



FCC PART 15, SUBPART F ISED C RSS-220, ISSUE 1, JULY 2018

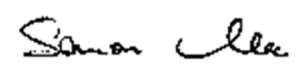
TEST REPORT

For

Culvert-IoT Corporation

1999 S Bascom Ave #230
Campbell, CA 95008, USA

FCC ID: 2AQ98-T0
IC: 26298-T0

Report Type: Original Report	Product Type: Handheld Positioning Unit
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* This report may contain data that are not covered by the A2LA accreditation and are marked with an asterisk “*”

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DOCUMENT REVISION HISTORY

Revision Number	Report Number	Description of Revision	Date of Revision
0	R2007292-519	Original Report	2020-08-19

1 General Description

1.1 Product Description for Equipment Under Test (EUT)

This test report was prepared on behalf of *Culvert-IoT Corporation*, and their product model: *T0*, *FCC ID: 2AQ98-T0*, *IC: 26298-T0* or the “EUT” as referred to in this report. The EUT is a Handheld Positioning Unit with BLE and UWB capabilities.

1.2 Objective

This report was prepared on behalf of *Culvert-IoT Corporation*, in accordance with Part 2, Subpart J, and Part 15, Subpart and F of the Federal Communication Commission’s rules and ISED RSS-220 Issue 1, July 2018.

The objective was to determine compliance with FCC Part 15.519 and ISED RSS-220 rules for Peak Fundamental Emission, Antenna Requirements, UWB Bandwidth, Average Radiated Emissions, Radiated Spurious Emissions and Ceasing Transmission requirements.

1.3 Related Submittal(s)/Grant(s)

FCC Part 15, Subpart C, Equipment Class: DTS with FCC ID: 2AQ98-T0, IC: 26298-T0

1.4 Test Methodology

All measurements contained in this report were conducted in accordance with ANSI C63.10-2013, American National Standard of Procedures for Compliance Testing of Unlicensed Wireless Devices and FCC KDB 393761 D01 UWB FAQ v02: Ultra-Wideband (UWB) Devices Frequently Asked Questions.

1.5 Measurement Uncertainty

All measurements involve certain levels of uncertainties, especially in the field of EMC. The factors contributing to uncertainties are spectrum analyzer, cable loss, antenna factor calibration, antenna directivity, antenna factor variation with height, antenna phase center variation, antenna factor frequency interpolation, measurement distance variation, site imperfections, mismatch (average), and system repeatability.

Parameter	Measurement uncertainty
Occupied Channel Bandwidth	±5 %
RF output power, conducted	±0.57 dB
Power Spectral Density, conducted	±1.48dB
Unwanted Emissions, conducted	±1.57dB
All emissions, radiated	±4.0 dB
AC power line Conducted Emission	±2.0 dB
Temperature	±2 ° C
Humidity	±5 %
DC and low frequency voltages	±1.0 %
Time	±2 %
Duty Cycle	±3 %

1.6 Test Facility Registrations

BACLs test facilities that are used to perform Radiated and Conducted Emissions tests are currently recognized by the Federal Communications Commission as Accredited with NIST Designation Number US1129.

BACL's test facilities that are used to perform Radiated and Conducted Emissions tests are currently registered with Industry Canada under Registration Numbers: 3062A-1, 3062A-2, and 3062A-3.

BACL is a Chinese Taipei Bureau of Standards Metrology and Inspection (BSMI) validated Conformity Assessment Body (CAB), under Appendix B, Phase I Procedures of the APEC Mutual Recognition Arrangement (MRA). BACL's BSMI Lab Code Number is: SL2-IN-E-1002R.

BACL's test facilities that are used to perform AC Line Conducted Emissions, Telecommunications Line Conducted Emissions, Radiated Emissions from 30 MHz to 1 GHz, and Radiated Emissions from 1 GHz to 6 GHz are currently recognized as Accredited in accordance with the Voluntary Control Council for Interference [VCCI] Article 15 procedures under Registration Number A-0027.

1.7 Test Facility Accreditations

Bay Area Compliance Laboratories Corp. (BACL) is:

A- An independent, 3rd-Party, Commercial Test Laboratory accredited to ISO/IEC 17025:2005 by A2LA (Test Laboratory Accreditation Certificate Number 3297.01), in the fields of: Electromagnetic Compatibility and Telecommunications. Unless noted by an Asterisk (*) in the Compliance Matrix (See Section 3 of this Test Report), BACL's ISO/IEC 17025:2005 Scope of Accreditation includes all of the Test Method Standards and/or the Product Family Standards detailed in this Test Report.

BACL's ISO/IEC 17025:2005 Scope of Accreditation includes a comprehensive suite of EMC Emissions, EMC Immunity, Radio, RF Exposure, Safety and wireline Telecommunications test methods applicable to a wide range of product categories. These product categories include Central Office Telecommunications Equipment [including NEBS - Network Equipment Building Systems], Unlicensed and Licensed Wireless and RF devices, Information Technology Equipment (ITE); Telecommunications Terminal Equipment (TTE); Medical Electrical Equipment; Industrial, Scientific and Medical Test Equipment; Professional Audio and Video Equipment; Industrial and Scientific Instruments and Laboratory Apparatus; Cable Distribution Systems, and Energy Efficient Lighting.

B- A Product Certification Body accredited to ISO/IEC 17065:2012 by A2LA (Product Certification Body Accreditation Certificate Number 3297.02) to certify

- For the USA (Federal Communications Commission):

- 1- All Unlicensed radio frequency devices within FCC Scopes A1, A2, A3, and A4;
- 2- All Licensed radio frequency devices within FCC Scopes B1, B2, B3, and B4;
- 3- All Telephone Terminal Equipment within FCC Scope C.

- For the Canada (Industry Canada):

- 1 All Scope 1-Licence-Exempt Radio Frequency Devices;
- 2 All Scope 2-Licensed Personal Mobile Radio Services;
- 3 All Scope 3-Licensed General Mobile & Fixed Radio Services;
- 4 All Scope 4-Licensed Maritime & Aviation Radio Services;
- 5 All Scope 5-Licensed Fixed Microwave Radio Services
- 6 All Broadcasting Technical Standards (BETS) in the Category I Equipment Standards List.

- For Singapore (Info-Communications Development Authority (IDA)):

- 1 All Line Terminal Equipment: All Technical Specifications for Line Terminal Equipment – Table 1 of IDA MRA Recognition Scheme: 2011, Annex 2
2. All Radio-Communication Equipment: All Technical Specifications for Radio-Communication Equipment – Table 2 of IDA MRA Recognition Scheme: 2011, Annex 2

- For the Hong Kong Special Administrative Region:

- 1 All Radio Equipment, per KHCA 10XX-series Specifications;
- 2 All GMDSS Marine Radio Equipment, per HKCA 12XX-series Specifications;
- 3 All Fixed Network Equipment, per HKCA 20XX-series Specifications.

- For Japan:

- 1 MIC Telecommunication Business Law (Terminal Equipment):
 - All Scope A1 - Terminal Equipment for the Purpose of Calls;
 - All Scope A2 - Other Terminal Equipment
- 2 Radio Law (Radio Equipment):
 - All Scope B1 - Specified Radio Equipment specified in Article 38-2-2, paragraph 1, item 1 of the Radio Law
 - All Scope B2 - Specified Radio Equipment specified in Article 38-2-2, paragraph 1, item 2 of the Radio Law
 - All Scope B3 - Specified Radio Equipment specified in Article 38-2-2, paragraph 1, item 3 of the Radio Law

C- A Product Certification Body accredited to ISO/IEC 17065:2012 by A2LA (Product Certification Body Accreditation Certificate Number 3297.03) to certify Products to USA's Environmental Protection Agency (EPA) ENERGY STAR Product Specifications for:

- 1 Electronics and Office Equipment:
 - for Telephony (ver. 3.0)
 - for Audio/Video (ver. 3.0)
 - for Battery Charging Systems (ver. 1.1)
 - for Set-top Boxes & Cable Boxes (ver. 4.1)
 - for Televisions (ver. 6.1)

- for Computers (ver. 6.0)
- for Displays (ver. 6.0)
- for Imaging Equipment (ver. 2.0)
- for Computer Servers (ver. 2.0)
- 2 Commercial Food Service Equipment
 - for Commercial Dishwashers (ver. 2.0)
 - for Commercial Ice Machines (ver. 2.0)
 - for Commercial Ovens (ver. 2.1)
 - for Commercial Refrigerators and Freezers
- 3 Lighting Products
 - For Decorative Light Strings (ver. 1.5)
 - For Luminaires (including sub-components) and Lamps (ver. 1.2)
 - For Compact Fluorescent Lamps (CFLs) (ver. 4.3)
 - For Integral LED Lamps (ver. 1.4)
- 4 Heating, Ventilation, and AC Products
 - for Residential Ceiling Fans (ver. 3.0)
 - for Residential Ventilating Fans (ver. 3.2)
- 5 Other
 - For Water Coolers (ver. 3.0)

D- A NIST Designated Phase-I and Phase-II Conformity Assessment Body (CAB) for the following economies and regulatory authorities under the terms of the stated MRAs/Treaties:

- Australia: ACMA (Australian Communication and Media Authority) – APEC Tel MRA -Phase I;
- Canada: (Innovation, Science and Economic development Canada - ISED) Foreign Certification Body – FCB – APEC Tel MRA -Phase I & Phase II;
- Chinese Taipei (Republic of China – Taiwan):
 - o BSMI (Bureau of Standards, Metrology and Inspection) APEC Tel MRA -Phase I;
 - o NCC (National Communications Commission) APEC Tel MRA -Phase I;
- European Union:
 - o EMC Directive 2014/30/EU US-EU EMC & Telecom MRA CAB (NB)
 - o Radio Equipment (RE) Directive 2014/53/EU US-EU EMC & Telecom MRA CAB (NB)
 - o Low Voltage Directive (LVD) 2014/35/EU
- Hong Kong Special Administrative Region: (Office of the Telecommunications Authority – OFTA) APEC Tel MRA -Phase I & Phase II
- Israel – US-Israel MRA Phase I
- Republic of Korea (Ministry of Communications - Radio Research Laboratory) APEC Tel MRA -Phase I
- Singapore: (Infocomm Media Development Authority - IMDA) APEC Tel MRA -Phase I & Phase II;
- Japan: VCCI - Voluntary Control Council for Interference US-Japan Telecom Treaty VCCI Side Letter-
- USA:
 - o ENERGY STAR Recognized Test Laboratory – US EPA
 - o Telecommunications Certification Body (TCB) – US FCC;
 - o Nationally Recognized Test Laboratory (NRTL) – US OSHA
- Vietnam: APEC Tel MRA -Phase I;

2 System Test Configuration

2.1 Justification

The EUT was configured for testing according to ANSI C63.10-2013.

The EUT was tested in a testing mode to represent worst-case results during the final qualification test.

2.2 EUT Exercise Software

Putty was used and software is compliant with the standard requirements being tested against.

