NVLAP Lab Code 200087-0

ROGERS LABS, INC.

4405 West 259th Terrace
Louisburg, KS 66053
Phone / Fax (913) 837-3214

Application For Grant of Certification

Product Marketing Name (PMN): Aranet4 PRO

902-928 MHz Hybrid Digital Transmission System

FCC ID: W9Z-A4MK2PRO
IC: 8855A-A4MK2PRO

SAF Tehnika AS

24a, Ganibu dambis
Riga Latvia LV-1005

FCC Designation: US5305
IC Test Site Registration: 3041A-1

Test Report Number: 210415

Test Date: April 15, 2021

Authorized Signatory: Scot D Rogers

Scot D. Rogers
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Revisions

Revision 1 Issued June 1, 2021

Executive Summary

The following information is submitted for consideration in obtaining Grant of Certification for License Exempt Hybrid Digital Transmission System Intentional Radiator operating under Title 47 Code of Federal Regulations (47CFR) Paragraph 15.247 and Industry Canada RSS-GEN, Issue 5, and RSS-247 Issue 2, operation in the 902-928 MHz band.

Name of Applicant: SAF Tehnika AS
24a, Ganibu dambis
Riga Latvia LV-1005

FCC ID: W9Z-A4MK2PRO IC: 8855A-A4MK2PRO

PMN: Aranet4 PRO HVIN: TDSPC0U3.002, TDSPC0U3.003, TDSPC0U3.004

Antenna: 915 MHz, PIFA (0 dBi)

Frequency Range: LoRa - 917.3-923.5 MHz
LoRa M-Mode, Output Power 0.001 W, 99% Occupied bandwidth 685.8 kHz
LoRa P-Mode, Output Power 0.028 W, 20-dB Occupied bandwidth 138.6 kHz

Opinion / Interpretation of Results

Tests Performed	Margin (dB)	Results
Restricted Bands Emissions per 47CFR 15.205, RSS-GEN	-39.4	Complies
AC Line Emissions per 47CFR 15.207, RSS-GEN	N/A	Complies
General Emissions as per 47CFR 15.209, RSS-GEN	-12.6	Complies
Harmonic Emissions per 47CFR 15.247, RSS-247	-39.4	Complies
Power Spectral Density per 47CFR 15.247, RSS-247	-6.1	Complies

Equipment Tested

Equipment	Model / PN	Serial Number
EUT #1 (Integral Antenna)	Aranet4 Pro	00913
EUT #2 (Antenna port connector)	Aranet4 Pro	00911

Test results in this report relate only to the items tested.

- Software version of "typical" Aranet4 Pro: v0.4.5 and higher
- Software version of "modified for testing" Aranet4 Pro: v0.4.4-4-gc220537

Equipment Function

The Equipment Under Test (EUT) provides sensor circuitry to monitor environmental conditions. The design may be provided using different CO_2 sensors interfaced with the identical transmitter board. Identification of the different sensors are provided under the different Hardware Version Identification Numbers (HVIN): TDSPC0U3.002, TDSPC0U3.003, and TDSPC0U3.004 (note: Numbers "0" are numeric zeros). The design incorporates radio transceivers providing wireless interface operation with compatible 902-928 MHz LoRa (Long Rang) devices and 2402-2480 MHz BLE (Bluetooth® Low Energy) equipment. The LoRa transmitter was tested for compliance as a Hybrid Digital Transmission System employing a combination of both frequency hopping and digital modulation techniques and the BLE system as Digital Transmission System. Two test samples were provided for testing. One sample representative of end product with integral antenna systems. The second sample was modified by replacing the integral antennas with 50-ohm RF connection ports. Both samples operated with special test software which provided testing personnel the capability to operate the transmitters in defined modes. The LoRa transmitter may operate one of two modes, either M-mode (500 kHz wide channel) or P-mode (125 kHz wide channel). The BLE transmitter provides either 1 or 2 MB data rates. LoRa operation in the M-mode operates as a Digital Modulation Transmission System and P-Mode employs a combination of both frequency hopping and Digital Modulation Techniques. BLE operates as Digital Transmission System across the 2402-2480 MHz band. Each operational mode was tested for compliance as documented in this report. The design operates from two (2) LR6 (AA) replaceable batteries only and offers no provision for alternate power source. Test samples were provided with test software to enable transmit operation on lowest, middle, and highest operating channels. The test software provided operation of the transmitter at 100% duty cycle for testing. For testing purposes, each test sample received power from new replaceable LR6 batteries and configured to operate in available modes. The equipment was tested for emissions compliance using the available configurations with the worst-case data presented. Test results in this report relate only to the products described in this report.

Equipment Operations

The Aranet products have distinct operation modes, which use the following radio frequency channels:

● Pairing mode utilized by all of the products (TX and RX) (M-mode)
○ 923.2 MHz @ 500 kHz

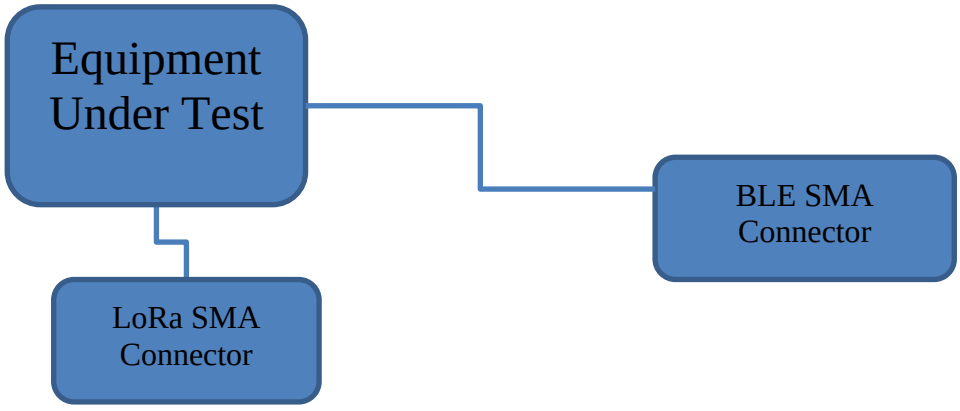
● Aranet4 PRO system mode utilized by sensors (TX) and Aranet Pro (RX) (P-mode)
○ 917.3 MHz; 922.9 MHz @ 125kHz
○ 917.5 MHz; 923.1 MHz @ 125kHz
○ 917.7 MHz; 923.3 MHz @ 125kHz
○ 917.9 MHz; 923.5 MHz @ 125kHz

Aranet4 PRO base stations choose their initial operational channel randomly when the device is first powered up.

Equipment Configuration

1) EUT #1 operating from replaceable LR6 (AA) internal battery

2) EUT #2 (Antenna Port Unit) operating from replaceable LR6 (AA) internal battery



Application for Certification

(1) Manufacturer: SAF Tehnika AS
24a, Ganibu dambis
Riga Latvia LV-1005

(2) Identification: M/N: Aranet4 Pro, HVIN: TDSPC0U3.002, TDSPC0U3.003, TDSPC0U3.004
FCC ID: W9Z-A4MK2PRO IC: 8855A-A4MK2PRO

(3) Instruction Book:

Refer to Exhibit for Instruction Manual.

(4) Description of Circuit Functions:

Refer to Exhibit of Operational Description.

(5) Block Diagram with Frequencies:

Refer to Exhibit of Operational Description.

(6) Report of Measurements:

Report of measurements follows in this Report.

(7) Photographs: Construction, Component Placement, etc.:

Refer to Exhibit for photographs of equipment.

(8) List of Peripheral Equipment Necessary for operation. The equipment operates from direct current power supplied from replaceable LR6 (AA) batteries and provides no other interface options as presented in this filing. The EUT offers no other connection ports than those presented in this filing.

(9) Transition Provisions of 47CFR 15.37 are not requested.

(10) Not Applicable. The unit is not a scanning receiver.

(11) Not Applicable. The EUT does not operate in the 59 – 64 GHz frequency band.

(12) The equipment is not software defined and this section is not applicable.

(13) Applications for certification of U-NII devices in the 5.15-5.35 GHz and the 5.47-5.85 GHz bands must include a high-level operational description of the security procedures that control the radio frequency operating parameters and ensure that unauthorized modifications cannot be made. This requirement is not applicable to his DTS device.

(14) Contain at least one drawing or photograph showing the test set-up for each of the required types of tests applicable to the device for which certification is requested. These drawings or photographs must show enough detail to confirm other information contained in the test report. Any photographs used must be focused originals without glare or dark spots and must clearly show the test configuration used. This information is provided in this report and Test Setup Exhibits provided with the application filing.

Applicable Standards & Test Procedures

The following information is submitted in accordance with the eCFR Federal Communications Code of Federal Regulations, dated April 15, 2021, Part 2, Subpart J, Paragraphs 2.907, 2.911, 2.913, 2.925, 2.926, 2.1031 through 2.1057, and applicable parts of paragraph 15, Part 15C Paragraph 15.247, and Industry Canada RSS-247 Issue 2, and RSS-GEN Issue 5. This equipment operates as Hybrid Digital Transmission System. 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, provides an average time of occupancy on any frequency not exceeding 0.4 seconds within a time period in seconds equal to the number of hopping frequencies employed multiplied by 0.4. The power spectral density conducted from the intentional radiator to the antenna due to the digital modulation operation of the hybrid system, with the frequency hopping operation turned off, remains below the 8 dBm in any 3-kHz band during any time interval of continuous transmission. Test procedures used are as defined in 558074 D01 15.247 Meas Guidance v05r02 and ANSI C63.10-2013.

Testing Procedures

AC Line Conducted Emission Test Procedure

The design operates solely from direct current power provided from LR6 (AA) 1.5-volt batteries. The design offers no provision for connection with Utility AC power system and is therefore exempt from AC Line conducted emissions testing.

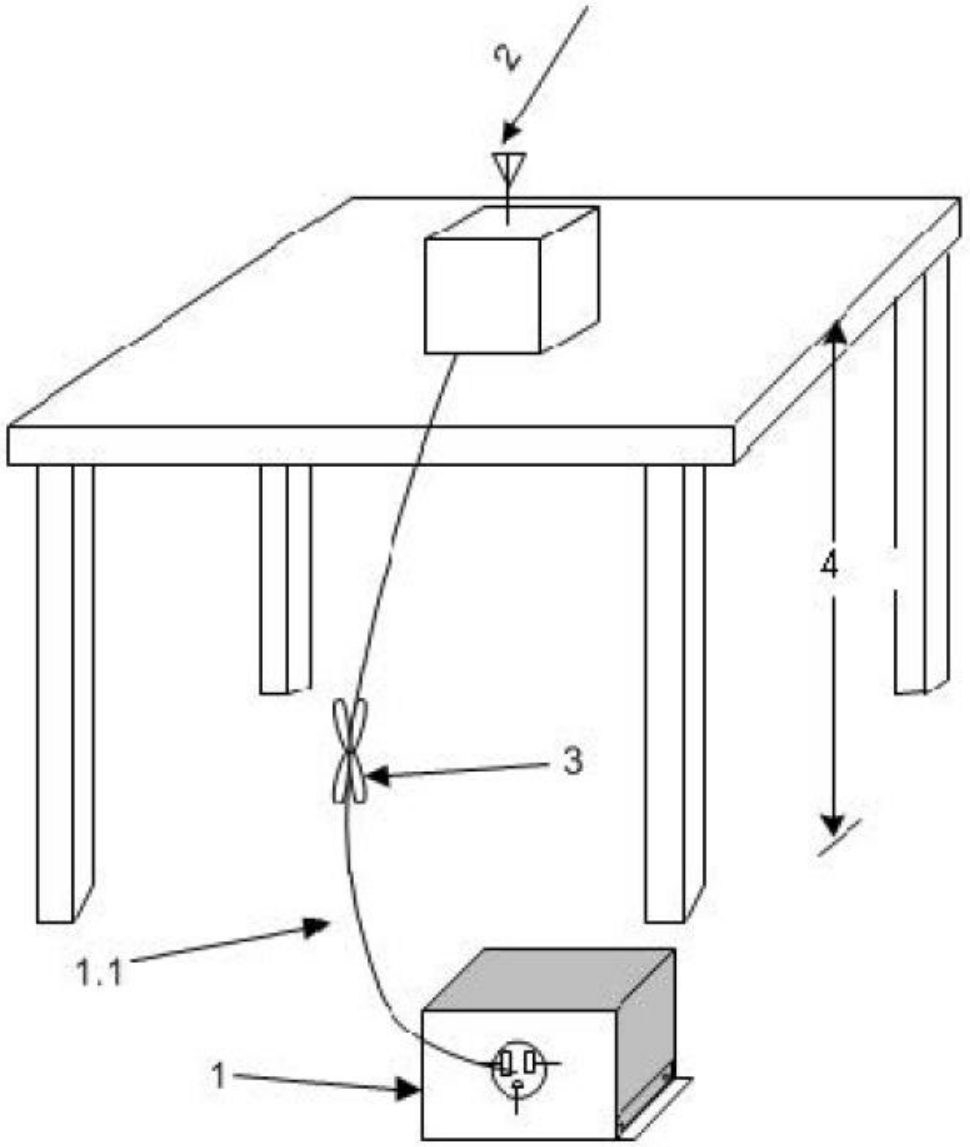
Radiated Emission Test Procedure

Radiated emissions testing was performed as required in 47CFR 15, RSS-247 and specified in ANSI C63.10-2013. The EUT was placed on a rotating 0.9 x 1.2-meter platform, elevated as required above the ground plane at a distance of 3 meters from the FSM antenna. EMI energy was maximized by equipment placement permitting orientation in three orthogonal axes, raising, and lowering the FSM antenna, changing the antenna polarization, and by rotating the turntable. Each emission was maximized before data was taken using a spectrum analyzer. The frequency spectrum from 9 kHz to 25,000 MHz was searched during preliminary investigation. Refer to diagrams one and two showing typical test arrangement and photographs in the test setup exhibits for specific EUT placement during testing.

Antenna-Port Conducted Emission Test Procedure

The EUT was assembled as required for operation and placed on a benchtop. This configuration provided the ability to connect test equipment to the provided test antenna port. Antenna Port conducted emissions testing was performed as presented in the regulations and specified in ANSI C63.10-2013. Antenna port conducted emissions testing was completed on a laboratory bench in a shielded room. The active antenna port of the device was connected to appropriate attenuation and the spectrum analyzer. Refer to diagram three showing typical test arrangement and photographs in the test setup exhibits for specific EUT placement during testing.

