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ELECTRICAL TESTING
0839.01

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TEST REPORT

ACCORDING TO:

FCC 47CFR part 15 subpart C §15.247 (DTS) and subpart B, Class B

FOR:

Hoopo Systems Ltd.

hoopoSense

Model: 502B1000-1A

FCC ID: 2AVS8-S01

This report is in conformity with ISO/ IEC 17025. The "A2LA Accredited" symbol endorsement applies only to the tests and calibrations that are listed in the scope of Hermon Laboratories accreditation. The test results relate only to the items tested. This test report shall not be reproduced in any form except in full with the written approval of Hermon Laboratories Ltd.

Table of contents

1 Applicant information ... 3
2 Equipment under test attributes ... 3
3 Manufacturer information ... 3
4 Test details ... 3
5 Tests summary ... 4
6 EUT description ... 5
6.1 General information ... 5
6.2 Test configuration ... 5
6.3 Changes made in EUT ... 5
6.4 Transmitter characteristics ... 6
7 Transmitter tests according to 47CFR part 15 subpart C requirements ... 7
7.1 Minimum 6 dB bandwidth ... 7
7.2 Field strength of spurious emissions ... 10
7.3 Peak output power ... 24
7.4 Band edge radiated emissions ... 31
7.5 Peak spectral power density ... 35
7.6 Antenna requirements ... 42
8 Emission tests according to 47CFR part 15 subpart B requirements ... 43
8.1 Radiated emission measurements ... 43
9 APPENDIX A Test equipment and ancillaries used for tests ... 47
10 APPENDIX B Test equipment correction factors ... 48
11 APPENDIX C Test laboratory description ... 51
12 APPENDIX D Measurement uncertainties ... 52
13 APPENDIX E Specification references ... 53
14 APPENDIX F Abbreviations and acronyms ... 54

1 Applicant information

Client name:	Hoopo Systems Ltd.
Address:	5 Ayalon St., Ramat Hasharon, 4700225 Israel
Telephone:	052-5192244
E-mail:	menachem@hoopo.tech
Contact name:	Mr. Menachem Tipris

2 Equipment under test attributes

Product name:	hoopoSense
Product type:	IoT Sensor
Model(s):	502B1000-1A
Serial number:	24
Hardware version:	0.0
Software release:	1.30
Receipt date	28-Nov-19

3 Manufacturer information

Manufacturer name:	Hoopo Systems Ltd.
Address:	5 Ayalon St., Ramat Hasharon, 4700225 Israel
Telephone:	052-5192244
E-Mail:	menachem@hoopo.tech
Contact name:	Mr. Menachem Tipris

4 Test details

Project ID:	35117
Location:	Hermon Laboratories Ltd. P.O. Box 23, Binyamina 3055001, Israel
Test started:	16-Dec-19
Test completed:	26-Dec-19
Test specification(s):	FCC 47CFR part 15 subpart C §15.247 (DTS) and subpart B, Class B

5 Tests summary

Test	Status
Transmitter characteristics	
FCC section 15.247(a)2 , 6 dB bandwidth	Pass
FCC section 15.247(b)3 , Peak output power	Pass
FCC section 15.247(i) , RF exposure	Pass, the exhibit to the application of certification is provided
FCC section 15.247(d) , Radiated spurious emissions	Pass
FCC section 15.247(d) , Emissions at band edges	Pass
FCC section 15.247) , Peak power density	Pass
FCC section 15.203 , Antenna requirement	Pass
FCC section 15.207(a) , Conducted emission	Not required
Unintentional emissions	
FCC section 15.107 Conducted emission at AC power port	Not required
FCC section 15.109 Radiated emission	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.

	Name and Title	Date	Signature
Tested by:	Mr. A. Morozov, test engineer, EMC & Radio Mrs. E. Pitt, test engineer, EMC & Radio	16-Dec-19 – 26-Dec-19	
Reviewed by:	Mrs. S. Peysahov Sheynin, test engineer, EMC & Radio	03-May-20	
Approved by:	Mr. S. Samokha, technical manager, EMC & Radio	14-June-20	

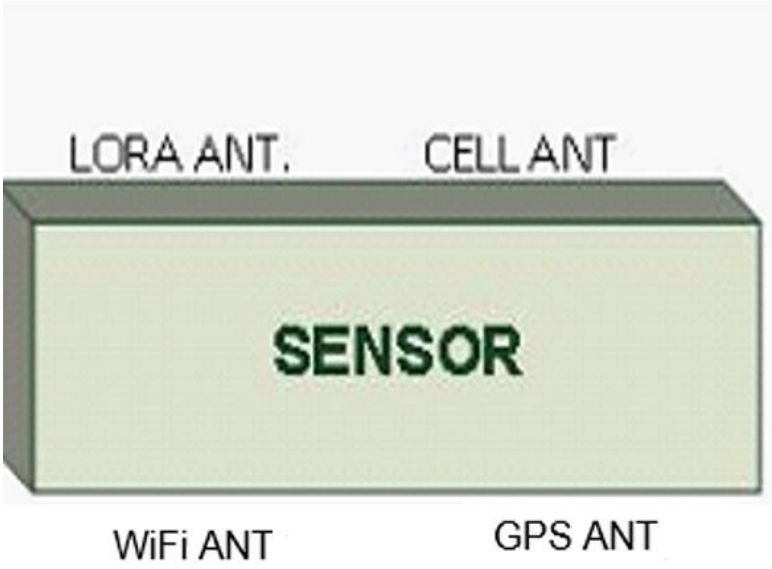
6 EUT description

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

6.1 General information

The EUT, a hoopoSense, is a low power device powered by four AA prime batteries. The device is equiped with a LoRa transceiver, an optional cellular modem, a WiFi receiver and a GPS device.

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 range	902.5 – 927.5 MHz

Maximum rated output power	At transmitter 50 Ω RF output connector	NA
	Peak output power	11.94 dBm

Is transmitter output power variable?		No			
	X	Yes		continuous variable	
			X	stepped variable with stepsize	1 dB
			minimum RF power		1.94 dBm
			maximum RF power		11.94 dBm

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

Antenna/s technical characteristics			
Type	Manufacturer	Model number	Gain
Internal	Hoopo systems	part of PCB	2 dBi

Type of modulation	LoRa
Modulating test signal (baseband)	PRBS

Transmitter power source					
X	Battery	**Nominal rated voltage**	3 VDC	Battery type	L91 or L6
	DC	**Nominal rated voltage**	VDC		
	AC mains	**Nominal rated voltage**	VAC	Frequency	

Test specification:	**Section 15.247(a)2, 6 dB bandwidth**		
Test procedure:	ANSI C63.10 section 11.8.1		
Test mode:	Compliance	**Verdict:**	PASS
Date(s):	19-Dec-19		
Temperature: 23 ºC	**Relative Humidity:** 38 %	**Air Pressure:** 1008 hPa	**Power:** 3 VDC
Remarks:			

7 Transmitter tests according to 47CFR part 15 subpart C requirements

7.1 Minimum 6 dB bandwidth

7.1.1 General

This test was performed to measure 6 dB bandwidth of the EUT carrier frequency. Specification test limits are given in Table 7.1.1.

Table 7.1.1 6 dB bandwidth limits

Assigned frequency, MHz	Modulation envelope reference points*, dBc	Minimum bandwidth, kHz
902.0 – 928.0	**6.0**	**500.0**
2400.0 – 2483.5		
5725.0 – 5850.0		

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

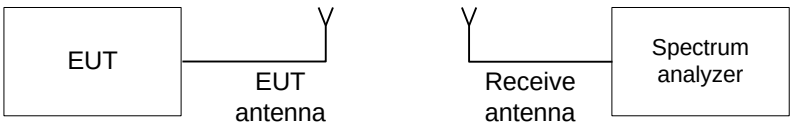
7.1.2 Test procedure

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.

7.1.2.3 The transmitter minimum 6 dB 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.

Figure 7.1.1 6 dB bandwidth test setup



Test specification:	**Section 15.247(a)2, 6 dB bandwidth**		
Test procedure:	ANSI C63.10 section 11.8.1		
Test mode:	Compliance	**Verdict:**	PASS
Date(s):	19-Dec-19		
Temperature: 23 ºC	**Relative Humidity:** 38 %	**Air Pressure:** 1008 hPa	**Power:** 3 VDC
Remarks:			

Table 7.1.2 6 dB bandwidth test results

ASSIGNED FREQUENCY BAND: 902-928 MHz
DETECTOR USED: Peak
RESOLUTION BANDWIDTH: 100 kHz
VIDEO BANDWIDTH: 300 kHz
MODULATION: LoRa
BIT RATE: 3.9 kbps

Carrier frequency, MHz	6 dB bandwidth, kHz	Limit, kHz	Margin, kHz	Verdict
902.5	788.217	500	288.217	Pass
915.0	812.001	500	312.001	Pass
927.5	772.904	500	272.904	Pass

BIT RATE: 21.9 kbps

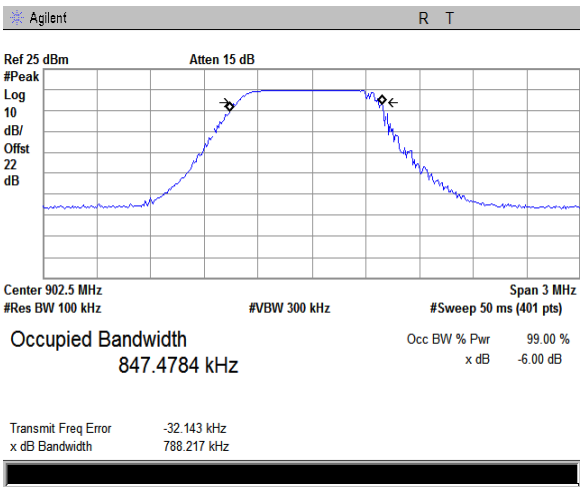
Carrier frequency, MHz	6 dB bandwidth, kHz	Limit, kHz	Margin, kHz	Verdict
902.5	783.667	500	283.667	Pass
915.0	783.055	500	283.055	Pass
927.5	769.521	500	269.521	Pass

Reference numbers of test equipment used

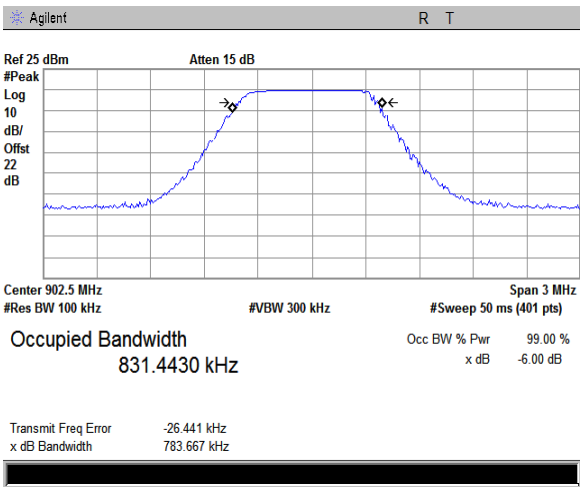
HL 2909	HL 5612	HL 5606	HL 5111					

Full description is given in Appendix A.

Plot 7.1.1 6 dB bandwidth test result at low frequency



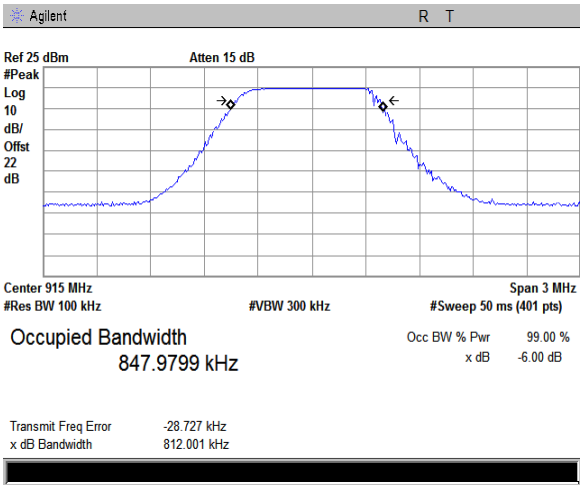
3.9 kBps



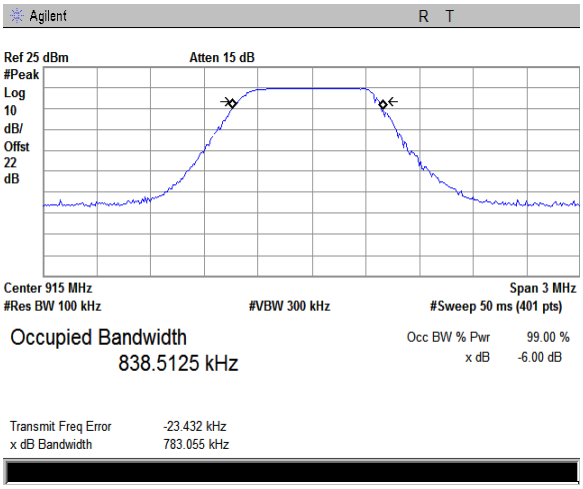
21.9 kBps

Test specification:	**Section 15.247(a)2, 6 dB bandwidth**		
Test procedure:	ANSI C63.10 section 11.8.1		
Test mode:	Compliance	**Verdict:**	PASS
Date(s):	19-Dec-19		
Temperature: 23 ºC	**Relative Humidity:** 38 %	**Air Pressure:** 1008 hPa	**Power:** 3 VDC
Remarks:			

Plot 7.1.2 6 dB bandwidth test result at mid frequency

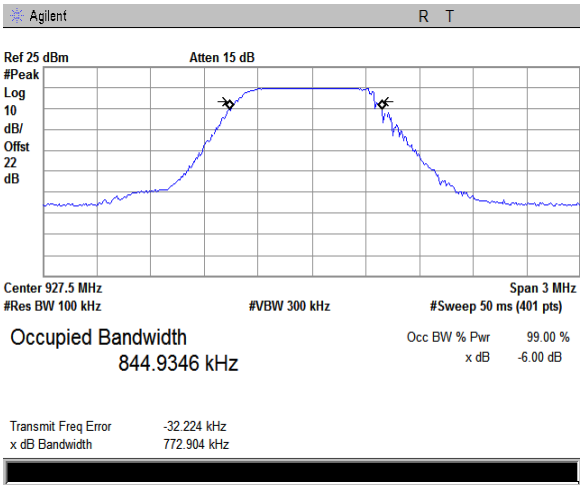


3.9 kBps

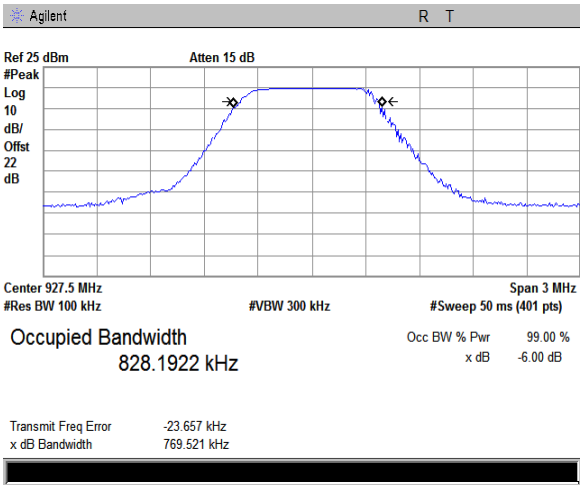


21.9 kBps

Plot 7.1.3 6 dB bandwidth test result at high frequency



3.9 kBps



21.9 kBps

Test specification:	**Section 15.247(d), Radiated spurious emissions**		
Test procedure:	ANSI C63.10 section 11.12.1		
Test mode:	Compliance	**Verdict:**	PASS
Date(s):	16-Dec-19		
Temperature: 22 ºC	**Relative Humidity:** 47 %	**Air Pressure:** 1020 hPa	**Power:** 3 VDC
Remarks:			

7.2 Field strength of spurious emissions

7.2.1 General

This test was performed to measure field strength of spurious emissions from the EUT. Specification test limits are given in Table 7.2.1.

