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ELECTRICAL TESTING
0839.01

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TEST REPORT

ACCORDING TO:

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

FOR:

Hoopo Systems Ltd.

FPX3 Gateway

Model: 501A001-1A

FCC ID: 2AVS8-G01

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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:	FPX3 Gateway
Product type:	LoRa Gateway
Model(s):	501A001-1A
Serial number:	122U, 123U
Hardware version:	0.0
Software release:	1.5
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:	Primary: Hermon Laboratories Ltd. P.O. Box 23, Binyamina 3055001, Israel Satellite: Hermon Laboratories Ltd. Hefetz-Haim 10, Tel Aviv 6744124, Israel
Test started:	29-Dec-19
Test completed:	08-Jan-20
Test specification(s):	FCC 47CFR part 15 subpart C § 15.247 (Hybrid) and subpart B, Class B

5 Tests summary

Test	Status
Transmitter characteristics	
Section 15.247(a)1, 20 dB bandwidth	Pass
Section 15.247(a)1, Frequency separation	Pass
Section 15.247(a)1, Number of hopping frequencies	Pass
Section 15.247(a)1, Average time of occupancy	Pass
Section 15.247(b), Peak output power	Pass
Section 15.247(e), Peak spectral density	Pass
Section 15.247(d), Radiated spurious emissions	Pass
Section 15.247(i), RF exposure	Pass*
Section 15.247(d), Emissions at band edges	Pass
Section 15.111, Conducted emission at receiver antenna port	Pass
Section 15.207(a), Conducted emission	Pass
Section 15.203, Antenna requirements	Pass
Unintentional emissions	
Section 15.107, Class B, Conducted emission at AC power port	Pass
Section 15.109, Class B, Radiated emission	Pass

* - Pass, the exhibit to the application of certification is provided.

Testing was not completed against all relevant requirements of the test standard. However, 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. I. Zilberstein, test engineer, EMC & Radio	29-Dec-19 – 08-Jan-20	
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	

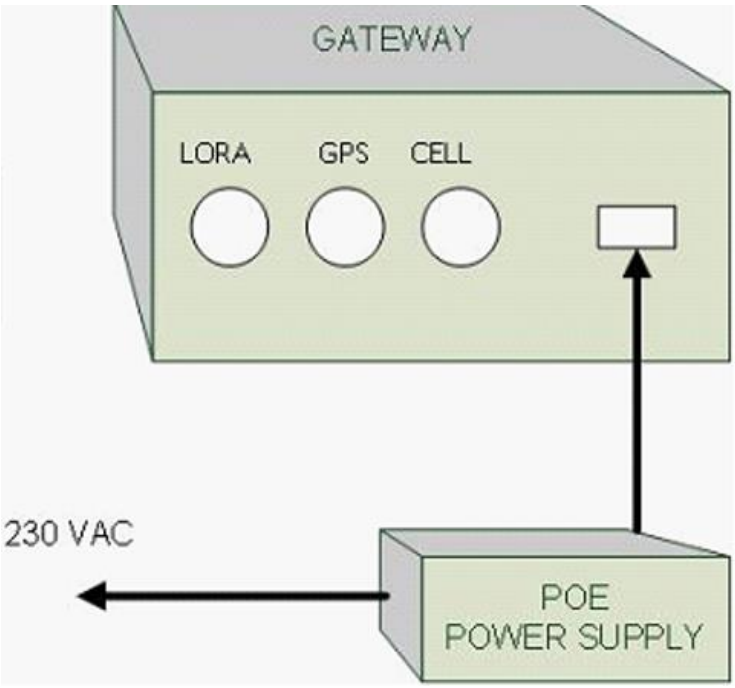
6 EUT description

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

6.1 General information

The EUT, a FPX3 Gateway, bridges the data received from hooposense sensors via LoRa transmissions to a cloud application for further processing. The EUT communicates with a cloud application via a cellular modem or via wired ethernet. The EUT is powered by external approved POE connection.

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 ranges	902 – 928 MHz
Operating frequencies	902.5 – 927.5 MHz
Maximum rated output power	At transmitter 50 Ω RF output connector
	Peak output power: 7.39 dBm

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

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

Antenna/s technical characteristics

Type	Manufacturer	Model number	Gain
External	TAOGLAS	OMB.915.B03F21	-2dBi average, 3.5 dBi peak

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

Transmitter power source

	Battery	**Nominal rated voltage**		Battery type	
	DC	**Nominal rated voltage**			
X	AC mains	**Nominal rated voltage**	110 VAC	Frequency	50 Hz

Common power source for transmitter and receiver X yes no

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

Spread spectrum parameters for transmitters tested per FCC 15.247 only

FHSS	Total number of hops	16
	Bandwidth per hop	152.63 kHz
	Max. separation of hops	200 kHz

Test specification:	**Section 15.247(a)1, 20 dB bandwidth**		
Test procedure:	ANSI C63.10, section 7.8.7		
Test mode:	Compliance	**Verdict:**	PASS
Date(s):	07-Jan-20		
Temperature: 24 ºC	**Relative Humidity:** 44 %	**Air Pressure:** 1018 hPa	**Power:** 110 VAC, 50 Hz
Remarks:			

7 Transmitter tests according to 47CFR part 15 subpart C 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

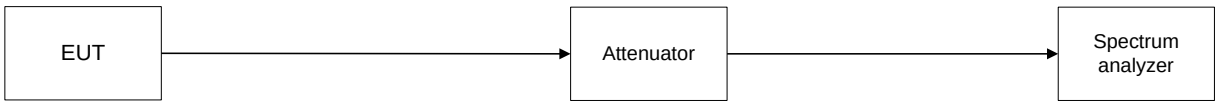
7.1.2.1 The EUT was set up as shown in Figure 7.1.1, energized and its proper operation was checked.

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, 20 dB bandwidth**		
Test procedure:	ANSI C63.10, section 7.8.7		
Test mode:	Compliance	**Verdict:**	PASS
Date(s):	07-Jan-20		
Temperature: 24 ºC	**Relative Humidity:** 44 %	**Air Pressure:** 1018 hPa	**Power:** 110 VAC, 50 Hz
Remarks:			

Table 7.1.2 The 20 dB bandwidth test results

ASSIGNED FREQUENCY BAND:	902-928 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	Symbol rate, Msymbols/s	20 dB bandwidth, kHz	Limit, kHz	Margin, kHz	Verdict
902.5	LoRa	980	NA	142.730	250	-107.270	Pass
		5470		149.933	250	-100.067	Pass
915.0	LoRa	980	NA	142.508	250	-107.492	Pass
		5470		152.630	250	-97.370	Pass
927.5	LoRa	980	NA	142.534	250	-107.466	Pass
		5470		151.533	250	-98.467	Pass

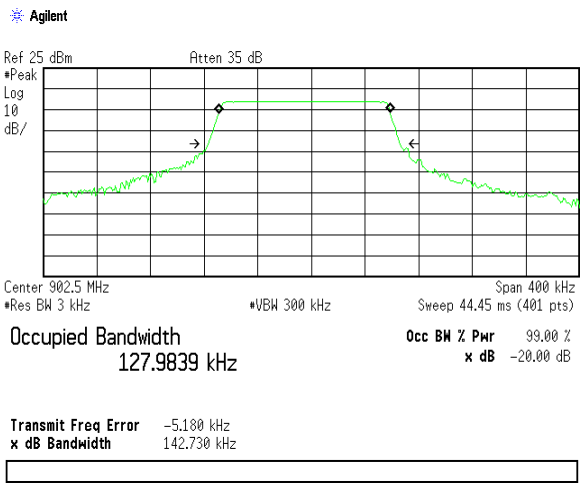
Reference numbers of test equipment used

HL 2909	HL 3901							

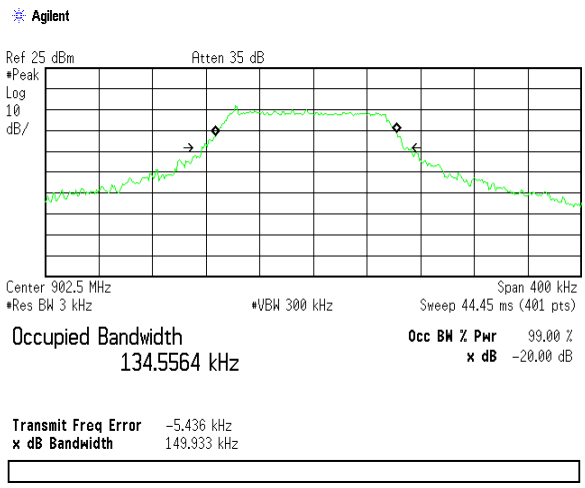
Full description is given in Appendix A.

Test specification:	**Section 15.247(a)1, 20 dB bandwidth**		
Test procedure:	ANSI C63.10, section 7.8.7		
Test mode:	Compliance	**Verdict:**	PASS
Date(s):	07-Jan-20		
Temperature: 24 ºC	**Relative Humidity:** 44 %	**Air Pressure:** 1018 hPa	**Power:** 110 VAC, 50 Hz
Remarks:			

Plot 7.1.1 The 20 dB bandwidth test result at low frequency



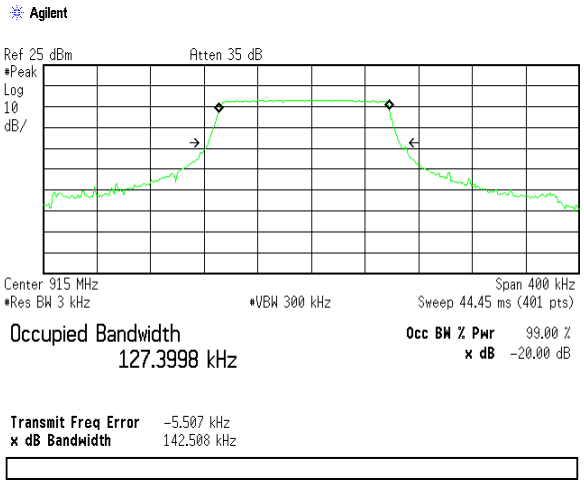
980 bps



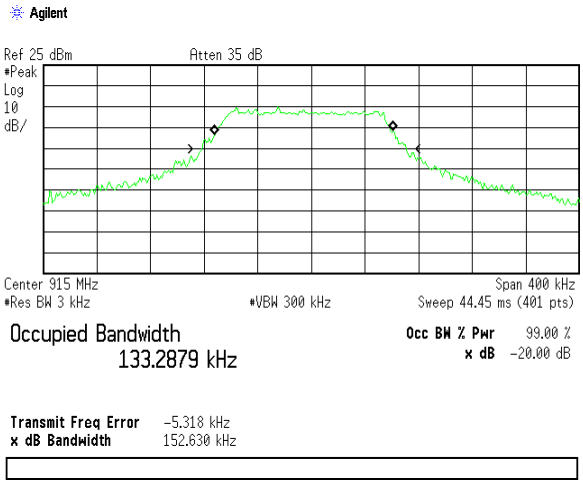
5470 bps

Test specification:	**Section 15.247(a)1, 20 dB bandwidth**		
Test procedure:	ANSI C63.10, section 7.8.7		
Test mode:	Compliance	**Verdict:**	PASS
Date(s):	07-Jan-20		
Temperature: 24 ºC	**Relative Humidity:** 44 %	**Air Pressure:** 1018 hPa	**Power:** 110 VAC, 50 Hz
Remarks:			

Plot 7.1.2 The 20 dB bandwidth test result at mid frequency

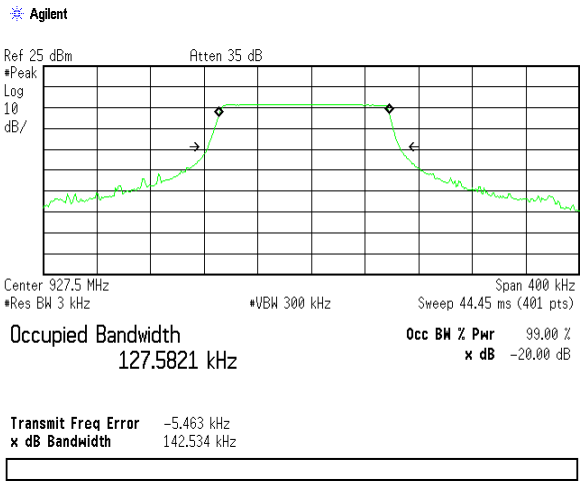


980 bps

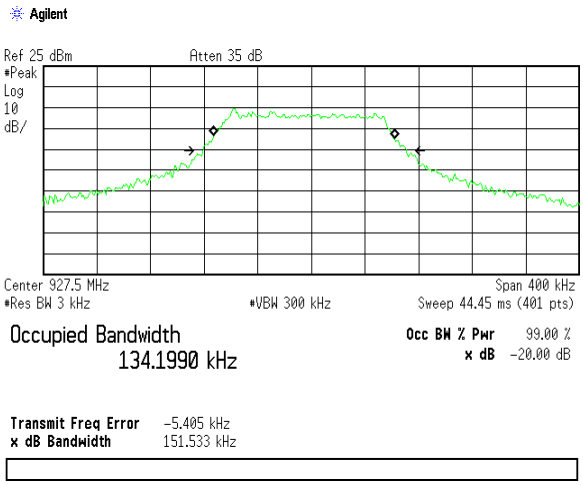


5470 bps

Plot 7.1.3 The 20 dB bandwidth test result at high frequency



980 bps



5470 bps

Test specification:	**Section 15.247(a)1, Frequency separation**		
Test procedure:	ANSI C63.10, section 7.8.2		
Test mode:	Compliance	**Verdict:**	PASS
Date(s):	07-Jan-20		
Temperature: 25.1 ºC	**Relative Humidity:** 32 %	**Air Pressure:** 1015 hPa	**Power:** 110 VAC, 50 Hz
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
902.0 – 928.0	25 kHz or 20 dB bandwidth of the hopping channel, whichever is greater

7.2.2 Test procedure

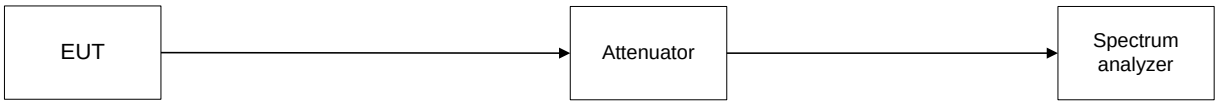
7.2.2.1 The EUT was set up as shown in Figure 7.2.1, energized with frequency hopping function enabled and its proper operation was checked.

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, Frequency separation**		
Test procedure:	ANSI C63.10, section 7.8.2		
Test mode:	Compliance	**Verdict:**	PASS
Date(s):	07-Jan-20		
Temperature: 25.1 ºC	**Relative Humidity:** 32 %	**Air Pressure:** 1015 hPa	**Power:** 110 VAC, 50 Hz
Remarks:			

Table 7.2.2 Carrier frequency separation test results

ASSIGNED FREQUENCY: 902-928 MHz
MODULATION: LoRa
DETECTOR USED: Peak
RESOLUTION BANDWIDTH: ≥ 1% of the span
VIDEO BANDWIDTH: ≥ RBW
FREQUENCY HOPPING: Enabled

ASSIGNED FREQUENCY 915.0 MHz
20 dB BANDWIDTH: 152.63 kHz

Carrier frequency separation, kHz	Limit, kHz	Margin*	Verdict
200.0	152.63	-47.37	Pass

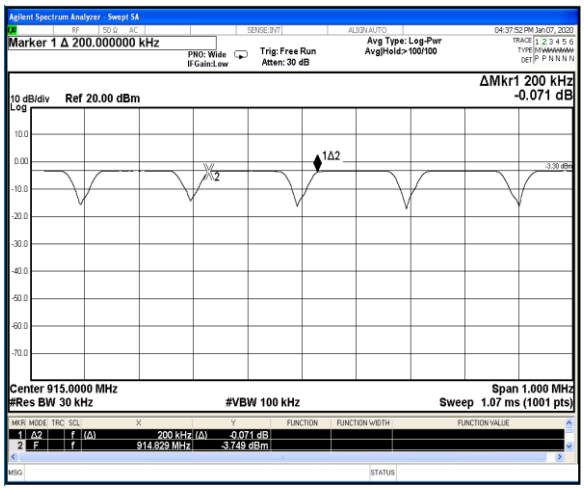
* - Margin = Carrier frequency separation – specification limit.

Reference numbers of test equipment used

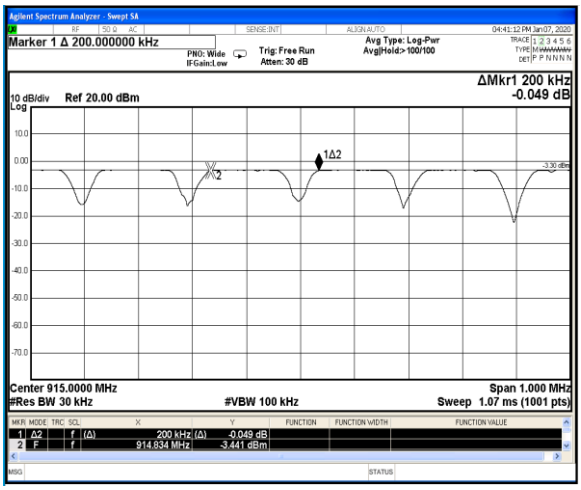
HL 4575	HL 3771	HL 4276					

Full description is given in Appendix A.

Plot 7.2.1 Carrier frequency separation at mid frequency



980 bps



5470 bps

Test specification:	**Section 15.247(a)1, Number of hopping frequencies**		
Test procedure:	ANSI C63.10, section 7.8.3		
Test mode:	Compliance	**Verdict:**	PASS
Date(s):	07-Jan-20		
Temperature: 25.1 ºC	**Relative Humidity:** 32 %	**Air Pressure:** 1015 hPa	**Power:** 110 VAC, 50 Hz
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)

7.3.2 Test procedure

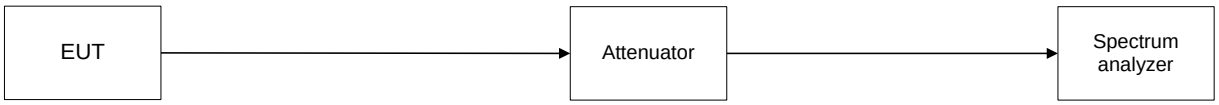
7.3.2.1 The EUT was set up as shown in Figure 7.3.1, energized with frequency hopping function enabled and its proper operation was checked.

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, Number of hopping frequencies**		
Test procedure:	ANSI C63.10, section 7.8.3		
Test mode:	Compliance	**Verdict:**	PASS
Date(s):	07-Jan-20		
Temperature: 25.1 ºC	**Relative Humidity:** 32 %	**Air Pressure:** 1015 hPa	**Power:** 110 VAC, 50 Hz
Remarks:			

Table 7.3.2 Hopping frequencies test results

ASSIGNED FREQUENCY: 902-928 MHz
MODULATION: LoRa
DETECTOR USED: Peak
VIDEO BANDWIDTH: ≥ RBW
FREQUENCY HOPPING: Enabled

Number of hopping frequencies	Minimum number of hopping frequencies	Margin*	Verdict
16	NA for hybrid mode	NA	Pass

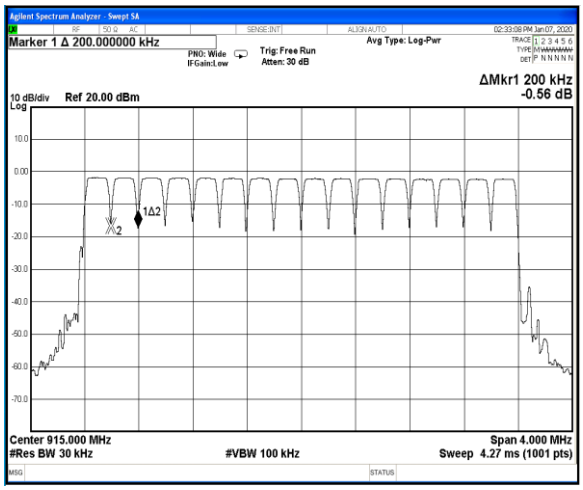
* - Margin = Number of hopping frequencies – Minimum number of hopping frequencies.

