313 West 12800 South, Suite 311
Draper, UT 84020
(801) 260-4040

Test Report

Certification

FCC ID	2ADZ3D001
Equipment Under Test	SFI-MD200
Test Report Serial No	V044354_02
Date of Test	March 12 and 13, 2018
Report Issue Date	March 15, 2018

Test Specifications:	Applicant:
FCC Part 15, Subpart C	Sure-Fi, Inc. 3000 Vista Way, Suite 1 Provo, UT 84606 U.S.A.

Testing
NVLAP Lab Code 100272-0

Certification of Engineering Report

This report has been prepared by VPI Laboratories, Inc. to document compliance of the device described below with the requirements of Federal Communications Commission (FCC) Part 15, Subpart C. This report may be reproduced in full. Partial reproduction of this report may only be made with the written consent of the laboratory. The results in this report apply only to the sample tested.

Applicant	Sure-Fi, Inc.
Manufacturer	Sure-Fi, Inc.
Brand Name	Sure-Fi
Model Number	SFI-MD200
FCC ID	2ADZ3D001

On this 15th day of March 2018, I, individually and for VPI Laboratories, Inc., certify that the statements made in this engineering report are true, complete, and correct to the best of my knowledge, and are made in good faith.

Although NVLAP has accredited the VPI Laboratories, Inc. EMC testing facilities, this report must not be used to claim product certification, approval, or endorsement by NVLAP, NIST, or any agency of the federal government.

VPI Laboratories, Inc.

Norman P Hansen

Tested by: Norman P. Hansen

Reviewed by: Joseph W. Jackson

Revision History		
Revision	**Description**	**Date**
01	Original Report Release	March 15, 2018
02	Remove reference to KDB 558074 from section 3.3. Show frequency range of 902.5 to 927.35 MHz in line 1 of Table in section 2.3 Amend table and drawing of section 7.3 to show EMCO 3142E-PA to include 6 dB attenuator and preamp that are part of the antenna assembly	March 27, 2018

Table of Contents

1 Client Information

1.1 Applicant

Company Name	Sure-Fi, Inc. 3000 Vista Way, Suite 1 Provo, UT 84606 U.S.A.
Contact Name	Mark Hall
Title	President

1.2 Manufacturer

Company Name	Sure-Fi, Inc. 3000 Vista Way, Suite 1 Provo, UT 84606 U.S.A.
Contact Name	Mark Hall
Title	President

2 Equipment Under Test (EUT)

2.1 Identification of EUT

Brand Name	Sure-Fi
Model Number	SFI-MD200
Hardware Version	Rev. 4
Serial Number	None
Dimensions (cm)	11.0 x 6.5

2.2 Description of EUT

The SFI-MD200 is a module containing a 902 – 928 MHz transceiver and a Raytac MDBT42Q BLE module. The BLE module carries FCC ID SH6MDBT42Q. The 902 – 928 MHz transceiver is a frequency hopping spread spectrum device that operates on 72 channels that are spaced 350 kHz apart, starting at 902.5 MHz and ending at 927.35 MHz. The SFI-MD200 uses a trace antenna with a maximum gain of 2.64 dBi. The BLE module or the 902-928 MHz transceiver are never used together as only one or the other is enabled at a time.

This report covers the circuitry of the devices subject to FCC Part 15, Subpart C. The circuitry of the device subject to FCC Subpart B was found to be compliant and is covered in VPI Laboratories, Inc. report V044353.

2.3 EUT and Support Equipment

The EUT and support equipment used during the test are listed below.

Brand Name **Model Number** **Serial Number**	**Description**	**Name of Interface Ports / Interface Cables**
BN: Sure-Fi MN: SFI-MD200 (Note 1) SN: None	902.5 – 927.35 MHz Transceiver Module	See Section 2.4
BN: CUI MN: SWI18-12-N SN: None	12 VDC power supply	DC out/2 unshielded conductors (Note 2)
BN: Codex MN: SEP-2420U SN: None	24 VAC power supply	AC out/2 unshielded conductors (Note 2)

Notes: (1) EUT

(2) Interface port connected to EUT (See Section 2.4)

The support equipment listed above was not modified in order to achieve compliance with this standard.

2.4 Interface Ports on EUT

Name of Ports	No. of Ports Fitted to EUT	Cable Description/Length
DC in	1	2 unshielded conductors/2 meters

2.5 Modification Incorporated/Special Accessories on EUT

There were no modifications or special accessories required to comply with the specification.

2.6 Deviation from Test Standard

There were no deviations from the test specification.

3 Test Specification, Methods and Procedures

3.1 Test Specification

Title	FCC PART 15, Subpart C (47 CFR 15) 15.203, 15.207, and 15.247 Limits and methods of measurement of radio interference characteristics of radio frequency devices.
Purpose of Test	The tests were performed to demonstrate initial compliance

3.2 Methods & Procedures

3.2.1 §15.203 Antenna Requirement

An intentional radiator shall be designed to ensure that no antenna other than that furnished by the responsible party shall be used with the device. The use of a permanently attached antenna or of an antenna that uses a unique coupling to the intentional radiator shall be considered sufficient to comply with the provisions of this Section. The manufacturer may design the unit so that a broken antenna can be replaced by the user, but the use of a standard antenna jack or electrical connector is prohibited. This requirement does not apply to carrier current devices or to devices operated under the provisions of Sections 15.211, 15.213, 15.217, 15.219, or 15.221. Further, this requirement does not apply to intentional radiators that must be professionally installed, such as perimeter protection systems and some field disturbance sensors, or to other intentional radiators which, in accordance with Section 15.31(d), must be measured at the installation site. However, the installer shall be responsible for ensuring that the proper antenna is employed so that the limits in this Part are not exceeded.

3.2.2 §15.207 Conducted Limits

(a) Except as shown in paragraphs (b) and (c) of this section, for an intentional radiator that is designed to be connected to the public utility (AC) power line, the radio frequency voltage that is conducted back onto the AC power line on any frequency or frequencies, within the band 150 kHz to 30 MHz, shall not exceed the limits in the following table, as measured using a 50 μH/50 ohms line impedance stabilization network (LISN). Compliance with the provisions of this paragraph shall be based on the measurement of the radio frequency voltage between each power line and ground at the power terminal. The lower limit applies at the boundary between the frequency ranges.

Frequency range (MHz)	Limit (dBμV)	
	Quasi-peak	Average
0.15 to 0.50*	66 to 56*	56 to 46*
0.50 to 5	56	46
5 to 30	60	50

*Decreases with the logarithm of the frequency.

Table 1: Limits for conducted emissions at mains ports of Class B ITE.

3.2.3 §15.247 Operation within the bands 902 – 928 MHz, 2400 – 2483.5 MHz, and 5725 – 5850 MHz

a) Operation under the provisions of this Section is limited to frequency hopping and digitally modulated intentional radiators that comply with the following provisions.

1) Frequency hopping systems shall have hopping channel carrier frequencies separated by a minimum of 25 kHz or the 20 dB bandwidth of the hopping channel, whichever is greater. Alternatively, frequency hopping systems operating in the 2400 – 2483.5 MHz band may have hopping channel carrier frequencies that are separated by 25 kHz or two-thirds of the 20 dB bandwidth of the hopping channel, whichever is greater, provided the systems operate with an output power no greater than 125 mW. The system shall hop to channel frequencies that are selected at the system hopping rate from a pseudorandomly ordered list of hopping frequencies. Each frequency must be used equally on the average by each transmitter. The system receivers shall have input bandwidths that match the hopping channel bandwidths of their corresponding transmitters and shall shift frequencies in synchronization with the transmitted signals.

   i. For frequency hopping systems operating in the 902-928 MHz band: if the 20 dB bandwidth of the hopping channel is less than 250 kHz, the system shall use at least 50 hopping frequencies and the average time of occupancy on any frequency shall not be greater than 0.4 seconds within a 20 second period; if the 20 dB bandwidth of the hopping channel is 250 kHz or greater, the system shall use at least 25 hopping frequencies and the average time of occupancy on any frequency shall not be greater than 0.4 seconds within a 10 second period. The maximum allowed 20 dB bandwidth of the hopping channel is 500 kHz.

   ii. Frequency hopping systems operating in the 5725-5850 MHz band shall use at least 75 hopping frequencies. The maximum 20 dB bandwidth of the hopping channel is 1 MHz. The average time of occupancy on any frequency shall not be greater than 0.4 seconds within a 30 second period.

   iii. Frequency hopping systems in the 2400-2483.5 MHz band shall use at least 15 non-overlapping channels. The average time of occupancy on any channel shall not be greater than 0.4 seconds within a period of 0.4 seconds multiplied by the number of hopping channels employed. Frequency hopping systems may avoid or suppress transmissions on a particular hopping frequency provided that a minimum of 15 non-overlapping channels are used.

2) Systems using digital modulation techniques may operate in the 902 - 928 MHz, 2400 - 2483.5 MHz, and 5725 - 5850 MHz bands. The minimum 6 dB bandwidth shall be at least 500 kHz.

b) The maximum peak output power of the intentional radiator shall not exceed the following:

1) For frequency hopping systems operating in the 2400-2483.5 MHz band employing at least 75 non-overlapping hopping channels, and all frequency hopping systems in the 5725-5850 MHz band: 1 watt. For all other frequency hopping systems in the 2400-2483.5 MHz band: 0.125 watts.

2) For frequency hopping systems operating in the 902-928 MHz band: 1 watt for systems employing at least 50 hopping channels; and, 0.25 watts for systems employing less than 50 hopping channels, but at least 25 hopping channels, as permitted under paragraph (a)(1)(i) of this section.

3) For systems using digital modulation in the 902-928 MHz, 2400-2483.5 MHz, and 5725 – 5850 MHz bands: 1 watt. As an alternative to a peak power measurement,

compliance with the Conducted Output Power is defined as the total transmit power delivered to all antennas and antenna elements averaged across all symbols in the signaling alphabet when the transmitter is operating at its maximum power control level. Power must be summed across all antennas and antenna elements. The average must not include any time intervals during which the transmitter is off or is transmitting at a reduced power level. If multiple modes of operation are possible (e.g., alternative modulation methods), the maximum conducted output power is the highest total transmit power occurring in any mode.

4) The conducted output power limit specified in paragraph (b) of this section is based on the use of antennas with directional gains that do not exceed 6 dBi. Except as shown in paragraph (c) of this section, if transmitting antennas of directional gain greater than 6 dBi are used, the conducted power from the intentional radiator shall be reduced below the stated values in paragraphs (b)(1), (b)(2), and (b)(3) of this section, as appropriate, by the amount in dB that the directional gain of the antenna exceeds 6 dBi.

c) Operation with directional antenna gains greater than 6 dBi.

1) Fixed point-to-point operation:

i. Systems operating in the 2400-2483.5 MHz band that are used exclusively for fixed, point-to-point operations may employ transmitting antennas with directional gain greater than 6 dBi provided the maximum peak output power of the intentional radiator is reduced by 1 dB for every 3 dB that the directional gain of the antenna exceeds 6 dBi.

ii. Systems operating in the 5725-5850 MHz band that are used exclusively for fixed, point-to-point operations may employ transmitting antennas with directional gain greater than 6 dBi without any corresponding reduction in transmitter peak output power.

iii. Fixed, point-to-point operation, as used in paragraphs (b)(4)(i) and (b)(4)(ii) of this section, excludes the use of point-to-multipoint systems, omnidirectional applications, and multiple co-located intentional radiators transmitting the same information. The operator of the spread spectrum or digitally modulated intentional radiator or, if the equipment is professionally installed, the installer is responsible for ensuring that the system is used exclusively for fixed, point-to-point operations. The instruction manual furnished with the intentional radiator shall contain language in the installation instructions informing the operator and the installer of this responsibility.

2) In addition to the provisions in paragraphs (b)(1), (b)(3), (b)(4) and (c)(1)(i) of this section, transmitters operating in the 2400-2483.5 MHz band that emit multiple directional beams, simultaneously or sequentially, for the purpose of directing signals to individual receivers or to groups of receivers provided the emissions comply with the following:

i. Different information must be transmitted to each receiver.

ii. If the transmitter employs an antenna system that emits multiple directional beams but does not emit multiple directional beams simultaneously, the total output power conducted to the array or arrays that comprise the device, i.e., the sum of the power supplied to all antennas, antenna elements, staves, etc. and summed across all carriers or frequency channels, shall not exceed the limit specified in paragraph (b)(1) or (b)(3) of this section, as applicable. However, the total conducted output power shall be reduced by 1 dB below the specified limits for each 3 dB that the directional gain of the antenna /antenna array exceeds 6 dBi. The directional antenna gain shall be computed as follows:

A. The directional gain shall be calculated as the sum of 10 log (number of array elements or staves) plus the directional gain of the element or stave having the highest gain.

B. A lower value for the directional gain than that calculated in paragraph (c)(2)(ii)(A) of this section will be accepted if sufficient evidence is presented, e.g., due to shading of the array or coherence loss in the beamforming.

iii. If a transmitter employs an antenna that operates simultaneously on multiple directional beams using the same or different frequency channels, the power supplied to each emission beam is subject to the power limit specified in paragraph (c)(2)(ii) of this section. If transmitted beams overlap, the power shall be reduced to ensure that their aggregate power does not exceed the limit specified in paragraph (c)(2)(ii) of this section. In addition, the aggregate power transmitted simultaneously on all beams shall not exceed the limit specified in paragraph (c)(2)(ii) of this section by more than 8 dB.

iv. Transmitters that emit a single directional beam shall operate under the provisions of paragraph (c)(1) of this section.

d) In any 100 kHz bandwidth outside the frequency band in which the spread spectrum or digitally modulated intentional radiator is operating, the radio frequency power that is produced by the intentional radiator shall be at least 20 dB below that in the 100 kHz bandwidth within the band that contains the highest level of the desired power, based on either an RF conducted or a radiated measurement, provided the transmitter demonstrates compliance with the peak conducted power limits. If the transmitter complies with the conducted power limits based on the use of RMS averaging over a time interval, as permitted under paragraph (b)(3) of this section, the attenuation required under this paragraph shall be 30 dB instead of 20 dB. Attenuation below the general limits specified in Section 15.209(a) is not required. In addition, radiated emissions which fall in the restricted bands, as defined in Section 15.205(a), must also comply with the radiated emission limits specified in Section 15.209(a) (see Section 15.205(c)).

e) For digitally modulated systems, the power spectral density conducted from the intentional radiator to the antenna shall not be greater than 8 dBm in any 3 kHz band during any time interval of continuous transmission. This power spectral density shall be determined in accordance with the provisions of paragraph (b) of this section. The same method of determining the conducted output power shall be used to determine the power spectral density.

f) For the purposes of this section, hybrid systems are those that employ a combination of both frequency hopping and digital modulation techniques. The frequency hopping operation of the hybrid system, with the direct sequence or digital modulation operation turned off, shall have an average time of occupancy on any frequency not to exceed 0.4 seconds within a time period in seconds equal to the number of hopping frequencies employed multiplied by 0.4. The digital modulation operation of the hybrid system, with the frequency hopping turned off, shall comply with the power density requirements of paragraph (d) of this section.

g) Frequency hopping spread spectrum systems are not required to employ all available hopping channels during each transmission. However, the system, consisting of both the transmitter and the receiver, must be designed to comply with all of the regulations in this section should the transmitter be presented with a continuous data (or information) stream. In addition, a system employing short transmission bursts must comply with the definition of a frequency hopping system and must distribute its transmissions over the minimum number of hopping channels specified in this section.

h) The incorporation of intelligence within a frequency hopping spread spectrum system that permits the system to recognize other users within the spectrum band so that it individually and independently chooses and adapts its hopsets to avoid hopping on occupied channels is permitted. The coordination of frequency hopping systems in any other manner for the express purpose of avoiding the simultaneous occupancy of individual hopping frequencies by multiple transmitters is not permitted.

i) Systems operating under the provisions of this section shall be operated in a manner that ensures that the public is not exposed to radio frequency energy levels in excess of the Commission's guidelines. See § 1.1307(b)(1) of this Chapter.

