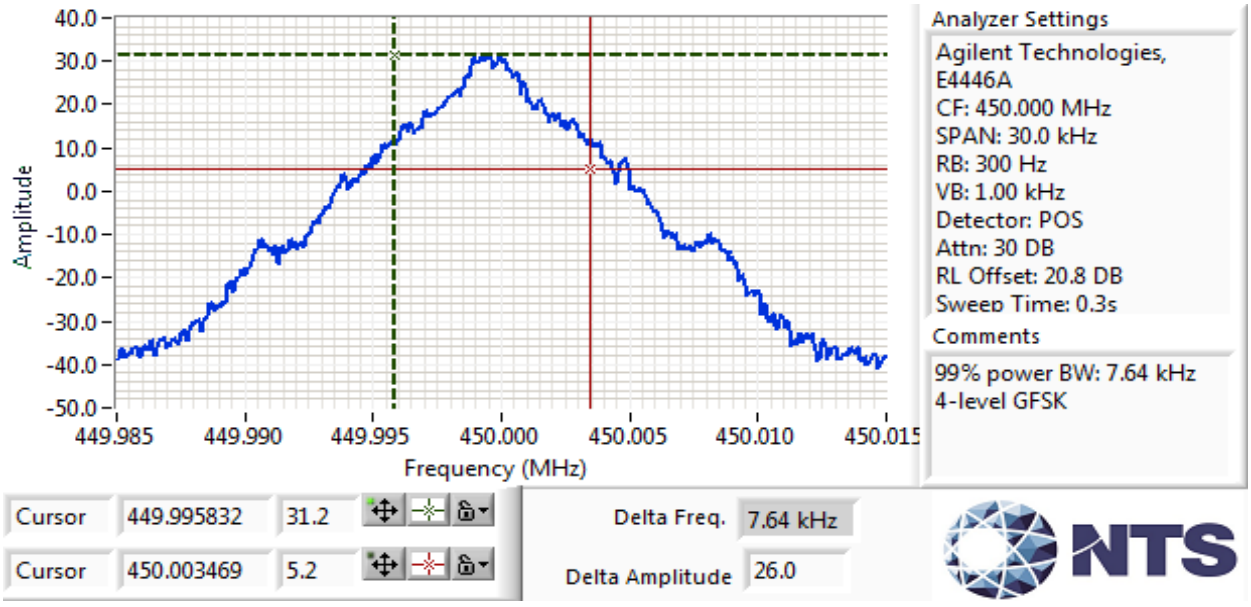
Date of Test: 6/5/2020 Config. Used: 1

Test Engineer: David Bare Config Change: None

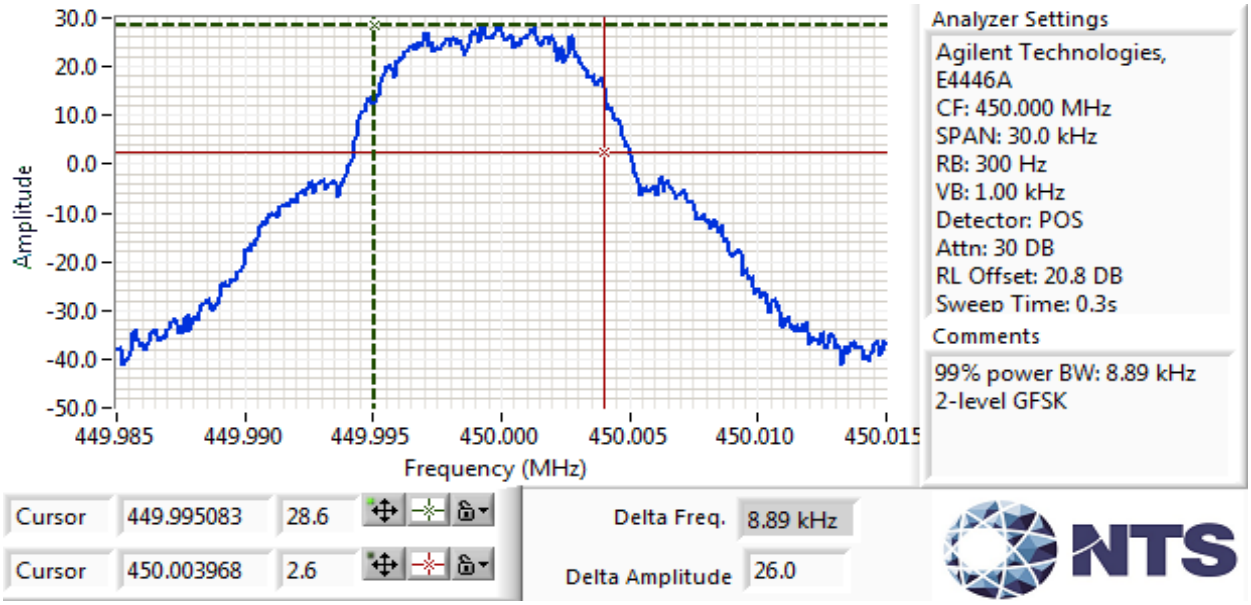
Test Location: Fremont Chamber #5 EUT Voltage: 12 VDC

Power Setting	Frequency (MHz)	Resolution Bandwidth	Bandwidth (kHz)	99%	
10	435	300 Hz		8.84	2-level GFSK
10	450	300 Hz		8.89	2-level GFSK
10	460	300 Hz		8.89	2-level GFSK
10	470	300 Hz		8.89	2-level GFSK
10	435	300 Hz		7.64	4-level GFSK
10	450	300 Hz		7.64	4-level GFSK
10	460	300 Hz		7.64	4-level GFSK
10	470	300 Hz		7.59	4-level GFSK

Note 1:	99% bandwidth measured in accordance with ANSI C63.10, with RB between 1% and 5% of the measured bandwidth and VB ≥ 3*RB and Span ≥ 1.5% and ≤ 5% of measured bandwidth.
Note 2:	435 MHz not used in Canada



Client:	FreeWave Technologies, Inc.	PR Number:	PR109246
Model:	LRS455A	T-Log Number:	TL109246-RANA
		Project Manager:	Deepa Shetty
Contact:	Michael Vidales	Project Engineer:	David Bare
Standard:	FCC Parts 15 & 90, RSS-119	Class:	N/A



Client:	FreeWave Technologies, Inc.	PR Number:	PR109246
Model:	LRS455A	T-Log Number:	TL109246-RANA
		Project Manager:	Deepa Shetty
Contact:	Michael Vidales	Project Engineer:	David Bare
Standard:	FCC Parts 15 & 90, RSS-119	Class:	N/A

Run #4: Out of Band Spurious Emissions, Conducted

Date of Test: 6/5/2020 Config. Used: 1
Test Engineer: David Bare Config Change: None
Test Location: Fremont Chamber #5 EUT Voltage: 12 VDC

Frequency (MHz)	Limit	Result
435	-20 dBm	Pass
450	-20 dBm	Pass
460	-20 dBm	Pass
470	-20 dBm	Pass

The limit is taken from FCC Part 90 Mask D.
Plots 20 Mhz wide centered on the signal frequency also provided for each channel bandwidth/spacing.