Reference numbers of test equipment used

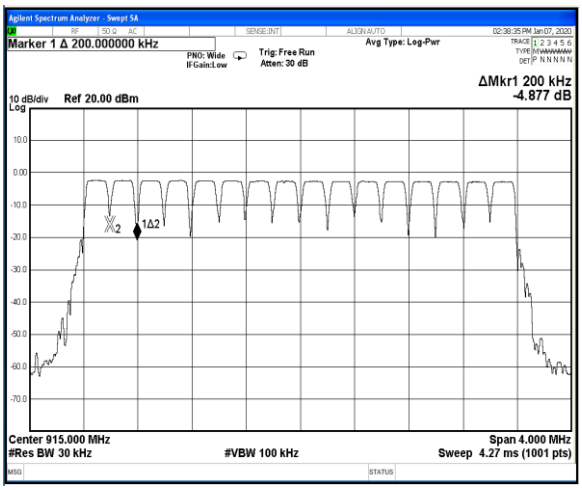
HL 4575	HL 3771	HL 4275					

Full description is given in Appendix A.

Plot 7.3.1 Number of hopping frequencies



980 bps



5470 bps

Test specification:	**Section 15.247(a)1, Average time of occupancy**		
Test procedure:	ANSI C63.10, section 7.8.4		
Test mode:	Compliance	**Verdict:**	PASS
Date(s):	07-Jan-20		
Temperature: 26.4 ºC	**Relative Humidity:** 33 %	**Air Pressure:** 1015 hPa	**Power:** 110 VAC, 50 Hz
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
902.0 – 928.0	0.4	10.0	< 50
902.0 – 928.0	**0.4**	**0.4 × N**	**N = 16**

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.

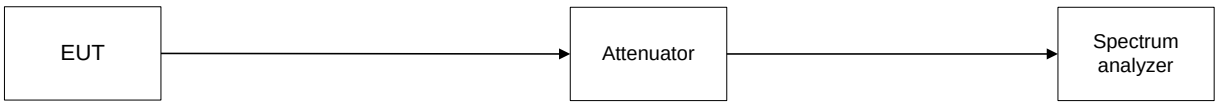
7.4.2.2 The spectrum analyzer span was set to zero centered on a hopping channel.

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)1, Average time of occupancy**		
Test procedure:	ANSI C63.10, section 7.8.4		
Test mode:	Compliance	**Verdict:**	PASS
Date(s):	07-Jan-20		
Temperature: 26.4 ºC	**Relative Humidity:** 33 %	**Air Pressure:** 1015 hPa	**Power:** 110 VAC, 50 Hz
Remarks:			

Table 7.4.2 Average time of occupancy test results

ASSIGNED FREQUENCY: 902-928 MHz
MODULATION: LoRa
DETECTOR USED: Peak
NUMBER OF HOPPING FREQUENCIES: 16
INVESTIGATED PERIOD: 6.4 s
FREQUENCY HOPPING: Enabled

Carrier frequency, MHz	Single transmission duration, ms	Single transmission period, s	Average time of occupancy*, s	Bit rate, bps	Symbol rate, Msymbol/s	Limit, s	Margin, s**	Verdict
915	288.5	> 6.4	0.2885	980	NA	0.4	0.1115	Pass
915	46.3	> 6.4	0.0463	5470	NA	0.4	0.3537	Pass

* - Average time of occupancy = the transmit time per hop × the number of hops in the investigated period.

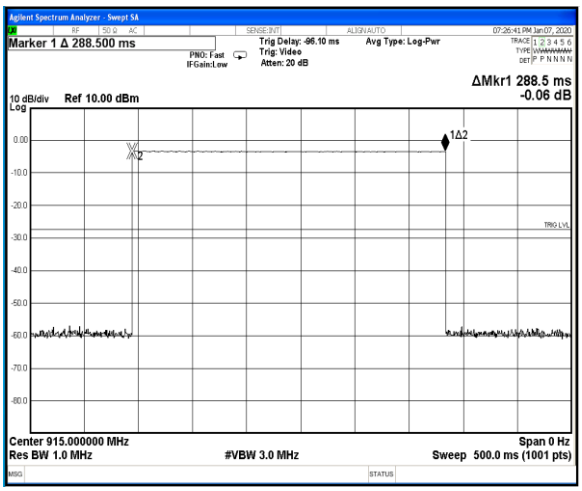
Reference numbers of test equipment used

HL 4575	HL 3771	HL 4275					

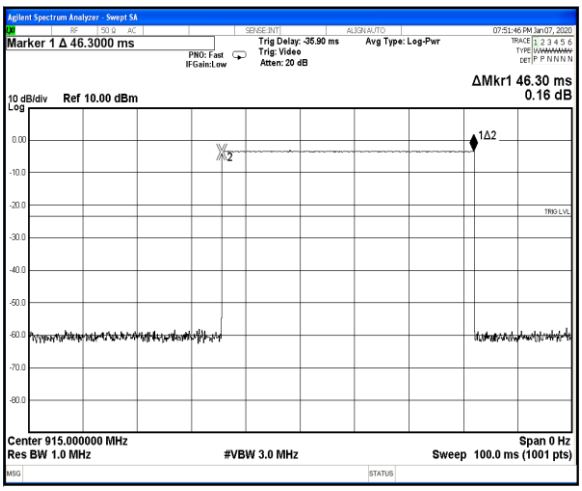
Full description is given in Appendix A.

Test specification:	**Section 15.247(a)1, Average time of occupancy**		
Test procedure:	ANSI C63.10, section 7.8.4		
Test mode:	Compliance	**Verdict:**	PASS
Date(s):	07-Jan-20		
Temperature: 26.4 ºC	**Relative Humidity:** 33 %	**Air Pressure:** 1015 hPa	**Power:** 110 VAC, 50 Hz
Remarks:			

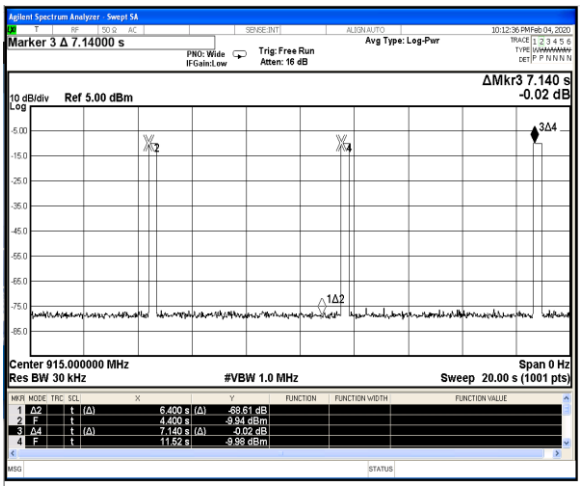
Plot 7.4.1 Single transmission duration at mid frequency



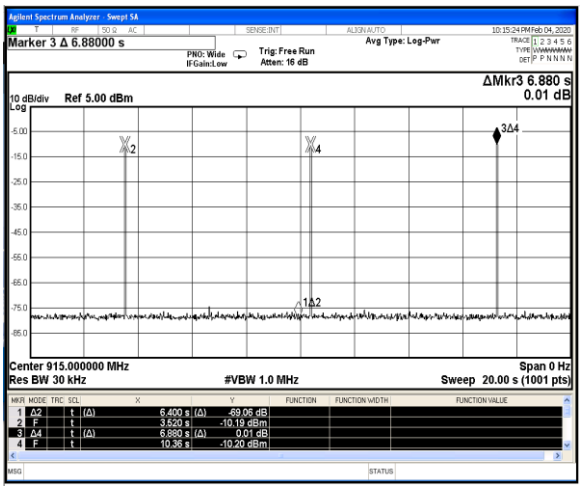
980 bps



5470 bps



980 bps



5470 bps

Test specification:	**Section 15.247(b), Peak output power**		
Test procedure:	ANSI C63.10, section 11.9.2.2.4		
Test mode:	Compliance	**Verdict:**	PASS
Date(s):	08-Jan-20		
Temperature: 23.6 ºC	**Relative Humidity:** 32 %	**Air Pressure:** 1015 hPa	**Power:** 110 VAC, 50 Hz
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	Maximum antenna gain, dBi	Peak output power*	
		W	dBm
902.0 – 928.0	6.0	0.25	24.0

*- 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.

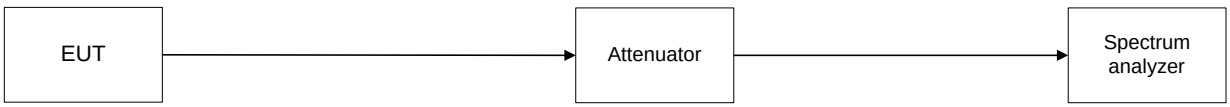
7.5.2 Test procedure

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), Peak output power**		
Test procedure:	ANSI C63.10, section 11.9.2.2.4		
Test mode:	Compliance	**Verdict:**	PASS
Date(s):	08-Jan-20		
Temperature: 23.6 ºC	**Relative Humidity:** 32 %	**Air Pressure:** 1015 hPa	**Power:** 110 VAC, 50 Hz
Remarks:			

Table 7.5.2 Peak output power test results

ASSIGNED FREQUENCY: 902.0 – 928.0 MHz
MODULATION: LoRa
BIT RATE: 980 bps/5470 bps
TRANSMITTER OUTPUT POWER SETTINGS: Maximum
DETECTOR USED: Peak
RESOLUTION BANDWIDTH: 1 MHz
VIDEO BANDWIDTH: 3 MHz
FREQUENCY HOPPING: Disabled
NUMBER OF FREQUENCY HOPPING CHANNELS: 16
Unom 110VAC
OBW: 125kHz
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
902.5	-4.06	10	0.92	6.86	24	-17.14	Pass
915.0	-3.57	10	0.92	7.35	24	-16.65	Pass
927.5	-5.06	10	0.92	5.86	24	-18.14	Pass

OBW: 125kHz
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
902.5	-3.95	10	0.92	6.97	24	-17.03	Pass
915.0	-3.53	10	0.92	7.39	24	-16.61	Pass
927.5	-5.04	10	0.92	5.88	24	-18.12	Pass

115%Unom 126.5VAC
OBW: 125kHz
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
902.5	-3.96	10	0.92	6.96	24	-17.04	Pass
915.0	-2.73	10	0.92	8.19	24	-15.81	Pass
927.5	-4.63	10	0.92	6.29	24	-17.71	Pass

115%Unom 126.5VAC
OBW: 125kHz
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
902.5	-3.93	10	0.92	6.99	24	-17.01	Pass
915.0	-2.83	10	0.92	8.09	24	-15.91	Pass
927.5	-4.54	10	0.92	6.38	24	-17.62	Pass

Test specification:	**Section 15.247(b), Peak output power**		
Test procedure:	ANSI C63.10, section 11.9.2.2.4		
Test mode:	Compliance	**Verdict:**	PASS
Date(s):	08-Jan-20		
Temperature: 23.6 ºC	**Relative Humidity:** 32 %	**Air Pressure:** 1015 hPa	**Power:** 110 VAC, 50 Hz
Remarks:			

85%Unom 93.5VAC
OBW: 125kHz
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
902.5	-3.98	10	0.92	6.94	24	-17.06	Pass
915.0	-3.20	10	0.92	7.72	24	-16.28	Pass
927.5	-4.57	10	0.92	6.35	24	-17.65	Pass

85%Unom 93.5VAC
OBW: 125kHz
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
902.5	-3.96	10	0.92	6.96	24	-17.04	Pass
915.0	-3.20	10	0.92	7.72	24	-16.28	Pass
927.5	-4.72	10	0.92	6.20	24	-17.80	Pass

* - Margin = Peak output power – specification limit.
Note: Maximum peak output power was obtained at Unom (115%Unom, 85%Unom) input power voltage.

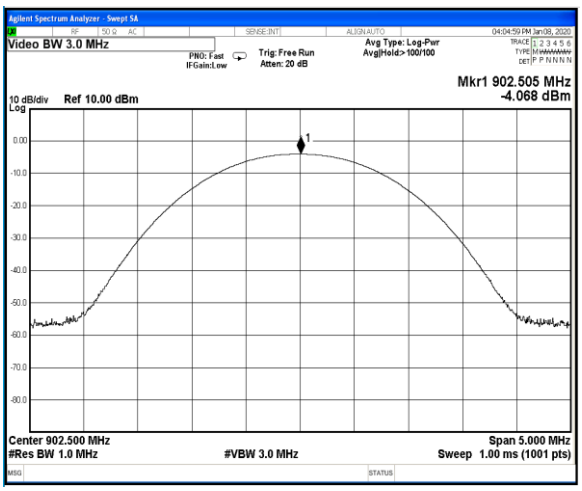
Reference numbers of test equipment used

HL 4575	HL 3771	HL 4275					

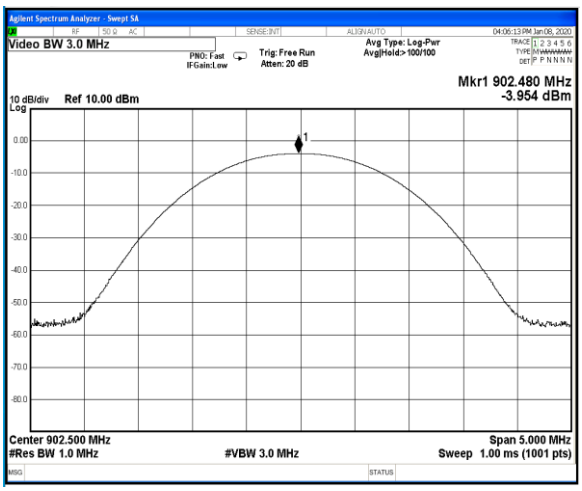
Full description is given in Appendix A.

Test specification:	**Section 15.247(b), Peak output power**		
Test procedure:	ANSI C63.10, section 11.9.2.2.4		
Test mode:	Compliance	**Verdict:**	PASS
Date(s):	08-Jan-20		
Temperature: 23.6 ºC	**Relative Humidity:** 32 %	**Air Pressure:** 1015 hPa	**Power:** 110 VAC, 50 Hz
Remarks:			

Plot 7.5.1 Peak output power at low frequency and Unom 110VAC

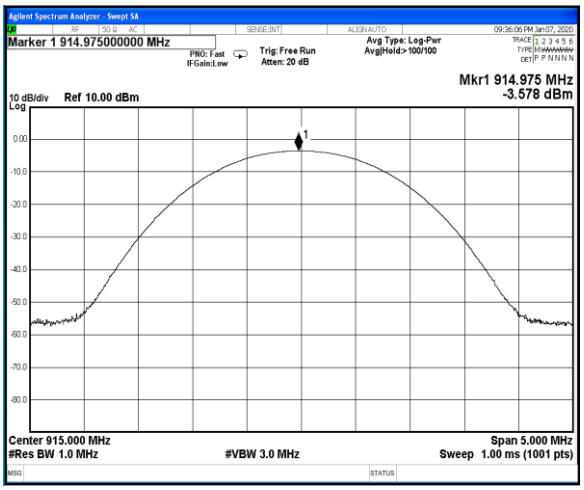


BIT RATE: 980 bps

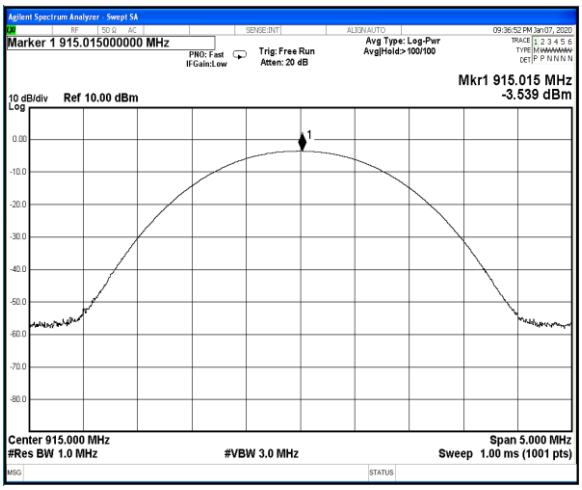


BIT RATE: 5470 bps

Plot 7.5.2 Peak output power at mid frequency and Unom 110VAC



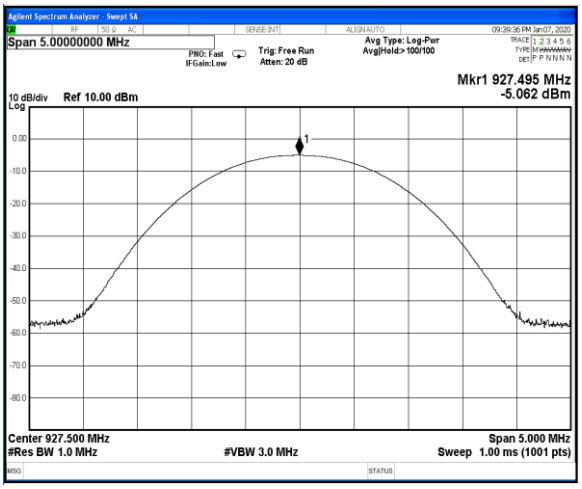
BIT RATE: 980 bps



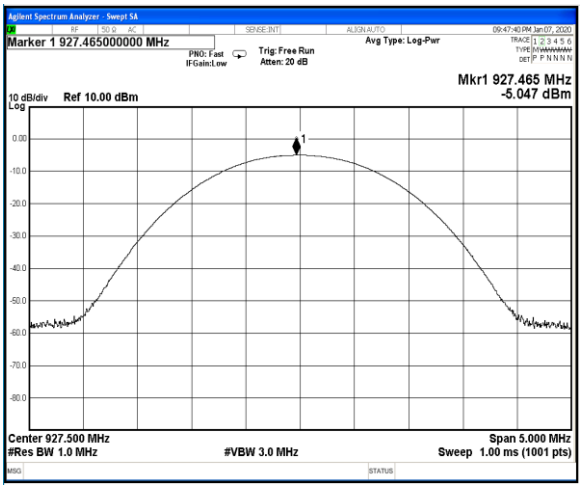
BIT RATE: 5470 bps

Test specification:	**Section 15.247(b), Peak output power**		
Test procedure:	ANSI C63.10, section 11.9.2.2.4		
Test mode:	Compliance	**Verdict:**	PASS
Date(s):	08-Jan-20		
Temperature: 23.6 ºC	**Relative Humidity:** 32 %	**Air Pressure:** 1015 hPa	**Power:** 110 VAC, 50 Hz
Remarks:			