Note: Spread spectrum systems are sharing these bands on a noninterference basis with systems supporting critical Government requirements that have been allocated the usage of these bands, secondary only to ISM equipment operated under the provisions of Part 18 of this Chapter. Many of these Government systems are airborne radiolocation systems that emit a high EIRP which can cause interference to other users. Also, investigations of the effect of spread spectrum interference to U. S. Government operations in the 902-928 MHz band may require a future decrease in the power limits allowed for spread spectrum operation.

3.3 Test Procedure

The testing was performed according to the procedures in ANSI C63.10-2013, DA-705 Filing and Measurement Guidelines for Frequency Hopping Spread Spectrum Systems, and 47 CFR Part 15. Testing was performed at the VPI Laboratories, Inc. Wanship Upper Open Area Test Site, located at 29145 Old Lincoln Highway, Wanship, UT. VPI Laboratories, Inc. is accredited by National Voluntary Laboratory Accreditation Program (NVLAP); NVLAP Lab Code: 100272-0, which is effective until September 30, 2018. VPI Laboratories, Inc. carries FCC Accreditation Designation Number US5263.

4 Operation of EUT During Testing

4.1 Operating Environment

Power Supply	12 VDC or 24 VAC/60 Hz

4.2 Operating Modes

The transmitter was tested on 3 orthogonal axes while in a constant transmit mode at the upper, middle, and lower channels. The voltage to the transceiver module was varied as required by §15.31(e) with no change seen in transmitter characteristics.

4.3 EUT Exercise Software

Sure-Fi Module Developer, Rev. 2.0 was used to exercise the EUT.

5 Summary of Test Results

5.1 FCC Part 15, Subpart C

5.1.1 Summary of Tests

Section	Environmental Phenomena	Frequency Range (MHz)	Result
15.203	Antenna Requirements	Structural requirement	Complied
15.207	Conducted Disturbance at Mains Ports	0.15 to 30	Complied
15.247(a)	Channel Separation	902 – 928	Complied
15.247(a)	20 dB Bandwidth	902 – 928	Complied
15.247(a)	Time of Occupancy	902 – 928	Complied
15.247(b)	Peak Output Power	902 – 928	Complied
15.247(d)	Antenna Conducted Spurious Emissions	0.009 – 9280	Complied
15.247(d)	Radiated Spurious Emissions in the Restricted Bands	0.009 – 9280	Complied
15.247(g)	Channel Usage	902 – 928	Complied (Note 1)
15.247(h)	Channel Intelligence/Avoidance	902 – 928	Complied (Note 1)
15.247(i)	RF Exposure	902 – 928	Complied (Note 1)
Note 1: Compliance with these requirements is shown in documents filed with the FCC at the time of Certification.			

5.2 Result

In the configuration tested, the EUT complied with the requirements of the specification.

6 Measurements, Examinations and Derived Results

6.1 General Comments

This section contains the test results only. Details of the test methods used and a list of the test equipment used during the measurements can be found in Section 7 of this report.

6.2 Test Results

6.2.1 §15.203 Antenna Requirements

The EUT uses a trace on the PCB as an antenna. A maximum gain of 2.64 dBi was calculated using measurements made at the time of testing.

Result

The EUT complied with the specification.

6.2.2 §15.207 Conducted Emissions at AC Mains Ports

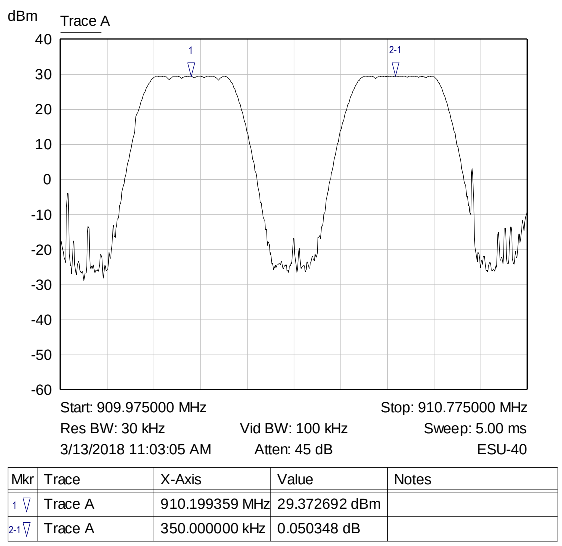
Frequency (MHz)	AC Mains Lead	Detector	Measured Level (dBμV)	Limit (dBμV)	Margin (dB)
0.17	Hot Lead	Peak (Note 1)	47.2	55.0	-7.8
0.22	Hot Lead	Peak (Note 1)	48.0	52.9	-4.9
0.28	Hot Lead	Peak (Note 1)	42.3	50.9	-8.6
0.40	Hot Lead	Peak (Note 1)	33.4	47.8	-14.4
0.46	Hot Lead	Peak (Note 1)	33.8	46.8	-13.0
0.56	Hot Lead	Peak (Note 1)	35.4	46.0	-10.6
0.59	Hot Lead	Peak (Note 1)	38.0	46.0	-8.0
0.18	Neutral Lead	Peak (Note 1)	50.8	54.3	-3.5
0.26	Neutral Lead	Peak (Note 1)	33.5	51.5	-18.0
0.31	Neutral Lead	Peak (Note 1)	30.3	50.1	-19.8
0.45	Neutral Lead	Peak (Note 1)	27.9	46.9	-19.0
0.59	Neutral Lead	Peak (Note 1)	32.5	46.0	-13.5
0.76	Neutral Lead	Peak (Note 1)	25.8	46.0	-20.2
4.85	Neutral Lead	Peak (Note 1)	27.2	46.0	-18.8
Note 1: The reference detector used for the measurements was Quasi-Peak or Peak and the data was compared to the average limit; therefore, the EUT was deemed to meet both the average and quasi-peak limits. Note 2: The reference detector used for the measurements was quasi-peak and average and the data was compared to the respective limits.					

Result

The EUT complied with the specification limit by a margin of 3.5 dB.

6.2.3 §15.247(a) Channel Separation

The EUT must have the hopping channel carrier frequencies separated by 25 kHz or the 20 dB bandwidth, whichever is greater. A plot showing a 350 kHz channel separation is shown below. The 20 dB bandwidth is 276 kHz when operating at 250 kHz LoRa and 147.1 kHz when operating at 125 kHz LoRa. Plots of the 20 dB bandwidths are shown in section 6.2.4.



Graph 1: Channel Separation Plot

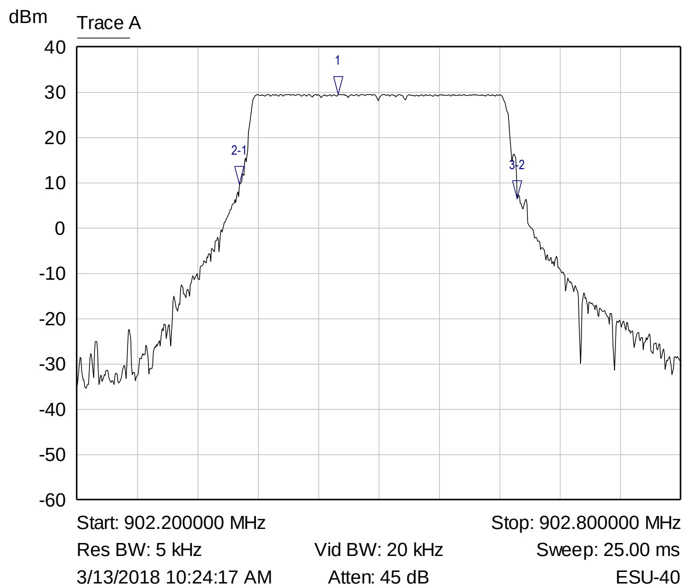
Result

The channel carrier frequency separation is 350 kHz, which is greater than the 20 dB bandwidth; therefore, the EUT complies with the specification.

6.2.4 §15.247(a)(2) Emissions Bandwidth

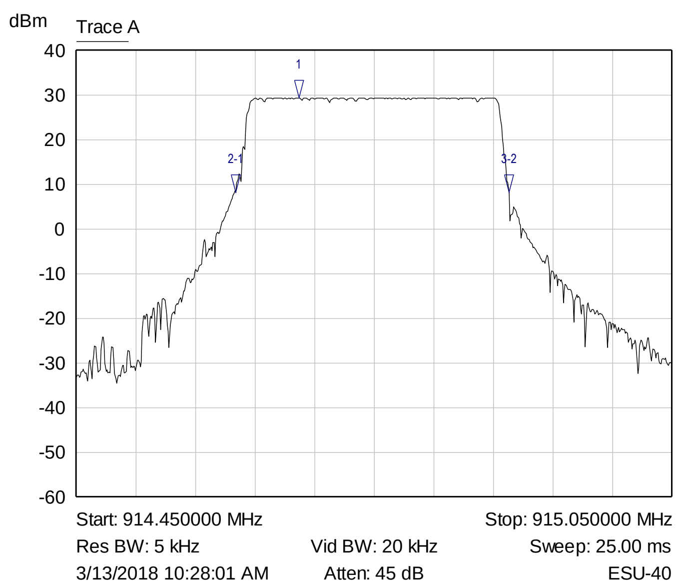
The 20 dB bandwidth of the hopping channels is shown in the table and plots below.

Operational Mode	Frequency (MHz)	Emissions 20 dB Bandwidth (kHz)
250 kHz LoRa	902.50	276.0
	914.75	275.0
	927.35	275.0
125 kHz LoRa	902.50	147.1
	914.75	145.2
	927.35	145.2



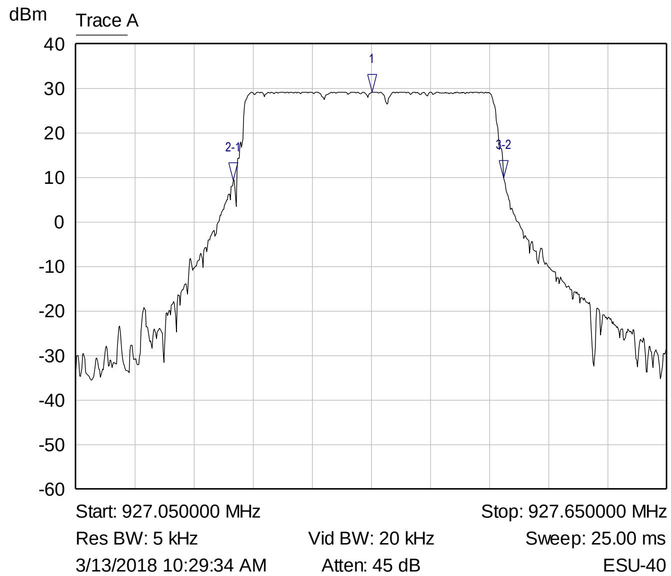
Mkr	Trace	X-Axis	Value	Notes
1 ▽	Trace A	902.459615 MHz	29.434632 dBm	
2-1 ▽	Trace A	-98.076923 kHz	-19.756952 dB	
3-2 ▽	Trace A	275.961538 kHz	-3.241194 dB	

Graph 2: Lowest Channel 20 dB Bandwidth – 250 kHz LoRa



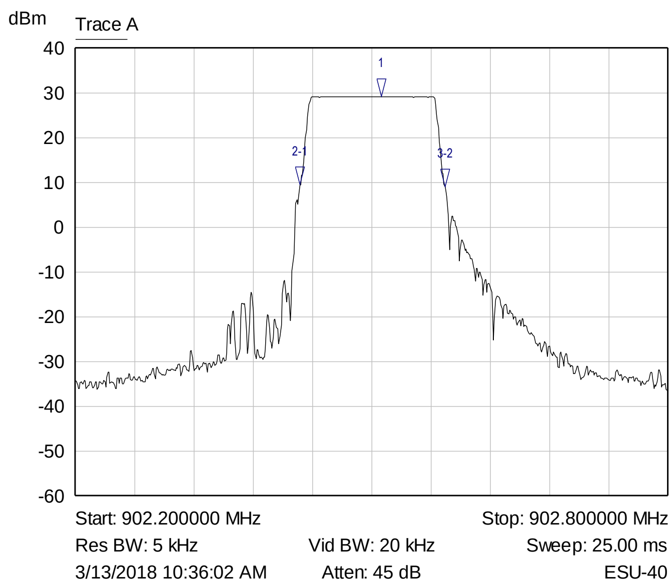
Mkr	Trace	X-Axis	Value	Notes
1 ▽	Trace A	914.674038 MHz	29.279576 dBm	
2-1 ▽	Trace A	-63.461539 kHz	-21.034238 dB	
3-2 ▽	Trace A	275.000000 kHz	-0.124427 dB	

Graph 3: Middle Channel 20 dB Bandwidth – 250 kHz LoRa



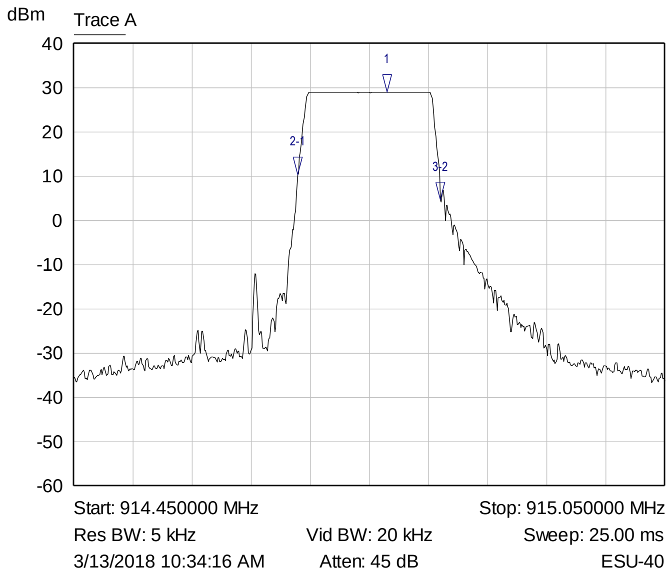
Mkr	Trace	X-Axis	Value	Notes
1 ▽	Trace A	927.350962 MHz	29.100735 dBm	
2-1 ▽	Trace A	-141.346153 kHz	-19.772203 dB	
3-2 ▽	Trace A	275.000000 kHz	0.422415 dB	

