HERMON LABORATORIES

ELECTRICAL TESTING
0839.01

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TEST REPORT

ACCORDING TO: FCC 47 CFR part 15 subpart C (DTS) and B;
RSS-247 (DTS) Issue 2 and ICES-003 Issue 6

FOR:

AeroScout Ltd.
Wireless sensor tag
Model: T15e
FCC ID:Q3HTAG15E
IC: 5115A-TAG15E

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

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1 Applicant information

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Telephone:	+972-8-936-9393
Fax:	+972-8-936-5977
E-mail:	reuven.amsalem@sbdinc.com
Contact name:	Mr. Reuven Amsalem

2 Equipment under test attributes

Product name:	Wireless sensor tag
Product type:	Transceiver
Model(s):	T15e
Serial number:	150253
Hardware version:	3.02
Software release:	2.1.14
Receipt date	20-Jan-19

3 Manufacturer information

Manufacturer name:	AeroScout Ltd.
Address:	2 Ilan Ramon St. ,Science Park, Ness-Ziona, 7403635, Israel
Telephone:	+972-8-936-9393
Fax:	+972-8-936-5977
E-Mail:	Eli.Aharon@sbdinc.com
Contact name:	Mr. Eli Aharon

4 Test details

Project ID:	32144
Location:	Hermon Laboratories Ltd. P.O. Box 23, Binyamina 3055001, Israel
Test started:	17-Feb-19
Test completed:	23-May-19
Test specification(s):	FCC 47 CFR part 15 subpart C and B; RSS-247 and ICES-003

5 Tests summary

Test	Status
Transmitter characteristics	
FCC section 15.247(a)(2), RSS-247 section 5.2(a), 6 dB bandwidth	Pass
FCC section 15.247(b)3, RSS-247 section 5.4(d) ,Peak output power	Pass
FCC section 15.247(b)5, RSS-102 section 2.5.1, RF exposure	Pass*
FCC section 15.247(d), RSS-247 section 5.5, Radiated spurious emissions	Pass
FCC section 15.247(d), RSS-247 section 5.5, Band edge emissions	Pass
FCC section 15.247(e), RSS-247 5.2(b), Peak power density	Pass
FCC section 15.203, RSS-Gen section 8.3, Antenna requirement	Pass
FCC section 15.207(a), RSS-Gen section 8.2, Conducted emission	Not required
Unintentional emissions	
FCC section 15.107, RSS-Gen section 8.8, Conducted emission at AC power port, Class B	Not required
FCC section 15.109, RSS-Gen section 7.1.2, Radiated emission, Class B	Pass

* - The exhibit to the application of certification is provided.

This test report supersedes the previously issued test report identified by Doc ID: AERRAD_FCC.32144_BLE

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

	Name and Title	Date	Signature
Tested by:	Mr. A. Morozov, test engineer	17-Feb-19 – 23-May-19	
	Mr. S. Samokha, test engineer		
Reviewed by:	Mrs. Y. Rapin, technical writer	12-Jun-19	
Approved by:	Mr. K. Zushchyk, project and customer manager, EMC and radio group	14-Jun-19	

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 tag, model T15e, is a platform for environmental monitoring, which can take measurements of internal sensors of humidity and ambient temperature or external sensors via 3 or less USB type C connectors located at the bottom of the device.

The tag has also data logging capabilities, optional display, up to 4 pushbuttons and wireless connectivity features (802.11b/g/n WIFI and BLE 5.0).

There are dedicated printed antennas on board, one for BLE and one for WIFI. External antennas are not supported for both RFs.

It can be powered by a standard 5V USB wall adapter connected to one of the USB connectors OR by non-rechargeable, replaceable AA alkaline batteries (2 in series).

When external power is connected, the batteries are for backup (not powering the device) which automatically engaged when the external power is disconnected.

The tag also supports an external temperature probe (RTD), contact sensor, voltage sensor (up-to 24V) and a current sensor (4-20mA) which either can be connected to any of the 3 USB connectors.

The cables length for the temperature probe and the contact sensor is up-to 15M, typically 3M and for the 2 other sensors is 3M.

6.2 Ports and lines

Port type	Port description	Conn. from	Conn. to	Qty.	Cable type	Cable length, m	Indoor / outdoor
Signal	Signal	EUT	RTD probe (temperature)	1	Unshielded	3-15 m	Indoor
Signal	Signal	EUT	Sensors (open/close contact)	2	Unshielded	3-15 m	Indoor
Signal	Signal	EUT	Sensors (voltage measure,current measure)	2	Unshielded	3 m	Indoor
Power	DC	EUT	Power supply	1	Unshielded	2.5 m	Indoor

6.3 Support and test equipment

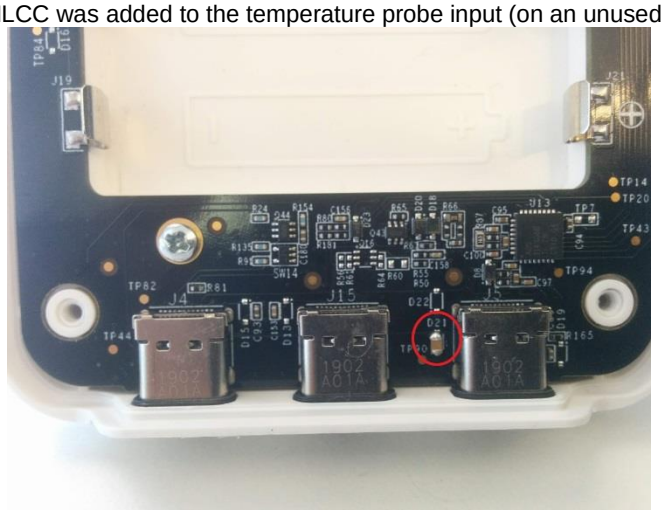
Description	Manufacturer	Model number	Serial number
PC	Lenovo	T420	NA
Gateway	Aeroscout	GW3100	MAC: 662055
Smartphone	IPhone	NA	NA

6.4 Operating frequencies

Source	Frequency, MHz					
Clock	40	-	-	-	-	-
Clock	32	-	-	-	-	-
Tx Rx Bluetooth	2402-2480	-	-	-	-	-
Tx Rx Wi-Fi	2412-2462	-	-	-	-	-

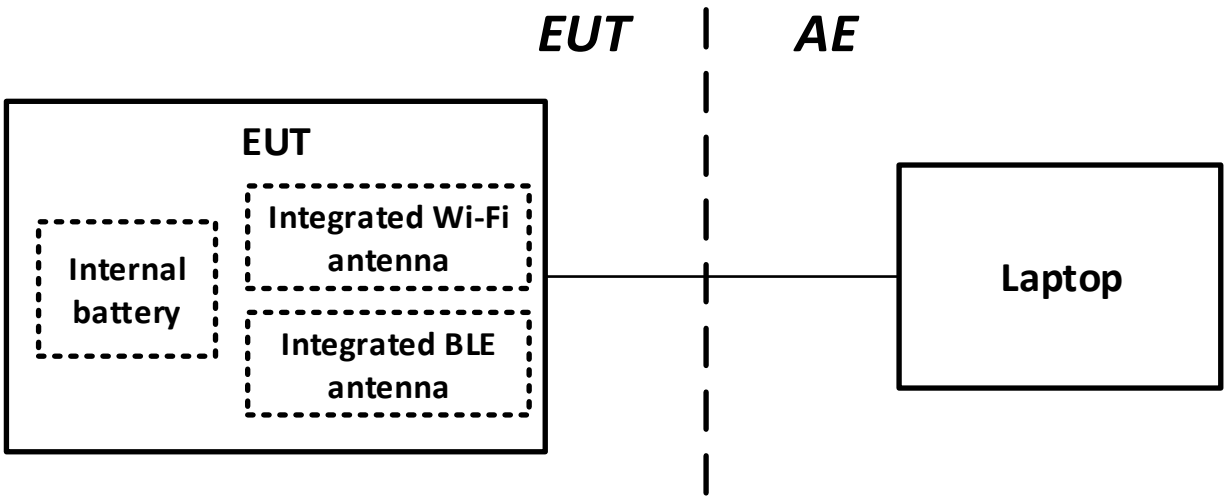
6.5 Changes made in EUT

Capacitor 1nF 0805 MLCC was added to the temperature probe input (on an unused location of D21).



It is manufacturer responsibility to implement the change in the production version of the EUT. In any case the test report applies to the tested item only.

6.6 Test configuration



6.7 Transmitter characteristics

Type of equipment	
V	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
V	mobile	Always at a distance more than 20 cm from all people
	portable	May operate at a distance closer than 20 cm to human body

Assigned frequency range	2400.0 – 2483.5 MHz
Operating frequency range	2402.0 – 2480.0 MHz
RF channel spacing	2 MHz

Maximum rated output power	At transmitter 50 Ω RF output connector (aggregate power of both RF chains)	NA
	EIRP density dBm / MHz (aggregate power of both RF chains) with maximum declared antenna gain	NA

Is transmitter output power variable?		No			
	V	Yes		continuous variable	
			V	stepped variable with stepsize	1.0 dB
			minimum RF power		-40 dBm
			maximum RF power		2.7 dBm

Antenna connection				
unique coupling	standard connector	**V**	Integral	with temporary RF connector
				V without temporary RF connector

Antenna/s technical characteristics			
Type	Manufacturer	Model number	Gain
Printed	N/A	N/A	5.3 dBi
			dBi

Transmitter 99% power bandwidth	Type of modulation			
2 MHz	GFSK	GFSK	-	-
	1Mbps	2Mbps	-	-

Type of multiplexing	TDD
Modulating test signal (baseband)	PRBS
Maximum transmitter duty cycle in normal use	1 %

Transmitter power source			
V	DC	Nominal rated voltage	5 VDC
V	DC	Nominal rated voltage	3V by 2 x 1.5V AA alkaline batteries connected in series

Common power source for transmitter and receiver	V	yes	no

Test specification:	FCC 47 CFR 15.247(a)2 / RSS-247 section 5.2(1), 6 dB bandwidth		
Test procedure:	ANSI C63.10 section 11.8.1		
Test mode:	Compliance	Verdict:	PASS
Date(s):	17-Feb-19 - 21-May-19		
Temperature: 25 ºC	Relative Humidity: 44 %	Air Pressure: 1016 hPa	Power: 3 VDC
Remarks:			

7 Transmitter tests according to FCC 47CFR part 15 subpart C and RSS-210

7.1 Minimum 6 dB bandwidth

7.1.1 General

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

Table 7.1.1 The 6 dB bandwidth limits

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

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

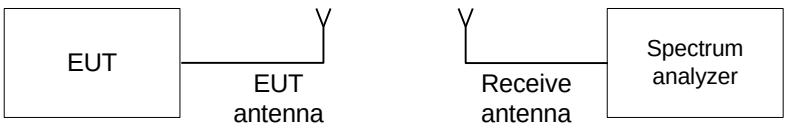
7.1.2 Test procedure

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

7.1.2.2 The EUT was set to transmit modulated carrier.

7.1.2.3 The transmitter minimum 6 dB bandwidth was measured with spectrum analyzer as frequency delta between reference points on modulation envelope and provided in Table 7.1.2 and associated plot.

Figure 7.1.1 The 6 dB bandwidth test setup



Test specification:	**FCC 47 CFR 15.247(a)2 / RSS-247 section 5.2(1), 6 dB bandwidth**		
Test procedure:	ANSI C63.10 section 11.8.1		
Test mode:	Compliance	**Verdict:**	PASS
Date(s):	17-Feb-19 - 21-May-19		
Temperature: 25 ºC	**Relative Humidity:** 44 %	**Air Pressure:** 1016 hPa	**Power:** 3 VDC
Remarks:			

Table 7.1.2 The 6 dB bandwidth test results

ASSIGNED FREQUENCY BAND:	2400.0 -2483.5 MHz
DETECTOR USED:	Peak
SWEEP MODE:	Max hold
SWEEP TIME:	Auto
MODULATION:	GFSK
MODULATION ENVELOPE REFERENCE POINTS:	6.0 dBc
RESOLUTION BANDWIDTH:	100 kHz
VIDEO BANDWIDTH:	>RBW

Carrier frequency, MHz	6 dB bandwidth, kHz	Limit, kHz	Margin, kHz*	Verdict
Bitrate 1 Mbps				
2402.0	684.384	500.0	-184.384	Pass
2440.0	687.455	500.0	-187.455	Pass
2480.0	679.869	500.0	-179.869	Pass
Bitrate 2 Mbps				
2402.0	613.518	500.0	-113.518	Pass
2440.0	629.466	500.0	-129.466	Pass
2480.0	615.737	500.0	-115.737	Pass

* - Margin = Specification limit – Measured Bandwidth

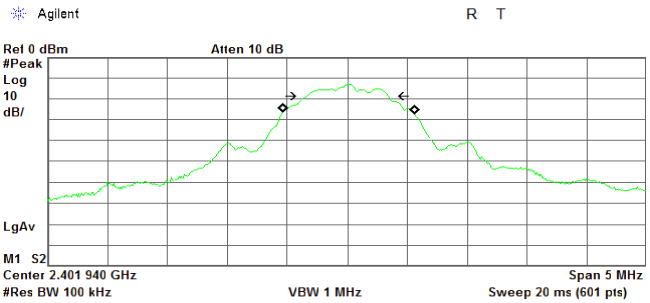
Reference numbers of test equipment used

HL 3818	HL 4135							

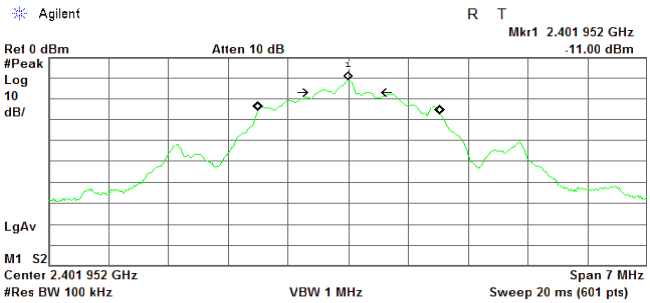
Full description is given in Appendix A.

Test specification:	**FCC 47 CFR 15.247(a)2 / RSS-247 section 5.2(1), 6 dB bandwidth**		
Test procedure:	ANSI C63.10 section 11.8.1		
Test mode:	Compliance	**Verdict:**	PASS
Date(s):	17-Feb-19 - 21-May-19		
Temperature: 25 ºC	**Relative Humidity:** 44 %	**Air Pressure:** 1016 hPa	**Power:** 3 VDC
Remarks:			

Plot 7.1.1 The 6 dB bandwidth test result at low frequency

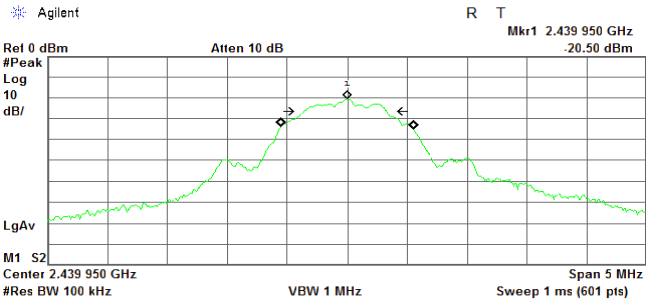


1 Mbps

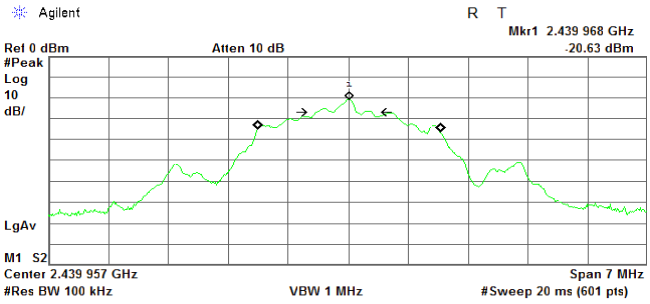


2 Mbps

Plot 7.1.2 The 6 dB bandwidth test result at mid frequency

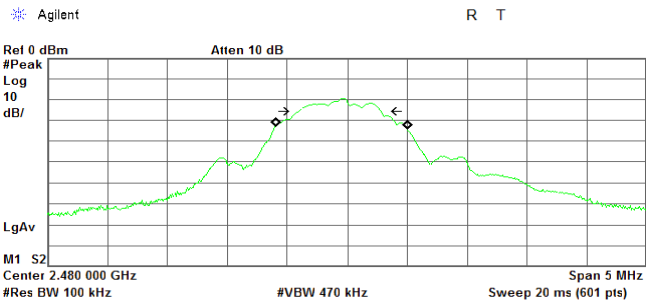


1 Mbps

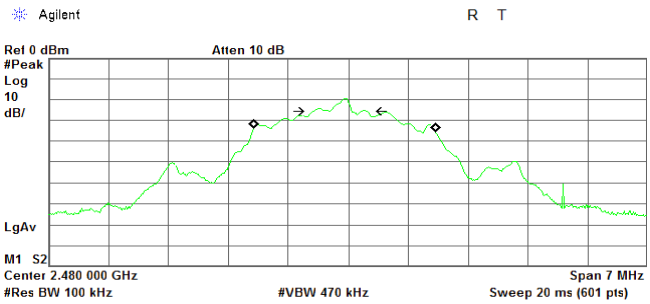


2 Mbps

Plot 7.1.3 The 6 dB bandwidth test result at high frequency



1 Mbps



2 Mbps

Test specification:	FCC 47 CFR 15.247(b)3 / RSS-247 section 5.4(4), Peak output power		
Test procedure:	ANSI C63.10-2013, section 11.9		
Test mode:	Compliance	Verdict:	PASS
Date(s):	19-May-19		
Temperature: 24 ºC	Relative Humidity: 46 %	Air Pressure: 1012 hPa	Power: 3 VDC
Remarks:			

7.2 Peak output power

7.2.1 General

This test was performed to measure the maximum peak output power radiated by transmitter. Specification test limits are given in Table 7.2.1.