Radio	Frequency (MHz)	Power Setting
UWB	6490	-11.5
	7987	-14.4

2.3 Duty Cycle Correction Factor

According to KDB 558074 D01 DTS Meas Guidance v05r02 section 6.0:

Preferably, all measurements of maximum conducted (average) output power will be performed with the EUT transmitting continuously (i.e., with a duty cycle of greater than or equal to 98%). When continuous operation cannot be realized, then the use of sweep triggering/signal gating techniques can be utilized to ensure that measurements are made only during transmissions at the maximum power control level. Such sweep triggering/signal gating techniques will require knowledge of the minimum transmission duration (T) over which the transmitter is on and is transmitting at its maximum power control level for the tested mode of operation. Sweep triggering/signal gating techniques can then be used if the measurement/sweep time of the analyzer can be set such that it does not exceed T at any time that data is being acquired (i.e., no transmitter off-time is to be considered).

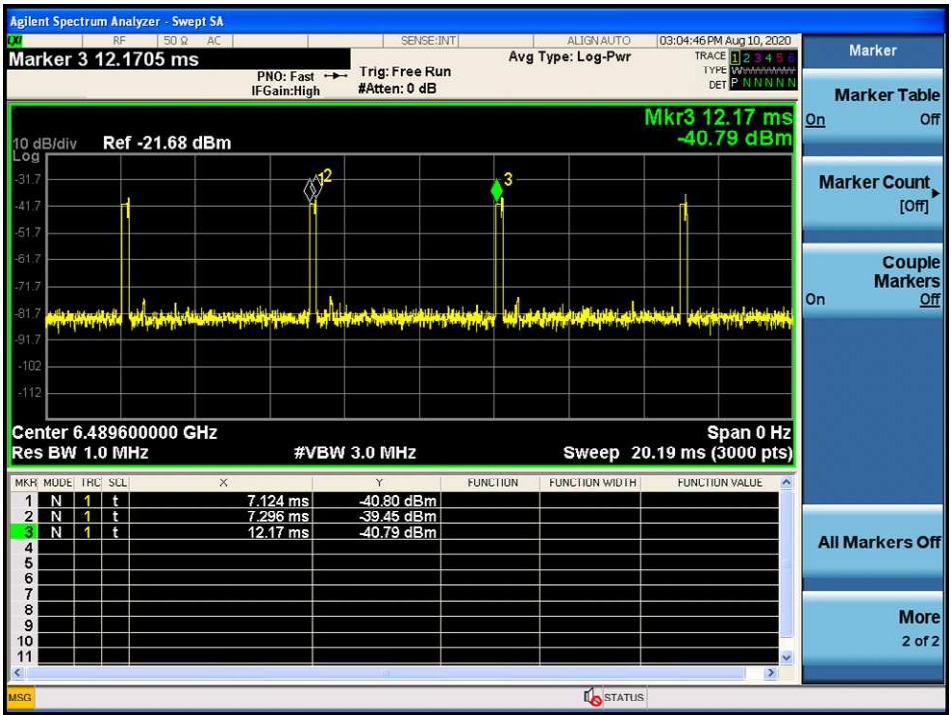
Radio Mode/ Channel	Total On Time (ms)	Period (ms)	Duty Cycle (%)	Duty Cycle Correction Factor (dB)
UWB/Channel 5	0.172	5.046	3	15.23
UWB/Channel 9	0.152	5.121	3	15.23

Duty Cycle = On Time (ms)/ Period (ms)

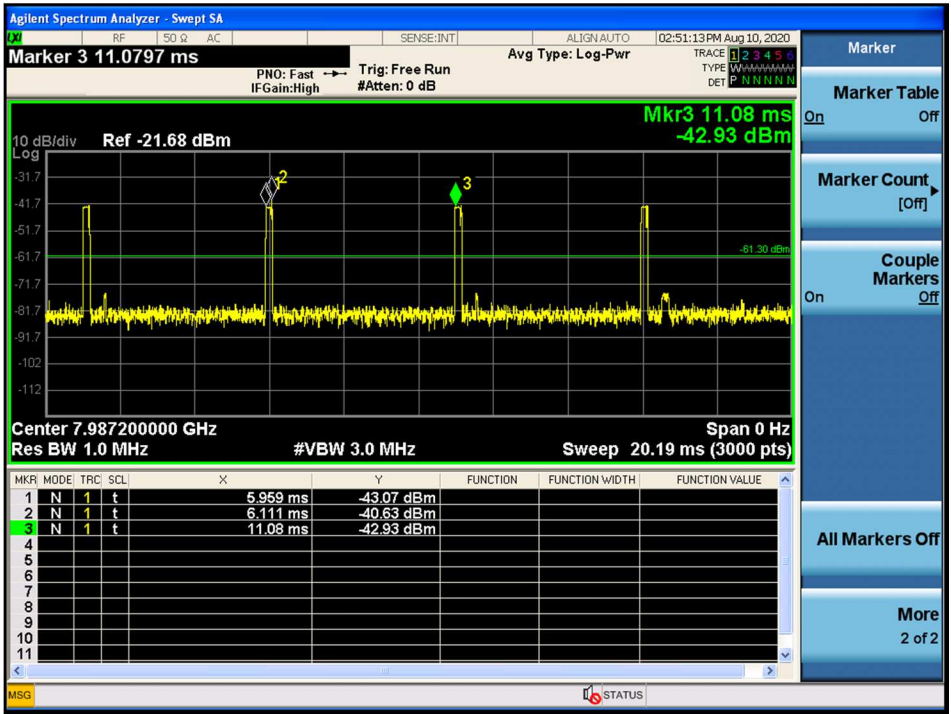
Duty Cycle Correction Factor (dB) = $10 \cdot \log(1/\text{Duty Cycle})$

Please refer to the following plots.

Channel 5



Channel 9



2.4 Equipment Modifications

None

2.5 Local Support Equipment

Manufacturer	Description	Model	Serial Number
Dell	Laptop	Latitude E6410	3CKRAQ1

2.6 Support Equipment

Manufacturer	Description	Model
Culvert	Debug Board	Culvert Dongle

2.7 Power Supply/Adapter

None

2.8 Interface Ports and Cabling

Description	Length (m)	To	From
USB to Micro USB	< 1 m	Laptop	Debug Board
USB C to USB C	< 1 m	Debug Board	EUT

3 Summary of Test Results

Results reported relate only to the product tested.

FCC and ISEDC Rules	Description of Test	Results
FCC §15.203 ISED RSS-Gen §6.8	Antenna Requirement	Compliant
FCC §15.207 ISED RSS-Gen §8.8	AC Line Conducted Emissions	N/A ¹
FCC §2.1093, §1.1310(d) (3) ISED RSS-102	RF Exposure	Compliant
FCC §2.1053, §15.205, §15.209, §15.519(c) ISED RSS-220 §3.4, §5.3.1(c), ISED RSS-Gen §8.9 and §8.10	Radiated Spurious Emissions	Compliant
FCC §15.503(d), §15.519(b) ISED RSS-220 §5.1(a) ISED RSS-Gen §6.7	UWB & 99% Emission Bandwidth	Compliant
FCC §15.519(e) ISED RSS-220 §5.3.1(g)	Peak Fundamental Emission	Compliant
FCC §15.519(c), §15.519(d) ISED RSS-220 §5.3.1(d), §5.3.1(e)	Average Radiated Emissions	Compliant
FCC §15.519(a)(1) ISED RSS-220 §5.3.1(b)	Cease Transmission	Compliant

Note¹: Radio does not operate while charging.

4 FCC §15.203 & ISED RSS-Gen §6.8 - Antenna Requirements

4.1 Applicable Standards

According to FCC §15.203:

An intentional radiator shall be designed to ensure that no antenna other than that furnished by the responsible party shall be used with the device. The use of a permanently attached antenna or of an antenna that uses a unique coupling to the intentional radiator shall be considered sufficient to comply with the provisions of this Section. The manufacturer may design the unit so that a broken antenna can be replaced by the user, but the use of a standard antenna jack or electrical connector is prohibited.

According to ISED RSS-Gen §6.8: Transmitter Antenna

The applicant for equipment certification shall provide a list of all antenna types that may be used with the transmitter, where applicable (i.e. for transmitters with detachable antenna), indicating the maximum permissible antenna gain (in dBi) and the required impedance for each antenna. The test report shall demonstrate the compliance of the transmitter with the limit for maximum equivalent isotropically radiated power (e.i.r.p.) specified in the applicable RSS, when the transmitter is equipped with any antenna type, selected from this list.

For expediting the testing, measurements may be performed using only the antenna with highest gain of each combination of transmitter and antenna type, with the transmitter output power set at the maximum level. However, the transmitter shall comply with the applicable requirements under all operational conditions and when in combination with any type of antenna from the list provided in the test report (and in the notice to be included in the user manual, provided below).

When measurements at the antenna port are used to determine the RF output power, the effective gain of the device's antenna shall be stated, based on a measurement or on data from the antenna's manufacturer.

The test report shall state the RF power, output power setting and spurious emission measurements with each antenna type that is used with the transmitter being tested.

For licence-exempt equipment with detachable antennas, the user manual shall also contain the following notice in a conspicuous location:

This radio transmitter [enter the device's ISED certification number] has been approved by Innovation, Science and Economic Development Canada to operate with the antenna types listed below, with the maximum permissible gain indicated. Antenna types not included in this list that have a gain greater than the maximum gain indicated for any type listed are strictly prohibited for use with this device.

Immediately following the above notice, the manufacturer shall provide a list of all antenna types which can be used with the transmitter, indicating the maximum permissible antenna gain (in dBi) and the required impedance for each antenna type.

4.2 Antenna Description

External/Internal/Integral	Maximum Antenna Gain (dBi)	Antenna Type
Integral	4.4	Trace Antenna

5 FCC §2.1093, §1.1310(d) (3) & ISED RSS-102 - RF Exposure

5.1 Applicable Standards

As per FCC §1.1310(d) (3), At operating frequencies above 6 GHz, the MPE limits listed in Table 1 in paragraph (e)(1) of this section shall be used in all cases to evaluate the environmental impact of human exposure to RF radiation as specified in §1.1307(b) of this part.

TABLE 1 TO §1.1310(E)(1)—LIMITS FOR MAXIMUM PERMISSIBLE EXPOSURE (MPE)

Frequency range (MHz)	Electric field strength (V/m)	Magnetic field strength (A/m)	Power density (mW/cm ²)	Averaging time (minutes)
(i) Limits for Occupational/Controlled Exposure				
0.3-3.0	614	1.63	*(100)	≤6
3.0-30	1842/f	4.89/f	*(900/f ²)	<6
30-300	61.4	0.163	1.0	<6
300-1,500			f/300	<6
1,500-100,000			5	<6
(ii) Limits for General Population/Uncontrolled Exposure				
0.3-1.34	614	1.63	*(100)	<30
1.34-30	824/f	2.19/f	*(180/f ²)	<30
30-300	27.5	0.073	0.2	<30
300-1,500			f/1500	<30
1,500-100,000			1.0	<30

f = frequency in MHz. * = Plane-wave equivalent power density.

According to ISED RSS-102 Issue 5 Section 3, devices operating above 6 GHz regardless of the separation distance shall undergo an RF exposure evaluation.