Table 7.2.1 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.

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

7.2.2.1 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.

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

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

7.2.3.1 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.

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

Test specification:	**Section 15.247(d), Radiated spurious emissions**		
Test procedure:	ANSI C63.10 section 11.12.1		
Test mode:	Compliance	**Verdict:**	PASS
Date(s):	16-Dec-19		
Temperature: 22 ºC	**Relative Humidity:** 47 %	**Air Pressure:** 1020 hPa	**Power:** 3 VDC
Remarks:			

Figure 7.2.1 Setup for spurious emission field strength measurements below 30 MHz

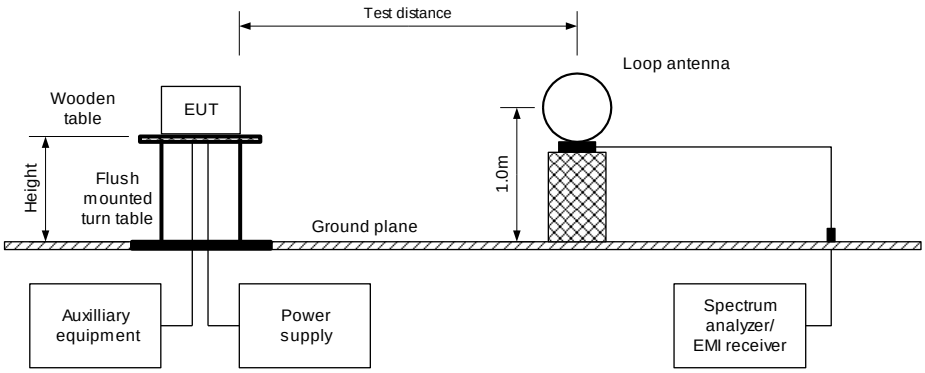
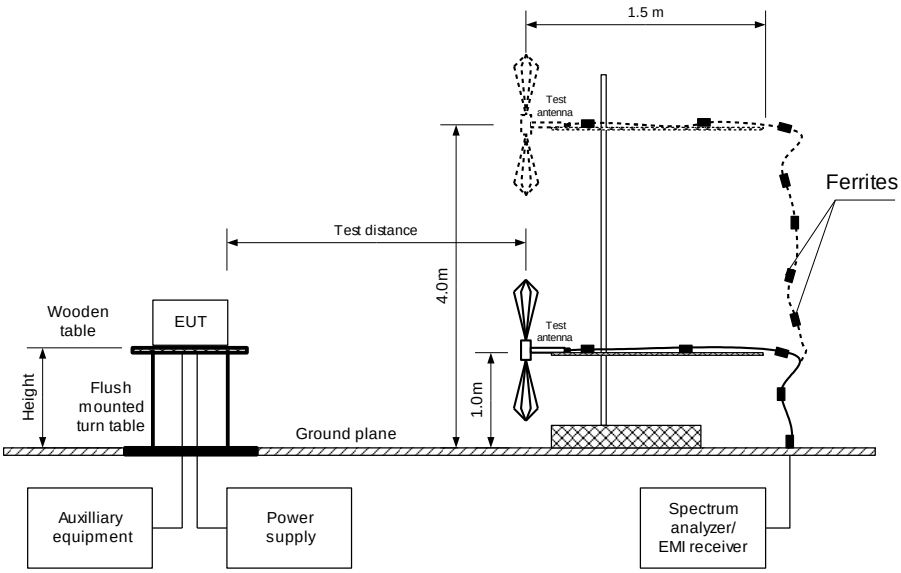
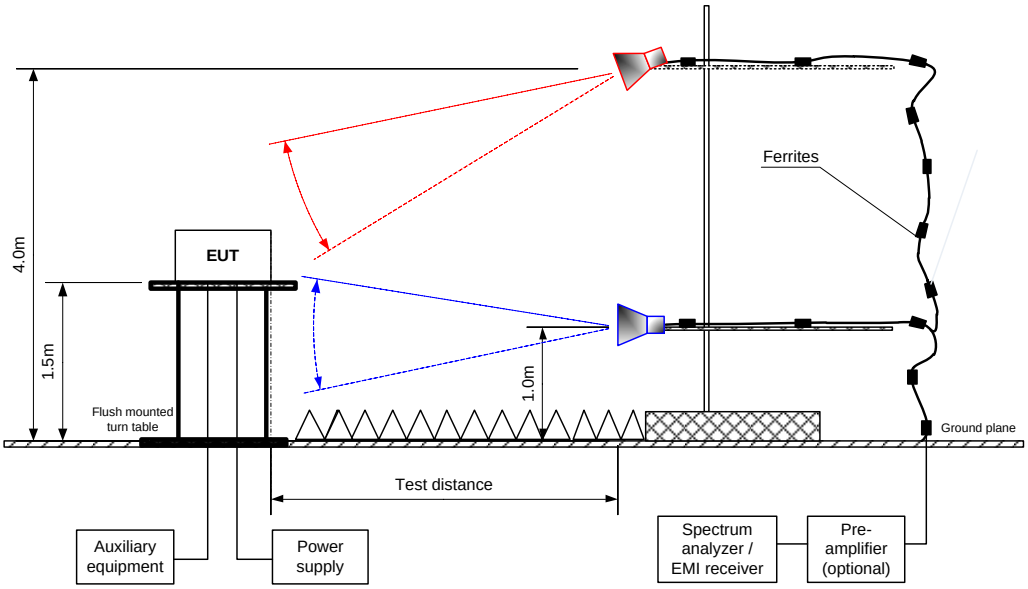


Figure 7.2.2 Setup for spurious emission field strength measurements in 30 – 1000 MHz



Test specification:	**Section 15.247(d), Radiated spurious emissions**		
Test procedure:	ANSI C63.10 section 11.12.1		
Test mode:	Compliance	**Verdict:**	PASS
Date(s):	16-Dec-19		
Temperature: 22 ºC	**Relative Humidity:** 47 %	**Air Pressure:** 1020 hPa	**Power:** 3 VDC
Remarks:			

Figure 7.2.3 Setup for spurious emission field strength measurements above1000 MHz



Test specification:	**Section 15.247(d), Radiated spurious emissions**		
Test procedure:	ANSI C63.10 section 11.12.1		
Test mode:	Compliance	**Verdict:**	PASS
Date(s):	16-Dec-19		
Temperature: 22 ºC	**Relative Humidity:** 47 %	**Air Pressure:** 1020 hPa	**Power:** 3 VDC
Remarks:			

Table 7.2.2 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: 3.9 kbps
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 902.5 MHz									
1805.050	54.55	Vertical	1.53	78	108.85	54.30	20.0	34.30	Pass
6316.555	53.29	Vertical	1.27	146		55.56		35.56	
7220.069	51.06	Vertical	1.00	173		57.79		37.79	
Mid carrier frequency 915.0 MHz									
1830.136	54.26	Vertical	2.05	239	105.99	51.73	20.0	31.73	Pass
5489.181	55.00	Horizontal	1.79	328		50.99		30.99	
6404.364	48.10	Horizontal	2.31	118		57.89		37.89	
High carrier frequency 927.5 MHz									
1854.670	55.21	Vertical	1.79	69	104.03	48.82	20.0	28.82	Pass
5564.216	53.62	Vertical	2.58	82		50.41		30.41	
6491.278	49.54	Vertical	2.05	130		54.49		34.49	

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

Test specification:	**Section 15.247(d), Radiated spurious emissions**		
Test procedure:	ANSI C63.10 section 11.12.1		
Test mode:	Compliance	**Verdict:**	PASS
Date(s):	16-Dec-19		
Temperature: 22 ºC	**Relative Humidity:** 47 %	**Air Pressure:** 1020 hPa	**Power:** 3 VDC
Remarks:			

Table 7.2.3 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: 3.9 kbps
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 902.5 MHz											
2707.183	Horizontal	1.27	270	60.39	74.0	-13.61	53.64	NA	54.0	-0.36	Pass
3610.815	Horizontal	1.79	215	51.80	74.0	-22.20	42.00	NA	54.0	-12.00	
4510.842	Vertical	2.05	252	50.18	74.0	-23.82	31.85	NA	54.0	-22.15	
5416.356	Horizontal	1.87	273	53.15	74.0	-20.85	39.90	NA	54.0	-14.10	
9027.281	Vertical	2.60	360	51.47	74.0	-22.53	36.36	NA	54.0	-17.64	
Mid carrier frequency 915.0 MHz											
2744.371	Vertical	1.27	360	62.22	74.0	-11.78	53.83	NA	54.0	-0.17	Pass
3661.106	Vertical	1.53	26	50.27	74.0	-23.73	38.08	NA	54.0	-15.92	
4574.446	Vertical	1.27	83	48.72	74.0	-25.28	34.71	NA	54.0	-19.29	
7318.638	Horizontal	1.27	343	50.95	74.0	-23.05	37.07	NA	54.0	-16.93	
8270.425	Vertical	3.36	69	48.26	74.0	-25.74	34.25	NA	54.0	-19.75	
High carrier frequency 927.5 MHz											
2782.165	Horizontal	1.80	269	58.12	74.0	-15.88	52.49	NA	54.0	-1.51	Pass
3710.779	Vertical	1.79	338	46.57	74.0	-27.43	35.06	NA	54.0	-18.94	
4637.721	Vertical	1.27	360	50.16	74.0	-23.84	29.75	NA	54.0	-24.25	
7419.706	Vertical	2.58	325	49.79	74.0	-24.21	35.48	NA	54.0	-18.52	

*****- 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 7.2.4 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), Radiated spurious emissions**		
Test procedure:	ANSI C63.10 section 11.12.1		
Test mode:	Compliance	**Verdict:**	PASS
Date(s):	16-Dec-19		
Temperature: 22 ºC	**Relative Humidity:** 47 %	**Air Pressure:** 1020 hPa	**Power:** 3 VDC
Remarks:			

Table 7.2.5 Field strength of spurious emissions below 1 GHz within restricted bands

ASSIGNED FREQUENCY:	902.0 – 928.0 MHz
INVESTIGATED FREQUENCY RANGE:	0.009 – 1000 MHz
TEST DISTANCE:	3 m
MODULATION:	LoRa
MODULATING SIGNAL:	PRBS
BIT RATE:	3.9 kbps
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 902.5 MHz								
No emissions were found								Pass
Mid carrier frequency 915.0 MHz								
No emissions were found								Pass
High carrier frequency 927.5 MHz								
No emissions were found								Pass

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

Table 7.2.6 Restricted bands

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	

Reference numbers of test equipment used

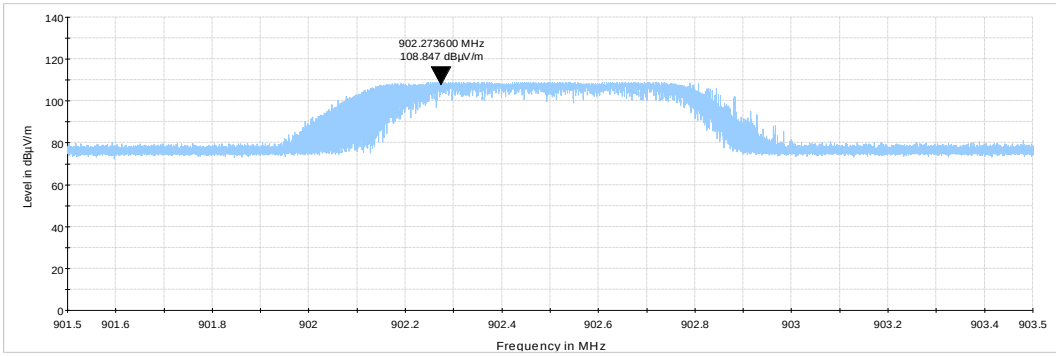
HL 3903	HL 4360	HL 4933	HL 5288	HL 5665			

Full description is given in Appendix A.