Diagram 1 Test arrangement for radiated emissions of tabletop equipment

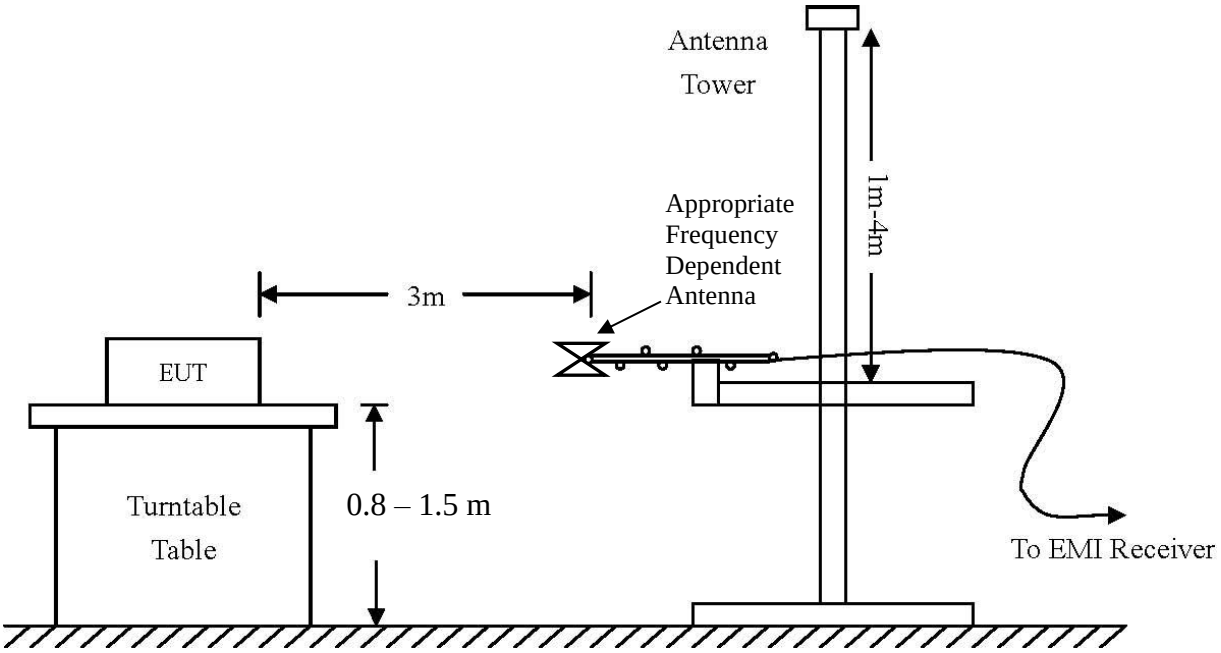


1. A LISN is optional for radiated measurements between 30 MHz and 1000 MHz but not allowed for measurements below 30 MHz and above 1000 MHz (see 6.3.1). If used, then connect EUT to one LISN. Unused LISN measuring port connectors shall be terminated in 50Ω loads. The LISN may be placed on top of, or immediately beneath, the reference ground plane (see 6.2.2 and 6.2.3.2).

1.1—LISN spaced at least 80 cm from the nearest part of the EUT chassis.

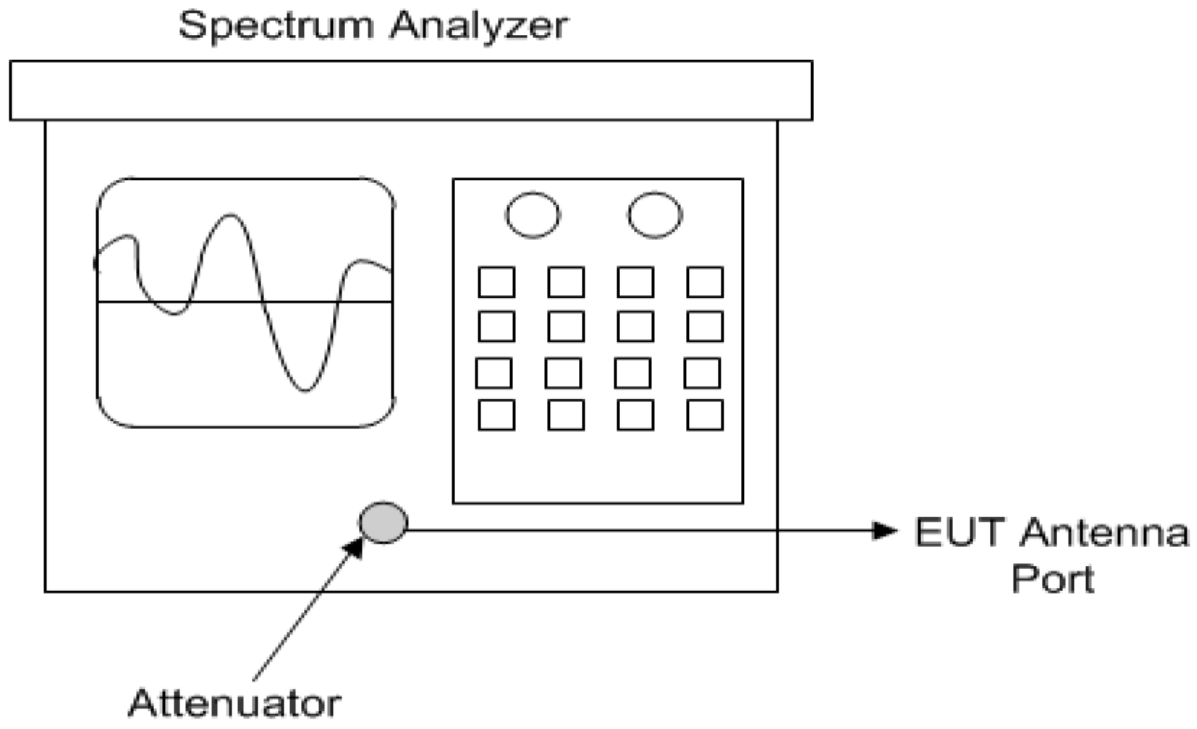
2. Antenna can be integral or detachable, depending on the EUT (see 6.3.1).
3. Interconnecting cables that hang closer than 40 cm to the ground plane shall be folded back and forth in the center forming a bundle 30 cm to 40 cm long (see 6.3.1).
4. For emission measurements at or below 1 GHz, the table height shall be 80 cm. For emission measurements above1 GHz, the table height shall be 1.5 m for measurements, except as otherwise specified (see 6.3.1 and 6.6.3.1).

Diagram 2 Test arrangement for radiated emissions tested on Open Area Test Site (OATS)



AC Line Conducted Emissions (0.150 -30 MHz)		
RBW	AVG. BW	Detector Function
9 kHz	30 kHz	Peak / Quasi Peak
Emissions (30-1000 MHz)		
RBW	AVG. BW	Detector Function
120 kHz	300 kHz	Peak / Quasi Peak
Emissions (Above 1000 MHz)		
RBW	Video BW	Detector Function
100 kHz	100 kHz	Peak
1 MHz	1 MHz	Peak / Average

Diagram 3 Test arrangement for Antenna Port Conducted emissions



Test Site Locations

Conducted EMI	AC line conducted emissions testing performed in a shielded screen room located at Rogers Labs, Inc., 4405 West 259th Terrace, Louisburg, KS
Antenna port	Antenna port conducted emissions testing was performed in a shielded screen room located at Rogers Labs, Inc., 4405 West 259th Terrace, Louisburg, KS
Radiated EMI	The radiated emissions tests were performed at the 3 meters, Open Area Test Site (OATS) located at Rogers Labs, Inc., 4405 West 259th Terrace, Louisburg, KS

Registered Site information: FCC Site: US5305, ISED: 3041A, CAB Identifier: US0096

NVLAP Accreditation Lab code 200087-0

Units of Measurements

Conducted EMI Data presented in dBµV; dB referenced to one microvolt

Antenna port Conducted Data is in dBm; dB referenced to one milliwatt

Radiated EMI Data presented in dBµV/m; dB referenced to one microvolt per meter

Note: Radiated limit may be expressed for measurement in dBµV/m when the measurement is taken at a distance of 3 or 10 meters. Data taken for this report was taken at distance of 3 meters. Sample calculation demonstrates corrected field strength reading for Open Area Test Site using the measurement reading and correcting for receive antenna factor, cable losses, and amplifier gains.

Sample Calculation:

RFS = Radiated Field Strength, FSM = Field Strength Measured

A.F. = Receive antenna factor, Losses = attenuators/cable losses, Gain = amplification gains

RFS (dBµV/m @ 3m) = FSM (dBµV) + A.F. (dB/m) + Losses (dB) - Gain (dB)

Environmental Conditions

Ambient Temperature 22.4° C

Relative Humidity 26%

Atmospheric Pressure 1025.4 mb

Statement of Modifications and Deviations

No modifications to the EUT were required for the design to demonstrate compliance with the 47CFR Part 15C, RSS-Gen, and RSS-247 emission requirements. There were no deviations to the specifications.

Intentional Radiators

The following information is submitted for demonstration of compliance with the requirements of 47CFR Subpart C paragraph 15.247, and Industry Canada RSS-247 and RSS-Gen.

Antenna Requirements

The EUT incorporates integral antenna system and offers no provision for connection to alternate antenna system. The antenna connection point complies with the unique antenna connection requirements. There are no deviations or exceptions to the specification.

Restricted Bands of Operation

Spurious emissions falling in the restricted frequency bands of operation were measured at the OATS. The EUT utilizes frequency, determining circuitry, which generates harmonics falling in the restricted bands. Emissions were investigated at the OATS, using appropriate antennas or pyramidal horns, amplification stages, and a spectrum analyzer. Peak and average amplitudes of frequencies above 1000 MHz were compared to the required limits with worst-case data presented below. Test procedures of ANSI C63.10-2013 paragraph 6 and KDB 558074 paragraph 12 were used during testing. No other significant emission was observed which fell into the restricted bands of operation. Computed emission values consider the received radiated field strength, receive antenna correction factor, amplifier gain stage, and test system cable losses.

Table 1 LoRa Radiated Emissions Data in Restricted Frequency Bands

Frequency in MHz	Horizontal Peak (dBµV/m)	Horizontal Average (dBµV/m)	Vertical Peak (dBµV/m)	Vertical Average (dBµV/m)	Limit @ 3m (dBµV/m)	Horizontal Average Margin (dB)	Vertical Average Margin (dB)
P-Mode							
2751.9	47.9	36.5	44.7	33.4	54.0	-40.5	-43.6
2760.9	49.2	37.6	44.6	32.6	54.0	-39.4	-44.4
2770.5	47.2	35.6	44.7	32.5	54.0	-41.4	-44.5
3669.2	36.3	23.2	36.0	22.6	54.0	-53.8	-54.4
3681.2	35.4	22.6	35.5	29.6	54.0	-54.4	-47.4
3694.0	36.3	20.4	36.0	20.4	54.0	-56.6	-56.6
4586.5	39.0	23.6	39.7	23.6	54.0	-53.4	-53.4
4601.5	38.8	23.2	39.1	23.2	54.0	-53.8	-53.8
4617.5	38.1	24.9	37.5	24.8	54.0	-52.1	-52.2
M-Mode							
2769.6	36.8	22.1	37.9	22.6	54.0	-54.9	-54.4
3692.8	36.1	20.3	36.4	20.2	54.0	-56.7	-56.8
4616.0	37.6	24.9	38.6	24.8	54.0	-52.1	-52.2

Other emissions present had amplitudes at least 20 dB below the limit. Peak and Quasi-Peak amplitude emissions are recorded for frequency below 1000 MHz. Peak and Average amplitude emissions are recorded for frequency range above 1000 MHz.

Summary of Results for Radiated Emissions in Restricted Bands

The EUT demonstrated compliance with the radiated emissions requirements of 47CFR Part 15C, RSS-Gen, and RSS-247 Intentional Radiators. The EUT demonstrated a worst-case minimum radiated emission in restricted bands providing a minimum margin of -39.4 dB below the radiated emissions requirements. Peak and average amplitudes were checked for compliance with the regulations. Worst-case emissions are reported with other emissions found in the restricted frequency bands at least 20 dB below the requirements.

AC Line Conducted Emissions Procedure

The design operates solely from direct current power provided from replaceable LR6 (AA) batteries. The design offers no provision for connection with the Utility AC power system and is therefore exempt from AC Line conducted emissions testing.

General Radiated Emissions Procedure

The EUT was arranged in a typical equipment configuration and operated through all available mode during testing. Both the LoRa and BLE transmitters were operating during testing. Preliminary testing was performed in a screen room with the EUT positioned 1 meter from the FSM. Radiated emissions measurements were performed to identify the frequencies, which produced the highest emissions. Each radiated emission was then maximized at the OATS location before final radiated measurements were performed. Final data was taken with the EUT located on the OATS at 3 meters distance between the EUT and the receiving antenna. The frequency spectrum from 9 kHz to 25,000 MHz was searched for general radiated emissions. Measured emission levels were maximized by EUT placement on the table, rotating the turntable through 360 degrees, varying the antenna height between 1 and 4 meters above the ground plane and changing antenna position between horizontal and vertical polarization. Antennas used were Loop from 9 kHz to 30 MHz, Broadband Biconical from 30 to 200 MHz, Biconilog from 30 to 1000 MHz, Log Periodic from 200 MHz to 1 GHz and or double Ridge or pyramidal horns and mixers above 1 GHz, notch filters and appropriate amplifiers and external mixers were utilized.

Table 2 General Radiated Emissions Data

Frequency in MHz	Horizontal Peak (dBµV/m)	Horizontal Quasi-Peak (dBµV/m)	Vertical Peak (dBµV/m)	Vertical Quasi-Peak (dBµV/m)	Limit @ 3m (dBµV/m)	Horizontal Average Margin (dB)	Vertical Average Margin (dB)
64.3	22.4	16.6	32.7	27.4	40.0	-23.4	-12.6
112.7	30.5	15.0	27.2	23.5	40.0	-25.0	-16.5
128.6	20.5	15.2	22.2	14.4	40.0	-24.8	-25.6
144.7	28.2	23.3	26.0	21.7	40.0	-16.7	-18.3
176.8	23.8	19.2	24.3	17.3	40.0	-20.8	-22.7
208.0	17.7	12.5	18.5	12.5	40.0	-27.5	-27.5
256.1	21.5	18.0	20.3	15.5	47.0	-29.0	-31.5

Other emissions present had amplitudes at least 20 dB below the limit. Peak and Quasi-Peak amplitude emissions are recorded for frequency range below 1000 MHz. Peak and Average amplitude emissions are recorded for frequency range above 1000 MHz.

Summary of Results for General Radiated Emissions

The EUT demonstrated compliance with the radiated emissions requirements of 47CFR Part 15C paragraph 15.209, RSS-247 and RSS-GEN Intentional Radiators. The EUT demonstrated a minimum margin of -12.6 dB below the requirements. Other emissions were present with amplitudes at least 20 dB below the Limits.

Operation in the Band 902-928 MHz (LoRa)

The requirements and demonstration of compliance with RSS-247 and 47CFR subpart 15.247 are addressed below and as specified in KDB 558074 D01 15.247 Meas Guidance v05r02. The LoRa transmitter provides operation as Hybrid and Digital Transmission System. Test sample #1 was used during radiated emissions measurements. Both the LoRa and BLE transmitters were operating during testing. Test sample #2 was provided for testing antenna port conducted emissions. Test sample #2 was modified by replacing the internal antenna with a 50-ohm antenna port connector and attenuator for testing purposes. Test procedures of ANSI C63.10-2013 paragraph 6, and KDB 558074 v05r02 were used during transmitter testing.

