RF TEST REPORT

FCC / ISED

APPLICANT

Nwave Technologies Inc

MODEL NAME

NPS-4.5

FCC ID

2ADCZ-NPS-4-5

ISED ID

12418A-NPS45

REPORT NUMBER

HA220510-NWT-001-R02

TEST REPORT

Date of Issue
October 26, 2022

Test Site
Hyundai C-Tech, Inc. dba HCT America, Inc.
1726 Ringwood Ave, San Jose, CA 95131, USA

Applicant	Nwave Technologies Inc
Applicant Address	1410 21st Street Suite R Sacramento, CA 95811 USA
FCC ID	2ADCZ-NPS-4-5
ISED ID	12418A-NPS45
Model Name	NPS-4.5
EUT Type	Nwave Wireless Vehicle Detection Sensor
FCC Classification	Frequency Hopping Spread Spectrum Transmitter (DSS)
FCC Rule Part(s)	Part 15.247
ISED Rule Part(s)	RSS-247 Issue 2 (February 2017) RSS-Gen Issue 5 Amd 2 (February 2021)
Test Procedure	ANSI C63.10-2013, KDB 558074 D01 v05r02

The device bearing the trade name and model specified above, has been shown to comply with the applicable technical standards as indicated in the measurement report and was tested in accordance with the measurement procedures required. The results of testing in this report apply only to the product which was tested. Other similar equipment will not necessarily produce the same results due to production tolerance and measurement uncertainties.

I attest to the accuracy of data. All measurements reported herein were performed by me or were made under my supervision and are correct to the best of my knowledge and belief. I assume full responsibility for the completeness of these measurements and vouch for the qualifications of all persons taking them.

Hyundai C-Tech, Inc. dba HCT America, Inc. certifies that no party to application has been denied the FCC benefits pursuant to Section 5301 of the Anti-Drug Abuse Act of 1988, 21 U.S.C 862

Tested By	**Reviewed By**
Yongsoo Park	Sunwoo Kim
Test Engineer	Technical Manager

REVISION HISTORY

The revision history for this document is shown in the table.

TEST REPORT NO.	DATE	DESCRIPTION
HA220510-NWT-001-R02	October 26, 2022	Initial Issue

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Hyundai C-Tech, Inc. dba HCT America, Inc., 1726 Ringwood Avenue, San Jose, CA 95131, USA TEL: +1-510-933-8848 FAX: +1-510-933-8849

1. GENERAL INFORMATION

EUT DESCRIPTION

Model	NPS-4.5
Product Name	Nwave Wireless Vehicle Detection Sensor
Serial Number	1013BF (Conducted) 1013C4 (Radiated)
Power Supply	Li-SOCI2 Battery 3.6 V d.c. (To convert to actual voltage 2500 mV)
RF Specification	LoRaWAN 1.0.3 Class A (125 kHz / 500 kHz) Bluetooth 5.1 LE (1M)
Transmitter Chain	LoRa : SISO Bluetooth LE : SISO
Operating Environment	Outdoor
Operating Temperature	-40 °C ~ +85 °C

RF SPECIFICATION SUBJECT TO THE REPORT

RF Specification	LoRa	
Frequency Range	125 kHz	902.3 MHz – 914.9 MHz
Max. RF Output Power	Peak : 16.536 dBm (45.040 mW)	
Modulation Type	CSS (Chirp Spread Spectrum)	
Number of Channels	64 Channels	
Antenna Specification [1)]	Antenna Type : Integrated antenna Peak Gain : 0.4 dBi	
Firmware Version [2)]	2.5.3	
Hardware Version [2)]	4.5.30	
Date(s) of Tests	August 1, 2022 ~ August 29, 2022 October 11, 2022 ~ October 26, 2022	

Note :
1. Antenna information is based on the document provided.
2. Firmware and Hardware Versions are provided by the client.

OPERATING FREQUENCY CHANNELS

LoRa (125 kHz)							
Channel	**Frequency (MHz)**	**Channel**	**Frequency (MHz)**	**Channel**	**Frequency (MHz)**	**Channel**	**Frequency (MHz)**
00	902.3	**16**	905.5	**32**	908.7	**48**	911.9
01	902.5	**17**	905.7	**33**	908.9	**49**	912.1
02	902.7	**18**	905.9	**34**	909.1	**50**	912.3
03	902.9	**19**	906.1	**35**	909.3	**51**	912.5
04	903.1	**20**	906.3	**36**	909.5	**52**	912.7
05	903.3	**21**	906.5	**37**	909.7	**53**	912.9
06	903.5	**22**	906.7	**38**	909.9	**54**	913.1
07	903.7	**23**	906.9	**39**	910.1	**55**	913.3
08	903.9	**24**	907.1	**40**	910.3	**56**	913.5
09	904.1	**25**	907.3	**41**	910.5	**57**	913.7
10	904.3	**26**	907.5	**42**	910.7	**58**	913.9
11	904.5	**27**	907.7	**43**	910.9	**59**	914.1
12	904.7	**28**	907.9	**44**	911.1	**60**	914.3
13	904.9	**29**	908.1	**45**	911.3	**61**	914.5
14	905.1	**30**	908.3	**46**	911.5	**62**	914.7
15	905.3	**31**	908.5	**47**	911.7	**63**	914.9

2. METHODOLOGY

Frequency Hopping Spread Spectrum System (FHSS) and the measurement procedure described in ANSI C63.10 (Version : 2013) 'the American National Standard of Procedures for Compliance Testing of Unlicensed Wireless Devices'.

EUT CONFIGURATION

The EUT configuration for testing is installed on RF field strength measurement to meet the Commissions requirement and operates in a manner that intends to maximize its emission characteristics in a continuous normal application.

EUT EXERCISE

The EUT was operated in engineering mode to fix the Tx frequency that was for the purpose of the measurements. According to its specifications, the EUT must comply with the requirements of Section 15.207, 15.209 and 15.247 under the FCC Rule Part 15 Subpart C and the Section 2.1091 under the FCC Rule Part 2 / the RSS-GEN issue 5, RSS-247 issue 2.

GENERAL TEST PROCEDURES

Conducted Emissions
The EUT is placed on the turntable, which is 0.8 m above ground plane. According to the requirements in Section 6.2 of ANSI C63.10. (Version :2013) Conducted emissions from the EUT measured in the frequency range between 0.15 MHz and 30MHz using CISPR Quasi-peak and average detector modes.

Radiated Emissions
The EUT is placed on a turn table, which is 0.8 m above ground plane below 1GHz. Above 1GHz with 1.5m using absorbers between the EUT and receive antenna. The turntable shall rotate 360 degrees to determine the position of maximum emission level. EUT is set 3 m away from the receiving antenna, which varied from 1 m to 4 m to find out the highest emission. Also, each emission was to be maximized by changing the polarization of the receiving antenna both horizontal and vertical. In order to find out the maximum emission, the relative positions of the transmitter (EUT) were rotated through three orthogonal axes according to the requirements in Section 8 of ANSI C63.10. (Version: 2013)

Conducted Antenna Terminal
KDB 558074 D01 v05r02

DESCRIPTION OF TEST MODES

The EUT has been tested at continuous operating mode. Teraterm was used to feed RF commands for controlling the channels, power setting, continuous TX and RX mode.

3. INSTRUMENT CALIBRATION

The measuring equipment, which was utilized in performing the tests documented herein, has been calibrated in accordance with the manufacturer's recommendations for utilizing calibration equipment, which is traceable to recognized national standards. Especially, all antenna for measurement is calibrated in accordance with the requirements of C63.5 (Version : 2017).

4. FACILITIES AND ACCREDITATIONS

FACILITIES

The SAC (Semi-Anechoic Chamber) and conducted measurement facility used to collect the radiated data are located at 1726 Ringwood Avenue, San Jose, California 95131, USA. (LAB CODE : US0198)
The site is constructed in conformance with the requirements of ANSI C63.4. (Version :2014) and CISPR Publication 22.

Accredited Laboratory

A2LA has accredited

HYUNDAI C-TECH, INC. DBA HCT AMERICA, INC.

San Jose, CA

for technical competence in the field of

Electrical Testing

This laboratory is accredited in accordance with the recognized International Standard ISO/IEC 17025:2017 *General requirements for the competence of testing and calibration laboratories*. This accreditation demonstrates technical competence for a defined scope and the operation of a laboratory quality management system (*refer to joint ISO-ILAC-IAF Communiqué dated April 2017*).

Presented this 10th day of June 2021.

Trace McInturff, Vice President, Accreditation Services
For the Accreditation Council
Certificate Number 4201.01
Valid to July 31, 2023

For the tests to which this accreditation applies, please refer to the laboratory's Electrical Scope of Accreditation.

EQUIPMENT

Radiated emissions are measured with one or more of the following types of Linearly polarized antennas: tuned dipole, bi-conical, log periodic, bi-log, and/or ridged waveguide, horn. Spectrum analyzers with pre-selectors and quasi-peak detectors are used to perform radiated measurements.

Conducted emissions are measured with Line Impedance Stabilization Networks and EMI Test Receivers. Calibrated wideband preamplifiers, coaxial cables, and coaxial attenuators are also used for making measurements.

All receiving equipment conforms to CISPR Publication 16-1, “Radio Interference Measuring Apparatus and Measurement Methods.”

5. ANTENNA REQUIREMENTS

According to FCC 47 CFR §15.203:

"An intentional radiator antenna shall be designed to ensure that no antenna other than that furnished by the responsible party can 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."

(1) The antenna of this E.U.T is permanently attached and there is no provision for connection to an external antenna.
(2) The E.U.T Complies with the requirement of §15.203

According to RSS-Gen Issue 5 (Section 6.8) :

The applicant for equipment certification shall provide a list of all antenna types that may be used with the transmitter, where applicable (i.e. for transmitters with detachable antenna), indicating the maximum permissible antenna gain (in dBi) and the required impedance for each antenna. The test report shall demonstrate the compliance of the transmitter with the limit for maximum equivalent isotropically radiated power (e.i.r.p.) specified in the applicable RSS, when the transmitter is equipped with any antenna type, selected from this list.

For expediting the testing, measurements may be performed using only the antenna with highest gain of each combination of transmitter and antenna type, with the transmitter output power set at the maximum level. However, the transmitter shall comply with the applicable requirements under all operational conditions and when in combination with any type of antenna from the list provided in the test report (and in the notice to be included in the user manual, provided below).

When measurements at the antenna port are used to determine the RF output power, the effective gain of the device's antenna shall be stated, based on a measurement or on data from the antenna's manufacturer.

The test report shall state the RF power, output power setting and spurious emission measurements with each antenna type that is used with the transmitter being tested.

6. MEASUREMENT UNCERTAINTY

The measurement uncertainties shown below were calculated in accordance with the requirements of ANSI C63.10-2013.

All measurement uncertainty values are shown with a coverage factor of k = 2 to indicate a 95 % level of confidence. The measurement data shown herein meets or exceeds the U_{CISPR} measurement uncertainty values specified in CISPR 16-4-2 and, thus, can be compared directly to specified limits to determine compliance.