Test specification:	**Section 15.247(d), Radiated spurious emissions**		
Test procedure:	ANSI C63.10 section 11.12.1		
Test mode:	Compliance	**Verdict:**	PASS
Date(s):	16-Dec-19		
Temperature: 22 ºC	**Relative Humidity:** 47 %	**Air Pressure:** 1020 hPa	**Power:** 3 VDC
Remarks:			

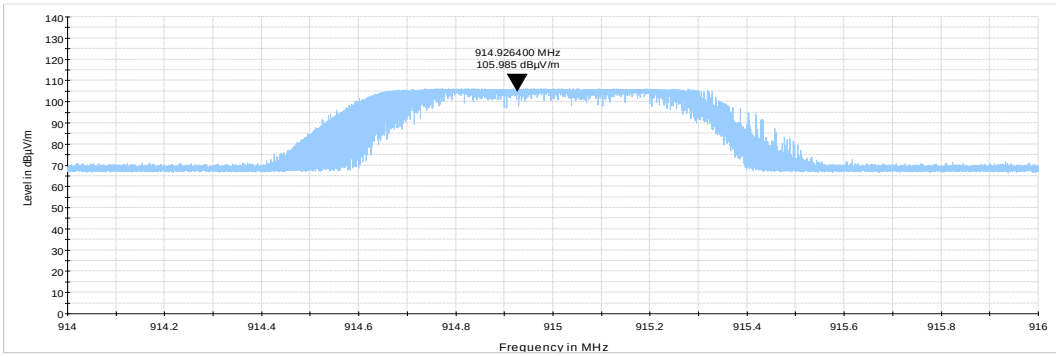
Plot 7.2.1 Radiated emission measurements at the low carrier frequency

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



Plot 7.2.2 Radiated emission measurements at the mid carrier frequency

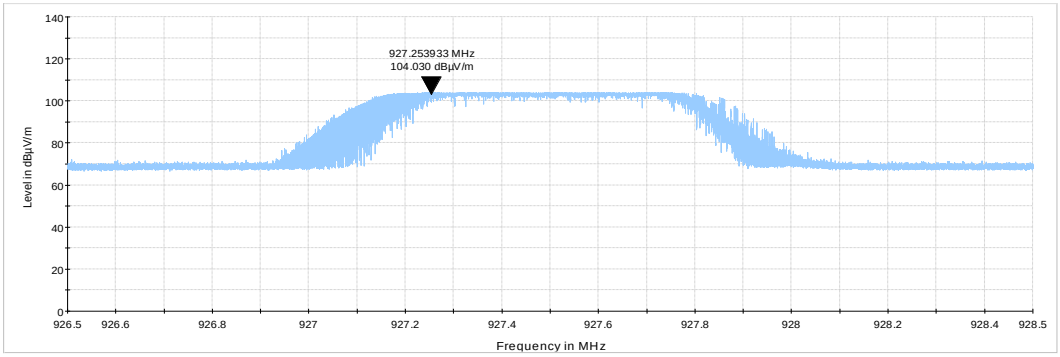
TEST SITE: Semi anechoic chamber
TEST DISTANCE: 3 m
ANTENNA POLARIZATION: Vertical and horizontal



Test specification:	**Section 15.247(d), Radiated spurious emissions**		
Test procedure:	ANSI C63.10 section 11.12.1		
Test mode:	Compliance	**Verdict:**	PASS
Date(s):	16-Dec-19		
Temperature: 22 ºC	**Relative Humidity:** 47 %	**Air Pressure:** 1020 hPa	**Power:** 3 VDC
Remarks:			

Plot 7.2.3 Radiated emission measurements at the high carrier frequency

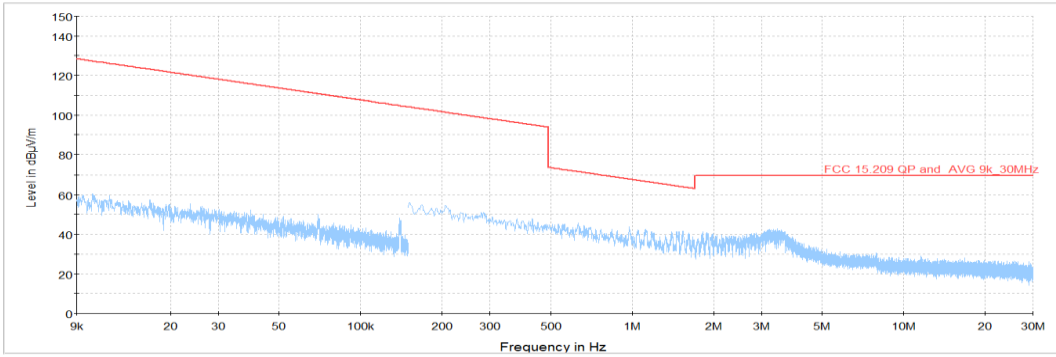
TEST SITE: Semi anechoic chamber
TEST DISTANCE: 3 m
ANTENNA POLARIZATION: Vertical and horizontal



Test specification:	**Section 15.247(d), Radiated spurious emissions**		
Test procedure:	ANSI C63.10 section 11.12.1		
Test mode:	Compliance	**Verdict:**	PASS
Date(s):	16-Dec-19		
Temperature: 22 ºC	**Relative Humidity:** 47 %	**Air Pressure:** 1020 hPa	**Power:** 3 VDC
Remarks:			

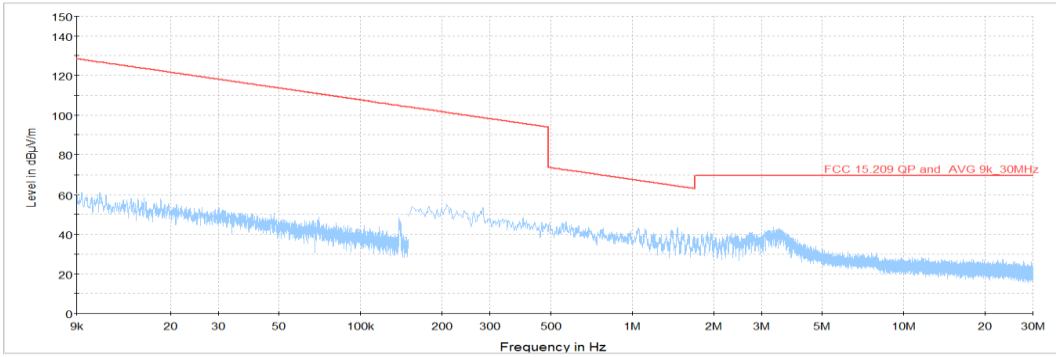
Plot 7.2.4 Radiated emission measurements from 9 kHz to 30 MHz at the low, mid, high carrier frequency

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



Plot 7.2.5 Radiated emission measurements from 9 kHz to 30 MHz at the low, mid, high carrier frequency

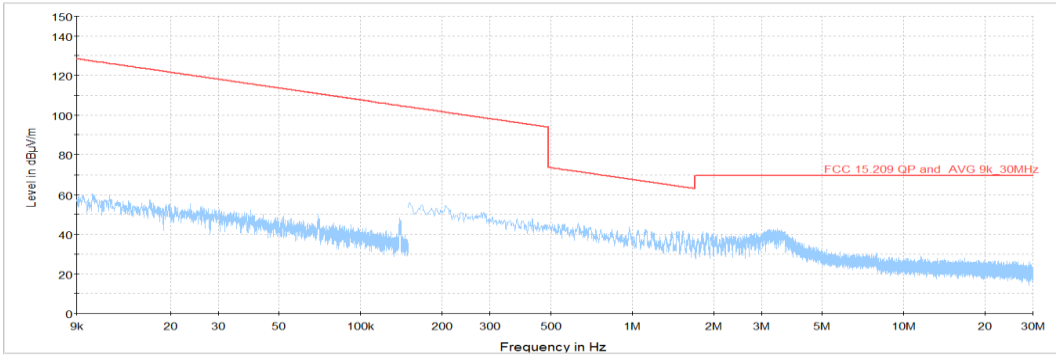
TEST SITE: Semi anechoic chamber
TEST DISTANCE: 3 m
ANTENNA POLARIZATION: Vertical
EUT POSIYION: Y



Test specification:	**Section 15.247(d), Radiated spurious emissions**		
Test procedure:	ANSI C63.10 section 11.12.1		
Test mode:	Compliance	**Verdict:**	PASS
Date(s):	16-Dec-19		
Temperature: 22 ºC	**Relative Humidity:** 47 %	**Air Pressure:** 1020 hPa	**Power:** 3 VDC
Remarks:			

Plot 7.2.6 Radiated emission measurements from 9 kHz to 30 MHz at the low, mid, high carrier frequency

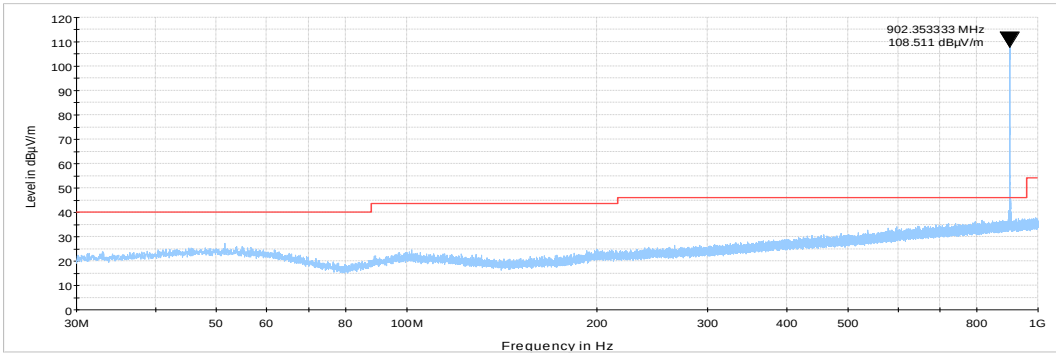
TEST SITE: Semi anechoic chamber
TEST DISTANCE: 3 m
ANTENNA POLARIZATION: Vertical
EUT POSIYION: Z



Test specification:	**Section 15.247(d), Radiated spurious emissions**		
Test procedure:	ANSI C63.10 section 11.12.1		
Test mode:	Compliance	**Verdict:**	PASS
Date(s):	16-Dec-19		
Temperature: 22 ºC	**Relative Humidity:** 47 %	**Air Pressure:** 1020 hPa	**Power:** 3 VDC
Remarks:			

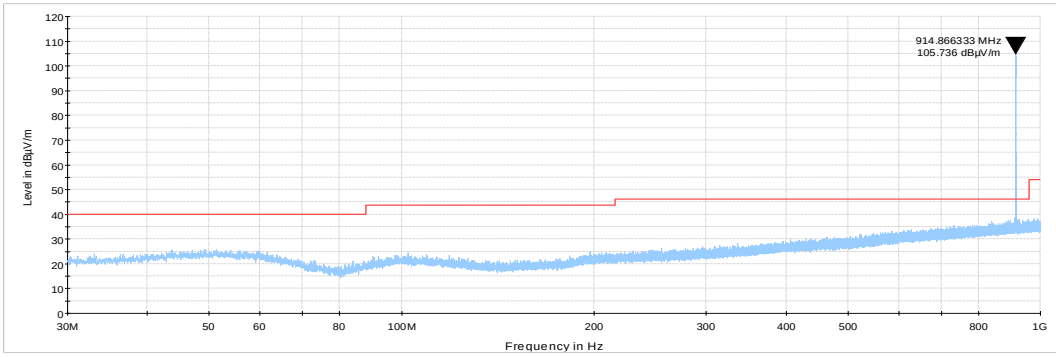
Plot 7.2.7 Radiated emission measurements from 30 to 1000 MHz at the low carrier frequency

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



Plot 7.2.8 Radiated emission measurements from 30 to 1000 MHz at the mid carrier frequency

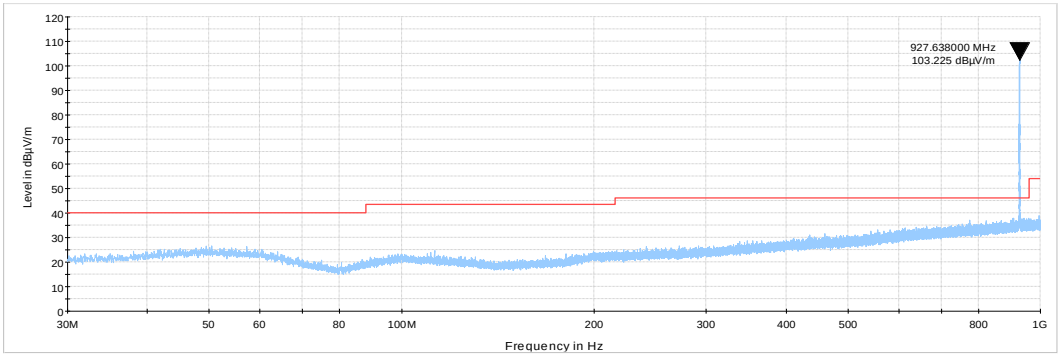
TEST SITE: Semi anechoic chamber
TEST DISTANCE: 3 m
ANTENNA POLARIZATION: Vertical and Horizontal



Test specification:	**Section 15.247(d), Radiated spurious emissions**		
Test procedure:	ANSI C63.10 section 11.12.1		
Test mode:	Compliance	**Verdict:**	PASS
Date(s):	16-Dec-19		
Temperature: 22 ºC	**Relative Humidity:** 47 %	**Air Pressure:** 1020 hPa	**Power:** 3 VDC
Remarks:			

Plot 7.2.9 Radiated emission measurements from 30 to 1000 MHz at the high carrier frequency