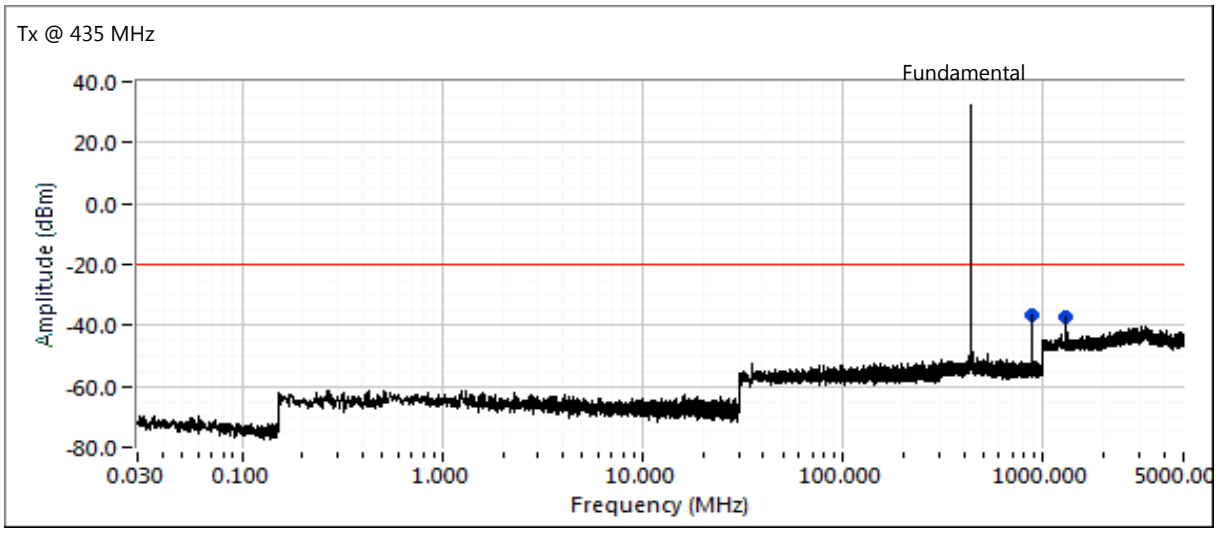
Final peak readings

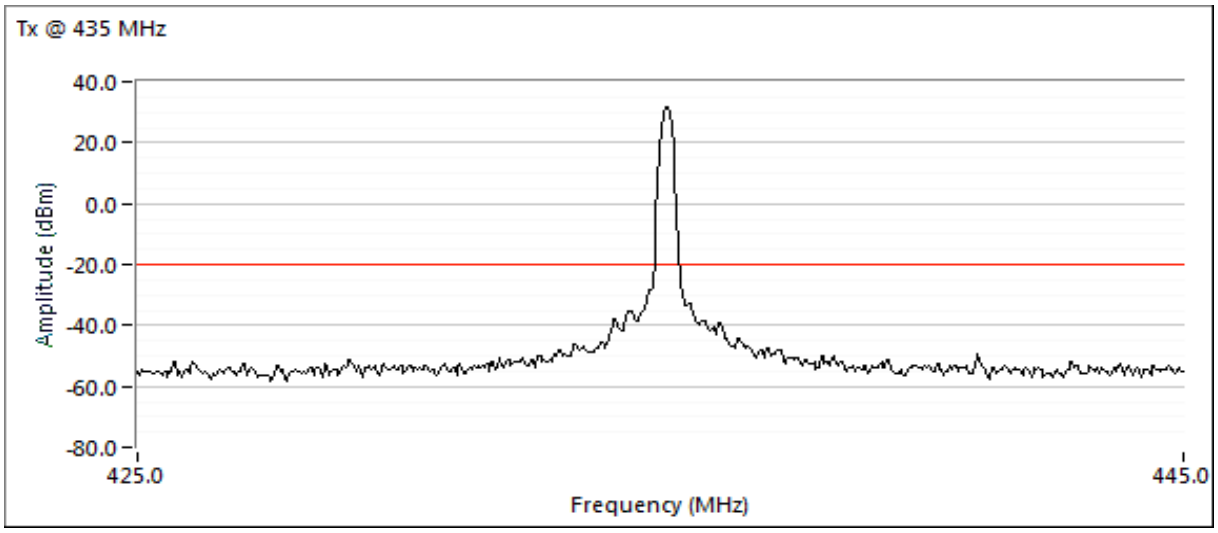
Frequency	Level		FCC 90.210		Detector	Comments	
MHz	dBm	Port	Limit	Margin	QP/Ave		
870.006	-37.7	RF Port	-20.0	-17.7	PK	PK (CISPR)-RB 120 kHz; VB: 1 MHz	435 MHz
1305.020	-36.5	RF Port	-20.0	-16.5	PK	PK (CISPR)-RB 1 MHz; VB: 3 MHz	435 MHz
899.999	-37.6	RF Port	-20.0	-17.6	PK	PK (CISPR)-RB 120 kHz; VB: 1 MHz	450 MHz
1350.010	-36.4	RF Port	-20.0	-16.4	PK	PK (CISPR)-RB 1 MHz; VB: 3 MHz	450 MHz
919.992	-37.5	RF Port	-20.0	-17.5	PK	PK (CISPR)-RB 120 kHz; VB: 1 MHz	460 MHz
1380.000	-36.0	RF Port	-20.0	-16.0	PK	PK (CISPR)-RB 1 MHz; VB: 3 MHz	460 MHz
940.008	-37.7	RF Port	-20.0	-17.7	PK	PK (CISPR)-RB 120 kHz; VB: 1 MHz	470 MHz
1409.840	-36.6	RF Port	-20.0	-16.6	PK	PK (CISPR)-RB 1 MHz; VB: 3 MHz	470 MHz

Note 1:	435 MHz not used in Canada

Client:	FreeWave Technologies, Inc.	PR Number:	PR109246
Model:	LRS455A	T-Log Number:	TL109246-RANA
		Project Manager:	Deepa Shetty
Contact:	Michael Vidales	Project Engineer:	David Bare
Standard:	FCC Parts 15 & 90, RSS-119	Class:	N/A

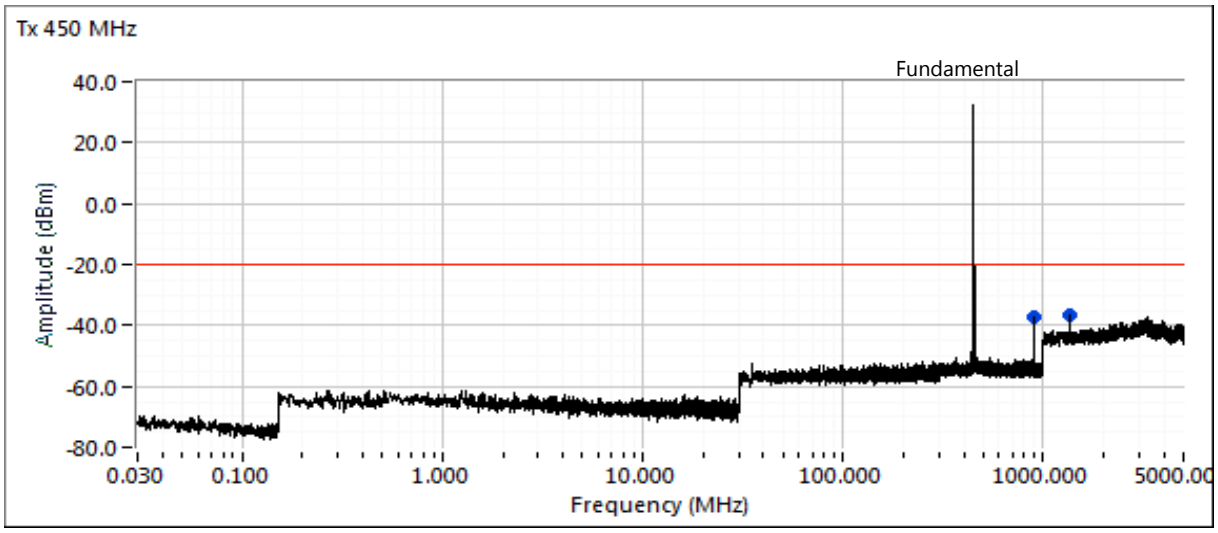
Plots for low channel, power setting(s) = 10