Table 4: RF Field Strength Limits for Devices Used by the General Public (Uncontrolled Environment)				
Frequency Range (MHz)	Electric Field (V/m rms)	Magnetic Field (A/m rms)	Power Density (W/m²)	Reference Period (minutes)
0.003-10	83	90	-	Instantaneous*
0.1-10	-	$0.73/f$	-	6**
1.1-10	$87/f^{0.5}$	-	-	6**
10-20	27.46	0.0728	-2	6
20-48	$58.07/f^{0.25}$	$0.1540/f^{0.25}$	$8.944/f^{0.5}$	6
48-300	22.06	0.05852	1.291	6
300-6000	$3.142 f^{0.3417}$	$0.008335 f^{0.3417}$	$0.02619 f^{0.6834}$	6
6000-15000	61.4	0.163	10	6
15000-150000	61.4	0.163	10	$616000/f^{1.2}$
150000-300000	$0.158 f^{0.5}$	$4.21 \times 10^{-4} f^{0.5}$	$6.67 \times 10^{-5} f$	$616000/f^{1.2}$
Note: f is frequency in MHz. * Based on nerve stimulation (NS). ** Based on specific absorption rate (SAR).				

5.2 MPE Prediction

Predication of MPE limit at a given distance, Equation from OET Bulletin 65, Edition 97-01

$$S = PG/4\pi R^2$$

Where: S = power density

P = power input to antenna

G = power gain of the antenna in the direction of interest relative to an isotropic radiator

R = distance to the center of radiation of the antenna

5.3 MPE Results for the FCC and IC

<u>Maximum peak output power at antenna input terminal (dBm):</u>	<u>-38.715</u>
<u>Maximum peak output power at antenna input terminal (mW):</u>	<u>0.0001</u>
<u>Prediction distance (cm):</u>	<u>0.5</u>
<u>Prediction frequency (MHz):</u>	<u>6490</u>
<u>Maximum Antenna Gain, typical (dBi):</u>	<u>4.4</u>
<u>Maximum Antenna Gain (numeric):</u>	<u>2.754</u>
<u>Power density of prediction frequency at 0.5 cm (mW/cm²):</u>	<u>0.0001</u>
<u>FCC MPE limit for uncontrolled exposure at prediction frequency (mW/cm²):</u>	<u>1.0</u>
<u>Power density of prediction frequency at 0.5 cm (W/m²):</u>	<u>0.0012</u>
<u>IC MPE limit for uncontrolled exposure at prediction frequency (W/m²):</u>	<u>10</u>

The device is compliant with the FCC requirement MPE limit for uncontrolled exposure. The maximum power density at the distance of 0.5 cm is 0.0001 mW/cm². Limit is 1.0 mW/cm².

The device is compliant with the IC requirement MPE limit for uncontrolled exposure. The maximum power density at the distance of 0.5 cm is 0.0012 W/m². Limit is 10 W/m².

Worst Case Colocation MPE Calculation: BLE and UWB:

	Radio	Max Average Conducted Power (dBm)	Evaluated Distance (cm)	Worst-Case Exposure Level	Limit	Worst-Case Ratios	Sum of Ratios	Limit
Worst Case								
FCC	BLE	-18.74	0.5	0.0004W/kg	1.6 W/kg	0.03%	0.04%	100%
	UWB	-38.715	0.5	0.0001mW/cm ²	1.0 mW/cm ²	0.01%		
IC	BLE	-18.74	0.5	0.0004W/kg	1.6 W/kg	0.03%	0.042%	100%
	UWB	-38.715	0.5	0.0012W/m ²	10 W/m ²	0.012%		

Note: The BLE calculation for Colocation evaluation was determined using the standalone SAR value estimation defined in section 4.3.2.b.1 of KDB 447498 D01 General RF Exposure Guidance v06.

6 FCC §15.209, §15.519(c), (d) & ISEDC RSS-220 §3.4, §5.3.1(d), (e), RSS-Gen §8.9, §8.10 - Spurious Radiated Emissions

6.1 Applicable Standards

As per FCC §15.519(c), the radiated emissions at or below 960 MHz from a device operating under the provisions of this section shall not exceed the emission levels in §15.209

As per FCC §15.35(b): Unless otherwise specified, on any frequency or frequencies above 1000 MHz, the radiated emission limits are based on the use of measurement instrumentation employing an average detector function. Unless otherwise specified, measurements above 1000 MHz shall be performed using a minimum resolution bandwidth of 1 MHz.

As Per FCC §15.205(a) and RSS-Gen except as show in paragraph (d) of this section, only spurious emissions are permitted in any of the frequency bands listed below:

MHz	MHz	MHz	GHz
0.090 – 0.110	16.42 – 16.423	960 – 1240	4.5 – 5.15
0.495 – 0.505	16.69475 – 16.69525	1300 – 1427	5.35 – 5.46
2.1735 – 2.1905	25.5 – 25.67	1435 – 1626.5	7.25 – 7.75
4.125 – 4.128	37.5 – 38.25	1645.5 – 1646.5	8.025 – 8.5
4.17725 – 4.17775	73 – 74.6	1660 – 1710	9.0 – 9.2
4.20725 – 4.20775	74.8 – 75.2	1718.8 – 1722.2	9.3 – 9.5
6.215 – 6.218	108 – 121.94	2200 – 2300	10.6 – 12.7
6.26775 – 6.26825	123 – 138	2310 – 2390	13.25 – 13.4
6.31175 – 6.31225	149.9 – 150.05	2483.5 – 2500	14.47 – 14.5
8.291 – 8.294	156.52475 – 156.52525	2690 – 2900	15.35 – 16.2
8.362 – 8.366	156.7 – 156.9	3260 – 3267	17.7 – 21.4
8.37625 – 8.38675	162.0125 – 167.17	3332 – 3339	22.01 – 23.12
8.41425 – 8.41475	167.72 – 173.2	3345.8 – 3358	23.6 – 24.0
12.29 – 12.293	240 – 285	3600 – 4400	31.2 – 31.8
12.51975 – 12.52025	322 – 335.4		36.43 – 36.5
12.57675 – 12.57725	399.9 – 410		Above 38.6
13.36 – 13.41	608 – 614		

As per FCC §15.209(a): Except as provided elsewhere in this Subpart, the emissions from an intentional radiator shall not exceed the field strength levels specified in the following table

Frequency (MHz)	Field Strength (micro volts/meter)	Measurement Distance (meters)
0.009 - 0.490	2400/F(kHz)	300
0.490 - 1.705	24000/F(kHz)	30
1.705 - 30.0	30	30
30 - 88	100**	3
88 - 216	150**	3
216 - 960	200**	3
Above 960	500	3

** Except as provided in paragraph (g), fundamental emissions from intentional radiators operating under this Section shall not be located in the frequency bands 54-72 MHz, 76-88 MHz, 174-216 MHz or 470-806 MHz. However, operation within these frequency bands is permitted under other sections of this Part, e.g., Sections 15.231 and 15.241.

As per ISED RSS-Gen §8.9, except where otherwise indicated in the applicable RSS, radiated emissions shall comply with the field strength limits shown in the table below. Additionally, the level of any transmitter unwanted emission shall not exceed the level of the transmitter's fundamental emission.

General Field Strength Limits at Frequencies above 30 MHz

Frequency (MHz)	Field Strength ($\mu\text{V/m}$ at 3 meters)
30-88	100
88-216	150
216-960	200
Above 960	500

As per ISED RSS-220 §5.3.1(c), Radiated emissions at or below 960 MHz from a device shall not exceed the limits in section 3.4

As per ISED RSS-220 §3.4, Radiated emissions at or below 960 MHz for all subclasses of UWB device shall not exceed the following limits. Measurements of radiated emissions at and below 960 MHz are to be made using a CISPR quasi-peak detector. CISPR measurement bandwidth specifications are to be used

Radiated Emissions at or below 960 MHz			
Frequency (MHz)	Field Strength (Microvolts/m)	Measurement Distance (Metres)	E.i.r.p. (dBmW)
0.009-0.490	$2,400/F$ (F in kHz)	300	$10 \log (17.28 / F^2)$ (F in kHz)
0.490-1.705	$24,000/F$ (F in kHz)	30	$10 \log (17.28 / F^2)$ (F in kHz)
1.705-30	30	30	-45.7
30-88	100	3	-55.2
88-216	150	3	-51.7
216-960	200	3	-49.2

According to FCC §15.519(c): (c) The radiated emissions at or below 960 MHz from a device operating under the provisions of this section shall not exceed the emission levels in §15.209. The radiated emissions above 960 MHz from a device operating under the provisions of this section shall not exceed the following average limits when measured using a resolution bandwidth of 1 MHz:

Frequency in MHz	EIRP in dBm
960-1610	-75.3
1610-1990	-63.3
1990-3100	-61.3
3100-10600	-41.3
Above 10600	-61.3

According to ISED RSS-220 §5.3.1(d): Radiated emissions above 960 MHz from a device shall not exceed the following average limits when measured using a resolution bandwidth of 1 MHz.

Frequency	EIRP
960-1610 MHz	-75.3 dBm
1.61-4.75 GHz	-70.0 dBm
4.75-10.6 GHz	-41.3 dBm
Above 10.6 GHz	-61.3 dBm

According to FCC §15.519(c): (d) In addition to the radiated emission limits specified in the table in paragraph (c) of this section, UWB transmitters operating under the provisions of this section shall not exceed the following average limits when measured using a resolution bandwidth of no less than 1 kHz:

Frequency in MHz	EIRP in dBm
1164-1240	-85.3
1559-1610	-85.3

According to ISED RSS-220 §5.3.1(e): In addition to the limits specified in paragraph (d) of this section, radiated emissions shall not exceed the following average limits when measured using a resolution bandwidth greater than or equal to 1 kHz. The measurements shall demonstrate compliance with the stated limits at whatever resolution bandwidth is used.

Frequency	e.i.r.p. in a Resolution Bandwidth of no less than 1 kHz
1164-1240 MHz	-85.3 dBm
1559-1610 MHz	-85.3 dBm

6.2 Test Setup

The radiated emissions tests were performed in the 5-meter Chamber, using the setup in accordance with ANSI C63.10-2013. The specification used was the FCC 15 Subpart F and ISEDC RSS-220 limits.

The spacing between the peripherals was 10 centimeters.

External I/O cables were draped along the edge of the test table and bundle when necessary.

6.3 Measurement Procedure

The EUT host, and all support equipment power cords were connected to the AC floor outlet.

Maximizing procedure was performed on the highest emissions to ensure that the EUT complied with all installation combinations.

For radiated testing the EUT was set 1 meter away from the testing antenna, which was varied from 1-4 meter, and the EUT was placed on a turntable, which was 0.8 meter and 1.5 meter above the ground plane for below and above 960 MHz measurements, the table shall be rotated for 360 degrees to find out the highest emission. The receiving antenna's polarity should be changed between horizontal and vertical.

The spectrum analyzer or receiver was set as:

Below 960 MHz:

$$\text{RBW} = 100 \text{ kHz} / \text{VBW} = 300 \text{ kHz} / \text{Sweep} = \text{Auto}$$

Above 960 MHz:

The measurements were based on ANSI C63.10-2013, American National Standard of Procedures for Compliance Testing of Unlicensed Wireless Devices section 10.3: Radiated measurement procedure above 960MHz.