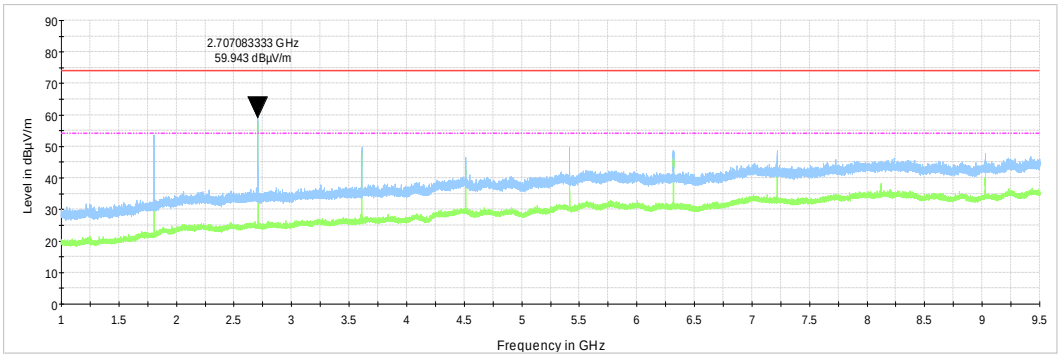
TEST SITE: Semi anechoic chamber
TEST DISTANCE: 3 m
ANTENNA POLARIZATION: Vertical and Horizontal



Test specification:	**Section 15.247(d), Radiated spurious emissions**		
Test procedure:	ANSI C63.10 section 11.12.1		
Test mode:	Compliance	**Verdict:**	PASS
Date(s):	16-Dec-19		
Temperature: 22 ºC	**Relative Humidity:** 47 %	**Air Pressure:** 1020 hPa	**Power:** 3 VDC
Remarks:			

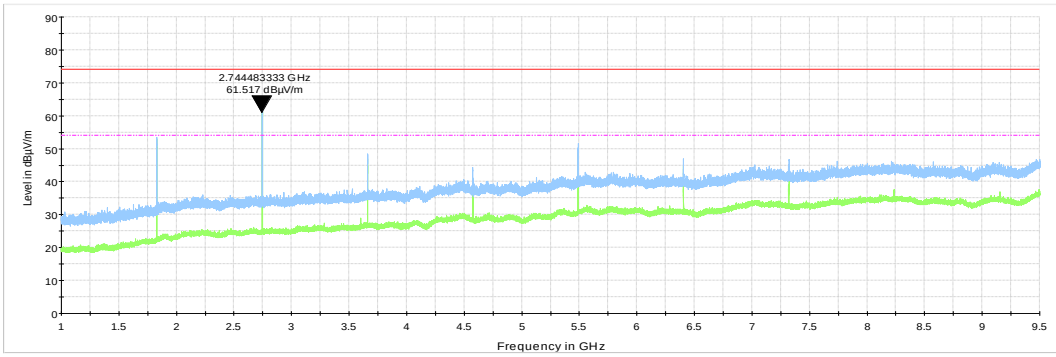
Plot 7.2.10 Radiated emission measurements from 1000 to 9500 MHz at the low carrier frequency

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



Plot 7.2.11 Radiated emission measurements from 1000 to 9500 MHz at the mid carrier frequency

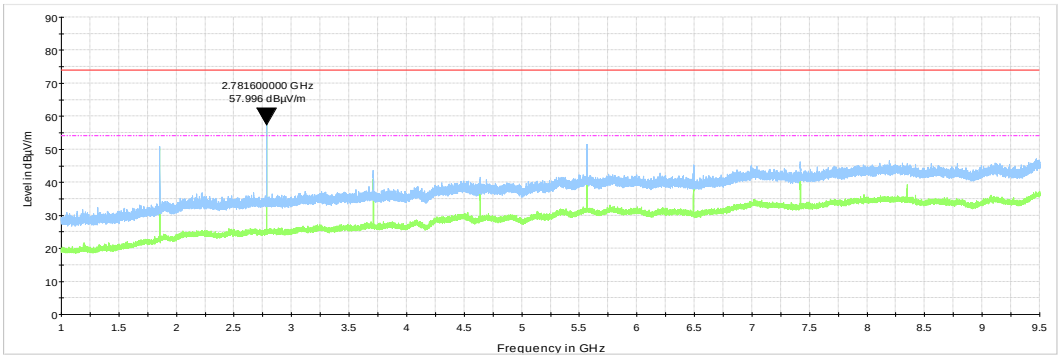
TEST SITE: Semi anechoic chamber
TEST DISTANCE: 3 m
ANTENNA POLARIZATION: Vertical and Horizontal



Test specification:	**Section 15.247(d), Radiated spurious emissions**		
Test procedure:	ANSI C63.10 section 11.12.1		
Test mode:	Compliance	**Verdict:**	PASS
Date(s):	16-Dec-19		
Temperature: 22 ºC	**Relative Humidity:** 47 %	**Air Pressure:** 1020 hPa	**Power:** 3 VDC
Remarks:			

Plot 7.2.12 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(b)3, Peak output power**		
Test procedure:	ANSI C63.10 section 11.9.1.1		
Test mode:	Compliance	**Verdict:**	PASS
Date(s):	16-Dec-19		
Temperature: 22 ºC	**Relative Humidity:** 47 %	**Air Pressure:** 1020 hPa	**Power:** 3 VDC
Remarks:			

7.3 Peak output power

7.3.1 General

This test was performed to measure the maximum peak output power radiated by transmitter. Specification test limits are given in Table 7.3.1.

Table 7.3.1 Peak output power limits

Assigned frequency range, MHz	Maximum antenna gain, dBi	Peak output power*		Equivalent field strength limit @ 3m, dB(μV/m)**
		W	dBm	
902.0 – 928.0	**6.0**	**1.0**	**30.0**	**131.2**
2400.0 – 2483.5				
5725.0 – 5850.0				

*- The limit is provided in terms of conducted RF power at the antenna connector. 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.

**- Equivalent field strength limit was calculated from the peak output power as follows: E=sqrt(30×P×G)/r, where P is peak output power in Watts, r is antenna to EUT distance in meters and G is transmitter antenna gain in dBi.

7.3.2 Test procedure

7.3.2.1 The EUT was set up as shown in Figure 7.3.1, energized and its proper operation was checked.

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

7.3.2.3 The resolution bandwidth of spectrum analyzer was set wider than 6 dB bandwidth of the EUT and the field strength of the EUT carrier frequency was measured with antenna connected to spectrum analyzer/ EMI receiver. To find maximum radiation the turntable was rotated 360^0 and the measuring antenna height was swept in both vertical and horizontal polarizations.

7.3.2.4 The maximum field strength of the EUT carrier frequency was measured as provided in Table 7.3.2 and associated plots.

7.3.2.5 The maximum peak output power was calculated from the field strength of carrier as follows:

$$P = (E \times d)^2 / (30 \times G),$$

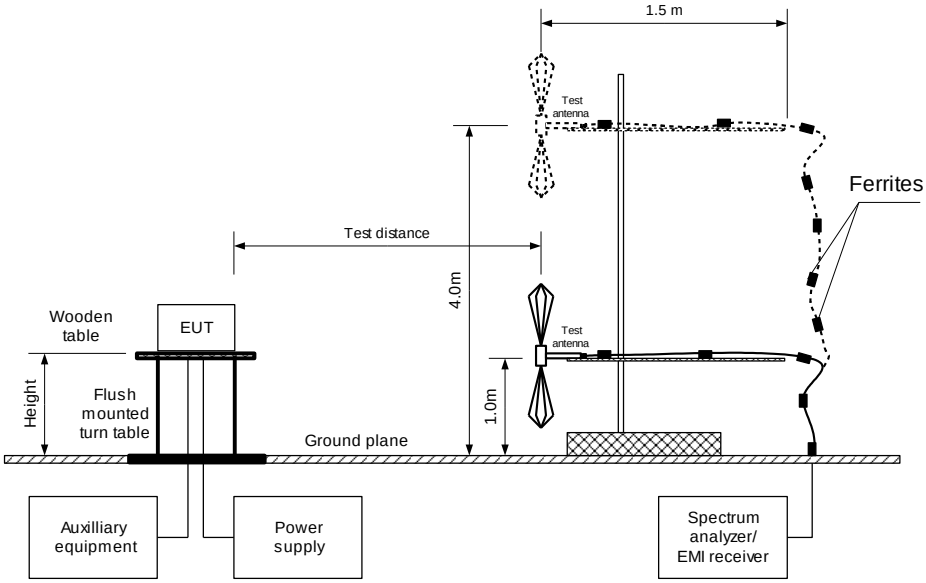
where P is the peak output power in W, E is the field strength in V/m, d is the test distance and G is the transmitter numeric antenna gain over an isotropic radiator.
The above equation was converted in logarithmic units for 3 m test distance:

Peak output power in dBm = Field strength in dB(μV/m) - Transmitter antenna gain in dBi – 95.2 dB

7.3.2.6 The worst test results (the lowest margins) were recorded in Table 7.3.2.

Test specification:	**Section 15.247(b)3, Peak output power**		
Test procedure:	ANSI C63.10 section 11.9.1.1		
Test mode:	Compliance	**Verdict:**	PASS
Date(s):	16-Dec-19		
Temperature: 22 ºC	**Relative Humidity:** 47 %	**Air Pressure:** 1020 hPa	**Power:** 3 VDC
Remarks:			

Figure 7.3.1 Setup for carrier field strength measurements



Test specification:	**Section 15.247(b)3, Peak output power**		
Test procedure:	ANSI C63.10 section 11.9.1.1		
Test mode:	Compliance	**Verdict:**	PASS
Date(s):	16-Dec-19		
Temperature: 22 ºC	**Relative Humidity:** 47 %	**Air Pressure:** 1020 hPa	**Power:** 3 VDC
Remarks:			

Table 7.3.2 Peak output power test results

ASSIGNED FREQUENCY: 902.0 – 928.0 MHz
TEST DISTANCE: 3 m
TEST SITE: Semi anechoic chamber
EUT HEIGHT: 0.8 m
DETECTOR USED: Peak
TEST ANTENNA TYPE: Biconilog (30 MHz – 1000 MHz)
Double ridged guide (above 1000 MHz)
MODULATION: LoRa
MODULATING SIGNAL: PRBS

TRANSMITTER OUTPUT POWER SETTINGS: Maximum
DETECTOR USED: Peak
RESOLUTION BANDWIDTH: 1 MHz
VIDEO BANDWIDTH: 10 MHz

BIT RATE: 3.9 kbps

Frequency, MHz	Field strength, dB(μV/m)	Antenna polarization	Antenna height, m	Azimuth, degrees*	EUT antenna gain, dBi	Peak output power, dBm**	Limit, dBm	Margin, dB***	Verdict
902.5	109.14	Vertical	1.25	0	2.0	11.94	30.0	-18.06	Pass
915.0	106.70	Vertical	1.00	10	2.0	9.50	30.0	-20.50	Pass
927.5	104.51	Vertical	1.10	15	2.0	7.31	30.0	-22.69	Pass

BIT RATE: 21.9 kbps

Frequency, MHz	Field strength, dB(μV/m)	Antenna polarization	Antenna height, m	Azimuth, degrees*	EUT antenna gain, dBi	Peak output power, dBm**	Limit, dBm	Margin, dB***	Verdict
902.5	108.41	Vertical	1.25	0	2.0	11.21	30.0	-18.79	Pass
915.0	105.73	Vertical	1.25	0	2.0	8.53	30.0	-21.47	Pass
927.5	104.18	Vertical	1.10	15	2.0	6.98	30.0	-23.02	Pass

*****- EUT front panel refer to 0 degrees position of turntable.
******- Peak output power was calculated from the field strength of carrier as follows: $P = (E \times d)^2 / (30 \times G)$,
where P is the peak output power in W, E is the field strength in V/m, d is the test distance in meters and G is the transmitter numeric antenna gain over an isotropic radiator. The above equation was converted in logarithmic units for 3 m test distance: *Peak output power in dBm = Field strength in dB(μV/m) - Transmitter antenna gain in dBi – 95.2 dB*
***- Margin = Peak output power – specification limit.
Note: Maximum peak output power was obtained at Unom (115%Unom, 85%Unom) input power voltage.

Reference numbers of test equipment used

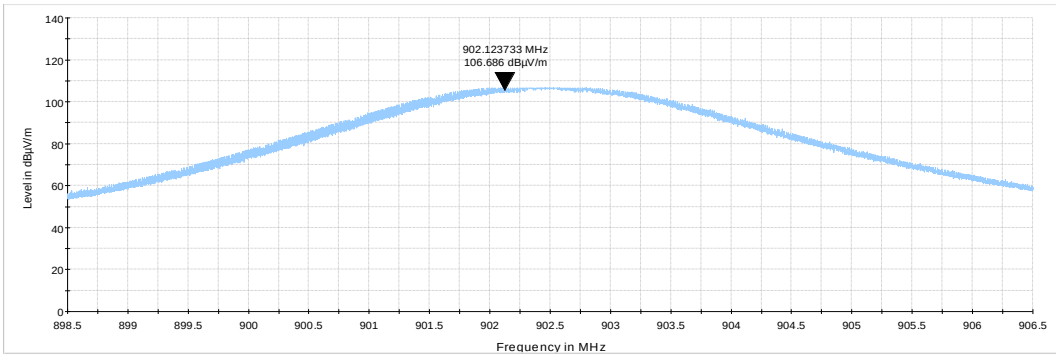
HL 3903	HL 4360	HL 5288	HL 5665				

Full description is given in Appendix A.