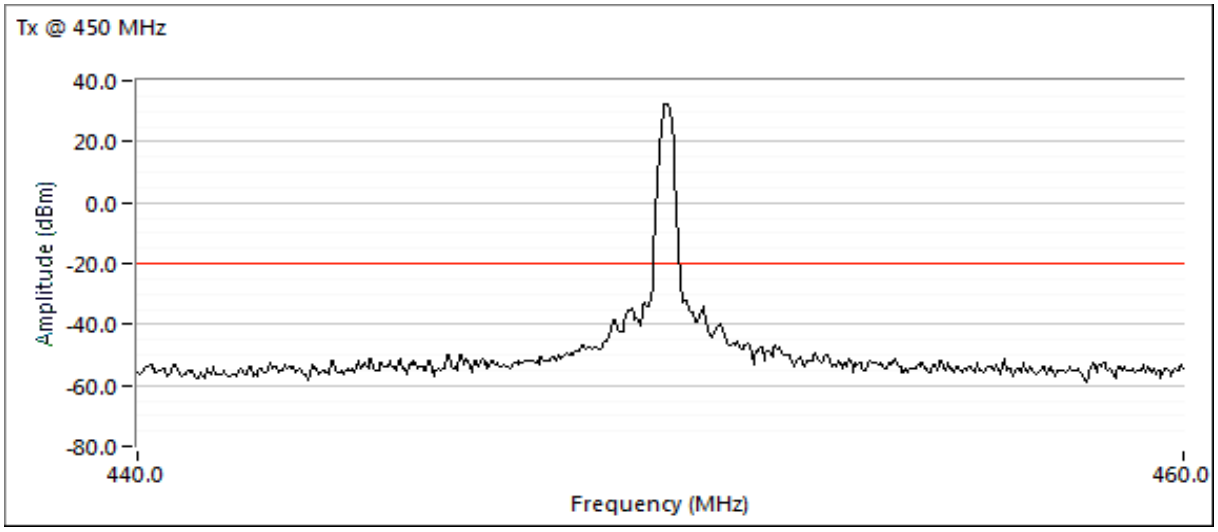




Client:	FreeWave Technologies, Inc.	PR Number:	PR109246
Model:	LRS455A	T-Log Number:	TL109246-RANA
		Project Manager:	Deepa Shetty
Contact:	Michael Vidales	Project Engineer:	David Bare
Standard:	FCC Parts 15 & 90, RSS-119	Class:	N/A

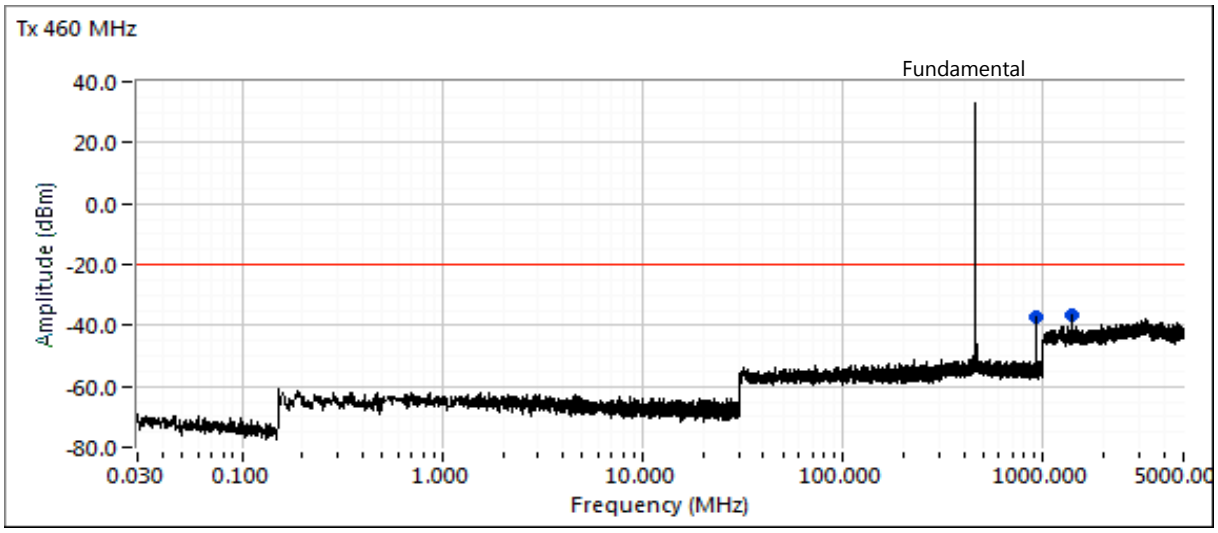
Plots for center channel, power setting(s) = 10

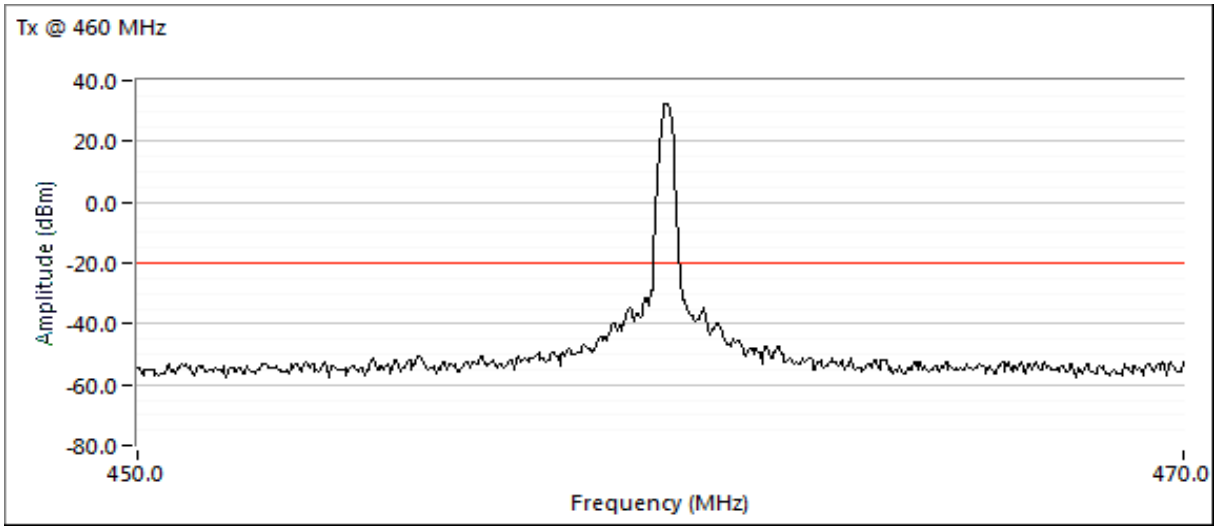




Client:	FreeWave Technologies, Inc.	PR Number:	PR109246
Model:	LRS455A	T-Log Number:	TL109246-RANA
		Project Manager:	Deepa Shetty
Contact:	Michael Vidales	Project Engineer:	David Bare
Standard:	FCC Parts 15 & 90, RSS-119	Class:	N/A