Graph 4: Highest Channel 20 dB Bandwidth – 250 kHz LoRa



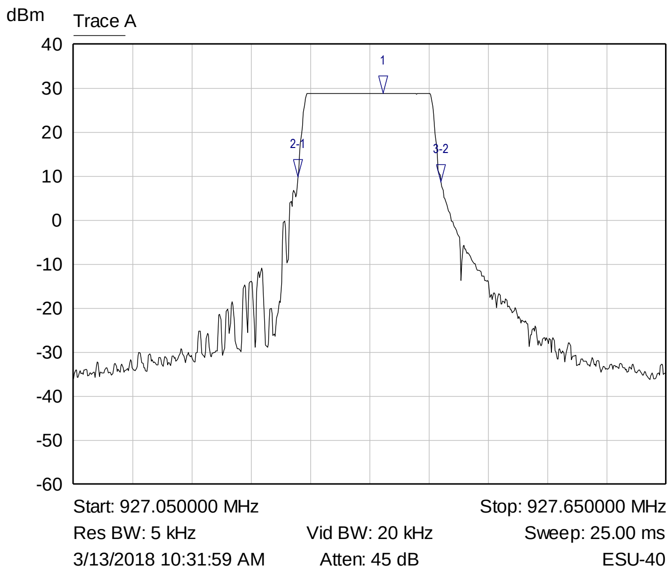
Mkr	Trace	X-Axis	Value	Notes
1 ▽	Trace A	902.509615 MHz	29.177169 dBm	
2-1 ▽	Trace A	-82.692308 kHz	-19.687885 dB	
3-2 ▽	Trace A	147.115385 kHz	-0.422905 dB	

Graph 5: Lowest Channel 20 dB Bandwidth – 125 kHz LoRa



Mkr	Trace	X-Axis	Value	Notes
1 ▽	Trace A	914.768269 MHz	29.052338 dBm	
2-1 ▽	Trace A	-91.346153 kHz	-18.712946 dB	
3-2 ▽	Trace A	145.192308 kHz	-5.600795 dB	

Graph 6: Middle Channel 20 dB Bandwidth – 125 kHz LoRa



Mkr	Trace	X-Axis	Value	Notes
1 ▽	Trace A	927.363462 MHz	28.893830 dBm	
2-1 ▽	Trace A	-86.538461 kHz	-19.124704 dB	
3-2 ▽	Trace A	145.192308 kHz	-1.048465 dB	

Graph 7: Highest Channel 20 dB Bandwidth – 125 kHz LoRa

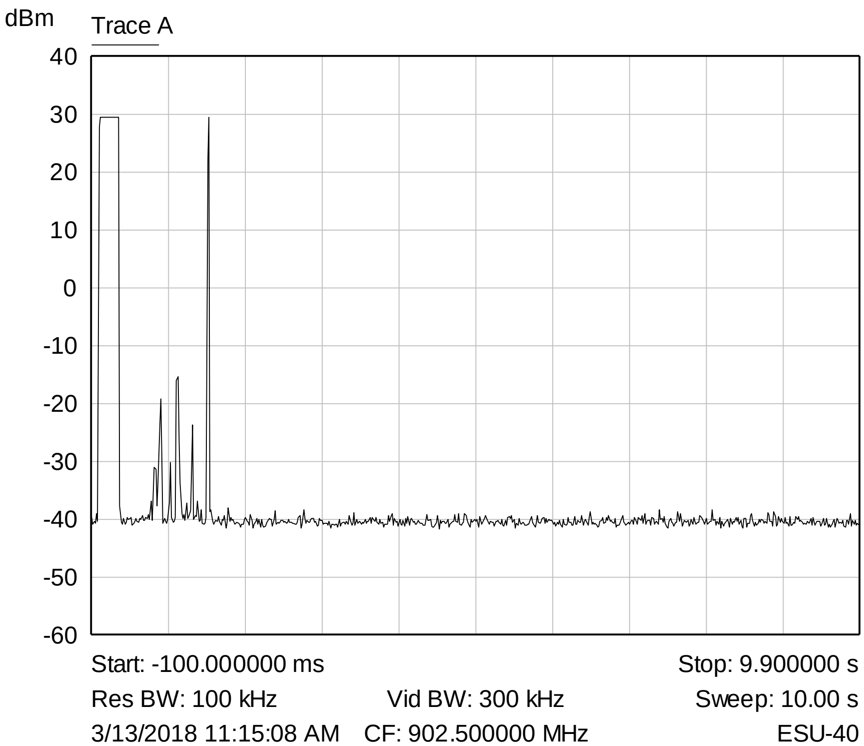
Result

In the configuration tested, the EUT uses 72 channels, the channel 20 dB bandwidth is less than 500 kHz, and the 20 dB bandwidth is less than the 350 kHz channel spacing; therefore, the EUT complied with the requirements of the specification.

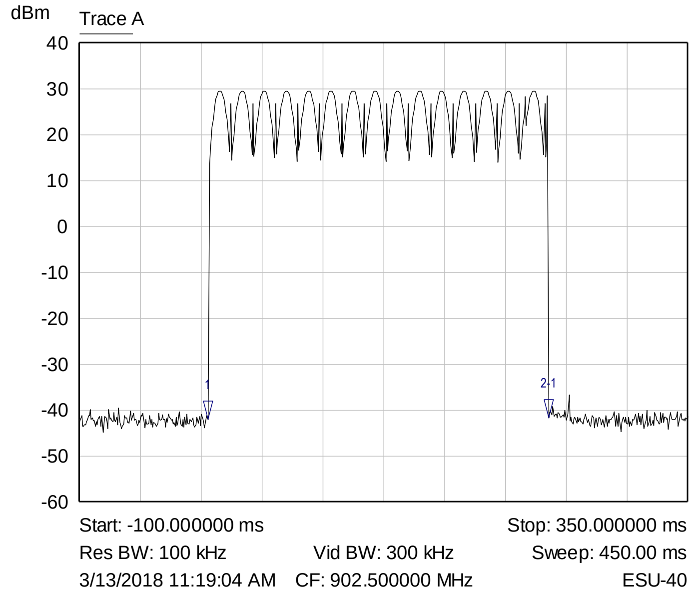
6.2.5 §15.247(a) Channel Occupancy

6.2.5.1 250 kHz LoRa Operation

The EUT transmissions on a single frequency must not exceed 0.4 seconds in a 10 second time period. The EUT transmits a total of 2 times in a 10 second period. One transmission is the preamble, lasting 251.68 ms and 1 data transmission of 16.51 ms. Total on time at one frequency in 10 seconds is 268.19 ms (251.68 +16.51 ms). See the plots below.

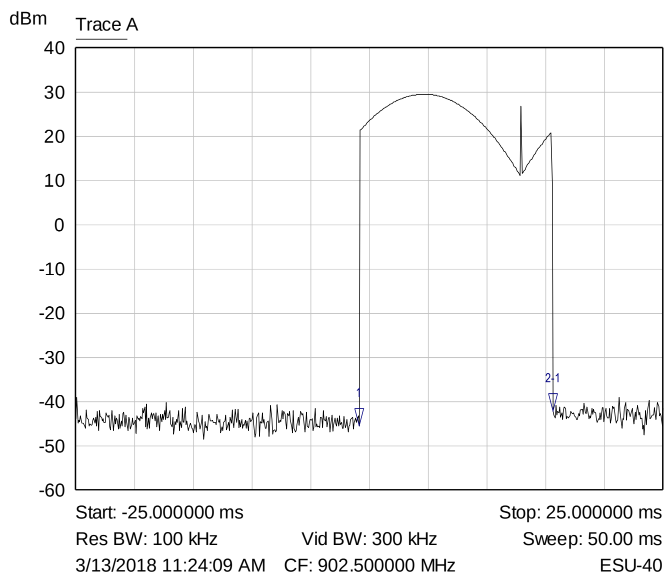


Graph 8: Hits in 10 seconds



Mkr	Trace	X-Axis	Value	Notes
1 ∇	Trace A	-4.807692 ms	-42.035114 dBm	
2-1 ∇	Trace A	251.682692 ms	0.343361 dB	

Graph 9: Preamble On Time



Mkr	Trace	X-Axis	Value	Notes
1 ∇	Trace A	-881.410256 us	-45.452496 dBm	
2-1 ∇	Trace A	16.506410 ms	3.204655 dB	

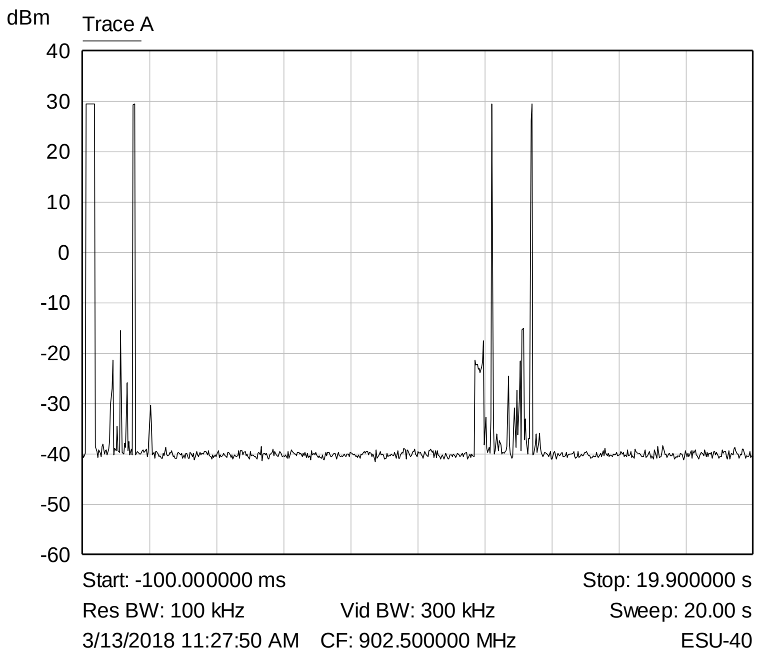
Graph 10: Data On Time

Result

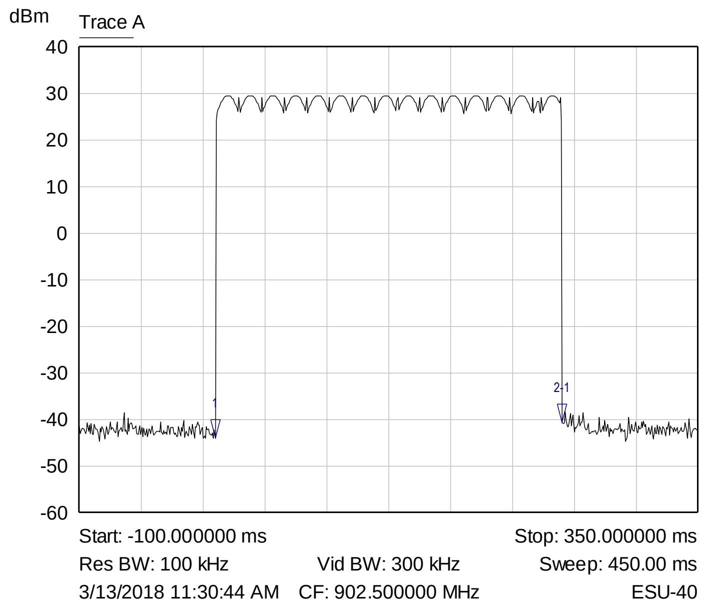
The EUT complies with the specification as the EUT transmits on an individual channel for a maximum of 268.19 milliseconds in 10 seconds, less than the 0.4 seconds allowed by the specification.

6.2.5.2 125 kHz LoRa Operation

The EUT transmissions on a single frequency must not exceed 0.4 seconds in a 20 second time period. The EUT transmits a total of 3 times in a 20 second period. One transmission is the preamble, lasting 252.40 ms and 3 data transmissions of 16.51 ms. Total on time at one frequency in 20 seconds is 301.93 ms (252.40 + (3 x 16.51)). See the plots below.

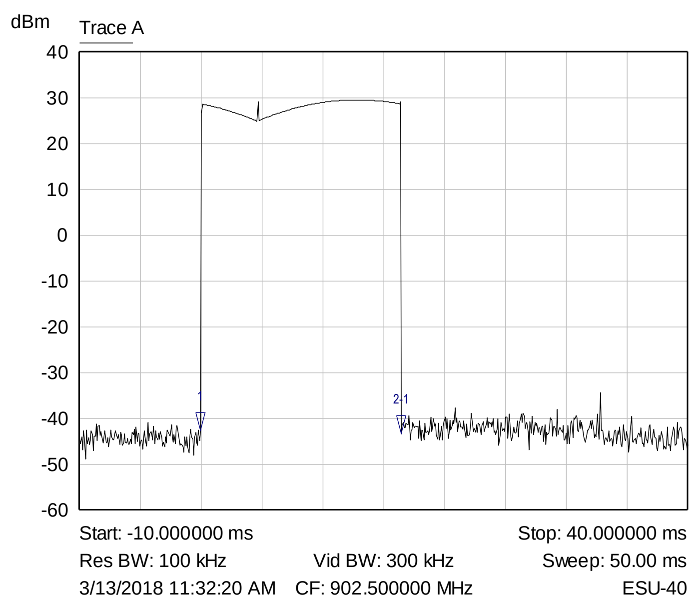


Graph 11: Hits in 10 Seconds



Mkr	Trace	X-Axis	Value	Notes
1 ▽	Trace A	-1.201923 ms	-43.990841 dBm	
2-1 ▽	Trace A	252.403846 ms	3.334599 dB	

Graph 12: Preamble On Time



Mkr	Trace	X-Axis	Value	Notes
1 ▽	Trace A	-64.102564 us	-42.740089 dBm	
2-1 ▽	Trace A	16.506410 ms	-0.630070 dB	

Graph 13: Data On Time

Result

The EUT complies with the specification as the EUT transmits on an individual channel for a maximum of 301.93 milliseconds in 20 seconds, less than the 0.4 seconds allowed by the specification.

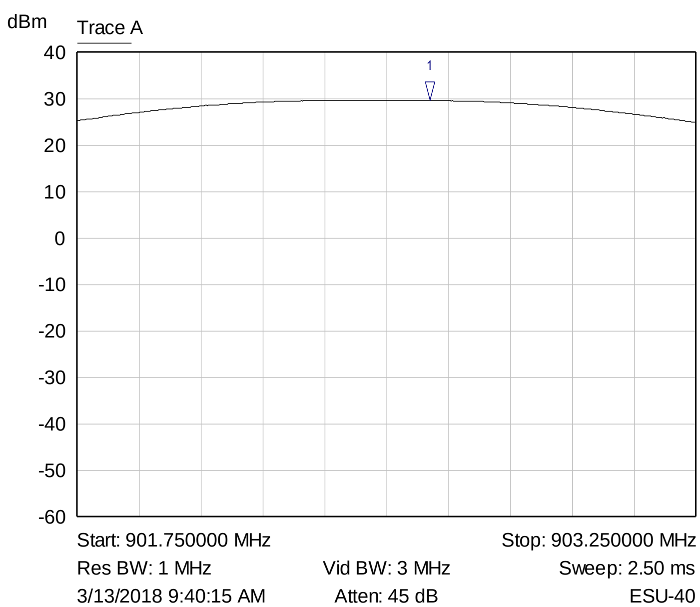
6.2.6 §15.247(b)(3) Peak Output Power

The antenna used with the EUT has a maximum gain of 2.64 dBi. The EUT used 72 hopping channels. The limit for this device is 30 dBm or 1 Watt. Plots are shown below and the results of this testing are summarized in the table.

