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FCC RF Test Report

Test Report Number	CBE-20042421-LC-FCC-AH110
Applicant	CubeWorks Inc.
Applicant Address	1600 HURON PARKWAY, OFC 520-2364, ANN ARBOR, MI 48109, USA
Product Name	CubiSensTM AH110 Wireless Sensor
Model (s)	AH110
Date of Receipt	05/21/2020
Date of Test	05/21/2020 – 05/27/2020
Report Issue Date	05/27/2020
Test Standards	47CFR Part 15.249, Subpart C
Test Result	**PASS**

Issued by:

Vista Compliance Laboratories
1261 Puerta Del Sol, San Clemente, CA 92673 USA
www.vista-compliance.com

Daniel Bruno (Test Technician)

David Zhang (Technical Manager)

REVISION HISTORY

Report Number	Version	Description	Issued Date
CBE-20042421-LC-FCC-AH110	01	Initial report	05/27/2020

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1 Test Summary

Test Item	Test Requirement	Test Method	Result
20 dB Bandwidth	47CFR Part 15, Subpart C Section 15.215	ANSI C63.10 (2013)	Pass
Occupied Bandwidth	47CFR Part 15, Subpart C	ANSI C63.10 (2013)	Pass
Duty Cycle	47CFR Part 15, Subpart C	ANSI C63.10 (2013)	Pass
Fundamental Field Strength and Radiated Spurious Emission	47CFR Part 15, Subpart C Section 15.205/15.209	ANSI C63.10 (2013)	Pass

2 General Information

2.1 Applicant

Applicant	CubeWorks, Inc.
Applicant address	1600 HURON PARKWAY, OFC 520-2364, ANN ARBOR, MI 48109, USA
Manufacturer	CubeWorks, Inc.
Manufacturer Address	1600 HURON PARKWAY, OF C520-2364, ANN ARBOR, MI 48109, USA

2.2 Product information

Product Name	CubiSensTM AH110 Wireless Sensor
Model Number	AH110
Family Models	N/A
Serial Number	1170
Frequency Band	904.5-926.5MHz
Type of modulation	N/A
Equipment Class	DXX
Antenna Information	Internal Antenna
Clock Frequencies	N/A
Input Power	Battery Operated
Power Adapter Manufacturer/Model	N/A
Power Adapter SN	N/A
Hardware version	N/A
Software version	N/A
Simultaneous Transmission	N/A
Additional Info	N/A

2.3 Test standard and method

Test standard	47CFR Part 15.249, Subpart C
Test method	ANSI C63.10 (2013)

3 Test Site Information

Lab performing tests	Vista Laboratories, Inc.
Lab Address	1261 Puerta Del Sol, San Clemente, CA 92673 USA
Phone Number	+1 (949) 393-1123
Website	www.vista-compliance.com

Test Condition	Temperature	Humidity	Atmospheric Pressure
RF Testing	23.5°C	58.2%	996 mbar

4 Modification of EUT / Deviations from Standards

N/A

5 Test Configuration and Operation

5.1 EUT Test Configuration

The EUT is powered by an internal battery. EUT was set to continuous transmission mode during TX testing.

The following software was used for testing and to monitor EUT performance

Software	Description
EMISoft Vasona	EMC/RF Spurious emission test software used during testing

5.2 Supporting Equipment

Description	Manufacturer	Model #	Serial #
-	-	-	-

6 Uncertainty of Measurement

Test item	Measurement Uncertainty (dB)
RF Conducted Measurement (30MHz – 18GHz)	±1.5 dB
Radiated Emission (30MHz-1GHz)	±4.6 dB
Radiated Emission (1-18GHz)	±4.9 dB
Radiated Emission (18-40GHz)	±3.5 dB

7 Test Results

7.1 20 dB Bandwidth

7.1.1 Requirement

§ 15.215 (c)

Intentional radiators operating under the alternative provisions to the general emission limits, as contained in §§15.217 through 15.257 and in subpart E of this part, must be designed to ensure that the 20 dB bandwidth of the emission, or whatever bandwidth may otherwise be specified in the specific rule section under which the equipment operates, is contained within the frequency band designated in the rule section under which the equipment is operated.

7.1.2 Test Setup

7.1.3 Test Procedure

According to subclause 6.9.2 of ANSI C63.10-2013:

a) The spectrum analyzer center frequency is set to the nominal EUT channel center frequency. The span range for the EMI receiver or spectrum analyzer shall be between two times and five times the OBW.

b) The nominal IF filter bandwidth (3 dB RBW) shall be in the range of 1% to 5% of the OBW and video bandwidth (VBW) shall be approximately three times RBW, unless otherwise specified by the applicable requirement.

c) Set the reference level of the instrument as required, keeping the signal from exceeding the maximum input mixer level for linear operation. In general, the peak of the spectral envelope shall be more than [10 log (OBW/RBW)] below the reference level. Specific guidance is given in 4.1.5.2.

d) Steps a) through c) might require iteration to adjust within the specified tolerances.

e) The dynamic range of the instrument at the selected RBW shall be more than 10 dB below the target "-xx dB down" requirement; that is, if the requirement calls for measuring the -20 dB OBW, the instrument noise floor at the selected RBW shall be at least 30 dB below the reference value.

f) Set detection mode to peak and trace mode to max hold.

g) Determine the reference value: Set the EUT to transmit an unmodulated carrier or modulated signal, as applicable. Allow the trace to stabilize. Set the spectrum analyzer marker to the highest level of the displayed trace (this is the reference value).

h) Determine the "−xx dB down amplitude" using [(reference value) - xx]. Alternatively, this calculation may be made by using the marker-delta function of the instrument.

