HERMON LABORATORIES

ELECTRICAL TESTING
0839.01

Hermon Laboratories Ltd.
P.O. Box 23, Binyamina 3055001, Israel
Tel. +972 4628 8001
Fax. +972 4628 8277
E-mail: mail@hermonlabs.com

TEST REPORT

ACCORDING TO: FCC 47CFR part 15 subpart C §15.247 (Hybrid);
RSS-247 Issue 2, RSS-Gen Issue 5

FOR:

ARAD TECHNOLOGIES
Digital Water meter
Model: INTERPRETER LR9
FCC ID: VIDLR9INTR
IC: 10232A-LR9INTER

Table of contents

1 Applicant information

Client name:	ARAD TECHNOLOGIES
Address:	POB 537, HaMada 4, Yokneam Ind. Zone, Yokneam Ilit 20692, Israel
Telephone:	04-9935222 Ext.277
Fax:	04-9935227
E-mail:	viorel.negreanu@aradtec.com
Contact name:	Mr.Vily Negreanu

2 Equipment under test attributes

Product name:	Digital Water meter
Product type:	Transceiver
Model(s):	INTERPRETER LR9
Trade mark:	Allegro IOT
Serial number:	70B3D5A9F0000B52
Hardware version:	06.01
Software release:	1A.XX
Receipt date	09-Jan-20

3 Manufacturer information

Manufacturer name:	ARAD TECHNOLOGIES
Address:	POB 537, HaMada 4, Yokneam Ind. Zone, Yokneam Ilit 20692, Israel
Telephone:	04-9935222 Ext.277
Fax:	04-9935227
E-Mail:	viorel.negreanu@aradtec.com
Contact name:	Mr.Vily Negreanu

4 Test details

Project ID:	36321
Location:	Hermon Laboratories Ltd. P.O. Box 23, Binyamina 3055001, Israel
Test started:	12-Jan-20
Test completed:	19-Jan-20
Test specification(s):	FCC 47CFR part 15 subpart C §15.247 (Hybrid)
	RSS-247 Issue 2:2017, RSS-Gen Issue 5 with Am.1:2019

5 Tests summary

Test	Status
Transmitter characteristics	
FCC section 15.247(a)1/ RSS-247 section 5.1(3), 20 dB bandwidth	Pass
FCC section 15.247(a)1/ RSS-247 section 5.1(2), Frequency separation	Pass
FCC section 15.247(a)1/ RSS-247 section 5.1(3), Number of hopping frequencies	Pass
FCC section 15.247(a)1/ RSS-247 section 5.1(3), Average time of occupancy	Pass
FCC section 15.247(b)/ RSS-247 section 5.4(1), Peak output power	Pass
FCC Section 15.247(e)/ RSS-247 section 5.4(1), Peak spectral density	Pass
FCC section 15.247(c)/ RSS-247 section 5.5, Radiated spurious emissions	Pass
FCC section 15.247(c)/ RSS-247 section 5.5, Emissions at band edges	Pass
FCC section 15.247(i)5/ RSS-102 section 2.5, RF exposure	Pass, the exhibit to the application of certification is provided
FCC section 15.203/ RSS-Gen section 6.8, Antenna requirements	Pass

Testing was completed against all relevant requirements of the test standard. The results obtained indicate that the product under test complies in full with the requirements tested.
The test results relate only to the items tested. Pass/ fail decision was based on nominal values.

This test report supersedes the previously issued test report identified by Doc ID:ARARAD_FCC.36321_Hybrid.

	Name and Title	Date	Signature
Tested by:	Mr. A. Morozov test engineer EMC & Radio	12-Jan-20 – 19-Jan-20	
Reviewed by:	Mrs. S Peysahov Sheynin test engineer EMC & Radio	24-Sep-20	
Approved by:	Mr. S. Samokha, technical manager, EMC & Radio	24-Sep-20	

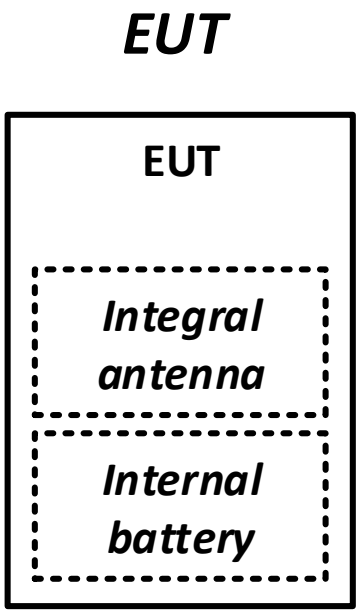
6 EUT description

Note: The following data in this clause is provided by the customer and represents his sole responsibility

6.1 General information

Battery powered Digital Water Meter comprising a built-in long range (LoRaWAN) radio module operating in 902.0 -928.0 MHz frequency range.

6.2 Test configuration



6.3 Changes made in EUT

No changes were implemented in the EUT during the testing.

6.4 Transmitter characteristics

Type of equipment	
X	Stand-alone (Equipment with or without its own control provisions)
	Combined equipment (Equipment where the radio part is fully integrated within another type of equipment)
	Plug-in card (Equipment intended for a variety of host systems)

Intended use		**Condition of use**
	fixed	Always at a distance more than 2 m from all people
X	mobile	Always at a distance more than 20 cm from all people
	portable	May operate at a distance closer than 20 cm to human body

Assigned frequency range	902 - 928 MHz
Operating frequency	902.3- 914.9 MHz
Maximum rated output power	**Peak output power** 20.28 dBm

Is transmitter output power variable?				
	X	No		
		Yes		continuous variable
				stepped variable with stepsize dB
			minimum RF power	dBm
			maximum RF power	dBm

Antenna connection			
unique coupling	standard connector	X integral	with temporary RF connector
			X without temporary RF connector

Antenna/s technical characteristics			
Type	Manufacturer	Model number	Gain
Custom made	Arad Technologies	ANT00064	(-3) – 0 dBi

Modulation	LoRa
Transmitter aggregate data rate/s	980 bps / 5470 bps
Modulating test signal (baseband)	PRBS

Transmitter power source						
X	Battery	**Nominal rated voltage**	3.6VDC	Battery type	TL4920
	DC	**Nominal rated voltage**	VDC		
	AC mains	**Nominal rated voltage**	VAC	Frequency	

Spread spectrum technique used		
		Frequency hopping (FHSS)
		Digital transmission system (DTS)
	X	Hybrid

Test specification:	Section 15.247(a)(1), RSS-247 section 5.1(c), 20 dB bandwidth		
Test procedure:	ANSI C63.10 section 7.8.7		
Test mode:	Compliance	Verdict:	PASS
Date(s):	14-Jan-20		
Temperature: 25 ºC	Relative Humidity: 41 %	Air Pressure: 1025 hPa	Power: 3.6 VDC
Remarks:			

7 Transmitter tests according to 47CFR part 15 subpart C and RSS-247 requirements

7.1 20 dB bandwidth

7.1.1 General

This test was performed to measure 20 dB bandwidth of the transmitter hopping channel. Specification test limits are given in Table 7.1.1.

Table 7.1.1 The 20 dB bandwidth limits

Assigned frequency, MHz	Maximum bandwidth, kHz	Modulation envelope reference points*, dBc
902.0 – 928.0	250	20

* - Modulation envelope reference points provided in terms of attenuation below the peak of modulated carrier.

7.1.2 Test procedure

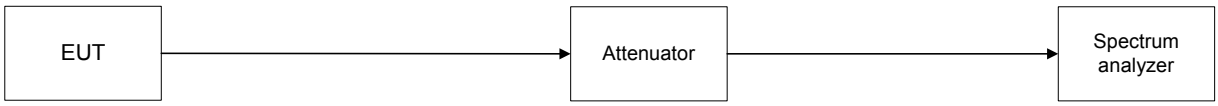
7.1.2.1 The EUT was set up as shown in Figure 7.1.1, energized and its proper operation was checked.

7.1.2.2 The EUT was set to transmit modulated carrier at maximum data rate.

7.1.2.3 The transmitter bandwidth was measured with spectrum analyzer as frequency delta between reference points on modulation envelope and provided in Table 7.1.2 and associated plot.

7.1.2.4 The test was repeated for each data rate and each modulation format.

Figure 7.1.1 The 20 dB bandwidth test setup



Test specification:	**Section 15.247(a)(1), RSS-247 section 5.1(c), 20 dB bandwidth**		
Test procedure:	ANSI C63.10 section 7.8.7		
Test mode:	Compliance	**Verdict:**	PASS
Date(s):	14-Jan-20		
Temperature: 25 ºC	**Relative Humidity:** 41 %	**Air Pressure:** 1025 hPa	**Power:** 3.6 VDC
Remarks:			

Table 7.1.2 The 20 dB bandwidth test results

ASSIGNED FREQUENCY BAND: 902.0 – 928.0 MHz
DETECTOR USED: Peak
SWEEP TIME: Auto
VIDEO BANDWIDTH: ≥ RBW
MODULATION ENVELOPE REFERENCE POINTS: 20.0 dBc
MODULATING SIGNAL: PRBS
FREQUENCY HOPPING: Disabled

Carrier frequency, MHz	Type of modulation	Data rate, bps	20 dB bandwidth, kHz	Limit, kHz	Margin, kHz	Verdict
Low frequency						
902.3	LoRa	980	139.1	250.0	-110.90	Pass
		5470	145.3	250.0	-104.70	Pass
Mid frequency						
908.6	LoRa	980	139.0	250.0	-111.00	Pass
		5470	145.7	250.0	-104.30	Pass
High frequency						
914.9	LoRa	980	138.1	250.0	-111.90	Pass
		5470	144.6	250.0	-105.40	Pass

Reference numbers of test equipment used

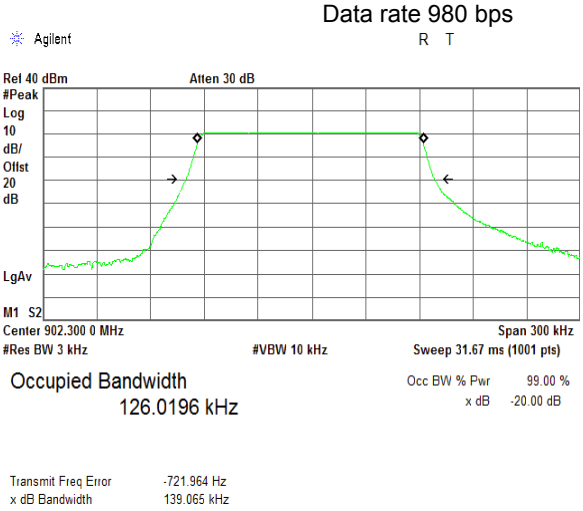
HL 3442	HL 3818							

Full description is given in Appendix A.

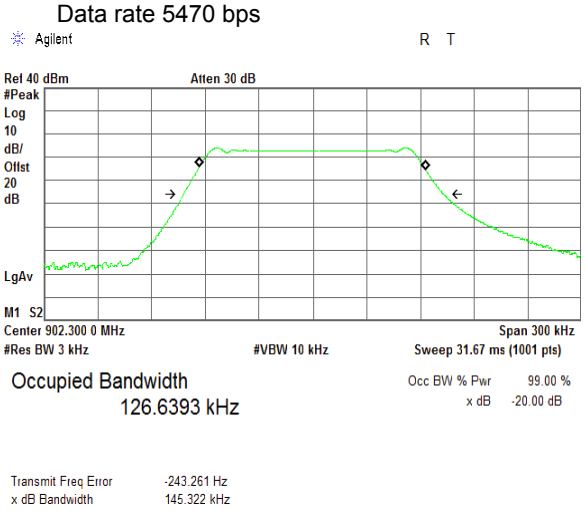
Test specification:	Section 15.247(a)(1), RSS-247 section 5.1(c), 20 dB bandwidth		
Test procedure:	ANSI C63.10 section 7.8.7		
Test mode:	Compliance	Verdict:	PASS
Date(s):	14-Jan-20		
Temperature: 25 ºC	Relative Humidity: 41 %	Air Pressure: 1025 hPa	Power: 3.6 VDC
Remarks:			

Plot 7.1.1 The 20 dB bandwidth test result at low frequency

Data rate 980 bps

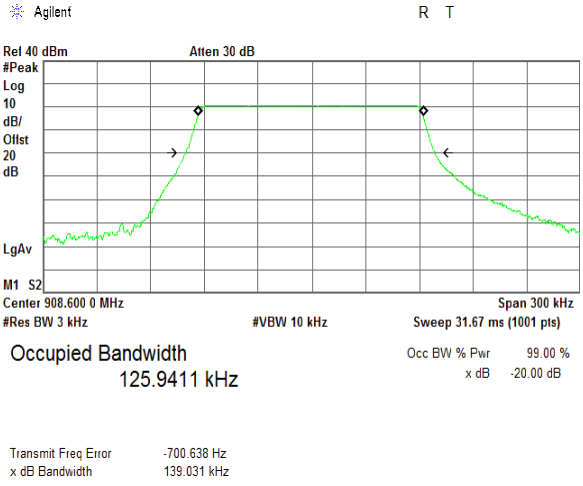


Data rate 5470 bps

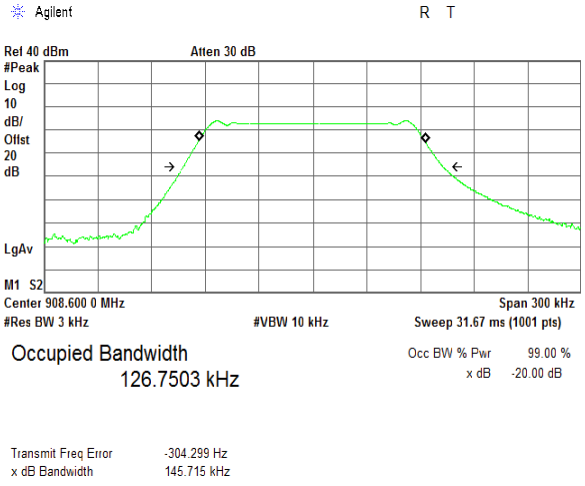


Plot 7.1.2 The 20 dB bandwidth test result at mid frequency

Data rate 980 bps



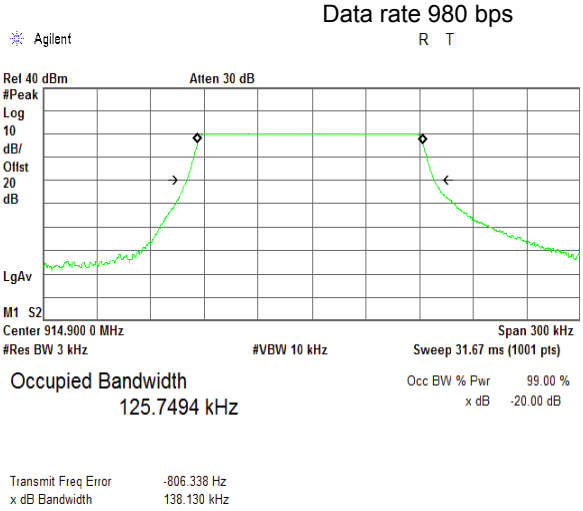
Data rate 5470 bps



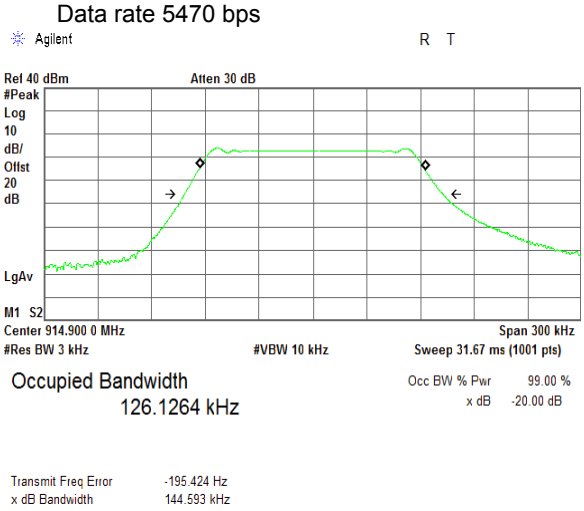
Test specification:	Section 15.247(a)(1), RSS-247 section 5.1(c), 20 dB bandwidth		
Test procedure:	ANSI C63.10 section 7.8.7		
Test mode:	Compliance	Verdict:	PASS
Date(s):	14-Jan-20		
Temperature: 25 ºC	Relative Humidity: 41 %	Air Pressure: 1025 hPa	Power: 3.6 VDC
Remarks:			

Plot 7.1.3 The 20 dB bandwidth test result at high frequency

Data rate 980 bps



Data rate 5470 bps



Test specification:	Section 15.247(a)1, RSS-247 section 5.1(b), Frequency separation		
Test procedure:	ANSI C63.10 section 7.8.3		
Test mode:	Compliance	Verdict:	PASS
Date(s):	19-Jan-20		
Temperature: 23 ºC	Relative Humidity: 53 %	Air Pressure: 1016 hPa	Power: 3.6 VDC
Remarks:			

7.2 Carrier frequency separation

7.2.1 General

This test was performed to measure frequency separation between the peaks of adjacent channels. Specification test limits are given in Table 7.2.1.