Operational Mode	Frequency (MHz)	Peak Output Power (dBm)	Peak Output Power (Watt)
250 kHz LoRa	902.50	29.65	0.92257
	914.75	29.50	0.89125
	927.35	29.32	0.85507
125 kHz LoRa	902.50	29.59	0.90991
	914.75	29.48	0.88716
	927.35	29.35	0.86099

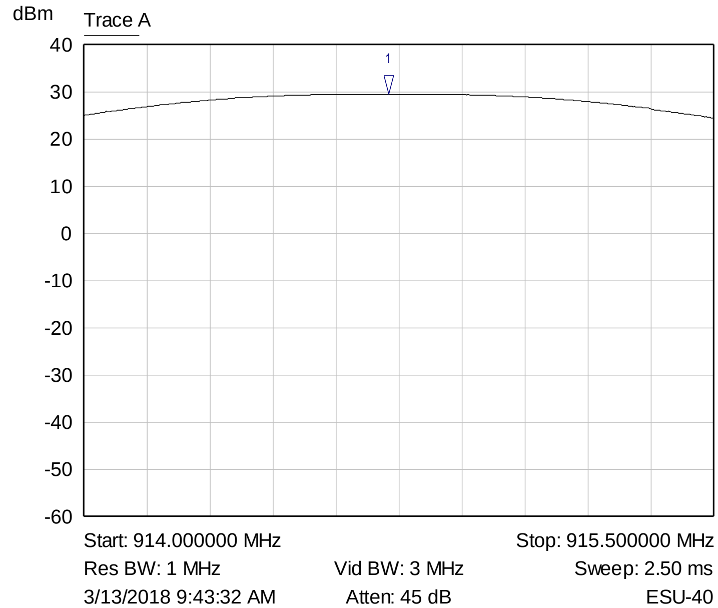
Result

In the configuration tested, the RF peak output power was less than 1 Watt; therefore, the EUT complied with the requirements of the specification.



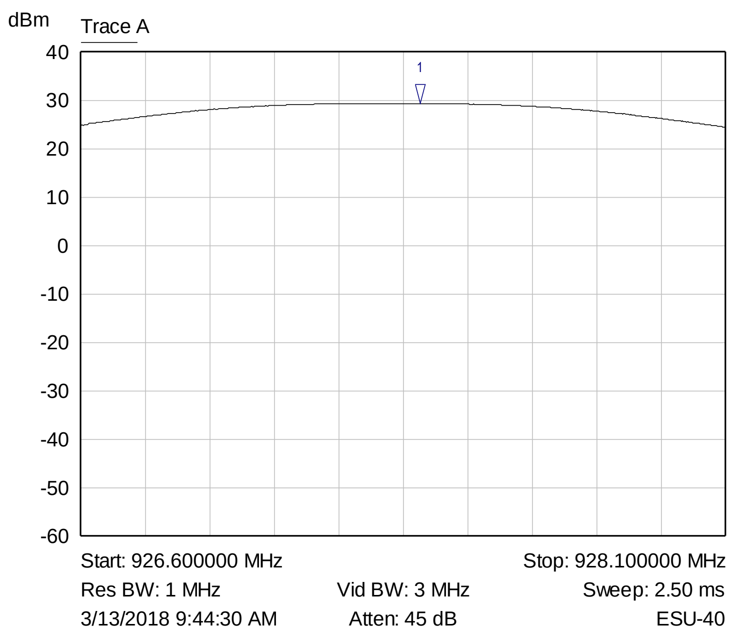
Mkr	Trace	X-Axis	Value	Notes
1 ▽	Trace A	902.605769 MHz	29.650532 dBm	

Graph 14: Lowest Channel Output Power – 250 kHz LoRa



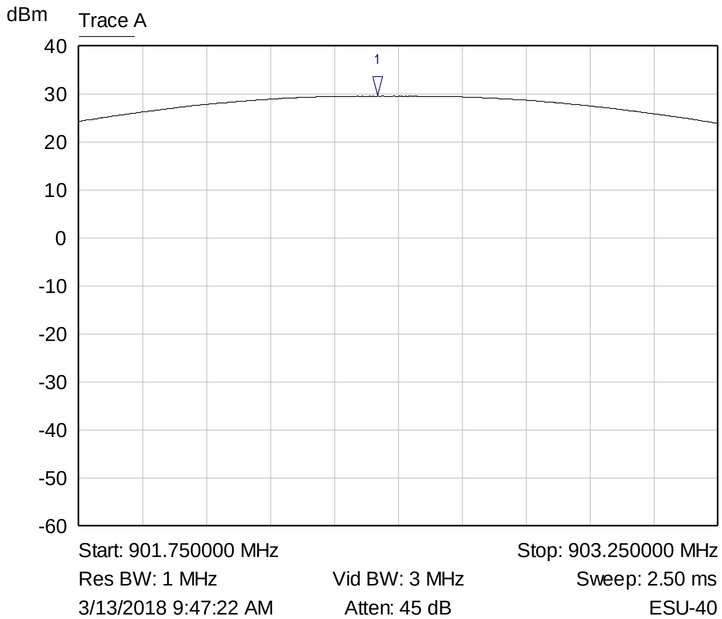
Mkr	Trace	X-Axis	Value	Notes
1 ∇	Trace A	914.725962 MHz	29.496635 dBm	

Graph 15: Middle Channel Output Power – 250 kHz LoRa



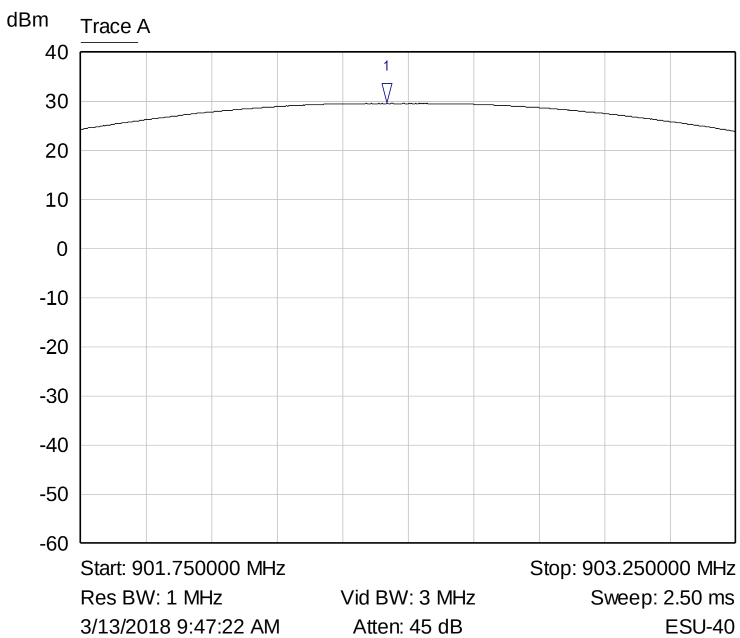
Mkr	Trace	X-Axis	Value	Notes
1 ∇	Trace A	927.388462 MHz	29.320265 dBm	

Graph 16: Upper Channel Output Power – 250 kHz LoRa



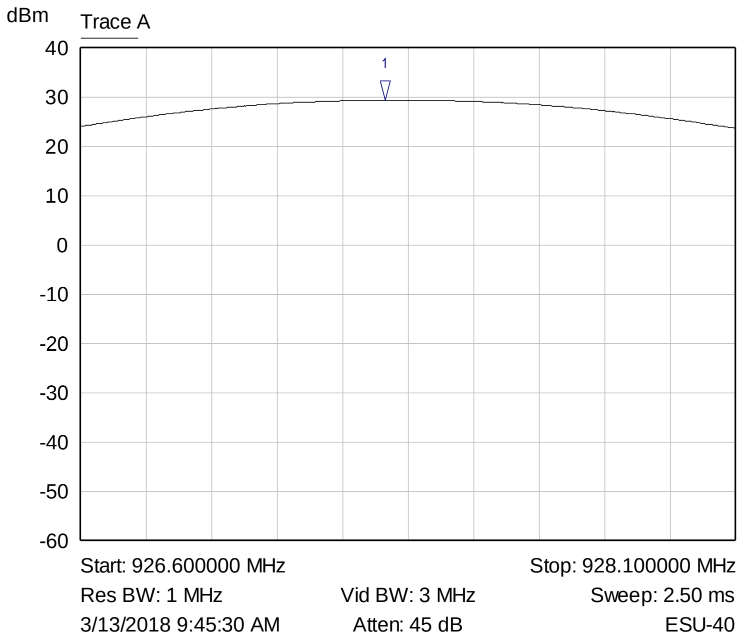
Mkr	Trace	X-Axis	Value	Notes
1 ∇	Trace A	902.451923 MHz	29.592697 dBm	

Graph 17: Lowest Channel Output Power – 125 kHz LoRa



Mkr	Trace	X-Axis	Value	Notes
1 ∇	Trace A	902.451923 MHz	29.592697 dBm	

Graph 18: Middle Channel Output Power – 125 kHz LoRa



Mkr	Trace	X-Axis	Value	Notes
1 ▽	Trace A	927.297115 MHz	29.346731 dBm	

Graph 19: Upper Channel Output Power – 125 kHz LoRa

6.2.7 §15.247(d) Spurious Emissions

6.2.7.1 Conducted Spurious Emissions

The frequency range from the lowest frequency generated or used in the device to the tenth harmonic of the highest fundamental frequency was investigated to measure any antenna-conducted emissions. The tables show the measurement data from spurious emissions noted across the frequency range when transmitting at the lowest frequency, middle frequency, and upper frequency. Shown below are plots with the EUT tuned to the upper and lower channels. These demonstrate compliance with the provisions of this section at the band edges.

The emissions must be attenuated 20 dB below the highest power level measured within the authorized band as measured with a 100 kHz RBW. The highest power measured using 250 kHz LoRa was 29.4 dBm; therefore, the criteria is 29.4 – 20 = 9.4 dBm. The highest power measured using 125 kHz LoRa was 29.2 dBm; therefore, the criteria is 29.2 – 20 = 9.2 dBm.

Result

In the configuration tested, the conducted spurious missions were attenuated more than 20 dB form the highest power measured using a 100 kHz RBW; therefore, the EUT complied with the requirements of the specification.

Frequency (MHz)	Corrected Level (dBm)	Criteria (dBm)	Margin (dB)
1805.00	-37.7	9.4	-47.1
2707.50	-37.2	9.4	-46.6

Frequency (MHz)	Corrected Level (dBm)	Criteria (dBm)	Margin (dB)
3610.00	-35.8	9.4	-45.2
4512.50	-37.8	9.4	-47.2
5415.00	-37.5	9.4	-46.9
6317.50	-38.2	9.4	-47.6
7220.00	-38.3	9.4	-47.7
8122.50	-38.1	9.4	-47.5
9025.00	-37.4	9.4	-46.8

Table 2: Transmitting on the Lowest Channel – 250 kHz LoRa

Frequency (MHz)	Corrected Level (dBm)	Criteria (dBm)	Margin (dB)
1829.50	-38.1	9.4	-47.5
2744.25	-32.7	9.4	-42.1
3659.00	-36.5	9.4	-45.9
4573.75	-38.5	9.4	-47.9
5488.50	-38.0	9.4	-47.4
6403.25	-38.2	9.4	-47.6
7318.00	-38.3	9.4	-47.7
8233.75	-37.4	9.4	-46.8
9147.50	-38.8	9.4	-48.2

Table 3: Transmitting on the Middle Channel – 250 kHz LoRa

Frequency (MHz)	Corrected Level (dBm)	Criteria (dBm)	Margin (dB)
1854.70	-38.4	9.4	-47.8
2782.05	-33.0	9.4	-42.4
3709.40	-36.4	9.4	-45.8
4636.75	-38.6	9.4	-48.0
5564.10	-37.5	9.4	-46.9
6491.45	-37.9	9.4	-47.3
7418.80	-38.4	9.4	-47.8
8346.15	-37.4	9.4	-46.8

Frequency (MHz)	Corrected Level (dBm)	Criteria (dBm)	Margin (dB)
9273.50	-37.9	9.4	-47.3

Table 4: Transmitting on the Highest Channel – 250 kHz LoRa

Frequency (MHz)	Corrected Level (dBm)	Criteria (dBm)	Margin (dB)
1805.00	-38.4	9.2	-47.6
2707.50	-38.1	9.2	-47.3
3610.00	-36.5	9.2	-45.7
4512.50	-38.2	9.2	-47.4
5415.00	-38.4	9.2	-47.6
6317.50	-37.6	9.2	-46.8
7220.00	-38.3	9.2	-47.5
8122.50	-38.2	9.2	-47.4
9025.00	-38.4	9.2	-47.6

Table 5: Transmitting on the Lowest Channel – 125 kHz LoRa

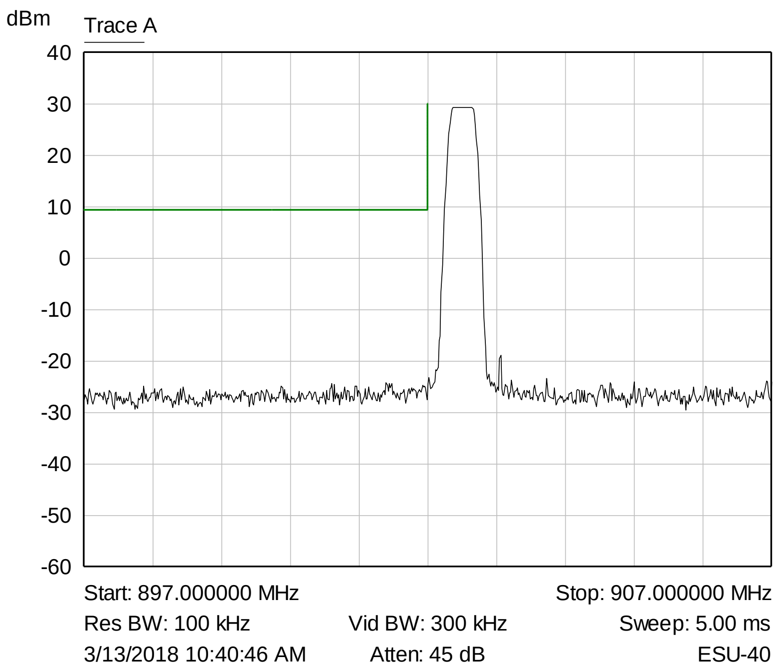
Frequency (MHz)	Corrected Level (dBm)	Criteria (dBm)	Margin (dB)
1829.50	-38.0	9.2	-47.2
2744.25	-33.0	9.2	-42.2
3659.00	-33.4	9.2	-42.6
4573.75	-38.6	9.2	-47.8
5488.50	-38.1	9.2	-47.3
6403.25	-38.4	9.2	-47.6
7318.00	-37.5	9.2	-46.7
8233.75	-37.9	9.2	-47.1
9147.50	-37.6	9.2	-46.8