Parameter	Expanded Uncertainty
Output Power, Conducted	± 0.35 dB
Occupied Bandwidth	± 12.4 kHz
Unwanted Emissions, Conducted	± 0.46 dB
Radiated Emissions (below 1 GHz)	± 6.09 dB
Radiated Emissions (Above 1 GHz)	± 5.23 dB

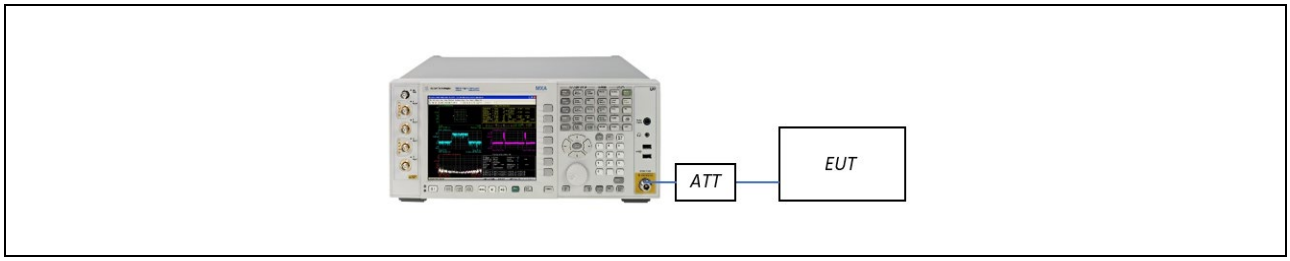
7. DESCRIPTION OF TESTS

7.1. 20 dB BANDWIDTH / OCCUPIED BANDWIDTH

LIMIT

§15.247(a)(1)(i) / RSS-247 Issue 2, Section 5.1(c)
The maximum allowed 20 dB bandwidth of the hopping channel is 500 kHz.

TEST SETUP



TEST PROCEDURE (20 dB Bandwidth)

The transmitter output is connected to the Spectrum Analyzer.
(Procedure Section 6.9.2 in ANSI C63.10-2013)

The Spectrum Analyzer Setting :

- RBW = 1% ~ 5% of 20 dB bandwidth
- VBW ≒ 3 x RBW
- Span : 2-5 times the 20 dB bandwidth, centered on the hopping channel
- Detector = Peak
- Trace mode = Max hold
- Sweep = Auto couple
- Allow the trace to stabilize
- Used the automatic bandwidth measurement capability of a spectrum analyzer, setting X dB as 20 dB.

TEST PROCEDURE (99% Occupied Bandwidth)

The transmitter output is connected to the spectrum analyzer.

- RBW = 1% ~ 5% of the occupied bandwidth
- VBW ≒ 3 x RBW
- Detector = Peak
- Trace mode = Max hold
- Sweep = Auto couple
- Allow the trace to stabilize
- Used the automatic bandwidth measurement capability of a spectrum analyzer.

Note :
Occupied bandwidth profile installed on the spectrum analyzer was used during measurement.

7.2. CARRIER FREQUENCY SEPARATION

LIMIT

§15.247(a)(1) / RSS-247 Issue 2, Section 5.1
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.

TEST SETUP

TEST PROCEDURE

The EUT output shall be in the hopping mode and connected to the Spectrum Analyzer.

Use the following spectrum analyzer setting :
(Procedure 7.8.2 in ANSI C63.10-2013 / Procedure 10(b)(6)(iii) in KDB 558074 v05r02)

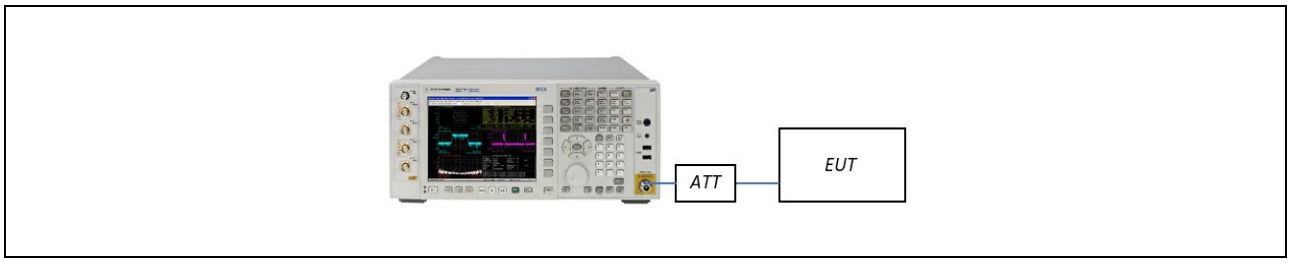
- RBW = Start with approximately 30% of the channel spacing; Then adjust as needed to best identify of each individual channel.
- VBW ≥ RBW.
- SPAN = Wide enough to capture two adjacent peaks.
- Sweep = Auto coupled.
- Detector = Peak.
- Trace mode = Max hold.
- Allow the trace to stabilize.

7.3. OUTPUT POWER

LIMIT

§15.247(b)(2) / RSS-247 Issue2, Section 5.4 (a)
For frequency hopping systems operating in the 902-928 MHz band:
1 watt (not exceeding 4.0 W e.i.r.p.) for systems employing at least 50 hopping channels.
0.25 watts (not exceeding 1.0 W e.i.r.p.) for systems employing less than 50 hopping channels, but at least 25 hopping channels, as permitted under paragraph (a)(1)(i)

TEST SETUP



TEST PROCEDURE

The EUT is connected to the Spectrum Analyzer. Hopping mode shall be disabled.

Use the following Spectrum Analyzer setting :
(Procedure Section 7.8.5 in ANSI C63.10-2013 / Procedure 10(b)(6)(i) in KDB 558074 v05r02)

- RBW ≥ 20 dB Bandwidth
- VBW ≥ RBW
- SPAN = Approximately 5 x RBW
- Detector Mode = Peak
- Sweep = Auto couple
- Trace Mode = Max hold
- Allow trace to fully stabilize.
- Use marker-to-peak function to determine the peak emission level

Note :
Conducted Output Power (Peak) = Reading Value + ATT loss + Cable loss

7.4. NUMBER OF HOPPING CHANNELS

LIMIT

§15.247(a)(1)(i) / RSS-247 Issue 2, Section 5.1(c)
For frequency hopping systems operating in 902 MHz – 928 MHz band,
The system shall use at least 50 hopping channels if the 20 dB bandwidth of the hopping channel is less than 250 kHz.
The system shall use at least 25 hopping channels if the 20 dB bandwidth of the hopping channel is 250 kHz or greater.

TEST SETUP

TEST PROCEDURE

The transmitter output is connected to the Spectrum Analyzer.
(Procedure 7.8.3 in ANSI C63.10-2013)

- RBW ≤ 30% of the channel spacing or the 20 dB bandwidth, whichever is smaller
- VBW ≥ RBW
- SPAN = Frequency band of operation. Depending on the number of channels the device supports, it may be necessary to divide the frequency range of operation across multiple spans to allow the individual channels to be clearly seen.
- Sweep = Auto.
- Detector = Peak.
- Trace mode = Max hold.
- Allow the trace to stabilize.

7.5. TIME OF OCCUPANCY (DWELL TIME)

LIMIT

§15.247(a)(1)(i) / RSS-247 Issue 2, Section 5.1(c)
The average time of occupancy on any channel shall be less than or equal to 0.4 seconds within a period of 0.4 seconds multiplied by the number of hopping channels employed.

TEST SETUP

TEST PROCEDURE

The EUT output shall be in the hopping mode and connected to the Spectrum Analyzer.

Use the following spectrum analyzer setting :
(Procedure 7.8.4 in ANSI C63.10-2013 / Procedure 10(b)(6)(iv) in KDB 558074 v05r02)

- RBW ≤ Channel spacing and where possible, RBW should be set >> 1/T, where T is the expected dwell time per channel.
- VBW ≥ RBW.
- Span = Zero span, centered on a hopping channel.
- Sweep = As needed to capture entire dwell time per hopping channel (Use video trigger and trigger delay for the transmitted signal to better show the plot little after start). Second plot might be needed with longer sweep time to show two successive hops on a channel
- Detector = Peak.
- Trace mode = Max hold.

Use the marker-delta function to determine the dwell time.
Repeat the test for each different mode of operation.

Note :
Sample Calculation

No of hops specified in the requirement
- No of hops on spectrum analyzer x (period specified in the requirement / sweep time on SA)

Dwell Time (s)
- Transmit time per hops x No of hops specified in the requirement

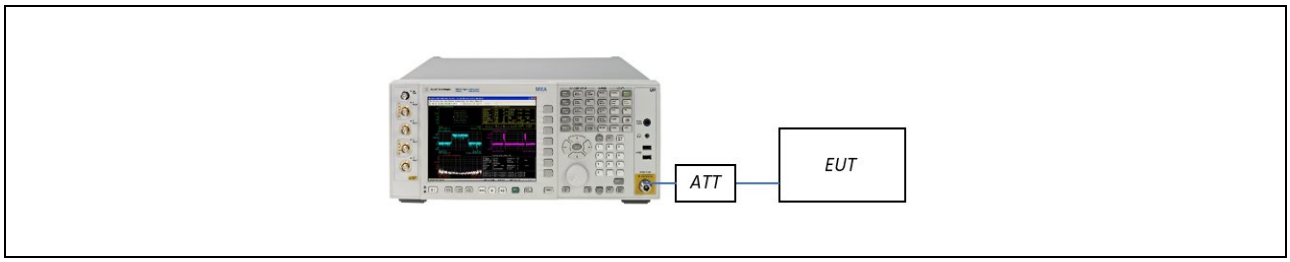
7.6. CONDUCTED BAND EDGE / CONDUCTED SPURIOUS EMISSIONS

LIMIT

§15.247(d) / RSS-247(Issue 2) Section 5.5
In any 100kHz 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 below that in the 100kHz bandwidth within the band that contains the highest level of the desired power, the attenuation shall be as below:

The attenuation shall be at least 20dB when the conducted power is measured

TEST SETUP



TEST PROCEDURE

The transmitter output port is connected to the spectrum analyzer.
(Procedure 7.8.6 and 7.8.8 in ANSI C63.10-2013)

- RBW = 100 kHz
- VBW ≥ 3 x RBW
- Set span to encompass the spectrum to be examined
- Detector = Peak
- Trace Mode = max hold
- Sweep time = auto couple
- Ensure that the number of measurement points ≥ 2*Span/RBW
- Allow trace to fully stabilize.
- Use peak marker function to determine the maximum amplitude level.

The band edge measurements are conducted with both hopping ON and OFF modes.
The Spurious emission measurements are made from 30 MHz to 10th harmonics of the operating frequency in GHz for the lowest, middle, and highest channels.