Information from KDB 558074 D01 15.247 Meas Guidance v05r02

10. HYBRID SYSTEM EQUIPMENT UNDER SECTION 15.247

The following information is for certification of hybrid spread-spectrum devices under Section 15.247.

a) Use Form-731 equipment-class code DSS.

b) Hybrid system device measurement guidelines are as follows.

1) As specified in Section 15.247(f), a hybrid system must comply with the power density standard of 8 dBm in any 3 kHz band when the frequency hopping function is turned off.

2) The transmission must comply with a 0.4 second/channel maximum dwell time when the hopping function is turned on.

3) There is no requirement for this type of hybrid system to comply with the 500 kHz minimum bandwidth normally associated with a DTS device.

4) There is no minimum number of hopping channels associated with this type of hybrid system. While there is not a specific minimum limit, the hop sequence is required to appear as pseudorandom per Section 15.247(a)(1) (see Section 3 of this document).

5) The hopping function must be a true frequency hopping system, as described in Section 15.247(a)(1). The specific requirements in Section 15.247(a)(1) are:

i) a minimum channel separation;

ii) pseudo-random hop sequence;

iii) equal use of each frequency; and

iv) receiver matching bandwidth and synchronization.

6) Generally, use the test procedures for DTS and FHSS devices in Clause 11 and 7.8 of ANSI C63.10, respectively.

i) Output power: use 11.9 of ANSI C63.10;

ii) Peak Power Density: use 11.10 of ANSI C63.10;

iii) Carrier channel separation: use 7.8.2 of ANSI C63.10;

iv) Dwell time: use 7.8.4 of ANSI C63.10.

The design operates as P-mode equipment for communications during typical operation and pairing with remote base station.

Example of P-mode operation after initial pairing of sensor with base, the base continuously listens to both frequencies.

- Upon the sensor awakening, the wake-up counter is started.
- The sensor generates random number between 0.4 and 3.5. This variable is referenced as "T"
- Assuming the sensor operating in this channel group (for this example) is allowed to transmit data at either 917.3MHz or 922.9MHz
- Before each data transmission, the sensor will pseudo randomly chose frequency in which to transmit data - 917.3MHz or 922.9MHz
- Assuming that this time the pseudo random generation has chosen 917.3 MHz frequency in which to transmit data
- The sensor then "listens" to frequency 917.3MHz, to determine if the frequency is open or occupied.
- If frequency 917.3MHz is open, the sensor will send data to base. If frequency is occupied, it will wait for "T" seconds and "listen" again. "Listening" can happen only 2 times. If both times frequency 917.3MHz is occupied, on 3rd time the sensor will transmit data at 917.3MHz.
- Length of data transmission from sensor to base is 250ms and can only happen once every minute at highest data rate and once every 10 minutes for longest battery life.
- After data is transmitted, sensor goes to "sleep" and wakes up only when wake-up counter hits 600s + "T" seconds spent on listening if frequency 917.3MHz was occupied.
- When counter is done, sensor will wake-up and pseudo randomly chose frequency in which to transmit data - 917.3MHz or @ 922.9MHz and begin the cycle again.

Modulation information:

Modulation parameters during sensor pairing mode (18229.17 bits per second; 0.26ms symbol time). Modulation parameters during regular operation (813.8 bits per second; 8.19ms symbol time)

Compliance for operation as Digital Modulation System addresses the 6-dB DTS bandwidth, output power, power spectral density, and emissions in 100 kHz bands. LoRa (M-Node) 902-928 MHz plots demonstrating compliance with DTS requirements are presented in figures one through seven.

Compliance for Hybrid operation addresses 0.4 second/channel maximum dwell time, minimum channel separation, Pseudo-random hop sequence, equal use of frequency, receiver bandwidth

matching and synchronization. LoRa (P-Node) 902-928 MHz plots demonstrating compliance with these requirements are presented in figures eight through eighteen.

The amplitude of each harmonic and general radiated emission was measured on the OATS at distance of 3 meters from the FSM antenna (testing was performed on samples 1 representative of production equipment with integral antenna). The EUT was positioned on supporting turntable elevated as required above the ground plane, at a distance of 3 meters from the FSM antenna. Radiated emission investigations were performed from 9 kHz to 10,000 MHz. Each radiated emission was maximized by varying the FSM antenna height and polarization, and by rotating the turntable. The worst-case amplitude of each emission was then recorded from the analyzer display. The peak and quasi-peak amplitude of frequencies below 1000 MHz were measured using a spectrum analyzer. The peak and average amplitude of frequencies above 1000 MHZ were measured using a spectrum analyzer. A Loop antenna was used for measuring emissions from 0.009 to 30 MHz, Biconilog Antenna for 30 to 1000 MHz, Double-Ridge, and/or Pyramidal Horn Antennas above 1 GHz.

Figure 1 LoRa (M-Mode) Plot of Transmitter Emissions in Operational Frequency Band