Plot 7.5.3 Peak output power at high frequency and Unom 110VAC

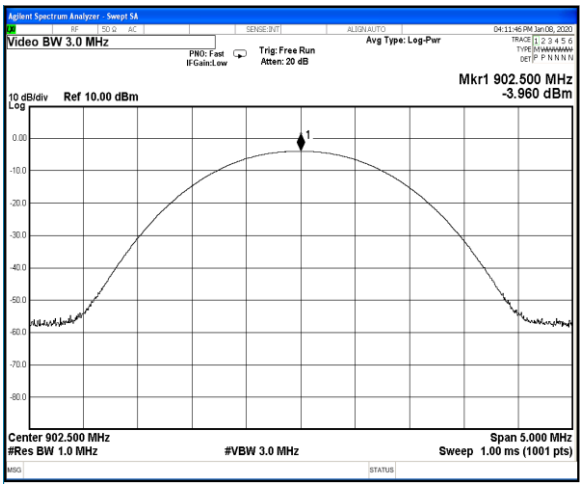


BIT RATE: 980 bps

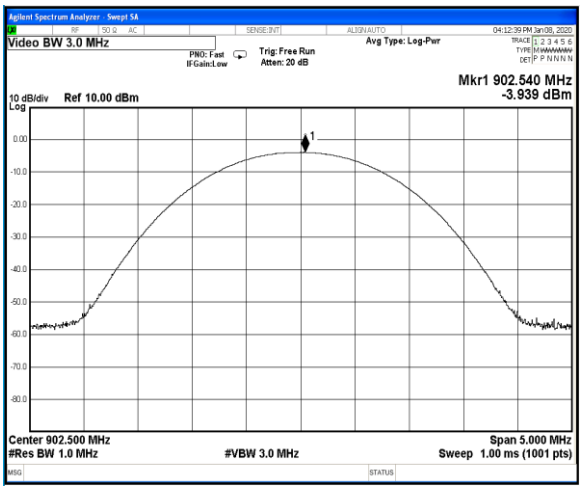


BIT RATE: 5470 bps

Plot 7.5.4 Peak output power at low frequency and 115%Unom 126.5VAC



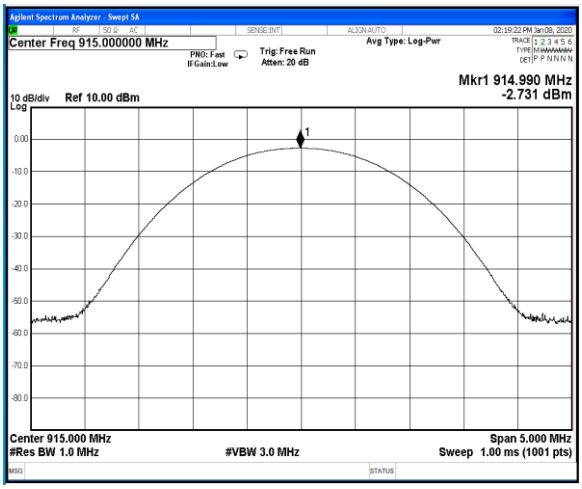
BIT RATE: 980 bps



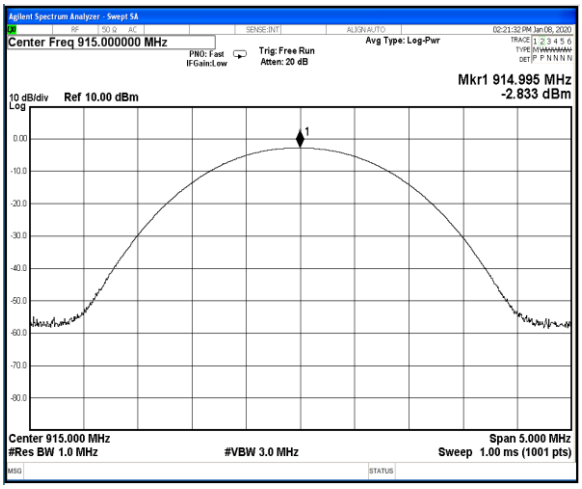
BIT RATE: 5470 bps

Test specification:	**Section 15.247(b), Peak output power**		
Test procedure:	ANSI C63.10, section 11.9.2.2.4		
Test mode:	Compliance	**Verdict:**	PASS
Date(s):	08-Jan-20		
Temperature: 23.6 ºC	**Relative Humidity:** 32 %	**Air Pressure:** 1015 hPa	**Power:** 110 VAC, 50 Hz
Remarks:			

Plot 7.5.5 Peak output power at mid frequency and 115%Unom 126.5VAC

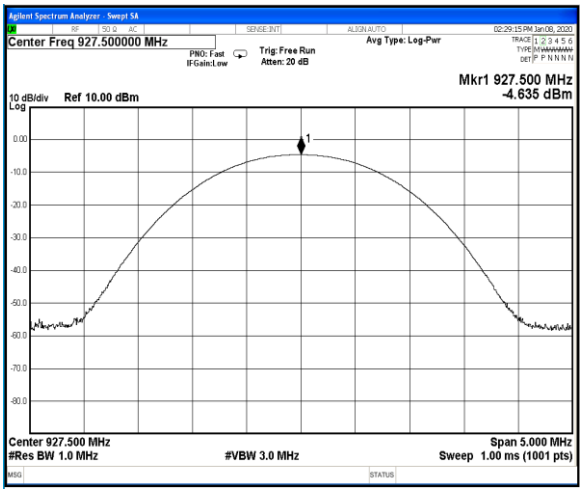


BIT RATE: 980 bps

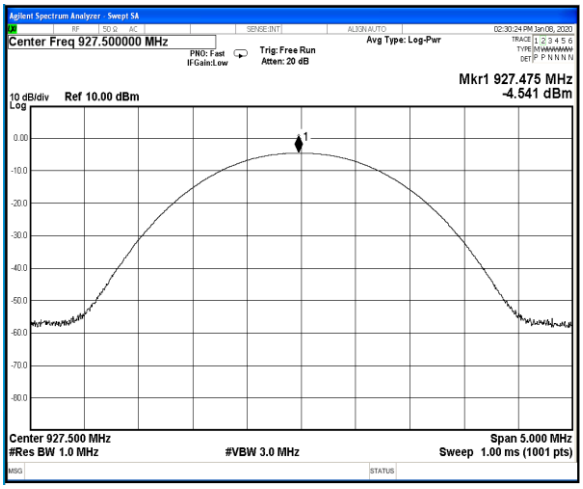


BIT RATE: 5470 bps

Plot 7.5.6 Peak output power at high frequency and 115%Unom 126.5VAC



BIT RATE: 980 bps



BIT RATE: 5470 bps

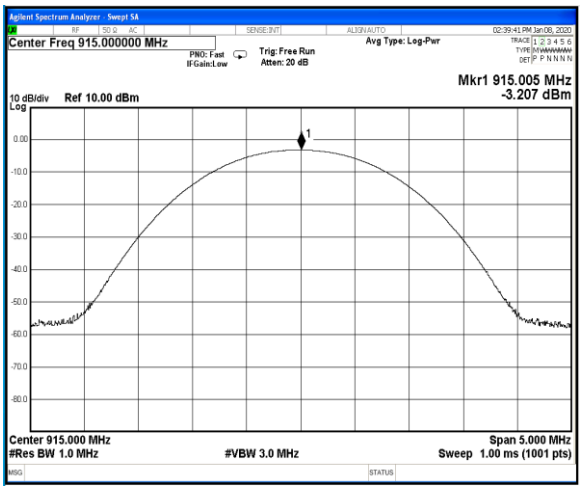
Test specification:	**Section 15.247(b), Peak output power**		
Test procedure:	ANSI C63.10, section 11.9.2.2.4		
Test mode:	Compliance	**Verdict:**	PASS
Date(s):	08-Jan-20		
Temperature: 23.6 ºC	**Relative Humidity:** 32 %	**Air Pressure:** 1015 hPa	**Power:** 110 VAC, 50 Hz
Remarks:			

Plot 7.5.7 Peak output power at low frequency and 85%Unom 93.5VAC

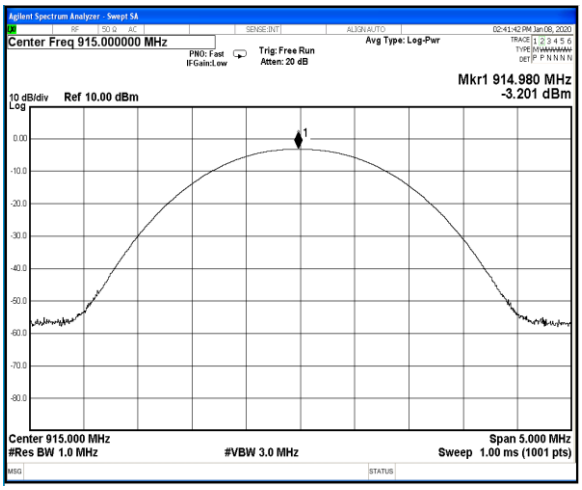
BIT RATE: 980 bps

BIT RATE: 5470 bps

Plot 7.5.8 Peak output power at mid frequency and 85%Unom 93.5VAC



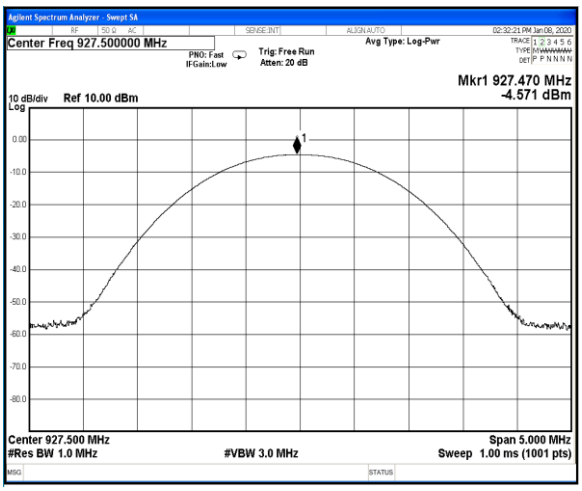
BIT RATE: 980 bps



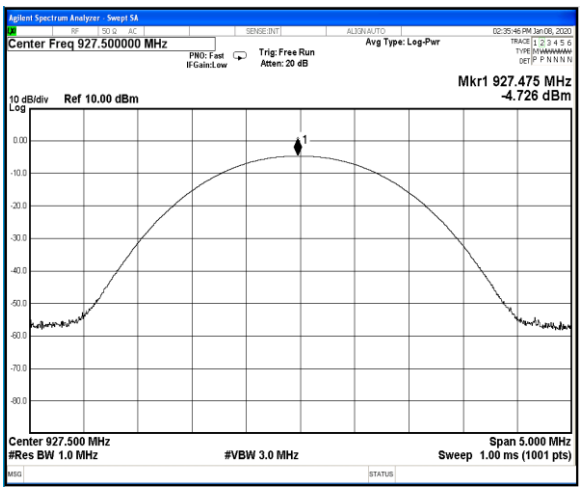
BIT RATE: 5470 bps

Test specification:	**Section 15.247(b), Peak output power**		
Test procedure:	ANSI C63.10, section 11.9.2.2.4		
Test mode:	Compliance	**Verdict:**	PASS
Date(s):	08-Jan-20		
Temperature: 23.6 ºC	**Relative Humidity:** 32 %	**Air Pressure:** 1015 hPa	**Power:** 110 VAC, 50 Hz
Remarks:			

Plot 7.5.9 Peak output power at high frequency and 85%Unom 93.5VAC



BIT RATE: 980 bps



BIT RATE: 5470 bps

Test specification:	**Section 15.247(d), Peak power density**		
Test procedure:	ANSI C63.10, section 11.10.5		
Test mode:	Compliance	**Verdict:**	PASS
Date(s):	08-Jan-20		
Temperature: 24.4 ºC	**Relative Humidity:** 32 %	**Air Pressure:** 1015 hPa	**Power:** 110 VAC, 50 Hz
Remarks:			

7.6 Peak spectral power density

7.6.1 General

This test was performed to measure the peak spectral power density conducted by the transmitter RF antenna. 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

* - 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.

7.6.2 Test procedure for field strength measurements

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 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.

7.6.2.4 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.

7.6.2.5 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 7.6.2 and associated plots.

Test specification:	**Section 15.247(d), Peak power density**		
Test procedure:	ANSI C63.10, section 11.10.5		
Test mode:	Compliance	**Verdict:**	PASS
Date(s):	08-Jan-20		
Temperature: 24.4 ºC	**Relative Humidity:** 32 %	**Air Pressure:** 1015 hPa	**Power:** 110 VAC, 50 Hz
Remarks:			

Figure 7.6.1 Setup for carrier field strength measurements

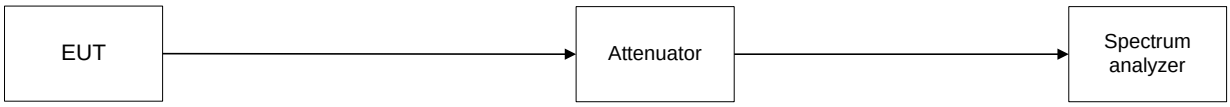


Table 7.6.2 Field strength measurement of peak spectral power density

ASSIGNED FREQUENCY: 902.0 – 928.0 MHz
MODULATION: LoRa
BIT RATE: 980 bps/5470 bps
TRANSMITTER OUTPUT POWER SETTINGS: Maximum
DETECTOR USED: Peak
RESOLUTION BANDWIDTH: 3 kHz
VIDEO BANDWIDTH: 10 kHz
FREQUENCY HOPPING: Disabled
NUMBER OF FREQUENCY HOPPING CHANNELS: 16
Unom 110VAC
OBW: 125kHz
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
902.5	-3.70	10	0.92	7.22	8	-0.78	Pass
915.0	-3.30	10	0.92	7.62	8	-0.38	Pass
927.5	-4.81	10	0.92	6.11	8	-1.89	Pass

OBW: 125kHz
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
902.5	-6.26	10	0.92	4.66	8	-3.34	Pass
915.0	-6.18	10	0.92	4.74	8	-3.26	Pass
927.5	-7.32	10	0.92	3.6.	8	-4.40	Pass

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

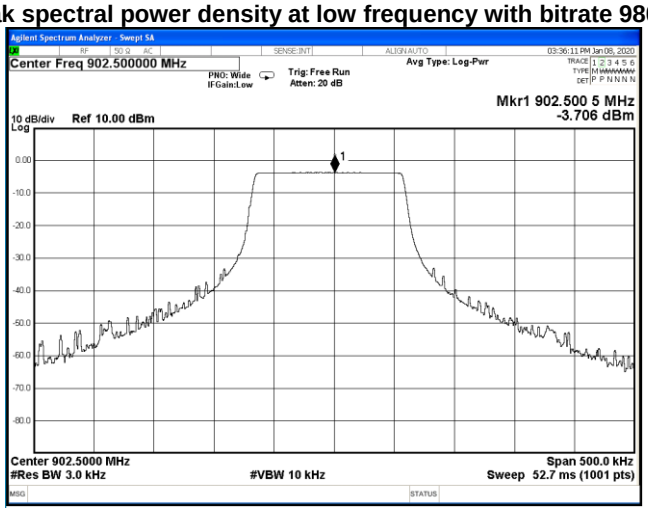
Reference numbers of test equipment used

HL 4575	HL 3771	HL 4275					

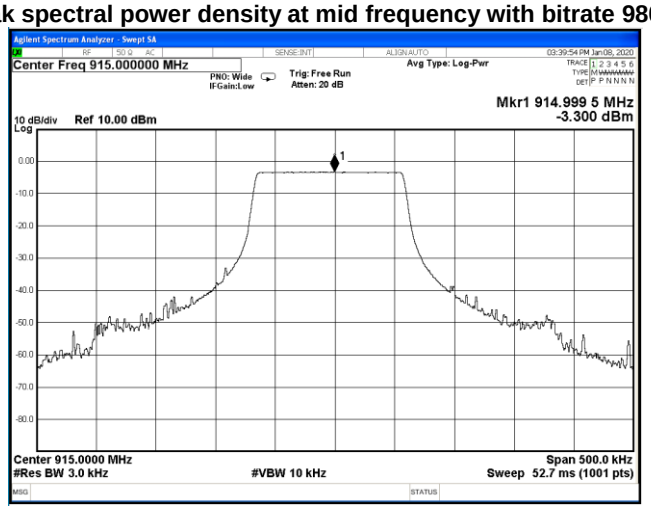
Full description is given in Appendix A.

Test specification:	**Section 15.247(d), Peak power density**		
Test procedure:	ANSI C63.10, section 11.10.5		
Test mode:	Compliance	**Verdict:**	PASS
Date(s):	08-Jan-20		
Temperature: 24.4 ºC	**Relative Humidity:** 32 %	**Air Pressure:** 1015 hPa	**Power:** 110 VAC, 50 Hz
Remarks:			

Plot 7.6.1 Peak spectral power density at low frequency with bitrate 980 bps

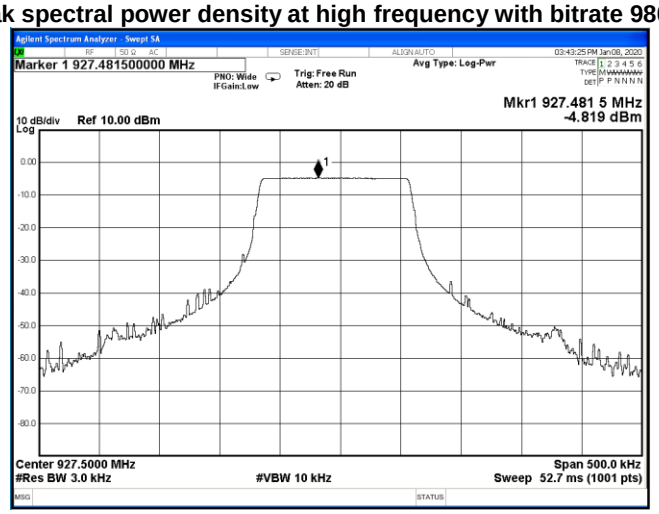


Plot 7.6.2 Peak spectral power density at mid frequency with bitrate 980 bps



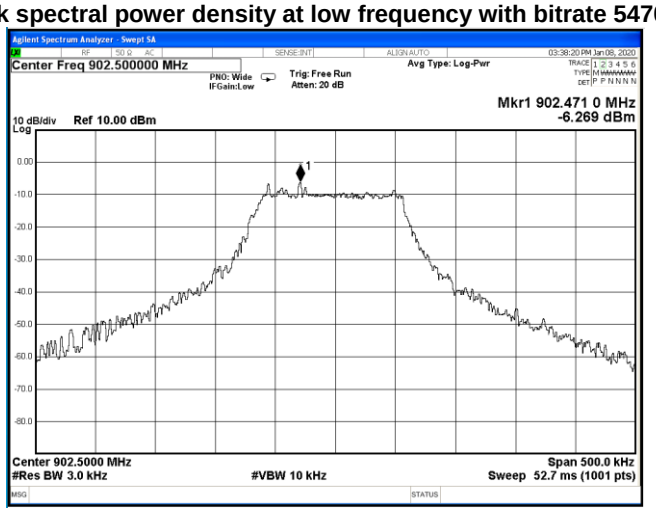
Test specification:	**Section 15.247(d), Peak power density**		
Test procedure:	ANSI C63.10, section 11.10.5		
Test mode:	Compliance	**Verdict:**	PASS
Date(s):	08-Jan-20		
Temperature: 24.4 ºC	**Relative Humidity:** 32 %	**Air Pressure:** 1015 hPa	**Power:** 110 VAC, 50 Hz
Remarks:			

Plot 7.6.3 Peak spectral power density at high frequency with bitrate 980 bps

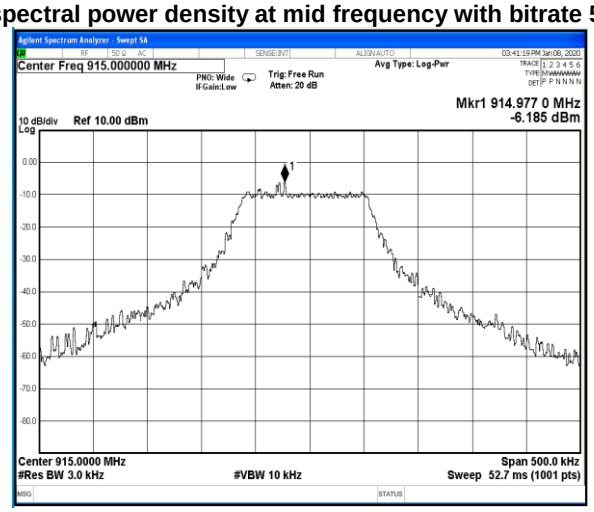


Test specification:	**Section 15.247(d), Peak power density**		
Test procedure:	ANSI C63.10, section 11.10.5		
Test mode:	Compliance	**Verdict:**	PASS
Date(s):	08-Jan-20		
Temperature: 24.4 ºC	**Relative Humidity:** 32 %	**Air Pressure:** 1015 hPa	**Power:** 110 VAC, 50 Hz
Remarks:			

Plot 7.6.4 Peak spectral power density at low frequency with bitrate 5470 bps

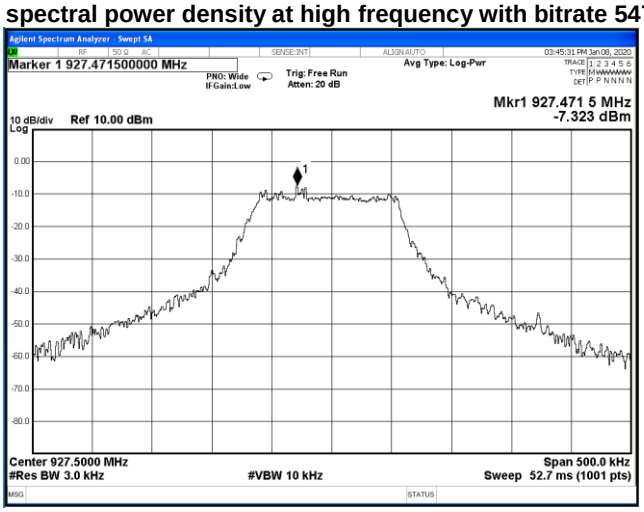


Plot 7.6.5 Peak spectral power density at mid frequency with bitrate 5470 bps



Test specification:	**Section 15.247(d), Peak power density**		
Test procedure:	ANSI C63.10, section 11.10.5		
Test mode:	Compliance	**Verdict:**	PASS
Date(s):	08-Jan-20		
Temperature: 24.4 ºC	**Relative Humidity:** 32 %	**Air Pressure:** 1015 hPa	**Power:** 110 VAC, 50 Hz
Remarks:			