Table 6: Transmitting on the Middle Channel – 125 kHz LoRa

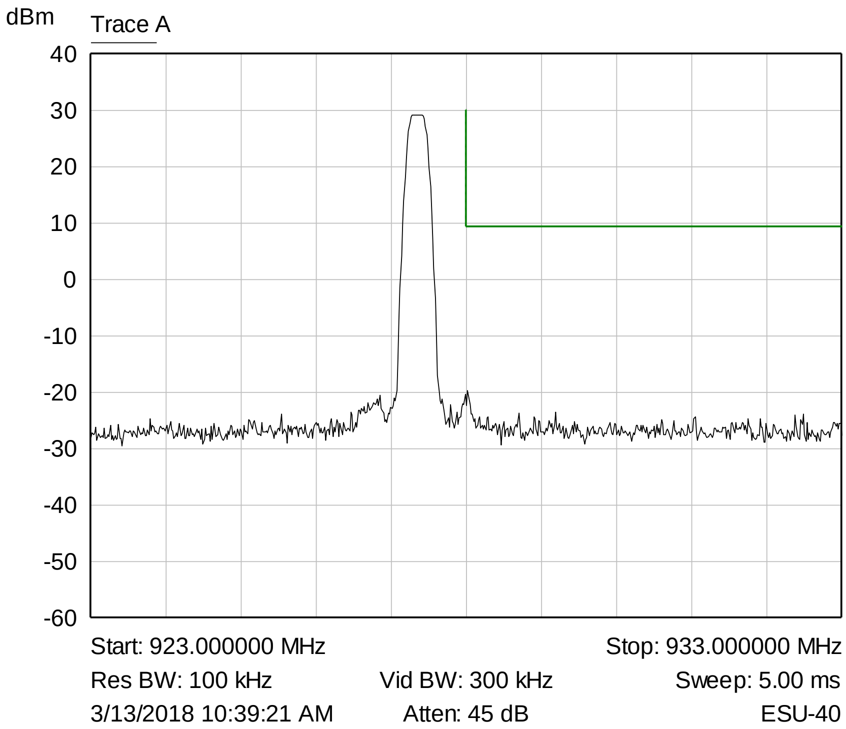
Frequency (MHz)	Corrected Level (dBm)	Criteria (dBm)	Margin (dB)
1854.70	-37.9	9.2	-47.1
2782.05	-33.2	9.2	-42.4

Frequency (MHz)	Corrected Level (dBm)	Criteria (dBm)	Margin (dB)
3709.40	-35.9	9.2	-45.1
4636.75	-36.6	9.2	-45.8
5564.10	-38.2	9.2	-47.4
6491.45	-38.0	9.2	-47.2
7418.80	-38.0	9.2	-47.2
8346.15	-38.7	9.2	-47.9
9273.50	-38.0	9.2	-47.2

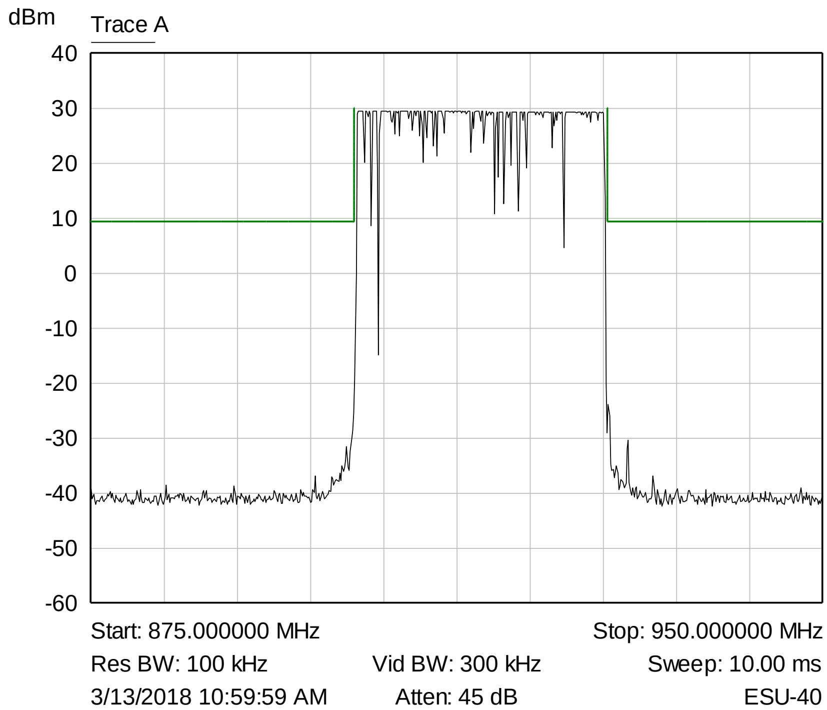
Table 7: Transmitting on the Highest Channel – 125 kHz LoRa



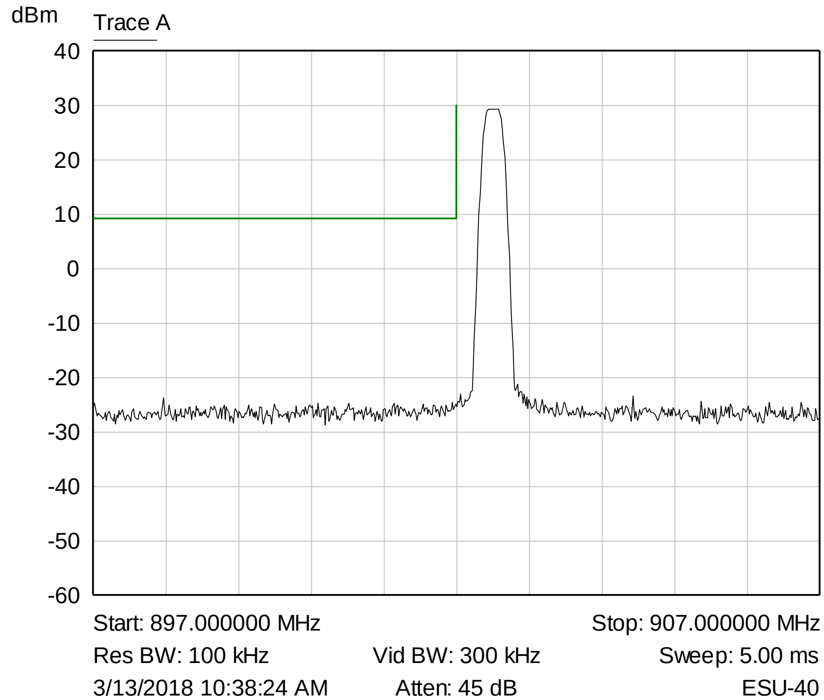
Graph 20: Lower Channel Plot – 250 kHz LoRa



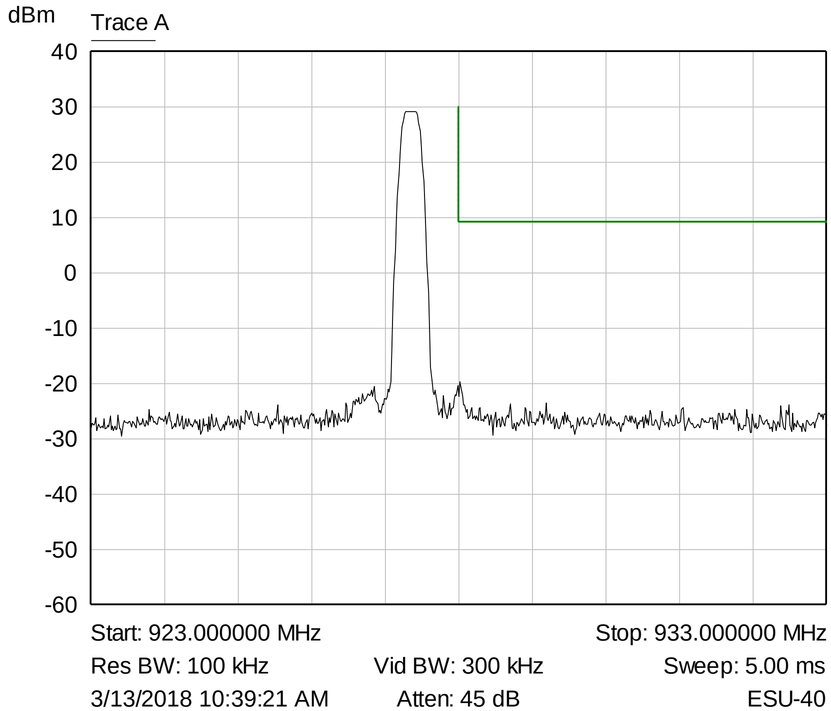
Graph 21: Upper Channel Plot – 250 kHz LoRa



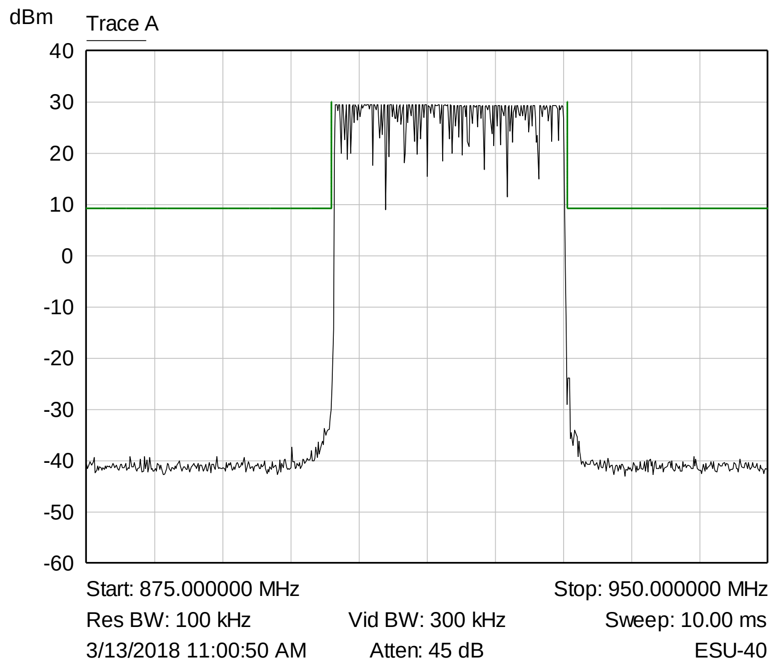
Graph 22: Operating Band Plot While Hopping – 250 kHz LoRa



Graph 23: Lower Channel Plot – 125 kHz LoRa



Graph 24: Upper Channel Plot – 125 kHz LoRa



Graph 25: Operating Band While Hopping – 125 kHz LoRa

6.7.2.2 Radiated Spurious Emissions in the Restricted Bands of §15.205

The frequency range from the lowest frequency generated or used in the device to the tenth harmonic of the highest fundamental emission was investigated to measure any radiated emissions in the restricted bands. The following tables show measurements of any emission that fell into the restricted bands of §15.205. The tables show the worst-case emission measured from the EUT. The emissions in the restricted bands must meet the limits specified in §15.209. Tabular data for each of the spurious emissions is shown below for each of the units.

Result

The radiated spurious emissions in the restricted bands met the limits specified in §15.209; therefore, the EUT complies with the specification.

Frequency (MHz)	Detector	Antenna Polarity	Receiver Reading (dBμV)	Correction Factor (dB)	Field Strength (dBμV/m)	Limit (dBμV/m)	Margin (dB)
2707.5	Peak	Vertical	11.6	34.0	45.6	74.0	-28.4
2707.5	Average	Vertical	8.4	34.0	42.4	54.0	-11.6
2707.5	Peak	Horizontal	12.7	34.0	46.7	74.0	-27.3
2707.5	Average	Horizontal	9.5	34.0	43.5	54.0	-10.5
3610.0	Peak	Vertical	8.0	37.3	45.3	74.0	-28.7
3610.0	Average	Vertical	3.2	37.3	40.5	54.0	-13.5
3610.0	Peak	Horizontal	10.4	37.3	47.7	74.0	-26.3
3610.0	Average	Horizontal	7.2	37.3	44.5	54.0	-9.5

Frequency (MHz)	Detector	Antenna Polarity	Receiver Reading (dBµV)	Correction Factor (dB)	Field Strength (dBµV/m)	Limit (dBµV/m)	Margin (dB)
4512.5	Peak	Vertical	4.9	39.1	44.0	74.0	-30.0
4512.5	Average	Vertical	-1.8	39.1	37.3	54.0	-16.7
4512.5	Peak	Horizontal	8.2	39.1	47.3	74.0	-26.7
4512.5	Average	Horizontal	4.0	39.1	43.1	54.0	-10.9
5415.0	Peak	Vertical	3.6	41.3	44.9	74.0	-29.1
5415.0	Average	Vertical	-6.0	41.3	35.3	54.0	-18.7
5415.0	Peak	Horizontal	5.1	41.3	46.4	74.0	-27.6
5415.0	Average	Horizontal	-1.8	41.3	39.5	54.0	-14.5
7220.0	Peak	Vertical	5.5	44.6	50.1	74.0	-23.9
7220.0	Average	Vertical	-0.8	44.6	43.8	54.0	-10.2
7220.0	Peak	Horizontal	5.8	44.6	50.4	74.0	-23.6
7220.0	Average	Horizontal	0.1	44.6	44.7	54.0	-9.3
8122.5	Peak	Vertical	6.1	46.5	52.6	74.0	-21.4
8122.5	Average	Vertical	0.7	46.5	47.2	54.0	-6.8
8122.5	Peak	Horizontal	9.5	46.5	56.0	74.0	-18.0
8122.5	Average	Horizontal	5.0	46.5	51.5	54.0	-2.5
9025.0	Peak	Vertical	4.4	47.9	52.3	74.0	-21.7
9025.0	Average	Vertical	-4.1	47.9	43.8	54.0	-10.2
9025.0	Peak	Horizontal	5.1	47.9	53.0	74.0	-21.0
9025.0	Average	Horizontal	-2.2	47.9	45.7	54.0	-8.3

Table 8: Transmitting at the Lowest Frequency – 250 kHz LoRa

Frequency (MHz)	Detector	Antenna Polarity	Receiver Reading (dBµV)	Correction Factor (dB)	Field Strength (dBµV/m)	Limit (dBµV/m)	Margin (dB)
2744.3	Peak	Vertical	12.0	34.2	46.2	74.0	-27.8
2744.3	Average	Vertical	8.9	34.2	43.1	54.0	-10.9
2744.3	Peak	Horizontal	12.6	34.2	46.8	74.0	-27.2
2744.3	Average	Horizontal	9.6	34.2	43.8	54.0	-10.2
3659.0	Peak	Vertical	6.5	37.5	44.0	74.0	-30.0
3659.0	Average	Vertical	1.0	37.5	38.5	54.0	-15.5
3659.0	Peak	Horizontal	12.6	37.5	50.1	74.0	-23.9
3659.0	Average	Horizontal	9.5	37.5	47.0	54.0	-7.0
4573.8	Peak	Vertical	6.0	39.3	45.3	74.0	-28.7