Table 7.2.1 Peak output power limits

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

*- The limit is provided in terms of conducted RF power at the antenna connector. If transmitting antennas of directional gain greater than 6 dBi are used, the peak output power limit shall be reduced below the stated value as follows:

by 1 dB for every 3 dB that the directional gain of antenna exceeds 6 dBi for fixed point-to-point transmitters operate in 2400-2483.5 MHz band;

without any corresponding reduction for fixed point-to-point transmitters operate in 5725-5850 MHz band;

by the amount in dB that the directional gain of antenna exceeds 6 dBi for the rest of transmitters.

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

7.2.2 Test procedure

7.2.2.1 The EUT was set up as shown in Figure 7.2.1, energized and its proper operation was checked.

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

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

7.2.2.4 The maximum field strength of the EUT carrier frequency was measured as provided in Table 7.2.2 and associated plots.

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

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

where P is the peak output power in W, E is the field strength in V/m, d is the test distance and G is the transmitter numeric antenna gain over an isotropic radiator.

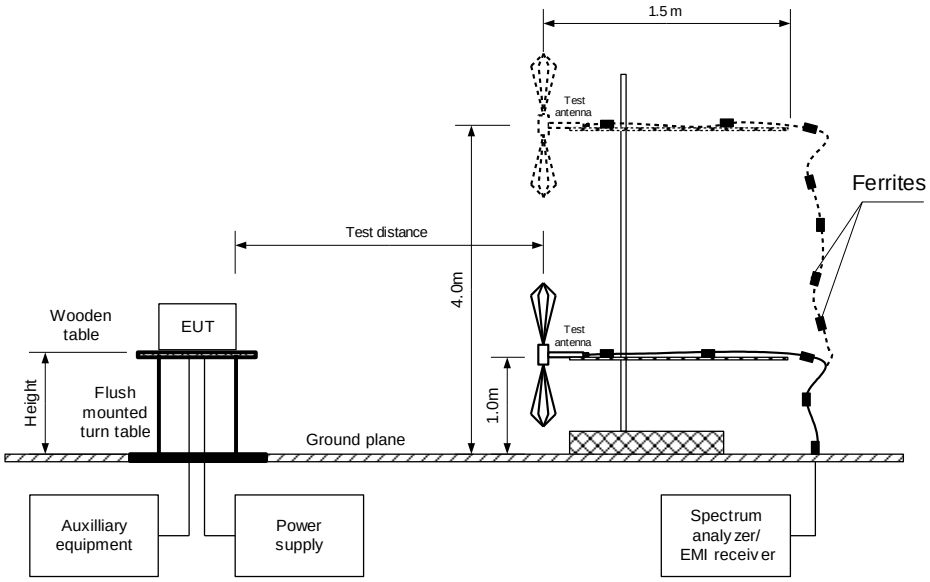
The above equation was converted in logarithmic units for 3 m test distance:

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

7.2.2.6 The worst test results (the lowest margins) were recorded in Table 7.2.2.

Test specification:	**FCC 47 CFR 15.247(b)3 / RSS-247 section 5.4(4), Peak output power**		
Test procedure:	ANSI C63.10-2013, section 11.9		
Test mode:	Compliance	**Verdict:**	PASS
Date(s):	19-May-19		
Temperature: 24 ºC	**Relative Humidity:** 46 %	**Air Pressure:** 1012 hPa	**Power:** 3 VDC
Remarks:			

Figure 7.2.1 Setup for carrier field strength measurements



Test specification:	**FCC 47 CFR 15.247(b)3 / RSS-247 section 5.4(4), Peak output power**		
Test procedure:	ANSI C63.10-2013, section 11.9		
Test mode:	Compliance	**Verdict:**	PASS
Date(s):	19-May-19		
Temperature: 24 ºC	**Relative Humidity:** 46 %	**Air Pressure:** 1012 hPa	**Power:** 3 VDC
Remarks:			

Table 7.2.2 Peak output power test results

ASSIGNED FREQUENCY: 2400.0 – 2483.5 MHz
TEST DISTANCE: 3 m
TEST SITE: Semi anechoic chamber
EUT HEIGHT: 1.5 m
DETECTOR USED: Peak
TEST ANTENNA TYPE: Double ridged guide (above 1000 MHz)
MODULATION: GFSK
TRANSMITTER OUTPUT POWER SETTINGS: Maximum
DETECTOR USED: Peak
RESOLUTION BANDWIDTH: 3 MHz
VIDEO BANDWIDTH: 10 MHz

BIT RATE: 1 Mbps

Frequency, MHz	Field strength, dB(µV/m)	Antenna polarization	Antenna height, m	Azimuth, degrees*	EUT antenna gain, dBi	Peak output power, dBm**	Limit, dBm	Margin, dB***	Verdict
2402.0	102.12	Vertical	1.0	103	5.3	1.62	30.0	-28.38	Pass
2440.0	102.76	Vertical	1.0	136	5.3	2.26	30.0	-27.74	Pass
2480.0	102.87	Vertical	1.0	132	5.3	2.37	30.0	-27.63	Pass

BIT RATE: 2 Mbps

Frequency, MHz	Field strength, dB(µV/m)	Antenna polarization	Antenna height, m	Azimuth, degrees*	EUT antenna gain, dBi	Peak output power, dBm**	Limit, dBm	Margin, dB***	Verdict
2402.0	101.92	Vertical	1.0	103	5.3	1.42	30.0	-28.58	Pass
2440.0	103.20	Vertical	1.0	136	5.3	2.70	30.0	-27.30	Pass
2480.0	102.93	Vertical	1.0	132	5.3	2.43	30.0	-27.57	Pass

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

Reference numbers of test equipment used

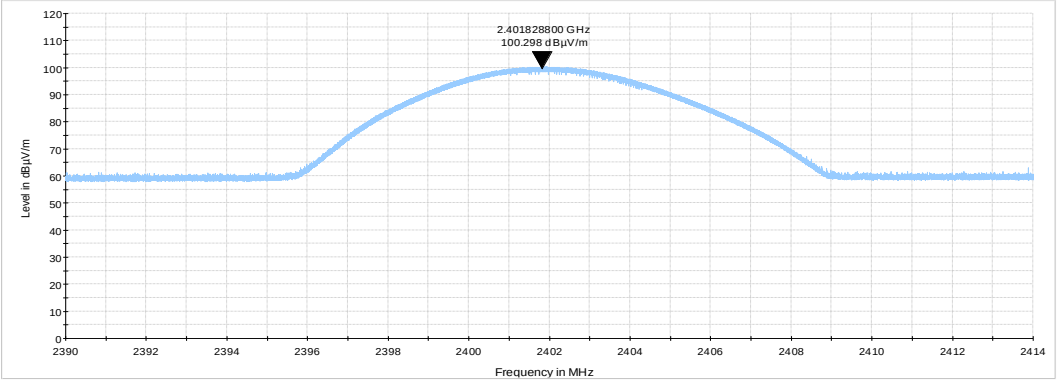
HL 3903	HL 4360	HL 4933	HL 5405				

Full description is given in Appendix A.

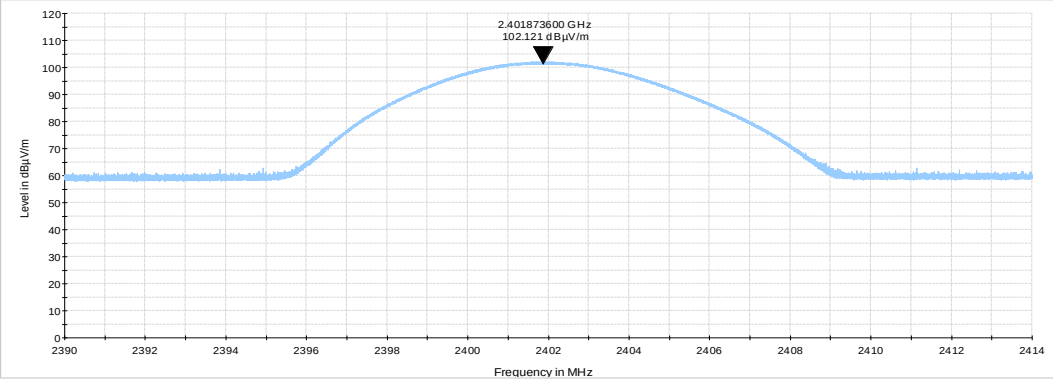
Test specification:	**FCC 47 CFR 15.247(b)3 / RSS-247 section 5.4(4), Peak output power**		
Test procedure:	ANSI C63.10-2013, section 11.9		
Test mode:	Compliance	**Verdict:**	PASS
Date(s):	19-May-19		
Temperature: 24 ºC	**Relative Humidity:** 46 %	**Air Pressure:** 1012 hPa	**Power:** 3 VDC
Remarks:			

Plot 7.2.1 Field strength of carrier at low frequency with bitrate 1 Mbps

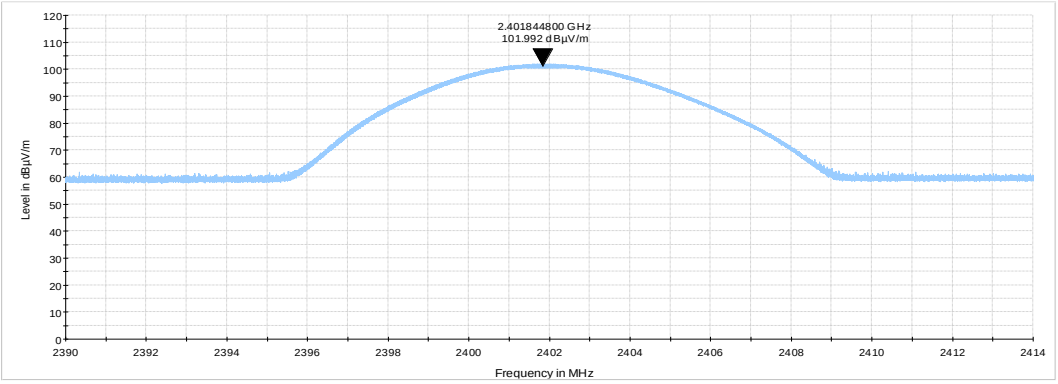
EUT position X



EUT position Y



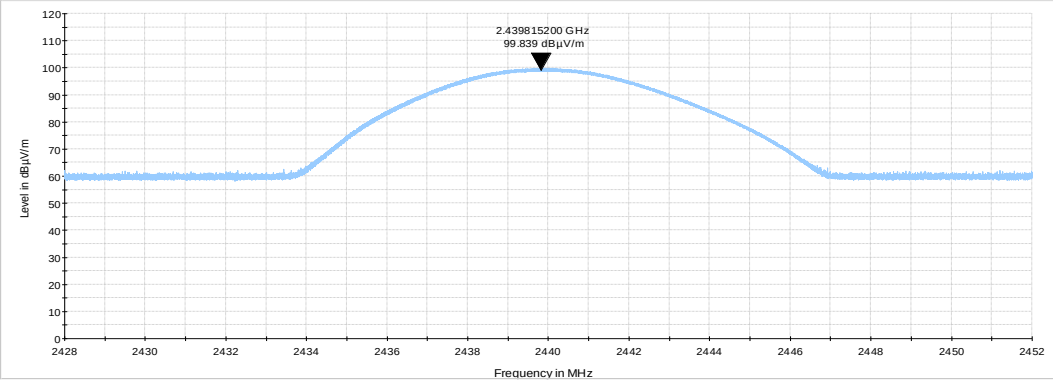
EUT position Z



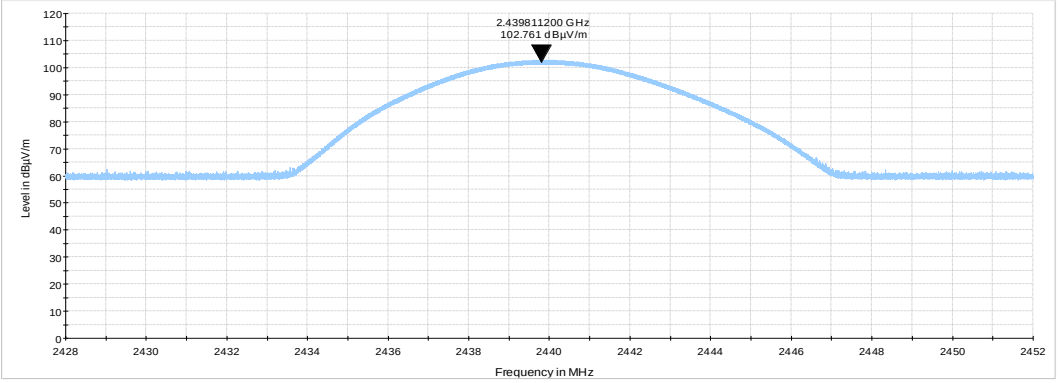
Test specification:	**FCC 47 CFR 15.247(b)3 / RSS-247 section 5.4(4), Peak output power**		
Test procedure:	ANSI C63.10-2013, section 11.9		
Test mode:	Compliance	**Verdict:**	PASS
Date(s):	19-May-19		
Temperature: 24 ºC	**Relative Humidity:** 46 %	**Air Pressure:** 1012 hPa	**Power:** 3 VDC
Remarks:			

Plot 7.2.2 Field strength of carrier at mid frequency with bitrate 1 Mbps

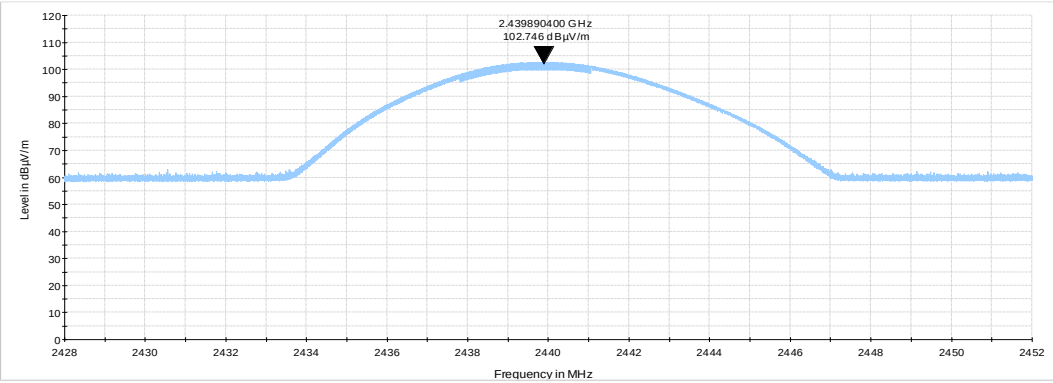
EUT position X



EUT position Y



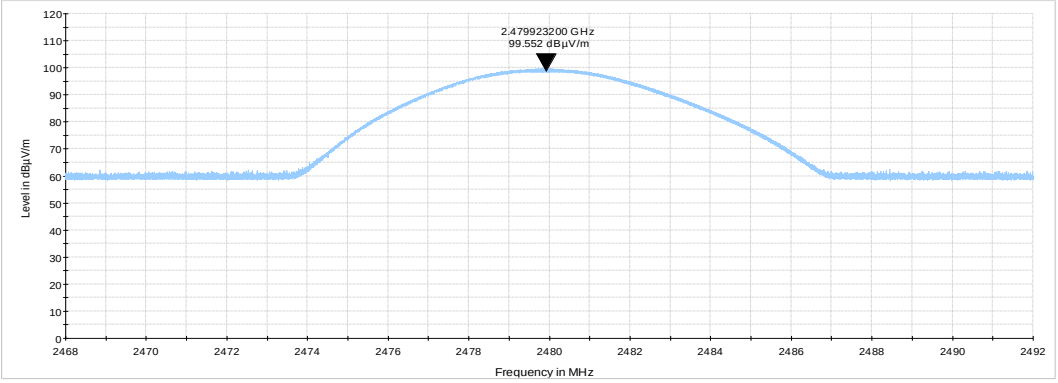
EUT position Z



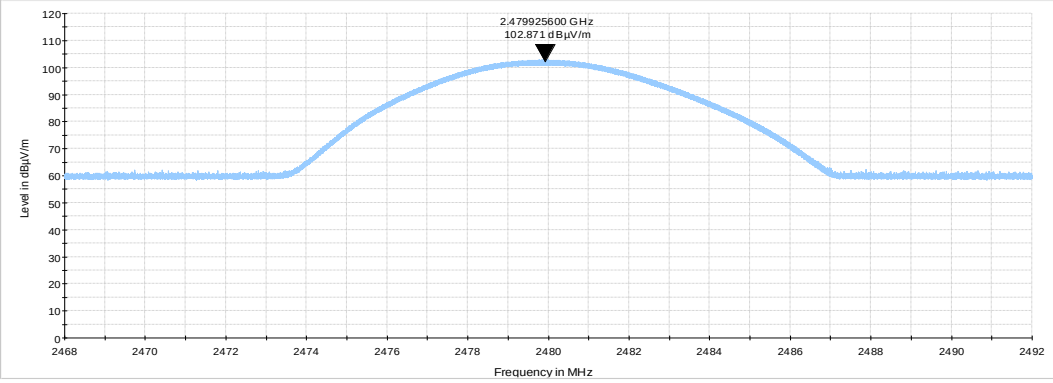
Test specification:	**FCC 47 CFR 15.247(b)3 / RSS-247 section 5.4(4), Peak output power**		
Test procedure:	ANSI C63.10-2013, section 11.9		
Test mode:	Compliance	**Verdict:**	PASS
Date(s):	19-May-19		
Temperature: 24 ºC	**Relative Humidity:** 46 %	**Air Pressure:** 1012 hPa	**Power:** 3 VDC
Remarks:			