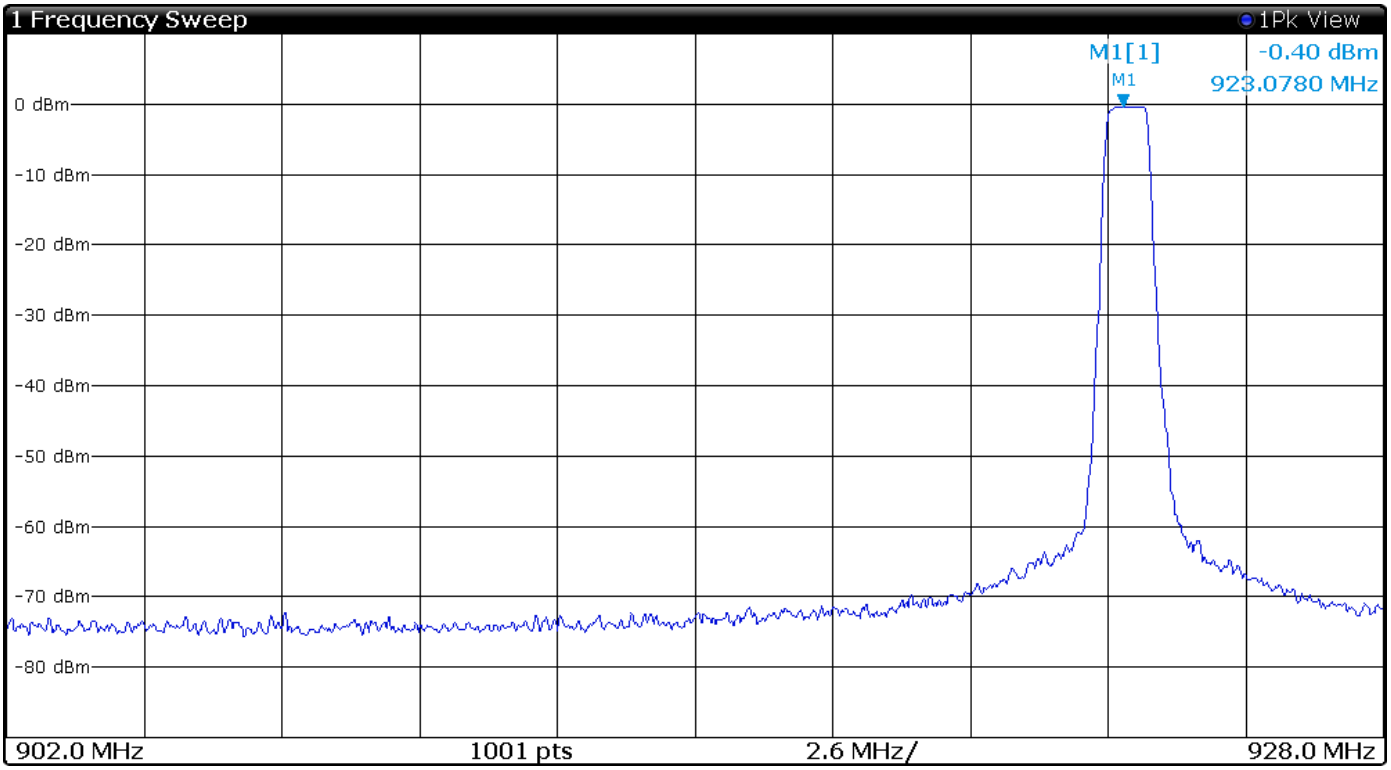


Figure 2 LoRa (M-Mode) Plot of Lower Band Edge

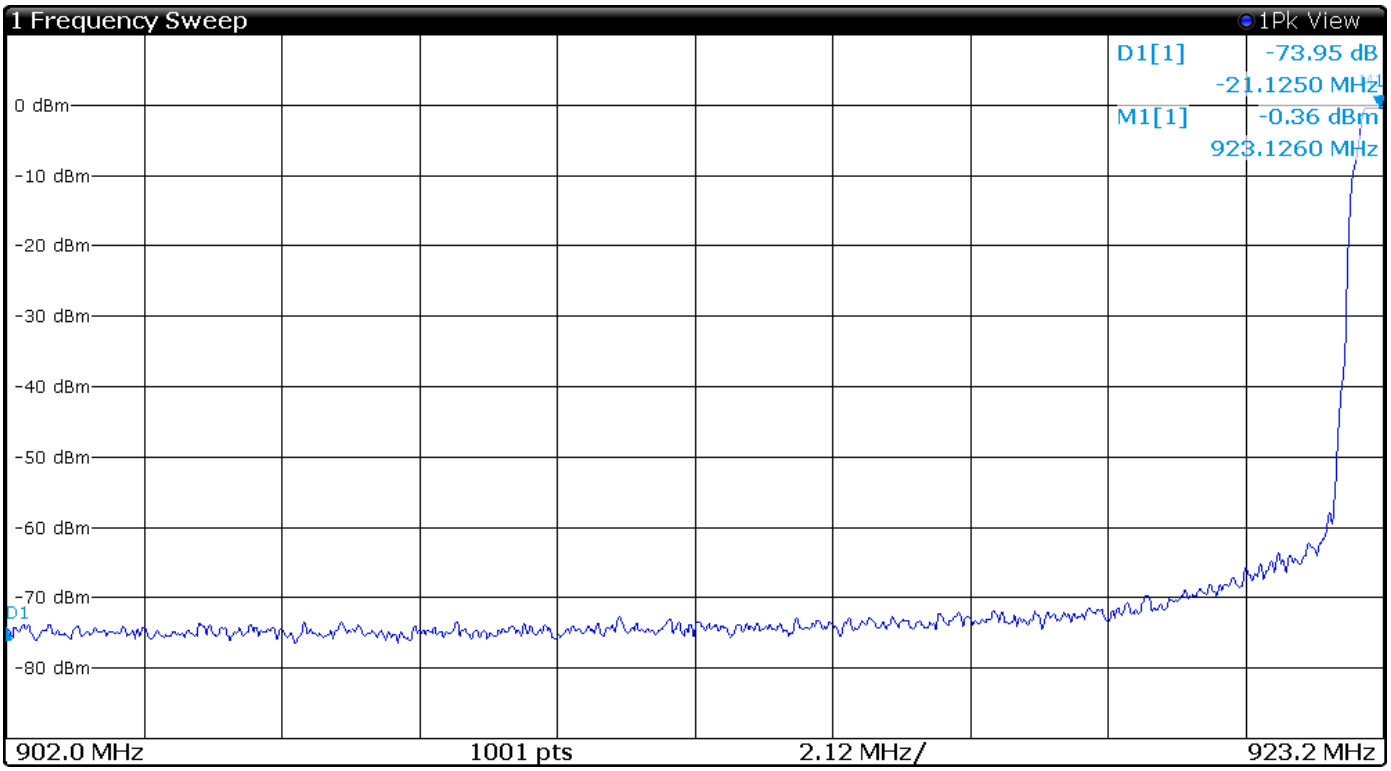


Figure 3 LoRa (M-Mode) Plot of Upper Band Edge

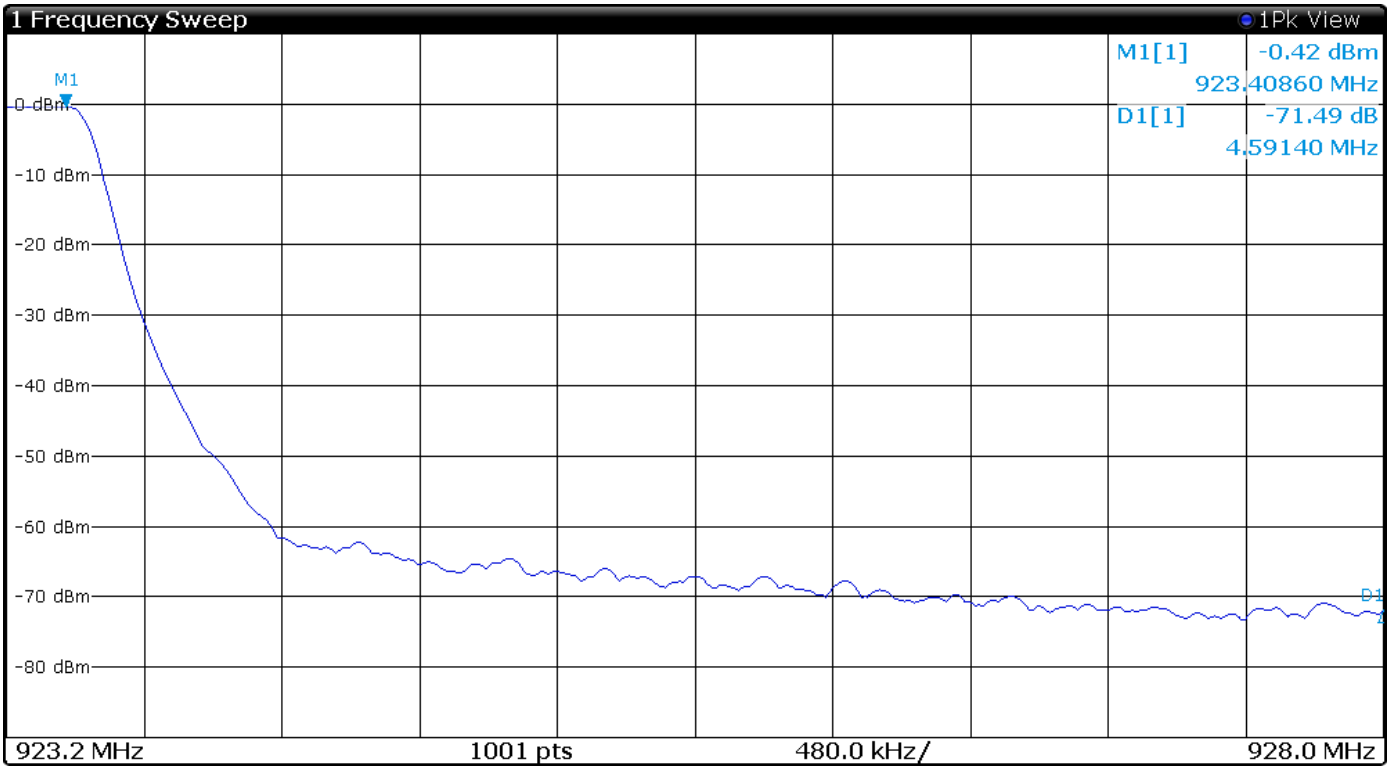
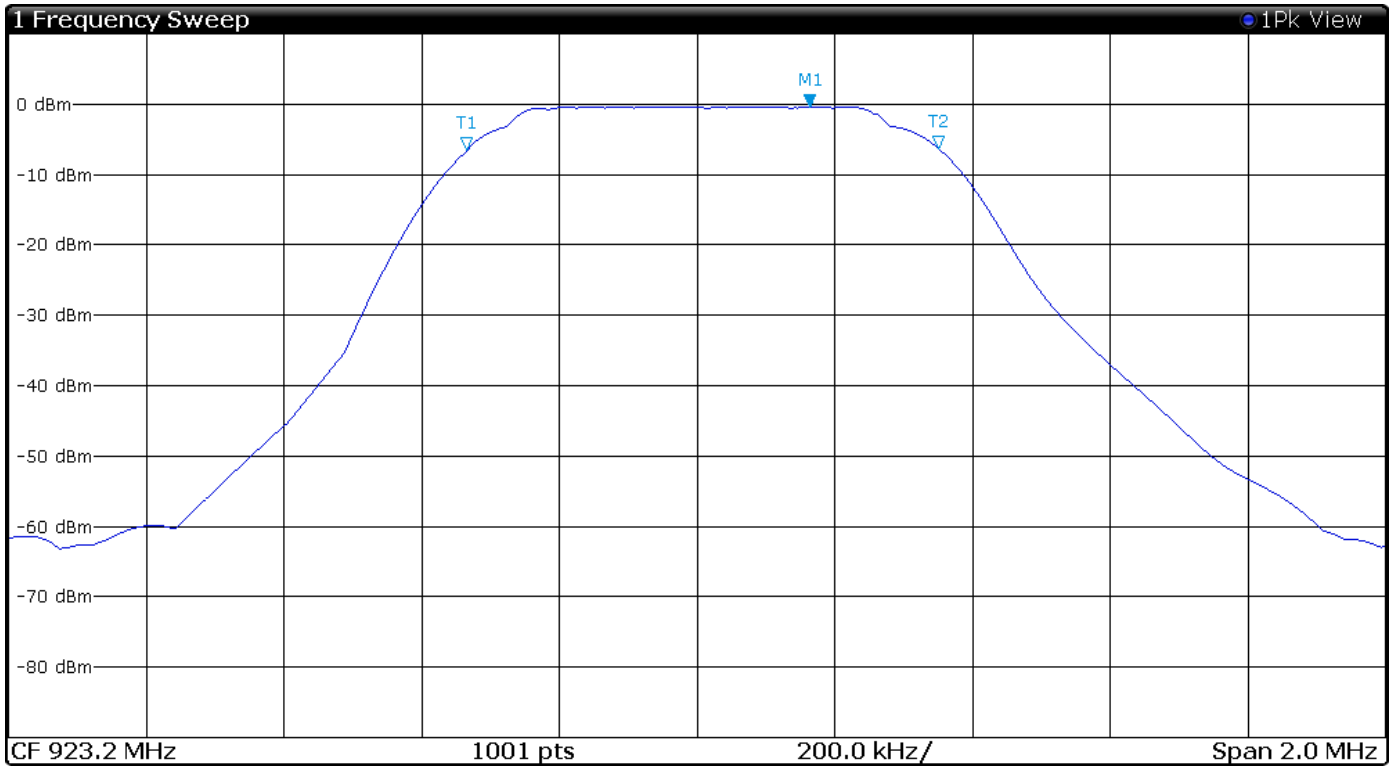
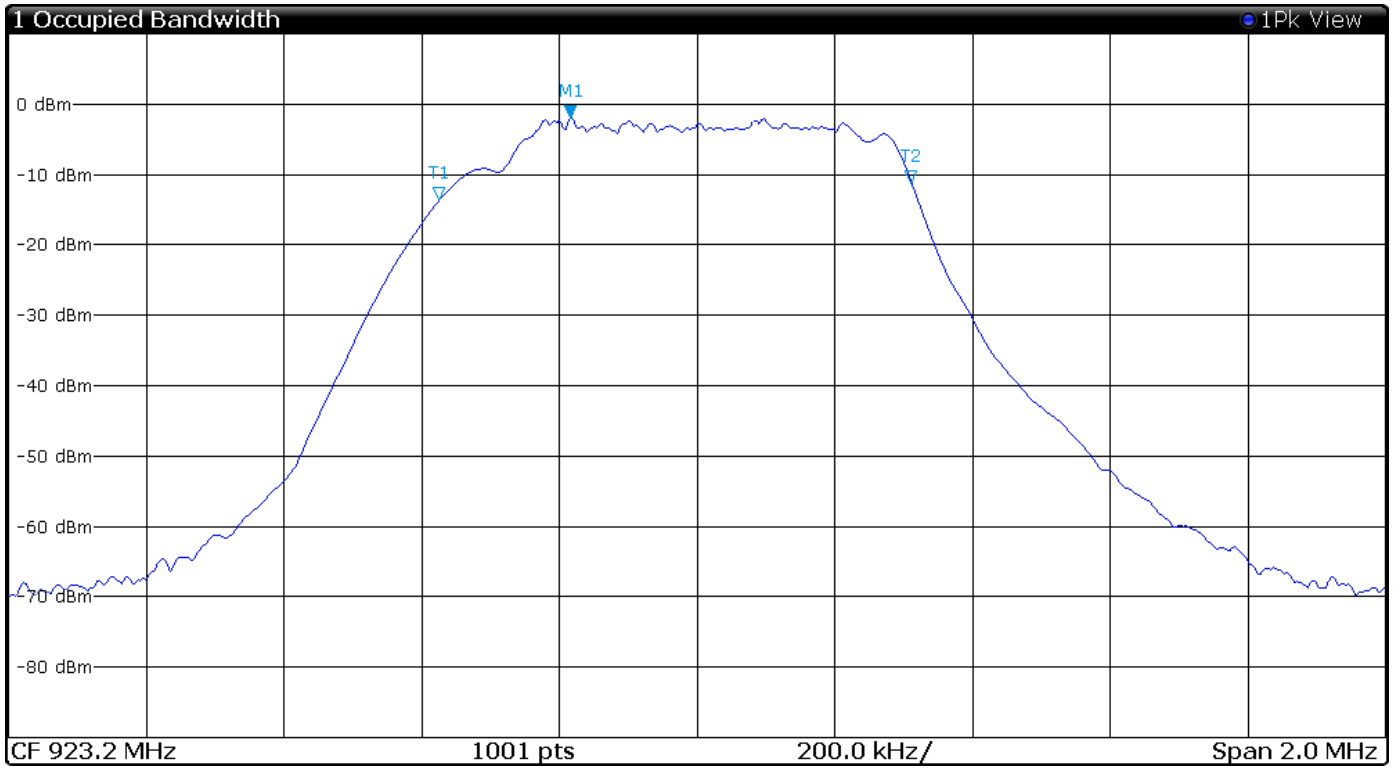


Figure 4 LoRa (M-Mode) Plot of Transmitter 6-dB Occupied Bandwidth



Type	Ref Trace	X-Value	Y-Value	Function	Func Result
M1	1	923.4 MHz	-0.5 dBm	ndB	6 dB
T1	1	922.9 MHz	-6.5 dBm	ndB down BW	685.3 kHz
T2	1	923.6 MHz	-6.4 dBm	Q Factor	1347

Figure 5 LoRa (M-Mode) Plot of Transmitter 99% Occupied Bandwidth



Type	Ref Trace	X-Value	Y-Value	Function	Func Result
M1	1	923 MHz	-2 dBm	99% Occ Bw	685.8 kHz
T1	1	922.8 MHz	-13.7 dBm	Occ Bw Centroid	923.2 MHz
T2	1	923.5 MHz	-11.2 dBm	Occ Bw Freq Offset	-31.91 kHz

Figure 6 LoRa (M-Mode) Plot of Power Spectral Density

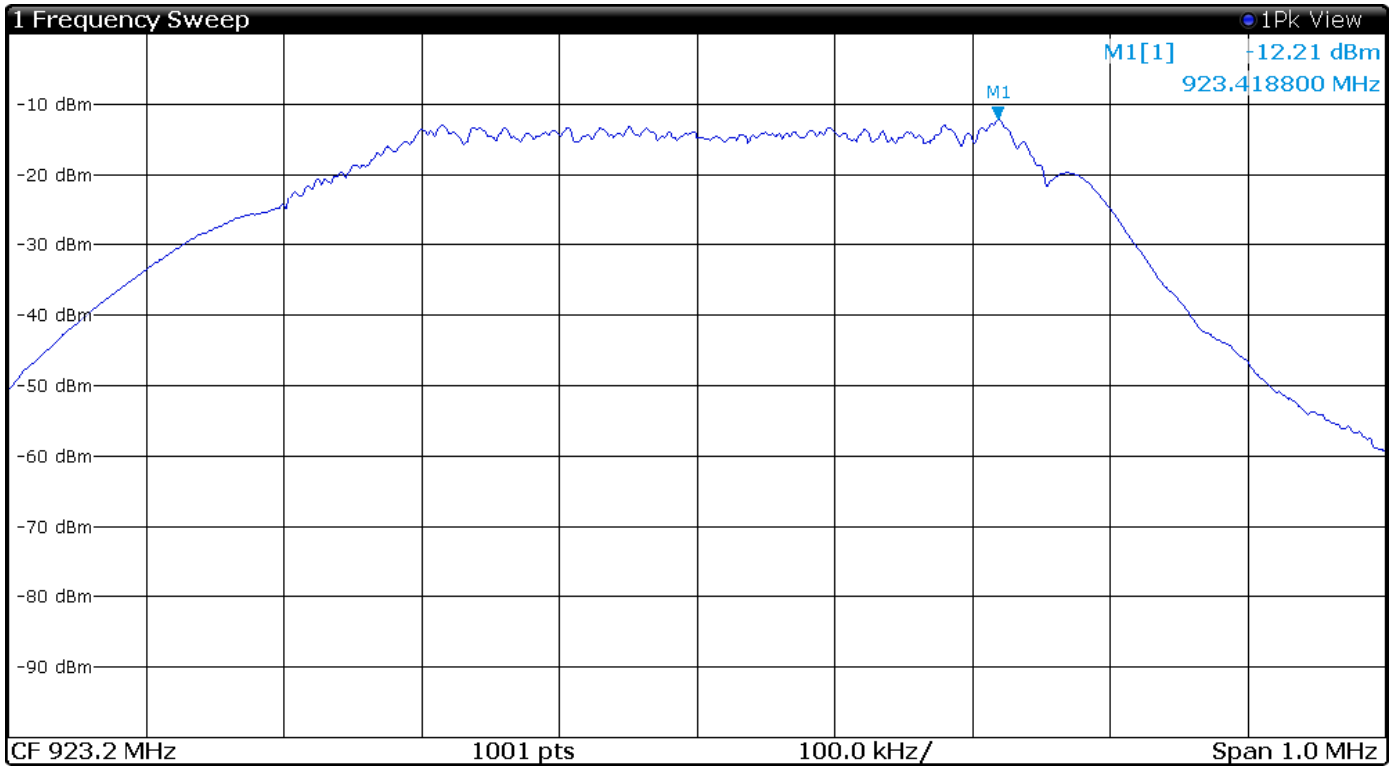
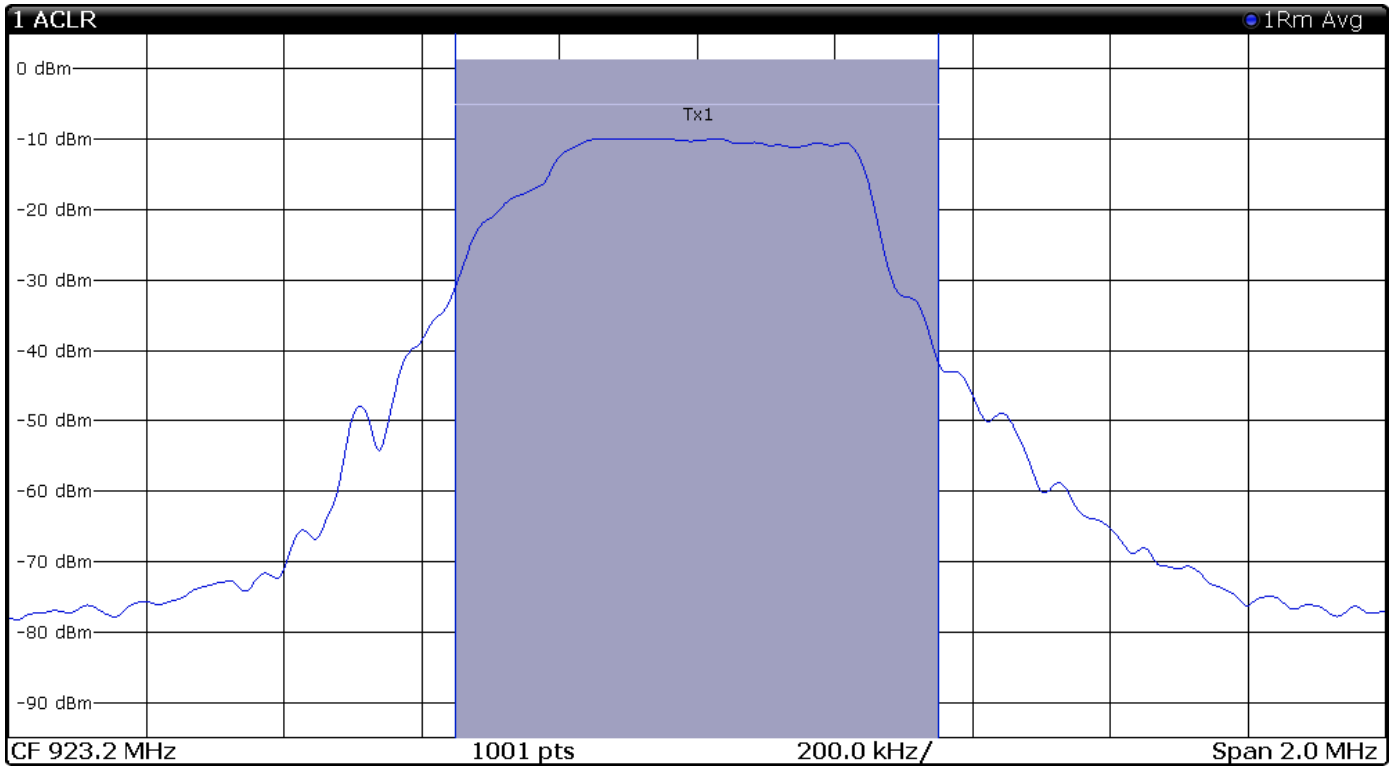