Frequency (MHz)	Detector	Antenna Polarity	Receiver Reading (dBμV)	Correction Factor (dB)	Field Strength (dBμV/m)	Limit (dBμV/m)	Margin (dB)
4573.8	Average	Vertical	0.1	39.3	39.4	54.0	-14.6
4573.8	Peak	Horizontal	6.1	39.3	45.4	74.0	-28.6
4573.8	Average	Horizontal	0.2	39.3	39.5	54.0	-14.5
5488.5	Peak	Vertical	3.5	41.5	45.0	74.0	-29.0
5488.5	Average	Vertical	-5.2	41.5	36.3	54.0	-17.7
5488.5	Peak	Horizontal	5.3	41.5	46.8	74.0	-27.2
5488.5	Average	Horizontal	-1.6	41.5	39.9	54.0	-14.1
7318.0	Peak	Vertical	5.9	44.9	50.8	74.0	-23.2
7318.0	Average	Vertical	0.4	44.9	45.3	54.0	-8.7
7318.0	Peak	Horizontal	4.9	44.9	49.8	74.0	-24.2
7318.0	Average	Horizontal	-1.6	44.9	43.3	54.0	-10.7
8232.8	Peak	Vertical	8.4	46.6	55.0	74.0	-19.0
8232.8	Average	Vertical	2.9	46.6	49.5	54.0	-4.5
8232.8	Peak	Horizontal	3.5	46.6	50.1	74.0	-23.9
8232.8	Average	Horizontal	-3.8	46.6	42.8	54.0	-11.2
9147.5	Peak	Vertical	4.6	48.0	52.6	74.0	-21.4
9147.5	Average	Vertical	-2.7	48.0	45.3	54.0	-8.7
9147.5	Peak	Horizontal	5.4	48.0	53.4	74.0	-20.6
9147.5	Average	Horizontal	-1.3	48.0	46.7	54.0	-7.3

Table 9: Transmitting at the Middle Frequency – 250 kHz LoRa

Frequency (MHz)	Detector	Antenna Polarity	Receiver Reading (dBμV)	Correction Factor (dB)	Field Strength (dBμV/m)	Limit (dBμV/m)	Margin (dB)
2782.1	Peak	Vertical	10.5	34.4	44.9	74.0	-29.1
2782.1	Average	Vertical	6.0	34.4	40.4	54.0	-13.6
2782.1	Peak	Horizontal	12.0	34.4	46.4	74.0	-27.6
2782.1	Average	Horizontal	8.6	34.4	43.0	54.0	-11.0
3709.5	Peak	Vertical	7.2	37.7	44.9	74.0	-29.1
3709.5	Average	Vertical	1.9	37.7	39.6	54.0	-14.4
3709.5	Peak	Horizontal	12.4	37.7	50.1	74.0	-23.9
3709.5	Average	Horizontal	8.9	37.7	46.6	54.0	-7.4
4636.8	Peak	Vertical	7.7	39.4	47.1	74.0	-26.9
4636.8	Average	Vertical	3.5	39.4	42.9	54.0	-11.1

Frequency (MHz)	Detector	Antenna Polarity	Receiver Reading (dBμV)	Correction Factor (dB)	Field Strength (dBμV/m)	Limit (dBμV/m)	Margin (dB)
4636.8	Peak	Horizontal	5.3	39.4	44.7	74.0	-29.3
4636.8	Average	Horizontal	1.3	39.4	40.7	54.0	-13.3
5564.2	Peak	Vertical	3.8	41.6	45.4	74.0	-28.6
5564.2	Average	Vertical	-6.7	41.6	34.9	54.0	-19.1
5564.2	Peak	Horizontal	4.4	41.6	46.0	74.0	-28.0
5564.2	Average	Horizontal	-5.3	41.6	36.3	54.0	-17.7
7418.9	Peak	Vertical	4.9	45.3	50.2	74.0	-23.8
7418.9	Average	Vertical	-0.6	45.3	44.7	54.0	-9.3
7418.9	Peak	Horizontal	4.2	45.3	49.5	74.0	-24.5
7418.9	Average	Horizontal	-3.8	45.3	41.5	54.0	-12.5
8346.2	Peak	Vertical	4.3	46.8	51.1	74.0	-22.9
8346.2	Average	Vertical	-4.4	46.8	42.4	54.0	-11.6
8346.2	Peak	Horizontal	6.0	46.8	52.8	74.0	-21.2
8346.2	Average	Horizontal	-0.2	46.8	46.6	54.0	-7.4
9273.5	Peak	Vertical	4.6	48.1	52.7	74.0	-21.3
9273.5	Average	Vertical	-3.9	48.1	44.2	54.0	-9.8
9273.5	Peak	Horizontal	4.8	48.1	52.9	74.0	-21.1
9273.5	Average	Horizontal	-4.2	48.1	43.9	54.0	-10.1

Table 10: Transmitting at the Highest Frequency – 250 kHz LoRa

Frequency (MHz)	Detector	Antenna Polarity	Receiver Reading (dBμV)	Correction Factor (dB)	Field Strength (dBμV/m)	Limit (dBμV/m)	Margin (dB)
2707.5	Peak	Vertical	11.6	34.0	45.6	74.0	-28.4
2707.5	Average	Vertical	8.4	34.0	42.4	54.0	-11.6
2707.5	Peak	Horizontal	12.5	34.0	46.5	74.0	-27.5
2707.5	Average	Horizontal	9.2	34.0	43.2	54.0	-10.8
3610.0	Peak	Vertical	7.6	37.3	44.9	74.0	-29.1
3610.0	Average	Vertical	3.0	37.3	40.3	54.0	-13.7
3610.0	Peak	Horizontal	9.6	37.3	46.9	74.0	-27.1
3610.0	Average	Horizontal	6.0	37.3	43.3	54.0	-10.7
4512.5	Peak	Vertical	5.2	39.1	44.3	74.0	-29.7
4512.5	Average	Vertical	-2.1	39.1	37.0	54.0	-17.0
4512.5	Peak	Horizontal	8.4	39.1	47.5	74.0	-26.5

Frequency (MHz)	Detector	Antenna Polarity	Receiver Reading (dBµV)	Correction Factor (dB)	Field Strength (dBµV/m)	Limit (dBµV/m)	Margin (dB)
4512.5	Average	Horizontal	4.6	39.1	43.7	54.0	-10.3
5415.0	Peak	Vertical	3.8	41.3	45.1	74.0	-28.9
5415.0	Average	Vertical	-5.2	41.3	36.1	54.0	-17.9
5415.0	Peak	Horizontal	5.3	41.3	46.6	74.0	-27.4
5415.0	Average	Horizontal	-2.3	41.3	39.0	54.0	-15.0
7220.0	Peak	Vertical	5.4	44.6	50.0	74.0	-24.0
7220.0	Average	Vertical	-1.1	44.6	43.5	54.0	-10.5
7220.0	Peak	Horizontal	5.9	44.6	50.5	74.0	-23.5
7220.0	Average	Horizontal	-1.2	44.6	43.4	54.0	-10.6
8122.5	Peak	Vertical	6.3	46.5	52.8	74.0	-21.2
8122.5	Average	Vertical	0.7	46.5	47.2	54.0	-6.8
8122.5	Peak	Horizontal	9.5	46.5	56.0	74.0	-18.0
8122.5	Average	Horizontal	5.6	46.5	52.1	54.0	-1.9
9025.0	Peak	Vertical	5.6	47.9	53.5	74.0	-20.5
9025.0	Average	Vertical	-2.6	47.9	45.3	54.0	-8.7
9025.0	Peak	Horizontal	4.5	47.9	52.4	74.0	-21.6
9025.0	Average	Horizontal	-4.4	47.9	43.5	54.0	-10.5

Table 11: Transmitting at the Lowest Frequency – 125 kHz LoRa

Frequency (MHz)	Detector	Antenna Polarity	Receiver Reading (dBµV)	Correction Factor (dB)	Field Strength (dBµV/m)	Limit (dBµV/m)	Margin (dB)
2744.3	Peak	Vertical	11.8	34.2	46.0	74.0	-28.0
2744.3	Average	Vertical	8.7	34.2	42.9	54.0	-11.1
2744.3	Peak	Horizontal	12.3	34.2	46.5	74.0	-27.5
2744.3	Average	Horizontal	9.3	34.2	43.5	54.0	-10.5
3659.0	Peak	Vertical	6.5	37.5	44.0	74.0	-30.0
3659.0	Average	Vertical	0.1	37.5	37.6	54.0	-16.4
3659.0	Peak	Horizontal	11.0	37.5	48.5	74.0	-25.5
3659.0	Average	Horizontal	8.4	37.5	45.9	54.0	-8.1
4573.8	Peak	Vertical	5.4	39.3	44.7	74.0	-29.3
4573.8	Average	Vertical	-0.7	39.3	38.6	54.0	-15.4
4573.8	Peak	Horizontal	5.7	39.3	45.0	74.0	-29.0
4573.8	Average	Horizontal	0.4	39.3	39.7	54.0	-14.3

Frequency (MHz)	Detector	Antenna Polarity	Receiver Reading (dBµV)	Correction Factor (dB)	Field Strength (dBµV/m)	Limit (dBµV/m)	Margin (dB)
5488.5	Peak	Vertical	3.3	41.5	44.8	74.0	-29.2
5488.5	Average	Vertical	-5.1	41.5	36.4	54.0	-17.6
5488.5	Peak	Horizontal	6.0	41.5	47.5	74.0	-26.5
5488.5	Average	Horizontal	-0.7	41.5	40.8	54.0	-13.2
7318.0	Peak	Vertical	5.1	44.9	50.0	74.0	-24.0
7318.0	Average	Vertical	-1.9	44.9	43.0	54.0	-11.0
7318.0	Peak	Horizontal	4.8	44.9	49.7	74.0	-24.3
7318.0	Average	Horizontal	-2.3	44.9	42.6	54.0	-11.4
8232.8	Peak	Vertical	5.4	46.6	52.0	74.0	-22.0
8232.8	Average	Vertical	-0.9	46.6	45.7	54.0	-8.3
8232.8	Peak	Horizontal	8.0	46.6	54.6	74.0	-19.4
8232.8	Average	Horizontal	3.2	46.6	49.8	54.0	-4.2
9147.5	Peak	Vertical	6.3	48.0	54.3	74.0	-19.7
9147.5	Average	Vertical	1.0	48.0	49.0	54.0	-5.0
9147.5	Peak	Horizontal	4.3	48.0	52.3	74.0	-21.7
9147.5	Average	Horizontal	-3.5	48.0	44.5	54.0	-9.5

Table 12: Transmitting at the Middle Frequency – 125 kHz LoRa

Frequency (MHz)	Detector	Antenna Polarity	Receiver Reading (dBµV)	Correction Factor (dB)	Field Strength (dBµV/m)	Limit (dBµV/m)	Margin (dB)
2782.1	Peak	Vertical	9.2	34.4	43.6	74.0	-30.4
2782.1	Average	Vertical	3.8	34.4	38.2	54.0	-15.8
2782.1	Peak	Horizontal	11.9	34.4	46.3	74.0	-27.7
2782.1	Average	Horizontal	8.5	34.4	42.9	54.0	-11.1
3709.5	Peak	Vertical	7.7	37.7	45.4	74.0	-28.6
3709.5	Average	Vertical	2.8	37.7	40.5	54.0	-13.5
3709.5	Peak	Horizontal	11.9	37.7	49.6	74.0	-24.4
3709.5	Average	Horizontal	9.2	37.7	46.9	54.0	-7.1
4636.8	Peak	Vertical	8.2	39.4	47.6	74.0	-26.4
4636.8	Average	Vertical	3.6	39.4	43.0	54.0	-11.0
4636.8	Peak	Horizontal	5.8	39.4	45.2	74.0	-28.8
4636.8	Average	Horizontal	-0.5	39.4	38.9	54.0	-15.1
5564.2	Peak	Vertical	3.0	41.6	44.6	74.0	-29.4

Frequency (MHz)	Detector	Antenna Polarity	Receiver Reading (dBμV)	Correction Factor (dB)	Field Strength (dBμV/m)	Limit (dBμV/m)	Margin (dB)
5564.2	Average	Vertical	-7.6	41.6	34.0	54.0	-20.0
5564.2	Peak	Horizontal	4.1	41.6	45.7	74.0	-28.3
5564.2	Average	Horizontal	-4.9	41.6	36.7	54.0	-17.3
7418.9	Peak	Vertical	5.6	45.3	50.9	74.0	-23.1
7418.9	Average	Vertical	-2.4	45.3	42.9	54.0	-11.1
7418.9	Peak	Horizontal	4.6	45.3	49.9	74.0	-24.1
7418.9	Average	Horizontal	-0.9	45.3	44.4	54.0	-9.6
8346.2	Peak	Vertical	4.2	46.8	51.0	74.0	-23.0
8346.2	Average	Vertical	-4.6	46.8	42.2	54.0	-11.8
8346.2	Peak	Horizontal	5.9	46.8	52.7	74.0	-21.3
8346.2	Average	Horizontal	0.0	46.8	46.8	54.0	-7.2
9273.5	Peak	Vertical	4.2	48.1	52.3	74.0	-21.7
9273.5	Average	Vertical	-2.5	48.1	45.6	54.0	-8.4
9273.5	Peak	Horizontal	4.1	48.1	52.2	74.0	-21.8
9273.5	Average	Horizontal	-4.1	48.1	44.0	54.0	-10.0

Table 13: Transmitting at the Highest Frequency –125 kHz LoRa

No other emissions were seen in the restricted bands.

7 Test Procedures and Test Equipment

7.1 Conducted Emissions at Mains Ports

The conducted emissions at mains and telecommunications ports from the EUT were measured using a spectrum analyzer with a quasi-peak adapter for peak, quasi-peak and average readings. The quasi-peak adapter uses a bandwidth of 9 kHz, with the spectrum analyzer's resolution bandwidth set at 100 kHz, for readings in the 150 kHz to 30 MHz frequency ranges.

The conducted emissions at mains ports measurements are performed in a screen room using a (50 Ω/50 µH) Line Impedance Stabilization Network (LISN).

Where mains flexible power cords are longer than 1 m, the excess cable is folded back and forth as far as possible so as to form a bundle not exceeding 0.4 m in length.

Where the EUT is a collection of devices with each device having its own power cord, the point of connection for the LISN is determined from the following rules:

- Each power cord, which is terminated in a mains supply plug, shall be tested separately.
- Power cords, which are not specified by the manufacturer to be connected via a host unit, shall be tested separately.
- Power cords which are specified by the manufacturer to be connected via a host unit or other power supplying equipment shall be connected to that host unit and the power cords of that host unit connected to the LISN and tested.
- Where a special connection is specified, the necessary hardware to effect the connection is supplied by the manufacturer for the testing purpose.
- When testing equipment with multiple mains cords, those cords not under test are connected to an artificial mains network (AMN) different than the AMN used for the mains cord under test.