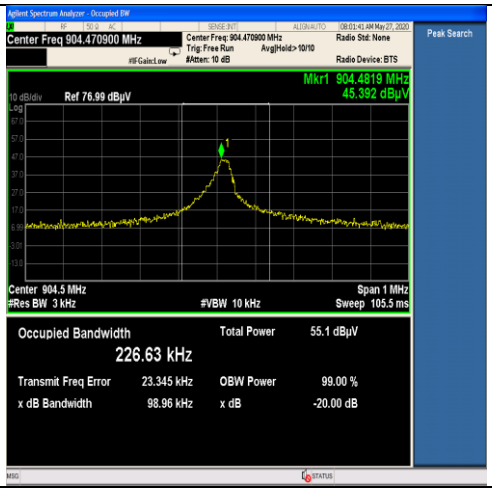
i) If the reference value is determined by an unmodulated carrier, then turn the EUT modulation ON, and either clear the existing trace or start a new trace on the spectrum analyzer and allow the new trace to stabilize. Otherwise, the trace from step g) shall be used for step j).

j) Place two markers, one at the lowest frequency and the other at the highest frequency of the envelope of the spectral display, such that each marker is at or slightly below the "-xx dB down amplitude" determined in step h). If a marker is below this "-xx dB down amplitude" value, then it shall be as close as possible to this value. The occupied bandwidth is the frequency difference between the two markers. Alternatively, set a marker at the lowest frequency of the envelope of the spectral display, such that the marker is at or slightly below the "-xx dB down amplitude" determined in step h). Reset the marker-delta function and move the marker to the other side of the emission until the delta marker amplitude is at the same level as the reference marker amplitude. The marker-delta frequency reading at this point is the specified emission bandwidth.

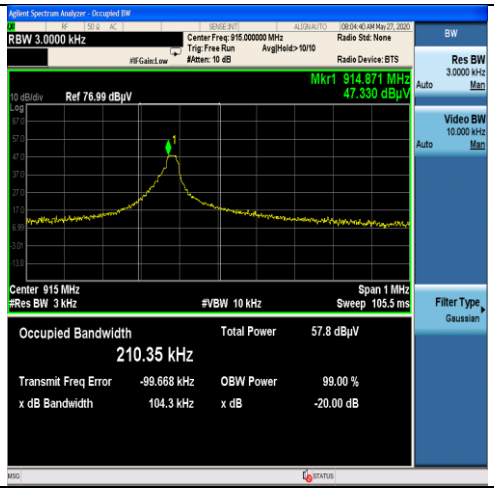
k) The occupied bandwidth shall be reported by providing plot(s) of the measuring instrument display; the plot axes and the scale units per division shall be clearly labelled. Tabular data may be reported in addition to the plot(s).

7.1.4 Test Result

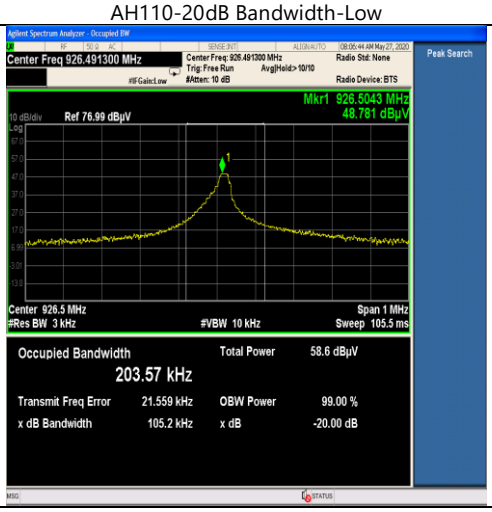
Channel	Frequency (MHz)	Measured Bandwidth (kHz)	Frequency Lower (MHz)	Frequency Upper (MHz)	Result
Low	904.5	98.96	904.45	904.55	Pass
Mid	915.0	104.3	914.95	915.05	Pass
High	926.5	105.2	926.45	926.55	Pass



AH110-20dB Bandwidth-Low



AH110-20dB Bandwidth-Mid



AH110-20dB Bandwidth-High

7.2 Occupied Bandwidth (99%)

7.2.1 Requirement

The 99% OBW is for reporting purpose only. The occupied bandwidth is the frequency bandwidth such that, below its lower and above its upper frequency limits, the mean powers are each equal to 0.5% of the total mean power of the given emission.

7.2.2 Test Procedure

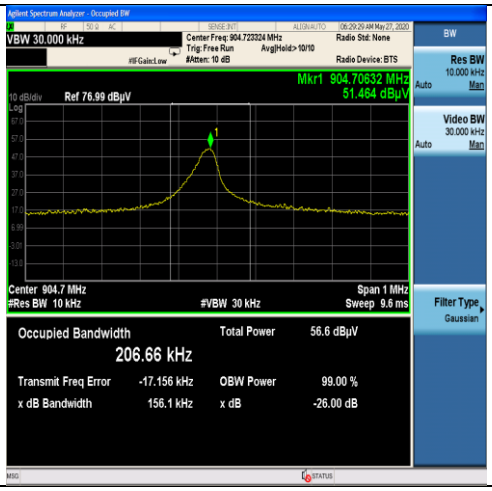
According to subclause 6.9.3 of ANSI C63.10-2013:

1. Set RBW = 1% to 5% of the actual occupied BW.
2. Set the video bandwidth (VBW) ≥ 3 x RBW.
3. Detector = Peak.
4. Trace mode = max hold.
5. Sweep = auto couple.
6. Span = large enough to capture all products of the modulation process
7. Allow the trace to stabilize.
8. Use automatic bandwidth measurement capability on instrument to obtain BW result.

