# CERTIFICATION TEST REPORT

**Report Number :** 14236793-E1V3

**Applicant :** UNIVERSITY OF HAWAII
1000 POPE ROAD, MSB 402,
HONOLULU, HI 96822, U.S.A.

**Model :** MK3-PW-PA-TX

**FCC ID :** 2A562-MK3-PW-PA-TX

**EUT Description :** OCEANOGRAPHIC HIGH FREQUENCY DOPPLER RADAR

**Test Standard :** FCC CFR 47 PART 90 SUBPART F

**Date Of Issue:**
April 19, 2022

**Prepared by:**
UL Verification Services Inc.
47173 Benicia Street
Fremont, CA 94538, U.S.A.
TEL: (510) 319-4000
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ACCREDITED
CERT #0751.05

Revision History

| Rev. | Issue Date | Revisions | Revised By |
|---|---|---|---|
| V1 | 04/11/22 | Initial Issue | GP Chin |
| V2 | 04/14/22 | Updated Description of EUT in Section 5.1<br>Updated Power Summary Table in Section 5.3<br>Added Notes on Pg. 32 and Pg. 35 | GP Chin |
| V3 | 04/19/22 | Added Note on Pg. 17 in Section 8.3. | GP Chin |



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# 1. ATTESTATION OF TEST RESULTS

**COMPANY NAME:** UNIVERSITY OF HAWAII
1000 POPE ROAD, MSB 402,
HONOLULU, HI 96822, U.S.A.

**EUT DESCRIPTION:** OCEANOGRAPHIC HIGH FREQUENCY DOPPLER RADAR

**MODEL:** MK3-PW-PA-TX

**SERIAL NUMBER:** 3-003

**DATE TESTED:** MARCH 9TH - 17TH, 2022

| APPLICABLE STANDARDS | |
|---|---|
| **STANDARD** | **TEST RESULTS** |
| FCC PART 90.103F | Complies |

UL Verification Services Inc. tested the above equipment in accordance with the requirements set forth in the above standards. The test results show that the equipment tested is capable of demonstrating compliance with the requirements as documented in this report.

The results documented in this report apply only to the tested sample, under the conditions and modes of operation as described herein. It is the manufacturer's responsibility to assure that additional production units of this model are manufactured with identical electrical and mechanical components. All samples tested were in good operating condition throughout the entire test program. Measurement Uncertainties are published for informational purposes only and were not taken into account unless noted otherwise.

This document may not be altered or revised in any way unless done so by UL Verification Services Inc. and all revisions are duly noted in the revisions section. Any alteration of this document not carried out by UL Verification Services Inc. will constitute fraud and shall nullify the document. This report must not be used by the client to claim product certification, approval, or endorsement by A2LA, NIST, or any agency of the Federal Government.

Approved & Released For
UL Verification Services Inc. By:

GIA-PIAO (GP) CHIN
OPERATIONS LEADER
UL Verification Services Inc.

Tested By:

PAUL BASTAKI
LABORATORY ENGINEER
UL Verification Services Inc.

# 2. TEST METHODOLOGY

The tests documented in this report were performed in accordance with the following standards:

- FCC CRF 47 Part 2
- FCC CRF Part 90 Subparts F & I
- ANSI C63.26-2015
- Recommendation ITU-R SM.329-10

# 3. FACILITIES AND ACCREDITATION

UL Verification Services Inc. is accredited by A2LA, certification #0751.05, for all testing performed within the scope of this report. Testing was performed at the locations noted below.

| | Address | ISED CABID | ISED Company No. | FCC Registration |
|---|---|---|---|---|
| ☒ | Building 1: 47173 Benicia Street, Fremont, California, USA | US0104 | 2324A | 208313 |
| ☐ | Building 2: 47266 Benicia Street, Fremont, California, USA | US0104 | 22541 | 208313 |
| ☒ | Building 4: 47658 Kato Rd, Fremont, California, USA | US0104 | 2324B | 208313 |



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# 4. CALIBRATION AND UNCERTAINTY

## 4.1. METROLOGICAL TRACEABILITY

All test and measuring equipment utilized to perform the tests documented in this report are calibrated on a regular basis, with a maximum time between calibrations of one year or the manufacturers' recommendation, whichever is less, and where applicable is traceable to recognized national standards.

## 4.2. DECISION RULES

The Decision Rule is based on Simple Acceptance in accordance with ISO Guide 98-4:2012 Clause 8.2. (Measurement uncertainty is not taken into account when stating conformity with a specified requirement.)

## 4.3. MEASUREMENT UNCERTAINTY

Where relevant, the following measurement uncertainty levels have been estimated for tests performed on the apparatus:

| PARAMETER | $U_{LAB}$ |
|---|---|
| Worst Case Conducted Antenna Port Emission Measurement – Direct Method | 1.94 dB |
| Worst Case Radiated Disturbance, 9 kHz to 30 MHz | 2.87 dB |
| Worst Case Radiated Disturbance, 30 to 1000 MHz | 6.01 dB |
| Occupied Channel Bandwidth | ±2.75 % |
| Temperature | ±2.26 °C |
| Voltages | ±0.57 % |
| Time | ±3.39 % |

Uncertainty figures are valid to a confidence level of 95%.



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# 5. EQUIPMENT UNDER TEST

## 5.1. DESCRIPTION OF EUT

The MK3-PW-PA-TX is an Oceanographic High Frequency Doppler radar consists of two units or subsystems: the synthesizer/transmitter (TX) unit, and an optional receiver/digitizer (RX) unit. It is designed with bare minimum features to ensure low production cost, low power requirement, and easy maintenance.

The operation of the MK3-PW-PA-TX consists of transmitting frequency-modulated continuous radio waves that are channeled along the surface of the conducting ocean as ground waves, in the wavelength range of 10 to 100 m (frequency 3 to 30 MHz). These radio waves are coherently back-scattered by the ocean's surface gravity waves at half the radio wavelength (5 to 50 m), and captured by an array of receive antennas.

For "Region 2", the International Telecommunication Union has recommended, and the Federal Communication Commission has selected dedicated secondary frequency bands for operating Oceanographic High Frequency Doppler radars, as follows:

| Frequency Band | Occupied Bandwidth |
|---|---|
| (MHz) | (kHz) |
| 4.438 – 4.488 | 50 |
| 5.250 – 5.275 | 25 |
| 13.450 – 13.550 | 100 |
| 16.100 – 16.200 | 100 |
| 24.450 – 24.650 | 200 |
| 26.200 – 26.420 | 220 |

The digital synthesizer is programmed to emit a repetition of ramps (chirp) with 100% duty cycle at a radar mode rate of 1 Hz to 5 Hz or a call-sign mode rate of 1 kHz, and a bandwidth of 25 to 220 kHz determined by the frequency allocation, resulting in a frequency-modulated continuous wave (FMCW mode, emission designation F1N).

This test report covers the device operating at 4.438 - 4.488 MHz and 5.250 - 5.275 MHz frequency bands, with the slow radar mode rate of 1 Hz – 5 Hz to represent the worst case mode.

## 5.2. DESCRIPTION OF AVAILABLE ANTENNAS

The radar system utilizes external transmitting antenna which come in the form of normal-mode helical monopole antenna over finite ground plane with a typical gain of 2 dBi. The transmitting antenna is connected to the output port of synthesizer/transmitter via a cable with an attenuation of at least 5 dB, depending on the operating frequency. All antenna port measurements were made at the end of the minimum cable length to determine the power of fundamental and spurious emissions at the antenna input.

## 5.3. MAXIMUM OUTPUT POWER

The highest peak output power under normal environmental conditions (+20°C and 120 VAC) in each mode is as followed:

| Mode | Peak Cond. Pwr (dBm) | Peak Power (dBm EIRP) | Peak Power (W) |
|---|---|---|---|
| 4.438 to 4.488 MHz | 46.74 | 43.74 | 23.66 |
| 5.250 to 5.275 MHz | 47.02 | 44.02 | 25.23 |

## 5.4. SOFTWARE AND FIRMWARE

The test utility software used during testing was Canonical Inc., Ubuntu 20.04.3.

The FPGA Controller Firmware used during testing was D-Tacq Solutions Inc., ACQ1001-RADCELF, Release #394.



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# 6. DESCRIPTION OF TEST SETUP

## SUPPORT EQUIPMENT

| PERIPHERAL SUPPORT EQUIPMENT LIST | | | |
|---|---|---|---|
| **Description** | **Manufacturer** | **Model** | **Serial Number** |
| Laptop | Lenovo, Inc | Yoga14-20FY2US | R9-0KXNVG |
| Laptop Power supply | Lenovo, Inc | ADLX45NCC2A | -- |

## I/O CABLES

| I/O Cable List | | | | | | |
|---|---|---|---|---|---|---|
| **Cable No.** | **Port** | **# of identical ports** | **Connector Type** | **Cable Type** | **Cable Length (m)** | **Remarks** |
| 1 | AC | 1 | 3-prong | Unshielded | 2 | -- |
| 2 | Ant | 1 | N-Type | Shielded | 2 | -- |
| 3 | DC | 1 | Mag set | Shielded | 1 | -- |
| 4 | AC | 1 | 3-prong | Shielded | 1.8 | -- |
| 5 | Ethernet | 1 | Cat-6 | Shielded | 2.15 | -- |

## TEST SETUP

The EUT is connected to a laptop computer. Software within the computer is used to configure and exercise the EUT.

All measurements of Duty Cycle, Occupied Bandwidth, Peak Output Power, $T_X$ Conducted Spurious Emissions and Band-edge were performed at 20°C and 120 VAC nominal, utilizing the conducted test setup with spectrum analyzer.

The total Correction Factor of attenuators and cables was applied as “Offset” to the taken plots of Measured Peak on this report, therefore,

$$Peak\ EIRP\ (dBm) = Measured\ Peak\ (dBm) + Cable\ Loss\ (dB) + EUT\ Ant.Gain\ (dBi)$$



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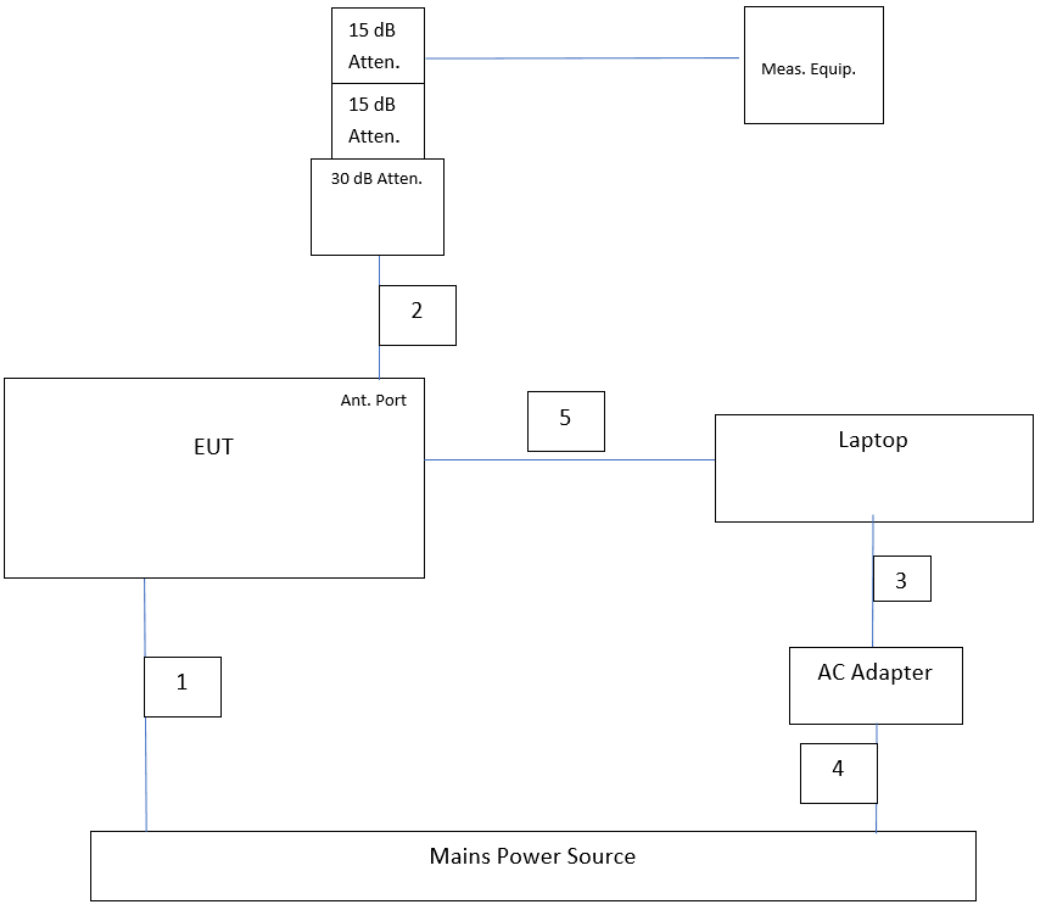
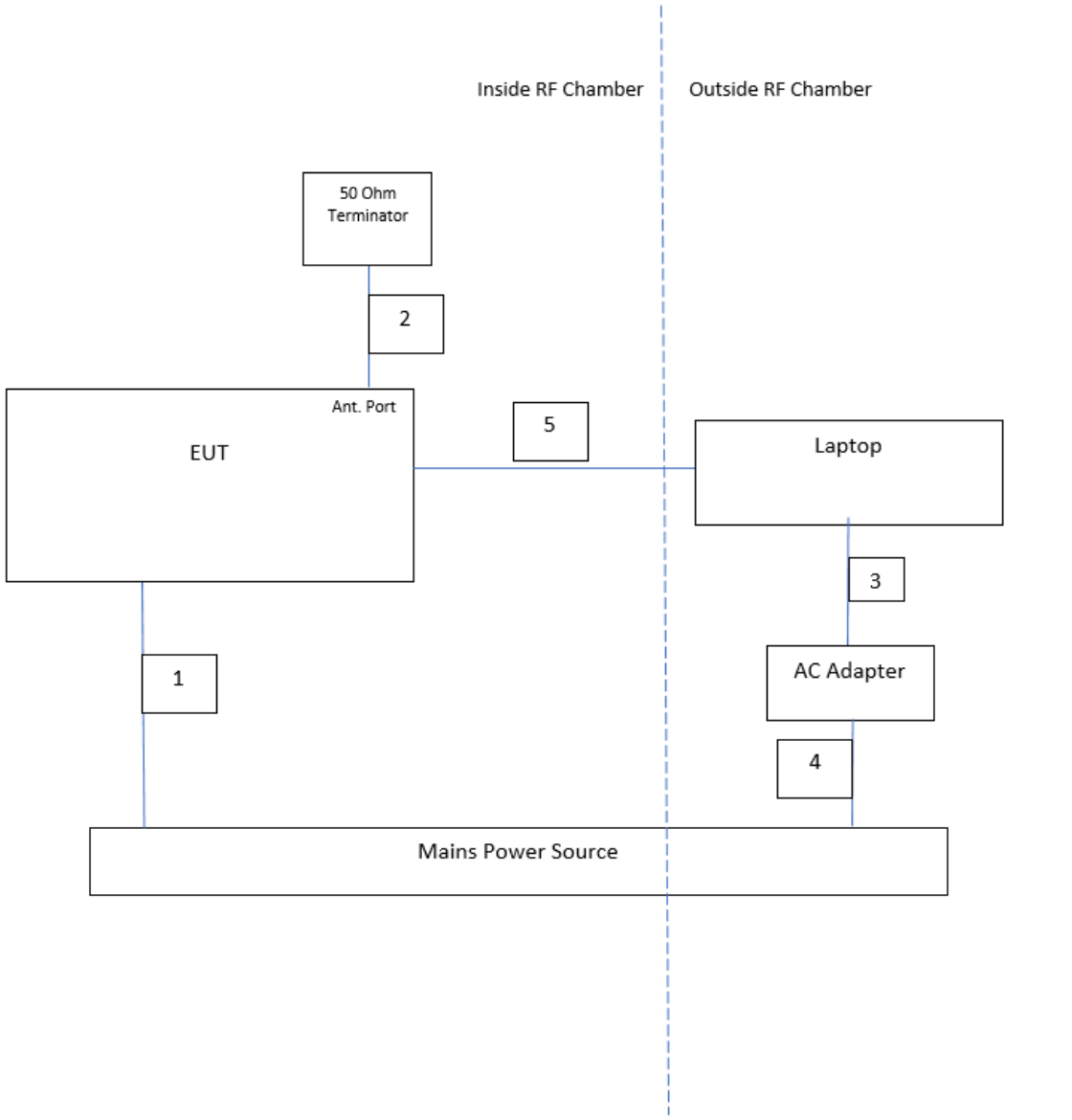
## SETUP DIAGRAMS FOR TESTS

### TX CONDUCTED RF TESTS



## TX RADIATED RF TESTS



# 7. TEST AND MEASUREMENT EQUIPMENT

The following test and measurement equipment was utilized for the tests documented in this report:

| Test Equipment List | | | | | |
|---|---|---|---|---|---|
| **Description** | **Manufacturer** | **Model** | **Local ID** | **Last Cal** | **Cal Due** |
| Spectrum Analyzer, 50 GHz | Rohde & Schwarz | FSW50 | 198710 | 2/22/2022 | 2/22/2023 |
| Variable AC Transformer | Superior Electric | 3PN136B | 44407 | CNR | CNR |
| Power Analyzer | Yokogawa Electric | WT310E | 155294 | 04/16/2021 | 04/16/2022 |
| 15 dB Attenuator, 1 W | JFW Indust. Inc. | 50F-0150-N | -- | CNR | CNR |
| 30 dB Attenuator, 100 W | Bird Inc. | 100-SA-FFN-30 | -- | CNR | CNR |
| 50 Ohm Terminator | RF-Lambda | RFST200G02NM | T1355 | CNR | CNR |
| EMI Test Receiver, 44 GHz | Rohde & Schwartz | ESW44 | PRE0179367 | 2/16/2022 | 2/16/2023 |
| Antenna, Broadband Hybrid, 30 MHz to 2000 MHz | Sunol Sciences Corp. | JB1 | T1199 | 10/01/21 | 10/01/2022 |
| Amplifier, 9 kHz – 1 GHz, 32 dB | Sonoma Instrument | 310 | 175953 | 02/08/2022 | 02/08/2023 |
| Antenna, Passive Loop 30Hz – 1 MHz | Electro-Metrics | EM-6871 | 170014 | 06/08/2021 | 06/08/2022 |
| Antenna, Passive Loop 100 kHz – 30 MHz | Electro-Metrics | EM-6872 | 170016 | 06/08/2021 | 06/08/2022 |
| Temperature Chamber | Espec | EWPX 674(2)-(2)12NAL | 135568 | 4/19/19 | 4/30/22 |
| UL EMC Radiated Software | Version: | Rev 9.5.21 Jan 2021 | | | |



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# 8. APPLICABLE LIMITS AND TEST RESULTS

## 8.1. DUTY CYCLE

**LIMIT**

For reporting purposes only.

**TEST PROCEDURE**

All measurements were performed with the CW signals of $F_c$ = 4.463 MHz and $F_c$ = 5.263 MHz, representing the 4.438 - 4.488 MHz and 5.250 - 5.275 MHz modes, respectively.

The duty cycle factor is calculated as:

$$Duty\ Cycle\ Factor\ (dB)\ =\ 10 \times Log\ (1/x),$$
$$where\ x\ =\ Duty\ Cycle\ (linear)$$

**RESULTS**

Employee ID: 25368
Location: mmWave Chamber 1
Test Date: 3/9/22

| Band | Fc (MHz) | (msec) | (msec) | (linear) | (%) |
|---|---|---|---|---|---|
| 4.438 - 4.488 MHz | 4.463 | 2000 | 2000 | 1.000 | 100.00 |
| 5.250 - 5.275 MHz | 5.263 | 2000 | 2000 | 1.000 | 100.00 |



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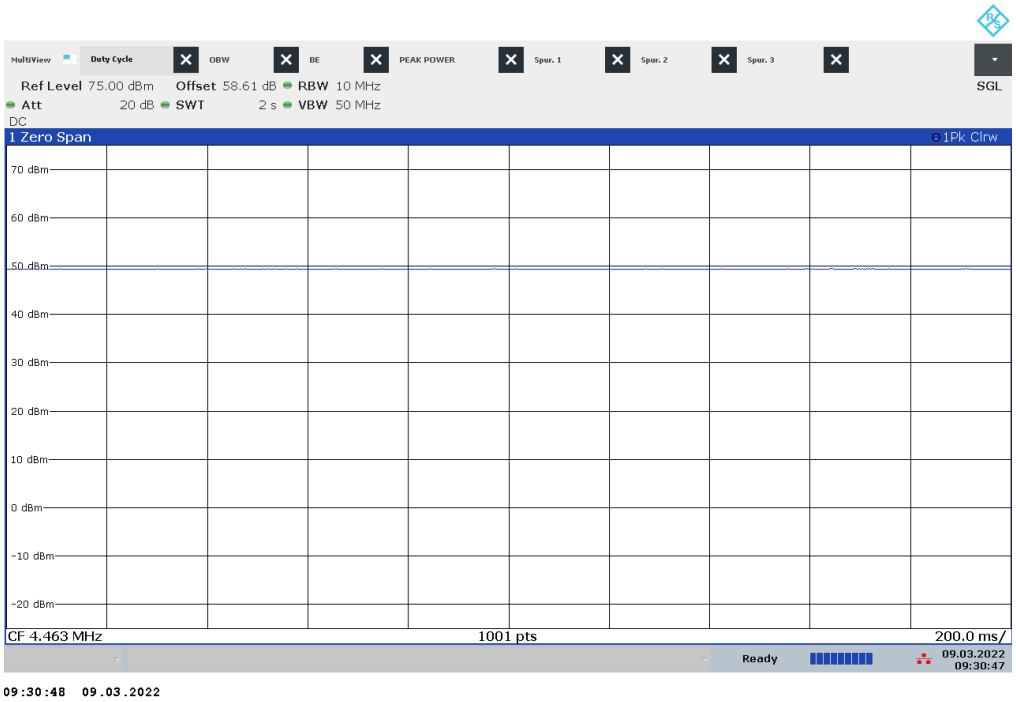
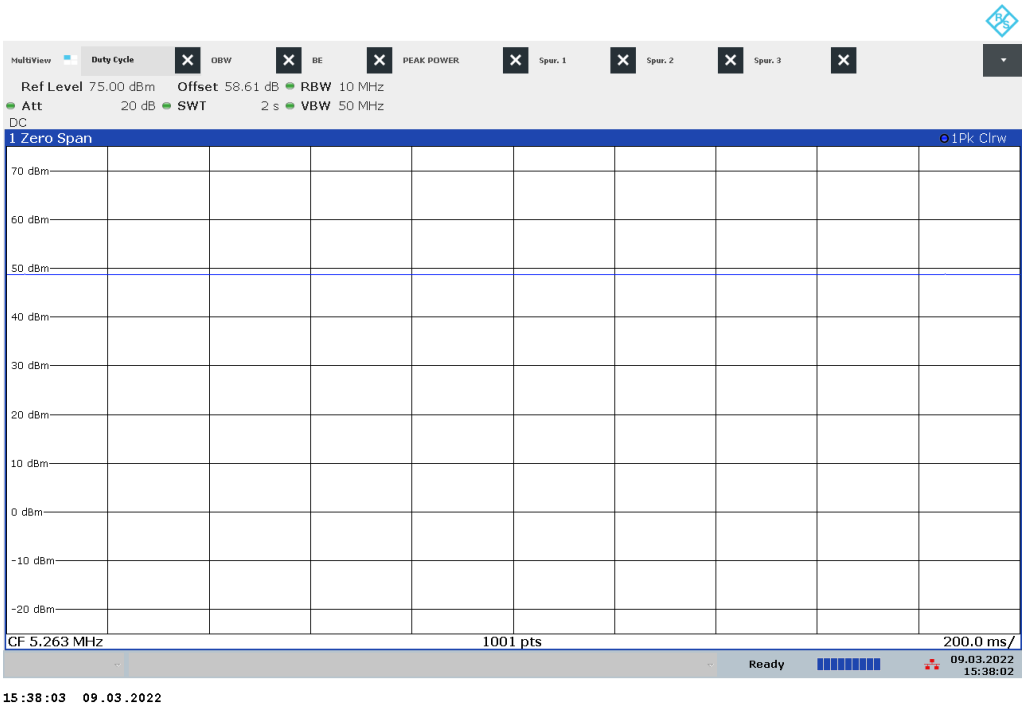
## 4.463 MHz CW Mode




## 5.263 MHz CW Mode



## 8.2. OCCUPIED BANDWIDTH

**RULE PART**

§2.1049

**LIMIT**

99% Bandwidth measured shall fall within the frequency band listed in FCC Part 90.103 (F).

Applicable limits for bands tested in this report is as follows:

| Frequency Band |
|---|
| 4.438 to 4.488 MHz |
| 5.250 to 5.275 MHz |

**TEST PROCEDURE**

ANSI C63.26-2015 Clause 5.4.4

99% bandwidth measurement function of the spectrum analyzer was used to measure 99% occupied bandwidth.

**RESULTS**

Employee ID: 25368
Location: mmWave Chamber 1
Test Date: 3/9/22

| Mode | Meas. 99% BW (kHz) | Meas. FL (MHz) | Limit (MHz) | Pass/Fail | Meas. FH (MHz) | Limit (MHz) | Pass/Fail |
|---|---|---|---|---|---|---|---|
| 4.438 to 4.488 MHz | 48.381 | 4.4388 | 4.438 | Pass | 4.4872 | 4.488 | Pass |
| 5.250 to 5.275 MHz | 23.909 | 5.2506 | 5.250 | Pass | 5.2745 | 5.275 | Pass |



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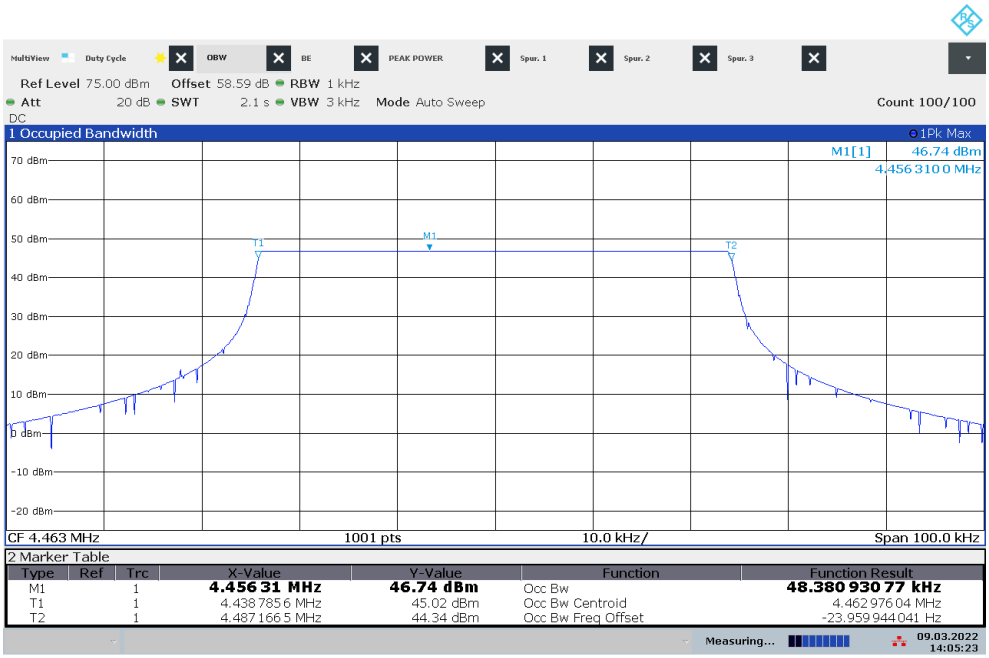
## 4.438 - 4.488 MHz Mode

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## 5.250 - 5.275 MHz Mode


15:06:25 09.03.2022

## 8.3. PEAK OUTPUT POWER

**RULE PARTS**

§2.1046 & §90.205 (r)

**LIMIT**

Per §90.103 (c)(3): Operations in this band are limited to oceanographic radars using transmitters with a peak equivalent isotropically radiated power (EIRP) not to exceed 25 dBW (316 W or +55 dBm). Oceanographic radars shall not cause harmful interference to, nor claim protection from interference caused by, stations in the fixed or mobile services as specified in §2.106, footnotes 5.132A, 5.145A, and US132A. See Resolution 612 of the ITU Radio Regulations for international coordination requirements and for recommended spectrum sharing techniques.

Per Resolution 612 (REV. WRC-12), (d)(2): The Peak E.I.R.P. of an oceanographic radar shall not exceed 25 dBW (316 W or +55 dBm).

**TEST PROCEDURE**

ANSI C63.26-2015 Clause 5.2.3.5

**RESULTS**

Employee ID: 25368
Location: mmWave Chamber 1
Test Date: 3/9/22

| Mode | Frequency (MHz) | Meas. Peak (dBm) | Cable Loss (dB) | EUT Ant. Gain (dBi) | Peak EIRP (dBm) | Peak EIRP (W) | Limit (W) | Pass or Fail |
|---|---|---|---|---|---|---|---|---|
| 4.438 to 4.488 MHz | 4.475 | 46.74 | 5 | 2 | 43.74 | 23.66 | 316 | Pass |
| 5.250 to 5.275 MHz | 5.273 | 47.02 | 5 | 2 | 44.02 | 25.23 | 316 | Pass |

Peak EIRP is based on the use of normal-mode helical monopole antenna over finite ground plane, which has a maximum gain of 2 dBi, declared by manufacturer. The actual peak EIRP values are based on a minimum of 5 dB cable loss of RG213 or RG214 between the RF output and the antenna (power measurement was made at the end of the cable).

As the signal is a swept CW signal, the instantaneous emission bandwidth is much less than the 10 kHz used for the peak power measurement. The sweep rate is slow enough to not require any correction for desensitization, which is further supported by comparing the peak power levels are the same for the occupied bandwidth measurement made using a 1 kHz RBW and the power measurement.



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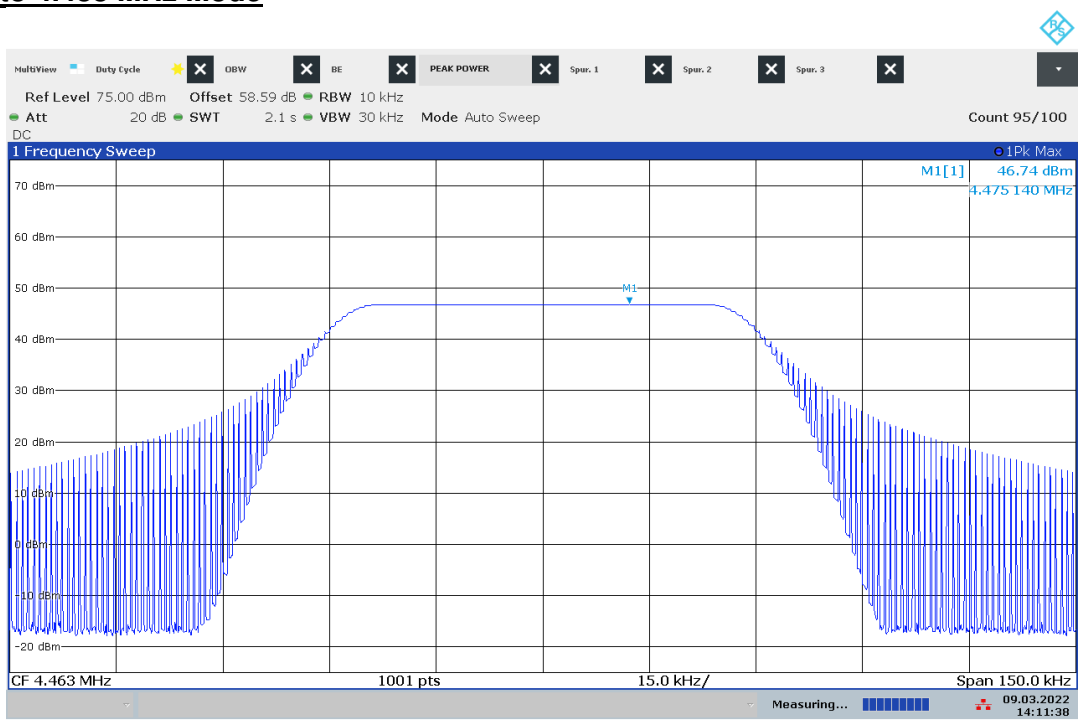
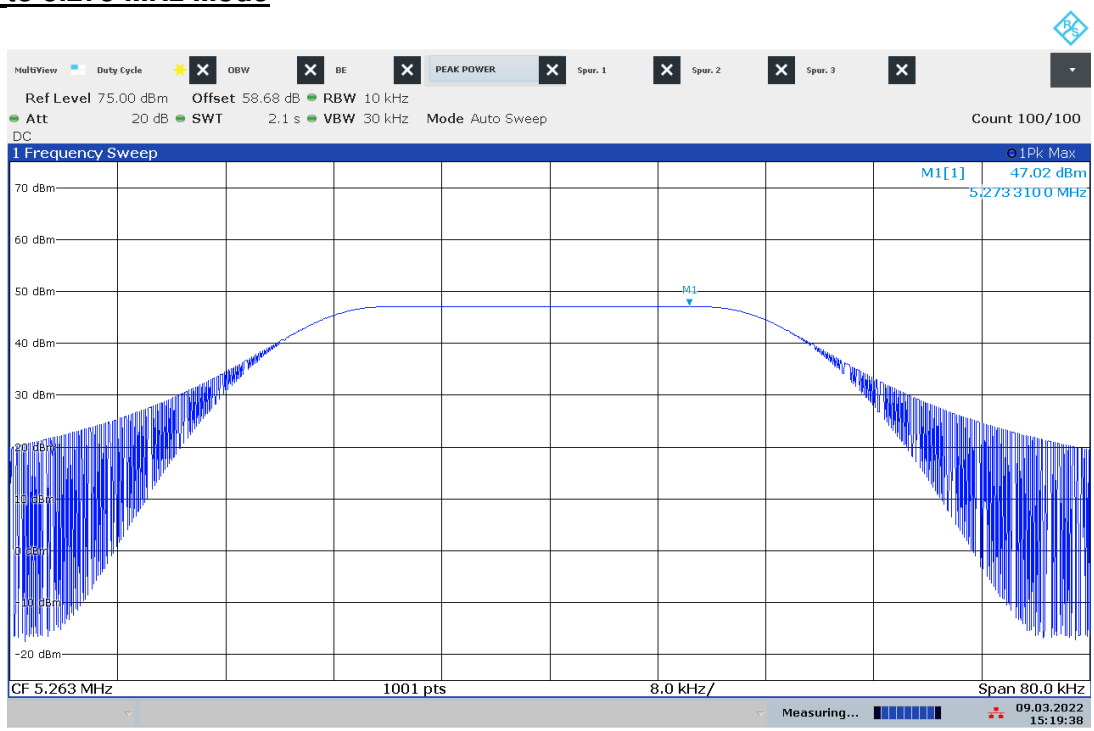
## 4.438 to 4.488 MHz Mode




14:11:38 09.03.2022

## 5.250 to 5.275 MHz Mode

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## 8.4. FREQUENCY STABILITY

**RULE PARTS**

§2.1055 (a)(1): From −30° to + 50° centigrade for all equipment except that specified in paragraphs (a) (2) and (3) of this section.

