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Zephyr BioModule LoRa Transceiver including Bluetooth

tested to the

47 Code of Federal Regulations

Part 15 - Radio Frequency Devices

Subpart C – Intentional Radiators

Section 15.247 - Operation in the band 902 – 928 MHz

for

Lune Digital Ltd

This Test Report is issued with the authority of:

A handwritten signature in black ink, appearing to read "Andrew Cutler", is shown on a light blue background.

Andrew Cutler - General Manager



All tests reported
herein have been
performed in accordance
with the laboratory's
scope of accreditation

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EMC
Technologies

1. COMPLIANCE STATEMENT

The **Zephyr BioModule LoRa Transceiver including Bluetooth** complies with FCC Part 15 Section 15.247 as an Intentional Radiator when the methods as described in ANSI C63.10 - 2013 are applied.

2. RESULT SUMMARY

The results of testing carried out in March 2021 are summarised below.

Clause	Parameter	Result
15.201	Equipment authorisation requirement	Certification of this transmitter is required.
15.203	Antenna requirement	Not applicable. Antennas are integral to the devices.
15.204	External PA and antenna modifications	Noted.
15.205	Restricted bands of operation	Complies.
15.207	Conducted limits	Not applicable. Internal battery powered device
15.209	Radiated emission limits	Complies
15.247		
(a)(1)	Hopping channel separation	Complies
(a)(1)(i)(iii)	Channel occupancy / Bandwidth	Complies
(b)(1)(2)	Peak output power	Complies
(b)(4)	Antenna gain less than 6 dBi	Not applicable. Antennas are integral.
(d)	Out of band emissions	Complies
(e)	Spectral density	Complies
(f)	Hybrid Systems	Complies
(g)	Use of all channels	Not applicable
(h)	Intelligent frequency hopping	Not applicable
(i)	Radio frequency hazards	Complies

3. ATTESTATION

This report describes the tests and measurements performed for the purpose of determining compliance with the specification with the following conditions:

The client selected the test sample.

The report relates only to the sample tested.

This report does not contain corrections or erasures.

Measurement uncertainties with statistical confidence intervals of 95% are shown below test results. Both Class A and Class B uncertainties have been accounted for, as well as influence uncertainties where appropriate.

In addition this equipment has been tested in accordance with the requirements contained in the appropriate Commission regulations.

All compliance statements have been made with respect of the specification limit with no reference to the measurement uncertainty.

To the best of my knowledge, these tests were performed using measurement procedures that are consistent with industry or Commission standards and demonstrate that the equipment complies with the appropriate standards.

I further certify that the necessary measurements were made by EMC Technologies NZ Ltd, 47 MacKelvie Street, Grey Lynn, Auckland, New Zealand.



Andrew Cutler
General Manager
EMC Technologies NZ Ltd

4. CLIENT INFORMATION

Company Name Lune Digital Ltd

Address 11C Corban Avenue
Henderson

City Auckland 0612

Country New Zealand

Contact Mr Stephen Fellner

5. TEST SAMPLE DESCRIPTION

Brand Name Zephyr

Model Number BioModule

Product LoRa Transceiver including Bluetooth.

Manufacturer Zephyr Technologies Ltd

Designed in New Zealand / United States

Serial Number Sample not serialised

The device tested is a LoRa device that operates using as a 900 MHz Frequency Hopping Spread Spectrum Transceiver that operates in the 902 - 928 MHz band.

The device operates as a Hybrid device where by a digital device hops over a limited number of channels using LoRa operating principles.

While the LoRa device can operate between 902 – 928 MHz using 128 channels the device would typically operate using LoRa principle in blocks of 8 channels.

A FCC LoRa certified module has been utilised which has FCC ID: 2AZSMKF82J

In addition a Bluetooth FCC certified module has been utilised which has FCC ID: T7V1316

The certified modules have both been installed in-accordance with the module supplier's installation instructions.

Verification testing has been carried out as during the development process high levels of harmonic emissions were detected from the LoRa device and also to ensure that the LoRa device and the Bluetooth module can operate simultaneously.

The device tested had the following specifications:

Transmitter Conducted Output Power (Measured)

LoRa: 0.0049 Watts (+6.9 dBm)
Bluetooth: 0.0041 Watts (+6.1 dBm)

FCC Band:

LoRa: 902 - 928 MHz
Bluetooth: 2402 – 2480 MHz

Channel Spacing:

LoRa: 200 kHz
Bluetooth: 100 kHz

Modes of operation:

LoRa operating principles
Bluetooth Low Energy

Test frequencies / No of channels etc

LoRa device testing has been carried out as follows:

125 channels between 902.300 – 927.700 MHz

8 channels between 902.300 - 903.700 MHz

8 channels between 922.000 – 923.700 MHz

Specific LoRa device tests were also carried out on the following discrete frequencies:

902.300 MHz, 915.000 MHz, 927.700 MHz

Specific testing was not carried out on the Bluetooth device but it was configured to advertise continually on the following channels:

2402 MHz, 2426 MHz, 2480 MHz

Power Supply

Internal 3 Vdc device battery

6. TEST RESULTS

Standard

The sample was tested in accordance with 47 CFR Part 15 Subpart C and in particular section 15.247

Methods and Procedures

The following measurement methods and procedures have been applied:

- ANSI C63.10 – 2013

Section 15.201: Equipment authorisation requirement

Certification as detailed in Subpart J of Part 2 is required for this device.

Section 15.203: Antenna requirement

This device uses an internal integral antenna that cannot be modified

Result: Complies

Section 15.204: External radio frequency power amplifiers and antenna modifications

The device is NOT supplied with an external power amplifier and the user manual defines the types of antennas that can be used with this device.

Result: Complies.

Section 15.205: Restricted bands of operation

The device tested can operate between 902 - 928 MHz and 2400 – 2483.5 Mhz

The requirements of the restricted bands have been noted

Result: Complies.

Section 15.247(f) – Hybrid Systems

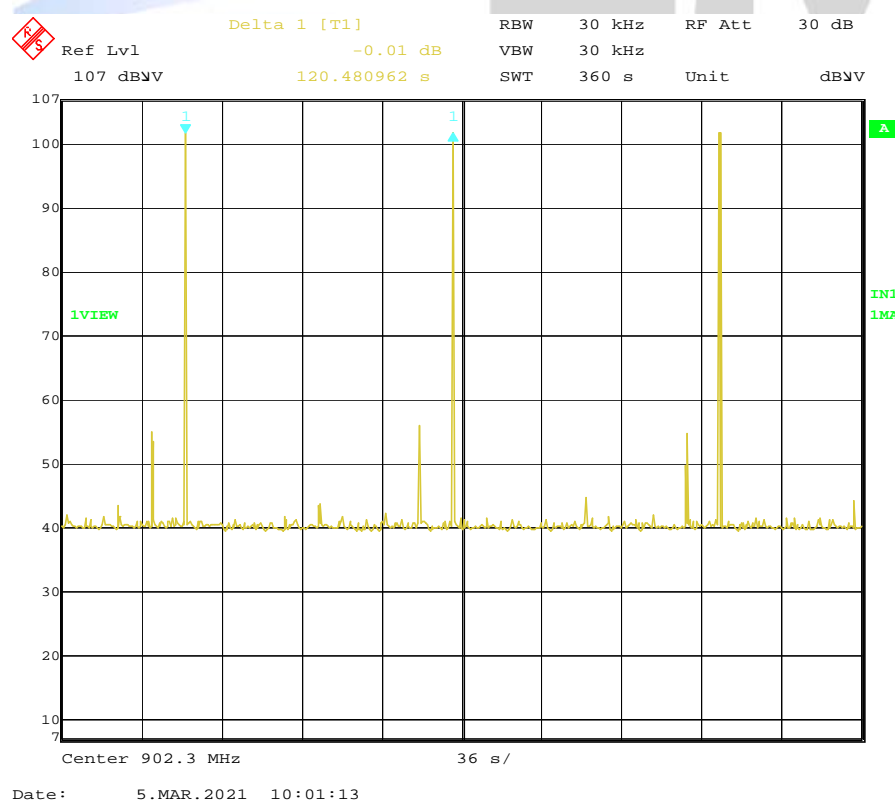
The results are summarised as follows:

Parameter	Limit	Observation
Number of channels	No minimum specified	Can operate with up to 128 channels but typically 8 channels
20 dB bandwidth	Less than the channel spacing	A bandwidth of 166.3 kHz was measured
Hop interval	Greater than 20 dB bandwidth	A 200 kHz hop interval was measured.
Dwell time	Not to exceed 400 ms	A 372 ms dwell time was measured
Channel Transmit Period	-	Transmitter observed to transmit every 120 seconds

This device operates a Hybrid Device that uses a combination of a Frequency Hopping Spread Spectrum device and a Digital Modulation transmitter in the 902 - 928 MHz band that operates over a limited number of channels.