6.4 Corrected Amplitude and Margin Calculation

The Corrected Amplitude (CA) is calculated by adding the Antenna Factor (AF), the Cable Loss (CL), the Attenuator Factor (Atten) and subtracting the Amplifier Gain (Ga) to indicated Amplitude (Ai) reading. The basic equation is as follows:

$$\text{CA} = \text{Ai} + \text{AF} + \text{CL} + \text{Atten} - \text{Ga}$$

For example, a corrected amplitude of 40.3 dBuV/m = Indicated Reading (32.5 dBuV) + Antenna Factor (+23.5dB) + Cable Loss (3.7 dB) + Attenuator (10 dB) - Amplifier Gain (29.4 dB)

The “**Margin**” column of the following data tables indicates the degree of compliance within the applicable limit. For example, a margin of -7 dB means the emission is 7 dB below the maximum limit. The equation for margin calculation is as follows:

$$\text{Margin} = \text{Corrected Amplitude} - \text{Limit}$$

6.5 Test Equipment List and Details

Manufacturer	Description	Model No.	Serial No.	Calibration Date	Calibration Interval
Rhode & Schwarz	EMI Test Receiver	ESCI 1166.5950K03	100044	2018-10-26	2 years
Rhode & Schwarz	Spectrum Analyzer	FSV40	1321.3008K39-101203-UW	2020-02-06	1 year
Agilent	Spectrum Analyzer	E4446A	MY48250238	2019-06-26	18 months
Sunol Sciences	System Controller	SC99V	011003-1	N/R	N/A
Sunol Sciences	Biconilog Antenna	JB3	A020106-2	2019-11-20	2 years
ETS Lindgren	Horn Antenna w/ built in Preamplifier	3117 PA	203557	2018-10-15	2 years
Wisewave	Antenna, Horn	ARH-2823-02	10555-01	2020-02-05	2 years
Wisewave	Antenna, Horn	ARH-2823-02	10555-02	2020-02-05	2 years
MDP Digital	Times Microwave LMR 400 UltraFex Coaxial Cable 35'	LMR400UF	BACL1904161	2020-05-20	1 year
-	SMA cable	-	-	Each time ¹	N/A
IW Microwave	157 Series Cable Armored with 2.92mm Male Plugs on Both Sides	KPS-1571AN-2400	DC 1922	2020-06-06	1 year
HP	Pre Amplifier	8447D	2443A04374	2019-08-17	1 year
AH Systems	Preamplifier	PAM 1840 VH	170	2019-09-24	1 year
Vasona	Test software	V6.0 build 11	10400213	N/R	N/R

Note¹: cables and notch filter included in the test set-up will be checked each time before testing.

Statement of Traceability: *BACL Corp.* attests that all of the calibrations on the equipment items listed above were traceable to NIST or to another internationally recognized National Metrology Institute (NMI), and were compliant with A2LA Policy P102 (dated 02 October 2018) "A2LA Policy on Metrological Traceability".

6.6 Test Environmental Conditions

Temperature:	20-22 °C
Relative Humidity:	42-50 %
ATM Pressure:	102.7 kPa

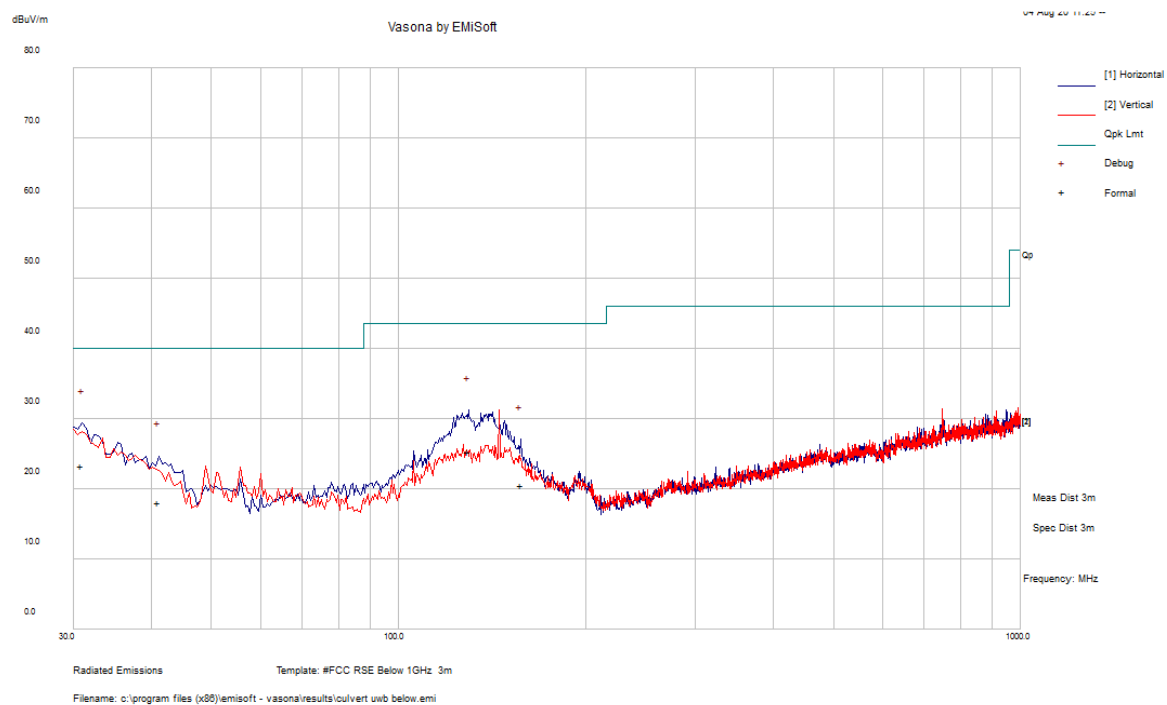
The testing was performed by Christian McCaig from 2020-08-03 to 2020-09-03 in 5m chamber 3.

6.7 Test Results below 960 MHz

Worst Case Channel: 7987 MHz

Please refer to the following graph and table.

30 MHz – 1 GHz Worst case measured at 3 meters



Frequency (MHz)	Corrected Amplitude (dB μ V/m)	Antenna Height (cm)	Antenna Polarity (H/V)	Turntable Azimuth (degrees)	Limit (dB μ V/m)	Margin (dB)	Comment
30.896	23.26	277	H	110	40	-16.74	QP
129.3235	25.39	197	H	258	43.5	-18.11	QP
41.10025	18.07	257	H	84	40	-21.93	QP
157.15375	20.6	265	H	21	43.5	-22.9	QP

Note: Only highest 4 emissions selected by software for formal testing as rest were greater than 20dB from limits.

6.8 Test Results above 960 MHz

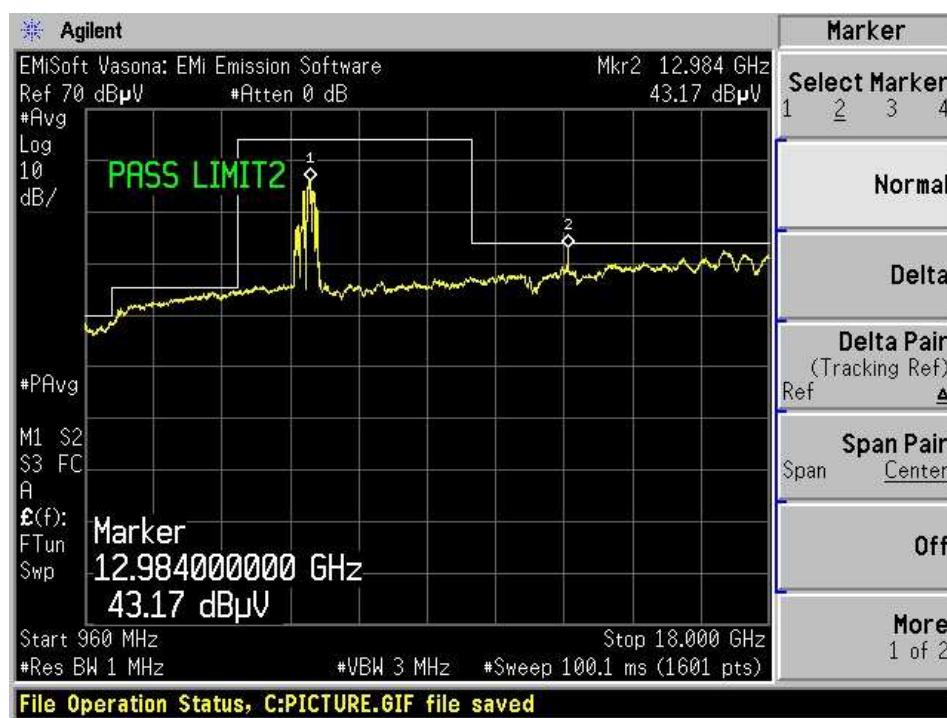
Note: Measurement was performed at 1m distance. IC limit was used to demonstrate compliance.

Average Radiated Spurious Emissions: 960MHz-26.5GHz

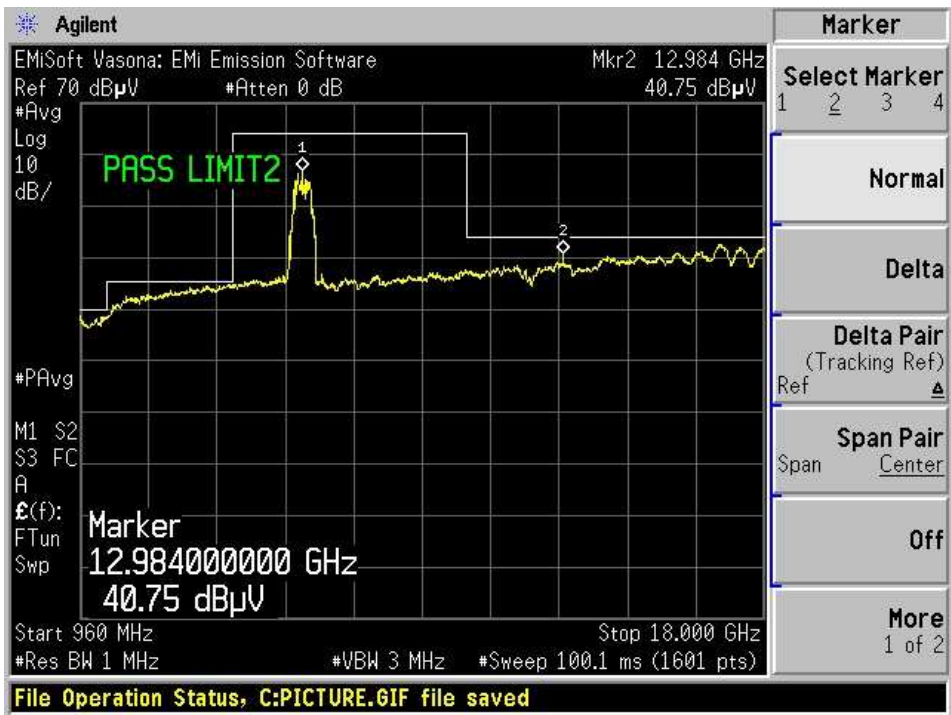
Channel 5

Measured Emission Frequency (GHz)	Antenna Pol (H/V)	Field Strength (dBμV/m at 1m)	Corrected Average Field Strength (dBμV/m at 3m)	EIRP (dBm)	Limit (dBm)	Margin (dB)
6.487	V	56.87	47.33	-47.97	-41.3	-6.67
6.562	H	56.01	46.47	-48.83	-41.3	-7.53
12.984	V	40.75	31.21	-64.09	-61.3	-2.79
12.984	H	43.17	33.63	-61.67	-61.3	-0.37
25.305	H	41.94	32.40	-62.90	-61.3	-1.60