§2.1055 (d)(1): Vary primary supply voltage from 85 to 115 percent of the nominal value for other than hand carried battery equipment.

The EUT is operated near the coast and installed only in climate-controlled enclosure or building with the following conditions:

Temperature: -30°C to +50°C
Nominal Voltage: 120 VAC

**LIMIT**

§90.213 (a)

**TABLE 1 TO §90.213(a)—MINIMUM FREQUENCY STABILITY**

[Parts per million (ppm)]

| Frequency range (MHz) | Fixed and base stations | Mobile stations | |
|---|---|---|---|
| | | Over 2 watts output power | 2 watts or less output power |
| Below 25 | [1 2 3]100 | 100 | 200 |

Applicable Limit: 100 ppm

**TEST PROCEDURES**

ANSI C63.26-2015 Clause 5.6.5

All measurements were performed with the CW signals of $F_c$ = ~4.463 MHz and $F_c$ = ~5.2625 MHz, representing the 4.438 - 4.488 MHz and 5.250 - 5.275 MHz modes, respectively.



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**Test procedures for temperature variation:**

a. Position the EUT in temperature/humidity chamber.
b. Set chamber temperature to +20°C, stabilize the EUT for at least 45 minutes and record the $F_c$.
c. Adjust chamber temperature from -30°C to +50°C at 10°C interval. Record maximum change in $F_c$ at each temperature.
d. A period of at least 45 minutes is provided to allow stabilization of the equipment at each temperature level.

**Test procedures for voltage variation:**

a. Position the EUT in temperature/humidity chamber.
b. Set chamber temperature to +20°C.
c. The primary supply voltage is varied from 85% to 115% of the nominal value.

- Voltages:

Nominal: 120 VAC
85% of the Nominal: 102 VAC
115% of the Nominal: 138 VAC



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**RESULTS**

Employee ID: 25368
Location: Environmental Chamber
Test Date: 3/10/22 - 3/11/22

| 4.438 to 4.488 MHz Mode | | | | |
|---|---|---|---|---|
| Temp (°C) | Input Power (AC) | CW (Fc) | | |
| | | Meas. Freq. (MHz) | Freq. Drift (ppm) | Pass/Fail |
| 50 | Nominal | 4.4630 | 0.0000 | Pass |
| 40 | Nominal | 4.4630 | 0.0000 | Pass |
| 30 | Nominal | 4.4630 | 0.0000 | Pass |
| 20 | Nominal | 4.4630 | -- | -- |
| 10 | Nominal | 4.4630 | 0.0000 | Pass |
| 0 | Nominal | 4.4630 | 0.0000 | Pass |
| -10 | Nominal | 4.4630 | 0.0000 | Pass |
| -20 | Nominal | 4.4630 | 0.0000 | Pass |
| -30 | Nominal | 4.4630 | 0.0000 | Pass |
| 20 | 85% | 4.4630 | 0.0000 | Pass |
| 20 | 115% | 4.4630 | 0.0000 | Pass |

| 5.250 to 5.275 MHz Mode | | | | |
|---|---|---|---|---|
| Temp (°C) | Input Power (AC) | CW (Fc) | | |
| | | Meas. Freq. (MHz) | Freq. Drift (ppm) | Pass/Fail |
| 50 | Nominal | 5.2625 | 0.0000 | Pass |
| 40 | Nominal | 5.2625 | 0.0000 | Pass |
| 30 | Nominal | 5.2625 | 0.0000 | Pass |
| 20 | Nominal | 5.2625 | -- | -- |
| 10 | Nominal | 5.2625 | 0.0000 | Pass |
| 0 | Nominal | 5.2625 | 0.0000 | Pass |
| -10 | Nominal | 5.2625 | 0.0000 | Pass |
| -20 | Nominal | 5.2625 | 0.0000 | Pass |
| -30 | Nominal | 5.2625 | 0.0000 | Pass |
| 20 | 85% | 5.2625 | 0.0000 | Pass |
| 20 | 115% | 5.2625 | 0.0000 | Pass |

# 8.5. TX CONDUCTED SPURIOUS EMISSIONS AND BAND EDGE

## RULE PARTS

§2.1057 (a) (1): In all the measurements set forth in §2.1051 and §2.1053, the spectrum shall be investigated from the lowest radio frequency signal generated in the equipment, without going below 9 kHz, up to at least the frequency shown below: If the equipment operates below 10 GHz: to the tenth harmonic of the highest fundamental frequency or to 40 GHz, whichever is lower.

10th harmonic of highest fundamental frequency $= 10 \times (5.275\ MHz) = 52.75\ MHz$
Thus, spurious emissions are investigated from 9 kHz thru 1 GHz.

## LIMIT

§ 90.210 (n): Other frequency bands. Transmitters designed for operation under this part on frequencies other than listed in this section must meet the emission mask requirements of Emission Mask B. Equipment operating under this part on frequencies allocated to but shared with the Federal Government, must meet the applicable Federal Government technical standards.

§ 90.210 (b): Emission Mask B. For transmitters that are equipped with an audio low-pass filter, the power of any emission must be attenuated below the unmodulated carrier power (P) as follows:

(1) On any frequency removed from the assigned frequency by more than 50 percent, but not more than 100 percent of the authorized bandwidth: At least 25 dB.
(2) On any frequency removed from the assigned frequency by more than 100 percent, but not more than 250 percent of the authorized bandwidth: At least 35 dB.
(3) On any frequency removed from the assigned frequency by more than 250 percent of the authorized bandwidth: At least $43 + 10\ log(P)\ dB$.

The more stringent Peak power limit on § 90.210 (b)(3), which is the same limit as Rec ITU-R SM.329-10 Standard, is applied for spurious emissions and band edge.

Determination of Limit:

Maximum Declared Peak Conducted Power of EUT,

$$P_{max} = 44\ dBm\ (25\ W)$$

$$\begin{aligned} Applicable\ Peak\ Limit &= 44 - \big(43 + 10log(25)\big) \\ &= 44 - 57 \\ &= -13\ dBm \end{aligned}$$

## TEST PROCEDURE

ANSI C63.26-2015 Clause 5.7

The widest emission bandwidth of EUT was used at 9 kHz – 1 GHz spurious emission tests.

For Bandedge, the measurements were measured by transmitting the CW signals of low-end ($F_L$) and the high-end ($F_H$) of each frequency band.

## RESULTS

Employee ID: 25368
Location: mmWave Chamber 1
Test Date: 3/9/22 - 3/17/22

| Mode | 9 - 150 kHz | 150 kHz - 30 MHz | 30 MHz - 1 GHz | Bandedge |
|---|---|---|---|---|
| 4.438 - 4.488 MHz | Pass | Pass | Pass | Pass |
| 5.250 - 5.275 MHz | Pass | Pass | Pass | Pass |



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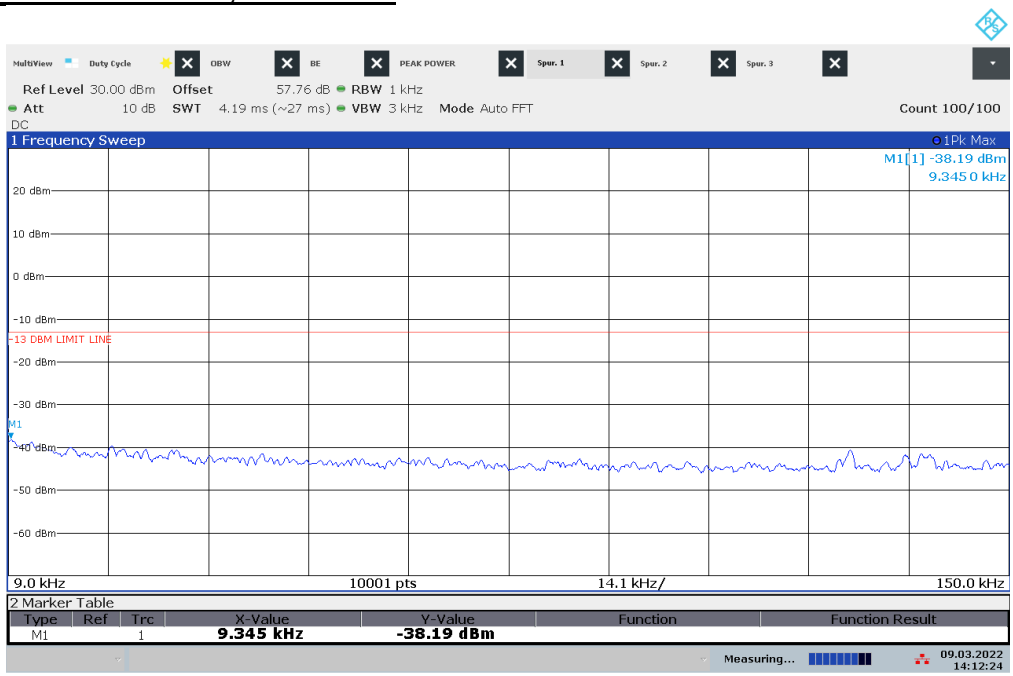
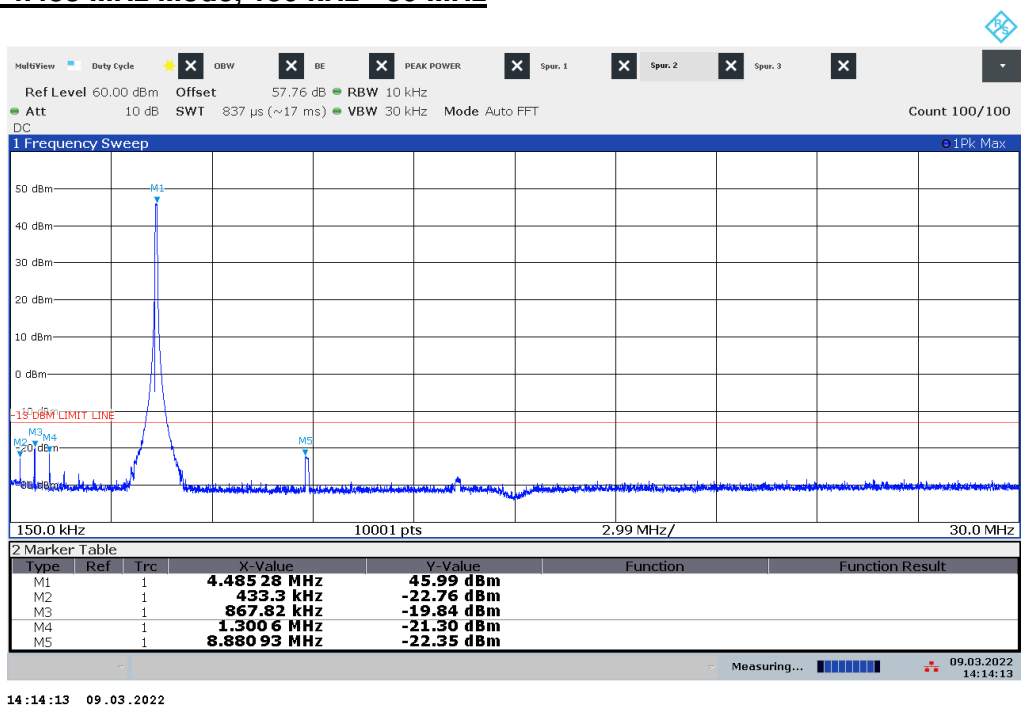
## 8.5.1. SPURIOUS EMISSIONS

### 4.438 to 4.488 MHz Mode, 9 - 150 kHz




### 4.438 to 4.488 MHz Mode, 150 kHz - 30 MHz




*Marker M1 is the fundamental signal.



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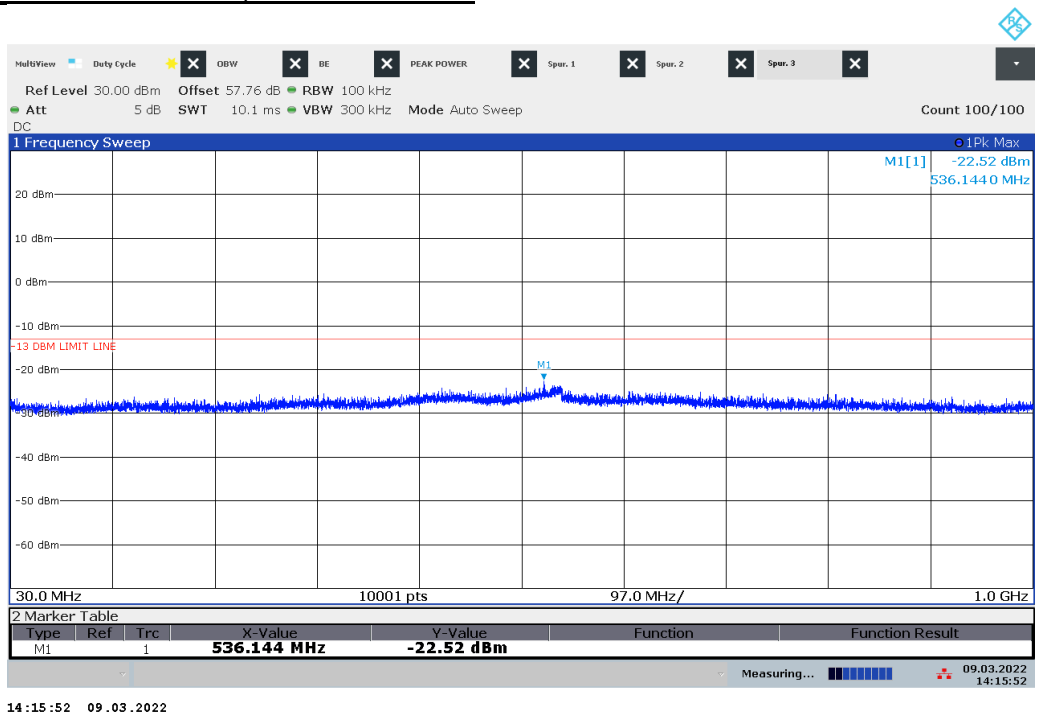
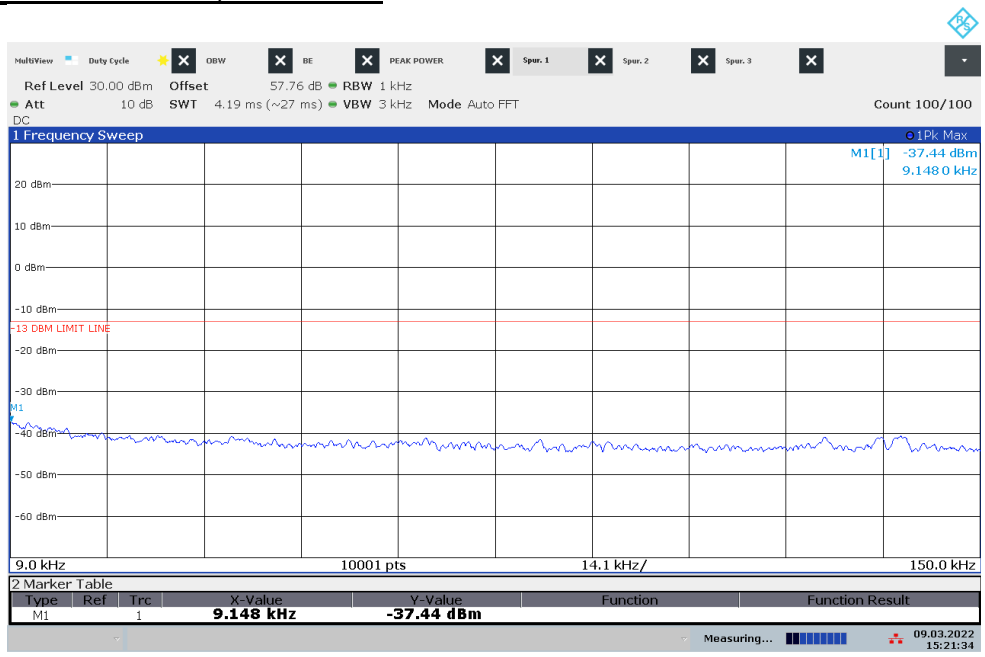
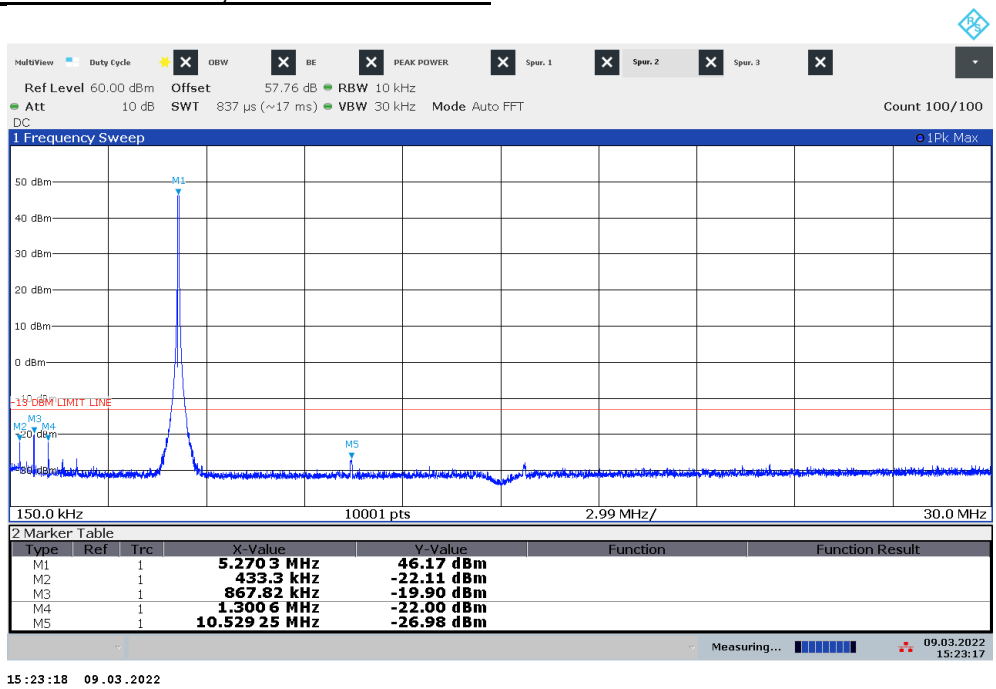
## 4.438 to 4.488 MHz Mode, 30 MHz – 1 GHz



## 5.250 to 5.275 MHz Mode, 9 - 150 kHz




## 5.250 to 5.275 MHz Mode, 150 kHz to 30 MHz




*Marker M1 is the fundamental signal.



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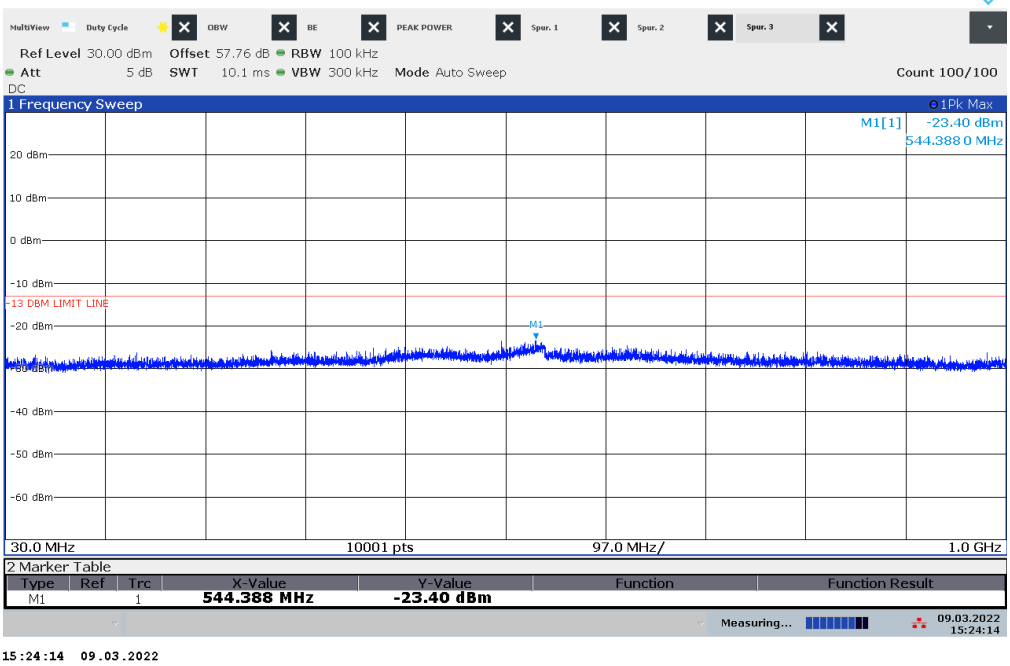
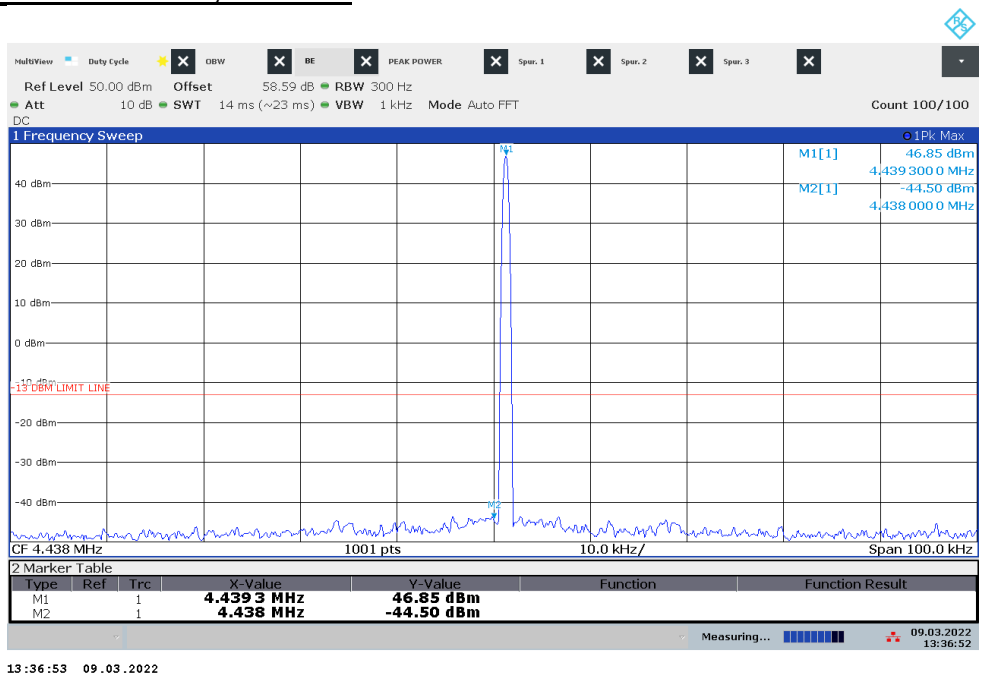
## 5.250 to 5.275 MHz Mode, 30 MHz – 1 GHz



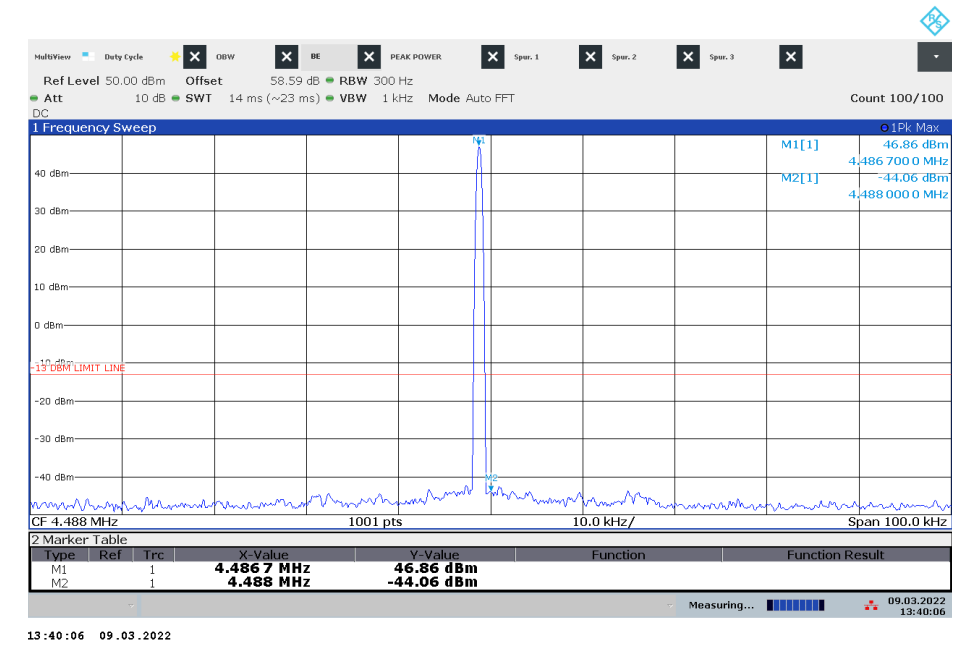

15:24:14 09.03.2022

## 8.5.2. BAND EDGE

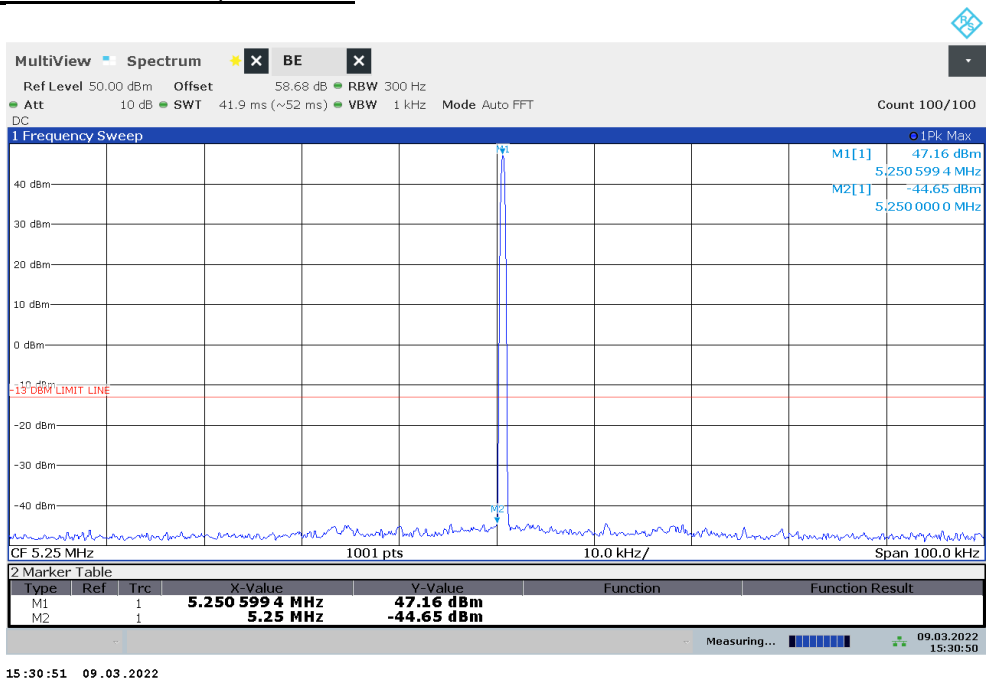
### 4.438 to 4.488 MHz Mode, Low End



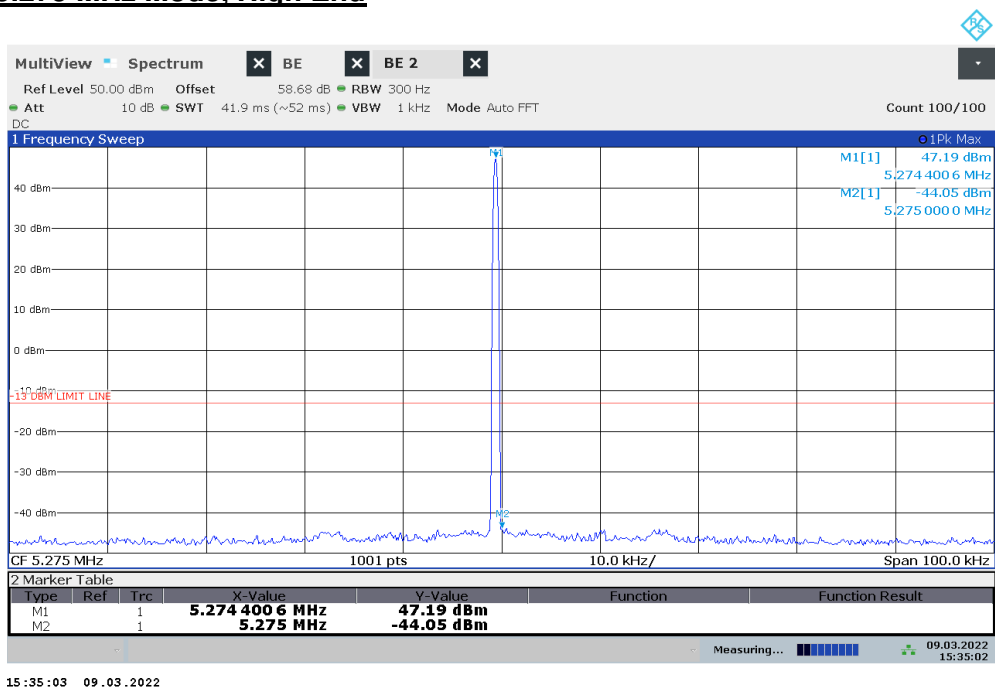

### 4.438 to 4.488 MHz Mode, High End



## 5.250 to 5.275 MHz Mode, Low End




## 5.250 to 5.275 MHz Mode, High End



# 8.6. TX RADIATED SPURIOUS EMISSIONS

**RULE PARTS**

§2.1057 (a) (1): In all the measurements set forth in §2.1051 and §2.1053, the spectrum shall be investigated from the lowest radio frequency signal generated in the equipment, without going below 9 kHz, up to at least the frequency shown below: If the equipment operates below 10 GHz: to the tenth harmonic of the highest fundamental frequency or to 40 GHz, whichever is lower.

10th harmonic of highest fundamental frequency $= 10 \times (5.275\ MHz) = 52.75\ MHz$
Thus, spurious emissions are investigated from 9 kHz thru 1 GHz.

**LIMIT**

§ 90.210 (n): Other frequency bands. Transmitters designed for operation under this part on frequencies other than listed in this section must meet the emission mask requirements of Emission Mask B. Equipment operating under this part on frequencies allocated to but shared with the Federal Government, must meet the applicable Federal Government technical standards.

§ 90.210 (b): Emission Mask B. For transmitters that are equipped with an audio low-pass filter, the power of any emission must be attenuated below the unmodulated carrier power (P) as follows:

(1) On any frequency removed from the assigned frequency by more than 50 percent, but not more than 100 percent of the authorized bandwidth: At least 25 dB.
(2) On any frequency removed from the assigned frequency by more than 100 percent, but not more than 250 percent of the authorized bandwidth: At least 35 dB.
(3) On any frequency removed from the assigned frequency by more than 250 percent of the authorized bandwidth: At least $43 + 10\ log(P)\ dB$.

The more stringent Peak power limit on § 90.210 (b)(3), which is the same limit as Rec ITU-R SM.329-10 Standard, is applied for spurious emissions and bandedge.

Determination of Limit:

Maximum Declared Peak Conducted Power of EUT,

$$P_{max} = 44\ dBm\ (25\ W)$$

$$\begin{aligned} Applicable\ Peak\ Limit &= 44 - \big(43 + 10log(25)\big) \\ &= 44 - 57 \\ &= -13\ dBm \end{aligned}$$

## TEST PROCEDURE

ANSI C63.26-2015 Clause 5.5.4

Below 30 MHz spurious emission testing was performed in chamber other than open area test site. Adequate comparison measurements were confirmed against 30-meter open area test site and sufficient tests were made to demonstrate that the alternative site produces results that correlate with the ones of tests made in an open field based on KDB 414788.