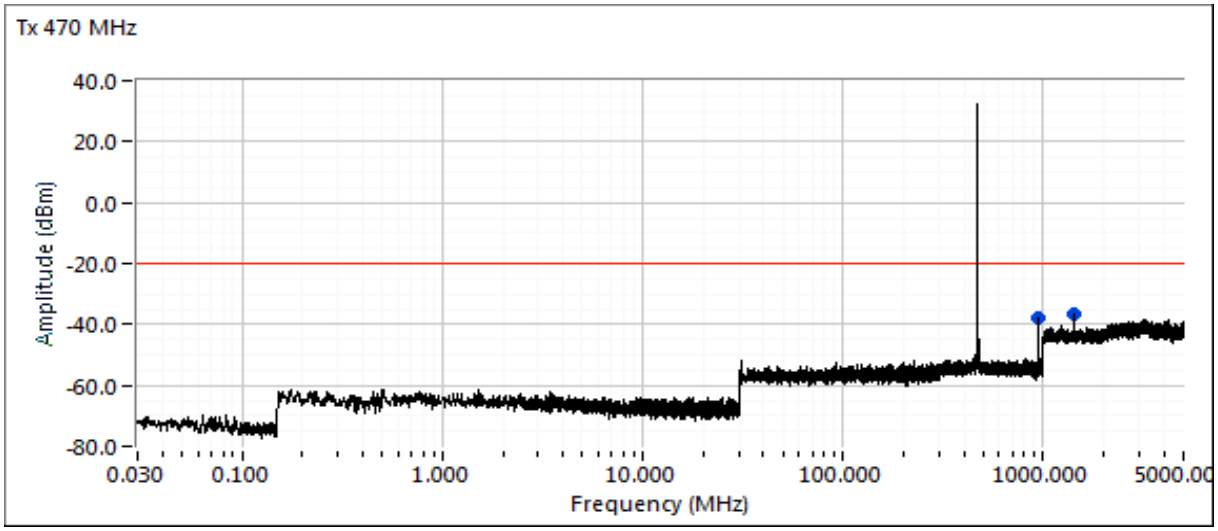
Plots for center channel, power setting(s) = 10

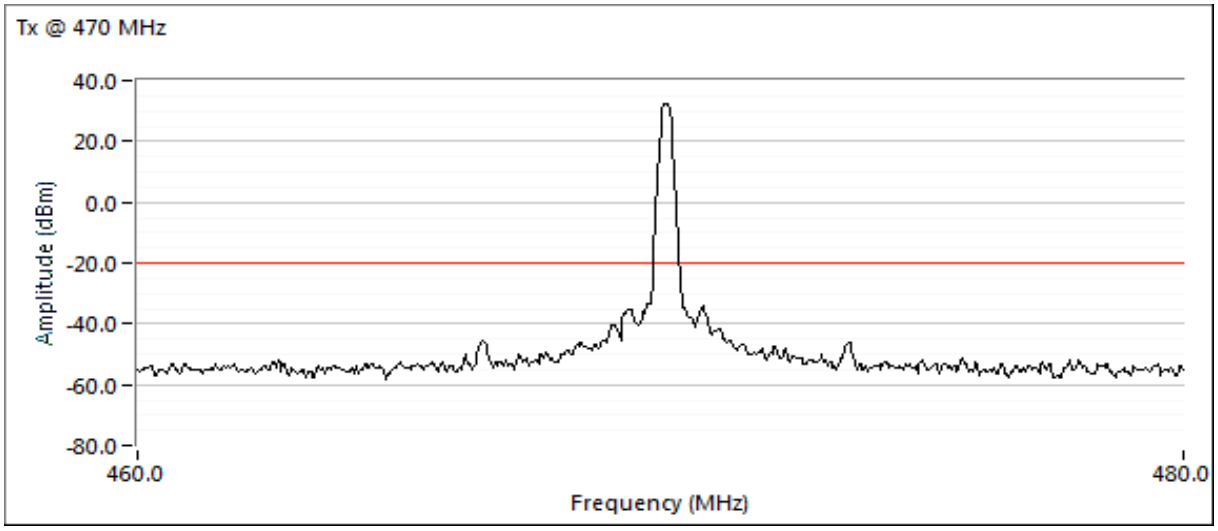




Client:	FreeWave Technologies, Inc.	PR Number:	PR109246
Model:	LRS455A	T-Log Number:	TL109246-RANA
		Project Manager:	Deepa Shetty
Contact:	Michael Vidales	Project Engineer:	David Bare
Standard:	FCC Parts 15 & 90, RSS-119	Class:	N/A

Plots for high channel, power setting(s) = 10





Client:	FreeWave Technologies, Inc.	PR Number:	PR109246
Model:	LRS455A	T-Log Number:	TL109246-RANA
		Project Manager:	Deepa Shetty
Contact:	Michael Vidales	Project Engineer:	David Bare
Standard:	FCC Parts 15 & 90, RSS-119	Class:	N/A

Run #5: Out of Band Spurious Emissions, Radiated

Conducted limit (dBm): -20
Approximate field strength limit @ 3m: 75.3

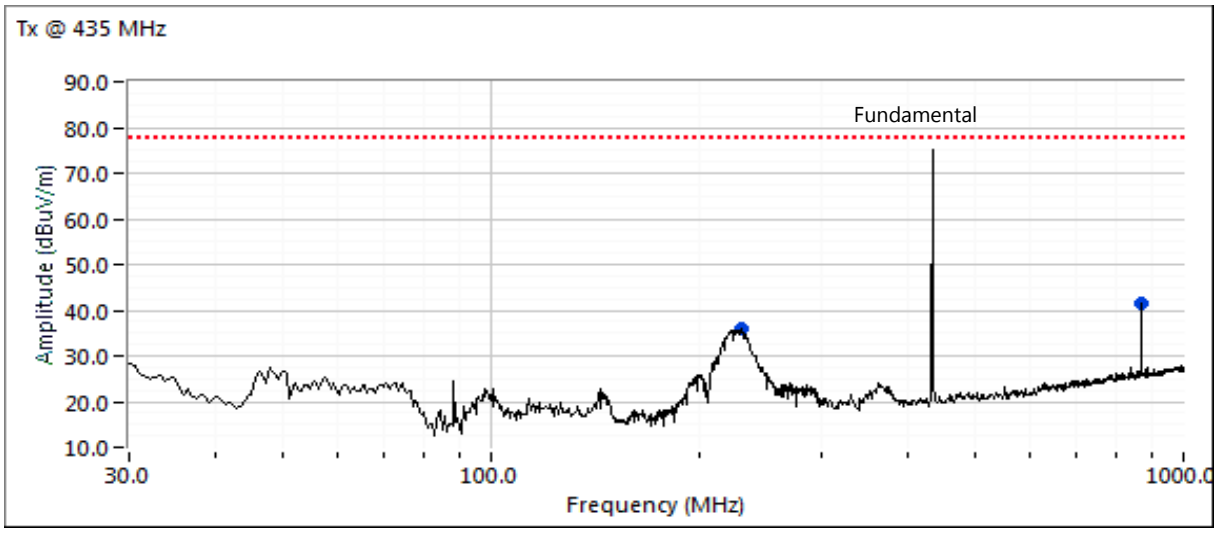
The limit is taken from FCC Part 90 Mask D
Run #5a - Preliminary measurements
Date of Test: 6/4 & 6/5/2020 Config. Used: 1
Test Engineer: David Bare & Y K Soo Config Change: None
Test Location: Fremont Chamber #4 & 5 EUT Voltage: 12VDC