Plot 7.6.6 Peak spectral power density at high frequency with bitrate 5470 bps



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):	07-Jan-20		
Temperature: 24 ºC	**Relative Humidity:** 44 %	**Air Pressure:** 1018 hPa	**Power:** 110 VAC, 50 Hz
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 nergized 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), Radiated spurious emissions**		
Test procedure:	ANSI C63.10 section 11.12.1		
Test mode:	Compliance	**Verdict:**	PASS
Date(s):	07-Jan-20		
Temperature: 24 ºC	**Relative Humidity:** 44 %	**Air Pressure:** 1018 hPa	**Power:** 110 VAC, 50 Hz
Remarks:			

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

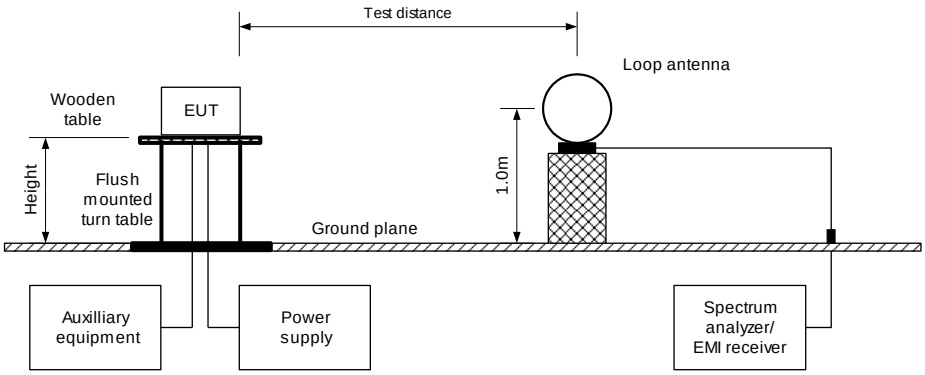
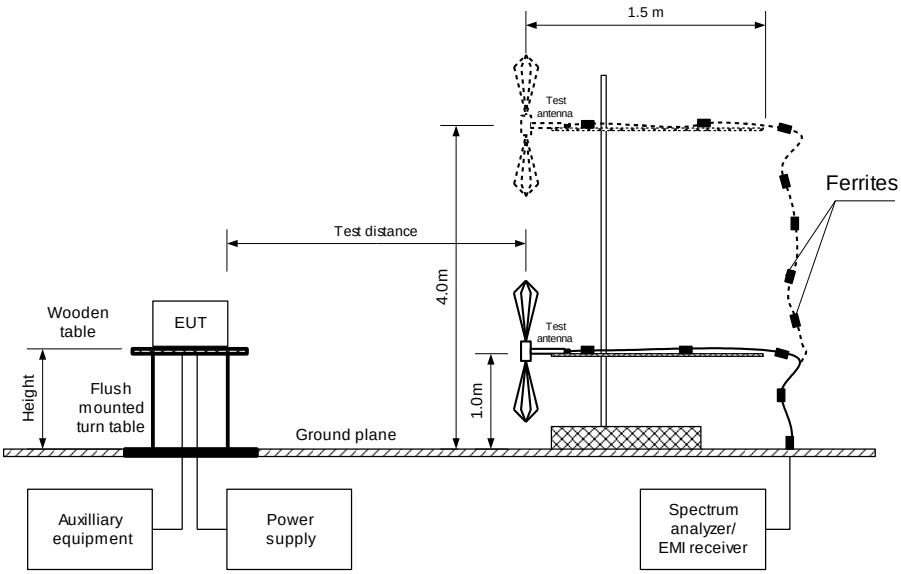
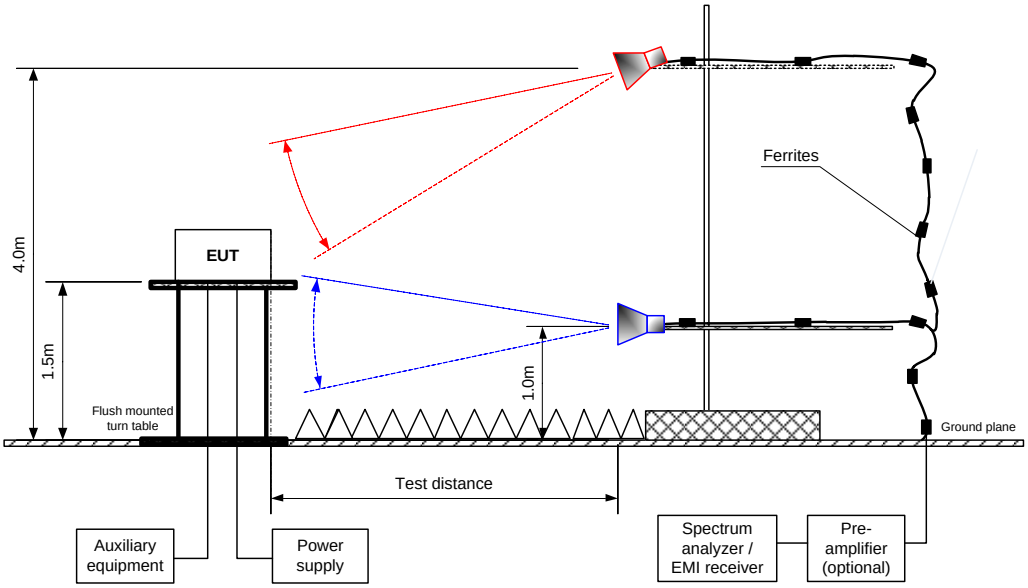


Figure 7.7.2 Setup for spurious emission field strength measurements in 30 – 1000 MHz



Test specification:	**Section 15.247(d), Radiated spurious emissions**		
Test procedure:	ANSI C63.10 section 11.12.1		
Test mode:	Compliance	**Verdict:**	PASS
Date(s):	07-Jan-20		
Temperature: 24 ºC	**Relative Humidity:** 44 %	**Air Pressure:** 1018 hPa	**Power:** 110 VAC, 50 Hz
Remarks:			

Figure 7.7.3 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):	07-Jan-20		
Temperature: 24 ºC	**Relative Humidity:** 44 %	**Air Pressure:** 1018 hPa	**Power:** 110 VAC, 50 Hz
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
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 902.5 MHz									
1804.950	38.09	Vertical	2.06	131	107.98	69.89	20.0	49.89	Pass
Mid carrier frequency 915.0 MHz									
1829.950	40.70	Vertical	2.31	337	107.09	66.39	20.0	46.39	Pass
High carrier frequency 927.5 MHz									
1855.100	41.96	Vertical	2.57	315	105.79	63.83	20.0	43.83	Pass

*****- 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):	07-Jan-20		
Temperature: 24 ºC	**Relative Humidity:** 44 %	**Air Pressure:** 1018 hPa	**Power:** 110 VAC, 50 Hz
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
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 902.5 MHz											
All emissions are more than 20 dB below the limit											Pass
Mid carrier frequency 915.0 MHz											
All emissions are more than 20 dB below the limit											Pass
High carrier frequency 927.5 MHz											
All emissions are more than 20 dB below the limit											Pass

*****- EUT front panel refers to 0 degrees position of turntable.
******- Margin = Measured field strength - 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):	07-Jan-20		
Temperature: 24 ºC	**Relative Humidity:** 44 %	**Air Pressure:** 1018 hPa	**Power:** 110 VAC, 50 Hz
Remarks:			

Table 7.7.4 Field strength of spurious emissions below 1 GHz within restricted bands

ASSIGNED FREQUENCY:	902.0 MHz
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, mid, high carrier frequencies (were measured worst cases from all EUT positions and carrier frequencies)								
73.917	31.26	26.11	40.0	-13.89	Vertical	1.73	14	Pass
109.989	33.29	31.10	43.5	-12.40	Vertical	1.01	70	
130.001	37.89	35.78	43.5	-7.72	Vertical	1.00	250	
150.007	44.31	40.85	43.5	-2.65	Vertical	1.04	10	
163.487	45.20	40.56	43.5	-2.94	Vertical	1.03	14	
170.062	44.75	39.53	43.5	-3.97	Vertical	1.01	10	
250.021	40.07	37.17	46.0	-8.83	Horizontal	1.04	325	
329.999	37.23	35.73	46.0	-10.27	Horizontal	1.02	297	
610.023	38.58	33.99	46.0	-12.01	Vertical	1.31	213	

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

Table 7.7.5 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

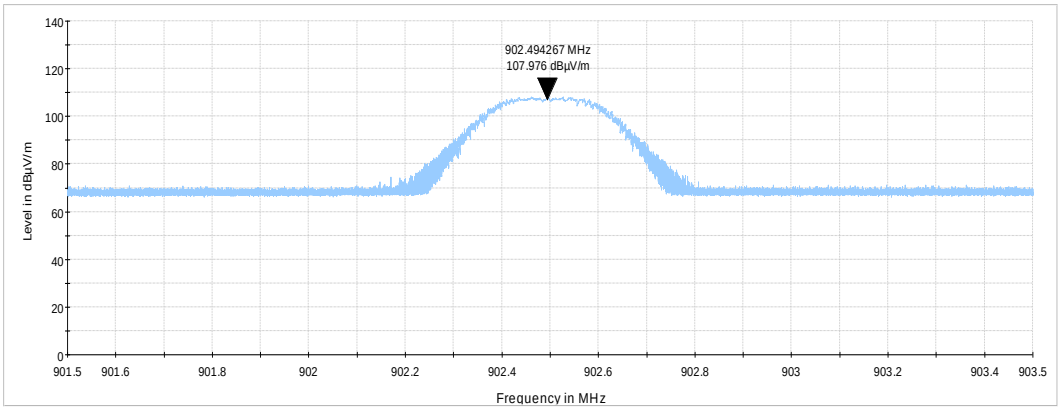
HL 0446	HL 3903	HL 4360	HL 4933	HL 5288	HL 5372	HL 5665	

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):	07-Jan-20		
Temperature: 24 ºC	**Relative Humidity:** 44 %	**Air Pressure:** 1018 hPa	**Power:** 110 VAC, 50 Hz
Remarks:			

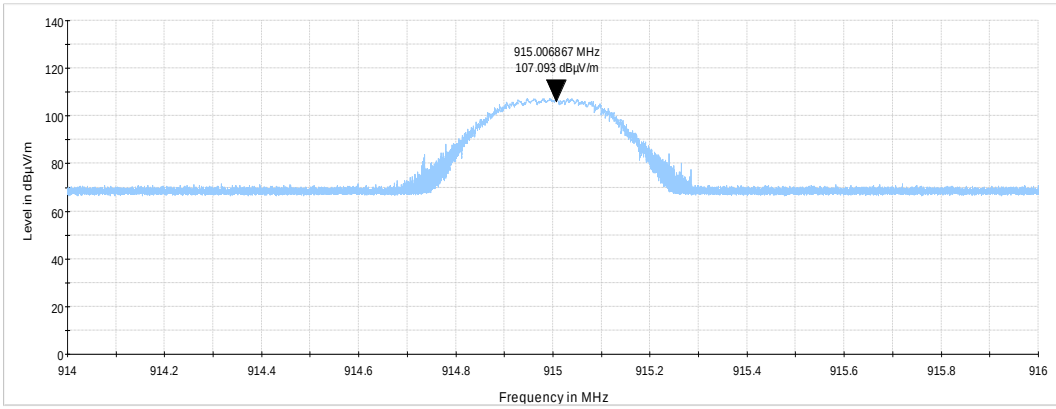
Plot 7.7.1 Radiated emission measurements at the low carrier frequency

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

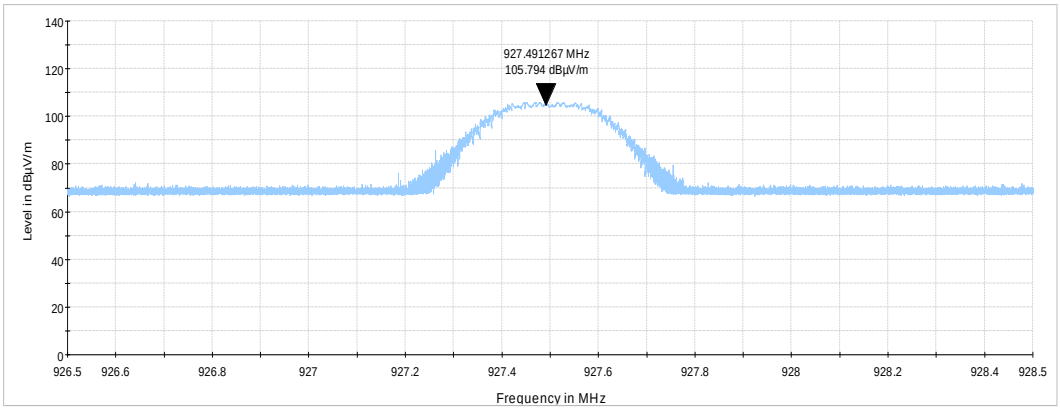
TEST SITE: Semi anechoic chamber
TEST DISTANCE: 3 m
ANTENNA POLARIZATION: Vertical and horizontal



Test specification:	**Section 15.247(d), Radiated spurious emissions**		
Test procedure:	ANSI C63.10 section 11.12.1		
Test mode:	Compliance	**Verdict:**	PASS
Date(s):	07-Jan-20		
Temperature: 24 ºC	**Relative Humidity:** 44 %	**Air Pressure:** 1018 hPa	**Power:** 110 VAC, 50 Hz
Remarks:			

Plot 7.7.3 Radiated emission measurements at the high carrier frequency

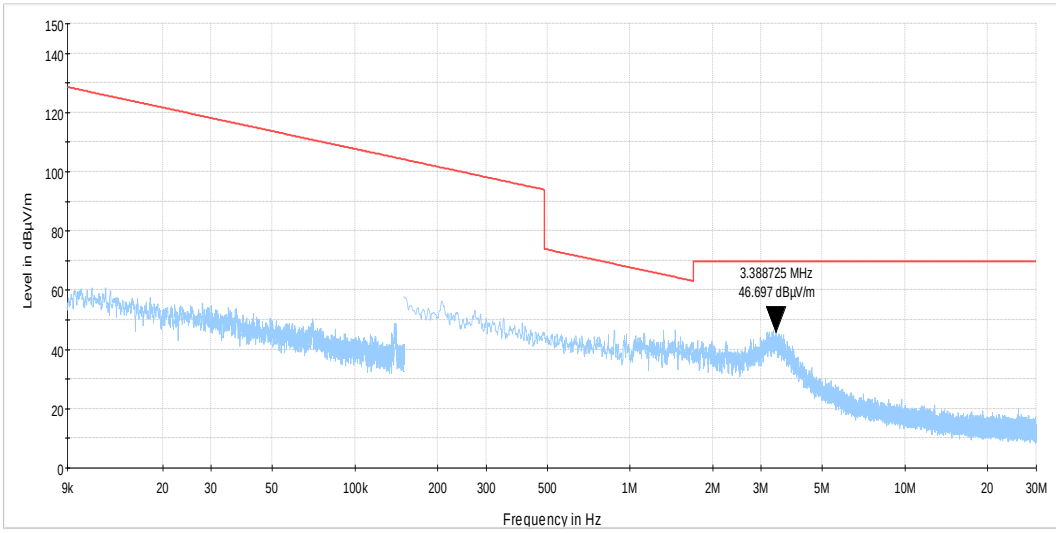
TEST SITE: Semi anechoic chamber
TEST DISTANCE: 3 m
ANTENNA POLARIZATION: Vertical and horizontal



Test specification:	**Section 15.247(d), Radiated spurious emissions**		
Test procedure:	ANSI C63.10 section 11.12.1		
Test mode:	Compliance	**Verdict:**	PASS
Date(s):	07-Jan-20		
Temperature: 24 ºC	**Relative Humidity:** 44 %	**Air Pressure:** 1018 hPa	**Power:** 110 VAC, 50 Hz
Remarks:			

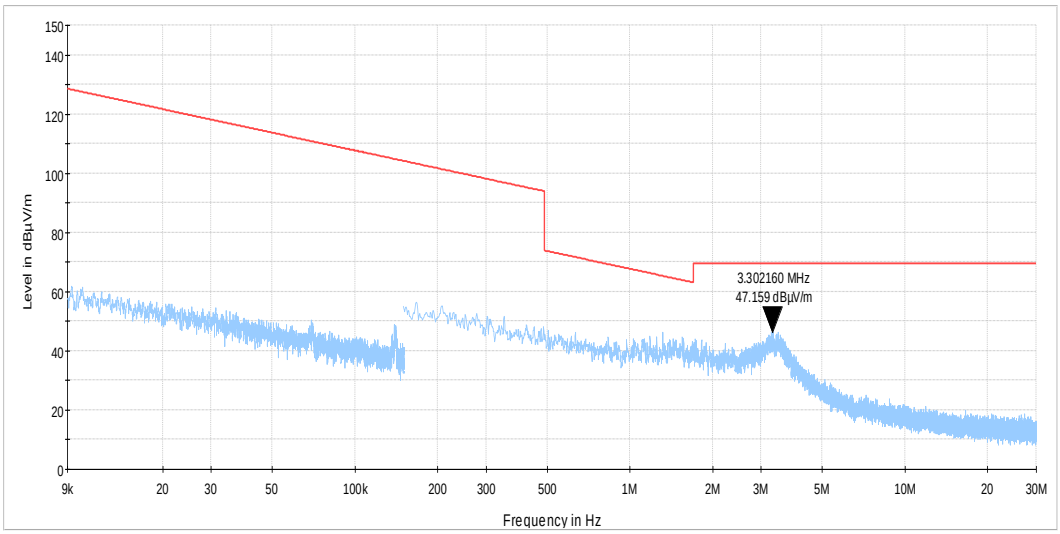
Plot 7.7.4 Radiated emission measurements from 9 kHz to 30 MHz at the low carrier frequency

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 high carrier frequency

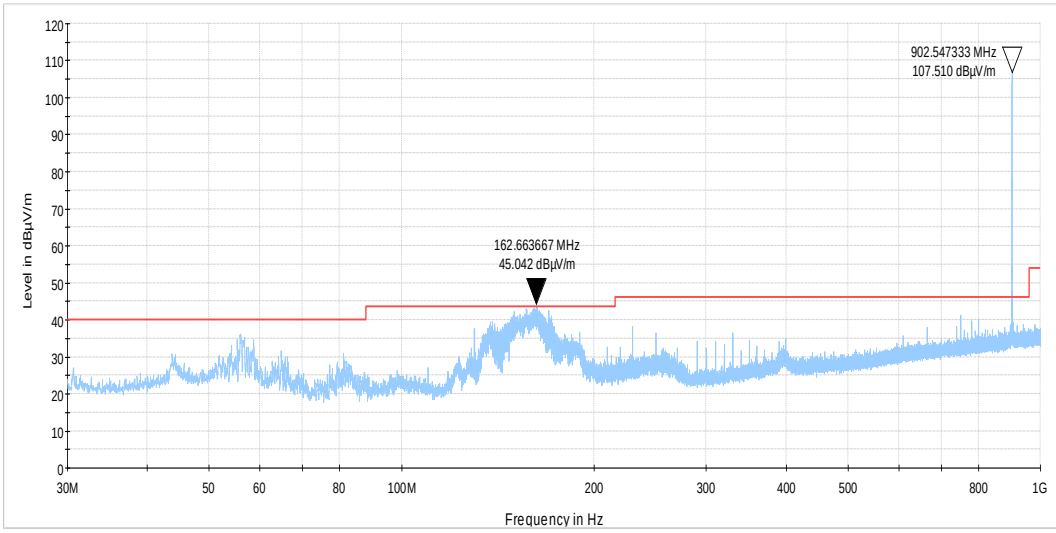
TEST SITE: Semi anechoic chamber
TEST DISTANCE: 3 m
ANTENNA POLARIZATION: Vertical