## RADIATED EMISSION

Where relevant, the following sample calculations are provided:

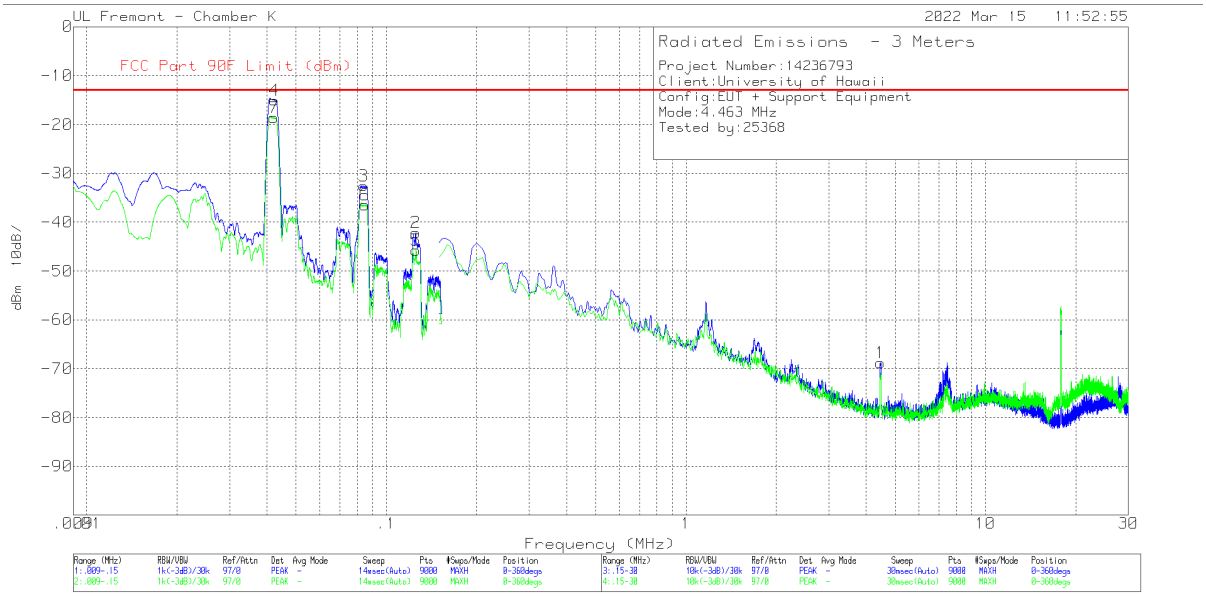
$$EIRP(dBm) = \text{Meter Reading } (dBuV) + \text{Antenna Factor}(dB/m) + \text{PreAmp Gain/Cbl Loss } (dB) + (dBuV - to - dBm) \text{ Unit Conversion Factor @ } 3m$$
$$= 34.27\ dBm\ +\ 48.3\ dB/m\ +\ (-32.2)\ dB\ +\ (-95.2)$$
$$= -44.83\ dBm$$

$$EIRP(dBm) = \text{Meter Reading } (dBm) + \text{Antenna Factor } (dB/m) + \text{ PreAmp Gain/Cbl Loss } (dB) + (dBm - to - dBm) \text{ Unit Conversion Factor @ } 3m$$
$$= -60\ dBm\ +\ 28\ dB/m\ +\ (-27)\ dB\ +\ 11.7$$
$$= -47.3\ dBm$$

## RESULTS

Employee ID: 25368
Location: Chamber K
Test Date: 3/14/22 - 3/15/22

## 4.438 to 4.488 MHz MODE, 9 kHz to 30 MHz




### Trace Markers - Pre-scan

| Marker | Frequency (MHz) | Meter Reading (dBuV) | Det | Loop Ant (E ACF) | Amp/Cbl (dB) | Unit Conversion | Corrected Reading dBm | FCC Part 90F Limit (dBm) | Margin (dB) | Azimuth (Degs) | Antenna Face |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 2 | .1254 | 29.47 | Pk | 55.8 | -32.2 | -95.2 | -42.13 | -13 | -29.13 | 0-360 | On |
| 3 | .0841 | 39.16 | Pk | 55.7 | -32.2 | -95.2 | -32.54 | -13 | -19.54 | 0-360 | On |
| 4 | .0424 | 55.07 | Pk | 57.2 | -32.1 | -95.2 | -15.03 | -13 | -2.03 | 0-360 | On |
| 5 | .1257 | 25.85 | Pk | 55.8 | -32.2 | -95.2 | -45.75 | -13 | -32.75 | 0-360 | Off |
| 6 | .0847 | 35.23 | Pk | 55.7 | -32.2 | -95.2 | -36.47 | -13 | -23.47 | 0-360 | Off |
| 7 | .0421 | 51.48 | Pk | 57.2 | -32.1 | -95.2 | -18.62 | -13 | -5.62 | 0-360 | Off |
| 1* | 4.4654 | 21.9 | Pk | 36.5 | -32 | -95.2 | -68.8 | -13 | -55.8 | 0-360 | On |

Pk - Peak detector
Power levels of emissions were lower with antenna face-down, comparing to face-on and face-off, at pre-scan.

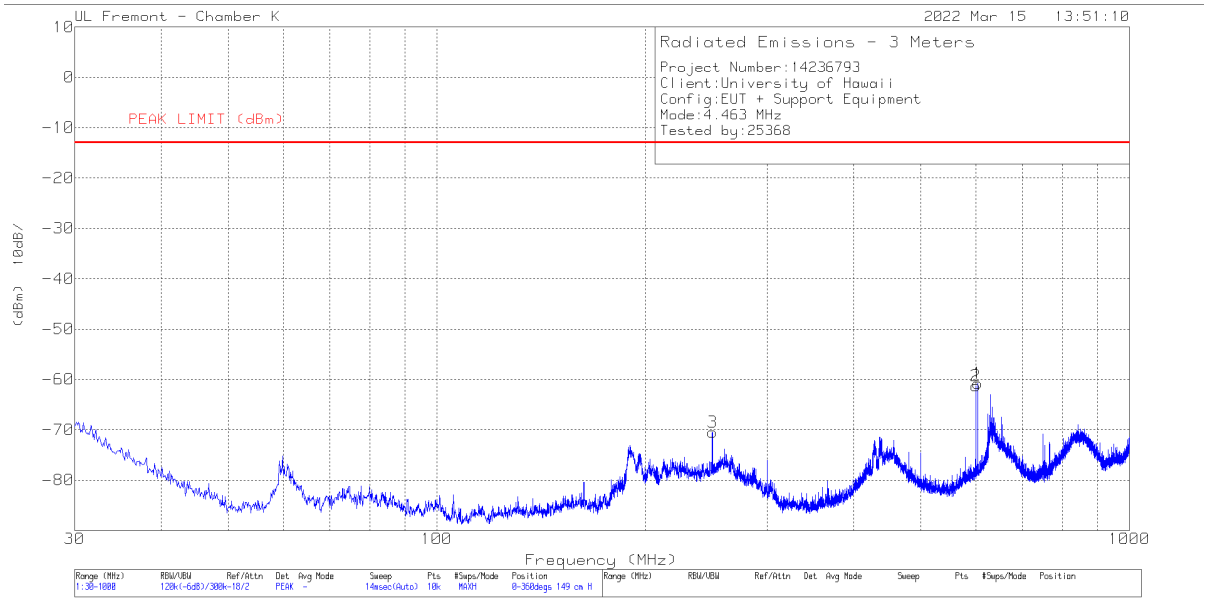
*Marker 1 is the fundamental signal.

### Radiated Emissions – Final Data

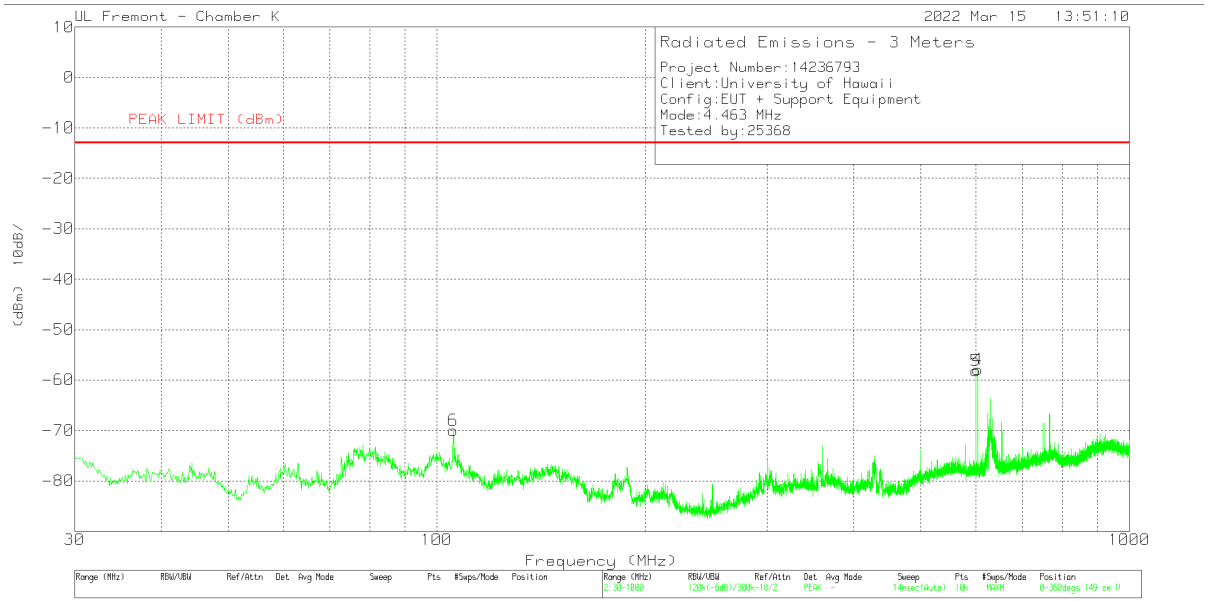
| Frequency (MHz) | Meter Reading (dBuV) | Det | Loop Ant (E ACF) | Amp/Cbl (dB) | Unit Conversion | Corrected Reading dBm | FCC Part 90F Limit (dBm) | Margin (dB) | Azimuth (Degs) | Antenna Face |
|---|---|---|---|---|---|---|---|---|---|---|
| .0404 | 55.58 | Pk | 57.2 | -32.1 | -95.2 | -14.52 | -13 | -1.52 | 87 | On |
| .0832 | 39.19 | Pk | 55.7 | -32.2 | -95.2 | -32.51 | -13 | -19.51 | 82 | On |
| .1237 | 29.07 | Pk | 55.8 | -32.2 | -95.2 | -42.53 | -13 | -29.53 | 97 | On |
| .1239 | 25.12 | Pk | 55.8 | -32.2 | -95.2 | -46.48 | -13 | -33.48 | 154 | Off |
| .0831 | 35.78 | Pk | 55.7 | -32.2 | -95.2 | -35.92 | -13 | -22.92 | 193 | Off |
| .0408 | 52.29 | Pk | 57.2 | -32.1 | -95.2 | -17.81 | -13 | -4.81 | 185 | Off |

Pk - Peak detector

## 4.438 to 4.488 MHz MODE, 30 to 1000 MHz




FCC Part 90F 30-1000 MHz Tx.TST 02970 22 Aug 2019




FCC Part 90F 30-1000 MHz Tx.TST 02970 22 Aug 2019

## Trace Markers - Pre-scan

| Marker | Frequency (MHz) | Meter Reading (dBm) | Det | 82258 ACF (dB) | Amp/Cbl (dB) | Sub Factor (dB) | Corrected Reading (dBm) | PEAK LIMIT (dBm) | Margin (dB) | Azimuth (Degs) | Height (cm) | Polarity |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 603.949 | -64.37 | Pk | 25.2 | -28.8 | 7.2 | -60.77 | -13 | -47.77 | 0-360 | 149 | H |
| 2 | 599.972 | -64.71 | Pk | 25.2 | -28.7 | 6.9 | -61.31 | -13 | -48.31 | 0-360 | 149 | H |
| 3 | 249.996 | -73.52 | Pk | 18 | -30 | 15 | -70.52 | -13 | -57.52 | 0-360 | 149 | H |
| 4 | 603.949 | -61.54 | Pk | 25.2 | -28.8 | 7.2 | -57.94 | -13 | -44.94 | 0-360 | 149 | V |
| 5 | 599.972 | -61.76 | Pk | 25.2 | -28.7 | 7.1 | -58.16 | -13 | -45.16 | 0-360 | 149 | V |
| 6 | 105.66 | -69.47 | Pk | 18.1 | -30.9 | 12.3 | -69.97 | -13 | -56.97 | 0-360 | 149 | V |

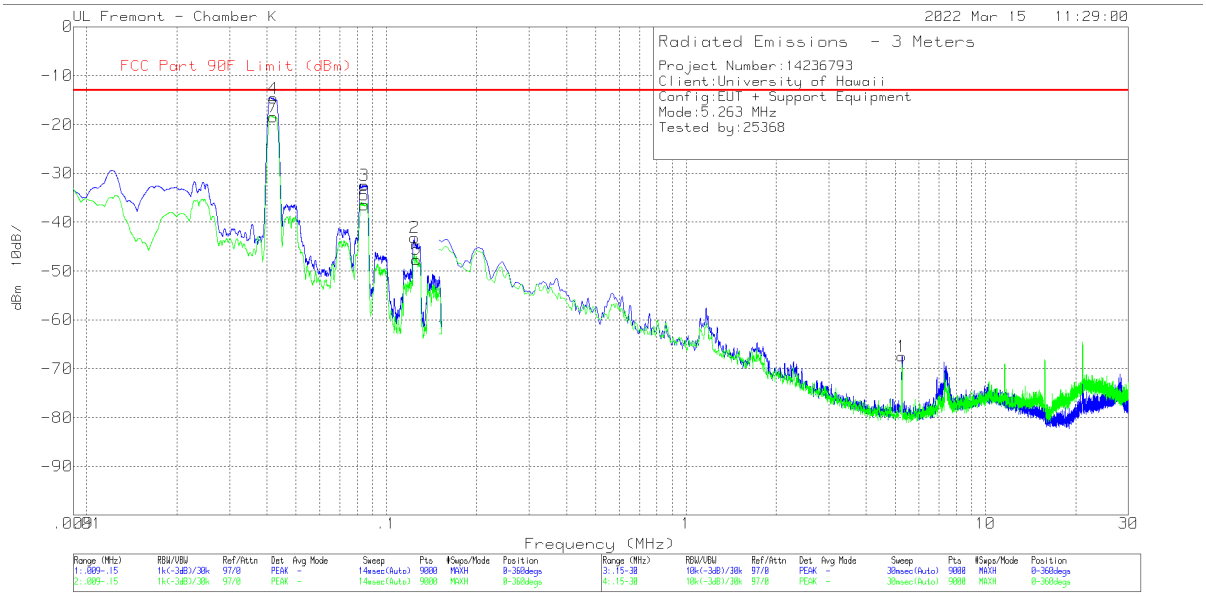
Pk - Peak detector

## Radiated Emissions – Final Data

| Frequency (MHz) | Meter Reading (dBm) | Det | 82258 ACF (dB) | Amp/Cbl (dB) | Sub Factor (dB) | Corrected Reading (dBm) | PEAK LIMIT (dBm) | Margin (dB) | Azimuth (Degs) | Height (cm) | Polarity |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 603.972 | -63.56 | Pk | 25.2 | -28.8 | 7.2 | -59.96 | -13 | -46.96 | 102 | 152 | H |
| 599.996 | -63.82 | Pk | 25.2 | -28.7 | 6.9 | -60.42 | -13 | -47.42 | 0 | 163 | H |
| 250.01 | -72.14 | Pk | 18 | -30 | 15 | -69.14 | -13 | -56.14 | 264 | 105 | H |
| 603.978 | -60.87 | Pk | 25.2 | -28.8 | 7.3 | -57.17 | -13 | -44.17 | 66 | 161 | V |
| 599.995 | -60.98 | Pk | 25.2 | -28.7 | 7.1 | -57.38 | -13 | -44.38 | 58 | 157 | V |
| 105.689 | -67.51 | Pk | 18.1 | -30.9 | 12.3 | -68.01 | -13 | -55.01 | 343 | 129 | V |

Pk - Peak detector

## 5.250 to 5.275 MHz MODE, 9 kHz to 30 MHz




### Trace Markers - Pre-scan

| Marker | Frequency (MHz) | Meter Reading (dBuV) | Det | Loop Ant (E ACF) | Amp/Cbl (dB) | Unit Conversion | Corrected Reading dBm | FCC Part 90F Limit (dBm) | Margin (dB) | Azimuth (Degs) | Antenna Face |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 2 | .1242 | 28.42 | Pk | 55.8 | -32.2 | -95.2 | -43.18 | -13 | -30.18 | 0-360 | On |
| 3 | .0846 | 39.27 | Pk | 55.7 | -32.2 | -95.2 | -32.43 | -13 | -19.43 | 0-360 | On |
| 4 | .042 | 55.47 | Pk | 57.2 | -32.1 | -95.2 | -14.63 | -13 | -1.63 | 0-360 | On |
| 5 | .1263 | 23.89 | Pk | 55.8 | -32.2 | -95.2 | -47.71 | -13 | -34.71 | 0-360 | Off |
| 6 | .0844 | 35.2 | Pk | 55.7 | -32.2 | -95.2 | -36.5 | -13 | -23.5 | 0-360 | Off |
| 7 | .042 | 51.67 | Pk | 57.2 | -32.1 | -95.2 | -18.43 | -13 | -5.43 | 0-360 | Off |
| 1* | 5.2615 | 23.96 | Pk | 35.7 | -31.9 | -95.2 | -67.44 | -13 | -54.44 | 0-360 | On |

Pk - Peak detector

Power levels of emissions were lower with antenna face-down, comparing to face-on and face-off, at pre-scan.

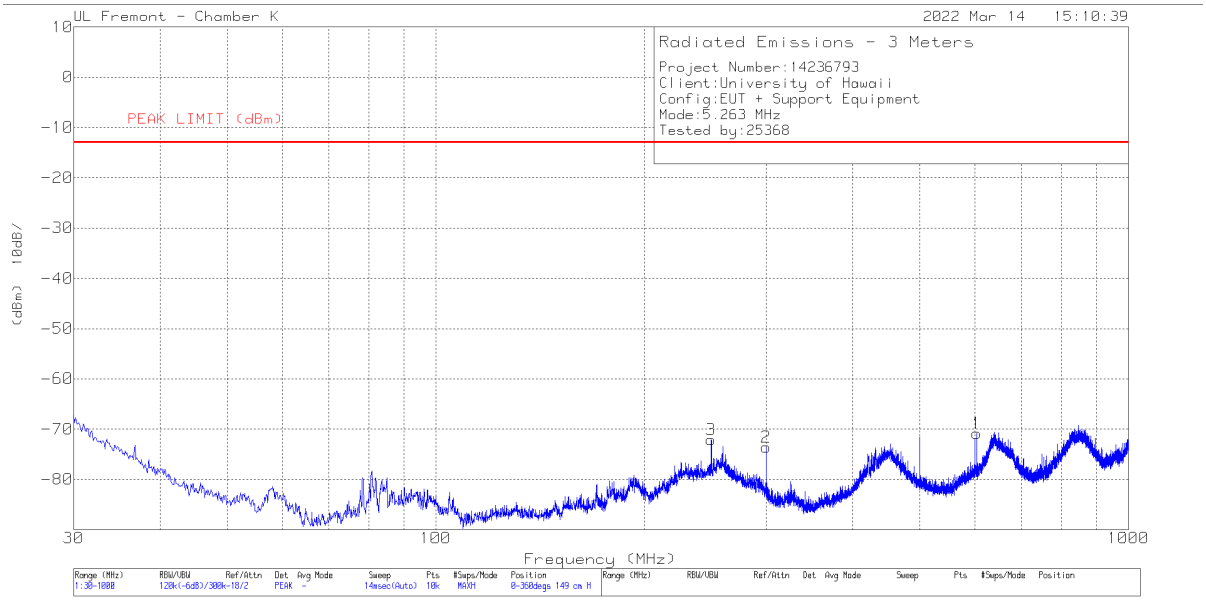
*Marker 1 is the fundamental signal.

### Radiated Emissions – Final Data

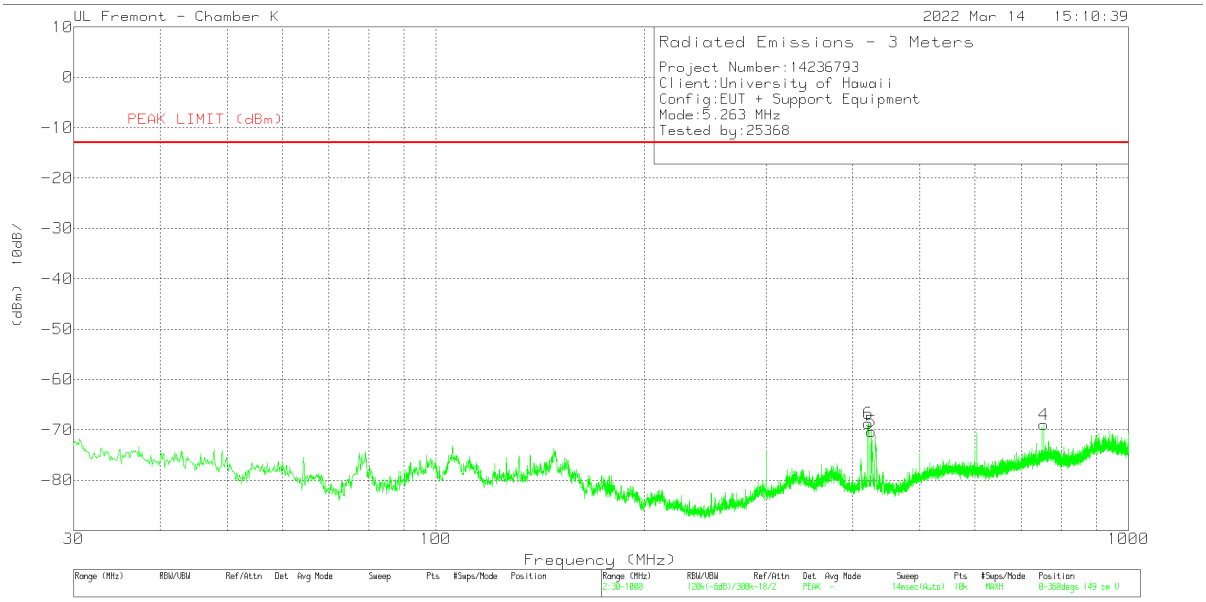
| Frequency (MHz) | Meter Reading (dBuV) | Det | Loop Ant (E ACF) | Amp/Cbl (dB) | Unit Conversion | Corrected Reading dBm | FCC Part 90F Limit (dBm) | Margin (dB) | Azimuth (Degs) | Antenna Face |
|---|---|---|---|---|---|---|---|---|---|---|
| .0403 | 55.73 | Pk | 57.2 | -32.1 | -95.2 | -14.37 | -13 | -1.37 | 87 | On |
| .0835 | 39.32 | Pk | 55.7 | -32.2 | -95.2 | -32.38 | -13 | -19.38 | 79 | On |
| .1232 | 29.93 | Pk | 55.8 | -32.2 | -95.2 | -41.67 | -13 | -28.67 | 89 | On |
| .1244 | 25.1 | Pk | 55.8 | -32.2 | -95.2 | -46.5 | -13 | -33.5 | 171 | Off |
| .0826 | 35.62 | Pk | 55.7 | -32.2 | -95.2 | -36.08 | -13 | -23.08 | 159 | Off |
| .0403 | 52.1 | Pk | 57.2 | -32.1 | -95.2 | -18 | -13 | -5 | 167 | Off |

Pk - Peak detector

## 5.250 - 5.275 MHz MODE, 30 to 1000 MHz




FCC Part 90F 30-1000 MHz Tx.TST 02970 22 Aug 2019




FCC Part 90F 30-1000 MHz Tx.TST 02970 22 Aug 2019

## Trace Markers - Pre-scan

| Marker | Frequency (MHz) | Meter Reading (dBm) | Det | 82258 ACF (dB) | Amp/Cbl (dB) | Sub Factor (dB) | Corrected Reading (dBm) | PEAK LIMIT (dBm) | Margin (dB) | Azimuth (Degs) | Height (cm) | Polarity |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 603.949 | -74.41 | Pk | 25.2 | -28.8 | 7.2 | -70.81 | -13 | -57.81 | 0-360 | 149 | H |
| 2 | 299.951 | -71.14 | Pk | 19.8 | -29.8 | 7.6 | -73.54 | -13 | -60.54 | 0-360 | 149 | H |
| 3 | 249.899 | -75.03 | Pk | 18 | -30 | 15 | -72.03 | -13 | -59.03 | 0-360 | 149 | H |
| 4 | 754.978 | -75.92 | Pk | 27.3 | -28.1 | 7.8 | -68.92 | -13 | -55.92 | 0-360 | 149 | V |
| 5 | 425.954 | -70.68 | Pk | 22.7 | -29.3 | 6.9 | -70.38 | -13 | -57.38 | 0-360 | 149 | V |
| 6 | 421.589 | -69.28 | Pk | 22.7 | -29.3 | 7.1 | -68.78 | -13 | -55.78 | 0-360 | 149 | V |

Pk - Peak detector

## Radiated Emissions – Final Data

| Frequency (MHz) | Meter Reading (dBm) | Det | 82258 ACF (dB) | Amp/Cbl (dB) | Sub Factor (dB) | Corrected Reading (dBm) | PEAK LIMIT (dBm) | Margin (dB) | Azimuth (Degs) | Height (cm) | Polarity |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 603.947 | -73.40 | Pk | 25.2 | -28.8 | 7.2 | -69.80 | -13 | -56.80 | 259 | 249 | H |
| 300.008 | -69.37 | Pk | 19.8 | -29.8 | 7.6 | -71.77 | -13 | -58.77 | 236 | 108 | H |
| 250.002 | -72.29 | Pk | 18 | -30 | 15 | -69.29 | -13 | -56.29 | 6 | 139 | H |
| 754.974 | -71.53 | Pk | 27.3 | -28.1 | 7.8 | -64.53 | -13 | -51.53 | 281 | 132 | V |
| 425.979 | -66.74 | Pk | 22.7 | -29.3 | 6.9 | -66.44 | -13 | -53.44 | 297 | 131 | V |
| 421.015 | -66.62 | Pk | 22.7 | -29.3 | 7.1 | -66.12 | -13 | -53.12 | 300 | 123 | V |

Pk - Peak detector

# CERTIFICATION TEST REPORT

**Report Number :** 14236793-E2V3

**Applicant :** UNIVERSITY OF HAWAII
1000 POPE ROAD, MSB 402,
HONOLULU, HI 96822, U.S.A.

**Model :** MK3-PW-PA-TX

**FCC ID :** 2A562-MK3-PW-PA-TX

**EUT Description :** OCEANOGRAPHIC HIGH FREQUENCY DOPPLER RADAR

**Test Standard :** FCC CFR 47 PART 90 SUBPART F

**Date Of Issue:**
April 19, 2022

**Prepared by:**
UL Verification Services Inc.
47173 Benicia Street
Fremont, CA 94538, U.S.A.
TEL: (510) 319-4000
FAX: (510) 661-0888

ACCREDITED
CERT #0751.05

Revision History

| Rev. | Issue Date | Revisions | Revised By |
|---|---|---|---|
| V1 | 04/11/22 | Initial Issue | GP Chin |
| V2 | 04/14/22 | Updated Description of EUT in Section 5.1<br>Updated Power Summary Table in Section 5.3<br>Added Notes on Pg. 32 and Pg. 35 | GP Chin |
| V3 | 04/19/22 | Added Note on Pg. 17 in Section 8.3. | GP Chin |



UL VERIFICATION SERVICES INC
47173 BENICIA STREET, FREMONT, CA 94538, USA TEL: (510) 319-4000 FAX: (510) 661-0888

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UL VERIFICATION SERVICES INC
47173 BENICIA STREET, FREMONT, CA 94538, USA TEL: (510) 319-4000 FAX: (510) 661-0888

# 1. ATTESTATION OF TEST RESULTS

**COMPANY NAME:** UNIVERSITY OF HAWAII
1000 POPE ROAD, MSB 402,
HONOLULU, HI 96822, U.S.A.

**EUT DESCRIPTION:** OCEANOGRAPHIC HIGH FREQUENCY DOPPLER RADAR

**MODEL:** MK3-PW-PA-TX

**SERIAL NUMBER:** 3-003

**DATE TESTED:** MARCH 8TH - 17TH, 2022

| APPLICABLE STANDARDS | |
|---|---|
| **STANDARD** | **TEST RESULTS** |
| FCC PART 90.103F | Complies |

UL Verification Services Inc. tested the above equipment in accordance with the requirements set forth in the above standards. The test results show that the equipment tested is capable of demonstrating compliance with the requirements as documented in this report.

The results documented in this report apply only to the tested sample, under the conditions and modes of operation as described herein. It is the manufacturer's responsibility to assure that additional production units of this model are manufactured with identical electrical and mechanical components. All samples tested were in good operating condition throughout the entire test program. Measurement Uncertainties are published for informational purposes only and were not taken into account unless noted otherwise.

This document may not be altered or revised in any way unless done so by UL Verification Services Inc. and all revisions are duly noted in the revisions section. Any alteration of this document not carried out by UL Verification Services Inc. will constitute fraud and shall nullify the document. This report must not be used by the client to claim product certification, approval, or endorsement by A2LA, NIST, or any agency of the Federal Government.

Approved & Released For
UL Verification Services Inc. By:

GIA-PIAO (GP) CHIN
OPERATIONS LEADER
UL Verification Services Inc.

Tested By:

PAUL BASTAKI
LABORATORY ENGINEER
UL Verification Services Inc.

# 2. TEST METHODOLOGY

The tests documented in this report were performed in accordance with the following standards:

- FCC CRF 47 Part 2
- FCC CRF Part 90 Subparts F & I
- ANSI C63.26-2015
- Recommendation ITU-R SM.329-10

# 3. FACILITIES AND ACCREDITATION

UL Verification Services Inc. is accredited by A2LA, certification #0751.05, for all testing performed within the scope of this report. Testing was performed at the locations noted below.

| | Address | ISED CABID | ISED Company No. | FCC Registration |
|---|---|---|---|---|
| ☒ | Building 1: 47173 Benicia Street, Fremont, California, USA | US0104 | 2324A | 208313 |
| ☐ | Building 2: 47266 Benicia Street, Fremont, California, USA | US0104 | 22541 | 208313 |
| ☒ | Building 4: 47658 Kato Rd, Fremont, California, USA | US0104 | 2324B | 208313 |



UL VERIFICATION SERVICES INC
47173 BENICIA STREET, FREMONT, CA 94538, USA TEL: (510) 319-4000 FAX: (510) 661-0888

# 4. CALIBRATION AND UNCERTAINTY

## 4.1. METROLOGICAL TRACEABILITY

All test and measuring equipment utilized to perform the tests documented in this report are calibrated on a regular basis, with a maximum time between calibrations of one year or the manufacturers' recommendation, whichever is less, and where applicable is traceable to recognized national standards.

## 4.2. DECISION RULES

The Decision Rule is based on Simple Acceptance in accordance with ISO Guide 98-4:2012 Clause 8.2. (Measurement uncertainty is not taken into account when stating conformity with a specified requirement.)

## 4.3. MEASUREMENT UNCERTAINTY

Where relevant, the following measurement uncertainty levels have been estimated for tests performed on the apparatus:

| PARAMETER | $U_{LAB}$ |
|---|---|
| Worst Case Conducted Antenna Port Emission Measurement – Direct Method | 1.94 dB |
| Worst Case Radiated Disturbance, 9 kHz to 30 MHz | 2.87 dB |
| Worst Case Radiated Disturbance, 30 to 1000 MHz | 6.01 dB |
| Occupied Channel Bandwidth | ±2.75 % |
| Temperature | ±2.26 °C |
| Voltages | ±0.57 % |
| Time | ±3.39 % |

Uncertainty figures are valid to a confidence level of 95%.



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# 5. EQUIPMENT UNDER TEST

## 5.1. DESCRIPTION OF EUT

The MK3-PW-PA-TX is an Oceanographic High Frequency Doppler radar consists of two units or subsystems: the synthesizer/transmitter (TX) unit, and an optional receiver/digitizer (RX) unit. It is designed with bare minimum features to ensure low production cost, low power requirement, and easy maintenance.

The operation of the MK3-PW-PA-TX consists of transmitting frequency-modulated continuous radio waves that are channeled along the surface of the conducting ocean as ground waves, in the wavelength range of 10 to 100 m (frequency 3 to 30 MHz). These radio waves are coherently back-scattered by the ocean's surface gravity waves at half the radio wavelength (5 to 50 m), and captured by an array of receive antennas.

For "Region 2", the International Telecommunication Union has recommended, and the Federal Communication Commission has selected dedicated secondary frequency bands for operating Oceanographic High Frequency Doppler radars, as follows:

| Frequency Band | Occupied Bandwidth |
|---|---|
| (MHz) | (kHz) |
| 4.438 – 4.488 | 50 |
| 5.250 – 5.275 | 25 |
| 13.450 – 13.550 | 100 |
| 16.100 – 16.200 | 100 |
| 24.450 – 24.650 | 200 |
| 26.200 – 26.350 | 220 |

The digital synthesizer is programmed to emit a repetition of ramps (chirp) with 100% duty cycle at a radar mode rate of 1 Hz to 5 Hz or a call-sign mode rate of 1 kHz, and a bandwidth of 25 to 220 kHz determined by the frequency allocation, resulting in a frequency-modulated continuous wave (FMCW mode, emission designation F1N).

This test report covers the device operating at 13.45 - 13.55 MHz and 16.10 - 16.20 MHz frequency bands, with the slow radar mode rate of 1 Hz – 5 Hz to represent the worst case mode.

## 5.2. DESCRIPTION OF AVAILABLE ANTENNAS

The radar system utilizes external transmitting antenna which come in the form of normal-mode helical monopole antenna over finite ground plane with a typical gain of 2 dBi. The transmitting antenna is connected to the output port of synthesizer/transmitter via a cable with an attenuation of at least 5 dB, depending on the operating frequency. All antenna port measurements were made at the end of the minimum cable length to determine the power of fundamental and spurious emissions at the antenna input.



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## 5.3. MAXIMUM OUTPUT POWER

The highest peak output power under normal environmental conditions (+20°C and 120 VAC) in each mode is as followed:

| Mode | Peak Cond. Pwr (dBm) | Peak Power (dBm EIRP) | Peak Power (W) |
|---|---|---|---|
| 13.45 to 13.55 MHz | 44.81 | 41.81 | 15.17 |
| 16.10 to 16.20 MHz | 44.76 | 41.76 | 15.00 |

## 5.4. SOFTWARE AND FIRMWARE

The test utility software used during testing was Canonical Inc., Ubuntu 20.04.3.

The FPGA Controller Firmware used during testing was D-Tacq Solutions Inc., ACQ1001-RADCELF, Release #394.



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# 6. DESCRIPTION OF TEST SETUP

## SUPPORT EQUIPMENT

| PERIPHERAL SUPPORT EQUIPMENT LIST | | | |
|---|---|---|---|
| **Description** | **Manufacturer** | **Model** | **Serial Number** |
| Laptop | Lenovo, Inc | Yoga14-20FY2US | R9-0KXNVG |
| Laptop Power supply | Lenovo, Inc | ADLX45NCC2A | -- |

## I/O CABLES

| I/O Cable List | | | | | | |
|---|---|---|---|---|---|---|
| **Cable No.** | **Port** | **# of identical ports** | **Connector Type** | **Cable Type** | **Cable Length (m)** | **Remarks** |
| 1 | AC | 1 | 3-prong | Unshielded | 2 | -- |
| 2 | Ant | 1 | N-Type | Shielded | 2 | -- |
| 3 | DC | 1 | Mag set | Shielded | 1 | -- |
| 4 | AC | 1 | 3-prong | Shielded | 1.8 | -- |
| 5 | Ethernet | 1 | Cat-6 | Shielded | 2.15 | -- |

## TEST SETUP

The EUT is connected to a laptop computer. Software within the computer is used to configure and exercise the EUT.