7.7. RADIATED EMISSIONS

RADIATION EMISSION LIMIT

FCC : 47 CFR § 15.209		
Frequency (MHz)	**Field Strength (uV/m)**	**Measurement Distance (m)**
0.009 – 0.490	2400/F(kHz)	300
0.490 – 1.705	24000/F(kHz)	30
1.705 – 30	30	30
30-88	100	3
88-216	150	3
216-960	200	3
Above 960	500	3

ISED : RSS-GEN Section 8.9		
Frequency (MHz)	**Field Strength (uV/m)**	**Measurement Distance (m)**
0.009 – 0.490	6.37/F(kHz)	300
0.490 – 1.705	63.7/F(kHz)	30
1.705 – 30	0.08	30
30-88	100	3
88-216	150	3
216-960	200	3
Above 960	500	3

RECEIVER RADIATED EMISSION LIMIT

ISED : RSS-GEN Section 7.3		
Frequency (MHz)	**Field Strength (uV/m)**	**Measurement Distance (m)**
30-88	100	3
88-216	150	3
216-960	200	3
Above 960	500	3

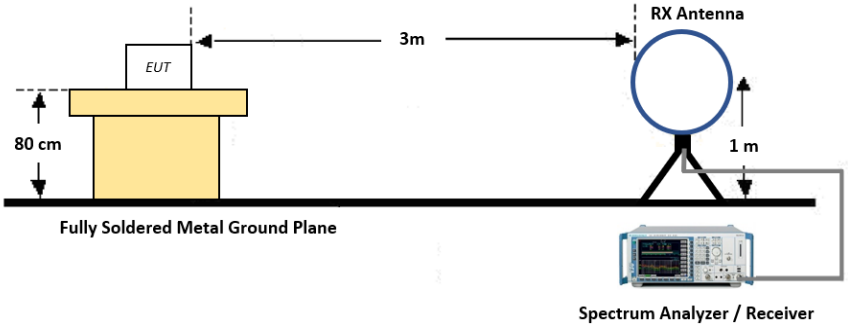
RESTRICTED BANDS OF OPERATION

FCC : 47 CFR § 15.205(a)				
Frequency (MHz)	**Frequency (MHz)**	**Frequency (MHz)**	**Frequency (MHz)**	**Frequency (MHz)**
0.090 – 0.110	12.29 - 12.293	149.9 - 150.05	1660.0 - 1710.0	8025 - 8500
0.495 - 0.505	12.51975 - 12.52025	156.52475 - 156.52525	1718.8 - 1722.2	9000 - 9200
2.1735 - 2.1905	12.57675 - 12.57725	156.7 - 156.9	2200.0 - 2300.0	9300 - 9500
4.125 - 4.128	13.36 - 13.41	162.0125 - 167.17	2310.0 - 2390.0	10600 - 12700
4.17725 - 4.17775	16.42 - 16.423	167.72 - 173.2	2483.5 - 2500.0	13250 - 13400
4.20725 - 4.20775	16.69475 - 16.69525	240.0 - 285.0	2690.0 - 2900.0	14470 - 14500
6.215 - 6.218	16.80425 - 16.80475	322.0 - 335.4	3260.0 - 3267.0	15350 - 16200
6.26775 - 6.26825	25.5 - 25.67	399.9 - 410.0	3332.0 - 3339.0	17700 - 21400
6.31175 - 6.31225	37.5 - 38.25	608.0 - 614.0	3345.8 - 3358.0	22010 - 23120
8.291 - 8.294	73 - 74.6	960.0 - 1240.0	3600.0 - 4400.0	23600 - 24000
8.362 - 8.366	74.8 - 75.2	1300.0 - 1427.0	4500.0 - 5150.0	31200 - 31800
8.37625 - 8.38675	108 - 121.94	1435.0 - 1626.5	5350.0 - 5460.0	36430 - 36500
8.41425 - 8.41475	123 - 138	1645.5 - 1646.5	7250.0 - 7750.0	Above 38600

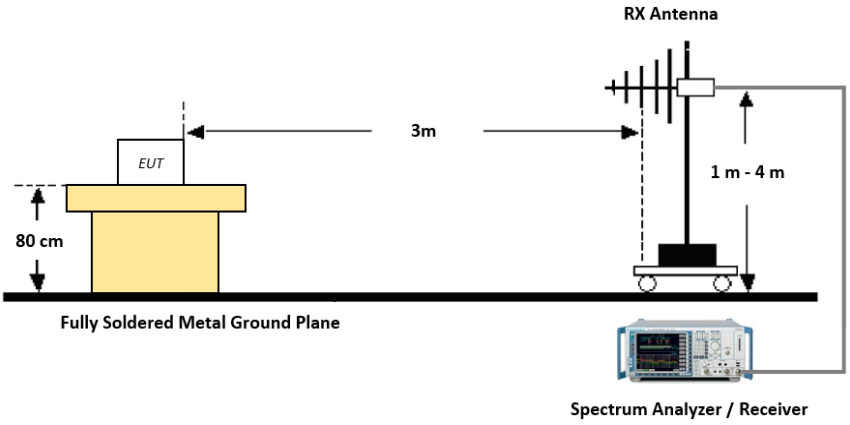
ISED : RSS-GEN Section 8.10				
Frequency (MHz)	**Frequency (MHz)**	**Frequency (MHz)**	**Frequency (MHz)**	**Frequency (MHz)**
0.090 - 0.110	8.37625 - 8.38675	108 – 138	1660 - 1710	8025 - 8500
0.495 - 0.505	8.41425 - 8.41475	149.9 - 150.05	1718.8 - 1722.2	9000 - 9200
2.1735 - 2.1905	12.29 - 12.293	156.52475 - 156.52525	2200 - 2300	9300 - 9500
3.020 - 3.026	12.51975 - 12.52025	156.7 - 156.9	2310 - 2390	10600 - 12700
4.125 - 4.128	12.57675 - 12.57725	162.0125 - 167.17	2483.5 - 2500	13250 - 13400
4.17725 - 4.17775	13.36 - 13.41	167.72 - 173.2	2655 - 2900	14470 - 14500
4.20725 - 4.20775	16.42 - 16.423	240 - 285	3260 - 3267	15350 - 16200
5.677 - 5.683	16.69475 - 16.69525	322 - 335.4	3332 - 3339	17700 - 21400
6.215 - 6.218	16.80425 - 16.80475	399.9 - 410	3345.8 - 3358	22010 - 23120
6.26775 - 6.26825	25.5 - 25.67	608 - 614	3500 - 4400	23600 - 24000
6.31175 - 6.31225	37.5 - 38.25	960 - 1427	4500 - 5150	31200 - 31800
8.291 - 8.294	73 - 74.6	1435 - 1626.5	5350 - 5460	36430 - 36500
8.362 - 8.366	74.8 - 75.2	1645.5 - 1646.5	7250 - 7750	Above 38600

TEST SETUP

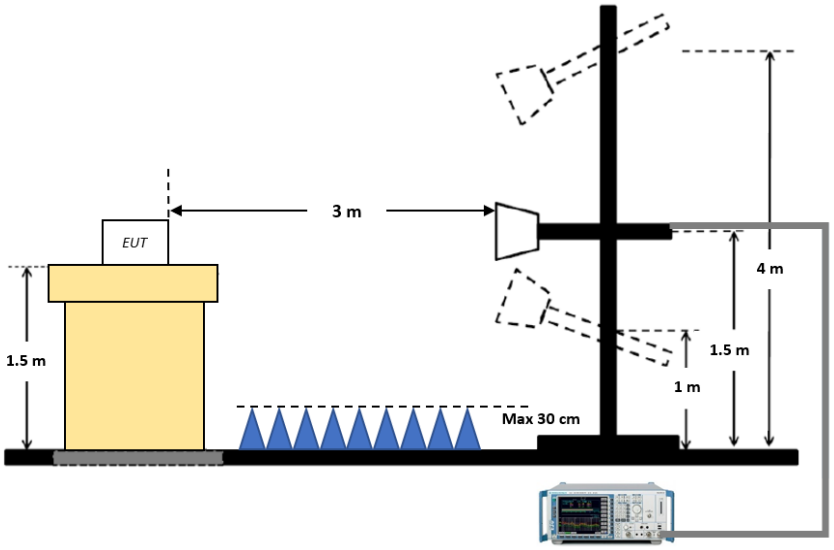
Below 30 MHz



30 MHz - 1 GHz



Above 1 GHz



TEST PROCEDURE OF RADIATED SPURIOUS EMISSIONS (Below 30 MHz)

1. The EUT was placed on a non-conductive table located on semi-anechoic chamber.
2. The loop antenna was placed at a location 3m from the EUT
3. The EUT is placed on a turntable, which is 0.8m above ground plane.
4. We have done x, y, z planes in EUT and horizontal and vertical polarization in detecting antenna.
5. The turntable shall be rotated for 360 degrees to determine the position of maximum emission level.
6. Distance Correction Factor (0.009 MHz – 0.490 MHz) = 40*log(3 m/300 m) = - 80 dB
   Measurement Distance: 3 m
7. Distance Correction Factor (0.490 MHz – 30 MHz) = 40*log(3 m/30 m) = - 40 dB
   Measurement Distance: 3 m
8. Spectrum Setting

   - Frequency Range = 9 kHz ~ 30 MHz
   - Detector = Peak
   - Trace = Max hold
   - RBW = 9 kHz
   - VBW ≥ 3*RBW

9. Total = Reading Value + Antenna Factor (A.F) + Cable Loss (C.L)
10. There is a comparison data both open-field test site and alternative test site – semi-Anechoic chamber according to KDB 414788 D01. And the results are properly calibrated.

TEST PROCEDURE OF RADIATED SPURIOUS EMISSIONS (30 MHz – 1GHz)

1. The EUT was placed on a non-conductive table located on semi-anechoic chamber.
2. The EUT is placed on a turntable, which is 0.8 m above ground plane.
3. We have done x, y, z planes in EUT and horizontal and vertical polarization in detecting antenna.
4. The turntable shall be rotated for 360 degrees to determine the position of maximum emission level.
5. Spectrum Setting

   (1) Measurement Type (Peak):
   - Measured Frequency Range: 30 MHz – 1 GHz
   - Detector = Peak
   - Trace = Max hold
   - RBW = 100 kHz
   - VBW ≥ 3*RBW

   (2) Measurement Type(Quasi-peak):
   - Measured Frequency Range: 30 MHz – 1 GHz
   - Detector = Quasi-Peak
   - RBW = 120 kHz

   Method (2) has been applied

6. Total = Reading Value + Antenna Factor (A.F) + Cable Loss (C.L)

TEST PROCEDURE OF RADIATED SPURIOUS EMISSIONS (Above 1 GHz)

1. The EUT is placed on a turntable, which is 1.5 m above ground plane.
2. We have done x, y, z planes in EUT and horizontal and vertical polarization in detecting antenna.
3. The turntable shall be rotated for 360 degrees to determine the position of maximum emission level.
4. EUT is set 3 m away from the receiving antenna, which is varied from 1m to 4m to find out the highest emissions.
5. Maximum procedure was performed on the six highest emissions to ensure EUT compliance.
6. Each emission was to be maximized by changing the polarization of receiving antenna both horizontal and vertical.
7. Use the following Spectrum Analyzer setting :

   (1) Measurement Type(Peak):
   - Measured Frequency Range : Up to 10^{th} harmonics
   - Detector = Peak
   - Trace = Max hold
   - RBW = 1 MHz
   - VBW ≥ 3*RBW

   (2) Measurement Type(Average):
   - Duty Cycle Correction Factor (DCCF) was applied to derive the average field strength from the peak field strength according to the rule part 15.35(c)
   - Duty Cycle = T_{ON} / 100 ms (or T_{ON} / One complete pulse train), whichever comes shorter.
   - T_{ON} = No (Pulse1) x Length (Pulse1) + No (Pulse2) x Length (Pulse2) + …
   - Average Emission Level = Peak Emission Level + 20 log(Duty Cycle)

8. Measurement value only up to 6 maximum emissions noted or would be lesser if no specific emissions from the EUT are recorded (i.e.: margin > 20 dB from the applicable limit) and considered that is already beyond the background noise floor.

9. Sample Calculation

   (1) Total (Peak) = Reading Value + Antenna Factor(A.F) + Cable Loss(C.L) - Amp Gain(G)
   (2) Total (Average) = Total (Peak) + 20 log(Duty Cycle)

Note :
If the duty cycle is greater than 100 ms, then use 1/T for VBW

7.8. AC POWER LINE CONDUCTED EMISSIONS

LIMIT

47 CFR § 15.207, RSS-GEN Section 8.8
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).

Frequency Range (MHz)	Limits (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.