Figure 7 LoRa (M-Mode) Plot of Output Power



Channel	Bandwidth	Power
Tx1 (Ref)	700 kHz	1.2 dBm
Tx Total		1.2 dBm

Figure 8 LoRa (P-Mode) Plot of Transmitter Emissions in Operational Frequency Band

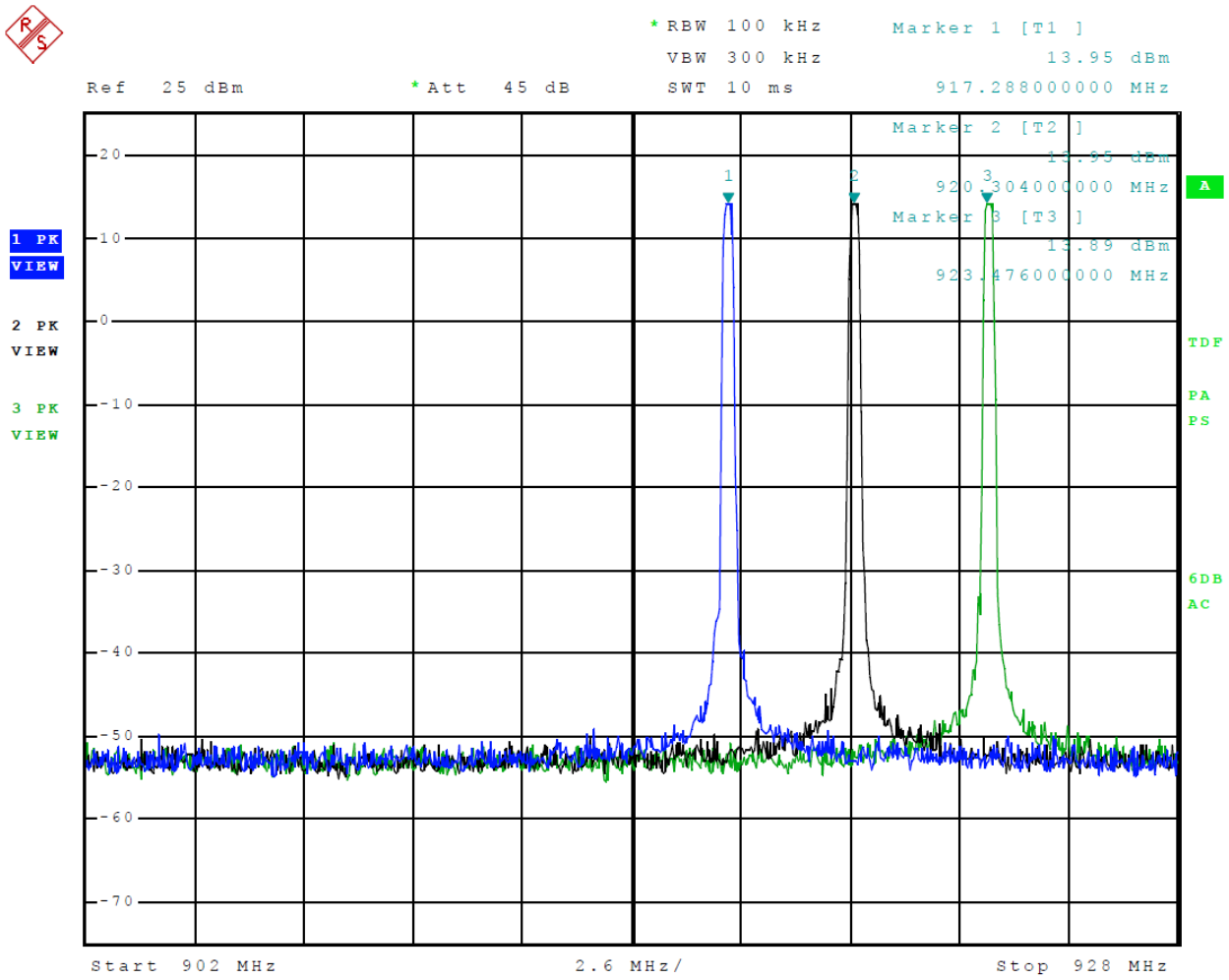


Figure 9 LoRa (P-Mode) Plot of Lower Band Edge

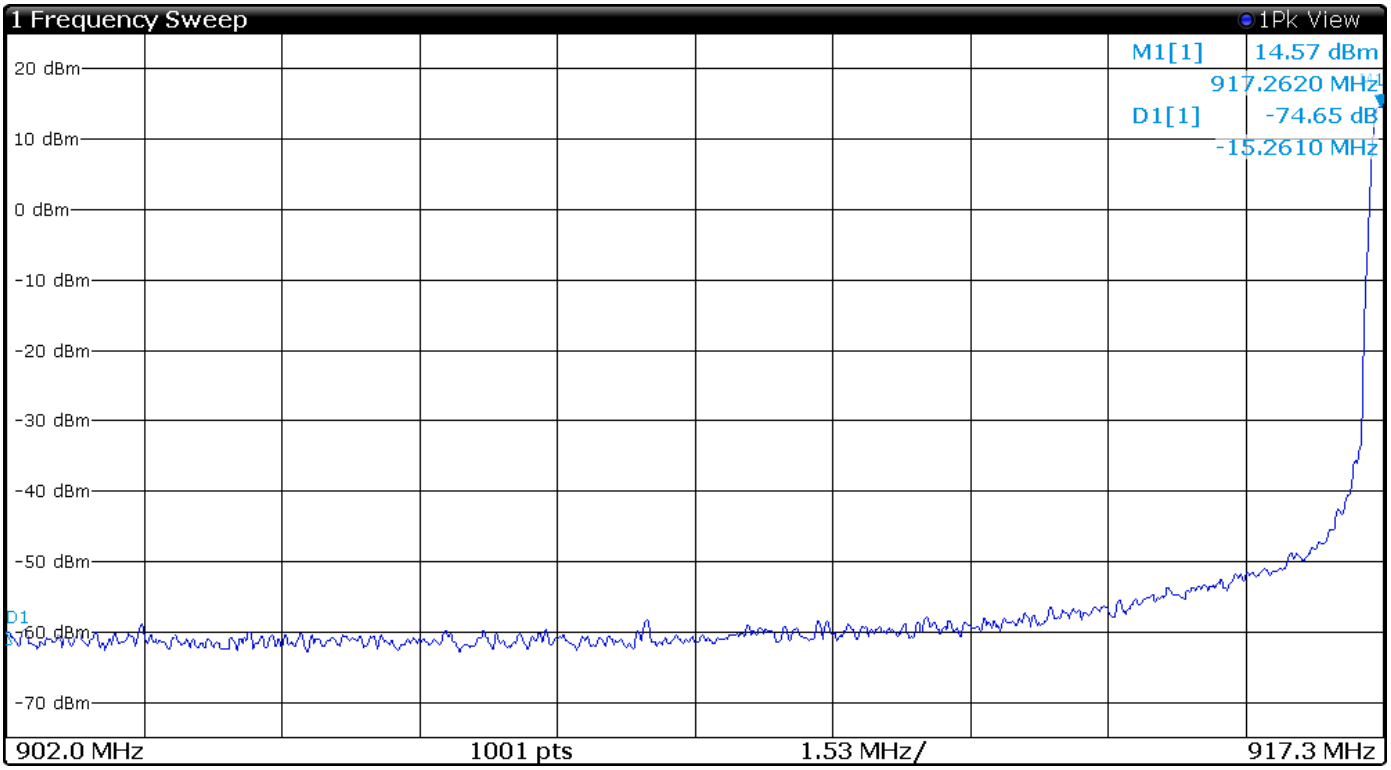


Figure 10 LoRa (P-Mode) Plot of Upper Band Edge

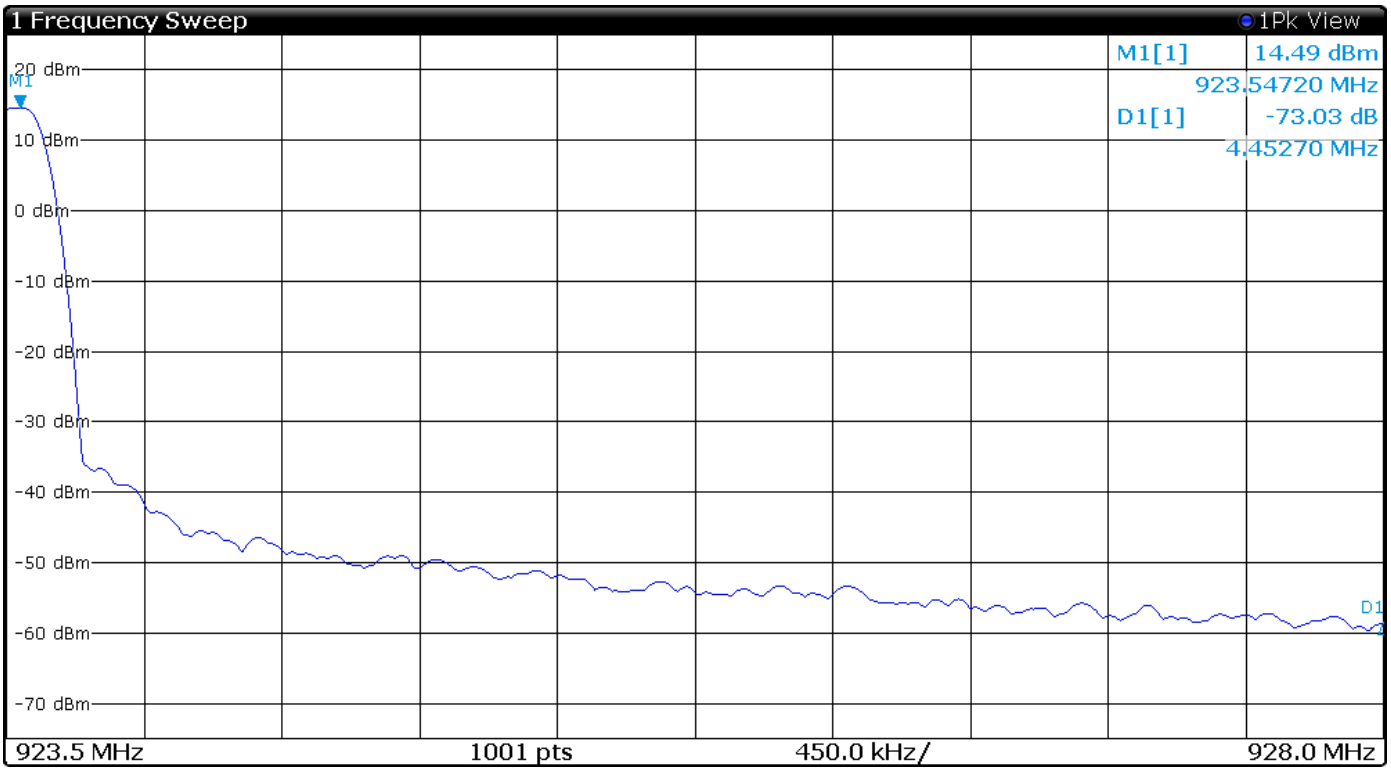
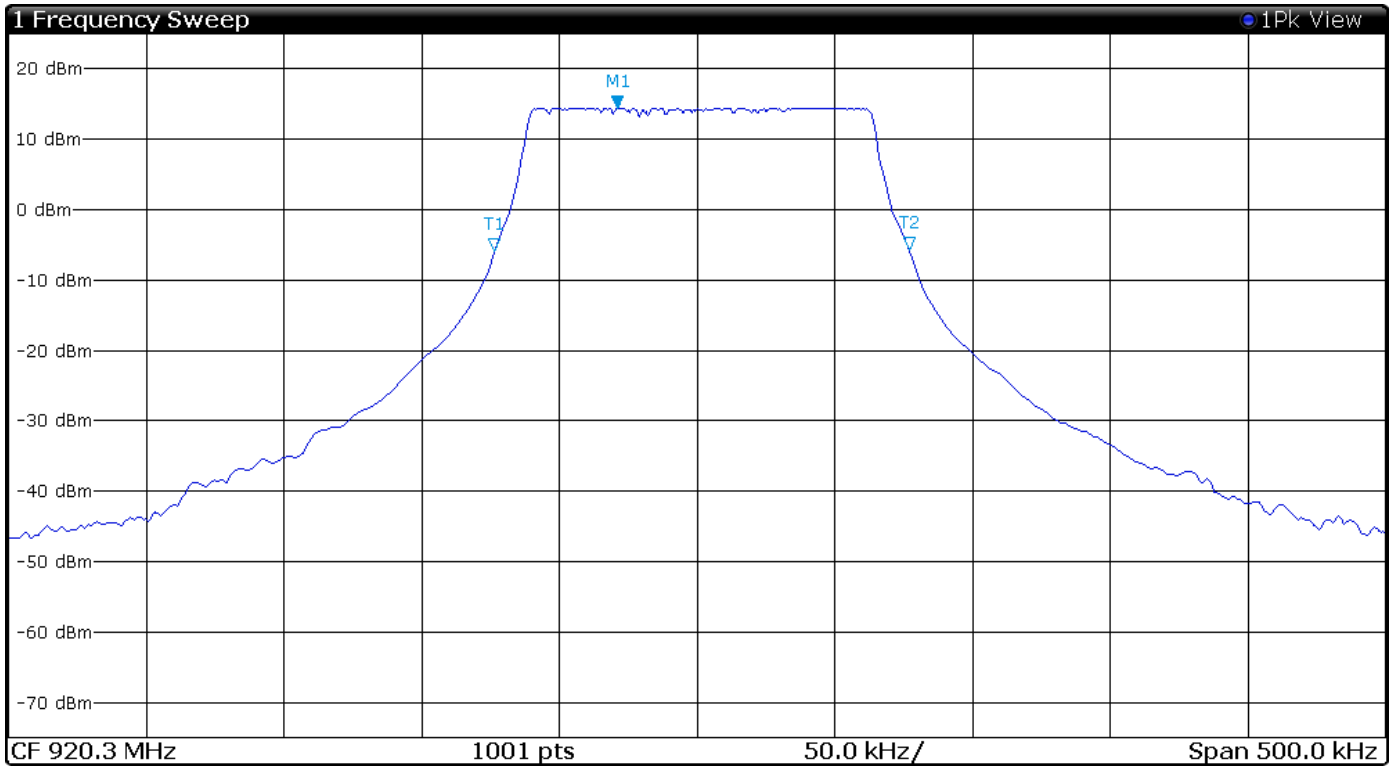


Figure 11 LoRa (P-Mode) Plot of Transmitter 20-dB Occupied Bandwidth



Type	Ref Trace	X-Value	Y-Value	Function	Func Result
M1	1	920.3 MHz	14.5 dBm	ndB	20 dB
T1	1	920.2 MHz	-5.8 dBm	ndB down BW	150.3 kHz
T2	1	920.4 MHz	-5.6 dBm	Q Factor	6121