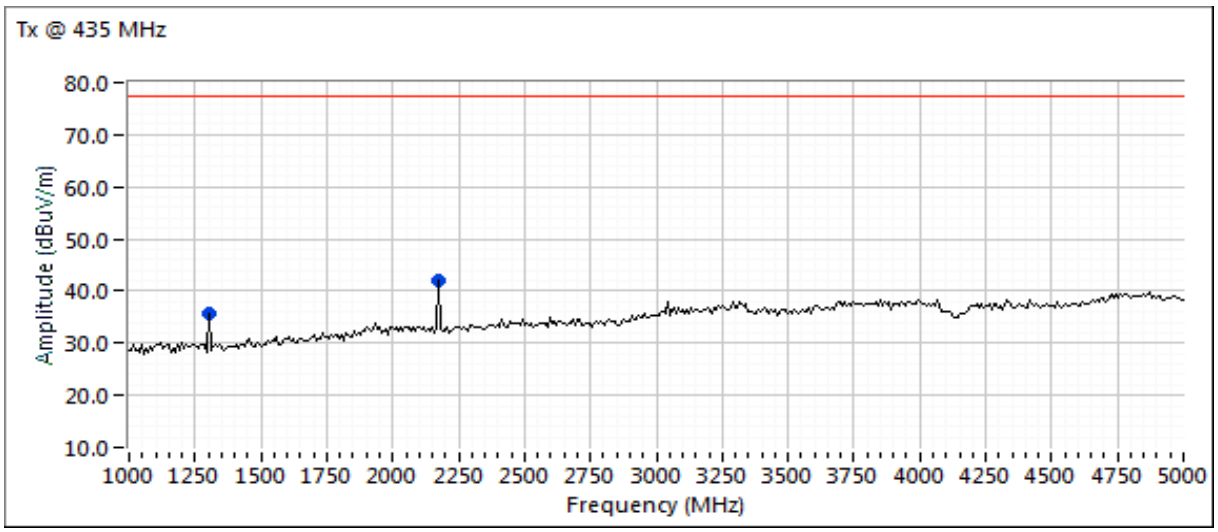
Frequency	Level	Pol	FCC Part 90		Detector	Azimuth	Height	Comments	Channel
MHz	dBµV/m	v/h	Limit	Margin	Pk/QP/Avg	degrees	meters		
230.741	35.8	H	75.3	-39.5	Peak	320	1.5		435 MHz
870.942	41.7	H	75.3	-33.6	Peak	159	2.0		435 MHz
1305.030	35.6	V	75.3	-39.7	Peak	77	2.5		435 MHz
2175.040	41.9	V	75.3	-33.4	Peak	143	2.0		435 MHz
232.365	35.2	H	75.3	-40.1	Peak	280	1.5		450 MHz
900.401	42.0	H	75.3	-33.3	Peak	145	2.0		450 MHz
1350.030	34.2	V	75.3	-41.1	Peak	93	2.0		450 MHz
2250.040	37.3	H	75.3	-38.0	Peak	77	1.0		450 MHz
233.513	35.4	H	75.3	-39.9	Peak	283	1.5		460 MHz
920.009	41.7	H	75.3	-33.6	Peak	156	1.0		460 MHz
1380.000	35.3	V	75.3	-40.0	Peak	91	2.0		460 MHz
2300.000	37.8	V	75.3	-37.5	Peak	76	1.5		460 MHz
3220.010	38.7	V	75.3	-36.6	Peak	215	1.5		460 MHz
223.645	35.4	H	75.3	-39.9	Peak	306	1.5		470 MHz
940.007	46.2	V	75.3	-29.1	Peak	76	1.0		470 MHz
1410.020	33.8	V	75.3	-41.5	Peak	84	1.5		
2350.020	37.5	V	75.3	-37.8	Peak	94	1.0		
3290.010	45.4	H	75.3	-29.9	Peak	342	1.0		

Note 1:	The field strength limit in the tables above was calculated from the erp/eirp limit detailed in the standard using the free space propagation equation: $E=\sqrt{(30PG)}/d$. This limit is conservative - it does not consider the presence of the ground plane and, for erp limits, the dipole gain (2.2dBi) has not been included. The erp or eirp for all signals with less than 20dB of margin relative to this field strength limit is determined using substitution measurements.
Note 2:	Measurements are made with the antenna port terminated.

Client:	FreeWave Technologies, Inc.	PR Number:	PR109246
Model:	LRS455A	T-Log Number:	TL109246-RANA
		Project Manager:	Deepa Shetty
Contact:	Michael Vidales	Project Engineer:	David Bare
Standard:	FCC Parts 15 & 90, RSS-119	Class:	N/A

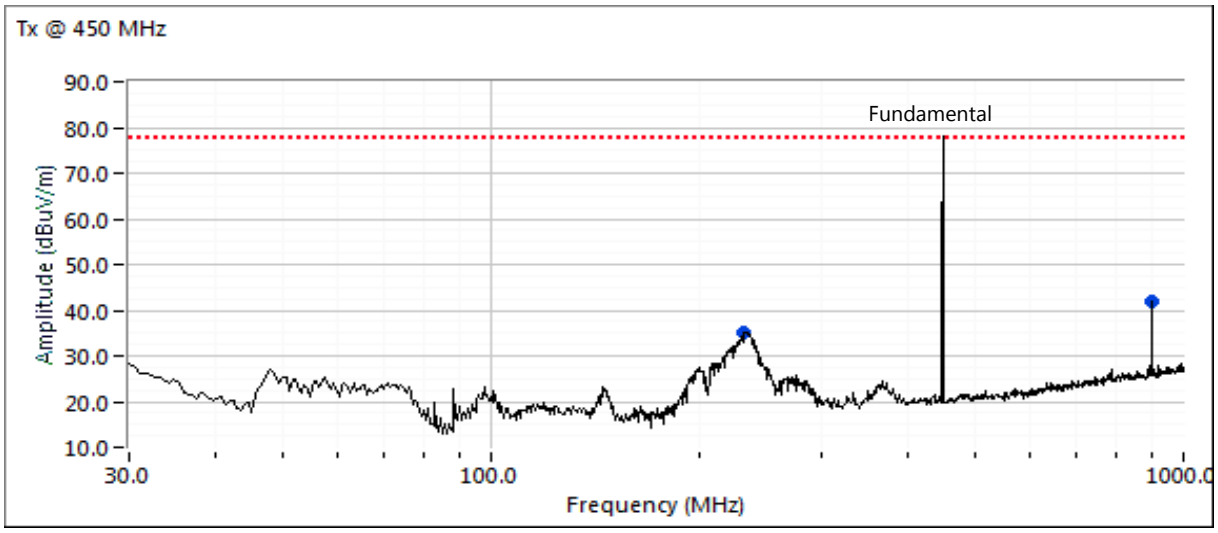
Plots for low channel, power setting(s) = 10

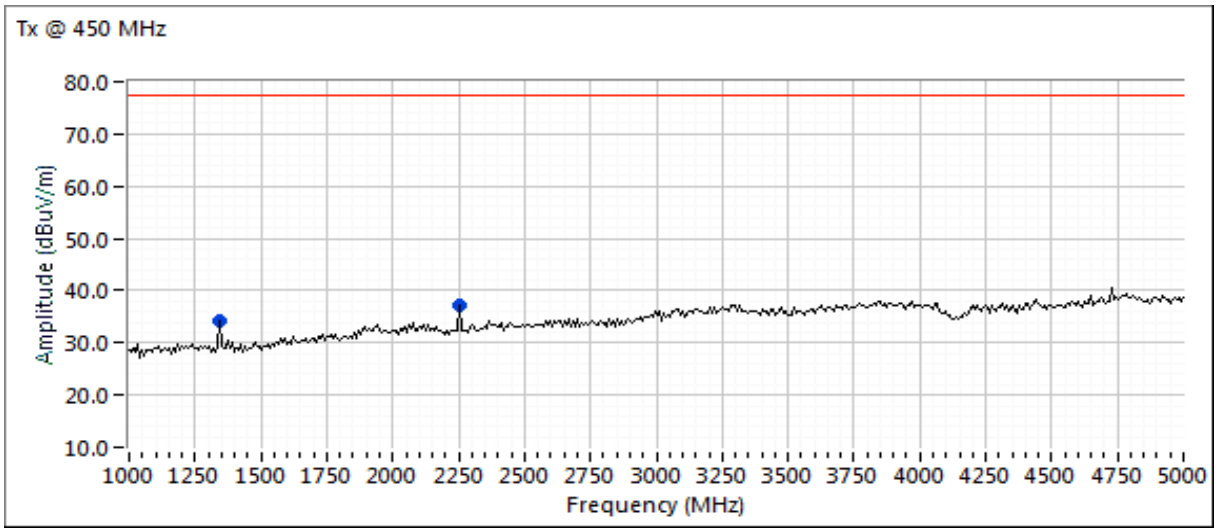




Client:	FreeWave Technologies, Inc.	PR Number:	PR109246
Model:	LRS455A	T-Log Number:	TL109246-RANA
		Project Manager:	Deepa Shetty
Contact:	Michael Vidales	Project Engineer:	David Bare
Standard:	FCC Parts 15 & 90, RSS-119	Class:	N/A

