FCC PART 15, SUBPART C

TEST REPORT

For

Tesla Motors, Inc.

3500 Deer Creek Road,
Palo Alto, CA 94304, USA

FCC ID: 2AEIM-1616631

Report Type: Original Report	**Product Type:** Vehicle Millimeter-wave Radar Sensor

Prepared By: Zhao Zhao, Test Engineer

Report Number: R2012144-255

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ACCREDITED
CERTIFICATE #3297.02

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DOCUMENT REVISION HISTORY

Revision Number	Report Number	Description of Revision	Date of Revision
0	R2012144-255	Original Report	2020-01-05

1 General Description

1.1 Product Description for Equipment Under Test (EUT)

This test report was prepared on behalf of *Tesla Motors, Inc,* and their product *model: 1616631*, *FCC ID: 2AEIM-1616631,* or the "EUT" as referred to in this report. The equipment under test (EUT) was an Vehicle Millimeter-wave Radar Sensor operating in 60 GHz band (60-64 GHz).

The EUT measures approximately 67mm (L) x 48mm (W) x 11mm (H) and weighs approximately 0.1kg.

Serial Number: R2012144-001 assigned by BACL

1.2 Objective

This report was prepared on behalf of *Tesla Motors, Inc*, in accordance with Part 2, Subpart J, and Part 15, Subpart C of the Federal Communication Commission's rules.

The objective was to determine compliance with FCC Part 15.255 for Output Power, Antenna Requirements, 20 dB Bandwidth, Fundamental EIRP, and Radiated Spurious Emissions.

1.3 Related Submittal(s)/Grant(s)

N/A

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.

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 º 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 3297.02)*****,** 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 3297.03)*** 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 3297.01)*** 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 - ISEDC) Foreign Certification Body – FCB – APEC Tel MRA -Phase I & Phase II;
- Chinese Taipei (Republic of China – Taiwan):
  - BSMI (Bureau of Standards, Metrology and Inspection) APEC Tel MRA -Phase I;
  - NCC (National Communications Commission) APEC Tel MRA -Phase I;
- European Union:
  - EMC Directive 2014/30/EU US-EU EMC & Telecom MRA CAB (NB)
  - Radio Equipment (RE) Directive 2014/53/EU US-EU EMC & Telecom MRA CAB (NB)
  - 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:
    - ENERGY STAR Recognized Test Laboratory – US EPA
    - Telecommunications Certification Body (TCB) – US FCC;
    - 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

The test firmware was provided by Tesla Motors, Inc Two modes are able to be set, normal mode and testing mode. Normal mode is FM-CW signal sweeping in the operating band. Testing mode is one carrier signal operating at fixed frequency.

Mode	Frequency (GHz)	Power Setting
Sweeping	60-64	-8
Sweeping stop	60, 62, 64	-8

2.3 Equipment Modifications

No equipment modifications were made to the EUT

2.4 Local Support Equipment

Manufacturer	Description	Model	Serial Number
Dell	Laptop	Latitude E6410	3CKRAQ1
Volteq	Power Supply	HY5003D	180100168

2.5 Remote Support Equipment

Manufacturer	Description	Model	Serial Number
PEAK-SYSTEM	PCAN-USB adapter	IPEH-002022-267801	-
Tesla	Serial to serial debug board	1020358-00-A Rev 01	-

2.6 Interface Ports and Cabling

Cable Description	Length (m)	To	From
Power cord	<1	EUT	Power Supply
Serial Cable	<1	EUT	Laptop

3 Summary of Test Results

Results reported relate only to the product tested.

FCC Rules	Description of Test	Results
§15.203	Antenna Requirement	Compliant
§2.1091, §15.255(g)	RF Exposure	Compliant
§15.207	AC Line Conducted Emissions	N/A[1]
§2.1053, §15.205, §15.209, §15.255(d)	Radiated Spurious Emissions	Compliant
§15.215	Emission Bandwidth	Compliant
§15.255(c)(3), §15.255(e)	Fundamental EIRP Output Power	Compliant
§15.255(c)(3), §15.255(e)	Conducted Peak Output Power	Compliant[2]
§15.255(f)	Frequency Stability	Compliant

Note[1]: The EUT was powered by battery.
Note[2]: Conducted Peak Output Power was not tested because the EUT does not have a conducted antenna port. The conducted output power recorded in this report to compare with the limit was derived from the measured e.i.r.p. and antenna gain.

4 FCC §15.203 - 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.

4.2 Antenna Description

Antenna usage	Band of Operation (GHz)	Maximum Antenna Gain (dBi)
Integral antenna within the Integrated Circuit package	60-64	9.2

Note: The maximum antenna gain was provided by the manufacturer

5 FCC §2.1091 & §15.255(g) - 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

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

Maximum E.I.R.P (dBm):	-1.4
Maximum E.I.R.P (mW):	0.72
Prediction distance (cm):	20
Prediction frequency (MHz):	64000
Power density of prediction frequency at 20.0 cm (mW/cm^2):	0.00014
FCC MPE limit for uncontrolled exposure at prediction frequency (mW/cm^2):	1.0

The device is compliant with the FCC requirement MPE limit for uncontrolled exposure. The maximum power density at the distance of 20 cm is 0.00014 mW/cm^2. Limit is 1.0 mW/cm^2.

6 FCC §15.209 & §15.255(d) - Spurious Radiated Emissions

6.1 Applicable Standards

As per FCC §15.35(d): 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 0.495 – 0.505 2.1735 – 2.1905 4.125 – 4.128 4.17725 – 4.17775 4.20725 – 4.20775 6.215 – 6.218 6.26775 – 6.26825 6.31175 – 6.31225 8.291 – 8.294 8.362 – 8.366 8.37625 – 8.38675 8.41425 – 8.41475 12.29 – 12.293 12.51975 – 12.52025 12.57675 – 12.57725 13.36 – 13.41	16.42 – 16.423 16.69475 – 16.69525 25.5 – 25.67 37.5 – 38.25 73 – 74.6 74.8 – 75.2 108 – 121.94 123 – 138 149.9 – 150.05 156.52475 – 156.52525 156.7 – 156.9 162.0125 –167.17 167.72 – 173.2 240 – 285 322 – 335.4 399.9 – 410 608 – 614	960 – 1240 1300 – 1427 1435 – 1626.5 1645.5 – 1646.5 1660 – 1710 1718.8 – 1722.2 2200 – 2300 2310 – 2390 2483.5 – 2500 2690 – 2900 3260 – 3267 3.332 – 3.339 3 3458 – 3 358 3.600 – 4.400	4. 5 – 5. 15 5. 35 – 5. 46 7.25 – 7.75 8.025 – 8.5 9.0 – 9.2 9.3 – 9.5 10.6 – 12.7 13.25 – 13.4 14.47 – 14.5 15.35 – 16.2 17.7 – 21.4 22.01 – 23.12 23.6 – 24.0 31.2 – 31.8 36.43 – 36.5 Above 38.6

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 FCC §15.255(d):

(1) The power density of any emissions outside the 57-71 GHz band shall consist solely of spurious emissions.
(2) Radiated emissions below 40 GHz shall not exceed the general limits in §15.209.
(3) Between 40 GHz and 200 GHz, the level of these emissions shall not exceed 90 pW/cm^2 at a distance of 3 meters.
(4) The levels of the spurious emissions shall not exceed the level of the fundamental emission.