Plot 7.2.3 Field strength of carrier at high frequency with bitrate 1 Mbps

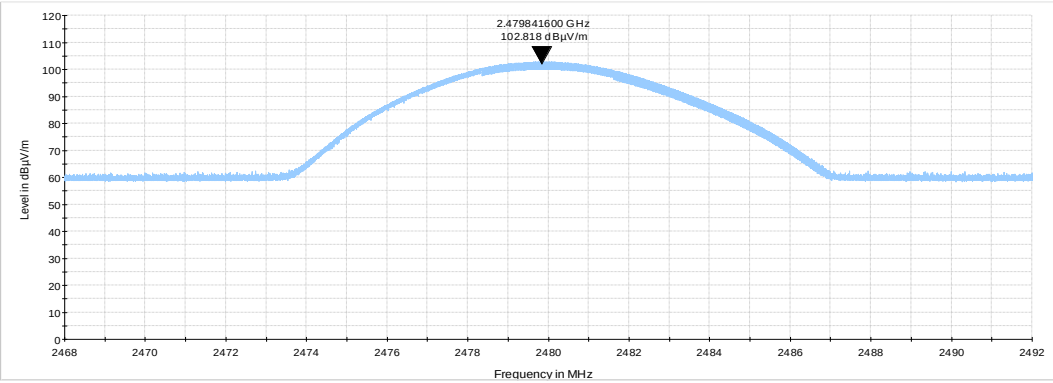
EUT position X



EUT position Y



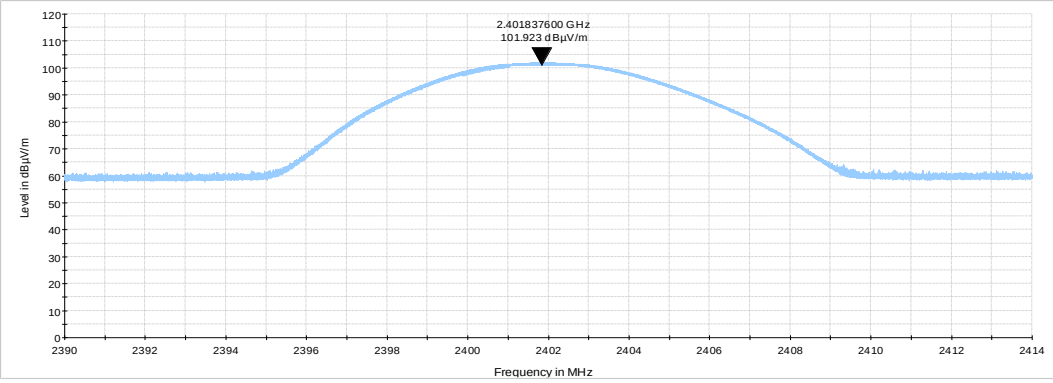
EUT position Z



Test specification:	**FCC 47 CFR 15.247(b)3 / RSS-247 section 5.4(4), Peak output power**		
Test procedure:	ANSI C63.10-2013, section 11.9		
Test mode:	Compliance	**Verdict:**	PASS
Date(s):	19-May-19		
Temperature: 24 ºC	**Relative Humidity:** 46 %	**Air Pressure:** 1012 hPa	**Power:** 3 VDC
Remarks:			

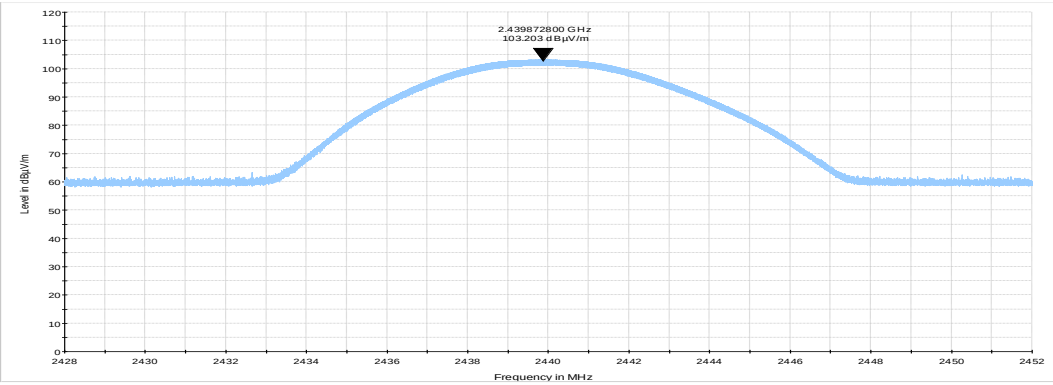
Plot 7.2.4 Field strength of carrier at low frequency with bitrate 2 Mbps

EUT position Y (as worst case according to bitrate 1 Mbps measurements)



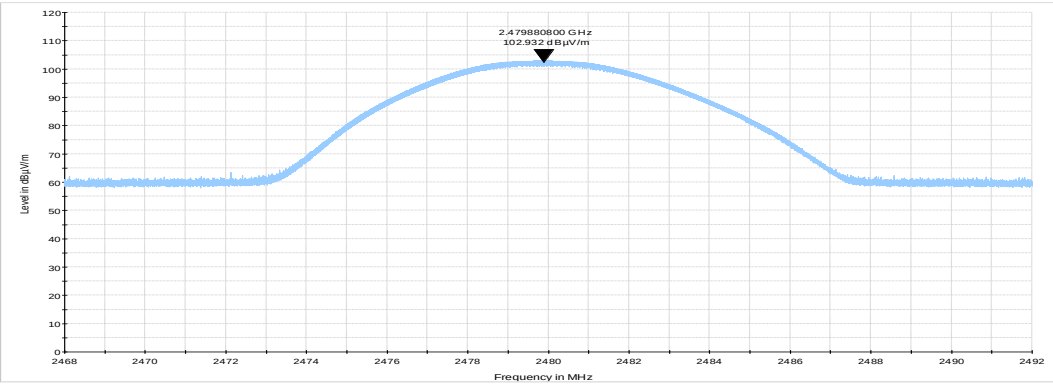
Plot 7.2.5 Field strength of carrier at mid frequency with bitrate 2 Mbps

EUT position Y (as worst case according to bitrate 1 Mbps measurements)



Plot 7.2.6 Field strength of carrier at high frequency with bitrate 2 Mbps

EUT position Y (as worst case according to bitrate 1 Mbps measurements)



Test specification:	FCC 47 CFR 15.247(d) / RSS-247 section 5.5, Radiated spurious emissions		
Test procedure:	ANSI C63.10, Section 6.3, 6.5, 6.6, 11.12.1		
Test mode:	Compliance	Verdict:	PASS
Date(s):	19-May-19		
Temperature: 24 ºC	Relative Humidity: 46 %	Air Pressure: 1012 hPa	Power: 3 VDC
Remarks:			

7.3 Field strength of spurious emissions

7.3.1 General

This test was performed to measure field strength of spurious emissions from the EUT. Specification test limits are given in Table 7.3.1.

Table 7.3.1 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 10th harmonic of the highest fundamental frequency.

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

7.3.2.1 The EUT was set up as shown in Figure 7.3.1, energized and the performance check was conducted.

7.3.2.2 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.

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

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

7.3.3.1 The EUT was set up as shown in Figure 7.3.2 / Figure 7.3.3, energized and the performance check was conducted.

7.3.3.2 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.

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

Test specification:	**FCC 47 CFR 15.247(d) / RSS-247 section 5.5, Radiated spurious emissions**		
Test procedure:	ANSI C63.10, Section 6.3, 6.5, 6.6, 11.12.1		
Test mode:	Compliance	**Verdict:**	PASS
Date(s):	19-May-19		
Temperature: 24 ºC	**Relative Humidity:** 46 %	**Air Pressure:** 1012 hPa	**Power:** 3 VDC
Remarks:			

Figure 7.3.1 Setup for spurious emission field strength measurements below 30 MHz

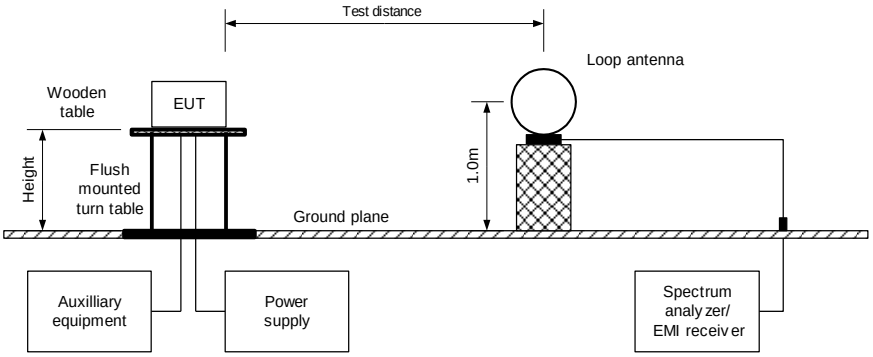


Figure 7.3.2 Setup for spurious emission field strength measurements in 30 -1000 MHz

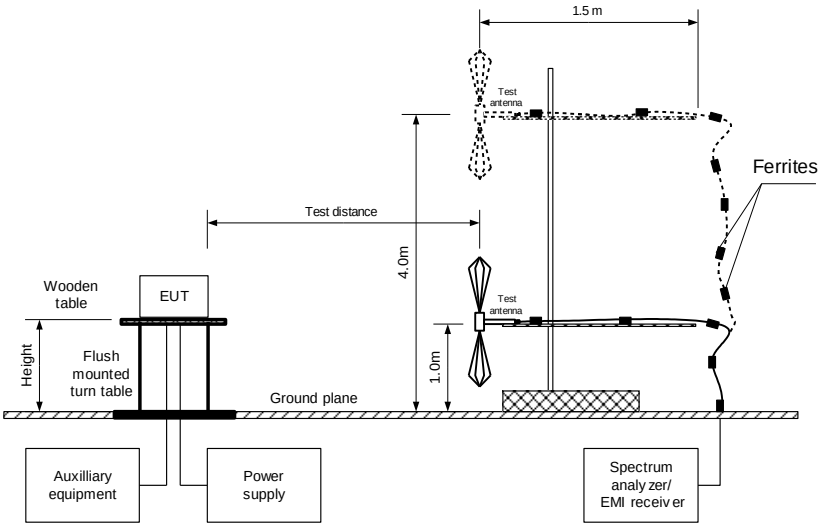
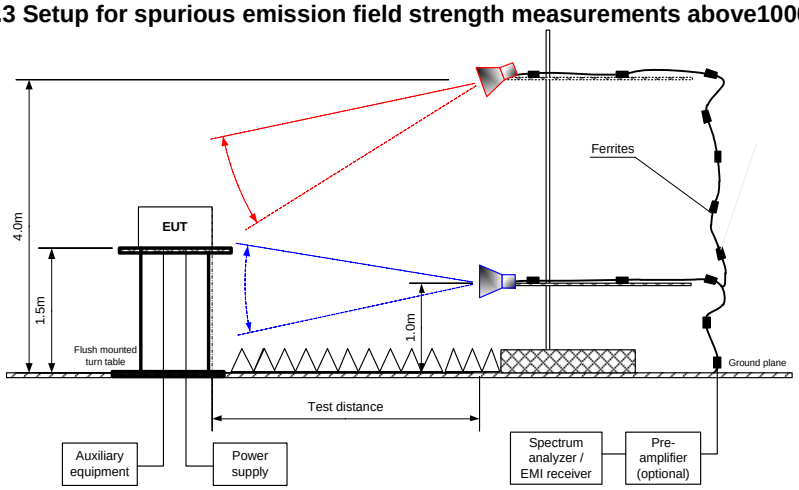


Figure 7.3.3 Setup for spurious emission field strength measurements above1000 MHz



Test specification:	FCC 47 CFR 15.247(d) / RSS-247 section 5.5, Radiated spurious emissions		
Test procedure:	ANSI C63.10, Section 6.3, 6.5, 6.6, 11.12.1		
Test mode:	Compliance	Verdict:	PASS
Date(s):	19-May-19		
Temperature: 24 ºC	Relative Humidity: 46 %	Air Pressure: 1012 hPa	Power: 3 VDC
Remarks:			

Table 7.3.2 Field strength of emissions outside restricted bands

ASSIGNED FREQUENCY:	2400.0 – 2483.5 MHz
INVESTIGATED FREQUENCY RANGE:	0.009 - 25000 MHz
TEST DISTANCE:	3 m
MODULATION:	GFSK
MODULATING SIGNAL:	PRBS
BIT RATE:	2 Mbps
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									
7206.000	62.97	Vertical	2.05	316	101.67	38.70	20.0	18.70	Pass
Mid carrier frequency									
All emissions are more than 20 dB below the limit									Pass
High carrier frequency									
All emissions are more than 20 dB below the limit									Pass

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

Test specification:	FCC 47 CFR 15.247(d) / RSS-247 section 5.5, Radiated spurious emissions		
Test procedure:	ANSI C63.10, Section 6.3, 6.5, 6.6, 11.12.1		
Test mode:	Compliance	Verdict:	PASS
Date(s):	19-May-19		
Temperature: 24 ºC	Relative Humidity: 46 %	Air Pressure: 1012 hPa	Power: 3 VDC
Remarks:			

Table 7.3.3 Field strength of spurious emissions above 1 GHz within restricted bands

ASSIGNED FREQUENCY:	2400.0 – 2483.5 MHz
INVESTIGATED FREQUENCY RANGE:	1000 - 25000 MHz
TEST DISTANCE:	3 m
MODULATION:	GFSK
MODULATING SIGNAL:	PRBS
BIT RATE:	2 Mbps
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)	Limit, dB(μV/m)	Margin, dB**	
Low carrier frequency										
2275.639	Vertical	1.78	156	52.43	74.0	-21.57	39.15	54.00	-14.85	Pass
2488.441	Vertical	1.21	12	48.54	74.0	-25.46	40.51	54.00	-13.94	
4804.000	Vertical	2.05	270	61.26	74.0	-12.74	52.27	54.00	-1.73	
12011.00	Horizontal	1.53	357	56.07	74.0	-17.93	42.00	54.00	-12.00	
Mid carrier frequency										
2291.456	Vertical	1.20	23	47.64	74.0	-26.36	33.45	54.00	-20.55	Pass
2487.455	Vertical	1.30	246	45.56	74.0	-28.44	38.78	54.00	-15.22	
4880.000	Vertical	1.53	289	61.97	74.0	-12.03	53.08	54.00	-0.92	
7320.000	Horizontal	1.53	315	59.91	74.0	-14.09	48.41	54.00	-5.59	
12199.00	Horizontal	2.06	357	54.16	74.0	-19.84	40.92	54.00	-13.08	
High carrier frequency										
2285.412	Horizontal	1.23	142	46.78	74.0	-27.22	38.56	54.00	-15.44	Pass
2483.500	Horizontal	1.50	67	50.25	74.0	-23.75	39.41	54.00	-14.59	
4960.000	Vertical	1.00	297	60.51	74.0	-13.49	51.47	54.00	-2.53	
7440.000	Horizontal	1.00	317	60.84	74.0	-13.16	49.34	54.00	-4.66	
12398.50	Horizontal	2.06	360	51.70	74.0	-22.30	37.94	54.00	-16.06	

*****- EUT front panel refers to 0 degrees position of turntable.
******- Margin = Measured field strength - specification limit.