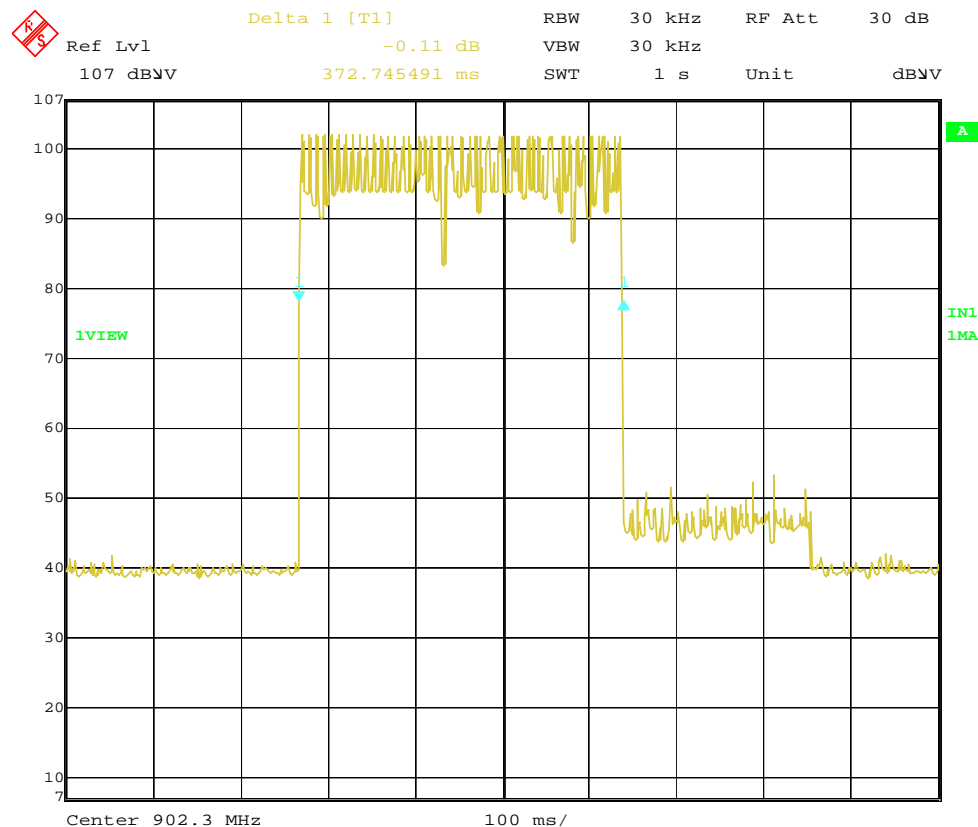
Typically the device would periodically hop using 8 channels upon demand using LoRa operating principles.

The transmitter was observed to operate on a discrete channel once every 120 seconds when operating with 8 channels.

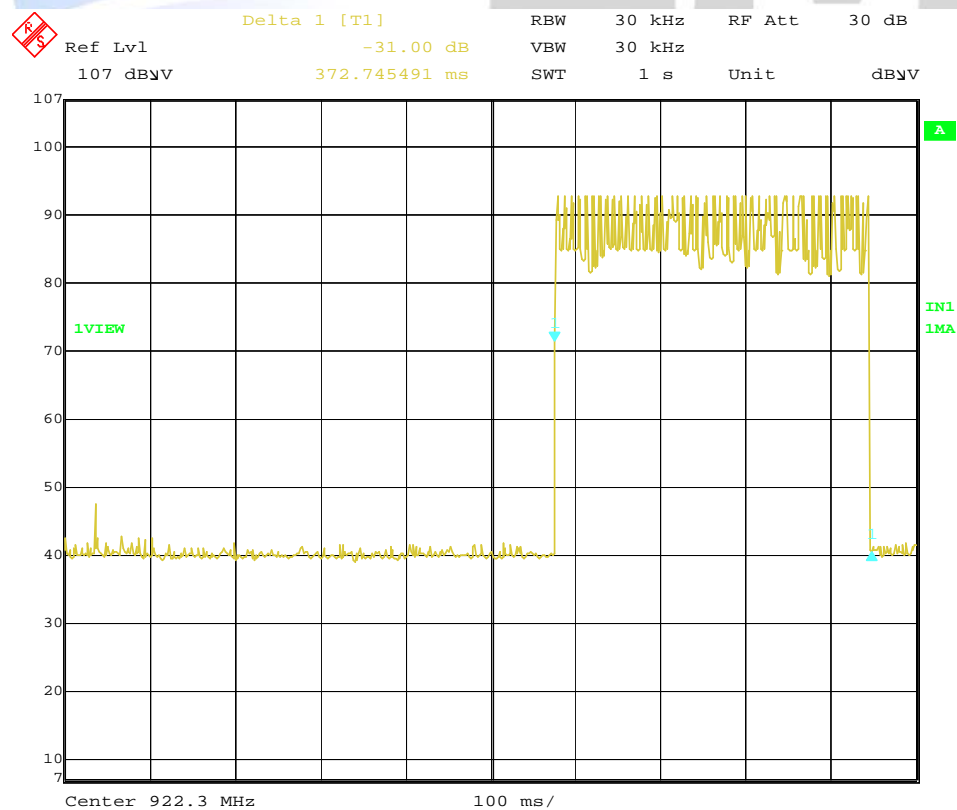


If operating with 8 channels the time between transmissions should be greater than 0.4 seconds x 8 or 128 channels = 3.2 seconds or 51.2 seconds

In frequency hopping mode the device was observed to have a dwell time of 372 ms which is less than the maximum dwell time of 400 ms