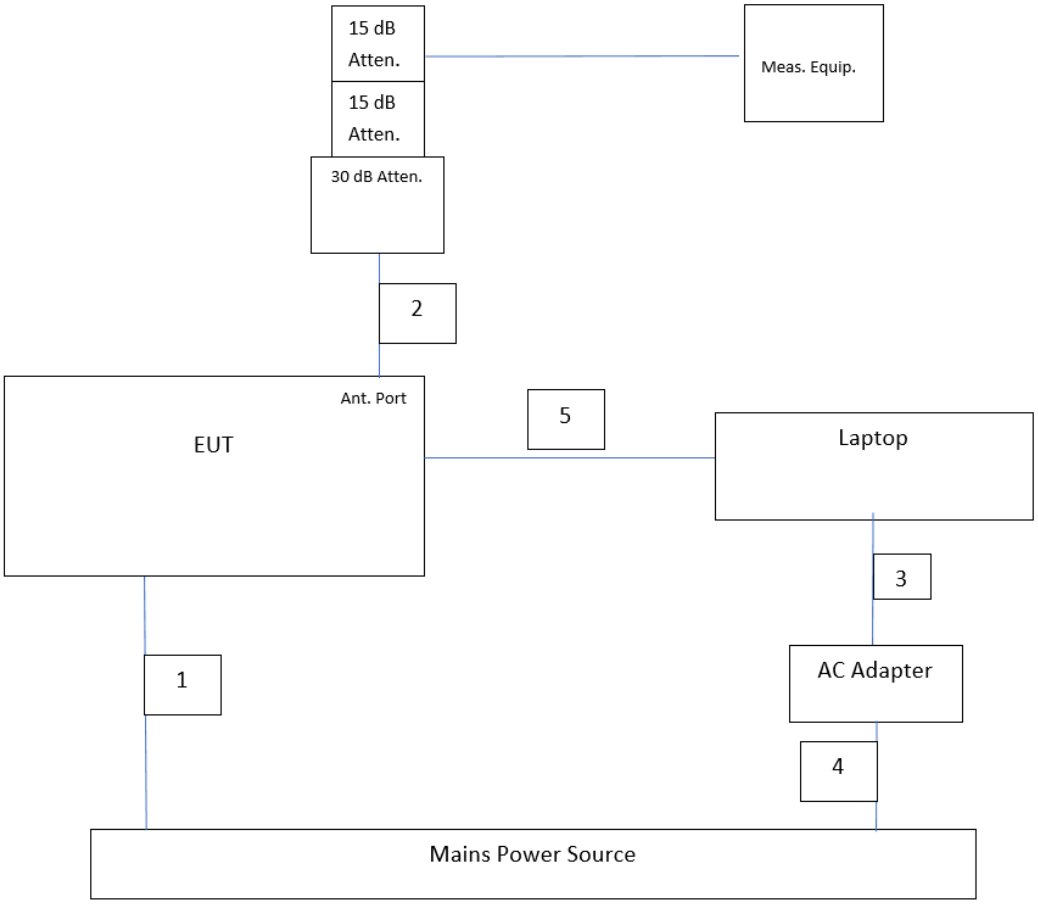
All measurements of Duty Cycle, Occupied Bandwidth, Peak Output Power, $T_X$ Conducted Spurious Emissions and Band-edge were performed at 20°C and 120 VAC nominal, utilizing the conducted test setup with spectrum analyzer.

The total Correction Factor of attenuators and cables was applied as “Offset” to the taken plots of Measured Peak on this report, therefore,

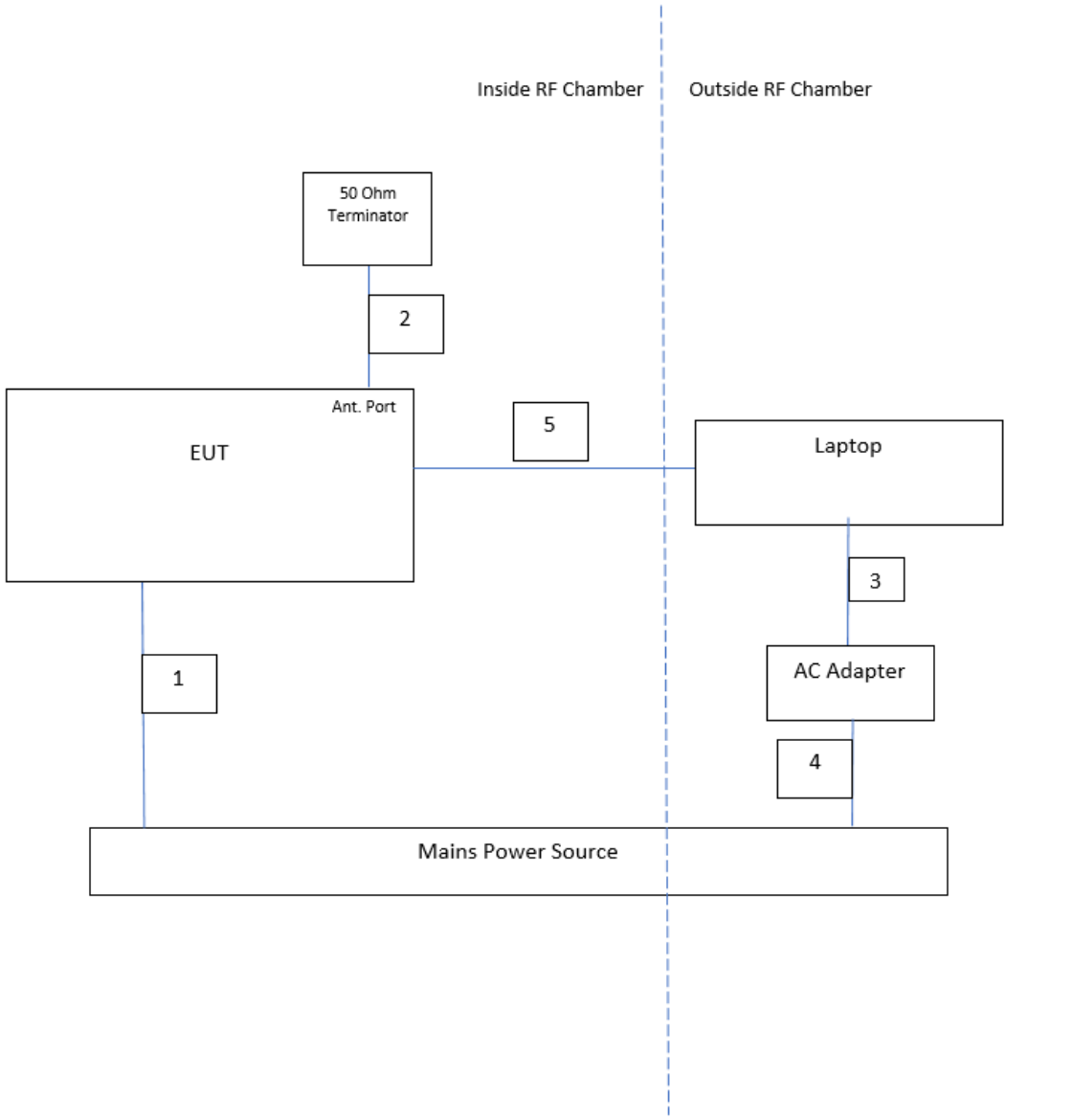
$$Peak\ EIRP\ (dBm) = Measured\ Peak\ (dBm) + Cable\ Loss\ (dB) + EUT\ Ant.Gain\ (dBi)$$

## SETUP DIAGRAMS FOR TESTS

### TX CONDUCTED RF TESTS



## TX RADIATED RF TESTS



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# 7. TEST AND MEASUREMENT EQUIPMENT

The following test and measurement equipment was utilized for the tests documented in this report:

| Test Equipment List | | | | | |
|---|---|---|---|---|---|
| **Description** | **Manufacturer** | **Model** | **Local ID** | **Last Cal** | **Cal Due** |
| Spectrum Analyzer, 50 GHz | Rohde & Schwarz | FSW50 | 198710 | 2/22/2022 | 2/22/2023 |
| Variable AC Transformer | Superior Electric | 3PN136B | 44407 | CNR | CNR |
| Power Analyzer | Yokogawa Electric | WT310E | 155294 | 04/16/2021 | 04/16/2022 |
| 15 dB Attenuator, 1 W | JFW Indust. Inc. | 50F-0150-N | -- | CNR | CNR |
| 30 dB Attenuator, 100 W | Bird Inc. | 100-SA-FFN-30 | -- | CNR | CNR |
| 50 Ohm Terminator | RF-Lambda | RFST200G02NM | T1355 | CNR | CNR |
| EMI Test Receiver, 44 GHz | Rohde & Schwartz | ESW44 | PRE0179367 | 2/16/2022 | 2/16/2023 |
| Antenna, Broadband Hybrid, 30 MHz to 2000 MHz | Sunol Sciences Corp. | JB1 | T1199 | 10/01/21 | 10/01/2022 |
| Amplifier, 9 kHz – 1 GHz, 32 dB | Sonoma Instrument | 310 | 175953 | 02/08/2022 | 02/08/2023 |
| Antenna, Passive Loop 30Hz – 1 MHz | Electro-Metrics | EM-6871 | 170014 | 06/08/2021 | 06/08/2022 |
| Antenna, Passive Loop 100 kHz – 30 MHz | Electro-Metrics | EM-6872 | 170016 | 06/08/2021 | 06/08/2022 |
| Temperature Chamber | Espec | EWPX 674(2)-(2)12NAL | 135568 | 4/19/19 | 4/30/22 |
| UL EMC Radiated Software | Version: | Rev 9.5.21 Jan 2021 | | | |



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# 8. APPLICABLE LIMITS AND TEST RESULTS

## 8.1. DUTY CYCLE

**LIMIT**

For reporting purposes only.

**TEST PROCEDURE**

All measurements were performed with the CW signals of $F_c$ = 13.5 MHz and $F_c$ = 16.15 MHz, representing the 13.45 – 13.55 MHz and 16.10 – 16.20 MHz modes, respectively.

The duty cycle factor is calculated as:

$$Duty\ Cycle\ Factor\ (dB)\ =\ 10 \times Log\ (1/x),$$
$$where\ x\ =\ Duty\ Cycle\ (linear)$$

**RESULTS**

Employee ID: 25368
Location: mmWave Chamber 1
Test Date: 3/8/22 – 03/16/22

| Band | Fc (MHz) | (msec) | (msec) | (linear) | (%) |
|---|---|---|---|---|---|
| 13.45 to 13.55 MHz | 13.5 | 2000 | 2000 | 1.000 | 100.00 |
| 16.10 TO 16.20 MHz | 16.15 | 2000 | 2000 | 1.000 | 100.00 |



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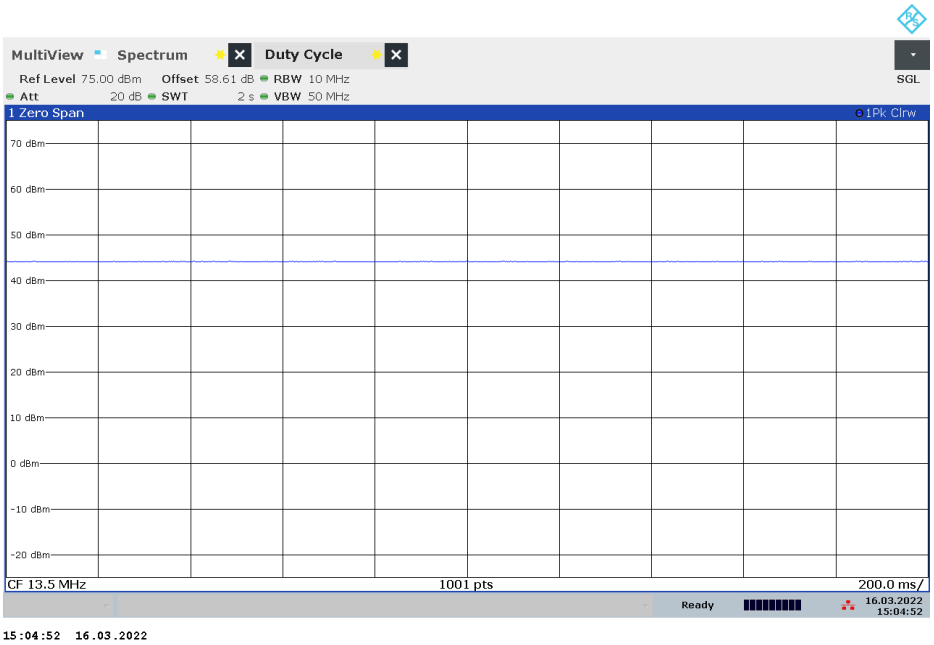
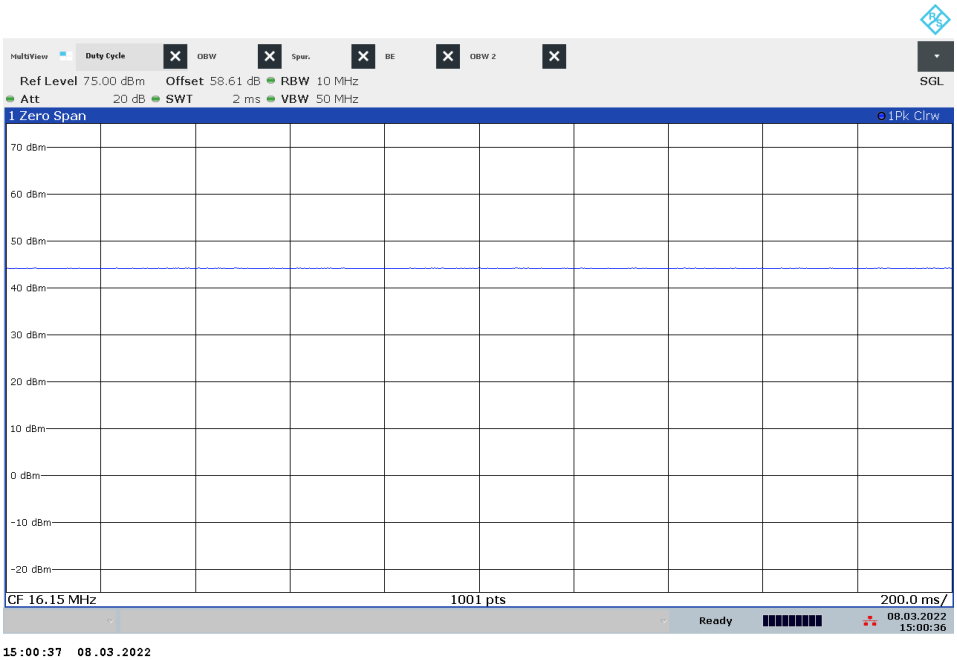
## 13.5 MHz CW Mode




## 16.15 MHz CW Mode



## 8.2. OCCUPIED BANDWIDTH

**RULE PART**

§2.1049

**LIMIT**

99% Bandwidth measured shall fall within the frequency band listed in FCC Part 90.103 (F).

Applicable limits for bands tested in this report is as follows:

| Frequency Band |
|---|
| 13.45 to 13.55 MHz |
| 16.10 to 16.20 MHz |

**TEST PROCEDURE**

ANSI C63.26-2015 Clause 5.4.4

99% bandwidth measurement function of the spectrum analyzer was used to measure 99% occupied bandwidth.

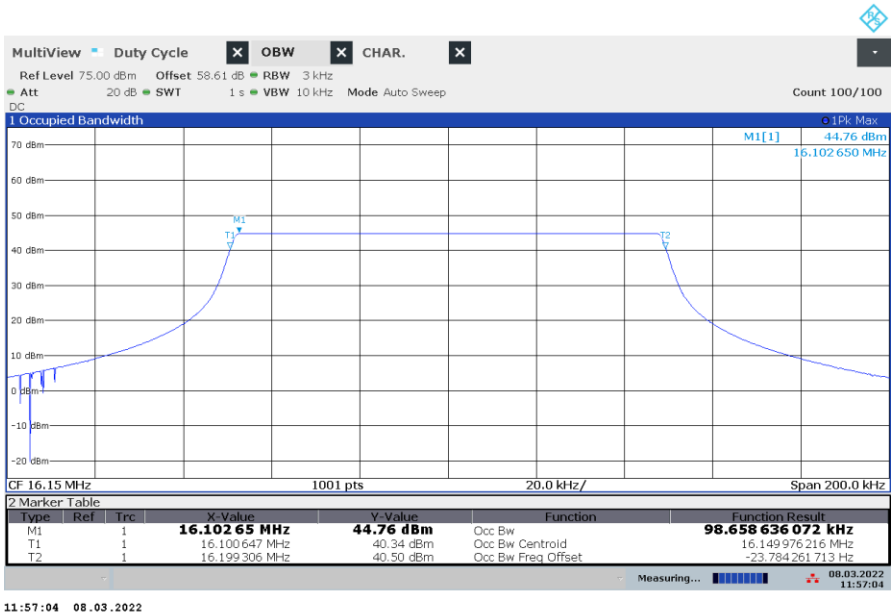
**RESULTS**

Employee ID: 25368
Location: mmWave Chamber 1
Test Date: 3/8/22 - 3/9/22

| Mode | Meas. 99% BW (kHz) | Meas. FL (MHz) | Limit (MHz) | Pass/Fail | Meas. FH (MHz) | Limit (MHz) | Pass/Fail |
|---|---|---|---|---|---|---|---|
| 13.45 to 13.55 MHz | 98.600 | 13.451 | 13.45 | Pass | 13.549 | 13.55 | Pass |
| 5.250 to 5.275 MHz | 98.659 | 16.101 | 16.10 | Pass | 16.199 | 16.2 | Pass |

## 13.45 to 13.55 MHz Mode


## 16.10 to 16.20 MHz Mode



## 8.3. PEAK OUTPUT POWER

**RULE PARTS**

§2.1046 & §90.205 (r)

**LIMIT**

Per §90.103 (c)(3): Operations in this band are limited to oceanographic radars using transmitters with a peak equivalent isotropically radiated power (EIRP) not to exceed 25 dBW (316 W or +55 dBm). Oceanographic radars shall not cause harmful interference to, nor claim protection from interference caused by, stations in the fixed or mobile services as specified in §2.106, footnotes 5.132A, 5.145A, and US132A. See Resolution 612 of the ITU Radio Regulations for international coordination requirements and for recommended spectrum sharing techniques.

Per Resolution 612 (REV. WRC-12), (d)(2): The Peak E.I.R.P. of an oceanographic radar shall not exceed 25 dBW (316 W or +55 dBm).

**TEST PROCEDURE**

ANSI C63.26-2015 Clause 5.2.3.5

**RESULTS**

Employee ID: 25368
Location: mmWave Chamber 1
Test Date: 3/8/22

| Mode | Frequency (MHz) | Meas. Peak (dBm) | Cable Loss (dB) | EUT Ant. Gain (dBi) | Peak EIRP (dBm) | Peak EIRP (W) | Limit (W) | Pass or Fail |
|---|---|---|---|---|---|---|---|---|
| 13.45 to 13.55 MHz | 13.454 | 44.81 | 5 | 2 | 41.81 | 15.17 | 316 | Pass |
| 16.10 to 16.20 MHz | 16.103 | 44.76 | 5 | 2 | 41.76 | 15.00 | 316 | Pass |

Peak EIRP is based on the use of normal-mode helical monopole antenna over finite ground plane, which has a maximum gain of 2 dBi, declared by manufacturer. The actual peak EIRP values are based on a minimum of 5 dB cable loss of RG213 or RG214 between the RF output and the antenna (power measurement was made at the end of the cable).

As the signal is a swept CW signal, the instantaneous emission bandwidth is much less than the 10 kHz used for the peak power measurement. The sweep rate is slow enough to not require any correction for desensitization, which is further supported by comparing the peak power levels are almost the same for the occupied bandwidth measurement made using a 1 kHz RBW and the power measurement.



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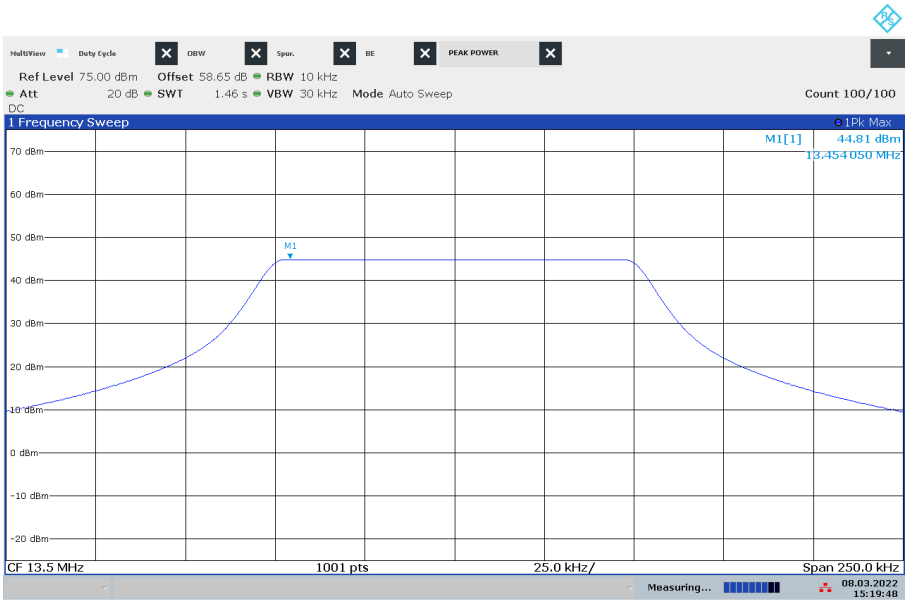
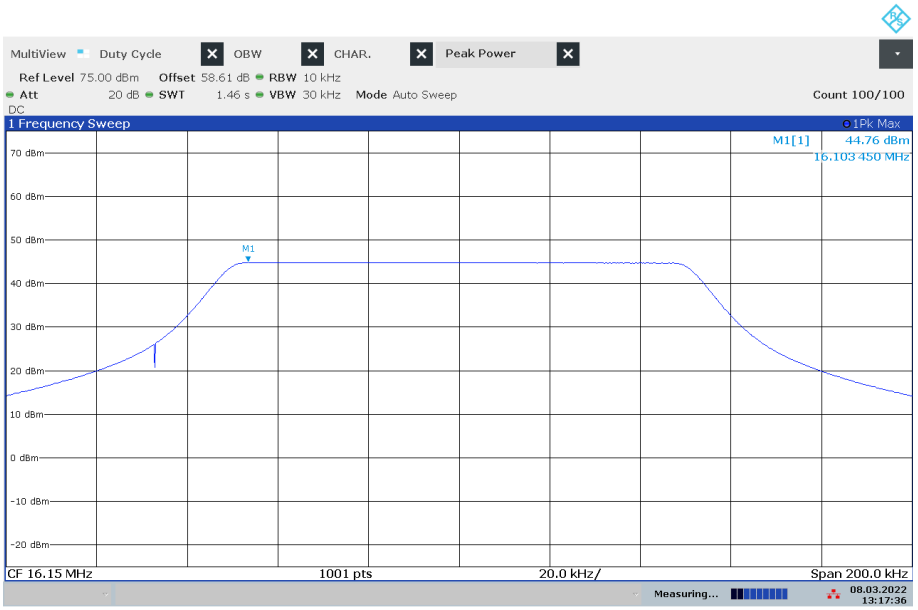
## 13.45 to 13.55 MHz Mode




## 16.10 to 16.20 MHz Mode



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## 8.4. FREQUENCY STABILITY

**RULE PARTS**

§2.1055 (a)(1): From −30° to + 50° centigrade for all equipment except that specified in paragraphs (a) (2) and (3) of this section.

§2.1055 (d)(1): Vary primary supply voltage from 85 to 115 percent of the nominal value for other than hand carried battery equipment.

The EUT is operated near the coast and installed only in climate-controlled enclosure or building with the following conditions:

Temperature: -30°C to +50°C
Nominal Voltage: 120 VAC

**LIMIT**

§90.213 (a)

**TABLE 1 TO §90.213(a)—MINIMUM FREQUENCY STABILITY**

[Parts per million (ppm)]

| Frequency range (MHz) | Fixed and base stations | Mobile stations | |
|---|---|---|---|
| | | Over 2 watts output power | 2 watts or less output power |
| Below 25 | [1 2 3]100 | 100 | 200 |

Applicable Limit: 100 ppm

**TEST PROCEDURES**

ANSI C63.26-2015 Clause 5.6.5

All measurements were performed with the CW signals of Fc = ~13.5 MHz and Fc = ~16.15 MHz, representing 13.45 to 13.55 MHz Mode and 16.10 to 16.20 MHz Mode, respectively.

**Test procedures for temperature variation:**

a. Position the EUT in temperature/humidity chamber.
b. Set chamber temperature to +20°C, stabilize the EUT for at least 45 minutes and record the $F_c$.
c. Adjust chamber temperature from -30°C to +50°C at 10°C interval. Record maximum change in $F_c$ at each temperature.
d. A period of at least 45 minutes is provided to allow stabilization of the equipment at each temperature level.

**Test procedures for voltage variation:**

a. Position the EUT in temperature/humidity chamber.
b. Set chamber temperature to +20°C.
c. The primary supply voltage is varied from 85% to 115% of the nominal value.

- Voltages:

Nominal: 120 VAC
85% of the Nominal: 102 VAC
115% of the Nominal: 138 VAC



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**RESULTS**

Employee ID: 25368
Location: Environmental Chamber
Test Date: 3/10/22 - 3/11/22

| 13.45 to 13.55 MHz Mode | | | | |
|---|---|---|---|---|
| Temp (°C) | Input Power (AC) | CW (Fc) | | |
| | | Meas. Freq. (MHz) | Freq. Drift (ppm) | Pass/Fail |
| 50 | Nominal | 13.5000 | 0.0000 | Pass |
| 40 | Nominal | 13.5000 | 0.0000 | Pass |
| 30 | Nominal | 13.5000 | 0.0000 | Pass |
| 20 | Nominal | 13.5000 | - | - |
| 10 | Nominal | 13.5000 | 0.0000 | Pass |
| 0 | Nominal | 13.5000 | 0.0000 | Pass |
| -10 | Nominal | 13.5000 | 0.0000 | Pass |
| -20 | Nominal | 13.5000 | 0.0000 | Pass |
| -30 | Nominal | 13.5000 | 0.0000 | Pass |
| 20 | 85% | 13.5000 | 0.0000 | Pass |
| 20 | 115% | 13.5000 | 0.0000 | Pass |

| 16.10 to 16.20 MHz Mode | | | | |
|---|---|---|---|---|
| Temp (°C) | Input Power (AC) | CW (Fc) | | |
| | | Meas. Freq. (MHz) | Freq. Drift (ppm) | Pass/Fail |
| 50 | Nominal | 16.1500 | 0.0000 | Pass |
| 40 | Nominal | 16.1500 | 0.0000 | Pass |
| 30 | Nominal | 16.1500 | 0.0000 | Pass |
| 20 | Nominal | 16.1500 | - | -- |
| 10 | Nominal | 16.1500 | 0.0000 | Pass |
| 0 | Nominal | 16.1500 | 0.0000 | Pass |
| -10 | Nominal | 16.1500 | 0.0000 | Pass |
| -20 | Nominal | 16.1500 | 0.0000 | Pass |
| -30 | Nominal | 16.1500 | 0.0000 | Pass |
| 20 | 85% | 16.1500 | 0.0000 | Pass |
| 20 | 115% | 16.1500 | 0.0000 | Pass |


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# 8.5. TX CONDUCTED SPURIOUS EMISSIONS AND BAND EDGE

## RULE PARTS

§2.1057 (a) (1): In all the measurements set forth in §2.1051 and §2.1053, the spectrum shall be investigated from the lowest radio frequency signal generated in the equipment, without going below 9 kHz, up to at least the frequency shown below: If the equipment operates below 10 GHz: to the tenth harmonic of the highest fundamental frequency or to 40 GHz, whichever is lower.

10th harmonic of highest fundamental frequency $= 10 \times (16.20\ MHz) = 162.0\ MHz$
Thus, spurious emissions are investigated from 9 kHz thru 1 GHz.

## LIMIT

§ 90.210 (n): Other frequency bands. Transmitters designed for operation under this part on frequencies other than listed in this section must meet the emission mask requirements of Emission Mask B. Equipment operating under this part on frequencies allocated to but shared with the Federal Government, must meet the applicable Federal Government technical standards.

§ 90.210 (b): Emission Mask B. For transmitters that are equipped with an audio low-pass filter, the power of any emission must be attenuated below the unmodulated carrier power (P) as follows:

(1) On any frequency removed from the assigned frequency by more than 50 percent, but not more than 100 percent of the authorized bandwidth: At least 25 dB.
(2) On any frequency removed from the assigned frequency by more than 100 percent, but not more than 250 percent of the authorized bandwidth: At least 35 dB.
(3) On any frequency removed from the assigned frequency by more than 250 percent of the authorized bandwidth: At least $43 + 10\ log(P)\ dB$.

The more stringent Peak power limit on § 90.210 (b)(3), which is the same limit as Rec ITU-R SM.329-10 Standard, is applied for spurious emissions and bandedge.

Determination of Limit:

Maximum Declared Peak Conducted Power of EUT,

$$P_{max} = 42\ dBm\ (15\ W)$$

$$\begin{aligned} Applicable\ Peak\ Limit &= 42 - \big(43 + 10log(15)\big) \\ &= 42 - 55 \\ &= -13\ dBm \end{aligned}$$

## TEST PROCEDURE

ANSI C63.26-2015 Clause 5.7

The widest emission bandwidth of EUT was used at 9 kHz – 1 GHz spurious emission tests.

For Bandedge, the measurements were measured by transmitting the CW signals of low-end ($F_L$) and the high-end ($F_H$) of each frequency band.

## RESULTS

Employee ID: 25368
Location: mmWave Chamber 1
Test Date: 3/8/22 - 3/17/22

| Mode | 9 - 150 kHz | 150 kHz - 30 MHz | 30 MHz - 1 GHz | Bandedge |
|---|---|---|---|---|
| 13.45 to 13.55 MHz | Pass | Pass | Pass | Pass |
| 16.10 to 16.20 MHz | Pass | Pass | Pass | Pass |



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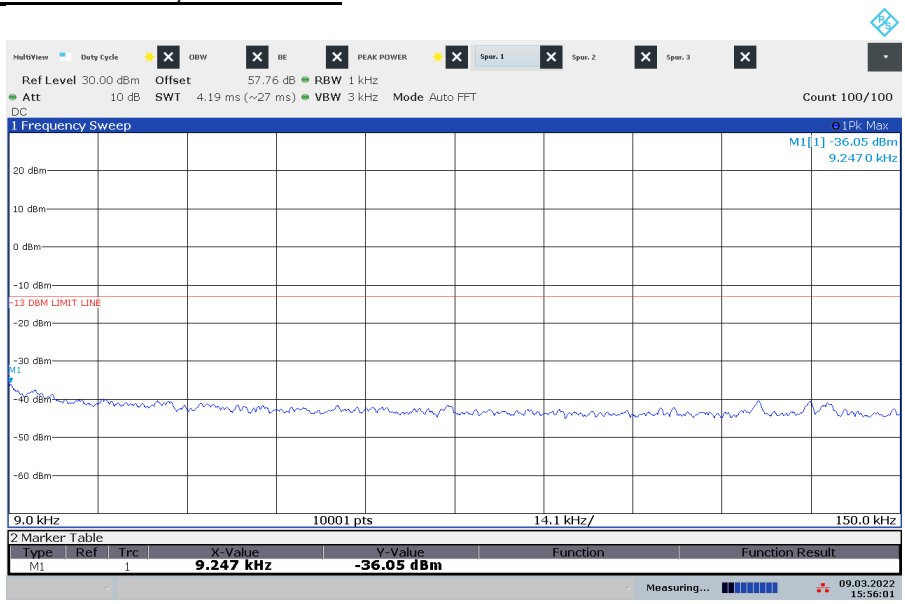
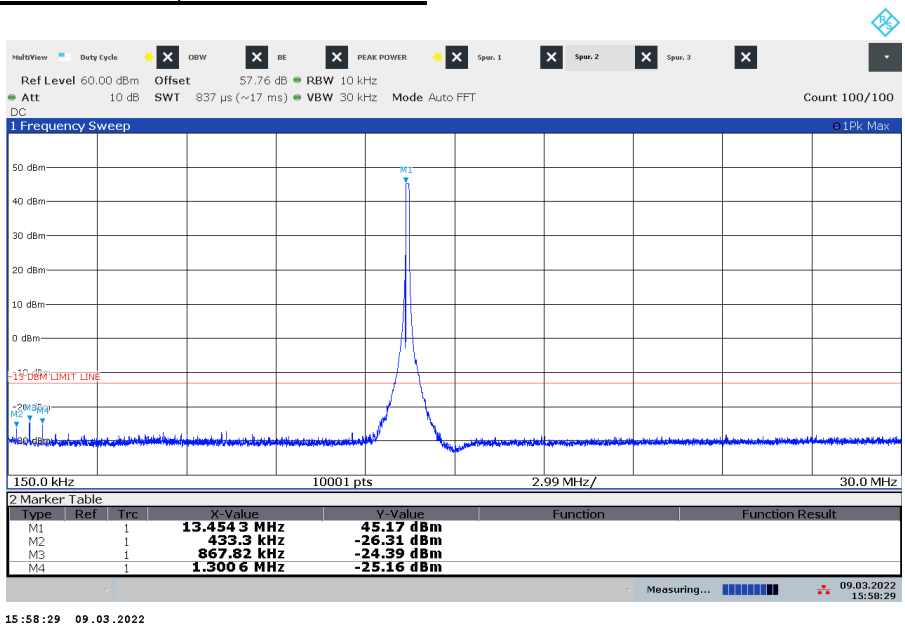
## 8.5.1. SPURIOUS EMISSIONS

### 13.45 to 13.55 MHz Mode, 9 - 150 kHz

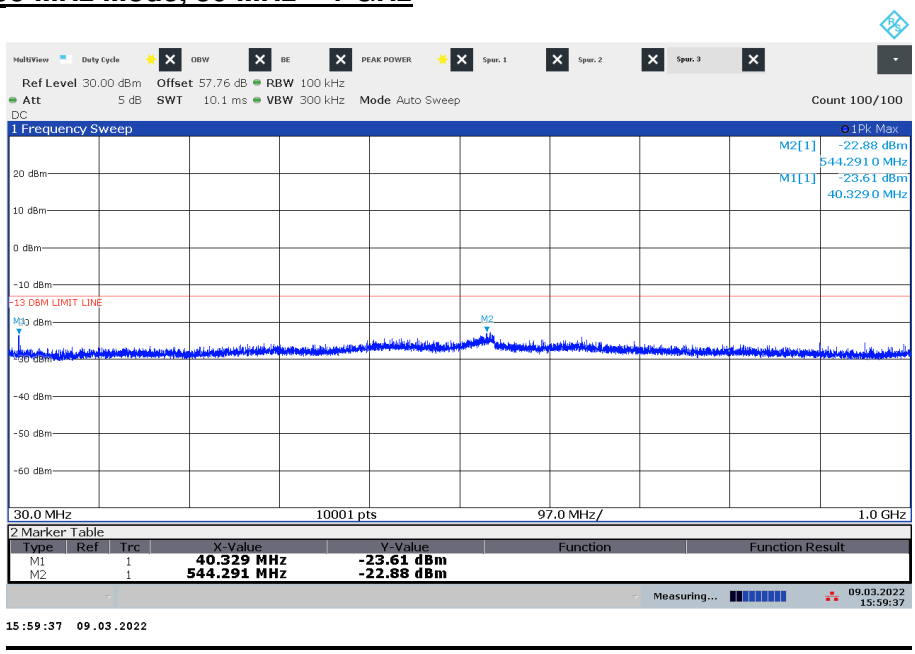



### 13.45 to 13.55 MHz Mode, 150 kHz - 30 MHz

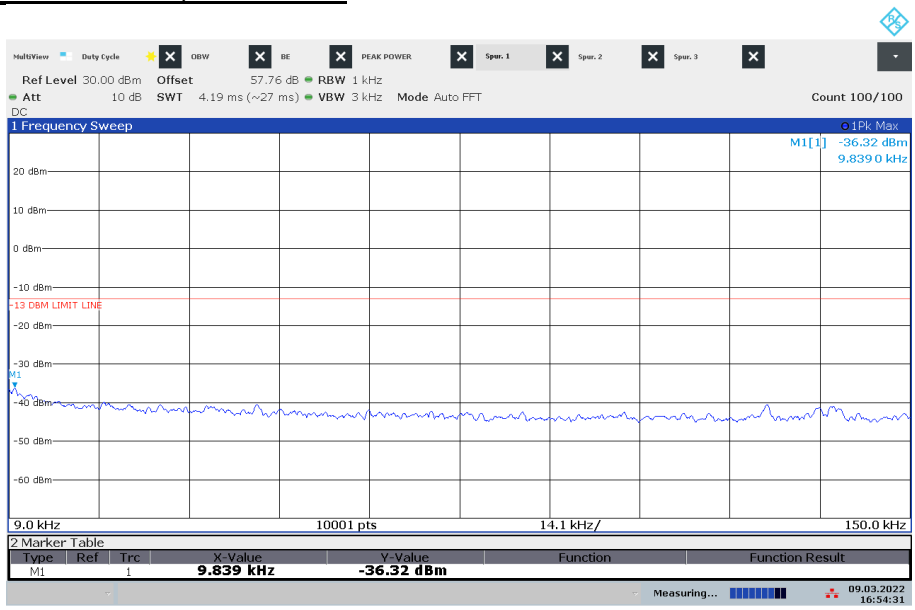



*Marker M1 is the fundamental signal.