Table 7.2.1 Carrier frequency separation limits

Assigned frequency range, MHz	Carrier frequency separation	
	Output power 30 dBm	Output power 21 dBm
902.0 – 928.0	25 kHz or 20 dB bandwidth of the hopping channel, whichever is greater	25 kHz or two-thirds of the 20 dB bandwidth of the hopping channel, whichever is greater

7.2.2 Test procedure

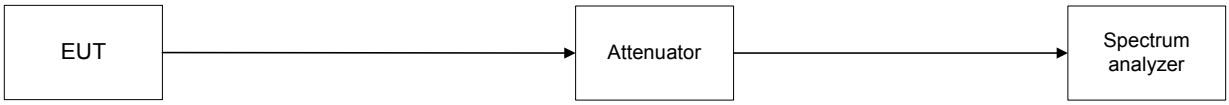
7.2.2.1 The EUT was set up as shown in Figure 7.2.1, energized with frequency hopping function enabled and its proper operation was checked.

7.2.2.2 The spectrum analyzer span was set to capture the carrier frequency and both of adjacent channels, the lower and the higher. The resolution bandwidth was set wider than 1 % of the frequency span.

7.2.2.3 The spectrum analyzer was set in max hold mode and allowed trace to stabilize.

7.2.2.4 The frequency separation between the peaks of adjacent channels was measured as provided in Table 7.2.2 and associated plots.

Figure 7.2.1 Carrier frequency separation test setup



Test specification:	**Section 15.247(a)1, RSS-247 section 5.1(b), Frequency separation**		
Test procedure:	ANSI C63.10 section 7.8.3		
Test mode:	Compliance	**Verdict:**	PASS
Date(s):	19-Jan-20		
Temperature: 23 ºC	**Relative Humidity:** 53 %	**Air Pressure:** 1016 hPa	**Power:** 3.6 VDC
Remarks:			

Table 7.2.2 Carrier frequency separation test results

ASSIGNED FREQUENCY: 902.0 – 928.0 MHz
MODULATION: LoRa
MODULATING SIGNAL: PRBS
DETECTOR USED: Peak
RESOLUTION BANDWIDTH: ≥ 1% of the span
VIDEO BANDWIDTH: ≥ RBW
FREQUENCY HOPPING: Enabled

BIT RATE: 980 bps
20 dB BANDWIDTH: 139.1 kHz

Carrier frequency separation, kHz	Limit, kHz	Margin, kHz*	Verdict
200	139.1	60.9	Pass

BIT RATE: 5470 bps
20 dB BANDWIDTH: 145.7 kHz

Carrier frequency separation, kHz	Limit, kHz	Margin, kHz*	Verdict
200	145.7	54.3	Pass

* - Margin = Carrier frequency separation – specification limit.

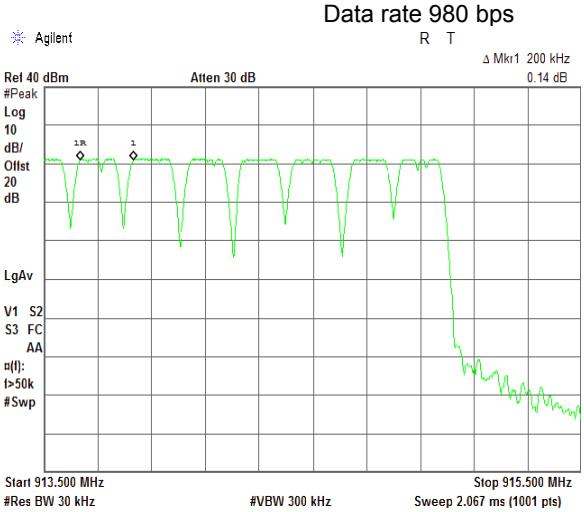
Reference numbers of test equipment used

HL 3442	HL 3818						

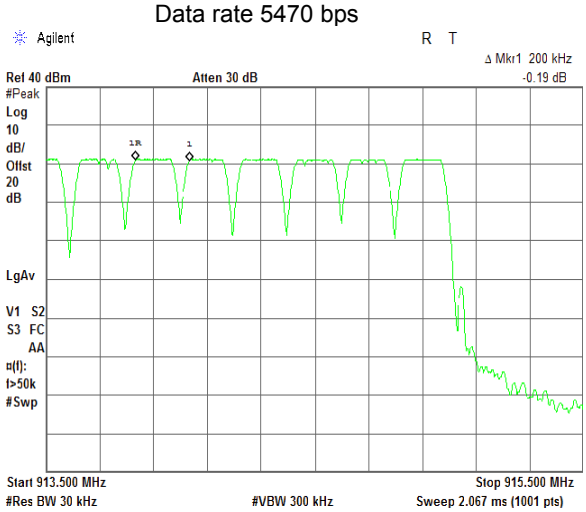
Full description is given in Appendix A.

Plot 7.2.1 Carrier frequency separation

Data rate 980 bps



Data rate 5470 bps



Test specification:	Section 15.247(a)1, RSS-247 section 5.1(c), Number of hopping frequencies		
Test procedure:	ANSI C63.10 section 7.8.3		
Test mode:	Compliance	Verdict:	PASS
Date(s):	19-Jan-20		
Temperature: 23 ºC	Relative Humidity: 53 %	Air Pressure: 1016 hPa	Power: 3.6 VDC
Remarks:			

7.3 Number of hopping frequencies

7.3.1 General

This test was performed to calculate the number of hopping frequencies used by the EUT. Specification test limits are given in Table 7.3.1.

Table 7.3.1 Minimum number of hopping frequencies

Assigned frequency range, MHz	Number of hopping frequencies
902.0 – 928.0	50 (if the 20 dB bandwidth is less than 250 kHz) 25 (if the 20 dB bandwidth is 250 kHz or greater)

7.3.2 Test procedure

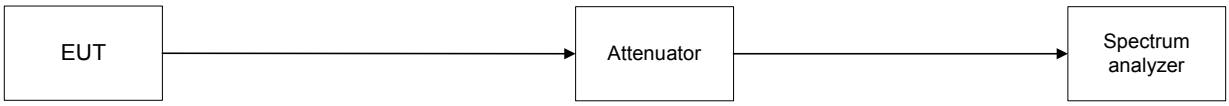
7.3.2.1 The EUT was set up as shown in Figure 7.3.1, energized with frequency hopping function enabled and its proper operation was checked.

7.3.2.2 Initially the spectrum analyzer span was set equal to frequency band of operation and the resolution bandwidth was set wider than 1 % of the frequency span. If the separate hopping channels were not clearly resolved the frequency band of operation was broken to sections and the resolution bandwidth was set wider than 1 % of the frequency span of each section.

7.3.2.3 The spectrum analyzer was set in max hold mode and allowed trace to stabilize.

7.3.2.4 The number of frequency hopping channels was calculated as provided in Table 7.3.2 and associated plots.

Figure 7.3.1 Hopping frequencies test setup



Test specification:	**Section 15.247(a)1, RSS-247 section 5.1(c), Number of hopping frequencies**		
Test procedure:	ANSI C63.10 section 7.8.3		
Test mode:	Compliance	**Verdict:**	PASS
Date(s):	19-Jan-20		
Temperature: 23 ºC	**Relative Humidity:** 53 %	**Air Pressure:** 1016 hPa	**Power:** 3.6 VDC
Remarks:			

Table 7.3.2 Hopping frequencies test results

ASSIGNED FREQUENCY: 902.0 – 928.0 MHz
MODULATION: LoRa
MODULATING SIGNAL: PRBS
DETECTOR USED: Peak
RESOLUTION BANDWIDTH: ≥ 1% of the span
VIDEO BANDWIDTH: ≥ RBW
FREQUENCY HOPPING: Enabled

BIT RATE: 980 bps

Number of hopping frequencies	Minimum number of hopping frequencies	Margin*	Verdict
64	50	14	Pass

BIT RATE: 5470 bps

Number of hopping frequencies	Minimum number of hopping frequencies	Margin*	Verdict
64	50	14	Pass

* - Margin = Number of hopping frequencies – Minimum number of hopping frequencies.

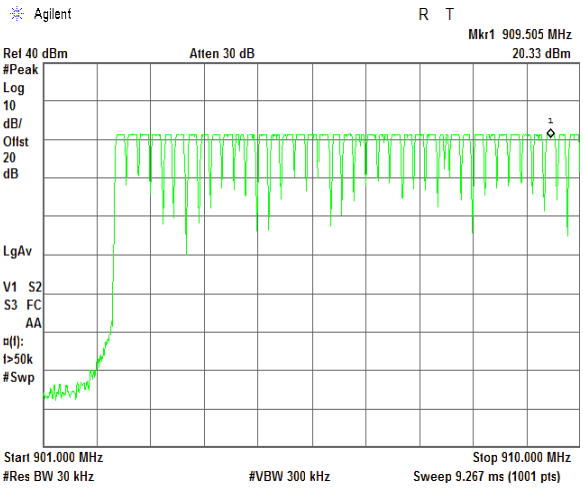
Reference numbers of test equipment used

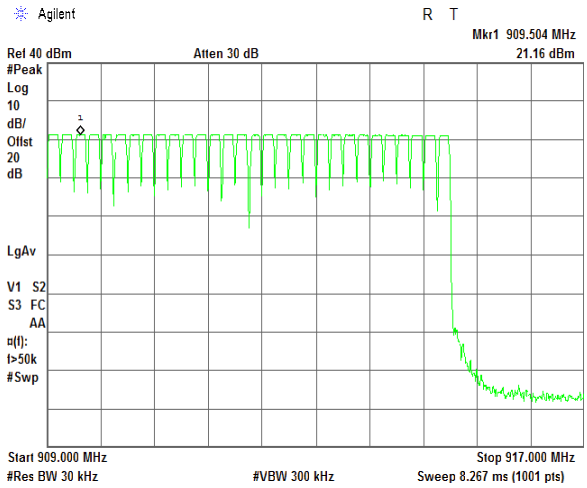
HL 3442	HL 3818						

Full description is given in Appendix A.

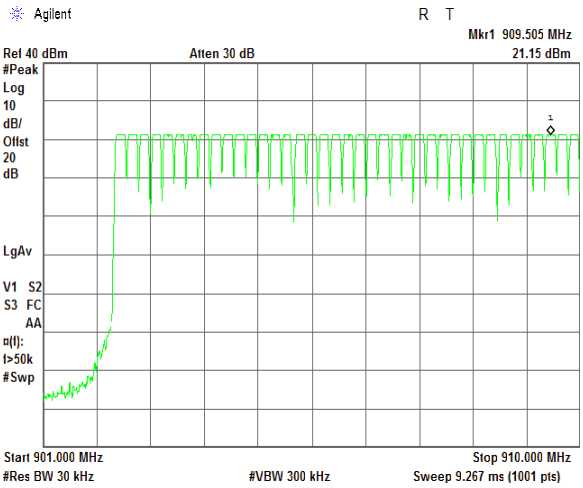
Test specification:	Section 15.247(a)1, RSS-247 section 5.1(c), Number of hopping frequencies		
Test procedure:	ANSI C63.10 section 7.8.3		
Test mode:	Compliance	Verdict:	PASS
Date(s):	19-Jan-20		
Temperature: 23 ºC	Relative Humidity: 53 %	Air Pressure: 1016 hPa	Power: 3.6 VDC
Remarks:			

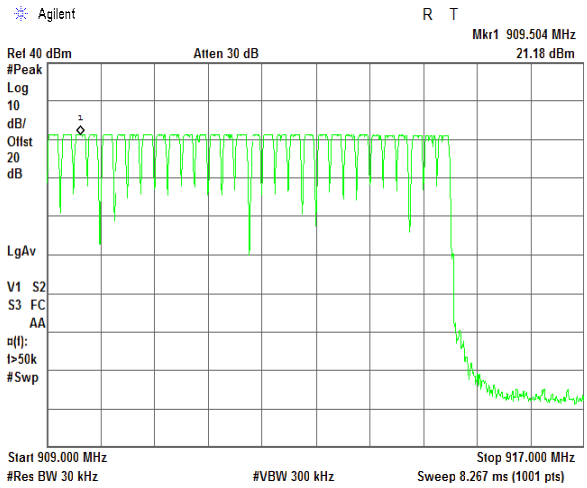
Plot 7.3.1 Number of hopping frequencies with bit rate 980 bps





Plot 7.3.2 Number of hopping frequencies with bit rate 5470 bps





Test specification:	Section 15.247(a), RSS-247 section 5.1(c), Average time of occupancy		
Test procedure:	ANSI C63.10 section 7.8.4		
Test mode:	Compliance	Verdict:	PASS
Date(s):	19-Jan-20		
Temperature: 23 ºC	Relative Humidity: 53 %	Air Pressure: 1016 hPa	Power: 3.6 VDC
Remarks:			

7.4 Average time of occupancy

7.4.1 General

This test was performed to calculate the average time of occupancy (dwell time) on any frequency channel of the EUT. Specification test limits are given in Table 7.4.1.

Table 7.4.1 Average time of occupancy limits

Assigned frequency range, MHz	Maximum average time of occupancy, s	Investigated period, s	Number of hopping frequencies
902.0 – 928.0	0.4	20.0	≥ 50

7.4.2 Test procedure

7.4.2.1 The EUT was set up as shown in Figure 7.4.1, energized with frequency hopping function enabled and its proper operation was checked.

7.4.2.2 The spectrum analyzer span was set to zero centered on a hopping channel.

7.4.2.3 The single transmission duration and period were measured with oscilloscope.

7.4.2.4 The average time of occupancy was calculated as the single transmission time multiplied by the investigated period and divided by the single transmission period.

7.4.2.5 The test was repeated at each data rate and modulation type as provided in Table 7.4.2 and associated plots.

Figure 7.4.1 Average time of occupancy test setup

Test specification:	**Section 15.247(a), RSS-247 section 5.1(c), Average time of occupancy**		
Test procedure:	ANSI C63.10 section 7.8.4		
Test mode:	Compliance	**Verdict:**	PASS
Date(s):	19-Jan-20		
Temperature: 23 ºC	**Relative Humidity:** 53 %	**Air Pressure:** 1016 hPa	**Power:** 3.6 VDC
Remarks:			

Table 7.4.2 Average time of occupancy test results

ASSIGNED FREQUENCY:	902.0 – 928.0 MHz
MODULATION:	LoRa
MODULATING SIGNAL:	PRBS
DETECTOR USED:	Peak
RESOLUTION BANDWIDTH:	30 kHz
VIDEO BANDWIDTH:	300 kHz
NUMBER OF HOPPING FREQUENCIES:	1
INVESTIGATED PERIOD:	21 s
FREQUENCY HOPPING:	Enabled

Carrier frequency, MHz	Single transmission duration, s	Number of transmissions within investigated period	Average time of occupancy*, s	Bit rate, bps	Limit, s	Margin, s**	Verdict
914.9	0.33	1	0.33	980	0.4	-0.07	Pass
914.9	0.33	1	0.33	5470	0.4	-0.07	Pass

* - Average time of occupancy = (Single transmission duration × Investigated period) / (Single transmission period × number of hopping channels).
** - Margin = Average time of occupancy – specification limit.