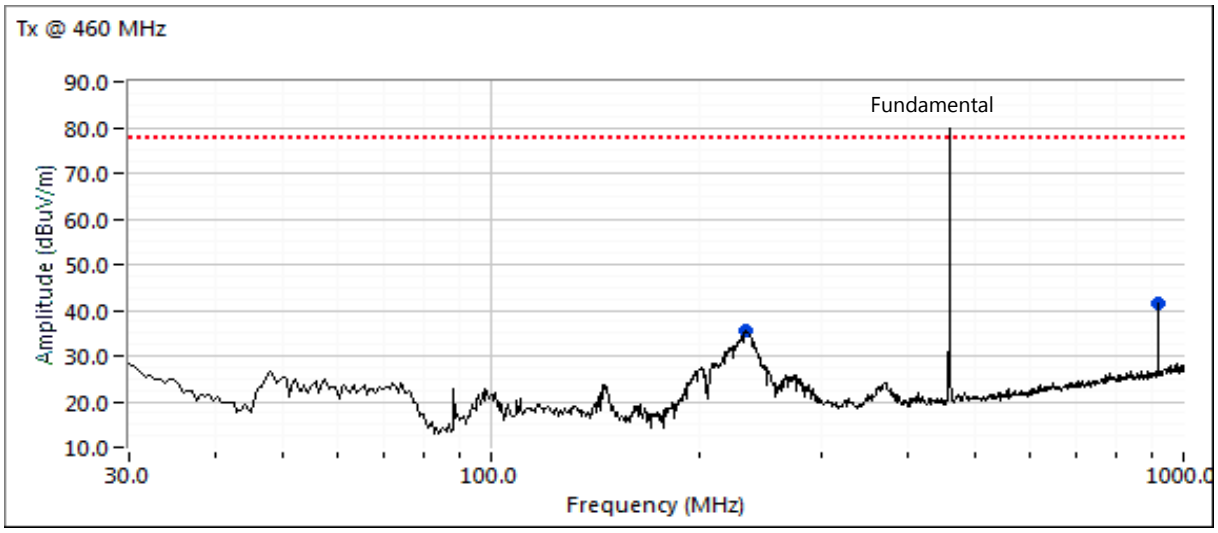
Plots for center channel, power setting(s) = 10

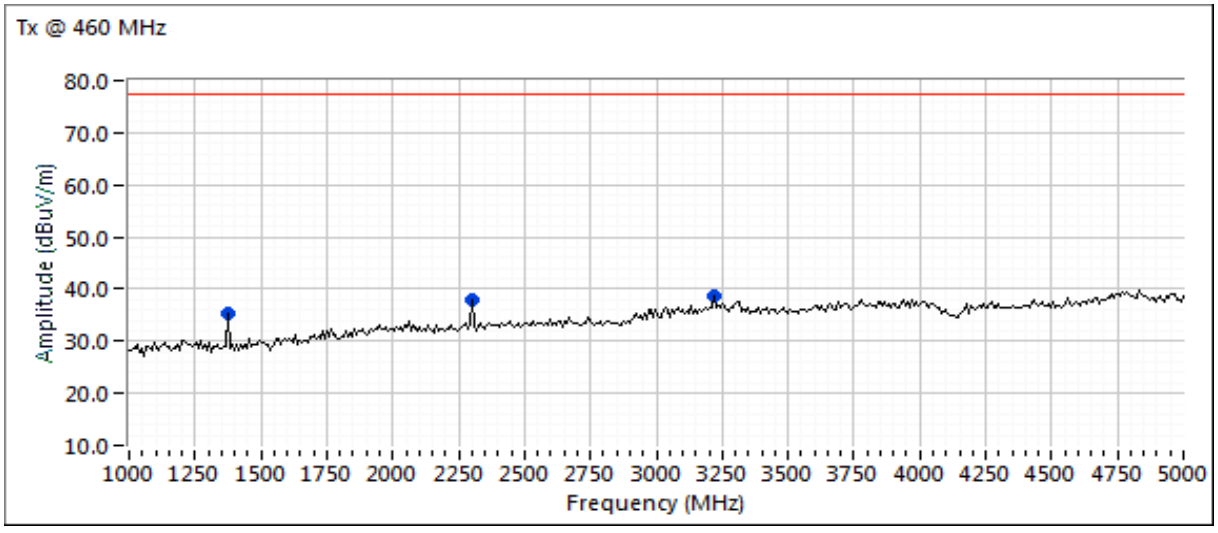




Client:	FreeWave Technologies, Inc.	PR Number:	PR109246
Model:	LRS455A	T-Log Number:	TL109246-RANA
		Project Manager:	Deepa Shetty
Contact:	Michael Vidales	Project Engineer:	David Bare
Standard:	FCC Parts 15 & 90, RSS-119	Class:	N/A

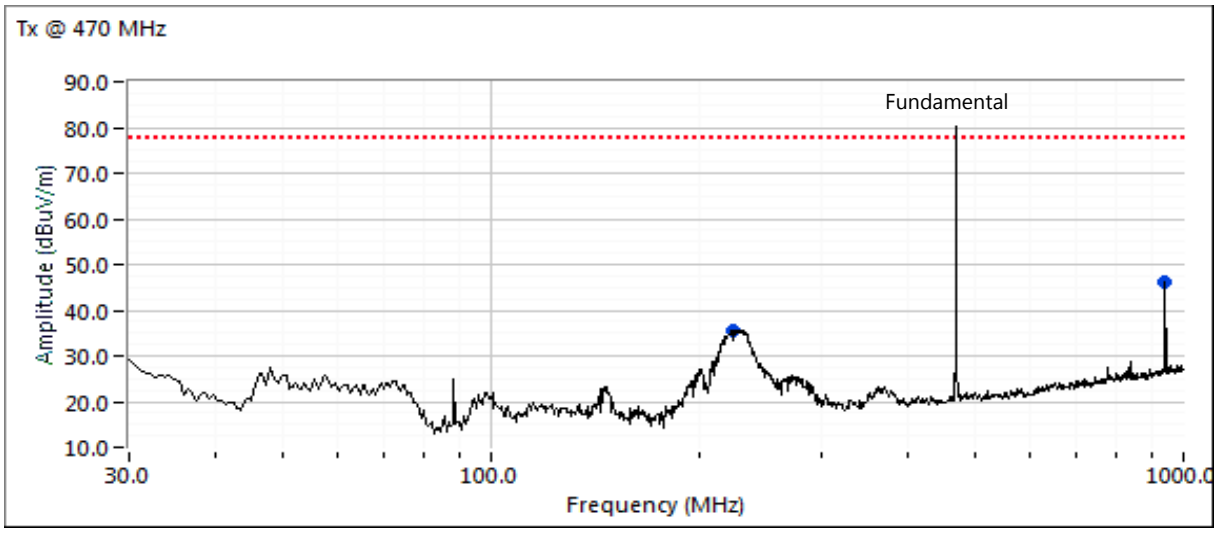
Plots for center channel, power setting(s) = 10