Compliance with this provision shall be based on the measurement of the radio frequency.
voltage between each power line (LINE and NEUTRAL) and ground at the power terminals.

TEST SETUP

See test photographs attached in Annex A for the actual connections between EUT and support equipment.

TEST PROCEDURE

1. The EUT is placed on a wooden table 80 cm above the reference ground plane.
2. The EUT is connected via LISN to a test power supply.
3. The measurement results are obtained as described below:
4. Detectors : Quasi Peak and Average Detector.

According to FCC KDB 174176 D01 Line Conducted FAQ v01r01 :

Devices Operating Above 30 MHz

For a device with a permanent or detachable antenna operating above 30 MHz, measurements must be performed with the antenna connected as specified in clause 6.2 of ANSI C63.10-2013.

Devices Operating Below 30 MHz

For a device with a permanent or detachable antenna operating at or below 30 MHz, the FCC will accept measurements performed with a suitable dummy load in lieu of the antenna under the following conditions:
(1) Perform the AC power-line conducted tests with the antenna connected to determine compliance with Section 15.207 limits outside the transmitter's fundamental emission band;
(2) Retest with a dummy load in lieu of the antenna to determine compliance with Section 15.207 limits within the transmitter's fundamental emission band. For a detachable antenna, remove the antenna and connect a suitable dummy load to the antenna connector. For a permanent antenna, remove the antenna and terminate the RF output with a dummy load or network which simulates the antenna in the fundamental frequency band. All measurements must be performed as specified in clause 6.2 of ANSI C63.10-2013.

Note :
Sample Calculation : Quasi-peak(Final Result) = Reading Value + Correction Factor

8. SUMMARY OF TEST RESULTS

Test Description	FCC Part Section(s)	IC Part Section(s)	Test Limit	Test Condition	Test Result
20 dB Bandwidth	§15.247(a)(1)(i)	RSS-247, 5.1(c)	≤ 500 kHz	Conducted	PASS
Occupied Bandwidth	-	RSS-GEN, 6.7	-		PASS
Carrier Frequency Separation	§15.247(a)(1)	RSS-247, 5.1	≥ 25 kHz or 20dB BW Whichever is greater		PASS
Conducted Maximum Peak Output Power	§15.247(b)(2)	RSS-247, 5.4(a)	≤ 1 W (channels ≥ 50)		PASS
Maximum e.i.r.p.	-	RSS-247, 5.4(a)	≤ 4 W e.i.r.p. (channels ≥ 50)		PASS
Number of Hopping Channels	§15.247(a)(1)(i)	RSS-247, 5.1(c)	≤ 8 dBm / 3 kHz		PASS
Time of Occupancy	§15.247(a)(1)(i)	RSS-247, 5.1(c)	≤ 0.4 s (within 10s period)		PASS
Conducted Band Edge / Spurious Emission	§15.247(d)	RSS-247, 5.5	≥ 20 dBc		PASS
AC Power line Conducted Emissions	§15.207	RSS-GEN, 8.8	cf. Section 7.8		N/A [1)]
Radiated Spurious Emissions	§15.247(d) §15.209	RSS-GEN, 8.9	cf. Section 7.7	Radiated	PASS
Receiver Radiated Spurious Emissions	-	RSS-GEN, 7.3	cf. Section 7.7		PASS

Note :

1. Not applicable since the device is non-rechargeable battery operated

WORST CASE CONFIGURATION

RADIATED TEST

1. EUT Axis

All X, Y, and Z positions for horizontal / vertical antenna polarization were investigated to find the worst-case position. Y position was selected as the worst-case for full evaluation.

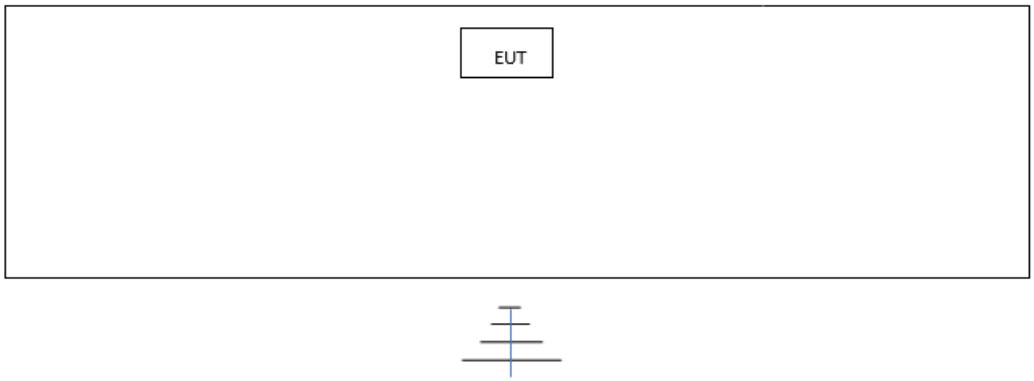
CONDUCTED TEST

1. Output powers were checked at SF7 – SF10. The final tests were performed at the worst case SF10.

OUTPUT POWER SETTING

Frequency (MHz)	Channel	Output Power Setting
902.3	0	16 dBm
908.5	31	16 dBm
914.9	63	16 dBm

EUT SETUP CONFIGURATION

Radiated Emission


LIST OF SUPPORT EQUIPMENT

Equipment Type	Model No.	Serial Number	Manufacturer	Qty	Note
-	-	-	-	-	-

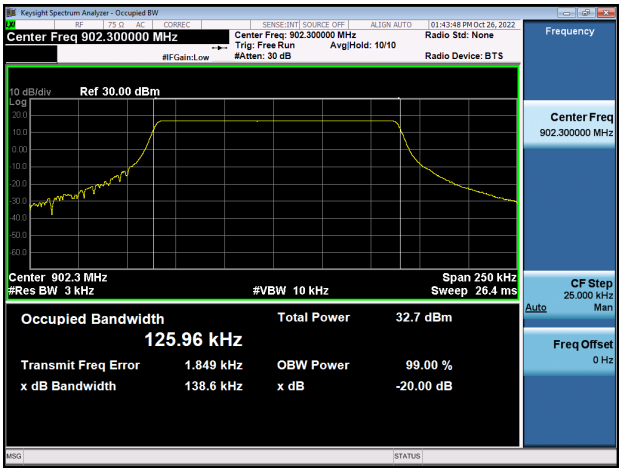
9. TEST RESULT

9.1. 20 dB BANDWIDTH / 99% Bandwidth

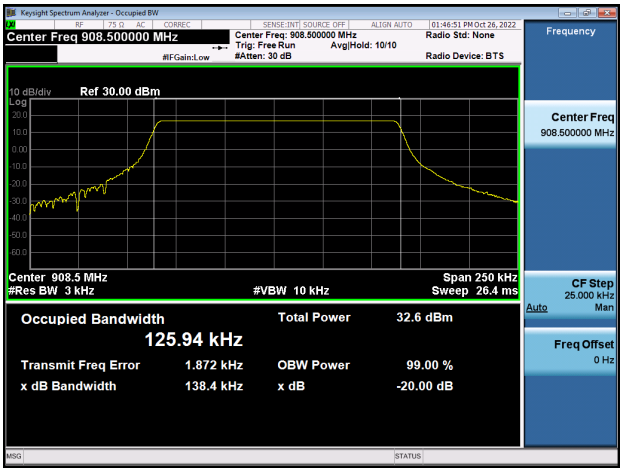
LoRa (125 kHz) : SF10		99% Bandwidth (kHz)	20 dB Bandwidth (kHz)	
Frequency (MHz)	Channel	Test Result	Test Result	Limit
902.3	0	125.96	138.6	≤ 500 kHz
908.5	31	125.94	138.4	
914.9	63	125.79	138.2	

▣ TEST PLOTS

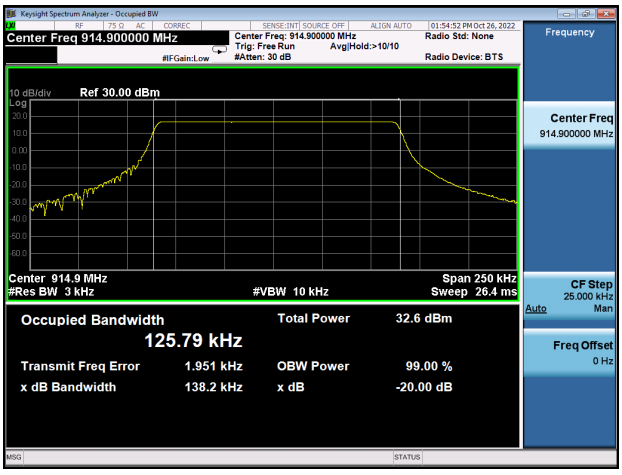
20dB BW / 99% OBW (CH 0)



20dB BW / 99% OBW (CH 31)



20dB BW / 99% OBW (CH 63)

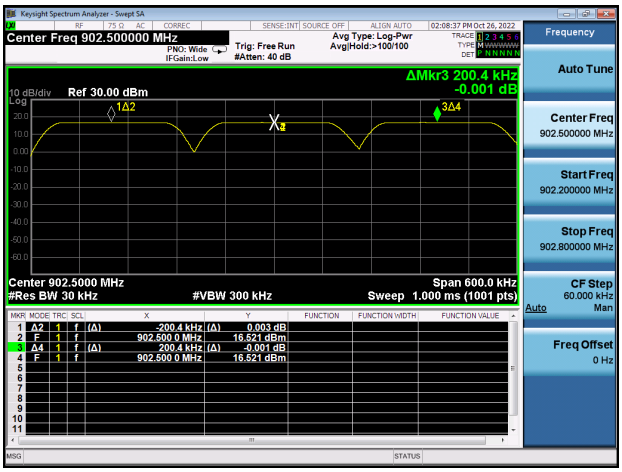


9.2. CARRIER FREQUENCY SEPARATION

LoRa (125 kHz) : SF10		Test Result			
Frequency (MHz)	Channel	Separation (kHz)	20 dB BW (kHz)	Limit (dBm) [1]	Result
902.3	0	200.4	138.6	≥ 138.6	Compliant
908.5	31		138.4	≥ 138.4	Compliant
914.9	63		138.2	≥ 138.2	Compliant

Note :
1. The limit shall be a minimum of 25 kHz or 20 dB bandwidth, whichever is greater.