Figure 12 LoRa (P-Mode) Plot of Transmitter 99% Occupied Bandwidth

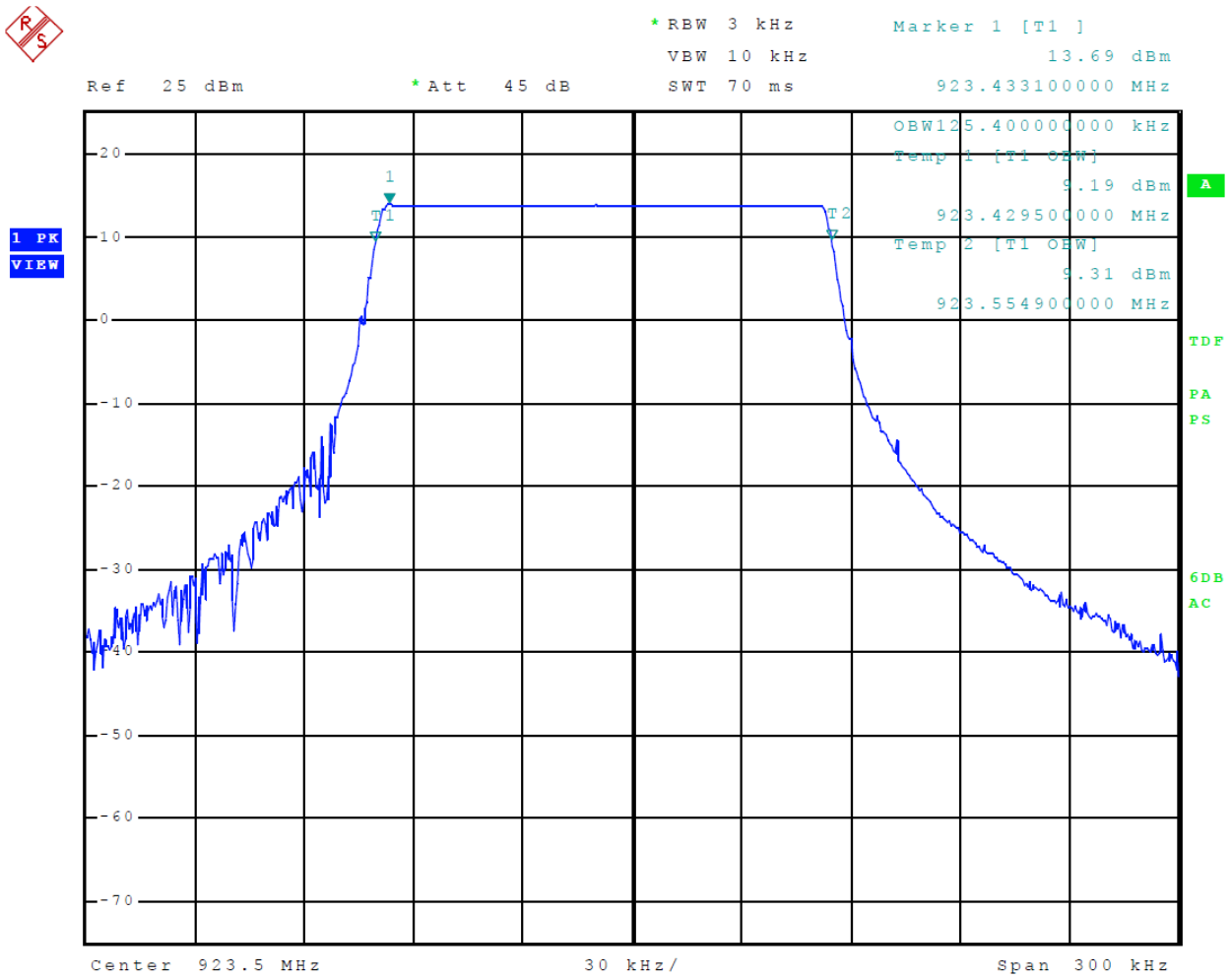


Figure 13 LoRa (P-Mode) Plots of Power Spectral Density

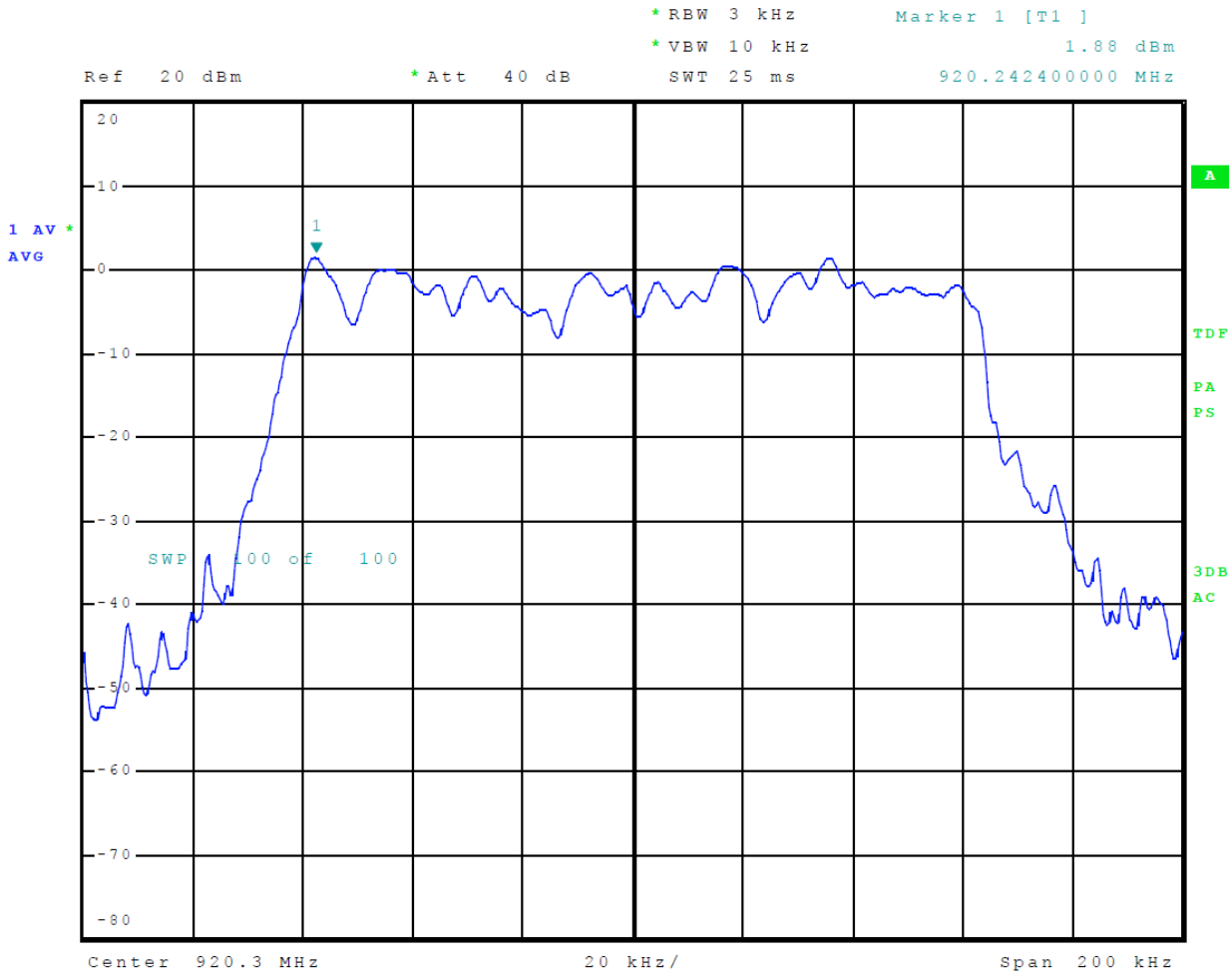
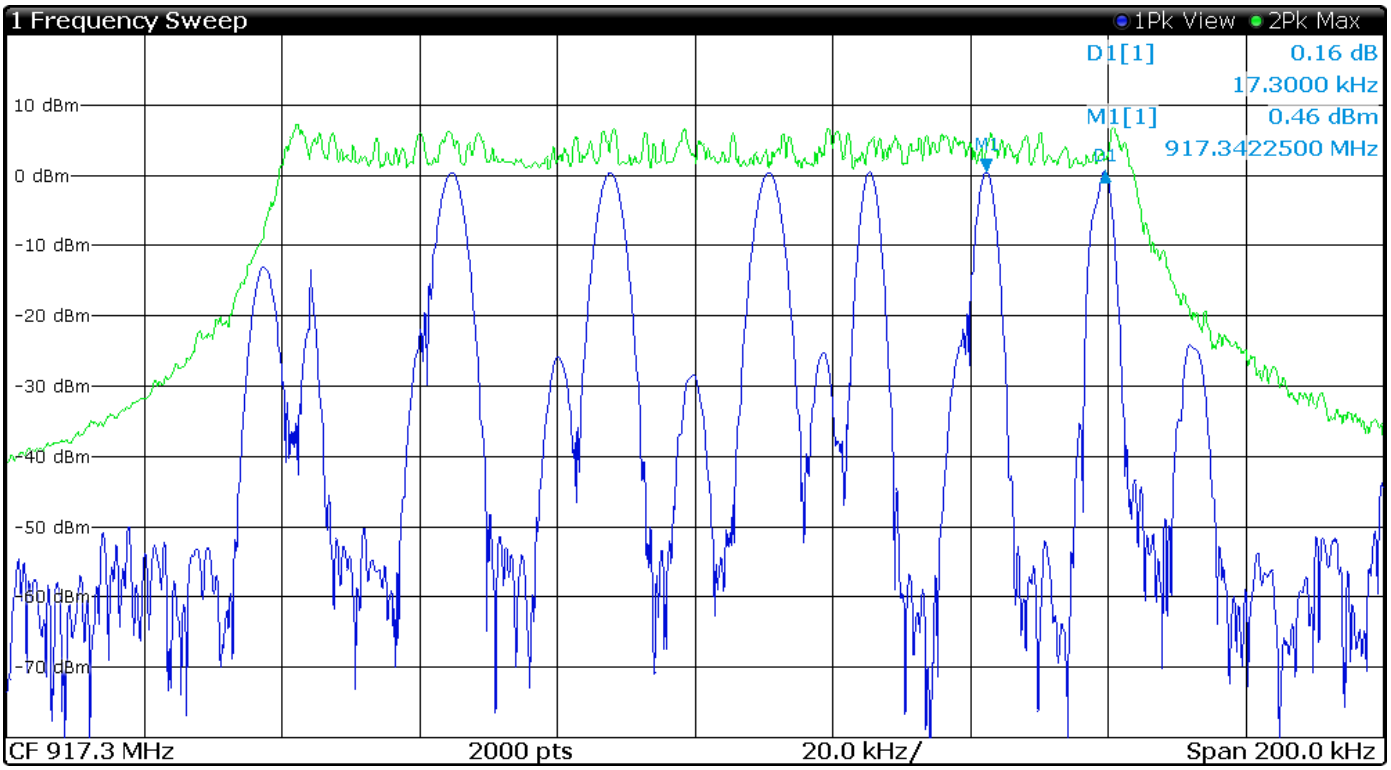


Figure 14 LoRa (P-Mode) Plot of Channel Separation



Center Freq: 917.3 MHz	Freq Offset: 0 Hz	Start: 917.2 MHz	Stop: 917.4 MHz
Span: 200 kHz	RBW: 500 Hz	Filter Type: Normal(3dB)	VBW: 2 kHz
SWT: 83.7 ms	Ref Level: 20 dBm	Level Offset: 0 dB	Rf Att: 25 dB
Input: 1 AC	Preamplifier: OFF	Preselector: On	Filter Split: Off
Notch Filter 1: Off	Notch Filter 2: Off		