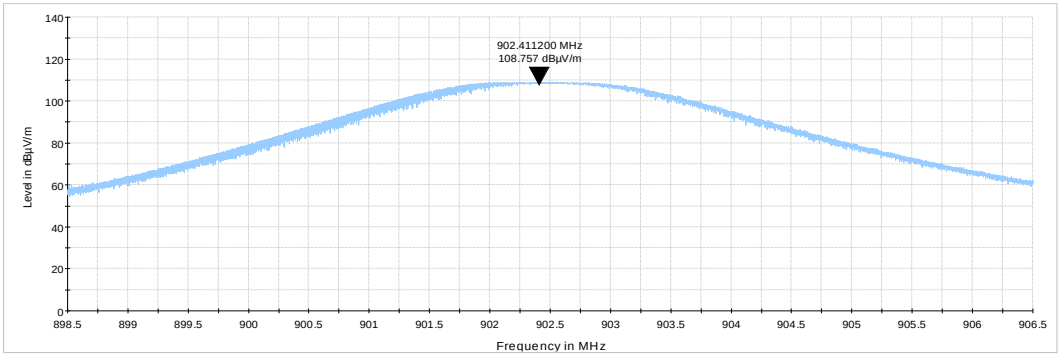
Test specification:	**Section 15.247(b)3, Peak output power**		
Test procedure:	ANSI C63.10 section 11.9.1.1		
Test mode:	Compliance	**Verdict:**	PASS
Date(s):	16-Dec-19		
Temperature: 22 ºC	**Relative Humidity:** 47 %	**Air Pressure:** 1020 hPa	**Power:** 3 VDC
Remarks:			

Plot 7.3.1 Field strength of carrier at low frequency and bitrate 3.9 kbps

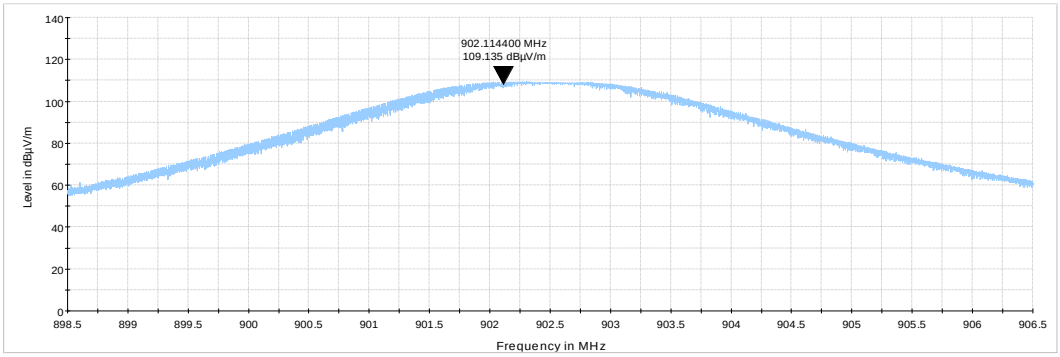
EUT position: X



EUT position: Y



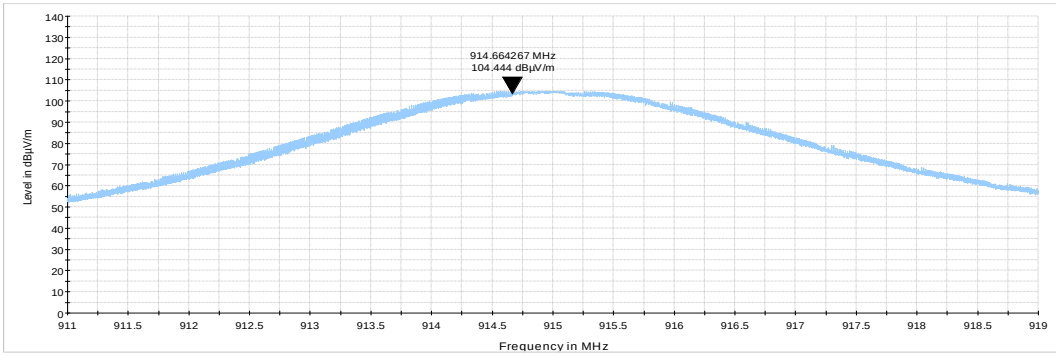
EUT position: Z



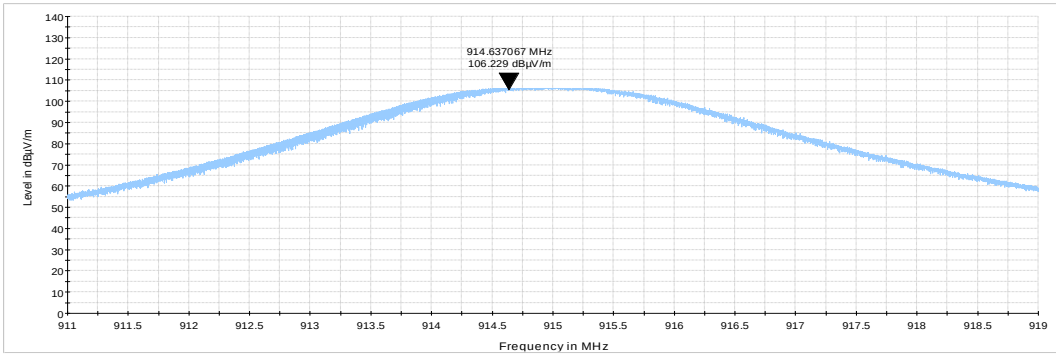
Test specification:	**Section 15.247(b)3, Peak output power**		
Test procedure:	ANSI C63.10 section 11.9.1.1		
Test mode:	Compliance	**Verdict:**	PASS
Date(s):	16-Dec-19		
Temperature: 22 ºC	**Relative Humidity:** 47 %	**Air Pressure:** 1020 hPa	**Power:** 3 VDC
Remarks:			

Plot 7.3.2 Field strength of carrier at mid frequency and bitrate 3.9 kbps

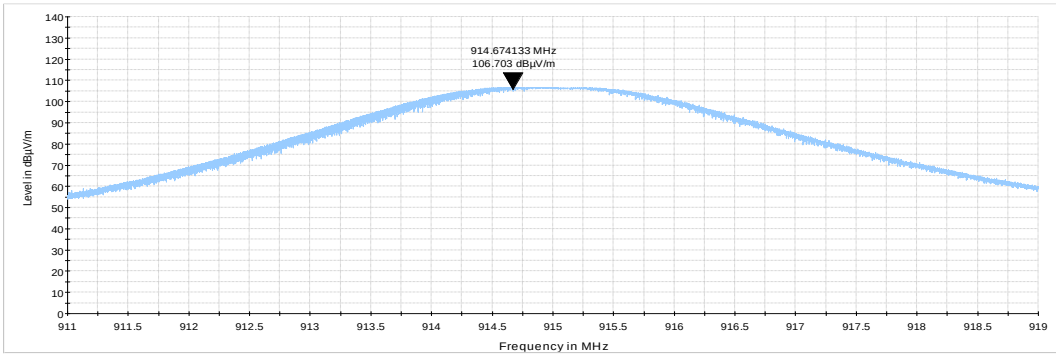
EUT position: X



EUT position: Y



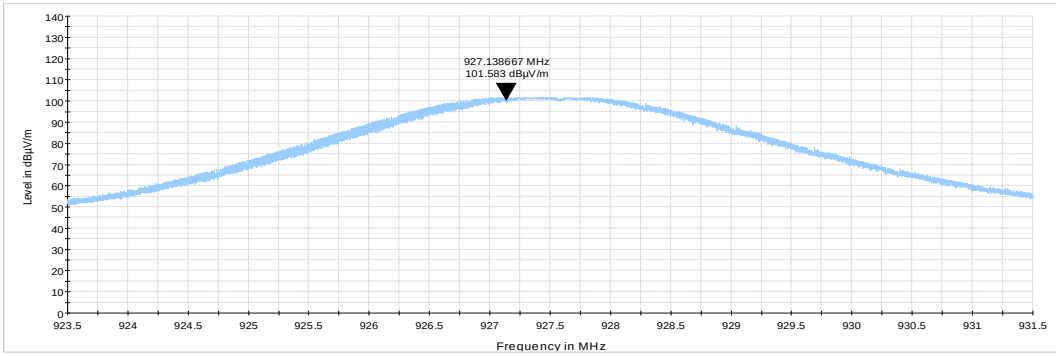
EUT position: Z



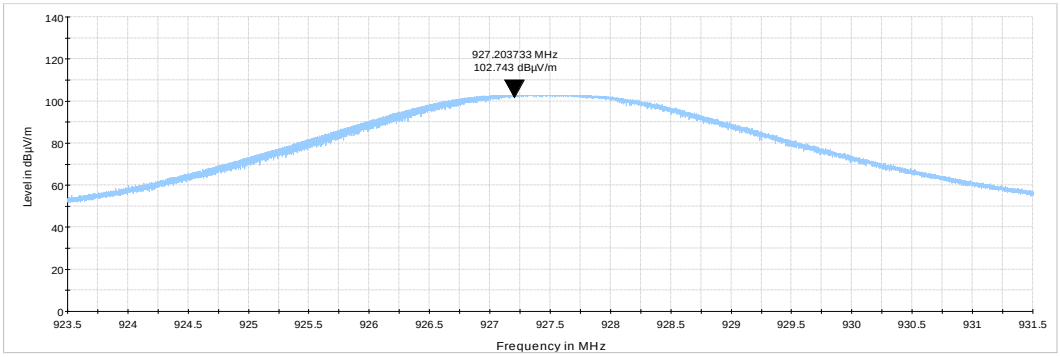
Test specification:	**Section 15.247(b)3, Peak output power**		
Test procedure:	ANSI C63.10 section 11.9.1.1		
Test mode:	Compliance	**Verdict:**	PASS
Date(s):	16-Dec-19		
Temperature: 22 ºC	**Relative Humidity:** 47 %	**Air Pressure:** 1020 hPa	**Power:** 3 VDC
Remarks:			

Plot 7.3.3 Field strength of carrier at high frequency and bitrate 3.9 kbps

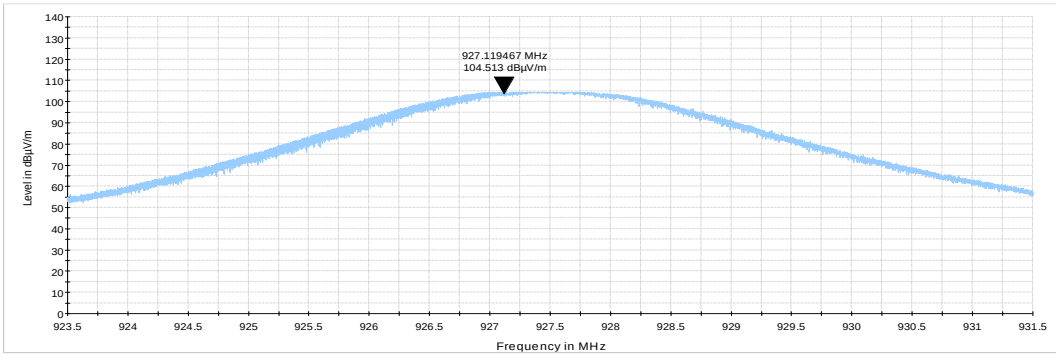
EUT position: X



EUT position: Y

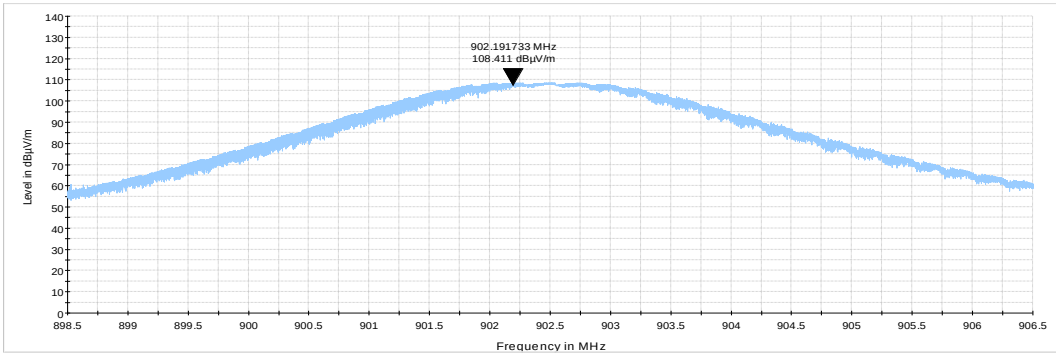


EUT position: Z

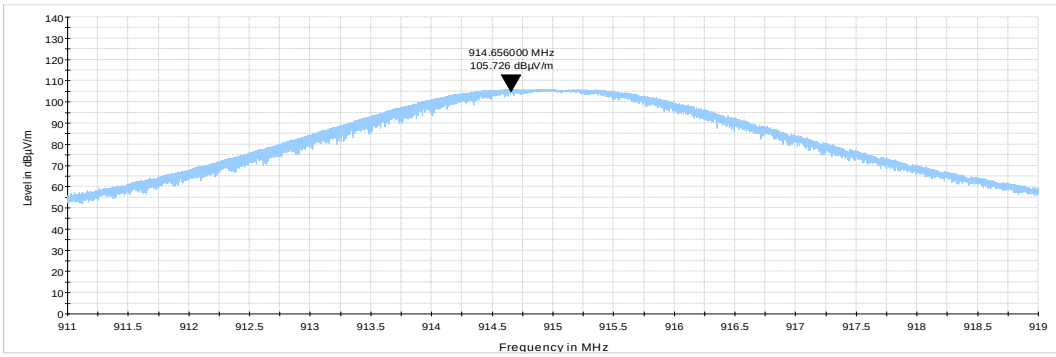


Test specification:	**Section 15.247(b)3, Peak output power**		
Test procedure:	ANSI C63.10 section 11.9.1.1		
Test mode:	Compliance	**Verdict:**	PASS
Date(s):	16-Dec-19		
Temperature: 22 ºC	**Relative Humidity:** 47 %	**Air Pressure:** 1020 hPa	**Power:** 3 VDC
Remarks:			

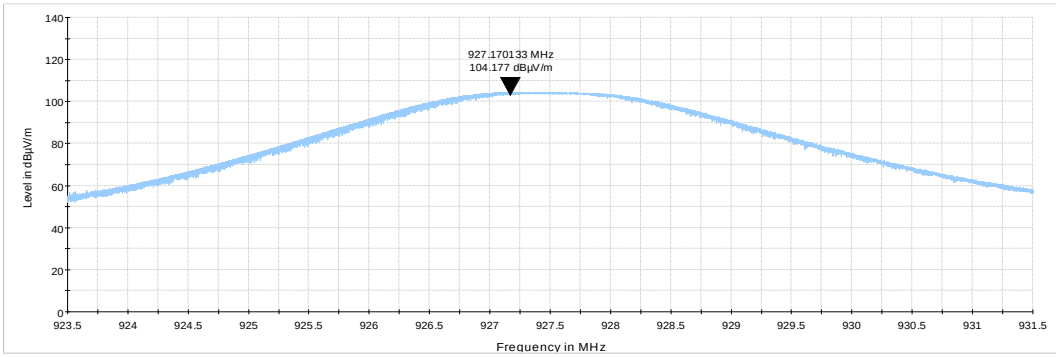
Plot 7.3.4 Field strength of carrier at low frequency and bitrate 21.9 kbps
EUT position: Z



Plot 7.3.5 Field strength of carrier at mid frequency and bitrate 21.9 kbps
EUT position: Z



Plot 7.3.6 Field strength of carrier at high frequency and bitrate 21.9 kbps
EUT position: Z



Test specification:	**Section 15.247(d), Band edge emissions**		
Test procedure:	ANSI C63.10 section 11.12.1		
Test mode:	Compliance	**Verdict:**	PASS
Date(s):	16-Dec-19		
Temperature: 22 ºC	**Relative Humidity:** 47 %	**Air Pressure:** 1020 hPa	**Power:** 3 VDC
Remarks:			

7.4 Band edge radiated emissions

7.4.1 General

This test was performed to measure emissions, radiated from the EUT at the assigned frequency band edges. Specification test limits are given in Table 7.4.1.