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 C.

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 Test Procedure

The EUT was connected to DC power supply, 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.

Using equation $2D^2/\lambda$ to calculate the far-field boundary distance. D is the largest antenna dimension and λ is wavelength.

D is 0.002 meter, and λ is about 0.0048 meter. Therefore, the far-field boundary is 0.0016 meter.

The EUT was placed on a turntable, which was 0.8 meter (for measurements below 1 GHz and above 40 GHz) or 1.5 meters (for measurements between 1 GHz and 40 GHz) in height, and 3 meters (for measurements below 1 GHz) or 1 meter (for measurements above 1 GHz) away from measurement antenna. To find the highest emission, the antenna height was varied between 1 and 4 meters, and the turntable was rotated for 360 degrees. The measurement antenna's polarity was also changed between horizontal and vertical.

The spectrum analyzer or receiver was set as:

Below 1000 MHz:

(1) CISPR Quasi-Peak detector and the related measurement bandwidths

Above 1000 MHz:

(2) Peak: RBW = 1MHz / VBW = 3MHz / Sweep = 100 ms
(3) Average: RBW = 1MHz / VBW = 10Hz / Sweep = Auto

6.4 Corrected Amplitude and Margin Calculation

For the emissions from 30 MHz to 40 GHz:

The Corrected Amplitude (CA) is calculated by adding the Correction Factor to the S.A. Reading. The basic equation is as follows:

$$CA = S.A.\ Reading + Correction\ Factor$$

For example, a corrected amplitude of 40.3 dBuV/m = S.A. Reading (32.5 dBuV) + Correction Factor (7.8 dB/m)

The Correction Factor is calculated by adding the Antenna Factor (AF), the Cable Loss (CL), the Attenuator Factor (Atten) and subtracting the Amplifier Gain (Ga) together. This calculation is done in the measurement software, and reported in the test result section. The basic equation is as follows:

$$Correction\ Factor = AF + CL + Atten - Ga$$

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:

$$Margin = Corrected\ Amplitude - Limit$$

For the emissions from 40 GHz to 200 GHz:

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:

$$CA = Ai + AF + CL + Atten - Ga$$

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 e.i.r.p. is calculated from the corrected field strength by using the following formula,

$$EIRP = E\text{-}meas + 20\log(d\text{-}meas) - 104.7$$

Where:
EIRP: is the equivalent isotropically radiated power in dBm
E-meas: is the field strength of the emission at the measurement distance, in dBuV/m
d-meas: is the measurement distance, in m

Finally, use the formula below to calculate the power density and compare the result with the limit.

$$PD = EIRP_{Linear}/4\pi d^2$$

Where:
PD: is the power density at the distance specified by the limit, in W/m^2
$EIRP_{linear}$: is the equivalent isotropically radiated power, in watts
d: is the distance at which the power density limit is specified, in m

The specified distance is 3m.

6.5 Test Equipment List and Details

Manufacturer	Description	Model No.	Serial No.	Calibration Date	Calibration Interval
Agilent	Analyzer, Spectrum	E4446A	US44300386	2019-08-24	1.5 years
Sunol Sciences	System Controller	SC99V	011003-1	N/R	N/A
Rohde & Schwarz	Receiver, EMI Test	ESCI 1166.5950.03	100338	2020-03-17	1 year
OML	Harmonic Mixer and Horn Antenna Set	M03HWA; M05HWA; M08HWA; M12HWA; M19HWA	170615-1	N/R	N/R
Sonoma Instruments	Amplifier, Pre	315	303125	2020-07-20	1 year
IW	157 Series Cable Armored with 2.92mm Male Plugs on Both Sides	KPS-1571AN-2400	DC 1922	2020-06-06	1 year
-	RF cable	-	-	Each time[1]	N/A
Times Microwave	Coaxial Cable	LMR400-UF	1	2020-03-27	1 year
BACL	5m3 Sensitivity Box	1	2	2020-10-27	1 year
Sunol Sciences	Antenna, Biconi-Log	JB3	A020106-3	2020-03-02	2 years
Wisewave	Antenna, Horn	ARH-2823-02	10555-02	2020-02-05	2 years
Wisewave	Antenna, Horn	ARH-4223-02	10555-01	2020-02-27	2 years
AH Systems	18-40GHz Pre-Amplifier	PAM-1840VH	170	2020-10-27	1 year
ETS Lindgren	Horn Antenna	3117	00218973	2019-02-13	2 years

Note[1]: cables 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 the latest version of A2LA policy P102 "A2LA Policy on Metrological Traceability".*

6.6 Test Environmental Conditions

Temperature:	22 ºC
Relative Humidity:	57 %
ATM Pressure:	102.1 kPa

The testing was performed by Zhao Zhao on 2020-12-31 in 5m chamber 3.

6.7 Summary of Test Results

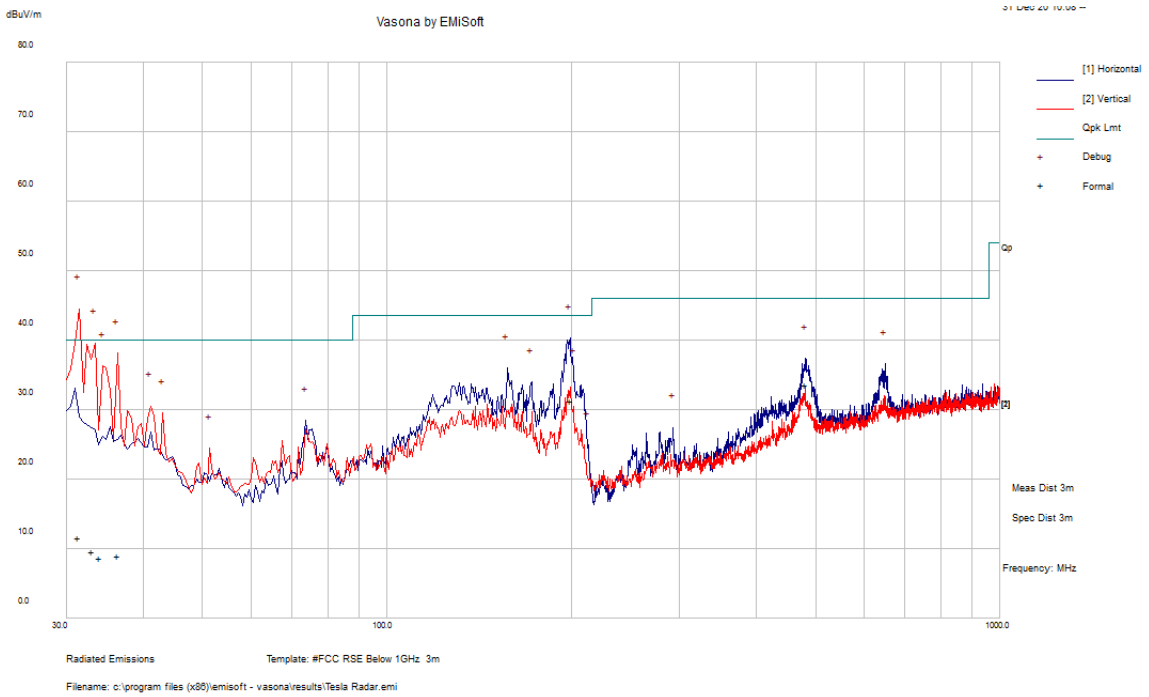
According to the data hereinafter, the EUT complied with FCC Title 47, Part 15C's standard's radiated emissions limits, and had the worst margin of:

Margin (dB)	Frequency (MHz)	Mode
-3.19	37457.04	TX @ 64 GHz

6.8 Spurious Emissions Test Results

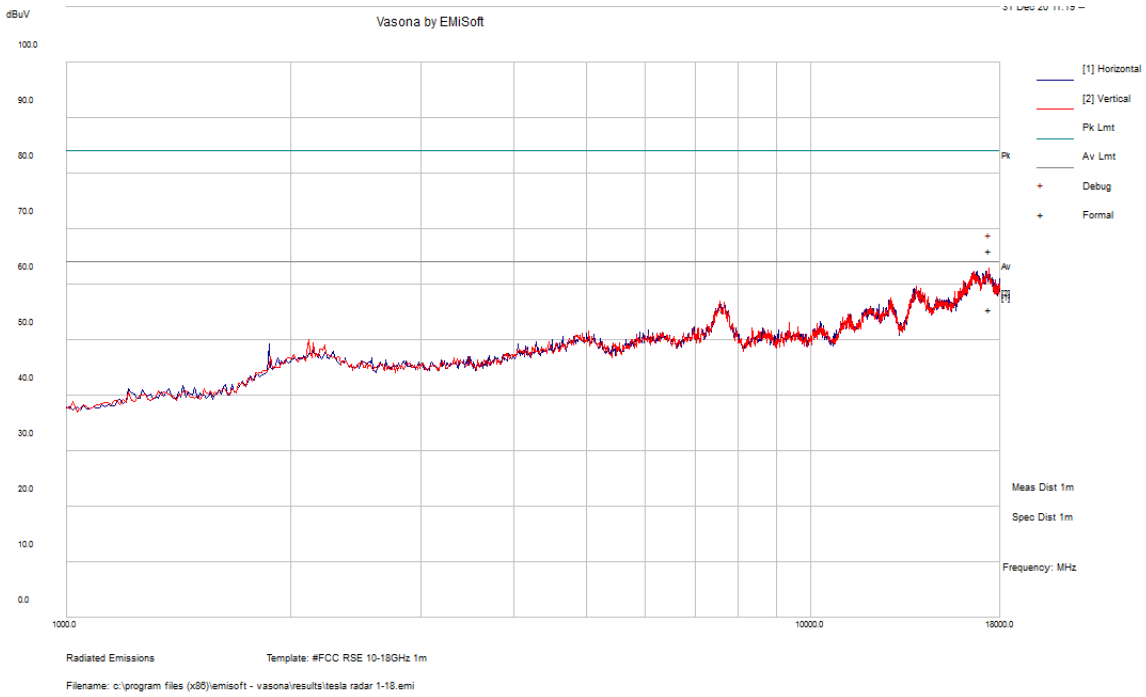
EUT test mode: sweeping stop. Both low, middle, and high channels were pre-scanned, and high channel was determined to be the worst case for final testing.

1) 30 MHz to 1GHz measured at 3 meters



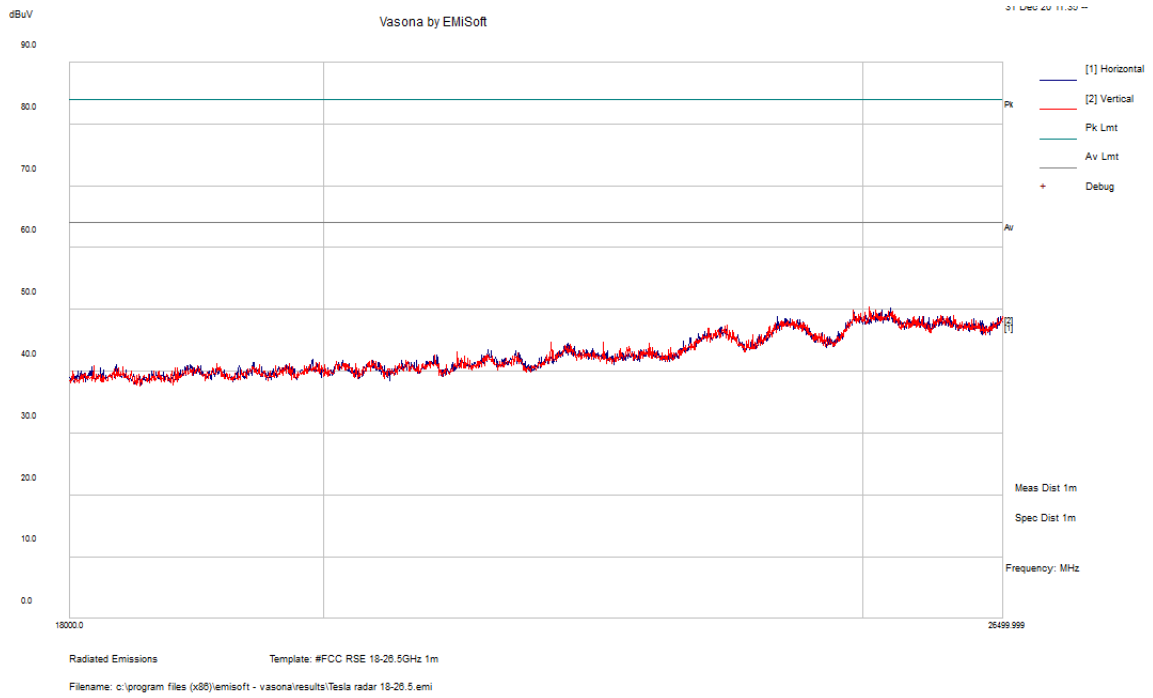
Frequency (MHz)	S.A. Reading (dBuV)	Correction Factor (dB/m)	Corrected Amplitude (dBµV/m)	Antenna Height (cm)	Antenna Polarity (H/V)	Turntable Azimuth (degrees)	Limit (dBµV/m)	Margin (dB)	Comment
31.45	9.02	2.62	11.64	132	H	144	40	-28.36	QP
33.04	8.26	1.4	9.66	193	V	14	40	-30.34	QP
36.47	10.28	-1.22	9.06	261	H	101	40	-30.94	QP
199.15	35.7	-4.39	31.31	243	H	255	43.5	-12.19	QP
34.00	8.22	0.54	8.76	261	H	131	40	-31.24	QP
481.04	32.64	1.03	33.67	174	H	201	46	-12.33	QP