Date: 5.MAR.2021 10:03:36

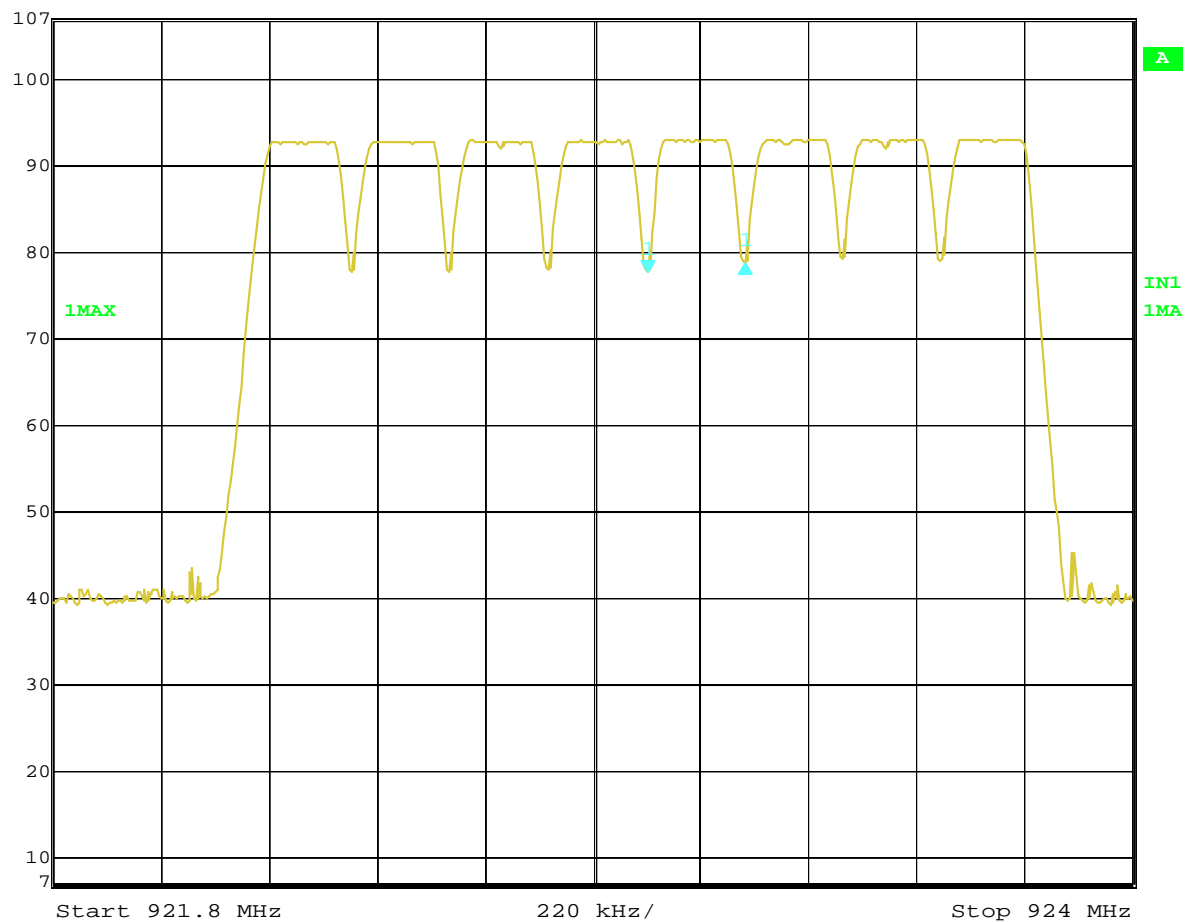


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The device was observed to have a hop channel interval of 200 kHz as observed below.



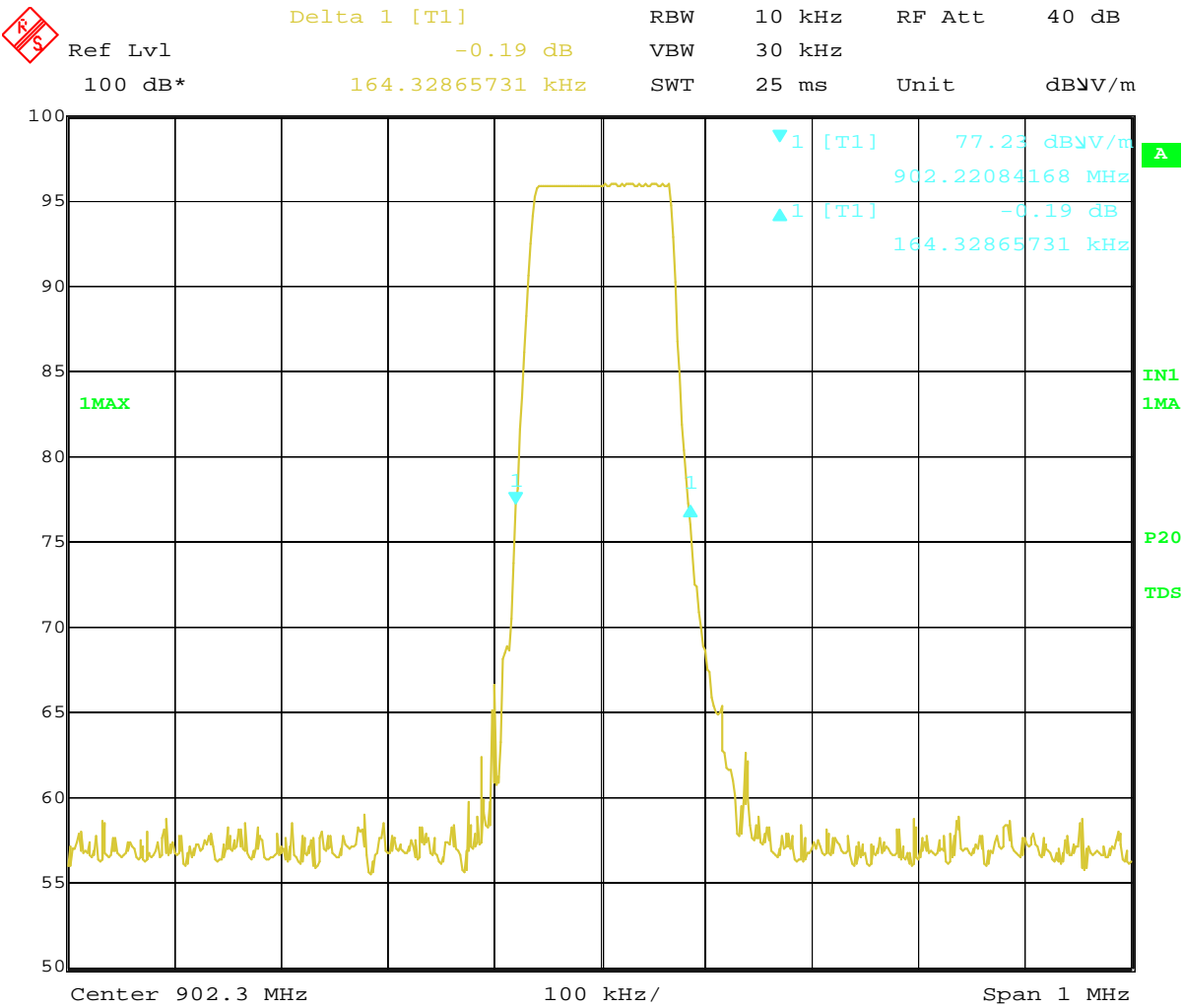
Ref Lvl	Delta 1 [T1]	RBW	30 kHz	RF Att	30 dB
107 dBμV	0.95 dB	VBW	30 kHz		
	198.39679359 kHz	SWT	6.5 ms	Unit	dBμV



Date: 5.MAR.2021 11:04:07

The -20 dB bandwidth has been determined below.