Figure 15 LoRa (P-Mode) Plot of Dwell Time on channel

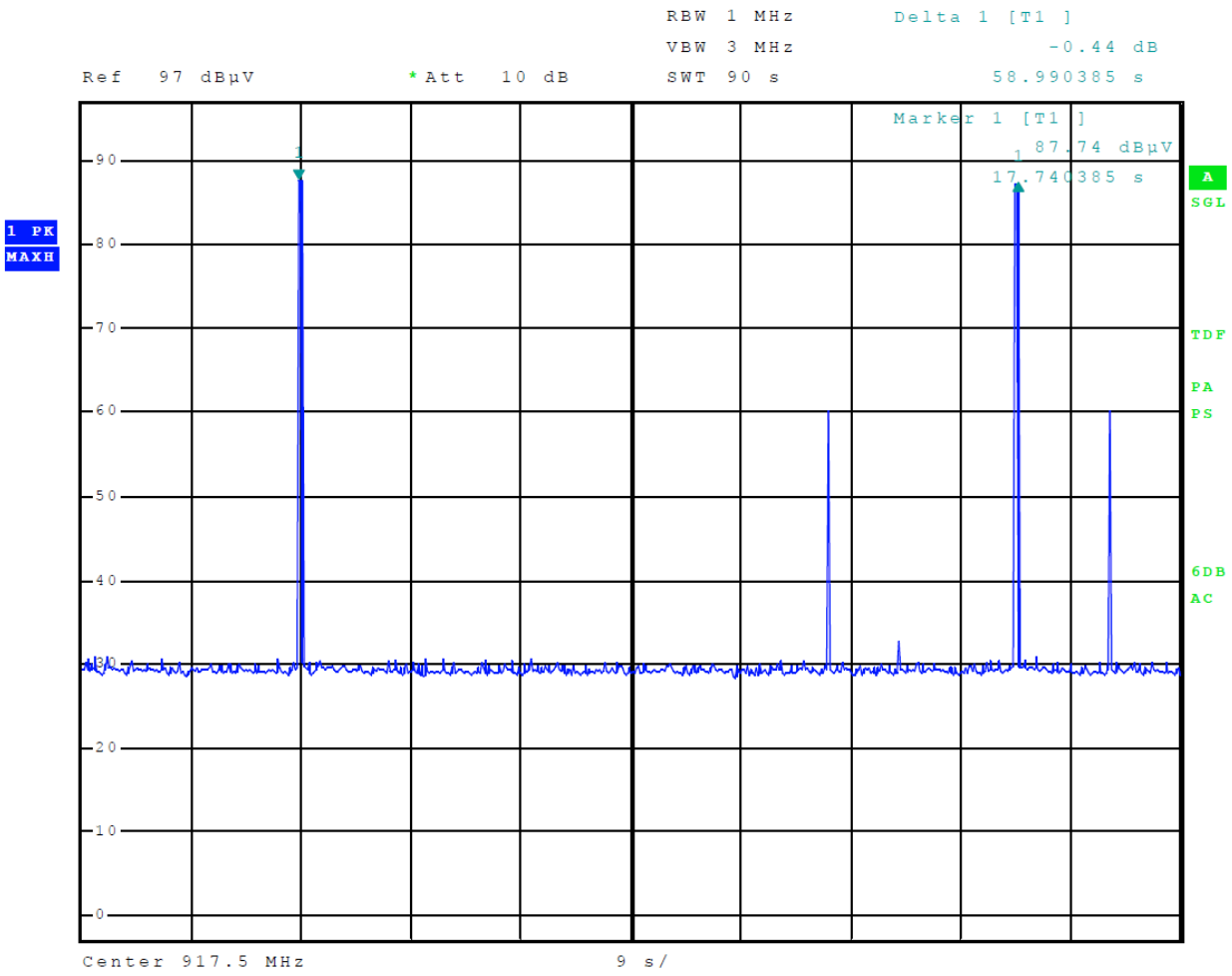
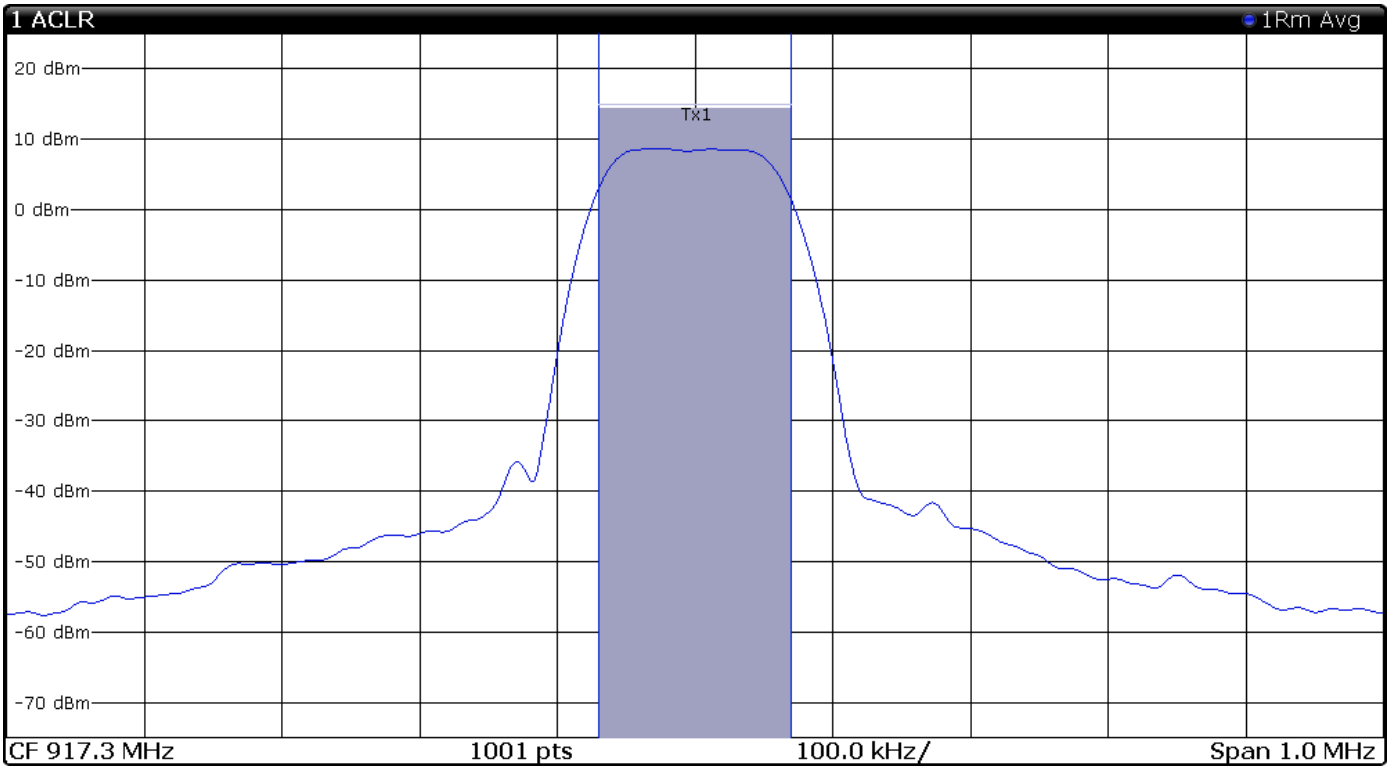
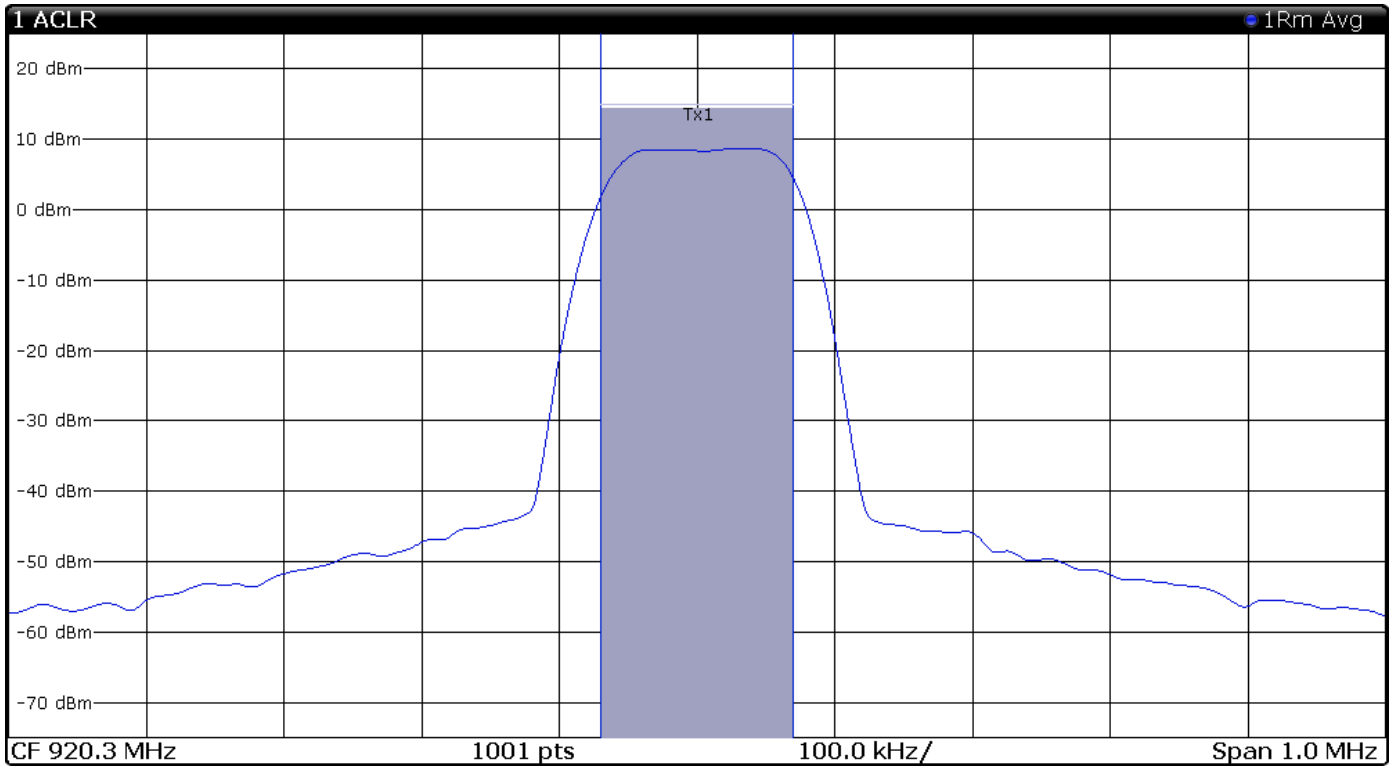


Figure 16 LoRa (P-Mode) Plot of Output Power



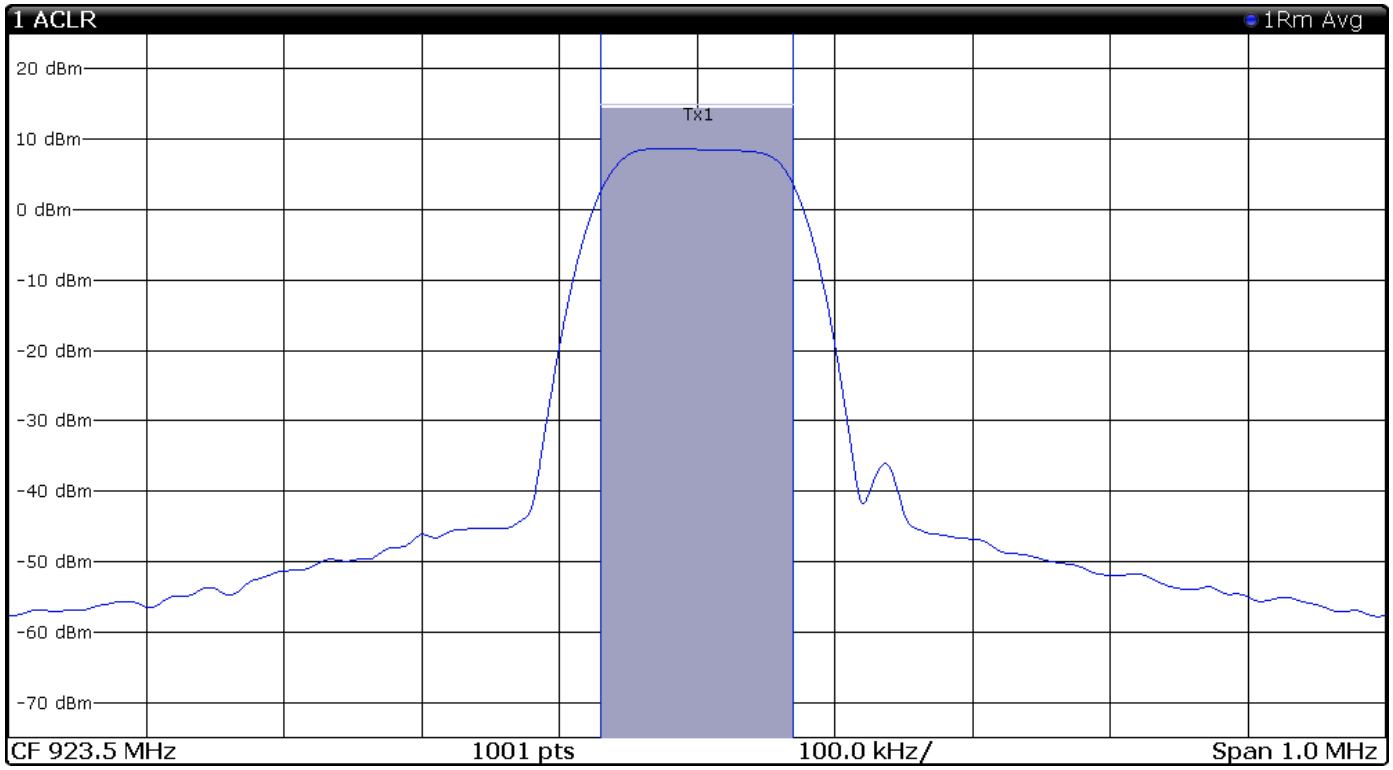
Channel	Bandwidth	Power
Tx1 (Ref)	140 kHz	14.29 dBm
Tx Total		14.29 dBm

Figure 17 LoRa (P-Mode) Plot of Output Power



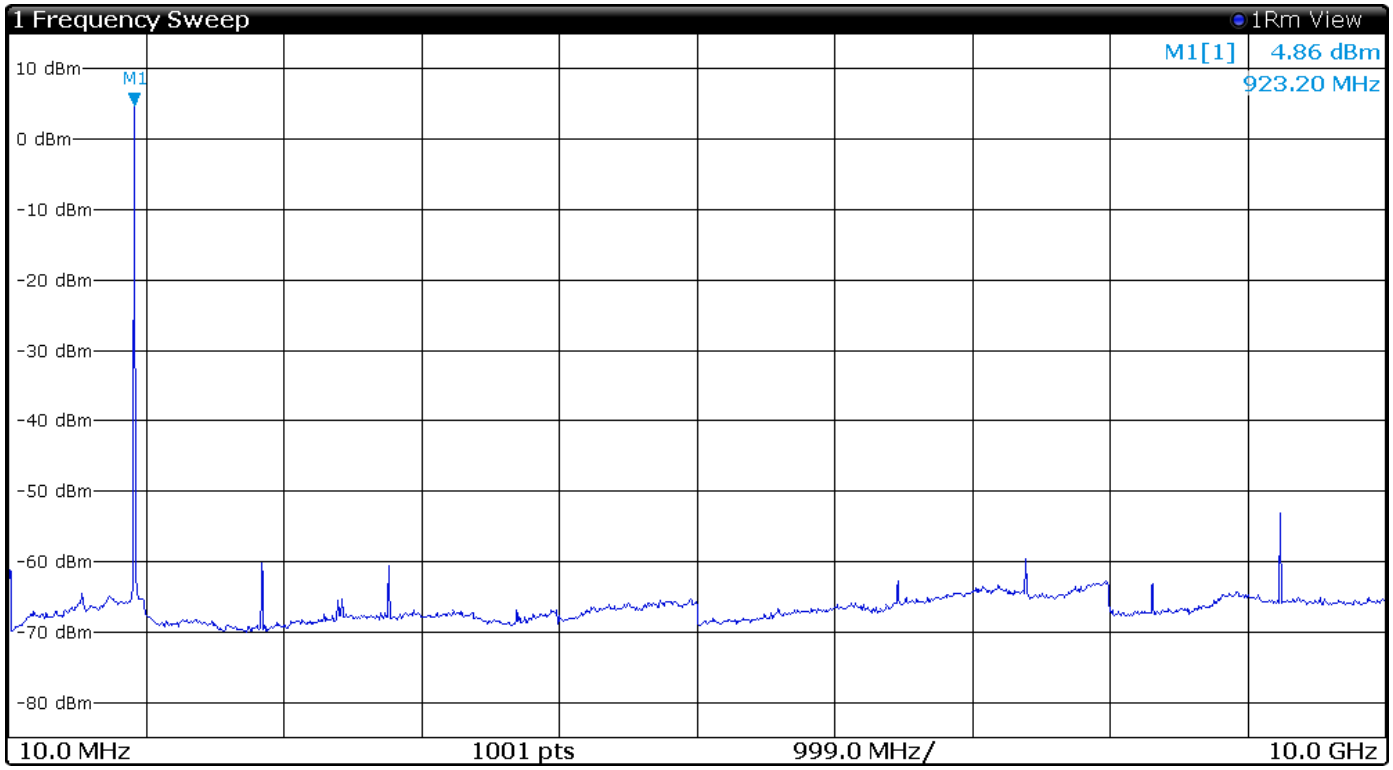
Channel	Bandwidth	Power
Tx1 (Ref)	140 kHz	14.39 dBm
Tx Total		14.39 dBm