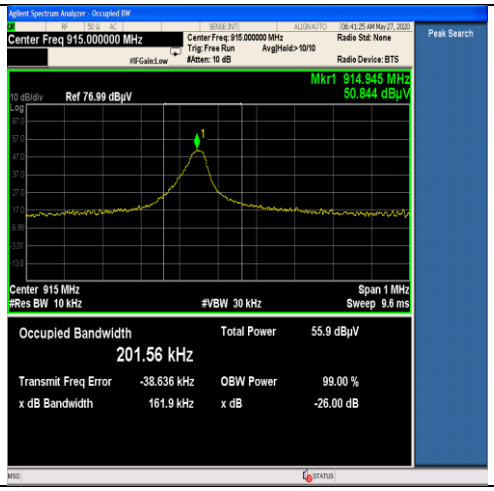
7.2.3 Test Setup

7.2.4 Test Results

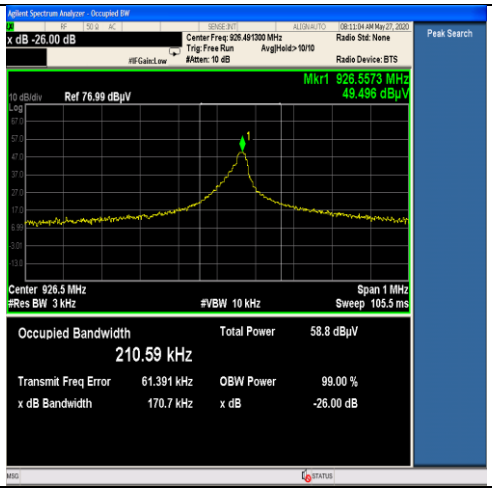
Channel	Frequency (MHz)	Measured Bandwidth (kHz)	Limit (KHz)	Result
Low	904.5	206.66	N/A	N/A
Mid	915.0	201.56	N/A	N/A
High	926.5	210.59	N/A	N/A



AH110-99% Bandwidth-Low



AH110-99% Bandwidth-Mid



AH110-99% Bandwidth-High

7.3 Duty Cycle

7.3.1 Requirement

The duty cycle is for reporting purpose only.

7.3.2 Test Procedure

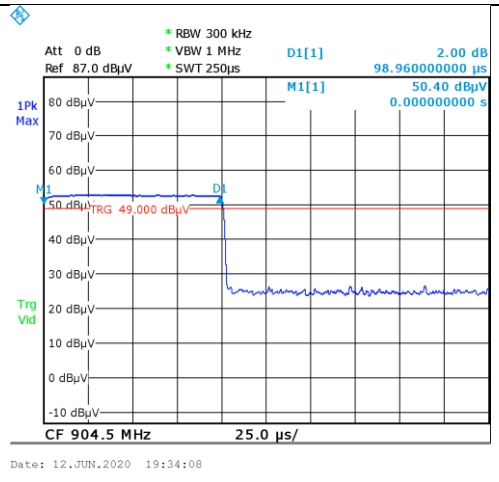
According to subclause 11.6 of ANSI C63.10-2013:

1. Set spectrum analyser to zero span mode and center frequency to the test frequency.
2. Set RBW ≥ OBW
3. Set the video bandwidth (VBW) ≥ RBW.
4. Detector = Peak.
5. Trace mode = max hold.
6. Sweep = auto couple.
7. The zero-span measurement method shall not be used unless both RBW and VBW are > 50/T and the number of sweep points across duration T exceeds 100. (For example, if VBW and/or RBW are limited to 3 MHz, then the zero-span method of measuring the duty cycle shall not be used if T ≤16.7 uS)

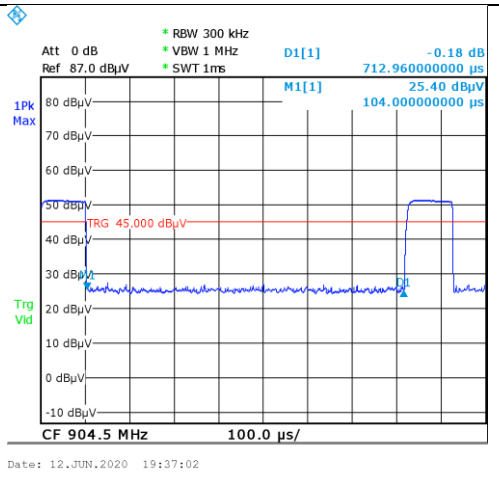
7.3.3 Test Setup

7.3.4 Test Result

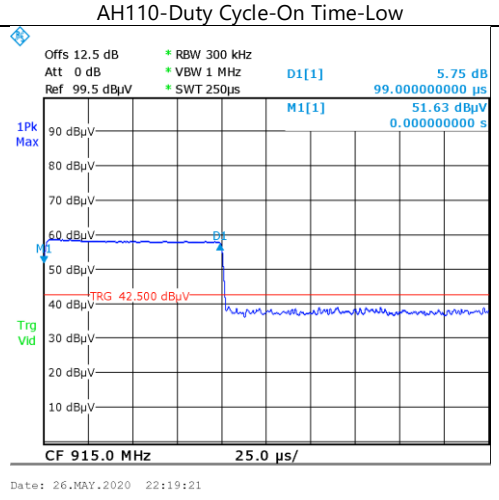
Mode/Bandwidth	Frequency (MHz)	On Time (ms)	Off Time (ms)	Duty Cycle (%)	1/T Minimum VBW (kHz)
Low	904.5	0.09896	0.71296	0.122	10.11
Mid	915.0	0.09900	0.69650	0.124	10.10
High	926.5	0.10100	0.71096	0.124	9.90