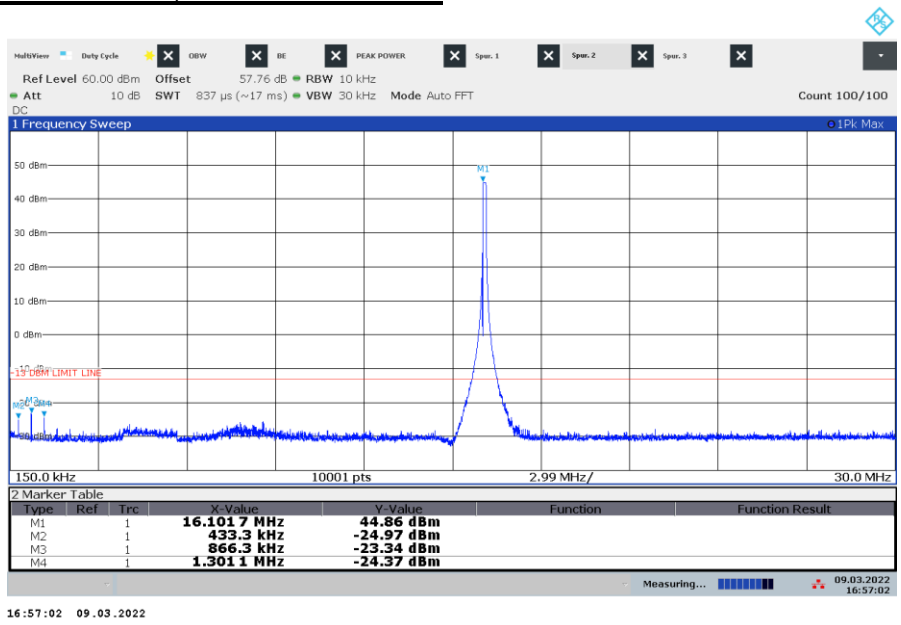
## 13.45 to 13.55 MHz Mode, 30 MHz – 1 GHz



## 16.10 to 16.20 MHz Mode, 9 - 150 kHz

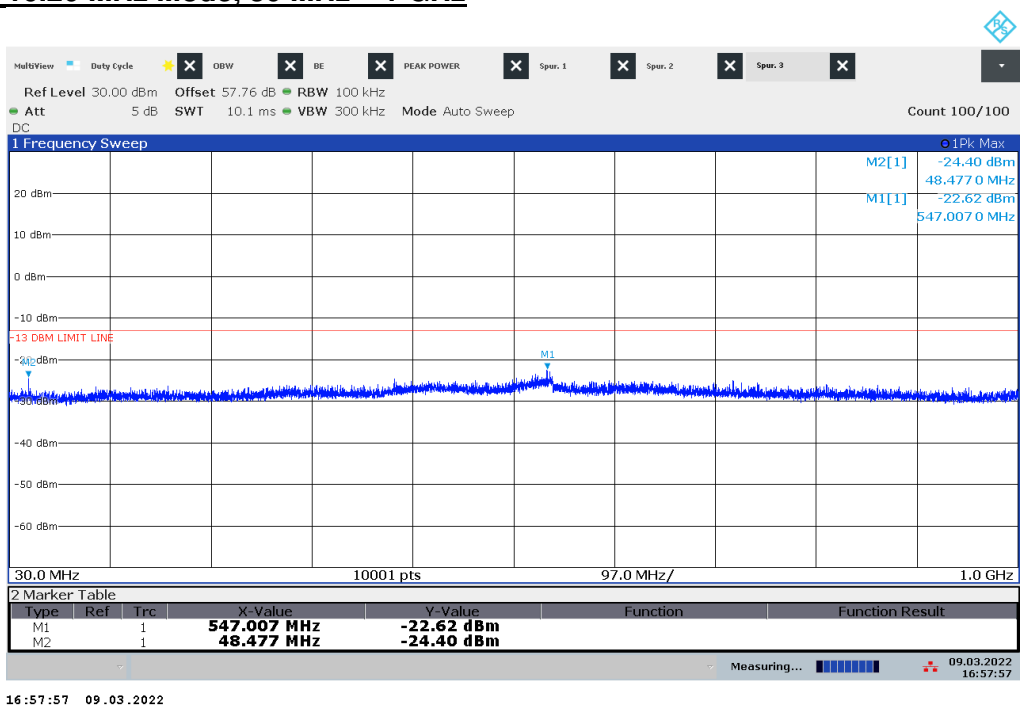



## 16.10 to 16.20 MHz Mode, 150 kHz to 30 MHz



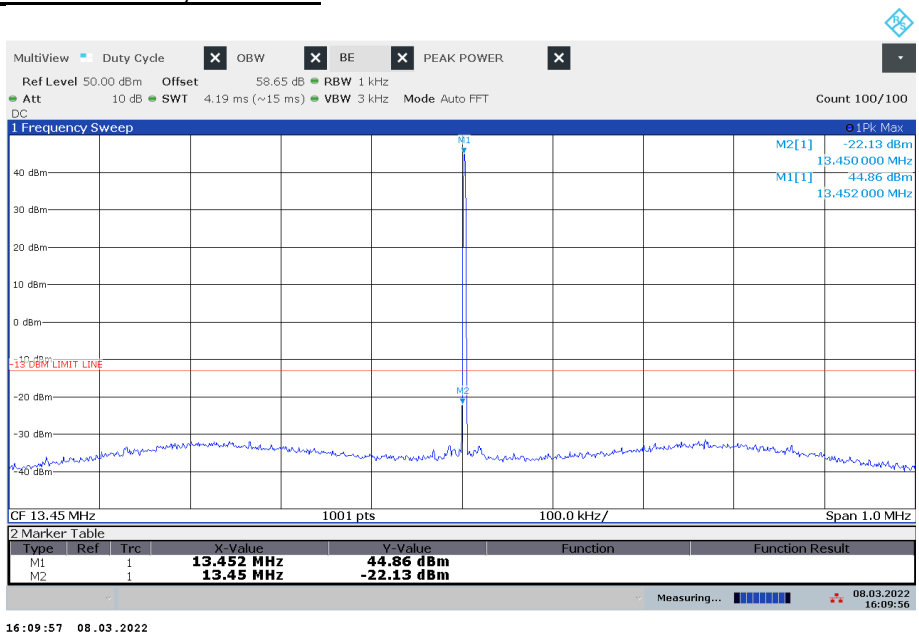

*Marker M1 is the fundamental signal.

## 16.10 to 16.20 MHz Mode, 30 MHz – 1 GHz

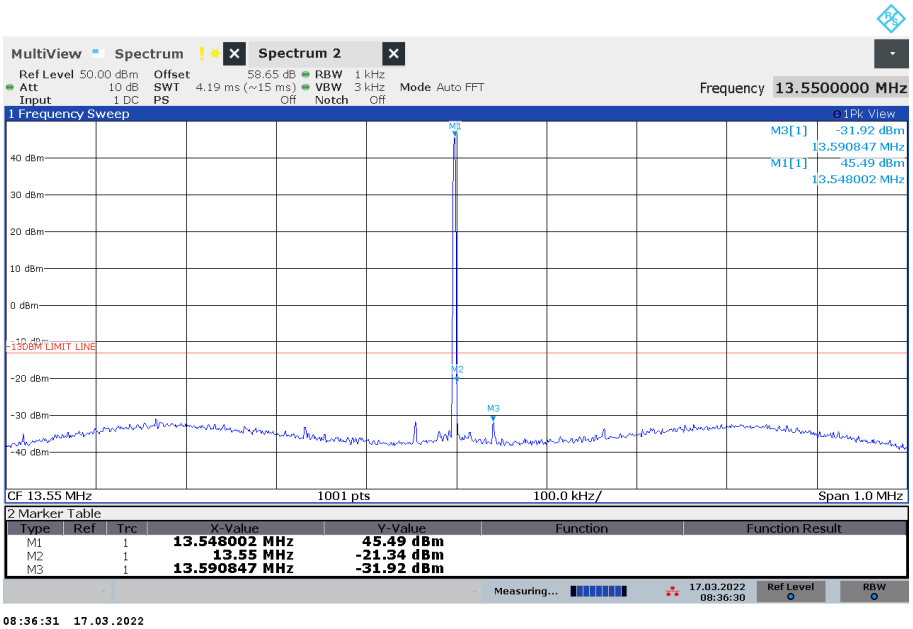


## 8.5.2. BAND EDGE

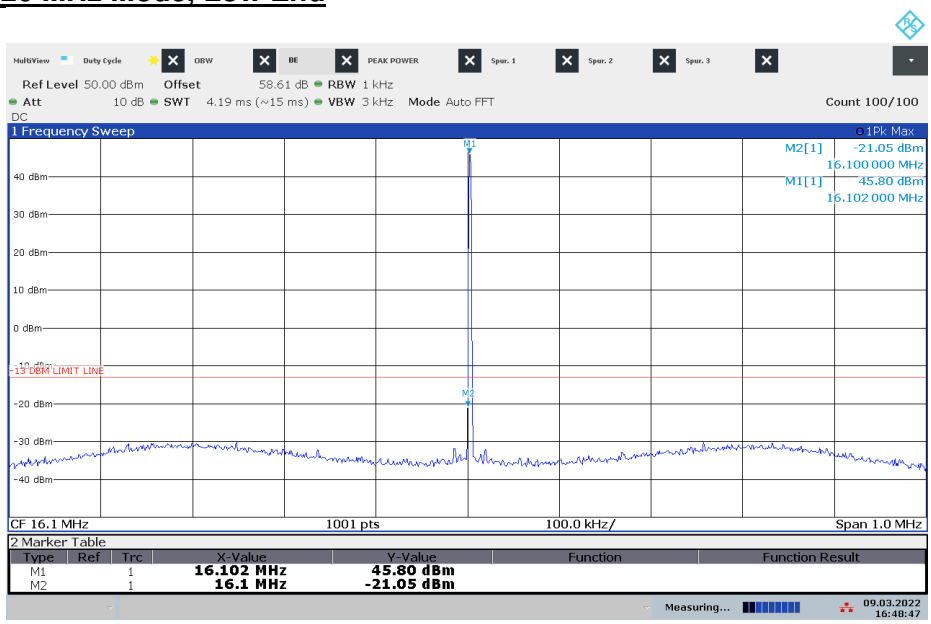
### 13.45 to 13.55 MHz Mode, Low End




### 13.45 to 13.55 MHz Mode, High End



## 16.10 to 16.20 MHz Mode, Low End

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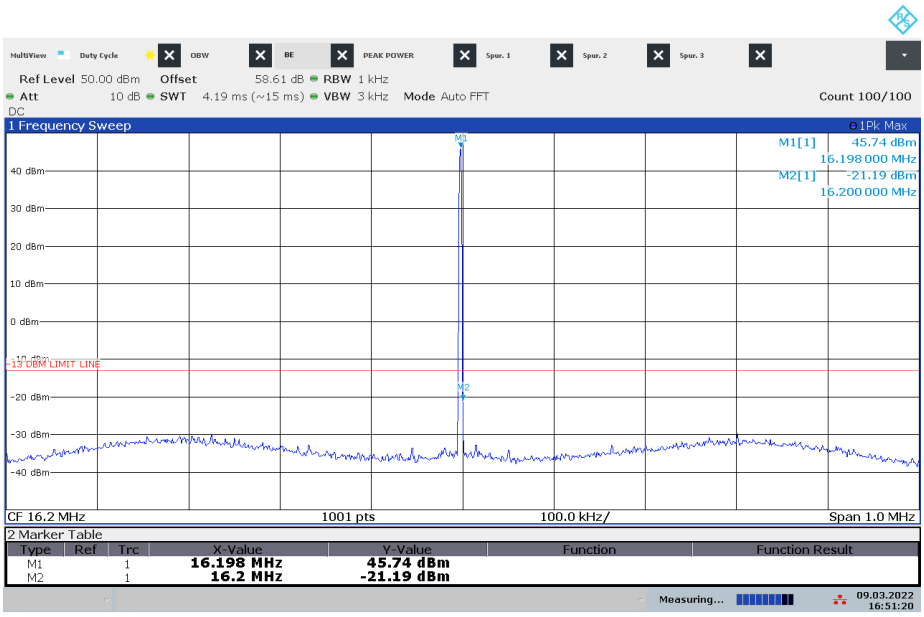
## 16.10 to 16.20 MHz Mode, High End

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# 8.6. TX RADIATED SPURIOUS EMISSIONS

## RULE PARTS

§2.1057 (a) (1): In all the measurements set forth in §2.1051 and §2.1053, the spectrum shall be investigated from the lowest radio frequency signal generated in the equipment, without going below 9 kHz, up to at least the frequency shown below: If the equipment operates below 10 GHz: to the tenth harmonic of the highest fundamental frequency or to 40 GHz, whichever is lower.

10th harmonic of highest fundamental frequency $= 10 \times (16.20\ MHz) = 162.0\ MHz$
Thus, spurious emissions are investigated from 9 kHz thru 1 GHz.

## LIMIT

§ 90.210 (n): Other frequency bands. Transmitters designed for operation under this part on frequencies other than listed in this section must meet the emission mask requirements of Emission Mask B. Equipment operating under this part on frequencies allocated to but shared with the Federal Government, must meet the applicable Federal Government technical standards.

§ 90.210 (b): Emission Mask B. For transmitters that are equipped with an audio low-pass filter, the power of any emission must be attenuated below the unmodulated carrier power (P) as follows:

(1) On any frequency removed from the assigned frequency by more than 50 percent, but not more than 100 percent of the authorized bandwidth: At least 25 dB.
(2) On any frequency removed from the assigned frequency by more than 100 percent, but not more than 250 percent of the authorized bandwidth: At least 35 dB.
(3) On any frequency removed from the assigned frequency by more than 250 percent of the authorized bandwidth: At least $43 + 10\ log(P)\ dB$.

The more stringent Peak power limit on § 90.210 (b)(3), which is the same limit as Rec ITU-R SM.329-10 Standard, is applied for spurious emissions and bandedge.

Determination of Limit:

Maximum Declared Peak Conducted Power of EUT,

$$P_{max} = 42\ dBm\ (15\ W)$$

$$\begin{aligned} Applicable\ Peak\ Limit &= 42 - \big(43 + 10log(15)\big) \\ &= 42 - 55 \\ &= -13\ dBm \end{aligned}$$

## TEST PROCEDURE

ANSI C63.26-2015 Clause 5.5.4

Below 30 MHz spurious emission testing was performed in chamber other than open area test site. Adequate comparison measurements were confirmed against 30-meter open area test site and sufficient tests were made to demonstrate that the alternative site produces results that correlate with the ones of tests made in an open field based on KDB 414788.

## RADIATED EMISSION

Where relevant, the following sample calculations are provided:

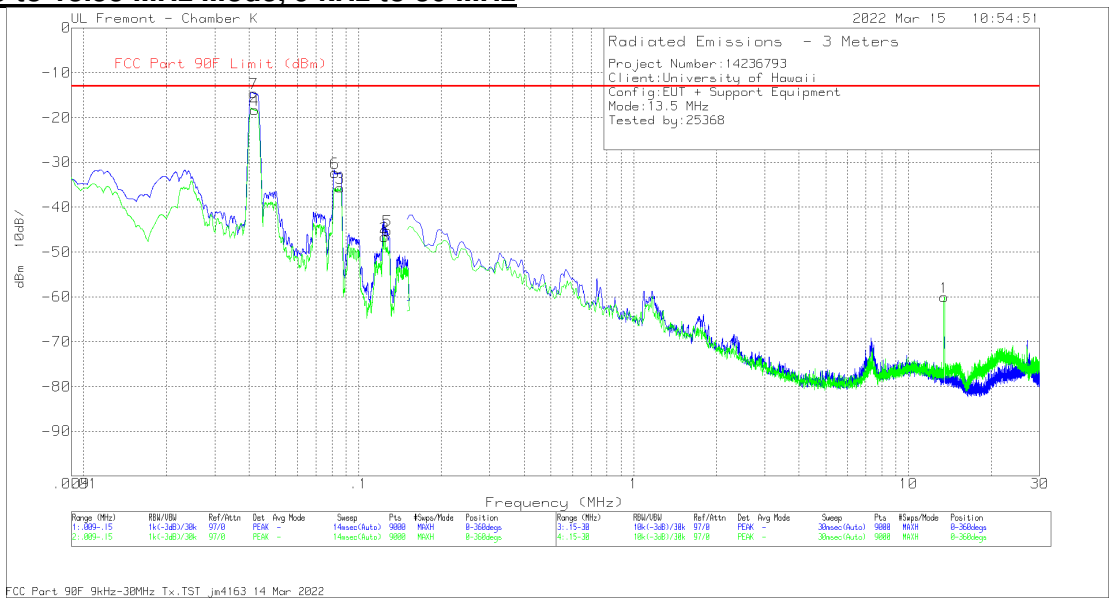
$$EIRP(dBm) = \text{Meter Reading } (dBuV) + \text{Antenna Factor}(dB/m) + \text{PreAmp Gain/Cbl Loss } (dB) + (dBuV - to - dBm) \text{ Unit Conversion Factor @ } 3m$$
$$= 34.27\ dBm\ +\ 48.3\ dB/m\ +\ (-32.2)\ dB\ +\ (-95.2)$$
$$= -44.83\ dBm$$

$$EIRP(dBm) = \text{Meter Reading } (dBm) + \text{Antenna Factor } (dB/m) + \text{ PreAmp Gain/Cbl Loss } (dB) + (dBm - to - dBm) \text{ Unit Conversion Factor @ } 3m$$
$$= -60\ dBm\ +\ 28\ dB/m\ +\ (-27)\ dB\ +\ 11.7$$
$$= -47.3\ dBm$$

## RESULTS

Employee ID: 25368
Location: Chamber K
Test Date: 3/14/22 - 3/15/22

## 13.45 to 13.55 MHz Mode, 9 kHz to 30 MHz




## Trace Markers - Prescan

| Marker | Frequency (MHz) | Meter Reading (dBuV) | Det | Loop Antenna (E ACF) | Amp/Cbl (dB) | Unit Conversion | Corrected Reading dBm | FCC Part 90F Limit (dBm) | Margin (dB) | Azimuth (Degs) | Antenna Face |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 5 | .1274 | 26.37 | Pk | 55.8 | -32.2 | -95.2 | -45.23 | -13 | -32.23 | 0-360 | On |
| 6 | .0821 | 39.37 | Pk | 55.7 | -32.2 | -95.2 | -32.33 | -13 | -19.33 | 0-360 | On |
| 7 | .0416 | 55.58 | Pk | 57.2 | -32.1 | -95.2 | -14.52 | -13 | -1.52 | 0-360 | On |
| 2 | .1242 | 24.92 | Pk | 55.8 | -32.2 | -95.2 | -46.68 | -13 | -33.68 | 0-360 | Off |
| 3 | .0858 | 35.96 | Pk | 55.8 | -32.2 | -95.2 | -35.64 | -13 | -22.64 | 0-360 | Off |
| 4 | .0419 | 51.78 | Pk | 57.2 | -32.1 | -95.2 | -18.32 | -13 | -5.32 | 0-360 | Off |
| 1* | 13.5109 | 32.64 | Pk | 34.2 | -31.7 | -95.2 | -60.06 | -13 | -47.06 | 0-360 | |

Pk - Peak detector

Power levels of emissions were lower with antenna face-down, comparing to face-on and face-off, at pre-scan.

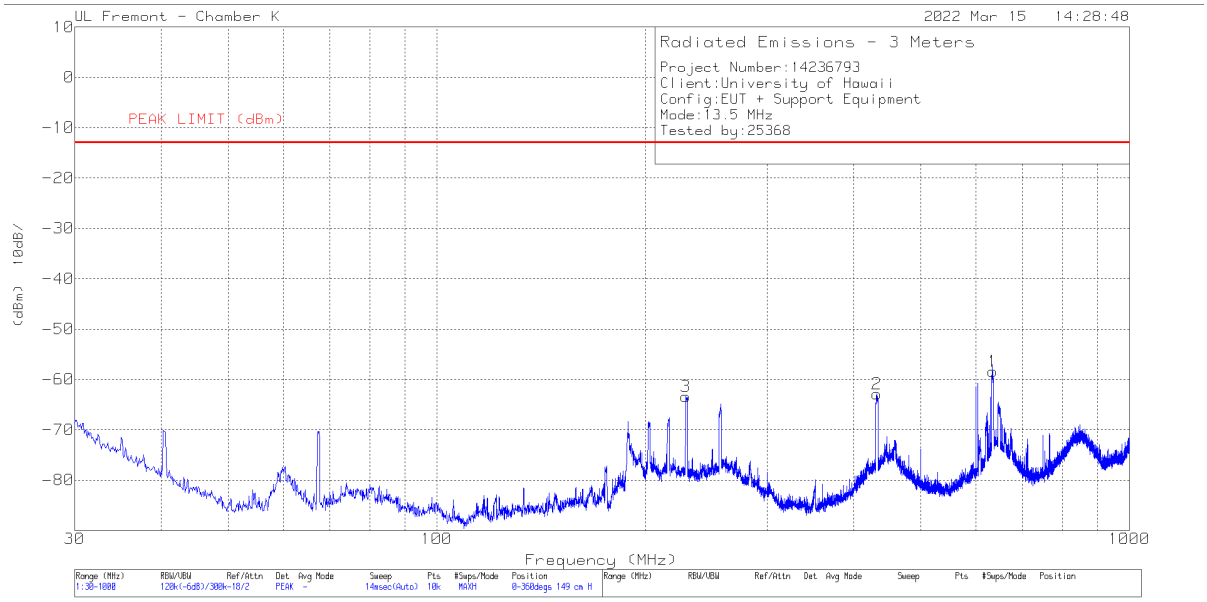
*Marker 1 is the fundamental signal.

## Radiated Emissions – Final Data

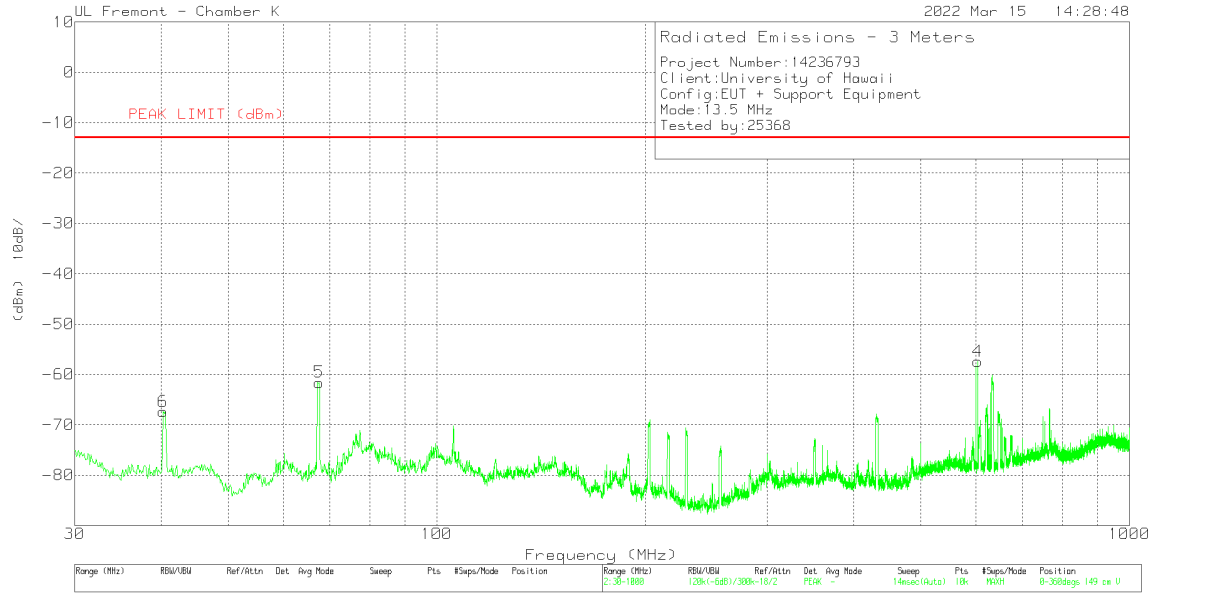
| Frequency (MHz) | Meter Reading (dBuV) | Det | Loop Antenna (E ACF) | Amp/Cbl (dB) | Unit Conversion | Corrected Reading dBm | FCC Part 90F Limit (dBm) | Margin (dB) | Azimuth (Degs) | Antenna Face |
|---|---|---|---|---|---|---|---|---|---|---|
| .0418 | 55.52 | Pk | 57.2 | -32.1 | -95.2 | -14.58 | -13 | -1.58 | 75 | On |
| .0804 | 39.83 | Pk | 55.7 | -32.2 | -95.2 | -31.87 | -13 | -18.87 | 77 | On |
| .1267 | 26.52 | Pk | 55.8 | -32.2 | -95.2 | -45.08 | -13 | -32.08 | 90 | On |
| .1238 | 25.66 | Pk | 55.8 | -32.2 | -95.2 | -45.94 | -13 | -32.94 | 158 | Off |
| .0839 | 36.05 | Pk | 55.7 | -32.2 | -95.2 | -35.65 | -13 | -22.65 | 164 | Off |
| .0403 | 52.07 | Pk | 57.2 | -32.1 | -95.2 | -18.03 | -13 | -5.03 | 178 | Off |

Pk - Peak detector

## 13.45 to 13.55 MHz Mode, 30 - 1000 MHz




FCC Part 90F 30-1000 MHz Tx.TST 02970 22 Aug 2019




FCC Part 90F 30-1000 MHz Tx.TST 02970 22 Aug 2019

## Trace Markers - Prescan

| Marker | Frequency (MHz) | Meter Reading (dBm) | Det | 82258 ACF (dB) | Amp/Cbl (dB) | Sub Factor (dB) | Corrected Reading (dBm) | PEAK LIMIT (dBm) | Margin (dB) | Azimuth (Degs) | Height (cm) | Polarity |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 634.407 | -67.85 | Pk | 26 | -28.6 | 12 | -58.45 | -13 | -45.45 | 0-360 | 149 | H |
| 2 | 431.968 | -67.35 | Pk | 22.7 | -29.3 | 11.1 | -62.85 | -13 | -49.85 | 0-360 | 149 | H |
| 3 | 228.947 | -63.3 | Pk | 17.6 | -30.1 | 12.4 | -63.4 | -13 | -50.4 | 0-360 | 149 | H |
| 4 | 603.949 | -60.99 | Pk | 25.2 | -28.8 | 7.2 | -57.39 | -13 | -44.39 | 0-360 | 149 | V |
| 5 | 67.636 | -54.87 | Pk | 14.1 | -31.1 | 10.3 | -61.57 | -13 | -48.57 | 0-360 | 149 | V |
| 6 | 40.282 | -61.77 | Pk | 19.9 | -31.4 | 5.9 | -67.37 | -13 | -54.37 | 0-360 | 149 | V |

Pk - Peak detector

## Radiated Emissions – Final Data

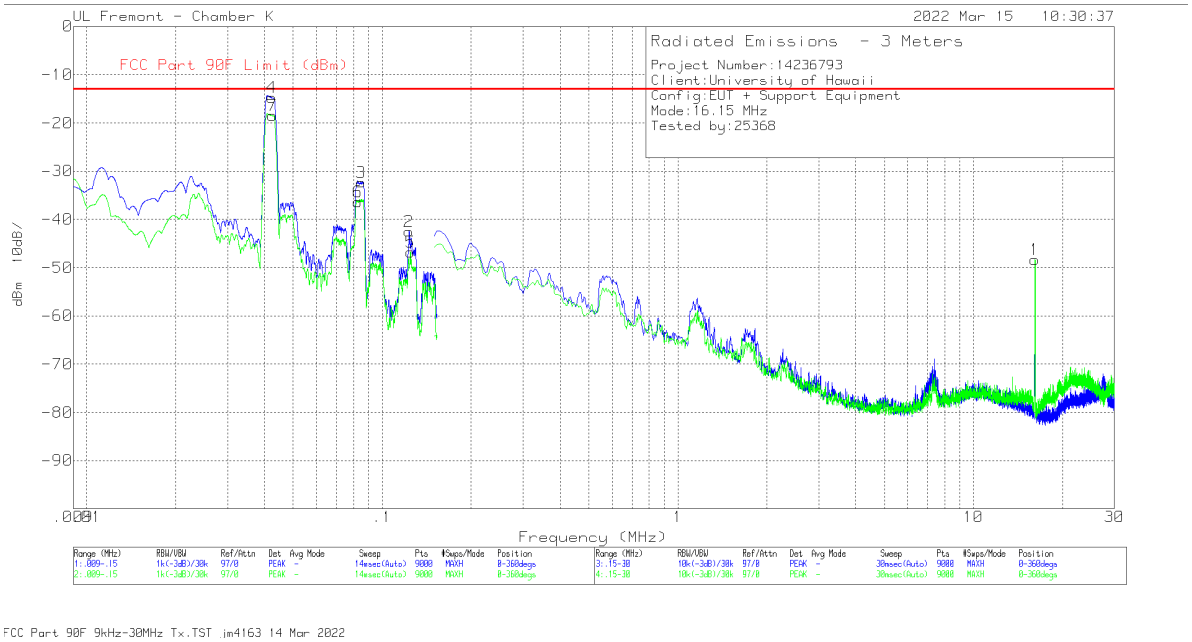
| Frequency (MHz) | Meter Reading (dBm) | Det | 82258 ACF (dB) | Amp/Cbl (dB) | Sub Factor (dB) | Corrected Reading (dBm) | PEAK LIMIT (dBm) | Margin (dB) | Azimuth (Degs) | Height (cm) | Polarity |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 634.256 | -67.26 | Pk | 26 | -28.6 | 12 | -57.86 | -13 | -44.86 | 3 | 153 | H |
| 431.863 | -66.46 | Pk | 22.7 | -29.3 | 11 | -62.06 | -13 | -49.06 | 161 | 158 | H |
| 229.034 | -63.28 | Pk | 17.6 | -30.1 | 12.5 | -63.28 | -13 | -50.28 | 311 | 154 | H |
| 603.982 | -60.39 | Pk | 25.2 | -28.8 | 7.3 | -56.69 | -13 | -43.69 | 70 | 165 | V |
| 67.5132 | -53.88 | Pk | 14.1 | -31.1 | 10.4 | -60.48 | -13 | -47.48 | 9 | 115 | V |
| 40.4901 | -59.75 | Pk | 19.7 | -31.4 | 6.2 | -65.25 | -13 | -52.25 | 62 | 100 | V |

Pk - Peak detector



UL VERIFICATION SERVICES INC
47173 BENICIA STREET, FREMONT, CA 94538, USA TEL: (510) 319-4000 FAX: (510) 661-0888

## 16.10 to 16.20 MHz Mode, 9 kHz to 30 MHz




FCC Part 90F 9kHz-30MHz Tx.TST jm4163 14 Mar 2022

### Trace Markers - Prescan

| Marker | Frequency (MHz) | Meter Reading (dBuV) | Det | Loop Antenna (E ACF) | Amp/Cbl (dB) | Unit Conversion | Corrected Reading dBm | FCC Part 90F Limit (dBm) | Margin (dB) | Azimuth (Degs) | Antenna Face |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 2 | .1233 | 29.14 | Pk | 55.8 | -32.2 | -95.2 | -42.46 | -13 | -29.46 | 0-360 | On |
| 3 | .085 | 39.41 | Pk | 55.7 | -32.2 | -95.2 | -32.29 | -13 | -19.29 | 0-360 | On |
| 4 | .0424 | 55.4 | Pk | 57.2 | -32.1 | -95.2 | -14.7 | -13 | -1.7 | 0-360 | On |
| 5 | .1246 | 24.85 | Pk | 55.8 | -32.2 | -95.2 | -46.75 | -13 | -33.75 | 0-360 | Off |
| 6 | .0827 | 35.37 | Pk | 55.7 | -32.2 | -95.2 | -36.33 | -13 | -23.33 | 0-360 | Off |
| 7 | .0425 | 51.65 | Pk | 57.2 | -32.1 | -95.2 | -18.45 | -13 | -5.45 | 0-360 | Off |
| 1 | 16.1379 | 44.73 | Pk | 33.9 | -31.7 | -95.2 | -48.27 | -13 | -35.27 | 0-360 | |

Pk - Peak detector
Power levels of emissions were lower with antenna face-down, comparing to face-on and face-off, at pre-scan.