902.300 MHz – 164.3 kHz



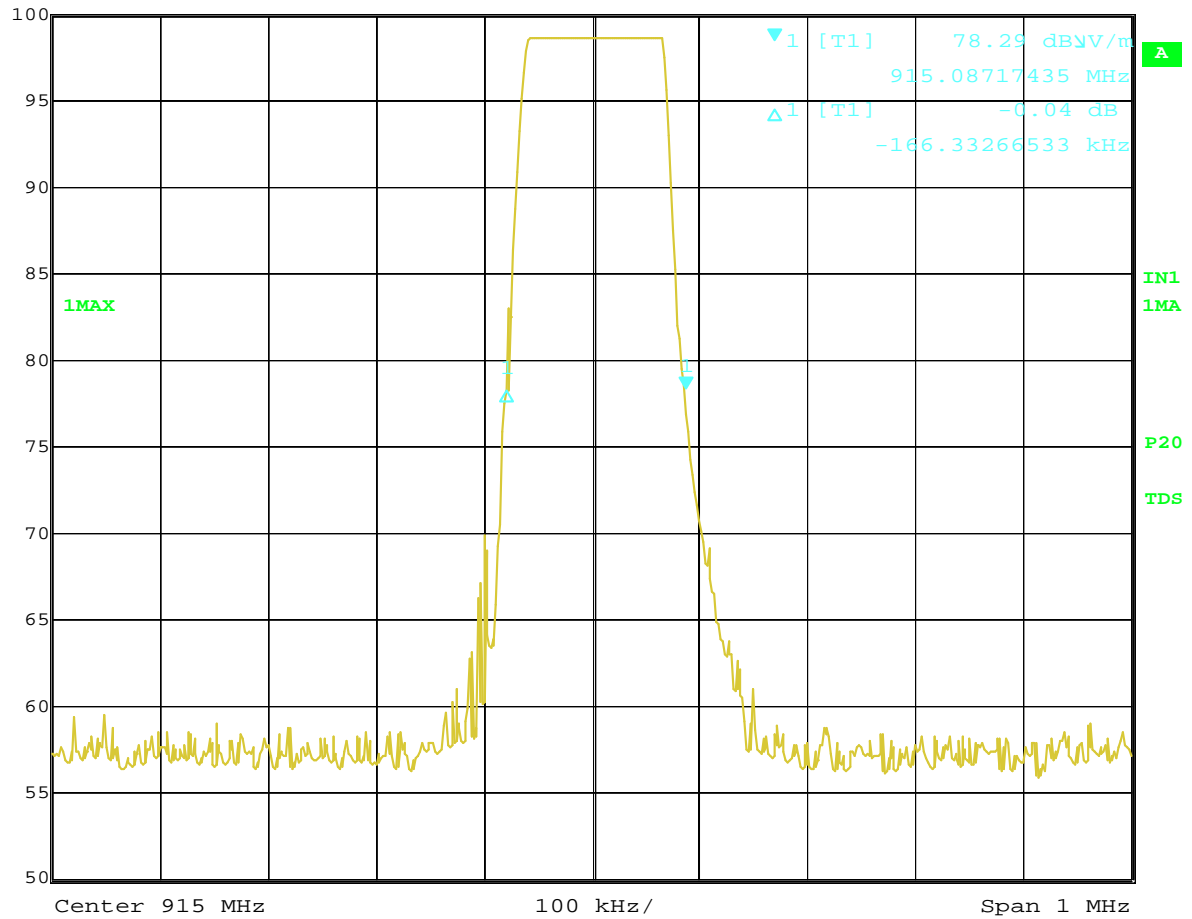
Date: 1.JAN.1997 03:00:00

-20 dBc bandwidth

915.000 MHz – 166.3 kHz




Marker 1 [T1] RBW 10 kHz RF Att 40 dB
Ref Lvl 78.29 dBV/m VBW 30 kHz
100 dB* 915.08717435 MHz SWT 25 ms Unit dBV/m

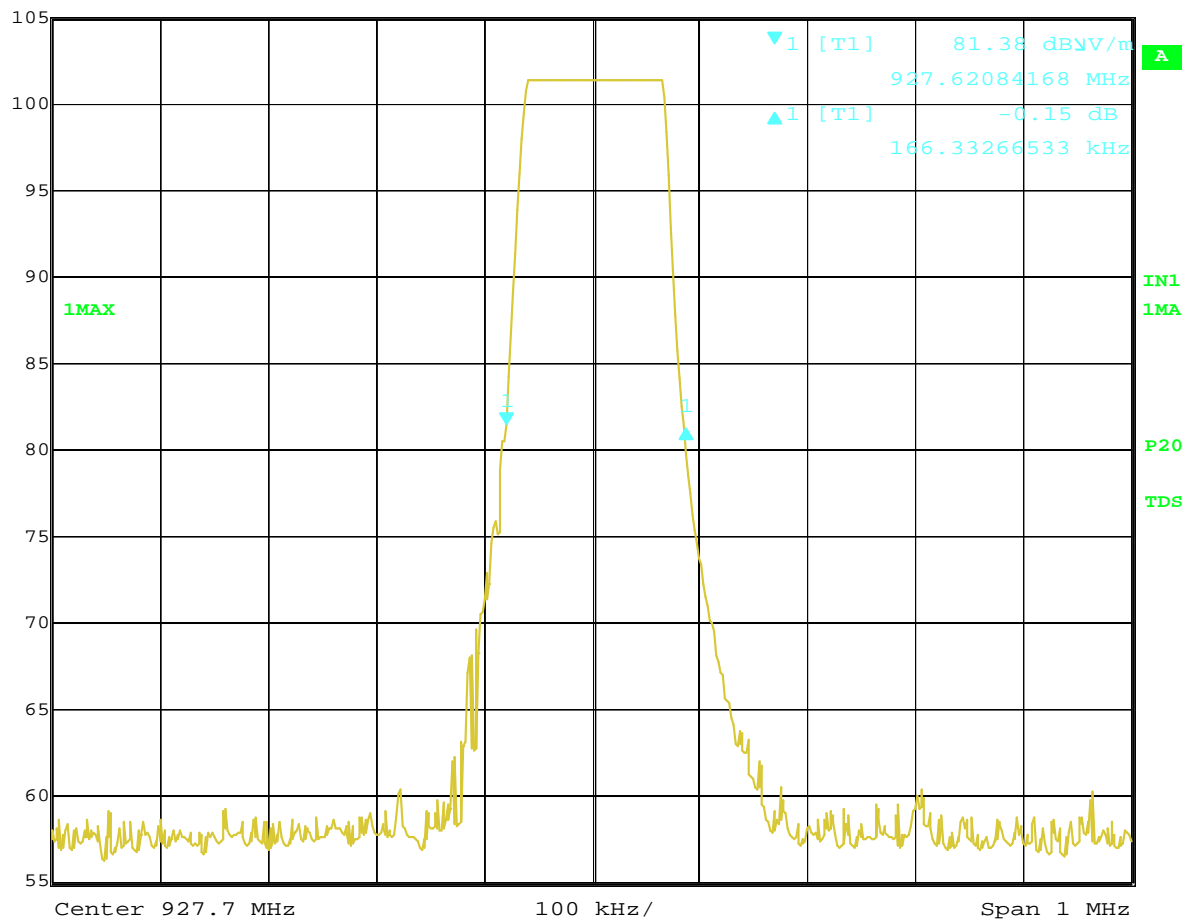


Date: 1.JAN.1997 02:56:22

-20 dB bandwidth

927.700 MHz – 166.3 kHz

	Ref Lvl	Delta 1 [T1]	RBW	10 kHz	RF Att	40 dB
	105 dB*	-0.15 dB	VBW	30 kHz		
		166.33266533 kHz	SWT	25 ms	Unit	dBV/m



Date: 1.JAN.1997 02:50:26

Section 15.247(b) (1) + (2) – Peak output power

Conducted Power

As the LoRa device and the Bluetooth Device operate using integral antennas testing was carried out to confirm the maximum radiated power from each transmitter which was then compared against the FCC conducted limit.

Radiated measurements were made on a low, middle and high frequency at the test site.

Measurements were made using a measuring receiver using a peak detector with a 1 MHz bandwidth.

LoRa Device

Axis	Frequency (MHz)	Level (dBuV/m)	Level (dBm)	Limit (dBm)	Polarity	Margin (dB)	Result
X	902.300	96.4	1.2	30.0	Horizontal	28.8	Pass
Y	902.300	97.5	2.3	30.0	Horizontal	27.7	Pass
Z	902.300	97.4	2.2	30.0	Vertical	27.8	Pass
X	915.000	96.0	0.8	30.0	Horizontal	29.2	Pass
Y	915.000	99.3	4.1	30.0	Horizontal	25.9	Pass
Z	915.000	99.2	4.0	30.0	Vertical	26.0	Pass
X	927.700	99.5	4.3	30.0	Horizontal	25.7	Pass
Y	927.700	102.1	6.9	30.0	Horizontal	23.1	Pass
Z	927.700	98.6	3.4	30.0	Vertical	26.6	Pass

Bluetooth Device

Axis	Frequency (MHz)	Level (dBuV/m)	Level (dBm)	Limit (dBm)	Polarity	Margin (dB)	Result
Y	2402.000	95.5	0.3	30.0	Horizontal	31.9	Pass
Y	2426.000	93.9	-1.3	30.0	Horizontal	33.5	Pass
Y	2480.000	101.3	6.1	30.0	Horizontal	26.1	Pass

A conducted power limit of 1 watt (+30 dBm) is specified for this device

Result: Complies.