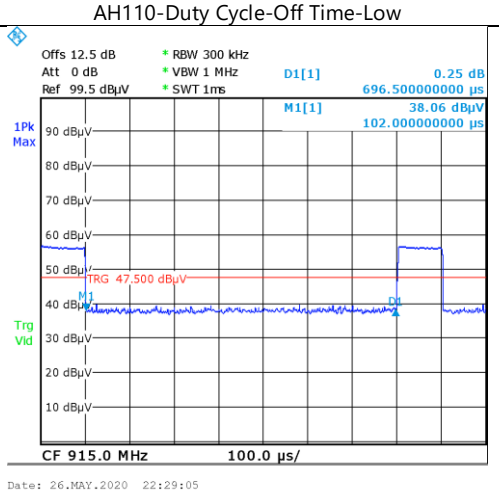
AH110-Duty Cycle-On Time-Low



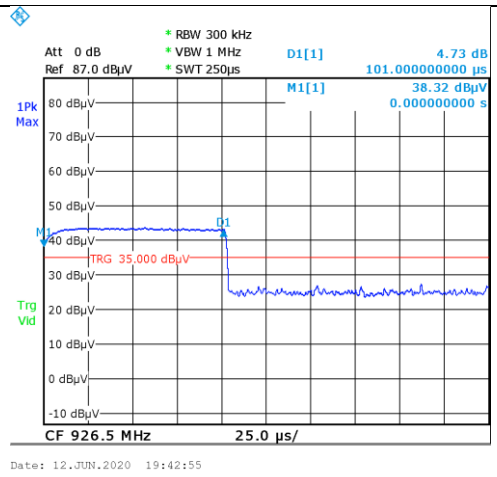
AH110-Duty Cycle-Off Time-Low



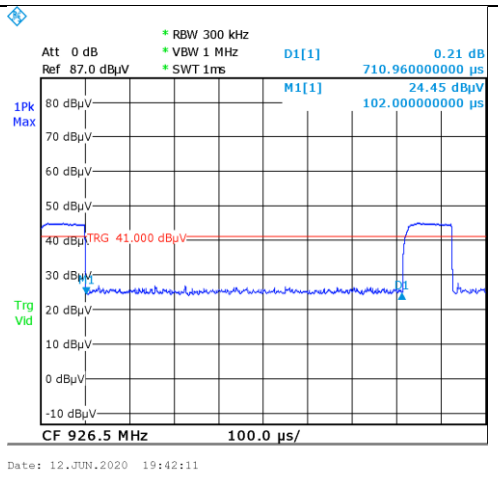
AH110-Duty Cycle-On Time-Mid



AH110-Duty Cycle-Off Time-Mid



AH110-Duty Cycle-On Time-High



AH110-Duty Cycle-Off Time-High

7.4 Fundamental Field Strength and Radiated Spurious Emission

7.4.1 Requirement

§ 15.249 (a)

Except as provided in paragraph (b) of this section, the field strength of emissions from intentional radiators operated within these frequency bands shall comply with the following:

Fundamental frequency	Field strength of fundamental (millivolts/meter)	Field strength of harmonics (microvolts/meter)
902-928 MHz	50	500
2400-2483.5 MHz	50	500
5725-5875 MHz	50	500
24.0-24.25 GHz	250	2500

(c) Field strength limits are specified at a distance of 3 meters.

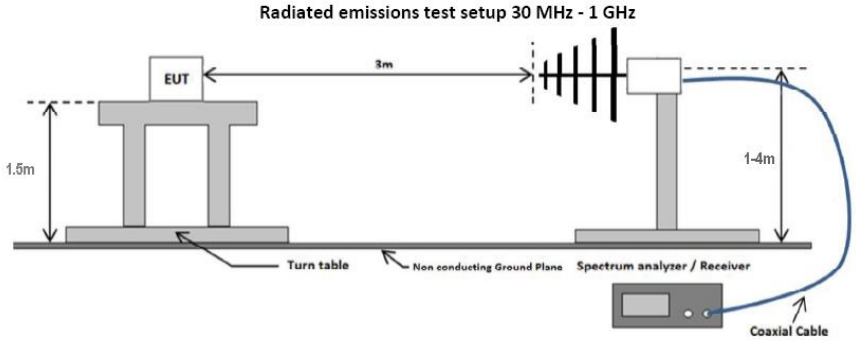
(d) Emissions radiated outside of the specified frequency bands, except for harmonics, shall be attenuated by at least 50 dB below the level of the fundamental or to the general radiated emission limits in §15.209, whichever is the lesser attenuation.

Frequency Range (MHZ)	Field Strength (μV/m)
0.009~0.490	2400/F(kHz)
0.490~1.705	24000/F(kHz)
1.705~30.0	30
30 – 88	100
88 – 216	150
216 960	200
Above 960	500

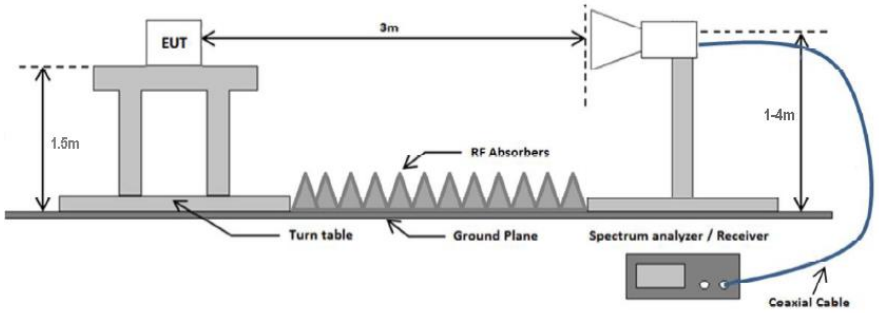
(e) As shown in §15.35(b), for frequencies above 1000 MHz, the field strength limits in paragraphs (a) and (b) of this section are based on average limits. However, the peak field strength of any emission shall not exceed the maximum permitted average limits specified above by more than 20 dB under any condition of modulation. For point-to-point operation under paragraph (b) of this section, the peak field strength shall not exceed 2500 millivolts/meter at 3 meters along the antenna azimuth