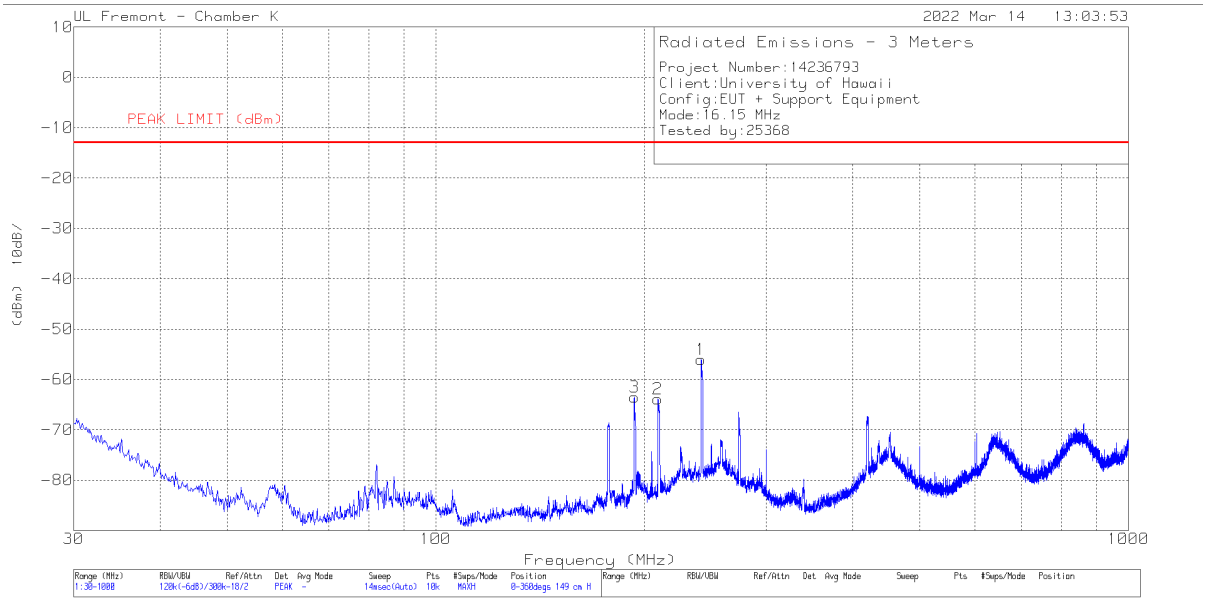
*Marker 1 is the fundamental signal.

### Radiated Emissions – Final Data

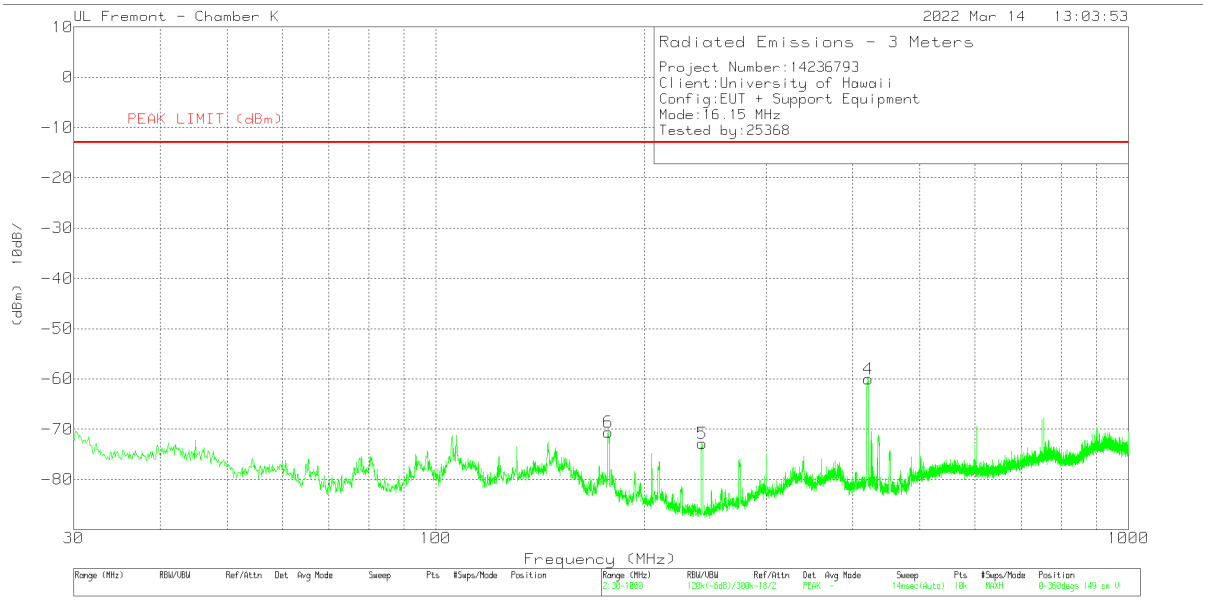
| Frequency (MHz) | Meter Reading (dBuV) | Det | Loop Antenna (E ACF) | Amp/Cbl (dB) | Unit Conversion | Corrected Reading dBm | FCC Part 90F Limit (dBm) | Margin (dB) | Azimuth (Degs) | Antenna Face |
|---|---|---|---|---|---|---|---|---|---|---|
| .0404 | 55.78 | Pk | 57.2 | -32.1 | -95.2 | -14.32 | -13 | -1.32 | 82 | On |
| .0848 | 39.64 | Pk | 55.7 | -32.2 | -95.2 | -32.06 | -13 | -19.06 | 91 | On |
| .1227 | 29.18 | Pk | 55.8 | -32.2 | -95.2 | -42.42 | -13 | -29.42 | 86 | On |
| .1229 | 25.25 | Pk | 55.8 | -32.2 | -95.2 | -46.35 | -13 | -33.35 | 144 | Off |
| .0816 | 35.96 | Pk | 55.7 | -32.2 | -95.2 | -35.74 | -13 | -22.74 | 163 | Off |
| .0407 | 52.22 | Pk | 57.2 | -32.1 | -95.2 | -17.88 | -13 | -4.88 | 171 | Off |

Pk - Peak detector

## 16.10 to 16.20 MHz Mode, 30 to 1000 MHz




FCC Part 90F 30-1000 MHz Tx.TST 02970 22 Aug 2019




FCC Part 90F 30-1000 MHz Tx.TST 02970 22 Aug 2019

## Trace Markers – Prescan

| Marker | Frequency (MHz) | Meter Reading (dBm) | Det | 82258 ACF (dB) | Amp/Cbl (dB) | Sub Factor (dB) | Corrected Reading (dBm) | PEAK LIMIT (dBm) | Margin (dB) | Azimuth (Degs) | Height (cm) | Polarity |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 241.654 | -58.2 | Pk | 18 | -30.1 | 14.3 | -56 | -13 | -43 | 0-360 | 149 | H |
| 2 | 209.353 | -58.92 | Pk | 17.1 | -30.2 | 8.1 | -63.92 | -13 | -50.92 | 0-360 | 149 | H |
| 3 | 193.542 | -59.22 | Pk | 18.1 | -30.3 | 7.9 | -63.52 | -13 | -50.52 | 0-360 | 149 | H |
| 4 | 420.813 | -60.36 | Pk | 22.7 | -29.4 | 7.1 | -59.96 | -13 | -46.96 | 0-360 | 149 | V |
| 5 | 242.721 | -67.95 | Pk | 18 | -30 | 7.1 | -72.85 | -13 | -59.85 | 0-360 | 149 | V |
| 6 | 177.246 | -67.32 | Pk | 17.6 | -30.4 | 9.5 | -70.62 | -13 | -57.62 | 0-360 | 149 | V |

Pk - Peak detector

## Radiated Emissions – Final Data

| Frequency (MHz) | Meter Reading (dBm) | Det | 82258 ACF (dB) | Amp/Cbl (dB) | Sub Factor (dB) | Corrected Reading (dBm) | PEAK LIMIT (dBm) | Margin (dB) | Azimuth (Degs) | Height (cm) | Polarity |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 242.155 | -61.44 | Pk | 18 | -30.1 | 14.3 | -59.24 | -13 | -46.24 | 302 | 128 | H |
| 210.447 | -63.48 | Pk | 17.1 | -30.2 | 8.3 | -68.28 | -13 | -55.28 | 34 | 165 | H |
| 194.04 | -67.26 | Pk | 18.2 | -30.3 | 7.9 | -71.46 | -13 | -58.46 | 22 | 174 | H |
| 421.097 | -58.87 | Pk | 22.7 | -29.3 | 7.1 | -58.37 | -13 | -45.37 | 302 | 117 | V |
| 242.491 | -66.6 | Pk | 18 | -30 | 7.1 | -71.5 | -13 | -58.5 | 80 | 200 | V |
| 177.177 | -64.44 | Pk | 17.6 | -30.4 | 9.5 | -67.74 | -13 | -54.74 | 130 | 109 | V |

Pk - Peak detector

# CERTIFICATION TEST REPORT

**Report Number :** 14236793-E3V3

**Applicant :** UNIVERSITY OF HAWAII
1000 POPE ROAD, MSB 402,
HONOLULU, HI 96822, U.S.A.

**Model :** MK3-PW-PA-TX

**FCC ID :** 2A562-MK3-PW-PA-TX

**EUT Description :** OCEANOGRAPHIC HIGH FREQUENCY DOPPLER RADAR

**Test Standard :** FCC CFR 47 PART 90 SUBPART F

**Date Of Issue:**
April 19, 2022

**Prepared by:**
UL Verification Services Inc.
47173 Benicia Street
Fremont, CA 94538, U.S.A.
TEL: (510) 319-4000
FAX: (510) 661-0888

ACCREDITED
CERT #0751.05

Revision History

| Rev. | Issue Date | Revisions | Revised By |
|---|---|---|---|
| V1 | 04/11/22 | Initial Issue | GP Chin |
| V2 | 04/14/22 | Updated Description of EUT in Section 5.1<br>Updated Power Summary Table in Section 5.3<br>Added Notes on Pg. 32 and Pg. 35<br>Updated Limit Table in Section 8.4 | GP Chin |
| V3 | 04/19/22 | Added Note on Pg. 17 in Section 8.3. | GP Chin |



UL VERIFICATION SERVICES INC
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UL VERIFICATION SERVICES INC
47173 BENICIA STREET, FREMONT, CA 94538, USA TEL: (510) 319-4000 FAX: (510) 661-0888

# 1. ATTESTATION OF TEST RESULTS

**COMPANY NAME:** UNIVERSITY OF HAWAII
1000 POPE ROAD, MSB 402,
HONOLULU, HI 96822, U.S.A.

**EUT DESCRIPTION:** OCEANOGRAPHIC HIGH FREQUENCY DOPPLER RADAR

**MODEL:** MK3-PW-PA-TX

**SERIAL NUMBER:** 3-003

**DATE TESTED:** MARCH 8TH - 15TH, 2022

| APPLICABLE STANDARDS | |
|---|---|
| **STANDARD** | **TEST RESULTS** |
| FCC PART 90.103F | Complies |

UL Verification Services Inc. tested the above equipment in accordance with the requirements set forth in the above standards. The test results show that the equipment tested is capable of demonstrating compliance with the requirements as documented in this report.

The results documented in this report apply only to the tested sample, under the conditions and modes of operation as described herein. It is the manufacturer's responsibility to assure that additional production units of this model are manufactured with identical electrical and mechanical components. All samples tested were in good operating condition throughout the entire test program. Measurement Uncertainties are published for informational purposes only and were not taken into account unless noted otherwise.

This document may not be altered or revised in any way unless done so by UL Verification Services Inc. and all revisions are duly noted in the revisions section. Any alteration of this document not carried out by UL Verification Services Inc. will constitute fraud and shall nullify the document. This report must not be used by the client to claim product certification, approval, or endorsement by A2LA, NIST, or any agency of the Federal Government.

Approved & Released For
UL Verification Services Inc. By:

GIA-PIAO (GP) CHIN
OPERATIONS LEADER
UL Verification Services Inc.

Tested By:

PAUL BASTAKI
LABORATORY ENGINEER
UL Verification Services Inc.

# 2. TEST METHODOLOGY

The tests documented in this report were performed in accordance with the following standards:

- FCC CRF 47 Part 2
- FCC CRF Part 90 Subparts F & I
- ANSI C63.26-2015
- Recommendation ITU-R SM.329-10

# 3. FACILITIES AND ACCREDITATION

UL Verification Services Inc. is accredited by A2LA, certification #0751.05, for all testing performed within the scope of this report. Testing was performed at the locations noted below.

| | Address | ISED CABID | ISED Company No. | FCC Registration |
|---|---|---|---|---|
| ☒ | Building 1: 47173 Benicia Street, Fremont, California, USA | US0104 | 2324A | 208313 |
| ☐ | Building 2: 47266 Benicia Street, Fremont, California, USA | US0104 | 22541 | 208313 |
| ☒ | Building 4: 47658 Kato Rd, Fremont, California, USA | US0104 | 2324B | 208313 |



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# 4. CALIBRATION AND UNCERTAINTY

## 4.1. METROLOGICAL TRACEABILITY

All test and measuring equipment utilized to perform the tests documented in this report are calibrated on a regular basis, with a maximum time between calibrations of one year or the manufacturers' recommendation, whichever is less, and where applicable is traceable to recognized national standards.

## 4.2. DECISION RULES

The Decision Rule is based on Simple Acceptance in accordance with ISO Guide 98-4:2012 Clause 8.2. (Measurement uncertainty is not taken into account when stating conformity with a specified requirement.)

## 4.3. MEASUREMENT UNCERTAINTY

Where relevant, the following measurement uncertainty levels have been estimated for tests performed on the apparatus:

| PARAMETER | $U_{LAB}$ |
|---|---|
| Worst Case Conducted Antenna Port Emission Measurement – Direct Method | 1.94 dB |
| Worst Case Radiated Disturbance, 9 kHz to 30 MHz | 2.87 dB |
| Worst Case Radiated Disturbance, 30 to 1000 MHz | 6.01 dB |
| Occupied Channel Bandwidth | ±2.75 % |
| Temperature | ±2.26 °C |
| Voltages | ±0.57 % |
| Time | ±3.39 % |

Uncertainty figures are valid to a confidence level of 95%.



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# 5. EQUIPMENT UNDER TEST

## 5.1. DESCRIPTION OF EUT

The MK3-PW-PA-TX is an Oceanographic High Frequency Doppler radar consists of two units or subsystems: the synthesizer/transmitter (TX) unit, and an optional receiver/digitizer (RX) unit. It is designed with bare minimum features to ensure low production cost, low power requirement, and easy maintenance.

The operation of the MK3-PW-PA-TX consists of transmitting frequency-modulated continuous radio waves that are channeled along the surface of the conducting ocean as ground waves, in the wavelength range of 10 to 100 m (frequency 3 to 30 MHz). These radio waves are coherently back-scattered by the ocean's surface gravity waves at half the radio wavelength (5 to 50 m), and captured by an array of receive antennas.

For "Region 2", the International Telecommunication Union has recommended, and the Federal Communication Commission has selected dedicated secondary frequency bands for operating Oceanographic High Frequency Doppler radars, as follows:

| Frequency Band | Occupied Bandwidth |
|---|---|
| (MHz) | (kHz) |
| 4.438 – 4.488 | 50 |
| 5.250 – 5.275 | 25 |
| 13.450 – 13.550 | 100 |
| 16.100 – 16.200 | 100 |
| 24.450 – 24.650 | 200 |
| 26.200 – 26.420 | 220 |

The digital synthesizer is programmed to emit a repetition of ramps (chirp) with 100% duty cycle at a radar mode rate of 1 Hz to 5 Hz or a call-sign mode rate of 1 kHz, and a bandwidth of 25 to 220 kHz determined by the frequency allocation, resulting in a frequency-modulated continuous wave (FMCW mode, emission designation F1N).

This test report covers the device operating at 24.45 - 24.65 MHz and 26.20 - 26.42 MHz frequency bands, with the slow radar mode rate of 1 Hz – 5 Hz to represent the worst case mode.

## 5.2. DESCRIPTION OF AVAILABLE ANTENNAS

The radar system utilizes external transmitting antenna which come in the form of normal-mode helical monopole antenna over finite ground plane with a typical gain of 2 dBi. The transmitting antenna is connected to the output port of synthesizer/transmitter via a cable with an attenuation of at least 5 dB, depending on the operating frequency. All antenna port measurements were made at the end of the minimum cable length to determine the power of fundamental and spurious emissions at the antenna input.

## 5.3. MAXIMUM OUTPUT POWER

The highest peak output power under normal environmental conditions (+20°C and 120 VAC) in each mode is as followed:

| Mode | Peak Cond. Pwr (dBm) | Peak Power (dBm EIRP) | Peak Power (W) |
|---|---|---|---|
| 24.45 to 24.65 MHz | 45.08 | 42.08 | 16.14 |
| 26.20 to 26.42 MHz | 44.93 | 41.93 | 15.60 |

## 5.4. SOFTWARE AND FIRMWARE

The test utility software used during testing was Canonical Inc., Ubuntu 20.04.3.

The FPGA Controller Firmware used during testing was D-Tacq Solutions Inc., ACQ1001-RADCELF, Release #394.



UL VERIFICATION SERVICES INC
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# 6. DESCRIPTION OF TEST SETUP

## SUPPORT EQUIPMENT

| PERIPHERAL SUPPORT EQUIPMENT LIST | | | |
|---|---|---|---|
| **Description** | **Manufacturer** | **Model** | **Serial Number** |
| Laptop | Lenovo, Inc | Yoga14-20FY2US | R9-0KXNVG |
| Laptop Power supply | Lenovo, Inc | ADLX45NCC2A | -- |

## I/O CABLES

| I/O Cable List | | | | | | |
|---|---|---|---|---|---|---|
| **Cable No.** | **Port** | **# of identical ports** | **Connector Type** | **Cable Type** | **Cable Length (m)** | **Remarks** |
| 1 | AC | 1 | 3-prong | Unshielded | 2 | -- |
| 2 | Ant | 1 | N-Type | Shielded | 2 | -- |
| 3 | DC | 1 | Mag set | Shielded | 1 | -- |
| 4 | AC | 1 | 3-prong | Shielded | 1.8 | -- |
| 5 | Ethernet | 1 | Cat-6 | Shielded | 2.15 | -- |

## TEST SETUP

The EUT is connected to a laptop computer. Software within the computer is used to configure and exercise the EUT.

All measurements of Duty Cycle, Occupied Bandwidth, Peak Output Power, $T_X$ Conducted Spurious Emissions and Band-edge were performed at 20°C and 120 VAC nominal, utilizing the conducted test setup with spectrum analyzer.

The total Correction Factor of attenuators and cables was applied as "Offset" to the taken plots of Measured Peak on this report, therefore,

$$Peak\ EIRP\ (dBm) = Measured\ Peak\ (dBm) + Cable\ Loss\ (dB) + EUT\ Ant.Gain\ (dBi)$$



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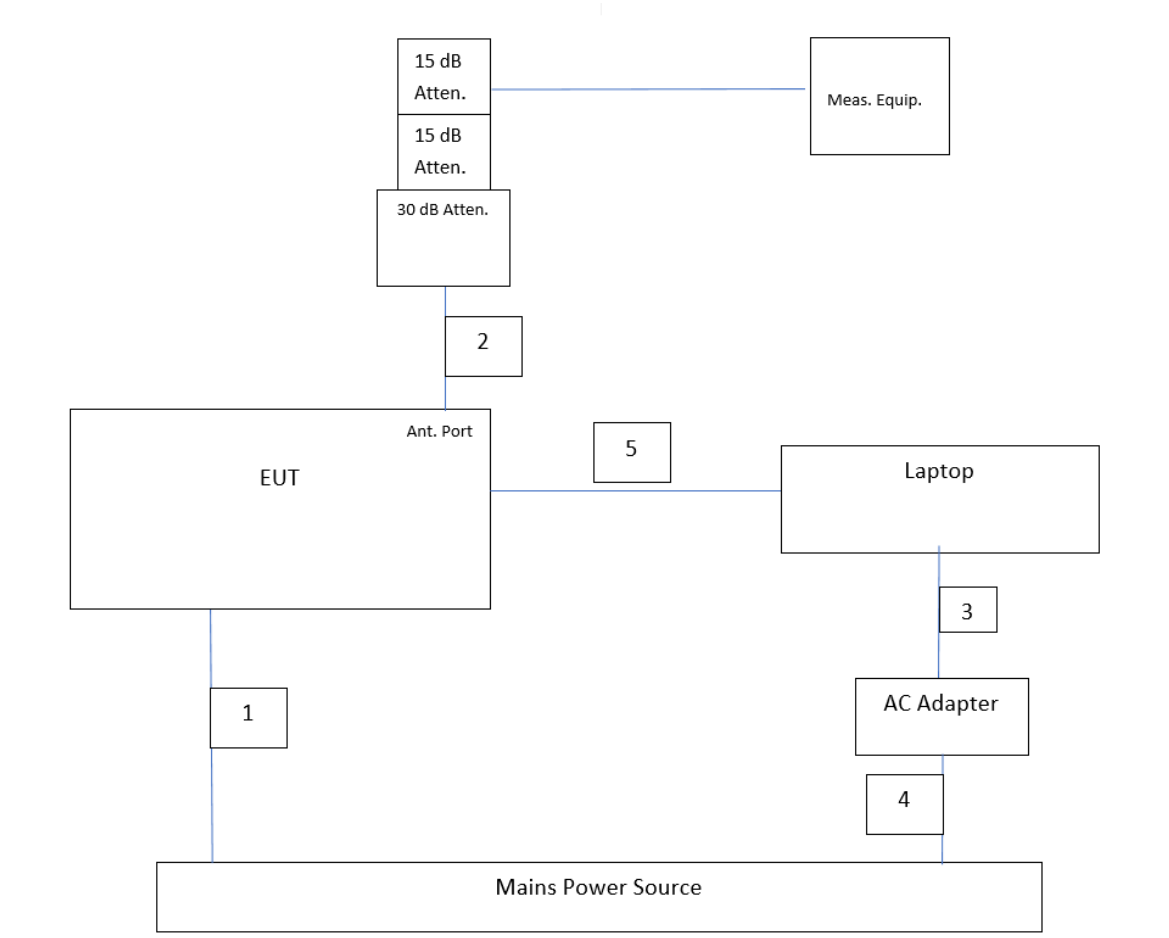
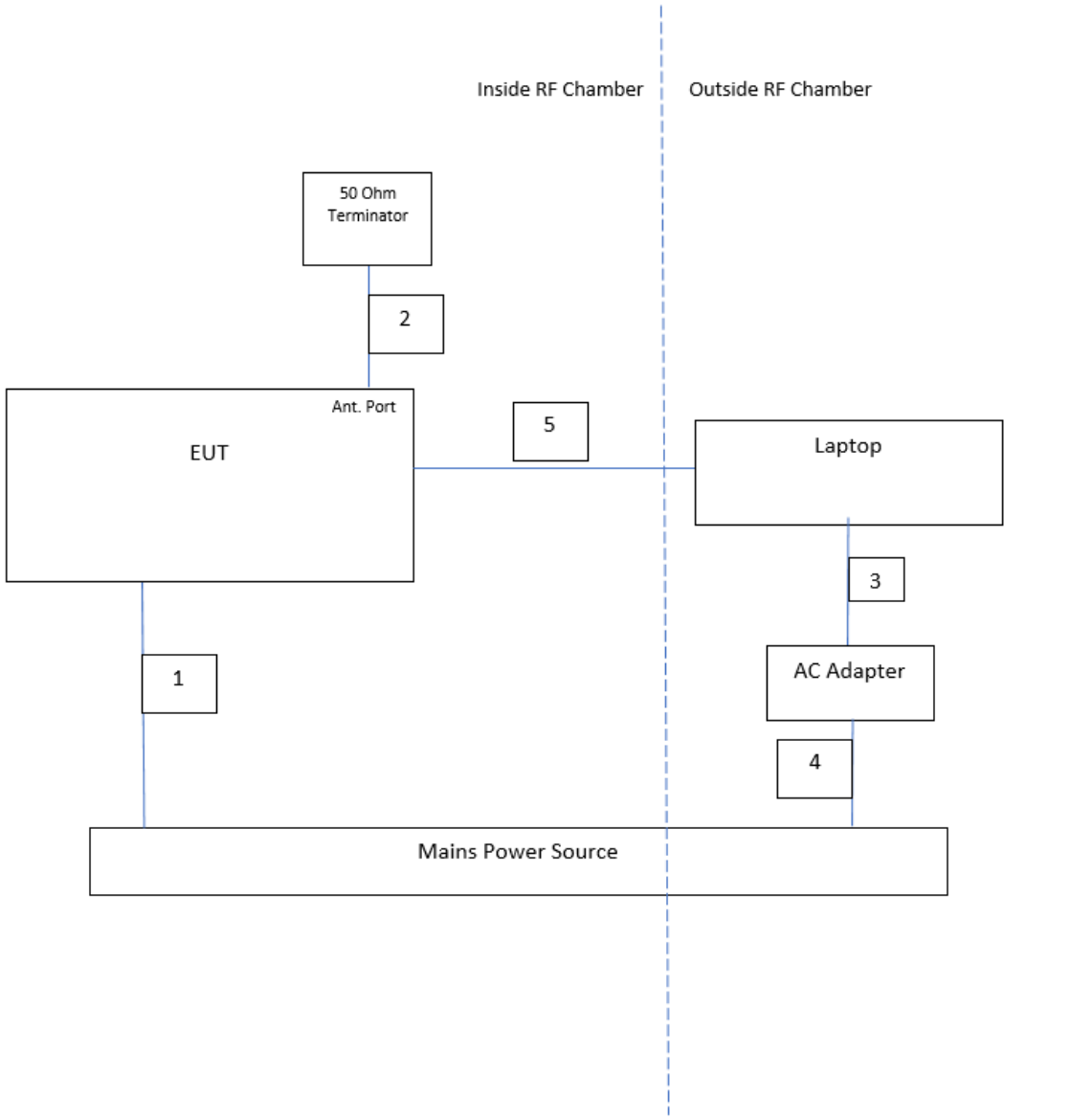
## SETUP DIAGRAMS FOR TESTS

### TX CONDUCTED RF TESTS



## TX RADIATED RF TESTS



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# 7. TEST AND MEASUREMENT EQUIPMENT

The following test and measurement equipment was utilized for the tests documented in this report:

| Test Equipment List | | | | | |
|---|---|---|---|---|---|
| **Description** | **Manufacturer** | **Model** | **Local ID** | **Last Cal** | **Cal Due** |
| Spectrum Analyzer, 50 GHz | Rohde & Schwarz | FSW50 | 198710 | 2/22/2022 | 2/22/2023 |
| Variable AC Transformer | Superior Electric | 3PN136B | 44407 | CNR | CNR |
| Power Analyzer | Yokogawa Electric | WT310E | 155294 | 04/16/2021 | 04/16/2022 |
| 15 dB Attenuator, 1 W | JFW Indust. Inc. | 50F-0150-N | -- | CNR | CNR |
| 30 dB Attenuator, 100 W | Bird Inc. | 100-SA-FFN-30 | -- | CNR | CNR |
| 50 Ohm Terminator | RF-Lambda | RFST200G02NM | T1355 | CNR | CNR |
| EMI Test Receiver, 44 GHz | Rohde & Schwartz | ESW44 | PRE0179367 | 2/16/2022 | 2/16/2023 |
| Antenna, Broadband Hybrid, 30 MHz to 2000 MHz | Sunol Sciences Corp. | JB1 | T1199 | 10/01/21 | 10/01/2022 |
| Amplifier, 9 kHz – 1 GHz, 32 dB | Sonoma Instrument | 310 | 175953 | 02/08/2022 | 02/08/2023 |
| Antenna, Passive Loop 30Hz – 1 MHz | Electro-Metrics | EM-6871 | 170014 | 06/08/2021 | 06/08/2022 |
| Antenna, Passive Loop 100 kHz – 30 MHz | Electro-Metrics | EM-6872 | 170016 | 06/08/2021 | 06/08/2022 |
| Temperature Chamber | Espec | EWPX 674(2)-(2)12NAL | 135568 | 4/19/19 | 4/30/22 |
| UL EMC Radiated Software | Version: | Rev 9.5.21 Jan 2021 | | | |

# 8. APPLICABLE LIMITS AND TEST RESULTS

## 8.1. DUTY CYCLE

**LIMIT**

For reporting purposes only.

**TEST PROCEDURE**

All measurements were performed with the CW signals of $F_c$ = 24.55 MHz and $F_c$ = 26.31 MHz, representing the 24.45 – 24.65 MHz and 26.20 – 26.42 MHz modes, respectively.

The duty cycle factor is calculated as:

$$Duty\ Cycle\ Factor\ (dB)\ =\ 10 \times Log\ (1/x),$$
$$where\ x\ =\ Duty\ Cycle\ (linear)$$

**RESULTS**

Employee ID: 25368
Location: mmWave Chamber 1
Test Date: 3/9/22

| Band | Fc (MHz) | (msec) | (msec) | (linear) | (%) |
|---|---|---|---|---|---|
| 24.45 - 24.65 MHz | 24.55 | 2000 | 2000 | 1.000 | 100.00 |
| 26.20 - 26.42 MHz | 26.31 | 2000 | 2000 | 1.000 | 100.00 |



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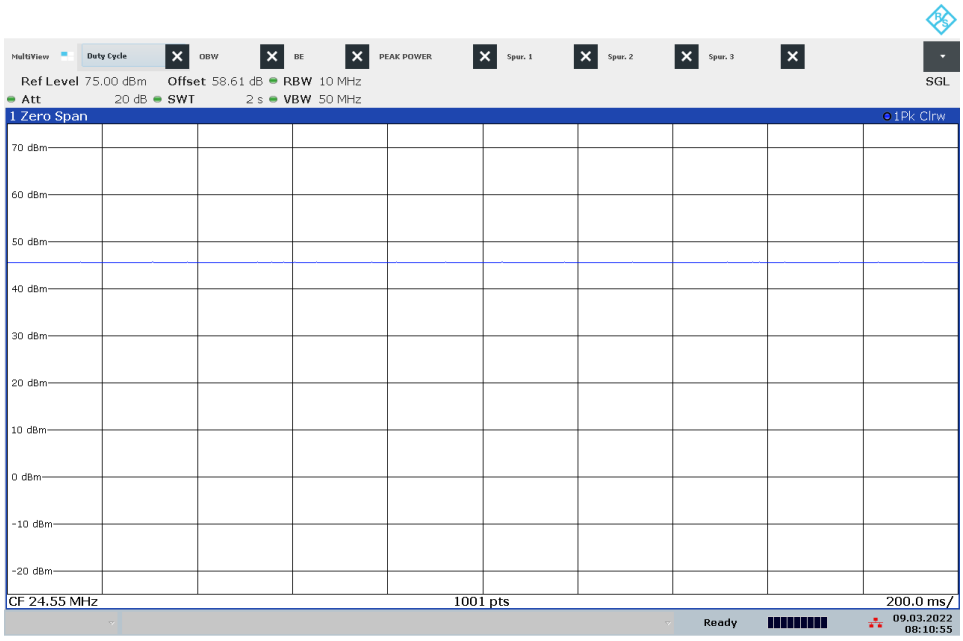
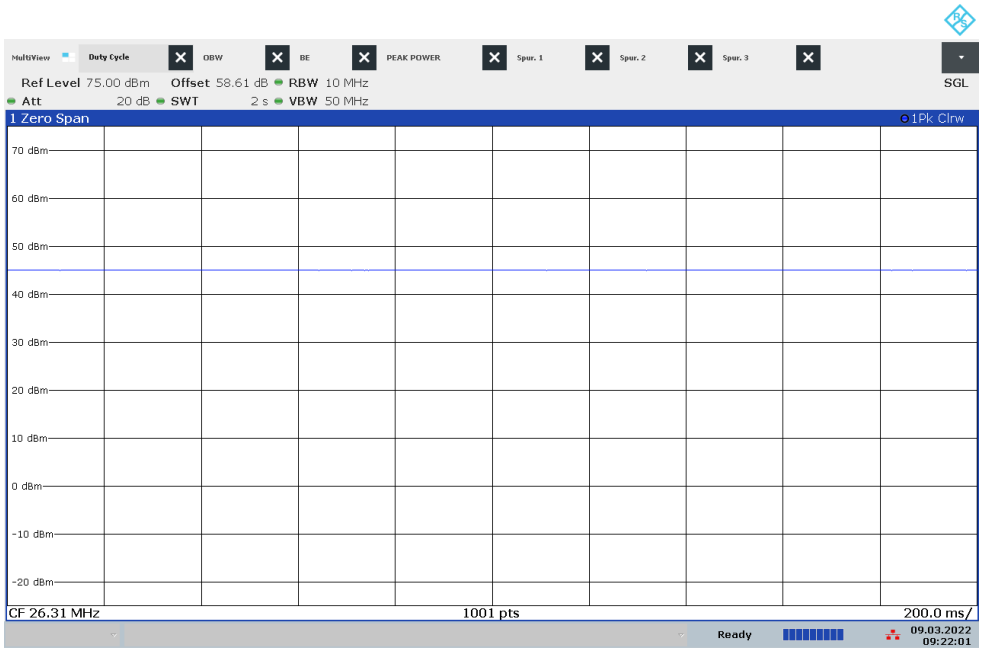
## 24.55 MHz CW Mode




## 26.31 MHz CW Mode



## 8.2. OCCUPIED BANDWIDTH

**RULE PART**

§2.1049

**LIMIT**

99% Bandwidth measured shall fall within the frequency band listed in FCC Part 90.103 (F).

Applicable limits for bands tested in this report is as follows:

| Frequency Band |
|---|
| 24.45 to 24.65 MHz |
| 26.20 to 26.42 MHz |

**TEST PROCEDURE**

ANSI C63.26-2015 Clause 5.4.4

99% bandwidth measurement function of the spectrum analyzer was used to measure 99% occupied bandwidth.