Test specification:	FCC 47 CFR 15.247(d) / RSS-247 section 5.5, Radiated spurious emissions		
Test procedure:	ANSI C63.10, Section 6.3, 6.5, 6.6, 11.12.1		
Test mode:	Compliance	Verdict:	PASS
Date(s):	19-May-19		
Temperature: 24 ºC	Relative Humidity: 46 %	Air Pressure: 1012 hPa	Power: 3 VDC
Remarks:			

Table 7.3.4 Field strength of spurious emissions below 1 GHz within restricted bands

ASSIGNED FREQUENCY:	2400.0 – 2483.5 MHz
INVESTIGATED FREQUENCY RANGE:	0.009 – 1000 MHz
TEST DISTANCE:	3 m
MODULATION:	GFSK
MODULATING SIGNAL:	PRBS
BIT RATE:	2 Mbps
DUTY CYCLE:	100 %
TRANSMITTER OUTPUT POWER SETTINGS:	Maximum
RESOLUTION BANDWIDTH:	0.2 kHz (9 kHz – 150 kHz) 9.0 kHz (150 kHz – 30 MHz) 120 kHz (30 MHz – 1000 MHz)
VIDEO BANDWIDTH:	> Resolution bandwidth
TEST ANTENNA TYPE:	Active loop (9 kHz – 30 MHz) Biconilog (30 MHz – 1000 MHz)

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

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

Test specification:	FCC 47 CFR 15.247(d) / RSS-247 section 5.5, Radiated spurious emissions		
Test procedure:	ANSI C63.10, Section 6.3, 6.5, 6.6, 11.12.1		
Test mode:	Compliance	Verdict:	PASS
Date(s):	19-May-19		
Temperature: 24 ºC	Relative Humidity: 46 %	Air Pressure: 1012 hPa	Power: 3 VDC
Remarks:			

Table 7.3.5 Restricted bands according to FCC section 15.205

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

Table 7.3.6 Restricted bands according to RSS-Gen

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

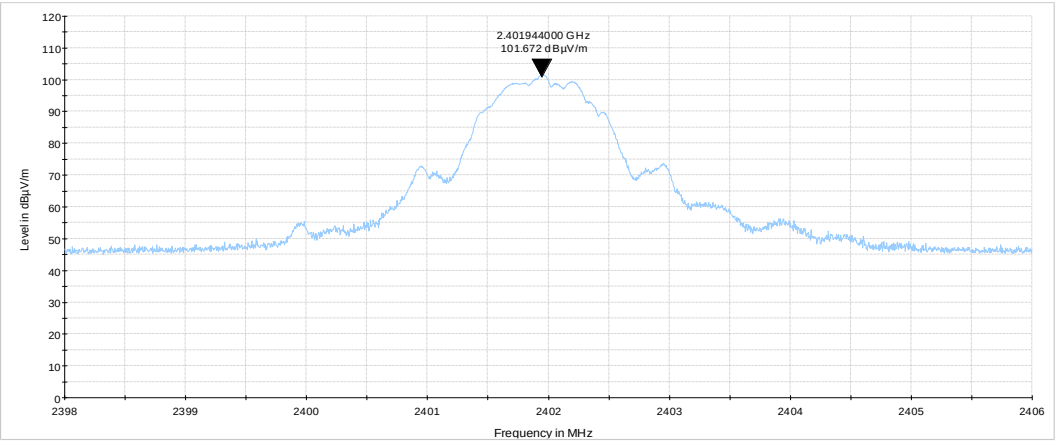
Reference numbers of test equipment used

HL 0446	HL 3903	HL 4360	HL 4933	HL 4956	HL 5111	HL 5405	

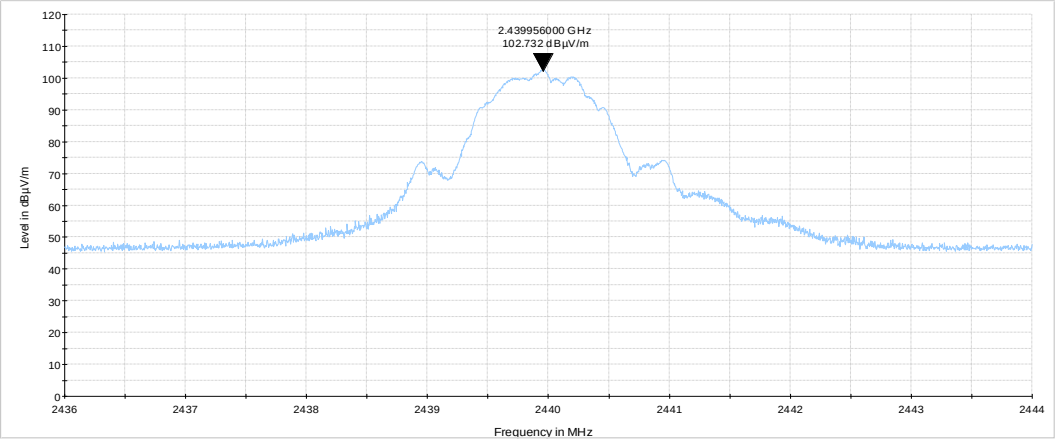
Full description is given in Appendix A.

Test specification:	FCC 47 CFR 15.247(d) / RSS-247 section 5.5, Radiated spurious emissions		
Test procedure:	ANSI C63.10, Section 6.3, 6.5, 6.6, 11.12.1		
Test mode:	Compliance	Verdict:	PASS
Date(s):	19-May-19		
Temperature: 24 ºC	Relative Humidity: 46 %	Air Pressure: 1012 hPa	Power: 3 VDC
Remarks:			

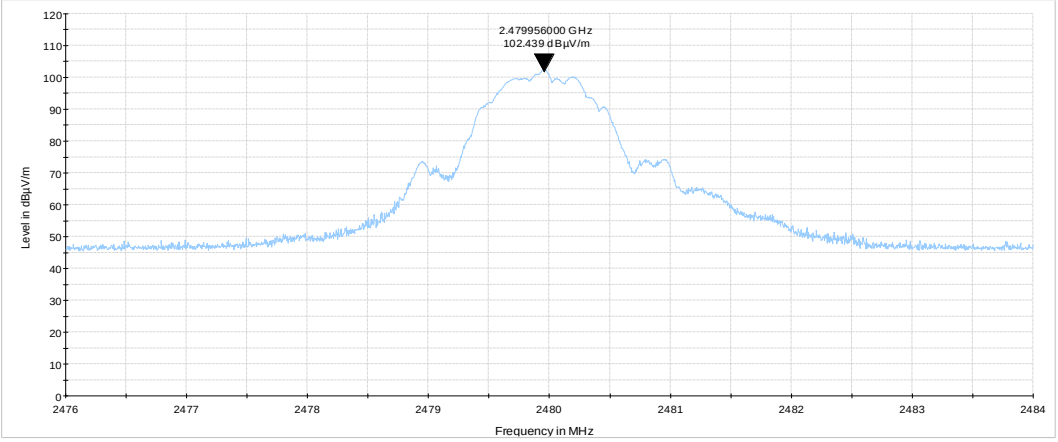
Plot 7.3.1 Fundamental emission measurements at the low carrier frequency



Plot 7.3.2 Fundamental emission measurements at the mid carrier frequency



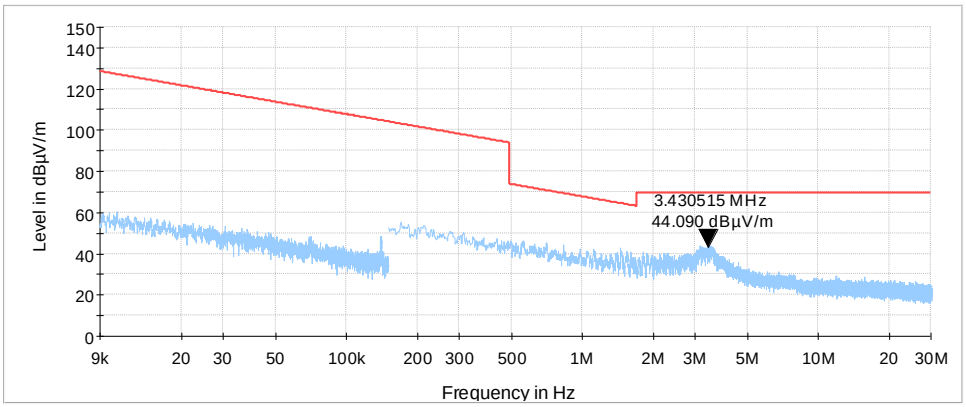
Plot 7.3.3 Fundamental emission measurements at the high carrier frequency



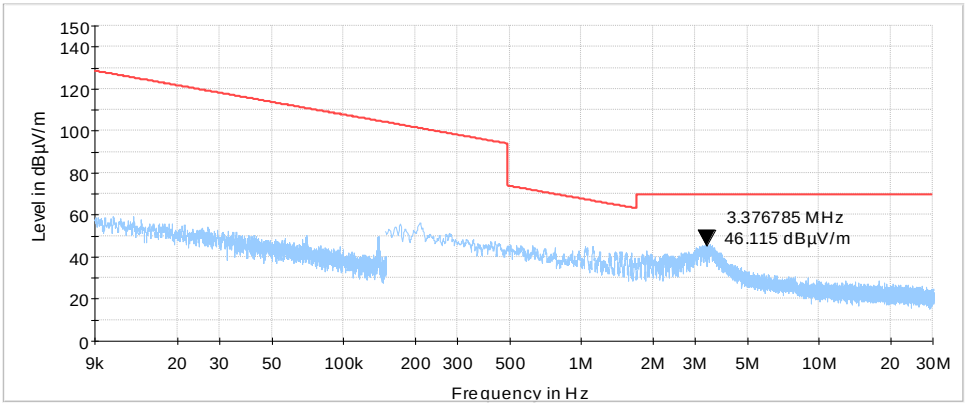
Test specification:	FCC 47 CFR 15.247(d) / RSS-247 section 5.5, Radiated spurious emissions		
Test procedure:	ANSI C63.10, Section 6.3, 6.5, 6.6, 11.12.1		
Test mode:	Compliance	Verdict:	PASS
Date(s):	19-May-19		
Temperature: 24 ºC	Relative Humidity: 46 %	Air Pressure: 1012 hPa	Power: 3 VDC
Remarks:			

Plot 7.3.4 Radiated emission measurements from 9 kHz to 30 MHz

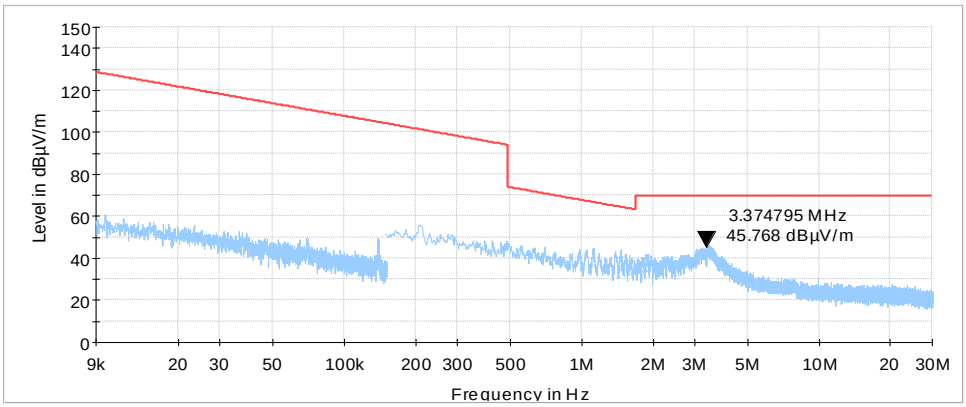
TEST SITE: Semi anechoic chamber
TEST DISTANCE: 3 m
ANTENNA POLARIZATION: Vertical



LOW CARRIER FREQUENCY



MID CARRIER FREQUENCY

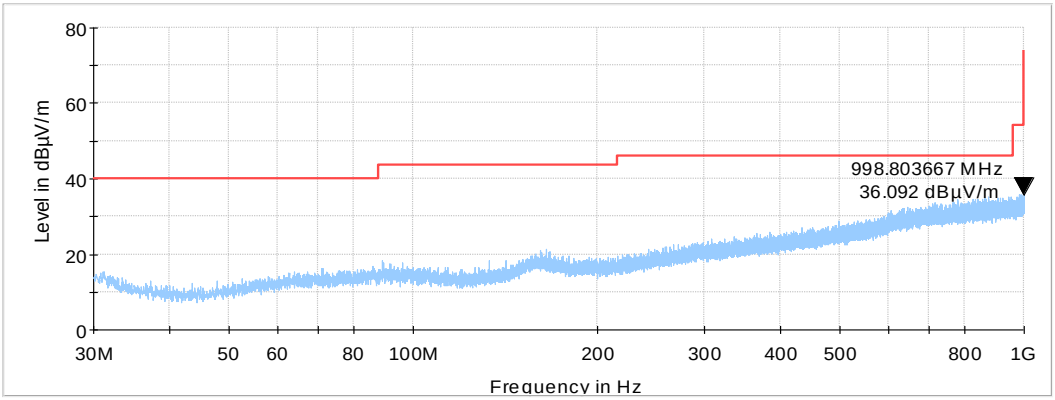


HIGH CARRIER FREQUENCY

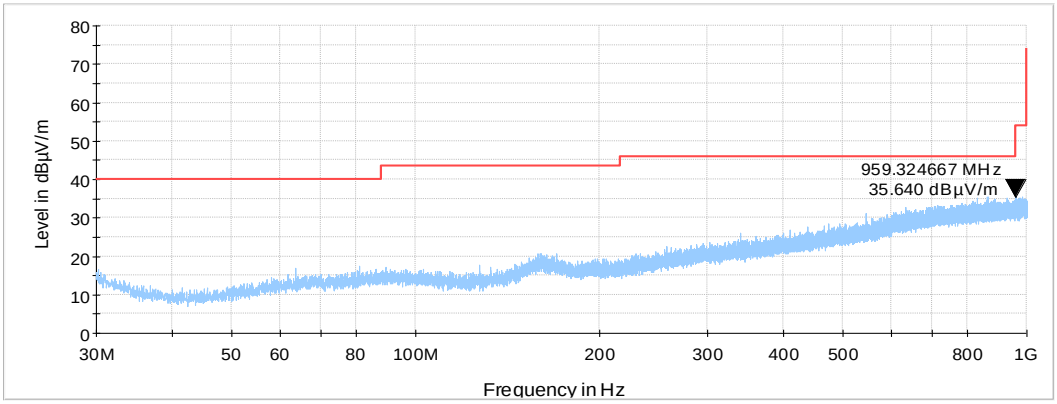
Test specification:	FCC 47 CFR 15.247(d) / RSS-247 section 5.5, Radiated spurious emissions		
Test procedure:	ANSI C63.10, Section 6.3, 6.5, 6.6, 11.12.1		
Test mode:	Compliance	Verdict:	PASS
Date(s):	19-May-19		
Temperature: 24 ºC	Relative Humidity: 46 %	Air Pressure: 1012 hPa	Power: 3 VDC
Remarks:			

Plot 7.3.5 Radiated emission measurements from 30 to 1000 MHz

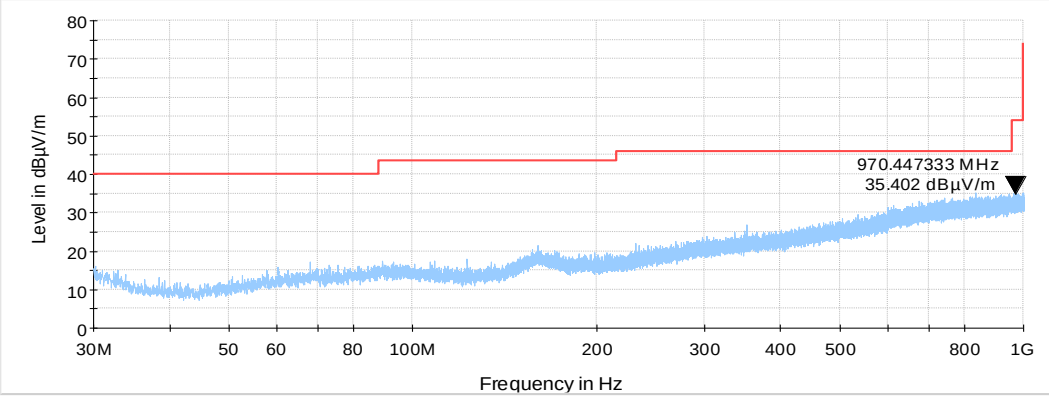
TEST SITE: Semi anechoic chamber
TEST DISTANCE: 3 m
ANTENNA POLARIZATION: Vertical and Horizontal