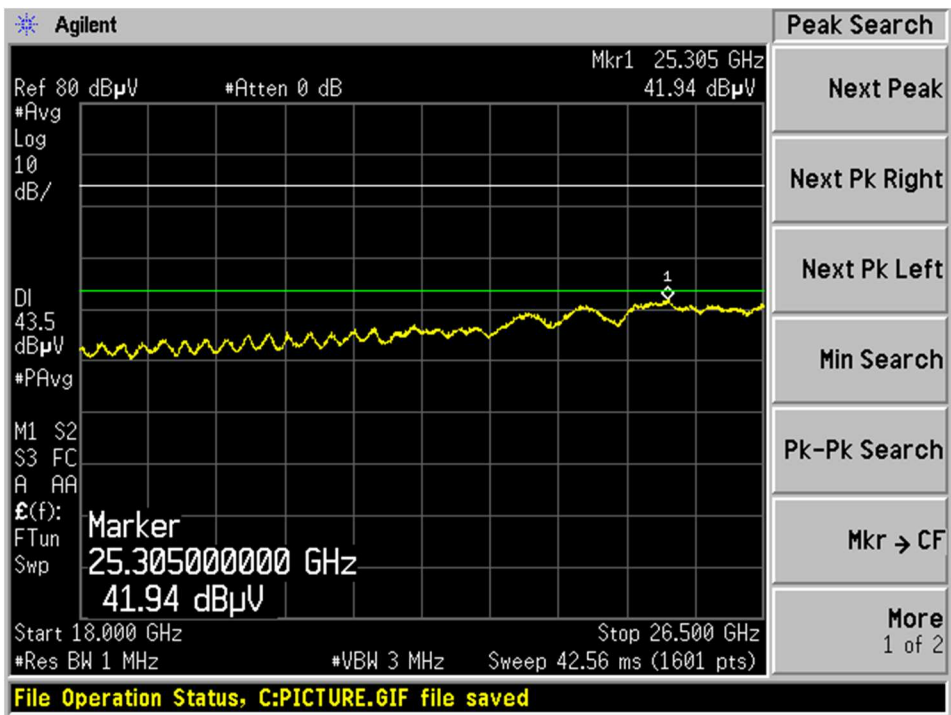
960MHz-18GHz H-Pol



960MHz-18GHz V-Pol



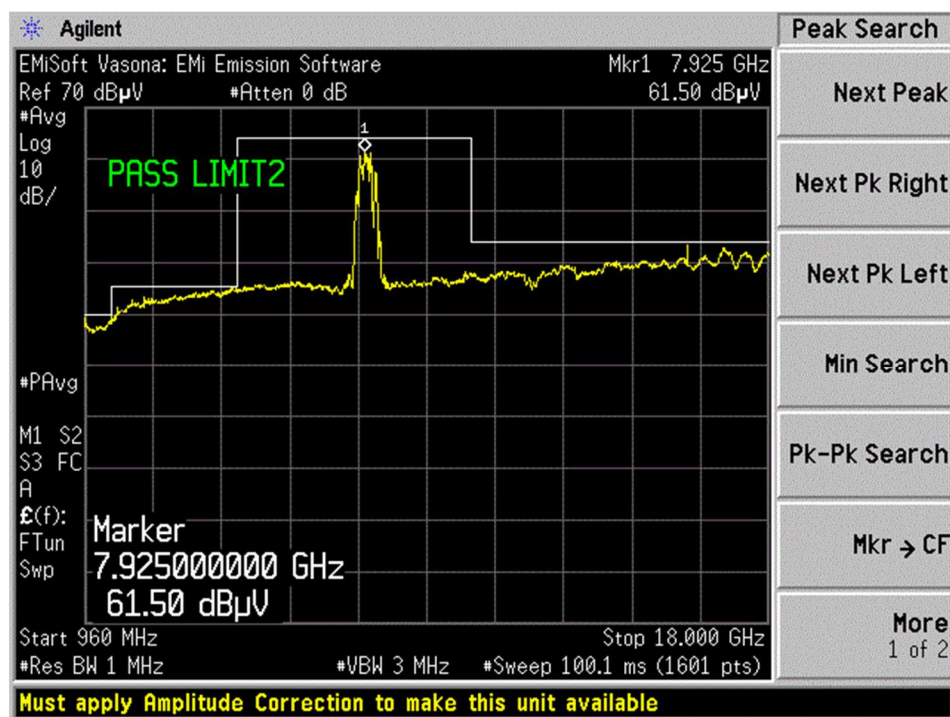
18GHz-26.5GHz H-Pol



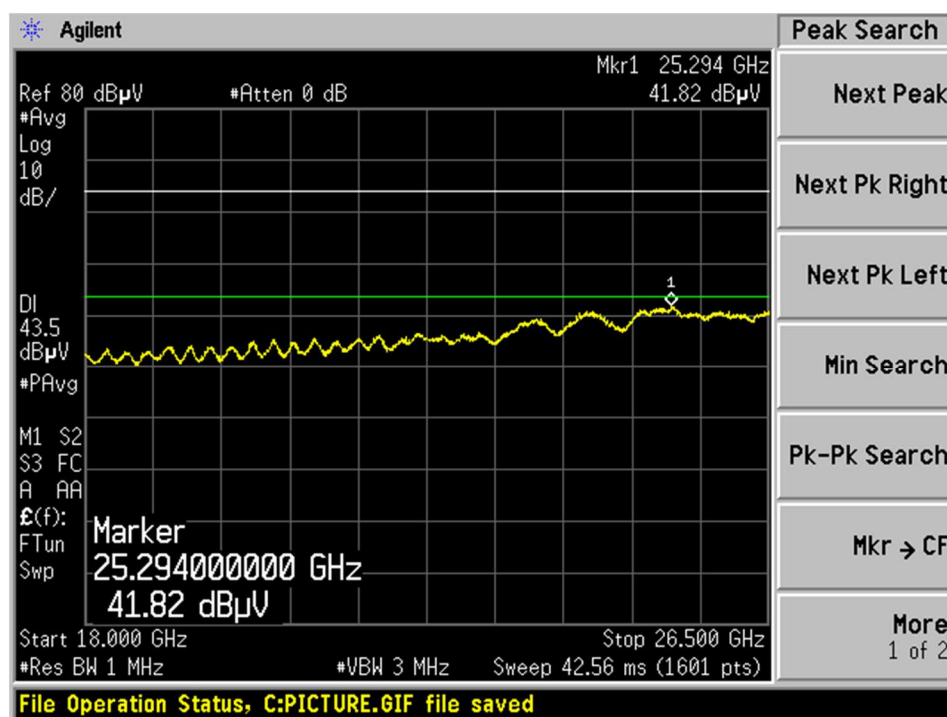
Channel 9

Measured Emission Frequency (GHz)	Antenna Pol (H/V)	Field Strength (dB μ V/m at 1m)	Corrected Average Field Strength (dB μ V/m at 3m)	EIRP (dBm)	Limit (dBm)	Margin (dB)
8.010	V	57.43	47.89	-47.41	-41.3	-6.11
7.925	H	61.50	51.96	-43.34	-41.3	-2.04
25.294	H	41.82	32.28	-63.02	-61.3	-1.72

960MHz-18GHz H-Pol



18GHz-26.5GHz



Note: In radiated measurement screenshots from 960MHz to 26.5GHz, shown emissions account for equipment factors to show corrected values compared to applicable limits.

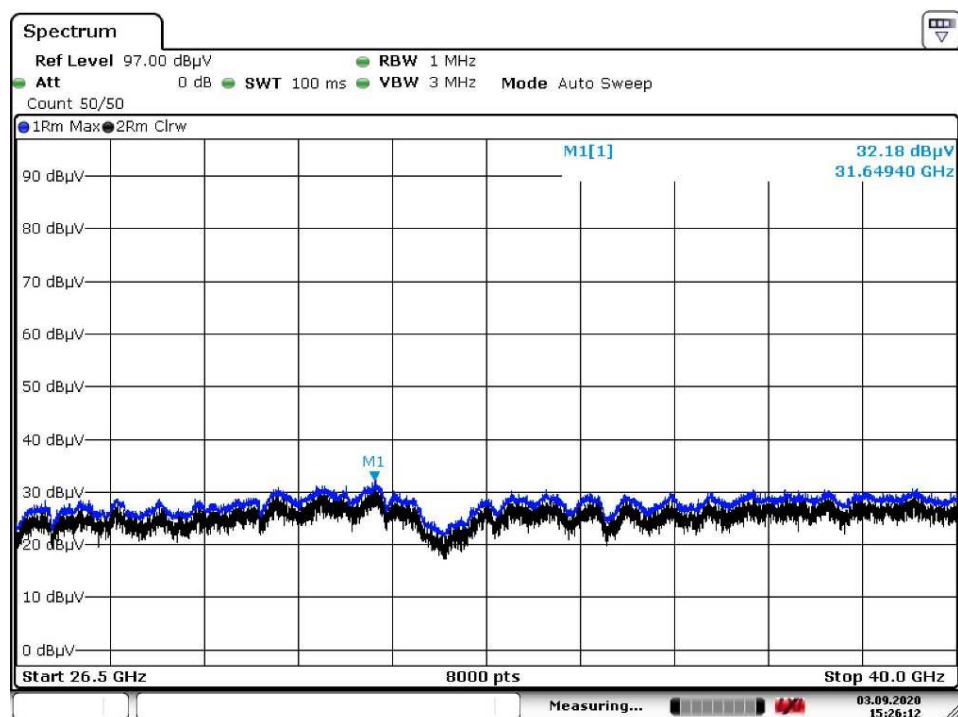
Note: According to ANSI C63.10 Section 10.3.9, measured field strength in dBμV/m was converted to EIRP in dBm to compare with the limit. The equation below was used,

$$\text{EIRP (dBm)} = E \text{ (dBμV/m)} - 95.3$$

Average Radiated Spurious Emissions: 26.5-40GHz

Channel 5

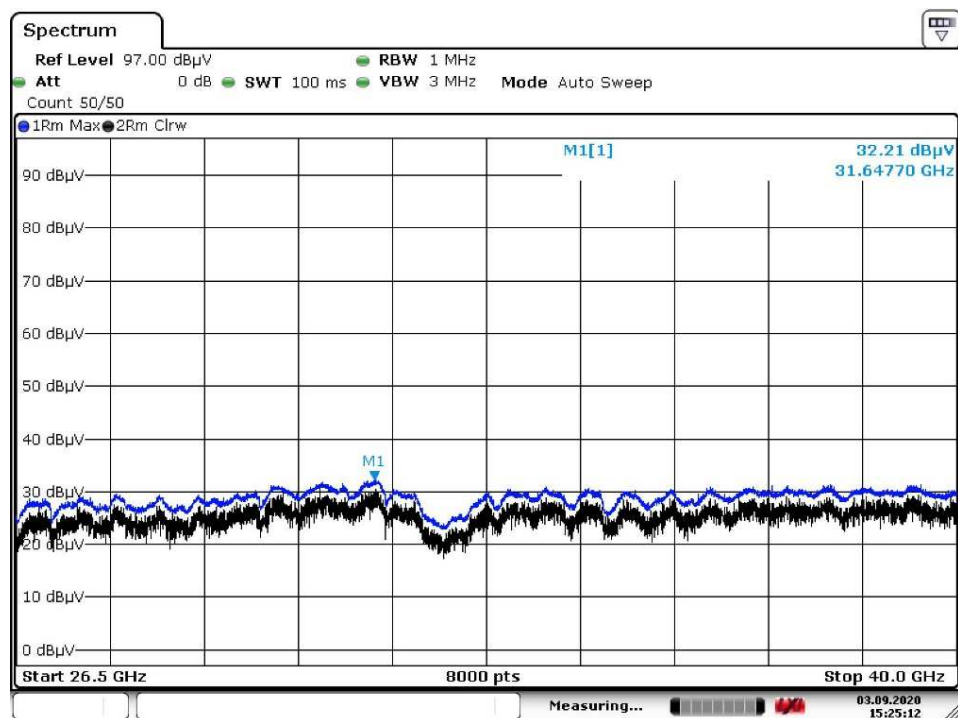
Measured Emission Frequency (GHz)	PSA Reading (dBμV)	Antenna Pol (H/V)	Antenna Factor (dB)	Cable Loss (dB)	Pre Amp Gain (dB)	Field Strength (dBμV/m at 1m)	Corrected Average Field Strength (dBμV/m at 3m)	EIRP (dBm)	Limit (dBm)	Margin (dB)
31.65	32.18	H	38.302	8.7	38.457	40.725	31.18	-64.12	-61.3	-2.82