2) 1–18 GHz Measured at 1 meter

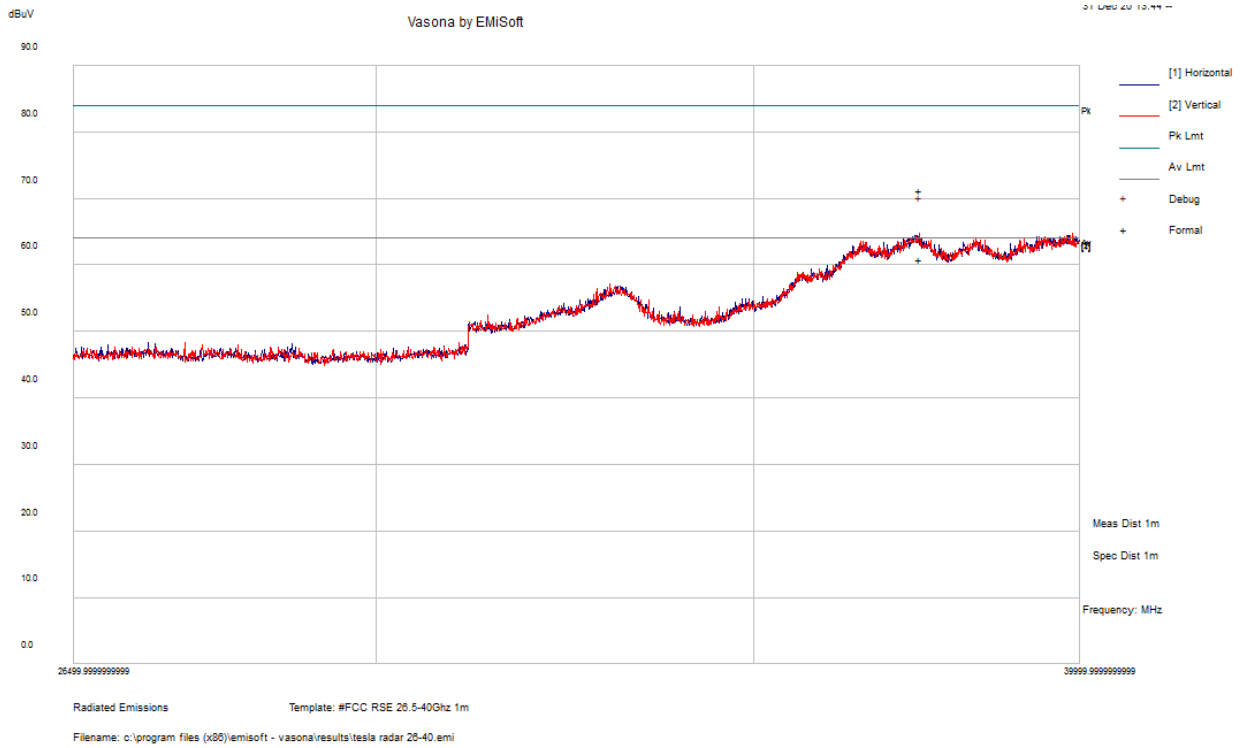


Frequency (MHz)	S.A. Reading (dBuV)	Correction Factor (dB/m)	Corrected Amplitude (dBµV/m)	Antenna Height (cm)	Antenna Polarity (H/V)	Turntable Azimuth (degrees)	Limit (dBµV/m)	Margin (dB)	Comment
17401.56	41.87	24.28	66.14	132	H	130	84	-17.86	Peak
17401.56	31.21	24.28	55.49	132	H	130	64	-8.51	Ave

3) 18-26.5 GHz Measured at 1 meter



4) 26.5-40 GHz Measured at 1 meter



Frequency (MHz)	S.A. Reading (dBuV)	Correction Factor (dB/m)	Corrected Amplitude (dBµV/m)	Antenna Height (cm)	Antenna Polarity (H/V)	Turntable Azimuth (degrees)	Limit (dBµV/m)	Margin (dB)	Comment
37457.04	54.48	16.81	71.28	168	H	101	84	-12.72	Peak
37457.04	44	16.81	60.81	183	V	339	64	-3.19	Ave

5) 40-200 GHz Measured at 1 meter

Frequency (MHz)	S.A. Reading (dBµV)	Turntable Azimuth (degrees)	Test Antenna		Cord. Reading (dBµV/m)	EIRP (dBm)	Power Density (pW/cm²) @3m	FCC	
			Height (cm)	Factor (dB/m)				Limit (pW/cm²)	Margin (pW/cm²)
40300	29.98	0	100	33.64	63.62	-41.08	0.0690	90	-89.9310
64820	29.82	0	100	40.52	70.34	-34.36	0.3240	90	-89.6760
92500	30.66	0	100	51.24	81.9	-22.8	4.6403	90	-85.3597
144130	29.93	0	100	58.57	88.5	-16.2	21.2103	90	-68.7897

7 FCC §15.215 - Emission Bandwidth

7.1 Applicable Standards

According to ECFR §15.215 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.

7.2 Measurement Procedure

The measurements are based on ANSI C63.10-2013.

7.3 Test Equipment List and Details

Manufacturer	Description	Model No.	Serial No.	Calibration Date	Calibration Interval
Rhode and Schwarz	Analyzer, Spectrum	FSU67	101360	2020-06-04	2 years
JUNKOSHA JUNFLOW MXW	RF cable	MWX261/B	1608T001	Each time[1]	N/A
LNF	Low Noise Amplifier 44 GHz to 77 GHz	LNR4577WA	022A	N/R	N/R
Millitech	Antenna Horn	56H-15-RA000	A17928	N/R	N/R

Note[1]: cable 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 the latest version of A2LA policy P102 "A2LA Policy on Metrological Traceability".*

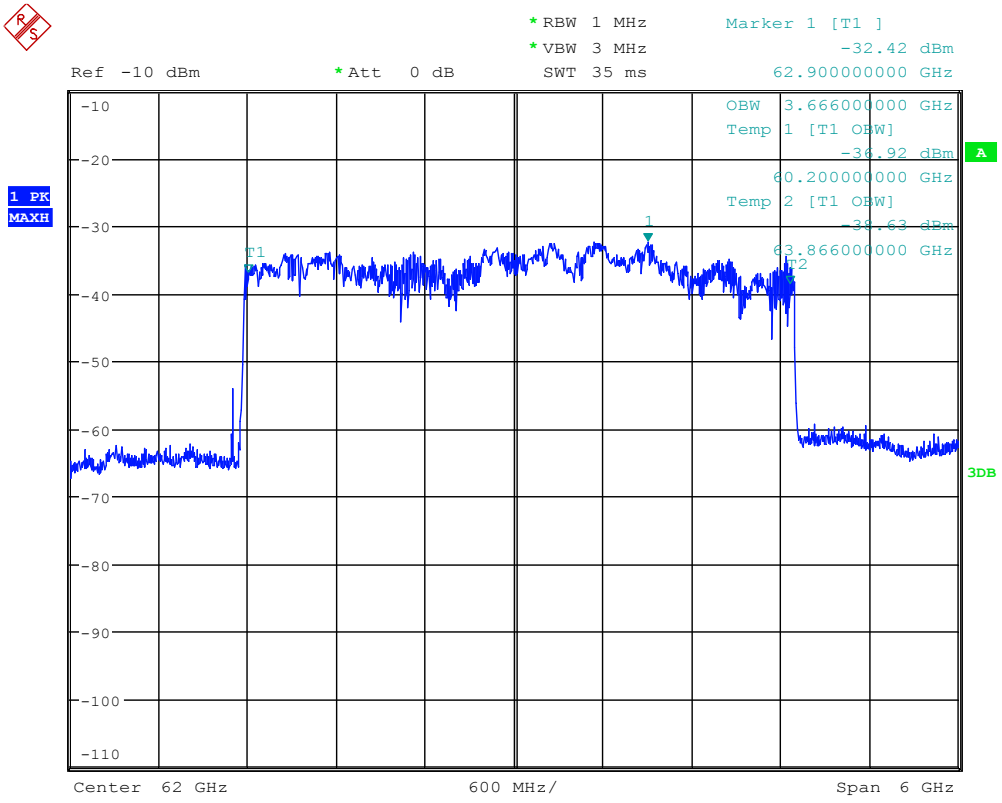
7.4 Test Environmental Conditions

Temperature:	22 ºC
Relative Humidity:	55 %
ATM Pressure:	101.9 kPa

The testing was performed by Zhao Zhao on 2020-12-20 at RF site.