**RESULTS**

Employee ID: 25368
Location: mmWave Chamber 1
Test Date: 3/8/22 - 3/9/22

| Mode | Meas. 99% BW (kHz) | Meas. FL (MHz) | Limit (MHz) | Pass/Fail | Meas. FH (MHz) | Limit (MHz) | Pass/Fail |
|---|---|---|---|---|---|---|---|
| 26.45 to 24.65 MHz | 191.913 | 24.454 | 24.45 | Pass | 24.646 | 24.65 | Pass |
| 26.20 to 26.42 MHz | 210.935 | 26.204 | 26.2 | Pass | 26.415 | 26.42 | Pass |



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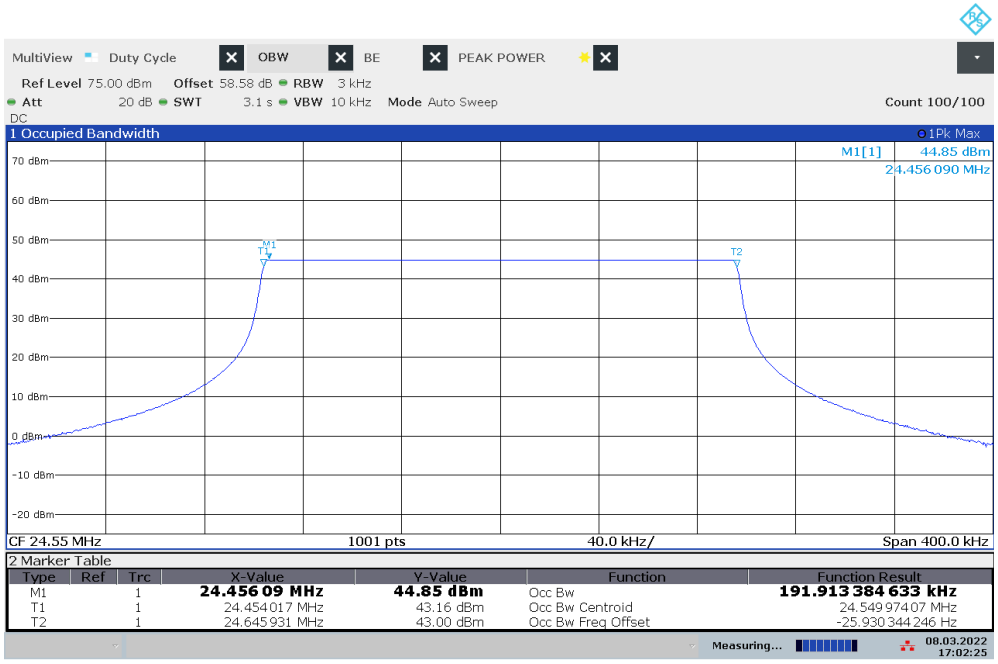
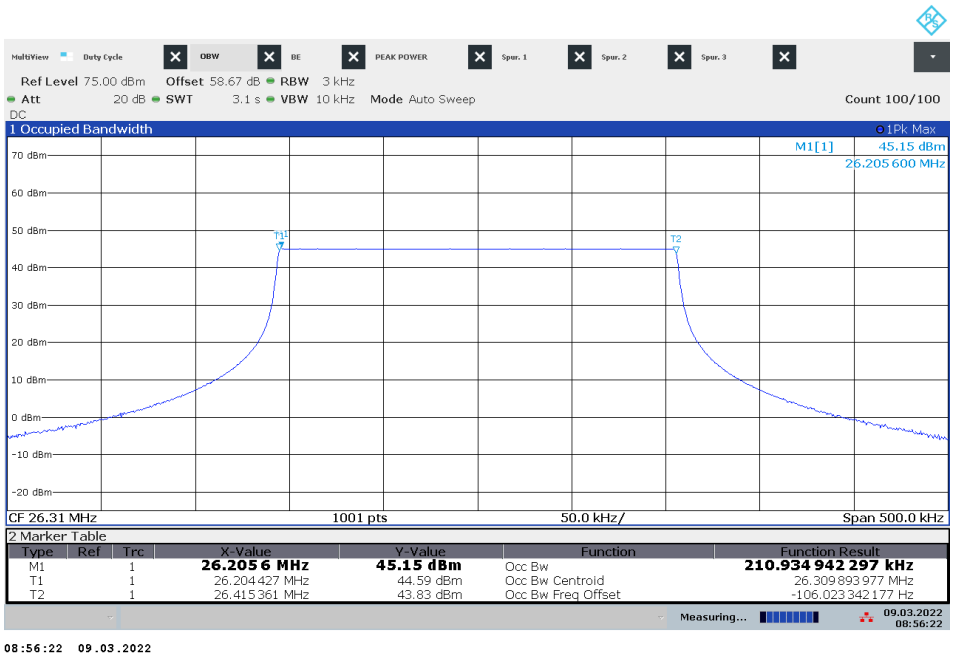
## 24.45 – 24.65 MHz Mode




## 26.20 – 26.42 MHz Mode



## 8.3. PEAK OUTPUT POWER

**RULE PARTS**

§2.1046 & §90.205 (r)

**LIMIT**

Per §90.103 (c)(3): Operations in this band are limited to oceanographic radars using transmitters with a peak equivalent isotropically radiated power (EIRP) not to exceed 25 dBW (316 W or +55 dBm). Oceanographic radars shall not cause harmful interference to, nor claim protection from interference caused by, stations in the fixed or mobile services as specified in §2.106, footnotes 5.132A, 5.145A, and US132A. See Resolution 612 of the ITU Radio Regulations for international coordination requirements and for recommended spectrum sharing techniques.

Per Resolution 612 (REV. WRC-12), (d)(2): The Peak E.I.R.P. of an oceanographic radar shall not exceed 25 dBW (316 W or +55 dBm).

**TEST PROCEDURE**

ANSI C63.26-2015 Clause 5.2.3.5

**RESULTS**

Employee ID: 25368
Location: mmWave Chamber 1
Test Date: 3/9/22

| Mode | Frequency (MHz) | Meas. Peak (dBm) | Cable Loss (dB) | EUT Ant. Gain (dBi) | Peak EIRP (dBm) | Peak EIRP (W) | Limit (W) | Pass or Fail |
|---|---|---|---|---|---|---|---|---|
| 24.45 to 24.65 MHz | 24.461 | 45.08 | 5 | 2 | 42.08 | 16.14 | 316 | Pass |
| 26.20 to 26.42 MHz | 26.228 | 44.93 | 5 | 2 | 41.93 | 15.60 | 316 | Pass |

Peak EIRP is based on the use of helical wound monopole antenna over finite ground plane, which has a maximum gain of 2 dBi, declared by manufacturer. The actual peak EIRP values are based on a minimum of 5 dB cable loss of RG213 or RG214 between the RF output and the antenna (power measurement was made at the end of the cable).

As the signal is a swept CW signal, the instantaneous emission bandwidth is much less than the 10 kHz used for the peak power measurement. The sweep rate is slow enough to not require any correction for desensitization, which is further supported by comparing the peak power levels are almost the same for the occupied bandwidth measurement made using a 1 kHz RBW and the power measurement.



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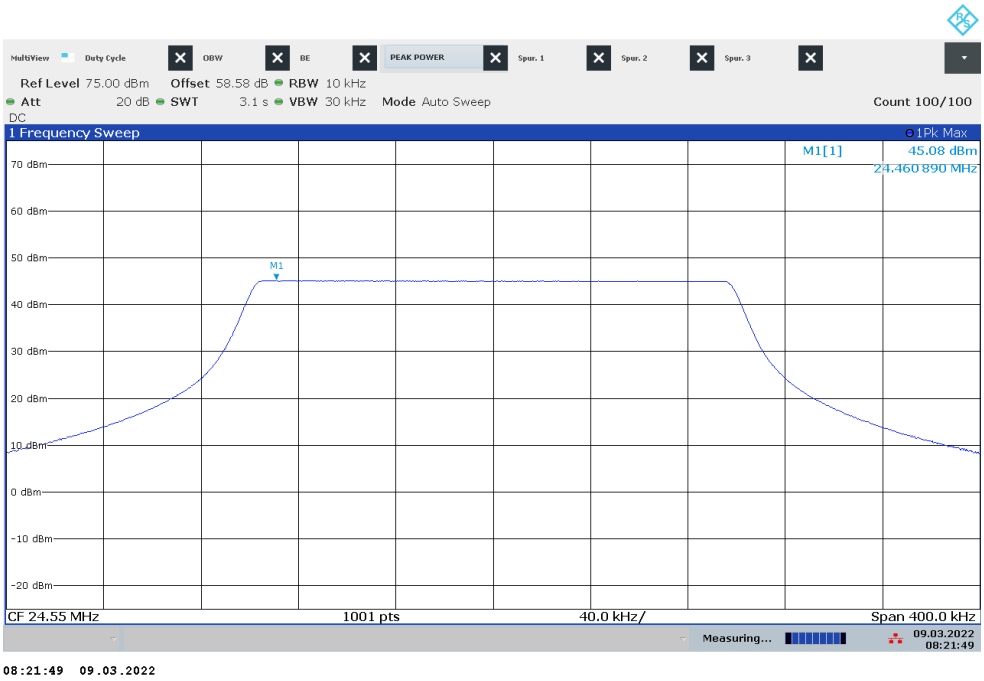
## 24.45 to 24.65 MHz Mode

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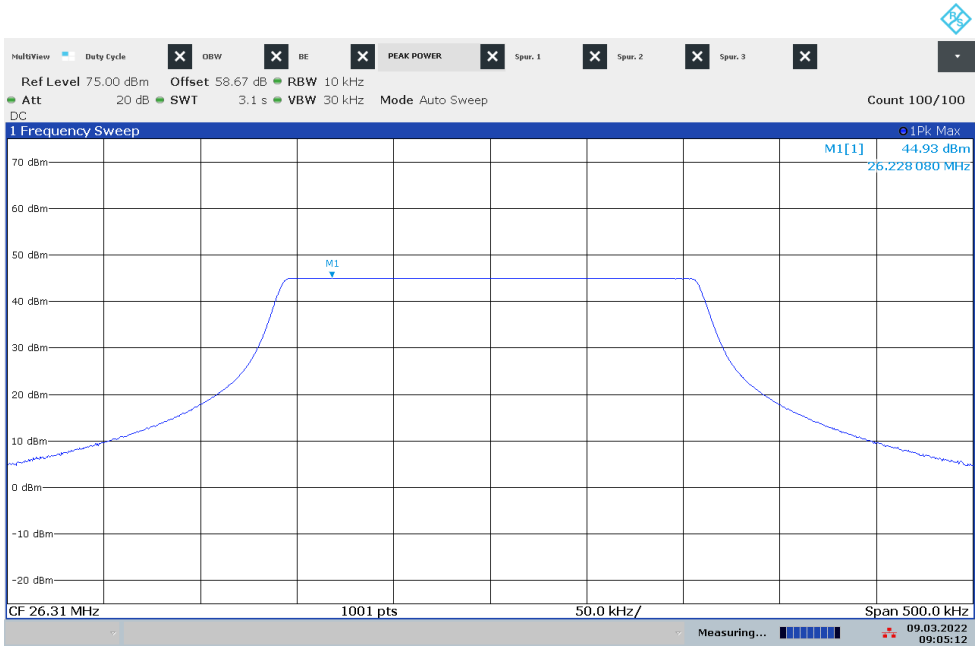
## 26.20 to 26.42 MHz Mode

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## 8.4. FREQUENCY STABILITY

**RULE PARTS**

§2.1055 (a)(1): From −30° to + 50° centigrade for all equipment except that specified in paragraphs (a) (2) and (3) of this section.

§2.1055 (d)(1): Vary primary supply voltage from 85 to 115 percent of the nominal value for other than hand carried battery equipment.

The EUT is operated near the coast and installed only in climate-controlled enclosure or building with the following conditions:

Temperature: -30°C to +50°C
Nominal Voltage: 120 VAC

**LIMIT**

§90.213 (a)

**TABLE 1 TO §90.213(a)—MINIMUM FREQUENCY STABILITY**

[Parts per million (ppm)]

| Frequency range (MHz) | Fixed and base stations | Mobile stations | |
|---|---|---|---|
| | | Over 2 watts output power | 2 watts or less output power |
| Below 25 | [1 2 3]100 | 100 | 200 |
| 25-50 | 20 | 20 | 50 |

Applicable Limit: 20 ppm

**TEST PROCEDURES**

ANSI C63.26-2015 Clause 5.6.5

All measurements were performed with the CW signals of $F_c$ = ~24.55 MHz and $F_c$ = ~26.31 MHz, representing the 24.45 – 24.65 MHz and 26.20 – 26.42 MHz modes, respectively.

**Test procedures for temperature variation:**

a. Position the EUT in temperature/humidity chamber.
b. Set chamber temperature to +20°C, stabilize the EUT for at least 45 minutes and record the $F_c$.
c. Adjust chamber temperature from -30°C to +50°C at 10°C interval. Record maximum change in $F_c$ at each temperature.
d. A period of at least 45 minutes is provided to allow stabilization of the equipment at each temperature level.

**Test procedures for voltage variation:**

a. Position the EUT in temperature/humidity chamber.
b. Set chamber temperature to +20°C.
c. The primary supply voltage is varied from 85% to 115% of the nominal value.

- Voltages:

Nominal: 120 VAC
85% of the Nominal: 102 VAC
115% of the Nominal: 138 VAC

**RESULTS**

Employee ID: 25368
Location: Environmental Chamber
Test Date: 3/10/22 - 3/11/22

| 24.45 to 24.65 MHz Mode | | | | |
|---|---|---|---|---|
| Temp (°C) | Input Power (AC) | CW (Fc) | | |
| | | Meas. Freq. (MHz) | Freq. Drift (ppm) | Pass/Fail |
| 50 | Nominal | 24.5500 | 0.0000 | Pass |
| 40 | Nominal | 24.5500 | 0.0000 | Pass |
| 30 | Nominal | 24.5500 | 0.0000 | Pass |
| 20 | Nominal | 24.5500 | -- | -- |
| 10 | Nominal | 24.5500 | 0.0000 | Pass |
| 0 | Nominal | 24.5500 | 0.0000 | Pass |
| -10 | Nominal | 24.5500 | 0.0000 | Pass |
| -20 | Nominal | 24.5500 | 0.0000 | Pass |
| -30 | Nominal | 24.5500 | 0.0000 | Pass |
| 20 | 85% | 24.5500 | 0.0000 | Pass |
| 20 | 115% | 24.5500 | 0.0000 | Pass |

| 26.20 to 26.42 MHz Mode | | | | |
|---|---|---|---|---|
| Temp (°C) | Input Power (AC) | CW (Fc) | | |
| | | Meas. Freq. (MHz) | Freq. Drift (ppm) | Pass/Fail |
| 50 | Nominal | 26.3100 | 0.0000 | Pass |
| 40 | Nominal | 26.3100 | 0.0000 | Pass |
| 30 | Nominal | 26.3100 | 0.0000 | Pass |
| 20 | Nominal | 26.3100 | -- | -- |
| 10 | Nominal | 26.3100 | 0.0000 | Pass |
| 0 | Nominal | 26.3100 | 0.0000 | Pass |
| -10 | Nominal | 26.3100 | 0.0000 | Pass |
| -20 | Nominal | 26.3100 | 0.0000 | Pass |
| -30 | Nominal | 26.3100 | 0.0000 | Pass |
| 20 | 85% | 26.3100 | 0.0000 | Pass |
| 20 | 115% | 26.3100 | 0.0000 | Pass |

# 8.5. TX CONDUCTED SPURIOUS EMISSIONS AND BAND EDGE

## RULE PARTS

§2.1057 (a) (1): In all the measurements set forth in §2.1051 and §2.1053, the spectrum shall be investigated from the lowest radio frequency signal generated in the equipment, without going below 9 kHz, up to at least the frequency shown below: If the equipment operates below 10 GHz: to the tenth harmonic of the highest fundamental frequency or to 40 GHz, whichever is lower.

10th harmonic of highest fundamental frequency $= 10 \times (26.42\ MHz) = 264.20\ MHz$
Thus, spurious emissions are investigated from 9 kHz thru 1 GHz.

## LIMIT

§ 90.210 (n): Other frequency bands. Transmitters designed for operation under this part on frequencies other than listed in this section must meet the emission mask requirements of Emission Mask B. Equipment operating under this part on frequencies allocated to but shared with the Federal Government, must meet the applicable Federal Government technical standards.

§ 90.210 (b): Emission Mask B. For transmitters that are equipped with an audio low-pass filter, the power of any emission must be attenuated below the unmodulated carrier power (P) as follows:

(1) On any frequency removed from the assigned frequency by more than 50 percent, but not more than 100 percent of the authorized bandwidth: At least 25 dB.
(2) On any frequency removed from the assigned frequency by more than 100 percent, but not more than 250 percent of the authorized bandwidth: At least 35 dB.
(3) On any frequency removed from the assigned frequency by more than 250 percent of the authorized bandwidth: At least $43 + 10\ log(P)\ dB$.

The more stringent Peak power limit on § 90.210 (b)(3), which is the same limit as Rec ITU-R SM.329-10 Standard, is applied for spurious emissions and band edge.

Determination of Limit:

Maximum Declared Peak Conducted Power of EUT,

$$P_{max} = 42\ dBm\ (16\ W)$$

$$\begin{aligned} Applicable\ Peak\ Limit &= 42 - \big(43 + 10log(16)\big) \\ &= 42 - 55 \\ &= -13\ dBm \end{aligned}$$

## TEST PROCEDURE

ANSI C63.26-2015 Clause 5.7

The widest emission bandwidth of EUT was used at 9 kHz – 1 GHz spurious emission tests.

For Bandedge, the measurements were measured by transmitting the CW signals of low-end ($F_L$) and the high-end ($F_H$) of each frequency band.

## RESULTS

Employee ID: 25368
Location: mmWave Chamber 1
Test Date: 3/9/22

| Mode | 9 - 150 kHz | 150 kHz - 30 MHz | 30 MHz - 1 GHz | Bandedge |
|---|---|---|---|---|
| 24.45 – 24.65 MHz | Pass | Pass | Pass | Pass |
| 26.20 – 26.42 MHz | Pass | Pass | Pass | Pass |

## 8.5.1. SPURIOUS EMISSIONS

### 24.45 to 24.65 MHz Mode, 9 - 150 kHz


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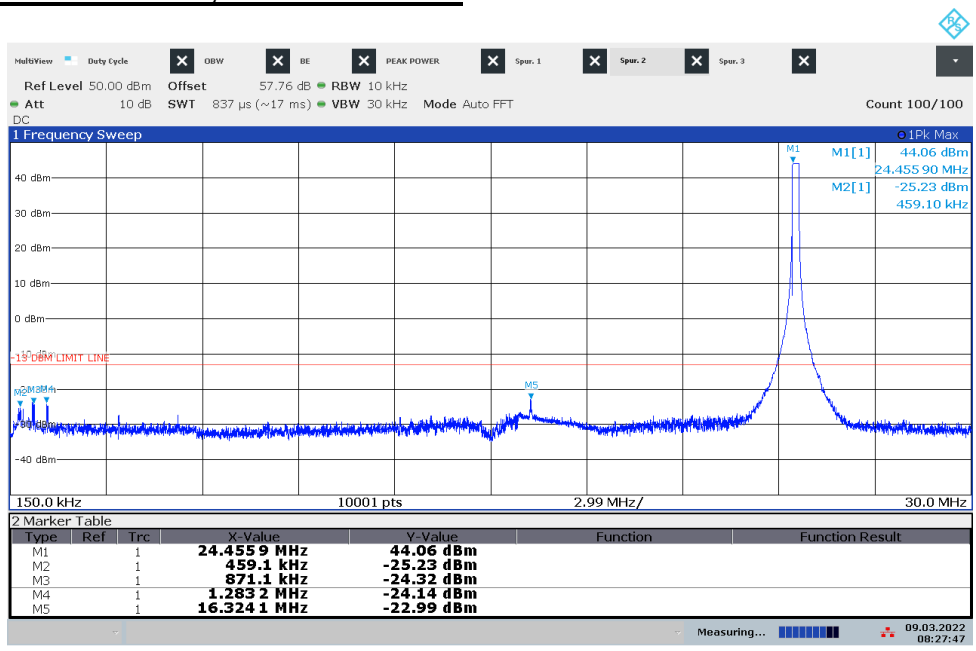
### 24.45 to 24.65 MHz Mode, 150 kHz - 30 MHz

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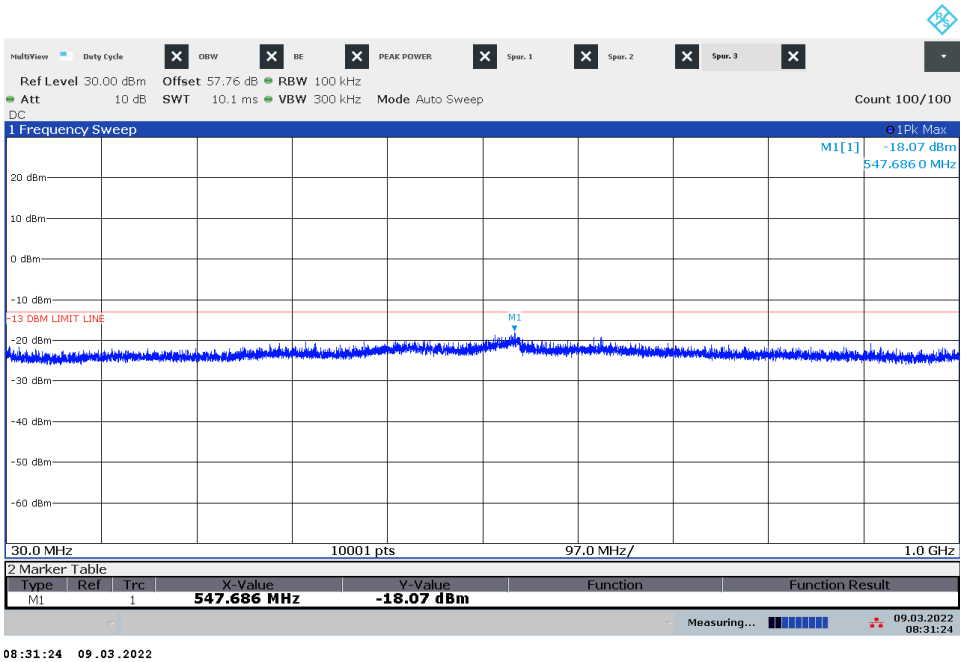
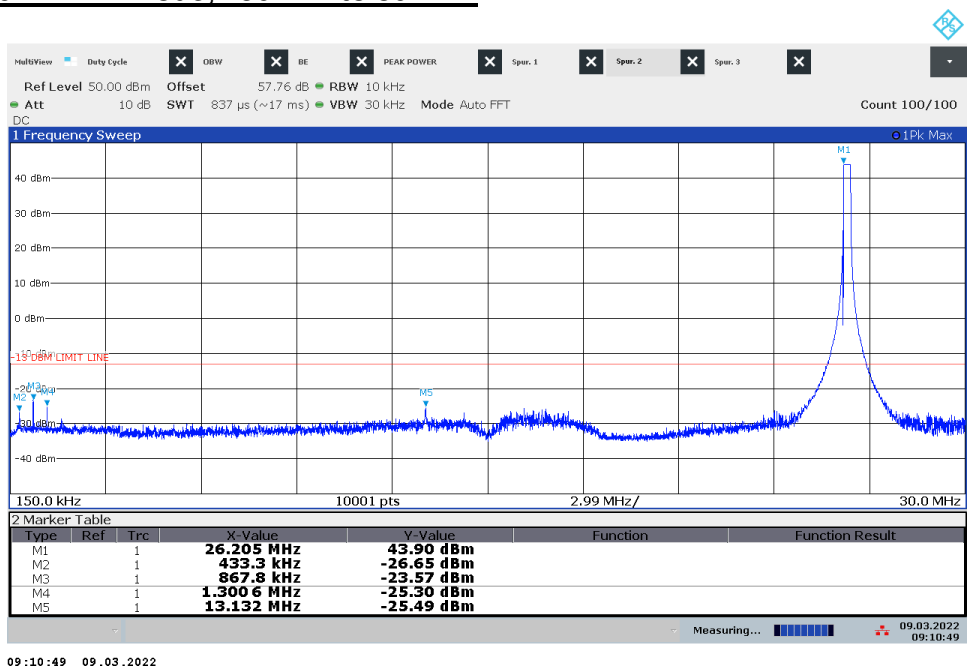
*Marker M1 is the fundamental signal.

## 24.45 to 24.65 MHz Mode, 30 MHz - 1 GHz



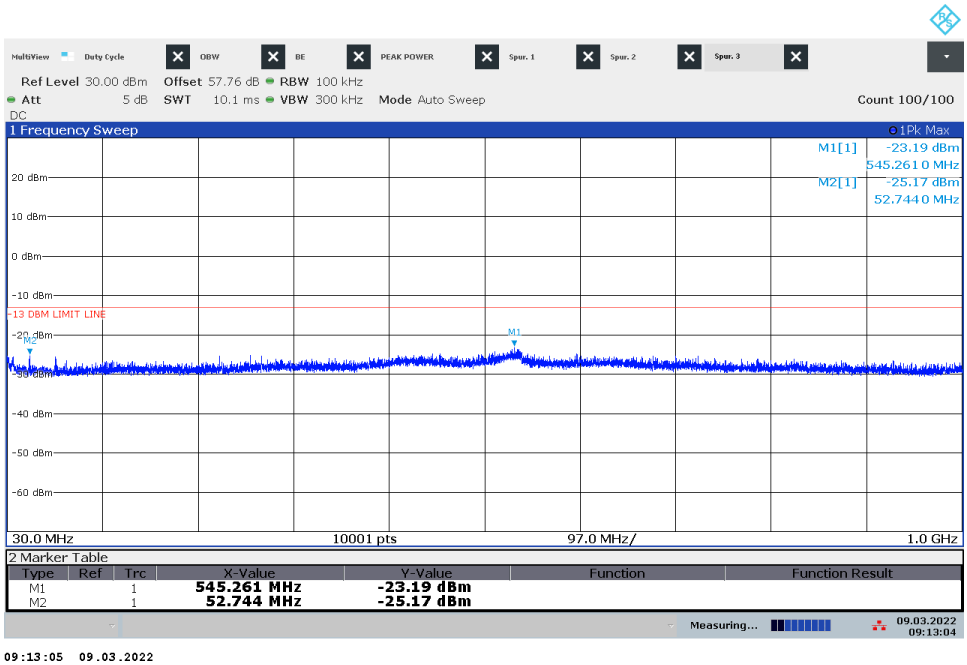
## 26.20 to 26.42 MHz Mode, 9 - 150 kHz


## 26.20 to 26.42 MHz Mode, 150 kHz to 30 MHz



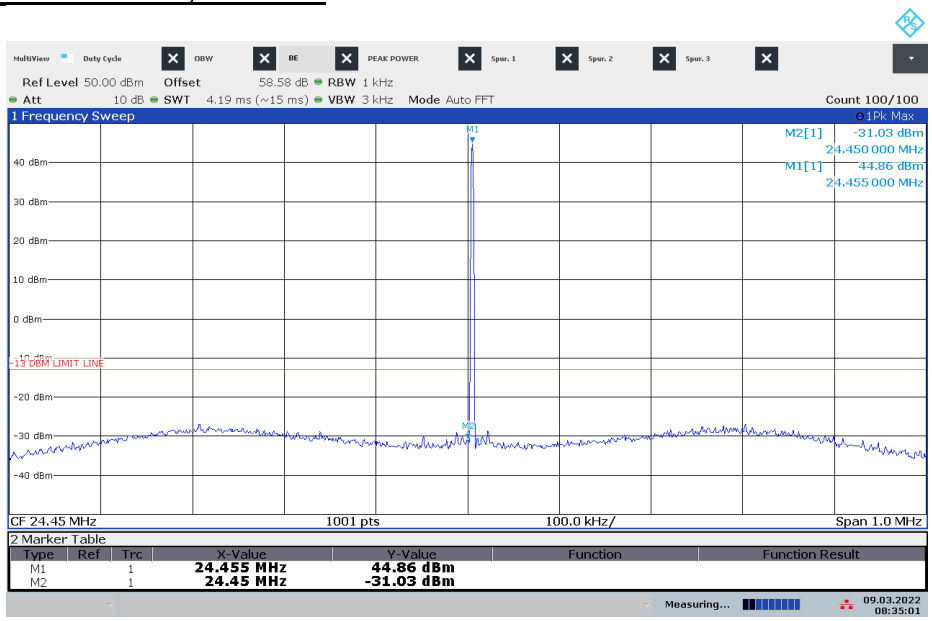

*Marker M1 is the fundamental signal.

## 26.20 to 26.42 MHz Mode, 30 MHz – 1 GHz



## 8.5.2. BAND EDGE

### 24.45 to 24.65 MHz Mode, Low End

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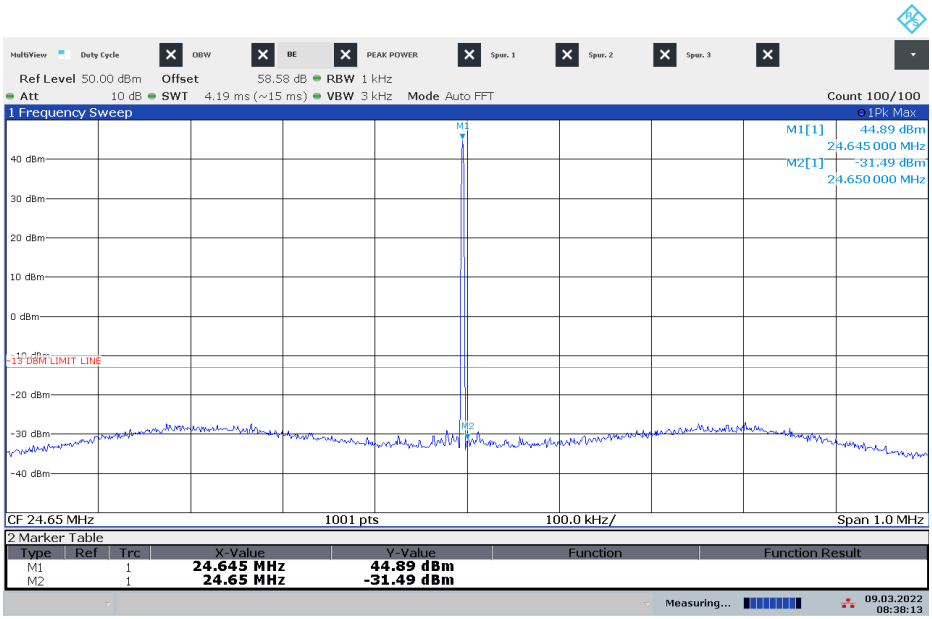
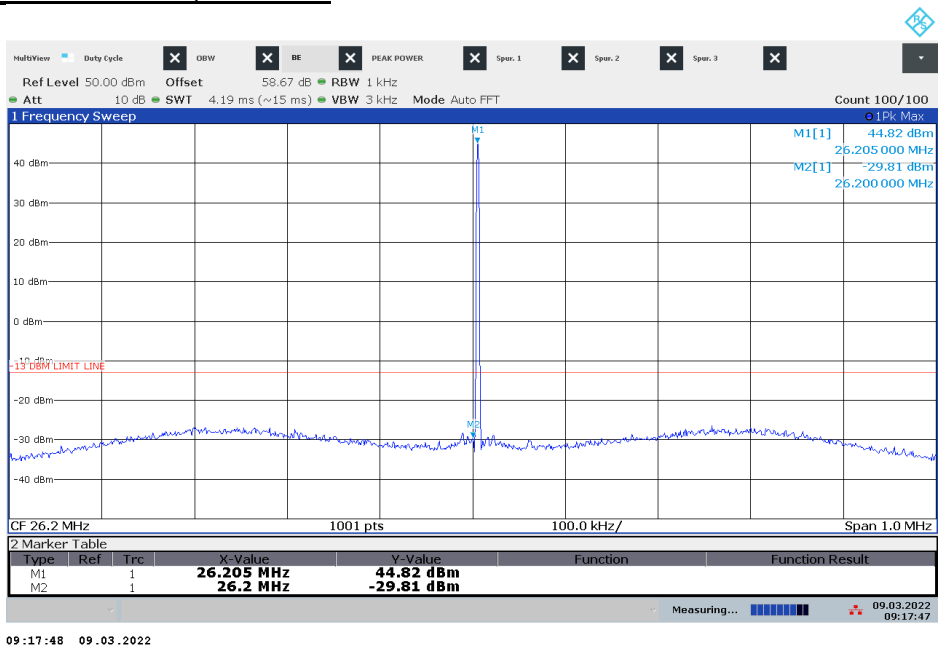
### 24.45 to 24.65 MHz Mode, High End



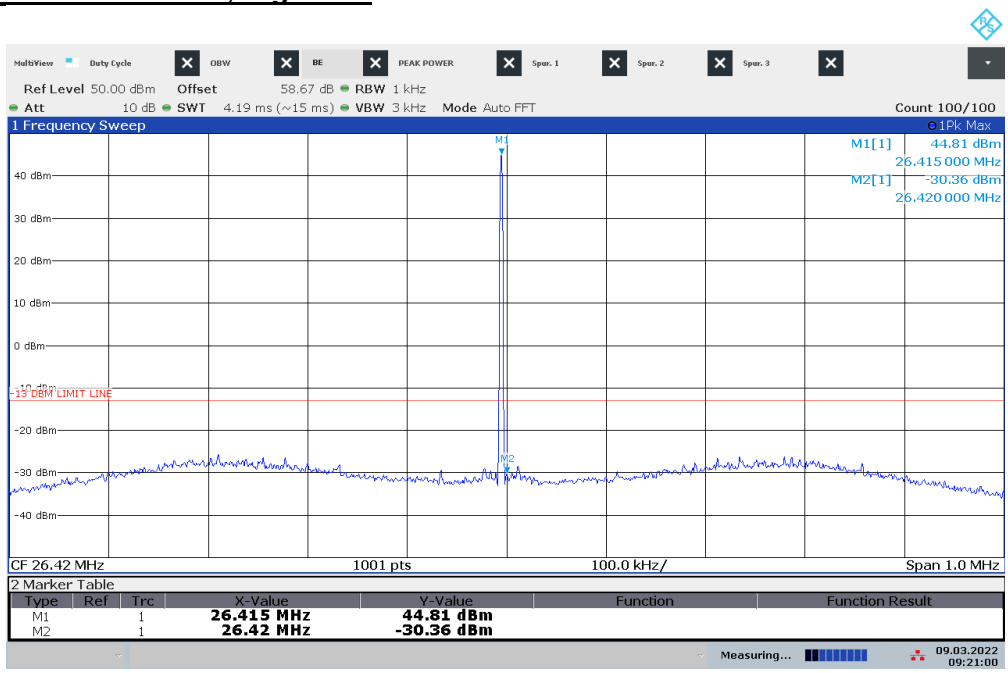

08:38:13 09.03.2022

## 26.20 to 26.42 MHz Mode, Low End




09:17:48 09.03.2022

## 26.20 to 26.42 MHz Mode, High End

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# 8.6. TX RADIATED SPURIOUS EMISSIONS

**RULE PARTS**

§2.1057 (a) (1): In all the measurements set forth in §2.1051 and §2.1053, the spectrum shall be investigated from the lowest radio frequency signal generated in the equipment, without going below 9 kHz, up to at least the frequency shown below: If the equipment operates below 10 GHz: to the tenth harmonic of the highest fundamental frequency or to 40 GHz, whichever is lower.