Reference numbers of test equipment used

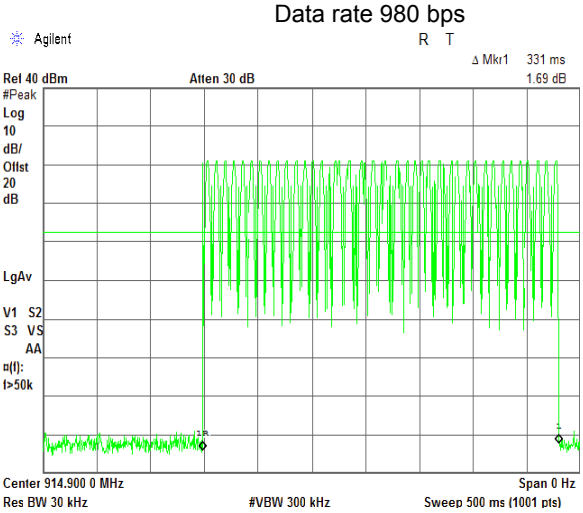
HL 3442	HL 3818						

Full description is given in Appendix A.

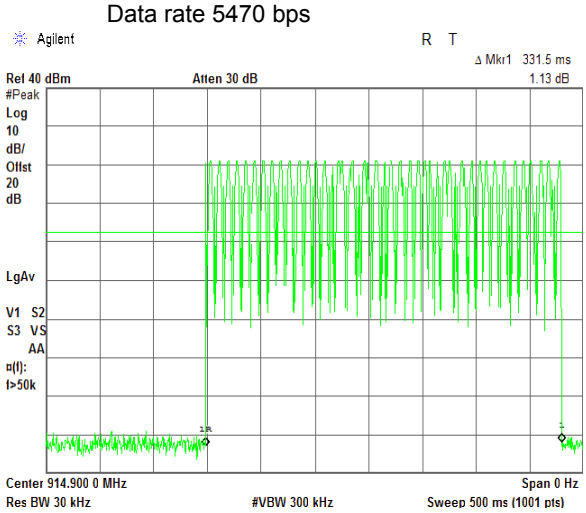
Test specification:	Section 15.247(a), RSS-247 section 5.1(c), Average time of occupancy		
Test procedure:	ANSI C63.10 section 7.8.4		
Test mode:	Compliance	Verdict:	PASS
Date(s):	19-Jan-20		
Temperature: 23 ºC	Relative Humidity: 53 %	Air Pressure: 1016 hPa	Power: 3.6 VDC
Remarks:			

Plot 7.4.1 Single transmission duration

Data rate 980 bps

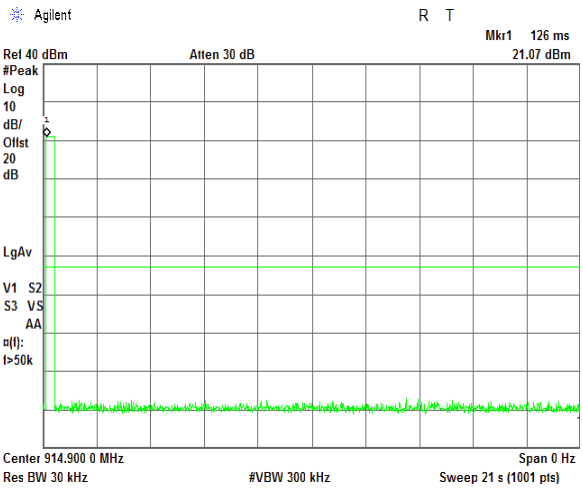


Data rate 5470 bps

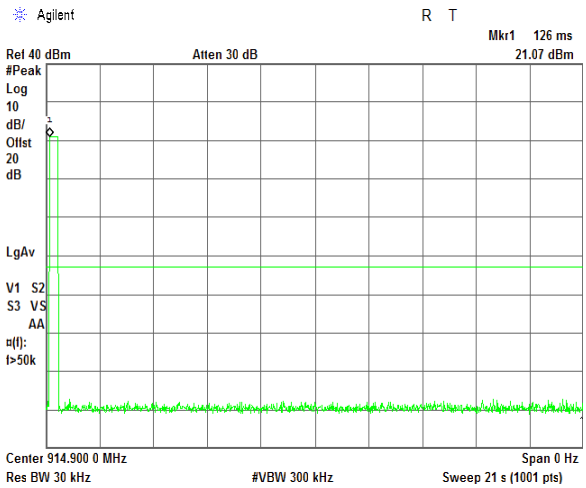


Plot 7.4.2 Number of transmission within 21 s

Data rate 980 bps



Data rate 5470 bps



Test specification:	Section 15.247(b), RSS-247 section 5.4(a), Peak output power		
Test procedure:	ANSI C63.10 section 7.8.5		
Test mode:	Compliance	Verdict:	PASS
Date(s):	19-Jan-20		
Temperature: 22 ºC	Relative Humidity: 54 %	Air Pressure: 1016 hPa	Power: 3.6 VDC
Remarks:			

7.5 Peak output power

7.5.1 General

This test was performed to measure the maximum peak output power at the transmitter RF antenna connector. Specification test limits are given in Table 7.5.1.

Table 7.5.1 Peak output power limits

Assigned frequency range, MHz	Peak output power*		Equivalent field strength limit @ 3m, dB(μV/m)*	Maximum antenna gain, dBi
	W	dBm		
902.0 – 928.0	**0.25 (<50 hopping channels)** 1.0 (≥50 hopping channels)	**24.0(<50 hopping channels)** 30.0 (≥50 hopping channels)	**125.2 (<50 hopping channels)** 131.2 (≥50 hopping channels)	**6.0***

*- If transmitting antennas of directional gain greater than 6 dBi are used, the peak output power limit shall be reduced below the stated value as follows:

- by 1 dB for every 3 dB that the directional gain of antenna exceeds 6 dBi for fixed point-to-point transmitters operate in 2400-2483.5 MHz band;
- without any corresponding reduction for fixed point-to-point transmitters operate in 5725-5850 MHz band;
- by the amount in dB that the directional gain of antenna exceeds 6 dBi for the rest of transmitters.

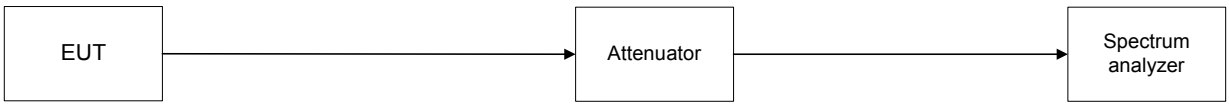
7.5.2 Test procedure

7.5.2.1 The EUT was set up as shown in Figure 7.5.1, energized and its proper operation was checked.

7.5.2.2 The EUT was adjusted to produce maximum available for end user RF output power.

7.5.2.3 The frequency span of spectrum analyzer was set approximately 5 times wider than 20 dB bandwidth of the EUT and the resolution bandwidth was set wider than 20 dB bandwidth of the EUT. The spectrum analyzer trace was allowed to stabilize and the maximum peak output power was measured as provided in Table 7.5.2 and associated plots.

Figure 7.5.1 Peak output power test setup



Test specification:	**Section 15.247(b), RSS-247 section 5.4(a), Peak output power**		
Test procedure:	ANSI C63.10 section 7.8.5		
Test mode:	Compliance	**Verdict:**	PASS
Date(s):	19-Jan-20		
Temperature: 22 ºC	**Relative Humidity:** 54 %	**Air Pressure:** 1016 hPa	**Power:** 3.6 VDC
Remarks:			

Table 7.5.2 Peak output power test results

ASSIGNED FREQUENCY: 902.0 – 928.0 MHz
MODULATION: LoRa
MODULATING SIGNAL: PRBS
TRANSMITTER OUTPUT POWER SETTINGS: Maximum
DETECTOR USED: Peak
RESOLUTION BANDWIDTH: 3 kHz
VIDEO BANDWIDTH: 30 kHz
FREQUENCY HOPPING: Disabled
NUMBER OF FREQUENCY HOPPING CHANNELS: 64

BIT RATE: 980 bps

Carrier frequency, MHz	Spectrum analyzer reading, dBm	External attenuation, dB	Cable loss, dB	Peak output power, dBm	Limit, dBm	Margin*, dB	Verdict
902.3	20.28	NA	NA	20.28	24.0	-3.72	Pass
908.6	20.14	NA	NA	20.14	24.0	-3.86	Pass
914.9	20.00	NA	NA	20.00	24.0	-4.00	Pass

BIT RATE: 5470 bps

Carrier frequency, MHz	Spectrum analyzer reading, dBm	External attenuation, dB	Cable loss, dB	Peak output power, dBm	Limit, dBm	Margin*, dB	Verdict
902.3	20.13	NA	NA	20.13	24.0	-3.87	Pass
908.6	20.00	NA	NA	20.00	24.0	-4.00	Pass
914.9	19.87	NA	NA	19.87	24.0	-4.13	Pass

* - Margin = Peak output power – specification limit.

Reference numbers of test equipment used

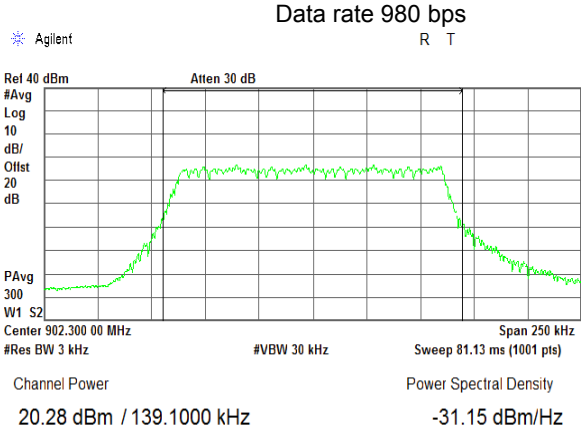
HL 3442	HL 3818						

Full description is given in Appendix A.

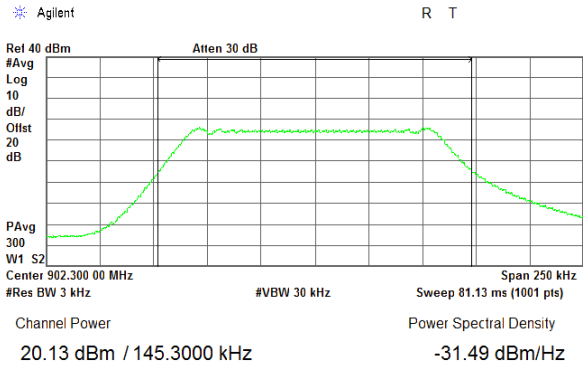
Test specification:	Section 15.247(b), RSS-247 section 5.4(a), Peak output power		
Test procedure:	ANSI C63.10 section 7.8.5		
Test mode:	Compliance	Verdict:	PASS
Date(s):	19-Jan-20		
Temperature: 22 ºC	Relative Humidity: 54 %	Air Pressure: 1016 hPa	Power: 3.6 VDC
Remarks:			

Plot 7.5.1 Peak output power at low frequency

Data rate 980 bps

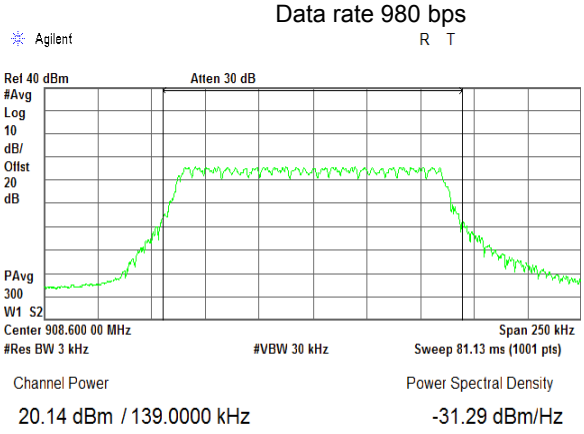


Data rate 5470 bps

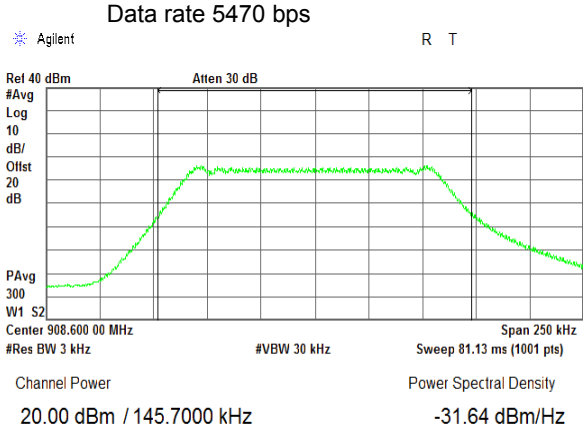


Plot 7.5.2 Peak output power at mid frequency

Data rate 980 bps



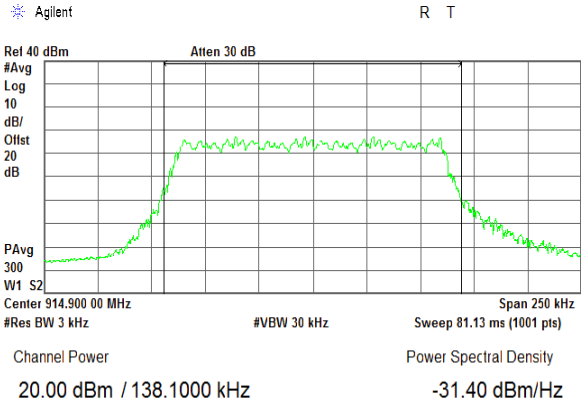
Data rate 5470 bps



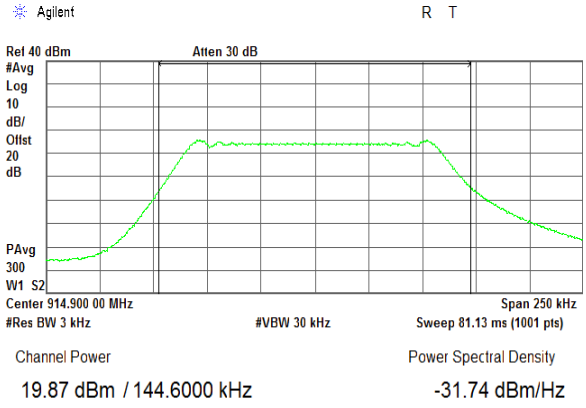
Test specification:	Section 15.247(b), RSS-247 section 5.4(a), Peak output power		
Test procedure:	ANSI C63.10 section 7.8.5		
Test mode:	Compliance	Verdict:	PASS
Date(s):	19-Jan-20		
Temperature: 22 ºC	Relative Humidity: 54 %	Air Pressure: 1016 hPa	Power: 3.6 VDC
Remarks:			

Plot 7.5.3 Peak output power at high frequency

Data rate 980 bps



Data rate 5470 bps



Test specification:	Section 15.247(d), RSS-247 section 5.4(a), Peak power density		
Test procedure:	ANSI C63.10, section 11.10.5		
Test mode:	Compliance	Verdict:	PASS
Date(s):	12-Jan-20		
Temperature: 22 ºC	Relative Humidity: 48 %	Air Pressure: 1024 hPa	Power: 3.6 VDC
Remarks:			

7.6 Peak spectral power density

7.6.1 General

This test was performed to measure the peak spectral power density at the transmitter RF antenna connector. Specification test limits are given in Table 7.6.1.