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Channel 9

Measured Emission Frequency (GHz)	PSA Reading (dBμV)	Antenna Pol (H/V)	Antenna Factor (dB)	Cable Loss (dB)	Pre Amp Gain (dB)	Field Strength (dBμV/m at 1m)	Corrected Average Field Strength (dBμV/m at 3m)	EIRP (dBm)	Limit (dBm)	Margin (dB)
31.65	32.21	H	38.302	8.7	38.457	40.755	31.21	-64.09	-61.3	-2.79



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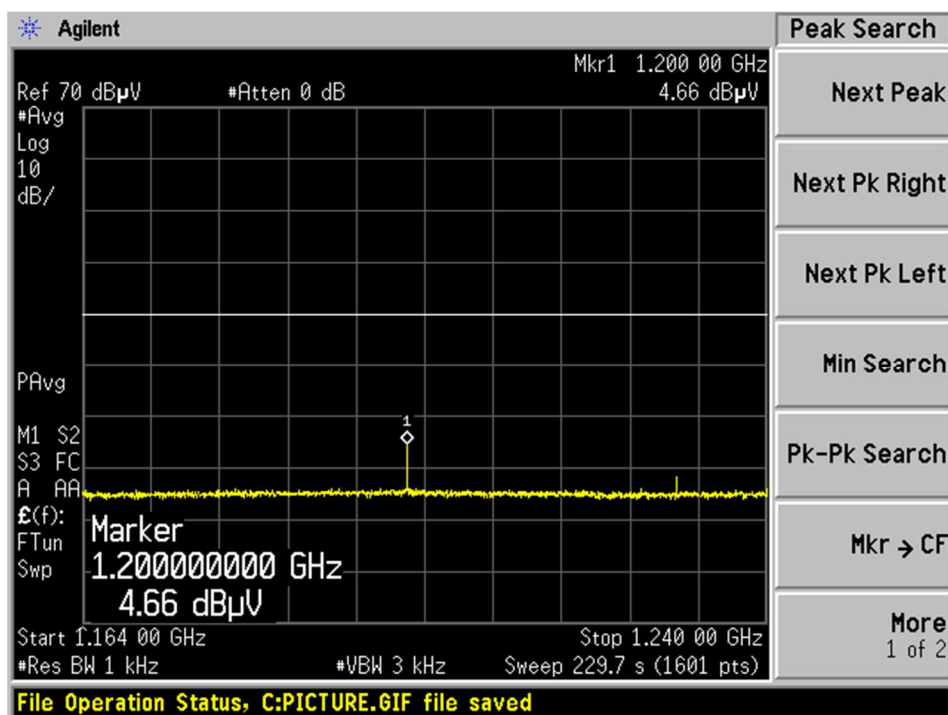
Note: In radiated measurement screenshots from 26.5GHz to 40GHz, shown emissions do not account for equipment factors. In this case, highest emission was chosen and corrected value was calculated given equipment factors in order to compare to limit.

Additional Radiated Average Spurious Emissions with RBW of 1 kHz

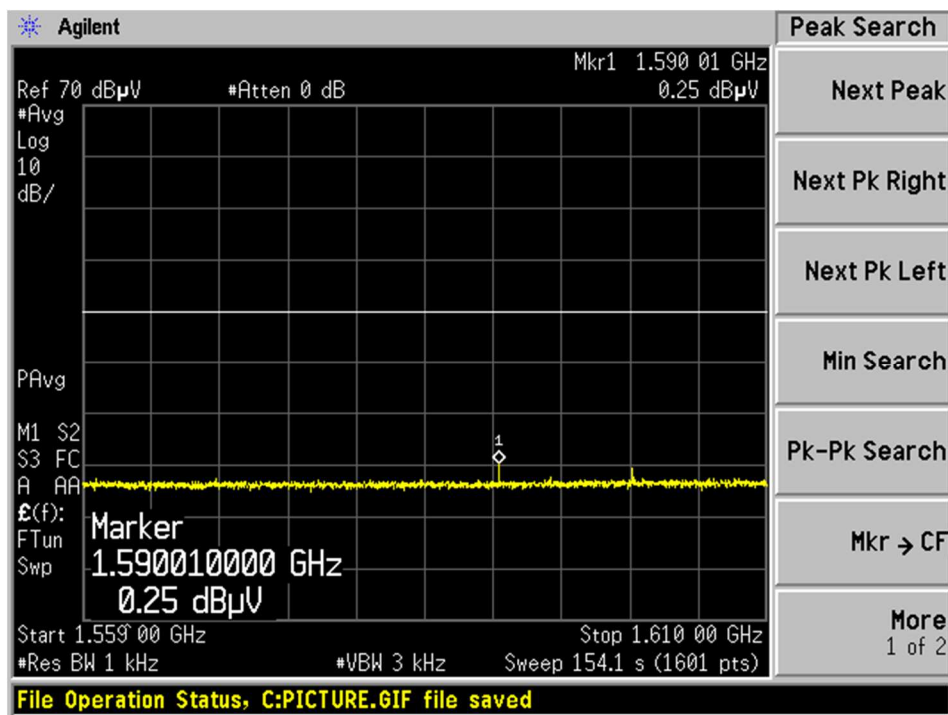
Channel	Frequency Range (MHz)	Emission Frequency (MHz)	Highest Emission (dBuV/m at 1 meter)	Corrected Value (dBuV/m at 3 meters)	EIRP	Limit (dBm)	Margin (dB)
5	1164-1240	1200	4.66	-4.88	-100.18	-85.3	-14.88
	1559-1610	1590.01	0.25	-9.29	-104.59	-85.3	-19.29
9	1164-1240	1229.98	-3.00	-12.54	-107.84	-85.3	-22.54
	1559-1610	1608.15	-2.23	-11.77	-107.07	-85.3	-21.77

Channel 5

1164MHz-1240MHz

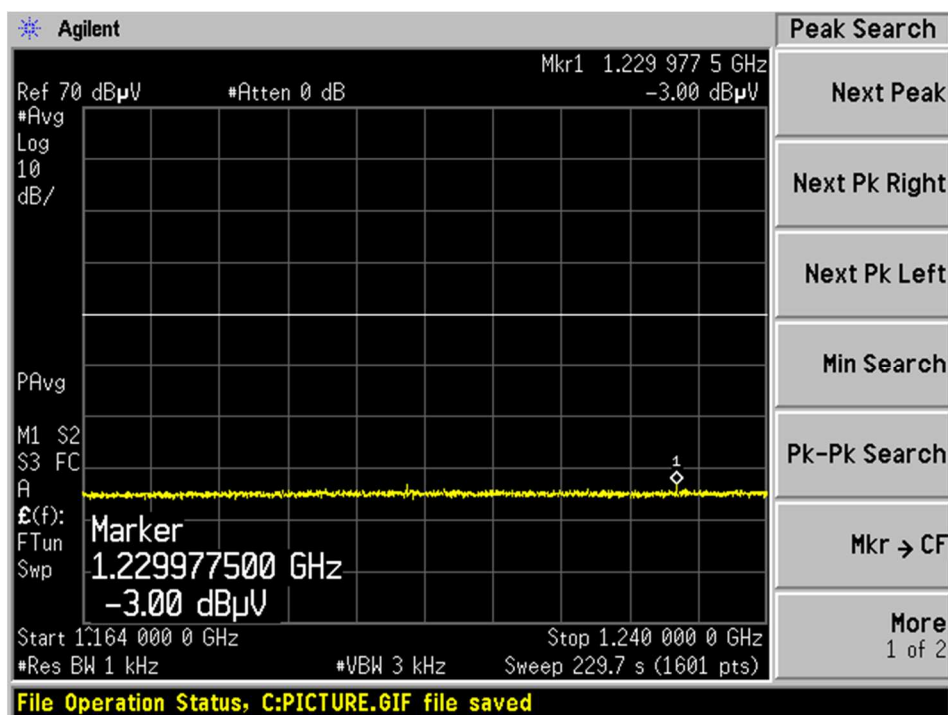


1559MHz-1610MHz

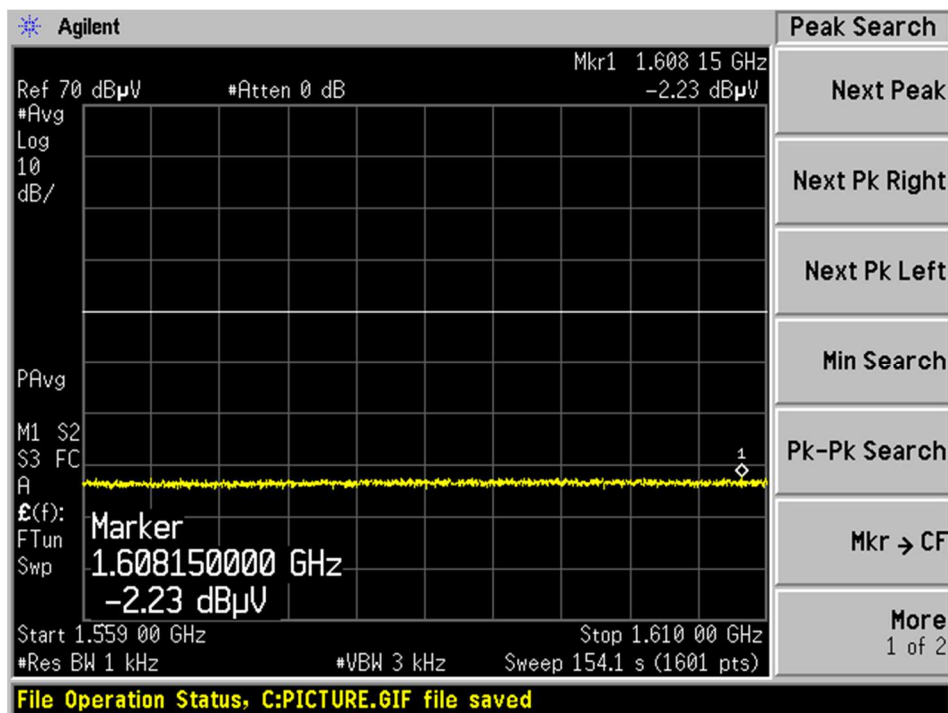


Channel 9

1164MHz-1240MHz



1559MHz-1610MHz



Note: In radiated measurement screenshots from 1164MHz to 1610MHz, shown emissions account for equipment factors to show corrected values.