7.4.2 Test Setup

Radiated emissions test setup 30 MHz - 1 GHz



Radiated emissions test setup above 1 GHz



7.4.3 Test Procedure

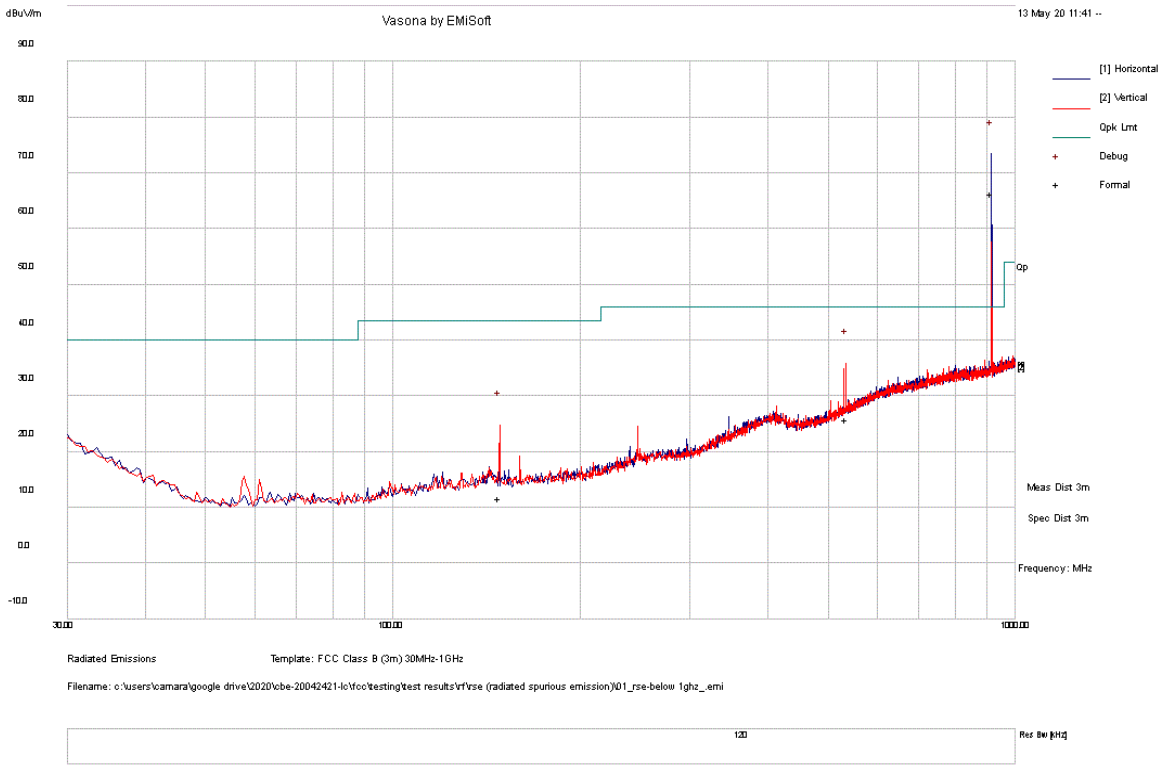
According to subclause 11.12.2.7, Radiated spurious emission measurements, in ANSI C63.10-2013:

1. The EUT was switched on and allowed to warm up to its normal operating condition.
2. The test was carried out at the selected frequency points obtained from the EUT characterization. Maximization of the emissions, was carried out by rotating the EUT, changing the antenna polarization, and adjusting the antenna height in the following manner:
    a. Vertical or horizontal polarization (whichever gave the higher emission level over a full rotation of the EUT was chosen.
    b. The EUT was then rotated to the direction that gave the maximum emission.
    c. Finally, the antenna height was adjusted to the height that gave the maximum emission.
3. The resolution bandwidth and video bandwidth of test receiver/spectrum analyzer is 300 Hz for frequencies below 150KHz.
4. The resolution bandwidth and video bandwidth of test receiver/spectrum analyzer is 10 kHz for frequency between 150KHz – 30MHz.
5. The resolution bandwidth and video bandwidth of test receiver/spectrum analyzer is 120 kHz for Quasi-Peak detection at frequency between 30MHz - 1GHz.
6. The resolution bandwidth of test receiver/spectrum analyzer is 1MHz and video bandwidth is 3MHz with Peak detection for Peak and average measurement at frequency above 1GHz.
7. Steps 2 and 3 were repeated for the next frequency point, until all selected frequency points were measured.

7.4.4 Test Result

FUNDAMENTAL FIELD STRENGTH

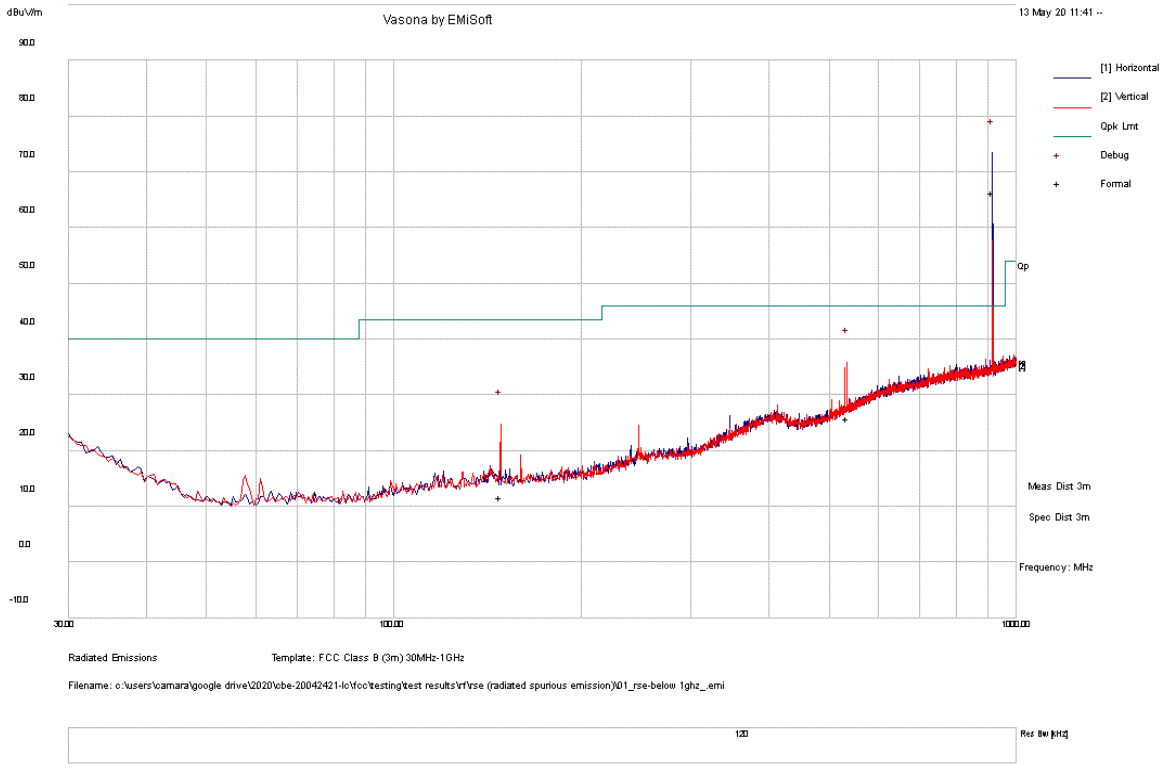
Test Standard:	15.249	Mode:	Fundamental Field Strength
Frequency Range:	30 MHz - 1 GHz	Test Date:	05/21/2020 - 05/27/2020
Antenna Type/Polarity:	Bi-Log/Hor & Ver	Test Personnel:	Daniel Bruno
Remark:	N/A	Test Result:	Pass