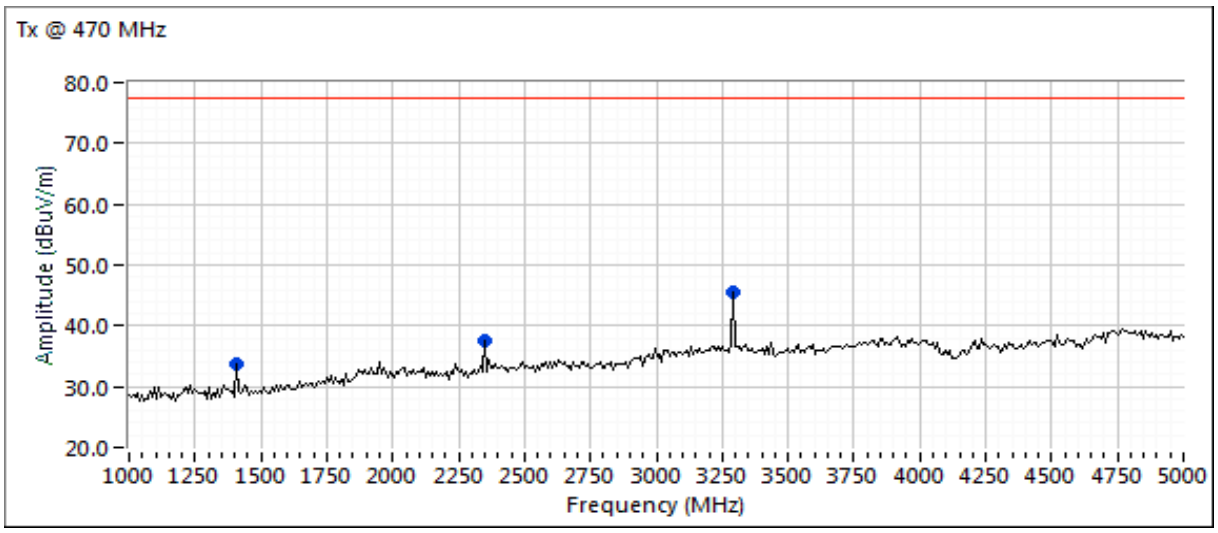




Client:	FreeWave Technologies, Inc.	PR Number:	PR109246
Model:	LRS455A	T-Log Number:	TL109246-RANA
		Project Manager:	Deepa Shetty
Contact:	Michael Vidales	Project Engineer:	David Bare
Standard:	FCC Parts 15 & 90, RSS-119	Class:	N/A

Plots for high channel, power setting(s) = 10





Client:	FreeWave Technologies, Inc.	PR Number:	PR109246
Model:	LRS455A	T-Log Number:	TL109246-RANA
		Project Manager:	Deepa Shetty
Contact:	Michael Vidales	Project Engineer:	David Bare
Standard:	FCC Parts 15 & 90, RSS-119	Class:	N/A

Run #5b: - Final Field Strength Measurements and Substitution Measurements

Date of Test: 6/4 & 6/5/2020 Config. Used: 1

Test Engineer: David Bare & Y K Soo Config Change: None

Test Location: Fremont Chamber #4 & 5 EUT Voltage: 12VDC

EUT Field Strength

Frequency	Level	Pol	FCC Part 90		Detector	Azimuth	Height	Comments	Channel
MHz	dBµV/m	v/h	Limit	Margin	Pk/QP/Avg	degrees	meters		
920.009	43.1	H	75.3	-32.2	PK	156	1.0	PK (0.10s)	460 MHz
233.513	36.4	H	75.3	-38.9	PK	282	1.4	PK (0.10s)	460 MHz
230.677	35.5	H	75.3	-39.8	PK	298	1.4	PK (0.10s)	435 MHz
870.002	42.4	H	75.3	-32.9	PK	158	1.8	PK (0.10s)	435 MHz
2175.040	46.1	V	75.3	-29.2	PK	145	2.1	PK (0.10s)	435 MHz
900.005	43.8	H	75.3	-31.5	PK	144	1.8	PK (0.10s)	450 MHz
940.004	46.5	V	75.3	-28.8	PK	74	1.1	PK (0.10s)	470 MHz
3290.010	50.9	H	75.3	-24.4	PK	340	1.0	PK (0.10s)	470 MHz

Note 1:	The field strength limit in the tables above was calculated from the erp/eirp limit detailed in the standard using the free space propagation equation: $E=\sqrt{(30PG)}/d$. This limit is conservative - it does not consider the presence of the ground plane and, for erp limits, the dipole gain (2.2dBi) has not been included. The erp or eirp for all signals with less than 20dB of margin relative to this field strength limit is determined using substitution measurements.
Note 2:	Measurements are made with the antenna port terminated.

Substitution measurements

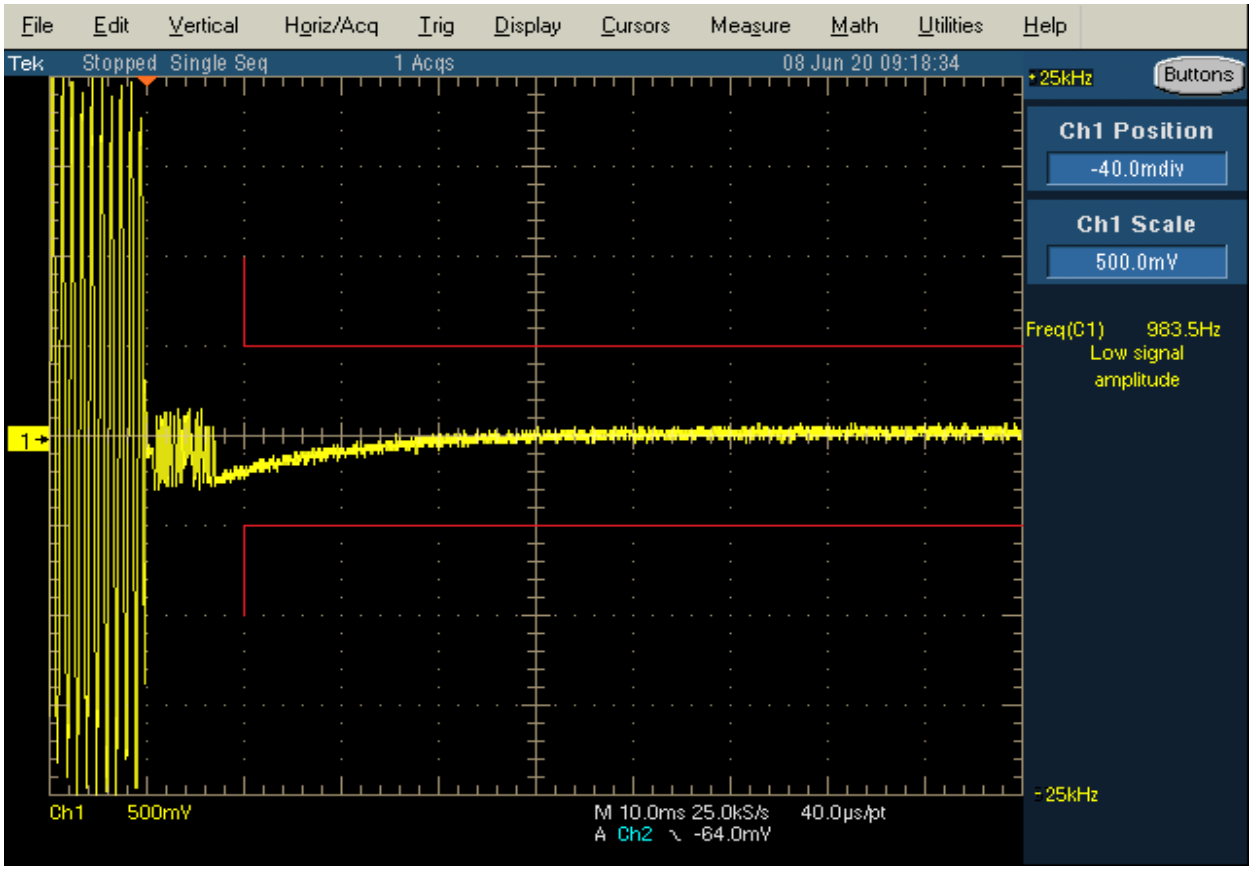
Note 1:	As none of the emissions were within 20 dB of the calculated field strength limit, no substitution measurements are required.