▣ TEST PLOTS

Frequency Separation – LoRa (125 kHz) : SF10	
	

9.3. OUTPUT POWER

Peak Power

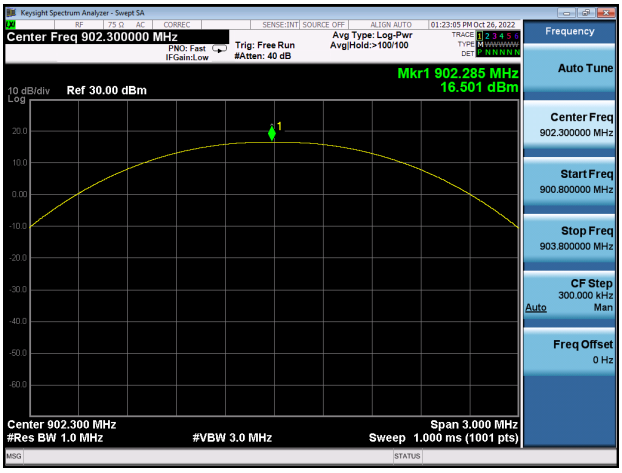
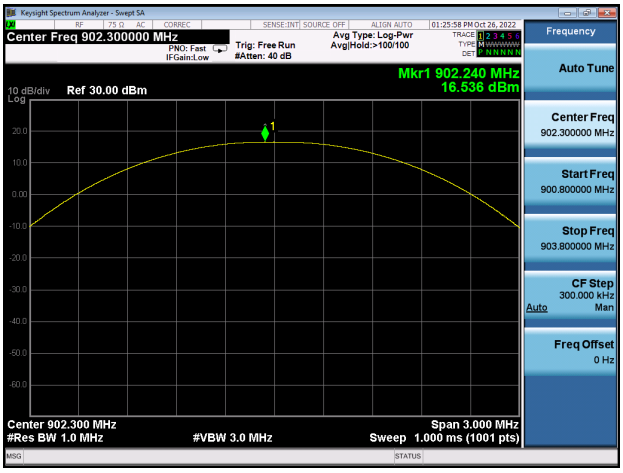
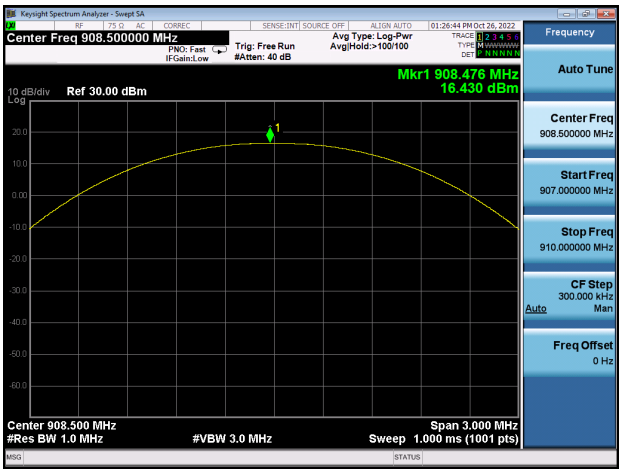
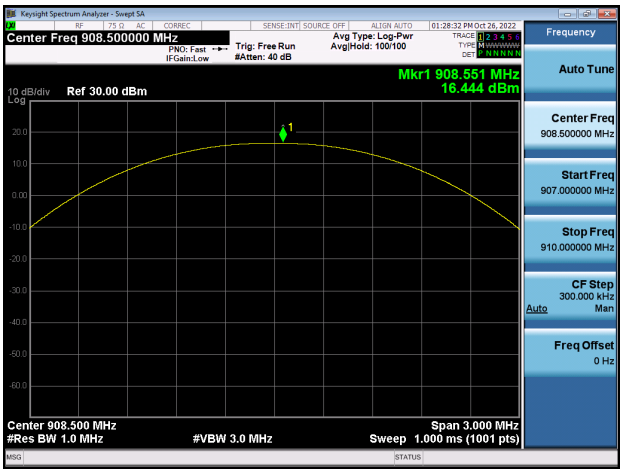
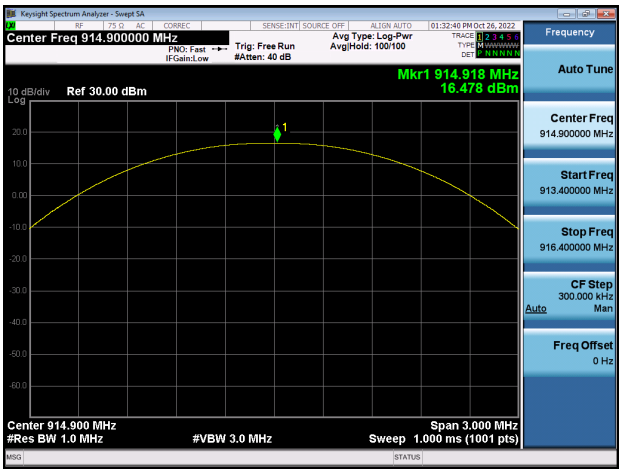
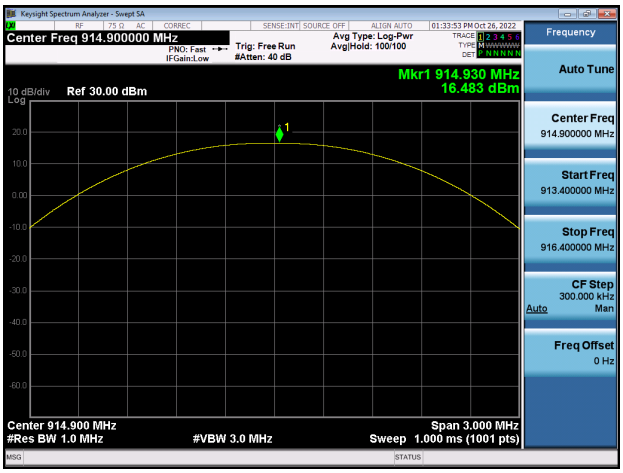
LoRa (125 kHz) : SF7		Test Result		
Frequency (MHz)	**Channel**	**Measured Power (dBm)**	**Limit (dBm)**	**Result**
902.3	0	16.501	30	Compliant
908.5	31	16.430	30	Compliant
914.9	63	16.478	30	Compliant

LoRa (125 kHz) : SF10		Test Result		
Frequency (MHz)	**Channel**	**Measured Power (dBm)**	**Limit (dBm)**	**Result**
902.3	0	16.536	30	Compliant
908.5	31	16.444	30	Compliant
914.9	63	16.483	30	Compliant

Note :

1. The output power results in plot include the spectrum offset, which is a combination loss of the attenuator and the cable used for testing

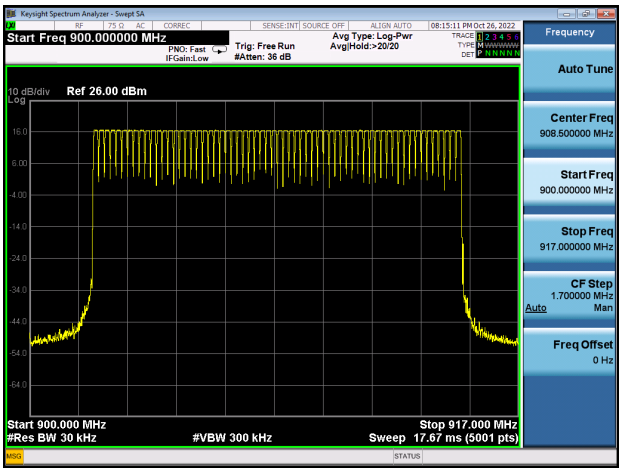
▣ TEST PLOTS

Output Power (902.3 MHz) : LoRa (125 kHz) – SF7	Output Power (902.3 MHz) : LoRa (125 kHz) – SF10
	
Output Power (908.5 MHz) : LoRa (125 kHz) – SF7	**Output Power (908.5 MHz) : LoRa (125 kHz) – SF10**
	
Output Power (914.9 MHz) : LoRa (125 kHz) – SF7	**Output Power (914.9 MHz) : LoRa (125 kHz) – SF10**
	

9.4. NUMBER OF HOPPING CHANNELS

LoRa (125 kHz) : SF10	Test Result		
Frequency Range (MHz)	No. of Channels	Limit	Result
902.3 – 914.9	64	≥ 50	Compliant

▣ TEST PLOTS

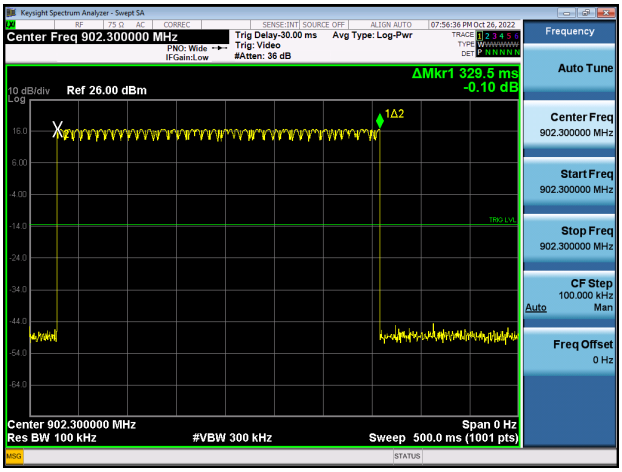
Number of Hopping Channels : SF10	
	

9.5. TIME OF OCCUPANCY

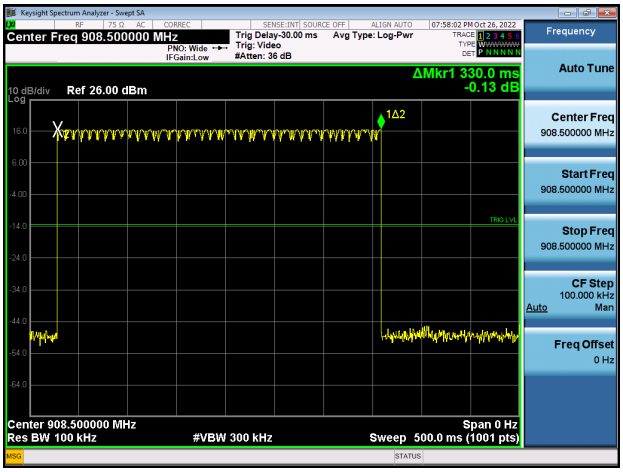
LoRa (125 kHz) : SF10		Test Result		
Frequency (MHz)	Channel	Time of Occupancy (ms)	Limit (ms)	Result
902.3	0	329.5	≤ 400	Compliant
908.5	31	330.0		Compliant
914.9	63	330.0		Compliant