7 FCC §15.519(c), (e), §15.521(e) & ISEDC RSS-220 §5.3.1(g), §5.3.1(d) – Peak Fundamental Emission

7.1 Applicable Standards

According to FCC §15.519(e): There is a limit on the peak level of the emissions contained within a 50 MHz bandwidth centered on the frequency at which the highest radiated emission occurs, f_M . That limit is 0 dBm EIRP. It is acceptable to employ a different resolution bandwidth, and a correspondingly different peak emission limit, following the procedures described in §15.521.

According to FCC §15.521(e): The frequency at which the highest radiated emission occurs, f_M , must be contained within the UWB bandwidth.

According to ISEDC RSS-220 §5.3.1(g): The peak level of the transmissions shall not exceed the peak equivalent of the average limit contained within any 50 MHz bandwidth, as defined in section 4 of the Annex

According to ISEDC RSS-220 Annex 4(c): Peak measurements shall be made in addition to average measurements. Transmissions shall not exceed 0 dBm e.i.r.p. in any 50 MHz bandwidth when the average limit is -41.3 dBm/MHz.

According to FCC §15.521(g): When a peak measurement is required, it is acceptable to use a resolution bandwidth other than the 50 MHz specified in this subpart. This resolution bandwidth shall not be lower than 1 MHz or greater than 50 MHz, and the measurement shall be centered on the frequency at which the highest radiated emission occurs, f_M . If a resolution bandwidth other than 50 MHz is employed, the peak EIRP limit shall be $20 \log (RBW/50)$ dBm where RBW is the resolution bandwidth in megahertz that is employed. This may be converted to a peak field strength level at 3 meters using $E(\text{dBuV/m}) = P(\text{dBm EIRP}) + 95.2$. If RBW is greater than 3 MHz, the application for certification filed with the Commission must contain a detailed description of the test procedure, calibration of the test setup, and the instrumentation employed in the testing.

According to FCC §15.519(c): (c) The radiated emissions at or below 960 MHz from a device operating under the provisions of this section shall not exceed the emission levels in §15.209. The radiated emissions above 960 MHz from a device operating under the provisions of this section shall not exceed the following average limits when measured using a resolution bandwidth of 1 MHz:

Frequency in MHz	EIRP in dBm
960-1610	-75.3
1610-1990	-63.3
1990-3100	-61.3
3100-10600	-41.3
Above 10600	-61.3

According to ISEDC RSS-220 §5.3.1(d): Radiated emissions above 960 MHz from a device shall not exceed the following average limits when measured using a resolution bandwidth of 1 MHz.

Frequency	EIRP
960-1610 MHz	-75.3 dBm
1.61-4.75 GHz	-70.0 dBm
4.75-10.6 GHz	-41.3 dBm
Above 10.5 GHz	-51.3 dBm

7.2 Measurement Procedure

The measurements were based on ANSI C63.10-2013, American National Standard of Procedures for Compliance Testing of Unlicensed Wireless Devices section 10.3: Radiated measurement procedure above 960MHz.

7.3 Test Equipment List and Details

Manufacturer	Description	Model No.	Serial No.	Calibration Date	Calibration Interval
Rhode & Schwarz	Spectrum Analyzer	FSV40	1321.3008K39-101203-UW	2020-02-06	1 year
Sunol Sciences	System Controller	SC99V	011003-1	N/R	N/A
ETS Lindgren	Horn Antenna	3117	00218973	2019-02-13	2 years
Agilent	Preamplifier	8449B	3147A00400	2020-02-27	1 year
-	SMA cable	-	-	Each time ¹	N/A
IW Microwave	157 Series Cable Armored with 2.92mm Male Plugs on Both Sides	KPS-1571AN-2400	DC 1922	2020-06-06	1 year

Note¹: cables and notch filter included in the test set-up will be checked each time before testing.

Statement of Traceability: *BACL Corp.* attests that all of the calibrations on the equipment items listed above were traceable to NIST or to another internationally recognized National Metrology Institute (NMI), and were compliant with A2LA Policy P102 (dated 02 October 2018) "A2LA Policy on Metrological Traceability".

7.4 Test Environmental Conditions

Temperature:	23° C
Relative Humidity:	42 %
ATM Pressure:	102.7 KPa

The testing was performed by Christian McCaig on 2020-08-04 and 2020-08-10 in bench and 5m3.

7.5 Test Results

Channel Number	Channel Frequency (MHz)	PSA Reading (dBμV)	Antenna Factor (dB/m)	Cable Loss (dB)	Pre Amp Gain (dB)	Field Strength (dBμV/m at 1m)	Corrected Field Strength (dBμV/m at 3m)	Limit ¹ (dBμV/m at 3m)	Margin (dB)
5	6490	56.57	36	11.578	35.28	68.868	59.33	61.22	-1.89
9	7987	57.7	36.3	12.613	36.03	70.583	61.04	61.22	-0.18

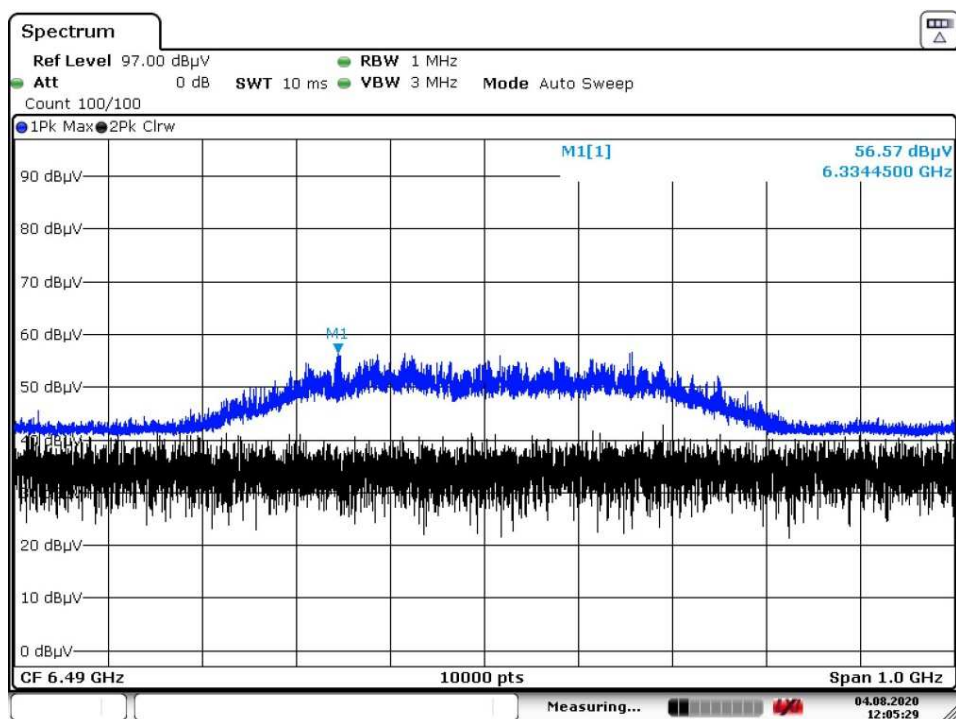
Note¹: Radiated Peak limit determined using a 1MHz measurement BW. (i.e. $20 \cdot \log(\text{RBW}/50) = -33.98\text{dBm}$) then adding 95.2dB for field strength at 3 meters as instructed to in FCC §15.521(g)

Channel Number	Channel Frequency (MHz)	f _M (MHz)	Range of UWB BW ² (MHz)	Result
5	6490	6334.5	6259.2-6767.1	Pass
9	7987	7902.6	7748.9-8255.1	Pass

Note²: please refer to Section 8.5 of this report for the UWB bandwidth measurement result.

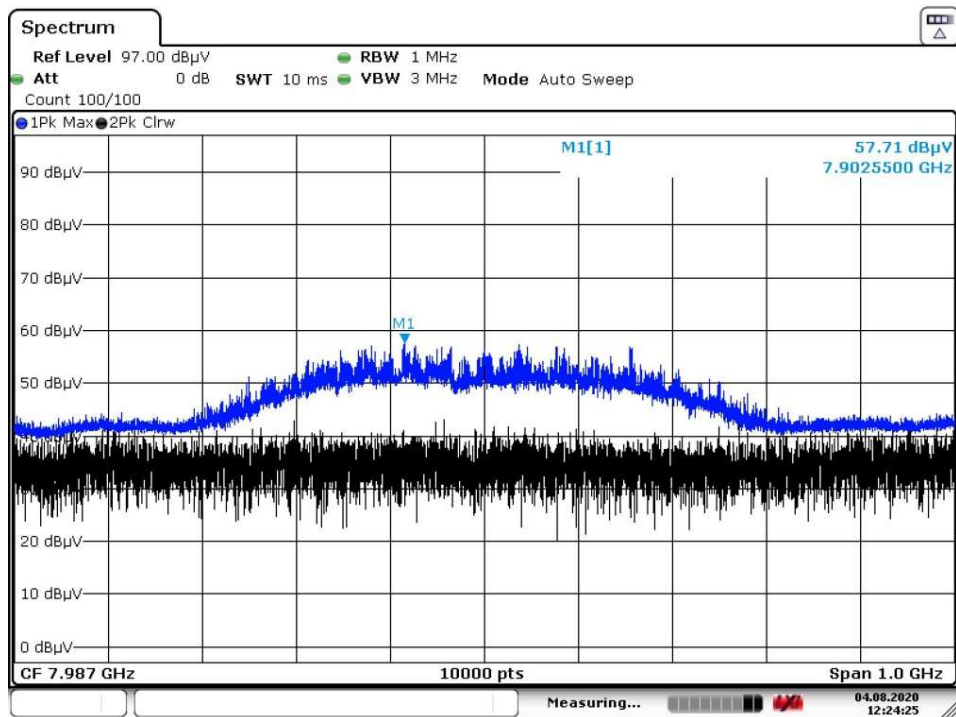
Please refer to the following plots.

Channel 5, Fundamental Peak Measurement



Date: 4.AUG.2020 12:05:29

Channel 9, Fundamental Peak Measurement



Date: 4.AUG.2020 12:24:26

8 FCC §15.503(d), §15.519(b) & ISEDC RSS-220 §5.1(a), RSS-Gen §6.7 -Emission Bandwidth

8.1 Applicable Standards

According to ECFR §15.503(a), For the purpose of this subpart, the UWB bandwidth is the frequency band bounded by the points that are 10 dB below the highest radiated emission, as based on the complete transmission system including the antenna.