LOW CARRIER FREQUENCY



MID CARRIER FREQUENCY

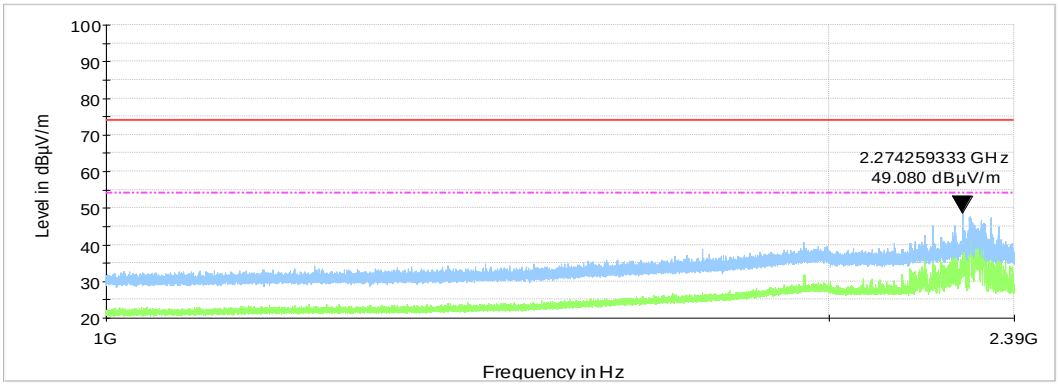


HIGH CARRIER FREQUENCY

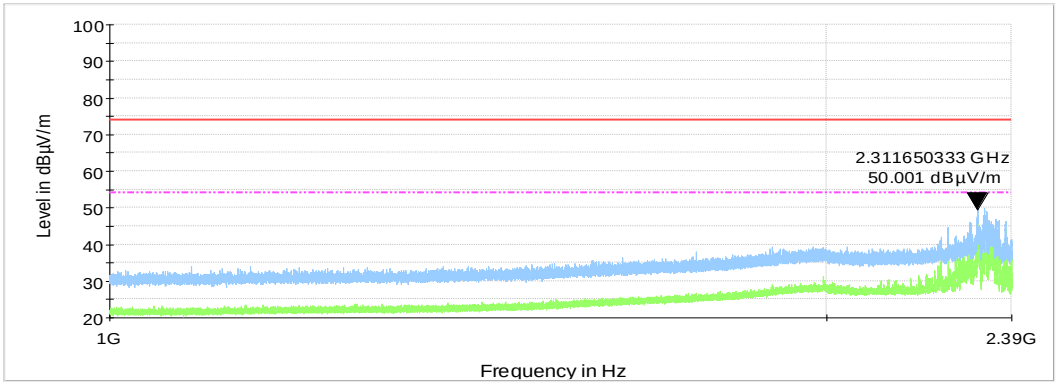
Test specification:	FCC 47 CFR 15.247(d) / RSS-247 section 5.5, Radiated spurious emissions		
Test procedure:	ANSI C63.10, Section 6.3, 6.5, 6.6, 11.12.1		
Test mode:	Compliance	Verdict:	PASS
Date(s):	19-May-19		
Temperature: 24 ºC	Relative Humidity: 46 %	Air Pressure: 1012 hPa	Power: 3 VDC
Remarks:			

Plot 7.3.6 Radiated emission measurements from 1 to 2.39 GHz

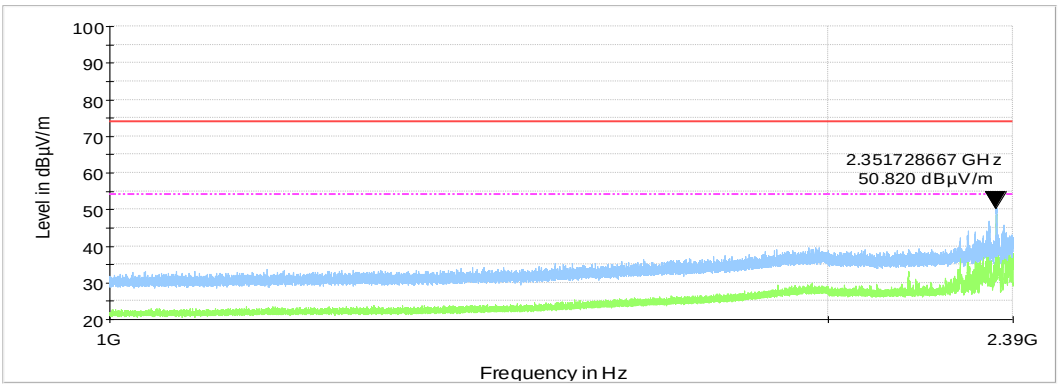
TEST SITE: Semi anechoic chamber
TEST DISTANCE: 3 m
ANTENNA POLARIZATION: Vertical and Horizontal



LOW CARRIER FREQUENCY



MID CARRIER FREQUENCY

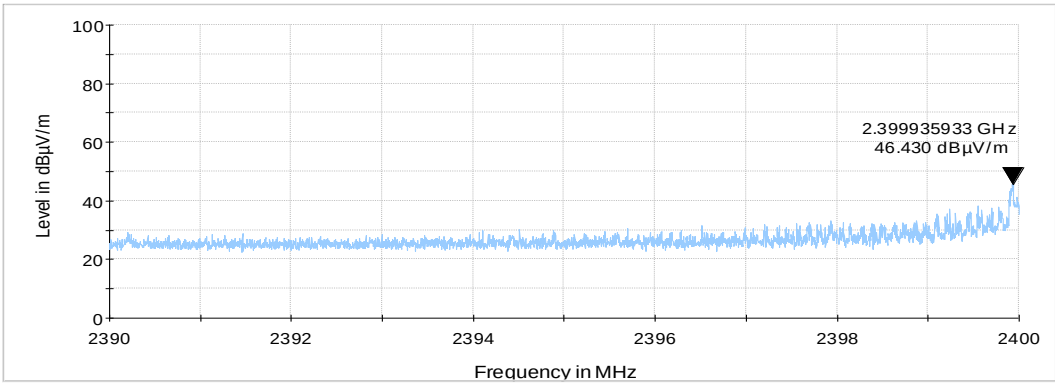


HIGH CARRIER FREQUENCY

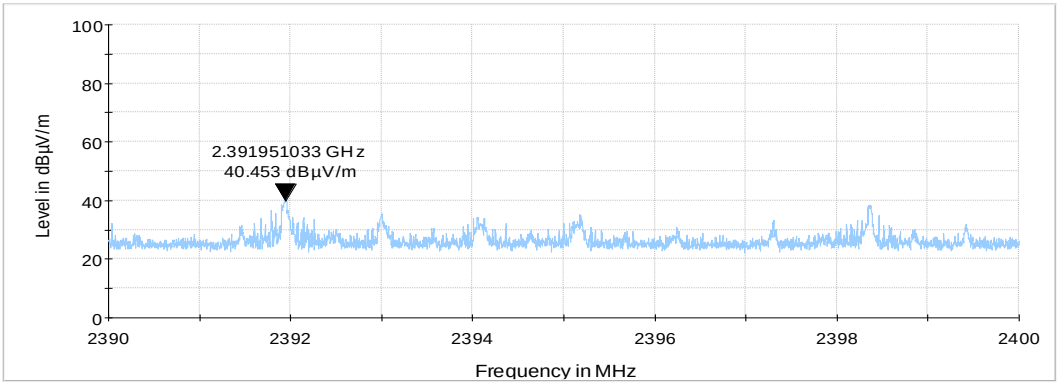
Test specification:	FCC 47 CFR 15.247(d) / RSS-247 section 5.5, Radiated spurious emissions		
Test procedure:	ANSI C63.10, Section 6.3, 6.5, 6.6, 11.12.1		
Test mode:	Compliance	Verdict:	PASS
Date(s):	19-May-19		
Temperature: 24 ºC	Relative Humidity: 46 %	Air Pressure: 1012 hPa	Power: 3 VDC
Remarks:			

Plot 7.3.7 Radiated emission measurements from 2.39 to 2.4 GHz

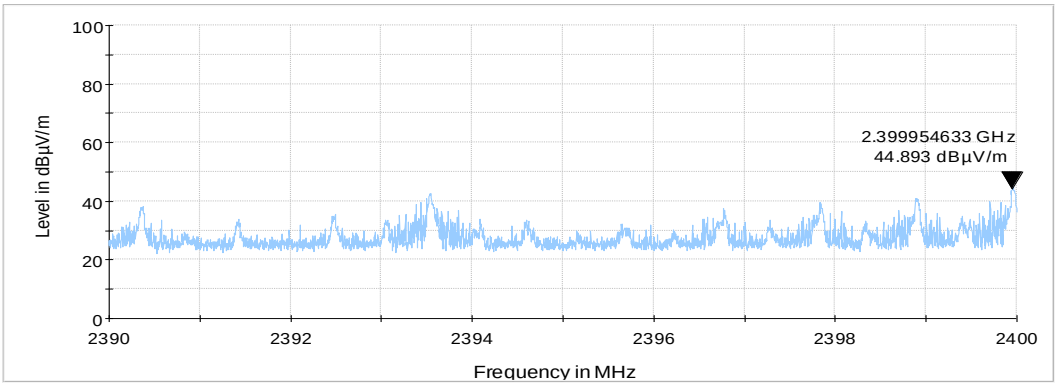
TEST SITE: Semi anechoic chamber
TEST DISTANCE: 3 m
ANTENNA POLARIZATION: Vertical and Horizontal



LOW CARRIER FREQUENCY



MID CARRIER FREQUENCY

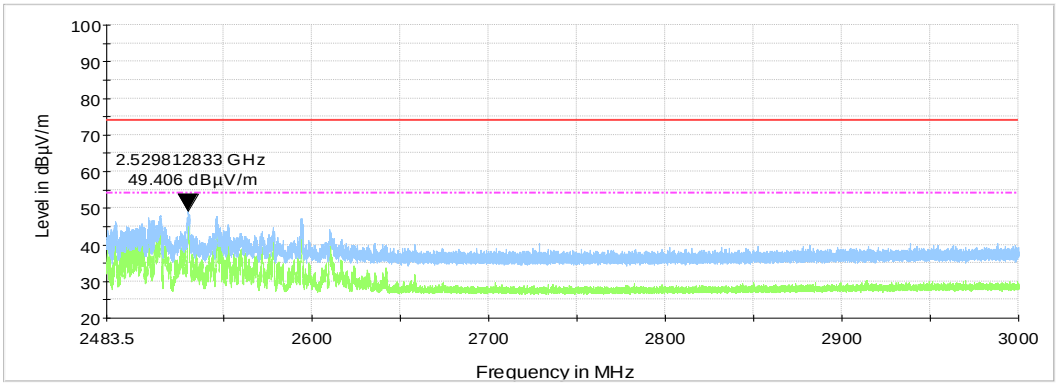


HIGH CARRIER FREQUENCY

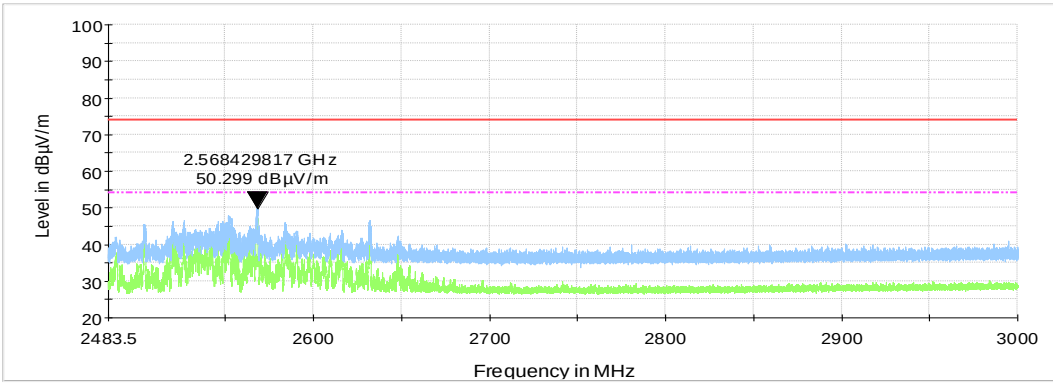
Test specification:	FCC 47 CFR 15.247(d) / RSS-247 section 5.5, Radiated spurious emissions		
Test procedure:	ANSI C63.10, Section 6.3, 6.5, 6.6, 11.12.1		
Test mode:	Compliance	Verdict:	PASS
Date(s):	19-May-19		
Temperature: 24 ºC	Relative Humidity: 46 %	Air Pressure: 1012 hPa	Power: 3 VDC
Remarks:			

Plot 7.3.8 Radiated emission measurements from 2.4835 to 3 GHz

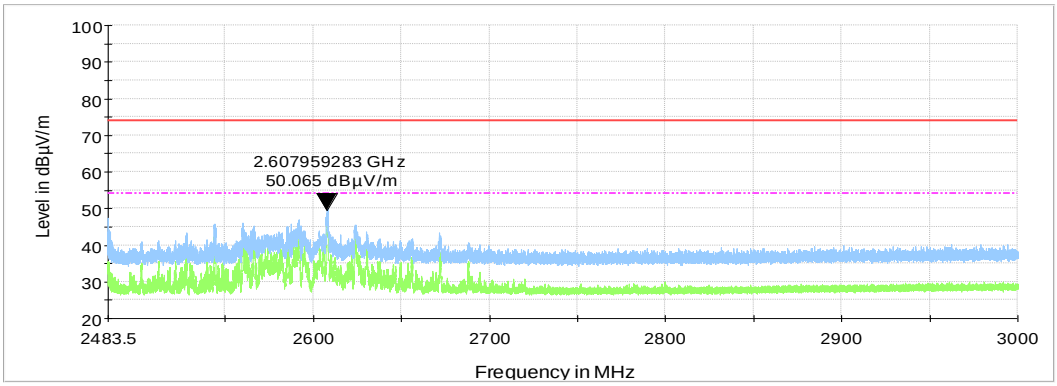
TEST SITE: Semi anechoic chamber
TEST DISTANCE: 3 m
ANTENNA POLARIZATION: Vertical and Horizontal



LOW CARRIER FREQUENCY



MID CARRIER FREQUENCY

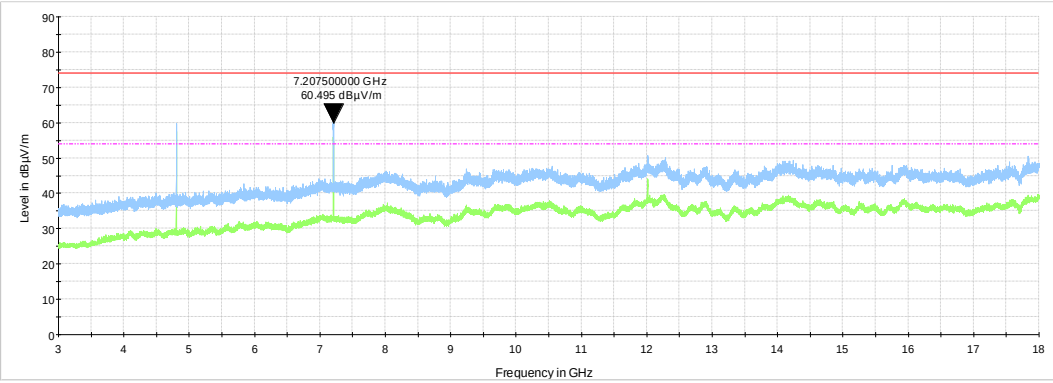


HIGH CARRIER FREQUENCY

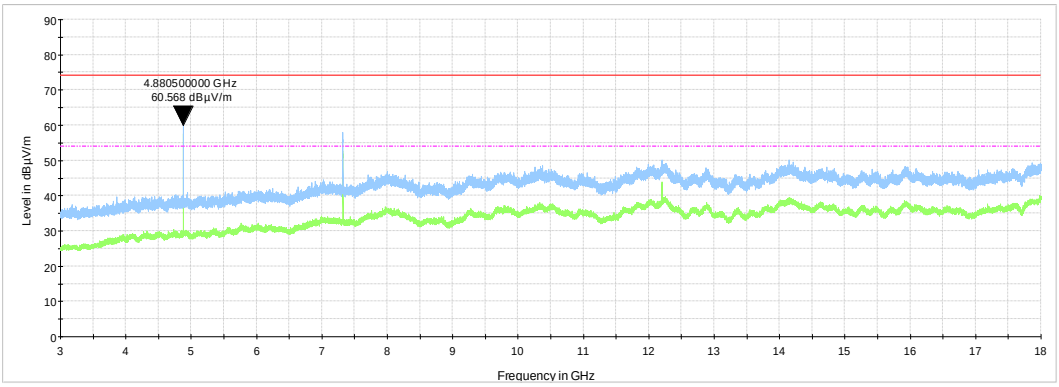
Test specification:	FCC 47 CFR 15.247(d) / RSS-247 section 5.5, Radiated spurious emissions		
Test procedure:	ANSI C63.10, Section 6.3, 6.5, 6.6, 11.12.1		
Test mode:	Compliance	Verdict:	PASS
Date(s):	19-May-19		
Temperature: 24 ºC	Relative Humidity: 46 %	Air Pressure: 1012 hPa	Power: 3 VDC
Remarks:			