Table 7.6.1 Peak spectral power density limits

Assigned frequency range, MHz	Measurement bandwidth, kHz	Peak spectral power density, dBm
902.0 – 928.0	3.0	8.0

7.6.2 Test procedure

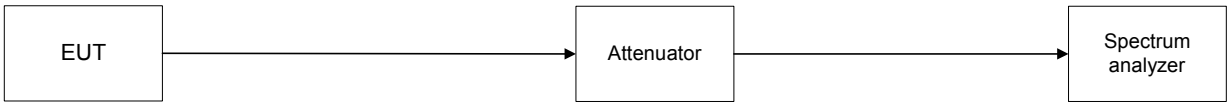
7.6.2.1 The EUT was set up as shown in Figure 7.6.1, energized and its proper operation was checked.

7.6.2.2 The EUT was adjusted to produce maximum available to end user RF output power.

7.6.2.3 The frequency span of spectrum analyzer was set to capture the entire 6 dB band of the transmitter, in peak hold mode with resolution bandwidth set to 3.0 kHz, video bandwidth wider than resolution bandwidth, auto sweep time and sufficient number of sweeps was allowed for trace stabilization. The spectrum lines spacing was verified to be wider than 3 kHz. Otherwise the resolution bandwidth was reduced until individual spectrum lines were resolved and the power of individual spectrum lines was integrated over 3 kHz band.

7.6.2.4 The peak of emission was zoomed with span set just wide enough to capture the emission peak area and sweep time was set equal to span width divided by resolution bandwidth. Spectrum analyzer was set in peak hold mode, sufficient number of sweeps was allowed for trace stabilization and peak spectral power density was measured as provided in Table 7.6.2 and associated plots.

Figure 7.6.1 Peak spectral power density test setup



Test specification:	**Section 15.247(d), RSS-247 section 5.4(a), Peak power density**		
Test procedure:	ANSI C63.10, section 11.10.5		
Test mode:	Compliance	**Verdict:**	PASS
Date(s):	12-Jan-20		
Temperature: 22 ºC	**Relative Humidity:** 48 %	**Air Pressure:** 1024 hPa	**Power:** 3.6 VDC
Remarks:			

Table 7.6.2 Peak spectral power density test results

ASSIGNED FREQUENCY: 902.0 – 928.0 MHz
MODULATION: LoRa
MODULATING SIGNAL: PRBS
TRANSMITTER OUTPUT POWER SETTINGS: Maximum
DETECTOR USED: Average
RESOLUTION BANDWIDTH: 3 kHz
VIDEO BANDWIDTH: 10 kHz

BIT RATE: 980 bps

Carrier frequency, MHz	Spectrum analyzer reading, dBm	External attenuation, dB	Cable loss, dB	Peak power density, dB(mW/3 kHz)	Limit, dBm	Margin*, dB	Verdict
902.3	6.35	NA	NA	6.35	8.0	-1.65	Pass
908.6	6.09	NA	NA	6.09	8.0	-1.91	Pass
914.9	6.14	NA	NA	6.14	8.0	-1.86	Pass

BIT RATE: 5470 bps

Carrier frequency, MHz	Spectrum analyzer reading, dBm	External attenuation, dB	Cable loss, dB	Peak power density, dB(mW/3 kHz)	Limit, dBm	Margin*, dB	Verdict
902.3	5.84	NA	NA	5.84	8.0	-2.16	Pass
908.6	5.88	NA	NA	5.88	8.0	-2.12	Pass
914.9	5.93	NA	NA	5.93	8.0	-2.07	Pass

* - Margin = Peak power density – specification limit.

Reference numbers of test equipment used

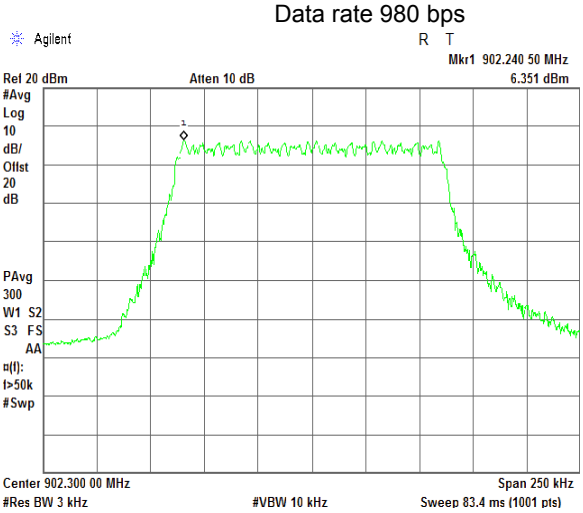
HL 3442	HL 3818						

Full description is given in Appendix A.

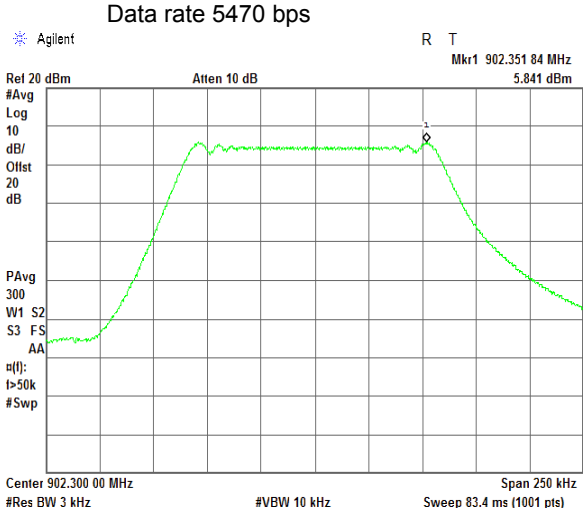
Test specification:	Section 15.247(d), RSS-247 section 5.4(a), Peak power density		
Test procedure:	ANSI C63.10, section 11.10.5		
Test mode:	Compliance	Verdict:	PASS
Date(s):	12-Jan-20		
Temperature: 22 ºC	Relative Humidity: 48 %	Air Pressure: 1024 hPa	Power: 3.6 VDC
Remarks:			

Plot 7.6.1 Peak spectral power density at low frequency

Data rate 980 bps

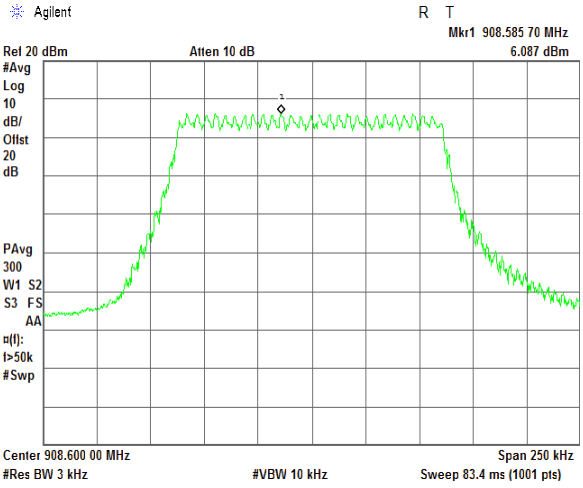


Data rate 5470 bps

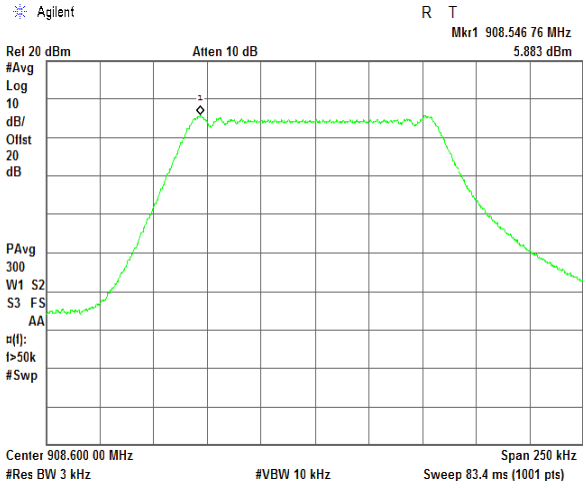


Plot 7.6.2 Peak spectral power density at mid frequency

Data rate 980 bps



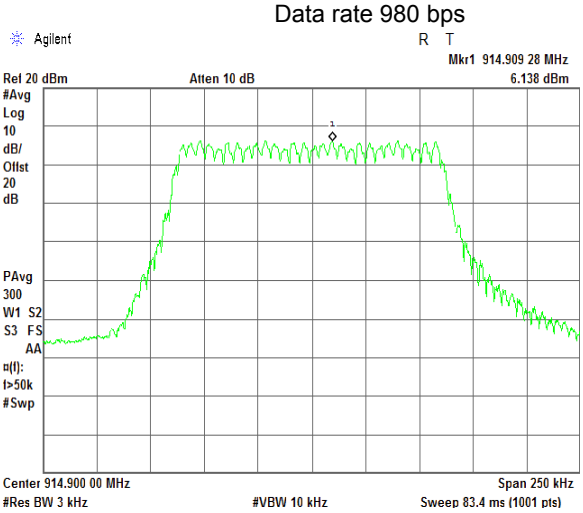
Data rate 5470 bps



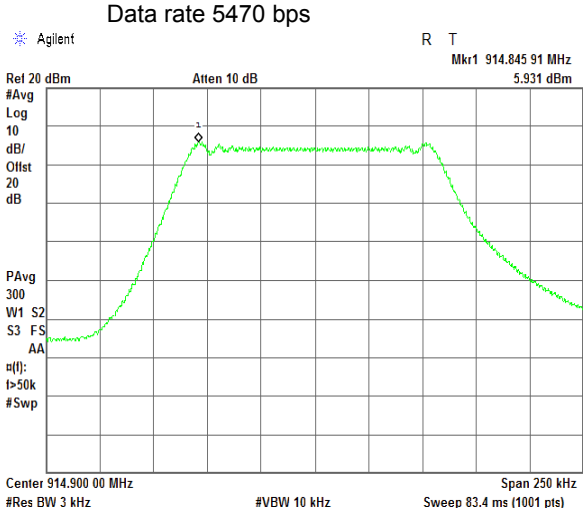
Test specification:	Section 15.247(d), RSS-247 section 5.4(a), Peak power density		
Test procedure:	ANSI C63.10, section 11.10.5		
Test mode:	Compliance	Verdict:	PASS
Date(s):	12-Jan-20		
Temperature: 22 ºC	Relative Humidity: 48 %	Air Pressure: 1024 hPa	Power: 3.6 VDC
Remarks:			

Plot 7.6.3 Peak spectral power density at high frequency

Data rate 980 bps



Data rate 5470 bps



Test specification:	Section 15.247(d), RSS-247 section 5.5, Radiated spurious emissions		
Test procedure:	ANCI C63.10 section 6.5 & 6.6		
Test mode:	Compliance	Verdict:	PASS
Date(s):	12-Jan-20		
Temperature: 22 ºC	Relative Humidity: 48 %	Air Pressure: 1024 hPa	Power: 3.6 VDC
Remarks:			

7.7 Field strength of spurious emissions

7.7.1 General

This test was performed to measure field strength of spurious emissions from the EUT. Specification test limits are given in Table 7.7.1

Table 7.7.1 Radiated spurious emissions limits

Frequency, MHz	Field strength at 3 m within restricted bands, dB(μV/m)*			Attenuation of field strength of spurious versus carrier outside restricted bands, dBc***
	Peak	Quasi Peak	Average	
0.009 – 0.090	148.5 – 128.5	NA	128.5 – 108.5**	20.0
0.090 – 0.110	NA	108.5 – 106.8**	NA	
0.110 – 0.490	126.8 – 113.8	NA	106.8 – 93.8**	
0.490 – 1.705	NA	73.8 – 63.0**	NA	
1.705 – 30.0*		69.5		
30 – 88		40.0		
88 – 216		43.5		
216 – 960		46.0		
960 - 1000		54.0		
1000 – 10th harmonic	74.0	NA	54.0	

*- The limit for 3 m test distance was calculated using the inverse square distance extrapolation factor as follows:

$$Lim_{S2} = Lim_{S1} + 40 \log (S_1/S_2),$$

where S_1 and S_2 – standard defined and test distance respectively in meters.

**- The limit decreases linearly with the logarithm of frequency.

*** - The field strength limits applied from the lowest radio frequency generated in the device, without going below 9 kHz up to the tenth harmonic of the highest fundamental frequency.

7.7.2 Test procedure for spurious emission field strength measurements in 9 kHz to 30 MHz band

7.7.2.1 The EUT was set up as shown in Figure 7.7.1 energized and the performance check was conducted.

7.7.2.2 The specified frequency range was investigated with antenna connected to spectrum analyzer/ EMI receiver. To find maximum radiation the turntable was rotated 360^0 and the measuring antenna was rotated around its vertical axis.

7.7.2.3 The worst test results (the lowest margins) were recorded and shown in the associated plots.

7.7.3 Test procedure for spurious emission field strength measurements above 30 MHz

7.7.3.1 The EUT was set up as shown in Figure 7.7.2, Figure 7.7.3, energized and the performance check was conducted.

7.7.3.2 The specified frequency range was investigated with antenna connected to spectrum analyzer/ EMI receiver. To find maximum radiation the turntable was rotated 360^0, the measuring antenna height was changed from 1 to 4 m, its polarization was switched from vertical to horizontal.

7.7.3.3 The worst test results (the lowest margins) were recorded and shown in the associated plots.

Test specification:	Section 15.247(d), RSS-247 section 5.5, Radiated spurious emissions		
Test procedure:	ANCI C63.10 section 6.5 & 6.6		
Test mode:	Compliance	Verdict:	PASS
Date(s):	12-Jan-20		
Temperature: 22 ºC	Relative Humidity: 48 %	Air Pressure: 1024 hPa	Power: 3.6 VDC
Remarks:			

Figure 7.7.1 Setup for spurious emission field strength measurements below 30 MHz