Measurement Uncertainty: ± 2.1 dB

Section 15.247 (d) – Out of band emissions

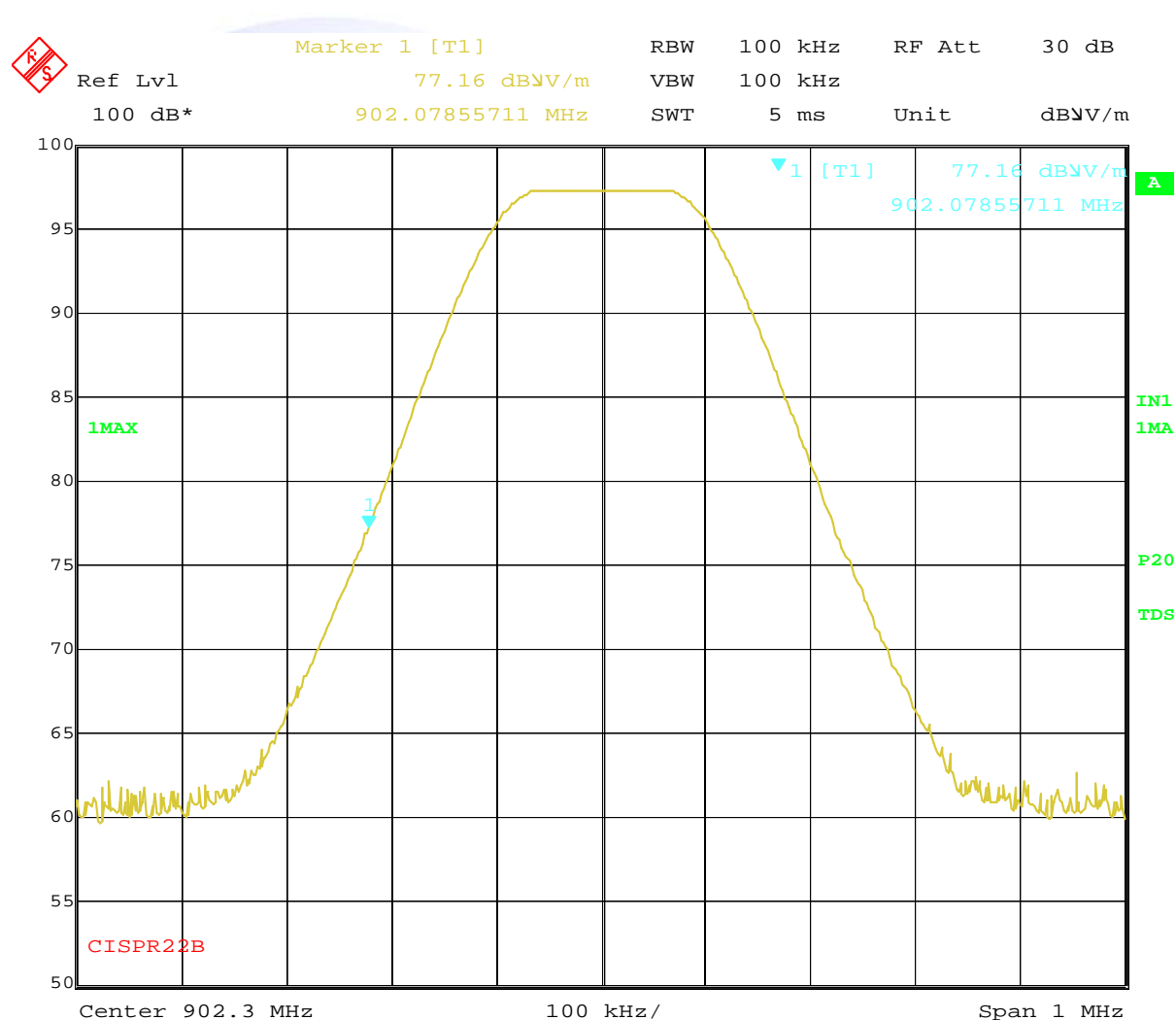
Band edge measurements:

Measurements were made on the LoRa device but not the Bluetooth device.

At the band edges of 902 and 928 MHz all emissions are required to be attenuated by more than 20 dB relative to the highest 100 kHz resolution bandwidth emission level observed in the band of operation.

Relative measurements were made when the device was operating on 902.300 MHz and 927.700 MHz

902.300 MHz band edge is 902.078 MHz

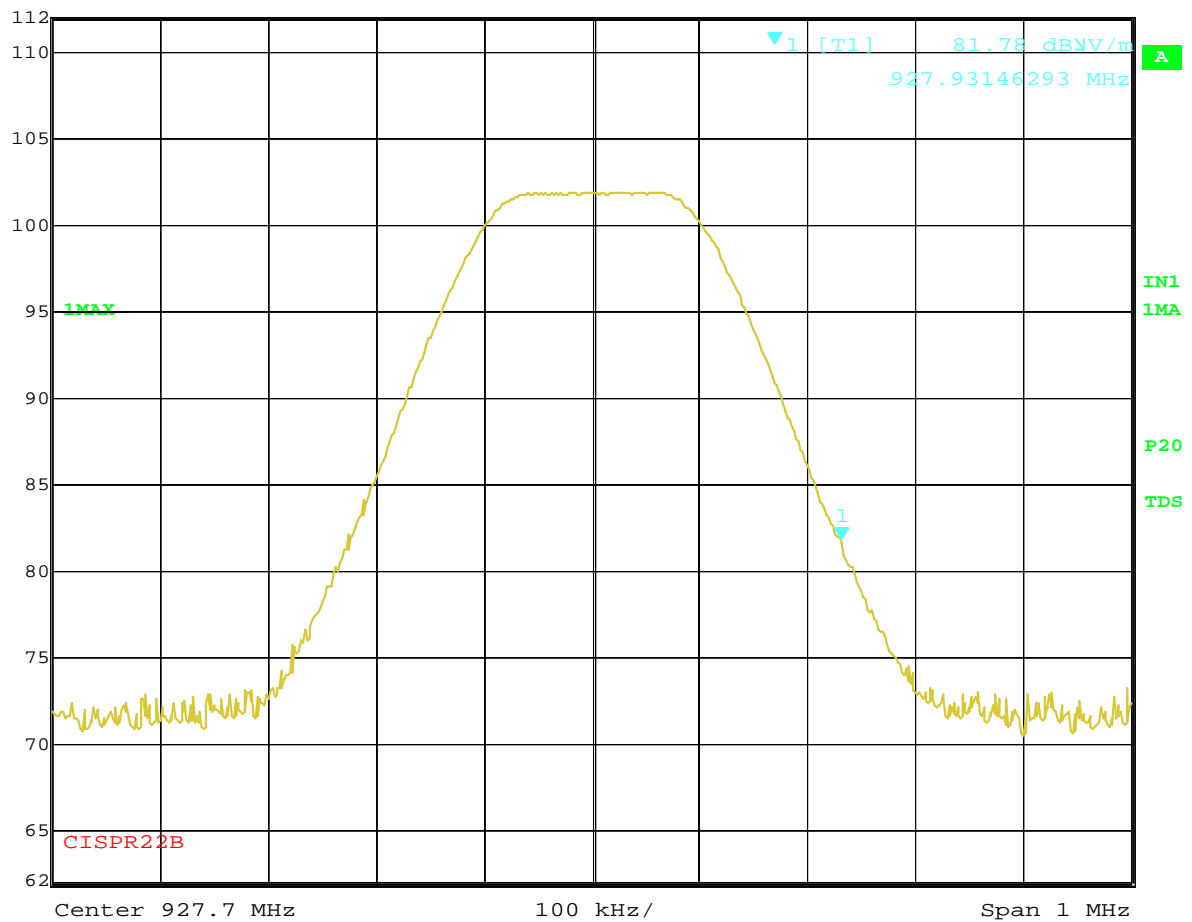


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927.700 MHz band edge is 927.931 MHz