Plot 7.3.9 Radiated emission measurements from 3 to 18 GHz

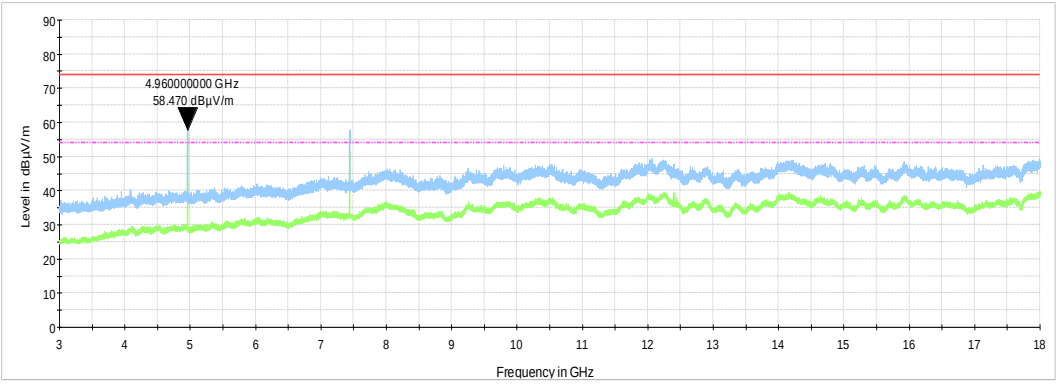
TEST SITE: Semi anechoic chamber
TEST DISTANCE: 3 m
ANTENNA POLARIZATION: Vertical and Horizontal



LOW CARRIER FREQUENCY



MID CARRIER FREQUENCY

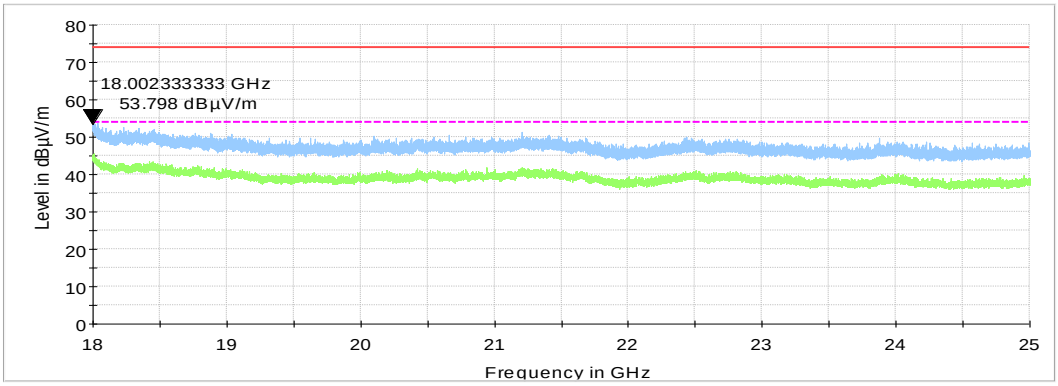


HIGH CARRIER FREQUENCY

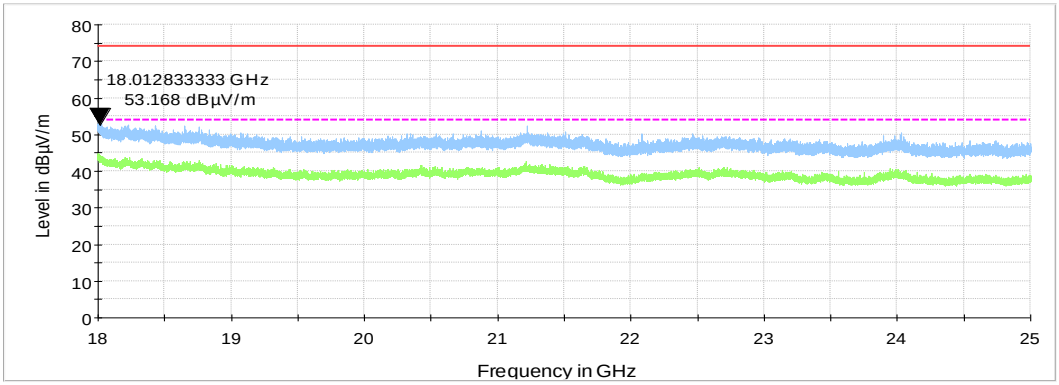
Test specification:	FCC 47 CFR 15.247(d) / RSS-247 section 5.5, Radiated spurious emissions		
Test procedure:	ANSI C63.10, Section 6.3, 6.5, 6.6, 11.12.1		
Test mode:	Compliance	Verdict:	PASS
Date(s):	19-May-19		
Temperature: 24 ºC	Relative Humidity: 46 %	Air Pressure: 1012 hPa	Power: 3 VDC
Remarks:			

Plot 7.3.10 Radiated emission measurements from 18 to 25 GHz

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



LOW CARRIER FREQUENCY



MID CARRIER FREQUENCY

HIGH CARRIER FREQUENCY

Test specification:	FCC 47 CFR 15.247(d) / RSS-247 section 5.5, Band edge emissions		
Test procedure:	ANSI C63.10 section 11.12.1		
Test mode:	Compliance	Verdict:	PASS
Date(s):	20-May-19		
Temperature: 24 ºC	Relative Humidity: 46 %	Air Pressure: 1012 hPa	Power: 3 VDC
Remarks:			

7.4 Band edge radiated emissions

7.4.1 General

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

Table 7.4.1 Band edge emission limits

Output power	Assigned frequency, MHz	Attenuation below carrier*, dBc	Field strength at 3 m within restricted bands, dB(µV/m)	
			Peak	Average
Peak	902.0 – 928.0	20.0	74.0	54.0
	2400.0 – 2483.5			
	5725.0 – 5850.0			
Averaged over a time interval	902.0 – 928.0	30.0	74.0	54.0
	2400.0 – 2483.5			
	5725.0 – 5850.0			

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

7.4.2 Test procedure

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

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

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

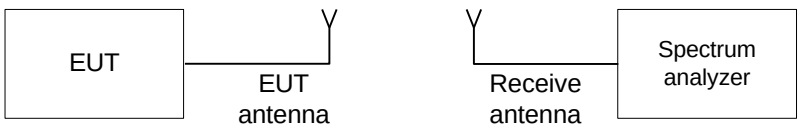
7.4.2.4 The spectrum analyzer was set in max hold mode and allowed trace to stabilize. The highest emission level within the authorized band was measured.

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

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

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

Figure 7.4.1 Band edge emission test setup



Test specification:	**FCC 47 CFR 15.247(d) / RSS-247 section 5.5, Band edge emissions**		
Test procedure:	ANSI C63.10 section 11.12.1		
Test mode:	Compliance	**Verdict:**	PASS
Date(s):	20-May-19		
Temperature: 24 ºC	**Relative Humidity:** 46 %	**Air Pressure:** 1012 hPa	**Power:** 3 VDC
Remarks:			

Table 7.4.2 Low band edge emission test results

ASSIGNED FREQUENCY RANGE: 2400.0 – 2483.5 MHz
DETECTOR USED: Peak
MODULATION: GFSK
MODULATING SIGNAL: PRBS
BIT RATE: 2 Mbps
TRANSMITTER OUTPUT POWER SETTINGS: Maximum
TRANSMITTER OUTPUT POWER: 101.67 dBuV/m at low carrier frequency
RESOLUTION BANDWIDTH: ≥ 1% of the span
VIDEO BANDWIDTH: ≥ RBW

Frequency, MHz	Band edge emission, dBuV/m	Emission at carrier, dBuV/m	Attenuation below carrier, dBc	Limit, dBc	Margin, dB*	Verdict
2399.987	75.72	101.67	25.95	20.0	5.95	Pass

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

Table 7.4.3 High band edge emission test results

ASSIGNED FREQUENCY: 2400.0 – 2483.5 MHz
MODULATION: GFSK
MODULATING SIGNAL: PRBS
BIT RATE: 2 Mbps
TRANSMITTER OUTPUT POWER SETTINGS: Maximum
DETECTOR USED: Peak
RESOLUTION BANDWIDTH: 1000 kHz

Frequency, MHz	Peak field strength(VBW=3 MHz)			Average field strength(VBW=10 Hz)				Verdict
	Measured, dB(μV/m)	Limit, dB(μV/m)	Margin, dB**	Measured, dB(μV/m)	Calculated, dB(μV/m)	Limit, dB(μV/m)	Margin, dB***	
2435.500	58.51	74.0	-15.49	43.52	NA	54.0	-10.48	Pass

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

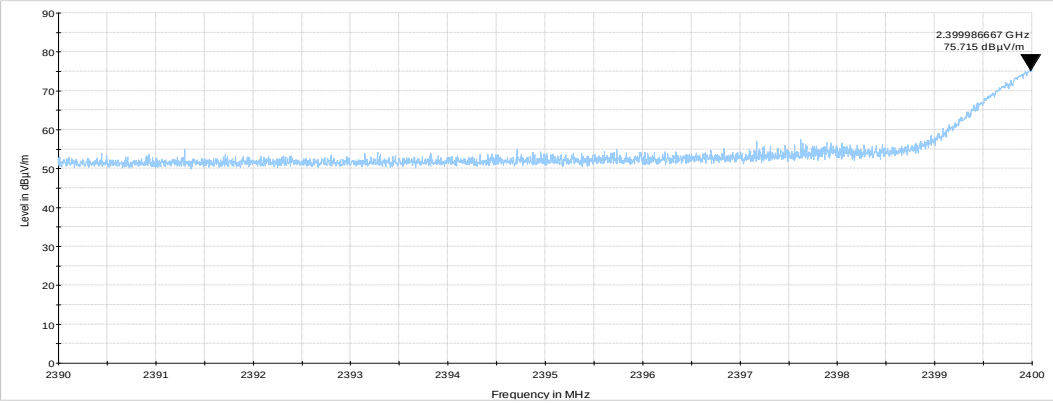
Reference numbers of test equipment used

HL 3903	HL 4360	HL 4933	HL 5405				

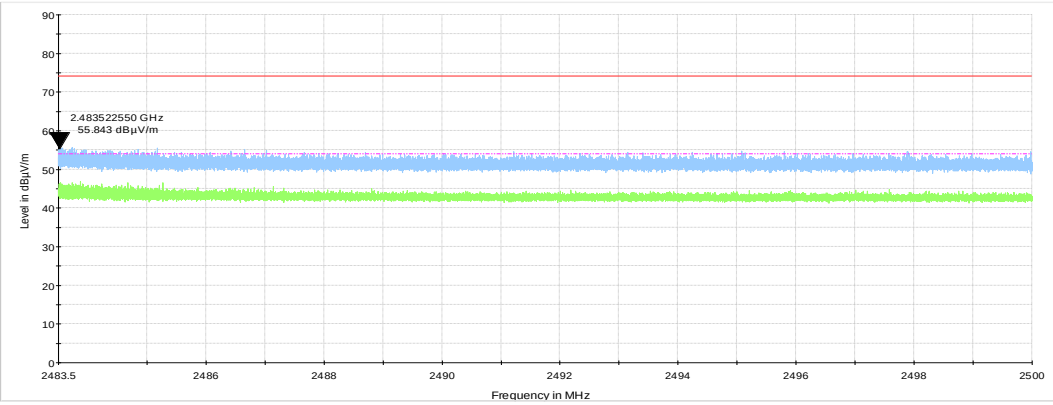
Full description is given in Appendix A.

Test specification:	**FCC 47 CFR 15.247(d) / RSS-247 section 5.5, Band edge emissions**		
Test procedure:	ANSI C63.10 section 11.12.1		
Test mode:	Compliance	**Verdict:**	PASS
Date(s):	20-May-19		
Temperature: 24 ºC	**Relative Humidity:** 46 %	**Air Pressure:** 1012 hPa	**Power:** 3 VDC
Remarks:			

Plot 7.4.1 The highest emission level within the assigned band



LOW CARRIER FREQUENCY



HIGH CARRIER FREQUENCY

Test specification:	FCC 47 CFR 15.247(e) / RSS-247 section 5.2(2), Peak power density		
Test procedure:	ANSI C63.10, Section 11.10.2		
Test mode:	Compliance	Verdict:	PASS
Date(s):	19-May-19		
Temperature: 24 ºC	Relative Humidity: 46 %	Air Pressure: 1012 hPa	Power: 3 VDC
Remarks:			

7.5 Peak spectral power density

7.5.1 General

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

Table 7.5.1 Peak spectral power density limits

Assigned frequency range, MHz	Measurement bandwidth, kHz	Peak spectral power density, dBm	Equivalent field strength limit @ 3m, dB(µV/m)*
902.0 – 928.0	3.0	8.0	103.2
2400.0 – 2483.5			
5725.0 – 5850.0			

* - 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.

7.5.2 Test procedure for field strength measurements

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

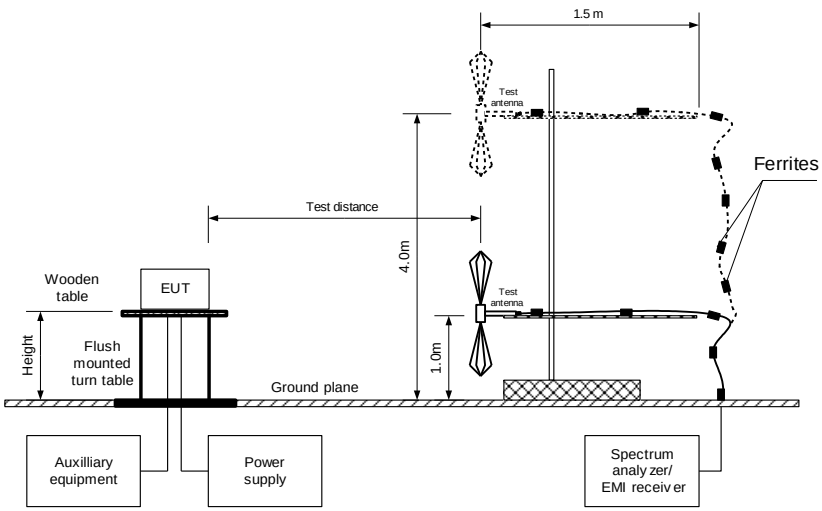
7.5.2.2 The EUT was adjusted to produce maximum available to end user RF output power.

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

7.5.2.4 The frequency span of spectrum analyzer was set to capture the entire 6 dB band of the transmitter, in peak hold mode with resolution bandwidth set to 10.0 kHz, video bandwidth wider than resolution bandwidth, auto sweep time and sufficient number of sweeps was allowed for trace stabilization. The spectrum lines spacing was verified to be wider than 3 kHz. Otherwise the resolution bandwidth was reduced until individual spectrum lines were resolved and the power of individual spectrum lines was integrated over 3 kHz band.

7.5.2.5 The peak of emission was zoomed with span set just wide enough to capture the emission peak area and sweep time was set equal to span width divided by resolution bandwidth. Spectrum analyzer was set in peak hold mode, sufficient number of sweeps was allowed for trace stabilization and peak spectral power density was measured as provided in Table 7.5.2 and associated plots.