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):	07-Jan-20		
Temperature: 24 ºC	**Relative Humidity:** 44 %	**Air Pressure:** 1018 hPa	**Power:** 110 VAC, 50 Hz
Remarks:			

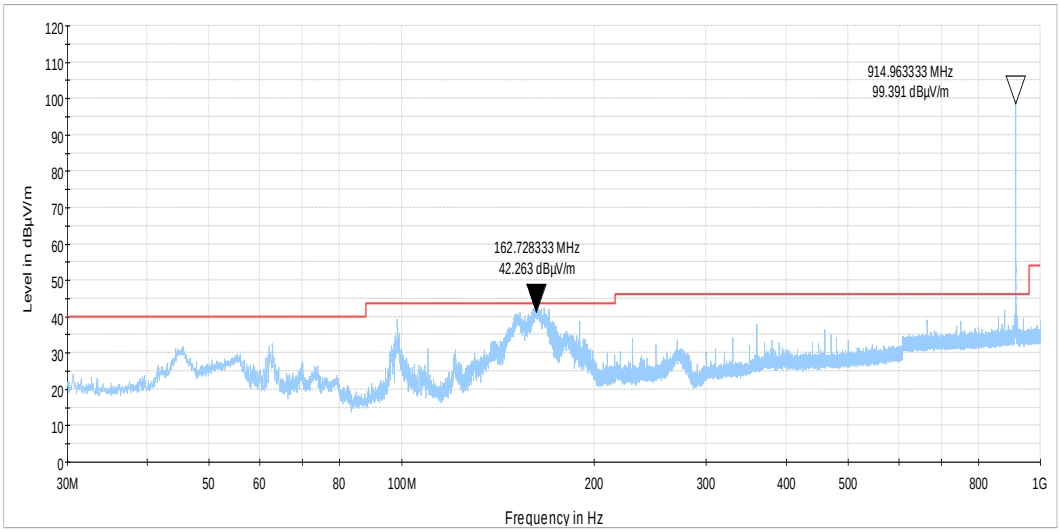
Plot 7.7.6 Radiated emission measurements from 30 to 1000 MHz at the low carrier frequency

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



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

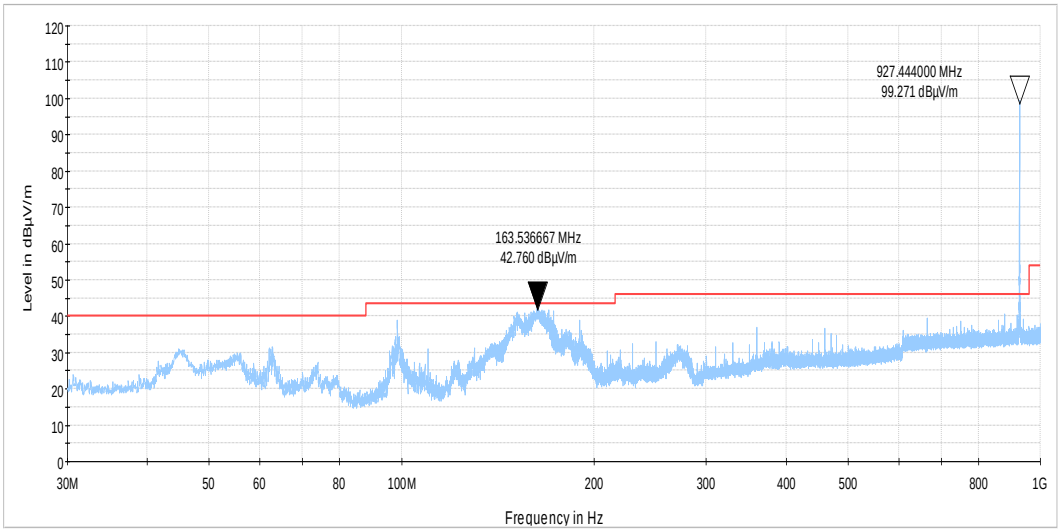
TEST SITE: Semi anechoic chamber
TEST DISTANCE: 3 m
ANTENNA POLARIZATION: Vertical and Horizontal



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):	07-Jan-20		
Temperature: 24 ºC	**Relative Humidity:** 44 %	**Air Pressure:** 1018 hPa	**Power:** 110 VAC, 50 Hz
Remarks:			

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

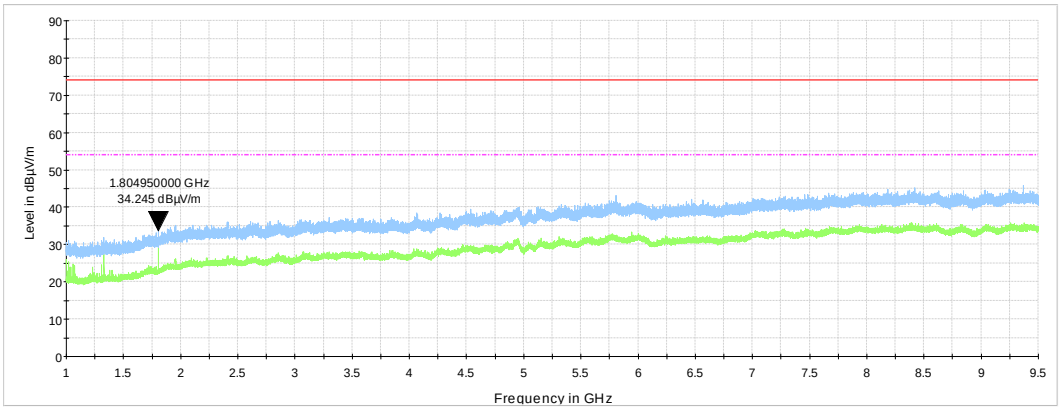
TEST SITE: Semi anechoic chamber
TEST DISTANCE: 3 m
ANTENNA POLARIZATION: Vertical and Horizontal



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):	07-Jan-20		
Temperature: 24 ºC	**Relative Humidity:** 44 %	**Air Pressure:** 1018 hPa	**Power:** 110 VAC, 50 Hz
Remarks:			

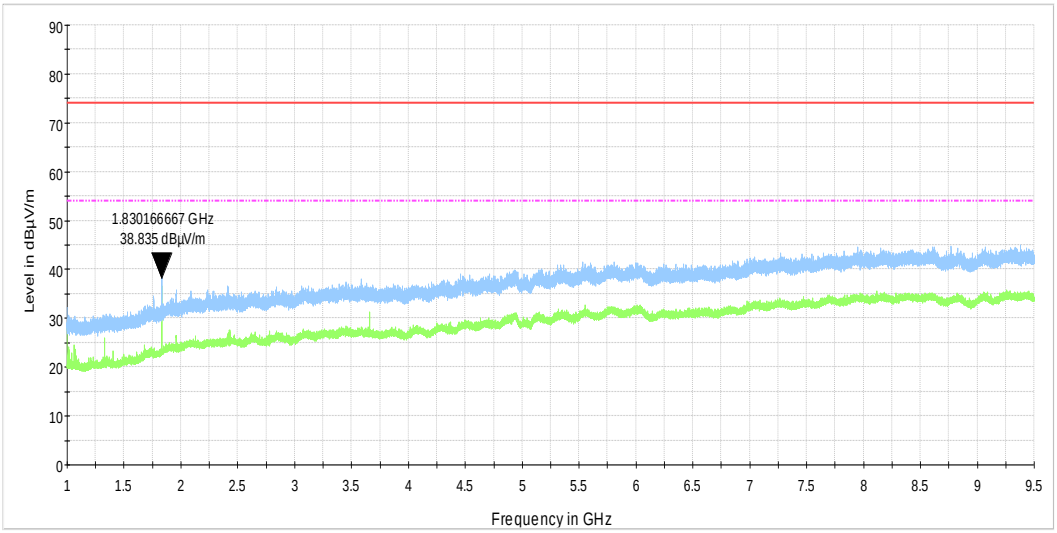
Plot 7.7.9 Radiated emission measurements from 1000 to 9500 MHz at the low carrier frequency

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



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

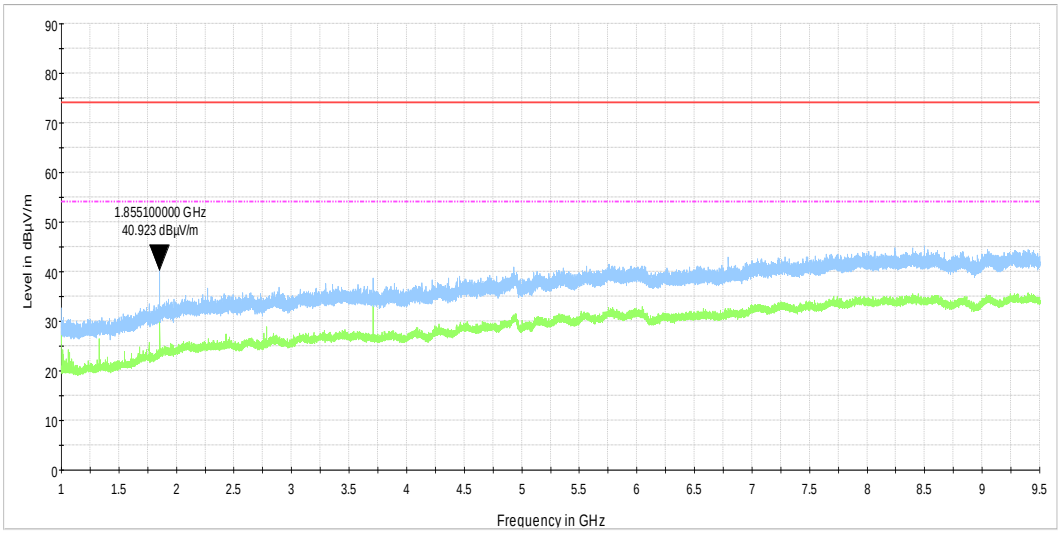
TEST SITE: Semi anechoic chamber
TEST DISTANCE: 3 m
ANTENNA POLARIZATION: Vertical and Horizontal



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):	07-Jan-20		
Temperature: 24 ºC	**Relative Humidity:** 44 %	**Air Pressure:** 1018 hPa	**Power:** 110 VAC, 50 Hz
Remarks:			

Plot 7.7.11 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(c), Emissions at band edges**		
Test procedure:	ANSI C63.10, Sections 12.7.4		
Test mode:	Compliance	**Verdict:**	PASS
Date(s):	07-Jan-20		
Temperature: 24 ºC	**Relative Humidity:** 44 %	**Air Pressure:** 1018 hPa	**Power:** 110 VAC, 50 Hz
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.

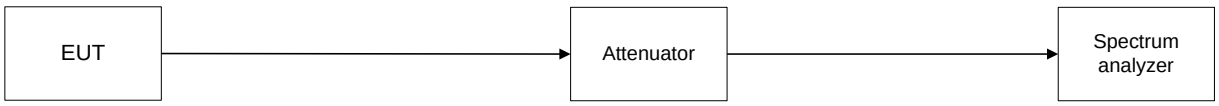
7.8.2.4 The spectrum analyzer was set in max hold mode and allowed trace to stabilize. The highest emission level within the authorized band was measured.

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(c), Emissions at band edges**		
Test procedure:	ANSI C63.10, Sections 12.7.4		
Test mode:	Compliance	**Verdict:**	PASS
Date(s):	07-Jan-20		
Temperature: 24 ºC	**Relative Humidity:** 44 %	**Air Pressure:** 1018 hPa	**Power:** 110 VAC, 50 Hz
Remarks:			

Table 7.8.2 Band edge emission test results

ASSIGNED FREQUENCY RANGE: 902-928 MHz
DETECTOR USED: Peak
MODULATION: LoRa
RESOLUTION BANDWIDTH: 100 kHz
VIDEO BANDWIDTH: 300 kHz

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	-36.98	8.54	45.52	20.0	25.52	Pass
928	-36.93	5.99	42.92		22.92	
Frequency hopping enabled						
902	-36.48	9.82	46.30	20.0	26.30	Pass
928	-38.36	7.16	45.52		25.52	

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	-37.20	8.63	45.83	20.0	25.83	Pass
928	-37.38	6.15	43.53		23.53	
Frequency hopping enabled						
902	-37.84	9.79	47.63	20.0	27.63	Pass
928	-37.87	6.35	44.22		22.22	

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

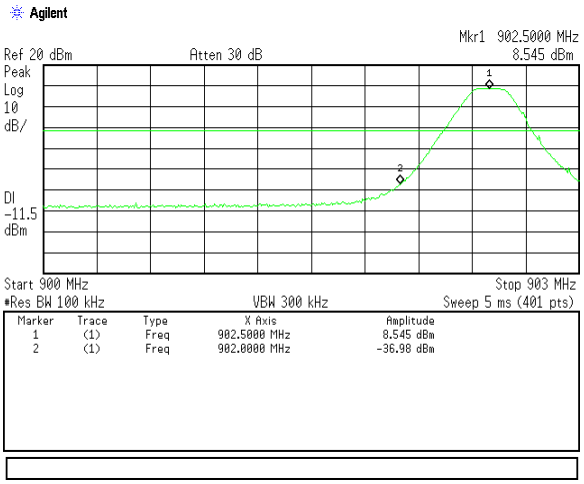
Reference numbers of test equipment used

HL 2909	HL 3901						

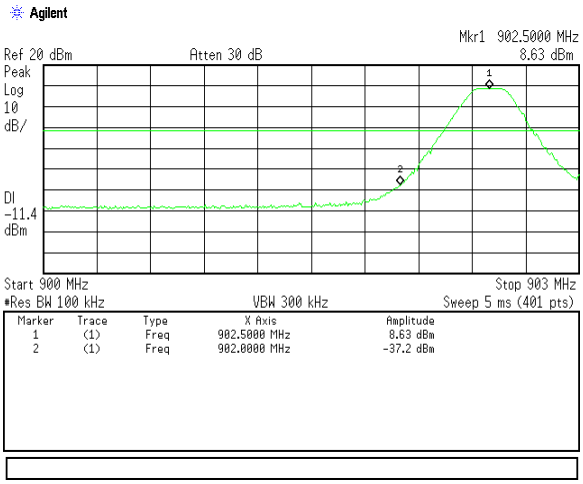
Full description is given in Appendix A.

Test specification:	**Section 15.247(c), Emissions at band edges**		
Test procedure:	ANSI C63.10, Sections 12.7.4		
Test mode:	Compliance	**Verdict:**	PASS
Date(s):	07-Jan-20		
Temperature: 24 ºC	**Relative Humidity:** 44 %	**Air Pressure:** 1018 hPa	**Power:** 110 VAC, 50 Hz
Remarks:			

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

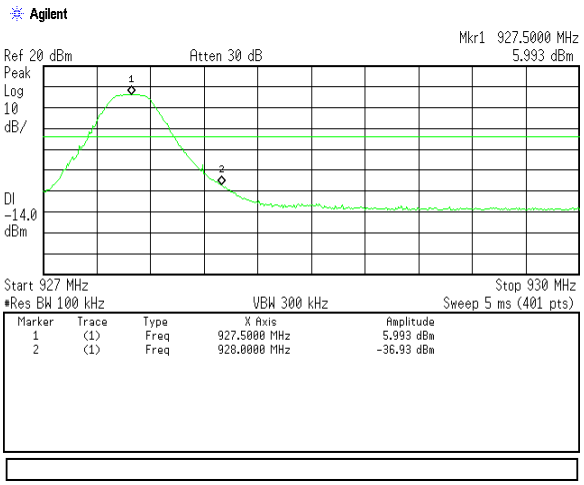


980 bps

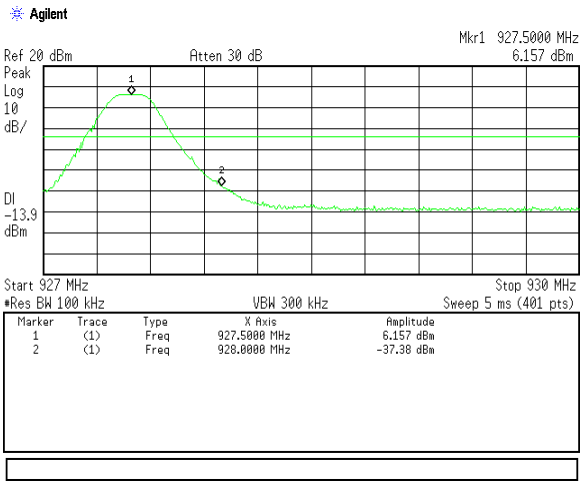


5470 bps

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



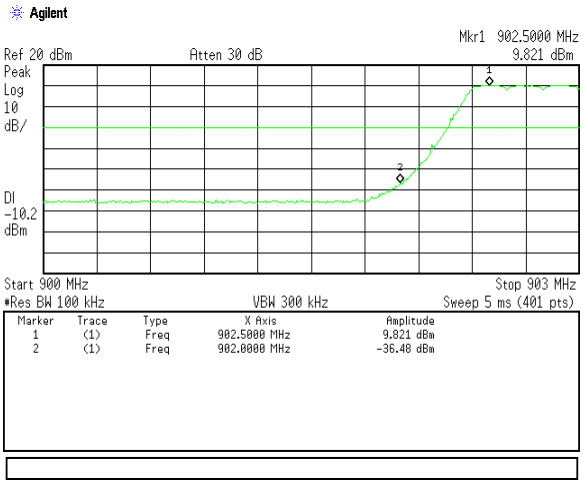
980 bps



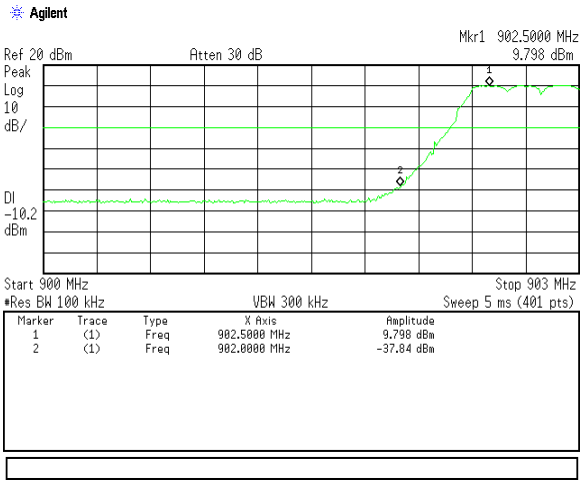
5470 bps

Test specification:	**Section 15.247(c), Emissions at band edges**		
Test procedure:	ANSI C63.10, Sections 12.7.4		
Test mode:	Compliance	**Verdict:**	PASS
Date(s):	07-Jan-20		
Temperature: 24 ºC	**Relative Humidity:** 44 %	**Air Pressure:** 1018 hPa	**Power:** 110 VAC, 50 Hz
Remarks:			

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

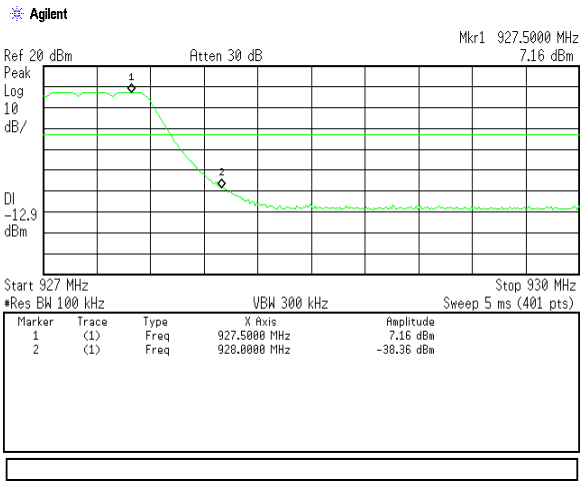


980 bps

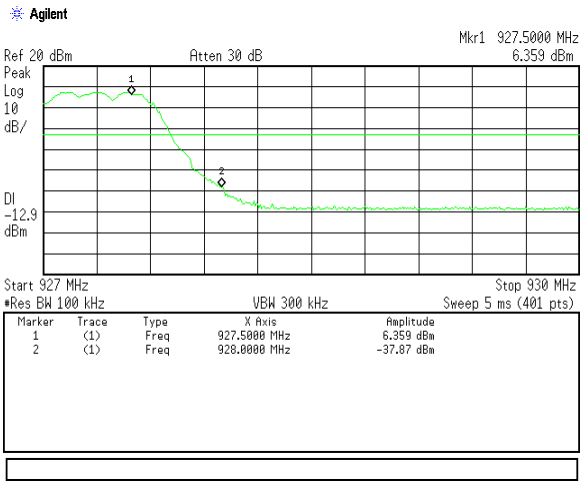


5470 bps

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



980 bps



5470 bps

Test specification:	**Section 15.247(c), Conducted spurious emissions**		
Test procedure:	ANSI C63.10, Sections 12.7.4		
Test mode:	Compliance	**Verdict:**	PASS
Date(s):	08-Jan-20		
Temperature: 24.9 ºC	**Relative Humidity:** 32 %	**Air Pressure:** 1015 hPa	**Power:** 110 VAC, 50 Hz
Remarks:			

7.9 Spurious emissions at RF antenna connector

7.9.1 General

This test was performed to measure spurious emissions at RF antenna connector. Specification test limits are given in Table 7.9.1. The test results are provided in Table 7.9.2 and associated plots.