Table 7.4.1 Band edge emission limits

Output power	Assigned frequency, MHz	Attenuation below carrier*, dBc	Field strength at 3 m within restricted bands, dB(µV/m)	
			Peak	Average
Peak	**902.0 – 928.0**	**20.0**	**74.0**	**54.0**
	2400.0 – 2483.5			
	5725.0 – 5850.0			

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

7.4.2 Test procedure

7.4.2.1 The EUT was set up as shown in Figure 7.4.1, energized normally modulated at the maximum data rate and its proper operation was checked.

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

7.4.2.3 The spectrum analyzer span was set to capture the carrier frequency and associated modulation products. The resolution bandwidth was set to 100 KHz.

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

7.4.2.5 The maximum band edge emission and modulation product outside of the band were measured as provided in Table 7.4.2 and associated plots and referenced to the highest emission level measured within the authorized band.

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

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

Figure 7.4.1 Band edge emission test setup

Test specification:	**Section 15.247(d), Band edge emissions**		
Test procedure:	ANSI C63.10 section 11.12.1		
Test mode:	Compliance	**Verdict:**	PASS
Date(s):	16-Dec-19		
Temperature: 22 ºC	**Relative Humidity:** 47 %	**Air Pressure:** 1020 hPa	**Power:** 3 VDC
Remarks:			

Table 7.4.2 Band edge emission test results

ASSIGNED FREQUENCY RANGE: 902-928 MHz
DETECTOR USED: Peak
MODULATION: LoRa
RESOLUTION BANDWIDTH: 100 kHz
VIDEO BANDWIDTH: ≥ RBW

BIT RATE: 3.9 kBps

Frequency, MHz	Emission at carrier, dBm (RBW=100kHz)	Delta marker dB(RBW=30kHz)	Emission @ band edge dBm	Limit, dBc	Margin, dB*	Verdict
902.5	13.95	34.73	-20.78	20.0	14.73	Pass
927.5	14.41	32.66	-18.25	20.0	12.66	

BIT RATE: 21.9 kBps

Frequency, MHz	Emission at carrier, dBm (RBW=100kHz)	Delta marker dB(RBW=30kHz)	Emission @ band edge dBm	Limit, dBc	Margin, dB*	Verdict
902.5	14.51	33.96	-19.45	20.0	13.96	Pass
927.5	14.39	32.20	-17.81	20.0	12.20	

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

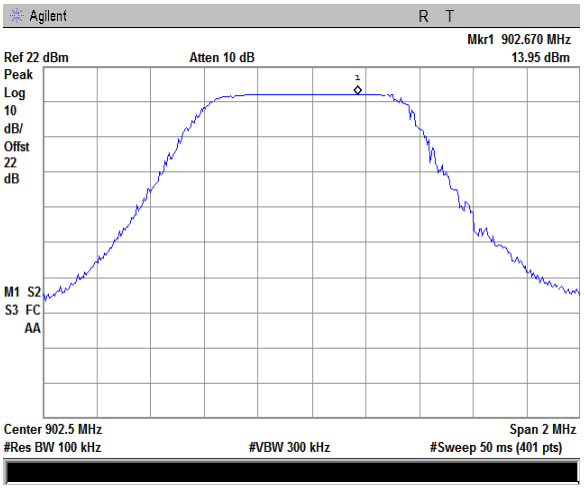
Reference numbers of test equipment used

HL 2909	HL 5111	HL 5612	HL 5606	HL	HL	HL	HL

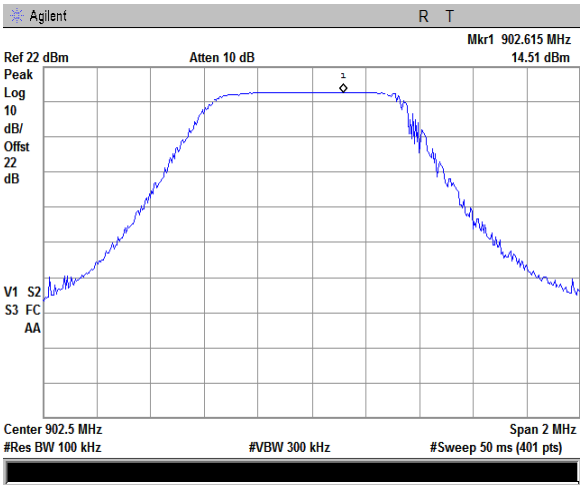
Full description is given in Appendix A.

Test specification:	**Section 15.247(d), Band edge emissions**		
Test procedure:	ANSI C63.10 section 11.12.1		
Test mode:	Compliance	**Verdict:**	PASS
Date(s):	16-Dec-19		
Temperature: 22 ºC	**Relative Humidity:** 47 %	**Air Pressure:** 1020 hPa	**Power:** 3 VDC
Remarks:			

Plot 7.4.1 The highest emission level within the assigned band at low carrier frequency

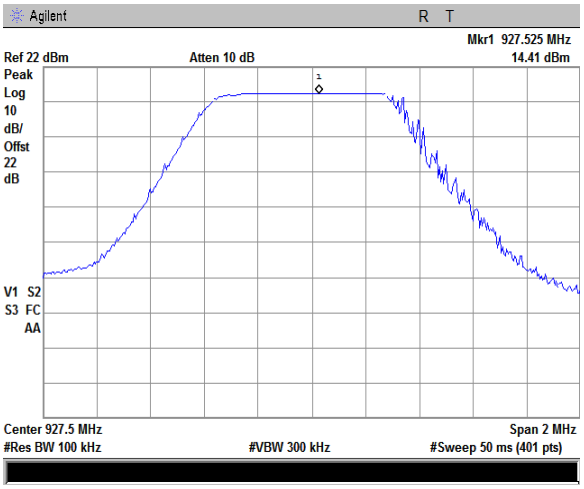


3.9 kBps

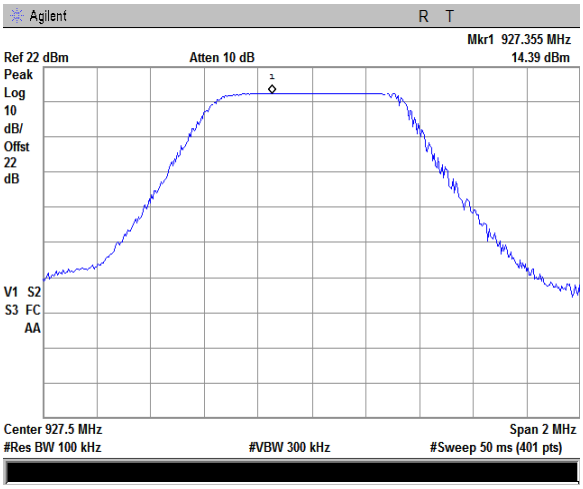


21.9 kBps

Plot 7.4.2 The highest emission level within the assigned band at high carrier frequency



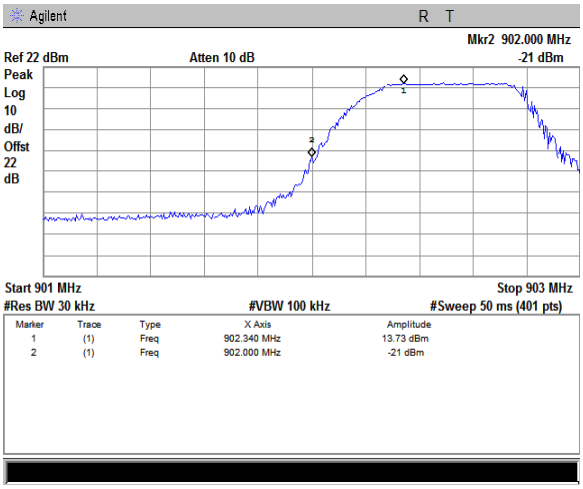
3.9 kBps



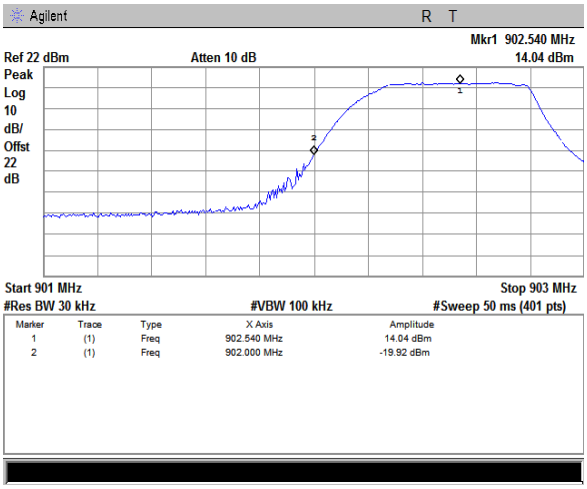
21.9 kBps

Test specification:	**Section 15.247(d), Band edge emissions**		
Test procedure:	ANSI C63.10 section 11.12.1		
Test mode:	Compliance	**Verdict:**	PASS
Date(s):	16-Dec-19		
Temperature: 22 ºC	**Relative Humidity:** 47 %	**Air Pressure:** 1020 hPa	**Power:** 3 VDC
Remarks:			

Plot 7.4.3 The highest band edge emission at low carrier frequency

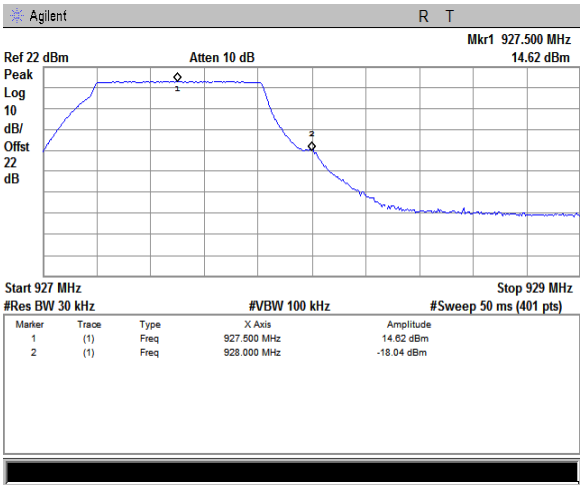


3.9 kBps

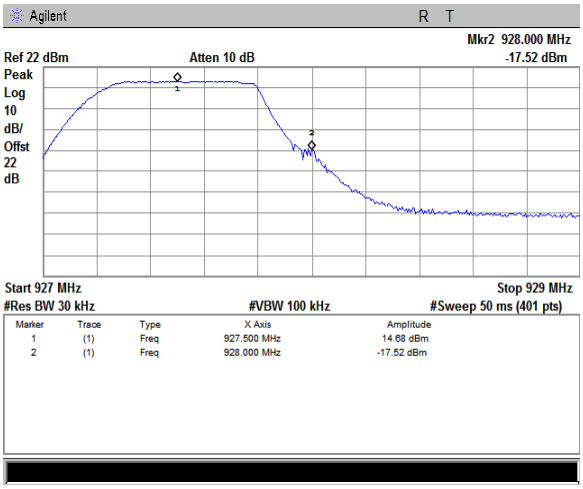


21.9 kBps

Plot 7.4.4 The highest band edge emission at high carrier frequency



3.9 kBps



21.9 kBps

Test specification:	**Section 15.247(d), Peak power density**		
Test procedure:	ANSI C63.10 section 11.10.2		
Test mode:	Compliance	**Verdict:**	PASS
Date(s):	16-Dec-19		
Temperature: 22 ºC	**Relative Humidity:** 47 %	**Air Pressure:** 1020 hPa	**Power:** 3 VDC
Remarks:			

7.5 Peak spectral power density

7.5.1 General

This test was performed to measure the peak spectral power density radiated by the transmitter RF antenna. Specification test limits are given in Table 7.5.1.

Table 7.5.1 Peak spectral power density limits

Assigned frequency range, MHz	Measurement bandwidth, kHz	Peak spectral power density, dBm	Equivalent field strength limit @ 3m, dB(μV/m)*
902.0 – 928.0	3.0	8.0	103.2

* - Equivalent field strength limit was calculated from the peak spectral power density as follows: E=sqrt(30×P)/r, where P is peak spectral power density and r is antenna to EUT distance in meters.

7.5.2 Test procedure for field strength measurements

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 to end user RF output power.