Figure 7.5.1 Setup for carrier field strength measurements



Test specification:	**FCC 47 CFR 15.247(e) / RSS-247 section 5.2(2), Peak power density**		
Test procedure:	ANSI C63.10, Section 11.10.2		
Test mode:	Compliance	**Verdict:**	PASS
Date(s):	19-May-19		
Temperature: 24 ºC	**Relative Humidity:** 46 %	**Air Pressure:** 1012 hPa	**Power:** 3 VDC
Remarks:			

Table 7.5.2 Field strength measurement of peak spectral power density

ASSIGNED FREQUENCY: 2400.0 – 2483.5 MHz
TEST DISTANCE: 3 m
TEST SITE: Semi anechoic chamber
EUT HEIGHT: 1.5 m
DETECTOR USED: Peak
RESOLUTION BANDWIDTH: 10 kHz
VIDEO BANDWIDTH: 30 kHz
TEST ANTENNA TYPE: Double ridged guide (above 1000 MHz)
MODULATION: GFSK
MODULATING SIGNAL: PRBS
TRANSMITTER OUTPUT POWER SETTINGS: Maximum

BIT RATE: 1 Mbps

Frequency, MHz	Field strength, dB(μV/m)	EUT antenna gain, dBi	Limit, dBm	Margin, dB*	Antenna polarization	Antenna height, m	Turn-table position**, degrees
2402.0	101.22	5.3	8.0	-7.28	Vertical	1.0	103
2440.0	102.18	5.3	8.0	-6.32	Vertical	1.0	136
2480.0	101.93	5.3	8.0	-6.57	Vertical	1.0	132

BIT RATE: 2 Mbps

Frequency, MHz	Field strength, dB(μV/m)	EUT antenna gain, dBi	Limit, dBm	Margin, dB*	Antenna polarization	Antenna height, m	Turn-table position**, degrees
2402.0	101.29	5.3	8.0	-7.21	Vertical	1.0	103
2440.0	102.31	5.3	8.0	-6.19	Vertical	1.0	136
2480.0	102.01	5.3	8.0	-6.49	Vertical	1.0	132

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

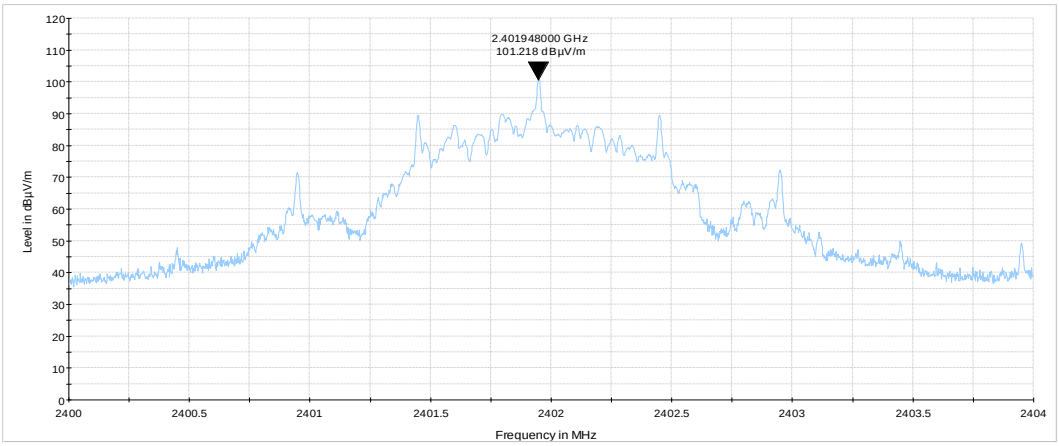
Reference numbers of test equipment used

HL 3903	HL 4360	HL 4933	HL 5405				

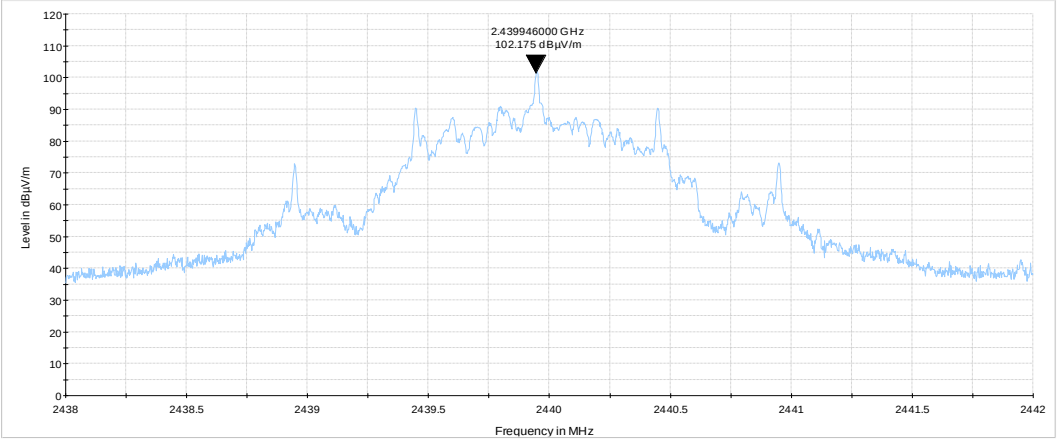
Full description is given in Appendix A.

Test specification:	**FCC 47 CFR 15.247(e) / RSS-247 section 5.2(2), Peak power density**		
Test procedure:	ANSI C63.10, Section 11.10.2		
Test mode:	Compliance	**Verdict:**	PASS
Date(s):	19-May-19		
Temperature: 24 ºC	**Relative Humidity:** 46 %	**Air Pressure:** 1012 hPa	**Power:** 3 VDC
Remarks:			

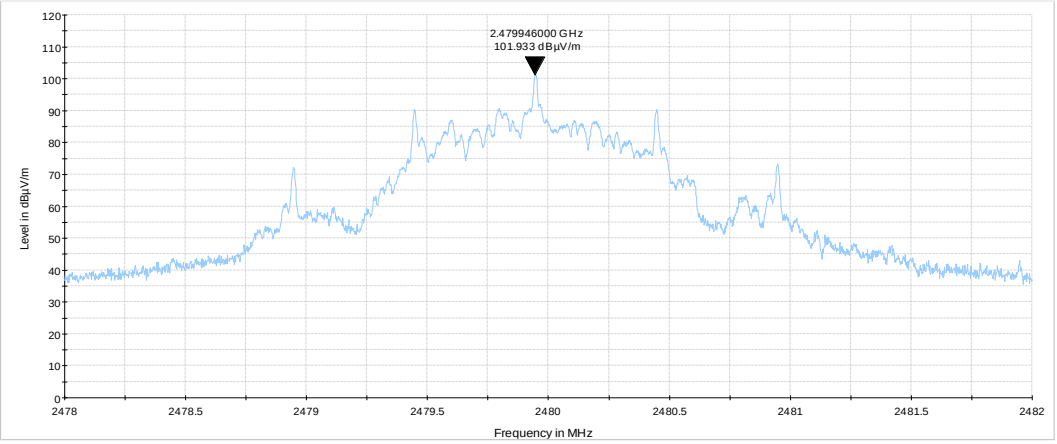
Plot 7.5.1 Peak spectral power density at low frequency with bitrate 1 Mbps



Plot 7.5.2 Peak spectral power density at mid frequency with bitrate 1 Mbps

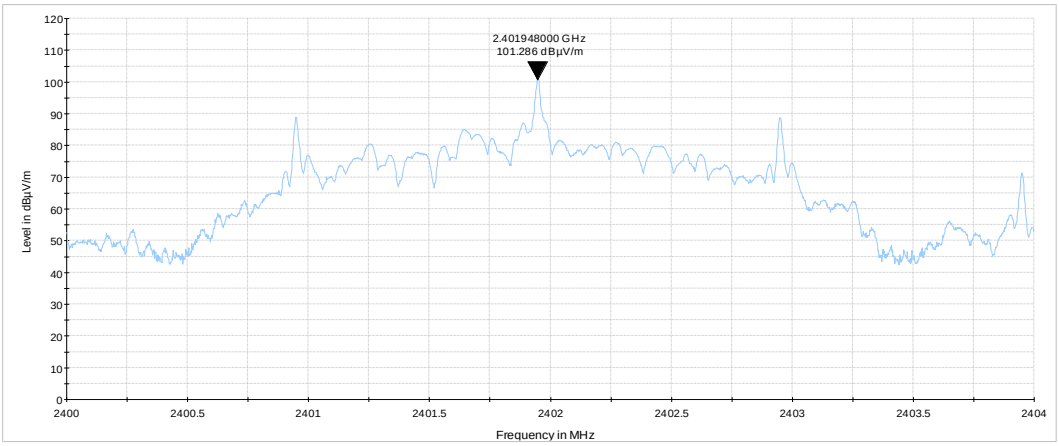


Plot 7.5.3 Peak spectral power density at high frequency with bitrate 1 Mbps

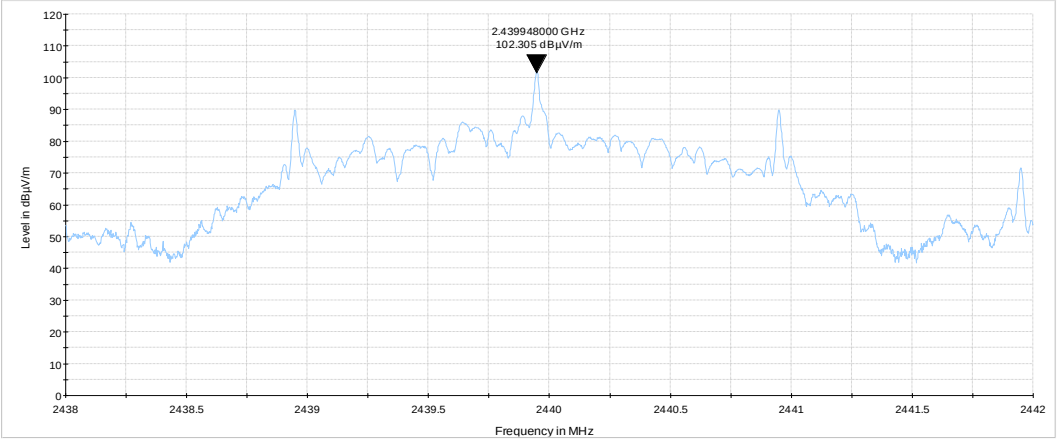


Test specification:	FCC 47 CFR 15.247(e) / RSS-247 section 5.2(2), Peak power density		
Test procedure:	ANSI C63.10, Section 11.10.2		
Test mode:	Compliance	Verdict:	PASS
Date(s):	19-May-19		
Temperature: 24 ºC	Relative Humidity: 46 %	Air Pressure: 1012 hPa	Power: 3 VDC
Remarks:			

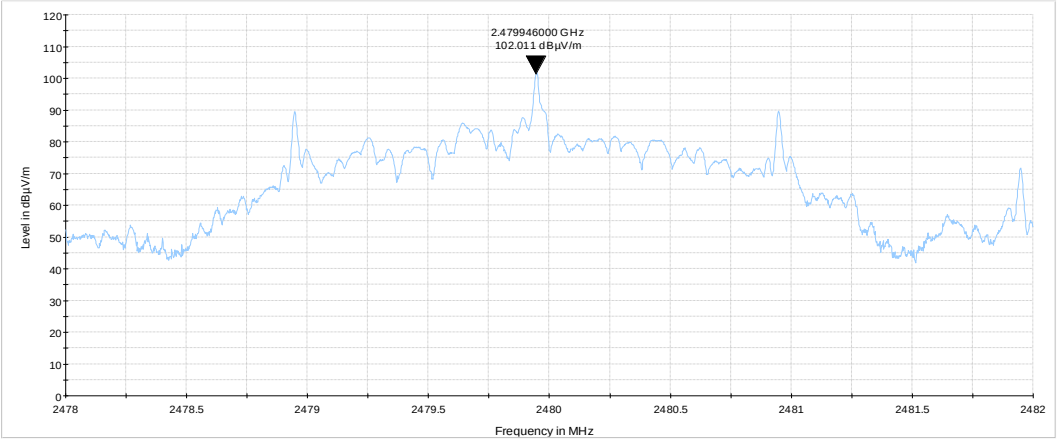
Plot 7.5.4 Peak spectral power density at low frequency with bitrate 2 Mbps



Plot 7.5.5 Peak spectral power density at mid frequency with bitrate 2 Mbps



Plot 7.5.6 Peak spectral power density at high frequency with bitrate 2 Mbps



Test specification:	**FCC 47 CFR 15.203, RSS-Gen section 8.3, Antenna requirements**		
Test procedure:			
Test mode:	Compliance	**Verdict:**	PASS
Date(s):	19-May-19		
Temperature: 24 ºC	**Relative Humidity:** 46 %	**Air Pressure:** 1012 hPa	**Power:** NA
Remarks:			

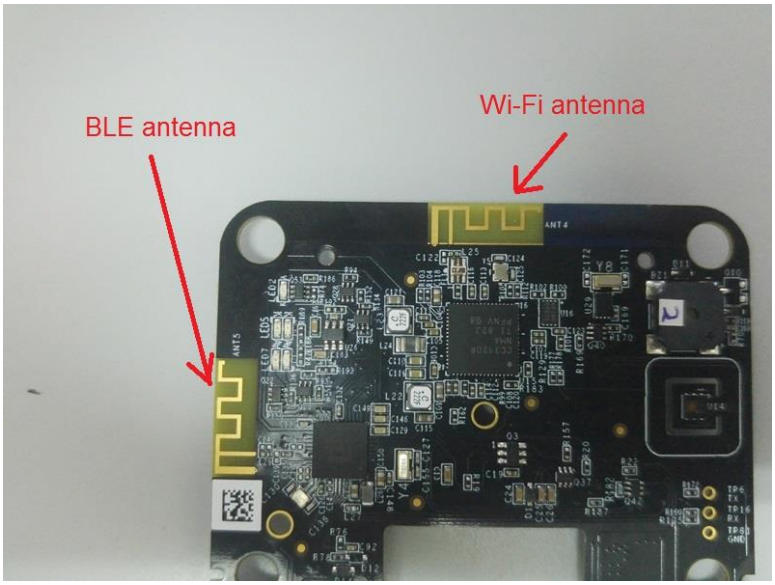
7.6 Antenna requirements

The EUT was verified for compliance with antenna requirements. A transmitter shall be designed to ensure that no antenna other than that furnished by the responsible party will be used with the device. It may be either permanently attached or employs a unique antenna connector for every antenna proposed for use with the EUT. This requirement does not apply to professionally installed transmitters.
The rationale for compliance with the above requirements was either visual inspection results or supplier declaration. The summary of results is provided in Table 7.6.1.

Table 7.6.1 Antenna requirements

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

Photograph 7.6.1 Antenna assembly



Test specification:	FCC 47 CFR 15.109 / ICES-003 section 6.2, Radiated emission		
Test procedure:	ANSI C63.4, Sections 11.6 and 12.1.4		
Test mode:	Compliance	Verdict:	PASS
Date(s):	19-May-19		
Temperature: 24 ºC	Relative Humidity: 46 %	Air Pressure: 1012 hPa	Power: 3 VDC
Remarks:			

8 Unintentional emissions according to FCC 47CFR part 15 subpart B and ICES-003

8.1 Radiated emission measurements

8.1.1 General

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

Table 8.1.1 Radiated emission test limits

Frequency, MHz	Class B limit, dB(μV/m)		Class A limit, dB(μV/m)	
	10 m distance	3 m distance	10 m distance	3 m distance
30 - 88	29.5*	40.0	39.0	49.5*
88 - 216	33.0*	43.5	43.5	54.0*
216 - 960	35.5*	46.0	46.4	56.9*
Above 960	43.5*	54.0	49.5	60.0*

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

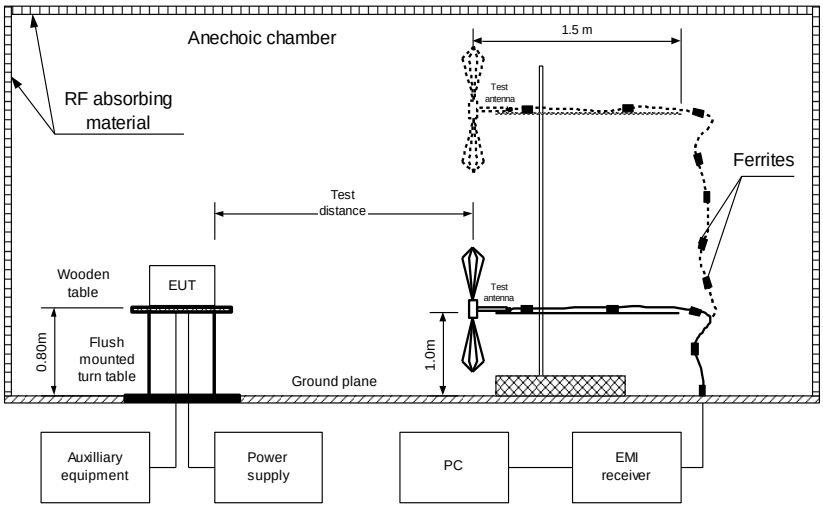
8.1.2 Test procedure for measurements in semi-anechoic chamber

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

8.1.2.2 The measurements were performed in the anechoic chamber at 3 m test distance. The specified frequency range was investigated with the antenna connected to the EMI receiver. To find the highest emission the turntable was rotated 360^0 and the measuring antenna height was swept from 1 to 4 m in both, vertical and horizontal polarizations. The EUT cables position was varied to maximize emission.