Table 7.9.1 Spurious emission limits

Frequency*, MHz	Attenuation below carrier*, dBc
0.009 – 10th harmonic	20.0 (30.0)

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

7.9.2 Test procedure

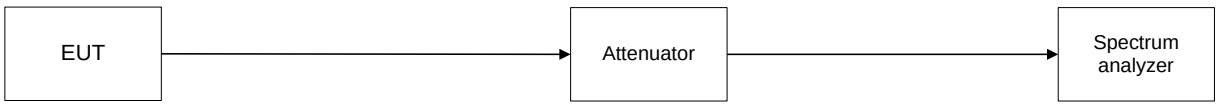
7.9.2.1 The EUT was set up as shown in Figure 7.9.1, energized and its proper operation was checked.

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

7.9.2.3 The highest emission level within the authorized band was measured.

7.9.2.4 The spurious emission was measured with spectrum analyzer as provided in Table 7.9.2 and associated plots and referenced to the highest emission level measured within the authorized band.

Figure 7.9.1 Spurious emission test setup



Test specification:	**Section 15.247(c), Conducted spurious emissions**		
Test procedure:	ANSI C63.10, Sections 12.7.4		
Test mode:	Compliance	**Verdict:**	PASS
Date(s):	08-Jan-20		
Temperature: 24.9 ºC	**Relative Humidity:** 32 %	**Air Pressure:** 1015 hPa	**Power:** 110 VAC, 50 Hz
Remarks:			

Table 7.9.2 Spurious emission test results

ASSIGNED FREQUENCY RANGE:	902-928 MHz
INVESTIGATED FREQUENCY RANGE:	0.009 -9300 MHz
DETECTOR USED:	Peak
RESOLUTION BANDWIDTH:	100 kHz
VIDEO BANDWIDTH:	300 kHz
MODULATION:	LoRa
TRANSMITTER OUTPUT POWER SETTINGS:	Maximum

Frequency, MHz	Spurious emission, dBm	Emission at carrier, dBm	Attenuation below carrier, dBc	Limit, dBc	Margin, dB*	Verdict
All emissions are more than 20 dB below the limit						Pass

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

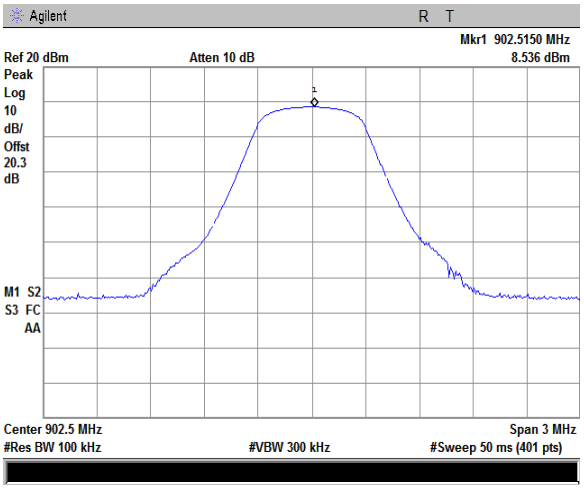
Reference numbers of test equipment used

HL 2909	HL 5621	HL 3384	HL	HL	HL	HL	HL

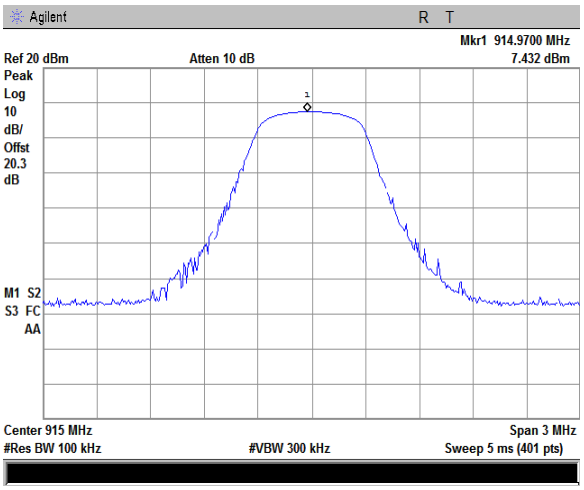
Full description is given in Appendix A.

Test specification:	**Section 15.247(c), Conducted spurious emissions**		
Test procedure:	ANSI C63.10, Sections 12.7.4		
Test mode:	Compliance	**Verdict:**	PASS
Date(s):	08-Jan-20		
Temperature: 24.9 ºC	**Relative Humidity:** 32 %	**Air Pressure:** 1015 hPa	**Power:** 110 VAC, 50 Hz
Remarks:			

Plot 7.9.1 The highest emission level within the assigned band at low carrier frequency

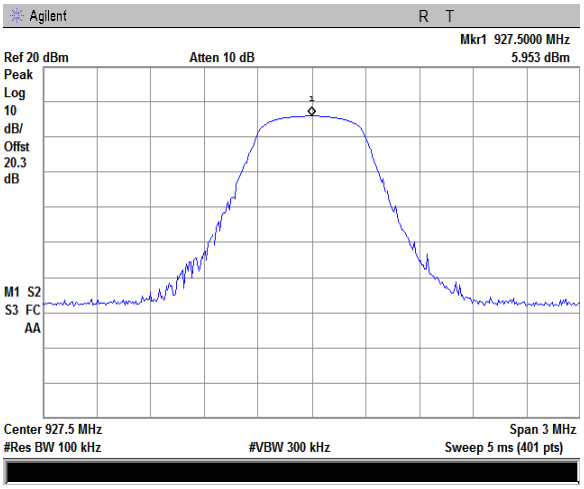


Plot 7.9.2 The highest emission level within the assigned band at mid carrier frequency

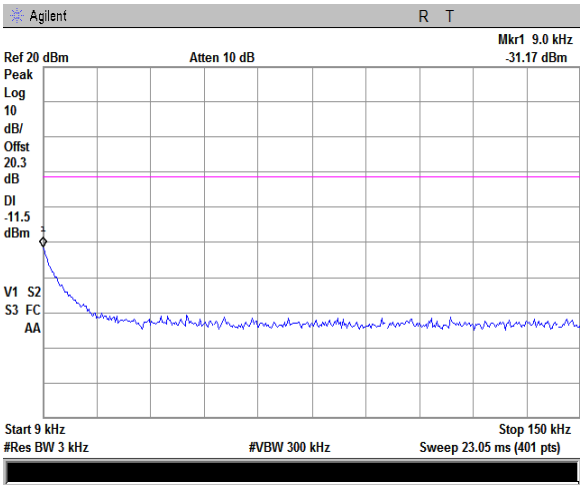


Test specification:	**Section 15.247(c), Conducted spurious emissions**		
Test procedure:	ANSI C63.10, Sections 12.7.4		
Test mode:	Compliance	**Verdict:**	PASS
Date(s):	08-Jan-20		
Temperature: 24.9 ºC	**Relative Humidity:** 32 %	**Air Pressure:** 1015 hPa	**Power:** 110 VAC, 50 Hz
Remarks:			

Plot 7.9.3 The highest emission level within the assigned band at high carrier frequency

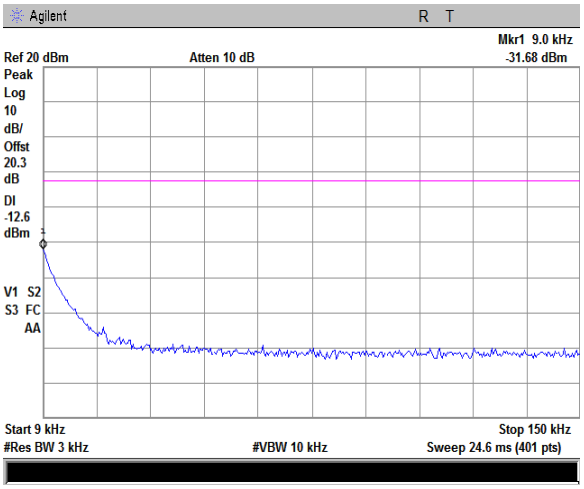


Plot 7.9.4 Spurious emission measurements in 9 - 150 kHz range at low carrier frequency

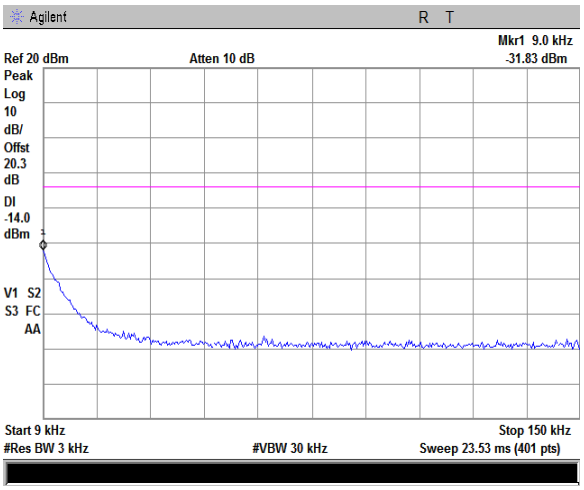


Test specification:	**Section 15.247(c), Conducted spurious emissions**		
Test procedure:	ANSI C63.10, Sections 12.7.4		
Test mode:	Compliance	**Verdict:**	PASS
Date(s):	08-Jan-20		
Temperature: 24.9 ºC	**Relative Humidity:** 32 %	**Air Pressure:** 1015 hPa	**Power:** 110 VAC, 50 Hz
Remarks:			

Plot 7.9.5 Spurious emission measurements in 9 - 150 kHz range at mid carrier frequency

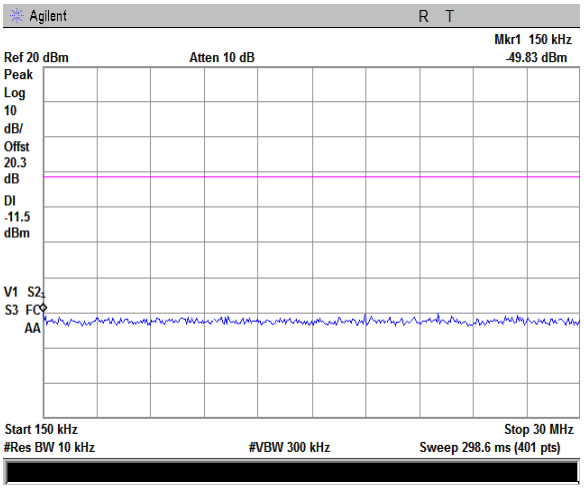


Plot 7.9.6 Spurious emission measurements in 9 - 150 kHz range at high carrier frequency

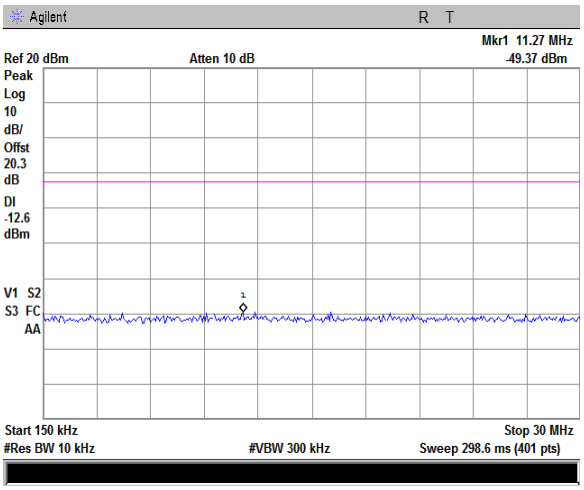


Test specification:	**Section 15.247(c), Conducted spurious emissions**		
Test procedure:	ANSI C63.10, Sections 12.7.4		
Test mode:	Compliance	**Verdict:**	PASS
Date(s):	08-Jan-20		
Temperature: 24.9 ºC	**Relative Humidity:** 32 %	**Air Pressure:** 1015 hPa	**Power:** 110 VAC, 50 Hz
Remarks:			

Plot 7.9.7 Spurious emission measurements in 0.15 - 30 MHz range at low carrier frequency

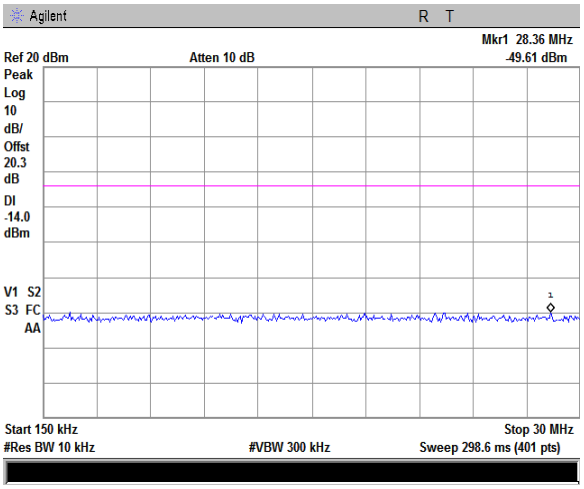


Plot 7.9.8 Spurious emission measurements in 0.15 - 30 MHz range at mid carrier frequency

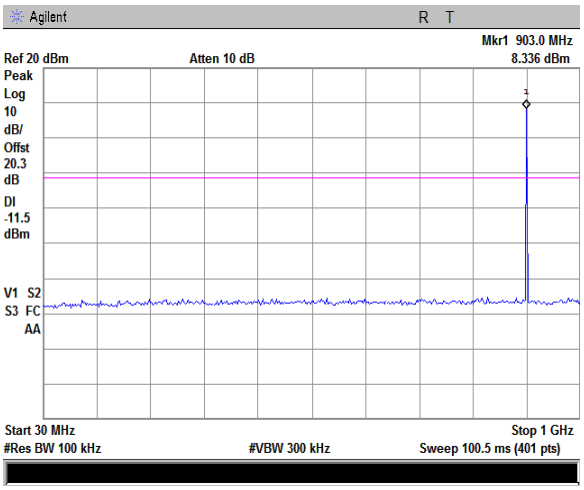


Test specification:	**Section 15.247(c), Conducted spurious emissions**		
Test procedure:	ANSI C63.10, Sections 12.7.4		
Test mode:	Compliance	**Verdict:**	PASS
Date(s):	08-Jan-20		
Temperature: 24.9 ºC	**Relative Humidity:** 32 %	**Air Pressure:** 1015 hPa	**Power:** 110 VAC, 50 Hz
Remarks:			

Plot 7.9.9 Spurious emission measurements in 0.15 - 30 MHz range at high carrier frequency

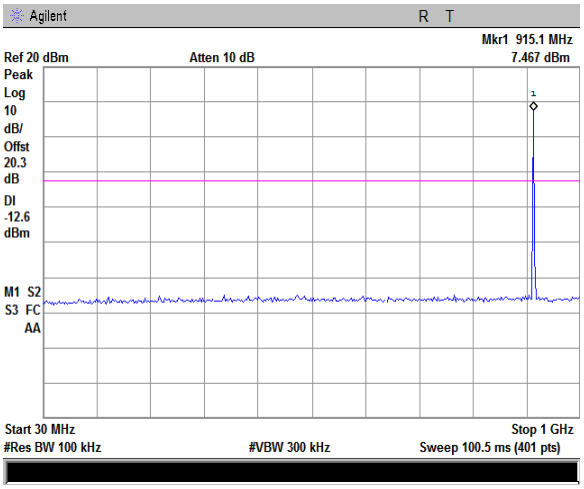


Plot 7.9.10 Spurious emission measurements in 30 - 1000 MHz range at low carrier frequency

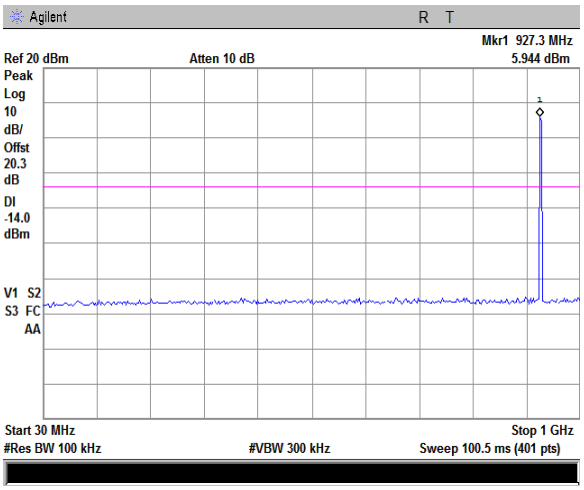


Test specification:	**Section 15.247(c), Conducted spurious emissions**		
Test procedure:	ANSI C63.10, Sections 12.7.4		
Test mode:	Compliance	**Verdict:**	PASS
Date(s):	08-Jan-20		
Temperature: 24.9 ºC	**Relative Humidity:** 32 %	**Air Pressure:** 1015 hPa	**Power:** 110 VAC, 50 Hz
Remarks:			

Plot 7.9.11 Spurious emission measurements in 30 - 1000 MHz range at mid carrier frequency

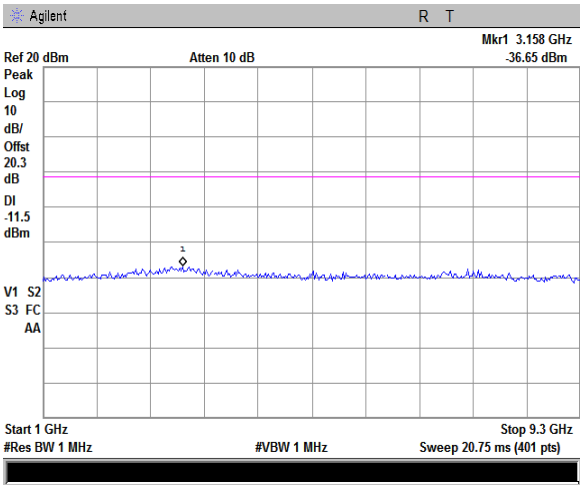


Plot 7.9.12 Spurious emission measurements in 30 - 1000 MHz range at high carrier frequency

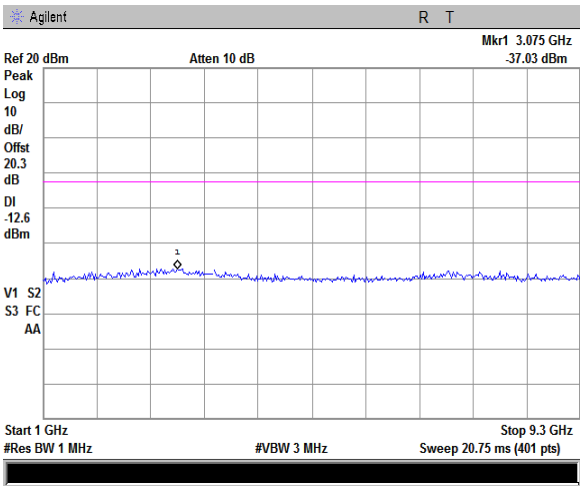


Test specification:	**Section 15.247(c), Conducted spurious emissions**		
Test procedure:	ANSI C63.10, Sections 12.7.4		
Test mode:	Compliance	**Verdict:**	PASS
Date(s):	08-Jan-20		
Temperature: 24.9 ºC	**Relative Humidity:** 32 %	**Air Pressure:** 1015 hPa	**Power:** 110 VAC, 50 Hz
Remarks:			

Plot 7.9.13 Spurious emission measurements in 1000 - 9300 MHz range at low carrier frequency

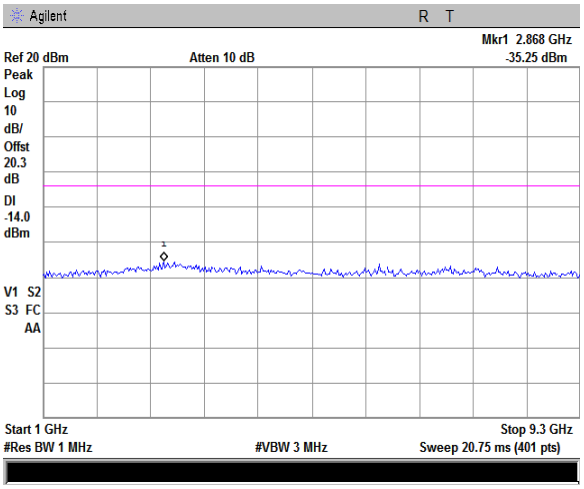


Plot 7.9.14 Spurious emission measurements in 1000 - 9300 MHz range at mid carrier frequency



Test specification:	**Section 15.247(c), Conducted spurious emissions**		
Test procedure:	ANSI C63.10, Sections 12.7.4		
Test mode:	Compliance	**Verdict:**	PASS
Date(s):	08-Jan-20		
Temperature: 24.9 ºC	**Relative Humidity:** 32 %	**Air Pressure:** 1015 hPa	**Power:** 110 VAC, 50 Hz
Remarks:			

Plot 7.9.15 Spurious emission measurements in 1000 - 9300 MHz range at high carrier frequency



Test specification:	**Section 15.207, Conducted emission at AC power port**		
Test procedure:	ANSI C63.10, Sections 6.7		
Test mode:	Compliance	**Verdict:**	PASS
Date(s):	08-Jan-20		
Temperature: 24.9 ºC	**Relative Humidity:** 32 %	**Air Pressure:** 1015 hPa	**Power:** 110 VAC, 50 Hz
Remarks:			

7.10 Conducted emissions

7.10.1 General

This test was performed to measure common mode conducted emissions at the power port. Specification test limits are given in Table 7.10.1. The worst test results (the lowest margins) were recorded in Table 7.10.2 and shown in the associated plots.