Marker 1 [T1] RBW 100 kHz RF Att 40 dB
Ref Lvl 81.78 dBV/m VBW 100 kHz
112 dB* 927.93146293 MHz SWT 5 ms Unit dBV/m

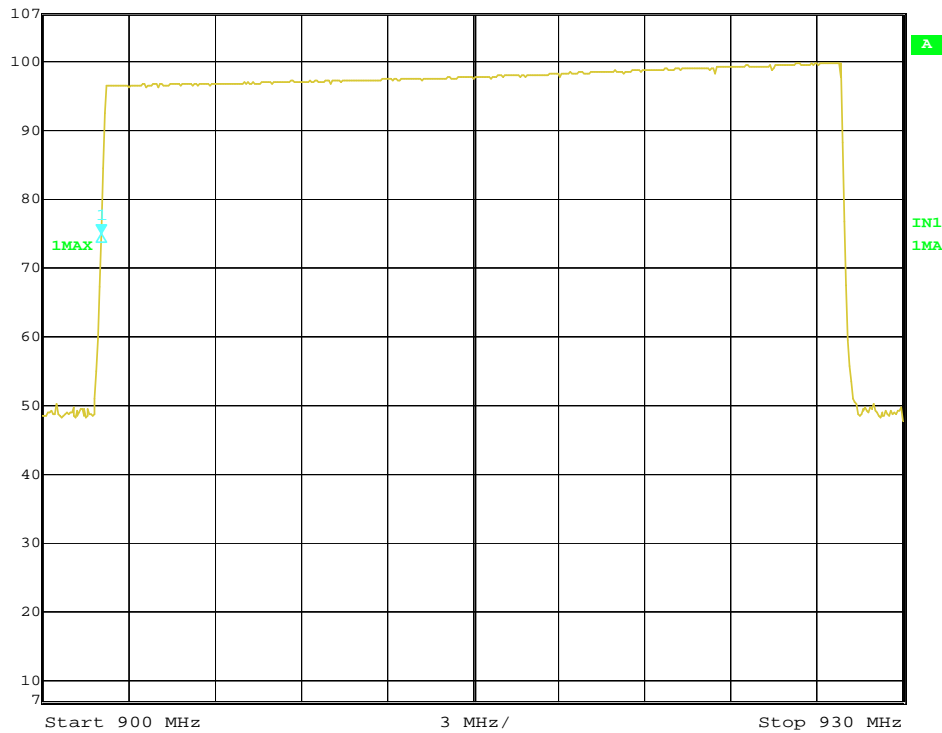


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-20 dB band edge when operating in 128 channel hopping mode


Low band edge: 902.044 MHz

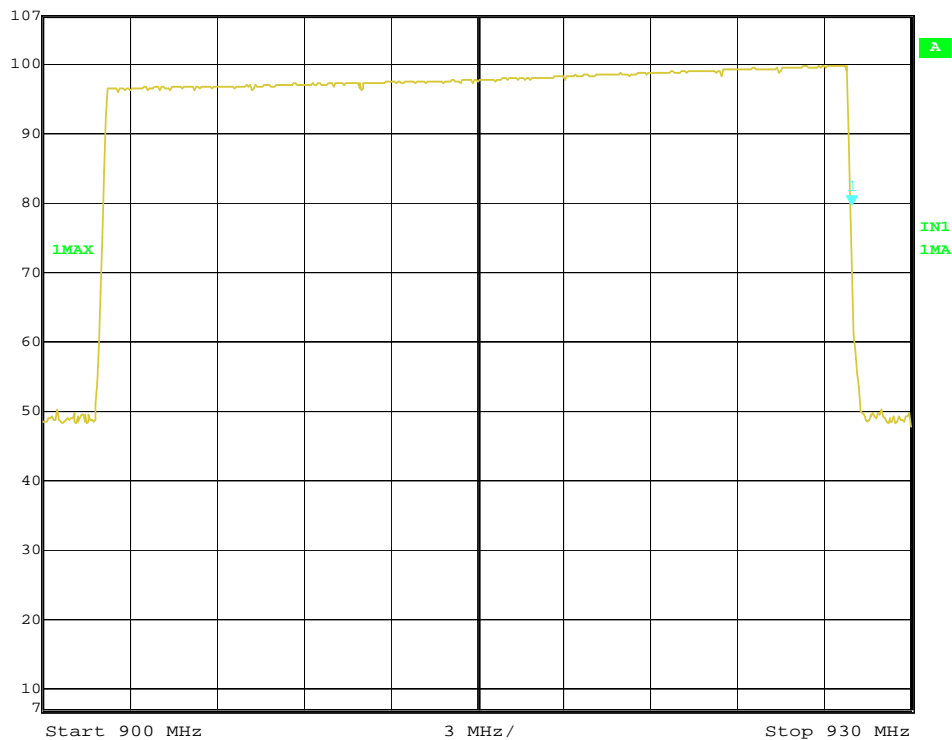
 Ref Lvl 107 dBV 74.99 dBV RBW 100 kHz RF Att 30 dB
Marker 1 [T1] 902.04408818 MHz VBW 100 kHz
SWT 7.5 ms Unit dBV



Date: 5.MAR.2021 08:51:48

High band edge: 927.956 MHz

 Ref Lvl 107 dBV 79.52 dBV RBW 100 kHz RF Att 30 dB
Marker 1 [T1] 927.95591182 MHz VBW 100 kHz
SWT 7.5 ms Unit dBV



Date: 5.MAR.2021 08:51:01

Radiated spurious emissions

Radiated spurious emission testing was carried out when the device was transmitting on a low, middle and high frequency and while the Bluetooth device was continually advertising in the 2400 – 2483.5 MHz band.

The device was configured to operate on discrete frequencies of 902.300, 915.000 and 927.700 MHz.

Measurements were made up to a frequency of 10 GHz ($10 \times F_c$) when the device was placed in 3 axis as it is a portable device.

Measurements below 1000 MHz were made at a test height of 1.0 metre with measurements over 1000 MHz being made at a test height of 1.5 metres.

The general limits as defined in section 15.209 have been applied.

Measurements below 1000 MHz were made using a Quasi Peak detector with a bandwidth of 120 kHz.

Above 1000 MHz measurements were made using a Peak detector and an Average detector with a 1 MHz bandwidth.

As a worst case the general limits have been applied with no reference being made to the list of restricted frequencies and the relaxed limit that could be applied.

In addition a general sweep was carried out between 30 MHz and 26 GHz in both vertical and horizontal polarisations when the LoRa device and the Bluetooth device were operating continuously.

No other spurious emissions were detected except for the emissions detailed below which were from the LoRa device.

Result: Complies.

Measurement uncertainty: ± 2.1 dB

Transmitting on 902.300 MHz

Frequency (MHz)	Vertical (dBuV/m)	Horizontal (dBuV/m)	Limit (dBuV/m)	Margin (dB)	Antenna	Detector
1804.600	53.5	54.6	74.0	19.4	Horizontal	Peak
1804.600	39.6	44.1	54.0	9.9	Horizontal	Average
-	-	-	-	-	-	-
2706.900	> 59.5	> 59.7	74.0	< 14.3	Horizontal	Peak
2706.900	> 46.6	> 46.6	54.0	< 7.4	Horizontal	Average
-	-	-	-	-	-	-
3609.200	> 51.0	> 51.0	74.0	< 23.0	Vertical	Peak
3609.200	> 40.0	> 40.0	54.0	< 14.0	Vertical	Average
-	-	-	-	-	-	-
4511.500	> 54.0	> 54.0	74.0	< 20.0	Vertical	Peak
4511.500	> 43.0	> 43.0	54.0	< 11.0	Vertical	Average
-	-	-	-	-	-	-
5413.800	> 57.0	> 57.0	74.0	< 17.0	Vertical	Peak
5413.800	> 47.0	> 47.0	54.0	< 7.0	Vertical	Average
-	-	-	-	-	-	-
6316.100	> 60.0	> 60.0	74.0	< 14.0	Vertical	Peak
6316.100	> 50.0	> 50.0	54.0	< 4.0	Vertical	Average
-	-	-	-	-	-	-
7218.400	55.4	59.4	74.0	14.6	Horizontal	Peak
7218.400	48.4	51.5	54.0	2.5	Horizontal	Average
-	-	-	-	-	-	-
8120.700	57.0	60.5	74.0	13.5	Horizontal	Peak
8120.700	46.5	51.3	54.0	2.7	Horizontal	Average
-	-	-	-	-	-	-
9023.000	58.1	58.1	74.0	15.9	Vertical	Peak
9023.000	47.6	47.6	54.0	6.4	Vertical	Average

No other spurious emissions were detected from the device except for the harmonic emissions recorded above when the LoRa device and the Bluetooth device were transmitting simultaneously.