Frequency MHz	Raw dBuV	Cable Loss	AF dB	Level dBuV/m	Measurement Type	Pol	Hgt cm	Azt Deg	Limit dBuV/m	Margin dB	Pass/Fail
915.36	72.10	7.67	-6.43	73.40	Peak Max	H	146	189	94.00	-20.60	Pass
915.36	65.14	7.67	-6.43	66.38	Quasi Max	H	146	189	94.00	-27.62	Pass

RADIATED SPURIOUS EMISSION BELOW 1GHZ

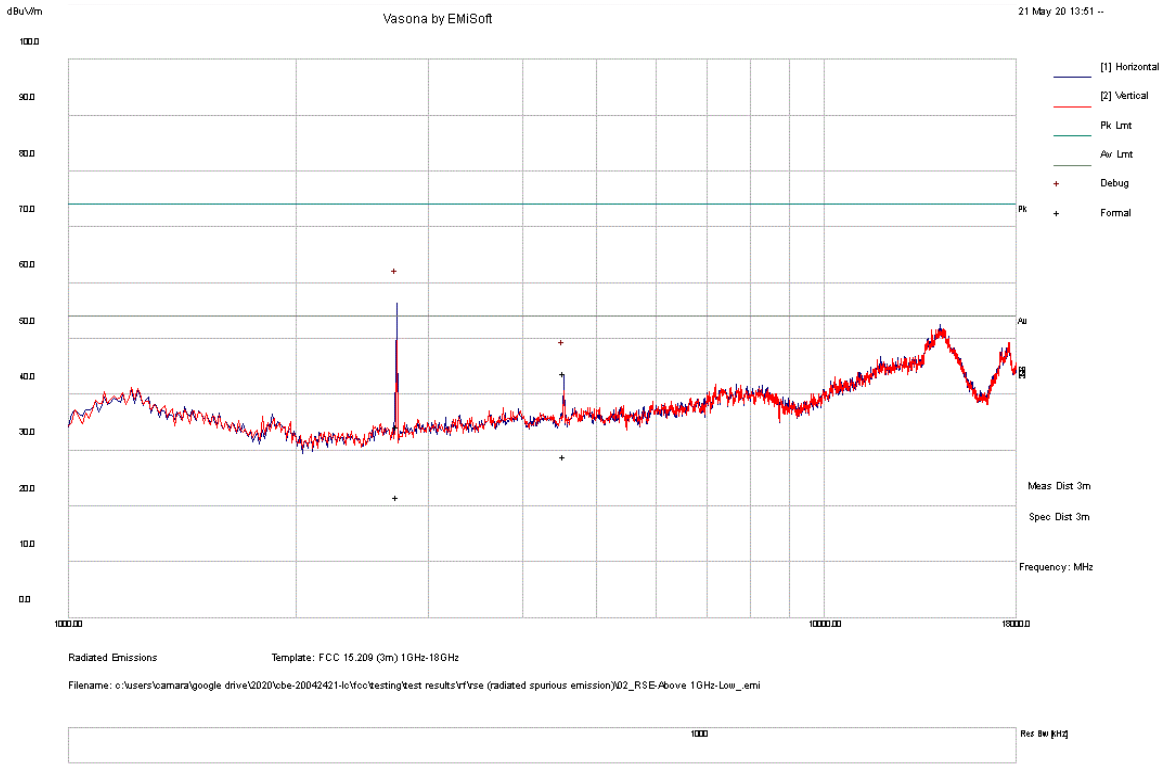
Test Standard:	15.249, 15.209	Mode:	RSE-Below 1GHz
Frequency Range:	30 MHz - 1 GHz	Test Date:	05/21/2020 - 05/27/2020
Antenna Type/Polarity:	Bi-Log/Hor & Ver	Test Personnel:	Daniel Bruno
Remark:	N/A	Test Result:	Pass



Frequency MHz	Raw dBuV	Cable Loss	AF dB	Level dBuV/m	Measurement Type	Pol	Hgt cm	Azt Deg	Limit dBuV/m	Margin dB	Pass/Fail
915.36	65.14	7.67	-6.43	66.38	Quasi Max	H	146	189	94.00	-27.62	Pass
534.05	31.01	6.47	-11.73	25.75	Quasi Max	V	100	198	46.00	-20.25	Pass
148.38	29.68	4.23	-22.33	11.57	Quasi Max	V	125	288	43.50	-31.93	Pass