Table 7.10.1 Limits for conducted emissions

Frequency, MHz	Class B limit, dB(μV)	
	QP	AVRG
0.15 - 0.5	66 - 56*	56 - 46*
0.5 - 5.0	56	46
5.0 - 30	60	50

* The limit decreases linearly with the logarithm of frequency.

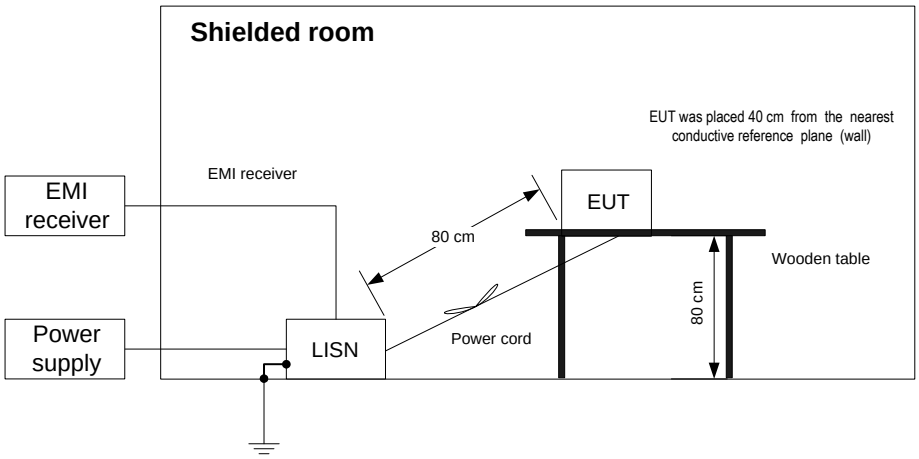
7.10.2 Test procedure

7.10.2.1 The EUT was set up as shown in Figure 7.10.1 and associated photographs, energized and the performance check was conducted.

7.10.2.2 The measurements were performed at power terminals with the LISN, connected to a spectrum analyzer in the frequency range referred to in Table 7.10.2 Unused coaxial connector of the LISN was terminated with 50 Ohm. Quasi-peak and average detectors were used throughout the testing.

7.10.2.3 The position of the device cables was varied to determine maximum emission level.

Figure 7.10.1 Setup for conducted emission measurements, table-top equipment



Test specification:	**Section 15.207, Conducted emission at AC power port**		
Test procedure:	ANSI C63.10, Sections 6.7		
Test mode:	Compliance	**Verdict:**	PASS
Date(s):	08-Jan-20		
Temperature: 24.9 ºC	**Relative Humidity:** 32 %	**Air Pressure:** 1015 hPa	**Power:** 110 VAC, 50 Hz
Remarks:			

Table 7.10.2 Conducted emission test results

LINE:	AC mains
LIMIT:	Class B
EUT OPERATING MODE:	Tx / Rx
EUT OPERATING MODE:	Transmit
EUT SET UP:	TABLE-TOP
TEST SITE:	SHIELDED ROOM
DETECTORS USED:	QUASI-PEAK / AVERAGE
FREQUENCY RANGE:	150 kHz - 30 MHz

35117_CE_FCC_AC_L1
Margin: 20 dB

	Frequency [MHz]	QPeak [dBµV]	Limit 55022bqp [dBµV]	Delta [dB]	Avg [dBµV]	Limit 55022bav [dBµV]	Delta [dB]	Factor DC Limite.. [dB]	Factor LISN HL 2.. [dB]	Factor Cable HL .. [dB]
1	0.57536	45.58	56.00	-10.42	40.56	46.00	-5.44	10.00	0.10	0.05
2	0.720555	40.53	56.00	-15.47	29.07	46.00	-16.93	10.00	0.09	0.06
3	0.810535	44.98	56.00	-11.02	31.87	46.00	-14.13	10.00	0.11	0.06
4	1.50788	38.51	56.00	-17.49	27.43	46.00	-18.57	10.00	0.13	0.06
5	1.94142	44.59	56.00	-11.41	33.08	46.00	-12.92	10.00	0.14	0.06
6	2.381095	46.30	56.00	-9.70	33.14	46.00	-12.86	10.00	0.15	0.07
7	3.06208	39.55	56.00	-16.45	29.52	46.00	-16.48	10.00	0.16	0.07
8	3.939385	42.61	56.00	-13.39	32.03	46.00	-13.97	10.00	0.20	0.08
9	12.749245	40.64	60.00	-19.36	37.03	50.00	-12.97	10.00	0.60	0.14
10	13.481355	44.14	60.00	-15.86	40.72	50.00	-9.28	10.00	0.63	0.15
11	14.15416	44.48	60.00	-15.52	41.21	50.00	-8.79	10.00	0.67	0.15
12	15.25437	39.69	60.00	---	35.73	50.00	-14.27	10.00	0.72	0.16
13	16.229835	38.35	60.00	---	34.71	50.00	-15.29	10.00	0.77	0.17
14	20.442535	34.66	60.00	---	33.41	50.00	-16.59	10.00	0.96	0.20

35117_CE_FCC_AC_L2
Margin: 20 dB

	Frequency [MHz]	QPeak [dBµV]	Limit 55022bqp [dBµV]	Delta [dB]	Avg [dBµV]	Limit 55022bav [dBµV]	Delta [dB]	Factor DC Limite.. [dB]	Factor LISN HL 2.. [dB]	Factor Cable HL .. [dB]
1	0.577405	46.40	56.00	-9.60	41.13	46.00	-4.87	10.00	0.10	0.05
2	0.745095	43.07	56.00	-12.93	31.89	46.00	-14.11	10.00	0.10	0.06
3	0.80031	43.80	56.00	-12.20	31.18	46.00	-14.82	10.00	0.11	0.06
4	1.50379	39.33	56.00	-16.67	28.08	46.00	-17.92	10.00	0.13	0.06
5	1.939375	44.84	56.00	-11.16	33.54	46.00	-12.46	10.00	0.14	0.06
6	2.37496	47.64	56.00	-8.36	33.83	46.00	-12.17	10.00	0.15	0.07
7	3.121385	39.80	56.00	-16.20	31.02	46.00	-14.98	10.00	0.16	0.07
8	3.943475	43.14	56.00	-12.86	32.75	46.00	-13.25	10.00	0.20	0.08
9	12.810595	40.78	60.00	-19.22	37.04	50.00	-12.96	10.00	0.60	0.14
10	13.42205	44.51	60.00	-15.49	41.09	50.00	-8.91	10.00	0.63	0.15
11	14.213465	44.33	60.00	-15.67	41.03	50.00	-8.97	10.00	0.67	0.15
12	15.252325	39.35	60.00	---	35.52	50.00	-14.48	10.00	0.72	0.16
13	20.4364	32.62	60.00	---	31.58	50.00	-18.42	10.00	0.96	0.20
14	21.17669	35.14	60.00	---	34.04	50.00	-15.96	10.00	1.00	0.20

***- Margin = Measured emission - specification limit.**

Reference numbers of test equipment used

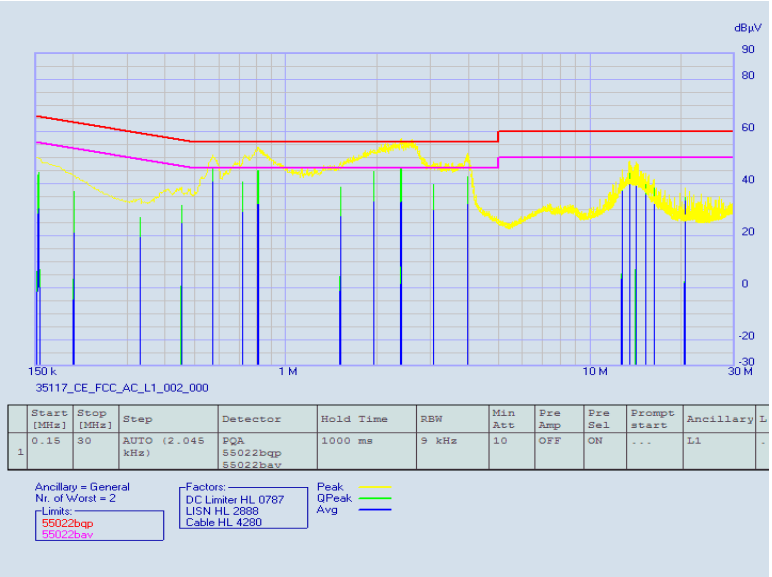
HL 5707	HL 787	HL 4280	HL 2888				

Full description is given in Appendix A.

Test specification:	**Section 15.207, Conducted emission at AC power port**		
Test procedure:	ANSI C63.10, Sections 6.7		
Test mode:	Compliance	**Verdict:**	PASS
Date(s):	08-Jan-20		
Temperature: 24.9 ºC	**Relative Humidity:** 32 %	**Air Pressure:** 1015 hPa	**Power:** 110 VAC, 50 Hz
Remarks:			

Plot 7.10.1 Conducted emission measurements

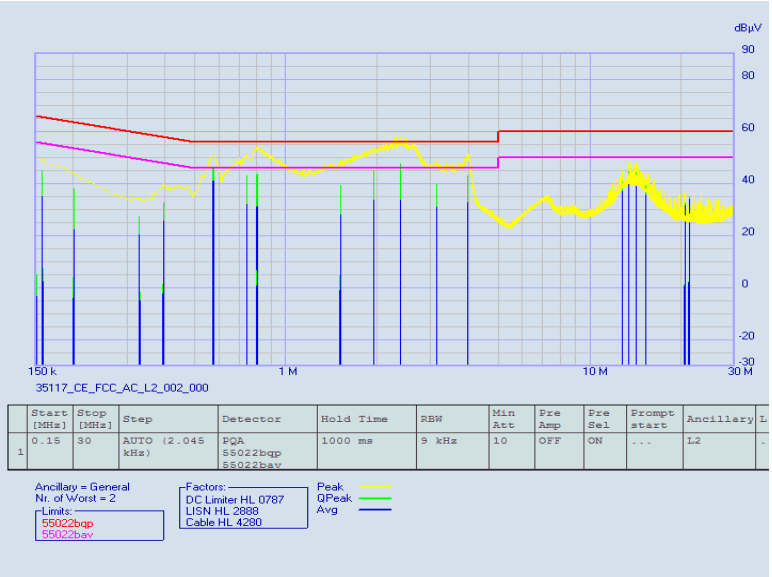
LINE: L1
EUT OPERATING MODE: Transmit
LIMIT: QUASI-PEAK, AVERAGE
DETECTOR: PEAK



Test specification:	**Section 15.207, Conducted emission at AC power port**		
Test procedure:	ANSI C63.10, Sections 6.7		
Test mode:	Compliance	**Verdict:**	PASS
Date(s):	08-Jan-20		
Temperature: 24.9 ºC	**Relative Humidity:** 32 %	**Air Pressure:** 1015 hPa	**Power:** 110 VAC, 50 Hz
Remarks:			

Plot 7.10.2 Conducted emission measurements

LINE: L2
EUT OPERATING MODE: Transmit
LIMIT: QUASI-PEAK, AVERAGE
DETECTOR: PEAK



	Start [MHz]	Stop [MHz]	Step	Detector	Hold Time	RBW	Min Att	Pre Amp	Pre Sel	Prompt start	Ancillary	L
1	0.15	30	AUTO (2.045 kHz)	PQA SS022bqp SS022bav	1000 ms	9 kHz	10	OFF	ON	...	L2	.

Test specification:	**Section 15.203, Antenna requirements**		
Test procedure:	Visual inspection		
Test mode:	Compliance	**Verdict:**	PASS
Date(s):	08-Jan-20		
Temperature: 24.9 ºC	**Relative Humidity:** 32 %	**Air Pressure:** 1015 hPa	**Power:** 110 VAC, 50 Hz
Remarks:			

7.11 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 7.11.1.

Table 7.11.1 Antenna requirements

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

Test specification:	**Section 15.107, Conducted emission at AC power port**		
Test procedure:	ANSI C63.4, Sections 11.5 and 12.1.3		
Test mode:	Compliance	**Verdict:**	PASS
Date(s):	01-Jan-20		
Temperature: 23 ºC	**Relative Humidity:** 49 %	**Air Pressure:** 1018 hPa	**Power:** 110 VAC, 50 Hz
Remarks:			

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

8.1 Conducted emissions

8.1.1 General

This test was performed to measure common mode conducted emissions at the mains power port.
Specification test limits are given in Table 8.1.1. The worst test results (the lowest margins) were recorded in Table 8.1.2 and shown in the associated plots.

Table 8.1.1 Limits for conducted emissions

Frequency, MHz	Class B limit, dB(μV)	
	QP	AVRG
0.15 - 0.5	66 - 56*	56 - 46*
0.5 - 5.0	56	46
5.0 - 30	60	50

* The limit decreases linearly with the logarithm of frequency.

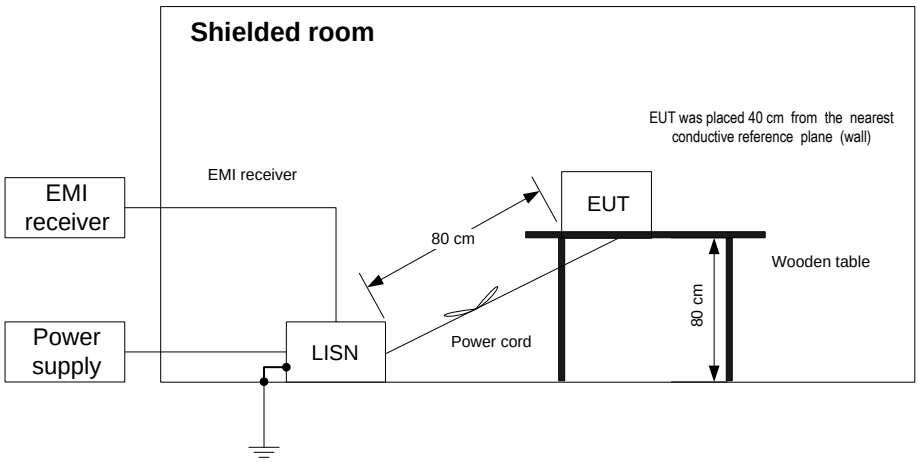
8.1.2 Test procedure

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

8.1.2.2 The measurements were performed at power terminals with the LISN, connected to a spectrum analyzer in the frequency range referred to in Table 8.1.2. Unused coaxial connector of the LISN was terminated with 50 Ohm. Quasi-peak and average detectors were used throughout the testing.

8.1.2.3 The position of the device cables was varied to determine maximum emission level.

Figure 8.1.1 Setup for conducted emission measurements, table-top equipment



Test specification:	**Section 15.107, Conducted emission at AC power port**		
Test procedure:	ANSI C63.4, Sections 11.5 and 12.1.3		
Test mode:	Compliance	**Verdict:**	PASS
Date(s):	01-Jan-20		
Temperature: 23 ºC	**Relative Humidity:** 49 %	**Air Pressure:** 1018 hPa	**Power:** 110 VAC, 50 Hz
Remarks:			

Table 8.1.2 Conducted emission test results

LINE:	AC mains
TEST SITE:	SHIELDED ROOM
DETECTORS USED:	QUASI-PEAK / AVERAGE
FREQUENCY RANGE:	150 kHz - 30 MHz
RESOLUTION BANDWIDTH:	9 kHz

35117_CE_FCC_AC_L1
Margin: 20 dB

	Frequency [MHz]	QPeak [dBµV]	Limit 55022bqp [dBµV]	Delta [dB]	Avg [dBµV]	Limit 55022bav [dBµV]	Delta [dB]	Factor DC Limite.. [dB]	Factor LISN HL 2.. [dB]	Factor Cable HL .. [dB]
1	0.573315	45.62	56.00	-10.38	40.70	46.00	-5.30	10.00	0.10	0.05
2	0.687835	42.03	56.00	-13.97	30.75	46.00	-15.25	10.00	0.09	0.05
3	0.8044	42.81	56.00	-13.19	30.05	46.00	-15.95	10.00	0.11	0.06
4	1.632625	40.45	56.00	-15.55	29.70	46.00	-16.30	10.00	0.13	0.06
5	1.92915	44.65	56.00	-11.35	32.63	46.00	-13.37	10.00	0.14	0.06
6	2.303385	46.60	56.00	-9.40	33.85	46.00	-12.15	10.00	0.15	0.07
7	3.117295	39.08	56.00	-16.92	29.88	46.00	-16.12	10.00	0.16	0.07
8	3.93734	42.48	56.00	-13.52	31.77	46.00	-14.23	10.00	0.20	0.08
9	12.7472	40.33	60.00	-19.67	36.64	50.00	-13.36	10.00	0.60	0.14
10	13.42205	44.64	60.00	-15.36	41.35	50.00	-8.65	10.00	0.63	0.15
11	14.213465	44.45	60.00	-15.55	41.24	50.00	-8.76	10.00	0.67	0.15
12	15.00897	38.79	60.00	---	34.71	50.00	-15.29	10.00	0.71	0.16
13	16.23188	38.16	60.00	---	34.64	50.00	-15.36	10.00	0.77	0.17
14	20.454805	35.24	60.00	---	33.55	50.00	-16.45	10.00	0.96	0.20

35117_CE_FCC_AC_L2
Margin: 20 dB

	Frequency [MHz]	QPeak [dBµV]	Limit 55022bqp [dBµV]	Delta [dB]	Avg [dBµV]	Limit 55022bav [dBµV]	Delta [dB]	Factor DC Limite.. [dB]	Factor LISN HL 2.. [dB]	Factor Cable HL .. [dB]
1	0.156135	45.77	65.67	-19.90	35.20	55.67	---	10.00	0.08	0.05
2	0.57536	46.52	56.00	-9.48	41.48	46.00	-4.52	10.00	0.10	0.05
3	0.67352	40.80	56.00	-15.20	30.95	46.00	-15.05	10.00	0.09	0.05
4	0.785995	41.86	56.00	-14.14	30.75	46.00	-15.25	10.00	0.11	0.06
5	1.65921	39.95	56.00	-16.05	30.78	46.00	-15.22	10.00	0.13	0.06
6	1.972095	44.25	56.00	-11.75	33.37	46.00	-12.63	10.00	0.14	0.06
7	2.28907	47.46	56.00	-8.54	34.69	46.00	-11.31	10.00	0.15	0.07
8	3.019135	38.59	56.00	-17.41	29.27	46.00	-16.73	10.00	0.16	0.07
9	3.955745	43.26	56.00	-12.74	32.36	46.00	-13.64	10.00	0.20	0.08
10	12.80855	40.46	60.00	-19.54	36.76	50.00	-13.24	10.00	0.60	0.14
11	13.42205	44.40	60.00	-15.60	41.03	50.00	-8.97	10.00	0.63	0.15
12	14.213465	44.20	60.00	-15.80	41.00	50.00	-9.00	10.00	0.67	0.15
13	15.25437	40.06	60.00	-19.94	35.82	50.00	-14.18	10.00	0.72	0.16
14	16.23188	38.06	60.00	---	34.49	50.00	-15.51	10.00	0.77	0.17
15	21.20941	34.21	60.00	---	33.71	50.00	-16.29	10.00	1.00	0.20

***- Margin = Measured emission - specification limit.**

Reference numbers of test equipment used

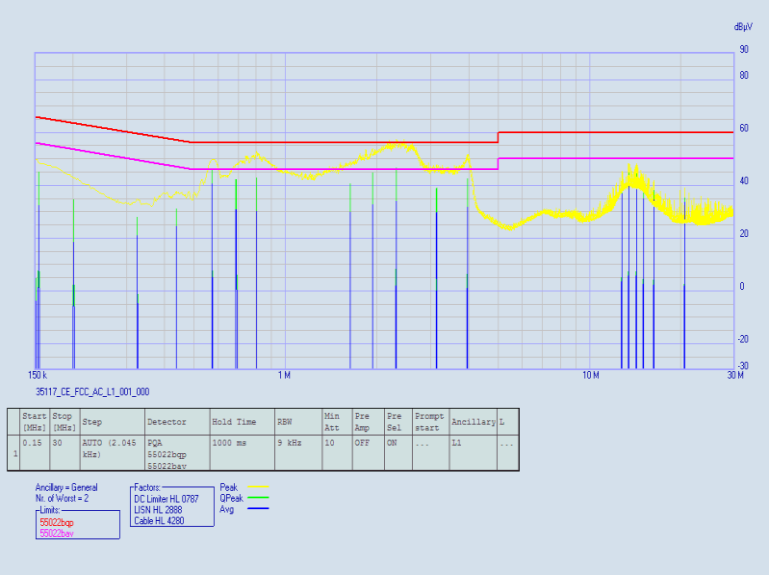
HL 5707	HL 787	HL 4280	HL 2888				

Full description is given in Appendix A.