7.5 Test Results

The 99% emission bandwidth is 3.666 GHz.



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8 FCC §15.255(c)(3) - Fundamental EIRP Output Power Measurement

8.1 Applicable Standards

According to ECFR §15.255 (c) (3) for fixed field disturbance sensors other than those operating under the provisions of paragraph (c)(2) of this section, and short-range devices for interactive motion sensing, the peak transmitter conducted output power shall not exceed −10 dBm and the peak EIRP level shall not exceed 10 dBm.

8.2 Measurement Procedure

The measurements for Fundamental E.I.R.P Output Power where done by following the procedure in ANSI C63.10-2013 Clause 9.11Measurement of the fundamental emission using an RF detector.

The Setup was performed as follows:

1) Using equation $2D^2/\lambda$ to calculate the far-field boundary distance. D is the largest antenna dimension and λ is wavelength. D is 0.012 meter, and λ is about 0.0048 meter. Therefore the far-field boundary is 0.06 meter.
2) The measurement instrument shall be a mm-wave RF detector that has an RF bandwidth encompassing the entire authorized frequency band. The input VSWT of the mm-wave detector shall be less than 3:1.
3) For radiated emissions measurements of transmitter output power, connect the test antenna for the fundamental frequency band to the mm-wave RF detector. Place the test horn in the main beam of the EUT at a distance that will provide a signal within the operating range of the RF detector.
4) Connect the video output of the detector to the 50 Ω input of a DSO.
5) Set the sampling rate of the DSO to at least twice the cutoff frequency of any LPF used or to at least twice the signal bandwidth without a LPF. Adjust the memory depth, the triggering, and the sweep speed to obtain a display that is representative of the signal considering the type of modulation.
6) Determine the maximum measurement distance and set the EUT within the distance.

The Test procedure was performed as follows:

1) Record the average and peak voltages from the DSO.
2) Disconnect the test antenna or EUT (as applicable for radiated or conducted tests) from the RF input port of the instrumentation system.
3) Connect an mm-wave source to the RF input port of the instrumentation system via a waveguide variable attenuator.
4) The mm-wave source shall be unmodulated.
5) Adjust the frequency of the mm-wave source to the center of the frequency range occupied by the transmitter.
6) Adjust the amplitude of the mm-wave source and/or the variable attenuator such that the DSO indicates a voltage equal to the peak voltage recorded
7) Disconnect the waveguide variable attenuator from the RF input port of the instrumentation system.
8) Without changing any settings, connect the waveguide variable attenuator to a wideband mm-wave power meter with a thermocouple detector or equivalent.
9) Measure and note the power.
10) Repeat the measurement for the average voltage.
11) Do calculation using the equations in ANSI C63010-2013 Clause 9

8.3 Test Equipment List and Details

Manufacturer	Description	Model No.	Serial No.	Calibration Date	Calibration Interval
Rhode and Schwarz	Analyzer, Spectrum	FSU67	101360	2020-06-04	2 years
Agilent	Power Meter	N1914A	MY5000822	2019-07-28	2 years
HP	Power Sensor	V8488A	US39010099	2019-10-12	2 years
OML	Harmonic Mixer/Multiplier	S12MS	130423-1	N/A	N/A
Vaunix	Signal Generator 6 GHz to 18 GHz	LMS-183DX	19760	2020-08-05	2 years
A-InfoMW	20 dBi Standard Gain Horn Antenna	LB-15-20-A	5202062579	N/R	N/R
LNF	Low Noise Amplifier 44 GHz to 77 GHz	LNR4577WA	022A	N/R	N/R
Millitech	Variable Level Set Attenuator 0 to 25 dBm	LSA-15-R0000	248-A17928	Each time[1]	N/R
Tektronix	Oscilloscope	TDS2024B	C047044	2019-10-17	2 years
Millitech	RF Detector	DET-15	-	N/R	N/R
JUNKOSHA JUNFLOW MXW	RF cable	MWX261/B	1608T001	Each time[1]	N/A

Note[1]: cable 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 the latest version of A2LA policy P102 "A2LA Policy on Metrological Traceability".*

8.4 Test Environmental Conditions

Temperature:	22º C
Relative Humidity:	52 %
ATM Pressure:	102.1 kPa

The testing was performed by Zhao Zhao on 2020-12-30 at RF site.

8.5 Test Results

The fundamental was measured at 0.15 meter.

DSO Reading (V)	P (dBm)	G (dBi)		E-field (dBuV/m)	EIRP (dBm)	Limit (dBm)	Margin (dB)	Detector
		Antenna Gain	Pre-amp Gain					
60 GHz								
2.92	-4.96	20	31.27	116.59	-4.59	10	-14.59	Peak
1.76	-9.13	20	31.27	112.42	-8.76	-	-	Ave.
62 GHz								
2.84	-5.71	20	31.27	116.13	-5.05	10	-10.51	Peak
1.60	-9.94	20	31.27	111.90	-9.28	-	-	Ave.
64 GHz								
3.76	-2.33	20	31.27	119.78	-1.40	10	-11.40	Peak
2.48	-6.84	20	31.27	115.27	-5.91	-	-	Ave.

$$E = 126.8 - 20\log(\lambda) + P - G \quad (19)$$

where

E is the field strength of the emission at the measurement distance, in dBμV/m
P is the power measured at the output of the test antenna, in dBm
λ is the wavelength of the emission under investigation [$300/f_{MHz}$], in m
G is the gain of the test antenna, in dBi

NOTE—The measured power P includes all applicable instrument correction factors up to the connection to the test antenna.

$$\text{EIRP} = E_{Meas} + 20\log(d_{Meas}) - 104.7 \quad (22)$$

where

EIRP is the equivalent isotropically radiated power, in dBm
E_{Meas} is the field strength of the emission at the measurement distance, in dBμV/m
d_{Meas} is the measurement distance, in m

NOTE—Because this equation yields the identical result whether the field strength is extrapolated using the default 20 dB/decade of distance extrapolation factor, or the field strength is not extrapolated for distance, this equation can generally be applied directly (with no further correction) to determine EIRP. In some cases, a different distance correction factor may be required; see 9.1.

Peak Conducted Output Power

Peak EIRP (dBm)	Antenna Gain (dBi)	Peak Conducted Output Power (dBm)	Limit (dBm)	Margin (dB)	Result
-1.40	9.2	-10.60	-10	-0.6	Pass

9 FCC §15.255(f) - Frequency Stability

9.1 Applicable Standards

According to FCC §15.255(f) *Frequency stability.* Fundamental emissions must be contained within the frequency bands specified in this section during all conditions of operation. Equipment is presumed to operate over the temperature range −20 to + 50 degrees Celsius with an input voltage variation of 85% to 115% of rated input voltage, unless justification is presented to demonstrate otherwise.