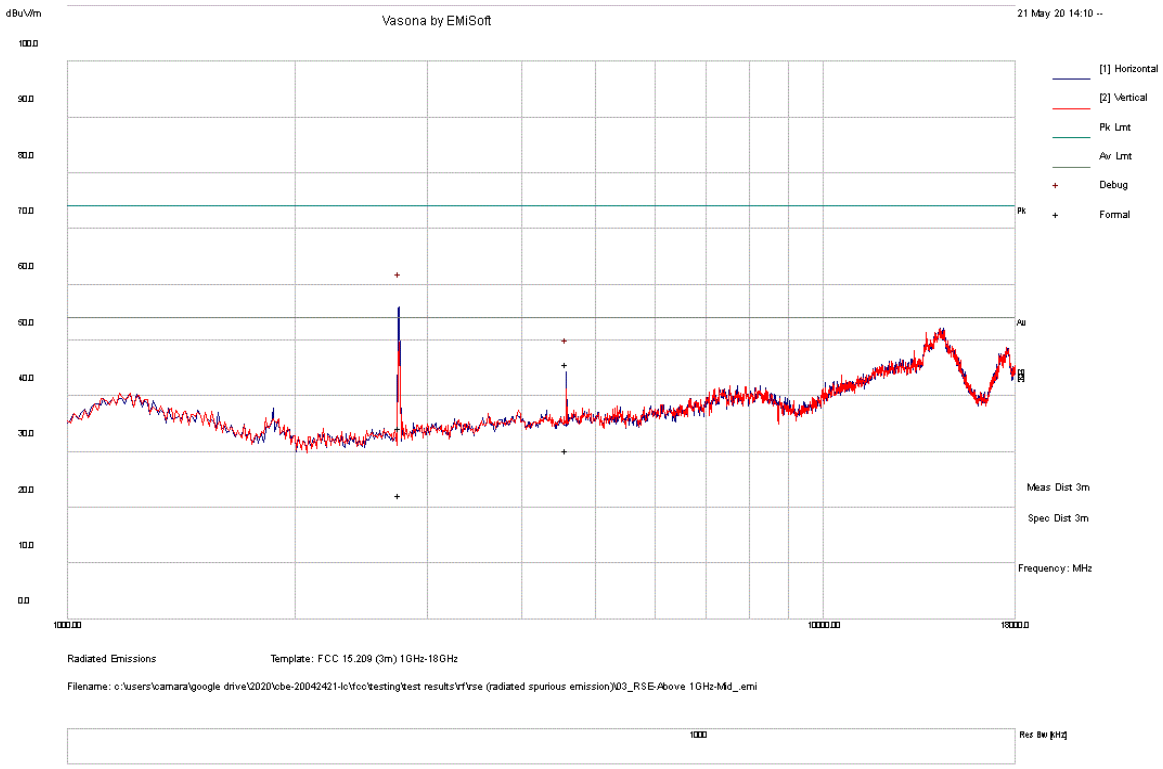
RADIATED SPURIOUS EMISSION ABOVE 1GHZ

Test Standard:	15.249, 15.209	Mode:	RSE-Above 1GHz-Low
Frequency Range:	1 GHz - 18 GHz	Test Date:	05/21/2020 - 05/27/2020
Antenna Type/Polarity:	Horn/Hor & Ver	Test Personnel:	Daniel Bruno
Remark:	N/A	Test Result:	Pass



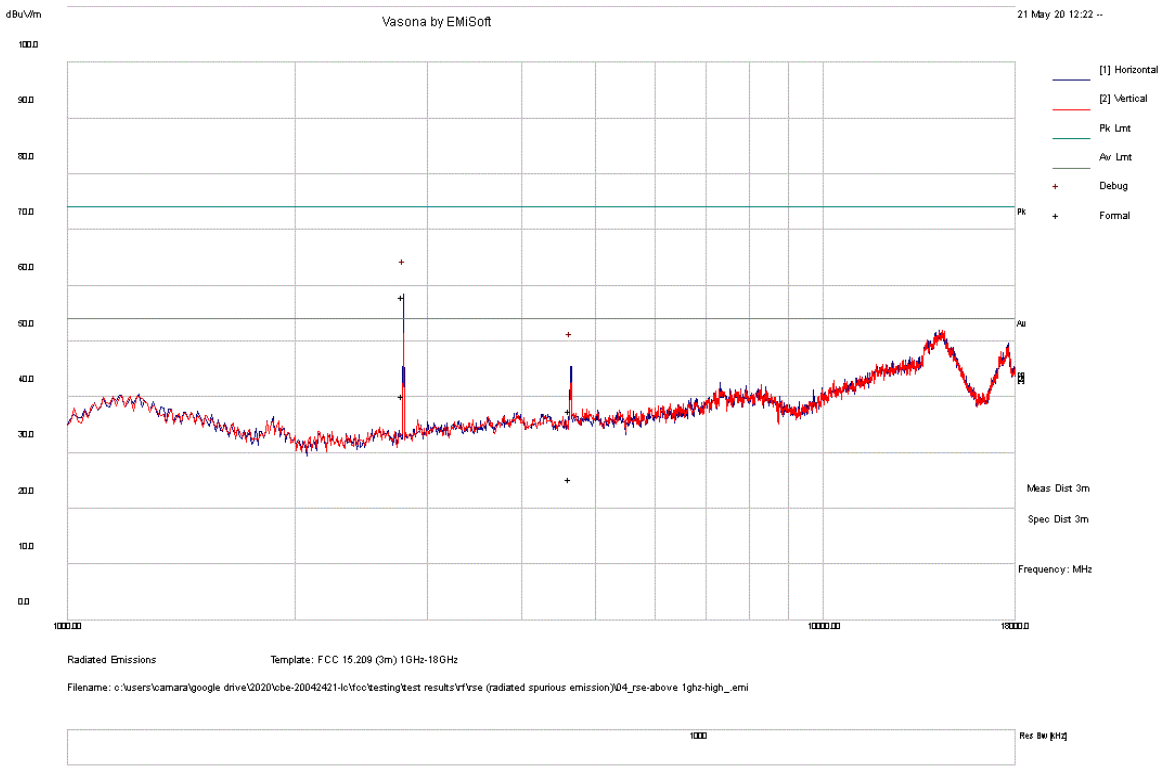
Frequency MHz	Raw dBuV	Cable Loss	AF dB	Level dBuV/m	Measurement Type	Pol	Hgt cm	Azt Deg	Limit dBuV/m	Margin dB	Pass/Fail
2721.36	27.76	15.05	-8.50	34.31	Peak Max	H	386	272	74.00	-39.69	Pass
4528.57	29.92	17.28	-3.35	43.85	Peak Max	H	269	247	74.00	-30.15	Pass
2721.36	15.05	15.05	-8.50	21.60	Average Max	H	386	272	54.00	-32.40	Pass
4528.57	14.91	17.28	-3.35	28.84	Average Max	H	269	247	54.00	-25.16	Pass