Test specification:	**Section 15.107, Conducted emission at AC power port**		
Test procedure:	ANSI C63.4, Sections 11.5 and 12.1.3		
Test mode:	Compliance	**Verdict:**	PASS
Date(s):	01-Jan-20		
Temperature: 23 ºC	**Relative Humidity:** 49 %	**Air Pressure:** 1018 hPa	**Power:** 110 VAC, 50 Hz
Remarks:			

Plot 8.1.1 Conducted emission measurements

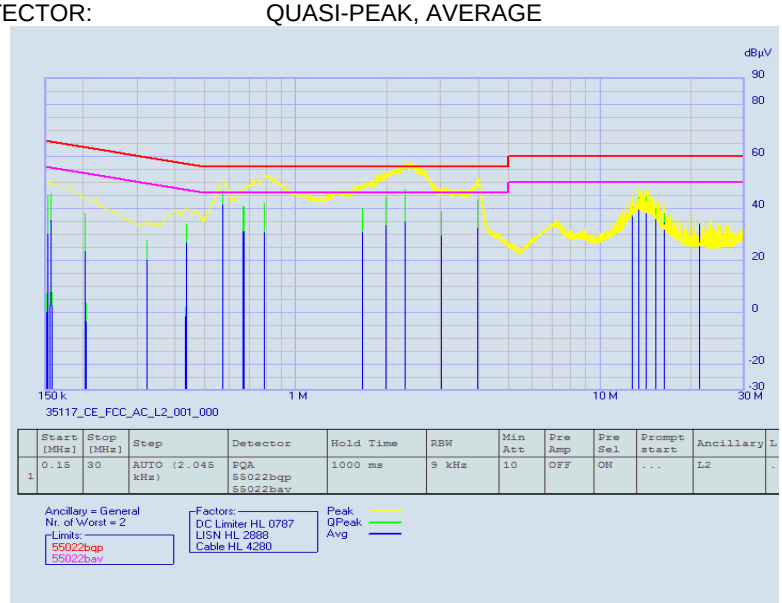
LINE:	L1
LIMIT:	Class B
EUT OPERATING MODE:	Receive / Stand-by
LIMIT:	QUASI-PEAK, AVERAGE
DETECTOR:	QUASI-PEAK, AVERAGE



Test specification:	**Section 15.107, Conducted emission at AC power port**		
Test procedure:	ANSI C63.4, Sections 11.5 and 12.1.3		
Test mode:	Compliance	**Verdict:**	PASS
Date(s):	01-Jan-20		
Temperature: 23 ºC	**Relative Humidity:** 49 %	**Air Pressure:** 1018 hPa	**Power:** 110 VAC, 50 Hz
Remarks:			

Plot 8.1.2 Conducted emission measurements

LINE:	L2
LIMIT:	Class B
EUT OPERATING MODE:	Receive / Stand-by
LIMIT:	QUASI-PEAK, AVERAGE
DETECTOR:	QUASI-PEAK, AVERAGE



	Start [MHz]	Stop [MHz]	Step	Detector	Hold Time	RBW	Min Att	Pre Amp	Pre Sel	Prompt start	Ancillary	L
1	0.15	30	AUTO (2.045 kHz)	PQA SS022bqp SS022bav	1000 ms	9 kHz	10	OFF	ON	...	L2	.

Test specification:	**Section 15.109, Radiated emission**		
Test procedure:	ANSI C63.4, Sections 11.6 and 12.1.4		
Test mode:	Compliance	**Verdict:**	PASS
Date(s):	29-Dec-19		
Temperature: 22 ºC	**Relative Humidity:** 48 %	**Air Pressure:** 1015 hPa	**Power:** 110 VAC, 50 Hz
Remarks:			

8.2 Radiated emission measurements

8.2.1 General

This test was performed to measure radiated emissions from the EUT enclosure. Specification test limits are given in Table 8.2.1.

Table 8.2.1 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.

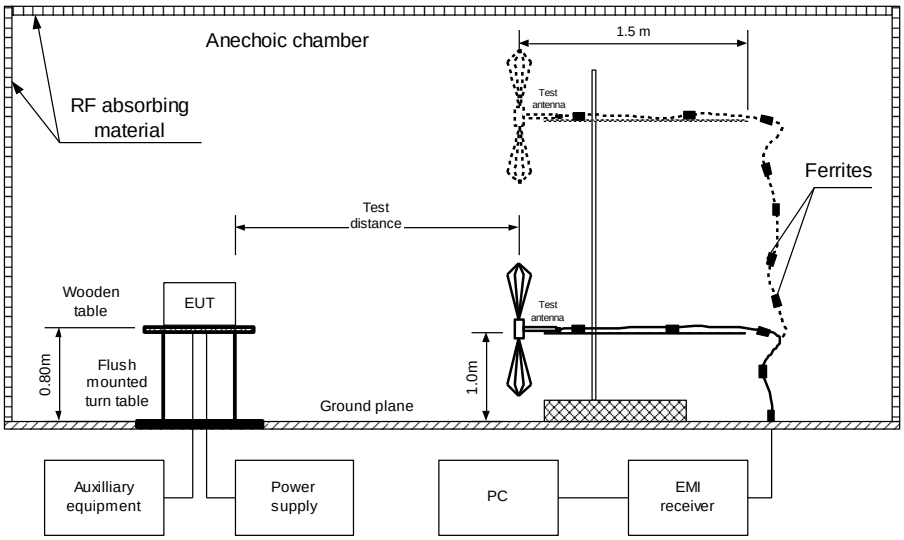
8.2.2 Test procedure for measurements in semi-anechoic chamber

8.2.2.1 The EUT was set up as shown in Figure 8.2.1 and associated photograph/s, energized and the performance check was conducted.

8.2.2.2 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.

8.2.2.3 The worst test results (the lowest margins) were recorded in Table 8.2.2 and shown in the associated plots.

Figure 8.2.1 Setup for radiated emission measurements in anechoic chamber, table-top equipment



Test specification:	**Section 15.109, Radiated emission**		
Test procedure:	ANSI C63.4, Sections 11.6 and 12.1.4		
Test mode:	Compliance	**Verdict:**	PASS
Date(s):	29-Dec-19		
Temperature: 22 ºC	**Relative Humidity:** 48 %	**Air Pressure:** 1015 hPa	**Power:** 110 VAC, 50 Hz
Remarks:			

Table 8.2.2 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*				
38.973	32.81	27.35	40.0	-12.65	Vertical	1.02	312	Pass
44.442	30.96	25.91	40.0	-14.09	Vertical	1.02	125	
56.441	35.06	30.51	40.0	-9.49	Vertical	1.02	63	
66.287	34.41	30.81	40.0	-9.19	Vertical	1.02	260	
74.580	36.31	31.28	40.0	-8.72	Vertical	1.77	201	
138.996	40.13	32.97	43.5	-10.53	Vertical	1.04	299	
150.017	44.14	40.25	43.5	-3.25	Vertical	1.02	10	
159.413	43.11	37.95	43.5	-5.55	Vertical	1.02	0	
190.008	42.59	39.24	43.5	-4.26	Horizontal	1.02	0	
229.994	40.93	38.46	46.0	-7.54	Horizontal	1.41	325	
750.005	43.62	41.86	46.0	-4.14	Horizontal	1.00	226	

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*				
All emissions were found more than 20 dB below the limit										Pass

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

Reference numbers of test equipment used

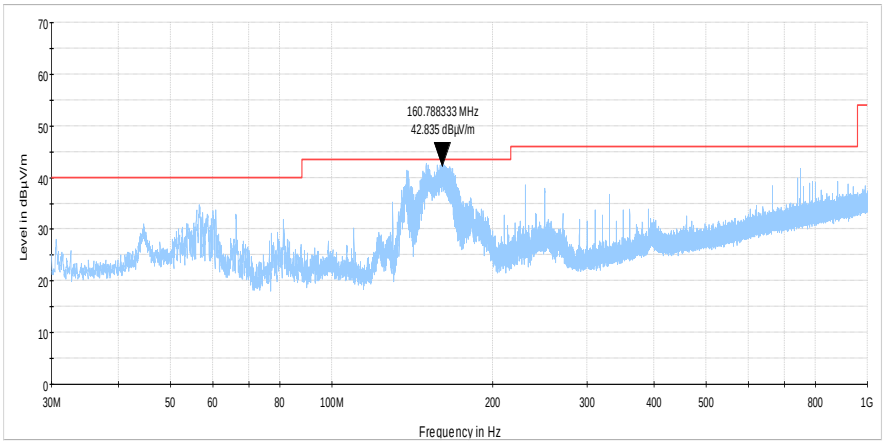
HL 3903	HL 4360	HL 4933	HL 5288	HL 5372	HL 5665		

Full description is given in Appendix A.

Test specification:	**Section 15.109, Radiated emission**		
Test procedure:	ANSI C63.4, Sections 11.6 and 12.1.4		
Test mode:	Compliance	**Verdict:**	PASS
Date(s):	29-Dec-19		
Temperature: 22 ºC	**Relative Humidity:** 48 %	**Air Pressure:** 1015 hPa	**Power:** 110 VAC, 50 Hz
Remarks:			

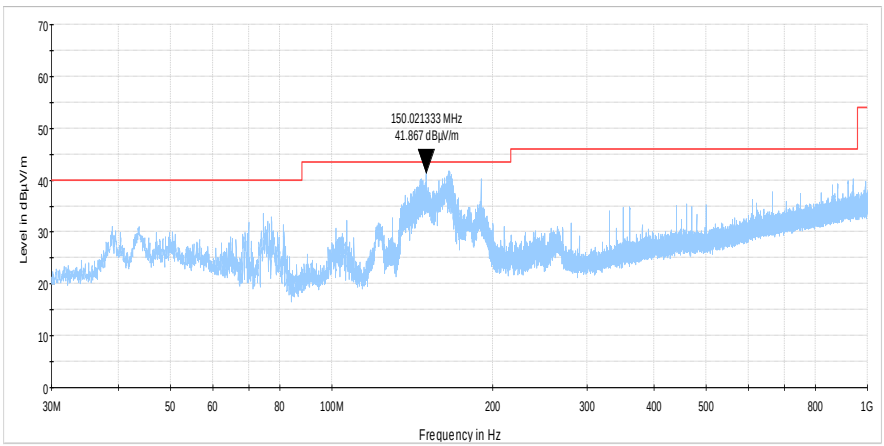
Plot 8.2.1 Radiated emission measurements in 30 – 1000 MHz range, vertical and horizontal antenna polarization

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



Plot 8.2.2 Radiated emission measurements in 30 – 1000 MHz range, vertical and horizontal antenna polarization

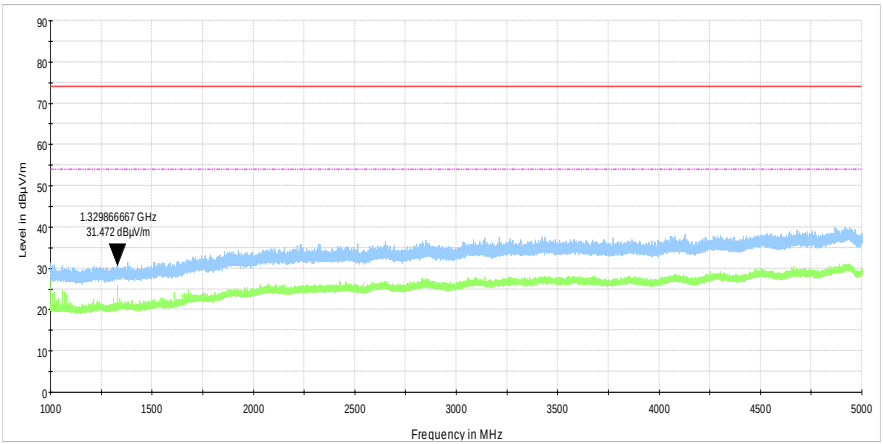
TEST SITE: Semi anechoic chamber
LIMIT: Class B
TEST DISTANCE: 3 m
EUT OPERATING MODE: Receive
EUT POSITION: Y



Test specification:	**Section 15.109, Radiated emission**		
Test procedure:	ANSI C63.4, Sections 11.6 and 12.1.4		
Test mode:	Compliance	**Verdict:**	PASS
Date(s):	29-Dec-19		
Temperature: 22 ºC	**Relative Humidity:** 48 %	**Air Pressure:** 1015 hPa	**Power:** 110 VAC, 50 Hz
Remarks:			

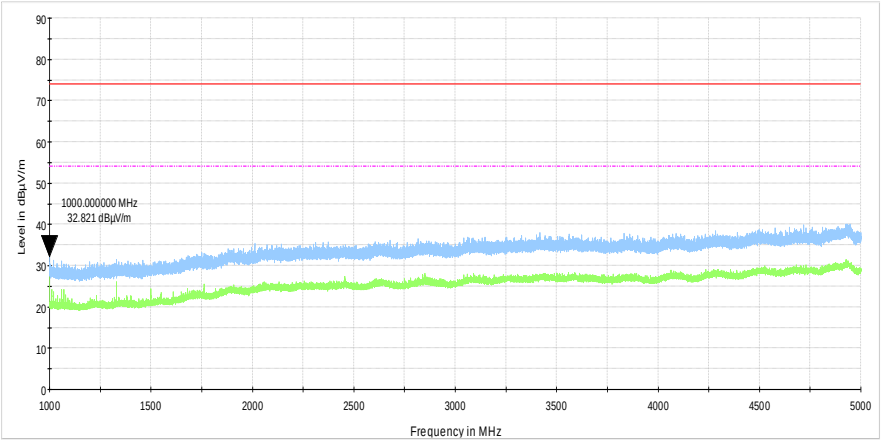
Plot 8.2.3 Radiated emission measurements above 1000 MHz, vertical and horizontal antenna polarization

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



Plot 8.2.4 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
EUT POSITION: Y



9 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-19	24-Feb-20
0787	Transient Limiter 9 kHz-200 MHz	Hewlett Packard	11947A	3107A01877	08-Oct-19	08-Oct-20
2888	LISN Two-line V-Network 50 Ohm / 50 uH + 5 Ohm, 16A, MIL STD 461E, CISPR 16-1	Rolf Heine	NNB-2/16Z	02/10018	19-Mar-19	19-Mar-20
2909	Spectrum analyzer, ESA-E, 100 Hz to 26.5 GHz	Agilent Technologies	E4407B	MY41444762	04-Apr-19	04-Apr-20
3384	Microwave Cable Assembly, 26.5 GHz, 1.0 m, N type/N type	Suhner Sucoflex	104EA	3384	31-Jan-19	31-Jan-20
3771	Attenuator, N-type, 10 dB, DC to 18 GHz, 5 W	Mini-Circuits	BW-N10W5+	NA	11-Aug-19	11-Aug-20
3901	Microwave Cable Assembly, 40.0 GHz, 3.5 m, SMA/SMA	Huber-Suhner	SUCOFLEX 102A	1225/2A	07-Apr-19	07-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
4275	Test Cable , DC-18 GHz, 1.8 m, SMA/M - N/M	Mini-Circuits	CBL-6FT-SMNM+	70050	21-Apr-19	21-Apr-20
4276	Test Cable , DC-18 GHz, 3.05 m, N/M - N/M	Mini-Circuits	APC-10FT-NMNM+	0747A	07-Aug-19	07-Aug-20
4280	Test Cable , DC-18 GHz, 4.6 m, N/M - N/M	Mini-Circuits	APC-15FT-NMNM+	0763A	01-Aug-19	01-Aug-20
4360	EMI Test Receiver, 20 Hz to 40 GHz.	Rohde & Schwarz	ESU40	100322	31-Dec-18	31-Dec-19
4575	EXA Signal Analyzer, 9 kHz - 26.5 GHz	Agilent Technologies	N9010A	MY48030110	18-Apr-19	18-Aug-20
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-19	18-Jun-20
5621	Precision Fixed Attenuator, 50 Ohm, 5 W, 20 dB, DC to 18 GHz	Mini Circuits	BW-N20W5+	NA	06-Oct-19	06-Oct-20
5665	Cable SF118/11N(x2)/6M, 18 GHz, 11N/11N	Huber-Suhner	SF118	501644/118	23-Oct-19	23-Oct-20
5707	EMI receiver	PMM / Narda	PMM 9010F	060WW91101	22-Nov-19	22-Nov-21

10 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	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.

HL 2888 LISN Two-line V-Network 50 Ohm / 50 uH + 5 Ohm, 16A
Rolf Heine, model: NNB-2/16Z, s/n 02/10018, HL 2888

Voltage division factor (insertion loss)

Frequency,	L1, dB	L2, dB	Uncertainty, dB
150	0.09	0.07	±0.09
170	0.08	0.07	±0.09
200	0.08	0.06	±0.09
250	0.09	0.06	±0.09
300	0.09	0.06	±0.09
350	0.09	0.07	±0.09
400	0.09	0.07	±0.09
500	0.09	0.07	±0.09
600	0.09	0.07	±0.09
700	0.10	0.08	±0.09
800	0.10	0.08	±0.09
900	0.11	0.08	±0.09
1000	0.11	0.08	±0.09
1200	0.11	0.09	±0.16
1500	0.12	0.10	±0.16
2000	0.14	0.12	±0.16
2500	0.15	0.12	±0.16
3000	0.16	0.14	±0.16
4000	0.19	0.16	±0.16
5000	0.23	0.19	±0.16
7000	0.30	0.25	±0.16
10000	0.46	0.40	±0.16
15000	0.71	0.62	±0.16
20000	0.94	0.85	±0.16
30000	1.41	1.33	±0.32

11 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.

12 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 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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13 APPENDIX E Specification references

FCC 47CFR part 15:2019	Radio Frequency 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.
ANSI C63.10:2013	American National Standard of Procedures for Compliance Testing of Unlicensed Wireless Devices

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