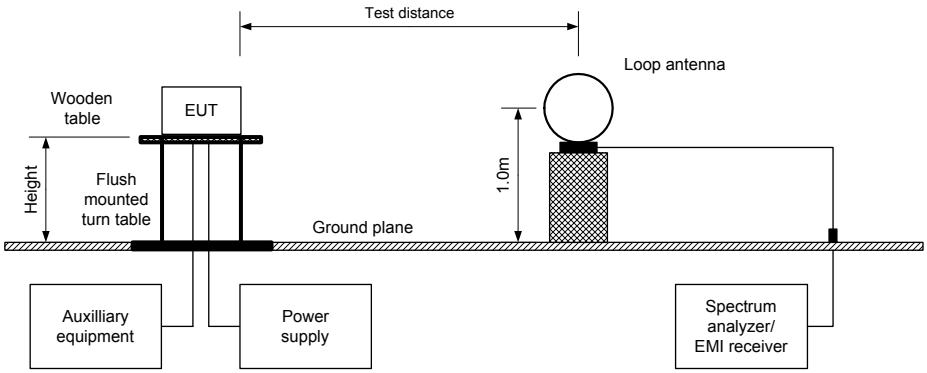
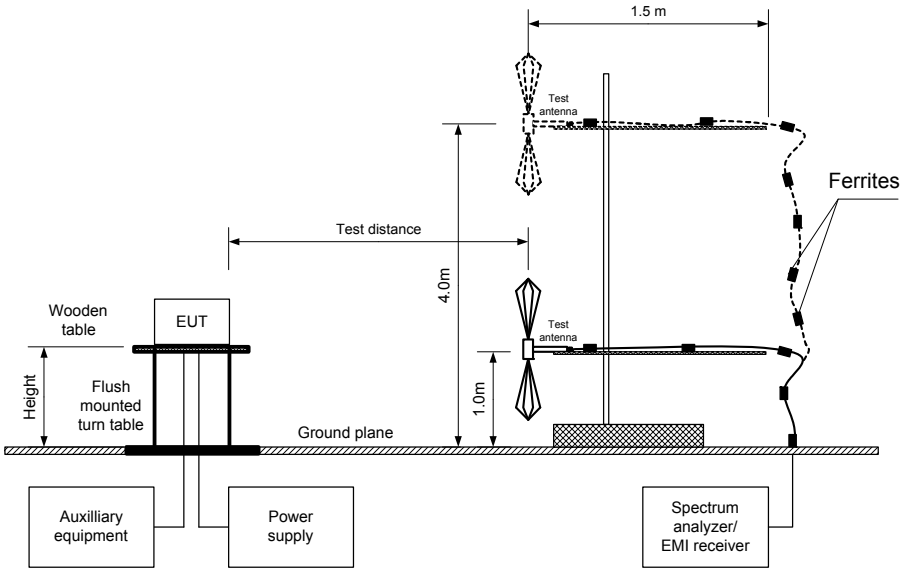
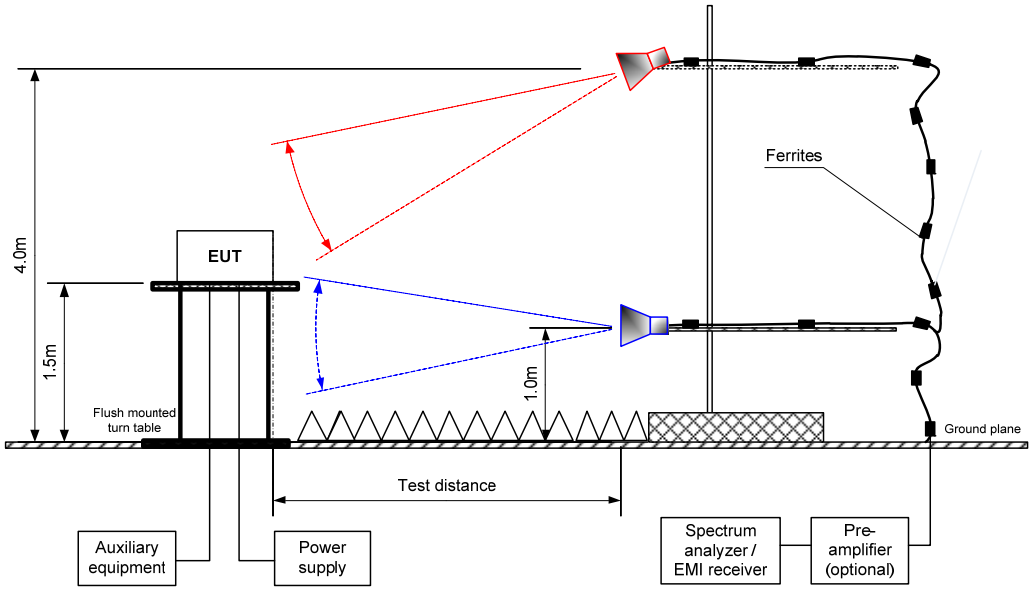


Figure 7.7.2 Setup for spurious emission field strength measurements in 30 – 1000 MHz



Test specification:	Section 15.247(d), RSS-247 section 5.5, Radiated spurious emissions		
Test procedure:	ANCI C63.10 section 6.5 & 6.6		
Test mode:	Compliance	Verdict:	PASS
Date(s):	12-Jan-20		
Temperature: 22 ºC	Relative Humidity: 48 %	Air Pressure: 1024 hPa	Power: 3.6 VDC
Remarks:			

Figure 7.7.3 Setup for spurious emission field strength measurements above1000 MHz



Test specification:	**Section 15.247(d), RSS-247 section 5.5, Radiated spurious emissions**		
Test procedure:	ANCI C63.10 section 6.5 & 6.6		
Test mode:	Compliance	**Verdict:**	PASS
Date(s):	12-Jan-20		
Temperature: 22 ºC	**Relative Humidity:** 48 %	**Air Pressure:** 1024 hPa	**Power:** 3.6 VDC
Remarks:			

Table 7.7.2 Field strength of emissions outside restricted bands

ASSIGNED FREQUENCY: 902.0 – 928.0 MHz
INVESTIGATED FREQUENCY RANGE: 0.009 – 9500 MHz
TEST DISTANCE: 3 m
MODULATION: LoRa
MODULATING SIGNAL: PRBS
BIT RATE: 980 bps
DUTY CYCLE: 100 %
TRANSMITTER OUTPUT POWER SETTINGS: Maximum
DETECTOR USED: Peak
RESOLUTION BANDWIDTH: 100 kHz
VIDEO BANDWIDTH: 300 kHz
TEST ANTENNA TYPE: Active loop (9 kHz – 30 MHz)
Biconilog (30 MHz – 1000 MHz)
Double ridged guide (above 1000 MHz)

Frequency, MHz	Field strength of spurious, dB(µV/m)	Antenna polarization	Antenna height, m	Azimuth, degrees*	Field strength of carrier, dB(µV/m)	Attenuation below carrier, dBc	Limit, dBc	Margin, dB**	Verdict
Low carrier frequency 902.3 MHz									
1804.383	47.29	Vertical	1.54	147	113.56	66.27	20.0	46.27	Pass
6313.400	47.97	Vertical	1.54	307		65.59		45.59	
Mid carrier frequency 908.6 MHz									
1817.133	46.41	Vertical	1.79	192	113.08	66.67	20.0	46.67	Pass
6359.817	46.65	Vertical	3.37	358		66.43		46.43	
High carrier frequency 914.9 MHz									
1829.600	45.12	Vertical	2.06	298	112.55	67.43	20.0	47.43	Pass
5489.133	46.27	Vertical	2.33	138		66.28		46.28	
6403.583	50.03	Vertical	1.54	167		62.52		42.52	

*****- EUT front panel refers to 0 degrees position of turntable.
******- Margin = Attenuation below carrier – specification limit.

Test specification:	**Section 15.247(d), RSS-247 section 5.5, Radiated spurious emissions**		
Test procedure:	ANCI C63.10 section 6.5 & 6.6		
Test mode:	Compliance	**Verdict:**	PASS
Date(s):	12-Jan-20		
Temperature: 22 ºC	**Relative Humidity:** 48 %	**Air Pressure:** 1024 hPa	**Power:** 3.6 VDC
Remarks:			

Table 7.7.3 Field strength of spurious emissions above 1 GHz within restricted bands

ASSIGNED FREQUENCY: 902.0 – 928.0 MHz
INVESTIGATED FREQUENCY RANGE: 1000 - 9500 MHz
TEST DISTANCE: 3 m
MODULATION: LoRa
MODULATING SIGNAL: PRBS
BIT RATE: 980 bps
DUTY CYCLE: 100 %
TRANSMITTER OUTPUT POWER SETTINGS: Maximum
DETECTOR USED: Peak
RESOLUTION BANDWIDTH: 1000 kHz
TEST ANTENNA TYPE: Double ridged guide

Frequency, MHz	Antenna		Azimuth, degrees*	Peak field strength(VBW=3 MHz)			Average field strength(VBW=10 Hz)				Verdict
	Polarization	Height, m		Measured, dB(µV/m)	Limit, dB(µV/m)	Margin, dB**	Measured, dB(µV/m)	Calculated, dB(µV/m)	Limit, dB(µV/m)	Margin, dB***	
Low carrier frequency 902.3 MHz											
2706.583	Vertical	1.28	223	52.88	74.0	-21.12	49.32	NA	54.0	-4.68	Pass
3609.000	Vertical	1.54	281	41.24	74.0	-32.76	31.40	NA	54.0	-22.60	
5413.267	Vertical	2.06	37	44.91	74.0	-29.09	33.66	NA	54.0	-20.34	
Mid carrier frequency 908.6 MHz											
2725.500	Horizontal	2.32	220	53.53	74.0	-20.47	50.31	NA	54.0	-3.69	Pass
3633.933	Vertical	2.32	0	40.34	74.0	-33.66	28.98	NA	54.0	-25.02	
5451.450	Vertical	1.28	168	44.18	74.0	-29.82	34.91	NA	54.0	-19.09	
High carrier frequency 914.9 MHz											
2744.767	Vertical	2.06	261	52.85	74.0	-21.15	51.12	NA	54.0	-2.88	Pass
3659.367	Vertical	2.07	198	41.11	74.0	-32.89	32.42	NA	54.0	-21.58	
7319.183	Vertical	1.28	336	48.72	74.0	-25.28	35.00	NA	54.0	-19.00	
9152.017	Vertical	2.58	179	47.16	74.0	-26.84	34.68	NA	54.0	-19.32	

*****- EUT front panel refers to 0 degrees position of turntable.
******- Margin = Measured field strength - specification limit.
***- Margin = Calculated field strength - specification limit,
where Calculated field strength = Measured field strength + average factor.

Table 7.7.4 Average factor calculation

Transmission pulse		Transmission burst		Transmission train duration, ms	Average factor, dB
Duration, ms	Period, ms	Duration, ms	Period, ms		
NA	NA	NA	NA	NA	NA

*- Average factor was calculated as follows

for pulse train shorter than 100 ms: $$Average\ factor = 20 \times \log_{10}\left(\frac{Pulse\ duration}{Pulse\ period} \times \frac{Burst\ duration}{Train\ duration} \times Number\ of\ bursts\ within\ pulse\ train\right)$$

for pulse train longer than 100 ms: $$Average\ factor = 20 \times \log_{10}\left(\frac{Pulse\ duration}{Pulse\ period} \times \frac{Burst\ duration}{100\,ms} \times Number\ of\ bursts\ within\ 100\,ms\right)$$

Test specification:	**Section 15.247(d), RSS-247 section 5.5, Radiated spurious emissions**		
Test procedure:	ANCI C63.10 section 6.5 & 6.6		
Test mode:	Compliance	**Verdict:**	PASS
Date(s):	12-Jan-20		
Temperature: 22 ºC	**Relative Humidity:** 48 %	**Air Pressure:** 1024 hPa	**Power:** 3.6 VDC
Remarks:			

Table 7.7.5 Field strength of spurious emissions below 1 GHz within restricted bands

ASSIGNED FREQUENCY:	902.0 – 928.0MHz
INVESTIGATED FREQUENCY RANGE:	0.009 – 1000 MHz
TEST DISTANCE:	3 m
MODULATION:	LoRa
MODULATING SIGNAL:	PRBS
BIT RATE:	980 bps
DUTY CYCLE:	100 %
TRANSMITTER OUTPUT POWER SETTINGS:	Maximum
RESOLUTION BANDWIDTH:	0.2 kHz (9 kHz – 150 kHz) 9.0 kHz (150 kHz – 30 MHz) 120 kHz (30 MHz – 1000 MHz)
VIDEO BANDWIDTH:	> Resolution bandwidth
TEST ANTENNA TYPE:	Active loop (9 kHz – 30 MHz) Biconilog (30 MHz – 1000 MHz)

Frequency, MHz	**Peak emission, dB(μV/m)**	**Quasi-peak**			**Antenna polarization**	**Antenna height, m**	**Turn-table position**, degrees**	**Verdict**
		Measured emission, dB(μV/m)	**Limit, dB(μV/m)**	**Margin, dB***				
Low carrier frequency 902.3 MHz								
No emissions were found								Pass
Mid carrier frequency 908.6 MHz								
No emissions were found								Pass
High carrier frequency 914.9 MHz								
No emissions were found								Pass

*****- Margin = Measured emission - specification limit.
******- EUT front panel refer to 0 degrees position of turntable.

Test specification:	**Section 15.247(d), RSS-247 section 5.5, Radiated spurious emissions**		
Test procedure:	ANCI C63.10 section 6.5 & 6.6		
Test mode:	Compliance	**Verdict:**	PASS
Date(s):	12-Jan-20		
Temperature: 22 ºC	**Relative Humidity:** 48 %	**Air Pressure:** 1024 hPa	**Power:** 3.6 VDC
Remarks:			

Table 7.7.6 Restricted bands according to FCC section 15.205

MHz	MHz	MHz	MHz	MHz	GHz
0.09 - 0.11	8.37625 - 8.38675	73 - 74.6	399.9 - 410	2690 - 2900	10.6 - 12.7
0.495 - 0.505	8.41425 - 8.41475	74.8 - 75.2	608 - 614	3260 - 3267	13.25 - 13.4
2.1735 - 2.1905	12.29 - 12.293	108 - 121.94	960 - 1240	3332 - 3339	14.47 - 14.5
4.125 - 4.128	12.51975 - 12.52025	123 - 138	1300 - 1427	3345.8 - 3358	15.35 - 16.2
4.17725 - 4.17775	12.57675 - 12.57725	149.9 - 150.05	1435 - 1626.5	3600 - 4400	17.7 - 21.4
4.20725 - 4.20775	13.36 - 13.41	156.52475 - 156.52525	1645.5 - 1646.5	4500 - 5150	22.01 - 23.12
6.215 - 6.218	16.42 - 16.423	156.7 - 156.9	1660 - 1710	5350 – 5460	23.6 - 24
6.26775 - 6.26825	16.69475 - 16.69525	162.0125 - 167.17	1718.8 - 1722.2	7250 - 7750	31.2 - 31.8
6.31175 - 6.31225	16.80425 - 16.80475	167.72 - 173.2	2200 - 2300	8025 – 8500	36.43 - 36.5
8.291 - 8.294	25.5 - 25.67	240 - 285	2310 - 2390	9000 - 9200	Above 38.6
8.362 - 8.366	37.5 - 38.25	322 - 335.4	2483.5 - 2500	9300 - 9500	

Table 7.7.7 Restricted bands according to RSS-Gen

MHz	MHz	MHz	MHz	MHz	GHz
0.09 - 0.11	8.291 - 8.294	16.80425 - 16.80475	399.9 - 410	3260 - 3267	10.6 - 12.7
2.1735 - 2.1905	8.362 - 8.366	25.5 - 25.67	608 - 614	3332 – 3339	13.25 - 13.4
3.020 – 3.026	8.37625 - 8.38675	37.5 - 38.25	960 – 1427	3345.8 – 3358	14.47 – 14.5
4.125 – 4.128	8.41425 - 8.41475	73 - 74.6	1435 – 1626.5	3500 – 4400	15.35 – 16.2
4.17725 – 4.17775	12.29 – 12.293	74.8 - 75.2	1645.5 – 1646.5	4500 – 5150	17.7 – 21.4
4.20725 – 4.20775	12.51975 – 12.52025	108 – 138	1660 - 1710	5350 – 5460	22.01 – 23.12
5.677 – 5.683	12.57675 – 12.57725	156.52475 – 156.52525	1718.8 - 1722.2	7250 - 7750	23.6 - 24
6.215 - 6.218	13.36 – 13.41	156.7 - 156.9	2200 - 2300	8025 – 8500	31.2 - 31.8
6.26775 - 6.26825	16.42 - 16.423	240 - 285	2310 - 2390	9000 - 9200	36.43 - 36.5
6.31175 - 6.31225	16.69475 - 16.69525	322 - 335.4	2655 - 2900	9300 - 9500	Above 38.6

Reference numbers of test equipment used

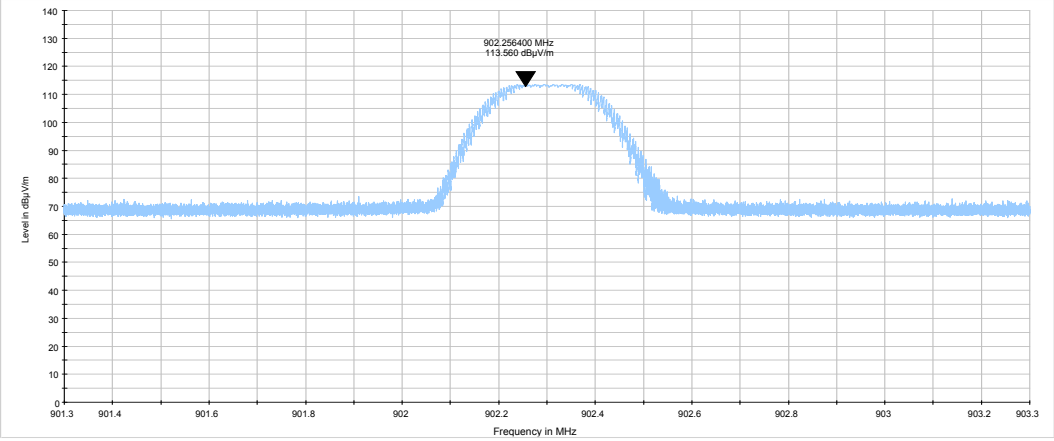
HL 0446	HL 3903	HL 4933	HL 5288	HL 5372	HL 5665		

Full description is given in Appendix A.