Test Standard:	15.249, 15.209	Mode:	RSE-Above 1GHz-Mid
Frequency Range:	1 GHz - 18 GHz	Test Date:	05/21/2020 - 05/27/2020
Antenna Type/Polarity:	Horn/Hor & Ver	Test Personnel:	Daniel Bruno
Remark:	N/A	Test Result:	Pass



Frequency MHz	Raw dBuV	Cable Loss	AF dB	Level dBuV/m	Measurement Type	Pol	Hgt cm	Azt Deg	Limit dBuV/m	Margin dB	Pass/Fail
2751.84	27.62	15.08	-8.41	34.29	Peak Max	H	380	292	74.00	-39.71	Pass
4580.38	31.62	17.30	-3.08	45.84	Peak Max	H	237	254	74.00	-28.16	Pass
2751.84	15.63	15.08	-8.41	22.30	Average Max	H	380	292	54.00	-31.70	Pass
4580.38	16.07	17.30	-3.08	30.29	Average Max	H	237	254	54.00	-23.71	Pass

Test Standard:	15.249, 15.209	Mode:	RSE-Above 1GHz-High
Frequency Range:	1 GHz - 18 GHz	Test Date:	05/21/2020 - 05/27/2020
Antenna Type/Polarity:	Horn/Hor & Ver	Test Personnel:	Daniel Bruno
Remark:	N/A	Test Result:	Pass



Frequency MHz	Raw dBuV	Cable Loss	AF dB	Level dBuV/m	Measurement Type	Pol	Hgt cm	Azt Deg	Limit dBuV/m	Margin dB	Pass/Fail
2783.26	51.20	15.11	-8.29	58.02	Peak Max	H	178	259	74.00	-15.98	Pass
4632.28	23.03	17.31	-2.85	37.49	Peak Max	H	165	262	74.00	-36.51	Pass
2783.26	33.32	15.11	-8.29	40.14	Average Max	H	178	259	54.00	-13.86	Pass
4632.28	10.93	17.31	-2.85	25.39	Average Max	H	165	262	54.00	-28.62	Pass

8 Test Instrument List

Equipment	Manufacturer	Model	Instrument Number	Cal. Date	Cal. Due
Semi-Anechoic Chamber	ETS-Lindgren	10M	VL001	10/18/19	10/18/20
Shielding Control Room	ETS-Lindgren	Series 81	VL006	N/A	N/A
Spectrum Analyzer	Keysight	N9020A	MY50110074	6/17/19	6/17/20
EMC Test Receiver	R&S	ESL6	100230	6/14/19	6/14/20
LISN (9KHz – 30MHz)	EMCO	3816/2	9705-1066	5/4/20	5/4/21
Bi-Log Antenna	ETS-Lindgren	3142E	217921	11/15/2019	11/15/2020
Horn Antenna (1-18GHz)	Electro-Metrics	EM-6961	6292	5/14/2020	5/14/2021
Horn Antenna (18-40GHz)	Com-Power	AH-840	101109	6/24/19	6/24/20
Preamplifier	RF Bay, Inc.	LPA-10-20	11180621	7/15/2019	7/15/2020
True RMS Multi-meter	UNI-T	UT181A	C173014829	5/5/2020	5/5/2021
Temp / Humidity / Pressure Meter	PCE Instruments	PCE-THB 40	R062028	5/15/2020	5/15/2021
RF Attenuator	Pasternack	PE7005-3	VL061	7/16/2019	7/16/2020
Preamplifier 100KHz - 40GHz	Aeroflex	33711-392-77150-11	064	7/16/2019	7/16/2020
EM Center Control	ETS-Lindgren	7006-001	160136	N/A	N/A
Turn Table	ETS-Lindgren	2181-3.03	VL002	N/A	N/A
Boresight Antenna Tower	ETS-Lindgren	2171B	VL003	N/A	N/A
Loop Antenna (9k-30MHz)	Com-Power	AL-130	121012	5/16/20	5/16/21
RE test cable(below 6GHz)	Vista	RE-6GHz-01	RE-6GHz-01	7/16/2019	7/16/2020
RE test cable (1-18GHz)	PhaseTrack	II-240	RE-18GHz-01	7/16/2019	7/16/2020
RE test cable (>18GHz)	Sucoflex	104	344903/4	7/16/2019	7/16/2020
Pulse limiter	Com-Power	LIT-930A	531727	7/16/2019	7/16/2020
CE test cable #1	FIRST RF	FRF-C-1002-001	CE-6GHz-01	7/16/2019	7/16/2020
CE test cable#2	FIRST RF	FRF-C-1002-001	CE-6GHz-02	7/16/2019	7/16/2020