For testing, desktop EUT are placed on a non-conducting table at least 0.8 meters from the metallic floor and placed 40 cm from the vertical coupling plane (copper plating in the wall behind EUT table). Floor standing equipment is placed directly on the earth grounded floor.

Type of Equipment	Manufacturer	Model Number	Asset Number	Date of Last Calibration	Due Date of Calibration
Spectrum Analyzer	Hewlett Packard	8566B	2747A-05734	02/09/2018	02/09/2019
Quasi-Peak Detector	Hewlett Packard	85650A	V033345	08/04/2017	08/04/2018
LISN	VPI Labs	LISN-COMM-50	V034431	10/13/2017	10/13/2018
Conductance Cable Wanship Upper Site	VPI Labs	Cable J	V034832	01/09/2018	01/09/2019
Transient Limiter	Hewlett Packard	11947A	V033591	01/09/2018	01/09/2019
Test Software (AC)	VPI Labs	Revision 01	V035674	N/A	N/A

Table 14: List of equipment used for conducted emissions testing at mains ports.

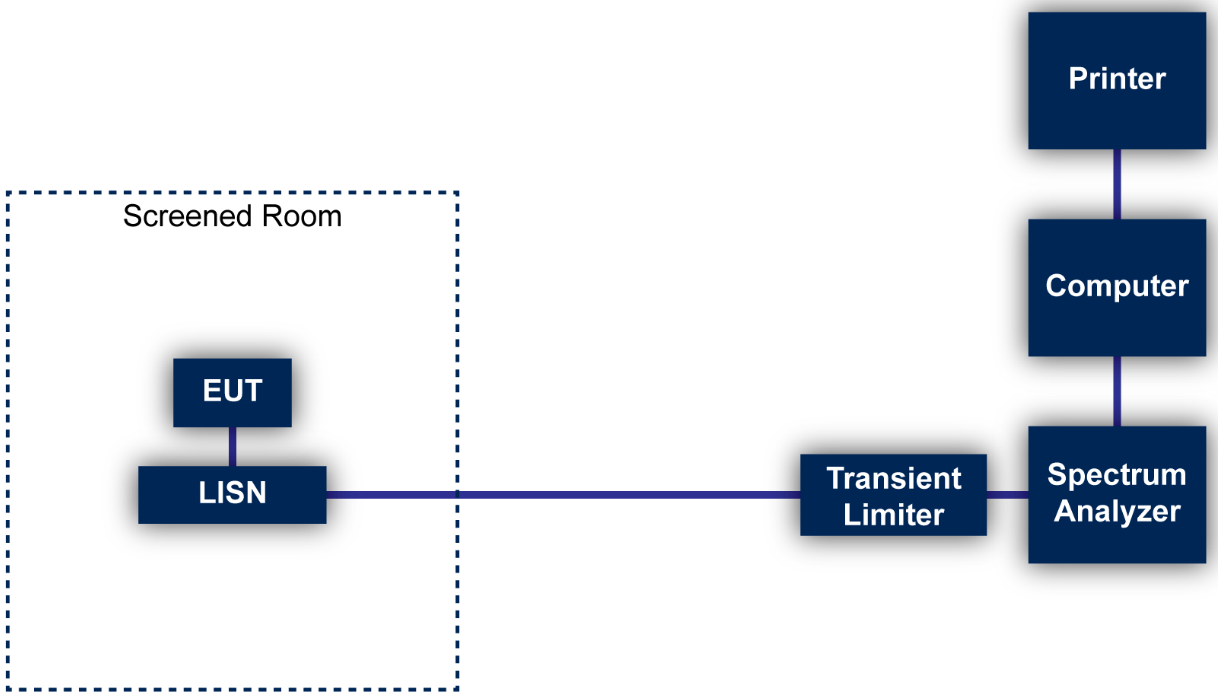


Figure 1: Conducted Emissions Test

7.2 Direct Connection at the Antenna Port Test

Type of Equipment	Manufacturer	Model Number	Asset Number	Date of Last Calibration	Due Date of Calibration
Spectrum Analyzer/Receiver	Rohde & Schwarz	ESU40	V033119	06/06/2017	06/06/2018
6 dB Attenuator	Pasternack	PE7004-6	V033645	01/09/2018	01/09/2019
Low Loss Cable	N/A	N/A	V034173	01/09/2018	01/09/2019

Table 15: List of equipment used for direct connection at the antenna port testing

7.2.1 Test Configuration Block Diagram

Figure 2: Direct Connection at the Antenna Port Test

7.3 Radiated Emissions

The radiated emissions from the EUT were measured using a spectrum analyzer with a quasi-peak adapter for peak and quasi-peak readings.

A preamplifier with a fixed gain of 26 dB and a power amplifier with a fixed gain of 22 dB were used to increase the sensitivity of the measuring instrumentation. The quasi-peak adapter uses a bandwidth of 120 kHz, with the spectrum analyzer's resolution bandwidth set at 1 MHz, for readings in the 30 to 1000 MHz frequency ranges. For frequencies below 30 MHz, a 9 kHz resolution Bandwidth was used.

A loop antenna was used to measure frequencies below 30 MHz. A biconilog antenna was used to measure the frequency range of 30 to 1000 MHz, at a distance of 10 meters from the EUT. The readings obtained by these antennas are correlated to the levels obtained with a tuned dipole antenna by adding antenna factors. A double-ridged guide antenna was used to measure the emissions at frequencies above 1000 MHz at a 3 meter or 1 meter distance from the EUT.

The configuration of the EUT was varied to find the maximum radiated emission. The EUT was connected to the peripherals listed in Section 2.3 via the interconnecting cables listed in Section 2.4. A technician manually manipulated these interconnecting cables to obtain worst-case radiated emissions. The EUT was rotated 360 degrees, and the antenna height was varied from 1 to 4 meters to find the maximum radiated emission. Where there were multiple interface ports all of the same type, cables are either placed on all of the ports or cables added to these ports until the emissions do not increase by more than 2 dB.

Desktop EUT are measured on a non-conducting table 0.8 meters above the ground plane. For frequencies above 1000 MHz, the EUT is placed on a table 1.5 meters above the ground plane. The table is placed on a turntable, which is level with the ground plane. For equipment normally placed on floors, the equipment shall be placed directly on the turntable.

For radiated emissions testing that is performed at distances closer than the specified distance; an inverse proportionality factor of 20 dB per decade is used to normalize the measured data for determining compliance.

Type of Equipment	Manufacturer	Model Number	Asset Number	Date of Last Calibration	Due Date of Calibration
Spectrum Analyzer/Receiver	Rohde & Schwarz	ESU40	V033119	06/06/2017	06/06/2018
Spectrum Analyzer	Hewlett Packard	8566B	2747A-05734	02/09/2018	02/09/2019
Quasi-Peak Detector	Hewlett Packard	85650A	V033345	08/04/2017	08/04/2018
Loop Antenna	EMCO	6502	V034216	01/25/2017	01/25/2019
Biconilog Antenna with 6 dB attenuator and preamp	EMCO	3142E-PA	V035736	06/24/2016	06/24/2018
Double Ridged Guide Antenna	EMCO	3115	V034194	03/08/2017	03/08/2019
High Frequency Amplifier	Miteq	AFS4-001018000-35-10P-4	V033997	01/09/2018	01/09/2019
900 MHz High Pass Filter	Micro-Tronics	HPM50108-03	V034185	01/09/2018	01/09/2019

Type of Equipment	Manufacturer	Model Number	Asset Number	Date of Last Calibration	Due Date of Calibration
6' High Frequency Cable	Microcoax	UFB197C-0-0720-000000	V033638	01/09/2018	01/09/2019
20' High Frequency Cable	Microcoax	UFB197C-1-3120-000000	V033979	01/09/2018	01/09/2019
3 Meter Radiated Emissions Cable Wanship Upper Site	Microcoax	UFB205A-0-4700-000000	V033639	01/09/2018	01/09/2019
Test Software (FCC)	VPI Labs	Revision 01	V035673	N/A	N/A

Table 16: List of equipment used for radiated emissions testing.

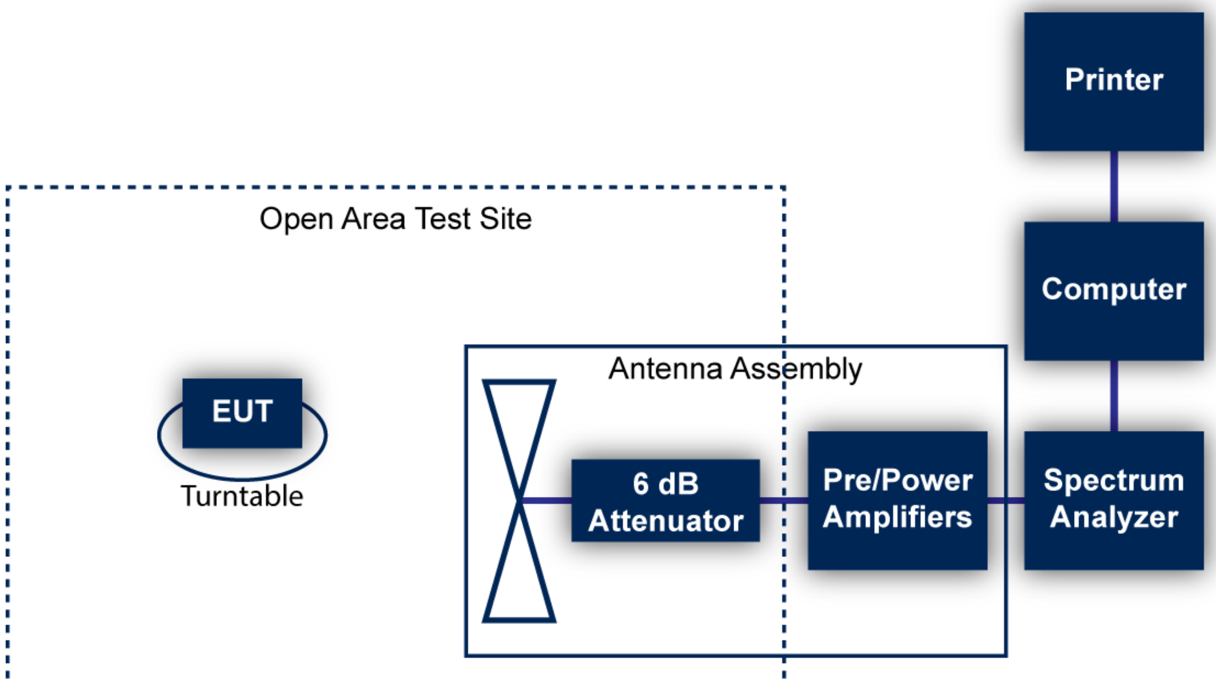


Figure 3: Radiated Emissions Test

7.4 Equipment Calibration

All applicable equipment is calibrated using either an independent calibration laboratory or VPI Laboratories, Inc. personnel at intervals defined in ANSI C63.4:2014 following outlined calibration procedures. All measurement instrumentation is traceable to the National Institute of Standards and Technology (NIST). Supporting documentation relative to tractability is on file and is available for examination upon request.

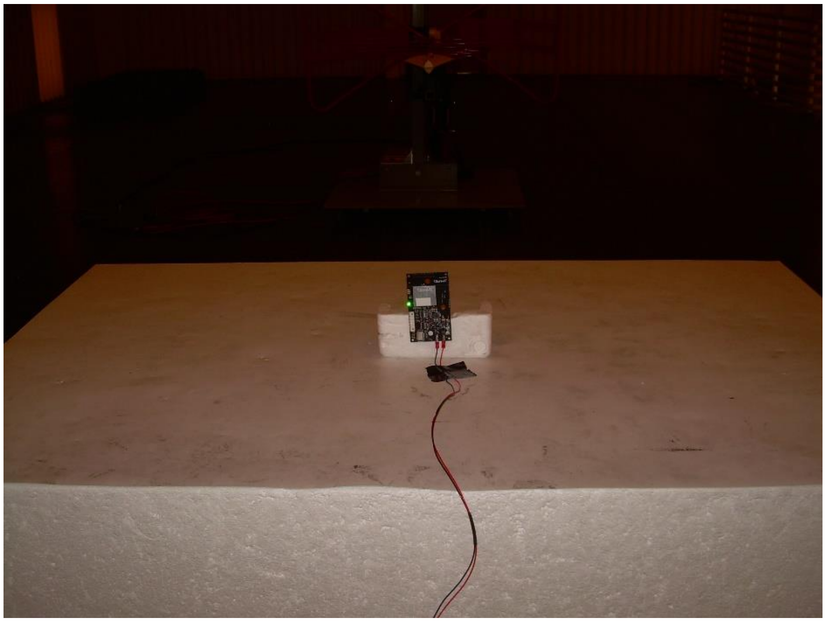
7.5 Measurement Uncertainty

Test	Uncertainty (±dB)	Confidence (%)
Conducted Emissions	2.8	95

Test	Uncertainty (±dB)	Confidence (%)
Radiated Emission (9 kHz to 30 MHz)	3.3	95
Radiated Emissions (30 MHz to 1 GHz)	3.4	95
Radiated Emissions (1 GHz to 18 GHz)	5.0	95
Radiated Emissions (18 GHz to 40 GHz)	4.1	95

8 Photographs

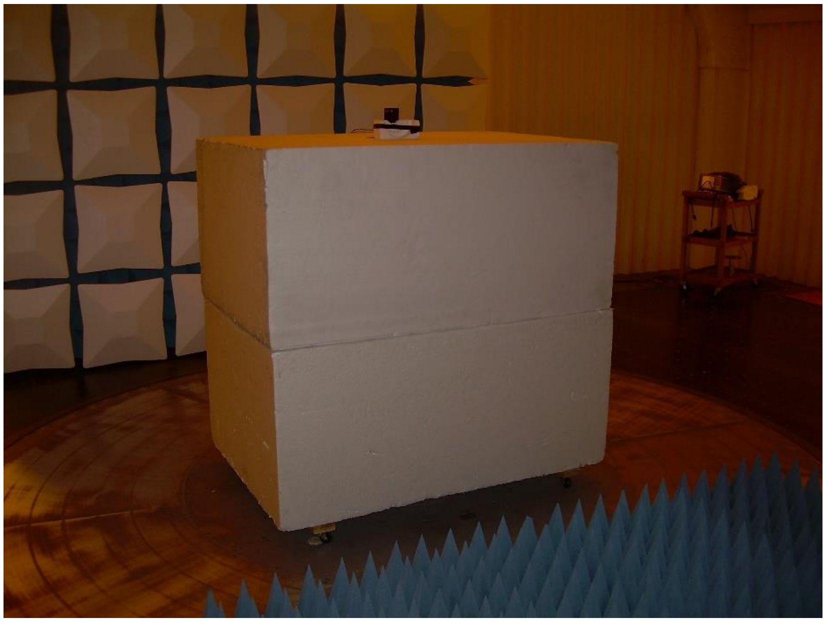
Photograph 1: Front View Radiated Emissions Below 1000 MHz – Vertical Configuration