9.2 Measurement Procedure

The measurements are based on ANSI C63.10-2013.

9.3 Test Equipment List and Details

Manufacturer	Description	Model No.	Serial No.	Calibration Date	Calibration Interval
Rhode and Schwarz	Analyzer, Spectrum	FSU67	101360	2020-06-04	2 years
JUNKOSHA JUNFLOW MXW	RF cable	MWX261/B	1608T001	Each time[1]	N/A
A-InfoMW	20 dBi Standard Gain Horn Antenna	LB-15-20-A	5202062579	N/R	N/R
LNF	Low Noise Amplifier 44 GHz to 77 GHz	LNR4577WA	022A	N/R	N/R
Volteq	Power Source	HY5003D	180100168	N/R	N/R
BACL	Chamber, Humidity	BTH-150-40	30078	2020-06-25	1 year

Note[1]: cable 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 the latest version of A2LA policy P102 "A2LA Policy on Metrological Traceability".*

9.4 Test Environmental Conditions

Temperature:	22º C
Relative Humidity:	55 %
ATM Pressure:	101.9 KPa

The testing was performed by Zhao Zhao on-2020-12-20 in temperature chamber.

9.5 Test Results

Extreme Temperature

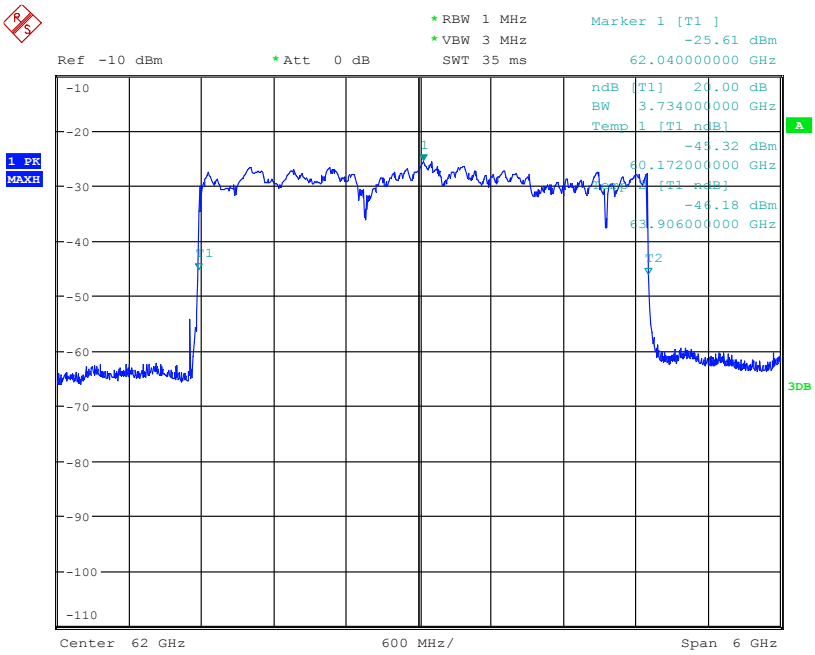
Voltage (V_{DC})	Temperature (°C)	Low Frequency (GHz)	High Frequency (GHz)	Limit (GHz)	Results
16V	-20	60.172	63.906	57-71	pass
	-10	60.172	63.906	57-71	pass
	0	60.172	63.908	57-71	pass
	10	60.170	63.906	57-71	pass
	20	60.168	63.908	57-71	pass
	30	60.170	63.900	57-71	pass
	40	60.168	63.908	57-71	pass
	50	60.166	63.906	57-71	pass

Extreme Voltage

Temperature (°C)	Voltage (V_{DC})	Low Frequency (GHz)	High Frequency (GHz)	Limit (GHz)	Results
20	13.6	60.166	63.904	57-71	pass
	18.4	60.166	63.902	57-71	pass

Please refer to the following plots for details

-20 °C



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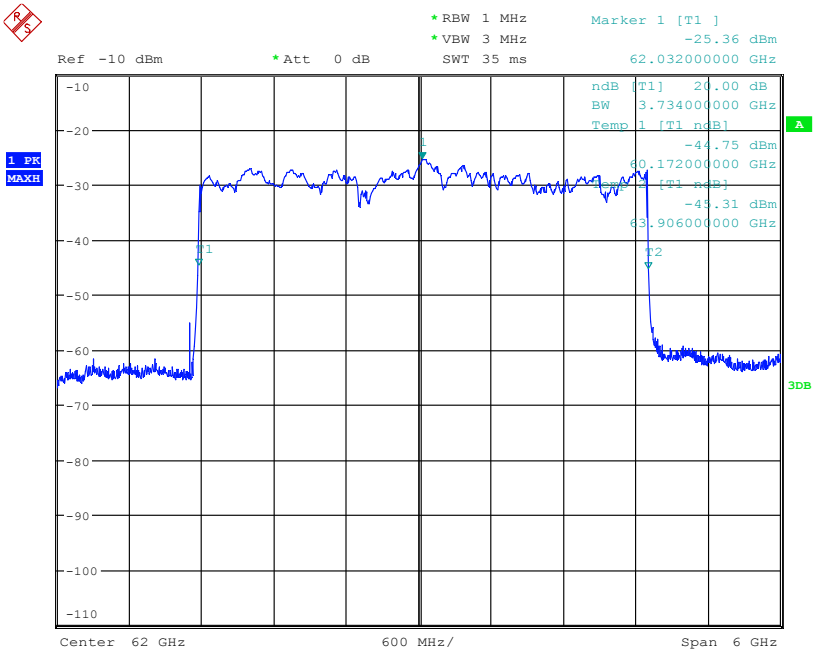
-10 °C



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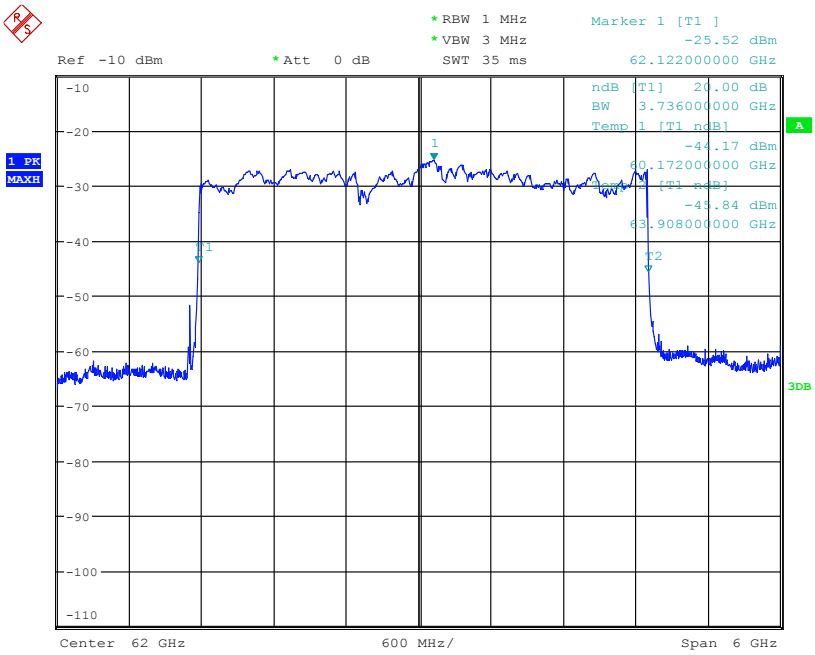
0 °C