▣ TEST PLOTS

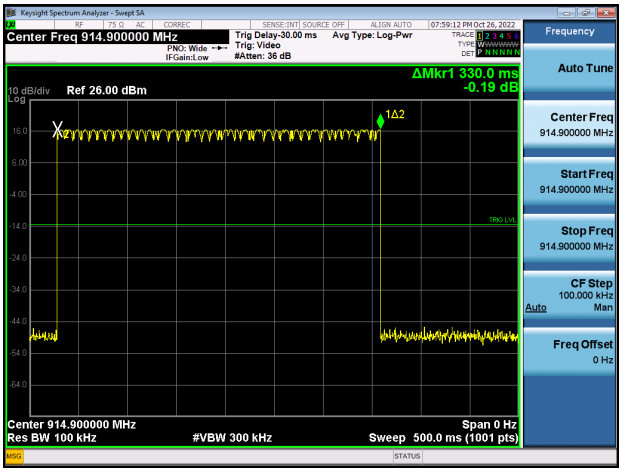
Time of Occupancy (902.3 MHz) : SF10



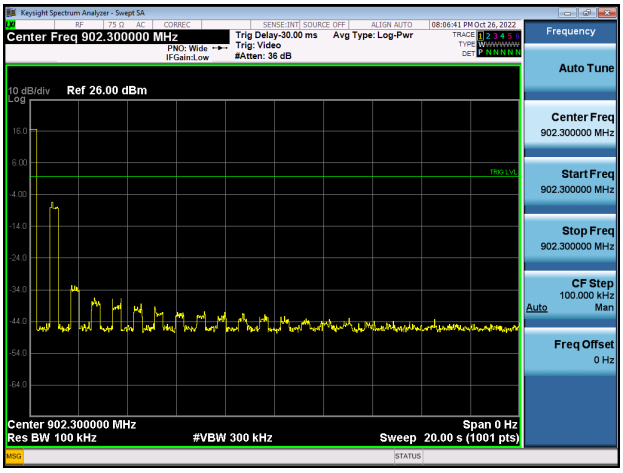
Time of Occupancy (908.5 MHz) : SF10



Time of Occupancy (914.9 MHz) : SF10



No. of hops / channel in 20 sec (SF10) : 1



9.6. CONDUCTED BAND EDGE & SPURIOUS EMISSIONS

Out of Band Emissions at the Band Edge : Non-Hopping Mode

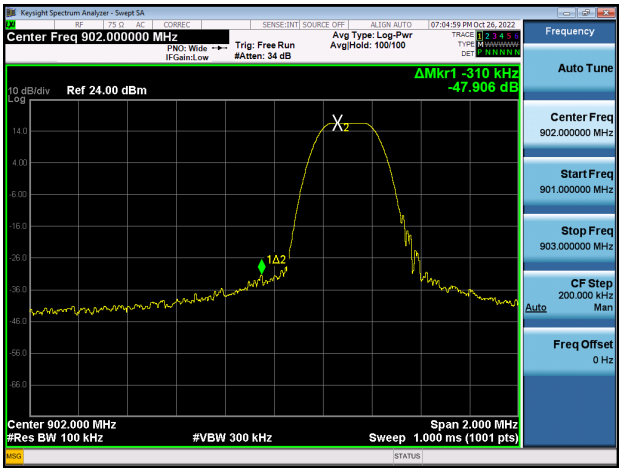
LoRa (125 kHz) : SF10			Test Result		
Frequency [MHz]	Channel	Position	Measured Level [dB]	Limit [dBc]	Result
902.3	0	Low	47.906	≥ 20	Compliant
914.9	63	High	62.426	≥ 20	Compliant

Out of Band Emissions at the Band Edge : Hopping Mode

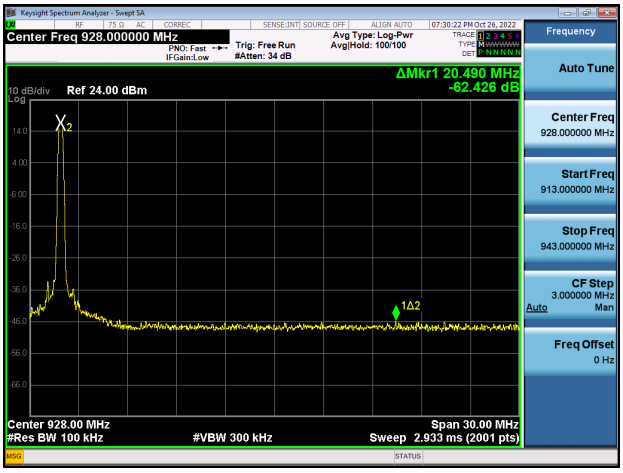
LoRa (125 kHz) : SF10		Test Result		
Frequency [MHz]	Position	Measured Level [dB]	Limit [dBc]	Result
Hopping (902.3 MHz – 914.9 MHz)	Low	50.351	≥ 20	Compliant
Hopping (902.3 MHz – 914.9 MHz)	High	62.013	≥ 20	Compliant

▣ TEST PLOTS

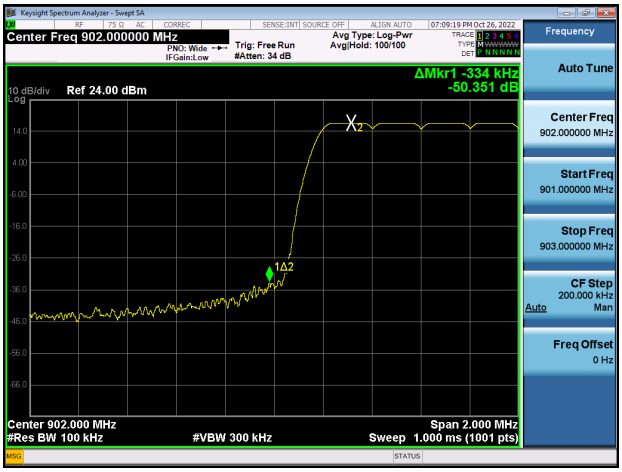
Low Band Edge (902.3 MHz) : SF10



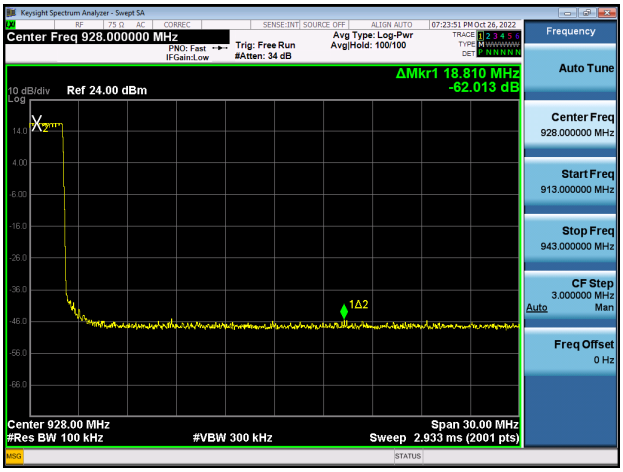
High Band Edge (914.9 MHz) : SF10



Low Band Edge (Hopping) : SF10



High Band Edge (Hopping) : SF10

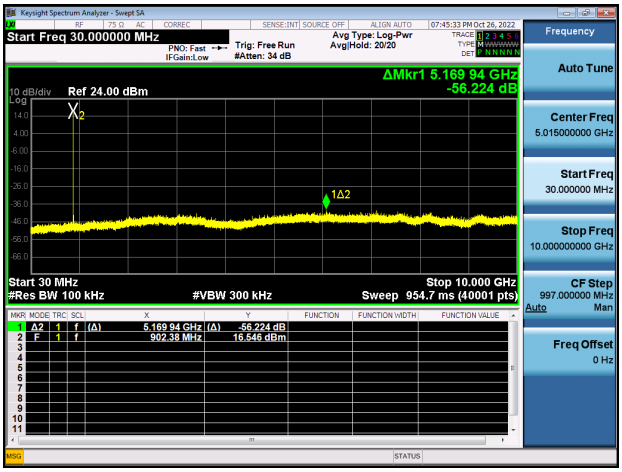


Conducted Spurious Emissions

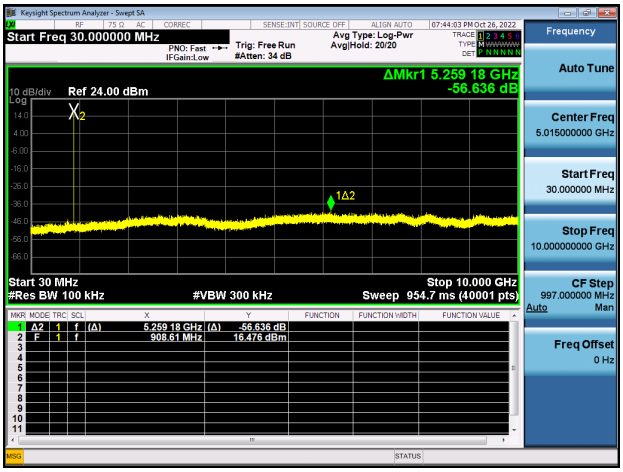
LoRa (125 kHz) : SF10			Test Result		
Frequency [MHz]	Channel	Position	Measured Level [dB]	Limit [dBc]	Result
902.3	0	Low	56.224	≥ 20	Compliant
908.5	31	Middle	56.636	≥ 20	Compliant
914.9	63	High	56.720	≥ 20	Compliant

▣ TEST PLOTS

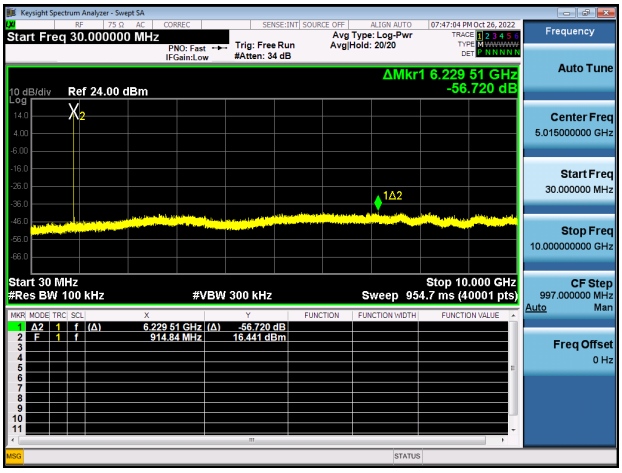
CSE 30 MHz – 10 GHz (902.3 MHz) : SF10



CSE 30 MHz – 10 GHz (908.5 MHz) : SF10



CSE 30 MHz – 10 GHz (914.9 MHz) : SF10



9.7. RADIATED SPURIOUS EMISSIONS

Frequency Range : Below 1 GHz

Test Mode LoRa (125 kHz) : TX mode
Operating Frequency 902.3 MHz (CH 0)

Frequency (MHz)	Polarization	Reading (dBuV)	Corr.[1] (dB)	Total (dBuV/m)	Limit (dBuV/m)	Margin (dB)	Measurement Type
No peak found							

Test Mode LoRa (125 kHz) : TX mode
Operating Frequency 908.5 MHz (CH 31)

Frequency (MHz)	Polarization	Reading (dBuV)	Corr.[1] (dB)	Total (dBuV/m)	Limit (dBuV/m)	Margin (dB)	Measurement Type
No peak found							

Test Mode LoRa (125 kHz) : TX mode
Operating Frequency 914.9 MHz (CH 63)

Frequency (MHz)	Polarization	Reading (dBuV)	Corr.[1] (dB)	Total (dBuV/m)	Limit (dBuV/m)	Margin (dB)	Measurement Type
No peak found							

Note :
1. Correction Factor: Antenna Factor + Cable loss + Preamplifier Gain.