Transmitting on 915.000 MHz

Frequency (MHz)	Vertical (dBuV/m)	Horizontal (dBuV/m)	Limit (dBuV/m)	Margin (dB)	Antenna	Detector
1830.000	52.5	55.1	74.0	18.9	Horizontal	Peak
1830.000	39.3	45.3	54.0	8.7	Horizontal	Average
-	-	-	-	-	-	-
2745.000	> 60.0	> 60.0	74.0	< 14.0	Vertical	Peak
2745.000	> 46.6	> 46.6	54.0	< 7.4	Vertical	Average
-	-	-	-	-	-	-
3660.000	> 51.0	> 51.0	74.0	< 23.0	Vertical	Peak
3660.000	> 40.0	> 40.0	54.0	< 14.0	Vertical	Average
-	-	-	-	-	-	-
4575.000	> 54.0	> 54.0	74.0	< 20.0	Vertical	Peak
4575.000	> 43.0	> 43.0	54.0	< 11.0	Vertical	Average
-	-	-	-	-	-	-
5490.000	> 57.0	> 57.0	74.0	< 17.0	Vertical	Peak
5490.000	> 47.0	> 47.0	54.0	< 7.0	Vertical	Average
-	-	-	-	-	-	-
6405.000	> 60.0	> 60.0	74.0	< 14.0	Vertical	Peak
6405.000	> 50.0	> 50.0	54.0	< 4.0	Vertical	Average
-	-	-	-	-	-	-
7320.000	55.4	60.3	74.0	13.7	Horizontal	Peak
7320.000	47.8	53.3	54.0	0.7	Horizontal	Average
-	-	-	-	-	-	-
8235.000	57.0	60.8	74.0	13.2	Horizontal	Peak
8235.000	46.5	51.9	54.0	2.1	Horizontal	Average
-	-	-	-	-	-	-
9150.000	58.0	57.8	74.0	16.0	Vertical	Peak
9150.000	47.7	47.2	54.0	6.3	Vertical	Average

No other spurious emissions were detected from the device except for the harmonic emissions recorded above when the LoRa device and the Bluetooth device were transmitting simultaneously.

Transmitting on 927.700 MHz

Frequency (MHz)	Vertical (dBuV/m)	Horizontal (dBuV/m)	Limit (dBuV/m)	Margin (dB)	Antenna	Detector
1855.400	53.1	57.1	74.0	16.9	Horizontal	Peak
1855.400	40.1	50.5	54.0	3.5	Horizontal	Average
-	-	-	-	-	-	-
2783.100	> 60.0	60.7	74.0	13.3	Horizontal	Peak
2783.100	> 47.0	47.4	54.0	6.6	Horizontal	Average
-	-	-	-	-	-	-
3710.800	> 51.0	> 51.0	74.0	< 23.0	Vertical	Peak
3710.800	> 40.0	> 40.0	54.0	< 14.0	Vertical	Average
-	-	-	-	-	-	-
4638.500	> 54.0	> 54.0	74.0	< 20.0	Vertical	Peak
4638.500	> 43.0	> 43.0	54.0	< 11.0	Vertical	Average
-	-	-	-	-	-	-
5566.200	> 57.0	> 57.0	74.0	< 17.0	Vertical	Peak
5566.200	> 47.0	> 47.0	54.0	< 7.0	Vertical	Average
-	-	-	-	-	-	-
6493.900	> 60.0	> 60.0	74.0	< 14.0	Vertical	Peak
6493.900	> 50.0	> 50.0	54.0	< 4.0	Vertical	Average
-	-	-	-	-	-	-
7421.600	55.8	61.1	74.0	12.9	Horizontal	Peak
7421.600	45.9	53.5	54.0	0.5	Horizontal	Average
-	-	-	-	-	-	-
8349.300	57.0	62.6	74.0	11.4	Horizontal	Peak
8349.300	48.1	54.0	54.0	0.0	Horizontal	Average
-	-	-	-	-	-	-
9277.000	57.7	57.9	74.0	16.1	Horizontal	Peak
9277.000	46.7	46.6	54.0	7.3	Vertical	Average

No other spurious emissions were detected from the device except for the harmonic emissions recorded above when the LoRa device and the Bluetooth device were transmitting simultaneously.

Section 15.247(e) – Power Spectral Density

As the LoRa device is classed as a hybrid device under Section 15.247(f) the power spectral density has been measured when operating on the discrete frequencies listed below.

As it does not have an antenna port radiated measurements have been made and compared against the conducted power spectral density limit.

Measurements were made using a spectrum analyser using a peak detector with a 3 kHz bandwidth.

Radiated measurements were made as alternative on a low, middle and high frequency at the test site.

Frequency (MHz)	Level (dBuV/m)	Level (dBm)	Limit (dBm)	Polarity	Margin (dB)	Result
902.300	95.3	0.1	8.0	Horizontal	7.9	Pass
-	-	-	-	-	-	-
915.000	97.9	2.7	8.0	Horizontal	5.3	Pass
-	-	-	-	-	-	-
927.700	100.9	5.7	8.0	Horizontal	2.3	Pass
-	-	-	-	-	-	-

A conducted power spectral density limit of +8 dBm in any 3 kHz is specified for this device

Result: Complies.

Measurement Uncertainty: ± 2.1 dB

Section 15.247(i) – Radio Frequency Hazard Information

As per Section 15.247 (i) Spread spectrum transmitters operating in the 902 – 928 MHz band are required to be operated in a manner that ensures that the public is not exposed to RF energy levels in accordance with CFR 47, Section 1.1307(b)(1).

In accordance with this section, and also Section 2.1091, this device has been defined as a portable whereby a distance of 20 cm or greater cannot normally be maintained between the user and the device antenna.

The RF Exposure Procedures as defined in KDB 447498 D01 have been applied.

The maximum radiated power for the LoRa device has been measured to be +6.9 dBm or 4.9 mW.

The maximum radiated power for the Bluetooth device has been measured to be +6.1 dBm or 4.0 mW.

As per clause 4.3.1 a) the 1-g the SAR test exclusion thresholds have been calculated to be:

LoRa device:

$$[(\text{transmitter power (mW)}) / \text{separation distance (mm)}] \times [\sqrt{F(\text{GHz})}] \leq 3.0$$

$$[4.9 \text{ mW} / \text{distance (mm)}] \times [\sqrt{0.9277}] = 3.0$$

$$4.9 / (3.0 / 0.963) = 1.6 \text{ mm}$$

Bluetooth device:

$$[(\text{transmitter power (mW)}) / \text{separation distance (mm)}] \times [\sqrt{F(\text{GHz})}] \leq 3.0$$

$$[4 \text{ mW} / \text{distance (mm)}] \times [\sqrt{2.4}] = 3.0$$

$$4 / (3.0 / 1.55) = 2.1 \text{ mm}$$

The overall separation distance is determined by addition the two distances together.

$$\text{Overall separation distance} = 1.6 + 2.1 = 3.7 \text{ mm}$$

The devices can be shown to be transmitting at a power level that allows the SAR test excursion to be applied providing a 5 mm separation distance is applied.