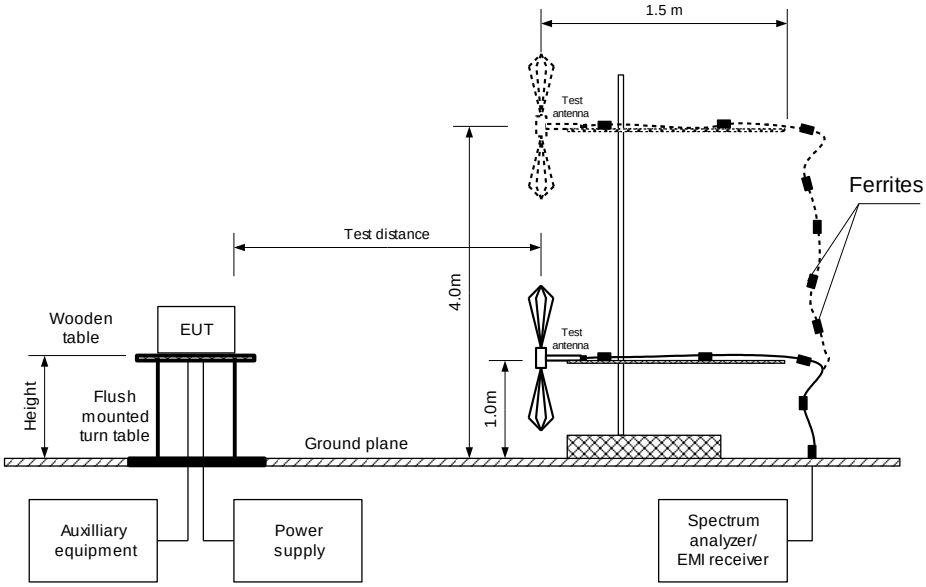
7.5.2.3 The field strength of the EUT carrier frequency was measured with antenna connected to spectrum analyzer/ EMI receiver. To find maximum radiation the turntable was rotated 360^0 and the measuring antenna height was swept in both vertical and horizontal polarizations.

7.5.2.4 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.

7.5.2.5 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 7.5.2 and associated plots.

Test specification:	**Section 15.247(d), Peak power density**		
Test procedure:	ANSI C63.10 section 11.10.2		
Test mode:	Compliance	**Verdict:**	PASS
Date(s):	16-Dec-19		
Temperature: 22 ºC	**Relative Humidity:** 47 %	**Air Pressure:** 1020 hPa	**Power:** 3 VDC
Remarks:			

Figure 7.5.1 Setup for carrier field strength measurements



Test specification:	**Section 15.247(d), Peak power density**		
Test procedure:	ANSI C63.10 section 11.10.2		
Test mode:	Compliance	**Verdict:**	PASS
Date(s):	16-Dec-19		
Temperature: 22 ºC	**Relative Humidity:** 47 %	**Air Pressure:** 1020 hPa	**Power:** 3 VDC
Remarks:			

Table 7.5.2 Field strength measurement of peak spectral power density

ASSIGNED FREQUENCY: 902.0 – 928.0 MHz
TEST DISTANCE: 3 m
TEST SITE: Semi anechoic chamber
EUT HEIGHT: 0.8 m
DETECTOR USED: Peak
RESOLUTION BANDWIDTH: 3 kHz
VIDEO BANDWIDTH: 10 kHz
TEST ANTENNA TYPE: Biconilog (30 MHz – 1000 MHz)
MODULATION: LoRa
MODULATING SIGNAL: PRBS
TRANSMITTER OUTPUT POWER SETTINGS: Maximum

BIT RATE: 3.9 kbps

Frequency, MHz	Field strength, dB(μV/m)	EUT antenna gain, dBi	Limit, dB(μV/m)	Margin, dB*	Antenna polarization	Antenna height, m	Turn-table position**, degrees
902.5	102.71	2.0	103.2	-2.49	Vertical	1.25	0
915.0	100.79	2.0	103.2	-4.41	Vertical	1.00	10
927.5	98.74	2.0	103.2	-6.46	Vertical	1.10	15

BIT RATE: 21.9 kbps

Frequency, MHz	Field strength, dB(μV/m)	EUT antenna gain, dBi	Limit, dB(μV/m)	Margin, dB*	Antenna polarization	Antenna height, m	Turn-table position**, degrees
902.5	95.75	2.0	103.2	-9.45	Vertical	1.25	0
915.0	93.06	2.0	103.2	-12.14	Vertical	1.00	10
927.5	91.81	2.0	103.2	-13.39	Vertical	1.10	15

*****- Margin = Field strength - EUT antenna gain - calculated field strength limit.
******- EUT front panel refer to 0 degrees position of turntable.

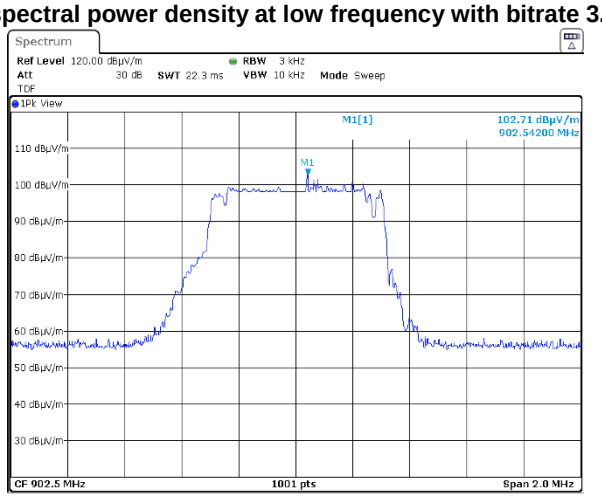
Reference numbers of test equipment used

HL 3903	HL 4355	HL 5288	HL 5665				

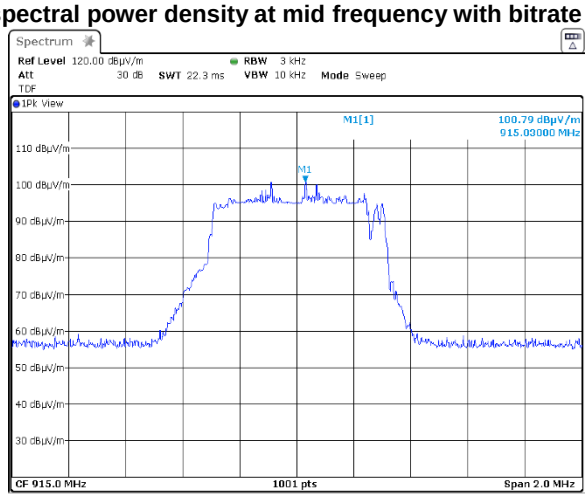
Full description is given in Appendix A.

Test specification:	**Section 15.247(d), Peak power density**		
Test procedure:	ANSI C63.10 section 11.10.2		
Test mode:	Compliance	**Verdict:**	PASS
Date(s):	16-Dec-19		
Temperature: 22 ºC	**Relative Humidity:** 47 %	**Air Pressure:** 1020 hPa	**Power:** 3 VDC
Remarks:			

Plot 7.5.1 Peak spectral power density at low frequency with bitrate 3.9 kbps

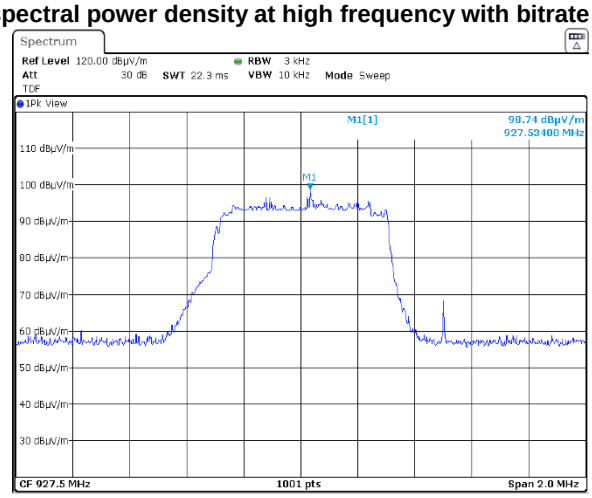


Plot 7.5.2 Peak spectral power density at mid frequency with bitrate 3.9 kbps



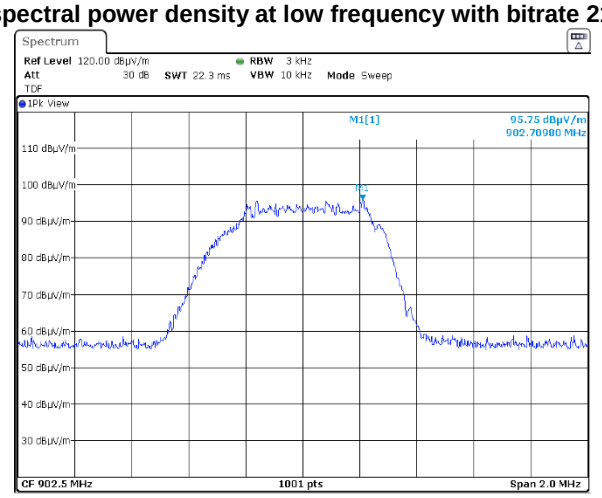
Test specification:	**Section 15.247(d), Peak power density**		
Test procedure:	ANSI C63.10 section 11.10.2		
Test mode:	Compliance	**Verdict:**	PASS
Date(s):	16-Dec-19		
Temperature: 22 ºC	**Relative Humidity:** 47 %	**Air Pressure:** 1020 hPa	**Power:** 3 VDC
Remarks:			

Plot 7.5.3 Peak spectral power density at high frequency with bitrate 3.9 kbps

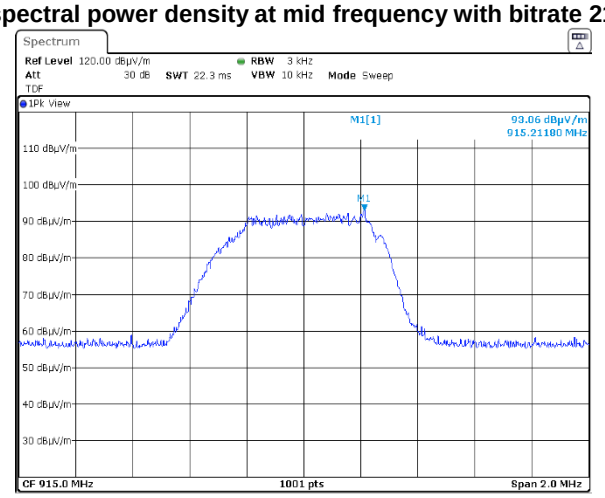


Test specification:	**Section 15.247(d), Peak power density**		
Test procedure:	ANSI C63.10 section 11.10.2		
Test mode:	Compliance	**Verdict:**	PASS
Date(s):	16-Dec-19		
Temperature: 22 ºC	**Relative Humidity:** 47 %	**Air Pressure:** 1020 hPa	**Power:** 3 VDC
Remarks:			

Plot 7.5.4 Peak spectral power density at low frequency with bitrate 21.9 kbps

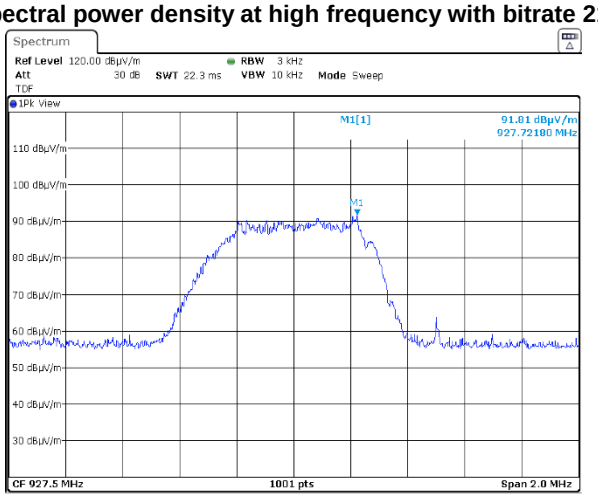


Plot 7.5.5 Peak spectral power density at mid frequency with bitrate 21.9 kbps



Test specification:	**Section 15.247(d), Peak power density**		
Test procedure:	ANSI C63.10 section 11.10.2		
Test mode:	Compliance	**Verdict:**	PASS
Date(s):	16-Dec-19		
Temperature: 22 ºC	**Relative Humidity:** 47 %	**Air Pressure:** 1020 hPa	**Power:** 3 VDC
Remarks:			

Plot 7.5.6 Peak spectral power density at high frequency with bitrate 21.9 kbps



Test specification:	**Section 15.203, Antenna requirements**		
Test procedure:	Visual inspection		
Test mode:	Compliance	**Verdict:**	PASS
Date(s):	16-Dec-19		
Temperature: 22 ºC	**Relative Humidity:** 47 %	**Air Pressure:** 1020 hPa	**Power:** 3 VDC
Remarks:			

7.6 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 7.6.1.

Table 7.6.1 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	

Test specification:	**Section 15.109, Radiated emission**		
Test procedure:	ANSI C63.4, Sections 8.3 and 12.2.5		
Test mode:	Compliance	**Verdict:**	PASS
Date(s):	16-Dec-19		
Temperature: 22 ºC	**Relative Humidity:** 47 %	**Air Pressure:** 1020 hPa	**Power:** 3 VDC
Remarks:			

8 Emission tests according to 47CFR part 15 subpart B requirements

8.1 Radiated emission measurements

8.1.1 General

This test was performed to measure radiated emissions from the EUT enclosure. Specification test limits are given in Table 8.1.1.

Table 8.1.1 Radiated emission test limits

Frequency, MHz	Class B limit, dB(μV/m)	
	10 m distance	3 m distance
30 - 88	29.5*	40.0
88 - 216	33.0*	43.5
216 - 960	35.5*	46.0
Above 960	43.5*	54.0

* The limit for test distance other than specified was calculated using the inverse linear distance extrapolation factor as follows: $Lim_{S2} = Lim_{S1} + 20 \log (S_1/S_2)$,
where S_1 and S_2 – standard defined and test distance respectively in meters.