According to ECFR §15.519(b) and ISEDC RSS-220 §5.1(a), the UWB bandwidth of a device operating under the provisions of this section must be contained between 3100 MHz and 10,600 MHz.

According to ECFR §15.503(b) and ISEDC RSS-220 §5.1(a), An intentional radiator that, at any point in time, has a fractional bandwidth equal to or greater than 0.20 or has a UWB bandwidth equal to or greater than 500 MHz, regardless of the fractional bandwidth.

According to ISEDC RSS-Gen§6.7, The occupied bandwidth or the “99% emission bandwidth” is defined as the frequency range between two points, one above and the other below the carrier frequency, within which 99% of the total transmitted power of the fundamental transmitted emission is contained. The occupied bandwidth shall be reported for all equipment in addition to the specified bandwidth required in the applicable RSSs.

8.2 Measurement Procedure

The UWB bandwidth measurements were based on ANSI C63.10-2013, American National Standard of Procedures for Compliance Testing of Unlicensed Wireless Devices section 10.1: Evaluation of -10dB bandwidth.

8.3 Test Equipment List and Details

Manufacturer	Description	Model No.	Serial No.	Calibration Date	Calibration Interval
Agilent	Spectrum Analyzer	E4446A	MY48250238	2019-06-26	18 months
Sunol Sciences	System Controller	SC99V	011003-1	N/R	N/A
ETS Lindgren	Horn Antenna	3117	00218973	2019-02-13	2 years
Agilent	Preamplifier	8449B	3147A00400	2020-02-27	1 year
-	SMA cable	-	-	Each time ¹	N/A
IW Microwave	157 Series Cable Armored with 2.92mm Male Plugs on Both Sides	KPS- 1571AN-2400	DC 1922	2020-06-06	1 year

Note¹: cables and notch filter included in the test set-up will be checked each time before testing.

Statement of Traceability: *BACL Corp.* attests that all of the calibrations on the equipment items listed above were traceable to NIST or to another internationally recognized National Metrology Institute (NMI), and were compliant with A2LA Policy P102 (dated 02 October 2018) "A2LA Policy on Metrological Traceability".

8.4 Test Environmental Conditions

Temperature:	23° C
Relative Humidity:	42 %
ATM Pressure:	102.7 KPa

The testing was performed by Christian McCaig on 2020-08-03 and 2020-09-03 in bench and 5m3.

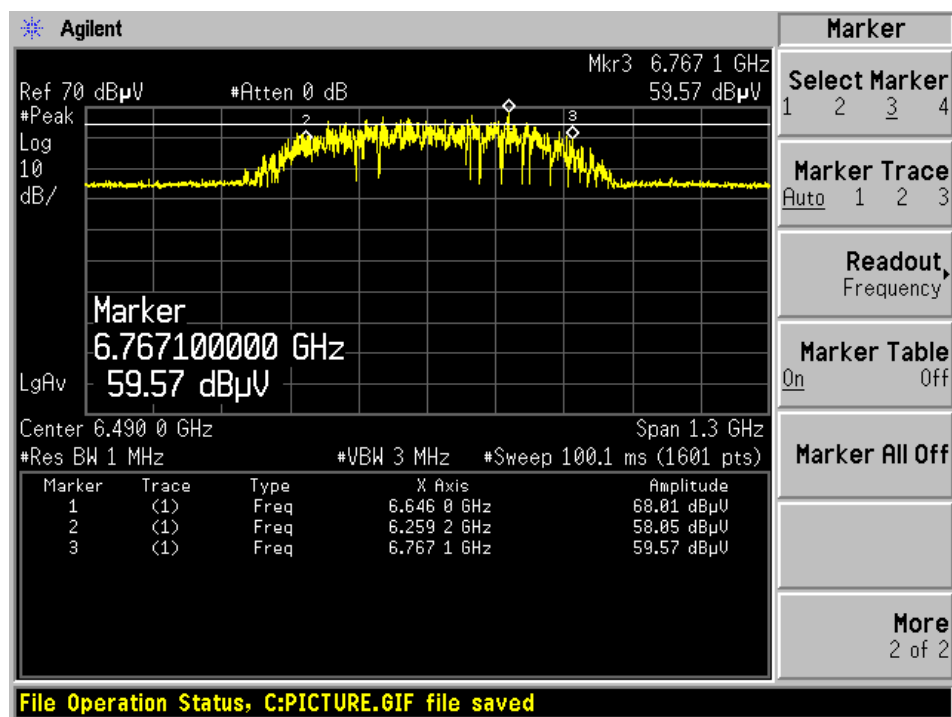
8.5 Test Results

10 dB Bandwidth

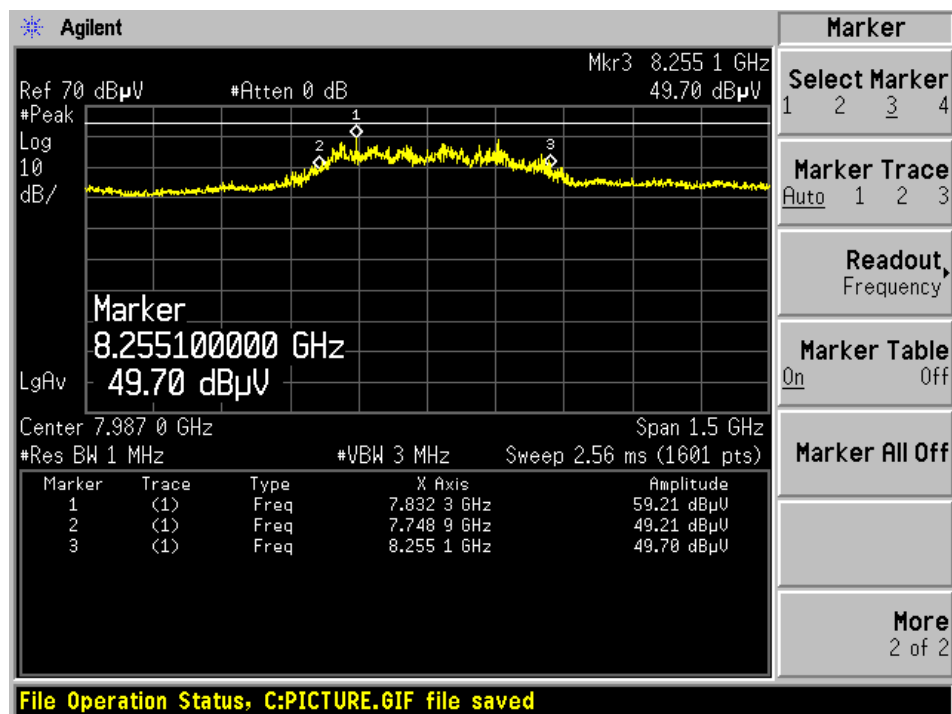
Channel	Frequency (MHz)	10 dB BW (MHz)	10 dB BW limit (MHz)	10 dB BW within 3100MHz-10600MHz
5	6490	507.9	>500	Pass
9	7987	506.2	>500	Pass

Please refer to the following plots.

Channel 5



Channel 9



9 FCC §15.519(a) (1) & ISEDC RSS-220 §5.3.1(b) – Cease Transmission

9.1 Applicable Standards

According to FCC §15.519(a)(1) and RSS-220 §5.3.1(b): A UWB device operating under the provisions of this section shall transmit only when it is sending information to an associated receiver. The UWB intentional radiator shall cease transmission within 10 seconds unless it receives an acknowledgement from the associated receiver that its transmission is being received. An acknowledgment of reception must continue to be received by the UWB intentional radiator at least every 10 seconds or the UWB device must cease transmitting.

9.2 Measurement Procedure

Transmission monitored over a 20 second period. Device will begin transmitting during this period and it is recorded how long the transmission continues without receiving an acknowledgement of reception.

9.3 Test Equipment List and Details

Manufacturer	Description	Model No.	Serial No.	Calibration Date	Calibration Interval
Agilent	Spectrum Analyzer	E4446A	MY48250238	2019-06-26	18 months
ETS Lindgren	Horn Antenna	3117	00218973	2019-02-13	2 years

Statement of Traceability: BACL Corp. attests that all of the calibrations on the equipment items listed above were traceable to NIST or to another internationally recognized National Metrology Institute (NMI), and were compliant with A2LA Policy P102 (dated 02 October 2018) “A2LA Policy on Metrological Traceability”.

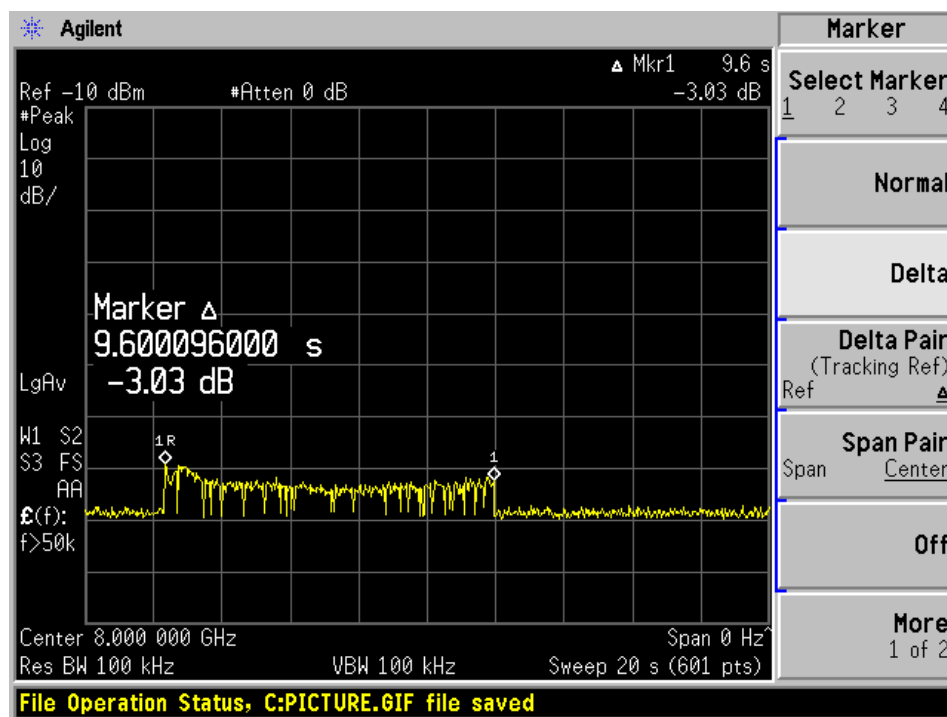
9.4 Test Environmental Conditions

Temperature:	23° C
Relative Humidity:	42 %
ATM Pressure:	102.7 KPa

The testing was performed by Christian McCaig on 2020-08-04 in 5m chamber 3.

9.5 Test Results

Transmission Time (Seconds)	Limit (Seconds)
9.6	< 10



Note: The cease of transmission function operates the same way on the two channels of this device. Therefore, only channel 9 was selected for testing.

10 Annex A - EUT Photographs

Please see attachments:

- Exhibit – EUT Test Setup Photographs
- Exhibit – EUT External Photographs
- Exhibit – EUT Internal Photographs

11 Annex B (Normative) - A2LA Electrical Testing Certificate



Please follow the web link below for a full ISO 17025 scope

<https://www.a2la.org/scopepdf/3297-02.pdf>

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