10th harmonic of highest fundamental frequency $= 10 \times (26.42\ MHz) = 264.20\ MHz$
Thus, spurious emissions are investigated from 9 kHz thru 1 GHz.

**LIMIT**

§ 90.210 (n): Other frequency bands. Transmitters designed for operation under this part on frequencies other than listed in this section must meet the emission mask requirements of Emission Mask B. Equipment operating under this part on frequencies allocated to but shared with the Federal Government, must meet the applicable Federal Government technical standards.

§ 90.210 (b): Emission Mask B. For transmitters that are equipped with an audio low-pass filter, the power of any emission must be attenuated below the unmodulated carrier power (P) as follows:

(1) On any frequency removed from the assigned frequency by more than 50 percent, but not more than 100 percent of the authorized bandwidth: At least 25 dB.
(2) On any frequency removed from the assigned frequency by more than 100 percent, but not more than 250 percent of the authorized bandwidth: At least 35 dB.
(3) On any frequency removed from the assigned frequency by more than 250 percent of the authorized bandwidth: At least $43 + 10\ log(P)\ dB$.

The more stringent Peak power limit on § 90.210 (b)(3), which is the same limit as Rec ITU-R SM.329-10 Standard, is applied for spurious emissions and band edge.

Determination of Limit:

Maximum Declared Peak Conducted Power of EUT,

$$P_{max} = 42\ dBm\ (16\ W)$$

$$\begin{aligned} Applicable\ Peak\ Limit &= 42 - \big(43 + 10log(16)\big) \\ &= 42 - 55 \\ &= -13\ dBm \end{aligned}$$

## TEST PROCEDURE

ANSI C63.26-2015 Clause 5.5.4

Below 30 MHz spurious emission testing was performed in chamber other than open area test site. Adequate comparison measurements were confirmed against 30-meter open area test site and sufficient tests were made to demonstrate that the alternative site produces results that correlate with the ones of tests made in an open field based on KDB 414788.

## RADIATED EMISSION

Where relevant, the following sample calculations are provided:

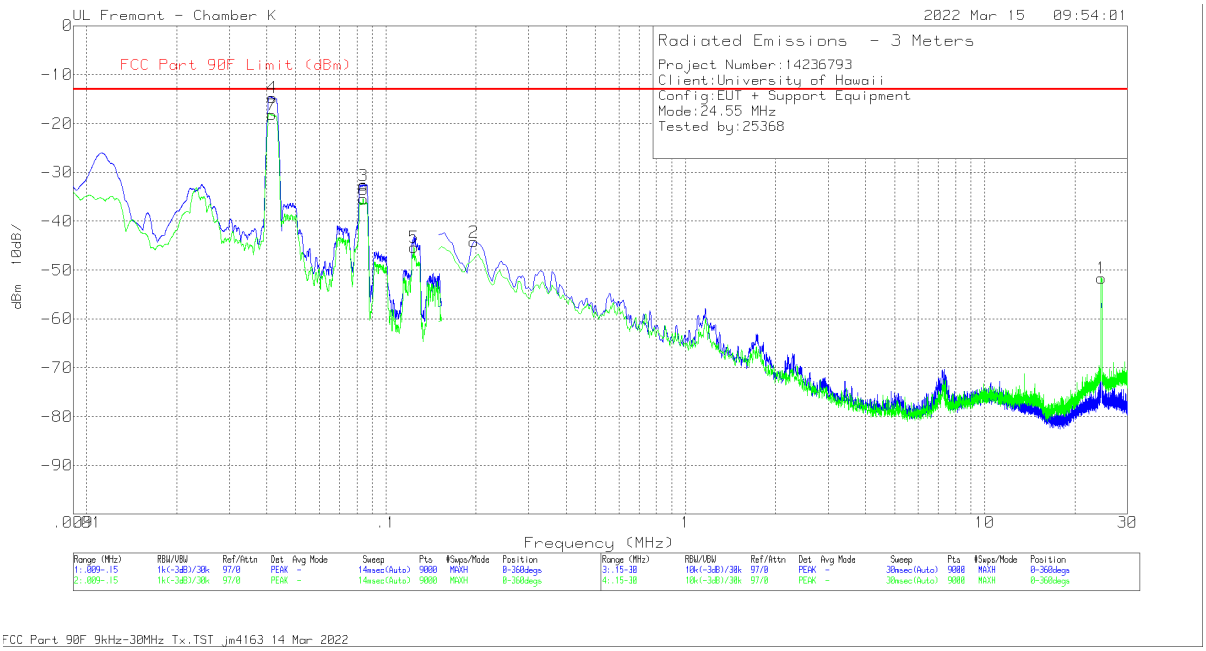
$$EIRP(dBm) = \text{Meter Reading } (dBuV) + \text{Antenna Factor}(dB/m) + \text{PreAmp Gain/Cbl Loss } (dB) + (dBuV - to - dBm) \text{ Unit Conversion Factor @ } 3m$$
$$= 34.27\ dBm\ +\ 48.3\ dB/m\ +\ (-32.2)\ dB\ +\ (-95.2)$$
$$= -44.83\ dBm$$

$$EIRP(dBm) = \text{Meter Reading } (dBm) + \text{Antenna Factor } (dB/m) + \text{ PreAmp Gain/Cbl Loss } (dB) + (dBm - to - dBm) \text{ Unit Conversion Factor @ } 3m$$
$$= -60\ dBm\ +\ 28\ dB/m\ +\ (-27)\ dB\ +\ 11.7$$
$$= -47.3\ dBm$$

## RESULTS

Employee ID: 25368
Location: Chamber K
Test Date: 3/14/22 - 3/15/22

## 24.45 – 24.65 MHz Mode, 9 kHz to 30 MHz




### Trace Markers - Pre-scan

| Marker | Frequency (MHz) | Meter Reading (dBuV) | Det | Loop Ant (E ACF) | Amp/Cbl (dB) | Unit Conversion | Corrected Reading dBm | FCC Part 90F Limit (dBm) | Margin (dB) | Azimuth (Degs) | Antenna Face |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 3 | .0842 | 39.04 | Pk | 55.7 | -32.2 | -95.2 | -32.66 | -13 | -19.66 | 0-360 | On |
| 4 | .0417 | 55.42 | Pk | 57.2 | -32.1 | -95.2 | -14.68 | -13 | -1.68 | 0-360 | On |
| 5 | .124 | 26.23 | Pk | 55.8 | -32.2 | -95.2 | -45.37 | -13 | -32.37 | 0-360 | On |
| 6 | .0839 | 36.21 | Pk | 55.7 | -32.2 | -95.2 | -35.49 | -13 | -22.49 | 0-360 | Off |
| 7 | .0416 | 51.88 | Pk | 57.2 | -32.1 | -95.2 | -18.22 | -13 | -5.22 | 0-360 | Off |
| 2 | .1964 | 23.05 | Pk | 60.1 | -32.2 | -95.2 | -44.25 | -13 | -31.25 | 0-360 | Off |
| 1* | 24.5698 | 41.68 | Pk | 33.5 | -31.6 | -95.2 | -51.62 | -13 | -38.62 | 0-360 | On |

Pk - Peak detector
Power levels of emissions were lower with antenna face-down, comparing to face-on and face-off, at pre-scan.

*Marker 1 is the fundamental signal.

### Radiated Emissions – Final Data

| Frequency (MHz) | Meter Reading (dBuV) | Det | Loop Ant (E ACF) | Amp/Cbl (dB) | Unit Conversion | Corrected Reading dBm | FCC Part 90F Limit (dBm) | Margin (dB) | Azimuth (Degs) | Antenna Face |
|---|---|---|---|---|---|---|---|---|---|---|
| .0829 | 39.34 | Pk | 55.7 | -32.2 | -95.2 | -32.36 | -13 | -19.36 | 77 | On |
| .0406 | 55.91 | Pk | 57.2 | -32.1 | -95.2 | -14.19 | -13 | -1.19 | 88 | On |
| .1224 | 26.59 | Pk | 55.8 | -32.2 | -95.2 | -45.01 | -13 | -32.01 | 158 | On |
| .0823 | 35.68 | Pk | 55.7 | -32.2 | -95.2 | -36.02 | -13 | -23.02 | 174 | Off |
| .0401 | 52.28 | Pk | 57.2 | -32.1 | -95.2 | -17.82 | -13 | -4.82 | 172 | Off |
| .2115 | 24.75 | Pk | 59.5 | -32.2 | -95.2 | -43.15 | -13 | -30.15 | 91 | Off |

Pk - Peak detector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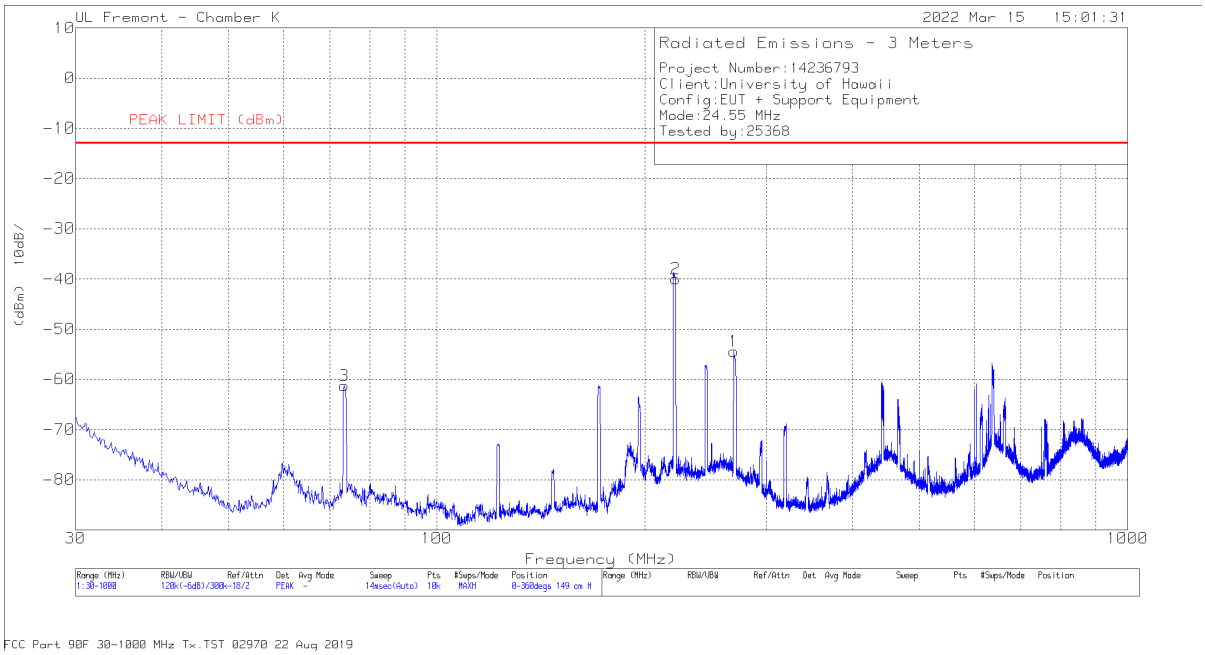
## 24.45 – 24.65 MHz Mode, 30 to 1000 MHz




## Trace Markers - Pre-scan

| Marker | Frequency (MHz) | Meter Reading (dBm) | Det | 82258 ACF (dB) | Amp/Cbl (dB) | Sub Factor (dB) | Corrected Reading (dBm) | PEAK LIMIT (dBm) | Margin (dB) | Azimuth (Degs) | Height (cm) | Polarity |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 269.008 | -56.01 | Pk | 19.5 | -29.9 | 12 | -54.41 | -13 | -41.41 | 0-360 | 149 | H |
| 2 | 221.672 | -37.91 | Pk | 17.4 | -30.2 | 10.7 | -40.01 | -13 | -27.01 | 0-360 | 149 | H |
| 3 | 73.456 | -52.22 | Pk | 14.2 | -31.1 | 7.8 | -61.32 | -13 | -48.32 | 0-360 | 149 | H |
| 4 | 269.008 | -56.92 | Pk | 19.5 | -29.9 | 6.6 | -60.72 | -13 | -47.72 | 0-360 | 149 | V |
| 5 | 220.023 | -38.92 | Pk | 17.4 | -30.2 | 7.3 | -44.42 | -13 | -31.42 | 0-360 | 149 | V |
| 6 | 73.359 | -46.34 | Pk | 14.2 | -31.1 | 9.2 | -54.04 | -13 | -41.04 | 0-360 | 149 | V |

Pk - Peak detector

## Radiated Emissions – Final Data

| Frequency (MHz) | Meter Reading (dBm) | Det | 82258 ACF (dB) | Amp/Cbl (dB) | Sub Factor (dB) | Corrected Reading (dBm) | PEAK LIMIT (dBm) | Margin (dB) | Azimuth (Degs) | Height (cm) | Polarity |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 269.03 | -54.24 | Pk | 19.5 | -29.9 | 12 | -52.64 | -13 | -39.64 | 339 | 106 | H |
| 220.088 | -36.24 | Pk | 17.4 | -30.2 | 10.2 | -38.84 | -13 | -25.84 | 192 | 108 | H |
| 73.4248 | -50.23 | Pk | 14.2 | -31.1 | 7.8 | -59.33 | -13 | -46.33 | 82 | 248 | H |
| 269.09 | -55.53 | Pk | 19.5 | -29.9 | 6.6 | -59.33 | -13 | -46.33 | 196 | 128 | V |
| 220.115 | -38.17 | Pk | 17.4 | -30.2 | 7.3 | -43.67 | -13 | -30.67 | 351 | 168 | V |
| 73.5348 | -44.09 | Pk | 14.1 | -31.1 | 9.2 | -51.89 | -13 | -38.89 | 5 | 99 | V |

Pk - Peak detector



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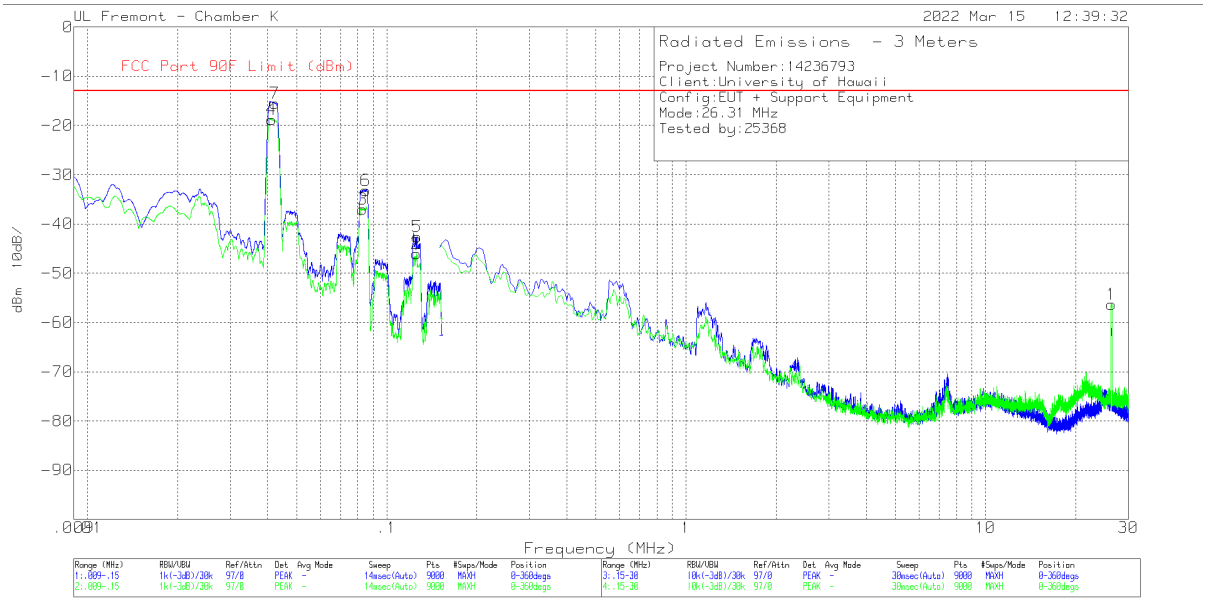
## 26.20 to 26.42 MHz Mode, 9 kHz to 30 MHz




FCC Part 90F 9kHz-30MHz Tx.TST jm4163 14 Mar 2022

### Trace Markers - Pre-scan

| Marker | Frequency (MHz) | Meter Reading (dBuV) | Det | Loop Ant (E ACF) | Amp/Cbl (dB) | Unit Conversion | Corrected Reading dBm | FCC Part 90F Limit (dBm) | Margin (dB) | Azimuth (Degs) | Antenna Face |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 5 | .1261 | 29.07 | Pk | 55.8 | -32.2 | -95.2 | -42.53 | -13 | -29.53 | 0-360 | On |
| 6 | .0849 | 38.47 | Pk | 55.7 | -32.2 | -95.2 | -33.23 | -13 | -20.23 | 0-360 | On |
| 7 | .0422 | 54.65 | Pk | 57.2 | -32.1 | -95.2 | -15.45 | -13 | -2.45 | 0-360 | On |
| 2 | .1258 | 25.63 | Pk | 55.8 | -32.2 | -95.2 | -45.97 | -13 | -32.97 | 0-360 | Off |
| 3 | .0829 | 34.66 | Pk | 55.7 | -32.2 | -95.2 | -37.04 | -13 | -24.04 | 0-360 | Off |
| 4 | .0412 | 51.36 | Pk | 57.2 | -32.1 | -95.2 | -18.74 | -13 | -5.74 | 0-360 | Off |
| 1* | 26.2946 | 37.24 | Pk | 33.3 | -31.6 | -95.2 | -56.26 | -13 | -43.26 | 0-360 | On |

Pk - Peak detector
Power levels of emissions were lower with antenna face-down, comparing to face-on and face-off, at pre-scan.

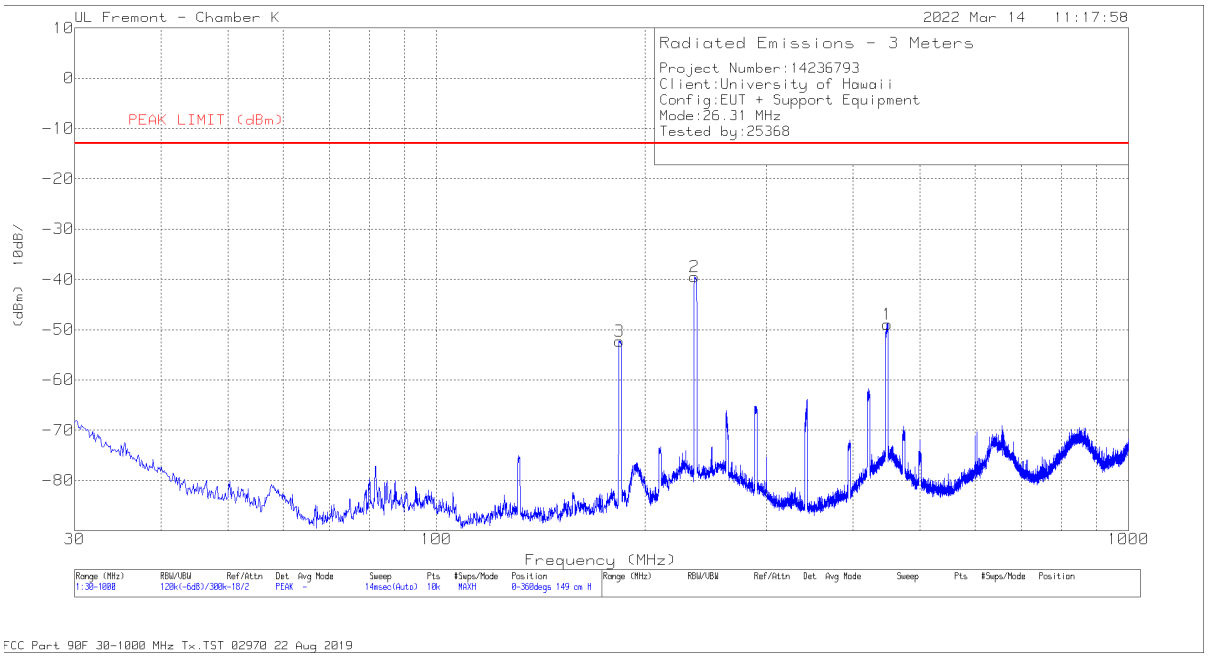
*Marker 1 is the fundamental signal.

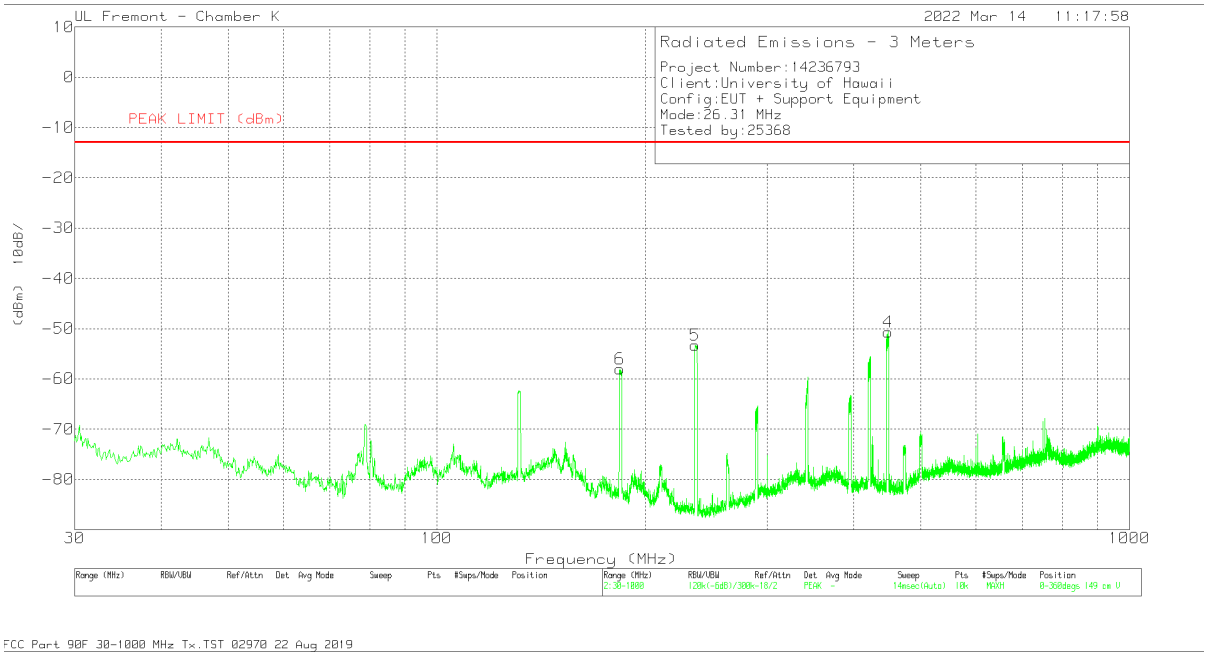
### Radiated Emissions – Final Data

| Frequency (MHz) | Meter Reading (dBuV) | Det | Loop Ant (E ACF) | Amp/Cbl (dB) | Unit Conversion | Corrected Reading dBm | FCC Part 90F Limit (dBm) | Margin (dB) | Azimuth (Degs) | Antenna Face |
|---|---|---|---|---|---|---|---|---|---|---|
| .0403 | 54.95 | Pk | 57.2 | -32.1 | -95.2 | -15.15 | -13 | -2.15 | 111 | On |
| .0846 | 38.44 | Pk | 55.7 | -32.2 | -95.2 | -33.26 | -13 | -20.26 | 118 | On |
| .1262 | 27.88 | Pk | 55.8 | -32.2 | -95.2 | -43.72 | -13 | -30.72 | 130 | On |
| .1253 | 25.62 | Pk | 55.8 | -32.2 | -95.2 | -45.98 | -13 | -32.98 | 177 | Off |
| .0829 | 34.62 | Pk | 55.7 | -32.2 | -95.2 | -37.08 | -13 | -24.08 | 177 | Off |
| .0402 | 51.73 | Pk | 57.2 | -32.1 | -95.2 | -18.37 | -13 | -5.37 | 177 | Off |

Pk - Peak detector

## 26.20 – 26.42 MHz Mode, 30 to 1000 MHz



### Trace Markers - Pre-scan

| Marker | Frequency (MHz) | Meter Reading (dBm) | Det | 82258 ACF (dB) | Amp/Cbl (dB) | Sub Factor (dB) | Corrected Reading (dBm) | PEAK LIMIT (dBm) | Margin (dB) | Azimuth (Degs) | Height (cm) | Polarity |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 448.07 | -55.61 | Pk | 22.9 | -29.2 | 13 | -48.91 | -13 | -35.91 | 0-360 | 149 | H |
| 2 | 235.931 | -40.87 | Pk | 17.9 | -30.1 | 13.6 | -39.47 | -13 | -26.47 | 0-360 | 149 | H |
| 3 | 183.745 | -46.06 | Pk | 17.6 | -30.4 | 6.6 | -52.26 | -13 | -39.26 | 0-360 | 149 | H |
| 4 | 448.361 | -50.68 | Pk | 22.9 | -29.2 | 6.3 | -50.68 | -13 | -37.68 | 0-360 | 149 | V |
| 5 | 236.125 | -48.25 | Pk | 17.9 | -30.1 | 7.1 | -53.35 | -13 | -40.35 | 0-360 | 149 | V |
| 6 | 183.939 | -54.18 | Pk | 17.6 | -30.4 | 9 | -57.98 | -13 | -44.98 | 0-360 | 149 | V |

Pk - Peak detector

### Radiated Emissions – Final Data

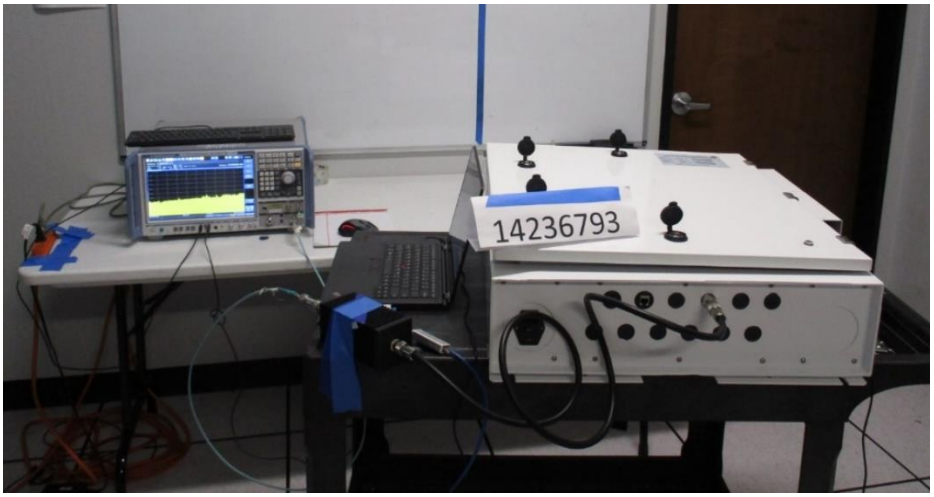
| Frequency (MHz) | Meter Reading (dBm) | Det | 82258 ACF (dB) | Amp/Cbl (dB) | Sub Factor (dB) | Corrected Reading (dBm) | PEAK LIMIT (dBm) | Margin (dB) | Azimuth (Degs) | Height (cm) | Polarity |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 448.131 | -54.48 | Pk | 22.9 | -29.2 | 13 | -47.78 | -13 | -34.78 | 51 | 279 | H |
| 235.902 | -41.14 | Pk | 17.9 | -30.1 | 13.6 | -39.74 | -13 | -26.74 | 293 | 134 | H |
| 183.455 | -46.69 | Pk | 17.6 | -30.4 | 6.5 | -52.99 | -13 | -39.99 | 265 | 150 | H |
| 448.978 | -48.91 | Pk | 22.9 | -29.2 | 6.3 | -48.91 | -13 | -35.91 | 174 | 109 | V |
| 236.039 | -42.86 | Pk | 17.9 | -30.1 | 7.1 | -47.96 | -13 | -34.96 | 78 | 201 | V |
| 183.872 | -51.08 | Pk | 17.6 | -30.4 | 9 | -54.88 | -13 | -41.88 | 78 | 201 | V |

Pk - Peak detector

# 9. SETUP PHOTOS

**RF CONDUCTED MEASUREMENT SETUP**

**TX CONDUCTED RF TESTS**



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## FREQUENCY STABILITY MEASUREMENT SETUP

INSIDE TEMP. CHAMBER PHOTO


OUTSIDE TEMP. CHAMBER PHOTO




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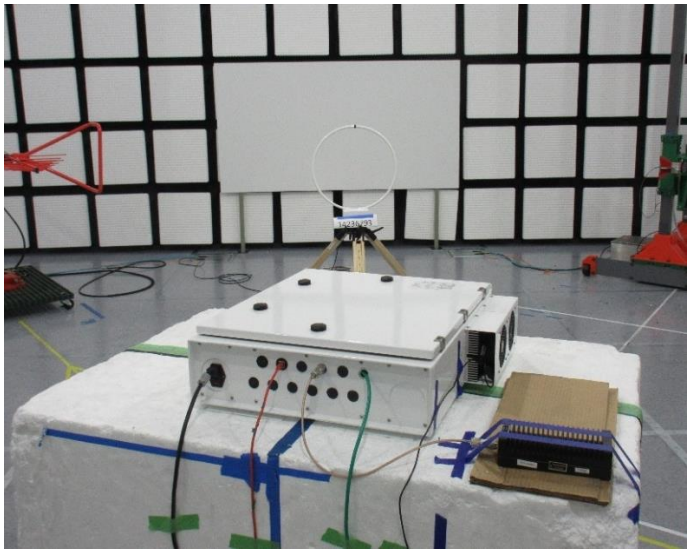
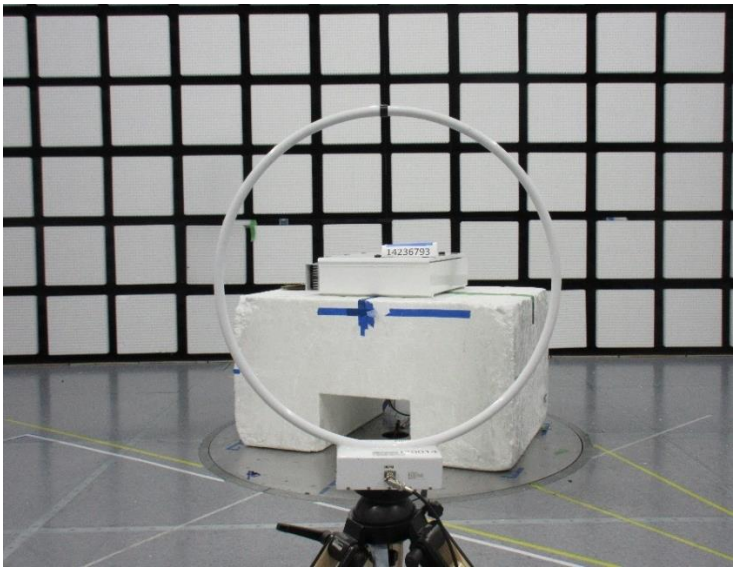
## RF RADIATED MEASUREMENT SETUP, 9 kHz - 30 MHz

FRONT PHOTO



BACK PHOTO



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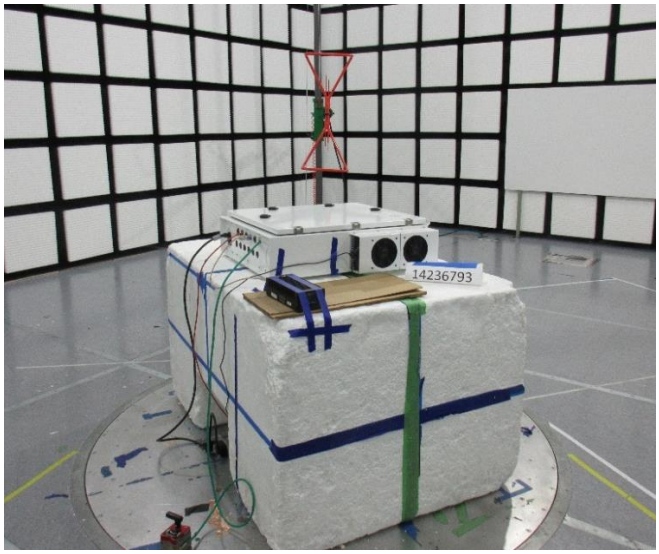
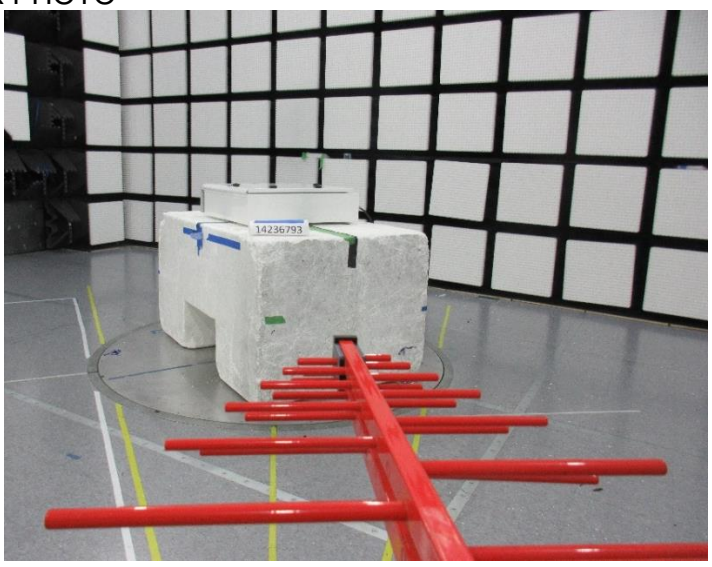
**RF RADIATED MEASUREMENT SETUP, 30 - 1000 MHz**

FRONT PHOTO




BACK PHOTO




# END OF REPORT



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