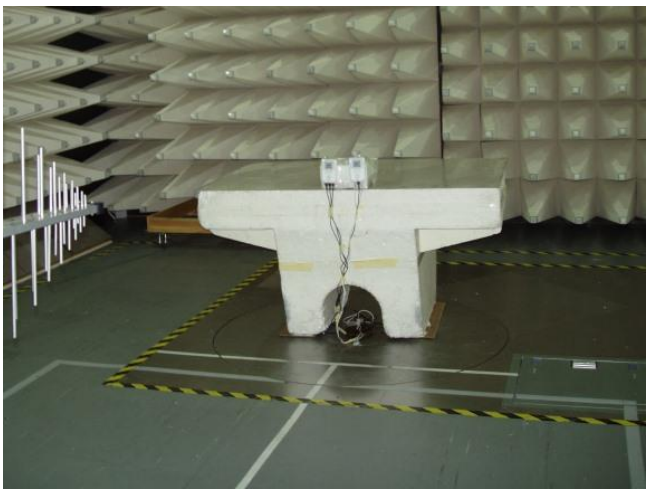
8.1.2.3 The worst test results with respect to the limits were recorded in Table 8.1.2 and shown in the associated plots.

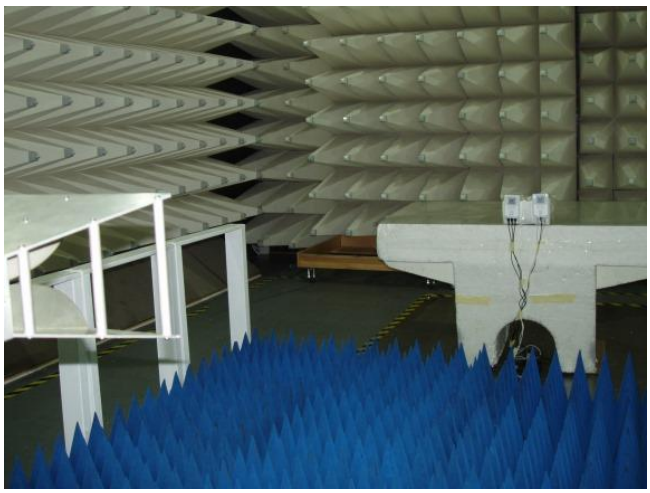
Figure 8.1.1 Setup for radiated emission measurements



Test specification:	FCC 47 CFR 15.109 / ICES-003 section 6.2, Radiated emission		
Test procedure:	ANSI C63.4, Sections 11.6 and 12.1.4		
Test mode:	Compliance	Verdict:	PASS
Date(s):	19-May-19		
Temperature: 24 ºC	Relative Humidity: 46 %	Air Pressure: 1012 hPa	Power: 3 VDC
Remarks:			

Photograph 8.1.1 Setup for radiated emission measurements, general view





Photograph 8.1.2 Setup for final radiated emission measurements, EUT cabling

Test specification:	**FCC 47 CFR 15.109 / ICES-003 section 6.2, Radiated emission**		
Test procedure:	ANSI C63.4, Sections 11.6 and 12.1.4		
Test mode:	Compliance	**Verdict:**	PASS
Date(s):	19-May-19		
Temperature: 24 ºC	**Relative Humidity:** 46 %	**Air Pressure:** 1012 hPa	**Power:** 3 VDC
Remarks:			

Table 8.1.2 Radiated emission test results

EUT SET UP: TABLE-TOP
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*				
30.021900	28.36	21.70	40.0	-18.30	Horizontal	4.00	283	Pass
39.456630	23.90	15.12	40.0	-24.88	Vertical	1.00	351	
46.586173	24.06	17.38	40.0	-22.62	Vertical	1.24	82	
66.595271	25.06	21.00	40.0	-19.00	Horizontal	2.16	8	
71.984533	28.91	23.70	40.0	-16.30	Horizontal	1.02	250	
80.020167	27.20	24.41	40.0	-15.59	Horizontal	1.02	7	
148.527232	26.18	20.24	43.5	-23.26	Horizontal	2.46	102	
445.493728	38.57	34.50	46.0	-11.50	Horizontal	1.53	180	
30.021900	28.36	21.70	40.0	-18.30	Horizontal	4.00	283	
891.016075	40.97	35.82	46.0	-10.18	Vertical	4.00	321	

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

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

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

Reference numbers of test equipment used

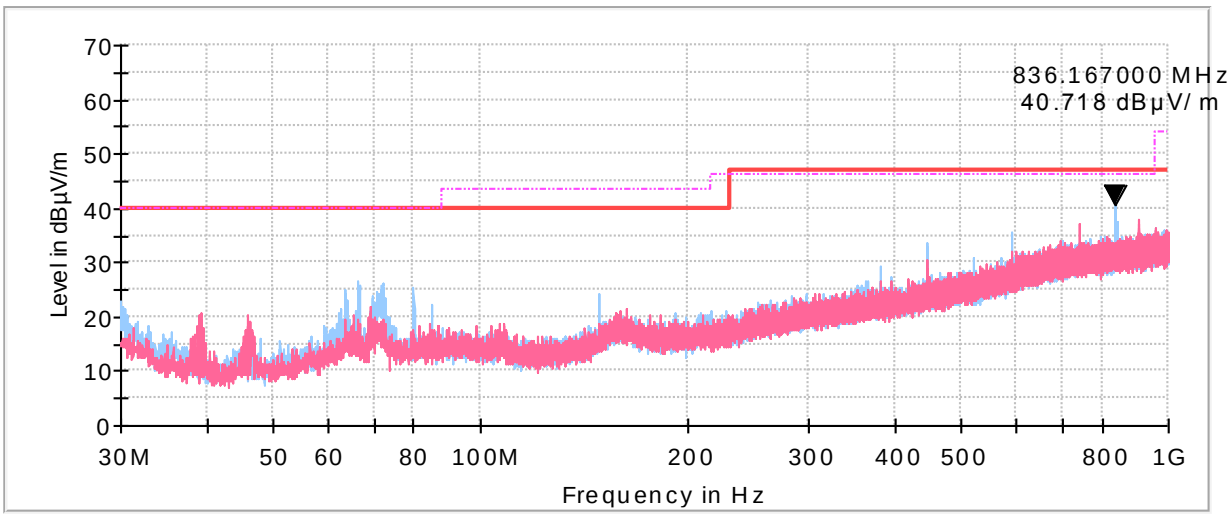
HL 0604	HL 3903	HL 4011	HL 4360	HL 4933	HL 5084	HL 5405	

Full description is given in Appendix A.

Test specification:	FCC 47 CFR 15.109 / ICES-003 section 6.2, Radiated emission		
Test procedure:	ANSI C63.4, Sections 11.6 and 12.1.4		
Test mode:	Compliance	Verdict:	PASS
Date(s):	19-May-19		
Temperature: 24 ºC	Relative Humidity: 46 %	Air Pressure: 1012 hPa	Power: 3 VDC
Remarks:			

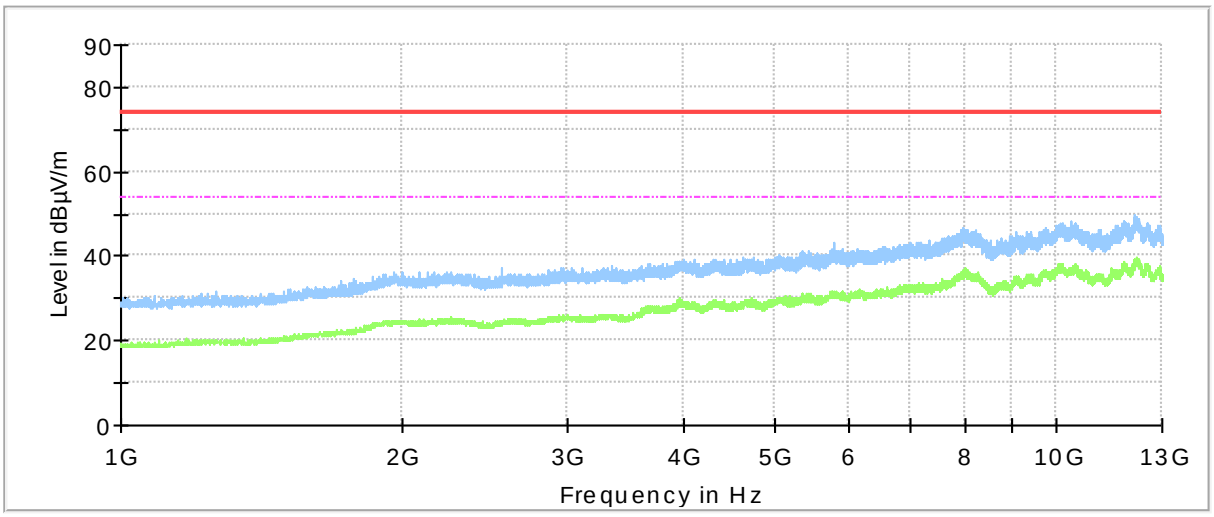
Plot 8.1.1 Radiated emission measurements in 30 - 1000 MHz range, vertical and horizontal antenna polarization

TEST SITE: Anechoic chamber
TEST DISTANCE: 3 m



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

TEST SITE: Anechoic chamber
TEST DISTANCE: 3 m



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
0604	Antenna BiconiLog Log-Periodic/T Bow-TIE, 26 - 2000 MHz	EMCO	3141	9611-1011	03-Jun-18	03-Jun-19
3818	PSA Series Spectrum Analyzer, 3 Hz- 44 GHz	Agilent Technologies	E4446A	MY48250288	24-Apr-19	24-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
4011	Temp. & Humidity Meter, (-50 - +70) deg, (20 - 99)% RH	Mad Electronics	HTC-1	NA	06-Aug-18	06-Aug-19
4135	Shield Box	TESCOM CO., LTD	TC-5916A	5916A000136	24-Apr-19	24-Apr-20
4360	EMI Test Receiver, 20 Hz to 40 GHz.	Rohde & Schwarz	ESU40	100322	31-Dec-18	31-Dec-19
4933	Active Horn Antenna, 1 GHz to 18 GHz	COM-POWER CORPORATION	AHA-118	701046	06-Jan-19	06-Jan-20
4956	Active horn antenna, 18 to 40 GHz	COM-POWER CORPORATION	AHA-840	105004	25-Jan-19	25-Jan-20
5084	Attenuator, 4 dB, DC - 6 GHz, 1 W	Mini-Circuits	UNAT-4+	NA	05-Jun-18	05-Jun-19
5111	RF cable, 40 GHz, 5.5 m, K-type	Huber-Suhner	SF102EA/11SK/11SK/5500MM	502493/2EA	18-Apr-19	18-Apr-20
5405	RF cable, 18 GHz, N-N, 6 m	Huber-Suhner	SF118/11N(x2)	500023/118	01-Aug-18	01-Aug-19

10 APPENDIX B Test laboratory description

Tests were performed at Hermon Laboratories Ltd., which is a fully independent, private, EMC, Radio, Safety, Environmental and Telecommunication testing facility.
Hermon Laboratories is recognized and accredited by the Federal Communications Commission (USA) for relevant parts of Code of Federal Regulations 47 (CFR 47), Test Firm Registration Number is 927748, Designation Number is IL1001; Recognized by Innovation, Science and Economic Development Canada for wireless and terminal testing (ISED), CAB identifier is IL1001, ISED# number 2186A; 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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website: www.hermonlabs.com

Person for contact: Mr. M. Nikishin, EMC and radio group leader

11 APPENDIX C 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 0604: Antenna BiconiLog Log-Periodic/T Bow-TIE
EMCO, model 3141, serial number 9611-1011

Frequency, MHz	Antenna factor, dB/m
30	12.1
35	9.1
40	8.0
45	8.3
50	9.0
60	10.5
70	11.4
80	12.3
90	13.4
100	13.0
120	11.4
140	12.5

Frequency, MHz	Antenna factor, dB/m
160	14.9
180	14.4
200	13.7
250	16.3
300	17.2
400	19.8
500	22.0
600	24.3
700	25.8
800	26.9
900	27.3
1000	28.5

The antenna factor shall be added to receiver reading in dBμV to obtain field strength in dBμV/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 4956: Active horn antenna
COM-POWER Corp., model: AHA-840, s/n 105004

Frequency, MHz	Measured antenna factor, dB/m
18000	5.1
18500	3.6
19000	2.2
19500	0.7
20000	0.7
20500	0.8
21000	0.5
21500	-1.3
22000	-2.1
22500	-2.0
23000	-1.6
23500	-2.9
24000	-2.3
24500	-2.6
25000	-1.8
25500	-1.2
26000	-0.5
26500	-1.2
27000	-0.1
27500	-1.0
28000	-0.7
28500	0.5

Frequency, MHz	Measured antenna factor, dB/m
29500	1.4
30000	2.9
30500	2.9
31000	2.9
31500	1.2
32000	0.7
32500	0.2
33000	-1.7
33500	-2.2
34000	2.3
34500	-1.1
35000	0.7
35500	-1.1
36000	0.1
36500	1.4
37000	3.7
37500	5.8
38000	6.6
38500	7.3
39000	6.5
39500	7.3
40000	7.1

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

HL 5111: RF cable

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

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

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

HL 5405: RF cable
Huber-Suhner, SF118/11N(x2), s/n 500023/118

Set / Applied, MHz	Measured, dB	Uncertainty, dB
0.1	0.01	±0.07
50	0.23	±0.07
100	0.32	±0.07
200	0.45	±0.08
300	0.55	±0.08
400	0.64	±0.08
500	0.71	±0.08
600	0.78	±0.08
700	0.85	±0.08
800	0.91	±0.08
900	0.97	±0.08
1000	1.02	±0.08
1100	1.07	±0.08
1200	1.12	±0.08
1300	1.16	±0.08
1400	1.21	±0.08
1500	1.25	±0.08
1600	1.30	±0.08
1700	1.34	±0.08
1800	1.38	±0.08
1900	1.42	±0.08
2000	1.47	±0.08
2500	1.64	±0.10
3000	1.81	±0.10
3500	1.97	±0.10
4000	2.11	±0.10
4500	2.25	±0.10

Set / Applied, MHz	Measured, dB	Uncertainty, dB
5000	2.38	±0.10
5500	2.48	±0.10
6000	2.59	±0.10
6500	2.72	±0.10
7000	2.84	±0.13
7500	2.97	±0.13
8000	3.08	±0.13
8500	3.21	±0.13
9000	3.31	±0.13
9500	3.42	±0.13
10000	3.52	±0.13
10500	3.62	±0.13
11000	3.72	±0.13
11500	3.81	±0.13
12000	3.93	±0.13
12500	4.00	±0.18
13000	4.09	±0.18
13500	4.18	±0.18
14000	4.26	±0.18
14500	4.35	±0.18
15000	4.45	±0.22
15500	4.54	±0.22
16000	4.61	±0.22
16500	4.69	±0.22
17000	4.78	±0.22
17500	4.84	±0.22
18000	4.92	±0.27

12 APPENDIX D Measurement uncertainties

Expanded uncertainty at 95% confidence in Hermon Labs EMC measurements

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

Hermon Laboratories is accredited by A2LA for calibration according to present requirements of ISO/IEC 17025 and NCSL Z540-1. The accreditation is granted to perform calibration of parameters that are listed in the Scope of Hermon Laboratories Accreditation.
Hermon Laboratories calibrates its reference and transfer standards by calibration laboratories accredited to ISO/IEC 17025 by a mutually recognized Accreditation Body or by a recognized national metrology institute. All reference and transfer standards used in the calibration system are traceable to national or international standards.
In-house calibration of all test and measurement equipment is performed on a regular basis according to Hermon Laboratories calibration procedures, manufacturer calibration/verification procedures or procedures defined in the relevant standards. The Hermon Laboratories test and measurement equipment is calibrated within the tolerances specified by the manufacturers and/or by the relevant standards.

13 APPENDIX E Specification references

FCC 47CFR part 15:2017	Radio Frequency Devices.
RSS-247:2017, Issue 2	Digital Transmission Systems (DTSs), Frequency Hopping Systems (FHSs) and License-Exempt Local Area Network (LE-LAN) Devices
RSS-Gen:2018, Issue 5 +A1(19)	General Requirements for Compliance of Radio Apparatus
ICES-003:2016, Issue 6 updated (2019)	Information Technology Equipment (Including Digital Apparatus) — Limits and Methods of Measurement
ANSI C63.2:2016	American National Standard for Instrumentation-Electromagnetic Noise and Field Strength, 10 kHz to 40 GHz-Specifications.
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
558074 D01 DTS Meas_Guidance v05	Guidance for compliance measurements on Digital Transmission System, Frequency Hopping Spread Spectrum System, and Hybrid System Devices operating under section 15.247 of the FCC rules

14 APPENDIX F Abbreviations and acronyms

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

END OF DOCUMENT