Test specification:	Section 15.247(d), RSS-247 section 5.5, Radiated spurious emissions		
Test procedure:	ANCI C63.10 section 6.5 & 6.6		
Test mode:	Compliance	Verdict:	PASS
Date(s):	12-Jan-20		
Temperature: 22 ºC	Relative Humidity: 48 %	Air Pressure: 1024 hPa	Power: 3.6 VDC
Remarks:			

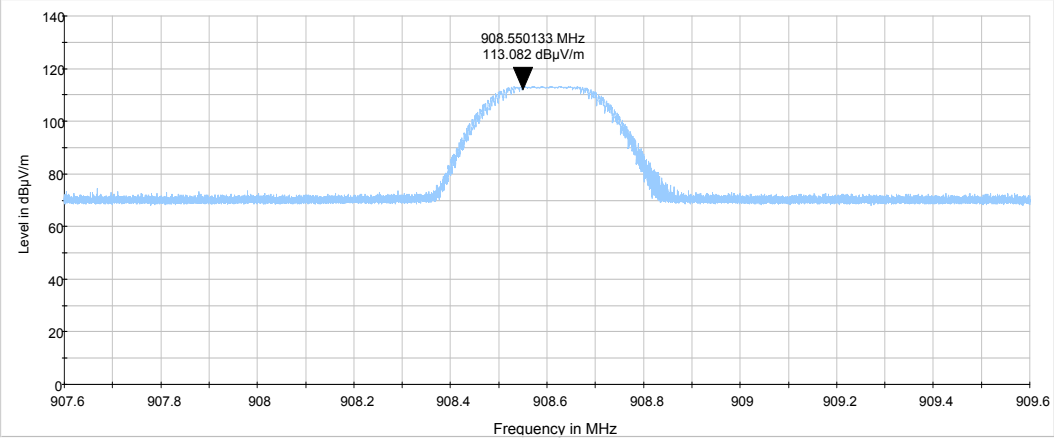
Plot 7.7.1 Radiated emission measurements at the low carrier frequency

TEST SITE: Semi anechoic chamber
TEST DISTANCE: 3 m
ANTENNA POLARIZATION: Vertical and horizontal



Plot 7.7.2 Radiated emission measurements at the mid carrier frequency

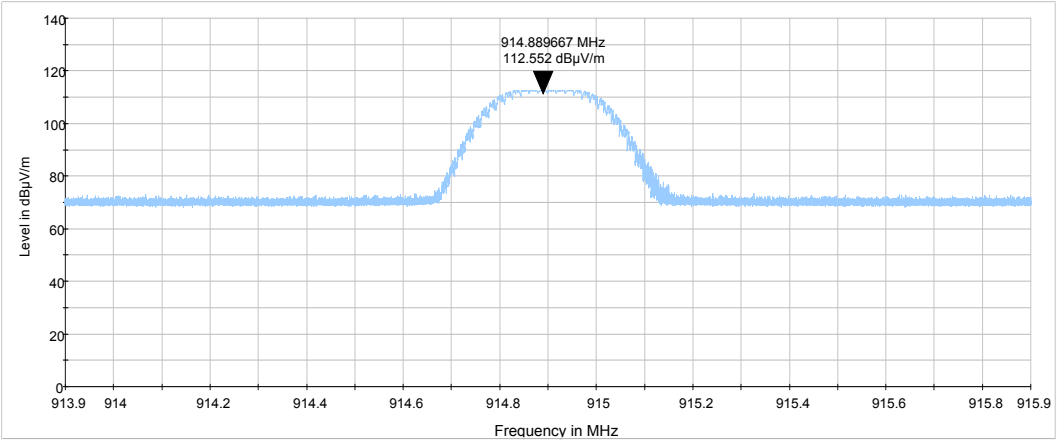
TEST SITE: Semi anechoic chamber
TEST DISTANCE: 3 m
ANTENNA POLARIZATION: Vertical and horizontal



Test specification:	**Section 15.247(d), RSS-247 section 5.5, Radiated spurious emissions**		
Test procedure:	ANCI C63.10 section 6.5 & 6.6		
Test mode:	Compliance	**Verdict:**	PASS
Date(s):	12-Jan-20		
Temperature: 22 ºC	**Relative Humidity:** 48 %	**Air Pressure:** 1024 hPa	**Power:** 3.6 VDC
Remarks:			

Plot 7.7.3 Radiated emission measurements at the high carrier frequency

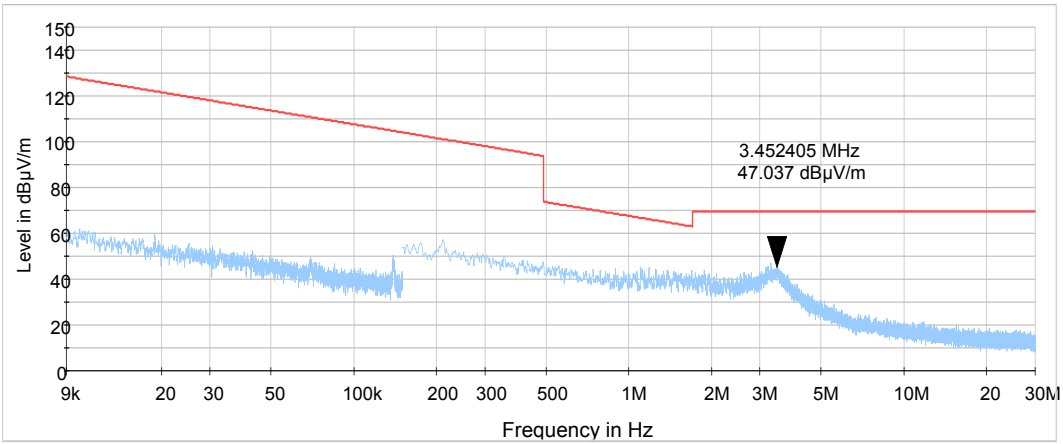
TEST SITE: Semi anechoic chamber
TEST DISTANCE: 3 m
ANTENNA POLARIZATION: Vertical and horizontal



Test specification:	Section 15.247(d), RSS-247 section 5.5, Radiated spurious emissions		
Test procedure:	ANCI C63.10 section 6.5 & 6.6		
Test mode:	Compliance	Verdict:	PASS
Date(s):	12-Jan-20		
Temperature: 22 ºC	Relative Humidity: 48 %	Air Pressure: 1024 hPa	Power: 3.6 VDC
Remarks:			

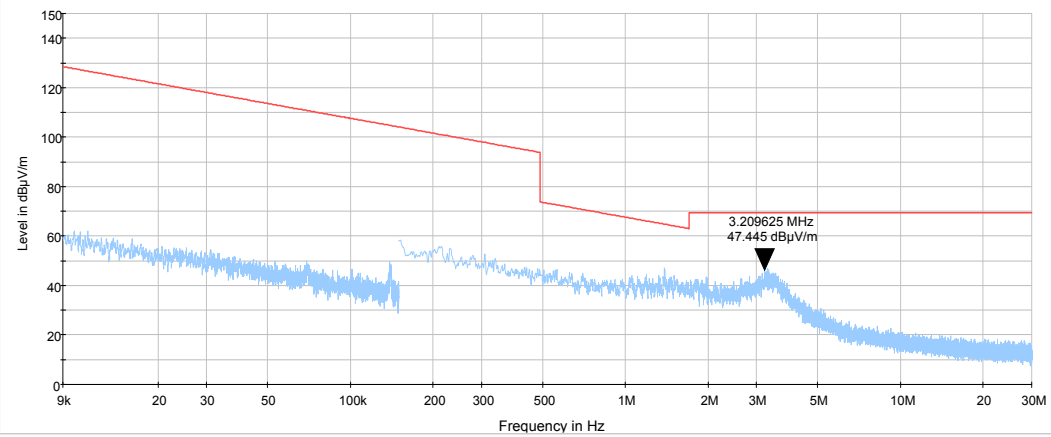
Plot 7.7.4 Radiated emission measurements from 9 kHz to 30 MHz at the low carrier frequency

TEST SITE: Semi anechoic chamber
TEST DISTANCE: 3 m
ANTENNA POLARIZATION: Vertical



Plot 7.7.5 Radiated emission measurements from 9 kHz to 30 MHz at the mid carrier frequency

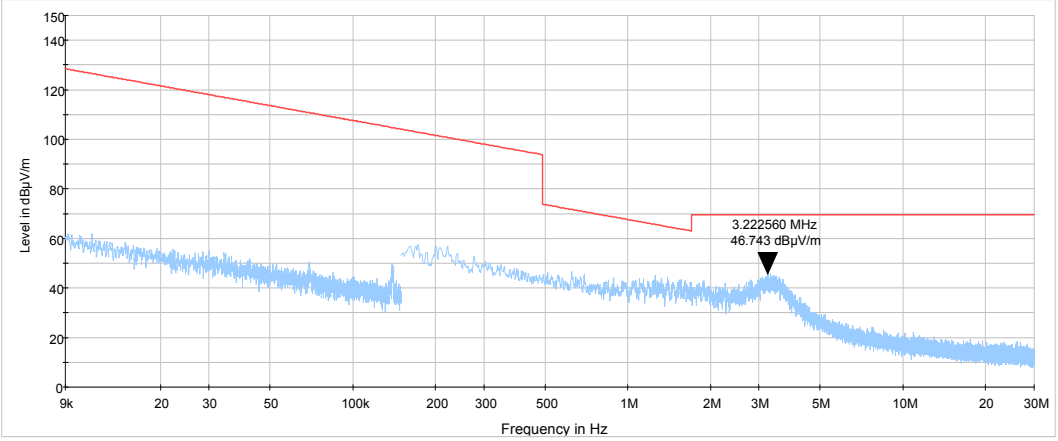
TEST SITE: Semi anechoic chamber
TEST DISTANCE: 3 m
ANTENNA POLARIZATION: Vertical



Test specification:	Section 15.247(d), RSS-247 section 5.5, Radiated spurious emissions		
Test procedure:	ANCI C63.10 section 6.5 & 6.6		
Test mode:	Compliance	Verdict:	PASS
Date(s):	12-Jan-20		
Temperature: 22 ºC	Relative Humidity: 48 %	Air Pressure: 1024 hPa	Power: 3.6 VDC
Remarks:			

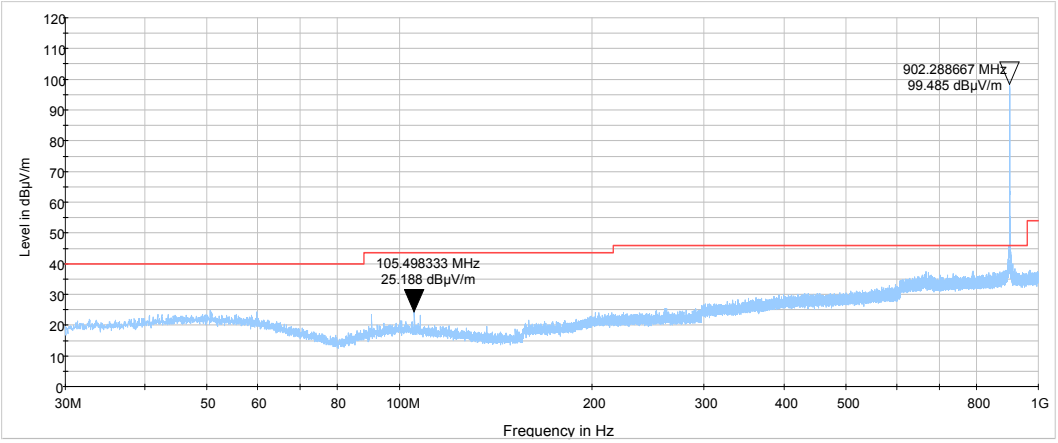
Plot 7.7.6 Radiated emission measurements from 9 kHz to 30 MHz at the high carrier frequency

TEST SITE: Semi anechoic chamber
TEST DISTANCE: 3 m
ANTENNA POLARIZATION: Vertical



Plot 7.7.7 Radiated emission measurements from 30 to 1000 MHz at the low carrier frequency

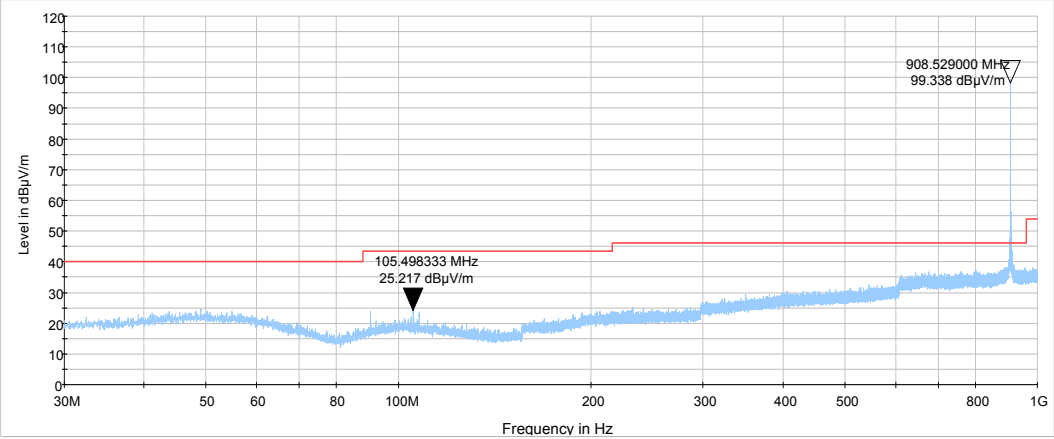
TEST SITE: Semi anechoic chamber
TEST DISTANCE: 3 m
ANTENNA POLARIZATION: Vertical and Horizontal



Test specification:	Section 15.247(d), RSS-247 section 5.5, Radiated spurious emissions		
Test procedure:	ANCI C63.10 section 6.5 & 6.6		
Test mode:	Compliance	Verdict:	PASS
Date(s):	12-Jan-20		
Temperature: 22 ºC	Relative Humidity: 48 %	Air Pressure: 1024 hPa	Power: 3.6 VDC
Remarks:			

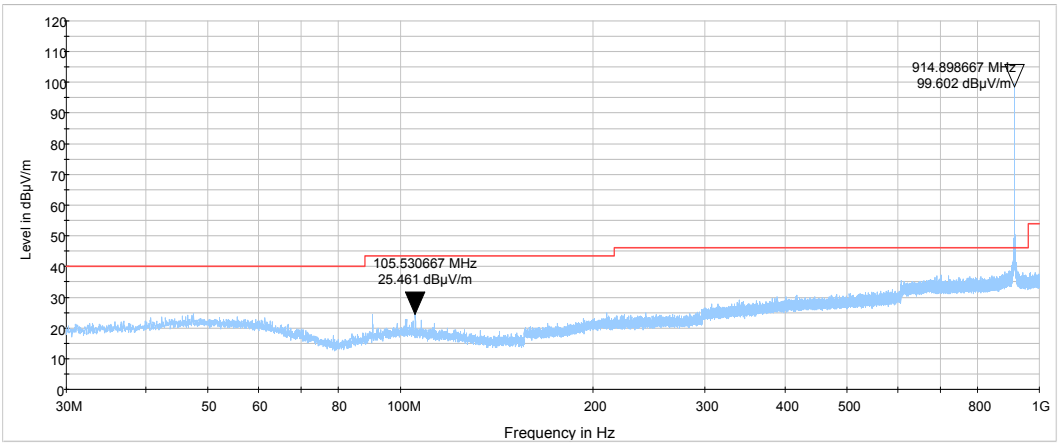
Plot 7.7.8 Radiated emission measurements from 30 to 1000 MHz at the mid carrier frequency