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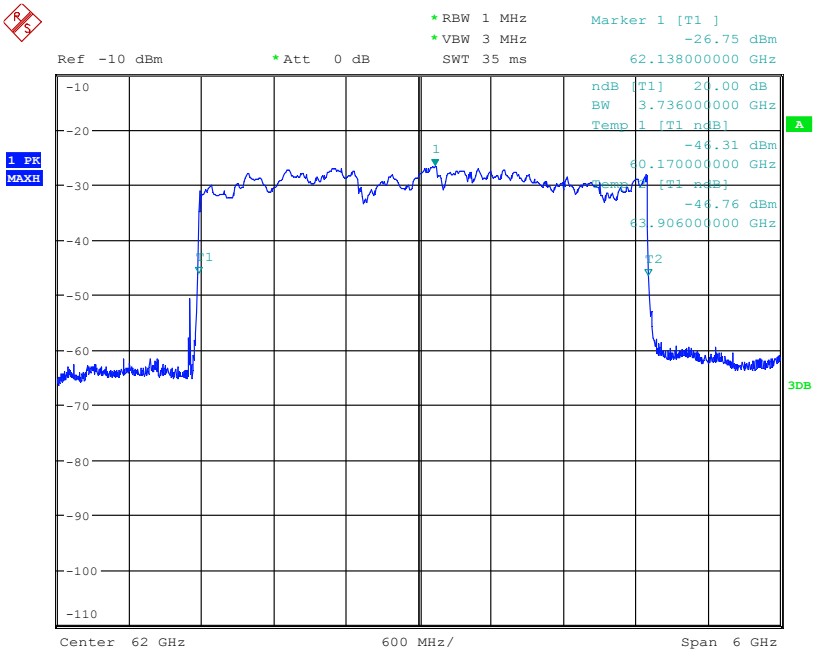
10 °C



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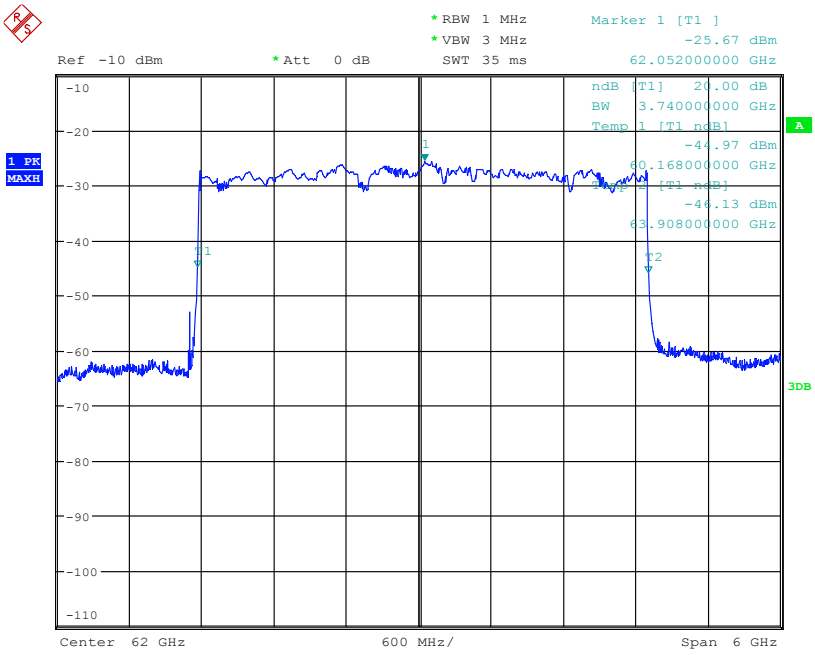
20 °C



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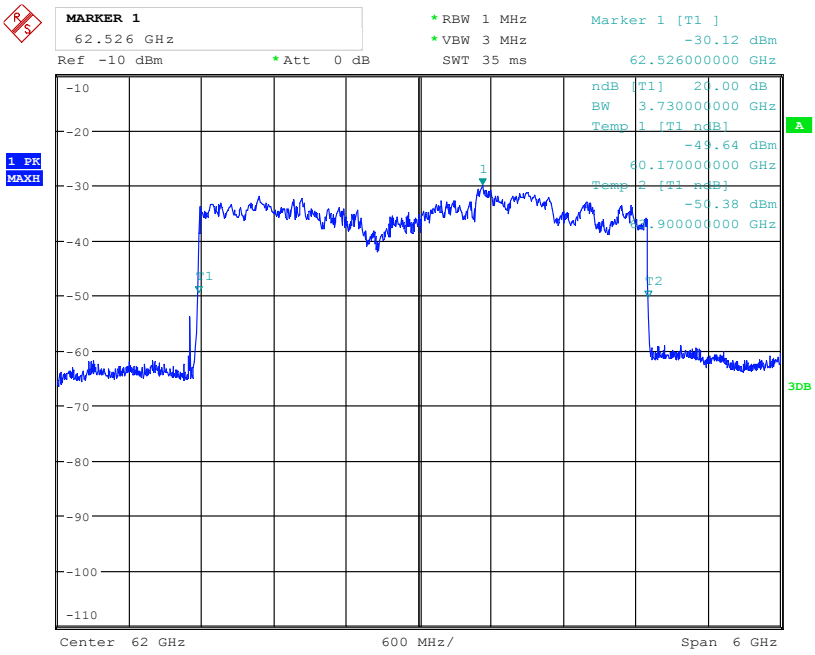
30 °C