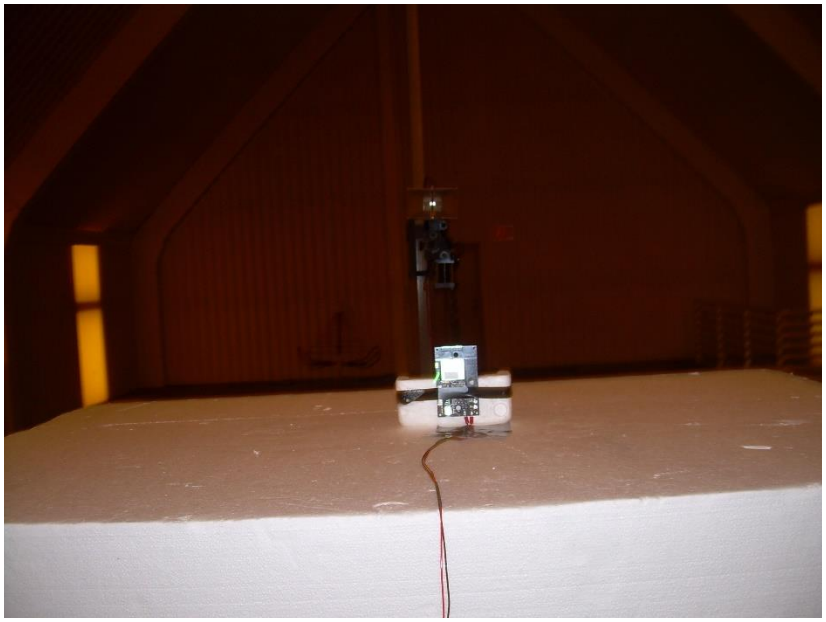
Photograph 2: Back View Radiated Emissions 30 – 1000 MHz – Vertical Configuration

Photograph 3: Front View Radiated Emissions Below 1000 MHz – Flat Configuration

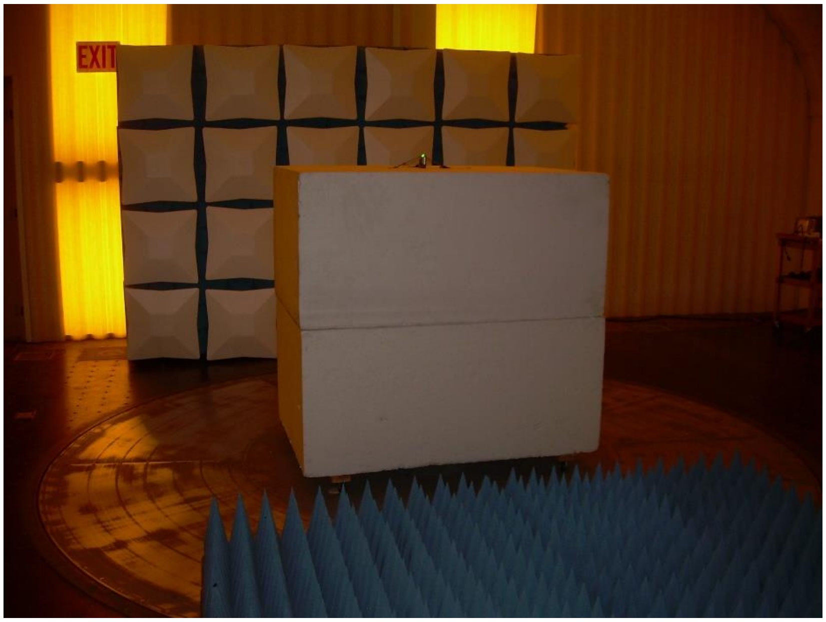
Photograph 4: Front View Radiated Emissions Below 1000 MHz – On Edge Configuration



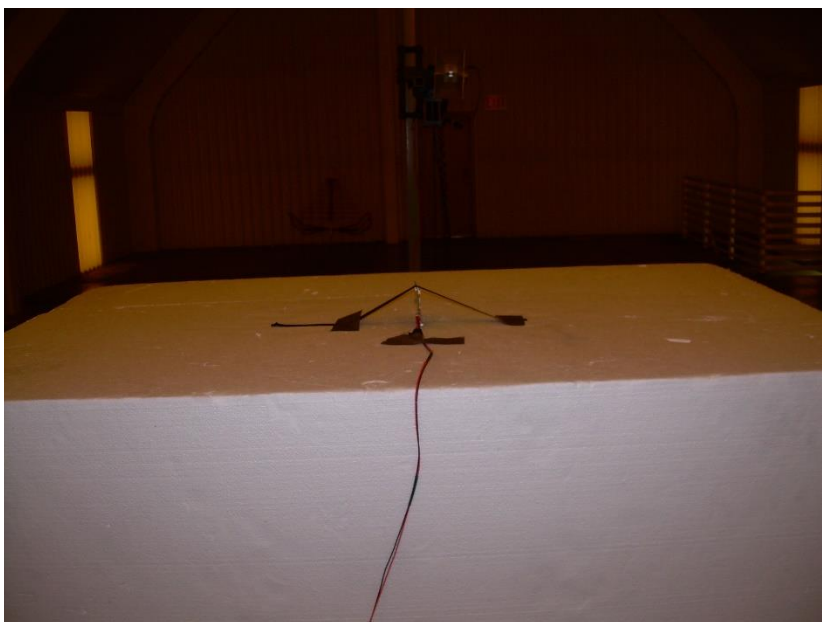
Photograph 5: Front View Radiated Emissions Above 1000 MHz – Vertical Configuration



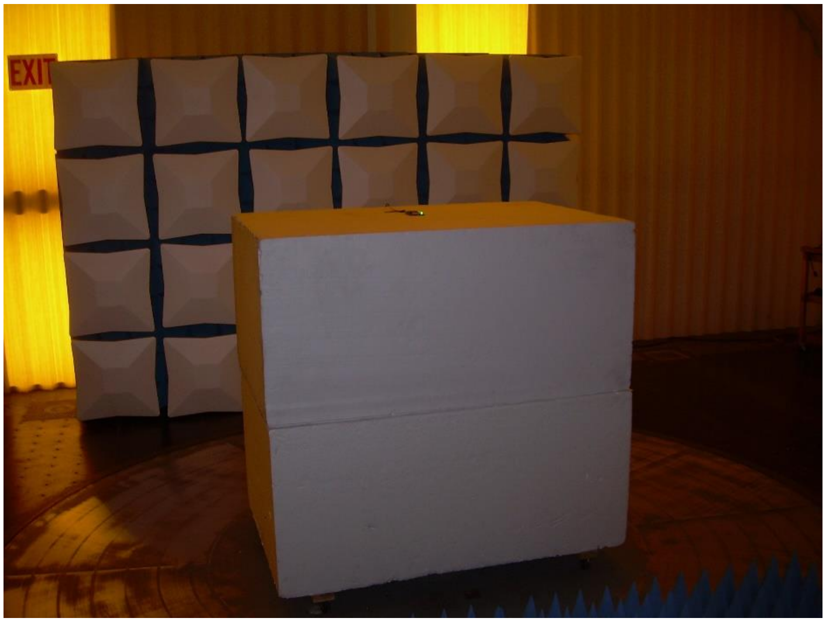
Photograph 6: Back View Radiated Emissions 30 – 1000 MHz – Vertical Configuration



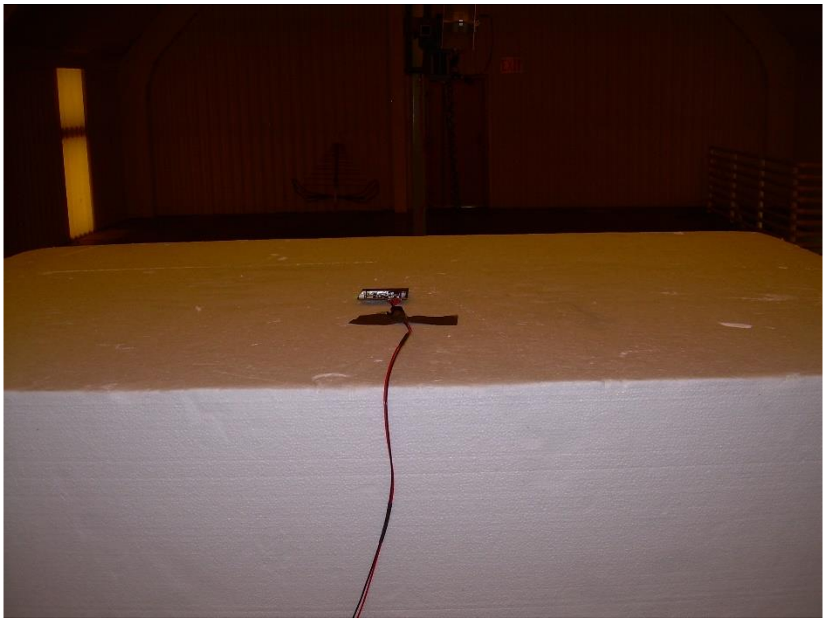
Photograph 7: Front View Radiated Emissions Above 1000 MHz – On Edge Configuration



Photograph 8: Back View Radiated Emissions Above 1000 MHz – On Edge Configuration



Photograph 9: Front View Radiated Emissions Above 1000 MHz – Flat Configuration

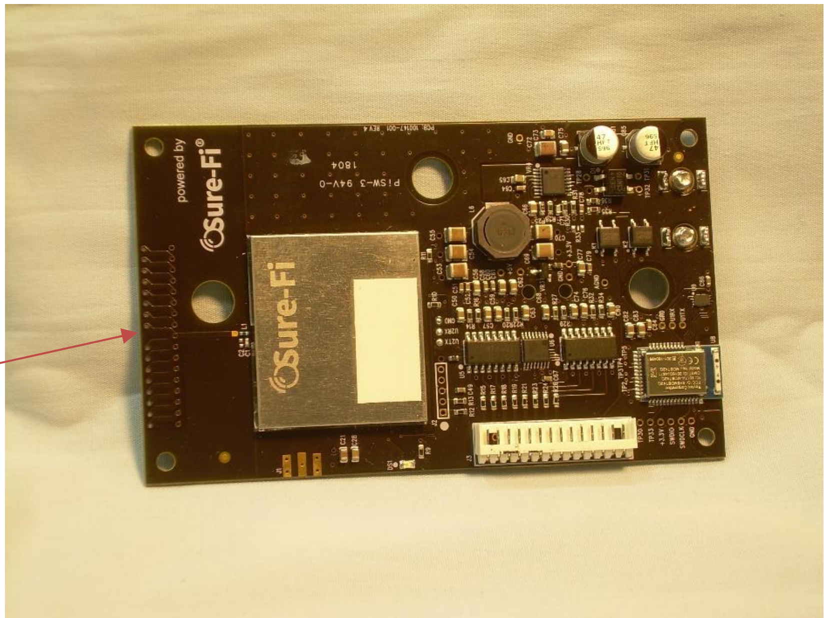


Photograph 10: Back View Radiated Emissions Above 1000 MHz – Flat Configuration

Photograph 11 – Front View Conducted Emissions Worse-Case Configuration

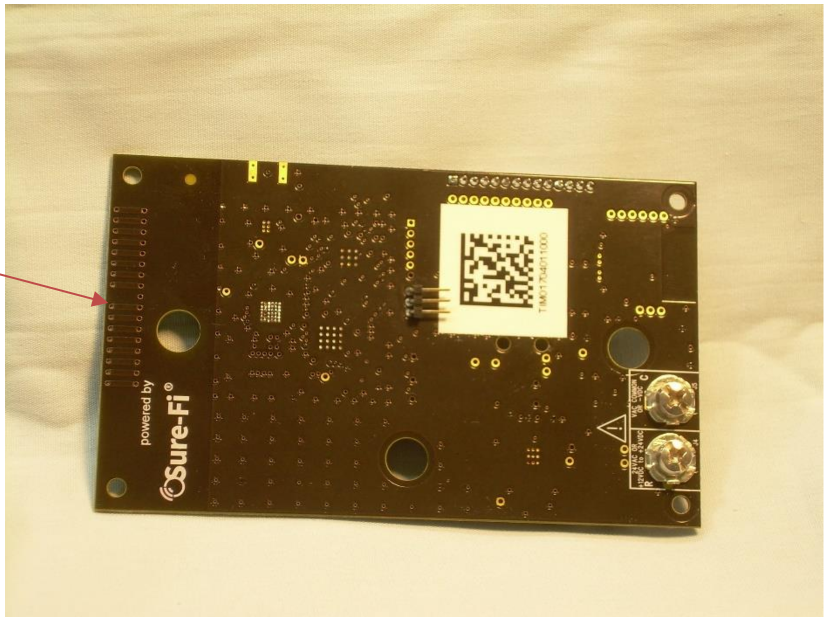
Photograph 12 – Back View Conducted Emissions Worst-Case Configuration

Antenna

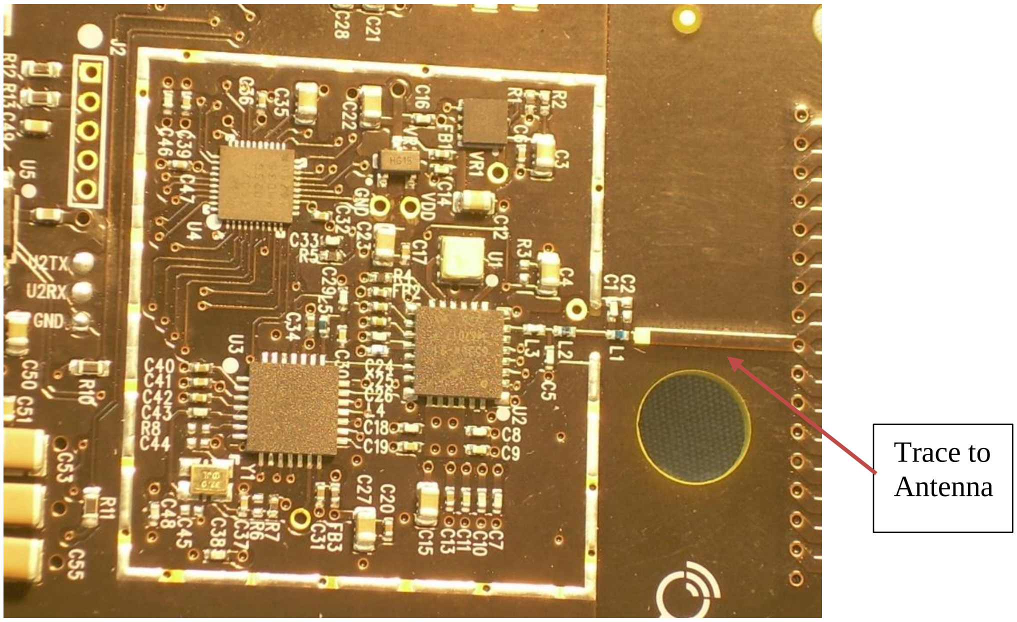


Photograph 13 – Front View of the EUT

Antenna



Photograph 14 – Back View of the EUT



Photograph 15 – View of the Circuitry Under the RF Shield

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