TEST SITE: Semi anechoic chamber
TEST DISTANCE: 3 m
ANTENNA POLARIZATION: Vertical and Horizontal



Plot 7.7.9 Radiated emission measurements from 30 to 1000 MHz at the high carrier frequency

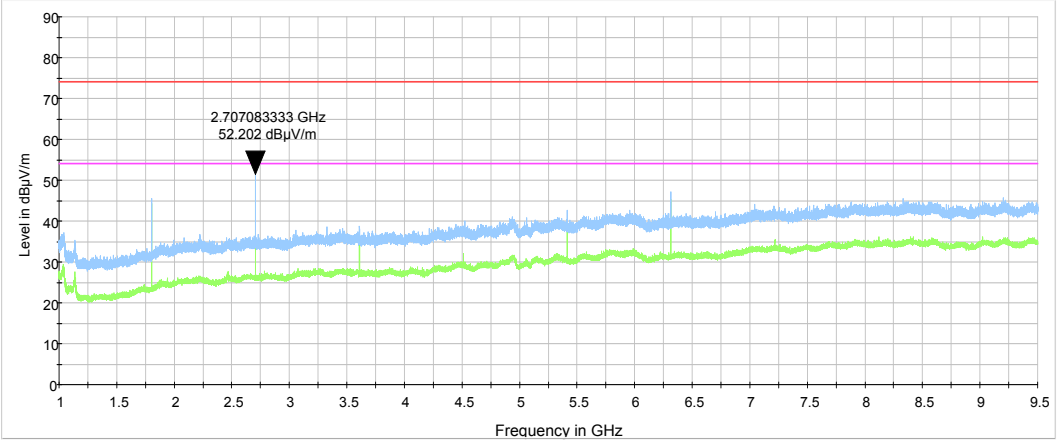
TEST SITE: Semi anechoic chamber
TEST DISTANCE: 3 m
ANTENNA POLARIZATION: Vertical and Horizontal



Test specification:	**Section 15.247(d), RSS-247 section 5.5, Radiated spurious emissions**		
Test procedure:	ANCI C63.10 section 6.5 & 6.6		
Test mode:	Compliance	**Verdict:**	PASS
Date(s):	12-Jan-20		
Temperature: 22 ºC	**Relative Humidity:** 48 %	**Air Pressure:** 1024 hPa	**Power:** 3.6 VDC
Remarks:			

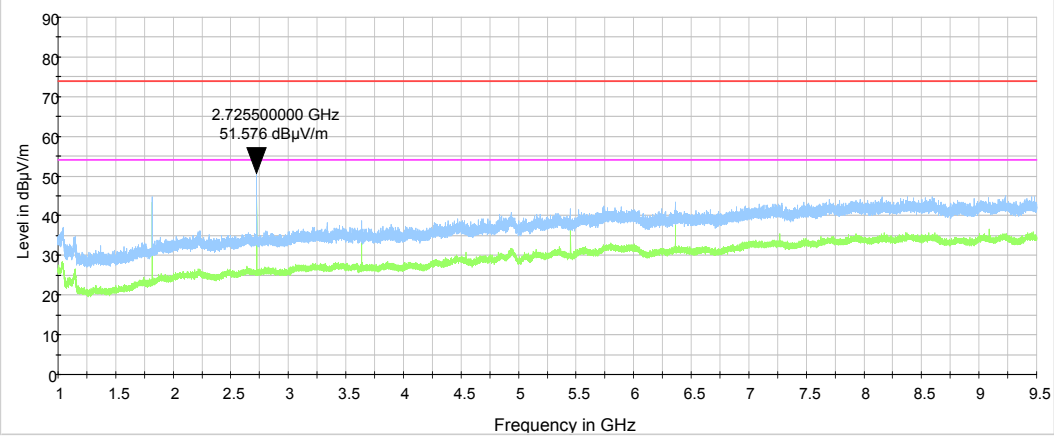
Plot 7.7.10 Radiated emission measurements from 1000 to 9500 MHz at the low carrier frequency

TEST SITE: Semi anechoic chamber
TEST DISTANCE: 3 m
ANTENNA POLARIZATION: Vertical and Horizontal



Plot 7.7.11 Radiated emission measurements from 1000 to 9500 MHz at the mid carrier frequency

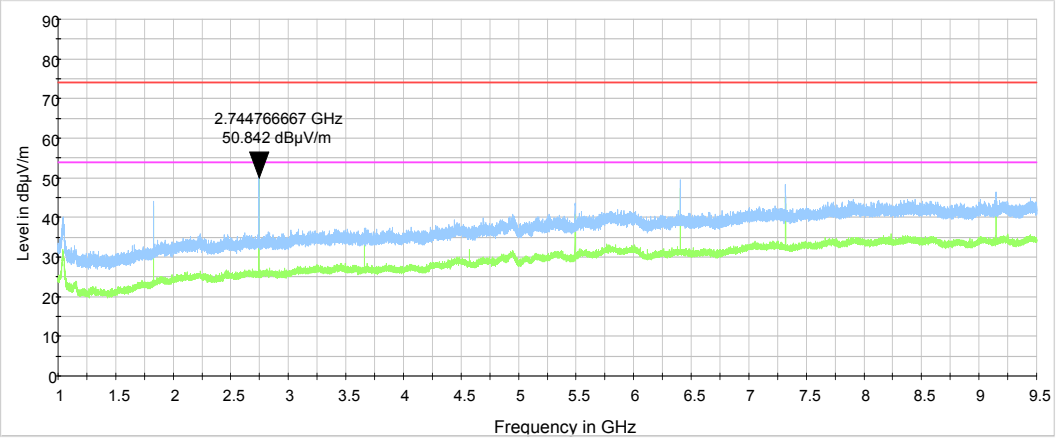
TEST SITE: Semi anechoic chamber
TEST DISTANCE: 3 m
ANTENNA POLARIZATION: Vertical and Horizontal



Test specification:	Section 15.247(d), RSS-247 section 5.5, Radiated spurious emissions		
Test procedure:	ANCI C63.10 section 6.5 & 6.6		
Test mode:	Compliance	Verdict:	PASS
Date(s):	12-Jan-20		
Temperature: 22 ºC	Relative Humidity: 48 %	Air Pressure: 1024 hPa	Power: 3.6 VDC
Remarks:			

Plot 7.7.12 Radiated emission measurements from 1000 to 9500 MHz at the high carrier frequency

TEST SITE: Semi anechoic chamber
TEST DISTANCE: 3 m
ANTENNA POLARIZATION: Vertical and Horizontal



Test specification:	Section 15.247(d), RSS-247 section 5.5, Emissions at band edges		
Test procedure:	ANSI C63.10 section 6.10		
Test mode:	Compliance	Verdict:	PASS
Date(s):	14-Jan-20		
Temperature: 25 ºC	Relative Humidity: 41 %	Air Pressure: 1025 hPa	Power: 3.6 VDC
Remarks:			

7.8 Band edge emissions at RF antenna connector

7.8.1 General

This test was performed to measure band edge emissions at RF antenna connector. Specification test limits are given in Table 7.8.1.

Table 7.8.1 Band edge emission limits

Assigned frequency, MHz	Attenuation below carrier*, dBc
902.0 – 928.0	20.0

* - Band edge emission limit is provided in terms of attenuation below the peak of modulated carrier measured with the same resolution bandwidth.

7.8.2 Test procedure

7.8.2.1 The EUT was set up as shown in Figure 7.8.1, energized normally modulated at the maximum data rate with its hopping function disabled and its proper operation was checked.

7.8.2.2 The EUT was adjusted to produce maximum available to end user RF output power at the lowest carrier frequency.

7.8.2.3 The spectrum analyzer span was set to capture the carrier frequency and associated modulation products. The resolution bandwidth was set wider than 1 % of the frequency span.

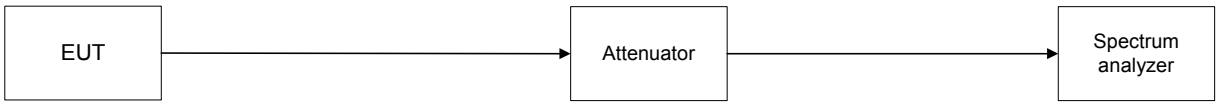
7.8.2.4 The spectrum analyzer was set in max hold mode and allowed trace to stabilize. The highest emission level within the authorized band was measured.

7.8.2.5 The maximum band edge emission and modulation product outside of the band were measured as provided in Table 7.8.2 and associated plots and referenced to the highest emission level measured within the authorized band.

7.8.2.6 The above procedure was repeated with the EUT adjusted to produce maximum RF output power at the highest carrier frequency.

7.8.2.7 The above procedure was repeated with the frequency hopping function enabled.

Figure 7.8.1 Band edge emission test setup



Test specification:	**Section 15.247(d), RSS-247 section 5.5, Emissions at band edges**		
Test procedure:	ANSI C63.10 section 6.10		
Test mode:	Compliance	**Verdict:**	PASS
Date(s):	14-Jan-20		
Temperature: 25 ºC	**Relative Humidity:** 41 %	**Air Pressure:** 1025 hPa	**Power:** 3.6 VDC
Remarks:			

Table 7.8.2 Band edge emission test results

ASSIGNED FREQUENCY RANGE: 902.0 – 928.0 MHz
DETECTOR USED: Peak
MODULATION: LoRa
MODULATING SIGNAL: PRBS
TRANSMITTER OUTPUT POWER SETTINGS: Maximum
RESOLUTION BANDWIDTH: ≥ 1% of the span
VIDEO BANDWIDTH: ≥ RBW

BIT RATE: 980 bps

Frequency, MHz	Band edge emission, dBm	Emission at carrier, dBm	Attenuation below carrier, dBc	Limit, dBc	Margin, dB*	Verdict
Frequency hopping disabled						
902.3	-28.29	20.23	48.52	20.0	28.52	Pass
914.9	-44.66	19.97	64.63		44.63	
Frequency hopping enabled						
902.3	-30.42	21.26	51.68	20.0	31.68	Pass
914.9	-42.72	21.10	63.82		43.82	

BIT RATE: 5470 bps

Frequency, MHz	Band edge emission, dBm	Emission at carrier, dBm	Attenuation below carrier, dBc	Limit, dBc	Margin, dB*	Verdict
Frequency hopping disabled						
902.3	-28.25	20.23	48.48	20.0	28.48	Pass
914.9	-43.84	19.99	63.83		43.83	
Frequency hopping enabled						
902.3	-31.72	21.33	53.05	20.0	33.05	Pass
914.9	-42.88	21.11	63.99		43.99	

*****- Margin = Attenuation below carrier – specification limit.

Reference numbers of test equipment used

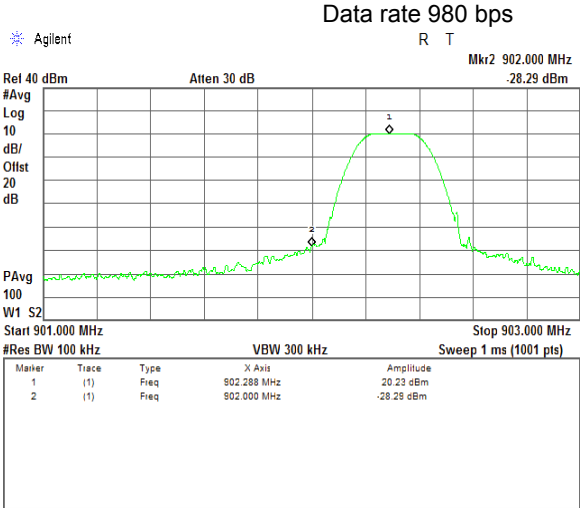
HL 3442	HL 3818						

Full description is given in Appendix A.

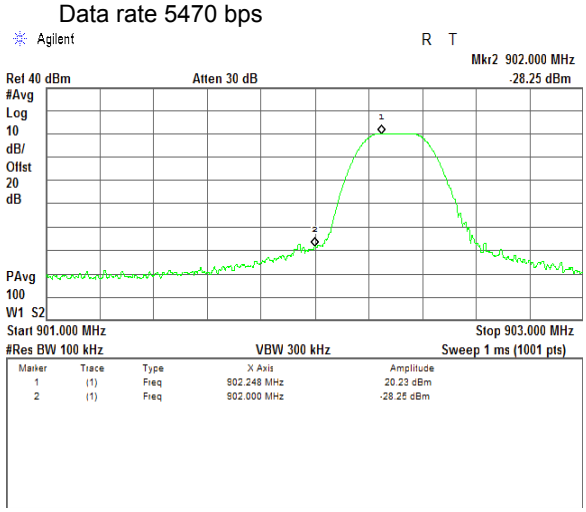
Test specification:	Section 15.247(d), RSS-247 section 5.5, Emissions at band edges		
Test procedure:	ANSI C63.10 section 6.10		
Test mode:	Compliance	Verdict:	PASS
Date(s):	14-Jan-20		
Temperature: 25 ºC	Relative Humidity: 41 %	Air Pressure: 1025 hPa	Power: 3.6 VDC
Remarks:			

Plot 7.8.1 The lowest band edge emission at low carrier frequency with hopping function disabled

Data rate 980 bps

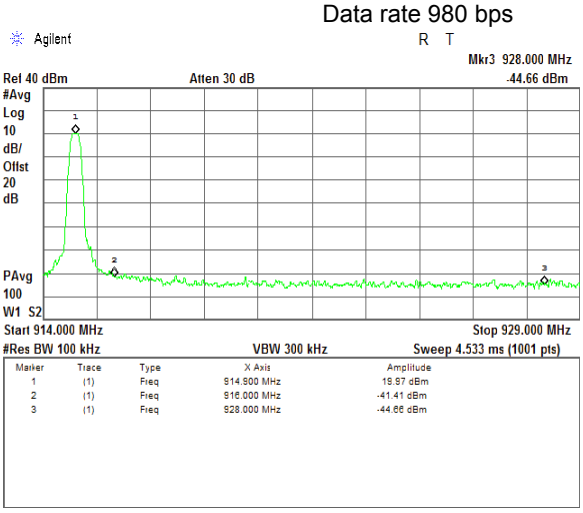


Data rate 5470 bps

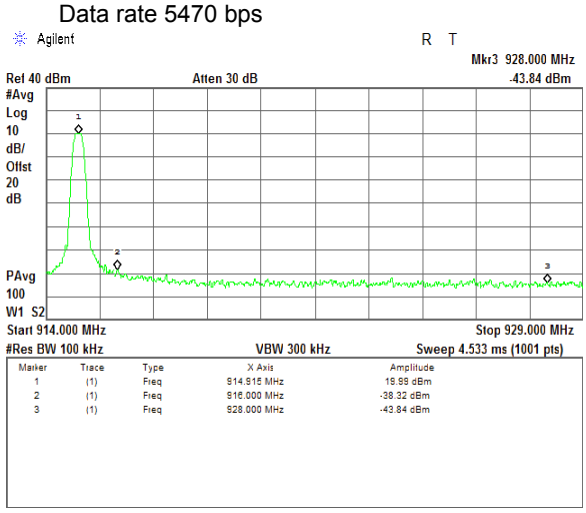


Plot 7.8.2 The highest band edge emission at high carrier frequency with hopping function disabled