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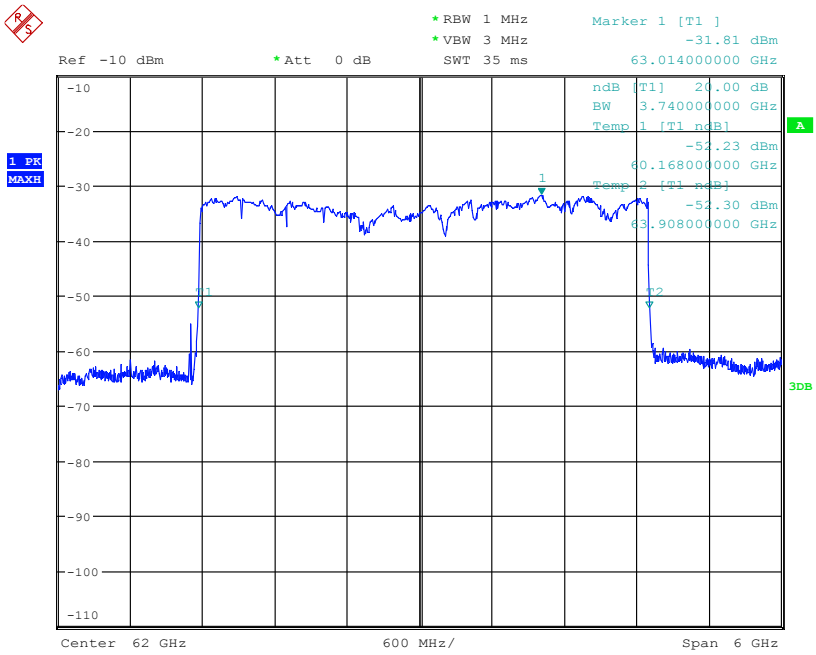
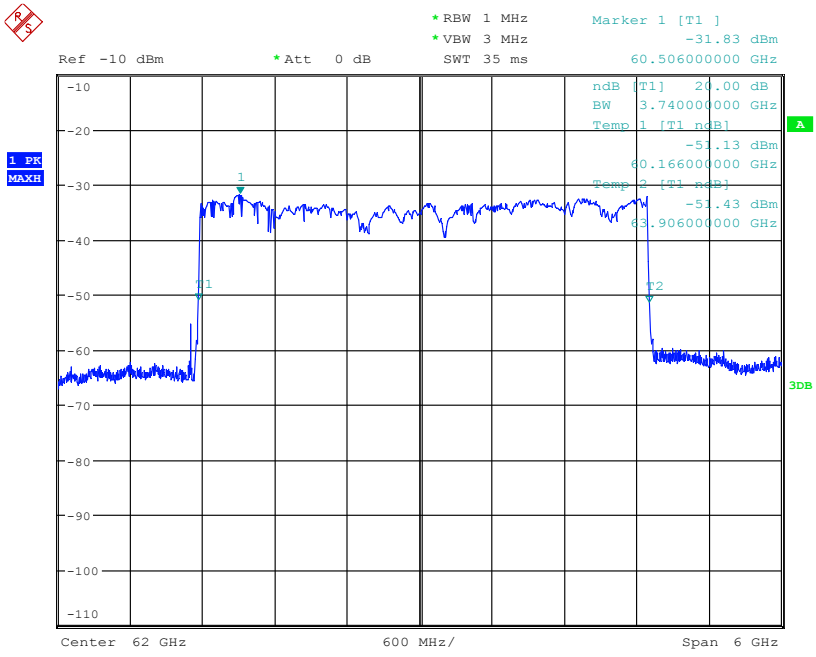
40 °C



Date: 20.DEC.2020 13:53:06

50 °C



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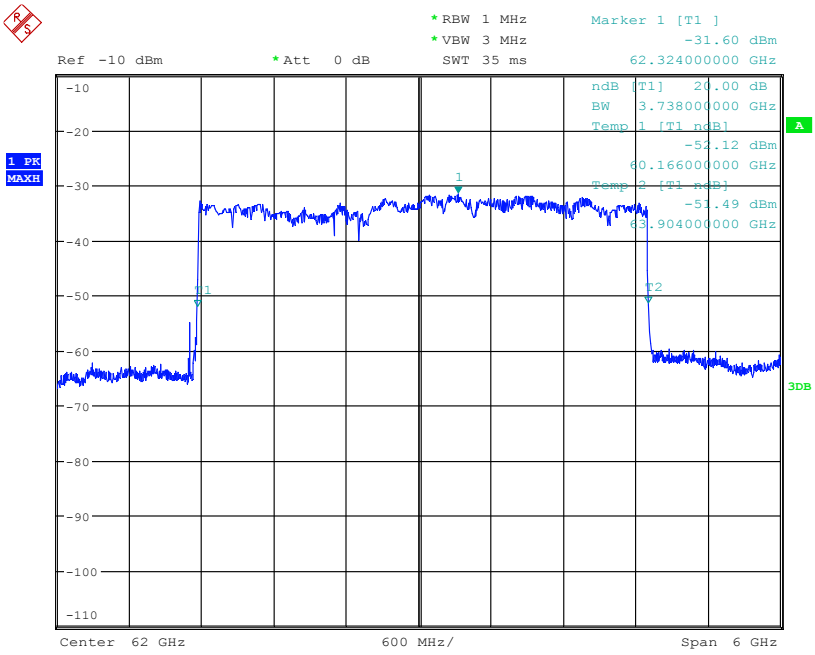
13.6 V_{DC}



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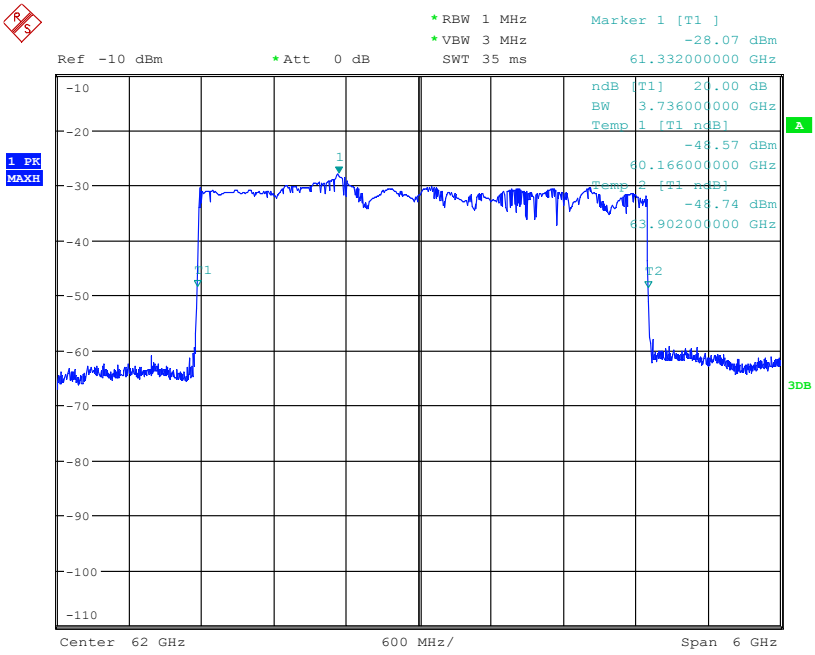
18.4 V_{DC}



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10 Annex A - EUT Test Setup Photographs

Please refer to the attachment.

11 Annex B - EUT External Photographs

Please refer to the attachment.

12 Annex C - EUT Internal Photographs

Please refer to the attachment.

13 Annex D (Normative) - A2LA Electrical Testing Certificate

Accredited Laboratory

A2LA has accredited

BAY AREA COMPLIANCE LABORATORIES CORP.

Sunnyvale, CA

for technical competence in the field of

Electrical Testing

This laboratory is accredited in accordance with the recognized International Standard ISO/IEC 17025:2017 *General requirements for the competence of testing and calibration laboratories*. This laboratory also meets A2LA R222 - *Specific Requirements EPA ENERGY STAR Accreditation Program*. This accreditation demonstrates technical competence for a defined scope and the operation of a laboratory quality management system (*refer to joint ISO-ILAC-IAF Communiqué dated April 2017*).

Presented this 2nd day of October 2018.

Vice President, Accreditation Services
For the Accreditation Council
Certificate Number 3297.02
Valid to February 28, 2021
Revised December 04, 2020

For the tests to which this accreditation applies, please refer to the laboratory's Electrical Scope of Accreditation.

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

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

--- END OF REPORT ---