Frequency Range : Above 1 GHz

Test Mode LoRa (125 kHz) : TX mode

Operating Frequency 902.3 MHz (CH 0)

Frequency (MHz)	Polarization	Reading (dBuV)		Factor (dB)		Level (dBuV/m)		Limit (dBuV/m)		Margin (dB)	
		AV	PK	Corr.[1)]	Duty	AV	PK	AV	PK	AV	PK
1804.597	H	54.7	57.3	-12.4	-	42.3	44.9	54	74	11.7	29.1
1804.617	V	52.1	55.1	-12.4	-	39.7	42.7	54	74	14.3	31.3
2706.909	V	53.8	56.8	-10.3	-	43.5	46.5	54	74	10.5	27.5
2706.933	H	56.7	59.4	-10.3	-	46.4	49.1	54	74	7.6	24.9
3609.218	V	50.6	54.9	-8.4	-	42.2	46.5	54	74	11.8	27.5
3609.234	H	55.2	58.1	-8.4	-	46.8	49.7	54	74	7.2	24.3
5413.792	H	50.4	54.2	-4.1	-	46.3	50.1	54	74	7.7	23.9
5413.835	V	46	51.4	-4.1	-	41.9	47.3	54	74	12.1	26.7
7218.403	V	44.7	50.5	-0.6	-	44.1	49.9	54	74	9.9	24.1
7218.473	H	46.5	51.9	-0.6	-	45.9	51.3	54	74	8.1	22.7
9023.033	H	40.2	48.0	2.4	-	42.6	50.4	54	74	11.4	23.6
9023.065	V	40.9	48.2	2.4	-	43.3	50.6	54	74	10.7	23.4
9925.276	H	41.2	49.4	1.9	-	43.1	51.3	54	74	10.9	22.7

Test Mode LoRa (125 kHz) : TX mode

Operating Frequency 908.5 MHz (CH 31)

Frequency (MHz)	Polarization	Reading (dBuV)		Factor (dB)		Level (dBuV/m)		Limit (dBuV/m)		Margin (dB)	
		AV	PK	Corr.[1)]	Duty	AV	PK	AV	PK	AV	PK
1816.981	V	51.1	54.6	-12.4	-	38.7	42.2	54	74	15.3	31.8
1816.998	H	58.1	59.8	-12.4	-	45.7	47.4	54	74	8.3	26.6
2725.505	V	52.5	55.6	-10.4	-	42.1	45.2	54	74	11.9	28.8
2725.513	H	57.1	59.1	-10.4	-	46.7	48.7	54	74	7.3	25.3
3634.010	H	55.3	58.0	-8.4	-	46.9	49.6	54	74	7.1	24.4
4542.524	H	48.6	53.6	-6.9	-	41.7	46.7	54	74	12.3	27.3
5450.986	H	49.5	53.9	-4.0	-	45.5	49.9	54	74	8.5	24.1
7268.023	H	45.5	51.4	-0.5	-	45.0	50.9	54	74	9.0	23.1
7268.063	V	45.6	51.1	-0.5	-	45.1	50.6	54	74	8.9	23.4
9084.987	V	40.9	48.1	2.4	-	43.3	50.5	54	74	10.7	23.5
9085.078	H	40.6	47.9	2.4	-	43.0	50.3	54	74	11.0	23.7

Note :

1. Correction Factor = Antenna Factor + Cable loss + Preamplifier Gain

Test Mode LoRa (125 kHz) : TX mode

Operating Frequency 914.9 MHz (CH 63)

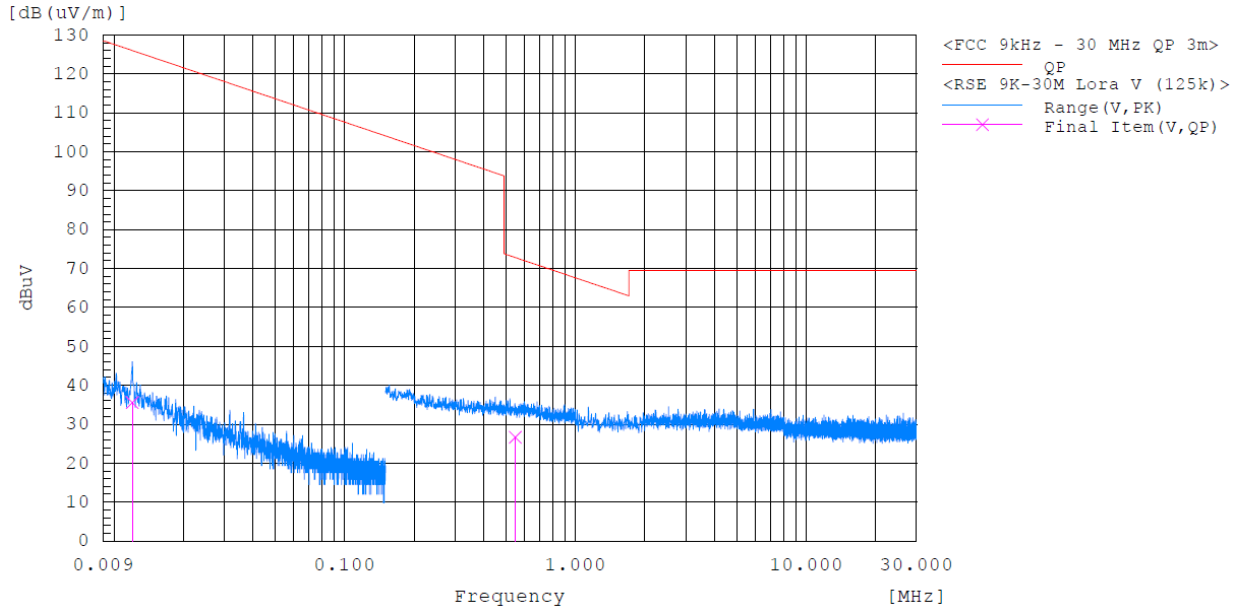
Frequency (MHz)	Polarization	Reading (dBuV)		Factor (dB)		Level (dBuV/m)		Limit (dBuV/m)		Margin (dB)	
		AV	PK	Corr.[1)]	Duty	AV	PK	AV	PK	AV	PK
1829.789	H	58.1	59.7	-12.4	-	45.7	47.3	54	74	8.3	26.7
1829.820	V	51.8	55.2	-12.4	-	39.4	42.8	54	74	14.6	31.2
2744.711	V	52.5	55.4	-10.5	-	42.0	44.9	54	74	12.0	29.1
2744.734	H	56.7	58.8	-10.5	-	46.2	48.3	54	74	7.8	25.7
3659.635	H	55	57.8	-8.3	-	46.7	49.5	54	74	7.3	24.5
3659.635	V	46.7	52.1	-8.3	-	38.4	43.8	54	74	15.6	30.2
5489.437	H	49.2	53.6	-3.9	-	45.3	49.7	54	74	8.7	24.3
7319.184	H	47.3	52.6	-0.3	-	47.0	52.3	54	74	7.0	21.7
7319.217	V	46.6	51.8	-0.3	-	46.3	51.5	54	74	7.7	22.5
9148.990	H	39.9	47.7	2.2	-	42.1	49.9	54	74	11.9	24.1
9149.051	V	42.4	49.3	2.2	-	44.6	51.5	54	74	9.4	22.5

Note :

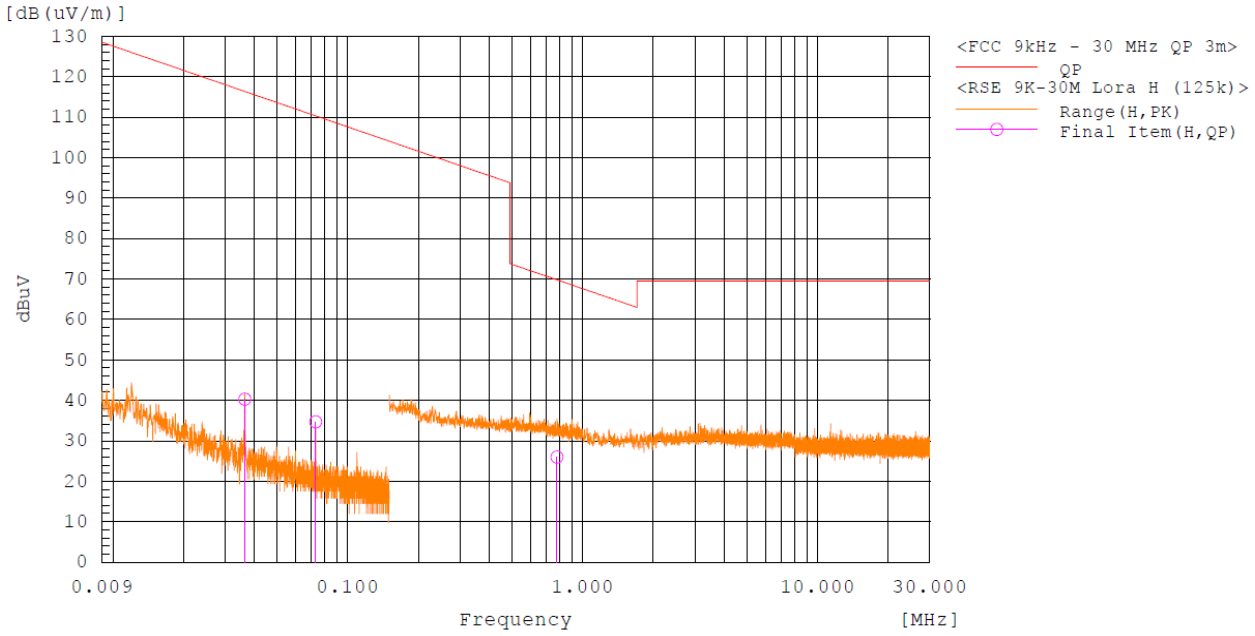
1. Correction Factor = Antenna Factor + Cable loss + Preamplifier Gain

▣ TEST PLOTS

Radiated Spurious Emission 9 kHz – 30 MHz (Antenna Position 90°) : 914.9 MHz (125k) - SF10



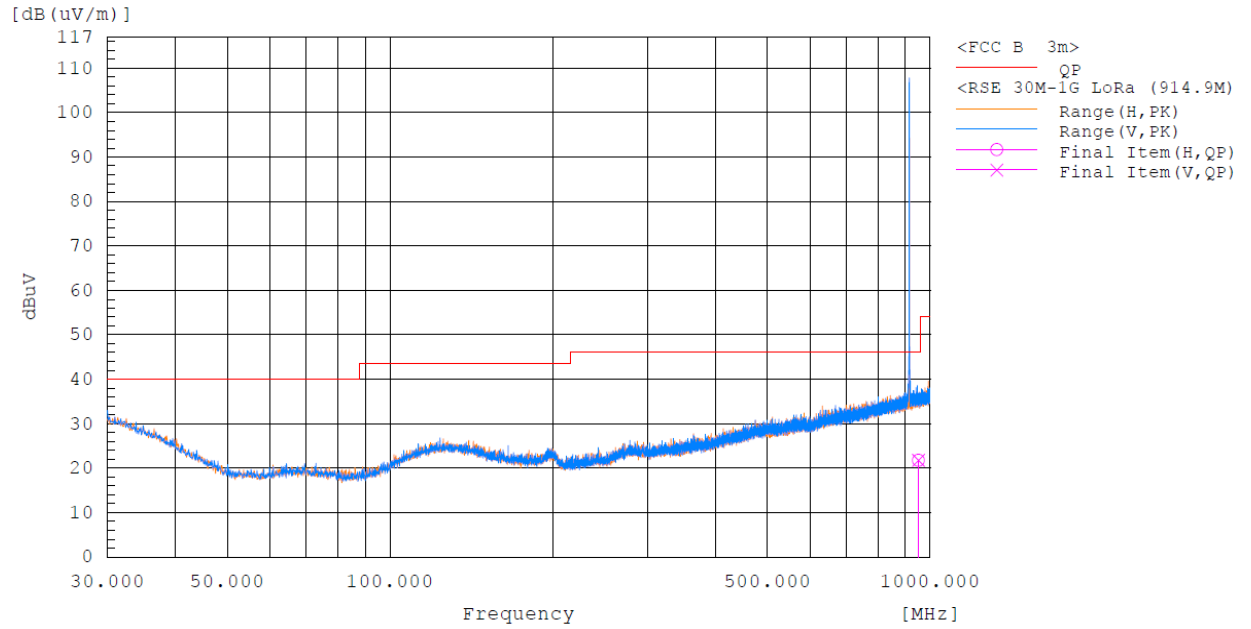
Radiated Spurious Emission 9 kHz – 30 MHz (Antenna Position 180°) : 914.9 MHz (125k) - SF10