Data rate 980 bps



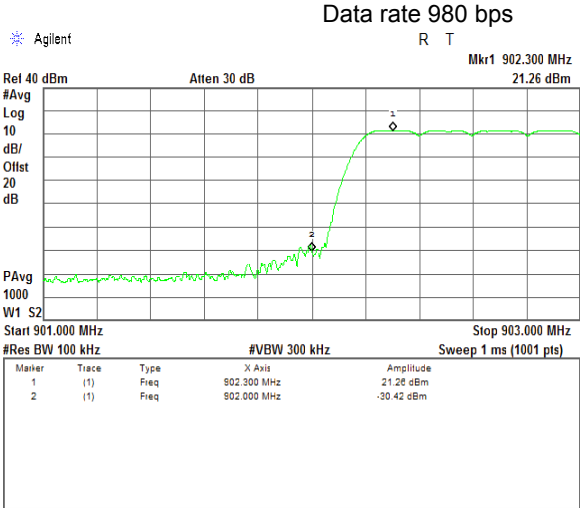
Data rate 5470 bps



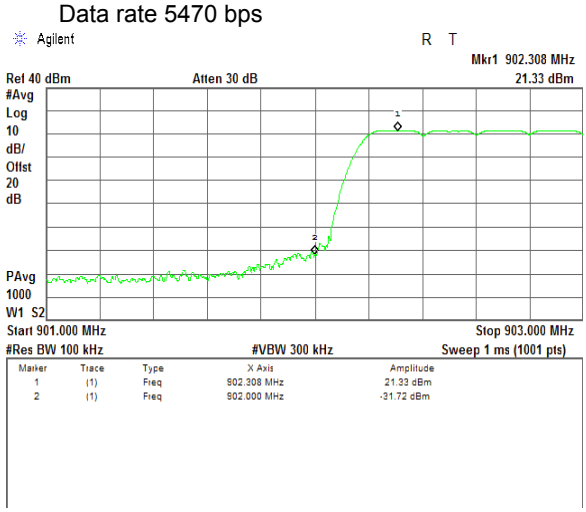
Test specification:	Section 15.247(d), RSS-247 section 5.5, Emissions at band edges		
Test procedure:	ANSI C63.10 section 6.10		
Test mode:	Compliance	Verdict:	PASS
Date(s):	14-Jan-20		
Temperature: 25 ºC	Relative Humidity: 41 %	Air Pressure: 1025 hPa	Power: 3.6 VDC
Remarks:			

Plot 7.8.3 The lowest band edge emission at low carrier frequency with hopping function enabled

Data rate 980 bps

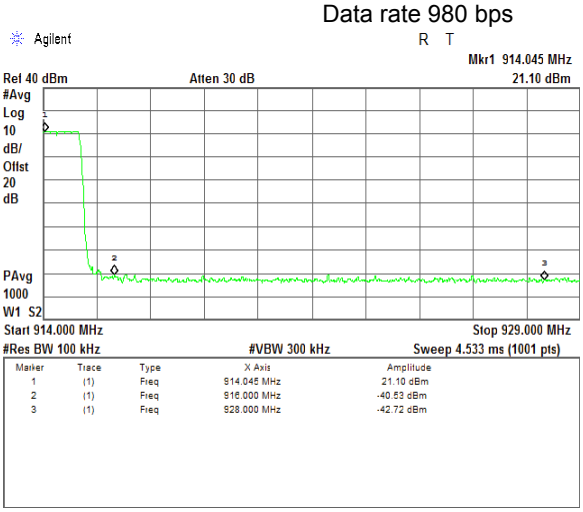


Data rate 5470 bps

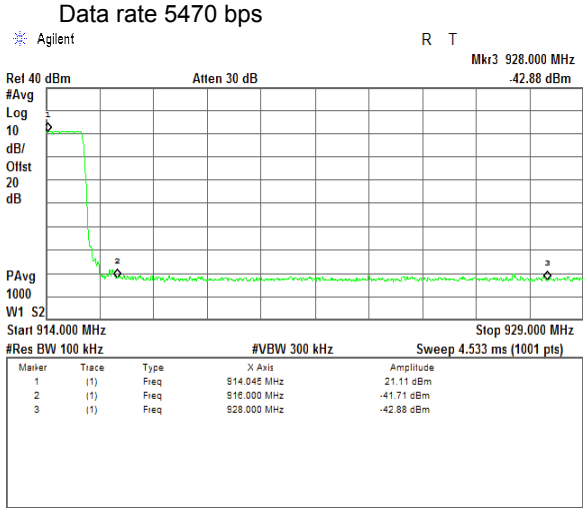


Plot 7.8.4 The highest band edge emission at high carrier frequency with hopping function enabled

Data rate 980 bps



Data rate 5470 bps



Test specification:	Section 15.203, RSS-Gen section 6.8, Antenna requirements		
Test procedure:	Visual inspection		
Test mode:	Compliance	Verdict:	PASS
Date(s):	23-Aug-18		
Temperature: 24 ºC	Relative Humidity: 48 %	Air Pressure: 1008 hPa	Power: 3.6 VDC
Remarks:			

7.9 Antenna requirements

The EUT was verified for compliance with antenna requirements. A transmitter shall be designed to ensure that no antenna other than that furnished by the responsible party will be used with the device. It may be either permanently attached or employs a unique antenna connector for every antenna proposed for use with the EUT. This requirement does not apply to professionally installed transmitters.
The rationale for compliance with the above requirements was either visual inspection results or supplier declaration. The summary of results is provided in Table 7.9.1.

Table 7.9.1 Antenna requirements

Requirement	Rationale	Verdict
The transmitter antenna is permanently attached	Visual inspection	Comply
The transmitter employs a unique antenna connector	NA	
The transmitter requires professional installation	NA	

8 APPENDIX A Test equipment and ancillaries used for tests

HL No	Description	Manufacturer	Model	Ser. No.	Last Cal./ Check*	Due Cal./ Check*
0446	Antenna, Loop, Active, 10 (9) kHz - 30 MHz	EMCO	6502	2857	24-Feb-20	24-Feb-21
3442	Precision Fixed Attenuator, 50 Ohm, 5 W, 20 dB, DC to 18 GHz	Mini-Circuits	BW-S20W5+	NA	25-Feb-20	25-Feb-21
3818	PSA Series Spectrum Analyzer, 3 Hz- 44 GHz	Agilent Technologies	E4446A	MY48250288	24-Apr-20	24-Apr-21
3903	Microwave Cable Assembly, 40.0 GHz, 1.5 m, SMA/SMA	Huber-Suhner	SUCOFLEX 102A	1226/2A	06-Apr-20	06-Apr-21
4933	Active Horn Antenna, 1 GHz to 18 GHz	COM-POWER CORPORATION	AHA-118	701046	06-Jan-20	06-Jan-21
5288	Trilog Antenna, 25 MHz - 8 GHz, 100W	Frankonia	ALX-8000E	00809	08-Feb-19	08-Feb-22
5372	MXE EMI receiver, 3 Hz to 44 GHz	Keysight Technologies	N9038A	MY57290155	18-Jun-20	18-Jun-21
5665	Cable SF118/11N(x2)/6M, 18 GHz, 11N/11N	Huber-Suhner	SF118	501644/118	23-Oct-19	23-Oct-20

*The calibration was valid at the test time.

9 APPENDIX B Test equipment correction factors

HL 0446: Active Loop Antenna
EMCO, model: 6502, s/n 2857

Frequency,	Measured antenna factor, dBS/m	Measurement uncertainty, dB
10	-33.4	±1.0
20	-37.8	±1.0
50	-40.5	±1.0
75	-41.0	±1.0
100	-41.2	±1.0
150	-41.2	±1.0
250	-41.1	±1.0
500	-41.2	±1.0
750	-41.3	±1.0
1000	-41.3	±1.0

Frequency,	Measured antenna factor, dBS/m	Measurement uncertainty, dB
2000	-41.4	±1.0
3000	-41.4	±1.0
4000	-41.5	±1.0
5000	-41.5	±1.0
10000	-41.7	±1.0
15000	-42.1	±1.0
20000	-42.7	±1.0
25000	-44.2	±1.0
30000	-45.8	±1.0

The antenna factor shall be added to receiver reading in dBμV to obtain field strength in dBμA/m

HL 4933: Active Horn Antenna
COM-POWER CORPORATION, model: AHA-118, s/n 701046

Frequency, MHz	Measured antenna factor (with preamplifier), dB/m
1000	-16.1
1500	-15.1
2000	-10.9
2500	-11.9
3000	-11.1
3500	-10.6
4000	-8.6
4500	-8.3
5000	-5.9
5500	-5.7
6000	-3.3
6500	-4.0
7000	-2.2
7500	-1.7
8000	1.1
8500	-0.8
9000	-1.5
9500	-0.2

Frequency, MHz	Measured antenna factor (with preamplifier), dB/m
10000	1.8
10500	1.0
11000	0.3
11500	-0.5
12000	3.1
12500	1.4
13000	-0.3
13500	-0.4
14000	2.5
14500	2.2
15000	1.9
15500	0.5
16000	2.1
16500	1.2
17000	0.6
17500	3.1
18000	4.2

The antenna factor shall be added to receiver reading in dBμV to obtain field strength in dBμV/m.

HL 5288: Trilog Antenna
Frankonia, model: ALX-8000E, s/n: 00809
30-1000 MHz

Frequency, MHz	Antenna factor, dB/m
30	14.96
35	15.33
40	16.37
45	17.56
50	17.95
60	16.87
70	13.22
80	10.56
90	13.61
100	15.46
120	14.03
140	12.23

Frequency, MHz	Antenna factor, dB/m
160	12.67
180	13.34
200	15.40
250	16.42
300	17.28
400	19.98
500	21.11
600	22.90
700	24.13
800	25.25
900	26.35
1000	27.18

The antenna factor shall be added to receiver reading in dBμV to obtain field strength in dBμV/m.

above 1000 MHz

Frequency, MHz	Antenna factor, dB/m
1000	26.9
1100	28.1
1200	28.4
1300	29.6
1400	29.1
1500	30.4
1600	30.7
1700	31.5
1800	32.3
1900	32.6
2000	32.5
2100	32.9
2200	33.5
2300	33.2
2400	33.7
2500	34.6
2600	34.7
2700	34.6
2800	35.0
2900	35.5
3000	36.2
3100	36.8
3200	36.8
3300	37.0
3400	37.5
3500	38.2

Frequency, MHz	Antenna factor, dB/m
3600	38.9
3700	39.4
3800	39.4
3900	39.6
4000	39.7
4100	39.8
4200	40.5
4300	40.9
4400	41.1
4500	41.4
4600	41.3
4700	41.6
4800	41.9
4900	42.3
5000	42.7
5100	43.0
5200	42.9
5300	43.5
5400	43.6
5500	44.3
5600	44.7
5700	45.0
5800	45.0
5900	45.3
6000	45.9

The antenna factor shall be added to receiver reading in dBμV to obtain field strength in dBμV/m.

10 APPENDIX C Measurement uncertainties

Expanded uncertainty at 95% confidence in Hermon Labs EMC measurements

Test description	Expanded uncertainty
Conducted carrier power at RF antenna connector	Below 12.4 GHz: ± 1.7 dB 12.4 GHz to 40 GHz: ± 2.3 dB
Conducted emissions at RF antenna connector	9 kHz to 2.9 GHz: ± 2.6 dB 2.9 GHz to 6.46 GHz: ± 3.5 dB 6.46 GHz to 13.2 GHz: ± 4.3 dB 13.2 GHz to 22.0 GHz: ± 5.0 dB 22.0 GHz to 26.8 GHz: ± 5.5 dB 26.8 GHz to 40.0 GHz: ± 4.8 dB
Occupied bandwidth	± 8.0 %
Duty cycle, timing (Tx ON / OFF) and average factor measurements	± 1.0 %
Conducted emissions with LISN	9 kHz to 150 kHz: ± 3.9 dB 150 kHz to 30 MHz: ± 3.8 dB
Radiated emissions at 3 m measuring distance Horizontal polarization Vertical polarization	 Biconilog antenna: ± 5.3 dB Biconical antenna: ± 5.0 dB Log periodic antenna: ± 5.3 dB Double ridged horn antenna: ± 5.3 dB Biconilog antenna: ± 6.0 dB Biconical antenna: ± 5.7 dB Log periodic antenna: ± 6.0 dB Double ridged horn antenna: ± 6.0 dB

Hermon Laboratories is accredited by A2LA for calibration according to present requirements of ISO/IEC 17025 and NCSL Z540-1. The accreditation is granted to perform calibration of parameters that are listed in the Scope of Hermon Laboratories Accreditation.

Hermon Laboratories calibrates its reference and transfer standards by calibration laboratories accredited to ISO/IEC 17025 by a mutually recognized Accreditation Body or by a recognized national metrology institute. All reference and transfer standards used in the calibration system are traceable to national or international standards.

In-house calibration of all test and measurement equipment is performed on a regular basis according to Hermon Laboratories calibration procedures, manufacturer calibration/verification procedures or procedures defined in the relevant standards. The Hermon Laboratories test and measurement equipment is calibrated within the tolerances specified by the manufacturers and/or by the relevant standards.

11 APPENDIX D Test laboratory description

Tests were performed at Hermon Laboratories Ltd., which is a fully independent, private, EMC, Radio, Safety, Environmental and Telecommunication testing facility.
Hermon Laboratories is recognized and accredited by the Federal Communications Commission (USA) for relevant parts of Code of Federal Regulations 47 (CFR 47), Test Firm Registration Number is 927748, Designation Number is IL1001; Recognized by Innovation, Science and Economic Development Canada for wireless and terminal testing (ISED), ISED #2186A, CAB identifier is IL1001; Certified by VCCI, Japan (the registration numbers are R-10808 for OATS, R-1082 for anechoic chamber, G-10869 for RE measurements above 1 GHz, C-10845 for conducted emissions site and T-11606 for conducted emissions at telecommunication ports).
The laboratory is accredited by American Association for Laboratory Accreditation (USA) according to ISO/IEC 17025 for electromagnetic compatibility, product safety, telecommunications testing, environmental simulation and calibration (for exact scope please refer to Certificate No. 839.01, 839.03 and 839.04).

Address: P.O. Box 23, Binyamina 3055001, Israel.
Telephone: +972 4628 8001
Fax: +972 4628 8277
e-mail: mail@hermonlabs.com
website: www.hermonlabs.com

Person for contact: Mr. Michael Nikishin, EMC&Radio group manager

12 APPENDIX E Specification references

FCC 47CFR part 15: 2019	Radio Frequency Devices
ANSI C63.10: 2013	American National Standard of Procedures for Compliance Testing of Unlicensed Wireless Devices
RSS-247 Issue 2: 2017	Digital Transmission Systems (DTSs), Frequency Hopping Systems (FHSs) and Licence- Exempt Local Area Network (LE-LAN) Devices
RSS-Gen Issue 5 with Am.1: 2019	General Requirents for Compliance of Radio Apparatus

13 APPENDIX F Abbreviations and acronyms

A	ampere
AC	alternating current
AM	amplitude modulation
AVRG	average (detector)
cm	centimeter
dB	decibel
dBm	decibel referred to one milliwatt
dB(μV)	decibel referred to one microvolt
dB(μV/m)	decibel referred to one microvolt per meter
dB(μA)	decibel referred to one microampere
DC	direct current
EIRP	equivalent isotropically radiated power
ERP	effective radiated power
EUT	equipment under test
F	frequency
GHz	gigahertz
GND	ground
H	height
HL	Hermon laboratories
Hz	hertz
k	kilo
kHz	kilohertz
LO	local oscillator
m	meter
MHz	megahertz
min	minute
mm	millimeter
ms	millisecond
μs	microsecond
NA	not applicable
NB	narrow band
OATS	open area test site
Ω	Ohm
PM	pulse modulation
PS	power supply
ppm	part per million (10^{-6})
QP	quasi-peak
RE	radiated emission
RF	radio frequency
rms	root mean square
Rx	receive
s	second
T	temperature
Tx	transmit
V	volt
WB	wideband

END OF DOCUMENT