Figure 18 LoRa (P-Mode) Plot of Output Power



Channel	Bandwidth	Power
Tx1 (Ref)	140 kHz	14.35 dBm
Tx Total		14.35 dBm

Figure 19 LoRa (P-Mode) Plot of Out of Band Emissions



Transmitter Emissions Data

Table 3 LoRa Transmitter Radiated Emission Worst-case Data

Frequency in MHz	Horizontal Peak (dBµV/m)	Horizontal Average (dBµV/m)	Vertical Peak (dBµV/m)	Vertical Average (dBµV/m)	Limit @ 3m (dBµV/m)	Horizontal Average Margin (dB)	Vertical Average Margin (dB)
917.3	--	--	--	--	--	--	--
1834.6	37.7	1.2	37.1	0.2	54.0	-52.8	-53.8
2751.9	47.9	13.5	44.7	10.4	54.0	-40.5	-43.6
3669.2	36.3	0.2	36.0	-0.4	54.0	-53.8	-54.4
4586.5	39.0	0.6	39.7	0.6	54.0	-53.4	-53.4
5503.8	40.5	1.7	40.3	1.9	54.0	-52.3	-52.1
6421.1	44.1	5.5	43.9	4.2	54.0	-48.5	-49.8
920.3	--	--	--	--	--	--	--
1840.6	34.4	4.5	38.6	2.3	54.0	-49.5	-51.7
2760.9	49.2	14.6	44.6	9.6	54.0	-39.4	-44.4
3681.2	35.4	-0.4	35.5	6.6	54.0	-54.4	-47.4
4601.5	38.8	0.2	39.1	0.2	54.0	-53.8	-53.8
5521.8	39.3	0.4	40.5	0.8	54.0	-53.6	-53.2
6442.1	44.0	6.1	44.5	5.2	54.0	-47.9	-48.8
923.5	--	--	--	--	--	--	--
1847.0	36.1	1.0	42.1	5.6	54.0	-53.0	-48.4
2770.5	47.2	12.6	44.7	9.5	54.0	-41.4	-44.5
3694.0	36.3	-2.6	36.0	-2.6	54.0	-56.6	-56.6
4617.5	38.1	1.9	37.5	1.8	54.0	-52.1	-52.2
5541.0	39.6	0.8	39.2	0.6	54.0	-53.2	-53.4
6464.5	44.5	6.5	45.1	7.1	54.0	-47.5	-46.9

Other emissions present had amplitudes at least 20 dB below the limit. Peak and Quasi-Peak amplitude emissions are recorded for frequency below 1000 MHz. Peak and Average amplitude emissions are recorded for frequency range above 1000 MHz.

Table 4 Transmitter Antenna Port Data

Frequency MHz	Antenna Port Output Power (Watts)	99% Occupied Bandwidth (kHz)	20-dB Occupied Bandwidth (kHz)	6-dB Occupied Bandwidth (kHz)	Peak Power Spectral Density (dBm/3kHz)
P-mode					
917.3	0.027	125.4	138.6	N/A	0.29
920.3	0.028	125.4	137.4	N/A	1.88
923.5	0.027	125.4	138.0	N/A	0.59
M-mode					
923.2	0.001	685.8	N/A	685.3	-12.2

Summary of Results for Transmitter Radiated Emissions of Intentional Radiator

The EUT demonstrated compliance with the radiated emissions requirements of 47CFR Part 15.247, RSS-GEN, and RSS-247 Hybrid Digital Transmission System. The LoRa (902-928 MHz) average antenna port conducted output power measured was 0.028 Watts. The LoRa power spectral density measured at the antenna port presented a minimum margin of -6.1 dB below the requirements. The LoRa transmitter demonstrated a minimum margin of -39.4 dB below the harmonic emissions requirements.

There were no other significantly measurable emissions in the restricted bands other than those recorded in this report. Other emissions were present with amplitudes at least 20 dB below the requirements. There were no other deviations or exceptions to the requirements.

Annex

- Annex A Measurement Uncertainty Calculations
- Annex B Additional Test Equipment
- Annex C Rogers Qualifications
- Annex D Laboratory Certificate of Accreditation

Annex A Measurement Uncertainty Calculations

The measurement uncertainty was calculated for all measurements listed in this test report according To CISPR 16–4. Result of measurement uncertainty calculations are recorded below. Component and process variability of production devices similar to those tested may result in additional deviations. The manufacturer has the sole responsibility of continued compliance.

Measurement	Expanded Measurement Uncertainty $U_{(lab)}$
3 Meter Horizontal 0.009-1000 MHz Measurements	4.16
3 Meter Vertical 0.009-1000 MHz Measurements	4.33
3 Meter Measurements 1-18 GHz	5.14
3 Meter Measurements 18-40 GHz	5.16
10 Meter Horizontal Measurements 0.009-1000 MHz	4.15
10 Meter Vertical Measurements 0.009-1000 MHz	4.32
AC Line Conducted	1.75
Antenna Port Conducted power	1.17
Frequency Stability	1.00E-11
Temperature	1.6˚C
Humidity	3%

Annex B Additional Test Equipment

Equipment	Manufacturer	Model (SN)	Band	Cal Date(m/d/y)	Due
☐ LISN	FCC	FCC-LISN-50-25-10(1PA) (160611)	.15-30MHz	4/21/2020	4/21/2021
☐ LISN	Compliance Design	FCC-LISN-2.Mod.cd,(126)	.15-30MHz	10/14/2020	10/14/2021
☒ Cable	Huber & Suhner Inc.	Sucoflex102ea(L10M)(303073)	9kHz-40 GHz	10/14/2020	10/14/2021
☐ Cable	Huber & Suhner Inc.	Sucoflex102ea(1.5M)(303069)	9kHz-40 GHz	10/14/2020	10/14/2021
☒ Cable	Huber & Suhner Inc.	Sucoflex102ea(1.5M)(303070)	9kHz-40 GHz	10/14/2020	10/14/2021
☐ Cable	Belden	RG-58 (L1-CAT3-11509)	9kHz-30 MHz	10/14/2020	10/14/2021
☐ Cable	Belden	RG-58 (L2-CAT3-11509)	9kHz-30 MHz	10/14/2020	10/14/2021
☒ Antenna	Com Power	AL-130 (121055)	.001-30 MHz	10/14/2020	10/14/2021
☐ Antenna:	EMCO	6509	.001-30 MHz	10/14/2020	10/14/2022
☐ Antenna	ARA	BCD-235-B (169)	20-350MHz	10/14/2020	10/14/2021
☐ Antenna:	Schwarzbeck Model	VHBB 9124 (9124-627)		4/21/2020	4/21/2021
☒ Antenna	Sunol	JB-6 (A100709)	30-1000 MHz	10/14/2020	10/14/2021
☐ Antenna	ETS-Lindgren	3147 (40582)	200-1000MHz	10/14/2020	10/14/2022
☐ Antenna:	Schwarzbeck Model:	VULP 9118 A (VULP 9118 A-534)		4/21/2020	4/21/2021
☒ Antenna	ETS-Lindgren	3117 (200389)	1-18 GHz	4/21/2020	4/21/2022
☐ Antenna	Com Power	AH-118 (10110)	1-18 GHz	10/14/2020	10/14/2022
☒ Antenna	Com Power	AH-840 (101046)	18-40 GHz	4/21/2020	4/21/2021
☒ Analyzer	Rohde & Schwarz	ESU40 (100108)	20Hz-40GHz	3/2/2021	3/2/2022
☒ Analyzer	Rohde & Schwarz	ESW44 (101534)	20Hz-44GHz	1/12/2021	1/12/2022
☐ Analyzer	Rohde & Schwarz	FS-Z60, 90, 140, and 220	40GHz-220GHz	12/22/2017	12/22/2027
☒ Amplifier	Com-Power	PA-010 (171003)	100Hz-30MHz	10/14/2020	10/14/2021
☒ Amplifier	Com-Power	CPPA-102 (01254)	1-1000 MHz	10/14/2020	10/14/2021
☒ Amplifier	Com-Power	PAM-118A (551014)	0.5-18 GHz	10/14/2020	10/14/2021
☒ Amplifier	Com-Power	PAM-840A (461328)	18-40 GHz	10/14/2020	10/14/2021
☐ Power Meter	Agilent	N1911A with N1921A	0.05-40 GHz	4/21/2020	4/21/2021
☐ Generator	Rohde & Schwarz	SMB100A6 (100150)	20Hz-6 GHz	4/21/2020	4/21/2021
☐ Generator	Rohde & Schwarz	SMBV100A6 (260771)	20Hz-6 GHz	4/21/2020	4/21/2021
☐ RF Filter	Micro-Tronics	BRC50722 (009).9G notch	30-18000 MHz	4/21/2020	4/21/2021
☐ RF Filter	Micro-Tronics	HPM50114 (017)1.5G HPF	30-18000 MHz	4/21/2020	4/21/2021
☐ RF Filter	Micro-Tronics	HPM50117 (063) 3G HPF	30-18000 MHz	4/21/2020	4/21/2021
☐ RF Filter	Micro-Tronics	HPM50105 (059) 6G HPF	30-18000 MHz	4/21/2020	4/21/2021
☐ RF Filter	Micro-Tronics	BRM50702 (172) 2G notch	30-18000 MHz	4/21/2020	4/21/2021
☐ RF Filter	Micro-Tronics	BRC50703 (G102) 5G notch	30-18000 MHz	4/21/2020	4/21/2021
☐ RF Filter	Micro-Tronics	BRC50705 (024) 5G notch	30-18000 MHz	4/21/2020	4/21/2021
☐ Attenuator	Fairview	SA6NFNF100W-40 (1625)	30-18000 MHz	4/21/2020	4/18/2021
☐ Attenuator	Mini-Circuits	VAT-3W2+ (1436)	30-6000 MHz	4/21/2020	4/21/2021
☐ Attenuator	Mini-Circuits	VAT-3W2+ (1445)	30-6000 MHz	4/21/2020	4/21/2021
☐ Attenuator	Mini-Circuits	VAT-3W2+ (1735)	30-6000 MHz	4/21/2020	4/21/2021
☐ Attenuator	Mini-Circuits	VAT-6W2+ (1438)	30-6000 MHz	4/21/2020	4/21/2021
☐ Attenuator	Mini-Circuits	VAT-6W2+ (1736)	30-6000 MHz	4/21/2020	4/21/2021
☒ Weather station	Davis	6312 (A81120N075)		11/4/2020	11/4/2021

NVLAP Lab Code 200087-0

List of Test Equipment				Calibration	Date (m/d/y)	Due
☐ Frequency Counter: Leader LDC-825 (8060153					4/21/2020	4/21/2021
☐ LISN: Com-Power Model LI-220A					10/14/2020	10/14/2021
☐ LISN: Com-Power Model LI-550C					10/14/2020	10/14/2021
☐ ISN: Com-Power Model ISN T-8					4/21/2020	4/21/2021
☐ LISN: Fischer Custom Communications Model: FCC-LISN-50-16-2-08					4/21/2020	4/21/2021
☐ Cable	Huber & Suhner Inc.	Sucoflex102ea(1.5M)(303072)	9kHz-40 GHz		10/14/2020	10/14/2021
☐ Cable	Huber & Suhner Inc.	Sucoflex102ea(L1M)(281183)	9kHz-40 GHz		10/14/2020	10/14/2021
☐ Cable	Huber & Suhner Inc.	Sucoflex102ea(L4M)(281184)	9kHz-40 GHz		10/14/2020	10/14/2021
☐ Cable	Huber & Suhner Inc.	Sucoflex102ea(L10M)(317546)	9kHz-40 GHz		10/14/2020	10/14/2021
☐ Cable	Time Microwave	4M-750HF290-750 (4M)	9kHz-24 GHz		10/14/2020	10/14/2021
☐ RF Filter	Micro-Tronics	BRC17663 (001) 9.3-9.5 notch	30-1800 MHz		4/21/2020	4/21/2021
☐ RF Filter	Micro-Tronics	BRC19565 (001) 9.2-9.6 notch	30-1800 MHz		10/16/2018	4/21/2021
☐ Analyzer	HP	8562A (3051A05950)	9kHz-125GHz		4/21/2020	4/21/2021
☐ Analyzer	HP External Mixers	11571, 11970	25GHz-110GHz		4/18/2015	4/18/2025
☐ Analyzer	HP	8591EM (3628A00871)			4/21/2020	4/21/2021
☐ Wave Form Generator Keysight		33512B (MY57400128)			4/21/2020	4/21/2021
☐ Antenna: Solar 9229-1 & 9230-1					2/22/2021	2/22/2022
☐ CDN: Com-Power Model CDN325E					10/14/2020	10/14/2021
☐ Injection Clamp Luthi Model EM101					10/14/2020	10/14/2021
☐ Oscilloscope Scope: Tektronix MDO 4104					2/22/2021	2/22/2022
☐ EMC Transient Generator HVT TR 3000					2/22/2021	2/22/2022
☐ AC Power Source (Ametech, California Instruments)					2/22/2021	2/22/2022
☐ Field Intensity Meter: EFM-018					2/22/2021	2/22/2022
☐ ESD Simulator: MZ-15					2/22/2021	2/22/2022
☐ R.F. Power Amp ACS 230-50W					not required	
☐ R.F. Power Amp EIN Model: A301					not required	
☐ R.F. Power Amp A.R. Model: 10W 1010M7					not required	
☐ R.F. Power Amp A.R. Model: 50U1000					not required	
☐ Tenney Temperature Chamber					not required	
☒ Shielded Room					not required	

Annex C Rogers Qualifications

Scot D. Rogers, Engineer

Rogers Labs, Inc.

Mr. Rogers has 35 years' experience in the field of electronics. Work experience includes working in the automated controls industry and remaining years working with the design, development and testing of radio communications and electronic equipment.

Positions Held:

Systems Engineer:	A/C Controls Mfg. Co., Inc.	6 Years
Electrical Engineer:	Rogers Consulting Labs, Inc.	5 Years
Electrical Engineer:	Rogers Labs, Inc.	Current

Educational Background:

1) Bachelor of Science Degree in Electrical Engineering from Kansas State University

2) Bachelor of Science Degree in Business Administration Kansas State University

3) Several Specialized Training courses and seminars pertaining to Microprocessors and Software programming.

Annex D Laboratory Certificate of Accreditation

United States Department of Commerce
National Institute of Standards and Technology

Certificate of Accreditation to ISO/IEC 17025:2017

NVLAP LAB CODE: 200087-0

Rogers Labs, Inc.
Louisburg, KS

is accredited by the National Voluntary Laboratory Accreditation Program for specific services, listed on the Scope of Accreditation, for:

Electromagnetic Compatibility & Telecommunications

This laboratory is accredited in accordance with the recognized International Standard ISO/IEC 17025:2017. This accreditation demonstrates technical competence for a defined scope and the operation of a laboratory quality management system (refer to joint ISO-ILAC-IAF Communique dated January 2009).

2021-02-19 through 2022-03-31
Effective Dates

For the National Voluntary Laboratory Accreditation Program