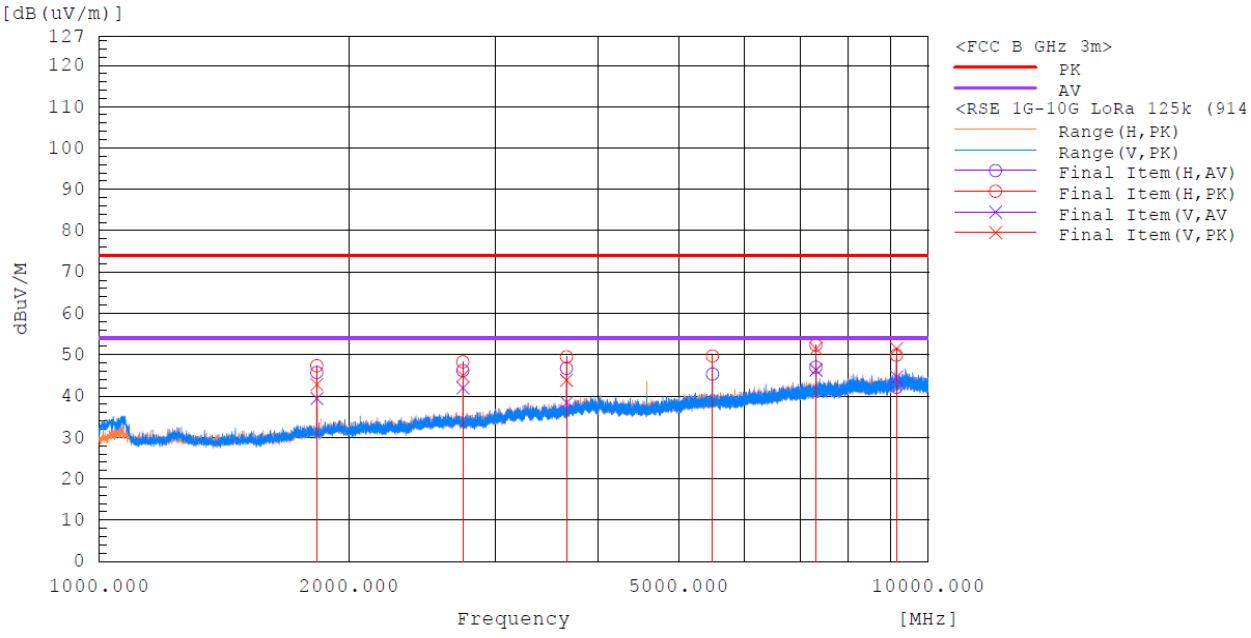
Note :
The worst-case plots are included in this report.

▣ TEST PLOTS

Radiated Spurious Emission 30 MHz – 1 GHz : 914.9 MHz (125k) - SF10



Radiated Spurious Emission 1 GHz – 10 GHz : 914.9 MHz (125k) - SF10



Note :
The worst-case plots are included in this report.

9.8. RECEIVER SPURIOUS EMISSION

Test Mode	LoRa (125 kHz) : RX mode
Operating Frequency	914.9 MHz (CH 63)

Frequency Range : Below 1 GHz

Frequency (MHz)	Polarization	Reading (dBuV)	Corr. [1)] (dB)	Level (dBuV/m)	Limit (dBuV/m)	Margin (dB)	Measurement Type
No peak found							

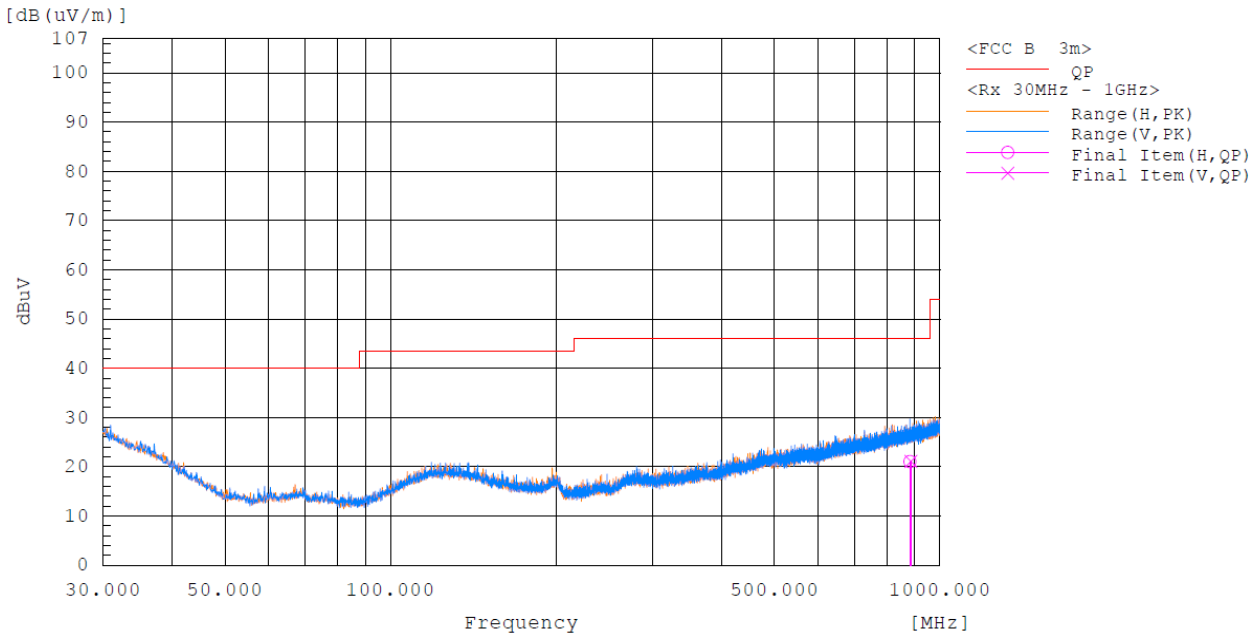
Frequency Range : Above 1 GHz

Frequency (MHz)	Polarization	Reading (dBuV)	Corr. [1)] (dB)	Level (dBuV/m)	Limit (dBuV/m)	Margin (dB)	Measurement Type
No peak found							

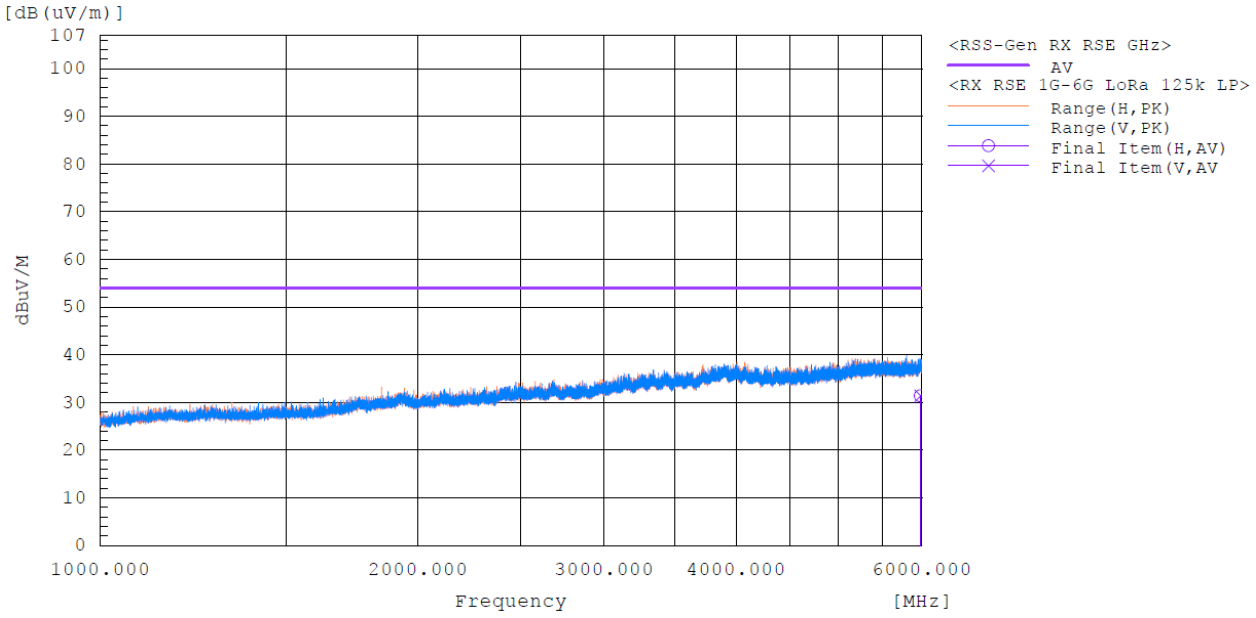
Note:
1. Correction Factor: Antenna Factor + Cable loss + Preamplifier Gain
2. The test was conducted in the worst case mode.

▣ TEST PLOTS

Receiver Spurious Emission below 1 GHz : 914.9 MHz (125k) - SF10



Receiver Spurious Emission above 1 GHz : 914.9 MHz (125k) - SF10



Note :
The worst-case plots are included in this report.

10. LIST OF TEST EQUIPMENT

No.	Instrument	Model No.	Calibration Due (mm/dd/yy)	Manufacture	Serial No.
☒	Signal Analyzer (20 Hz ~ 40.0 GHz)	ESU40	12/03/2022	Rohde & Schwarz	100529
☒	Signal Analyzer (1 Hz ~ 40.0 GHz)	ESW44	10/25/2023	Rohde & Schwarz	102015
☒	Signal Analyzer (10 Hz ~ 26.5 GHz)	N9020A	11/04/2022	Keysight	MY52091291
☐	Attenuator (20 dB, DC ~ 26.5 GHz)	CFADC262002	01/13/2023	CERNEX	-
☒	Attenuator (10 dB, DC ~ 26.5 GHz)	CFADC261002	01/13/2023	CERNEX	-
☒	Loop Antenna (0.009 ~ 30 MHz)	HLA 6121	09/15/2023	TESEQ	43964
☒	BI-LOG Antenna (30 MHz ~ 2 GHz)	JB1	04/16/2023	Sunol	A061416
☒	LNA (30 MHz ~ 1GHz)	PAM-103	04/14/2023	Com-Power	18020254
☒	Horn Antenna (1 GHz ~ 18 GHz)	DRH-118	01/28/2023	Sunol	A061616
☒	LNA (1 GHz ~ 18 GHz)	PAM-118A	06/21/2023	Com-Power	18040074
☐	Horn Antenna (18 GHz ~ 40 GHz)	DRH-1840	02/16/2023	Sunol	17121
☐	LNA (18 GHz ~ 40 GHz)	CBL18405045-01	02/10/2023	CERNEX, Inc.	27973
☒	High Pass Filter (1 GHz)	WHK1X12-900-1000-15000-60SS	08/26/2023	Wainwright	13
☐	EMI Test Receiver	ESR3	12/03/2022	Rohde & Schwarz	102363
☐	LISN	ENV216	01/19/2023	Rohde & Schwarz	101349

Note :

1. All the equipment listed above was properly calibrated before using for the test. Any equipment which is past due on calibration is used after calibration is completed or the equipment is used before calibration due.

ANNEX A. TEST SETUP PHOTOS

The setup photos are provided as a separate document.

ANNEX B. PHOTOGRAPHS OF EUT

B.1. EXTERNAL PHOTOS

The external photos are provided as a separate document.

B.2. INTERNAL PHOTOS

The internal photos are provided as a separate document.

END OF TEST REPORT

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