Client:	FreeWave Technologies, Inc.	PR Number:	PR109246
Model:	LRS455A	T-Log Number:	TL109246-RANA
		Project Manager:	Deepa Shetty
Contact:	Michael Vidales	Project Engineer:	David Bare
Standard:	FCC Parts 15 & 90, RSS-119	Class:	N/A

Run #6: Transient Frequency Behavior

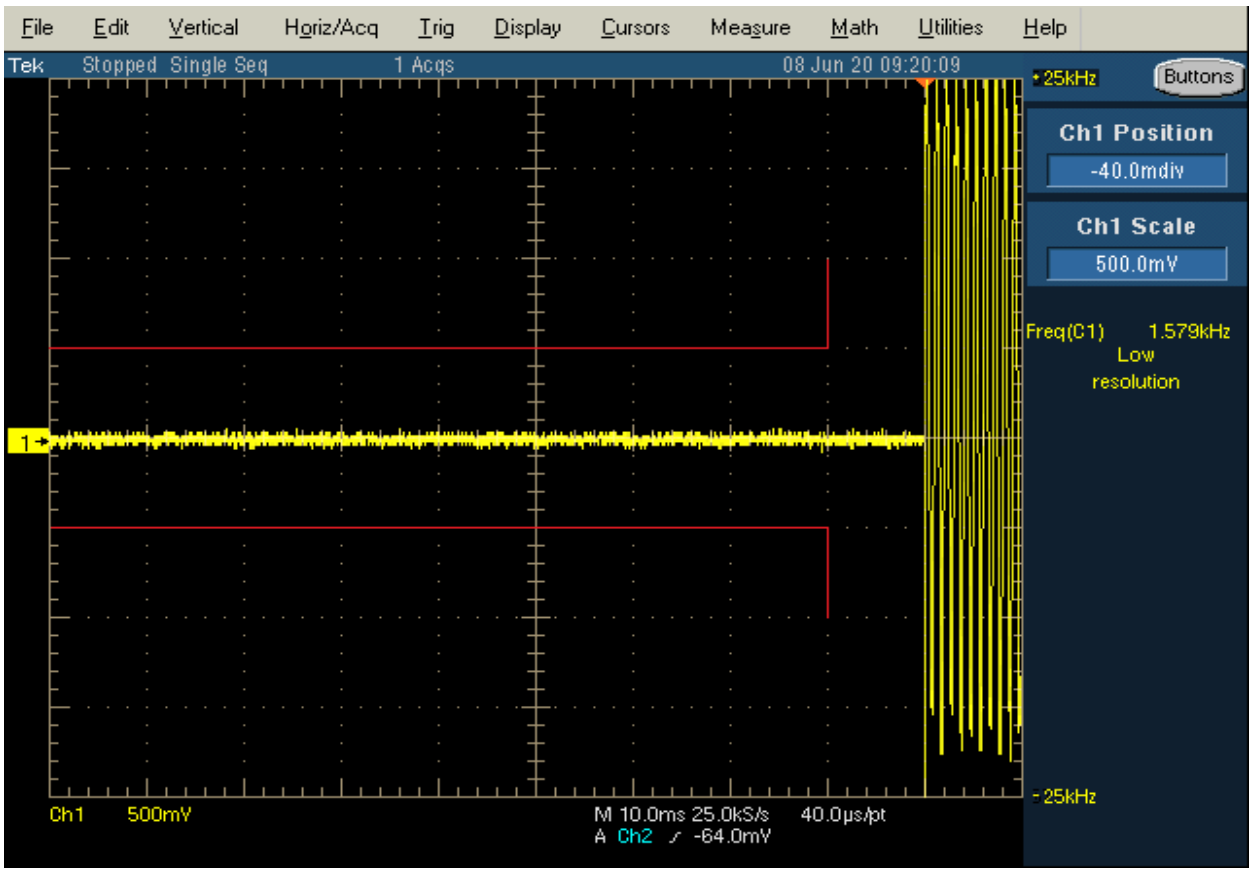
Date of Test: 6/8/2020 Config. Used: 1
Test Engineer: David Bare Config Change: None
Test Location: Fremotn Chamber #5 EUT Voltage: 12 VDC

Run #6a
Carrier Frequency: 450 MHz
Channel Spacing: 12.5 kHz
Modulation: 2-level GFSK
Description: Switch on condition ton, t1, and t2



Client:	FreeWave Technologies, Inc.	PR Number:	PR109246
Model:	LRS455A	T-Log Number:	TL109246-RANA
		Project Manager:	Deepa Shetty
Contact:	Michael Vidales	Project Engineer:	David Bare
Standard:	FCC Parts 15 & 90, RSS-119	Class:	N/A

Run #6b
Carrier Frequency: 450 MHz
Channel Spacing: 12.5 kHz
Modulation: 2-level GFSK
Description: Switch off condition t3 and toff



Client:	FreeWave Technologies, Inc.	PR Number:	PR109246
Model:	LRS455A	T-Log Number:	TL109246-RANA
		Project Manager:	Deepa Shetty
Contact:	Michael Vidales	Project Engineer:	David Bare
Standard:	FCC Parts 15 & 90, RSS-119	Class:	N/A

Run #8: Frequency Stability

Date of Test: 6/8/2020 Config. Used: 1

Test Engineer: David Bare Config Change: None

Test Location: Fremont EMC Lab #3 EUT Voltage: 12 VDC

Nominal Frequency: 449.9970 MHz

Frequency Stability Over Temperature

The EUT was soaked at each temperature for a minimum of 30 minutes prior to making the measurements to ensure the EUT and chamber had stabilized at that temperature.

Temperature	Frequency Measured	Drift	
(Celsius)	(MHz)	(Hz)	(ppm)
-30	449.996923	-77	0.2
-20	449.996891	-109	0.2
-10	449.996891	-109	0.2
0	449.996827	-173	0.4
10	449.996827	-173	0.4
20	449.997000	0	0.0
30	449.996731	-269	0.6
40	449.996811	-189	0.4
50	449.996843	-157	0.3
	Worst case:	-269	0.6

Frequency Stability Over Input Voltage

Nominal Voltage is 12Vdc.

Voltage	Frequency Measured	Drift	
(DC)	(MHz)	(Hz)	(ppm)
85%	449.996859	-141	0.3
115%	449.996859	-141	0.3
	Worst case:	-141	0.6

Battery endpoint is 3.1 Vdc

Voltage	Frequency Measured	Drift	
(DC)	(MHz)	(Hz)	(ppm)
3.3	449.995953	-1047	2.3

Note 1:	Maximum drift of fundamental frequency before it shut down at 3.3 Vdc.

End of Report

This page is intentionally blank and
marks the last page of this test report.