Result: Complies

7. TEST EQUIPMENT USED

Instrument	Manufacturer	Model	Serial No	Asset Ref	Cal Due	Period
Aerial Controller	EMCO	1090	9112-1062	RFS 3710	Not applic	Not applic
Aerial Mast	EMCO	1070-1	9203-1661	RFS 3708	Not applic	Not applic
Biconical Antenna	Schwarzbeck	BBA 9106	-	3680	1 Jan 2022	3 years
Horn Antenna	EMCO	3115	9511-4629	E1526	1 Jan 2022	3 years
Log Periodic	Schwarzbeck	VUSLP 9111	9111-112	EMC4025	1 Jan 2022	3 years
Loop Antenna	EMCO	6502	9003-2485	3798	1 Jan 2022	3 years
Receiver	R & S	ESIB 40	100295	INV0818	28 Aug 2021	2 year
Turntable	EMCO	1080-1-2.1	9109-1578	RFS 3709	Not applic	Not applic
VHF Balun	Schwarzbeck	VHA 9103	9594	3696	1 Jan 2022	3 years

At the time of testing all test equipment was within calibration.

8. ACCREDITATIONS

Testing was carried out in accordance with EMC Technologies NZ Ltd designation as a FCC Accredited Laboratory by International Accreditation New Zealand, designation number: NZ0002 under the APEC TEL MRA.

All testing was carried out in accordance with the terms of EMC Technologies (NZ) Ltd International Accreditation New Zealand (IANZ) Accreditation to NZS/ISO/IEC 17025.

All measurement equipment has been calibrated in accordance with the terms of the EMC Technologies (NZ) Ltd International Accreditation New Zealand (IANZ) Accreditation to NZS/ISO/IEC 17025.

International Accreditation New Zealand has Mutual Recognition Arrangements for testing and calibration with various accreditation bodies in a number of economies. This includes NATA (Australia), UKAS (UK), SANAS (South Africa), NVLAP (USA), A2LA (USA), SWEDAC (Sweden). Further details can be supplied on request.

9. PHOTOGRAPHS

Radiated emissions test set up

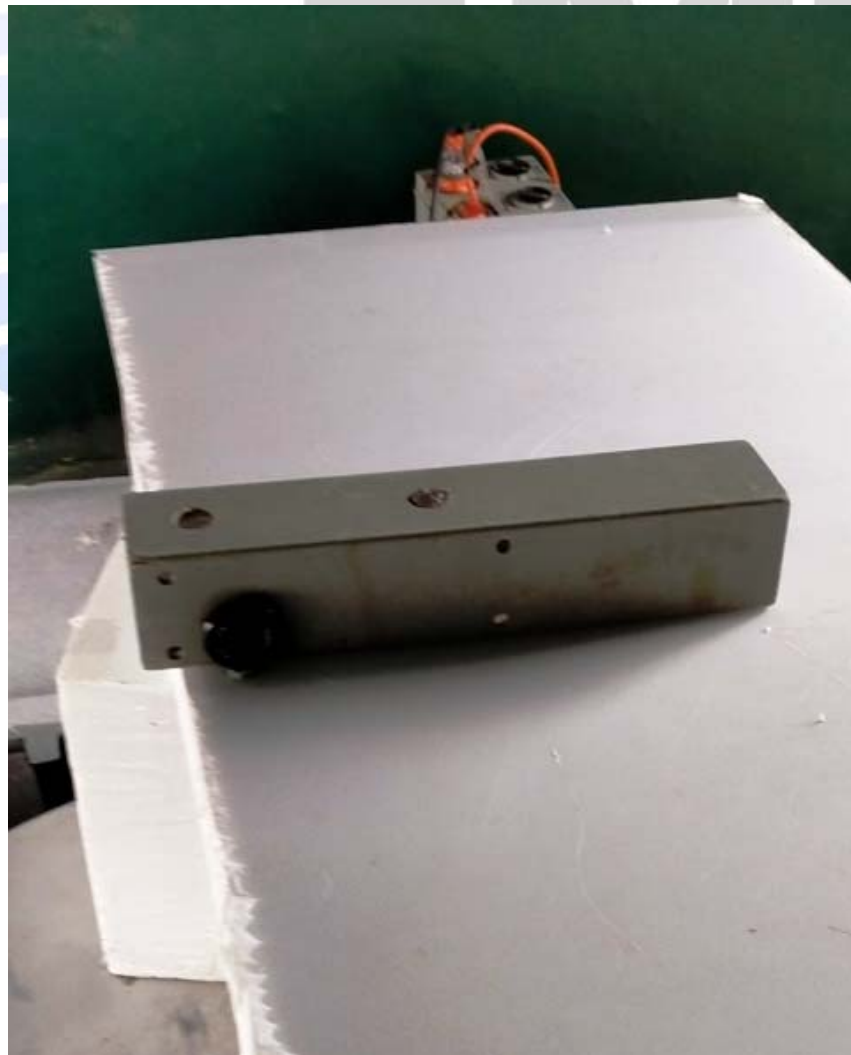
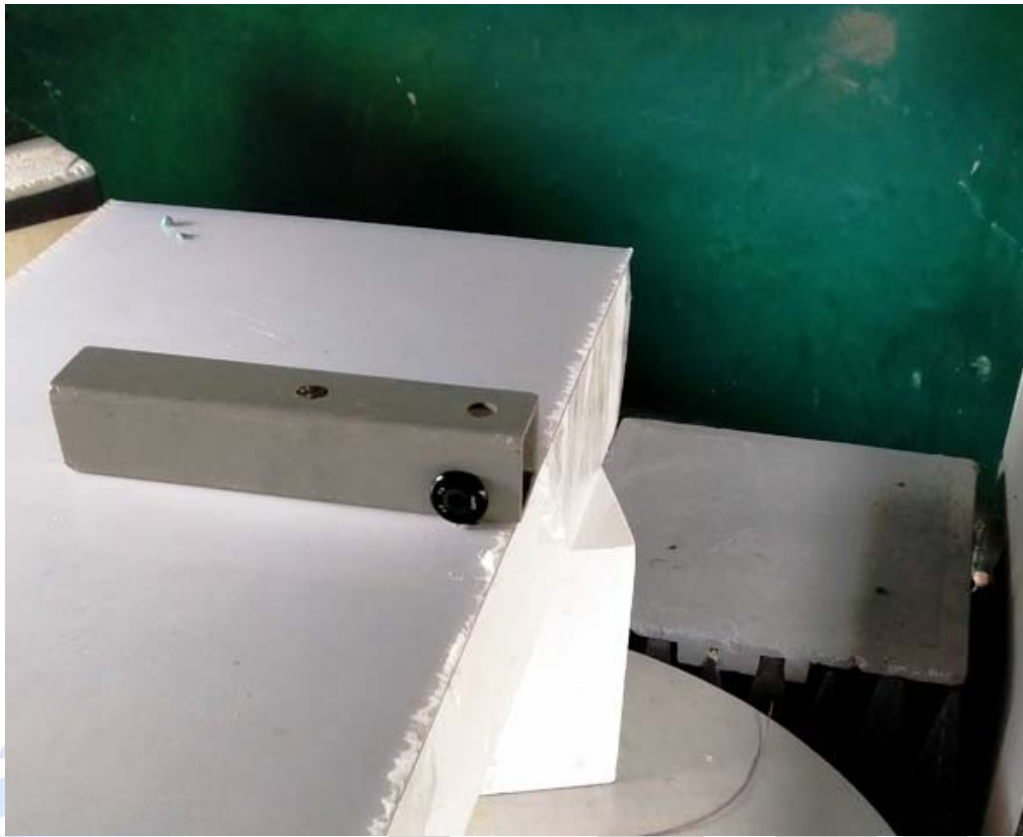
X Plane set up – standing upright





Z plane standing up right but turned 90 degrees





Y plane – Laying flat on the test table