8.1.2 Test procedure for measurements in semi-anechoic chamber

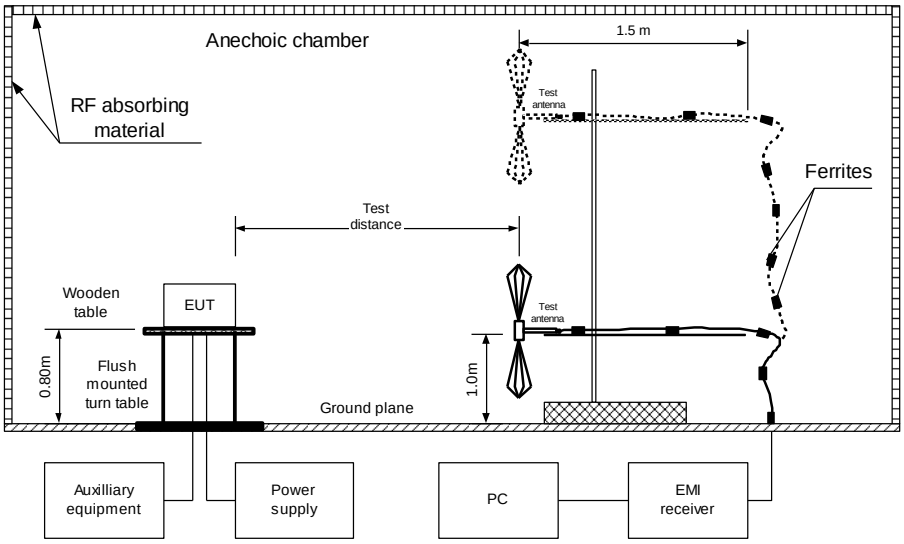
8.1.2.1 The EUT was set up as shown in Figure 8.1.1 and associated photograph/s, energized and the performance check was conducted.

8.1.2.2 The specified frequency range was investigated with biconilog antenna connected to 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 and the EUT cables position was varied.

8.1.2.3 The worst test results (the lowest margins) were recorded in Table 8.1.2 and shown in the associated plots.

Test specification:	**Section 15.109, Radiated emission**		
Test procedure:	ANSI C63.4, Sections 8.3 and 12.2.5		
Test mode:	Compliance	**Verdict:**	PASS
Date(s):	16-Dec-19		
Temperature: 22 ºC	**Relative Humidity:** 47 %	**Air Pressure:** 1020 hPa	**Power:** 3 VDC
Remarks:			

Figure 8.1.1 Setup for radiated emission measurements in anechoic chamber, table-top equipment



Test specification:	**Section 15.109, Radiated emission**		
Test procedure:	ANSI C63.4, Sections 8.3 and 12.2.5		
Test mode:	Compliance	**Verdict:**	PASS
Date(s):	16-Dec-19		
Temperature: 22 ºC	**Relative Humidity:** 47 %	**Air Pressure:** 1020 hPa	**Power:** 3 VDC
Remarks:			

Table 8.1.2 Radiated emission test results

EUT SET UP: TABLE-TOP
LIMIT: Class B
EUT OPERATING MODE: Receive
TEST SITE: SEMI ANECHOIC CHAMBER
TEST DISTANCE: 3 m
DETECTORS USED: PEAK / QUASI-PEAK
FREQUENCY RANGE: 30 MHz – 1000 MHz
RESOLUTION BANDWIDTH: 120 kHz

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*				
No emissions were found								Pass

TEST SITE: SEMI ANECHOIC CHAMBER
TEST DISTANCE: 3 m
DETECTORS USED: PEAK / AVERAGE
FREQUENCY RANGE: 1000 MHz – 5000 MHz
RESOLUTION BANDWIDTH: 1000 kHz

Frequency, MHz	Peak			Average			Antenna polarization	Antenna height, m	Turn-table position**, degrees	Verdict
	Measured emission, dB(μV/m)	Limit, dB(μV/m)	Margin, dB*	Measured emission, dB(μV/m)	Limit, dB(μV/m)	Margin, dB*				
No emissions were found										Pass

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

Reference numbers of test equipment used

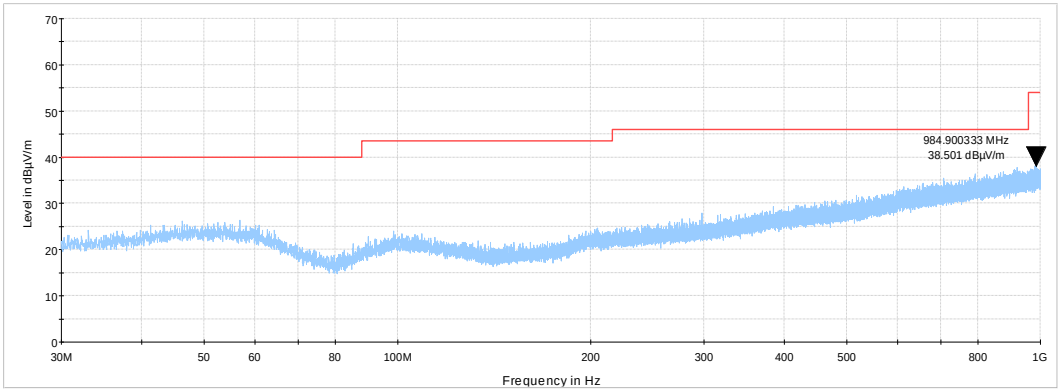
HL 3903	HL 4360	HL 4933	HL 5288	HL 5665			

Full description is given in Appendix A.

Test specification:	**Section 15.109, Radiated emission**		
Test procedure:	ANSI C63.4, Sections 8.3 and 12.2.5		
Test mode:	Compliance	**Verdict:**	PASS
Date(s):	16-Dec-19		
Temperature: 22 ºC	**Relative Humidity:** 47 %	**Air Pressure:** 1020 hPa	**Power:** 3 VDC
Remarks:			

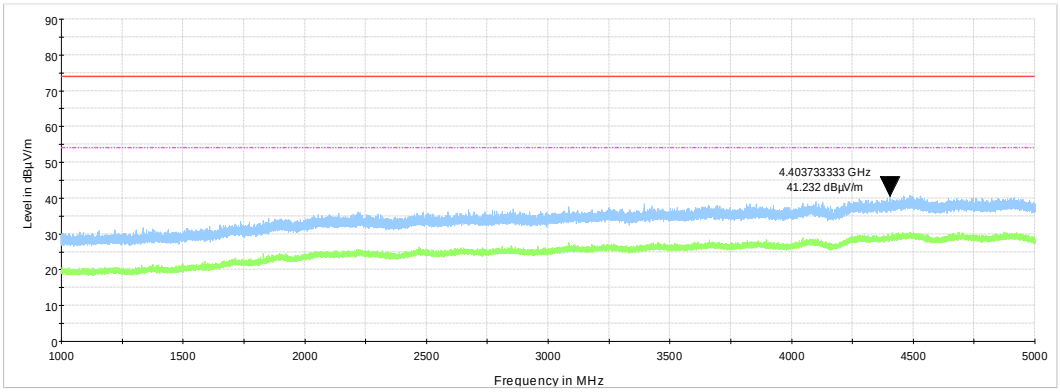
Plot 8.1.1 Radiated emission measurements in 30 - 1000 MHz range, vertical and horizontal antenna polarization

TEST SITE: Semi anechoic chamber
LIMIT: Class B
TEST DISTANCE: 3 m
EUT OPERATING MODE: Receive



Plot 8.1.2 Radiated emission measurements above 1000 MHz, vertical and horizontal antenna polarization

TEST SITE: Semi anechoic chamber
LIMIT: Class B
TEST DISTANCE: 3 m
EUT OPERATING MODE: Receive



9 APPENDIX A Test equipment and ancillaries used for tests

HL No	Description	Manufacturer	Model	Ser. No.	Last Cal./ Check	Due Cal./ Check
2909	Spectrum analyzer, ESA-E, 100 Hz to 26.5 GHz	Agilent Technologies	E4407B	MY41444762	04-Apr-19	04-Apr-20
3903	Microwave Cable Assembly, 40.0 GHz, 1.5 m, SMA/SMA	Huber-Suhner	SUCOFLEX 102A	1226/2A	07-Apr-19	07-Apr-20
4355	Signal and Spectrum Analyzer, 9 kHz to 7 GHz	Rohde & Schwarz	FSV 7	101630	04-Aug-19	04-Aug-20
4360	EMI Test Receiver, 20 Hz to 40 GHz.	Rohde & Schwarz	ESU40	100322	31-Dec-18	31-Dec-19
4933	Active Horn Antenna, 1 GHz to 18 GHz	COM-POWER CORPORATION	AHA-118	701046	06-Jan-20	06-Jan-21
5111	RF cable, 40 GHz, 5.5 m, K-type	Huber-Suhner	SF102EA/11SK/11SK/5500MM	502493/2EA	14-Aug-19	14-Aug-20
5288	Trilog Antenna, 25 MHz - 8 GHz, 100W	Frankonia	ALX-8000E	00809	08-Feb-19	08-Feb-22
5606	Precision Fixed Attenuator, 50 Ohm, 5 W, 10 dB, DC to 18000 MHz	Mini Circuits	BW-N10W5+	NA	24-Sep-19	24-Sep-20
5612	Precision Fixed Attenuator, 50 Ohm, 5 W, 10 dB, DC to 18 GHz	Mini Circuits	BW-S10W5+	NA	24-Sep-19	24-Sep-20
5665	Cable SF118/11N(x2)/6M, 18 GHz, 11N/11N	Huber-Suhner	SF118	501644/118	23-Oct-19	23-Oct-20

10 APPENDIX B Test equipment correction factors

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 5111: RF cable

Huber-Suhner, SF102EA/11SK/11SK/5500MM, s/n 502493/2EA

Set / Applied, MHz	Measured, dB	Uncertainty, dB
100	0.70	±0.07
200	0.99	±0.08
300	1.21	±0.08
500	1.56	±0.08
1000	2.20	±0.08
1500	2.69	±0.08
2000	3.11	±0.08
2500	3.50	±0.10
3000	3.85	±0.10
3500	4.16	±0.10
4000	4.47	±0.10
4500	4.74	±0.10
5000	5.03	±0.10
5500	5.30	±0.10
6000	5.57	±0.10
6500	5.76	±0.10
7000	6.00	±0.10
7500	6.20	±0.10
8000	6.44	±0.10
8500	6.67	±0.10
9000	6.82	±0.10
9500	7.04	±0.10
10000	7.18	±0.10
10500	7.36	±0.10
11000	7.55	±0.10
11500	7.75	±0.10
12000	7.90	±0.10
12500	8.08	±0.13
13000	8.19	±0.13
13500	8.39	±0.13
14000	8.58	±0.13
14500	8.76	±0.18
15000	8.92	±0.18
15500	9.03	±0.18
16000	9.18	±0.18
16500	9.34	±0.18
17000	9.51	±0.18
17500	9.66	±0.18
18000	9.80	±0.18
18500	9.94	±0.23
19000	10.05	±0.23
19500	10.22	±0.23

Set / Applied, MHz	Measured, dB	Uncertainty, dB
20000	10.32	±0.23
20500	10.48	±0.23
21000	10.60	±0.23
21500	10.73	±0.23
22000	10.87	±0.23
22500	10.97	±0.29
23000	11.09	±0.29
23500	11.26	±0.29
24000	11.37	±0.29
24500	11.50	±0.29
25000	11.61	±0.23
25500	11.72	±0.23
26000	11.87	±0.23
26500	11.99	±0.23
27000	12.09	±0.33
27500	12.24	±0.33
28000	12.34	±0.40
28500	12.47	±0.40
29000	12.61	±0.40
29500	12.70	±0.40
30000	12.86	±0.40
30500	12.92	±0.33
31000	13.09	±0.33
31500	13.16	±0.33
32000	13.33	±0.33
32500	13.40	±0.33
33000	13.62	±0.33
33500	13.70	±0.33
34000	13.88	±0.33
34500	13.97	±0.40
35000	14.05	±0.40
35500	14.23	±0.40
36000	14.25	±0.40
36500	14.46	±0.40
37000	14.49	±0.33
37500	14.72	±0.33
38000	14.77	±0.33
38500	14.97	±0.33
39000	15.04	±0.33
39500	15.22	±0.33
40000	15.63	±0.47

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

Frequency, MHz	Antenna factor, dB/m	Frequency, MHz	Antenna factor, dB/m
30	14.96	160	12.67
35	15.33	180	13.34
40	16.37	200	15.40
45	17.56	250	16.42
50	17.95	300	17.28
60	16.87	400	19.98
70	13.22	500	21.11
80	10.56	600	22.90
90	13.61	700	24.13
100	15.46	800	25.25
120	14.03	900	26.35
140	12.23	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	Frequency, MHz	Antenna factor, dB/m
1000	26.9	3600	38.9
1100	28.1	3700	39.4
1200	28.4	3800	39.4
1300	29.6	3900	39.6
1400	29.1	4000	39.7
1500	30.4	4100	39.8
1600	30.7	4200	40.5
1700	31.5	4300	40.9
1800	32.3	4400	41.1
1900	32.6	4500	41.4
2000	32.5	4600	41.3
2100	32.9	4700	41.6
2200	33.5	4800	41.9
2300	33.2	4900	42.3
2400	33.7	5000	42.7
2500	34.6	5100	43.0
2600	34.7	5200	42.9
2700	34.6	5300	43.5
2800	35.0	5400	43.6
2900	35.5	5500	44.3
3000	36.2	5600	44.7
3100	36.8	5700	45.0
3200	36.8	5800	45.0
3300	37.0	5900	45.3
3400	37.5	6000	45.9
3500	38.2		

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

11 APPENDIX C 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 1, 2, 15, 18 parts of Code of Federal Regulations 47 (CFR 47), Test Firm Registration Number is 927748, Designation Number is IL1001; registered by Industry Canada for electromagnetic emissions, file number IC 2186A-1 for OATS, 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).

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Person for contact: Mr. Michael Nikishin, EMC and radio group manager

12 APPENDIX D 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.

13 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
ANSI C63.4: 2014	American National Standard for Methods of Measurement of Radio-Noise Emissions from Low-Voltage Electrical and Electronic Equipment in the Range of 9 kHz to 40 GHz

14 APPENDIX F Abbreviations and acronyms

A	ampere
AC	alternating current
A/m	ampere per meter
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